# Portorož 2025: Particle Physics from Early Universe to Future Colliders

Monday 21 April 2025 - Friday 25 April 2025

# Book of Abstracts

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## Searches for light new physics at Mu3e with displaced vertices

**Author:** Michele Tammaro[None]

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A new set of experiments will deliver in the next few years unprecedented sensitivity to Lepton Flavor Violating (LFV) muon decays. Mu3e, proposed at PSI (Switzerland), will focus on observing $\mu \to 3e$ decays, with a projected target of $10^{15}$ muons decaying at rest, and excellent electron/positron track reconstruction. In this talk I will review the current and future statues of these probes, and I will delve in the potential of Mu3e to search for New Physics. In particular, I will show that Mu3e has unique sensitivity for new light particles decaying displaced and produced in two-body, three-body and four-body decays of the muon, providing a complimentary opportunity to probe large portions of unexplored parameter space.

**Early universe / 5**

## Leptogenesis during a first-order cosmological phase transition

**Author:** Stephane Lavignac[1]

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In this talk, I will discuss the generation of a lepton asymmetry during a first-order cosmological phase transition at which the sterile neutrinos of the seesaw mechanism acquire their masses. Contrary to previous works who studied the same problem, we compute the lepton asymmetry by solving quantum kinetic equations derived from nonequilibrium quantum field theory, which take into account the time variation of the sterile neutrino masses and the subsequent particle creation.
We consider two scenarios: (i) the so-called mass gain mechanism, in which the origin of the asymmetry is the decays of the sterile neutrinos brought strongly out of equilibrium by the phase transition; (ii) the ARS mechanism, in which the asymmetry is produced by the oscillations of GeV-scale sterile neutrinos. In both cases, we identify the region of parameter space leading to successful leptogenesis.

**Collider / 6**

## Enhancing DM searches at the LHC with Machine Learning

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Despite extensive efforts, the fundamental nature of Dark Matter remains unknown. Collider searches provide a unique window into potential Dark Matter interactions, particularly through the "monojet" channel—characterized by a small number of energetic jets recoiling against significant missing transverse momentum in a lepton-free final state. Traditional analysis methods often struggle to identify subtle signals of Dark Matter amidst overwhelming Standard Model backgrounds. In this talk, I will present a novel approach based on Graph Neural Networks (GNNs) that integrates high-level kinematic variables with low-level particle information to enhance sensitivity in monojet

searches. Using benchmark theoretical scenarios where the Dark Matter candidate is a supersymmetric neutralino, we systematically evaluate the effectiveness of our method, derive implications for the underlying model, and interpret the network's learned features.

**Wine & cheese poster session / 8**

## Neutrino Masses and Nucleon Decay as Probes of Standard Model Linear Extensions

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Baryon and lepton number are excellent low-energy symmetries of the Standard Model (SM) that tightly constrain the form of its extensions. In this work, we investigate the possibility that these accidental symmetries are violated in the deep UV, in such a way that one multiple necessary for their violation lives at an intermediate energy M above the electroweak scale. We write down the simplest effective operators containing each multiplet that may couple linearly to the SM at the renormalisable level and estimate the dominant contribution of the underlying UV model to the pertinent operators in the SMEFT: the dimension-5 Weinberg operator and the baryon-number-violating operators up to dimension 7. Our results are bounds on the scale M for each multiplet–operator pair, derived from neutrino-oscillation data as well as current and prospective nucleon-decay searches. In addition, we advocate that our framework provides a convenient and digestible way of organising the space of UV models that violate these symmetries.

**Flavor / 10**

## Heavy sterile neutrinos contributions to the angular distribution of $B \to D^* \ell \nu$ decays

**Author:** Marco Fedele[None]

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In this talk, I will review the bounds that can be inferred on New Physics couplings to heavy sterile neutrinos $N$ from the recent measurements performed by the Belle collaboration of the angular analysis of $B \to D^* \ell \nu$ decays, with $\ell = e, \mu$. Indeed, a sterile neutrino N may lead to competing $B \to D^* \ell N$ decays and Belle might have measured an incoherent sum of these two independent channels. After reviewing the theoretical formalism required to describe this phenomenon in full generality, I will first discuss the bump hunt in the $M^2_{\rm miss}$ Belle distribution performed to search for evidences of an additional massive neutrino, which produced a small hint at $M^2_{\rm miss} \sim (354\ \mathrm{MeV})^2$. However, the Belle angular analysis is sensitive to N masses up to $O(50\ \mathrm{MeV})$, preventing us to further inspect this hint. I will therefore review the studied potential impact of this additional channel in the allowed mass range on the measured angular distributions and extract model-independent bounds on the new-physics couplings which could mediate such an interaction. In particular, in the mass window that we inspected, I will give the most stringent bounds for vector and left-handed scalar operators to date.

