M2 and PhD thesis subject proposal 2024

Title

Characterizing the charm hadronization with the LHCb experiment

Laboratory/research team

Laboratoire Leprince-Ringuet, École polytechnique / LHCb heavy ions

Local team

Experimentalists: Heavy ions

Oscar Boente Garcia (postdoc), Frédéric Fleuret (DR, CNRS), Chenxi Gu (postdoc), Qiuchan Lu (PhD student), Kara Mattioli (postdoc), Émilie Maurice (Assistant Professor, École polytechnique), Gabriel Ricart (PhD student, CEA)

Luminosity

Vlasdislav Balagura (DR, CNRS), Rita Sadek (postdoc)

Research project

One of the defining features of Quantum Chromodynamics (QCD) is color confinement, which prohibits isolated quarks and gluons from being observed. Instead, the partons which carry color charge are found only as constituents of color-neutral hadrons. Quarks that are produced at colliders such as the Large Hadron Collider (LHC), evolve into observable hadrons through a process known as hadronization. Factorization theorems in QCD typically assume that hadronization is a universal process, independent of the colliding beam species.

One mechanism of hadronization is fragmentation, where the potential between outgoing partons grows until it is energetically favourable to produce other partons from vacuum that neutralize the initiating parton's color charge. Fragmentation functions, which describe the evolution of a parton into a jet, are constrained by data from e^+e^- collisions.

An additional hadronization mechanism can arise when quarks that are produced near each other combine to form color-neutral hadrons through a process called coalescence. Models of coalescence generally require individual parton wave functions to overlap in position and velocity space, and have successfully described a range of collider and fixed-target data. In these models, the density of partons produced in the underlying event has a significant effect on the hadronization process, and is expected to be especially important in heavy-ion collisions.

From 2024, the LHCb experiment will collect the first significant large fixed-target samples of proton-nuclei and lead-nuclei at centre of mass energies of ~100 GeV. Thanks to this unique system at the LHC, the hadronization process will be deeply studied in various collisions systems. It will shed light on the hadronization and its interplay with the coalescence models. In addition, these hadronization studies will initiate a new field of research at the LHC by precisely investigating the nucleon content in a novel way.

The proposed PhD subject contains two parts. First, the candidate will analyse the LHC Run 3 data with the measurement of open charm hadrons production in proton-nuclei collisions collected in 2024. In parallel, the student will contribute to the future upgrade of the LHCb detector. The LLR is currently contributing to the conception and design of a new tracking detector for the LHCb upgrade II (2030 horizon). This detector, using the CMOS MAPS technology (Monolithic Active Pixel Sensors), will significantly improve the LHCb detector performances, including heavy ion collisions. Therefore, this new detector is a critical element of the LHCb future. The candidate will be deeply involved in this new activity.

Thesis project

The proposed thesis will be the first analysis on LHCb fixed-target run 3 data. It includes:

- A participation in the data taking from 2024, including proton-nuclei collisions (several stays at CERN are foreseen),
- A leading role in the open charm hadrons production in proton-nuclei collisions,
- A major role in the electronics characterization and optimization.

The interpretation of these data in the context of phenomenological work in close relationships with theorists may be an important part of the thesis project, depending on the student's interest.

The PhD student will participate in the dissemination of these results in publications and international conferences.

Master and doctoral school

- Master 2 in particle physics
- Doctoral school of Institut Polytechnique Paris

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