Title: Higgs Boson Physics at complementary Colliders, through the search for double-Higgs boson production in the bb$\tau\tau$ final state for the measurement of the Higgs boson self-coupling at the LHC, and prospects for Higgs boson mass, ZH cross section and Higgs Self-coupling measurements at the Future Circular Collider in the e+e- collision mode.

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Equipe: ATLAS/FCC

Description :
The ATLAS experiment is installed at the Large Hadron Collider (LHC) at CERN near Geneva, Switzerland. Two data taking periods have already taking place:
a) Run 1 (2011–2012), at 7 and 8 TeV in the center of mass (c.o.m). In this Run ATLAS and CMS discovered a standard model-like Higgs boson at 125 GeV (H), mainly through its bosonic decay modes.
b) Run 2 (2015–2018), at an energy of 13 TeV in the c.o.m, with greater integrated luminosity which allowed the observation of the main fermionic interactions of the Higgs boson ($H \rightarrow \tau\tau$, $H \rightarrow bb$, ttH production).
- Run3 (2022-2025) has started this year to integrate around 300 fb-1 of pp collisions at 13.6 TeV by end of 2025. The following runs will correspond to the high luminosity operation until 2040 aiming to accumulate 3000 fb-1 ("high luminosity phase"). This large sample of data will allow the first observation of di-Higgs production and access to the self-coupling of the Higgs boson, but also the measurements of the Higgs boson couplings to other elementary particles with few % predictions, which could further validate (or invalidate) the predictions of the Standard Model.

To continue the study of the Higgs boson with higher precision, an e+e- “Higgs factory” has been set in 2020 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) and proton-proton collisions in a second phase. 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.

This thesis will be divided in two parts:

a) the analysis of the ATLAS Run3 data for the search of the production of two Higgs bosons for the measurement of its self-coupling, decaying in bb + $\tau\tau$, with the ATLAS data from Run3 of the LHC (2022–2025), with an optimization of the sensitivity of the analysis compared to Run2 and the use of multivariate analysis techniques to maximize the separation between signal and background. We are targeting to have first evidence for this process with the larger dataset, improved analysis techniques of Run3 compared to Run2 and combination of the different channels of ATLAS and CMS results. The measurement will put constraints on the self-coupling of the Higgs boson and on models of physics beyond the Standard Model.

The candidate will also give a contribution to the activities of the team on the construction or on the software preparation of the future tracking detector (ITK) for the high-luminosity upgrade of the LHC.

b) In addition, the candidate will contribute to the ongoing feasibility and R&D studies on FCC-ee which has to be finished by end of 2025. The expected measurements of ZH production, Higgs self-coupling, and of the Higgs boson mass at FCC-ee will be studied in detail. These expected Higgs measurements will be used as benchmarks to compare the performance of different detector designs and layout currently under study.

Working place: APC, Paris

Mobility: regular trips to CERN for ATLAS and FCC analysis team meetings and ATLAS data taking shifts. Two presentations at an international conference (one on ATLAS the other on FCC) and participation in a summer school in high energy physics.

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