**Flavor / 11**

## The role of nonperturbative dynamics in D-meson mixing

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The theoretical predictions for the $D - \bar{D}$ mixing parameters fall significantly short of experimental measurements, with discrepancies spanning several orders of magnitude. This divergence is largely attributed to the Glashow–Iliopoulos–Maiani (GIM) mechanism, which suppresses leading-order contributions. However, higher-order corrections and nonperturbative effects have the potential to mitigate this suppression, particularly through flavor SU(3) symmetry breaking. In this work, we explore the long-distance contributions arising from nonlocal QCD condensates, incorporating for the first time the impact of mixed condensates within multiple models. Our results demonstrate an improvement in the predicted values of $D - \bar{D}$ mixing parameters by an order of magnitude, providing insights into the role of nonperturbative QCD dynamics. While the theoretical estimates remain below experimental values, this study represents a crucial step toward bridging the gap between theory and observation, highlighting the importance of nonlocal QCD effects in understanding $D - \bar{D}$ mixing.

**BSM / 12**

## Gravothermalizing into primordial black holes, boson stars, and cannibal stars

**Author:** Takeshi Kobayashi[None]

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I will present a novel mechanism for producing primordial black holes (and beyond) in the post-inflation universe. The mechanism invokes an epoch of early matter domination, and self-interactions of the dominating particles, which trigger a gravothermal collapse of halos into black holes. The gravothermal collapse also gives rise to other exotic compact objects including boson stars, as well as "cannibal stars" which are supported by heat produced in number-changing reactions.

**Early universe / 13**

## Probing Ultralight Dark Matter with Quantum Clocks

**Author:** Eric Madge Pimentel[1]

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Ultralight dark matter can induce oscillations in fundamental constants of nature, such as the fine-structure constant, the strength of the strong interaction, and particle masses. These oscillations can be probed through highly precise measurements of transition frequencies in atomic, molecular, and nuclear systems. This talk will focus on the potential for detecting ultralight dark matter that predominantly couples to nuclei, a particularly challenging aspect to probe using atomic transitions alone. While atomic systems have limitations in detecting such couplings, molecular rotational and

vibrational transitions offer a promising avenue for testing these theories. I will present an analysis of the potential constraints on dark matter nuclear interactions derived from frequency comparisons between a molecular iodine ion and a calcium ion clock, demonstrating that such experiments can explore previously untested regions of parameter space. Looking ahead, the development of nuclear clocks, particularly following the recent breakthrough in laser excitation of the nuclear transition in Th-229, promises even greater sensitivity. While full-fledged nuclear clocks are still in their early stages, I will show that spectroscopic data from these pioneering efforts already provide the opportunity to derive initial constraints on ultralight dark matter.

**Axion-like particles / 14**

## Imperfect Axion Precludes the Domain Wall Problem

**Author:** Yue Zhang[None]

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The QCD axion does not need to be a perfect pseudoscalar for solving the strong CP problem. I will discuss a cosmological role of such imperfectness by solving the domain wall problem that prevails in post-inflationary axion models with discrete symmetry. Effective operators, where the Peccei-Quinn field linearly couples to Standard Model particles, can provide a dynamical solution to the domain wall problem and lead to useful predictions in the axion mass range and interactions.

**Collider / 15**

## Machine Learning for Hadronization

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A fundamental part of event generation, hadronization is currently simulated with the help of fine-tuned empirical models. Motivated by the difficulties of these models, in this talk I'll present MLHAD: a proposed alternative where the empirical model is replaced by a surrogate Machine Learning-based model to be ultimately data-trainable. I'll detail the current stage of development and discuss challenges and possible ways forward.

**Early universe / 16**

## Majoron dark matter and leptogenesis from proton stability

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We revisit a class of lepton-flavor non-universal U(1) gauge extensions of the Standard Model, first introduced in~\cite{Davighi:2022qgb}, which provides a subtle mechanism to simultaneously accommodate the observed neutrino masses and mixing angles via a high-scale seesaw while predicting exact proton stability to all orders in the effective field theory, ensured by a residual discrete gauge symmetry at low energies. The minimal thermal leptogenesis scenario is naturally realized. In addition, an inevitable consequence of this framework is the existence of a light pseudo-Goldstone

boson. We examine the phenomenological implications of this boson, with a particular focus on its potential role as Majoron dark matter.

