



Identified charged hadron production in Pb–Pb collisions at the LHC with the ALICE Experiment

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Abstract

Identified particle spectra represent a crucial tool to understand the behavior of the matter created in high-energy heavy-ion collisions. The transverse momentum p_T distributions of identified hadrons contain informations about the transverse expansion of the system and constrain the freezeout properties of the matter created. The ALICE experiment has good particle identification performance over a broad p_T range. In this contribution the results for identified pions, kaons and protons in heavy-ion collisions at 2.76 TeV center-of-mass energy are presented. These results are compared with other identified particle measurements obtained by previous experiments, and discussed in terms of the thermal and hydrodynamic pictures. The status of extensions of this analysis, with the study of identified particles as a function of event-by-event flow in Pb–Pb collisions, is also discussed.

The ALICE experiment has unique particle identification (PID) capabilities. The combination of different detectors which use different PID techniques allows identification over a broad p_T range [1]. The results presented here are obtained using the Pb–Pb data at $\sqrt{s_{NN}} = 2.76$ TeV collected at the Large Hadron Collider (LHC) during the fall 2010. The central tracking and (PID) detectors cover the pseudorapidity window $|\eta| \leq 0.9$. Particles are identified using dE/dx signal in the silicon Inner Tracking System (ITS) and in the Time Projection Chamber (TPC) and the information from the Time Of Flight (TOF) detector. A pair of forward scintillator hodoscopes, the VZERO detectors ($2.8 < \eta < 5.1$ and $-3.7 < \eta < -1.7$), is used for triggering [2]. The centrality of the collision can be estimated using the signal in the VZERO detector, the reconstructed multiplicity in the central barrel, or other forward detectors [2].

1. p_T distribution of identified hadrons

The p_T distribution of hadrons contains the information about the collective expansion of the fireball (radial flow) and the temperature of kinetic freezeout (T_{kin}). The ALICE measurement of identified particle spectra in central (0–5%) Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV is represented by the red symbols in Figure 1, left (from [4]). The p_T distributions of positive and negative particles are found to be compatible within errors, for this reason results for summed charge states are presented. Hadron spectra are reported for primary particles, defined as prompt particles produced in the collision, including decay products, except those from weak decays of

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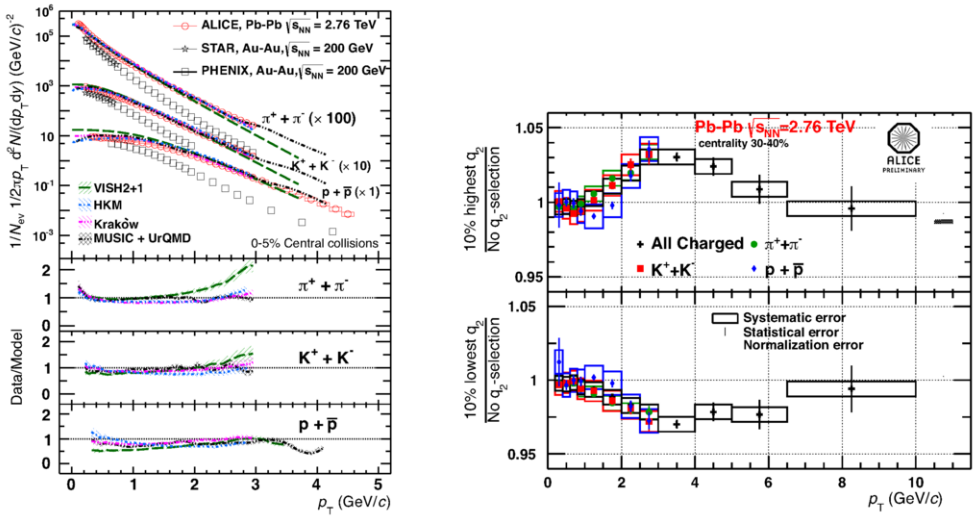


Figure 1: Left: transverse momentum distributions of the sum of positive and negative particles (box: systematic errors; statistical errors smaller than the symbol for most data points) compared to RHIC data and hydrodynamic models. Right: ratio between the raw spectra in the sample with 10% highest (lowest) q_2 and the unbiased sample.

