

M2 and PhD thesis subject proposal 2026

Title

Characterizing charm hadronization mechanisms with baryons with the LHCb experiment

Laboratory/research team

Laboratoire Leprince-Ringuet, École polytechnique / LHCb heavy ions

Local team

Heavy ions

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Luminosity

Vlasdislav Balagura (DR, CNRS)

Research project

One of the defining characteristics of Quantum Chromodynamics (QCD) is color confinement, which prevents the direct observation of isolated quarks and gluons. Instead, partons carrying color charge are only observed as constituents within color-neutral hadrons. Quarks produced at colliders like the Large Hadron Collider (LHC) undergo the process of hadronization, evolving into observable hadrons. Factorization theorems in QCD generally assume that hadronization is a universal process, independent of the specific colliding beam species.

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

Another hadronization mechanism occurs when quarks produced near each other combine to form color-neutral hadrons through a process called coalescence. Coalescence models typically require individual parton wave functions to overlap in position and velocity space, successfully describing various collider and fixed-target data. In these models, the Bjorken- x of the partons and their density in the underlying event significantly influence the hadronization process, particularly in heavy-ion collisions.

Starting in 2024, the LHCb experiment has collected significant large fixed-target samples of proton-nuclei and lead-nuclei collisions at center-of-mass energies of approximately 100 GeV. This unique system at the LHC will allow for a thorough study of the hadronization process in various collision systems and a kinematical region involving target valence quarks (large Bjorken- x), shedding light on its interplay between fragmentation and coalescence. These studies will initiate a new research field at the LHC by precisely investigating nucleon content in a novel way.

The proposed PhD subject comprises two parts. First, the candidate will pioneer LHC Run 3 data, focusing on the measurement of open charm baryons production in proton-nuclei collisions collected in 2024.

In parallel, the student will contribute to general interest activities, either to the trigger setup and tuning for further proton-nucleus and Pb-nucleus data acquisition, or to the future upgrade of the LHCb detector.

The LLR is actively involved in the conception and design of a new tracking detector for the LHCb upgrade II (2030 horizon), employing CMOS MAPS technology. This new detector, crucial for the LHCb's future, will significantly enhance detector performance, especially in heavy-ion collisions, making the candidate a key participant in this new endeavor.

The proposed PhD project consists of two main components:

1. **Physics Analysis**

The candidate will perform the first measurement of open-charm baryon production in proton-nucleus collisions using the whole fixed-target dataset from LHC Run 3. This analysis will provide crucial input to constrain hadronization models and test the transition between fragmentation and coalescence regimes.

2. **Detector Development (LHCb Upgrade II)**

The Laboratoire Leprince-Ringuet (LLR) is deeply involved in the design and prototyping of a new tracking detector for the LHCb Upgrade II, based on CMOS Monolithic Active Pixel Sensors (MAPS) technology. This detector will significantly enhance tracking capabilities, especially in high-multiplicity environments such as heavy-ion collisions. The PhD candidate will contribute to this R&D effort, becoming an integral part of the team shaping the next generation of the LHCb experiment.

Master and doctoral school

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

Contact

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