WIFAI 2024

Tuesday, 12 November 2024 - Friday, 15 November 2024

Palazzo Hercolani

Book of Abstracts

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cLFV ALP search with MEG II

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This study focuses on the Single Event Sensitivity (SES) of the MEGII apparatus concerning a muon's charged Lepton Flavour Violating (cLFV) three-body decay involving an Axion-like particle (ALP). Many theories beyond the Standard Model (SM) predict this decay, which does not exist in the SM. Observing this decay would provide compelling evidence of New Physics.

The decay under investigation is $\mu^+ \longrightarrow e^+ a \gamma$ in a V-A chirality configuration. Monte Carlo simulations were conducted within the GEANT4 environment, and data were analyzed using the ROOT-Cern framework. It was determined that a low muon beam rate intensity (Rμ ⊠ 1×10^{6} μ/s) and a low photon energy (10 MeV) trigger selection can maximize experimental efficiency and SES. A few days of data collection are sufficient to improve upon the best results for this decay using this optimal configuration.

A sensitivity limit on the ALP decay constant of $F_{v-a} \geq 1.52 \times 10^{9}$ GeV @ 95% C.L. was estimated with the statistics collected over the past three years by the MEG collaboration, amounting to 8.7 days of data intake. This limit is more stringent than the current best result. This study demonstrates how this search could enhance the world-leading results in the search for this decay.

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Search for higgsinos in compressed mass spectra using a low-momentum displaced track with the ATLAS detector

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Supersymmetry (SUSY) models with nearly mass-degenerate higgsinos could solve the hierarchy problem as well as offer a suitable dark matter candidate consistent with the observed thermal-relic dark matter density. However, the detection of SUSY higgsinos at the LHC remains challenging especially if their mass-splitting is O(1 GeV) or lower. A novel search using proton-proton collision data collected by the ATLAS detector at a center-of-mass energy $\sqrt{s} = 13$ TeV and corresponding to 140 fb^{-1} of integrated luminosity is presented. This search targets final states with an energetic jet, missing transverse momentum and a low-momentum track with a large transverse impact parameter. Results are interpreted in terms of SUSY simplified models and mass-splittings between the lightest charged and neutral higgsinos from 0.3 GeV to 0.9 GeV are excluded up to 170 GeV of higgsino mass for the first time since the LEP era.

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New insights on the physical Riemann surfaces of the ratio G_E^Λ/G_M^Λ

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Recently, the BESIII collaboration has produced new data for the Λ baryon electric and magnetic form factor's ratio G_E^Λ/G_M^Λ with high accuracy. By assuming the analyticity of the baryon form factors, a dispersive procedure can be used can be used to determine the modulus and the phase determination of the form factor's ratio, based on a set of theoretical an experimental constraints. Different classes of solutions are taken into account, each with its probability of occurrence. The results are used to gain insight on interesting properties of the baryon, such as the number of zeroes on the electric form factor G_E^Λ and the charge radius of the Λ baryon.

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Connecting low- and high-energy observables at future colliders

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Establishing the physics potential of future colliders is one of the main objectives of the HEP community in the coming years. The aim is on the one hand to consolidate the physics expectations from a circular collider working between the Z-pole and the ttbar threshold (FCC-ee at CERN) and exploring completely new avenues and technologies such as a multi-TeV e+e- or even mu+mu- collider. In light of that, this work aims at connecting the potentialities of low-energy experiments (e.g. the muon g-2 experiment at Fermilab, Belle II at KEK, MEG-II at PSI) with the possibilities that will open at precision e+e- colliders. The main point is to access information on the SM which is currently out of reach. In particular, an initial study is aimed at the phenomenology of Lepton Flavor Violation (LFV) where we have investigated the reaches of low-energy experiments as well as high-energy experiments (like the HL-LHC and future colliders). Assuming heavy New Physics (NP), the study of LFV effects is based on tools and techniques of effective field theories. In particular, we evaluated the decay rates for several LFV processes as well as the cross sections for the LFV high-energy scatterings in the SMEFT. In addition, we placed bounds on the fundamental parameters of the NP framework, showing that new infrastructure can better constrain the parameter space than low-energy experiments, specifically for observables related to tau production.

