Inclusive Photon and Charged–Particle Production in Proton–Proton and Proton–Lead Collisions at LHC Energies with ALICE

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Introduction

One of the primary goals of heavy-ion collision experiments, such as ALICE, is to study and understand the properties of the deconfined state of nuclear matter, commonly known as the quark-gluon plasma (QGP). The first step in characterising the produced QGP matter is the measurement of global observables, such as the number of produced particles (particle multiplicity) and their distribution in pseudorapidity. These measurements are essential to understand the underlying mechanisms of particle production. Such studies in proton–proton (pp) and proton–lead (p–Pb) collisions are also important as they provide baselines for the interpretation of measurements in heavy-ion collisions. In addition, the study of pp and p–Pb collisions is also interesting on its own right. Recent experimental results in high-multiplicity pp and p–Pb collisions have shown interesting features usually attributed to QGP formation in heavy-ion collisions. The origin of these phenomena still needs to be fully understood, and therefore, it is of great interest to investigate and understand the global properties of such collision systems, which makes measurements of multiplicity distributions invaluable.

This thesis focused on new measurements of inclusive photon and charged–particle multiplicities in pp and p–Pb collisions using the ALICE detector at the LHC [1]. The data from p–Pb collisions were recorded for two beam configurations: in one (denoted as p–Pb), the lead beam travelled towards positive $\eta_{\rm lab}$ and in the other configuration (denoted as Pb–p), it moved towards negative $\eta_{\rm lab}$. A highly granular photon multiplicity detector, entirely designed by the Indian group, was used to measure inclusive photons at forward rapidity ($2.3 < \eta_{\rm lab} < 3.9$). On the other hand, charged–particle multiplicities were measured over a wide pseudorapidity interval ($-3.4 < \eta_{\rm lab} < 5.1$) using the combined information of the Forward Multiplicity Detector and the Silicon Pixel Detector. The data analysis procedures of these two measurements involve extracting the raw signal, obtaining the uncorrected distributions followed by corrections for instrumental and other effects using the unfolding method, and finally estimating the systematic uncertainties from various sources. All these steps are discussed in great detail in Ref. [1]. Below, we briefly describe the key findings of these two measurements.

A. Study of inclusive photon production

Several measurements at the LHC have been done for photons at midrapidity; however, there has been limited effort to detect photons at forward rapidities. In this thesis, we reported a detailed study of inclusive photon production at forward rapidities for minimum bias (MB) pp, p–Pb collisions and for various centrality classes in p–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02\,\text{TeV}$. This is the first time we studied the dependence of inclusive photon production on the average number of participating nucleons ($\langle N_{\rm part}\rangle$) in the p–Pb collision and its scaling behaviour at the LHC. Since inclusive photons primarily originate from the decays of neutral pions, these studies complement existing measurements of charged–particle production and provide insights into

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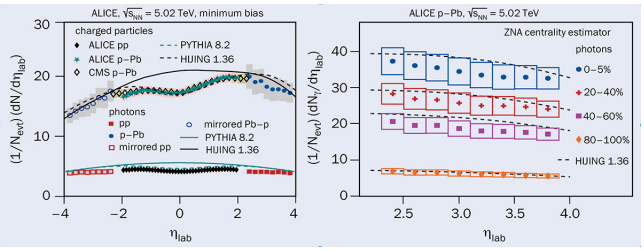

FIG. 1: The $dN_\gamma/d\eta_{lab}$ for MB events in pp, p–Pb, and Pb–p collisions (left), and for different centrality classes (right) in p–Pb collisions. The results are compared with theoretical model calculations and with similar measurements for charged particles at midrapidity. The figure is taken from Ref. [2].

the similarities and differences in the underlying production mechanisms for charged and neutral particles.

Figure 1 (left) presents the pseudorapidity distributions of inclusive photons ($dN_\gamma/d\eta_{lab}$) at forward rapidity for MB events in pp, p–Pb, and Pb–p collisions and compares the results to that of charged particles at midrapidity. The pseudorapidity distribution of inclusive photons at forward rapidity smoothly matches that of charged particles at midrapidity, indicating that the production mechanisms for charged and neutral pions are similar. Figure 1 (right) shows the measured $dN_\gamma/d\eta_{lab}$ in p–Pb collisions for different centrality classes as estimated using the energy deposited in the zero-degree calorimeter (ZNA) at beam rapidity. The multiplicity in the most central (0–5%) collisions reaches values twice as large as those in MB events. The measurements are compared with predictions from theoretical models. The data and models agree within one sigma of the measurement uncertainties.

In addition, we measured the multiplicity distributions of inclusive photons in pp, p–Pb, and Pb–p collisions and compared with various theoretical model predictions, revealing that none of the considered models could accurately reproduce the inclusive photon multiplicity distributions in the reported multiplicity range [1]. We also observed that in p–Pb collisions, the $\langle N_\gamma \rangle$ normalised by the $\langle N_{part} \rangle$ scales linearly with $\langle N_{part} \rangle$ and points towards pp data at $\sqrt{s} = 5.02$ TeV at low $\langle N_{part} \rangle$. This trend is consistent with charged–particle measurements at midrapidity.

B. Study of charged–particle production

At the LHC, charged–particle multiplicity distributions ($P(N_{ch})$) have been extensively measured for pp collisions, but there have been no experimental measurements of fully corrected $P(N_{ch})$ for p–Pb, and Pb–Pb collisions. We performed a comprehensive set of measurements of $P(N_{ch})$ in p–Pb collisions in four increasingly wider pseudorapidity ranges, $|\eta_{lab}| < 2.4$, $|\eta_{lab}| < 3.0$, $|\eta_{lab}| < 3.4$, and $-3.4 < \eta_{lab} < 5.1$. We determined the mean ($\langle N_{ch} \rangle$), standard deviation (σ), skewness (S), and kurtosis (κ) of the multiplicity distributions and compared the obtained values to those predicted by various theoretical models. This gives us a quantitative comparison of the performance of these models. None of the considered models is found to describe the data, indicating the need for new constraints to understand better the charged–particle production mechanisms in high-energy proton–nucleus collisions.

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References

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