Strange Particle Production in pp Collisions at $\sqrt{s} = 0.9$ and 7 TeV measured with the ALICE Experiment

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Abstract

Hadrons measured in proton-proton collisions at $\sqrt{s} = 0.9$ and 7 TeV with the ALICE detector have been identified using various techniques: the specific energy loss and the time-of flight information for charged pions, kaons and protons, the displaced vertex resulting from their weak decay for K^0, Λ and Ξ and the kink topology of decaying charged kaons. These various particle identification tools give the best separation at different momentum ranges and the results are combined to obtain spectra from $p_t = 100$ MeV/c to 2.5 GeV/c. This allows to extract total yields. In detail we discuss the K/π ratio together with previous measurements and we show a fit using a statistical approach.

Key words: Particle and resonance production, Inclusive production with identified hadrons
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1. Introduction

The bulk of particles produced both in heavy-ion and in pp collisions has transverse momenta below 1 GeV/c. Their spectral shapes and their composition are major observables that help understanding the hadronic interactions and the hadronization process. With the Large Hadron Collider (LHC) at CERN much higher energies are reached opening a new area where particle production occurs mainly via hard interactions.

From about 1 A GeV up to the highest energies a statistical concept has successfully described the chemical composition of hadrons, consisting of u, d and s quarks, measured in heavy-ion reactions and to some extend also in elementary collisions. The much higher collision energies at the LHC will crucially test this picture in the realms of hard partonic interactions. Furthermore, it will allow to compare results from pp collisions at high multiplicities with those from the heavy-ion collisions at the same multiplicity.

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The ALICE detector with its excellent particle identification (PID) capability is perfectly suited for these studies. In these proceedings the various PID techniques are shortly mentioned and the results obtained in pp collisions at $\sqrt{s} = 0.9$ TeV are presented.

2. The ALICE Experiment and data analysis

The ALICE detector and its performance are described in detail in [1–3]. The first pp collisions at $\sqrt{s} = 0.9$ TeV are analysed using various PID techniques and the results are reported in two recent papers [4,5].

Charged π, K and p are identified using the Inner Tracking System (ITS), the Time Projection Chamber (TPC) and the Time-Of-Flight array (TOF) [5]. Weakly decaying strange particles are identified by their displaced vertex using the tracking information in ITS and TPC. These studies are reported in detail in [4]. Charged kaons decaying within the TPC are identified by their typical kink topology. All three techniques for kaon identification agree very well and have optimal performance at different momenta [4,5].

Particle identification in the TPC is based on the specific energy deposit by each particle in the drift gas, shown in Fig. 1, left, as a function of momentum separately for positive and negative charges. The solid curves show Bethe-Bloch parametrization. The ITS being closer to the interaction point, is able to identify also particles with low momenta which are absorbed before reaching the TPC using the dE/dx in the silicon material. Particles reaching the TOF system are identified by measuring their momentum and velocity simultaneously. The velocity $\beta = L/t_{\mathrm{TOF}}$ is obtained from the measured time of flight t_{TOF} and the reconstructed flight path L along the track trajectory. The measured velocities are shown in Fig. 1, right, as a function of the momentum p at the vertex. The bands corresponding to charged pions, kaons and protons, are clearly visible and show that particles can be separated up to about 2.5 GeV/c.

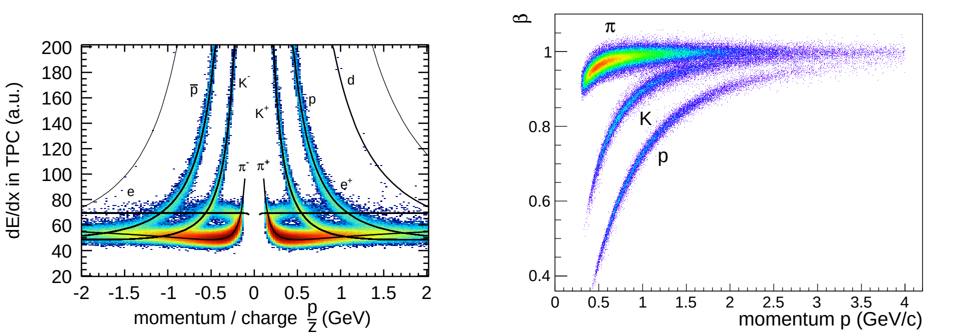

Fig. 1. Examples of PID techniques using in pp collisions at 0.9 TeV [5]. Left: Specific energy loss dE/dx vs. momentum for tracks measured with the ALICE TPC. The solid lines are a parametrization of the Bethe-Bloch curve. Right: β of particles measured by TOF vs. their momentum.

3. Results

Figure 2 shows the spectra of positive pions, kaons and protons using different PID techniques: ITS stand-alone, ITS-TPC combined, TPC and TOF. Each of them is optimal for a given momentum range. The good agreement demonstrates that the relevant efficiencies are well reproduced by the detector simulations.

The spectra from ITS standalone, TPC and TOF are combined in order to cover a large momentum range as shown in Fig. 2, right. The spectra have been averaged, using the systematic errors as weights. From this weighted average, the combined, p_{t}-dependent, systematic error is derived. These spectra are fitted with Lévy (or Tsallis) functions [5]. This function gives a good description of the spectra and has been used to extract the total yields and the $\langle p_{\mathrm{t}} \rangle$. The fraction of the yield contained in the extrapolation of the spectra to zero momentum ranges from 10% to 25%. The extrapolation to infinite momentum gives a negligible contribution.

