Dark Matter Studies in Accelerator Physics

Tuesday, 26 September 2023 - Thursday, 28 September 2023

Padova

Book of Abstracts

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Welcom message from the Head of the Department of Physics and Astrophysics of the Padua University

Poster session / 35

Novel loop-diagrammatic approach to QCD θ parameter and application to the left-right model

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When the QCD axion is absent in full theory, the strong CP problem has to be explained by an additional mechanism, e.g., the left-right symmetry. Even though tree-level QCD θ̄ parameter is restricted by the mechanism, radiative corrections to θ̄ are mostly generated, which leads to a dangerous neutron electric dipole moment (EDM). The ordinary method for calculating the radiative θ̄ utilizes an equation θ̄ = −arg det mloop based on the q chiral rotations of complex quark masses. In this paper, we point out that when full theory includes extra heavy quarks, the ordinary method is unsettled for the extra quark contributions and does not contain its full radiative corrections. We formulate a novel method to calculate the radiative corrections to θ̄ through a direct loop-diagrammatic approach, which should be more robust than the ordinary one. As an application, we investigate the radiative θ̄ in the minimal left-right symmetric model. We first confirm a seminal result that two-loop level radiative θ̄ completely vanishes (corresponding to one- loop corrections to the quark mass matrices). Furthermore, we estimate the size of a non- vanishing radiative θ̄ at three-loop level. It is found that the resultant induced neutron EDM is comparable to the current experimental bound, and the expected size is restricted by the perturbative unitarity bound in the minimal left-right model.

Abstract for a poster:

all program topics can be contemplated

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Performance evaluation and electronics development of a new inner-station TGC detector for the ATLAS experiment at HL-LHC

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This poster presents the performance evaluation and electronics development of a new inner-station Thin Gap Chamber (TGC) detector for the ATLAS experiment at HL-LHC. The ATLAS experiment at HL-LHC aims to obtain up to 4000 fb^-1 of proton collision data to improve the sensitivity for the search of new particles, including candidates for dark matter. To select interesting events from the vast amount of data, upgrades for detectors and trigger systems are being developed. The TGC detectors located inside the magnetic field region will be changed from 2 layers to 3 layers to suppress low-momentum muons and charged particles not directly originating from proton-proton collisions. The first module of the new TGC detectors has been assembled, and the performance was evaluated with a DAQ system based on SoC devices. The noise level and detection efficiency have been obtained. In addition, the coincidence logic for the new TGC detectors has been developed and validated using simulation with straight tracks.

Abstract for a poster:

all program topics can be contemplated

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Excited bound states and their role in dark matter production

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[hep-ph/2308.01336]
We explore the impact of highly excited bound states on the evolution of number densities of new physics particles, specifically dark matter, in the early Universe. Focusing on dipole transitions within perturbative, unbroken gauge theories, we develop an efficient method for including around a million bound state formation and bound-to-bound transition processes. This enables us to examine partial-wave unitarity and accurately describe the freeze-out dynamics down to very low temperatures. In the non-Abelian case, we find that highly excited states can prevent the particles from freezing out, supporting a continuous depletion in the regime consistent with perturbativity and unitarity. We apply our formalism to a simplified dark matter model featuring a colored and electrically charged t-channel mediator. Our focus is on the regime of superWIMP production which is commonly characterized by a mediator freeze-out followed by its late decay into dark matter. In contrast, we find that excited states render mediator depletion efficient all the way until its decay, introducing a dependence of the dark matter density on the mediator lifetime as a novel feature. The impact on the viable dark matter mass can amount to an order of magnitude, relaxing constraints from Lyman-α observations.

Abstract for a poster:

all program topics can be contemplated

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Precise estimate of chargino decay

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The neutralinos are well-motivated dark matter candidates and have been studied extensively. If the mass difference between the neutralino and chargino is relatively small, then they can be detected as, for example, disappearing charged tracks or soft pions in collider experiments. The constraint on the chargino mass by those experiments strongly depends on the chargino lifetime and branching fractions. Hence, it is important to evaluate the decay rate precisely for a given mass difference.
We will discuss the up-to-date estimation of the decay branching and decay rate of the chargino including electroweak radiative corrections and expected errors. We will also mention the experimental implications provided by our results.

Abstract for a poster:

all program topics can be contemplated

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Constraints on the axion-like particles with Perseus data of MAGIC

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We present constraints on Axion-Like Particles using very-high-energy gamma-ray data from the MAGIC telescopes in the direction of the Perseus Galaxy Cluster. Axion is envisioned and theorized as a solution to the Strong CP problem of the Standard Model. As a generalization of the axion, axion-like particles are introduced. Depending on the specifics of their production mechanisms in the Early Universe, their properties make them viable candidates for Dark Matter particles. Traveling through the astrophysical environments embedded in magnetic fields, axion-like particles can interact with high-energy gamma rays. Depending on their coupling and mass, this would leave a distinctive signature in their spectra in the form of hardening, softening, or spectral distortions. Using the MAGIC dataset of two sources located in the Perseus cluster, we set constraints on the ALPs mass, reaching several hundred neV and improving the current limits on the strength of their coupling to photons.

Abstract for a poster:

all program topics can be contemplated

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Pseudodyons from dark topological defects

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We discuss a dark photon model with the successive symmetry breaking $\mathrm{SU}(2)_\mathrm{D} \to \mathrm{U}(1)_\mathrm{D} \to \mathbb{Z}_2$ in the dark sector. Various dark topological defects appear, such as monopoles, dyons, strings and beads. They are shown to induce QED electromagnetic fields through kinetic and magnetic mixing between $\mathrm{U}(1)_\mathrm{QED}$ and $\mathrm{U}(1)_\mathrm{D}$. In particular, dark beads appear from a distance to be particles with magnetic and electric charge, which we call pseudodyons.

Based on: Phys. Rev. D **108**, 035044

Abstract for a poster:

all program topics can be contemplated

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Searching for dark matter with GERDA and beyond

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The GERmanium Detector Array (GERDA) experiment at the Laboratori Nazionali del Gran Sasso (LNGS, Italy) searched for the lepton-number-violating neutrinoless double-beta ($0\nu\beta\beta$) decay of ^{76}Ge. The potential discovery of such a phenomenon would have significant implications in cosmology and particle physics, helping unrevealing the Majorana nature of neutrinos.

The main feature of the GERDA experimental design consisted of operating an array of bare germanium diodes enriched in ^{76}Ge in an active liquid argon shield. Starting in December 2015, Phase II physics run reached an unprecedentedly low background index of 5.2×10^{-4} counts/(keV kg yr) in the $0\nu\beta\beta$ signal region, collecting an exposure of 103.7 kg yr while being in a background-free regime.
The shielded environment and the excellent energy resolution of the operated Ge detectors made the experiment suitable for searching for others beyond the standard model processes. GERDA is sensitive to light exotic fermions, including sterile neutrinos in the mass range 100-900 keV/c^2. Here, the most stringent limits obtained with ^{76}Ge were set to date. Additionally, data collected by GERDA are ideal for probing the interaction of pseudoscalar and vector bosonic keV-scale dark matter candidates. Photoelectric absorptions and Compton scatterings of these candidates were included in the final interaction rate, leading to the most stringent coupling constraints in the mass region from 140 keV/c^2 to twice the mass of the electron.

This contribution will review the dark matter searches performed at GERDA, providing on top of that an overview of the broader dark matter program of the next LEGEND (Large Enriched Germanium Detector for Neutrinoless $\beta\beta$ Decay) experiment project.

Abstract for a poster:

all program topics can be contemplated