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ICHEP2022
Since 1984 the Italian groups of the Istituto Nazionale di Fisica Nucleare (INFN), collaborating with the DOE laboratory of Fermilab (US) have been running a two-month summer training program for Italian university students. While in the first year the program involved only four physics students of the University of Pisa, in the following years it was extended to engineering students. This extension was very successful and the engineering students have been since then extremely well accepted by the Fermilab Technical and Accelerator Division groups.

Since 2004 the program has been supported in part by DOE in the frame of an exchange agreement with INFN. An additional agreement for sharing support for engineers of the School of Advanced Studies of S.Anna (SSSA) of Pisa was established in 2007 between SSSA and Fermilab. In the frame of this program four SSSA students are supported each year. Over its 35 years of history, under the management of the Cultural Association of Italians at Fermilab, the program has grown in scope and size and has involved more than 500 Italian students from more than 20 Italian Universities. Since the program does not exclude appropriately-selected non-italian students, a handful of students of European and non-European Universities were also accepted in the years.

Each intern is supervised by a Fermilab Mentor who is responsible for performing the program. Training programs spanned from Tevatron, CMS, MicroBooNE, Icarus, SBND, Dune, Nova experimental data analysis, development of particle detectors (e.g. silicon trackers, calorimeters, drift chambers, neutrino and dark matter detectors), design of the Muon “g-2” and Mu2e experiments, design of electronic and accelerator components, development of infrastructures and software for tera-data handling, research on superconductive elements and on accelerating cavities, theory of particle accelerators.

Since 2010, within an extended CAIF program supported by the Italian Space Agency and the Italian National Institute of Astrophysics, a total of 25 students in physics, astrophysics and engineering have been hosted for two months in summer at US space science Research Institutes and laboratories.

In 2015 the University of Pisa included these programs within its own educational programs. Accordingly, Summer School students are enrolled at the University of Pisa for the duration of the internship and are identified and ensured as such. At the end of the internship the students are required to write summary reports on their achievements, which are saved in the Fermilab web pages and in the CAIF archives. After positive evaluation by a University Examining Board, interns are acknowledged 6 ECTS credits for their Diploma Supplement.

The program is now part of the outreach activities of the European Projects MUSE (H2020-MSCA-RISE-2015 GA 690835), NEWS (H2020-MSCA-RISE-2016 GA 754303) and INTENSE (H2020-MSCA-RISE-2018 GA 822185), and is expected to grow further in the near future.

Information on student recruiting methods, on training programs of recent years and on final students’ evaluation process at Fermilab and at the University of Pisa will be given in the presentation.
Considering the relatively large value of the last measured neutrino mixing angle $\theta_{13}$, the way is now open to observe for the first time a possible CP violation in the leptonic sector. The measured value of $\theta_{13}$ also privileges the 2nd oscillation maximum for the discovery of CP violation instead of the usually used 1st oscillation maximum. The sensitivity at this 2nd oscillation maximum is significantly higher than for the 1st oscillation maximum inducing a lower influence of systematic errors. Going to the 2nd oscillation maximum necessitates a very intense neutrino beam with the appropriate energy. The world’s most intense pulsed spallation neutron source, the European Spallation Source, will have a proton linac with the unprecedented power of 5 MW and 2 GeV energy. This linac, under construction, also has the potential to become the proton driver of the world’s most intense neutrino beam with very high potential to discover and well measure a neutrino CP violation. The physics performance of that neutrino Super Beam in conjunction with a megaton underground Water Cherenkov neutrino detector installed at a distance of about 500 km from ESS has been evaluated. In addition, the choice of such detector will extent the physics program to proton–decay, atmospheric neutrinos and astrophysics searches. The ESS proton linac upgrades, the accumulator ring needed for proton pulse compression, the target station optimization and the physics potential are described. In addition to neutrinos, this facility will also produce at the same time a copious number of muons which could be used by a low energy nuSTORM facility, a Neutrino Factory or/and a muon collider. The ESS neutron facility will be fully ready by 2025 at which moment the upgrades for the neutrino facility could start.

This project is supported by the COST Action CA15139 "Combining forces for a novel European facility for neutrino-antineutrino symmetry-violation discovery" (EuroNuNet). It has also received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 777419.
as many photons as previously expected, thus significantly lowering the number of unexplained
electron-like events.

Secondary track (number):

Neutrino Physics / 19

Testing MSW effect in Supernova Explosion with Neutrino event rates

Authors: Kwang-Chang Lai\textsuperscript{1}; Chun Sing Jason Leung\textsuperscript{2}; Guey-Lin Lin\textsuperscript{2}

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Flavor transitions in supernova neutrinos are yet to be determined. We present a method to probe whether or not the Mikheyev-Smirnov-Wolfenstein effects occur as SN neutrinos propagate outward from the SN core by investigating time evolutions of neutrino event rates for different flavors in different kinds of detectors. As the MSW effect occurs, the $\nu_e$ flux swaps with the $\nu_x$ flux, which represents any one of $\nu_\mu$, $\nu_\tau$, $\bar{\nu}_\mu$, and $\bar{\nu}_\tau$ flux, either fully or partially depending on the neutrino mass hierarchy. During the neutronization burst, the $\nu_e$ emission evolves in a much different shape from the emissions of $\bar{\nu}_e$ and $\nu_x$ while the latter two evolve in a similar pattern. Meanwhile, the luminosity of the $\nu_e$ emission is much larger than those of the $\bar{\nu}_e$ and $\nu_x$ emissions while the latter two are roughly equal. As a consequence, the time-evolution pattern of the $\nu_e$Ar event rates in the absence of the MSW effect will be much different from that in the occurrence of the MSW effect, in either mass hierarchy. With the simulated SN neutrino emissions, the $\nu_e$Ar and inverse beta decay event rates are evaluated. The ratios of the two cumulative event rates are calculated for different progenitor masses up to 100 ms. We show that the time evolutions of this cumulative ratios can effectively determine whether MSW effects really occur for SN neutrinos or not.

Secondary track (number):

Beyond the Standard Model / 21

Search for New Physics with the SHiP experiment at CERN

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The SHiP Collaboration has proposed a general-purpose experimental facility operating in beam dump mode at the CERN SPS accelerator with the aim of searching for light, long-lived exotic particles of Hidden Sector models. The SHiP experiment incorporates a muon shield based on magnetic sweeping and two complementary apparatuses. The detector immediately downstream of the muon shield is optimised both for recoil signatures of light dark matter scattering and for tau neutrino physics, and consists of a spectrometer magnet housing a layered detector system with heavy target plates, emulsion film technology and electronic high precision tracking. The second detector system aims at measuring the visible decays of hidden sector particles to both fully reconstructible final states and to partially reconstructible final states with neutrinos, in a nearly background free environment. The detector consists of a 50 m long decay volume under vacuum followed by a spectrometer and particle identification with a rectangular acceptance of 5 m in width and 10 m in height. Using the high-intensity beam of 400 GeV protons, the experiment is capable of integrating $2 \times 10^{20}$
protons in five years, which allows probing dark photons, dark scalars and pseudo-scalars, and heavy neutrinos with GeV-scale masses at sensitivities that exceed those of existing and projected experiments. The sensitivity to heavy neutrinos will allow for the first time to probe, in the mass range between the kaon and the charm meson mass, a coupling range for which baryogenesis and active neutrino masses can be explained. The sensitivity to light dark matter reaches well below the elastic scalar Dark Matter relic density limits in the range from a few MeV/c$^2$ up to 200 MeV/c$^2$.

Following the review of the Technical Proposal, the Collaboration recently submitted to the CERN SPS Committee a Comprehensive Design Study. These studies have resulted in a mature proposal discussed at the European Strategy for Particle Physics Update meeting in Granada.

A measurement with a SHiP target replica of the flux of muons from 400GeV proton interactions was performed at SPS during 2019 and will be reported at this conference.

I read the instructions:

Secondary track (number):

Neutrino Physics / 22

Neutrino Physics with the SHiP experiment at CERN

Author: Collaboration SHIP

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The SHiP Collaboration has proposed a general-purpose experimental facility operating in beam dump mode at the CERN SPS accelerator with the aim of searching for light, long-lived exotic particles of Hidden Sector models. The SHiP experiment incorporates a muon shield based on magnetic sweeping and two complementary apparatuses. The detector immediately downstream of the muon shield is optimised both for recoil signatures of light dark matter scattering and for tau neutrino physics, and consists of a spectrometer magnet housing a layered detector system with heavy target plates, emulsion film technology and electronic high precision tracking. The second detector system aims at measuring the visible decays of hidden sector particles to both fully reconstructible final states and to partially reconstructible final states with neutrinos, in a nearly background free environment. Using the high-intensity beam of 400 GeV protons, the experiment is capable of integrating $2 \times 10^{20}$ protons in five years, which allows probing dark photons, dark scalars and pseudo-scalars, and heavy neutrinos with GeV-scale masses at sensitivities that exceed those of existing and projected experiments. The sensitivity to heavy neutrinos will allow for the first time to probe, in the mass range between the kaon and the charm meson mass, a coupling range for which baryogenesis and active neutrino masses can be explained. The sensitivity to light dark matter reaches well below the elastic scalar Dark Matter relic density limits in the range from a few MeV/c$^2$ up to 200 MeV/c$^2$.

The tau neutrino deep-inelastic scattering cross-sections will be measured with a statistics a thousand times larger than currently available, with the extraction of the $F_4$ and $F_5$ structure functions, never measured so far, and allow for new tests of lepton non-universality with sensitivity to BSM physics.

Following the review of the Technical Proposal, the Collaboration recently submitted to the CERN SPS Committee a Comprehensive Design Study. These studies have resulted in a mature proposal discussed at the European Strategy for Particle Physics Update meeting in Granada.

A measurement of charm production with a SHiP-like target interleaved with emulsion-based detectors was performed at SPS during 2019 and will be reported at this conference.

I read the instructions:

Secondary track (number):
Probing QED in the strong-field regime with LUXE

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In this talk LUXE (Laser Und XFEL Experiment) is discussed. It is an experiment that aims to use the high-quality and high-energy electron beam of the European XFEL and a powerful laser. The scientific objective of the experiment is to study quantum electrodynamics processes in the regime of strong fields. High-energy electrons, accelerated by the European XFEL linear accelerator, and high-energy photons, produced via Bremsstrahlung of those beam electrons, colliding with a laser beam shall experience an electric field up to three times larger than the Schwinger critical field (the field at which the vacuum itself is expected to become unstable and spark with spontaneous creation of electron – positron pairs) and access a new regime of quantum physics. The processes to be investigated, which include nonlinear Compton scattering and nonlinear Breit-Wheeler pair production, are relevant to a variety of phenomena in Nature, e.g. in the areas of astrophysics and collider physics and complement recent results in atomic physics. The setup requires in particular the extraction of a minute fraction of the electron bunches from the European XFEL accelerator, the installation of a powerful laser with sophisticated diagnostics, and an array of precision detectors optimised to measure electrons, positrons and photons. Physics sensitivity projections based on simulations are also shown.

Beyond the Standard Model - Posters / 26

The Next Higgs Bosons in $E_6$ Inspired Supersymmetric Models with CP Violation

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We investigate the effect of CP violation in the Higgs sector of the $U(1)'$-extended MSSM. We are particularly interested in the mass and decay dependence of the second lightest neutral Higgs boson, in the presence of CP violating phases for $\mu_{eff}$. The masses of the neutral Higgs bosons are calculated at the one-loop level by taking into account the contributions from top and bottom scalar quark sectors. We study the production and decay channels of the second lightest neutral Higgs boson for a set of benchmark points consistent with the current experimental constraints. We then implement the model into standard packages and perform a detailed and systematic analysis of production and decay modes at the HE-LHC with 27 TeV.
Sbottoms as probes to MSSM with nonholomorphic soft interactions

Authors: Samadrita Mukherjee¹; Utpal Chattopadhyay²; AseshKrishna Datta³; Abhaya Kumar Swain⁴

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Presence of non-holomorphic soft SUSY breaking terms is known to be a possibility in the popular setup of the Minimal Supersymmetric Standard Model (MSSM). It has been shown that such a scenario known as Non-Holomorphic Supersymmetric Standard Model (NHSSM) could remain 'natural' (i.e., not fine-tuned) even in the presence of a rather heavy higgsino-like LSP. In a first study of such a scenario at colliders (LHC), we explore a possible way that focuses on the sbottom phenomenology. This exploits the usual tanβ-dependence (enhancement) of the bottom Yukawa coupling but reinforced/altered in the presence of non-vanishing nonholomorphic soft trilinear parameter A'_b. For a given set of masses of the sbottom(s) and the light electroweakinos (LSP, lighter chargino etc.) which are known from experiments, the NHSSM could manifest itself via event rate in the 2b + MET final state, which could be characteristically different from its MSSM expectation. Impact on the phenomenology of the stops at the LHC is also touched upon.

Beyond the Standard Model - Posters / 32

Contribution of the dipole moments of the tau-neutrino in the stellar energy loss rates

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Within the context of a $U(1)_{B-L}$ model, we develop and present novel analytical formulas to assess the effects of the anomalous magnetic moment and electric dipole moment of the tau-neutrino on the stellar energy loss rates through some common physical process of pair-annihilation $e^+e^- \rightarrow (\gamma, Z, Z') \rightarrow \nu\bar{\nu}$. Our results show that the stellar energy loss rates strongly depends on both momenta of the neutrino, but also on the parameters which characterize the adopted $U(1)_{B-L}$ model.

Computing and Data Handling / 33

Application of Quantum Machine Learning to High Energy Physics Analysis at LHC using IBM Quantum Computer Simulators and IBM Quantum Computer Hardware

Authors: Sau Lan Wu¹; Chen Zhou¹
Using IBM Quantum Computer Simulators and Quantum Computer Hardware, we have successfully employed the Quantum Support Vector Machine Method (QSVM) for a ttH (H to two photons), Higgs production in association with a top quark pair analysis at the LHC.

We will present our experiences and results of a study on LHC high energy physics data analysis with IBM Quantum Computer Simulators and IBM Quantum Computer Hardware using IBM Qiskit. The work is in the context of a Qubit platform. Taking into account the limitation of a low number of qubits, the result using the Quantum Computer Simulators expressed in a ROC curve is comparable with the results using classical machine learning methods (BDT and classical SVM). This study is applied to a ttH physics analysis, one of the flagship physics channels at the LHC, with 5 qubits, 100 training events and 100 test events. Here the ROC curve is defined as the Receiver Operating Characteristics curve in the plane of background rejection versus signal efficiency.

In addition, we have employed the IBM QSVM Variational quantum machine learning algorithm using 5 qubits on the IBM Quantum Computer Hardware of 20 qubits ("IBM Boeblingen"), with 100 training events and 100 test events, again for a ttH (H to two photons) analysis at the LHC. The present result from the IBM Quantum Hardware is about 10% in performance below the Quantum Simulation.

The work is performed by an international and interdisciplinary collaboration with Department of Physics and Department of Computer Sciences of University of Wisconsin, CERN Openlab of IT Division, IBM Research Zurich and Fermilab Quantum Institute.

This work pioneers a close collaboration of academic institutions with industrial corporations in a High Energy Physics analysis effort.

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 34

MURMUR: a new low-noise experiment for the search of neutron-hidden neutron transitions in the context of braneworld scenarios

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MURMUR is a new passing-through-wall neutron experiment installed near the BR2 nuclear reactor at the Belgian Nuclear Research Center (SCK.CEN, Mol, Belgium) and designed to search neutron interbrane transitions in the context of braneworld scenarios. In such scenarios, our Universe could be a 3-brane embedded in a multidimensional Universe, called the bulk, which could contain many other invisible adjacent 3-branes. Theoretical works have shown that the existence of hidden braneworlds can be experimentally tested thanks to neutron exchanges between braneworlds which must occur. A neutron n in our visible brane can be converted into a hidden neutron n’ propagating in a hidden braneworld when scattered by a nucleus with a cross section $\sigma(n \rightarrow n') \propto \sigma_E(n \rightarrow n) \times p$, where $\sigma_E$ is the usual elastic cross-section and $p$ the neutron swapping probability. Hidden neutrons could thus be generated in the moderator of the BR2 nuclear reactor where a high neutron flux undergoes many
elastic scatterings. This hidden neutron flux could be free to travel out of the biological shielding of the reactor up to a matrix made of lead, acting as an antenna, which makes possible to regenerate hidden neutrons into visible ones thanks to reverse swapping. These regenerated neutrons can be detected thanks to a neutron detector placed inside the lead block. The experimental setup of MURMUR is described, as well as the different improvements which have been included in comparison with the first experiment of this kind carried out at the ILL (Grenoble, France) in 2015. Then, the first results of MURMUR are presented and discussed. Finally, some upcoming modifications of the experimental setup of MURMUR are introduced.

I read the instructions:

Secondary track (number):

Neutrino Physics / 36

Preliminary results of the R2D2 project: a new neutrinoless double beta decay experiment

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The search for neutrinoless double beta decay could cast light on one critical piece missing in our knowledge i.e. the nature of the neutrino mass. Its observation is indeed the most sensitive experimental way to prove that neutrino is a Majorana particle. The observation of such a potentially rare process demands a detector with an excellent energy resolution, an extremely low radioactivity and a large mass of emitter isotope. Nowadays many techniques are pursued but none of them meets all the requirements at the same time. The goal of R2D2 is to prove that a spherical high pressure TPC could meet all the requirements and provide an ideal detector for the 0νββ decay search. The prototype has demonstrated an excellent resolution with Argon and the preliminary results with Xenon are already very promising. In the proposed talk the first R2D2 results with Xenon will be discussed as well as the project roadmap and future developments.

Secondary track (number):

13

Strong Interactions and Hadron Physics / 37

QCD effects in lepton angular distributions of Drell-Yan/Z production and jet discrimination

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Measuring lepton angular distributions of Drell-Yan process provides a powerful tool to explore the reaction mechanisms and the parton distributions of colliding hadrons. For example, the Lam-Tung relation has been proposed as a benchmark of the pQCD effect in Drell-Yan process. Violations of Lam-Tung relation were observed in the measurements of fixed-target experiments as well as $\gamma^*/Z$ production in the large transverse-momentum regions recently measured by the CMS and ATLAS experiments at LHC. It is important to understand the origin of these violations.

In this talk, we present a comparison of data with the fixed-order pQCD calculations by which the baseline of pQCD effects is illustrated. Then using an intuitive geometric approach, we show that these dependencies can be readily understood. The violation of the Lam-Tung relation, appearing at large transverse-momentum region, is attributed to the presence of a “non-coplanarity” effect. This interpretation is consistent with the appearance of violation beyond LO-QCD effect. Furthermore, we predict that $A_0$ and $A_2$ for $Z$ plus single gluon-jet events are very different from that of $Z$ plus single quark-jet events, allowing a new experimental tool for checking various algorithms which attempt to discriminate quark jets from gluon jets.

References


Neutrino Physics / 38

Detecting and studying high-energy neutrinos with FASERnu at the LHC

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FASER, the Forward Search Experiment at the Large Hadron Collider (LHC), is an experiment aiming to search for light, weakly-interacting new particles. The particle detector will be located 480 m downstream of the ATLAS interaction point. In addition to searches for new particles, we proposed a new detector (FASER$^\nu$) to study neutrinos at the highest man-made energies and got approval by the CERN Research Board in December 2019. To date, neutrino cross-section data exist up to a few 100 GeV with accelerator-based neutrino beams. With FASER$^\nu$, the neutrino cross-sections will be measured in the currently unexplored energy range between a few 100 GeV and 6 TeV. In particular, electron-neutrino and tau-neutrino cross sections will be measured at the highest energy ever. Furthermore, the channels associated with heavy quark (charm and beauty) production could be studied. As a feasibility study, we performed a test run in 2018 at the proposed detector location with a 30-kg lead/tungsten emulsion detector and collected data of 12.5 fb$^{-1}$. By analyzing the data, we selected several neutrino interaction candidates and are performing a multivariate analysis for the separation from the background towards a first detection of neutrinos at the LHC. From 2021 to 2023 (2024) during Run 3 of the LHC, we will deploy an emulsion detector with a target mass of 1.2 tons, possibly coupled with the FASER magnetic spectrometer, which would yield roughly 1,300 $\nu_e$, 20,000 $\nu_\mu$, and 20 $\nu_\tau$ interacting in the detector. Here, we present an overview and the status of the FASER$^\nu$ program, as well as the analysis for the neutrino detection in the 2018 data.
Neutrino Physics / 40

**Experiment DsTau (NA65) - study of tau neutrino production at CERN SPS**

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The tau neutrino interaction cross-section is known with much larger uncertainties compared to other types of neutrinos. In particular, first time measured in 2008 in the DONuT experiment, it had a large systematical error of 50% due to a poor knowledge of the tau neutrino flux in beam dump experiments. If known with better accuracy, the cross section would allow testing the Lepton Flavour Universality (LFU) of Standard Model in neutrino interactions. Several results for B-meson decay asymmetry (LHCb, Babar, Belle) demonstrate hints of possible LFU violation, perhaps due to Physics Beyond Standard Model effects. The measurement of the tau neutrino interaction cross section is also needed for decreasing of systematics in the future neutrino experiments. The tau neutrinos in accelerator beams are mostly produced in $D^0$ mesons decay to $K^-$ and $\pi^+$, with a further decay of $K^-$ lepton providing another $\nu$ neutrino. DsTau experiment has been proposed to measure an inclusive differential cross-section of a $\nu$ production in p-A interaction with a consecutive decay to tau lepton. This measurement will allow reducing the systematical error due to the tau neutrino flux uncertainty in the DONuT’s result from 50% to 10%. The peculiar $D^0$ to $\bar{K}$ cascade decay topology (“double kink”) in a few mm range will be detected by the nuclear emulsion tracker thanks to its excellent spatial resolution. Large amount of charmed particles decay events ($\sim 10^5$) is expected to be detected as well, providing a possibility for interesting by-product studies, in particular a search for intrinsic charm in a proton.

A pilot data sample was collected at CERN SPS in 2018. Given the actuality of the study and encouraging results of the data analysis, CERN had approved in 2019 the DsTau project as a new experiment NA65. Main data sample (x10 more) will be collected in 2021-22.

In this talk, the status, prospects of NA65 as well as the results of the pilot run are presented.

I read the instructions:

Secondary track (number):

Neutrino Physics / 41

**Extraction of the optical potential for final state nucleons and $\Delta$ resonances for electron and neutrino scattering on nuclear targets**

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Precise modeling of neutrino (and electron) interactions on nuclear targets is essential for neutrino oscillations experiments. The modeling the energy of final state leptons and nucleons in quasielastic scattering on bound nucleons requires knowledge of both the removal energy of the bound nucleon as well as the Coulomb and nuclear optical potentials for the final state nucleon in the field of the spectator (A-1) nucleus. We compare the values of the optical potential for final state protons extracted from electron scattering data on nuclear targets in the quasielastic region to the extracted values of the optical potential for $\Delta$ resonances in the final state. This is the first measurement of the optical potential for the $\Delta$ resonance. We find that the optical potential for a $\Delta$ resonance in the final state is larger than the optical potential for a final state proton.

Secondary track (number):
Dark Matter Detection / 42

The Light Dark Matter eXperiment, LDMX

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The constituents of dark matter are still unknown, and the viable possibilities span a very large mass range. Specific scenarios for the origin of dark matter sharpen the focus on a narrower range of masses: the natural scenario where dark matter originates from thermal contact with familiar matter in the early Universe requires the DM mass to lie within about an MeV to 100 TeV. Considerable experimental attention has been given to exploring Weakly Interacting Massive Particles in the upper end of this range (few GeV – ~TeV), while the region ~MeV to ~GeV is largely unexplored. Most of the stable constituents of known matter have masses in this lower range, tantalizing hints for physics beyond the Standard Model have been found here, and a thermal origin for dark matter works in a simple and predictive manner in this mass range as well. It is therefore a priority to explore. If there is an interaction between light DM and ordinary matter, as there must be in the case of a thermal origin, then there necessarily is a production mechanism in accelerator-based experiments. The most sensitive way, (if the interaction is not electron-phobic) to search for this production is to use a primary electron beam to produce DM in fixed-target collisions. The Light Dark Matter eXperiment (LDMX) is a planned electron-beam fixed-target missing-momentum experiment that has unique sensitivity to light DM in the sub-GeV range. This contribution will give an overview of the theoretical motivation, the main experimental challenges and how they are addressed, as well as projected sensitivities in comparison to other experiments.

I read the instructions:

Secondary track (number):

Beyond the Standard Model / 43

FASER: Forward Search Experiment at the LHC

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FASER is an approved small and inexpensive experiment designed to search for light, weakly-interacting particles during Run 3 of the LHC. Such particles may be produced in large numbers along the beam collision axis, travel for hundreds of meters without interacting, and then decay to standard model particles. To search for such events, FASER will be located 480 m downstream of the ATLAS IP in the unused service tunnel TI12. This talk will describe the discovery potential of FASER for new particles and the current status of the detector construction and commissioning.

I read the instructions:

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 44

Pileup and Underlying Event Mitigation with Iterative Constituent Subtraction
Authors: Peter Berta¹; Lucia Masetti¹; David Miller²; Martin Spousta³

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Hard-scatter processes in hadronic collisions are often significantly contaminated by background contributions from pileup in proton-proton collisions or underlying event in heavy-ion collisions. It is crucial to mitigate this background since it has a significant impact on hadronic jet reconstruction and on the ability to identify the substructures of hadronically decaying boosted objects.

We present a new background subtraction method for jet and event observables, called Iterative Constituent Subtraction [1]. This new method is based on the Constituent Subtraction algorithm [2], which is used extensively in the heavy-ion community. In the new method, an iterative approach is adopted to the event-wide implementation of Constituent Subtraction. Using particle-level simulation, we provide a comparison of Iterative Constituent Subtraction with several existing methods. The new method has the best performance for the pileup conditions at the upcoming LHC data taking and at the High Luminosity LHC. Possibilities to use information from charged particles to mitigate pileup effects from neutral particles are also discussed.


Secondary track (number): 12 (useful also for 7)

Beyond the Standard Model / 45

Exploring the lifetime frontier with the proposed MATHUSLA experiment

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Observation of neutral long-lived particle (LLP) can be the first sign for physics beyond the Standard Model at the LHC. These particles are invisible until they decay into detectable Standard Model particles some macroscopic distance away from the collision. Their existence is theoretically well motivated and can provide explanations to known unexplained phenomena such as Dark Matter, the Baryon Asymmetry of the universe, neutrino masses, and the Hierarchy Problem. The current LHC search programs focus mostly on energetic final states produced promptly within subatomic distances of the proton collision. These searches are largely insensitive to neutral LLPs. An LLP surface detector may be the only way of discovering new physics and, by that, solving fundamental puzzles of the incomplete Standard Model. These considerations prompt the MATHUSLA experiment (MAssive Timing Hodoscope for Ultra-Stable neutraL pArticles), which opens a new avenue for discovery of Physics Beyond the Standard Model at the LHC. The large-volume detector will be placed above the CMS experiment with O(100) m of rock separation from the LHC interaction point. It is instrumented with a tracking system to observe LLP decays inside its empty volume. The experiment is composed of a modular array of detectors covering together (100 × 100) m² × 25 m high. It is planned in time for the high luminosity LHC runs. MATHUSLA, with a large detection area and good granularity tracking system, is also an efficient cosmic-ray Extended Air Shower detector. We will describe the basic detector concept and layout, the current status of the project, the on-going cosmic ray studies, as well as the future plans. Moreover, we will report on the background studies and the results obtained with the test stand installed on the surface above the ATLAS detector in 2018.
Astro-particle Physics and Cosmology - Posters / 46

Tachyon Logamediate Inflation on DGP Braneworld Gravity

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Inflation as the intersection of cosmology and high energy physics will be studied in this manuscript. Among many inflationary models we consider the one with a logarithmic scale factor, called logamediate inflation. On the other hand, the idea of extra dimensions in cosmology is closely related to high energy physics and here, we are interested in studying the logamediate inflationary paradigm in the context of a special extra dimensional theory proposed by Dvali, Gabadadze and Porrati (DGP), in which our 4D universe is assumed to be a brane embedded in a 5D infinite Minkowski bulk. To drive inflation we use a tachyon scalar field as the inflaton field. After the reconstruction of the tachyonic potential and calculating the slow-roll parameters, we turn to perturbation theory and constrain our model parameters using new observational data. then we will show this model can be compatible with the latest observational data.

Beyond the Standard Model / 48

The MoEDAL Experiment - The LHC’s First Dedicated Search Experiment – Results and Future Plans

Author: James Pinfold

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The unprecedented collision energy of the LHC has opened up a new a discovery frontier, where a theory underlying the Standard Model may yet be revealed. Now that the Higgs boson - the last piece of the Standard model puzzle - has apparently been discovered, the search for such new phenomena has assumed a key importance. However, the LHC has been running for several years and no signals for physics beyond the Standard Model have been observed. Either this new physics is simply not there, or it is somehow evading detection by the general-purpose LHC experiments, ATLAS and CMS. We will present the current results and future plans of the LHC’s pioneering dedicated search detector, MoEDAL. As far as future plans are concerned we will concentrate on the new sub-detector MAPP due to be installed for LHC’s Run-3, to enhance the physics reach of MoEDAL and widen the LHC’s discovery horizon.
**Dark Matter Detection / 49**

**MeV neutrino dark matter: Relic density, lepton flavour violation and electron recoil**

**Authors:** Juri Fiaschi; Michael Klasen; Miguel Vargas; Christian Philipp Weinheimer; Sybrand Zeinstra

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Right-handed neutrinos with MeV to GeV mass are very promising candidates for dark matter (DM). Not only can they solve the missing satellite puzzle, the cusp-core problem of inner DM density profiles, and the too-big-to-fail problem, i.e. that the unobserved satellites are too big to not have visible stars, but they can also account for the Standard Model (SM) neutrino masses at one loop. We perform a comprehensive study of the right-handed neutrino parameter space and impose the correct observed relic density and SM neutrino mass differences and mixings. We find that the DM masses are in agreement with bounds from big-bang nucleosynthesis, but that these constraints induce sizeable DM couplings to the charged SM leptons. We then point out that previously overlooked limits from current and future lepton flavour violation experiments heavily constrain the allowed parameter space. Since the DM is leptophilic, we also investigate electron recoil as a possible direct detection signal, in particular in the XENON1T experiment.

**Secondary track (number):**

**Beyond the Standard Model / 50**

**Resummation effects in weak SUSY processes**

**Authors:** Juri Fiaschi; Michael Klasen

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**Corresponding Authors:** fiaschi@uni-muenster.de, michael.klasen@uni-muenster.de

Updated results for electroweak production of SUSY particles at the LHC Run-II are given with NLO+NLL (next-to-leading-order plus next-to-leading-logarithmic) accuracy, consistently computed with novel PDFs with resummation-improved matrix elements. A factorisation method is applied to exploit the smaller PDF uncertainty of the global PDF sets and to avoid complications arising in the refitting of threshold-resummation improved PDF replicas in Mellin space. The reduction of the scale uncertainty due to the resummation is, however, explicitly taken into account. As expected, the resummation contributions in the PDF fits partially compensate the cross section enhancements induced by those in the partonic matrix elements. Results are given for neutralino and chargino pair production in their mostly higgsino or gaugino configuration, and for left-handed selectron/smuon, right-handed and maximally mixed stau pair production. For the case of slepton pair production further improved results with next-to-next-to-leading logarithmic (NNLL) accuracy, matched to approximate next-to-next-to-leading order (aNNLO) QCD corrections are presented, showing a further significant reduction of the factorisation and renormalisation scale dependence that stabilises the predictions to the permil level.

**Secondary track (number):**

**Neutrino Physics / 51**
New results from the DANSS experiment

Authors: Mikhail Danilov\textsuperscript{1}; for the DANSS Collaboration\textsuperscript{None}

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We present new results of the DANSS experiment on searches for sterile neutrinos. They are based on more than 3 million of inverse beta decay events collected at 3 distances from the reactor core of the 3.1 GW Kalinin Nuclear Power Plant in Russia. This data sample is more than 3 times larger than the data sample in the previous DANSS publication. In addition to the most robust analysis based on the comparison of the antineutrino energy spectrum shape at different distances, we will present also the analysis which uses information about the counting rates as well. We compare the shape of the antineutrino energy spectrum with theoretical predictions. The antineutrino energy spectrum dependence on fuel composition is also presented. We present the relative IBD rate dependence on the fission fraction of $^{239}$Pu for different antineutrino energy ranges as in the Daya Bay analysis with comparable errors and a somewhat larger range of $^{239}$Pu fission fraction. We compare obtained results with the theoretical expectations and with the results from Daya Bay and RENO. We have also measured the reactor power using the IBD event rate during more than 3 years with a statistical accuracy of 1.5% in 2 days.

Secondary track (number):

Technology Applications, Industrial Opportunities and Sustainability / 52

Characterization of background noise in muography using the Muon Telescope (MuTe)

Authors: Jesús Peña Rodríguez\textsuperscript{1}; Luis Nuñez\textsuperscript{1}

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The MuTe is a hybrid muon telescope used for density imaging of volcanos by means of measurements of the atmospheric muon flux attenuation depending on the amount of rock crossed at different angles. The detector will be placed at one of the most dangerous volcanoes in Colombia, the Cerro Machin volcano, located in the South-West of Colombia. MuTe hodoscope reconstructs 3841 different directions reaching an angular resolution of 32 mrad for an inter-panel distance of 2.5 m. The MuTe has a spatial resolution of ~25.6 m assuming an 800 m distance to the volcano.

Taking into account muography suffers of contamination from different physical sources such as upward coming muons, scattered muons, particles of the soft component of Extended Air Showers (EAS) and particles arriving simultaneously, MuTe incorporates two particle identification systems, a water Cherenkov detector (WCD) and a Time-of-Flight system in order to filter such fake events. The WCD measures the energy loss (> 50 MeV) of the detected particles (muons or background) allowing us to differentiate single muons, electrons/positrons, and multiparticle events. On the other hand, using ToF measurements (~50 ps resolution), Mute is able to estimate the momentum of detected muons establishing an energy threshold for reducing the background contribution of scattered muons. Additionally, upward coming muons are filtered using the arrival direction of detected particles which is determined also by the ToF system.

We found that near 36% of the recorded events belong to the electromagnetic component of EAS (electrons and positrons), roughly 30.4% is caused by multiparticle events that arrive with time differences < 100 ns and the last 34% are caused by muons. The muonic component of the data is composed of scattered muons, upward coming muons and high energy muons (> 1 GeV).

Secondary track (number):
First Demonstration of Ionization Cooling by the Muon Ionization Cooling Experiment

Author: Jaroslaw Pasternak

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Muon colliders have the potential to carry the search for new phenomena to energies well beyond the reach of the LHC in the same or smaller footprint. Muon beams may be created through the decay of pions produced in the interaction of a proton beam with a target. To produce a high-brightness beam from such a source requires that the beam be cooled. Ionization cooling is the novel technique by which it is proposed to cool the beam. The Muon Ionization Cooling Experiment collaboration has constructed a section of an ionization cooling cell and used it to provide the first demonstration of ionization cooling. Here the observation of ionization cooling is described. The cooling performance is studied for a variety of beam and magnetic field configurations. The cooling performance is related to the performance of a possible future muon collider facility.

I read the instructions:

Secondary track (number):

Muon accelerators

Muon Ionization Cooling Demonstration by Normalized Transverse Emittance Reduction in MICE 'Flip Mode'

Author: Paul Jurj

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Low emittance muon beams are central to the development of facilities such as a Neutrino Factory or a Muon Collider. The international Muon Ionization Cooling Experiment (MICE) was designed to demonstrate and study the cooling of muon beams. Several million individual muon tracks have been recorded passing through a liquid hydrogen or a lithium hydride absorber. Beam sampling routines were employed to account for imperfections in beam matching at the entrance into the cooling channel and enable an improvement of the cooling performance. A study of the change in normalized transverse emittance in a flipped polarity magnetic field configuration is presented and the characteristics of the cooling effect are discussed.

I read the instructions:
Emittance exchange in MICE

Author: craig brown

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Highly brilliant muon beams for a muon collider can be made from the bombardment of protons against a target producing pions, which subsequently decay into muons. Such a muon beam occupies a large phase-space volume and must be cooled to achieve luminosities suitable for a muon collider. The Muon Ionization Cooling Experiment (MICE) has demonstrated transverse ionization cooling. A muon collider requires both longitudinal and transverse cooling. This can be achieved through a wedge-shaped absorber, where both the longitudinal and transverse phase spaces are simultaneously manipulated during the ionization cooling process. The change in longitudinal and transverse phase space densities obtained from placing a polyethylene wedge into the MICE cooling channel are presented here.

I read the instructions:

Secondary track (number):
Muon accelerators

Transverse Emittance Change in MICE 'Solenoid Mode' with Muon Ionization Cooling

Author: Tom Lord

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Emittance reduction of muon beams is an important requirement in the design of a next-generation Neutrino Factory or Muon Collider. Ionization cooling has been proposed to meet this requirement, whereby beam emittance is reduced by passing a beam through absorbing material. Tight focussing is required in both horizontal planes, which is achieved in many designs using solenoid focusing. Ionization cooling has been demonstrated in the Muon Ionization Cooling Experiment (MICE) in 'flip' mode, where the solenoid field flips polarity across the absorber. We present the performance of MICE in 'solenoid' mode, where the field polarity does not change across the absorber.

I read the instructions:

Secondary track (number):
Muon accelerators
NEWSdm: Directional Dark Matter Search with Nuclear Emulsion

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The nature of dark matter (DM) is one of the most relevant open problems both in cosmology and particle physics. Many different experimental techniques have been developed to detect Weakly Interactive Massive Particles (WIMPs) as dark matter candidates via their scattering with detector atoms. The NEWSdm experiment, located in the Gran Sasso underground laboratory in Italy, is based on a novel nuclear emulsion technology with nanometric resolution and new emulsion scanning microscopy that can detect recoil track lengths down to one hundred nanometers. Thus, NEWsdm is able to reconstruct the direction of the nucleus recoiling, thus being capable of confirming the Galactic origin of the dark matter. We discuss the potentiality, both in terms of exclusion limits and discovery potential, of a directional experiment based on the use of a solid target made by newly developed nuclear emulsions and read-out systems reaching nanometric resolution. We also report the results of the test exposure conducted in Gran Sasso.

I read the instructions:

Secondary track (number):

Neutrino Physics / 58

Production of $\nu_\tau$ neutrinos and $\bar{\nu}_\tau$ antineutrinos - elaborate calculation for a fixed target experiment SHiP

Authors: Rafal Maciula¹; Antoni Szczurek²

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We discuss how to calculate cross sections as well as rapidity, transverse momentum and energy distributions of $\nu_\tau$ and $\bar{\nu}_\tau$ produced from the direct $D^+ \rightarrow \nu_\tau/\bar{\nu}_\tau$ and chain $D_s^0 \rightarrow \tau^+/\tau^- \rightarrow \nu_\tau/\bar{\nu}_\tau$ decays in $p^{36}$Mo scattering with proton beam $E_{\text{lab}} = 400$ GeV \textit{i.e.} at $\sqrt{s_{NN}} = 27.4$ GeV. Both direct neutrinos and neutrinos from $\tau$ lepton decays (chain decays) are included. The $\tau$ decays are simulated with the help of the \textsc{Tauola} code and include large number of decay channels. In our calculations we include $D^\pm_s$ from charm fragmentation ($c \rightarrow D^\pm_s$ and $\bar{c} \rightarrow D^-_s$) as well as those from subleading fragmentation of strange quarks/antiquarks $s \rightarrow D^-_s$ and $\bar{s} \rightarrow D^+_s$. The $s \neq \bar{s}$ asymmetry of the strange quark content of proton is included. The different contributions to $D^\pm_s$ and $\nu_\tau/\bar{\nu}_\tau$ are shown explicitly. We discuss and quantify a not discussed so far effect of asymmetries for production of $\nu_\tau$ and $\bar{\nu}_\tau$ caused by (helicity) polarization of $\tau^\pm$ from the first (weak) decay $D^\pm_s \rightarrow \tau^\pm$. We try to estimate also effect of the production asymmetry caused by subleading fragmentation mechanism and discuss related uncertainties. A potential measurement of the asymmetry is discussed. Estimates of a number of observed $\nu_\tau/\bar{\nu}_\tau$ in the $\nu_\tau/\bar{\nu}_\tau +^{208}$Pb reaction, with 2m long target are given with the help of the NuWro program. We refer also to the production of the high-energy (anti)neutrinos in the atmosphere.

R. Maciula, A. Szczurek, J. Zaremba and I. Babiarz,
"Production asymmetry of $\nu_\tau$ neutrinos and $\bar{\nu}_\tau$ antineutrinos from a fixed target experiment SHiP" J. High Energy Phys. 01, 116 (2020).
**Top Quark and Electroweak Physics / 59**

**γγ → γγ in heavy ion collisions – new results and prospects**

**Authors:** Mariola Kłusek-Gawenda\(^1\); Antoni Szczurek\(^2\)

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So far light-by-light scattering (\(\gamma\gamma \rightarrow \gamma\gamma\)) was not accessible for experiments because the corresponding cross section is rather low. Measurements of diphotons in ultra-peripheral collisions (UPCs) of lead-lead have been reported recently by the ATLAS and CMS Collaborations. Our theoretical results based on equivalent photon approximation in the impact parameter space are in good agreement with the current data.

We will discuss how to extend such studies to lower \(\gamma\gamma\) energies where photoproduction of pseudoscalar and scalar resonances contribute to the two-photon final state. In addition, we consider the dominant background that arises from \(\gamma\gamma\) fusion into pairs of neutral pions. Such \(\pi^0\)-pairs contribute to the background when only two of the four decay photons are within the experimental acceptance, the other two photons escape undetected. We will discuss in detail how to reduce the unwanted background.

We will present differential distributions and total cross section in ultra-peripheral Pb-Pb collisions at \(\sqrt{s_{NN}} = 5.05\) and 5.52 TeV and cross section for Ar-Ar collisions at the energy equal to 6.3 TeV. Results for ALICE and LHCb acceptance will be presented.

[1] M. Kłusek-Gawenda, R. McNulty, R. Schicker, A. Szczurek

"Two-gluon exchange contribution to elastic \(\gamma\gamma \rightarrow \gamma\gamma\) scattering and production of two-photons in ultraperipheral ultrarelativistic heavy ion and proton-proton collisions", Phys.Lett. B761 (2016) 399,

[3] M. Kłusek-Gawenda, P. Lebiedowicz, A. Szczurek

**Heavy Ions / 60**

**Dielectron production: QGP versus photon – photon mechanism**

**Authors:** Mariola Kłusek-Gawenda\(^1\); Antoni Szczurek\(^2\); Wolfgang Schaefer\(^3\)

\(^1\) IFJ PAS
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\(^3\) Institute of Nuclear Physics PAN

**Secondary track (number):**

04
We calculate cross sections for di-lepton photoproduction in ultrarelativistic heavy-ion collisions from low (SPS) to high (LHC) energy. We study the invariant-mass distributions of dileptons produced in ultrarelativistic heavy-ion collisions at very low pair transverse momenta, $P_T < 0.15$ GeV. Specifically, we investigate the interplay of thermal radiation with initial photon annihilation processes, $\gamma \gamma \rightarrow \ell^+ \ell^-$, triggered by the coherent electromagnetic fields of the incoming nuclei. For the thermal radiation, we employ the emission from the QGP and hadronic phases with in-medium vector spectral functions which describes the inclusive excess radiation observed over a wide range of collision energies. For the coherent photon fusion processes, whose spectrum is much softer than for thermal radiation, we employ initial fluxes from the Fourier transform of charge distributions of the colliding nuclei in the equivalent-photon approximation.

We first verify that the combination of photon fusion, thermal radiation and final-state hadron decays gives a fair description of the low-$P_T$ invariant-mass as well as $P_T$ spectra as recently measured by the STAR collaboration in $\sqrt{s_{NN}} = 200$ GeV Au+Au collisions for different centrality classes, including experimental acceptance cuts. The coherent contribution dominates in peripheral collisions, while thermal radiation shows a markedly stronger increase with centrality. We extend the calculations to lower collision energies ($\sqrt{s_{NN}} = 17.3$ GeV) and compare to the acceptance-corrected dimuon excess spectra measured by the NA60 experiment at the CERN SPS; the contribution from photoproduction turns out to be negligible. We also provide predictions for the ALICE experiment at the LHC. The resulting excitation function from SPS to LHC energies reveals a nontrivial interplay of photoproduction and thermal radiation.


Secondary track (number): 06

Dark Matter Detection / 61

Status and Plan of PandaX Experiment

Author: Ning Zhou

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The PandaX experiment uses liquid xenon as the target material to perform the dark matter direct detection at China Jinping Underground Laboratory. In 2019, the PandaX-II experiment with 580 kg liquid xenon in the sensitive volume finished the data-taking and the total exposure is around 140 ton-day. Currently, the PandaX collaboration is planning for the next generation multi-ton liquid xenon experiment. The immediate next step is a 4-ton scale liquid xenon experiment, PandaX-4T, with which we expect to extend the sensitivity to WIMP search by one order of magnitude as compared to the PandaX-II experiment. In this talk, I will discuss the latest results from the PandaX-II experiment and the progress of the PandaX-4T experiment.

Secondary track (number):
Constraints on nonstandard interactions and the neutron radius from coherent elastic neutrino-nucleus scattering experiments

**Author:** Alexander Parada Valencia

**Co-authors:** Omar Miranda ; Blanca Cañas ; Estela Garcés ; Gonzalo Sanchez

1 Universidad Santiago de Cali

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There are expectations for achieving new measurements of the coherent elastic neutrino-nucleus scattering (CENNS) by using electron antineutrinos from reactor experiments and through muon (electron) neutrinos from spallation neutrino sources (SNS). The first scenario takes into account very low energy neutrinos while the second one includes relatively higher energy neutrinos. These measurements would allow improve our knowledge about standard and beyond Standard Model physics, for instance as regards the nuclear radius and nonstandard interactions, respectively. In this talk we will show constraints on the neutron radius and nonstandard parameters obtained from CENNS processes in experiments of both reactor neutrinos and SNS. We will also display that a combination of several experiments could give rise to more robust constraints on the parameters mentioned above.

I read the instructions:

Secondary track (number):

Dark Matter Detection/Diversity and Inclusion - Posters / 63

Colliding light to make dark matter at the LHC

**Author:** Jesse Liu

**Co-author:** Lydia Audrey Beresford

1 University of Chicago

2 University of Oxford (GB)

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Dark matter is mysterious because it doesn’t interact with light. How remarkable it would be if we made it in the lab by colliding light. Electromagnetic fields surrounding protons at the LHC source the world’s highest energy beam of photons. Interestingly, the photon-photon collision rate is sufficiently high for pair production of new heavy states such as supersymmetric particles decaying to dark matter. Importantly, the protons remain intact and can be tagged using recently installed Roman Pot detectors, allowing complete initial state and missing momentum 4-vector reconstruction. This proposal opens a new class of dark matter search at accelerators with sensitivity to current blind spots that excitingly could be realised with today’s dataset. Based on Phys. Rev. Lett. 123 (2019) 141801

Secondary track (number):
Lambdac physics and prospects at BESIII

Author: Le Li

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BESIII collected an e+e- collision data set corresponding to an integrated luminosity of 0.567 fb-1 at a center-of-mass energy of 4.6 GeV. This energy is above the threshold for Lambdac Lambdac-production. This talk reports measurements of the absolute branching fractions of both Cabibbo-favoured and Cabibbo-suppressed hadronic decays. In addition, measurements of semileptonic and inclusive final state branching fractions, as well as the weak decay asymmetry, are reported. These measurements are either the first or more precise than previous ones. During 2020 additional data with integrated luminosity of 3-4 fb-1 will be accumulated at centre-of-mass energies between 4.62 to 4.70 GeV. The prospects for Lambdac physics with this new data set are presented.

The MCP based Large Area PMTs for Neutrino Detector

Author: Sen Qian

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The large scalar neutrino detectors (JUNO, HyperK), need the 20 inch area PMTs as the photo-detection device for their large photocathode coverage and less electronic channels. In 2009, the researchers at IHEP have conceived a new concept of large area PMTs, of which the small MCP units replace the bulky Dynode chain. After several years R&D, the 20 inch MCP-PMT was successfully produced. This type of PMT has large sensitive area, high QE, and large P/V for good single photon detection. The JUNO ordered 15000 pic 20 inch MCP-PMTs in Dec.2015. Then, from 2017 to 2020, all the 20-inch PMTs will be produced and tested one by one in the company for JUNO. This presentation will talk about the R&D, the mass production and batch test result of the 13K pieces of MCP-PMT prototypes for JUNO. Further more, another Flower-liked MCP-PMT was designed with the TTS less than 5ns, and this new type of 20 inch MCP-PMT has already evaluated by the PMT group in HyperK, and also be used in the LHAASO project in China.

The R&D of the Ultra Fast 8X8 Readout MCP-PMTs

Author: Sen Qian

Corresponding Author: qians@ihep.ac.cn

The large scalar neutrino detectors (JUNO, HyperK), need the 20 inch area PMTs as the photo-detection device for their large photocathode coverage and less electronic channels. In 2009, the researchers at IHEP have conceived a new concept of large area PMTs, of which the small MCP units replace the bulky Dynode chain. After several years R&D, the 20 inch MCP-PMT was successfully produced. This type of PMT has large sensitive area, high QE, and large P/V for good single photon detection. The JUNO ordered 15000 pic 20 inch MCP-PMTs in Dec.2015. Then, from 2017 to 2020, all the 20-inch PMTs will be produced and tested one by one in the company for JUNO. This presentation will talk about the R&D, the mass production and batch test result of the 13K pieces of MCP-PMT prototypes for JUNO. Further more, another Flower-liked MCP-PMT was designed with the TTS less than 5ns, and this new type of 20 inch MCP-PMT has already evaluated by the PMT group in HyperK, and also be used in the LHAASO project in China.
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The Micro-Channel Plate (MCP) is a specially crafted microporous plate with millions of independent channels, which have secondary electron emission capability. The MCP could be used as the electronic multiplier amplifier in the PMTs. There are two types of MCP Photomultiplier tube (MCP-PMT), large-area electrostatic focusing PMTs (LPMT) and small size proximity focusing PMTs (FPMT) respectively. The LPMT always used in the large scalar neutrino detector for its large area efficiency photocathode. The small size FPMT has many advantages such as fast time response, strong anti-interference ability, small volume and light weight, which could be widely used in high energy physics, optical instruments, Medical imaging and other fields. The MCP-PMT Collaboration Group in China has successfully research and developed the 20 inch large area MCP-PMT (LPMT) for JUNO in 2017, and plan to research a new type of small plant MCP-PMT (FPMT) with multi-anode readout (4X4, 8X8). In this talk, we will introduce some design of the FPMTs for the time measurement, and the performance of the several different prototypes with different readout channels.

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**Strong Interactions and Hadron Physics / 67**

**QCD analysis for Transverse momentum dependent of fragmentation functions for light hadrons from e+e^- annihilation process**

**Author:** Maryam Soleymaninia¹

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In this paper we determine a new set of transverse momentum dependence of unpolarized fragmentation function (TMD FF) in single inclusive hadron production in electron-positron annihilation (SIA) process. In this analysis, we use the most recent TMD production cross sections of charged pions, kaons and protons/antiprotons measured in inclusive e⁺e⁻ collisions by Belle Collaboration. These datasets are the first transverse momentum dependence of identified light charged hadron measurements SIA process. The uncertainties in the extraction of TMD FFs are estimated using the standard “Hessian” technique. For all hadron species, we found a very good agreement between this particular set of experimental data and the corresponding theory calculations over a relatively wide range of transverse momentum $P_T$.

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**Quark and Lepton Flavour Physics / 68**

**Radiative and Rare Charm Decays at BESIII**

**Author:** Bo Zheng¹

¹ University of South China
In this talk, we present the latest result on radiative and rare/forbidden decays for D mesons at the BESIII experiment based on 2.92 fb-1 and 3.19 fb-1 data taken at the center-of-mass energy 3.773 GeV with the BESIII detector, respectively. Based the data at 4.178 GeV, a search for the rare radiative leptonic decay $D_s \rightarrow \gamma e^+ \nu$ is performed for the first time with negative result and an upper limit (UL) of the branching fraction (BF) is set to be less than $1.3 \times 10^{-4}$ at 90\% confidence level (CL). With this data sample, we also search for the rare decay $D_s \rightarrow p \bar{p} e^+ \nu$. No significant signal is observed, and an UL $B(D_s \rightarrow p \bar{p} e^+ \nu) < 2.0 \times 10^{-4}$ is determined at the 90\% CL. Using the dataset at 3.773 GeV, we search for rare decays of $D \rightarrow h(h')e^+e^-$ with double tag method, where $h(\bar{h})$ are hadrons. No significant excess over the expected backgrounds is observed, the ULs on the signal BF at the 90\% CL are determined. For the $D^+$ decays, the searches are performed for the first time, while for $D_0$ decays, the ULs are improved in general by a factor of 10, compared to previous measurements. All the ULs on the BF, at the level of $10^-5 \ldots 10^-6$, are above the SM predictions, which include both LD and SD contributions. Also, we search for the Majorana neutrino in the leptonic number violating ($LNV$) decays $D \rightarrow K\pi e^+e^-$. No significant signal is observed, and the ULs on the BF at the 90\% CL are set to be less than few $10^-6$. The Majorana neutrino is searched for with different mass assumptions ranging from 0.25 to 1.0 GeV. The constraints on the mixing matrix element $|V_{eN}|^2$ are also evaluated.

Beyond the Standard Model / 69

BNV/LNV searches in charmonium decays at BESIII

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The observed matter-antimatter asymmetry in the universe poses a serious challenge to our understanding of nature. BNV/LNV decay has been searched in many experiments to understand this large-scale observed fact. In the case of $e^+e^-$ collision, few experiments are performed. Here we proposed to search BNV and LNV with the world largest $J/\psi$ data sets in $e^+e^-$ c. The BNV and LNV channel $J/\psi \rightarrow \Lambda\bar{\Lambda}$ is studied, and no signal event is observed. The upper limit of the branching fraction is set to be $6.9 \times 10^-8$ at 90\% C.L., which is still much higher than the estimation based on SM. For the process with Delta B=2, a search of Lambda-Lambdabar oscillation is performed in the $J/\psi$ decay. The results of the oscillation rate and oscillation parameter are determined, respectively.

Strong Interactions and Hadron Physics / 71

Light meson decays at BESIII

Author: Isabella Garzia

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Due to the high production rate of light mesons in J/psi decays, the high statistics sample of 1.3 billion J/psi events provide an ideal lab to investigate the decay dynamics of light mesons, in particular for eta and eta prime. Recently the BESIII experiment made significant progresses in eta and prime decays, including their hadronic and rare decays, which will be reported in this talk.

I read the instructions:

Secondary track (number):

Strong Interactions and Hadron Physics / 72

**Light baryon spectroscopy at BESIII**

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Based on the large samples of Jpsi and Psi(2S) events accumulated at the BESIII detector, the recent results on baryon spectroscopy will be presented. Most recently, the 10 billion J/psi events is available at BESIII experiment, the perspectives on the baryon spectroscopy at BESIII will also be discussed.

I read the instructions:

Secondary track (number):

Strong Interactions and Hadron Physics / 73

**Polarised and entangled hyperon-antihyperon pairs in BESIII**

**Author:** Stina Karin Schoenning

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Structure, interactions and decays of hyperons can be studied at an electron-positron collider in annihilations to a hyperon-antihyperon pair. The well-defined and simple, initial state makes a baryon-antibaryon pair production at an electron-positron collider a perfect system to test discrete symmetries in the baryon sector and to study baryon properties. In particular the 1e10 J/Psi events collected at BESIII allow for precision studies of the ground state octet baryon-antibaryon pair production.

The highlight so far is the observation of Lambda hyperon polarization in the J/psi->Lambda anti-Lambda decay, the result recently published in Nature Phys. (Nature Phys. 15, 631 (2019)). The polarization allows to determine both the Lambda->p pi- Lambda and anti-Lambda->anti-p pi+ decay asymmetries. Of major importance is the result for the Lambda->p pi- asymmetry parameter of 0.750+/-0.009+/-0.004 which is 17(3)% larger than the reference value used in all experiments measuring Lambda polarization for nearly 50 years. Studies of the remaining ground state baryon-antibaryon pairs under way and preliminary results will be presented e.g. for Sigma+Sigma- where the polarization is also observed.

The e+e–> Lambda anti-Lambda reaction was studied at BESIII also outside the J/psi resonance at c.m. energy of 2.396 GeV. The result is the first complete determination of the time-like elastic form factors G_M and G_E including the relative phase of (37+12+6)^o (PRL 123 (2019) 122003).

About 10 billion J/psi events have been collected by the BESIII detector at BEPCII recently. The decay rates of J/psi to hyperon anti-hyperon (Lambda, Sigma, Xi etc.) are at the order of 10^-3, therefore about a few millions of quantum-correlated hyperon-anti-hyperon pairs, which allows to measure...
the decay parameters (including CPV) and polarizations with higher precision. In particular, it is also offer a unique opportunity to investigate the CP asymmetry in the hyperon production (EDM) and decays, as well rare hyperon decays, which are sensitive to the physics beyond Standard Model. In this talk, the recent results on hyperon physics will be reported.

I read the instructions:

Secondary track (number):

Strong Interactions and Hadron Physics / 74

Recent result on XYZ states at BESIII

Author: Peirong Li

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Starting from the observation of X(3872) in 2003, tens of new structures located in the charmonium energy region above the open-charm threshold have been observed. They carry exotic properties comparing to the conventional charmonium states, and are called as charmonium-like or XYZ states. Utilizing about 17 fb^-1 electron positron collision data samples accumulated at center of mass energies between 3.8 and 4.6 GeV at the BESIII experiment, recent studies of the XYZ states will be presented. New and more precise decay information of X(3872) will be discussed. The Y states are studied from the energy dependent cross section of new processes of pi^+ pi^+ psi(3770), D_1(2430)^0 D^0, Xi Xi-bar, and eta(‘) psi(1,2S). New evidence of the charged Zc(3900) decay into rho eta_c will also been introduced.

I read the instructions:

Secondary track (number):

Strong Interactions and Hadron Physics / 75

New observation in charmonium decays

Author: Weimin Song

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The world’s larges sample of 4.48 \times 10^8 \psi(2S) events provides good opportunities for the study of \chi_cJ, eta_c, and h_c decays via its radiative transition. Using this data sample, a lot of progress on \chi_cJ and h_c decays has been made. New results, including the observation of OZI suppressed decays \chi_cJ -> phi omega, measurements of \chi_cJ -> phi phi eta, observation of \chi_cJ -> 4 Ks and sigma p-bar Ks, observation of new h_c hadronic decay modes will be introduced.

I read the instructions:

Secondary track (number):
Study of \( \phi(2170) \) at BESIII

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For \( e^+e^- \) collision between 2 and 3 GeV, excited states of rho, omega and phi could be produced directly, some of them are not fully studied yet, especially several resonances around 2GeV like rho(2000), rho(2150) and \( \phi(2170) \). Theorists explain \( \phi(2170) \) as a traditional s s-bar state, s s-bar g hybrid, tetraquark state, Lambda Lambda-bar bound state, and phi KK resonance state, and predict very different decay width with different nature of \( \phi(2170) \). In review of experimental side, the number of decay modes of \( \phi(2170) \) are limited, and there is inconsistencies on mass and width of \( \phi(2170) \). With energy scan data collected by BESIII detector between 2.0GeV and 3.08GeV, we performed PWA of \( e^+e^- \rightarrow K^+K^-\pi^0\pi^0 \), and extracted lineshape of \( K(892)K(892)^\text{bar} \), \( KK_1(1460) \), \( KK_1(1270) \) and \( KK_1(1400) \), and compared BESIII results that of theory prediction (arXiv: 2001.04131). We report results on \( \phi(2170) \rightarrow \phi \eta' \) and \( \phi \eta \), compare their ratio with that of hybrid prediction on \( \phi(2170) \). We also present results on \( e^+e^- \rightarrow K^+K^- \) (Phys. Rev. D99, 032001 (2019)), \( \phi K^+K^- \) (Phys. Rev. D100, 032009(2019)), omega pi0 and omega eta. We also use lineshape of \( e^+e^- \rightarrow \eta' \pi^+ \pi^- \) to study rho(2000) and rho(2150).

Semileptonic and leptonic charm decays at BESIII

Author: Sanqiang Qi

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BESIII has collected data samples corresponding to luminosities of 2.93 fb\(^{-1}\) and 3.19 fb\(^{-1}\) at center-of-mass energies of 3.773 and 4.178 GeV, respectively. In addition, data samples with a luminosity of about 3 fb\(^{-1}\) at center-of-mass energies between 4.19 and 4.23 GeV are used to study Ds decays in some analyses. We report recent measurements that include the decays D(s)+ \( \rightarrow l^+ \) nu (l=e, mu, tau), D0(+) \( \rightarrow K^0\bar{\pi}^0 l^+ \) nu, D+ \( \rightarrow K^+(\pi^0) l^+ \) nu, D(s)+ \( \rightarrow \phi l^+ \) nu, D(s)+ \( \rightarrow \phi \eta(980) l^+ \) nu, D(s)+ \( \rightarrow \phi \eta') l^+ \) nu, D(s)+ \( \rightarrow \phi \eta'' l^+ \) nu, and Ds \( \rightarrow \eta' l^+ \) nu, and Ds \( \rightarrow \phi l^+ \) nu. The first searches for Ds \( \rightarrow \gamma l^+ \) nu and Ds \( \rightarrow p \bar{p} l^+ \) nu are also presented. From these analyses, the decay constants \( f_D(s) \), the semileptonic form factors \( f^P_+(0) \) [P=K, pi, eta(‘)], the CKM matrix elements \( |V_{cs}| \) and \( |V_{cd}| \) are determined precisely. These results can verify the LQCD calculations of \( f_D(s) \), \( f^P_+(0) \) and the CKM matrix unitarity. Precision tests of lepton-flavor universality are also made via D(s)+ \( \rightarrow l^+ \) nu and D0(+) \( \rightarrow K^0\bar{\pi} l^+ \) nu, decays.

Hadronic charm meson decays at BESIII

Author: Chuangxin Lin

Quark and Lepton Flavour Physics / 79
BESIII has collected data samples corresponding to luminosities of 2.93 fb\(^{-1}\) and 3.19 fb\(^{-1}\) at center-of-mass energies of 3.773 and 4.178 GeV, respectively. The data set collected at 3.773 GeV contains quantum-correlated D0\(\bar{D}\)0 pairs that allow access to the phase differences between amplitudes. We report the measurements of strong phase differences in D0 decays, including KS/L pi\(^+\) pi\(^-\), which can reduce the gamma/phi3 measurement systematic uncertainty at LHCb and Belle II. In addition, we report the measurements of the absolute branching fractions and the amplitude analyses of D+, D0, and Ds decays.

Neutrino Physics / 81

**Matter vs Vacuum Oscillations in Atmospheric Neutrinos**

**Authors:** Jaydeep Datta\(^1\); Mohammad Nizam\(^1\); Ali Ajmi\(^1\); Sankagiri Umasankar\(^2\)

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Atmospheric neutrinos travel very long distances through earth matter. It is expected that the matter effects lead to significant changes in the neutrino survival and oscillation probabilities. Initial analysis of atmospheric neutrino data by the Super-Kamiokande collaboration is done using the vacuum oscillation hypothesis, which provided a good fit to the data. Existence of matter effects is well established for solar neutrino oscillations but not for atmospheric neutrino oscillations. In this work, we did a study to differentiate the effects of vacuum oscillations and matter modified oscillations in the atmospheric neutrino data. We find that magnetized iron detector, ICAL at INO, can make a 3 \(\sigma\) discrimination between vacuum oscillations and matter oscillations in ten years, for both normal and inverted hierarchies.

Quark and Lepton Flavour Physics / 82

**Towards establishing the second b-flavored CKM unitarity triangle**

**Author:** Zhi-zhong Xing\(^1\)

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With the help of the generalized Wolfenstein parametrization of quark flavor mixing and CP violation, we calculate fine differences between the twin b-flavored unitarity triangles defined by

\[ V_{ub}^* V_{ud} + V_{cb}^* V_{cd} + V_{tb}^* V_{td} = 0 \text{ and } V_{ud}^* V_{td} + V_{us}^* V_{ts} + V_{ub}^* V_{tb} = 0 \]

in the complex plane. We find that apexes of the rescaled versions of these two triangles, described respectively by

\[ \tilde{\eta} = -\frac{(V_{ub}^* V_{ub})}{(V_{cb}^* V_{cd})} \text{ and } \tilde{\rho} + i\tilde{\eta} = -\frac{(V_{ub}^* V_{tb})}{(V_{us}^* V_{ts})} \],

are located on a circular arc whose center
and radius are given by $O = (0.5, 0.5 \cot \alpha)$ and $R = 0.5 \csc \alpha$ with $\alpha$ being their common inner angle. The small difference between $(\rho, \eta)$ and $(\bar{\rho}, \bar{\eta})$ is characterized by $\rho - \bar{\rho} \sim \eta - \bar{\eta} \sim \mathcal{O}(\lambda^2)$ with $\lambda \approx 0.22$ being the Wolfenstein expansion parameter, and these two apexes are insensitive to the two-loop renormalization-group running effects up to the accuracy of $\mathcal{O}(\lambda^4)$. We suggest that the second $b$-flavored unitarity triangle can be established with the observables from $B^+_b$ and $B^{0}_b$ systems based on the high-precision measurements to be done at the upgraded LHCb and Belle II experiments, and a comparison between the twin $b$-flavor unitarity triangles will provide a consistency check of the CKM picture for CP violation and probe possible new physics in this connection.

Based on arXiv:1911.03292 accepted for publication in Phys. Lett. B.

### Operation, Performance and Upgrade of Present Detectors / 83

#### The Mu2e Electromagnetic Calorimeter

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The "muon-to-electron conversion" (Mu2e) experiment at Fermilab will search for the Charged Lepton Flavour Violating neutrino-less coherent conversion $\mu^- N(A,Z) \rightarrow e^- N(A,Z)$ of a negative muon into an electron in the field of an aluminum nucleus. The observation of such physics process would be the unambiguous evidence of the existence of physics beyond the Standard Model. The Mu2e detector is composed of a tracker and an electromagnetic calorimeter and an external veto for cosmic rays. The calorimeter plays an important role in providing excellent particle identification capabilities, a fast online trigger filter and aiding track reconstruction. The calorimeter requirements are to provide a large acceptance for $\sim 100$ MeV electrons and reach: 1) a time resolution better than 0.5 ns; 2) an energy resolution $O(10\%)$; 3) a position resolution of 1 cm. The detector has been designed as a state-of-the-art crystal calorimeter and employs pure Cesium Iodide (CsI) crystals and UV-extended Silicon PhotoMultipliers (SiPMs) readout by fast analog electronics with a digitization at 200 Msps. A design consisting of two disks, each one made of 674 crystals readout by two large area 2x3 arrays of SiPMs of 6x6 mm$^2$ area can largely satisfy Mu2e requirements. The detector has to satisfy many other demanding requests, such as keeping the required performance in an extremely hostile environment with 1 tesla axial magnetic field, high radiation level and $10^{-4}$ Torr vacuum. We have verified with a campaign of test beams that the CsI crystals will withstand the expected dose and fluence with a small light yield loss and the SiPMs will function under the expected neutron irradiation when cooled to 0 C. This requires a good engineering design of the calorimeter mechanics and its cooling system, in terms of performance as well as reliability. A large scale detector prototype has been constructed and tested at the beam test facility in Frascati. It consists of 51 pre-production crystals readout by a 102 SiPMs. All the tests and progresses done so far to define the calorimeter design, the satisfying results obtained with the test beam of the prototypes as well as the current production phase will be reported in this presentation. At the moment, all the components for the first disk have been tested and characterized. According to the Mu2e Collaboration plans, calorimeter construction will begin in spring 2020.

### Strong Interactions and Hadron Physics / 84
Searching for odderon exchange in exclusive $pp \rightarrow pp\phi$ and $pp \rightarrow pp\phi\phi$ reactions at the LHC

Authors: Piotr Lebiedowicz¹; Otto Nachtmann²; Antoni Szczurek³

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We discuss the possibility to use the $pp \rightarrow pp\phi$ and $pp \rightarrow pp\phi\phi$ reactions in identifying the odderon exchange. So far there is no unambiguous experimental evidence for the odderon, the charge conjugation $C = -1$ counterpart of the $C = +1$ pomeron, introduced on theoretical grounds in [1]. Last year results of the TOTEM collaboration [2] suggest that the odderon exchange can be responsible for a disagreement of theoretical calculations and the TOTEM data [4] for elastic proton-proton scattering. Similar conclusion can be drawn when comparing recent result for $\sqrt{s} = 2.76$ TeV with the Tevatron data [3]. It is premature to draw definite conclusion. Here we present some recent studies for two related processes where the odderon exchange may show up. We apply recently proposed tensor-pomeron and vector-odderon model for soft high-energy reactions [5].

The first reaction is central exclusive production of pairs of $\phi$ mesons. Here odderon exchange is not excluded by the WA102 experimental data [8] for high $\phi\phi$ invariant masses. The process is advantageous [6] as here odderon does not couple to protons (the corresponding coupling constant is probably small). Predictions for the LHC will be presented. The observation of $M_{\phi\phi}$ and the rapidity difference $Y_{\phi\phi}$ seems well suited to identify odderon exchange.

Finally we discuss the $pp \rightarrow pp\phi$ reaction [7]. At high energies probably the photon-pomeron fusion is the dominant process. The odderon-pomeron fusion is an interesting alternative. Adding odderon exchange with parameters adjusted for the $\phi\phi$ production improves considerably description of the proton-proton angular correlations measured by the WA102 collaboration [9]. At the low energy we consider also some other subleading processes that turned out to be rather small. Predictions for the LHC will be presented.


Secondary track (number):

Formal Theory / 85

Axial vector transition form factors in holographic QCD and their contribution to the muon g-2

Authors: Josef Leutgeb¹; Anton Rebhan²

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We evaluate axial vector transition form factors in holographic QCD models that have been shown to reproduce well recent experimental and theoretical results for the pion transition form factor. Comparing with L3 data on $f_1 \rightarrow \gamma \gamma^*$ we find remarkable agreement regarding the shape of single-virtual form factors, while deviating, in the double-virtual case, from a simple dipole model used previously to estimate the axial vector contribution to the anomalous magnetic moment of the muon through hadronic light-by-light scattering. We demonstrate that the holographic models can satisfy the Melnikov-Vainshtein short-distance constraint, if and only if the infinite tower of axial vector states is included. Numerically, we obtain a contribution to $g-2$ that is smaller than the original estimate by Melnikov and Vainshtein, but larger than other phenomenological approaches.

Secondary track (number):

Strong Interactions and Hadron Physics / 86

Central exclusive diffractive production of axial-vector $f_1(1285)$ and $f_1(1420)$ mesons in proton-proton collisions at the LHC

Authors: Piotr Lebiedowicz¹; Josef Leutgeb²; Otto Nachtmann³; Anton Rebhan¹; Antoni Szczurek⁴

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We present a new study of the central exclusive diffractive production of $f_1(1285)$ and $f_1(1420)$ resonances in proton-proton collisions within the tensor-pomeron approach [1], [2]. Two pomeron-pomeron-$f_1$ (l, S) tensorial couplings are possible a priori: $(l, S) = (2,2)$ and $(4,4)$. We adjust the parameters of our model to the WA102 experimental data [3] and compare with predictions of the Sakai-Sugimoto model, where the pomeron-pomeron-$f_1$ couplings are determined by the mixed axial-gravitational anomaly of QCD [4]. Then we present our predictions for the energies available at the LHC. The total cross section and several differential distributions are presented. We find for the $f_1(1285)$ a total cross section of about 35 µb for $\sqrt{s} = 13$ TeV and a rapidity cut on the $f_1$ meson of $|y| < 2.5$. Absorption corrections are included for our final distributions. Our results may be used to investigate the $pp \rightarrow pp\pi^+\pi^-\pi^+\pi^-$ reaction at LHC energies; see [5] for other diffractive mechanisms. The four-pion final state is also interesting in searches for glueballs. We predict a much larger cross section for production of $f_1(1285)$ than for production of $f_2(1270)$ (calculated within the same approach [6]) in the $\pi^+\pi^-\pi^+\pi^-$ decay channel for the LHC energies. This opens a possibility to study the $f_1(1285)$ meson in experiments planned at the LHC. We present several predictions for the ATLAS, CMS, ALICE, and LHCb experiments. Some effort to measure central exclusive four pion production at the energy $\sqrt{s} = 13$ TeV was initiated already by the ATLAS Collaboration [7].

Heavy Ions / 87

Tau g-2

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The electromagnetic moments of the tau lepton are highly sensitive to new physics but are challenging to measure due to the short tau lifetime. Given observed tensions for other lepton generations it is crucial to pin down the moments of the tau. We propose a strategy using heavy ion collisions at the LHC as an intense source of photon collisions in order to surpass 15 year old lepton collider constraints on the tau anomalous magnetic moment. This exciting possibility could be achievable today using data which has already been recorded. Based on arXiv:1908.05180 [hep-ph].

Secondary track (number):
05

Computing and Data Handling / 88

Providing the computing and data to the physicists: Overview of the ATLAS distributed computing system

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The ATLAS experiment at CERN uses more than 150 sites in the WLCG to process and analyze data recorded by the LHC. The grid workflow system PanDA routinely utilizes more than 400 thousand CPU cores of those sites. The data management system Rucio manages about half an exabyte of detector and simulation data distributed among these sites. With the ever-improving performance of the LHC, more data is expected to come and the ATLAS computing needs to evolve and adapt to that. Disk space will become more scarce which should be alleviated by more active usage of tapes and caches and new smaller data formats. Grid jobs can run not just on the WLCG sites but also on opportunistic resources, i.e. clouds and HPCs. A new grafana-based monitoring system facilitates operation of the ATLAS computing. This presentation will review and explain the improvements put in place for the upcoming Run 3 and will provide an outlook to the many improvements needed for the HL-LHC.

Secondary track (number):

Top Quark and Electroweak Physics / 89
**Recent measurements of electroweak boson properties at D0**

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We present a measurement of the shape of the transverse momentum distribution for W boson in the \(W \rightarrow e\nu\) decay channel using 4.3 fb\(^{-1}\) of \(p\bar{p}\) data at \(\sqrt{s} = 1.96\) TeV. The results are compared to QCD predictions both at reconstructed and particle level. We also present a measurement of the shape of the Z boson rapidity using \(Z/\gamma^* \rightarrow \mu^+\mu^-\) events produced in 8.6 fb\(^{-1}\) of \(p\bar{p}\) data. This measurement is compared to NNLO QCD predictions using different sets of parton density functions.

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**Quark and Lepton Flavour Physics / 91**

**Latest D0 results on exotic hadrons produced in \(p\bar{p}\) collision**

*Authors*: Bob Hirosky\(^1\); Boris Tuchming\(^2\); Alexey Drutskoy\(^{None}\)

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We selected candidate events for production of the exotic charged charmonium-like states \(Z_c^\pm(3900)\) decaying to \(J/\psi\pi^\pm\) and \(X(3872)\) decaying to \(J/\psi\pi^\pm\pi^\mp\). We use 10.4 fb\(^{-1}\) of \(p\bar{p}\) collisions recorded by the D0 experiment at the Tevatron collider at \(\sqrt{s} = 1.96\) TeV. We measure the \(Z_c\) mass and natural width using subsample of candidates originating from semi-inclusive weak decays of b-flavored hadrons and search for the \(Z_c\) prompt production. We measure different production properties of the \(X(3872)\), such as the prompt fraction as a function of the transverse momentum, that are compared to \(\psi(2S) \rightarrow \psi\pi^\pm\pi^\mp\) production. The sample of 10.4 fb\(^{-1}\) is also used to search for the inclusive production of the pentaquark states observed in \(pp\) collisions at LHCb, \(P_c(4400)\) and \(P_c(4457)\), decaying to \(J/\psi p\).

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**Strong Interactions and Hadron Physics / 92**

**Exclusive and semiexclusive production of vector mesons in proton-proton collisions with electromagnetic dissociation of protons**

*Authors*: Anna Cisek\(^1\); Wolfgang Schaefer\(^2\)

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We calculate distributions of different vector mesons in purely exclusive ($pp \rightarrow ppV$) and semiexclusive ($pp \rightarrow pXV$) processes with the electromagnetic dissociation of a proton. The cross section for exclusive production depends on wave function of the vector mesons and unintegrated gluon distribution function. We show results for rapidity and transverse momentum of vector mesons distributions. The cross section for the electromagnetic dissociation is expressed through electromagnetic structure functions of the proton. We include the transverse momentum distribution of initial photons in the associated flux. Contributions of the exclusive and semiexclusive processes are compared for different vector mesons ($V = \phi, J/\psi, \Upsilon$). We show the ratio of semiexclusive to exclusive contributions and we compare for different mesons in different variables ($y, pt$).

Secondary track (number):

Heavy Ions - Posters / 93

A generalized approach to study low as well as high pT regime of transverse momentum spectra

Author: Rohit Gupta
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Studying the QCD matter produced under extreme condition of temperature and density called Quark Gluon Plasma (QGP) is among the important goal of heavy-ion collision experiments. QGP is a state where quarks and gluons are free to move inside a nuclear volume rather than only in nucleonic volume. Transition from hadronic state to QGP occur at the phase boundary where the critical temperature ($T_c$) is sufficient enough to support the formation of QGP droplet. Search for $T_c$ and the type of phase transition is being explored in the experiments by scanning the QCD phase diagram. In order to get the information of temperature, we utilize the transverse momentum spectra ($p_T$) of final state particles that are free streaming to the detectors.

Due to the asymptotic freedom and the very nature of QCD coupling constant, the coupling strength is very strong at low $p_T$ values and hence we cannot apply perturbative theories to study the $p_T$-spectra in this regime. To tackle this issue, we resort to the phenomenological approach with most accepted being the statistical thermodynamical models. However, we have a well established perturbative QCD based power-law form of the distribution function to explain the spectra in high $p_T$ regime which is dominated by the particles produced in hard scattering processes.

In this presentation, we will discuss a unified formalism to explain the spectra including both low as well as high $p_T$ regime. We will present in detail the formalism along with the results obtained using this generalized model with the $p_T$-spectra of charged hadrons produced in Pb−Pb collision at different centralities & centre of mass energies. We will also discuss how this generalized model can be used to get the information about the elliptic flow coefficient directly from the transverse momentum spectra.

Secondary track (number):

06
Strong Interactions and Hadron Physics / 95

Measurement of rho(770) photoproduction at HERA

Author: Arthur Bolz

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Exclusive photoproduction of $\rho(770)$ mesons is studied using the H1 detector at HERA. The analysis is based on a sample of about 900000 events that were collected in the years 2006-2007. It is used to measure single- and double-differential cross sections for the reaction $\gamma p \rightarrow \pi^+\pi^- Y$. Reactions where the proton stays intact ($M_Y = M_p$) are statistically separated from those where the proton dissociates to a low-mass hadronic system ($M_p < M_Y < 10$ GeV). The double differential cross sections are measured as a function of the invariant mass $m_{\pi\pi}$ of the decay pions and the squared momentum transfer at the proton vertex $t$. These measurements are repeated in bins of the photon-proton collision energy $W_{\gamma p}$. The phase-space restrictions are $0.5 < m_{\pi\pi} < 2.2$ GeV, $|t| < 1.5$ GeV$^2$ and $20 < W_{\gamma p} < 80$ GeV. Cross-section measurements are presented for both elastic and dissociative scattering. The observed kinematic dependencies are described by analytic functions. In particular, a Soding model is used to extract the $\rho(770)$ contribution to the $\pi^+\pi^-$ cross-sections. From the resulting single-differential $\rho(770)$ cross-section as a function of $t$, measured in bins of $W_{\gamma p}$, the leading effective Regge trajectory is extracted.

I read the instructions:

Secondary track (number):

07

Beyond the Standard Model / 97

Estimation of CP violating EDMs from known mechanisms in the SM

Author: Prajwal Mohanmurthy

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New sources of CP violation, beyond the known sources in the standard model (SM), are required to explain the baryon asymmetry of the universe. Measurement of a non-zero permanent electric dipole moment (EDM) of fundamental particles, such as in an electron or a neutron, or nuclei or atoms can help us gain a handle on the sources of CP violation, both in SM and beyond. Multiple mechanisms within the SM can generate CP violating EDMs, viz. through the CKM matrix in the weak sector or through the QCD $\theta_s$ parameter in the strong sector. We will estimate the maximum possible EDMs of leptons, certain baryons, select atoms and molecules in the (CKM $\bigoplus \theta_s$) framework, assuming that the EDM wholly originates from either of the two SM mechanisms, independently. These estimates have been presented in light of the current experimental upper limits on the EDMs. Particularly to drive home the point that EDMs in different systems constraint CP-violating interactions differently, such that the same constraint on EDM in two different systems may not actually be equally constraining on CP violating parameters. We will also show the systems in which the experimental constraints are closest to the SM EDM, and the systems in which an EDM measurement would effectively be SM background free.

Secondary track (number):
Statistical combination of searches for the X(5568) state decaying into $B_s^{0\pm}$

Author: Paolo Iengo

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A statistical combination of the search results for the X(5568) resonance decaying into $0\pm$ is reported, based on published results from the ATLAS, CMS, CDF and LHCb Collaborations. A narrow structure in the invariant mass distribution of $0\pm$ has been observed by the D0 Collaboration with a mass value of 5568 MeV and interpreted as the first observation of a possible tetra-quark state with four different flavours. The evidence of such a state was not confirmed by any of the latest searches from LHCb, CDF, ATLAS and CMS Collaborations. CDF and the LHC experiments have set limits on $\rho$, the relative production rate of the X(5568) and $0$ states times the branching ratio for the $(5568) \rightarrow 0\pm$ decay. With a statistical combination of limits set by the three LHC experiments, we derive a limit, at 95% Confidence Level, of $\rho < 0.92\%$ for $(0) > 10$ GeV, and $\rho < 0.91\%$ for $(0) > 15$ GeV, which represent the most stringent upper limits up to present.

The talk will review the experimental results from Tevatron and LHC, will describe the combination procedure and the obtained results. The effect of including the results from Tevatron experiments in the statistical combination will also be discussed.

NNLO QCD fits to extract PDFs from HERA inclusive and jet data

Authors: Matthew Wing1; Stefan Schmitt2; Collaboration H13

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NNLO predictions for jet production in Deep Inelastic Scattering have recently become available. These are used to extend the QCD HERAPDF2.0Jets fits, that were made to extract PDFs from inclusive HERA data and HERA jet data, from NLO to NNLO. In addition new jet data sets have become available since the publication of HERAPDF2.0 and these are also considered. A simultaneous fit to these data to extract PDFs and $\alpha_s$ results in a new NNLO determination of $\alpha_s(M_Z)$.

Beyond the Standard Model / 100

Limits on contact interactions and leptoquarks at HERA
High-precision HERA data corresponding to a luminosity of around 1 fb$^{-1}$ have been used in the framework of eeqq contact interactions (CI) to set limits on possible high-energy contributions beyond the Standard Model to electron–quark scattering. Measurements of the inclusive deep inelastic cross sections in neutral and charged current $ep$ scattering were considered. The analysis of the $ep$ data has been based on simultaneous fits of parton distribution functions including contributions of CI couplings to $ep$ scattering. Several general CI models and scenarios with heavy leptoquarks were considered. Improvements in the description of the inclusive HERA data were obtained for a few models. Since a statistically significant deviation from the Standard Model cannot be established, limits in the TeV range were set on all models considered.

Measurement of the azimuthal decorrelation angle between the leading jet and scattered lepton in deep inelastic scattering at HERA

The azimuthal decorrelation angle between the leading jet and scattered lepton in deep inelastic scattering is studied with the ZEUS detector at HERA. The data was taken in the HERA II data-taking period and corresponds to an integrated luminosity of 330 pb$^{-1}$. Azimuthal angular decorrelation has been proposed to study the $Q^2$ dependence of the evolution of the transverse momentum distributions (TMDs) and understand the small-$x$ region, providing unique insight to nucleon structure. Previous decorrelation measurements of two jets have been performed in proton-proton collisions at very high transverse momentum; these measurements are well described by perturbative QCD at next-to-leading order. The azimuthal decorrelation angle obtained in these studies shows good agreement with predictions from Monte Carlo models including leading order matrix elements and parton showers.

Dedicated data analyses for improving PDFs: Study of proton parton distribution functions at high $x$ and charm production in charged DIS at HERA

Authors: Matthew Wing$^{1}$; Ritu Aggarwal$^{2}$
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Proton parton distribution functions (PDFs) are poorly constrained by existing data for Bjorken x larger than 0.6, and the PDFs extracted from global fits differ considerably from each other. A technique for comparing predictions based on different PDF sets to observed event numbers is presented. It is applied to compare predictions from the most commonly used PDFs to published ZEUS data at high Bjorken x. A wide variation is found in the ability of the PDFs to predict the observed results. A scheme for including the ZEUS high-x data in future PDF extractions is discussed.

Charm production in charged current deep inelastic scattering has been measured for the first time in $\pi^\pm$ collisions, using data collected with the ZEUS detector at HERA, corresponding to an integrated luminosity of 358 pb$^{-1}$ separately for $+\pi^-$ and $-\pi^+$ scattering at a centre-of-mass energy of $\sqrt{s} = 318$ GeV within a kinematic phase-space region of $200 \text{ GeV}^2 < q^2 < 60000 \text{ GeV}^2$ and $x < 0.9$, where $q^2$ is the squared four-momentum transfer and $x$ is the inelasticity. The measured cross sections of electroweak charm production are consistent with expectations from the Standard Model within the large statistical uncertainties.

Heavy Ions / 104

Two-particle azimuthal correlations as a probe of collective behaviour in deep inelastic ep scattering at HERA

Authors: Matthew Wing$^1$, Achim Geiser$^2$

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Two-particle azimuthal correlations have been measured in neutral current deep inelastic ep scattering with virtuality $Q^2 > 5 \text{ GeV}^2$ at a centre-of-mass energy $\sqrt{s} = 318$ GeV recorded with the ZEUS detector at HERA. The correlations of charged particles have been measured in the range of laboratory pseudorapidity $-1.5 < \eta < 2$ and transverse momentum $0.1 < p_T < 5 \text{ GeV}$ and event multiplicities $N_{ch}$ up to six times larger than the average $\langle N_{ch}\rangle \approx 5$. The two-particle correlations have been measured in terms of the angular observables $c_n\{2\} = \langle \cos n\Delta \phi \rangle$, where $n$ is between 1 and 4 and $\Delta \phi$ is the relative azimuthal angle between the two particles. The correlations observed in HERA data do not indicate the kind of collective behaviour recently observed at the highest RHIC and LHC energies in high-multiplicity hadronic collisions. Available Monte Carlo models of deep inelastic scattering, tuned to reproduce inclusive particle production, provide a qualitative description of the HERA data.
Recent highlights and plans of the AWAKE experiment

Author: Matthew Wing

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The Advanced Wakefield Experiment (AWAKE) is an accelerator R&D experiment at CERN using, for the first time, a high-energy proton bunch to drive wakefields in plasma and accelerating electrons to the GeV energy scale. The principle of the AWAKE experiment is described. We show experimental results of the seeded self-modulation process of the long 400 GeV SPS proton bunch, transforming the bunch into a train of micro-bunches and driving resonantly the wakefields in the 10 m long Rb plasma. We also show that externally-injected electrons can be accelerated by these wakefields to several GeV. The next steps of the AWAKE experimental programme are shown. Possible first applications to high-energy physics experiments, where the scheme takes advantage of the large energy stored in the proton bunch to reach very high energy gain in a single plasma, are described.

Strong Interactions and Hadron Physics / 106

QCD Instantons at the LHC

Authors: Matthias Schott¹; Valentin V Khoze²; Frank Martin Krauss³

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It is a common belief that the last missing piece of the Standard Model of particles physics was found with the discovery of the Higgs boson at the Large Hadron Collider. However, there remains a major prediction of quantum tunnelling processes mediated by instanton solutions in the Yang-Mills theory, that is still untested in the Standard Model. The direct experimental observation of instanton-induced processes, which are a consequence of the non-trivial vacuum structure of the Standard Model and of quantum tunnelling in QFT, would be a major breakthrough in modern particle physics. We present and discuss for the first time a full calculation of QCD instanton-induced processes in proton-proton collisions accounting for quantum corrections due to both initial and final state gluon interactions, a first implementation in an MC event generator as well as a basic strategy how to observe these effects experimentally.

Beyond the Standard Model / 107

On the reinterpretation of fiducial cross-section measurements in the view of new physics

Authors: Alexander Sydorenko¹; Matthias Schott²

Johannes Gutenberg Universitaet Mainz (DE)
Fiducial production cross-section measurements of Standard Model processes, in principle, provide constraints on new physics scenarios via a comparison of the predicted Standard Model cross-section and the observed cross-section. This approach received significant attention in recent years, both from direct constraints on specific models and the interpretation of measurements in the view of effective field theories. A generic problem in the reinterpretation of Standard Model measurements is the corrections application of to data to account for detector effects. These corrections inherently assume the Standard Model to be valid, thus implying a model bias of the final result. In this work, we study the size of this bias by studying several new physics models and fiducial phase–space regions. The studies are based on fast detector simulations of a generic multi-purpose detector at the Large Hadron Collider. We conclude that the model bias in the associated reinterpretations is negligible only in specific cases, however, typically on the same level as systematic uncertainties of the available measurements.

Neutrino Physics - Posters / 109

Collective neutrino oscillations accounting for neutrino quantum decoherence

Author: Konstantin Stankevich
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The effect of neutrino quantum decoherence has attracted a growing interest during the last 15 years. Most of already performed corresponding studies deal with searches of neutrino quantum decoherence in terrestrial reactor and solar neutrino experiments (see, for example, [1]). The forthcoming new large volume neutrino detectors (e.g. JUNO, DUNE and Hyper-Kamiokande), will provide a new frontier in high-statistics measurements of neutrino fluxes from supernovae that will give a new opportunity to study the effect of neutrino quantum decoherence also in supernovae fluxes. In [2-4] we suggested a new mechanism of neutrino quantum decoherence in the supernovae due to the neutrino interaction with external environment and showed that it becomes significant in the region where the collective neutrino oscillations occur. In this work we are presenting our new results on the numerical calculations of collective neutrino oscillations in supernovae accounting for the neutrino quantum decoherence and study the possibility to detect the effect of neutrino quantum decoherence in supernovae neutrino fluxes in the future terrestrial experiments.

Universal features of the medium-induced gluon cascade and jet quenching in expanding media

Author: Souvik Priyam Adhya
Co-authors: Carlos Albert Salgado Lopez; Martin Spousta; Konrad Tywoniuk

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We present a study of the impact of the expansion of deconfined medium on single-gluon emission spectra and the jet suppression factor () within the BDMPS-Z formalism. These quantities are calculated for three types of media (static medium, exponentially decaying medium and Bjorken expanding medium). The distribution of medium-induced gluons and the jet are calculated using the evaluation of in-medium evolution with splitting kernels derived from the gluon emission spectra. A universal behavior of splitting kernels is derived for low- and high- regimes in the asymptote of large times and its impact on the resulting jet is discussed. For the full phase-space of the radiation, the scaling of jet with an effective quenching parameter is derived. The importance of the medium expansion for precise modeling of jet quenching phenomena as well as steps towards generalizing the results to other jet quenching observables are discussed.

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques

New beam test results of 3D pixel detectors constructed with polycrystalline CVD diamond

Authors: William Trischuk; Harris Kagan; on behalf of the RD42 Collaboration

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Detectors based on Chemical Vapor Deposition (CVD) diamond have been used successfully in beam conditions monitors in the highest radiation areas of the LHC. Future experiments at CERN will to accumulate an order of magnitude larger fluence. As a result, an enormous effort is underway to identify detector materials that will operate after fluences of \(10^{16}/\text{cm}^2\).

Diamond is one candidate due to its large displacement energy that enhances its radiation tolerance. Over the last 2 years the RD42 collaboration has constructed 3D CVD diamond pixel detectors that use laser fabricated electrodes to enhance radiation tolerance. We will present beam test results of these devices. The cells in these detectors had a size of 50µm x 50µm with columns 2.6µm in diameter ganged in 1 x 5 and 3 x 2 patterns to match the ATLAS and CMS pixel read-out electronics. In beam tests, a tracking efficiency of 99.3% was achieved. The efficiency of both devices plateaus at a bias voltage of 30V.
Top Quark and Electroweak Physics / 112

KKMC-hh for Precision EW Phenomenology at the LHC

Author: Scott Alan Yost

Co-authors: Staszek Jadach; Zbigniew Andrzej Was; Bennie Ward

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We describe the program KKMC-hh, which calculates Z boson processes in hadronic collisions using coherent exclusive exponentiation (CEEX) with exact second-order photonic corrections at next-to-leading log and first-order weak vertex corrections, including initial and final state photonic radiation and initial-final interference. We describe current applications to precision forward-backward asymmetry calculations for the measurement of the Weinberg angle at the LHC and upgrades in progress for use with an NLO QCD shower.

Strong Interactions and Hadron Physics / 113

Recent results on e+e- annihilation to hadrons from the SND experiment.

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Recent results on e+e- annihilation to hadrons below 2 GeV obtained at the SND experiment at the VEPP-2000 collider are presented. In particular, we discuss measurements of the e+e- → π+π-, e+e- → n̅n, e+e- → ηπ0γ cross sections, and a search for the rare process e+e- → f₁(1285).

Heavy Ions - Posters / 114

Twisted particles in heavy-ion collisions

Author: Alexander Silenko

Co-authors: Pengming Zhang; Liping Zou

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An importance of twisted (vortex) particles in heavy-ion collisions is analyzed. Free twisted photons and electrons can possess giant intrinsic orbital angular momenta. Twisted photons have a nonzero effective mass [1] and are spatially localized. They are naturally radiated at a spiral motion of charges, are rather ubiquitous in laboratories and nature [2,3], and can be emitted, like other twisted particles, in heavy-ion collisions. Charged twisted particles can be recognized by their dynamics and specific effects [4] in external fields.


Secondary track (number):

**Astro-particle Physics and Cosmology** / 115

**Analysis on the black hole formations inside old neutron stars by isospin-violating dark matter with self-interaction**

**Author:** Yen-Hsun Lin

**Co-author:** Guey-Lin Lin

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Fermionic dark matter (DM) with attractive self-interaction is possible to form black holes (BH) inside the Gyr-old neutron stars (NS). Therefore by observing such NS corresponding to their adjacent DM environments can place bounds on DM properties, eg. DM-baryon cross section $\sigma_{\chi b}$, DM mass $m_\chi$, dark coupling $\alpha_\chi$ and mediator mass $m_\phi$. In case of isospin violation, DM couples to neutron and proton in different strengths. Even NS is composed of protons roughly one to two percent of the total baryons, the contribution from protons to the DM capture rate could be drastically changed in the presence of isospin violation. We demonstrate that this effect can be important in certain cases. On the other hand, DM-forming BH inside the star is subject to many criteria and the underlying dynamics is rich with interesting features. We also systematically review the relevant physics based on the virial equation.

I read the instructions:

Secondary track (number):

03
Measurement of production mode cross sections of the Higgs boson in decays to bosons using the ATLAS detector

Author: Liza Mijovic

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With the pp collision dataset collected at 13 TeV, detailed measurements of Higgs boson properties can be performed. This talk presents measurements of Higgs boson properties using Higgs boson decays to two photons, two Z bosons, and two W bosons, including production mode cross sections and simplified template cross sections.

I read the instructions:

Secondary track (number):

Higgs Physics / 117

Measurement of differential cross sections and the Higgs mass in Higgs boson decays to bosons using the ATLAS detector

Author: Antoine Laudrain

1 Laboratoire de l’Accélérateur Linéaire (FR)

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With the pp collision dataset collected at 13 TeV, detailed measurements of Higgs boson properties can be performed. This talk presents measurements of differential cross sections in Higgs boson decays to two photons or to four leptons. Furthermore, the measurement of the Higgs boson mass and constraints on the width are presented.

I read the instructions:

Secondary track (number):

Higgs Physics / 118

Measurements of Higgs boson production in decays to two tau leptons with the ATLAS detector

Author: Christian Grefe

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Testing the couplings of the Higgs boson to leptons is important to understand the origin of lepton masses. This talk presents measurements of Higgs boson production in Higgs boson decays to two tau leptons based on pp collision data collected at 13 TeV, as well as studies of the CP-nature of the HVV coupling in H→tautau decay.
Higgs Physics / 119

Measurements and searches of Higgs boson decays to two quarks at the ATLAS experiment

Author: Marco Battaglia

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Testing the couplings of the Higgs boson to fermions is an important part to understand the origin of fermion masses. The talk presents cross section measurements in Higgs boson decays to two $b$ quarks, as well as interpretations of the measurements. It also presents a search for Higgs boson decays to two $c$ quarks. Both analyses are based on pp collision data collected at 13 TeV.

Higgs Physics / 120

Higgs boson production in association with a $t\bar{t}$ pair at the ATLAS experiment

Author: Jelena Jovicevic

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The measurement of Higgs boson production in association with a $t\bar{t}$ pair is essential to understand the top-quark couplings to the Higgs boson. This talk presents the analyses using Higgs boson decays to $b\bar{b}$ pairs, to two Z bosons, to other multi-lepton final states, and to a pair of photons, using pp collision data collected at 13 TeV.

Higgs Physics / 121

Combined Higgs boson measurements at the ATLAS experiment

Author: Matthew Henry Klein

1
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The most precise measurements of Higgs boson cross sections, using the framework of simplified template cross sections, are obtained from a combination of the measurements performed in the different Higgs boson decay channels. This talk presents the combined measurements, as well as their interpretation.

I read the instructions:

Secondary track (number):

Higgs Physics / 122

Constraining the Higgs boson self-coupling in a combined measurement of single and double Higgs boson channels at the ATLAS experiment

Author: Maximilian J Swiatlowski

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The most precise measurements of Higgs boson single and double Higgs production cross sections are obtained from a combination of measurements performed in different Higgs boson production and decay channels. While double Higgs production can be used to directly constrain the Higgs boson self-coupling, the latter can be also constrained by exploiting higher-order electroweak corrections to single Higgs boson production. A combined measurement of both results yields the overall highest precision, and reduces model dependence by allowing for the simultaneous determination of the single Higgs boson couplings. Results for this combined measurement are presented based on pp collision data collected at a center-of-mass energy of 13 TeV with the ATLAS detector.

I read the instructions:

Secondary track (number):

Higgs Physics / 123

Search for rare and lepton flavor violating decays of the Higgs boson with the ATLAS detector

Author: Hanna Maria Borecka-Bielska

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The Standard Model predicts several rare Higgs boson decay channels, which have not yet been observed, but that could be enhanced in theories beyond the Standard Model. Among these are decays to light leptons, e.g. H→mumu. In addition, theories beyond the Standard Model may predict lepton-flavor violating decays of the Higgs boson. Results for these searches based on full Run-2 dataset collected at 13 TeV will be presented.
Search for Higgs boson in the final state with two leptons and a photon produced in pp collisions at a center-of-mass energy of 13 TeV with the ATLAS detector

Author: Artem Basalaev

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A search for decays of the Higgs boson in the final state with two leptons (electrons or muons) and a photon produced in pp collisions at a center-of-mass energy of 13 TeV with the ATLAS detector is presented. Estimates of Higgs boson signal and background contributions are performed for the three-body invariant mass distribution of the di-lepton plus photon system. Background estimates and corresponding systematic uncertainties are shown. Expected and observed limits on the corresponding Higgs boson cross-section are presented.

Measurement of Higgs boson production at high momentum in the VH, H → bb channel with the ATLAS detector

Author: Brian Moser

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With the rapidly increasing proton-proton collision data-set recorded by the ATLAS experiment at the LHC, one gains access to Higgs bosons produced with ever higher transverse momenta. Measurements in this phase space are well motivated by a vast variety of BSM models which predict effects that scale with the square of the involved energy scale. The associated production of a Higgs boson H with a heavy vector boson V allows to probe the HVV interaction at high momentum scales. Combining this production mode with the most prominent decay into a pair of bottom quarks promises a large enough signal yield in this rare topology. Requiring the vector boson to further decay leptonically ensures a clean detector signature to separate signal from background. A measurement of the production cross section times the decay branching fraction of the Higgs boson into two b-quarks will be presented, based on data collected at a center-of-mass energy of 13 TeV.
Higgs Boson measurements in the H->WW->lvlv decay channel

Author: Anamika Aggarwal

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Having the second highest branching ratio, the decay of the Higgs boson into two W bosons is one of the most promising channels to study the CP properties of the Higgs boson, couplings of Higgs to the other particles as well as inclusive and differential cross-section measurements. It is the only analysis sensitive to the forward Higgs production with pseudorapidities of the Higgs boson above 2.5. The leptonic final state lvlv provides a clean signature and allows for the use of efficient lepton triggers. Yet, several different backgrounds processes (top, misidentified leptons, etc.) remain relevant for this analysis and different measures are taken to reduce them. The combination of high rate and clean signature provides a unique opportunity to measure all the major production modes (ggF, VBF, WH, ZH) in a single decay channel. The studies presented here are based on the proton-proton collision data recorded by the ATLAS detector at the LHC at a centre-of-mass energy of 8 and 13 TeV. The rates are measured separately for the two leading production modes of gluon fusion and Vector Boson Fusion, both inclusive and differential.

I read the instructions:

Secondary track (number):

Higgs Physics - Posters / 128

Searching for lepton-flavour-violating decays of the Higgs boson with the ATLAS detector

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The observation of neutrino oscillations indicates that lepton flavour violation (LFV) occurs in nature and that lepton flavour is not an exact symmetry. However, no observation has been made in the charged sector, which would be a clear indication of physics Beyond the Standard Model (BSM). There are BSM models which predict LFV decays of the Higgs boson into a pair of leptons with different flavours such as models with more than one Higgs doublet, composite Higgs models, models with flavour symmetries, Randall–Sundrum models and many more. In this poster we present the search for Higgs Bosons decaying into a tau lepton and either an electron or a muon, using data collected by the ATLAS detector at a centre-of-mass energy of 13 TeV. The searches for H->e tau and H->mu tau decays were performed independently and in both cases, the search was split into cases where the tau lepton decayed leptonically or hadronically. Multivariate techniques were used in this search to discern the LFV signal from the SM background. The achieved results will be discussed in this poster.

I read the instructions:

Secondary track (number):
Search for new resonances in high-mass diphoton final states using proton-proton collision data collected with the ATLAS detector

Author: Yufeng Wang

Corresponding Author: yufeng.wang@cern.ch

Since the discovery of the 125 GeV Higgs boson at the LHC, studies of the Higgs sector have become an important topic of the ATLAS physics program. There are many potential extensions of the Standard Model (SM) that predict new high-mass states decaying into two photons. Among which, two types of signal models are considered: a spin-0 resonance which was predicted in theories with an extended Higgs sector such as the two-Higgs doublet models (2HDM), and a spin-2 graviton excitation of a Randall-Sundrum model with one warped extra dimension. The diphoton final state played an important role when the H(125) Higgs boson was discovered, and is chosen for this search as it provides a clean experimental signature with excellent invariant mass resolution and moderate backgrounds. This poster presents the search for new resonances decaying into two photons, using pp collisions collected with the ATLAS detector at LHC at a centre-of-mass energy of 13 TeV. Pairs of isolated photon candidates with high invariant masses are selected. The results of this search will be discussed in this poster.

Fake-Rate determination for the ttH coupling measurement with a signature of two same electric charge light leptons associated with a tau using the ATLAS detector at the LHC

Author: Santu Mondal

Corresponding Author: santu.mondal@cern.ch

After the discovery of a Higgs boson, the measurements of its properties are at the forefront of research. The determination of the associated production of a Higgs boson and a pair of top quarks is of particular importance as the ttH Yukawa coupling is large and can probe for physics beyond the Standard Model. The analysis is based on data taken by the ATLAS experiment recorded from 13 TeV proton-proton collisions. The ttH production was analysed in various final states. The focus of this presentation is on the fake rate determination in the final state with two light leptons of same electric charge and one hadronically decaying tau lepton.

Constraints on the Higgs boson self-coupling from the combination of single-Higgs and double-Higgs production analyses performed with the ATLAS experiment
 Constraints on the Higgs boson self-coupling are set by combining the single Higgs boson analyses targeting the γγ, ZZ, WW, tau+tau- and bb decay channels and the double Higgs boson analyses in the bbbb, bbtb+tau- and bbγγ decay channels, using data collected at sqrt(s)=13 TeV with the ATLAS detector at the LHC. With the assumption that new physics affects only the Higgs boson self-coupling (λ_HHH), the measured values for λ_HHH will be discussed. Results with less stringent assumptions are also provided, introducing additional coupling modifiers for the Higgs boson interactions with the other Standard Model particles.

Measurement of Higgs boson production in association with a top-quark pair in the di-photon decay channel using LHC data collected at √s = 13 TeV by the ATLAS experiment

A measurement of the ttH production in the di-photon decay channel is performed using pp collision data at a center-of-mass energy √s = 13 TeV, recorded by the ATLAS experiment at the LHC. Two regions are defined to target either the fully hadronic or semi-leptonic decay of the top quark. In each, a boosted decision tree (BDT) is trained to create ttH enhanced categories. The measurement is then performed with a simultaneous fit to the diphoton mass in these BDT-based categories. The ttH production is observed in the diphoton decay mode and the resulting measurements will be discussed in this poster.

Measurement of the Higgs boson coupling to tau leptons in proton-proton collisions at √s = 13 TeV with the ATLAS detector at the LHC

The thus far only observed coupling of the Higgs boson to leptons is that to tau leptons. Its coupling strength is measured using decays of Higgs boson into two tau leptons in the gluon-fusion and vector-boson-fusion production channels. A measurement of the coupling of the Higgs boson to a pair of τ leptons is presented. The application of machine-learning techniques in this channel is
investigated. The analysis uses proton-proton collision data recorded at a center-of-mass energy $\sqrt{s} = 13$ TeV with ATLAS detector at the LHC.

I read the instructions:

Secondary track (number):

Higgs Physics / 135

**Searches for invisible Higgs boson decays at the ATLAS experiment**

**Author:** Benjamin John Rosser

1 *University of Pennsylvania (US)*

**Corresponding Author:** bjr@sas.upenn.edu

In the Standard Model, the branching ratio for Higgs boson decays to invisible final states is very small, but it can be significantly enhanced in extensions of the Standard Model. This talk presents searches for Higgs boson decays to invisible final states with the full run 2 data.

I read the instructions:

Secondary track (number):

Dark Matter Detection / 136

**Dark Matter searches with the ATLAS detector**

**Author:** Ben Carlson

1 *University of Pittsburgh*

**Corresponding Author:** bcarlson@cern.ch

The presence of a non-baryonic dark matter (DM) component in the Universe is inferred from the observation of its gravitational interaction. If dark matter interacts weakly with the Standard Model it would be produced at the LHC, escaping the detector and leaving a large missing transverse momentum as their signature. The ATLAS detector has developed a broad programme to directly search for DM. The results of recent searches on 13 TeV pp data, their interplay and interpretation will be presented.

I read the instructions:

Secondary track (number):

Beyond the Standard Model / 137

**Search for new physics in final states with heavy-flavour quarks using the ATLAS detector**
Searches for new resonances whose decays contain top quarks and/or b-quarks cover a wide range of beyond the Standard Model (SM) physics, such as generic heavy vector resonances or vector like quarks. These searches offer great potential to reduce SM backgrounds but also significant challenges in reconstructing and identifying the decay products as well as modelling the remaining background. The results of recent ATLAS searches on 13 TeV pp data, along with the associated improvements in identification techniques, will be reported.

Secondary track (number):

Beyond the Standard Model / 138

Searches for new physics at high-mass with leptons using the ATLAS detector

Author: Federico Scutti

1 University of Melbourne (AU)

Corresponding Author: federico.scutti@cern.ch

Many theories beyond the Standard Model predict new phenomena, such as Z', W' bosons or heavy neutrinos, in final states with isolated, high-pt leptons (e/mu/nu). Searches for new physics with such signatures, produced either resonantly or non-resonantly, are performed using the ATLAS experiment at the LHC. The recent 13 TeV pp results will be reported.

Secondary track (number):

Beyond the Standard Model / 139

Search for Leptoquarks using the ATLAS detector

Author: Yasuyuki Okumura

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Leptoquarks (LQ) are predicted by many new physics theories to describe the similarities between the lepton and quark sectors of the Standard Model and offer an attractive potential explanation for the lepton flavour anomalies observed at flavour factories. The ATLAS experiment has a broad program of direct searches for leptoquarks produced either in pairs or singly, coupling to the first-, second- or third-generation particles. This talk will present the most recent 13 TeV results on ATLAS leptoquark searches, covering all three generations including cross-generation production, and highlight their complementarity.
Search for Long-lived Particles and Unconventional Signatures with the ATLAS detector

Author: Monica Verducci

1 INFN Sezione di Pisa, Universita' e Scuola Normale Superiore, P

Corresponding Author: monica.verducci@cern.ch

Many theories beyond the Standard Model (BSM) predict unique signatures which are difficult to reconstruct and for which estimating the background rates is also a challenge. These signatures include fractionally charged, highly ionizing and a wide range of proposed long-lived particles. These striking signatures are explored with the ATLAS detector using 13 TeV pp data, covering displaced decays anywhere from the inner detector to the muon spectrometer.

Searches for new heavy resonances in hadronic final states with the ATLAS detector

Author: Jeremy Robert Love

1 Argonne National Laboratory (US)

Corresponding Author: jlove@anl.gov

Many theories beyond the Standard Model predict new phenomena which decay to jets. These are of particular interest at the LHC since new phenomena produced in parton collisions are likely to produce final states with (at least) two partons. This talk presents the latest 13 TeV ATLAS results, covering exclusive searches for dijet resonances along with searches for dijet events produced in association with additional particles such as an additional isolated lepton, which overcomes the trigger limitations to extend to lower dijet masses.

Search for di-Higgs production at 13 TeV in ATLAS
The latest results on production of Higgs boson pairs at 13 TeV by the ATLAS experiment are reported, including a combination of six different decay modes. Results include bbtautau, bbbb, bbgamgam, bbWW, WWWW and WWgamgam final states, and they are interpreted both in terms of sensitivity to the SM and as limits on kappa_lambda, a scaling of the triple-Higgs interaction strength.

I read the instructions:

Secondary track (number):

**Beyond the Standard Model / 143**

**Fully Hadronic Diboson searches in ATLAS**

**Author:** Steven Schramm

1 *Universite de Geneve (CH)*

**Corresponding Author:** steven.schramm@cern.ch

Many extensions to the Standard Model predicts new particles decaying into two bosons (W, Z, photon, or Higgs bosons) making these important signatures in the search for new physics. Searches for such diboson resonances have been performed in different final states and new jet substructure techniques to disentangle the hadronic decay products in highly boosted configuration are being used. Novel analysis techniques, unsupervised learning, are also used to extract new feature from the data. This talk summarizes recent ATLAS diboson searches with LHC Run 2 data in fully hadronic final state.

I read the instructions:

Secondary track (number):

**Beyond the Standard Model / 144**

**Searching for new resonances in partially-hadronic states in ATLAS**

**Author:** Stefan Raimund Maschek

**Corresponding Author:** stefan.raimund.maschek@cern.ch

Many extensions to the Standard Model predicts new particles decaying into two bosons (VV, VH, Vgamma) making these important signatures in the search for new physics. Searches for such diboson resonances have been performed in final states with different numbers of leptons, photons and jets where new jet substructure techniques to disentangle the hadronic decay products in highly boosted configuration are being used. This talk summarizes ATLAS searches for diboson resonances with LHC Run 2 data in semileptonic final states.

