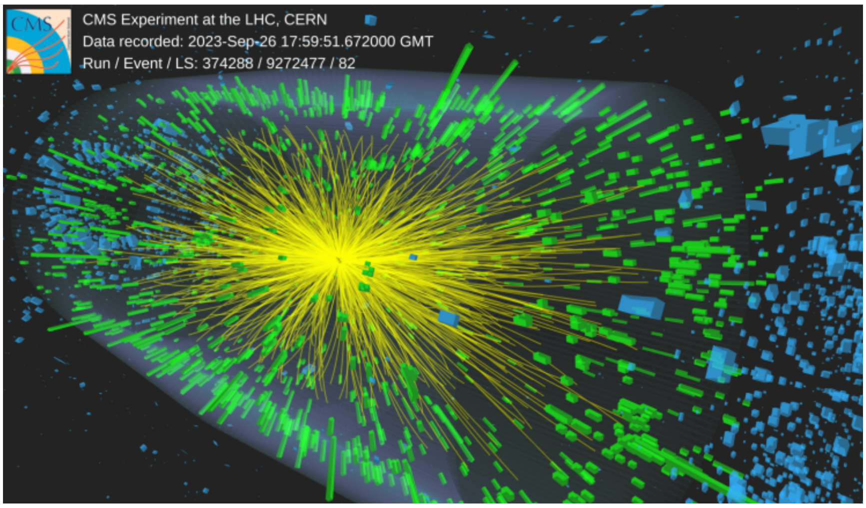
Master internship in experimental high-energy physics: jet substructure of gluon splitting with CMS @ the LHC



The bottom quark plays a privileged role in high-energy physics. Hadrons containing b quarks decay with a flight distance (hundreds of microns) which is measurable with charged particle tracking detectors. These decays allow us to identify jets (collimated sprays of particles) that result from the hadronization of b quarks. Such b-tagged jets can be used to better understand the properties of jets that originate from quarks. They are also an integral part of the HEP toolbox, e.g., for identifying top quark decays or Higgs decays into b-quark pairs.

The emergent field of jet substructure employs techniques that seek to mimic the fractal-like parton branching process in quantum chromodynamics (QCD). In the b quark sector, such studies have been hindered by the decays of the b-hadrons, which tend to obscure the underlying parton branchings of interest. Within the last year, a PhD student in our group has made a breakthrough on this front by aggregating the b-hadron decay products using a multi-variate analysis of the charged hadron track and vertex properties. The resulting improved jet clustering allows us to expose the radiation of a hard gluon from the b quark, as well as the predicted "dead cone" of gluon radiation in the direction of the massive quark, which is a fundamental prediction from gauge quantum field theories.

An interesting and challenging extension of this methodology would be the reconstruction of the splitting of a gluon into a b quark-antiquark pair, where the pair is unresolved, ending up in a single jet. This "antenna" configuration is particularly interesting to probe mass effects in QCD and gluon polarization effects, but also as an eventual probe of the spatial resolution power of the Quark-Gluon Plasma created in ultra-relativistic heavy-ion collisions. The technique we have developed will need to

be modified and re-optimized for the substructure of these double-pronged jets, using the same basic machine learning tools developed for the single b-quark analysis
This project is ideal for a master level intern, and has excellent prospects for an eventual PhD thesis on measurements of these jets from gluon splitting (although it also serves as an excellent stand-alone project).

The student will perform their research within a group dedicated to measurements of QCD phenomena with the Compact Muon Solenoid experiment at the LHC. We focus on measurements of jets and quarkonia, both in collisions of protons and in heavy ions. Recent measurements include a decomposition of the jet tree using the so-called Lund Jet Plane [1,2] and a measurement of the substructure of jets recoiling from a prompt photon in proton and heavy-ion collisions [2]. Our group is also deeply involved in the development of reconstruction algorithms, activities related to data taking, and detector upgrades for the upcoming High-Luminosity LHC and the future Electron-Ion Collider. The student would be involved in one or more of these activities should they continue for a PhD thesis.

For more information, please contact me at Matthew.Nguyen@cern.ch

[1] https://cms.cern/news/fractal-tree-quarks-and-gluons
[2] https://inspirehep.net/files/81733ebeca02eaa50b366644000d32c6
[3] https://cds.cern.ch/record/2867449/files/HIN-23-001-pas.pdf