**Early universe / 17**

## Precise computation of thermal-phase-transition parameters

**Author:** Mikael Chala[1]

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I will discuss recent progress in the determination of parameters of thermal-phase transitions, relevant for describing production of gravitational wave backgrounds in the early Universe, using effective field theory (EFT) methods. I will highlight the importance of including previously neglected terms in the EFT expansion and the difficulties and solutions for computing the corresponding corrections to the action around non-homogeneous field configurations (e.g. bounce).

**Early universe / 18**

## Cosmic Colliders: High Energy Physics with First-Order Phase Transitions

**Author:** Bibhushan Shakya[None]

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Vacuum decay through runaway first order phase transitions presents a unique opportunity for particle physics and cosmology: collisions of vacuum bubbles can act as cosmic scale high energy colliders close to the Planck scale, providing access to high energy physics far beyond any temperature or energy scale ever reached in the history of our Universe. This talk will cover recent developments and challenges in the physics for understanding such frameworks, as well as their broad applications for particle physics and cosmology, from dark matter to leptogenesis to gravitational waves.

**Flavor / 19**

## Unitarity bounds for b-hadron decays

**Author:** Nico Gubernari[1]

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We derive a generalisation of the Boyd-Grinstein-Lebed (BGL) parametrization. Most form factors (FFs) in $b$-hadron decays exhibit additional branch cuts — namely subthreshold and anomalous branch cuts — beyond the "standard" unitarity cut. These additional cuts cannot be adequately accounted for by the BGL parametrization. For instance, these cuts arise in the FFs for $B \to D^{(*)}$, $B \to K^{(*)}$, and $\Lambda_b \to \Lambda$ processes, which are particularly relevant from a phenomenological standpoint. We demonstrate how to parametrize such FFs and derive unitarity bounds in the presence of subthreshold and/or anomalous branch cuts. Our work paves the way for a wide range of new FF analyses based solely on first principles, thereby minimising systematic uncertainties.

**Flavor / 20**

## Leptoquark-fermion couplings at low and high energy

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Any study of leptoquark (LQ) searches at colliders must include constraints on the parameter space from low-energy physics. I show that radiative corrections to the leptoquark-fermion couplings can be large and have a particularly simple pattern: If only one LQ species is present, the radiative corrections are universal and deplete all LQ-fermion couplings probed at high energies (in on-shell LQ decays) by the same factor w.r.t. their low-energy values probed in flavour observables. I present numerical examples for choices of parameters mitigating the flavour anomalies, including the fixed-point solutions of the renormalisation group evolution with lepton-flavour universality.

**Axion-like particles / 21**

## Axion experiments

**Author:** Giuseppe Ruoso[None]

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The axion was originally introduced in the 70s to explain the absence of CP-violating effects in quantum chromodynamics (QCD) through the Peccei-Quinn (PQ) mechanism. It is a pseudo-scalar boson whose mass and couplings to standard model particles are related to the energy scale where the so called Peccei and Quinn symmetry is broken. Several axion models have been proposed, with the common feature of low mass and very weak interactions, making this particle also an excellent Dark Matter candidate. Axions, and the related Axion Like Particles (ALPS), have been searched for in laboratory experiments since their proposal: a variety of uncommon techniques have been employed and new ones are also appearing in the literature with incredible frequency. In this talk I will briefly illustrate the main lines of experimental research for these elusive particles, and then discuss in more details the haloscopes, i.e. experiments to search for axion as a main component of our galaxy dark matter halo.

**Collider / 22**

## Do we know the sign of the gauge-Higgs coupling?

**Author:** Daniel Stolarski[1]

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I will explore measurements at the LHC and future colliders that are sensitive to the relative sign of the coupling between the Higgs and the W and the Higgs and the Z. The relative sign of these couplings can be opposite that of the Standard Model in models with Higgs multiplets larger than doublet. Finally, I will explain the caveats in recent experimental searches that claim to measure the sign of the coupling.

