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K/π ratio and strangeness suppression in pp collisions at the LHC

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Analysis of particle yields in pp collisions at the LHC energies demonstrates the smaller strangeness suppression comparing to experiments at lower energies. The PYTHIA 6.4 predictions for strange particle spectra are calculated with new ATLAS tunes and with proposed smaller strangeness suppression.

LHC on the March,
November 16-18, 2011
Protvino, Moscow region, Russian Federation

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PoS(IHEP-LHC-2011)008

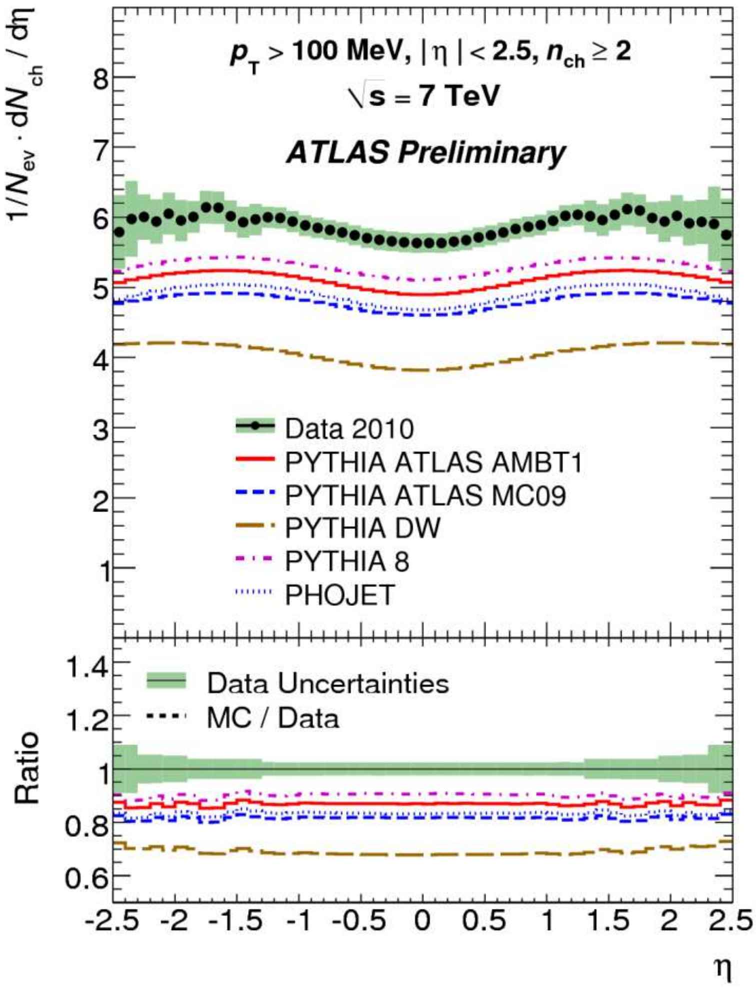

Figure 1: Charged particle multiplicity density in pseudorapidity in pp collisions at 7 TeV in comparison with different MC generators predictions from the ATLAS experiment [3].

1. Introduction

First physics results from proton-proton collisions at the LHC presented charged multiplicities and transverse momentum spectra of charged particles at center-of-mass energies 0.9, 2.36 and 7 TeV [1 – 3]. These measurements are sensitive to the soft QCD dynamics, hadronization mechanism and contribution of hard interactions, mostly in the form of Multi-Parton Interactions (MPI). The phenomenological models of these processes are realized in Monte Carlo (MC) event generators with parameters, tuned to existing experimental data. Charged particle pseudorapidity densities at the LHC demonstrates increase compare to MC generators predictions, tuned to the lower energy data. As an example, the comparison of the ATLAS experimental results with predictions of PYTHIA different tunes and PHOJET are presented in (Figure 1).

This discrepancy initiated first stage of MC tunes to reproduce charged particle production data of the LHC. The LHC measurements of strange particles yield and p_T spectra show the similar discrepancies with MC generators predictions [4, 5]. The rapidity densities of strange particles from the CMS experiment in comparison with MC predictions are presented in Figure 2.

