Laboratoire d'Annecy de Physique des Particules

M2 Internship proposal

Title: Search for a new phenomena in the dilepton final state in association with jets or missing transverse momentum

Internship supervisor

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Subject / activities

Summary of the work required:

Resonant searches in the dilepton (dielectron and dimuon) final state have a long and illustrious history with the discovery of the J/ψ meson in 1974 and Y meson in 1977 as well as the Z boson in 1983. As these were key steps which led to the establishment of the Standard Model (SM) of particle physics, the study of the same final state could help to pave the way to a better understanding of the physics processes beyond it. A common theme in many beyond SM theories is a presence of the new neutral gauge bosons (Z') with mass at a TeV scale. They have been extensively searched for at the Large Hadron Collider (LHC). The most recent lower limit on the mass of the Z'_{SSM} decaying to dileptons was set by the ATLAS experiment to be 5.1TeV [Phys. Lett. B 796 (2019) 68]. This result used the full Run 2 (2015-2018) data set recorded in proton–proton collisions at a centre-of-mass energy of 13 TeV and corresponds to an integrated luminosity of 139 fb^{-1}.

The searches to date assume that a Z' boson is produced through quark-anti-quark annihilation. But if the coupling of the Z' boson to the SM quarks is small, the dominant production channel becomes vector-boson-fusion (VBF). Its signature is a resonance in the dilepton spectrum combined with a presence of two back-to-back jets in the event. There are also models in which a Z'_{DM} boson is produced in association with invisible dark matter particles, signature for which is missing transverse momentum in the detector. The current inclusive searches do not have sensitivity to such models and they might have eluded the detection up to now. These are first searches of this kind at the LHC.

The ATLAS group at LAPP has been active in the inclusive dilepton searches since the start of the LHC data-taking. One of its student had the leadership for the full Run2 paper. The existing analysis framework developed at LAPP for the inclusive dilepton search will be extended to the associated production. The goal is to do a basic data analysis to understand the reach of such searches. This work will require extensive use of the ROOT framework.

LAPP is located 50 km from CERN which will allow for several visits to it if sanitary situation allows.

Optional information on a possible PhD subject:

The M2 internship can be expanded into a PhD focused on the resonant and non-resonant searches for new phenomena in the dilepton final state in proton-proton collisions with the ATLAS experiment at the LHC at CERN and one of the ATLAS detector upgrade tasks which group is participating in.

The resonant search will be an extension of the feasibility study done during the M2 internship to a full data analysis in a final state with two leptons and two back-to-back jets in the event or missing transverse momentum. Novel techniques, such as Gaussian Processes might need to be used for the background modelling. An inclusion of these results into the ATLAS Dark Matter combined search and the ATLAS heavy vector boson combined search is also envisioned.

The non-resonant search in dilepton final state will be performed in the context of the measurement of the double-differential cross-sections of the Drell-Yan process for the dilepton mass up to 1.5 TeV on the full Run 2 dataset. If there are no new low scale particles, the only tools available for studying deviations from the SM predictions are effective field theories (EFT). “Low scale” physics is assumed to be sensitive to the presence of higher dimension operators. The current Run 2 analysis is designed for the SM measurement and its sensitivity to EFT effects can be improved with dedicated optimizations. The goal of this work will be to explore complementary information about the parameters of the EFT from the Drell-Yan measurements and the measurements in the Higgs and gauge boson pair production sectors, which are also performed in LAPP, for potential insights into the underlying physics.

The technical part of the thesis will be related to one of the detector upgrade projects in the group. The LAPP team constructed high speed and high bandwidth digital electronics which allows to deliver fully calibrated transverse energy to the first level of the calorimeter trigger for the Run 3 ATLAS data-taking, student can participate in the commissioning of the upgraded system and the analysis of data collected with it as LHC restarts data-taking in early 2022. The group also participates in the construction of the new inner tracking pixel detector (ITK-pixel) for the High Luminosity LHC (2027+), student can work on the set up and the operation of the system test for the ITK modules assembled at LAPP.

The duration of the thesis is three years. An extended, few months long, stay in CERN, is possible during the PhD thesis. The geographical proximity of LAPP to CERN facilitates the direct implication of the student in the life of the experiment including shifts and collaboration meetings. The contacts with theoreticians are also facilitated by the presence of the theoretical physics laboratory LAPTh in the same building.

Members of the team	C. Adam-Bourdarios, N. Berger, T. Berger-Hryn’ova, M. Delmastro, L. Di Ciaccio, C. Goy, T.Guillemin, S. Jézéquel, I. Koletsou, J. Levêque, N. Lorenzo Martinez, E. Sauvan