Master 2 & PhD

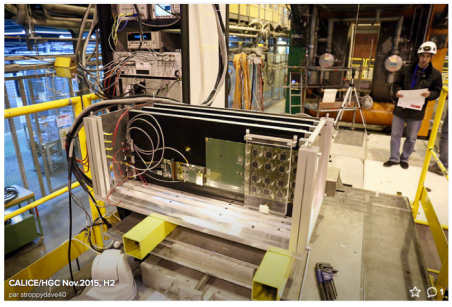
Imaging Calorimetry for Tera-Scale detectors

La calorimétrie ultra-granulaire pour des détecteurs au TeV.

After the discovery of the Higgs Boson, its properties must be precisely determined. This will be started with the High-Luminosity phase of the LHC, to be started in 2023, and with very high precision Lepton Colliders (ILC, CEPC, FCC-ee); all these projects are planning the use of a new generation of detectors, combining the best instrumental and algorithmic mixing: *Imaging Calorimetry* and full *Particle Flow* reconstruction. In this new paradigm the measurement of every individual particle in jets, allows to fully benefit from the performance of the trackers for all charged particles and use the calori - meters “only” for neutral ones, providing a doubling of performances in term of jet energy resolution w.r.t. standard measurements.

This is only possible thanks to the recent development of *imaging* or *ultra-granular calorimeter,* typically a factor of 1000 in the density of channel w.r.t. present experiments. The images of showers of can be 3D (i.e. purely spatial for digital calorimeter), 4D (standard ones, with energy), or 5D (adding the timing).

A first generation of high-granularity electromagnetic calori- meter (ECAL) has been build by the CALICE / ILC group of LLR at École polytechnique (Palaiseau). It was tested in particle beams over the last few years. A second generation prototype 4 times the density of channel (~10 000 in 8 dm^3) and including several im- portant improvements in design will be heavily tested in beam (CERN, maybe SLAC) in 2017 and 2018.



In combination with Semi-Digital HCAL built at IPNL (Lyon), 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 to treat the complexity. 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 or (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-HGCAL and the ATLAS-HGTD end-cap upgrades. We work in close collaboration with the implied CMS and ATLAS groups.

Subject of internship

It is proposed to work on data analysis of 2015 and 2016 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 and statistics could work on the improvement of PF algorithms development.

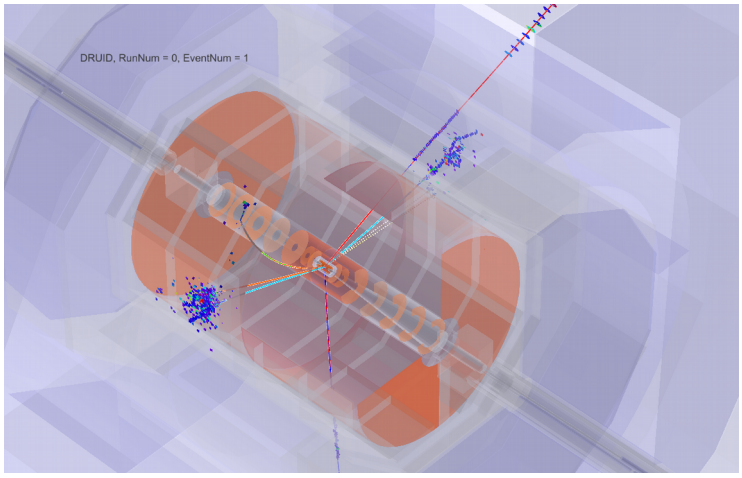
Subject of PhD thesis:

- 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 on-going 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).



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

For further information

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References

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