Ljubljana Summer School on Particle Physics and Cosmology

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Book of Abstracts

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Poster session and reception

Poster session / **28**

LHC tau-pair production constraints on a and d

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We point out that relevant constraints on the anomalous magnetic (a) and electric (d) moment of the tau lepton can be derived from tau-pair production measurements performed at the LHC. Our conclusion is based on the observation that the leading relative deviations from the Standard Model prediction for $pp \to {}^{+-}$ due to a and d are enhanced at high energies. Less precise measurements at hadron colliders can therefore offer the same or better sensitivity to new physics with respect to high-precision low-energy measurements performed at lepton machines. We derive bounds on a and d using the full LHC Run II data set on tau-pair production and compare our findings with the current best limits on the tau anomalous moments.

Poster session / **29**

The shift-invariant orders of an ALP

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Usually, effective field theories (EFTs) for axion-like particles (ALPs) are built assuming a shift symmetry for the ALP due to the global U(1) Peccei-Quinn (PQ) symmetry that is at the heart of the axion mechanism. However, it is generally believed that global symmetries, in particular axion

shift symmetries, can only be approximate. Therefore, it is important to include shift-breaking interactions in the EFT description and find a clear way to implement the different power countings of the shift-conserving and shift-breaking sectors. Focusing on the flavorful effective Yukawa couplings to Standard Model fermions, I will present Jarlskog-like flavor invariants which act as order parameters for shift symmetry breaking of the axion. In this description, shift-breaking couplings are characterized in an explicit and flavor-invariant way and it is straightforward to give different power countings to the shift-conserving and shift-breaking sectors. I will discuss properties of the invariants like their CP parities, enabling us to make non-trivial connections between conservation of CP in the theory and an almost conserved shift-symmetry for the ALP. Finally, I will discuss examples of matching UV theories to the invariants and how they can be used to identify shift-breaking contributions in observables.

Poster session / **30**

An updated view on the Atomki anomalies

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In view of the latest experimental results recently released by the ATOMKI collaboration, we critically re-examine the possible theoretical interpretation of the observed anomalies in terms of a new BSM boson X with mass ~ 17 MeV. Employing a multipole expansion method, we estimate the range of values of the nucleon couplings to the new light state in order to match the experimental observations. Our conclusions identify the axial vector state as the most promising candidate, while other spin/parity assignments seem disfavored for a combined explanation.

Poster session / **31**

Investigating new physics in $\tau - \mu$ sector via LFU ratios $R_K^{\tau\mu}$ and $R_{K^*}^{\tau\mu}$

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We explore the potential of the ratios $R^{\tau\mu}$ in the decays $B \to K\ell\ell$ and $B \to K^*\ell\ell$ ($\ell = \mu, \tau$) as a means to probe new physics effects within the $\tau - \mu$ sector.We find that these ratios deviate from their SM predictions even for universal couplings. This indicates that the observed deviation of these ratios from their SM predictions alone is insufficient to definitively establish the underlying nature of new physics. For this, we need to compare the allowed range of $R^{\tau\mu}$ for a class of solutions with only universal couplings to leptons and solutions having both universal and non-universal components. By comparing the predictions of $R_K^{\tau\mu}$ and $R_{K^*}^{\tau\mu}$ for the two classes of solutions using the current data, we find that the distinction becomes feasible if the measured value of $R_{K^*}^{\tau\mu}$ exceeds the SM prediction.

Poster session / **32**

New tests of short-distance dynamics in $b \to s\bar{\ell}\ell$ decays

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The rare $B \to K^{(*)}\bar{\ell}\ell$ decays exhibit a long-standing tension with Standard Model (SM) predictions, which can be attributed to a lepton-universal short-distance $b \to s\bar{\ell}\ell$ interaction.
We present two novel methods to disentangle this effect from long-distance dynamics: one based on the determination of the inclusive $b \to s\bar{\ell}\ell$ rate at high dilepton invariant mass ($q^2 \geq 15\ \mathrm{GeV}^2$), the other based on the analysis of the q^2 spectrum of the exclusive mode $B \to K\bar{\ell}\ell$ (in the entire q^2 range).

Using the first method, we show that the SM prediction for the inclusive $b \to s\bar{\ell}\ell$ rate at high dilepton invariant mass is in good agreement with the result obtained summing the SM predictions for one- and two-body modes (K, K^*, $K\pi$). This observation allows us to perform a direct comparison of the inclusive $b \to s\bar{\ell}\ell$ rate with data. This comparison shows a significant deficit ($\sim 2\sigma$) in the data, fully compatible with the deficit observed at low-q^2 on the exclusive modes. This provides independent evidence of an anomalous $b \to s\bar{\ell}\ell$ short-distance interaction, free from uncertainties on the hadronic form factors.
To test the short-distance nature of this effect we use a second method, where we analyze the exclusive $B \to K\bar{\ell}\ell$ differential branching ratio data in the entire q^2 region. Here, after using a dispersive parametrization of the narrow charmonia resonances, we extract the non-SM contribution to the universal Wilson coefficient C_9 for every bin in q^2. The q^2-independence of the result, and its compatibility with the inclusive determination, provide a consistency check of the short-distance nature of this effect.

(Based on arXiv:2305.03076)

Poster session / **33**

NNLO+PS event generation for $pp \to Zh$ with contributions from electroweak SMEFT operators

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The associated production of a Higgs boson, i.e. $pp \to Zh$, allows for precise measurements of the Higgs boson couplings. In particular, Zh with $Z \to \ell^+\ell^-$ and $h \to b\bar{b}$ is the most sensitive channel for detecting $h \to b\bar{b}$ decays at the LHC. It will be probed extensively in future LHC runs. We present a comprehensive next-to-next-toleading order plus parton shower (NNLO+PS) accurate event generator based on the MiNNLO PS method that allows to simulate non-standard Higgs interactions in Vh. In particular, we extend previous work to include the effects of the relevant electroweak SM effective field theory (SMEFT) operators and anomalous Higgs couplings. The ensuing phenomenology is discussed, presenting observables where the non-standard Higgs interactions in question lead to interesting changes in the event shapes.