PhD thesis subject Proposal 2019

Measuring the Higgs properties with multi-leptons channels with the CMS detector and development of High Granular CALorimeter

Scientific Context

The discovery of the Higgs boson (H) at the Large Hadron Collider (LHC) in 2012 by the ATLAS and CMS experiments [1][2] is a major breakthrough in the understanding of the fundamental interactions. Precisely measuring its properties and coupling to the fundamental fields is a unique way to understand its role in the electroweak symmetry breaking (EWSB) while providing a portal to new phenomena.

The couplings to gauge bosons are now firmly established and coupling measurements are entering a precision era. All major production modes have been observed. The Yukawa couplings to the third generation fermions have been recently established. The measurements are in agreement with the predictions from the Standard Model (SM), within the current experimental and theoretical uncertainties (ranging from about 10 to 30%).

The exploration of the scalar sector is just beginning and remains one of the best portal to reveal uncharted territories. The physics program is extremely rich: precision measurements of couplings (where any departure from the SM expectations would be clear sign of new physics), measurement of the Higgs potential (via the double Higgs process in particular), searches for additional Higgs, rare or forbidden decays, Dark Matter (via "invisible" decay), …

The LHC has delivered up to 150 fb^{-1} of proton-proton collisions data at $\sqrt{s}$ =13 TeV from 2016 to 2018. It will stop for a period of 2 years called Long Shutdown 2 (LS2) for improvements of the acceleration chain. It will re-start in 2021 for 3 years, aiming for additional 150 fb-1, possibly at $\sqrt{s}$ =14 TeV.

In parallel, the experiments are preparing the High Luminosity phase (HL-LHC) aiming at accumulating ten times more data in 10 years and starting in 2026. The extreme data taking conditions foreseen (very high levels of radiations and pile-up) implies major upgrades of the CMS experiment. In particular, the endcap calorimeters will be replaced by an innovative Si-based "imaging" calorimeter called "High Granular CALorimeter" (HGCAL) currently under development.

Thesis project

The main objectives of the thesis will be to constrain the Higgs couplings (with emphasis on the top quark Yukawa coupling) with multi-leptons channels (eg, $H \rightarrow ZZ \rightarrow 4$ leptons) as well as to contribute to the HGCAL project.

The thesis will start in Fall 2019, during LS2. It will be the perfect time for the PhD student to participate to the development of new analysis techniques (trigger, lepton identification algorithms, …) in preparation of the new data taking in 2021.

It is also expected that the PhD student will participate to the final R&D and tests on HGCAL project. Depending on the interest of the student, tasks will include development of Particle Flow Reconstruction algorithms (with the usage of state-of-the-art Deep-Neural Net technologies) or mountings and tests of final prototypes.

Host team at Laboratoire Leprince Ringuet (École Polytechnique)

The CMS group at LLR is currently formed by 12 permanent physicists, 2 post-docs and 7 PhD students. It is a founding member of the CMS Collaboration. It has designed and built the ECAL L1 trigger and it is responsible for its daily operation and monitoring. The group has major involvement in particle reconstruction and identification (electrons, taus, particle flow). It is involved in Electroweak (di-bosons, triple gauge couplings, etc…), Heavy Ions and Higgs physics.

The group is one of the main protagonists for the discovery of a Higgs boson and the first measurement of its properties. It has been playing a leading role in some of the high priority Higgs analysis of CMS ($H\rightarrow$2 taus, $H\rightarrow ZZ\rightarrow$4 leptons in various production modes, $HH\rightarrow bb\tau\tau$ or $ttH\rightarrow\tau\tau$). It has developed strong ties with physicists from many other groups in the CMS Collaboration from Europe and the USA.

The group is also strongly involved in the development of the Phase II CMS Upgrades with major responsibilities in the mechanics, trigger and software algorithms of the future endcap calorimeters (HGCAL).

Master and doctoral school

M2 High-Energy Physics
PHENIICS doctoral school – Université Paris-Saclay

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References

[1] G. Aad et al.[ATLAS Collaboration], *Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC*, Phys.Lett.B 716 (2012) 1
[2] S.Chatrchyan *et al.* [CMS Collaboration], *Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC*, Phys.Lett.B 716 (2012) 30