PROCEEDINGS OF SCIENCE

Identified Primary Hadron Spectra in pp and Pb-Pb Collisions with the ALICE Detector at the LHC

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The ALICE experiment at the LHC collected data from pp collisions at $\sqrt{s} = 0.9$, 2.76 and 7 TeV and Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. ALICE has several detectors dedicated to Particle IDentification (PID), covering complementary transverse momentum (p_t) ranges; this enables ALICE to reconstruct identified charged hadron spectra over a wide p_t range at mid-rapidity. After a brief review of the different ALICE identification techniques and performance, the π/K/p transverse momentum spectra obtained in pp ($\sqrt{s} = 0.9$ TeV and 7.0 TeV) and Pb-Pb ($\sqrt{s_{NN}} =$ 2.76 TeV) collisions will be presented. In addition, studies on the energy dependence of the spectral shape, transverse radial flow estimation and comparison with Monte Carlo models will be shown.

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1. Introduction

The ALICE experiment [1] has been designed to measure ultra-relativistic Pb-Pb collisions in order to study the properties of the Quark-Gluon-Plasma (QGP), predicted by lattice QCD to be formed at high temperature or density. The measurement of identified particle p_t spectra provides a link to the thermal parameters of the system created in heavy-ion collisions at the kinetic and chemical freezeout. ALICE provides identified particle spectra not only in Pb-Pb collisions but also in pp interactions. Data from pp define the reference for heavy-ion data and are crucial to tune Monte Carlo models.

In this paper we give details on the PID performance of the detectors used in this analysis (sec. 2) then the spectra in pp collisions at $\sqrt{s} = 7\,\text{TeV}$ (sec. 3) and finally in Pb-Pb at $\sqrt{s_{\text{NN}}} = 2.76\,\text{TeV}$ are presented.

2. Particle identification

The ALICE detector has several central detectors dedicated to particle identification using different PID techniques and covering complementary p_t ranges. The main ones are the Inner Tracking System (ITS), the Time Projection Chamber (TPC), the Transition Radiation Detector (TRD), the Time Of Flight (TOF) and the High Momentum Particle IDentification (HMPID). In this paper we report on results obtained with ITS, TPC and TOF. They have full azimuthal coverage and are able to identify particles in the central pseudorapidity region ($|\eta| \leq 0.9$).

The ITS [2] consists of six cylindrical layers of silicon detectors. The four outer layers provide analogue readout identifying particles via $d\text{E}/d\text{x}$ measurements in the non-relativistic ($1/\beta^2$) region ($0.1 < p_t < 0.5$ GeV/c). The TPC [3] provides up to 159 dE/dx measurements and extend the identification to $p_t < 1.7$ GeV/c. The p_t reach is increased further by the TOF detector [4] which identifies particles through the measurement of the time taken to travel from the primary vertex to the TOF sensible layer. The reach in p_t depends on the total time resolution σ_{tot} that is the sum in quadrature of the intrinsic TOF time resolution and of the start time resolution which is function of the event multiplicity (in Pb-Pb collisions σ_{tot} = 85 ps whereas in pp collision σ_{tot} = 120 ps). Here the reach in p_t is 2.5 GeV/c for protons and 1.6 GeV/c for pions and kaons.

Four independent analyses have been performed. The global tracking (combining TPC and ITS information) was used in two independent studies with either the TPC or the ITS PID information, in order to cross-check the PID performance. The TOF information was used, with global tracks, to extend the reach at high p_t. Finally, the ITS was also used as a standalone tracker to extend the coverage at low p_t. For more details see [6]. The spectra from these four analyses have been found to be compatible and were combined using systematic errors as weights. In this paper we present results for primary particles, defined as prompt particles produced in the collision including electromagnetic and strong decays but excluding weak decays of strange particles.

3. Identified primary hadron spectra in pp collisions at $\sqrt{s} = 7\,\text{TeV}$

In Fig. 1 the Minimum-Bias (MB) combined p_t spectra for negative π, K and p in pp collisions at $\sqrt{s} = 7\,\text{TeV}$ are shown. To obtain the integrated yields and the mean p_t they are fitted with a

Lévy-Tsallis function (see [5]) that describes the shape of the p_t spectra within few percent. Similar results have been obtained for positive particles.