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Deep Learning Techniques for Particle Tracking in NA62

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The NA62 experiment at the Super Proton Synchrotron at CERN is designed to measure the branching ratio of the ultra-rare channel $K^+ \to \pi^+\nu\bar{\nu}$ with BR = $(8.6 \pm 0.42) \times 10^{-11}$. The GigaTracker, a silicon pixel detector, measures the momentum and direction of incoming hadron beam particles at a rate of 750 MHz.
The success of the experiment relies on effectively managing pile-up, temporal matching, and vertex reconstruction between beam kaons and decay pions, a challenging task due to the combinatorial

track-building approach currently adopted. This research is focused on integrating machine learning best practices in the current modeling strategies applied in the NA62 experiment. In this study, we present an extensive evaluation of different deep learning architectures for particle tracking, addressing the limitations of inefficient methods and showing the most effective approaches. In particular, we designed and implemented three distinct approaches based on Multi-Layer Perceptron, Transformer and Graph Neural Network. All the methods were evaluated on the basis of the efficiency, the purity and the fake tracks. The best results showed high efficiency and purity levels with a low fake tracks ratio.

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Status of $B \to h^+h'^-$ decays at LHCb

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The LHCb experiment is designed to perform flavour physics measurements at the Large Hadron Collider. The latest results obtained by the LHCb experiment in studying $H_b \to h^+h'^-$ decays, where H_b can be either a B^0 meson, a B^0_s meson or a Λ^0_b baryon, while h and h' stand for π, K or p, will be presented. Such decays are sensitive probes of the Cabibbo-Kobayashi-Maskawa matrix and have the potential to reveal the presence of New Physics.

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Status of the MUonE experiment

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The MUonE experiment aims to measure the hadronic vacuum polarization contribution to the muon anomaly a_μ^{HLO} better than 1%. An innovative approach is proposed, using elastic scattering of 160 GeV muons on atomic electrons in a low-Z target. A precision of 10ppm on the angular distribution of the scattering particles in the muon-electron scattering process is required. The M2 beamline at CERN
provides the necessary intensity to reach the statistical goal in few years of data taking. In summer 2024 a Proposal has been sent to the CERN SPSC asking for the Phase 1 of MUonE to be performed with a small scale experiment in 2025. This is expected to obtain a first measurement of the hadronic contribution to the running QED coupling, $\Delta\alpha_{had}$, with a 20% statistical uncertainty. We will present the progress achieved in the last years, the current status, and the future plans of the experiment.

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An FPGA-based tracking system for accelerating event reconstruction at LHCb

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Studying physics at high intensity is requiring HEP experiments to continuously push the frontier of data acquisition. With ever increasing data rates, reconstruction and trigger systems need to be reconsidered up to their fundamental architectures and new solutions have to be sought after. The "Artificial Retina"architecture answers this call, offering a high-parallelised tracking system implemented on FPGAs, exploiting their low latency response, low power consumption and high bandwidth capability.

LHCb, with its bandwidth outputted by the front-end being the highest in the field, is planning to implement such system for the upcoming LHC Run 4. The aim is offering, before the event-building, pre-reconstructed tracks (primitives) from the SciFi subdetector to the trigger system. As of consequence, time and resources required for event reconstruction are saved up and can be redirected to more complex tasks.

The feasibility of the Retina system is supported by results yielded both by a real-size demonstrator, reconstructing a portion of a LHCb subtetector, and in-depth studies of the physics performance and resource gains reachable with its embedding into the LHCb DAQ system. Alongside these results, its linear scalability w.r.t. the instantaneous luminosity is presented as well, showing its appeal for future HL-LHC and possibly beyond.

