

# 6th International Conference on New Frontiers in Physics (ICNFP2017)

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## Book of Abstracts



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**A Particle Physics / 1208**

## **Azimutal angular correlations in high energy processes in QCD**

**Author:** Jamal Jalilian-Marian<sup>1</sup>

<sup>1</sup> *Baruch College/Ecole Polytechnique*

**Corresponding Author:** jamal.jalilian-marian@baruch.cuny.edu

We study azimuthal angular correlations among final state particles produced in high energy processes in QCD and show that these correlations are a sensitive probe of dynamics of QCD at small  $x$ .

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1265**

## **The Quark Parton Model of the Nucleon - Missing Links**

**Author:** Gerassimos Petratos<sup>1</sup>

<sup>1</sup> *Kent State University*

**Corresponding Author:** gpetrato@kent.edu

To be submitted

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1435**

## **Chiral fluids: a few theoretical issues**

**Author:** Valentin Zakharov<sup>1</sup>

<sup>1</sup> *Institute for Theoretical and Experimental Physics (RU)*

**Corresponding Author:** vzakharov@itep.ru

We consider chiral fluids, with (nearly) massless fermionic constituents, in the confining phase. Chiral vortical effect (CVE) is the flow of axial current along the axis of rotation of the fluid while the spin alignment is a non-vanishing correlation of polarizations of baryons with the axis of rotation.

As the theoretical framework we use the model of pionic superfluidity induced by a non-vanishing isotopic chemical potential. We note that the average value of spin of virtual baryons reproduces the CVE. The role of defects, or vortices is crucial. The model does not apply directly to the quarkgluon

plasma but might indicate existence of a mechanism to produce baryons with relatively large polarization in heavy-ion collisions.

**Topic::**

**Summary:**

**A Particle Physics / 1452**

## **What Physics Beyond the Standard Model?**

**Author:** John Ellis<sup>1</sup>

<sup>1</sup> *CERN*

**Corresponding Author:** johnellis@fastmail.fm

TBA

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 977**

## **ATLAS overview highlight talk**

**Author:** Lorenzo Bellagamba<sup>None</sup>

**Corresponding Author:** lorenzo.bellagamba@cern.ch

plenary talk : ATLAS overview highlight talk

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1189**

## **Jet and photon production and extraction of $\alpha_s$ at HERA.**

**Author:** Radek Zlebcik<sup>1</sup>

<sup>1</sup> *Deutsches Elektronen-Synchrotron (DE)*

**Corresponding Author:** radek.zlebcik@cern.ch

Measurements of jet and photon production in  $ep$  collisions at HERA are presented, each analysis based on data with an integrated luminosity of about  $300 \text{ pb}^{-1}$ .

Inclusive jet, dijet and trijet cross sections are measured by the H1 collaboration in deep inelastic scattering, with virtualities of the photon exchange between  $5.5$  and  $15000 \text{ GeV}^2$ . The data are compared to NLO, approximative NNLO and full NNLO QCD predictions. The strong coupling constant is extracted at NNLO precision using the inclusive jet and dijet data.

The production of prompt photons accompanied with jets is measured by the ZEUS collaboration in deep-inelastic scattering. Cross sections are studied differentially in several kinematics variables.

The azimuthal angle difference and the pseudorapidity difference between the prompt photon and the leading jet is particularly sensitive to possible higher order effects.

The cross sections are compared to two alternative theoretical models: NLO QCD predictions based on collinear PDFs and the calculations using  $k_T$ -factorization approach.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1447**

## LHCb overview

**Author:** Yasmine Sarah Amhis<sup>1</sup>

<sup>1</sup> *Unknown*

**Corresponding Author:** yasmine.sarah.amhis@cern.ch

LHCb overview

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1453**

## CMS Overview

**Corresponding Author:** malgorzata.kazana@cern.ch

**Topic::**

**Summary:**

**A Particle Physics / 1329**

## Physics perspectives of PANDA at FAIR

**Author:** Johan Messchendorp<sup>None</sup>

**Corresponding Author:** j.g.messchendorp@rug.nl

The non-perturbative nature of the strong interaction leads to spectacular phenomena, such as the formation of hadronic matter, color confinement, and the generation of the mass of visible matter. To get deeper insight into the underlying mechanisms remains one of the most challenging tasks within the field of subatomic physics. The antiProton ANnihilations at DArmstadt (PANDA) collaboration has the ambition to address key questions in this field by exploiting a cooled beam of antiprotons at the High Energy Storage Ring (HESR) at the future Facility for Antiproton and Ion Research (FAIR) combined with a state-of-the-art and versatile detector. This contribution will address some of the unique features of PANDA that give rise to a promising and long-term physics program together with state-of-the-art technological developments.

**Topic::**

Mini-workshop: FAIR-NICA-SPS-BES RHIC Physics

**Summary:**

I presume that this invited talk on Panda was intended for the mini workshop related to new facilities. Feel free to move it to another session, if the organizers wish to do so.

**A Particle Physics / 1111**

## Exotica searches at CMS

**Author:** Anastasia Karavdina<sup>1</sup>

<sup>1</sup> *Hamburg University (DE)*

**Corresponding Author:** anastasia.karavdina@desy.de

An overview of the results of the experimental searches for exotica at the CMS experiment with 13 TeV collision data is presented. The results cover various models with different topologies such as searches for new heavy resonances, extra space dimensions, black holes and leptoquarks.

**Topic::**

Mini-workshop: Latest Results and New Physics in the Higgs Sector

**Summary:**

**A Particle Physics / 982**

## Hunting New Physics with ATLAS [ATLAS]

**Author:** Vasiliki Mitsou<sup>1</sup>

<sup>1</sup> *IFIC Valencia & CERN*



**Corresponding Author:** vasiliki.mitsou@cern.ch

Highlights from recent new physics searches with the ATLAS detector at the CERN LHC will be presented. They include searches for extra-dimension models, compositeness, new gauge bosons, leptoquarks, supersymmetry, among others. Results are based on analysis of pp collision data recorded at a centre-of-mass energy of 13 TeV.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1482**

## Scale hierarchies in particle physics and cosmology

**Author:** Ignatios Antoniadis<sup>1</sup>

<sup>1</sup> *Ecole Polytechnique*

**Corresponding Author:** ignatios.antoniadis@cpht.polytechnique.fr

Scale hierarchies in particle physics and cosmology

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1478**

## New Searches in High Energy Particle Physics

**Author:** Alexandra Carvalho Antunes De Oliveira<sup>1</sup>

<sup>1</sup> *UNESP - Universidade Estadual Paulista (BR)*

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

Summary of the workshop

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1449**

## Gauge Theories and non-Commutative Geometry. A review

**Author:** Jean Iliopoulos<sup>1</sup>

<sup>1</sup> LPTENS

**Corresponding Author:** ilio@lpt.ens.fr

TBA

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1490**

## Prediction and discovery of doubly-heavy baryon

**Author:** Marek Karliner<sup>1</sup>

<sup>1</sup> Tel Aviv U.

**Corresponding Author:** marek@post.tau.ac.il

Baryons are the extended family of the proton and the neutron, containing three quarks out of possible five progressively heavier “flavors” - up (u), down (d), strange (s), charm (c) and bottom (b). I will describe the prediction and the very recent experimental discovery of the first doubly-heavy baryon  $\Xi_{cc}^{++}$ , with quark content (ccu) and mass  $3621.40 \pm 0.72 \pm 0.27 \pm 0.14$  MeV, very close to our theoretical prediction  $3627 \pm 12$  MeV.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1200**

## Search for magnetic monopoles with the MoEDAL forward trapping detector in 13 TeV proton-proton collisions at the LHC

**Author:** Anthony Lioni<sup>1</sup>

<sup>1</sup> Universite de Geneve (CH)

**Corresponding Author:** anthony.eric.lionti@cern.ch

The MoEDAL experiment addresses a decades-old issue, the search for an elementary magnetic monopole, first theorised in 1931 by Dirac to explain electric charge quantisation. Since then it was showed that magnetic monopoles occur naturally in grand unified theories as solutions of classical equations of motion.

The dedicated experiment can enjoy a new energy regime opened at the LHC allowing direct probes of magnetic monopoles at the TeV scale for the first time.

In this talk, recent results obtained with 13 TeV proton-proton collision data at the MoEDAL experiments will be presented and discussed. MoEDAL pioneered a technique in which monopoles would be

slowed down in a dedicated aluminium array and the presence of trapped monopoles is probed by analysing the samples with a superconducting magnetometer, obtaining the first LHC constraints for monopoles carrying twice or thrice the Dirac charge.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1269**

## **: Possible origin(s) of RD(\*) flavor anomalies**

**Author:** Amarjit Soni<sup>1</sup>

<sup>1</sup> *Brookhaven National Lab*

**Corresponding Author:** adlersoni@gmail.com

Three key issues pertaining to the semi-leptonic RD(\*) anomalies will be addressed here:

- 1) How robust are the SM predictions?
- 2) What are the model-independent collider signature of these anomalies?
- 3) What are some of the simplest BSM explanations for these?

In answer to 1) latest information from on and off the lattice will be critically examined to question, in particular the reliability of the stated theory error.

Reg 2) It will be shown that the semi-leptonic anomalies rigorously imply unavoidable collider signatures that the LHC experimental community should ASAP vigorously pursue to confirm or refute these anomalies. Lastly, but nevertheless of considerable importance, reg 3), is the issue of what interesting, and theoretically well motivated, underlying extensions of the SM are that could be responsible for these anomalies assuming they withstand further scrutiny and the test of time.

This talk is based in significant part on work done and in progress with Wolfgang Altmannshofer and Bhupal Dev.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1450**

## **Precision RENORM / MBR Diffraction Predictions Tested by Recent LHC Results**

**Author:** Konstantin Goulianos<sup>None</sup>

**Corresponding Author:** konstantin.goulianos@cern.ch

TBA

**Topic::**

**Summary:**

A Particle Physics / 1203

## Latest results on diffraction at HERA

**Author:** Mariusz Przybycien<sup>1</sup>

<sup>1</sup> AGH University of Science and Technology (PL)

**Corresponding Author:** mariusz.przybycien@agh.edu.pl

Recent results on diffraction from the H1 and ZEUS experiments at HERA are presented. Measurement of open charm production in diffractive DIS has been performed by the H1 experiment using the event topology, given by  $ep \rightarrow eXY$ , where the system X, containing at least one  $D^*(2010)$  meson, is separated from a leading low-mass proton dissociative system Y by a large rapidity gap. The kinematics of  $D^*$  candidates are fully reconstructed in the  $D^* \rightarrow K\pi\pi$  decay channel. The measured cross sections are compared at the level of stable hadrons with NLO QCD predictions obtained in the massive scheme, where the charm quark is produced via the boson-gluon fusion. The calculations rely on the collinear factorization theorem and are based on diffractive parton densities previously obtained by H1 from fits of the inclusive diffractive cross sections. The measured data are further used to estimate the ratio of diffractive to inclusive open charm production in deep inelastic scattering. The photoproduction of isolated photons is measured using diffractive events recorded by the ZEUS experiment. Cross sections are evaluated in the photon transverse-energy and pseudorapidity ranges  $5 < E_{\gamma T} < 15$  GeV and  $-0.7 < \eta_{\gamma} < 0.9$ , inclusively and with a jet with transverse-energy and pseudorapidity in the ranges  $4 < E_{jet T} < 35$  GeV and  $-1.5 < \eta_{jet} < 1.8$ . A number of kinematic variables are studied and compared to predictions from the RAPGAP Monte Carlo model. In considering the fraction of the energy of the colourless (Pomeron) exchange that is transferred to the photon-jet final state,  $z_P$ , it is found that the data lie above the RAPGAP predictions for  $z_P > 0.9$ , giving evidence for direct-Pomeron interactions. The shapes of the kinematic distributions of events below and above this value of  $z_P$  are separately well described by RAPGAP. This and other features provide evidence for a universal set of parton distribution functions in the Pomeron. The exclusive deep inelastic electroproduction and photoproduction of  $\psi(2S)$  and  $J/\psi(1S)$  has been studied by ZEUS. The cross-section ratio  $\sigma(\psi(2S))/\sigma(J/\psi(1S))$  has been measured by ZEUS as a function of  $Q^2$ ,  $W$  and  $t$ . The results are compared to many predictions of QCD-inspired models, providing tests of the models in a region of soft to hard diffraction.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

A Particle Physics / 1389

## Overview talk on upgrades, future plans and prospects of the CMS experiment at the future HL-LHC

**Author:** Kerstin Hoepfner<sup>1</sup>

<sup>1</sup> RWTH Aachen

**Corresponding Author:** kerstin.hoepfner@cern.ch

To extend the LHC physics program, it is foreseen to operate the LHC in the future with an unprecedented high luminosity. To maintain the experiment's physics potential in such harsh environment, the detector components will be upgraded. At the same time the detector acceptance will be extended and new features such as a L1 track trigger will be implemented. Simulation studies evaluated the performance of the new, proposed detector components in comparison to the present detector. The impact of the expected phase-2 performance on representative physics channels is studied. Several new studies were performed recently to evaluate in detail rare Higgs decays and Higgs couplings. Standard model measurements such as precision measurement of the top mass will gain due to the

improved performance. The sensitivity to find new physics beyond the SM is improved and will allow to extend the SUSY reach, search for dark matter and exotic long-lived signatures.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1451**

## Future Prospects (ATLAS)

**Author:** Marcello Bindi<sup>None</sup>

plenary

The physics prospects at the luminosity upgrade of LHC, HL-LHC, with a data set equivalent to 3000 fb<sup>-1</sup> simulated in the ATLAS detector, are presented and discussed.

The ultimate precision attainable on measurements of 125 GeV Higgs boson couplings to elementary fermions and bosons is discussed, as well as the searches for partners associated with this new particle. The electroweak sector is further studied with the analysis of the vector boson scattering, testing the SM predictions at the LHC energy scale.

Supersymmetry is still one of the best motivated extensions of the Standard Model. The current searches at the LHC have yielded sensitivity to TeV scale gluinos and 1st and 2nd generation squarks, as well as to 3rd generation squarks. The sensitivity to electro-weakinos has reached the hundreds of GeV mass range. Benchmark studies are presented to show how the sensitivity improves at the future high-luminosity LHC runs.

Prospects for searches for new heavy bosons and dark matter candidates at 14 TeV pp collisions are explored, as well as the sensitivity of searches for anomalous top decays.

For all these studies, a parameterised simulation of the upgraded ATLAS detector response is used, taking into account the expected pileup conditions.

**Topic::**

**Summary:**

**A Particle Physics / 1053**

## GERDA: first background free search for neutrinoless double beta decay

**Authors:** Konstantin Gusev<sup>None</sup>; GERDA collaboration<sup>None</sup>

**Corresponding Author:** kngusev@gmail.com

GERDA (GERmanium Detector Array) experiment is designed to search for neutrinoless double beta decay with semiconductor detectors made from germanium enriched in <sup>76</sup>Ge. In GERDA for the first time ever detectors are directly immersed in liquid argon which works as a cooling medium and at the same time as an additional shield against external radioactivity. There are two phases of the GERDA experiment.

Phase I has employed coaxial detectors made from <sup>76</sup>Ge (total mass ~ 18 kg) adopted for liquid argon operations and has successfully finished in May 2013 after reaching the exposure of 20 kg yr. The background index in the region of interest was 0.01 counts/(keV kg yr). The half-life limit for  $0\nu\beta\beta$  decay  $> 2.1 \times 10^{25}$  years has been set (90% C.L.).

In the ongoing GERDA Phase II (started in December 2015) we have the possibility to detect scintillation light in liquid argon surrounding the detectors. Thus argon acts as active veto. In Phase II together with coaxial diodes about 20 kg of novel detectors (so-called BEGe) with enhanced pulse shape discrimination capability are being used to double the target mass. All this has helped to reach the unprecedented background index of 0.001 counts / (keV kg yr). No background event should be left in the energy region where the  $0\nu\beta\beta$  signal is expected until the end of data taking in 2019. Thereby GERDA is the first “background-free” experiment in the field. After the first five months of data taking (about 10 kg yr) no  $0\nu\beta\beta$  decays have been observed and a half-life limit has been improved to  $T_{1/2}^{0\nu} > 5.3 \times 10^{25}$  yr (90% C.L.). At the time of the Conference a total Phase II exposure of about 40 kg yr is planned to be available.

This talk is dedicated to provide an overview of the GERDA experiment and the physics results achieved in Phase II.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1092**

## Collective phenomena from high energy proton-proton to heavy-ion collisions at the LHC

**Author:** Daniele Fasanella<sup>1</sup>

<sup>1</sup> *Università and INFN, Bologna (IT)*

**Corresponding Author:** daniele.fasanella@cern.ch

The LHC offers an unprecedented environment where p-p, p-Pb and Pb-Pb collisions are produced at the largest ever collision energies, up to more than one order of magnitude larger than previously achieved. Experiments at LHC has probed the properties of the deconfined matter state expected in Heavy Ions collisions, with results compatible with an hydrodynamical description. What have been particularly striking are the findings in p-Pb and in high multiplicity events in p-p collisions, where similar features have been observed, starting from the CMS “ridge” in the long range near side angular correlation in 2010. This talk will give a wide review of the experimental results on collective phenomena for the CMS, ATLAS and ALICE experiments, connecting what have been observed in Heavy Ions collisions to the p-p results.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**A Particle Physics / 1032**

## Flavourful roads to New Physics

**Author:** Vladimir Gligorov<sup>1</sup>

<sup>1</sup> *Centre National de la Recherche Scientifique (FR)*

**Corresponding Author:** vladimir.gligorov@cern.ch

The absence of any direct signals of new particles or force carriers at the LHC forces us to contemplate the real possibility of what was called the nightmare scenario a decade ago : the LHC has found the Higgs, but the physics which lies beyond the Standard Model (BSM) also lies beyond its energy reach. A growing number of flavour physics anomalies, however, may not only be giving us a glimpse of BSM particles, but can also help us to understand their properties long before any direct detection is possible. In this talk I will review the current flavour physics anomalies and their possible interpretations, before describing how the upgrades of the LHCb detector will drive a precise understanding of these anomalies and any BSM physics which may be causing them. In particular, I will discuss the physics case for the recently proposed Phase II upgrade of the LHCb detector, which aims to collect 300fb<sup>-1</sup> of data at an instantaneous luminosity of 2e34cm<sup>-2</sup>s<sup>-1</sup> from 2031 onwards. Key to this physics case will be extending the full real-time analysis of the collected data, pioneered by LHCb since 2015, to the 1000 times greater data rate of the Phase II upgrade, and I will discuss this and the other technical challenges which will have to be overcome in order to fully understand what flavour is telling us about possible BSM physics and where it may be found.

**Topic::**

Topic: High Energy Particle Physics

**Summary:****A Particle Physics / 1502****Search for asymptotic QCD effects at collider energies****Author:** Victor Kim<sup>1</sup><sup>1</sup> *St. Petersburg Nuclear Physics Institute - PNPI, Gatchina***Corresponding Author:** victor.kim@cern.ch

TBA

**Topic::****Summary:****A Particle Physics / 1508****The Hyper-Kamiokande Experiment****Author:** Sandro Bravar<sup>1</sup><sup>1</sup> *Universite de Geneve (CH)***Corresponding Author:** alessandro.bravar@unige.ch

Hyper-Kamiokande (HK) is a next generation large underground water Cherenkov detector, based on the highly successful Super-Kamiokande experiment. HK is the logical continuation of the highly successful program of neutrino physics and proton decay searches using a water Cherenkov technique, with an order of magnitude larger mass than predecessor experiments. HK will offer a broad science program such as neutrino oscillation studies, proton decay searches, and neutrino astrophysics with unprecedented sensitivities. In this talk I'll present the current status of the HK project and discuss the physics potential of HK.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1470**

## **ATLAS and CMS prospects for Higgs measurements and searches at the high luminosity LHC**

**Author:** Rainer Mankel<sup>1</sup>

<sup>1</sup> *Deutsches Elektronen-Synchrotron (DE)*

**Corresponding Author:** rainer.mankel@cern.ch

The High Luminosity LHC (HL-LHC) targets a rich physics programme with a total integrated luminosity of 3000 fb<sup>-1</sup>. The collider will produce an unprecedented number of Higgs bosons, which will greatly improve the precision of measuring the properties of the state at 125 GeV. Also the reach of searches for additional Higgs bosons is considerably extended. This presentation will review projections from the ATLAS and CMS experiments for Higgs physics at the HL-LHC.

**Topic::**

Special Session: Astro-Cosmo-Gravity

**Summary:**

**A Particle Physics / 1506**

## **Searching for exotic long lived particles with dedicated experiments at the LHC**

**Author:** Albert De Roeck<sup>None</sup>

**Corresponding Author:** deroeck@mail.cern.ch

The Large Hadron Collider has opened a new energy frontier for searches for new physics. Initial results of the 13 TeV run have not yet revealed signals for new physics in ATLAS, CMS, LHCb and MoEDAL. Of particular interest are searches for long lived particles, for which the the LHC detectors have developed a comprehensive search program during the past years.

Do these detectors allow us to search at all places where such physics could show up? In this presentation we look at some scenarios where small dedicated experiments will allow to considerably extend our search horizon. The explicit examples of the proposed MilliQan experiment - a search for millicharge particles- and the MATHUSLA experiment - a search for ultra-long lived particles that decay well outside the CMS and ATLAS detectors, will be discussed. These experiments are of a similar type as the already approved and running MoEDAL experiment - a search for monopoles - which also considers the extension for searched for long lived particles

**Topic::**

Mini-workshop: Latest Results and New Physics in the Higgs Sector

**Summary:**



**A Particle Physics / 1201**

## Summary of the Workshop on Exotic Hadrons

**Author:** Tomasz Skwarnicki<sup>1</sup>

<sup>1</sup> *Syracuse University (US)*

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While most of known hadrons fit the minimal quark model, with  $q\bar{q}$  mesons and  $qqq$  baryons, experimental evidence for “exotic” hadrons, with more quarks or with gluons as constituents have been mounting, especially over the last decade. Reviewing the status of known exotic hadron candidates together with their interpretation, as well as of on-going and future searches for them, is a subject of the Workshop on Exotic Hadrons, which is a part of ICNFP2017. We will summarize the workshop, which will serve as a review of exotic hadron spectroscopy.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1383**

## Review of neutrino properties

**Author:** Peter Minkowski<sup>1</sup>

<sup>1</sup> *AEC-ITP, University of Bern*

**Corresponding Author:** peter.minkowski@cern.ch

The main results on oscillations from experiments and analyses are reviewed and updated.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

The proposed talk shall pass in revue the achieved results on the masses and mixing angles of the neutrino mass matrix as observed and analyzed up to the present .

**A Particle Physics / 1223**

## Probing the Origin of the Proton Spin at STAR

**Author:** Carl Gagliardi<sup>1</sup>

<sup>1</sup> *Texas A&M University*

**Corresponding Author:** cggroup@comp.tamu.edu

The STAR Collaboration at RHIC is exploring the partonic origin of the proton spin with a broad range of measurements in polarized  $pp$  collisions. STAR measurements of the longitudinal double-spin asymmetry,  $A_{LL}$ , for inclusive jet production in  $pp$  collisions at 200 GeV provide the first clear evidence that the gluons in the proton with  $x > 0.05$  are polarized. Recent follow-up studies include measurements of  $A_{LL}$  for inclusive jets in 510 GeV  $pp$  collisions, which push the sensitivity to gluon polarization down to  $x \sim 0.02$ , and measurements of  $A_{LL}$  for di-jet production at 200 and 510 GeV, which provide more precise information regarding the shape of  $x\Delta g(x)$ . STAR measurements of the transverse single-spin asymmetry,  $A_N$ , for  $W$  boson production provide the first experimental investigation of the non-universality of the Sivers function. Precise follow-up measurements of  $A_N$  for direct photon production, Drell-Yan di-electron production, and  $W$  boson production are underway that will both provide a definitive test of the non-universality and constrain evolution of transverse-momentum-dependent distributions (TMDs) over a very wide  $Q^2$  range. STAR measurements of interference fragmentation functions and the transverse single-spin dependence of the azimuthal modulation of pions in jets provide the first observations of transversity in  $pp$  collisions. The results enable tests of universality and factorization-breaking effects for TMDs in hadronic interactions. Additional transverse modulations provide limits on gluon linear polarization and the twist-3 analog of the gluon Sivers distribution. The current status of these analyses and the prospects to extend them in the near future will be discussed.

**Topic::**

Topic: High Energy Particle Physics

**Summary:****A Particle Physics / 948****PHENIX spin overview****Author:** Ralf Seidl<sup>1</sup><sup>1</sup> *RIKEN***Corresponding Author:** ralf.seidl@gmail.com

The spin program at the relativistic heavy ion collider RHIC set out to understand the contribution of gluon and sea quark spins to the total spin of the nucleon. In the PHENIX experiment gluon spins are being accessed via double longitudinal spin asymmetries of neutral final-state pions as well as other final state particles. Using center-of-mass collision energies from 62 to 510 GeV a clear, non-zero gluon polarization at intermediate  $x$  could be established. The analysis of final state particles in more forward rapidities also allows to study and constrain the spin contributions to lower  $x$ .

In order to access the sea quark spin contribution the production of real  $W$  bosons has been studied. The parity violation of the weak interaction allows to select the helicity of the participating quark-antiquark pair and the charge of the produced  $W$  boson selects the flavor. Single longitudinal spin asymmetries from leptonic  $W$  decays into electrons at central rapidities and muons at forward rapidities have been measured and indicate an asymmetric, polarized light sea.

Furthermore, large transverse single spin asymmetries once thought to be low energy effects persisted to the highest collision energies. They sparked substantial improvements in the understanding of the spin structure of the nucleon and its dynamics while the complete origin of these effects is still not entirely understood. Recent polarized proton-nucleus collisions allowed PHENIX to extend the asymmetry measurements to nuclei and new surprises, especially for forward neutron asymmetries were found.

This presentation will summarize the current status of the PHENIX spin program and a potential future extension.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**A Particle Physics / 1002****Searches for electroweak production of supersymmetric gauginos and sleptons with the ATLAS detector****Author:** Athina Kourkouveli-Charalampidi<sup>None</sup>**Corresponding Author:** athinakour@hotmail.com

Many supersymmetry models feature gauginos and also sleptons with masses less than a few hundred GeV. These can give rise to direct pair production rates at the LHC that can be observed in the data sample recorded by the ATLAS detector. The talk presents results from searches for gaugino and slepton pair production in final states with leptons or long-lived particles, using the data collected during the LHC Run 2.

**Topic::**

Topic: High Energy Particle Physics

**Summary:****A Particle Physics / 1121****Coherent Diffusive Photonics****Author:** Natalia Korolkova<sup>1</sup><sup>1</sup> *University of St. Andrews***Corresponding Author:** nvk@st-andrews.ac.uk

N. Korolkova, University of St. Andrews, UK; D. Mogilevtsev, Institute of Physics, Belarus Academy of Sciences, Belarus; S. Mukherjee, R. R. Thomson, Heriott-Watt University, UK.

The engineering of dissipation to a common reservoir generates a vast array of novel structures for photonic application and quantum simulation [1]. We suggest here novel possibilities for photonics that are generated by diffusive light propagation [2]. The dissipative coupling of bosonic modes can allow light to flow like heat, whilst retaining coherence and even entanglement. The Photonic Circuit has generally been a structure in which light propagates by unitary exchange and where photons transfer reversibly between channels. In contrast, the term 'diffusive' is more akin to a chaotic propagation in scattering media, where light is driven out of coherence towards a thermal mixture. We have devised a way to unite these opposites, founded from the dynamics of open quantum systems and resulting in novel techniques for coherent light control. The crucial feature of these photonic structures is dissipative coupling between modes; an interaction with a common reservoir. We demonstrate experimentally that such systems can perform optical equalisation to smooth multimode light, or act as a distributor, guiding it into selected channels. Quantum thermodynamically, these systems can act as catalytic coherent reservoirs by performing perfect non-Landauer erasure. When extending to lattice structures, localized stationary states can be supported in the continuum, similar to compacton-like states in conventional flat band lattices. In the future, we believe that diffusive photonic systems will find practical application both in studying the fundamental processes of structurally engineered open systems and in an array of integrated photonic technologies.

[1] G. M. Palma, K-A. Suominen, and A. K. Ekert: *Quantum Computers and Dissipation*, Proc. Roy. Soc. London Ser. A 452, 567 (1996).

[2] S. Mukherjee, D. Mogilevtsev, G. Ya. Slepyan, T. H. Doherty, R. R. Thomson, N. Korolkova: *Coherent Diffusive Photonics*, arXiv:1703.06025 [quant-ph] (2017).

**Topic::**

Topic: Quantum Physics, Quantum Optics and Quantum Information

**Summary:**

The dissipative coupling of bosonic modes can allow light to flow like heat, whilst retaining coherence and even entanglement. A linear system of dissipatively coupled waveguides can act as an optical equaliser, smoothing fluctuations in amplitude and phase towards a common output. Non-classical input will evolve into a completely symmetrized, correlated, state of the whole system. This equalising action has been experimentally demonstrated using laser inscribed waveguides. The system is of interest for the simulation of complex quantum many-body systems, for quantum thermodynamics and for photonics applications.

**B Heavy Ion Physics Session / 1026****Vorticity and global polarization in heavy ion collisions**

**Author:** Sergei Voloshin<sup>1</sup>

<sup>1</sup> *Wayne State University*

**Corresponding Author:** voloshin@wayne.edu

Ultrarelativistic nuclear collisions provide unique possibility to study the matter at extreme conditions not available in any other laboratory settings. These include highest temperature and energy density, strongest electro-magnetic fields, lowest viscosity over entropy density (ideal liquid) and, what is the main theme of this presentation, the highest vorticity, originating in the large angular momentum of the system. I will present the recent developments in understanding of the role of vorticity in high energy nuclear collision dynamics, as well as latest experimental measurements of the global polarizations - the particle spin alignment with the system orbital momentum. The relation of the global polarization effect to Barnett and Einstein-de Haas effects, as well as to chiral anomalous effects, both in nuclear collisions and condensed matter, will be also briefly discussed.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:****B Heavy Ion Physics Session / 1458****ALICE Overview**

**Author:** Torsten Dahms<sup>1</sup>

<sup>1</sup> *Technische Universitaet Muenchen (DE)*

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ALICE Overview

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**B Heavy Ion Physics Session / 1285**

## Heavy Ion Physics (ATLAS)

**Author:** Mariusz Przybycien<sup>1</sup>

<sup>1</sup> *AGH University of Science and Technology*

**Corresponding Author:** mariusz.przybycien@agh.edu.pl

The ATLAS experiment at the Large Hadron Collider has undertaken a broad physics program to probe and characterize the hot nuclear matter created in relativistic lead-lead collisions. This talk presents recent results on production of jet, electroweak bosons and quarkonium, electromagnetic processes in ultra-peripheral collisions, and bulk particle collectivity from Pb+Pb and p+Pb collisions.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**B Heavy Ion Physics Session / 1448**

## Heavy Ion Physics

**Author:** Emilie Maurice<sup>1</sup>

<sup>1</sup> *Universite de Paris-Sud 11 (FR)*

**Corresponding Author:** emilie.maurice@llr.in2p3.fr

Heavy Ion Physics (LHCb)

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**B Heavy Ion Physics Session / 1228**

## Overview of recent heavy-flavor and jet results from STAR

**Author:** Jaroslav Bielcik<sup>1</sup>

<sup>1</sup> *Czech Technical University (CZ)*

**Corresponding Author:** jaroslav.bielcik@fffi.cvut.cz

The STAR experiment has produced convincing evidence that strongly interacting partonic matter, Quark Gluon Plasma (QGP), is created in the

central collisions of heavy ions. Among the probes used experimentally to study the QGP properties, the hard probes: jets and heavy flavor quarks are unique since they are dominantly produced at the early stages of the collision and subsequently experience the entire evolution of the system. With its large and uniform acceptance STAR is well-equipped to study jets in the QGP matter. Moreover during recent years including the Heavy Flavor Tracker and the Muon Telescope Detector, STAR has launched a comprehensive heavy-flavor program which enables unique high precision measurements of charm and bottom quark and quarkonia properties. In this talk, recent STAR results on jets, open heavy flavor and quarkonia measurements will be discussed.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:****B Heavy Ion Physics Session / 1365****Status of the NICA project**

**Author:** Vladimir Kekelidze<sup>1</sup>

**Co-authors:** Viktor Matveev<sup>2</sup>; Alexander Sorin<sup>1</sup>; Grigory Trubnikov<sup>3</sup>; Richard Lednicky<sup>4</sup>; Igor Meshkov<sup>5</sup>; Alexander Kovalenko<sup>6</sup>

<sup>1</sup> *Joint Inst. for Nuclear Research (RU)*

<sup>2</sup> *Joint Institute for Nuclear Research (RU)*

<sup>3</sup> *JINR*

<sup>4</sup> *Joint Institute for Nuclear Research, Dubna, Russia*

<sup>5</sup> *Joint Institute for Nuclear Research (JINR)*

<sup>6</sup> *Joint Institute for Nuclear Research*

**Corresponding Authors:** alexander.sorin@cern.ch, trubnikov@jinr.ru, viktor.matveev@cern.ch, lednicky@fzu.cz, vladimir.kekelidze@cern.ch, meshkov@nu.jinr.ru, kovalen@dubna.ru

The project NICA (Nuclotron-based Ion Collider fAcility) is under realization at the Joint Institute for Nuclear Research. The main goals are to study hot and dense baryonic matter at the extreme conditions and to investigate nucleon spin structure. The plan of NICA accelerator block development include an upgrade of existing superconducting (SC) synchrotron Nuclotron, construction of new injection complex, SC Booster, and SC Collider with two interaction points (IP). The collider will provide heavy ion collisions in the energy range up to 11.0 A GeV (for gold) and up to 27 GeV (for polarized protons). The heavy ion collision program will be performed with the fixed target experiment Baryonic Matter at Nuclotron (BM@N) in the beam extracted from the Nuclotron, and with Multi Purpose Detector (MPD) at the first IP of NICA Collider. Investigation of nucleon spin structure and polarization phenomena is foreseen with Spin Physics Detector (SPC) at the second IP of the Collider.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:****B Heavy Ion Physics Session / 1271**

## Cosmic matter in the laboratory - the Compressed Baryonic Matter Experiment at FAIR

**Author:** Peter Senger<sup>1</sup>

<sup>1</sup> *GSI Darmstadt*

**Corresponding Author:** p.senger@gsi.de

The Compressed Baryonic Matter (CBM) experiment will be one of the major scientific pillars of the future Facility for Antiproton and Ion Research (FAIR) in Darmstadt. The goal of the CBM research program is to explore the QCD phase diagram in the region of high baryon densities using high-energy nucleus-nucleus collisions. This includes the study of the equation-of-state of nuclear matter at neutron star core densities, and the search for the deconfinement and chiral phase transitions. The CBM detector is designed to measure rare diagnostic probes such as hadrons including multi-strange (anti-) hyperons, lepton pairs, and charmed particles with unprecedented precision and statistics. Most of these particles will be studied for the first time in the FAIR energy range. In order to achieve the required precision, the measurements will be performed at very high reaction rates of 1 to 10 MHz. This requires very fast and radiation-hard detectors, a novel data read-out and analysis concept based on free streaming front-end electronics, and a high-performance computing cluster for online event selection. The status of FAIR and the physics program of the proposed CBM experiment will be discussed.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**B Heavy Ion Physics Session / 956**

## PHENIX Measurements of Charm and Bottom Decays

**Author:** Timothy Rinn<sup>1</sup>

<sup>1</sup> *Iowa State University*

**Corresponding Author:** trinn@iastate.edu

Heavy flavor quarks are a particularly good tool to probe nuclear collisions at RHIC energies, as they are produced dominantly through the initial parton-parton collision rather than during thermalization. This causes them to experience the full evolution of the collision system. PHENIX has produced several measurements of both bottom and charm quarks through their decays, providing insight to the mass dependent energy loss quarks experience while propagating through the Quark Gluon Plasma (QGP). This talk will focus on preliminary results of measurements of bottom and charm quarks through their semileptonic decays at  $\sqrt{s} = 200$  GeV including their nuclear modification factor ( $R_{AA}$ ) and measurements of the nuclear modification of B mesons through the  $B \rightarrow J/\psi$  decay.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**B Heavy Ion Physics Session / 1055**

## Correlations of anisotropic flow in relativistic heavy-ion collisions at the LHC

**Author:** You Zhou<sup>1</sup>

<sup>1</sup> *Niels Bohr Institute (DK)*

**Corresponding Author:** you.zhou@cern.ch

Anisotropic flow is one of the key observables used to probe the properties and evolution of the hot and dense matter produced in heavy-ion collisions. It was recently realized that event-by-event initial geometry fluctuations in heavy-ion collisions lead to a new type of correlation between different order anisotropic flow, which has unique sensitivity to initial conditions and shear viscosity over entropy density ratio  $\eta/s$ . In this talk, I discuss the correlation strength between various anisotropic flow harmonics, named (normalized-)symmetric cumulants, in both transport and hydrodynamic model calculations. In addition, the correlations between different order flow symmetry plane will be presented. The results can be naturally understood with recent development of non-linear hydrodynamic response of the created hot and dense matter to initial anisotropy coefficients. A detailed comparison of model calculations and recent experimental measurement, is also presented. Last but not least, I will show how to improve the current development of global Bayesian analysis on constraining the initial conditions and the extraction of the properties of the created QGP in relativistic heavy-ion collisions.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**C Quantum Optics and Quantum Information / 1250**

## Finally making sense of the double-slit experiment

**Authors:** Yakir Aharonov<sup>1</sup>; Eliahu Cohen<sup>2</sup>; Fabrizio Colombo<sup>None</sup>; Tomer Landsberger<sup>None</sup>; Sabadini Irene<sup>None</sup>; Daniele Struppa<sup>None</sup>; Jeff Tollaksen<sup>None</sup>

<sup>1</sup> *Tel Aviv University and Chapman University*

<sup>2</sup> *University of Bristol*

**Corresponding Authors:** yakir@post.tau.ac.il, eliahu.cohen@bristol.ac.uk

We put forth a time-symmetric interpretation of quantum mechanics that does not stem from the wave properties of the particle. Rather, it posits corpuscular properties along with nonlocal properties, all of which are deterministic. This change of perspective points to deterministic properties in the Heisenberg picture as primitive instead of the wave function, which remains an ensemble property. This way, within a double-slit experiment, the particle goes only through one of the slits. In addition, a nonlocal property originating from the other distant slit has been affected through the Heisenberg equations of motion. Under the assumption of nonlocality, uncertainty turns out to be crucial to preserve causality. Hence, a (qualitative) uncertainty principle can be derived rather than assumed.

This talk will be partially based on:

Y. Aharonov, E. Cohen, F. Colombo, T. Landsberger, I. Sabadini, D.C. Struppa, J. Tollaksen, Finally making sense of the double-slit experiment, Proceedings of the National Academy of Sciences (2017) doi: 10.1073/pnas.1704649114

**Topic::**

Topic: Quantum Physics, Quantum Optics and Quantum Information



**Summary:**

**C Quantum Optics and Quantum Information / 1431**

## **Boson sampling, quantum simulators and the quest for superior quantum devices**

**Author:** Jens Eisert<sup>1</sup>

<sup>1</sup> *FU Berlin*

**Corresponding Author:** jenseisert@gmail.com

Quantum simulators promise to give rise to new insights into dynamical and static properties of complex quantum systems, beyond what is available on classical supercomputers. There is already some good evidence that quantum simulators have the potential to outperform classical computers. Yet, in order to be prone against arguments claiming a lack of imagination, this superior computational capabilities should be expressed in terms of notions of computational complexity. One of the main milestones in quantum information science is hence to realize quantum devices that exhibit an exponential computational advantage over classical ones without being universal quantum computers in complexity theoretic terms, a state of affairs dubbed exponential quantum computational advantage or simply “quantum computational supremacy”. The paradigmatic boson samplers are devices of this type. We end the talk by discussing a number of surprisingly simple and physically plausible schemes that once realized show such a quantum computational supremacy. Both aspects of physical implementation are discussed as well as mathematical arguments used in proofs relating to notions of computational complexity. We will see that while there is good evidence that these devices outperform classical computers, they can still be efficiently and rigorously certified in their trustworthy functioning.

**Topic::**

Topic: Quantum Physics, Quantum Optics and Quantum Information

**Summary:**

**C Quantum Optics and Quantum Information / 1202**

## **Weak measurements and weak values – recent theoretical and experimental results**

**Author:** Eliahu Cohen<sup>1</sup>

<sup>1</sup> *University of Bristol*

**Corresponding Author:** eliahu.cohen@bristol.ac.uk

I will present some recent works of ours examining the topic of quantum nonlocality from various perspectives. Weak measurements and weak values will be shown to have a significant role in most of these works. Upcoming experiments will be discussed as well.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**C Quantum Optics and Quantum Information / 1423**

## **Nature's optics and our understanding of light**

**Author:** Michael Berry<sup>None</sup>

TBA

**Topic::**

Topic: Quantum Physics, Quantum Optics and Quantum Information

**Summary:**

**C Quantum Optics and Quantum Information / 1459**

## **Gravity in the quantum lab**

**Author:** Ivette Fuentes<sup>None</sup>

**Corresponding Author:** ivy7.fuentes@gmail.com

**Abstract:** Quantum experiments are reaching relativistic regimes. Quantum communication protocols have been demonstrated between Earth and Satellite-based links. At these regimes the Global Positioning System requires relativistic corrections. Therefore, it is necessary to understand how does motion and gravity will affect long-range quantum experiments. Interestingly, relativistic effects can also be observed at small lengths scales. Some effects have been demonstrated in superconducting circuits involving boundary conditions moving at relativistic speeds and quantum clocks have been used to measure time dilation in table-top experiments. In this talk I will present a formalism for the study of gravitational effects on quantum technologies. This formalism is also applicable in the development of new quantum technologies that can be used to deepen our understanding of physics in the overlap of quantum theory and relativity. Examples include accelerometers, gravitational wave detectors and spacetime probes underpinned by quantum field theory in curved spacetime.

**Topic::**

Mini-workshop: Continuous Variables and Relativistic Quantum Information

**Summary:**

**Abstract:** Quantum experiments are reaching relativistic regimes. Quantum communication protocols have been demonstrated between Earth and Satellite-based links. At these regimes the Global Positioning System requires relativistic corrections. Therefore, it is necessary to understand how does motion and gravity will affect long-range quantum experiments. Interestingly, relativistic effects can also be observed at small lengths scales. Some effects have been demonstrated in superconducting circuits involving boundary conditions moving at relativistic speeds and quantum clocks have been used to measure time dilation in table-top experiments. In this talk I will present a formalism for the study of gravitational effects on quantum technologies. This formalism is also applicable in the development of new quantum technologies that can be used to deepen our understanding of physics in the overlap of quantum theory and relativity. Examples include accelerometers, gravitational wave detectors and spacetime probes underpinned by quantum field theory in curved spacetime.

**C Quantum Optics and Quantum Information / 950**

## **Models of spontaneous wave function collapse: what they are and how they can be tested**

**Author:** Angelo Bassi<sup>1</sup>

<sup>1</sup> *University of Trieste*

**Corresponding Author:** bassi@ts.infn.it

To make quantum theory consistent, models of spontaneous wave function collapse (collapse models) propose to modify the Schrödinger equation by including nonlinear and stochastic terms, which describe the collapse of the wave function in space. These spontaneous collapses are “rare” for microscopic systems, hence their quantum properties are left almost unaltered. At the same time, since these effects add coherently in composite systems, macroscopic spatial superpositions of macro-objects are rapidly suppressed. I will review the main features of collapse models, in a pedagogical way, by presenting the GRW (Ghirardi-Rimini-Weber) collapse model. Next, I will present an update of the most promising ways of testing them in interferometric and non-interferometric experiments, showing the current lower and upper bounds on their parameters.

**Topic::**

Topic: Quantum Physics, Quantum Optics and Quantum Information

**Summary:**

**C Quantum Optics and Quantum Information / 1220**

## Would Nega-Particles Prove to be Essential Ingredients of Quantum Reality?

**Authors:** Avshalom Elitzur<sup>1</sup>; Avshalom Elitzur<sup>2</sup>

<sup>1</sup> *Iyar*

<sup>2</sup> *The Israeli Institute for Advanced Research*

**Corresponding Author:** avshalom@iyar.org.il

The alleged wave-function collapse becomes especially intriguing when detection does not occur (IFM), nevertheless exerting causal, even nonlocal effects. How can a non-event be causally equivalent to an actual one? Our answer is based of two recent advances. i) Quantum Oblivion [1-4] is a basic quantum interaction recently discovered, showing that even non-events are events which very briefly occur and then “unoccur” prior to the final macroscopic collapse. ii) The Two-State-Vector Formalism (TSVF) [5] renders the quantum interaction a combination of two wave-functions going along both time directions. A recent prediction [6,7] of this formalism, verifiable with ordinary quantum measurements, obliges the disappearance and reappearance of a particle under special conditions. The former occurs when the particle and its counterpart, possessing negative mass (nega-particle) occupy the same spacetime region, while the latter follows when they are apart again. These two lines of investigation suggest a simple and natural account of many quantum phenomena.

References

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- [7] Y. Aharonov, E. Cohen, A.C. Elitzur, R. Okamoto, S. Takeuchi, *Nonlocal position changes of a particle under special pre- and post-selection, revealed by strong measurements and proved by Bell’s theorem*, forthcoming.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**D Astroparticle, Cosmology,d Gravity, Math Phys / 1138**

## **Overview of Dark Matter Direct Searches**

**Author:** Giuliana Fiorillo<sup>1</sup>

<sup>1</sup> *Universita e INFN, Napoli (IT)*

**Corresponding Author:** giuliana.fiorillo@cern.ch

WIMPs, Weekly Interacting Massive Particles with masses between 1 GeV and 1 TeV, might be the constituents of cosmological dark matter.

During the last twenty years, experiments aiming at direct detection of these particles have gained 6 orders of magnitude in sensitivity, yet there is no solid evidence of their existence.

I will review the main technologies and experimental results and discuss future directions.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**D Astroparticle, Cosmology,d Gravity, Math Phys / 1175**

## **Core-collapse supernovae explored by neutrino transfer and nuclear data**

**Author:** Kosuke Sumiyoshi<sup>1</sup>

<sup>1</sup> *Numazu College of Technology*

**Corresponding Author:** sumi@numazu-ct.ac.jp

Core-collapse supernovae are vital for the evolution of elements, stars and galaxies. I would like to overview the current status of supernova studies with neutrino and nuclear physics. I focus on recent progress of the neutrino-radiation hydrodynamics in 2D/3D and remaining mysteries. Recently we can solve directly the Boltzmann equation in 6D (3D space + 3D momentum of neutrino) coupled with 2D/3D hydrodynamics under recent supercomputing technologies. I report the latest results of the core-collapse simulations of massive stars, which lead to successful/non-successful explosions. We are now at a new stage to examine the neutrino and nuclear physics for supernova explosions by solving the neutrino transfer without the approximations used so far. I would like to discuss influence of nuclear physics (dense matter and neutrino reactions) on explosions and observational signals such as supernova neutrinos.

**Topic::**

Special Session: Astro-Cosmo-Gravity

**Summary:**

**D Astroparticle, Cosmology,d Gravity, Math Phys / 966**

## **The Pierre Auger Observatory: latest results and future perspectives**

**Authors:** Mario Buscemi<sup>1</sup>; Pierre Auger Collaboration<sup>None</sup>

<sup>1</sup> *INFN - National Institute for Nuclear Physics*

**Corresponding Author:** mario.buscemi@ct.infn.it

The Pierre Auger Observatory is the largest ultrahigh-energy cosmic ray observatory in the world. The huge amount of high quality data collected since 2004 up to now, with a total exposure approaching to  $60.000 \text{ km}^2 \text{ sr yr}$ , led to great improvements in our knowledge of the ultra-energetic cosmic rays.

The suppression of the cosmic-ray flux at highest energies was clearly established. For the first time the proton-proton cross sections was measured at the energy 57 TeV in the center of mass system. On the other hand, measurements of the depth of shower maximum indicate a puzzling trend in the mass composition of cosmic rays at energy around the ankle up to the highest energy.

The just started upgrade of the Observatory, dubbed AugerPrime, will improve the identification of the mass of primaries and then will allow to disentangle among models of origin and propagation of cosmic rays.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**D Astroparticle, Cosmology,d Gravity, Math Phys / 1442**

## **Resolving the singularities in General Relativity**

**Author:** Slava Mukhanov<sup>None</sup>

**Corresponding Author:** mukhanov@physik.lmu.de

We find a simple modification of the longitudinal mode in General Relativity which incorporates the idea of limiting curvature. In this case the singularities in contracting Friedmann and Kasner universes are avoided, and instead, the universe has a regular bounce which takes place during the time inversely proportional to the square root of the limiting curvature. Away from the bounce, corrections to General Relativity are negligible. In addition the non-singular modification of General Relativity delivers for free a realistic candidate for Dark Matter.

**Topic::**

**Summary:**

**D Astroparticle, Cosmology,d Gravity, Math Phys / 1266**

## **Noncommutative geometry at the new frontiers of theoretical physics**

**Author:** Michal Eckstein<sup>1</sup>

<sup>1</sup> Jagiellonian University

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The idea that spacetime might be quantised was already pondered by Heisenberg in 1930s, as a potential remedy to the divergencies lurking in quantum electrodynamics. However, the concept of a 'noncommutative spacetime geometry' needed over a half of century to become established as a mathematical structure. Although it has not fulfilled the original Heisenberg's dream (so far), it revealed a completely new perspective on fundamental physics and found applications ranging from condensed matter and particle physics to gravity and cosmology.

The talk will be a friendly introduction to the misty realm of noncommutative spacetimes and an invitation to the workshop on 'Noncommutative Geometry at the Forefront of Physics'.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**D Astroparticle, Cosmology,d Gravity, Math Phys / 939**

## **Indirect dark-matter searches with gamma-rays experiments : status and future plans from 300 KeV to 100 TeV**

**Author:** Aldo Morselli<sup>1</sup>

<sup>1</sup> INFN

**Corresponding Author:** aldo.morselli@roma2.infn.it

Detection of gamma rays and cosmic rays from the annihilation or decay of dark matter particles is a promising method for identifying dark matter, understanding its intrinsic properties, and mapping its distribution in the universe. I will review recent results from the Fermi Gamma-ray Space Telescope and other space-based experiments, and highlight the constraints these currently place on particle dark matter models. I will also discuss the prospects for indirect searches to robustly identify or exclude a dark matter signal using upcoming experiments at energies below Fermi ( ASTROGAM ) and above Fermi: Magic, H.E.S.S. Veritas, CTA.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**D Astroparticle, Cosmology,d Gravity, Math Phys / 1511**

## **Status of Advanced Virgo**

**Author:** Annalisa Allocca<sup>1</sup>

<sup>1</sup> Università di Pisa / INFN Pisa

**Corresponding Author:** allocca@pi.infn.it

The LIGO and the Virgo collaborations have recently announced the first detections of Gravitational Waves. Due to their weak amplitude, Gravitational Waves are expected to produce a very small

effect on free-falling masses, which undergo a displacement of the order of  $10^{-18}$  m for a Km-scale distance. This discovery showed that interferometric detectors are suitable to reveal such a feeble effect, and therefore represent a new tool for astronomy, astrophysics and cosmology in the understanding of the Universe.

To better reconstruct the direction of the Gravitational Wave source and increase the signal-to-noise ratio of the events by means of multiple coincidence, a network of detectors is necessary.

In the USA, the LIGO project is currently carrying its second Observation Run (O2) with a couple of twin 4 kilometer-long arms detectors which are placed in Washington State and Louisiana.

Advanced VIRGO (AdV) is a 3 kilometer-long arms second generation interferometer situated in Cascina, near Pisa in Italy. The installation of AdV has been recently completed, and the first commissioning phase allowed to get to the target early-stage sensitivity.

The challenges and the current status of the commissioning of AdV will be presented, together with its current performances and future perspectives.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**D Astroparticle, Cosmology,d Gravity, Math Phys / 1554**

## **LIGO/VIRGO Overview talk**

**Author:** Giovanni Andrea Prodi<sup>1</sup>

<sup>1</sup> *Universita' di Trento and INFN, Italy*

**Corresponding Author:** giovanniandrea.prodi@unitn.it

LIGO/VIRGO Overview talk

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**H. Oeschler Memorial Session / 1380**

## **Helmut Oeschler and Particle Chemistry in Heavy Ion Collisions**

**Author:** Jean Cleymans<sup>1</sup>

<sup>1</sup> *University of Cape Town*

**Corresponding Author:** jean.cleymans@gmail.com

Helmut Oeschler and Particle Chemistry in Heavy Ion Collisions

**Topic::**

Memorial session for H. Oeschler

**Summary:**

**H. Oeschler Memorial Session / 1031****Probing resonance matter with HADES****Author:** Malgorzata Gumberidze<sup>1</sup><sup>1</sup> *TU Darmstadt***Corresponding Author:** gosia.gumberidze@gmail.com

In heavy-ion collisions at few GeV per nucleon energy regime, QCD matter with densities several times larger than the normal nuclear matter density and temperatures of about 80 MeV is created. At such extreme conditions the fundamental properties of the hadrons are expected to be modified. The properties of produced QCD matter can be extracted directly from its emissivity in electromagnetic sector or from the production of the rare (multi-) strange particles.

The High Acceptance DiElectron Spectrometer (HADES), installed at heavy-ion synchrotron SIS18 at the GSI Helmholtzzentrum für Schwerionenforschung (Germany), is currently the only experiment studying properties of strongly interacting matter in a few A GeV energy regime. It studies dielectron and hadron production in heavy-ion collisions, as well as in proton- and pion-induced reactions in the energy range of 1 – 4 GeV. HADES is a fixed-target experiment with large angular acceptance and high rate capabilities.

