Production of π/K/p in pp and Pb-Pb collisions measured with ALICE

Marek Chojnacki for the ALICE Collaboration

Niels Bohr Institute, Blegdamsvej 17, 2100 Copenhagen Denmark

E-mail: `Marek.Chojnacki@cern.ch`

Abstract. The ALICE experiment is a dedicated heavy-ion physics detector at the LHC, with unique capabilities for the study of identified particle production. In this paper, an overview of ALICE results on the measurement of pion, kaon and proton transverse momentum (p_{T}) spectra at mid-rapidity in proton-proton and Pb-Pb collisions at different energies is presented. The particle identification is performed using the following detectors: the Time Projection Chamber (TPC), the Inner Tracking System (ITS), the Time of Flight system (TOF) and a Ring-imaging Cherenkov system (HMPID).

1. Introduction

The ALICE detector [1, 2, 3] features multiple particle identification systems including: the Time Projection Chamber (TPC), the Inner Tracking System (ITS), the Time of Flight system (TOF) and a Ring-imaging Cherenkov detector (HMPID). This combination of detectors, along with the excellent tracking capabilities of ALICE, provides the opportunity to measure the production of pions, kaons and protons over a broad transverse momentum (p_{T}) range, from 100 MeV/c up to 20 GeV/c. Particle identification at low p_{T} (below $\sim$ 1 GeV/c) is performed using the energy loss of particles in the ITS. The TOF velocity measurement contributes to the identification for the p_{T} range between 0.5 GeV/c and 3-5 GeV/c (depending on the particle type and the colliding system). At high p_{T} (up to 20 GeV/c), particles are identified using the HMPID or the relativistic rise of the energy loss distribution in the TPC.

2. Results

Since November 2009, the LHC has produced collisions of different systems (pp, p-Pb and Pb-Pb) at several energies. For all of those systems, the ALICE collaboration has measured pion, kaon and proton production as a function of p_{T} at mid-rapidity. A detailed description of the analyses can be found in [4, 5, 6].

Figure 1 shows the p_{T} dependent $(K^{+}+K^{-})/(\pi^{+}+\pi^{-})$ and $(p+\bar{p})/(\pi^{+}+\pi^{-})$ ratios in pp collisions at $\sqrt{s}=2.76$ and 7 TeV with comparisons to some theoretical predictions. Within the systematic uncertainties, both ratios are consistent for two energies. The NLO based calculations of [7] do not reproduce the measured ratios. The PHYTIA Monte Carlo generator (tune Perugia 2011) does not fully reproduce the ratios, underestimating both ratios at intermediate p_{T}.

The results for Pb-Pb are summarized in [6]. Figure 2 shows the p_{T} spectra measured by ALICE for the 0-5% most central Pb-Pb collisions. The spectra are compared to RHIC results from Au-Au collisions at $\sqrt{s_{NN}}$ =200 GeV/c [8, 9] and theoretical models. Since the