I read the instructions:
Exotic Higgs decays in ATLAS

Author: Christopher Robyn Hayes¹

¹ University of Michigan (US)

Corresponding Author: christopher.hayes@cern.ch

Exotics decays of the Higgs boson provide a unique window for the discovery of new physics, as the Higgs may couple to hidden-sector states that do not interact under the Standard Model gauge transformations. Models predicting exotic Higgs decays to pseudoscalars can explain the galactic center gamma-ray excess, if the additional pseudoscalar acts as the dark matter mediator. This talk presents recent ATLAS searches for decays of the 125 GeV Higgs boson to a pair of new light bosons, $H \rightarrow aa$, where the $a$-bosons decay to various final states and rare Higgs decays. These searches use LHC collision data at $\sqrt{s} = 13$ TeV collected by the ATLAS experiment in Run2.

I read the instructions:

Secondary track (number):

Higgs Physics / 146

Searches for additional Higgs bosons in the ATLAS detector

Author: Jeanette Miriam Lorenz¹

¹ Ludwig Maximilians Universitat (DE)

Corresponding Author: jeanette.miriam.lorenz@cern.ch

Since the discovery of the Higgs boson with the mass of about 125 GeV much effort has been spent looking for further scalars, which are motivated in many scenarios. Here we report on searches for new neutral heavy Higgs bosons decaying to pairs of third generation fermions: tau leptons or $b$ quarks. These searches are based on full Run 2 data of the ATLAS experiment at the LHC.

I read the instructions:

Secondary track (number):

Beyond the Standard Model / 148

When jets MET SUSY: ATLAS searches for squarks and gluinos

Author: Aaron Paul O’Neill¹

¹ University of Oxford (GB)
In many supersymmetric scenarios, heavy Beyond Standard Model particles would decay to multiple massive Standard Model bosons or top quarks. The subsequent decays of these Standard Model particles into leptons and/or jets may then occur with significant branching ratios and can populate the events recorded by the ATLAS detector. This talk presents ATLAS searches for coloured superparticles decaying to jets and missing transverse momentum, which utilise cutting-edge object and event reconstruction to seek a buried signal in the full Run 2 LHC dataset. Combining these methods with powerful statistical analyses allows novel constraints to be applied to natural and unnatural SUSY, as well as shedding light on the existence of Dark Matter and other novel particles. Constraints on squarks and gluinos in final states populated by one or more leptons are also presented.

Beyond the Standard Model / 149

Searches for direct pair production of stops and sbottom with the ATLAS detector

Author: Thomas James Stevenson

Corresponding Author: thomas.james.stevenson@cern.ch

Naturalness arguments for weak-scale supersymmetry favour supersymmetric partners of the third generation quarks with masses light enough to be produced at the LHC. The ATLAS experiment has a variety of analyses devoted to stop and sbottom direct production exploiting novel reconstruction and analysis techniques. This talk presents recent results using the full Run 2 dataset from these searches and their interpretation in both supersymmetric models and simplified associated-production dark matter models.

Beyond the Standard Model / 150

Reconstruction techniques in supersymmetry searches with soft objects in the ATLAS experiment

Author: Shion Chen

Corresponding Author: shion.chen@cern.ch

Many supersymmetric scenarios feature final states with non-standard final state objects. When considering compressed scenarios, involving sparticle spectra with small mass-splittings and decays to low-momentum leptons or jets, analyses depend on novel methods for the reconstruction of these very soft particles. This talk will review the application of innovative techniques, including soft lepton reconstruction and soft b-hadron tagging, to supersymmetry searches in ATLAS.
Searches for the electroweak production of supersymmetric particles with the ATLAS detector

Author: Sara Alderweireldt

1 CERN

Corresponding Author: sara.alderweireldt@cern.ch

Analyses at the LHC are becoming increasingly sensitive to the direct production of electroweak SUSY particles, such as charginos, neutralinos, and sleptons, with important consequences on our understanding of dark matter and the naturalness of the Higgs mass. This talk will present the latest results from searches for electroweak SUSY production using data collected with the ATLAS experiment in Run 2 at the LHC. Several different signatures are explored with varying lepton multiplicities, and the results are interpreted as constraints on a variety of SUSY models.

Searches for SUSY with long-lived particles in ATLAS

Author: Tova Ray Holmes

Corresponding Author: tova.ray.holmes@cern.ch

Various SUSY scenarios lead to signatures with long-lived particles, such that the decay of the new particle is at a significant distance from the collision point. These signatures provide interesting technical challenges due to their special reconstruction requirements as well as their unusual backgrounds. This talk will present recent results in long-lived SUSY searches using ATLAS Run 2 data.

R-parity violating SUSY searches in ATLAS

Author: Johannes Josef Junggeburth

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Corresponding Author: johannes.josef.junggeburth@cern.ch

R-parity violating (RPV) SUSY models evade the stringent limits from missing-energy-based searches, and remain excellent candidates for low-scale SUSY. ATLAS has completed several dedicated searches for RPV signatures in Run 2, the most recent of which will be shown in this talk.
Beyond the Standard Model / 155

Searching outside the box for supersymmetry: beyond the cut-and-count in ATLAS analyses

Author: Frederik Ruehr

Albert Ludwigs Universitaet Freiburg (DE)

Corresponding Author: frederik.ruehr@cern.ch

The apparent absence of superpartners at the LHC suggests that complex decays may be obscuring hints of their existence. To maximize sensitivity in the large datasets available from Run 2 of the LHC, searches for supersymmetric particles have adopted progressively more advanced analysis strategies. This presentation features several analyses that have been carried out by the ATLAS collaboration, which push the boundaries of signal sensitivity using machine learning techniques, multi-variate analyses and multi-channel statistical analyses. These searches achieve unprecedented sensitivity to the signatures of sparticle production, while providing useful constraints on a wider variety of Beyond-the-Standard-Model particles.

Dark Matter Detection/Diversity and Inclusion - Posters / 156

Search for new phenomena in mono-X final states using pp collision data collected in Run-2 by the ATLAS experiment at the LHC

Author: Sergio Gonzalez Fernandez

The Barcelona Institute of Science and Technology (BIST) (ES)

Corresponding Author: sergio.gonzalez.fernandez@cern.ch

Cosmological and astrophysical observation point to the existence of an exotic type of matter known as Dark Matter (DM) that accounts for about 80% of the mass of the Universe. If DM is realized in the form of weakly interacting massive particles (WIMPs) it could be produced at the LHC pp collider. At colliders, mono-X final states are considered golden channels, for which DM particles are produced in association with energetic jets of hadrons, photons, W/Z bosons or top-quarks. Here we present the latest results from the ATLAS collaboration on the mono-jet and the mono-photon searches in pp collisions at 13 TeV using an integrated luminosity of up to 139 fb⁻¹. The results were translated into exclusion limits in different model for new physics including DM simplifies models, supersymmetry inspired models, models with large extra spatial dimensions, and models for the production of axion-like particles.
Search for high mass resonance in di-jet and di-b-jet events using 139 fb−1 of pp collisions at √s=13 TeV with the ATLAS detector

Author: Dengfeng Zhang

1 Tsinghua University (CN)

Corresponding Author: dengfeng.zhang@cern.ch

New resonances decaying into pairs of quarks or gluons appear in a variety of new physics models from simple gauge extensions of the standard model to Grand Unified Theories. The dijet final state at high transverse momentum can probe the highest energies reached in a collider experiment. This corresponds to the largest reach in mass for the production of new particles. Some BSM particles may preferentially decay into bb or bj, so besides of the search in generic di-jets, we also considered the case in which one or two jets identified as b-jets. This poster will show the latest results of search for new resonance in di-jet and di-b-jet events using the full Run 2 pp collision dataset at √s = 13 TeV, corresponding to an integrated luminosity of 139 fb-1 collected from 2015 to 2018 with the ATLAS detector.

Search for Scalar Leptoquark Pair Production Decaying into Top-Quarks and Leptons at √s = 13 TeV with ATLAS detector

Author: Vincent Wai Sum Wong

1 University of British Columbia (CA)

Corresponding Author: vincent.wai.sum.wong@cern.ch

This poster presents a search for pair-produced scalar leptoquarks decaying to leptons and hadronic top quarks using 139 fb-1 of data recorded by the ATLAS detector at √s = 13 TeV. As well as being predicted by various extensions of the Standard Model to describe the similarity between the quark and lepton sectors, leptoquarks provide a promising explanation for anomalies observed in both the lepton universality tests in B decays and muon anomalous magnetic moment measurement. Searches for pair-produced scalar leptoquarks decaying to electron-top or muon-top pairs have been performed in final states with exactly two leptons. A parameterized gradient boosted decision trees approach is used to suppress the standard model background. Improved exclusion limits are set on the leptoquark masses are set at 95% confidence level.
Search for Invisibly Decaying Vector Boson Fusion Produced Higgs Bosons with 139/fb of pp collisions with the ATLAS Detector

**Author:** Amanda Lynn Steinhebel

**Corresponding Author:** asteinhe@uoregon.edu

While the Standard Model (SM) predicts a branching ratio of the Higgs boson decaying to invisible particles of O(0.001), the current measurement of the Higgs boson coupling to other SM particles allows for up to 30% of the Higgs boson width to originate from decays beyond the SM (BSM). The small SM-allowed rate of Higgs boson decays to invisible particles can be enhanced if the Higgs boson decays into a pair of weakly interacting massive particles (WIMPS), which may explain the nature of dark matter. The Vector Boson Fusion (VBF) production mechanism of the Higgs boson provides a distinctive signature (with two forward jets that are largely separated in pseudorapidity leading to a large invariant mass) that can be used to target events with invisible Higgs decays, where particles invisible to the detector are a source of missing transverse energy. The most recent ATLAS results of VBF-produced Higgs bosons decaying invisibly are presented, utilizing the full Run-2 dataset of 139/fb of 13 TeV center-of-mass proton–proton collisions. Further interpretations set limits on the VBF production of other heavy scalars, and the WIMP-nucleon cross-section.

I read the instructions:

Secondary track (number):

Beyond the Standard Model - Posters / 160

Search for Type-III SeeSaw heavy leptons in multileptonic final states using 139/fb of pp collision at sqrt(s) = 13 TeV with the ATLAS detector

**Author:** Giuseppe Carratta

**Corresponding Author:** giuseppe.carratta@cern.ch

The discovery of neutrino oscillations implies they have non-null masses much smaller than charged leptons. This is difficult to accommodate in a natural way through a pure Standard Model Yukawa coupling to the Higgs field. Type-III SeeSaw mechanism is a proposed beyond the SM model, introducing at least two new triplets of fermionic fields with zero hypercharge in the adjoint representation of SU(2)L, resulting in two heavy Dirac charged leptons and an heavy Majorana neutral lepton. I’ll present the search for these heavy leptons in multileptonic final states using the data collected by ATLAS detector at sqrt(s) = 13 TeV with a integrated luminosity of 140/fb corresponding to the full Run-2 dataset recorded between 2015-2018. The analysis includes all the possible production and boson decay channels of these heavy leptons, which are assumed to be degenerate in mass. The search is optimized for each lepton multiplicity final state, considering 2, 3 and 4 leptons. The power of the considered semi-leptonic channels lies in the low expected background from Standard Model processes. The result of this search will be a cross section exclusion limit placing a lower bound to the heavy leptons mass obtained with a 95% CL.

I read the instructions:

Secondary track (number):

Higgs Physics - Posters / 162
Searching for Neutral BSM Higgs Bosons in the Tau Tau Final State at ATLAS

Author: Janina Anna Krzysiak

Corresponding Author: janinakrzysiak@gmail.com

A search for heavy neutral Higgs bosons is performed using the LHC Run 2 data, corresponding to an integrated luminosity of 139 fb\(^{-1}\) of proton–proton collisions at \(\sqrt{s} = 13\) TeV recorded with the ATLAS detector. The heavy resonance is searched for in the \(\tau^+\tau^-\) decay mode with at least one \(\tau\) lepton decaying into final states with hadrons and a neutrino. The search covers the mass range of 0.2–2.5 TeV. The data are in good agreement with the background predicted by the Standard Model. In the context of the Mh-125 scenario of the Minimal Supersymmetric Standard Model, the data exclude \(\tan\beta > 21\) for \(m_A = 1.5\) TeV at the 95% confidence level.

I read the instructions:

Secondary track (number):

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Higgs Physics - Posters / 163

New results of the \(H^+\rightarrow tb\) search using full Run-2 data with the ATLAS detector

Authors: Imma Riu\(^1\); ATLAS Collaboration

\(^1\) IFAE Barcelona (ES)

Corresponding Authors: adrian.salvador.salas@cern.ch, imma.riu@cern.ch

A new search for heavy charged Higgs bosons decaying to a pair of top and bottom quarks is performed using the full LHC Run-2 proton-proton data with the ATLAS detector. The search is performed using multi-jet final states with one electron or muon. Events are categorised according to the multiplicity of jets and how likely these are to have originated from hadronisation of a bottom quark. A mass-parameterised neural network is used to discriminate between signal and background events in four separate signal regions and simultaneously included in a maximum-likelihood fit to the data. Results are interpreted in the context of the hMSSM and Mh-125 scenario of the Minimal Supersymmetric Standard Model.

I read the instructions:

Secondary track (number):

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Beyond the Standard Model - Posters / 164

Search for SUSY with missing transverse momentum and multiple b-jets in ATLAS

Author: Meisam Ghasemi Bostanabad

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A search for supersymmetry involving the pair production of gluinos decaying via third generation squarks into the lightest neutralino is performed. The final state contains large missing transverse momentum, leptons, and several energetic jets (including at least three b-tagged jets). This poster
summarizes the recent ATLAS result on this search which was performed with LHC pp collision
data at a center-of-mass energy of sqrt(13) TeV, with an integrated luminosity of 139 fb−1.

I read the instructions:

Secondary track (number):

Neutrino Physics - Posters / 165

Searches for Non-Standard Interactions (NSI) of Neutrinos using the NOvA Experiment

Authors: Prabhjot Singh¹; Brajesh Choudhary²

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² University of Delhi (IN)

Corresponding Authors: brajesh.choudhary@cern.ch, prabhjot@fnal.gov

The observation of neutrino oscillations by the atmospheric, solar, accelerator, and reactor neutrino
experiments substantiate that neutrinos are not massless particles. In 1978, L. Wolfenstein predicted
that even massless neutrinos can change their flavor through flavor-changing neutral current (NC)
interactions, also called non-standard interactions (NSI). The Standard Model of particle physics sup-
presses such as flavor-changing NC interactions, resulting in the hypothesis of these non-standard
interactions beyond the standard model. Accelerator-based, long-baseline experiments, provide
an opportunity for searches of these NSI when considering the oscillations of neutrinos traveling
through matter. The NOvA experiment is a long-baseline neutrino oscillation experiment that uses
the upgraded NuMI beam from Fermilab to detect both electron appearance and muon disappear-
ance. NOvA employs two functionally identical detectors: a Near Detector, located at Fermilab, and
a Far Detector, located at Ash River, Minnesota over an 810 km baseline. The presence of NSI could
alter the production, detection, and propagation of neutrinos, and can arise as an effect on measure-
ments of neutrino oscillation parameters. In this poster, I will present the current status of searches
for NSI via neutrino oscillations by the NOvA experiment.

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 166

Design and performance studies of the calorimeter system for an FCC-hh experiment

Authors: Jana Faltova¹; Anna Zaborowska²; Martin Aleksa²; Coralie Neubuser¹; Ana Maria Henriques Correia²; Clement Helsens²

¹ Charles University (CZ)
² CERN
³ Universita degli Studi di Trento and INFN (IT)

Corresponding Author: jana.faltova@cern.ch

The physics reach and feasibility of the Future Circular Collider (FCC) with centre of mass energies
up to 100 TeV and unprecedented luminosity has delivered a Conceptual Design Report early 2019.
The new energy regime opens the opportunity for the discovery of physics beyond the standard
model. Proton-proton collisions at 100 TeV will produce very high energetic particle showers in the
calorimeters from both light jets and boosted bosons/top. The reconstruction of such objects sets the calorimeter performance requirements in terms of shower containment, energy resolution and granularity. Furthermore, high-precision measurements of photons and electrons over a wide energy range are crucial to fully exploit the FCC-hh physics potential, especially given the large amount of collisions per bunch crossing the detectors will have to face (pile-up of $\langle \sigma \rangle = 1000$).

We will present the current reference technologies for the high-granularity calorimeter system of the FCC-hh detector: Liquid Argon (LAr) as the active material in the electromagnetic calorimeters, and the hadronic calorimeters for $R > 1.3$ (Endcap and Forward region), and a Scintillator-Steel (Tile) calorimeter as hadronic calorimeter in the Barrel region. The talk will focus on the performance studies for single particles and jets in the combined calorimeter system. We will introduce the simulation framework and the reconstruction chain, that includes the calibration and clustering of calorimeter cells and the estimation of pile-up induced, and electronics noise. In conclusion, the achieved performances will be compared to the physics benchmarks of the FCC-hh experiment.

I read the instructions:

Secondary track (number):

Higgs Physics / 167

Searching for Light Boson via the Yukawa Process at Lepton Colliders

Authors: Tanmoy Mondal$^1$; Eung Jin Chun$^1$

$^1$ Korea Institute for Advanced Study

Corresponding Authors: ejchun@kias.re.kr, tanmoy@kias.re.kr

I will present the prospect of Yukawa production of a light boson which can exist in an extended Higgs sector. A particularly interesting case is the light pseudoscalar in Type-X two Higgs doublet model which can explain the anomalous magnetic moment of muon at large $\tan \beta$. Considering ILC “Higgs factory” with CM Energy of 250 GeV, we show that the available parameter space can be fully examined by the (tau) Yukawa process at 5 $\sigma$ with integrated luminosity of 2000 $fb^{-1}$. We also demonstrate the mass reconstruction of such a light particle which helps to minimize the background events considerably.

Secondary track (number):

01

Top Quark and Electroweak Physics / 168

Measurements of vector-boson production via weak-boson fusion at ATLAS

Author: Jun Guo$^1$

$^1$ Shanghai Jiao Tong University (CN)

Corresponding Author: jun.guo@cern.ch

Measurements that exploit electroweak boson scattering and electroweak boson fusion (VBF) processes have become increasingly common at the Large Hadron Collider in the last few years. All of these measurements and searches rely on accurate theoretical modelling of the VBF and VBS
production mechanisms. The production of single vector-boson production via weak boson fusion provides a standard candle for studying the weak-boson fusion and scattering processes. In this talk, we present the latest studies of single vector-boson production via weak-boson fusion using proton-proton collision data collected by the ATLAS experiment.

I read the instructions:

Secondary track (number):

Top Quark and Electroweak Physics / 169

Observations of weak boson scattering with the ATLAS detector

Author: Takuya Nobe

1 University of Tokyo (JP)

Corresponding Author: takuya.nobe@cern.ch

The scattering of electroweak bosons tests the gauge structure of the Standard Model and is sensitive to anomalous quartic weak boson self interactions. In this talk, we present the latest results on weak-boson scattering from the ATLAS experiment using proton-proton collisions at \( \sqrt{s}=13 \) TeV. This will include the first observation of ZZ production, evidence for \( Z\gamma \) production via weak-boson scattering, as well as a measurement of diboson production via weak-boson scattering in semileptonic decay channels.

I read the instructions:

Secondary track (number):

Top Quark and Electroweak Physics / 170

Measurements of inclusive multi-boson production at ATLAS

Author: Siyuan Sun

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Corresponding Author: siyuan.sun@cern.ch

The production of multiple weak vector bosons at the LHC constitutes a stringent test of the electroweak sector and provide a model-independent means to search for new physics at the TeV scale. In this talk, we present the latest results from the ATLAS experiment for multi-boson production in proton-proton collisions at \( \sqrt{s}=13 \) TeV. The measurements exploit both the leptonic and hadronic decays of the weak vector bosons. Differential cross sections are measured that probe the topology of each final state. The data are corrected for detector inefficiency and resolution and are compared to theoretical predictions at NLO (and NNLO) in perturbative QCD. The measurements are sensitive to anomalous triple gauge couplings and are reinterpreted in terms of an effective field theory to constrain new physics beyond the Standard Model.

I read the instructions:

Secondary track (number):
Measurements of photon-photon fusion at ATLAS

Author: Mateusz Dyndal

CERN

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Photon-photon fusion is a rare process at hadron and ion colliders. It is particularly interesting as a remarkably clean interaction with little (if any) remnant activity from the interacting particles. In this talk, we present the status of photon-photon fusion measurements at the ATLAS detector. This includes the production of photon pairs via light-by-light scattering in heavy ion collisions as well as photon-photon fusion measurements in proton-proton collisions that contain two charged leptons in the final state. The experimental techniques used in the proton-proton and heavy-ion measurements are different, due to the different amounts of pile-up activity, and will be be discussed.

Measurements of differential cross-sections of top-quark-antiquark pair-production with the ATLAS detector

Author: Teng Jian Khoo

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Comprehensive measurements of differential cross-sections of top-quark-antiquark pair-production are presented. The measurements are performed in the electron-muon, the lepton+jets and the all-hadronic channels. The latter two allow for reconstruction of the top-quark and top-quark-pair kinematic distributions. In the electron-muon channel, kinematic properties of the two leptons are measured differentially. High sensitivity of some distributions to PDFs is demonstrated. The lepton+jets and all-hadronic channels are complementary in terms of range and resolution for several top-quark variables. All three measurements use data recorded in the years 2015 and 2016 during Run 2 of the LHC. The measurements are compared quantitatively with predictions from several setups of next-to-leading order matrix-element generators combined with parton-shower generators and from fixed order calculations at NNLO in QCD. In addition, the total cross-section is measured in the electron-muon channel. A precision of 2.4 % is reached, well below the uncertainty of predictions at next-to-next-to-leading order in QCD. The total cross-section is compared to predictions by different sets of parton distribution functions and is used to determine the top-quark mass. A total cross-section measurement based on the full Run 2 dataset in the lepton+jets channel is also presented.
Recent measurements of the top-quark mass using the ATLAS detector at the LHC

Author: Serena Palazzo

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The top-quark mass is an important fundamental parameter of the Standard Model, since higher-order corrections involving top quarks have a large impact due to the high value of the top-quark mass. A new measurement of the top-quark mass is presented. The analysis is based on top-quark-antiquark pair events in which a soft muon is reconstructed which originates in a large fraction of the cases from the b hadron from top-quark decay. This measurement method is less sensitive to the jet energy calibration and has therefore different systematic uncertainties than conventional measurements. In addition, a measurement of the top-quark pole mass is performed using the normalised differential cross section of top-quark-antiquark pair production in association with an energetic jet in the lepton+jets final state unfolded to parton level. A comparison between the experimental distribution and the theoretical prediction allows the top-quark mass to be extracted in the in the pole mass scheme and in the MSbar scheme.

I read the instructions:

Secondary track (number):

Top Quark and Electroweak Physics / 174

Using associated production of top quarks to neutral bosons to probe standard model couplings and search for new physics

Author: Knut Zoch

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The unprecedentedly large integrated luminosity accumulated by the ATLAS detector at the highest proton-proton collision energy provided by LHC allows the study of rare SM processes. The associated production of top quarks with neutral bosons is such an example: it directly probes top-quark couplings to photons and Z bosons and tests for deviations from the standard model.

Three measurements are presented.

The cross sections for the production of top quark pairs in association to a photon (ttgamma) or to a Z boson (ttZ) are measured both inclusively and differentially as a function of kinematic variables characterizing the tt+boson system. Both sets of measurements use the full Run2 data set consisting of 139/fb of integrated luminosity. Final states with three and four leptons and b-jets are used to extract ttZ rates, while tt+gamma cross sections are derived from final states with one photon, one electron and one muon of opposite sign and at least two jets. The measurements are compared to predictions obtained by NLO+PS Monte Carlo and fixed order NLO calculations.

The single top-quark production in association with a Z boson (tZq) probes two SM couplings in the same process (WWZ and tZ coupling) and it is a background to the rare associated production of a single top quark and a Higgs Boson. Using a total integrated luminosity of 139/fb collected in the LHC Run-2 from 2015 to 2018, events containing three isolated charged leptons (electrons or muons) and two or three jets, one of which is identified as containing a b-hadron are selected. A neural network is used to improve the background rejection and extract the signal. The measured cross section for tl+1-q production, including non-resonant dilepton pairs with dilepton mass larger than 30 GeV is presented and compared with the SM prediction.
Top Quark and Electroweak Physics / 175

Searches for flavour violation and flavour changing neutral currents in top quark final states

Author: Nicolas Maximilian Koehler

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The remarkably large integrated luminosity collected by the ATLAS detector at the highest proton-proton collision energy provided by LHC allows to probe the presence on new physics that might break well established symmetries or enhance extremely rare processes in the SM. Two such significant examples are lepton universality and Flavour Changing Neutral Currents (FCNC). Recent measurements involving B-meson decays sparked renewed interest in testing lepton universality between tau and light leptons because of observed deviations at the four-standard-deviation level. On the other hand, SM FCNC involving the top-quark decay to another up-type quark and a neutral boson are so small that any measurable branching ratio for such a decay is an indication of new physics.

By selecting events with two opposite sign leptons (muon pairs and electron-muon pairs) and at least two b-tagged jets, a highly pure sample of top-quark pair decays is assembled and used to extract a large unbiased sample of W bosons decaying to leptons down to low transverse momenta. A fit to the two dimensional distribution for the transverse momentum and the transverse impact parameter of the lepton is then used to differentiate between leptons originating directly from the W boson and those resulting from the W-boson-to-tau-lepton decay chain. This results into a precise measurement of the ratio between the probability for the W boson decay to tau to the probability for its decay to muon.

In addition, three searches for FCNC couplings are presented. First, the search for the FCNC coupling between the top quark and the Higgs boson uses events with one electron or muon, missing energy and three or four jets to search for both the production of a single top in association with a Higgs boson or the production of a top-quark pair with one top quark decaying to a Higgs boson and an up or a charm quark. A neural network is used to improve background rejection. The results are interpreted also in terms of effective field theory couplings describing the tqH vertex. Second, the FCNC interactions between the top quark, a gluon and a charm or an up-quark is searched for in events producing a single top-quark decay leptonically by selecting final states with one lepton, one b-jet and missing transverse momentum. A neural network is used to discriminate signal from background. The results are also interpreted in terms of anomalous and Effective field theory couplings. Finally, 81/fb of integrated luminosity are used to search for FCNC via the coupling of a top quark, a photon and an up or charm quark in events with one photon, one lepton (electron or muon), one b-tagged jet and missing transverse momentum.

Measurement of four-top-quarks production with the ATLAS detector at the Large Hadron Collider
Author: Nedaa Alexandra Asbah

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The hard scattering process in which two top-quark-antiquark pairs are produced is also called four-top-quarks production and is predicted to have a small cross-section of 12 fb in the standard model. This very rare process has not been observed yet. The background is mainly given by top-quark-antiquark production in association with heavy flavor jets. In this presentation, two analyses are presented which aim to establish experimental evidence for this process based on the full Run 2 dataset recorded with the ATLAS detector. The first analysis selects events with exactly one charged lepton and several jets or two charged leptons of opposite electric charge. The second analysis is based on a lepton pair with the same electric charge or events with more than two leptons. In both channels multivariate techniques are used to optimize the separation between signal and background events and enhance the sensitivity. Finally, both channels are combined.

Top Quark and Electroweak Physics / 177

Measurement of top-quark properties with the ATLAS detector at the LHC

Author: Kentaro Kawade

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Due to its high mass top quarks decay before top-flavoured hadrons are formed. This feature leads to interesting phenomenological consequences, among them is the access to spin polarisation effects in top-quark production. While top-quarks are produced unpolarized in top-quark-antiquark pair production, there exists a correlation between the spins of the top-quark and the top-antiquark. In the presentation, last year’s measurement of spin correlation in top-quark-antiquark pair events is reviewed, including recent changes which were implemented for the resubmission to the journal. Besides the measurement of the standard model effect, the observed data are also interpreted as search for supersymmetric top-quark partners.

In addition, the talk covers a measurement of the charge asymmetry in top-quark-antiquark pair production. The asymmetry is due to a subtle interference effect of quark-antiquark-annihilation amplitudes in quantum chromodynamics. Based on the full Run 2 data set the effect is established at a level of more than four standard deviations. The analysis is performed in the lepton-plus-jets and in the di-lepton channel. In the later channel, a pure leptonic asymmetry is measured in addition. The third analysis presented measures the top-quark width, also in both channels, lepton-plus-jets and in the di-lepton channel.

Top Quark and Electroweak Physics - Posters / 178

Measurements of inclusive four-lepton production at ATLAS

Author: Xiaotian Liu
Measurements of the four-lepton invariant mass spectrum are made with the ATLAS detector, using proton-proton collisions at $\sqrt{s}=13$ TeV delivered by the Large Hadron Collider. The measurement is done selecting events that contain two same-flavour opposite-sign lepton pairs. The four-lepton mass exhibits a rich structure, with different mass regions dominated by single $Z$ production, Higgs production and on-shell ZZ production, with a complex mix of interference terms and possible contributions from beyond-the-Standard model (BSM) physics. The measurement is corrected for detector effects and compared to state-of-the-art Standard Model calculations, which are found to be consistent with the data. Constraints on example BSM scenarios are evaluated, and further re-interpretations can be made with the provided information.

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Secondary track (number):

Top Quark and Electroweak Physics - Posters / 179

Top-quark-antiquark production in association with a photon in the electron-muon channel at a centre-of-mass energy of 13 TeV with the ATLAS detector

Author: John Kamal Rizk Meshreki\textsuperscript{home}

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The cross-section of top-quark-antiquark pair production in association with a photon is important in order to determine the electromagnetic coupling of the top-quark with high precision. It is also of great significance to test deviations from the Standard Model (SM), such as anomalous dipole moments of the top-quark. Furthermore, such cross-section can be interpreted in effective field theories which would allow for probing effects of higher-dimensional operators of the SM fields.

The presentation covers the inclusive and differential cross-section measurements of top-quark production in association with a photon in the electron-muon channel at $\sqrt{s}=13$ TeV with the ATLAS detector.

Both measurements are performed in a fiducial volume. The inclusive cross-section is extracted using a profile likelihood fit, while the differential cross-section is measured at parton level as a function of various observables, such as the photon transverse momentum and angular variables related to the photon and the leptons. The measurements are compared to the most recent next-to-leading order theory calculation [JHEP 10 (2018) 158] and state-of-the-art Monte Carlo simulations. The results are found to be in good agreement with the predictions within uncertainties.

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Secondary track (number):

Quark and Lepton Flavour Physics / 181

Measurement of the weak mixing phase $\phi_s$ through time-dependent CP violation in $B_{s}^{0} \rightarrow J/\psi\phi$ decay in ATLAS

Author: Tomas Jakoubek\textsuperscript{1}
In the Standard Model of particle physics, CP violation arises due to a single complex phase in the Cabibbo–Kobayashi–Maskawa (CKM) quark mixing matrix. Precise measurements of the CKM parameters therefore constrain the Standard Model, and may reveal new physics effects. The measurement of the time–dependent decay rates of \( B_{0s} \rightarrow J/\psi \phi \) provides a theoretically clean method for extracting CP–violating weak mixing phase \( \phi_s \).

This talk will present the most recent results from ATLAS on the CP-violating mixing phase \( \phi_s \) and on several other parameters describing the \( B_{0s} \) meson system.

Quark and Lepton Flavour Physics / 182

**ATLAS results on Heavy Flavour production and decay (including rare processes)**

**Author:** Sally Seidel

1 University of New Mexico / ATLAS

**Corresponding Author:** sally.seidel@cern.ch

The heavy flavour production and decays are studied with the ATLAS detector, mainly through final states containing muons. This talk will summarise recent results from ATLAS, including measurements on \( B_c \) mesons decaying in different final states and of \( D_s \) cross-sections. The latest results on the studies of rare processes are also presented. Particular attention will be given to Flavour Changing Neutral Current processes, such as the decay of \( B_s \) and \( B_0 \) into two muons.

Quark and Lepton Flavour Physics / 183

**ATLAS results on quarkonia and associated production**

**Author:** Brad Abbott

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The associated production of vector boson with quarkonia is a key observable for understanding the quarkonium production mechanisms, including the separation of single and double parton scattering components. This talk will present the latest measurements from ATLAS on charmonium production at high transverse momentum, and the associated production of a W-boson with a \( J/\psi \) meson.
Quark and Lepton Flavour Physics / 184

ATLAS studies of Spectroscopy and exotics

Author: Semen Turchikhin

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Searches for, and measurements of exotic states are studied with the ATLAS detector. The latest results from ATLAS on studies of pentaquark structures in the decays of heavy flavour are presented. In addition, recent results from heavy flavour spectroscopy are reported.

Quark and Lepton Flavour Physics - Posters / 185

The study of the rare decays $B^0_s \rightarrow \mu^+ \mu^-$ at $\sqrt{s} = 13$ TeV with the ATLAS detector

Author: Mazuza Ghneimat

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The flavour-changing neutral currents of the rare decays $B^0_s \rightarrow \mu^+ \mu^-$ provide a favourable environment to observe new physics. The study of these decays, using the data collected by the ATLAS detector, is presented. Their branching ratios are measured relative to the reference decay mode $B^{+/-} \rightarrow J/\psi K^{+/-}$, which is abundant and has a well-measured branching fraction $B(B^{+/-} \rightarrow J/\psi K^{+/-}) \times B(J/\psi \rightarrow \mu^+ \mu^-)$. The event yields of the reference and the rare-decay channels are extracted employing the unbinned maximum likelihood fit approach.

Strong Interactions and Hadron Physics / 186

Determination of the Parton Density Functions of the Proton with the ATLAS data

Author: Mark Sutton

None

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In this talk we present fits to determine parton distribution functions (PDFs) using inclusive W/Z-boson and W+jets measurements from the ATLAS experiment at the LHC. The ATLAS measurements are used in combination with deep-inelastic scattering data from HERA. The ATLAS W and Z boson data exhibit sensitivity to the valence quark distributions and the light quark sea composition. The parton distribution functions extracted using W+jets data show an improved determination of
the high-x sea-quark densities, while confirming the unsuppressed strange-quark density at lower x<0.02 found by previous ATLAS analyses.

I read the instructions:

Secondary track (number):

Strong Interactions and Hadron Physics / 187

Measurements of prompt photon production with the ATLAS detector

Author: Frank Siegert

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Corresponding Author: frank.siegert@cern.ch

The production of prompt isolated photons at hadron colliders provides stringent tests of perturbative QCD and can be used to evaluate the probability density functions of partons in the proton. In this talk, we present the latest measurements of prompt photon production using proton-proton collision data collected by the ATLAS experiment at √s=13 TeV. This includes the measurement of isolated photon differential cross sections as well as a measurement that probes the event topologies of prompt isolated photons produced in association with two hadronic jets. Each measurement is corrected for detector inefficiency and resolution and the results are compared to state-of-the-art theory predictions, indicating several interesting discrepancies.

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Secondary track (number):

Strong Interactions and Hadron Physics / 188

Measurement of jet substructure and jet fragmentation using the ATLAS detector

Author: Jennifer Kathryn Roloff

Corresponding Author: jroloff2@gmail.com

Measurements of the internal properties of jets allow QCD to be studied at a new regime at a hadron collider. In this talk, we discuss recent measurements jet substructure and jet fragmentation that were performed using data collected by the ATLAS experiment at a centre-of-mass energy of √s=13 TeV. This includes a comprehensive suite of substructure observables measured for jets reconstructed with the soft-drop algorithm applied as well as a measurement of the Lund Plane using charged particles. The fragmentation properties of jets containing b-quarks will also be presented. All of the measurements are corrected for detector effects and are compared to the predictions of state-of-the-art Monte Carlo event generators.

I read the instructions:

Secondary track (number):
Precision measurements of jet production at the ATLAS experiment

Author: Peter Loch¹

¹ University of Arizona (US)

Corresponding Author: loch@physics.arizona.edu

Measurements of jet production are sensitive to the strong coupling constant, high order perturbative calculations and parton distribution functions. In this talk, we present the most recent ATLAS measurements of jet production at 13 TeV. Depending on the availability of the results, we may show measurements of jet and multijet production as well as measurements sensitive to the strong coupling constant.

Precision measurements of single vector boson production at ATLAS

Author: Kristin Lohwasser¹

¹ University of Sheffield (GB)

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Precision measurements of the production cross-sections of W/Z boson at LHC provide important tests of perturbative QCD and information about the parton distribution functions for quarks within the proton. In this talk, we present fiducial and differential cross sections for inclusive W⁺, W⁻ and Z boson production using data collected by the ATLAS experiment at center-of-mass energies of 2.76 TeV, 8 TeV and 13 TeV. The measurements are corrected for detector inefficiency and resolution and compared with state-of-the-art theoretical calculations.

Top quark pair reconstruction using an attention-based neural network

Authors: Seungjin Yang¹; Jason Lee²; Ian James Watson³; Inkyu Park¹

¹ University of Seoul, Department of Physics (KR)
² University of Seoul (KR)
³ University of Seoul
For many top quark measurements, it is essential to reconstruct the top quark from its decay products. For example, the top quark pair production process in the all-jets final state has six jets initiated from daughter partons and additional jets from initial/final state radiation. Due to the many possible permutations, it is very hard to assign jets to partons. We use a deep neural network with an attention-based architecture together with a new objective function to the jet-parton assignment problem. Our novel deep learning model and the physics-inspired objective function enable jet-parton assignment with high-dimensional data while the attention mechanism bypasses the combinatorial explosion that usually leads to intractable computational requirements. The model can also be applied as a classifier to reject the overwhelming QCD background, showing increased performance over standard classification methods.

Strong Interactions and Hadron Physics / 192

Measurements of W/Z boson production in association with jets at ATLAS

Author: Camilla Vittori

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Measurements of W/Z-boson production in association with jets provide important test of perturbative QCD prediction and also yield information about the parton distribution functions of the proton. In this talk, differential cross-sections for vector-boson production in association with jets using proton-proton collisions collected by the ATLAS experiment are presented. The data are corrected for detector inefficiency and resolution and compared to state-of-the-art theoretical predictions. The impact of the choice of parton distribution function is also presented.

Strong Interactions and Hadron Physics / 193

Measurements of soft-QCD and diffractive processes with ATLAS

Author: Rafał Staszewski

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In this talk we present various measurements sensitive to non-perturbative physics performed using data collected by the ATLAS experiment at the LHC. Inclusive single diffractive dissociation (pp→pX) is studied using data collected by the ATLAS forward spectrometer spectrometers, while charged particles from the dissociative system (X) are reconstructed and measured using the ATLAS inner tracking detector and calorimeters. In addition, measurements of charged-particle production that are sensitive to the properties of the underlying event and the hadronisation mechanism are also presented. The measurements are corrected for detector inefficiency and resolution and compared with the predictions of various Monte Carlo generators.
Jet Measurements in Heavy Ion Collisions with the ATLAS Experiment

Author: Helena Santos

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Jets are an important tool to study the hot, dense matter produced in Pb+Pb collisions at the LHC. They are produced at the early stages of the collisions and are expected to be modified as they propagate through the hot and dense medium. This leads to energy loss as well as modification of the jet structure. This talk presents the latest jet measurements from Run 2 heavy-ion collisions data from ATLAS. The results shown in this talk include measurements of the angular distribution of charged particles around the jet axis, measurements of the flavor-dependence of energy loss via b-jets and jets associated with photons and Z bosons, and measurements of the jet internal structure characterized by the transverse momentum scale for the hardest splitting. Furthermore, the latest results on the dijet momentum balance in pp, Xe+Xe, and Pb+Pb collisions will be presented. The talk will also show a measurement of the single jet yields as a function of the azimuthal angle with respect to the event plane in Pb+Pb collisions. The data are compared to state of the art theoretical models and provide important information to understand the strength and mechanism of the jet quenching.

Recent ATLAS measurements of correlations in Pb+Pb and Xe+Xe collisions

Author: Krzysztof Wieslaw Wozniak

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ATLAS measurements of flow harmonics ($v_n$) and their fluctuations in Pb+Pb and Xe+Xe collisions covering a wide range of transverse momenta, pseudorapidity and collision centrality are presented. The measurements are performed using data from Xe+Xe collisions at 5.44 TeV and Pb+Pb collisions at 2.76 and 5.02 TeV. The $v_n$ are measured up to $n = 6$ using the two-particle correlations, multi-particle cumulants, and scalar product methods. The $v_n$ values are also performed using a non-flow subtraction technique that was developed for flow measurements in pp and p+Pb collisions. This non-flow subtraction is found to have a significant effect on the measured $v_n$ at high-$p_T$ and in peripheral collisions. A universal scaling in the $p_T$ dependence of the $v_n$ is observed for both systems. Measurements of correlations between the $v_n$ for different order $n$, studied with three- and four-particle mixed-harmonic cumulants, are also presented, and contributions to these correlations from “centrality fluctuations” are also discussed. Measurements of longitudinal flow decorrelations involving two- and four-particle correlations for $v_2$ and $v_3$ in Xe+Xe and Pb+Pb collisions are also presented and compared with predictions from theoretical calculations. The four-particle decorrelation is found to
not factorize as a product of two-particle decorrelations. The ability of such measurements to dis-
tinguish between different models of initial geometry and to reduce the uncertainty in determining
the effective shear-viscosity to entropy-density ratio of the QGP is demonstrated.

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Secondary track (number):

Heavy Ions / 196

Recent ATLAS measurements of correlations in $pp$ and $p+Pb$ col-
lisions

Author: Adam Trzupek

Corresponding Author: adam.trzupek@cern.ch

This talk presents recent measurements from the ATLAS collaboration that study features of the
azimuthal distributions for charged particles in $pp$ and $p+Pb$ collisions. The measurement of the
azimuthal anisotropy of charged hadrons in $p+Pb$ collisions up to a transverse momentum of 50 GeV
is presented. In A+A collisions non-zero flow coefficients at high-$p_T$ are understood to arise from
the path-length dependent energy loss of jets. Thus, these measurements in $p+Pb$ collisions, can
provide information on the origin of these collective phenomena. To further assess properties of the
azimuthal anisotropy in $p+Pb$ collisions, the correlation between the mean transverse momentum
and the magnitudes of the flow harmonics is also measured. The measurements are performed in
5.02 TeV $p+Pb$ collisions for several intervals of the charge particle transverse momentum and as a
function of the event-multiplicity. The measured correlations are compared to similar measurements
in Pb+Pb collisions. Measurements of correlations in ultra-peripheral Pb+Pb collisions, in which the
nuclei do not interact hadronically, but a quasi-real photon from the EM field of one nucleus can
interact with the other nucleus are also presented. These photons may reach energies up to 80
GeV and readily fluctuate into vector-meson configurations, resulting in these collisions effectively
being vector-meson+Pb collisions. Prior measurements of two-particle correlations in $pp$ collisions
have demonstrated long-range azimuthal correlations between charged particle pairs. The impact-
parameter dependence of these correlations are studied in events containing a $Z$-boson, which acts
as an independent handle on the impact parameter of the $pp$ collision. Measurements of the $p_T$ and
event-multiplicity dependence of the azimuthal anisotropy in such $Z$-tagged $pp$ collisions at 8 and
13 TeV are also presented. Measurements of the azimuthal anisotropy of muons from heavy-flavor
decays in $pp$ collisions at 13 TeV, which may further elucidate the origin of these correlations in $pp$
collisions, are also presented.

I read the instructions:

Secondary track (number):

Heavy Ions / 197

Electroweak probes in heavy-ion collisions with ATLAS

Author: Jakub Andrzej Kremer

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Electroweak bosons produced in lead-lead (Pb+Pb) collisions are an excellent tool to constrain initial-
state effects which affect the rates of hard-scattering processes in nucleus-nucleus interactions. The
production yields of massive electroweak bosons, observed via their lepton decay channels, offer a
high-precision test of the binary collision scaling expected in Pb+Pb and a way to quantify nuclear
modifications of the parton distribution functions (PDFs). The large samples of Pb+Pb data at \( \sqrt{s_{\text{NN}}} = 5.02 \) TeV collected by the ATLAS experiment in 2015, and the corresponding high-statistics pp data at the same collision energy used as a baseline, allow for a detailed experimental study of these phenomena and comparisons to predictions from a variety of theoretical calculations. This talk presents the latest ATLAS results on electroweak boson production, including updated results on Z production and high-precision W boson results in Pb+Pb collisions. Inclusive production of prompt photons in proton-lead (p+Pb) collisions at \( \sqrt{s_{\text{NN}}} = 8.16 \) TeV is also covered. Various predictions of nuclear modifications to PDFs are discussed.

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Secondary track (number):

Heavy Ions - Posters / 198

Can we constrain anomalous magnetic and/or electric dipole moments of tau lepton from PbPb \( \rightarrow \) PbPb\( \tau^+ \tau^- \) reaction at the LHC?

Authors: Mariola Klusek-Gawenda\(^1\); Antoni Szczurek\(^2\); Mateusz Dyndal\(^3\); Matthias Schott\(^4\)

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We will discuss the sensitivity of the \( \gamma\gamma \rightarrow \tau^+\tau^- \) process in ultraperipheral Pb+Pb collisions on the anomalous magnetic moment of \( \tau \) lepton (\( a_\tau \)) at LHC energies. We derive the corresponding cross sections by folding the elementary cross section with the heavy-ion photon fluxes and considering semi-leptonic decays of both \( \tau \) leptons in the fiducial volume of ATLAS and CMS detectors. We present predictions for total and differential cross sections, and for the ratios to \( \gamma\gamma \rightarrow e^+e^- (\mu^+\mu^-) \) process. These ratios allow to cancel theoretical and experimental uncertainties when performing precision measurement of \( a_\tau \) at the LHC. The expected limits on \( a_\tau \) with existing Pb+Pb dataset are found to be better by a factor of two comparing to the current best experimental limits and can be further improved by another factor of two at High Luminosity LHC. In addition, our results for tau lepton electric dipole moment, \( d_\tau \), can be competitive with the current best limits that were measured by Belle experiment.

Secondary track (number):

07

Formal Theory - Posters / 199

Electroweak magnetic monopole: The lower mass bound

Author: Petr Beneš\(^1\)

Co-author: Filip Blaschke \(^2\)

\(^1\) Czech Technical University in Prague
We present exact solutions to the electroweak Cho-Maison magnetic monopole in a family of effective extensions of Standard Model that have a Bogomol'nyi-Prasad-Sommerfield (BPS) limit. We find that the lower bound to the mass of the magnetic monopole is \( M \geq 2\pi v/g \approx 2.37 \) TeV. We argue that this bound holds universally, not just in theories with a BPS limit.

**Neutrino Physics / 200**

**The diffuse supernova neutrino background in Super-Kamiokande**

**Author:** Sonia El Hedri

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Neutrinos have played a key role in astrophysics, from the characterization of nuclear fusion processes in the Sun to the observation of supernova SN1987A and multiple extragalactic events. The Super-Kamiokande experiment has played a major part in these astrophysical studies by investigating low energy O(10) MeV neutrinos and currently exhibits the best sensitivity to the diffuse neutrino background from distant supernovae. Discovering and characterizing this signal however presents significant challenges due to important backgrounds from cosmic muon spallation and atmospheric neutrinos. Reducing these backgrounds will require implementing state-of-the-art neutron tagging algorithms to discriminate between different types of interactions, as well as a thorough characterization of spallation-inducing mechanisms. Here, I present an overview of the search for the diffuse supernova background in Super-Kamiokande, and discuss how the current strategies will evolve after the SuperK-Gd upgrade.

**Education and Outreach / 201**

**A taste of particle physics**

**Authors:** Katharine Leney\(^1\); Kathryn Grimm\(^2\)

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A novel approach to science communication is presented, using cake to explain particle physics ideas to engage new audiences. This talk will present a public engagement strategy where baking has been used to engage the general public, in events such as the CERN Open Days in 2019, and using online platforms such as social media. This innovative approach using the juxtaposition of cake and physics makes for a fun and memorable experience, and has been demonstrated to engage new and low science capital audiences and spark their interest in particle physics.
The Belle II diamond-detector for radiation monitoring and beam abort

Author: Yifan Jin
Co-author: (for the Belle II SVD collaboration)

INFN-Trieste

The SuperKEKB electron-positron collider at the KEK laboratory in Japan aims to achieve a maximum luminosity 50x higher than its predecessors KEKB and PEPII, positioning the Belle II experiment at the forefront of searches for non-standard-model physics in the next decade. High collision intensity implies high beam-induced radiation, which can damage essential Belle II sub-detectors and SuperKEKB components. Twenty-eight diamond sensors, read-out by purpose-built electronics, are installed on the beam-pipe to measure radiation and prevent damage. The sensors operate as solid-state ionization chambers, providing measurements of pA to mA currents, which are proportional to the radiation-dose rates, to monitor instantaneous radiation, record integrated radiation, and trigger beam aborts. This talk introduces the system features and discusses in detail the 2018-2019 operations and performance in early Belle II data taking.

Color-allowed bottom baryon to s-wave and p-wave charmed baryon non-leptonic decays

Author: Chun-Khiang Chua

We study color allowed bottom baryon to s-wave and p-wave charmed baryon non-leptonic decays. The charmed baryons include spin-1/2 and spin-3/2 states. Explicitly, we consider \( \Lambda_b \to \Lambda_c^{(*)} M^- \), \( \Xi_b \to \Xi_c^{(*)} M^- \), and \( \Omega_b \to \Omega_c^{(*)} M^- \) decays with \( M = \pi, K, K^+, a_1, D, D_s, D_s^*, D_s^{**}, \Lambda_c^{(*)} \) = \( \Lambda_c, \Lambda_c(2505), \Lambda_c(2625), \Lambda_c(2770), \Omega_c(2815), \Xi_c(2940), \Xi_c(3050), \Omega_c(3090), \Xi_c(3120). \)

There are six types of transitions, namely, (i) \( \text{cal}B_b(3\ell, 1/2^+) \) to \( \text{cal}B_c(3\ell, 1/2^+) \), (ii) \( \text{cal}B_b(6\ell, 1/2^+) \) to \( \text{cal}B_c(6\ell, 1/2^+) \), (iii) \( \text{cal}B_b(6\ell, 3/2^+) \) to \( \text{cal}B_c(6\ell, 3/2^+) \), and \( \text{cal}B_b(3\ell_f, 1/2^+) \) to \( \text{cal}B_c(3\ell_f, 1/2^+) \), and \( \text{cal}B_b(3\ell_f, 3/2^+) \) to \( \text{cal}B_c(3\ell_f, 3/2^+) \) transitions. Types (i) to (iii) involve spin 1/2 and 3/2 s-wave charmed baryons, while types (iv) to (vi) involve spin 1/2 and 3/2 p-wave charmed baryons. The light diquarks are spectatoring in these transitions. The transition form factors are calculated in the light-front quark model approach. All of the form factors in the 1/2 \( \to 1/2 \) and 1/2 \( \to 3/2 \) transitions are extracted, and they are found to reasonably satisfy the relations obtained in the heavy quark limit, as we are using heavy but finite \( m_b \) and \( m_c \). Using naive factorization, decay rates and up-down asymmetries of the above modes are predicted and can be checked experimentally. The study on these decay modes may shed light on the quantum numbers of \( \Lambda_c(2770), \Lambda_c(2940), \Omega_c(3050), \Omega_c(3090) \) and \( \Omega_c(3120). \)
Beyond the Standard Model / 204

Muon $g - 2$ and scalar leptoquark mixing

Authors: Svjetlana Fajfer$^1$, Olcyr Sumensari$^None$; Ilja Dorsner$^None$

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The observed muon anomalous magnetic moment deviates from the Standard Model (SM) predictions. There are two scalar leptoquarks with simultaneous couplings to the quark-muon pairs of both chiralities that can singly explain this discrepancy. We discuss an alternative mechanism that calls for mixing of two scalar leptoquarks of the same electric charge through the interaction with the Higgs field, where the two leptoquarks separately couple to the quark-muon pairs of opposite chirality structures. Three scenarios that satisfy this requirement are $S1 & S3$, $S1 & S3$, and $R2 & R2$, where the first scenario is realised with the up-type quarks running in the loops while the other two scenarios proceed through the down-type quark loops. We constrain the leptoquark mixing parameters with oblique corrections and introduce only two non-zero Yukawa couplings to quarks and muon, at the time, to study ability of these three scenarios to explain $(g - 2)_\mu$ and be in accord with existing constraints. We find that the $S1 & S3$ scenario with the (charm) top quark loops is (not) viable, whereas the $S1 & S3$ and $R2 & R2$ scenarios require at least one of the two Yukawa couplings to be an O(1) parameter to accommodate the $(g - 2)_\mu$ discrepancy. If Yukawa couplings are to remain perturbative for the $S1 & S3$ scenario with the top quark loops, we find an upper bound on the leptoquark mass scale to be at 15TeV.

Secondary track (number):

05.

Quark and Lepton Flavour Physics / 205

Angular analysis of modes with $b \rightarrow c\ell\bar{\nu}$ transition and new physics

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We discuss the four-fold angular distribution for the semileptonic decay $\bar{B} \rightarrow D^{*}_2 (\rightarrow D\pi) \ell\bar{\nu}$ where $D^{*}_2(2460)$ is a tensor meson. We start with the most general beyond the Standard Model (SM) dimension-six effective Hamiltonian which comprises (axial)vector, (pseudo)scalar and tensor operators for both quark and lepton currents, and it also includes the right-handed neutrinos. The decay can be described by 16 transversity amplitudes and it provides a multitude of observables which can be extracted from data. We investigate the observables in the context of the SM and the new physics scenarios which can explain the intriguing discrepancies observed in the $b \rightarrow c\tau\bar{\nu}$ data.

I read the instructions:

Secondary track (number):
Operational Experience and Performance with the ATLAS Pixel detector at the Large Hadron Collider at CERN

Author: Soshi Tsuno

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The tracking performance of the ATLAS detector at the Large Hadron Collider (LHC) at CERN relies critically on its 4-layer Pixel Detector, consisting of four barrel layers at 33, 50.5, 88.5, and 122.5 mm from the geometric center of the ATLAS detector and a total of six disk layers, three at each end of the barrel region. It has undergone significant hardware and readout upgrades to meet the challenges imposed by the higher collision energy, pileup and luminosity that are delivered by the LHC, with record breaking instantaneous luminosities of $2 \times 10^{34}$ cm$^{-2}$ s$^{-1}$.

By the end of the proton-proton collision runs in 2018, the innermost layer IBL had received an integrated fluence of $\Phi = 9 \times 10^{14}$ 1 MeV neq/cm$^2$. The key status and performance metrics of the ATLAS Pixel Detector are summarised, and the operational experience and requirements to ensure optimum data quality and data taking efficiency will be described, with special emphasis to radiation damage experience.

Muon Identification and Performance in the ATLAS Experiment

Author: Rustem Ospanov

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Muon reconstruction and identification play a fundamental role in many analyses of central importance in the LHC run-2 Physics programme. The algorithms and the criteria used in ATLAS for the reconstruction and identification of muons with transverse momentum from a few GeV to the TeV scale will be presented. Their performance is measured in data based on the decays of $Z$ and $J/\psi$ to pair of muons, that provide a large statistics calibration sample. Reconstruction and identification efficiencies are evaluated, and the results are used to derive precise MC simulation corrections. Isolation selection criteria and their performance in presence of high pileup will also be presented.
Status of the MUonE experiment

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The precision measurement of the anomalous magnetic moment of the muon presently exhibits a 3.5σ discrepancy with the Standard Model (SM) prediction. In the next few years this measurement will reach an even higher precision at Fermilab and J-PARC. While the QED and electroweak contributions to the muon g-2 can be determined very precisely, the leading hadronic (HLO) correction is affected by a large uncertainty which dominates the error of the SM prediction.

A novel approach has been proposed to determine the HLO contribution to the muon g-2 based on the measurement of the effective electromagnetic coupling in the space-like region at low-momentum transfer. We will discuss the possibility of performing this measurement at CERN by the MUonE experiment which aims at a very precise determination of the muon-electron elastic differential cross-section, exploiting the scattering of 150 GeV muons (currently available at CERN’s North area) on atomic electrons of a low-Z target. The status of the proposal in view of the test run on a reduced detector expected in 2021 will be presented.

Muon Trigger using Deep Neural Networks accelerated by FPGAs

Authors: Jason Lee¹; Youngwan Son²; Ian James Watson²; Seungjin Yang³; Seulgi Kim³; Inkyu Park³

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Accuracy and latency are crucial to the trigger system in high luminosity particle physics experiments. We investigate the usage of deep neural networks (DNN) to improve the accuracy of the muon track segment reconstruction process at the trigger level. Track segments, made by hits within a detector module, are the initial partial reconstructed objects which are the typical building blocks for muon triggers. Currently, these segments are coarsely reconstructed on FPGAs to keep the latency manageable. DNNs are ideal for these types of pattern recognition problems, and so we examine the potential for DNN based track segment reconstruction to be accelerated by dedicated FPGAs to improve both processing speed and latency for the trigger system.
Spallation background in the Super-Kamiokande experiment

Author: Laura Bernard

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The Super-Kamiokande experiment has played a major role in astrophysics by investigating low energy O(10)-MeV neutrinos. It has notably been instrumental in characterizing the 8B solar neutrino spectrum and currently exhibits the best sensitivity to relic neutrinos from distant supernovae. Fully realizing the potential of low energy astrophysical searches however requires significantly reducing backgrounds from cosmic muon spallation. Here, I present an in-depth study of spallation backgrounds, in particular of the showers produced by muons passing through the detector. This study, and in particular the implementation of new FLUKA-based simulations, are expected to significantly impact analysis strategies for a wide variety of low energy searches in Super-Kamiokande.

Secondary track (number):

Astro-particle Physics and Cosmology / 211

On the Abraham-Minkowski controversy: Can the time delay of the gamma-ray bursts travelling through interstellar space be explained without invoking the Lorentz-invariance violation?

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The ANTARES neutrino telescope and other experiments are searching for more detailed information on the previously observed shifted high-energy neutrinos from the gamma-ray bursts travelling through interstellar space. Many theoretical models have been proposed to explain this phenomenon, based on assuming the Lorentz-invariance violation. In this talk I shall show that the dispersion phenomenon of gamma-ray in an interstellar space considered as a cosmic plasma can explain this effect. This in turn indicates that invoking the drastic assumption of Lorentz-invariance violation for such a problem can be premature.

I read the instructions:

Secondary track (number):

Neutrino Physics - Posters / 212

0νββ in left-right theories with Higgs doublets and gauge coupling unification
We consider a version of Left-Right Symmetric Model in which the scalar sector consists of a Higgs bidoublet (Φ) with $B - L = 0$, Higgs doublets ($H_{L,R}$) with $B - L = 1$ and a charged scalar ($\delta^+ \uparrow$) with $B - L = 2$ leading to radiatively generated Majorana masses for neutrinos and thereby, leads to new physics contributions to neutrinoless double beta decay ($0\nu\beta\beta$). We show that such a novel framework can be embedded in a non-SUSY SO(10) GUT leading to successful gauge coupling unification at around $10^{16}$ GeV with the scale of left-right symmetry breaking around $10^{10}$ GeV. The model can also be extended to have left-right symmetry breaking at TeV scale, enabling detection of $W_R, Z_R$ bosons in LHC and future collider searches. In the context of neutrinoless double beta decay, this model can saturate the present bound from GERDA and KamLAND-Zen experiments. Also, we briefly explain how keV-MeV range RH neutrino arising from our model can saturate various astrophysical and cosmological constraints and can be considered as warm Dark Matter (DM) candidate to address various cosmological issues. We also discuss on left-right theories with Higgs doublets without having scalar bidoublet leading to fermion masses and mixings by inclusion of vector like fermions.

Secondary track (number):

Neutrino Physics - Posters / 213

A comparative study of $0\nu\beta\beta$ decay in symmetric and asymmetric left-right model

Author: Supriya Senapati

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We study the new physics contributions to neutrinoless double beta decay ($0\nu\beta\beta$) in a TeV scale left-right model with spontaneous D-parity breaking mechanism where the values of the $SU(2)_L$ and $SU(2)_R$ gauge couplings, $g_L$ and $g_R$ are unequal. Neutrino mass is generated in the model via gauge extended inverse seesaw mechanism. We embed the model in a non-supersymmetric SO(10) GUT with the purpose of quantifying the results due to the condition $g_L \neq g_R$. We compare the predicted numerical values of half life of $0\nu\beta\beta$ decay, effective Majorana mass parameter and other lepton number violating parameters for three different cases; (i) for manifest left-right symmetric model ($g_L = g_R$), (ii) for left-right model with spontaneous D parity breaking ($g_L \neq g_R$), (iii) for Pati-Salam symmetry with D parity breaking ($g_L \neq g_R$). We show how different contributions to $0\nu\beta\beta$ decay are suppressed or enhanced depending upon the values of the ratio $\frac{g_L}{g_R}$ that are predicted from successful gauge coupling unification.

Secondary track (number):

Formal Theory / 214
Intrinsic quantum coherence in particle oscillations

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The quantum field theoretical description of coherence in the oscillations of particles, especially neutrinos, is a standing problem in particle physics. In this talk, several inconsistencies of the standard approach to particle oscillations will be explained, and how they are resolved in a process-independent manner, by a novel approach inspired by the Bardeen-Cooper-Schrieffer theory of superconductivity and the Nambu-Jona-Lasinio model. The formalism leads to corrections to the neutrino oscillation probability originally written by Pontecorvo and Gribov, however the standard probability is validated in the ultrarelativistic neutrino limit. The massive neutrino states are interpreted as quasiparticles on a vacuum condensate of "Cooper pairs" of massless flavour neutrinos. The newly defined oscillating particle states are for neutrino oscillations what the Klauder-Sudarshan-Glauber coherent states are for quantum optics.

Secondary track (number):

03.

Astro-particle Physics and Cosmology / 215

MONTE CARLO SIMULATION ON THE EFFECT OF AIR MASS ABOVE THE PRINCESS SIRINDHORN NEUTRON MONITOR TO ATMOSPHERIC NEUTRONS FROM COSMIC RAYS

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Neutron monitors are recognized as a key tool for studying the time variations of galactic cosmic rays, especially with regard to solar effects. Cosmic-ray detectors inside the atmosphere do not record cosmic ray particles directly. The so-called primary cosmic rays interact with nuclei in the atmosphere to produce secondary daughter products. Neutron monitors record predominantly the secondary neutrons from these atmospheric showers. The Princess Sirindhorn Neutron Monitor (PSNM) is the first neutron monitor station in Chiang Mai, Northern Thailand, which installed at a high vertical cutoff rigidity of 16.8 GV. It provides unique data on the energy dependence of solar synodic variations, cosmic ray anisotropy, Forbush decreases, and solar modulation. In this work we performed Monte Carlo simulations of the atmospheric structure effects on secondary neutron counts above The Princess Sirindhorn Neutron Monitor by using the FLUKA program. These atmospheric processes are well understood, and the response of neutron monitors to these secondary particles is simulated. This work also provides the techniques for further analysis and a better understanding of those effects.

Secondary track (number):

12
Systematic Uncertainties of the NOvA Neutrino Oscillation Analysis

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\textsuperscript{1} Charles University, Institute of Particle and Nuclear Physics

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NOvA is a two detector long-baseline neutrino oscillation experiment using Fermilab’s 700 kW NuMI muon neutrino beam. It studies the disappearance of muon (anti)neutrinos and the appearance of electron (anti)neutrinos in the beam over a distance of 810 km between the detectors. The observations can be used to constrain neutrino oscillation parameters: $\theta_{23}$, $\Delta m^{2}_{32}$ and $\delta_{\text{CP}}$ in the standard 3 active neutrinos paradigm. Although statistical uncertainties currently dominate in these measurements, understanding the major sources of systematic uncertainties and their correlations is vital for both the interpretation and precision of the results and also for further improvements of the analysis. This poster presents details of the systematic uncertainties affecting NOvA’s neutrino oscillation analysis results and how we evaluate them by generating systematically shifted predictions.

Secondary track (number):

Accelerator: Physics, Performance, and R&D for Future Facilities - Posters / 218

High energy plasma in vacuum system generated by microwave surfatron generator surfatron resonator

Author: jihye kim\textsuperscript{None}

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With the continued down scaling of devices and structure changed to 3-dimensional, new engineering processes are in great demand. Microwave surfatron plasma is considered new plasma source because it enables very low-temperature deposition and good quality due to its low electron temperature and higher plasma density. For adopting surfatron plasma source to new vacuum chamber, it is essential to understand the physical properties of generated plasma with the varying gas atmosphere. Also we are requested to achieve acceptable homogeneity on large area. Thus, in this work, we investigated plasma parameters with various gas, pressure, flow and various distances from the plasma outlet with optimized design of plasma nozzle.

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 219

The CMS Tracker Upgrade for the High Luminosity LHC

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The LHC machine is planning an upgrade program which will smoothly bring the luminosity to about $5 - 7.5 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$, to possibly reach an integrated luminosity of $3000 - 4000 \text{fb}^{-1}$ over about a decade. This High Luminosity LHC scenario, HL-LHC, starting in 2027, will require an upgrade program of the LHC detectors known as Phase-2 upgrade. The current CMS Outer Tracker, already running beyond design specifications, and CMS Phase-1 Pixel Detector will not be able to survive HL-LHC radiation conditions and CMS will need completely new devices, in order to fully exploit the highly demanding conditions and the delivered luminosity. The new Outer Tracker should have also trigger capabilities. To achieve such goals, R&D activities have explored options for both the Outer Tracker and for the Inner Tracker. The solutions developed will allow to include tracking information in the first level trigger stage. The design choices for the Tracker upgrades are discussed along with some highlights on technological approaches and R&D activities.

I read the instructions:

Secondary track (number):
12.

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques - Posters / 220

A muon tracking algorithm for Level 1 trigger in the CMS barrel muon chambers during HL-LHC

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The electronics of the CMS (Compact Muon Solenoid) DT (Drift Tubes) chambers will need to be replaced for the HL-LHC (High Luminosity Large Hadron Collider) operation due to the increase of occupancy and trigger rates in the detector, which cannot be sustained by present system. A system is being designed that will forward asynchronously the totality of the chambers signals to the control room, at full resolution. A new backend system will be in charge of building the trigger primitives of each chamber out of this asynchronous information, aiming at achieving resolutions comparable to the ones that the offline High Level Trigger can obtain nowadays. In this way, the new system will provide improved functionality with respect to present system, allowing to improve the resilience to potential aging situations. An algorithm for the trigger primitive generation that will run in this new backend system has been developed and implemented in firmware. The performance of this algorithm has been validated through different methods: from a software emulation approach to hardware implementation tests. The performance obtained is very good, with optimal timing and position resolutions, close to the ultimate performance of the DT chamber system. One important validation step has included the implementation of this algorithm in a prototype chain of the HL-LHC electronics, which has been operated with real DT chambers under cosmic data taking campaigns. The new trigger primitive generation has been implemented in the so-called AB7, spare uTCA boards from present DT system which host Xilinx Virtex 7 FPGAs. The performance of this prototyping system has been verified and will be presented in this contribution, showing the goodness of the design for the expected functionality during HL-LHC.

I read the instructions:

Secondary track (number):
12.
Tracker alignment of the CMS detector

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The positions of the nearly twenty-thousands silicon sensors of the CMS central tracking system must be determined with a precision better than their intrinsic resolution in order to provide an optimal reconstruction of charged particle trajectories. The procedure, referred as the alignment, includes also the adjustment of the orientations and the determination of the deviation from flatness of the sensor surfaces.

Data-driven methods used to carefully align the detector and validate the alignment will be presented with CMS Run-2 data, collected from 2016 to 2018. Systematic distortions such as weak modes are discussed, as well as the impact of the variation of the conditions during data taking over time, in particular effects related to the radiation damage.

Finally, we illustrate the impact on physics of the recent developments included in the legacy re-processing, which was performed with the aim to greatly improve the physics potential for precision measurements, such as the reconstruction of the invariant mass spectrum of the dilepton systems.

Upgrade of the CMS Cathode Strip Chambers for the HL-LHC

Author: Sven Dildick

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The Large Hadron Collider (LHC) will be upgraded in several phases to significantly expand its physics program, and these upgrades present major challenges to the operations of the CMS cathode-strip-chamber muon system. After the current long shutdown from 2018-2020 (LS2) the accelerator luminosity will be increased to $2 - 3 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$, exceeding the design value of $10^{34}\text{cm}^{-2}\text{s}^{-1}$, allowing the CMS experiment to collect approximately 100 $\text{fb}^{-1}$ per year. A subsequent upgrade in 2022-23 will increase the luminosity up to $5 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$. The CMS muon system must be able to sustain a physics program after the LS2 shutdown that maintains sensitivity to electroweak scale physics and for TeV scale searches similar to what was achieved up to now for the Cathode Strip Chamber (CSC) muon detectors, the electronics will be upgraded to handle the expected higher data rates. The design of the upgraded CSC electronics will be discussed as well as the status of the first phase of the electronics installation. In addition, accelerated irradiation tests are being performed to study the behavior of the CSC electronics under conditions which are nearly an order of magnitude beyond the original design values. Studies have also been performed of chamber gas mixtures to reduce greenhouse-gas impacts. The status of this irradiation campaign and results will be presented.
Precision calorimetry at high luminosity: the CMS electromagnetic calorimeter from the LHC Run 2 to the HL-LHC

Author: Dario Soldi¹

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The CMS experiment at the LHC is equipped with a high granularity lead tungstate crystal electromagnetic calorimeter (ECAL) offering an excellent energy resolution. The ECAL was crucial in the discovery and subsequent characterization of the Higgs boson, particularly in the two photon and two Z boson decay channels. The LHC has reached an unprecedented luminosity during Run 2 (2016-2018), leading to a high numbers of proton-proton interactions per bunch collision (pileup), exceeding the design value and resulting in a very high radiation environment. We will present how we maintain the high performance of the calorimeter in these difficult conditions, challenging for both the calibration and the reconstruction. A new readout is being developed to operate the calorimeter at the high-luminosity LHC (HL-LHC) with an even higher luminosity, reaching an average pileup of up to 200. Precise signal time measurement and limitation of the dark current induced by radiation damaged are key ingredients to maintain a high energy resolution in the HL-LHC conditions. This upgrade of the CMS electromagnetic calorimeter will be represented.

Development of the CMS MTD Endcap Timing Layer for HL-LHC

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The MIP Timing Detector (MTD) of the Compact Muon Solenoid (CMS) is designed to provide precision timing information (with resolution of ~40 ps per layer) for charged particles, with hermetic coverage up to a pseudo-rapidity of |η|=3. This upgrade will reduce the effects of pileup expected under the High-Luminosity LHC (HL-LHC) running conditions and brings new and unique capabilities to the CMS detector. The time information assigned to each track will enable the use of 4D reconstruction algorithms and will further discriminate in the time domain interaction vertices within the same bunch crossing to recover the track purity of vertices in current LHC conditions. The endcap region of the MTD, called the Endcap Timing Layer (ETL), will be instrumented with silicon-based low gain avalanche detectors (LGADs), covering the high radiation pseudo-rapidity region between |η|=1.6 and 3.0. Each endcap will be instrumented with a two-disk system of LGADs, read out by
Endcap Timing Readout Chips (ETROCs), being designed for precision timing measurements. We will go over the motivations for the MTD and will present an overview of the MTD ETL design. We will also present the R&D and test beam studies that were integral for achieving the ETL design, as well as recent progress on the development of the ETROC readout electronics.

I read the instructions:

Secondary track (number):

12.

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 225

Precision Timing with the CMS MTD Barrel Timing Layer for HL-LHC

Author: Nan Lu

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The Compact Muon Solenoid (CMS) detector at the CERN Large Hadron Collider (LHC) is undergoing an extensive Phase II upgrade program to prepare for the challenging conditions of the High-Luminosity LHC (HL-LHC). A new timing detector in CMS will measure minimum ionizing particles (MIPs) with a time resolution of ~30-40 ps and hermetic coverage up to a pseudo-rapidity of $|\eta|=3$. The precision time information from this MIP Timing Detector (MTD) will reduce the effects of the high levels of pileup expected at the HL-LHC, enhancing and expanding the physics reach of the CMS detector. For instance, in the analysis of di-Higgs boson production, a timing resolution of 30-40 ps is expected to improve the effective luminosity by about 25% through gains in $b$-tagging and isolation efficiency. The central Barrel Timing Layer (BTL) will be based on LYSO:Ce crystals read out with silicon photomultipliers (SiPMs). The BTL will use elongated crystal bars, with double-sided read out (a SiPM on each end of the crystal), in order to maximize detector performance within the constraints of space, cost, and channel count. We will present an overview of the MTD BTL design, highlighting some of physics analyses impacted by the MTD. We will review the extensive R&D studies carried out to optimize the BTL design and the test beam results in which the goal of 30 ps timing resolution has been achieved.

I read the instructions:

Secondary track (number):

12.

Operation, Performance and Upgrade of Present Detectors / 226

Performance and upgrade of the Precision Proton Spectrometer and performance of proton reconstruction with the CMS experiment

Author: Ada Solano

\[1 \text{ Univ. di Torino e Sez. dell’INFN} \]
The PPS (Precision Proton Spectrometer) detector system consists of silicon tracking stations as well as timing detectors to measure both the position and direction of protons and their time-of-flight with high precision. They are located at around 200 m from the interaction point in the very forward region on both sides of the CMS experiment. PPS is built to study Central Exclusive Production (CEP) in proton-proton collisions at the LHC, including the photon-photon production of W and Z boson pairs, high-mass diphoton and dilepton production, high-$p_T$ jet production, as well as searches for anomalous couplings and new resonances.

In this presentation the PPS operation, commissioning and performance are discussed. The PPS detector has taken data at high luminosity while fully integrated to the CMS experiment. The total data collected correspond to around 100 fb$^{-1}$ during the LHC Run 2. The detectors are placed in movable Roman pot stations within few mm from the LHC beam, and operate under highly non-uniform irradiation. The tracking detectors consist of 3D pixel sensors, bump bonded to the PSI46dig ROC and the timing detectors of scCVD diamond sensors. Ultra-fast silicon detectors have also been operated during Run 2. The upgrade of the timing system for the LHC Run 3 aims for a timing resolution better than 30 ps.

The full proton reconstruction chain has been developed and deployed for data analysis. It relies on the alignment and calibration of the tracking and timing sensors, and a parametrisation of the LHC magnet lattice, calibrated from the data. The proton reconstruction, alignment and calibration methods are discussed and performance results with the data collected are presented.

I read the instructions:

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 227

Material budget estimation of the CMS tracker with triplet method

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Silicon trackers are used extensively in high energy physics experiments. e.g. in ATLAS and CMS experiments at LHC, Belle II experiment at KeK. A common feature in these tracking systems is that they have multiple layers of silicon detectors. As charged particles pass through the silicon sensors, ionization gives rise to signal in individual channels of each detector. Hits in multiple layers of a tracking system are then used to reconstruct the tracks of the charged particles. The design of these tracking systems are optimized keeping in mind the material budget of the system. The alignment of the silicon detectors and the estimation of the material budget of tracking detectors is crucial for the physics programme of any experiment, especially for precision measurements, since they contribute to the relative precision of measurement of the transverse momentum. The CMS experiment is planning to perform a measurement of the W boson mass with a precision of at least 10 MeV: this requires the measurement of muon transverse momentum to a relative precision better than 10$^{-4}$. In this presentation, we shall propose a novel method to locally calibrate a multi layered silicon tracking system in a collider based experiment with the magnetic field along the beam direction. The idea is to use a small track segment, a triplet, built out of hits in three consecutive layers in the tracker and use the local sagitta of this triplet to estimate the material in the middle layer, and the relative alignment of the modules in the transverse plane which will ultimately be provided as input to the transverse momentum calibration. A comparison will be made between the results obtained from collision data and simulated events from the CMS detector.

I read the instructions:
The CMS Phase-2 high-granularity 5D calorimeter

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The CMS high-granularity endcap calorimeter (HGCAL) is a challenging detector that brings together tracking and calorimetry, silicon and scintillators, as well as linear collider detector concepts, to meet the harsh radiation and pileup environment of the High Luminosity LHC Phase (Phase 2) in the forward region and exploit challenging signatures such as VBF/VBS production. The HGCAL features unprecedented transverse and longitudinal segmentation in both its electromagnetic (ECAL) and hadronic (HCAL) compartments. This information allows to resolve the fine structure of showers, playing to the strengths of particle-flow reconstruction, and allowing to enhance pileup rejection and particle identification, while still achieving good energy resolution. The ECAL and a large fraction of HCAL will be based on hexagonal silicon sensors of 0.5 - 1 cm$^2$ cell size. The remainder of the HCAL will be based on highly-segmented scintillators read out by silicon photo-multipliers (SiPM). The intrinsic high-precision timing capabilities of the silicon sensors add a further measurement dimension, critical in event reconstruction, especially for pileup rejection. This presentation will overview the HGCAL project, covering the physics motivation, engineering design, readout and trigger concepts, performance (simulated and from beam tests), as well as ways in which the 5D information content may be exploited by cutting-edge machine learning techniques to enhance the overall physics performance of the forward region.

Paving the way to reconstruct the 5D information of the CMS HGCAL detector at the HL-LHC

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To maintain and improve physics performance under the harsher conditions of the high luminosity LHC phase from 2026, the CMS collaboration has designed a novel endcap calorimeter that uses silicon sensors to achieve radiation tolerance, with the additional benefit of a very high readout granularity. In regions characterised by lower radiation levels, small scintillator tiles with individual SiPM readout are employed. A novel reconstruction approach is being developed to fully exploit the granularity and other significant features of the detector like precision timing, with a view to deployment in the high pileup environment of HL-LHC. An iterative reconstruction framework (TICL) has been put in place, and is being actively developed. The inputs to the framework are clusters of energy deposited in individual calorimeter layers delivered by a density-based algorithm which has
recently been developed and tuned. In view of the expected pressure on the computing capacity in the HL-LHC era, the algorithms and their data structures are being designed with GPUs in mind. Preliminary results show that significant speed-up can be obtained running the clustering algorithm on GPUs. In addition, machine learning techniques based on cutting-edge techniques are being investigated and integrated into the reconstruction framework. This talk will describe the approaches being considered and show first results.

I read the instructions:

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 230

Level-1 Track Finding at CMS for the HL-LHC

Author: Andrew Evan Hart

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The success of the CMS physics program at the HL-LHC requires maintaining sufficiently low trigger thresholds to select processes at the electroweak scale. With an average expected 200 pileup interactions, critical to achieve this goal while maintaining manageable trigger rates is in the inclusion of tracking information in the Level-1 (L1) trigger. A 40 MHz silicon-based track trigger on the scale of the CMS detector has never before been built; it is a novel handle, which in addition to maintaining trigger rates can enable entirely new physics studies.

The main challenges of reconstructing tracks in the L1 trigger are the large data throughput at 40 MHz and the need for a trigger decision within 12.5 µs. To address these challenges, the CMS outer tracker for HL-LHC uses modules with closely-spaced silicon sensors to read out only the hits compatible with charged particles above 2-3 GeV ("stubs"). These are used in the back-end L1 track finding system, implemented using commercially available FPGA technology. The ever-increasing capability of modern FPGAs combined with their programming flexibility are ideal for implementing fast track finding algorithms. The proposed reconstruction algorithm forms track seeds ("tracklets") from pairs of stubs in adjacent layers of the outer tracker. These seeds provide roads where consistent stubs are included to form track candidates. Track candidates sharing multiple stubs are combined prior to being fitted. A Kalman Filter track fitting algorithm is employed to identify the final track candidates and determine the track parameters. The system is divided into nine sectors in the r-phi plane, and time-multiplexed by a factor of 18, so that each event in one sector is processed by a dedicated track finding board.

This presentation will discuss the CMS L1 track finding algorithm and its implementation, present simulation studies of estimated performance, and show recent results from a scalable system demonstrator based on prototype hardware.

I read the instructions:

Secondary track (number):

12.

Operation, Performance and Upgrade of Present Detectors / 231
CMS High Level Trigger performance in Run 2 and new developments for Run 3

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The CMS experiment selects events with a two-level trigger system, the Level-1 (L1) trigger and the High Level trigger (HLT). The HLT reduces the rate from 100 kHz to about 1 kHz and has access to the full detector readout and runs a streamlined version of the offline event reconstruction. In Run 2 the peak instantaneous luminosity reached values above 2X 10^{34} cm^{-2} sec^{-1}, posing a challenge to the online event selection. An overview of the object reconstruction and trigger selections used in the 2016-2018 data-taking period will be presented. The performance of the main trigger paths and the lessons learned will be summarized, together with the new developments in view of the coming Run 3.

I read the instructions:

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 232

The CMS Trigger system for the HL-LHC

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The CMS experiment has been designed with a two-level trigger system: the Level 1 Trigger, implemented on custom-designed electronics, and the High Level Trigger, a streamlined version of the CMS reconstruction software running on a computer farm. During its “Phase 2” the LHC will reach a luminosity of 7X10^{34} cm^{-2} sec^{-1} with a pileup of 200 collisions, integrating more than 3000 fb^{-1} over the full experimental run. To fully exploit the higher luminosity, the CMS experiment will introduce a more advanced Level 1 Trigger and increase the full readout rate from 100 kHz to 750 kHz. The higher luminosity, event complexity and input rate present an unprecedented challenge to the High Level Trigger, that aims to achieve a similar efficiency and rejection factor as today despite the higher pileup and more pure preselection. The ongoing studies and prospects for the online reconstruction and selection algorithms will be discussed.

I read the instructions:

Secondary track (number):

12.

Operation, Performance and Upgrade of Present Detectors / 233

New jet tagging techniques at CMS

Author: Dennis Schwarz

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The CMS experiment makes use of a large variety of algorithms to identify the origin of particle jets measured in the detector. Through the study of jet substructure properties, jets originating from quarks, gluons, W/ Z/Higgs bosons, top quarks and pileup interactions are discriminated. We present new techniques based on machine learning approaches developed for LHC Run 2 and Run 3 that significantly surpasses performance of classical taggers.

We present the methods and performance of jet and missing transverse momentum reconstruction in CMS. The latest reconstruction and calibration procedures for Run2 data are summarized and an outlook to the new techniques foreseen (online and offline) for Run3 is given. Among the most critical new event reconstruction techniques developed by CMS for LHC Run 2 and Run 3 are pileup mitigation tools that will be discussed in this talk.

Many physics analyses using the Compact Muon Solenoid (CMS) detector at the LHC require accurate, high resolution electron and photon energy measurements. Excellent energy resolution is crucial for studies of Higgs boson decays with electromagnetic particles in the final state, as well as searches for very high mass resonances decaying to energetic photons or electrons. The CMS electromagnetic calorimeter (ECAL) is a fundamental instrument for these analyses and its energy resolution is crucial for the Higgs boson mass measurement. Recently the energy response of the
calorimeter has been precisely calibrated exploiting the full Run 2 data, aiming at a legacy reprocessing of the data. A dedicated calibration of each detector channel has been performed with physics events exploiting electrons from W and Z boson decays, photons from p0/eta decays, and from the azimuthally symmetric energy distribution of minimum bias events. The calibration strategies that have been implemented and the excellent performance achieved by the CMS ECAL with the ultimate calibration of Run 2 data, in terms of energy scale stability and energy resolution, are presented.

I read the instructions:

Secondary track (number):

Heavy Ions / 236

Fire-streaks, electromagnetic effects, directed flow and lifetime of the plasma at SPS energies

Authors: Antoni Szczurek¹; Andrzej Rybicki²; Vitalii Ozvenchuk³

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We present our calculation [1] of electromagnetic effects, induced by the spectator charge on Feynman-\(x_F\) distributions of charged pions in peripheral \(Pb + Pb\) collisions at CERN SPS energies, including realistic initial space-time-momentum conditions for pion emission. The calculation is performed in the framework of the fire-streak model, adopted to the production of both \(\pi^-\) and \(\pi^+\) mesons. Isospin effects are included to take into account the asymmetry in production of \(\pi^+\) and \(\pi^-\) at high rapidity. A comparison to a simplified model from the literature is made. We obtain a good description of the NA49 data on the \(x_F\)- and \(p_T\)-dependence of the ratio of cross sections \(\pi^+ / \pi^-\). The experimental data favors short times (\(0.5 < \tau < 2 - \text{fm}/c\)) for fast pion creation in the local fire-streak rest frame. The possibility of the expansion of the spectators is considered in our calculation, and its influence on the electromagnetic effect observed for the \(\pi^+ / \pi^-\) ratio is discussed. We conclude that the fire-streak model, which properly describes the centrality dependence of \(\pi^-\) rapidity spectra at CERN SPS energies, also provides realistic initial conditions for pion production. Consequently, it provides a quantitative description of the electromagnetic effect on the \(\pi^+ / \pi^-\) ratio as a function of \(x_F\).

We shall discuss also charge splitting of the directed flow of pions for RHIC beam energy scan data in the same phenomenological approach [2].


I read the instructions:

Secondary track (number):

Strong Interactions and Hadron Physics / 237
Inclusive production of $f_2(1270)$ tensor mesons at the LHC via gluon-gluon fusion in the $k_t$-factorization approach

Authors: Antoni Szczurek¹; Piotr Lebiedowicz²

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The gluon-gluon fusion for $\eta_c$ and $\chi_c$ quarkonium production is known to be the dominant mechanism [1,2]. In contrast the mechanism of light $f_2(1270)$ tensor meson production is not known. We calculate inclusive cross section for $f_2(1270)$ tensor meson production for gluon-gluon fusion in the $k_t$-factorization approach using different unintegrated gluon distributions from the literature [3]. The process is also interesting in the context of searches for saturation effects encoded in unintegrated gluon distributions. The energy-momentum tensor, equivalent to $L = 2, J_z = 2$ and $L = 0, J_z = 0$ couplings are used for the $g^*g^* \rightarrow f_2(1270)$ vertices.

The parameters are extracted from $\gamma\gamma \rightarrow f_2(1270) \rightarrow \pi\pi$ reactions by comparison to Belle data on $\gamma\gamma \rightarrow \pi^+\pi^-$ and $\gamma\gamma \rightarrow \pi^0\pi^0$ reactions. The results strongly depend on the parametrization of the $g^*g^* \rightarrow f_2(1270)$ form factor. Our results for $pp \rightarrow f_2(1270)$ are compared to preliminary ALICE data. The agreement with the data can be achieved only at larger $f_2(1270)$ transverse momentum, only for some parametrizations of the $g^*g^* \rightarrow f_2(1270)$ form factor. No obvious sign of the onset of saturation is observed. At low transverse momenta one needs to include also final state pion-pion rescattering. The agreement with the ALICE data can be obtained by adjusting probability of formation and survival of $f_2(1270)$ in a harsh quark-gluon and multipion environment.


Neutrino Physics - Posters / 238

Updates on the ESSnuSB Target Station potentialities for CP violation discovery

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The large value of the last mixing angle of the PMNS mixing matrix measured by reactor experiments enable the search for CP violation in leptonic sector with a new generation of neutrino super beams. The ESSnuSB project proposes to use the European Spallation Source (ESS) based at Lund in Sweden to elaborate a high intensity neutrino super beam. The LINAC of this facility, under construction, will produce 5 MW proton beam with 2 GeV energy by 2025 and will be upgraded hereafter to produce in addition a neutrino super beam. This will require in addition an accumulator located at the end of the LINAC to reduce the initial time width (2.86 ms) of the proton pulses to microsecond level. The combination of the high beam intensity and these low energy protons allows the neutrino measurements to be made with a megaton Water Cherenkov detector installed 1000 m down in a mine at about 500 km from the neutrino source which is near the position of the second neutrino oscillation maximum. This baseline configuration allows to have improved sensitivity to CP violation
compared to the first oscillation maximum. A parametric study of the magnetic horns and on the target station facility has been performed to optimize the ESSnuSB sensitivity to CP violation and will be presented.

This project is now supported by the COST Action CA15139 "Combining forces for a novel European facility for neutrino-antineutrino symmetry-violation discovery" (EuroNuNet). It has also received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 777419.

Secondary track (number):

Top Quark and Electroweak Physics / 239

Recent $t\bar{t}$bar and single top inclusive cross sections results in CMS

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Latest results on inclusive top quark pair and single top quark production cross sections are presented using collision data collected by CMS. The single top quark analyses investigate separately the production of top quarks via t-channel exchange, via associated production with a W boson (tW), and via the s-channel.

I read the instructions:

Secondary track (number):

Top Quark and Electroweak Physics / 240

Recent measurements of top quark properties in CMS

Corresponding Author: giulia.negro@cern.ch

Measurements of top quark properties using data collected by the CMS experiment are presented. Among them, the latest results on top mass and its running, top Yukawa coupling, the top sector of the CKM matrix, $t\bar{t}$bar forward backward asymmetry, as well as other new results will be discussed.

I read the instructions:

Secondary track (number):

Top Quark and Electroweak Physics / 241

Top quark pair and single top differential cross sections in CMS
Differential measurements of top quark pair and single top quark production cross sections are presented using data collected by CMS. The cross sections are measured as a function of various kinematic observables of the top quarks and the jets and leptons of the event final state. The results are confronted with precise theory calculations.

Top Quark and Electroweak Physics / 242

**tt+X and t+X production in CMS: ttZ, ttW, ttgamma, tZ, tgamma in CMS**

**Author:** Jose Enrique Palencia Cortezon¹

¹ Universidad de Oviedo

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(Does not include EFT interpretation of ttV and any FCNC) A comprehensive set of measurements of top quark pair production in association with EWK bosons (W, Z or γ) is presented. Inclusive and differential measurements are shown using the data collected by CMS.

Top Quark and Electroweak Physics / 243

**Measurements of tt+jets and tt+bb production and tttt production in CMS**

**Author:** Andrea Castro¹

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(Does not include EFT interpretation and any FCNC) A comprehensive set of measurements of top quark pair production in association with light-flavored and b-jets is presented. The status of the search for four top quark production, to which the LHC experiments are starting to be sensitive, and that has important BSM re-interpretations, is also reported.
FCNC and EFT interpretations in top quark events in CMS

Author: Samuel May

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Top quark production can probe physics beyond the SM in different ways. The Effective Field Theory (EFT) framework allows searching for BSM effects in a model independent way. CMS experiment is pioneering EFT measurements that move towards using full potential of the data in the most global way possible. Searches for flavour-changing neutral currents (FCNC) and anomalous top quark interactions are also being pursued in CMS which are complementary to the EFT approach. This talk reviews the current limits on FCNC searches in the top sector, and EFT interpretations.

I read the instructions:

Secondary track (number):

Formal Theory / 245

Predictive electroweak gauge model with strong spontaneous-symmetry-breaking dynamics

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Higgs sector of the Standard model (SM) is replaced by the gauge $SU(3)_f$ quantum flavor dynamics (QFD) with scale $\Lambda$. Anomaly freedom demands addition of three right-handed neutrinos $\nu^i_R$. The QFD Schwinger-Dyson equation for fermion self-energies $\Sigma_f(p^2)$ spontaneously generates:

(I) three Majorana masses $M_{fR}$ of order $\Lambda$;

(II) three Dirac masses $m_f$ same for all SM fermion species in $f$ exponentially small with respect to $\Lambda$. (I) $M_{fR}$ give rise to masses of all flavor gluons $C_a$ of order $\Lambda$. (II) $m_f$ give rise:

(1) to $W, Z$ masses of order $\sum m_f$, the effective Fermi scale;

(2) to extra masses of six $C_a$ of order $m_f$. The symmetry partners of the composite ‘would-be’ NG bosons are:

(I) three Higgses $\chi_i$ with masses at $\Lambda$;

(II.1) the SM-like Higgs $h$ with mass at Fermi scale;

(II.2) two new Higgses $h_3$ and $h_8$ with masses at Fermi scale. Fermion mass splitting in $f$ is due to $\Sigma_f(p^2)$ dependent vectorial vertices of SM fermions with photon, $W$ and $Z$ enforced by WT identities.

Secondary track (number): 01

Operation, Performance and Upgrade of Present Detectors / 246

Precision luminosity measurement with proton-proton collisions at the CMS experiment in Run 2
Precision luminosity calibration is critical to determine fundamental parameters of the standard model and to constrain or to discover beyond-the-standard-model phenomena at LHC. The luminosity determination at the LHC interaction point 5 with the CMS detector, using proton-proton collisions at 13 and 5.02 TeV during Run 2 of the LHC (2015–2018), is reported. The absolute luminosity scale is obtained using beam-separation ("van der Meer") scans. The dominant sources of systematic uncertainty are related to the knowledge of the scale of the beam separation provided by LHC magnets and the nonfactorizability between the spatial components of the proton bunch density distributions in the transverse direction. When applying the van der Meer calibration to the entire data-taking period, a substantial contribution to the total uncertainty in the integrated luminosity originates from the measurement of the detector linearity and stability. The reported integrated luminosity in 2015–2016 is among the most precise luminosity measurements at bunched-beam hadron colliders.
Tetraquark Interpretation and Production Mechanism of the Belle

Alexander Parkhomenko

**Co-authors:** Ahmed Ali 2; Ishtiaq Ahmed 3; Muhammed Jamil Aslam 4; Abdur Rehman 5

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The LHCb collaboration have recently updated their analysis of the resonant \( J/\psi p \) mass spectrum in the decay \( \Lambda_b^0 \rightarrow J/\psi p K^- \), making use of their combined Run 1 and Run 2 data. In the updated analysis, three narrow states, \( P_c(4312)^+ \), \( P_c(4440)^+ \), and \( P_c(4457)^+ \), are observed. The spin-parity assignments of these states are not yet known. We interpret these narrow resonances as compact hidden-charm diquark-diquark-antiquark pentaquarks. Using an effective Hamiltonian, based on constituent quarks and diquarks, we calculate the pentaquark mass spectrum for the complete \( SU(3)_F \) lowest \( S^- \) and \( P^- \)-wave multiplets, taking into account dominant spin-spin, spin-orbit, orbital and tensor interactions. The resulting spectrum is very rich and we work out the quark flavors, compositions, masses, and \( J^P \) quantum numbers of the pentaquarks. However, heavy quark symmetry restricts the observable states in \( \Lambda_b \)-baryon, as well as in the decays of the other weakly-decaying \( b \)-baryons, \( \Xi_b \) and \( \Omega_b \). In addition, some of the pentaquark states are estimated to lie below the \( J/\psi p \) threshold in \( \Lambda_b \)-decays (and corresponding thresholds in \( \Xi_b \)- and \( \Omega_b \)-decays). They decay via \( cc \) annihilation into light hadrons or a dilepton pair, and are expected to be narrower than the \( P_c \)-states observed. We anticipate their discovery, as well as of the other pentaquark states present in the spectrum at the LHC, and in the long-term future at a Tera-\( Z \) factory.

**Secondary track (number):**

**Strong Interactions and Hadron Physics / 249**

**Tetraquark Interpretation and Production Mechanism of the Belle \( \Lambda_b(10750) \)-Resonance**

**Author:** Alexander Parkhomenko

**Co-authors:** Ahmed Ali 2; Luciano Maiani 3; Wei Wang 4

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Recently, the Belle Collaboration has updated the analysis of the cross sections for the processes \( e^+e^- \rightarrow \Upsilon(nS) \pi^+\pi^- (n = 1, 2, 3) \) in the \( e^+e^- \) center-of-mass energy range from 10.52 to 11.02 GeV. A new structure, called here \( Y_b(10750) \), with the mass \( M(Y_b) = (10752.7 \pm 5.9^{+2.0}_{-1.1}) \) MeV and the Breit-Wigner width \( \Gamma(Y_b) = (35.5^{+17.6}_{-14.3} \pm 3.9) \) MeV was observed. We interpret \( Y_b(10750) \) as a compact \( J^{PC} = 1^{--} \) state with a dominant tetraquark component. The mass eigenstate \( Y_b(10750) \) is treated as a linear combination of the diquark-antidiquark and \( bb \) components due to the mixing via gluonic exchanges shown recently to arise in the limit of large number of quark colors. The mixing angle between \( Y_b \) and \( \Upsilon(5S) \) can be estimated from the electronic width, recently determined to be \( \Gamma_{ee}(Y_b) = (13.7 \pm 1.8) \) eV. The mixing provides a plausible mechanism for \( Y_b(10750) \) production in high energy collisions from its \( bb \) component and we work out the Drell-Yan and prompt production cross sections for \( pp \rightarrow Y_b(10750) \rightarrow \Upsilon(nS) \pi^+\pi^- \) at the LHC. The resonant part of the dipion invariant mass spectrum in \( Y_b(10750) \rightarrow \Upsilon(1S) \pi^+\pi^- \) and the corresponding angular distribution of \( \pi^+ \)-meson in the dipion rest frame are presented as an example.
Strategic R&D Programme on Technologies for Future Experiments

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In a transparent bottom-up process, involving a significant part of the HEP community, CERN has defined a strategic R&D programme to address the primary technological challenges of the next generation experiments. The results of this new R&D programme will be building blocks, demonstrators and prototypes, which will form the basis for possible new experiments and experiment upgrades beyond the LHC Phase-II upgrades scheduled for the long shutdown LS3. Started up in January 2020, the programme is structured in work packages focusing on tracking, calorimetry and particle ID, as well as on equally demanding challenges in the domains of electronics, mechanics, cooling, magnets and software. A large part of the R&D work is carried out jointly with external groups from universities and research labs, and in close cooperation with industrial partners. We profit from cooperation with dynamic and efficient structures like the RD50 and RD51 collaborations, and networking on the European level. We will present an overview of the work programme and first results in a number of areas.

Global fits to neutrino masses and mixings

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In this talk, I will describe the updated status of global analyses to neutrino oscillation data in the three-flavor framework, with an emphasis on the recent hints in favor of normal mass ordering and maximal CP violation. I will focus on the current knowledge of the oscillation parameters as well as on the improvements that can be expected in the near future.

The LUX-Zeplin Dark Matter Experiment

Author: Hugh Lippincott
LUX-Zeplin (LZ) is a dark matter experiment under construction at the 4850-foot (4300 mwe) level of the Sanford Underground Research Facility in Lead, South Dakota. The experiment utilizes a two phase time projection chamber (TPC), containing seven active tonnes of liquefied xenon, to search for weakly interacting massive particles (WIMPs). Auxiliary veto detectors, including a liquid scintillator outer detector, improve rejection of unwanted backgrounds events in the central region of the detector. LZ has been designed to improve on current best sensitivities by a factor of 50 or more, and data taking is expected to begin this year. This talk will report on the current status of the LZ project and detector commissioning.

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The ENUBET experiment (*) aims at demonstrating the feasibility of a "monitored" neutrino beam, in which the absolute normalization of the neutrino flux produced by a narrow band meson beam can be constrained at the 1% level. The electron neutrino component is determined by monitoring large-angle positrons from Ke3 decays in a 40 m long instrumented decay tunnel (tagger). The measurement of muons in the tagger and after the hadron dump allows to determine the nu_mu flux from kaons and pions respectively. In addition, in a narrow band beam (p=8.5GeV +/- 10%), the transverse position of the neutrino interaction at the detector can be exploited to determine a priori, with significant precision, the neutrino energy spectrum without relying on the final state reconstruction. These concepts can be implemented in a single facility based on standard accelerator technologies for a new generation of high precision nu_e and nu_mu cross section measurements at the GeV scale and for precision searches of Physics beyond the standard three neutrino paradigm.

We will present the optimization and performances of a 20 m long focusing transfer line allowing for a continuous measurement of Ke3 positrons at single-particle level. The (quadrupole-based) focusing system is designed to be operated with a slow extraction proton scheme where protons can be diluted over several seconds. This timing allows for the direct monitoring of muons after the hadron dump and extends the original scope of the project towards a full-fledged "time-tagged" neutrino beam: time-coincidences among the lepton at the source and the neutrino at the detector would enable an unprecedented purity and the possibility to reconstruct the neutrino kinematics at source on an event by event basis.

At ICHEP we will present for the first time the design of the horn-based beamline. We have recently improved the initial transfer line design by introducing an additional dipole giving an increased bending angle for momentum selection (~8.5 GeV/c mesons). It ensures a reduced background from the untagged neutrino component at the neutrino detector and an higher purity of the meson beam at the expense of a reduced meson yield. The neutrino flux reduction is compensated in this option by a horn-based focusing and a "burst slow extraction" that has been recently demonstrated experimentally at CERN-SPS in the context of the ENUBET machine studies.

This contribution will report on another major milestone: the final design of the ENUBET demonstrator for the instrumented decay tunnel that is due end 2021, and has been selected on the basis of the results of the 2016-2018 testbeams. This large detector prototype will prove the scalability and performance of the selected detector technology: an iron-scintillator modular sampling calorimeter.
(for e/\pi separation) with a lateral light readout through WLS fibers connected to SiPMs, complemented by a photon veto system (for e/\pi0 separation) made by an inner ring of plastic scintillator trackers.

(*) ENUBET is an ERC project (2016-2021, p.i. Andrea Longhin). Since March 2019 ENUBET is also a CERN Neutrino Platform experiment, approved under the name NP06/ENUBET.

Operation, Performance and Upgrade of Present Detectors

THE LIGO-VIRGO OBSERVATION RUN 3 (APRIL 2019 – APRIL 2020)

Author: Nicolas Arnaud

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Observation Run 3 (O3) is the longest period of data taking for the two Advanced LIGO detectors and the Advanced Virgo detector to date. From April 1st, 2019 to April 30th, 2020, the instruments accumulated 12 months of data, with a 1-month commissioning break in October 2019. In this talk, I will review the performance of the three detectors both separately and within the global network of ground-based gravitational-wave interferometric detectors: sensitivity, duty cycle, noise stability and variations. I will briefly describe the O3 public alerts and the first published results of this run. To conclude, I will summarize the plans of the two collaborations for the coming years: alternatively upgrade phases and data taking periods with improved performance.

FROM OPEN PUBLIC ALERTS TO GRAVITATIONAL-WAVE CANDIDATES DURING THE LIGO-VIRGO THIRD OBSERVATION RUN O3

Author: Nicolas Arnaud

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Corresponding Author: narnaud@lal.in2p3.fr

One of the main challenges for the LIGO-Virgo Observation Run 3 (O3), 12 months of data taking plus a 1-month commissioning break between April 2019 and April 2020 – was to deliver reliable and timely public alerts to a large community of astronomers looking for counterparts of the gravitational-wave candidate signals. In this talk, I will describe the way such public alerts have been generated during O3, summarize the performance of the low-latency LIGO-Virgo framework and focus on the procedures used to vet the data quality of the candidate events. I will conclude by discussing prospects of improvements for future data-taking periods.
Status of Baikal-GVD

Author: Grigory Safronov

1 INR, JINR

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Baikal-GVD is a cubic-kilometer scale underwater neutrino detector being constructed in lake Baikal. It is designed to detect astrophysical neutrino of energies from few TeV to 100 PeV. Deployment started in spring 2015 and in 2019 telescope was operating 5 clusters each consisting of 8 strings holding 288 optical modules spanning from 750 m to 1250 m depths underwater. In the first phase of detector construction it is planned to deploy 8 clusters reaching the effective volume for detection of high-energy cascades of 0.4 km$^3$. In this talk we present design, status and first physics results from Baikal-GVD neutrino telescope.

Secondary track (number):

Vertex Reconstruction and Deep Learning Applications in JUNO

Author: Ziyuan Li

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The Jiangmen Underground Neutrino Observatory (JUNO), currently under construction in the south of China, will be the largest Liquid Scintillator (LS) detector in the world. JUNO is a multipurpose neutrino experiment designed to determine neutrino mass hierarchy, precisely measure oscillation parameters, and study solar neutrinos, supernova neutrinos, geo-neutrinos and atmosphere neutrinos. The central detector of JUNO contains 20,000 tons of LS and 18,000 20-inch as well as 25,600 3-inch Photomultiplier Tubes (PMTs). The energy resolution is expected to be 3%/sqrt(E(MeV)). To meet the requirements of the experiment, two algorithms for the vertex reconstruction have been developed. One is the maximum likelihood method which utilizes the time and charge information of PMTs with good understanding of the complicated optical processes in the LS. The other is the deep learning method with the Convolutional Neural Networks architecture, which is fast and avoids to consider the detail optical processes. In general, similar performances of both methods are achieved. The deep learning method tends to give more accurate prediction near the detector border region, where the optical processes are more complicated.

I read the instructions:

Secondary track (number):
Cosmic muon data accumulated by the NOvA neutrino detector, located 100m underground at Fermilab, allows for study of geological and man-made structures directly contributing to the overburden of the detector. We present results of a muon radiographic analysis of the cosmic ray data, obtained without subtracting the surface muon flux (free sky data). Instead, we use the internal geometrical symmetries of the NOvA fiducial volume to cancel out acceptance effects, thus obtaining differential 2-dimensional radiographic maps of overburden variations.

Strong Interactions and Hadron Physics / 259

Production of $\eta_c(1S, 2S)$ in $e^+e^-$ and $pp$ collisions

Authors: Antoni Szczurek\textsuperscript{1}; Izabela Babiarz\textsuperscript{2}; Wolfgang Schaefer\textsuperscript{3}

\textsuperscript{1} Institute of Nuclear Physics
\textsuperscript{2} IFJ PAN Krakow
\textsuperscript{3} Institute of Nuclear Physics PAN

We derive the light-front wave function (LFWF) representation of the $\gamma^*\gamma^* \rightarrow \eta_c(1S), \eta_c(2S)$ transition form factor $F(Q_1^2, Q_2^2)$ for two virtual photons in the initial state. For the LFWF, we use different models obtained from the solution of the Schr"odinger equation for a variety of $c\bar{c}$ potentials. We compare our results to the BaBar experimental data for the $\eta_c(1S)$ transition form factor, for one real and one virtual photon. We observe that the onset of the asymptotic behaviour is strongly delayed and discuss applicability of the collinear and/or massless limit. We present some examples of two-dimensional distributions for $F(Q_1^2, Q_2^2)$. A factorization breaking measure is proposed and factorization breaking effects are quantified and shown to be almost model independent. Factorization is shown to be strongly broken, and a scaling of the form factor as a function of $Q^2 = (Q_1^2 + Q_2^2)/2$ is obtained.

In addition, we present a thorough analysis of $\eta_c(1S, 2S)$ quarkonia hadroproduction in $k_{\perp}$-factorisation in the framework of the light-front potential approach for the quarkonium wave function. The off-shell matrix elements for the $g^*g^*\eta_c(1S, 2S)$ vertices are derived. We discuss the importance of taking into account the gluon virtualities. We present the transverse momentum distributions of $\eta_c$ for several models of the unintegrated gluon distributions. Our calculations are performed for four distinct parameterisations for the $c\bar{c}$ interaction potential consistent with the meson spectra. We compare our results for $\eta_c(1S)$ to measurements by the LHCb collaboration and present predictions for $\eta_c(2S)$ production.
References:
1.) I. Babiarz, V.P. Goncalves, R. Pasechnik, W. Sch"afer and A. Szczurek, "The $\gamma^* \gamma^* \rightarrow \eta_c(1S, 2S)$ transition form factors for spacelike photons," Phys.Rev. 1bf D100) 054018 (2019)
2.) I.-Babiarz, R.-Pasechnik, W.-Sch"afer and A.-Szczurek, "Prompt hadroproduction of $\eta_c(1S, 2S)$ in the $k_T$-factorization approach," JHEP (1bf 2002), 037 (2020) [arXiv

I read the instructions:

Secondary track (number):

Dark Matter Detection / 260

MADMAX: A Dielectric Haloscope Experiment

Author: Xiaoyue Li

1 Max Planck Institute for Physics

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Axions emerge naturally from the Peccei-Quinn (PQ) mechanism which addresses the absence of CP violation in QCD; they also turn out to be a good cold dark matter (CDM) candidate. If PQ symmetry breaking had occurred after inflation, the axion mass is likely to range from $\sim 26 \mu$eV to $\sim 1$ meV, which is yet to be explored experimentally.

We present a novel dielectric haloscope experiment dedicated to the direct detection of axion CDM in the mass range of 40 to 400 $\mu$eV — the MAgednetized Disc and Mirror Axion eXperiment (MADMAX). Multiple dielectric discs and a metal mirror are placed in a strong magnetic field ($\sim 10$ T dipole) to utilize the axion-induced coherent electromagnetic waves emitted from each disc surface and their resonances within the discs-mirror system, such that the axion-induced signal can be boosted to a level detectable by state-of-the-art low noise amplifiers. The design and sensitivity of MADMAX, ongoing R&D activities and the project roadmap will be presented.

Secondary track (number):

Neutrino Physics / 261

Sterile neutrino searches with the ICARUS detector

Author: Christian Farnese

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The ICARUS collaboration employed the 760-ton T600 detector in a successful three-year physics run at the underground LNGS laboratories studying neutrino oscillations with the CNGS neutrino beam from CERN, and searching for atmospheric neutrino interactions. ICARUS performed a sensitive search for LSND-like anomalous $\nu_e$ appearance in the CNGS beam, which contributed to the constraints on the allowed parameters to a narrow region around 1 eV$^2$, where all the experimental results can be coherently accommodated at 90% C.L. After a significant overhauling at CERN, the T600 detector has now been placed in its experimental hall at Fermilab where installation activities are in progress. It will be soon exposed to the Booster Neutrino Beam to search for a sterile neutrino
within the Short Baseline Neutrino (SBN) program, devoted to definitively clarify the open ques-
tions of the presently observed neutrino anomalies. The proposed contribution will address ICARUS 
achievements, its status and plans for the new run at Fermilab and the ongoing developments of the 
analysis tools needed to fulfill its physics program.

I read the instructions:
Secondary track (number):

Neutrino Physics / 262

DUNE experiment physics

Author: Seb Jones

Corresponding Author: ucapsbj@ucl.ac.uk

The Deep Underground Neutrino Experiment (DUNE) will feature a 40-kton liquid argon TPC detec-
tor situated a mile below the surface at the Sanford Underground Research Facility. A new broadband 
high-intensity neutrino source and Near Detector complex will be located at Fermilab, 1300 kilome-
ters away. This arrangement will provide unprecedented sensitivity in the search for neutrino CP 
violation, determination of the neutrino mass ordering, and precision measurements of neutrino 
mixing parameters. The underground Far Detector also allows for low background, low threshold 
observations of supernova neutrinos, with a unique sensitivity to the electron neutrino flux. Fur-
ther, DUNE will conduct a wide range of searches for physics beyond the Standard Model, including 
baryon number violation, rare scattering processes, and non-standard flavor transitions. In this talk, 
we review DUNE’s extensive physics program and show updated sensitivities.

I read the instructions:
Secondary track (number):

Beyond the Standard Model / 263

Beyond the Standard Model Physics Prospects at Deep Underground 
Neutrino Experiment

Author: Doojin Kim

1 University of Florida

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The Deep Underground Neutrino Experiment (DUNE) is an international project for neutrino physics 
and proton-decay searches, currently in the design and planning stages. Once built, DUNE will con-
sist of two detectors exposed to the world’s most intense neutrino beam. The near detector will 
record neutrino interactions near the beginning of the beamline, at Fermilab. The other, much larger, 
detector, comprising four 10-kton liquid argon time projection chambers (TPCs), will be installed at 
a depth of 1.5 km at the Sanford Underground Research Facility in South Dakota, about 1300 km 
away from the neutrino source.

The unique combination of the high-intensity neutrino beam with DUNE’s high-resolution near detec-
tor system and massive LArTPC far detector enables a variety of probes of BSM physics, either 
novel or with unprecedented sensitivity, from the potential discovery of new particles (sterile neu-
trinos or dark matter), to precision tests of beyond the three-flavor mixing paradigm, Non-standard 
Neutrino Interactions, Heavy Neutral Leptons, or the detailed study of rare processes (e.g. neutrino
trident production). The talk will review these physics topics and discuss the prospects for their discovery at the DUNE experiment.

I read the instructions:

Secondary track (number):

Astro-particle Physics and Cosmology / 264

Core-Collapse Supernovae Burst Neutrinos in DUNE

Author: Clara Cuesta Soria

1 CIEMAT

Corresponding Author: clara.cuesta@cern.ch

The Deep Underground Neutrino Experiment (DUNE), a 40-kton fiducial mass underground liquid argon time projection chamber experiment, will be sensitive to the electron-neutrino-flavor component of the burst of neutrinos expected from the next Galactic core-collapse supernova. Such an observation will bring unique insight into the astrophysics of core collapse as well as into the properties of neutrinos.

The talk will cover recent progress on detection and reconstruction of supernova burst neutrinos in DUNE, including the contribution of the light detection systems.