In this contribution main emphasis will be put on most recent results on strangeness and dielectron production in Au+Au collisions at  $\sqrt{s_{NN}} = 2.42$  GeV. The high statistics data allows for studying multi-differential distributions.

Experimental spectra will be confronted with results obtained by other experiments as well as with available model calculations. The future experimental program at SIS18 during FAIR Phase-0 will also be discussed.

**Topic::**

Memorial session for H. Oeschler

**Summary:****H. Oeschler Memorial Session / 1404****Linking the particle yields data in HIC and lattice QCD results****Author:** Krzysztof Redlich<sup>1</sup><sup>1</sup> *University of Wrocław***Corresponding Author:** redlich@ift.uni.wroc.pl

We will discuss the link between LQCD and particle yields data in heavy ion collisions to verify their thermal origin and to justify their description within the Hadron Resonance Gas (HRG) model. We will summarize the implementation of the model for different collision energies from SIS to LHC.

**Topic::****Summary:****H. Oeschler Memorial Session / 1568**



## Helmut's Oeschler's early days at GSI

**Author:** Peter Senger<sup>1</sup>

<sup>1</sup> GSI

**Corresponding Author:** p.senger@gsi.de

**Topic::**

**Summary:**

**H. Oeschler Memorial Session / 963**

## Using the Tsallis distribution for hadron spectra in pp collisions

**Author:** Smbat Grigoryan<sup>1</sup>

<sup>1</sup> Joint Institute for Nuclear Research (JINR)

**Corresponding Author:** smbat.grigoryan@cern.ch

A thermal model, based on the Tsallis distribution and blast-wave model, is proposed to compute hadron double-differential spectra  $d^2N/dp_T dy$  in  $pp$  (also high-energy  $p\bar{p}$ ) collisions. It successfully describes the available experimental data on pion and quarkonia ( $\phi$ ,  $J/\psi$ ,  $\psi(2S)$ , family) production at energies from  $\sqrt{s} = 5$  GeV to the LHC ones. Simple parametrizations for the  $\sqrt{s}$  dependence of the model parameters are provided allowing predictions for the yields of these particles at new collision energies.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Interdisciplinary Session / 1518**

## Complexity and unification in Physical theory

**Corresponding Author:** gpavlos@ee.duth.gr

Complexity and unification in Physical theory

**Topic::**

**Summary:**

**Joined Session of Workshop on Physics at FAIR-NICA-SPS-BES/RHIC and Mini-workshop:Correlations and Fluctuations in Relativistic Heavy Ion Collisions / 1198**

## Pion and kaon Bose-Einstein correlations from the BES program at STAR

**Author:** Grigory Nigmatkulov<sup>1</sup>

<sup>1</sup> *National Research Nuclear University MEPhI*

**Corresponding Author:** nigmatkulov@gmail.com

In high energy heavy-ion collisions, a hot and dense strongly interacting system of deconfined quarks and gluons (sQGP) is created. The Beam Energy Scan (BES) program at RHIC was performed to map the QCD phase diagram. Model calculations suggest, in high energy collisions, the transition from the hadronic matter to the deconfined state is a smooth crossover, at lower energies, the phase transition could be first order and there is a QCD critical point between the smooth cross-over and the first order region. The correlation femtoscopy method allows one to measure the space and time extent of the particle emitting source.

In this talk, we present preliminary results of the measurement of like-sign two-pion and two-kaon correlations from the BES program at STAR. Since kaons contain a strange quark and have smaller cross-sections with the hot hadronic matter compared to pions, they may provide additional information about the system evolution. The extracted radius parameters of kaons are presented as a function of collision centrality and transverse mass ( $m_T$ ) and compared to those for pions.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**Joined Session of Workshop on Physics at FAIR-NICA-SPS-BES/RHIC and Mini-workshop:Correlations and Fluctuations in Relativistic Heavy Ion Collisions / 1246**

## Equations of anisotropic hydrodynamics for quark and gluon fluids

**Author:** Ewa Maksymiuk<sup>1</sup>

<sup>1</sup> *Jan Kochanowski University*

**Corresponding Author:** maksymiukewa@gmail.com

Relativistic hydrodynamics has been a fundamental tool to understand the evolution of matter in heavy-ion experiments at RHIC and LHC. Despite the success of second order viscous hydrodynamics in reproducing collective behavior and particle spectra, there are still theoretical shortcomings that may question the validity of the approach in heavy-ion experiments conditions. Large gradients and fast longitudinal expansion produce very large pressure corrections, in contrast to the founding hypothesis of small deviation from local equilibrium and the perturbative treatment viscous corrections. One way to address this problem is anisotropic hydrodynamics. Most of the theoretical investigations about hydrodynamics started from a kinetic underlying substrate of a single species of particles. Unfortunately the striking agreement of anisotropic hydrodynamics with the exact solution of the Boltzmann equation was not preserved in the case of a mixtures of quarks and gluons. We recently extended the anisotropic hydrodynamics prescription for massless particles in 1+1-dimensions to the case of mixtures of fluids, largely improving the agreement with the exact solutions compared to previous works [1-3]. We allow quarks and gluons to have different momentum scales during the evolution and a non vanishing baryon chemical potential. We take the dynamical

equations from the zeroth, the first and the second moment of the Boltzmann equation [4]. We performed a test of the new formulation, comparing the results of anisotropic hydrodynamics with the exact solution of the Boltzmann equation for a mixture of fluid in the Bjorken flow limit, finding a very good agreement [5-6].

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[5] W.Florkowski, E.Maksymiuk, R.Ryblewski, L.Tinti, Phys.Rev. C92 (2015) no.5, 054912

[6] W. Florkowski, E. Maksymiuk, R. Ryblewski, in preparation

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**Joint Quantum Session / 1270**

## Fundamental quantum effects in the laboratory?

**Author:** Ralf Schuetzhold<sup>1</sup>

<sup>1</sup> *University Duisburg-Essen*

**Corresponding Author:** ralf.schuetzhold@uni-due.de

There are several fundamental predictions of quantum field theory, such as the Sauter-Schwinger effect (electron-positron pair creation out of the vacuum due to a strong electric field) or Hawking radiation (black hole evaporation), which have so far eluded a direct experimental verification.

After a brief introduction into the basics of these effects, this talk will be devoted to a discussion of the prospects for experimental studies, either directly or by means of suitable laboratory analogues.

**Topic::**

Mini-workshop: Continuous Variables and Relativistic Quantum Information

**Summary:**

**Joint Quantum Session / 1249**

## Quantum time mechanism, towards quantum spacetime

**Authors:** lorenzo maccone<sup>None</sup>; vittorio giovannetti<sup>None</sup>; seth lloyd<sup>None</sup>

We give a consistent quantum description of time, based on Page and Wootters' conditional probabilities mechanism, that overcomes the criticisms that were raised against similar previous proposals. In particular we show how the model allows to reproduce the correct statistics of sequential measurements performed on a system at different times. I also hint at the possible ways one can extend the

argument to include space, and trace a roadmap towards a possible quantum description of spacetime.

**Topic::**

Mini-workshop: Continuous Variables and Relativistic Quantum Information

**Summary:**

**Joint Quantum Session / 1564**

**From measurement of non-local variables to relativistic quantum cryptography and continuous variables teleportation**

**Author:** Lev Vaidman<sup>1</sup>

<sup>1</sup> *Tel Aviv University*

**Corresponding Author:** vaidman@post.tau.ac.il

TBA

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Lectures / 1376**

**Advances in Relativistic Fluid Dynamics, Observables, and Applications**

**Corresponding Author:** laszlo@csernai.no

Advances in Relativistic Fluid Dynamics,  
Observables, and Applications

**Topic::**

Memorial session for W. Greiner

**Summary:**

**Lectures / 979**

**Collider searches for DM (ATLAS+CMS)**

**Author:** Yoram Rozen<sup>None</sup>

**Corresponding Author:** yoram.rozen@cern.ch

plenary : Collider searches for DM (ATLAS+CMS)  
 ->result of negotiation with CMS : made by ATLAS

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

Lectures / 973

## Self-Interacting Dark Matter, Right-Handed Neutrinos and Small-Scale Cosmology “Crisis”

**Author:** Nikos Mavromatos<sup>1</sup>

<sup>1</sup> King’s College London, University of London (GB)

**Corresponding Author:** nikolaos.mavromatos@cern.ch

I discuss tensions between numerical simulations based on *Lambda*CDM cosmology and observations at galactic scales (Small-scale Cosmology “Crisis”) and then proceed to review ways of alleviating them, including the inclusion of self-interacting dark matter. As a specific model of such dark matter, I discuss minimal extensions of the standard model, involving right handed (Majorana) neutrinos, which however are assumed to be self-interacting via vector potentials in the dark sector. The galactic scale phenomenology of such a model, and ways of resolving the aforementioned issues in small-scale cosmology, are discussed. It is found that consistency with observations regarding galactic halo-core structure in several galaxies, including the Milky Way, requires a mass for the right-handed neutrino dark matter in the O(50) keV range, with a self interaction coupling (at low (keV) energies) about eight orders of magnitude stronger than the weak interaction Fermi coupling in the corresponding range of energies. This mass range of right-handed neutrinos is in a remarkable coincidence with that for the lightest right-handed Majorana neutrino in the so-called nuMSM (neutrino Minimal Standard Model) of Shaposhnikov and collaborators, which, though, is attained by a different reasoning. If time allows, I will also discuss a novel mechanism for generating such a mass, which goes beyond conventional mechanisms for neutrino masses.

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Nick E. Mavromatos (King’s Coll. London), Carlos R. Argüelles (ICRA, Pescara & Buenos Aires, CONICET & Buenos Aires U.), Remo Ruffini, Jorge A. Rueda (ICRA, Pescara & Rome U. & ICRA, Rome & ICRA, Rio de Janeiro). 2016. 28 pp.

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[2] The role of self-interacting right-handed neutrinos in galactic structure

C.R. Argüelles (Rome U. & ICRA, Pescara & INFN, Rome), N.E. Mavromatos (CERN & King’s Coll. London), J.A. Rueda, R. Ruffini (ICRA, Pescara & ICRA, Rome & Rome U.). Jan 31, 2015. 6 pp.

Published in JCAP 1604 (2016) no.04, 038

DOI: 10.1088/1475-7516/2016/04/038

e-Print: arXiv:1502.00136

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

I discuss tensions between numerical simulations based on *Lambda*CDM cosmology and observations at galactic scales (Small-scale Cosmology “Crisis”) and then proceed to review ways of alleviating them, including the inclusion of self-interacting dark matter. As a specific model of such dark matter, I discuss minimal extensions of the standard model, involving right handed (Majorana) neutrinos, which

however are assumed to be self-interacting via vector potentials in the dark sector. The galactic scale phenomenology of such a model, and ways of resolving the aforementioned issues in small-scale cosmology, are discussed. The galactic scale phenomenology of such a model, and ways of resolving the aforementioned issues in small-scale cosmology, are discussed. It is found that consistency with observations regarding galactic halo-core structure in several galaxies, including the Milky Way, requires a mass for the right-handed neutrino dark matter in the  $O(50)$  keV range, with a self interaction coupling (at low (keV) energies) about eight orders of magnitude stronger than the weak interaction Fermi coupling in the corresponding range of energies. This mass range of right-handed neutrinos is in a remarkable coincidence with that for the lightest right-handed Majorana neutrino in the so-called nuMSM (neutrino Minimal Standard Model) of Shaposhnikov and collaborators, which, though, is attained by a different reasoning. If time allows, I will also discuss a novel mechanism for generating such a mass, which goes beyond conventional mechanisms for neutrino masses.

**Lectures / 1457**

## Fluctuations and correlations

**Author:** Evgeny Zabrodin<sup>1</sup>

<sup>1</sup> *University of Oslo (NO)*

**Corresponding Author:** zabrodin@fys.uio.no

Fluctuations and correlations

**Topic::**

Lectures

**Summary:**

**Lectures / 1230**

## Gravity Wave signatures of Electroweak Phase Transition in Split NMSSM

**Authors:** Dmitry Gorbunov<sup>None</sup>; Sergey Demidov<sup>None</sup>; Dmitry Kirpichnikov<sup>None</sup>

The origin of Baryon Asymmetry of the Universe is one of the major questions in Particle Physics and Cosmology. We reconsider generation of the baryon asymmetry in the non-minimal split Supersymmetry model with an additional singlet superfield in the Higgs sector. We find that successful baryogenesis during the first order electroweak phase transition is possible within phenomenologically viable part of the model parameter space. We discuss several phenomenological consequences of this scenario, namely, predictions for the electric dipole moments of electron and neutron and collider signatures of light charginos and neutralinos. We also point out a possibility to probe the model with the next generation of gravitational interferometers, which may observe the gravitational waves produced at the Electroweak phase transition.

**Topic::**

Special Session: Astro-Cosmo-Gravity

**Summary:**

Can be presented either at Workshop on Future of Fundamental Physics - Accelerators in HEP and beyond or at Special session on Astro-Cosmo-Gravity

Lectures / 1465

## Elements and applications of Relativistic Quantum Information

**Author:** David Edward Bruschi<sup>1</sup>

<sup>1</sup> *University of York*

**Corresponding Author:** david.edward.bruschi@gmail.com

TBA

**Topic::**

Lectures

**Summary:**

Lectures / 1164

## Chaotic Quantum Many-Body Systems and Philosophy of Thermalization

**Author:** Vladimir Zelevinsky<sup>1</sup>

<sup>1</sup> *Department of Physics and Astronomy and National Superconducting Cyclotron Laboratory, Michigan State University*

**Corresponding Author:** zelevins@nscl.msu.edu

Quantum many-body chaos is described as a practical (theoretical, experimental, and computational) instrument in physics of mesoscopic systems of interacting particles.

Using nuclear, atomic and spin physics applications, it is shown that interactions of constituents create stationary states of high complexity with respect to the mean-field basis with observable properties smoothly changing along the spectrum. Both local chaotic features and the global evolution along the spectrum are used to understand many-body physics and define thermodynamic properties of isolated mesoscopic objects (no heat bath). Physical applications, experimental, theoretical and computational, are discussed. Artificially introduced chaotic elements can be used to explore the landscape of possible states of the system and predict phase transformations.

**Topic::**

Lectures

**Summary:**

Lectures / 1464

## Fragmentation of highly virtual partons

**Author:** Boris Kopeliovich<sup>1</sup>

<sup>1</sup> *UTFSM*

**Corresponding Author:** boris.kopeliovich@usm.cl

TBA

**Topic::**

Lectures

**Summary:**

**Lectures / 1521**

## **Infrared Quantum Information**

**Corresponding Author:** gordonws@phas.ubc.ca

Central to the solution of the infrared catastrophe of quantum electrodynamics and perturbative quantum gravity is the idea that detection apparatus inevitably have limited resolution and, in any scattering process, an infinite number of arbitrarily soft photons and gravitons are produced and escape detection. Photons and gravitons have polarizations and momenta and one might suspect that those which escape can carry away a significant amount of information. In this talk, I will examine the question as to the quantity of this information loss, its consequences and suggestions for experimental tests of the theoretical ideas, including whether precision interference experiments could see quantum gravitational effects.

**Mini-workshop on Highly Ionising Avatars of New Physics / 1377**

## **Searching for monopoles in polar ice samples**

**Author:** Adrian Bevan<sup>1</sup>

<sup>1</sup> *Queen Mary University of London (GB)*

**Corresponding Author:** a.j.bevan@qmul.ac.uk

Monopoles could be created in high-energy collisions of cosmic rays with the atmosphere. Cosmic rays have been bombarding the Earth constantly since the planet formed and if monopoles have been created, then they may be deposited in terrestrial samples of material. I will discuss the feasibility for monopole searches that could use ice core samples from climatology studies to complement sample studies that have been performed previously using other material samples such as rocks or water. This would complement the existing searches for exotic particles at MoEDAL and the LHC general-purpose detectors. The energy reach of monopoles created by cosmic rays is significantly greater than that available at the LHC.

**Topic::**

Mini-workshop on Highly Ionizing Avatars of New Physics

**Summary:**

**Mini-workshop on Highly Ionising Avatars of New Physics / 1034**



## Magnetic Monopoles from Global Monopoles in the presence of a Kalb-Ramond Field

**Authors:** Sarben Sarkar<sup>1</sup>; Nick Mavromatos<sup>None</sup>

<sup>1</sup> *King's College London*

**Corresponding Author:** sarben.sarkar@kcl.ac.uk

A classical solution for electromagnetic monopoles induced by gravitational (global) monopoles in the presence of a (four-dimensional) Kalb-Ramond axion field is found. The magnetic charge of such a solution is induced by a non-zero Kalb-Ramond field strength, prevalent in string theory. Bounds from the current run of the LHC experiments are used to constrain the parameters of the model. Because the production mechanism depends on the details of the model and its ultraviolet completion, such bounds, presently, are only indicative.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Mini-workshop on Highly Ionising Avatars of New Physics / 1075**

## The MoEDAL Detector at the LHC

**Author:** Richard Soluk<sup>1</sup>

<sup>1</sup> *University of Alberta (CA)*

**Corresponding Author:** rsoluk@ualberta.ca

The MoEDAL experiment consists of several types of detectors located around the LHCb interaction point at the LHC. Nuclear track detectors are used to look for highly ionizing particles while trapping detectors allow the detection of magnetically charged particles that stop in their volume. Solid state MediPix detectors allow characterization of the background particle flux. The current status of the MoEDAL detector will be discussed along with two planned subdetectors. The first is a scintillator based detector to monitor MoEDAL trapping volumes for the decays of captured very long-lived highly-ionizing electrically charged particles. This subdetector will be placed in an underground laboratory to reduce cosmic ray backgrounds. The second planned subdetector is designed to detect mini-charged particles and will be located approximately 40m from the interaction point of which 30m is shielding rock and concrete.

**Topic::**

Mini-workshop on Highly Ionizing Avatars of New Physics

**Summary:**

**Mini-workshop on Highly Ionising Avatars of New Physics / 1015**

## Perspectives on Detection of supersymmetric Dark Matter

**Authors:** Wim De Boer<sup>1</sup>; Conny Renate Beskidt<sup>1</sup>; Dmitry Kazakov<sup>2</sup>; Stefan Wayand<sup>1</sup>

<sup>1</sup> *KIT - Karlsruhe Institute of Technology (DE)*

<sup>2</sup> *JINR*

**Corresponding Authors:** stefan.wayand@cern.ch, wim.de.boer@kit.edu, kazakovd@theor.jinr.ru, beskidt@ekp.uni-karlsruhe.de

In the next-to minimal supersymmetric standard model (NMSSM) the lightest supersymmetric particle (LSP) is a candidate for the dark matter (DM) in the universe. It is a mixture from the various gauginos and Higgsinos and can be bino-, Higgsino- or singlino-dominated. These different scenarios are discussed in detail and compared with the sensitivity of future direct DM search experiments, where we use an efficient sampling technique of the parameter space.

The results will be compared with the MSSM.

We find that LSPs with a significant amount of Higgsino and bino admixture will have cross sections in reach of future direct DM experiments, so the background from coherent neutrino scattering is not yet limiting the sensitivity.

Both, the spin-dependent (SD) and spin-independent (SI) searches are important, depending on the dominant admixture.

If the predicted relic density is too low, additional dark matter candidates are needed, in which case the LSP direct dark matter searches loose sensitivity of the reduced LSP density. This is taken into account for expected sensitivity.

The most striking result is that the singlino-like LSP has regions of parameter space with cross sections below the “neutrino floor”, both for SD and SI interactions. In this region the background from coherent neutrino scattering is expected to be too high, in which case the NMSSM will evade discovery via direct detection experiments. Details on this and connected topics can be found in our papers: arXiv:1703.01255v1, arXiv:1610.07922, arXiv:1602.08707, arXiv:1402.4650, arXiv:1308.1333, arXiv:1207.3185.

**Topic::**

Mini-workshop on Highly Ionizing Avatars of New Physics

**Summary:**

The Higgs data from the LHC provides some arguments for an additional singlet in the Higgs sector within the framework of the NMSSM. This completely changes the nature of the dark matter candidates in Supersymmetry and has strong implications for future dark matter searches. I could discuss this in one or more lectures, including the state of the art of dark matter searches (direct, indirect, LHC). I also submitted an abstract for a talk on the origin of the GeV excess, which I could include in these lectures, if time permits.

**Mini-workshop on Highly Ionising Avatars of New Physics / 1399**

## Status of the searches for Magnetic Monopoles

**Author:** Laura Patrizii<sup>None</sup>

**Corresponding Author:** laura.patrizii@bo.infn.it

In this talk the status of the searches for classical magnetic monopoles (MMs) at accelerators, for GUT superheavy monopoles in the penetrating cosmic radiation and for Intermediate Mass MMs at high altitudes is discussed, with the emphasis on most recent results and future perspectives.

**Topic::**

Mini-workshop on Highly Ionizing Avatars of New Physics

**Summary:**

**Mini-workshop on Highly Ionising Avatars of New Physics / 1190**

## Magnetic monopole searches with IceCube

**Author:** Frederik Lauber<sup>1</sup>

<sup>1</sup> *IceCube*

**Corresponding Author:** pininety@googlemail.com

The IceCube experiment has instrumented a cubic kilometer of ice with 5160 photo-multipliers. While mainly developed to detect Cherenkov light, any visible light can be used to detect particles within the ice.

Magnetic monopoles are hypothetical particles predicted by many Beyond the Standard Model theories. They are carriers of a single elementary magnetic charge.

Different light production mechanisms dominate for this class of particle from direct Cherenkov light at highly relativistic velocities ( $> 0.76 c$ ), indirect Cherenkov light at mildly relativistic velocities ( $\approx 0.5 c$  to  $0.76 c$ ), luminescence light at low relativistic velocities ( $\approx 0.1 c$  to  $0.5 c$ ), as well as the propose proton decay at non relativistic velocities ( $< \approx 0.1 c$ ).

For each of this speed ranges, searches for magnetic monopoles at the IceCube experiment are either in progress or already set competitive limits on the flux of magnetic monopoles. A summary of these searches will be presented, outlining already existing results as well as methods used by the currently conducted searches.

**Topic::**

Mini-workshop on Highly Ionizing Avatars of New Physics

**Summary:**

**Mini-workshop on Highly Ionising Avatars of New Physics / 1392**

## Long-lived charged supersymmetric particles and MoEDAL

**Authors:** Vasiliki Mitsou<sup>1</sup>; Oscar Manuel Vives Garcia<sup>1</sup>; Kazuki Sakurai<sup>2</sup>; Roberto Ruiz De Austri<sup>3</sup>; Judita Mamuzic<sup>4</sup>

<sup>1</sup> *Univ. of Valencia and CSIC (ES)*

<sup>2</sup> *University of Warsaw*

<sup>3</sup> *Instituto de Fisica Corpuscular (ES)*

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**Corresponding Authors:** kazuki.sakurai@cern.ch, oscar.vives@uv.es, roberto.ruiz.de.austri@cern.ch, vasiliki.mitsou@cern.ch, judita.mamuzic@cern.ch

MoEDAL is designed to search for highly ionising emissaries of new physics and extend the discovery horizon of the LHC in a complementary way to ATLAS and CMS. A number of supersymmetric scenarios give rise to highly ionising particles that may be detected, measured and even trapped by the MoEDAL detector. Such scenarios will be reviewed and the sensitivity of MoEDAL will be presented.

**Topic::**

Mini-workshop on Highly Ionizing Avatars of New Physics

**Summary:**

**Mini-workshop on Highly Ionising Avatars of New Physics / 1116****Cosmic Electroweak Monopole****Author:** Yongmin CHO<sup>1</sup><sup>1</sup> *Konkuk University***Corresponding Author:** ymcho7@konkuk.ac.kr

We discuss the cosmological production and the successive evolution of the electroweak monopole in the standard model, and estimate the remnant monopole density at present universe. We confirm that, although the electroweak phase transition is of the first order, it is very mildly first order. So, the monopole production arises from the thermal fluctuations of the Higgs field after the phase transition, not the vacuum bubble collisions during the phase transition. Moreover, while the monopoles are produced copiously around the Ginzburg temperature  $T_G \simeq 59.6$  TeV, most of them are annihilated as soon as created. This annihilation process continues very long, until the temperature cools down to about 29.5 MeV. As the result the remnant monopole density in the present universe becomes very small, of  $10^{-11}$  of the critical density, too small to affect the standard cosmology and too small comprise a major component of dark matter. We discuss the physical implications of our results on the ongoing monopole detection experiments, in particular on MoEDAL, IceCube, ANTARES, and Auger.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

Invited talk

**Mini-workshop on Highly Ionising Avatars of New Physics / 1514****Machine LEarning, Monopoles and MoEDAL****Authors:** Jonathan Hays<sup>1</sup>; Adrian Bevan<sup>2</sup><sup>1</sup> *University of London (GB)*<sup>2</sup> *Queen Mary University of London (GB)***Corresponding Authors:** a.j.bevan@qmul.ac.uk, j.hays@qmul.ac.uk

Etching of the plastic nuclear track detectors from MoEDAL reveals pits that may indicate the passage of highly ionising particles - such as magnetic monopoles. Scanning of the plastic sheets after etching produces image data that is susceptible to automated analysis using modern machine learning techniques. We present some of the challenges involved in this approach and preliminary work we have done in this area.

**Topic::**

Mini-workshop on Highly Ionizing Avatars of New Physics

**Summary:**

**Mini-workshop on Highly Ionising Avatars of New Physics / 1507**

## **Distributed Computing for Small Collaborations**

**Author:** Daniela Bauer<sup>1</sup>

<sup>1</sup> *Imperial College (GB)*

**Corresponding Author:** daniela.bauer@cern.ch

The large LHC experiments have successfully used distributed (grid, cloud) computing for years. The same infrastructure yields large opportunistic resources for smaller collaborations. In addition, some national grid initiatives make dedicated resources for small collaborations available.

GridPP is a consortium of 19 UK universities, which provides resources and grid specific computing expertise for any experiment with a UK affiliation. I will present an overview of the services available and how to access them. This will include examples of how small collaborations have successfully incorporated distributed computing into their workflows.

I will discuss the approaches taken by these collaborations and how GridPP can facilitate access to distributed computing for your collaboration.

**Topic::**

Mini-workshop on Highly Ionizing Avatars of New Physics

**Summary:**

**Mini-workshop on Highly Ionising Avatars of New Physics / 1540**

## **LHC Constraint on Light-by-light Scattering, Born-Infeld theory and the mass of an Electroweak Monopole**

**Author:** John Ellis<sup>1</sup>

<sup>1</sup> *CERN*

**Corresponding Author:** johnellis@fastmail.fm

TBA

**Topic::**

Mini-workshop on Highly Ionizing Avatars of New Physics

**Summary:**

**Mini-workshop on Highly Ionising Avatars of New Physics / 1541**

## **Magnetic monopole production in photon fusion process.**

**Authors:** Arka Santra<sup>1</sup>; Ameer Shaa Bin Akber Ali<sup>None</sup>; Vasiliki Mitsou<sup>2</sup>

<sup>1</sup> *Univ. of Valencia and CSIC (ES)*

<sup>2</sup> *IFIC Valencia & CERN*

**Corresponding Authors:** santra.arka@gmail.com, ameir.shaa.bin.akber.ali@cern.ch, vasiliki.mitsou@cern.ch

Magnetic monopoles, if they exist, can be produced via various processes in collider experiments. Previous searches for magnetic monopoles at the LHC were carried out for Drell-Yan process. However the cross section of monopole production in the photon-fusion process is dominant compared to the Drell-Yan process. We will show kinematic distributions for spin 0, spin  $\frac{1}{2}$  and spin 1 monopoles when they are produced in two photon fusion.

**Topic::**

Mini-workshop on Highly Ionizing Avatars of New Physics

**Summary:**

**Mini-workshop on Highly Ionising Avatars of New Physics / 1542**

## **Magnetic monopole production in heavy ion collisions**

**Author:** Oliver Gould<sup>1</sup>

<sup>1</sup> *Imperial College London*

**Corresponding Author:** o.gould13@imperial.ac.uk

Magnetic monopoles, if they exist, would be produced amply in strong magnetic fields and high temperatures via the thermal Schwinger process. Such circumstances arise in heavy ion collisions, for which we have constructed the cross section for pair production of magnetic monopoles. We discuss this result, which is largely model independent and show how it allows the derivation of lower mass bounds for magnetic monopoles. It also indicates that heavy ion collisions are particularly promising for experimental searches such as MoEDAL.

**Topic::**

Mini-workshop on Highly Ionizing Avatars of New Physics

**Summary:**

**Mini-workshop on Highly Ionising Avatars of New Physics / 1468**

## **The MoEDAL Experiment Past, Present and Future.**

**Author:** James Pinfold<sup>1</sup>

<sup>1</sup> *University of Alberta (CA)*

**Corresponding Author:** james.pinfold@cern.ch

MoEDAL is a pioneering experiment designed to search for highly ionising messengers of new physics such as magnetic monopoles or massive (pseudo-)stable charged particles, that are predicted to exist in a plethora of models beyond the Standard Model. It started data taking at the LHC at a centre-of-mass energy of 13 TeV, in 2015. Its ground breaking physics program defines a number of scenarios that yield potentially revolutionary insights into such foundational questions as: are there extra dimensions or new symmetries; what is the mechanism for the generation of mass; does magnetic charge exist; and what is the nature of dark matter. MoEDAL purpose is to meet such far-reaching challenges at the frontier of the field. We will present the first results from the

MoEDAL detector on Magnetic Monopole production that are the world's best for Monopoles with multiple magnetic charge. In conclusion, plans to install a new MoEDAL sub-detector designed to search for very long-lived neutral particles as well as mini-charged particles will be very briefly discussed.

**Topic::**

Mini-workshop on Highly Ionizing Avatars of New Physics

**Summary:**

**Mini-Workshop on Latest Results and New Physics in the Higgs Sector / 996**

## **Search for neutral and charged BSM Higgs Bosons with the ATLAS detector**

**Author:** Pawel Bruckman De Renstrom<sup>1</sup>

<sup>1</sup> *Polish Academy of Sciences (PL)*

**Corresponding Author:** pawel.bruckman.de.renstrom@cern.ch

Several theories beyond the Standard Model, like the EWS or 2HDM models, predict the existence of high mass neutral or charged Higgs particles. In this presentation the latest ATLAS results on searches for these particles will be discussed.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Mini-Workshop on Latest Results and New Physics in the Higgs Sector / 997**

## **Search for rare and exotic Higgs Boson decay modes and Higgs boson pair production with the ATLAS detector**

**Author:** Suyog Shrestha<sup>None</sup>

Several theories beyond the Standard Model predict enhanced production rates for Higgs Boson pair production. Other theories predict Lepton Flavour Violating decays of the Higgs boson or enhanced decay rates into rare modes like Z-photon, J/Psi-photon, Phi-photon or into pairs of light pseudoscalar bosons "a". In this presentation the latest ATLAS results on searches for these particles will be discussed.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Mini-Workshop on Latest Results and New Physics in the Higgs Sector / 1240**

## Measurement of $Z \rightarrow b\bar{b}$ cross section and search for Higgs-like particle produced in association with b quarks at CDF

**Author:** Luigi Marchese<sup>1</sup>

<sup>1</sup> *University of Oxford (GB)*

**Corresponding Author:** luigi.marchese@cern.ch

We present a measurement of the  $Z \rightarrow b\bar{b}$  production cross section in  $p\bar{p}$  collisions at  $\sqrt{s} = 1.96\text{TeV}$ . We use a data set of  $5.46\text{fb}^{-1}$  collected by the CDF experiment at the Tevatron collider during Run II using a dedicated trigger path which required a displaced vertex compatible with a b-hadron decay. A data-driven procedure is applied to estimate the dijet mass spectrum of the non-resonant multijet background. Using a similar strategy we set one of the most stringent upper limits on the production of a Higgs-like particle in association with b quarks. We also set a limit on the inclusive SM  $H \rightarrow b\bar{b}$ .

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Mini-Workshop on Latest Results and New Physics in the Higgs Sector / 960**

## Measurements of the Higgs H(125) boson at CMS

**Author:** Valeria Botta<sup>1</sup>

<sup>1</sup> *Deutsches Elektronen-Synchrotron (DE)*

**Corresponding Author:** valeria.botta@cern.ch

The talk reviews the measurements of the 125 GeV Higgs boson in several final states, performed by the CMS collaboration. The main focus is on results obtained with data from LHC proton-proton collisions at a centre-of-mass energy of 13 TeV.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Mini-Workshop on Latest Results and New Physics in the Higgs Sector / 1150**

## Search for rare and exotic Higgs Boson decay modes at CMS

**Author:** Junquan Tao<sup>1</sup>

<sup>1</sup> *Institute of High Energy Physics, Chinese Academy of Sciences (CN)*

**Corresponding Author:** junquan.tao@cern.ch

A summary of the searches for the rare decays, exotic production and decays of standard model Higgs boson is presented. For the rare decays, the results from di-muon,  $Z\gamma$ ,  $\gamma^*\gamma$ ,  $J/\psi\gamma$  final states will be included. For the searches for exotic production and decays, the



invisible and quasi invisible decays, lepton flavour violation (emu, etau, mutau) decays, decays to light scalars, will be reviewed.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Mini-Workshop on Latest Results and New Physics in the Higgs Sector / 978**

**BEH overview (ATLAS)**

**Author:** Clara Jean May Nellist<sup>None</sup>

plenary : BEH overview (ATLAS)

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Mini-Workshop on Latest Results and New Physics in the Higgs Sector / 995**

**Measurement of cross sections and couplings of the Higgs Boson in fermionic production and decay modes with the ATLAS detector**

**Author:** Liaoshan Shi<sup>1</sup>

<sup>1</sup> *Academia Sinica (TW)*

**Corresponding Author:** liaoshan.shi@cern.ch

After the discovery of the Higgs boson, the measurement of its coupling properties are of particular importance. In this talk measurement of the cross sections and couplings of the Higgs boson in ttH production and fermionic decay channels with the ATLAS detector are presented.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Mini-Workshop on Latest Results and New Physics in the Higgs Sector / 1290**

**ttH Coupling Measurement with the ATLAS Detector at the LHC**

**Authors:** Asma Hade<sup>1</sup>; Asma Hade<sup>2</sup>

<sup>1</sup> *CPPM, Aix-Marseille Université, CNRS/IN2P3*

<sup>2</sup> *Royal Holloway University of London*

**Corresponding Authors:** asma.hadef.2012@rhul.ac.uk, asma.hadef@cern.ch

To be included later

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Mini-Workshop on Latest Results and New Physics in the Higgs Sector / 1391**

## **Higgs parameters measurement with CMS data**

**Author:** Anna Kropivnitskaya<sup>1</sup>

<sup>1</sup> *The University of Kansas (US)*

**Corresponding Author:** anna.kropivnitskaya@cern.ch

The status of most recent measurements of the Higgs boson properties is presented in this talk. The studies are based on data recorded by the CMS experiment at 13 TeV.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Mini-Workshop on Latest Results and New Physics in the Higgs Sector / 1006**

## **The Higgs and cosmology**

**Author:** Oleg Lebedev<sup>None</sup>

I will review the status of the Higgs field as a probe of the hidden sector. In particular, I will focus on its role as our (possibly) only link to the dark matter and inflaton sectors. I will report on the recent progress in understanding the cosmological implications of metastability of the electroweak vacuum.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Mini-Workshop on Latest Results and New Physics in the Higgs Sector / 1054**

## **Search for Anomalous Quartic Photon Coupling at the LHC**

**Author:** Justin Andrew Williams<sup>1</sup>

<sup>1</sup> *The University of Kansas (US)*

**Corresponding Author:** ja.williams@cern.ch

A search for anomalous quartic photon coupling with forward proton tagging is presented. The motivation for this coupling stems from theories of new phenomena (Composite Higgs, Kaluza-Klein, Warped Extra Dimensions). Forward proton tagging in CMS-TOTEM and Atlas Forward Physics spectrometers allows us to search for anomalous couplings with an unprecedented sensitivity. By imposing conservation of four-momenta on the system, we are able to probe a background free selection in a model independent way. This independence allows us to consider applications such as generic contributions from charged and neutral particles as well as dark matter searches.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Mini-Workshop on Latest Results and New Physics in the Higgs Sector / 1304**

## **Phenomenological scenarios to fit a possible excess in the di-muon + jets channel**

**Author:** Luca Panizzi<sup>1</sup>

<sup>1</sup> *Universita' di Genova & INFN (Italy) - University of Southampton & STFC (UK) - Rutherford Appleton Lab. (UK)*

**Corresponding Author:** panizzi@ge.infn.it

A reanalysis of LEP data has shown a slight excess in a channel characterised by two muons and bottom quarks. Triggered by this fluctuations, I will discuss phenomenological scenarios of new physics which can generate such signature and discuss their compatibility with data from LHC currently under scrutiny.

**Topic::**

Mini-workshop: Latest Results and New Physics in the Higgs Sector

**Summary:**

**Mini-Workshop on Latest Results and New Physics in the Higgs Sector / 1162**

## **Single Higgs production at LHC as a probe for anomalous Higgs self coupling**

**Author:** Pier Paolo Giardino<sup>1</sup>

<sup>1</sup> *Brookhaven National Laboratory*

**Corresponding Author:** pierpaolo.giardino@roma3.infn.it

The Higgs trilinear coupling is still a missing piece in the Standard Model puzzle. Although its theoretical value can be extracted from its relation to the mass of the Higgs and the Fermi constant, its measurement through the double Higgs production is particularly challenging. We explore the possibility of probing an anomalous trilinear coupling indirectly, through the production and decay of a single Higgs. Indeed, although these processes do not depend on this coupling at tree level, they are sensitive to the Higgs self-coupling at NLO. This gives us the opportunity to derive the constraints

on the trilinear coupling from various observables, like the signal strength of the different channels or the cross-section of the associate Higgs production with top quarks.

**Topic::**

Mini-workshop: Latest Results and New Physics in the Higgs Sector

**Summary:**

**Mini-Workshop on Latest Results and New Physics in the Higgs Sector / 1287**

## **Search for new physics in HH final state in CMS**

**Author:** Konstantin Androsov<sup>1</sup>

<sup>1</sup> *INFN Pisa (IT)*

**Corresponding Author:** konstantin.androsov@cern.ch

Summarise the status of the searches for new physics in HH final state at CMS and projections for CMS

**Topic::**

Mini-workshop: Latest Results and New Physics in the Higgs Sector

**Summary:**

**Mini-Workshop on Latest Results and New Physics in the Higgs Sector / 1513**

## **Introduction to the Mini-Workshop on Latest Results and New Physics in the Higgs Sector**

**Author:** Maxime Gouzevitch<sup>1</sup>

<sup>1</sup> *Universite Claude Bernard-Lyon I (FR)*

**Corresponding Author:** maxime.gouzevitch@cern.ch

Introduction to the Mini-Workshop on Latest Results and New Physics in the Higgs Sector

**Topic::**

Mini-workshop: Latest Results and New Physics in the Higgs Sector

**Summary:**

**Opening talk of the Conference / 1560**

## **Great Russian mathematical physicist Ludvig Faddeev and his main scientific results**

**Corresponding Author:** lipatov@thd.pnpi.spb.ru

**Parallel session / 994**

## **Measurement of cross sections and couplings of the Higgs Boson in bosonic decay channels with the ATLAS detector**

**Author:** Nikita Belyaev<sup>None</sup>

After the discovery of the Higgs boson, the measurement of its coupling properties are of particular importance. In this talk measurement of the cross sections and couplings of the Higgs boson in bosonic decay channels with the ATLAS detector are presented.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1082**

## **Lattice QCD at finite baryon density using analytic continuation**

**Author:** Vitaly Bornyakov<sup>1</sup>

<sup>1</sup> *IHEP*

**Corresponding Author:** bornvit@gmail.com

We simulate lattice QCD with two flavors at imaginary baryon chemical potential. We use results for the baryon number density computed in the confining and deconfining phases at imaginary baryon chemical potential to determine the baryon number density and higher cumulants as well as the phase transition line at real chemical potential.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**Parallel session / 953**

## **The analogy of equation of rotation in complex plane with the Dirac equation, and its foundation**

**Author:** Mohammed Sanduk<sup>1</sup>

<sup>1</sup> *University of Surrey*

**Corresponding Author:** m.sanduk@surrey.ac.uk

Quantum mechanics is based or formulated on postulates. The first postulate states that the state of quantum mechanics system is defined by the wave function. The Schrödinger equation has the form of a differential equation describing the evolution process of the function. Dirac equation is derived on the base of that postulate of wave function evolution in addition to Dirac's proposed linearized Hamiltonian form.

Within the frame of Dirac's relativistic quantum theory, Hestenes in 1990 refers the complex wave

function to a kinematic origin (Zitterbewegung), and Arminjon argued that Dirac field is a complex vector field.

The present project is not in quantum mechanics. It tries to propose a mathematical model. This model is based on the mathematical foundations of the complex phase factor and the complex vector, those has been proposed by Hestenes and Arminjon. The model is a complex vector in terms of complex phase factor. The project is in two parts. The first tries to find analogy between time differentiation of the complex vector and the position-space Dirac equation. The second tries to find a physical explanation for the complex vector.

In the first part, the equation of time differentiation of the complex vector shows analogy with the Dirac equation form. The two obtained coefficients those corresponding to the Dirac coefficients have similar properties of those of Dirac. These two coefficients are related to the rotation of the point. The second derivative of the complex vector shows analogy with Klein-Gordon equation.

In the second part, the complex vector is considered in trigonometrical form. That led to assume a general real algebraic form for the complex vector, and the complex vector is a special case of the real form. The real trigonometrical form exhibits a real kinematical model. Transformation from real kinematical model to complex form is attributed to partial observation, which is an empirical problem. Sanduk in 2012 proposed the partial observation as an empirical technique for that transformation.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Parallel session / 1039**

## **The MURAVES project and parallel activities on cosmic-ray muon absorption radiography**

**Authors:** Lorenzo Bonechi<sup>1</sup>; Giulio Saracino<sup>2</sup>; Raffaello D'Alessandro<sup>3</sup>; Paolo Strolin<sup>4</sup>; Fabio Ambrosino<sup>2</sup>; Luigi Cimmino<sup>2</sup>; Pasquale Noli<sup>5</sup>; Nicola Mori<sup>1</sup>; Barbara Melon<sup>1</sup>; Giovanni Macedonio<sup>6</sup>; Flora Giudicepietro<sup>6</sup>; Marcello Martini<sup>6</sup>; Massimo Orazi<sup>6</sup>; Rosario Peluso<sup>6</sup>

<sup>1</sup> INFN Florence (IT)

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<sup>3</sup> Università e INFN, Florence (IT)

<sup>4</sup> Università & INFN, Napoli-Unknown-Unknown

<sup>5</sup> Istituto Nazionale di Fisica Nucleare (INFN)

<sup>6</sup> INGV Osservatorio Vesuviano

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The **MURAVES** (MUon Radiography of VESuvius) project is a joint activity of the University of Naples and Florence, INGV and INFN. The collaboration, following the experience gained within the previous R&D INFN project MURAY, is currently completing the production of a robust four square meter low power consumption detector to be installed on the flanks of mount Vesuvius (Italy). The detector is supposed to collect data for at least one year, thus allowing performing a scan of the structure of the Vesuvius volcanic cone. The activity around the MURAVES project has triggered the involved groups to investigate the possibility to test the application of the same technique to other fields, like Archaeology. An overview of MURAVES and of the connected activities will be presented.

**Topic::**

Special Session on Instruments and Methods in HEP

**Summary:**

**Parallel session / 1232**

## **Modified Navier-Stokes equation for conceptual tests of pure field physics**

**Author:** Igor Bulyzhenkov<sup>1</sup>

<sup>1</sup> *Moscow Institute of Physics and Technology*

**Corresponding Author:** bulyzhenkov.ie@mipt.ru

Energy tensor of the continuous nonempty space in the pure field physics of Einstein and Infeld is described by the analog of the Einstein equation for nondual matter. The modified Einstein equation results in the vector geodesic consequences for material 4-flows of scalar Ricci densities. Nonrelativistic 3-flows of these mass-energies modify the Navier-Stokes equation by the 1738 Bernoulli potential.

Based on arXiv 1705.04155

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

Double unification of charges / masses with their fields was presented on ICNFP2015. Now the testable modifications of the Einstein equation and the Navier-Stokes equations stand behind the concept of a continuous mass.

**Parallel session / 1057**

## **KamLAND-Zen 800 status and future prospects**

**Co-author:** KamLAND-Zen collaboration

**Corresponding Author:** masayukikoga64@gmail.com

KamLAND-Zen is the neutrinoless double beta decay experiment using  $^{136}\text{Xe}$  in the 1,000ton ultra pure liquid scintillator KamLAND. The observation of the neutrinoless double beta decay would help our understanding of neutrino mass and hierarchy by demonstrating the Majorana particle. KamLAND-Zen 400 was ended successfully in 2015. We measured the  $^{136}\text{Xe}$  double beta decay life time precisely, and got the limit of neutrinoless double beta decay life time. KamLAND-Zen 800 is a improved experiment using 800kg of  $^{136}\text{Xe}$ . This experiment have a potential to survey in inverted hierarchy region of the neutrino mass. I will report KamLAND-Zen 800 status and future prospect.

**Topic::**

Workshop on Future of Fundamental Physics

**Summary:**

I am sorry. I cannot find suitable tracks and topic. My talk is related to the neutrino mass, neutrino mass hierarchy, lepton-number violation and Majorana nature.

**Parallel session / 1000**

## **Inclusive searches for squarks and gluinos with the ATLAS detector**

**Author:** Shunsuke Adachi<sup>None</sup>

Despite the absence of experimental evidence, weak scale supersymmetry remains one of the best motivated and studied Standard Model extensions. This talk summarises recent ATLAS results on inclusive searches for supersymmetric squarks and gluinos, including third generation squarks produced in the decay of gluinos, and considering both R-parity conserving and R-Parity violating SUSY scenarios. The searches involve final states containing jets, missing transverse momentum with and without light leptons, taus or photons, as well as long-lived particle signatures.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 936**

## **On the relationship between electromagnetic curvature and acceleration of charges**

**Authors:** Yaron Hadad<sup>1</sup>; Eliahu Cohen<sup>2</sup>; Ido Kaminer<sup>3</sup>; Avshalom Elitzur<sup>4</sup>

<sup>1</sup> *University of Arizona*

<sup>2</sup> *University of Bristol*

<sup>3</sup> *MIT*

<sup>4</sup> *The Israeli Institute for Advanced Research*

**Corresponding Author:** yaron.hadad@gmail.com

Faraday introduced electric field lines as a powerful tool for understanding the electric force, and field lines are still used today in classrooms and textbooks teaching the basics of electromagnetism within the electrostatic limit. However, despite attempts at generalizing this concept beyond the electrostatic limit, there is currently no field line theory that can be consistent with the complete theory of electromagnetism.

This work will discuss the notion of covariant electromagnetic field lines. We will show that it naturally extends electric field lines to general relativistic systems and derive a closed-form formula for the field lines curvature.

The curvature of electromagnetic field lines completely determines the dynamics of any electric charge and may entail new insights regarding long-standing problems such as radiation-reaction and self-force. In particular, the electromagnetic field lines curvature has the attractive property of being non-singular everywhere, thus eliminates all self-field singularities without using renormalization techniques.

Time permitting, the relationship between field lines curvature to gravity and/or quantum system will be discussed.

**Topic::**



Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

A deep equivalence between the geometry of electromagnetic field lines and the dynamics of charges will be discussed.

**Parallel session / 1040**

## Overview of LHCf results for Cosmic Ray Studies

**Author:** Lorenzo Bonechi<sup>1</sup>

<sup>1</sup> *INFN Florence (IT)*

**Corresponding Author:** lorenzo.bonechi@fi.infn.it

The LHCf collaboration has successfully completed at the end of 2016 the main part of its measurement campaign of neutral particles produced in the forward direction at the Large Hadron Collider. The main purpose of these measurements is to provide the Cosmic Ray and High Energy Physics communities with a missing unique set of information for the improvement of the hadronic interaction models used to simulate air showers produced by cosmic rays in the Earth atmosphere. The last two data sets collected at the LHC have been obtained with p+p collisions, at an energy of 13 TeV in the CM frame, and p+Pb collisions, at an energy of the colliding nucleon pair of 5.2 TeV and 8.1 TeV in the CM frame. A review of the main results of LHCf and of the recent and on-going activities will be presented.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1363**

## Magnetic structure of vector mesons in lattice QCD

**Authors:** Elena Luschevskaya<sup>1</sup>; Olga Solovjeva<sup>2</sup>; Oleg Teryaev<sup>3</sup>

<sup>1</sup> *State Scientific Center of Russian Federation - Institute of Theoretical and Experimental Physics*

<sup>2</sup> *Alikhanov Institute of Theoretical and Experimental Physics*

<sup>3</sup> *JINR*

**Corresponding Authors:** teryaev@theor.jinr.ru, luschevskaya@itep.ru, cooper\_ts@mail.ru

We calculate the magnetic moments of the  $\rho^\pm$  and  $K^{*\pm}$  mesons using background field method in lattice quantum chromodynamics. The magnetic dipole polarizability and hyperpolarizability have been obtained for the  $\rho^\pm$  meson for an every spin projection on the field direction.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

Parallel session / 1010

## Initial state correlations in the CGC wave function

**Author:** Michael Lublinsky<sup>None</sup>

**Co-authors:** Alexander Kovner<sup>1</sup>; Nestor Armesto Perez<sup>2</sup>; Tolga Altinoluk ; Vladimir Skokov<sup>3</sup>

<sup>1</sup> *University of Connecticut*

<sup>2</sup> *Universidade de Santiago de Compostela (ES)*

<sup>3</sup> *Brookhaven national laboratory*

**Corresponding Authors:** kovner@phys.uconn.edu, v.skokov@gsi.de, tolga.altinoluk@cern.ch, nestor.armesto@usc.es, lublinsky@phys.uconn.edu

Origin of particle correlations in pA and pp collisions will be discussed from the initial state point of view. The light cone wave function of a fast hadron has built-in QCD-induced intrinsic correlations among its Fock components. These correlations get imprinted as correlated flows of particles produced in a collision. As an example, Bose enhancement of gluons in the wave functions leads to a ridge-like correlation in two-particle inclusive cross section. I will present most recent developments of these ideas, which include short-range correlations induced by Pauli blocking of quarks in the wave function, the origin of odd harmonics ( $v_3$ ), etc.

**Topic::**

Mini-workshop: Correlations and Fluctuations in Relativistic Heavy Ion Collisions

**Summary:**

Parallel session / 1229

## The measurement of $J/\Psi$ production as function of multiplicity in pp and p-pb collisions with ALICE

**Author:** Anisa Khatun<sup>1</sup>

<sup>1</sup> *Aligarh Muslim University (IN)*

**Corresponding Author:** anisa.khatun@cern.ch

The increase of hadronic production as a function of multiplicity in proton-proton and proton-lead collisions is considered as an interesting observable to study multi-parton interactions. The correlation between  $J/\Psi$  production and multiplicity has been studied in pp collisions at  $\sqrt{s} = 7$  and 13 TeV and p-Pb collisions at  $\sqrt{s_{NN}} = 5.02$  TeV by ALICE. An increase of the relative  $J/\Psi$  yields with respect to the relative multiplicity has been observed.

In the present talk, results on the multiplicity dependence of the  $J/\Psi$  production in pp collisions at  $\sqrt{s} = 2.76$  and 5.02 TeV, measured at forward rapidity, will be presented for the first time. Similar results for p-Pb collisions at  $\sqrt{s_{NN}} = 8.16$  TeV at forward rapidity will also be shown. Results will be compared to the available ALICE measurements obtained in pp collisions at  $\sqrt{s} = 7$  and 13 TeV and p-Pb collisions at  $\sqrt{s_{NN}} = 5.02$  TeV as well as with theoretical model predictions.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

Parallel session / 976

## Sub-leading flow modes in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV from HYDJET++ model

Author: Jovan Milosevic<sup>1</sup><sup>1</sup> University of Belgrade, Vinca Institute of Nuclear Sciences

Corresponding Author: jovan.milosevic@cern.ch

Recent LHC results on the appearance of sub-leading flow modes in PbPb collisions at 2.76 TeV, related to initial-state fluctuations, are analyzed and interpreted within the HYDJET++ model. Using the newly introduced Principal Component Analysis (PCA) method applied to two-particle azimuthal correlations extracted from the model calculations, the leading and the sub-leading flow modes are studied as a function of the transverse momentum ( $p_T$ ) over a wide centrality range. The leading modes of the elliptic ( $v_2^{(1)}$ ) and triangular ( $v_3^{(1)}$ ) flow calculated within the HYDJET++ model reproduce rather well the  $v_2\{2\}$  and  $v_3\{2\}$  coefficients experimentally measured using the two-particle correlations. Within the  $p_T \leq 3$  GeV/c range where hydrodynamics dominates, the sub-leading flow effects are greatest at the highest  $p_T$  of around 3 GeV/c. The sub-leading elliptic flow mode ( $v_2^{(2)}$ ), which corresponds to  $n = 2$  harmonic, has a small non-zero value and slowly increases from central to peripheral collisions, while the sub-leading triangular flow mode ( $v_3^{(2)}$ ), which corresponds to  $n = 3$  harmonic, is even smaller and does not depend on centrality. For  $n = 2$ , the relative magnitude of the effect measured with respect to the leading flow mode shows a shallow minimum for semi-central collisions and increases for very central and for peripheral collisions. For  $n = 3$  case, there is no centrality dependence. The sub-leading flow mode results obtained from the HYDJET++ model are in a rather good agreement with the experimental measurements of the CMS Collaboration.