**Neutrino / 23**

## Discovering Long-lived Particles at DUNE

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Long-lived particles (LLPs) arise in many theories beyond the Standard Model. These may be copiously produced from meson decays (or through their mixing with the LLP) at neutrino facilities and leave a visible decay signal in nearby neutrino detectors. We compute the expected sensitivity of the DUNE liquid argon (LAr) and gaseous argon (GAr) near detectors (ND) to light LLP decays. In doing so, we determine the expected backgrounds for both detectors, which have been largely overlooked in the literature, taking into account their angular and energy resolution. We show that searches for LLP decays into muon pairs, or into three pions, would be extremely clean. Conversely, decays into two photons would be affected by large backgrounds from neutrino interactions for both near detectors; finally, the reduced signal efficiency for e+e− pairs leads to a reduced sensitivity for ND-LAr. Our results are first presented in a model-independent way, as a function of the mass of the new state and its lifetime. We also provide detailed calculations for several phenomenological models with axion-like particles (coupled to gluons, to electroweak bosons, or to quark currents). Some of our results may also be of interest for other neutrino facilities using a similar detector technology (e.g. MicroBooNE, SBND, ICARUS, or the T2K Near Detector).

**Collider / 24**

## SMEFT and HEFT expansions and HH production

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The Standard Model and Higgs Effective Field Theories (SMEFT and HEFT) are well-established theoretical frameworks for the parameterization of potential new physics signals from nearly decoupled BSM sectors. The two EFTs differ in the scalar field content and - most notably - in the power counting, i.e. the way they organize BSM effects into a series expansion. While in SMEFT the power counting simply expands in inverse powers of the EFT cutoff $\Lambda$, HEFT presents a more confusing power counting due to the simultaneous presence of linear and non-linear field representations.
This talk revisits general power counting rationales in EFTs with a focus on phenomenology, and discusses an example application to double Higgs production in gluon fusion, which is one of the main test benches for HEFT-SMEFT comparisons at the LHC.

**Flavor / 26**

## $B$-Anomalies in a Post-$R_{K^{(*)}}$ World

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For several years, many long-standing anomalies in rare $b \to s\ell\bar{\ell}$ decays have raised questions about possible hints of physics beyond the Standard Model (SM). These anomalies appear not only

in branching ratios of $B \to K$, $B \to K^*$, and $B_s \to \phi$ in both high- and low-$q^2$ regions (with $q^2$ the invariant mass of the dilepton pair), but also in angular observables such as $P_5'$, and are consistent with a $\sim 20 - 25\%$ shift to the SM Wilson coefficient $C_9$, potentially from new physics. However, with the recent disappearance of anomalies in the lepton flavor universality violating ratios $R_K$ and $R_{K^*}$, doubts have been raised about such new-physics interpretations, particularly due to long-distance charm rescattering effects which are as-yet incalculable within the SM. In this talk, I will give an overview of the current status of anomalies in $b \to s\ell\bar{\ell}$ decays as well as discuss the first steps taken towards estimating the possible size of such charm rescattering effects.

**Flavor / 27**

## Non-Perturbative Parameters in Lambda-b Decays and Small Velocity Sum Rules

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In this talk, we discuss inclusive decays of heavy hadrons containing a b-quark, specifically focusing on Lambda-b baryons within the framework of the heavy quark expansion (HQE). By utilising recent lattice QCD calculations of exclusive form factors, we aim to identify the regions in the plane of non-perturbative parameters—namely the kinetic and Darwin terms—that are consistent with small velocity sum rules for the semi-leptonic decays of Lambda-b baryons.

**Flavor / 30**

## Experimental overview of recent results at LHCb and Belle II experiments

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A selection of recent results from the Belle II and LHCb experiments are presented.

**Axion-like particles / 31**

## From Light to Heavy, Two Faces of ALPs: Cosmic Relics and Hidden Sector Portals

**Author:** Francesco D'Eramo[1]

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Axion-like particles (ALPs) are a common feature in many extensions of the Standard Model. However, their stability is not guaranteed by any symmetry, making the consideration of their lifetime crucial when investigating their cosmological consequences. In this talk, I will explore two distinct ALP mass regimes and their corresponding signatures. First, I will focus on sub-eV ALPs, presenting recent advancements in predictions for ALP dark radiation. I will introduce a phase-space approach to refine the predictions for the ALP dark radiation abundance and demonstrate how spectral distortions are typically expected due to non-instantaneous decoupling. In the second part, I will turn to GeV-scale ALPs, which act as a portal between the visible sector and a scalar dark matter (DM) candidate. I will discuss how the interaction between the ALP and the DM reveals a deep connection to the underlying global symmetry that stabilizes the DM particle, highlighting the key features of this scenario: a relic density independent of ALP couplings to the visible sector and enriched indirect detection spectra.

