Identified charged hadrons and strange particle production in 900 GeV proton-proton collisions with the ALICE experiment

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The Large Hadron Collider provided the first proton-proton collisions at the end of 2009. The ALICE experiment took a rich proton-proton data sample for detector calibrations as well as for first physics measurements. Those measurements provide an essential baseline for the studies in heavy-ion collisions. In this contribution, ALICE measurements at central rapidity of identified charged hadron spectra and strange particles reconstructed from first proton-proton data at a center-of-mass energy of 900 GeV are reported.

1 Introduction

ALICE, A Large Ion Collider Experiment, is the dedicated detector to study highly-dense strongly interacting matter in collisions of heavy atomic nuclei at the CERN-Large Hadron Collider (LHC). If the energy density in such collisions exceeds a critical value ($\approx$0.7 GeV/fm^3), the formation of a novel state of matter, the Quark-Gluon Plasma (QGP), is expected to occur, where the constituents of nucleons, quarks and gluons, are liberated. The initial energy density in the collision zone is expected to be about one order of magnitude higher than at the RHIC facility ($\approx$100 GeV/fm^3). The higher energy density allows thermal equilibrium to be reached more quickly and creates a relatively long-lived QGP phase. The energy domain reached by the LHC will allow to characterise the properties of the QGP. The heavy-ion physics program of ALICE can be found in [1].

2 Detector setup and performance

The ALICE detector is designed to handle large particle multiplicities (> 4000 per unit rapidity) expected in lead-lead collisions at LHC energies [2]. The characteristic features of the ALICE central detector are its very low momentum cut-off (100 MeV/c), the low material budget and the excellent particle identification and vertexing capabilities, as illustrated in Figure 1, left panel.

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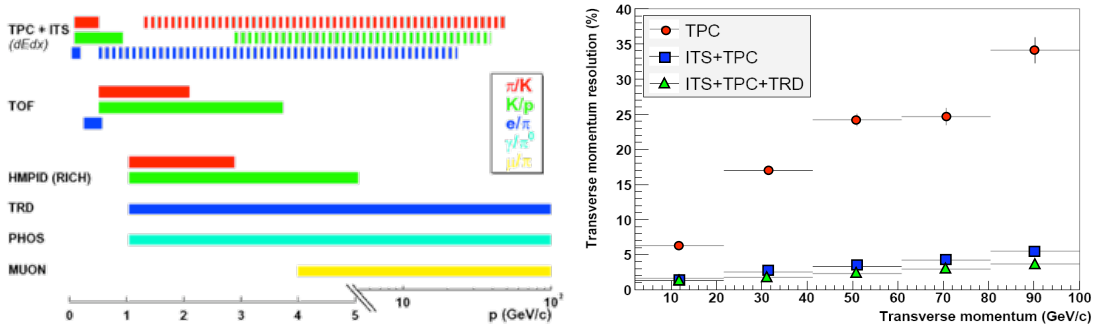

Figure 1: Particle identification capabilities of the ALICE detectors (left panel) and transverse momentum resolution (right panel) using TPC only (red circles), ITS+TPC (blues squares) and ITS+TPC+TRD detectors (green triangles).

Tracking and particle identification by the measurement of the specific energy loss (dE/dx) is performed by the large volume Time Projection Chambers (TPC) located inside a solenoidal magnetic field of $B = 0.5$ T. The TPC has an coverage of -0.9 to 0.9 in pseudo-rapidity and 2π in azimuth. Figure 2 shows the specific energy loss of the stable particle species. The relative dE/dx resolution is 5-6% and the relative momentum resolution $\Delta p/p$ is 5% at 100 GeV/c (cf. Figure 1, right panel). The Inner Tracking System, determing the vertex resolution of the system, consists of six concentric cylindrical layers of silicon detectors. Two layers of silicon pixel detectors (SPD) are closest to the interaction point (4 cm). The SPD is followed by two layers of silicon drift detectors (SDD) and two layers of silicon strip detectors (SSD) which provide matching to the TPC and additional particle identification at very low transverse

