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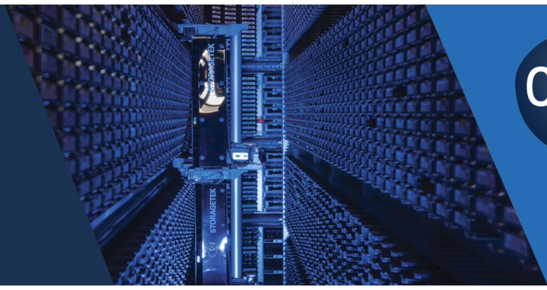
Centre de Calcul
de l'Institut National de Physique Nucléaire
et de Physique des Particules



Heterogenous Architectures For Particle Reconstruction in High Energy Physics

Contact: Adriano Di Florio (CC-IN2P3): adriano.di-florio@cc.in2p3.fr

Context

Research in high-energy physics is currently in an exciting and transformative phase. Despite its remarkable success, the Standard Model (SM), the theory that describes matter and fundamen- tal forces with impressive accuracy, still leaves several important questions unresolved. The Large Hadron Collider (LHC) at CERN offers a unique opportunity to study the particles that constitute our world and address many of these pressing questions. The high-luminosity upgrade will provide 20 times the current dataset, allowing physicists to observe elusive SM phenomena and expand the search for new processes beyond the Standard Model (BSM).

The Compact Muon Solenoid (CMS) detector [1] is one of the major experiments at LHC and it generates a tremendous amount of data (several hundred gigabytes of information per second) with collisions happening at a rate of 40 MHz. To handle this vast data flow and select the most interesting physics events for further analysis, the experiment relies on a two-stage trigger system [2]. The first is called the Level-1 Trigger (L1T)implemented in custom hardware and FPGAs and reduces the rate down to 100 kHz. The second is the High-level Trigger (HLT) which runs a stream- lined version of CMS reconstruction software (CMSSW). It makes further selections on the physics objects reconstructed, thereby bringing the rate down to few kHz. This process is referred to as online reconstruction.

The first years of operations of the LHC (known as Run-1 and Run-2) saw the online reconstruc- tion algorithms run on a CPU farm (~30000 CPUs in 2018). Since the start of Run 3, CMS has used GPUs for online reconstruction within the HLT [3]. Several HLT algorithms can now be executed on GPUs, including electromagnetic calorimeter (ECAL) and hadronic calorimeter (HCAL) deposit reconstruction, as well as pixel tracking and vertex reconstruction. Offloading these tasks to GPUs has led to a notable increment in the number of events processed per second (+80%) while reducing the power consumption (-30%) and improving the quality of the collected data.
All the pieces currently ported to GPU account for ~35% of the whole chain (in terms of timing). For the next phase of the data taking, known as Phase-2 and starting in 2030, the goal for CMS is to bring this percentage to 80% by allowing the offloading on heterogeneous architectures of further pieces of the reconstruction. On one hand, adopting new reconstruction algorithms requires re-engineering the existing code which can in turn bring gains in physics performance. On the other hand computing power allows CMS to invest in a more detailed reconstruction, enhancing the discovery potential of the data collected.

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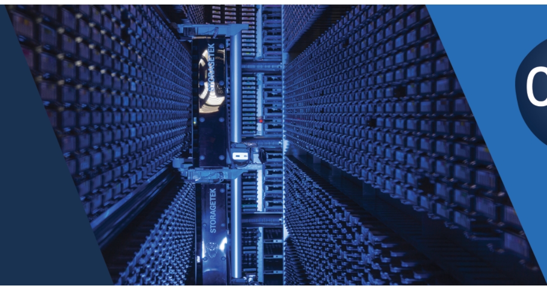

Goal

In this internship we aim to develop advanced algorithms and machine learning methods to enhance the reconstruction of data from the Tracker detector in the CMS Phase-2. The tracker detector is the one devoted to the detection of charged particles and the estimation of their helicoid trajectories. We will explore techniques such as advanced clustering, deep learning and graph neural networks to improve particle trajectories reconstruction and identification.

Work Environment

The Centre de Calcul de l'Institut national de physique nucl´eaire et de physique des particules (CC-IN2P3) is a support and research unit of the CNRS. It is involved in about fifty international experiments, and plays a key role in the data management of the major physics experiment. In particular, it is one of the 14 main international data processing centres for experiments at CERN's LHC accelerator. It also provides computing resources for the VIRGO gravitational wave experiment. Future challenges for CC-IN2P3 include data processing for the future High Luminosity LHC project at CERN, the new SPIRAL 2 particle gas pedal at GANIL, the BELLE II detector in Japan, as well as promising astroparticle physics projects such as the future LSST telescope, and the European EUCLID satellite.

Practical Informations

- Location: The internship will take place at CC-IN2P3 in Villeurbane, in the Universit´e Claude Bernard Lyon 1 university campus area.
- Supervisors: Adriano Di Florio (CC-IN2P3), Felice Pantaleo (CERN).
- Prerequisites: Good knowledge of C++ and Python programming. Familiarity with GPU programming is an asset. Particle physics understanding is not a requirement.
- Duration: 4 to 6 months (starting date anytime between Jan 2025 to April 2025).

Submit your application with your relevant grades. Salary will be according to the french internship rules.

21 avenue Pierre de Coubertin
CS 70202 - F-69627 Villeurbanne CEDEX

Tél. : +33 (0)4 78 93 08 80
Fax : +33 (0)4 72 69 41 70

Web : https://cc.in2p3.fr
Twitter : @cc.in2p3