PROCEEDINGS OF SCIENCE

Underlying Event studies and search for jet-like modifications in pp and p–Pb collisions with ALICE at the LHC

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It is well-established that high-multiplicity pp and p–Pb collisions exhibit various signatures associated with the formation of QGP in heavy-ion collisions. In this contribution, we present results obtained using Underlying Event (UE) techniques, used to measure the average number density and the average total transverse momentum (p_{T}) in the Transverse region with respect to the leading trigger particle, but employed in novel ways. A conventional UE analysis is applied in p–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV to test the similarities between pp and p–Pb collisions. The results are compared with predictions from QCD-inspired Monte Carlo event generators. Finally, the UE studies are used to search for jet-like modifications by subtracting the UE contributions measured in the Transverse region from the Toward and the Away regions.

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1. Introduction

Quantum Chromodynamics (QCD) is the quantum field theory of the strong interaction. Superficially QCD appears like a stronger version of Quantum Electrodynamics (QED) with eight gluons replacing the single photon, but as the gluons carry the charge of the force, QCD interactions become non-perturbative in the soft limit and are therefore not calculable from first principles.

In Underlying Event (UE) studies we measured the components of particle production in hadronic interactions, which are not directly related to the hardest interaction. UE studies is based on the study of all the final state hadronic processes including beam remnants fragmentations, initial and final state radiations and multi-partonic interactions (MPI) excluding the hardest scattering [1]. In MPI-based models such as PYTHIA8 and EPOS LHC, the height of the plateau is sensitive to the impact-parameter dependence upon the number of MPI per event [2]. Figure 1 shows an illustration of a pp interaction, including both the hardest scattering and the UE [3].

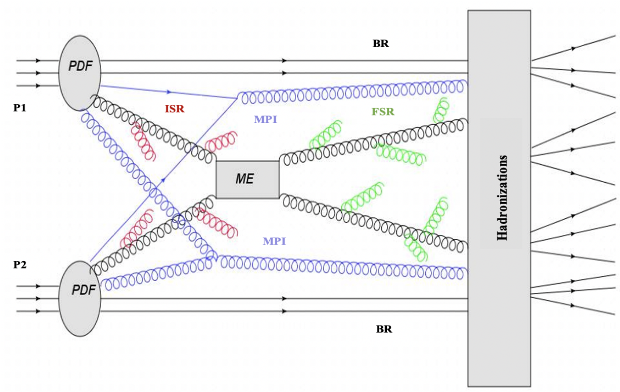

Figure 1: Illustration of all the interactions taking place in a pp collision. The hardest scattering is given by the Matrix Element (ME). The rest of the interactions and the radiation is the Underlying Event.

The UE is measured in a region with respect to the leading trigger particle where the particle production from the hardest scattering is expected to be negligible. The Transverse region method has been adopted for UE studies by ALICE [4], CDF [5], STAR [6], ATLAS [7] and CMS [8] collaborations. The UE results are valuable inputs to tune Monte Carlo event generators, e.g., to describe the uncorrelated background in jet studies. These studies are also helpful to provide high precision predictions for Standard Model (SM) and lead new ways in searches for the physics beyond the SM, where a good description of the UE is needed to understand backgrounds.

2. UE observables and analysis strategy

The traditional UE analysis is based on the measurement of particle production in three distinct topological regions, i.e., Transverse, Toward and Away regions, shown in the figure 2 [9]. The transverse region is more sensitive for UE. The UE observables in pp and p–Pb collisions for similar event classes (same $p_{\mathrm{T}}^{\mathrm{leading}}$ and same $\sqrt{s_{\mathrm{NN}}}$) are compared. Only primary charged particles in the

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limited acceptance of the ALICE central barrel detector system are considered. Results are obtained for associated particles within the pseudo-rapidity range ($|\eta| < 0.8$) and with $p_{\mathrm{T}} > 0.5$ GeV/c. The average number density and average sum p_{T} density are studied as a function of $p_{\mathrm{T}}^{\mathrm{leading}}$.

The average number density (average charged particle density vs $p_{\mathrm{T}}^{\mathrm{leading}}$) is defined as:

$$\frac{1}{\Delta\eta\Delta\phi}\frac{1}{N_{\mathrm{ev}}(p_{\mathrm{T}}^{\mathrm{leading}})}N_{\mathrm{ch}}(p_{\mathrm{T}}^{\mathrm{leading}}), \tag{1}$$

and the average sum p_{T} density (average summed p_{T} density vs $p_{\mathrm{T}}^{\mathrm{leading}}$) is defined as:

$$\frac{1}{\Delta\eta\Delta\phi}\frac{1}{N_{\mathrm{ev}}(p_{\mathrm{T}}^{\mathrm{leading}})}\sum p_{\mathrm{T}}(p_{\mathrm{T}}^{\mathrm{leading}}), \tag{2}$$

where $N_{\mathrm{ev}}(p_{\mathrm{T}}^{\mathrm{leading}})$ is the total number of events selected in a given leading-track transverse-momentum bin.

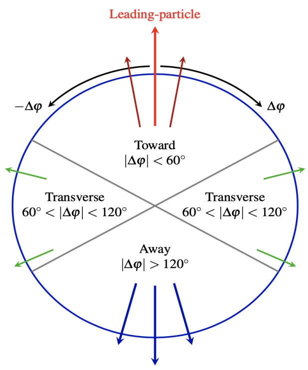

Figure 2: Definition of the different topological regions: Toward, Transverse and Away.

