PhD thesis topic:

Search for the production of a pair of Higgs bosons with the ATLAS experiment at the LHC

Louis D'Eramo

LPCA, CNRS-IN2P3 Université Clermont Auvergne

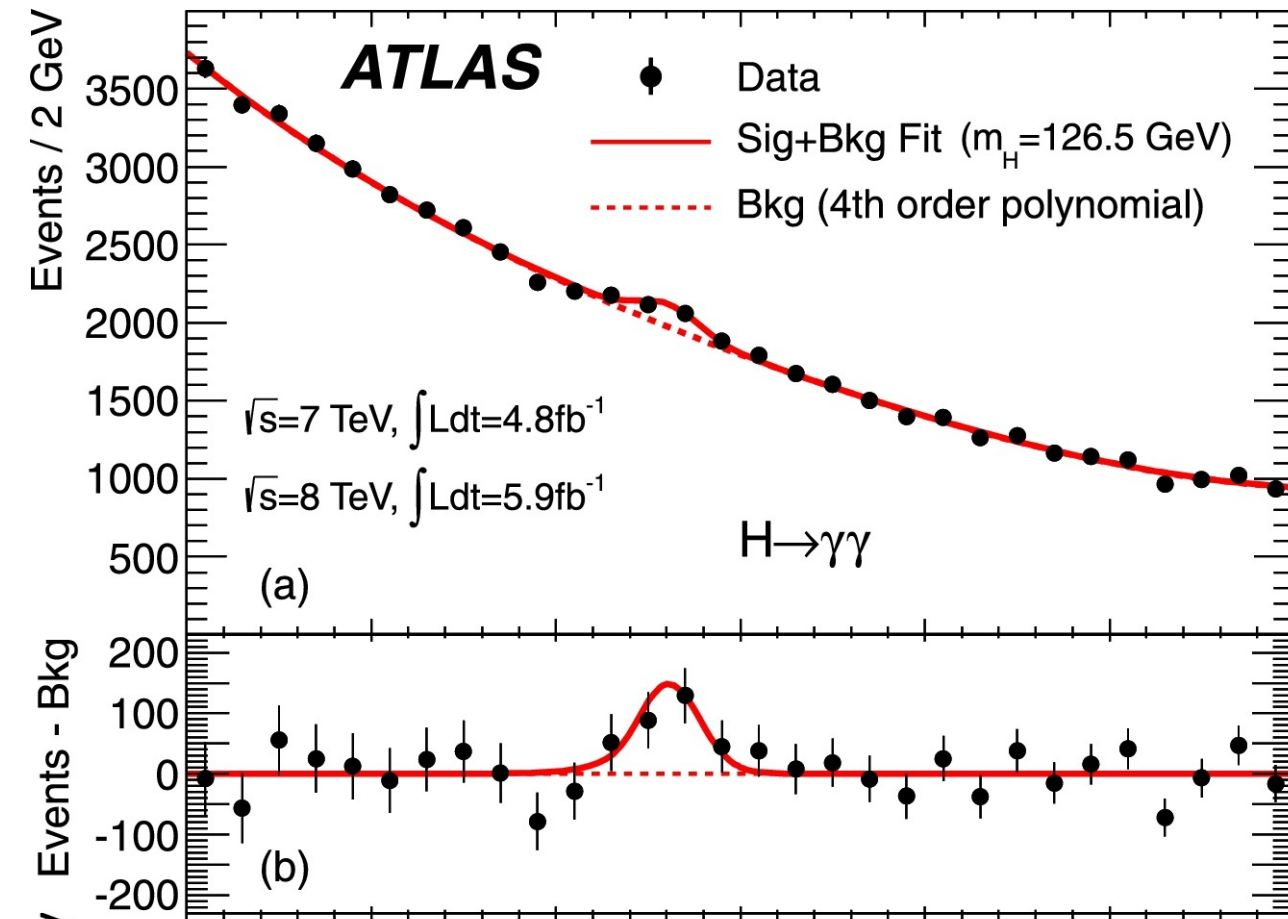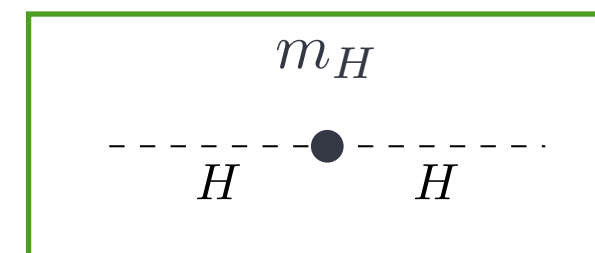# Introduction: the physics topic

