Production of pions, kaons and protons at high $p_T$ in $\sqrt{s_{NN}} = 2.76$ TeV Pb-Pb collisions

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Abstract

In this work we report on the production of charged pions, kaons, and (anti) protons in pp and Pb−Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV for $3 < p_T < 20$ GeV/$c$. The evolution of the nuclear modification factor, $R_{AA}$, with collision centrality and transverse momentum is discussed.

Keywords: LHC, ALICE, identified particles, high $p_T$, heavy ions.

1. Introduction

The particle identification (PID) is an important tool to study the hot and dense matter created in relativistic heavy ion collisions. At intermediate $p_T$ (2-8 GeV/$c$) hadrons can be produced not only by fragmentation but also by quark recombination. It allows us to learn how the medium affects the particle composition [1]. In Section 2 we describe the analysis to measure the production of $\pi/K/p$ as a function of $p_T$ (3-20 GeV/$c$). The discussion of the results and conclusions are presented in Sections 3 and 4, respectively.

2. Identification of charged hadrons at high $p_T$

The measurement of the yields of charged pions, kaons and (anti) protons in the range $3 < p_T < 20$ GeV/$c$ is statistically performed exploiting the peculiarity of the mean energy loss, $(dE/dx)$, of particles traversing the TPC gas [2], in the relativistic rise regime ($\beta\gamma$: 3.6−1000) of the Bethe-Bloch (BB) curve.

The TPC response was calibrated using a clean sample of $\pi$ (p) identified through the weak decay topology of $K^0_S$ (Λ). Primary pions and electrons were tagged using the Time of Flight (TOF) detector. After parametrization of the BB curve and of the $dE/dx$ resolution as a function of the calibrated $(dE/dx)$, the measured resolution of minimum ionizing particles were 5.6% and 7.5% for low (pp) and high (Pb−Pb 0-5%) multiplicity environment, respectively.

The yields were extracted by fitting the quantity $\Delta_x = dE/dx - \langle dE/dx \rangle_x$ to a sum of four Gaussian functions ($\pi/K/p/e$) in each $p_T$ interval. The means and sigmas were constrained using the aforementioned parametrization and the $p_T$ spectra obtained via factorization, as described in [3].

1 A list of members of the ALICE Collaboration and acknowledgements can be found at the end of this issue.
The main source of systematic uncertainty comes from the estimation of the parameters of the fitted functions. A range of variation for those parameters was evaluated running the analysis without exploiting the information from topological and TOF PID. The parameters were randomly varied in the estimated ranges, then the yields were extracted using the same algorithm as in data. At high $p_T$ (> 10 GeV/c) the systematic uncertainties were 5%, 10% and ~ 30 – 40% for $\pi$, K and p, respectively. Also, we added the systematic errors from the spectra of inclusive charged particles [4].

3. Results

Figure 1 shows $(p + \bar{p})/(\pi^+ + \pi^-)$ as a function of $p_T$ for Pb–Pb and pp collisions at $\sqrt{s_{NN}} = 2.76$ TeV. For completeness the lower $p_T$ results are also displayed for Pb–Pb [5, 6]. At intermediate $p_T$ the ratio is enhanced, this phenomenon was first observed at RHIC [7]. The maximum is located at 3 GeV/c and reaches ~ 0.8 (~ 0.4) for the most central (peripheral) events. For higher $p_T$ (> 8 GeV/c), the ratio is consistent with fragmentation in vacuum. Figure 2 shows a comparison with the ratio in pp collisions at $\sqrt{s} = 7$ TeV. It is interesting that even the pp data exhibit a maximum in the same $p_T$ region as observed in Pb–Pb collisions.

ALICE previously reported the nuclear modification factor ($R_{AA}$) for $\pi$ and $p + K$ [3]. Now Figure 3 shows the $R_{AA}$ as a function of $p_T$ for pions, kaons and protons, the results are presented for 0-5% and 60-80%. For the most central events and at intermediate $p_T$ (2-8 GeV/c), $R_{AA}$ for $p$ and $R_{AA}$ for $\pi$ are equally suppressed at high $p_T$, no significant species dependence is seen at high $p_T$.

4. Conclusions

At intermediate $p_T$, we observe an enhancement of the $(p + \bar{p})/(\pi^+ + \pi^-)$ ratio. Within systematics, $\pi/K/p$ are equally suppressed at high $p_T$ which suggests that the fragmentation is not modified by the medium.

Figure 1: Centrality dependence of the $(p + \bar{p})/(\pi^+ + \pi^-)$ ratio as a function of $p_T$ compared to pp at 2.76 TeV. Statistical and systematic uncertainties are displayed as error bars and boxes, respectively. The low $p_T$ results come from the combined PID of ITS, TPC and TOF [6].

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Figure 2: Comparison of the $\frac{(p + \bar{p})}{(\pi^+ + \pi^-)}$ ratio as a function of $p_T$ between Pb–Pb and pp collisions at $\sqrt{s_{NN}} = 2.76$ TeV and 7 TeV, respectively. Statistical and systematic uncertainties are displayed as error bars and boxes, respectively. The low $p_T$ results come from the combined PID of ITS, TPC and TOF [6]. In addition the pp result includes the information of the Cherenkov detector, HMPID.

Figure 3: $R_{AA}$ as a function of $p_T$ for $\pi/K/p$ in 0-5% (left) and 60-80% (right) Pb – Pb collisions. Statistical and systematic uncertainties are displayed as error bars and boxes, respectively.
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