Simulations and physics analysis for a vertex detector optimization of a future Higgs factory (FCCee/ILC): from heavy flavor tagging to long lived particles searches.

DIRECTEURS DE THESE : AUGUSTE BESSON ET ZIAD EL BITAR
GROUPE : PICSEL
INSTITUT PLURIDISCIPLINAIRE HUBERT CURIEN , DÉPARTEMENT RECHERCHE SUBATOMIQUE (IPHC-DRS),
23 RUE DU LOESS - BP28
67037 STRASBOURG CEDEX 2
TEL : 03 88 10 68 01 ;
E-MAIL : ABESSON@IN2P3.FR & ZIAD.ELBITAR@IPHC.CNRS.FR

The internship will be welcomed by the PICSEL group (Physics with Integrated Cmos Sensors and ELectron machines) which works closely with the microelectronic platform of IPHC. Together, they've been proposing, designing and testing CMOS pixel sensors since 1999. In the last 20 years, they played a pioneer role in using this technology in subatomic physics. The PICSEL group has been engaged in a long term effort to equip vertex detectors in e+e- machines with CMOS pixels sensors, and in particular in the future Higgs factory, considered as the highest priority next collider beyond LHC. There are 4 Higgs factory projects (ILC, FCCee, CEPC, CLIC) that could start in the 2030s. All of them contain a very rich Higgs physics program by producing (e+e- -> Z H) with a center of mass energy around sqrt(s) = 250 GeV. Historically, the PICSEL group has been involved in the ILC project but our R&D is generic enough to allow to work also in the context of FCCee.

The physics program of the Higgs factories will cover a wide spectrum, including studying the Higgs boson and measuring its properties very precisely but also top physics, electroweak physics and searches beyond the Standard Model. The expected precision of the measurements in the Higgs sector will be typically at the per mil level, improving significantly the HL-LHC measurements. This will allow constraining or excluding unambiguously the different theories beyond the Standard Model.

To accomplish this ambitious program, the foreseen detectors will have to reach unprecedented performances. The vertex detector, probably equipped with CMOS pixels sensors, will have to allow an impact parameter measurement resolution on the vertex of the order of 5 microns with a material budget below ~ 0.15% X0 per layer while being able to cope with the data flow governed by the beam background. The vertex detector will play a crucial role to tag heavy flavors (b and c quarks, tau leptons), to allow jet charge measurements and to reconstruct low momentum tracks.

The vertex detector requirements are well established. However a fine optimization remains to be done and can only be performed thanks to a complete physics analysis where the vertex detector plays a prominent role, like in analysis where the final states contains heavy flavour-quarks or displaced vertex. For instance, the Higgs to c-cbar coupling, the e+e- -> c cbar production or any final states containing a W boson decaying into c-s could allow to study extensively the expected performances of the vertex detector. Another very promising benchmark consists in studying the long lived particles production in the e+e- -> h + Z production.

Internship:

The goal of the internship will be to characterize and optimize the performances of the vertex detector in terms of b/c tagging performances in the full simulation software of ILC and/or FCCee for different vertex design options.

The working plan is the following:

- Generation and production of Monte-Carlo samples of events containing b/c-quarks in the final states (e.g. e+e- -> b bar ; e+ e- -> c cbar ; e+ e- -> Z Z, etc.) as well as production of background events (e+ e- -> u ubar, d dbar, s sbar) in the software framework of ILC/FCCee which shares common tools.
- Reconstruction of simulated events using the flavor tagging existing tools which provides the (LCFI+).
- Production of tagging efficiency vs background rejection curves.
- Development of a simple and standalone heavy flavor tagger as much as possible independent of other reconstruction algorithms (vertex finder, tracking, etc.).
- Comparison of the performances between different detector geometries and design options.

The added value of this study will allow improving significantly our fine understanding of the vertex detector requirements and hence guides us in the CMOS sensor R&D in the future.

The internship could naturally be pursued by a PHD. The main goal of the PhD will be to perform a complete physics analysis using full simulation tools which will allow optimizing the vertex detector and the tracking system. The proposed physics benchmark which will be the core of the thesis consists in studying the long lived particles (LLP) production in the golden channel (e+e- -> h + Z).