Laboratoire LEPRINCE-RINGUET

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Study of the quartic couplings of the gauge bosons at LHC and HL-LHC with the new high granularity calorimeter of the CMS experiment.

The non-Abelian structure of the Standard Model (SM) of electroweak interactions gives precise predictions for the three- and four- gauge boson self-interactions which are entirely determined by their trilinear and quadrilinear (so-called quartic) couplings. In the SM the gauge bosons acquire a longitudinal component via the Higgs mechanism and the scattering behavior of gauge bosons is regularized by the virtual exchange of a Higgs Boson associated with the Higgs field responsible for spontaneous Electroweak Symmetry Breaking (EWSB). Besides the measurements of the properties of the Higgs boson elucidating its role in the EWSB if of paramount importance.

At the LHC, the measurement of the two-gauge boson production rates allowed the determination at the percent level of the trilinear couplings of the gauge bosons. On the contrary the quartic couplings WWγγ, WWZγ, WWWW and WWZZ are by far less well determined.

The direct study of four-gauge boson couplings requires the production of events with at least three-gauge bosons or the observation of vector-boson scattering processes. Thus performing two complementary measurements will give access to the WWZZ quartic coupling, namely :

- at the LHC by observing the three-gauge boson WWZ(WZZ) production via the purely leptonic decay modes in leptons (electrons/muons) and neutrino of the W and Z gauge bosons in events pp → WWZ(WZZ) → 4(5) leptons + missing transverse energy
- at the High Luminosity LHC (HL-LHC) by characterising the scattering of the longitudinal component of the gauge boson in events pp → WZ(ZZ) + 2 jets → 3(4) leptons + 2 jets

Thanks to the very good performance of the LHC the CMS experiment will collect until the end of 2018 around 120 fb^{-1} of luminosity. This luminosity will allow the recording of the first 5 leptons + missing transverse energy events from the WZZ production and several dozen of 4 leptons + missing transverse energy events from the WWZ production.

In 2015 the CMS experiment decided to replace its forward calorimeters by a new radiation resistant and highly granular combined forward calorimeter (HGCAL) which is currently under design. In the harsh experimental conditions of the HL-LHC an average of about 140 proton-proton collisions will overlap at each beam collision (pile-up). This will induce contamination of the signal events by particles unrelated to the interesting pp collisions. The high segmentation of the proposed HGCAL is pivotal for removing this contamination.

The thesis should be concerned with the problematic of studying the interplay of an observation of the three gauge bosons production WWZ(WZZ) in their purely leptonic decay modes at the LHC and the characterization of the vector boson scattering in their purely leptonic decay modes at the HL-LHC by the upgraded CMS experiment with the HGCAL for the measurement of the quartic gauge coupling WWZZ. The anticipated planning of the thesis is divided into two seperate periods. During the first two years the PhD student will participate to the analysis of the events recorded during the period [2016-2018] searching for the three-gauge boson WWZ(WZZ) production. In autumn 2018 he will gradually joign the group effort for elaborating the strategy of the analysis which will be put in place for the characterization of the vector boson scattering at the HL-LHC. The acquired expertise during the first period will be highly beneficial for this task.

The internship and the thesis will be conducted at LLR in the CMS group with frequent stays at CERN. The CMS group is a founding member of the CMS Collaboration. It has designed and built the ECAL L1 trigger and is responsible for its daily operation and monitoring. It 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 CMS group is one of the main protagonists for the introduction of the high granularity calorimetry concept for the CMS forward calorimeters and has a leading role in both the design of the mechanics and L1 trigger system of HGCAL.

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