

M2 internship proposal - AY 2025-2026

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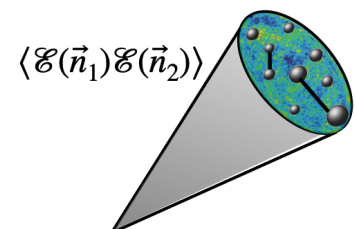
Possible PhD follow up: Yes

Energy correlators at the Large Hadron Collider

In a collider experiment such as the LHC, we measure the energies of the particles produced in a collision, which happens at incredibly short distances, of around 10^{-15} m, but are detected far away, at distances of about 10 m, effectively “at infinity”. In Quantum Field Theory (QFT), this energy flux at infinity is described by the energy flow operator, a special kind of light-ray operator. In this sense, a collider can be thought of as measuring correlations of the energy flow operator, known as energy correlators. Very recently, it has become possible to actually measure energy correlators at the LHC, providing an exciting way to connect formal QFT with what we see in the detectors.

Energy correlators first attracted attention in the context of conformal field theories (CFTs), where they show a simple power-law behavior. It was later realized that they also have another key feature: they are sensitive to physical scales, which necessarily break their simple power-law behavior. This sensitivity makes them a versatile tool with many applications in collider physics.

In particular, energy correlators have become a very active tool to study jet substructure, the internal structure of the collimated sprays of particles known as jets. They are especially useful because they can probe the angular distribution of energy inside a jet with very high precision. In fact, energy correlators are now the jet substructure observables calculated with the highest accuracy in perturbative QCD. The first experimental measurements of energy correlators inside jets, such as the two-point energy correlator shown in the cartoon, were reported in proton–proton collisions at the LHC two years ago. These data confirmed the power-law behavior predicted in CFTs, as well as its breaking at small angles due to the emergence of the confinement scale Λ_{QCD} . Measurements in collisions involving nuclei, such



as proton-lead and lead-lead collisions, have further shown that the scaling is not only broken by confinement at small angles, but also at large angles, revealing additional nuclear modifications.

The goal of this project is to compute energy correlators in nuclear collisions using a novel approach that combines their formal properties, such as their light-ray operator expansion, with perturbative QCD calculations of matrix elements. This project will allow the intern to gain experience in perturbative QCD methods, developing skills in theoretical calculations while maintaining a link to phenomenological applications, in a topic that is currently at the forefront of research in collider physics.