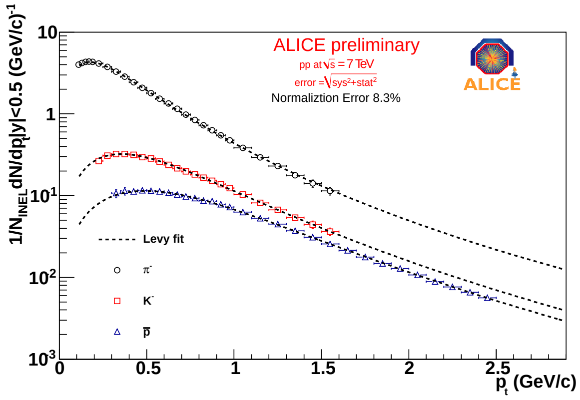

Figure 1: Transverse momentum spectra of negative π, K, p in pp collisions at $\sqrt{s} = 7$ TeV. The lines are the Lévy-Tsallis fits.

In Fig. 2 the ratio of integrated yields K/π is shown for different collision energies. This ratio does not vary from 0.9 TeV (already published in [6]) to 7 TeV ALICE data while it has a slight increase at the lower energies.

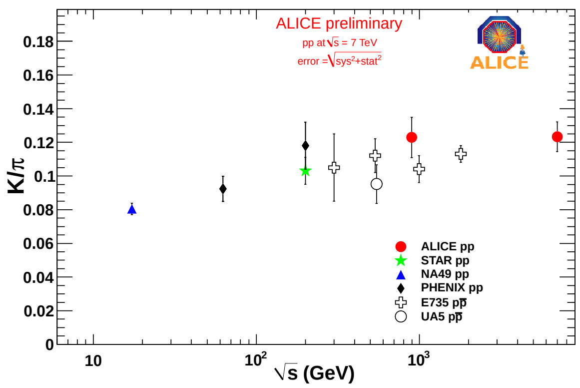

Figure 2: K/π integrated yield ratios in pp collisions as a function of collision energy.

In Fig. 3 the K/π ratio obtained in pp collisions at 7 TeV is compared with different Monte Carlo models: Phojet and three Pythia tunings (D6T, Perugia0 and Perugia 2011). It is clear that the ratio is not described by any Monte Carlo model. The K/π ratio obtained at 0.9 TeV is superimposed as reference.

In Fig. 4 the p/π ratio is shown for separate charges to point out how the baryon/antibaryon asymmetry vanishes at LHC energies (as already reported in [7]).

In Fig. 5 the p/π ratio obtained in pp collisions at $\sqrt{s} = 7$ TeV is compared with different Monte Carlo models: Phojet and three Pythia tunings (D6T, Perugia0 and Perugia 2011). Only the Pythia D6T model is able to describe roughly the ratio for $p_t < 1.6$ GeV/c. The p/π ratio obtained in pp collisions at $\sqrt{s} = 0.9$ TeV is superimposed as reference.

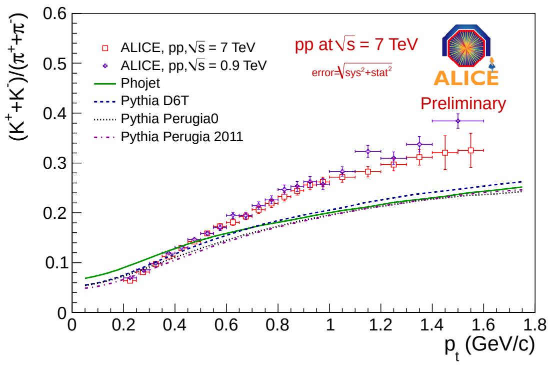

Figure 3: Comparison between the K/π ratio obtained in pp collisions at $\sqrt{s} = 7$ TeV and different Monte Carlo models.