**BSM / 32**

## ”Extreme energy cosmic rays: where do they all come from?”

**Author:** Zurab Berezhiani[None]

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Abstract: I discuss paradoxical situation in detection of the highest energy cosmic rays by Telescope Array and Pierre Auger experiments, in particular, a strong discrepancy between their results for cosmic ray fluxes at energies above the GZK cutoff, most notably at E>100 EeV. I also discuss ideas of new BSM physics and dark matter identity which could naturally resolve these paradoxes.

**Collider / 33**

## Pushing the Frontiers: Precision and Discovery at the LHC

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The Large Hadron Collider (LHC) at CERN is currently our most powerful tool for exploring the fundamental laws of nature at the energy frontier. Beyond its role as a discovery machine, the LHC has also demonstrated remarkable capability as a precision machine. In this presentation, I will highlight key results from precision measurements of Standard Model processes and searches for new phenomena conducted by the ATLAS and CMS experiments, based on the complete Run 2 dataset and, in some cases, a partial Run 3 dataset. Additionally, I will outline the potential of the high-luminosity phase of the LHC (HL-LHC) for further advancing our understanding, paving the way for future discoveries.

**Axion-like particles / 34**

## Interplay of vertical and horizontal gauge symmetry for a high-quality axion

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We present an axion model based on the Pati-Salam group, where $\mathrm{SU}(3)_{f_R}$ (part of flavor symmetry) has also been gauged. The choice of field content ensures a careful interplay of the two symmetries, such that an accidental global $\mathrm{U}(1)$ Peccei-Quinn (PQ) symmetry emerges. The resulting axion is of high quality for the breaking scale in a certain range, and the model's Yukawa sector is realistic. A characteristic feature of having both a vertical (Pati-Salam) and horizontal (flavor) symmetry are anomalons - parametrically light fermions required to cancel gauge anomalies. We analyze their interplay with neutrinos and their production in the early universe. Their effect on $\Delta N_{\mathrm{eff}}$ could serve as a low energy probe for the underlying dynamics of PQ quality.

**Flavor / 35**

## Testing SU(3) flavour symmetry in non-leptonic B and D decays

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Non-leptonic B decays are great probes of CP violation and the most precise probes for the CKM angles. These determinations use golden modes, data and/or isospin symmetry to reduce the theoretical uncertainties, as non-leptonic decays remain notoriously challenging to calculate from QCD principles. At the same time, there is a wealth of experimental data that can be exploited to obtain insights into strong decay dynamics, or even possibly show signs of new interactions. In this talk, I will discuss the limitations of using SU(3) flavour symmetry to link the many non-leptonic decays and show a new analysis of all non-leptonic B decay data, including for the first time data on mixing-induced CP asymmetries and factorizable SU(3)-breaking effects. In addition, I will briefly discuss also SU(3) tests in non-leptonic D decays including linear SU(3) breaking.

**Axion-like particles / 36**

## Varieties of High Quality Axion from Gauged U(1) Symmetry

**Author:** Kaladi Babu[None]

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Strong interactions can potentially violate Charge Parity (CP) symmetry, but experimentally there has been no evidence for it. The Peccei-Quinn (PQ) mechanism which assumes a global U(1) symmetry provides an elegant solution to this “strong CP problem”, in terms of a light particle, the axion. However, global symmetries, such as the ones employed in the PQ mechanism, are not respected by quantum gravity, which could destabilize the PQ solution. In this talk I will suggest a variety of models that solves this “axion quality problem” through a gauged U(1) symmetry, which is safe from gravity corrections. The QCD axion that solves the strong CP problem arises automatically in these models. A unified SO(10) model will be presented, which has a high quality axion of a hybrid nature, which interpolates between two popular (DFSZ and KSVZ) models. Other classes of models will be presented, including one with a gauged flavor symmetry which also explains the hierarchical structure of quark and lepton masses. Possible ways to test these models in axion physics will be outlined.

**Collider / 38**

## SMEFT searches at the LHC and beyond

**Author:** Luca Mantani[1]

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After more than a decade of operations, the LHC is entering into a new era of precision physics. This evolution demands the refinement of our tools to uncover New Physics (NP), leveraging the statistical advantages of unprecedented data volume. Assuming NP lies beyond the current energy reach, the Standard Model Effective Field Theory (SMEFT) emerges as a powerful framework for an indirect discovery program. SMEFT enables a minimal, model-independent extension of the SM, providing a consistent and systematic parameterization of modified interactions. In this talk, I will present our latest efforts to constrain these interactions using a global and comprehensive analysis of current data, while exploring the potential of future collider experiments. I will emphasize the critical importance of theoretical precision, focusing on the role of renormalization group evolution (RGE) in ensuring consistency across datasets spanning multiple energy scales. Finally, I will highlight the intricate interplay between SMEFT parameters and parton distribution functions (PDFs). As PDFs are extracted from datasets overlapping with SMEFT analyses, an inconsistent treatment risks absorbing NP effects into the proton's structure.