Topic::

Topic: Heavy Ion Collisions and Critical Phenomena

Summary:

Parallel session / 1475

## Heavy Ions (CMS)

Author: Jovan Milosevic<sup>1</sup><sup>1</sup> University of Belgrade (RS)

Corresponding Author: jovan.milosevic@fys.uio.no

TBA

Topic::

Other

Summary:

Parallel session / 986

## Electron and Photon ID

**Author:** Tetiana Hryn'ov<sup>None</sup>

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Photon and electron identifications are a crucial input to many ATLAS physics analysis. The identification of prompt photons and the rejection of background coming mostly from photons from hadron decays relies on the high granularity of the ATLAS calorimeter. The electron identification used in ATLAS for run 2 is based on a likelihood discrimination to separate isolated electron candidates from candidates originating from photon conversions, hadron misidentification and heavy flavor decays. In addition, isolation variables are used as further handles to separate signal and background. Several methods are used to measure with data the efficiency of the photon identification requirements, to cover a broad energy spectrum. At low energy, photons from radiative Z decays are used. In the medium energy range, similarities between electrons and photon showers are exploited using  $Z \rightarrow ee$  decays. At high energy, inclusive photon samples are used. The measurement of the efficiencies of the electron identification and isolation cuts are performed with the data using tag and probe techniques with large statistics sample of  $Z \rightarrow ee$  and  $J/\psi \rightarrow ee$  decays. These measurements performed with pp collisions data at  $\sqrt{s}=13$  TeV in 2016 (2015) corresponding to an integrated luminosity of 33.9 (3.1)fb<sup>-1</sup> of  $\sqrt{s}=13$  TeV pp are presented.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1474**

## Search for Charged Lepton Flavour Violation at CMS

**Author:** Swagata Mukherjee<sup>1</sup>

<sup>1</sup> *Rheinisch-Westfaelische Tech. Hoch. (DE)*

**Corresponding Author:** s.mukherjee@cern.ch

Lepton flavour is a conserved quantity in the standard model of particle physics, but it does not follow from an underlying gauge symmetry. After the discovery of neutrino oscillation, it has been established that lepton flavour is not conserved in the neutral sector. Thus the lepton sector is a great place to look for New Physics, and in this perspective the Charged Lepton Flavour Violation is interesting. Various extensions of the standard model predicts lepton flavour violating decays that can be observed at LHC. This talk presents several searches for lepton flavour violation with data collected by CMS detector.

**Topic::**

Other

**Summary:**

**Parallel session / 1473**

## SUSY (CMS)

**Author:** Alexis Kalogeropoulos<sup>1</sup>

<sup>1</sup> DESY

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TBA

**Topic::**

Other

**Summary:**

**Parallel session / 1106**

## **Forward Physics at the LHC: from the Pomeron structure to the search for anomalous coupling**

**Author:** Christophe Royon<sup>1</sup>

<sup>1</sup> *The University of Kansas (US)*

**Corresponding Author:** christophe.royon@cern.ch

We will first describe how we can constrain the structure of the Pomeron in terms of quarks and gluons using diffractive data at the LHC using proton tagging. We will then study the sensitivity to extra dimensions or composite Higgs models at the LHC via quartic anomalous couplings between photons, Z and W bosons. Tagging protons at the LHC allows us to obtain the best possible reaches at the LHC to date.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1017**

## **Searches for Neutrinoless Double Beta Decays**

**Author:** Bernhard Schwingenheuer<sup>1</sup>

<sup>1</sup> *Max-Planck-Institut Kernphysik*

**Corresponding Author:** b.schwingenheuer@mpi-hd.mpg.de

Neutrinoless double beta decay might be our only window to observe lepton number violation. Most extensions of the Standard Model predict that neutrinos are Majorana particles and in this case neutrinoless double beta decay will exist. The talk discusses the motivation and experimental programs in this field with special emphasis on experiments using Ge-76. The latter have the lowest background and best energy resolution.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**Parallel session / 958**

## **Towards the first measurement of matter-antimatter gravitational interaction**

**Author:** Craig William Evans<sup>1</sup>

<sup>1</sup> *Politecnico di Milano (IT)*

**Corresponding Author:** craig.william.evans@cern.ch

The AEGIS (Antimatter Experiment: gravity, Interferometry, Spectroscopy) is a CERN based experiment with the central aim to measure directly the gravitational acceleration of antihydrogen. Antihydrogen atoms will be produced via charge exchange reactions which will consist of Rydberg-excited positronium atoms sent to cooled antiprotons within an electromagnetic trap. The resulting Rydberg antihydrogen atoms would then be horizontally accelerated by an electric field gradient (Stark effect), they will then pass through a moiré deflectometer. The vertical deflections caused by the Earth gravitational field will test for the first time the Weak Equivalence principle for antimatter. Detection will be undertaken via a position sensitive detector. Around  $10^3$  antihydrogen atoms are needed for the gravitational measurement to be undertaken.

The present status, current achievements and results will be presented, with special attention to the strategies to produce positronium atoms in different geometries.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

Invited talk AEGIS

**Parallel session / 999**

## **Search for pair production of new particles in ATLAS**

**Author:** Simon Paul Berlendis<sup>None</sup>

With the advent of 13 TeV collisions and the start of Run 2 of the LHC, the potential to directly observe new particles produced in pairs has been greatly increased. This presentation will discuss a recent search from the ATLAS collaboration searching for pair production of new particles using the Run 2 dataset.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1219**

## **Dark Matter searches at CMS**

**Authors:** Annapaola De Cosa<sup>1</sup>; CMS Collaboration<sup>None</sup>

<sup>1</sup> *Universitaet Zuerich (CH)*

**Corresponding Author:** annapaola.de.cosa@cern.ch

DM production in proton-proton collisions can be probed at the LHC by looking for missing energy signatures. We present an overview of the results from DM searches performed with the CMS experiment using proton–proton collision data collected during LHC Run 2 at a center of mass energy of 13 TeV. Signatures investigated include those yielding energetic jets and large missing transverse momentum as well as heavy flavour quarks plus missing transverse energy.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1291**

## Standard Model Measurements at CMS

**Author:** Norbert Neumeister<sup>1</sup>

<sup>1</sup> *Purdue University (US)*

**Corresponding Author:** norbert.neumeister@cern.ch

Recent results of Standard Model physics using data recorded by the CMS detector are presented. This overview includes the latest electroweak and QCD results. In particular precise measurements of the inclusive and differential cross sections for W and Z boson productions, results on V+jets production with light and heavy flavours, multiboson measurements and anomalous couplings searches and also the latest results on jet production and properties. The outlined results are compared to the prediction of the Standard Model.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1072**

## Excited Charmed Baryons

**Author:** Elena Solovieva<sup>1</sup>

<sup>1</sup> *MIPT, LPI*

**Corresponding Author:** lena@lebedev.ru

A report on a present status of experimentally observed states of charmed baryons will be given.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1284**

## **Forward Physics at CMS**

**Author:** Sercan Sen<sup>1</sup>

<sup>1</sup> *Hacettepe University (TR)*

**Corresponding Author:** sercan.sen@cern.ch

In this talk, we will give an overview of the recent forward physics measurements performed with the CMS detector at the LHC.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1303**

## **Beyond the phenomenology of the BCS model**

**Author:** Dragos-Victor Anghel<sup>1</sup>

<sup>1</sup> *IFIN-HH*

**Corresponding Author:** dragos@theory.nipne.ro

The BCS model is revisited and it is shown that the phenomenology predicted by it is much richer than it was thought before. I will show in realistic situations that the phase transition from the superconducting state to the normal (metal) state may be of the first order (the energy gap may have a jump at the phase transition), there may be two solutions for the energy gap equation, etc.

I show both, zero temperature [1] and finite temperature results [2].

[1] D. V. Anghel, arXiv:1609.07931.

[2] D. V. Anghel and G. A. Nemnes, Physica A 464, 74 (2016).

**Topic::**

Topic: Quantum Physics, Quantum Optics and Quantum Information

**Summary:**

**Parallel session / 1089**

## **Invisible Trojan-horse attack**

**Authors:** shihan sajeed<sup>1</sup>; Carter Minshull<sup>None</sup>; nitin jain<sup>None</sup>; vadim makarov<sup>None</sup>

<sup>1</sup> *university of waterloo*

**Corresponding Author:** shihan.sajeed@gmail.com



Quantum key distribution (QKD) allows two remote parties, Alice and Bob, to obtain symmetric keys – random but correlated sequence of bits – by exchanging quantum states [1]. The security relies on the fact that an adversary Eve cannot eavesdrop without introducing noticeable errors. However, due to gaps existing between theory and practice, it is often possible for an eavesdropper, Eve to implement some attacks to extract information about the keys without introducing noticeable errors. Such gaps can arise due to imperfections in the physical devices and/or incorrect assumptions in the theoretical security proofs [2,3]. Hence, before trying to promote and commercialize QKD, it is of utmost importance to identify these gaps and evaluate their effects on the security.

This is where security evaluation of QKD comes in. It involves investigating practical QKD implementations to identify such theory-practice deviations, demonstrate the resultant vulnerability, and propose countermeasures to protect Alice and Bob from Eve. In this work, we have done such a security evaluation of the practical QKD system Clavis2 [4] running the Scarani-Acin-Ribordy-Gisin QKD protocol [5]. We evaluated security against the so-called Trojan-horse attack (THA) [6].

In a THA, Eve can probe the properties of a component inside Alice or Bob by sending in a bright pulse into the system and analyzing a suitable back-reflected portion of it. This attack was previously attempted [7] at telecom wavelength with the intention to breach the security of a similar system and was successful in remotely reading the phase modulator settings in Bob via a homodyne measurement. However, the resultant increase in afterpulsing [8] at Bob's InGaAs single-photon detectors (SPDs) led to an elevated quantum bit error rate (QBER) which disclosed the presence of Eve.

In this work, we have tested the experimental feasibility of a Trojan-horse attack that remains nearly invisible and evaluated the security of Clavis2 system against it. The invisibility has been achieved by using a different wavelength where detectors are expected to be less sensitive. To quantify the decrease in afterpulsing probabilities, we have compared the afterpulsing at  $\lambda_l = 1924$  nm with that at  $\lambda_s = 1536$  nm.

From Eve's point of view, the benefit of reduced afterpulsing at  $\lambda_l$  comes at the expense of a much higher attenuation inside Bob. Additionally, the degree of modulation received at  $\lambda_l$  differs from that at  $\lambda_s$  substantially. We quantify the increased optical attenuation and the suboptimal modulator response by means of further experimental measurements. Taking all these factors into account as well as optimizing the attack path through Bob, we evaluate the attack performances in the long wavelength regime. By means of a numerical simulation, we conclude that a Trojan-horse attack at  $\lambda_l$  can extract keys from the system at the same time being invisible to Alice and Bob. The invisible nature of the current attack poses a threat to the security of practical QKD if proper countermeasures are not adopted. We end by remarking that the attack can be mitigated by using a wavelength filter at the input of the QKD device.

[1] C. H. Bennett and G. Brassard, in Proceedings of IEEE International Conference on Computers, Systems, and Signal Processing (IEEE Press, New York, Bangalore, India, 1984) pp. 175–179.

[2] V. Scarani, H. Bechmann-Pasquinucci, N. J. Cerf, M. Dušek, N. Lutkenhaus, and M. Peev, Rev. Mod. Phys. 81, 1301 (2009).

[3] N. Jain, B. Stiller, I. Khan, D. Elser, C. Marquardt, and G. Leuchs, Contemporary Physics 57, 366 (2016), <http://dx.doi.org/10.1080/00107514.2016.1148333>.

[4] Clavis2 specification sheet, <http://www.idquantique.com/images/stories/PDF/clavis2-quantum-key-distribution/clavis2-specs.pdf>, visited 28 May 2016.

[5] V. Scarani, A. Acín, G. Ribordy, and N. Gisin, Phys. Rev. Lett. 92, 057901 (2004).

[6] N. Gisin, S. Fasel, B. Kraus, H. Zbinden, and G. Ribordy, Phys. Rev. A 73, 022320 (2006).

[7] N. Jain, E. Anisimova, I. Khan, V. Makarov, C. Marquardt, and G. Leuchs, New J. Phys. 16, 123030 (2014).

[8] C. Wiechers, L. Lydersen, C. Wittmann, D. Elser, J. Skaar, C. Marquardt, V. Makarov, and G. Leuchs, New J. Phys. 13, 013043 (2011).

**Topic::**

Topic: Quantum Physics, Quantum Optics and Quantum Information

**Summary:**

**Parallel session / 1281**

## Measurements of the CP violating phase $\phi_s$ at LHCb

**Author:** Varvara Batozskaya<sup>1</sup>

<sup>1</sup> *National Centre for Nuclear Research (PL)*

**Corresponding Author:** varvara.batozskaya@cern.ch

The measurement of the mixing-induced CP-violating phase  $\phi_s$  in the  $B_s$ - $B_s$ bar system is one of the key goals of the LHCb experiment. It has been measured at LHCb exploiting the Run I data set and using several decay channels. In particular, the most recent Run I results have been obtained analyzing  $B_s^0 \rightarrow J/\psi(-\rightarrow \mu^+\mu^-) K^+K^-$  candidates in the mass region above the  $\phi(1020)$  resonance and  $B_s^0 \rightarrow J/\psi(-\rightarrow e^+e^-) \phi$  candidates. However, the precision of  $\phi_s$  is still limited by the statistics. In this conference, we will present recent results obtained analyzing the Run-II data collected during 2015-2016. Namely, we will present measurements obtained analyzing the golden channel,  $B_s^0 \rightarrow J/\psi K^+K^-$  in  $\phi(1020)$  region, and  $B_s^0 \rightarrow J/\psi \pi^+\pi^-$ , both with  $J/\psi \rightarrow \mu^+\mu^-$ .

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1445**

## TBA

**Author:** Konstantin Astapov<sup>1</sup>

<sup>1</sup> *INR of RAS*

**Corresponding Author:** asapovk@gmail.com

TBA

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1294**

## LEGEND: new opportunity to discover the neutrinoless double beta decay

**Authors:** Konstantin Gusev<sup>None</sup>; LEGEND collaboration<sup>None</sup>

**Corresponding Author:** kngusev@gmail.com

No abstract yet

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1364**

## The Belle II Experiment

**Author:** Zdenek Dolezal<sup>1</sup>

**Co-author:** Andrzej Bozek<sup>2</sup>

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<sup>2</sup> Krakow

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The Belle II experiment at the asymmetric  $e^+e^-$  SuperKEKB collider is a major upgrade of the Belle experiment, which ran at the KEKB collider at the KEK laboratory in Japan. The design luminosity of SuperKEKB is  $8 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$ , which is about 40 times higher than that of KEKB. The expected integrated luminosity of Belle II is  $50 \text{ ab}^{-1}$  in five years of running. The experiment will focus on searches for new physics beyond the Standard Model via high precision measurements of heavy flavor decays, and searches for rare signals. To reach these goals, the accelerator, detector, electronics, software, and computing systems are all being substantially upgraded. In this talk we present the status of the accelerator and Belle II detector upgrades, as well as the expected sensitivity to new physics of the Belle II data set.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1425**

## Quantum simulators, boson sampling, and the quest for superior quantum devices

**Corresponding Author:** jenseisert@gmail.com

Quantum simulators promise to give rise to new insights into dynamical and static properties of complex quantum systems, beyond what is available on classical supercomputers. There is already some good evidence that quantum simulators have the potential to outperform classical computers. Yet, in order to be prone against arguments claiming a lack of imagination, this superior computational capabilities should be expressed in terms of notions of computational complexity. One of the main milestones in quantum information science is hence to realize quantum devices that exhibit an exponential computational advantage over classical ones without being universal quantum computers in complexity theoretic terms, a state of affairs dubbed exponential quantum computational advantage or simply “quantum computational supremacy”. The paradigmatic boson samplers are

devices of this type. We end the talk by discussing a number of surprisingly simple and physically plausible schemes that once realized show such a quantum computational supremacy. Both aspects of physical implementation are discussed as well as mathematical arguments used in proofs relating to notions of computational complexity. We will see that while there is good evidence that these devices outperform classical computers, they can still be efficiently and rigorously certified in their trustworthy functioning.

**Parallel session / 985**

## **ATLAS Jet Reconstruction, Energy Scale Calibration, and Tagging of Lorentz-boosted Objects**

**Author:** Steven Schramm<sup>None</sup>

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

The reconstruction and calibration of jets in ATLAS is a critical component in producing precise analyses, whether precision measurements or searches for new physics. This talk describes the steps involved in deriving the jet energy scale (JES) and presents the results. Calibrations and their uncertainties are shown using the full 2015 + 2016 datasets. The study of jet substructure has also become increasingly more prevalent throughout a wide array of searches and measurements. We also report on the latest results from ATLAS for the reconstruction and tagging of large-R jets as well as the calibration and determination of the uncertainties associated with these techniques.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1036**

## **Electromagnetic field effects on $\Upsilon$ meson suppression in PbPb collisions at LHC energies**

**Authors:** Johannes Hoelck<sup>1</sup>; Georg Wolschin<sup>2</sup>

<sup>1</sup> *University of Heidelberg*

<sup>2</sup> *Heidelberg University*

**Corresponding Authors:** wolschin@uni-hd.de, hoelck@stud.uni-heidelberg.de

We investigate the effect of the electromagnetic field generated in relativistic heavy-ion collisions on the suppression of  $\Upsilon$  mesons. The electromagnetic field is calculated using a simple model which characterises the emerging quark-gluon plasma (QGP) by its conductivity only. A numerical estimate of the field strength experienced by  $\Upsilon$  mesons embedded in the expanding QGP and its consequence on the  $\Upsilon$  dissociation is made. The electromagnetic field effects prove to be negligible compared to the established strong-interaction suppression mechanisms. In particular, they cannot substantially modify our model prediction for the suppression of the  $\Upsilon(2S)$  state in peripheral collisions.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

Parallel session / 1013

## Mass problem in the Standard Model

Author: Roberto Martinez<sup>1</sup><sup>1</sup> Universidad Nacional de Colombia

Corresponding Author: remartinezm@unal.edu.co

We propose a new  $SU(3)_{C \times SU(2)_L \times U(1)_Y \times U(1)_X}$  gauge model which is non universal respect to the three fermion families of the Standard Model. We introduce additional one top-like quark, two bottom-like quarks, three right handed neutrinos and two charged leptons in order to have an anomaly free theory. We also consider additional three right handed neutrinos which are singlets respect to the gauge symmetry of the model to implement see saw mechanism and give masses to the light neutrinos according to the neutrino oscillation phenomenology. In the context of this horizontal gauge symmetry we find mass ansatz for leptons and quarks. In particular from the analysis of solar, atmospheric, reactor and accelerator neutrino oscillation experiments we get the allow region for the Yukawa couplings for the charged and neutral lepton sectors according with the mass squared differences and mixing angles for the two neutrino hierarchy schemes, normal and inverted.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

We propose a new  $SU(3)_{C \times SU(2)_L \times U(1)_Y \times U(1)_X}$  gauge model which is non universal respect to the three fermion families of the Standard Model. We introduce additional one top-like quark, two bottom-like quarks and three right handed neutrinos in order to have an anomaly free theory. We also consider additional three right handed neutrinos which are singlets respect to the gauge symmetry of the model to implement see saw mechanism and give masses to the light neutrinos according to the neutrino oscillation phenomenology. In the context of this horizontal gauge symmetry we find mass ansatz for leptons and quarks. In particular from the analysis of solar, atmospheric, reactor and accelerator neutrino oscillation experiments we get the allow region for the Yukawa couplings for the charge and neutral lepton sectors according with the mass squared differences and mixing angles for the two neutrino hierarchy schemes, normal and inverted.

Parallel session / 1257

## CMS Search for new physics in events with jets, b-tagged jets, and large missing transverse momentum in the all-hadronic channel at $\sqrt{s} = 13$ TeV

Author: Samuel Louis Bein<sup>1</sup><sup>1</sup> Hamburg University (DE)

Corresponding Author: samuel.bein@cern.ch

A search for new physics in events with jets, b-tagged jets, missing transverse momentum, and 0-leptons, corresponding to an integrated luminosity of 35.9 fb<sup>-1</sup> collected by the CMS experiment at  $\sqrt{s} = 13$  TeV, is presented. No significant excess of events above the standard model background expectation is observed. Results are interpreted in terms of a number of simplified supersymmetry models, corresponding to di-gluino production, as well as 1st and 3rd generation di-squark production, with a variety of gluino and squark decay modes. For a massless lightest supersymmetric particle, lower limits on the gluino (squark) mass are established in the range 1.80-1.95 TeV (1.00-1.05 TeV), depending on the model considered.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1090**

## Recent CMS B physics results

**Author:** Sergey Polikarpov<sup>1</sup>

<sup>1</sup> *National Research Nuclear University MEPhI (RU)*

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Particles containing heavy quarks are produced in LHC pp collisions at 7, 8, and 13 TeV and constitute an excellent laboratory to test the Standard Model and probe for New Physics effects. Recent results by the CMS Collaboration on heavy flavor production and properties are reported.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:**

**Parallel session / 1216**

## Search for new physics in events with two low momentum opposite-sign leptons and missing transverse energy at $\sqrt{s} = 13$ TeV

**Author:** Georgios Karathanasis<sup>1</sup>

<sup>1</sup> *University of Athens*

**Corresponding Author:** georgios.karathanasis@cern.ch

A search for new physics in events with low-momentum, opposite-sign leptons and moderate missing transverse momentum, using 35.9 1/fb of integrated luminosity collected by the CMS experiment at  $\sqrt{s} = 13$  TeV, is presented. The observed data is consistent with the expectation from the standard model. The results are interpreted in terms of pair production of charginos and neutralinos with nearly degenerate masses, as expected in natural compressed higgsino models, and in terms of the pair production of top squarks for the case that the neutralino and the top squark have similar masses. The mass region excluded was so far constrained only by LEP experiments. An interpretation is also provided in terms of top squark pair production processes with degenerate mass spectra and chargino-mediated decays.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 988**

## Measurements of the Vector boson production with the ATLAS Detector

**Author:** Konstantinos Kordas<sup>None</sup>

**Corresponding Author:** kostas.kordas@cern.ch

((W Mass - STDM-2014-18, Z3D (W/Z precision 7 TeV - STDM-2012-20, W+jets 8 TeV - STDM-2016-14, Z+1jet 8TeV - STDM-2016-11, kt splitting scales - STDM-2015-14, Z+jets 13TeV STDM-2016-01))  
 The electroweak sector of the Standard model can be tested by precision measurements of its fundamental parameters, such as the W boson mass or the electroweak mixing angle. In this talk, we present the first measurement of the W boson mass, based on the 7 TeV data set corresponding to an integrated luminosity of 4.6 fb<sup>-1</sup>. With these samples the detector and physics modelling has been studied in great detail, leading to an overall uncertainty of 19 MeV. The ATLAS collaboration also performed a new precise triple differential cross-section measurement as a function of M(l $\bar{l}$ ), dilepton rapidity and cos $\theta^*$  defined in the Collins-Soper frame. This measurement provides sensitivity to the PDFs and the Z forward-backward asymmetry, AFB, which is derived and will be presented. This builds the foundation for a possible future extraction of the weak-mixing angle. The production of jets in association with vector bosons is an important process to study perturbative QCD in a multi-scale environment. The ATLAS collaboration has performed new measurements of vector boson + jets cross sections, differential in several kinematic variables, in proton-proton collision data taken at center-of-mass energies of 8 TeV and 13 TeV, which will be presented. The measurements are compared to state-of-the-art theory predictions. They are sensitive to higher-order pQCD effects, probe flavour and mass schemes and can be used to constrain the proton structure. In addition, we present a new measurement of the splitting scales of the kt jet-clustering algorithm for final states containing a Z-boson candidate at a centre-of-mass energy of 8 TeV.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1088**

## The ATLAS Run-2 Trigger Menu for higher luminosities: Design, Performance and Operational Aspects

**Authors:** Jiri Masik<sup>None</sup>, Rainer Stamen<sup>None</sup>

**Co-author:** Arantxa Ruiz Martinez<sup>1</sup>

<sup>1</sup> Carleton University (CA)

**Corresponding Authors:** aranzazu.ruiz.martinez@cern.ch, jiri.masik@manchester.ac.uk, stamen@kip.uni-heidelberg.de

The ATLAS experiment aims at recording about 1 kHz of physics collisions, starting with an LHC design bunch crossing rate of 40 MHz. To reduce the massive background rate while maintaining a high selection efficiency for rare physics events (such as beyond the Standard Model physics), a two-level trigger system is used. Events are selected based on physics signatures such as presence of energetic leptons, photons, jets or large missing energy. The trigger system exploits topological information, as well as multi-variate methods to carry out the necessary physics filtering. In total, the ATLAS online selection consists of thousands of different individual triggers.

A trigger menu is a compilation of these triggers which specifies the physics algorithms to be used during data taking and the bandwidth a given trigger is allocated. Trigger menus reflect not only the physics goals of the collaboration for a given run, but also take into consideration the instantaneous luminosity of the LHC and limitations from the ATLAS detector readout and offline processing farm. For the 2017 run, the ATLAS trigger has been enhanced to be able to handle higher instantaneous luminosities (up to  $2.0 \times 10^{34} \text{cm}^{-2} \text{s}^{-1}$ ) and to ensure the selection robustness against higher average multiple interactions per bunch crossing.

In this presentation, we describe the design criteria for the trigger menus used for Run 2 at the LHC. We discuss several aspects of the process, from the validation of the algorithms, the fine-tuning of the prescales, and the monitoring tools that ensure the smooth operation of the trigger during data-taking. We also report on the physics performance of a few trigger algorithms.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1047**

## Low Momentum Direct Photon Measurement

**Author:** Wenqing Fan<sup>1</sup>

<sup>1</sup> *PHENIX*

Direct photons have long been considered as golden probes to study the properties of the Quark Gluon Plasma (QGP). They do not interact strongly with the medium and are produced at all stages of the collision, hence carrying information of the entire evolution of the system to the detectors. The PHENIX experiment discovered a large excess of low  $p_T$  photons in Au+Au collisions at  $\sqrt{s_{NN}} = 200$  GeV compared to reference p+p collisions, which has been interpreted as thermal radiation from the QGP and hadron-gas medium. At the same time, the excess photons show a large elliptic and triangular flow. These results are challenging for the current theoretical models to describe simultaneously, because on one hand the large yield suggests early stage emissions when the temperature is high, on the other hand the large anisotropy is expected to be formed only at later stages of the collision when the system has cooled off and the thermal photon production rate is expected to be smaller.

Using a variety of high statistics datasets across different collision systems and energies in PHENIX, simultaneous analyses of yields and azimuthal asymmetries of direct photons with higher precision are performed to provide more constraints to the theoretical calculations. In this talk, we will present recent results on low  $p_T$  direct photons measured via their external conversions to electron-positron pairs, including new results from Au+Au at lower beam energies of 39 and 62.4 GeV, as well as Cu+Cu at 200GeV.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**Parallel session / 1236**

## Non-exponential decay in a quantum field theoretical treatment

**Authors:** Francesco Giacosa<sup>1</sup>; Stanislaw Mrowczynski<sup>2</sup>

<sup>1</sup> *Kielce University*

<sup>2</sup> *Jan Kochanowski University*

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It is nowadays theoretically understood that in Quantum Mechanics (QM) the exponential decay is only an approximation. Deviations have been experimentally measured both at short and at long times. In turn, the non-exponential decay is responsible of the (also measured) Quantum Zeno Effect. Yet, an interesting open question, presented in this talk, is the emergence of non-exponential decay in the context of relativistic quantum field theory (QFT). Namely, this is the correct environment for creation and annihilation of particles. By using standard QFT techniques, we aim to evaluate the short-time behavior in a straightforward calculation. We shall find that non-exponential decay is also present in each QFT but is typically very small. An interesting exception is that of superrenormalizable theory, where deviations can be more sizable.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

Non-exponential decay in Quantum Field theory

**Parallel session / 991**

## Measurements of low energy observables, elastic pp interactions and exclusive production in proton-proton collisions with the ATLAS Detector

**Author:** Peter Bussey<sup>None</sup>

Low energy phenomena have been studied in detail at the LHC, providing important input for improving models of non-perturbative QCD effects. The ATLAS collaboration has performed several new measurements in this sector, which will be discussed. In particular, we present studies on the correlated hadron production, as they are an important source for information on the early stages of hadron formation and allow to study coherent particle production. The results are compared to the predictions of a helical QCD string fragmenting model.

In the absence of forward proton tagging, exclusive processes can be distinguished in the central part of the ATLAS detector exploiting the absence of charged particles reconstructed in the inner tracking detector. We present a first measurement of the exclusive two-photon production of muon pairs in proton-proton collisions at a center-of-mass energy of 13 TeV. The results show significant deviations from the pure QED prediction, which can be explained by proton-proton rescattering effects. We also show a first measurement of the exclusive production of pions, using the ALFA detector to tag forward protons and, if available, a first study of diffractive jet production using the new AFP detector.

**Topic::**

Topic: High Energy Particle Physics

**Summary:****Parallel session / 1255**

## $f_1(1285) \rightarrow e^+e^-$ decay and direct $f_1$ production in $e^+e^-$ collisions

**Author:** Alexander Rudenko<sup>1</sup>

<sup>1</sup> Novosibirsk State University

**Corresponding Author:** alexander.s.rudenko@gmail.com

The width of  $f_1(1285) \rightarrow e^+e^-$  decay is calculated in the vector meson dominance model. The result depends on the relative phase between two coupling constants describing  $f_1 \rightarrow \rho^0\gamma$  decay. The  $\Gamma(f_1 \rightarrow e^+e^-)$  is estimated to be  $\simeq 0.07 \div 0.19$  eV. Direct  $f_1$  production in  $e^+e^-$  collisions is discussed, and the  $e^+e^- \rightarrow f_1 \rightarrow a_0\pi \rightarrow \eta\pi\pi$  cross section is calculated. Charge asymmetry in the  $e^+e^- \rightarrow \eta\pi^+\pi^-$  reaction due to interference between the  $e^+e^- \rightarrow f_1$  and  $e^+e^- \rightarrow \eta\rho^0$  amplitudes is studied.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

Parallel session / 1155

## Quantum scattering beyond the plane-wave approximation

**Author:** Dmitry Karlovets<sup>1</sup>

<sup>1</sup> Tomsk State University

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We develop a quantum scattering theory with the different wave packets: coherent states, Schroedinger cats, vortex beams with orbital angular momentum, Airy beams, etc. Examples from QED, QCD and potential scattering on atoms are treated. A phase-space picture of the quantum scattering (via the Wigner functions) is developed and a contribution of possible negativity of the incoming packets' Wigner functions to the cross-section is studied. The means of extracting a contribution of phases of the scattering amplitudes (of a Coulomb- and a hadronic one) in a collision experiment beyond the plane-wave approximation are discussed.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

Parallel session / 1125

## The ICARUS experiment

**Author:** Christian Farnese<sup>1</sup>

<sup>1</sup> Universita e INFN, Padova (IT)

**Corresponding Author:** christian.farnese@cern.ch

The 760 ton liquid argon ICARUS T600 detector performed 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 in cosmic rays. A sensitive search for LSND like anomalous  $\nu_e$  appearance was performed, contributing to constrain the allowed parameters to a narrow region around  $\Delta m^2 \sim eV^2$ , where all the experimental results can be coherently accommodated at 90% C.L.

The T600 detector will be redeployed at Fermilab, after a significant overhauling, to be exposed to the Booster Neutrino Beam acting as the far station to search for sterile neutrino within the SBN program.

The proposed contribution will address ICARUS LNGS achievements and the ongoing analyses also finalized to the next physics run at Fermilab.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1048**

## Top-quark results at CMS

**Author:** Luca Lista<sup>1</sup>

<sup>1</sup> *INFN Sezione di Napoli*

**Corresponding Author:** luca.lista@cern.ch

Experimental results on top-quark physics obtained at the CMS experiment are reported based on the data recorded at centre-of-mass energy up to 13 TeV. Inclusive and differential cross sections for both top-quark pair and single top-quark production are presented, as well as measurements of top-quark properties in production and decay, and searches for anomalous couplings. The presented measurements test theoretical predictions, including recent perturbative QCD calculations, provide constraints of fundamental standard model parameters, and set limits on physics beyond the standard model.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 968**

## Transverse momentum spectra and nuclear modification factors of identified charged hadrons in p-Pb and Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with ALICE

**Author:** Maria Vasileiou on behalf of the ALICE Collaboration<sup>1</sup>

<sup>1</sup> *National and Kapodistrian University of Athens*

**Corresponding Author:** mvasili@phys.uoa.gr

The ALICE experiment has measured the production of identified light-flavour hadrons in p-Pb and Pb-Pb collisions at 5.02 TeV in a wide range of transverse momentum ( $p_T$ ). The newest ALICE results on pion, kaon and proton transverse momentum spectra, yield ratios and nuclear modification factors will be presented and discussed in comparison to lower energy results and hydrodynamical models. In particular, the production of identified hadrons in most central Pb-Pb collisions relative to pp collisions is found to be strongly suppressed at high transverse momenta ( $p_T > 8$  GeV/c) whereas in p-Pb collisions the nuclear modification factors are consistent with unity. This indicates that the strong suppression of high- $p_T$  hadrons measured in central Pb-Pb collisions is not due to an initial state effect but instead to the energy loss of partons traversing a hot and dense QCD medium.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**Parallel session / 1494**

## Directional dark matter search with nuclear emulsion

**Authors:** Takashi Asada<sup>1</sup>; NEWSdm Collaboration<sup>None</sup>

<sup>1</sup> *LNGS*

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Direct dark matter searches are promising techniques to identify the nature of dark matter particles. A variety of experiments have been developed over the past decades, aiming to detect Weakly Interactive Massive Particles (WIMPs) via their scattering in a detector medium. Exploiting directionality would also give a proof of the galactic origin of dark matter making it possible to have a clear and unambiguous signal to background separation. The directional detection of Dark Matter requires very sensitive experiment combined with highly performant technology. The NEWSdm experiment, based on nuclear emulsions, is proposed to measure the direction of WIMP-induced nuclear recoils. We discuss the potentiality, both in terms of exclusion limits and potential discovery, of a directional experiment based on the use of a solid target made by newly developed nuclear emulsions and read-out systems reaching sub-micrometric resolution.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

NEWSdm collaboration recently submitted paper entitled “Discovery potential for directional Dark Matter detection with nuclear emulsions” to Phys.Rev. D. We give prospects towards neutrino floor.

**Parallel session / 1441**

## Search for heavy neutrinos at the NA48 and NA62 experiments at CERN

**Author:** Letizia Peruzzo<sup>1</sup>

<sup>1</sup> *Johannes-Gutenberg-Universitaet Mainz (DE)*

**Corresponding Author:** letizia.peruzzo@cern.ch

The NA48 at CERN has recently published a limit on the presence of heavy neutrinos from decays of charged kaons into a pion and muons. The following NA62 experiment at CERN collected a large sample of charged kaon decays in flight with a minimum bias trigger in 2007. Upper limits on the rate of the charged kaon decay into a muon and a heavy neutral lepton (HNL) obtained from this data are reported for a range of HNL masses. The NA62 experiment has collected further data in 2015 with a completely new and improved detector. New limits on heavy neutrinos from kaon decays into pion, electron and positron will be presented.

**Topic::**

Topic: High Energy Particle Physics

**Summary:****Parallel session / 1440****Search for  $K^+$  to  $\pi^+ \nu \nu$  at NA62****Author:** Riccardo Aliberti<sup>1</sup><sup>1</sup> *Johannes-Gutenberg-Universitaet Mainz (DE)***Corresponding Author:** riccardo.aliberti@cern.ch

$K \rightarrow \pi \nu \nu$  is one of the theoretically cleanest meson decay where to look for indirect effects of new physics complementary to LHC searches. The NA62 experiment at CERN SPS is designed to measure the branching ratio of the  $K^+ \rightarrow \pi^+ \nu \nu$  decay with 10% precision. NA62 took data in 2015 and 2016 reaching the Standard Model sensitivity. The status of the experiments will be reviewed, and prospects will be presented.

**Topic::**

Topic: High Energy Particle Physics

**Summary:****Parallel session / 1129****New results from the OPERA experiment****Author:** OPERA Collaboration<sup>None</sup>**Co-author:** Sergey Dmitrievsky<sup>1</sup><sup>1</sup> *Joint Institute for Nuclear Research*

The OPERA experiment reached its main goal by proving the appearance of  $\nu_\tau$  in the CNGS  $\nu_\mu$  beam. A total sample of 5 candidates fulfilling the analysis defined in the proposal was detected with a S/B ratio of about ten allowing to reject the null hypothesis at  $5.1 \sigma$ . The search has been extended to  $\nu_\tau$ -like interactions failing the kinematical analysis defined in the experiment proposal to obtain a statistically enhanced, lower purity, signal sample. Based on the enlarged data sample the estimation of  $\Delta m_{23}^2$  in appearance mode is presented. The search for  $\nu_e$  interactions has been extended over the full data set with a more than twofold increase in statistics with respect to published data. The analysis of the  $\nu_\mu \rightarrow \nu_e$  channel is updated and the implications of the electron neutrino sample in the framework of the 3+1 sterile model is discussed. An analysis of  $\nu_\mu \rightarrow \nu_\tau$  interactions in the framework of the sterile neutrino model has also been performed. Moreover the results of the analysis of the annual modulation of the cosmic muon rate will be presented.

**Topic::**

Topic: High Energy Particle Physics

**Summary:****Parallel session / 1028**

## Resonance production in Pb-Pb collisions measured with the ALICE experiments at the LHC

**Author:** Viktor Riabov<sup>1</sup>

<sup>1</sup> Petersburg Nuclear Physics Institut (RU)

**Corresponding Author:** viktor.riabov@cern.ch

Resonance production in Pb-Pb collisions measured with the ALICE detector at the LHC

V. Riabov for the ALICE Collaboration

Hadronic resonances are very useful in exploring various aspects of heavy-ion collisions. Due to their short lifetimes, yields of resonances measured via hadronic decay channels can be affected by particle rescattering and regeneration in the hadronic gas phase. The momentum dependence of rescattering and regeneration cross sections may also modify the observed momentum distributions of the reconstructed resonances. Resonances as hadrons with different masses and quark composition also contribute to the systematic study of in-medium parton energy loss at high transverse momentum and help to distinguish among different mechanisms responsible for particle production at intermediate momentum.

In this talk we present the most recent ALICE results on  $\rho(770)^0$ ,  $K^*(892)^0$ ,  $\phi(1020)$ ,  $\Sigma(1385)^\pm$ ,  $\Lambda(1520)$  and  $\Xi(1530)^0$  production in pp, p-Pb and Pb-Pb collisions at various collision energies including results from the latest Pb-Pb run at  $\sqrt{s_{NN}} = 5.02$  TeV. The comprehensive set of resonance measurements is used to study strangeness production, the role of re-scattering and regeneration in the hadronic phase as well as particle production at intermediate and high transverse momentum. Production spectra, integrated yields, mean transverse momenta and particle ratios are presented, discussed and compared to model predictions and lower energy measurements.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**Parallel session / 1001**

## Searches for direct pair production of third generation squarks with the ATLAS detector

**Author:** Nicolas Maximilian Koehler<sup>None</sup>

Naturalness arguments for weak-scale supersymmetry favour supersymmetric partners of the third generation quarks with masses not too far from those of their Standard Model counterparts. Top or bottom squarks with masses less than or around one TeV can also give rise to direct pair production rates at the LHC that can be observed in the data sample recorded by the ATLAS detector. The talk presents recent ATLAS results from searches for direct stop and sbottom pair production considering both R-parity conserving and R-parity violating scenarios, using the data collected during the LHC Run 2.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1410**

## Measurement of the hadronic cross sections with the CMD-3 and SND detectors at the VEPP-2000 collider

**Author:** Aleksandr Korol<sup>1</sup>

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Since December 2010 the CMD-3 and SND detectors collect data at the VEPP-2000 electron-positron collider. In 2013-2015 the injection facility of the collider has undergone an upgrade of the injection system. The new BINP injection complex has been connected to the VEPP-2000 collider, so the restrictions connected to the lack of positrons and limited beam energy transfer do not apply any more. The collider luminosity in whole energy range is restricted now only by beam-beam effects. A maximal beam-beam parameter value  $\xi$  achieved is about 0.12. VEPP-2000 collider started to collect data with two detectors at 2016 year. The collected data sample since 2010 corresponds more than  $100 \text{ pb}^{-1}$  of integrated luminosity per detector in the c.m. energy between 0.32 and 2  $\text{GeV}$ . We will report here results of analysis of various hadronic cross sections from detectors both published and preliminary. These measurements are important by themselves and also because of the implications for anomaly of the magnetic moment of a muon ( $g - 2$ ) discrepancy.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 992**

## Top quark production cross-section measurements

**Author:** Ye Chen<sup>None</sup>

**Corresponding Author:** y.chen@cern.ch

Measurements of the inclusive and differential cross-sections for top-quark pair and single top production cross sections in proton-proton collisions with the ATLAS detector at the Large Hadron Collider are presented at center-of-mass energies of 8 TeV and 13 TeV. The inclusive measurements reach high precision and are compared to the best available theoretical calculations. These measurements, including results using boosted tops, probe our understanding of top-pair production in the TeV regime. The results are compared to Monte Carlo generators implementing LO and NLO matrix elements matched with parton showers and NLO QCD calculations. For the t-channel single top measurement, the single top-quark and anti-top-quark total production cross-sections, their ratio, as well as differential cross sections are also presented. A measurement of the production cross-section of a single top quark in association with a W boson, the second largest single-top production mode, is also presented. Finally, measurements of the properties of the  $Wtb$  vertex allow to set limits on anomalous couplings. All measurements are compared to state-of-the-art theoretical calculations.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1086**

## Double Chooz double-detector results

**Author:** Denise Hellwig<sup>1</sup>

<sup>1</sup> RWTH Aachen University

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Double Chooz is a reactor antineutrino disappearance experiment located in Chooz, France, to measure the neutrino mixing angle  $\theta_{13}$ . By detecting the unique inverse beta decay (IBD) prompt-delayed signal antineutrinos can be precisely identified. The experiment consists of two liquid scintillator detectors of identical design; a far detector at a distance of about 1 km is operating since 2011; a near detector at a distance of about 400 m is operating since begin 2015. This double-detector setup with iso-flux configuration allows to fit the far detector data to the near detector data without relying on the reactor neutrino flux prediction where systematic uncertainties are suppressed to per mill level. Statistical uncertainties are reduced by not only using the delayed signal of neutron capture on Gadolinium but adding neutron captures on Hydrogen yielding a statistics increase of more than a factor of two.

To validate the measurement and suppression mechanism in the fit, multiple statistical methods as well as multiple fit configurations using the two detectors have been developed in Double Chooz. They are supplementary to each other to deliver a precise and accurate  $\theta_{13}$  value. This contribution will present the latest results of the Double Chooz collaboration.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

Latest results for the neutrino mixing angle  $\theta_{13}$  from the Double Chooz experiment

**Parallel session / 959**

## Recent PHENIX results on high-pT light hadron production

**Author:** Wenqing Fan<sup>None</sup>

**Co-authors:** Alexander Berdnikov <sup>1</sup>; Sergei Zharko <sup>1</sup>; Viktor Riabov <sup>2</sup>; Yaroslav Berdnikov <sup>3</sup>

<sup>1</sup> Peter the Great Saint-Petersburg Polytechnic University

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Production of Quark Gluon Plasma (QGP) has been established in central heavy ion collisions (Au+Au, Cu+Cu) at RHIC energies. Observation of strong suppression of hadron yields at high transverse momentum served as one of the most important evidences in favor of production of a new state of matter in such collisions. Recent RHIC run with asymmetric collision system (Cu+Au) provides the means to systematically study suppression pattern of hadrons in different nuclear overlap geometry needed to improve theoretical description of parton energy loss in QGP.

Non-zero elliptic flow and a hint of suppression of high pT hadrons suggests that mini-QGP can be formed in collisions of light and heavy nuclei characterized by high charged particle multiplicities. To address the question of collective behavior in small systems RHIC provided series of geometry controlled experiments with highly asymmetric systems (p+Al, p+Au, He3+Au).

The recent results from PHENIX experiment at RHIC on charged hadron, pi-zero, eta and phi meson production in asymmetric systems will be presented and discussed.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena



**Summary:**

Parallel session / 993

**Top quark properties and mass measurements with the ATLAS detector**Author: Tomas Dado<sup>None</sup>

Corresponding Author: tomas.dado@cern.ch

The top quark is unique among the known quarks in that it decays before it has an opportunity to form hadronic bound states. This makes measurements of its properties particularly interesting as one can access directly the properties of a bare quark. The latest measurements of these properties with the ATLAS detector at the LHC are presented. Measurements of top quark spin observables in top-antitop events, each sensitive to a different coefficient of the spin density matrix, are presented and compared to the Standard Model predictions. The helicity of the W boson from the top decays and the production angles of the top quark are further discussed. Limits on the rate of flavour changing neutral currents in the production or decay of the top quark are reported. The production of top-quark pairs in association with W and Z bosons is also presented. The measurement probes the coupling between the top quark and the Z boson. The cross-section measurement of photons produced in association with top-quark pairs is also discussed. These process are all compared to the best available theoretical calculations. The latest ATLAS measurements of the top quark mass in lepton+jets, dilepton, and all-hadronic final states are also reported. In addition, measurements aiming to measure the mass in a well-defined scheme are presented.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

Parallel session / 1503

**Hadronic molecules in a constituent quark model**Author: Pablo G. Ortega<sup>1</sup><sup>1</sup> University of Salamanca

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TBA

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

Parallel session / 1163

**Gluons, Heavy and Light Quarks in the QCD Vacuum**

**Author:** Mirzayusuf Musakhanov<sup>1</sup>

<sup>1</sup> *National University of Uzbekistan*

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Outline of the talk is:

- QCD vacuum, QCD instanton vacuum [1].
- Instanton Liquid Model (ILM) vs Dyons Liquid Model (DLM) [2].
- Gluons in the ILM. Poylitsa Eq. [3] for the gluon propagator in the ILM. Dynamical gluon mass.
- Heavy quarks  $Q$  in the ILM [4].  $Q\bar{Q}$ -potential within the ILM.
- Heavy and light quarks in the ILM [5].
- Heavy quark light mesons interactions [6].
- Conclusion.

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**Topic::**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:**

**Parallel session / 1509**

## Recent Results from T2K

**Author:** Sandro Bravar<sup>1</sup>

<sup>1</sup> *Universite de Geneve (CH)*

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Recent results from T2K will be presented.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1035**

## Measurements of D-meson production in p-Pb and Pb-Pb collisions with the ALICE detector at the LHC

**Author:** Cristina Bedda<sup>1</sup>

<sup>1</sup> *Utrecht University (NL)*

**Corresponding Author:** cristina.bedda@cern.ch

Heavy quarks (charm and beauty) are a powerful tool to study the properties of the Quark-Gluon Plasma (QGP), the hot and dense medium formed in high-energy heavy-ion collisions. Due to their large masses, heavy quarks are produced in hard partonic scattering processes in the initial stages of the collision. Therefore, they experience the whole system evolution interacting with the medium constituents. The measurement of heavy-flavour production can give us different information depending on the type of collision. In p-Pb collisions, it makes it possible to study cold nuclear matter effects, such as shadowing,  $k_T$  broadening and initial-state energy loss, as well as possible geometrical and collective effects in high-multiplicity events. In Pb-Pb collisions, it allows us to test parton energy-loss models and to investigate the participation of heavy quarks in the collective expansion of the system.

In ALICE, open charm production is measured through the full reconstruction of D-meson hadronic decays at mid-rapidity.

In this talk, the ALICE results on the production of prompt D mesons in p-Pb and Pb-Pb collisions will be presented, focusing on the recent results from LHC Run II data.

The main physical observables measured are: the nuclear modification factor ( $R_{AA}$ ), which compares the D-meson yields in p-Pb (Pb-Pb) collisions to the binary scaled D-meson yields in pp collisions, and the elliptic flow ( $v_2$ ), the second Fourier coefficient of the D-meson azimuthal distribution. We will report the D-meson cross section and nuclear modification factor in p-Pb collisions as a function of the event multiplicity. In addition, the  $R_{AA}$  and  $v_2$  in different Pb-Pb collision centralities will be discussed. The results will be also compared with theoretical predictions.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**Parallel session / 1466**

## Critical nucleus charge in a superstrong magnetic field

**Authors:** Sergey Godunov<sup>1</sup>; Mikhail Vysotskiy<sup>None</sup>; Bruno Machet<sup>2</sup>

<sup>1</sup> *ITEP*

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Due to strong enhancement of loop effects in a superstrong magnetic field ( $B \gg m^2/e^3$ ) the Coulomb potential becomes screened. This phenomenon dramatically changes the dependence of the electron energy levels on magnetic field. In particular, the freezing of energy levels occurs so the ground energy level of light ions can never reach the lower continuum (become critical), no matter how strong the field is.

Therefore, the magnetic field affects the critical nucleus charge  $Z_{cr}$  in two ways: i. it makes the electron movement essentially one-dimensional diminishing the value of  $Z_{cr}$ ; ii. it makes the potential weaker increasing the value of critical charge.

**Topic::**

Memorial session for W. Greiner

**Summary:**

Parallel session / 1197

## Fluctuations in non-ideal pion gas with dynamically fixed particle number

**Authors:** Evgeni Kolomeitsev<sup>1</sup>; Dmitry Voskresensky<sup>2</sup>

<sup>1</sup> *Matej Bel University*

<sup>2</sup> *National Research Nuclear University MEPhI*

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We consider a non-ideal hot pion gas with the dynamically fixed number of particles in the model with the  $\lambda\phi^4$  interaction. The effective Lagrangian for the description of such a system is obtained after dropping the terms responsible for the change of the total particle number. Reactions  $\pi^+\pi^-\leftrightarrow\pi^0\pi^0$ , which determine the isospin balance of the medium, are permitted. Within the self-consistent Hartree approximation we compute the effective pion mass, thermodynamic characteristics of the system and the variance of the particle number at temperatures above the critical point of the induced Bose-Einstein condensation when the pion chemical potential reaches the value of the effective pion mass. We analyze conditions for the condensate formation in the process of thermalization of an initially non-equilibrium pion gas. The normalized variance of the particle number increases with a temperature decrease but remains finite in the critical point of the Bose-Einstein condensation. This is due to the non-perturbative account of the interaction and is in contrast to the ideal-gas case. In the kinetic regime of the condensate formation the variance is shown to stay finite also.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

Parallel session / 989

## Recent Tests of the Standard Model with Multi boson final states at the ATLAS Detector

**Author:** Mario Campanelli<sup>None</sup>

Measurements of the cross sections of the production of two and three electroweak gauge bosons at the LHC constitute stringent tests of the electroweak sector of the Standard Model and provide a model-independent means to search for new physics at the TeV scale.

The ATLAS collaboration has performed new measurements of integrated and differential cross sections of the production of heavy di-boson pairs in fully-leptonic and semi-leptonic final states at centre-of-mass energies of 8 and 13 TeV. We present in particular new measurements of WW, WZ and Z+photon cross sections in semi-leptonic or hadronic decays using standard or boosted technologies and new measurements of the inclusive and differential ZZ cross section at 13 TeV in various decay modes.

In addition, the ATLAS collaboration has recently searched for the production of three W bosons or of a W boson and a photon together with a Z or W boson at a center of mass energy of 8 TeV. Moreover, the electroweak production in vector boson fusion of single W and Z bosons with two jets at high invariant mass at centre-of-mass energies of 7, 8 and 13 TeV are studied in different phase space regions. All results are compared to state-of-the-art theory predictions and have been used to constrain anomalous quartic gauge couplings.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

Parallel session / 961

**Low-energy  $K^-$  interaction with light nuclei by the AMADEUS collaboration****Author:** Raffaele Del Grande<sup>1</sup><sup>1</sup> LNF-INFN**Corresponding Author:** raffaele.delgrande@lnf.infn.it

The AMADEUS collaboration is aiming to study the  $K^-$  hadronic interaction with light nuclei in the low-energy regime with high precision. The main goal is to provide information on the  $\bar{K}N$  interaction in nuclear medium, fundamental for the understanding of the non-perturbative QCD in the strangeness sector, with implications going from nuclear physics to astrophysics. Hyperon-nucleon/nuclei ( $YN$ ) and hyperon-pion ( $Y\pi$ ) correlation studies are performed with the aim to explore the possible existence of deeply bound kaonic states in nuclei and the properties of hyperon resonances in nuclear environment. AMADEUS takes advantage of the DAΦNE collider, which provides a unique source of monochromatic low-momentum kaons ( $p_K \sim 127$  MeV/c). As a first step, we explore the hadronic interaction of the negative kaons in the materials of the KLOE detector, which is used as large acceptance and resolution active target, providing a high statistic sample of  $K^-$  nuclear absorption on H,  $^4\text{He}$ ,  $^9\text{Be}$  and  $^{12}\text{C}$  nuclei. Future plans will be also discussed.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

Parallel session / 990

**Probing QCD with Photons and Jets at the ATLAS Detector****Author:** Giuseppe Callea<sup>None</sup>**Corresponding Author:** giuseppe.callea@cern.ch

The production of jets and prompt isolated photons at hadron colliders provides a stringent test of perturbative QCD at the highest energies. The process can also be used to probe the proton structure.

The ATLAS collaboration has recently measured the inclusive and differential jet and dijet production cross section in data collected at a center-of-mass energy of 8 TeV and 13 TeV. We also present new measurements of transverse energy-energy correlations (TEEC) and their associated asymmetries (ATEEC) in multi-jet events at a center-of-mass energy of 8 TeV. The data is unfolded to the particle level and is used to extract the strong coupling constant and test the renormalization group equations. The Strong coupling constant is also extracted from a measurement of the dijet azimuthal decorrelation.