I read the instructions:

Secondary track (number):

Neutrino Physics

Astro-particle Physics and Cosmology / 265

Supernova Neutrino Pointing with DUNE

Author: AJ Roeth

1 Duke University

Corresponding Author: ajroeth110@gmail.com

The Deep Underground Neutrino Experiment (DUNE) will be capable of observing the burst of neutrinos from a nearby core-collapse supernova. The detector will furthermore have the excellent capability for determination of the direction of the supernova via reconstruction of anisotropic interactions in its liquid argon time projection chambers.

This talk will describe studies of DUNE’s supernova pointing capabilities under realistic assumptions.

I read the instructions:

Secondary track (number):

Neutrino Physics
Neutrino Physics / 266

Neutrino event reconstruction in DUNE using Pandora

Author: Leigh Howard Whitehead¹

¹ University of Cambridge (GB)

Corresponding Author: leigh.howard.whitehead@cern.ch

The Deep Underground Neutrino Experiment is a next-generation neutrino oscillation experiment that will search for CP-violation. A key component of this analysis is separating neutral-current backgrounds from the charged-current electron neutrino signal interactions. The wide-band neutrino beam produces highly detailed and complex final state event topologies in the liquid argon time projection chambers, requiring state-of-the-art event reconstruction algorithms. This talk details the application of the Pandora Software Development Kit, a framework to facilitate a multi-algorithm approach to event reconstruction, to DUNE simulated interactions. The picture of the overall event is gradually built up through a chain of algorithms, each focusing on a small piece of the overall problem until the neutrino interaction is fully reconstructed in 3D. The methods used in the algorithms range from simple cluster pattern recognition to deep learning techniques using convolutional neural networks.

I read the instructions:

Secondary track (number):

14

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 267

ProtoDUNE Dual Phase: Design, Construction and First Results

Author: Guillaume Eurin¹

¹ Université Paris-Saclay (FR)

Corresponding Author: guillaume.eurin@cea.fr

The Deep Underground Neutrino Experiment (DUNE) will use large liquid argon (LAr) detector consisting of four modules, each with a fiducial mass of 10 ktons of LAr. One of the technology options for the far detector modules is a liquid-argon Time Projection Chamber (TPC) working in Dual-Phase mode. In a Dual-Phase TPC, ionisation charge deposited in the liquid argon volume is drifted towards the liquid surface, extracted into the argon vapour, amplified by Large Electron Multipliers (LEM) and collected by an anode plane with strip readout. To validate this technology, a kton-scale prototype, ProtoDUNE Dual-Phase, has been constructed and is currently operating at the CERN neutrino platform.

In this talk, we will cover the principal features of the detector design, discuss its operation, and show some preliminary results from the collected cosmic ray data samples.

I read the instructions:

Secondary track (number):

12
Beyond the Standard Model / 268

Nucleon decay search with DUNE

Author: Christoph Alt

1 ETH Zurich

Corresponding Author: christoph.alt@cern.ch

The Deep Underground Neutrino Experiment (DUNE) is an international project aiming at neutrino physics and astrophysics and a search for phenomena predicted by theories beyond the standard model. The excellent imaging capability of Liquid Argon Time Projection Chamber (LArTPC) technology, particle tracking and identification utilized in the Far Detector allow the experiment to achieve high sensitivity to various rare processes. Grand Unified Theories (GUTs) predict a baryon number non-conservation effects, such as nucleon decay. Some GUTs, including those based on Supersymmetry (SUSY), favor nucleon decays with a kaon in the final state. Here we discuss the sensitivity of DUNE to some nucleon decay modes. With full event simulation and reconstruction using the LArSoft package, we have investigated the background to nucleon decay events from atmospheric neutrino interactions, and particle misidentification and utilized machine learning techniques to enhance the discrimination between signal and background.

I read the instructions:

Secondary track (number):

2

Computing and Data Handling / 270

Computing for the DUNE Long Baseline Neutrino Oscillation Experiment

Author: Michael Kirby

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The DUNE long-baseline neutrino oscillation collaboration consists of over 180 institutions from 33 countries. The experiment is in preparation now with the commissioning of the first 10kT fiducial volume Liquid Argon TPC expected over the period 2025-2028 and a long data-taking run with 4 modules expected from 2029 and beyond.

An active prototyping program is already in place with a short test beam run with a 700T, 15,360 channel prototype of single-phase readout at the neutrino platform at CERN in late 2018 and tests of a similar sized dual-phase detector scheduled for mid-2019. The 2018 test beam run was a valuable live test of our computing model. The detector produced raw data at rates of up to ~2GB/s. These data were stored at full rate on tape at CERN and Fermilab and replicated at sites in the UK and the Czech Republic. In total, 1.8 PB of raw data were produced and reconstructed during the six-week test beam run.

DUNE already benefits from existing Grid infrastructure developed for the LHC. Multiple US and European sites are part of this resource pool and have made significant contributions to the Proto-DUNE single and dual-phase programs. We expect this global computing model to grow and evolve as we move towards data from the full DUNE detectors in the middle of the next decade.
Baseline predictions for the full DUNE detector data, starting in the mid-2020s are 30-60 PB of raw data per year. In contrast to traditional HEP computational problems, DUNE’s Liquid Argon TPC data consist of simple but very large (many GB) 2D data objects which share many characteristics with astrophysical images. This presents opportunities to use advances in machine learning and pattern recognition as a frontier user of High-Performance Computing facilities capable of massively parallel processing.

I read the instructions:

Secondary track (number):
12

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 271

Status of the DUNE near detector

Author: Patrick James Dunne

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DUNE is a long-baseline neutrino oscillation experiment that will take data in a wideband neutrino beam at Fermilab in the latter half of the 2020s. The experiment is planning to build a very capable near detector to facilitate the high precision extraction of oscillation parameters. Part of the mission of the near detector is to acquire powerful data sets that can be used to constrain the fits used in the oscillation analyses and improve the neutrino interaction model. In this talk, the status of the DUNE near detector design is reviewed.

I read the instructions:

Secondary track (number):

Neutrino Physics / 272

Neutrino interaction physics and the DUNE near detector

Author: Mateus F. Carneiro

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Corresponding Author: mateusc@fnal.gov

DUNE is a long-baseline neutrino oscillation experiment that will take data in a wideband neutrino beam at Fermilab in the latter half of the 2020s. The experiment is planning to build a very capable near detector to facilitate the high precision extraction of oscillation parameters. Part of the mission of the near detector is to acquire powerful data sets that can be used to constrain the fits used in the oscillation analyses and improve the neutrino interaction model. In this talk, the importance and the potential of a vibrant program of neutrino interaction physics using this detector is described. A few case studies that illustrate the power of the DUNE near detector for studying neutrino interaction physics are described.

I read the instructions:
ArgonCube: A Novel Design for Modular Liquid Argon Time Projection Chambers

Author: Roman Berner

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Corresponding Author: roman.berner@lhep.unibe.ch

ArgonCube is a novel design for Liquid Argon Time Projection Chambers (LAr TPCs), segmenting the total detector volume into a number of electrically and optically isolated TPCs sharing a common cryostat. For the charge-readout, a pixelated anode plane is employed, providing unambiguous 3D event reconstruction. In order to maximise the active TPC volume a new technology is used for field-shaping, replacing the classical field-cage with a continuous resistive plane. Large dielectric light-collection tiles within the TPC allow for an efficient detection of prompt scintillation light. ArgonCube has found application in the near-detector of the Deep Underground Neutrino Experiment, DUNE, and is also proposed for one of the four far-detectors.

Hadron-argon cross-section measurements in ProtoDUNE-SP

Author: Heng-Ye Liao

Corresponding Author: liao@phys.ksu.edu

The single-phase liquid argon ProtoDUNE detector (ProtoDUNE-SP) is located at CERN’s neutrino platform facility and it serves as a prototype to validate the technology for the 10-kton fiducial mass liquid argon detectors for the DUNE experiment. ProtoDUNE-SP was exposed to a variety of test-beam particles (electrons, muons, pions, kaons, and protons) towards the end of 2018 collecting data in a broad range of momenta, from 0.3 - 7 GeV/c. These cross-sections will improve the understanding of final-state interactions in neutrino-argon cross-sections. The progress of the analyses towards the cross-section measurements on argon from the test-beam data collected at protoDUNE-SP will be presented.
The accumulation of positive ions in a LArTPC located on the surface can distort the electric field and the reconstructed particle trajectories. It is critical to understand and correct for the space charge effects in order to achieve the desired spatial and calorimetric resolutions in the LArTPC. This talk will present the measurement of space charge effects using cosmic ray muons in ProtoDUNE-SP.

Energy calibration of the ProtoDUNE-SP TPC

Author: Richard Diurba

Corresponding Author: diurb001@umn.edu

The single-phase liquid argon prototype at CERN (ProtoDUNE-SP) acts as a validation of the design for the DUNE single-phase far detector. With a total mass of 770 tons, it is the largest monolithic liquid argon single-phase time projection chamber in the world. ProtoDUNE-SP collected test-beam in autumn of 2018 and has been collecting cosmic and special calibration data since the end of 2018. With more than 500 days of continuous operation, the long-term performance, stability and calorimetric measurements of the detector will be discussed in this talk.

Performance of photon detectors in ProtoDUNE-SP

Author: Dante Totani

Corresponding Author: dante.totani@cern.ch

The single-phase liquid argon prototype at CERN (ProtoDUNE-SP) is designed to act as a testbed and prototype for the elements of the first far detector module of DUNE. ProtoDUNE-SP collected data in the H4-VLE beamline at CERN in the autumn of 2018 and accumulated 4M particles (electrons, muons, pion, kaons and protons) ranging from 0.3 to 7 GeV/c and a large number of cosmic ray events since then. ProtoDUNE-SP employs three different photon detector technologies. This talk will
present the performance of the photon detectors in ProtoDUNE-SP, including detector calibration, efficiency measurements, attenuation studies, timing resolution, calorimetric energy reconstruction from scintillation light and energy resolution of electrons.

I read the instructions:

Secondary track (number):
13

Operation, Performance and Upgrade of Present Detectors / 278

Construction, installation and operation of ProtoDUNE-SP

Author: Stefania Bordoni¹

¹ Michigan State University (US)

Corresponding Author: stefania.bordoni@cern.ch

The single-phase liquid argon TPC at CERN (ProtoDUNE-SP) is an engineering prototype for the first module of the DUNE far detector. This prototype which has dimensions of a cube of about 10m edge, provide full validation of the use of the membrane tank technology for large dimension cryostats. Furthermore, the very high performance of the protoDUNE-SP TPC with more than 500 days of continuous and stable operation, demonstrated the reliability of the LAr detection technology at a scale never tested before. In this talk we will review the main characteristics and milestones of the construction and installation of protoDUNE-SP which provide a series of benchmarks for DUNE. The performance for several different detector working points will also be discussed.

I read the instructions:

Secondary track (number):
13

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques - Posters / 279

The OLVE-HERO calorimeter prototype beam tests at CERN SPS

Authors: Ilyas Satyshev¹; Anatoliy Pan²

¹ JINR
² Joint Institute for Nuclear Research

Corresponding Authors: pan.1992@bk.ru, satyshev@jinr.ru

A project of the OLVE-HERO space detector is proposed for CR measurement in the range $10^{12}$-$10^{16}$ eV and will include a large ionization-neutron 3D calorimeter with a high granularity and geometric factor of ~16 m² sr. The 3D structure of the calorimeter will allow registering CR particles coming from different directions. As the main OLVE-HERO detector is expected an image calorimeter of a boron loading of plastic scintillator with tungsten absorber. Such a calorimeter allows to measure an additional neutron signal which will improve the energy resolution of the detector. The more
importantly, the rejection power between electromagnetic and nuclear CR components will be increased by factor 30-50 in the whole energy range. The boron loading scintillator detector prototype was designed and tested at the H8 beam test area at CERN SPS during heavy ion runs in 2016 - 2018. Results of the beam tests and the corresponding Monte-Carlo simulation will be presented

Secondary track (number):
8

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 280

Calibrating the DUNE LArTPC Detectors for Precision Physics

Author: Viktor Pec

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The Deep Underground Neutrino Experiment (DUNE) is an international collaboration focused on studying neutrino oscillation over a long baseline (1300 km). DUNE will make use of a near detector and O(GeV) neutrino beam originating at Fermilab in Batavia, IL, and a far detector operating 1.5 km underground at the Sanford Underground Research Facility in Lead, South Dakota. The near and far detectors will use the LArTPC (Liquid Argon Time Projection Chamber) technology to image neutrino interactions. In order to make precise physics measurements at DUNE, such as the amount of CP violation in the neutrino sector, it is essential to be able to accurately reconstruct particle energies and other kinematic quantities; this in turn necessitates an extensive calibration program for DUNE’s LArTPC detectors. In this presentation, we describe the requirements for calibrating the DUNE detectors, emphasizing the challenges of massive multi-kiloton LArTPC detectors which are to operate for multiple years deep underground. A preliminary DUNE detector calibration program, including use of both dedicated calibration hardware and cosmogenic/beam-induced calibration sources, is presented. First results on detector calibration at the ProtoDUNE-SP prototype detector located at CERN, and associated impact on calibrations at the DUNE far detector, are also emphasized.

I read the instructions:

Secondary track (number):
12

Computing and Data Handling / 281

DUNE Data Management Experience with Rucio

Author: Steve Timm

Corresponding Author: timm@fnal.gov

The DUNE collaboration has been using Rucio since 2018 to transport data to our many European remote storage elements. We currently have 13.8 PB of data under Rucio management at 13 remote storage elements.

We present our experience thus far, as well as our future plans to make Rucio our sole file location catalog. We will present our planned data discovery system and the role of Rucio in the data ingest
system and data delivery of files to jobs. We will describe the associated metadata service which is in development. Finally, we will describe some of the unique challenges of configuring Rucio to the tape-backed dCache/Enstore disk store at Fermilab.

I read the instructions:

Secondary track (number):

Heavy Ions / 282

Considerations on the suppression of charged particle production in high energy heavy ion collisions

Authors: Mihai Petrovici¹; Amelia Lindner¹; Amalia Pop¹

¹ Horia Hulubei National Institute of Physics and Nuclear Engineering

Corresponding Authors: amelia.lindner@cern.ch, amalia.pop@cern.ch, mihai.petrovici@cern.ch

Results from RHIC for Au-Au and from LHC for Pb-Pb collisions are compiled in terms of $R_{AA}$, $R_{CP}$ and ratio of the $p_T$ spectra, normalized with the corresponding $dN_{ch}/d\eta$, for each centrality to the most peripheral one ($R_{CP}^N$). The studies are focused on the $p_T$ range in the region of maximum suppression evidenced in the experiment. The $R_{CP}$ for 4 GeV/c < $p_T$ < 6 GeV/c as a function of $\sqrt{s_{NN}}$ evidences a suppression enhancement from $\sqrt{s_{NN}} = 39$ GeV up to 200 GeV after which a saturation sets in up to the highest energy of $\sqrt{s_{NN}} = 5.02$ TeV. For collision energies from 200 GeV (Au-Au) up to 5.02 TeV (Pb-Pb), within the error bars, a good scaling of $R_{AA}$ as a function of $<N_{part}>$ is evidenced. This scaling improves for $R_{AA}$, when only the core contribution is considered. $R_{CP}^N$ evidences the same saturation starting from 200 GeV collision energy and a very good scaling as a function of $<N_{part}>$ for $\sqrt{s_{NN}} = 200$ GeV (Au-Au) and for $\sqrt{s_{NN}} = 2.76$ TeV and $\sqrt{s_{NN}} = 5.02$ TeV (Pb-Pb). A comparison in terms of Bjorken energy density times formation time ($\varepsilon_{Bj} \cdot \tau$) and particle density per unit of rapidity and overlapping area ($(dN/dy)/S_\perp$) is presented.

Secondary track (number):

Higgs Physics / 283

Higgs boson measurements in final states with taus at CMS

Author: Daniel Winterbottom¹

¹ Imperial College, Univ. of London

Corresponding Author: daniel.winterbottom@cern.ch

The most recent CMS results on Higgs boson measurements in final states with tau leptons will be presented.
Higgs boson measurements in the WW and ZZ final states with the CMS Detector

Author: Matteo Bonanomi

1 LLR, Ecole Polytech., IN2P3-CNRS

Corresponding Author: matteo.bonanomi@cern.ch

The most recent measurements of Higgs boson properties in the H->WW and H->ZZ channels at CMS will be presented.

I read the instructions:

Secondary track (number): Higgs Physics / 285

Higgs boson measurements in final states with photons at CMS

Author: Hualin Mei

1 UC Santa Barbara

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Recent measurements of Higgs boson properties in the diphoton channel from CMS will be presented.

I read the instructions:

Secondary track (number): Higgs Physics / 286

Higgs boson measurements in hadronic final states at CMS

Author: Nick Smith

1 Fermi National Accelerator Lab.

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Recent CMS measurements of Higgs boson properties in hadronic final states will be presented.

I read the instructions:

Secondary track (number):
Higgs Physics / 287

Searches for Higgs boson rare and invisible decays at CMS

Author: Vukasin Milosevic

1 Imperial College, Univ. of London

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The most recent results of the searches for rare standard model Higgs boson decays by the CMS collaboration will be presented. Searches for Higgs bosons decaying to invisible particles will also be covered.

I read the instructions:

Secondary track (number):

Higgs Physics / 288

Measurements of ttH and tH associated production at CMS

Author: Sergio Sanchez Cruz

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Corresponding Author: sergio.sanchez.cruz@cern.ch

Recent CMS measurements of ttH and tH associated production in multiple final states will be presented.

I read the instructions:

Secondary track (number):

Higgs Physics / 289

Searches for non-resonant HH production at CMS

Author: Ivan Ovtin

1 Novosib. State Univ.

Corresponding Author: ivan.ovtin@cern.ch

The most recent results of the searches for non-resonant di-Higgs production at CMS will be presented.

I read the instructions:

Secondary track (number):
Higgs boson combination and coupling measurements at CMS

Author: Adinda De Wit

1 DESY

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The most recent CMS results on Higgs boson properties from the combination of different final states will be presented, including the Higgs boson mass, couplings, and interpretations in the context of effective field theories extending the standard model.

I read the instructions:

Secondary track (number):

Searches for additional Higgs bosons with the CMS detector

Author: Dermot Anthony Moran

1 CIEMAT

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The most recent results from the CMS collaboration on the searches for additional Higgs bosons will be presented, including both neutral and charged Higgs bosons.

I read the instructions:

Secondary track (number):

03.

Searches for exotic Higgs boson decays at CMS

Author: Fengwangdong Zhang

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Corresponding Author: fengwangdong.zhang@cern.ch

Most recent CMS results on searches for Higgs boson decays not expected in the standard model, such as lepton-flavour-violating decays and decays to pairs of new light scalar or pseudoscalar particles, will be presented. Searches for decays with mesons in the final states, expected in the standard model but with extremely small branching ratios, will also be covered.
Higgs Physics / 293

Higgs boson fiducial and differential measurements at CMS

Author: Lorenzo Viliani¹

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Recent measurements from the CMS collaboration on Higgs boson fiducial and differential cross sections will be presented.

Higgs Physics / 294

Measurements of anomalous Higgs boson couplings at CMS

Author: Savvas Kyriacou¹

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The results of the most recent searches for anomalous Higgs boson couplings at CMS will be presented, including probes for CP violation in the Higgs boson interactions.

Higgs Physics / 295

Search for resonant di-Higgs production at CMS

Author: Alessia Saggio¹

¹ Deutsches Elektronen-Synchrotron (DE)
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Latest result from searches for resonances decaying into pairs of Higgs bosons at CMS will be presented, both in resolved and in boosted topologies.

Quark and Lepton Flavour Physics / 296

Search for New Physics via the $K_L \rightarrow \pi^0 \nu \bar{\nu}$ decay at the J-PARC KOTO experiment

Author: Nobuhiro Shimizu

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The purpose of the KOTO experiment, being conducted at J-PARC (Ibaraki Japan), is to search for New Physics via the rare decay $K_L \rightarrow \pi^0 \nu \bar{\nu}$ using the high intensity $K_L$ beam provided by the 30-GeV proton synchrotron. The $K_L \rightarrow \pi^0 \nu \bar{\nu}$ decay is suppressed in the standard model, and its observation may reveal hints of new physics. The signature of $K_L \rightarrow \pi^0 \nu \bar{\nu}$ is two $\gamma$’s from a $\pi^0$ and no other particles in the detectors surrounding the decay region.

For the data collected between 2016 and 2018, a blind analysis technique was adopted to avoid human bias in the determination of the selection criteria. We unblinded the signal region in the summer of 2019, and observed candidate events. Since then, we have been checking our software and hardware, and possibilities of backgrounds that we might have missed.

In this presentation, we report the progress in the analysis and the obtained feedback from the data taken in 2019 and 2020.

Top Quark and Electroweak Physics / 297

Vector Boson Scattering results from CMS

Author: Kaur Sandeep

1 Panjab Univ.
ICHEP 2020 / Book of Abstracts

Corresponding Author: sandeep.kaur.hundal@cern.ch

Latest VBS Run-2 results from CMS.

I read the instructions:

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 298

Tau identification exploiting deep learning techniques

Author: Andrea Cardini

1 DESY

Corresponding Authors: andrea.cardini@desy.de, andrea.cardini@cern.ch

The recently deployed DeepTau algorithm for the discrimination of taus from light flavor quark or gluon induced jets, electrons, or muons is an ideal example for the exploitation of modern deep learning neural network techniques. With the current algorithm a suppression of mis-identification rates by factors of two and more have been achieved for the same identification efficiency for taus as for the MVA identification algorithms used for the LHC Run-1, leading to significant performance gains for many tau related analyses. The algorithm and its performance will be discussed.

I read the instructions:

Secondary track (number):

13.

Beyond the Standard Model / 299

Searching for supersymmetric partners of top quarks at the CMS

Corresponding Author: soham.elessar@gmail.com

The newest results for classic searches for the pair-production of supersymmetric top partners in final states with and without leptons with the CMS detector are presented. The analysis strategies are developed to cover different scenarios of heavy stop particles as well as those with stop mass close to the SM top particles. The results are based on proton-proton collisions recorded at sqrt(s) = 13 TeV with the CMS detector using the full Run 2 dataset of 137 fb-1.

I read the instructions:

Secondary track (number):

Beyond the Standard Model / 300
Searching for pair production of SUSY particle in leptonic final states at the CMS

Author: Ashraf Mohamed

1 DESY

Corresponding Author: ashraf.mohamed@cern.ch

The most recent results for searches of pair production of charged and neutral electroweak SUSY particles are presented. The analyses are performed in the final states containing one or more leptons, and presence of a boosted Higgs boson. The results are based on proton-proton collisions recorded at $\sqrt{s} = 13$ TeV with the CMS detector using the full Run 2 dataset of 137 fb$^{-1}$.

Beyond the Standard Model / 301

Digging deeper into SUSY parameter space with the CMS experiment

Author: Sezen Sekmen

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Corresponding Author: sezen.sekmen@cern.ch

Since the classic searches have not given any strong indication for new physics, more and more supersymmetry searches target the more difficult scenarios. This talk focuses on searches looking for signatures of stealth supersymmetry as well as those searches focusing on the scenarios with compressed mass spectra that require using dedicated tools. The results are based on proton-proton collisions recorded at $\sqrt{s} = 13$ TeV with the CMS detector.

Operation, Performance and Upgrade of Present Detectors / 302

Heavy flavour tagging in CMS in Run 2

Author: Alessandro Calandri

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Jet reconstruction, identification and classification is of prime interest in an hadronic environment such as the LHC. Algorithms were developed in order to separate jets emerging from the decay of charm and bottom quarks, and to identify large jets produced from the decays of heavy resonances. In Run 2, such algorithms have benefited from the use of increasingly complex deep neural network
architectures. Improved performance are now allowing to probe physics processes thought to be unreachable at hadron colliders. In parallel, new methods have been investigated to derive corrections to apply to the simulation to match the data taken at the LHC.

I read the instructions:

Secondary track (number):

**Operation, Performance and Upgrade of Present Detectors / 303**

**Performance of the reconstruction and identification of high-momentum muons collected with CMS in 13 TeV data**

**Author:** Carlo Battilana¹

¹ *Univ. di Bologna e Sez. dell’INFN*

**Corresponding Author:** carlo.battilana@cern.ch

The CMS detector at the LHC has recorded events from proton-proton collisions, with muon momenta reaching up to 1.8 TeV in the collected dimuon samples. These high-momentum muons allow direct access to new regimes in physics beyond the standard model. Because the physics and reconstruction of these muons are different from those of their lower-momentum counterparts, this talk presents for the first time dedicated studies of efficiencies, momentum assignment, resolution, scale, and showering of very high momentum muons produced at the LHC.

I read the instructions:

Secondary track (number):

**Neutrino Physics - Posters / 304**

**Electromagnetic neutrino interactions in elastic neutrino-proton scattering**

**Authors:** Alexander Studenikin¹; Fedor Lazarev²; Konstantin Kouzakov³

¹ *M.V. Lomonosov Moscow State University (RU)*

² *MSU*

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**Corresponding Authors:** fedek302@gmail.com, studenik@srdf.sinp.msu.ru, kouzakov@gmail.com

We develop a basic theoretical apparatus for the search of electromagnetic neutrino interactions in experiments on elastic neutrino-nucleus scattering [1]. Using our approach developed for the case of elastic neutrino-electron collisions in [2], we take into account all electromagnetic form factors of massive neutrinos [3] in the present treatment. In this contribution we focus on elastic neutrino-proton scattering, which can be important for studying supernova neutrinos in experiments, for example, such as JUNO [4]. In our consideration we take into account all electromagnetic form factors not only of a neutrino, but of a proton as well.


Monte Carlo Modelling and Tuning in CMS

Author: Gerrit Van Onsem

1 CERN

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New sets of CMS underlying-event tunes are presented for the PYTHIA 8 with various colour reconnection models, and Herwig 7 event generator. Comparisons of the predictions of the new tunes are provided for observables sensitive to the global underlying event, to soft multiparton interactions, and to double-parton scattering contributions, as well as for observables measured in various final states, such as multijet, Drell-Yan, and top quark-antiquark pair production. The measurements characterizing the properties of the underlying event in top quark pair production and the Drell-Yan processes are also presented.

Neutrino Physics / 307

New results from the CUORE experiment

Corresponding Author: andrea.giacchero@mib.infn.it

The Cryogenic Underground Observatory for Rare Events (CUORE) is the first bolometric experiment searching for neutrinoless double-beta (0νββ) decay that has been able to reach the one-ton scale. The detector, located at the Laboratori Nazionali del Gran Sasso in Italy, consists of an array of 988 TeO$_2$ crystals arranged in a compact cylindrical structure of 19 towers. Following the completion of the detector construction in August 2016, CUORE began its first physics data run in 2017 at a base temperature of about 10 mK. Following multiple optimization campaigns in 2018, CUORE is currently in stable operating mode. In 2019, CUORE released its 2nd result of the search for 0νββ corresponding to a TeO$_2$ exposure of 372.5 kg∙yr and a median exclusion sensitivity to a $^{130}$Te 0νββ decay half-life of $1.7 \times 10^{25}$ yr. We find no evidence for 0νββ decay and set a 90% C.L. Bayesian lower limit of $3.2 \times 10^{25}$ yr on the $^{130}$Te 0νββ decay half-life. In this talk, we present the current status of CUORE’s search for 0νββ, as well as review the detector performance. We finally give an update of the CUORE background model and the measurement of the $^{130}$Te two neutrino double-beta (2νββ) decay half-life.

I read the instructions:
A new way of understanding the role of each measurement at future Higgs factories in SMEFT

Author: Junping Tian

Co-authors: Michael Peskin, Keisuke Fujii

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Corresponding Authors: keisuke.fujii@cern.ch, tian@icepp.s.u-tokyo.ac.jp, m peskin@slac.stanford.edu

Starting from precision measurements at an e+e− Higgs factory, it is possible to extract the Higgs boson couplings using a general fit to the parameters of Standard Model Effective Field Theory (SMEFT). To understand the precisions that are possible, and to evaluate the role of each measurement offered by various Higgs factory proposals, it is important to understand the dependence of each output couplings on the accuracies of a large number of input measurements. In this talk, we present those dependencies in a new and transparent way and discuss their physics implications.

Phenomenological study of keV scale sterile neutrino dark matter with $S_4$ flavor symmetry

Author: Nayana Gautam

Co-author: Mrinal Kumar Das

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2 Tezpur University

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Searching for the cosmological origin, constituents and the interactions of dark matter has been a great challenge to the fundamental science today. With the motivation of connecting dark matter phenomenology with neutrino, we have chosen inverse seesaw ISS (2,3) framework which is the extension of the standard model by the addition of two right handed neutrinos and three sterile fermions. The significance of the model is that it leads to a light sterile state with the mass in the keV range along with three light active neutrino states. The lightest sterile neutrino in keV scale can account for a feasible dark matter (DM) candidate. To strengthen our dark matter model, $S_4$ flavor symmetry has been incorporated which is further augmented by $Z_4 \times Z_3$ symmetry to constrain the Yukawa Lagrangian. We have performed detailed numerical analysis including the calculation of DM mass and mixing with the active neutrinos, decay rates of possible interaction as well as the relic abundance which are the key factors for considering sterile neutrino as a viable dark matter candidate. We constrain the parameter space of our model with the latest astrophysical and cosmological data.
Muon reconstruction and identification performance at CMS during Run 2

**Author:** Sergio Sanchez Cruz

1 *Universidad de Oviedo (ES)*

**Corresponding Author:** sergio.sanchez.cruz@cern.ch

The Compact Muon Solenoid (CMS) detector is one of the main experiments of the Large Hadron Collider (LHC). Many aspects of its broad physics program rely on our ability to trigger, reconstruct and identify events with muons in a wide range of momenta, from a few GeV to the TeV scale. We study the performance of muon identification and isolation in CMS in pp collision data at 13 TeV recorded during the Run 2 of the LHC. Additionally, techniques for the identification of muons produced in Z and W bosons, and tau decays for the use in SM precision measurements and searches for BSM physics are presented. Finally, the performance on benchmark models is shown.

**Secondary track (number):**

Beyond the Standard Model - Posters / 313

Electroweak SUSY production in multileptonic final states at CMS

**Author:** Carlos Francisco Erice Cid

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Electroweak production of supersymmetric particles becomes relevant whenever strongly coupled SUSY is present only at relatively high masses. Due to the strict constraints in squark and gluino properties obtained at the LHC experiments, low mass sleptons and/or gauginos could dominate SUSY production at LHC. A search for supersymmetric particles in multileptonic final states using data obtained with the CMS experiment during the LHC Run II operations at a center of mass energy of $\sqrt{s}=13$ TeV is presented. Final states with up to four leptons -including hadronic taus- are scrutinized. Results are interpreted in terms of simplified models describing R-parity conserving gaugino pair production in both light and heavy slepton scenarios.

**Secondary track (number):**

Top Quark and Electroweak Physics - Posters / 314

WZ production in leptonic decays at CMS

**Author:** Bárbara Álvarez González

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**Corresponding Author:** balvarez@cern.ch

The study of the associated production of W and Z bosons is performed in proton-proton collisions using data collected by the CMS experiment. WZ production is one of the dominant multiboson production processes at the LHC energies. Thus, a good understanding of this process improves our understanding of the Standard Model. Inclusive cross section measurements and differential
cross section measurements for different variables are provided. Anomalous couplings and boson polarization are also presented.

I read the instructions:

Secondary track (number):

Beyond the Standard Model - Posters / 315

Search for scalar top quark pair production in the top corridor region

Author: Andrea Trapote Fernandez

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A search for scalar top quark pair production at the LHC is presented. This search targets a region of parameter space where the kinematics of top squark pair production and top quark pair production are very similar, because of the mass difference between the top squark and the neutralino being close to the top quark mass. The search is performed with the full run 2 data set of proton-proton collisions at a centre-of-mass energy of 13 TeV, collected by the CMS detector, using events containing one electron-muon pair with opposite charge. A DNN algorithm is used to separate signal from background.

Secondary track (number):

Top Quark and Electroweak Physics / 316

Optimising top-quark pair-production threshold scan at future $e^+e^-$ colliders

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1 University of Warsaw
2 University of Warsaw (PL)

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One of the main goals of the future $e^+e^-$ colliders is to measure the top-quark mass and width in a scan of the pair production threshold. Yet, the shape of the threshold cross section depends also on other model parameters as the top Yukawa coupling and the strong coupling constant. We study the expected precision of the top-quark mass determination from the threshold scan at CLIC, ILC and FCCee. We use the most general fit approach with all relevant model parameters and expected constraints from earlier measurements taken into account. We demonstrate that even in the most general approach the top-quark mass can be extracted with statistical precision of the order of 20 to 30 MeV. Additional improvement is possible if the running scenario is optimized. We propose the optimisation procedure based on the genetic algorithm. When optimising the mass measurement the statistical uncertainty can be reduced by about 30%, corresponding to factor of 2 increase in the integrated luminosity.

Secondary track (number):
Top Quark and Electroweak Physics / 317

Enhancing fits of SMEFT Wilson coefficients in the top-quark sector

Authors: Kevin Alexander Kroeninger¹; Johannes Erdmann²; Cornelius Grunwald¹; Gudrun Hiller¹; Stefan BißmannNone

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Over the last years, various efforts were made for interpreting measurements of top-quark observables in the context of the Standard Model Effective Field Theory (SMEFT). In this talk, we point out aspects for enhancing fits constraining Wilson coefficients of dimension-six operators that should be considered when aiming towards a global fit of SMEFT coefficients in the top-quark sector.

On the one hand, we discuss the importance of taking into account correlations between the uncertainties of measurements by demonstrating the impact correlations can have on the constraints of Wilson coefficients. On the other hand, we discuss the advantages of combining measurements from top-quark and $B$ physics for constraining top-quark couplings. Considering $\sigma(t\bar{t}\gamma)$ together with $\text{BR}(\bar{B} \rightarrow X_s\gamma)$ as an example, we present the steps necessary for including observables from different energy scales in a combined fit and highlight the benefits of this approach.

Secondary track (number):

Beyond the Standard Model / 318

Searches for heavy resonances decaying into Z, W and Higgs bosons at CMS

Author: Dennis Mario Roy¹

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A summary of searches for heavy resonances with masses exceeding 1 TeV decaying into pairs or triplets of bosons is presented, performed on data produced by LHC pp collisions at $\sqrt{s} = 13$ TeV and collected with the CMS detector during 2016, 2017, and 2018. The common feature of these analyses is the boosted topology, namely the decay products of the considered bosons (both electroweak $W$, $Z$ bosons and the Higgs boson) are expected to be highly energetic and close in angle, leading to a non-trivial identification of the quarks and leptons in the final state. The exploitation of jet substructure techniques allows to increase the sensitivity of the searches where at least one boson decays hadronically. Various background estimation techniques are adopted, based on data-MC hybrid approaches or relying only in control regions in data. Results are interpreted in the context of the Warped Extra Dimension and Heavy Vector Triplet theoretical models, two possible scenarios beyond the standard model.

I read the instructions:

Secondary track (number):

Beyond the Standard Model / 319
Searches for vector-like quarks at CMS

Author: Julie Hogan

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We present results of searches for massive vector-like top and bottom quark partners using proton-proton collision data collected with the CMS detector at the CERN LHC at a center-of-mass energy of 13 TeV. Single and pair production of vector-like quarks are studied, with decays into a variety of final states, containing top and bottom quarks, electroweak gauge and Higgs bosons. We search using several categories of reconstructed objects, from multi-leptonic to fully hadronic final states. We set exclusion limits on both the vector-like quark mass and cross sections, for combinations of the vector-like quark branching ratios.

Beyond the Standard Model / 320

Search for new resonances coupling to third generation quarks at CMS

Author: Alexander Froehlich

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Corresponding Author: alexander.froehlich@desy.de

We present an overview of searches for new physics with top and bottom quarks in the final state, using proton-proton collision data collected with the CMS detector at the CERN LHC at a center-of-mass energy of 13 TeV. The results cover non-SUSY based extensions of the SM, including heavy gauge bosons or excited third generation quarks. Decay channels to vector-like top partner quarks, such as T', are also considered. We explore the use of jet substructure techniques to reconstruct highly boosted objects in events, enhancing the sensitivity of these searches.

Operation, Performance and Upgrade of Present Detectors / 321

CMS track reconstruction performance during Run 2 and developments for Run 3

Author: Walaa Elmetenawee

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The efficient and precise reconstruction of charged particle tracks is crucial for the overall performance of the CMS experiment. During the LHC Run 2, significant upgrades were made to the track
reconstruction algorithms, both to accommodate the high pileup environment and the installation of an upgraded pixel detector in 2017. Performance measurements of the track reconstruction both in simulation and collision data will be presented. Developments are ongoing to further improve track reconstruction in Run 3, especially in the CMS high level trigger, and the status of these improvements will be discussed.

I read the instructions:

Secondary track (number):

1. Performing precision measurements and new physics searches at the HL-LHC with the upgraded CMS Level-1 Trigger

**Author:** Emily Mac Donald

*University of Colorado at Boulder*

Corresponding Author: emma8317@colorado.edu

The High-Luminosity LHC will open an unprecedented window on the weak-scale nature of the universe, providing high-precision measurements of the standard model as well as searches for new physics beyond the standard model. Such precision measurements and searches require information-rich datasets with a statistical power that matches the high-luminosity provided by the Phase-2 upgrade of the LHC. Efficiently collecting those datasets will be a challenging task, given the harsh environment of 200 proton-proton interactions per LHC bunch crossing. For this purpose, CMS is designing an efficient data-processing hardware trigger (Level-1) that will include tracking information and high-granularity calorimeter information. The current conceptual system design is expected to take full advantage of FPGA and link technologies over the coming years, providing a high-performance, low-latency computing platform for large throughput and sophisticated data correlation across diverse sources. The envisaged L1 system will more closely replicate the full offline object reconstruction instead of performing a more sophisticated and optimized selection. Algorithms such as particle flow reconstruction can be implemented and complemented by standalone trigger object reconstruction. The expected performance and physics implications of such algorithms are studied using Monte Carlo samples with high pile-up, simulating the harsh conditions of the HL-LHC. The trigger object requirements are not only driven by the need to maintain physics selection thresholds to match those of the Phase-1, the selection of exotic signatures including displaced objects must be provided to help expanding the physics reach of the experiment. The expected acceptance increase on selected benchmark signals obtained by the upgraded CMS Phase-2 Level-1 trigger will be summarized in this presentation.

I read the instructions:

Secondary track (number):

12.

**Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques - Posters / 323**

**Triggering on electrons, photons, tau leptons, Jets and energy sums at HL-LHC with the upgraded CMS Level-1 Trigger**

**Author:** Jack Li

Page 133
The High-Luminosity LHC will open an unprecedented window on the weak-scale nature of the universe, providing high-precision measurements of the Standard Model as well as searches for new physics beyond the standard model. The Compact Muon Solenoid (CMS) experiment is planning to replace entirely its trigger and data acquisition system to achieve this ambitious physics program. Efficiently collecting those datasets will be a challenging task, given the harsh environment of 200 proton-proton interactions per LHC bunch crossing. The new Level-1 trigger architecture for HL-LHC will improve performance with respect to Phase I through the addition of tracking information and subdetector upgrades leading to higher granularity and precision timing information. In this poster, we present a large panel of trigger algorithms for the upgraded Phase II trigger system, which benefit from the finer information to reconstruct optimally the physics objects. Dedicated pile-up mitigation techniques are implemented for lepton isolation, particle jets and missing transverse energy to keep the rate under control. The expected performance of the new trigger algorithms will be presented, based on simulated collision data of the HL-LHC. The selection techniques used to trigger efficiently on benchmark analyses will be presented, along with the strategies employed to guarantee efficient triggering for new resonances and other new physics signals.
Neutrino spin-flavour and collective oscillations in supernovae

Authors: Konstantin Kouzakov¹; Yufeng Li²; Konstantin Stankevich¹; Z. Y. Yuan²; Studenikin¹; Alexander Studenikin³

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We present an analysis of a neutrino flux evolution in an extreme astrophysical environment peculiar to supernovae accounting for effects of an arbitrarily moving media and a strong magnetic field. For neutrinos propagating inside a supernova the resonances in the flavour and spin-flavour oscillations engendered by the neutrino magnetic moment interaction with a magnetic field and weak interactions with the transversally moving matter are accounted for [1,2]. In addition, we also account for the effect of the collective neutrino oscillations and discuss possible spectral splits of the final neutrino fluxes that can arise due to spin and spin-flavour oscillations in this case.


I read the instructions:

Secondary track (number): 08

Operation, Performance and Upgrade of Present Detectors - Posters / 326

The Forward Diffractive Detector for ALICE

Author: Solangel Rojas Torres¹

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ALICE (A Large Ion Collider Experiment) is one of the four main detectors at CERN LHC. In order to exploit the increased luminosity and interaction rate during the upcoming LHC Run 3 and 4, ALICE is now implementing a significant upgrade of its detectors and systems. The minimum latency interaction trigger, luminosity monitoring, precision collision time, and determination of centrality and event plane for heavy-ion collisions will be provided by the Fast Interaction Trigger (FIT). FIT consists of three subsystems, including the Forward Diffractive Detector (FDD).

In this work, we introduce the FDD, which is the upgrade of the former ALICE Diffractive (AD) detector. The FDD detector consists of two stations covering the pseudorapidity ranges of 4.7<η<6.3 and -6.9<η<-4.9, respectively. This coverage allows FDD to efficiently tag diffractive and ultraperipheral events. The stations are made of two layers of plastic scintillators, divided into four quadrants. Each quadrant has two wavelengths shifting (WLS) bars connected to individual PMTs via a bundle of clear optical fibres. Among the main improvements of the FDD with respect to the AD are faster plastic scintillators and WLS, and the use of the newly developed front-end electronics suitable for operation both in a triggered and in a continuous readout mode.
Secondary track (number):

Quark and Lepton Flavour Physics / 327

A novel computational paradigm for a precise determination of the hadronic contribution to $(g-2)_\mu$ from lattice QCD

Author: Leonardo Giusti
Co-authors: Mattia Dalla Brida ; Tim Harris ; Michele Pepe

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Current lattice determinations of the hadronic contribution to the muon anomalous magnetic moment $a_\mu$ have uncertainties of a few percent. This translates into an overall error on the Standard Model prediction of $a_\mu$ which is one order of magnitude larger than the expected final uncertainty from the ongoing E989 experiment. The bottleneck is the large statistical error in the Monte Carlo evaluation of the required correlation functions which can hardly be tamed by brute force. Here we propose to solve the problem by using multi-level Monte Carlo integration. This way the decrease of the statistical error of correlation functions with the cost of the simulation is accelerated with respect to the standard inverse square-root dependence. We test our proposal in two-flavour QCD by simulating a lattice with linear extension of 3.0 fm, lattice spacing of 0.065 fm and a pion mass of approximately 270 MeV. By using a two-level integration scheme we show that the statistical error scales de-facto with the inverse of the cost of the simulation rather than with its squared root, allowing us to reach a precision of a few per mille for the Hadron Vacuum Polarization with a moderate computational cost. This result opens the way for a sub-percent precision determination of $a_\mu$ from first principle lattice calculations.

I read the instructions:

Secondary track (number):

06

Neutrino Physics - Posters / 328

Neutrino oscillations in a magnetic field: the three-flavor case

Authors: Alexander Studenikin$^1$; Alexey Lichkunov$^2$; Artem Popov$^3$

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We develop the approach to the problem of neutrino oscillations in a magnetic field introduced in [1] and extend it to the case of three neutrino generations. The theoretical framework suitable for computation of the Dirac neutrino spin, flavour and spin-flavour oscillations probabilities in a magnetic field is given. The closed analytic expressions for the probabilities of oscillations are obtained accounting for the normal and inverted hierarchies and the possible effect of CP violation. In particular, it is shown that the probabilities of the conversions without neutrino flavor change,
i.e. $\nu^L_e \rightarrow \nu^L_e$ and $\nu^L_e \rightarrow \nu^R_e$, do not exhibit the dependence on the CP phase, while the other neutrino conversions are affected by the CP phase. In general, the neutrino oscillation probabilities exhibit quite a complicated interplay of oscillations on the magnetic $\mu, B$ and vacuum frequencies. The obtained results are of interest in applications to neutrino oscillations under the influence of extreme astrophysical environments, for example peculiar to magnetars and supernovas, as well as in studying neutrino propagation in interstellar magnetic fields (see [2]).

I read the instructions:

Secondary track (number):

Quark and Lepton Flavour Physics / 329

Probing NP in four-fermion interactions with dipole processes

Author: Luiz Vale Silva

Co-authors: Sebastian Jager ¹; Kirsten Leslie ²

¹ Unknown
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Four-fermion effective interactions have played a major role in the formulation of the Standard Model (SM) of particle physics. Nowadays, they are of fundamental importance in establishing the viability of extensions of the SM, since this category of operators is sensitive to the flavor structure of New Physics (NP), including new sources of CP violation. Following the renormalization of four-fermion operators, they mix into dipole operators, thus inducing powerful constraints on their effective coupling constants (i.e., their Wilson coefficients). For many four-fermion operators, such mixing is absent at one-loop. Here, I would like to present the calculation of their leading-order two-loop mixing into dipoles, and the resulting phenomenological bounds on generic NP models that generate four-fermion effective interactions at energies much above the ElectroWeak scale.

Secondary track (number):

03

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 330

Photon detection system of the single phase DUNE far detector

Author: Wei Mu

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One of the most important experimental programs that will address some of the open questions in neutrino physics is the Deep Underground Neutrino Experiment (DUNE). It will be the first mega-science project on the US sole, which involves more than 1000 physicists. It will perform measurements of the CP violation in the leptonic sector, the neutrino mass hierarchy and on the $\theta_{23}$ octant. The DUNE foresees the realization of a neutrino beam and a near detector, both located at Fermilab (USA) and of a gigantic far detector based on the technology of liquid argon time projection chambers that will be installed at the Sanford Underground Research Facility in South Dakota, 1300 km away from Fermilab.
The photon detection system (SPPDS) is a fundamental component of the (single-phase) far detector, which will be used for timing, triggering and to improve the energy resolution of the detector for low energy events. Its baseline design relies on a newly developed technology, the ARAPUCA. Its operating principle is based on the combination of active silicon photon sensors with a passive collector. The latter allows increasing the effective detection efficiency of the active sensors by trapping the photons inside a highly reflective box. The design and the main features of the single-phase photon detection system (SPPDS) of DUNE, together with the impact on the physics reach of the experiment will be illustrated.

New Properties of primary and secondary cosmic rays measured by AMS

Authors: Vitaly Choutko1; Yi Jia1; Qi Yan1; Alberto Oliva2; Laurent Yves Marie Derome3; Mercedes Paniccia4; Valerio Formato5; Duc Phan6; Javier Berdugo Perez7

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We present precision high statistics measurements of primary cosmic rays protons, Helium, Carbon and Oxygen and the secondary cosmic rays Lithium, Beryllium and Boron measured by Alpha Magnetic Spectrometer on ISS in the rigidity range from 2 GV to 3 TV. These measurements are based on more than one billion nuclei collected by AMS during first 7 years of operation from May 2011 to May 2018. The unexpected properties of these cosmic rays as well as high statistics secondary-to-primary flux ratios such as Li/C, Be/C, B/C, Li/O, Be/O and B/O will be discussed.

Results and perspectives on hadron physics at KLOE/KLOE-2

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The KLOE-2 data-taking at the e+e- DAPHNE collider in Frascati has been completed by achieving an integrated luminosity of more than 5 fb-1 at the phi peak. KLOE-2 is an updated version of KLOE experiment with new detectors and an extended physics program, including light mesons investigations at unprecedented statistics. The KLOE/KLOE-2 data sample corresponds to more than 3x10^8 eta meson events. The huge available statistics has been used to search for the P, CP violating
The eta -> p0 gamma gamma decay is an important test of ChPT because of its sensitivity to the p^6 term on both the branching ratio and the M(gg) spectrum. A preliminary BR KLOE measurement, based on 450 pb^-1, provided a 4 sigma's lower value w.r.t. the most accurate determination from Crystal Ball. A new analysis with a larger data sample is in progress and confirm this result. The same five photon final state could be used to look for the B boson, a postulated leptophobic mediator of dark forces; the status of this investigation will be presented.

Scintillator hodoscopes installed by means of roman pots in the DAPHNE beam pipe allow to investigate gamma-gamma physics at the phi resonance from the reaction e^+e^- -> e^+e^- gamma gamma -> e^+e^-X by tagging final state leptons. Single pseudoscalar production provides the determination of the two-photon decay widths of these mesons. The analysis for the p0 final state is in progress, aiming to achieve an accuracy of O(1%). The p0 production from two-photon fusion is tagged by requiring the coincidence between the HET detector and the KLOE calorimeter when two-cluster bunches are reconstructed, and evaluating the uncorrelated HET-KLOE time coincidences. Data stability studies, based on very low angle Bhabha cross section measurement, and updates on gg->p0 search will be presented.

I read the instructions:

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 333

CMS electron and photon performance at Run 2 and prospects for Run 3

Author: Livia Soffi

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The Compact Muon Solenoid (CMS) detector is one of the two multi-purpose experiments at the Large Hadron Collider (LHC) and has a broad physics program. Many aspects of this program depend on our ability to trigger, reconstruction and identify events with final state electrons, positrons, and photons with the CMS detector with excellent efficiency and high resolution.

In this talk we present the full process of electron and photon reconstruction in CMS, starting from tracker hits and energy deposits in the electromagnetic calorimeter, the method to achieve the ultimate precision in Run II energy measurements, the trigger and identification strategies (based both on cut based approach and on multivariate analysis) to discriminate prompt electrons and photons from background, and the methods to estimate the associated systematic uncertainties. Finally the performance on benchmark channels will be shown together with prospects for Run 3.

I read the instructions:

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 334
Next-generation ultra-compact calorimeters based on oriented crystals

Authors: Alessandro Berra\textsuperscript{1}; Alexei Sytov\textsuperscript{2}; Alice Levkovitch\textsuperscript{None}; Andrea Mazzolari\textsuperscript{3}; Davide De Salvador\textsuperscript{4}; Enrico Bagli\textsuperscript{2}; Evgeniy Lutsenko\textsuperscript{1}; Gianluca Cavoto\textsuperscript{1}; Giovanni Ballerini\textsuperscript{1}; Laura Bandiera\textsuperscript{2}; Luca Bomben\textsuperscript{1}; Marco Romagnoni\textsuperscript{1}; Matthew Moulson\textsuperscript{6}; Mattia Soldani\textsuperscript{2}; Michela Prest\textsuperscript{4}; Nicola Argiolas\textsuperscript{7}; Riccardo Camattari\textsuperscript{2}; Valerio Mascagna\textsuperscript{1}; Victor Tikhomirov\textsuperscript{8}; Viktar Haurylavets\textsuperscript{9}; Vincenzo Guidi\textsuperscript{2}

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Scintillating crystal calorimeters provide unparalleled resolution in measuring the energy of electromagnetic particles. Recent experiments performed at CERN and DESY beamlines by the AXIAL/ELIOT collaboration demonstrated a significant reduction in the radiation length inside PbWO$_4$, the material used for the CMS ECAL, observed when the incident particle trajectory is aligned with a crystal axis within $\sim 0.1^\circ$. This remarkable effect, being observed over the wide energy range from a few GeV to 1 TeV or higher, paves the way for the development of an innovative calorimeter based on oriented crystals, featuring a design significantly more compact than currently achievable while rivaling the current state of the art in terms of energy resolution in the range of interest for present and future forward detectors (such as the KLEVER Small Angle Calorimeter at CERN SPS), beam dumps for light dark matter search and source-pointing space-borne $\gamma$-ray telescopes.

I read the instructions:

Secondary track (number):
12

Neutrino Physics / 335

First Measurement of Electron Neutrino Cross Section on Argon

Author: Rory Fitzpatrick\textsuperscript{1}
Co-author: ArgoNeuT Collaboration

\textsuperscript{1} University of Michigan

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ArgoNeuT has produced the first fully-automated reconstruction and selection of GeV-scale electron neutrinos scattering on argon, extracting a $\nu_e + \bar{\nu}_e$ total cross section. This talk will describe those results, emphasizing the novel electromagnetic shower classification tools developed for identifying GeV-scale $\nu_e$-like interactions among complex backgrounds and the broader context with respect to DUNE oscillation physics, where electron neutrino classification at the GeV scale is highly relevant but data-based studies are largely absent.
Top Quark and Electroweak Physics / 336

The electro-weak couplings of the top quark: current constraints, prospects and impact in a combined top-Higgs EFT fit

Authors: Martin Perello Rosello¹; Martin Perelló Roselló²; Marcel Vos³; Junping Tian⁴; Sunghoon Jung⁵

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The electro-weak couplings of the top and bottom quarks are sensitive probes of new physics. Especially the former were very poorly constrained until recently. We derive limits on the relevant Wilson coefficients of the Standard Model Effective Field Theory using ATLAS and CMS data on associated top quark production, single top-quark production and top decay, and LEP data on the Zbb vertex. These bounds are compared to the prospects of the High-Luminosity phase of the LHC and a future electron-positron collider operated above the top-quark pair-production threshold. Finally, we assess the interplay between Higgs and EW precision measurements and the top quark.

Secondary track (number):

Neutrino Physics - Posters / 337

Astrophysical neutrino oscillation accounting for neutrino charge radii

Authors: Alexander Studenikin¹; Fedor Lazare²; Konstantin Stankevich³; Vadim Shakhov⁴

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It is believed that the running (for instance, COHERENT) and forthcoming terrestrial neutrino experiments will be sensitive to the neutrino charge radius [1] that is one of the neutrino fundamental electromagnetic characteristics [2] predicted [3] to be non-zero even in the Standard Model. In this work we derive the neutrino evolution equation accounting for charge radii for the case of the neutrino propagation in an extreme astrophysical environment. On this basis, we study conditions for new neutrino oscillation resonances in astrophysical environments (such as supernovae, neutron and binary neutron stars) accounting for neutrino magnetic moments and charge radii. We discuss possibilities to have reasonable effects of the charge radii on supernovae neutrino fluxes in the forthcoming large volume neutrino experiments.
Neutrino Physics / 339

Neutrino-Nucleus Interaction Physics with the Most Recent MINERvA Low-Energy Beam Data

Author: Xianguo Lu

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MINERvA at FNAL is an experiment dedicated to the study of neutrino-nucleus interaction physics. Its goal is to provide constraints on nuclear effects that are crucial for present and future neutrino
oscillation measurements, and to illustrate the interplay between hadronic and nuclear physics at
the few-GeV regime. As the analysis of the Low-Energy data—the beam flux peaks at about 3 GeV
with most of the rate between 1-6 GeV—is coming to a conclusion, nuclear effects are shown to be a
complex phenomenon which challenges many of the popular theoretical descriptions. In this talk, a
summary of the most recent MINERvA Low-Energy Beam results will be presented, alongside with
discussions on their implication for future neutrino oscillation measurements.

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 340

Construction and performance of 4-D CsI calorimeter for the \( K_L \rightarrow \pi^0 \nu \bar{\nu} \) search of KOTO experiment

Author: Katsushige Kotera

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One of the key issues of the search for the \( K_L \rightarrow \pi^0 \nu \bar{\nu} \) decay mode is to suppress the backgrounds
to the signature with only two photons from the \( \pi^0 \) in the final state. We use an electromagnetic
calorimeter and hermetic veto counters in the KOTO experiment at J-PARC. The calorimeter is made
of 50 cm-long undoped CsI crystals stacked in a 1.9 m-diameter cylinder. Each crystal is read out with
a PMT on the back surface of the crystals. A major background is caused by neutrons generating
two showers in the calorimeter. Neutrons tend to have interactions deeper than photons. In the
autumn of 2018 we upgraded the calorimeter by installing 4000 silicon photomultipliers (SiPMs)
on the front surface of the crystals. The depth information is available by measuring the timing
difference between SiPMs and PMTs. The construction and performance of this new calorimeter
by using data of 2019 will be presented. Less than 0.5 neutron background events are expected
when we reach the sensitivity of one \( K_L \rightarrow \pi^0 \nu \bar{\nu} \) event. The signature has a branching fraction of
\((3.0 \pm 0.3) \times 10^{-11}\) in the standard model.

I read the instructions:

Secondary track (number):

13

Diversity and Inclusion / 341

Diversity and Inclusion Activities in the Belle II Collaboration

Author: Hannah Wakeling

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Belle II is an international collaboration that has over 1000 members
from institutions in 26 countries. In 2018 Belle II created two posts
of diversity officers, to raise awareness of diversity and inclusion
issues, promote an inclusive atmosphere within the collaboration,
provide a safe and confidential point to contact for collaborators to
report any issues, particularly those related to discrimination and harassment, and ensure that persons from underrepresented groups are considered for positions of responsibility within the collaboration. We will show how the demographics of the Belle II collaboration have evolved, and discuss diversity and inclusion activities and initiatives undertaken in Belle II.

Event plane determination with the new ALICE FIT detector

**Author:** Heidi Maria Rytkonen

1 University of Jyvaskyla (FI)

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Event plane determination with the new ALICE FIT detector

The Fast Interaction Trigger (FIT) [1] is one of the new detectors being constructed for the upgrade of the ALICE experiment at CERN. FIT is a thoroughly modernized design, combining the functionality of four detectors used by ALICE during the LHC Run 2: the T0, V0, AD and FMD. During the upcoming LHC Run 3 and 4, in addition to the multiple triggering tasks, FIT will monitor luminosity, measure precisely the collision time, and determine centrality and event plane for heavy-ion collisions.

In non-central collisions, the geometry of the colliding nuclei can be described by the reaction plane that is determined by the beam axis and impact parameter. Since the impact parameter cannot be measured, one cannot determine the reaction plane precisely. An approximation for the reaction-plane angle $\Psi_{RP}$ is the second-order event plane $\psi_2$, often called simply event plane $\psi$, that is given by the flow vector determined from the measured final hadrons. The difference between $\Psi_{RP}$ and $\psi$ is measured with event-plane resolution, that is evaluated using the sub-event method. [2]

In this presentation, I will summarise the FIT performance in Pb-Pb collisions during the Run 3 based on simulations using realistic detector- and beam pipe geometry. The focus will be on the influence of sub-event selection on event plane determination and resolution. These results will be compared to the performance of the ALICE setup during the LHC Run 2.

**References**


Flavor Physics and Discrete Symmetries at KLOE-2

**Author:** Michal Silarski

**Secondary track (number):**
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Present data sample of 8 fb$^{-1}$ collected by KLOE and KLOE-2 experiments at the upgraded DAΦNE collider of the INFN Laboratori Nazionali di Frascati corresponds to the largest sample ever collected at the $\phi(1020)$ meson peak at an $e^+e^-$ collider - $2.4 \times 10^{10}$ $\phi$-mesons produced.

The lepton charge asymmetry measured in $K_S$ semileptonic decays with 1.7 fb$^{-1}$ of KLOE data, improving the statistical uncertainty of the present result by about a factor two, will be presented together with the test of CPT in transitions in $\phi \rightarrow K_S K_L \rightarrow \pi e^+ \pi^-$ and $\pi e^+ \pi^-$ decays. Latest results on $K_S$ rare decays will be discussed in the framework of Flavour Physics and CP Violation tests. Among these the first measurement ever on the $K_S \rightarrow \pi \mu \nu$ branching ratio at a 4.4% total accuracy, using 1.7 fb$^{-1}$ KLOE data allowing a new determination of the $V_{us}$ CKM matrix element and the test of lepton-flavour universality using $K_S$ mesons, and the search for the pure CP-violating $K_S \rightarrow 3\pi^0$ decay with the newly acquired KLOE-2 data set.

I read the instructions:

Secondary track (number):

Education and Outreach / 344

ENGAGING DIVERSE AUDIENCES WORLDWIDE TO THE QUEST FOR GRAVITATIONAL WAVES

Author: Nicolas Arnaud$^1$

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Less than five years have passed since the first detection of a gravitational-wave signal, on September 14th, 2015. Yet, the status of the field has changed drastically, with a growing number of detections made by a global network of ground-based interferometric detectors with unprecedented sensitivities and high duty cycles. A truly new window onto the Universe, symbolized by multimessenger astronomy with gravitational waves, has been opened. The LIGO Scientific Collaboration and the Virgo Collaboration have developed a wide set of resources to communicate the excitement of this new field to the general public. This talk will review the main tools used to achieve this goal, that range from classic site visits, outreach publications or educational materials, to social medias, games or apps displaying gravitational-wave public alerts live. We will also describe the target audiences we have identified and show how the diversity of our collaborations is an asset to reach them out.

Secondary track (number):

Higgs Physics / 345

Expectations for Precision Tests of the Standard Model at the ILC$^\text{a}$

Authors: Gerald Eigen$^1$; Michael Peskin$^\text{None}$

$^1$ University of Bergen (NO)
In the past year, studies for the European Strategy for Particle Physics have led to a much clearer understanding of the capabilities of the International Linear Collider to measure the Standard Model parameters with high precision. The new projections for ILC improve the expected precision on Higgs boson couplings, tests of electroweak interactions at the Z pole, high energy WW interactions, 2-fermion production processes, and direct and indirect measurements of the Higgs boson self-coupling. The use of Standard Model Effective Field Theory gives a unified framework for analyzing all of these Standard Model tests, and demonstrates their synergy in using precision to search for new physics. This talk will review this framework and summarize the current expectations for the ILC.

Secondary track (number):

Accelerator: Physics, Performance, and R&D for Future Facilities / 346

Polarized Beams at Future e+e- Colliders

Authors: Gerald Eigen\(^1\); Michael Peskin\(^{None}\)

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Linear e+e- colliders uniquely offer the opportunity to study collisions with longitudinally polarized electron and positron beams. In recent studies of precision tests of the Standard Model at the International Linear Collider, it has been seen that this capability can play an unexpectedly important role. This comes, first, from the ability of polarization asymmetries to access essential physics parameters. In addition, because the ILC experiments are designed to with several distinct ways of measuring the beam polarizations, polarized observables can be determined with very small systematic errors. This will play an especially important role in the improvement of precision electroweak measurements. This talk will present an overview of beam polarization measurement at the ILC and its implications in the search for deviations from the Standard Model.

I read the instructions:

Secondary track (number):

Heavy Ions / 347

Overview of the latest jet physics results from ALICE

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Collisions of ultra-relativistic heavy ions are used to create strongly interacting matter in the regime of high-energy densities and temperatures. Under these conditions color confinement of quarks and gluons in hadrons breaks down and a new state of matter called Quark-Gluon Plasma is formed. Properties of this medium can be inferred based on observed modifications of produced jets. Recently, new tools were developed to study jet properties more differentially. These observables are based on jet-shape and jet-substructure measurements or employ hadron-jet correlations. The talk will review the latest results from these jet analyses performed by the ALICE Collaboration in pp and Pb-Pb collisions.
First direct measurement of the dead-cone effect at colliders with iterative declustering techniques in pp collisions at 13 TeV with ALICE

Author: Leticia Cunqueiro Mendez

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We report the first direct measurement of the dead-cone effect at colliders, using iterative jet declustering techniques in pp collisions at $\sqrt{s} = 13$ TeV. The iterative declustering is applied to the angular ordered C/A tree of jets associated with $D^0$ mesons. Following the $D^0$ branch in the splitting history the corresponding Lund plane diagram is constructed, which enables to suppress hadronization effects by appropriate kinematic selections. The reported variable is the splitting angle with respect to momentum of the emitter, which is updated after each splitting. Track-based jet finding, along with the low-$p_T$ reach of the ALICE detector, allows for an accurate reconstruction of the splitting angle in the phase-space where the dead-cone effect is expected to be largest. The results are compared to those of inclusive jets and theoretical models.

Small-Pad Resistive Micromegas – Rate capability for different spark protection resistive schemes

Author: Maria Teresa Camerlingo

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Micromegas are among the most promising micro pattern gaseous detector (MPGD) technologies for applications in high energy physics (HEP). Micromegas are very versatile. They can be used for precision tracking and trigger, in particle flow calorimetry sampling, as anode planes for RICH detectors or for time projection chambers.
Driven mainly by future upgrades of existing experiments at high-luminosity LHC (HL-LHC) and for applications at future accelerators, we started a R&D project to push further this technology for operations under very high particle flow. Small Pad resistive Micromegas detectors were designed to operate as precision trackers up to rates of tens MHz/cm², three orders of magnitudes higher than current applications. The miniaturization of the readout elements and the optimization of the spark protection system, as well as the stability and robustness under operation, are the primary challenges of the project. Several small-pad Micromegas detectors have been built with similar anode planes, segmented with a matrix of 48x16 readout pads with a rectangular shape (0.8x2.8 mm²) and with a pitch of 1 and 3 mm in the two coordinates. The active surface is 4.8x4.8 cm² with a total number of 768 channels, routed off-detector for readout. Covering the anode plane, a resistive layer quenches the spark occurrences, improving the robustness of the Micromegas design. The scheme and configuration of the resistive spark suppression layer is specific to the geometry of the readout electrodes. For the small-pad resistive Micromegas detectors, two different schemes were implemented to be compatible with their small rectangular pad electrodes. The first scheme involves a pad-patterned layer with embedded resistors for each readout pad. The second scheme implements a double layer of uniform Diamond-Like-Carbon (DLC) resistive foils as resistive planes, covering all the active area. In this scheme a net of low resistive silver vias evacuates the current from the double layer of DLC to ground, avoiding that the current spread on all the planes, encountering a large resistance and in turn reducing the rate capability. For each technique different configurations and resistivity values have been adopted. Characterization and performance studies of the detectors have been carried out by means of radioactive sources, X-Rays. Conclusive results and a comparison of the performance obtained with the different resistive layouts and different configurations will be presented. In particular, they concern on the response under high irradiation and high rate exposure, and its dependence on the dimensions of the exposed surface. Results from high energy muon beam (at CERN-SPS) and from a first test beam of 300 MeV/c pions (at PSI) will also be presented.

Secondary track (number):

Heavy Ions / 350

Vector meson photoproduction in ultra-peripheral Pb-Pb collisions at the LHC with ALICE

Author: Valeri Pozdniakov

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The electromagnetic field of a fast charged particle, described as a flux of quasi-real photons whose intensity is proportional to its squared electric charge, provides copious photonuclear interactions in the case of lead ions circulating in the LHC. If the impact parameter of the colliding ions is larger than the sum of their radii, photon-induced processes dominate the interaction rate via ultra-peripheral collisions (UPC).

The cross section of a $\rho^0$ photonuclear production in Pb-Pb UPC at the LHC is so large that it becomes a proper tool to research the approach to the black-disk limit of QCD. ALICE presents the coherent $\rho^0$ photoproduction measurements. The results are compared with model predictions for different nuclear-breakup classes.

ALICE measured the $J/\psi$ photoproduction cross sections in Pb-Pb UPC at the forward and central rapidities. The results are compared to the newest models describing possible saturation and gluon shadowing at small $x$.

I read the instructions:
Characterizing the particle-emitting source using femtoscopy in pp collisions at ALICE

Author: Andreas Mathis

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The precise knowledge of the size of the source producing primary hadrons and resonances in pp collisions at the LHC can be employed to study the onset of collective phenomena in such systems. Indeed, the multiplicity and transverse momentum dependence of the pion and kaon source sizes, extracted by the femtoscopy analysis, was often interpreted as due to collective effects in heavy-ion collisions. Since in pp collisions at the LHC typical source sizes are about 1 fm, the contribution of strong resonances decays has to be corrected for to determine the characteristics of the particle-emitting source. In this talk we discuss the results obtained in studying baryon-baryon and pion-pion correlations in high multiplicity pp collisions at 13 TeV measured by ALICE. A differential analysis as a function of multiplicity and transverse momentum, combined with a detailed modelling of strong resonances, allows for the extraction of the primaries source size. The results are discussed in the context of the search of a universal source for all species of primary particles produced in pp collisions.

Beauty to charmonuim decays at LHCb

Authors: Stefania Ricciardi; Peilian Li

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The latest results of beauty meson decays to final states with charmonium resonances from LHCb are presented. This includes measurements of time-dependent CP violation parameters and branching fractions.

Isospin amplitudes in b-baryon decays at LHCb

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Ratios of isospin amplitudes in hadron decays are a useful probe of the interplay between weak and strong interactions, and allow searches for physics beyond the Standard Model. We present results on isospin amplitudes in b-baryon decays using proton-proton collision LHCb data collected at center-of-mass energies of 7, 8 and 13 TeV.

Secondary track (number):
06

Spreading interest in particle physics among high-school students – What matters?

Author: Sarah Maria Zoechling

Co-authors: Martin Hopf; Julia Woithe; Sascha Schmeling

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Spreading interest in physics among high-school students is crucial for course and career choices. When investigating interest in science, previous studies focused on four aspects: interesting contents (e.g. mechanics), contexts (e.g. biological), tasks (e.g. conduct an experiment), and learning environments (e.g. Science Centre). Overall, researchers agree that when trying to arouse interest, context matters the most. However, it is not clear yet how the familiarity of a context affects the arousal and development of interest. Furthermore, previous studies did not include modern physics contents such as particle physics. In the framework of a PhD project at CERN, a new study will examine which contents and contexts arouse interest in physics among high-school students. Different interest types will be identified while considering clustering variables beyond gender. This contribution provides an overview of the current state of research.

Secondary track (number):

Quark and Lepton Flavour Physics

Time-integrated measurements of the CKM angle gamma at LHCb

Authors: Stefania Ricciardi; Sneha Sirirshkumar Malde

1 Science and Technology Facilities Council STFC (GB)
2 University of Oxford (GB)
The tree-level determination of the CKM angle gamma is a standard candle measurement of CP violation in the Standard Model. The latest LHCb results from time-integrated measurements of CP violation using beauty to open charm decays are presented. These include updates to previous Run 1 measurements using the full LHCb Run 1+2 data sample and the latest LHCb gamma combination.

Quark and Lepton Flavour Physics / 356

Time-dependent measurement from beauty to open charm at LHCb

Authors: Stefania Ricciardi¹; Evelina Mihova Gersabeck²

¹ Science and Technology Facilities Council STFC (GB)
² University of Manchester (GB)

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The latest time-dependent CP violation measurements using beauty to open charm decays from LHCb are presented. These decays provide sensitivity to important CKM parameters such as the angles beta and gamma from the unitarity triangle. Measurements include the latest results from new decay channels, analysed for the first time, including data from both LHCb Run 1 and Run 2.

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Secondary track (number):

Quark and Lepton Flavour Physics / 357

Beauty to open charm final states at LHCb

Authors: Stefania Ricciardi¹; Wojciech Krupa²

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The latest studies of beauty-meson decays to open-charm final states from LHCb are presented. Several branching fraction measurements using Run 1 and Run 2 data samples are shown, including first observations. These decay modes will provide important inputs to other analyses and to studies of spectroscopy.

I read the instructions:

Secondary track (number):
Excited charm meson spectroscopy from B decays at LHCb

Authors: Stefania Ricciardi\textsuperscript{1}; Raul Rabadan\textsuperscript{2}

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The latest measurements of excited charm and charm-strange mesons in amplitude analyses of beauty mesons decaying to open charm final states at LHCb are reported. The spectroscopy results include first observations of new excited charm states and precise measurements of their masses, widths and quantum numbers. These results additionally provide tests of the predictions from lattice QCD and HQET.

Measurements of CP violation in charmless 2-body B meson decays at LHCb

Authors: Stefania Ricciardi\textsuperscript{1}; Davide Fazzini\textsuperscript{2}

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Measurements of mixing-induced and direct CP violation in charmless 2-body B decays provide stringent tests of the Standard Model. In addition to new phases that may enter the mixing loop, charmless B decays have an additional opportunity for unknown particles to induce deviations from the Standard Model expectation due to the sizeable contribution to these decays from penguin topologies. We present new results from the analyses of charmless 2-body B decays at LHCb, including CP asymmetries and branching fractions.

Measurements of CP violation in charmless 3-body B meson decays at LHCb

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Measurements of CP violation in charmless 3-body B decays at LHCb provide new stringent tests of the Standard Model. We present new results from the analyses of charmless 3-body B decays at LHCb, including CP asymmetries and branching fractions.
Short and long-distance dynamics along with a sizeable effective weak phase caused by the interference between tree and penguin topologies in charmless 3-body B decays leads to a rich structure of CP violation as a function of the phase space. We present the latest studies with charmless $B \to 3h$ decays at LHCb, including CP asymmetries and branching fractions.

The violation of CP symmetry is now very well established in the meson sector. However, CP violation has yet to be observed in the baryonic sector. Charmless $b$-baryon decays represent a promising opportunity in this respect since their amplitudes receive contributions from a $b \to u$ tree diagram carrying the sizeable phase gamma. We present the most recent measurements of charmless $b$-baryon decays performed by LHCb.

Results on the Drell-Yan differential and inclusive cross section measurements. Forward-Backward asymmetry and Angular Coefficients are also discussed. Both electron and muon channels are covered.
Jet measurements at CMS

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Measurements of jet production in proton-proton collisions at the LHC are crucial for precise tests of QCD, improving the understanding of the proton structure and are important tool for searches for physics beyond the standard model. We present recent measurements of double-differential cross section of jet production at centre-of-mass energy of 13 TeV with 2016 data and compare them to various predictions. We also report studies on the impact of these measurements on the determination of the strong coupling and of parton density functions of the proton.

Search for heavy triboson production in leptonic final states with full Run II data at CMS

Author: Philip Chang

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We present the search for heavy triboson production, specifically targeting the production of WWW, WWZ, WZZ and ZZZ processes in multileptonic final states with 137 fb$^{-1}$ of data collected by the CMS detector during Run II of the LHC at $\sqrt{s} = 13$ TeV. An event selection consisting of identically charged dileptons and trileptons is constructed to primarily study the WWW process, while the WWZ, WZZ and ZZZ processes are explored in four, five and six lepton final states. The analysis utilizes both traditional cut-based and multivariate techniques using boosted decision trees.
The study of the associated production of vector bosons and jets constitutes an excellent testbench to check numerous QCD predictions. Total and differential cross sections of vector bosons produced in association with jets have been studied in pp collisions at 7, 8 and 13 TeV center-of-mass energies. Differential distributions as function of a broad range of kinematical observables are measured and compared with theoretical predictions. Final states with a vector boson and jets can be also used to study electroweak initiated processes, such as the vector boson fusion production of a Z or W boson that are accompanied by a pair of energetic jets with large invariant mass.

Strong Interactions and Hadron Physics / 367

Studies of exotic baryonic states at LHCb

Authors: Stefania Ricciardi¹; Daniel Johnson²

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The discovery of pentaquark candidates in Lb -> J/psi p K decays at LHCb has opened a new field in exotic spectroscopy. Analysis of b-baryon decays in the full dataset collected during Run I and II provides opportunities to study the established states with better precision and to search for new pentaquark candidates. The presentation will summarize recent progress in this area.

Strong Interactions and Hadron Physics / 368

V+heavy flavor jets and constraints to PDFs in CMS

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The associated production of vector bosons V (W, Z or gamma) and jets originating from heavy-flavour (c or b) quarks is a large background source in measurements of other standard model processes, Higgs boson studies, and many searches for physics beyond the SM. The study of events with a vector boson accompanied by heavy-flavour jets is crucial to refine the theoretical calculations.
in perturbative QCD, as well as to validate associated Monte Carlo predictions. Differential cross sections in V+ c/b jets are measured as a function of several kinematic observables with the CMS detector at 8 and 13 TeV. The study of the associated production of a vector boson with jets from a c-quark is especially interesting, as it allows to extract information on the proton parton density functions.

I read the instructions:

Secondary track (number):
04.

Top Quark and Electroweak Physics / 369

W boson measurements with the CMS experiment

Author: Riccardo Salvatico

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Latest results on W boson measurements are presented using collision data collected by CMS. Multi-differential production cross sections, charge asymmetry, polarization measurements will be discussed, and new other results.

I read the instructions:

Secondary track (number):

Strong Interactions and Hadron Physics / 370

Studies of quarkonia and doubly-heavy mesons at LHCb

Author: Zhiyu Xiang

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Both heavy quarkonium and double heavy hadrons, such as Bc mesons, provide rich material for testing effective theories of the strong interaction via production, decay, and spectroscopy studies. This talk presents recent progress in these areas, based on analyses of the full dataset collected during runs I and II of the LHC.

I read the instructions:

Secondary track (number):
05
Track-based muon system alignment of the CMS detector

Author: Hyunyong Kim

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The alignment of the CMS muon detector is critical to maintaining accurate position determination of muon hits, thereby affecting momentum resolution and the sensitivity of physics analyses involving muons in the final state. Muon track data from both the muon system and the inner tracker is used to perform a multidimensional fit on the misalignment degrees of freedom. Several new capabilities have been added to this fitting procedure to solve weak misalignment modes in the muon system that have not been addressed by the algorithm in its previous states. The performance of this track-based alignment algorithm is validated by using muons in Z boson decays and evaluating the alignment’s accuracy in reconstructing the mass peak. Chamber alignment accuracies on the order of 100 μm are achieved and alignment performance is presented using Run 2 data.

I read the instructions:

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 372

The CMS Muon Spectrometer Upgrade

Author: Daniele Fasanella

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The luminosity delivered to the experiments by the High Luminosity Large Hadron Collider (HL-LHC) is expected to be at least five times the original design, exceeding the value of $5 \times 10^{34}$ cm$^{-2}$ s$^{-1}$. The detectors will therefore undergo critical upgrades to sustain the higher particle fluxes and improve the tracking and triggering performance. In the current CMS muon system, different detector technologies have been chosen to optimize the CMS detector with respect to performance. Drift Tubes (DT) and Resistive Plate Chambers (RPC) are installed in the barrel, complemented by the two endcaps hosting cathode strip chambers (CSC) and RPC. The upgrade of the Muon Spectrometer will act on the improvement of the electronics installed on DT and CSC and on the extension of the coverage with the installation of additional muon stations in the endcaps - ME0, GE1/1, GE2/1, RE3/1 and RE4/1. Due to the extended lifetime now expected of the LHC experiments (2008-2040) and the significantly larger integrated luminosity accumulated, additional aging tests are required and taking place for the existing muon detectors. The CSC electronics upgrade is planned to take place during the current Long Shutdown 2 (LS2) and is almost completed. The electronics upgrade of the DT is planned for LS3; currently, a slice test exercise is installed and giving the first results. The production, qualification and installation of GE1/1 detectors has completed in spring 2020, followed by the ongoing commissioning in the CMS experiment. The production of GE2/1 is about to start, while the R&D for ME0 and improved RPC (iRPC) is now in the final phase. The presentation will give an overview of the Muon Spectrometer upgrades, describing the aging studies conducted and the frontend on-chamber electronics developments for the DT and CSC. We will provide an overview on the design of GEM and iRPC detectors, as well as a detailed report on the preliminary results obtained during the production, qualification, installation and commissioning of GE1/1 in CMS.

I read the instructions:

Secondary track (number):
Strong Interactions and Hadron Physics / 373

Studies of b-hadrons at LHCb

Authors: Stefania Ricciardi¹; Slava Matiunin²

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The large dataset collected during Runs I and II of the LHC has opened new possibilities to study singly heavy b-hadron states and broaden knowledge of their spectroscopy and production. Recent results on searches for new excited b-hadron states, and studies of b-hadron production, will be presented.

Astro-particle Physics and Cosmology / 374

Heat Engine for Black Holes in Presence of Cyclic Thermodynamics Behavior

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The study of astrophysics context of massive theory leads to the black hole heat engine may be regarded as a possible energy source of the high energy astrophysical phenomena. Therefore, a black hole engine may be regarded as a possible source of power gamma rays and ultrahigh energy cosmic rays. Propose of this research was study to heat engine provided by black holes in presence of cyclic thermodynamics behavior. The main motivation was to investigate the rate of change of the cyclic process based on massive theory leads to the effect as different of the efficiency of black hole engines in massive gravity. It would be interesting to investigate the efficiency calculated on the horizon with these three different topologies were spherical flat and hyperbolic which then make a comparison. The results in this research will be shown that the highest efficiency for the heat engine belongs to black holes with the hyperbolic horizon, while the lowest one belongs to the spherical black holes.

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 375
ALICE upgrades for LHC Run 4 and beyond

**Author:** Andrea Rossi

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While ALICE is currently undergoing major upgrades which will come online for LHC Run 3 (starting in 2021), further projects are already on their way. ALICE is developing thinned wafer-sized monolithic active pixel sensors to replace the inner tracking layers in the Long Shutdown 3 (starting in 2025). This resulting detector will have an unprecedentedly low material budget, and consequently drastically reduced interaction probabilities and unparalleled vertexing performance. Furthermore, we will present the plans for the installation of a Forward Calorimeter (FoCal) comprising a Si-W electromagnetic calorimeter with pad and pixel readout and a hadronic calorimeter with conventional metal-scintillator technology with optical readout, covering 3.4 < eta < 5.8. Finally, we will present ideas for a thin, light, fast detector fully based on silicon sensors for tracking, time-of-flight and shower measurements. This combines the advantages of extremely low material budget, fast readout and high resolution which will enable novel measurements of electromagnetic and hadronic probes of the QGP at very low momentum.

**Prospects for Proton Decay Searches in JUNO**

**Authors:** Yuhang Guo1; Livia Ludhova2; Wanlei Guo3; Qingming Zhang4

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Proton Decay is one of the apparent consequences of Baryon Number Violation, which has been predicted in many Grand Unified Theories. It would become an explanation to the asymmetry of matter and anti-matter in the universe. Many experiments have been contributing to search for this rare but key sign of new physics. Among them, SuperK has acquired the best result. On the channel p to ν and K+, the lower limit of proton lifetime has been predicted to be 5.9×10^33 years. Jiangmen Underground Neutrino Observatory (JUNO), which is a 20 kton liquid scintillator detector under construction in China, should have high sensitivity based on our recent research. With a high detection efficiency and large sensitive mass, it is expected to reach the order of 10^34 in ten years running time. In this poster, the preliminary study including simulation work and algorithm design will be presented.
Status of the Fast Interaction Trigger for ALICE Upgrade

Author: Maciej Slupecki

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As part of the preparations for the LHC Run 3 and 4, the ALICE experiment at CERN is making a thorough upgrade of the setup. In particular, all ALICE subsystems have to cope with the increased interaction rate of 50 kHz in Pb-Pb and up to 1 MHz in pp collisions. Comparing with Run 2, this is up to two orders of magnitude more collisions. The solution for the majority of ALICE detectors is to switch to a continuous readout, but several of the older systems (TRD, CPV, HMPID, EMCAL, DCAL and PHOS) would still need an external trigger or a wakeup signal.

The Fast Interaction Trigger (FIT) will generate a minimum-bias and a multiplicity trigger with the maximum latency below 425 ns. It will also measure collision time with a resolution of < 40 ps and serve as the main ALICE luminometer, providing direct, real-time feedback to the LHC for the beam tuning. In the offline analysis FIT will aid in the reconstruction of the vertex position, assess forward particle multiplicity, centrality and event plane, and will be used for the study of diffractive physics at forward rapidity.

FIT consists of three sub-systems: a fast Cherenkov detector array using MCP-PMTs as photosensors, a large scintillator ring employing a novel light collection system, and a scintillator-based Forward Diffractive Detector. After a short description of the detector components, functionalities and a brief summary of the physics objectives, the key test results of the assembled detector will be presented and discussed.

I read the instructions:

Secondary track (number):

Beyond the Standard Model / 378

A case study about the mass exclusion limits for the BSM vector resonances with the direct couplings to the third quark generation

Author: Josef Jurán

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The upper bounds that the LHC measurements searching for heavy resonances beyond the Standard model set on the resonance production cross sections are not universal. They depend on various characteristics of the resonance under consideration, and their validity is also limited by the assumptions and approximations applied to their calculations. The bounds are typically used to derive the mass exclusion limits for the new resonances.

We address some of the issues that emerge when deriving the mass exclusion limits for the strongly coupled composite SU(2)L+R vector resonance triplet which would interact directly to the third quark generation only. We investigate the restrictions on the applicability of the generally used limit-obtaining procedure to this particular type of vector resonances.

Secondary track (number):
Beyond the Standard Model - Posters / 379

Loop Amplitudes Induced by Tensor Fermionic Current in Constant Homogeneous Electromagnetic Fields

Author: Alexander Parkhomenko

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The non-diagonal correlator of vector and tensor fermionic currents is considered as the concrete example of the two-point one-loop amplitudes modified by a constant homogeneous magnetic field. The crossed-field limit of this correlator is found. The tensor current is a fermionic part of the Pauli Lagrangian relevant for the electromagnetic interaction of fermions through the anomalous magnetic moment. Under assumption that this interaction enters the effective QED Lagrangian, the contribution to the photon polarization operator linear in AMM is calculated.

Secondary track (number):
03

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 380

Development of a Penetrating particle ANalyzer for high-energy radiation measurements in space

Authors: Xin Wu; Giovanni Ambrosi; Philipp Azzarello; Benedikt Bergmann; Bruna Bertucci; Petr Burian; Frank Raphael Cadoux; Michael Campbell; Matteo Duranti; Yannick Favre; Tomoya Izawa; Maria Ionica; Merlin Reynaard Kole; Milan Malich; Petr Manek; Lukas Meduna; Ysid Mora Sierra; Mercedes Paniccia; Christina Plainaki; Stanislav Pospisil; Jerome Staufer; Pierre Alexandre Thonet; Nicola Tomassetti; Andrii Tykhonov

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The Penetrating particle ANalyzer is an instrument designed to operate in space to precisely measure and monitor the flux, composition, and direction of highly penetrating particles of energy ranging from 100 MeV/n to 20 GeV/n filling the current observational gap in this energy interval. The detector design is based on a modular magnetic spectrometer of small size and reduced power consumption and weight to make the instrument suitable for deep space and interplanetary missions. The high-field permanent magnet sectors are instrumented with high resolution silicon micro-strip detectors, Time-OF-Flight scintillator counters readout by SiPMs, and active Pixel detectors to maintain the detection capabilities in high rate conditions occurring during solar energetic particle events (SEPs) or when traversing radiation belts around planets. We will present the PAN concept together with the ongoing activity on the development of a demonstrator, Mini.PAN, for the in-orbit validation of the key functionalities of the instrument.

I read the instructions:

Secondary track (number):
08

Operation, Performance and Upgrade of Present Detectors / 381

ALICE upgrades for Run 3

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The ALICE detector at the LHC is undergoing major upgrades during the Long Shutdown 2 (2019/20). A new Inner Tracking System (ITS) is being installed and the Time Projection Chamber (TPC) has been equipped with new GEM-based read-out chambers. Together with the new front-end-electronics they will enable us to read out the TPC continuously and record the full minimum-bias interaction rate of 50 kHz in Pb-Pb. The new Monolithic Active Pixel Sensors used for the ITS will significantly improve the impact parameter resolution and tracking efficiency, especially for particles with low transverse momentum, as well as the readout rate capability. In addition, a pixel tracker will be installed in front of the muon spectrometer, and the readout electronics of several other detectors are being replaced with faster technology. These upgrades also require a completely new online computing system that has the dual task of data acquisition and performing the first pass of the reconstruction to compress data and remove noise hits from the data stream. This talk will summarize the motivation and realization of the upgrades and report on the status of the installation and commissioning.

I read the instructions:

Secondary track (number):

Beyond the Standard Model / 382

Search for new phenomena in leptonic final states at CMS

Author: Saranya Samik Ghosh

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Page 162
Many new physics models, e.g., compositeness, extra dimensions, extended Higgs sectors, supersymmetric theories, and dark sector extensions, are expected to manifest themselves in the final states with leptons and photons. This talk presents searches in CMS for new phenomena in the final states that include leptons and photons, focusing on the recent results obtained using the full Run-II data-set collected at the LHC.

I read the instructions:

Secondary track (number):

Beyond the Standard Model / 383

Search for new new phenomena using jets at CMS

Author: Dimitrios Karasavvas

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Many new physics models, e.g., compositeness, extra dimensions, extended Higgs sectors, supersymmetric theories, and dark sector extensions, are expected to manifest themselves in the final states with hadronic jets. This talk presents searches in CMS for new phenomena in the final states that include jets, focusing on the recent results obtained using the full Run-II data-set collected at the LHC.

I read the instructions:

Secondary track (number):

Beyond the Standard Model / 384

Search for heavy neutral leptons at CMS

Author: Martina Vit

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The smallness of neutrino masses, which together with neutrino oscillations could be pointing to physics beyond the standard model, can be naturally accommodated by the so-called "seesaw" mechanism, in which new Heavy Neutral majorana Leptons (HNL) are postulated. A model providing HNLs that incorporates the seesaw mechanism, while also providing a DM candidate and giving a possible explanation for the baryon asymmetry, is the neutrino minimal standard model (vMSM). This talk presents searches for HNLs in CMS using the full Run-II data-set collected at the LHC.

I read the instructions:

Secondary track (number):
In pursuit of authenticity – CMS Open Data in education

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There are some universally acknowledged problems in school sciences. Across the developed countries worldwide, young people are not interested in studying STEM-subjects. Whether that is because of perceived lack of personal relevance, disconnect from the actual fields of study, “sanitized” school practices or other factors is up to debate, but it is eminently clear that as educators we have to do our best in combating this trend.

In this speech we present the CMS Open Data project and feedback from Finnish teachers who have received training in using these freely available programming resources to bring modern physics research into their teaching. There is an added benefit of learning general scientific methods and cross-disciplinary data handling skills as well, but the main focus here is on the teachers’ perception of authenticity in the use of “real world” research data.

I read the instructions:

Secondary track (number):

Dark Matter Detection / 386

Search for dark matter at CMS

Author: Raman Khurana

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Searches in CMS for dark matter particles, mediators, and dark sector extensions will be presented. Various final states, topologies, and kinematic variables are explored utilizing the full Run-II data-set collected at the LHC.

I read the instructions:

Secondary track (number):
03.

Beyond the Standard Model / 387

Search for leptoquarks at CMS

Author: Ben Kilminster
Leptoquarks are hypothetical color-triplet bosons, which carry both baryon and lepton quantum numbers and have fractional electric charge. They are predicted by many extensions of the standard model, such as theories invoking grand unification, technicolor, or compositeness. Third-generation scalar LQs have recently received considerable theoretical interest, as their existence can explain the anomaly in the $B \to D\tau\nu$ and $B \to D^*\tau\nu$ decay rates reported by the BaBar, Belle, and LHCb Collaborations. This talk presents latest results from searches for leptoquarks in CMS using the full Run-II data-set collected at the LHC.
Neutrino Oscillations Results from the T2K Experiment

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The T2K experiment probes the masses and mixing of neutrinos through measurements of neutrino oscillations. A beam of muon neutrinos or muon antineutrinos is generated at the J-PARC proton accelerator on the east coast of Japan, and the beam’s composition is measured 295 km away in the Super-Kamiokande detector. The transition of muon neutrinos and antineutrinos to other flavors and the appearance of electron neutrinos and antineutrinos are governed by neutrino mixing and mass parameters, including the phase $\delta_{CP}$, which determines the amount of CP violation in neutrino mixing. Previous measurements from T2K have shown a strong constraint on $\delta_{CP}$ with the exclusion of a significant fraction of $\delta_{CP}$ values at 3$\sigma$ confidence. Here, we present the latest results from T2K with data collected through 2020 and the prospects for more sensitive measurements by T2K in the future.

Recent Cross-section Results from the T2K Experiment

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One of the largest systematic uncertainties affecting neutrino oscillation measurement comes from present limited knowledge of (anti-)neutrino-nucleus interactions. Neutrino scattering understanding is crucial for the interpretation of neutrino oscillation since it affects background estimation and neutrino energy reconstruction. Thus, precise (anti-)neutrino-nucleus cross section measurements are vital for the present and future long-baseline neutrino oscillation experiments. The T2K long-baseline neutrino oscillation experiment, in addition to its contributions to neutrino oscillation measurement, has a wide program of neutrino interaction cross-section measurements using its near detector complex. With multiple targets (carbon, water, argon, iron), and with on- and off-axis detectors which sample different neutrino spectra from the same beamline, T2K is able to investigate atomic number and energy dependent behavior in a single experiment. In this talk an overview of the T2K neutrino cross sections, focusing on the latest results is presented.

The T2K ND280 Upgrade
In view of the J-PARC program of upgrades of the beam intensity, the T2K collaboration is preparing towards an increase of the exposure aimed at establishing leptonic CP violation at $3\sigma$ level for a significant fraction of the possible $\delta_{CP}$ values. To reach this goal, an upgrade of the T2K near detector ND280 will be installed at J-PARC in 2021, with the aim of reducing the overall statistical and systematic uncertainties at the appropriate level of better than 4%. We have developed an innovative concept for this neutrino detection system, comprising the totally active Super-Fine-Grained-Detector (SuperFGD), two High Angle TPC (HA-TPC) and six TOF planes.

The SuperFGD, a highly segmented scintillator detector, acting as a fully active target for the neutrino interactions, is a novel device with dimensions of $\sim2\times1.8\times0.6$ m$^3$ and a total mass of about 2 tons. It consists of about 2 millions of small scintillator cubes each of 1 cm$^3$. Each cube is covered by a chemical reflector. The signal readout from each cube is provided by wavelength shifting fibers inserted connected to micro-pixel avalanche photodiodes MPPCs. The total number of channels will be $\sim60\,000$. We have demonstrated that this detector, providing three 2D projections, has excellent PID, timing and tracking performance, including a $4\pi$ angular acceptance, especially important for short proton and pion tracks.

The HA-TPC will be used for 3D track reconstruction, momentum measurement and particle identification. These TPC, with overall dimensions of $2\times2\times0.8$ m$^3$, will be equipped with 32 resistive Micromegas. The thin field cage (3 cm thickness, 4% rad. length) will be realized with laminated panels of Aramid and honeycomb covered with a kapton foil with copper strips. The 34x42 cm$^2$ resistive bulk Micromegas will use a 500 kOhm/square DLC foil to spread the charge over the pad plane, each pad being appr. 1 cm$^2$. The front-end cards, based on the AFTER chip, will be mounted on the back of the Micromegas and parallel to its plane.

The time-of-flight (TOF) detector will allow to reject events generated in the passive areas of the detector and improve particle identification. The TOF will consist of 6 planes with about 5 m$^2$ surface area surrounding the SuperFGD and the TPCs. Each plane will be assembled with 2.2 m long cast plastic scintillator bars with light collected by arrays of large-area MPPCs from two ends. The time resolution at the bar centre is 150 ps.

In this talk we will report on the design of these detectors, their performance, the results of the test beam and the plan for the construction.
Development of high resolution low power silicon pixel sensors for the CEPC vertex detector

Author: Qun Ouyang

Co-authors: Yang Zhou; Ying Zhang; Ping Yang; Yunpeng Lu

1 Institute of High Energy Physics, Chinese Academy of Sciences
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The Circular Electron Positron Collider (CEPC) has been proposed as a Higgs/Z0 (flavor) factory, which would allow precision measurements of the Higgs boson properties, as well as of W±/Z0 bosons. The baseline design of CEPC vertex system consists of three concentric double-sided pixel layers, to reach the unprecedented impact parameter resolution. Driven by physics studies and experimental conditions, the silicon pixel sensor of vertex system has similar performance requirements to that of ILC detectors, such as a single point resolution of around 3μm, very low material budget of 0.15%X0 per single layer and power consumption of below 50mW/cm2, but without power-pulsing, which leads to significantly additional constrains on detector specifications, especially for the case of machine operating at Z-pole energy region with high luminosity. In this presentation, I will give an overview of the conceptual design, the requirements and challenges for the CEPC vertex system. The on-going R&D activities will be mainly reported, based on monolithic CMOS pixel sensor (CPS) and Silicon on Insulator (SOI) pixel sensor technologies, for the purpose of development of high resolution and low power consumption pixel sensors. To reach the target, several CMOS and SOI pixel prototypes with small pitch (~20μm) and digital readout are explored. Recent R&D achievements will be presented, and the prospects of future R&D with novel stitching and 3D sensor technologies will also be shown.

CP violation and mixing in charm hadrons at LHCb

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In 2019 the LHCb experiment published the first observation of CP violation in charmed particles, using decay channels D0→π+π- and D0→K+K-. Further measurements in different decay modes are essential in order to understand whether this effect can be explained by the Standard Model, or if new sources of CPV are needed. Here we present the latest searches for direct CP violation in several decay channels of charm hadrons, and discuss prospects for future measurements in LHC Run 3 and beyond.
With the recent discovery of time-independent CP violation in charm meson decays, the search for mixing-induced CP violation in the charm system becomes even more interesting. Here we report the latest LHCb measurements of charm mixing parameters and searches for time-dependent CPV using data collected in LHC Runs 1-2, and corresponding to the largest sample of charm mesons ever analysed. Measurements from several decay modes are presented, as well as prospects for future sensitivities.

Rare charm decays at LHCb

Authors: Stefania Ricciardi\(^1\); Chris Burr\(^2\)

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LHCb is playing a crucial role in the study of rare and forbidden decays of charm hadrons, which might reveal effects beyond the Standard Model. We present the latest searches for, and measurements using, rare charm decay processes with two leptons in the final state.

Charmed hadron properties and spectroscopy at LHCb

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In 2017 LHCb made the first observation of the doubly-charged, doubly-charmed baryon Xicc++. This has prompted significant experimental and theoretical work to predict and measure the properties of the new baryon, and search for other doubly-charmed baryons Xicc+ and Omegacc+. Here we present several searches for, and studies of, these new states. We also present several measurements using singly-charmed baryons, including searches for excited states and for CP violation.
Search for heavy neutral lepton production at the NA62 experiment

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Searches for heavy neutral lepton production in K+ -> e+N and K+ -> mu+N decays using the data set collected by the NA62 experiment at CERN in 2016-18 are presented. Upper limits on the elements of the extended neutrino mixing matrix $|U_{e4}|^2$ and $|U_{\mu 4}|^2$ are established at the levels of $10^{-9}$ and $10^{-8}$, respectively, improving on the earlier searches for heavy neutral lepton production and decays in the kinematically accessible mass range.

Searches for lepton flavour and lepton number violation in K+ decays

Author: Joel Chistopher Swallow

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The NA62 experiment at CERN collected a large sample of charged kaon decays into final states with multiple charged particles in 2016-2018. This sample provides sensitivities to rare decays with branching ratios as low as $10^{-11}$. Searches for lepton flavour and lepton number violating decays of the charged kaon into final states containing a lepton pair based on this data set are presented.

New result on the search for the $K^+ \rightarrow \pi^+ \nu\bar{\nu}$ decay at the NA62 experiment at CERN

Author: Radoslav Marchevski

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The ultra-rare $K^+ \rightarrow \pi^+ \nu\bar{\nu}$ decay benefits from a precisely predicted branching ratio in the SM $(8.4 \pm 1.0) \times 10^{-11}$, being almost free from theoretical uncertainties, and most importantly from a very high sensitivity to a variety of beyond-the-standard-model scenarios, making it one of the best
candidates to reveal indirect effects of new physics in the flavour sector.
The NA62 experiment at the CERN SPS, designed to measure the branching ratio of $K^+ \rightarrow \pi^+\text{nu}\text{nu}$ with a decay-in-flight technique, collected data in 2016-2018. New results from the analysis of 2018 data, the largest data set so far collected, will be presented. The result will represent the most accurate measurement so far achieved of this ultra-rare decay. Future prospects and plans for data taking from 2021 will also be presented.

I read the instructions:

Secondary track (number):
03

Heavy Ions / 402

**Beauty production and anisotropy with ALICE at the LHC**

**Author:** Xinye Peng

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In hadronic collisions, beauty quarks are produced in hard scattering processes with large momentum transfer. Their production provides a very important test of perturbative QCD calculations in pp collisions. Measurements in p-Pb collisions are crucial to investigate the effects of cold nuclear matter on their production. In heavy-ion collisions, the measurement of beauty hadron production is a unique tool to investigate the properties of the quark-gluon plasma. In particular, beauty quarks, being four times heavier than charm quarks, can be utilised to study the in-medium mass dependent energy loss. Interaction with the medium pushes the heavy quarks towards thermalization, causing them to move along with the flow of the surrounding medium constituents. Measurement of the production anisotropy of particles coming from beauty-hadron decays can help quantify the effect of the interaction without the need of a reference measurement.

With the ALICE detector, beauty quarks are studied by measuring electrons and non-prompt D mesons coming from beauty hadron decays at mid-rapidity. A more direct access to the initial parton kinematics is obtained by measuring beauty-tagged jets. They can provide further constraints for energy loss models adding information on how the radiated energy is dissipated.

In this contribution, the latest measurements of beauty production using beauty-decay electrons, non-prompt D mesons and beauty-tagged jets in pp collisions at $\sqrt{s} = 5.02$ TeV, and their comparison to pQCD calculations will be presented. New measurements of beauty-tagged jet production down to low $p_T$ in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV will be discussed. The latest results on the centrality dependence of $R_{AA}$ and elliptic flow of beauty-decay electrons and non-prompt D mesons in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV compared to different theoretical models will be presented.

I read the instructions:

Secondary track (number):

Strong Interactions and Hadron Physics - Posters / 403

**Inclusive $\Upsilon(1S) \rightarrow \eta(l) + X$ Decays with Account of $\alpha_s$ Running in Effective $\eta(l)g^*g$-Vertex**
The $\eta'$-meson energy spectrum in the inclusive $\Upsilon(1S) \to \eta'ggg \to \eta'X$ decay measured by the CLEO Collaboration in 2002 allowed one to constrain the lowest Gegenbauer coefficients $B_{q2}$ and $B_{g2}$ of the quark-antiquark and gluonic distribution amplitudes of the $\eta'$-meson entering the $\eta'g^*g$ effective vertex function (EVF). The fitting procedure of the CLEO data on the hard part of the $\eta'$-meson energy spectrum was based on the theoretical expression calculated in the leading-order perturbative QCD in the static-quark limit for the orthoquarkonium. The resulting constraints were combined with the existing ones on these coefficients from an analysis of the $\eta' - \gamma$ transition form factor. The updated measurements of the $\eta'$-meson energy spectrum by the CLEO Collaboration in 2006 results a worser consistency with theoretical expectations and require some improvements from a theory. As a first step, we assume the dependence of the strong coupling constant in the $\eta'g^*g$ EVF on the quark energy the $\eta'$-meson and repeat the fitting procedure within the improved approach. The corresponding results for the Gegenbauer coefficients are presented. With this values we plot the QCD-based $\eta$-meson energy spectrum in the inclusive $\Upsilon(1S) \to \eta ggg \to \eta + X$ decay in the leading-order perturbative QCD in the static-quark limit for the orthoquarkonium. Both the $\eta$- and $\eta'$-meson energy spectra in the decays considered can be checked by the Belle Collaboration based on the existing and forthcoming data on $\Upsilon(1S)$-meson.

Dielectrons and dimuons are a powerful probe of the quark-gluon plasma (QGP) created in ultrarelativistic heavy-ion collisions, since they do not interact strongly and are emitted during all stages of the collisions. At low invariant mass, the dilepton spectrum is sensitive to in-medium modification of the $\rho$ meson spectral function and to effects related to the chiral symmetry restoration. In the intermediate-mass region the dominant contribution is given by correlated pairs from semileptonic decays of charm and beauty hadrons. Thermal radiation from the QGP contributes as well to the dilepton yield over a broad mass range and gives insight into the temperature of the medium. At very low pair transverse momenta, dielectrons are produced by mainly coherent photon-photon interactions as well. Measurements in pp and p-Pb collisions are the necessary reference for heavy-ion studies. Moreover, they can be used to extract charm and beauty cross sections. In this talk, we will present the latest measurements of $e^+e^-$ and $\mu^+\mu^-$ pair production in pp, p-Pb and Pb-Pb collisions performed by ALICE at different energies. In particular, results from the 2018 Pb-Pb run and multiplicity dependent studies in pp collisions, including a soft dielectron excess over known hadronic sources, will be shown. The expected performance of dilepton measurements with the upgraded ALICE detector in LHC Run 3 and 4 will also be discussed.
Measurement of charmonium production in Pb-Pb and p-Pb collisions at the LHC with ALICE

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Among the many possible probes to study the quark-gluon plasma (QGP), a high energy-density medium formed in relativistic heavy-ion collisions, heavy quarks are particularly interesting as they are expected to be produced in the initial stages of the collisions, by hard partonic scatterings, and to experience the full evolution of the medium. In particular, charmonia (bound c\bar{c} states) have been measured in nucleus-nucleus collisions with high precision at the LHC leading to the observation of new signatures of deconfinement such as the recombination of c\bar{c} pairs into charmonium states. In this contribution, the latest ALICE results on the J/\psi nuclear modification factor (R_{AA}) in Pb-Pb collisions at \sqrt{s_{NN}} = 5.02 TeV will be presented as a function of centrality, \pT and rapidity. This will be complemented by a discussion of the recent results on the elliptic and triangular flow coefficients of inclusive J/\psi which can be inherited from flowing charm quarks. In addition, results on J/\psi and \psi(2S) measurements in p-Pb collisions at \sqrt{s_{NN}} = 5.02 and 8.16 TeV will be presented as a tool to study cold nuclear matter effects which may alter the quarkonium production in heavy-ion collisions regardless of the QGP formation. All the shown results will be compared to various theoretical calculations.

Flavor Phenomenology with Scalar Leptoquarks

Authors: Oleyr Sumensari 1; S Fajfer 2; Nejc Košnik 3; Federico Mescia 4; Aleks Smolković 5; Damir Becirevic 6; Florentin Jaffredo 7

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An attractive solution to the problem of B-anomalies is to combine two O(1 TeV) scalar leptoquarks in a coherent renormalizable scenario. We show that the combination of S3 and R2 leptoquarks provide such a framework that satisfies all of the low energy and high energy experimental constraints. Similarly, one can combine S1 and S3 leptoquarks but with more Yukawa couplings. The advantage
of the later scenario, however, is that one can include right handed couplings to S1 leptoquark and fully accommodate the experimental value for the muon’s $g-2$.

I read the instructions:

Secondary track (number):
03

Dark Matter Detection / 407

**Axion search with BabyIAX0 in view of IAXO**

**Author:** IAXO Collaboration

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Axions are a natural consequence of the Peccei-Quinn mechanism, the most compelling solution to the strong-CP problem. Similar axion-like particles (ALPs) also appear in a number of possible extensions of the Standard Model, notably in string theories. Both axions and ALPs are very well motivated candidates for Dark Matter, and in addition, they would be copiously produced at the sun’s core. A relevant effort during the last decade has been the CAST experiment at CERN, the most sensitive axion helioscope to-date. The International Axion Observatory (IAXO) is a large-scale 4th generation helioscope. As its primary physics goal, IAXO will look for solar axions or ALPs with a signal to background ratio of about 5 orders of magnitude higher than CAST.

Recently the IAXO collaboration has proposed and intermediate experimental stage, BabyIAXO, conceived to test all IAXO subsystems (magnet, optics, detectors and sun-tracking systems) at a relevant scale for the final system and thus serve as pathfinder for IAXO but at the same time as a fully-fledged helioscope with record and relevant physics reach in itself with potential for discovery. BabyIAXO was endorsed by the Physics Review committee of DESY last May 2019. Here we will review the status and prospects of BabyIAXO and its potential to probe the most physics motivated regions of the axion & ALPs parameter space.

I read the instructions:

Secondary track (number):
08

Astro-particle Physics and Cosmology / 408

**The GAPS Experiment: Probing Unique Dark Matter Parameter Space With Low Energy Cosmic Ray Antinuclei**

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Despite numerous recent efforts at colliders and multi-ton scale experiments, there has not been an unambiguous detection of particle dark matter. While progress has been made excluding large regions of parameter space, there remain many viable candidates, some of which can evade collider and direct detection sensitivities. Sub-GeV (50-250 MeV/n) cosmic ray antideuterons (D) are a
compelling, mostly unmapped window into such models, and benefit from extremely low astrophysical background contamination. The General AntiParticle Spectrometer (GAPS) is a first generation Antarctic balloon-borne experiment tailored to $\overline{\text{D}}$ detection. GAPS is also sensitive to antihelium and will detect many antiprotons at low kinetic energies (70-200 MeV).

Unlike traditional spectrometers, GAPS does not utilize a magnet, but instead relies on exotic atom formation and decay, permitting the use of more active target material for a larger overall acceptance. The design is based on a tandem Si(Li) tracker and large area ($\sim 53 \, \text{m}^2$) scintillator based time of flight system.

In this contribution, I will outline the dark matter models GAPS can probe and review the cosmic ray indirect detection approach. Following this, I’ll describe the exotic atom technique and detail the detector design. I will conclude with construction progress leading up to the Antarctic launch in late 2021, along with current detector performance.

Secondary track (number):

Neutrino Physics / 409

Non-Standard Interactions in Radiative Neutrino Mass Models

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Models of radiative Majorana neutrino masses require new scalars and/or fermions to induce lepton number violating interactions. We show that these new particles also generate observable neutrino nonstandard interactions (NSI) with the matter. We classify radiative models as type-I or II, with type-I models containing at least one Standard Model (SM) particle inside the loop diagram generating neutrino mass, and type-II models having no SM particle inside the loop. While type-II radiative models do not generate NSI at tree-level, popular models which fall under the type-I category are shown, somewhat surprisingly, to generate observable NSI at tree-level, while being consistent with direct and indirect constraints from colliders, electroweak precision data and charged lepton flavor violation (cLFV). We survey such models where neutrino masses arise at one, two and three loops. The most stringent constraints on the diagonal NSI are found to come from neutrino oscillation and scattering experiments, while the off-diagonal NSI are mostly constrained by low-energy processes, such as atomic parity violation and cLFV. These results will be presented.

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 410

Production of Large Area Picosecond Photo-Detectors – LAPPDTM: Status Update

Author: Michael Foley$^1$

Co-authors: Melvin Aviles$^2$; Satya Butler$^1$; Till Cremer$^1$; Camden Ertley$^1$; Cole Hamel$^1$; Alexey Lyashenko$^4$; Michael Minot$^4$; Mark Popecki$^1$; Travis Rivera$^1$; Michael Stochaj$^1$; Evan Angelico$^5$; Andrey Elagin$^5$; Henry Frisch$^6$; Eric Spieglan$^5$; Bernhard Adams$^7$
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Abstract:
Incom Inc is now producing a “baseline” version of the Large Area Picosecond Photo-Detector (LAPPD) – the largest commercially-available planar-geometry photodetector based on microchannel plates (ALD-GCA-MCPs). It features a stacked chevron pair of “next generation” large area 20um pore MCPs produced by applying resistive and emissive Atomic Layer Deposition (ALD) coatings to glass capillary array (GCA) substrates encapsulated in a borosilicate glass hermetic package. The entry window of the detector is coated with a high sensitivity semitransparent bi-alkali photocathode with 350 cm² detection area. Signals are read out on microstrip anodes applied to the bottom plate. The “baseline” devices have demonstrated electron gains of 10⁷, low dark noise rates (15-30 Hz/cm²), single photoelectron (PE) timing resolution of 52 picoseconds RMS (electronics-limited), and single photoelectron spatial resolution along and across strips of 2.4 mm and 0.76 mm RMS respectively (also electronics-limited), high (up to 28%) QE uniform bi-alkali photocathodes and low sensitivity to magnetic fields up to 0.8 T (no tests at higher field have been performed at this time). A version with a Fused Silica window featuring an extended UV sensitivity photocathode is also being developed. Production of baseline tiles have increased from one/month in 2018, to four/month in 2020. Apart from the “baseline” LAPPDs, Incom Inc. is developing a Gen II LAPPD product line featuring a capacitively-coupled readout with a resistive anode. Several GEN II LAPPD have been produced. Their performance is now being evaluated.

An effort has been initiated on the development of a smaller format 10 cm X 10 cm High Rate Picosecond Photo-Detector (HRPPD) that, in addition to all of the LAPPD attractive features, would have a fully active area with no x-spacers (structural supports), even lower sensitivity to magnetic fields with new 10um pore MCPs and sub-mm position resolution with a new anode design. LAPPDs can be employed in particle collider experiments (e.g. SolID, future EIC), neutrinoless double-beta decay experiments (e.g. THEIA), neutrino experiments (e.g. ANNIE, WATCHMAN, DUNE), medical (PET) and nuclear non-proliferation applications.

We report on the recent progress in the production of the “baseline” LAPPD and discuss new developments.