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A hydrogen-filled Cherenkov detector for Kaon tagging at the NA62 experiment at CERN

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To ensure the necessary precision for the $K \to \pi\nu\bar{\nu}$ analysis, the NA62 kaon identification detector is required to have a time resolution better than 100 ps, at least 95% kaon tagging efficiency, and a pion mis-identification probability of less than 10^{-4}. For data collected up to 2022, the tagging of kaons in the NA62 beam has been performed with a Cherenkov detector filled with nitrogen gas as radiator. In 2023 a new detector using hydrogen (CEDAR-H) as the Cherenkov radiator has been built for the kaon identification in NA62. The CEDAR-H leads to a reduction of beam particle scattering

in the gas and background from pile-up events in the detector. The CEDAR-H was commissioned in a two-weeks test beam at CERN at the end of 2022, and approved by the NA62 collaboration to be used in the data taking from 2023. The test beam results, commissioning and detector performance on the NA62 beam line are presented in this talk.

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Time resolution studies for the future LHCb Electromagnetic Calorimeter

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During Runs 5 and 6, the LHCb experiment at CERN will operate at a luminosity up to 1.5×10^{34} cm^{-2}s^{-1}, requiring substantial upgrades to its Electromagnetic Calorimeter (ECAL) to handle high radiation doses and achieve time resolutions of few tens of picoseconds mitigating pile-up effects.

The detector under development is a Spaghetti Calorimeter (SpaCal) composed of scintillating fibres (polystyrene or garnet crystals) in a dense absorber (lead or tungsten). Ongoing investigations are focused on the photodetectors (PMTs) selection and their impact on the overall timing performance.

Simulation studies of a lead-polystyrene module show that fast PMTs result in worse time resolutions due to the longitudinal showers' fluctuations, which introduce a bias in the time stamps defined by the Constant Fraction Discriminator (CFD) algorithm. A correction procedure has been developed to remove such bias, improving the time resolution by few tens of picoseconds. Additionally, a correlation between signal rise time and shower depth has been observed.

Data from a test beam campaign conducted at the CERN SPS in June 2024 have been analysed to measure the timing resolution of two tungsten-polystyrene SpaCal prototypes, comparing four PMT models and two fibre types. By exploiting a rise-time-based correction procedure, time resolutions below 20 ps at high energies have been reached, with the fastest PMTs undergoing larger corrections, as expected from simulations.

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Measurement of the differential distributions of Bs0 -> Ds* mu nu decay with the LHCb detector

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This analysis aims to a comprehensive study of the decay kinematics of the semileptonic decay $B_s^0 \to D_s^* \mu\nu$, with $D_s^* \to D_s\gamma$ and $D_s \to K^- K^+ \pi$, using data collected by LHCb in Run 2. The study of semileptonic decays of B_s^0 meson plays a crucial role in the validation of the Standard Model, since these help to constrain the parameters of the CKM matrix, to test Lepton Flavour Universality, to understand CP violation and to investigate New Physics effects. With this work a first measurement of the form factors describing the B_s^0 meson semileptonic decay is provided, performing a four-dimensional binned fit in the space given by the variables describing the decay kinematics, namely q^2, $\cos\theta_l$, $\cos\theta_d$ and χ. Taking into account the detector acceptance, as well as the reconstruction efficiencies and the resolution effects, the full differential distribution is evaluated; then, a fit to this distribution is performed using different parameterizations for the $B_s^0 \to D_s^*$ transition form factors and including a term for New Physics contribution. Furthermore, the unfolded distributions are also computed and compared with the theoretical predictions and the Belle-II experiment results. Finally, using the unfolded shapes, a model-independent approach is tested and its compatibility with the model-dependent results is studied.

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The role of neutral kaons in the high-precision measurements of CP violation in the charm sector

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High-precision measurements of CP violation in charm decays are of paramount importance, since physical CP-violating asymmetries are highly suppressed in the Standard Model, at the level of (10^{-3}–10^{-4}) and even lower for the time-dependent observables.

The first observation of CP violation in the charm sector, with the famous ΔA_{CP} mechanism, $\Delta A_{CP} = a_d(KK) - a_d(\pi\pi) = (-15.4 \pm 2.9) \times 10^{-4}$, is still highly debated, as it is not yet clear whether it has a standard or non-standard nature. Any new observation of CP violation therefore would provide valuable theoretical insights to solve the current puzzle.

