Master 2 & PhD

Imaging Calorimetry for Tera-Scale detectors

La calorimétrie ultra-granulaire pour des détecteurs au TeV.

Anticipating the success of the LHC and the discovery of the Higgs, several projects for extension or future accelerators have been developed; the LHC will be upgraded for higher luminosity in 2023, and 3 projects of e^+e^- colliders – circular (FCC-ee, CEPC) or linear (ILC) – are being furbished for the next decade. The upgrades large detectors designed for these colliders all use imaging calorimetry as a mean to achieve higher performances, through a complete reconstruction of the flux of particles from the interaction(s), a technique named «Particle Flow».

The development of imaging or high-granularity calorimeters – a factor of 1000 in the density of channel w.r.t. present experiments – is a complex task involving instrumentation, high level software and physics performances. The images of showers of can be 3D (i.e. purely topological for digital calorimeter), 4D (standard ones, with energy), or 5D (adding the timing).

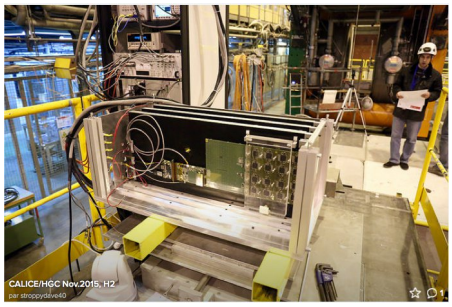
The ILC/CALICE group at LLR – a historical leader in imaging calorimetry – studies all aspects are studied: conception of detectors, design, construction and testing of prototypes, associated data acquisition systems, and the PF reconstruction algorithms, estimation of the global performances on key physics channels.

A first generation of high-granularity electromagnetic calorimeter (ECAL) has been tested in particle beams over the last few years. A second generation prototype with 10 000 channels in 8 dm^3 and including several important improvements in design will be heavily tested in beam (CERN, maybe SLAC) in 2016 and 2017. The beam test data will be used to improve the understanding of hadronic shower development and the knowledge building by the reconstruction algorithms, possibly by machine learning.

While the algorithm are more or less universal, the optimal design depends on physics performances, and selected channels for each machine.

Our studies concern mainly the most probable next particle accelerator in the Tera-Scale range, the ILC, a linear collider running at centre-of-mass energies from 250 GeV to 1 TeV, to be build in Japan before 2030. Such a machine will bring unprecedented precision to the measurement of particle physics at the tera-scale, for example the properties of the Higgs boson, the top quark sector and (yet to be found) supersymmetric particles. Recently the activities were extended to the CEPC, a circular collider promoted by China at about the same time. Since 2015, imaging calorimetry has been chosen for the CMS end-cap upgrade, the HGCAL, and we work in close collaboration with the CMS groups.

Subject of internship



It is proposed to work on data analysis of November 2015 beam test data of the first final design of sensors, and depending on dates to take part to the next campaign at CERN.

Alternatively student versed in complex algorithms could work on the improvement of PF algorithms development by machine learning.

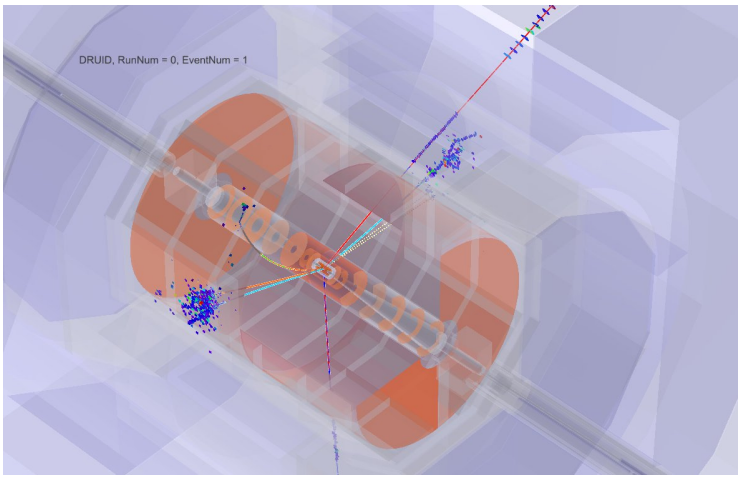
Subject of PhD thesis:

- Participation in and data analysis of test beam campaigns of 2nd generation ECAL prototype. First tests took place in 2012 and 2013; large-scale tests are foreseen in 2015–2017 at CERN.
- Development of calorimeter reconstruction algorithms for Particle Flow. Dedicated pattern recognition algorithms are required to make the most of the very detailed information provided by the calorimeter detectors. These will be studied both in simulations of a complete detector, and in real data collected in test beams.
- Studies of the potential for physics measurements at a future collider. Numerous studies are possible, according to the affinity of the student. Reconstruction of Tau's with the help of improved pattern reconstruction techniques and evaluation of the performances for the Higgs coupling estimation and for the Higgs CP state.

Regular travel both inside and outside France will be required: CERN (Geneva) and/or DESY (Hamburg) for beam tests, as well as for regular meetings of the CALICE and ILC communities (typically in Japan, US, and Europe). Short stay in Japan (Kyushu) or in China (Beijing) could be organised.

About the group

The ILC/CALICE group of LLR is a key player in the development of this novel type of calorimeters. Its scope of expertise ranges from broad detector design and optimisation, using parametric geometry for detailed simulation, data analysis and advance reconstruction algorithms, to detector prototype realisation implying all the technological challenging aspects of a strongly integrated calorimetry (silicon sensor design, mechanics, thermic, electronics and readout).
A dozen of physicist and research engineers are involved.



$ee \to Z \to ZH$; $Z \to \mu\mu$, $H \to \tau\tau$ in one of the ILD models.

For further information

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References

http://www.linearcollider.org/about
http://llr.in2p3.fr/spip.php?rubrique50
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