Transverse Momentum Distributions of Charged Particles and Identified Hadrons in p–Pb Collisions at the LHC

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The transverse momentum distributions (p_T) of charged particles and identified hadrons in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV have been measured by ALICE at the LHC. Charged-particle tracks are reconstructed at mid-rapidity over a large momentum range $0.15 < p_T < 50$ GeV/c. Light-flavour hadrons and resonances are identified in the various momentum regions, ranging from 0.15 GeV/c to 15 GeV/c, using specific energy loss (dE/dx), time-of-flight, topological particle-identification and invariant-mass reconstruction techniques. p_T spectra are measured for different charged particle multiplicity intervals. Results from p–Pb collisions are compared with pp and Pb–Pb results, and with theoretical models.

1 Introduction

Production of light-flavor hadrons in high energy p–Pb collisions at the LHC is used to study the cold nuclear matter effects (Cronin effect [1], shadowing and gluon saturation [2]), which might influence particle production. It is also possible to search for collective phenomena or indication of the final state effects, which might modify the measured hadron spectra. Here, the question is whether the p–Pb can be considered as a reference system for measurements in Pb–Pb collisions, where the quark-gluon plasma (QGP) [3] is expected to be produced.

In these proceedings, we present results on primary charged particles (98% hadrons) and identified light-flavor hadrons ($\pi^\pm$, $K^\pm$, K^0_s, p, $\bar{p}$, Λ, $\bar{\Lambda}$, Ξ^-, $\bar{\Xi}^+$) obtained by ALICE. Primary charged particles are defined in ALICE as all charged particles produced in the collision and their decay products, except for particles from weak decays of strange hadrons.

In order to quantify nuclear effects, the particle production in p–Pb collisions is compared to pp with use of nuclear modification factor,

$$R_{pPb}(p_T) = \frac{\mathrm{d}^2 N_{ch}^{pPb}/\mathrm{d}\eta \mathrm{d}p_T}{\langle T_{pPb}\rangle \mathrm{d}^2 \sigma_{ch}^{pp}/\mathrm{d}\eta \mathrm{d}p_T}, \tag{1}$$

where N_{ch}^{pPb} is the particle multiplicity in minimum-bias p–Pb collisions, σ_{ch}^{pp} is the pp cross section, and $\langle T_{pPb}\rangle = 0.0983 \pm 0.0035$ mb^{-1} is the average nuclear overlap function calculated for minimum bias p–Pb collisions [4] based on Glauber Monte Carlo simulations [5]. The pp reference spectra are constructed [6] using pp measurements at $\sqrt{s} = 2.76$ and 7 TeV at the LHC.