These high-precision measurements require extreme care as very small experimental biases, such as charge asymmetric effects in particle production and detection, must be accounted for with very high accuracy. This experimental challenge, which is already extremely difficult and complex today, will become even more so with the data sample that the LHCb Upgrade I experiment is collecting during LHC Run 3 and 4. It will be particularly challenging during its second upgrade phase, at very high instantaneous luminosity in LHC Run 5 and beyond, where an unprecedented data sample of heavy-flavour decays, amounting to approximately 300 fb^{-1} of integrated luminosity, will be collected.

The most common approaches to precisely bound or measure such biases rely on fully data-driven methods, typically using one or more calibration channels where the CP violation is expected to be much smaller than the experimental uncertainties involved. Some of the more promising decay modes to be used as references in the high-precision regime are the $D^0 \to K_S^0 \pi^+\pi^-$ and the $D^+ \to K_S^0 \pi^+$ decays.

The particle-antiparticle asymmetry in these channels is highly influenced by the time evolution of neutral kaons, which can travel several metres in the detector before decaying. The $K^0 - \overline{K}^0$ mixing and interactions of neutral kaons with the detector create an asymmetry in the detection of the K_S^0 produced by D or $\overline{D}$ mesons, which must be modelled and precisely determined using the abundant samples available of neutral and charged D mesons. This talk presents the extension of the current methods employed to determine the neutral kaon asymmetry in a very high-precision regime, and

its application to the ongoing and future searches for CP violation in the charm sector at the LHCb experiment.

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Silicon Pixel Detector Development for Director Measurement of Charm Baryon Dipole Moments at LHC

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TWOCRYST is a proof-of-principle test in Run3 for the proposed ALADDIN experiment, for the direct measurement the dipole moments of charm baryons at LHC. A silicon pixel detector for the measurement of signal charm baryons is under construction. It is based on the LHCb VELO pixel sensors and readout system and it will work in the secondary vacuum of a Roman Pot, positioned inside the LHC beam pipe. The design and integration of the pixel detector within the Roman Pot will be discussed, as well as the expected performance.

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The LHCb Upstream Tracker: operations and performance in Run3

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The Upstream Tracker is a critical component of the tracking system in the LHCb Upgrade I detector. It has been commissioned and is now operational, collecting data during Run 3. The tracker enhances the reconstruction of charged particle tracks and long-lived particles, such as Λ and K^0_S, thereby improving the performance of the software trigger. This presentation will cover experiences with detector operations and data acquisition, along with the performance results based on Run 3 data.

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Rare Decays: Introduction

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Probing new physics with rare decays

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Status and prospects of rare decay searches at LHCb

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20+5 min

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Status and prospects of rare decay searches at Belle II

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20+5 min

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Evolution of trigger and TDAQ system for rare decay searches at LHCb

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20+5 min

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Reviewing the Role of Lattice QCD for Rare Decays: Achievements and Future Challenges

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20+5 min

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Status and prospects of rare decay searches at NA62

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Status and prospects of rare decay searches at ATLAS and CMS

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20+5 min

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Prospects for searches of rare decays in the flavor sector at future colliders

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20+5 min

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Search for CP violation in charm barion decays

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The LHCb experiment was designed to play a crucial role in particle physics and flavour physics research. Since its beginning, LHCb has performed high-precision measurements of CP violation in decays of hadrons containing the charm quark, observing direct CP violation in the decays of the D0 meson into two charged particles for the first time in 2019. However, CP violation in baryon decays has never been observed, and this measurement complements various measurements made to date. These measurements are a crucial aspect of the Standard Model for understanding baryon asymmetry in the universe and identifying signals of New Physics. This contribution presents recent developments in the measurement of direct CP violation, ΔA_{CP}, of the Λ_c^+ baryon in single Cabibbo-suppressed decays $\Lambda_c^+ \to pK^+K^-$ and $\Lambda_c^+ \to p\pi^+\pi^-$, using data collected by LHCb during Run 2. This analysis will improve the precision of ΔA_{CP} by an order of magnitude with respect to the previous measurement made by LHCb with data from Run 1.

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Introduction

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Theoretical review on Light Meson Spectroscopy

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Experimental review on Light Meson Spectroscopy

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Spectroscopy of open flavor hadrons

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Spectroscopy of new heavy baryons

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The new inner tracker CGEM-IT of BESIII

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Crystal calorimetry for cLFV

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