FAKT Workshop 2022: Particle Physics Retreat

Thursday, February 24, 2022 - Friday, February 25, 2022

Book of Abstracts

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EXO-21-006: Search for long-lived particles decaying to a pair of muons in proton-proton collisions at 13 TeV

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Abstract: An inclusive search for long-lived exotic particles decaying to a pair of muons is presented. The search uses a data set collected by the CMS experiment at the LHC in proton-proton collisions at 13 TeV in 2016 and 2018 and corresponding to an integrated luminosity of 97.6 fb−1. The experimental signature is a pair of oppositely charged muons originating from a common secondary vertex spatially separated from the proton interaction point by distances ranging from several hundred μm to several meters. The results are interpreted in the frameworks of the Hidden Abelian Higgs model, in which the Higgs boson decays to a pair of long-lived dark photons, and of a simplified model, in which long-lived particles are produced in decays of an exotic heavy neutral scalar boson.

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Low-energy effective description of dark Sp(4) theories

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We consider a dark Sp(4) gauge theory with $N_f = 2$ fermions in the pseudo-real fundamental representation and construct the chiral low-energy effective theory. We determine the flavor multiplet structure and the chiral Lagrangian with the inclusion of the Wess-Zumino-Witten term for (non-)degenerate flavors. We provide implications when coupling to the Standard Model with a dark U(1) sector via its kinetic mixing with the hypercharge field strength, especially in view of dark matter stability. We use dedicated lattice simulations to determne the validity of the chiral low-energy effective theory and determine low-energy constants.

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Future Prospects of Event Generators (and news from Graz)

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I will review recent development of Monte Carlo event generators, and in particualr their core, parton shower, component. Several improvements on the accuracy of these algorithms, and their relation to and use in analytic resummation, have been developed and start to impact the design of phenomenological models as well as pave the way to the inclusion of electroweak and beyond the Standard Model effects. I will also summarize recent events and developments at the University of Graz.

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Hadronic light-by-light scattering and the muon g-2

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Recently the Fermilab g-2 experiment has confirmed the long standing discrepancy between experimental measurement and Standard Model prediction of the muon's anomalous magnetic moment. This makes it timely to improve also the Standard Model calculation both in precision and robustness. In this talk, I will review recent progress in this direction with particular emphasis on the dispersive evaluation of hadronic light-by-light scattering. I will also explain how this low-energy description can be connected with constraints from perturbative QCD and the operator product expansion to extend the prediction to all energy regimes relevant to g-2.

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Electroweak and Finite-Lifetime Corrections for Boosted Top Quark Production

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High-precision jet mass measurements for processes involving boosted top quark pair production relevant for the determination of the top quark mass eventually require the systematic inclusion of electroweak and finite lifetime effects. For boosted top quark initiated inclusive jets we apply an electroweak Soft-Collinear-Effective-Theory (SCET) framework that allows for a coherent resummation of electroweak Sudakov logarithms and finite-lifetime effects together with large logs from QCD. Apart from double top resonant effects, the factorization approach can also account for single-resonant effects which are related to the interference of final states originating from top quark decays and background processes leading to the top decay final state. Concretely we address electroweak effects in inclusive (hemisphere mass) top-dijet production at lepton colliders.

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Dark bi-portals at direct detection

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In the context of direct detection experiments, we consider the scenario where dark matter and Standard Model particles interact through two dark vector mediators, one light and one heavy with respect to the momentum transfer in the experiment. From such phenomenology interference effects arise at the level of scattering amplitudes, leading to novel shape features in the differential recoil spectra. We identify the region in parameters space for our model where such effects are

dominant and show that high-resolution experiments with composite targets of large atomic mass differences are ideal to explore these scenarios. Using a profile likelihood approach we investigate published results by the CRESST-III experiment and projections of future sensitivities for the COSINUS experiment to constrain the parameter space in our model, thereby showing the potential of such an analysis on a class of dark matter models which exhibit non-standard features in the recoil spectra.

Reference to paper: arXiv:2112.05668

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Search for long-lived dark photons and measurement of tt+gamma with CMS

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Low-energy effective description of dark Sp(4) theories

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Future Prospects of Event Generators (and news from Graz)

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Hadronic light-by-light scattering and the muon g-2

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Towards the ”Cosmic matters” full proposal

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TBA

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News from NuPECC

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I will present recent developments within NuPECC, e.g. the next planned JENAS seminar, an LoI of the European EIC community, and the start of the next Long Range Plan.

