Master Thesis / M2 internship Proposal at the LPCA FCC-ee Group:

General Context

The Standard Model of Particle Physics (SM) describes the elementary physics interactions and has passed many experimental tests among which those realised at particle colliders are of special importance. A prominent example of colliders is the Large Hadron Collider (LHC) at CERN, used to discover in particular a narrow scalar particle of 125 GeV mass, consistent so far with the fundamental scalar boson of the SM. Although the SM well describes interactions up to O(100 GeV) energy scale, it has several shortcomings. The next energy scale of new physics that could mitigate these shortcomings is however unknown. Pushing the limits forward, the future circular collider project (FCC) with its colliding electron and positron beams crossing the four relevant electroweak thresholds is expected to tighten constraints on beyond SM (BSM) theories. Several detector concepts are promoted to address this physics casse and it is timely to assess their perfomance.

Scientific Motivation

Among the multiple projections of a wide physics case, the FCC experiments should gather several trillions of Z boson decays into a pair of fermion-antifermion. The knowledge of their electroweak properties will therefore potentially improve by two orders of magnitude if one compares to the number of events recorded at the previous e^+e^- machine, the LEP.

The physics of the τ lepton at FCC-ee is particularly appealing. Its mass and its lifetime shall be measured with unprecedented precision, via the τ decays into three charged tracks. The reconstruction technique developed to measure these properties can in turn be used to determine experimentally the vectorial and axial-vector couplings of the τ to the intermediate Z boson and compare to the SM predictions.

Proposed Master Thesis / Internship Topic

The proposed master thesis / internship subjects consists in developing a complete physics analysis using simulated data of $e^+e^- \to \tau^+\tau^-$ at the Z pole reconstructed with a fast simulation detector concept. Several steps will be taken:

- Actual simulation of $e^+e^-Z \to \tau\tau$ events in FCC-ee;
- Study of the phenomenology of the three-prongs $\tau \to \pi\pi\pi\nu_\tau$ decay;

- Reconstruction of these signal event;
- Development of an Dalitz analysis to measure the fundamental amplitudes governing this decay;
- Using the amplitudes to assess/invent a method to measure the polarisation of the τ lepton.

Supervision and Work Environment

The work will be supervised within the FCC-ee group, in close collaboration with the PhDs, the post-docs team, and the senior researchers. The first period of the thesis / internship will involve hands-on tutorial to get acquainted with the FCC software framework. The progresses of this work will be shared and discussed in weekly meetings.

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