Secondary track (number):

Heavy Ions / 411

Open heavy-flavour production from small to large collision systems with ALICE at the LHC

Author: Lucas Anne Vermunt

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Open heavy flavours are effective probes of the hot and dense matter, the quark-gluon plasma (QGP), produced in ultra-relativistic heavy-ion collisions. Due to the very short time scale characterising their production, they experience the whole evolution of the system. In particular, measurements of open heavy-flavour production in Pb-Pb collisions at the LHC energies, including nuclear modification factors, give insight on the mechanisms of heavy-quark transport and energy loss in the hot and dense QCD matter.

The measurements of elliptic flow ($v_2$) of open heavy-flavour particles provide information about the thermal degrees of freedom of heavy quarks in the QGP, path-length dependence of heavy-quark in-medium energy loss and recombination effects during the hadronization. To study the higher flow harmonics, such as the triangular flow ($v_3$), provides further constraints on fluctuations in the initial state of the system and on the ratio of the shear viscosity to the entropy density of the QGP, $\eta/s$. The directed flow ($v_1$) of open heavy-flavour particles is sensitive to the unprecedentedly strong magnetic fields present in the early stages of the collision, and so measurements of its charge dependence are key to constraining the electrical conductivity of the QGP.

In small hadronic systems like pp and p-Pb, open heavy-flavour production provides the baseline for the investigation of hot-medium effects in heavy-ion collisions, as well as tests of perturbative QCD and measurements of cold-matter effects in the nuclear medium.

In this contribution, ALICE results on open heavy-flavour production in pp, p-Pb and Pb-Pb collisions at various energies will be discussed. New measurements will be presented for fully reconstructed charmed mesons, as well as for single electrons and muons from open heavy-flavour hadron decays.
processes. Finally, the status and prospects for $\Xi_c$ and $\Sigma_c$ measurements, as well as the planned measurements of $\Lambda_b$ during LHC Run 3 data taking will be discussed.

I read the instructions:

Secondary track (number):

**Strong Interactions and Hadron Physics / 413**

**Heavy-flavour correlations, jets and multiplicity dependent studies on heavy-flavour hadrons in small systems with ALICE**

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In this contribution, the latest heavy-flavour results on the pp and p–Pb data samples collected during the LHC Run 2 with ALICE at several center-of-mass energies will be presented.

A comprehensive study of the multiplicity dependent open heavy-flavour hadron production and quarkonium self-normalised yields in pp collisions at $\sqrt{s} = 13$ TeV will be shown. Such measurements constitute a valuable tool to characterize Multi-Parton Interactions (MPI), as well as the interplay between hard and soft particle production mechanisms. In particular, these studies include $\psi(2S)$ production at forward rapidity, while multiplicity dependent measurements at mid-rapidity will be discussed for D mesons, heavy-flavour decay electrons and inclusive $J/\psi$.

Moreover, the multiplicity dependent self-normalised yields of heavy-flavour decay electrons at mid-rapidity, as well as $v_2$ measurements in high-multiplicity events for heavy-flavour decay muons at forward rapidity, will be discussed. Such studies aim to investigate possible collective effects in p–Pb collisions. In addition, measurements of heavy-flavor jet production and fragmentation and heavy-flavour correlations will be presented. These studies give direct access to the initial parton kinematics and allow us to characterize the heavy-quark fragmentation process, as well as to gain information on heavy-quark production mechanisms in pp collisions. Heavy-flavour jets studies are extended to heavy-flavour hadron decay electrons and D-meson tagged charged jets measurements in pp and p–Pb collisions at $\sqrt{s} = 5.02$ and $13$ TeV and $\sqrt{s_{NN}} = 5.02$ TeV, respectively. The results of the jet-momentum fraction carried by the D meson at $\sqrt{s} = 5.02$ and $13$ TeV and by the $\Lambda_c$ baryon at $\sqrt{s} = 13$ TeV will be discussed as well. The angular correlations of D-mesons and charged particles in pp and p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV will be shown and comparison with model calculations will be discussed.

I read the instructions:

Secondary track (number):

**Heavy Ions - Posters / 414**

**Production of D$^\pm$ mesons in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV at the STAR experiment**

*Author:* Jan Vaněk

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Charm quarks are an excellent probe of the quark-gluon plasma created in heavy-ion collisions as they are produced at very early stages of such collisions and subsequently experience the whole evolution of the system. At the STAR experiment, charm quark production can be measured by direct topological reconstruction of open-charm hadrons thanks to the exceptional spatial resolution of the Heavy-Flavor Tracker detector.

In this poster, we will present a measurement of $D^\pm$ meson production in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV by the STAR experiment using data collected in 2014 and 2016. Supervised machine-learning techniques were used to maximize signal significance in raw yield extraction from the three body hadronic decay channel $D^\pm \rightarrow K^{\mp}\pi^\pm\pi^\pm$. The $D^\pm$ invariant spectrum was then obtained in 0-10%, 10-40%, and 40-80% central Au+Au collisions. The measured nuclear modification factor $R_{AA}(p_T)$ reveals a significant suppression of high-$p_T$ $D^\pm$ mesons in central (0-10%) and mid-central (10-40%) Au+Au collisions with respect to p+p collisions. The $(D^+ + D^-)/(D^0 + \bar{D}^0)$ yield ratio has also been extracted and compared to that from PYTHIA calculations.

Secondary track (number):
The High Luminosity upgrade of Large Hadron Collider (HL-LHC) will increase LHC Luminosity by an order of magnitude increasing the density of particles on the detector by an order of magnitude. For protecting the inner detectors of experiments and for monitoring the delivered luminosity, a radiation hard beam monitor is being developed. We are developing a set of detectors based on polycrystalline Chemical Vapor Deposition (pCVD) diamonds and a dedicated ASIC. Due to the large range of particle flux through the detector, flexibility is very important. To satisfy the constraints imposed by the HL-LHC, our solution is based on segmenting each single diamond sensor into multiple devices of varying size and reading them out with a new multichannel readout chip. In this talk we describe the proposed system, present preliminary results from the first detectors fabricated using our prototype ASIC and present the noise distribution and efficiency for single MIPs.

The planned upgrade of the ALICE Inner Tracking System (ITS) aims at improving the capabilities of ALICE in terms of read-out rate as well as track pointing resolution and track finding efficiency, especially for particles with low transverse momenta. The new ITS will be a low material budget detector with high granularity and read-out speed. It comprises seven concentric layers of Monolithic Active Pixel Sensors (MAPS) with a total active surface of about 10 m$^2$. The developed MAPS are based on the TowerJazz 180 nm CMOS technology. The sensor is called ALPIDE. A single sensor with dimensions 15 mm $\times$ 30 mm contains half a million pixels distributed in 512 rows and 1024 columns. The detection efficiency of the sensors is higher than 99%, fake-hit rate is orders of magnitude lower than the required $10^{-6}$/pixel/ event, and spatial resolution is within the required 5 $\mu$m. These sensors maintain this performance while being radiation hard to some $10^{13}$ 1 MeV n$_{eq}$ cm$^{-2}$ (NIEL), which ten times exceeds the expected radiation load during the detector lifetime. A series of beam tests were performed to verify this and to prove that the design requirements are completely fulfilled.

In the poster, we will present the setup used for measurements with inclined tracks and we will discuss the sensor efficiency obtained using $\pi$ beams with a momentum of 6 GeV/c at the Proton Synchrotron (PS) at CERN. Some sensors were irradiated before the beam.
test using the cyclotron facility of the Nuclear Physics Institute of the Czech Academy of Sciences (NPI CAS) to induce radiation damage to the sensor. Measurements at different operating points (thresholds, bias voltages) provide important information about cluster-shape frequencies, needed to tune the ALICE Monte-Carlo generators. Very good agreement between test-beam data and simulations is obtained.

Secondary track (number):

Neutrino Physics / 418

Deep Learning Event Reconstruction at DUNE

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DUNE is a next-generation neutrino experiment designed to make precision measurements of neutrino oscillation parameters, discover potential neutrino CP violation, observe neutrinos produced in supernovas, and search for physics beyond the standard model. DUNE uses liquid argon time projection chamber (LArTPC) technology in its 40-kt far detector. LArTPC offers an excellent spatial resolution, high neutrino detection efficiency, and superb background rejection. Reconstruction of neutrino events in DUNE’s high-resolution detectors is complicated by missing energy due to argon impurities, nonlinear detector energy response, invisible energy, complicated final states, and overlapping particles. To address these issues, neutrino events can be reconstructed directly from images of the interactions in DUNE’s detectors with deep learning methods, such as Convolutional Neural Networks (CNNs). In this talk, we will focus on the development of deep-learning-based reconstruction at DUNE.

I read the instructions:

Secondary track (number):

Neutrino Physics / 419

Latest Oscillation Results Combining Neutrino and Antineutrino Data from the NOvA Experiment

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The NOvA experiment is a long-baseline neutrino oscillation experiment that uses the NuMI beam from Fermilab to detect both electron and muon flavored neutrinos in a Near Detector, located at Fermilab, and a Far Detector, located at Ash River, Minnesota. NOvA’s primary physics goals include precision measurements of neutrino oscillation parameters, such as $\theta_{23}$ and the atmospheric mass-squared splitting, along with probes of the mass hierarchy and the CP violating phase. This talk will present the latest NOvA results using a combined neutrino and anti-neutrino dataset based on a beam exposure of approximately $13 \times 10^{20}$ protons-on-target in each dataset.

Secondary track (number):
Overview of Upsilon production studies performed with the STAR experiment

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The $\Upsilon$ states are a clean probe of the properties of quark-gluon plasma, which can be created in heavy-ion collisions. Each of the $\Upsilon$ states dissociates at a different temperature in the plasma due to Debye-like screening of color charges. In order to understand the Cold Nuclear Matter effects, the $\Upsilon$ production has to be studied in small colliding systems such as p+Au and d+Au collisions. Measurements of $\Upsilon$ production cross section in p+p collisions allow to study the production mechanism while the dependence on charged particle multiplicity provides information on the interplay of hard vs. soft QCD processes.

In this talk, we will present an overview of the measurements on the production of $\Upsilon$ states done by the STAR experiment. The rapidity spectra in p+p collisions at $\sqrt{s} = 200$ GeV and $\sqrt{s} = 500$ GeV, and $p_T$ spectra of different states at $\sqrt{s} = 500$ GeV will be presented. Nuclear modification factors measured in p+Au, d+Au, Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV will also be shown.

Energy and vertex reconstruction in JUNO

Author: GuiHong Huang

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JUNO is a next generation multi-purpose neutrino oscillation experiment. Its main physics goal is to determine the neutrino mass ordering by studying the energy spectrum of medium-baseline reactor neutrinos. The energy resolution of JUNO needs to achieve 3%/\sqrt{E}, which is challenging for the energy and vertex reconstruction. This poster will introduce the maximum likelihood estimation reconstruction method utilizing charge, time and photoelectron number (nPE) information of the photomultiplier tubes of the central detector of JUNO and present the reconstruction performances in simulation.

RAADsat: a cubesat mission for the detection of Terrestrial Gamma-ray Flashes

Authors: Adriano Di Giovanni; Francesco Arneodo

Corresponding Authors: adriano.digiovanni@nyu.edu, francesco.arneodo@nyu.edu
RAADsat (Rapid Acquisition Atmospheric Detector) is a three unit Cubesat mission that will be launched in the first quarter of 2021 and deployed from the International Space Station. The mission will target Terrestrial Gamma Ray Flashes (TGF), sudden bursts of gamma-ray radiation occurring on sub-millisecond timescales, and triggered by lightning or thunderstorms. RAADsat is sensitive to the energy range 20 keV – 3000 keV and consists of two arrays, one equipped with four Low Background Cerium Bromide (CeBr3(LB)) crystals and four Hamamatsu S13361-6050AE-04 MPPCs, the other with two CeBr3(LB) and two Lanthanum Bromo Chloride (LBC) crystals four Hamamatsu R11265-200 PMTs. The mission will be also used as proof of concept and to space-qualify the proposed technology opening for the deployment of a constellation of Cubesats to improve the collection efficiency, the sensitivity and to localize the origin of TGF events. The immediate scientific goals are to explore the average atmospheric cut-off at low energies, search for the 511 keV electron-positron annihilation line and search for microsecond structure in the brightest TGF.

**Secondary track (number):**

**Neutrino Physics / 423**

**Reactor neutrino anomalies and possible solutions**

Author: Yufeng Li

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Recent reactor neutrino experiments have shown anomalous results in both the reactor flux and spectrum measurements. Compared the measurements, Reactor neutrino flux shows a 6% deficit while reactor neutrino spectrum illustrates a bump-like structure at around 5 MeV region. In this talk we will employ the methods of both theoretical model prediction and global neutrino data analysis to explore all the possible solutions to these reactor anomalies. We will discuss drawbacks of the model predictions within the standard model, and the possible new physics solution beyond the standard model.

References:


**Secondary track (number):**

**Heavy Ions / 424**

**Bottomonium measurements in nucleus-nucleus and proton-nucleus collisions with ALICE**

Author: Robin Caron

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Bound states of a heavy quark-antiquark-pair, quarkonia, are unique model systems to probe the deconfinement property of strongly interacting matter created in heavy-ion collisions. At the LHC, a unique comprehensive and precise set of measurements is available for the heavy bottom-antibottom vector states, which is a complementary probe to the lighter charmonium system thanks to its heavier mass.

In this talk, recent results on bottomonium results of nuclear modification factors in nucleus-nucleus collisions and azimuthal anisotropies at forward rapidities will be discussed. In addition, ALICE \( \Upsilon \) measurements in proton-nucleus collisions at forward rapidity and its implications for the interpretation of nucleus-nucleus collision data will be presented.

I read the instructions:

Secondary track (number):

Heavy Ions / 426

Measurement of electroweak-boson production in p-Pb and Pb-Pb collisions with ALICE at the LHC

Author: Mingrui Zhao\(^1\)

\(^1\) China Institute of Atomic Energy (CN)

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W and Z bosons are clean probes of the initial-state effects in hadronic collisions, being formed in the hard scatterings taking place in the initial stages, and being insensitive to the presence of any strongly-interacting medium. This is especially true at the LHC energies, where having a clear picture of the initial state is mandatory to properly interpret the later stages characterising the complex evolution of p-Pb and Pb-Pb collisions. In particular, measurement of W and Z boson production in p-Pb and Pb-Pb collisions at the LHC provides constraints on the nPDFs of the (anti-)quarks in a phase-space region that is poorly constrained by previous experiments.

ALICE measures W and Z boson production in the muonic decay channels at forward rapidities \( (2.5 < y_{lab} < 4) \). In this contribution, recent measurements on the Z and W boson production in p-Pb and Pb-Pb collisions at the center-of-mass energies per nucleon pair of \( \sqrt{s_{NN}} = 8.16 \) and 5.02 TeV, respectively, are presented. Results, including invariant production yield and nuclear modification factors as a function of rapidity and collision centrality, are compared to calculations obtained with or without including nuclear modifications of the PDFs, as well as to results obtained by other LHC experiments.

I read the instructions:

Secondary track (number):

06

Dark Matter Detection / 427

Searches for dark matter with the CRESST III-Experiment

Authors: Jochen Schieck\(^1\); for the CRESST collaboration\(^{\text{None}}\)

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CRESST-III is a cryogenic dark matter experiment operated at the Gran Sasso laboratory in Italy. The primary research interest is the search for dark matter in the sub-GeV/$c^2$ mass region. Dark matter particles are detected by measuring the nuclear recoil energy from the elastic scatter with the dark matter particle. The experimental challenge for reaching such a low mass region is to achieve the lowest possible energy detection threshold. Currently CRESST-III has obtained an energy detection threshold of 30.1 eV. The target material is a 23.6g CaWO₄ crystal operated at a temperature of about 15 mK and using a dual read-out scheme. By measuring the phonons and the scintillation light an active background suppression can be reached. We will present the spin-independent results from direct dark matter searches with a sensitivity for dark matter masses down to 160 MeV/$c^2$. We will discuss a GEANT4 based electromagnetic background model to evaluate the content and the composition of the background. Currently 68+-16% of the overall background can be explained by this model. The latest R&D efforts are presented and an outlook of the future stages of the experiment will be given.

Secondary track (number):

Dark Matter Detection / 428

Measurement of the anti-nuclei nuclear inelastic cross sections with ALICE and implications for indirect Dark Matter searches

Author: Stephan Alexander Konigstorfer¹

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The measurement of low-energy cosmic anti-deuterons may reveal the existence of exotic processes such as dark-matter annihilation, since the production rate of these ions through ordinary secondary processes is very low. However, the lack of experimental data at low energies, where both the anti-nuclei production and inelastic cross sections are very poorly known, prevents precise predictions of anti-nuclei fluxes near Earth.

In ultra-relativistic pp, p-Pb and Pb-Pb collisions at the CERN LHC, matter and antimatter are produced in almost equal abundances. This allows us to study the production cross sections of (anti-)nuclei with high precision as well as to measure the absorption process of produced (anti-)nuclei in the detector material.

In this talk we present the first results on the anti-deuteron and anti-$^3$He absorption cross sections in the ALICE detector material.

The reconstructed antimatter to matter ratios are compared to the results from full-scale GEANT4 simulations of the ALICE detector. Experimental constraints on the anti-deuteron nuclear inelastic cross-section are extracted in the momentum range between 0.5 and 4.0 GeV/$c$ and the first measurement of the nuclear inelastic cross-section of anti-$^3$He is shown.

Finally, we discuss the implications of these results for indirect Dark Matter searches using cosmic anti-deuterons.

I read the instructions:

Secondary track (number):

Dark Matter Detection / 429
Understanding the background in dark matter searches by studying anti-nucleosynthesis in the laboratory with ALICE

Author: Sebastian Hornung

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Anti-nuclei are considered to be one of the most promising probes in the indirect search of dark matter annihilation in space. However, in light of the recent results on the production of light anti-nuclei in pp collisions at the LHC, an abundant production of light (anti-)nuclei is also expected from Standard Model collisions of primary cosmic rays with the interstellar medium. Hence further precise measurements are required to constrain the production models of anti-nuclei in SM collisions to be sensitive to the DM annihilation events.

In this talk all the most recent results of the ALICE collaboration on the production of anti-deuterons and anti-$^3$He in pp and p-Pb collisions are shown.

These results challenge the state-of-the-art calculations of the production models currently used to estimate the SM background to DM searches and a detailed comparison of the new ALICE measurements with the models will be shown.

Hadronic resonance production measured by ALICE at the LHC

Author: Paraskevi Ganoti

Corresponding Author: paraskevi.ganoti@cern.ch

Hadronic resonances with different lifetimes are very useful to probe the hadronic phase of heavy-ion collisions. Due to their relatively short lifetimes compared to the duration of the hadronic phase, resonances are good candidates to investigate the interplay between particle re-scattering and regeneration in the hadronic phase. In addition, having different masses, quantum numbers and quark content, hadronic resonances carry a wealth of information on different aspects of ion-ion collisions, including the processes that determine the shapes of particle momentum spectra, strangeness production, and the possible onset of collective effects in small systems. We here present the latest results on $^3\rho(770)^0$, $K^*(892)$, $f_0(980)$, $\phi(1020)$, $\Sigma(1385)^+$, $\Lambda(1520)$, $\Xi(1530)$ and $\Xi(1820)$ production in pp, p-Pb, Pb-Pb and Xe-Xe collisions at different energies. Results include system-size and collision-energy evolution of transverse momentum spectra, integrated yields, mean transverse momenta and particle ratios. These results will be given through comparisons to measurements from lower energy and theoretical models.
The Data-Acquisition System of the KOTO Experiment

Author: Chieh Lin¹

Co-authors: Bob Hsiung ²; Joseph Redeker ³; Mircea Arghir Bogdan ⁴; Qi Sen Lin ⁵; Tong Wu ¹; Yau W. Wah ³; Yu Ting Luo ⁵; Yu-Chen Tung ³

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The KOTO experiment searches for the rare kaon decay $K^0_L \rightarrow \pi^0 \nu \bar{\nu}$. Because of the small theoretical uncertainty in the Standard Model, it is sensitive to the new physics. In order to collect the signal events, pipeline readout is developed to enable two-level trigger decisions. The first level requires energy sum in the calorimeter and the absence of signal in other detector components. The second level requires two electromagnetic showers (clusters) in the calorimeter. Pulses from nearly 4000 channels are digitized and recorded by the custom analog-to-digital (ADC) modules with a pipeline depth of about 5.2 μs. The entire system was completed in June 2018. The dead time was measured to be 0.16 μs and the live time ratio was > 99%. In the near future, custom modules with multiple optical receivers will be used to transfer data from the ADCs and to build events. Then complete events are sent to the PC farms via 10 Gbps optical links for sophisticated trigger decisions (Level-3). In addition to improve the data collection efficiencies, it broadens the physics triggering capabilities for the KOTO experiment. The overall architecture and the prospects of this upgrade will be presented.

I read the instructions:

Secondary track (number):

Neutrino Physics - Posters / 432

Improved Limits on Sterile Neutrino Mixing from a Joint Search of the MINOS, MINOS+, Daya Bay, and Bugey-3 Experiments

Authors: Bedrich Roskovec¹; Zhuojun Hu²

¹ University of California at Irvine
² Sun Yat-sen University

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The Daya Bay, MINOS and MINOS+ experiments have searched for sterile neutrino mixing using electron antineutrino and muon (anti)neutrino disappearance, respectively, within a minimally extended four-neutrino scenario. They have recently combined their results, together with those from the Bugey-3 reactor neutrino experiment, to set the most stringent limits to date on the $\theta_{14}$ mixing angle over five orders of magnitude in the sterile mass-squared difference $\Delta m^2_{41}$. The new constraints are significantly more stringent than the previous ones and exclude the sterile-neutrino parameter space allowed by the LSND and MiniBooNE observations at 90% CL, for $\Delta m^2_{41} < 5$ eV$^2$, weakening the interpretation of these observations by the presence of a sterile neutrino. The result of the joint Daya Bay, MINOS, MINOS+ and Bugey-3 search along with a brief overview of the searches done by each experiment will be presented in this poster.

I read the instructions:
Neutrino Physics / 433

Constraining dark matter-neutrino interactions with IceCube-170922A

Authors: Carsten Rott1; Jongkuk KimNone; Ki-Young Choi2

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Astrophysical neutrinos travel long distances from their sources to the Earth traversing dark matter halos of clusters of galaxies and that of our own Milky Way. The interaction of neutrinos with dark matter may affect the flux of neutrinos. The recent multimessenger observation of a high energy neutrino, IceCube-170922A, can give a robust upper bound $M_{dm} \leq 5.1 \times 10^{-23} \text{cm}^2/\text{GeV}$ on the interaction between neutrino and dark matter at a neutrino energy of 290 TeV allowing 90% suppression. Combining the constraints from cosmic microwave background and Large Scale Structure at different neutrino energies, we can constrain models of dark matter-neutrino interactions.

Quark and Lepton Flavour Physics / 434

Signatures of complex new physics in $b \rightarrow c \tau \bar{\nu}$ anomalies

Authors: Suman Kumbhakar1; Sankagiri Umasankar1

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Recent measurements of $R_{D^*}\cdot R_{D^*}$ by Belle collaboration are in agreement with the Standard Model predictions. After inclusion of these measurements, the tension between global average and the SM prediction has reduced to 3.1σ. Assuming the new physics Wilson coefficients to be complex, we do a global fit to present $b \rightarrow c \tau \bar{\nu}$ data. We find that there are only two (three) allowed solutions respecting the upper limit of $B(B_s \rightarrow \tau \bar{\nu})$ to be 30% (60%). We calculate the predictions of $\tau$ polarization fraction and forward-backward asymmetry in $B \rightarrow D \tau \bar{\nu}$ and forward-backward asymmetry in $B \rightarrow D^* \tau \bar{\nu}$ for each new physics solution. Further we determine the predictions for CP violating triple product asymmetries in $B \rightarrow D^* \tau \bar{\nu}$ decay for the allowed solutions. We find that one of the three asymmetries can be enhanced only up to $2-3\%$ due to presence of two of the three new physics solutions.

Quark and Lepton Flavour Physics - Posters / 435
Discriminating new physics scenarios in $b \rightarrow s \mu^+ \mu^-$ via transverse polarization asymmetry of $K^*$ in $B \rightarrow K^* \mu^+ \mu^-$ decay

Authors: Suman Kumbhakar$^1$; Sankagiri Umasankar$^1$; Ashutosh Alok$^2$

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A global fit to current $b \rightarrow s l^+ l^-$ data suggest several new physics solutions. Considering only one operator at a time and new physics in the muon sector, it has been shown that the new physics scenarios (I) $C_{NP}^{9} < 0$, (II) $C_{NP}^{9} = -C_{NP}^{10}$, (III) $C_{NP}^{9} = -C_{NP}^{9'}$ can account for all data in this sector. In order to discriminate between these scenarios one needs to have a handle on additional observables in $b \rightarrow s \mu^+ \mu^-$ sector. In this work we study transverse polarization asymmetry of $K^*$ polarization in $B \rightarrow K^* \mu^+ \mu^-$ decay, $A_T$, to explore such a possibility. We show that $A_T$ is a good discriminant of all the three scenarios. The measurement of this asymmetry with a percent accuracy can confirm which new physics scenario is the true solution, at better than 3σ C.L.

Secondary track (number):

Test-beam performance of a TORCH prototype module

Authors: Michal Kreps$^1$; Srishti Bhasin$^2$; Thomas Blake$^3$; Nicholas BROOK$^4$; Flavia Cicala$^1$; Thomas Conneely$^5$; David Cussans$^6$; Roger Forty$^7$; Christoph Frei$^8$; Emmy Pauline Maria Gabriel$^9$; Rui Gao$^8$; Timothy Gershon$^1$; Thierry Gys$^8$; Thomas Henry Hancock$^8$; Neville Harnew$^9$; James Milnes$^9$; Jonas Rademacker$^2$; Maarten Van Dijk$^9$

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The TORCH time-of-flight detector is designed to provide a 15 ps timing resolution for charged particles, resulting in $K/\pi$ ($p/K$) particle identification up to 10 (15) GeV/c momentum over a 10 m flight path. Cherenkov photons, produced in a quartz plate of 10 mm thickness, are focused onto an array of micro-channel plate photomultipliers (MCP-PMTs) which measure the photon arrival times and spatial positions. A half-scale (660 x 1250 x 10 mm$^3$) TORCH demonstrator module instrumented with customised MCP_PMTs has been tested in a 5 GeV/c mixed proton-pion beam at the CERN PS. The MCP-PMTs with the active area 53 x 53 mm$^2$ and granularity 64 x 8 pixels have been developed in collaboration with an industrial partner (Photek). With 30 photons per particle detected, the 15 ps per particle time resolution requires single-photon resolution of 70 ps. The timing performance and photon yields have been measured as a function of beam position in the radiator, giving measurements which are consistent with expectations. A possible TORCH design
of the particle identification system in the LHCb experiment has been simulated and the potential for particle identification performance for high luminosity running has been evaluated.

Secondary track (number):

Higgs Physics / 438

Higgsstrahlung and double Higgs production at high-energy CLIC operation

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The Compact Linear Collider (CLIC) is a mature option for a future electron-positron collider operating at centre-of-mass energies of up to 3 TeV. CLIC would be built and operated in a staged approach with three centre-of-mass energy stages currently assumed to be 380 GeV, 1.5 TeV, and 3 TeV. This presentation focusses on unique opportunities at the multi-TeV stages in the area of Higgs physics. Two physics studies based on full detector simulations will be discussed: Higgsstrahlung ($e^+e^- \rightarrow ZH$) and the extraction of the Higgs self-coupling from double Higgs production. The first is particularly interesting as contributions from BSM effects to the Higgsstrahlung process grow with energy. Substructure information can be used to identify fully hadronic ZH events at 3 TeV to maximise the statistical precision. B-tagging in boosted Higgs boson decays was studied for the first time for CLIC. New projections for the ZH event rate and angular distributions will be shown. The Higgs self-coupling is of particular interest: for determining the shape of the Higgs potential, and due to its sensitivity to a variety of BSM physics scenarios. At the higher-energy stages CLIC will produce Higgs boson pairs both via double Higgsstrahlung and via vector-boson fusion. Measurements of these processes lead to a determination of the Higgs self-coupling with a precision around 10%.

I read the instructions:

Secondary track (number):

Beyond the Standard Model / 439

The CLIC potential for new physics

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The Compact Linear Collider (CLIC) is a mature option for a future electron-positron collider operating at centre-of-mass energies of up to 3 TeV. CLIC would be built and operated in a staged approach with three centre-of-mass energy stages currently assumed to be 380 GeV, 1.5 TeV, and 3 TeV. A selection of results from recent studies will be presented showing that CLIC has excellent sensitivity to many BSM physics scenarios. New particles can be discovered in a model-independent way almost up to the kinematic limit. Compared with hadron colliders, the low background conditions at CLIC provide extended discovery potential, in particular for the production through electroweak and/or Higgs boson interactions. This includes long-lived states, for example through the reconstruction of disappearing tracks. In addition to studying new particles directly, BSM models can be probed up to scales far beyond the centre-of-mass energy of the collider via precision measurements of Standard Model processes. Beam polarisation allows further constraints on the underlying theory in many cases.

I read the instructions:
Commissioning and prospects of first GEM station at the CMS experiment

Author: Giovanni Mocellin

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The CMS Collaboration has been developing a Gas Electron Multiplier (GEM) detector in the endcap regions of the CMS muon system to maintain the high level of performance achieved during Run 2 in the challenging environment of the High Luminosity phase of the LHC (HL-LHC). The GEM chambers at endcap station 1 (GE1/1) have been installed in the second long shutdown. The technical and operational challenges of large-area GEM chambers have been identified during the commissioning of five GEM supper chambers ("slice test") in Run 2. This lead to a modification in its system design. A test with cosmic-ray muons is the final stage of quality control before the full-scale installation in the CMS detector. We review the performance of muon detection in the slice test, an improvement of the readout system, commissioning status, and prospects for the muon trigger for Run 3.

Modeling Radiation Damage to Pixel Sensors in the ATLAS Detector

Author: Marco Bomben

LPNHE & Université de Paris, Paris (FR)

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Silicon pixel detectors are at the core of the current and planned upgrade of the ATLAS detector at the Large Hadron Collider (LHC). As the closest detector component to the interaction point, these detectors will be subjected to a significant amount of radiation over their lifetime: prior to the High Luminosity LHC (HL-LHC), the innermost layers will receive a fluence of $1-5 \times 10^{15}$ 1 MeV neq/cm$^2$ and the HL-HLC detector upgrades must cope with an order of magnitude higher fluence integrated over their lifetimes. Simulating radiation damage is critical in order to make accurate predictions for current future detector performance that will enable searches for new particles and forces as well as precision measurements of Standard Model particles such as the recently discovered Higgs boson. A model of pixel digitization is presented that includes radiation damage effects to the ATLAS pixel sensors for the first time. In addition to a thorough description of the setup, predictions are presented for basic pixel cluster properties alongside early studies with LHC Run 2 proton-proton collision data.
The Alignment of the ATLAS Forward Proton Detector

Author: ATLAS Collaboration
Corresponding Author: jesse.liu@cern.ch

The ATLAS Forward Proton detectors consists of four horizontal precision trackers, two stations located at 210 m on each side of the ATLAS interaction region. We describe the relative alignment of the four tracker planes in each station and the relative alignment of the stations in each arm. The absolute alignment is done with exclusive di-lepton events and cross-checked with data from survey data and Beam Position Monitors. The absolute position resolution per arm is about 200 um per proton at 210 m in the horizontal coordinate which is directly correlated with the relative energy loss of the proton.

The ATLAS Forward Proton Time-of-Flight Detector System

Author: ATLAS Collaboration
Corresponding Author: karel.cerny@cern.ch

The Time-of-Flight (ToF) detectors of the ATLAS Forward Proton (AFP) system are designed to measure the primary vertex z-position of the pp -> pXp processes by comparing the arrival times measured in the ToF of the two intact protons in the final state.

We present the results obtained from a performance study of the AFP ToF detector operation in 2017. A time resolutions of individual channels ranging between 20 ps and 40 ps are extracted, even though the AFP ToF efficiency is below 10%. The overall time resolution of each ToF detector is found to be $20(26) \pm 4(5)$ ps for side A(C). This represents a superb time resolution for a detector operating at few millimeters from the LHC beams.

Events from ATLAS physics runs at moderate pile-up taken at the end of 2017 are selected with signals in ToF stations at both sides of ATLAS. The difference of the primary vertex z-position measured by ATLAS and the value obtained by the AFP ToFs is studied. The distribution of the time difference constitutes of a background component from combinatorics due to non-negligible pile-up, and significantly narrower signal component from events where protons from the same interaction are detected in ToF. The fits performed to the distribution of the reconstructed time difference yield the vertex position resolution of about 5 mm $\pm$ 1 mm, which is in agreement with the expectation based on single-ToF channel resolution.
Status of the SK-Gd project

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Super-Kamiokande (SK) is a 50 kton water Cherenkov detector located approximately 1 km beneath mount Ikenoyama, Gifu, Japan. While SK can reconstruct charged particle tracks over a wide energy range, the detection efficiency of neutrons is very low. Achieving efficient neutron tagging is useful in all analyses, from the observation of the diffuse supernova neutrino background for the first time, to proton decay studies and oscillation analyses.

**SK gadolinium (SK-Gd)** is the upgrade project to make neutron tagging efficient. After extensive studies, the SK collaboration approved the SK-Gd project on June 27 2015. In the second half of 2018 we refurbished the detector and in the first half of 2020 we will add gadolinium to the SK tank for the first time. This talk will report the preparations that led to SK-Gd and its current status.

I read the instructions:

**Secondary track (number):** 445

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Silicon Vertex and Tracking Detector R&D for CLIC

**Corresponding Author:** katharina.dort@cern.ch

The physics aims at the proposed future CLIC high-energy linear e+e- collider pose challenging demands on the performance of the detector system. In particular, the vertex and tracking detectors have to combine a spatial resolution of a few micrometres and a low material budget with a few nanoseconds time-stamping accuracy. For the vertex detector, fine pitch sensors, dedicated 65nm readout ASICs, fine-pitch bonding techniques using solder bumps or anisotropic conductive films as well as monolithic devices based on Silicon-On-Insulator technology are explored. Fully monolithic CMOS sensors with large (High-Voltage CMOS) and small (High-Resistivity CMOS) collection electrodes are under investigation for the large surface CLIC tracker. This contribution gives an overview of the CLIC vertex and tracking detector R&D, focussing on recent results from test-beam campaigns and simulation-based sensor optimisation studies.

**Secondary track (number):** 446

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A High-Granularity Timing Detector for the Phase-II upgrade of the ATLAS Calorimeter system: detector concept, description and R&D and beam test results

**Author:** Chiara Rizzi

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The increase of the particle flux (pile-up) at the HL-LHC with luminosities of \( L = 7.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1} \) will have a severe impact on the ATLAS detector reconstruction and trigger performance. The end-cap and forward region where the liquid Argon calorimeter has coarser granularity and the inner tracker has poorer longitudinal vertex position resolution will be particularly affected. A High Granularity Timing Detector (HGTD) is proposed in front of the LAr end-cap calorimeters for pile-up mitigation and for luminosity measurement.

It will cover the pseudo-rapidity range from 2.4 to 4.0. Two Silicon sensors double sided layers will provide precision timing information for MIPs with a resolution better than 30 ps per track in order to assign each particle to the correct vertex. Readout cells have a size of 1.3 mm \( \times \) 1.3 mm, leading to a highly granular detector with 3 millions of channels. Low Gain Avalanche Detectors (LGAD) technology has been chosen as it provides enough gain to reach the large signal over noise ratio needed. A dedicated ASIC is being developed and some prototypes have been already submitted and measured.

The requirements and overall specifications of the HGTD will be discussed. LGAD R&D campaigns are carried out to study the sensors, the related ASICs, and the radiation hardness. Laboratory and test beam results will be presented.
Many searches for physics beyond the Standard Model make use of large radius jets to reconstruct hadronically decaying electroweak bosons or top quarks with high transverse momenta. Algorithms have been developed in ATLAS that take advantage of the different radiation pattern within the large radius jet depending on the initiating particle to efficiently reject quark- or gluon-initiated jets from background processes. The performance of these algorithms, their calibration in data, and their usage in analysis will be presented. The sensitivity enhancement in searches for new physics resulting from the usage of these algorithms will be demonstrated based on recent analyses searching for new resonances whose decays contain hadronically-decaying massive particles.

I read the instructions:

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 449

ATLAS LAr Calorimeter Commissioning for LHC Run-3

Author: Pavol Strizene
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Liquid argon (LAr) sampling calorimeters are employed by ATLAS for all electromagnetic calorimetry in the pseudo-rapidity region $|\eta| < 3.2$, and for hadronic and forward calorimetry in the region from $|\eta| = 1.5$ to $|\eta| = 4.9$. In the first LHC run a total luminosity of 27 fb$^{-1}$ has been collected at center-of-mass energies of 7-8 TeV. After detector consolidation during a long shutdown, Run-2 started in 2015 and about 150 fb$^{-1}$ of data at a center-of-mass energy of 13 TeV was recorded. With the end of Run-2 in 2018 a multi-year shutdown for the Phase-I detector upgrades was begun.

As part of the Phase-I upgrade, new trigger readout electronics of the ATLAS Liquid-Argon Calorimeter have been developed. Installation began at the start of the LHC shut down in 2019 and is expected to be completed in 2020. A commissioning campaign is underway in order to realize the capabilities of the new, higher granularity and higher precision level-1 trigger hardware in Run-3 data taking. This contribution will give an overview of the new trigger readout commissioning, as well as the preparations for Run-3 detector operation and changes in the monitoring and data quality procedures to cope with the increased pileup.

I read the instructions:

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 450

Development of the ATLAS Liquid Argon Calorimeter Readout Electronics for the HL-LHC

Author: Narei Lorenzo Martinez
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To meet new TDAQ buffering requirements and withstand the high expected radiation doses at the high-luminosity LHC, the ATLAS Liquid Argon Calorimeter readout electronics will be upgraded. The triangular calorimeter signals are amplified and shaped by analogue electronics over a dynamic range of 16 bits, with low noise and excellent linearity. Developments of low-power preamplifiers and shapers to meet these requirements are ongoing in 130nm CMOS technology. In order to digitize the analogue signals on two gains after shaping, a radiation-hard, low-power 40 MHz 14-bit ADCs is developed using a pipeline+SAR architecture in 65 nm CMOS. Characterization of the prototypes...
of the frontend components show good promise to fulfill all the requirements. The signals will be sent at 40MHz to the off-detector electronics, where FPGAs connected through high-speed links will perform energy and time reconstruction through the application of corrections and digital filtering. Reduced data are sent with low latency to the first level trigger, while the full data are buffered until the reception of trigger accept signals. The data-processing, control and timing functions will be realized by dedicated boards connected through ATCA crates. Results of tests of prototypes of frontend components will be presented, along with design studies on the performance of the off-detector readout system.

I read the instructions:

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 451

Luminosity measurement with the ATLAS experiment at the LHC

Author: Joseph William Carter

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Many physics measurements made by the ATLAS experiment at the LHC require a precise measurement of the integrated luminosity of the data sample. This talk will describe the ATLAS luminosity measurement for the full Run-2 dataset, including the absolute calibration of the luminosity scale using the van der Meer scan technique in dedicated LHC running, the extrapolation of this calibration to high-luminosity data-taking, and studies of the stability throughout the year. Prospects for further improvements with the Run-2 and later future datasets will also be discussed.

I read the instructions:

Secondary track (number):

Heavy Ions / 452

Quarkonia and open heavy flavor production in pA collisions

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We present LHCb results on production of quarkonia and of open-heavy-flavour hadrons in proton-lead collisions, using data collected at sqrt(s_NN) = 5 and 8.16 TeV. Measurements are performed in the forward pseudorapidity region (2<eta<5), covering both forward (pPb configuration) and backward (PbP configuration) rapidities. Measurements for charmonium states include prompt and from-b-decay components which are disentangled; the large increase of the data sample, with respect to the 5 TeV sample collected in 2013, allows a remarkable improvement in the accuracy of the studies of nuclear matter effects. A rich set of open charm mesons and baryons is also observed with abundant statistics and, thanks to LHCb’s forward acceptance, studied down to zero pT. Beauty hadrons, with signal counts up to a few thousands in the fully reconstructed decays in the pPb data samples, are also shown. Comparisons between theory predictions and data regarding the nuclear modification factors, forward-to-backward production ratios and baryon-to-meson ratios are made. The impact of the results, in particular on the improvement of nuclear PDF and parton saturation, are discussed.
The open charm production in fixed-target collisions of LHCb is also presented, which provides crucial constraints on intrinsic charm and nuclear parton distribution functions at moderate and large Bjorken x.

I read the instructions:

Secondary track (number):

Heavy Ions / 453

X(3872) production in pp with particle multiplicity

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The last decade of hadron spectroscopy has unveiled a wealth of states that do not have the properties expected of particles composed of 2 or 3 valence quarks. Among the most intriguing of these exotics is the X(3872), which various models attempt to describe as a hadronic molecule, a compact tetraquark, an unexpected charmonium state, or their mixtures. Heavy-ion collisions, as well as high-multiplicity pp collisions, offer a new window on the properties of this poorly understood hadron. In these systems, promptly produced X(3872) hadrons can interact with other particles in the nucleus and/or those produced in the collision. The influence of these interactions on the observed X(3872) yields provides information that can help discriminate between the various models of its structure, as well as give insight into the dynamics of the bulk particles produced in these collisions. With a full range of precision vertexing, tracking, and particle ID capabilities covering 2 to 5 in units of rapidity, the LHCb experiment is especially well suited to measurements of both prompt and non-prompt exotic hadrons. This talk will present new LHCb measurements of X(3872) production in high multiplicity pp collisions through the decay to $J/\psi \pi^+ \pi^-$. 

I read the instructions:

Secondary track (number):

Heavy Ions / 454

Quarkonia photo-production and Z production in heavy ion collisions

Authors: Stefania Ricciardi1; Giulia Manca2

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Vector meson photo-production in ultra-peripheral Pb-Pb collisions is sensitive to nuclear parton distribution functions, and probe models of vector meson production in nuclear interactions with strong electromagnetic fields. In pPb collisions, measurements of the Z production in the forward (pPb) and backward (Ppb) configurations are sensitive to the nPDFs in different kinematic domains, such that both probes enable complementary studies of the structure of the nucleus. In this talk, we present the latest results on charmonium production in PbPb ultra-peripheral collisions and on Z production in pPb and Ppb collisions at LHCb.
Searches for Dark Photons at LHCb

Authors: Stefania Ricciardi; Xabier Cid Vidal

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The LHCb detector at the LHC offers unique coverage of forward rapidities. The detector also has a flexible trigger that enables low-mass states to be recorded with high efficiency, and a precision vertex detector that enables excellent separation of primary interactions from secondary decays. This allows LHCb to make significant (and world-leading) contributions in these regions of phase space in the search for dark photons and other low-mass resonances that decay to dimuon final states. A selection of results from these searches will be presented, alongside the potential for future measurements that probe the low-mass region using dimuon, dielectron, and diphoton final states.

Exotic Searches at LHCb

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The unique design of the LHCb detector, with a flexible trigger and a precision vertex detector, enables competitive or even world-best limits on the production of long-lived particles, particularly for low mass states and for states that have a short lifetime. Searches have been performed at LHCb in fully hadronic and semileptonic final states.
Authors: Stefania Ricciardi\textsuperscript{1}; Lorenzo Sestini\textsuperscript{2}

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The LHCb detector at the LHC offers unique coverage of forward rapidities, allowing the experiment to play an important role in measurements of Standard Model processes at the LHC. Measurements of W, Z, top and jet production at LHCb will be presented, and future prospects will be discussed.

I read the instructions:

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 459

Upgrade of the ATLAS Muon Drift Tube (MDT) electronics for HL-LHC runs

Author: Xueye Hu\textsuperscript{1}

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The ATLAS monitored drift tube (MDT) chambers are the main component of the precision tracking system in the ATLAS muon spectrometer. The MDT system is capable of measuring the sagitta of muon tracks to an accuracy of 60 μm, which corresponds to a momentum accuracy of about 10% at pT=1 TeV. To cope with large amount of data and high event rate expected from the High-Luminosity LHC (HL-LHC) upgrade, ATLAS plans to use the MDT detector at the first-trigger level to improve the muon transverse momentum resolution and reduce the trigger rate. The new MDT trigger and readout system will have an output event rate of 1 MHz and a latency of 6 us at the first-level trigger. A new trigger and readout system has been proposed. Prototypes for two frontend ASICs and a data transmission board have been designed and tested, and detailed simulation of the trigger latency has been performed. We will present the overall design of the trigger and readout system and focus on latest results from different ASIC and board prototypes and system integration.

I read the instructions:

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 460

Small-Strip Thin Gap Chambers and electronics performance for the Muon Spectrometer Upgrade of the ATLAS Experiment

Author: Mohsen Naseri\textsuperscript{1}

\textsuperscript{1} Carleton University (CA)
The largest phase-1 upgrade project for the ATLAS Muon System is the replacement of the present first station in the forward regions with the New Small Wheels (NSWs). The NSWs consist of two detector technologies: Micromegas (MM) and small-strip Thin-Gap Chamber (sTGC). The sTGC chambers will be used as both trigger and precision tracking muon detectors in the high background environment of the high luminosity LHC. The frontend electronics are implemented in about 2000 boards including the 4 custom-designed ASICs capable of driving trigger and tracking primitives to the backend trigger processor and readout system. The readout data flow is designed through a high-throughput network approach. The large number of readout channels, short time available to prepare and transmit trigger data, large volume of output data, harsh radiation environment, and the need of low power consumption all impose great challenges on the system design, integration and commissioning. The design, construction, performance and status of the ATLAS sTGC upgrade projects will be discussed, along with results from tests of the chambers with nearly final electronics with beams, cosmic rays and high-intensity radiation sources.

The LHC at CERN plans to have a series of upgrades to increase its instantaneous luminosity to 7.5×10^{34} \, \text{cm}^{-2}\text{s}^{-1}. The luminosity increase drastically impacts the ATLAS trigger and readout data rates. The inner-most station of the ATLAS muon spectrometer, the so-called Small Wheels, will be replaced with a New Small Wheel (NSW) system, consisting of Micromegas (MM) and sTGC detectors, which is expected to be installed in the ATLAS underground cavern at the end of 2020. With the final MM quadruplets (modules) already produced from the different construction sites, the integration activities of the modules into the final, fully equipped MM double-wedges, that are then installed on the wheel structure, are currently in full swing in the integration facility at CERN. One crucial part of the integration workflow is the installation, testing and validation of the on-detector electronics & readout chain for a very large system with a more than 2.1 M electronic channels in total. These include ~4K MM Front-End Boards (MMFE8), custom printed circuit boards each one housing eight 64-channel VMM Application Specific Integrated Circuits (ASICs) that interface with the ATLAS Trigger and Data Acquisition (TDAQ) system through ~1K data-driver Cards (ADDC & L1DDC, respectively). The readout chain is based on optical link technology (GigaBit Transceiver links) connecting the backend to the front-end electronics via the Front-End LInk eXchange (FELIX), is a newly developed system that will serve as the next generation read out driver for ATLAS. Experience and performance results from the first large-scale electronics integration tests performed at CERN on final NSW MM double-wedges, including system validation tests with cosmic-rays, will be presented.

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**Lepton Flavour Violation at LHCb**

*Author:* Steffen Georg Weber

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Recent hints of lepton-universality violation in $b \to c l \nu u$ and anomalies observed in $b \to s l l$ transitions could imply the existence of lepton-flavour violating $B$ decays. The LHCb experiment is well suited to search for these decays thanks to its large acceptance and trigger efficiency, as well as its excellent invariant mass resolution and particle identification capabilities. Recent results on searches for lepton-flavour violating decays from the LHCb experiment will be presented.

**Quark and Lepton Flavour Physics / 463**

**Purely Leptonic Rare decays at LHCb**

*Author:* Lauren Emma Yeomans

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During Run 1 and 2 of the LHC, the LHCb experiment has collected large samples of beauty-hadron decays corresponding to an integrated luminosity of $9/\text{fb}$ at pp centre-of-mass energy of 7, 8 and 13 TeV. Very rare decays are discussed, with an emphasis on Flavour-Changing Neutral-Current processes of the type $B_0^{0(s)} \to l^+l^-$. Anomalies in the branching fractions of these decays are also discussed and connected with tests of Lepton-Flavour-Universality.

**Electroweak Penguin Decays at LHCb**

*Authors:* Stefania Ricciardi; David Gerick

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Rare $b \to s l l$ decays are Flavour-Changing Neutral-Current processes that are forbidden at the lowest perturbative order in the Standard Model (SM). As a consequence, new particles in SM extensions may affect the branching fractions of these decays and their angular distributions. The LHCb experiment is ideally suited for the analysis of these decays due to its high trigger efficiency, as well
as excellent tracking and particle identification performance. Recent results from the LHCb experiment in the area of b\to s \ell \ell decays (aside from tests of lepton flavour universality) and in particular the angular analyses are presented and their interpretation are discussed.

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Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 465

Performance of the ATLAS RPC detector and L1 Muon Barrel trigger at \sqrt{s} = 13 TeV

Author: Kunlin Han

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Resistive Plate Chambers (RPCs) are gaseous ionisation detectors that are employed by the Level-1 muon trigger system in the barrel region of the ATLAS muon spectrometer. The Level-1 muon trigger system selects muon candidates that are produced in proton-proton collisions at the Large Hadron Collider (LHC). Muon candidates are associated by the Level-1 system with the correct LHC bunch crossing and with one of the six transverse momentum thresholds. The RPCs are arranged in three concentric double layers and consist of approximately 3700 gas volumes, with a total surface of more than 4000 square meters. They operate in a toroidal magnetic field of approximately 0.5 Tesla and provide up to 6 position measurements along the muon trajectory, with a space-time resolution of about 1 cm x 1 ns.

This talk will present performance of the RPC detector and Level-1 Muon Barrel trigger system during the latest data taking period at a centre-of-mass energy of 13 TeV. New measurements of RPC cluster size, detector efficiency and timing resolution will be presented. Trigger efficiency measurements obtained using Z boson decays to a muon pair will be summarised. Measurements of gas-gap currents as a function of RPC high voltage and of environmental parameters will be also presented, both with/without beams in the LHC and with an instantaneous luminosity of up to 2x10^{34} cm^{-2} s^{-1}. Results of the extrapolations of the RPC detector response to the expected High Luminosity LHC luminosity will be shown. Finally, measurements of the RPC detector response at different high voltage and threshold settings will be discussed, also in the context of expected detector response at the High Luminosity LHC.

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Secondary track (number):

Quark and Lepton Flavour Physics / 466

Lepton Flavour Universality tests in electroweak penguin decays at LHCb

Authors: Stefania Ricciardi\(^1\); Carla Marin Benito\(^2\)

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The coupling of the electroweak gauge bosons of the Standard Model (SM) to leptons is flavour universal. Extensions of the SM do not necessarily have this property. Rare decays of heavy flavour are
suppressed in the SM and new particles may give sizeable contributions to these processes, therefore, their precise study allows for sensitive tests of lepton flavour universality. Of particular interest are rare $b \to s l l$ decays that are well accessible at the LHCb experiment. Recent results from LHCb on lepton flavour universality in rare $b \to s l l$ decays are discussed.

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Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 467

Irradiation and Gas studies of Micromegas production chambers for the ATLAS New Small Wheel

Author: Lorenzo Pezzotti

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The ATLAS upgrade for the HL-LHC phase involves the construction of two New Small Wheel (NSW) for addressing the high rate expected at high rapidity, up to 20 kHz/cm2. The wheels will be equipped with two different technologies, small-strips Thin Gap Chambers (sTGC) and Micromegas (MM), with both tracking and triggering capabilities. About 70% of the MM chambers for the first wheel have been tested at the Gamma Irradiation Facility (GIF++) at CERN, where they were exposed to a 14 TBq 137Cs source. The chambers were tested at different particle fluxes, up to 60 kHz/cm2. Long-term irradiation tests were also performed with different gases in order to test the MM stability. Several parameters have been studied, among them the spark rates, the current linearity as a function of the applied flux and the uniformity among layers and sectors. The role of gas parameters, such as humidity and gas flow, on the chamber performance was also studied. These results showed that the MM technology is capable to afford the high rate expected for the HL-LHC phase.

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Secondary track (number):

Quark and Lepton Flavour Physics / 468

Rare Radiative decays at LHCb

Authors: Stefania Ricciardi1; Boris Quintana2; Martino Borsato3

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Radiative, rare, $b$-hadron decays are sensitive probes of New Physics through the study of branching fractions, angular observables, CP asymmetries and measurements of the polarisation of the photon emitted in the decay. The LHCb experiment is ideally suited for the analysis of these decays due to its high trigger efficiency, as well as excellent tracking and particle identification performance. Recent results from the LHCb experiment are presented and their interpretation is discussed.
Large size multi-gap resistive Micromegas for the ATLAS New Small Wheel at CERN

Author: Dimitris Fassouliotis

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Large size multi-gap resistive Micromegas have been chosen together with the small-strips TGC (sTGC) to be mounted on the New Small Wheel (NSW) upgrade of the ATLAS Muon Spectrometer. The NSW is the most ambitious and challenging upgrade of the ATLAS experiment for LHC-Phase1 (the current long shutdown) and will exploit its full capabilities after the Phase2 upgrade of LHC when the luminosity will reach values up to $7.5 \times 10^{34}$ cm$^{-2}$ s$^{-1}$ severely impacting on the ATLAS muon forward reconstruction and trigger. Four types of large size quadruplets Micromegas detectors are currently in series production in France, Germany, Italy, Russia and Greece. At CERN the integration of the modules and their assembly in sectors composing the wheel is well advanced. All the procedures of quality control are in place and steadily running. In this presentation the main challenges of the project will be reviewed. The achievement of the requirements for these detectors revealed to be even more challenging than expected, when scaling from the small prototypes to the large dimensions. We will describe the encountered problems, to a large extent common to other micro-pattern gaseous detectors, and the adopted solutions. In addition, the work of the integration of the detectors at CERN and the results from the validation tests at CERN on Micromegas sectors in their final configuration, including tests with cosmic rays, will be also presented.

Rare decays of Lambda_b, Bc, and other b-hadrons at LHCb

Authors: Stefania Ricciardi\textsuperscript{1}; Anna Lupato\textsuperscript{2}

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Rare b-hadron decays are sensitive probes of New Physics through the study of branching fractions, angular observables, CP asymmetries. Moreover, the LHCb experiment has the opportunity to study the rare decays of heavy b-quark hadrons such as Bc mesons or Lambda_b baryons, which cannot be explored at the B factories. Recent results from the LHCb experiment are presented and their interpretation is discussed.
The ATLAS New Small Wheel Simulation and Reconstruction Software and Detector Performance Studies

Author: Chara Kitsaki

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In view of the ongoing series of LHC luminosity upgrades, the New Small Wheels (NSW) will replace the present innermost stations of the ATLAS endcap Muon spectrometer with new detector assemblies. The aim of the NSW is to maintain the same level of efficiency and momentum resolution of the present detector in the expected higher background level and to keep an acceptable muon trigger rate maintaining the same muon momentum threshold of the present detectors. The NSW are equipped with two completely new detector technologies: the small strips Thin Gap Chambers (sTGC) and the Micromegas (MM). Currently the series production of the detectors is well advanced, the integrations in sectors and assembly on the wheels is in progress. Quality control tests, including cosmic ray’s data taking are in full swing. The software for simulation and reconstruction of the NSW is also well advanced. The detectors response is simulated and compared with real data from cosmosics and test-beam, nominal geometries and misalignments and deformations are implemented, as well as other possible deviations from ideal operating conditions. Finally, trigger and reconstruction performance studies are carried out in different configurations of the detectors and background levels. After an overview of the software implementation and the adopted strategies for simulations and reconstruction, a summary of the studies will be presented.

Lepton Universality tests using semileptonic b-hadron decays

Authors: Stefania Ricciardi; Beatriz Garcia Plana

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In the Standard Model, the three charged leptons are identical copies of each other, aside from differences in mass. Experimental tests of this principle in semileptonic decays of b-hadrons are highly sensitive to New Physics particles which couple differently among the leptonic families. This talk reports the most recent lepton universality tests in semileptonic b->c transitions at LHCb.

Production and Test of Micromegas boards for the ATLAS New Small Wheel project

Author: Luigi Longo
ICHEP 2020 / Book of Abstracts

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The muon system of the ATLAS Experiment will be upgraded in 2021 with Micromegas detectors covering an active area of about 1280 m², being the largest system based on Micro Pattern Gaseous Detector (MPGD) ever built so far. The key element of the detectors are the anode boards which carry the readout strips, the resistive protection layer and the insulating pillars supporting the mesh. In total more than 2000 boards of 16 different types with size up to 40x220 cm² have to be produced. The boards are produced by two industries in Europe, which opened the road to MPGD mass production, with the production being now reaching the end. The boards undergo a detailed quality control and quality assurance checks at CERN, prior to be mounted into the final detectors. The talk will review the technological transfer effort made by CERN and ATLAS to make the Micromegas board production an industrial process. The main problems encountered during the industrialisation and the adopted solution will be presented in detail, together with the results of the QA/QC performed at CERN.

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Secondary track (number):

Operation, Performance and Upgrade of Present Detectors - Posters / 474

Geometrical precision alignment of the Micromegas detectors for the ATLAS New Small Wheel upgrade

Author: Manisha Manisha

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The upgrade of the Large Hadron Collider (LHC) to the High Luminosity LHC (HL-LHC) is required to probe the physics beyond Standard Model. After the ongoing long shutdown (LS2) and eventually after LS3 in 2026, the accelerator luminosity will be increased up to 7 times as compared to designed luminosity value i.e. 1034 cm⁻²s⁻¹. To meet the requirements of higher rates environment of HL-LHC era, the muon system of ATLAS detector needs to be upgraded. Therefore, the small wheel comprised of Cathode Strip Chambers (CSC), monitored Drift Tubes (MDT) chambers and Thin Gap Chambers (TGC) will be replaced by the New Small Wheel (NSW). The NSW will be constituted by MicroMegas gaseous detectors (from the MPGD family) and small-strip Thin Gap Chambers (sTGC). Micromegas detectors will be used for tracking as well as triggering purpose. For each of the two NSW, 16 modules will be installed in 16 sectors i.e. 8 large sectors and 8 small sectors; covering total area of ~ 1200 m², each detector with an individual area between 2 and 3 m². Micromegas are ionization-based gaseous detectors made up of parallel plates, having a thin amplification region separated from the conversion region via a thin metallic mesh. The construction of Micromegas detectors as well as methods adopted to achieve the challenging required geometrical precision are presented. Specific measurement devices have been developed in the last few years to determine the mechanical metrology quality of Micromegas chambers, required for NSW. Planarity measurements of readout panels as well as module after assembly are done with a specifically developed co-ordinate measuring machine (CMM). The methodology to obtain such results as well as obtained results will be presented. Results of in-plane measurements (XY co-ordinate) performed using Rasnik masks etched on the PCBs are also shown.

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Secondary track (number):
Quark and Lepton Flavour Physics / 475

Measurements of CKM matrix elements

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Exclusive semileptonic b-hadron decays are under good theoretical control, which allows for precise determinations of the CKM matrix elements Vcb and Vub. The large production of Bs mesons at the LHC allows LHCb to provide complementary information with respect to the B-factories in this sector. The latest LHCb results on CKM matrix element determination and related measurements are presented.

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Secondary track (number):

Quark and Lepton Flavour Physics / 476

Study of b-hadron properties with semileptonic b-hadron decays

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With large branching fractions and controllable theoretical uncertainties, semileptonic B decays are excellent tools for measuring B hadron properties as well as testing QCD calculations. The large samples of Bs mesons and b-baryons uniquely available at LHCb extend the experimental reach into this sector, allowing differential decay rates of these hadrons to be probed for the first time. The observation and study of B -> p pbar mu nu decays offer the opportunity to investigate hadronic meson-to-baryon-pair transitions. The most recent measurements of b-hadron properties using semileptonic b-hadron decays are presented.

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Secondary track (number):

Beyond the Standard Model / 477

Simulating hard photon production with WHIZARD

Authors: Aleksander Filip Zarnecki¹; Jan Henryk Kalinowski²; Krzysztof Mekala¹; Pawel Sopicki²; Wojciech Kotlarski³

¹ University of Warsaw
One of the important goals of the proposed future $e^+e^-$ collider experiments is the search for the dark matter particles using different experimental approaches. The most general search approach is based on the mono-photon signature, which is expected when production of the invisible final state is accompanied by a hard photon from initial state radiation. Analysis of the energy spectrum and angular distributions of those photons can shed light on the nature of a dark matter and its interactions. Therefore, it is crucial to be able to simulate the signal and background samples in the uniform framework, to avoid possible systematic biases. The WHIZARD program is a flexible tool, which is widely used by $e^+e^-$ collaborations for simulation of many different "new physics" scenarios.

We propose the procedure of merging the matrix element calculations with the lepton ISR structure function implemented in WHIZARD. It allows us to reliably simulate the mono-photon events, including the two main Standard Model background processes: radiative neutrino pair production and radiative Bhabha scattering. We demonstrate that cross sections and kinematic distributions of mono-photon in neutrino pair-production events agree with corresponding predictions of the LEP-tuned KKMC generator.

**Heavy Ions / 480**

**Constraining the transport properties of quark-gluon plasma with latest flow measurements in ALICE**

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Collisions of relativistic heavy ions at the LHC are carried out to understand the fundamental properties of one of the extreme phases of QCD matter, the quark-gluon plasma (QGP). Anisotropic flow is one of the most sensitive probes to study the QGP transport properties, such as the shear viscosity over entropy density ratio ($\eta/s$), the value of which was found to be close to a universal lower bound for any liquid set by the AdS/CFT theory. However, the temperature dependence of $\eta/s$ is poorly constrained. In addition, the choice of initial conditions or determination of other properties, such as the bulk viscosity or hadron momentum distribution at freeze-out, affects the resulting values of $\eta/s$ extracted from hydrodynamical model comparisons to the data. Therefore, more sensitive measurements able to scrutinise the individual parameters are of great interest.

The ALICE detector plays a leading role in performing state-of-the-art measurements to characterise the properties of the QGP at the LHC. In this talk, we will present measurements of anisotropic flow, its fluctuations, and recently developed observables such as symmetric cumulants, non-linear flow modes, and correlations among symmetry planes. Both unidentified charged particles and identified hadrons were used for the analysis, using the unique identification capabilities of the ALICE detector among the LHC experiments. Comparison of these measurements to recent hydrodynamic calculations allow for unprecedented constraints of the initial conditions and the temperature dependence of the shear and bulk viscosities of the QGP, which was not feasible with earlier flow measurements. The complexity of these measurements, together with several model comparisons, will bring invaluable insight into the geometry of the fluctuating initial state and the dynamical evolution of the hot and dense medium produced in ultra-relativistic heavy-ion collisions.
ALICE data processing for Run 3 and Run 4 at the LHC

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During the upcoming Runs 3 and 4 of the LHC, ALICE will take data at a peak Pb-Pb collision rate of 50 kHz. This will be made possible thanks to the upgrade of the main tracking detectors of the experiment, and with a new data processing strategy. In order to collect the statistics needed for the precise measurements that ALICE aims at, a continuous readout will be adopted. This brings about the challenge of handling unprecedented data rates. The ~3.5 TB/s of raw data from the detectors will be reduced to about 600 GB/s on the First Level Processing (FLP) nodes, and sent to the Event Processing layer for further processing and reduction to less than 100 GB/s of data to be stored permanently. This synchronous processing stage, which will include reconstruction, calibration and compression procedures, will be followed by an asynchronous one to account for final calibrations. Quality Control (QC) will be intensively used in all the processing stages. This talk illustrates the processing flow for ALICE in Runs 3 and 4, with emphasis on the components of the synchronous processing. The chosen software design will be described. An overview of the data analysis framework is included as well.

Studies of Quantum Mechanical Coherency Effects in Neutrino-Nucleus Elastic Scattering

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Neutrino-nucleus elastic scattering provides a unique laboratory to study the quantum mechanical coherency effects in electroweak interactions. We present an analytical formulation [1] to quantify the coherency effects, relate this to nuclear form factors and experimental cross-section ratios, and characterize how its energy dependence leads to complementary among measurements at various neutrino sources with different targets. The latest results and prospects of observing this process at the Kuo-Sheng Reactor Neutrino Laboratory with germanium detectors with O(100 eV) threshold [2] will also be presented.


Secondary track (number):

Neutrino Physics / 483

**Sufficient and necessary conditions for CP conservation with Majorana neutrinos**

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As is well-known, there exist totally three CP-violating phases in the leptonic sector if three ordinary neutrinos are massive Majorana particles. In this talk, we raise the question whether the number of sufficient and necessary conditions for CP conservation in the leptonic sector with massive Majorana neutrinos is three or four. An intuitive answer to this question would be three, which is also the total number of independent CP-violating phases. However, we give a counter example, in which three conditions are in general not sufficient for CP conservation. Only for all the lepton masses and mixing angles within their experimentally allowed ranges can we demonstrate that it is possible to find out three weak-basis invariants, which should be vanishing to guarantee leptonic CP conservation.

Secondary track (number):

05

Strong Interactions and Hadron Physics / 485

**Topological studies of light-flavor hadron production in high multiplicity pp collisions with ALICE at the LHC**

**Author:** Sushanta Tripathy

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Recent measurements in high-multiplicity pp and p-A collisions have revealed that these small collision systems exhibit collective-like behaviour, formerly thought to be achievable only in heavy-ion collisions. To understand the origins of these unexpected phenomena, event shape observables can be exploited, as they serve as a powerful tool to disentangle soft and hard contributions to particle production.

Results on the production of light flavor hadrons (π, K, φ and Ξ) as a function of Transverse Sphericity (S₀) and Relative Transverse Activity (Rₜ) in high multiplicity pp collisions at √s = 13-TeV measured with the ALICE detector are presented. Hadron-to-pion ratios in different S₀ and Rₜ classes are presented and compared with state-of-the-art QCD-inspired Monte Carlo event generators. The evolution of charged particle average transverse momentum with multiplicity, S₀ and Rₜ is also discussed in the context of radial flow or flow-like effects.
Study of hadronization through the measurement of light-flavour particle production in different colliding systems with ALICE

Author: Giacomo Volpe

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Studies of the production of light-flavour hadrons in different collision systems are of prominent importance to investigate the hadronisation process. In the recent past, the ALICE Collaboration has presented results from pp, p-A and A-A collisions, exploiting its detector’s excellent tracking and PID capabilities down to low transverse momentum. Pions, kaons, protons and (multi-)strange hadrons have been measured at different energies. The results revealed unexpected features which are quantitatively similar across colliding systems if the charged particle multiplicity generated in the collision is used as a reference.

New results on strange particle production as a function of the charged particle multiplicity for pp collisions at \( \sqrt{s} = 5 \) TeV will be presented. The multiplicity progression of particle yields will therefore be tested at a different center-of-mass energy, the lowest at the LHC for which the collected statistics allow a multiplicity-differential analysis. These new results have the potential for solidifying or discarding the present understanding of the strange quark hadronisation process, accessing lower multiplicities and increasing precision in the datapoints. New measurements will be discussed along with the large set of previous ALICE results, data from lower energy energy experiments, and state-of-the-art phenomenological models.

Investigating the hyperon-nucleon strong interaction with a precision measurement of the hypertriton lifetime in ALICE

Author: Francesco Mazzaschi

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The hypertriton is a bound state of proton, neutron and lambda. Studying it provides insights about the strong interaction between the lambda and ordinary nucleons. In particular, the hypertriton is an extremely loosely bound object, with a lambda separation energy \( E_\Lambda \) of 150 ± 8 keV. One way to investigate the hypertriton’s internal structure, and thus hyperon-nucleon interactions, is to measure the hypertriton lifetime precisely.

In the past, these measurements had large uncertainties and did not give a clear answer. However, thanks to the very large set of Pb-Pb collisions collected during the run 2 of the LHC the ALICE collaboration has performed systematic studies on the hypertriton lifetime. Both the two and three body decay channels have been studied with the help of machine learning techniques for the signal
The precision of the new ALICE results on the hypertriton lifetime is comparable with the current world average, thus providing strong constraints on models describing hyperon-nucleon interactions.

I read the instructions:

Secondary track (number):

Heavy Ions / 488

Latest results on light (anti-)nuclei production in Pb-Pb collisions with ALICE at the LHC

Author: Chiara Pinto

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New results on the production of light nuclei, including deuterons, tritons, $^3$He, $^4$He and the corresponding anti-nuclei in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV and $\sqrt{s_{NN}} = 5.02$ TeV will be presented and compared with theoretical predictions to provide insight into their production mechanisms in heavy-ion collisions.

Furthermore, new measurements of the elliptic and the triangular flow of deuteron and $^3$He produced in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV will be presented and compared to lower energy results and to the expectations from coalescence and hydrodynamic models. The measurement of the elliptic and triangular flow of light nuclei provides a powerful tool to give insight into their production mechanism and freeze-out properties at a late stage of the collision evolution.

Finally, the large variety of measurements performed with the ALICE apparatus at different energies allows us to constrain the models of the production mechanisms of light flavour baryon clusters, in particular those based on the coalescence and statistical hadronisation approaches.

I read the instructions:

Secondary track (number):

Quark and Lepton Flavour Physics / 489

Oscillations of $B^0_s$ mesons as a probe of decays with unreconstructed particles

Authors: Anton Poluektov; Adam Morris

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Many heavy-flavour measurements involve studies or searches for decays of hadrons into final states with neutral particles that are difficult or impossible to reconstruct with collider detectors, such as neutrinos, neutrons, $K^0_L$ mesons, or various dark-matter candidates. These decays are difficult to deal with, especially in the hadronic environment, such as at LHCb.

We propose a novel technique that uses $B^0_s$ oscillations as a tool to study $B^0_s$ decays with invisible (unreconstructed) particles. When combined with the information about the topology of the decay,
High-frequency $B^0_s$ oscillations provide a strong kinematic constraint on decays with invisible particles and suppresses any non-$B^0_s$ backgrounds. Contrary to other methods involving topological reconstruction at LHCb, where assumptions are needed on the mass of the missing particle, this technique provides the information about the mass (or even the spectrum of invariant masses) of the invisible state(s).

I read the instructions:

Secondary track (number):

Computing and Data Handling / 491

**GPU-based online-offline reconstruction in ALICE for LHC Run 3**

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In LHC Run 3, ALICE will increase the data taking rate significantly to read out 50 kHz minimum bias Pb-Pb collisions. Such a large increase poses challenges for online and offline reconstruction as well as for data compression. Compared to Run 2, the online farm will process 50 times more events per second and achieve a higher data compression factor. To address this challenge ALICE will rely on GPUs to perform real time processing and data compression in some of the most critical steps of the synchronous online reconstruction during the data taking. The software is written in a generic way, such that it can also run on processors on the WLCG with the same reconstruction output. We give an overview of the status and the current performance of the reconstruction and the data compression implementations on GPUs.

I read the instructions:

Secondary track (number):

Dark Matter Detection / 492

**New Limits on WIMP Dark Matter from Annual Modulation Analysis of the CDEX Experiment at the China Jinping Underground Laboratory**

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Positive signatures in direct searches of WIMP dark matter are so far derived from Annual Modulation (AM) studies. We present the analysis and results of AM search [1] with data from a 1-kg p-type point-contact germanium detector of the CDEX experiment at the China Jinping Underground Laboratory [2]. The allowed regions due to DAMA/LIBRA and CoGeNT AM-data are probed and excluded. These results represent the most stringent bounds at WIMP-mass less than 6 GeV among WIMP-AM measurements. New limits on Light DM with Migdal effects [3] and on dark photons [4] will also be presented.
The phase-1 upgrade of the ATLAS level-1 calorimeter trigger

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The ATLAS level-1 calorimeter trigger (L1Calo) is a hardware-based system that identifies events containing calorimeter-based physics objects, including electrons, photons, taus, jets, and missing transverse energy. In preparation for Run 3, when the LHC is expected to run at higher energy and instantaneous luminosity, L1Calo is currently implementing a significant programme of planned upgrades. The existing hardware will be replaced by a new system of feature extractor (FEX) modules, which will process finer-granularity information from the calorimeters and execute more sophisticated algorithms to identify physics objects; these upgrades will permit better performance in a challenging high-luminosity and high-pileup environment. This talk will introduce the features of the upgraded L1Calo system and the plans for production, installation, and commissioning. In addition, the expected performance of L1Calo in Run 3 will be discussed.
many physics analyses pursued by the ATLAS collaboration. In Run 2, around 1500 individual selections, the trigger chains, are comprised in the trigger menu specifying the selection algorithms to be used for data taking, their rate and the bandwidth. Trigger menus must reflect the physics goals for a given data-taking period, taking the instantaneous luminosity of the LHC and limitations from the ATLAS detector readout and offline processing farm into account. We will give an overview of the 2015-2018 trigger menu and its performance, allowing the audience to get a taste of the broad physics program that the trigger is supporting. We present the tools that allow us to predict and optimize the trigger rates and CPU consumption for the anticipated LHC luminosities and outline the system to monitor deviations from the individual trigger target rates, and to quickly react to the changing LHC conditions and data taking scenarios. As an outlook to the upcoming ATLAS data-taking period during Run 3 (2021 onwards), we present the design principles and currently ongoing implementation of the new trigger software within the multi-threaded framework AthenaMT.

The ATLAS Muon Trigger Design and Performance

Author: Yu Nakahama Higuchi

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Muon triggers are essential for studying a variety of physics processes in the ATLAS experiment, including both standard model measurements and searches for new physics. The ATLAS muon trigger consists of a hardware based system (Level 1), as well as a software based reconstruction (High Level Trigger). The muon triggers have been optimised during Run 2 to provide a high efficiency while keeping the trigger rate low. We will present an overview of how we trigger on muons, recent improvements, the performance of the muon trigger in Run 2 data and the improvements underway for Run 3.

ATLAS Level-1 Endcap Muon Trigger for Run-3

Author: Junpei Maeda

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The LHC is expected to increase its centre-of-mass energy to 14 TeV and to keep longer time with an instantaneous luminosity of about $2.0 \times 10^{34}$ cm$^{-2}$s$^{-1}$ for Run-3 scheduled from 2021 to 2024. In order to cope with the high event rate, upgrades of the ATLAS trigger system are required. The level-1 endcap muon trigger system identifies muons with high transverse momentum by combining data from a fast muon trigger detector, Thin-Gap Chamber. In the ongoing upgrade in this year, new detectors called the New-Small-Wheel (NSW) and RPC-BIS78, will be installed in the inner station region for the endcap muon trigger. Finer track information from the NSW and RPC-BIS78 can be used as part of the muon trigger logic to enhance performance significantly. In order to handle data from both TGC and NSW, some new electronics have been developed, including the trigger...
processor board known as Sector Logic (SL). The SL board has a modern FPGA to make use of Multi-Gigabit transceiver technology, which will be used to receive data from the NSW. The readout system for trigger data has also been re-designed, with the data transfer implemented with TCP/IP instead of a dedicated ASIC. This makes it possible to minimise the use of custom readout electronics and instead use some commercial computers and network switches to collect, format and send the data. This presentation describes the aforementioned upgrades of the level-1 endcap muon trigger system. Particular emphasis will be placed on the new algorithm in Sector Logic and the current status of installation and commissioning. The expected trigger performance by the new algorithm will also be discussed.

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Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 497

Triggering on Hadronic Signatures with the ATLAS Detector

Author: Benjamin Taylor Carlson

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At the Large Hadron Collider, many important searches for new particles and Standard Model measurements probe final states with hadronic jets and missing transverse momentum. Such events are also fundamental for precision calibration. Trigger selection of hadronic events is a extremely challenging due to immense backgrounds. This presentation summarises the implementation of hadronic triggers in the ATLAS experiment, discussing how improvements during LHC Run 2 address the background challenge and improve delivery of data for physics analysis. The evolution of jet and missing transverse momentum trigger performance is illustrated.

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Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 498

Projected ATLAS Electron and Photon Trigger Performance in Run 3

Author: Fernando Monticelli

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ATLAS electron and photon triggers covering transverse energies from 5 GeV to several TeV are essential to record signals for a wide variety of physics: from Standard Model processes to searches for new phenomena. During Run 3 (2021-2024) main triggers used for those physics studies will be a single-electron trigger with ET threshold around 25 GeV and a diphoton trigger with thresholds at 25 and 35 GeV. Relying on those simple, general-purpose triggers is a robust trigger strategy, tested already in Run 2 (2015-2018), at a cost of slightly higher trigger output rates, than to use a large number of analysis-specific triggers. In preparation for Run 3 data-taking, the ATLAS detector is undergoing an upgrade of the first, hardware, level of the calorimeter trigger and trigger software is being migrated to the multi-threaded framework AthenaMT. Impact from these modifications on the electron and photon triggers as well as their projected performance in Run 3 is presented.
Upgrade of the ATLAS Muon Trigger for the HL-LHC

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The present Level-1 Muon Trigger System of the ATLAS experiment will be upgraded for the HL-LHC to the Level-0 (L0) Muon Trigger with increased trigger latency of 10 ms and output rate of 1 MHz. The longer buffers in the front-end allow for more complex processing of the data, maintaining a high trigger efficiency even at highest event rates. For this purpose, the Sector Logic (SL) boards processing data from the RPC and TGC trigger chambers, is complemented by the NSW and MDT Trigger Processors processing respectively the information from the NSW trigger chambers and the MDT precision tracking chambers. To operate the future L0 Muon Trigger, the entire front-end electronics for the RPC, TGC and MDT chambers will be upgraded to cope with required rates and latencies. All RPC and TGC hit data will be transmitted from the front-end boards to the SL and the MDT hits to the MDT Trigger processors in a trigger-less mode over high-speed optical links. The low-resolution coordinates of the muon track hits supplied by the RPC, TGC and NSW trigger chambers will be used as a seed for the MDT Trigger Processors. These seeds provide Regions of Interest (RoIs) and bunch crossing identification. The MDT Trigger Processor assigned to a given sector of MDT chambers then only considers the MDT hits in a RoI, allowing for a large reduction of the relevant data volume. Hits in a RoI, together with the coarse track direction supplied by the trigger chambers, are fed to the MDT Trigger Processor to reconstruct a muon track segment in each MDT chamber and combine the segments into a muon track with significantly improved transverse momentum resolution. The much higher accuracy of the MDT hit coordinates (~0.1 mm) compared to the ones supplied by the primary trigger chambers (20-30 mm), leads to a reduction of the single muon trigger rate by about a factor 3. The MDT Trigger Processor returns the measured pT to the SL for the final muon trigger decision. Upon a L0 trigger accept, it also transmits the MDT hits to the read out system (FELIX) for the final storage. The realisation of the MDT Trigger Processor imposes several technical challenges. To maintain the latency budget, the communication with MDT front-end electronics, the SL and the read out system must be performed via a large number high-speed optical links. The identification of track segments in the RoI also needs fast processors and firmware, which is robust against all possible hit patterns. A hardware demonstrator of the MDT Trigger Processor, based on state-of-the-art FPGA and SoC technology, is currently under production. It is implemented as an ATCA board consisting of two separate modules, the Service Module responsible for the board infrastructure and the Command Module for the data processing. The presentation will cover the description of the new L0 Muon Trigger System and the status of the firmware and hardware development for MDT Trigger Processors.

The ATLAS Inner Detector Trigger performance in pp collisions at 13 TeV during LHC Run 2

Author: Mario Grandi
The Inner Detector (ID) trigger plays an essential role in the ATLAS trigger system, enabling the high purity reconstruction of physics objects - electron, tau, muon, bjet candidates etc., providing access to regions of the phase space populated by these objects which span a wide range of kinematic regimes. These are essential for the core physics programme at ATLAS: Standard Model measurements; Flavour physics; and Beyond the Standard Model searches. Having highly efficient tracking trigger algorithms is therefore essential to pursue the ATLAS physics goals, both in the Run-2 analyses and for the preparations for Run-3. Here, the design and performance of the ATLAS ID trigger used at the Large Hadron Collider during the full Run-2 data taking period is discussed, as well as proposed developments for the start of Run-3 and beyond. The detailed efficiencies and resolutions for the trigger for a wide range of physics signatures, including muons, electrons, taus and b-jets, are presented. These results demonstrate the continued excellent performance of the ID trigger in the extreme pile-up conditions of Run-2. During the current 2019-2021 long shutdown, the ATLAS High-Level Trigger software is being redesigned to cope with the running conditions of Run-3 and beyond, whilst maintaining or improving upon the excellent performance from Run-2. This poses significant challenges for the design of the algorithms in terms of execution time and physics performance. Following this redesign, the ID Trigger will continue to lie at the heart of the ATLAS trigger and to be central to the successful fulfilment of the ATLAS physics programme.

I read the instructions:

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors - Posters / 501

The ATLAS trigger menu: from Run 2 to Run 3

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The ATLAS experiment aims to record about 1 kHz of physics collisions. This is achieved by using a two-level trigger system to select interesting physics events while reducing the data rate from the 40 MHz LHC crossing frequency. Events are selected based on physics signatures such as the presence of energetic leptons, photons, jets or large missing energy. The wide physics programme carried out by ATLAS is achieved by running around 1000 triggers during data taking. A Trigger Menu is the compilation of these triggers, specifying the physics selection algorithms to be used during data taking and the rate and bandwidth a given trigger is allocated. Trigger menus must reflect the physics goals for a given run, and also must take into consideration the instantaneous luminosity of the LHC and limitations from the ATLAS detector readout and offline processing farm. We will describe the design criteria for the ATLAS trigger menu. We discuss several aspects of the process of planning the trigger menu, including how rate, bandwidth, and CPU constraints are folded in during the compilation of the menu. Improvements made during the run to react to changing LHC conditions and data taking scenarios are discussed and we conclude with an outlook on how the trigger menu will evolve with the detector upgrades currently being installed for the start of Run 3.

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Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 502
Performance studies of the Run 3 jFEX algorithms in the ATLAS calorimeter trigger

Author: Elena Michelle Villhauer

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The Run 2 ATLAS trigger system is comprised of two levels: a hardware level (L1) and a software higher level trigger (HLT). Between late 2018 and early 2021, the ATLAS trigger system is undergoing upgrades. Two major sets of upgrades to the ATLAS level 1 trigger system will be the increase in read-out granularity in the LAr detectors (“supercells”) and the addition of new Feature EXtractors (FEXs): Jet FEX (jFEX), global FEX (gFEX), and electromagnetic FEX (eFEX). The jFEX identifies jets and calculates missing transverse momentum and other energy sums. The gFEX identifies large radius jets. The new Run 3 L1 jets will make use of the improved resolution and the added algorithm flexibility provided by these upgrades. The incorporation of the jFEX and gFEX in Run 3 will cause L1 jet triggers to change significantly. To maintain the efficiency of the HLT and L1 jet chains and to maximize use of L1 rate, it is crucial that the performance of Run 3 L1 jet triggers is optimized. Jet triggers for low-threshold multijet triggers and for trigger-level analyses will benefit from polished Run 3 L1 jets. Studying the performance of Run 2 L1 jets allows for the determination of areas of improvement for Run 3 L1 jet triggers. Presented are trigger efficiencies for Run 2 L1 jets for various years, as well as the expected trigger performance for Run 3 L1 jets. Performance studies are also included for the jFEX MET algorithm.

Preparing the ATLAS Trigger Software for Multi-threaded Operation

Author: Mark Stockton

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Athena is the software framework used in the ATLAS experiment throughout the data processing path, from the software trigger system through offline event reconstruction to physics analysis. The shift from high-power single-core CPUs to multi-core systems in the computing market means that the throughput capabilities of the framework have become limited by the available memory per process. For Run 2 of the Large Hadron Collider (LHC), ATLAS has exploited a multi-process forking approach with the copy-on-write mechanism to reduce the memory use. To better match the increasing CPU core count and the, therefore, decreasing available memory per core, a multi-threaded framework, AthenaMT, has been designed and is now being implemented. The ATLAS High Level Trigger (HLT) system has been remodelled to fit the new framework and to rely on common solutions between online and offline software to a greater extent than in Run 2. We present the implementation of the new HLT system within AthenaMT, which is being commissioned now for ATLAS data-taking during LHC Run 3 (2021 onwards).
Real-time flavour tagging selection in ATLAS

Author: Carlo Varni

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In high-energy physics experiments, online selection is crucial to select interesting collisions from the large data volume. ATLAS b-jet triggers are designed to identify heavy-flavour content in real-time and provide the only option to efficiently record events with fully hadronic final states containing b-jets. In doing so, two different, but related, challenges are faced. The physics goal is to optimise as far as possible the rejection of light jets, while retaining a high efficiency on selecting b-jets and maintaining affordable trigger rates without raising jet energy thresholds. This maps into a challenging computing task, as tracks and their corresponding vertexes must be reconstructed and analysed for each jet above the desired threshold, regardless of the increasingly harsh pile-up conditions. We present an overview of the ATLAS strategy for online b-jet selection for the LHC Run 2, including the use of novel methods and sophisticated algorithms designed to face the above mentioned challenges. The evolution of the performance of b-jet triggers in Run 2 data is presented, including the use of novel triggers designed to select events containing heavy flavour jets in heavy ion collisions.

Development of magnetic fields in cosmic string wakes

Author: Sovan Sau

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We describe a novel method of generating magnetic fields in cosmic string wakes from neutrino currents. We show that neutrino currents act as a cross-perturbation across the cosmic string wake. This cross perturbation along with the high Reynolds number generates a magnetic field in the wake of the cosmic string. The neutrino current is generated by the neutrinos rotating around the Abelian Higgs strings. As the string moves through the cosmic plasma, the velocity kick generated by the motion of the string will enhance the neutrino current in the wake region. The neutrino current density depends on its distance from the string and is oscillatory in nature. This leads to neutrino density gradients in the plasma. We have shown that these neutrino gradients give rise to electron gradients in the plasma, which in turn generate magnetic fields of the order of $10^{13}$ Gauss.

Performance of the ATLAS Tile Calorimeter

Author: Siarhei Harkusha

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The Tile Calorimeter (TileCal) is a sampling hadronic calorimeter covering the central region of the ATLAS experiment, with steel as absorber and plastic scintillators as active medium. The scintillators are read-out by the wavelength shifting fibres coupled to the photomultiplier tubes (PMTs). The analogue signals from the PMTs are amplified, shaped, digitized by sampling the signal every 25 ns and stored on detector until a trigger decision is received. The TileCal frontend electronics reads out the signals produced by about 10000 channels measuring energies ranging from about 30 MeV to about 2 TeV. Each stage of the signal production from scintillation light to the signal reconstruction is monitored and calibrated. During LHC Run-2, high-momentum isolated muons have been used to study and validate the electromagnetic scale, while hadronic response has been probed with isolated hadrons. The calorimeter time resolution has been studied with multi-jet events. A summary of the performance results, including the calibration, stability, absolute energy scale, uniformity and time resolution, will be presented.

Upgrade of ATLAS Hadronic Tile Calorimeter for the High Luminosity LHC

Author: Seyedali Moayedi

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The Tile Calorimeter (TileCal) is a sampling hadronic calorimeter covering the central region of the ATLAS experiment, with steel as absorber and plastic scintillators as active medium. The High-Luminosity phase of LHC, delivering five times the LHC nominal instantaneous luminosity, is expected to begin in 2026. TileCal will require new electronics to meet the requirements of a 1 MHz trigger, higher ambient radiation, and to ensure better performance under high pileup conditions. Both the on- and off-detector TileCal electronics will be replaced during the shutdown of 2024-2025. PMT signals from every TileCal cell will be digitized and sent directly to the back-end electronics, where the signals are reconstructed, stored, and sent to the first level of trigger at a rate of 40 MHz. This will provide better precision of the calorimeter signals used by the trigger system and will allow the development of more complex trigger algorithms. The modular front-end electronics feature radiation-tolerant commercial off-the-shelf components and redundant design to minimise single points of failure. The timing, control and communication interface with the off-detector electronics is implemented with modern Field Programmable Gate Arrays (FPGAs) and high speed fibre optic links running up to 9.6 Gb/s. The TileCal upgrade program has included extensive R&D and test beam studies. A Demonstrator module with reverse compatibility with the existing system was inserted in ATLAS in August 2019 for testing in actual detector conditions. The ongoing developments for on- and off-detector systems, together with expected performance characteristics and recent results of test-beam campaigns with the electronics prototypes will be discussed.
Tracking and flavor-tagging performance at ATLAS

Author: Carlo Varni

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The identification of jets originating from heavy-flavour quarks (b, c) is central to the LHC physics program. High-performance flavour tagging is necessary both in precise Standard Model measurements and in searches for new physics. To achieve this, distinct characteristics of heavy-flavour decays are exploited, such as the presence of secondary vertices and displaced particles. This requires an accurate picture of the charged-particle activity within jets, which is obtained performing efficient and precise track reconstruction in the ATLAS Inner Detector. After providing details on the role of track reconstruction in b-tagging, we present the latest heavy-flavour jet tagging algorithms developed by the ATLAS collaboration. In addition we report, for both track reconstruction and flavour tagging tasks, recent performance results as expected in simulation and as measured in collision data.

Efficiency calibrations for ATLAS b-jet identification algorithms

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Many analyses in ATLAS rely on the identification of jets containing b-hadrons (b-jets) at high efficiency while rejecting more than 99% of non-b-jets. Identification algorithms, called b-taggers, exploit b-hadron properties such as their long lifetime, their high mass, and high decay multiplicity to achieve this. Recently developed ATLAS b-taggers using neural networks are expected to outperform previous b-taggers by a factor of two in terms of non-b-jet rejection. The performance of these taggers is measured in data, and simulated LHC collision events are corrected to reflect the data performance through calibration scale factors. Due to recent improvements in measurement procedures, the data efficiency precision is at the level of a few percent for b-jet identification efficiency and at the level of 10-20% for light- and charm-jet mistag rates. The methods to calibrate the b-jet identification and the charm- and light-jet mistag efficiencies of the recent b-taggers and the calibration results will be presented in this poster.

Luminosity Determination using Z->ll Counting for Run-2 ATLAS Data

Author: Michael William O’Keefe

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During Run 2, LHC delivered instantaneous luminosities of \( \approx 10^{34} \, \text{cm}^{-2} \, \text{s}^{-1} \) at \( \sqrt{s} = 13 \, \text{TeV} \). This permitted monitoring of the luminosity over a time granularity as short as 60 s, using the counts of \( Z \to \ell \ell \) events reconstructed by selecting two, well-identified high \( p_T \) electrons or muons in the invariant mass range of \( 66 < m_{\ell \ell} < 116 \, \text{GeV} \).

The poster illustrates the measurement principles based on time-dependent trigger and reconstruction efficiency corrections and shows the stability of using both \( Z \to ee \) and \( Z \to \mu\mu \) boson counting as luminometers. Emphasis is given to illustrate with selected LHC run examples the robustness of the method with respect to pile-up and the LHC bunch structure, which are of particular importance for reliable luminosity monitoring at the upcoming high luminosity phase of the LHC.

### Measuring luminosity with track counting in the ATLAS experiment

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The precise measurement of the luminosity is one of the key requirements for every ATLAS analysis at the Large Hadron Collider (LHC) at CERN. Particularly in high precision experiments, the uncertainty on the luminosity can be one of the main limitations. Therefore, its reduction is the prime goal of the ATLAS luminosity program, requiring a precise understanding of the contributing factors. The two largest individual components are the calibration transfer and the long term stability, both being determined involving the track counting luminosity measurement. The track counting method uses the average number of reconstructed charged particle tracks in the ATLAS Inner Detector as measure for the instantaneous luminosity in proton-proton collisions.

In the track counting luminosity measurement, a number of effects influence the measured number of tracks. These include, for example, the number of simultaneous pp collisions, denoted as \( \mu \), and the filling pattern of the individual proton bunches.

The poster discusses the impact of the different components on the uncertainty of the luminosity measurement in general and the track counting luminosity measurement in particular. The primary focus is the dependence on the LHC filling pattern. A better understanding of these effects will help to reduce the uncertainty in the ATLAS luminosity measurement.
With the upgraded beam luminosity in LHC run-3, the detector technology for the innermost end-cap muon station (Small Wheel) of the ATLAS detector needs to be upgraded. The new technology should be able to meet the demands of better position resolution, high efficiency, fast response at the expected high background rate. The detectors for precision tracking and triggering at the New Small Wheel (NSW) will be Micromegas (MM) and small strip Thin Gas Chamber (sTGC). The detectors are also complementary to each other. Each of the two NSWs will consist of 8 large and 8 small sectors. A sector is a combination of the sTGC wedges on either side of a double Micromegas wedge. The Micromegas quadruplets are received at CERN from different construction sites. 4 MM quadruplets are integrated to build a MM double wedge. After the electronic integration is completed, the double wedges are tested with cosmic muons at the Cosmic Stand of B899 at CERN (BB5). There is a sequence of procedures for testing the double wedges at the Cosmic Stand. Here, we make sure of the final high voltage configuration, measure the efficiency, cluster size, strip multiplicity per readout layers of the double wedge and qualify the Micromegas sector for the final integration with the sTGC wedges before mounting them on the New Small Wheel. The procedure and the final results from the MM double wedges will be presented.

Operation, Performance and Upgrade of Present Detectors / 513

Performance of the LHCb detector in the Run 2

Author: Martina Pili

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The LHCb experiment is a flavour physics detector, designed to study decays of b and c hadrons for measurements of CP violation and rare decays. Its performance is based on precision tracking and particle-identification systems. In order to accomplish its wide program of physics measurements, the LHCb collaboration has developed in the past years a set of algorithms for reconstruction of the trajectories of charged particles, as well as identification of charged and neutral particles. Several data-driven approaches have been developed to provide a precise calibration of the tracking and particle-identification efficiencies, which are crucial ingredients of many physics analysis. A number of novel strategies have been developed during Run 2 of the LHC to improve the precision of this calibration. This talk presents an overview of the LHCb performance in Run 2 of the LHC, with emphasis on recent improvements.

Collection of web tools for ATLAS Tile Calorimeter data quality tasks

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The ATLAS Tile Calorimeter (TileCal), as a substantial part of the hadronic calorimeter system of the ATLAS detector, records energy deposits and jointly with other calorimeters reconstructs hadrons, jets, tau-particles and missing transverse energy. It also assists in muon identification. The TileCal is the hadronic sampling calorimeter, which is constructed out of alternating iron absorber layers and active scintillating tiles and covers region |eta| < 1.7. Its operation is closely monitored by several systems, which were independently developed to meet distinct collaboration requirements. Any problem or indication of a problem is reported and immediately investigated, which resulted in data quality (DQ) efficiency close to 100% in the last several years. Although the TileCal tools are maintained and still being developed, the underlying technologies on which they were developed, especially web related tools, are becoming gradually outdated.

The goal of the Tile-in-One (TiO) web platform is to integrate all the different TileCal DQ tools, independently developed over long period of time by different groups and individuals into one cohesive system without any non-necessary overlap in functionality. It is implemented as a collection of relatively small independent web applications designed for one specific task, which are accessed through the main TiO server, which handles the authentication. Every application is isolated in its own virtual machine and is called plugin. Currently, the platform operates with around 13 plugins in various stages of development and focuses not only on reimplementing of the old tools but also creation of new ones. The implementation details of the Tile-in-One web platform and also a selection of plugins will be presented.

I read the instructions:

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors - Posters / 515

Measurements of Luminosity in ATLAS with Tile Calorimeter

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Luminosity measurements in ATLAS are provided primarily by LUCID detector, but rely on other detectors for determining the systematics associated with this measurement. The Tile Calorimeter, the central hadronic calorimeter at the ATLAS experiment, plays an especially important role because the Tile luminosity measurement is independent of pileup, a feature shared with the Track counting luminosity measurement. Comparison of the LUCID luminosity measurements in different run conditions to those obtained by Tile and Tracking, as well as a comparison of Tile to Tracking, is used to measure and study the dominate systematic uncertainty associated with the LUCID Luminosity measurement. Here the methods of measuring ATLAS luminosity with the Tile Calorimeter and its transformation to a systematic uncertainty are described.

I read the instructions:

Secondary track (number):

Computing and Data Handling / 516
Fast Simulations at LHCb

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The LHCb detector at the LHC is a single-arm forward spectrometer designed for the study of b- and c-hadron states. During Run 1 and 2, the LHCb experiment has collected a total of 9/fb of data, corresponding to the largest charmed hadron dataset in the world and providing unparalleled datasets for studies of CP violation in the B system, hadron spectroscopy and rare decays, not to mention heavy-ion and fixed-target datasets. The LHCb experiment is currently undergoing an upgrade to nearly all parts of the detector to cope with the increased luminosity of Run 3 and beyond. Simulation for the analysis of such datasets is paramount, but the detailed simulation of the detector response would be prohibitively slow and prevent the production of sufficient simulated events to fully exploit the datasets that will be collected. In this talk, we explore the suite of fast simulations which LHCb has employed to meet the needs of the Run 3 and beyond, including the reuse of the underlying event and parameterized simulations, and the possibility of porting the framework to multithreaded environments.

I read the instructions:

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Operation, Performance and Upgrade of Present Detectors - Posters / 517

ATLAS Tile Calorimeter time calibration, monitoring and performance in Run 2

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The Tile Calorimeter (TileCal) is the central section of hadronic calorimeter of the ATLAS experiment at the LHC. This sampling device uses steel plates as absorber and scintillating tiles as active medium and its response is calibrated to electromagnetic scale by means of several dedicated calibration systems.

The accurate time calibration is important for the energy reconstruction, non-collision background removal as well as for specific physics analyses. The initial time calibration using so-called splash events and subsequent fine-tuning with collision data are presented. The monitoring of the time calibration with laser system and physics collision data is discussed as well as the corrections for sudden changes performed still before the recorded data are processed for physics analyses. Finally, the time resolution as measured with jets in Run 2 is presented.

I read the instructions:

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Computing and Data Handling / 518

Fast calorimeter simulation at LHCb

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During Run 2, the simulation of physics events at LHCb has taken about 80% of the distributed computing resources available to the experiment. The large increase in luminosity and trigger rates with the upgraded detector in Run 3 will require much larger simulated samples to match the increase of collected data. About 50% of the overall CPU time in the simulation of physics events is spent in the calorimeter system. In this talk we describe the solution adopted in Gauss, the LHCb simulation software framework, to avoid the need to simulate the calorimeter response to particles with the Geant4 toolkit, instead inserting the corresponding hits in a with a fast simulation. Two paths are being pursued to simulate the hits, based on libraries of pre-simulated energy deposits, or using machine-learning techniques for their generation at runtime. We discuss the performance of both approaches and their readiness in view of the start of Run 3.

I read the instructions:

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 519

Flexible physics selections at 30 MHz

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The first LHCb upgrade will take data at an instantaneous luminosity of 2E33cm⁻²s⁻¹ starting in 2021. Due to the high rate of beauty and charm signals LHCb has chosen as its baseline to read out the entire detector into a software trigger running at the LHC collision frequency of 30MHz. This High Level Trigger will enable unprecedented flexibility for trigger selections. In this talk we present the challenges of triggering in the MHz signal era. We pay particular attention to the need for flexibility in the selection and reconstruction of events without sacrificing performance. We also discuss the most important benchmarks for the selection at Run 3.

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Operation, Performance and Upgrade of Present Detectors / 520

Physics and throughput performance of the real-time reconstruction for the LHCb upgrade

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In the beginning of 2021, the upgraded LHCb experiment will use a triggerless readout system collecting data at an event rate of 30 MHz. During the first stage of High-Level Trigger (HLT1), a
sub-set of the full offline track reconstruction for charged particles is run to select particles of interest based on single or two-track selections. After this first stage, the event rate is reduced by at least a factor 30. Track reconstruction at 30 MHz represents a significant computing challenge, requiring a renovation of current algorithms and the underlying hardware. In this talk both the computing and physics performance of the full HLT1 chain will be presented. We will particularly focus on the development of highly parallel algorithms optimized for many-core architectures.

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Operation, Performance and Upgrade of Present Detectors / 521

Real-time alignment, calibration, and software quality assurance for the LHCb upgrade

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In this talk, we will present an overview of the LHCb trigger during Runs I and II, including real-time calibration of the detector, and detail plans for the trigger to be used during Run III of the experiment. For Run III data-taking, the level-0 hardware trigger used in the previous runs has been removed, requiring the first stage of the software trigger to process events at the LHC bunch-crossing rate of 30 MHz. In order to achieve this goal, an unprecedented effort in all the real-time systems will be needed. The talk focuses primarily on real-time alignment and calibration of detector performance. The ways of making the throughput flawless in terms of software will also be discussed.

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Computing and Data Handling / 522

The evolution of the LHCb offline computing towards the Run3 Upgrade

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The LHCb experiment is being upgraded for data taking in 2021 and subsequent years. The offline computing model is undergoing several changes that are needed in order to cope with the much higher data volumes originating from the detector and the associated demands of simulated samples of ever-increasing size. This contribution presents the evolution of the data processing model, followed by a review of the various activities in the domains of core software, software infrastructure,
LHCb is one of the four main experiments operating at the LHC and it is dedicated to measurements of CP violation and to the search for new physics beyond Standard Model in the rare decays of hadrons containing heavy quarks. Particle identification information (PID) at LHCb is provided by two Ring Imaging Cherenkov systems, RICH1 and RICH2. The two LHCb RICH detectors operated at the luminosity of $4 \times 10^{32}$ cm$^{-2}$s$^{-1}$, providing an excellent PID until the end of Run2 in 2018. From the beginning of Run3 in 2021 the Level 0 hardware trigger of the experiment will be removed to allow a data readout at the full rate of 40 MHz and the luminosity will be increased to $2 \times 10^{33}$ cm$^{-2}$s$^{-1}$. In order to adapt the RICH system to the new readout rate the current HPD detectors with embedded electronics limited to readout event rate of 1 MHz will be replaced by MaPMTs with external readout electronics. Moreover, in order to maintain the average occupancy of the old RICH detector in the upgraded configuration, a reoptimization of the optics is required. In this talk the state of the art of the upgraded opto-electronics chain and the performance expected for Run3 will be presented together with the automated procedures to test the quality of the RICH photon detectors and support electronics.

In the LHCb Upgrade there will be four layers of tracking provided using silicon strips located after the Vertex Locator and in the fringe field in front of the analysis magnet, allowing for a fast determination of track momentum, essential for the software only trigger. We will discuss the design, including novel features such as embedded pitch adaptors and top-side HV bias, as well as construction progress, and the increase of the physics potential provided by this detector.
Flavour Physics at the High Luminosity LHC: LHCb Upgrade II

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The LHCb Collaboration is planning an Upgrade II, a flavour physics experiment for the high luminosity era. This will be installed in LS4 (2030) and targets an instantaneous luminosity of $1.5 \times 10^{34}$ cm$^{-2}$ s$^{-1}$, and an integrated luminosity of at least 300fb$^{-1}$. Consolidation of the current experiment will also be introduced in LS3 (2025). Physics goals include probing new physics scenarios in lepton flavour universality, obtaining unprecedented precision on CKM tests, and expanding the LHCb programme into new measurement areas such as Higgs decays to charm. The detector design options include the introduction of timing information with tens of ps resolution across multiple subdetectors. Opportunities for novel detector development are available across 4D vertexing, MAPS and scintillating fibre tracking, 5D electromagnetic calorimetry, hadron particle identification, DAQ and triggering. Preliminary studies for the LHC suggest that the luminosity goals will be achievable. Following the issue of a physics case and accelerator note in 2018, the collaboration was approved by the LHCC to proceed to the preparation of a TDR and R&D programmes are underway across all subdetectors.

I read the instructions:

Secondary track (number):
12

The LHCb VELO Upgrade

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The LHCb experiment is a detector at the LHC designed to capture decays of b- and c-hadrons for the study of CP violation and rare decays. At the end of Run-II, many of the LHCb measurements remain statistically dominated. For this reason the experiment is currently being transformed, in the Upgrade I programme, to run at higher luminosity from Run III onwards. The trigger scheme will be transformed to read out at 40 MHz to a flexible software trigger. In order to allow the new readout scheme the front end electronics will be changed, and the detectors need cope with the increased occupancy and radiation levels anticipated at the upgrade. The Vertex Locator (VELO) surrounding the interaction region, whose role is to reconstruct and trigger on the primary and secondary vertices of the events.

The upgraded VELO is composed of 52 hybrid silicon pixel modules placed along the beam axis, divided into 2 retractable halves. Each module is equipped with 4 silicon pixel tiles, each read out by 3 VeloPix ASICs. The pixels have a square pitch of 55 microns and the sensors are produced in 0.2 mm thick p-in-n type silicon. The sensors must withstand an integrated fluence of $\mu$m$^{-2}$, a roughly equivalent dose of 400 MRad. The highest occupancy ASICs will have pixel hit rates of 800 Mhit/sf, with a total rate of 1.6 Tbit/s for the whole detector. The VELO upgrade tiles are mounted onto a cooling substrate made of thin silicon plates with embedded micro-channels that allow the flow of...
liquid CO$_2$. The secondary vacuum in which the modules are located is separated from the beam vacuum by a thin custom made foil. This foil is be manufactured through a novel milling process and possibly thinned further by chemical etching. The upgraded VELO is currently under construction. The detector R&D, module thermal performance, and the VELO Upgrade production status will be presented.

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Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 527

The LHCb VELO Upgrade Programme for High Luminosity running at the LHC and HL-LHC

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The detector currently under construction is designed to run throughout Run 3 and 4, after which a further major Upgrade will be implemented to enable the LHCb Upgrade II physics goals. The Upgrade II detector is designed to run at instantaneous luminosities of $2 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$, an order of magnitude above Upgrade I, and accumulate a sample of more than 300 fb$^{-1}$. At this intensity, the mean number of visible proton-proton interactions per crossing would be 56, producing around 2500 charged particles within the LHCb acceptance. The Upgrade II programme is reliant on an efficient and precise vertex detector (VELO). This subdetector enables real time reconstruction of tracks from all LHC bunch crossings in the software trigger system. The Upgrade II luminosity poses significant challenges which necessitate the construction of a new VELO with enhanced capabilities. Compared to Upgrade I there will be a further order of magnitude increase in data output rates accompanied by corresponding increases in radiation levels and occupancies. To cope with the large increase in pile-up, new techniques to assign correctly each b hadron to the primary vertex from which it originates, and to address the challenge of real time pattern recognition, are needed. These challenges will be met by the development of a new 4D hybrid pixel detector with enhanced rate and timing capabilities in the ASIC and sensor. Improvements in the mechanical design of the Upgrade II VELO will also be needed to allow for periodic module replacement. The design will be further optimised to minimise the material before the first measured point on a track (which is dominated by the secondary vacuum enclosure) and to achieve a more fully integrated module design with thinned sensors and ASICs combined with a lightweight cooling solution. It is envisaged that the readout ASIC will follow the VeloPix/Timepix4 development path with a novel design including in-pixel timing and calibration, allowing the pixel time stamps to reach a precision of 10s of picoseconds, and a new custom output serialiser will be included. The R&D programme will explore the capabilities of combining fast timing information with small pixel size, and examine clock distribution issues for fine timing over a full system. The capabilities of the sensor to deliver fast timing will be explored for different sensor designs. The needs of the Upgrade II VELO will be outlined, along with the R&D steps envisaged to achieve the goal of a 4D pixel tracker.

I read the instructions:

Secondary track (number):
12
The LHCb Upgrade Programme for Run 3 and Run 4

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The LHCb experiment at the LHC is designed to capture decays of b- and c-hadrons for the study of CP violation and rare decays. It has already had a transformative impact in the field of flavour physics as well as making many general purpose physics measurements in the forward region. At the end of Run-II, many of the LHCb measurements will remain statistically dominated. For this reason the experiment is being upgraded in a first step - Upgrade I - to run at higher luminosity of \(2 \times 10^{33} \text{cm}^{-2} \text{s}^{-1}\) after 2020. The trigger scheme, which currently has a 1 MHz lowest level hardware rate, will be transformed to a strategy whereby the entire experiment is read out at 40 MHz to a flexible software trigger. The increased luminosity and trigger efficiency anticipated at the upgrade will allow a huge increase in precision, in many cases to the theoretical limit, and the ability to perform studies beyond the reach of the current detector. In addition the flexible trigger and unique acceptance opens up opportunities in topics apart from flavour, reinforcing the role of LHCb as a general purpose detector in the forward region In order to allow the triggerless readout the front-end electronics of all subdetectors will be changed, and many subdetectors will be upgraded to cope with the increased occupancy and radiation levels. During the long shutdown between Run 3 and Run 4 the most irradiated parts of the detector will be replaced and other detector consolidation and improvement steps will be carried out.

Neutrino Physics / 529

Cryogenic Instrumentation at ProtoDUNE

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The Deep Underground Neutrino Experiment (DUNE) is a next-generation long-baseline experiment. The DUNE far detectors are based on liquid argon time projection chamber (LArTPC) technology. The large DUNE far detector single-phase (ProtoDUNE-SP) and dual-phase (ProtoDUNE-DP) LArTPC prototypes at CERN have taken beam and cosmic data in 2018-2020. In this talk, we will discuss the design and the first results of ProtoDUNE’s cryogenic instrumentation aimed towards understanding liquid argon quality and behavior, along with providing input to calibration.
Purity monitoring for ProtoDUNE

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The next-generation neutrino experiment, DUNE, will utilize a high-intensity neutrino beam produced to measure electron-neutrino appearance and muon-neutrino disappearance with its 40 kiloton (fiducial mass) liquid argon far detector. Liquid argon purity is crucial to use liquid argon time projection chambers (LArTPC) in DUNE’s large detectors. A purity monitor is a miniature TPC that measures the lifetime of photoelectrons generated by its UV-illuminated gold photocathode to measure the purity of liquid argon. ProtoDUNE is a full-scale DUNE prototype LArTPC built at CERN and performs beam tests. This poster will discuss the design, implementation, and results of liquid argon purity monitors deployed in ProtoDUNE.

Movable Thermometer System in ProtoDUNE

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The movable temperature profiler is a 7m vertical array of 22 sensors which measure cryogenic temperatures with a precision of a few mK. This precision is necessary to monitor the efficiency of recirculation and purification of liquid argon inside large liquid argon-based neutrino detectors. Liquid argon temperature impacts electron (signal) drift velocity, liquid argon flow, purity distribution and thus the overall energy calibration. The temperature profiler is motorized and moves vertically, while in the detector, and cross-calibrates neighboring sensors. The temperature offsets between each sensor cancel the effects of electromagnetic noise. This poster reports on the temperature measurements and such in-situ cross-calibrations at ProtoDUNE (single phase) at CERN.
Measurement of the Higgs boson production in association with top quarks in final states with multileptons using data taken during the Run 2 of the LHC with CMS

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The production of the Higgs boson in association with a pair of top quarks is studied in final states with multiple leptons using proton-proton collision data collected by the CMS experiment at √s = 13 TeV centre-of-mass energy, during the Run 2 of the LHC. Machine learning and matrix element techniques are used to enhance the sensitivity of the analysis by discriminating signal and backgrounds. The measured production rates are used to determine constraints on the Yukawa coupling of the Higgs boson to the top quark.

Strong Interactions and Hadron Physics / 533

ALICE measurements of Ξ- and Ω-nucleon interactions and constraints on lattice QCD potentials

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A precise understanding of the Equation of State of dense objects like neutron stars is limited by the knowledge about hyperon interactions and the precision of the models describing the latter. Recently, the ALICE Collaboration has demonstrated that two-particle correlation measurements, which are sensitive to the source of particle emission and to the interaction of the particle pair, can provide precise data on hyperon-nucleon and hyperon-hyperon interaction potentials. In small collision systems this makes it possible to map the core of the potential at small distances and is currently the only viable way to provide a sensitive experimental measurement against which theoretically predicted potentials can be tested. In this talk we show the first precise study of the pΞ and pΩ interactions, measured in pp collisions at 13 TeV with the ALICE detector. For the first time, clear signatures of the strong attractive interaction can be observed for these particles.