2   ALICE experiment

ALICE [7] is the dedicated heavy-ion experiment at the LHC. The particle tracks are reconstructed using the hit information from the six silicon layers of the Inner Tracking System (ITS) and up to 159 space points from the Time Projection Chamber (TPC). The relative p_T resolution obtained with the ITS and TPC combined tracking amounts to $\sigma_{p_T}/p_T = 1$–5% for $p_T = 0.1$–20 GeV/c. ALICE has excellent particle identification (PID) capabilities in the broad transverse momentum range $p_T = 0.1$–20 GeV/c, which is unique at the LHC. Charged hadrons with $p_T = 0.1$–5 GeV/c are identified using the energy loss ($\mathrm{d}E/\mathrm{d}x$) from the ITS and TPC detectors, the time-of-flight measurement with TOF detector, and Cherenkov light from the high momentum particle identification detector (HMPID). Above $p_T = 5$ GeV/c, they are identified based on the $\mathrm{d}E/\mathrm{d}x$ in the relativistic rise range of the Bethe-Bloch curve in the TPC. Strange hadrons which decay into charged particles ($\mathrm{K}_s^0 \to \pi\pi$, $\Lambda \to \pi p$ and $\Xi \to \pi\Lambda$) are identified via their decay topology and invariant mass analysis. In addition, the PID information for their decay products is used to improve signal to background ratio. More details about tracking and particle identification can be found in [8].
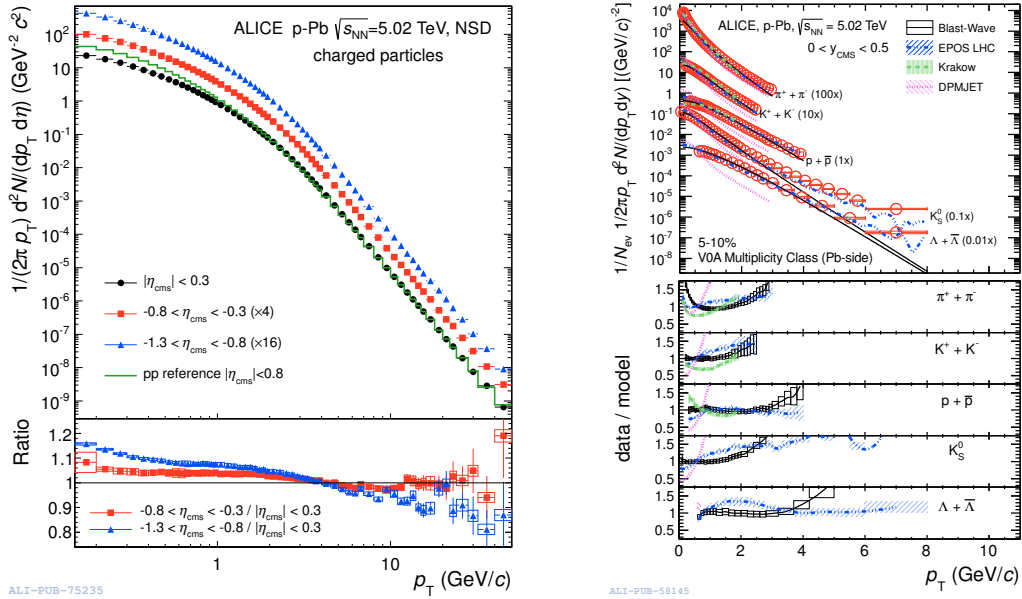

Figure 1: Left: p_T spectra measured in p–Pb collisions in three pseudorapidity ranges [4]. The pp reference spectrum is also shown [6]. Right: p_T spectra of identified hadrons measured in high multiplicity p–Pb collisions [9] compared to hydrodynamic models (see text for details).

3   Results

Figure 1 (left) shows the p_T spectra measured for charged particles in p–Pb collisions in three pseudorapidity ranges [4]. The constructed pp reference [6] at central rapidity is also shown. In the bottom panel, the ratios of the p_T spectra measured in two forward pseudorapidity regions with respect to central-pseudorapidity production are shown, indicating that the spectral shape is changing (spectra become softer) with increasing psedorapidity. The effect is particularly visible for p_T spectra measured in the most forward pseudorapidity interval, $-1.3 < \eta_{\mathrm{cms}} < -0.8$.

Figure 1 (right) shows the p_T spectra of identified hadrons measured in high multiplicity p–Pb collisions [9] in comparison to hydrodynamic (Blast-Wave [10], Kraków [11], EPOS LHC [12]) and QCD-inspired (DPMJET [13]) models. The hydrodynamic models describe data reasonably well for $p_T < 2$ GeV/c while DPMJET fails in describing data for all p_T. This might indicate that collective phenomena (e.g. flow etc.) are present in high multiplicity p–Pb collisions.

Figure 2 shows p/π and Λ/K_s^0 ratios measured in low and high multiplicity p–Pb collisions [9] in comparison to measurements in peripheral and central Pb–Pb collisions [14]. Similar to Pb–Pb, the baryon-to-meson ratio increases with event multiplicity, however, the increase is smaller compared to Pb–Pb.
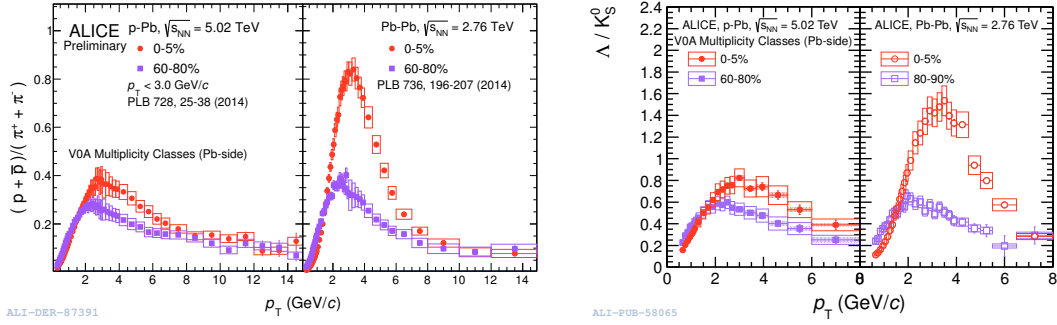

