

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

Title: Vector boson production in heavy-ion collisions with ALICE in LHC Run 3

ALICE Principal Investigators:

Assoc. Prof. Zinhle Buthelezi (zinhle@tlabs.ac.za) iThemba LABS/WITS School of Physics

Dr. SV Förtsch (forstch@tlabs.ac.za), iThemba LABS

Project Description:

The objective of this project is to investigate the production of vector bosons ($W^\pm$). Due to the weak coupling of vector bosons, their production is not sensitive to the quark-gluon plasma (QGP) hot nuclear matter effects. Therefore, in heavy-ion collisions (A-A) W bosons provide a good reference for the medium-induced effects on other probes, e.g. hadrons containing heavy quarks. The production mechanism of W is dependent on the isospin. For this reason, W bosons are affected by the initial-state effects such as isospin, Fermi motion, EMC effect, shadowing, and nuclear absorption. In A-A and p-A collisions, W boson production can be used to test some of these initial-state effects. Furthermore, W bosons can be used to provide a non-arbitrary reference to QGP probes. Traditionally, in A-A collisions, hard processes are expected to scale with the number of binary collisions thus a precise study of W bosons can be used to test the factorization assumed in models used to determine centrality. This unique property of W bosons makes them essential probes to study the possible inherent bias in centrality determination, while in proton-proton (pp) collisions, their production can be used to obtain information on the quark Parton distribution functions (PDF).

For this project, we intend to use data collected by ALICE - A Large Ion Collider Experiment the CERN Large Hadron Collider (LHC) [1]. The ALICE detector is designed to study ultra-relativistic heavy-ion collisions, in which a hot and dense, strongly interacting medium is created. The production of W bosons is studied in Pb-Pb [2], p-Pb [3], and pp collision systems at LHC energies. The single muon decay channel will be used for their measurements at forward pseudorapidity $-4.0 < \eta < -2.5$ utilizing the ALICE subsystems including the Muon Spectrometer and Muon Forward Tracker. Data collected during the LHC Run 3 (2022-2026) will be utilized. The leptonic decay channel is facilitated by fast online triggers (selection of interesting physics events) that extend the measurements to high transverse momentum, p_T .

In the analysis, we will extract the W boson total single muon spectrum, determine their normalized differential yield, and compute the production cross sections as functions of centrality and pseudorapidity. The W bosons' nuclear modification factor, R_{AA} (ratio of the yield of heavy quark in A-A to that in pp collisions normalized to nucleon-nucleon binary collisions) is an interesting observable, and since W bosons are not expected to be modified they would be ideal to compare their R_{AA} with that of heavy quarks since they are probes of the QGP. These results will be compared with those obtained from other LHC experiments as well as those obtained from theoretical calculations based on available models.

Objective

The project scope is limited to the analysis of pp, p-Pb, and Pb-Pb data, where available, collected by ALICE in LHC Run 3 and theoretical calculations using available models. This analysis will be done using the ALICE Analysis Tools and data samples available on the ALICE Grid as per the requirement of the ALICE Collaboration. The data analysis, presentation of results, and regular updates will be done in line with the ALICE Physics Analysis Group Heavy Flavour Muons (PAG-HFM) and the main coordination ALICE Physics Working Group Heavy Flavour (PWG-HF) at CERN.

In this project, the candidate will learn how to work in a high-performance computing (HPC) environment, in this instance, the ALICE GRID. This requires authentication as per ALICE regulations. The project requires basic knowledge of the ALICE Analysis Tools to analyze the data and a good theoretical background.

References:

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

[2] $W^\pm$ -boson production in p-Pb collisions at $\sqrt{s_{NN}}=8.16$ TeV and PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, ALICE Collaboration, [JHEP 05 \(2022\) 036](#).

[3] W and Z boson production in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, ALICE Collaboration, [JHEP 02 \(2017\) 077](#),