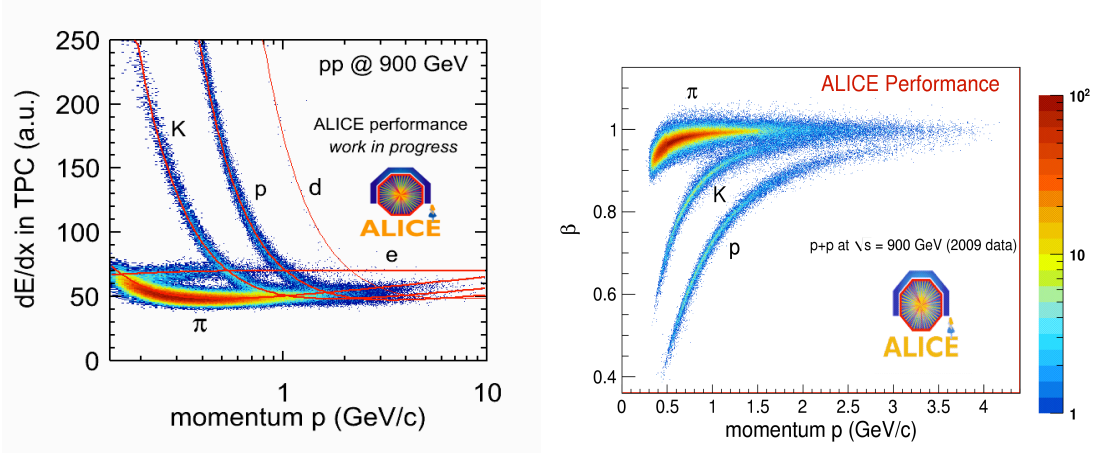

Figure 2: Left: Specific energy loss dE/dx in the TPC together with Bethe-Bloch curves for the different particle species (red curves). Right: Velocity $\beta = L/(ct)$, where L is the flight path of the track, versus particle momentum measured with the TPC.

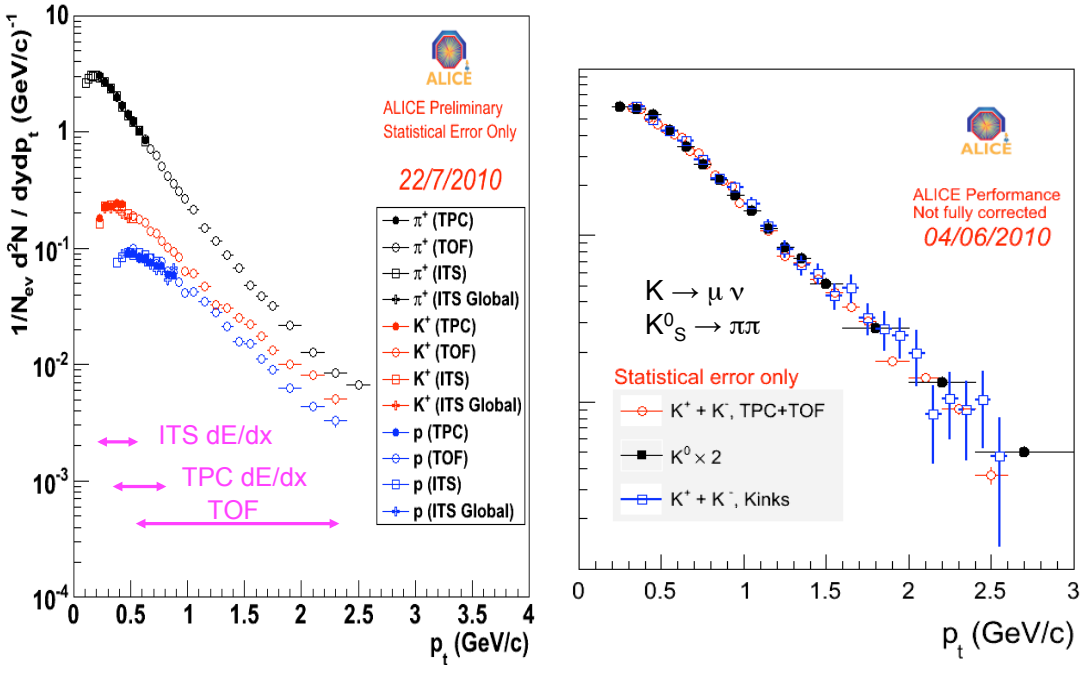

Figure 3: Left: Transverse momentum (p_T) distribution for pions (black symbols), kaons (red symbols) and protons (blue symbols) identified by different ALICE sub-detectors as indicated in the graph. Right: Compilation of the p_T spectra of kaons identified through three independent methods.

momentum (p_T). The Time-of-Flight (ToF) detector with a time resolution of 90 ps provides particle identification at high p_T.