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Status of NUCLEUS, CRAB and ELOISE

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Coherent neutrino-nucleus scattering (CEvNS) is a promising new tool in the toolbox of electroweak precision measurements at low q-transfer. It will enable precise measurements of standard model (SM) physics but also the search for new physics beyond the SM.

The NUCLEUS experiment aims for the first fully coherent CEvNS detection at a new experimental site, the Very Near Site (VNS), between the two 4 GW_{th} reactor cores of the Chooz power plant. The signature of a CEvNS event will be a nuclear recoil at the 10 eV-scale inside a CaWO₄ target crystal. Already in its prototype phase, NUCLEUS successfully demonstrated an unprecedented low detection threshold of 19.7 eV. Currently, the installation of the first phase of NUCLEUS with 10 g of target mass at the VNS is under preparation.

CRAB plans to perform a low-energy calibration that is crucial for NUCLEUS' operation. Any experiment looking for nuclear recoils at the 10 eV-scale requires a completely new type of calibration because common radioactive sources are already too energetic. CRAB intends to develop a new calibration technique relying on the capture of thermal neutrons inside the CaWO4 target crystal under emission of gamma rays of O(10 MeV) followed by a nuclear recoil with a recoil energy of about 100 eV. Currently CRAB is in its R&D phase and prepares first prototype tests. At a later stage, measurements at the TRIGA reactor at TU Wien are planned.

The recently started ELOISE project will provide reliable simulations of electromagnetic particle interactions in CaWO₄ down to O(10eV) which is a necessity for NUCLEUS and CRAB. However, all standard simulation packages have higher applicability limits above 250 eV. Furthermore, even at this “high” energy, the accuracy is only assessed for few materials but not CaWO₄. Within a time scale of four years, ELOISE plans to tackle this issue in a two-stage process: First, to

evaluate the accuracy and second, if needed, to develop bespoken simulation code with increased accuracy.

In this contribution, we will first introduce the respective projects and highlight the Austrian contributions. Afterwards, we will report their current state before we finally will give an outlook to their future.

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Low Energy Dark Sector Searches at ATI

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Despite intense efforts to understand its nature, the dark sector proves elusive. Rising tensions in observational data with Λ-CDM add to long-standing problems that clearly indicate that the present standard model/GR picture of our universe is incomplete.
As the landscape of candidate theories is vast, one possible approach is to search for easily classifyable effective low-energy manifestations of higher energy theories. Kostelecky's standard model extension and the 16 potentials of Moody and Wilczek provide a suitable framework for that.
At ATI, we use two entirely different experiments - Cannex and qBounce - to search for various terms in this framework that each correspond to a different type of 'fifth' force. This talk gives an overview of the status and prospects of both experiments, and their possible contributions in the search for the nature of the dark sector.

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Annihilation studies with slow extracted antiprotons

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Antiproton-nucleus annihilation at rest is a process that is not well understood, despite substantial previous experimental and theoretical work on its different aspects. One of the main reasons for its complexity are final-state interactions (FSIs), i.e. the interactions between the primary mesons produced and the residual nucleus. A model that accounts for all the observed effects is still missing, as well as measurements at ultra-low energies, to validate the nuclear models in this regime. The antiproton-nucleus reactions at rest have a notable application in experiments at the Antiproton Decelerator (AD) at CERN, the purpose of which are atomic-physics and high-precision tests of fundamental symmetries [1,2,3,4,5]. They rely on simulation models that were developed for high energy physics, and behave unsatisfactorily at energies relevant for these experiments.

In this talk we will present the experimental work on antiproton-nucleus annihilation at the ASACUSA experiment at CERN using slow extracted antiprotons [6], including preliminary results from an initial study with carbon, molybdenum and gold nuclei. We will also introduce a recently started project aiming to measure, for individual annihilation events the multiplicity of the prongs, their angular distribution and their energy in almost 4Pi solid angle, for a representative set of about 15 different nuclei. The results are expected to have twofold application: on one hand, they will allow to validate new calculation within the INCL (Intranuclear Cascade of Liège) model [7] and to tune the Geant4 [8] simulations, thus providing the first reliable model for low energy antiproton-nucleus annihilation. On the other hand, they will yield quantitative and qualitative information about the final

state interactions and their evolution with the atomic number, potentially identifying novel nuclear physics process not yet included in the models.