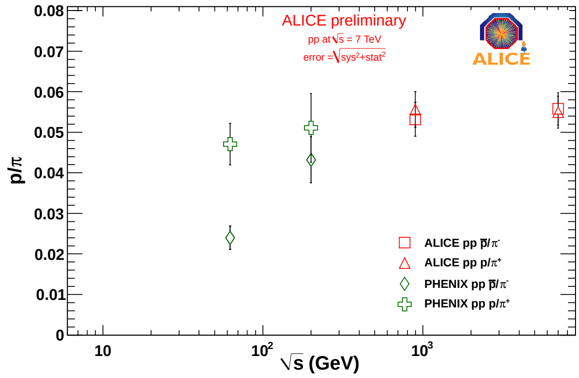

Figure 4: p/π integrated yield ratios in pp collisions as a function of collision energy.

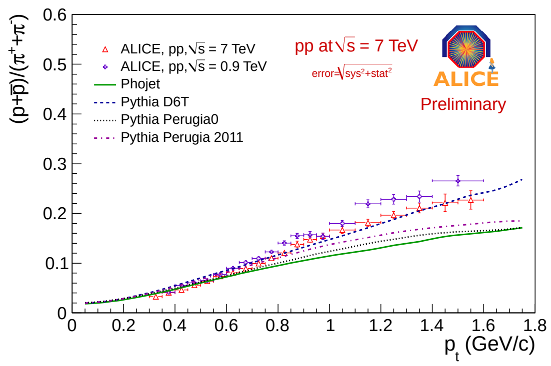

Figure 5: Comparison between the p/π ratio obtained in pp collisions at $\sqrt{s} = 7$ TeV and different Monte Carlo models.

In Fig. 6 the mean p_t for π, K and p at different collision energies is reported. An increase of the mean p_t with both the mass of the particles and the collision energy (harder spectra) is observed.

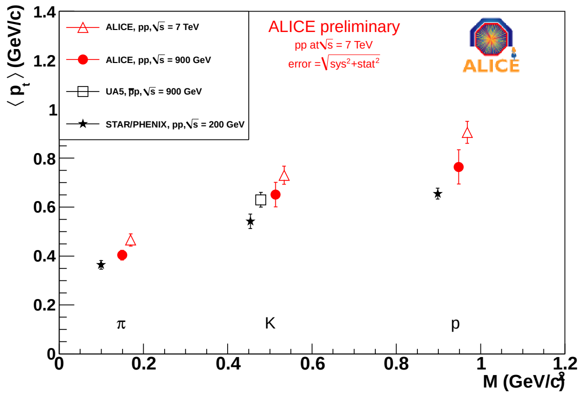

Figure 6: Mean p_t for π, K and p at different pp collision energies.

4. Identified primary hadron spectra in Pb-Pb collisions at $\sqrt{s_{\rm NN}} = 2.76\,\text{TeV}$

The same analysis has been performed for Pb-Pb interactions at $\sqrt{s_{NN}} = 2.76$ TeV selecting different centrality regions. In Fig. 7 Pb-Pb spectra for the 5seen that ALICE spectra are harder than those from RHIC. The inverse slope increases with particle mass, presumably due to radial flow.