Two forward scintillator hodoscopes (VZERO), located on either side of the interaction region, covering regions of $2.8 < \eta < 5.1$ and $-3.7 < \eta < -1.7$, complement these detectors and are used for triggering purposes. The very good detector performance as well as the efficient data processing have impressively been demonstrated by the first ALICE publication at the LHC facility [3].

3 Results

ALICE already measured the charged primary particle pseudo-rapidity density and multiplicity distributions in a high-statistics proton-proton data sample at $\sqrt{s} = 900$ GeV [4]. The ALICE measurement on the inclusive charged particle differential transverse momentum yield at the same energy is reported in [5]. First results on the measurements of two-particle correlations in pp collisions are presented in [6].

The measurements reported in this paper are based on about 300,000 inelastic proton-proton collisions at $\sqrt{s} = 900$ GeV, corresponding to an integrated luminosity of about 10.3 μb^{-1}. The minimum bias offline event selection is based on a signal in either of the VZERO counters or at least one hit in one of the SPD layers.

3.1 Identified charged particle spectra

Particle identification for pions, kaons and protons is performed using the specific energy loss in the inner tracking silicon detector and the TPC. In addition, the ToF information is used to identify hadrons at higher momenta. The distinctive kink topology of the weak decay of charged kaons, $K^{\pm} \rightarrow \mu^{\pm}\nu_{\mu}$ (BR = 63.55%), is studied to provide an alternative method of extraction of the kaon transverse momentum spectra. Since these various particle identification tools give the best separation capabilities over the different momentum ranges, the results have been combined to extract spectra from 200 MeV/c to 2.5 GeV/c. The transverse momentum distribution for these particle species are shown in Figure 3, left panel. Lévy functions describe the data well in the measured p_T range. The kaon p_T spectra from the kink and K^0_s analyses are compared to the charged kaons identified by the TPC and ToF detectors in Figure 3, right panel, and show reasonably good agreement.

3.2 Strange particle production

Neutral strange hadrons are identified by reconstructing their characteristic V0 decay topology $\Lambda \rightarrow p\pi^-$, $\bar{\Lambda} \rightarrow \bar{p}\pi^+$ and $K^0_s \rightarrow \pi^+\pi^-$ with a branching fraction of 63.9% and 69.2%, respectively. The measured Λ yield includes that of the short-lived Σ^0, which decay electromagnetically into $\Lambda\gamma$. The charged decay products are measured with the TPC. A set of selection cuts, such as the impact parameter of the particle tracks, are applied to suppress the background of uncorrelated pairs. Figure 4 shows the invariant mass distributions for $\pi^+\pi^-$ and $p\pi^-$ ($\bar{p}\pi^+$) pairs. Clear signals are observed with very good signal-to-background ratios. Within the experimental uncertainties, the measured masses agree with the nominal value, indicated by the arrows.

The raw yields are extracted after subtracting the background, which is well described by a 1st-order polynomial. Corrections are applied for geometrical acceptance and tracking efficiency

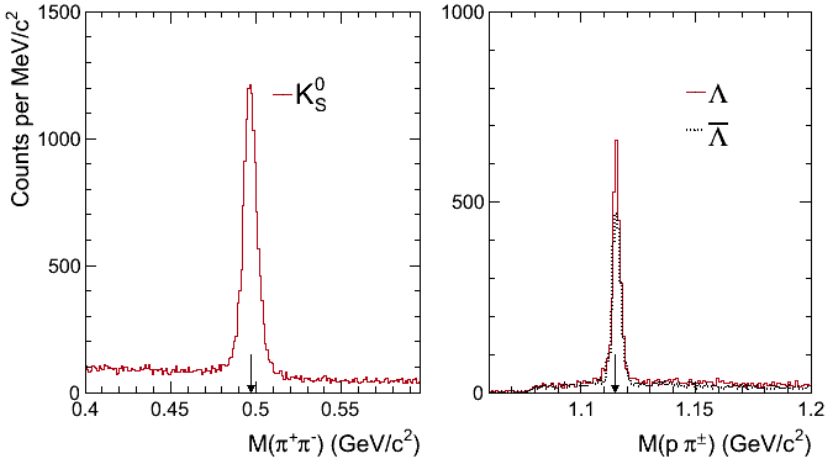

Figure 4: Invariant mass distribution for $\pi^+\pi^-$ (left panel) and $p\pi^-$ ($\bar{p}\pi^+$) pairs (right panel) in proton-proton collisions at 900 GeV. The arrows indicate the nominal values.

