Ecole Doctorale PNC PhD proposal 2014

(about 1 page)

- Laboratory/ research team : Laboratoire Leprince Ringuet (LLR)/CMS

- Title : Probing the Higgs coupling to the top quark at the LHC in the CMS experiment

- Overview of the research :

After the discovery of an elementary scalar boson (so-called Higgs boson) in 2012 by both the ATLAS and CMS experiment at LHC, the main focus of the research is now on the determination of its properties, as for example the coupling constants to the different particles. Given that in the standard model, these coupling constants only depend on the mass of the Higgs boson, a mass already known with high precision, stringent consistency tests of the theory can be performed. Minute deviations could be evidence for physics beyond the standard model. Due to the very large mass of the top quark (compared to all other fermions), the top quark might play a particular role in the context of the electroweak symmetry breaking. Therefore, it is fundamental to measure the coupling of the Higgs boson to the top quark (ttH).

So far, the measurements have been only sensitive to the top quark via contributions in virtual loops of the Higgs production via gluon fusion. However, with the increase of luminosity and energy expected in 2015 at LHC, direct measurement of the top-Higgs coupling will become feasible. This is the purpose of this thesis. The comparison of this direct measurement of the coupling with the one inferred from the cross section measurement can put limits on the contribution of new physics to the gluon-gluon loop. The Higgs boson cannot decay to on-shell top quarks but the top-Higgs coupling is however involved when the Higgs boson is produced in association with a top quark-antiquark pair $pp \rightarrow ttH$. This process can be used to measure directly the top-Higgs coupling at tree level. We propose to focus on final states with multileptons (ie electrons or muons) where the 2 tops decay semi-leptonically and the Higgs boson decays in 4 leptons ($H \rightarrow ZZ^* \rightarrow 4l^{\pm}$), 2 leptons ($H \rightarrow \tau\tau \rightarrow 1^{\pm}\nu_l\nu_\tau\, 1^{\pm}\nu_l\nu_\tau$) or 1 lepton ($H \rightarrow \tau\tau \rightarrow 1^{\pm}\nu_l\nu_\tau\, \tau_h$). The student will profit from the expertise of the CMS group at LLR in multilepton channels (our group is leader in the discovery channel $H \rightarrow ZZ^* \rightarrow 4l^{\pm}$).

In a second step, we propose to study the single top and Higgs associated production. The top pair and Higgs associated production described previously allows to measure the magnitude of ttH coupling whereas the single top and Higgs associated production gives in addition its sign. So far, the sign (supposed to be positive in the standard model) has been investigated thanks to the decay of the Higgs in 2 photons, the top appearing virtually in a loop as well as a W boson. The interference between the 2 contributions gives indication of the relative sign. The same interference (but with real top this time) occurs in the single top and Higgs associated production. The t-channel for single top and Higgs associated production is particularly sensitive to the magnitude of the coupling and the relative phase, because of the strong destructive interference in the SM matrix element involved (see arXiv :1211.0499v2). This novel approach is very promising, challenging, and has never been tried so far.

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