**Flavor / 39**

## The fermion mass hierarchy problem

**Author:** Raymond Volkas[1]

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The fact that the quark and charged-lepton mass spectrum is hierarchical remains a tantalising hint that beyond-SM physics might be at play. I will review work I completed with Baker and Cox on a systematic analysis of 1-loop generation of the bottom and tau masses, which are, of course, known to be suppressed compared to the fundamental electroweak scale. Note that both of those species have weak isospin I = -1/2. I will then expand on that to include 1-loop generation of I = +1/2 fermion masses, in particular the Dirac mass of neutrinos (from unpublished work by L. Stockdale in her MSc thesis). Experimental and theoretical constraints will be discussed. I will finish with a few brief words about how the construction of a complete theory of hierarchical radiative masses might be approached.

**Neutrino / 40**

## Coherent elastic neutrino-nucleus scattering in the Standard Model and beyond

**Author:** Valentina De Romeri[1]

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I will discuss the physics potential of coherent elastic neutrino-nucleus scattering (CEvNS), a neutral-current process in which a neutrino scatters off an entire nucleus. I will first briefly review the main features of CEvNS and the status of current observations. Then, I will discuss how these measurements have opened the window to many physics applications, from Standard Model precision tests to searches for new physics, including implications for dark matter direct detection searches.

**Collider / 41**

# Anomaly detection for LHC searches

**Author:** Barry Dillon[1]

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Deep-learning methods have given us new tools for finding outliers in datasets, and opens up new opportunities for new-physics search strategies based on these anomaly-detection tools. In this talk I will discuss Normalised AutoEncoders, and how self-supervised learning can be used to find effective sets of observables for the analyses.

**Wine & cheese poster session / 42**

# Nonlocal condensate contributions to $D$-meson mixing

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A longstanding mismatch of the theoretical predictions and experimental measurements of $D$-meson mixing parameters stands at a couple orders of magnitude. The Glashow–Iliopoulos–Maiani (GIM) mechanism is responsible for the cancellations which leave $SU(3)$ breaking effects highly suppressed - to the fourth power. Higher order corrections, as well as nonperturbative effects, may give rise to stronger $SU(3)$ breaking, and account for the missing contribution. In this poster, we present our calculation of the contribution of nonlocal QCD condensates to the mass difference parameter of $D$-meson mixing. We give a comparison of two nonlocal models for the QCD condensates, as well as, for the first time, include the mixed condensate contribution. We show these contributions are larger than the box-diagram prediction, lifting the final result by an order of magnitude. Even though we unfortunately do not meet the experimental value, this research presents a clear improvement and gives a better understanding of nonperturbative QCD dynamics.

**Neutrino / 43**

# Trident production at accelerator neutrino facilities

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Neutrino trident production is a rare Standard Model process, sensitive to the structure of the electroweak interaction. Flavour-violating tridents are also an important background to searches for deviations from lepton flavour symmetry beyond the Standard Model. Entering a frontier of precision neutrino physics comes with new regimes of energy-spread and intensity of accelerator neutrino beams, opening up new opportunities for trident studies. In this talk I will focus especially on the distinction between the structure of trident interactions for lighter lepton species those involving third-generation leptons, and provide projected reaches for present and future accelerator facilities.

**Collider / 44**

## Symmetry-restoring finite counter-terms of SMEFT four-fermion operator insertions at one-loop

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Some effects induced by SMEFT operators at one-loop have been fully computed, in particular, the renormalization of divergences by physical operators in single insertions of dimension-six operators. Important non-logarithmically enhanced contributions remain to be calculated. We discuss dimensional regularization in the Breitenlohner-Maison 't Hooft-Veltman scheme. The goal here consists of determining in this scheme unexplored quantum effects in chiral theories at one-loop. Namely, the determination of finite counter terms that reestablish the Slavnov-Taylor identities at one-loop. These counter terms are necessary due to the presence of evanescent symmetry-breaking terms in the classical Lagrangian, that are needed to regularize fermion propagators. We consider a technique that allows an easier automation in the calculation of such finite effects. We focus on dimension-six four-fermion operators, and as expected find no obstructions to the Slavnov-Taylor identities that cannot be cured by finite counter-terms. We briefly point out phenomenological implications for higher order calculations.