Figure 2: p/π (left) and Λ/K_s^0 (right) ratios measured in low (60-80%) and high (0-5%) multiplicity p–Pb collisions [9] in comparison to measurements in peripheral (60-80%) and central (0-5%) Pb–Pb collisions [14].

Figure 3 (left) shows the nuclear modification factor R_{pPb} measured in minimum bias p–Pb collisions [4] in comparison to nuclear modification factors measured in central Pb–Pb collisions ([4] and references therein). The results, showing a strong suppression in central Pb–Pb collisions and almost no suppression in p–Pb, indicate that the effect observed in Pb–Pb collisions is related to interaction with the matter in the final state. Figure 3 (right) shows R_{pPb} for identified hadrons measured in minimum bias p–Pb collisions. At low $p_T < 2$ GeV/c, similar depletion is observed for all particle species. At intermediate $2 < p_T < 7$ GeV/c, enhanced production of protons and Ξ is observed with the characteristic mass dependence, which might be related to collective phenomena (e.g. flow etc.). At high $p_T > 7$ GeV/c, no modification of hadron production is observed, $R_{\mathrm{pPb}} \approx 1$.
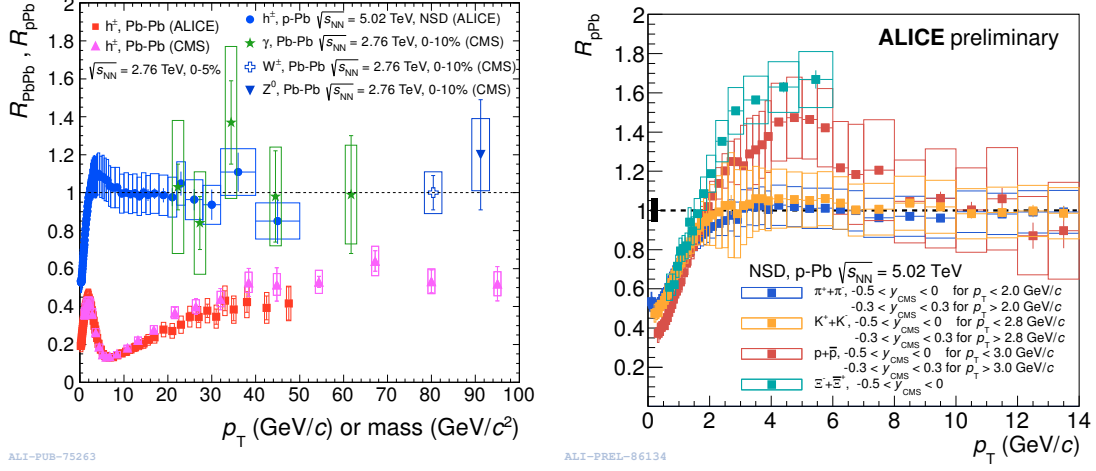
Figure 3: Left: Nuclear modification factors measured as a function of p_T in minimum-bias p–Pb collisions [4] and central Pb–Pb collisions ([4] and references therein). Right: R_{pPb} for identified hadrons measured in minimum-bias p–Pb collisions.

In summary, p_T spectra measured for light-flavor hadrons in minimum-bias p–Pb collisions, when compared to the reference pp spectrum, show a depletion at low p_T (similar for all hadron species), mass dependent enhancement at intermediate p_T, and no modification at high p_T. The study of the p_T spectra measured as a function of multiplicity in p–Pb collisions suggests that collective-like phenomena might develop in high multiplicity p–Pb events.

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