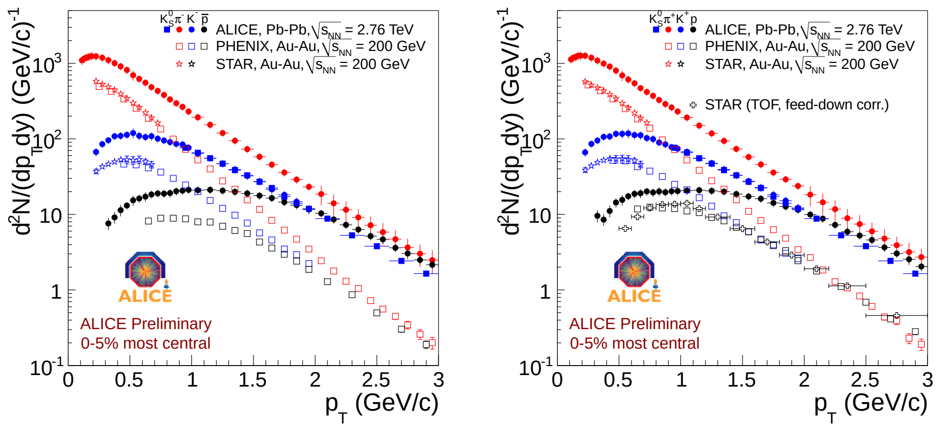

Figure 7: Transverse momentum spectra for π, K and p negative (left) and positive (right) for the 5% most central collisions. A comparison between results obtained by ALICE, STAR and PHENIX Collaborations is shown.

To determine integrated yields and average p_t, fits on individual particles with a Blast-Wave function [12] have been performed. In Fig. 8 the K^-/π^- ratios obtained at ALICE and STAR are shown for different event multiplicity. An increase both with the centrality (same trend for STAR and ALICE) and going from pp to Pb-Pb collisions is evident. In Fig. 9 the ALICE and RHIC $\overline{p}/\pi^-$ ratios, constant for every centrality and respect to pp interactions, are shown (see [8 – 10] for RHIC results). The results are compatible taking into account that STAR $\overline{p}$ are not feed-down corrected.

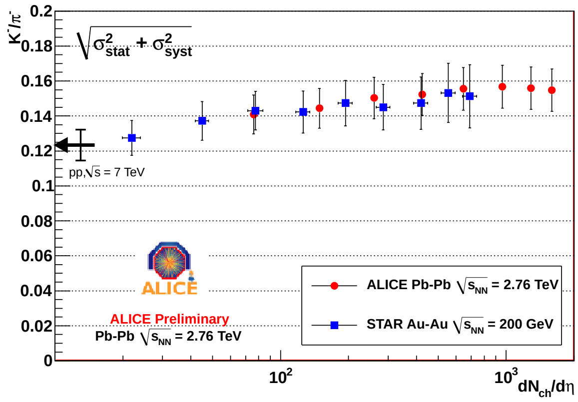

Figure 8: K^-/π^- ratios as a function of $\mathrm{dN_{ch}}/\mathrm{d}\eta$.

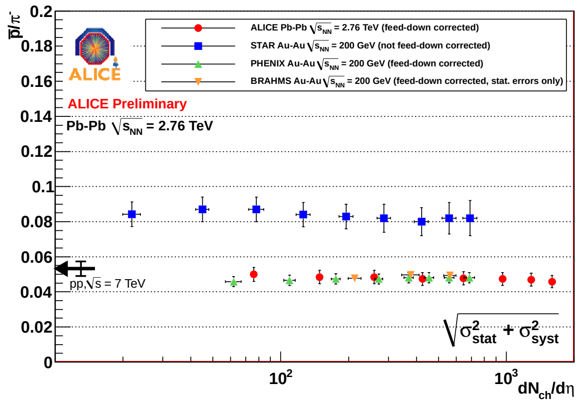

Figure 9: $\overline{p}/\pi^-$ ratios as a function of $\mathrm{dN_{ch}}/\mathrm{d}\eta$.

In order to get information on the thermal properties of the medium at the chemical freezeout, the ratios between different particle species measured by ALICE in Pb-Pb collisions have been compared with thermal model predictions. The measured ratios are compared in Fig. 10 with predictions [11] at a temperature $T = 164$ MeV. The agreement is good for kaons and multi-strange particles while p/π are not well described. Setting the temperature at $T = 148$ MeV helps the description of kaons and protons but underestimates the multi-strange production.

From Fig. 11 the increase of mean p_t with the particle mass and the collision centrality can be seen. It is also evident that the mean p_t measured at the LHC is higher than the one measured at RHIC.