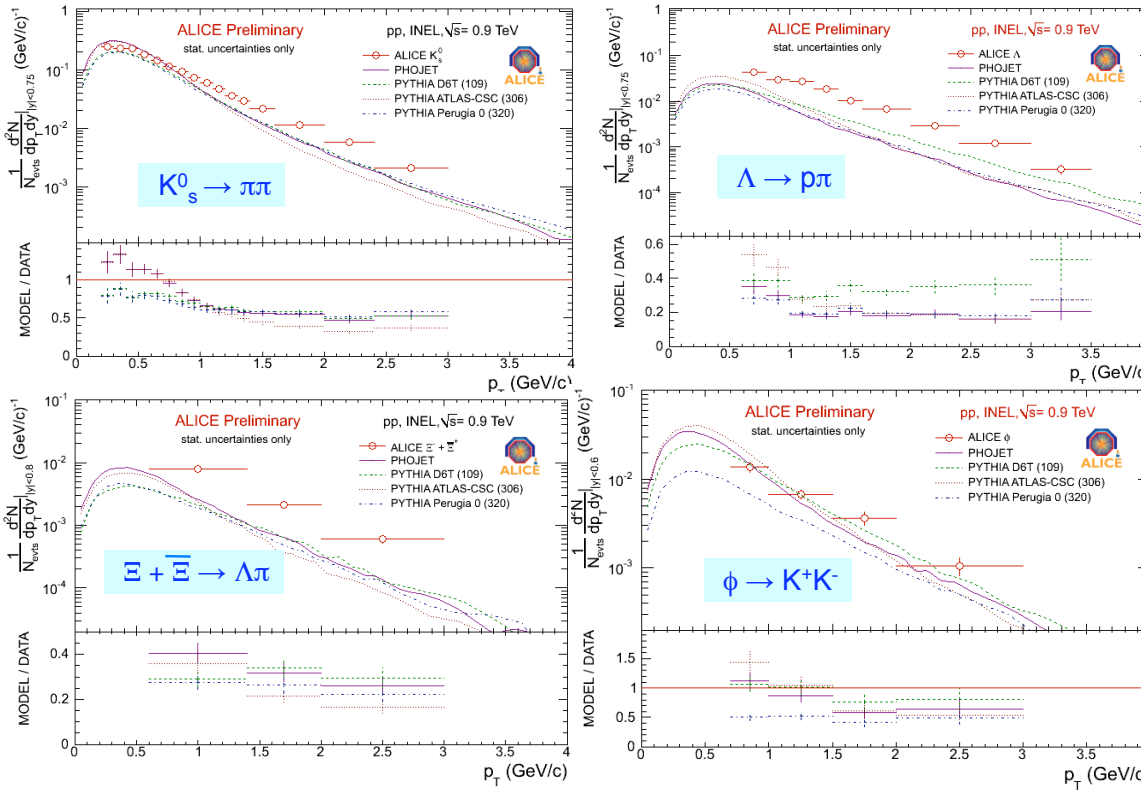

Figure 5: Transverse momentum spectra of K^0_s (upper left panel), Λ (upper right panel), Ξ (lower left) and ϕ mesons (lower right panel) in proton-proton collisions at $\sqrt{s} = 900$ GeV. The data are compared with calculations from the PYTHIA event generator using different tunes, indicated by the coloured curves.

using a full Monte Carlo simulation of the detector response in GEANT. Figure 5 depicts preliminary results on the transverse momentum spectra for K^0_s, Λ, Ξ and ϕ mesons, which are reconstructed in the decay channel $\phi \to K^+K^-$ ($BR = 49.2\%$). The data are compared with calculations from the PYTHIA event generator using different tunes. The PYTHIA curves lie below the data points, especially at high transverse momentum. Reasonably good agreement is obtained for the ϕ mesons.

4 Summary

In this contribution, first ALICE measurements of identified charged and strange hadrons in proton-proton collisions at 900 GeV are discussed. Stable particles are well identified at mid-rapidity from 100 MeV/c up to 2.5 GeV/c. Signals are studied for K^0, Λ, Ξ hyperons and ϕ mesons. First lead-lead collisions at $\sqrt{s} = 2.76$ TeV per nucleon nucleon pair are anticipated for November 2010.

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