We will also present precise measurements of the inclusive production of isolated prompt photons at a center-of-mass energy of 13 TeV, differential in both rapidity and the photon transverse momentum. This will be complemented by measurements of isolated photon pair and tri-photon production at 8 TeV. The production of prompt photons in association with jets combines jet and photon final states and provides an additional testing ground for perturbative QCD with a hard colourless probe less

affected by hadronisation effects than jet production also. The ATLAS collaboration has studied the dynamics of isolated-photon plus jet production and of the isolated photon+heavy flavour final states in pp collisions at a centre-of-mass energy of 8TeV and 13 TeV, which will be presented and discussed.

All results have been compared with state-of-the-art theory predictions at NLO and NNLO in pQCD, interfaced with different parton distribution functions and can be used to constrain the proton structure.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

Parallel session / 987

## Tracking and Vertexing with the ATLAS Inner Detector in the LHC Run2 and Beyond

**Author:** Stewart Patrick Swift<sup>None</sup>

Run-2 of the LHC has provided new challenges to track and vertex reconstruction with higher centre-of-mass energies and luminosity leading to increasingly high-multiplicity environments, boosted, and highly-collimated physics objects. To achieve this goal, ATLAS is equipped with the Inner Detector tracking system built using different technologies, silicon planar sensors (pixel and micro-strip) and gaseous drift-tubes, all embedded in a 2T solenoidal magnetic field. In addition, the Insertable B-layer (IBL) is a fourth pixel layer, which was inserted at the centre of ATLAS during the first long shutdown of the LHC. An overview of the use of each of these subdetectors in track and vertex reconstruction, as well as the algorithmic approaches taken to the specific tasks of pattern recognition and track fitting, is given. The performance of the Inner Detector tracking and vertexing will be summarised. These include a factor of three reduction in the reconstruction time, optimisation for the expected conditions, novel techniques to enhance the performance in dense jet cores, time-dependent alignment of sub-detectors and special reconstruction of charged particles produced at large distance from interaction points. Moreover, data-driven methods to evaluate vertex resolution, fake rates, track reconstruction inefficiencies in dense environments, and track parameter resolution and biases will be shown. Luminosity increases in 2017 and beyond will also provide challenges for the detector systems and offline reconstruction, and strategies for mitigating the effects of increasing occupancy will be discussed. Finally, the upgraded 'ITk' tracking detector for operation at the High-Luminosity LHC will be presented. The tracking performance of the all-silicon tracker, which includes an increased tracking acceptance up to  $|\eta| < 4.0$ , under expected HL-LHC conditions with up to 200 interactions per bunch crossing will be shown. Ongoing optimisation of the track reconstruction and future approaches that may improve the physics and/or technical performance of the ATLAS track reconstruction for HL-LHC are considered.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

Parallel session / 1538

## Searches for electroweak production of supersymmetric gauginos and sleptons with the ATLAS detector

**Author:** Athina Kourkouveli-Charalambidi<sup>1</sup>

<sup>1</sup> *Aristotle Univ. of Thessaloniki (GR)*

**Corresponding Author:** athina.kourkoumeli-charalambidi@cern.ch

Many supersymmetry models feature gauginos and also sleptons with masses less than a few hundred GeV. These can give rise to direct pair production rates at the LHC that can be observed in the data sample recorded by the ATLAS detector. The talk presents results from searches for gaugino and slepton pair production in final states with leptons or long-lived particles, using the data collected during the LHC Run 2.

**Parallel session / 1546**

## SUSY (ATLAS)

**Author:** Andre Sopczak<sup>1</sup>

<sup>1</sup> *Czech Technical University (CZ)*

**Corresponding Author:** andre.sopczak@cern.ch

During the data-taking period at LHC (Run-II), several searches for supersymmetric particles were performed. The results from searches by the ATLAS collaborations are concisely reviewed. Model-independent and model-dependent limits on new particle production are set, and interpretations in supersymmetric models are given.

**Topic::**

Other

**Summary:**

**Parallel session / 1233**

## Ultra long-lived particles searches with MATHUSLA

**Author:** Cristiano Alpigiani<sup>1</sup>

<sup>1</sup> *University of Washington, Seattle*

**Corresponding Author:** cristiano.alpigiani@cern.ch

Many extensions of the Standard Model (SM) include particles that are neutral, weakly coupled, and long-lived that can decay to final states containing several hadronic jets. Long-lived particles (LLPs) can be detected as displaced decays from the interaction point, or missing energy if they escape. ATLAS and CMS have performed searches at the LHC and significant exclusion limits have been set in recent years.

However, the current searches performed at colliders have limitations. An LLP does not interact with the detector and it is only visible once it decays. Unfortunately, no existing or proposed search strategy will be able to observe the decay of non-hadronic electrically neutral LLPs with masses above  $\sim$  GeV and lifetimes near the limit set by Big Bang Nucleosynthesis ( $c\tau \sim 107$ - $108$  m). Therefore, ultra-long-lived particles (ULLPs) produced at the LHC will escape the main detector with extremely high probability.

In this talk we describe the concept of the MATHUSLA surface detector (MASSive Timing Hodoscope for Ultra Stable neutral pArticles), which can be implemented with existing technology and in time for the high luminosity LHC upgrade to find such ultra-long-lived particles, whether produced in exotic Higgs decays or more general production modes. The MATHUSLA detector will consist of resistive plate chambers (RPC) and scintillators with a total sensitive area of  $200 \times 200$  m square. It

will be installed on the surface, close to the ATLAS or CMS detectors.

A small-scale test detector (~ 6 m square) will be installed on the surface above ATLAS in early summer 2017. It will consist of three layers of RPCs used for timing/tracking and two layers of scintillators for timing measurements. It will be placed above the ATLAS interaction point to estimate cosmic backgrounds and proton-proton backgrounds coming from ATLAS during nominal LHC operations. We will report on the status of the test detector, on the on-going background studies, and plans for the MATHUSLA detector.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Parallel session / 1562**

## Unruh effect in heavy ion collisions

**Corresponding Author:** machur@ukr.net

**Parallel session / 1152**

## Towards topological quantum computer

**Authors:** Dmitry Melnikov<sup>None</sup>; Andrey Mironov<sup>None</sup>; Sergey Mironov<sup>1</sup>; Alexei Morozov<sup>2</sup>; Andrey Morozov<sup>None</sup>

<sup>1</sup> *INR*

<sup>2</sup> *Unknown*

**Corresponding Authors:** morozov@itep.ru, sa.mironov\_1@physics.msu.ru

One of the principal obstacles on the way to quantum computers is the lack of distinguished basis in the space of unitary evolutions and thus the lack of the commonly accepted set of basic operations (universal gates). A natural choice, however, is at hand: it is provided by the quantum R-matrices, the entangling deformations of non-entangling (classical) permutations, distinguished from the points of view of group theory, integrable systems and modern theory of non-perturbative calculations in quantum field and string theory. Observables in this case are (square modules of) the knot polynomials, and their pronounced integrality properties could provide a key to error correction. We suggest to use R-matrices acting in the space of irreducible representations, which are unitary for the real-valued couplings in Chern-Simons theory, to build a topological version of quantum computing.

**Topic::**

Topic: Quantum Physics, Quantum Optics and Quantum Information

**Summary:**

**Parallel session / 1567**

## Entanglement entropy in Yang-Mills theory: lattice measurements and qualitative features



**Author:** Valentin Zakharov<sup>1</sup>

<sup>1</sup> *Institute for Theoretical and Experimental Physics (RU)*

**Corresponding Author:** [vzakharov@itep.ru](mailto:vzakharov@itep.ru)

We review briefly lattice measurements of entanglement entropy in SU(3) Yang-Mills theory, following mostly the paper E. Itou et al., PTEP 2016 (2016) no.6, 061B01. We confront qualitative features emerging from the measurements with theoretical predictions based on field theory and holographic models.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**Parallel session / 1574**

## New evidence for a flowing medium

**Author:** Claude Andre Pruneau<sup>1</sup>

<sup>1</sup> *Wayne State University (US)*

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New evidence for a flowing medium

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**Parallel session / 935**

## The SHiP experiment at CERN

**Author:** Collaboration SHiP<sup>1</sup>

**Co-author:** Walter Marcello Bonivento <sup>2</sup>

<sup>1</sup> *CERN*

<sup>2</sup> *INFN Cagliari*

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SHIP is a new general purpose fixed target facility, whose Technical Proposal has been recently reviewed by the CERN SPS Committee and by the CERN Research Board. The two boards recommended that the experiment proceeds further to a Comprehensive Design phase in the context of the new CERN Working group “Physics Beyond Colliders”, aiming at presenting a CERN strategy for the European Strategy meeting of 2019. In its initial phase, the 400GeV proton beam extracted from the SPS will be dumped on a heavy target with the aim of integrating  $2 \times 10^{20}$  pot in 5 years. A dedicated detector, based on a long vacuum tank followed by a spectrometer and particle identification detectors, will allow probing a variety of models with light long-lived exotic particles and masses below  $O(10) \text{ GeV}/c^2$ . The main focus will be the physics of the so-called Hidden Portals, i.e.

search for Dark Photons, Light scalars and pseudo-scalars, and Heavy Neutrinos. 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 could also be explained. Another dedicated detector will allow the study of neutrino cross-sections and angular distributions.  $\nu\tau$  deep inelastic scattering cross sections will be measured with a statistics 1000 times larger than currently available, with the extraction of the F4 and F5 structure functions, never measured so far and allow for new tests of lepton non-universality with sensitivity to BSM physics.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Persian poems / 1539**

## **What are we? Where do we come from? Where are we going?**

**Author:** John Ellis<sup>1</sup>

<sup>1</sup> *CERN*

**Corresponding Author:** johnellis@fastmail.fm

Particle physics addresses Gauguin's fundamental questions about the Universe, its past and future, and our place within it.

**Topic::**

Lectures

**Summary:**

**Persian poems / 1483**

## **Η γεννεση της μαζας στο αρχεγονο συμπαν (The generation of mass in the early universe)**

**Author:** Jean Iliopoulos<sup>1</sup>

<sup>1</sup> *LPTENS*

**Corresponding Author:** ilio@lpt.ens.fr

The generation of mass in the early universe

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Persian poems / 1572**

## Poems from Iran

**Author:** Mohammad M. Qaemmaqami<sup>1</sup>

<sup>1</sup> *Institute for Research in Fundamental Sciences (IPM)*

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**Persian poems / 1573**

## Religion, Science and Philosophy

**Author:** Georgios Pavlos<sup>1</sup>

<sup>1</sup> *Democritus University of Thrace*

**Corresponding Author:** gpavlos@ee.duth.gr

**Poster session / 946**

## Surrounding matter theory

**Author:** Frederic Lassaille<sup>None</sup>

**Corresponding Author:** lumimi2003@hotmail.com

In this paper, S.M.T. (Surrounding Matter Theory), an alternative theory to dark matter, is presented. It is based on a modification of Newton's law. This modification is done by multiplying a Newtonian potential by a given factor, which is varying with local distribution of matter, at the location where the gravitational force is exerted. With this new equation the model emphasizes that a gravitational force is roughly inversely proportional to mass density at the location where this force is applied. After presentation of the model, its dynamic is quickly illustrated by cosmology. Some possible caveats of the model are identified. But the simple mechanism described above suggests the idea of a solution to the following issues: virial theorem mystery, the value of cosmological critical density, the fine tuning issue, and expansion acceleration. A de Sitter Universe is predicted. The predicted time since last scattering is . This study gives motivation for scientific comparisons with experimental data.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

An alternative theory to dark matter, is presented, it is based on a modification of Newton's law.

This modification of Newton's law is done by multiplying a Newtonian potential by a given factor, which is varying with mass density, at the location where the gravitational force is exerted.

**Poster session / 1231**

## Search for R-parity violating supersymmetry and Quantum black-holes in $e+\mu$ final state in CMS

**Author:** Swagata Mukherjee<sup>1</sup>

<sup>1</sup> *Rheinisch-Westfaelische Tech. Hoch. (DE)*

**Corresponding Author:** s.mukherjee@cern.ch

This poster presents a search for heavy particles decaying into  $e\mu$  final states with 13 TeV proton-proton collision data recorded with the CMS detector at the LHC. The search is interpreted using two different benchmark models. One of them is the scenario of resonant  $\tau$  sneutrino production in R-parity violating supersymmetry, and the other is the non-resonant signal of Quantum Black Hole (QBH) production in models with extra dimensions.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Poster session / 1387**

## Nuclear phase transition and thermodynamic instabilities in dense nuclear matter

**Author:** Andrea Lavagno<sup>1</sup>

<sup>1</sup> *Politecnico di Torino, Italy*

**Corresponding Author:** andrea.lavagno@polito.it

We study the presence of thermodynamic instabilities in a nuclear medium at finite temperature and density where nuclear phase transitions can take place. Similarly to the low density nuclear liquid-gas phase transition, we show that such a phase transition is characterized by pure hadronic matter with both mechanical instability (fluctuations on the baryon density) that by chemical-diffusive instability (fluctuations on the strangeness concentration).

The analysis is performed by requiring the global conservation of baryon number and zero net strangeness in the framework of an effective relativistic mean field theory with the inclusion of the Delta(1232)-isobars, hyperons and the lightest pseudoscalar and vector meson degrees of freedom. It turns out that in this situation hadronic phases with different values of strangeness content may coexist, altering significantly baryon-antibaryon ratios.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**Poster session / 1126**

## The new front end and DAQ of the ICARUS detector

**Author:** Christian Farnese<sup>1</sup>

<sup>1</sup> *Universita e INFN, Padova (IT)*

**Corresponding Author:** christian.farnese@cern.ch

Icarus is the largest imaging LAr TPC ever operated. During its LNGS run on the CNGS neutrino beam, from 2010 to 2013, produced some thousands neutrino events of unprecedented quality. This was possible thanks its mechanical precision and stability, liquid argon purity and electronics front-end and DAQ. In this poster the last issue (front-end and DAQ) will be presented in detail. Actually Icarus T600, in view of its operation at FNAL on the SBN neutrino beam, is undergoing a major overhauling that implies cathode mechanics improvement, additional PMTs installation and a new electronics front-end and DAQ. This electronics implements a new architecture, integrated onto the flange proprietary design, and a new front-end that improves S/N and induction signals treatment. Also this issue will be presented in detail together with data recently recorder at CERN in the Icarino, 50 litres, LAr facility.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

The poster addresses innovative electronic front end and DAQ for ICARUS T600 detector, representing the status of the art of Liquid Argon TPC detectors.

**Poster session / 1049**

## muon performance

**Authors:** Luigi Marchese<sup>1</sup>; Luigi Marchese<sup>2</sup>

<sup>1</sup> *University of Oxford (GB)*

<sup>2</sup> *Fermilab*

**Corresponding Authors:** luigi.marchese@cern.ch, marchese@fnal.gov

Muons are of key importance to study some of the most interesting physics topics at the LHC. We show the status of the performance of the muon reconstruction in the analysis of proton-proton collisions at the LHC, recorded by the ATLAS detector in 2016 and 2017. Reconstruction efficiency and momentum resolution have been measured using J/Psi and Z decays for different classes of reconstructed muons.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

Muons are of key importance to study some of the most interesting physics topics at the LHC. We show the status of the performance of the muon reconstruction in the analysis of proton-proton collisions at the LHC, recorded by the ATLAS detector in 2016 and 2017. Reconstruction efficiency and momentum resolution have been measured using J/Psi and Z decays for different classes of reconstructed muons.

**Poster session / 1046**

## Insecurity of detector-device-independent quantum key distribution

**Authors:** shihan sajeed<sup>1</sup>; anqi huang<sup>2</sup>; Shihai sun<sup>3</sup>; feihu xu<sup>4</sup>; Vadim makarov<sup>2</sup>; marcos curty<sup>5</sup>

<sup>1</sup> *University of Waterloo*

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Quantum key distribution (QKD) [1] is a technique that allows distribution of a secret random bit string between two separated parties (Alice and Bob). In theory, QKD provides information-theoretic security based on the laws of quantum physics. In practice, however, it does not, as standard QKD realizations cannot typically fulfill the demands imposed by the theory. As a result, any unaccounted device imperfection might constitute a side-channel which could be used by an eavesdropper (Eve) to extract the secret key without being detected. To bridge this gap, various approaches have been proposed, with measurement-device-independent QKD (mdiQKD) [2] probably being the most promising one in terms of feasibility and performance. Compared to standard prepare-and-measure QKD schemes [1], its security is based on post-selected entanglement. This allows to remove all detector side-channels from QKD implementations. Also, its practicality has been already confirmed both in laboratories and via field trials [3, 4]. However, one drawback of mdiQKD is that it requires high-visibility two-photon interference between independent sources, which makes its implementation more demanding than that of standard prepare-and-measure QKD schemes. Another limitation is its security proofs require larger post-processing data block sizes than those of standard QKD.

To overcome these limitations, a novel approach, so-called detector-device-independent QKD (ddiQKD), has been introduced recently [5–8]. It avoids the problem of interfering photons from independent light sources by using the concept of a single-photon Bell state measurement (BSM) [9]. As a result, it achieves the robust security of MDI-QKD, and at the same time provides the ease of implementation like standard prepare-and-measure QKD schemes. Also, its post-processing data block sizes are expected to be similar to those of standard prepare-and-measure QKD schemes [10]. To summarize, DDI-QKD was assumed to become the ‘holy grail’ of quantum key distribution protocols.

In this talk, I will show that, although it is widely assumed that DDI-QKD is robust to detector side-channels, it is in practice not true. Our main contributions are twofold. First, we show that, in contrast to mdiQKD, the security of ddiQKD cannot be based on post-selected entanglement alone, as initially thought in [5–8]. Hence, its security is not as robust as MDI-QKD. Second, we show that DDI-QKD is actually insecure against detector side-channel attacks by presenting various eavesdropping strategies that can fully compromise the security of the system.

The manuscript can be found at:

<https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.117.250505>

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**Topic::**

Topic: Quantum Physics, Quantum Optics and Quantum Information

**Summary:**

**Poster session / 1087**

## Antiproton-nucleus annihilation cross section at low energy

**Authors:** Hossein Aghai Khozani<sup>1</sup>; Andrea Bianconi<sup>2</sup>; Maurizio Corradini<sup>3</sup>; Ryugo Hayano<sup>4</sup>; Masaki Hori<sup>5</sup>; Marco Leali<sup>6</sup>; Evandro Lodi-Rizzini<sup>7</sup>; Valerio Mascagna<sup>6</sup>; Yohei Murakami<sup>4</sup>; Michela Prest<sup>8</sup>; Erik Vallazza<sup>9</sup>; Luca Venturelli<sup>6</sup>; Hiroyuki Yamada<sup>4</sup>

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The antinucleon-nuclei annihilation cross sections at low energies were systematically measured at CERN in the 80's and 90's with the LEAR facility and later with the Antiproton Decelerator. Unfortunately only few data exist for very low energy antiprotons ( $p < 500$  MeV/c) on medium and heavy nuclei.

A deeper knowledge is required by fundamental physics and can have consequence also in cosmology and medical physics.

In order to fill the gap, the ASACUSA Collaboration has very recently measured the annihilation cross section of 100 MeV/c antiproton on carbon.

In the present work the experimental result is presented together with a comparison both with the antineutron data on the same target at the same energies and with the other existing antiproton data at higher energies.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

Poster session / 1077

## Experimental technique for p-nucleus annihilation cross section measurements at low energy

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The interaction of very low energy  $\bar{p}$  and  $\bar{n}$  with nuclei is interesting for its influence on both fundamental cosmology and nuclear physics. Measuring the annihilation cross section of antimatter on matter can help in solving the universe matter-antimatter puzzle and could give relevant hints in the definition of strong interaction model parameters as well.

The ASACUSA collaboration recently measured the antiproton-carbon annihilation cross section at 5.3-MeV of kinetic energy of the incoming antiproton. The experimental apparatus consisted in a vacuum chamber containing thin foils ( $\sim 0.7-1\text{-}\mu\text{m}$ ) of carbon crossed by a bunched beam of antiprotons from the CERN Antiproton Decelerator (AD). The fraction of antiprotons annihilating on the target nucleons gives origin to charged pions which can be detected and counted by segmented scintillators placed outside the chamber. This work describes the experimental details of the apparatus and the technique to perform the cross section measurements.

**Topic::**

Special Session on Instruments and Methods in HEP

**Summary:**

Poster session / 1033

## A-dependence of $\Lambda\Lambda$ -bond and charge symmetry energies

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The  $\Lambda\Lambda$  bond energies ( $\Delta B_{\Lambda\Lambda}$ ) of double- $\Lambda$  hypernuclei provide a measure of the nature of the in-medium strength of the  $\Lambda\Lambda$  interaction. Likewise, the charge symmetry breaking in mirror nuclei with  $\Lambda$  and  $\Lambda\Lambda$  is expected to shed light on  $\Lambda N$  and  $\Lambda\Lambda N$  interactions. The  $\Lambda\Lambda$ -separation energy ( $B_{\Lambda\Lambda}$ ) from a double- $\Lambda$  nucleus exceeds twice the value of the  $\Lambda$ -separation energy ( $B_{\Lambda}$ ) of a single- $\Lambda$  nucleus and this excess is known as the bond energy given by,



$$\Delta B_{\Lambda\Lambda} = B_{\Lambda\Lambda}(^A_{\Lambda\Lambda}Z) - 2B_{\Lambda}(^A_{\Lambda}Z),$$

where  $A$  is the mass number with the hyperon number included. A generalized mass formula, constructed earlier with broken SU3 symmetry, is employed to calculate the separation energies from light to heavy nuclei. The newly available experimental data on  $\Lambda\Lambda$ -separation energy of several double- $\Lambda$  nuclei, and some single- $\Lambda$  nuclei put stringent constraint on this formula leading to a modification of one of its parameters. The  $B_{\Lambda}$ ,  $B_{\Lambda\Lambda}$  and  $\Delta B_{\Lambda\Lambda}$  values calculated with this revised mass formula are in good agreement with the experimental data. Results are also compared with the recent predictions from the quark mean-field model (QMF) and the relativistic mean-field (RMF) approach. The mass formula enables prediction of the bond energy and symmetry energy for a wide range of nuclei for which experimental  $\Lambda$ - and  $\Lambda\Lambda$ -separation energy values are not yet available. Both the bond energies and the charge symmetry breaking in mirror nuclei are found to have definite  $A$ -dependence.

**Topic::**

Other

**Summary:**

**Poster session / 1226**

## Quantization Aspects of a Hypercomplex Field

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We seek to construct a quantum theory of hypercomplex fields, the commutative ring of hypercomplex numbers allows us to have as internal symmetry  $U(1) \times S_0(1,1)$ . The hypercomplex fields encode information fields two charged particle. Normal ordering is not required to control the divergence of the vacuum.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**Poster session / 1173**

## Possible Approach to Dynamical Supersymmetry Breaking via Nambu–Jona-Lasinio Model

**Authors:** Yifan Cheng<sup>1</sup>; Yan-Min Dai<sup>2</sup>; Gaber Faisal<sup>3</sup>; Otto Kong<sup>4</sup>

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Supersymmetry is undoubtedly a popular candidate for physics beyond the Standard Model. However, the origin of soft supersymmetry breaking masses has been usually depicted intricately in the

literature via extra hidden/mediating sectors. Thus, a simple theory for the generation of the soft masses would be more compelling. Recently, our group discussed in two sequential papers a new approach to dynamical supersymmetry breaking via Nambu–Jona-Lasinio Model, which has been missed since the first investigation of supersymmetric NJL model. We introduce a four-superfield interaction term that induces a real two-superfield composite with vacuum condensate. The latter has supersymmetry breaking parts, which we show to bear nontrivial solutions following a standard nonperturbative analysis for a NJL type model. In the talk, I will discuss this possibility of dynamical supersymmetry breaking, and present the prototype model, with the analysis of effective theory picture. The presence of the expected Goldstino along with the supersymmetry breaking will be also demonstrated.

**Topic::**

Topic: High Energy Particle Physics

**Summary:****Poster session / 1282**

## Experimental Relativistic Quantum Information with a Geostationary Satellite

**Authors:** Ömer Bayraktar<sup>1</sup>; Kevin Günthner<sup>1</sup>; Imran Khan<sup>1</sup>; Dominique Elser<sup>1</sup>; Christoph Marquardt<sup>1</sup>; Gerd Leuchs<sup>1</sup>

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With quantum science in space we reach a regime of physics, where the interplay between general relativity and quantum theory is unclear. A contemporary experimental scenario is satellite-based quantum communication, where an investigation of the impact of gravitational effects is of both, fundamental and technological interest. Specifically, quantum field theory in curved space-time (or relativistic quantum information) is used to describe the aforementioned scenario, while experimental evidence for the predictions are not existing yet [1]. However, the rapid development of quantum technologies in space necessitates a thorough experimental investigation of the relevant physics [2, 3]. Therefore, we investigate potential realization of relativistic quantum information experiments, based on a space-to-ground quantum communication link with a satellite in the geostationary Earth orbit [4]. Thereby, we aim to complement quantum field theory in curved space-time with experimental evidence and to explore possible limitations of satellite-based quantum communication.

[1] R. Howl et al., arXiv:1607.06666 (2016).

[2] D. Rideout et al., *Class. Quantum Gravity* 29, 224011 (2012).

[3] G. Vallone et al., *Phys. Rev. Lett.* 116, 253601 (2016).

[4] K. Günthner et al., arXiv:1608.03511 (2016).

**Topic::**

Mini-workshop: Continuous Variables and Relativistic Quantum Information

**Summary:****Poster session / 1059**

## Thermodynamics along individual trajectories of a quantum bit

**Authors:** M. Naghiloo<sup>1</sup>; D. Tan<sup>1</sup>; P. Harrington<sup>1</sup>; J. Castaneda<sup>2</sup>; E. Lutz<sup>3</sup>; A. Romito<sup>None</sup>; K. Murch<sup>1</sup>

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The laws of thermodynamics are fundamental laws of nature that classify energy changes for macroscopic systems as work performed by external driving and heat exchanged with the environment. The extension of thermodynamics to include quantum fluctuations faces unique challenges, such as the proper identification of heat and work, and the clarification of the role of quantum coherence. We use a near-quantum-limited detector to experimentally track individual quantum trajectories of a driven qubit formed by the hybridization of a waveguide cavity and a transmon circuit. For each measured quantum coherent trajectory, we separately identify energy changes of the qubit as heat and work, and verify the first law of thermodynamics for an open quantum system. We further employ a novel quantum feedback loop to compensate for the exchanged heat and effectively isolate the qubit. By verifying the Jarzynski equality for the distribution of applied work, we demonstrate the validity of the second law of thermodynamics. Our results establish thermodynamics along individual quantum trajectories.

**Topic::**

Mini-workshop: [Quantum Foundations](#) and [Quantum Information](#)

**Summary:**

**Poster session / 1477**

## Jet-flavour tagging using deep-learning in the CMS experiment

**Author:** Anna Stakia<sup>1</sup>

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The identification of jets originating from heavy flavour quarks is a crucial aspect in numerous searches at the Large Hadron Collider. In the context of the CMS experiment, a new tagger, Deep-Flavour, that uses Deep Neural Networks has been developed. DeepFlavour is a multiclassifier that is found to outperform significantly other taggers used in CMS, being so far tested in simulation. This gain in performance, especially for jets with high transverse momenta, can lead to improved sensitivity for several analyses both on searches for New Physics and on Standard Model processes.

**Topic::**

Other

**Summary:**

**Poster session / 1024**

## Gravity until equipartition of relativistic kinetic energies.

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We discuss nonempty space physics of material fields in the 1938 interpretation of Einstein and Infeld. The extended carrier of radial energies contains chaotic motions of material densities associated to the rest mass-energy or internal relativistic heat. Chaotic (internal) and ordered (translation) kinetic energies tend to equal values under the free gravitational fall. This universal tendency of any falling body to equipartition of its relativistic kinetic energies can shed a new light on the cyclic geodetic motion and on the periodic evolution of multi-body systems.

Thermal radiation/absorption can vary geodesic paths of free bodies. Einstein's relativistic dynamics of full energies incorporates variable heat of real thermodynamic bodies even at low speeds. The Newton model of masses without temperature cannot be a true nonrelativistic limit for SR/GR references. We explain quantitatively why "Einstein's theory can be accepted only with the recognition that Newton's was wrong." (S. Kuhn. *The Structure of Scientific Revolutions*, 1962, p.98).

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**Poster session / 1493**

## Applications of Advances in Relativistic Fluid Dynamics to Laser Fusion

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Inertial Confinement Fusion is a promising option to provide massive, clean, and affordable energy for mankind in the future. The present status of research and development is hindered by hydrodynamical instabilities occurring at the intense compression of the target fuel by energetic laser beams.

We show here an analytical model. The compression of the target pellet can be negligible and rapid volume ignition is achieved by a laser pulse, which is as short as the penetration time of the light across the pellet. The reflectivity of the target can be made negligible, and the absorptivity is varied so that the light pulse can reach the opposite side of the pellet.

The short light pulse can heat the target so that most of the interior will reach the ignition temperature simultaneously. This prevents the development of any kind of instability, which would prevent complete ignition of the target.

**Topic::**

Other

**Summary:**

Poster session / 1497

## Search for displaced lepton jets with the ATLAS experiment

**Author:** Cristiano Sebastiani<sup>1</sup>

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Several possible extensions of the Standard Model predict the existence of a dark sector that is weakly coupled to the visible one: i.e. the two sectors couple via the vector portal, where a dark photon with mass in the MeV to GeV range mixes kinetically with the SM photon. If the dark photon is the lightest state in the dark sector, it will decay to SM particles, mainly to leptons and possibly light mesons. Due to its weak interactions with the SM, it can have a non-negligible lifetime. At the LHC, these dark photons would typically be produced with large boost resulting in collimated jet-like structures containing pairs of leptons and/or light hadrons, the so-called lepton-jets (LJs).

This work is focused on the search for displaced LJs, which are produced away from the interaction point and their constituents are limited to electrons, muons, and pions. The requested topology includes one or two LJs + leptons/jets/MET. The most recent ATLAS results based on samples collected at a center of mass energy of 13 TeV will be presented.

Results are interpreted in terms of the Falkowsky-Ruderman-Volansky-Zupan models where dark photons are generated through the decay of a Higgs boson to intermediate hidden fermions. The Higgs boson is supposed to be produced via gluon-fusion and for the first time, results are also presented in terms of the associated production of a Higgs boson with a W/Z and in the context of inelastic thermal relic dark matter.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

Poster session / 1186

## Procedure for event characterization in Pb-Pb collisions at 40 AGeV in the NA49 experiment at CERN SPS

**Authors:** Elisaveta Zherebtsova<sup>None</sup>; Viktor Klochkov<sup>1</sup>; Ilya Selyuzhenkov<sup>2</sup>; Arkadiy Taranenko<sup>3</sup>

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The time evolution of the strongly interacting matter created in a heavy-ion collision depends on the initial geometry and the collision centrality. This makes important the experimental determination of the collision geometry. In this presentation a procedure for event classification and estimation of the geometrical parameters in inelastic Pb-Pb collisions at the beam energy of 40 AGeV recorded with the fixed target experiment NA49 at CERN SPS is discussed. In the NA49 experiment, event classes can be defined using measured multiplicity of particles in the Time Projection Chamber (TPC) or energy of spectators deposited in forward Veto or Ring calorimeters. Using the Monte-Carlo Glauber model, these event classes can be related to average values of the geometric quantities such as impact parameter or number of nucleon-nucleon collisions. The implementation of this procedure within a software framework of the future CBM experiment was adopted for event classification in the NA49 experiment. In the future, this procedure will be used for analysis of the new Pb-Pb data

collected by the NA61/SHINE experiment and for comparison with the results previously obtained by STAR at RHIC and the NA49 at CERN SPS Collaborations.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Poster session / 1008**

## **ttH Coupling Measurement with the ATLAS Detector at the LHC**

**Author:** Andre Sopczak<sup>1</sup>

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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 thus a probe for physics beyond the Standard Model.

The ttH production was analysed in various final states with multileptons and covering as well

$H \rightarrow \gamma\gamma$  and

$H \rightarrow bb$ .

The analysis was based on data taken by the ATLAS experiment recorded from 13-TeV proton-proton collisions.

The combined results are compared with the Standard Model (SM) expectation allowing models beyond the SM to be constrained.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Poster session / 1065**

## **Cylindrical symmetry: II. The Green's function in 3 + 1 dimensional curved space**

**Author:** Gopinath Kamath<sup>1</sup>

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An exact solution to the heat equation in curved space is a much sought after; this report presents a derivation wherein the cylindrical symmetry of the metric in 3 + 1 dimensional curved space has a pivotal role. To elaborate, the spherically symmetric Schwarzschild solution is a staple of textbooks on general relativity; not so perhaps, the static but cylindrically symmetric ones, though they were obtained almost contemporaneously by H.Weyl, Ann.Phys.Lpz.54,117(1917) and T. Levi-Civita, Atti Acc. Lincei Rend. 28,101(1919). A renewed interest in this subject recently

in C.S. Trenafileva and S.A. Fulling ,Eur.J.Phys. 32,1663(2011) – to which the reader is referred to for more references – motivates this work, the first part of which (cf.Kamath, PoS (ICHEP2016)791) reworked the Antonsen-Bormann idea – arXiv:hep-th/9608141v1 – that was originally intended to compute the heat kernel in curved space to determine – following D.McKeon and T.Sherry,Phys.Rev.D35,3584(1987) – the zeta-function associated with the Lagrangian density for a massive real scalar field theory in 3 + 1 dimensional stationary curved space to one-loop order, the metric for which is cylindrically symmetric. Using the same Lagrangian density the second part reported here essentially revisits the second paper by Bormann and Antonsen – arXiv:hep-9608142v1 but relies on the formulation by the author in S.G.Kamath, AIP Conf.Proc.1246,174 (2010) to obtain the Green’s function directly by solving a sequence of first order partial differential equations that is preceded by a second order partial differential equation.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:****Poster session / 1218****The new CMS Barrel Muon Track Finder**

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To maintain the excellent performance achieved during Run 1 of the LHC, the Level-1 Trigger of the Compact Muon Solenoid (CMS) experiment underwent a significant upgrade. One part of this upgrade was the re-organization of the muon trigger path from a subsystem-centric view in which hits in the drift tubes (DT), the cathode strip chambers (CSC), and the resistive plate chambers (RPC) are treated separately in dedicated track-finding systems, to one in which complementary detector systems for a given region (barrel, overlap, and endcap) are merged at the track-finding level.

An overview of the new track-finder system for the barrel region, the Barrel Muon Track Finder (BMTF) as well as a comparison with the previous trigger are presented.

**Topic::**

Special Session on Instruments and Methods in HEP

**Summary:****Poster session / 947****Search for the violation of Pauli principle at LNGS - first physics result of VIP2 experiment**

**Author:** HEXI SHI<sup>None</sup>

**Co-authors:** Alberto Clozza <sup>1</sup>; Alessandro Scordo <sup>2</sup>; Alessandro d’Uffizi <sup>1</sup>; Alexandru Mario Bragadireanu <sup>3</sup>; Andreas Pichler ; Antonio Romero Vidal <sup>4</sup>; Carlo Guaraldo <sup>5</sup>; Carolina Berucci <sup>6</sup>; Catalina Curceanu <sup>1</sup>; Diana Laura Sirghi <sup>1</sup>; Dorel Pietreanu <sup>7</sup>; Eberhard Widmann <sup>8</sup>; Edoardo Milotti <sup>9</sup>; Florin Sirghi <sup>1</sup>; Jean-Pierre Egger <sup>10</sup>; Johann Marton <sup>11</sup>; Johann Zmeskal <sup>8</sup>; Kristian Piscicchia <sup>12</sup>; Laura Sperandio <sup>1</sup>; Luca De Paolis <sup>1</sup>; Massimiliano Bazzi <sup>1</sup>; Matthias Laubenstein <sup>13</sup>; Michael Cargnelli <sup>14</sup>; Mihail Antoniu Iliescu <sup>15</sup>; Oton Vazquez Doce <sup>16</sup>; Sergio Bartalucci <sup>1</sup>; Sergio Bertolucci <sup>17</sup>; Sergio Di Matteo <sup>18</sup>; T Ponta <sup>19</sup>

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We search for x-rays from abnormal atomic orbit electron transitions that may violate the Pauli Exclusion Principle, in the VIP-2 experiment at Gran Sasso national laboratory. The candidate events come from a  $2p$  electron transits into a  $1s$  orbit which is occupied by two electrons. Such event, if exists, will have detectable energy difference from normal  $2p - 1s$  atomic transition by few hundreds of electron-volts in case it occurs in a copper atom, and the energy difference is expected to be the result of the electromagnetic shielding effect from the additional electron in the ground state.

The experimental setup with the complete detector system was mounted in the underground laboratory in 2015, and we started the physics run without the final passive lead shielding since October 2016.

From two months of data taking, we confirmed the performance of the apparatus that will fulfill the designed goal of the experiment. Moreover preliminary result from the first period of physics run already improved the upper limit set by the previous VIP experiment.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Poster session / 1014**

## Molecular Clouds as the Origin of the Gamma-Ray GeV excess

**Authors:** Wim De Boer<sup>1</sup>; Iris Gebauer<sup>1</sup>; Alexander Neumann<sup>2</sup>; Peter Biermann<sup>2</sup>

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The “GeV-excess” of the diffuse gamma-rays, as observed by the Fermi-LAT satellite, is studied with a spectral template fit based on energy spectra for each possible process of gamma-ray emission. If all physical processes are included, one should be able to describe the whole gamma-ray sky in all regions, including the Galactic center, the Fermi Bubbles and the “GeV-excess”. In addition to the “standard” physical processes for gamma-ray production from  $\pi_0$  decays produced by diffused cosmic rays, inverse Compton scattering and Bremsstrahlung we find clear evidence for two additional processes:  $\pi_0$  production in sources during acceleration and  $\pi_0$  production in molecular clouds. The first one is characterized by nuclear cosmic rays with the hard  $1/E^{2.1}$  spectrum, expected from diffusive shock wave acceleration. The second one is characterized by nuclear cosmic rays inside molecular clouds with a sharp cutoff below 14 GV, due to a process analogous to the geomagnetic cutoff, which is most clearly observed in the dense Central Molecular Zone encircling the Galactic center in the Galactic disk. Such a suppression of low energy nuclei leads to a shift in the maximum of the gamma-ray spectrum to higher energies, the hall-mark of the “GeV-excess”. To see if this excess can indeed be explained by the propagation inside molecular clouds, one needs to check in addition the spatial distribution. Fortunately, molecular clouds can be traced by the rotation lines of the CO molecule. Furthermore, the nuclear cosmic rays can be traced by the 1.8 MeV gamma-ray line from radioactive  $^{26}\text{Al}$  decays, which is synthesized in sources.

The similar morphology between sources, high-energy tail in gamma-ray spectra, molecular clouds and the “GeV-excess” establishes the two new processes discussed above and provides evidence that the “GeV-excess” is produced inside molecular clouds, thus excluding the interpretation of a dark matter annihilation signal. This erroneous interpretation is easily explained by the fact that the column density of molecular clouds resembles the spatial distribution of an annihilation signal, at least if the field-of-view is limited to a cone of less than  $20^\circ$  around the Galactic center, while the shift of the maximum of the gamma-ray energy spectrum inside molecular clouds, most likely originating from a magnetic cutoff and energy losses, resembles the spectral shape of a dark matter annihilation signal of 60 GeV dark matter particles.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

The GeV gamma-ray excess of the Fermi Satellite has been in discussion for a signal of dark matter annihilation, see e.g. Nature, <http://www.nature.com/news/mysterious-galactic-signal-points-lhc-to-darkmatter-1.17485>.

However, the bump at 2 GeV can either be caused by a depletion below 2 GeV or a new source peaking at 2 GeV. The latter could be from dark matter annihilation, but the first one from magnetic cut-offs in molecular clouds. Recently, the Planck satellite has provided a beautiful sky map of molecular clouds.

So to distinguish between the two possibilities one simply has to compare the Planck data with the Fermi data: if the 2 GeV bump in the Fermi data always coincides with a molecular cloud, it cannot be dark matter, since the latter has a completely different spatial distribution.

We did this comparison using the public data from both satellites and the answer was clear: the GeV excess from Fermi originates from the magnetic cut-off of protons trying to enter the molecular clouds. Only the high energy ones succeed and the low energy ones are bent away by the magnetic fields, thus depleting the gamma-ray spectrum at low energies as well. More details can be found in the preprint arXiv:1610.08926.

**Poster session / 1063**

## New Mathematical Formulation of the Correspondence Principle

**Authors:** Jorge Alejandro Bernal Arroyo<sup>1</sup>; Jorge Mauricio Paulin Fuentes<sup>2</sup>

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The problem about the classical limit of Quantum Mechanics is a thorny and intriguing issue at the core of modern physics. There remain many doubts about this fundamental question of the foundations of Quantum Mechanics. In the literature, there are many procedures to abord this matter, the best known and used are the Planck's limit ( ) and the Bohr's Correspondence Principle ( $n \gg 1$ ). Nathan Rosen and Richard Libboff have affirmed that this limits are not equivalent and that none of them has a universal charcater.

In this work we propose a new mathematical formulation of the Correspondence Principle. This new approach consists of obtaining the asymptotic limit of quantum probability density. As a result of this procedure, Classical Physics emerges as an asymptotic case of Quantum Mechanics. We show as examples of this procedure the cases of the quantum harmonic oscillator, the Kepler problem, the particle en the square infinity well and the quantum free falling.

With this approach one can understand the difference between the Planck's limit and the Bohr's Correspondence Principle. It also allows to clarify some of the differences that exist between Quantum Mechanics al Classical Physics.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Poster session / 1476**

## **Search for supersymmetry in events with one lepton, multiple jets and missing transverse momentum in proton-proton collisions at $\sqrt{s} = 13$ TeV**

**Author:** Anna Stakia<sup>1</sup>

<sup>1</sup> *CERN*

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A search for supersymmetry in events with a single electron or muon, hadronic jets and missing transverse momentum is presented. The data corespond to  $35.9 \text{ fb}^{-1}$  of proton-proton collisions recorded in 2016 by the CMS experiment at a center-of-mass energy of 13 TeV. The events are sorted into several exclusive search samples based on the number of jets and b-tagged jets, the scalar sum of the jet transverse momenta, and the scalar sum of the missing transverse momentum and the transverse momentum of the lepton. The numbers of events observed in all search samples are consistent with the expectations from standard model processes, and the results are used to set lower limits on superymmetric particle masses in the context of two simplified models of gluino pair production. In the first model, each gluino decays via a three- body process to a top quark-antiquark pair and a neutralino, which is assumed to escape udetected. Gluinos with masses up to 1.8 TeV are excluded for neutralino masses below 800 GeV. In the second model, each gluino decays via a three-body process to a light quark-antiquark pair and a chargino, which subsequently decays to a W boson and a neutralino. The mass of the chargino is taken to be midway between the gluino and neutralino masses. In this model, gluinos with masses below 1.9 TeV are excluded for neutralino masses below 300 GeV.

**Topic::**

Other

**Summary:**

Poster session / 1504

## On bimodal size distribution of spin clusters in the one-dimensional Ising model

**Authors:** Oleksii Ivanytskyi<sup>1</sup>; Volodymyr Chelnokov<sup>1</sup>

<sup>1</sup> *National Academy of Sciences of Ukraine (UA)*

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The size distribution of geometrical spin clusters is exactly found for the one-dimensional Ising model of finite extent. For the values of lattice constant  $\beta$  above some “critical value”  $\beta_c$  the found size distribution demonstrates the non-monotonic behavior with the peak corresponding to the size of the largest available cluster. In other words, for high values of the lattice constant there are two ways to fill the lattice: either to form a single largest cluster or to create many clusters of small sizes. This feature closely resembles the well-know bimodal size distribution of clusters which is usually interpreted as a robust signal of the first order liquid-gas phase transition in finite systems. It is remarkable that the bimodal size distribution of spin clusters appears in the one-dimensional Ising model of finite size, i.e. in the model which in thermodynamic limit has no phase transition at all.

**Topic::**

Other

**Summary:**

Poster session / 1551

## Latest results on azimuthal anisotropy at RHIC-PHENIX

**Authors:** Hiroshi Nakagomi<sup>1</sup>; Ralf Seidl<sup>2</sup>

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<sup>2</sup> *RIKEN*

**Corresponding Author:** ralf.seidl@gmail.com

Relativistic heavy ion collisions are a unique way to form the quark gluon plasma (QGP). Measurements of the azimuthal anisotropy of particle production in relativistic heavy ion collisions have been used to study the initial condition and the relativistic hydrodynamic response of the hot and dense matter. The hydrodynamical response of the QGP to a given initial condition can be studied by selecting different collision systems. For this purpose, symmetric Au+Au/Cu+Cu and asymmetric Cu+Au collisions have been operated at RHIC, and the azimuthal anisotropy strength  $v_n$  have been measured in these collision systems.

In addition, RHIC has operated small collision systems, p/d/3<sup>4</sup>He+Au collisions which have been considered too small to form the QGP. Although a finite  $v_n$  has been considered to arise from the strong hydrodynamical expansion, recent measurements of  $v_n$  in the small collision systems at RHIC show similar strengths as seen in heavy ion collisions. Measurements of  $v_n$  in small collision systems could provide a better understanding of the hydrodynamical limit and other mechanisms which cause the large anisotropy in small collision systems.

In this poster, we will present the latest results on azimuthal anisotropies in symmetric and asymmetric heavy ion collisions as well as small colliding systems at PHENIX.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**Poster session / 1565**

## **Hybrid photonic loss resilient entanglement swapping**

**Author:** Ryan Parker<sup>1</sup>

<sup>1</sup> *University of York*

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Hybrid photonic loss resilient entanglement swapping

**Topic::**

**Summary:**

**S. Belyaev Memorial Session / 1154**

## **Some Aspects of Neutron-Antineutron Oscillation**

**Author:** Arkady Vainshtein<sup>1</sup>

<sup>1</sup> *University of Minnesota*

**Corresponding Author:** vainshte@umn.edu

We discuss certain aspects of neutron-antineutron transition breaking conservation of baryon charge. In particular, we analyze discrete C, P, T symmetries and comparison between oscillations in vacuum and limitations from nuclei stability.

**Topic::**

Memorial session for S. Belyaev

**Summary:**

**S. Belyaev Memorial Session / 1401**

## **Exploring collective modes in mesoscopic systems with new techniques**

**Author:** Alexander Volya<sup>1</sup>

<sup>1</sup> *Florida State University*

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The interest of modern nuclear physics in weakly bound nuclei far from stability and in emergence of collective phenomena generates new attention to questions related to formation of mean field, pairing, other collective modes, and their interplay. The theoretical methods borrowed from macroscopic techniques turn out to be insufficient for finite systems such as nuclei. For example, weak pairing that inhibits Cooper phenomenon, particle number non-conservation, proximity of continuum states, strong coupling of collective modes, weak mean field, all suggest the need for these theories to be revised. In this presentation we tackle these problems; we take the path laid out by S.T. Belyaev and use equations of motion to couple the collectivities and to establish simple numerical

procedures allowing for solutions with exact particle-number conservation. We use simple models and configuration interaction solutions to demonstrate the workings of proposed methods.

**Topic::**

Memorial session for S. Belyaev

**Summary:**

**S. Belyaev Memorial Session / 1156**

## **Bose condensation of triplons in quantum magnets**

**Authors:** Harley Scammell<sup>1</sup>; Oleg Sushkov<sup>2</sup>

<sup>1</sup> *University of New South Wales*

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We overview the physics of magnetic Bose condensation and demonstrate how the Bose condensation and the “asymptotic freedom” of magnons manifests itself in a vicinity of a quantum critical point. These effects have been already observed experimentally and also in Quantum Monte Carlo lattice simulations. We present a comparison of theory and observations. Finally we predict an ultranarrow (long life time) Higgs excitation in the magnetic Bose condensate phase.

**Topic::**

Memorial session for S. Belyaev

**Summary:**

**S. Belyaev Memorial Session / 1166**

## **Self-consistent description of particle-phonon coupling effects. Pole and tadpole diagrams.**

**Author:** Eduard Saperstein<sup>1</sup>

<sup>1</sup> *NRC “Kurchatov Institute”, 123182 Moscow, Russia*

**Corresponding Author:** saper43\_7@mail.ru

Since the famous article of 1959 by S.T. Belyaev [1], a crucial role of the first 2+ excitations in even-even nuclei, the quadrupole “phonons”, is one of conventional cornerstones of nuclear theory. The quadrupole phonons are the surface vibrations, belonging to the Goldstone branch related to the spontaneous breaking of the translation symmetry in nuclei. In the modern self-consistent nuclear theories based on the use of the effective energy density functionals (EDFs), a problem of accounting for effects of particle-phonon coupling (PC) effects looks rather delicate as they are included to the EDF phenomenological parameters on average. Hence, there is a problem of “double counting”.

Within the self-consistent Theory of Finite Fermi Systems (TFFS), we developed a model for consideration of the PC corrections to electromagnetic moments of odd spherical nuclei in which

the fluctuating part of such corrections is taken into account only. The main idea of this model is to separate and explicitly consider such PC diagrams that behave in a non-regular way, depending significantly on the nucleus under consideration and the single-particle state of the odd nucleon. The rest (and the major part) of the PC corrections is supposed to be regular and included in the initial values of the TFFS parameters. In addition to the usual pole diagrams, so-called tadpole ones are included to the calculation scheme. The self-consistent scheme we use is based on the Fayans EDF [2].

In such approach, the quadruple phonons are most important, as their collectivity behaves in a non-regular way, changing dramatically from double magic nuclei to non-magic neighbors. The model is developed for semi-magic nuclei, which contain a superfluid subsystem and a normal one, and besides the odd nucleon belongs to the normal subsystem. It simplifies the problem drastically. In addition, a non-regular behavior of the PC corrections is typical namely for the normal subsystem of a semi-magic nucleus. The model was used for finding PC corrections to the magnetic [3] and quadrupole [4] moments of the proton-odd neighbors of the even Pb and Sn isotopes. Among the PC terms, the "end correction" and the induced interaction one are sufficiently bigger than all other. However, they have opposite signs and cancel each other significantly. Therefore, the self-consistency of the calculations is of primary importance. In the result, "small corrections", in particular the one due to the magnetic moment or quadrupole moment of the phonon, play also a role. In the last case, the tadpole diagram is of principal importance. In our calculations, rather good description of the data was obtained without any adjusted parameters.

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**Topic::**

Memorial session for S. Belyaev

**Summary:**

**S. Belyaev Memorial Session / 1400**

## **Quartet condensation in nuclear systems. A nuclear Quantum Phase Transition.**

**Author:** Peter Schuck<sup>1</sup>

<sup>1</sup> *Institut de Physique Nucleaire Orsay*

**Corresponding Author:** schuck@ipno.in2p3.fr

It is shown that low density nuclear matter is unstable with respect to alpha particle (quartet) formation. Since alpha particles are bosons, there occurs Bose-Einstein condensation (BEC). We calculate the critical temperature and solve the orderparameter equation at zero temperature. It is demonstrated that there exists a critical density at which quartet condensation disappears. Density, therefore, triggers a quantum phase transition (QPT). This does not happen for pairing where no QPT as a function of density exists. Rather there is a smooth transition from BEC to the BCS regime. The famous Hoyle  $0^+_{\alpha}$  state at 7.65 MeV in  $^{12}\text{C}$  will be identified as a precursor of alpha particle condensation. Applying this scenario to the Hoyle state all known experimental facts of the Hoyle state are well reproduced without adjustable parameter. This is in particular true for the inelastic form factor. Other possible Hoyle-like states in heavier self-conjugate nuclei will be identified.

**Topic::**

Memorial session for S. Belyaev

**Summary:****S. Belyaev Memorial Session / 1165****Covariant density functionals in nuclear physics and their microscopic origin.****Author:** Peter Ring<sup>1</sup><sup>1</sup> *Technical University Munich***Corresponding Author:** ring@ph.tum.de

The description of the structure of nuclei in the framework of effective mean-field models are remarkably successful over almost the entire periodic table. Relativistic and non-relativistic versions of this approach enable an effective description of the nuclear many-body problem as an energy density functional. Such theories are used with great success in all quantum mechanical many-body systems. In Coulombic systems, density functional theory is exact and can be derived from the bare Coulomb force without additional phenomenological parameters. In nuclear physics with spin and isospin degrees of freedom, the situation is much more complicated due to the strong nucleon-nucleon and three-body forces. At present, all attempts to derive these functionals directly from the bare forces do not reach the required accuracy. In recent years, however, there have been several attempts to derive semi-microscopic functionals. They start with microscopic Brueckner-Hartree-Fock calculations in nuclear matter. These results are then mapped on a Walecka model to adjust in this way basic properties of the covariant density functionals. Only very few additional, phenomenological parameters are necessary to for a fine-tuning and in this way universal covariant density functionals have been derived which provide an excellent description of ground states and excited states all over the periodic table with a high predictive power.

These semi-microscopic functionals suffer from the fact, that there form is not directly derived from ab initio calculations, only there parameters are adjusted. Therefore, recently, Relativistic Brueckner-Hartree-Fock

theory in finite nuclei has been used to derive the self-consistent mean field and the ground state properties of spherical doubly closed shell nuclei. Starting from a realistic bare nucleon-nucleon (NN) force adjusted to nuclear scattering data, the relativistic G-matrix is obtained as an effective interaction by solving the Bethe-Goldstone equation in a self-consistent basis. This G-matrix is inserted in a relativistic Hartree-Fock code for finite nuclei and in each step of the iteration a new G-matrix is calculated by solving the Bethe-Goldstone equation for the Pauli-operator derived from the corresponding Fermi surface in the finite system. The self-consistent solution of this iteration process allows to calculate ground state properties of finite nuclei without any adjustable parameters. No three-body forces are used. First results are shown for the doubly magic nuclei  $^4\text{He}$ ,  $^{16}\text{O}$ , and  $^{48}\text{Ca}$ . Their ground state properties, such as binding energies, charge radii, or spin-orbit splittings are largely improved as compared with the results obtained from non-relativistic Brueckner-Hartree-Fock theory. It is discussed that this theory provides a method to study also the ground state properties of heavy nuclei in *ab initio* calculations.