~ 1960s

Several theoreticians, working on phase transitions, postulated a mechanism that could explain why certain particles have a mass while others don't.

It implied the existence of a new particle: the **Higgs Boson**. However, the theory left two free parameter: the mass and the self-coupling λ.

$$V(H) \supset \underbrace{\mu^2}_{\frac{1}{2}m_H^2} H^2 + \lambda\nu\, H^3$$
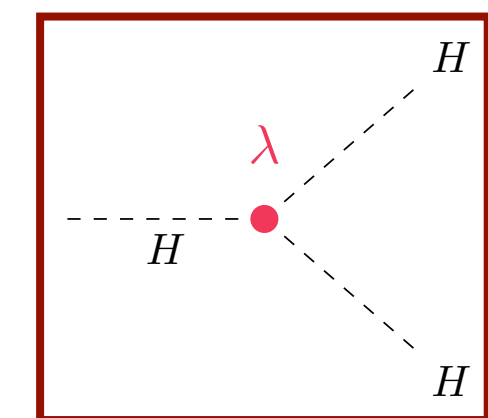

2012

After decades of searches, the ATLAS and CMS collaborations finally reported **its discovery** at the LHC. One of the free parameter, the mass, was measured !

$$m_H$$
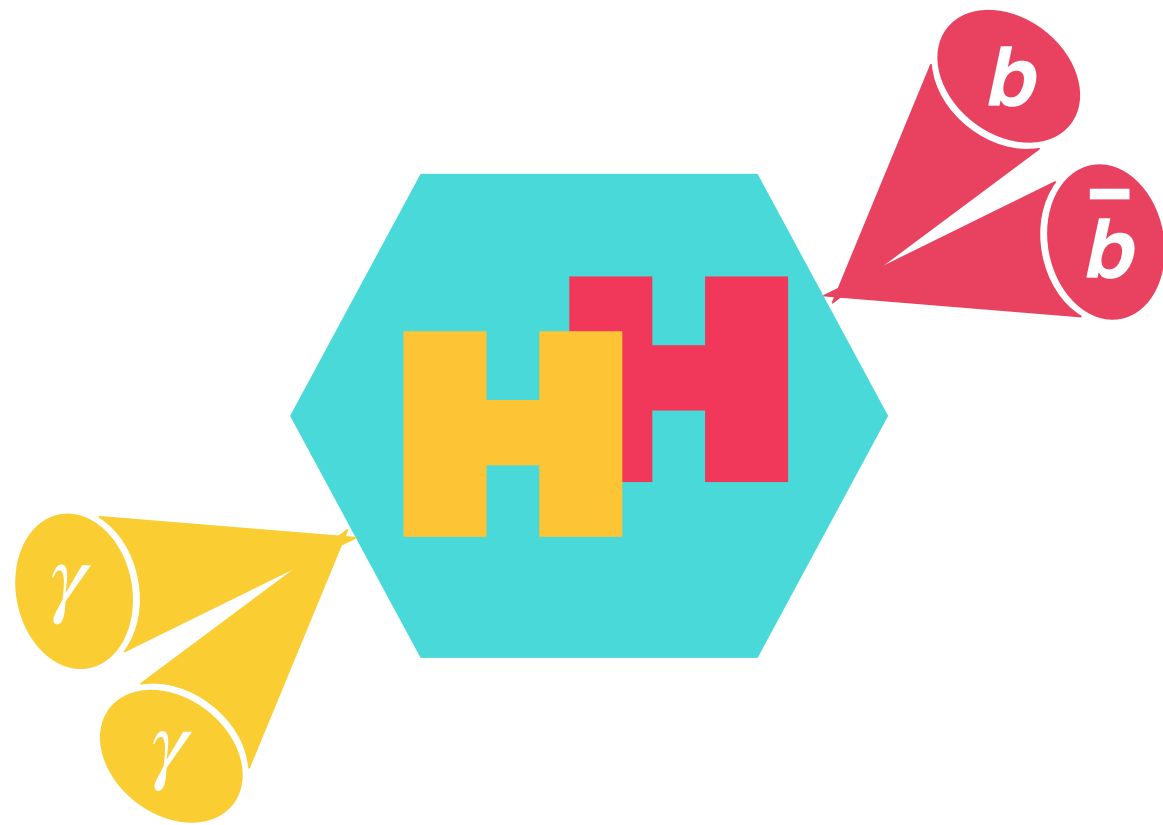$$H \quad\bullet\quad H$$

After a decade of studying the Higgs boson we are still to understand if the Higgs potential is the one predicted in the 60s, and to understand its fundamental nature. This search involves studying diagrams involving the Higgs self coupling: hence the production of **pair of Higgs bosons**.
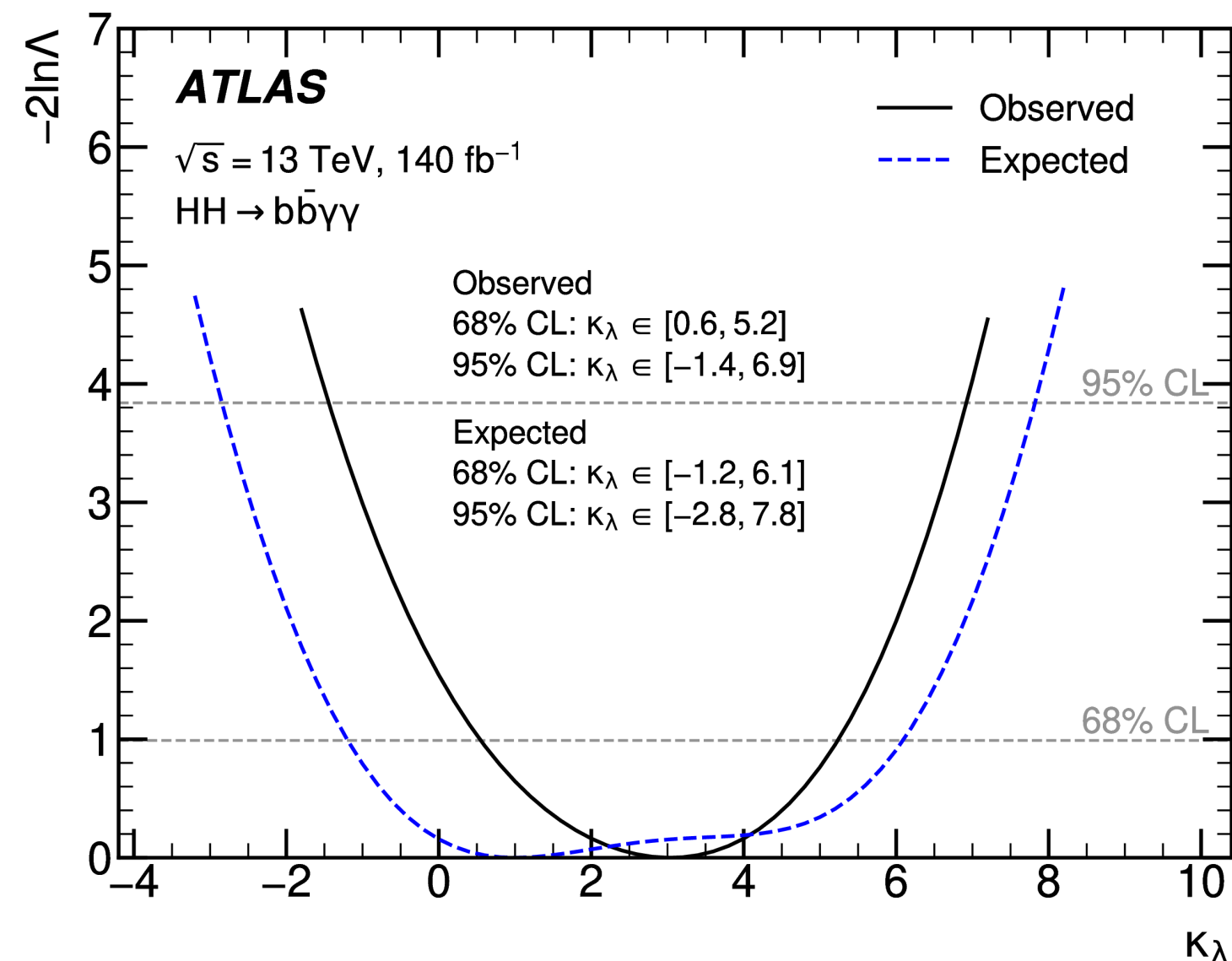
2024