Traditionally, meson exchange models are used to describe the hyperon sector and are constrained by the scarce scattering and hypernuclei data, almost exclusively available for Λ hyperons. Recently the HAL-QCD collaboration conducted calculations without relying on constraints by data and with quarks and gluons as degrees of freedom. Their results converge for the interactions between heavier Ξ and Ω hyperons and nucleons, and in the pΩ system they predict a bound state. The potentials provided by HAL-QCD calculations and meson-exchange are applied to describe the experimentally measured correlation function. For the pΞ interaction the HAL-QCD prediction is strongly favoured by the data compared to the meson-exchange model. For the pΩ channel, strongly bound systems are largely excluded and the comparison between data and calculations only leaves room for binding energies below 1 MeV.
**Probing the prospective FCC-he sensitivities on the electromagnetic dipole moments of the top-quark**

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The measurement of the top-quark anomalous electromagnetic couplings is one of the most important goals of the top-quark physics program in the present and future collider experiments. This would provide direct information on the non-standard interactions of the top-quark. We study a top-quark pair production scenario at the Future Circular Hadron-Electron Collider (FCC-he) through \(e^-p \rightarrow e^-\gamma p \rightarrow \bar{t}\nu_e bp\) collisions, which will provide information about sensitivities on anomalous \(\hat{a}_V\) and \(\hat{a}_A\) couplings at a 95% C.L., and the possibility of probing new physics.

**Secondary track (number):**

08

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**Direct comparison of sterile neutrino constraints from cosmological data, electron neutrino disappearance data and muon neutrino to electron neutrino appearance data in a 3+1 model**

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We present a quantitative, direct comparison of constraints on sterile neutrinos derived from neutrino oscillation experiments and from Planck data, interpreted assuming standard cosmological evolution. We extend a 1 + 1 model, which is used to compare exclusions contours at the 95% CL derived from Planck data to those from \(\nu_e\)-disappearance measurements, to a 3 + 1 model. This allows us to compare the Planck constraints with those obtained through \(\nu_\mu \rightarrow \nu_e\) appearance searches, which are sensitive to more than one active-sterile mixing angle. We find that the cosmological data fully exclude the allowed regions published by the LSND, MiniBooNE and Neutrino-4 collaborations, and those from the gallium and rector anomalies, at the 95% CL. Compared to the exclusion regions from the Daya Bay \(\nu_e\)-disappearance search, the Planck data are more strongly excluding above \(|\Delta m^2_{41}| \approx 0.1 \text{ eV}^2\) and \(m^\text{sterile} \approx 0.2 \text{ eV}\), with the Daya Bay exclusion being stronger below these values. Compared to the combined Daya Bay/Bugey/MINOS exclusion region on \(\nu_\mu \rightarrow \nu_e\) appearance, the Planck data is more strongly excluding above \(\Delta m^2_{31} \approx 5 \times 10^{-2} \text{ eV}^2\), with the exclusion strengths of the Planck data and the Daya Bay/Bugey/MINOS combination becoming comparable below this value.

**Secondary track (number):**

08
**Higgs Physics / 536**

**Higgs boson pair production at N3LO QCD**

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The Higgs boson pair production via gluon fusion at high-energy hadron colliders, such as the LHC, is vital in deciphering the Higgs potential and in pinning down the electroweak symmetry breaking mechanism. We carry out the next-to-next-to-next-to-leading order (N3LO) QCD calculations in the infinite top-quark mass limit. Such corrections are indispensable in stabilising the perturbative expansion of the cross section in the strong coupling constant. Given that the inclusion of the top-quark mass effects is essential for the phenomenological applications, we use several schemes to incorporate the N3LO results in the infinite top-quark mass limit and the next-to-leading order (NLO) results with full top-quark mass dependence. Our results provide one of the most precise theoretical predictions for the process.

**Heavy Ions / 537**

**Measurements of open charm hadrons in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV by the STAR experiment**

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At RHIC energies, charm quarks are primarily produced at early stages of ultra-relativistic heavy-ion collisions, in hard partonic scatterings. This makes them an excellent probe of the Quark-Gluon Plasma (QGP) since they experience the whole evolution of the hot and dense medium. STAR is able to study the production of charm quarks and their interaction with the QGP through direct reconstruction of hadronic decays of $D^\pm$, $D^0$, $D_{s}$, and $\Lambda^\pm_c$ hadrons. This is possible thanks to the excellent vertex resolution provided by the Heavy Flavor Tracker.

In this talk, we will present the most recent results on open charm hadron production in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV from the STAR experiment. In particular, we will discuss the nuclear modification factors of $D^\pm$ and $D^0$ mesons which give access to the charm quark energy loss in the QGP, and also $D_s/D^0$ and $\Lambda_c^+/D^0$ yield ratios as functions of transverse momentum and collision centrality which help us better understand the charm quark hadronization process in heavy-ion collisions. In addition, we will present the rapidity-odd directed flow of $D^0$ mesons, which can be used to probe the initial tilt of the QGP bulk and effects of early-time magnetic field.
Neutrino Physics - Posters / 538

**Status of the Veto System of JUNO**

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The JUNO experiment is under construction in China. Its main goal is to determine the neutrino mass ordering via the precise measurement of the energy spectrum of anti-neutrinos from nuclear reactors 53 km away.

For JUNO’s measurements, it is essential to suppress and control the background rate that mimic the signal from anti-neutrinos in the Central Detector (CD). The backgrounds that are hardest to identify are the cosmogenic isotopes produced by atmospheric muons crossing the detector.

To suppress this background, a veto will be applied along the muon track. The Veto System will be employed to provide precise information about passing muons. The Veto System of JUNO consists of the Water Cherenkov Detector (WCD), an instrumented ultra-pure water buffer surrounding the CD, and the Top Tracker, a 3-layers plastic scintillator detector covering ~1/3 of the area above the WCD.

This poster will discuss JUNO’s Veto System design, status and expected performance.

Secondary track (number):

**Beyond the Standard Model / 539**

**Z polarization as a probe of anomalous gauge-Higgs couplings**

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We show how the $Z$ boson polarization can be used to study the $ZH$ production at future $e^+e^-$ colliders and at the LHC. We calculate the 8 independent polarization parameters of the spin-1 $Z$ boson which are sensitive to anomalous gauge-Higgs couplings, using $Z$ spin density matrix. By constructing angular asymmetries from the $Z$ boson decay leptons, which are related to the polarization observables, we constrain the anomalous $ZZH$ couplings. Taking into account possible longitudinal beam polarizations at two different center of mass energies, we find that oppositely polarized beams at 500 GeV c.m. energy provides tighter bounds on the couplings than the same sign polarized and unpolarized beams. We find that most of the $1\sigma$ limits are of the order of a few times $10^{-3}$ for 14 TeV LHC with integrated luminosity of 1000 fb$^{-1}$ and for 500 GeV $e^+e^-$ colliders with oppositely polarized beams.

Secondary track (number):

**Strong Interactions and Hadron Physics / 541**
**ω and η′ production in proton-proton collisions at the LHC measured with ALICE**

**Author:** Florian Jonas

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While the ω and η′ mesons are composed out of the lightest quarks, they are among the heaviest vector and pseudoscalar mesons, respectively, without having net strangeness. As such, they serve as ideal laboratory to test and constrain perturbative quantum chromodynamics in a regime where it is difficult to constrain the fragmentation of the lightest quarks into the different hadrons. Furthermore, the ω/π⁰ particle momentum distribution ratio carries information about the probability of the corresponding spin states to be produced in the hadronization as they consist of the same quarks. In addition, their measurements in pp collisions provide a baseline for heavy-ion collisions, where a large fraction of the mesons will decay within the produced quark-gluon plasma, which might lead to a change of the mass and/or width of the meson with respect to their values in vacuum.

In this talk, the first results on the ω production cross sections at mid-rapidity in pp collisions at √s = 7 and 13 TeV measured in the π⁺π⁻π⁰ decay channel by the ALICE collaboration will be presented. These spectra reach unprecedented transverse momenta and complement the overall picture of parton fragmentation into neutral mesons. They will be compared to different event generators and a recent next-to-leading order calculation attempting to simultaneously describe the fragmentation into ω and ϕ mesons using a broken SU(3) symmetry. Furthermore, the first results on the η′ production in the ALICE central barrel detectors will be presented using the γγ and π⁺π⁻η decay channels.

I read the instructions:

Secondary track (number):

**Top Quark and Electroweak Physics - Posters / 542**

**Probing the structure of weak interactions**

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The Standard Model as a very successful theory of electroweak interactions postulates the basic assumption about the pure „V(ector)-A(xial vector)” character of the interaction. Nevertheless, even after more than half a century of development of the model and experimental testing of its fundamental ingredients, experimental data still rule out the existence of other types of weak interactions (Scalar, Tensor) only at the few % level. Low-energy searches for these „forbidden components” studying e.g. beta-neutrino angular correlations in beta-decay are complementary to high-energy experiments e.g. at the LHC.

A new project at ISOLDE/CERN to search for these forbidden components of weak interactions (or at least significantly improve their current experimental limits) WISArD (Weak-Interaction Studies with 32Ar Decay) is being prepared. Experimental setup WISArD online on the beam of isotope separator ISOLDE plans to probe the existence of scalar currents in the weak interactions via the study of beta-delayed protons emitted in the decay of 32Ar. High precision measurement of the kinematic energy shift of the protons emitted from the isobaric analogue state in moving recoil nuclei 32Cl after the beta-decay of 32Ar carries information about beta-neutrino angular correlations (different compared to the dominant Vector current).

Current status of the WISArD setup, first results of the commissioning proof-of-principle runs and perspectives of the present approach with its potential final precision will be presented.
Computing and Data Handling / 543

MARTY: a C++ symbolic computation library for High Energy Physics

Author: Grégoire Uhlrich

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Studies Beyond the Standard Model (BSM) will become more and more important in the near future with a rapidly increasing amount of data from different experiments around the world. The full study of BSM models is in general an extremely time-consuming task involving long and difficult computations. It is in practice not possible to do exhaustive predictions in these models by hand, in particular if one wants to perform a statistical comparison with data and the SM. Some Mathematica packages can perform this kind of computations automatically. However we are some times interested in a different formulation of a given theory, a low energy effective theory. In this case, one must compute Wilson coefficients instead of amplitudes. This is the case in flavor physics, the study of flavor-changing quark currents which concentrates many hopes of new physics discovery, where physical observables are fully expressed in terms of an effective theory.

Here we present CSL (C++ Symbolic computation Library) together with CSL-HEP (CSL extended for High Energy Physics), a new C++ framework that fully automates computations from the lagrangian to physical quantities such that amplitudes or cross-sections. This framework can fully simplify, automatically and symbolically, physical quantities in a very large variety of models. CSL-HEP can also compute Wilson coefficients for arbitrary operators in an effective theory. This will considerably facilitate the study of BSM models in flavor physics.

CSL-HEP aims to give a unique, free, open-source, powerful and user-friendly tool for high-energy physicists studying predictive BSM models, in effective or full theories, up to the 1-loop order. With a few lines of code and in very little time (less than a second to a few seconds for one process) one can gather final expressions that may be evaluated numerically for statistical analysis. Features like automatic generation and manual edition of Feynman diagrams, exhaustive and comprehensive manual and documentation, clear and easy to handle user interface, will make the life of users easier.
The International Particle Physics Outreach Group - Reaching Across the Globe with Science

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The International Particle Physics Outreach Group (IPPOG) is a network of scientists, science educators and communication specialists working across the globe in informal science education and outreach for particle physics. The primary methodology adopted by IPPOG requires the direct involvement of scientists active in current research with education and communication specialists, in order to effectively develop and share best practices in outreach. IPPOG member activities include the International Particle Physics Masterclass programme, International Day of Women and Girls in Science, Worldwide Data Day, InternationalMuon Week and International Cosmic Day organisation, and participation in activities ranging from public talks, festivals, exhibitions, teacher training, student competitions, and open days at local institutions. These independent activities, often carried out in a variety of languages to public with a variety of backgrounds, all serve to gain the public trust and to improve worldwide understanding and support of science. We present our vision of IPPOG as a strategic pillar of particle physics, fundamental research and evidence-based decision-making around the world.

Secondary track (number):

Beyond the Standard Model - Posters / 545

New physics contributions to muon anomalous magnetic moment and kinetic mixing in left-right model

Authors: Prativa Pritimita; Urjit Yajnik; Sudhanwa Patra; Chayan Majumdar; Supriya Senapati

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We estimate the new physics contributions to the calculation of muon anomalous magnetic moment, \( a_\mu \), in a \( U(1)_{L_\mu - L_\tau} \) extension of left-right symmetric model based on the gauge group \( SU(2)_L \times SU(2)_R \times U(1)_{B-L} \times SU(3)_C \times U(1)_{L_\mu - L_\tau} \).

The gauged \( U(1)_{L_\mu - L_\tau} \) symmetry helps in realising low-scale inverse seesaw mechanism for origin of neutrino mass and allows MeV scale mass for the associated \( Z_{\mu\tau} \) gauge boson which is required for explaining muon anomalous magnetic moment. The new \( Z_{\mu\tau} \) gauge boson when lies at MeV scale can also explain the unexpected dip in the energy spectrum of high energy cosmic neutrinos reported by the IceCube Collaboration. It is also capable of mediating interactions between dark matter particles and muons inside a NS. Since there are two \( U(1) \) groups in the model, we show kinetic mixing between them.

We also show correlation plots for the variation of gauge coupling with the mass of \( Z_{\mu\tau} \) gauge boson.
Communicating ATLAS – Reaching new audiences

Author: Katarina Anthony

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A core objective of the ATLAS Collaboration is the communication of the status and achievements of the ATLAS Experiment. ATLAS has tailored its communication strategy to match an ever-changing media landscape, producing content that effectively targets key audiences effectively across multiple platforms. The most recent additions and improvements to ATLAS communications strategy are explored, the effect on user experience is evaluated, and best practices are shared.

ATLAS Open Data at 13TeV - The journey to a fully educational HEP dataset

Author: Kate Shaw

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ATLAS is the first LHC collaboration releasing data recorded at 13 TeV centre-of-mass energy. Billions of real events that correspond to proton-proton collisions recorded in 2016 are accompanied by several orders of magnitude more events of simulated samples of Standard Model processes and New Physics hypothetical processes. We intend to show the development of this open educational project through the eyes of the researchers, developers, professors and students, and communicators that designed, constructed, deployed, tested and consolidated the dataset and a series of tools for teaching High Energy Physics (HEP) and its related Computer Science to students worldwide. The ATLAS Open Data project puts in evidence the necessity of multidisciplinary and multicultural teams. ATLAS Open Data enables the teaching of High-Energy Physics and the science of Big Data through the use of real ATLAS technology and techniques. The 2020 dataset release will be presented.

ATLAS, Play! – Teaching particle physics through educational games

Author: Sascha Mehlhase
Educational games and activities have proven benefits for achieving learning objectives. They motivate competition, provide immediate rewards for success, and encourage collaborative, problem-based learning - all while framed as a fun activity, rather than laborious task. An overview of ATLAS educational games is given, including: "Making a Splash", a water-balloon game teaching the physics of colliders; "Proton Cookies", explaining the constituents of a proton through baked goods; and "Particle Twister", teaching the Standard Model through the game of Twister. Use cases of these games are described and user feedback is presented.

I read the instructions:

Secondary track (number):

Education and Outreach / 549

ATLAS public engagement: The CERN Open Days experience

Author: Anna Sfyrla

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The ATLAS experiment at the Large Hadron Collider is collecting unprecedented amounts of proton-proton collision data. The ATLAS Collaboration analyses these data, seeking to give answers to questions that have puzzled particle physicists for many decades now. In this process, the Standard Model is being precisely measured and searches for new physics are performed in sophisticated and clever data analyses. When ATLAS physicists explain to non-experts what they are doing and why, they use their passion to come up with equally clever means to achieve that. Their aim is both to motivate the younger generations as potential future scientists, and to reach out to the general public, creating an audience more interested in future achievements and convincing them of the importance of their pursuits. While there are many opportunities for interacting with the public, events like the CERN Open Days in 2019, with about 70000 visitors, carry a special weight in terms of potential impact. This contribution will highlight activities the ATLAS Collaboration used to connect with the visitors during the 2019 CERN Open Days. It will discuss the experience of the event preparation and will conclude with impressions of the impact of the proposed activities to the interactions with the amazing visitors, which made the 2019 CERN Open Days weekend a memorable event.

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Secondary track (number):

Education and Outreach / 550

ATLAS Virtual Visits – Take part from anywhere in the world

Author: Ben Carlson

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The Virtual Visit service run by the ATLAS Collaboration has been provided since 2010. The ATLAS Collaboration has used this popular and effective method to bring the excitement of scientific exploration and discovery into classrooms and other public places around the world. The programme, which uses a combination of video conferencing, webcasts, and video recording to communicate with remote audiences has already reached tens of thousands of viewers, with a large number of languages, from tens of countries covering the six populated continents.

We present a summary of the ATLAS Virtual Visit service that is currently in use: the booking system, the video conference that is held from the ATLAS Visit Centre and ATLAS Control Room, the possibility to make virtual tours from the ATLAS cavern, and the new system that is being installed in the ATLAS cavern to provide high-quality underground virtual visits. In addition, we show the reach of the programme over the last few years.

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Secondary track (number):

Education and Outreach / 551

The ATLAS public website - Evolution to Drupal 8

Author: Meirin Oan Evans

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Four years after the deployment of the ATLAS public website using the Drupal 7 content management system, the ATLAS Education & Outreach group is in the process of migrating to the new CERN Drupal 8 infrastructure. We present lessons learned from the development, usage and evolution of the original web site, and how the choice of technology helped to shape and reinforce our communication strategy. We then discuss tactics for the migration to Drupal 8, including our choice to use the CERN Override theme. This theme was developed by the CERN web team to support clients like ATLAS to develop web sites in the relatively complex and non-intuitive environment of Drupal. Furthermore, CERN has encouraged usage of this theme to mitigate support and ease future migration. We present the effects this choice has on the design, implementation, operation and maintenance of the new site.

I read the instructions:

Secondary track (number):

Diversity and Inclusion / 552

Evolution of Regional, Age and Gender Demographics in the ATLAS Collaboration

Author: Clara Nellist

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The ATLAS Collaboration consists of more than 5000 members, from about 100 different countries. This study presents data showing aspects of the regional, age and gender demographics of the collaboration, including the time evolution over the lifetime of the experiment. In particular the relative fraction of women is discussed, including their share of contributions, recognition and positions of responsibility, and showing how this depends on other demographic measures.

I read the instructions:

Secondary track (number):

Neutrino Physics - Posters / 553

Baryogenesis, thermal and non-thermal production of dark matter within the IHDM desert in Scotogenic model

Authors: Lavina Sarma\textsuperscript{1}; Mrinal Kumar Das\textsuperscript{1}

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The Scotogenic model is a minimal extension of Standard Model by three neutral singlet fermions ($N_k$) and an inert scalar doublet ($\eta$) which are $Z_2$ odd. Considering this model, we choose the lightest neutral scalar ($\eta_0$) as the DM candidate with its mass lying in the intermediate mass range, i.e $M_W < M_{DM} \leq 550$ GeV to show relic abundance and the lightest of $N_k$ with $M_{N_1}$ as low as 10 TeV to show $N_1$ baryogenesis. The calculation of baryogenesis is carried out with the lightest neutrino mass obeying the recent Planck limit and the effective neutrino mass satisfying the bounds from KamLAND-Zen. The mass splitting of the other scalars in $\eta$ field is varied to see how it affects the thermal as well as non-thermal production of observed relic. We also scan the parameter space for DM-Higgs coupling $\lambda_L$ and $M_{DM}$, taking into account bounds from relic abundance and direct detection experiment XENON1T.

Secondary track (number):

08

Neutrino Physics / 555

Status and Recent Results of the MAJORANA DEMONSTRATOR

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The MAJORANA DEMONSTRATOR (MJD) experiment is searching for neutrinoless double beta ($0\nu\beta\beta$) decay of $^{76}$Ge with an array of high-purity Germanium (HPGe) detectors, taking data since 2015 on the 4850’ level of the Sanford Underground Research Facility (SURF) in Lead, South Dakota, USA. The DEMONSTRATOR has achieved an energy resolution of 2.53 keV FWHM at the $0\nu\beta\beta$ decay $Q$-value, which is the best among all $0\nu\beta\beta$ decay experiments. The excellent energy resolution and ultra-low background allow the DEMONSTRATOR to establish stringent limits on both $0\nu\beta\beta$ decay and physics beyond the Standard Model, such as bosonic dark matter and axions. In this talk, we will discuss improved analysis and new findings from the background model development of the
DEMONSTRATOR. We will present recent MJD results on $0\nu\beta\beta$ decay and other physics, along with the status and near-term plans of the experiment.

Secondary track (number):

Quark and Lepton Flavour Physics / 556

Study of time-dependent and direct CP violation at Belle

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We present the first measurement of CP-violation parameters in a time-dependent angular analysis of the decay channel $B^0 \to D^{*\pm}\rho^\mp$. Thanks to the angular analysis of the vector-vector final state, all the information necessary to extract $2\phi_1 + \phi_3$ can be determined from this decay. This is in contrast to $B^0 \to D^{(*)\pm}\pi^\mp$, where SU(3) flavour assumptions or QCD calculations are required to determine CP-violation parameters. The prospects for this measurement at Belle II will be discussed. We also report a new measurement of time-dependent CP violation in $B \to K^0_S K^0_S K^0_S$, and direct CP violation in $B \to D^0\pi^0$. These studies are based on the full Belle data set of $772 \times 10^6$ $B\bar{B}$ pairs collected at the $\Upsilon(4S)$ resonance.

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Secondary track (number):

Quark and Lepton Flavour Physics / 557

New results on semileptonic and leptonic B meson decays from the Belle experiment

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Semileptonic $B$ meson decays allow to determine the magnitudes of the Cabibbo-Kobayashi-Maskawa matrix elements $|V_{cb}|$ and $|V_{ub}|$. $B$ decays with a heavy $\tau$ lepton in the final state constitute a powerful probe for physics beyond the standard model as well as a test for lepton flavour universality. Finally, $B$ decays with leptonic final states enable us to search for lepton flavour violation. We present new results on these topics based on the full data set recorded by the Belle detector at the KEKB $e^+e^-$ collider containing 772 million $B\bar{B}$ pairs.

I read the instructions:

Secondary track (number):

Quark and Lepton Flavour Physics / 558
Tests of lepton flavour universality and a search for lepton and baryon number violation at Belle

Author: Debashis Sahoo

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The electroweak penguin $B$ decays mediated by $b \to s \ell^+\ell^-$ transitions are flavour-changing neutral current processes, and are thus sensitive to new physics because of possible contributions of heavy particles in the quantum loop. Recently, Belle and LHCb obtained interesting results, where the lepton flavour universality violation (LFUV) effects might be seen. We report new measurements of LFUV observables $R_K$ and $R_{K^*}$, the ratio of branching fractions of $B \to K(\pi)\mu^+\mu^-$ to $B \to K(\pi)e^+e^-$, based on the full data sample recorded by Belle at the $\Upsilon(4S)$ resonance from $e^+e^-$ collisions produced by the KEKB collider. We also cover other studies related to lepton flavour universality or violation at Belle, such as lepton and baryon number violating decays of the $\tau$ lepton.

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Secondary track (number):

Quark and Lepton Flavour Physics / 560

Study of $B$ and $B_s$ Decays at Belle

Author: Nisar Nellikunnimmel

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We present the study of $B_s$ decays using 121.4 fb$^{-1}$ of data collected at $\Upsilon(5S)$ resonance with the Belle detector at the KEKB asymmetric-energy electron-positron collider. We search for $B_s \to \eta'\eta$ and $B_s \to \eta'K_S^0$, which are suppressed in the standard model (SM) and can receive contribution of physics beyond the SM. We also report the first model-independent measurement of $B(B_s \to D_sX)$ using $B_s$ semileptonic tagging; this is necessary for measuring absolute rates and branching fractions of other $B_s$ decays. In addition, we present precise measurements of the branching fraction and CP asymmetry in $B \to \phi\phi K^0$ decays using Belle data that corresponds to 772 million $B\bar{B}$ pairs. These decays are mediated by the $b \to s$ FCNC transition, where one can observe large CP violation due to interference of potential new-physics amplitudes appearing in the loop with the $b \to c$ tree-level transition of $B \to \eta_c K$, $\eta_c \to \phi\phi$.

I read the instructions:

Secondary track (number):

Quark and Lepton Flavour Physics / 561

Recent charm results from Belle

Author: Longke Li
Using the full data collected with the Belle detector at the KEKB asymmetric-energy $e^+ e^-$ collider, we report the first measurement of charm-mixing $\mathcal{UCP}$ in $D^0$ decays to the CP-odd final state $K^0_S \omega$. We present a Dalitz-plot analysis of the three-body decay $D^0 \rightarrow K^- \pi^+ \eta$. Along with these, we present other results related to charm physics at Belle.

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**Strong Interactions and Hadron Physics / 562**

**Study of conventional and non-conventional hadrons at Belle**

**Author:** Sen Jia

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The large data sample accumulated by the Belle experiment at the KEKB asymmetric-energy $e^+ e^-$ collider provides a unique opportunity to perform studies related to hadron spectroscopy utilising various production mechanisms. We report a search for $X(3872)$ in the two-photon process $e^+ e^- \rightarrow e^+ e^- J/\psi \pi^+ \pi^-$ and a study of $\chi_{c2}(1P) \rightarrow J/\psi \gamma$ again in the two-photon process. A search for the transitions from $\Upsilon(4S, 5S)$ to $\eta_b(1S)$ and $\eta_b(2S)$ with the emission of an $\omega$ meson is reported. We also cover other searches such as $\eta_{c2}(1D)$ in $B$ decays or studies of charmed baryons including the first measurement of branching fractions of $B \rightarrow \Lambda_c \Xi_c$ decays.

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**Strong Interactions and Hadron Physics / 563**

**New measurement of inclusive cross-section of light charged hadrons**

**Author:** Ralf Seidl

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We report new measurements of the production cross sections of pairs of charged pions and kaons as a function of their fractional energies. With an aim at either identifying dihadron cross sections in terms of single-hadron fragmentation functions, or providing a means to characterise the transverse momentum created in the fragmentation process, two different fractional-energy definitions are used and compared to the conventional fractional-energy definition reported earlier. The cross sections are obtained using 558 fb$^{-1}$ data sample collected at the $\Upsilon(4S)$ resonance with the Belle detector at the KEKB asymmetric-energy $e^+e^-$ collider.
Search for long range flow-like correlation in hadronic $e^+e^-$ collisions with Belle

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The first measurement of two-particle angular correlation functions is reported in high-multiplicity $e^+e^-$ collisions recorded at $\sqrt{s} = 10.52$ and 10.58 GeV with the Belle detector at KEKB. The main goal of this measurement based on high-statistics low energy data is to search for the long-range (large pseudorapidity difference $\Delta \eta$) near-side (small azimuthal angle difference $\Delta \phi$) "ridge signal", which is a widely observed phenomenon in high multiplicity $pp$ and $pA$ collisions but not yet fully understood. A previous analysis of the ALEPH archived data from hadronic $Z$ decays, which is limited by the available statistics, has shown no significant long-range correlation signal in the correlation function. We report the two-particle angular correlation function measured for the first time at Belle energies. In addition to this search for a flow-like signal in the unexplored high-statistics Belle data, our measurements are compared to the predictions from PYTHIA and HERWIG event generators, which could provide new constraints to the phenomenological models.

Hadron production measurements for neutrino oscillation experiments at NA61/SHINE

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Hadron production measurements are crucial for helping long baseline neutrino oscillation experiments constrain their beam flux uncertainties. These uncertainties represent a leading systematic uncertainty on measured neutrino oscillation parameters. At the NA61/SHINE experiment on CERN’s Super Proton Synchrotron, interactions of charged hadrons with various materials relevant to neutrino production are recorded and analyzed, resulting in differential cross-sections of charged and neutral particles contributing to neutrino flux. Both thin targets and replica targets have been measured at NA61/SHINE, and more replica target measurements are foreseen after CERN’s Long Shutdown 2. New thin target results will be shown.
Higgs physics possibilities at a Muon Collider

Authors: Lorenzo Sestini¹; Donatella Lucchesi¹; Nazar Bartosik²; Massimo Casarsa³

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Muon collisions at multi-TeV center-of-mass energies are ideal for studying the Higgs-boson properties. The number of produced Higgs bosons will allow to measure its couplings to fermions and bosons with an unprecedented precision. At $\sqrt{s}$ of the order of or greater than 10 TeV the double (triple) Higgs-boson production rate will be sufficiently high to directly measure the parameters of trilinear (quadrilinear) self-couplings, enabling the precise determination of the Higgs boson potential. In this contribution a study of the $\mu\mu \to H\nu\nu$ and $\mu\mu \to HH\nu\nu$ processes, where the Higgs bosons decay in two b-jets, is presented based on the full simulation of the detector with an evaluation of the beam-induced background.

I read the instructions:

Secondary track (number):

05

The Belle II Experiment: Status and Prospects

Author: Kodai Matsuoka¹

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The Belle II experiment at the SuperKEKB energy-asymmetric $e^+e^-$ collider is a substantial upgrade of the B factory facility at the Japanese KEK laboratory. The design luminosity of the machine is $8 \times 10^{35}$ cm$^{-2}$s$^{-1}$ and the Belle II experiment aims to record 50 ab$^{-1}$ of data, a factor of 50 more than its predecessor. With this data set, Belle II will be able to measure the Cabibbo-Kobayashi-Maskawa (CKM) matrix, the matrix elements and their phases, with unprecedented precision and explore flavor physics with $B$ and charmed mesons, and $\tau$ leptons. Belle II has also a unique capability to search for low mass dark matter and low mass mediators. We also expect exciting results in quarkonium physics with Belle II. In this presentation, we will review the status of the Belle II detector, the results of the planned measurements with data collected in 2019, and the prospects for physics at Belle II.

I read the instructions:

Secondary track (number):

05

Detector Performance Study at Muon Collider
A Muon Collider represents a possible option for the next generation of high-energy collider machines. Among the technological challenges in the realization of such a machine, the mitigation of the beam-induced background is one of the most critical issues for the detectors. At the desired luminosity the muons decay rate is very high, beam decay products and subsequent particles from secondary interactions with the machine elements can reach the interaction point, jeopardizing the physical performance of the detector. In this talk the characterization of the beam-induced-background and the strategies for its mitigation are discussed. The detector performance has been studied in full-simulated samples, in particular the tracking efficiencies and the jet reconstruction in the calorimeters are presented. It will be shown that the use of novel detector technologies with state-of-the-art timing resolution allows to keep the detector occupancy at a manageable level.

I read the instructions:

Secondary track (number):

Quark and Lepton Flavour Physics / 569

First results on $V_{ub}$ and $V_{cb}$ with Belle II

Author: Rachaa Cheaib

1 University of British Columbia

Corresponding Author: rachac@mail.ubc.ca

Precision measurements of $V_{ub}$ and $V_{cb}$ play a central role in precision tests of the CKM sector of the Standard Model and complement direct measurements of CP violation of B meson decays. In this talk, we present first studies for measuring $V_{ub}$ and $V_{cb}$ with semileptonic decays using collision events recorded at the $\Upsilon(4S)$ resonance by the Belle II experiment. Belle II is located at the SuperKEKB accelerator complex near Tokyo in Japan, and started recording collision data in Spring 2019. We report the status of measuring branching fractions and kinematic properties of inclusive and exclusive $b \rightarrow c\ell\bar{\nu}_\ell$ and $b \rightarrow u\ell\bar{\nu}_\ell$ decays using untagged and tagged approaches and the full available Belle II data set.

I read the instructions:

Secondary track (number):

Quark and Lepton Flavour Physics / 570

Leptonic and semileptonic decays with taus at the Belle II experiment

Author: Marco Milesi
The lepton flavour universality predicted by the Standard Model is challenged by various measurements of $b$-hadron decays involving tau and light leptons. The Belle II experiment started recording first collision data in Spring 2019 and offers a unique laboratory to study lepton flavour universality in leptonic and semileptonic decays of $B$ mesons at high precision. In this talk, we report the status of establishing first measurements of $B\to \tau\bar{\nu}_\tau$, $B\to \mu\bar{\nu}_\mu$, and $B\to D^{(*)}\tau\bar{\nu}_\tau$ processes using the available Belle II data and discuss the future potential of investigating the $R(D^{(*)})$ anomaly.

I read the instructions:

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 571

Status and Future development of the Full Event Interpretation Algorithm at Belle II

Author: William Sutcliffe

Corresponding Author: william.sutcliffe08@gmail.com

The Full Event Interpretation (FEI) is an exclusive tagging algorithm, that was developed for the Belle II experiment. By employing multivariate classifiers the FEI can identify and reconstruct semileptonic and hadronic $B$ meson decay cascades with high efficiency. In this talk the status and performance of the FEI using recorded Belle II collision data is presented. Calibration studies of the FEI efficiency using standard candle processes such as $B\to X\ell\bar{\nu}_\ell$ are reported to evaluate the algorithm's tagging performance. Further, we discuss the status of future developments to extend the capabilities of the algorithm to reconstruct $B_s$ mesons and to include baryonic $B$ meson decay cascades.

I read the instructions:

Secondary track (number):

Quark and Lepton Flavour Physics / 572

Results and Prospects of Radiative and Electroweak Penguin Decays at Belle II

Author: Yo Sato

Corresponding Author: sato.yo@desy.de

In the recent years, several measurements of $B$-decays with flavor changing neutral currents, i.e. $b\to s$ transitions hint at deviations from the Standard Model (SM) predictions. These decays are forbidden at tree-level in the SM and can only proceed via suppressed loop level diagrams. Rare
decays of $B$ mesons are an ideal probe to search for phenomena beyond the SM, since contributions from new particles can affect the decays on the same level as SM particles.

The Belle II experiment is a substantial upgrade of the Belle detector and operates at the SuperKEKB energy-asymmetric $e^+e^-$ collider. Early physics goals of the Belle II physics program are to rediscover these rare decays. Radiative $b \rightarrow s\gamma$ decays is already rediscovered with only a small dataset of Belle II and we are aiming to rediscover the electro-weak penguin $b \rightarrow s\ell\ell$ decays too. Ultimately, the unique setup at Belle II allows to study of modes with missing energies like $B \rightarrow K^*\nu\bar{\nu}$.

We will discuss about the prospects of these radiative and electroweak penguin decays with the expected $50ab^{-1}$ dataset of Belle II.

I read the instructions:

Secondary track (number):
05

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**Operation, Performance and Upgrade of Present Detectors / 573**

**B lifetimes at Belle II**

**Author:** Cyrille Praz

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The Belle II detector was completed with the installation of a silicon vertex detector that covers most of the solid angle around the interaction region. In 2019 Physics Run before summer shutdown, 5.15 fb of data were collected at a center of mass energy corresponding to the mass of the Y(4S). We utilize this dataset to characterize the performance of the detector about tracking of charged particles, reconstruction of known resonances, and capability of identifying displaced decay vertices. In order to assess the B Physics capabilities of the experiment, one of the first benchmarks to be reached consists in the measurement of the lifetime of $B$ mesons and of the $B_0$-$B_0\bar{\nu}$ mixing frequency. We present the first results, based on samples of $B$ mesons that decay to hadronic and semi-leptonic final states.

I read the instructions:

Secondary track (number):
05

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**Quark and Lepton Flavour Physics / 575**

**Measurement of $\gamma (\phi_3)$ and CP violation first results at Belle II**

**Author:** Niharika Rout

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The CKM angle $\gamma$ is the least well known of the angles of the unitarity triangle and the only one that is accessible with tree-level decays in a theoretically clean way. The key method to measure $\gamma$ is through the interference between $B^+ \to D^0 K^+$ and $B^+ \to D^0 K^+$ decays which occurs if the final state of the charm-meson decay is accessible to both the $D^0$ and $D^0$ mesons. The Belle II experiment at the SuperKEKB energy-asymmetric $e^+ e^-$ collider is a substantial upgrade of the B factory facility at the Japanese KEK laboratory. The design luminosity of the machine is $8 \times 10^{35}$ cm$^{-2}$s$^{-1}$ and the Belle II experiment aims to record 50 ab$^{-1}$ of data, a factor of 50 more than its predecessor. Main operation of SuperKEKB has started in March 2019 and results from a data sample corresponding to an integrated luminosity of $O(100)$ fb$^{-1}$ will be presented. To achieve the best sensitivity, a large variety of $D$ and $B$ decay modes is required, which is possible at Belle II experiment as almost any final state can be reconstructed including those with photons. With the ultimate Belle II data sample of 50 ab$^{-1}$, a determination of $\gamma$ with a precision of 1 degree or better is foreseen. This talk will explain the details of the planned measurement at Belle II and include results related to these measurements obtained with the data already collected, including the first studies of the golden mode for $\phi_3$ at Belle II: $B^+ \to D(\bar{K}_S \pi^+ \pi^-) K^+$. 

The Belle II Experiment started its first Physics Run in Spring 2019 and continued to collect data in 2020. The integrated luminosity collected with the Belle detector including vertex detectors is used to establish the performance of the detector in terms of reconstruction efficiency of final states of interest for the measurement of time-dependent CP violation, both for charm (such as J/psi K(*)0) and charmless (such as eta' K0). We will present the first results based on samples of B mesons that decays to the CP-eigenstates for time dependent analysis, along with a first assessment of the B Flavor Tagging capabilities, together with estimates of the Belle II sensitivity to the CKM angles.

Quark and Lepton Flavour Physics / 576

Early charmless B decay physics at Belle II

Author: Eldar Ganiev

1 INFN - National Institute for Nuclear Physics

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The physics of charmless B decays is an essential portion of the Belle II program. The expected large yields of charmless B decays will enable significant advancements in the understanding of quark dynamics, including a world-leading determination of the CKM phase $\alpha/\phi_2$, a conclusive understanding of the so-called K-pi CP-puzzle, and a deeper insight into phenomenological models of non-perturbative QCD in heavy meson decays. We present preliminary results based on the Belle II sample collected in 2019-2020. First charmless B signals are reconstructed for a variety of two-body and multibody decays. Measurements of their branching fractions and CP-violating asymmetries are used as data-driven benchmarks of current and projected detector and reconstruction performance.

I read the instructions:

Secondary track (number):

12
Charm potential at Belle II

Author: Giulia Casarosa¹

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The Charm sector provides a unique environment for the searches of Physics Beyond the Standard Model. Recent observation of CP violation in the D0 decays by the LHCb collaboration has renewed this interest and calls for confirmation in other channels and by other experiments. As we will discuss in this talk, Belle II will play a crucial role in measuring CP violation in many decay channels, especially those having neutral particles in the final state. We will show the improved reconstruction capabilities of the Belle II detector in charm decays with respect to first generation B-factories using the data collected in 2019 and 2020. Finally, we will show a preliminary result on the measurement of the D0 lifetime, that would be the first at B-Factories, demonstrating the excellent vertexing capabilities of the Belle II detector.

Track reconstruction efficiency measurement using e+e- → τ+τ- events at Belle II

Corresponding Author: zani@cppm.in2p3.fr

We present the measurement of the Belle II track reconstruction efficiency and Monte Carlo efficiency correction factors using τ-pair events, in which one τ lepton decays leptonically (τ → lνν, l = e, µ) while the other decays hadronically into three charged pions (τ → 3πν + nπ0). These measurements are performed using the e+e- collision data recorded during the early Phase III of data taking.
**Trigger efficiency measurement using e+e- → τ+τ- events at Belle II**

**Corresponding Author:** petar.rados@desy.de

The Belle II detector was completed with the installation of a silicon vertex detector that covers most of the solid angle around the interaction region. In 2019 Physics Run before summer shutdown, 5.15/fb of data were collected at a center of mass energy corresponding to the mass of the Y(4S).

We present the measurement of the L1 and high-level trigger efficiencies at Belle II using the τ-pair events. The 1x3, 3x3, 1x5 and 1x1 τ-pair decay modes are considered. These measurements were performed using the e+e collision data recorded by Belle II during the early Phase III of data taking.

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**Quark and Lepton Flavour Physics / 581**

**Tau physics prospects at Belle II**

**Author:** Kenji Inami

1 Nagoya university

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The Belle II experiment is a substantial upgrade of the Belle detector and will operate at the SuperKEKB energy-asymmetric e+e− collider. The design luminosity of the machine is 8 × 10^35 cm^{-2}s^{-1} and the Belle II experiment aims to record 50 ab^{-1} of data, a factor of 50 more than its predecessor. From February to July 2018, the machine has completed a commissioning run and main operation of SuperKEKB has started in March 2019. Belle II has a broad τ physics program, in particular in searches for lepton flavour and lepton number violations (LFV and LNV), benefiting from the large cross section of the pair wise τ lepton production in e+e− collisions. We expect that after 5 years of data taking, Belle II will be able to reduce the upper limits on LF and LN violating τ decays by an order of magnitude. Any experimental observation of LFV or LNV in τ decays constitutes an unambiguous sign of physics beyond the Standard Model, offering the opportunity to probe the underlying New Physics. In this talk we will review the τ lepton physics program of Belle II.

Using the Belle II data from the early Phase III data taking, we rediscover the tau leptons using the 3-prong τ decays. This decay mode is used for the tau-lepton mass measurement using the pseudomass technique developed by the ARGUS experiment. Though this measurement is expected to be limited by statistics and imperfect knowledge of the detector performance, we foresee that Belle II will provide the best pseudomass measurement once a larger data set with fully understood and operational detector components is available.
Beyond the Standard Model / 582

First results and prospects for tau LFV decay $\tau \rightarrow e + \alpha$(invisible) at Belle II

**Corresponding Author:** francesco.tenchini@desy.de

The Belle II experiment at SuperKEKB, an asymmetric $e^+e^-$ collider, aims at a total integrated luminosity of 50 ab$^{-1}$, to pursue a rich program of Standard Model and Beyond the Standard Model physics. In its first year of operation, approximately 10 fb$^{-1}$ were collected at the Upsilon(4S) resonance, with about 100 fb$^{-1}$ expected by the end of 2020. This results in a sizeable sample of tau pairs, enabling detailed studies of Standard and Beyond the Standard Model measurements, including searches for Lepton Flavor Violating (LFV) decays. One of the first channels where competitive limits are expected is the $\tau \rightarrow e + \alpha$(invisible) process, where alpha is a Goldstone boson. Here, the currently best limit has been obtained by ARGUS with an integrated luminosity of 475 pb$^{-1}$. Belle II is expected to be able to improve on this result already with the data recorded. This contribution will discuss selected analysis details and present first preliminary results and the prospects for future larger datasets.

I read the instructions:

Secondary track (number):
05

Dark Matter Detection / 583

Dark Sector first results at Belle II

**Author:** Enrico Graziani$^{1}$

$^{1}$ Universita’ di Roma III

**Corresponding Author:** enrico.graziani@roma3.infn.it

The Belle II experiment at the SuperKEKB energy-asymmetric $e^+e^-$ collider is a substantial upgrade of the B factory facility at the Japanese KEK laboratory. The design luminosity of the machine is $8 \times 10^{35}$ cm$^{-2}$s$^{-1}$ and the Belle II experiment aims to record 50 ab$^{-1}$ of data, a factor of 50 more than its predecessor. During 2018, the machine has completed a commissioning run, recording a data sample of about 0.5 fb$^{-1}$. Main operations started in March 2019 with the complete Belle II detector: an integrated luminosity of 10 fb$^{-1}$ has been collected so far. These early data sets, with specifically designed low multiplicity triggers, offer already the possibility to search for a large variety of dark sector particles in the GeV mass range, complementary to LHC and to dedicated low energy experiments. The talk will review the status of the dark sector searches at Belle II, with a focus on the discovery potential of the early data, and show the first results.

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Secondary track (number):
First results from Belle II on exotic and conventional quarkonium

Author: Roberto Mussa

1 INFN Torino

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The Belle II experiment at the SuperKEKB energy-asymmetric $e^+ e^-$ collider is a substantial upgrade of the B factory facility at KEK in Tsukuba, Japan. The experiment began full operation in early 2019 and aims to record a factor of 50 times more data than its predecessor. Belle II is uniquely capable of studying the so-called “XYZ” particles: heavy exotic hadrons consisting of more than three quarks. First discovered by Belle, these now number in the dozens, and represent the emergence of a new category within quantum chromodynamics. This talk will present recent results in new Belle II data, and future prospects to explore both exotic and conventional quarkonium physics.

Spin alignment measurements of vector mesons with ALICE at the LHC

Author: Bedangadas Mohanty

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Corresponding Author: bedanga.mohanty@cern.ch

In the presence of the large initial angular momentum occurring in non-central heavy-ion collisions, vector mesons can be produced in a polarized state. This might be either due to spin-orbital-angular-momentum interaction or by hadronization from polarized quarks. Experimentally, vector meson polarization is measured from the angular distribution of the decay daughters with respect to a quantization axis. A significant deviation from a non-uniform angular distribution would indicate the presence of spin alignment. We will present recent measurements of spin alignment for $K^+(892)^0$ and $\phi(1020)$ mesons at midrapidity in Pb-Pb and pp collisions at the LHC with the ALICE detector. The results indicate presence of spin alignment of $K^+$ and $\phi$ vector mesons in Pb-Pb collisions with respect to the event plane, whereas no spin alignment is observed for the $K_{0s}$ scalar meson. In pp collisions, no spin alignment is observed also for the vector mesons, indicating that the phenomenon arises from heavy-ion phenomenology and it is qualitatively consistent with expectations from the effect of large initial angular momentum in non-central collisions.
Results from the HEPD detector on-board the CSES satellite

Author: Roberto Iuppa¹

¹ Universita degli Studi di Trento and INFN (IT)

Corresponding Author: roberto.iuppa@cern.ch

The magnetic field around the Earth traps electrons and protons of energy 0.1-100 MeV. The dynamics of these particles is influenced by solar activity and the impact of intense geomagnetic storms on communication systems and infrastructures is widely recognised. So far, space weather models have been mostly based on data from electromagnetic probes, plasma probes and low-energy particle detectors. Fewer inputs are available from the highest energy range, 10-100 MeV, very important because particles are sufficiently fast to promptly probe large fractions of the ionosphere. To fill the gap, INFN and partners constructed the HEPD detector, launched on-board the CSES satellite on February 2nd 2018: HEPD will allow the use of the Earth magnetosphere as a giant magnetic spectrometer, using analysis tools similar to those used at magnetic detectors at particle accelerators with potential new application in the field of space science. This paper reports on particle detection technologies, event reconstruction algorithms and observational results of the HEPD detector, demonstrating how knowledge from high-energy physics can be successfully transferred to other fields of science and technology.

Secondary track (number):

Quark and Lepton Flavour Physics / 587

Search for New Physics with rare decays at CMS

Author: Ozlem Ozcelik Ozludil¹

¹ Bogaziçi Univ., Dept of Physics

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Recent CMS results are reported either for the observation of the B0s to mu+mu- decay and for the search of the B0 to mu+mu- decay by adding the 2016 13TeV data to the Run-I data and for the search of the tau to 3 muons decay, with 2016 13 TeV data, by considering tau leptons coming both from Ds and W decays.

I read the instructions:

Secondary track (number):

Quark and Lepton Flavour Physics / 588

CPV in B hadron decays at CMS

Author: Enrico Lusiani¹

¹ Univ. di Padova e Sez. dell’INFN

Corresponding Author: enrico.lusiani@cern.ch

A new CMS measurement of CP Violation in B0s to J/psi phi decay with 2017 and 2018 13TeV data will be presented.
Search for new physics in b to s l+ l- transitions at CMS

**Corresponding Author:** alessio.boletti@pd.infn.it

New CMS results in the measurement of observables sensitive to New Physics by exploiting b \(\rightarrow s\) l+ l- transitions with Run-II data will be discussed.

Production studies of double Bottomonia and of Bottomonium in association with an electroweak Boson at CMS

**Author:** Sheila Silva Do Amaral

\(^1\) Univ. Estado Rio de Janeiro

**Corresponding Author:** sheila.silva.do.amaral@cern.ch

New CMS measurements of the Y(1S) pair production cross section at 13TeV and of the production of Y(nS) mesons in association with an electroweak boson will be discussed.

Search for QCD exotic states at CMS

**Author:** Sergey Polikarpov

\(^1\) Moscow Eng. Phys. Inst.

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Novel CMS results in searches for “old” and new quarkonium-like states will be discussed.
New results in Lambda_b baryon physics at CMS

Author: Nikita Petrov

1 Moscow Institute of Physics and Technology

I read the instructions:
Secondary track (number):
06.

Production studies of D and B mesons at CMS

Author: Valentina Mariani

1 Univ. di Perugia e Sez. dell’INFN

I read the instructions:
Secondary track (number):
06.
Author: Muhammad Imran¹

¹ National Centre for Physics, Quaid-I-Azam Univ.

Corresponding Author: muhammad.imran@cern.ch

The CMS experiment heavily relies on CMSWEB cluster to host critical services for its operational needs. The cluster is deployed on virtual machines (VMs) from the CERN Openstack cloud and is manually maintained by operator and developers. The release cycle is composed of several steps, from building RPMs, their deployment, validation and coordination tests. To enhance the sustainability of the CMSWEB cluster, CMS decided to migrate it to a containerized solution such as docker, orchestrated with Kubernetes (k8s). This allows us to significantly reduce the release upgrade cycle, follow end-to-end deployment procedure, and reduce operational cost. This contribution gives an overview of the current CMSWEB cluster and its issues. We describe the new architecture of the CMSWEB cluster in k8s and its implementation strategy. We also provide a comparison of VM and k8s deployment approaches, emphasizing pros and cons of the new architecture and report on lessons learned during the migration process.

Model Unspecific Search in CMS (MUSiC)

Author: Lorenzo Vigilante¹

¹ Rheinisch Westfaelische Tech. Hoch. (DE)

Corresponding Author: lorenzo.vigilante@cern.ch

The Model Unspecific Search in CMS (MUSiC) analysis searches for anomalies in data that can be probed for new physics phenomena based purely on the comparison of the recorded data to the expectation according to the standard model (SM), obtained from simulations. Events selected with at least one lepton are classified into several hundred event classes based on their final state topology, taking electrons, muons, photons, jets, b-tagged jets, and missing transverse momentum into account, and an automated search algorithm subsequently surveys kinematic distributions of the data for deviations from the SM expectation without any explicit input of any particular new physics models. The search strategy and the results of the MUSiC analysis using 35.9fb⁻¹ of data recorded by the CMS detector at the CERN LHC during proton-proton collisions at a center of mass energy of 13 TeV will be presented.

Search for new physics using final states with photons at CMS

Author: Justin Andrew Williams¹

¹ The Univ. of Kansas
Several theories of physics beyond the standard model predict new phenomena and interactions involving photons. This talk covers searches for new physics performed using data collected with the CMS detector at the LHC, which target final states consisting of photons.

Corresponding Author: ja.williams@cern.ch

Astro-particle Physics and Cosmology / 598

Cosmological scalar fields and Big-Bang nucleosynthesis

Author: Jean-FRANCOIS COUPECHOUX
Co-author: Alexandre Arbey

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Scalar fields are widely used in cosmology, in particular to emulate dark energy, for example in quintessence models, or to explain dark matter, in particular within the fuzzy dark matter model. In addition many scenarios involving primordial scalar fields which could have driven inflation or baryogenesis are currently under scrutiny. Here we study the impact of such scalar fields on Big-Bang nucleosynthesis and derive constraints on their parameters using the observed abundance of the elements and try to find set-ups which simultaneously satisfy the helium-4, helium-3, deuterium constraints and the lithium-7 one.

Dark fluid models with scalar fields replacing simultaneously dark matter and dark energy are extremely constrained both by dark matter constraints at local and large scales and by dark energy constraints at cosmological scales. We showed that in the most simple models, no constraints can be obtained from BBN contrary to primordial scalar fields which have decayed during BBN. In this case, they are more likely to have affected the abundance of the elements, in two different ways. First the scalar field density increases the total density and affects the expansion rate of the Universe. Second the decay into radiation injects entropy which modifies the relation between time and temperature and generates a reheating at the BBN epoch.

In my talk, I will present our study of the cosmological evolution of such scalar fields and show their impact on Big-Bang nucleosynthesis.

Beyond the Standard Model / 599

New measurement of the neutron electric dipole moment at PSI

Author: Benoit Eric Clement

1 Centre National de la Recherche Scientifique (FR)
The electric dipole moment (EDM) of the neutron is a strong probe of CP violation beyond the Standard Model. In particular, its value could reveal information on baryogenesis. We report the latest result from the nEDM collaboration, which operates an experiment to measure the neutron EDM at the Paul Scherrer Institute using Ramsey’s method of separated oscillating magnetic fields with ultracold neutrons. The salient features of this experiment were the use of a $^{199}$Hg comagnetometer and an array of optically pumped cesium vapor magnetometers to cancel and correct for magnetic-field changes. Two separate groups performed the statistical analysis on blinded datasets, while the estimation of systematic effects profited from an unprecedented knowledge of the magnetic field. Therefore, the obtained precision is dominated by statistical uncertainties. The systematic precision was improved by a factor 5 with respect to previous experiments opening the way to improved sensitivity in the next generation of experiments. The observed EDM is compatible with zero and a new improved limit, $|d| < 1.8 \times 10^{-26} \text{ e.cm @ 90\% CL, was set.}$

Neutrino Physics / 600

The COHERENT Experiment at the Spallation Neutron Source

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The pioneering experiments by the COHERENT collaboration at the Spallation Neutron Source (SNS) at the Oak Ridge National Laboratory yielded the first observations of coherent elastic neutrino nuclear scattering (CEvNS). The first observation on argon was recently presented and demonstrates the potential of this new neutrino laboratory to exploit CEvNS as a new probe of physics topics including electromagnetic properties, searches for physics beyond the standard model, and nuclear form factors. COHERENT is deploying two new instruments to measure CEvNS on sodium and germanium nuclei and is pursuing multiple ton-scale detectors to improve precision and accuracy. The SNS is also ideally suited for a broader set of high-precision neutrino physics measurements and dark matter searches because of the accelerator’s intensity, pulsed-structure, and proton beam energy. The experimental features of this new capability as well as the recent results of our operating detectors will be presented.

Accelerator: Physics, Performance, and R&D for Future Facilities / 601

The HL-LHC: Strategies for beam optics commissioning

Author: Lukas Malina

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Secondary track (number):

3
Beam optics control in the HL-LHC will present significant challenges, relating to the extremely low $\beta^*$ in the two main experiments: ATLAS and CMS. The luminosity delivered to the experiments during the first several hours of HL-LHC fills will be kept constant via $\beta^*$-levelling. Such an extensive optimisation will require the commissioning of a large number of optical configurations, further challenging the efficiency of the beam optics measurement and correction methods. Throughout the LHC’s run 2, beam-based studies have helped identify critical challenges and their solutions. Based on the experience and the achieved level of optics control, we discuss strategies of HL-LHC optics commissioning and its implications for the experiments.

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Secondary track (number):

Astro-particle Physics and Cosmology / 602

Probing hadronic interactions with measurements at ultra-high energies with the Pierre Auger Observatory

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The characteristics of an extensive air shower derive from both the mass of the primary ultra-high-energy cosmic ray that seeds its development and the properties of the hadronic interactions that feed it. With its hybrid detector design, the Pierre Auger Observatory measures both the longitudinal development of showers in the atmosphere and the lateral distribution of particles arriving at the ground, from which a number of parameters are calculated and compared with predictions from current hadronic interaction models tuned to LHC data. At present, a tension exists concerning
the production of muons, where the measured abundance exceeds all predictions. This discrepancy, measured up to center-of-mass energies of ~140 TeV, is irresolvable through mass composition arguments, constrained by measurements of the depth of the electromagnetic-shower maximum. Here, we present a compilation of hadronically-sensitive shower observables and their comparisons with model predictions and conclude with a brief discussion of what measurements with the new detectors of the AugerPrime upgrade will bring to the table.

Secondary track (number):

Education and Outreach / 603

Social media and storytelling: tools to raise engagement with physics

Author: Valentina Scotti

Corresponding Author: scottiv@na.infn.it

According to the Global Digital Report 2020, social media active users reach 49% of the world population, with an annual growth of 9%. Due to the penetration of social media in everyday life, many scientific collaborations and institutions are present on different social media platforms and recognize the role they play in reaching a wider audience. Social media engagement can positively influence not only scientific communication, but also the day-to-day job of scientists involved, since their presence on social networks can increase their networking and impact beyond the research community.

I will share my experience as a social media manager of INFN Napoli and the CSES-Limadou Collaboration. We used social media as a tool to convey a correct message about research activities and to share the emotional side of research. I will discuss the strategies implemented on different platforms, and the way we used storytelling to increase the engagement. Social media proved to be very powerful in connecting physicists with the non-specialized public, in particular with students, and each other.

Increasing the visibility and engagement of physicists can have a huge impact on how non-physicists see scientists and their relationships to science and the scientific community.

Secondary track (number):

Heavy Ions / 604

Hard probes in heavy ion collisions with CMS

Author: Xiao Wang

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We review recent CMS results on hard probes of heavy ion collisions, including jet and electroweak boson production.

I read the instructions:
Soft probes in heavy ion collisions with CMS

Author: Serguei Petrushanko¹

¹ Moscow State Univ.

Corresponding Author: serguei.petrushanko@cern.ch

We review recent CMS results on heavy flavour hadron production, including quarkonia, in heavy ion collisions, as well as particle correlations.

Diffractive and exclusive processes in heavy ion collisions with CMS

Author: Aleksandr Bylinkin¹

¹ The University of Kansas (US)

Corresponding Author: alexandr.bylinkin@cern.ch

We review recent CMS results on diffractive and exclusive processes in heavy ion collisions, including photon-induced processes in ultra-peripheral collisions.

Search for lepton flavour violating decays of the Higgs boson with Run II data

Author: Lourdes Urda¹

Co-authors: Varun Sharma ²; Ka Wa Ho ³; Maria Cepeda ⁴; Prasanna Kumar Siddireddy ⁵

¹ CIEMAT (Madrid)
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³ University of Notre Dame (US)
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Corresponding Authors: ka.wa.ho@cern.ch, varun.sharma@cern.ch, lourdes.urda@cern.ch, maria.cepeda@cern.ch, prasanna.siddireddy@cern.ch
A search for lepton flavour violating (LFV) decays of the Higgs boson to a muon and a tau, denoted as $\mu\tau$ and an electron and a tau, denoted as $e\tau$ will be presented. A dataset of $137fb^{-1}$ of proton-proton collisions collected by the CMS detector in Run II, at a center-of-mass energy of $\sqrt{s} = 13TeV$ is being used to perform the search. The dominant background contributions for this search are coming from the Drell-Yan process, misidentified leptons, and the top-quark pair-production process. We are using data-driven techniques to estimate the majority of the background. In our previous search using 2016 data, we set the observed (expected) upper limits on the LFV branching fractions of the Higgs boson to be $B(H \rightarrow \mu\tau) < 0.25\%(0.25\%)$ and $B(H \rightarrow e\tau) < 0.61\%(0.37\%)$, at 95% confidence level. With the current search, we anticipate setting the most stringent limits to date on these branching fractions using the full Run II data.

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Secondary track (number):

Computing and Data Handling / 608

VegasFlow: accelerating Monte Carlo simulation across platforms with dataflow graphs

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We present VegasFlow, a new software for fast evaluation of high dimensional integrals based on Monte Carlo integration using dataflow graphs. The growing complexity of calculations and simulations in many areas of science have been accompanied by advances in the computational tools which have helped their developments. VegasFlow enables developers to delegate all complicated aspects of hardware or platform implementation to the library so they can focus on the problem at hand. This software is inspired on the Vegas algorithm, ubiquitous in the particle physics community as the driver of cross section integration, and based on Google’s powerful TensorFlow library. We benchmark the performance of this library on many different consumer and professional grade GPUs and CPUs, finding up to a 10x improvement with respect to other implementations of the Monte Carlo algorithms considered.

Secondary track (number):

17

Strong Interactions and Hadron Physics / 609

Investigation of high energy behaviour of HERA data

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We analyse the high precision HERA $F_2$ data in the low-$x$, $x < 0.01$, and very-low-$x$, $x < 0.001$, regions using $\lambda$-fits. $\lambda$ is a measure of the rate of rise of $F_2$ defined by $F_2 \propto (1/x)^\lambda$. We show that $\lambda$ determined in these two regions, at various $Q^2$ values, is systematically smaller in the very-low-$x$ region as compared to the low-$x$ region. We discuss some possible physical interpretations of this effect.

Our observation that the value of the exponent $\lambda$ decreases at small values of $x$, indicates that measurements at the future ep colliders, like VHEeP or LHeC will become exciting, as they will approach the high energy limit of the virtual photon-hadron cross sections, where DGLAP and BFKL meet and the confinement effects should become simple.


**Data Analysis with GPU-Accelerated Kernels**

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At HEP experiments, processing billions of records of structured numerical data can be a bottleneck in the analysis pipeline. This step is typically more complex than current query languages allow, such that numerical codes are used. As highly parallel computing architectures are increasingly important in the computing ecosystem, it may be useful to consider how accelerators such as GPUs can be used for data analysis. Using CMS and ATLAS Open Data, we implement a benchmark physics analysis with GPU acceleration directly in Python based on efficient computational kernels using Numba/LLVM, resulting in an order of magnitude throughput increase over a pure CPU-based approach. We discuss the implementation and performance benchmarks of the physics kernels on CPU and GPU targets. We demonstrate how these kernels are combined to a modern ML-intensive workflow to enable efficient data analysis on high-performance servers and remark on possible operational considerations.
Geometry and dynamics of the particle-emitting source in heavy-ion collisions can be inferred via femtoscopy method. Two-particle correlations at small relative momentum exploit Quantum Statistics (QS) and the Final State Interactions (FSI) which allow one to study the space-time characteristics of the source of the order of $10^{-15}$ m and $10^{-23}$ s. The RHIC Beam Energy Scan (BES) program covers significant part of the QCD Phase Diagram using collisions of Au nuclei for several beam energies from 7.7 to 200 GeV, which baryon-rich region is studied via femtoscopy. Baryon measurements together with meson ones provide complementary information about source characteristics. In this talk, results on femtoscopic measurements of various particle combinations at different collision energies and centralities will be shown. The results of non-identical particles enables studies of space-time asymmetries in emission process. In addition, femtoscopy enables investigation of FSI between hadrons.

I read the instructions:

Secondary track (number):

Computing and Data Handling / 612

Resource provisioning and workload scheduling of CMS Offline Computing

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The CMS experiment requires vast amounts of computational power in order to generate, process and analyze the data coming from proton-proton collisions at the Large Hadron Collider, as well as Monte Carlo simulations. CMS computing needs have been mostly satisfied up to now by the supporting Worldwide LHC Computing Grid (WLCG), a joint collaboration of more than a hundred computing centers geographically distributed around the world. However, as CMS faces the Run 3 and HL-LHC challenges, with increasing luminosity and event complexity, growing demands for CPU have been estimated. In these future scenarios, additional contributions from more diverse types of resources, such as Cloud and High Performance Computing (HPC) clusters, will be required to complement the limited growth of the capacities of WLCG resources. A number of strategies are being evaluated on how to access and use WLCG and non-WLCG processing capacities as part of a combined infrastructure, successfully exploit an increasingly more heterogeneous pool of resources, efficiently schedule computing workloads according to their requirements and priorities, and timely deliver analysis results to the collaboration, which will be presented in this contribution.

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 613

Quantum Sensors of the Dark Universe: Exploiting Quantum Entanglement in the Laboratory for Detection of Exotic Particles and Fields

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Our immediate familiar natural world as well as the universe beyond, are “quantum-entangled” from the microscopic to the macroscopic scale, from the “inner” to the “outer” dimensions. This fundamental “quantum entanglement” can be harnessed to sense and probe extremely “weak” processes in nature around us, to create novel materials and to probe and sense signals left over from the very “early” and “dark” universe, allowing us to be ‘cosmic archaeologists’. After an exposition of the basics, I will illustrate “quantum entanglement” at work via its manifestation and controlled exploitation in the world of particles, fields, cosmos, novel quantum topological materials in the detection of exotic particles and fields.

Density Dependent B-parameter model of Compact object with Strange Quark Matter

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A class of relativistic solutions for compact cold objects with strange quark matter in a pseudo-spheroidal space-time is presented here. Considering strange matter equation of state namely, $p = \frac{1}{3}(|\rho - 4B|)$, where $\rho$, $p$ and $B$ are energy density, pressure and MIT Bag parameter respectively, stellar models are obtained. Stellar models are explored where the Bag parameter varies with the energy density ($\rho$) inside the compact object in presence of anisotropy with a pseudo-spheroidal geometry described by Vaidya-Tikekar metric. The density dependence of $B$ for different anisotropy including isotropic case is determined here. It is noted that although $B$ varies with anisotropy inside the star, finally at the surface it attains a value which is independent of the anisotropy. The Bag parameter $B$ is found to increase with an increase in anisotropy for a given compactness factor ($M/b$) and spheroidicity parameter ($\lambda$). It is also noted that for a star with given mass ($M$) and radius ($b$), the parameter $B$ increases with the increase of $\lambda$ and finally at large value of $\lambda$ it attains a constant value. We note that in this model equation of state (EoS) obtained from geometrical consideration with allowable value of ‘B’ is similar to that obtained by earlier investigators from consideration of microphysics. The stability of the stellar models for compact objects with anisotropy in hydro-static equilibrium is also studied.

CEPC Accelerator Towards TDR

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In Nov 2018, CEPC CDR was completed and released publicly. In May 2019 CEPC strategy plan was submitted to European high energy physics strategy meeting for discussion. Since the formal entering into the CEPC accelerator TDR phase, many progresses have been made in optimization designs, hardware R&D, industrialization, such as high efficiency klystron, SC accelerator system, magnets, vacuum system, civil engineering, site selection, CIPC industry collaboration, international collaboration, etc, which will be reported in this talk.

Secondary track (number):

Strong Interactions and Hadron Physics / 616

TMD densities at leading and higher order from the Parton Branching method

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We present a new determination of Transverse Momentum Dependent (TMD) parton distributions obtained with the Parton Branching (PB) method at LO, NLO and NNLO. The PB TMDs are extracted from fits to precision DIS data using DGLAP splitting functions at leading and higher order. We extract both the collinear part and the transverse momentum dependent part of the parton densities. In addition the fit sensitivity to dynamical resolution scales on TMD evolution in different kinematical region of $x$ and $Q^2$ will be investigated.

Secondary track (number):

Neutrino Physics / 619

First detection of solar neutrinos from CNO cycle with Borexino

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Borexino is running at the “Laboratori del Gran Sasso” in Italy since 2007. Its major distinctive feature is the unprecedented ultralow background of the inner scintillating core, which is the foundation of the outstanding achievements it has accumulated over the years. In the present talk, after recalling the main features of the detector, the impressive solar data gathered so far by the experiment will be summarized. Special emphasis will be given to the new and striking results on solar neutrinos in the 1 MeV range revealed for the first time by Borexino, a detection which crowns the long quest of the experiment to chase the neutrino components from the whole set of the nuclear reactions occurring in the core of our star. Together with the already measured neutrinos from the pp chain, such a result put Borexino in the unique situation of being the only detector able to perform solar neutrino spectroscopy over the entire solar spectrum. The talk will be concluded outlining the implications of the Borexino data in the understanding of the flavor conversion of the solar neutrino flux, in particular with the full validation across the solar energy range of the MSW-LMA oscillation paradigm.
Strong Interactions and Hadron Physics / 620

Going off-shell: matrix element, parton densities and shower

Author: Krzysztof Kutak

In the talk I am going to report on recent results obtained within QCD kt-factorization i.e. formalizm that at high energies accounts for transverse momentum dependence of both parton densities and coefficient functions. In particular I am will present results for complete parton shower description of production of di-jets at LHC. This relies on application of hard matrix elements that depend on transversal momentum and parton densities that depend on transversal momentum. Furthermore I will present new evolution equations which have kernels build from transverse momentum dependent splitting functions. The equations generalize the BFKL and DGLAP splitting functions. I will also present preliminary application of the formalizm to DIS processes with focus on Electron Ion Collider kinematics.

Neutrino Physics / 621

Improved geoneutrino results from Borexino

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Borexino is a 280-ton liquid scintillator detector located at the Laboratori Nazionali del Gran Sasso (LNGS), Italy and is one of the two detectors that has measured geoneutrinos so far. The unprecedented radio-purity of the scintillator, the shielding with highly purified water, and the placement of the detector at a 3800 m w.e. depth have resulted in very low background levels and has made Borexino an excellent apparatus for geoneutrino measurements. This talk will summarize the latest geoneutrino analysis with Borexino, using the data obtained from December 2007 to April 2019. Enhanced analysis techniques, such as an increased fiducial volume, improved veto for cosmogenic backgrounds, extended energy and coincidence time windows, as well as a more efficient α/β particle discrimination have been adopted in this measurement. The updated statistics and these elaborated techniques have led to more than a factor two increase in exposure and an improvement in the precision from 27% to around 18%, when compared to the previous measurement in 2015. The talk will highlight the geological interpretations of the obtained results, namely, the estimation of the mantle signal by exploiting the relatively well-known lithospheric contribution, the calculation of the radiogenic heat, as well as the comparison of these results to the various predictions. Even though the results are compatible with all the Earth models, there is a 2.4σ tension with those models that predict the lowest concentration of heat-producing elements inside the mantle. Additionally, we present the upper limits for a hypothetical georeactor that might be present at different locations inside the Earth.
Performance studies of RPC detectors operated with new environmentally friendly gas mixtures in presence of LHC-like radiation background

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Resistive Plate Chamber (RPC) detectors are widely used thanks to their excellent time resolution and low production cost. At the CERN LHC experiments, the large RPC systems are operated in avalanche mode thanks to a Freon-based gas mixture containing C2H2F4 and SF6, both greenhouse gases with a very high global warming potential (GWP). The search of new environmentally friendly gas mixtures is advisable for reducing greenhouse gas emissions, costs as well as to optimize RPC performance and possible detector aging issues.

Several hydrofluorocarbons, hydrofluoroolefins (HFOs) and innovative industrial alternative to SF6 gases with very low GWP have been identified as possible replacements of C2H2F4 and SF6. More than 60 environmentally friendly gas mixtures have been investigated on 2 mm single-gap RPCs. The RPC detectors have been tested in laboratory conditions and at the CERN Gamma Irradiation Facility (GIF++), which provides a high energy muon beam combined with an intense gamma source allowing to simulate the background expected at HL-LHC.

RPCs performance have been studied at different gamma rates with the new environmentally friendly gases by measuring efficiency, streamer probability, rate capability, induced charge, cluster size and time resolution. Encouraging results of RPC operation in avalanche mode have been obtained with 4 and 5 components gas mixtures.

A complete overview of the results obtained will be presented. To finalize the studies, the RPCs are now operated under gas recirculation with the selected new gas mixture and exposed to the intense gamma radiation at the CERN GIF++ facility for evaluating possible long-term aging effects, gas damage due to radiation and compatibility of LHC gas system with new gases.

Secondary track (number):
12

Strategies for reducing the use of greenhouse gases from particle detectors operation at the CERN LHC experiments

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A wide range of gas mixtures is used for the operation of different gaseous detectors at the CERN LHC experiments. Some gases, as C2H2F4, CF4, C4F10 and SF6, are greenhouse gases (GHG) with
The reduction of GHG emissions is an objective of paramount importance for CERN: four different strategies have been identified to achieve it.

The first strategy is based on the use of gas mixture recirculation systems. This solution is used in all plants supplying gaseous mixtures to the CERN LHC detector systems. The approach and the development of such technology made at CERN will be presented. Furthermore, to protect detectors against their intrinsic fragility, the development of additional modules is ongoing to achieve a pressure and flow stability which goes beyond original design.

The second research line is based on the development of systems for the recuperation of used gas mixtures followed by separation of the most critical GHGs for their re-use. Systems allowing the recuperation of different gases were developed in the past for several detectors: CMS CSC (CF4), ATLAS TGC (nC5H12), LHCb RICH1 (C4F10) and LHCb RICH2 (CF4). R&D studies are now on-going to improve the efficiency of the present systems and for the design of a C2H2F4 recuperation plant. Indeed, C2H2F4 represents the major contribution to GHG consumption at CERN. A first prototype was tested at the end of Run 2 on a LHC RPC system and further tests are nowadays on-going for the development of the final version for Run 3.

A third approach is making use of industrial available solutions for disposal of GHG when gases cannot be recuperated or re-used. However, these abatement systems solve only the GHG emission problem but not difficulties related to availability and price increase of these gases in the future.

Finally, the last research line is based on the long-term replacement of currently used gases for the operation of LHC detectors. The research of new eco-friendly gases is subject of many R&D programs by the particle research communities, in particular for the replacement of C2H2F4. Few new gases have been tested but finding a suitable replacement for the RPC systems at the LHC experiments is particularly challenging.

The four strategies will be compared by considering investment required, potential return benefit and technological readiness.

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**Heavy Ions / 624**

**Jet quenching and effects of non-Gaussian transverse-momentum broadening on di-jet observables**

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I am going to report on recent study, at a qualitative level, production of jet pairs in ultrarelativistic nuclear collisions within a framework combining High Energy Factorisation (HEF) and in-medium propagation of jet particles that takes into account stochastic transverse forces as well as medium-induced radiation. We find that the resulting di-jet observables feature the behaviour deviating from that of jet-pairs which undergo transverse-momentum broadening following the Gaussian distribution. The result follows from application of only recently solved by Kutak, Straka, Placzek evolution equation formulated by Blaizot, Dominguez, Iancu, Mehtar-Tani, Dominguez.

The application of recently solved equation allows for studies of interplay of energy loss via branchings and rescattering leading to broadening therefore in the end to more detailed study of structure of jets in Heavy Ion Collisions.

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I read the instructions:
Implementation of large imaging calorimeters

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The next generation of collider detectors will make full use of Particle Flow algorithms, requiring high precision tracking and full imaging calorimeters. The latter, thanks to granularity improvements by 2 to 3 orders of magnitude compared to existing devices, have been developed during the past 15 years by the CALICE collaboration and are now reaching maturity. The state-of-the-art status and the remaining challenges will be presented for all investigated readout types: silicon diode and scintillator for a electromagnetic calorimeter, gaseous with semi-digital readout as well as scintillator with SiPM readout for a hadronic one. We will describe the commissioning, including beam test results, of large scale technological prototypes and the raw performances such as energy resolution, linearity and studies exploiting the distinct features of granular calorimeters regarding pattern recognition. Beyond these prototypes, the design of experiments addressing the requirements and potential of imaging calorimetry will be discussed. In addition, less established but promising techniques for dedicated devices inverse APD or segmented crystal calorimeters will also be highlighted.

Exploring the structure of hadronic showers and the hadronic energy reconstruction with highly granular calorimeters

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Prototypes of electromagnetic and hadronic imaging calorimeters developed and operated by the CALICE collaboration provide an unprecedented wealth of highly granular data of hadronic showers for a variety of active sensor elements and different absorber materials. In this presentation, we discuss detailed measurements of the spatial and the time structure of hadronic showers to characterise the different stages of hadronic cascades in the calorimeters, which are then confronted with GEANT4-based simulations using different hadronic physics models. These studies also extend to the two different absorber materials, steel and tungsten, used in the prototypes. The high granularity of the detectors is exploited in the reconstruction of hadronic energy, both in individual detectors and combined electromagnetic and hadronic systems, making use of software compensation and semidigital energy reconstruction. Further we show how granularity and the application of multivariate analysis algorithms enable the separation of close-by particles. We will report on the performance of these reconstruction techniques for different electromagnetic and hadronic calorimeters, with silicon, scintillator and gaseous active elements.
Search for a light charged Higgs boson decaying to a W boson and a CP-odd Higgs boson in trilepton final states in pp collisions at 13 TeV with CMS

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A search for a light charged Higgs boson (H+) decaying to a W boson and a CP-odd Higgs boson (A) using trilepton final states (electron-dimuon or trimuon) is presented. The result is based on data from pp collisions at 13 TeV, recorded by the CMS detector, corresponding to an integrated luminosity of 35.9 /fb. In this search, it is assumed that the H+ boson is produced in decays of top quarks, and the A boson decays to two oppositely charged muons. The first upper limits are set on the combined branching fraction for the decay chain.

Secondary track (number):

Heavy Ions / 628

The Shape of the Correlation Function

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Correlation femtoscopy has become a standard technique for measuring and probing the space-time evolution of heavy-ion collisions. Usually, two-particle correlation functions are fitted to a Gaussian form. However, the real shape of the correlation function is often strongly non-Gaussian and better described by a Lévy-stable distribution. A Lévy index much below 2 has recently been observed experimentally. It has been suggested that an even lower value of the Lévy index equal to 0.5 may identify matter produced at the critical endpoint of the QCD phase diagram. Despite this, there are non-critical effects which can also influence the value of the Lévy index significantly, and it is crucial to quantify the magnitudes of these effects before assigning physical significance to a measurement of the Lévy index.

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors - Posters / 629

Abstract for The JUNO Calibration Strategy and its Simulation

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Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kton liquid scintillator detector under construction in China, which is designed to primarily determine the neutrino Mass Hierarchy(MH).
by detecting reactor anti-neutrinos via inverse beta decay. JUNO energy response is strongly position-dependent due to the detector structure and dimension. The energy resolution should be $<3\%$ (the quantity under the square root sign is $E$) to determine $M_{\nu}$ in $3\sigma$ in 6 years, so the calibration complex is very critical and has been designed. In this poster, the study including Calibration Strategy and simulation work will be presented.

Secondary track (number):

**Strong Interactions and Hadron Physics / 630**

**Revealing proton structure with neural networks**

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Understanding the internal structure of the proton — that is, how it is built from its fundamental constituents, quarks and gluons — is one of the great challenges of modern high-energy physics. The three-dimensional distribution of quarks and gluons is encoded in terms of the so called generalized parton distributions (GPDs), and the most promising access to these functions is via the process of deeply virtual Compton scattering (DVCS).

We will show our global analyses of the available DVCS data leading to the extraction of relevant structure functions in a model-dependent way. To overcome the problem of model bias, which is particularly dangerous in this context, we describe the analogous procedure using unbiased neural networks. As an application, we discuss the possibility of measurement of pressure inside the proton [1].


Secondary track (number):

**Accelerator: Physics, Performance, and R&D for Future Facilities - Posters / 631**

**Integrated luminosity measurement at CEPC**

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The very forward region of a detector at future $e^+e^-$ collider is the one of the most challenging regions to instrument. A luminometer — compact calorimeter dedicated for precision measurement of the integrated luminosity at a permille level or better is needed. Here we review a feasibility of such precision at CEPC, considering detector mechanical precision and beam-related requirements.
We also discuss capabilities of experimental determination of the beam-energy spread, from the perspective of integrated luminosity precision requirements at the Z0 pole.

Secondary track (number):

Accelerator: Physics, Performance, and R&D for Future Facilities - Posters / 632

Irradiation setup at the U-120M cyclotron facility

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The poster will describe the U-120M cyclotron facility at the Nuclear Physics Institute of the Czech Academy of Sciences and parameters of the provided beams. The facility is extensively used for tests of radiation hardness of various electronic components for high-energy physics including silicon sensors and FPGAs. The poster will present a dedicated setup that is used for these irradiation studies and it will discuss methods used for on-line monitoring of beam parameters and total ionizing dose.

Secondary track (number):

Formal Theory - Posters / 633

GUT inspired gauge-Higgs unification model

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SO(5) $\times$ U(1) $\times$ SU(3) gauge-Higgs unification model inspired by SO(11) gauge-Higgs grand unification is constructed in the Randall-Sundrum warped space. The 4D Higgs boson is identified with the Aharonov-Bohm phase in the fifth dimension. Fermion multiplets are introduced in the bulk in the spinor, vector and singlet representations of SO(5) such that they are implemented in the spinor and vector representations of SO(11). We discuss the symmetry breakings, mass spectrum and the flavor mixing in the model.

Secondary track (number):

Neutrino Physics / 634

JUNO Physics

Author: Cecile Jollet\textsuperscript{1}
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The Jiangmen Underground Neutrino Observatory is a 20 kton multi-purpose liquid scintillator detector currently being built in a dedicated underground laboratory in China, expected to start data taking in 2022. JUNO’s primary physics goal is the determination of the neutrino mass ordering, with an expected significance of 3-4 sigma in about six years of data taking, by measuring the oscillation pattern of electron antineutrinos coming from two nuclear power plants at a baseline of 53 km. To reach the proposed goal an unprecedented energy resolution of 3% at 1 MeV is needed. Besides the main physics goal, JUNO will have a very rich physics program including the measurement of neutrino oscillation parameters with a sub-percent precision, and the detection of solar, galactic core-collapse supernova and atmospheric neutrinos. JUNO will also implement a dedicated multi-messenger trigger system to maximize the potential as a neutrino telescope. In addition JUNO will be a perfect observatory for nucleon decays. In this talk I will give an overview on the JUNO physics potential, the experimental status, and the performances of the JUNO detector for the different physics cases.

Computing and Data Handling / 635

Generating the full SM at linear colliders

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Future linear e+e- colliders aim for extremely high precision measurements. To achieve this, not only excellent detectors and well controlled machine conditions are needed, but also the best possible estimate of backgrounds. To avoid that lacking channels and too low statistics becomes a major source of systematic errors in data-MC comparisons, all SM channels with the potential to yield at least a few events under the full lifetime of the projects need to be generated, with statistics largely exceeding that of the real data. Also machine conditions need to be accurately taken into account. This includes beam-polarisation, interactions due to the photons inevitably present in the highly focused beams, and coherent interactions of whole bunches. This endeavour has already been partly achieved in preparing design documents for both the ILC and CLIC: Comprehensive samples of fully simulated and reconstructed events are available for use.

In this contribution, we present how the generation of physics events at linear colliders is categorised and organised, and the tools used. Also covered is how different aspects of machine conditions, different sources of spurious interactions (such as beam-induced backgrounds) are treated and the tools involved for these aspects.

Strong Interactions and Hadron Physics / 636

Soft-gluon effective coupling

Author: Daniel Enrique De Florian Sabaris\textsuperscript{1}
We consider the extension of the CMW soft-gluon effective coupling in the context of soft-gluon resummation for QCD hard-scattering observables beyond the next-to-leading logarithmic accuracy. We present two proposals of a soft-gluon effective coupling that extend the CMW coupling to all perturbative orders. Although both effective couplings are well-defined in the physical four-dimensional space time, we examine their behaviour in \( \mathbb{R}^{4-2\epsilon} \) space time dimensions. We uncover an all-order perturbative relation with the cusp anomalous dimension: the (four dimensional) cusp anomalous dimension is equal to the \( \mathbb{R}^{\epsilon} \)-dimensional soft-gluon effective coupling at the conformal point \( \epsilon = \frac{1}{\alpha_s} \). We present the explicit expressions of the two soft-gluon couplings up to \( O(\alpha_s^2) \).

In the four-dimensional case we compute the two soft couplings up to \( O(\alpha_s^3) \).

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**Secondary track (number):**

**Astro-particle Physics and Cosmology / 637**

**Measurements of Light Nuclear Isotopic Composition in Cosmic Rays with the Alpha Magnetic Spectrometer on the International Space Station**

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The average lifetime of cosmic rays in the Galaxy related with their confinement within the Galactic propagation halo, is a very important parameter to understand cosmic-ray propagation processes and the cosmic-ray origin. The measurement of the \( ^{10}\text{Be}/^{9}\text{Be} \) secondary isotope ratio, as \( ^{10}\text{Be} \) has half-life of 1.39 million years, can be used to constrain the propagation lifetime. The \( ^{6}\text{Li}/^{7}\text{Li} \) ratio, as both isotopes are secondary and stable, is expected to reflect the ratio between the production cross sections and therefore constitute a good check of the reconstruction method. Measurement of the lithium and beryllium isotopic ratio \( ^{6}\text{Li}/^{7}\text{Li} \) and \( ^{10}\text{Be}/^{9}\text{Be} \) as a function of the kinetic energy per nucleon from 0.5 GeV/nuc to 10 GeV/nuc based on data collected by AMS during the first 7 years of operation are presented. Prospects for measurement of the boron isotopic ratios with AMS-02 will be presented.

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**Secondary track (number):**

**Operation, Performance and Upgrade of Present Detectors / 638**

**The Belle II Silicon Vertex Detector: Performance and Running Experience**

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In spring 2019 the fully equipped Belle II experiment started data taking at the energy of the Y(4S) resonance. The new vertex detector (VXD) consists of two inner layers of DEPFET pixels (PXD) and four layers of double-sided silicon strip detectors (SVD). It plays a crucial role in recording high-quality data in the new high-luminosity environment of the SuperKEKB collider, characterized by severe beam backgrounds. The SVD was operated reliably during the 2019 physics run, showing high stability of the noise levels and calibration parameters. The SVD performance, measured with first data, showed excellent hit and tracking efficiency, high signal-to-noise ratio and cluster energy distribution in fair agreement with the expectations. Detailed studies of the good spatial resolution achieved will be shown. The excellent hit-time resolution has also been measured, which will be exploited for background rejection in the coming years of running at higher luminosity.

I read the instructions:

Secondary track (number):

Accelerator: Physics, Performance, and R&D for Future Facilities / 640

Prospects on Muon Colliders

Authors: Nadia Pastrone¹; Jean-Pierre Delahaye¹; Jean-Pierre Delahaye¹; Marcella Diemoz²; Kenneth Long¹; Bruno Mansouline⁴; Lenny Rivkin²; Daniel Schulte¹; Alexander Skrinisky⁶; Andrea Wulzer⁷

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In the framework of the European Strategy Update on Particle Physics, the working group appointed to review the Muon Colliders has become the de facto seed of an on-going international effort. A muon collider, if demonstrated to be feasible, is a unique discovery machine and the best tool to fully study the Higgs potential, since it can offer collisions of point-like particles at very high energies, significantly surpassing the energy reach of other lepton colliders. It can even match the discovery potential of a proton collider with much higher energy, since the muon collision energy is fully available at the constituent level unlike for protons. The need for high luminosity faces technical challenges which arise from the short muon lifetime at rest and the difficulty of producing large numbers of muons in bunches with small emittance. Addressing these challenges requires the development of innovative concepts and demanding technologies, exploiting synergies with other new accelerator projects. A plan to launch the studies for a vigorous and conclusive R&D programme has been presented and is under discussion. A well-focused international community will be required to exploit existing key competencies and to develop such a novel and promising project for the future of High Energy Physics.

I read the instructions:

Secondary track (number):

Neutrino Physics / 641
Review of MINERvA’s Medium Energy Neutrino Physics Program

Authors: Heidi Marie Schellman\(^1\); MINERvA Collaboration\(^{None}\)

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The MINERvA experiment completed its physics run using the 6-GeV, on-axis NuMI ME beam at Fermilab. The experiment received a total of \(12 \times 10^{20}\) protons on target in both neutrino and antineutrino mode running. This allows MINERvA a new level of statistical precision in neutrino interaction measurements with the ability to measure multi-dimensional differential cross sections. In order to make the most of this jump in statistics, a new level of precision in flux prediction has also been required. This talk will cover MINERvA’s Medium Energy (ME) physics program, including the new kinematic regimes that are now accessible, and will also discuss the exceptional precision reached in flux determination.

Secondary track (number):

11

Astro-particle Physics and Cosmology / 642

Precision Measurement of the Monthly Boron, Carbon and Oxygen Fluxes in Cosmic Rays with the Alpha Magnetic Spectrometer on the International Space Station

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Cosmic Rays (CR) inside the Heliosphere are subject to the effects of the Solar Modulation, resulting from their interaction with the solar wind and with the interplanetary magnetic field. These effects are strongly related to the solar activity and lead to a temporal variation of the cosmic ray intensity near Earth for rigidities up to few tens of GV. Previous AMS results on proton and helium spectra showed how the two fluxes behave differently in time. To better understand these unexpected results, one should therefore study the next most abundant species such as carbon, oxygen, and boron.

In this contribution, the precision measurements of the monthly boron, carbon and oxygen fluxes for the period from May 2011 to May 2018 with Alpha Magnetic Spectrometer on the International Space Station are presented. This period covers the ascending phase of solar cycle 24 together with the reversal of the Sun’s magnetic field polarity through the maximum. The detailed temporal variations of the boron, carbon and oxygen fluxes are shown up to rigidities of 60 GV. The time dependence of the B/C, B/O and C/O fluxes ratios are also presented.

Secondary track (number):

Formal Theory / 643

Supersymmetric theories and Graphene

Author: Antonio Gallerati\(^1\)
We discuss a 2+1 dimensional model holographically realized as the boundary theory of a four-dimensional gravity model in Anti de Sitter (AdS) spacetime. The result is achieved through suitable boundary conditions for the D=4 fields, and an effective model for massive spin-1/2 fields on a curved background is obtained.

The (unconventional) supersymmetry of the boundary model allows to introduce extra internal degrees of freedom, which can provide an application of the model to the description of the charge carriers properties of graphene-like 2D materials at the Dirac points K and K'. In particular, the two valleys correspond to the two independent sectors of the boundary model, connected by a parity transformation. The fermion masses entering the corresponding Dirac equations are related to the torsion parameters of the substrate in the three-dimensional model: the parity-even and odd components of the corresponding masses are identified with Semenoff and Haldane-type mass contributions, respectively.

The construction follows a top-down approach, in that the effective 2+1 dimensional theory for a condensed matter system at the boundary originates from a well-defined supersymmetric effective supergravity in the bulk.

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Usage of PEN as self-vetoing structural material in low background experiments

Authors: Luis Manzanillas¹; Working group PENNone

¹ Max Planck Institute for Physics

PEN is an industrial polyester plastic which has become interesting for the physics community as a new type of plastic scintillator. PEN scintillates in the blue regime, which is ideal for most photo-sensor devices. In addition, PEN has excellent mechanical properties and very good radiopurity has been achieved. Thus, it is an ideal candidate for active structural components in low-background experiments. One possible application are holders for germanium detectors operating in cryogenic liquids (LAr, LN2). Such structures can help to reject surface and external backgrounds, boosting the sensitivity of the experiments. The R&D on PEN will be outlined and an evaluation of the first production of PEN structures for the LEGEND-200 experiment will be presented.

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Precision measurements of 3He-to-4He ratio and individual 3He and 4He fluxes in Cosmic Rays with the Alpha Magnetic Spectrometer on the International Space Station

Author: Francesca Giovacchini¹

¹ CIEMAT
The spectral shape of the secondary isotopes in cosmic rays is completely determined by the source spectrum of the parent elements and by the propagation process. In particular, $^3$He in cosmic rays is believed to result from the interaction of primary $^4$He with the interstellar medium, providing a powerful tool to constrain the parameters of the galactic cosmic rays propagation models. Precise measurements of the $^3$He and $^4$He fluxes and the $^3$He/$^4$He flux ratio are presented in the rigidity range from 1.9 to 15 GV for $^3$He, from 2.1 to 21 GV for $^4$He, and from 2.1 to 15 GV for the $^3$He/$^4$He flux ratio based on data collected by AMS during the first 6.5 years of operation. The $^3$He and $^4$He fluxes are measured in 21 time periods of four Bartels’ rotations (108 days) each.

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Preliminary design of the Interaction Region (IR) of the future Electron-Ion Collider (EIC) at BNL

Author: Jaroslav Adam$^1$

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The Electron-Ion Collider (EIC) will be built to address fundamental questions which include the origin of the nucleon spin, space and momentum distribution of partons inside nucleons, interaction of jets in nuclear medium and the dynamics of the gluon density at high energies.

In this talk we present an overview of the Interaction Region (IR) design for the EIC. The design takes into account the requirements imposed by the aforementioned physics goals.

The IR features 9 m of available space for the central detector system, a forward spectrometer for the detection of hadrons scattered at small angles, and a luminosity detector and a detector for scattered electrons at the rear side, at the direction of the outgoing electron beam.

The talk will discuss the present status and challenges of the IR design.

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The E989 Muon $g-2$ Experiment at Fermilab aims to measure the muon magnetic anomaly, $a_\mu$, more precisely than the previous experiment at Brookhaven National Laboratory. There stands a greater than 3 standard deviations discrepancy between the Brookhaven measurement of $a_\mu$ and the theoretical value predicted using the Standard Model. The Fermilab experiment seeks to either resolve or confirm this discrepancy, which may be an indication of new physics. Measuring $a_\mu$ requires a
precise determination of the muon anomalous precession frequency (spin precession relative to mo-
mentum) and the average magnetic field seen by the muons as they circulate in a storage ring. The
anomalous precession frequency is imprinted on the time-dependent energy distribution of decay
positrons observed by 24 electromagnetic calorimeters placed around the inside of the ring. A suite
of pulsed NMR probes continually monitors the magnetic field. This talk will present the preces-
sion frequency analysis of the 2018 Run 1 dataset, which is similar in size to the entire Brookhaven
dataset.

Secondary track (number):

Beyond the Standard Model / 648

Looking for Monopoles in ALICE

Author: M.Beatriz Gay Ducati¹

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The magnetic monopole-antimonopole pair production, and their bound state, are estimated for
colliders, focusing mainly in ALICE. The calculation is based on Dirac’s theory and considers photon
fusion and Drell-Yan, using the mass range from 300 GeV up to 3 TeV. The number of expected events
is given considering LHC energies and luminosity. In case of pp collisions, the higher contribution
to the cross section comes from photon fusion process, while for the monopolium it comes from
Drell-Yan. In a complement to the cross sections, energy and momentum distributions, that can
improve the chances of detection, are analyzed. It is also discussed the inclusion of a magnetic
moment parameter, given higher values to the cross sections and enlarging the applicability of the
theory.

Secondary track (number):

03

Neutrino Physics / 649

Electromagnetic neutrino properties: new constraints and new
effects

Author: Alexander Studenikin¹

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We continue our discussions [1-3] of neutrino electromagnetic properties and give a short intro-
duction to the derivation of the general structure of the electromagnetic form factors of Dirac and
Majorana neutrinos. Then we consider experimental constraints on neutrino magnetic and electric
dipole moments, electric millicharge, charge radii and anapole moments from the terrestrial labora-
tory experiments (the bounds obtained by the reactor MUNU, TEXONO and GEMMA experiments
and the solar Super-Kamiokande and the recent Borexino experiments). A special credit is done to
the recent and most severe constraints on neutrino magnetic moments, millicharge and charge radii
magnetic moments, as well as bounds on millicharge from the reactor [6] neutrinos fluxes are in-
cluded in the recent issues of the Review of Particle Physics (see the latest Review: M. Tanabashi et
We present results of the recent detailed study \[12\] of the electromagnetic interactions of massive neutrinos in the theoretical formulation of low-energy elastic neutrino-electron scattering. The formalism of neutrino charge, magnetic, electric, and anapole form factors defined as matrices in the mass basis with account for three-neutrino mixing is presented. Using the derived new expression for a neutrino electromagnetic scattering cross section \[13\], we further developed studies of neutrino electromagnetic properties using the COHERENT data \[7\] and obtained \[8\] new bounds on the neutrino charge radii from the COHERENT experiment. Worthy of note, our paper \[8\] has been included by the Editors Suggestion to the Phys. Rev. D “Highlights of 2018”, and the obtained constraints on the nondiagonal neutrino charge radii has been included by the Particle Data Group to the 2019 upgrade of the Review of Particle Physics.

The main manifestation of neutrino electromagnetic interactions, such as: 1) the radiative decay in vacuum, in matter and in a magnetic field, 2) the neutrino Cherenkov radiation, 3) the plasmon decay to neutrino-antineutrino pair, 4) the neutrino spin light in matter, and 5) the neutrino spin and spin-flavour precession are discussed. Phenomenological consequences of neutrino electromagnetic interactions (including the spin light of neutrino \[13\]) in astrophysical environments are also reviewed.

The second part of the proposed talk is dedicated to results of our mostly recently performed detailed studies of new effects in neutrino spin, spin-flavour and flavor oscillations under the influence of the transversal matter currents \[14\] and a constant magnetic field \[15, 16\], as well as to our newly developed approach to the problem of the neutrino quantum decoherence \[17\] and also to our recent proposal \[18\] for an experimental setup to observe coherent elastic neutrino-atom scattering (CEνAS) using electron antineutrinos from tritium decay and a liquid helium target that as we have estimated opens a new frontier in constraining the neutrino magnetic moment.

The discovered new phenomena in neutrino oscillations should be accounted for reinterpretation of results of already performed experiments on detection of astrophysical neutrino fluxes produced in astrophysical environments with strong magnetic fields and dense matter. These new neutrino oscillation phenomena are also of interest in view of future experiments on observations of supernova neutrino fluxes with large volume liquid-scintillator and water Chernkov detectors like JUNO and Hyper_Kamiokande, for instance.

Two other new results discussed in the concluding part of the talk are as follows:

1) it is shown \[14\] that neutrino spin and spin-flavor oscillations can be engendered by weak interactions of neutrinos with the medium in the case when there are the transversal matter currents; different possibilities for the resonance amplification of oscillations are discussed, the neutrino Standard Model and non-standard interactions are accounted for;

2) within a new treatment \[15\] of the neutrino flavor, spin and spin-flavour oscillations in the presence of a constant magnetic field, that is based on the use of the exact neutrino stationary states in the magnetic field, it is shown that there is an interplay of neutrino oscillations on different frequencies; in particular: a) the amplitude of the flavour oscillations \(\nu_{Le} \leftrightarrow \nu_{L\mu}\) at the vacuum frequency is modulated by the magnetic field frequency \(\mu B\), and b) the neutrino spin oscillation probability (without change of the neutrino flavour) exhibits the dependence on the neutrino energy and mass square difference \(\Delta m^2\).

The discussed in the second part of the talk new results include two new effects that can be summarized as follows:

3) a new theoretical framework, based on the quantum field theory of open systems applied to neutrinos, has been developed \[17\] to describe the neutrino evolution in external environments accounting for the effect of the neutrino quantum decoherence; we have used this approach to consider a new mechanism of the neutrino quantum decoherence engendered by the neutrino radiative decay to photons and dark photons in an astrophysical environment, the corresponding new constraints on the decoherence parameter have been obtained;

4) in \[18\] we have proposed an experimental setup to observe coherent elastic neutrino-atom scattering (CEνAS) using electron antineutrinos from tritium decay and a liquid helium target and shown that the sensitivity of this apparatus (when using 60 g of tritium) to a possible electron neutrino magnetic moment can be of order about \(7 \times 10^{-13}\mu_B\) at 90% C.L., that is more than one order of magnitude smaller than the current experimental limit.
The best world experimental bounds on neutrino electromagnetic properties are confronted with the predictions of theories beyond the Standard Model. It is shown that studies of neutrino electromagnetic properties provide a powerful tool to probe physics beyond the Standard Model.

References:


Neutrino Oscillation in Dense Matter

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As the increasing of neutrino energy or matter density, the neutrino oscillation in matter may undergo "vacuum-dominated", "resonance" and "matter-dominated" three different stages successively. Neutrinos endure very different matter effects, and therefore present very different oscillation behaviors in these three different cases. In this talk, we focus on the less discussed matter-dominated case, discuss the intriguing features of the effective neutrino mass and mixing parameters as well as neutrino oscillation probabilities in dense matter. We show that as the matter potential growing larger, the effective mixing matrix in matter evolves approaching a fixed constant real matrix which is free of CP violation and can be described using only one simple mixing angle. As for the neutrino oscillation behavior, electron neutrinos decoupled in the matter-dominated case due to its intense charged-current interaction with electrons while a two-flavor oscillation are still presented between the muon neutrinos and tau neutrinos.

After these general discussion, we make a very bold comparison of the oscillation behaviors between neutrinos passing through the Earth and passing through a typical white dwarf and show that when neutrinos passing through a compact object like white dwarf, its energy spectrum would be distorted due to the intense matter effect. We call this interesting result the "neutrino lensing" effect. And different from the gravitational lensing effect which is capable of uncovering the mass distribution in our universe, this "neutrino lensing" effect could be sensitive to the distribution of electrons (or positrons) in the space through their weak interactions with neutrinos.

This talk is based on an recently published paper of us with the same title. (https://doi.org/10.1103/PhysRevD.101.033005)

I read the instructions:

Secondary track (number):

Neutrino Physics / 651

CPT violation sensitivity of NoVA, T2K and INO experiments using $\nu$ and $\bar{\nu}$ oscillation parameters

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Charge-Parity-Time (CPT) symmetry governs that the oscillation parameters for neutrinos and anti-neutrinos are to be identical. Different mass and mixing parameters for these particles may give us a possible hint for CPT violation in the neutrino sector. Using this approach, we discuss the ability of long-baseline and atmospheric neutrino experiments to determine the difference between mass squared splittings ($\Delta m^2_{12}$ - $\Delta m^2_{13}$) and atmospheric mixing angles ($\sin^2 \theta_{12}$ - $\sin^2 \theta_{23}$) of neutrinos and anti-neutrinos. We show the joint sensitivity of the T2K, NOvA and INO experiments to such CPT violating observables in different possible combinations of octant for neutrinos and anti-neutrinos.
Development and evaluation of prototypes for the ATLAS ITk pixel detector

Authors: ATLAS Collaboration\textsuperscript{Non}, Florian Hinterkeuser\textsuperscript{1}

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The ATLAS tracking system will be replaced by an all-silicon detector for the HL-LHC upgrade around 2025. The innermost five layers of the detector system will be pixel detector layers which will be most challenging in terms of radiation hardness, data rate and readout speed. A serial power scheme will be used for the pixel layers to reduce the radiation length and power consumption in cables. New elements are required to operate and monitor a serially powered detector including a detector control system, constant current sources and front-end electronics with shunt regulators. Prototypes for all subsystems are built to verify the concept and operate multiple serial power chains as a system test. The evaluation of both the readout of multi-modules and mechanical integration are further aims of the prototyping campaign. In the contribution, results will be presented of this prototyping effort. Moreover, details and features of serial powering for full detector systems will be given.

ATLAS ITk Pixel Detector Overview

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For the HL-LHC upgrade the current ATLAS Inner Detector is replaced by an all-silicon system. The Pixel Detector will consist of 5 barrel layers and a number of rings, resulting in about 14 m2 of instrumented area. Due to the huge non-ionizing fluence (1e16 neq/cm2) and ionizing dose (5 MGy), the two innermost layers, instrumented with 3D pixel sensors (L0) and 100μm thin planar sensors (L1) will be replaced after about 5 years of operation. All hybrid detector modules will be read out by novel ASICs, implemented in 65nm CMOS technology, with a bandwidth of up to 5 Gb/s. Data will be transmitted optically to the off-detector readout system. To save material in the servicing cables, serial powering is employed for low voltage. Large scale prototyping programs are being carried out by all sub-systems. The talk will give an overview of the layout and current status of the development of the ITk Pixel Detector.
The ATLAS ITk Strip Detector System for the Phase-II LHC Upgrade

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The ATLAS experiment at the Large Hadron Collider is currently preparing for a major upgrade of the Inner Tracking for the Phase-II LHC operation (known as HL-LHC), scheduled to start in 2026. In order to achieve the integrated luminosity of 4000 fb⁻¹, the instantaneous luminosity is expected to reach unprecedented values, resulting in about 200 proton-proton interactions in a typical bunch crossing. The radiation damage at the full integrated luminosity implies integrated hadron fluencies over 2x10⁻¹⁶ neq/cm² requiring a complete replacement of the existing Inner Detector. An all-silicon Inner Tracker (ITk) is under development with a pixel detector surrounded by a strip detector, aiming to provide increased tracking coverage up to |η|=4.

The ITk Strip Detector system consisting of four barrel layers in the centre and forward regions composed of six disks at each end, is described in the ATLAS Inner Tracker Strip Detector Technical Design Report (TDR). With the recent completion of Final Design Reviews (FDRs) in a number of key areas, such as Sensors, Modules, ASICs and Front-end electronics, the prototyping phase has been completed successfully. The pre-production phase is about to start at the institutes involved. In this contribution we present an overview of the ITk Strip Detector System, including the final layout of the ITk Strip Detector System, and highlight the final design choices of sensors, module designs and ASICs. We will give an extended summary of the R&D results achieved in the prototyping phase. Some of the modules were irradiated with a range of fluencies and reaching up to and in some cases exceeding HL-LHC doses, demonstrating the excellent radiation hardness achieved. In addition, we will outline the current status of pre-production on various detector components, with an emphasis on QA and QC procedures. We will also discuss the status of preparations and the plans for the forthcoming pre-production and production phase.

Test Beam Studies of Barrel and End-Cap Modules for the ATLAS ITk Strip Detector before and after Irradiation

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The ATLAS experiment at the Large Hadron Collider is currently preparing for the High-Luminosity LHC (HL-LHC). In order to achieve the integrated luminosity of 4000 fb⁻¹, the instantaneous luminosity is expected to reach unprecedented values. The radiation damage at the full integrated luminosity implies integrated hadron fluencies over 2x10⁻¹⁶ neq/cm² requiring a replacement of the entire existing Inner Detector. In order to cope with the occupancy and radiation doses expected at the HL-LHC, the ATLAS experiment will replace its Inner Detector with an all-silicon Inner Tracker (ITk), consisting of pixel and strip subsystems. The strip subsystem will be built from modules, consisting of one n+-in-p silicon strip sensor, manufactured by Hamamatsu Photonics, and one or two PCB hybrids containing the front-end electronics glued directly onto the active surface of the sensor. A power-board, containing an HV switch, a monitoring and control ASIC, and a DC-DC converter, is also glued to the sensor.

In the last three years, several prototype ITk strip modules have been produced and tested extensively using beams of high-energy electrons and charged pions produced at the DESY-II and CERN...
SPS test-beam facilities. Tracking was provided by EUDET telescopes, consisting of six Mimosa26 pixel planes, resulting in a track resolution of around 2 μm. The modules tested were built from two sensor types: the rectangular ATLAS17LS sensor, which will be used in the central barrel region of the detector, and the annular ATLAS12EC sensor, designed for the innermost ring (R0) of the forward endcap region. Every sensor geometry has been tested using both the final prototype version of the front-end electronics, known as "star" chipset, as well as a previous prototype chipset developed for lower trigger rate specification. Additionally, a dedicated carbon-fibre based mechanical support, similar to the final support structure, with two R0 modules positioned back-to-back has been measured, demonstrating space point reconstruction using the stereo angle of the strips. Finally, two R0 modules, one with each chipset, have been measured after radiation doses up to factor of 1.5 over the expected end-of-lifetime fluence of the ATLAS ITk.

Based on the large set of test beam data obtained, we will present results of thorough tests of the module performance, including charge collection, noise occupancy, detection efficiency, and tracking performance. Additionally, the excellent tracking resolution allows for detailed studies of various sensor features. The results give confidence that the ITk strip detector will meet the requirements of the ATLAS experiment at the Phase-II LHC Upgrade.
order to cope with the large radiation doses and to maintain the physics performance reached during Phase 1, the current ATLAS Inner Detector will be replaced with a new all-silicon Inner Tracker (ITk) and completed with a new High-Granularity Timing Detector (HGTD) in the forward region. In this talk, the latest results on the expected ITk tracking performance and HGTD timing reconstruction will be presented, including their impact on physics object reconstruction.

I read the instructions:

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 660

Performance of the SoLid reactor neutrino detector

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The SoLid collaboration operates since 2018 a 1.6 ton neutrino detector near the Belgian BR2 reactor, with as a main goal the search for observation of the oscillation of electron anti-neutrinos to previously undetected flavor states. The highly segmented SoLid detector employs a novel compound scintillation technology based on PVT scintillator in combination with a LiFZnS screens containing 6Li isotopes. The experiment has demonstrated a channel-to-channel response that can be controlled to the level of a few percent, an energy resolution of better than 14% at 1 MeV, and a determination of the interaction vertex with a precision of 5cm.

In this contribution we will discuss the technology choices that were made to construct the SoLid experiment, the experience gained from its commissioning, calibration, and the detector performance characteristics during two years of non-stop operation. We will also discuss an ongoing upgrade program of the detector and the expected improvements in performance associated with that.

I read the instructions:

Secondary track (number):

Neutrino Physics / 661

First results from the SoLid reactor neutrino experiment

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The SoLid Collaboration

The SoLid experiment intends to search for active-to-sterile anti-neutrino oscillations at the very short baseline (6-9 m) of the SCK•CEN BR2 research reactor (Mol, Belgium) to address the so called "Reactor Anti-neutrino Anomaly". Discrepancies between data and the theoretical predictions in some earlier neutrino experiments at short distances were observed when compared to the new
predicted flux and spectra. This deficit could be explained by flavor oscillations of a new type of neutrino: the sterile neutrino.

A novel detector approach to detect the reactor anti-neutrinos was developed based on an innovative hybrid scintillator technology combining PVT and 6LiF:ZnS scintillators. The first scintillator serves as an anti-neutrino target for Inverse Beta Decay (IBD) reaction and measure the positron energy. The second scintillator tags the neutron capture by 6Li and allows to measure the characteristic IBD delay time. The system is highly segmented (5 cm) and read out by a network of wavelength shifting fibers and MPPCs. High experimental sensitivity can be achieved compared to other standard technologies thanks to the combination of high granularity, high neutron-gamma discrimination using 6LiF:ZnS(Ag) scintillator and precise localization of the IBD signals. The reconstruction of the full topology of the events allows a strong background rejection, necessary given the low overburden at the reactor building.

The detector has been taking physics data since 2018. We will present an overview of the experiment, the performances in terms of detector response, background rejection capabilities and the in articular the first physics results demonstrating the ability to probe the reactor antineutrino anomaly.

I read the instructions:

Secondary track (number):

Quark and Lepton Flavour Physics / 662

The COMET experiment: A search for muon-to-electron conversion at J-PARC

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The COMET Experiment at J-PARC aims to search for the lepton-flavour violating process of muon to electron conversion in a muonic atom, $\mu^- N \rightarrow e^- N$, with a 90% confidence level branching-ratio sensitivity of $6 \times 10^{-17}$, in order to explore the parameter region predicted by most well-motivated theoretical models beyond the Standard Model. The need for this sensitivity places several stringent requirements on both the muon beam and the detector system. In order to realize the experiment effectively and timely, a staged approach to deployment is employed, and the COMET Phase-I experiment will commence engineering runs in 2022. At the Phase-I experiment, a precise muon-beam measurement will be conducted, and a search for $\mu^- N \rightarrow e^- N$ will also be carried out with an intermediate sensitivity of $7 \times 10^{-15}$ (90% CL upper limit). In this paper, the current status of R&D and construction of the experiment is presented in addition to the experimental overview.

I read the instructions:

Secondary track (number):

Astro-particle Physics and Cosmology / 663

Multi-Messenger studies with the Pierre Auger Observatory

Author: Lukas Zehrer

Multi-messenger astrophysics has emerged over the past decade as a distinct discipline, providing unique insights into the properties of high-energy phenomena in the Universe. The Pierre Auger Observatory, located in Malargüe, Argentina, is the world’s largest cosmic ray detector and is sensitive to photons, neutrinos and hadrons at ultra-high energies. Using its data, stringent limits on photon and neutrino fluxes at EeV energies have been obtained. The collaboration uses the excellent angular resolution and the neutrino identification capabilities of the Observatory for follow-up studies of events detected in gravitational waves, or other messengers, through a cooperation with the global Astrophysical Multimessenger Observatory Network (AMON). A science motivation together with an overview of the multi-messenger capabilities and results of the Pierre Auger Observatory are presented.

Secondary track (number):

Beyond the Standard Model / 664

A combined explanation of the $B$-decay anomalies with a single vector leptoquark

Author: Jonathan Kriewald

Co-authors: Chandan Hati, Ana M. Teixeira, Jean Orloff

In order to simultaneously account for both $R_{D^{(*)}}$ and $R_{K^{(*)}}$ anomalies in $B$-decays, we consider an extension of the Standard Model by a single vector leptoquark field, and study how one can achieve the required lepton flavour non-universality, starting from a priori universal gauge couplings. While the unitary quark-lepton mixing induced by $SU(2)_L$ breaking is insufficient, we find that effectively nonunitary mixings hold the key to simultaneously address the $R_{K^{(*)}}$ and $R_{D^{(*)}}$ anomalies. As an intermediate step towards various UV-complete models, we show that the mixings of charged leptons with additional vector-like heavy leptons successfully provide a nonunitary framework to explain $R_{K^{(*)}}$ and $R_{D^{(*)}}$. These realisations have a strong impact for electroweak precision observables and for flavour violating ones: isosinglet heavy lepton realisations are already excluded due to excessive contributions to lepton flavour violating $Z$-decays. Furthermore, in the near future, the expected progress in the sensitivity of charged lepton flavour violation experiments should allow to fully probe this class of vector leptoquark models.

