PhD proposal

Title : Inclusion of precise timing in the APRIL Particle Flow Algorithm and the measurement of the Higgs-W-W coupling.

Abstract:

After the discovery of the Higgs boson at the LHC[1, 2], the detailed study of the Higgs properties is ongoing. The coupling strengths of the Higgs boson to other elementary particles is the origin of the particles' mass. To measure this coupling strengths with unprecedented accuracy, few projects for a new particle colllider are currently under scrutiny. These collider projects are ILC[3] in Japan, CEPC[4] in China and FCC[5] in Europe. Each collider project comes with associated projects for multi purpose particle detectors. The IP2I FLC group has been working mainly within the ILD detector project[6], one of the detector project associated with the ILC collider project. Additionally, studies for the CEPC and FCC detectors are also pursued by the group.

In a particle collider experiments, the goal of a detector is to reconstruct all the particles emanating from the particle collision point. Among them quarks and gluons are producing jets of collimated hadronic particles. Traditionally, hadronic jets were reconstructed globally. A newer strategy, Particle Flow Algorithms (PFA) has been developed recently[7]. This approach consists in reconstructing jets by following each of the jet particle into the detector and use the most precise sub-detector to estimate each particle energy. PFA have been developed for ILC detectors like ILD. The first PFA algorithm developed for the ILD detector has been PandoraPFA[8]. An other PFA has been developed in Lyon, APRIL (previously named ArborPFA).[9, 10] Both PandoraPFA and APRIL are build on PandoraSDK[11]. PandoraSDK is a software development toolkit to perform complex pattern reconstruction in particle detectors.

To achieve PFA, new kinds of calorimeter, with high granularity, are needed. High energy hadrons lose their energy in matter by producing a tree of ionising particles called a shower. High granularity calorimeters aim at measuring and visualising such trees. Prototypes for high granularity calorimeters have been developed within the CALICE collaboration. The IP2I group has lead the developments of the Semi-Digital Hadronic CALorimeter (SDHCAL)[12]. This device is a calorimeter sampling hadronic showers with a granularity of 2.5 cm in the longitudinal direction and 1 cm in both lateral direction. An exemple of a recorded shower is shown on figure 1.

Recent developments in detector technologies leads to the possibility to measure for each SDHCAL detecting cell, the interaction time of the shower with the cell with a resolution of a few tens of picoseconds. This will allow to follow the time propagation of the hadronic shower inside the calorimeter. APRIL PFA is better suited to incorporate time information than PandoraPFA.

The PhD work would consist in modifying the APRIL PFA to include time information in it and assert the impact of the time information on the jet reconstruction and on the measurement of the Higgs boson properties. In particular, the group has started a study to study the measurement of the Higgs coupling to W bosons using the channel $e^+e^- \rightarrow \nu_e\bar{\nu}_e H$. The impact of APRIL jet reconstruction on this study is part of this thesis proposal.

The PhD candidate is expected to have good knowledge of experimental particle physics and to be experienced with software developments and highly skilled with programmation in C++.

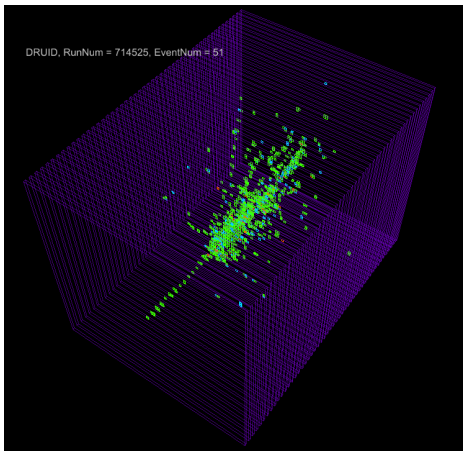

Figure 1: 3D event display of a 90 GeV pion interacting in the SDHCAL prototype.

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References

[1] Georges Aad et al. Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC. *Phys. Lett. B*, 716:1–29, 2012.

[2] Serguei Chatrchyan et al. Observation of a New Boson at a Mass of 125 GeV with the CMS Experiment at the LHC. *Phys. Lett. B*, 716:30–61, 2012.

[3] The International Linear Collider Technical Design Report - Volume 1: Executive Summary. 6 2013.

[4] CEPC Conceptual Design Report: Volume 1 - Accelerator. 9 2018.

[5] A. Abada et al. FCC-ee: The Lepton Collider: Future Circular Collider Conceptual Design Report Volume 2. *Eur. Phys. J. ST*, 228(2):261–623, 2019.

[6] Halina Abramowicz et al. The International Linear Collider Technical Design Report - Volume 4: Detectors. 6 2013.

[7] JEAN-CLAUDE BRIENT. Improving the jet reconstruction with the particle flow method: An introduction. *Calorimetry in Particle Physics*, Feb 2005.

[8] M. A. Thomson. Particle Flow Calorimetry and the PandoraPFA Algorithm. *Nucl. Instrum. Meth. A*, 611:25–40, 2009.

[9] Remi Ete. *Développement d'un algorithme de suivi de particules pour l'ILC : outils de surveillance de qualité de données en ligne*. Theses, Université de Lyon, March 2017.

[10] B. Li, R. Été, G. Grenier, and I. Laktineh. APRIL : a novel Algorithm for Particle Reconstruction at ILC. *JINST*, 15(05):C05016, 2020.

[11] J. S. Marshall and M. A. Thomson. The Pandora Software Development Kit for Pattern Recognition. *Eur. Phys. J. C*, 75(9):439, 2015.

[12] G. Baulieu et al. Construction and commissioning of a technological prototype of a high-granularity semi-digital hadronic calorimeter. *JINST*, 10(10):P10039, 2015.