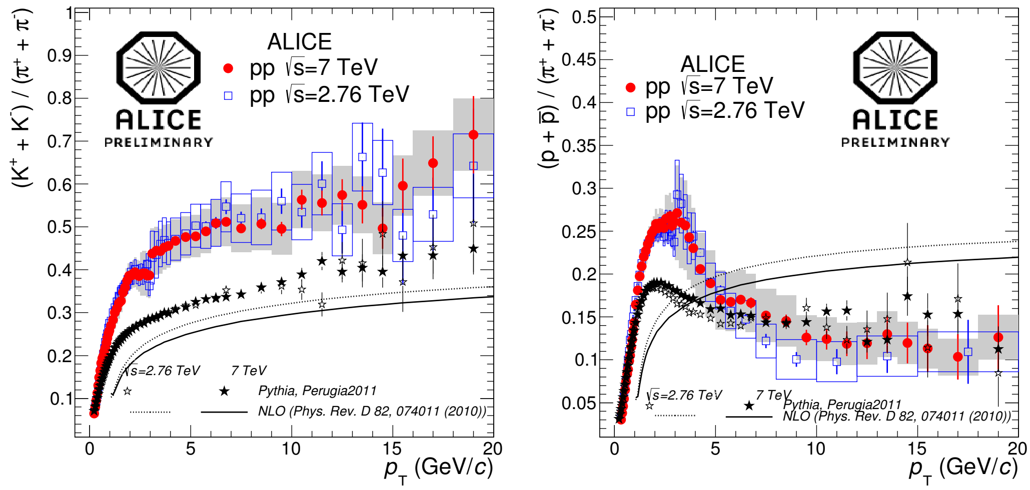

Figure 1. Ratios of kaon, proton and antiproton p_{T} spectra to the pion p_{T} spectra in pp collisions at $\sqrt{s}$ = 2.76 and 7 TeV compared to PYTHIA Monte Carlo predictions and NLO calculations.

ALICE spectra for positive and negative particles are compatible within systematic uncertainties, the combined spectra (summed charge states) are used. The ALICE results show harder distributions compared to the RHIC results which indicates a significantly stronger radial flow at LHC energies. The comparison to hydrodynamical models shows that VISH2+1 [10] describes the pion and kaon spectra below p_{T} 1.5 GeV/c well, but it does not describe the proton spectra. The lack of the hadronic phase in this model could explain the discrepancy with the shape of the proton spectra. This hypothesis is supported by comparison to the HKM Model [11], which better agrees with the data. This model uses a hadronic cascade model to describe the system evolution after the hydrodynamic phase until the final decoupling. The Kraków model [12], which also shows a good agreement with data, uses non-equilibrium corrections due to the bulk viscosity which changes the effective T_{ch}. The EPOS model, which uses breakup of flux tubes created during initial hard scatterings, describes the spectra shapes in a broad p_{T} range.
The ratios of the production yields at mid-rapidity were compared (see Figure 3) to the RHIC results and thermal model predictions [14, 15], (for μ_B= 1 MeV and T_{ch} = 164 MeV or 170 MeV). The baryochemical potential μ_B vanishes because the yields of antiparticles and particles are equal within uncertainties. The thermal models do not reproduce the proton to pion ratio. To better understand this discrepancy, the production yields of different particles were also compared with the thermal model predictions (see Figure 4). It seems that a simple equilibrium thermal model cannot describe the data. Possible solutions for this unexpected observation include: baryon annihilation after chemical freeze-out [16], non-equilibrium statistical hadronization [17], flavour hierarchy in the QCD phase transition [18], missing higher mass resonance states in the equilibrium thermal model[19].

Figure 5 shows the pion, kaon and proton nuclear modification factors (R_{AA}) for the 0-5% and 60-80% centrality bins. At lower p_{T} a difference in the suppression pattern of different particle species can be seen, with the heavier particles being less suppressed. This reflects the "baryon anomaly" also observed e.g. in the Λ/K^0_S ratio [20] and could be a consequence of radial flow or quark coalescence. At higher p_{T}, above 8 GeV/c, the R_{AA} for all particle species are consistent within uncertainties. Theoretical calculations based on the separate treatment of radiative and collisional energy losses [21] can reproduce the measured R_{AA} in this region. Any difference between R_{AA} for different particle species at high p_{T} could be interpreted as a