**Collider / 45**

## How large can the light fermion Yukawa couplings be?

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While the Higgs boson's couplings to massive gauge bosons and third-generation fermions align with Standard Model predictions, those to the light quarks and the electron remain experimentally elusive. In this talk, I will classify and investigate simplified UV models that can significantly enhance Yukawa couplings of light fermions. These models generate operators in Standard Model Effective Field Theory at tree level and one-loop, constrained by electroweak precision observables, Higgs data, flavor physics, and direct searches. Considering all bounds, we identify the models in which first-generation quark Yukawa couplings can be enhanced by up to several hundred times their Standard Model value, while the Higgs couplings to charm (strange) can increase by factors of a few (few tens). Given the importance of electroweak precision data, we discuss projections for future measurements at the FCC-ee collider. Additionally, we explore the potential for significant deviations in the electron Yukawa coupling, assessing how future intensity-frontier measurements, including the anomalous moment of the electron, can provide competitive probes relative to a dedicated FCC-ee run at the Higgs pole mass.

**BSM / 46**

## Topological structures and inflationary cosmology

**Author:** Qaisar Shafi[None]

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We discuss a variety of topological structures that are predicted in realistic extensions of the Standard Model.
We also show how primordial monopoles, cosmic strings and other extended structures can cope with cosmic inflation.

**Neutrino / 47**

## Electromagnetic Properties of Neutrino

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**Axion-like particles / 49**

## TBA

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**BSM / 50**

## Q-balls perturbations in details

**Author:** Aleksandr Azatov[1]

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I will briefly review the physics of the Q-balls. Particular attention will be paid on the Q balls interactions with its perturbations and its phenomenological aspects for the early universe.

**BSM / 51**

## Searching for New Physics with Plasma Wakefield Colliders

**Author:** Toby Opferkuch[1]

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Plasma wakefield acceleration offers a new path toward building compact, high-energy colliders, with the potential to open up fresh opportunities for new physics searches. In this talk, I'll introduce the basic ideas behind the technology and discuss what a future plasma wakefield collider could look like. I'll then explore its reach for discovering new particles using simple benchmark models, and highlight some of the key challenges that still need to be addressed.

**Neutrino / 52**

## TBA

**Author:** Malte Buschmann[None]

**Collider / 54**

## Accuracy Complements Energy: Hunting for New Physics at FCC-ee

**Author:** Benjamin Stefanek[1]

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A new run on the Z-pole producing more than 1 trillion Z bosons (Tera-Z) such as proposed at FCC-ee will have indirect sensitivity to heavy new physics up to the tens of TeV scale via higher-order loop contributions to electroweak precision observables. I discuss how new physics with the right flavor structure to lie within reach of future colliders populates a specific subset of SMEFT operators that is almost completely covered by loop-level probes at Tera-Z. These indirect quantum effects may provide complementary, or even better, sensitivity to potential deviations from the Standard Model that are typically thought to best be constrained at leading order at higher energies above the Z-pole, e.g. Higgs couplings. A thorough Tera-Z program may thus anticipate aspects of physics runs at higher energies and provide a wider scope of quantum exploration of the TeV scale than had previously been appreciated.

**Collider / 55**

## TBA

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**Flavor / 56**

## Indirect constraints on third-generation baryon number violation

**Author:** Alexey Petrov[1]

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The non-observation of baryon number violation suggests that the scale of baryon-number violating interactions at zero temperature is comparable to the GUT scale. However, the pertinent measurements involve hadrons made of the first-generation quarks, such as protons and neutrons. One may entertain the idea that new flavor physics breaks baryon number at a much lower scale, but only in the coupling to a third-generation quark, leading to observable baryon-number violating b-hadron decay rates. We will discuss such a scenario to show that indirect constraints on the new physics scale from the existing bounds on the proton lifetime do not allow for this possibility.

**Flavor / 58**

## Lessons from $c \to se\nu$

**Author:** Damir Becirevic[1]

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We consider various modes based on $c \to se\nu$ in order to see what precision of LQCD results for relevant hadronic matrix elements and of the experimental data are needed to probe the effects of physics beyond the SM.
$c \to se\nu$ case is good for many reasons, including the fact that all of its couplings to physics BSM are strongly constrained by the measured high-pT tails of the relevant Drell-Yan processes studied at LHC (including the right-handed ones, which is a novelty). We discuss the lessons drawn from this research.