strange particles. The fraction of primaries in the track sample at a given p_T bin was estimated from data by fitting the DCA_{xy} distribution with three Monte Carlo templates: primary particles, secondaries from material and secondaries from weak decays [3]. A detailed description of the systematic error and PID procedure can be found in [4]. Spectra measured at the LHC are compared with RHIC results for Au–Au collisions at $\sqrt{s_{NN}} = 200$ GeV (black-empty markers). The spectral shape is significantly harder at the LHC with respect to RHIC. The kinetic freezeout parameters $\langle\beta_T\rangle$ and T_{kin} can be extracted from a simultaneous blast wave fit to the π , K and p spectra. The p_T ranges used in the fit are 0.5-1 GeV/c, 0.2-1.5 GeV/c, 0.3-3 GeV/c for π , K and p. Data are well described by the blast wave function with $\langle\beta_T\rangle = 0.65 \pm 0.02$ and $T_{kin} = 95 \pm 10$ MeV. It should be noted that T_{kin} is sensitive to the pion fit range (due to large contribution from resonances) while $\langle\beta_T\rangle$ does not strongly depend on the p_T range used in the fit. A similar fit to central Au–Au collisions at $\sqrt{s_{NN}} = 200$ GeV was performed in [5]: the $\langle\beta_T\rangle$ is $\sim 10\%$ larger at the LHC with respect to RHIC and T_{kin} is compatible within errors. The comparison with predictions (see [4] for details) seems to suggest that hydrodynamic models with a refined late fireball description are able to reproduce the measured p_T spectra at the LHC.

In order to further investigate the hydrodynamic behaviour of the hadron production two of the main features of hydrodynamics were correlated: p_T distribution of hadrons and elliptic flow. For a given centrality the eccentricity of the collision (related with the initial geometry) fluctuates. A strategy to select events based on the geometry of the overlapping region (so called “event shape engineering”) was presented for the first time during this conference in [6, 7]. One way to do this is using the VZERO detector to calculate the flow vector \vec{Q}_2 on an event-by-event basis, a 2D vector with components $Q_{2,x} = \sum_i w_i \cos(2\phi_i)$ and $Q_{2,y} = \sum_i w_i \sin(2\phi_i)$, where the sum i runs over all the channels of the VZERO detector, w_i is the multiplicity of channel i and

ϕ_i is the angle of channel i . The module of the \vec{Q}_2 vector is normalized by the multiplicity M in the VZERO: $q_2 = |Q_2|/\sqrt{M}$. In [6, 7] it has been shown that the sample with large (small) q_2 shows a significantly larger (smaller) v_2 with respect to the unbiased sample and that the non-flow contributions are negligible. Systematic checks show that this selection does not introduce trivial biases related with multiplicity shift or jet contribution. A modification of the p_T spectrum in semi-central (30-40%) Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV in the intermediate p_T region (from ~ 1 up to ~ 5 GeV/ c) is observed, when events are selected according to the event shape engineering (Figure 1, right): higher (lower) v_2 means harder (softer) spectra. This modification vanishes at high p_T supporting a correlation related with hydrodynamics rather than with hard processes. A hint of mass ordering can be observed in the region between ~ 1 up to ~ 3 GeV/ c . A more detailed study (including comparison with models and hydrodynamic fit of particle spectra) will allow to better understand the observed correlation between v_2 and radial flow.

2. Thermal production of hadrons at the LHC

The thermal description of hadron production was found to be successful over a broad range of energies (from $\sqrt{s_{NN}} = 2$ GeV to $\sqrt{s_{NN}} = 200$ GeV [8, 9]). There are only these three parameters which govern the thermal model: the chemical freezeout temperature T_{ch} , the baryon-chemical potential μ_B and the volume V . In order to extract the parameters T_{ch} , μ_B and V a thermal fit [8] of integrated yields at midrapidity dN/dy in central (0-20%) Pb–Pb collisions was performed. It is reported in Figure 2 (left). Results from strange and multi-strange particle analyses [10] are also included in the fit. The antibaryon over baryon ratios suggest a vanishing baryon-chemical potential at the LHC: for this reason μ_B is fixed to 1 MeV in the fit. ϕ and K^{*0} are not included in the fit.

