PhD/MSc Project in ALICE 2025 with the South African team

Project title: Heavy quark vs multiplicity in small systems in ALICE at LHC energies

ALICE Principal Investigators:

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Project description

Multiplicity-dependent studies in high multiplicity pp and p-A collisions in LHC Run 2 show remarkable similarities with AA collisions in the strangeness enhancement in the light-flavor sector [1] and collectivity (ridge formation, elliptic flow) [2]. Recent studies [3] show that the results from heavy quark vs charged-particle multiplicity in pp at 8 and 13 TeV compared to EPOS [4] and PYTHIA 8 [5] calculations (using default tunes) in the leptonic decay channel underestimate the linear increase observed at high multiplicity. Similar measurements are ongoing in pp and p-Pb collisions at $\sqrt{s}$ = 5 and 13 TeV and $\sqrt{s_{NN}}$ = 8.16 TeV in ALICE [6], respectively. Significantly, pp measurements at $\sqrt{s}$ = 5 TeV provide a reference for Pb-Pb and p-Pb collisions at the same $\sqrt{s}$.

Heavy-flavour hadrons are produced in initial hard scattering processes, hence, their production can be predicted with good precision using Quantum Chromodynamics (QCD) based theories. They are abundantly produced at LHC energies, where proton-proton (pp) collisions are used to test QCD theories as well as provide a benchmark for heavy-ion (AA) and proton-nucleus (p-A) collisions. Heavy flavour decays in various ways, e.g. the leptonic (electron or muon) decay channel has a branching ratio of ~10%. At the LHC high-energy and luminosity environment, the production mechanisms are complicated by multi-parton interactions (MPI - the number of hard partonic interactions that occur in a single event). Recent ALICE measurements of heavy-quark production yields vs charged-particle multiplicity in pp collisions at $\sqrt{s}$ = 8 and 13 TeV showed a similar linear increase [7]. The data were reproduced by QCD models including MPIs such as EPOS and PYTHIA 8.
In this study, data from pp, p-Pb, and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5 TeV will be analyzed and compared with similar studies in the central barrel and other experiments. Additionally, EPOS and PYTHIA 8 calculations will be performed and compared with the experimental results.

In this study anchored Monte Carlo (MC) data are analyzed, i.e. MC including realistic detector configuration, after which it will be extended to analyze dedicated pp/Pb-Pb data collected by ALICE in Run 3. The tools and data samples are available on the ALICE GRID as a requirement of the ALICE Collaboration. ALICE data analysis tutorials are presented three times a year by the ALICE O2 team.

The candidate will learn to work in a modern high-energy physics data analysis framework, written in C++ and based on ROOT and ALICE O2. The work will also include Monte-Carlo simulations within this framework and the usage of the worldwide LHC ALICE computing grid.

Requirements:

The candidate will be expected to follow the tutorials to familiarize with the analysis techniques.

The data analysis, presentation of results, and regular updates will be done in line with the ALICE Physics Working Group Heavy Flavour (PWG-HF), the O2 project.

The candidate will learn to work in a modern high-energy physics data analysis framework, written in C++ and based on ROOT and ALICE Online-Offline (O2). The work will also include Monte-Carlo simulations within this framework and the usage of the worldwide LHC ALICE computing grid.

References:

[1] Enhanced production of multi-strange hadrons in high-multiplicity proton-proton collisions, ALICE Collaborations, Nature Physics volume 13, pages 535–539 (2017)

[2] ALICE measurements of flow coefficients and their correlations in small (pp and p–Pb) and large (Xe–Xe and Pb–Pb) collision systems, The ALICE Collaboration, Nuclear Physics .A 982 (2019) 487-490, https://doi.org/10.1016/j.nuclphysa.2018.09.006.

[3] Study of heavy-flavour hadron decay electrons as a function of charged-particle multiplicity in pp collisions at √s = 13 TeV with ALICE. Shreyasi Acharya. PoS, LHCP2018:044, 2018.

[4] EPOS Model and Ultra High Energy Cosmic Rays, T.Pierog and K.Werner, Dec 2009. Nuclear Physics B -Proceedings Supplements,arXiv:0905.1198 [hep-ph], https://doi.org/10.48550/arXiv.0905.1198 ,

[5] A comprehensive guide to the physics and usage of PYTHIA 8.3 C. Bierlich et al, SciPost Phys. Codebases 8-r8.3 (2022) [arXiv:2203.11601 [hep-ph]].

[6] The ALICE experiment at the CERN LHC, The ALICE Collaboration, et al, 2008 JINST 3 S08002, 10.1088/1748-0221/3/08/S08002.

[7] Forward rapidity J/ψ production as a function of charged particle multiplicity in pp collisions at √s = 5.02 and 13 TeV. ALICE Collaboration, arXiv, doi: 10.48550/ARXIV.2112.09433. https://arxiv.org/abs/2112.09433, 2021.