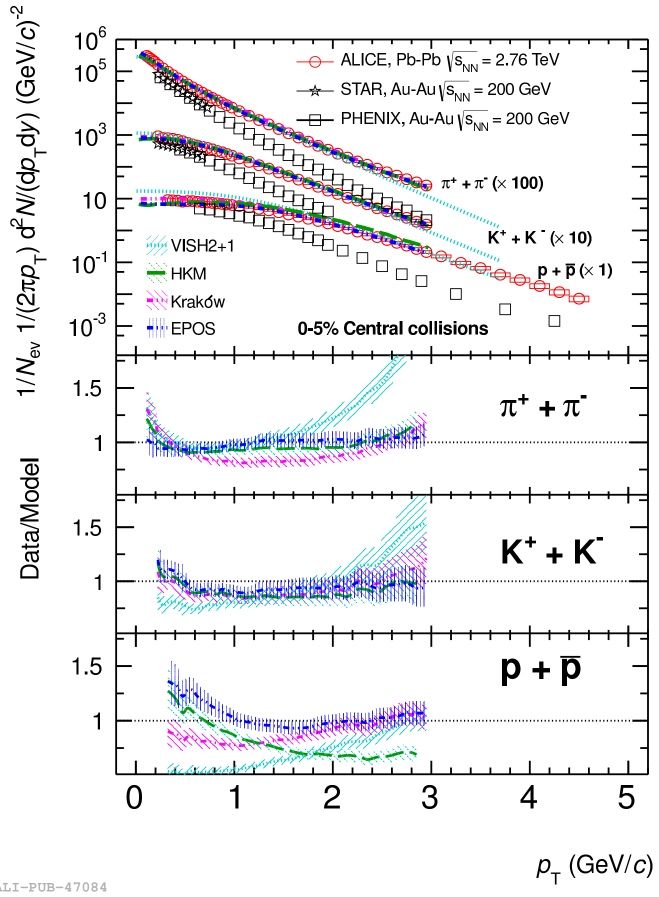

Figure 2. Pion, kaon and proton spectra in the most central Pb-Pb collisions at $\sqrt{s_{NN}}$ =2.76 TeV compared to the results from lower energies and model predictions.

difference in the fragmentation functions within the medium. However, no strong constraints on the fragmentation functions can be extracted from the present data.

3. Conclusion

The ALICE collaboration has successfully measured the p_{T} dependence of pion, kaon and proton production at several energies for different colliding systems. The ALICE results for pp collisions show no energy dependence in hadronic ratios as function of p_{T}. In Pb-Pb collisions, p_{T} spectra indicate a stronger radial flow than at lower (RHIC) energies. The proton production is significantly lower than thermal model predictions with a chemical freeze-out temperature T_{ch} = 160 - 170 MeV. At higher p_{T}, current measurements indicate that the medium does not significantly affect the parton fragmentation.

References

[1] ALICE Collaboration 2004 *J. Phys.* G **30** 1517-1763
[2] ALICE Collaboration 2006 *J. Phys.* G **32** 1295-2040
[3] ALICE Collaboration 2008 *J. Instrum.* **3** SO8002
[4] ALICE Collaboration 2011 *Eur. Phys. J.* C **71**(6) 1655
[5] ALICE Collaboration 2012 *Phys. Rev. Lett.* **109** 252301
[6] ALICE Collaboration 2013 *Phys. Rev.* C **88** 044910

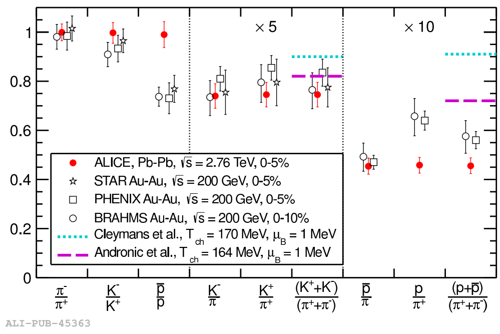

Figure 3. Ratios of pion, kaon and proton yields in the most central (0-5%) Pb-Pb collisions at $\sqrt{s_{NN}}$ =2.76 TeV compared to predictions from thermal models.

