Search for Higgs-pair production with ATLAS@LHC in the HH->bbbb channel

In the CERN Summer School last September, during the Q&A session with the students, the CERN Director General, Fabiola Gianotti was asked: “If you were a PhD student today, what topic would you chose for your research project?”. Her answer was: “Without a doubt, Higgs-pair production.”!

Exploring the shape of the Higgs field potential and the nature of electroweak phase transition is the highest profile topic today (and for at least the next decade) in collider physics at the energy frontier. You can find a few high-level slides discussing this in [1]. The project proposed here is appropriate for students coming from Physics, Computer Science or Electrical Engineering background, and will give you the flexibility to follow the directions that fit best your background, skills and interests.

The HH->bbbb channel is one of the three most sensitive channels in the search for non-resonant Higgs-pair production, and the most sensitive one in the search for new heavy particles (at the TeV mass scale) decaying to a pair of Higgs boson. At UCL, we pioneered this search at the LHC around ten years ago and we have been playing a leading role ever since, providing the lead editor in the most recent ATLAS publication [2]. The next four years will be very exciting, as the available statistics will more than double, and we will be tantalizingly close to the first observation of the di-Higgs production process for the first time ever. For this, we will need to explore (or develop further) novel ML techniques for background modelling, such as normalizing flows and diffusion models, or graph-based techniques for better signal-to-background discrimination.

Looking further into the future, the High-Luminosity phase of the LHC (HL-LHC) is due to start towards the end of this decade and continue through to the early 2040s. HL-LHC will produce an unprecedented rate of proton-proton collisions, with up to 200 such collisions happening every time bunches cross at the heart of ATLAS (at 40MHz rate), and will increase the available datasets for physics studies at the energy frontier by an order of magnitude. ATLAS is preparing major upgrades to cope with the challenges of HL-LHC, and UCL has a leading role in the Global Hardware Trigger (GHT) project, which aims to inspect the data from every bunch crossing in ATLAS in real-time, with latency of a few microseconds, and select ~1 in every 40 events. As part of this project, you may involve in developing novel ML algorithms for selecting the interesting events, that will be implemented in firmware and deployed on powerful FPGAs of the GHT. This work will involve optimizing algorithms (quantization, trimming etc) for making optimal use of the GHT FPGA resources. You can see details of this type of work in [3]. The focus of the algorithms you will be exploring is on the use of data from the ATLAS Calorimeters to maximise the acceptance for special/rare signal events like HH->bbbb.

[1] https://liveuclac-my.sharepoint.com/:b:/g/personal/ucapnik_ucl_ac_uk/EdUXPSwcEk9Bine3Ao_ESjcBIljcjmgKp2HT1Gi8ovuQ7g?e=X5Jh3w
[2] https://arxiv.org/abs/2301.03212
[3] https://liveuclac-my.sharepoint.com/:b:/g/personal/ucapnik_ucl_ac_uk/EVyauM3kAXNNhs1LtWMXvJkBw90UxVrA-VLG82u-yhw0HA?e=At4vuz