Phenomenology at the future FCCee: detector sensitivity to exotic long-lived particles

Research in particle physics is in progress in the view to have a better understanding of the interactions between particles and to exceed the limits of the Standard Model. After the High-Luminosity Large Hadron Collider (HL-LHC) adventure at CERN, the next generation of colliders will be leptonic. Currently, four projects are developed around the world: the International Linear Collider (ILC) in Japan, the Compact Linear Collider (CLIC) at CERN, the Circular Electron Positron Collider (CEPC) in China and the Future Circular Collider (FCC-ee) at CERN. The latter one will establish the context of the internship because the IPHC institute is fully involved in the R&D of future sensor technologies for devoted detectors.

First, the student must acquaint himself/herself with the FCC-ee program of physics. More specifically, he/she will focus the theoretical models which predict the production and the decay of exotic Long-Lived Particles (LLP). Indeed, the LLPs are interesting in contrast to promptly decaying particles. The LLP can fly a significant distance from the primary vertex and can go through one or several detection layers before decaying in standard (or not) particles. This secondary vertex leads to several very promising experimental signatures such as *displaced tracks*, *displaced jets*, *multitrack displaced vertices*, *etc*. Three theoretical and hypothetical scenarii predicting LLPs are usually considered in the FCCee community: Heavy Neutral Leptons, Axion-like particles and exotic Higgs decay.

In a second step, the student will learn how to produce realistic Monte-Carlo samples and will be responsible to produce signal samples corresponding to scenarii of LLPs. In this production, will be considered the matrix element calculation, the initial and final state radiation (ISR and FSR), the parton showering, the hadronization and potentially specific effects related to electronic colliders such as beams pinching, bremsstrahlung emissions, *etc*. In order to reproduce the effects of a detector, a very-fast detector-simulation will be applied on the top of the events. At FCCee, two main detector concepts have been designed: the CLD (CLIC-Like Detector) and the IDEA (Innovative Detector for Electron-positron Accelerator). The simulation of one of these detectors will be implemented step-by-step for pedagogical purposes: starting with a very simple simulation *à la* PGS (Pretty Good Simulation) and finishing with the use of an advanced software package called DELPHES.

Once the technical part of the work will be under control, the student will reconstruct and isolate the secondary vertices corresponding to the LLP decay with the help of the reconstructed tracks. From this result, the most interesting region of the theoretical model parameters should be highlighted. Besides, it is expected that optimizations of the tracker geometry should be proposed to enhance the sensitivity of the experimental signature.

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