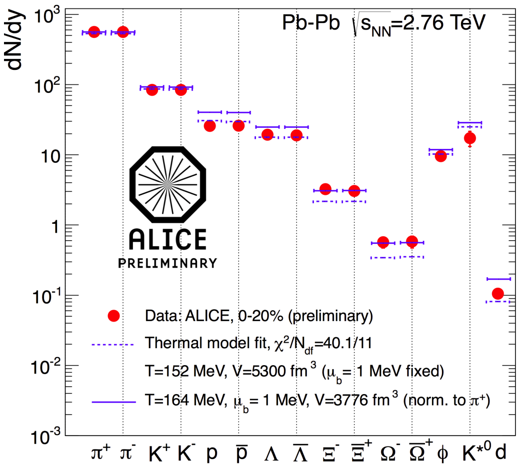

Figure 4. The production yields of different particles in the most central (0-20%) Pb-Pb collisions at $\sqrt{s_{NN}}$ =2.76 TeV compared to predictions from thermal models.

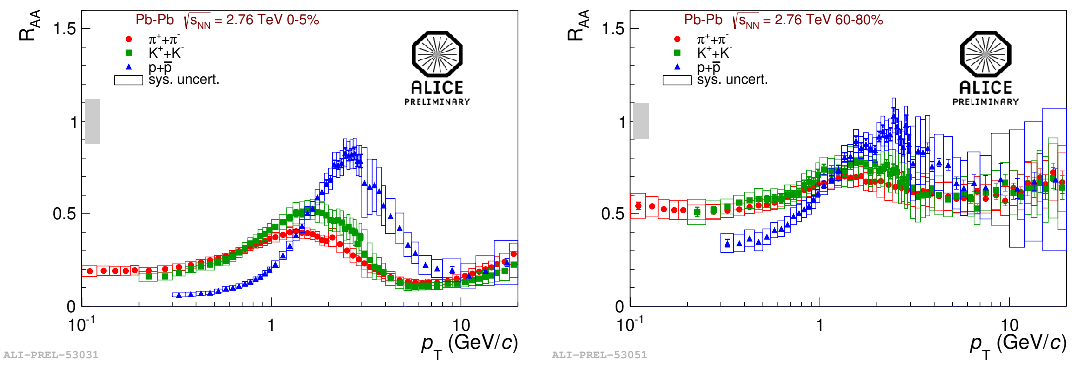

Figure 5. Pion, kaon and proton nuclear modification factors in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV in two centrality bins.

[7] Sassot R, Zurita P and Stratmann M 2010 *Phys. Rev.* D **82** 074011
[8] STAR Collaboration 2009 *Phys. Rev.* C **79** 034909
[9] PHENIX Collaboration 2004 *Phys. Rev.* C **69** 034909
[10] Shen C, Heinz U, Huovinen P and Song H 2011 *Phys. Rev.* C **84** 044903
[11] Karpenko I, Sinyukov Y and Werner K 2013 *Phys. Rev.* C **87** 024914
[12] Bożek P 2012 *Phys. Rev.* C **85** 034901
[13] Werner K, Karpenko I, Bleicher M, Pierog T and Porteboeuf-Houssais S 2012 *Phys. Rev.* C **85** 064907
[14] Andronic A, Braun-Munzinger P and Stachel J 2009 Phys. Lett. B **673** 142
[15] Cleymans J, Kraus I, Oeschler H, Redlich K and Wheaton S 2006 *Phys. Rev.* C **74** 034903
[16] Becattini F, Bleicher M, Kollegger T, Schuster T, Steinheimer J and Stock R 2013 *Phys. Rev. Lett.* **111** 082302
[17] Petran M, Letessier J, Petracek V and Rafelski J 2013 *Phys. Rev.* C **88** 034907
[18] Ratti C, Bellwied R, Cristoforetti M and Barbaro M 2012 *Phys. Rev.* D **85** 014004
[19] Stachel J *these proceedings*
[20] ALICE Collaboration 2013 *Phys. Rev. Lett.* **111** 222301
[21] Djordjevic M and Djordjevic M *Preprint* arXiv:1307.4714