\* Work supported by the DFG (Germany) cluster of excellence "Origin and Structure of the Universe" ([www.universe-cluster.de](http://www.universe-cluster.de))

**Topic::**

Memorial session for S. Belyaev

**Summary:**

**S. Belyaev Memorial Session / 1169**

## **The Gamow Shell Model - Towards the unified theory of nuclear structure and reactions**

**Author:** Marek Ploszajczak<sup>1</sup>

<sup>1</sup> *GANIL*

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Gamow shell model (GSM), the complex-energy continuum shell model in Berggren basis, can be equivalently formulated either in the basis of Slater determinants, or in the basis of reaction channels, providing the unified approach to nuclear structure and reactions. In the Slater determinant representation, GSM is a tool par excellence for nuclear structure studies of bound and unbound many-body states. In the second representation, GSM provides the microscopic theory of low energy reactions and many-body resonances. In the talk, I will present this unified theory of structure and reactions and give examples of recent applications.

**Topic::**

Memorial session for S. Belyaev

**Summary:**

**S. Belyaev Memorial Session / 1438**

## **Introduction**

**Author:** Vladimir Zelevinsky<sup>1</sup>

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TBA

**Topic::**

**Summary:**

**S. Belyaev Memorial Session / 1276**

## **Isospin dynamics in nuclear structure**

**Authors:** Elena Litvinova<sup>1</sup>; Caroline Robin<sup>1</sup>

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I will discuss relativistic nuclear field theory (RNFT) as a novel approach to the nuclear many-body problem, which is based on QHD meson-nucleon Lagrangian and relativistic field theory. RNFT connects consistently the high-energy scale of heavy mesons, the medium-energy range of pion, and the low-energy domain of emergent collective vibrations (phonons) [1]. Mesons and phonons



build up the effective interaction in various channels, in particular, the phonon-exchange part takes care of the retardation effects, which are of great importance for the fragmentation of single-particle states, spreading of collective giant resonances and soft modes, quenching and beta-decay rates with significant consequences for astrophysics and theory of weak processes in nuclei.

Over the past decade, RNFT has demonstrated a very good performance in various nuclear structure calculations across the nuclear chart [1,2-4]. Recent progress on the response theory in the proton-neutron channel [5] has allowed a very good description of spin-isospin-flip excitations, which are formed predominantly by pions coupled to proton-neutron configurations in nuclear medium. Such excitations as, for instance, Gamow-Teller and spin-dipole resonances in medium-mass nuclei are of a high astrophysical importance as they are in the direct relation to beta-decay and electron capture rates. More exotic isospin-flip excitations studied lately at NSCL facility have been described very well by RNFT [6]. Presently, excitation modes in the deuteron transfer channel are considered in view of their role in mediating the isoscalar pairing and discussed as constraints for the delta-meson contribution to the nuclear forces [7].

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**Topic::**

Memorial session for S. Belyaev

**Summary:**

**S. Belyaev Memorial Session / 1149**

## **DAMPING OF SIMPLE MODES OF HIGH-ENERGY NUCLEAR EXCITATIONS**

**Author:** Michael Urin<sup>1</sup>

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The physical content and some implementations of the semi-microscopic models, which are able to describe the high-energy single-quasiparticle and particle-hole-type nuclear excitations in medium-heavy mass spherical nuclei, are presented in this report. The particle-hole dispersive optical model, developed recently [1], is mainly discussed. Being an extension of the standard and non-standard continuum-RPA versions to a phenomenological (and in average over the energy) consideration of the spreading effect, the model possess a set of unique possibilities in description of the high-energy particle-hole-type nuclear excitations. This set includes the description: of the particle-hole strength distribution in a wide excitation-energy interval, which includes distant "tails" of giant resonances; of the double transition density, which determines the corresponding hadron-nucleus inelastic scattering cross sections; of direct-nucleon-decay properties of the mentioned excitations and related phenomena. Some implementations of the model [2, 3] are presented together with current results concerned with charge-exchange excitations.

As applied to description of deep-hole states, formulation of the single-quasiparticle dispersive optical model in terms of corresponding Green functions [4] is discussed. Such a method allows one to propose an unitary version of the model. This version is employed for a quantitative estimation of the spreading (dispersive) contribution to the optical-model potential.

This work is partially supported by RFBR (grant No. 15-02-08007).

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**Topic::**

Memorial session for S. Belyaev

**Summary:**

**S. Belyaev Memorial Session / 1563**

## **Bose Condensate**

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**Topic::**

**Summary:**

**Session on Physics Education and Outreach / 1264**

## **Active Learning Teaching for Introductory Physics**

**Author:** Mina Katramatou<sup>1</sup>

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To be submitted

**Topic::**

Special Session on Physics Education and Outreach

**Summary:**

**Session on Physics Education and Outreach / 1416**

## **The Hellenic Open University Cosmic Ray Telescope: Research and Educational Activities**

**Author:** Antonios Leisos<sup>1</sup>

<sup>1</sup> *Hellenic Open University*

**Corresponding Author:** leisos@eap.gr

The Hellenic Open University Cosmic Ray Telescope consists of three autonomous stations installed at the University Campus in the city of Patras in western Greece. Each station comprises three large (1 square meter) plastic scintillators and a Codalema type RF antenna detecting Extensive Air Showers originating from primary particles with an energy threshold of 10 TeV. The construction of the charge particle detectors, the calibration procedures, the experimental methods as well as the operation and the performance of the Telescope are presented, demonstrating also its educational utilization in the framework of the Hellenic LYceum Cosmic Observatories Network (HELYCON).

**Topic::**

Special Session on Physics Education and Outreach

**Summary:**

**Session on Physics Education and Outreach / 1446**

## **Opening up Greek Universities: opencourses.gr**

**Author:** Lazaros Merakos<sup>None</sup>

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The “open online education” paradigm is challenging the future role of Universities, open or conventional, as well as that of their faculty members. Some say that large traditional universities will have the fate of the dinosaurs, unless they adapt quickly to the new environment. This issue has been at the heart of a debate among faculty, administrators and students in Greek universities, since the launching in 2013 of the “Opening up Greek Universities” initiative, an ambitious project aiming at opening up approximately 3,900 courses selected from the undergraduate and graduate curricula of 26 Greek universities. The developed open courses have been made freely available to the general public through a national portal. The project results are presented, including the specifications of the online courses, and the support services and technological infrastructure. Also, views and policies regarding the development of open educational material and courses, and the new opportunities and risks are also discussed.

**Topic::**

Special Session on Physics Education and Outreach

**Summary:**

**Session on Physics Education and Outreach / 1328**

## **The European Researchers’ Night: concepts and impact**

**Author:** Georgios Fanourakis<sup>1</sup>

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“The European Researchers’ Night: concepts and impact” -  
Dr George Fanourakis -  
Institute of Nuclear and Particle Physics, NCSR “Demokritos”, Greece

**Abstract:** The European Researchers' Nights is a European instrument to allow the general public, whichever their age and background, to meet researchers and consequently get informed about the importance and the benefits of Scientific Research as well as to motivate young people to follow Scientific Research carriers. It is defined as the last Friday of every September, it runs at University, Research Center Campuses and other well established public places and it deploys many innovative and imaginative methodologies to invite the public of all ages to attend and enjoy the event. This year is the 12th year of the European Researchers' Night event and as usual it will take place in more than 300 cities in Europe. In this presentation, we will discuss the concepts of this renowned Night in Europe and we will present our experience of RENA, a Greek consortium of Research and Educational establishments, with the activities and measured impact of the European Researchers' Night.

**Topic::**

Special Session on Physics Education and Outreach

**Summary:****Session on Physics Education and Outreach / 1327**

## **Learning about A Level Physics students' understandings of particle physics using concept mapping**

**Author:** Helen Gourlay<sup>1</sup>

<sup>1</sup> *Brunel University London*

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This talk describes a small-scale piece of research using concept mapping to elicit A Level students' understandings of particle physics, a paper about which was published in *Physics Education* (52). Fifty-nine Year 12 (16- and 17-year-old) students from two London schools participated. The exercise took place during school physics lessons. Students were instructed how to make a concept map and were provided with 24 topic-specific key words. Students' concept maps were analysed by identifying the knowledge propositions they represented, enumerating how many students had made each one, and by identifying errors and potential misconceptions, referring to the examination specification they were studying. The only correct statement made by most of the students in both schools was that annihilation takes place when matter and antimatter collide, although there was evidence that some students were unable to distinguish between annihilation and pair production. A high proportion of students knew of up, down and strange quarks, and that the electron is a lepton. However, some students appeared to have a misconception that everything is made of quarks. Students found it harder to classify tau particles than they did electrons and muons. Where students made incorrect links about muons and tau particles their concept maps suggested that they thought they were mesons or quarks.

**Topic::**

Special Session on Physics Education and Outreach

**Summary:**

My proposed talk concerns a research project conducted with 17 and 18-year-old students in London schools, in which I assessed their understanding of A level particle physics using concept mapping.

**Session on Physics Education and Outreach / 1484**

## **Trends in Undergraduate Physics Education in the US**

**Author:** Gerassimos Petratos<sup>1</sup>

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Efforts by the United States Physics Departments to improve their Undergraduate Physics Programs and Curricula, and to increase the number of B.S. degrees awarded, as initiated by the American Physical Society, the American Institute of Physics and the American Association of Physics teachers will be presented. Recent efforts to modernize the undergraduate program and curriculum of the Physics Department of Kent State University in Ohio will be also presented. The revised program is based on a new curriculum, a new student advising structure and the creation of an environment of community and belonging for undergraduate physics students. The new curriculum aims at preparing students not only for entry into the graduate school but also for employment in the industrial and high-technology private sector.

**Topic::**

Special Session on Physics Education and Outreach

**Summary:**

**Special session on Astro-Cosmo-Gravity / 1191**

## **Domain Walls in the Early Universe and Generation of Matter and Antimatter Domains**

**Authors:** Alexander Dolgov<sup>1</sup>; Sergey Godunov<sup>2</sup>; Alexander Rudenko<sup>3</sup>; Igor Tkachev<sup>4</sup>

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We present a model where it is possible to generate cosmologically large domains of matter and anti-matter separated by cosmologically large distances. Domain walls existed only in the early universe and later they disappeared. So the problem of domain walls in this model does not exist. These features are achieved through a postulated form of interaction between inflaton and a new scalar field.

This scenario inspired a study of the related problem - evolution of the domain wall width in expanding universe. According to classical results there is a region of parameter space where the solutions with constant physical width exist. Numerical study of the problem demonstrates that initial configurations tend to these solutions with time. However, we have found that the wall width can grow exponentially outside of that parameter region. These results are briefly discussed.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**Special session on Astro-Cosmo-Gravity / 1071**

## Exotic events in cosmic ray experiments at super high energies: a manifestation of New Physics?

**Author:** Alexander Borisov<sup>1</sup>

<sup>1</sup> *P.N.Lebedev Physical Institute, Russian Academy of Sciences*

**Corresponding Author:** asborisov55@mail.ru

Cosmic ray experiments with emulsion chambers exhibit several unusual phenomena which are hard to interpret within the Standard Model. We present the systematic survey of most intriguing exotic events such as coplanar or aligned events, penetrating hadrons with abnormally weak absorption in lead, ‘Centaurus’-type events, gamma-hadron families with huge halos and some other types of events which are detected at energies and in kinematic regions beyond the reach of modern colliders including the LHC and RHIC. However, several new phenomena recently observed at colliders seem to be relevant to the cosmic ray unusual events. Possible theoretical approaches for explanation of exotic phenomena are discussed.

**Topic::**

Mini-workshop: Latest Results and New Physics in the Higgs Sector

**Summary:**

Several new phenomena recently observed at LHC and RHIC seem to be relevant to unusual events detected few decades ago in cosmic ray experiments exploiting emulsion chambers.

**Special session on Astro-Cosmo-Gravity / 962**

## Cosmological bounce and Genesis beyond Horndeski

**Authors:** Nikolay Sukhov<sup>None</sup>; Roman Kolevatov<sup>1</sup>; Sergey Mironov<sup>2</sup>; Viktoriya Volkova<sup>None</sup>

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We study a “classical” bouncing scenario in beyond Horndeski theory. We give an example of spatially flat bouncing solution that is non-singular and stable throughout the whole evolution. The model is arranged in such a way that the scalar field driving the cosmological evolution initially behaves like full-fledged beyond Horndeski, whereas at late times it becomes a massless scalar field minimally coupled to gravity.

Based on arXiv:1705.06626 [hep-th]

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**Special session on Astro-Cosmo-Gravity / 1415**

## Self-consistent calculations of supernova matter

**Author:** Igor Mishustin<sup>None</sup>

TBA

**Topic::**

**Summary:**

**Special session on Astro-Cosmo-Gravity / 1402**

## **Pedal coordinate, dark Kepler and other force problems**

**Author:** Petr Blaschke<sup>1</sup>

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We will make the case that *pedal coordinates* (instead of polar or Cartesian coordinates) are more natural settings in which to study force problems of classical mechanics in the plane. We will show that the trajectory of a test particle under the influence of central and Lorentz-like forces can be translated into pedal coordinates at once without the need of solving any differential equation. This will allow us to generalize Newton theorem of revolving orbits to include nonlocal transforms of curves. Finally, we apply developed methods to solve the “dark Kepler problem”, i.e. central force problem where in addition to the central body, gravitational influences of dark matter and dark energy are assumed.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**Special session on Astro-Cosmo-Gravity / 1095**

## **Relativity with a preferred frame. Astrophysical and cosmological implications**

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The present analysis is motivated by the fact that, although the local Lorentz invariance is one of the cornerstones of modern physics, cosmologically a preferred system of reference does exist. Modern cosmological models are based on the assumption that there exists a typical (privileged) Lorentz frame, in which the universe appear isotropic to “typical” freely falling observers. The discovery of the cosmic microwave background provided a stronger support to that assumption (it is tacitly assumed that the privileged frame, in which the universe appears isotropic, coincides with the CMB frame).

The view, that there exists a preferred frame of reference, seems to unambiguously lead to the abolishment of the basic principles of the special relativity theory: the principle of relativity and the principle of universality of the speed of light.

Correspondingly, the modern versions of experimental tests of special relativity and the “test theories” of special relativity

reject those principles and presume that a preferred inertial reference frame, identified with the CMB frame, is the only frame in which the two-way speed of light (the average speed from source to observer and back) is isotropic while it is anisotropic in relatively moving frames.

In the present study, the existence of a preferred frame is incorporated into the framework of the special relativity, based on the relativity principle and universality of the (two-way) speed of light, at the expense of the freedom in assigning the one-way speeds of light that exists in special relativity. In the framework developed, a degree of anisotropy of the one-way speed acquires meaning of a characteristic of the really existing anisotropy caused by motion of an inertial frame relative to the preferred frame.

The anisotropic special relativity kinematics is developed based on the first principles: (1) Space-time transformations between inertial frames leave the equation of anisotropic light propagation invariant and (2) A set of the transformations possesses a group structure. The Lie group theory apparatus is applied as in [1] to define groups of transformations.

The corresponding extension to general relativity, like the standard general relativity, is based on the existence of locally inertial frames and the equivalence principle. Despite the fact that, in the special relativity with a preferred frame developed as described above, the interval is not invariant but conformally modified under the transformations between inertial frames, the complete apparatus of general relativity can be applied based on the existence of an invariant combination which, upon a change of the time and space variables, takes the form of the Minkowski interval. However, to calculate physical effects, an inverse change of variables to the 'physical' time and space is needed. Among the applications of the relativity with a preferred frame, is a possible resolution of the so-named 'acceleration problem' which appeared after the discovery that the present expansion of the universe is accelerated, made using the luminosity distance versus redshift relation of type Ia supernovae. It is interpreted as that the time evolution of the expansion rate cannot be described by a matter-dominated Friedman-Robertson-Walker cosmological model of the universe. In order to explain the discrepancy within the context of General Relativity, a new component of the energy density of the universe, known as Dark Energy (vacuum energy), with exotic properties is usually introduced, and also some other non-standard alternatives are considered. In the framework of the relativity with a preferred frame, the deceleration parameter in the luminosity distance - redshift relation is corrected such that the observed deceleration parameter can be negative. Thus, the observed negative values of the deceleration parameter do not exclude the Friedman dynamics corresponding to the matter-dominated decelerating universe.

#### References

[1] Burde G.I.: Special relativity kinematics with anisotropic propagation of light and correspondence principle. *Found. Phys.*, Vol. 46, No 12, Pages: 1573-1597

#### Topic::

Special Session: Astro-Cosmo-Gravity

#### Summary:

### Special session on Astro-Cosmo-Gravity / 1289

## On perturbations in Horndeski theories

**Author:** Victoria Volkova<sup>1</sup>

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TBA



**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**Special session on Astro-Cosmo-Gravity / 1277**

## **Anisotropy of dark matter velocity distribution measured with directional detection**

**Author:** Keiko Nagao<sup>1</sup>

<sup>1</sup> *National Institute of Technology, Niihama College*

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Directional dark matter detection is next-generation experiment of dark matter search. By means of directional information, it can give a constraint on the velocity distribution of dark matter. Especially we investigate the possibility to measure anisotropy of the distribution with gaseous and solid detector in this work.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**Special session on Astro-Cosmo-Gravity / 1030**

## **Search for rare processes with DAMA experimental set-ups**

**Authors:** Pierluigi Belli<sup>1</sup>; Rita Bernabei<sup>2</sup>; Fabio Cappella<sup>3</sup>; Vincenzo Caracciolo<sup>4</sup>; Riccardo Cerulli<sup>4</sup>; Annelisa d'Angelo<sup>3</sup>; Alessandro Di Marco<sup>None</sup>; Antonella Incicchitti<sup>3</sup>; Vittorio Merlo<sup>5</sup>; Francesco Montecchia<sup>6</sup>; Roman Boiko<sup>7</sup>; Dmitry Chernyak<sup>8</sup>; Fedor Danevich<sup>7</sup>; Dmytro Kasperovych<sup>7</sup>; Vladislav Kobychiev<sup>7</sup>; Valentyna Mokina<sup>9</sup>; Denys Poda<sup>10</sup>; Oksana Polischuk<sup>7</sup>; Vladimir Tretyak<sup>7</sup>; Alexander Barabash<sup>11</sup>; V.B. Brudanin<sup>12</sup>; Sergey Konovalov<sup>11</sup>; V.N. Shlegel<sup>13</sup>; V.I. Umatov<sup>11</sup>; C.J. Dai<sup>14</sup>; H.L. He<sup>14</sup>; H.H. Kuang<sup>14</sup>; X.H. Ma<sup>14</sup>; X.D. Sheng<sup>14</sup>; R.G. Wang<sup>14</sup>; Z.P. Ye<sup>15</sup>

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Profiting of the favourable conditions offered by the Gran Sasso underground laboratory and of the several low-background DAMA set-ups, many and competitive results have been obtained. In particular, this talk will review the main DAMA searches on double beta decays, on other rare decays and transitions and on some investigation on matter stability. Moreover, perspectives of a complementary investigation on Dark Matter by exploiting the directionality approach (which is sensitive to Dark Matter candidates inducing nuclear recoils) with the anisotropic ZnWO<sub>4</sub> scintillators, will be introduced.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**Special session on Astro-Cosmo-Gravity / 1467**

## Fermions from Oscillons

**Author:** Paul Saffin<sup>1</sup>

<sup>1</sup> *University of Nottingham*

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Following a period of inflation one must reheat the Universe, and a particularly efficient way to do this is through preheating, where the homogeneous inflaton condensate produces particles due to a resonance.

The break-up of the inflaton condensate can lead to long-lived localized lumps of oscillating condensate, known as oscillons, and we shall show that these lumps are able to produce particles in a similar manner to preheating physics, even producing fermions that are heavier than the condensate field itself.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**Special session on Astro-Cosmo-Gravity / 1334**

## Observationally constraining gravitational wave emission from short gamma-ray burst remnants

**Author:** Kostas Glampedakis<sup>1</sup>

**Co-author:** Paul Lasky

<sup>1</sup> *Universidad de Murcia*

**Corresponding Authors:** kostas@um.es, paul.lasky@unimelb.edu.au

Observations of short gamma-ray bursts indicate ongoing energy injection following the prompt emission, with the most likely candidate being the birth of a rapidly rotating, highly magnetised neutron star. In this talk we discuss how X-ray observations of the burst remnant can constrain properties of the nascent neutron star (such as the magnetic field-induced ellipticity and the saturation amplitude of various oscillation modes) and derive strict upper limits on the gravitational wave emission from these objects.

**Topic::**

Special Session: Astro-Cosmo-Gravity

**Summary:**

**Special session on Astro-Cosmo-Gravity / 1081**

## **Observation of ultra-high energy cosmic rays with the Telescope Array experiment**

**Author:** Ryuji Takeishi<sup>1</sup>

**Co-author:** for the Telescope Array Collaboration

<sup>1</sup> *ICRR Univ. Tokyo*

**Corresponding Author:** take@icrr.u-tokyo.ac.jp

The origin of ultra-high energy cosmic rays (UHECRs) has been a long-standing mystery. The Telescope Array (TA) is the largest experiment in the northern hemisphere observing UHECR in Utah, USA. It aims to reveal the origin of UHECR by studying the energy spectrum, mass composition and anisotropy of cosmic rays. TA is a hybrid detector comprised of three air fluorescence stations which measure the fluorescence light induced from cosmic ray extensive air showers, and 507 surface scintillator counters which sample charged particles from air showers on the ground. We present the cosmic ray spectrum observed with the TA experiment. We also discuss our results from measurement of the mass composition. In addition, we present the results from the analysis of anisotropy, including the excess of observed events in a region of the northern sky at the highest energy. Finally, we introduce the TAx4 experiment which quadruples TA, and the TA low energy extension (TALÉ) experiment.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**Special session on Astro-Cosmo-Gravity / 970**

## **DAMA/LIBRA results and perspectives**

**Authors:** Vincenzo Caracciolo<sup>1</sup>; DAMA collaboration<sup>None</sup>

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The DAMA/LIBRA experiment is in data taking in the underground Gran Sasso Laboratory. The data collected by DAMA/LIBRA-phase1 have been released, and considering also the former DAMA/NaI experiment, the data of 14 independent annual cycles (total exposure 1.33 ton x yr) - analysed by exploiting the model-independent Dark Matter (DM) annual modulation signature - have given evidence at  $9.3\sigma$ ; C.L. for the presence of DM particles in the galactic halo. No systematic or side reaction able to mimic the observed effect has been found or suggested by anyone. Other kinds of investigations have been recently performed and will be introduced here.

At present, after an upgrade of the experiment, DAMA/LIBRA is running in its phase-2 with increased sensitivity. R&D's towards a possible future phase-3 are in progress. Finally, the possibility of a low background pioneer experiment to exploit the directionality approach by using anisotropic ZnWO<sub>4</sub> scintillators is discussed.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**Special session on Astro-Cosmo-Gravity / 1263**

## Neutron stars equation of state consistent with high-energy nuclear physics data

**Authors:** Violetta Sagun<sup>1</sup>; Ilidio Lopes<sup>2</sup>

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A novel equation of state with the surface tension induced by particles interaction was generalized to describe properties of the neutron stars. Interaction between particles accounted via hard-core repulsion taken into account by the proper volumes of particles and phenomenological attraction term. Recently, this model was successfully applied to the description of the properties of nuclear and hadron matter created in collisions of nucleons. New model is free of causality problems and fully thermodynamically consistent that enable us to use it to the investigation of the strongly interacting matter phase diagram properties in wide range of temperatures and baryon densities, including neutron stars. We calculated the mass-radius relations for a compact star using the Tolmann-Oppenheimer-Volkov equation for two sets of parameters which satisfy the existing constraints. The found values of the model parameters are in good correspondence with the nuclear-nuclear collision results.

**Topic::**

Special Session: Astro-Cosmo-Gravity

**Summary:**

**Special session on Astro-Cosmo-Gravity / 1386**

## Cooling of Compact High Mass Twin Stars

**Author:** Hovik Grigorian<sup>1</sup>

<sup>1</sup> *JINR*

**Corresponding Author:** hovikgrigorian@gmail.com

Existence of the high mass pulsars PSR J1614-2230 and PSR J0348-0432 with masses of about  $2 M_{\text{sun}}$  requires a sufficiently stiff equation of state (EoS) of the stellar matter to fulfill this constraint. We succeeded to explain the thermal evolution of compact stars with stiff hadronic EoS in the framework of the “nuclear medium cooling” scenario. This requires an appropriate selection of proton gap profiles together with properly defined medium corrections (effective pion gaps)[1]. Under the assumption that a phase transition to quark matter is possible for higher densities it is possible to describe stable hybrid stars that form a third family of compact stars. In this case high-mass twin stars could exist characterized by the same gravitational mass but different size. We have investigated the features of cooling curves of such possible high-mass twin-star sequences and show that cooling scenarios could have a discriminating power for selecting optimal EoS models for compact stars.

1. H. Grigorian, D. N. Voskresensky and D. Blaschke, *Eur. Phys. J. A*, \*\*52\*\*, no. 3, 67 (2016).

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**Special session on Astro-Cosmo-Gravity / 1100**

## **Direct dark matter search with ultra-low thresholds in the CRESST-III experiment**

**Author:** Martin Stahlberg<sup>1</sup>

<sup>1</sup> *Vienna University of Technology*

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The CRESST (Cryogenic Rare Event Search with Superconducting Thermometers) experiment located at Laboratori Nazionali del Gran Sasso in Italy searches for dark matter particles elastically scattering off nuclei. The target consists of scintillating CaWO<sub>4</sub> crystals operated as cryogenic calorimeters at millikelvin temperature. Separate cryogenic light detectors observe the scintillation light produced in particle interactions to allow event-by-event particle identification for background suppression. CRESST-II phase 2, completed in 2015, puts the most stringent limits on elastic spin-independent dark matter-nucleon scattering for particle masses below  $1.7 \text{ GeV}/c^2$ . The CRESST-III experiment started taking data in August 2016 with a new generation of detector modules designed for unprecedented sensitivity to low-mass dark matter. The achieved detector performance and first results from CRESST-III will be presented.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Special session on Astro-Cosmo-Gravity / 1187****Hot and dense nuclear matter in astrophysics****Author:** Constantinos Constantinou<sup>None</sup>**Corresponding Author:** c.constantinou@fz-juelich.de

An essential ingredient in the dynamical evolution of core-collapse supernovae and binary mergers of compact objects is the equation of state (EOS) of nuclear matter for densities up to 10 times the nuclear equilibrium density, temperatures up to 100 MeV, and lepton-to-baryon fractions in the range 0 to 0.6. Moreover, the EOS controls electron capture and neutrino emission rates and, therefore, it affects the conditions for nucleosynthesis and the cooling of protoneutron stars.

We discuss various approaches used in the construction of the EOS for use in simulations of the above astrophysical phenomena. After a brief survey of the constraints on the EOS from laboratory experiments and astrophysical observations, we address supranuclear densities where a uniform hadronic phase of matter resides. For the description of this phase both microscopic (e.g. Green's functions, variational, Brueckner-Hartree-Fock, chiral effective theory) as well as phenomenological (e.g. nonrelativistic potential models based on the Skyrme or the Gogny forces, relativistic mean-field theory, etc) techniques are employed. Finally, we review methods such as nuclear statistical equilibrium, the single-nucleus approximation, virial expansion, and molecular dynamics that are used in the subnuclear regime where matter is a heterogeneous mixture of nucleons, nuclei, and other structures (collectively known as "pasta").

**Topic::**

Special Session: Astro-Cosmo-Gravity

**Summary:****Special session on Astro-Cosmo-Gravity / 1067****Pontryagin trace anomaly****Author:** Predrag Dominis Prester<sup>1</sup><sup>1</sup> *University of Rijeka - Department of Physics***Corresponding Author:** pprester@phy.uniri.hr

It is known that quantum field theories defined on curved spacetimes develop quantum anomalies of a trace of the energy-momentum tensor, called trace anomalies. These anomalies can be classified by using cohomology analysis, which in 4D establishes three possible types of trace anomalies: Euler (or Gauss-Bonnet), Weyl and Pontryagin. While the appearance of Euler and Weyl trace anomalies is a generic property confirmed by explicit calculations, e.g., in the simple theory of free massless Dirac or Weyl spin 1/2 field, the status of Pontryagin anomaly is still not resolved. Moreover, several arguments were stated in the literature which apparently forbid appearance of Pontryagin anomaly for free spin 1/2 fields.

In this talk results that counter this standard story will be presented, showing that free Weyl spin 1/2 fermion on curved four-dimensional spacetime has Pontryagin anomaly, with the imaginary coefficient in front of the Pontryagin density. We have obtained this surprising result by explicit one-loop calculations using dimensional regularisation, by two different methods: (1) direct calculation using the Weyl fermion, (2) by exploiting the coupling to "axial gravity", which allowed us to work with the Dirac instead of the Weyl field. The Pontryagin anomaly of the Dirac and the Majorana spin 1/2 field is vanishing.

This result has some important consequences, some of which will be discussed. One is that the supposed equivalence between quantum free Majorana and Weyl fields in purely gravitational background cannot be correct. There is also a question of the imaginary value of the anomaly, which may possibly signal the problems with chiral theories in which Weyl fermions are not appearing in pairs with both chiralities, or may have some importance in cosmology due to its unusual gravitational parity-odd nature.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:****Special session on Astro-Cosmo-Gravity / 1135****Strongly interacting matter in neutron stars**

**Author:** Alex Gezerlis<sup>1</sup>

<sup>1</sup> *University of Guelph*

**Corresponding Author:** gezerlis@uoguelph.ca

In this talk I will touch upon several features of modern ab initio low-energy nuclear theory. I will start by discussing what “ab initio” means in this context. Specifically, I will spend some time going over nucleon-nucleon and three-nucleon interactions and their connections with the underlying theory of Quantum Chromodynamics. I will then show how these interactions are combined with many-body techniques to describe infinite nucleonic matter, which is of astrophysical relevance. In addition to results on the equation-of-state of homogeneous matter [1,2,3], I will also discuss recent work on the static response of neutron matter, as well as its consequences for neutron stars [4,5].

[1] A. Gezerlis *et al*, Phys. Rev. Lett. **111**, 032501 (2013).

[2] A. Gezerlis *et al*, Phys. Rev. C **90**, 054323 (2014).

[3] I. Tews, S. Gandolfi, A. Gezerlis, and A. Schwenk, Phys. Rev. C **93**, 024305 (2016).

[4] M. Buraczynski and A. Gezerlis, Phys. Rev. Lett. **116**, 152501 (2016).

[5] M. Buraczynski and A. Gezerlis, Phys. Rev. C **95**, 044309 (2017).

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:****Special session on Astro-Cosmo-Gravity / 1439****On the Butterfly Effect in 3D Gravity**

**Author:** Mohammad M. Qaemmaqami<sup>1</sup>

<sup>1</sup> *Institute for Research in Fundamental Sciences (IPM)*

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We study the butterfly effect by considering shock wave solutions near the horizon of the AdS black brane in some of 3-dimensional Gravity models including; 3D Einstein Gravity, Minimal Massive 3D Gravity, New Massive Gravity, Generalized Massive Gravity, Born-Infeld 3D Gravity and New Bi-Gravity. We calculate the butterfly velocities of these models and also we consider the critical points and different limits in some of these models. By studying the butterfly effect in the Generalized Massive Gravity, we observed a correspondence between the butterfly velocities and right-left moving degrees of freedom or the central charges of the dual 2D Conformal Field Theories.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:****Special session on Astro-Cosmo-Gravity / 1050****Viabale production mechanism of keV sterile neutrino with large mixing angle**

**Author:** Anton Chudaykin<sup>1</sup>

<sup>1</sup> *Institute for Nuclear Research*

**Corresponding Author:** chudy@ms2.inr.ac.ru

We study a model of keV-scale sterile neutrino with relatively large mixing with the Standard Model sector. Usual considerations predict active generation of such particles in the Early Universe, which leads to constraints from the total Dark Matter density and absence of X-ray signal from sterile neutrino decay. These bounds together may deem any attempt of creation of the keV scale sterile neutrino in the laboratory unfeasible. We argue that for models with a hidden sector coupled to the sterile neutrino these bounds can be evaded, opening new perspectives for the experimental studies at neutrino facilities such as Troitsk  $\nu$ -mass and KATRINE. We estimate the generation of sterile neutrinos in scenarios with the hidden sector dynamics keeping the sterile neutrinos either massless or superheavy in the early Universe; in both cases the generation by oscillations from active neutrinos in plasma is suppressed.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:****Special Session on Instruments and Methods in HEP / 1332****Lecture on Statistical analysis methods by ATLAS**

**Author:** Nicolas Berger<sup>1</sup>

<sup>1</sup> *Centre National de la Recherche Scientifique (FR)*



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Statistical methods have been the focus of increasing attention at LHC experiments, for instance in the context of Higgs searches and measurements carried out by the ATLAS and CMS experiments. This presentation will review the various techniques used by the ATLAS experiment to estimate confidence interval and set upper limits on physical quantities, and to compute discovery p-values and significances to quantify deviations with respect to the standard model expectation.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Special Session on Instruments and Methods in HEP / 1056**

## The Short Baseline Neutrino Detector at Fermilab

**Author:** Thomas Josua Mettler<sup>1</sup>

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SBND (Short-Baseline Near Detector) is a 112 ton liquid argon TPC neutrino detector under construction on the Fermilab Booster Neutrino Beam. Together with MicroBooNE and ICARUS-T600, SBND will search for short-baseline neutrino oscillations in the  $1 \text{ eV}^2$  mass range. SBND will also perform detailed studies of the physics of neutrino-argon interactions, thanks to a data sample of millions of electron and muon neutrino interactions. Finally SBND plays an important role in the on-going R&D effort to develop the LArTPC technology, testing several technologies that can be used in a future kiloton-scale neutrino detectors for a long-baseline experiment. I will discuss the detector design, its current status, and present the physics program.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Special Session on Instruments and Methods in HEP / 1305**

## New Capabilities of Modern Accelerators for Heavy Ion Nuclear Physics

**Author:** Boris Sharkov<sup>1</sup>

<sup>1</sup> *JINR*

**Corresponding Author:** boris.sharkov@fair-center.eu

Recent developments of heavy ion accelerator facilities based on superconducting linacs and large synchrotron rings offer new capabilities for heavy ion nuclear physics. Considerations are focused on new largest heavy ion drivers - mega-science projects NICA and FAIR being under construction - Nuclotron-based Ion Collider Facility in Dubna and the Facility for Antiproton and Ion Research in Darmstadt. Both will provide worldwide unique accelerator and experimental facilities allowing for a large variety of unprecedented fore-front research in beam

physics, high energy density physics and applied science.

This presentation outlines recent achievements in high power linear accelerator injection chains, rapid cycling superconducting magnets of large synchrotron rings, ultra-high dynamic vacuum technologies, efficient accumulation and cooling of intense heavy ion beams.

Reference: <http://nica.jinr.ru/>  
[www.fair-center.eu](http://www.fair-center.eu)

**Topic::**

Special Session on Instruments and Methods in HEP

**Summary:**

**Special Session on Instruments and Methods in HEP / 1076**

## **Overview talk on detector performances (CMS)**

**Author:** Silvia Goy Lopez<sup>1</sup>

<sup>1</sup> *Centro de Investigaciones Energéticas Medioambientales y Tecnológicas*

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The performance of CMS detector on early 2017 data will be presented. Especial attention will be given to the performance of the recently upgraded components, and in particular to the newly installed silicon pixel detector.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Special Session on Instruments and Methods in HEP / 1397**

## **Development of Micro Pattern Gas Detectors for HEP and Nuclear Physics experiments and applications**

**Author:** Theodoros Geralis<sup>1</sup>

<sup>1</sup> *NCSR Demokritos*

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Driven by the availability of modern photolithographic techniques, Micro Pattern Gas Detectors (MPGD) have been introduced at the end of the 20th century by pioneer developments: Microstrip Gas Chambers (MSGC), Gas Electron Multipliers (GEM) and Micromegas, later followed by thick-GEM (THGEM), resistive GEM (RETGEM) and other novel micro-pattern devices. Nowadays intensive R&D activities in the field of MPGDs and their diversified applications are pursued by the large CERN- RD51 collaboration. The aims are to facilitate the development of advanced gas-avalanche detector concepts and technologies and associated electronic-readout systems, for applications in basic and applied research. MPGD systems now offer robustness, very high rate operation, high precision spatial resolution (sub 100-micron), and protection against discharges. MPGDs became important instruments in current particle-physics experiments and are in development and design stages for future ones. They are significant components of the upgrade plans for ATLAS, CMS, and ALICE at

the LHC, exemplifying the beneficial transfer of detector technologies to industry. Beyond their design for experiments at future facilities (e.g. ILC), MPGDs are considered for rare-event searches, e.g. dark matter, double beta decay and neutrino scattering experiments. Detectors sensitive to x-rays, neutrons and light are finding applications in other diverse areas such as material sciences, hadron therapy systems, homeland security etc. The areas of research activities within the RD51 MPGD collaboration includes detector physics & technology, model simulations, readout electronics, production techniques, common test facilities, and applications. By this broad coverage RD51 brings together leading experts in the field of detector science and detectors users, resulting in effective progress over a wide array of applications. This talk will review the activities of the RD51, its major accomplishments so far, and future plans.

**Topic::**

Special Session on Instruments and Methods in HEP

**Summary:****Special Session on Instruments and Methods in HEP / 1207****Overview talk on trigger performances (CMS)****Author:** Silvio Donato<sup>1</sup><sup>1</sup> *Universitaet Zuerich (CH)***Corresponding Author:** silvio.donato@cern.ch

During its second run of operation (Run 2) which started in 2015, the LHC will deliver a peak instantaneous luminosity that may reach  $2 \cdot 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$  with an average pile-up of about 55, far larger than the design value. Under these conditions, the online event selection is a very challenging task. In CMS, it is realized by a two-level trigger system: the Level-1 (L1) Trigger, implemented in custom-designed electronics, and the High Level Trigger (HLT), a streamlined version of the offline reconstruction software running on a computer farm.

In order to face this challenge, the L1 trigger has been through a major upgrade compared to Run 1, whereby all electronic boards of the system have been replaced, allowing more sophisticated algorithms to be run online. Its last stage, the global trigger, is now able to perform complex selections and to compute high-level quantities, like invariant masses. Likewise, the algorithms that run in the HLT go through big improvements; in particular, new approaches for the online track reconstruction lead to a drastic reduction of the computing time, and to much improved performances. This presentation will describe the performance of the upgraded trigger system in Run 2.

**Topic::**

Topic: High Energy Particle Physics

**Summary:****Special Session on Instruments and Methods in HEP / 1167****Electron Ion Collider: 3D-Imaging the Nucleon****Author:** Marco Radici<sup>None</sup>**Corresponding Author:** marco.radici@pv.infn.it

The Electron Ion Collider (EIC) is the project for a new US-based, high-energy, high-luminosity facility, capable of a versatile range of beam energies, polarizations, and ion species. Its primary goal

is to precisely image quarks and gluons and their interactions inside hadrons, in order to investigate their confined dynamics and elucidate how visible matter is made at its most fundamental level. I will describe the current status of the project and briefly touch upon the main physics questions addressed by such a facility. If time allows, I will give few more details on the topic of Transverse Momentum Dependent parton distributions (TMDs).

**Topic::**

Special Session on Instruments and Methods in HEP

**Summary:****Special Session on Instruments and Methods in HEP / 1147****The LUCID-2 detector**

**Author:** Antonio Sbrizzi<sup>1</sup>

<sup>1</sup> *Universita e INFN, Bologna (IT)*

**Corresponding Author:** antonio.sbrizzi@cern.ch

The LUCID-2 detector is the main online and offline luminosity provider of the ATLAS experiment. It provides over 100 different luminosity measurements from different algorithms for each of the 2808 LHC bunches. LUCID was entirely redesigned in preparation for LHC Run 2: both the detector and the electronics were upgraded in order to cope with the challenging conditions expected at the LHC center of mass energy of 13 TeV with only 25 ns bunch-spacing. While LUCID-1 used gas as a Cherenkov medium, the LUCID-2 detector is in a new unique way using the quartz windows of small photomultipliers as the Cherenkov medium. The main challenge for a luminometer is to keep the efficiency constant during years of data-taking. LUCID-2 is using an innovative calibration system based on radioactive <sup>207</sup>Bi sources deposited on the quartz window of the readout photomultipliers. This makes it possible to accurately monitor and control the gain of the photomultipliers so that the detector efficiency can be kept stable at a percent level. A description of the detector and its readout electronics will be given, as well as preliminary results on the ATLAS luminosity measurement and related systematic uncertainties.

**Topic::**

Special Session on Instruments and Methods in HEP

**Summary:****Special Session on QCD / 1118****Weyl symmetric Abelian Decomposition and Monopole**

**Author:** Yongmin Cho<sup>1</sup>

<sup>1</sup> *Konkuk University*

**Corresponding Author:** ymcho7@konkuk.ac.kr

We demonstrate the monopole condensation in QCD. We present the gauge independent and Weyl symmetric Abelian (Cho-Duan-Ge) decomposition of the SU(3) QCD, and obtain an infra-red finite and gauge invariant integral expression of the one-loop effective action.

Integrating it gauge invariantly imposing the color reflection invariance (“the C-projection”) we show that the effective potential generates the stable monopole condensation which generates the mass gap.

**Topic::**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:**

**Special Session on QCD / 1052**

## **Gluon correlators and gluon effective mass in lattice QCD**

**Authors:** Alla Bogolubskaya<sup>1</sup>; Igor Bogolubsky<sup>1</sup>

<sup>1</sup> *JINR, Dubna*

**Corresponding Authors:** abogol@jinr.ru, bogolubs@jinr.ru

We plan to discuss appearance of effective gluon masses in lattice experiments in the Landau gauge gluodynamics framework. We consider both gluon propagator in momentum space and zero-momentum correlator in coordinate space (the latter under various boundary conditions) and observe characteristic “massive” behaviour of correlators considered.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Special Session on QCD / 972**

## **SU(2) Yang-Mills thermodynamics: a priori estimate and radiative corrections**

**Authors:** Ingolf Bischer<sup>1</sup>; Thierry Grandou<sup>2</sup>; Ralf Hofmann<sup>1</sup>

<sup>1</sup> *ITP, U Heidelberg*

<sup>2</sup> *CNRS*

**Corresponding Authors:** r.hofmann@thphys.uni-heidelberg.de, bischer@stud.uni-heidelberg.de, thierry.grandou@inln.cnrs.fr

We discuss the structure of the deconfining ground state, its particle and wavelike excitations, and how well effective radiative corrections are controlled. In particular, we elucidate the contributions to the pressure of massive 2PI bubble diagrams with dihedral symmetry of arbitrarily high loop order and how these are resummed to exhibit hierarchical suppression compared to one- and two-loop order.

**Topic::**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:**

Theoretical work.

**Special Session on QCD / 1119**

## **Hadron Resonances from Lattice QCD**

**Author:** Christian Lang<sup>None</sup>

**Corresponding Author:** christian.lang@uni-graz.at

It took more than 40 years until Lattice QCD tools have become evolved far enough to address excited hadrons in a reliable way. Still, we are confined to the low lying resonances with a few coupled two-hadron channels, mostly in the meson-meson sector. Phase shifts at a few energy values for simple system have been determined in this first principles approach. Meson-nucleon results are scarce. Comparison of lattice results with model calculations are helpful. I will survey methods and highlights in the light and heavy quarks sector.

**Topic::**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:**

**Special Session on QCD / 1109**

## **Pion-Dressing Effects in Nucleon and Delta Masses and Form Factors**

**Author:** Willibald Plessas<sup>1</sup>

<sup>1</sup> *University of Graz*

**Corresponding Author:** plessas@uni-graz.at

Low-energy baryons can be effectively described with regard to most of their properties on the basis of valence-quark configurations. This is particularly the case for the baryonic ground states, e.g. along the relativistic constituent-quark model, lattice quantum chromodynamics, or effective field theories. However, all approaches based on quantum chromodynamics presently struggle with a proper description of baryon resonances. The reasons mainly lie in their strong couplings to a number of hadronic decay channels, which have usually not yet been taken into account explicitly. In the attempt to construct a relativistic coupled-channels quark model going beyond valence-quark degrees of freedom, we have made a study of explicit pionic effects for the nucleon and Delta. In particular we have investigated in a relativistic coupled-channels framework the influences of the pion channel on the nucleon and Delta masses as well as the pion-nucleon/Delta interaction vertices. Sizeable effects are found already for one-pion dressing. We take this as an indication of the absolute necessity of explicitly including strong-decay channels in a realistic description especially of baryon resonances.

**Topic::**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:**

**Special Session on QCD / 1283**

## **SU(2N<sub>F</sub>) symmetry of confinement in QCD and its observation at high T**

**Author:** Leonid Glozman<sup>None</sup>

**Corresponding Author:** leonid.glozman@uni-graz.at

We review our previous results on SU(2N<sub>F</sub>) symmetry of hadrons upon artificial subtraction of the near-zero modes of the Dirac operator, which is a symmetry of confinement in QCD. We show our recent lattice results on spatial correlators at high temperature that reveal the same SU(2N<sub>F</sub>) symmetry which has far reaching implications for nature and structure of the strongly interacting matter at high temperatures.

**Topic::**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:**

**Special Session on QCD / 1104**

## **Effective locality and non-abelian gauge-invariance**

**Authors:** Herbert Fried<sup>1</sup>; Ralf Hofmann<sup>2</sup>; Thierry Grandou<sup>3</sup>

<sup>1</sup> Brown University USA

<sup>2</sup> IPS: Institute for Photon Science and Synchrotron Radiation Hermann-von-Helmholtz-Platz 1 D-76344 Eggenstein-Leopoldshafen Germany

<sup>3</sup> UMR-CNRS-7335, INLN, France.

**Corresponding Authors:** ralf.hofmann2@kit.edu, herbert\_fried@brown.edu, thierry.grandou@inln.cnrs.fr

The fermionic Green's functions of QCD exhibit an unexpected property of *effective locality*, which appears to be exact, involving no approximation. This property is non-perturbative, resulting from a full integration of the elementary gluonic degrees of freedom of QCD but can hardly be thought of in terms of a *duality*. Recalling and extending the derivations of effective locality, focus will be put on the way non-abelian gauge-invariance gets realized in the non-perturbative regime of QCD. Another very deep aspect of effective locality, regarding mass scales will be discussed.

**Topic::**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:**

**Special Session on QCD / 1022**

## **The linear covariant gauge beyond perturbation theory**

**Author:** David Dudal<sup>None</sup>

**Corresponding Author:** dadudal@gmail.com

In this talk, we extend the Faddeev-Popov construction of the familiar linear covariant gauge. We take into account the Gribov gauge fixing ambiguity. We pay attention to the BRST invariance of the construction, its renormalizability and we discuss the Nielsen identities that restrict the pole structure of the non-perturbative propagators.

We also make a bridge to the lattice version of the linear covariant gauge, in particular to suitably define the ghost propagator.

Finally, we also show, for the 1st time to our knowledge, how to derive the non-Abelian Landau-Khalatnikov-Fradkin transformations, which implement a gauge variation at the level of quantum correlation functions. We verify the well-established Abelian limit case and specify, also for the non-Abelian case, the special role of the Landau gauge.

**Topic::**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:**

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**Special Session on QCD / 1097**

## **Stiff self-interacting strings in high temperature phase of QCD.**

**Author:** Ahmed Bakry<sup>1</sup>

**Co-authors:** X Chen<sup>1</sup>; Maksym Deliyergiyev<sup>2</sup>; A Galal<sup>3</sup>; A Khalaf<sup>4</sup>; P-M Zhang<sup>5</sup>

<sup>1</sup> *Institute of Modern Physics, Lanzhou, China*

<sup>2</sup> *Institute of Modern Physics*

<sup>3</sup> *Physics Department, Faculty of Sciences, Azhar University, Cairo, Egypt.*

<sup>4</sup> *Physics department, Faculty of sciences, Azhar University, Cairo, Egypt*

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We investigate the predictions of Nambu-Goto (NG) and Polyakov-Kleinert (PK) effective string actions for the Casimir energy and the width of the quantum delocalization of the string at two loop order in 4-dim pure SU(3) Yang-Mills lattice gauge theory. Intermediate and large color source separation distance, before the string breaks in full QCD, at two temperature scales are considered near the deconfinement point.

At a temperature closer to the critical point  $T/T_c = 0.9$ , we found that the next to leading-order (NLO) contributions from the expansion of the NG string to improve the match to lattice data in the intermediate distance scales for both the quark-antiquark potential and broadening of the color tube compared to the free string approximation. Nevertheless, the Nambu-Goto string action in the next-to-leading order approximation does not provide a precise match with the numerical data for both the quark-antiquark potential and broadening profile.

We conjecture possible stiffness of the QCD string through studying the effects of extrinsic curvature term in Polyakov-Kleinert action. The consequences of adding a smoothing term proportional to the extrinsic curvature to the Nambu-Goto string action, as suggested by Polyakov, are investigated. The mean square width of the flux tube of the smooth open-string is derived considering Dirichlet boundary condition. We find that the theoretical predictions derived based on this smooth string formalism return a good fitting behavior for the lattice Mont-Carlo data at both long and intermediate quark separations regions.



**Topic::**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:**

**Special Session on QCD / 1115**

## **Confinement-deconfinement phase transition in two-color QCD with nonzero baryon density**

**Authors:** Aleksandr Nikolaev<sup>1</sup>; Alexander Molochkov<sup>1</sup>; Andrey Kotov<sup>None</sup>; Ernst-Michael Ilgenfritz<sup>2</sup>; Ilya Kudrov<sup>3</sup>; Roman Rogalyov<sup>4</sup>; Victor Braguta<sup>4</sup>; Vitaly Bornyakov<sup>4</sup>

<sup>1</sup> *Far Eastern Federal University*

<sup>2</sup> *Joint Institute for Nuclear Research Dubna, Russia*

<sup>3</sup> *ITEP*

<sup>4</sup> *IHEP*

**Corresponding Authors:** ilgenfri@theor.jinr.ru, bornvit@gmail.com, kotov@itep.ru, victor.v.braguta@gmail.com, nikolaev@gmail.com, molochkov.alexander@gmail.com

In this report we study the properties of the dense SU(2) QCD. The lattice simulations are carried out with improved gauge action and smaller lattice spacing as compared to our previous work. This allowed us to approach closer to the continuum limit and reach larger densities without lattice artifacts. We measured string tension and Polyakov loop as a function of chemical potential and temperature. At sufficiently large baryon density and zero temperature we observe confinement/deconfinement transition which manifests itself as a vanishing of string tension and rising of Polyakov loop.

**Topic::**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:**

**Special Session on QCD / 1234**

## **Non-linear effect of the fluctuation for the inhomogeneous chiral phase transition**

**Authors:** Ryo Yoshiike<sup>1</sup>; Tong-Gyu Lee<sup>2</sup>; Toshitaka Tatsumi<sup>3</sup>

<sup>1</sup> *Kyoto university*

<sup>2</sup> *Kyoto University*

<sup>3</sup> *Kyoto U.*

**Corresponding Authors:** lee@ruby.scphys.kyoto-u.ac.jp, yoshiike@ruby.scphys.kyoto-u.ac.jp, tatsumi@ruby.scphys.kyoto-u.ac.jp

We discuss the non-linear effects of the fluctuation in the chiral-restored phase just before the inhomogeneous chiral phase transition. The fluctuations consist of quark-antiquark and quark particle-hole excitations, and included by the random phase approximation within the two-flavor Nambu-Jona-Lasinio model.

The particular roles of thermal and quantum fluctuations can be understood systematically. The fluctuations give rise to the first order phase transition from the chiral-restored phase to the inhomogeneous chiral phase while the phase transition is the second order one within the mean field approximation. The change can be discussed regardless of the type of the inhomogeneous condensate and the effect of the thermal fluctuation is more crucial than the quantum one.

In addition, it is argued that anomalous behavior of the thermodynamic quantities due to the fluctuation should have phenomenological implications for the inhomogeneous chiral transition. Some common features for other phase transitions, such as those from the normal to the inhomogeneous Fulde-Ferrell-Larkin-Ovchinnikov state in superconductivity, are also emphasized.

**Topic::**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:****Special Session on QCD / 1278****Worldline colour fields and non-Abelian quantum field theory**

**Author:** James Edwards<sup>1</sup>

**Co-author:** Olindo Corradini <sup>2</sup>

<sup>1</sup> *Universidad Michoacana de San Nicolás de Hidalgo*

<sup>2</sup> *Universidad Autonoma de Chiapas, Mexico*

**Corresponding Authors:** jedwards@ifm.umich.mx, olindo.corradini@gmail.com

The worldline formalism is a first quantised approach to quantum field theory, inspired by string theory and based upon the evaluation of point particle path integrals as an alternative to traditional field theory techniques. It represents a reorganisation of the physical information of the theory with the advantage of maintaining manifest gauge invariance and simplifying the calculation of scattering amplitudes.

I will describe recent advances in the worldline approach to non-Abelian field theory, explaining how the coupling to the gauge field can be incorporated into the worldline action by introducing auxiliary “colour” fields. I will show how these colour fields generate Wilson loop interactions and how a novel Chern-Simons term provides a projection onto an irreducible representation of the gauge group. The calculational efficiency of the worldline formalism is preserved by extending a worldline supersymmetry to include the colour fields. Finally I will sketch a similar approach to pure Yang-Mills theory and some ongoing work on fields in non-commutative space-time with  $U(N)$  symmetry.

