PhD research proposal

Search for Vector Like Leptons in the data collected by the CMS detector at the LHC

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One of the most intriguing hints for physics beyond the Standard Model is the so-called **flavour anomalies**, referring to a range of experimental results that show some degree of **tension with the Lepton Flavor Universality (LFU)**. The LHCb experiment in particular has performed measurements of several ratios of branching fractions of D and K mesons in final states with either electrons or muons that consistently deviate from the standard model prediction at the level of 3 standard deviations. LFU can be violated in models beyond the SM by new particles that couple preferentially to certain generations of leptons. Several models have been proposed, generally extending the Standard Model symmetry group to SU(4) x SU(3) x SU(2) x U(1). One of those models in particular, so called 4321 [1, 2] model, gives a possible explanation for the aforementioned flavour-nonuniversal results, while simultaneously respecting many other measurements that are in good agreement with the SM expectations and lepton flavour universality symmetry group to the Standard Model.

We propose a search for the lightest particles predicted by the 4321 model, the vector-like leptons in final states with τ leptons and b-jets, with the τ leptons decaying leptonically, using data collected by the CMS detector. A similar analysis has been carried on with hadronic decaying τs by the CMS collaboration [3], showing an unsettling excess. A leptonic analysis has the potential to corroborate these observations with possibly groundbreaking consequences.

The research program foresees the re-analysis of LHC Run 2 data and the top-up with the currently ongoing LHC Run 3 data. The hired PhD student is expected to contribute to the understanding and calibration of the relevant physics objects (electrons, muons,

missing transverse energy, b-jets), the development of the analysis strategy leveraging Machine Learning techniques and generally take ownership of the responsibility of the analysis. They are also expected to spend a fraction of their time at CERN, to both carry out the analysis and participate and contribute to the data taking.

References and Further reading

[1] https://www.youtube.com/watch?v=ko4R8S8XYV4

[2] C. Cornella et al. "Reading the footprints of the B-meson flavor anomalies", *JHEP* 08 (2021) 050, https://doi.org/10.1007/JHEP08(2021)050

[3] CMS Collaboration, "Search for pair-produced vector-like leptons in ≥3b+N*ℓ* final states", CMS-PAS-B2G-21-004

The research group

The hired PhD student will work in the context of the CMS Florence group. The group consists of 17 people, and includes staff personnel from the University and the INFN as well as five PhD students. The group is deeply involved in the upgrade of the CMS detector and in the data analysis. For the latter the reference persons are the ones mentioned at the beginning. Data analysis conducted in Florence revolves around final states with leptons, especially in the context of the characterization of the Higgs boson decay to W bosons. This context is ideal for the development of the proposed research, as it provides rich experience with all the physics objects that are relevant.