3. Results and discussion

Figure 3 shows the average number density in the Transverse region (TS, Transverse Side) as a function of $p_{\mathrm{T}}^{\mathrm{leading}}$ in pp and p–Pb collisions with same p_{T} threshold, i.e., $p_{\mathrm{T}} > 0.5$ GeV/c. We found that pp and p–Pb collisions show a similar trend, in agreement with other types of comparisons between pp and p–Pb collisions [10]. A larger magnitude of the UE is observed in p–Pb collisions as expected. At low $p_{\mathrm{T}}^{\mathrm{leading}}$ there is a steep rise in the event activity whereas in the plateau region ($p_{\mathrm{T}}^{\mathrm{leading}} \geq 5$ GeV/c) the event activity is almost independent of $p_{\mathrm{T}}^{\mathrm{leading}}$ in both pp and p–Pb collisions. In comparison with QCD event generator models, it is observed that both EPOS LHC and PYTHIA8 gives a good description of the pp results (Fig. 3 left), neither of the models captures the trend or the magnitude of the UE in p–Pb collisions (Fig. 3 right). As the impact parameter dependence of individual nucleon–nucleon collisions is constrained by the pp results, we suspect that the p–Pb results can be used to understand better the dependence on the number of nucleon-nucleon collisions in the models.

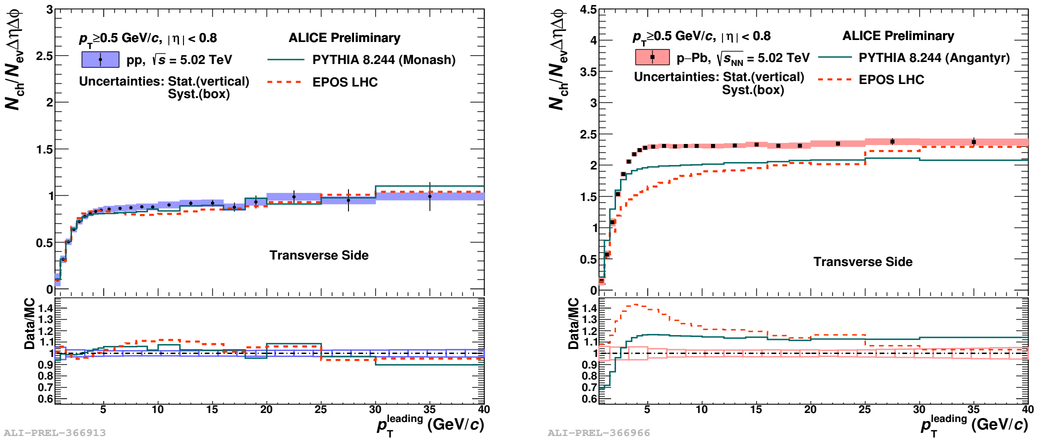

Figure 3: The average number density as a function of $p_{\mathrm{T}}^{\mathrm{leading}}$ in pp (blue) and p–Pb (red) collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV are displayed in the left and right plots respectively, with comparison with MC models PYTHIA8 (solid green line) and EPOS LHC (dotted orange line).

To search for jet-like modifications, we have studied the jet-like region by subtracting the Transverse region (TS, Transverse Side) from the Toward region (NS, Near Side). Figure 4 shows the result of Near Side after the subtraction of Transverse side (NS–TS). The average number and average sum p_{T} densities are the same for pp and p–Pb for large $p_{\mathrm{T}}^{\mathrm{leading}}$ as one would expect if the hard process is the same. There is a small difference at low $p_{\mathrm{T}}^{\mathrm{leading}}$ which is possibly due to the effect of flow. We plan to investigate this further by switching on and off flow in EPOS LHC.

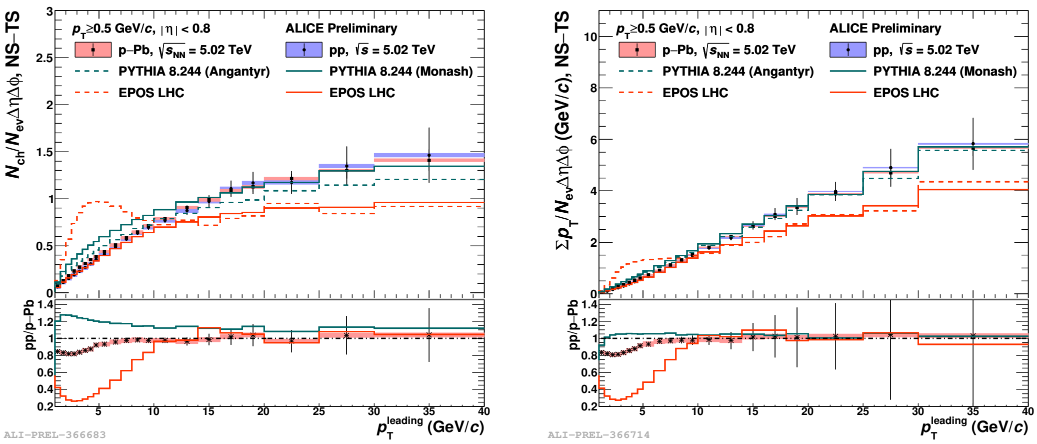

Figure 4: The average number density and average sum p_{T} density as a function of $p_{\mathrm{T}}^{\mathrm{leading}}$ in pp (blue) and p–Pb (red) collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV are displayed for the Near Side jet-like region in the left and right plots respectively, including comparisons with MC-model predictions PYTHIA8 (solid green line) and EPOS LHC (dotted orange line).

4. Summary

The Underlying Event exhibits qualitative similarities for pp and p–Pb collisions but its magnitude is much larger for p–Pb due to large numbers of multi-parton interactions. The jet-like regions were compared for pp and p–Pb collisions and no indications of jet-like modifications were observed for high $p_{\mathrm{T}}^{\mathrm{leading}}$ within the current measurement precision.

Acknowledgements

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