**Topic::**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:****Special Session on QCD / 1517****Memorial lecture dedicated to Ludvig Faddeev (23/03/1944-26/02/2017)**

**Author:** Lev Lipatov<sup>1</sup>

<sup>1</sup> *Petersburg Nuclear Physics Institute*

**Corresponding Author:** lipatov@thd.pnpi.spb.ru

Memorial lecture dedicated to Ludvig Faddeev (23/03/1944-26/02/2017)

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Special Session on QCD / 1102**

## Hamiltonian approach to QCD in Coulomb gauge

**Author:** Hugo Reinhardt<sup>1</sup>

<sup>1</sup> *Universität Tübingen*

**Corresponding Author:** h.reinhardt@uni-tuebingen.de

I will review recent results obtained within the Hamiltonian approach to QCD in Coulomb gauge both at zero and finite temperatures. The temperature is introduced by compactifying a spatial dimension. Results are presented for the chiral and dual quark condensate as well as for the Polyakov loop. The continuum approach is also confronted to recent lattice data.

**Topic::**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:**

**Special Session on QCD / 1060**

## Quark, gluon and meson correlators of unquenched QCD

**Authors:** Anton Cyrol<sup>None</sup>; Mario Mitter<sup>None</sup>; Jan M. Pawłowski<sup>1</sup>; Nils Strodthoff<sup>2</sup>

<sup>1</sup> *University of Heidelberg*

<sup>2</sup> *LBNL*

**Corresponding Authors:** mario.mitter@uni-graz.at, j.pawlowski@thphys.uni-heidelberg.de, nstrodthoff@lbl.gov, cyrol@thphys.uni-heidelberg.de

We present first-principle results for the 1PI correlation functions of two-flavour Landau-gauge QCD in the vacuum. These correlation functions carry the full information about the theory. They are obtained by solving their Functional Renormalisation Group equations in a systematic vertex expansion, aiming at apparent convergence. This work represents an indispensable and pivotal prerequisite for quantitative first-principle studies of the QCD phase diagram and the hadron spectrum within this framework.

In particular, we have computed the gluon, ghost, quark and scalar-pseudoscalar meson propagators, as well as gluon, ghost-gluon, quark-gluon, quark, quark-meson, and meson interactions. Our results stress the crucial importance of the correct semi-perturbative running of the different vertices in order to quantitatively describe the phenomena and scales of confinement and spontaneous chiral

symmetry breaking without further phenomenological input. Furthermore, preliminary results for the correlation functions of pure Yang-Mills at finite temperature are presented.

**Topic:**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:**

**Special Session on QCD / 1536**

## Temperature dependence of shear viscosity of $SU(3)$ -gluodynamics within lattice simulation

**Author:** Nikita Astrakhantsev<sup>None</sup>

**Co-authors:** Victor Braguta <sup>1</sup>; Andrey Kotov

<sup>1</sup> *IHEP*

**Corresponding Authors:** nikita.astronaut@gmail.com, victor.v.braguta@gmail.com, kotov@itep.ru

In this talk we will discuss the  $SU(3)$ -gluodynamics shear viscosity temperature dependence on the lattice. We measured the correlation functions of the energy-momentum tensor in the range of temperatures  $T/T_c \in [0.9, 1.5]$  and extracted shear viscosity using two approaches. The first one was to fit the lattice data with a physically motivated ansatz for the spectral function with unknown parameters and then determine the shear viscosity. The second approach was to apply the Backus-Gilbert method allowing to extract the shear viscosity from the lattice data nonparametrically. The results obtained within both approaches agree with each other. Our results allow us to conclude that within the range  $T/T_c \in [0.9, 1.5]$  the  $SU(3)$ -gluodynamics reveals the properties of a strongly interacting system, which cannot be described perturbatively, and has the ratio  $\eta/s$  close to the value  $1/4\pi$  of the  $N = 4$  Supersymmetric Yang-Mills theory.

**Topic:**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:**

I will arrive in the morning 17th of August and leave at 21th of August. If it will be impossible for me to give a talk here, will you please tell me the alternative?

**Special Session on QCD / 1120**

## Form factor decompositions of the QCD four-gluon vertex

**Author:** Christian Schubert<sup>1</sup>

**Co-author:** Naser Ahmadinia<sup>2</sup>

<sup>1</sup> *IFM/UMSNH*

<sup>2</sup> *CORELS, Institute for Basic Science*

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The Bern-Kosower formalism, originally developed around 1990 as a novel way of obtaining on-shell amplitudes in field theory as limits of string amplitudes, has recently shown to be extremely efficient

as a tool for obtaining form factor decompositions of the N gluon vertices. Its main advantages are that gauge invariant structures can be generated by certain systematic integration-by-parts procedures, making unnecessary the usual tedious analysis of the non-abelian off-shell Ward identities, and that the scalar, spinor and gluon loop cases can be treated in a unified way. After discussing the method in general for the N gluon case, I will show in detail how to rederive the Ball-Chiu decomposition of the three gluon vertex, and finally present two slightly different decompositions of the four gluon vertex, one generalizing the Ball Chiu one, the other one closely linked to the QCD effective action.

**Topic::**

Special Session: The QCD: from vacuum to finite temperatures

**Summary:**

**W. Greiner Memorial Session / 1375**

## **Relaxation to Equilibrium in Relativistic Heavy-Ion Collisions**

**Author:** Larissa Bravina<sup>None</sup>

TBA

**Topic::**

Memorial session for W. Greiner

**Summary:**

**W. Greiner Memorial Session / 1373**

## **Experimental investigation of fusion-fission mechanisms for superheavy nuclei**

Experimental investigation of fusion-fission mechanisms for superheavy nuclei

**Topic::**

Memorial session for W. Greiner

**Summary:**

**W. Greiner Memorial Session / 1374**

## **Exotic Matter in Neutron Stars**

**Author:** Stefan Schramm<sup>None</sup>

**Corresponding Author:** schramm@fias.uni-frankfurt.de

TBA

**Topic::**

Memorial session for W. Greiner

**Summary:**

**W. Greiner Memorial Session / 1210**

## Super Heavy Elements - experimental developments

**Author:** Gottfried Münzenberg<sup>1</sup>

<sup>1</sup> *GSI Darmstadt*

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Super Heavy Elements - experimental developments  
Gottfried Münzenberg

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With his theoretical work our mentor Walter Greiner pioneered heavy-and super heavy element research and motivated us as young scientists. As member of the “Kernphysikalische Arbeitsgemeinschaft Hessen, KAH” he actively shaped the profile of GSI. Cold heavy-ion fusion proposed by Yuri Oganessian, theoretically supported by Walter Greiner, paved the way to the super heavy elements. We are happy that still during his lifetime we could prove some of his predictions

Experimental developments paving the way to super heavy elements were the cold fusion of heavy ions to create super heavy nuclei, separation in-flight, and the implantation of the separated nuclei into position sensitive surface-barrier detectors to observe the decay history of individual nuclei. With the discovery of oganesson,  $Z=118$ , the heaviest element known today, produced in hot fusion reaction using beams of  $^{48}\text{Ca}$ , we have come to the end of this series. New experimental ideas and development are needed and under way.

A primary challenge for SHE research is the search for reactions to pass beyond oganesson and to explore the predicted island of superheavy elements. To measure cross-sections of femtobarns near and beyond  $Z=118$ , dedicated SHE factories are under construction. Reaction studies include new target-projectile combinations and transfer reactions. The next-generation of radioactive beam facilities will allow for large-scale studies. To which extent the use of rare-isotope beams can contribute to SHE research is under discussion.

The new SHE facilities include in-flight separators coupled to ion-catchers and multi-reflection time-of-flight mass spectrometers with isobaric mass resolution. These allow the isotopic identification of single atomic nuclei, determining nuclear mass and charge. For the first time superheavy nuclei can be identified directly “still alive” independent from their decay mode. First promising results have already been obtained.

**Topic::**

Special session for Super Heavy Elements

**Summary:**

**W. Greiner Memorial Session / 1151**

## Vorticity and polarization in baryon-rich matter formed in heavy ion collisions

**Authors:** Mircea Baznat<sup>1</sup>; Konstantin Gudima<sup>1</sup>; Alexander Sorin<sup>2</sup>; Oleg Teryaev<sup>2</sup>

<sup>1</sup> *Institute of Applied Physics, Academy of Sciences of Moldova*

<sup>2</sup> *Joint Inst. for Nuclear Research (RU)*

**Corresponding Authors:** alexander.sorin@cern.ch, baznat@theor.jinr.ru, oleg.teryayev@cern.ch, gudima@cc.acad.md

We study the structure of vorticity and hydrodynamic helicity fields in peripheral heavy ion collisions using the kinetic Quark-Gluon String and Hadron-String Dynamics models. We observe the formation of specific toroidal structures of vorticity field (vortex sheets). Their existence is mirrored in the polarization of hyperons of the percent order. Its rapid decrease with energy was predicted and recently confirmed by STAR collaboration. The energy dependence is sensitive to the temperature dependent term derived and discussed in various theoretical approaches. The antihyperon polarization is of the same sign and larger magnitude. The crucial role of strange vector mesons is also discussed.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**W. Greiner Memorial Session / 1011**

## Superheavy Nuclei to Hypernuclei: A Tribute to Walter Greiner

**Author:** Chhanda Samanta<sup>1</sup>

<sup>1</sup> *Virginia Military Institute*

**Corresponding Author:** samantac@vmi.edu

In nuclear physics, superheavy and hypernuclei are two of the most important fields of research. The prediction of islands of superheavy elements ( $Z = 114, N = 184, 196$  and  $Z = 164, N = 318$ ) in late sixties by the Frankfurt school played a key role in extending the periodic table of elements up to atomic number 118. Similarly, the demonstration that nuclear matter can be compressed 510 times of its original volume by nuclear shock waves, produced during heavy ion collision, led to the production of single- and double-lambda hypernuclei, as well as anti-matter nuclei. Recent observation of antihypertriton—comprising an antiproton, an antineutron, and an antilambda hyperon, by the STAR collaboration has now made it possible to envision a 3-dimensional nuclear chart of hypernuclei. My own interest in superheavy and hypernuclei was shaped from my first meeting with Walter Greiner at the International Conference on Atomic and Nuclear clusters held at Santorini, Greece in 1993. I will present a brief summary of these exciting developments, including some of our own work. Professor Greiner's vision, enthusiasm, and encouragement touched many lives and I was one of those privileged ones.

**Topic::**

Memorial session for W. Greiner

**Summary:**

**W. Greiner Memorial Session / 1366**

## Greiner and exotic matter

**Author:** Igor Mishustin<sup>1</sup>

<sup>1</sup> *Goethe University*

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**Topic::**

Memorial session for W. Greiner

**Summary:**

**W. Greiner Memorial Session / 1382**

## Eighty Years of Research on Super-heavy Elements

**Author:** Sigurd Hofmann<sup>1</sup>

<sup>1</sup> *GSI*

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Professor Walter Greiner, our friend and teacher, passed away in the age of eighty. During his lifetime, the search for elements beyond uranium started and elements up to the so far heaviest one with atomic number 118 were discovered. In this talk I will present a short history from early searches for 'trans-uraniums' up to the production and safe identification of shell-stabilized 'Super-Heavy Nuclei (SHN)'. The nuclear shell model reveals that these nuclei should be located in a region with closed shells for the protons at  $Z = 114, 120$  or  $126$  and for the neutrons at  $N = 184$ . The outstanding aim of experimental investigations is the exploration of this region of spherical SHN. Systematic studies of heavy ion reactions for the synthesis of SHN revealed production cross-sections which reached values down to one picobarn and even below for the heaviest species. The systematics of measured cross-sections can be understood only on the basis of relatively high fission barriers as predicted for nuclei in and around the island of SHN. A key role in answering some of the open questions plays the synthesis of isotopes of element 120. Attempts aiming for synthesizing this element at the velocity filter SHIP will be reported.

**Topic::**

Memorial session for W. Greiner

**Summary:**

**W. Greiner Memorial Session / 1252**

## Predictability analysis of $\alpha$ decay formulae and the $\alpha$ partial half-lives of exotic nuclei.

**Author:** Nabanita Dasgupta-Schubert<sup>1</sup>

<sup>1</sup> *Facultad de Ciencias Físico Matemáticas*



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$\alpha$  decay is one of the main decay modes of Super-heavy nuclei (SHN) and highly neutron deficient medium-mass nuclei, collectively termed ‘exotic’ nuclei. In the synthesis of such nuclei and the radiochemical characterization of their longer-lived decay products, the identification is aided by the theoretical predictions of  $\alpha$  decay half-lives ( $T_{1/2}$ ) and decay energies. We examine the ability of 3 phenomenological alpha decay formulae, the Generalised Liquid Drop Model (GLDM), the Sobiczewski-Parkhomenko and the Viola-Seaborg formulae, to predict the  $\alpha$  partial  $T_{1/2}$  of 100 exotic nuclei by the statistical quantification of their accuracy and precision. These quantities were derived using a method based on standard experimental benchmarking wherein the  $\alpha$  spectroscopic data of 302 well-established alpha decaying nuclei (calibration data set) were used. Experimental masses as well as Finite Range Droplet Model masses were used to compute  $Q_\alpha$ . Improved coefficients for the three formulae were derived resulting in modified formulae. A simple linear optimization allowed adjustment of the modified formulae for the insufficient statistics of the odd-even and odd-odd decays of the calibration data set, without changing the modified formulae. Relatively better figures of merit for the odd-odd and the SHN were obtained using the modified GLDM formula.

**Topic::**

Memorial session for W. Greiner

**Summary:**

This work analyses the predictive ability of 3 well-known analytical formulae of alpha decay towards predicting the alpha partial half-lives of exotic alpha emitters. The appropriate statistical analysis is presented as well as the modified formulae with improved coefficients. Prof. Greiner had made seminal contributions to the fields of alpha and cluster radioactivity and fission dynamics as well as in the physics of Super Heavy Nuclei, amongst others. It is only appropriate that this talk be presented in the Memorial Session for Walter Greiner, as my small contribution towards the collective homage to his legacy.

**W. Greiner Memorial Session / 1500**

## **Anisotropic dissipative fluid dynamics**

**Author:** Dirk Rischke<sup>1</sup>

<sup>1</sup> *University Frankfurt*

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TBA

**Topic::**

**Summary:**

**W. Greiner Memorial Session / 1045**

## **Atomic physics with highly-charged heavy ions at GSI/FAIR**

**Author:** Alexandre Gumberidze<sup>None</sup>

**Corresponding Author:** alex.gumberidze@gmail.com

Highly charged ions (HCI) combine extremely strong electromagnetic fields and a simple electronic structure, which makes them ideal testing grounds for fundamental theories such as quantum mechanics, relativity and quantum electrodynamics (QED) in the domain of strongest electromagnetic fields available for experimental investigation. In the heaviest one- and few-electron ions, such as hydrogen-like uranium, the field strength exposed on the electron in the ground-state is already very close to the Schwinger limit. Therefore, the structure (and also the dynamics) of highly-charged ions is significantly influenced by the effects of the quantum vacuum.

The new international accelerator Facility for Antiproton and Ion Research (FAIR) which is currently under construction in Darmstadt, offers a wide range of exciting new opportunities in the field of atomic physics and related fields. These include (among others); cooled and stored heavy-ion beams of excellent quality and intensity, with a very broad energy range; from relativistic down to virtually at rest.

In this presentation, an overview of the program of the Stored Particle Atomic Research Collaboration (SPARC) at the FAIR facility will be given. Particular emphasis will be on precision experiments with highly-charged heavy ions devoted to stringent tests of Quantum Electrodynamics in extreme electromagnetic fields as well as to the experimental program aimed to study low-energy (near-)symmetric ion-atom/ion collisions in storage rings at GSI and FAIR. One of the main (long-term) goals here is to gain better insight into the details of heavy quasi-molecular systems formed in such encounters and thereby access the physics of critical electromagnetic fields.

**Topic::**

Memorial session for W. Greiner

**Summary:**

**W. Greiner Memorial Session / 1368**

## **Comparison of hydrodynamical and transport theoretical calculations for p+A and A+A collisions**

**Author:** Carsten Greiner<sup>1</sup>

<sup>1</sup> *University of Frankfurt*

**Corresponding Author:** carsten.greiner@th.physik.uni-frankfurt.de

Comparison of hydrodynamical and transport theoretical calculations for p+A and A+A collisions

**Topic::**

Memorial session for W. Greiner

**Summary:**

**Workshop on (Super)gravity, String theory and Related Topics / 1489**

## **Supergravity solutions from the double copy**

**Author:** Silvia Nagy<sup>None</sup>

The idea that gravity (with or without supersymmetry) can be written as a double copy of Yang-Mills theories has become an established framework for understanding scattering amplitudes in gravitational theories.

I will describe two newer directions of research springing from this idea. One is that gravitational solutions (such as black holes) can be constructed directly from the simpler solutions of Yang-Mills theories. To this end I will present a dictionary where each field in a supergravity theory is constructed as a convolution of two fields belonging to gauge theories. The dictionary is built to be automatically compatible with the equations of motion and as such there is hope that it can become a solution generating technique.

On the quantum side, I will describe how BRST quantization and the introduction of the associated ghosts lends itself to a double copy dictionary description. This has the potential to further clarify and aid with graviton amplitude calculations.

**Topic::**

Workshop on Supergravity, Strings and Related Matters

**Summary:**

**Workshop on (Super)gravity, String theory and Related Topics / 1395**

## Non-perturbative Gauge-Higgs Unification

**Author:** Nikos Irges<sup>1</sup>

<sup>1</sup> NTUA

**Corresponding Author:** irges@mail.ntua.gr

We describe a way to generate a 4d Higgs mechanism from a 5d pure gauge theory without a compact extra dimension or fermions. The analysis is necessarily non-perturbative and thus new, since the quantum behaviour of higher dimensional gauge theories is very little understood.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Workshop on (Super)gravity, String theory and Related Topics / 1524**

## Exotic branes and non-geometric fluxes in string theory

**Author:** Fabio Riccioni<sup>1</sup>

<sup>1</sup> INFN - National Institute for Nuclear Physics

**Corresponding Author:** fabio.riccioni@roma1.infn.it

We obtain a complete classification of the half-supersymmetric branes of IIA/IIB string theory compactified on tori based on non-perturbative dualities. Many of these branes are 'exotic', in the sense that they do not arise from the dimensional reduction of branes in ten dimensions. We then consider a specific N=1 model in four dimensions with fluxes turned on, and we determine the subset of the space-filling 3-branes of the maximal theory that are not projected out in the model. We point out that all such branes can simultaneously be included to cancel the tadpoles induced by the fluxes,

giving in principle many new solutions to the consistency conditions that these fluxes must satisfy.

**Topic::**

**Summary:**

**Workshop on (Super)gravity, String theory and Related Topics / 1527**

**TBA**

**Author:** Anastasios Petkou<sup>1</sup>

<sup>1</sup> *Unknown*

**Corresponding Author:** tassos.petkou@cern.ch

TBA

**Topic::**

**Summary:**

**Workshop on (Super)gravity, String theory and Related Topics / 1525**

## **Using Numerical Relativity to explore Fundamental Physics and Astrophysics**

**Author:** Luciano Rezzolla<sup>1</sup>

<sup>1</sup> *Goethe University Frankfurt*

**Corresponding Author:** rezzolla@th.physik.uni-frankfurt.de

Recent years have seen a major progress in Numerical Relativity and the solution of the simplest and yet among the most challenging problems in classical General Relativity: the evolution of two objects interacting only gravitationally. I will review the results obtained so far when modelling binaries of black holes or of neutron stars and also discuss the impact these studies have in detection of gravitational waves, in Astrophysics, and in our understanding of General Relativity.

**Topic::**

**Summary:**

**Workshop on (Super)gravity, String theory and Related Topics / 1528**

## **Cosmology with PLANCK: exploring the early Universe via the CMB**

**Author:** Paolo Natoli<sup>1</sup>

<sup>1</sup> *Università di Ferrara*

**Corresponding Author:** natoli@fe.infn.it

I will discuss highlights from the latest PLANCK release and present the most stringent bounds to date on a widely accepted cosmological picture. The  $\Lambda$ CDM model has withstood a large collection of tests at increasing precision over the last decade and gains, with the Planck results, further strength. At the same time, we see small quirks in the data that may or not hint to new Physics in the early Universe.

**Topic::**

**Summary:**

**Workshop on (Super)gravity, String theory and Related Topics / 1531**

## **Non-Linear Supersymmetry and some Applications**

**Author:** Emilian Dudas<sup>1</sup>

<sup>1</sup> *Ecole Polytechnique*

**Corresponding Author:** emilian.dudas@cpht.polytechnique.fr

I will review the recent progress in constructing non-linear realizations of supersymmetry using standard superspace techniques and constrained superfields, whose effects is to eliminate some field components from the spectrum. I will then proceed with some of their supergravity applications to Cosmology.

**Topic::**

**Summary:**

**Workshop on (Super)gravity, String theory and Related Topics / 1535**

## **Introduction**

**Author:** Augusto Sagnotti<sup>1</sup>

<sup>1</sup> *Scuola Normale Superiore and INFN-Sezione di Pisa (IT)*

**Corresponding Author:** sagnotti@sns.it

**Topic::**

**Summary:**

**Workshop on (Super)gravity, String theory and Related Topics / 1534**

## **Primordial Inflation and Power Spectra**

**Author:** Tsamis Nikolaos<sup>None</sup>

**Corresponding Author:** tsamis@physics.uoc.gr

After an introduction to primordial inflation and de Sitter physics we present a formalism which allows to compute primordial power spectra for non-constant geometries analytically and we obtain interesting quantitative results.

**Topic::**

**Summary:**

**Workshop on (Super)gravity, String theory and Related Topics / 1522**

## **Recent progress on M5-branes at singularities**

**Author:** Alessandro Tomasiello<sup>1</sup>

<sup>1</sup> *Milan Bicocca University*

**Corresponding Author:** tomasiel@gmail.com

The dynamics of M5-branes is one of the most mysterious aspects of string theory. Recently the issue was reconsidered from the point of view of 6d conformal field theory, also using techniques borrowed from F-theory and holography. Some surprising phenomena came to light regarding the behavior of M5s at singularities, such as the possibility of “fractionation” and the presence of a rich moduli space related to the space of nilpotent orbits in a Lie group.

**Topic::**

**Summary:**

**Workshop on (Super)gravity, String theory and Related Topics / 1512**

## **Quantum aspects of 3D higher-spin gauge theories**

**Author:** Andrea Campoleoni<sup>None</sup>

**Corresponding Author:** a.campoleoni@gmail.com

Three-dimensional models are a particularly promising setup for the study of the quantisation of higher-spin gauge theories. One can take advantage both of the simplicity brought about by the absence of local degrees of freedom and of the tools of two-dimensional conformal field theory that can be introduced via holographic scenarios. After a brief review of the basic setup, we shall show how a judicious choice of variables in the bulk allows one to set up a quantisation scheme following the lines of the free-field realisations of quantum W-algebras in 2D CFT.

**Topic::**

Workshop on Supergravity, Strings and Related Matters

**Summary:**

**Workshop on (Super)gravity, String theory and Related Topics / 1532**

## String Theory and the Omega Background

**Author:** Carlo Angelantonj<sup>1</sup>

<sup>1</sup> *Universita e INFN Torino (IT)*

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

The Omega background is a deformation of Euclidean space-time that allows exact and explicit computations in four-dimensional N=2 gauge theories. Its extension to String Theory has been quite elusive so far, and only partial results have been obtained. In particular, it has been conjectured that it can be described in String Theory in terms of suitable topological amplitudes computed on flat space-time. In this talk I shall present one further example in support of this conjecture and, if time permits, I shall argue that the Omega background actually allows for an exact CFT description in String Theory.

**Topic::**

**Summary:**

**Workshop on (Super)gravity, String theory and Related Topics / 1530**

## On higher spin supertranslations and superrotations

**Author:** Dario Francia<sup>1</sup>

<sup>1</sup> *Scuola Normale Superiore*

**Corresponding Author:** dario.francia@sns.it

We study the large gauge transformations of massless higher-spin fields in four-dimensional Minkowski space. Suitable extensions of the Bondi gauge allow to identify an infinite-dimensional asymptotic symmetry algebra whose Ward identities imply Weinberg's soft theorem beyond spin two. We speculate on the possible role of these investigations as a tool to shed some light on the still mysterious infrared physics of higher-spin massless quanta.

**Topic::**

**Summary:**

**Workshop on (Super)gravity, String theory and Related Topics / 1556**

## Conclusion

**Author:** Augusto Sagnotti<sup>1</sup>

<sup>1</sup> *Scuola Normale Superiore and INFN-Sezione di Pisa (IT)*

**Corresponding Author:** sagnotti@sns.it

**Topic::**

**Summary:**

**Workshop on (Super)gravity, String theory and Related Topics / 1526****Anti-de Sitter gravity/fluid correspondence and its flat/Carrollean limit****Author:** Marios Petropoulos<sup>1</sup><sup>1</sup> *Centre National de la Recherche Scientifique (CNRS)***Corresponding Author:** marios.petropoulos@cern.ch

I will discuss the reconstruction of exact four-dimensional Einstein (asymptotically anti-de Sitter) spacetimes from boundary data consisting of the three-dimensional spacetime boundary metric and the second fundamental form playing the role of energy-momentum tensor. To this end, the data must be appropriately tuned and the way to proceed is inspired from gravitational self-duality. The set-up under consideration admits a non-trivial flat limit, in which the asymptotically flat spacetime emerges as a resummed series based on data defined on a two-dimensional space-like surface. These data can be thought of as a Carrollian fluid obeying energy conservation law and Euler-like equations.

Compared to previous attempts, the present approach provides a more general and robust perspective on flat-space holography for fluids. I will illustrate it with the Robinson-Trautman family of Einstein spacetimes, showing in particular that the dissipation phenomena occurring in the corresponding relativistic and Carrollian fluids are due to thermal conduction, where the two-dimensional Gauss curvature plays the role of a temperature.

**Topic::****Summary:****Workshop on (Super)gravity, String theory and Related Topics / 1533****Corner contributions to holographic entanglement entropy in AdS<sub>4</sub>/BCFT<sub>3</sub>****Author:** Domenico Seminara<sup>1</sup><sup>1</sup> *Physics Department***Corresponding Author:** seminara@fi.infn.it

In the context of the AdS<sub>4</sub>/BCFT<sub>3</sub> correspondence, where also the gravitational spacetime is bounded by a hypersurface which encodes the boundary conditions characterising the dual BCFT<sub>3</sub>, we study the holographic entanglement entropy of spatial regions with corners, whose vertices are located on the boundary of the BCFT<sub>3</sub>. The case where the boundary of the BCFT<sub>3</sub> is a flat hyperplane is considered. Analytic expressions for the simplest corner functions are presented. A numerical analysis is performed by computing the area of the minimal area surfaces corresponding to finite domains.

**Topic::****Summary:****Workshop on continuous variables and quantum information / 1274**



## Squeezed light enhanced sensing of a micro-mechanical oscillator

**Authors:** J Bilek<sup>1</sup>; C Schäfermeier<sup>1</sup>; B Li<sup>2</sup>; U B Hoff<sup>1</sup>; H Kerdoncuff<sup>1</sup>; A Huck<sup>1</sup>; H Fu<sup>1</sup>; G Harris<sup>2</sup>; W Bowen<sup>2</sup>; T Gehring<sup>1</sup>; U L Andersen<sup>1</sup>

<sup>1</sup> *Technical University of Denmark*

<sup>2</sup> *University of Queensland*

Ultra-precise measurements of various parameters such as the mass of nano-particles, magnetic fields or gravity can be attained by probing the phononic modes of a micro-mechanical oscillator with light. The sensitivity of such measurements is in part governed by the noise of the phononic mode as well as the noise of the probing light mode, so by decreasing the noise of the probe beam an enhanced sensitivity can be expected. We demonstrate this effect by using squeezed states of light where the quantum uncertainty of the relevant quadrature is reduced below the shot noise level. Using this squeezing-enhanced sensitivity effect, we demonstrate 1) improved feedback cooling of a phononic mode in a microtoroidal cavity and 2) improved sensing of a magnetic field using the coupling to a microtoroidal phononic mode via a magnetostrictive material. We present our recent experimental results and discuss future directions.

**Topic::**

Topic: Quantum Physics, Quantum Optics and Quantum Information

**Summary:**

**Workshop on continuous variables and quantum information / 1253**

## Highly nonlinear quantum optics and optomechanics

**Author:** Radim Filip<sup>1</sup>

<sup>1</sup> *Palacky University in Olomouc*

**Corresponding Author:** filip@optics.upol.cz

The talk will present an overview of recent theoretical and experimental activities in highly nonlinear quantum optics and optomechanics with continuous variables and a progress in current merging of these two fields. First, we will focus on a generation of instable strong cubic quantum nonlinearities for optical, atomic and optomechanical systems and diagnostics of non-equilibrium and nonclassical states produced by that nonlinearity. Second, we will concentrate on thermally induced nonlinear effects producing nonclassical states of light and motion.

**Topic::**

Topic: Quantum Physics, Quantum Optics and Quantum Information

**Summary:**

**Workshop on continuous variables and quantum information / 1069**

## Gaussian quantum steering of two bosonic modes in a squeezed thermal environment

**Author:** Mihaescu Tatiana<sup>1</sup>

**Co-author:** Aurelian Isar<sup>2</sup>

<sup>1</sup> *Horia Hulubei National Institute of Physics and Nuclear Engineering, Department of Theoretical Physics*

<sup>2</sup> *National Institute of Physics and Nuclear Engineering, Bucharest-Magurele, Romania*

**Corresponding Authors:** mihaescu92tatiana@gmail.com, aurelianisar@gmail.com

Einstein-Podolsky-Rosen steerability of quantum states is a property that is different from entanglement and Bell nonlocality. We describe the time evolution of a recently introduced measure that quantifies steerability for arbitrary bipartite Gaussian states in a system consisting of two bosonic modes embedded in a common squeezed thermal environment.

We work in the framework of the theory of open systems. If the initial state of the subsystem is taken of Gaussian form, then the evolution under completely positive quantum dynamical semigroups assures the preservation in time of the Gaussian form of the states.

It was shown that the thermal noise and dissipation introduced by the thermal environment destroy the steerability between the two bosonic modes. In the case of the squeezed thermal bath we show the dependence of the Gaussian steering on the squeezing parameters of the bath and of the initial state of the system. A comparison with other quantum correlations for the same system shows that, unlike Gaussian quantum discord, which is decreasing asymptotically in time, the Gaussian quantum steerability suffers a sudden death behaviour, like quantum entanglement.

**Summary:**

**Topic::**

Mini-workshop: Continuous Variables and Relativistic Quantum Information

**Workshop on continuous variables and quantum information / 1159**

## Mixing of positive and negative frequency waves at the optical horizon

**Author:** Maxime Jacquet<sup>1</sup>

**Co-authors:** Vyome Singh<sup>1</sup>; Friedrich Koenig<sup>2</sup>

<sup>1</sup> *University of St Andrews*

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There exist various conditions under which waves of positive and negative Klein-Gordon norm can be made to convert into each other.

For example, upon propagating on a curved background, waves of positive and negative norm mix to generate outgoing waves.

As a result of this scattering process, field quanta are spontaneously emitted from the vacuum – the most famous instance of this effect undoubtedly is the mixing of positive and negative norm waves at the horizon of black holes, which results in a steady thermal flux to be emitted from the hole, Hawking radiation [1].

The event horizon of the black hole is the point at which the curvature of spacetime is such that the escape velocity out to infinity becomes superluminal, thus restricting wave propagation to one direction only: toward the central singularity.

Wave propagation on a curved background geometry is not restricted to astrophysics: it is possible to realise an effectively curved geometry with moving wave media in the laboratory, and, in particular, the kinematics of waves at the horizon [2].

An artificial event horizon can be created when a refractive index front (RIF) is moving at the speed of light in a dispersive optical medium [3].

The RIF could be created by a pulse of light that modifies the refractive index by the optical Kerr

effect – a nonlinear effect by which the refractive index depends upon the square of the electric field in the medium.

Light under the pulse will be slowed and thus the front of the pulse exhibits – for some frequencies – a black-hole type horizon capturing light. The back of the pulse acts as an impenetrable barrier, a white-hole horizon.

Both event horizons separate two discrete regions: under the pulse, where light is slow and the pulse moves superluminally and outside the pulse, where the pulse speed is subluminal.

We reveal the properties of spontaneous emission from the vacuum at a moving refractive index step in a dispersive dielectric by expanding on an analytical model for light-matter interaction [4]. We establish the conditions for event horizons as a function of the speed and height of the step in the medium, and study the various configurations of modes of the field in the vicinity of the step with and without analogue horizons. We then analytically calculate the emission spectra from all modes of positive and negative norm in the laboratory frame [5]. We find that, as a result of the various mode configurations, the spectrum is highly structured into intervals with black hole-, white hole-, and no horizon.

The emission spectrum in the laboratory frame is found to be a combination of emissions corresponding to different frequencies in the frame moving with the pulse, leading to a characteristic shape. In particular, the existence of a peak in the ultraviolet, associated with emission into a mode with negative norm, is an interesting feature of our spectrum.

We show how emission in this peak may be stimulated by scattering a coherent wave at the horizon.

We also report on an experiment to study the dynamics of waves at the optical horizon.

A weak CW-probe is made to scatter on a RIF created by an intense, ultrashort pulse in a photonic crystal fibre under fine-tuned horizon-like conditions.

As a result of mode conversion at the horizon, light at different wavelengths is generated: the probe is partially shifted in frequency – positive-to-positive norm conversion occurs as predicted by our theory.

Furthermore, we investigate the companion effect of stimulated emission in a negative norm wave. The effect of mode conversion is clearly shown to be a feature of horizon physics.

This experiment is a stimulated version of the spontaneous quantum effect at the heart of Hawking radiation.

[1] S. Hawking, *Nature* 248, 30 (1974).

[2] W.G. Unruh, *Phys. Rev. Lett.* 46 (1981).

[3] T.G. Philbin et al *Science* 319, 1367 (2008).

[4] S. Finazzi and I. Carusotto, *Phys. Rev. A* 87, 023803 (2013).

[5] M. Jacquet and F. Koenig, *Phys. Rev. A* 92, 023851 (2015).

#### Topic::

Mini-workshop: Continuous Variables and Relativistic Quantum Information

#### Summary:

We analytically calculate the laboratory-frame spectrum of light spontaneously emitted from the vacuum as a result of the mixing of waves with positive and negative norm at an optical horizon in a dispersive medium. We perform a stimulated experiment in which energy is converted from a positive-norm continuous wave to outgoing waves of different frequency.

Workshop on continuous variables and quantum information / 1094

## Ultrafast Quantum Key Distribution with Ultra-Broad Squeezed Light

Author: Avi Pe'er<sup>1</sup>

<sup>1</sup> Bar Ilan University

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A scheme for parallel, high-throughput continuous-variable QKD (CV-QKD) is presented that efficiently utilizes the optical bandwidth resource of broadband squeezed vacuum (of order 10 – 100THz), using a novel method for broadband spectrally resolved parametric homodyne measurement. Large multi-bit frames of data can be encoded simultaneously onto the squeezed vacuum spectrum by shaping its spectral phase using a Fourier-domain pulse shaper. This data can later be decoded at the receiving end by measuring the spectral quadrature fluctuation across the entire spectrum on a linear array of fast detectors using the pump field as a single local oscillator for all frequency pairs in the spectrum. The speed-up of the proposed protocol compared to standard protocols is proportional to the number of detectors in the array, which ideally can reach  $10^5$  (defined by the ratio of the total bandwidth to the modulation rate of a single channel), and practically can be well over 100.

Our Scheme relies on a common version of CV-QKD, where the data is encoded onto the amplitude and phase of squeezed vacuum light (or the field quadratures) and is read out by coherent homodyne detection against a local oscillator [1]. CV-QKD is considered faster than discrete variable QKD because of the technical details of homodyne detection, which allow faster measurement than photon counting. In addition it may allow use of multiple photons per detection (and transfer multiple data bits per detection correspondingly) [2]. The security of the communication relies on the inability to measure both quadratures simultaneously, indicating that a receiving party can measure only one quadrature with no information on the other. Moreover, variation of the quadrature axis (phase of the pump) between  $(0, \pi/2)$  and  $(\pi/4, -\pi/4)$  naturally defines two mutually exclusive bases, where measurement along the  $(\pi/4, -\pi/4)$  axis cannot provide any information for a state that was squeezed along the other  $(0, \pi/2)$  axis, very similar to measuring the polarization of a single photon along the wrong axis of polarization.

### References

1. T. Gehring, V. Handchen, J. Duhme, F. Furrer, T. Franz, C. Pacher, R. F. Werner and R. Schnabel, “Implementation of continuous-variable quantum key distribution with composable and one-sided-device-independent security against coherent attacks”, *Nature Communications* 6, 8795 (2015).
2. F. Grosshans, G. Van Assche, J. Wenger, R. Brouri, N. J. Cerf and P. Grangier, “Quantum key distribution using gaussian-modulated coherent states”, *Nature* 421, 238 (2003)
3. A. M. Weiner, “Ultrafast optical pulse shaping: A tutorial review”, *Opt. Commun.* 284, 3669 (2011).

**Summary:**

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Workshop on continuous variables and quantum information / 1139**

## Phase supersensitivity in an unbalanced SU(1,1) interferometer

**Author:** Maria Chekhova<sup>None</sup>

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A nonlinear interferometer, generally, is a sequence of two nonlinear effects occurring coherently. We investigate the properties of such an interferometer consisting of two unseeded high-gain degenerate optical parametric amplifiers (DOPAs). This configuration is known in the literature as an SU(1,1) interferometer and it enables achieving the Heisenberg limit in phase sensitivity. Moreover, by making the two DOPAs unbalanced, the parametric gain of the second one considerably exceeding the one of the first one, one can overcome the detection losses [1].

In our experiment, we demonstrate a phase sensitivity overcoming the shot noise limit by more than 2dB, with the number of photons in the interferometer being between 1 and 10. We show that the phase sensitivity is considerably improved by increasing the parametric gain of the second DOPA.

The observed tolerance to detection losses will be very important for phase measurements, including the ones related to gravitational-wave detection, in 'difficult' spectral ranges where detection is inefficient.

[1] M. Manceau, F. Khalili, and M. Chekhova, *New Journal of Physics* 19, 013014 (2017).

**Topic::**

Topic: [Quantum Physics](#), [Quantum Optics](#) and [Quantum Information](#)

**Summary:**

**Workshop on continuous variables and quantum information / 1222**

## From Quantum-Limited Measurements towards Quantum Squeezing Detection over Satellite Links

**Author:** Christian Ralf Müller<sup>1</sup>

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Quantum optics allows implementing cryptographic protocols that are verifiably immune against any conceivable attack. Standard telecommunication components allow for an efficient implementation of quantum communication using continuous-variables (CV) of light. At MPL, we routinely implement CV quantum communication based on phase-shift keying of coherent states in combination with homodyne detection [1,2].

Existing fiber infrastructure is not suitable for long-haul links between metropolitan networks since classical telecom repeaters cannot relay quantum states. A space borne Laser Communication Terminal (LCT), however, would be capable to relay quantum key distribution (QKD) between a large number of hubs on ground. To this end, we demonstrated quantum-limited measurements of signals from the Alphasat satellite in geostationary Earth orbit (GEO) [3]. Our results underpin the feasibility of satellite quantum communication based on existing technology.

On the fundamental research side, the large gravitational potential difference between GEO and ground offers an ideal testbed to investigate gravitational effects on quantum states.

Our measurements from the Alphasat satellite showed that atmospheric noise can be overcome and that merely the huge diffraction losses pose challenges for the detection of quantum properties such as quantum squeezing.

For homodyne detectors in classical telecommunication, the precise measurement value of the continuous quadrature observable is of minor significance. The signals in BPSK encoding, for instance, are discriminated based on the sign of the measurement outcome, such that the signals are often projected onto their sign bit thereby precluding the access to the continuous quadrature spectrum. We investigate the implications of this extremal discretization with regard to the detection of quantum squeezing and find that it can still be witnessed efficiently [4].

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 (in preparation)

**Topic::**

Mini-workshop: Continuous Variables and Relativistic Quantum Information

**Summary:**

**Workshop on continuous variables and quantum information / 1061**

## Dynamics of quantum correlations in two-mode Gaussian open quantum systems

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In the framework of the theory of open systems based on completely positive quantum dynamical semigroups, we make a comparison of the behaviour of continuous variable quantum correlations (quantum entanglement, entropic quantum discord, geometric quantum discord, quantum steering) for a system consisting of: 1) two non-coupled; 2) two coupled bosonic modes embedded in a common environment of the form of a thermal bath or of a squeezed thermal bath. We solve the Markovian master equation for the time evolution of the considered system and describe the quantum correlations in terms of the covariance matrix for Gaussian input states. Depending on the values of the parameters characterizing the initial state of the system (squeezing parameter, average photon numbers), the coefficients describing the interaction of the system with the reservoir (temperature, dissipation constant), and the intensity of the interaction between the two modes, one may notice phenomena like generation of quantum correlations, their suppression (sudden death), periodic revivals and suppressions, or an asymptotic decay in time of quantum correlations.

**Topic::**

Mini-workshop: Continuous Variables and Relativistic Quantum Information

**Summary:**

**Workshop on continuous variables and quantum information / 1214**

## Gigahertz quantum signatures compatible with telecommunication technologies

**Authors:** Matthew Thornton<sup>1</sup>; Callum Croal<sup>1</sup>; Imran Khan<sup>2</sup>; Christoph Marquardt<sup>2</sup>; Gerd Leuchs<sup>2</sup>; Natalia Korolkova<sup>3</sup>

<sup>1</sup> *University of St Andrews*

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Modern cryptography covers much more than encryption of messages in order to keep them secret. Many other cryptographic primitives exist, and it is important to consider how the security of these will be affected in a quantum future. Digital Signatures are a widely used cryptographic primitive, found eg. in e-mail, e-commerce and digital banking, and they form the basis for larger protocols. A signature  $\sigma_m$  appended to a classical message  $m$  ensures the authenticity and transferability of the message, whilst preventing forgery and repudiation. By employing quantum mechanics to distribute the  $\sigma_m$  between recipients, unconditionally secure signature schemes can be constructed [1-4].

As the development of quantum security progresses, one must consider how to implement these schemes using currently existing technology.

To this end, we present a continuous-variable quantum signature scheme with an emphasis on compatibility with existing telecommunication technologies. Our scheme is information-theoretically secure against repudiation attacks and collective forging attacks, and can be implemented even when some QKD-based signature protocols fail. We note that this is the first implemented continuous-variable quantum signature scheme which does not require secure quantum channels between participants, although discrete-variable protocols have been proposed and implemented [5-6].

In the simplest scenario, quantum digital signature (QDS) schemes involve three parties: Alice, who wishes to sign  $m$ , and two recipients, Bob and Charlie. In a Distribution stage, Alice forms sequences of quantum states,  $\rho_B^m$  and  $\rho_C^m$ , and sends them to Bob and Charlie, who measure the states and record their outcomes. The quantum states can be thought of as Alice's public key". Her corresponding-private key", containing classical information about which states she sent, is used as the signature  $\sigma_m$ . Crucially, since a QDS scheme relies on quantum measurement, recipients gain only partial information about  $\sigma_m$ . Later, in an entirely classical Messaging stage Alice sends  $(m, \sigma_m)$ . Bob and Charlie compare  $\sigma_m$  to their measurement results, and accept or reject  $m$  accordingly.

We have implemented our scheme by distributing an alphabet of phase-modulated coherent states over a 20-km optical fiber, and have devised the corresponding security proof. In particular, we prove that a dishonest forger who interacts with the quantum states cannot then declare some  $\sigma'_m$  which will be accepted by honest recipients, except with negligible probability (security against forging). The probability of successful forgery is related to the smooth min-entropy, which can be interpreted as the uncertainty that an eavesdropper has about an honest participant's measurement outcomes [7]. Hence, by estimating a lower bound for the smooth min-entropy we prove security of our protocol, considering the finite-size effects intrinsic to signatures. As tighter bounds are developed these can readily be incorporated. Furthermore, Bob's and Charlie's measurement outcomes are symmetrised with respect to Alice, which makes it unlikely that a dishonest Alice can find some  $\sigma''_m$  which Bob will accept but that she can later deny sending (security against repudiation).

Our system is built from telecom components running at a wavelength of 1553.33-nm and is completely fiber-integrated. The coherent states are distributed by Alice at a rate of 10-GHz and are measured using homodyne detection at Bob/Charlie. With our security proof the signature lengths are of the order of  $10^6$  to sign  $m$  with a 0.01% chance of failure, meaning a 1-bit message can be signed in 0.1-ns. This opens the possibility of efficiently distributing quantum signatures on a large scale with minimal installation cost, and makes our scheme competitive in a landscape where both practicality and security are important.

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**Topic::**

Mini-workshop: Continuous Variables and Relativistic Quantum Information

**Summary:**

We present an implement a continuous-variable quantum digital signatures (QDS) protocol, which guarantees the authenticity, integrity and transferability of a classical message. Our protocol is secure against eavesdropping by a malevolent party, and secure against a malevolent sender, Alice, trying to deny her message. Our implementation is highly compatible with existing telecom infrastructure.

**Workshop on continuous variables and quantum information / 1272****Gaussian intrinsic entanglement**

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Entanglement measures proved to be a vital tool for development of quantum information science. For example, an important property of entanglement called monogamy is quantitative, and therefore cannot be captured without introducing entanglement measures. Additionally, entanglement measures provide useful bounds on several important hardly computable quantities, and they are indispensable in proofs of some quantum-information no-go theorems. In experiment, entanglement measures are needed to assess the quality of prepared entangled states and entangling gates, and they set bounds one has to surpass to demonstrate some crucial quantum protocols such as entanglement distillation.

A common feature of a vast majority of currently used entanglement measures is that either they possess a good physical meaning or are computable but not both. We probe the gap between computable and physically meaningful entanglement measures by introducing a new quantifier of entanglement which we call intrinsic entanglement (IE) [1,2]. The proposed quantity is a modification of the so called classical measure of entanglement [3], which is obtained by maximin optimization of intrinsic information [4] giving an upper bound on the secret-key rate in the classical secret key agreement protocol [5]. We investigate the IE within the framework of an important class of Gaussian states, operations, and measurements. We show, that in the Gaussian scenario IE simplifies to the mutual information of a Gaussian distribution of outcomes of measurements on parts of the system, conditioned on the outcomes of a measurement on a purifying subsystem,



which is first minimized with respect to measurements on the purifying part and subsequently maximized over the remaining measurements. It is further demonstrated that the Gaussian intrinsic entanglement (GIE) vanishes only on separable states and it exhibits monotonicity under Gaussian local trace-preserving operations and classical communication. Finally, in the case of two-mode states we compute GIE for all pure states, all symmetric states with a three-mode purification, asymmetric squeezed thermal states with a three-mode purification and restricted local noises, as well as for symmetric squeezed thermal states with a four-mode purification and restricted local noises. Surprisingly, in all of these cases, GIE is equal to Gaussian Rényi-2 entanglement [6], which leads us to a conjecture that the two quantities are equal on all Gaussian states. As GIE is operationally associated to the secret-key agreement protocol and can be computed for several important classes of states, it offers a compromise between computable and physically meaningful entanglement quantifiers.

References:

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**Topic::**

Mini-workshop: Continuous Variables and Relativistic Quantum Information

**Summary:**

**Workshop on continuous variables and quantum information / 1333**

## **Quantum Frequency Combs: generation, characterization and applications**

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Multimode entanglement is an essential resource for quantum information processing. However, multimode entangled states are generally constructed by targeting a specific entanglement configuration. This yields to a fixed experimental setup that therefore exhibits reduced versatility and scalability. Here we demonstrate a reconfigurable highly multimode entangled state generated by para-

metric down conversion of a mode locked laser source. Without altering either the initial squeezing source or the experimental architecture, we realize the construction of many cluster states of various sizes and connectivities. More generally we show that this system enables the complete characterization of quantum correlations and fluctuations for any multimode Gaussian state. Progress in the direction of non-gaussian multimode states will be also reported.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Workshop on continuous variables and quantum information / 1205**

## Continuous quantum variables: from quantum computing to relativistic quantum information

**Author:** Nicolas Menicucci<sup>1</sup>

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Quantum information has traditionally employed *qubits* (quantum bits) to encode and process quantum information because of their obvious analogy to (classical) bits and the fact that digitisation allows for errors to be corrected, even at the quantum level. Nevertheless, *continuous quantum variables* afford distinct advantages in terms of producing extremely large-scale resource states (cluster states with over 1 million entangled modes) for quantum computing while using only minimal experimental equipment. In addition, this approach offers new tools for nonperturbative analysis of the behaviour of quantised detectors interacting with a relativistic quantum field. I will provide an overview of the latest theoretical and experimental advances at the forefront of continuous-variable quantum theory and technology for use in quantum computing and relativistic quantum information.

**Topic::**

Mini-workshop: Continuous Variables and Relativistic Quantum Information

**Summary:**

**Workshop on continuous variables and quantum information / 1136**

## Work is the source of gravity

**Author:** David Edward Bruschi<sup>1</sup>

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Relativistic Quantum Information is a novel area of research that aims at understanding the interplay of relativity and quantum physics, using tools from different fields of science, such as Gravity, Quantum Field Theory in Curved Spacetime, Quantum Information, Quantum Metrology and Quantum Thermodynamics.

Research in this area of science has provided novel insight on the role that paradigmatic quantum features, such as entanglement, have in physical processes that encompass relativistic and quantum

features. Experiments aimed at testing these predictions, as well as developing novel technologies based on this body of work, are currently being developed.

Ultimately, scientists in this field believe that planned experiments might provide unexpected deviations from the theoretical predictions, an event that will stimulate novel theoretical directions.

We present recent advances in the field of Relativistic Quantum Information. We focus on a newly established line of research that aims at understanding the role of entanglement in the theory of gravitation. On the testable side, we discuss predicted effects of curved spacetime on lab-based experiments and space-based quantum information protocols. On the more challenging and exotic side, we propose the idea that not all energy gravitates. We motivate this idea and discuss applications and implications, and how this proposal promises to change our understanding of gravitation of quantum systems.

**Topic::**

Mini-workshop: Continuous Variables and Relativistic Quantum Information

**Summary:**

**Workshop on continuous variables and quantum information / 1204**

## **Tripartite continuous-variables coherence and entanglement from vacuum fluctuations**

**Authors:** Pasi Lähteenmäki<sup>1</sup>; Juha Hassel<sup>2</sup>; Sorin Paraoanu<sup>1</sup>; Pertti Hakonen<sup>None</sup>

<sup>1</sup> *Aalto University*

<sup>2</sup> *VTT - Technical Research Centre Finland*

Vacuum fluctuations play a decisive role in many effects in quantum field theory and cosmology. When a parameter in the Lagrangian of the field is modulated by an external pump, vacuum fluctuations stimulate spontaneous downconversion processes, resulting in squeezing between modes symmetric with respect to half of the frequency of the pump. We have observed this phenomenon in the microwave domain, by using an array of SQUIDs with flux-bias tunable Josephson inductance, which creates a tunable speed of light along the array. We have extracted the full  $4 \times 4$  covariance matrix of the emitted microwave radiation, demonstrating that photons at frequencies symmetrical with respect to half of the modulation frequency are entangled [PNAS 110, 4234 (2013)]. Next, we have shown that by double parametric pumping of a superconducting microwave cavity, it is possible to generate another type of correlation, namely coherence between photons in separate frequency modes [Nature Communications 7, 12548 (2016)]. The coherence correlations are controllable by the phases of the pumps and are established by a quantum fluctuation that stimulates the simultaneous creation of two photon pairs. We have shown that the origin of this vacuum-induced coherence is the absence of which-way information in the frequency space. In this contribution I will also discuss the prospects of utilizing superconducting circuits for realizing analog relativistic and cosmological effects.

**Topic::**

Mini-workshop: Continuous Variables and Relativistic Quantum Information

**Summary:**

**Workshop on continuous variables and quantum information / 1206**

## **Observing superradiance in a vortex flow**

**Author:** Théo Torres Vicente<sup>1</sup>

**Co-authors:** Sam Patrick <sup>1</sup>; Antonin Coutant <sup>1</sup>; Mauricio Richartz <sup>2</sup>; Edmund W. Tedford <sup>3</sup>; Silke Weinfurter <sup>1</sup>

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<sup>2</sup> *Universidade Federal do ABC (UFABC),*

<sup>3</sup> *University of British Columbia*

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Shallow water waves scattering on a draining and rotating flow constitute the analogue of a rotating black hole. In such a spacetime, it has been shown theoretically that, at low frequency, waves can extract angular momentum, hence energy from the black hole. Such a process is known as superradiance. In this talk, I will present the experiment conducted at the University of Nottingham that led to the first detection of superradiance in a vortex flow. In addition, I will give a geometric interpretation to one aspect of our result by extending the notion of geodesics to a dispersive system.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**Workshop on continuous variables and quantum information / 1286**

## Counting Unruh particles

**Author:** Andrzej Dragan<sup>1</sup>

**Co-author:** Andrzej Dragan

<sup>1</sup> *University of Warsaw*

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We discuss the question of how many Unruh particles can be found in a finite volume.

**Topic::**

Topic: Quantum Physics, Quantum Optics and Quantum Information

**Summary:**

**Workshop on continuous variables and quantum information / 1254**

## Relativistic and Device Independent Verifiable Quantum Computation

**Author:** Petros Wallden<sup>1</sup>

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As quantum technologies develop the question of verifying/certifying the correctness of the quantum devices is crucial. In particular, as quantum computers will outperform classical, it may be

impossible to test the correctness of the quantum computer using a classical. Instead, one need to perform verifiable quantum computation (VBQC). A number of such protocols exist, and we focus on protocols that exploit blind quantum computation (e.g. Fitzsimons, Kashefi 2012). For those protocols the (honest) parties need to trust their devices. We developed a protocol that is device independent (Gheorghiu, Kashefi, Wallden 2015), however that protocol similarly to other works (e.g. Reichardt, Unger, Vazirani 2012) impose an unphysical assumption of no-communication between parties that cannot be enforced using spacelike separation. In this contribution we develop a protocol that avoids this problem by first formulating the VBQC in a “step-wise” form and then giving a truly device-independent protocol where the no-communication of the parties is enforced from relativistic constraints.