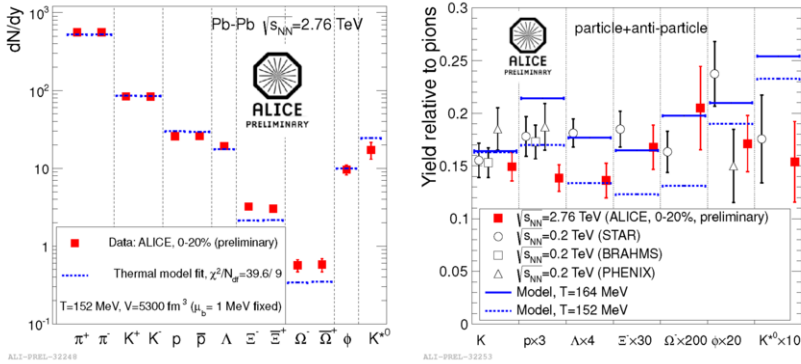


Figure 2: Left: integrated yields at mid-rapidity dN/dy in central (0-20%) Pb–Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV with results from thermal fit. Right: integrated yields at mid-rapidity dN/dy in central (0-20%) Pb–Pb collisions relative to pions with RHIC comparison and thermal model predictions.

The temperature extracted from the fit $T_{ch} = 152 \pm 3$ MeV is lower with respect to the temperature one would expect considering T_{ch} constant above SPS energies (164 MeV). From Figure 2 (left) it is possible to see some tension between the data and the fit especially for strange and multi-strange particles. This is reflected also in the large value of the $\chi^2/N_{d.f.} = 39.6/9$. The

comparison of integrated yields relative to pions (Figure 2, right) with RHIC hints to decreasing ratios at the LHC, especially for what concerns p/π and Λ/π . The prediction from the thermal model is reported with two different values of the freezeout temperature: $T_{ch} = 164$ MeV (value obtained from fit to RHIC data) and $T_{ch} = 152$ MeV (from the fit described above). $T_{ch} = 164$ MeV seems to reproduce the multi-strange ratios quite well, but some discrepancy is observed for p/π and Λ/π . On the other hand the model prediction using $T_{ch} = 152$ MeV obtained from the fit is closer to the measured p/π and Λ/π ratios but it misses ratios involving multi-strange hadrons. It has already been pointed out that interactions in the hadronic phase, in particular via the large cross section channel for antibaryon-baryon annihilation, could explain the significant deviation from the usual thermal ratios [11, 12].

3. Conclusions

p_T distributions of π , K, p in central (0-5%) Pb–Pb collisions at the LHC are harder than previously measured at RHIC. They are well described by hydrodynamic models including a refined description of the late fireball stages. Fitting the spectra with a hydrodynamic-inspired blast wave model results in the highest radial flow parameter ever measured, $\langle\beta_T\rangle = 0.65 \pm 0.02$.

Event shape engineering is a powerful tool to select events with different values of the elliptic flow based on the magnitude of the flow vector \vec{Q}_2 . The p_T distributions of π , K, p in semi-central (30-40%) Pb–Pb collisions show a correlation between radial flow and elliptic flow: high (low) elliptic flow events mean harder (softer) spectra.

In central (0-20%) Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV a significant deviation from the usual thermal production is observed, especially for p and Λ . The temperature obtained from thermal fit to integrated yields at mid-rapidity dN/dy is lower than expected from previous experiments. This discrepancy can be explained in terms of interaction in the hadronic phase which can modify the relative hadron abundances. It should be noted that a refined description of the hadronic phase is also needed to reproduce femtoscopy correlations at the LHC [13].

Identified hadron results at the LHC cast a new light upon the hydrodynamic and thermal behavior of the hadron production in heavy-ion collisions. The p-A run expected at the LHC at the beginning of 2013, together with the continuously improving experimental precision and description from the theory, will provide further insights (and model constraints) on the heavy-ion puzzle.

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