The physics analysis

The LPCA group has a recognised expertise in the HH searches:

Looking at the decay chain involving **2 b-jets and 2 photons**:
- ‣ Despite a low branching fraction, it suffers from low background;
- ‣ One of the 3 golden channels to observe HH production;
- ‣ Best limit on the self-coupling set by an individual channel so far;
- ‣ Main PhD supervisor led 2 of the last ATLAS analyses on the subject.

ATLAS

$\sqrt{s}$ = 13 TeV, 140 fb^{-1}

HH → b$\bar{\text{b}}$γγ

Observed
68% CL: $\kappa_\lambda \in$ [0.6, 5.2]
95% CL: $\kappa_\lambda \in$ [−1.4, 6.9]

Expected
68% CL: $\kappa_\lambda \in$ [−1.2, 6.1]
95% CL: $\kappa_\lambda \in$ [−2.8, 7.8]

Observed
Expected

95% CL

68% CL

Main analysis contribution is supposed to take place within that analysis using the LHC **Run-2 and Run-3 datasets**: from the event selection with machine learning new ideas, to the analysis framework development there is a lot to do !

The group has also some expertise in working with top quark associated production: looking for the rare ttHH production mode.
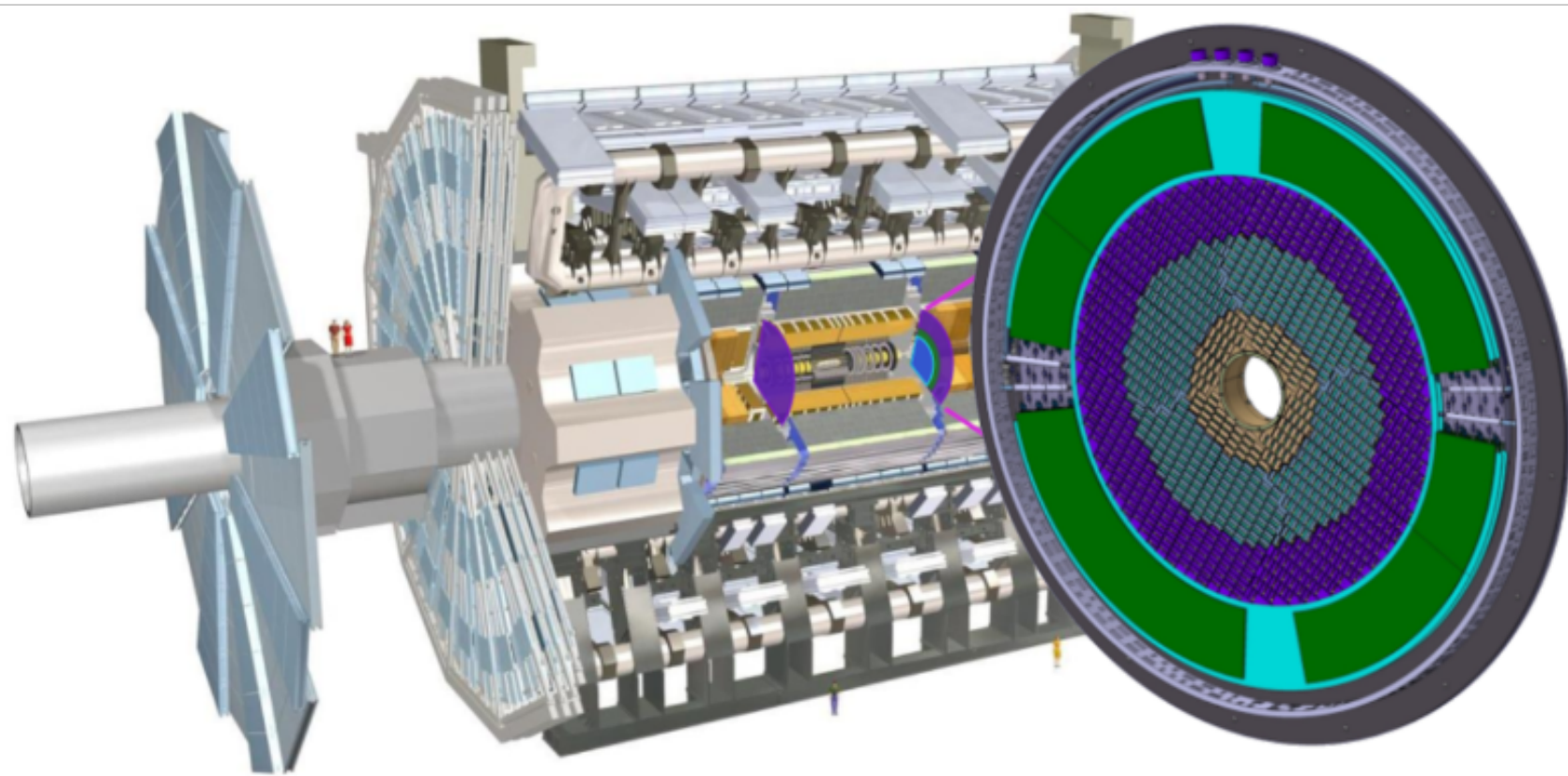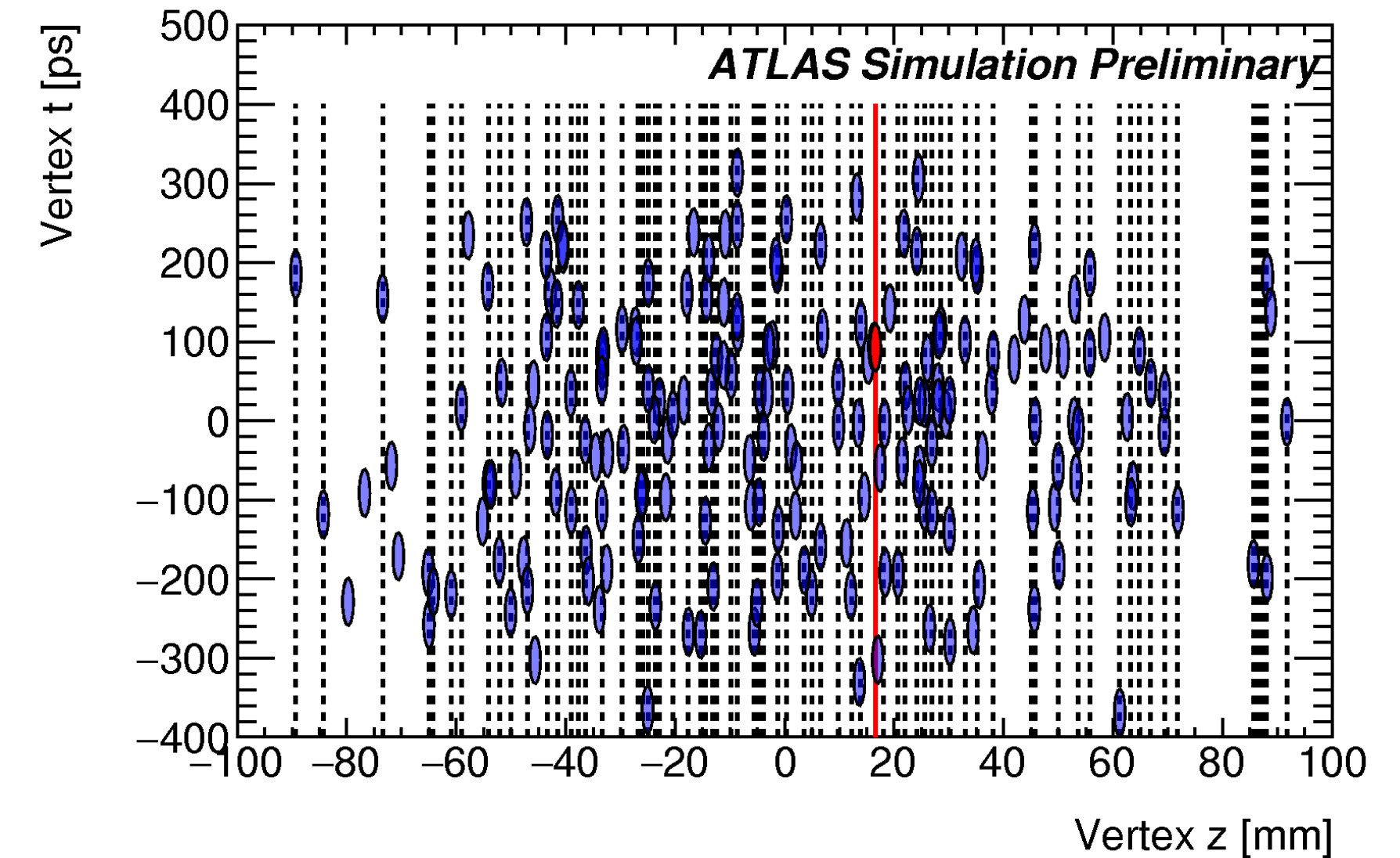
The hardware involvement

