LHCb FIP Physics Workshop

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CERN

Book of Abstracts

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Revised phenomenology of models with particles in GeV mass range

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In this talk, I will discuss the phenomenology of various benchmark models proposed by the Physics Beyond Colliders initiative to explore new physics in the GeV mass range - HNLs, dark photons, axion-like particles, and Higgs-like scalars, as well as the models of other vector mediators and elastic/inelastic dark matter. I will consider the recent advances in the phenomenology description of these models, paying special attention to the theoretical uncertainty, which may reach a few orders of magnitude depending on the model. I will then show how these uncertainties affect the model's parameter space, considering past and future laboratory experiments, including the Downstream algorithm@LHCb.

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Benchmark models for heavy neutral lepton searches

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The sensitivity of direct searches for heavy neutral leptons (HNLs) in accelerator-based experiments depends strongly on the particles properties. Commonly used benchmark scenarios are important to ensure comparability and consistency between experimental searches, reinterpretations, and sensitivity studies for different facilities.
In models where the HNLs are primarily produced and decay through the weak interaction, benchmarks are in particular defined by fixing the relative strengths of their mixing with SM neutrinos of different flavours, and the interpretation of experimental data is known to strongly depend on those ratios.
The commonly used benchmarks in which a single HNL flavour exclusively interacts with one Standard Model generation do not reflect what is found in realistic neutrino mass models. We identify two additional benchmarks for accelerator-based direct HNL searches, which we
primarily select based on the requirement to provide a better approximation for the phenomenology of realistic neutrino mass models in view of present and future neutrino oscillation data.

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Multi-Component Dark Matter from Minimal Flavor Violation

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Minimal Flavor Violation (MFV) offers an appealing framework for exploring physics beyond the Standard Model. Interestingly, within the MFV framework, a new colorless field that transforms non-trivially under a global SU(3)3 quark flavor group can naturally be stable. Such a new field is thus a promising dark matter candidate, provided it is electrically neutral. We extend the MFV framework for dark matter and demonstrate that dark matter can naturally be multi-component across a broad parameter space. For illustration, we consider a gauge singlet, flavor triplet scalar field and identify parameter spaces for multi-component dark matter, where only the lightest flavor component is absolutely stable and heavy flavor components are decaying with lifetimes sufficiently longer than the age of the universe. Phenomenological, cosmological and astrophysical aspects of multi-component flavored dark matter are briefly discussed.

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Dark Vector Splitting Functions in Proton Bremsstrahlung

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Exclusive displaced hadronic decay of light scalars at LHCb

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I will discuss the prospects for LHCb to detect light scalars that decay into a pair of displaced kaons, based on JHEP 01 (2020) 115 (arXiv:1910.05225). It is important to note that the Kaon final state is acting as an illustrative example, and depending on the specific scalar mass other decay channels are within LHCb range (e.g. pions, D-mesons).

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Heavy neutrino-antineutrino oscillations

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Collider detectable heavy neutrinos predicted by type I seesaw models are generically expected to be pseudo-Dirac pairs of two almost mass degenerate Majorana neutrinos. The tiny mass splitting is not only directly related to the masses of the light neutrinos but also leads to heavy neutrino-antineutrino oscillations. The observation of such oscillations would allow to quantify the amount of lepton number violation introduce by the seesaw.

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Not-so-inelastic Dark Matter

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Models of inelastic (or pseudo-Dirac) Dark Matter (DM) commonly assume an accidental symmetry between the left-handed and right-handed mass terms in order to suppress diagonal couplings. We point out that this symmetry is unnecessary, because for Majorana fermions the diagonal couplings are not strongly constrained. Removing the requirement of such an accidental ad-hoc symmetry instead relaxes the relic density constraint due to additional annihilation modes and provides a smooth transition between pseudo-Dirac and Majorana dark matter.

In the talk, I will introduce a simple UV-complete model realizing the new asymmetric set-up. Then, I will explain how traditional constraints from (in)direct detection, beam dump experiments and colliders are modified indicating two viable mass regions for the DM particle, around a few hundred MeV and around a few GeV. The former region can be fully tested by near-future analyses of current running high energy experiments, while the latter turns out to be challenging to explore even with future experiments.

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Hadronic decay rate of a scalar within GDA approach

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We describe recently suggested new approach to calculate hadronic branching ratio of a 1-GeV mass scale scalar coupled to the Standard Model particles via Higgs portal. The approach is based on application of the Generalised Distribution Amplitude. The required matrix element is the quark energy momentum tensor between vacuum and S-wave state of a pion pair. It is extracted from experimental data on pion pair production by one real and one virtual photons. We evaluate the decay rates, estimate the uncertainties and compare the result with those in literature obtained with alternative approaches.

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Heavy neutrino-antineutrino oscillations

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Dark photon production in proton bremsstrahlung

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In the talk, I will review the production of dark photons with masses 0.4-1.8 GeV in pp-collisions. First, I will briefly summarize the existing approaches to calculating the cross sections of both elastic and inelastic proton bremsstrahlung. Next, I will consider the non-zero momentum transfer between the protons during elastic bremsstrahlung and show that our results agree well with the Weizsacker-Williams approximation for proton beams. Additionally, I will present our results on the factorization of the inelastic proton bremsstrahlung cross section. In our recent work we have included an earlier overlooked contribution to the ppA' vertex related to the Pauli form factor, and thus obtained two new splitting functions. To illustrate the importance of these corrections, I will show the updated sensitivity of the T2K, DUNE and SHiP experiments to visible decays of dark photons. The talk is based on arXiv preprints 2306.15800, 2409.11089 and 2409.11386.

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Production of new physics particles via mixing with neutral mesons

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We revise the production of hypothetical new physics particles in the GeV range via their mixing with neutral mesons —a channel that is important for various extensions of the Standard Model. To do this, we implement the sub-processes of the production via the string fragmentation and decays of heavier mesons in **pythia8** and study how the overall flux and kinematic distributions depend on the particle's mass. We find that our results may differ from the approximate description used previously in the literature by an order of magnitude. We also discuss the importance of the production via mixing for axion-like particles and vector mediators.

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New Mesogenesis discovery opportunities at LHCb

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Mesogenesis is a class of mechanisms for generating the baryon asymmetry and the dark matter abundance of our Universe. Mesogenesis leverages the CP violation within neutral or charged Standard Model meson systems which subsequently decay into a baryon and dark sector particle. The first such mechanism was introduced in 2018; neutral B-Mesogenesis leverages the CP violation in neutral B meson oscillations and leads to a myriad of signals linking the baryon asymmetry to experimental observables e.g. the decay of b-flavored hadrans into mesons and missing energy (see the 2022 Stealth Physics at LHCb white paper). Since then four other mechanisms have been introduced which use the CP violation in charged D, B, and Bc mesons to generate the baryon asymmetry. Each mechanism leads to a variety of direct and indirect signals at LHCb. After reviewing Mesogenesis I will summarize the theoretical progress made since the 2022 white paper. I will then discuss the specific signals arising in each mechanism of Mesogenesis that would be most relevant for LHCb.

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Production of new physics particles via mixing with neutral mesons

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New Mesogenesis discovery opportunities at LHCb

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New pathways for ALP discovery

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Various Composite Higgs Models predict the existence of additional light scalars that are difficult to search for in standard experimental setups such as ATLAS or CMS. LHCb offers a unique opportunity to constraint these models, targeting various channels such as muon pairs, tau pairs, di-photons, but also charmed and bottom mesons. We review previous work (2106.12615) done in this context, and point to new possibilities opened by the recent upgrades and extension of Run3.

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