**Axion-like particles / 59**

## Open String Axiverse

**Author:** Rudin Petrossian-Byrne[1]

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The cosmological history of axions is most predictive when their associated symmetry is restored in the post-inflationary universe, producing a network of cosmic strings. On the other hand, arguably the most well-motivated (high-quality) axions —those arising from extra dimensions and string theory —are often thought to be in tension with this scenario. In this talk, I explain how these are easily reconciled from a theoretical point of view and discuss phenomenological prospects.

**Wine & cheese poster session / 61**

## Stabilising the FxFx algorithm in the MadGraph event generator for the usage at the LHC

**Author:** Lenart Jerala[1]

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In this poster, we present an in-depth investigation of the recently found issues in the FxFx matching-merging procedure in MadGraph5_aMC@NLO for usage at the LHC. We compare the predictions for $W + 3$ jets and $Z + 3$ jets against corresponding measurements from ATLAS and CMS, studying a variety of final-state kinematic distributions and highlighting regions where mismatches are most pronounced. Our analysis includes a systematic survey of different processes and observables, incorporating both parton-level and post-parton-shower (PS) outputs. We also examine the patterns exhibited by, among others, LHE weights, scale variations, jet multiplicities, software versions, and matching algorithms, aiming to identify and quantify the sources of the observed discrepancies. Finally, we present the fixes proposed by one of the FxFx authors, Rikkert Frederix, demonstrating how these modifications can substantially improve consistency between theoretical predictions and experimental data.

**BSM / 62**

## TBA

**Neutrino / 64**

## TBA

**Neutrino / 65**

## TBA

**Flavor / 66**

## TBA

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TBA

**Wine & cheese poster session / 67**

## PT2GWFinder: A Package for Cosmological First Order Phase Transitions and Gravitational Waves

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The study of cosmological first order phase transitions, and the associated gravitational wave signal, has seen growing interest in recent years, driven by the prospects of detection with next-generation ground- and space-based interferometers.
Here, I present PT2GWFinder, a Mathematica package designed to compute phase transition parameters and the gravitational wave power spectrum for an arbitrary scalar theory exhibiting a first-order phase transition in a single direction.

**Wine & cheese poster session / 68**

# Minimal scalar leptoquark model for RD(*)

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Motivated by the long-standing discrepancy in lepton flavor universality ratios $R_D$ and $R_{D^*}$ we assess the status of scalar leptoquark states $R_2$, $\widetilde{R}_2$ and $S_1$ which can in principle provide a desired enhancement of $\mathcal{B}(B \to D^{(*)}\tau\nu)$ in a minimal setup with two Yukawa couplings only. We consider unavoidable low-energy constraints, $Z$-pole measurements as well as high-$p_T$ constraints. After setting mass of each leptoquark to 1.5 TeV we find that of all considered states only $S_1$ leptoquark, coupled to both chiralities of leptons and quarks, is still a completely viable solution. On the other hand, the scenario with $R_2$ is in growing tension with $\Gamma(Z \to \tau\tau)$ and with the LHC constraints on the di-tau tails at high-$p_T$ while the $\widetilde{R}_2$ scenario is in tension with the $\mathcal{B}(B \to K^{(*)}\nu\nu)$ observable. We comment on the future experimental tests of $S_1$ scenario. Furthermore, a scenario of the $S_1$ leptoquark coupled exclusively to right-handed SM fermions and a right-handed neutrino $N_R$ is also investigated as a potential solution for the $R_{D^{(*)}}$ with possible effects also in $\mathcal{B}(B \to K^{(*)}\nu\nu)$.

**Wine & cheese poster session / 69**

# Functional determinants and lifetime of the Standard Model

**Author:** Katarina Trailović[1]

**Co-authors:** Miha Nemevšek ; Pietro Baratella ; Yutaro Shoji ; Lorenzo Ubaldi

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We revisit the computation of the electroweak vacuum decay rate in the Standard Model, incorporating the full one-loop prefactor and focusing on the gauge degrees of freedom. Using group theoretical arguments, we derive the correct degeneracy factors in the functional determinant and identify an overcounting of transverse modes in previous calculations. The new result modifies the

gauge fields'contribution by 6% and leads to a slight decrease of the previously predicted lifetime of the electroweak vacuum.