The group is also involved in building the upgrade of the ATLAS detector for the H-LHC phase.

One of the challenge is the increased pile-up density that will be comparable to the longitudinal (z_0) track resolution in the forward region: Solution: add timing information with a small enough resolution.

The High Granularity Timing Detector will have a timing resolution of $30 - 50 \ ps$ per track. It will be based on LGAD (Low Gain Avalanche Detectors) of $50 \ \mu m$ thickness.

We are involved in several areas of development on which a contribution is expected:
‣ Design of the calibration procedure;
‣ Tests of the readout chip;
‣ Design of a prototype of data acquisition system for the detector.

The group

The Laboratoire de Physique de Clermont Auvergne joined ATLAS before it was even named ATLAS !
- ATLAS group is composed of 7 permanents, 3 post-docs to start this year, 3 PhDs and many research engineers;
- We have an historical involvement in the design of the Tile Calorimeter, top physics and recently long lived particles;
- The lab also covers the other LHC experiments (LHCb, ALICE), astroparticles, theoretical physics as well as nuclear physics for the environment.
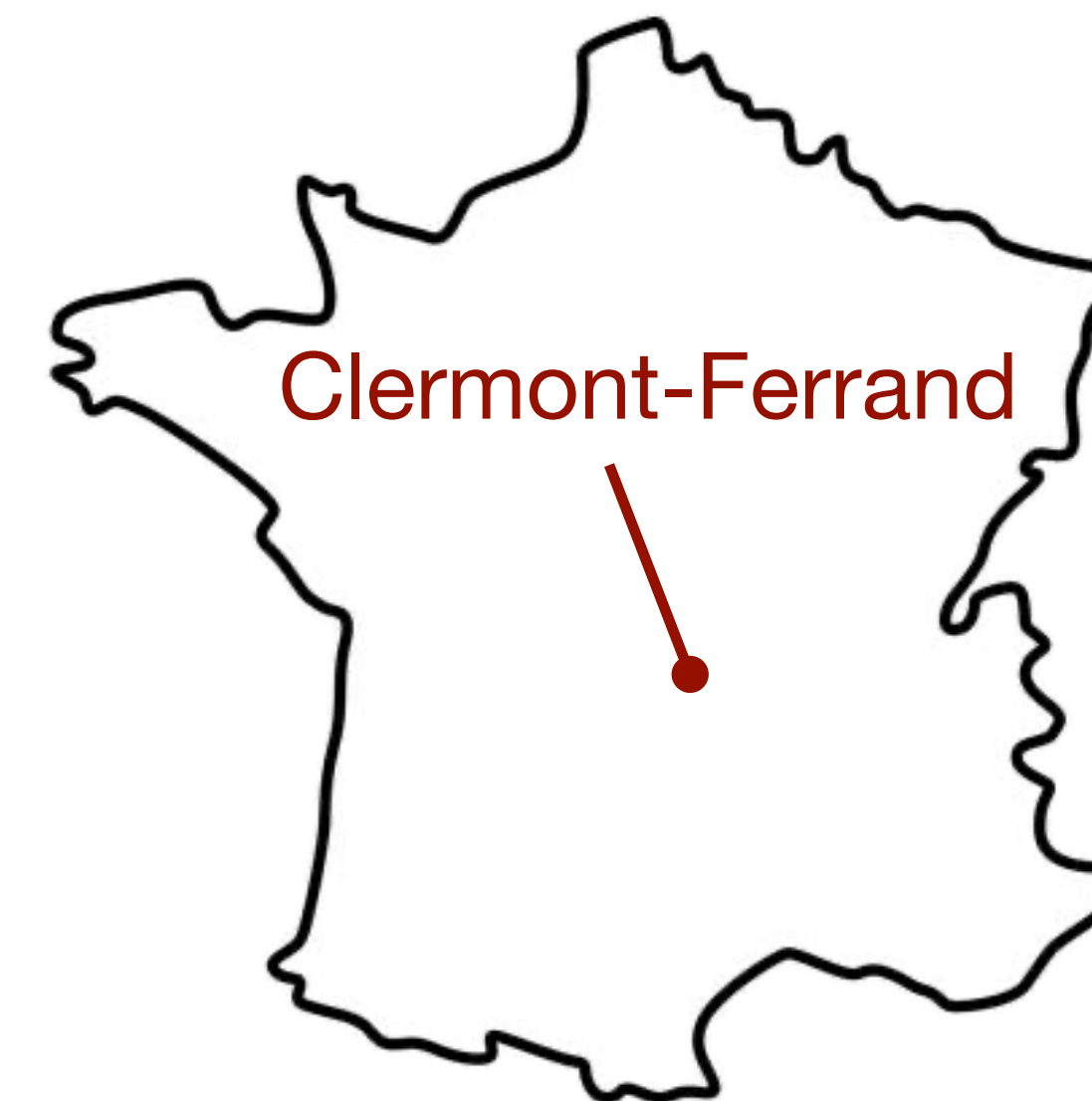
Technical details

cnrs

‣ Contract length: 3 years;
‣ Starting date: 1st of October 2024;
‣ Position will be attributed by the École Doctorale:
  • Limited number of contracts offered;
  • Several subjects are in competition.
  • Application on specific website <u>adum.fr</u> → **deadline 20th of May 2024**
‣ Real job contract in France:
  • Salary of ~ 1700€ / month after taxes
  • Standard national health insurance included;
  • 5 weeks of paid holidays.

Clermont-Ferrand

Position based in Clermont-Ferrand:
• City of 300k inhabitants in the middle of France;
• High fraction of student (16%) in the town population;
• Famous for its rugby team, Michelin tire company and surrounded by (extinguished) volcanoes;
• Average cost for a flat is 400-500€/month;
• ~3h30 from CERN by car (4h45 by train) → frequent travels to CERN planned.

Requirements:
• Holding a master degree (or equivalent);
• Past experience in experimental particle physics might be a plus, but not mandatory;
• Existing knowledge in programming (python/C++) is always welcomed.
• French speaking is not required, might be thought during PhD.