In order to obtain information on the thermal properties of the medium at the kinetic freezeout, a global fit of the spectra with a Blast Wave function in which the kinetic freezeout temperature (T_{fo}) and the radial flow ($< \beta >$) are free parameters, is used. In Fig. 12 the fit parameters for ALICE and STAR in different centrality bins are shown. It can be noticed that the radial flow is $\sim 10\%$ higher at $\sqrt{s_{\mathrm{NN}}} = 2.76\,\mathrm{TeV}$ than at $\sqrt{s_{\mathrm{NN}}} = 0.2\,\mathrm{TeV}$ although some systematics on the T_{fo} is related to the pion fit range (the effect of resonances has to be investigated).

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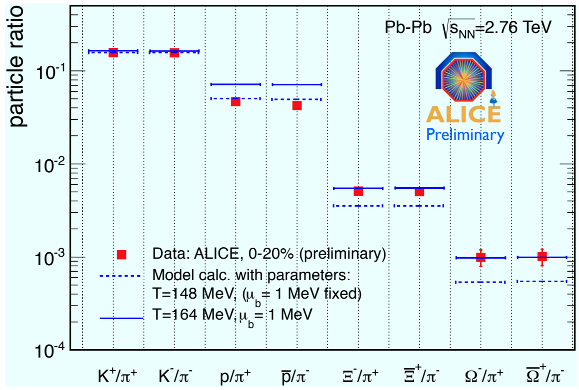

Figure 10: Comparison between the particle ratios measured by ALICE in the most central events and thermal model prediction [11].

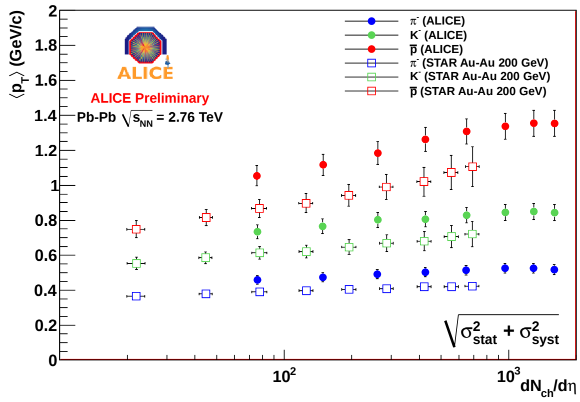

Figure 11: Mean p_t for π, K and p at different event multiplicity for ALICE and STAR.

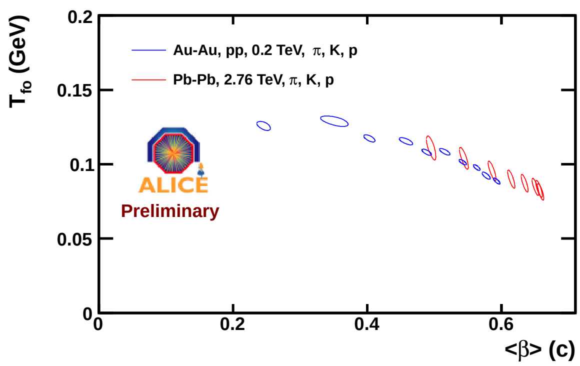

Figure 12: Kinetic freezeout temperature and radial flow parameter as obtained from a global fit of the spectra with a Blast Wave function for increasing centrality. To be noticed that the first point was obtained in pp collisions.

5. Conclusions

In this paper we have shown that, thanks to its excellent PID performance, ALICE is able to identify particles over a wide p_t range both in pp and in Pb-Pb collisions.

We have shown that particle ratios are similar in 0.9 and 7 TeV pp collisions, the baryon/anti-baryon asymmetry vanishes at the LHC energy (as expected), the spectra become harder with the collision energy and no MC model is able to describe the data. The p_t spectra measured by ALICE in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76\,\mathrm{TeV}$ are harder than RHIC ones, the K/π ratio increases with the centrality while p/π is constant and the mean p_t increases with the multiplicity. In order to extract information on the thermal property of the medium at the kinetic freezeout a global Blast Wave fit of the spectra has been performed showing that the transverse radial flow measured with ALICE is $\sim 10\%$ higher than at RHIC. Finally the particle ratios have been compared with thermal model predictions.

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