INSTITUT POLYTECHNIQUE DE PARIS
Laboratoire LEPRINCE-RINGUET

PhD thesis subject Proposal 2022

Search for New Physics with the Higgs boson in 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 collaborations 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. All major production modes have been observed as well as the Yukawa couplings to the third generation fermions. The measurement of Higgs boson couplings is now entering a precision era. All results are so far in agreement with the predictions from the Standard Model (SM), within the current experimental and theoretical uncertainties (ranging from about 10 to 20%).

The exploration of the scalar sector is just at the 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 boson potential (via the double Higgs boson production), 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 re-start in spring 2022 for several years, aiming for additional 150-200 fb-1, possibly at $\sqrt{s}$ =14 TeV, after a period of improvements on both the acceleration chain and on the detector subsystems.

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 2027. 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 search for new physics by measuring the the Higgs boson couplings 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 Autumn 2022. An internship is foreseen in Spring 2022. It will be the perfect time for the PhD student to participate to the development of new analysis techniques and participate to the re-start of the experiment.

In particular, some of the current measurements are still dominated by statistical uncertainties and in addition to the new data, it is crucial to enlarge the phase space of the analysis by exploring

Higgs boson events decaying to particles with lower momentum than previously considered (ie, down to 3 GeV for muons) or lower Z boson invariant mass (below 12 GeV). This will require the development of innovative algorithms to reconstruct those leptons efficiently and new tools using stat-of-the-art Deep-Neural Net technologies to reject the important backgrounds perturbing the measurements.

Many observables will be used to constraint the Higgs boson couplings: inclusive and differential cross-sections (e.g. Higgs boson transverse momentum), fully exploiting the kinematics of the Higgs boson production modes and decay products.

It is also expected that the PhD student will participate to the final R&D and tests on the HGCAL project. This new calorimeter will make use of more than 6 million channels, combining Si Sensors and plastic scintillators, measure the energy, position and time of incident particles with unprecedented precision. The amount of data registered by this device make it a natural playground to develop Particle Flow Reconstruction algorithms using Artificial Intelligence techniques. Mounting and tests of final prototypes may be considered as well, depending on the interest of the student.

Host team at Laboratoire Leprince Ringuet (École Polytechnique)

The CMS group at LLR is currently formed by 12 permanent physicists, 6 post-docs and 12 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
Ecole Doctorale IPP

Contact

For any and all inquiries please do not hesitate to send us an email

Christophe Ochando
ochando@cern.ch
+33 1 69 33 55 33

Roberto Salerno
salerno@llr.in2p3.fr
+33 1 69 33 55 94