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Dark matter searches with cryogenic detectors

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In the past decades, numerous experiments have emerged to unveil the nature of dark matter (DM), one of the most discussed open questions in modern particle physics. Direct detection experiments aim to measure scattering of relic DM particles off a target material. Cryogenic solid-state detectors equipped with transition edge sensors have proved to compete very well in the quest for sensitivity to low-mass DM particles, and provide unique properties for particle discrimination. HEPHY's rare event search group participates in two experiments using named technology, we introduce both in our talk:

The CRESST-III experiment, located in the Laboratori Nazionali del Gran Sasso (LNGS) provides some of the strongest upper limits on sub-GeV DM achieved today. In recent measurements, an excess signal was discovered below recoil energies of 200 eV. Similar signals were observed by multiple other experiments, however, a DM origin is unlikely. We discuss details and further plans in our talk.

The COSINUS experiment is specialized to verify the DAMA 13.7 σ DM signal claim, a mysterious result obtained from detectors with NaI targets, featuring the annual modulation expected from DM particles in the milky way. The tension of these results with many other measurements has motivated a set of new experiments to use NaI as target material. Among these experiments, COSINUS is the only one with the unique features provided by cryogenic detectors. The experiment is commissioned and currently being constructed at the LNGS. First data and results are expected in 2023/24.

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A geometric model in 3+1D space-time for electrodynamic phenomena

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With three rotational degrees of freedom of spatial Dreibeins and an appropriate Lagrangian we describe electromagnetic phenomena. Stable solitonic excitations we compare with the lightest fundamental electric charges, electrons and positrons. Two Goldstone bosons we relate to the properties

of photons. These particles are characterised by three topological quantum numbers, corresponding to charge, spin and photon number.

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Outreach Program FAKT + IDM + Strings, March - July 2022

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I describe planned outreach activities from March - July 2022 and how FAKT members could get involved in some of them.

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Dielectron production studies in nuclear collisions with the ALICE experiment

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The aim of this project is to study the production of dielectrons with the ALICE experiment at the LHC.
The production of low-mass dielectrons is one of the most promising tools for the understanding of the chiral symmetry restoration and of the thermodynamical properties of the Quark-Gluon plasma (QGP), created in ultra-relativistic heavy-ion collisions. Since such pairs do not interact strongly and are emitted during all stages of the collisions, they provide information about the full time evolution and dynamics of the medium created.
There are several sources of dielectrons. Most of them are not produced directly in the QGP but e.g. from decays of particles containing heavy (charm and beauty) quarks. So it is important to understand the origin of the observed dielectrons and measure the contributions connected to the QGP.
This measurement in Pb-Pb collisions is very challenging, due to the high background components. For this, we need to study dielectron production also in smaller systems, i.e. pp and p–Pb collisions, which are simpler environments where we expect the QGP not to be formed. Dielectron production in p-Pb collisions can be used to investigate initial state effects, due to the presence of cold nuclear matter in the collision.
We use Monte Carlo simulations to get the expected distributions of electrons from different sources, and the most up-to-date techniques for data analysis, in particular machine learning methods to separate efficiently background and signal components.

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Low Energy Dark Sector Searches at ATI

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Dielectron production studies in nuclear collisions with the ALICE experiment

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A geometric model in 3+1D space-time for electrodynamic phenomena

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Dark matter searches with cryogenic detectors

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News from Nupecc

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Status of NUCLEUS, CRAB and ELOISE

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AdS/QCD for hadrons and neutron stars

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Dark bi-portals at direct detection

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Electroweak and Finite-Lifetime Corrections for Boosted Top Quark Production

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AdS/QCD for hadrons and neutron stars

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AdS/QCD for hadrons and neutron stars

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After recalling the successes of simple AdS/QCD models in describing hadronic observables, results for the phase diagram at finite baryon chemical potential and the equation of state of dense nuclear matter as well as numeric simulations of neutron star mergers using the AdS/QCD are presented.

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Dielectron production studies in nuclear collisions with the ALICE experiment (cancelled)

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Low-energy effective description of dark Sp(4) theories

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FAKT matters

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Short break

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Belle developments (including towards the CoE)

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