Secondary track (number):

05.
A combined explanation of the $B$-decay anomalies with a single vector leptoquark

**Author:** Jonathan Kriewald

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**Secondary track (number):**
05.

Heavy Ions - Posters / 666

Deuteron (and cluster) production in ultrarelativistic heavy-ion collisions

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We consider two mechanisms for the light clusters production: the coalescence model and the thermal static model. The first one postulates that light nuclei are formed only at late times of the fireball evolution by recombination of protons and neutrons with close positions and velocities on the kinetic freeze-out surface. On the other hand, the thermal model assumes that there is a perfect chemical equilibrium above the chemical freeze-out temperature. Then the thermal model describes yields of all hadron species with the unique temperature of $T = 156$ MeV. This would mean that light nuclei seem to behave like all other hadrons. This is very surprising because it is hard to imagine that loosely bound sizeable nuclei can exist in the hot and dense hadron gas. From previous studies, we know that both models predict similar deuteron yields. We try to understand the cluster production and to distinguish between models also with the help of the anisotropic flow of the clusters.
**Timepix3 as solid-state time-projection chamber in particle and nuclear physics**

**Authors:** Benedikt Bergmann\(^1\); Claude Leroy\(^2\); Hugo Natal da Luz\(^3\); Michal Suk\(^4\); Petr Burian\(^4\); Petr Manek\(^4\); Rudolf Sykora\(^5\); Stanislav Pospisil\(^4\); Thomas Remy Victor Billoud\(^2\); Vlasios Petousis\(^4\)

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Timepix3 detectors are the latest member of the Medipix/Timepix family of hybrid pixel detectors developed at CERN. These detectors feature a segmented detector (256 x 256 pixels, pixel-pitch of 55 µm) flip-chip bump-bonded to the readout ASIC. In each pixel, Time-over-Threshold and Time-of-Arrival are measured simultaneously, while keeping a counting mode capability. The per-pixel dead time amounts to 475 ns.

In this contribution, we show that the time resolution of approximately 2 ns is sufficient to measure drift times of charge carriers, which in turn are used to reconstruct particle trajectories in 3D (creating a solid-state time-projection chamber). Using 40 GeV/c pion test beam data, we show that a z-resolution of 30 µm and 60 µm can be achieved in 500 µm thick silicon and 2 mm thick CdTe sensor layers, respectively. We show how the 3D information increases the particle type sensitivity and angular resolving power.

We apply the presented techniques to the evaluation of data taken in the ATLAS and MoEDAL experiments at CERN, where Timepix3 detectors (with 500 µm thick silicon sensors) are used as active radiation detectors. We describe how such methodology improves vertex reconstruction and angular correlation function measurement of internally created electron positron pairs in an experiment carried out at the Van-de-Graaff accelerator of the Institute of Experimental and Applied Physics.

**Jet production and fragmentation at colliders**

**Author:** Alexandre Shabetai\(^1\)

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Fragmentation (or in general, hadronization) is the transition from a colored and energetic parton to a colorless hadron is a rich and dynamical process in QCD quantified by the fragmentation function.
Fast moving hadrons (or jets) are produced by the fragmentation of colored quarks or gluons that are produced during hard collisions at short distances. The determination of a characteristic time scale for the color neutralization would shed light on the properties of color confinement and help answer the question: how hadrons emerge out of quarks and gluons?

Since the earliest days of collider physics, jets have been an important tool in the exploration of QCD and have provided important discoveries and insights, in all colliding systems, including e-e, e-p hadron-hadron, and nucleus-nucleus. With the advances in experimental techniques, and corresponding theoretical progress over time, jets have become precision tools for studying the partonic structure of matter.

Starting at the Relativistic Heavy Ion Collider (RHIC) at BNL, a suppression by a factor of five of the yield of high $p_T$ hadrons in Au-Au collisions, compared to proton-proton collision at the same energy was observed and called "jet quenching". The same phenomenon was confirmed by the heavy-ion program at the CERN’s Large Hadron Collider (LHC) where the jet quenching phenomenon was observed at much greater collision energies that became accessible, allowing new and more detailed characterization of the quark-gluon plasma. While interacting with the medium, a modification of the jet structure and a redistribution of jet energy as well as a modification of their fragmentation pattern is expected.

Jets in (SI)DIS are also guaranteed to contribute at the Electron-Ion Collider (EIC) to a variety of key electron-nucleus and electron-hadron physics topics in particular the study of hadronization, aiming to shed light on the nature of color neutralization and confinement.

A selection of results (not focussed on a particular experiment) on jet physics will be discussed and compared to theoretical calculations. The measurements that will be discussed may include $p_T$- differential jet production cross sections or detailed studies of the parton shower through observables like the jet mass, jet fragmentation functions or jet substructure observables. Well defined jet shapes observables can also provide complementary information on the fragmentation process.

Secondary track (number):

Beyond the Standard Model / 671

Precise spectroscopy of muonium hyperfine structure at J-PARC

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Muonium is the bound state of a positive muon and an electron. Muonium Spectroscopy Experiment Using Microwave (MuSEUM) collaboration has been performing precise spectroscopy of the ground state muonium hyperfine structure (MuHFS) with high-intensity pulsed muon beam at Japan Proton
Accelerator Research Complex (J-PARC). Our goal is a ten-fold improvement in precision of MuHFS compared to the previous experiment at Los Alamos Meson Physics Facility (LAMPF) [1]. In the previous experiments, the dominant uncertainty came from the limited number of muonium used for spectroscopy. We address this issue with the pulsed muon beam with the world’s highest intensity available at J-PARC.

One of major motivations for this new measurement is the test of the bound-state QED. Muonium is a purely leptonic system and so is free from the finite size effect of nuclei unlike ordinary atoms. That enables theorists to calculate its energy levels very precisely. In addition, muonium has an additional advantage over other leptonic hydrogen-like exotic atoms such as positronium because of its relatively long lifetime. Hence, muonium is one of the best probes to test the bound-state QED. Although QED is often quoted as the most accurate physics theory, andlightly so as demonstrated in the comparison of the experimental value and theoretical calculation of electron anomalous magnetic moment, the application of QED to a bound state introduces its own difficulties, and its validity needs to be tested.

The other is to contribute towards the measurement of the muon anomalous magnetic moment $a_\mu$. There is a discrepancy of more than $3\sigma$ between the theoretical and experimental values of $a_\mu$[2], and it has been suggested that this discrepancy is due to an additional contribution by BSM physics, such as supersymmetric particle loops. In order to address this problem, two groups at J-PARC and Fermilab have been planning to measure $a_\mu$ with 4 times higher precision than the previous experiment. In order to determine $a_\mu$ in these experiments, they need an additional value of a physical quantity, which is the muon-to-proton magnetic moment ratio $\mu_\mu/\mu_p$ and can be precisely determined from the MuHFS spectroscopy. MuSEUM collaboration aims to achieve the 20 ppb precision of $\mu_\mu/\mu_p$ without comparison of theoretical and experimental MuHFS value.

There have been two types of MuHFS measurement: one is at zero magnetic field and the other is in a high magnetic field (1.7 T). MuSEUM group has been planning to perform both of them because they have different types of systematic uncertainties and so are complementary. In MuSEUM experiment, the zero field measurement is in progress and the high field one is in preparation due to construction of beamline at J-PARC.

In this presentation, we will report the recent results of the measurement at zero magnetic field and R&D for the high magnetic field measurement.


**Neutrino Physics / 673**

**Reactor antineutrino flux and spectrum measurement at Daya Bay**

**Author:** An Fengpeng

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This talk presents the latest results of reactor antineutrino flux and spectrum measurement at Daya Bay. The Daya Bay Reactor Neutrino Experiment uses an array of eight underground detectors to study antineutrinos from six reactor cores at different baselines. Four antineutrino detectors in the two near experimental halls are used for the measurements. The reactor antineutrino flux measurement is improved by reducing the systematic uncertainty of neutron detection efficiency. A new measurement of the prompt energy spectrum of reactor antineutrinos with 1958 days of data shows a significant discrepancy in the shape of the spectrum compared with the Huber-Mueller model prediction. The individual IBD yield and spectra of U-235 and Pu-239 are also extracted for
the first time from the time evolution of IBD prompt energy spectra as the reactor fuel composition changes.

I read the instructions:

Secondary track (number):

Beyond the Standard Model / 674

Search for Proton Decay via \( p \rightarrow e^+\pi^0 \) and \( p \rightarrow \mu^+\pi^0 \) in 450 kiloton-years Exposure of the Super-Kamiokande Detector

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Super-Kamiokande is a 50 kton water Cherenkov detector in Japan. One of the main physics goals is to test Grand Unified Theory by searching for proton decay. The \( p \rightarrow e^+\pi^0 \) and \( p \rightarrow \mu^+\pi^0 \) decay modes are the most prospective because they are predicted in many theories, and because of their unique event topologies, signal and atmospheric neutrino background events that can be clearly discriminated experimentally. Super-Kamiokande has been operating from April 1996 and accumulated a large amount of data with a great potential for discovery. In order to further improve the search sensitivity, we have enlarged the fiducial mass of the Super-Kamiokande detector by 20% and added 25% more exposure by livetime update since the last published results in 2017, resulting in 1.5 times larger statistics. In this talk, the latest proton decay search results, especially via \( p \rightarrow e^+\pi^0 \) and \( p \rightarrow \mu^+\pi^0 \) modes with the larger fiducial mass will be presented.

Secondary track (number):

02

Astro-particle Physics and Cosmology / 675

New Properties of Neon, Magnesium, Silicon, and Sulfur Primary Cosmic Rays observed by the Alpha Magnetic Spectrometer on the International Space Station

Author: Qi Yan

Co-authors: Vitaly Choutko; Alberto Oliva; Mercedes Paniccia

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Neon, Magnesium, Silicon, and Sulfur nuclei in cosmic rays are thought to be mainly of primary origin, they are mainly produced and accelerated in astrophysical sources. We report the latest precise measurements of the Ne, Mg, Si, and S individual spectra in the rigidity range from 2 GV to 3 TV by the Alpha Magnetic Spectrometer based on the data collected during its first 7 years of operation. Unexpectedly, compared with the spectra of light nuclei Helium, Carbon, and Oxygen, the spectra of heavy nuclei Ne, Mg, Si, and S show distinctly different new properties.

Secondary track (number):

**Astro-particle Physics and Cosmology / 676**

**Measurements of the Deuteron flux and of the Deuteron to proton flux ratio in Cosmic Rays with AMS on the ISS**

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Deuterons represent about 1% of the charge 1 nuclei in the cosmic rays flux. They are produced in the large part by spallation reactions of primary cosmic 4He nuclei on the interstellar medium, and represent a very sensitive tool to verify and constrain CR propagation models in the galaxy. Given the smaller cross section for 4He->D with respect C->B the deuteron flux provides additional information about the cosmic rays propagation with respect the Boron over Carbon ratio. We will present the high precision measurement of the deuteron flux obtained by the high-statistics data sample collected by the Alpha Magnetic Spectrometer during its first eight years of operation on the International Space Station.

I read the instructions:

Secondary track (number):

**Accelerator: Physics, Performance, and R&D for Future Facilities / 677**

**Proton and x-ray irradiation of silicon devices at the TIFPA-INFN facilities in Trento (Italy)**

**Author:** Benedetto Di Ruzza

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Proton and x-ray irradiation are essential procedure required to characterize the effects of TID and displacement damage designing silicon sensors for charged particle. The experimental area of a new new medical facility located in Trento (Italy) allow to perform irradiation on silicon pixel sensors, SiPM, and experimental electronic devices using protons with energy in the range of 70-230 MeV. The irradiation isocenter is in air, the circular beam spot can achieve a radius up to 3 cm with both uniform or gaussian profiles and a fluence up to $10^{13}$ protons/cm$^2$. This energy range is especially suitable for testing devices oriented to medical and space applications, but is also useful for high-energy detector upgrades. In the TIFPA-INFN laboratories is located also a tungsten anode x-ray source allowing a complete characterization of experimental silicon devices.
In this talk will be described the experimental area of the Trento proton medical irradiation facility, and some results of the proton and x-ray irradiation on prototype sensors for charged particle.

Secondary track (number):
13

Neutrino Physics / 678

Perturbative Charm Production and the Prompt Atmospheric Neutrino Flux in light of RHIC and LHC

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We evaluate the prompt atmospheric neutrino flux at high energies using three different frameworks for calculating the heavy quark production cross in QCD: NLO perturbative QCD, kT factorization including low-x resummation, and the dipole model including parton saturation. We use QCD parameters, the value for the charm quark mass and the range for the factorization and renormalization scales that provide the best description of the total charm cross section measured at fixed target experiments, at RHIC and at LHC. Using these parameters we calculate differential cross sections for charm and bottom production and compare with the latest data on forward charm meson production from LHCb at 7 TeV and at 13 TeV, finding good agreement with the data. In addition, we investigate the role of nuclear shadowing by including nuclear parton distribution functions (PDF) for the target air nucleus using two different nuclear PDF schemes. Depending on the scheme used, we find the reduction of the flux due to nuclear effects varies from 10% to 50% at the highest energies. Finally, we compare our results with the IceCube limit on the prompt neutrino flux, which is already providing valuable information about some of the QCD models.

I read the instructions:

Secondary track (number):
08

Astro-particle Physics and Cosmology / 679

Probing Secret Interactions of eV-scale Sterile Neutrinos with the Diffuse Supernova Neutrino Background

Author: Mary Hall Reno

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Sterile neutrinos with mass in the eV-scale and large mixings of order θ_0 \approx 0.1 could explain some anomalies found in short-baseline neutrino oscillation data. We consider a neutrino portal scenario in which eV-scale sterile neutrinos have self-interactions via a new gauge vector boson φ. Their production in the early Universe via mixing with active neutrinos can be suppressed by the induced effective potential in the sterile sector. We study how different cosmological observations can constrain this model, in terms of the mass of the new gauge boson, M_φ, and its coupling to sterile neutrinos, g_s. We explore how to probe part of the allowed parameter space of this particular model with future observations of the diffuse supernova neutrino background by the Hyper-Kamiokande and DUNE detectors. For M_φ \sim 5 - 10 \text{ keV} and g_s \sim 10^{-4} - 10^{-2}, as allowed by cosmological constraints, we find that interactions of diffuse supernova neutrinos with relic sterile neutrinos on their way to the Earth would result in significant dips in the neutrino spectrum which would produce unique features in the event spectra observed in these detectors.

I read the instructions:

Secondary track (number):
03

Dark Matter Detection / 680

Probing Heavy Dark Matter with the 6-year IceCube HESE data

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We consider the possibility that the IceCube’s 6-year high-energy starting events (HESE) data may be better explained by a combination of neutrino fluxes from dark matter decay and an isotropic astrophysical power-law than purely by the latter. We find that the combined two-component flux qualitatively improves the fit to the observed data over a purely astrophysical one, and discuss how these updated fits compare against a similar analysis done with the 4-year HESE data. We also show fits involving dark matter decay via multiple channels, without any contribution from the astrophysical flux. We find that a DM-only explanation is not excluded by neutrino data alone. Finally, we also consider the possibility of a signal from dark matter annihilations and perform analogous analyses to the case of decays, commenting on its implications.

I read the instructions:

Secondary track (number):
08
Neutrino mass ordering obscured by the non-standard interactions

Authors: Sabya Sachi Chatterjee\textsuperscript{1}; Antonio Palazzo\textsuperscript{2}; Francesco Capozzi\textsuperscript{3}

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One of the major open questions in particle physics is the issue of the neutrino mass ordering (NMO). The current data of the two long-baseline experiments NOvA and T2K, interpreted in the standard 3-flavor scenario, provide a $\sim 2.4\sigma$ indication in favor of the normal neutrino mass ordering. We show that such an indication is completely washed out if one assumes the existence of neutral-current non-standard interactions (NSI) of the flavor changing type involving the $e - \tau$ flavors. This implies that the claim for a discovery of the NMO will require a careful consideration of the impact of hypothetical NSI. In this context we also show that among the future LBL experiments, DUNE will have the best chances to remove the NMO confusion issue plaguing the present data. Finally, we mention that if no prior on the test value of $|\epsilon_{e\tau}|$ is assumed, the sensitivity of DUNE to the NMO further deteriorates, never reaching the $3\sigma$ level.

Improved determination of $|V_{us}|$ with tau decays

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We present improved determinations of $|V_{us}|$ with tau decays relying on the HFLAV tau branching fractions global fit results. Precision improvements come from using recent results from BaBar and recent evaluations with lattice of the electromagnetic (e.m.) and strong isospin-breaking corrections to the $\pi^+\rightarrow\mu^+\nu[\gamma]$ and $K^+\rightarrow\mu^+\nu[\gamma]$ leptonic decay rates. A third determination of $|V_{us}|$ has been added to the two ones that are included in the HFLAV 2017 report. The last HFLAV report is available as a preprint and is being submitted for publication at the beginning of 2020.
Production of heavy particle pairs via photon-photon processes at the LHC in proton-proton scattering

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Photon-induced processes in proton-proton interactions have become recently very topical. The large energy at the LHC, when combined with relatively large luminosity at run II, allows to start the exploration of such processes.

We discuss production of $W^+W^-$ pairs and $t\bar{t}$ quark-antiquark pairs in proton-proton collisions induced by two-photon fusion including, for a first time, transverse momenta of incoming photons. The unintegrated inelastic fluxes (related to proton dissociation) of photons are calculated based on modern parametrizations of deep inelastic structure functions in a broad range of $x$ and $Q^2$.

We focus on processes with single and double proton dissociation. Highly excited remnant systems hadronise producing particles that can be vetoed in the calorimeter. We calculate associated effective gap survival factors. The gap survival factors depend on the process, mass of the remnant system and collision energy. The rapidity gap survival factor due to remnant fragmentation for double dissociative (DD) collisions is smaller than that for single dissociative (SD) process. We observe approximate factorisation: $S_{R,DD} \approx S_{R,SD}^2$, when imposing rapidity veto. For the $W^+W^-$ final state, the remnant fragmentation leads to a taming of the cross section when the rapidity gap requirement is imposed. Also for $t\bar{t}$ quark-antiquark pairs such a condition reverses the hierarchy observed for the case when such condition is taken into account.

Our results imply that for the production of such heavy objects as $t$ quark and $\bar{t}$ antiquark the virtuality of the photons attached to the dissociative system are very large ($Q^2 < 10^4$ GeV$^2$). A similar effect was observed for the $W^+W^-$ system.


Dark Matter Detection / 684

Search for the axion dark matter in the mass range of 6.62–6.82 μeV

Authors: Saehyeok Ahn¹; Soohyung Lee²; Jihoon ChoiNone; ByeongRok Ko²; Yannis Semertzidis³

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The axion is a hypothetical particle associated with the spontaneous symmetry breaking of the U(1) symmetry, proposed by Pecci and Quinn to resolve the Charge-Parity problem in quantum chromodynamics. For invisible axions, cosmological and astrophysical observations impose the lower and upper limits on axion mass of μeV and meV respectively. The axion in such mass range could be
a promising candidate for cold dark matter. CAPP-8TB haloscope searches for axion by detecting photons, produced by the axion-photon coupling, resonating in a microwave cavity. CAPP-8TB has recently obtained a result of axion search in the mass range of 6.62–6.82 μeV. At the 90% confidence level the experiment probed the QCD axion down to the theoretical boundary, which is the most sensitive experimental result in the specific mass range to date. In this presentation I will explain the detail of the experimental setup, parameters and analysis procedure. A plan for the next phase of the experiment for different mass ranges will also be discussed.

I read the instructions:

Secondary track (number):

Strong Interactions and Hadron Physics - Posters / 686

Study of the central exclusive production of $\pi^+\pi^-$, $K^+K^-$ and $p\bar{p}$ pairs in proton-proton collisions at $\sqrt{s} = 510$ GeV with the STAR detector at RHIC

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We shall report the measurement of the central exclusive production process $pp \rightarrow pXp$ in proton-proton collisions at RHIC with the STAR detector at $\sqrt{s} = 510$ GeV. At this energy, this process is dominated by a Double Pomeron Exchange mechanism. The tracks of centrally produced system $X$ were reconstructed in the central detector of STAR, the Time Projection Chamber and the Time of Flight systems, and identified using the ionization energy loss and the time of flight method. The diffractively scattered protons, moving intact inside the RHIC beam pipe after the collision, were measured in the Roman Pots system allowing full control of the interaction’s kinematics and verification of its exclusivity. The preliminary results on the invariant mass distributions of centrally produced $\pi^+\pi^-$, $K^+K^-$ and $p\bar{p}$ pairs measured within the STAR acceptance will be presented.

Secondary track (number):

Computing and Data Handling / 687

PDFflow: hardware accelerating parton density access

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We present the PDFflow library for parton density functions (PDFs) access which takes advantages of multi-threading CPU and graphical processing unit (GPU). PDFflow is built in python and it leverages the PDF interpolation algorithm with TensorFlow. The resulting optimized computation graph accelerates and parallelizes algorithm when a large grid of interpolated PDF points is requested. Thus new approach differs from state of the art libraries such as LHAPDF6, which are limited to sequentially interpolate PDF points, with parallelism through hardware acceleration. We benchmark
PDFflow against the latest LHAPDF6 release and we show performance improvements of orders of magnitude concerning execution time while maintaining similar levels of accuracy.

I read the instructions:

Secondary track (number):

Astro-particle Physics and Cosmology / 688

Antiproton Flux and Properties of Elementary Particle Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the ISS

Author: Zhicheng Tang

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The fluxes and flux ratios of charged elementary particles in cosmic rays are presented in the absolute rigidity range from 1 up to 2000 GV. In the absolute rigidity range ∼60 to ∼500 GV, the antiproton, proton, and positron fluxes are found to have nearly identical rigidity dependence and the electron flux exhibits different rigidity dependence. Below 60 GV, the antiproton-to-proton, antiproton-to-positron, and proton-to-positron flux ratios each reaches a maximum. Particular emphasis is made on new observations of the properties of elementary particles in the rigidity range above 500 GV.

Secondary track (number):

Astro-particle Physics and Cosmology / 689

Anisotropy of Elementary Particle Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the ISS

Author: Iris Gebauer

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Analysis of anisotropy of the arrival directions of galactic protons, electrons and positrons has been performed with the Alpha Magnetic Spectrometer on the International Space Station. These results allow to differentiate between point-like and diffuse sources of cosmic rays for the explanation of the observed excess of high energy positrons. The AMS results on the dipole anisotropy are presented along with the discussion of implications of these measurements.

I read the instructions:

Secondary track (number):
Daily Cosmic-Ray Electron Fluxes by the Alpha Magnetic Spectrometer on the ISS

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High-statistics, precision measurements by AMS of the daily cosmic-ray electron fluxes from May 2011 to December 2018 are presented. Detailed comparison of these fluxes with the daily fluxes of other cosmic rays measured by AMS results in several new and surprising observations.

Neutrino Physics / 691

Latest Reactor Neutrino Oscillation Results from the Daya Bay Experiment

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In 2012, the Daya Bay experiment made the first statistically significant observation of a non-zero neutrino oscillation parameter $\theta_{13}$ based on neutron capture on gadolinium (nGd). Later on, the experiment provided another independent measurement with neutron capture on hydrogen (nH). Since the beginning of data taking, the experiment has accumulated nearly 4 million reactor neutrino candidates in about 2000 days and improved the systematics. In this talk, I will present the latest Daya Bay nGd and nH neutrino oscillation results and the sterile neutrino search.

Astro-particle Physics and Cosmology / 693

Towards Understanding the Origin of Cosmic-Ray Positrons

Author: Zhili Weng

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Precision measurements of cosmic ray positrons are presented up to 1 TeV based on 1.9 million positrons collected by the Alpha Magnetic Spectrometer on the International Space Station. The positron flux exhibits complex energy dependence. Its distinctive properties are: (a) a significant excess starting from 25.2 GeV compared to the lower-energy, power-law trend; (b) a sharp drop-off above 284 GeV; (c) in the entire energy range the positron flux is well described by the sum of a term associated with the positrons produced in the collision of cosmic rays, which dominates at low
energies, and a new source term of positrons, which dominates at high energies; and (d) a finite energy cutoff of the source term at 810 GeV is established with a significance of more than 4σ. These experimental data on cosmic ray positrons show that, at high energies, they predominantly originate either from dark matter annihilation or from new astrophysical sources.

Secondary track (number):
09

Computing and Data Handling / 695

On the impact of modern deep-learning techniques to the performance and time-requirements of classification models in experimental high-energy physics

Author: Giles Chatham Strong

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Beginning from a basic neural-network architecture, we test the potential benefits offered by a range of advanced techniques for machine learning and deep learning in the context of a typical classification problem encountered in the domain of high-energy physics, using a well-studied dataset: the 2014 Higgs ML Kaggle dataset. The advantages are evaluated in terms of both performance metrics and the time required to train and apply the resulting models. Techniques examined include domain-specific data-augmentation, learning rate and momentum scheduling, (advanced) ensembling in both model-space and weight-space, and alternative architectures and connection methods. Following the investigation, we arrive at a model which achieves equal performance to the winning solution of the original Kaggle challenge, whilst requiring about 2% of the training time and less than 5% of the inference time using much less specialised hardware. Additionally, a new wrapper library for PyTorch called LUMIN is presented, which incorporates all of the techniques studied.

Secondary track (number):

Astro-particle Physics and Cosmology - Posters / 696

Detector Simulation and Reconstruction of Supernova Neutrinos with JUNO

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Since the detection of neutrinos emitted by the supernova SN 1987A, no neutrinos from other supernovae have been observed to date. The Jiangmen Underground Neutrino Observatory (JUNO) will be capable of measuring the neutrino burst from a galactic supernova explosion. High statistics, a low detection threshold and an excellent energy resolution will strongly constrain the details of the neutrino-driven supernova mechanism. JUNO will be sensitive to signals from all neutrino flavors via different detection channels.
These are the inverse beta decay, elastic scattering on protons and electrons and various interactions with carbon. The capability of separating these channels is challenging but crucial for flavor dependent analyses of the supernova burst. We present initial results of an event classification that is based on a full detector simulation.

**Secondary track (number):**

02

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**Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques - Posters / 699**

### The CMS Level-1 Endcap Muon Trigger at the High-Luminosity LHC

**Author:** Daniel Guerrero

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**Corresponding Author:** daniel.guerrero@cern.ch

In the CMS endcap region, muon reconstruction in the Level-1 (L1) trigger is not straightforward because of the non-uniform magnetic field, high pile-up and punch-through interactions. However, the new muon detectors and the upgraded trigger processing capabilities proposed for the Phase-2 upgrade will allow the implementation of novel techniques that successfully address these challenges. For instance, track-finding and reconstruction of the standalone and displaced muons are carried out by a neural network-based algorithm. In addition, a proposed Global Muon Trigger system will have access to tracker tracks, muon trigger tracks and standalone muon detector hits. These objects can then be combined to improve the muon momentum resolution, reduce the muon trigger rates, and form multi-object triggers such as lepton-flavour violating tau->3mu decays. We present here preliminary studies addressing all these new capabilities.

**Secondary track (number):**

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**Quark and Lepton Flavour Physics / 700**

### Complementary test of lepton flavor universality violation in $B_s \rightarrow f'_2 (1525) \rightarrow K^{+} K^{-} \mu^+ \mu^-$ decays

**Authors:** Rajeev N1; Rupak Dutta1; Niladribihari Sahoo2

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The lepton flavor universality violation has been reported in the various flavor ratios such as $R_K$, $R_{K^{*}}$, and $P_\mu$ in $B \rightarrow K^{(*)} \mu^+ \mu^-$ decays. In this context, we perform an angular analysis of the four-body differential decay of $B_s \rightarrow f'_2 (1525) \rightarrow K^{+} K^{-} \mu^+ \mu^-$ in a model independent effective field theory formalism and provide a complementary information on the lepton flavor universality violation. The underlying decay mode proceed via similar $b \rightarrow s l^+ l^-$ quark level transition. We give predictions of various physical observables for $B_s \rightarrow f'_2 (1525) \rightarrow K^{+} K^{-} \mu^+ \mu^-$ decays in SM and in the presence of various NP scenarios. This can be easily tested in the upcoming LHCb experiments.
I read the instructions:

Secondary track (number):

Neutrino Physics / 701

KM3NeT/ORCA: status and perspectives for neutrino oscillation and mass hierarchy measurements

Corresponding Author: pkalaczynski@km3net.de

A next-generation neutrino telescope, the Kilometer Cube Neutrino Telescope (KM3NeT), is currently under deployment in the Mediterranean Sea. Its low energy configuration ORCA (Oscillations Research with Cosmics in the Abyss) is optimised for the detection of atmospheric neutrinos with energies above ∼1 GeV. The main research target of the ORCA detector is the measurement of the neutrino mass ordering and atmospheric neutrino oscillation parameters, while the detector is also sensitive to a wide variety of other physics topics, such as dark matter, non-standard interactions and sterile neutrinos.

The presentation will provide an overview of the ORCA detector and introduce its research programme, alongside early analyses of data collected with the array in its current, 6-lines configuration.

I read the instructions:

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques - Posters / 702

Measurement of Liquid Scintillator Nonlinearity

Authors: Tadeas DohnalNone; Tomáš TmějNone; Vit Vorobel1

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Organic liquid scintillator (LS) is a common choice for detectors precisely measuring energy of electron antineutrinos. Accurate knowledge of the relation between scintillation light response and the energy deposited by a particle is essential for determination of the antineutrino energy. The response is not exactly linear. Deviation from the LS linearity is the subject of the presented investigation. The method of measurement is using Compton scattering of gammas of well known energy in the LS and precise measurement of the scattered gamma energy with HPGe detector.

Secondary track (number):

Dark Matter Detection / 703

NEWS-G: Search for Light Dark Matter with a Spherical Proportional Counter
The NEWS-G collaboration is searching for light dark matter candidates using a spherical proportional counter. Access to the mass range from 0.1 to 10 GeV is enabled by the combination of low energy threshold, light gaseous targets (H, Ne), and highly radio-pure construction. The current status of the experiment will be presented, along with the first NEWS-G results obtained with SEDINE, a 60 cm in diameter spherical proportional counter operating at LSM (France), excluding cross-sections above $4.4 \times 10^{37} \text{ cm}^2$ for 0.5 GeV WIMP using a neon-based gas mixture. The construction of the next generation, 140 cm in diameter, spherical proportional counter using 4N copper at LSM will be discussed, along with the latest advances in SPC instrumentation. The detector, following initial commissioning at LSM is currently being installed at SNOLAB (Canada), with the first physics run scheduled for later this year. Finally, future prospects and applications of spherical proportional counters will be summarised.

I read the instructions:

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 705

The AugerPrime Upgrade of the Pierre Auger Observatory.

Author: Gabriella Cataldi

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To answer many questions still open in the field of Ultra-High-Energy Cosmic Rays, the Pierre Auger Collaboration started a significant upgrade of the Observatory, called AugerPrime.

The main goal of the upgrade is to improve the mass composition sensitivity of the surface detector on a shower-to-shower basis, in order to explore the cosmic ray composition at energies above $10^{19}$ eV. At energies unexplored by terrestrial accelerators, it will be possible to study the properties of multi-particle production and to search for new or unexpected changes of hadronic interactions. Moreover, in the region of the suppression of the cosmic ray flux, charged particle astronomy will benefit from the knowledge of the fraction of light primaries for composition-selected anisotropy searches.

After a discussion of the motivations for upgrading the Pierre Auger Observatory, a description of the detector upgrade will be provided, together with an evaluation of the expected performance and the improved physics sensitivity. Finally the first data collected will be presented.

Secondary track (number):

Higgs Physics / 706
Measurement of Higgs to WW in the all-jet final state at CEPC √s=250 GeV

Author: Mila Pandurovic¹

¹ Vinca Institute of Nuclear Sciences, University of Belgrade, Serbia

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The most important pillar in the physics case of future electron-positron colliders in high energy physics is the measurement of the Higgs boson, with its main goal to precisely measure the its properties and to probe potential of associated new physics. All next generation electron positron facilities in high energy physics will make use of the Higgstrahlung Higgs production channel. The physics potential of CEPC for measurement of the cross-section times branching ratio of subdominant decay H→WW⁺ is presented. The Higgstrahlung Higgs production channel is used, at the center of mass energy of 250 GeV. The fully hadronic decay, containing six soft-jets in the final state is of great importance for the detector design, jet pairing and reconstruction as showing the capability of CEPC for W/Z separation. The analysis is performed in full simulation.

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 707

Design and Performance of the Belle II High Level Trigger

Authors: Markus Prim¹; R. Itoh¹; M Nakao¹; S Yamada¹; S. Y. Suzuki¹; Q. Zhou¹; T. Konno¹; O. Hartbrich¹; S. H. Park¹; C. Li¹; N. Braun¹; Y. Guan¹; K. Lautenbach¹; S. Reiter¹; B. Spruck¹; T. Kunigo¹; M. Remnev¹

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The data acquisition system of Belle II is designed for a sustained first-level trigger rate of up to 30 kHz at the design luminosity of the SuperKEKB collider. The raw data read out from the subdetector frontends is delivered in realtime into an online High Level Trigger (HLT) farm, consisting of up to 20 computing nodes housing around 5000 processing cores. The HLT then reconstructs the events in realtime using the full Belle II reconstruction software. Based on this online reconstruction, events are filtered before being stored to disk for later offline processing and analysis.

In this talk, we will present the implementation of the newly developed data flow throughout the HLT system utilizing the open-source library ZeroMQ, which was first used in the beam run period in fall 2019. Additionally, we will present the physics performance of the filtering on the online system.

Secondary track (number):

14

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 708

Radiation hard monolithic CMOS sensors with small electrodes for the HL-LHC and beyond

Author: Carlos Solans Sanchez¹
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The upgrade of tracking detectors for experiments at the HL-LHC and future colliders requires the development of novel radiation hard silicon sensors. We target the replacement of hybrid pixel detectors with Depleted Monolithic Active Pixel Sensors (DMAPS) that are radiation hard monolithic CMOS sensors. We designed, manufactured and tested DMAPS in the TowerJazz 180nm CMOS imaging technology with small electrodes pixel designs, that have a pixel pitch well below the current hybrid pixel detectors, and less multiple scattering due to a total silicon thickness of only 50 micrometers. Furthermore monolithic CMOS sensors can substantially reduce detector costs. This contribution will present the development of the MALTA and MiniMALTA sensors, and the preliminary test-beam results that show the necessary steps to achieve radiation hardness at $1 \times 10^{15}$ 1MeV neq/cm$^2$.

The SiD Detector for the International Linear Collider

Authors: Andrew White$^1$; Marcel Stanitzki$^2$

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The SiD Detector is one of two validated detector designs for the future International Linear Collider. SiD features a compact, cost-constrained design for precision Higgs and other measurements, and sensitivity to a wide range of possible new phenomena. A robust silicon vertex and tracking system, combined with a 5 Tesla central solenoidal field, provides excellent momentum resolution. The highly granular calorimeter system is optimized for Particle Flow application to achieve very good jet energy resolution over a wide range of energies. Details of the proposed implementation of the SiD subsystems, as driven by the physics requirements, will be given. Integration with the accelerator, the push-pull mechanism, and the detector assembly procedures at the Kitakami site will be described, together with the estimated timeline for construction in relation to the overall ILC Project.

Double beta decay results from the CUPID-0 experiment

Author: Davide Chiesa$^1$

Co-author: CUPID-0 collaboration

$^1$ INFN - National Institute for Nuclear Physics

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A convincing observation of neutrino-less double beta decay (0$eta$DBD) relies on the possibility of operating high energy-resolution detectors in background-free conditions. Scintillating cryogenic calorimeters are one of the most promising tools to fulfill the requirements for a next-generation experiment. Several steps have been taken to demonstrate the maturity of this
technique, starting from the successful experience of CUPID-0. The CUPID-0 experiment demonstrated the complete rejection of the dominant alpha background measuring the lowest counting rate in the region of interest for this technique. Furthermore, the most stringent limit on the Se-82 0DBD was established running 26 ZnSe crystals during two years of continuous detector operation. In this contribution we present the final results of CUPID-0 Phase I including a detailed model of the background, the measurement of the Se-82 2DBD half-life and the evidence that this nuclear transition is single state dominated. The first results obtained after the upgrade of the detector in 2019 are presented as well.

Secondary track (number):

Accelerator: Physics, Performance, and R&D for Future Facilities / 711

The Gamma Factory path to high-luminosity LHC with isoscalar beams

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Following the successful initial phase of the Gamma Factory (GF) R&D studies—showing that atomic beams can be efficiently produced and accelerated in the CERN rings up to the top LHC energy—the GF collaboration proposes, as the next R&D phase, a Proof-of-Principle (PoP) experiment to study collisions of the laser photons with partially stripped ions at the SPS. Following the presentation of the PoP experiment proposal, I shall concentrate on one of its multiple aspects: a proof of a new, ultra-fast beam cooling technique allowing to reduce the transverse emittance of the SPS ion beam. The positive outcome of the PoP experiment could pave the road to a high-luminosity version of the LHC with colliding isoscalar beams. Such beams are superior with respect to proton beams in multiple aspects of the LHC research programme in particular for the EW and BSM studies.

Secondary track (number):

7, 4

Heavy Ions - Posters / 712

Proton number fluctuations due to mundane effects

Author: Boris Tomasik

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Fluctuations of the proton number are measured in ultrarelativistic heavy-ion collisions as a proxy for the fluctuations of the number of baryons. In grand-canonical ensemble, the moments of the baryon number distribution are related to the derivatives of the logarithm of the partition function.
In realistic situations corresponding to the measurements, the fluctuations are also determined by the conservation of the baryon number and a limited acceptance of the detector. In this work, we study the influence of the rapidity distribution of the net baryons on the observed moments of the proton number distribution, as functions of the width and position of the rapidity window for different collision energies.

Secondary track (number):

Neutrino Physics / 713

Long-baseline neutrino oscillation sensitivities with Hyper-Kamiokande

Author: Mark Scott

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The discovery of neutrino oscillations implies that neutrinos are massive particles, which in turn requires new physics beyond the Standard Model. Over the past two decades, the study of neutrino oscillations within the PMNS paradigm has produced measurements of all three mixing angles and both mass-splittings. Neutrino oscillation also provides a mechanism to violate the CP symmetry which would be a clue towards understanding the origin of the matter-antimatter asymmetry of the universe. Measuring CP violation in neutrino oscillation is one of the goals of Hyper-Kamiokande. Hyper-Kamiokande is a next-generation water Cherenkov detector that is under construction in Japan. The baseline design has a fiducial volume 8 times the size of the currently-running Super-Kamiokande detector and is instrumented with new photosensors that offer significant improvements in performance. Combined with the upgraded J-PARC neutrino beam, Hyper-Kamiokande will be able to measure neutrino oscillations with an unprecedented statistical precision. This talk presents the sensitivity of Hyper-Kamiokande to CP violation along with the expected precision on the other oscillation parameters and mass hierarchy.

I read the instructions:

Secondary track (number):

Neutrino Physics / 714

Sensitivity Study for Astrophysical Neutrinos at Hyper-Kamiokande

Author: Takatomi Yano

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Hyper-Kamiokande (Hyper-K) is a next generation underground large water Cherenkov detector. The detector is filled with ultra-pure water and surrounded with newly developed photo sensors. In total, it will provide the fiducial volume of 0.19 Mt, which is 8 times larger than preceding experiment Super-Kamiokande. The energies, positions, directions and types of charged particles produced by neutrino interactions are detected using its Cherenkov light in water. Hyper-K will be located at deep underground to reduce the cosmic muon flux and its spallation products, which is a dominant background for the analysis of the low energy astrophysical neutrinos. With its fruitful physics research programs Hyper-K will play a critical role in the next neutrino
physics frontier, including the neutrino astrophysics. It will provide important information for astrophysical neutrino measurements, i.e., solar neutrino, supernova burst neutrinos and supernova relic neutrino. Here, we will discuss about physics potential of Hyper-K neutrino astrophysics.

I read the instructions:

Secondary track (number):
8

Diversity and Inclusion / 715

Promoting gender equality and diversity in physics from IFIC

Author: Mariam Törtola
Co-author: Enrique Nacher Gonzalez

1 IFIC, Valencia University/CSIC
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In October 2017, IFIC (joint center of CSIC and the University of Valencia) launched the Office of Young Researchers, Gender and Diversity (Jóvenes Investigadores, Género y Diversidad, JIGD). The main objective of this pioneering initiative is to try to eliminate the discrimination or harassment that may take place in the Institute, ensuring equal opportunities for all its members and favoring good relationships between the components of all its sections. This talk will present the main activities carried out by the JIGD-IFIC office in the areas of gender, diversity and inclusion.

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 716

Preparation of large aperture Photo-Detectors for the Hyper-Kamiokande

Author: Takuya Tashiro

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Hyper-Kamiokande is a large water Cherenkov detector in Japan to explore various neutrino physics and discover a nucleon decay. Its construction started in 2020 and the mass production of a large aperture photo-detector is planned from the end of 2020. We developed a photomultiplier tube (PMT) with a 50 cm diameter, R12860 by Hamamatsu Photonics K.K. and installed over a hundred of them into Super-Kamiokande. A hundred PMTs were evaluated in Super-Kamiokande and compared with an R3600 PMT for Super-Kamiokande. It was confirmed that the resolutions and detection efficiency are doubly improved. A noise reduction of the PMT was also achieved with suppressing radioactive contaminations in the glass. In addition, another large aperture photodetector using a micro channel plate was developed. A part of the detection wall with the optical acrylic window and several designs of a shockwave prevention cover are constructed for a test to
demonstrate a coming construction work. A PMT calibration facility is also under preparation. We present the recent development and improved performance of the large-aperture photo-detectors.

I read the instructions:

Secondary track (number):

Heavy Ions / 717

Self-similarity, fractality and entropy principle in collisions of hadrons and nuclei at Tevatron, RHIC and LHC

Authors: Imrich Zborovsky¹; Mikhail Tokarev²

¹ The Czech Academy of Science, Nuclear Physics Institute
² Joint Institute for Nuclear Research

Corresponding Authors: tokarev@jinr.ru, zborovsky@ujf.cas.cz

z-Scaling of inclusive spectra as a manifestation of self-similarity and fractality of hadron interactions is illustrated. The scaling for negative particle production in Au+Au collisions from BES-I at RHIC is demonstrated. The scaling variable z depends on momentum fractions of colliding objects carried by the interacting constituents and momentum fractions of the scattered and recoil constituents carried by the inclusive particle and its counterpart. Structures of the colliding objects and fragmentation processes are expressed by fractal dimensions. Produced medium is described by a specific heat. The scaling function reveals energy, angular, multiplicity, and flavor independence. It has a power behavior at high z (high pT). Based on entropy principle and z-scaling, energy loss as a function of the collision energy, centrality and pT of inclusive particle is estimated. New conservation law including fractal dimensions is found. Quantization of fractal dimensions is discussed.


Secondary track (number):

06

Neutrino Physics / 718

The NOvA Test Beam Program

Author: Alexandre Sousa¹

¹ University of Cincinnati

Corresponding Authors: wallbank@fnal.gov, alex.sousa@uc.edu

NOvA is a long-baseline oscillation neutrino experiment designed to study and measure a wide range of important topics for neutrino physics such as the neutrino mixing parameters, the neutrino mass hierarchy, and CP violation in the lepton sector. The NOvA Test Beam experiment uses a scaled-down detector of 30 tons to analyze tagged beamline particles. A new tertiary beamline deployed at Fermilab can select and identify electrons, muons, pions, kaons and protons with energies from 0.3 to 2 GeV. Using these data, the Test Beam program will provide NOvA with a better understanding of the largest systematic uncertainties impacting NOvA’s analyses, which include the detector response,
calibration, and hadronic and electromagnetic energy resolution. In this talk, I will present the status and future plans for the NOvA Test beam program, along with preliminary results.

I read the instructions:

Secondary track (number):


Neutrino Physics / 719

Near Detectors for the Hyper-K Neutrino Experiment

Author: Mark Hartz

1 TRIUMF & Kavli IPMU, University of Tokyo

Corresponding Author: mhartz@triumf.ca

The neutrino oscillation measurement program of Hyper-K requires unprecedented accuracy for the modeling of neutrino fluxes and neutrino-nucleus interaction cross sections. The Hyper-K experiment will include a suite of near detectors to control systematic uncertainties on neutrino flux and interaction models. In this talk we will describe the baseline Hyper-K near detector suite, which includes beam direction measurement detectors, a magnetized tracking detector, and a kilo-ton scale water Cherenkov detector. We will discuss the measurements these detectors will make to control systematic errors for the accelerator-based neutrino oscillation program, as well as the atmospheric neutrino and nucleon decay programs of Hyper-K.

I read the instructions:

Secondary track (number):

13

Neutrino Physics - Posters / 720

Revealing new processes with superfluid liquid helium detectors: The coherent elastic neutrino-atom scattering

Author: Emmanuele Picciau

Co-authors: Alexander Studenikin 2; Carlo Giunti 3; Francesca Dordei 4; Konstantin Kouzakov 5; Matteo Cadeddu 3

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The particle physics community is studying and developing new technologies to measure processes never detected before. Among these, strong efforts are put into studying innovative He detectors based on the quantum evaporation phenomenon. The main outcome of such detectors is the possibility to detect light dark matter particles. However, they also might have a great potential for exploring neutrino properties. Indeed, we propose an experimental setup to observe coherent elastic neutrino-atom scattering (C$
u$eVAS) [1] using electron antineutrinos from tritium decay and a liquid helium target. In this neutrino scattering process with the whole atom, that has not been observed so far, the electrons tend to screen the weak charge of the nucleus as seen by the electron antineutrino probe. In addition to this discovery, it may be possible to measure fundamental weak interaction parameters at very low energy scale, never reached before, and achieve an unprecedented sensitivity to electromagnetic properties of neutrinos [2], for example, such as the neutrino magnetic moments.


I read the instructions:

Secondary track (number):

Computing and Data Handling / 721

Fast Entropy Coding for ALICE Run 3

Author: Michael Lettrich

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Corresponding Author: michael.lettrich@cern.ch

In LHC Run 3, the upgraded ALICE detector will record 50kHz Pb-Pb collisions using continuous readout. The resulting stream of raw data at ~3.5TB/s - a fiftyfold increase over Run 2 - must be processed with a set of lossy and lossless compression and data reduction techniques to decrease the data rate to storage to ~100GB/s without affecting the physics. This contribution focuses on lossless entropy coding for ALICE Run 3 data which is the final component in the compression stage. It describes the challenges imposed by the source data with a non-standard, patchy distribution of up to 25Bit per symbol. It then explains how we use rANS, a variant of Asymmetric Numeral System coders for compression with special emphasis on our adaptations and additions to the algorithm. Finally, we will show the first production ready rANS implementation for both CPU and GPU as part of the ALICE O² framework and demonstrate its capability of compressing data close to entropy at rates of up to 750 MB/s.

I read the instructions:

Secondary track (number):

Top Quark and Electroweak Physics / 722

New results from TopFitter

Authors: Stephen Brown; Andy Buckley; Christoph Peter Englert; James Edward Ferrando; Peter Galler; David Miller; Chaowaroj Wanotayaroj; Neil Warrack; Chris White

University of Glasgow
We present updated results for a global fit of dimension six operators in the top quark sector of the Standard Model Effective Field Theory using experimental data from the Tevatron and the LHC at 7, 8 and 13 TeV center-of-mass energy. We include all contributions from dimension six operators up to and including $\Lambda^{-4}$ in the effective field theory expansion and study the effects of two operator insertions at the order $\Lambda^{-4}$. Furthermore we take the top quark decay into account and include in the fit experimental measurements which provide results for observables that depend on the kinematics of the top (anti)quark decay products. This increases the sensitivity to operators that can also contribute for example in single top production and opens up the possibility to study additional operators such as four-fermion operators which couple top quarks directly to leptons. A new strategy for sampling the parameter space of Wilson coefficients and treatment of systematic uncertainties is employed. The results are presented in terms of bounds on individual operators as well as marginalized bounds.

Heavy Ions / 723

Jets and medium evolution in Pb-Pb collisions at the LHC energies from the EPOS initial state

Author: Iurii Karpenko

Co-authors: Pol Bernard Gossiaux; Joerg Aichelin; Martin Rohrmoser; Klaus WERNER

We present updated results for a global fit of dimension six operators in the top quark sector of the Standard Model Effective Field Theory using experimental data from the Tevatron and the LHC at 7, 8 and 13 TeV center-of-mass energy. We include all contributions from dimension six operators up to and including $\Lambda^{-4}$ in the effective field theory expansion and study the effects of two operator insertions at the order $\Lambda^{-4}$. Furthermore we take the top quark decay into account and include in the fit experimental measurements which provide results for observables that depend on the kinematics of the top (anti)quark decay products. This increases the sensitivity to operators that can also contribute for example in single top production and opens up the possibility to study additional operators such as four-fermion operators which couple top quarks directly to leptons. A new strategy for sampling the parameter space of Wilson coefficients and treatment of systematic uncertainties is employed. The results are presented in terms of bounds on individual operators as well as marginalized bounds.

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Heavy Ions / 723

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Author: Iurii Karpenko

Co-authors: Pol Bernard Gossiaux; Joerg Aichelin; Martin Rohrmoser; Klaus WERNER

We present updated results for a global fit of dimension six operators in the top quark sector of the Standard Model Effective Field Theory using experimental data from the Tevatron and the LHC at 7, 8 and 13 TeV center-of-mass energy. We include all contributions from dimension six operators up to and including $\Lambda^{-4}$ in the effective field theory expansion and study the effects of two operator insertions at the order $\Lambda^{-4}$. Furthermore we take the top quark decay into account and include in the fit experimental measurements which provide results for observables that depend on the kinematics of the top (anti)quark decay products. This increases the sensitivity to operators that can also contribute for example in single top production and opens up the possibility to study additional operators such as four-fermion operators which couple top quarks directly to leptons. A new strategy for sampling the parameter space of Wilson coefficients and treatment of systematic uncertainties is employed. The results are presented in terms of bounds on individual operators as well as marginalized bounds.

Secondary track (number):

Heavy Ions / 723

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Secondary track (number):
Performance of the CMS Level-1 Trigger during Run 2

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The CMS Level-1 (L1) Trigger system was upgraded in 2016 in order to cope with the three fold increase in peak luminosity of Run 2 compared to Run 1. The upgraded trigger features advanced clustering, calibration, and particle identification techniques. More sophisticated algorithms, for example involving the invariant mass of pairs of L1 candidates, were also implemented. The upgrades reduced the trigger rate from background processes and increased the efficiency for a variety of physics signals. This poster highlights a number improvements that the upgraded L1 Trigger provided during the Run 2 program at CMS.

Searching for Sterile Neutrino Oscillations with the PROSPECT Experiment

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\textsuperscript{1} Illinois Institute of Technology

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PROSPECT is a reactor antineutrino experiment consisting of a segmented liquid scintillator antineutrino detector designed to probe short-baseline neutrino oscillations and precisely measure the antineutrino spectrum of the primary fission isotope U-235. PROSPECT’s neutrino oscillation analysis utilizes target segmentation to look for differences in measured inverse beta decay (IBD) positron spectra at different positions in its detector. With a current baseline coverage of between 7 and 9 meters, the analysis will probe sterile oscillations in the ~1-10 eV$^2$ mass-splitting range, with sensitivities largely independent of the underlying reactor antineutrino flux. This poster will summarize the current status of PROSPECT’s oscillation analysis, including discussion of input signal and background datasets, estimation and implementation of systematic uncertainties, statistical approaches in the oscillation fit, and most recent oscillation results.
Neutron beam test with 3D-projection scintillator tracker prototypes for long-baseline neutrino oscillation experiments

Authors: CHRISTOPHER MAUGER¹; Guang Yang²; Etam Noah Messomo³; Chang Kee Jung⁴

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The long-baseline neutrino oscillation experiments rely on detailed models of neutrino interactions on nuclei to relate observations made at near detector locations to far detector locations in order to extract precision measurements on the oscillation parameters. These models constitute an important source of systematic uncertainty, driven in part because detectors to date have been blind to the neutrons produced in neutrino interactions. We are proposing a 3D-projection scintillator tracker as a near detector component in the next generation long-baseline neutrino experiments such as T2K upgrade and DUNE. Such a detector consists of a large number of 1 cm x 1 cm x 1 cm scintillator cubes with three orthogonal optical fibers crossing through each cube. Benefitted by the good timing resolution and fine granularity, this detector will be capable of measuring neutrons including its kinetic energy in neutrino interactions on an event-by-event basis and thus will provide valuable data for refining neutrino interaction models. Two prototypes have been exposed to the neutron beamline in Los Alamos National Lab (LANL) with neutron energy ranged from 0 to 800 MeV. This beam test, aimed at characterizing the detectors’ response to neutrons, is a critical step in demonstrating the potential of this technology. In this presentation, the prototype detectors and the LANL beam test setup will be described, and the preliminary data analysis results will be shown.

I read the instructions:

Secondary track (number):

Neutrino Physics / 727

KM3NeT: Status and Prospects for Neutrino Astronomy at Low and High Energies

Author: Feifei Huang¹

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KM3NeT is a multi-purpose cubic-kilometer neutrino observatory currently being deployed at the bottom of the Mediterranean Sea. It consists of two detectors: ORCA and ARCA (for Oscillation and Astroparticle Research with Cosmics in the Abyss). ARCA will instrument 1 Gton of seawater, with the primary goal of detecting cosmic neutrinos with energies between several tens of GeV and PeV. Due to its position in the Northern Hemisphere, ARCA will provide an optimal view of the Southern sky including the Galactic Center. ORCA is a smaller (~ few Mtons) and denser array, optimized for the detection of atmospheric neutrinos in the 1 - 100 GeV. It can also study low-energy neutrino astronomy, such as MeV-scale core-collapse supernova. This talk presents the current status of the KM3NeT infrastructure, its outlook on neutrino astronomy, and its multi-messenger program status.

Secondary track (number):

08
Meson factories are powerful drivers of diverse physics programs and play a major role in particle physics at the intensity frontiers.

Currently PSI delivers the most intense continuous muon beam in the world up to few $10^8$ $\mu^+$/s. The High Intensity Muon Beam (HiMB) project at PSI aims at developing new muon beam lines able to deliver up to $10^9$ $\mu^+$/s, with a huge impact for low energy muon based searches.

While next generation of proton drivers with beam powers in excess of the current limit of 1.4 MW still requires significant research, the focus of HiMB is the optimisation of existing target stations and beam lines. Detailed Monte Carlo simulations show that geometrical target optimisations would imply beam intensity gains in the range of 30-60%, that could be further increased by using novel target materials such as boron carbide. Higher muon capture and transmission beam line efficiencies can be obtained with the design of a beam line optics based on pure solenoid elements. The expectation is an increased of the total fraction of captured and transmitted muons by more than one order of magnitude with respect to the current hybrid beam lines.

During the 2019 a new production target, the so called target E*, has been installed and tested along the primary beam line at PSI, proving that the expected increase of muon yield associated with the new target can be achieved, consistently with the Monte Carlo simulation prediction. Putting into perspective the target optimisation only it would correspond to effectively raising the proton beam power at PSI by 650 kW, equivalent to a proton beam power of almost 2 MW without additional complications such an increased energy and radiation deposition into the target and its surroundings.

In this talk the most recent results about the new target installation and the status of the project will be reported in detail.

Secondary track (number):
PERLE: an ERL Facility at Orsay

Author: Ben Hounsell

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The realisation of the top energy electron-hadron colliders at CERN requires the development of the energy recovering technique in multipass mode and for large currents $\mathcal{O}(10)$ mA in the SRF cavities. For this purpose, a technology development facility, PERLE, is under design to be built at ICLab Orsay, for which a Technical Design Report will be presented this year. Besides having the key LHeC/FCC-eh ERL parameters in terms of configuration, source, current, frequency and technical solutions, cryomodule and stacked magnets, this facility may be used for magnet and detector testing, and comprises an interesting low energy physics program. In this talk we review the design and comment on the status of PERLE.

Precision QCD at the LHeC and the FCC-eh

Author: Claire Gwenlan

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The LHeC and the FCC-eh are the cleanest, high resolution microscopes that the world can build in the nearer future. Through a combination of neutral and charged currents and heavy quark tagging, they will unfold the parton structure of the proton with full flavour decomposition and unprecedented precision. In this talk we will present the most recent studies on the determination of proton parton densities as contained in 2020 White Paper on the LHeC. We will also demonstrate the prospects for a per mille accuracy determination of the strong coupling constant, both through scaling violations in inclusive DIS and jet production, as well as their combination.

Precision Top and EW measurements at the LHeC and the FCC-eh
The LHeC and the FCC-eh offer unique prospects for the measurement of EW parameters and top properties in energy frontier, luminous ep scattering. In this talk we will revisit the determination of $Z$, $W$ and top mass through inclusive measurements, showing the latest results as contained in the 2020 LHeC White Paper. Next, we will show the possibilities for the determination of the vector and axial couplings of light quarks, of the effective weak mixing angle and of PDFs through electroweak interference probing the proton structure. We will discuss also direct $W$ and $Z$ production and the possibilities for determination of anomalous triple couplings. Finally, we will address top physics with the possibilities for precise determinations of the $Wtq$ couplings and competitive FCNC top coupling measurements.

I read the instructions:

Secondary track (number):

Higgs Physics / 734

Higgs physics at the LHeC and the FCC-eh

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Higgs production cross sections at LHeC (FCC-eh) energies are as large as (larger than) those at future $Z^- H e^+ e^-$ colliders. This provides alternative and complementary ways to obtain very precise measurements of the Higgs couplings, primarily from luminous, charged current DIS. Recent results for LHeC and FCC-eh, as contained in the 2020 LHeC White paper, are shown and their combination with pp (HL-LHC) cross sections is presented leading to precision comparable for some couplings to the most promising $e^+ e^-$ colliders. We will show the results for the determination of several signal strengths and couplings to quarks, leptons and EW bosons, and discuss the possibilities for measuring the coupling to top quarks and its CP phase, and the search for invisible decays.

I read the instructions:

Secondary track (number):

Heavy Ions / 735

Electron-Ion Collisions at the LHeC and FCC-eh

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The LHeC and the FCC-eh will open a new realm in our understanding of nuclear structure and the dynamics in processes involving nuclei, in an unexplored kinematic domain. In this talk we will review the most recent studies as shown in the update of the 2012 LHeC CDR to be delivered in March
We will discuss the determination of nuclear parton densities in the framework of global fits and for a single nucleus. Then we will discuss diffraction, both inclusive and exclusive. Finally we will demonstrate the unique capability of these high-energy colliders for proving the long sought non-linear regime of QCD, saturation, to exist (or to disprove). This is enabled through the simultaneous measurements, of similar high precision and range, of ep and eA collisions which will eventually disentangle non-linear parton-parton interactions from nuclear environment effects.

Beyond the Standard Model / 736

BSM Physics at the LHeC and the FCC-eh

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The LHeC and the FCC-eh offer fascinating, unique possibilities for discovering BSM physics in DIS, both due to their large centre-of-mass energies and high luminosities. In this talk we will review most recent studies as presented in the 2020 LHeC White Paper. We will show the prospects for observing extensions of the Higgs sectors both with charged and neutral scalars, anomalous Higgs couplings and exotic decays. Then we will discuss searches for $R$-parity conserving and violating supersymmetry with both prompt and long-lived particles, and of feeble interacting particles like sterile neutrinos, fermion triplets, dark photons and axion-like particles. Finally we will address anomalous couplings and searches for heavy resonances like leptoquarks and vector-like quarks, excited fermions and colour-octet leptons.

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 737

The Updated LHeC Detector

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The physics programmes at the LHeC and the FCC-eh require a large acceptance detector with high resolution tracking and calorimetry plus forward and backward detectors. Based on the 2012 design and considering the development of detector technology and as well new physics demands, especially from Higgs and BSM physics, a detector upgrade for the LHeC as contained in the 2020 LHeC White Paper is presented, which is also shown to be scaled to FCC-eh requirements. New consideration of forward taggers are presented as well.
Diversity and Inclusion / 738

The CMS Collaboration communication efforts focused on promoting women in STEM

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Creating pathways to accelerate gender parity, and inviting more women and girls to science, technology, engineering and mathematics (STEM) continues to be a challenge in today’s world. Large international collaborations are an obvious place where diverse groups work together, embracing differences and celebrating their richness. Therefore, it’s critical that they take steps to combat stereotypes and unleash people’s potential by inviting more women into the field of science. Communication has a critical role to play here.

The CMS Collaboration would like to present the efforts we made in building engaging communication campaigns focused on promoting women in science and technology, to convey that our diversity of background is real and boost girl’s participation in STEM studies.

I read the instructions:

Secondary track (number):

15.

Education and Outreach / 739

CMS Virtual Visits: engaging audiences worldwide into conversation about cutting edge science

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Advances in information and communications technologies (ICTs) have given rise to innovative uses of web-based video tools for global communication, enhancing the impact of large research facilities, including their outreach and education programmes. As an example, the CMS Virtual Visits programme launched by the CMS collaborations at CERN, uses videoconferencing to communicate with schools and other public around the globe.

The goal of the programme is to break down geographical barriers and allow more people to enter the world of science, physics and particle physics. CMS Virtual Visits offer students, teachers and the general public a unique opportunity to explore the experimental site of the CMS detector. Through a web-based videoconference, CMS scientists interact with “remote” visitors in their native language, explain the physics and technology behind the CMS detector, and answer their questions.

Since September 2014, more than 35,000 people, from all of the world, have participated in CMS Virtual Visits. We present an overview of our experience, feedback collected from participants and discuss potential development for the future.

I read the instructions:
Engaging the youth in programming and physics through an online educational activity

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The rapid economic growth is building new trends in careers. Almost every domain, including high-energy physics, needs people with strong capabilities in programming. In this evolving environment, it is highly desirable that young people are equipped with computational thinking (CT) skills, such as problem-solving and logical thinking, as well as the ability to develop software applications and write code. These are crucial elements of Science, Technology, Engineering, and Mathematics education (STEM).

The CMS Collaboration presents an outcome from a Proof of Concept of educational online activity. The project consists of building a first step of an interactive coding tutorial that will aim to introduce young people to computer science and particle physics principles in a fun and engaging way. This online educational asset equip educators with a new tool to introduce STEM education and digital literacy in the classrooms, to eventually inspire young people to acquire necessary skills to be ready for a digital economic growth and future jobs.
The Data Quality Monitoring in CMS experiment

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The Data Quality Monitoring (DQM) service is critical in several key aspects of the data analysis for the CMS detector. From the Online world, for real-time detector monitoring, to the detailed checks and fine-grained data analysis in Offline, in order to provide the best possible data quality for Physics analyses. Besides, the DQM software is extensively used to validate reconstruction software and simulated data production, key ingredients for any successful physics measurement.

The DQM system achieved excellent performance in LHC Run1 and Run2 data taking periods: a stable set of needed software tools has been established and specific, mature, monitoring procedures for single subdetectors or “physics objects” reconstruction are available. This solid baseline will be described, with emphasis on the main developments and challenges faced in these exciting years. In addition, during the current LS2 several improvements and important upgrades in the core DQM software to exploit more efficiently the multithreading computing have been achieved, which will be presented along with other few interesting new activities like trying to introduce Machine Learning techniques into the process in preparation for Run3.

Muon to electron conversion search in the presence of Al nuclei at the Fermilab Mu2e experiment: Motivation, Design and Progress

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Mu2e experiment aims to find charged lepton flavor violation (CLFV) by measuring the monochromatic electrons from $\mu^- N \rightarrow e^- N$ conversion with an unprecedented single event sensitivity of $3 \times 10^{-17}$. When completed the experiment will improve the current limit by $10^4$ and make a previously unexplored phase space available for the search for beyond the standard model physics. We will establish the physics motivation for the experiment and explain our design choices for the detectors and various sub systems. The construction of Mu2e experiment is well underway and we will provide a progress update for each sub-system. Commissioning will begin in late 2020 with first data-taking in late 2023 and 4-5 years of data-taking to reach our goal.
Production of Thermal Axions across the ElectroWeak Phase Transition

Author: Fernando Arias Aragón

Co-authors: Luca Merlo; Francesco D’Eramo; Alessio Notari; Ricardo Zambujal Ferreira

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If there are light axions in nature they will very probably leave a cosmic background, just like neutrinos. In this work we complete the study of thermal axion production above the QCD Phase Transition (QCDPT) by including the scatterings of the axion with the longitudinal components of the W and Z bosons. We study the predictions for particular QCD axion scenarios, like the KSVZ and the so-called Minimal Flavour Violating Axion.

Neutron Background Simulations for LEGEND-1000 in a Geant4-based Framework

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The LEGEND (Large Enriched Germanium Experiment for Neutrinoless ββ Decay) Collaboration will begin the construction of its initial phase, LEGEND-200, using the recently-decommissioned GERDA infrastructure, with a final 1000-kg installation (LEGEND-1000) planned. A simulation study of the neutron background is underway, using a custom simulation module based on Geant4. So far, the primary focus of this module’s use has been cosmogenically-induced neutrons, as well as neutrons generated in (α,n) reactions. The goal of these studies is to quantify the effect of various shielding material and cryostat designs on the neutron backgrounds, and to understand the effects site selection will have. I will be discussing the progress and status of this work.
Search for non-Newtonian gravity with optically-levitated microspheres

Authors: Charles Blakemore\textsuperscript{None}; Alexander Fieguth\textsuperscript{None}; Akio Kawasaki\textsuperscript{None}; Denzal Martin\textsuperscript{None}; Alexander Rider\textsuperscript{None}; Giorgio Gratta\textsuperscript{None}

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The universal law of gravitation has undergone stringent tests for many decades over a significant range of length scales, from atomic to planetary. Of particular interest is the short distance regime, where modifications to Newtonian gravity may arise from axion-like particles or extra dimensions. We have constructed an ultra-sensitive force sensor based on optically-levitated microspheres with a force sensitivity of $10^{-17}$ N$/\sqrt{\text{Hz}}$ for the purpose of investigating non-Newtonian forces in the 1-100 $\mu$m range. Microspheres interact with a variable-density attractor mass made by alternating silicon and gold segments with periodicity of 50 $\mu$m. The attractor can be located as close as 10 $\mu$m from a microsphere. I describe the characterization of this system, its sensitivity, and some preliminary results. Further technological developments to reduce background are expected to provide orders of magnitude improvement in the sensitivity, probing beyond current constraints on non-Newtonian interactions.

I read the instructions:

Secondary track (number):
8

Quark and Lepton Flavour Physics / 747

New measurement of the $K^+ \rightarrow \pi^+ \mu^+ \mu^-$ decay at NA62

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The flavour-changing neutral current decay $K^+ \rightarrow \pi^+ \mu^+ \mu^-$ is induced at the one-loop level in the Standard Model, and is well suited to explore its structure and, possibly, its extensions. The NA62 experiment took data in 2016–2018 with the main goal of measuring the $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ decay. A scaled down di-muon trigger chain was operating along with the main trigger during the whole data taking period resulting in a large sample of about $3 \times 10^{12}$ kaon decays in the fiducial volume recorded using the di-muon trigger. New results from an analysis of the $K^+ \rightarrow \pi^+ \mu^+ \mu^-$ decay using this sample will be presented.

I read the instructions:

Secondary track (number):
03

Dark Matter Detection / 749

Dark matter search results from DEAP-3600 at SNOLAB
Dark matter search results and a detailed background model for DEAP-3600 will be presented. DEAP-3600 is searching for dark matter interactions with a liquid argon target, shielded from cosmic rays by over 2 km of rock at SNOLAB in Sudbury, Canada. The spherical detector consists of 3.3 tonnes of liquid argon in a large ultralow-background acrylic cryostat instrumented with 255 photomultiplier tubes. DEAP-3600 is sensitive to nuclear recoils from dark matter particles, which cause the emission of prompt scintillation light. Backgrounds come from alpha particles on the inner detector surfaces, from external neutrons, from argon-39 beta decays, and from trace radioactivity in detector components. This talk presents the latest results from DEAP-3600, which demonstrate excellent performance for pulse-shape discrimination, event reconstruction, background rejection and sensitivity to dark matter.

I read the instructions:

Secondary track (number):

08

Reactor Antineutrino Flux and Spectrum Measurement at Daya Bay and Precise Determination of Its High Energy Component

The Daya Bay reactor neutrino experiment uses eight antineutrino detectors deployed in two near and one far underground experimental halls to detect electron antineutrinos produced by six nuclear reactors each with 2.9 GW\textsubscript{th}. In this poster, we will present an improved reactor antineutrino flux measurement with reduced dominant uncertainties and the first measurement of the individual $^{235}$U and $^{239}$Pu antineutrino spectra as well as the total one. Both flux and spectra measurements exhibit significant deviations from the prediction of the Huber-Mueller model. The Daya Bay experiment with its largest reactor antineutrino sample collected up to date has an ideal chance to study the high-energy end of the reactor antineutrino spectrum. A preview of the precise reactor antineutrino spectrum measurement with energies above 8 MeV will be shown.

I read the instructions:

Secondary track (number):

751

Education initiatives in the experimental area of the Trento Proton Therapy Center (Italy)

Author: Benedetto Di Ruzza\textsuperscript{1}

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The experimental area of the Trento Proton Therapy Center (Italy) is a experimental area devoted to research on particle physics sensors and biophysics. In this area particle physics sensors can be tested with a proton beam with an energy range between 70 and 130 MeV. This area is also specially suitable for education initiatives addressed to both students or general public because in this space all the elements of a complex test-beam facility are accessible to the visitors: beam transport magnets, beam monitor devices, dose measurement devices, DAQ systems, target experimental sensors and remote monitoring systems for sensors. In this poster will be presented a description of the experimental Trento Proton Therapy Center accelerator and experimental area and also the public success obtained there during the “Trento Smart City Week 2019” initiative in September 2019.

Results of the GERDA Phase II experiment

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The only known practical way to probe the Majorana nature of neutrinos experimentally is via the discovery of the neutrinoless double beta decay. During the last years the GERDA (GERmanium Detector Array) experiment at the Laboratori Nazionali del Gran Sasso of INFN, Italy, remains one of the leaders in this field. In GERDA the Ge detectors, enriched in 76Ge, are directly immersed in liquid argon which works as a cooling medium and as an active shield against external radioactivity. Data taking in Phase II started in December 2015. GERDA has achieved the background of $10^{-3}$ counts/(keV kg yr) and for the first time surpassed the sensitivity of $10^{26}$ yr.

At the end of 2019 the Phase II design exposure of 100 kg yr was reached and data taking was stopped. The final analysis of full GERDA Phase II data set is being performed. At the Conference the final results of the GERDA Phase II experiment are going to be presented.

Higgs decay into a lepton pair and a photon revisited

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We present new calculations of the differential decay rates for $H \rightarrow \ell^+ \ell^− \gamma$ with $\ell = e$ or $\mu$ in the Standard
Model. The branching fractions and forward-backward asymmetries, defined
in terms of the flight direction of the photon relative to the
lepton momenta, depend on the cuts on energies and invariant masses
of the final state particles.
For typical choices of these cuts we find the branching ratios
$B(H \rightarrow e\bar{e}\gamma) = 6.1 \cdot 10^{-5}$ and $B(H \rightarrow \mu\bar{\mu}\gamma) = 6.7 \cdot 10^{-5}$ and the forward-backward asymmetries
$A_{FB}^{(e)} = 0.366$ and
$A_{FB}^{(\mu)} = 0.280$.

I read the instructions:

Secondary track (number):
04.

Operation, Performance and Upgrade of Present Detectors / 757

The MicroBooNE Experiment

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MicroBooNE is a 100-ton scale liquid-argon time projection chamber (LArTPC) neutrino experiment
located on the Booster neutrino beamline at Fermilab. The experiment first started collecting neutrino data in October 2015. The detector, the first in the short-baseline neutrino program at Fermilab, is the longest operating LArTPC to date and plays an important role in a phased program towards the construction of massive kiloton scale detectors for future long-baseline neutrino physics (DUNE).

We present results on the operation and performance of the detector after four years of data taking, highlighting accomplishments towards reconstruction, calibration and detector physics.

I read the instructions:

Secondary track (number):

Neutrino Physics / 758

Search for a Low-energy Excess with MicroBooNE

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MicroBooNE is a neutrino experiment based at Fermilab that utilizes a liquid argon time projection chamber (LArTPC) located on-axis in the Booster Neutrino Beam (BNB) at Fermilab. One of the experiment’s main goals is to search for excess low-energy electromagnetic-like events as seen by the MiniBooNE experiment, located just downstream of MicroBooNE in the BNB. This talk will present MicroBooNE’s low-energy excess search, including targeted searches for both single-photon-like and single-electron-like events.
Neutrino Physics / 759

Recent Cross-section Measurements from MicroBooNE

Author: Raquel Castillo Fernandez

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MicroBooNE is a liquid argon time projection chamber in the Booster Neutrino Beam at Fermilab. The large event rate and 3 mm wire spacing of the detector provide high-statistics, precise-resolution imaging of neutrino interactions leading to low-threshold, high-efficiency event reconstruction with full angular coverage. As such, MicroBooNE is an ideal place to probe neutrino-argon interactions in the hundreds-of-MeV to few-GeV energy range, and to study the impact of nuclear effects through detailed measurements of hadronic final states. This will be the subject of this talk.

Beyond the Standard Model / 760

Searches for long-lived particle decays in MicroBooNE

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The MicroBooNE experiment consists of a 50 m$^3$ active volume liquid argon time projection chamber (TPC) that sits 470 m from an 8 GeV proton beam on a beryllium target, and 690 m from a 120 GeV proton-on-graphite fixed target. These high-intensity beams may be creating a large flux of neutral long-lived particles (LLPs) with masses in the few-hundred MeV range, that are decay products of kaons produced in the fixed target collisions. Amongst other LLPs, the experiment has sensitivity to light scalars that can be produced, in association with pions, in kaon decays; such scalar decay modes have been proposed to explain an anomalous excess of $K_L^0 \rightarrow \pi^+\pi^-\pi^0$ events recently observed by the KOTO experiment. If the LLPs can reach and decay inside the TPC, they will be observed through their daughter decay electrons, muons and/or pions. In this talk I will present the latest results from the experiment for the searches of these LLPs decaying within the detector.
Search for heavy neutral leptons decaying into muon-pion pairs in the MicroBooNE detector

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We will present upper limits on the production of heavy neutral leptons (HNLs) decaying to muon-pion pairs using data collected with the MicroBooNE liquid-argon time projection chamber (TPC) operating at Fermilab. This search is the first of its kind performed in a liquid-argon TPC and the first beyond the Standard Model result obtained with the MicroBooNE detector. We use data collected in 2017 and 2018 corresponding to an exposure of $2 \times 10^{20}$ protons on target from the Fermilab Booster Neutrino Beam, which produces mainly muon neutrinos with an average energy of about 800 MeV. HNLs with higher mass are expected to have a longer time-of-flight to the liquid-argon TPC than Standard Model neutrinos. The data are therefore recorded with a dedicated trigger configured to detect HNL decays that occur after the neutrino spill reaches the detector. We set upper limits at the 90\% confidence level on the element $U_{\mu 2}$ of the extended PMNS mixing matrix in the range for Dirac HNLs and Majorana HNLs, assuming HNL masses between 260 and 385 MeV.

I read the instructions:

Secondary track (number):
02

Neutral Current Pi0 Rate Measurement with the MicroBooNE Detector

Author: Mark Ross-Lonergan

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The talk presents the first measurement of Neutral Current (NC) $\pi^0$ production on argon in a sub-GeV neutrino beam with the MicroBooNE liquid argon time projection chamber (LArTPC) detector. The analysis qualifies data to Monte Carlo agreement in several reconstructed kinematic variables, and investigates contributions from coherent and non-coherent NC $\pi^0$ production processes independently. Those are the dominant contributing backgrounds to MicroBooNE’s search for low-energy excess single-photon events, for two separate exclusive final state samples. A data-driven determination of the NC $\pi^0$ rate and coherent fraction is critical for constraining backgrounds to MicroBooNE’s single-photon search.

I read the instructions:

Secondary track (number):
Multi-Differential and Unbinned Measurements of Hadronic Event Shapes in e+e- Collisions at sqrt(s)=91 GeV from ALEPH Open Data

Authors: Patrick Komiske; Eric Metodiev; Jesse Thaler; Yen-Jie Lee; Austin Alan Baty; Christopher McGinn; Anthony Badea

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First results are presented on the use of a new machine-learning based unfolding technique, OmniFold, applied to archival hadronic e+e- collisions using 730 pb^-1 of data collected at 91 GeV with the ALEPH detector at LEP. With the archived data and unfolding procedure, multiple classic hadronic event-shape variables are measured in a fully unbinned and multi-differential manner. Of particular interest, the differential distribution of log one minus thrust is presented and is expected to be helpful for extracting alpha_s via a fit to precision QCD calculations. The analysis is accompanied by a public release of the archived data set and the unfolding results, so that users may make their own versions of plots, either with different binning or with different combinations of observables in a multi-differential distribution. The details of this release are also presented.

Neutrino Physics / 764

Charged-Current Electron Neutrino measurement with the MicroBooNE detector

Author: Wouter Van De Pontseele

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MicroBooNE is the first phase of Fermilab’s Short Baseline Neutrino (SBN) Liquid Argon Time Projection Chamber (LArTPC) programme. This talk outlines the first characterisation of electron neutrinos in a muon neutrino beam with the LArTPC detector technology. The Booster Neutrino Beam has an energy peaking around 1 GeV and an electron content of approximately 0.5%. The analysis investigates electrons produced in charged-current electron neutrino interactions. The kinematics of the electrons are measured along with comparisons to simulation. Most of the systematic uncertainties are constrained using a data-driven sample of charged-current muon neutrino events. The measurement of electron neutrinos originating from the Booster Neutrino Beam is a crucial component to understand the nature of the observed excess of low energy electromagnetic-like events at MiniBooNE.
Daya Bay neutrino oscillation results based on neutron captured on hydrogen

Author: Jinjing Li

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The Daya Bay reactor neutrino experiment is the first experiment that measured a nonzero value for the $\theta_{13}$ neutrino mixing angle in 2012. Antineutrinos from six 2.9 GW$_{th}$ reactors are detected in eight functionally identical antineutrino detectors deployed in two near (flux-weighted baseline 470 m and 576 m) and one far (1648 m) underground experimental halls. The near-far arrangement of antineutrino detectors allows for a relative measurement by comparing the observed antineutrino rates at various baselines. In 2014, the Daya Bay experiment reported an independent measurement of the nonzero neutrino oscillation parameter $\theta_{13}$, utilizing the data set of neutron captured on hydrogen (nH) with distinct systematic uncertainties from the data set of neutrons captured on gadolinium, and has been improving this measurement since then. In this poster, I shall show the latest result of the Daya Bay nH neutrino oscillation analysis with improved statistics and systematic control.

ILD, a Detector for the International Linear Collider

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The International Large Detector (ILD) is a detector designed primarily for the International Linear Collider (ILC), a high-luminosity linear electron-positron collider with an initial center-of-mass energy of 250 GeV, extendable to 1 TeV. The ILD concept is based on particle flow for overall event reconstruction, which requests outstanding detector capabilities including superb tracking, very precise detection of secondary vertices and high-granularity calorimetry. In the past years the ILD design has focused on building subdetector technological prototypes scalable to the full ILD size, studying their integration into a coherent detector, benchmarking the ILD performance and preparing for an optimization of the overall ILD size and costing. The current status has recently been made public in an ILD Interim Design Report (IDR) of interest for any future e$^+$e$^-$ collider detector. The presentation will summarize the main IDR results and the plans to prepare a technical proposal for a detector at the ILC, should ILC move forward.
Heavy quark production in high energy electron positron collisions

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The process $ee \rightarrow q\bar{q}$ with $q\bar{q}=cc, bb, tt$ plays a central role in the physics programs of high energy electron-positron colliders. Polarised beams as available at the international collider ILC are an essential input for the complete measurement of the helicity amplitudes that govern the production cross section. Heavy quarks are likely messengers to new physics and at the same time they are ideal benchmark processes for detector optimisation. All three processes call for superb primary and secondary vertex measurements and a high tracking efficiency to correctly measure the vertex charge. Charm and bottom production are already available below the $tt$ threshold. The program must be completed by the measurement of electroweak $tt$ production. We will show with detailed detector simulations of the ILD Detector that production rate and the forward backward asymmetries of the three processes can be measured at the $0.1\% - 0.5\%$ level and how systematic errors can be controlled to reach this level of accuracy. The discovery potential in terms of Randall-Sundrum models with warped extra dimensions will be outlined.

Improving Electroweak Precision Observables Including $m_W, \Gamma_W, A_{LR}$ and TGCs with the ILD Detector

Corresponding Author: graham.wilson@cern.ch

We discuss the improvements that the ILC can make in precision electroweak observables based on studies with the ILD detector concept. These include observables from WW production and radiative return to the Z at a centre of mass energy of 250 GeV, and from a dedicated stage of running at the Z pole. These improvements take advantage of the ILC capabilities for polarized electron and positron beams, and an accelerator design that accommodates data-taking at a wide range of beam energies. We also present new results on precision measurements of fermion pair production. The studies include experimental considerations evaluated in the context of the ILD detector concept and discussion of experimental strategies targeted at controlling relevant systematic uncertainties.

ILC as a SUSY discovery and precision instrument.

Corresponding Author: maria-teresa.nunez-pardo-de-vera@desy.de
Data from the LHC at 7, 8, and 13 TeV have so far yielded no evidence for new particles beyond the 125 GeV Higgs boson; in particular, there have been no signs of SUSY. However, the complementary nature of physics with $e^+e^-$ collisions still offers many interesting scenarios in which SUSY can be discovered at the ILC. These scenarios take advantage of the capability of $e^+e^-$ collisions to observe events with missing four-momentum - a signature not available at hadron colliders, where only transverse imbalance is observable. Due to low backgrounds and trigger-less operation, detectors at $e^+e^-$ colliders can observe events with much less visible energy than what is possible at hadron colliders. In this contribution, we will present detailed simulation studies done with the ILD concept at the ILC. These studies include simulation of the full SM background, as well as realistic accelerator conditions. We will show results both on expected discovery and exclusion reaches for the most challenging SUSY channels, such as higgsinos or winos at low mass differences. Evaluations of precision of model-parameter measurements, in case of discovery, will also be given. We also report on how such measurements can be used to put constraints on parts of the sparticle-spectrum beyond direct reach, and to discriminate between different models of SUSY breaking at high scales.

I read the instructions:

Secondary track (number):

Computing and Data Handling / 770

The ILD Software Tools and Detector Performance

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The ILD detector is a detector concept designed for high precision physics at the ILC. It is optimized for particle flow event reconstruction with extremely precise tracking capabilities and highly granular calorimeters. Over the last decade ILD has developed a suite of sophisticated software components for simulation and reconstruction in the context of the iLCSoft ecosystem in collaboration with other future collider projects. We will present an overview of the ILD software from the detailed and realistic modeling of the detector with DD4hep, over the event reconstruction algorithms with its pattern recognition and particle flow algorithms to the high level reconstruction for flavor tagging and particle identification. Most of the these tools have been developed in a detector agnostic way and are also applicable to other future lepton colliders. Finally we will present an overview of the resulting detector performance that can be achieved with ILD following the ILD Interim Design Report (IDR) that recently has been made public.

I read the instructions:

Secondary track (number):

Higgs Physics / 771

JHU generator framework: new features for Higgs boson studies

Author: Meng Xiao

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The JHU generator framework includes an event generator of anomalous HVV and Hff interactions of the Higgs boson in production and decay and a MELA library for matrix element analysis. This framework allows constraints on dimension-six operators of an effective field theory from a joint analysis of on-shell and off-shell production of the Higgs boson and of triple and quartic gauge boson interactions. Gluon fusion, vector boson fusion, and associated production with a vector boson are considered. Potential contributions from new states are included. Associated production with one or two top quarks and gluon fusion process allow access to the CP structure of Yukawa interactions. Practical applications to the EFT analysis of the current and future LHC datasets are discussed.

I read the instructions:

Secondary track (number):

Formal Theory / 772

Composite Higgs scenario in mass-split models

Author: Oliver Witzel

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Mass-split composite Higgs models naturally accommodate the experimental observation of a light 125 GeV Higgs boson and predict a large scale separation to other heavier resonances. We explore the SU(3) gauge system with four light (massless) and six heavy (massive) flavors by performing numerical simulations. Since the underlying system with degenerate and massless ten flavors is infrared conformal, this system inherits conformal hyperscaling and allows to study near-conformal dynamics. Carrying out nonperturbative lattice field theory simulations, we present the low-lying particle spectrum as well a first determination of baryon mass anomalous dimensions. The proximity of a conformal infrared fixed point leads to a highly predictive particle spectrum which is quite distinctive to QCD.

Secondary track (number):

Formal Theory / 773

Coupled $\mathcal{N} = 2$ supersymmetric quantum systems: Symmetries and supervariable approach

Author: Saurabh Gupta

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We consider specific examples of $\mathcal{N} = 2$ supersymmetric quantum mechanical models and list out all the novel symmetries. In each case, we show the existence of two sets of discrete symmetries that correspond to the Hodge duality operator of differential geometry. Thus, we are able to provide a proof of the conjecture which endorses the existence of more than one discrete symmetry transformation as the analogue of Hodge duality operation. Finally, we extend our analysis to a more general case and derive on-shell nilpotent symmetries within the framework of supervariable approach.
Nonperturbative calculations of form factors for exclusive semileptonic $B(s)$ decays

Author: Oliver Witzel

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A key ingredient to searches for new physics in the flavor sector are precise theoretical predictions derived from the Standard Model. Due to its large mass and long lifetime processes involving $b$ quarks are of particular interest. Focusing at the nonperturbative QCD contributions, we carry out lattice QCD simulations with the focus on semileptonic $B_s \rightarrow D_s \ell \nu$ and $B_s \rightarrow K \ell \nu$ form factors with full $q^2$ dependence, discuss the extraction of CKM matrix elements $|V_{cb}|$ and $|V_{ub}|$, as well the determination of $R$-ratios testing the universality of lepton flavors.

Our calculations are based on the set of 2+1 flavor domain wall Iwasaki gauge field configurations generated by the RBC-UKQCD collaboration featuring three lattice spacings of $1/a = 1.78$, $2.38$, and $2.78$. Heavy $b$-quarks are simulated using the relativistic heavy quark action.

J-PARC Neutrino Beamline Upgrades towards 1.3 MW Beam Power for Long-Baseline Neutrino Oscillation Experiments in Japan

Author: Tetsuro Sekiguchi

Co-authors: Son Cao 1; Megan Friend 2; Yoshiaki Fujii 1; Taku Ishida 1; Takashi Kobayashi 1; Tsunayuki Matsubara 1; Takeshi Nakadaïra 3; Kazuo Nakayoshi 1; Yuichi Oyama 1; Ken Sakashita 2; Masaru Tada 1

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The J-PARC neutrino beamline produces a high intensity neutrino beam using 30 GeV protons from the J-PARC Main Ring (MR) accelerator for the T2K long baseline neutrino oscillation experiments. The MR accelerator and neutrino beamline achieved 515kW stable operation during the most recent run. MR upgrades toward 1.3 MW beam power are being planned for further running of the T2K and future Hyper-Kamiokande experiments by shortening the repetition cycle (2.48s to 1.16s) and increasing the number of protons per spill ($2.6 \times 10^{14}$ to $3.2 \times 10^{14}$ protons per spill). The neutrino beamline will also be upgraded to accept the 1.3 MW proton beam. The main challenges in the neutrino beamline are precise and safe handling of the very high intensity proton beam and robustness of the secondary beamline components in a very high radiation environment. We will present the ongoing beamline upgrade project including development of new beam monitors, an enhanced...
remote handling system, cooling capacity improvements for secondary beamline components, enforcement of radioactive waste treatment, neutrino flux improvement with higher horn current, and DAQ/control system upgrades.

Secondary track (number):

Heavy Ions / 776

Precision Jet/Event Substructure Using Collinear Drop

Authors: Yang-Ting Chien¹; Yen-Jie Lee²

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I will present a new class of jet/event substructure observable called collinear drop and its use in the search for novel signatures of jet modifications and medium responses. It is demonstrated using Monte Carlo simulations generated with Jewel how underlying jet-medium interactions can be systematically examined using collinear-drop observables. Studies using LEP open data and applications to Electron Ion Collider will be discussed. Analytic insights on the modifications of such observables will also be given using soft-collinear effective theory with Glauber gluon interactions.

Secondary track (number):

Heavy Ions / 777

Nuclear shadowing in DIS for future electron-ion colliders

Author: Michal Krelina¹
Co-author: Jan Nemcik ²

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We present the comprehensive study of shadowing in deep-inelastic scattering off nuclei in kinematical regions accessible by future experiments at electron-ion colliders. The calculations of shadowing are performed within the color dipole formalism using a rigorous Green function technique. This allows incorporating naturally the effects of quantum coherence and color transparency, which are not consistently included in present calculations. We analyze as well the magnitude of gluon shadowing representing the shadowing correction coming from higher Fock states of the photon containing gluons. We present for the first time the theoretical uncertainties in predictions of shadowing using different models for the dipole cross section. The magnitude of shadowing is confronted with results of standard parametrizations of nuclear parton distribution functions within the collinear QCD-parton model. Finally, our predictions for the nuclear shadowing are compared with available data, as well as they are presented for future measurements corresponding to planned experiments at electron-ion colliders.
Strong Interactions and Hadron Physics / 778

How can the photon-like heavy quarkonium $V \rightarrow Q\bar{Q}$ transition falsify our predictions?

Author: Michal Krelina

Co-authors: Jan Nemchik; Roman Pasechnik

1 Czech Technical University in Prague
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The diffractive electroproduction of the $S$-wave heavy quarkonia ($V$) is an efficient tool for studies the structure of $V \rightarrow Q\bar{Q}$ transition. The most of existing studies in the literature are based on the unjustified assumption about a similar structure of both $\gamma^* \rightarrow Q\bar{Q}$ and $V \rightarrow Q\bar{Q}$ vertices, typically adopted in the light-front frame. The photon-like $V \rightarrow Q\bar{Q}$ vertex, besides an $S$-wave component, also contains an extra $D$-wave admixture in the $Q\bar{Q}$ rest frame. However, the relative weight of these contributions cannot be justified by any reasonable non-relativistic $Q\bar{Q}$ potential model. In this work, we investigate and discuss the relative role of the $D$-wave contribution by a comparison of our predictions based on the color dipole formalism with the available data. We found that the production of radially excited heavy quarkonia states is more efficient for studies of the $V \rightarrow Q\bar{Q}$-structure due to a stronger sensitivity of the $D$-wave contribution to the nodal structure of quarkonium wave functions.

Secondary track (number):

Higgs Physics / 779

Two-loop corrections to the Higgs trilinear coupling in models with extended scalar sectors

Authors: Johannes Braathen; Shinya KANEMURA

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The Higgs trilinear coupling provides a unique opportunity to study the structure of the Higgs sector and probe indirect signs of BSM Physics – even if new states are somehow hidden. In models with extended Higgs sectors, large deviations in the Higgs trilinear coupling can appear at one loop because of non-decoupling effects in the radiative corrections from the additional scalar states. It is then natural to ask how two-loop corrections modify this result, and whether new large corrections can appear again. I will present new results on the dominant two-loop corrections to the Higgs trilinear coupling in several models with extended scalar sectors. I will illustrate the analytical expressions with numerical examples and show that, while they remain smaller than their one-loop counterparts and do not modify significantly the non-decoupling effects observed at one loop, the two-loop corrections are not entirely negligible – a typical size being 10-20% of the one-loop corrections.

Secondary track (number):

1. Beyond the Standard Model
Beyond the Standard Model / 781

Polarization effects in the search for vector dark boson at $e^+e^-$ colliders

Authors: Fei-Fan Lee $^1$; Quang Nhat Vo$^2$; Guey-Lin Lin$^3$

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We argue that the search for vector dark boson through $e^+e^-\rightarrow Z'\gamma$ can determine the Lorentz structure of $Z' l^+l^-$ couplings with the detection of leptonic decays $Z'\rightarrow l^+l^-$. We assume a general framework that the vector dark boson interacts with ordinary fermions through vector and axial-vector couplings. As a consequence of Ward-Takahashi identity, $Z'$ is transversely polarized in the limit $m_{Z'} \ll \sqrt{s}$ while all polarizations of $Z'$ are produced for heavier $Z'$. Such polarization effects can be analyzed through the angular, or equivalently, energy distributions of final-state particles in $Z'$ decays. Taking $l^\pm \equiv \mu^\pm$, we study the energy distributions of final-state muons that correspond to parent $Z'$s moving in either the forward or backward directions relative to the electron beam axis in the CM frame of $e^+e^-$ pair. Such energy distributions can be used to probe the relative strengths of vector and axial-vector couplings between $Z'$ and muons. We discuss such measurements in Belle II detector with appropriate acceptance cuts and various stages of integrated luminosities taken into account.

I read the instructions:

Secondary track (number):

1. Quark and Lepton Flavor Physics

Accelerator: Physics, Performance, and R&D for Future Facilities / 782

The CLIC accelerator project status and plans

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The Compact Linear Collider (CLIC) collaboration has presented a project implementation plan for construction of a 380 GeV $e^+e^-$ linear collider ‘Higgs and top factory’ that is upgradable in stages to 3 TeV. The CLIC concept is based on high-gradient normal-conducting accelerating structures operating at X-band (12 GHz) frequency. We present the CLIC accelerator concept and the latest status of the project design and performance goals. We report on high-power tests of X-band structures using test facilities across the collaboration, as well as CLIC system verification studies and the technical development of key components of the accelerator, and we present updated studies of the luminosity performance. We also present developments for application of the X-band technology to more compact accelerators for particle physics studies (e.g. Light Dark Matter Searches) and e.g. as X-ray FELs and in medicine. A rapidly increasing number of installations are taking the technology and opening up co-ordinated programmes for further industrial developments in the next phase of the project.

Secondary track (number):
Advances in simulation and reconstruction for Hyper-Kamiokande

Author: Nick Prouse

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The next generation of neutrino experiments will require improvements to detector simulation and event reconstruction software matching the reduced statistical errors and increased and precision of new detectors.

This talk will present progress for the software of the Hyper-Kamiokande experiment being developed to enable reduction of systematic errors to below the 1% level.

The current status and future prospects of this software will be presented, including advances in detector simulation and reconstruction using traditional techniques as well as new developments using modern machine-learning based approaches.

Applications for improved event selections and analysis of low-energy and high-energy neutrinos from astrophysical, atmospheric and neutrino beam sources will be discussed.

A multi-PMT photodetector system for the Hyper-Kamiokande experiment

Author: Gianfranca De Rosa

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Hyper-Kamiokande (Hyper-K) is the next generation large volume water Cherenkov detector to be built in Japan. The fiducial volume will be approximately 8 times larger than its precursor Super-Kamiokande.

Its broad physics program includes nucleon decay, neutrinos from astronomical and accelerator neutrinos, with the main focus to determine the leptonic CP violation.

In order to detect the weak Cherenkov light generated by neutrino interactions or proton decay, a system of small photomultipliers as implemented in the KM3NeT experiment, the so called multi-PMT module (mPMT), is considered as an option to improve Hyper-K physics capability.

A mPMT Optical Module based on a pressure vessel instrumented with multiple small diameter photosensors, readout electronics and power, offers several advantages as increased granularity, reduced dark rate, weaker sensitivity to Earth’s magnetic field, improved timing resolution and directional information with an almost isotropic field of view.

In this contribution the development of a mPMT module for Hyper-K and the prospects for physics capabilities with a hybrid configurations of the photosensor system with 20” PMTs and mPMTs will be discussed.
A Novel Two-Dimensional Readout Design for Floating Strip Micromegas Detectors

Author: Felix Fidelio Klitzner

Co-authors: Otmar Biebel; Jonathan Frederik Bortfeldt; Bernhard Matthias Flierl; Maximilian Herrmann; Ralf Hertenberger

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Floating strip Micromegas detectors are highest-rate capable particle detectors with excellent spatial and time resolution, allowing single particle tracking with fluxes up to at least 7 MHz/cm² by collecting the amplified ionization charge on copper anode strips kept at a slightly floating electrical potential. The charge signal is decoupled by two layers of readout strips in x and y, insulated by thin Kapton layers. A complete understanding of the signal formation in the detector, particularly on the y-strips, is achieved: simulations disentangle the signal coupling due to alternating weighting field lines with respect to the ion velocity vector and the response of charge sensitive front-end electronics.

Different two-dimensional anode designs with optimized field geometry have been developed based on the simulations. We present the performance of the detector for the different designs measured in 20 MeV proton/neutron and 180 GeV pion/muon beams, using APV25 front-end boards.

Neutrino Physics / 787

Why matter effects are important for MBL experiments?

Author: Amir Khan

Co-authors: Hiroshi Nunokawa; Stephen Parke

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We discuss perturbative expansions for the solar oscillation parameters in terms of the matter potential relevant for MBL experiments. These expansions, up to second order in the matter potential, while simple, allow one to calculate the electron antineutrino survival probability to a precision much better than needed for the JUNO experiment. We also quantitatively explain the shift caused by the matter effects on the solar neutrino mixing parameters \(\Delta m^2_{21}\) and \(\theta_{12}\) which do not satisfy the naïve expectations and are significant given the precision that can be achieved by the JUNO experiment.
Search for a colorless C-odd three-gluon state from comparison of elastic proton proton and proton antiproton scattering

Author: Christophe Royon

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Elastic scattering is usually described by the $t$-channel exchange of a $C$-even state (the "Pomeron") that contributes equally to the $pp$ and $p\bar{p}$ cross sections. QCD also predicts the exchange of a sub-dominant $C$-odd state (the "Odderon") that has opposite sign in the $pp$ and $p\bar{p}$ amplitudes and that QCD describes as a three-gluon state at leading order. At TeV energies where other exchanges than gluonic are expected to be negligible, a difference between the $pp$ and $p\bar{p}$ elastic differential cross sections ($d\sigma_{el}/dt$) would give evidence for $C$-odd three-gluon exchange.

The $pp$ elastic cross sections at 2.76, 7, 8 and 13 TeV measured by TOTEM at the LHC have characteristic diffractive minima ("dips") and second maxima ("bumps"), whereas the $p\bar{p}$ cross section at 1.96 TeV measured by D0 at the Tevatron has no dip. We have performed an extrapolation of the $pp$ $d\sigma_{el}/dt$ from TOTEM to 1.96 TeV and compared it with the D0 data to search for the presence of $C$-odd three-gluon exchange.

I read the instructions:

Secondary track (number):

Technology Applications, Industrial Opportunities and Sustainability / 790

Fast neutron spectroscopy with a nitrogen based gaseous detector

Authors: Ioannis Katsioulas; Patrick Knights; Ioannis Giomataris; Tom Neep; Konstantinos Nikolopoulos; Thomas Papaevangelou; Robert James Ward

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A simple, efficient, safe to use but also affordable fast neutron spectroscopy system is of paramount importance for many scientific and industrial communities. $^3$He based detectors provide a solution that fulfils most of the requirements but its high demand in combination with its scarcity created a worldwide shortage and efforts are focused on finding an alternative solution. A number of detectors are proposed for this task, such as BF3 proportional counters, plastic scintillators, and recoil detectors, all having disadvantages that make their adoption challenging. We propose the N2SPHERE system that utilises a spherical proportional counter filled with nitrogen-based gas mixtures to exploit the $^{14}$N$(n,\alpha)$B$^{11}$ and $^{14}$N$(n,p)$C$^{14}$ reactions for the detection of fast neutrons. $^3$He and N$^2$ have comparable Q-values and absorption cross sections for fast neutron capture, offering similar detection capabilities. For the demonstration of this method, a N2SPHERE is operated in the Boulby...
Underground Laboratory aiming to the measurement of neutron fluxes, as neutrons constitute an important background to rare event searches.

Secondary track (number):
9

Computing and Data Handling / 791

**A simulation framework for Spherical Proportional Counters**

**Authors:** Ioannis Katsioulas¹; Patrick Knights¹; Jack Matthews³; Tom Neep³; Konstantinos Nikolopoulos²; Robert James Ward²

¹ University of Birmingham
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The spherical proportional counter is a novel gaseous detector, with many applications, including dark matter searches and neutron spectroscopy. A simulation framework has been developed, which combines the strengths of the Geant4 and Garfield++ toolkits. The framework allows the properties of spherical proportional counters to be studied in detail, providing insights for detector R&D, experiment design optimisation, and data analysis and interpretation. The details of the framework will be presented, along with its performance in terms of computing resources. Representative physics results will be shown, demonstrating its predictive power. The validation of the simulation using data collected at the University of Birmingham and at the Boulby Underground Laboratory will be discussed.

Secondary track (number):

Education and Outreach / 792

**Creative science|arts pedagogies for the next generation of physicists**

**Author:** Konstantinos Nikolopoulos¹

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Scientific developments have seen reality dissolved into smaller and smaller invisible particles that the physicist has to make visible. This journey, from something hidden to something revealed, is mirrored by the artist attempting to express thoughts and emotions through the manipulation of materials in visual arts, or the movements of the human body in dance. This – potentially unexpected but remarkable – similarity in the creative processes of science and art, provides a unique basis for novel science|arts approaches to enthuse students regarding STEM subjects. Workshops for school children of a wide age range, that stimulate inquiry and enhance learning through creative activities, have been developed, where physics concepts are communicated through visual arts and dance. The development,
trailing, and evaluation of these workshops is presented and discussed. Reflections on the experience acquired by engaging in transdisciplinary science/art pedagogical activities are summarised.

Secondary track (number):

Higgs Physics / 793

Higgs Boson Measurements and HH production at the High-Luminosity LHC with the CMS detector

Author: Sandhya Jain

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The High-Luminosity Large Hadron Collider (HL-LHC) is expected to deliver an integrated luminosity of up to 3000 fb⁻¹. The very high instantaneous luminosity will lead to about 200 proton-proton collisions per bunch crossing (‘pileup’) superimposed to each event of interest, therefore providing extremely challenging experimental conditions. Prospects for measurements of the properties of the standard model Higgs boson and searches for beyond the standard model Higgs bosons with the CMS experiment at the HL-LHC are presented. CMS prospects on Higgs self-coupling measurements and HH production at the HL-LHC are also presented.

Secondary track (number):

Dark Matter Detection / 794

COSINUS: Direct dark matter search with cryogenic NaI detectors

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Today, the situation in direct dark matter detection is controversial: The DAMA/LIBRA experiment observes an annual modulation signal at high confidence. Furthermore, this signal is perfectly compatible in terms of period and phase with the expectation for a galactic halo of dark matter particles which interact in their NaI target crystals. However, in the so-called standard scenario on dark matter halo and dark matter interaction properties, the DAMA/LIBRA signal contradicts null-results of numerous other experiments.

The new experiment COSINUS aims for a model-independent cross-check of the DAMA/LIBRA signal. Such a cross-check is absent up to now and necessarily requires the use of the same target material (NaI). While several experimental efforts are planned or already ongoing, COSINUS is the only experiment operating NaI as cryogenic detector which yields several distinctive advantages: Discrimination between electronic interactions and nuclear recoils off sodium and iodine on
event-by-event basis, a lower nuclear recoil energy threshold and a better energy resolution. In this contribution we will review the prototype measurements performed so far, present the plans for the new underground facility currently installed at LNGS and give an outlook on the COSINUS timescale.

Secondary track (number):

**Accelerator: Physics, Performance, and R&D for Future Facilities / 795**

**A flexible tool for Beam Induced Background Simulations at a Muon Collider**

**Author:** Francesco Collamati

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A Muon Collider represents a very interesting possibility for a future machine to explore the energy frontier in particle physics. However, to reach the needed luminosity, beam intensities of the order of $10^9-11$ muons per bunch are needed. In this context, the beam Induced Background must be taken into account for its effects on the magnets and on the detector. Several optimisations can be conceived with the aim to mitigate them. In this view, it is of crucial importance to develop a flexible tool that allows to easily reconstruct the machine geometry in a Monte Carlo code, allowing to simulate in detail the interaction of muon decay products in the machine, while being able to change the machine optics itself to find the best configuration. In this contribution, a possible approach to such a purpose is presented, based on FLUKA for the Monte Carlo simulation and on LineBuilder for the geometry reconstruction. First results based on 1.5TeV machine optics developed by the MAP collaboration are discussed, as well as a first approach to possible mitigation strategies.

Secondary track (number):

**Quark and Lepton Flavour Physics / 796**

**Confronting quark-lepton unification with LFUV**

**Author:** Matej Hudec

1 IPNP, Charles University, Prague

**Co-authors:** Michal Malinský 1; Werner Rudolf Porod 2; Thomas Faber 2

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Quark-lepton SU(4) symmetry is an appealing paradigm, a step towards grand unification. It has been identified decades ago that the minimal potentially realistic models with the quark-lepton symmetry have the $SU(4) \times SU(2) \times U(1)$ gauge structure and naturally contain both gauge and scalar leptoquarks. Such models have been thoroughly studied by several authors. In recent years, a lot of interest have been aroused by the experimental hints of lepton flavour universality violation (LFUV) in the B-meson decays. These are often interpreted as signals of existence of leptoquarks. We will present the study of the capability of the minimal SU(4) models to accommodate the LFUV. In particular, we will argue that leptoquark interactions in the considered models...
can partially accommodate subsets of the anomalous B-meson decay data, unavoidably predicting lepton flavour violating processes which will be testable at Belle II during the next years. On the other hand, the models are unable to explain the current central values of the B-anomalies and, thus, will be disproved if these are confirmed as signals of New Physics.

I read the instructions:

Secondary track (number):

03

Neutrino Physics - Posters / 797

Determining cosmic and atmospheric background with (stopping) muons in the SoLid experiment

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SoLid is a short baseline anti-neutrino experiment that is positioned at the BR2 Nuclear Reactor in Mol, Belgium. The aim of the experiment is to search for short baseline neutrino oscillations and spectral anomalies by detecting electron anti-neutrinos, which are produced in the reactor core, through inverse beta decay (IBD).

One of the most important background signals in the IBD selection are particles with a cosmogenic or atmospheric origin. To reduce the effects of this background on the selection of IBD events, a dedicated study of the variation of this background was made.

This poster will show the dependence of the muon and stopping muon rate on multiple atmospheric variables. Furthermore, it will be demonstrated how this muon rate can be used as a probe for the cosmic and atmospheric background in the IBD selection.

Secondary track (number):

Strong Interactions and Hadron Physics - Posters / 799

An Inhomogeneous Phase in Quark Matter without the Sign Problem

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Recently, it was shown that the ground state of quantum chromodynamics in sufficiently strong magnetic fields and at moderate baryon densities carries a crystalline condensate of neutral pions: the chiral soliton lattice (CSL). This phase cannot be realized from first principles using standard lattice Monte Carlo simulations due to the infamous sign problem. On the other hand, we show that CSL, or a similar inhomogeneous phase, also appears in the phase diagram of a class of vector-like gauge theories that do not suffer from the sign problem even in the presence of a baryon chemical potential and external magnetic field. Hence, we give a class of explicit counterexamples to the long-standing conjecture that positivity of the determinant of the Dirac operator (that is, absence of the sign problem) in a vector-like gauge theory precludes spontaneous breaking of translational
invariance, and thus implies the absence of inhomogeneous phases in the phase diagram of the theory.

Secondary track (number):

**Strong Interactions and Hadron Physics / 800**

**Drell-Yan production at NLO in the Parton Branching method at low and high DY masses and low and high \( \sqrt{s} \)**

**Authors:** Hannes Jung\(^1\); Armando Bermudez Martinez\(^2\); Patrick Connor\(^1\); Luis Ignacio Estevez Banos\(^{None}\); Francesco Hautmann\(^3\); Aleksandra Anna Lelek\(^4\); Jindrich Lidrych\(^5\); Mikel Mendizabal\(^6\); Melanie Viola Schmitz\(^1\); Sara Taheri Monfared\(^1\); Qun Wang\(^7\); Thomas Wening\(^6\); Heng Yang\(^8\); Radek Zlebcik\(^9\)

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9. Charles University

Theoretical predictions agree well, within uncertainties, with measurements at the Large Hadron Collider (LHC). We also compute the transverse momentum spectrum of low mass DY production at low center-of-mass energies \( \sqrt{s} \) and compare our predictions with experimental measurements at low DY mass, and find very good agreement. In addition we use the low mass DY measurements at low \( \sqrt{s} \) to determine the width \( q_\perp \) of the intrinsic Gauss distribution of the PB-TMDs at low evolution scales and find values that have earlier been used in applications of PB-TMDs to high-energy processes at the LHC and HERA.

Secondary track (number):

**Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 801**

**Study progress of CEPC Sc-ECAL**

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The Circular Electron Positron Collider (CEPC) has been proposed as a Higgs factory. The scintillator-tungsten based ECAL (Sc-ECAL) is a particle flow oriented sampling electromagnetic calorimeter designed for the CEPC. The active layers are plastic scintillator consist of 5×45 mm² scintillator strips. The scintillator strips arrange in adjacent layers are perpendicular to each other to achieve a 5×5 mm² effective transverse size. Photons from each scintillator strip are read out by very compact photon sensor, SiPM, attached at the center of the strip. A mini-prototype of the Sc-ECAL with 30 layers has been constructed and studied. In this report, optimization of the prototype and preliminary cosmic-ray results will be discussed.

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 802

Development and Test of a Micro-Pattern Resistive Plate Detector.

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We present the design and preliminary tests of a resistive plate device built with techniques developed for micro-pattern gaseous detectors. It consists in two equal electrode plates made of FR4 substrate with 250 Cu readout strips. A 50 µm insulating foil, carrying resistive lines, is glued on top of the substrate. Both the Cu and the resistive strips have a pitch of 400 µm and width of 300 µm. The plates are spaced by a 2 mm gap and rotated by 90°, providing 2D tracking capability. With such a device the surface resistivity can be tuned to values below the ones of existing RPC (either glass or phenolic-melamine). The thin separation layer between the electrodes and the readout strips provides a better capacitive coupling of the signal, allowing to operate the detector at lower gain. Moreover, the strip-shaped resistive pattern reduces the induced charge size in the direction perpendicular to the strips. All these features go in the direction of improving the rate capability. The basic concept of this new device will be presented together with results of ongoing tests at CERN.

Secondary track (number):

Strong Interactions and Hadron Physics / 803

Isolated photon production and pion-photon correlations in high-energy pp and pA collisions

Authors: Michal Sumbera¹; Roman Pasechnik²; Victor Gonçalves³; Yuri Lima⁴

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A phenomenological study of the isolated photon production in high energy $pp$ and $pA$ collisions at RHIC and LHC energies is performed. Using the color dipole approach we investigate the production cross section differential in the transverse momentum of the photon considering three different phenomenological models for the universal dipole cross section. We also present the predictions for the rapidity dependence of the ratio of $pA/pp$ cross sections. As a further test of the formalism, for different energies and photon rapidities we analyse the correlation function in azimuthal angle $\Delta \phi$ between the photon and a forward pion. The characteristic double-peak structure of the correlation function around $\Delta \phi = \pi$ observed previously for Drell-Yan pair production is found for isolated photon emitted into the forward rapidity region which can be tested by future experiments.

Secondary track (number):

07

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**Higgs Physics - Posters / 804**

**Measurement of the Higgs CP in its decay to tau leptons (CMS)**

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In this presentation, we review a measurement of the CP quantum number of the Higgs boson in its decay to tau leptons via an analysis of the angular correlation between the tau decay planes. The theory behind this analysis and an explanation of some of the methods used for this measurement can be found in [1] and [2].

The analysis targets the full Run 2 data set of proton-proton collisions at a centre-of-mass energy of 13 TeV, amounting to 137.1 fb$^{-1}$. The analysis aims to include the majority of the hadronic and semileptonic decay modes. Different analysis techniques are deployed to reconstruct the tau decay planes and to optimise the significance of the measurement. Machine learning techniques are used to improve the separation between different tau decay modes and between signal and background.