**Topic::**

Mini-workshop: Continuous Variables and Relativistic Quantum Information

**Summary:**

**Workshop on continuous variables and quantum information / 1068**

## Quantum advantage and fault tolerant universal quantum computing in continuous variables

**Authors:** Tom Douce<sup>1</sup>; Giulia Ferrini<sup>2</sup>; Elham Kashefi<sup>3</sup>; Peter van Loock<sup>2</sup>; Damian Markham<sup>1</sup>

<sup>1</sup> *Université Pierre et Marie Curie*

<sup>2</sup> *University of Mainz*

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Continuous Variables are a promising platform for demonstrating large scale quantum information effects thanks to the experimental advantages they provide. In this framework, we define a general quantum computational model based on a continuous variables hardware. It consists in vacuum input states, a finite set of gates – including non-Gaussian elements – and homodyne detection. We show that this model enables the encoding of fault tolerant universal quantum computing. Furthermore, when restricted to only commuting gates it turns into a sampling problem that can't be simulated efficiently with a classical computer – unless the polynomial hierarchy collapses. Thus we provide a simple paradigm for short-term experiments relying on Gaussian states, homodyne detection and some form of non-Gaussian evolution.

**Topic::**

Mini-workshop: Continuous Variables and Relativistic Quantum Information

**Summary:**

**Workshop on continuous variables and quantum information / 1427**

## Quantum networks: topology and spectral characterization

**Author:** Vesna Berc<sup>1</sup>

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To utilize a scalable quantum network and perform a quantum state transfer within distant arbitrary nodes, the coherence and control of the dynamics of couplings between the information units must be achieved as a prerequisite ingredient for quantum information processing within a hierarchical structure. Graph-theoretic approach provides a powerful tool for the characterization of quantum networks with nontrivial clustering properties. By encoding the topological features of the underlying quantum graphs, relations between the quantum complexity measures are presented revealing the intricate links between a quantum and a classical networks dynamics.

**Topic::**

**Summary:**

**Workshop on continuous variables and quantum information / 1153**

## **Autonomous quantum machines and finite sized clocks**

**Authors:** Ralph Silva<sup>1</sup>; Jonathan Oppenheim<sup>2</sup>; Woods Mischa<sup>3</sup>

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The unitary itself is usually described by an external observer that manipulates an interaction. Including this control into a fully quantum description, a so-called “quantum clock”, is thus a critical step to placing quantum protocols on a firm footing as well as understanding the fundamental limitations of quantum clocks; especially since due to information gain-disturbance principles, it is impossible to perform these operations perfectly. Here we present a quantum clock that performs a general energy-preserving unitary autonomously with an error that is *exponentially* small in both the dimension and the energy of the quantum clock.

The full quantum setup, –system to be controlled plus quantum clock– is described by a time independent Hamiltonian. This is crucial if one desires to understand the full quantum limitations to control, since a time dependent Hamiltonian would require external control, not explicitly accounted for. The main result is to show that this setup with a clock initially in a Gaussian superposition state can implement to any desired precision, any energy preserving unitary on the system during an arbitrarily small time interval with a back-reaction on the clock which is exponentially small in both energy and clock dimension. How fast as a function of energy and dimension the error in the back-reaction approaches zero is of paramount importance for understanding quantum resource theories involving time and control, since if the decay in error is too slow, one would have to invest a lot of work in correcting the error, representing an unaccounted-for cost to quantum thermodynamic resource theories.

Previous to this work, it was only known that unitaries can be implemented perfectly in the infinite energy and dimension limit, from which it is impossible to estimate the true cost of control. The model we present for the quantum clock is based on a model introduced by Eugene Wigner in General Relativity and later investigated in the non-relativistic regime by Asher Peres. Crucially, we consider a quantum superposition of so-called “clock states”, in contrast to Asher’s study. This is a crucial difference, which due to quantum constructive and destructive interference, leads to a much more accurate clock which can achieve the exponentially small error.

Our contributions to the field of quantum clocks also has other applications. For example, rather than using the quantum clock to perform timed unitaries on quantum systems, one can also perform weak measurements on the clock to measure time. Preliminary results suggest that our clock outperforms classical clocks governed by stochastic dynamics and the quantum clocks in Asher Pere’s study.

In conclusion, our work has implications for the fundamental limitations to the precision of quantum clocks and other applications such as timed autonomous control via these quantum devices. Our

work is also both a benchmark for future implementations, as well as introducing a conjecture on the fundamental limitations of clocks and control.

Pre-print available on Arxiv: 1607.04591

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Workshop on continuous variables and quantum information / 1194**

## Quantum measurements in finite space-time domain

**Author:** Vladimir Shevchenko<sup>1</sup>

<sup>1</sup> *National Research Centre Kurchatov Institute (RU)*

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The talk is devoted to discussion of space-time domain finiteness effects for quantum Unruh-DeWitt detector which operates in this domain. We discuss a special renormalization procedure which happens to be different in finite and infinite domain cases. It is demonstrated that, as is typical for renormalization, a new dimensionfull parameter appears, having meaning of detector's recovery proper time. It plays no role at the leading order of perturbation theory but can be important non-perturbatively. We analyse the structure of finite time corrections to various observables. It is found that in large-time limit they can be described in a universal way, in a sense, and non-vanishing in adiabatic limit effects are of special interest. As an application, Landauer's principle interpretations for finite domain case are studied.

**Topic::**

Mini-workshop: Continuous Variables and Relativistic Quantum Information

**Summary:**

**Workshop on Exotic Hadrons / 1339**

## The X(3872) and other charmonium puzzles

**Author:** Stephen Lars Olsen<sup>None</sup>

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After more than ten years of experimental and theoretical scrutiny, the now venerable  $X(3872)$ ,  $X(3915)$  and other neutral  $XYZ$  states remain puzzling mysteries. It seems that the more we learn about them, the more they defy understanding. Basic properties of the  $X(3872)$ , including its natural width and whether its mass is above or below the  $(m_{D^0} + m_{D^{*0}})$  threshold, are still not known. Likewise  $X(3915)$   $J^{PC}$  determination, for its production in  $B \rightarrow KX(3915)$ ;  $X(3915) \rightarrow J/\psi\omega$  decays and in  $\gamma\gamma \rightarrow J/\psi\omega$  collisions, as well as observations (or stringent limits) on decays to other final states, such as  $\eta\eta_c$  and  $D\bar{D}$ , are needed. This talk will make some comments about strategies for distinguishing between different theoretical models and recommendations about possible directions for near-future research related to these particles.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:**

**Workshop on Exotic Hadrons / 1238**

## **Vector bottomonium-like states at Belle**

**Author:** Roman Mizuk<sup>1</sup>

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We will review the status and recent results on vector bottomonium-like states above the  $B\bar{B}$  threshold: the  $\Upsilon(4S)$ ,  $\Upsilon(5S)$  and  $\Upsilon(6S)$ . We will discuss their decays to both open and hidden flavor channels and their line-shapes in various exclusive cross sections. The properties of these states are at odds with the expectations for a pure  $b\bar{b}$  state, proposed explanations will be discussed.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:**

**Workshop on Exotic Hadrons / 1110**

## **Z<sub>c</sub> states observed in p $\pi$ i transitions to charmonium states**

**Author:** Xiao-Rui Lyu<sup>1</sup>

<sup>1</sup> *University of Chinese Academy of Sciences*

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In this talk we will present the experimental studies of the tetraquark candidate Z<sub>c</sub> states via its decays to charmonium states. The main results discussed are from the BESIII experiment, but results in other experiments will also be covered. We will show some model interpretations on these Z<sub>c</sub>'s and their potential connections to the Z<sub>c</sub> states observed in decays to open charm mesons.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:**

**Workshop on Exotic Hadrons / 1127**

## **BES III future prospects in exotic hadron spectroscopy**

**Author:** Kai Zhu<sup>1</sup>

<sup>1</sup> *Institute of High Energy Physics, China*



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Recent BESIII results on exotic hadron candidates, including both heavy charmonium-like states and light hadron exotics, will be reviewed, as well as introductions to the BEPCII collider and BEESIII detector. Future BESIII running plans, specially the physics program for the exotic hadron spectroscopy, will be discussed.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:**

**Workshop on Exotic Hadrons / 1209**

## Exotic meson candidates from amplitude analyses of B meson decays

**Author:** Tomasz Skwarnicki<sup>1</sup>

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A number of charged and neutral candidates for exotic mesons with hidden charm were observed in amplitude analyses of B meson decays, explaining the peaking structures in  $J/\psi\pi^\pm$ ,  $\chi_{c1}\pi^\pm$ ,  $\psi(2S)\pi^\pm$  and  $J/\psi\phi$  mass distributions. We review the experimental information on these candidates and discuss their possible interpretations.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:**

**Workshop on Exotic Hadrons / 1396**

## Discussion

**Workshop on Exotic Hadrons / 1244**

## Issues at forefront of heavy quark spectroscopy

**Author:** Marek Karliner<sup>1</sup>

<sup>1</sup> *Tel Aviv U.*

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I will discuss several topics of imminent interest in heavy quark spectroscopy, starting with deuteron-like exotic hadrons near two-hadron thresholds, including putative open flavor states, bottom analogue of X(3872), D<sub>s</sub>D<sub>s</sub><sup>\*</sup> states and doubly-heavy dibaryons. I will also discuss all-heavy tetraquarks and bottom analogues of the narrow D<sub>s</sub> states. In addition, I will focus

on two types of hadrons which are currently drawing much attention because of experimental progress: doubly-heavy baryons and excited Omega\_c baryons. While non exotic, they share much of the theoretical toolbox with the exotic states.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:****Workshop on Exotic Hadrons / 1096****Charmed states on the lattice**

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Study of the charmonium states play important role in understanding of the strong interaction. The most interesting charmonium states lie near or above open charm thresholds. Nature of such states is of interest to modern physics. Recent lattice calculations have performed the necessary extrapolations and considered spectra as well as certain radiative transitions. The lattice QCD simulations of  $X(3872)$  with  $J^{PC} = 1^{++}$  have been performed in this study. The mass of this state, 3872 MeV, is very close to the sum of the masses of the  $D^0$  and  $\overline{D}^{0*}$  mesons and decays to  $D^0$  and  $\overline{D}^{0*}$  were observed, giving rise to two other explanations for what the mysterious X could be: a loosely-bound “molecule” of the  $D^0$  and  $\overline{D}^{0*}$  mesons, or a “tetra-quark” binding a di-quark and a di-antiquark. We also have proposed the approach to determine the nature of this state.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:****Workshop on Exotic Hadrons / 1062****Threshold effects in hadron spectrum: a new spectroscopy?**

**Authors:** Francisco F. Fernandez<sup>1</sup>; David R Entem<sup>2</sup>; Pablo G Ortega<sup>1</sup>; Jorge Segovia<sup>3</sup>

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Between November 1974, when the  $J/\psi$  particle was discovered, and 2003, when the  $X(3872)$  resonance was hunted by the Belle Collaboration, the charmonium spectrum was fairly explained by naive quark models. However, the exploration of the spectrum for energies above the  $D\overline{D}$  threshold has led

to the appearance of unexpected states, difficult to accommodate in the naive quark model picture.

The mentioned  $X(3872)$  has properties that cannot be explained assuming a simple quark-antiquark structure; for example, its decay into  $\pi\pi J/\psi$  through a  $\rho$  meson is an isospin violating decay. However, this property can be nicely explained in a picture in which the  $X(3872)$  is understood as a  $D\bar{D}^*$  bound state, due to the isospin violation in the  $D$  and  $D^*$  masses and the close position of the state to the  $D^0\bar{D}^{*0}$  threshold. In addition to the  $X(3872)$ , there are other states such as the  $D_{s0}(2317)^*$  and  $D_{s1}(2460)$  which can be described as a  $DK$  and  $D^*K$  molecules, respectively; or the  $P_c^*(4380)$  and  $P_c^*(4450)$  which are two exotic structures discovered in 2015 by the LHCb Collaboration in the  $J/\psi p$  channel, lie near the  $\bar{D}\Sigma_c^{(*)}$  thresholds and are compatible with pentaquark interpretations.

The common feature among all these exotic states is the presence of nearby two-particle thresholds. This reinforces the intuition that the residual interaction between the two particles can form a new molecular state or renormalize the mass of the original naive  $q\bar{q}$  state. Some times the interaction is not enough to bind a molecule and a threshold cusp may be formed. Then, one can expect that near each meson-meson or baryon-meson thresholds some new structures might appear. The description of this type of structures is very tricky from a theoretical point of view because the strength of the residual interaction is usually model dependent and one can generate spurious states if this interaction is not under control.

In this talk, we review the status of a threshold effects calculation in the meson and baryon spectrum using a constituent quark model [1], that has been applied to a wide range of hadronic observables and thus all model parameters are completely constrained. In the meson sector, the model has been able, for instance, to reproduce the properties of the  $X(3872)$  as a mixture of  $c\bar{c}$  and  $D\bar{D}^*$  channels [2]; and to describe well the spectrum of the  $P$ -wave charm strange mesons when  $DK$  and  $DK^*$  structures are taken into account [3]. In the baryon sector, the model has described the  $\Lambda_c(2940)^+$  [4, 5] as a  $D^*N$  molecule, the  $X_c(3250)$  [6] as a  $D^*\Delta$  one, and the  $P_c^*(4380)$  and  $P_c^*(4450)$  states as  $\bar{D}\Sigma_c^*$  and  $\bar{D}\Sigma_c$  candidates [7]. Some new states which cannot be accommodated as molecular states will be also discussed.

\vspace{1cm}

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#### Topic::

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#### Summary:

In this talk, we review the status of a threshold effects calculation in the meson baryon spectrum using a constituent quark model, that has been applied to a wide range of hadronic observables and thus all model parameters are completely constrained. In the meson sector, the model has been able, for instance, to reproduce the properties of the  $X(3872)$  as a mixture of  $c\bar{c}$  and  $D\bar{D}^*$  channels [2]; and to describe well the spectrum of the  $P$ -wave charm strange mesons when  $DK$  and  $DK^*$  structures are taken into account [3]. In the baryon sector, the model has described the  $\Lambda_c(2940)^+$  [4, 5] as a  $D^*N$  molecule, the  $X_c(3250)$  [6] as a  $D^*\Delta$  one, and the  $P_c^*(4380)$  and  $P_c^*(4450)$  states as  $\bar{D}\Sigma_c^*$  and  $\bar{D}\Sigma_c$  candidates [7]. Some new states which cannot be accommodated as molecular states will be also discussed.

**Workshop on Exotic Hadrons / 1398**

## Round Table Discussion

**Workshop on Exotic Hadrons / 1331**

## Amplitude analysis of the exotic states

**Author:** Mikhail Mikhasenko<sup>1</sup>

**Co-authors:** Alessandro Pilloni<sup>2</sup>; Adam Szczepaniak<sup>3</sup>; Bernhard Ketzer<sup>1</sup>

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In the talk, I examine the issues of the amplitude analysis related to the exotic states.

A building of the cascade decay amplitude becomes a non-trivial problem especially in the presence of the spin of particles in the final state.

We compare the helicity amplitudes and the amplitudes in the tensor formalism considering singularities and the crossing properties.

An interpretation of results of the partial wave analysis is often ambiguous. A picture of the sequential two-body decays is spoiled by the rescattering processes.

I will demonstrate an example of  $a_1(1420)$  phenomenon observed in the  $J^{PC} = 1^{++} f_0\pi$   $P$ -wave by COMPASS experiment.

I will also discuss the  $Z_c(3900)$  exotic candidate as an application the advanced amplitude analysis to the heavy meson sector.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:**

**Workshop on Exotic Hadrons / 1134**

## Vector states above open charm threshold

**Author:** Zhi-yong Wang<sup>1</sup>

<sup>1</sup> *IHEP,CAS*

**Corresponding Author:** wangzy@ihep.ac.cn

Apart from the traditional vector charmonium states  $\psi(3770)$ ,  $\psi(4040)$ ,  $\psi(4160)$ , and  $\psi(4415)$  above open charm, some experiments have observed a lot of non-traditional vector charmonium state which we call Y states, such as Y(4260) in  $\pi^+\pi^-J/\psi(\pi^0\pi^0J/\psi)$  line shape, Y(4360) and Y(4660) in  $\pi^+p\bar{i}^-\psi(3686)$  line shape. People also observed the non-traditional state Y(4140) via B decay.

Recently, BESIII Collaboration found that there are finer structures Y(4220) and Y(4320) in  $e^+e^- \rightarrow \pi^+\pi^-J/\psi$  line shape around  $\sqrt{s} = 4.26$  GeV, Y(4220) and Y(4390) in  $e^+e^- \rightarrow \pi + \pi^-h_c$  line shape around  $\sqrt{s} = 4.30$  GeV. BESIII Collaboration try to search the potential Y state in  $e^+e^- \rightarrow \omega\chi_{cJ}$  line shape. However, no any exact conclusion is drawn with the current statistic. BESIII Collaboration also perform a search for Y(4140) via  $e^+e^- \rightarrow \gamma\phi J/\psi$ . However, no obvious signal is observed, either.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:**

**Workshop on Exotic Hadrons / 1148**

## Pentaquark candidates in LHCb

**Author:** Liming Zhang<sup>1</sup>

<sup>1</sup> *Tsinghua University (CHINA)*

**Corresponding Author:** liming.zhang@cern.ch

all LHCb measurements related to pentaquark candidates will are presented. Possible interpretations of the Pc(4450) and Pc(4380) states will be discussed.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:**

**Workshop on Exotic Hadrons / 1105**

## Structure of excited charmed baryons studied by pion emission decays

**Author:** Hideko Nagahiro<sup>1</sup>

**Co-authors:** A.J. Arifi ; S. Yasui ; A. Hosaka ; M. Oka ; H. Noumi

<sup>1</sup> *Nara Women's University*

**Corresponding Author:** nagahiro@cc.nara-wu.ac.jp

We investigate the decays of the charmed baryons aiming at the systematic understanding of hadron internal structures based on the quark model by paying attention to heavy quark symmetry. We evaluate the decay widths from the pion emission for the known excited  $\Lambda_c^*$  ( $L_c(2595)$ ,  $L_c(2625)$ ,  $L_c(2765)$ ,  $L_c(2880)$ ,  $L_c(2940)$ ) baryons. We find that we can explain the decay widths of the low-lying  $\Lambda_c^*$  and also predict those for higher excited  $\Lambda_c^*$ . It is interesting that, however, the large decay width of  $L_c^*(2765)$  cannot be explained by a simple quark model.

Such systematic studies by the quark model help us not only to understand their structures but also to establish the nature of exotic hadrons beyond the conventional quark model descriptions.

[Refs]

- H. Nagahiro, S. Yasui, A. Hosaka, M. Oka, and H. Noumi, PRD95(17)014023.
- H. Nagahiro, A. Hosaka, in preparation
- A.J. Arifi, H. Nagahiro, A. Hosaka. e-Print: arXiv:1704.00464.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:**

**Workshop on Exotic Hadrons / 1114**

## Heavy hadron production for the study of their structure

**Author:** Atsushi Hosaka<sup>1</sup>

<sup>1</sup> *Osaka University*

**Corresponding Author:** hosaka@rcnp.osaka-u.ac.jp

Heavy quark hadrons are subject to recent interests due to discoveries of new exotic states. To understand their properties with suitable constituents, production and decay reactions are useful. In my talk, I will discuss reaction mechanisms for possible future J-PARC experiments. First example is the pion induced  $P_c$  productions based on the Reggeon reaction mechanism. We discuss the cross sections depending on the coupling of  $P_c$  to relevant hadronic channels. Another example is the charmed baryon productions. Assuming a simple reaction mechanism we find characteristic selection rules among various production rates depending on the internal structure of the charmed baryons. Such analysis is useful to specify the internal degrees of freedom in hadrons.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:**

**Workshop on Exotic Hadrons / 1326**

## light exotic hadrons at BESIII

**Author:** Shuangshi Fang<sup>1</sup>

**Co-author:** Jianbin Jiao<sup>2</sup>

<sup>1</sup> *Institute of High Energy physics*

<sup>2</sup> *Shandong University*

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With the world's largest sample of J/Psi events accumulated at the BESIII detector, a few new observations were reported in recent years. In this talk, the progress on the light exotic candidates and the prospective are highlighted.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:**

**Workshop on Exotic Hadrons / 1117**

## Quark-Gluon Mixing in Abelian Decomposition of QCD

**Author:** Yongmin Cho<sup>1</sup>

<sup>1</sup> *Konkuk University*

**Corresponding Author:** ymcho7@konkuk.ac.kr

The Abelian decomposition of QCD which decomposes the gluons to the color neutral binding gluons (the neurons and the monopoles) and the colored valence gluons (the chromons) gauge independently naturally generalizes the quark model to the quark and chromon model which can play the central role in hadron spectroscopy. We discuss how the quark and chromon model describes the glueballs and the glueball-quarkonium mixing in QCD. We present the numerical analysis of glueball-quarkonium mixing in  $0^{++}$ ,  $2^{++}$ , and  $0^{-+}$  sectors below 2 GeV, and show that in the  $0^{++}$  sector  $f_0(500)$  and  $f_0(1500)$ , in the  $2^{++}$  sector  $f_2(1950)$ , and in the  $0^{-+}$  sector  $\eta(1405)$  and  $\eta(1475)$  could be identified as predominantly the glueball states. We discuss the physical implications of our result.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:**

**Workshop on Exotic Hadrons / 1142**

## Strange and Charm Baryon Spectroscopy at J-PARC

**Author:** H. Noumi<sup>None</sup>

I will introduce two activities on hadron spectroscopy at J-PARC.

(I) Since the  $\Lambda(1405)$  hyperon is located just below the  $\bar{K}N$  threshold, it is said that  $\Lambda(1405)$  is a deeply bound  $\bar{K}N$  state.

There is a long standing argument if  $\Lambda(1405)$  has a so-called double pole structure [1,2,3]. In particular, a chiral unitary model calculation claims that a pole coupled to the  $\bar{K}N$  state is located at around 1426 MeV [2]. In order to confirm this pole structure, we propose an experimental study to measure the  $\bar{K}N \rightarrow \pi\Sigma$  scattering below the  $\bar{K}N$  threshold via the  $(K^-, n)$  reaction on a deuterium target at the J-PARC K1.8BR Beam Line [4]. Since the  $d(K^-, n)X$  reaction is expected to enhance the S-wave  $\bar{K}N \rightarrow \pi\Sigma$  scattering even below the  $\bar{K}N$  threshold, the spectral shapes provide information on  $\Lambda(1405)$  coupled to the  $\bar{K}N$  state. We measured pion-Sigma missing mass spectra in the  $d(K^-, n)X$  reactions in all possible isospin final states. We will present the spectral shapes and discuss the nature of  $\Lambda(1405)$ .

(II) Baryons comprised with two light quarks and a heavy quark, such as charmed baryons, provide unique opportunities to learn diquark correlations in a baryon. It is important to investigate how quark correlations, such as diquark and/or hadron clusters, are developed inside hadrons in order to understand structure of exotic hadrons. We are planning to construct a new platform on precision spectroscopy of excited charmed baryons by using a high-resolution, high-momentum, intense pion beam provided at the High-momentum Beam Line at J-PARC [5]. Masses, widths, decay branching ratios, and production/formation cross sections of excited charmed baryons reflect their internal structure. We will measure them by means of missing mass techniques via the  $p(\pi^-, D^{*-})$  reaction.

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**Topic:**

Mini-workshop: Exotic Hadrons

**Summary:**

**Workshop on Exotic Hadrons / 1237**

## **Excited vector mesons: phenomenology and predictions for a yet unknown vector $\bar{s}s$ state with a mass of about 1.93 GeV**

**Author:** Milena Piotrowska<sup>1</sup>

**Co-authors:** Francesco Giacosa<sup>2</sup>; Christian Reisinger<sup>3</sup>

<sup>1</sup> Jan Kochanowski University

<sup>2</sup> Kielce University

<sup>3</sup> Goethe University Frankfurt

**Corresponding Authors:** milena.soltysiak@op.pl, fgiacosa@ujk.edu.pl

The firm understanding of standard quark-antiquark states (including excited states) is necessary to perform search of non-conventional mesons with the same quantum numbers. In this talk, we study the phenomenology of two nonets of excited vector mesons, which predominantly correspond to radially excited vector mesons with quantum numbers  $n^{2s+1}L_J = 2^3S_1$  and to orbital excited vector mesons characterised by quantum numbers  $n^{2s+1}L_J = 1^3D_1$ . We evaluate the decays of these mesons into two pseudoscalar mesons and into a pseudoscalar and ground-state vector meson by making use of a relativistic quantum field theoretical model which based on flavor symmetry.



Moreover, we also study the radiative decays into a photon and a pseudoscalar mesons by using vector meson dominance. We shall compare our results to the PDG and comment on open issues concerning the corresponding measured resonances. Within our approach, we are also able to make predictions for a not-yet discovered  $\bar{s}s$  state in  $n \ ^{2s+1}L_J = 1^3D_1$  nonet which has the mass of about 1.93 GeV. This resonance can be searched in the upcoming Gluex and Mesonex experiments which take place at Jefferson lab.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:****Workshop on Exotic Hadrons / 1176****Understanding X(3862), X(3872), and X(3930) in a Friedrichs-model-like scheme****Author:** Zhiguang Xiao<sup>1</sup>**Co-author:** Zhi-Yong Zhou<sup>2</sup><sup>1</sup> *University of Science and Technology of China*<sup>2</sup> *School of Physics, Southeast University***Corresponding Authors:** xiaozg@ustc.edu.cn, zhouzhy@seu.edu.cn

We developed a Friedrichs-model-like scheme in studying the hadron resonance phenomenology and present that the hadron resonances might be regarded as the Gamow states produced by a Hamiltonian in which the bare discrete state is described by the result of usual quark potential model and the interaction part is described by the quark pair creation model. In an almost parameter-free calculation, the  $X(3862)$ ,  $X(3872)$ , and  $X(3930)$  state could be simultaneously produced with a quite good accuracy by coupling the three P-wave states,  $\chi_{c2}(2P)$ ,  $\chi_{c1}(2P)$ ,  $\chi_{c0}(2P)$  predicted in the Godfrey-Isgur model to the  $D\bar{D}$ ,  $D\bar{D}^*$ ,  $D^*\bar{D}^*$  continuum states. At the same time, we predict that the  $h_c(2P)$  state is at about 3890 MeV with a width of about 44 MeV. In this calculation, the  $X(3872)$  state has a large compositeness. This scheme may shed more light on the long-standing problem about the general discrepancy between the prediction of the quark model and the observed values, and it may also provide reference for future search for the hadron resonance state.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:****Workshop on Exotic Hadrons / 1444****Is there a common Ariadne thread for all Exotic Hadrons?****Author:** Luciano Maiani<sup>None</sup>

Is there a common Ariadne thread for all Exotic Hadrons?

**Topic::****Summary:****Workshop on Exotic Hadrons / 1179****Narrow-width tetraquarks in large- $N_c$  QCD****Authors:** Hagop Sazdjian<sup>1</sup>; Wolfgang Lucha<sup>2</sup>; Dmitri Melikhov<sup>3</sup><sup>1</sup> *IPN, University Paris-Sud, Orsay*<sup>2</sup> *IHEP, Austrian Academy of Sciences, Vienna*<sup>3</sup> *IPN, Lomonosov Moscow State University, Moscow and Faculty of Physics, University of Vienna, Vienna***Corresponding Authors:** wolfgang.lucha@oeaw.ac.at, dmitri\_melikhov@gmx.de, sazdjian@ipno.in2p3.fr

We show, on the basis of an analysis of four-point correlation functions of quark bilinear currents in different channels and the properties of leading and subleading QCD diagrams in the large- $N_c$  limit, that if tetraquarks exist, then they generally contribute at  $N_c$ -subleading orders of connected amplitudes. This implies that, irrespective of their flavor content, tetraquarks should have narrow widths, of the order of  $N_c^{-2}$ , i.e., an order of magnitude smaller in  $N_c$  than the widths of ordinary mesons. Our results agree with those found earlier by Cohen and Lebed.

**Topic::**

Topic: High Energy Particle Physics

**Summary:****Workshop on Exotic Hadrons / 1241****“Dipole model analysis of highest precision HERA data, including very low  $Q^2$ ”****Author:** Agnieszka Łuszczak<sup>1</sup><sup>1</sup> *Cracow University of Technology@DESY Hamburg***Corresponding Author:** agnieszka.luszczak@gmail.com

We analyse, within a dipole model, the final, inclusive HERA DIS cross section data in the low  $x$  region, using fully correlated errors. We show, that these highest precision data are very well described within the dipole model framework starting from  $Q^2$  values of 3.5 GeV<sup>2</sup> to the highest values of  $Q^2 = 250$  GeV<sup>2</sup>. To analyze the saturation effects we evaluated the data including also the very low  $0.35 < Q^2$  GeV<sup>2</sup> region. The fits including this region show a preference of the saturation ansatz.

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Topic: High Energy Particle Physics

**Summary:**

We analyse, within a dipole model, the final, inclusive HERA DIS cross section data in the low  $x$  region, using fully correlated errors. We show, that these highest precision data are very well described within the dipole model framework starting from  $Q^2$  values of 3.5 GeV<sup>2</sup> to the highest values of  $Q^2 = 250$  GeV<sup>2</sup>. To analyze the saturation effects we evaluated the data including also the very low  $0.35 < Q^2 \text{ GeV}^2$  region. The fits including this region show a preference of the saturation ansatz.  
Published in Phys.Rev. D95 (2017) no.1, 014030

**Workshop on Exotic Hadrons / 1378****Prospects for Exotic Hadron Spectroscopy at PANDA**

**Author:** Johan Messchendorp<sup>None</sup>

**Corresponding Author:** j.g.messchendorp@rug.nl

A new Facility for Antiproton and Ion Research (FAIR) is being built at GSI in Darmstadt, where PANDA (antiProton Annihilations at Darmstadt) will be one of the key experiments. The versatile PANDA detector together with the usage of an intense and high quality antiproton beam provides a unique environment to study the formation of hadrons and the dynamics of color confinement. As the fundamental theory of strong interactions, QCD allows a large variety of color-singlet states, thereby predicting the existence of hadrons that differ from baryons and mesons. The field of hadron physics has been intensively studied for quite a long time to predict these exotic, non-conventional forms of matter and identify them experimentally. However the agreement is not yet satisfactory, since many predictions lack in experimental evidences, and many of the recent observations in the charmonium region either were unexpected or have unexpected properties. The unique features of PANDA provide complementary tools to address the properties of recently discovered exotic candidates and to probe regimes that have not been explored yet. In this talk, I will address the unique features of PANDA and discuss a few feasibility studies that serve as benchmarks of PANDA's capabilities in the field of exotic hadron spectroscopy.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:****Workshop on Exotic Hadrons / 1130****Exotic Baryons at MAMI**

**Author:** Dominik Werthmüller<sup>1</sup>

<sup>1</sup> University of Glasgow

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Finding evidence supporting the existence of exotic states is one of the most exciting aspects of modern hadron physics. In contrast to the meson sector, the existence of exotic baryons is much more controversial, especially since the unprecedented episode of the rise and fall of the  $uudd\bar{s}$  pentaquark. Recently though, the matter of pentaquarks has been resurrected by the observation of a  $c\bar{c}uud$  pentaquark as claimed by the LHCb collaboration. Although there are arguments favoring the inclusion of heavy quarks in stable pentaquarks, the question remains if such and other exotic states could also be formed by  $u$ ,  $d$  and  $s$  quarks only.

The tagged-photon beam experiment A2 at the MAMI electron accelerator facility in Mainz (Germany) allows the study of several photoproduction reactions in which exotic baryons could be involved in. A selection of current activities and recent results will be discussed: In  $\eta$  photoproduction off the neutron, the presence of an unusually narrow resonance is one possible explanation for a sharp structure observed in the total cross section. Recently, new insights could be gained by the measurement of spin-dependent cross sections. Experimental data allowing to search for an exotic state in the  $KN$  system of  $\gamma d \rightarrow \Lambda KN$  are also available and undergoing analysis. Furthermore, preliminary results of a search for the dibaryon supposedly discovered by the WASA-at-COSY collaboration were obtained. Finally, a newly approved experiment dedicated to the study of the  $\Lambda(1405)$  will be presented.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:****Workshop on Exotic Hadrons / 1239****Charged bottomonium-like states at Belle****Author:** Alex Bondar<sup>1</sup><sup>1</sup> *Budker Institute of Nuclear Physics (RU)***Corresponding Author:** a.e.bondar@inp.nsk.su

We will review the status and recent results on the charged bottomonium-like states  $Z_b(10610)$  and  $Z_b(10650)$ , produced in single pion transitions from the  $\Upsilon(5S)$  and  $\Upsilon(6S)$ . We will describe their observation in the  $\pi\Upsilon(nS)$  and  $\pi h_b(nP)$  channels, measurement of their spins and parities, and investigation of the open flavor decays. Possible interpretations of the  $Z_b$  states will also be discussed.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:****Workshop on Exotic Hadrons / 1293****Hunting for exotic doubly hidden-charm/bottom  $QQ\bar{Q}\bar{Q}$  tetraquark states****Author:** Wei Chen<sup>1</sup>**Co-authors:** Hua-Xing Chen <sup>2</sup>; Xiang Liu <sup>3</sup>; Tom Steele <sup>4</sup>; Shi-Lin Zhu <sup>5</sup><sup>1</sup> *Sun Yat-sen University*<sup>2</sup> *Beihang University*<sup>3</sup> *Lanzhou University*<sup>4</sup> *U of Saskatchewan*<sup>5</sup> *Peking University*

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We develop a moment QCD sum rule method augmented by fundamental inequalities to study the existence of exotic doubly hidden-charm/bottom  $QQ\bar{Q}\bar{Q}$  tetraquark states made of four heavy quarks. Using the compact diquark-antidiquark configuration, we calculate the mass spectra of these tetraquark states. There are 18 hidden-charm  $cc\bar{c}\bar{c}$  tetraquark currents with  $J^{PC} = 0^{++}, 0^{-+}, 0^{--}, 1^{++}, 1^{+-}, 1^{-+}, 1^{--},$  and  $2^{++}$ . We use them to perform QCD sum rule analyses, and the obtained masses are all higher than the spontaneous dissociation thresholds of two charmonium mesons, which are thus their dominant decay modes. The masses of the corresponding hidden-bottom  $bb\bar{b}\bar{b}$  tetraquarks are all below or very close to the thresholds of the  $\Upsilon(1S)\Upsilon(1S)$  and  $\eta_b(1S)\eta_b(1S)$ , except one current of  $J^{PC} = 0^{++}$ . Hence, we suggest to search for the doubly hidden-charm states in the  $J/\psi J/\psi$  and  $\eta_c(1S)\eta_c(1S)$  channels.

**Topic::**

Mini-workshop: Exotic Hadrons

**Summary:**

**Workshop on Future of Fundamental Physics / 1268**

## Advances in Direct CP violation

**Author:** Amarjit Soni<sup>1</sup>

<sup>1</sup> Brookhaven National Lab

**Corresponding Author:** adlersoni@gmail.com

Significant progress made in overcoming traditional challenges of direct CP due to non-perturbative QCD in certain class of B-decays and also in  $K \rightarrow \pi\pi$  decays will be discussed. In B decays specifically to generic  $D^0 K^*$ -like decays purely data driven methods have been developed to extract the unitarity angle  $\gamma$  to an incredible precision so that it can now serve as a “standard –candle” in search of new physics. In  $K \rightarrow \pi\pi$  decays, after over three decades of relentless efforts a good quantitative understanding of the origin of the  $\Delta I=1/2$  enhancement and a highly reliable methodology for calculation of the direct CP violation parameter,  $\epsilon'/\epsilon$  has been attained which is exceedingly sensitive to new phenomena. First results completed two years ago indicated consistency with the SM at about 2 sigma level and significantly improved calculations are now underway and are expected to finish in a few months.

**Topic::**

Workshop on Future of Fundamental Physics

**Summary:**

**Workshop on Future of Fundamental Physics / 1108**

## AWAKE: the proton-driven plasma wakefield accelerator experiment at CERN

**Author:** Erik Adli<sup>1</sup>

<sup>1</sup> University of Oslo (NO)

**Corresponding Author:** erik.adli@cern.ch

In order to achieve affordable and compact high-energy particle accelerators, machines with high accelerating gradients and high efficiency is necessary. The beam-driven plasma wakefield accelerator is a novel accelerator technique being developed for this purpose. The field has recently seen a rapid experimental progress. The AWAKE experiment at CERN is the first proton-driven plasma wakefield accelerator experiment. It uses the self-modulation instability (SMI) to transform the 12 cm long, 400 GeV proton bunch from the SPS into a train of bunches spaced by the plasma wavelength (~ 1mm). The train can then resonantly drive GV/m fields that can be used to accelerate electrons over 10s to 100s of meters. The first experiments started in December 2016 aiming at measuring the parameters of the proton bunch after it has experienced the SMI in a 10 m long rubidium plasma with an electron density in the  $1-10e14/cm^3$  range. The principle of SMI physics, the experimental goals and first experimental results will be presented. We also briefly discuss future plans for AWAKE, as well as ideas for high-energy physics applications.

**Topic::**

Special Session on Instruments and Methods in HEP

**Summary:**

**Workshop on Future of Fundamental Physics / 1196**

## Low emittance muon beam for multi-TeV muon collider

**Author:** Mario Antonelli<sup>1</sup>

<sup>1</sup> *INFN e Laboratori Nazionali di Frascati (IT)*

**Corresponding Author:** mario.antonelli@cern.ch

We are studying a new scheme to produce very low emittance muon beams using a positron beam of about 45 GeV interacting on electrons on target. This is a challenging and innovative scheme that needs a full design study. One of the innovative topics to be investigated is the behaviour of the positron beam stored in a low emittance ring with a thin target, that is directly inserted in the ring chamber to produce muons. Muons will be immediately collected at the exit of the target and transported to two mu+ and mu- accumulator rings. We will report about the study of the performances of this scheme.

**Topic::**

Workshop on Future of Fundamental Physics

**Summary:**

**Workshop on Future of Fundamental Physics / 1461**

## The CEPC/SppC project: status and challenges

**Author:** Jie Gao<sup>1</sup>

<sup>1</sup> *Institute of High Energy Physics, China*

**Corresponding Author:** gaoj@ihep.ac.cn

Invited plenary talk “The CEPC/SppC project: status and challenges”

**Topic::**

**Summary:**

**Workshop on Future of Fundamental Physics / 1460**

## **The challenges of large infrastructure physics projects in the 21st century**

**Author:** John William Womersley<sup>1</sup>

<sup>1</sup> *STFC - Rutherford Appleton Lab. (GB)*

**Corresponding Author:** john.womersley@stfc.ac.uk

Invited plenary talk on The challenges of large infrastructure physics projects in the 21st century

**Topic::**

**Summary:**

**Workshop on Future of Fundamental Physics / 1510**

## **Snapshots of neutrino oscillation physics today and a preview of tomorrow**

**Author:** Steven Laurens Manly<sup>1</sup>

<sup>1</sup> *University of Rochester (US)*

**Corresponding Author:** steven.laurens.manly@cern.ch

Though neutrinos were first observed over 60 years ago, many interesting and fundamental questions remain to be answered. This talk will provide a brief overview of neutrino oscillation physics and how it contributes to our overall understanding of neutrinos. Selected results from current long baseline and reactor experiments will be discussed. The increasingly important role played by neutrino interaction physics in oscillation analyses will be explored briefly. Finally, an overview of the status and goals of selected future experiments will be given.

**Topic::**

Topic: High Energy Particle Physics

**Summary:**

**Workshop on Future of Fundamental Physics / 1505**

## **Overview on $|V_{xb}|$ determination**

**Author:** Giulia Ricciardi<sup>1</sup>

<sup>1</sup> *Univ. Napoli Federico II***Corresponding Author:** giulia.ricciardi@na.infn.it

Flavour physics is currently well described by the Standard Model except for some measurements which could be signalling new physics. We discuss anomalies in rare exclusive semi-leptonic B decays and in  $R_{K/D^{(*)}}$  ratios, which appear to challenge a cornerstone of the Standard Model, the lepton universality. These anomalies have reached a high level of statistical significance. We survey the theoretical efforts towards convincing dynamics beyond the Standard Model, the experimental status, and the directions of further investigation.

**Topic::**

Topic: High Energy Particle Physics

**Summary:****Workshop on Future of Fundamental Physics / 1248**

## The Electron Ion Collider

**Author:** elke-caroline Aschenauer<sup>1</sup><sup>1</sup> *BNL***Corresponding Author:** elke@bnl.gov

The 2015 nuclear physics long-range plan in the US endorsed the realization of an Electron-Ion Collider (EIC) as the next large construction project in the United States. With its high luminosity ( $> 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ ), wide kinematic reach in center-of-mass-energy (20 GeV to 140 GeV) and high lepton and proton beam polarization, the EIC is an unprecedented opportunity to reach new frontiers in our understanding of the internal dynamic structure of nucleons. This new collider will provide definite answers to the following questions: How are the sea quarks and gluons, and their spins, distributed in space and momentum inside the nucleon? How the nuclear environment modifies these quark and gluon distributions? At what scale the growth in the distribution of gluons saturates? What is the role of the orbital motion of sea quarks and gluons in building up the nucleon spin? This presentation will highlight several key high precision measurements from the planned broad diffractive physics program at the electron-ion collider and the expected impact on our current understanding of the spatial structure of nucleons and nuclei, and the transition from a non-saturated to a saturated state.

**Topic::**

Workshop on Future of Fundamental Physics

**Summary:****Workshop on Future of Fundamental Physics / 1183**

## Recent Borexino results and perspectives of the SOX measurement

**Author:** Alessio Porcelli<sup>1</sup><sup>1</sup> *Johannes Gutenberg Universität Mainz*



**Corresponding Author:** ale\_led@yahoo.it

Borexino is a liquid scintillator detector sited underground in the Laboratori Nazionali del Gran Sasso (Italy). Its physics program, until the end of this year, is focussed on the study of solar neutrinos, in particular from the Beryllium, pp, pep and CNO fusion reactions. Knowing the reaction chains in the sun provides insights towards physics disciplines such as astrophysics (star physics, star formation, etc.), astroparticle and particle physics. Phase II started in 2011 and its aim is to improve the phase I results, in particular the measurements of the neutrino fluxes from the pep and CNO processes.

By the end of this year, data taking from the sun will be over and a new project is scheduled to launch: Short distance Oscillation with boreXino (SOX), which uses a Cerium source for neutrinos (100÷150 kCi of activity) and aims to confirm or rule out the presence of sterile neutrinos. This particle is hypothesised to justify the reactor, Gallium and LSND anomalies found and can reject extensions to the standard model.

The work presented is a summary of the solar neutrino results achieved so far, which lead not only to a precise study of the processes in the sun, but also to more Standard Model oriented measurements (such as the stability of the charge, i.e. the life time of the electron). Furthermore, the perspectives of the SOX program are discussed showing the experiment sensitivity to a fourth neutrino state covering almost entirely  $3\sigma$  of the preferred region of the anomalous neutrino experiments, and additional applications of the detector such as the study of geo-neutrinos.

**Topic::**

Workshop on Future of Fundamental Physics

**Summary:**

**Workshop on Future of Fundamental Physics / 1549**

## **LBNF/DUNE: status and future plans (Preliminary title TBC)**

**Author:** Sergio Bertolucci<sup>1</sup>

<sup>1</sup> *Istituto Nazionale Fisica Nucleare Frascati (IT)*

**Corresponding Author:** sergio.bertolucci@cern.ch

LBNF/DUNE: status and future plans (Preliminary title TBC)

**Topic::**

Workshop on Future of Fundamental Physics

**Summary:**

**Workshop on Future of Fundamental Physics / 1550**

## **Accelerators in the 21st century (Preliminary title, TBC)**

**Author:** Frank Zimmermann<sup>1</sup>

<sup>1</sup> *CERN*

**Corresponding Author:** frank.zimmermann@cern.ch

Accelerators in the 21st century (Preliminary title, TBC)

**Topic::**

Workshop on Future of Fundamental Physics

**Summary:**

**Workshop on Future of Fundamental Physics / 1555**

## **Challenges and approaches of unveiling the nature of antimatter at CERN (with a particular focus on the AEGIS experiment)**

**Author:** Lillian Smestad<sup>1</sup>

<sup>1</sup> *The Research Council of Norway/CERN, the AEGIS collaboration*

**Corresponding Author:** lillian.smestad@cern.ch

Unraveling the nature of antimatter is an ongoing quest on the frontiers of physics. Even though the existence of antimatter has been known since the early 1930s, there is still much to be learned about the nature of this elusive type of particles — in particular, which differences between matter and antimatter renders the observable universe possible. The Antimatter Factory at CERN has been built for this purpose and is currently host to five experiments, the majority of which create antihydrogen as the main pathway to investigating the apparent matter-antimatter asymmetry. The talk will present an introduction to antimatter physics and the Antiproton Decelerator facility, including such as setup of a typical antimatter experiment, methods to create antihydrogen, selected results in the history of antimatter research and future measurements and prospects. A particular focus will be given to the AEGIS experiment, aiming for a first precise direct measurement of the gravitational behaviour of antimatter; to test the Weak Equivalence Principle with antimatter in Earth's gravitational field.

**Topic::**

Topic: Cosmology, Astrophysics, Gravity, Mathematical Physics

**Summary:**

**Workshop on Future of Fundamental Physics / 1557**

## **The FCC-ee study (TBC)**

**Author:** m Koratzinos<sup>1</sup>

<sup>1</sup> *Universite de Geneve (CH)*

**Corresponding Author:** m.koratzinos@cern.ch

The FCC-ee study (TBC)

**Topic::**

Workshop on Future of Fundamental Physics

**Summary:**

## Workshop on Future of Fundamental Physics / 1302

### Status and plans of the Compact Linear Collider project

**Authors:** Davide Gamba<sup>1</sup>; Steinar Stapnes<sup>1</sup>; Roberto Corsini<sup>1</sup>; Philip Nicholas Burrows<sup>2</sup>

<sup>1</sup> CERN

<sup>2</sup> University of Oxford (GB)

**Corresponding Authors:** roberto.corsini@cern.ch, philip.burrows@cern.ch, steinar.stapnes@cern.ch, davide.gamba@cern.ch

The Compact Linear Collider (CLIC) project is investigating the possibility to build a multi-TeV linear electron-positron collider for high-energy frontier physics studies. CLIC is based on high-gradient normal-conducting accelerating structures. The high-power RF for the acceleration of the colliding beams is provided by a two-beam acceleration scheme, in which power is extracted from a high current drive beam that runs parallel with the main linac.

CLIC is foreseen to be built and operated in stages, which have been recently redefined taking into account the latest technology developments and the currently-known physics landscape.

The key ongoing studies involve accelerator parameters and cost optimisation, power consumption reduction, component development, and include a number of system performance studies in test facilities around the world.

An overview of the progress and the status of the corresponding studies will be given, as well as an outline of the preparation and work towards developing a CLIC implementation plan by 2019.

**Topic::**

Special Session on Instruments and Methods in HEP

**Summary:**

## Workshop on NCG / 1379

### Applications of non-associative geometry in particle physics

**Author:** Shane Farnsworth<sup>None</sup>

**Corresponding Author:** shane.farnsworth@aei.mpg.de

I will introduce the framework of non-associative geometry as a natural extension of Connes' non-commutative geometry. I will then give worked examples and describe applications in particle physics.

**Topic::**

Workshop on "Noncommutative Geometry at the Forefront of Physics"

**Summary:**

## Workshop on NCG / 1292

### What is the standard model of particle physics trying to tell us?

**Author:** Latham Boyle<sup>1</sup>

<sup>1</sup> Perimeter Institute

**Corresponding Author:** lboyle@pitp.ca

The standard model contains a rather strong hint that – instead of being simply an ordinary continuous 4D manifold – spacetime is actually the product of a 4D manifold and a certain discrete/finite space (i.e. there are discrete/finite “extra dimensions”). I will introduce this idea and the evidence for it in a simple way. I will describe recent progress in this direction, as well as some open puzzles and future directions.

**Topic::**

Workshop on “Noncommutative Geometry at the Forefront of Physics”

**Summary:**

**Workshop on NCG / 1258**

## **A Noncommutative Geometry inspired GUT**

**Author:** Nadir Bizi<sup>1</sup>

<sup>1</sup> *UPMC (Paris VI)*

**Corresponding Author:** nadir.bizi@impmc.upmc.fr

We present a Spin group GUT inspired from Noncommutative Geometry that breaks down to the Standard model and reproduces the results of the Spectral Model. We believe this model explains some of the less intuitive axioms of spectral triples.

**Topic::**

Workshop on “Noncommutative Geometry at the Forefront of Physics”

**Summary:**

**Workshop on NCG / 1295**

## **Causal relations in noncommutative spacetime**

**Author:** Tomasz Miller<sup>1</sup>

**Co-author:** Michal Eckstein<sup>2</sup>

<sup>1</sup> *Warsaw University of Technology*

<sup>2</sup> *Jagiellonian University*

**Corresponding Authors:** michal@eckstein.pl, t.miller@mini.pw.edu.pl

TBA

**Topic::**

Workshop on “Noncommutative Geometry at the Forefront of Physics”

**Summary:**

**Workshop on NCG / 1256****Families of spectral triples and foliations of spacetime****Author:** Koen van den Dungen<sup>1</sup><sup>1</sup> SISSA**Corresponding Author:** kdungen@sissa.it

We study a noncommutative analogue of a spacetime foliated by spacelike hypersurfaces. First, we consider a spacetime given by a family of spacelike hypersurfaces  $(M, g_t)$  parametrised by the real line. We then construct a ‘product spectral triple’ from the corresponding family of canonical spectral triples over  $M$  and the lapse function. This product spectral triple reproduces the canonical spectral triple of the product manifold equipped with the ‘Wick rotated’ Riemannian metric. The canonical Lorentzian Dirac operator can then be obtained as a ‘reverse Wick rotation’ of the Riemannian Dirac operator obtained from our product construction.

For the noncommutative scenario, we show that the construction of the product spectral triple also works in the case of a family of abstract spectral triples parametrised by the real line. Motivated by the classical case, we can then construct abstract ‘Lorentzian spectral triples’ as the reverse Wick rotation of such product spectral triples.

**Topic::**

Workshop on “Noncommutative Geometry at the Forefront of Physics”

**Summary:****Workshop on NCG / 1275****Introduction to noncommutative digital geometry****Author:** Anna Pachol<sup>None</sup>

Noncommutative geometry, as the generalised notion of geometry, allows us to model the quantum gravity effects in an effective description without full knowledge of quantum gravity itself. On a curved space one must use the methods of Riemannian geometry – but in their quantum version, including quantum differentials, quantum metrics and quantum connections – constituting quantum geometry. The mathematical framework behind it is the noncommutative differential graded algebra. After presenting the motivation and the general framework, I will discuss some recent results on the classification of noncommutative differential geometries, over the finite field  $F_2$  (instead that of  $C$ ), in  $n = 2, 3$  and 4 dimensions. The choice of the finite field proposes a new kind of ‘discretisation scheme’, which we called the ‘digital geometry’.

**Topic::**

Workshop on “Noncommutative Geometry at the Forefront of Physics”

**Summary:****Workshop on NCG / 1296****Physical models from noncommutative causality****Author:** Nicolas Franco<sup>1</sup><sup>1</sup> University of Namur

**Corresponding Author:** nicolas.franco@unamur.be

We introduced few years ago a new notion of causality for noncommutative spacetimes directly related to the Dirac operator and the concept of Lorentzian spectral triple. This notion of causality corresponds to the usual one for commutative spectral triples and could be extended in order to get a full Lorentzian metric. We explored the noncommutative causal structure of several toy models as almost commutative spacetimes and Moyal-Weyl spacetime. From those models, we discovered some unexpected physical interpretations as a geometrical explanation of the ‘Zitterbewegung’ trembling motion of a fermion and geometrical constraints on translations and energy jumps of wave packets on Moyal spacetime.

**Topic::**

Workshop on “Noncommutative Geometry at the Forefront of Physics”

**Summary:**

**Workshop on NCG / 1259**

## Noncommutative Spherically Symmetric Spacetimes at Semiclassical Order

**Authors:** Christopher Fritz<sup>1</sup>; Shahn Majid<sup>2</sup>

<sup>1</sup> *Sussex University*

<sup>2</sup> *Queen Mary, University of London*

**Corresponding Authors:** c.fritz@sussex.ac.uk, s.majid@qmul.ac.uk

The recent formalism of Poisson-Riemannian geometry provides a useful approach to studying noncommutative differential geometry. Utilizing functional methods, it allows for the construction of a quantum metric and quantum Levi-Civita connection up to first order in deformation based on a classical metric, Poisson tensor and compatible connection. I will give a brief overview of the formalism and outline recent work in [gr-qc/1611.04971] where we completely solve the case of generic spherically symmetric metrics and Poisson-bracket to find a unique answer for the quantum differential calculus, quantum metric and quantum Levi-Civita connection at semiclassical order.

