Search for new particles decaying to a pair of Higgs bosons with the ATLAS experiment

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In order to describe the most fundamental scale of the matter and its interaction, physicists have built an extensive but rather complete Standard Model (SM) of particle physics. This achievement was made possible thanks to a huge development from the theory and experimental side, allowing to make precise predictions with very different order of magnitudes. One of the latest missing pieces of the SM, the Higgs boson, was discovered in 2012 by the ATLAS and CMS experiments at CERN, nearly 50 years after being postulated. This particle illustrates why some fundamental particles bare a mass, while others like the photon are massless. However, we know that this model is not complete, as the dark matter, neutrino mass or even the hierarchy problem cannot be explained in this framework.

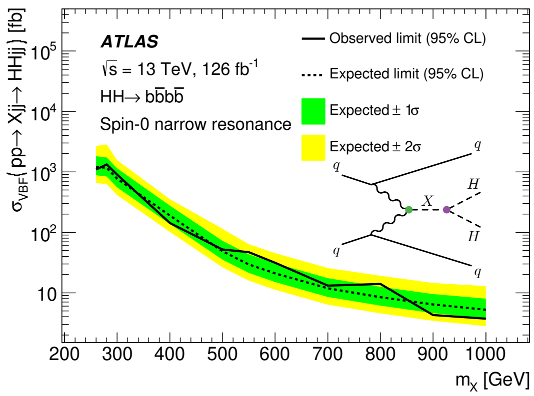

Figure 1: Observed and expected 95% CL upper limits on the production cross-section for resonant HH production via VBF as a function of the mass m_X [1]

To probe this "new physics", several theoretical frameworks have been proposed, most of them introducing new massive particles not yet discovered experimentally. Due to their nature, these particles should at least couple to the Higgs boson, making it a unique tool to scan a wide range of Beyond Standard Models (BSM). A recent interest has been growing inside searches for pairs of Higgs bosons (referred commonly as HH), a process predicted by the SM, but that could be also sensitive to the existence of extra particles. While the main HH production mode through the fusion of gluons (ggF) has been studied extensively already at the LHC, the sub-leading mode with a fusion of vector bosons (VBF) could be promising. Such an analysis has been conducted by the ATLAS experiment, in the Higgs boson's decay channel in two pairs of b quarks [1]. With no excess observed, a limit has been set on the production cross-section as illustrated in Figure 1.

In order to improve the constraints for the lower masses of the BSM particle, we propose here to perform a similar analysis in the final state where the Higgs bosons decay into a pair of photons and a pair of b-quarks. Indeed, despite the lower total decay branching ratio, the presence of photons allows to trigger events at a lower energy. The ATLAS group at the Laboratoire de Physique de Clermont has already been involved in the ggF analysis and has developed an extensive program of BSM searches that could be useful for the intern.

Students applying to this internship should have strong skills in python/C++ (or other major computing language), a good knowledge of high energy physics, and a willingness to develop and test new ideas.

This internship could lead into a PhD to a broader study of $HH \to b\bar{b}\gamma\gamma$ phenomena with the Run-2 and Run-3 datasets collected at the LHC with the ATLAS expriment, upon funding from the École Doctorale des Sciences Fondamentales.

[1] Search for the $HH \to b\bar{b}b\bar{b}$ process via vector-boson fusion production using proton-proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector, J. High Energ. Phys. 2020, 108 (2020).