Secondary track (number):

03

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**Top Quark and Electroweak Physics / 805**

**Boosted top tagging and measurement of boosted top polarization using jet images**

**Authors:** Soham Bhattacharya1; Monoranjan Guchait1; Aravind Holur Vijay$^{+}$

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The chiral nature of the top quark couplings can be modified by new physics. Hence, the polarization of top quarks serves as a promising window for exploring the existence and nature of new physics. Detecting the polarization of boosted top quark jets in colliders is quite challenging, and several studies have already explored different kinematic variables for this purpose. In my talk I will describe some novel image-based neural networks that can be used to tag and measure the polarization of both leptonic and hadronic boosted top jets. I will detail the performance of these algorithms and compare them to the existing techniques in the context of improving the search sensitivities of a few interesting physics processes.

Secondary track (number):

Computing and Data Handling / 806

Erratic server behavior detection using machine learning on basic monitoring metrics

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With the explosion of the number of distributed applications, a new dynamic server environment emerged grouping servers into clusters, utilization of which depends on the current demand for the application. To provide reliable and smooth services it is crucial to detect and fix possible erratic behavior of individual servers in these clusters. Use of standard techniques for this purpose requires manual work and delivers sub-optimal results. Using only application agnostic monitoring metrics our machine learning based method analyzes the recent performance of the inspected server as well as the state of the rest of the cluster, thus checking not only the behavior of the single server, but the load on the whole distributed application as well. We have implemented our method in a Spark job running in the CERN MONIT infrastructure. In this contribution we present results of testing multiple machine learning algorithms and pre-processing techniques to identify the servers erratic behavior. We also discuss the challenges of deploying our new method into production.

I read the instructions:

Secondary track (number):

Formal Theory / 807

The Theory of Resummed Quantum Gravity: Phenomenological Implications

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We present an overview of the phenomenological implications of the theory of resummed quantum gravity. We discuss its prediction for the cosmological constant in the context of the Planck scale cosmology of Bonanno and Reuter, its relationship to Weinberg’s asymptotic safety idea, and its
relationship to Weinberg’s soft graviton resummation theorem. We also discuss constraints and consistency checks of the theory.

Role of IR-Improvement in LHC/FCC Physics

Authors: Scott Yost\textsuperscript{1}; Bennie Ward\textsuperscript{2}

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One may use amplitude-based resummation in QED X QCD to achieve IR-improvement of unintegrable singularities in the infrared regime to arbitrary precision in principle. We illustrate such improvement in specific examples in precision LHC/FCC physics.

Top and quark contributions to electroweak-boson elastic-scattering at the LHC

Author: Antonio Dobado\textsuperscript{1}

Co-authors: Juan José Sanz-Cillero\textsuperscript{2}; Carlos Quezada Calonge\textsuperscript{2}

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In the context of the Equivalence Theorem we compute the one-loop contribution of top and bottom quarks to the would-be Nambu-Goldstone bosons elastic scattering. We pay attention to the renormalization and unitarity of the amplitude and provide examples of the applications to the LHC physics.
Search for CPT and Lorentz Violation Effects in the Muon g-2 Experiment at Fermilab

Author: Meghna Bhattacharya
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The Muon g–2 Experiment at Fermilab measures the anomalous magnetic moment of the muon, $a_\mu$, with improved precision compared to the previous experiment at Brookhaven National Lab (BNL). The value of $a_\mu$ from BNL currently differs from the Standard Model prediction by $\sim 3.6$ standard deviations or higher, suggesting the potential for new physics and therefore, motivating a new experiment.

The Fermilab experiment follows the measurement principles of the BNL experiment, injecting a beam of positive muons into a storage ring, which focuses the beam with a combination of magnetic and electric fields. The muon anomaly relies on the measurement of the spin precession frequency $\omega_a$ about the muon momentum.

The study and analysis of CPT and Lorentz violation in g-2 provide a good test of the standard model (SM) as well as strong constraints on new physics. The BNL g-2 experiment analyzed the spin precession frequency of the muons stored in the ring and searched for two Lorentz and CPT violating signatures. One of those signatures, the sidereal variation of $\omega_a(t)$, will be discussed for the Fermilab Muon g-2 Experiment in this presentation. This talk will present the methodology and give a status update on the Run 1 analysis.

EUSO-SPB2: a precursor for space observatory for multi-messenger astrophysics

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EUSO-SPB2 (Extreme Universe Space Observatory on a Super Pressure Balloon II) is a precursor mission for a future space observatory for multi-messenger astrophysics. This mission is the continuation of the JEM-EUSO science program on ultra-long duration balloons, started with the EUSO-SPB1.

The EUSO-SPB2 will host onboard two telescopes. One is a fluorescence telescope designed to detect ultra high energy cosmic rays via the UV fluorescence emission of the showers in the atmosphere. The other one measures direct Cherenkov UV/VIS light emission from air showers at PeV energies and other optical backgrounds for cosmogenic tau neutrino detection. Both the telescopes have 1-meter diameter apertures with modified Schmidt optics.

The planned launch date is 2022 with a flight duration target of 100 days. In this talk, we discuss the scientific motivation of the mission, the characteristics of each telescope and the current status.
The Mu3e Experiment Searching for the Lepton Flavour Violating Decay \( \mu^+ \rightarrow e^+e^+e^- \)

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The Mu3e experiment is a novel experiment to search for the lepton flavour violating (LFV) decay \( \mu^+ \rightarrow e^+e^+e^- \), with an ultimate sensitivity to a branching ratio of one in \( 2 \times 10^{15} \) in phase I and one in \( 10^{16} \) muon decays for phase II, at 90 \% CL. This would be an improvement in sensitivity by four orders of magnitude compared to previous searches by the SINDRUM experiment. Since this decay is suppressed to unobservable levels in the Standard Model of particle physics, any measurement of this decay would be a clear sign of new physics.

The experiment is currently under construction and will take place at the Paul Scherrer Institute in Switzerland. In order to reach this enormous number of muons, PSI is utilizing the world’s most intense muon beam, which produces \( 10^8 \mu/s \) at \( \pi E5 \) beamline (phase I) and a new high-intensity muon beamline HiMB is providing \( 10^9 \mu/s \) (phase II). To achieve the proposed sensitivity, the Mu3e experiment requires excellent vertex resolution, accurate timing, and momentum measurements. These are needed to reduce the main background processes, such as accidental coincidences of tracks from Michel decays with electron-positron pairs from Bhabha scattering or photon conversion.

The proposed poster will present an overview of the Mu3e experiment, and how this sensitivity is achieved based on high voltage monolithic active pixel sensors for high spatial resolution and scintillating fibres and tiles providing precise timing information at high particle rates.

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Physics and Rock’n’Roll : Expanding to New Audiences

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A team based around CERN in Geneva has organised public engagement and education activities at a variety of non-scientific venues. The core team now brands itself the Big Bang Collective, and local partners are engaged in each case, bringing in local knowledge and expertise. The principle recurring festivals that have been targeted are the WOMAD Festival (Charlton Park, UK, since 2016), joined from 2019 by Roskilde (Dk), Colours of Ostrava (Cz) and Pohoda (Sk). The goal of this effort is to engage new audiences who normally would not be drawn to science festivals and to investigate...
our ability to communicate scientific messages to broad, diverse audiences. Most of these festivals aim to present the broader culture, rather than just music; but none have a specifically scientific theme. They attract differing demographics, requiring individual customisation of the programme. In each case, the audience is not attending for the science, and have different prior levels of engagement. The results have been impressive, with 'meaningful engagement' (i.e. interactions upwards of 15 minutes) with over 20,000 people in 2019. We describe the presentation material and format, the hands-on workshops, and other methods employed, as well as lessons learned on how to best optimise audience engagement in each case.

I read the instructions:

Secondary track (number):

Computing and Data Handling / 814

Quantum-inspired Tensor Network machine learning on high-energy physics data

Authors: Lorenzo Sestini¹; Davide Zuliani¹; Donatella Lucchesi¹; Alessio Gianelle¹; Timo FelserNone; Simone MontangeroNone; Marco TrentiNone

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Tensor Networks are mathematical representations that have been invented to investigate quantum many-body systems on classical computers. Recently it has been shown that quantum-inspired Tensor Networks can be applied to solve machine learning tasks. Due to their quantum nature, Tensor Networks allow to easily compute quantities like correlations and entropy in order to gain insight into the learning data. In this contribution a study of Tensor Network machine learning applied to high-energy physics data is presented. The machine learning task considered is the identification of the charge of the b-quark that initiated a hadronic jet (b-jet vs \(\bar{b}\)-jet). Open data obtained from the LHCb experiment simulation have been used for the training and validation. In particular the identification performance of different algorithms, Tensor Network and Deep Neural Network, are compared. A discussion on the prediction time, a critical point for real-time applications, is also presented.

I read the instructions:

Secondary track (number):

Technology Applications, Industrial Opportunities and Sustainability / 815

Laser-hybrid Accelerator for Radiobiological Applications (LhARA)}

Author: Kenneth Richard Long¹

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The ‘Laser-hybrid Accelerator for Radiobiological Applications’, LhARA, is conceived as a novel, uniquely flexible facility dedicated to the study of radiobiology. The technologies that will be demonstrated in LhARA have the potential to allow particle-beam therapy to be delivered in a completely new regime, combining a variety of ion species in a single treatment fraction and exploiting ultra-high dose rates. LhARA will be a hybrid accelerator system in which laser interactions drive the creation of a large flux of protons or light ions that are captured using a plasma (Gabor) lens and formed into a beam. The laser-hybrid approach will allow radiobiological studies using a variety of ion species in completely new regimes.

LhARA will be developed in two stages. In the first stage, a programme of in vitro experiments will be served with proton beams with energies between 10\,MeV and 15\,MeV. In stage two, the beam will be accelerated using a fixed-field accelerator (FFA). This will allow experiments to be carried out in vitro, and particularly in vivo (e.g. using tumour-specific xenograft mouse models), with proton beam energies of up to 125\,MeV. In addition, ion beams, with energies up to $\sim$ 30\,MeV per nucleon for carbon, will be available for in vitro and in vivo experiments. This paper presents the conceptual design for LhARA and the R\&D programme by which the LhARA consortium seeks to establish the facility.

Secondary track (number):
11

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Heavy Ions / 816

Universality in High Energy Collisions of small and large systems

Authors: Alfredo Iorio\textsuperscript{1}; Helmut Satz\textsuperscript{2}; Lanteri Daniele\textsuperscript{3}; Martin Spousta\textsuperscript{4}; Paolo Castorina\textsuperscript{None}

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Recent experimental results in proton-proton and in proton-nucleus collisions at Large Hadron Collider energies show a strong similarity to those observed in nucleus-nucleus collisions, where the formation of a quark-gluon plasma is expected. We discuss the comparison between small colliding systems and nucleus-nucleus collisions, for: a) the strangeness suppression factor $\gamma_s$ and yields of multi-strange hadrons; b) the average transverse momentum with particular attention to the low $p_t$ region where soft, non-perturbative effects are important; c) the elliptic flow scaled by the participant eccentricity. The universal behavior in hadronic and nuclear high energy collisions emerges for all these observables in terms of a specific dynamical variable which corresponds to the entropy density of initial system in the collision and which takes into account the transverse size of the initial configuration and its fluctuations.

Secondary track (number):
06
Neutrino Physics / 817

nuSTORM: unique facility for neutrino physics and muon-collider test bed

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The nuSTORM facility will provide $\nu_e$ and $\nu_\mu$ beams from the decay of low energy muons confined within a storage ring. The instrumentation of the ring, combined with the excellent knowledge of muon decay, will make it possible to determine the neutrino flux at the %-level or better. The neutrino and anti-neutrino event rates are such that the nuSTORM facility serving a suite of near detectors will be able to measure $\nu_eN$ and $\nu_\mu N$ cross sections with the %-level precision required to allow the next generation of long-baseline neutrino-oscillation experiments to fulfil their potential. By delivering precise cross section measurements with a pure weak probe nuSTORM may have the potential to make measurements important to understanding the physics of nuclei. The precise knowledge of the initial neutrino flux also makes it possible to deliver uniquely sensitive sterile-neutrino searches. The concept for the nuSTORM facility will be presented together with an evaluation of its performance and its potential as a test-bed for the development of a muon collider.

Secondary track (number):

Neutrino Physics / 818

Neutron-antineutron oscillation search with MicroBooNE and DUNE

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The Deep Underground Neutrino Experiment (DUNE) is an international project aiming at neutrino physics and astrophysics and a search for phenomena predicted by theories beyond the standard model (BSM). The excellent imaging capability of Liquid Argon Time Projection Chamber (LArTPC) technology, particle tracking and identification utilized in the Far Detector, as well as the Far Detector size and underground placement, allow the experiment to achieve high sensitivity to various rare processes. BSM theories predict the existence of baryon number non-conservation effects, in particular when the baryon number changes by 2. Here we discuss the sensitivity of DUNE to neutron-antineutron oscillation. With full event simulation and reconstruction using the LArSoft package, we have investigated the background to potential signal events from atmospheric neutrino interactions and particle misidentification, and utilized machine learning techniques to enhance the discrimination between signal and background. The methodologies being developed for a high-sensitivity search for neutron-antineutron oscillation in DUNE can also be demonstrated with the currently running MicroBooNE LArTPC. We discuss progress on demonstrating the developed techniques with the first-ever search for neutron-antineutron oscillation in a LArTPC using Micro-BooNE data.

Secondary track (number):
Conclusions from TrackML the HEP Tracking Machine Learning challenge

Authors: David Rousseau1; Jean-Roch Vlimant2; Vincenzo Innocente3; Andreas Salzburger3; Isabelle GuyonNone; Laurent Basara4; Sabrina Amrouche5; Tobias Golling6; Moritz Kiehn6; Yetkin Yilmaz7; Paolo Calafiura8; Steven Farrell9; Heather Gray10; Vladimir Gligorov11; Victor Estrade12; Cecile Germain13; Edward Moyse14; Mikhail Hushchyn15; Andrey Ustyuzhanin16

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The HL-LHC will see ATLAS and CMS see proton bunch collisions reaching track multiplicity up to 10,000 charged tracks per event. To engage the Computer Science community to contribute new algorithms ideas, we have organized a Tracking Machine Learning challenge (TrackML). Participants are provided events with 100k 3D points, and are asked to group the points into tracks; they are also given a 100GB training dataset including the ground truth. The challenge is run in two phases. The first “Accuracy” phase has run on Kaggle platform from May to August 2018; algorithms were judged only on a score related to the fraction of correctly assigned hits. The second “Throughput” phase ran Sep 2018 to March 2019 on Codalab, required code submission; algorithms were then ranked by combining accuracy and speed. The first phase has seen 653 participants, with top performers with innovative approaches (see arXiv:1904.06778). The second phase has recently finished and featured some astonishingly fast solutions, which have been subsequently analysed. The talk will report on the lessons from the TrackML challenge and perspectives.

I read the instructions:

Secondary track (number):

Neutrino Physics / 820

New constraints on heavy neutral leptons coming from oscillation data analysis and precision $e^+$ $e^-$ physics

Author: Wojciech Jakub Flieger

Co-authors: Janusz Gluza 1, Kamil Porwit 2
The neutrino mixing matrix is characterized by singular values and contractions. The method of unitary dilation is introduced to extend 3-dimensional mixing matrices to a full unitary matrix. The minimal dimension of such an extension is not arbitrary but depends on singular values. It means that singular values encode information about the number of additional neutrinos. Taking this into account, scenarios with a different number of additional, non-standard neutrinos are investigated. For the 3+1 scenario (one additional neutrino) analytical formula for the light-heavy mixing between SM-active and a right-handed neutrino as a function of singular values is derived. New stringent bounds on light-heavy mixings are established. In particular, in a seesaw mass scheme with one heavy sterile neutrino, the upper bounds on active-sterile neutrino mixings are even two times stringent than before. Consequences of the updated results for the number of active neutrinos in the Z decay width (Jadach and Janot, 2019) on the light-heavy neutrino mixings are also discussed.

Secondary track (number):
03

Computing and Data Handling / 821

Using an Optical Processing Unit for tracking and calorimetry at the LHC

Authors: Aishik Ghosh¹, Laurent Basara², Biswajit Biswas¹, David Rousseau³

¹ Centre National de la Recherche Scientifique (FR)
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³ IJCLab-Orsay

The High Luminosity Large Hadron Collider is expected to have a 10 times higher readout rate than the current state, significantly increasing the computational load required. It is then essential to explore new hardware paradigms. In this work we consider the Optical Processing Units (OPU) from LightOn, which compute random matrix multiplications on large datasets in an analog, fast and economic way, fostering faster machine learning results on a dataset of reduced dimension. We consider two case studies.

1) "Event classification": high energy proton collision at the Large Hadron Collider have been simulated, each collision being recorded as an image representing the energy flux in the detector. The task is to train a classifier to separate a Susy signal from the background. The OPU allows fast end-to-end classification without building intermediate objects (like jets). This technique is presented, compared with more classical particle physics approaches.

2) “Tracking”: high energy proton collisions at the LHC yield billions of records with typically 100,000 3D points corresponding to the trajectory of 10,000 particles. Using two datasets from previous tracking challenges, we investigate the OPU potential to solve similar or related problems in high-energy physics, in terms of dimensionality reduction, data representation, and preliminary results.

I read the instructions:

Secondary track (number):
Beyond the Standard Model - Posters / 822

Bekenstein bound from the Pauli principle

Author: Luca Smaldone

Co-authors: Alfredo Iorio; Giovanni Acquaviva

1 Charles University Prague
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Assuming that the degrees of freedom of a black hole are finite in number and of fermionic nature, we naturally obtain, within a second-quantized toy model of the evaporation, that the Bekenstein bound is a consequence of the Pauli exclusion principle for these fundamental degrees of freedom. We show that entanglement, Bekenstein and thermodynamic entropies of the black hole all stem from the same approach, based on the entropy operator whose structure is the one typical of Takahashi and Umezawa's Thermofield Dynamics. We then evaluate the von Neumann black hole–environment entropy and noticeably obtain a Page-like evolution. We finally show that this is a consequence of a duality between our model and a quantum dissipative-like fermionic system.

I read the instructions:

Secondary track (number):

Diversity and Inclusion / 823

Early Career Initiatives at LHCb

Author: Martha Hilton

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Early career researchers in particle physics face a unique set of challenges. Newcomers to any experiment face steep learning curves, particularly with the familiarisation of software and internal standard procedure. The junior rank typical of early career researchers can also mean less agency or influence within a larger collaboration, and job insecurity brings further additional challenges, such as migration for work and a resulting lack of a consistent support network. This talk will discuss existing early career initiatives at LHCb, including the "Laura Bassi initiative", which brings together junior collaboration members interested in increasing diversity within the collaboration, and the "StarterKit" initiative, which provides introductory tutorials on LHCb software and relevant physics topics. We will also briefly discuss new ideas for future initiatives.

I read the instructions:

Secondary track (number):

Beyond the Standard Model / 824
Explaining the SM flavor structure with grand unified theories

Author: Renato Fonseca

Corresponding Author: fonseca@ipnp.mff.cuni.cz

We do not know why there are three fermion families in the Standard Model (SM), nor can we explain the observed pattern of fermion masses and mixing angles. Standard grand unified theories based on the SU(5) and SO(10) groups fail to shed light on this issue, since they also contain three copies of fermion representations of an enlarged gauge group.

However, it does not need to be so. In this talk, I will discuss the possibility that the Standard Model families are distributed over distinct representations of a grand unified model, in which case the gauge symmetry itself might discriminate the various families and explain (at least partially) the flavor puzzle.

Status and progress of the JUNO detector

Author: Jilei Xu

Corresponding Author: xjilei@ihep.ac.cn

The Jiangmen Underground Neutrino Observatory (JUNO) is a neutrino oscillation experiment with a 53 km distance from reactors and a 700m overburden, currently under construction in southern China. The primary goal is to measure the neutrino mass hierarchy with better than $3\sigma$ after 6 years of data taking. Therefore 20 kton high transparency liquid scintillator, high coverage (75%) of photomultiplier tubes and low backgrounds are needed to achieve energy resolution of 3% @ 1MeV and calibration error lower than 1%. This is the most challenging design in the reactor neutrino experiments throughout the world. The large detector also have the huge potential to measure three oscillation parameters and neutrinos from various terrestrial and extra-terrestrial sources. This talk will present JUNO project status, progress and also JUNO-TAO.

A gauge invariant description of phase transitions

Authors: Andreas Ekstedt; Johan Löfgren

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Phase transitions are of wide interest to be sure; whether it’s in superconductors or the early universe: Beyond the Standard Model scenarios like Baryogenesis cry out for a strong first-order phase
transition. So a precise description of phase transitions is vital. Phase transitions are, in field theory, studied with numerical methods (lattice) and perturbative calculations (the effective potential). Perturbative calculations are quite handy since lattice calculations are as yet rather resource expensive.

But perturbative calculations face a number of obstacles, to wit the expansion breaks down at high temperatures and is gauge dependent. The former problem is often remedied by a resummation; though, this resummation isn’t gauge invariant. And so I’ll present a gauge invariant method for describing phase transitions using the effective potential. This method also allays the high-temperature breakdown through a gauge invariant resummation.

Secondary track (number):
03

Neutrino Physics / 827

Atmospheric Neutrino Oscillation with Super-Kamiokande

Corresponding Author: vtakhist@physics.ucla.edu

We will present updated results on three-flavor atmospheric neutrino oscillation from the Super-Kamiokande experiment, covering the 373 kt-year exposure of Super-K I through IV. Atmospheric neutrinos cover a wide energy range, are comprised of both neutrinos and antineutrinos, have both electron and muon flavors, oscillate into a significant tau neutrino component, and experience matter effects in the earth. Through a detailed 3-flavor analysis this data is sensitive to the neutrino mass hierarchy, the octant of theta-23, and the CP-violating phase as well as beyond the standard model interactions. The data analysis presented has been updated to include improvements in event reconstruction and modeling of neutrino-nucleus interactions.

I read the instructions:

Secondary track (number):

Quark and Lepton Flavour Physics / 828

Study of $B \rightarrow D^* l\nu$ and $B \rightarrow D l\nu$ decays with a full angular analysis at BABAR

Author: Franco Simonetto

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We present results on the first full 4-dimensional angular analysis of the $B \rightarrow D^* l\nu$ and $B \rightarrow D l\nu$ decays, using the $e^+e^-$ collision dataset collected by the $BABAR$ experiment at the $\Upsilon(4S)$ resonance. One $B$ meson from the $\Upsilon(4S) \rightarrow BB$ decay is fully reconstructed in a hadronic decay mode which constrains the kinematics and provides a precise determination of the neutrino momentum vector. We extract the underlying hadronic form-factors employing the model-independent BGL approach and a value for the $CKM$ matrix element $|V_{cb}|$. Last, employing our measured BGL form-factors, we provide new predictions within the Standard Model, for observables related to the the semi-tauonic decay $B^- \rightarrow D^* \tau\nu$. 
Rare and forbidden decays of D0 meson

Author: Racha Cheaib

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We report the observation of the rare charm decay \( D^0 \rightarrow K^- \pi^+ e^+ e^- \), a search for nine lepton-number-violating and three lepton-flavor-violating neutral charm decays of the type \( D^0 \rightarrow h^- h'^- \ell^+ \ell'^- \), and \( D^0 \rightarrow h^- h'^+ \ell^+ \ell'^- \), and a search for seven lepton-number-violating decays of the type \( D^0 \rightarrow X^0 e^\pm \mu^\mp \), where \( h \) and \( h' \) represent a \( K \) or \( \pi \) meson, \( \ell \) and \( \ell' \) an electron or muon, and \( X^0 \) a \( \pi^0 \), \( K^0_S \), \( K^{*0} \), \( \rho^0 \), \( \phi \), \( \omega \), or \( \eta \) meson. The results are based on 468 fb\(^{-1} \) of \( e^+ e^- \) collision data collected at or close to the \( \Upsilon(4S) \) resonance with the \( BABAR \) detector at the SLAC National Accelerator Laboratory.
τ − µ lepton flavor universality in Υ(3S) decays at the BABAR experiment

Author: Alexei Sibidanov

1 University of Victoria

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We report on a precision measurement of the ratio $R_{τµ} = \frac{BF(Υ(3S) → τ^+τ^-)}{BF(Υ(3S) → µ^+µ^-)}$ using data collected with the BABAR detector at the SLAC PEP-II $e^+e^-$ collider. The measurement is based on a 28 fb$^{-1}$ data sample collected at a center-of-mass energy of 10.355 GeV/$c^2$ which corresponds to a sample 122 million Υ(3S) mesons. In order to estimate backgrounds from direct dilepton production we use 2.6 fb$^{-1}$ of data collected 30 MeV below the Υ(3S) resonance mass and 86 fb$^{-1}$ of data collected near the Υ(4S) resonance. The ratio is measured to $R_{τµ} = 0.9662 ± 0.0084 ± 0.0135$ and is in agreement with the Standard Model prediction. Its uncertainty is almost order of magnitude smaller than the only previous measurement reported by the CLEO collaboration.

Strong Interactions and Hadron Physics / 832

Study of $e^+e^-$ annihilation processes into 6 and 7 pion final states

Author: David Muller

1 SLAC

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The measurement of exclusive $e^+e^-$ to hadrons processes is a significant part of the physics program of BABAR experiment, aimed to improve the calculation of the hadronic contribution to the muon $g-2$ and to study the intermediate dynamics of the processes. We present the most recent results obtained by using the full data set of about 470 fb$^{-1}$ collected by the BABAR detector at the PEP-II $e^+e^-$ collider at a center-of-mass energy of about 10.6 GeV.

In particular, we report the results on $e^+e^-$ annihilation into six- and seven-pion final states. The study of the very rich dynamics of these processes can help to understand the observed difference between the QCD prediction and the sum of exclusive cross sections in the energy region around 2 GeV, thus improving the precision on the total hadronic cross section measurement and of the $g$-2 calculation.
Measurement of absolute branching fractions of $B \rightarrow K + X_{cc}$

**Author:** Fergus Wilson

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We present measurements of absolute branching fractions of the two-body decays of $B$ mesons $B \rightarrow K + X_{cc}$, where $X_{cc}$ is a charmonium state, by using a data set corresponding to about 470 fb$^{-1}$ collected by the BABAR detector at the PEP-II $e^+e^-$ collider. For events in which one $B$ is fully reconstructed, the charmonium spectrum can be observed in an unbiased way by looking at the distribution of the $K$ momentum in the rest frame of the recoiling $B$.

The absolute branching fraction $B^+ \rightarrow K^+X(3872)$ is measured for the first time at 3-sigma level, and from it a branching fraction for $BF(X(3872) \rightarrow J/\psi\pi^+\pi^-) = (4.1 \pm 1.3)\%$ is derived, supporting the hypothesis of a molecular component for this resonance.

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**Astroparticle Physics Outreach Program for High-School Students**

**Author:** Sabine Hemmer

**Co-author:** Collaboration OCRA

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The OCRA (Outreach Cosmic Ray Activities) INFN program includes public engagement events related to astroparticle physics and in particular it coordinates the twenty INFN Units that participated in the 2019 edition of the International Cosmic Day (ICD), an astroparticle physics outreach event organized by DESY. The ICD is dedicated to high school students from all over the world, who engage in measurements of the cosmic ray flux as a function of zenithal angles and discuss among themselves the results through remote conferences. Moreover, forty students who participated in the ICD will join a three-day school at the Frascati National Laboratories (LNF) of INFN in which they will launch an aerostatic balloon to measure the cosmic ray flux as a function of the atmospheric depth using a detector made by a scintillator layer and read out by SiPMs (Silicon Photomultipliers) named ArduSiPM. The students will carry out in a modern key the famous experiment by Victor Hess, which allowed the discovery of cosmic rays and earned him the Nobel Prize. The results of the measurements carried out during the school will be presented, as well as the ICD 2019 summary and some other activities coordinated by OCRA.

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**SuperCDMS Searches for Low-Mass Particle Dark Matter**

**Author:** Noah Kurinsky

1
The SuperCDMS collaboration has recently published results from two prototype detectors with thresholds below 20 eV, setting world-leading limits on dark matter nuclear recoils down to 90 MeV/c² in dark matter mass, and confirming the previous world-leading limits on electron-recoil dark matter down to ~500 keV/c² with improved resolution. Results from these prototype detectors have begun to probe regions of parameter space where detector response is unmeasured, and these detectors are also being used to measure the electron, x-ray, and nuclear recoil response of Si detectors below 1 keV. In this talk, I will present our recent dark matter results, discuss their implications for detector response models, and conclude with the status and plans for the upcoming SuperCDMS SNOLAB experiment.

Secondary track (number):

Dark Matter Detection / 836

Recent Searches for Hidden-Sector Particles with BABAR

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Many models of dark matter and hidden sectors predict new particles with masses below the electroweak scale. Low-energy electron-positron colliders such as BABAR are ideally suited to discover these hidden-sector particles. We present several recent BABAR searches for low-mass hidden-sector particles, including new searches for prompt and long-lived leptonically decaying hidden scalars produced in association with tau leptons. This search is sensitive to viable models that could account for the muon $g-2$ excess. We also present results a search for dark muonic forces, and for invisible particles produced in six-quark final states. These examples show the importance of B-factories in constraining and discovering new hidden-sector physics beyond the Standard Model.

Secondary track (number):

09 Dark matter detection

Search for an Axion-Like Particle in $B \to K a$, with $a \to \gamma \gamma$ at BABAR

Author: Brian Shuve

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Many extensions of the Standard Model include the possibility of light new particles, such as axions or dark matter candidates. These scenarios can be probed using the large data sets collected by B-factories, complementing measurements performed at the LHC.
We report on a search for an Axion-like particle (ALP), $a$, produced in the Flavor-Changing Neutral-Current decay $B \rightarrow Ka$, with $a \rightarrow \gamma\gamma$, which is expected to be competitive with the corresponding Standard-Model electroweak processes. This search, performed by using a dataset of about 470 million $B\bar{B}$ pairs collected by the $BABAR$ experiment at the PEP-II $e^+e^-$ collider, is sensitive to ALP masses in the range 0 - 4.78 GeV.

I read the instructions:

Secondary track (number):

Neutrino Physics - Posters / 840

The 3-inch Photomultiplier System of the JUNO Experiment

Authors: Cecile Jollet¹; Cedric Cerna¹

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JUNO is a multipurpose experiment under construction in China. In addition to 18,000 20-inch large photomultipliers (LPMTs) serving as the primary light-detection device, the JUNO central detector will be instrumented with 25,600 custom-made 3-inch small photomultipliers (SPMTs) to boost the physics potential of the experiment. The SPMTs will mostly operate in the photon-counting and will help to calibrate the energy response of the LPMTs. They will also aid the measurement of supernova neutrinos and will improve the muon track reconstruction whose performance is important for background rejection. The SPMTs, together with their power and readout systems, will have to operate under water for over 20 years, posing challenging constraints on the design, reliability and implementation of this major subsystem of JUNO. In this poster, we will present the innovative design of the JUNO SPMT system, its impact on physics, and the current status of SPMT production and testing.

Secondary track (number):

Beyond the Standard Model / 842

New bounds on sneutrino masses through collider searches

Author: Humberto Gilmer¹

Co-author: Linda Carpenter ²

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Though collider searches are constraining supersymmetric parameter space, generic model independent bounds on sneutrinos remain very low. We calculate new model independent lower bounds on general supersymmetric scenarios with sneutrino LSP and NLSPs. By recasting ATLAS LHC exotic searches in mono boson channels, we place an upper bound on the cross section on $pp \rightarrow \tilde{\nu}\tilde{\nu} + V$ processes in mono-photon, mono-$Z$ and mono-Higgs channels. We also evaluate the LHC discovery potential of sneutrinos in the HL-LHC 3 inverse attobarn run.

Secondary track (number):
Study of resonant-states production in $e^+e^-$ annihilation in the energy region around 2.2 GeV

Author: Evgeny Solodov

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Two vector resonances with a mass near 2.2 GeV/c² are presently known: the $\phi(2170)$ observed in several production processes, but seen to decay only to $\phi(1020) f_0(980)$, and the not well established $\rho(2150)$. Recently the BES-III experiment observed a clear interference pattern in the same energy region in $e^+e^- \rightarrow K^+K^-$, interpreted as a resonance with a mass of 2239 GeV and a width of 0.14 GeV. To shed light on the resonant states in this energy region we measure the reaction $e^+e^- \rightarrow K_S K_L$ with data collected with the BABAR detector, and analyse these data in conjunction with published BES-III data on $e^+e^- \rightarrow K^+K^-$ and BABAR data on $e^+e^- \rightarrow K^+K^-, \pi^+\pi^-, \pi^+\pi^-\eta, \pi^+\pi^-\omega$. This study supports the existence of an iso-vector resonance $\rho(2230)$ with mass $M = 2232 \pm 8 \pm 9$ MeV/c² and width $\Gamma = 133 \pm 14 \pm 4$ MeV/c², consistent with the resonance observed by BES-III.

Proton decay in the minimal realistic SO(10) GUT

Author: Katerina Jarkovska

Co-authors: Michal Malinský; Timon Mede; Vasja Susič

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The minimal realistic SO(10) model with adjoint representation causing GUT symmetry breaking is appealing candidate for realistic Grand Unified Theory. Moreover, the model allows one to make significant improvement in the proton lifetime error estimates due to the suppression of the potential gravitational effects influencing the GUT scale physics. We tackled the comprehensive numerical study of the proton decay width including one-loop quantum effects demanded by the physically relevant scenarios. The model’s study was also challenged by the improved perturbativity constraints.
Search for the Lepton Flavour Violating decays $\Upsilon(3S) \rightarrow e^\pm \mu^\mp$ and $\Upsilon(2S) \rightarrow e^\pm \mu^\mp$

**Author:** Nafisa Tasneem

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Charged lepton flavour violating processes are unobservable in the standard model, but they are predicted to be enhanced in several new physics extensions. We present a search for electron-muon flavour violation in $\Upsilon(3S)$ and $\Upsilon(2S)$ decays to the $e^\pm \mu^\mp$ final state. The search was conducted using data samples consisting of 118 million $\Upsilon(3S)$ and 96 million $\Upsilon(2S)$ mesons, collected at center-of-mass energies of 10.36 and 10.23 GeV, respectively, by the BABAR detector at the SLAC PEP-II $e^+e^-$ collider.

Education and Outreach / 847

**Cultural Collisions, a cross disciplinary science education format**

**Author:** Michael Hoch

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"Cultural Collisions" is a cross-disciplinary science and art engagement and networking program with special emphasis on educational methodologies. It is designed to trigger curiosity, creativity, and foster critical thinking in school students to help them overcome the scientific and technological challenges of the 21st century. The Cultural Collisions format has been implemented and tested in several European countries - Austria, Germany, Switzerland, Montenegro and recently in Czech Republic. During ICHEP2020 the final student artworks of Cultural Collisions Czech will be presented. Furthermore, it was the key component of a research project sponsored by the Ontario Ministry of Education, Canada, which assessed the educational impact on participating students. In the presentation, cross-disciplinary methodologies will be discussed as well as results will be presented. The evaluation is showing that the programme has demonstrated its capacity to increase motivation and interest in science via creative science engagement and increased the educational outcome.

The format was developed and evaluated within the EU funded project CREATIONS, the CMS experiment at CERN and during recent years by the ORIGIN collaboration. ORIGIN is a cooperation of scientific collaborations working on the secrets of the origin of the universe via particle physics, gravitational waves, neutrino physics, cosmology or astrophysics supporting interdisciplinary science engagement.

Jet production at NLO in the Parton Branching method
Authors: Francesco Hautmann¹, Armando Bermudez Martinez²

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Transverse momentum dependent (TMD) parton distributions obtained from the Parton Branching (PB) method are combined with next-to-leading-order (NLO) calculations of jet production to obtain predictions for LHC jet final states. In addition, a new initial state Parton Shower, which is based on the TMD distributions, and final state Parton Showers are included together with hadronization. We compare our predictions with jet and Z+jet measurements performed at the LHC, finding good agreement. We present first results for multi-jet merging with PB-TMDs, illustrating the application of the method to differential jet rates and transverse momentum spectra.

I read the instructions:

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 849

Running Experience and Performance of the Novel Time of Propagation (TOP) Barrel PID Detector in the Belle II Experiment

Author: Oskar Hartbrich¹

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The Time of Propagation (TOP) detector is a novel particle identification system developed for the barrel region of the Belle II detector at the SuperKEKB collider at KEK in Tsukuba, Japan. Cherenkov photons generated by charged particles traversing its quartz radiator are captured due to total internal reflection. The Cherenkov emission angle is then reconstructed from the propagation time of individual photons to the Micro-Channel Plate PMT sensor plane mounted at one end of the bar. The readout electronics for the 8192 channels of the TOP system are built around a switched capacitor array waveform sampling ASIC operating at 2.7 GSa/s. Realtime processing in the front end electronics extracts the individual timing of detected photons to better than 100 ps.

This talk presents the current experiences and results from commissioning, calibration and operation of the Belle II TOP detector in the first physics runs of the Belle II experiment up until the summer 2020.

Secondary track (number):

Accelerator: Physics, Performance, and R&D for Future Facilities / 850

Upgrading SuperKEKB with polarized e- beams

Author: Michael Roney¹
Upgrading the SuperKEKb $e^+e^-$ collider with a polarized $e^-$ beam is under consideration as it enables a new program of precision electroweak and other physics at 10.6 GeV, thereby opening exciting new windows in search of new physics. Measurements of left-right asymmetries ($A_{LR}$) of $e^+e^-$ transitions to pairs of muons, $c$- and $b$-quarks would yield substantial improvements to the determinations of the neutral current vector coupling of those final states and hence $\sin^2 \theta_W$. $A_{LR}$ measurements of final state $e^+e^-$ and taus would determine $\sin^2 \theta_W$ with the Z-pole precision but at much lower energy. These will probe the running and universality of neutral current couplings with unprecedented precision. Other Tau and QCD physics is also enhanced. This paper will include a discussion of the physics as well as the necessary upgrades to SuperKEKB: polarized $e^-$ source, precision polarimetry, and spin rotators that all must be introduced while maintaining the high luminosity.

**Secondary track (number):**

4.

**Analysis of the magnetic field in the Fermilab muon g-2 experiment**

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The muon g-2 experiment at Fermilab seeks to confirm or deny the ~3.5 $\sigma$ discrepancy between the Standard Model prediction of the muon anomalous magnetic moment, $a_\mu$, and its experimental value. The experiment measures $a_\mu$ directly from the ratio of the muon precession frequency in a uniform storage ring magnetic field to the Larmor frequency of free protons in the same field. Every few days, an NMR 'trolley' maps out the storage ring field. Field drifts between trolley runs are tracked by 'fixed' NMR probes embedded in the vacuum chamber walls. These measurements are interpolated to determine the field in the storage region, which is convolved with the muon beam distribution to determine the effective magnetic field, $<B>$. A precise determination of $<B>$ is crucial; half of the error budget is attributed to the magnetic field uncertainty. The magnetic field analysis techniques and a summary of the results will be presented.

**Secondary track (number):**

Operation, Performance and Upgrade of Present Detectors / 852

**Muon g-2 beam and spin systematic effects for Run-1**

**Author:** Sudeshna Ganguly

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The muon g-2 Experiment at Fermilab measures the anomalous magnetic moment, $a_\mu$, with improved precision compared to the previous experiment at Brookhaven National Lab.
The greater than 3 standard deviations difference between Standard Model prediction and the previous BNL, $\alpha_\mu$, measurement hints at the possibility of new physics. Positive polarized muons are circulated in the storage ring and the experiment precisely determines the muon anomalous precision frequency, $\omega_a$ (spin precession relative to momentum). The $\omega_a$ is determined from calorimeter measurements of decay positron time and energy. The experiment also needs to precisely determine the average magnetic field seen by the muons, which is based on continuous NMR probe measurements. A detailed understanding of beam and spin systematic effects is required for the precise determination of $\omega_a$. This talk gives a review of the beam and spin systematic effects that are significant for determination of $\omega_a$ in the 2018 Run-1 analysis.

**Secondary track (number):**

**Operation, Performance and Upgrade of Present Detectors - Posters / 853**

**Simulation study for the electromagnetic calorimeter trigger system of the Belle II experiment**

**Authors:** Cheolhun Kim\textsuperscript{None}; bongho kim\textsuperscript{1}; Insoo Lee\textsuperscript{2}; Sung-Hyun Kim\textsuperscript{3}; Yuji Unno\textsuperscript{2}; Byunggu Cheon\textsuperscript{None}

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The Belle II experiment using the SuperKEKB energy-asymmetric $e^+e^-$ collider at KEK in Japan started physics data-taking from 2018. In the Belle II operation, the Electromagnetic Calorimeter (ECL) trigger system was very crucial to operate the trigger/DAQ system. The ECL trigger simulation package has been prepared based on the Belle II Geant4-based analysis framework called Basf2. By the simulation tool, various ECL trigger logics were developed and confirmed by the intensive simulation study. So far, the ECL trigger system has been stably working from the early stage of the experiment. However, severe beam background is anticipated in the future due to a dramatic increase of instantaneous luminosity, so the background level should be estimated. Moreover, the simulation module should be upgraded to give more realistic predictions. In this report, we describe a background overlay simulation study and simulation module updates as well.

**Secondary track (number):**

**Strong Interactions and Hadron Physics / 854**

**Space-time Colour Reconnection in Herwig 7**

**Author:** Miroslav Myska\textsuperscript{1}

**Co-authors:** Stefan Gieseke\textsuperscript{2}; Andrzej Konrad Siodmok\textsuperscript{3}; Johannes Bellm\textsuperscript{4}; Cody Duncan\textsuperscript{5}

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We present a model for generating space-time coordinates in the Monte Carlo event generator Herwig 7, and perform colour reconnection by minimizing a boost-invariant distance measure of the system. We compare the model to a series of soft physics observables. We find reasonable agreement with the data, suggesting that pp-collider colour reconnection may be able to be applied in larger systems.

Secondary track (number):

Higgs Physics / 855

Constraining resonances by using the EW effective theory

Author: Ignasi Rosell¹

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Taking into account the mass gap between the Standard Model (SM) and possible new particles, the use of effective field theories is appropriate. We adopt here the non-linear realization of the electroweak symmetry breaking: the electroweak effective theory (EWET), also known as Higgs effective field theory (HEFT) or electroweak chiral Lagrangian (EWChL). At higher energies we assume a resonance Lagrangian which couples the SM states to bosonic and fermionic resonances. Integrating out the resonances and assuming a well-behaved short-distance behavior, we determine or constrain most of the bosonic low-energy constants in terms of resonance masses. The fit of these low-energy constants allows us to learn about the high-energy scales.

Secondary track (number):

03

Dark Matter Detection / 856

PICO: searching for dark matter with bubble chambers

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The PICO collaboration uses bubble chambers to search for dark matter, with world-leading sensitivity to spin-dependent (SD) WIMP-proton couplings via direct detection. The bubble chambers are operated in a moderately superheated state, providing excellent rejection of the dominant gamma background, and are located in the deep underground facility SNOLAB in Canada. The PICO-60 detector has set the most stringent limits to date for SD WIMP-proton couplings using C3F8; while the collaboration is currently commissioning PICO-40L, a new detector that will incorporate several design improvements to reduce backgrounds from neutrons and particulate contamination; and is also preparing PICO-500, a ton-scale bubble chamber designed to cover a large range of mass and...
cross section parameter space, proving a variety of theoretical models. The PICO collaboration has built a well established technology, easily scalable and relatively inexpensive with flexibility to easily exchange targets following a discovery.

The latest results of the PICO programme will be presented in this talk, as well as the current status of backgrounds control and Monte Carlo simulations for PICO-40L and PICO-500.

Secondary track (number):

Strong Interactions and Hadron Physics - Posters / 857

Parton Branching method and applications to pp and ep processes

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Transverse Momentum Dependent (TMD) parton distributions obtained within the Parton Branching (PB) approach offer a wide spectrum of applications to describe processes in pp as well as in ep interactions. We give an overview of the PB TMD distributions and show examples of applications of the PB TMD distributions to describe Drell-Yan processes, boosted W/Z production as well as jet production in high energy pp interactions. We also show applications to processes at ep colliders like HERA and the forthcoming EIC.

The PB TMD approach together with dedicated parton showers offer a new and consistent way to describe not only inclusive but also multi-jet distributions at different center-of-mass energies.

Secondary track (number):

Diversity and Inclusion / 858

The Early Career, Gender & Diversity at LHCb

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LHCb is a collaboration of over 1300 members from 83 institutions based in 19 countries, and representing many more nationalities. We aim to work together on experimental high energy physics, and to do so in the best and most collaborative conditions. The Early Career, Gender & Diversity (ECGD) office exists to support this goal, and in particular has a mandate to support early-career physicists, to work towards gender equality, and support diversity in the collaboration. The ECGD officers advise the LHCb management and act as LHCb contacts for all matters related to ECGD. They are available for listening to and advising - in a confidential manner - colleagues who have witnessed or have been subject to harassment, discrimination or other inappropriate behaviour. They help raise awareness in the collaboration for topics related to ECGD. In this talk we briefly introduce the ECGD office, discuss what we have learnt from analysis of the collaboration’s demographics and responses from a survey that we conducted recently, share our experience gained over the last years, and we present our vision for the future evolution of the ECGD.
Beyond the Standard Model / 859

Exotic Vector-Like Quark Phenomenology in the Minimal Linear Sigma Model

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Extensions of the Standard Model that include vector-like quarks commonly also include additional particles that may mediate new production or decay modes. Using as example the Minimal Linear Sigma Model, that reduces to the minimal SO(5)/SO(4) Composite Higgs Model in a specific limit, we consider the phenomenology of vector-like quarks when a scalar singlet (s) is present. This new particle may be produced in the decays T → t s, B → b s, where T and B are vector-like quarks of charges 2/3 and -1/3, respectively, with subsequent decay s → W+ W-, ZZ, hh. By scanning over the allowed parameter space we find that these decays may be dominant. In addition, we find that the presence of several new particles allows for single T production cross sections larger than those expected in minimal models. We discuss the observability of these new signatures in existing searches.

Operation, Performance and Upgrade of Present Detectors - Posters / 860

Offline Data Analysis of the Electromagnetic calorimeter trigger system in Belle II experiment

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Co-authors: Byunggu Cheon ; Cheolhun Kim ; bongho kim ¹; Sunhyun Kim ; Yuji Unno ²

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The main physics motivation of Belle II experiment is to probe the New Physics beyond the Standard Model and precise measurement of CP violation, CKM parameters by heavy quark/lepton flavor decays as well. The SuperKEKB e+e- Collider at KEK in Japan has been started beam collision from 2018 to collect Belle II physics data. The Electromagnetic Calorimeter (ECL) trigger system was very crucial to operate Belle II trigger/DAQ system in stable during the SuperKEKB luminosity run. In order to check stability of ECL trigger performance, we built an offline data monitoring module called Quality Assurance Monitor (QAM). The ECL trigger QAM module is based on Belle II Analysis
Framework (basf2). It mainly analyzes total energy and cluster energy using various High Level Trigger skinned data. In this report, we describe the performance of the ECL trigger QAM module in detail.

Secondary track (number):

Quark and Lepton Flavour Physics / 861

Updates on the Standard Model and beyond SM Unitarity Triangle fits and neutral charm mixing results by UTfit

Authors: Marcella Bona; Luca Silvestrini; Denis Derkach

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Flavour physics represents a unique test bench for the Standard Model (SM). New analyses performed at the LHC experiments are now providing unprecedented insights into CKM metrology and new results for rare decays. The CKM picture can provide very precise SM predictions through global analyses.

We present here the results of the latest global SM analysis performed by the UTfit collaboration including all the most updated inputs from experiments, lattice QCD and phenomenological calculations. We also present the perspectives for future UT analyses on the basis of existing extrapolations of experimental results from the Belle-II and LHCb experiments, as well as of expected improvements from Lattice QCD computations.

The Unitarity Triangle (UT) analysis can be used to constrain the parameter space in possible new physics (NP) scenarios. We present an update of the UT analysis beyond the SM by the UTfit collaboration. Assuming NP, all of the available experimental and theoretical information on DeltaF=2 processes is combined using a model-independent parametrisation. We determine the allowed NP contributions in the kaon, D, Bd, and Bs sectors and, in various NP scenarios, we translate them into bounds for the NP scale as a function of NP couplings.

We update our analysis of D meson mixing including the latest experimental results. We derive constraints on absorptive and dispersive CP violation by combining all available data, and discuss future projections. We also provide posterior distributions for observable parameters appearing in D physics.

I read the instructions:

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques - Posters / 864

Particle tracking in wide field-of-view with miniaturized pixel detector arrays for space weather and space radiation research

Author: Carlos Granja

Co-authors: Jan Jakubek; Pavel Soukop; Daniel Turecek; Cristina Oancea; Lukas Marek; Milan Malich; Stefan Gohl; Benedikt Bergmann; Stanislav Pospisil; Jiri Kraus; Vladimir Daniel; Maros Petro; Adam Smetana
Hybrid semiconductor pixel detectors Timepix and Timepix3 provide quantum sensitivity, per-pixel spectrometry, noiseless detection and particle tracking in wide field-of-view. Array architectures enhance the resolving power and angular resolution. Miniaturized arrays are developed for deployment on board spacecraft in space. Low-power radiation monitors for telecommunication satellites in GEO. A large-area focal-plane imager for astrophysics X-ray observation of stellar objects on board a Cubesat in LEO. Stack arrays of pixel detectors for directional detection of gamma rays and mapping of energetic charged particles in wide field-of-view. The platforms feature novel on-board data processing for autonomous operation. We describe the data products (LET-spectra, particle fluxes, dose rates, directional- time- and location-correlated distributions) and results of testing and calibrations in well-defined radiation fields. Development in frame of European Space Agency ESA Contract.

Secondary track (number):
07

Accelerator: Physics, Performance, and R&D for Future Facilities / 865

Circular vs linear e+e- colliders, another story of complementarity

Author: Patrizia Azzi¹

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The physics program proposed by circular and linear e+e- colliders at the electroweak and TeV scale exhibits considerable complementarity. This could be exploited on a world-wide scale if both a large circular and a linear infrastructures were available. A possible implementation of such a complementary program is shown.

I read the instructions:

Secondary track (number):
Physics opportunities and detector challenges for a Tera-Z factory

Author: Emmanuel Francois Perez

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The proposed circular electroweak factories offer extraordinary statistics of Z decays ($5 \times 10^{12}$ at the FCC-ee). This offers a number of great physics opportunities, but presents a number of novel detector challenges. We will review the questions related to the new domain of precision required for the EW observables, the huge b and tau physics program and the search for rare events.

I read the instructions:

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 867

A detector concept proposal for a circular e+e- collider

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Future circular electron-positron colliders have received much attention due to the extreme luminosity reachable at energies ranging from the Z pole to the top pair production threshold. An impressive and varied physics program is provided by these machines, but at the same time, they pose very specific detector issues, whose solutions differ in general from those adopted for linear e+e-colliders. We present IDEA, a detector concept optimized for these circular colliders; in particular we discuss the technical solutions chosen and show the expected performance on some key physics benchmarks.

I read the instructions:

Secondary track (number):

FCC-ee : beam Energy calibration and polarization

Authors: Patrizia Azzi1; Alain Blondel2

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The first stage of the FCC (Future Circular Collider) is a high-luminosity electron-positron collider (FCC-ee) with centre-of-mass energy ranging from 88 to 365 GeV, to study with high precision the Z, W, Higgs and top particles. A cornerstone of the physics program lays in ppm measurements of
the W and Z masses and widths, as well as forward-backward asymmetries. To this effect the centre-
of-mass energy distribution should be determined with high precision. This presentation describes
the capacity offered by FCC-ee, starting with transverse polarization of the beams around the Z pole
and the W pair threshold. A running scheme based on regular measurements, during physics data
taking, of the beam energy is proposed, using resonant depolarization of pilot bunches. The design
of polarization wigglers, polarmeter and depolarizer is outlined. The e± beam energies will be moni-
tored with a relative precision of one ppm. The derivation of centre-of-mass energy requires further
corrections, related to the beam RF acceleration, synchrotron radiation and beamstrahlung; these
effects are identified and evaluated. Dimuon events e+e−→μ+μ−, recorded in the detectors, provide
with great precision the beam crossing angle, the centre-of-mass energy spread, and the e+ and e−
energy difference. Monitoring methods to minimize absolute error and relative uncertainties are
discussed. The impact on the physics measurements is given. A programme of further simulations,
design, monitoring and R&D is outlined.

Secondary track (number):

Accelerator: Physics, Performance, and R&D for Future Facilities - Posters / 869

Measurement of the centre-of-mass energy and of its spread with
dimuon events at FCC-ee

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At FCC-ee, beamstrahlung is pushed at its limits to maximize the luminosity, which causes a large
beam energy spread, from 60 MeV at the Z pole to 350 MeV at the top energies, and therefore a centre-
of-mass energy spread from 90 to 500 MeV. Because the pertaining biases to the measurements of
ΓZ and αQED are two-to-three orders of magnitude larger than their target precisions, the centre-
of-mass energy spread must be measured to a few per mil. Dimuon events are instrumental for
this purpose. The effect of energy spread is to slightly boost the two muons along the “beam axis”
and modify their directions – in a way similar to the radiation of a photon (ISR) by one of the two
incoming particles. This “longitudinal” boost can be determined with the help of (E, p) conservation
from the muon polar and azimuthal angles, θ± and φ±. After unfolding ISR effects, the mean value
and shape of the boost distribution give - with the necessary precision - the difference between
the e± beam energies and the relative centre-of-mass energy spread, within a few minutes. The
measurement of the centre-of-mass energy and of its spread also requires an absolute knowledge of
the beam crossing angle α and of the two muon directions, and therefore an absolute alignment of the
detector with respect to the beam directions. The beam crossing angle α can be determined for each
event from the muon directions and (E, p) conservation, with a precision of 0.3 μrad within 5 minutes
at the Z pole at FCC-ee. An absolute alignment of the detector can be achieved by minimizing the
spread of the α distribution.

I read the instructions

Secondary track (number):

Formal Theory / 870

Electroweak precision pseudo-observables at the e+e- Z-resonance
region
Authors: Patrizia Azzi\textsuperscript{1}; Janusz Gluza\textsuperscript{2}

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Phenomenologically relevant electroweak precision pseudo-observables related to the Z-boson physics are discussed in the context of strong experimental demands of future $e^+e^-$ colliders. The recent completion of two-loop Z-boson results is summarized and a prospect for the 3-loop SM calculation of the Z-boson decay pseudo-observables is given.

Secondary track (number):

Education and Outreach / 871

Getting the public closer to the experimental facilities: How Virtual Reality helps HEP experiments engage public interest

Author: Ana Peixoto\textsuperscript{1}

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For many HEP experiments the experimental area is difficult to access for visitors. That makes engaging the public difficult. This is true both for educational purposes and for outreach and media events. The use of the latest technologies in Virtual Reality (VR), Augmented Reality (AR), and 360 degree visualization helps the experiments in getting the public closer to their research. By virtually entering the experimental area the public can visit the different facilities in an immersive and autonomous way; also, by getting closer to the detector, people can get a feeling of the size and the complexity of the experiment itself.

Here we will present the applications based on these technologies developed within the ATLAS Collaboration. We will show how they have been used successfully in presentations to funding agencies and in a number of public events to educate the public about the ATLAS experiment and to generally engage the public in High Energy Physics fundamental research.

I read the instructions:

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 872

WADAPT: Wireless Allowing Data and Power Transfer

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The WADAPT consortium (Wireless Allowing Data and Power Transfer) was created to study wireless (multi-gigabit) data transfer for high energy physics applications (LoI, CERN-LHCC-2017-002;
New millimeter frequency-band radio technologies allow fast signal transfer and efficient partitioning of detectors in topological regions of interest. Large bandwidths are available: 14 GHz to 60 GHz and 32 GHz to 140 GHz, respectively. An example of use is the transfer of information from a vertex detector widely used in our experiments. We are currently developing a coherent program with stages and deliverables over 3 years with the aim of building a demonstrator as proof of principle for use in future HEP experiments. For vertex detectors at HL-LHC, for example, the bandwidth of 60 GHz is adequate and commercial products are available. They have been tested for signal confinement, crosstalk, electromagnetic immunity and resistance to radiation (up to 1014 Neq / cm²). A 60 GHz demonstrator is currently being built in Heidelberg, using 130 nm SiGe BI-CMOS technology, with on-off keying. Following this development, an optimized demonstrator is planned to assess the feasibility and performance, refine the estimate of the required data transfer, energy consumption, BER, latency, mass, radiation resistance, high directivity antennas, cost and establish a solid foundation for designing the final reading system.

Larger bandwidth is available at 140 GHz and higher data rates (20 to over 100 Gbps, depending on the architecture) are possible for future FCC applications, without degrading performance. Once the proof of principle has been carried out, there would no longer be any obstacle to generalizing the use of wireless reading to other detectors, with the possibility of adding intelligence on the detector to perform a four-dimensional reconstruction of the traces and vertexes online, in order to attach the traces to their vertex with great efficiency even in difficult experimental conditions. The WADAPT project includes a long-term step aimed at transmitting energy wirelessly. Leti works on the concepts of simultaneous RF data and energy transmission, and energy recovery. This would create a new paradigm for the transmission of data and power in particle physics detectors.

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 873

Development and performance of compact LumiCal prototype calorimeter for future linear collider experiments

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The FCAL collaboration is preparing large-scale prototypes of special calorimeters to be used in the very forward region at a future electron-positron collider for a precise and fast luminosity measurement and beam-tuning. LumiCal is designed as a silicon-tungsten sandwich calorimeter with very thin sensor planes to keep the Moliere radius small, facilitating such the measurement of electron showers in the presence of background. Dedicated FE electronics has been developed to match the timing and dynamic range requirements.

A partially instrumented prototype was investigated in a 1 to 5 GeV electron beam at the DESY II synchrotron. In the recent beam tests, a multi-plane compact prototype equipped with thin detector planes fully assembled with readout electronics were installed in 1 mm gaps between tungsten plates of one radiation length thickness. High statistics data were used to perform sensor alignment, and to measure the longitudinal and transversal shower development in the sandwich. This talk will cover the latest status of the calorimeter prototype development and the selected commissioning results, the preparations for the upcoming DESY test beam, as well as the expected simulation performance.

I read the instructions:

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 874
The pixel vertex detector at Belle II

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The vertex detector at Belle II has four outer layers of silicon strip detectors (SVD) and two inner pixel layers (PXD) at a distance of 14 and 22 mm to the interaction point. The PXD is based on DEPFET technology, which combines signal generation and first amplification in a single device and allows for the construction of a very light-weight device. The material budget of a single layer inside the acceptance region is only about 0.2% of a radiation length including all structures needed for support and thermal management. This is only possible with the unique approach of the “all-silicon module” where all read-out ASICs and interconnects are integrated in a micro-machined piece of silicon with the active DEPFET pixel sensor as its integral part.

The Belle II PXD Collaboration designed and fabricated the sensor, the read-out and steering ASICs, the low-mass module and ladder concept, services and power supplies, cooling, DAQ system and slow control. It is the first time that the DEPFET technology is deployed in a HEP experiment.

The PXD is in operation as part of the Belle II experiment at KEK since March 2019 and is taking data with very good performance meeting the expectations. Since start of operation, the accelerator SuperKEKB reached a peak luminosity beyond 1e34 /cm²s and about 10 fb⁻¹ have been recorded at the time writing. The final goal for the peak luminosity of the machine is 8e35 /cm²s and the pixel detector is designed to be operated at this final luminosity up to the accumulated data set of 50 ab⁻¹. The lessons learned during construction, commissioning, and operation of the first DEPFET based vertex detector will be presented.

Secondary track (number):

Top Quark and Electroweak Physics - Posters / 875

Latest single top differential cross section measurements at CMS

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Single top quark production is the subleading production process of top quarks at the LHC after the top quark pair production. The latest differential measurements of single top quark production cross sections are presented using data collected by the CMS detector at a center-of-mass energy of 13 TeV. The cross sections are measured as a function of various kinematic observables of the top quarks and the jets and leptons of the events in the final state. The results are confronted with precise theory calculations.

Secondary track (number):

Technology Applications, Industrial Opportunities and Sustainability / 876

Quantum Track Reconstruction Algorithms for non-HEP applications

Authors: Daniel Dobos; Kristiane Sylvia Novotny; Cenk Tuysuz; Bilge Demirkoz; Karolos Potamianos
The expected increase in simultaneous collisions creates a challenge for accurate particle track reconstruction in High Luminosity LHC experiments. Similar challenges can be seen in non-HEP trajectory reconstruction use-cases, where tracking and track evaluation algorithms are used. High occupancy, track density, complexity and fast growth therefore exponentially increase the demand of algorithms in terms of time, memory and computing resources.

While traditionally Kalman filter (or even simpler algorithms) are used, they are expected to scale worse than quadratically and thus strongly increasing the total processing time. Graph Neural Networks (GNN) are currently explored for HEP, but also non HEP trajectory reconstruction applications. Quantum Computers with their feature of evaluating a very large number of states simultaneously are therefore good candidates for such complex searches in large parameter and graph spaces.

In this paper we present our work on implementing a quantum-based graph tracking machine learning algorithm to evaluate Traffic collision avoidance system (TCAS) probabilities of commercial flights.
Search for excited leptons in CMS

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Compositeness models are a popular explanation for the observed three generations of standard model (SM) particles. One consequence of compositeness would be the observation of excited leptons, such as excited electrons, e, or excited muons, mu. At the LHC such particles could be produced in pp collisions under the assumption that leptons are composite objects. Produced excited leptons are expected to transition to their corresponding SM lepton partner via gauge or via contact interaction. CMS has performed a recent search for e and mu in the contact interaction decay channel leading to a two-lepton plus two-jets final state using the 2016 and 2017 √s = 13 TeV dataset. While no signal was observed, the exclusion results provide the best limits to date. The poster also compares to other complementary search channels and discusses the greater context of excited leptons searches.

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors / 879

ALPIDE pixel detector for tracking in space.

Author: Paolo Zuccon

Co-authors: Franco Benotto; Stefania Beole; William Burger; Silvia Coli; Lorenzo De Cilladi; Simone Garaffa; Corrado Gargiulo; Giuseppe Gebbia; Roberto Iuppa; Francesco Nozzoli; Ester Ricci; Sergio Bruno Ricciarini; Enrico Serra

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The ALPIDE MAPS chip used in the ALICE silicon tracker upgrade, represents the state of the art for pixel-based tracking with silicon. We investigated the possibility to use the ALPIDE chip in space applications using a setup derived from the ALICE Outer Barrel HIC. We first addressed the issue of the power consumption and we will report on a special setup that provides a relevant power saving. We then passed to address heat dissipation, material qualification for space, performance in vacuum and resistance to launch vibrations. From our qualification test the ALPIDE chip results as a viable solution for space applications.
**Beyond the Standard Model / 880**

**Charged and neutral Higgs bosons in final states with 6 bottom quarks**

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In extensions of two Higgs doublet models with vectorlike quarks, the decays of vectorlike quarks may be easily dominated by cascade decays through charged or neutral Higgs bosons leading to signatures with 6 top or bottom quarks. Since top quark decays also contain bottom quarks, the 6 bottom quarks in final states is a common signature to a large class of possible decay chains. We present a search strategy focusing on this final state and find the mass ranges of vectorlike quarks and Higgs bosons that can be explored at the Large Hadron Collider. Among other results the sensitivity to the charged Higgs boson, extending above 2 TeV, stands out when compared to models without vectorlike matter.

**Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 882**

**Development of Scintillating Fiber Detectors for Precise Time and Position Measurements Read Out with Si-PMs**

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We present the development and performance of compact Scintillating Fiber (SciFi) detectors read out with Si-PMs for tracking and timing to be used at very high particle rates. The compact size, fast response, and insensitivity to magnetic fields make these detectors suitable for a variety of applications. Different scintillating fiber materials have been evaluated to achieve the best performance. In particular, we will present and discuss the performance of the SciFi tracker / time of flight detector under construction for the Mu3e experiment at PSI searching for the neutrinoless decay $\mu^+ \rightarrow e^+ e^+ e^+$ at very high rates. To suppress all forms of combinatorial background, a very thin (thickness $<$ 0.2% of radiation length) SciFi detector with few 100 ps time resolution, efficiency in excess of 96%, and spatial resolution of $\sim$100 um has been developed. Moreover the SciFi detector will help to determine the charge of the recurling tracks in the central region of the apparatus by time of flight measurements.
Neutrino Physics / 883

Paleo-Detectors for Galactic Supernova Neutrinos

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Paleo-detectors are a proposed experimental technique in which one would search for traces of recoiling nuclei in ancient minerals. Natural minerals on Earth are as old as $\mathcal{O}(1)$ Gyr and, in many minerals, the damage tracks left by recoiling nuclei are also preserved for time scales long compared to 1 Gyr once created. Thus, even reading out relatively small target samples of order 100 g, paleo-detectors would allow one to search for very rare events thanks to the large exposure, $\varepsilon \sim 100 \text{ g Gyr} = 10^5 \text{ t yr}$. Here, we explore the potential of paleo-detectors to measure nuclear recoils induced by neutrinos from galactic core collapse supernovae. We find that they would not only allow for a direct measurement of the average core collapse supernova rate in the Milky Way, but would also contain information about the time-dependence of the local supernova rate over the past $\sim 1$ Gyr. Since the supernova rate is thought to be directly proportional to the star formation rate, such a measurement would provide a determination of the local star formation history. We investigate the sensitivity of paleo-detectors to both a smooth time evolution and an enhancement of the core collapse supernova rate on relatively short time scales, as would be expected for a starburst period in the local group.

Secondary track (number):

Computing and Data Handling / 885

Accurate calculations of atomic data for He-like oxygen

Author: Dhia Elhak Salhi

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In the last few years, various theoretical and experimental research for providing atomic data for He-like ions have been carried out. For our calculations of atomic data for He-like oxygen, we have adopted the Multiconfigurational-Dirac-Hartree-Fock (MCDHF) method implemented in the General-Purpose Relativistic Atomic Structure Package (GRASP2K) code. Further relativistic corrections arising from the Breit interaction and QED effects have also been included. Additionally, in order to make a rigorous accuracy assessment of our results, we have also performed calculations by using the Many Body Perturbation Theory (MBPT) method implemented in the Flexible Atomic Code (FAC) of Gu. The accuracy of the present calculations is high enough to facilitate identification of many observed spectral lines. There are required in the study of high-temperature plasmas such as those occurring in fusion energy research and in astrophysical research.

Secondary track (number):

Astro-particle Physics and Cosmology / 886
Recent results of the ANTARES neutrino telescope

**Author:** Tommaso Chiarusi

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The ANTARES detector is the first Cherenkov neutrino telescope realised in the Mediterranean sea. It is continuously taking data since 2007, with the primary aim to detect astrophysical neutrinos in the TeV-PeV range. A very good angular resolution in all flavour neutrino interaction channels, together with the depth of the abyssal site (2500 m below the sea level) led to an unprecedented sensitivity in the searches for neutrino sources in the Southern Sky and in the energy range below 100 TeV. This has allowed constraining the origin of the cosmic neutrino flux discovered by the IceCube detector. ANTARES has also implemented a rich multi-messenger program, providing with both online and offline pipelines for alert sending and follow-up observations of interesting astrophysical events.

Among these, the searches triggered by gravitational wave observations are of prominent interest. Other physics topics are also covered: searches of dark matter annihilation or decay in massive objects; the search for relic massive magnetic monopoles and nuclearites; the study of atmospheric neutrinos and neutrino oscillations.

**Secondary track (number):**

02

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Dark Matter Detection / 887

**DarkSide-20k and the Direct Dark Matter Search with Liquid Argon**

**Author:** The Global Argon Dark Matter Collaboration

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Dual phase noble liquid Time Projection Chambers (TPCs) offer a competitive and scalable way to search for dark matter directly via elastically scattering off of detector target nuclei and electrons.

The Global Argon Dark Matter Collaboration (GADMC) is undertaking an ambitious global program from the extraction and purification of Underground Argon (UAr), depleted in 39Ar which reduces the internal background, to the development of $25cm^2$ Silicon Photo Multiplier (SiPM) modules capable of resolving single photoelectrons.

DarkSide-20k is the next stage of this program and will be the next generation dual phase Argon TPC. DarkSide-20k will be housed in the Gran Sasso underground laboratory (LNGS) and has an exposure goal of ~100 tonne-years with zero instrumental background in expectation of a WIMP-nucleon cross section of $10^{-47}cm^2$ for a WIMP mass of 1TeV/c$^2$ during a 5-year run. An overview of the DarkSide experimental program will be presented with a focus on the upcoming DarkSide-20k detector and the new technologies involved.

**I read the instructions:**

**Secondary track (number):**

Dark Matter Detection / 888
Latest Result from DarkSide-50 experiment at LNGS

Author: DarkSide Collaboration

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The DarkSide-50 direct-detection dark matter experiment is a dual-phase argon time projection chamber operating at Laboratori Nazionali del Gran Sasso (LNGS) of INFN. It is sensitive to WIMPs with masses above 50 GeV/c² by exploiting the exceptional pulse shape discrimination of the scintillation signal in LAr and to lower masses WIMPs by an analysis that uses solely the ionisation signal for which DarkSide-50 is fully efficient starting from 0.1 keVee. The latest results derived utilizing the full sample acquired by the experiment will be presented together with the calibration methods used in particular for the low mass WIMP searches.

I read the instructions:

Secondary track (number):

Beyond the Standard Model / 890

A new program of searches for baryon number violation via neutron conversions at ORNL and the ESS

Author: Leah Broussard

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Searches for free neutrons converting to anti-neutrons (|ΔB|=2) and/or sterile neutrons (|ΔB|=1) play a distinctive and complementary role in the worldwide program of baryon number violation searches. These searches provide an important test of a global symmetry that must be violated to create a baryon asymmetry in the universe, and offer a unique portal to a dark sector through these feeble interactions. An international collaboration has developed a staged program of searches for neutron conversions at Oak Ridge National Laboratory and the European Spallation Source, which will allow both precision searches and research and development for subsequent stages, culminating in an ultimate improvement in sensitivity of around three orders of magnitude compared with earlier work. We will outline this program and present results of the first-stage search for neutron conversions to sterile neutrons in large magnetic fields, suggested to explain the long-standing neutron lifetime anomaly.

Secondary track (number):

Quark and Lepton Flavour Physics / 891

Recent gems from kaon and their repercussions for future directions

Author: Amarjit Soni

Amarjit
Corresponding Author: adlersoni@gmail.com

Kaons have played a crucial role in Particle Physics from their early history including some profound discoveries. In this talk I will give account of recent progress on several challenging issues that have been with us for a long time. Seen in the light of this progress what can we learn from many of the flavor anomalies of the past many years will also be discussed.

I read the instructions:

Secondary track (number):

Heavy Ions / 892

Quantum tomography for Collider Physics

Authors: Daniel Tapia Takaki1; John P. Ralston1; John C. Martens1

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Quantum tomography reconstructs higher dimensional features of quantum mechanical systems from lower dimensional experimental information. The method is practical and directly processes experimental data while bypassing field-theoretic formalism. Quantum tomography can probe entanglement while avoiding model assumptions such as factorization. We review recent work applying quantum tomography to systematic analysis of collider reactions, including the inclusive production of dijets, and in ultra-peripheral heavy-ion collisions.

Secondary track (number):

Quark and Lepton Flavour Physics / 893

Probing Lepton Flavor Violating decays in MSSM with Non-Holomorphic Soft Terms

Authors: Utpal Chattopadhyay1; Debottam Das2; Samadrita Mukherjee1

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The Minimal Supersymmetric Standard Model (MSSM) can be extended to include non-holomorphic trilinear soft supersymmetry (SUSY) breaking interactions that may have distinct signatures. We consider non-vanishing off-diagonal entries of the coupling matrices associated with holomorphic (of MSSM) and non-holomorphic trilinear terms corresponding to sleptons with elements \( A^{ij}_l \) and \( A'^{ij}_l \). We first improve the MSSM charge breaking minima condition of the vacuum to include the off-diagonal entries \( A^{ij}_l \) (with \( i \neq j \)). We further extend this analysis for non-holomorphic trilinear interactions. No other sources of lepton flavor violation like that from charged slepton matrices are considered. We constrain the interaction terms via the experimental limits of processes like-charged leptons decaying with lepton flavor violation (LFV) and Higgs boson decaying to charged leptons with LFV. Apart from the leptonic decays we compute all the three neutral LFV Higgs boson decays of MSSM. We find that an analysis with non-vanishing \( A'_{e\mu} \) involving the first two generations of sleptons receives the dominant constraint from \( \mu \to e\gamma \). On the other hand, \( A'_{e\tau} \) or \( A'_{\mu\tau} \) can be constrained from the CMS 13 TeV analysis giving limits to the respective Yukawa couplings via
considering SM Higgs boson decaying into $e\tau$ or $\mu\tau$ final states. Contributions from $A_{ij}^l$ is too little to have any significance compared to the large effect from $A_{ij}^q$.

Secondary track (number):
Quark and Lepton Flavor Physics

Quark and Lepton Flavour Physics / 894

Lepton-flavor universality violations & their repercussions for IF & for EF

Author: Amarjit Soni

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In the past some years many indications of Lepton-flavor universality violations [LFUV] have emerged, here we’ll first voice some reservations for these. Assuming they stand further scrutiny a general theoretical framework will be used to analyze these. Then the consequences for the “Intensity Frontier (IF)” precision experiments and for the “Energy Frontier (EF)” collider experiments will be explored.

Secondary track (number):
03 Beyond the Standard Model

Operation, Performance and Upgrade of Present Detectors / 895

Status and Performance of the Belle II DAQ System

Authors: Oskar Hartbrich¹; Ryosuke Itoh²; Mikihiro Nakao³; Satoru Yamada⁴; Soh Suzuki⁵; Tomoyuki Konno⁶; Qidong Zhou⁷; Seokhee Park⁸; Chunhua Li⁹; Nils Braun¹⁰; Yinghui Guan¹¹; Markus Prim¹²; Björn Spruck¹³; Takuto Kunigo¹⁴; Simon Reiter¹⁵; Mikhail Remnev¹¹; Klemens Lautenbach¹⁶

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The Belle II DAQ system was completely overhauled as part of the detector upgrade from Belle. The raw detector event data is sent from the custom detector frontends through optical links to unified off-detector readout modules (COPPERs). The raw data of up to nine COPPERs is bundled in one readout server each, which forwards the data through a fully connected event builder switch to the High Level Trigger (HLT) and storage system. Apart from an online event selection, the HLT reconstruction is used to identify geometric regions of interest on the inner pixel detector which are then selectively read out and stored with the rest of the event data. As the COPPER system will be only marginally able to handle the Belle II data rate at full luminosity, a DAQ upgrade using PCIe40 cards to replace the COPPERs is under development.

This talk will present the latest running experiences and performance figures of the Belle II DAQ system, as well as the current status of the DAQ upgrade project.

Secondary track (number):

14

Diversity and Inclusion / 898

THE Port Humanitarian Hackathons at CERN for Diversity and Inclusion

Authors: Agnes Reka Jakab\textsuperscript{1}; Ines Knapper\textsuperscript{1}; Karolos Potamianos\textsuperscript{1}; Daniel Dobos\textsuperscript{2}; Benjamin Krikler\textsuperscript{3}

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Humanitarian and social challenges from the United Nations, Red Cross and Non Governmental Organisations meet HEP expertise at CERN for impactful innovation. THE Port association at CERN combines physicists and engineers working on HEP topics in their day job with researchers, refugees, entrepreneurs, artists, designers, humanitarian workers and other creative minds. In 60-hour hackathons they co-create prototypes, identify new methods, materials and processes, that can solve real-world problems of the humanitarian sector, and which sometimes even feed back into HEP. Examples of the last years of humanitarian hackathons at CERN, the first THE Port & InAct hackathon in India, their outcomes now utilised by UN, ICRC, UNITAR and others are presented. Future initiatives for HEP impact on society are discussed.

Secondary track (number):

(17)

Astro-particle Physics and Cosmology - Posters / 899

Search for Neutrino Events Associated with Gravitational Wave at Daya Bay

Author: Wei Wang\textsuperscript{1}

\textsuperscript{1} Sun Yat-Sen University
Corresponding Author: wangw223@mail.sysu.edu.cn

Several gravitational-wave (GW) events have been observed by the Advanced LIGO and Virgo detectors. Providing a connection between neutrino emission and GW bursts is obviously important for understanding the underlying physical processes associated with GW creation. The Daya Bay Reactor Neutrino Experiment is designed for measuring the neutrino mixing angle \( \theta_{13} \) using reactor antineutrinos at the Daya Bay Power Plant in South China. It has 8 antineutrino detectors with identical design positioned at multiple baselines that help in suppressing incoherent cosmogenic backgrounds and detector-related noises. During the years since the discovery of the first GW signal, Daya Bay has been running continuously and smoothly. In this poster, we will present the latest results of a search for electron anti-neutrino signals in coincidence with the detected GW events.

Secondary track (number):

Neutrino Physics - Posters / 900

Study of Reactor Fuel Evolution and Decomposition of Isotope Contributions

Author: Wei Wang

\(^{1}\) Sun Yat-Sen University

Corresponding Author: wangw223@mail.sysu.edu.cn

The Daya Bay Reactor Neutrino Experiment is designed to measure the smallest neutrino mixing angle \( \theta_{13} \) and it has 8 functionally identical antineutrino detectors (AD), 4 located at two near sites and 4 in the far hall. Due to the high power of the Daya Bay reactors and over 100-t target mass, Daya Bay has collected unprecedented amount of statistics of reactor antineutrino events at various fuel burnups. This has provided a great opportunity for the study of the reactor fuel evolution, namely, the correlation between antineutrino rates and the fuel burnup. Furthermore, given the precise energy response of the ADs, better than 0.5\%, combined with the data of fuel isotopes during burnup provided by the reactor operator, we are also able to resolve the antineutrino spectra of the two dominant isotopes, 235U and 239Pu. These two studies could provide important insights to the origin of the reactor antineutrino anomaly (RAA) and validity of the calculation of the reactor antineutrino fluxes and spectra of different fuel isotopes. In this poster, we will present the latest results from the fuel evolution and isotope decomposition studies.

Secondary track (number):

Dark Matter Detection / 901

Carbon nanostructures for directional light dark matter detection

Authors: Francesco Pandolfi\(^{1}\); Chris Tully\(^{2}\); Gianluca Cavoto\(^{3}\); Fang Zhao\(^{\text{None}}\); Alessandro Ruocco\(^{4}\)

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Carbon nanostructures offer exciting new possibilities in the detection of light dark matter. A dark matter particle with mass between 1 MeV and 1 GeV scattering off an electron in the Carbon lattice would transfer sufficient energy to eject the electron from the surface. In aligned Carbon nanotubes the ejected electron travels along the tube axis without being reabsorbed, and exits the carbon target, where it is accelerated by an external electric field, and detected by a single-electron detector. We report on the latest results in the development of a prototype based on this concept built at the University of Rome Sapienza and INFN Roma in the framework of the PTOLEMY collaboration. This same concept is applied to the field of UV light detection, in which detectors with photocathodes made of aligned nanotubes have the potential of drastically reducing photoelectron reabsorption, which is the leading cause of inefficiency in modern UV light detectors.

I read the instructions:

Secondary track (number):

Astro-particle Physics and Cosmology / 902

Primordial black hole dark matter and ways to find it

Author: Volodymyr Takhistov

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Primordial black holes (PBHs) constitute an attractive candidate for dark matter. I will describe a new generic mechanism for PBH formation from fragmentation of scalar fields. Then, I will revisit PBH formation from vacuum bubbles during inflation and show how resulting broad PBH mass-spectrum can simultaneously account for dark matter, reported HSC candidate, LIGO events as well as seeds of supermassive black holes. Finally, I will discuss how interactions with compact stars can shed light on small PBHs of "sublunar" mass that can compose all of the dark matter.

I read the instructions:

Secondary track (number):

Top Quark and Electroweak Physics - Posters / 903

Extraction of CKM matrix elements in the single-top t-channel events at 13 TeV with CMS

Author: Agostino De Iorio

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The dominant electroweak production mechanism for single top quarks is the $t$-channel and, it features a $tWq$ vertex, where $q$ stands for b, s, or d quarks, both in production and in decay. For this reason its cross section and branching fractions are sensitive to the strength of the electroweak coupling, making it a suitable channel for direct measurements of the magnitude of Cabibbo-Kobayashi-Maskawa matrix elements $|V_{tb}|$, $|V_{ts}|$, and $|V_{td}|$. A precise determination of the magnitude of these parameters of the Standard Model allows to search for hints of potential contributions from new physics beyond the Standard Model. This poster presents the first direct measurement of the Cabibbo-Kobayashi-Maskawa matrix elements $|V_{tb}|$, $|V_{ts}|$, and $|V_{td}|$, making use of single top quark $t$-channel events in proton-proton collision data with a centre-of-mass energy of 13 TeV, collected with the CMS experiment at the LHC. The subset of data analysed corresponds to an integrated luminosity of 35.89 fb$^{-1}$.
Diversity and Inclusion / 905

Diversity and Inclusion in the CMS collaboration

Author: Bo Jayatilaka

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The CMS collaboration, one of the largest collaborations in high-energy physics, formed a Diversity Office (DO) under a mandate from its collaboration board in 2017. We present here the efforts of the CMS DO in fulfilling its mandate to improve diversity and inclusion (D&I) within the CMS Collaboration. These efforts include tracking and analyzing statistics about CMS demographics, implementing a code of conduct, raising awareness about D&I matters within the collaboration, and facilitating outreach and communication outside of the collaboration about D&I.

Automated selection of particle-jet features for data analysis in High Energy Physics experiments

Authors: Andrea Di Luca¹; Francesco Maria Follega¹; Marco Cristoforetti²; Roberto Iuppa¹

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In high-energy physics experiments, the sensitivity of selection-based analyses critically depends on which observable quantities are taken into consideration and which ones are discarded as considered least important. In this process, scientists are usually guided by their cultural background and by literature.

Yet simple and powerful, this approach may be sub-optimal when machine learning strategies are envisaged and potentially all features are usable. On the other hand, training multivariate algorithms with all available features is often impossible, due to lack of calibration or computing power limitations. How to robustly choose the set of observables to use in a modern high-energy physics analysis?

We show here that it is possible to rank the relative importance of all available features in an automated fashion by engineering a fast and powerful classification model. Features are sorted with the Random Forest algorithm, then selected as input quantities for a Deep Learning Neural Network. We make it explicit the relation between Random Forest importance ranking and signal-to-background ratio increase, varying the number of features to feed the Neural Network with. We benchmark our procedure with the case of highly boosted di-jet resonances decaying to two b-quarks, to be selected against an overwhelming QCD background. Promising results from Monte Carlo simulation with HEP pseudo-detectors are shown.
Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 907

The Outer Detector (OD) system for Hyper-Kamiokande experiment

Author: Stephane Zsoldos

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Hyper-Kamiokande, scheduled to begin construction as soon as 2020, is a next generation underground water Cherenkov detector, based on the highly successful Super-Kamiokande experiment. It will serve as a far detector, 295-km away, of a long baseline neutrino experiment for the upgraded J-PARC beam in Japan. It will also be a detector capable of observing — far beyond the sensitivity of the Super-Kamiokande detector — proton decay, atmospheric neutrinos, and neutrinos from astronomical sources.

An Outer Detector (OD) consisting of PMTs mounted behind the inner detector PMTs and facing outwards to view the outer shell of the cylindrical tank, would provide topological information to identify interactions originating from particles outside the inner detector. Any optimization would lead to a significant improvement for the physics goals of the experiment, which are the measurement of the CP leptonic phase and the determination of the neutrino mass hierarchy.

An original setup using small 3” PMTs is being designed for the Hyper-Kamiokande OD. They would give better redundancy, spatial, and angular resolution, as they would be twice or three times more photosensors than the original 8” design proposal of the experiment, and for a reduce cost. Several 3” PMTs candidates considered for the Hyper-Kamiokande OD have been characterized for this study. They all show a very low dark counts and good collection efficiency, which makes them excellent choice to be used in the experiment.

In this talk/poster I will introduce the Hyper-K experiment with an emphasis on its sub-detector system. Then, I will show the expected performance of the system using a large array of 3” PMTs that performs better than the previous 8” design. The improvements on event selection with this new design will be discussed and how it affects the mass hierarchy sensitivity.

I read the instructions:

Secondary track (number):
2

Neutrino Physics / 908

Neutrino Portals to Dark Matter

Author: Salvador Rosauro Alcaraz

Co-authors: Enrique Fernandez Martinez ; Mattias Blennow ; Silvia Pascoli ; Arsenii Titov ; Andres Olivares

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3 University of Durham (GB)
We explore the possibility that dark matter interactions with Standard Model particles are dominated by interactions with neutrinos. We examine whether it is possible to construct such a scenario in a gauge invariant manner. We first study the coupling of dark matter to the full lepton doublet and confirm that this generally leads to the dark matter phenomenology being dominated by interactions with charged leptons. We then explore two different implementations of the neutrino portal in which neutrinos mix with a Standard Model singlet fermion that interacts directly with dark matter through either a scalar or vector mediator. In the latter cases we find that the neutrino interactions can dominate the dark matter phenomenology. Present neutrino detectors can probe dark matter annihilations into neutrinos and already set the strongest constraints on these realisations. Future experiments such as Hyper-Kamiokande, MEMPHYS, DUNE, or DARWIN could allow to probe dark matter-neutrino cross sections down to the value required to obtain the correct thermal relic abundance.

Secondary track (number):

**Education and Outreach / 909**

**Transforming the CMS Experiment site into a family village during CERN Open Days 2019**

Author: Marzena Lapka

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The Large Hadron Collider and its detectors are currently stopped and are benefitting from upgrade and renovation work. This period, called the “long shutdown”, has started at the end of 2018 and will end in May 2021. This maintenance break is an exceptional opportunity to open CERN’s facilities to the public allowing curious minds to discover groundbreaking technologies, have fun with physics and meet the people who work at the cutting edge of science and technology. This culminated in a big Open Days event hosted by CERN on 14-15 September 2019. On that occasion CMS welcomed more than 8,000 visitors on the experiment site, both underground and on the surface, transforming the LHC Point 5 into a cheerful family village.

We will present the variety of activities we offered during the CERN Open Days, that included taking a walk in the cathedral-sized cavern that houses the CMS detector, answering public’s questions on what it is like to work at the CMS experiment and what do we learn from CMS, as well as testing young public’s imagination by building CMS with Kapla wooden blocks and Lego bricks. All this was a truly collaborative effort; around 300 volunteers from various teams worked very hard to make sure that everyone is satisfied and profits the most of this event.

I read the instructions:

Secondary track (number):

**Quark and Lepton Flavour Physics / 910**

**Lepton flavor violating Z decays at future $e^+e^-$ colliders**

Author: Joydeep Roy
Flavor violation is an established fact for the quark sector of the Standard Model (SM) as it is for the neutral sector of leptons. But in charged sector this phenomenon has not been observed yet. We shall study the lepton flavor violation (LFV) processes from $Z$ boson decays (LFVZD), $Z \rightarrow l_i l_j$. For this we shall extend the SM with higher-dimensional gauge-invariant operators involving SM fields only and find how the corresponding Wilson coefficients effect the limit on LFV $Z$ decays. We will also comment on the prospect of such $Z$ decays at future $e^+e^-$ colliders.

### Latest results on rare kaon decays from the NA48/2 experiment at CERN

**Author:** Mauro Raggi

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The NA48/2 experiment at CERN reports the first observation of the $K^\pm \rightarrow \pi^\pm \pi^0 e^+ e^-$ decay from an exposure of $1.7 \times 10^4$ charged kaon decays recorded in 2003–2004. A sample of 4919 candidates with 4.9% background contamination allows the determination of the branching ratio in the full kinematic region. The study of the kinematic space shows evidence for a structure dependent contribution in agreement with predictions based on chiral perturbation theory. Several P- and CP-violating asymmetries are also evaluated.

The most precise measurement of the charged kaon semi-leptonic form factors obtained by NA48/2 with 4.4 million $Ke^3$ and 2.3 million $K\mu^3$ events collected in 2004 will also be presented.

### Resonant Extraction and Extinction Measurement for the Mu2e Experiment

**Author:** Timothy Matthew Jones

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The Mu2e experiment, currently under construction at Fermilab, will search for coherent neutrino-less muon to electron conversion, extending the sensitivity of searches for charged lepton flavor violation by four orders of magnitude in 3-5 years of data-taking. This improved sensitivity is made possible by using a pulsed beam structure that is optimized for reducing prompt backgrounds when muons are stopped on an aluminum target. Producing a high-rate pulsed beam is achieved using
resonant extraction of a circulating proton beam, an “AC dipole” with a time-varying field to deflect out-of-time protons, and a system to measure the extinction of out-of-time beam particles incident on the muon production target. This talk summarizes the systems that have been designed to achieve the required level of extinction and to continuously place limits on the presence of out-of-time beam hitting the production target with a sensitivity of <1e-10.

Secondary track (number):
03

Accelerator: Physics, Performance, and R&D for Future Facilities / 916

Future prospective for bent crystals in accelerators

Author: Marco Romagnoni

Co-authors: Alessandro Berra; Alexei Sytov; Andrea Mazzolari; Claudia Brizzolari; Claudia Durighello; Davide De Salvador; Enrico Bagli; Gianluca Cavoto; Giovanni Balerini; Laura Bandiera; Mattia Soldani; Michela Prest; Nicola Neri; Sara Carturan; Tais Maiolino; Valerio Mascagna; Victor Tikhomirov; Viktar Haurylavets; Vincenzo Guidi

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4 Università di Padova
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7 Università degli Studi dell’Insurbia & INFN Milano Bicocca
8 Università degli Studi e INFN Milano (IT)
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Bent crystals are a powerful mean for ultrarelativistic particles steering, achieving deflection equivalent to hundreds-tesla magnetic dipole in compact and zero-energy consumption devices. Currently, bent crystals are a candidate for the upgrade of LHC ion collimation. Novel experimental setups are being proposed, especially in the field of spin precession. Indeed, the unparalleled steering power of crystals enables magnetic and electric dipole moment studies on fast decaying particles like charmed baryons. Axial phenomena such as stochastic deflection and new materials such as Ge are also being tested as innovative solutions for future hadronic and leptonic accelerators (FCC, ILC and muon colliders). In the laboratories of the University of Ferrara and INFN, several prototypes for such applications have been developed. Design of bending mechanisms and fabrication process for samples are described, as well as curvature and lattice quality measurements. Finally, results are presented regarding testbeams performed at H8 and H4 extracted beamline of SPS at CERN, where steering performances are tested on 180 GeV/c π⁺ and 120 GeV/c e± beams.

I read the instructions:

Secondary track (number):
ARCADIA: innovative low-power, large area MAPS for HEP and applied science

Author: Piero Giubilato

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Recent advancements in Monolithic Active Pixel Sensors (MAPS) demonstrated the ability to survive in radiation environments characterized by TID levels up to many thousands of Grays, that increases their appeal as sensors for high-energy physics detectors. The most recent example in such application is the new ALICE Inner Tracking System, entirely instrumented with CMOS MAPS, that covers an area of about 10 m².

However, the true potentiality of such devices have not yet been realized, especially in respect to the size of the active area, power consumption, and the timing capabilities (fast signal acquisition). The ARCADIA experiment is developing MAPS characterized by an innovative sensor design, that uses a proprietary processing of the back side to improve the charge collection efficiency and timing over a wide range of operational (hit rate density) and environmental (radiation levels) conditions. Together with the innovative sensor design, ARCADIA is targeting very low power consumption levels, of the order of 20 mW cm⁻² at 100 MHz cm⁻² hit flux, to enable air-cooled operations of the sensors. Another key design parameter is the ability to further reduce the power regime of the sensor, down to 5 mW cm⁻² or better, for low hit density applications like the airborne and space ones. Maximizing the active area of the single sensor (10 cm² or bigger) simplifies and reduces the costs of detector construction, and even enables applications where no support material over the entire sensor area can be tolerated (e.g. medical scanners). ARCADIA has established innovative architectures to deal with "large" sensors, where the typical pixel column can reach many centimetres in length, with many thousands of pixels to read.

In this contribution, we will discuss the sensor design, characteristics, and testing results. Together with a detailed description of the chip characteristics and implementation, the highlight will be on the key features departing respect to the present state-of-the-art MAPS design. An overview of the synergies with other applications outside the HEP realm will also be given in order to illustrate how the next generation pixel sensors may come from fruitful collaboration with other fields in physics and science in general.

Secondary track (number):
17

Electroweak monopoles and their cosmological implications

Author: Archil Kobakhidze

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We describe electroweak monopoles within the Born-Infeld extension of (2) × (1) electroweak theory. We argue for topological stability of these monopoles and computed their mass in terms of the Born-Infeld mass parameters. We then propose a new mechanism for electroweak baryogenesis which takes advantage of the following salient features of the electroweak monopoles: (i) monopoles...
support extra CP violation in the topological sector of the electroweak theory; (ii) they mediate un-suppressed baryon number violating interactions; (iii) non-thermal production of monopoles during the electroweak phase transitions generates departure from thermal equilibrium. We demonstrate that the observed baryon asymmetry of the universe can be explained in our theory in the presence of electroweak monopoles of mass $10^4$ TeV.

Secondary track (number):

Dark Matter Detection / 919

The DARWIN experiment: the ultimate detector for direct dark matter search.

Author: Adriano Di Giovanni

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The DARWIN (DARk matter WImp search with liquid xenoN) experiment will be the ultimate ultra-low background underground detector for direct Dark Matter (DM) search. Its primary goal is to access the parameter space between the XENONnT maximal sensitivity and the so called "neutrino floor", where neutrino interactions with the target become an irreducible background for direct dark matter search detectors.

The unprecedented large xenon mass (about 40 tons of active target), the extremely low radioactive background and the low energy threshold will allow for a diverse science program (i.e. neutrino-less double beta decay) beyond the DM search. The detector core is a 2.6 m diameter - 2.6 m high dual phase Time Projection Chamber (TPC) equipped with two arrays of sensor for light/charge collection of the prompt (S1) and proportional scintillation signals (S2) installed above (Gas phase) and below (Liquid phase) the liquid xenon target. The project status, current design along with science requirements and sensitivity will be presented in details. The DARWIN collaboration currently consists of more than 160 members from 26 institutions of 12 countries.

Secondary track (number):

Operation, Performance and Upgrade of Present Detectors - Posters / 920

Alignment Belle II silicon vertex detector

Author: Jakub Kandra

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Silicon vertex detector is located in center of Belle II detector to provide precise measurement of vertex position decayed particles. It is composed by the DEPFET pixel and DSSD strip sensors. This poster will present experiences with determination, validation and monitoring alignment parameters of vertex detector.

Secondary track (number):

14
Search for vector-like quarks ($T'$) with the CMS Detector.

Author: Arjun Chhetri
Co-authors: Brajesh Choudhary, Sushil Chauhan

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Vector like quarks (VLQs) are hypothetical spin-1/2 particles of the fourth generation that have left- and right-handed components. They are postulated to solve the hierarchy problem and stabilize the Higgs mass, while escaping constraints on the Higgs cross section measurement. The poster will present the current status of the search for VLQs ($T'$) decaying to a top quark and a Higgs boson at the CMS experiment at the LHC. We will also discuss how jet substructure techniques can be used to identify the decays of top quarks and the Higgs bosons.

I read the instructions:

Secondary track (number): 01

Charged gravitational instantons: extra CP violation and charge quantisation in the Standard Model

Authors: Archil Kobakhidze, Suntharan Arunasalam

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We argue that quantum electrodynamics combined with quantum gravity results in a new source of CP violation, anomalous non-conservation of chiral charge and quantisation of electric charge. Further phenomenological and cosmological implications of this observation are briefly discussed within the standard model of particle physics and cosmology.

Secondary track (number):

The Data Driven Flavour Model

Author: Luca Merlo

1 Universidad Autonoma de Madrid
A bottom-up approach has been adopted to identify a flavour model that agrees with present experimental measurements. The charged fermion mass hierarchies suggest that only the top Yukawa term should be present at the renormalizable level. The flavour symmetry of the Lagrangian including the fermionic kinetic terms and only the top Yukawa is then a combination of U(2) and U(3) factors. Lighter charged fermion and active neutrino masses and quark and lepton mixings arise considering specific spurion fields. The associated phenomenology is investigated and the model turns out to have almost the same flavour protection of the Minimal Flavour Violation, in both quark and lepton sectors. Promoting the spurions to be dynamical fields, the associated scalar potential is also studied and a minimum is identified such that fermion masses and mixings are correctly reproduced.

I read the instructions:

Secondary track (number):
03

Heavy Ions / 924

Coherent photoproduction of $J/\psi$ in nucleus-nucleus collisions in the color dipole approach

Authors: Agnieszka Łuszczak$^1$; Wolfgang Schaefer$^2$

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We investigate the exclusive photoproduction of $J/\psi$-mesons in ultraperipheral heavy ion collisions in the color dipole approach.

We first test a number of dipole cross sections fitted to inclusive $F_2$-data against the total cross section of exclusive $J/\psi$-production on the free nucleon.

We then use the color-dipole formulation of Glauber-Gribov theory to calculate the diffractive amplitude on the nuclear target.

The real part of the free nucleon amplitude is taken into account consistent with the rules of Glauber theory.

We compare our results to recent published and preliminary data on exclusive $J/\psi$ production in ultraperipheral lead-lead collisions at $\sqrt{s_{NN}} = 2.76$ TeV and $\sqrt{s_{NN}} = 5.02$ TeV.

Especially at high $\gamma A$ energies there is room for additional shadowing corrections, corresponding to triple-Pomeron terms or shadowing from large mass diffraction.

It is based on publication Phys.Rev. C99 (2019) no.4, 044905.

Secondary track (number):

Neutrino Physics / 925

Neutrino physics with the PTOLEMY project

Author: Stefano Gariazzo$^1$
In this talk I will review the possibilities for the PTOLEMY experiment to study neutrino physics under different points of view. The main scope of the experiment is to obtain the first direct detection of the cosmic neutrino background, which however is an extremely challenging task. I will discuss how the experimental energy resolution and the amount of tritium inside the detector affect the detection possibilities, depending on the true value of the lightest neutrino mass and on the clustering of relic neutrinos in the local dark matter halo.

I will also show that a small prototype of PTOLEMY with a reduced amount of tritium can reach interesting results, in particular it may be able to constrain and possibly determine the absolute scale of the neutrino mass with more precision than current experiments.

Secondary track (number):

08

Beyond the Standard Model / 927

An extensive study of dark matter and neutrino phenomenology in the Triplet + Singlet Scotogenic Model

Author: Ivania Maturana

Co-authors: Valentina De Romeri; Jose Valle; Laura Duarte

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In this talk, I will address the possibility that the nature of dark matter is associated with neutrino mass generation. Focusing on an extension of the Standard Model where the light neutrino masses are generated radiatively, we study the properties of a dark matter candidate which is made stable by the same symmetry responsible for the radiative origin of neutrino masses. Also, the model studied proposes a dark matter candidate that could be both a neutral scalar or a fermion. I will discuss the phenomenology of both scenarios, studying the parameter space which allows to reproduce the observed dark matter abundance. I will also comment on the expected signals in direct detection experiments, via indirect detection probes and at colliders.

Secondary track (number):

Strong Interactions and Hadron Physics - Posters / 928

Hard exclusive $\pi^0$ muoproduction cross-section at COMPASS experiment

Author: Marketa Peskova

1 Charles University (CZ)
Investigation of GPDs and TMDs represents one of the major goals of the COMPASS-II program. Together, GPDs and TMDs provide the most complete description of the partonic structure of a nucleon. GPDs can be accessed by lepton-induced exclusive scattering processes, such as Deep Virtual Compton Scattering or Hard Exclusive Meson Production. The exclusive $\pi^0$ production is the main source of background for the DVCS, and it provides complementary information on GPD parametrization. The dedicated GPD program started with a pilot run in 2012, followed by data taking in 2016-2017, using 160 GeV/$c$ muon beam and a liquid hydrogen target, equipped by a recoil proton detector. We will present the first measurement from 2012 of the exclusive $\pi^0$ cross section and its $\phi$ and $|t|$-dependence in the $x_B$ domain from 0.01 to 0.15. These results will be compared with the phenomenological Goloskokov-Kroll model. Prospect will be given on upcoming results of the 2016-17 measurement.

Central exclusive and diffractive physics measurements at CMS and TOTEM

**Author:** Oliver Suranyi

$^1$ Eötvös Loránd University

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Exclusive and diffractive physics measurements are important for better understanding of the non-perturbative regime of QCD. Recent results of the CMS and TOTEM experiments are presented in this talk. The total and differential cross sections of central exclusive $\pi^+\pi^-$ production are measured at 5.02 and 13 TeV in the $p_T(\pi) > 0.2$ GeV and $|\eta(\pi)| < 2.4$ kinematic region. The invariant mass distribution is fitted by the sum of a continuum and four interfering relativistic Breit-Wigner functions. In the second part of the talk the measurement of the single diffractive dijets is presented, which are studied by using proton tagging capabilities of the TOTEM Roman Pot detectors. The total and differential cross sections are measured in the $0.03 < |t| < 1.0$ GeV$^2$ and $0 < x_i < 0.1$ kinematic region.

Jet substructure and boosted jet measurements at CMS

**Author:** Deniz Sunar Cerci

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Results on measurements involving jet substructure and boosted jets at CMS are reviewed here.
Flavourful Inert Doublet Dark Matter

Author: Lopamudra Mukherjee

Co-authors: Debasish Borah; Soumitra Nandi; Basabendu Barman

1 Indian Institute of Technology Guwahati
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In this talk I will elaborate on two of the most intriguing puzzles of the Universe, viz. the dark puzzle and the flavour anomaly puzzle, and try to correlate them by considering an extension of the Inert Higgs doublet model with SU(2)_L singlet vector like fermions. This model is capable of addressing some interesting anomalous results in b → sll decays (like R(K), R(K))) and in muon (g − 2) and also satisfies relevant constraints in the dark matter sector, while remaining within the reach of ongoing direct detection experiments. I will also show the discovery possibilities of such exotics in the future high luminosity (HL) runs of the LHC. The model also has the potential to explain the anomaly in R(D), R(D)) and the recent KOTO anomaly.

Performance and background expectations of the Belle II pixel vertex detector at SuperKEKB

Author: Slavomira Stefkova

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The Belle II experiment aims to collect 50 ab⁻¹ of e⁺e⁻ collision data at the SuperKEKB collider in Japan. The first collisions with the full Belle II detector were recorded in Spring 2019. Excellent performance of the innermost pixel vertex detector (PXD) is crucial for many high profile B-decay measurements, namely those which rely heavily on precise knowledge of decay vertices. Therefore, PXD performance parameters, such as the intrinsic resolution and hit efficiency, are being monitored continuously throughout data taking. As SuperKEKB approaches its design luminosity, Belle II will have to cope with significantly higher backgrounds. Understanding the composition and spatial dependence of the different background sources provides indispensable information for possible background mitigation. The comparison of dedicated measurements with the corresponding simulations allows for projecting background levels to design luminosity, which tests the PXD readiness for the runs to come.
**On the need of a “CERN for analogs”**

**Author:** Alfredo Iorio

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I shall present scientific/epistemological, as well as practical arguments in favor of a facility where to explore, with analogs, otherwise unreachable territories of the theoretical landscapes. In this facility, theorists (both of the HEP-TH and of the COND-MAT types) should sit next to experimentalists (mostly of the COND-MAT type). I shall call this facility HELIOS, an evocative name for something that should shed light on the darkness of the unknown, and an acronym for "High Energy Laboratory for Indirect Observations".

I read the instructions:

Secondary track (number):

**Strong Interactions and Hadron Physics / 935**

**On dispersive representation of kaon and eta decays to 3 pions**

**Author:** Martin Zdrahal

**Co-authors:** Marc KNECHT; Novotny Jiri; Karol Kampf

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We present and develop a general dispersive framework allowing to construct representations of the amplitudes for the processes $P\pi\rightarrow\pi\pi$, $P=K,\eta$, valid at the two-loop level in the low-energy expansion. The construction proceeds through a two-step iteration, starting from the tree-level amplitudes and their S and P partial-wave projections. The one-loop amplitudes are obtained for all possible configurations of pion masses. The second iteration is presented in detail in the cases where either all masses of charged and neutral pions are equal, or for the decay into three neutral pions. Issues related to analyticity properties of the amplitudes and of their lowest partial-wave projections are given particular attention. This study is introduced by a brief survey of the situation, for both experimental and theoretical aspects, of the decay modes into three pions of charged and neutral kaons and of the eta meson.

Secondary track (number):

**Heavy Ions - Posters / 936**

**Monte Carlo simulations of Upsilon meson production**

**Author:** Jakub Ceska

**Co-authors:** Leszek Koszarowski; Miroslav Myska; Jaroslav Bielcik

Page 411
Quarkonia are an important probe into studying the properties of quark-gluon plasma. Proton-proton collisions serve as an essential baseline for studying the effects of quarkonia in proton-nucleon and nucleon-nucleon collisions. This poster presents the main characteristics of Upsilon mesons from Monte Carlo generation of proton-proton collisions at $\sqrt{s_{NN}} = 500$ GeV. Monte Carlo event generators PYTHIA and Herwig were used to generate the data. Main aim of the simulations is to explore the dependence of normalised Upsilon meson yield on normalised event multiplicity. Normalised multiplicity dependence is a meaningful tool for understanding the particle production mechanisms and the interplay between soft and hard QCD processes.

**Secondary track (number):**

**Dark Matter Detection / 937**

**Latest results from XENON1T and a glimpse into the future with the XENONnT experiment**

**Author:** Alexey Elykov\(^1\)

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The xenon-based multi-ton-scale dark matter detectors XENON1T and XENONnT, are the latest in the XENON experiment series at the Laboratori Nazionali del Gran Sasso. XENON1T which operated from 2016 to 2018 was the largest liquid-xenon time projection chamber to date. With a fiducial mass of 1.3 ton and a ton year exposure, its data allowed us to place the most stringent limits on spin-independent WIMP interactions and to explore a multitude of other scientific channels. The successor to XENON1T is the upcoming XENONnT detector, which will start taking data in summer 2020. With a target mass of approximately 6 ton and a projected exposure of 20-ton years, XENONnT will allow us to probe new parameter spaces of potential dark matter candidates and search for long-sought-after decay processes. In this talk, the latest results from XENON1T will be presented as well as the latest developments and prospects of the XENONnT detector.

**Secondary track (number):**

**Formal Theory / 938**

**Scalar-Vector Effective Field Theories from Soft Limits**

**Authors:** Preucil Filip\(^1\); Novotny Jiri\(^1\); Trnka Jaroslav\(^1\); Karol Kampf\(^2\)

\(^1\) Charles University

\(^2\) Charles University (CZ)
We study a bottom-up construction of effective field theories of spin-0 and spin-1 massless particles using the infrared structure of scattering amplitudes. We try to employ previously discovered two distinct probes of soft kinematics: multiple chiral soft limits for vectors and enhanced single soft limits for scalars.

**Diversity and Inclusion / 939**

**LGBTQ+ Inclusivity in High Energy Physics**

**Author:** Flavia De Almeida Dias

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Embracing diversity in all its facets is key to doing good science. Building a career in physics is not just about doing your office work. It also includes cooperation with colleagues, networking, travelling to research conferences and collaboration meetings. The LGBTQ community faces concerns, extra burdens and impediments which make it difficult to explore the Universe without limits and fear.

The LGBTQ CERN group is a CERN-recognized Informal Network seeking to provide a welcoming space for lesbian, gay, bisexual, trans*, intersex, asexual, genderqueer and other LGBTQ individuals at CERN, also welcoming friends and allies. This talk will focus on the experiences of the LGBTQ CERN members in their careers in High Energy Physics, talk about the group’s outreach activities to the LGBTQ community and the broader CERN community, and discuss which concrete steps can be taken to create a safe, inclusive and supportive scientific work environment.

**Computing and Data Handling / 940**

**Hello RNTuple and friends: what the new ROOT means for your analysis**

**Author:** Axel Naumann

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**Corresponding Author:** axel.naumann@cern.ch

ROOT is one of HEP’s most senior active software projects; virtually every physicist uses it, and its TTree is the backbone of HEP data. But ROOT can do even better - and it’s getting there, step by step. It now features RDataFrame, a new, simple and super-fast way to write a data analysis. Soon TTree will have a successor, RNTuple, allowing for even faster data processing. Graphics will become web-based, sleek, and right-by-default. Python interfaces are promoted to become a first class citizen, and even histograms will see a new generation with more obvious, simpler interfaces and higher speed. This presentation will feature a sneak preview for all of this - because we do this for you, and we want your comments to get it right, for the next 30 years.
Measurement of differential \(tt\) production cross sections for high-\(p_T\) top quarks with CMS at 13 TeV

**Author:** Ioannis Papakrivopoulos

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**Corresponding Author:** ioannis.papakrivopoulos@cern.ch

A measurement of the production cross section for high transverse momentum top quark pairs is reported. The data set was collected during 2016 with the CMS detector at the LHC from pp collisions at 13 TeV, and corresponds to an integrated luminosity of 35.9 fb\(^{-1}\). The measurement uses events where either both top quark candidates decay hadronically and are reconstructed as large-radius jets with \(pt>400\) GeV, or where one top quark decays hadronically and is identified as a single large-radius jet with \(pt>400\) GeV and the other top quark decays leptonically to a b jet, an electron or a muon, and a neutrino. The cross section is extracted differentially as a function of kinematic variables of the top quark or the top quark pair system. The results are presented at the particle level, within a region of phase space close to that of the experimental acceptance, and at the parton level, and are compared to various theoretical models. The measured differential cross sections are significantly lower in both decay channels in the phase space of interest, compared to the theory predictions, while the normalized differential cross sections are consistent between data and theory.

**Secondary track (number):**

Computing and Data Handling / 943

What the new RooFit can do for your analysis

**Author:** Stephan Hageboeck

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**Corresponding Author:** stephan.hageboeck@cern.ch

RooFit is a toolkit for statistical modelling and fitting, and together with RooStats it is used for measurements and statistical tests by most experiments in particle physics. Since one year, RooFit is being modernised. In this talk, improvements already released with ROOT will be discussed, such as faster data loading, vectorised computations and more standard-like interfaces. These allow for speeding up unbinned fits by several factors, and make RooFit easier to use from both C++ and python. Furthermore, an overview of features in development is given, such as a fast implementation of "HistFactory" computations, easier data loading, and the prospects for RooFit computations on GPUs.

**Secondary track (number):**

Astro-particle Physics and Cosmology - Posters / 944

Constraints on the origin of the UHECR dipole anisotropy outside the Galaxy

**Author:** Alena Bakalova

None
The dipole anisotropy of ultra-high energy cosmic rays above 8 EeV detected by the Pierre Auger Observatory indicates an extragalactic origin of these particles. However, both the direction and the amplitude of the dipole of cosmic rays outside our Galaxy might be different than the one observed on Earth due to the effects of the Galactic magnetic field. We present an analysis of effects of the Galactic magnetic field on arrival directions of cosmic rays using numerical simulations within the CRpropa3 package. Jansson-Farrar model of the Galactic magnetic field is used to propagate particles inside the Galaxy. We investigate possible directions and amplitudes of the dipole outside the Galaxy for different mass composition scenarios so that the final direction and amplitude on Earth is compatible with the measured dipole.

Beyond the Standard Model / 945

Deep Learning Versatility in New Physics Searches

Author: Miguel Crispim Romao

Co-authors: Nuno Castro ¹; Rute Costa Batalha Pedro ²; Tiago Vale ²

LIP

LIP Laboratorio de Instrumentacao e Fisica Experimental de Part

In this talk, we will talk about the application of Deep Learning models as a discriminant step to improve sensitivity at searches for new physics. Of particular interest, we will focus on the transferability of Deep Learning models, where a neural network trained to isolate a specific signal can still provide sensitivity when deriving upper limits on a different process. This is expanded to include a discussion on the versatility of Deep Learning models to provide enough sensitivity in cases where the signal present in the sample does not follow the assumptions of an analysis.