**Topic::**

Workshop on “Noncommutative Geometry at the Forefront of Physics”

**Summary:**

**Workshop on Physics at FAIR-NICA-SPS-BES/RHIC / 1124**

## Three-fluid Hydrodynamics-based Event Simulator Extended by UrQMD final State interactions (THESEUS) for FAIR-NICA-SPS-BES/RHIC energies

**Authors:** P. Batyuk<sup>1</sup>; D. Blaschke<sup>2</sup>; M. Bleicher<sup>3</sup>; Yu. B. Ivanov<sup>4</sup>; Iu. Karpenko<sup>5</sup>; L. Malinina<sup>6</sup>; S. Merts<sup>1</sup>; M. Nahrgang<sup>7</sup>; H. Petersen<sup>8</sup>; O. Rogachevsky<sup>1</sup>

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- <sup>5</sup> Bogolyubov Institute for Theoretical Physics, 03680 Kiev, Ukraine; INFN - Sezione di Firenze, I-50019 Sesto Fiorentino (Firenze), Italy
- <sup>6</sup> Veksler and Baldin Laboratory of High Energy Physics, JINR Dubna, 141980 Dubna, Russia; M. V. Lomonosov Moscow State University, Moscow, Russia; D. V. Skobeltsyn Institute of Nuclear Physics, Moscow, Russia
- <sup>7</sup> Department of Physics, Duke University, Durham, North Carolina 27708-0305, USA; SUBATECH, UMR 6457, Université de Nantes, France
- <sup>8</sup> Frankfurt Institute for Advanced Studies (FIAS), Science Campus Riedberg, Ruth-Moufang-Strasse 1, 60438 Frankfurt am Main, Germany; Institut für Theoretische Physik, Goethe Universität, Max-von-Laue-Strasse 1, 60438 Frankfurt am Main, Germany; GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstrasse 1, 64291 Darmstadt, Germany

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A new event generator is presented which is based on the three-fluid hydrodynamics approach for the early stage of the collision, followed by a particlization at the hydrodynamic decoupling surface to join to a microscopic transport model, UrQMD, to account for hadronic final state interactions. The new simulation program has the unique feature that it can describe a hadron-to-quark matter transition which proceeds in the baryon stopping regime that is not accessible to previous simulation programs designed for higher energies. First results for nuclear collisions of the FAIR/NICA energy scan program (Au+Au collisions,  $\sqrt{s_{NN}} = 4 - 11$  GeV) are presented. The following topics are addressed: the directed flow, transverse-mass spectra, and rapidity distributions of protons, pions and kaons for two model EoS, one with a first-order phase transition, the other with a crossover transition. Preliminary results on the femtoscopy are also discussed.

**Topic::**

Mini-workshop: FAIR-NICA-SPS-BES RHIC Physics

**Summary:**

**Workshop on Physics at FAIR-NICA-SPS-BES/RHIC / 1300**

**Separate freeze-out of strange particles and the quark-hadron phase transition**

**Authors:** Oleksii Ivanytskyi<sup>1</sup>; Kyrill Bugaev<sup>2</sup>; Violetta Sagun<sup>3</sup>

<sup>1</sup> National Academy of Sciences of Ukraine (UA)

<sup>2</sup> Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine

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The scenario with the independent chemical freeze-outs of strange and non-strange particles is presented. Within such a scenario an apparent non-equilibration of strangeness is naturally explained by a separation of freeze-outs of strange and non-strange hadrons, which, nevertheless, are connected by the conservation laws of entropy, baryonic charge and third isospin projection. An interplay between the separate freeze-out of strangeness and its residual non-equilibration is studied within an elaborate version of the hadron resonance gas model. The developed model enables us to perform a high-quality fit of the hadron multiplicity ratios

measured at AGS, SPS and RHIC with an overall fit quality  $\chi^2/dof = 0.93$ . A special attention is paid to a description of the Strangeness Horn and to the well-known problem of selective suppression of  $\Lambda^-$  and  $\Xi$  hyperons. It is remarkable that, for all collision energies, the strangeness non-equilibrium factor  $\gamma_s$  is about 1 within the error bars. The only exception is found in the vicinity of the center-of-mass collision energy 7.6 GeV, at which a 20% enhancement of strangeness is observed. Our previous results about the existence of strong jumps of the chemical freeze-out pressure, temperature and effective number of degrees found at the center-of-mass collision energy from 4.3 to 4.9 GeV are also confirmed. The arguments in favor of an exceptional role of these irregularities as the signals of the quark-gluon-hadron mixed phase formation at this energies are given.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:****Workshop on Physics at FAIR-NICA-SPS-BES/RHIC / 1361****Physics with the CBM experiment****Author:** Volker Friese<sup>1</sup><sup>1</sup> *GSI - Helmholtzzentrum für Schwerionenforschung GmbH (DE)***Corresponding Author:** volker.friese@cern.ch

With the CBM experiment at FAIR, new opportunities will emerge for the investigation of strongly interacting matter, using nuclear collisions at medium collision energies. Being designed as a high-rate experiment, CBM will give access to rare observables like multi-strange hyperons and anti-hyperons, di-lepton pairs and charmed hadrons, which cannot be addressed by current or other projected heavy-ion experiments. In this talk, we will give an overview of the physics programme of CBM in the context of the worldwide efforts in the study of QCD matter at highest net-baryon densities.

**Topic::**

Mini-workshop: FAIR-NICA-SPS-BES RHIC Physics

**Summary:****Workshop on Physics at FAIR-NICA-SPS-BES/RHIC / 1170****Multi Purpose Detector at NICA: Status and Prospects****Author:** Vladimir Kekelidze<sup>1</sup>**Co-authors:** Alexander Sorin<sup>1</sup>; Viacheslav Golovatyuk<sup>2</sup>; Vadim Kolesnikov<sup>2</sup>; O. Rogachevsky<sup>3</sup><sup>1</sup> *Joint Inst. for Nuclear Research (RU)*<sup>2</sup> *Joint Institute for Nuclear Research (RU)*<sup>3</sup> *Veksler and Baldin Laboratory of High Energy Physics, JINR Dubna, 141980 Dubna, Russia*



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The Multi Purpose Detector (MPD) at the NICA Collider is under construction to study hot and baryon rich QCD matter in heavy ion collisions, up to gold, in the energy range  $\sqrt{s_{NN}} = 4 - 11$  GeV. The program includes the study of collective phenomena, dilepton, hyperon and hypernuclei production under extreme conditions of highest net baryonic density.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**Workshop on Physics at FAIR-NICA-SPS-BES/RHIC / 1180**

## The STAR detector upgrade and future plan

**Author:** Chi Yang<sup>1</sup>

<sup>1</sup> Shandong University

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The second phase of the Beam Energy Scan at RHIC, BES-II, is scheduled for 2019-2020 and will explore with precision measurements the high baryon density region of the QCD phase diagram. The program will examine the energy region of interest from 7.7 to 19.6 GeV which is determined from the results of BES-I.

Some of the key measurements anticipated are: the net-protons kurtosis that could pinpoint the position of a critical point, the directed flow that might prove a softening of the EOS, and the chiral restoration in the dilepton channel. The measurements will be possible with the order of magnitude better statistics provided by the electron cooling upgrade of RHIC and with the detector upgrades planned to extend STAR's experimental reach. The upgrades are: the inner TPC sectors (iTPC), the Event Plane Detector (EPD), and the end-cap TOF (eTOF).

We will present upgrade details both on detectors and collider for BES-II. The operation plan for BES-II will be shown. The physics opportunities enabled by these upgrades will be discussed. Future plan beyond 2020 at RHIC will also be discussed.

**Topic::**

Workshop on Future of Fundamental Physics

**Summary:**

**Workshop on Physics at FAIR-NICA-SPS-BES/RHIC / 1093**

## Event topology reconstruction in the CBM experiment at FAIR

**Author:** Ivan Kisel<sup>1</sup>

**Co-authors:** Valentina Akishina <sup>2</sup>; Pavel Kisel <sup>3</sup>; Peter Senger <sup>4</sup>; Iouri Vassiliev <sup>5</sup>; Maksym Zyzak <sup>4</sup>

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One of the main purposes of the physics program of the future heavy ion experiment CBM (FAIR, Germany) is to understand the properties of strongly interacting matter at very high baryonic densities and to study the possibility of a phase transition to a deconfined and chirally restored phase of quark matter. The experiment will operate at high interaction rates up to 10 MHz, that requires a full event reconstruction in real time.

In order to make an efficient event selection online a clean sample of particles has to be provided by the reconstruction package called First Level Event Selection (FLES). The FLES package operates in two stages. First, particles registered in the CBM detector system are reconstructed. Then short-lived particles decayed before or inside the setup are searched based on their charged and neutral daughter particles. Since the FLES package is developed to run on many-core computer architectures, the reconstruction of particles is done in parallel that provides a possibility for a global competition between particle candidates. Such a global event topology reconstruction significantly improves suppression of a combinatorial background and provides for further physics analysis a very clean sample of particles produced at different stages of heavy ion collision.

The global event topology reconstruction procedure and the results of its application to simulated collisions in the CBM detector setup are presented and discussed in details.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:****Workshop on Physics at FAIR-NICA-SPS-BES/RHIC / 1042**

## Two-particle correlations using THERMINATOR model for BES program

**Author:** Hanna Zbroszczyk<sup>1</sup><sup>1</sup> *Warsaw University of Technology***Corresponding Author:** gos@if.pw.edu.pl

THERMINATOR model is dedicated to heavy-ion collisions. Its current description allows one to work with data for the highest collision energies achieved by LHC and RHIC colliders. However it is possible to adapt THERMINATOR model to the lower energy spectrum as is used in Beam Energy Scan (BES) program at RHIC.

Femtoscropy of two particles investigates the properties of matter produced in heavy-ion collisions. It allows one to study the space-time characteristics of the medium.

We present single- and two-particle momentum distributions of particles generated for the energy spectrum for BES program. To verify how model predictions agree with experimental results, we present the correlation functions obtained for identical pions in Au+Au collisions at  $\sqrt{s_{NN}} = 7.7 - 62.4$  GeV.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**Workshop on Physics at FAIR-NICA-SPS-BES/RHIC / 1301****Probing the tricritical endpoint of QCD phase diagram at NICA-FAIR energies****Authors:** Kyrill Bugaev<sup>1</sup>; Violetta Sagun<sup>2</sup>; Oleksii Ivanytskyi<sup>3</sup><sup>1</sup> *Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine*<sup>2</sup> *Bogolyubov Institute for Theoretical Physics*<sup>3</sup> *National Academy of Sciences of Ukraine (UA)***Corresponding Authors:** bugaev@th.physik.uni-frankfurt.de, violettasagun@tecnico.ulisboa.pt, oleksii.ivanytskyi@cern.ch

In this talk I present several remarkable irregularities at chemical freeze-out which are found using an advanced version of the hadron resonance gas model. The most prominent of them are the sharp peaks of the trace anomaly and baryonic charge density existing at chemical freeze-out at the center-of-mass energies 4.9 GeV and 9.2 GeV. They are accompanied by two sets of highly correlated quasi-plateaus in the collision energy dependence of the entropy per baryon, total pion number per baryon, and thermal pion number per baryon which are found at the center-of-mass energies 3.8–4.9 GeV and 7.6–9.2 GeV. The low-energy set of quasi-plateaus was predicted a long time ago. On the basis of the generalized shock-adiabat model I show that the low-energy correlated quasi-plateaus give evidence for the anomalous thermodynamic properties inside the mixed phase found at the center-of-mass energies 4.3–4.9 GeV. Furthermore, I would like to discuss the thermostatic properties of the mixed phase and the ones of an exponential mass spectrum of hadrons and to present the practical conclusions for the chemical equilibration of strangeness in heavy ion collisions. Using the similarity of low- and high-energy irregularities I argue that the high-energy correlated quasi-plateaus may correspond to a second phase transition. Its possible origin and a possible location of the tricritical endpoint of QCD matter phase diagram are also discussed.

**Topic::**

Mini-workshop: FAIR-NICA-SPS-BES RHIC Physics

**Summary:****Workshop on Physics at FAIR-NICA-SPS-BES/RHIC / 1091****New Baryonic and Mesonic Observables from NA61/SHINE****Authors:** Nikolaos Davis<sup>1</sup>; Antoni Marcinek<sup>2</sup>; Andrzej Rybicki<sup>2</sup>**Co-authors:** Nikos Antoniou<sup>3</sup>; Fotis Diakonou<sup>3</sup><sup>1</sup> *Institute of Nuclear Physics PAN, Kraków, Poland*<sup>2</sup> *Polish Academy of Sciences (PL)*<sup>3</sup> *University of Athens, Physics Department, Section of Nuclear and Elementary Particle Physics, GR-15771***Corresponding Authors:** nikolaos.davis@cern.ch, andrzej.rybicki@cern.ch, nantonio@phys.uoa.gr, antoni.marcinek@gmail.com, fdiakonou@phys.uoa.gr

One of the main objectives of the NA61/SHINE experiment at CERN SPS is to search for the critical point on the transition line between the two phases of matter, the quark-gluon plasma and hadron gas. In this talk we present first results on three new observables relevant for the properties of the

system as it cools back from the QGP down to the hadronic phase, which recently enriched the NA61/SHINE strong interaction programme.

We investigate proton density fluctuations as a possible order parameter of the phase transition in the neighborhood of the critical point. To this end, we perform an intermittency analysis of the proton second scaled factorial moments (SSFMs) in transverse momentum space. A previous analysis of this sort revealed significant power-law fluctuations in the NA49 heavy ion collision experiment for the “Si”+Si system at 158A GeV/c. The fitted power-law exponent was consistent with the theoretically expected critical value, within errors, a result suggesting a baryochemical potential for the critical point in the vicinity of ~250 MeV. We now extend the analysis to NA61 systems of similar size, Be+Be and Ar+Sc, at 158A GeV/c.

We present the first ever measurements of Phi meson production in p+p collisions at 40 and 80 GeV/c, and most detailed ever experimental data at 158 GeV/c. We demonstrate the superior accuracy of the present dataset with respect to existing measurements. The comparison of p+p to Pb+Pb collisions demonstrates a non-trivial system size dependence of the longitudinal evolution of hidden strangeness production, contrasting with that of other mesons.

The electromagnetic (EM) effects on charged meson production give, for the first time, a consistent picture of the longitudinal evolution of the system at SPS energies. We discuss the role of energy-momentum conservation in the latter and present feasibility studies for EM effects in Be+Be, Ar+Sc and Pb+Pb collisions as a function of their centrality and energy.

**Topic::**

Topic: Heavy Ion Collisions and Critical Phenomena

**Summary:**

**Workshop on Physics at FAIR-NICA-SPS-BES/RHIC / 1544**

## Unruh effect in heavy ion collisions

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**Co-authors:** Evgeny Zabrodin<sup>2</sup>; Larisa Bravina<sup>2</sup>

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In high energy collisions system is expected to quickly (by the time of order of 1 fm/c) forget about its initial conditions (thermalization). However, description of such a fast thermalization is a challenging task by itself, since kinetics seems to be non-applicable at such a time scale. One of the possible approaches to the problem is the Unruh effect [1], that has been proposed in [2, 3, 4]. Here we try to apply the idea to the heavy ion collisions using the UrQMD model. Particles are considered as generated at the Unruh horizon thus allowing to estimate the Unruh temperature of the source. The analysis was provided for different types of mesons and their charge.

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**Topic::**

Mini-workshop: FAIR-NICA-SPS-BES RHIC Physics

**Summary:**

**Workshop on Physics at FAIR-NICA-SPS-BES/RHIC / 1362**

## **BM@N experiment for studies of Baryonic Matter at the Nuclotron**

**Author:** Mikhail Kapishin<sup>1</sup>

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BM@N (Baryonic Matter at Nuclotron) is the first experiment to be realized at the accelerator complex of NICA-Nuclotron in JINR. The aim of the experiment is to study interactions of relativistic heavy ion beams with energy from 1 up to 5.5 AGeV with fixed targets. The research program of the experiment includes studies of strange mesons, multi-strange hyperons and light hyper-nuclei which are produced in nucleus-nucleus collisions close to the kinematic threshold. The experiment combines high precision track measurements with time-of-flight information for particle identification and total energy measurements for the analysis of the collision centrality. The gold ion beam is planned in 2019. The argon and krypton beams are foreseen already in 2017. The BM@N physics program, results of feasibility studies, the performance of the BM@N set-up in the first runs and plans for the BM@N development are presented.

**Topic::**

Mini-workshop: FAIR-NICA-SPS-BES RHIC Physics

**Summary:**

**Workshop on Physics at FAIR-NICA-SPS-BES/RHIC / 1037**

## **Flow at SIS energies - overview of SIS18 results and prospect for SIS100**

**Author:** Andrej Kugler<sup>1</sup>

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In the talk overview of results about flow at SIS18 energies in general will be given. Perspective for future investigations within new FAIR project, results of comparison between models and available data and the corresponding R&D effort will be described as well. Particularly the data obtained with HADES spectrometer will be discussed in detail. The HADES spectrometer installed at GSI Darmstadt is a second generation experiment designed to measure  $e+e^-$  pairs (dielectrons) as well as charge hadrons in the SIS/BEVALAC energy regime. The main goal of the experiment is to learn about in-medium hadron properties. For this purpose a dedicated programme focusing on systematic investigation of dielectron and charge hadrons production in nucleon-nucleon, proton-nucleus and heavy ion reactions is on-going. A comparison of the nucleon-nucleon data to the one obtained in more complex systems allows for isolation of true in-medium effects. Recently, these investigations were complemented by study of secondary negative pion beam interactions with proton as well as with different nuclei. Furthermore, thank to excellent particle identification capabilities of the detector, investigations have also been extended to strangeness production, which at these energies is

confined to a high density zone of the collision. The obtained data call for further systematic investigations at higher baryonic densities, where no dielectron and very limited data on strangeness exist. For this reason, experiments with HADES and new CBM spectrometer on the coming FAIR facility are under preparation. The existing HADES spectrometer will be complemented by an electromagnetic calorimeter based on lead-glass modules. The calorimeter will enable to get in addition data on production of the  $\pi^0$  and  $\eta$  mesons via their two-photon decay. No respective data are presently available for the energy range 4–40 AGeV, with the consequence that such upgrade is needed to avoid interpretation of future dielectron data based solely on theoretical models.

**Topic::**

Mini-workshop: FAIR-NICA-SPS-BES RHIC Physics

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 1177**

**Matter waves exposed to the external world: Decoherence, gravity, complementarity and time irreversibility**

**Authors:** Ron Folman<sup>None</sup>; The atom chip group<sup>None</sup>

Matter-wave interferometry provides an excellent tool for probing the environment and studying its coupling to isolated atoms. We will present several interferometry experiments done with a BEC on an atom chip [1] and in which different effects of the environment have been investigated. First, we will discuss fluctuations in the nearby environment probed by an interference of atoms trapped in a magnetic lattice very close (5 $\mu$ m) to a room temperature surface [2,3]. Here an order-of-magnitude improvement has been obtained over previous atom-surface distances for which spatial interference has been observed. Next, we will present a new interferometry of self-interfering clocks and show, in a proof-of-principle experiment, how it could probe the interplay of QM and GR [4]. We will also describe a rule for “clock complementarity”, which we deduce theoretically and verify experimentally [5]. Finally, we will discuss Stern-Gerlach interferometry [6] and describe it in the context of time irreversibility [7]. To the best of our knowledge, this is the first time spatial Stern-Gerlach interferometry has been realized, and we analyze our data in the context of previous theoretical work relating the difficulties in realizing Stern-Gerlach interferometry to time irreversibility.

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**Topic::**

Topic: Quantum Physics, Quantum Optics and Quantum Information

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 1132**

## **Quantum Dynamical Simulation by Quantum Walk**

**Author:** Yutaka Shikano<sup>1</sup>

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The discrete time quantum walk defined as a quantum-mechanical analogue of the discrete time random walk have recently been attracted from various and interdisciplinary fields. The weak limit theorem, that is, the asymptotic behavior, of the one-dimensional discrete time quantum walk is analytically shown. From the limit distribution of the discrete time quantum walk, the discrete time quantum walk can be taken as the quantum dynamical simulator of some physical systems. In this talk, we would like to discuss the mathematical structures of the discrete time quantum walk and its experimental implementation.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 941**

## **Wave function collapse and gravity**

**Author:** Angelo Bassi<sup>1</sup>

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To make quantum theory consistent, models of spontaneous wave function collapse (collapse models) propose to modify the Schrödinger equation by including nonlinear and stochastic terms, which describe the collapse of the wave function in space. These spontaneous collapses are “rare” for microscopic systems, hence their quantum properties are left almost unaltered. At the same time, since the collapses add coherently in composite systems, macroscopic spatial superpositions of macro-objects are rapidly suppressed. I will review the main features of collapse models. In particular, I will discuss ideas to connect the collapse of the wave function to gravity: The Diosi-Penrose model, Adler’s model and the Schroedinger-Newton equation. Next, I will present an update of the most promising ways of testing them in interferometric and non-interferometric experiments, showing the current lower and upper bounds on their parameters.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 1225**

## **Fundamental mechanism of the quantum computational speedup**

**Author:** Giuseppe Castagnoli<sup>1</sup>

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A paradigmatic example of quantum computational speedup is the simplest instance of the quantum algorithm devised by Grover. Bob, the problem setter, hides a ball in one of four drawers. Alice, the problem solver, is to locate it by opening drawers. In the classical case, Alice needs to open up to three drawers, always one in the quantum case.

The drawer and ball problem is an example of oracle problem. The operation of checking whether the ball is in a drawer is an example of function evaluation. In the case of oracle problems, the quantum speedup comes from comparing the number of function evaluations required to solve the problem quantumly and classically. It should be noted that each speedup has been found by means of ingenuity. Outside the present unconventional approach, there is no fundamental explanation of the speedup, no unification of the various speedups, no way of foreseeing the number of function evaluations needed to solve a generic oracle problem in an optimal quantum way.

We note that the usual representation of quantum algorithms, limited to the input-output transformation typical of computation, is physically incomplete. Alice works on a quantum register  $A$  initially in a sharp state unrelated to the problem to be solved. By performing function evaluations interleaved with other unitary transformations, she sends this initial state into an output state that encodes the solution of the problem. Then she acquires the solution by measuring the content of  $A$ . The problem setting is not represented physically, namely by a quantum state – it is implicit in the mathematics of function evaluation. Furthermore, the complete representation of a quantum process must include the initial measurement, the unitary transformation of the state after measurement, and the final measurement.

We show that just completing the representation of quantum algorithms explains their speedup. This is done in three steps.

First, we extend the usual representation to the process of setting the problem. We add a possibly imaginary quantum register  $B$  meant to contain the problem setting – e. g. the number of the drawer with the ball. We assume that initially this register is in a uniform quantum superposition of all the possible problem settings. The initial state of register  $A$  is as before. An initial measurement of the content of  $B$  selects a problem setting at random. Ordinarily, Bob would unitarily send it into the desired setting; we jump this transformation for simplicity. Alice unitarily sends the random outcome of the initial measurement into an output state where register  $B$  still contains the problem setting selected by Bob and register  $A$  the corresponding solution. Then she acquires the solution by measuring the content of  $A$ . In view of what will follow, we note that this measurement leaves the quantum state unaltered; there is thus a unitary transformation  $U$  between the initial and final measurement outcomes.

Second. The extended representation works for Bob and any external observer, it does not for Alice. The input state of the representation (the outcome of the initial measurement), where register  $B$  is in a sharp state, would tell her the setting and thus the solution of the problem before she performs any function evaluation. To her, this setting must be hidden inside the black box that performs the function evaluations. We obtain Alice's view of the extended representation by postponing at the end of her problem-solving action the projection of the quantum state associated with the initial measurement. As well known, this kind of projection can be postponed at will along a unitary transformation that follows the measurement; furthermore, the content of register  $B$  and that of register  $A$  are commuting observables, so that the projection in question can be postponed after the final Alice's measurement. In particular, the input state of the quantum algorithm to Alice becomes one of complete ignorance of the problem setting selected by Bob. Now the unitary part of Alice's action yields a superposition of tensor products, each a possible problem settings multiplied by the corresponding solution. The final Alice's measurement of the content of  $A$  projects the superposition in question on the product of the problem setting selected by Bob and the corresponding solution. This particular projection is unforeseeable to Alice as usual, it is already known to Bob and any external observer.

Third, we physically represent the reversibility of the computation process between the initial and final measurement outcomes by symmetrizing it for time reversal. This is done by assuming that



the initial and final measurements, in presence of one another (contextually), reduce to partial measurements that evenly and without redundancy contribute to the selection of the problem setting and the solution, in all the possible ways in quantum superposition. The selection performed by the initial partial measurement should be propagated forward in time by  $U$ ; that performed by the final one backward in time by the inverse of  $U$ . We note that any uneven sharing would introduce a preferred direction of time unjustified in the present reversible context. This symmetrization leaves the representation to Bob and any external observer unaltered and changes that to Alice. It projects the former input state to her, of complete ignorance of the problem setting and thus of the solution, on a state where she knows half of the information that specifies the solution of the problem she will read in the future. Hiding to Alice the information coming to her from the initial measurement highlights the information coming to her from the final measurement.

An optimal quantum algorithm turns out to be a sum over classical histories in each of which Alice knows in advance one of the possible halves of the solution and performs the function evaluations necessary to identify the missing half. This quantitatively explains the quantum speedup and allows to predict the number of function evaluations required to solve a generic oracle problem in an optimal quantum way.

Reference: Castagnoli, G.: Completing the physical representation of quantum algorithms explains their computational speedups. <https://arxiv.org/abs/1705.02657>

**Topic:**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

The quantum computational speedup is the fact that quantum algorithms require fewer computation steps than their classical counterparts, sometimes fewer than classically possible. It should be noted that each quantum algorithm has been found by means of ingenuity and that no common mechanism of the computational speedup is known. We show that just completing the physical representation of quantum algorithms highlights the mechanism in question. This is done in three steps: (i) extending the usual representation, limited to the process of solving the problem, to the process of setting the problem, (ii) relativizing the extended representation with respect to the problem solver, who cannot know the problem setting, and (iii) symmetrizing the relativized representation for time-reversal, to physically represent the reversibility of the computation process. The third step projects the input state of the relativized representation, where the problem solver is completely ignorant of the problem setting and thus of the corresponding solution, on one where she knows half of the information that specifies the solution. The quantum algorithm turns out to be a sum over classical histories in each of which the problem solver knows in advance one of the possible halves of the solution and performs the computation steps (function evaluations) needed to find the other half. This explains the quantum speedup and allows to predict the number of steps required to solve any oracle problem in an optimal quantum way.

**Workshop on Quantum Foundations and Quantum Information / 1103**

## **Weak Measurements: from Measuring Non-Commuting Observables and Testing Quantum Contextuality to Protective Measurements**

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Measurements are the very basis of Physics, especially in Quantum Mechanics (QM), where they assume even a more fundamental role because of the wave function collapse occurring after a “strong” (projective) measurement. Furthermore, measuring a quantum-mechanical observable completely erases the information on its conjugate one (e.g., position measurement erases information on momentum, and vice-versa).

Nevertheless, in QM other kinds of measurement are possible. For example, wave function collapse can be overcome through Weak Measurements, i.e. measurements performed with an interaction weak enough to avoid inducing the original state collapse, featuring several interesting properties. An example of these are weak values [1-3], realised for the first time in [4-6], that have been used for addressing fundamental questions [7-12] as Contextuality and are also a tool for Quantum Metrology [13-19].

One of the most intriguing properties of Weak Measurements is that, since they are not affected by wave function collapse, they can allow gathering simultaneous information on non-commuting observables [20], impossible with the standard (projective) measurement protocols.

A second example is offered by Protective Measurements [21], a new technique able to extract information on the expectation value of an observable even measuring a single particle.

In this talk, after a general introduction to WMs, we present the first realisation of sequential weak value measurements [22], i.e. a measurement of the weak value of (incompatible) polarizations in sequence on a single photon.

Then, we present an experiment addressed to explore the connection between anomalous weak values and Contextuality [23], showing a clear violation of the inequality proposed in [12] while satisfying all the additional theoretical requests, unequivocally demonstrating the contextual nature of weak values.

Finally, we present and discuss the first implementation of Protective Measurements, showing unprecedented measurement capability and demonstrating how the expectation value of an observable can be obtained even with a single experiment on a single particle.

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**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 1058**

## Ubiquitous non-local entanglement with Majorana bound states

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Entanglement in quantum mechanics contradicts local realism, and is a manifestation of quantum non-locality. Its presence can be detected through the violation of Bell, or CHSH inequalities. Paradigmatic quantum systems provide examples of both, non-entangled and entangled states.

Here we consider entanglement of non-local degrees of freedom emerging from topological properties of many-body systems. Specifically, we consider a minimal complexity setup consisting of 6 Majorana bound states. We find that any allowed state in the degenerate Majorana space is non-locally entangled. We show how to measure (with available techniques) the CHSH-violating correlations, using either intermediate strength or weak measurement protocols.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 1242**

## Pure state post-selection is universal

**Author:** Lajos Diosi<sup>1</sup>

<sup>1</sup> *Wigner Research Centre for Physics*

**Corresponding Author:** diosi.lajos@wigner.mta.hu

I revisit earlier proposals on entangled and mixed state post-selections. Pure state post-selections are the primary ones, mixed state post-selections can be reduced from them. Accordingly, generic mixed-entangled two-states correspond to reductions and/or non-selective measurements of pure two-states. I discuss when Bob is able, via weak measurements, to decide if Alice prepared for him a non-trivial post-selected state, i.e., of post-selection rate less than 1.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 967**

## One quantum shutter can close two slits simultaneously

**Authors:** Ryo Okamoto<sup>1</sup>; Shigeki Takeuchi<sup>None</sup>

<sup>1</sup> *Kyoto University*

**Corresponding Author:** okamoto.ryo.4w@kyoto-u.ac.jp

The interference between two paths of a single photon at a double slit is widely considered to be the most paradoxical result of quantum theory. Here is a new interesting question to the phenomenon: can a single shutter simultaneously close two slits by effectively being in a superposition of different locations? Surprisingly, Aharonov and Vaidman have shown that it is indeed possible to construct a quantum shutter that can close two (or more) slits and reflect a probe photon perfectly when its initial and final states are appropriately selected [1]. Here, we demonstrate the protocol proposed by Aharonov and Vaidman using a photonic quantum circuit [2]. As a quantum shutter, we used a shutter photon in a superposition state in modes that control two photonic quantum routers for the nonlinear interaction with a probe photon. The experimental results show that when the shutter photon is found in the appropriate final state, the input probe photon is reflected by the quantum shutter, with a probability exceeding the classical limit. By checking the coherence of the output probe photon, we also verified that the quantum superposition of the probe photon is not destroyed by the shutter.

[1] Aharonov, Y., & Vaidman, L. How one shutter can close N slits. *Physical Review A*, 67, 1-3 (2003).

[2] Okamoto, R., & Takeuchi, S. Experimental demonstration of a quantum shutter closing two slits simultaneously. *Scientific Reports*, 6, 35161 (2016).

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 1172**

## Locality and nonlocality in the interaction-free measurement

**Authors:** Yakir Aharonov<sup>1</sup>; Tomer Landsberger<sup>2</sup>; Daniel Rohrlich<sup>3</sup>

<sup>1</sup> *Tel Aviv University and Chapman University*

<sup>2</sup> *Tel Aviv University*

<sup>3</sup> *Ben-Gurion University of the Negev*

**Corresponding Authors:** rohrlich@bgu.ac.il, yakir@post.tau.ac.il

We present a paradox involving a particle and a mirror. They exchange a nonlocal quantity - weak modular angular momentum,  $\langle L_z \bmod 2\hbar \rangle_w$  - but no local interaction between them seems to allow such an exchange. We demonstrate that the particle and mirror *do* interact locally via a *local current* of  $\langle L_z \bmod 2\hbar \rangle_w$ . In this sense, we transform the “interaction-free measurement” of Elitzur and Vaidman, in which two local quantities (the positions of a photon and a bomb in the two arms of a Mach-Zehnder interferometer) interact nonlocally, into a thought experiment in which two nonlocal quantities (the modular angular momentum of the particle and of the mirror) interact locally.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 1193**

## Experimental realization of a shortcut to adiabaticity by synthetic Aharonov-Bohm effect in a qutrit

**Authors:** Antti Vepsäläinen<sup>1</sup>; Sergey Danilin<sup>1</sup>; Sorin Paraoanu<sup>1</sup>

<sup>1</sup> *Aalto University*

**Corresponding Author:** sorin.paraoanu@aalto.fi

The adiabatic control of quantum systems has the advantage of robustness against experimental errors in pulse shape; however, to ensure the adiabaticity condition, the length of the pulses have to be rather long - a disadvantage especially in solid-state qubits where the coherence time is still not too large.

Here we demonstrate a protocol of “transitionless” drive proposed by Berry, Demirplack, and Rice, which uses a counterdiabatic Hamiltonian to cancel the nonadiabatic terms. Building on our previous realization of stimulated Raman adiabatic passage [Nature Communications 7, 10628 (2016)], we employ a superconducting qutrit with the three levels coupled by single-photon and two-photon transitions. This configuration is analogous to the Aharonov-Bohm effect, and we will show how a gauge-invariant phase can be constructed and utilized experimentally. We also study in detail the robustness properties of this protocol.

**Topic::**

Topic: Quantum Physics, Quantum Optics and Quantum Information

**Summary:**

The adiabatic theorem (1928, Born and Fock) is a major result in quantum physics. We show how nonadiabatic excitations, inevitably created in a finite-time evolution can be cancelled by an additional Hamiltonian. We use a superconducting circuit consisting of a qutrit coupled to a read-out resonator.

**Workshop on Quantum Foundations and Quantum Information / 971**

## Statistical superdegeneracy and quantum foundations

**Author:** Daniel Sheehan<sup>1</sup>

<sup>1</sup> *Dept. Physics, University of San Diego*

**Corresponding Author:** dsheehan@sandiego.edu

The foundations of quantum mechanics have always been closely tied to statistical physics; historically, of course, the former subject began through wrestling with unresolved issues in the latter. This presentation introduces a new concept, statistical superdegeneracy (unrelated to magnetism and band structures) that may have implications for quantum foundations. As one possible motivation, consider population inversion (e.g., in lasers). It is a nonequilibrium phenomenon owing to the dominance of the Boltzmann factor in determining state occupancy under thermal equilibrium. State degeneracy, while adding detail, is assumed to be of secondary importance. In this paper, a new type of degeneracy is explored, one that increases sufficiently rapidly with energy so as to dominate the Boltzmann exponential, thereby leading to new phenomena, like population inversion at thermal equilibrium as well as stationary quantum currents. Physical systems that might exhibit this anomalous degeneracy are proposed, and ramifications for quantum and statistical foundations are discussed.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 974**

## **Counter-intuitive phenomena in quantum mechanics emerging in matter-wave optical experiments**

**Author:** Yuji Hasegawa<sup>1</sup>

<sup>1</sup> *Vienna University of Technology*

**Corresponding Author:** yuji.hasegawa@tuwien.ac.at

Peculiarities of quantum mechanical predictions on a fundamental level are investigated intensively in matter-wave optical setups; in particular, neutron interferometric strategy has been providing almost ideal experimental circumstances for experimental demonstrations of quantum effects. In this device quantum interference between beams spatially separated on a macroscopic scale is put on explicit view. Recently, a new counter-intuitive phenomenon, called quantum Cheshire-cat, is observed in a neutron interferometer experiment. Weak measurement and weak values justify the access of the neutrons' dynamics in the interferometer. Moreover, another experiment reported full determination of weak-values of neutron's  $\frac{1}{2}$ -spin; this experiment is further applied to demonstrate quantum Pigeonhole effect and quantum contextual. In my talk, I am going to give an overview of neutron interferometry for investigation of quantum paradoxes.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 1227**

## **Quantum Uncertainty Relations and Related**

**Author:** Shao-Ming Fei<sup>1</sup>

<sup>1</sup> *Capital Normal University*

**Corresponding Author:** feishm@cnu.edu.cn

We study entropic, variance based, probabilistic, and weighted quantum uncertainty relations, as well as their experimental verifications. The related quantum coherence and quantum correlations like quantum discord, quantum entanglement, quantum steering, Bell non-locality are also investigated.

1. Wenchao Ma, Zhihao Ma, Hengyan Wang, Ying Liu, Zhihua Chen, Fei Kong, Zhaokai Li, Mingjun Shi, Fazhan Shi, Shao-Ming Fei, and Jiangfeng Du, Experimental demonstration of Heisenberg's measurement uncertainty relation based on statistical distances, *Phys. Rev. Lett.* 116 (2016) 160405.
2. Yunlong Xiao, Shao-Ming Fei, Naihuan Jing, Tao Li, Xianqing Li-Jost, Teng Ma and Zhixi Wang, Strong entropic uncertainty relations for multiple measurements, *Phys. Rev. A* 93 (2016) 042125.
3. Teng Ma, Ming-Jing Zhao, Shao-Ming Fei, Gui-Lu Long, Remote Creation of Quantum Coherence, *Phys. Rev. A* 94 (2016) 042312.
4. Yunlong Xiao, Naihuan Jing, Shao-Ming Fei and Xianqing Li-Jost, Improved Uncertainty Relation in the Presence of Quantum Memory, *J. Phys. A* (2016) 49LT01.
5. Tinggui Zhang, Hong Yang, Xianqing Li-Jost, Shao-Ming Fei, Uniform Quantification of Correlations for Bipartite Systems, *Phys. Rev. A* 95 (2017) 042316.
6. Ming Li, Huihui Qin, Jing Wang, Shao-Ming Fei, Chang-Pu Sun, Maximal violation of Bell inequalities under local filtering, *Scientific Reports* 7 (2017) 46505.
7. Teng Ma, Ming-Jing Zhao, Hai-Jun Zhang, Shao-Ming Fei and Gui-Lu Long, Accessible Coherence and Coherence Distribution, *Phys. Rev. A* 95 (2017) 042328.
8. Wenchao Ma, Bin Chen, Ying Liu, Mengqi Wang, Xiangyu Ye, Fei Kong, Fazhan Shi, Shao-Ming Fei, and Jiangfeng Du, Experimental Demonstration of Uncertainty Relations for the Triple Components of Angular Momentum, *Phys. Rev. Lett.* 118 (2017) 180402.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 1122**

## **Logical Information Theory: New Foundations for Classical and Quantum Information Theory**

**Author:** David Ellerman<sup>1</sup>

<sup>1</sup> *University of California Riverside*

**Corresponding Author:** david@ellerman.org

There is a new theory of information based on logic. The definition of Shannon entropy as well as the notions on joint, conditional, and mutual entropy as defined by Shannon can all be derived by

a uniform transformation from the corresponding formulas of logical information theory. Information is first defined in terms of sets of distinctions without using any probability measure. When a probability measure is introduced, the logical entropies are simply the values of the (product) probability measure on the sets of distinctions. The compound notions of joint, conditional, and mutual entropies are obtained as the values of the measure, respectively, on the union, difference, and intersection of the sets of distinctions. These compound notions of logical entropy satisfy the usual Venn diagram relationships (e.g., inclusion-exclusion formulas) since they are values of a measure (in the sense of measure theory). The uniform transformation into the formulas for Shannon entropy is linear so it explains the long-noticed fact that the Shannon formulas satisfy the Venn diagram relations—as an analogy or mnemonic—since Shannon entropy is not a measure in the sense of measure theory) on a given set.

What is the logic that gives rise to logical information theory? Partitions are dual (in a category-theoretic sense) to subsets, and the logic of partitions was recently developed in a dual/parallel relationship to the Boolean logic of subsets (the latter being usually mis-specified as the special case of “propositional logic”). Boole developed logical probability theory as the normalized counting measure on subsets. Similarly the normalized counting measure on partitions is logical entropy—when the partitions are represented as the set of distinctions that is the complement to the equivalence relation for the partition.

The ‘classical’ logical notion of entropy extends directly to the quantum case where a partition is replaced by the direct-sum decomposition defined by the eigenspaces of an observable. The multivariate notions of joint, conditional, and mutual logical entropy extend directly to the corresponding quantum notions for commuting observables.

**Topic::**

Topic: Quantum Physics, Quantum Optics and Quantum Information

**Summary:**

Introduction to classical and quantum versions of logical information theory.

**Workshop on Quantum Foundations and Quantum Information / 1133**

## Quantum Cryptography with Structured Photons

**Author:** Ebrahim Karimi<sup>1</sup>

<sup>1</sup> *University of Ottawa*

**Corresponding Author:** [ekarimi@uottawa.ca](mailto:ekarimi@uottawa.ca)

Complementarity prohibits one to measure two conjugate quantities simultaneously, such as position and momentum, relying on the existence of the Heisenberg uncertainty principle. This property can be used for sharing information securely between two parties, e.g. through the use of quantum key distribution (QKD). Moreover, the no-cloning theorem, a fundamental law in quantum mechanics, guarantees that attempts to copy the sent information will introduce detectable imperfections on the carrier. Therefore, monitoring imperfections (the channel noise), during key sharing, reveals the existence of an eavesdropper.

Photons, the quanta of light, are an excellent candidate for quantum communication since the encoded information can be transmitted with maximum speed, the speed of light, between separated parties without being significantly affected by the environment. The latter lies on the fact that light barely interacts with air, thus the information can be sent over very long distances. There have been efforts to utilise photons as information carriers; protocols using photonic polarisation have been explored, but are limited to a bi-dimensional encoding alphabet. Unlike polarisation, photonic orbital angular momentum (OAM) and radial quantum number (RQN), two newly used photon’s degrees of freedom, are inherently unbounded, and thus can be used as an unbounded alphabet for communication purposes. Quantum states of light resulting from an arbitrary coherent superposition of different polarisations, OAM and RQN, are referred to as structured photons; structuring photons may be used to realise higher-dimensional states of light.



In my talk, I will present the recent progress, challenges and development in performing high-dimensional quantum key distribution, quantum hacking as well as our recent achievements in simulating quantum computations with structure photons. These results show that implementing high-dimensional protocols will improve noise resistance, security, and increase data transmission rates.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

Recent achievements in performing high-dimensional quantum cryptography, quantum hacking via optimal cloning, and quantum simulations at the single photon regime will be discussed.

Workshop on Quantum Foundations and Quantum Information / 1443

## Opening words

Workshop on Quantum Foundations and Quantum Information / 1143

## Testing the superposition principle with individual trapped atoms

**Authors:** Carsten Robens<sup>1</sup>; Wolfgang Alt<sup>1</sup>; Dieter Meschede<sup>1</sup>; Clive Emary<sup>2</sup>; Andrea Alberti<sup>1</sup>

<sup>1</sup> *Institut für Angewandte Physik*

<sup>2</sup> *Joint Quantum Centre Durham-Newcastle*

**Corresponding Authors:** clive.emary@newcastle.ac.uk, w.alt@iap.uni-bonn.de, meschede@uni-bonn.de, robens@iap.uni-bonn.de, a.alberti82@gmail.com

We report on a stringent test of the *nonclassicality* of the motion of a massive quantum particle that propagates on a discrete lattice. Measuring temporal correlations of the position of single Cs atoms performing a quantum walk, we observe a  $6\sigma$  violation of the Leggett-Garg inequality [1]. Our results rigorously exclude (i.e., falsify) any explanation of the motion of a Cs atom based on classical, well-defined trajectories, and indicate instead that the atom must propagate in a superposition of multiple trajectories. For this experimental test, we have devised a new technique to realize ideal negative measurements—namely, the ability to measure a physical object avoiding any direct interaction with it. Interaction-free measurements are a prerequisite for any rigorous LG test, as without it, violations can simply be attributed to an unwitting invasiveness on behalf of the experimenter, rather than to the absence of a *realistic* description.

In 1993, Elitzur and Vaidman proposed a different setup that exploits interaction-free measurements to detect the presence of an object— in a dramatic scenario, a bomb—without interacting with it. In a recent experiment [2], we have implemented the “bomb test” with a single atom trapped in a spin-dependent optical lattice. We show the relation between the Elitzur-Vaidman bomb tester and Leggett-Garg falsification experiments by demonstrating an experimental violation of the Leggett-Garg inequality by  $21\sigma$ .

**References:**

[1] C. Robens, W. Alt, D. Meschede, C. Emary, and A. Alberti, Ideal Negative Measurements in Quantum Walks Disprove Theories Based on Classical Trajectories, *Phys. Rev. X* **5**, 011003 (2015).

[2] C. Robens, W. Alt, C. Emary, D. Meschede, and A. Alberti, Atomic “bomb testing”: the Eitzur–Vaidman experiment violates the Leggett–Garg inequality, *Appl. Phys. B* **123**, 12 (2016).

**Topic:**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 1199**

## **Quantum Mechanics is Two-Thirds Local Realistic**

**Authors:** Avishy Carmi<sup>1</sup>; Eli Cohen<sup>2</sup>; Daniel Moskovich<sup>1</sup>

<sup>1</sup> *Ben-Gurion University*

<sup>2</sup> *University of Bristol*

Bell’s theorem states that quantum theory violates the principle of local-realism. It is known, however, that several nonlocal models cannot reproduce the entire range of quantum mechanical correlations either. What is it then that distinguishes quantum nonlocality from the nonlocality of other potential theories? In this talk we will see that quantum nonlocality is unique in that it stems from a very moderate dismissal of local-realism. In particular, we will present three conditions that together fully characterize local realistic theories. Any pair of the conditions together lead to the set of quantum mechanical correlations. Any of the conditions alone implies that the correlations are “quantum-like”. And if all conditions are violated, the theory enables stronger-than-quantum correlations. The various implications of these results will be discussed.

**Topic:**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 1481**

## **Faster than Fourier (pre)visited: vorticulture, noise, fractals...**

**Author:** Michael Berry<sup>None</sup>

Faster than Fourier (pre)visited: vorticulture, noise, fractals...

**Topic:**

Topic: Quantum Physics, Quantum Optics and Quantum Information

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 1486**

## **Novel manifestations of quantum oblivion**

**Author:** Avshalom Elitzur<sup>1</sup>

<sup>1</sup> *The Israeli Institute for Advanced Research*

TBA

**Topic::**

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 1487**

## **The fascinating properties of weak values**

**Author:** Yakir Aharonov<sup>1</sup>

<sup>1</sup> *Chapman University*

**Corresponding Author:** aharonov@chapman.edu

TBA

**Topic::**

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 1043**

## **Ultrafast Optical Homodyne - Measuring the Fundamental Variables of Quantum Optics $10^5$ Times Faster**

**Authors:** Yaakov Shaked<sup>1</sup>; Yoad Michael<sup>1</sup>; Leon Bello<sup>1</sup>; Michael Rosenbluh<sup>1</sup>; Avi Pe'er<sup>1</sup>

<sup>1</sup> *Bar Ilan University*

**Corresponding Author:** avi.peer@biu.ac.il

Homodyne measurement is a corner-stone of quantum optics. It measures the fundamental variables of quantum electrodynamics - the quadratures of light, which represent the cosine-wave and sine-wave components of an optical field. The quadratures constitute the quantum optical analog of position and momentum in mechanics and obey quantum uncertainty, indicating the inherent inability to measure both simultaneously. The homodyne process, which extracts a chosen quadrature amplitude by correlating the optical field against an external quadrature reference (local-oscillator, LO), forms the backbone of coherent detection in physics and engineering, and plays a central role in quantum information processing. Homodyne can reveal non-classical phenomena, such as squeezing of the quadrature uncertainty; It is used in tomography to fully characterize quantum states of light; Homodyne detection can generate non-classical states, provide local measurements for teleportation and serve as a major detector for quantum key distribution (QKD) and quantum computing. Yet, standard homodyne suffers from a severe bandwidth limitation. While the bandwidth of optical states can easily span many THz, standard homodyne detection is inherently limited to the electrically accessible, MHz to GHz range, leaving a dramatic gap between the relevant optical phenomena and the measurement capability. This gap impedes effective utilization of the huge bandwidth resource of optical states and the potential enhancement of the information throughput \emph{by several orders of magnitude} with parallel processing in quantum computation, QKD and other applications of quantum squeezed light. Here we demonstrate a fully parallel optical homodyne measurement across an arbitrary optical bandwidth, effectively lifting the bandwidth limitation completely. Using optical parametric amplification, which amplifies one quadrature while attenuating the other,

we measure two-mode quadrature squeezing of 1.5dB below the vacuum level simultaneously across a bandwidth of 55THz using a single LO - the pump. This broadband parametric homodyne measurement opens a wide window for parallel processing of quantum information.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

Workshop on Quantum Foundations and Quantum Information / 1501

## The controversy about the past of a quantum particle

**Author:** Lev Vaidman<sup>1</sup>

<sup>1</sup> *Tel Aviv University*

**Corresponding Author:** vaidman@post.tau.ac.il

TBA

**Topic::**

**Summary:**

Workshop on Quantum Foundations and Quantum Information / 1548

## From Acceleration Radiation to Black Hole Entropy: A quantum optical perspective

**Author:** Marlan Scully<sup>1</sup>

<sup>1</sup> *Texas A&M University, Baylor University, Princeton University*

**Corresponding Author:** scully@tamu.edu

Acceleration radiation is caused by virtual processes in which an atom jumps from the ground state to an excited state, together with the emission of a photon. If an atom is accelerated away from the original point of virtual emission then there is a small probability that the virtual photon will “get away”. When ground-state atoms are accelerated through a high Q microwave cavity, radiation is produced with an intensity which can exceed the intensity of acceleration radiation in free space by many orders of magnitude. The reason is a strong nonadiabatic effect at cavity boundaries [1].

By formulating acceleration radiation as a flat space quantum optics problem one can obtain the entropy of a black hole (BH). Using this approach we find the famous Bekenstein-Hawking BH entropy formula via a simple “laser-like” density matrix analysis. In this way we calculate the entropy of the radiation emitted by a cloud of infalling atoms without introducing the BH temperature [2].

[1]. M.O. Scully, V.V. Kocharovskiy, A. Belyanin, E. Fry and F. Capasso, Phys. Rev. Lett. 91, 243004 (2003).

[2]. M.O. Scully, D. Lee, W. Schleich and A.A. Svidzinsky, Black hole acceleration radiation: from a quantum optical perspective, to be published.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

**Workshop on Quantum Foundations and Quantum Information / 1553**

## **From Acceleration Radiation to Black Hole Entropy: A Quantum Optical Perspective**

**Author:** Marlan Scully<sup>1</sup>

<sup>1</sup> *Texas A&M University, Baylor University, Princeton University*

**Corresponding Author:** scully@tamu.edu

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By formulating acceleration radiation as a flat space quantum optics problem one can obtain the entropy of a black hole (BH). Using this approach we find the famous Bekenstein-Hawking BH entropy formula via a simple “laser-like” density matrix analysis (see Fig. 1c at <http://iqse.tamu.edu/figure/Figure.pdf>). In this way we calculate the entropy of the radiation emitted by a cloud of infalling atoms without introducing the BH temperature [2].

[1]. M.O. Scully, V.V. Kocharovskiy, A. Belyanin, E. Fry and F. Capasso, *Phys. Rev. Lett.* 91, 243004 (2003).

[2]. M.O. Scully, D. Lee, W. Schleich and A.A. Svidzinsky, Black hole acceleration radiation: from a quantum optical perspective, to be published.

**Topic::**

Mini-workshop: Quantum Foundations and Quantum Information

**Summary:**

1308

## **Talk history of Crete in the veranda by Emanuela Larentzakis**

1309

## **Concert of classical music**

1317

## **Classical music (violin, cello, piano)**

1321

**Concert**

1307

**Culture event and talk by Katerina Karkala in the Church of OAC**

1319

**Excursion**

1314

**Public talk**

1316

**Excursion in Chania**

1315

**Opera gala**

1318

**Concert of classical music**

1310

**Culture event**

Visit to the Monastery and Museum Gonia and talk in the Veranda of the Museum

1485

**Concert of classical music in Great Arsenal of Chania**

1496

## Closing of the conference

1515

## Comparison of hydrodynamical and transport theoretical calculations for p+A and A+A collisions

**Corresponding Author:** carsten.greiner@th.physik.uni-frankfurt.de

**Topic::**

**Summary:**

1519

## Infrared Quantum Information

**Corresponding Author:** gordonws@phas.ubc.ca

Central to the solution of the infrared catastrophe of quantum electrodynamics and perturbative quantum gravity is the idea that detection apparatus inevitably have limited resolution and, in any scattering process, an infinite number of arbitrarily soft photons and gravitons are produced and escape detection. Photons and gravitons have polarizations and momenta and one might suspect that those which escape can carry away a significant amount of information. In this talk, I will examine the question as to the quantity of this information loss, its consequences and suggestions for experimental tests of the theoretical ideas, including whether precision interference experiments could see quantum gravitational effects.

**Topic::**

**Summary:**

1520

## Infrared Quantum Information

**Corresponding Author:** gordonws@phas.ubc.ca

Central to the solution of the infrared catastrophe of quantum electrodynamics and perturbative quantum gravity is the idea that detection apparatus inevitably have limited resolution and, in any scattering process, an infinite number of arbitrarily soft photons and gravitons are produced and escape detection. Photons and gravitons have polarizations and momenta and one might suspect that those which escape can carry away a significant amount of information. In this talk, I will examine the question as to the quantity of this information loss, its consequences and suggestions for experimental tests of the theoretical ideas, including whether precision interference experiments could see quantum gravitational effects.

1320

**Round Table discussion on “High Energy Physics after the LHC” (Sergio Bertolucci, University of Bologna and ex-CERN research director, Jie Gao, CEPC institution board vice-chairman and chairman of the Asia Linear Collider Steering Committee, Victor A. Matveev, director of JINR, Russia, Albert de Roeck, CERN, leader of the CERN neutrino group, Frank Zimmermann, CERN, deputy leader of FCC, John Womersley, Director General of the European Spallation Source, Moderator: Michael Koratzinos, ETH Zurich, CH)**

1559

**Memorial lecture dedicated to Ludvig Faddeev (23/03/1944-26/02/2017)**

**Corresponding Author:** [lipatov@thd.pnpi.spb.ru](mailto:lipatov@thd.pnpi.spb.ru)