Title: search for double-Higgs boson production in the bbγγ final state for the measurement of the Higgs boson self-coupling and prospects for Higgs boson coupling studies to quarks and gluons at future colliders

Director: Giovanni Marchiori - giovanni.marchiori@cern.ch

Equipe: ATLAS

Description :
The ATLAS experiment is installed at the Large Hadron Collider (LHC) at CERN near Geneva, Switzerland. There have already been two long series of data taken:
a) Run 1 (2011–2012), at 7-8 TeV in the center of mass (com), which allowed ATLAS and CMS to discover a Higgs boson at 125 GeV (H) mainly through its bosonic decays (γγ and ZZ).
b) Run 2 (2015–2018), at an energy of 13 TeV in the com, with a much greater integrated luminosity which allowed the clear observation of the main fermionic interactions of the Higgs boson ($H \rightarrow \tau\tau$, production of ttH and $H \rightarrow bb$).
A third data taking phase (Run3) has started in 2022 to integrate around 300 fb-1 of pp collisions at 13.6 TeV by end of 2025; in parallel, phases of construction and then installation of the upgrades of the ATLAS detector are planned by 2028 in view of a high luminosity operation until 2040 aiming to accumulate 3000 fb-1 ("high luminosity phase"). This large sample of data will allow the first measurement of the self-coupling of the Higgs boson and measurements of the Higgs boson couplings to other elementary particles with few % predictions, which would further validate the predictions of the Standard Model.

To understand the Higgs boson even better, an e+e- “Higgs factory” has been set as the priority for the European particle physics community after the LHC. Such Higgs factory could be the Future Circular Collider (FCC) project, which will use e+e- collisions in its first phase (FCC-ee). Detectors with excellent particle reconstruction and identification performance will be needed to achieve a precision better than 1% on the different couplings of the Higgs boson. Currently several R&D projects to develop detectors that can provide the necessary performance are underway.

Our team has taken part and played important roles in all these efforts: the Higgs boson discovery in the LHC Run1 with the diphoton channel; the observation of Higgs boson decays to bb with ATLAS Run2 data; the search for HH production with Run2 data in the bb+diphoton and bb+ditau channels, in view of the preparation of the Run3 and HL-LHC analyses. We are also strongly engaged in the ATLAS tracking detector upgrade activities, as well as in FCC-ee case studies and R&D.

The main subject of this thesis is the analysis of the ATLAS Run3 data for the search of the production of two Higgs bosons for the measurement of its self-coupling.
The thesis will focus on the search of the production of two Higgs bosons (decaying in bb + γγ) with the ATLAS data from Run3 of the LHC (2022–2025), with an optimization of the sensitivity of the analysis in function of new data taking conditions compared to Run2 and the use of multivariate analysis techniques to maximize the separation between signal and background. Although it is not expected that the

observation of this process can be carried out with the data of Run3, some initial evidence might be reached with the larger dataset and improved analysis techniques of Run3 compared to Run2. The measurement will anyway make it possible to put constraints on the self-coupling of the Higgs boson and on models of physics beyond the Standard Model.

In addition, the candidate will contribute to the ongoing feasibility and R&D studies on FCC-ee. Sensitivity studies to the measurement of Higgs boson couplings to quarks and gluons in future e+e- colliders and their comparison with ATLAS projections for the high-luminosity phase of the LHC will be performed. These benchmark Higgs processes will be used to compare the performance of different detector designs and layout.

Finally, the candidate is expected to give a contribution to the activities of the team on the construction or software preparation of the future tracking detector for the high-luminosity upgrade of the LHC.

Working place: APC, Paris

Mobility: regular trips to CERN for analysis team meetings and data taking shifts. Presentation at an international conference and participation in a summer school in high energy physics.

Contacts :
Giovanni Marchiori (responsible of the ATLAS activities and of the ATLAS/FCC team in APC), giovanni.marchiori@cern.ch