

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

Title: Double parton scattering and W boson plus correlated W and quarkonium associated production: a feasibility study in ALICE Run 3

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Project Description:

This project aims to investigate the feasibility of studying double parton scattering and vector boson and another vector boson and quarkonium-associated production in ALICE [1] during Run 3. A wide range of measurements of various quarkonium species production have been studied in ALICE for over a decade. This is due to the high production rates achieved at the LHC allowing not just a study of inclusive quarkonium production [2], but also testing more exclusive final states. One such observable is the associated vector boson plus quarkonium. According to [3] correlated W-boson and quarkonia production offers a clean test of the colour-octet mechanisms. The first experimental searches were conducted at the CDF using the $W+\psi$ channel [4]. The ATLAS collaboration has studied vector-boson scattering using a wide range of channels [5] (and references therein). A couple of interesting studies are $W+W$ [5] and $W+J/\psi$ [6]. These channels are accessible with the ALICE Run 3 detector [7] and beyond. W bosons [8,9] and J/ψ [2] have been studied extensively in ALICE. The advantage of studying double parton scattering in ALICE is centred around ALICE's capabilities, such as measuring all particle species to low transverse momentum (p_T) close to zero i.e. $p_T < 0.1$ GeV/c. The ALICE detector geometry is a huge advantage because it includes the central barrel ($|\eta| < 1$) and forward muon spectrometer ($-4 < \eta < -2.5$) enabling access to small Bjorken-x measurements. Therefore, measurements in ALICE provide a cross-check and complement measurements from other experiments such as ATLAS at the CERN's Large Hadron Collider (LHC).

This project intends to explore whether it is feasible to study $W(\rightarrow\mu\nu)$ boson candidates each correlated with another $W(\rightarrow\mu\nu)$ and with $J/\psi(\rightarrow\mu\mu)$ candidates in the same event in proton-proton (pp) collisions at 13.6 and 5.36 TeV using the ALICE detector in Run 3 [7]. This study will first be performed using PYTHIA [10] standalone simulations followed by realistic Monte Carlo (MC) simulations including the ALICE detector configuration to

estimate the expected rates for this signal in the analysis of experimental pp data at the same energy.

Objective

PYTHIA 8 calculations will be performed and compared with the results obtained from anchored Monte Carlo (MC) data which will be performed during this study. The analysis will be extended to pp 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.

References:

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- [2] Inclusive quarkonium production in pp collisions at $\sqrt{s}=5.02$ TeV, ALICE Collaboration, [Eur. Phys. J. C 83 \(2023\) 61](https://doi.org/10.1088/1748-0221/83/2/024001).
- [3] Double gluon fragmentation to J/ψ pairs at the Tevatron, Barger, Fleming, Phillips, Phys.Lett. B371 (1996) 111-116.
- [4] Search for Associated Production of Υ and Vector Boson in $p\bar{p}$ Collisions at $\sqrt{s}=1.8$ TeV, D. Acosta et al. (CDF Collaboration), Phys. Rev. Lett. 90, 221803.
- [5] Unraveling Nature's secrets: vector boson scattering at the LHC, The ATLAS Collaboration, <https://atlas.cern/updates/feature/vector-boson-scattering>, accessed, 10 October 2024).
- [6] Measurement of the production cross section of prompt J/ψ mesons in association with a $W^{+/-}$ boson in pp collisions at $\sqrt{s}=7$ TeV with the ATLAS detector. By ATLAS Collaboration. arXiv:1401.2831 [hep-ex]. JHEP 1404 (2014) 172.
- [7] [ALICE upgrades during the LHC Long Shutdown 2](https://doi.org/10.1088/1748-0221/19/05/P05062), ALICE Collaboration, JINST 19 (2024) P05062, <https://iopscience.iop.org/article/10.1088/1748-0221/19/05/P05062>.
- [8] 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](https://doi.org/10.1088/1748-0221/22/5/054001).

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

[10] [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]].