M2 (2021-2022) internship proposal at the Institut pluridisciplinaire Hubert Curien (IPHC)

Search for charge-parity (CP) violation in Higgs decays to two τ leptons

In 2012, the ATLAS and CMS experiments at the LHC discovered a new particle, whose properties are in good agreement with those predicted for the Higgs boson within the Standard Model (SM). Beside many other measurements, the measurement of its CP state draws a particular attention. Any deviation from a purely scalar state would be a clear sign for new physics beyond the SM. In contrary, a confirmation of a purely scalar state would allow to exclude new physics models such as several supersymmetry models.

Measurements of the Higgs CP state have been performed by ATLAS and CMS in different Higgs production channels. Additionally, the CMS experiment has performed, for the first time, the measurement of the CP state in the Higgs to two τ-leptons decay using the data collected in the Run 2 of the LHC (CMS-PAS-HIG-20-006). The IPHC group has contributed to this analysis with the analysis of the τ-lepton reconstructed from three charged pions. For that, the so-called "polarimetric vector method" has been developed to build a proxy for the CP state.

The proposed internship will focus on the reconstruction of the τ-leptons in CMS and reducing the systematic uncertainty on the measured τ energy scale. The energy scale is computed from $Z \to \tau\tau$ events from Run 2 data used as a well-known reference process, and based on a fit optimising the τ mass in each of its decay channels. The existing method can be improved by performing a simultaneous fit of the decay modes including the different uncertainties impacting the τ-lepton identification. Even though the $h \to \tau\tau$ analysis is currently dominated by the statistical uncertainty, this work will provide a deeper understanding of the τ-lepton reconstruction in CMS and be beneficial for a variety of analysis using τ-leptons.

The Run 3 data taking of the LHC will start in spring 2022. This internship could thus naturally lead to a PhD thesis within the Higgs to τ-leptons CP measurement analysis. The new data as well as further developments on discriminating observables and analysis techniques will help to significantly increase the precision of this measurement. A fraction of the time would further be devoted to the work on the tracking detector upgrade of the CMS experiment for the High-Luminosity-LHC. The IPHC group is strongly involved in the design and construction of one part of this detector.

Further information: http://www.iphc.cnrs.fr/-CMS-.html

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