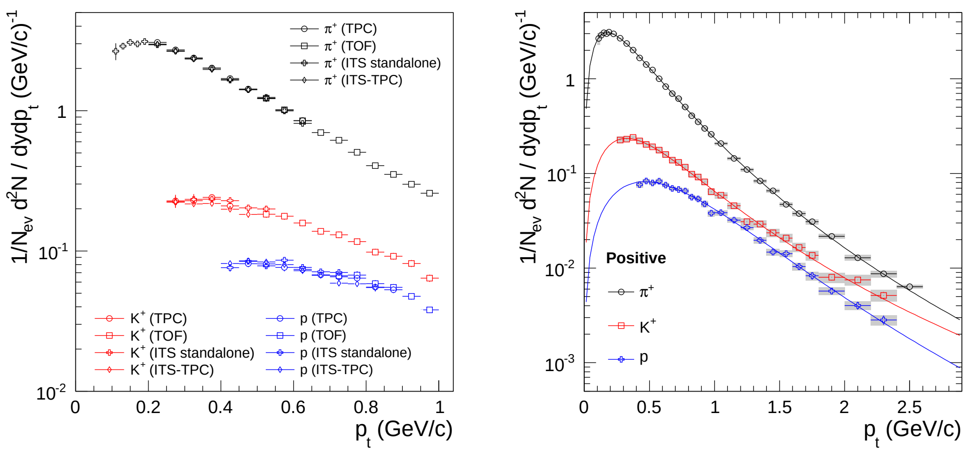

Fig. 2. Left: Transverse momentum spectra $\mathrm{d}^2N/(\mathrm{d}p_{\mathrm{t}}\mathrm{d}y)$ for $|y| < 0.5$ of positive hadrons from the various analyses. Only systematic errors are plotted. Right: Transverse momentum spectra of positive hadrons from pp collisions at $\sqrt{s} = 900$ GeV. Grey bands: total p_{t}-dependent error (systematic plus statistical); normalization systematic error (3.6%) not shown. The curves represent fits using a Lévy function. Both from [5].

In Fig. 3, left, we show the K/π ratio as a function of $\sqrt{s}$ both in pp (full symbols) and in $\overline{\mathrm{p}}$p (open symbols) collisions. The ALICE result is the solid red point. For most energies, $(\mathrm{K}^+ + \mathrm{K}^-)/(\pi^+ + \pi^-)$ is plotted, but for some cases K^0/π^0 is used instead. This ratio measured in pp reactions varies from $\sqrt{s}$= 200 GeV (K/π = 0.103 ± 0.008) [6] to $\sqrt{s}$= 900 GeV (K/π=$0.123 \pm 0.004 \pm 0.010$), yet consistent within the error bars. The results at 7 TeV will show whether the K/π ratio keeps rising slowly as a function of $\sqrt{s}$ or whether it saturates.

The measured yields of charged π, K, p and of K^0, Λ and Ξ [4,5] together with the measured $\overline{\mathrm{p}}$/p ratio [7] have been used in a statistical-model fit with THERMUS [8]. With a canonical description for the strangeness, we obtain a rather poor fit with a moderate χ^2/ndf of 7 as can be seen in Fig. 3, right. The fit overestimates the proton yield by about 30% while both the Λ and Ξ yields are underestimated. In view of this unsatisfying description, the resulting thermal parameters have to be taken with caution. We obtain a freeze-out temperature T of 161 ± 4 MeV, a baryo-chemical potential μ_B of 3 ± 2 MeV and a canonical radius R_c of 1.35 ± 0.07 fm where the radius of the fireball and the strangeness correlation volume are kept equal and $\gamma_s = 1$. As the K/π ratio is well described, fitting in addition γ_s results in very similar parameters. The ϕ has not been included in the fit. The inclusion of the ϕ meson causes only minor changes. It is interesting to note that the thermal fits to the STAR pp data [9] gave a better description, however similar deviation of the p and Λ yields can be noticed, yet within the errors.

The results from the pp data at $\sqrt{s} = 7$ TeV will be very important to observe whether the K/π ratio will increase with $\sqrt{s}$. These data will then allow a detailed analysis using high-multiplicity events.

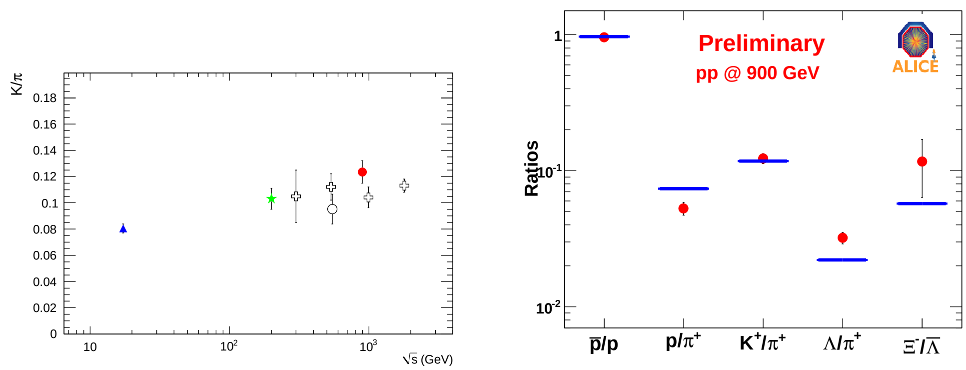

Fig. 3. Left: Ratios $(K^+ + K^-)/(\pi^+ + \pi^-)$ and K^0/π as a function of $\sqrt{s}$. The solid red point refers to the ALICE result. Other data are from pp collisions (full symbols, NA49, STAR) and from $\overline{p}$p interaction (open symbols, E735, UA5). For references see [5]. Right: Fit of the measured particle ratios with the statistical model code THERMUS exhibiting a rather poor description.

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