In addition, we will discuss if the inclusion of low-level features, for example Earth-Moving Distance calculated on detector information from reconstructed objects, can improve sensitivity on top of reconstructed event variables. This study opens the way to use Deep Learning as a tool to connect different physical observables and guide the study of creating new observables.

Beyond the Standard Model / 947

Probing CP-violation in photon-photon interactions

Authors: Gilad Perez¹; Inbar Savoray²; Marco Gorghetto²; Yotam Soreq³

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We are interested in probing CP Violation (CPV) in photon-photon interactions. Such interactions, effectively described by operators of the form $FFF\tilde{F}$, have yet to be directly constrained experimentally, and could point to new sources of CPV beyond the Standard Model (SM). One possible mediator of CP-violating photon-photon interactions could be the relaxion, which is theoretically motivated within a dynamical solution to the Hierarchy problem, and is expected to interact with the SM both through axion-like and scalar Higgs-portal couplings. We propose a method for isolating CP-violating non-linear electrodynamics using Superconducting Radiofrequency (SRF) cavities, thus eliminating the main SM background, related to the CP-conserving Euler-Heisenberg Lagrangian.

Secondary track (number):

Astro-particle Physics and Cosmology / 948

Post-Inflationary Production Of Light Dark Sector

Author: Anish Ghoshal

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Light dark sector particles, especially bosons if coupled to the inflaton can be copiously produced during the (p)reheating epoch courtesy to Bose enhancement. In many particle physics scenarios such light particles are often invoked to resolve tensions with cosmological bounds from Big Bang Nucleosynthesis (BBN), Cosmic Microwave Background (CMB) and Large Scale Structure (LSS). We will discuss two specific cases - one involving bosonic mediators with light sterile neutrinos invoked in context to several neutrino experimental anomalies and one in context to non-thermal production of dark matter. We will discuss the post-inflationary particle production in a large field inflationary model and highlight the region of the parameter space viable with early universe cosmology.

Secondary track (number):

03.

Beyond the Standard Model - Posters / 949

Infinite Derivative Field Theory: Stability, Asymptotic Safety, Trans-Planckian Scattering, Dark Matter, Inflation & LHC

Author: Anish Ghoshal

$L$

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Motivated by the stringy effects by modifying the local kinetic term of the Higgs field by the Gaussian kinetic term we show that the Higgs field does not possess any instability, the Yukawa coupling between the scalar and the fermion, the gauge coupling, and the self interaction of the Higgs yields exponentially suppressed running at high energies, showing that such class of theory never suffers
from vacuum instability. We discuss the scale invariance achieved in the model beyond the scale of non-locality. We also show the dimensional transmutation in Trans-Planckian scattering. We will also discuss Dark Matter and Inflationary Aspects of the model and finally conclude with LHC bounds.

Secondary track (number):
10.

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 950

The Radio Detector upgrade of the Pierre Auger Observatory

Authors: Sijbrand De Jong\textsuperscript{None}; for the Pierre Auger Collaboration\textsuperscript{None}

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Ultra-high-energy cosmic rays (UHECR), of energy \( > 10 \) EeV, arrive at the Earth regularly, but their sources, acceleration mechanisms, propagation through the universe, and particle composition remain mysteries. In addition, their interactions with the atmosphere show an unexpectedly high muon flux compared to simulations.

To address these issues, the Pierre Auger Observatory, a hybrid 3000 km\(^2\) ground based cosmic ray detector, is upgraded, notably adding a completely new detection layer to measure the radio frequency emission of extensive air showers.

Based on the Auger Engineering Radio Array and other radio arrays, the expected performance of this Radio Detector is similar in precision to existing ground array techniques and will provide novel measurements for inclined showers, complementary to the other techniques.

Design and production of the full 1660 station Radio Detector upgrade will be presented, as well as the expected reach in addressing the open questions in UHECR astroparticle physics.

Secondary track (number):
12 & 8

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 951

A Giant Radio Array for Neutrino Detection (GRAND)

Authors: Sijbrand De Jong\textsuperscript{None}; for the GRAND collaboration\textsuperscript{None}

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GRAND is a newly proposed series of radio arrays with a combined area of 200,000 km\(^2\), to be deployed in mountainous areas. Its primary goal is to measure cosmic ultra-high-energy tau-neutrinos (E\( > 1 \) EeV), through the interaction of this neutrino in rock and the decay of the tau-lepton in the atmosphere. This decay creates an air shower, whose properties can be inferred from the radio signal it creates. The huge area of GRAND makes it the most sensitive instrument proposed to date, ensured to measure neutrinos in all reasonable models of cosmic ray production and propagation. At the same time, GRAND will be a very versatile observatory with enormous exposure to ultra-high-energy cosmic rays and photons.

The talk will cover the scientific motivation, as well as the staged approach required in the R&D stages to get to a final design that will make the construction, deployment and operation of this vast detector affordable.
Many Body Perturbation Theory of energy levels, wavelengths, oscillator strengths, radiative rates and lifetimes of He-like Lithium

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In recent years, there have been extensive spectroscopic studies, both experimental and theoretical, of helium isoelectronic sequence. Such an analysis requires information for a wide range of atomic parameters, including energy levels, wavelengths, oscillator strengths, radiative rates and lifetimes. Our aim was to provide a set of accurate energy levels, wavelengths, oscillator strengths, radiative rates and lifetimes for helium-like ions. Accurate energy levels calculations among the lowest 71 levels arising of \(1s^2\) and \(1snl\) \((n \leq 6, l \leq (n-1))\) configurations of He-like lithium are carried out through the standard relativistic configuration interaction \((RCI)\) approach, the second-order many body perturbation theory \((MBPT)\) \(^1\). The calculation methods are derived by a modified self-consistent Dirac-Fock-Slater iteration. We have also considered relativistic effects by incorporating quantum electrodynamics (QED) and Breit corrections. We provide accurate calculations of energy levels, wavelengths, radiative rates and lifetimes of all types of transitions \((E_1, E_2, M_1\) and \(M_2\)) for He-like lithium. The use of the \(MBPT\) approach significantly improves the value of the energy levels. The maximum difference relative to the NIST data \(^2\) becomes 651 \(cm^{-1}\) while the majority of values of energy levels of \(RCI\) method are decreased by approximately 5000 \(cm^{-1}\). The average relative deviation don’t exceed 5\% for the three methods compared to the results from NIST. For the MBPT calculations we have \(-0.47 \pm 0.90\%\), for the RCI calculations we have \(2.62 \pm 1.70\%\) and for the standard FAC calculations we have \(3.13 \pm 1.60\%\). The present results are in good agreement with already published data in the literature (theoretical \(^3\) and experimental data). Several new energy levels were found out where no other theoretical or experimental results are available. We expect that our extensive calculations will be useful to experimentalists for identifying the fine-structure levels \(^4\).

**Beyond the Standard Model / 954**

**Probing Baryogenesis using Neutron-Anti-Neutron Oscillation**

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Neutron-Anti-neutron ($n\text{-}\bar{n}$) oscillation is a baryon number violating process that requires physics beyond the Standard model. Future experiments at ESS and DUNE aim to either discover $n\text{-}\bar{n}$ oscillation or to put more stringent constraints on the oscillation time. We study the impact of such a discovery on different baryogenesis scenarios in an effective field theory framework. We also study the implications of observing the mediators at the LHC and the possibility of falsifying some of the baryogenesis scenarios in the context of some simplified UV complete scenarios.

**Secondary track (number):**

05

**Accelerator: Physics, Performance, and R&D for Future Facilities / 955**

**Overview of the Path to 0.01% Theoretical Luminosity Precision for the FCC-ee and Its Possible Synergistic Effects for Other FCC Precision Theory Requirements**

**Authors:** Stanislaw Jadach; Wiesiek Placzek; Scott Yost; Bennie Ward

**Co-author:** Maciej Skrzypek

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To exploit properly the precision physics program at the FCC-ee, the theoretical precision tag on the respective luminosity will need to be improved from the 0.054 % (0.061%) results at LEP to 0.01%, where the former (latter) LEP result has (does not have) the pairs correction. We present an overview of the roads one may take to reach the required 0.01 % precision tag at the FCC-ee and we discuss possible synergistic effects of the walk along these roads for other FCC precision theory requirements.

I read the instructions:

Secondary track (number):

11

Elegance of fundamental laws of physics - outreach potential

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From Kepler to Einstein, Dirac and Weinberg (to name a few), most physicists believed that the ultimate explanation of the Universe must possess beauty. For some of them, beauty of the physical laws was as important as truth. Over the last few years, however, we hear more from dissenting voices fueled by the no new physics results at the LHC, which claim that we have been led astray by aesthetics. These claims range from constructive criticism to more or less open hostility towards particle physics. This situation calls for an assessment and a proper reaction. I will argue that beauty in physics is alive and well and offers a wonderful message that can be conveyed to the public. The topic was inspired by the discussions we had within IPPOG collaboration.

Heavy Ions / 958

Effects of initial state fluctuations on non-equilibrium phase transition on pp collisions at LHC energies

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Recent studies show that initial state fluctuations have important contributions to the collective medium form on small collisions systems at LHC energies. In general fluctuations of the initial state
should play an important role for small collision systems since in general, their effects increase as
the system size reduces. In this work, we present a study of the contribution of the initial state
fluctuations on the distribution of partons in the initial state for the high multiplicity events on pp
collisions showing that unlikely heavy-ion collisions their contribution leads to a non-equilibrium
phase transition.

Education and Outreach / 959

Global Cosmic

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Cosmic rays are a unique tool for introducing high-school students to particle physics concepts
and methods; their detection and study, with a variety of cosmic ray experiments in schools, is an
excellent way to acquaint them with the world of scientific research, motivate and inspire them.
Cosmic-ray experiments in schools, using a variety of detector types and sizes, exist in many coun-
tries, often as part of networks, and in some cases they also produce scientific results. In order to
better exploit the great potential of cosmic-ray experiments for particle physics outreach, IPPOG,
the International Particle Physics Outreach Group, started an effort to put such experiments under
a common umbrella; a workshop was organised in Rome in 2017 where a whole spectrum of cosmic-
ray related activities in schools were represented. Global cosmos – a working group of IPPOG –
follows up and reports during IPPOG meetings. Activities such as International Cosmic Day, organ-
ised by DESY and Cosmic Ray Week, organized by Quarknet are promoted and strongly encouraged
by IPPOG.

I read the instructions:

Secondary track (number):

Education and Outreach / 960

Current Status of International Particle Physics Masterclasses

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Until recently, the International Masterclasses (IMC) in Particle Physics have been based on hands-
on analysis of data from the four big LHC experiments. During the last years there has been a
spectacular broadening in the physics scope of particle physics masterclasses, now including mea-
surements with Belle II data, with data from neutrino experiments and a newly proposed masterclass
on searches for dark matter. In addition, a particle therapy masterclass has been developed, in or-
der to highlight some of the benefits for society from the technology developed for particle physics
research. In parallel to extending the physics scope, IPPOG is making efforts to extend the geo-
graphical reach of masterclasses, and it is encouraging to see new institutes and countries joining
Quark and Lepton Flavour Physics / 961

Lepton Flavor Violation and Dilepton Tails at the LHC

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Charged Lepton Flavor Violation (LFV) is a very clean probe of New Physics since it is forbidden in the Standard Model (SM). The observation of neutrino oscillation implies nonzero LFV rates, which however are highly suppressed by the smallness of neutrino masses. This makes LFV an appealing target of experimental searches, as its observation would unambiguously point to New Physics.

In this talk, I will discuss the constraints on LFV effective operators that can be derived from LHC data. I will show that semileptonic operators can be constrained by existing searches of $pp \rightarrow \ell_i \ell_j$ (with $i \neq j$) at high-$p_T$. I will explore the complementary of these constraints with the ones obtained from flavor-physics observables, by showing, in particular, that LHC data provides the most stringent limits on quark-flavor conserving operators. The relevance of these results for leptoquark models aiming to explain the $B$-physics anomalies will also be discussed.

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques - Posters / 962

Study of a MAPS detector prototype for the upgrade of the BESIII inner tracker

Author: Mingyi Dong
Co-authors: Chaoyue Qu; Xiaoxu Lu; Xingcheng Tian; Ye Wu; Hongyu Zhang; Jing Dong; Qun Ouyang; Xiaoyan Ma; Xiaoshan Jiang

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After running ten years, the inner drift chamber of the Beijing spectrometer III (BESIII) is suffering from the aging problems that lead to a performance degradation. As one of the prototype schemes of the BESIII inner chamber upgrade, a MAPS (monolithic active pixel sensor) detector prototype is under developed. The mass production and quality verification of the pixel detector ladders with low material budget and high chip position precision have been performed. The ladder consists of ten MIMOSA28 chips thinned to 50 μm, a flex cable and a carbon fiber support. In order to verify the design and quantify the performance of the ladders in terms of the spatial resolution, the detection efficiency, the gap between the neighboring chips and the material budget of the ladder, a detector prototype system, including five layer ladders, readout electronics and data acquisition was set up and tested with electron beam in DESY. The design of the prototype and the test results will be presented.

Quark and Lepton Flavour Physics / 963

Lepton flavour violation in hadron tau decays and $\ell$-$\tau$ conversion in nuclei

Author: Tomas Husek

Co-authors: Jorge Portoles; Kevin Monsalvez Pozo

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Within the framework of the Standard Model effective field theory, with operators up to dimension 6, we perform a model-independent analysis of the lepton-flavour-violating processes involving tau leptons. Namely, we study $\ell$-$\tau$ conversion in nuclei and hadronic tau decays. Based on available experimental limits, we establish bounds on the Wilson coefficients of the operators contributing to these processes. The related information from Belle II and foreseen future experiments can be easily incorporated in the resulting framework. Furthermore, motivated by the observed anomalies at LHCb and their possible explanation within the leptoquark framework, we study the most general leptoquark model, both in the scalar and vector sectors. The leptoquark couplings are constrained from the above-mentioned analysis.

Strong Interactions and Hadron Physics / 964

Radiative corrections for the decay $\Sigma^0 \rightarrow \Lambda e^+ e^-$

Author: Tomas Husek

Co-author: Stefan Leupold

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2 Uppsala University (S)
Electromagnetic form factors serve to explore the intrinsic structure of nucleons and their strangeness partners. With electron scattering at low energies the electromagnetic moments and radii of nucleons can be deduced. The corresponding experiments for hyperons are limited because of their unstable nature. Only for one process this turns to an advantage: the decay of the neutral Sigma hyperon to a Lambda hyperon and a real or virtual photon. Due to limited phase space the effects caused by the Sigma-to-Lambda transition form factors compete with the QED radiative corrections for the decay $\Sigma^0 \rightarrow \Lambda e^+e^-$. In this talk we address the complete set of the inclusive NLO QED corrections to the Dalitz plot, calculated beyond the soft-photon approximation, i.e., over the whole range of the Dalitz plot and with no restrictions on the energy of the radiative photon.

**Secondary track (number):**

**Heavy Ions / 965**

**Exploring the QCD phase diagram in the region of highest muB with HADES**

**Author:** Manuel Lorenz

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The exploration of the QCD phase diagram in the region of high net-baryon density has gained strong interest in recent years. Among the reasons for that are the observation of multi-messenger signals emitted by binary neutron star mergers and the quest for the existence of a first order phase transition to a deconfined and/or chirally restored phase another one. HADES is a second-generation fix-target experiment with large acceptance and high rate capability operated at the SIS18 synchrotron of GSI, Germany, recently a part of the physics program of the FAIR project (FAIR Phase-0). It allows investigation of rare probes like dielectrons or multi-strange baryons (rare at these beam energies) as well as multi-differential investigations of bulk observables. In this contribution we will present recent results on flow observables, strangeness production, event-by-event proton multiplicity fluctuations and dilepton emission. The results will be confronted to model predictions with emphasis on signatures, which allow the characterization of medium properties of the matter formed in the collision. The data has been obtained in two heavy-ion experiments, Au+Au at 1.23 AGeV and Ag+Ag at 1.56 AGeV. Also included in the in the talk will be results from elementary reactions addressing the electromagnetic properties of hadrons, the precise understanding of which is an important requisite for the interpretation of thermal dilepton radiation.

**I read the instructions:**

**Secondary track (number):**

**Beyond the Standard Model / 966**

**Uncovering hidden new physics patterns in jets using Bayesian probabilistic models**

**Authors:** Jernej Kamenik$^{None}$; Barry Dillon$^{None}$; Darius Faroughy$^{None}$

We apply techniques from Bayesian generative probabilistic modelling to discover hidden features in jet substructure observables. We show that our method is able to discriminate between different unknown short distance physical processes in events at the LHC. In particular, we use a mixed membership model known as Latent Dirichlet Allocation to model the main features appearing during jet
formation that are necessary for unsupervised jet or event classification tasks. We demonstrate the potential for discovering without supervision a hidden New Physics signature from a heavy W prime decay chain in multi-jet events. We also briefly discuss how both parametric and non-parametric Bayesian probability models can be used for clustering jets or modelling generic events at hadron colliders.

I read the instructions:

Secondary track (number):

14

Strong Interactions and Hadron Physics / 967

Green Functions of Chiral Currents within OPE

Author: Tomas Kadavy

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We present new results on contributions of the QCD condensates to the two-point and the three-point Green functions of chiral currents, calculated within the means of the operator product expansion (OPE). Further, for the Green functions of the odd-intrinsic parity sector of QCD, we show up-to-date knowledge of behavior of the matching between the calculations performed in the resonance chiral theory and OPE. This matching, however, as complicated as it is, can lead to important constraints on the coupling constants of the resonance Lagrangian, relevant in the odd-sector of QCD. We also discuss in detail some phenomenological applications of our study, such as the connection to the rare decays of mesons, which helps to subject the unknown couplings to significant restrictions.

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 968

Development of structural self-vetoing scintillators for low background experiments

Author: Michael Febbraro

Co-authors: Brennan Hackett; Luis Manzanillas; Felix Fischer; Bela Majorovits; Daniel Muenstermann; Yuri Efremenko; Oliver Schulz; Rami Rouhana; Markus Pohl; Maria Corominas

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The polyester poly(ethylene 2,6-naphthalate) (PEN) is an attractive candidate as a low-background material for future rare event physics experiments. The polyester exhibits ideal mechanical, electrical, and scintillation properties permitting its use not only as an active shield but also a structural component. Recent formulations have been developed which greatly improve optical clarity, reducing radio impurities, and aiding in production of complex geometries. In this presentation, we will provide an update on synthesis, characterization, and potential applications of PEN and PEN derivatives for low-background experiments. Examples will be provided on applications for future germanium-based ton-scale 0νββ experiments.

Secondary track (number):

Neutrino Physics / 969

The PTOLEMY experiment to look at the first second of the Universe

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The PTOLEMY project aims at accomplishing the Conceptual Design of a detector capable to detect Cosmological relic neutrinos. The idea is based an a novel idea where neutrinos of vanishing kinetic energy can be detected by means of a target of unstable atoms. In particular the Tritium was chosen for favourable values of cross section and lifetime.

The project is supported by an international collaboration which recently published a paper, among others, where major breakthroughs in the field of electrostatic particle filter have been published. This is not the only novel concept exploited in the concept off the PTOLEMY detector but also monatomic layers of graphene as support of T atoms is a very innovative idea with relevant new features in terms of energy definition of the electron from the T decay. In the talk all most relevant aspect of the project will be reported

I read the instructions:

Secondary track (number):

08

Strong Interactions and Hadron Physics / 970

Three flavour order parameters of chiral symmetry in low energy QCD

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The current state of knowledge of the order parameters, the quark condensate and the pseudoscalar decay constant in the chiral limit, will be reviewed, based on available phenomenological fits and lattice QCD calculations. It will be argued that while the theory is pretty well understood in the two flavour case, there is still a gap in the knowledge of the characteristics of the QCD vacuum in the three flavour one. Our results for the three flavour parameters obtained by a Bayesian statistical analysis of the decays of eta to three pions will be presented. A connection with the apparently terrible convergence of the decay widths in standard chiral perturbation theory will be discussed. Possible implications of a new analysis of subthreshold parameters of pion-pion scattering will be outlined.

Secondary track (number):

Education and Outreach / 971

Development of Web-Based Detector Display Application Tracer for ATLAS Experiment

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Nowadays, detector display software applications are playing an important role in particle physics experiments. There is a wide range of different requirements for the application, starting from Outreach’s virtual reality and education, to representation of physical events for the analysis. Another important requirement, coming from users, is an easy way to access applications, which means no installation and compatibility with the majority of hardware and software platforms. The last important requirement is to let users have maximum interactions with detector components, events, and graphical user interface, through the visualised scenes. All these create the necessity to develop a special architecture of an application with a core part with common functionalities and multiple super-systems with user-specific requirements.

Good results bring browser-based applications with the implementation of a Web Graphics Library. However, they have substantial limitations for the visualisation of scenes with certain numbers of facets, do not support Boolean cuts and more. The main task here is to find an agreement between lots of requirements coming from users and engine limitations.

This paper presents the development of the WebGL/three.js based event display application - Tracer, for the ATLAS experiment.

I read the instructions:

Secondary track (number):

Education and Outreach / 972

Development of Mixed Reality Software Applications for the ATLAS Experiment

Author: Mariam Pirtskhalava

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Visualisation plays an important cognitive role in understanding and learning different facilities and processes in high energy physics experiments. It can synthesise Augmented Reality and Virtual Environment to create Mixed Reality Applications with detector descriptions and high-level interactions like gesture or touch controls, easy and minimalistic UI and Lego-like interactions with geometries, for better cognition.

Several Mixed Reality detector display applications can be considered according to user-specific requirements: (ART) - Augmented Reality Table, an application where users will be able to place the detector in the desired location and interact with geometry using a real-time hand recognition system or touch controls and select or grab different components of the detector; (ARD) Augmented Reality Door, where users can place a virtual door in a real-life environment and navigate through the facilities; (LND) Augmented reality landscape, by this application users can place full-sized detectors in real-life environments; (ARB) Augmented Reality Book, users will scan certain images in books or leaflets and see corresponding 3D objects placed on paper.

This paper represents the methods and tools for the creation of the above mentioned Augmented Reality applications.

I read the instructions:

Secondary track (number):

Accelerator: Physics, Performance, and R&D for Future Facilities - Posters / 974

HEP Graph Analysis to Protect Children from Violence

Authors: Andrea Martini¹; Kristiane Sylvia Novotny²; Daniel Dobos¹; Karolos Potamianos⁴

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Data Analysis Methods from High Energy Particle Physics (HEP) have applications well beyond fundamental research or the obvious industrial use cases. We would like to present the results of two project together with the UNICEF hosted End Violence Against Children (EVAC) Global Partnership and the Terre des Hommes (TdH) Innovation Prize project ChildHub. We used HEP data analysis inspired techniques to analysis Millions of financial transactions of the United Nations in order to identify collaborations between different countries, institutions and thematic direction, as well as interconnections of data in document libraries and communities of Child Protection practitioners. Besides the presentation of the results we will discuss how data analysis techniques from fundamental HEP research can help to demonstrate the value and impact on society in often not obvious domains (like Ending Violence Against Children) and how they can be used for outreach towards fundamental science funding decision makers.

I read the instructions:

Secondary track (number):

(15)

Accelerator: Physics, Performance, and R&D for Future Facilities / 975

Bridging the Machine Detector Interface
Author: Laurie Nevay

Co-authors: Stewart Takashi Boogert; Andrey Abramov; Stephen Gibson; Helena Lefebvre; Stuart Derek Walker; William Shields; Siobhan Alden

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To make the best possible use of existing and proposed collider experiments, the precise measurement and understanding of machine induced backgrounds as well as forward collision products coupled back into the accelerator is crucial. Conventional detector simulations do not include the whole accelerator with thousands of magnets, nor does the numerical integration used to track through detector magnetic fields accurately represent the passage through an accelerator. We present the methodology for a truly combined detector and accelerator simulation with accurate accelerator tracking and a demonstration using the code BDSIM built on Geant4. Full multi-turn models of the Large Hadron Collider accelerator at CERN with particle matter interaction are presented. Comparison of simulation with measured forward physics debris reaching far throughout the accelerator is shown and the possible application to recently proposed far-forward detectors searching for long lived particles is discussed.

Secondary track (number):

Heavy Ions / 976

Measurements of $J/\psi$ photoproduction in ultra-peripheral collisions at RHIC

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Ultra-peripheral nucleus-nucleus and proton-nucleus collisions (UPC) are mediated by strong electromagnetic fields, offering the opportunity to study photon-nucleus and photon-proton processes at RHIC. In particular, coherent $J/\psi$ photoproduction in photon-nucleus interactions is sensitive to nuclear effects on the gluon density, and exclusive $J/\psi$ photoproduction in photon-proton collisions can probe the Generalized Parton Distributions in the case of polarized protons. The $J/\psi$ is an ideal probe of the above phenomena thanks to its large mass, which allows the use of perturbative Quantum Chromodynamics.

In this talk we present a brief overview of the topic and results on vector meson photoproduction in Au+Au collisions at 200 GeV and results on $J/\psi$ photoproduction in p+Au collisions at 200 GeV with a polarized proton beam.

Secondary track (number):

Quark and Lepton Flavour Physics / 977

DIPOLE-b: direct measurement of dipole moments of short-lived particles at the LHC(b)
Magnetic and electric dipole moments of fundamental particles are powerful probes for physics within and beyond the Standard Model. These have not been experimentally accessible to date for the case of short-lived particles, due to the difficulties imposed by their short lifetimes. In the recent years, direct measurements of electromagnetic dipole moments of heavy baryons and ultimately the tau lepton has been considered. Novel experimental techniques and feasibility studies of the proposed experiment based on the upgraded LHCb detector will be discussed, along with the physics opportunities using the dedicated fixed-target, proton-gas and proton-proton collisions. Perspectives for different luminosity scenarios will be outlined.
Liquid Argon Time Projection Chambers (LArTPCs) are currently being extensively used for neutrino physics due to their excellent capabilities in performing particle identification, and precise 3D and calorimetric energy reconstruction. The Liquid Argon In A Test Beam (LArIAT) experiment ran from 2015 to 2017 at Fermilab’s Test Beam Facility where it was exposed to a known beam of charged particles. The beamline instrumentation provides information about the charged particle species and momenta, giving LArIAT the ability to perform state-of-the-art analyses of the types of charged particles that are produced in neutrino interactions on argon. LArIAT has been an excellent test-bed to perform measurements of interaction of different charged particles on argon as well as performing R&D studies for future large LArTPCs such as the Short-Baseline Near Detector (SBND) and the Deep Underground Neutrino Experiment (DUNE). This talk will give an overview of the LArIAT detector as well as provide a highlight on recent results and on-going analyses.

How HEP contributes to Sustainable Investment?

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The Sustainable Development Goals (SDGs) of the United Nations as well as the Environmental, Social and corporate Governance (ESGs) are central factors in measuring the sustainability and societal impact of an action or an investment. Following research on sustainable investment with the Global Humanitarian Lab (GHL) we are analysing partnerships and collaborations between United Nations system organisations as well as private sector entities. The mapping and correlation techniques use models originally developed for HEP particle tracking and interconnected data graph/network analysis including Graph Neural Networks (GNN). We will present initial results of a mapping excursive in collaboration with Impact17 and the United Nations SDG Lab as well as discuss how HEP inspired analysis techniques can contribute to smart decision taking in sustainable investment and policy making, and through that showcase how fundamental research can contribute to create value for non-HEP domains.

Effective actions from string field theory
Authors: Martin Schnabl\textsuperscript{1}; Carlo Maccaferri\textsuperscript{2}; Harold Erbin\textsuperscript{3}

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We develop a formal framework for constructing tree-level effective actions for $A_\infty$ and $L_\infty$ string field theories using the ideas of homological perturbation theory. We apply our results to obtain effective actions for massless fields at finite momentum in a large class of both bosonic and superstring backgrounds, making use of a novel propagator to account for integrating out the massless auxiliary fields. In the superstring case, we show that the computation of the effective vertices at zero momentum localizes on the boundary of the worldsheet moduli space provided that the background is described by an $\mathcal{N} = 2$ superconformal field theory. We also discuss the definition of observables in general $A_\infty$ theories, deriving a novel observable for the EKS $A_\infty$ superstring field theory.

I read the instructions:

Secondary track (number):

Computing and Data Handling / 983

Belle II RAW data management - The Online-Offline data transfer system

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Data collection at the Belle II experiment started in the spring of 2019. During the early stages of the experiment it is important that the raw data are both copied to permanent storage and made available soon after being recorded to allow for the timely commissioning and calibration of the detector. Automated procedures have been developed to transfer the data from the detector in a timely manner; these procedures include fault management, performance monitoring, and quality checks. It is important that the systems put in place will also scale to the much higher data rates expected in the coming years at Belle II. The development, implementation, and operations of this Belle II online-offline data transfer system will be described.

Secondary track (number):

Computing and Data Handling / 984

Detector Simulation Upgrades for HL-LHC

Authors: Graeme A Stewart\textsuperscript{1}; Guilherme Amadio\textsuperscript{1}; Andrei Gheata\textsuperscript{1}; Pere Mato Vila\textsuperscript{1}; Witold Pokorski\textsuperscript{1}; Anna Zaborowska\textsuperscript{1}

\textsuperscript{1} CERN
The upgrade of the LHC accelerator for high-luminosity will allow CERN’s general purpose detectors, ATLAS and CMS, to take far more data than they do currently, with instantaneous luminosity of up to $7.5 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$ and pile-up of 200 events. In total HL-LHC targets $3 \text{ab}^{-1}$ of data. To best exploit this physics potential, trigger rates will rise by up to an order of magnitude, compared to LHC Runs 2 and 3.

To support this ten-fold increase in HL-LHC data rate to offline it will be necessary to generate many more simulated events to match these trigger rates. All of this additional computing must happen inside a flat budget envelope, implying that detector simulation for HL-LHC must become much faster than today’s performance. In this paper we outline the 3-pronged strategy for achieving the requisite performance. First, code modernisation and simplification inside Geant4, the main workhorse for the LHC experiments, can improve the throughput on modern CPUs, avoiding constant churn in data and instruction caches. In this respect the lessons from the GeantV R&D project are extremely valuable and will be discussed. Second, the use of fast simulation techniques, replacing traditional particle transport with parametric detector responses will need to be more widely used. Here, research into what techniques are generally applicable across detector types (particularly calorimeters) is very active, in addition to investigating the best way to utilise machine learning approaches and integrate them into Geant4. Finally, the use of non-CPU devices, which could offer new ways to approach detector simulation taking advantage of very different hardware, such as GPUs, and could be a way to exploit next generation systems that offer different computing opportunities.

We will present preliminary results from all three of these areas and discuss how all of them will be probably necessary to meet the challenge of HL-LHC detector simulation.

Secondary track (number):

Higgs Physics / 985

Precision Higgs physics at the ILC, and its impact on detector design.

Authors: Daniel Jeans\(^1\); Michael Peskin\(^{None}\)

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The International Linear Collider (ILC) has the goal of providing measurements of the Higgs boson properties at the 1% level or better. To achieve this, the ILC will require detectors with excellent performance in terms of material budget, calorimetric energy resolution, heavy flavor identification, and hermeticity. This talk will describe the precision Higgs measurements possible at ILC, and the solutions to the experimental challenges provided by the ILD and SiD detector concepts.

I read the instructions:

Secondary track (number):

Higgs Physics - Posters / 986

Recent Higgs to WW measurements with Run 2 CMS data

Author: Sarah Marika Freed\(^1\)
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The latest CMS results on the Higgs boson decays to a W boson pair are presented. The focus of the poster are the inclusive and differential cross section measurements performed using the full Run2 data collected by the CMS detector at LHC, as well as the constraints on the Higgs boson couplings to fermions and vector bosons arising from the simultaneous measurement of different production mechanisms.

Secondary track (number):

Neutrino Physics - Posters / 987

Sensitivity to leptonic $\delta_{CP}$ and $\theta_{12}$ with low energy atmospheric neutrinos

Authors: Lakshmi S. Mohan¹; Indumathi D. ²; Murthy M.V.N.³

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Leptonic CP violation phase $\delta_{CP}$ is one of the current unknowns in neutrino oscillation physics. Not knowing the hierarchy of neutrino masses can bring an ambiguity in the measurement of $\delta_{CP}$. While accelerator based long baseline experiments like the proposed DUNE experiment can determine $\delta_{CP}$ without hierarchy ambiguity, it is interesting to study low energy atmospheric neutrinos also for this purpose. Atmospheric neutrinos whose flux peaks at low (sub-GeV) energies will give a significant amount of events in addition to the event spectra being hierarchy independent at these energies. The effect of detector resolutions and systematic uncertainties on the sensitivity to $\delta_{CP}$ are studied.

It is also found that a detector which can separate neutrinos (ν) from anti-neutrinos (\bar{ν}) will give a better sensitivity to $\delta_{CP}$. In view of the large future neutrino detectors, low energy atmospheric neutrinos are interesting since a wide variety of physics other than $\delta_{CP}$ can be probed. We also study the sensitivity to $\theta_{12}$ using low energy atmospheric neutrinos.

Reference:

Secondary track (number):

Education and Outreach / 988

The engagement of ALICE with the public during CERN Open Days 2019

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The ALICE Collaboration uses a multitude of methods to reach out to the public. Visits of the experiment, both underground during LHC shutdown and of the new ALICE exhibition, are among the most important outreach activities. During the CERN Open Days in September 2019, 4600 persons visited the ALICE cavern and part of the LHC tunnel; in addition, a variety of activities were organized at LHC Point 2, bringing to children and adults the excitement of science. Talks, simple physics experiments and hands-on activities, involving building the ALICE detector out of cardboard or lego blocks, the cosmic piano and many others kept the whole family entertained. A team of few ALICE members, in collaboration with the CERN central organisers, prepared the event and trained the more than 200 enthusiastic volunteers. An overview of this memorable weekend will be presented.

Secondary track (number):

Education and Outreach / 989

The University of Michigan Semester Research Program at CERN

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Since 2013, the University of Michigan has hosted a semester-long research program for undergraduate students at CERN. The students are selected from a diverse mix of small and large universities across the USA and are embedded as CERN Users in active research programs on experiments at the laboratory. The program is modeled on the highly successful NSF-funded Research Experience for Undergraduates (REU) program, which brings 15 students each year to participate in the CERN Summer Student Program, but serves to address the very large demand for additional opportunities during the academic year. CERN mentors are selected due to their leadership skills on the experiments, as well as their ability to educate and inspire the students. Projects cover a wide range of activities from detector R&D to software development, trigger design, physics analysis and theoretical methodology, and touch nearly all aspects of the research program at CERN.

Each semester, around six students, selected from diverse backgrounds, often under-represented in our field, spend three months working at the laboratory. They live in apartment facilities in neighbouring St. Genis Pouilly, and enjoy periodic excursions to cultural centres located around Europe. Funding, which covers travel, per diem and a stipend, has come from a variety of sources, including the Richard Lounsbery Foundation, the University of Michigan Department of Physics, and most recently from the United States Mission to the International Organizations in Geneva. We present the growing success of the program, its strategic interest to the USA, and describe our current efforts to expand and improve its diverse reach to all students across the country.

Secondary track (number):

Formal Theory / 990

Torsion through time-loops on bidimensional Dirac materials

Authors: Adamantia Zampeli; Alfredo Iorio; Marcelo F. Ciappina; Pablo Pais

Charles University
After a brief review of how to describe the π electrons of Dirac materials and topological defects, such as disclinations and dislocations, we propose a scenario where the effects of dislocations, in bidimensional Dirac materials, can be described, at low energies, by a vertex proportional to the totally antisymmetric component of the torsion generated by such dislocations. It is suggested that the two-dimensional geometric obstructions, already known in the literature, can be avoided by including time in the description of π electrons. In particular, the emphasis is placed on exotic time-loops, which could be obtained from the hole-particle pair excitations. If torsion/dislocation is present, a net flow of particles-antiparticles (holes) can be inferred and, possibly, be measured.

**Secondary track (number):**

Beyond the Standard Model - Posters / 991

**CP-violating Wtb anomalous couplings through top-pair production via pp collision at LHC.**

**Author:** Apurba Tiwari

**Co-author:** Sudhir Gupta

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We discuss the CP-violating effects at partonic level arising due to anomalous Wtb vertices at the Large Hadron Collider in the semileptonic decay modes of the top-quark for the t\(\bar{t}\)bar events at the LHC. Limits on these anomalous couplings are also discussed for the 13 TeV LHC energy run. The improvements over these estimates for the forthcoming HL-LHC with 14 and 27 TeV and FCC-hh with 100 TeV centre-of-mass energies are also presented.

**Secondary track (number):**

Strong Interactions and Hadron Physics / 992

**Overview of the Electron Ion Collider physics program**

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The electron-ion collider, EIC, has been been identified as the top priority new construction project in the latest NSAC long range plan in the US and was very favorably reviewed by the National Academy of sciences. Recently, it received critical decision 0 (mission need) status by the DOE and Brookhaven National Lab was chosen as the site to host the EIC. The EIC will collide intense beams of spin-polarized electrons with intense beams of both polarized nucleons and unpolarized nuclei from deuterium to uranium at various center of mass energies from 5-18 GeV for electrons and 41-275 (110) GeV for protons (nuclei).

With these properties, the three-dimensional spatial and momentum structure of the nucleon can be
studied in detail and the role of gluons and sea quarks to the spin of the proton can be answered. The EIC can address the long-standing question of how 99% of the visible mass of the universe emerges from the strong interaction.

In the nuclear environment nonlinear dynamics at high gluon densities can be probed as well as the hadronization in nuclear matter and in the vacuum.

In this talk an overview over the EIC, its physics goals and status of accelerator and detector considerations will be given.

I read the instructions:

Secondary track (number):

**Neutrino Physics - Posters / 993**

**Production of 83Rb for calibration sources for dark matter and neutrino mass experiments**

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Short-lived isomer 83mKr with its discrete electron spectrum has ideal properties to be used in the crucial role of calibration source in low energy experiments like KATRIN or XENON. To ensure smooth long-term operation of these experiments, reliable routines for production of 83Rb, which decays to 83mKr, have to be developed. We describe the methods developed at the Nuclear Physics Institute of the Czech Academy of Sciences at Rez, where 83Rb sources are created for KATRIN predominantly via the reaction 84Kr(p,2n)83Rb by colliding accelerated protons with a target filled with natural krypton gas.

Secondary track (number):

**Beyond the Standard Model - Posters / 994**

**Observation of light-by-light scattering and search for axion-like particles with the CMS experiment**

**Authors:** Rebeka Lilla Böttger\textsuperscript{1}, Gabriella Pasztor\textsuperscript{2}

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Ultraperipheral lead-lead collisions at $\sqrt{s_{NN}} = 5.02$ TeV produce such very large photon fluxes that the fundamental, and very rare, quantum-mechanical process of Light-by-light (LbyL) scattering can be observed. The studies of LbyL scattering in ultraperipheral PbPb collisions data collected during the 2015 and 2018 LHC runs will be presented, using samples corresponding to integrated luminosities of about 0.4 nb$^{-1}$ and 1.6 nb$^{-1}$, respectively. The cross section for this process is sensitive to the
possible existence of axion-like particles. The four times more luminosity with 2018 PbPb collisions provides an access to axion mass and coupling ranges that are inaccessible with pp data, opening a unique window through which to search for physics beyond the Standard Model.

Secondary track (number):

1. Dark Matter Detection

Top Quark and Electroweak Physics / 995

NLO QCD corrections to the electroweak top-pair production beyond the Standard Model

Authors: Mohammad Mahdi AlTakah1; Michael Klasen2; Ingo Schienbein3; Jean-Nicolas Lang3; Tomas Jezo4

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We extend and improve a previous calculation of electroweak top-pair production at the LHC via Z' bosons to NLO QCD in POWHEG. In particular, we add the effects of t-channel W and W' exchange and allow for flavour–non-diagonal Z' and W' couplings. The calculation is matched to parton showers in the POWHEG BOX framework. As an application, we present numerical results for a model with flavor–non-diagonal couplings which has been proposed to explain the anomalies in B decays.

Secondary track (number):

Strong Interactions and Hadron Physics / 996

DVCS and exclusive meson production measurements at the COMPASS experiment

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COMPASS is a multipurpose high energy physics experiment located at the M2 beamline of the SPS at CERN. In 2016 and 2017 COMPASS collaboration performed measurements of lepton-induced hard exclusive reactions using 160 GeV positively and negatively charged muon beams scattering of a liquid hydrogen target. The Deeply Virtual Compton Scattering (DVCS) and Hard Exclusive Meson Production (HEMP) processes, which were explored by the experiment, serve as an important input for the study of the Generalized Parton Distributions (GPDs). The GPDs encode the information about the correlations between longitudinal momentum and transverse spatial distribution of the partons inside the nucleon. They play a crucial role in the description of the 3-dimensional structure of the nucleon in QCD.
Recent COMPASS results from DVCS and HEMP channels and their connection to the GPDs will be presented. Obtained results will be compared with available model predictions.

I read the instructions:

Secondary track (number):

**Strong Interactions and Hadron Physics / 997**

**Drell-Yan measurements at the COMPASS experiment**

*Author:* Marco Meyer-Conde

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In 2015 and 2018 the COMPASS experiment at CERN measured muon pair production reactions using 190 GeV $\pi^-$ beam impinging on a transversely polarised NH$_3$ and unpolarised nuclear (Al, W) targets. The main focus was given to the study of the dimuons produced in the Drell-Yan and J/psi production channels. Apart from the absolute cross-section measurements for both processes, COMPASS studies also the target spin (in)dependent azimuthal asymmetries in both channels. Assuming the valence quark-antiquark annihilation to be the main production mechanism, one can interpret the azimuthal asymmetries in terms of convolutions of pion and proton Transverse Momentum Dependent (TMD) Parton Distribution Functions (PDFs). The TMD PDFs are universal QCD objects providing a mapping of parton densities in the 3D momentum space. Recent results obtained by COMPASS for the Drell-Yan and J/psi channels will be discussed along with complementary semi-inclusive DIS measurements and theory predictions.

I read the instructions:

Secondary track (number):

**Formal Theory / 998**

**The scalar potential of the 331 model: theoretical constraints**

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We discuss the main features of the scalar sector of a class of BSM models with enlarged gauge symmetry, the so called 331 Models. The theoretical constraints on the scalar potential such as unitarity, perturbativity and boundedness-from-below, are presented, together with the analytical exact digitalization of the scalar sector. The phenomenology of exotic scenarios predicted by the 331 Models can be tested in light of these theoretical constraints.

Secondary track (number):

**Operation, Performance and Upgrade of Present Detectors / 999**
The sPHENIX experiment at RHIC

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The sPHENIX experiment is the successor the PHENIX experiment at RHIC and is optimized to study heavy flavor and jets arising from heavy ion collisions. The detector utilizes advanced technologies such as a monolithic active pixel vertex detector while also repurposing technologies originally from other high energy experiments such as BaBar, ATLAS and ALICE. In this talk we will show the design and status of the sPHENIX detector whilst also presenting the projected physics capabilities and planned measurements that the collaboration will work to achieve. sPHENIX is expected to begin data taking in 2023.

New generation of compact XFEL, based on the laser wake-field acceleration: current development and future perspectives

Authors: Alexander Molodozhentsev1; Konstantin Kruchinin1; Green Tyler1; Gabriele Grittani1; Dariusz Kocon1; Michal Nevrkla1; Sebastian Niekrasz1; Sergey Bulanov1; Georg Korn1

1 ELI-Beamlines

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Laser wakefield acceleration (LWFA) allows producing a few GeV electron beams in a plasma channel with a length of few cm with unique parameters such as bunch length of a few fsec and the bunch charge up to 100 pC. With the constant improvement of the electron beam parameters, in particular, the energy spread and the emittance of the electron beam, LWFA can be considered as a candidate for next generation of the soft and hard X-ray free-electron laser (X-FEL). ELI-Beamlines research centre, located near Prague (Czech Republic) is an international user facility for fundamental and applied research using ultra-intense lasers and ultra-short high-energy electron and proton beams. Combination of new laser development with better understanding and control of LWFA opens the way to develop at ELI-Beamlines a new generation of XFEL, based on the revolutionary laser technology and latest achievements in existing "linac-based" XFEL facilities. In the frame of this report, we overview the laser-driven FEL research program at ELI-Beamlines and discuss a possible extension of this research program to the hard X-ray laser-driven compact FEL.

Reactor Neutrino Measurement with PROSPECT

Author: Xianyi Zhang

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Current models of antineutrino production in nuclear reactors predict absolute detection rates and energy spectra at odds with the existing body of direct reactor antineutrino measurements. These discrepancies are indicative of a misunderstanding of neutrino production in nuclear reactor cores and/or the neutrino oscillation involving a sterile neutrino. New short-baseline reactor antineutrino measurements performed at highly enriched uranium reactors will enable independent testing of these two explanations for existing flux and spectrum anomalies. PROSPECT, the Precision Reactor Oscillation and Spectrum experiment, is currently operating a 4-ton segmented $^{6}$Li-doped liquid scintillator detector covering baseline ranges of ~7–9 meters from the $^{235}$U-enriched High Flux Isotope Reactor at Oak Ridge National Laboratory. This presentation describes the recent reactor antineutrino measurements performed by the PROSPECT experiment, which have demonstrated the feasibility of precision on-surface reactor antineutrino detection, advanced understanding of antineutrino production by the primary fission isotope $^{235}$U, and placed world-leading limits on sterile neutrino oscillations.

Part of this work was performed under the auspices of the US Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. LLNL-ABS-807098.

Secondary track (number):

Dark Matter Detection/Diversity and Inclusion - Posters / 1005

Non-commutative space-time: a viable hypothesis to explain the gamma-ray excess in the galactic center

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We explore the non-commutative space-time to revive the idea that gamma-ray excess in the galactic center can be the result of particle dark matter annihilation. In this scenario, photon spectrum is produced by direct (prompt) emission during an annihilation where a photon can be embed in the final state together with other direct products in a new triplet vertex. In the various configurations of dark matter phenomenology, we adopt the most common model known as singlet scalar. Calculating the relevant aspects of the model, we can obtain the photon flux in the galactic center. Comparing our numerical achievements with experimental data reveals that non-commutative space-time can be a reliable framework to explain gamma-ray excess and even (in the future) other indirect signals of dark matter detection.

Secondary track (number):

03 & 08

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 1006

A proposal of a drift chamber for the IDEA experiment for a future e+e- collider

Author: Giovanni F. Tassielli
An ultra-low mass Tracking Chamber with Particle Identification capabilities is proposed for a future e+e- collider. Details about the construction parameters of the drift chamber including both the inspection of new material for the wires, of new techniques for soldiering the wires, the development of an improved schema for the drift cell and the choice of a gas mixture are described. The performance of the tracking are studied together with the Improved particle identification capabilities obtained by using a cluster counting technique. Results obtained by using the chamber with electron and muons in a beam test area at CERN are reported and compared with the simulations.

Higgs measurements at the FCC-ee

Author: David d'Enterria

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Precision measurements and searches for new phenomena in the Higgs sector are among the most important goals in particle physics. The large circular e+e- collider FCC-ee will provide collisions up to an energy of 365 GeV, with extremely high luminosities. These collisions will allow the ultimate precision on studies of the Higgs boson couplings, mass, total width and CP parameters, as well as searches for exotic and invisible decays.

Search for the Higgs coupling to the electron with the FCC-ee

Author: David d'Enterria

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The possibility of observation of the s-channel production e+e- -> H(125) and thus measure the Higgs coupling to the electron at FCC-ee will be reviewed. To this effect, FCC-ee combines three unique properties: i) a high luminosity at sqrt(s) = 125 GeV, ii) the possibility of monochromatization of the center-of-mass using opposite sign horizontal dispersion at the IR, and iii) the possibility to track the beam energy to high precision with resonant depolarization.
Higgs Physics / 1009

Higgs measurements at the Future Circular Collider FCC-hh

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Very high energy proton-proton collisions (up to 100 TeV) provided by the FCC-hh will produce several $10^{10}$ Higgs bosons. This will allow high precision measurements of the Higgs boson rare decays such as $H\rightarrow \mu\mu$, $Z\rightarrow \gamma\gamma$, $\gamma\rightarrow \gamma\gamma$, of the Higgs coupling to the top quark and of the Higgs self-coupling. There is a remarkable complementarity of the FCC-ee and FCC-hh colliders, which in combination offer the best possible overall study of the Higgs boson properties.

Dark Matter Detection / 1010

The Scintillating Bubble Chamber (SBC) Experiment for Dark Matter and Reactor CEvNS

Author: Pietro Giampa

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The Scintillating Bubble Chamber (SBC) experiment is a novel low-background technique aimed at detecting low-mass (0.7-7 GeV/c²) WIMP interactions and coherent scattering of reactor neutrinos (CEvNS). The detector consists of a quartz-jar filled liquid Argon (LAr), which is spiked with 100 ppm of liquid Xenon (LXe) acting as a wavelength shifter. The target fluid is de-pressurized into a superheated state by a mechanically controlled piston. Particles interacting with the LAr+100ppmLXe can generate heat (bubbles) and scintillation light, depending on the energy intensity and density. The detector is further equipped with cameras to take pictures of the bubbles, Silicon-Photo-Multipliers to measure the scintillation light, and piezo-acoustic sensors to listen to bubble’s formation. By combining these observables, the SBC detector is aiming to reach a threshold for nuclear recoils of 100 eV and a projected WIMP-sensitivity of $3.0\times10^{-43} \text{ cm}^2$, for a WIMP mass of 0.7 GeV/c².

In this talk, I will present the design of the SBC experiment and provide an update on the ongoing construction and commissioning at Fermilab. Finally, I will discuss the collaboration’s plans for the SNOLAB installation/operation and the reactor CEvNS search.

Astro-particle Physics and Cosmology / 1011

SNEWS2.0: A Supernova Early Warning System for the Multi-Messenger Era

Author: Segev BenZvi

1 University of Rochester
The next supernova in the Milky Way will be a bonanza for astrophysics and fundamental physics. However, since local supernovae are exceedingly rare it will be crucial to capture all possible information in a coordinated multi-messenger effort. The observation of a prompt neutrino burst, expected to occur up to 12 hours before the detection of optical emission, would provide a unique early warning for worldwide optical follow-up. Detection of “pre-supernova” neutrinos during the progenitor’s Si-burning phase may further extend the early warning period to several days. Here we describe an upgrade to the SuperNova Early Warning System (SNEWS), a network of neutrino and dark matter detectors designed to report the detection of neutrinos from a Galactic supernova. SNEWS has operated continuously since 2005, and the SNEWS 2.0 upgrade will add several new capabilities to the existing network: public sub-threshold alerts; pointing to the supernova using inter-experiment triangulation; and searches for pre-supernova neutrinos. We will outline the capabilities and design of SNEWS 2.0, as well as its role in multi-messenger follow-ups.

I read the instructions:

Secondary track (number):

Higgs Physics / 1012

Suppression of fermionic operators in the HEFT

Authors: Juan José Sanz-Cillero\textsuperscript{1}; Fernando Alvarado\textsuperscript{2}; Adolfo Guevara\textsuperscript{3}

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The low-energy effective field theory for electroweak interactions -the so called Higgs Effective Field Theory (HEFT)- is studied in this talk. It embeds the Standard Model as a particular limit and parametrizes new physics deviations. We discuss some experimental resonant diboson searches and four-fermion operators analyses that seem to push the new physics scale well over the TeV. On the other hand, the more precise oblique parameter determinations allow new physics resonances in the few TeV range. This apparent contradiction is easily solved by postulating a Lagrangian of the Standard Model extension that only couples directly the new physics sector to the bosonic degrees of freedom of the Standard Model but not to the SM fermions.

Secondary track (number):

03, 04

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 1013

Low Radioactivity Argon for Dark Matter and Rare Event Searches

Author: DarkSide Collaboration\textsuperscript{None}

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The DarkSide-50 dark matter search experiment demonstrated that argon derived from deep underground sources can be highly reduced in 39Ar, and since then the demand for this commodity has
Several fundamental physics experiments require argon reduced in 39Ar as well as 42Ar, as well as other rising needs in other scientific fields (e.g., age-dating). With the expanded needs come the questions of availability and how to approach the challenges associated with its production and characterization.

This talk will provide a global picture of low-radioactivity underground argon procurement, from its production to quality control and quality assurance. We will detail the DarkSide-20k plan for extracting more argon from the DarkSide-50 source through a project called Urania, as well as another project which will serve to isotopically separate 39Ar from 40Ar, called Aria. Finally, DART is a small (~1 L) chamber that will measure the depletion factor of 39Ar in UAr. The detector will be immersed in the LAr active volume of ArDM (LSC, Spain), which will act as a veto for gammas, allowing a precise measurement of the 39Ar residual activity.

Neutrino Physics / 1014

The Accelerator Neutrino Neutron Interaction Experiment (AN-NIE)

Author: Mayly Sanchez

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The Accelerator Neutrino Neutron Interaction Experiment (AN-NIE) aims to measure the neutron abundance in the final state of neutrino-nucleus interactions. This measurement will have a direct impact on our understanding of neutrino interactions and could lead to a reduction of systematic uncertainties and improvements in signal-background discrimination for future neutrino detectors. The AN-NIE detector uses 30 tons of gadolinium-loaded water to enhance the neutron-capture cross section. It is instrumented with a combination of conventional photomultipliers and novel LAr Area Picosecond Photodetectors (LAPPDs). After a background characterization phase, the detectors has been installed in the Booster Neutrino beam at Fermilab and has begun taking data. This presentation will show first data from the AN-NIE experiment.

Quark and Lepton Flavour Physics / 1015

Measurement of hadronic cross sections at CMD-3

Author: Ivan Logashenko

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The CMD-3 experiment at VEPP-2000 collider in Novosibirsk carries out a comprehensive study of the of \( e^+e^- \) annihilation into hadrons in the center-of-mass energy range from the threshold, 0.32 GeV, to 2E<2 GeV. The energy scan of the whole energy range was performed in 2011-2013 and, after
detector and collider upgrade and increase of luminosity, was resumed in 2017-2019 and continue in 2020. About 280 1/pb has been collected so far.

The physics program of experiment includes measurement of cross-sections and intermediate dynamics of exclusive modes of $e^+e^- \rightarrow$ hadrons, study of hadron cross-sections at the nucleon-antinucleon threshold and a search for two-photon production of C-even resonances. The CMD-3 results provide an important input for calculation of the hadronic contribution to the muon anomalous magnetic moment.

Here we present the survey of results of data analysis, including various modes of electron-positron annihilation with pions and kaons in the final state.

I read the instructions:

Secondary track (number):

Diversity and Inclusion / 1016

Nurturing Girls’ Interest in Science with Particle Physics Masterclasses

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To help boost the number of women entering physics careers, the well-established program International Masterclasses is holding special events on the UN International Day of Women and Girls in Science (Feb 11). Girls aged 15-19 participate in a Masterclass under the supervision of female facilitators, who serve as role models. Particle Physics Masterclasses, organized by the International Particle Physics Outreach Group (IPPOG), are a proven tool to engage high school students with particle physics. In a Masterclass, participants learn about high energy physics in a day-long course and perform a tailor-made physics analysis with real LHC data. In 2020, universities and research labs organized 17 Masterclasses for girls, with participation from four continents. About 600 girls attended the Masterclasses. Videoconferences with CERN were held where the girls could talk to CERN women scientists and learn about the careers of these role models.

Secondary track (number):

Education and Outreach / 1017

Study on the career trajectories of people with a working experience at CERN

Authors: Paolo Giacomelli\(^1\); Chiara Bianchin\(^\text{None}\); Lydia Iconomidou-Fayard\(^2\); Jeremi Niedziela\(^3\); Barbara Sciascia\(^4\)

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A study aiming to measure the impact of CERN and of its environment on the career of people who worked at the laboratory was requested by CERN’s Director General and was carried out by the authors. The study and the results have recently been documented in a CERN Yellow Report, CERN-2019-004. The mandate, the methodology followed, the on-line questionnaires used, the analysis of the data collected and the results obtained will be presented.

Quark and Lepton Flavour Physics / 1018

Measurement of muon g-2/EDM at J-PARC

Authors: Tsutomu Mibe¹; Hiromi Iinuma²

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The muon g-2/EDM experiment at J-PARC aims to measure the anomalous magnetic moment (g-2) and electric dipole moment (EDM) of the positive muon with a novel technique utilizing a reaccelerated thermal muon beam and a 66 cm-diameter compact muon storage ring without focusing electric field. This experiment will be complementary to the previous BNL E821 experiment and ongoing Fermilab E989 experiment. In this contribution, present status and plan of the experiment will be presented.

Diversity and Inclusion / 1019

Demographics of the ALICE Collaboration

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The ALICE Collaboration at the LHC is made up of around 1900 people from 39 countries. This talk will discuss the composition of the Collaboration in terms of gender, geography, and career status. The distribution of responsibilities among various demographic groups will also be presented, and the time evolution of these statistics will be explored.
Radiation Protection at ELI Beamlines: A Unique Laser Driven Accelerator Facility

Authors: Andrea Tsinganis1; Anna Cimmino1; David Horvath1; Roberto Versaci1; Roman Trunecek1; Silvia Motta1; Veronika Olsovcova1; Vojtech Stransky1

ELI Beamlines

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The Extreme Light Infrastructure (ELI) Beamlines is a laser driven accelerator facility located in the outskirts of the city of Prague. With its state-of-the-art lasers, it will carry out an ambitious and diverse research program. Activities at ELI Beamlines can be broken down in complementary areas of scientific interest: development and testing of novel technologies for multi-PW laser systems, plasma physics, high field physics experiments (with intensities up to of $10^{24}$ W cm$^{-2}$), production of femtosecond secondary sources of ionizing radiation (extreme ultraviolet radiation, X rays, gamma, electrons, and protons) to be used in interdisciplinatory applications in physics, biology, medicine, and material sciences. In-house experiments are already taking place since the first half of 2018, first user calls and experiments started in 2019.

In this contribution, the ELI Beamlines accelerator facility and its current status of operation are presented in more details. Particular attention is paid to the design and implementation of the radiation protection program, with emphasis on the unique challenges this laser facility poses in terms of radiation safety.

An Experimental Search for Muon-Electron Conversion in Nuclear Field with Muonic Atoms Produced in a Primary Proton Target —DeeMe—

Authors: Masaharu Aoki1; on behalf of DeeMe Collaboration

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Muon-electron conversion in a nuclear field ($\mu^- + A \rightarrow e^- + A$) is a charged-lepton flavor violation (CLFV) process. It is possible that CLFV signals are present just under the current experimental limits.

DeeMe project aims to perform an experimental search for muon-electron conversion by utilizing muonic atoms copiously produced in a primary proton target. If muon-electron conversion occurs for these muonic atoms, mono-energetic electrons in delayed timing would emerge out of the primary proton target, and thus be easily identified by a simple magnetic spectrometer placed at the exit of a secondary beam line.

The physics sensitivity of DeeMe could reach to a level of $10^{-15}$, but the first physics run will aim to achieve $10^{-13}$ of a single event sensitivity. We are hoping to start the physics data taking soon after the beam line construction is completed at J-PARC MLF. The current status of DeeMe will be presented.

I read the instructions:
Latest results of the STEREO search for a sterile neutrino at a research reactor

Author: Loïc Labit

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During the last period, reactor neutrino experiments have played an increasing role in understanding neutrino oscillations, in particular with the precise measurement of the mixing angle $\theta_{13}$. However, following a reevaluation in 2011 of reactor antineutrino fluxes, a discrepancy between measured and expected fluxes, known as the Reactor Antineutrino Anomaly (RAA), was observed and has yet to be fully understood. This anomaly could result from the existence of an additional (thus sterile) light neutrino state participating in the oscillation. The parameter values that best match this conjecture are: $\sin^2(2\theta_{ee})=0.14$ and $\Delta m^2_{41}=2.4\text{ eV}^2$.

The STEREO experiment was designed to test this oscillation hypothesis independently of predicted antineutrino spectra and fluxes, using the antineutrinos emitted by the compact core of the research reactor at the Laue-Langevin Institute in Grenoble, France. The target located at about 10 m from the core is segmented in six cells, allowing for a measurement of the antineutrino energy spectrum at various baselines, so that the experiment is sensitive to the oscillation toward a sterile neutrino that would distort each cell’s spectrum differently.

Data taking began in 2016 and is ongoing. In 2018 the STEREO collaboration published its first results excluding the RAA best fit with a confidence level of more than 99% and excluding a large part of the parameter space. This talk will present the latest results of STEREO with significantly improved sensitivity to the oscillation of a sterile neutrino, and will include measurements of antineutrino flux normalization and spectrum shape emitted by a $^{235}\text{U}$-dominated nuclear fuel.

Secondary track (number):

The SENSEI Experiment: An Ultrasensitive Search for Sub-GeV Dark Matter

Author: Mariano Cababie

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Devices with low energy thresholds are one of the main pillars for the direct detection of dark matter, and tremendous progress has been made in the past few years in probing dark matter with sub-GeV mass. The SENSEI (Sub-Electron Noise Skipper Experimental Instrument) Collaboration has pioneered the silicon-based dark matter experiment and has achieved world-leading sub-GeV dark matter results. Over the past year, SENSEI has been testing, characterizing, and taking science data with new Skipper-CCDs, which will enable us to move towards the next phase of the SENSEI project. This phase will include the installation of about 100-grams of Skipper-CCDs at SNOLAB, allowing us to further probe the dark matter parameter space.

Beyond the Standard Model - Posters / 1025

Analysis of constrained minimal supersymmetric standard model in Higgs Era.

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The discovery of a 125 GeV Higgs boson and no other (under TeV) new resonance yet at the Large Hadron Collider poses a major challenge for the minimal supersymmetric standard model (MSSM). We present our search with the assistance of information theory and the prior experimental data, to find out the “finely-tuned” CMSSM under the aforesaid circumstances along with the dark-matter experiment.

Formal Theory / 1026

Novel methods for calculating Feynman integrals and applications to QCD processes

Author: Johannes Henn

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Feynman integrals are crucial for obtaining physical predictions from perturbative quantum field theory. Recent years have seen tremendous advances both in our understanding of Feynman integrals, and in our ability of computing them. In particular, novel ideas linking properties of loop integrands to the differential equation method have lead to an unprecedented degree of automation of calculations. As a result, the canonical differential equation method is now an indispensable tool for collider physics. Objectives that previously appeared prohibitive, such as full next-to-next-to-leading order corrections for QCD processes involving many particles, are now within reach. This removes an important bottleneck for a broad range of physics applications. In this talk, after reviewing the latest conceptual developments for Feynman integrals, I will present cutting-edge physics results obtained with the new methods, such as the complete result for the four-loop cusp anomalous...
dimension, as well as the three- and two-loop non-planar Feynman integrals needed for two- and three-jet production, respectively.

Secondary track (number):

**Technology Applications, Industrial Opportunities and Sustainability / 1027**

Proton tomography imaging for cancer treatment:

**Authors**: Piero Giubilato¹; Serena Mattiazzo¹; Devis Pantano²; Filippo Baruffaldi¹; Jeffery Wyss³; Davide Chiappara⁴

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Proton Computed Tomography (pCT) makes it possible to render 3D images of the human body like traditional x-ray Computed Tomography (CT), with the advantage of a much lesser dose delivered to the patient (1% to 10% respect to a traditional CT) and a far more accurate tissue density discrimination (i.e. the capability to map the different dE/dx stopping power of different tissues). The drawbacks mostly consist in a slightly worse spatial resolution, and indeed in the necessity to accelerate protons up to energies of about 250 MeV. Nevertheless, the superior tissue density discrimination characteristic makes it very desirable when applied in conjunction with cancer hadrotherapy, where the major limiting factor in correctly pinpointing the tumor cells comes from the uncertainty in the density of the tissues the ions beam must travel across before reaching the target.

Proton Computed Tomography apparatuses have been so far restricted to the R&D phase, the main limitation being the long acquisition times (orders of minutes), clearly non compatible with a real clinical use. However, within the iMPACT project, by employing the latest advancement in Monolithic Active Pixel Sensors (MAPS) and Silicon Photo-multipliers (SiPM) derived from the High Energy Physics research, such limitations have been overcome, and a prototype of a fast pCT scanner, capable to take a complete 3D image in some seconds, is currently being developed.

This contribution describes the design, realizition and first test results of the iMPACT scanner, a complete detector which employs the ALPIDE MAPS sensor (developed by the ALICE experiment) for its tracker, and a novel configuration of SiPM and plastic scintillators to implement an extremely fast, hermetic range calorimeter.

Secondary track (number):

**Dark Matter Detection / 1028**

iDMEu: Initiative for Dark Matter in Europe and beyond

**Author**: Gaia Lanfranchi¹

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Understanding dark matter, how it was produced in the early universe, what its nature is and where it is located in the cosmos is one of the fundamental physics problems of our century.

The large community working on dark matter is active and diversified, and includes particle physics theorists and astrophysicists with a wide range of interests, as well as particle physics experimentalists focusing on collider, fixed-target, beam-dump, direct and indirect dark matter detection experiments, as well as dedicated axion/ALP experiments.

A broad and common approach to dark matter research is necessary given the nature of the challenge.

The iDMEu expression of interest, which collects about 250 signatories to date, aims at creating a permanent and common platform to exploit synergies and complementarities in dark matter searches across different communities. We will discuss the origin of this initiative and its possible evolution in the future.

I read the instructions:

Secondary track (number):

Education and Outreach / 1029

An Outreach to the Public: Science of the Large Hadron Collider Exhibit

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The value of fundamental science, such as at the LHC, may be taken for granted by many engaged in this research. However, public awareness of the importance of both fundamental and applied science in their lives cannot be for granted. It has been alarming even in such countries as the United States, where science and technology have been strong historically, that new efforts are required to reinvigorate the interest of the nation’s youth in science. With this mission in mind, thousands of people gather for the biennial US National Science and Engineering Festival in Washington, DC. The CMS group from the Johns Hopkins University presented an exhibit called “Science of the Large Hadron Collider” starting with the very first Festival in 2010 and continuing through the decade now. This exhibit has also been presented at the annual Physics Fair on JHU campus. The exhibit explains that hadron (proton) collisions happen in the upper atmosphere and their debris penetrates everything and everybody at every instant. A dark area behind curtains contains a diffusion cloud chamber for the observation of the cosmic rays. The visitors can watch the increasing count in electronics from cosmic rays passing through the scintillator counters. Computer simulation of the exhibit and animated event displays from CMS connected these to the giant apparatus at CERN. In recent years, the exhibit was enhanced with the Virtual Tour to the control rooms at CERN and the Virtual Reality visit to the giant particle physics detectors. Even little kids had fun playing with the magnet colliders, weightless magnets, and other fun toys. This overall experience gives us hope that there will be strong support for the kind of science we do at the LHC.

Secondary track (number):

Neutrino Physics / 1030

KATRIN experiment: first neutrino mass result and future prospects
Author: Alexey Lokhov

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The KATRIN experiment aims to measure the effective electron antineutrino mass with a sensitivity of 0.2 eV/c^2 using a gaseous tritium source combined with the MAC-E filter technique. This direct neutrino mass measurement, based on the kinematics of the tritium beta-decay, provides a model-independent way of approaching the neutrino mass scale.

In this talk an overview of the KATRIN experiment, the first engineering and first science runs are presented. The first neutrino mass results from KATRIN are discussed. The talk closes with a report of the current status and an outlook on the future prospects of KATRIN.

Secondary track (number):

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 1031

Electrical Discharge Mitigation Strategies for Future CMS GEM Systems GE2/1 and ME0

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In 2019-2020, the first of the CMS gas electron multiplier (GEM) systems, GE1/1, was installed into the CMS muon endcaps, to be fully operational by Run 3. This represents the first of three major GEM-based additions into CMS, to be followed in future runs by GE2/1 and the very forward muon tagger ME0. R&D for these two future systems is currently well under way, with a focus on eliminating potential damage due to propagating electrical discharges within the detector, as was seen in the demonstrator system for GE1/1. This contribution presents results from the various mitigation strategies, including changes to the front-end readout electronics and to the construction of the detectors themselves. These results detail the reduction in propagating discharges from the various strategies, as well as unintended consequences of those strategies, such as the presence of bipolar crosstalk signals in chambers equipped with double-segmented GEM foils. Future prospects for the two systems will be discussed.

I read the instructions:

Secondary track (number):

12.

Education and Outreach / 1032

Netzwerk Teilchenwelt: Coordinated Outreach and Recruitment of Young Talents in Germany

Authors: Uta Bilow; Michael Kobel
Network Teilchenwelt is a Germany-wide outreach program comprising 30 universities and research labs. About 150 researchers are involved, bringing cutting edge science into the classroom. 3500 high school students each year take the opportunity to work with original data from HEP experiments in special masterclasses or to study cosmic particles with detectors. On advanced levels, motivated students continue to engage in research and attend workshops at CERN or conduct their research projects. Through a fellow program, highly motivated students are offered early contact with research groups, personal support, and further training. Activities are funded by the German Ministry of Education and Research as an integral part of HEP research. Within the current funding scheme, topics from hadron and nuclear physics are included and links to other projects are created which expand the range of target groups.

I read the instructions:

Secondary track (number):

Formal Theory / 1033

From Correlation Functions to Event Shapes

Authors: Kai YanNone; Johannes HennNone; Emery SokatchevNone; Dmitry ChicherinNone; Alexander ZhiboedovNone

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We present an approach to computing energy-energy correlations (EEC) directly from finite correlation functions. In this way, one completely avoids infrared divergences. In maximally supersymmetric Yang-Mills theory (N=4 sYM), we derive a new, extremely simple formula relating the EEC to a triple discontinuity of a four-point correlation function. We use this formula to compute the EEC in N=4 sYM at next-to-next-to-leading order in perturbation theory. Furthermore, the method can be applied to calculating event shapes in QCD based on correlation functions of conserved currents. As a proof of concept, we compute the correlation function of four electromagnetic currents at next-to-leading order and explain in detail the steps needed to extract the event shape from it.

Secondary track (number):

Higgs Physics / 1034

Flavor Changing Neutral Higgs Boson Meets the Top and the Tau at Hadron Colliders

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We investigate the prospects for discovering a top quark decaying into one light Higgs boson (h0) along with a charm quark in top quark pair production at the CERN Large Hadron Collider (LHC) and future hadron colliders. A general two Higgs doublet model is adopted to study the signature of flavor changing neutral Higgs (FCNH) interactions with $t \rightarrow ch^0$. 
followed by $h^0 \rightarrow \tau^+\tau^-$. We study the discovery potential for the FCNH signal and physics background from dominant processes with realistic acceptance cuts and tagging efficiencies. Promising results are found for the LHC running at 13 or 14 TeV collision energy as well as a future pp collider at 27 TeV.

Secondary track (number): 04 Top Quark and Electroweak Physics

Detectors for Future Facilities (incl. HL-LHC), R&D, Novel Techniques / 1035

The Southern Wide-field Gamma-ray Observatory (SWGO)

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The surface detection of gamma-ray showers has the advantage of a very high duty cycle and wide field-of-view observations across the sky in comparison to Cherenkov telescopes. The scientific potential of a wide-field gamma-ray observatory has already been demonstrated by the experiments HAWC, ARGO and LHAASO in the Northern hemisphere. The Southern Wide-field Gamma-ray Observatory (SWGO) will be located at a site in South America at an altitude above 4400 m a.s.l., and cover an energy range from 100s of GeV to 100s of TeV. I will present the scientific perspectives and concept for the future experiment SWGO, which is now starting its R&D phase.

Secondary track (number): Neutrino Physics / 1036

Recent Results from RENO

Author: Shin ChangDong

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The Reactor Experiment for Neutrino Oscillation (RENO) started data-taking from August 2011 and has successfully measured the smallest neutrino mixing angle $\theta_{13}$ by observing the disappearance of reactor electron antineutrinos. Electron antineutrinos from the six reactors at Hanbit Nuclear Power Plant in Korea are detected and compared by the two identical near-and-far detectors. RENO has published precise values of $\theta_{13}$ and its measurement of $\text{dm}^2_{\text{ee}}$ based on energy dependent disappearance probability. In this talk, we present an updated measurement of $\theta_{13}$ and $\text{dm}^2_{\text{ee}}$ based on roughly 3000 days of data, an independent measured value of $\theta_{13}$ based on 1500 days of data with neutron capture on hydrogen as a delayed signal, and a sterile neutrino search result.

Secondary track (number):
Completion of ELIMAIA: a laser-based ion beamline for multidisciplinary applications

Authors: Francesco Schillaci¹; Daniele Margarone²; Pablo Cirrone³

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The ELIMAIA (ELI Multidisciplinary Applications of laser-Ion Acceleration) beamline has been recently installed at ELI-Beamlines in the Czech Republic. The main goal of ELIMAIA is to offer short ion bunches accelerated by lasers with high repetition rate to users from different fields (physics, biology, material science, medicine, chemistry, archaeology) and, at the same time, to demonstrate that this source can be delivered through innovative and compact approaches. In fact, ELIMAIA will provide stable, fully characterized and tunable particle beams accelerated by PW-class lasers and will offer them to a broad community of users for multidisciplinary applied research, as well as fundamental science investigations.

An international scientific network, called ELIMED (ELI MEDical applications), particularly interested in future applications of laser-driven ions for hadrontherapy, has already been established. In such a perspective ELIMAIA will enable to use laser-driven proton/ion beams for medical research thanks to the reliability and accuracy of its particle beam transport and dose monitoring devices.

Secondary track (number):

Highlights from SuperKEKB Commissioning for early stage of Nano-Beam Scheme and Crab Waist Scheme

Authors: Yukiyoshi Ohnishi¹; Yoshihiro Funakoshi¹

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The SuperKEKB electron-positron collider has been commissioned at KEK to study a new physics in the B-meson decays. In order to accomplish this purpose, the luminosity of 40 times of the highest luminosity record at KEKB, $8 \times 10^{35}$ cm$^{-2}$s$^{-1}$ is necessary. We have applied a novel “nano-beam scheme” to squeeze the beta function at the interaction point (IP) down to 1 mm in the vertical, 60 mm in the HER and 80 mm in the LER in the horizontal direction, respectively. The beta function at the IP is the smallest value for the existing circular colliders in the world. However, the design value is 0.3 mm which is about 1/3 of the achievement. Recently, we also applied a “crab waist scheme” which proposed by P. Raimondi et al. to improve the luminosity more than the nano-beam scheme. We present the early stage of the commissioning of the nano-beam scheme as well as the crab waist scheme in Autumn run 2019 and Spring run 2020.

Secondary track (number):
Prospects for Higgs and di-Higgs at the ATLAS experiment

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The large dataset of about 3 ab-1 that will be collected at the High Luminosity LHC (HL-LHC) will be used to measure Higgs boson processes in detail. Studies based on current analyses have been carried out to understand the expected precision and limitations of these measurements. The large dataset will also allow for better sensitivity to di-Higgs processes and the Higgs boson self coupling. This talk will present the prospects for Higgs and di-Higgs results with the ATLAS detector at the HL-LHC.

CMS in your pocket: between serious game and demonstration tool

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CMS wishes to enable anyone to feel and interact with the gigantism of high energy experiments. For this purpose, we develop a light application downloadable on most smartphone that can render 3D and 360° immersive impression.

Thanks to existing developments of 3D representation of CMS (iSpy, CMS sketchup, 3D drawing of CMS cavern), we are already able to provide an application on specific headsets where the user will be immersed in the CMS cavern on the scaffolding and will see the whole CMS detector in a cutaway view and with the representation of real events. The application can also give access to any 3D/360° image or film that would be available in order to implement a complete virtual visit.

With such an application in his pocket, we hope any high energy physicist will enjoy showing the experiment to friends, colleagues, students...

Dark Matter interaction with He-4: an EFT approach

Author: Andrea Caputo

1 Valencia
I will discuss the possibility of looking for sub-MeV dark matter using superfluid helium-4, employing in particular the recently developed relativistic effective theory for the superfluid phonon to describe the response of the detector to the passing dark matter. Being formulated in a quantum field theory language, this approach is particularly suitable for a particle physics problem. I will apply the formalism to a model of dark matter with both a scalar and vector mediator, and discuss the prospects for these models. I will conclude with future prospects and directions.

Secondary track (number):

String fragmentation in supercool confinement as a new dark matter production mechanism

Author: Filippo Sala

LPTHE

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A new strongly-coupled sector can feature a supercooled confinement transition in the early universe. When fundamental quanta of the strong sector are swept into expanding bubbles of the confined phase, the distance between them is large compared to the confinement scale. The string of flux linking the fundamental quanta fragments and in the process produces an enhanced number of composite states. Furthermore, the resulting composite states are highly boosted in the CMB frame, which leads to additional particle production through the subsequent deep inelastic scattering. This opens several new avenues of investigation, in this talk I will focus on the one related to the composite dark matter relic density.

Secondary track (number):

Dark matter Annihilation in Most Luminous and the Most Massive Ultracompact Dwarf Galaxies (UCD)

Authors: Fortes Elaine; Oswaldo Miranda; Carlos Wuensche; Floyd Stecker

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We explore the potential astrophysical signatures of dark matter (DM) annihilations in ultracompact dwarf galaxies (UCDs) considering two of the richest known galaxy clusters within 100 million light-years, nominally, Virgo and Fornax. Fornax UCD3 is the most luminous UCD and M59 UCD3 is the most massive UCD. With the detection of a 3.5 million solar mass black hole (BH) in Fornax UCD3, we carefully model several DM enhanced profiles scenarios, considering both the presence of the supermassive black hole (SMBH) and DM. For Fornax UCD3, the comparison of the stellar and dynamical masses suggests that there is little content of DM in
UCDs. M59 UCD3 did not receive the same attention in simulations as Fornax UCD3, but deep radio imaging and X-ray observations were performed for M59 UCD3 and can be used to place limits in DM content of these UCDs. We work with an average estimative of dark matter content considering the Salpeter and Kroupa mass functions. We model Fornax UCD3 and M59 UCD3 to have a DM content that is the average of these mass functions. We then analyze the constraints for Fornax and M59 UCD3 coming from gamma-ray and radio sources considering in our simulations, a dark matter particle with mass between $10^{-34}$ GeV. In the absence of strong γ-ray signatures, we show that synchrotron emission from electrons and positrons produced by DM annihilations can be very sensitive to indirect DM search. We find that DM parameters can be significantly constrained at radio frequencies and the spike profiles play an interesting rule in order to deep study the enhancements of DM & BH interactions in ultracompact galaxies.

Secondary track (number):

Astro-particle Physics and Cosmology / 1044

Primordial Kerr Black Holes

Author: Alexandre Arbey

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Primordial Black Holes (PBHs) are appealing candidates for dark matter in the universe but are severely constrained by theoretical and observational constraints. I will focus on the Hawking evaporation limits extended to Kerr Black Holes. These results have been obtained with a new code entitled BlackHawk that I will briefly present. In particular, I will review the isotropic extragalactic gamma ray background constraint and show that the “window” in which PBHs can constitute all of the dark matter depends strongly on the PBH spin. Finally, I will present a way to distinguish between Black Holes of primordial and of stellar origins based on the Thorne limit on their spin.

Secondary track (number):

09

Beyond the Standard Model / 1045

Higgs properties: constraints and sensitivity on Supersymmetry?

Author: Nazila Mahmoudi

Corresponding Author: nazila@cern.ch

We present some highlights on the complementarity of the Higgs and SUSY searches at the LHC, using the 8 and 13 TeV results. In particular, we discuss the constraints that can be obtained on the MSSM parameters by the determination of the Higgs boson mass and couplings. In addition, we investigate the interplay with heavy Higgs searches, and evaluate how higher LHC luminosities and a future linear collider can help probing the pMSSM Higgs sector and reconstructing the underlying parameters.
Neutrino Physics - Posters / 1046

Calibration status of the SuperNEMO calorimeter

Authors: Hichem TedjditiNone; Cloé Girard-CarilloNone; Axel PinNone

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The SuperNEMO experiment aims at testing the Majorana nature of neutrinos, looking for the neutrinoless double beta decay. The final detector goal is to reach a sensitivity of $10^{20}$ years on the $0\nu\beta\beta$ decay half-life, i.e a Majorana neutrino mass of 50-100 meV. The first module of the SuperNEMO experiment is under construction at Laboratoire Souterrain de Modane (LSM), with 6.23 kg of $^{82}$Se. Electrons from disintegration are tracked when crossing the wire chamber, then their energies are measured by calorimetry. The calorimeter is composed of 712 optical modules, an assembly of large volume plastic scintillators, mainly coupled with 8 inch photomultipliers. It achieved a resolution of 8% FWHM in energy, and 400 ps in time at 1 MeV. The commissioning of the SuperNEMO calorimeter has begun in 2019. As photomultiplier signals are sampled by electronic boards, waveform parameter optimisations were implemented. The calorimeter response has been calibrated in energy using the internal $^{208}$Tl spectrum, and photomultipliers gain were equalised at 1 MeV. A Cobalt 60 source, emitting two gammas in coincidence, was used to determine the time resolution of all optical modules. The calorimeter performances of the first SuperNEMO module are presented.

Cloé Girard-Carillo, Hichem Tedjditi, Axel Pin, Malak Hoballah, Laurent Simard, Mathieu Bongrand, Christine Marquet, Yves Lemière, Emmanuel Chauveau, José Busto

Dark Matter Detection / 1048

Dark Matter - phonon scattering

Author: Simon Knapen

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Light dark matter interacting in a crystal or fluid must scatter off a collective excitation (phonon) rather than off individual nuclei. I will set up the appropriate low energy effective theory and show how to calculate the dark matter scattering rate for various dark matter models and target materials.
Diversity and Inclusion at Belle II

Author: Shanette De La Motte

Co-authors: Kay Kinoshita; Matthew Barrett

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The Belle II collaboration comprises over 1000 international high energy physicists, who investigate the properties of b-quarks and other particles at the luminosity frontier. In order to achieve our aim of a successful physics program, it is essential that we enable contributions from a diverse community, whether that be diversity in gender, sexuality, or disability, to name a few. 2018 saw the election of two officers to lead in this task, by promoting an inclusive atmosphere, raising awareness of diversity, and being a safe first point of call for issues of discrimination and harassment. This poster will summarise the above efforts, as well as examine the demographics of our community. We are committed to ensuring our scientific collaboration evolves towards being an accurate reflection of the global population.

Secondary track (number):

Computing and Data Handling / 1050

Parallelization for HEP Event Reconstruction

Authors: Sophie Berkman; Giuseppe Cerati; Matti Kortelainen; Allison Reinsvold Hall; Michael Wang; Brian Gravelle; Boyana Norris; Peter Elmer; Bei Wang; Steven R Lantz; Michael Reid; Daniel Sherman Riley; Peter Wittich; Mario Masciovecchio; Slava Krutelyov; Matevz Tadel; Frank Wuerthwein; Avi Yagil

1 Fermi National Accelerator Laboratory
2 Fermi National Accelerator Lab. (US)
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4 University of Oregon
5 Princeton University (US)
6 Cornell University (US)
7 Univ. of California San Diego (US)

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We report on developments targeting a boost in the utilization of parallel computing architectures in HEP reconstruction, particularly for LHC experiments and for neutrino experiments using Liquid Argon Time-Projection Chamber (LArTPC) detectors. Key algorithms in the reconstruction workflows of HEP experiments were identified and redesigned: charged particle track reconstruction for CMS, and hit finding for LArTPC detectors such as ICARUS and MicroBooNE. These algorithms are some of the most time-consuming steps of the event reconstruction, and optimizing their computational performance is key to defining the computing needs for the reconstruction software of the next-generation HEP experiments. With the use of advanced profiling tools and development techniques, the algorithms have been rewritten so that they can take full advantage of multi-threading and vectorization on modern multicore CPUs, while at the same time satisfying physics performance goals. On a single thread, the modified versions are faster than the original algorithms by a factor
ranging from 6 to 12x, depending on the application, and both the track reconstruction and hit finder algorithms have been integrated into the experiments’ reconstruction software. Portable implementations of the algorithms for usage at supercomputers and with heterogenous platforms have been explored.

I read the instructions:

Secondary track (number):

Dark Matter Detection / 1051

Axion-like particles and dark photons - hints from XENON1T and stellar cooling

Author: Felix Kahlhoefer

1 RWTH Aachen

Corresponding Author: kahlhoefer@physik.rwth-aachen.de

The recent excess of electron recoil events in XENON1T can be interpreted as the absorption of bosonic dark matter particles in the keV range such as axion-like particles or dark photons. The same particles could also be produced in astrophysical systems such as horizontal branch stars or white dwarfs and account for the anomalous cooling rates observed in these systems. In my talk I will investigate the possibility that these phenomena have a common origin and whether this interpretation is preferred over the background hypothesis from a statistical point of view.

I read the instructions:

Secondary track (number):

Strong Interactions and Hadron Physics / 1052

Central exclusive production of charged particle pairs in proton-proton collisions at sqrt(s)=200 GeV with the STAR detector at RHIC

Authors: Leszek Adamczyk; Rafal Sikora

1 AGH University of Science and Technology (PL)

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We report on the measurement of the Central Exclusive Production of charged particle pairs $h^+h^-$ ($h = \pi, K, p$) with the STAR detector at RHIC in proton-proton collisions at $\sqrt{s} = 200$ GeV. The charged particle pairs produced in the reaction $pp \rightarrow p' + h^+h^- + p'$ are reconstructed from the tracks in the central detector and identified using the specific energy loss and the time of flight method, while the forward-scattered protons are measured in the Roman Pot system. Exclusivity of the event is guaranteed by requiring the transverse momentum balance of all four final-state particles. Differential cross sections are measured as functions of observables related to the central hadronic final state and to the forward-scattered protons. They are measured in a fiducial region corresponding to the acceptance of the STAR detector and determined by the central particles’ transverse momenta and pseudorapidities as well as by the forward-scattered protons’ momenta. This fiducial region roughly corresponds to the square of the four-momentum transfers at the proton vertices in the range $0.04 \text{ GeV}^2 < -t_1, -t_2 < 0.2 \text{ GeV}^2$, invariant masses of the charged particle pairs up to a few
The measured cross sections are compared to phenomenological predictions based on the Double Pomeron Exchange (DPE) model. Structures observed in the mass spectra of $\pi^+\pi^-$ and $K^+K^-$ pairs are consistent with the DPE model, while angular distributions of pions suggest a dominant spin-0 contribution to $\pi^+\pi^-$ production.

For $\pi^+\pi^-$ production, the fiducial cross section is extrapolated to the Lorentz-invariant region, which allows decomposition of the invariant mass spectrum into continuum and resonant contributions. The extrapolated cross section is well described by the continuum production and at least three resonances, the $f_0(980)$, $f_2(1270)$, and $f_0(1500)$, with a possible small contribution from the $f_0(1370)$.

Fits to the extrapolated differential cross section as a function of $t_1$ and $t_2$ enabled extraction of the exponential slope parameters in several bins of the invariant mass of $\pi^+\pi^-$ pairs. These parameters are sensitive to the size of the interaction region.

**Secondary track (number):**

**Neutrinos from galactic sources**

*Author:* Viviana Niro

*Corresponding Author:* viviana.niro@apc.in2p3.fr

The HAWC telescopes has recently revealed new spectra for gamma-ray sources in the Galactic plane. In this talk I will review the possibility of detecting these sources at KM3 detectors. I will consider, with particular emphasis, the 2HWC J1825-134 source. Amongst the HAWC sources, it is indeed the most luminous in the multi-TeV domain and therefore is one of the first that should be searched for with a neutrino telescope in the northern hemisphere. I will show the prospects to detect this source at the KM3NeT detector and comment on the possibilities for others neutrino telescopes.

**Secondary track (number):**

**Fast Neutrino Flavor Conversion at Late Time**

*Author:* Soumya Bhattacharyya

1 *Tata Institute Of Fundamental Research*

*Corresponding Author:* soumyaastroparticle@gmail.com

The rate of neutrino oscillations is typically dictated by the vacuum oscillation frequency, $\omega$, and the matter potential, $\lambda$. Until the early 2000s, it was believed that this paradigm was sufficient to describe neutrino oscillations inside supernovae, as well. At that time, the outstanding problem of the field appeared to be an understanding of the effect of large and rapid changes in the background matter density. But later it became clear that the issue is more subtle. Owing to the large neutrino density, even free-streaming neutrinos experience significant forward-scattering off other neutrinos. Such scattering leads to a self-interaction potential, $\mu \gg \omega$, that is proportional to the neutrino density,
and can dominate over the vacuum term resulting in exciting nonlinear phenomena like rapid and complete neutrino flavor conversion of broadly two types: slow” collective and fast” conversion. Slow” collective effects occur with an intrinsic rate $\sim \sqrt{\omega_{\mu}}$ which are already faster than usual neutrino oscillations and can lead to a variety of new phenomena, e.g., synchronization, bipolar oscillations, spectral swaps, three-flavor effects, multi-angle effects, decoherence, and linear instabilities, including those that break symmetries of direction, space, and time. Fast” flavor conversions are much more rapid occurring with a frequency $\sim \mu$, and might have a drastic effect of interest to neutrino physics as well as supernova astrophysics.

The flavor evolution of a dense neutrino gas is governed by a large number of coupled nonlinear partial differential equations. These are almost always very difficult to solve. Although the linear stability analysis of such nonlinear flavor conversions has been studied which is useful to ascertain if or when such conversions take place. But it cannot directly answer the question about the impact of such flavor conversions on the observable neutrino fluxes or supernova explosion mechanism.

This requires understanding the nature of the system in the full nonlinear regime and is quite non-trivial. Moving towards this direction we study the fast flavor evolution of a non-stationary and inhomogeneous system of dense neutrinos at late times when the system becomes fully nonlinear. We find at late times the polarization vectors associated with the flavor dynamics of such systems become steady in time. Using this steady state approximation we show that the spatial variation of the polarization vectors is given by their precession around a gyrating flavor pendulum with a fixed length, spin, and energy. The polarization vectors, when averaged over space, however, exhibit complete (partial) decoherence for zero (nonzero) lepton asymmetry. For partial decoherence, the non-vanishing range of velocity modes are dictated by conservation of lepton numbers. This kinematic decoherence stems from randomization of the orientations of the transverse components of the polarization vectors.

Untagged analysis of $B \rightarrow \pi l \bar{\nu}$ and first measurement of $|V_{ub}|$ at Belle II

Author: Svenja Granderath

1 Rheinische Friedrich-Wilhelms-Universität Bonn

Corresponding Author: sgranderath@uni-bonn.de

A long standing discrepancy between the results of exclusive and inclusive measurements of the CKM matrix element $|V_{ub}|$ exists. The charmless semileptonic decay $B \rightarrow \pi l \bar{\nu}$ is one of the most accessible and powerful channels for determining $|V_{ub}|$ in exclusive modes at $e^+e^-$ B-factories. Using data from the Belle II experiment, a new precision measurement of $|V_{ub}|$ becomes possible. In preparation for first precision measurements, an untagged measurement method for extracting $B \rightarrow \pi l \bar{\nu}$ events is developed. Lepton and pion candidates are combined to form $B \rightarrow \pi l \bar{\nu}$ candidates. In order to increase the purity, a series of selections is imposed to suppress continuum and other backgrounds. Signal is extracted from a fit to the two-dimensional $AE$ and $M_{bc}$ distribution in bins of the momentum transfer squared of the $B$-meson to the pion final state. A simultaneous form factor fit to the measured partial branching fractions and lattice QCD input is carried out to determine values of $|V_{ub}|$. 

I read the instructions:
Neutrino Physics - Posters / 1057

Antineutrinos from the Sun and sterile neutrino decays

Author: Matheus Hostert

1 University of Minnesota

Corresponding Author: mhostert@umn.edu

Searches for solar antineutrinos from $\nu \rightarrow \bar{\nu}$ conversions of $B^8$ neutrinos are highly sensitive to any source of MeV antineutrinos from the Sun. In this work we adapt these searches to non-minimal neutrino decay models recently discussed in the context of the LSND, MiniBooNE, and reactor anomalies. The production of such sterile neutrinos in the Sun, followed their cascade-like decays $\nu_4 \rightarrow \nu \phi \rightarrow \nu \nu \tau$ via a new scalar $\phi$ results in upper limits for the neutrino mixing $|U_{e4}|^2$ of a few per mille. We then conclude with future prospects for Super-Kamiokande with added Gadolinium and comment on other interesting models for such decays.

Secondary track (number):

I read the instructions:
Yes

Neutrino Physics / 1059

Astrophysical Visible Neutrino Decay

Author: Peter Denton

1 Brookhaven National Laboratory

Co-author: Asli Abdullahi

2 Institute for Particle Physics Phenomenology (IPPP), Durham University

Corresponding Authors: asli_abdullahi@hotmail.co.uk, peterbd1@gmail.com

Neutrino decay modifies neutrino propagation in a unique way; not only is there flavor changing as there is in neutrino oscillations, there is also energy transport from initial to final neutrinos. The most sensitive direct probe of neutrino decay is currently IceCube which can measure the energy and flavor of neutrinos traveling over extragalactic distances. For the first time we calculate the flavor transition probability for the cases of visible and invisible neutrino decay, including the effects of the expansion of the universe, and consider the implications for IceCube. As an example, we demonstrate how neutrino decay addresses a tension in the IceCube data.

Secondary track (number):
Beyond the Standard Model / 1060

Search for millicharged particles at the LHC with the milliQan prototype

Author: Matthew Daniel Citron

1 Univ. of California Santa Barbara (US)

Corresponding Author: matthew.citron@cern.ch

In this talk, I will present the results of a recent search for fractionally charged particles using a data sample of proton-proton collisions provided by the CERN Large Hadron Collider in 2018. This search was carried out with a prototype scintillator-based detector, which allows the first sensitivity to particles with charges $\leq 0.1e$ at a hadron collider. The existence of new particles with masses between 20 and 4700 MeV is excluded at 95% confidence level for charges between 0.006e and 0.3e, depending on their mass. New sensitivity is achieved for masses larger than 700 MeV. I will discuss the concept of the experiment, the results of the search, and the plan for the full milliQan detector given the successful operation of the prototype.

Secondary track (number):
13

Quark and Lepton Flavour Physics - Posters / 1062

Measurement of CP Violation in the $B_0$ to $J/\psi (\mu^+\mu^-)\phi(K^+K^-)$ decay with 2017 and 2018 data in CMS

Author: Muhammad Alibordi

1 Indian Institute of Technology Madras (IN)

Corresponding Author: muhammad.muhammad.alibordi@cern.ch

Analysis details concerning the new CMS measurement of CP Violation in $B_0$ to $J/\psi$ phi decay with 2017 and 2018 13TeV data will be presented.

Secondary track (number):

I read the instructions:
Yes

Strong Interactions and Hadron Physics / 1063

HERA jet data in NNLO fits of HERAPDF and diffractive PDFs
NNLO predictions for jet production in Deep Inelastic Scattering have recently become available. These are used to extend the QCD HERAPDF2.0Jets fits, that were made to extract PDFs from inclusive HERA data and HERA jet data, from NLO to NNLO. In addition new jet data sets have become available since the publication of ERAPDF2.0 and these are also considered. A simultaneous fit to these data to extract PDFs and $\alpha_s$ results in a new NNLO determination of $\alpha_s(Z)$.

A new combined fit of diffractive parton distribution functions (DPDFs) to the H1 inclusive neutral-current and dijet production data in diffractive deep-inelastic scattering (DDIS) at next-to-next-to-leading order accuracy (NNLO) is presented. Compared to the previous HERA fits, the presented study includes the high-precision H1 HERA-II data, which represents 40 times higher luminosity for inclusive DDIS data sample and 6 times higher luminosity for the jet data, than previous studies by H1. In addition to the inclusive DDIS data at the nominal centre-of-mass energy $\sqrt{s} = 319$ GeV, also the inclusive data at 252 and 225 GeV are included into the fit. The inclusion of the most comprehensive dijet cross section data, together with their NNLO predictions, provide enhanced constraints to the gluon component of the DPDF. The extracted DPDFs are compared to the alternative existing DPDF at NLO accuracy, and are used to predict cross sections for a large number of the available dijet measurements.

I read the instructions: Yes

Strong Interactions and Hadron Physics / 1064

HERA data on azimuthal decorrelation and charged particle multiplicity spectra probing QCD dynamics and quantum entanglement effects

The azimuthal decorrelation angle between the leading jet and scattered lepton in deep inelastic scattering is studied with the ZEUS detector at HERA. The data was taken in the HERA II data-taking period and corresponds to an integrated luminosity of 330 pb$^{-1}$. Azimuthal angular decorrelation has been proposed to study the $Q^2$ dependence of the evolution of the transverse momentum distributions (TMDs) and understand the small-$x$ region, providing unique insight to nucleon structure. Previous decorrelation measurements of two jets have been performed in proton-proton collisions at very high transverse momentum; these measurements are well described by perturbative QCD at next-to-leading order. The azimuthal decorrelation angle obtained in these
studies shows good agreement with predictions from Monte Carlo models including leading order matrix elements and parton showers.

New experimental data on charged particle multiplicity distributions are presented, covering the kinematic ranges in momentum transfer $5 < Q^2 < 100 \text{ GeV}^2$ and inelasticity $0.0375 < y < 0.6$. The data were recorded with the H1 experiment at the HERA collider in positron-proton collisions at a centre-of-mass energy of 320 GeV. Charged particles are counted with transverse momenta $P_T > 150 \text{ MeV}$ and pseudorapidity $-1.6 < \eta_{\text{lab}} < 1.6$ in the laboratory frame, corresponding to high acceptance in the current hemisphere of the hadronic centre-of-mass frame. Charged particle multiplicities are reported on a two-dimensional grid of $Q^2, y$ and on a three-dimensional grid of $Q^2, y, \eta$. The observable is the probability $P(N)$ to observe $N$ particles in the given $\eta$ region. The data are confronted with predictions from Monte Carlo generators, and with a simplistic model based on quantum entanglement and strict parton-hadron duality.

Secondary track (number):

I read the instructions:

Yes
Plenary I / 1068

CMS highlights

Author: Roberto Carlin

1 Universita e INFN, Padova (IT)

Corresponding Author: roberto.carlin@cern.ch

Secondary track (number):

I read the instructions:

Plenary I / 1069

LHCb highlights

Author: Silvia Borghi

1 University of Manchester (GB)

Corresponding Author: silvia.borghi@cern.ch

Secondary track (number):

I read the instructions:

Plenary I / 1070

Latest Results from the AMS Experiment on the International Space Station

Corresponding Author: zhili.weng@cern.ch

Secondary track (number):

I read the instructions:

Plenary I / 1071

Formal theory development – Quantum fields, strings, and physical mathematics

Corresponding Author: psulkows@fuw.edu.pl
I will briefly review several important formal theory developments in quantum field theory and string theory that were reported at ICHEP conferences in past decades, explain how they led to the formation of a new field of physical mathematics, and discuss a few lines of research of current interest within this field, as well as their fascinating connections to various branches of contemporary mathematics.

Secondary track (number):

I read the instructions:

Plenary I / 1072

Higgs, experimental

Author: Chris Palmer

1 Princeton University (US)

Corresponding Author: christopher.allan.palmer@cern.ch

Secondary track (number):

I read the instructions:

Plenary I / 1073

Theory (SM Higgs, top, EW)

Corresponding Author: fabio.maltoni@cern.ch

Secondary track (number):

I read the instructions:

Plenary I / 1074

Accelerators for HEP: Challenges and R&D

Author: Vladimir Shiltsev

1 Fermilab

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Secondary track (number):

I read the instructions:
Plenary II / 1075

Strong interactions and hadron physics (experiment)

**Corresponding Author:** david.d'enterria@cern.ch

**Secondary track (number):**

I read the instructions:

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Plenary II / 1076

Exotic hadrons

**Author:** Xiaoyan Shen

1 IHEP Beijing

**Corresponding Author:** xiaoyan.shen@cern.ch

**Secondary track (number):**

I read the instructions:

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Plenary II / 1077

Strong interactions and hadrons, theory

**Author:** Marek Karliner

1 TAU

**Corresponding Author:** marek@tauex.tau.ac.il

**Secondary track (number):**

I read the instructions:

---

Plenary II / 1078

Heavy ions, experimental overview

**Author:** Yvonne Chiara Pachmayer

1 Ruprecht Karls Universitaet Heidelberg (DE)

**Corresponding Author:** yvonne.chiara.pachmayer@cern.ch

**Secondary track (number):**
Plenary II / 1079

Heavy ions, theory

Author: Urs Wiedemann\textsuperscript{1}

\textsuperscript{1} CERN

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Secondary track (number):

I read the instructions:

Plenary II / 1080

CMB, cosmology, other astroparticle physics

Author: David P. Kirkby\textsuperscript{None}

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Secondary track (number):

I read the instructions:

Plenary II / 1081

High-energy cosmic particles

Author: Silvia Mollerach\textsuperscript{1}

\textsuperscript{1} CONICET

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Secondary track (number):

I read the instructions:

Plenary II / 1082

Particle-like Dark Matter

Author: Lauren Hsu\textsuperscript{1}

\textsuperscript{1} CERN
Plenary II / 1083

Wave-like Dark Matter and Axions

Author: Chelsea Bartram

Corresponding Author: chelsea.bartram@gmail.com

Secondary track (number):

I read the instructions:

Plenary II / 1084

Dark matter theory

Corresponding Author: ekuflik@gmail.com

Secondary track (number):

I read the instructions:

Plenary II / 1085

C11 Report

Author: Heidi Marie Schellman

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Secondary track (number):

I read the instructions:

Plenary II / 1086

YSP 2020 award 1
Corresponding Author: bsafdi@umich.edu
Secondary track (number):
I read the instructions:

Plenary II / 1087

YSP 2020 award 2
Corresponding Author: marco.toliman.lucchini@cern.ch
Secondary track (number):
I read the instructions:

Plenary III / 1088

SUSY
Author: Cristina Botta¹

¹ Universitaet Zuerich (CH)
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Secondary track (number):
I read the instructions:

Plenary III / 1089

Exotics
Author: Viviana Cavaliere¹

¹ Brookhaven National Lab
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Secondary track (number):
I read the instructions:

Plenary III / 1090

Top/EW/SM
Plenary III / 1091

CPV and CKM: Experimental Overview

Author: Doris Kim

1 Soongil University

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Secondary track (number):

I read the instructions:

Plenary III / 1092

BSM Theory

Corresponding Author: alfonso.zerwekh@usm.cl

Secondary track (number):

I read the instructions:

Plenary III / 1093

Rare decays of B and D mesons

Author: Yasmine Sara Amhis

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Secondary track (number):

I read the instructions:
Plenary III / 1094

Rare decays of K mesons

Author: Giuseppe Ruggiero¹

¹ Lancaster University (GB)

Corresponding Author: giuseppe.ruggiero@cern.ch

Plenary III / 1095

Charged lepton flavor: Experimental overview

Author: Toshinori Mori¹

¹ University of Tokyo (JP)

Corresponding Author: mori@icepp.s.u-tokyo.ac.jp

Plenary III / 1096

Flavor theory & outlook

Corresponding Author: ghiller@physik.uni-dortmund.de

Plenary III / 1097

Detector R&D’s

Corresponding Author: paula.collins@cern.ch
Industry activities

Corresponding Author: massimo.caccia@uninsubria.it

Secondary track (number):

I read the instructions:

Neutrino oscillation parameter measurements

Author: Zhe Wang

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Secondary track (number):

I read the instructions:

CPV in the neutrino sector

Author: Atsuko Ichikawa

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Corresponding Author: ichikawa.atsuko.6e@kyoto-u.ac.jp

Secondary track (number):

I read the instructions:

LNV and neutrino masses

Author: Bjoern Lehnert

1 Berkeley Lab

Corresponding Author: bjoernlehnert@gmail.com

Secondary track (number):
Plenary IV / 1102

Future neutrino experiments and outlook

Author: Sowjanya Gollapinni

1 Los Alamos National Laboratory (US)

Corresponding Author: sowjanya@lanl.gov

Secondary track (number):

I read the instructions:

Plenary IV / 1103

Future collider projects

Author: Jorgen D'Hondt

1 Vrije Universiteit Brussel (BE)

Corresponding Author: jorgen.dhondt@cern.ch

Secondary track (number):

I read the instructions:

Plenary IV / 1104

Report on the European PP Strategy Update

Corresponding Author: halina.abramowicz@cern.ch

Secondary track (number):

I read the instructions:

Plenary IV / 1105

ICFA Report

Corresponding Author: geoffrey.taylor@cern.ch
Plenary IV / 1106

Computing & S/W

Author: James Catmore

1 University of Oslo (NO)

Corresponding Author: james.catmore@cern.ch

Secondary track (number):
I read the instructions:

Plenary IV / 1107

Outreach & Education

Corresponding Authors: abreu@lip.pt, pedro.abreu@cern.ch

Secondary track (number):
I read the instructions:

Plenary IV / 1108

Diversity and inclusion

Author: Jonas Rademacker

1 University of Bristol (GB)

Corresponding Author: jonas.rademacker@bristol.ac.uk

Secondary track (number):
I read the instructions:

Plenary IV / 1109

Conference Summary and Outlook

Corresponding Author: paris.sphicas@cern.ch

Secondary track (number):
I read the instructions:
Wrap-up and thanksgiving

Corresponding Author: zdenek.dolezal@cern.ch

Dark Matter Detection / 1111

New Inelastic Channels for Sub-GeV Dark Matter Scattering

Author: Yonatan Kahn

1 University of Illinois

Corresponding Author: yfkahn@illinois.edu

As the search for dark matter continues down to lower and lower masses, the kinematics of sub-GeV dark matter scattering require moving beyond the approximation of free-particle scattering. I will describe two inelastic channels relevant for sub-GeV dark matter detection which necessarily involve the condensed matter properties of common detector materials: the Migdal effect in liquid nobles, and plasmon excitation in semiconductors. I will outline the theoretical basis for these processes, discuss the importance of many-body effects in accurately predicting the scattering rates, and speculate on whether these processes have already been observed at numerous experiments.

Secondary track (number):

I read the instructions:

Yes

Neutrino Physics / 1112

Neutrino oscillations, flavor theories and dark matter

Author: Jose Valle

Corresponding Author: valle@ific.uv.es

After a brief review of the status of neutrino oscillation experiments I discuss some recent results on flavor extensions of the standard model and their possible implications for dark matter.

Secondary track (number):

I read the instructions:

Yes
Formal Theory / 1114

On soft theorems in multiflavour galileon theories

Corresponding Author: karol.kampf@cern.ch

We will first review the amplitudes of single Galileon theories with focus on the soft theorems. Both tree-level and one-loop level amplitudes will be studied. Generalization of multiflavour extension will be briefly discussed.

Diversity and Inclusion / 1115

Difficulty of Science in times of pandemic

Authors: Anders Garritt Knospe\textsuperscript{1}; Arantza De Oyanguren Campos\textsuperscript{2}; Clemencia Mora Herrera\textsuperscript{3}; Radek Zlebcik\textsuperscript{4}; Meenakshi Narain\textsuperscript{5}

\textsuperscript{1} University of Houston (US)
\textsuperscript{2} Univ. of Valencia and CSIC (ES)
\textsuperscript{3} Universidade do Estado do Rio de Janeiro (BR)
\textsuperscript{4} Deutsches Elektronen-Synchrotron (DE)
\textsuperscript{5} Brown University (US)

Corresponding Authors: meenakshi.narain@cern.ch, zlebcik@ipnp.mff.cuni.cz, anders.knospe@cern.ch, clemencia.mora.herrera@cern.ch, arantza.de.oyanguren.campos@cern.ch

During COVID-19 pandemic, the science community has turned all the efforts in helping: HEP laboratories have transformed into ventilators and mask manufacturers, computing data centers have invested their resources to understand the virus behind COVID-19 better, etc...

However, on the other side of the coin, there are new daily life challenges faced by researchers. In this talk we will talk about the difficulties faced by researchers in these circumstances. The effects of confinement on, families, job contracts, career development, travel constraints and working conditions can be intricate.

We will also talk on how the pandemia is having a global impact in our research field. Post COVID-19 consequences on, conferences, collaboration meetings, travelling and reactions from funding agencies, are some of the topics that will be discussed.

Secondary track (number):

I read the instructions:

Yes

IUPAP C11 / 1116

Introduction and C11 matters

Corresponding Authors: heidi.schellman@oregonstate.edu, canelli@physik.uzh.ch, nojiri@post.kek.jp
IUPAP C11 / 1117

Report from the LHCP series (LHCP2020, LHCP2021)

Corresponding Author: tulika.bose@cern.ch

IUPAP C11 / 1118

Report from the Neutrino series (Neutrino2020)

Corresponding Author: marshak@umn.edu

IUPAP C11 / 1119

Report from TIPP series

Corresponding Author: isabel.trigger@cern.ch

IUPAP C11 / 1120

Report from CHEP2021 (Jefferson Lab)

Corresponding Authors: heyes@jlab.org, amber@jlab.org

Secondary track (number):

I read the instructions:

IUPAP C11 / 1121

Report from WIN2021 (Minnessotta)

Corresponding Author: marshak@umn.edu

Secondary track (number):

I read the instructions:

IUPAP C11 / 1122

Report from LP2019

Corresponding Authors: william.trischuk@cern.ch, hirohisa.tanaka@cern.ch
IUPAP C11 / 1123

Report from ICHEP2020 (online-Prague) + ICHEP2024
Corresponding Author: zdenek.dolezal@cern.ch

IUPAP C11 / 1124

Report from ICHEP2022 (Bologna)
Corresponding Author: lorenzo.bellagamba@cern.ch

IUPAP C11 / 1125

Report from ICHEP2024 (Prague)
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IUPAP C11 / 1126

Report from LP2021

IUPAP C11 / 1127

Report from ICHEP2022 (Bologna)

IUPAP C11 / 1128

Report from ICHEP2024 (Prague)
ICHEP 2020 / Book of Abstracts

IUPAP C11 / 1129

Proposals LP2023

Corresponding Author: ulrik.ege@monash.edu

IUPAP C11 / 1130

ICFA report - executive session

IUPAP C11 / 1131

Executive session

ERC Information Session / 1132

Welcome and Overview of ERC grants and the application

Corresponding Author: christian.oswald@ec.europa.eu

ERC Information Session / 1133

ERC story: Discovery strategies for Dark Matter and new phenomena in hadronic signatures with the ATLAS detector at the Large Hadron Collider

Corresponding Author: caterina.doglioni@cern.ch

ERC Information Session / 1134

ERC story: Catastrophic Interactions of Binary Stars and the Associated Transients

ERC Information Session / 1135

Role of National Contact Points for ERC grants and the support offered by the Czech NCP
ERC Information Session / 1136

Q&A and discussion

IUPAP C11 / 1137

Report from LP2021

Corresponding Author: marco.gersabeck@cern.ch

1138

PUBLIC LECTURE: Understanding our Universe with Gravitational Waves (broadcast on Youtube, moderator M. Yexley)

Corresponding Author: barish@ligo.caltech.edu

Broadcast on Youtube
Moderator of the discussion: Melissa Yexley

Secondary track (number):

I read the instructions:

General Public / 1139

Live underground visit to the ATLAS experiment at CERN, Switzerland

General Public / 1140

A Day with Particles... Cartoon/Live Film

General Public / 1141

What a State We’re In! : Participatory Show

General Public / 1142
The Internet of Wild Things: Acoustics & A.I.

General Public / 1143

The Physics of Beer: Participatory Workshop

General Public / 1144

60 years in Space: The Past and Future

General Public / 1145

Universal Science

General Public / 1146

Virtual Mixer

General Public / 1147

ColliderScope Music

Plenary I / 1148

Welcome address of the Deputy Prime Minister

Secondary track (number):

I read the instructions:

Plenary I / 1149

Welcome address of the Minister of Education, Youth and Sports
Plenary I / 1150

Welcome address of the President of the Czech Academy of Sciences

Secondary track (number):

I read the instructions:

Plenary I / 1151

Welcome address of the Rector of the Czech Technical University in Prague

Corresponding Author: vojtech.petracek@cern.ch

Plenary I / 1152

Welcome address of the Rector of the Charles University

Diversity and Inclusion / 1153

Discussion session

Diversity and Inclusion / 1154

Discussion session

Discussion session: panel A / 1155

ATLAS, ALICE and CMS highlights

Plenary I / 1156

Welcome address of the special guest
Plenary IV / 1157

ICHEP2022

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