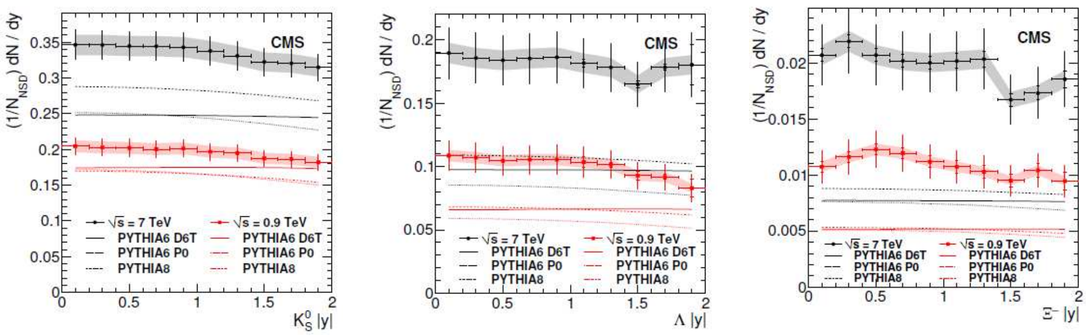

Figure 2: Rapidity densities for K_s^0, Λ and Ξ^- in pp collisions at 0.9 and 7 TeV in comparison with different MC generators predictions from the CMS experiment [4].

Strange particle production is a component of multiparticle production mechanism. Strange quark is a light quark. So, the higher strange particle yields can be expected from the effect, observed for the charged particles (Fig. 1). The relative proportion of strange particles is smaller in comparison with nonstrange hadrons. The reason for this is the suppression of strange quark production due to the mass difference with the lightest u and d quarks.

The results show an increase in the production rate of strange particles not yet simulated correctly in the current tunes of PYTHIA. There is a large increase in the measured production cross section of strange particles as the c.m. energy increases from 0.9 to 7 TeV. Also, the difference between predictions of strange particles production and measurements gets bigger as the particle mass and strangeness number increase.

ALICE experiment presented ratio of $K^\pm$ p_T spectrum with it for $\pi^\pm$ (Fig. 3).

2. The role of $c\bar{c}$ pairs production

The ATLAS measurements of $D^{\star+}$ and D^+ mesons production at 7 TeV [6] demonstrate agreement with POWHEG-PYTHIA within the large theoretical uncertainties (Fig. 4). The larger yields of c-quarks are possible. Because c-quark decays dominantly with s-quark production it is reasonable to estimate the possible role of increase of $c\bar{c}$ pairs produciton in K meson p_T spectrum.

The $K^\pm$ transverse momentum spectra were calculated with PYTHIA6 using CSC ATLAS tunes [7] for all minimum bias events and for events with c-quark production in pp interactions at $\sqrt{s} = 7$ TeV. The ration of these spectra is shown in Figure 5. The ratio of these spectra demonstrates the increased contribution of K from c-quarks decays for larger p_T. The next step is to increase yield of K mesons from events with c-quark to see possible effect of larger c-quark production. The calculated ratio of the p_T spectra for $K^\pm$ and $\pi^\pm$ in comparison with ALICE measurements is represented on Fig. 6. The cross section of c-quark production was doubled in the simulations. It is easy to see, that multiplying $c\bar{c}$-pairs production does not improve agreement with $K^\pm/\pi^\pm$ ration, measured by ALICE.

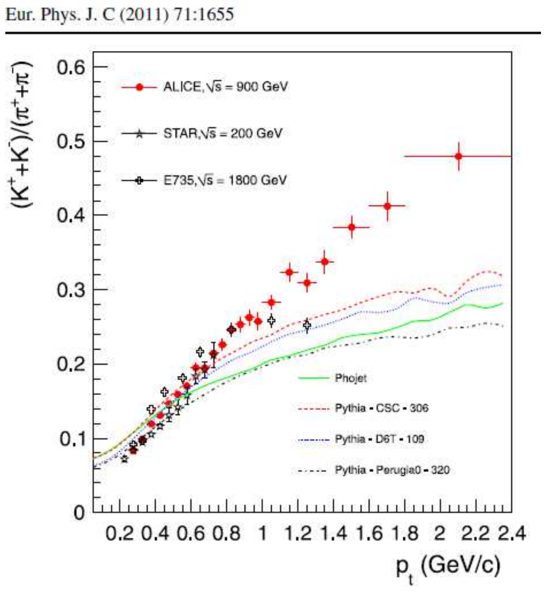

Figure 3: Ratio of the p_T spectra for $K^{\pm}$ and $\pi^{\pm}$-mesons at $\sqrt{s}$=0.9 TeV.

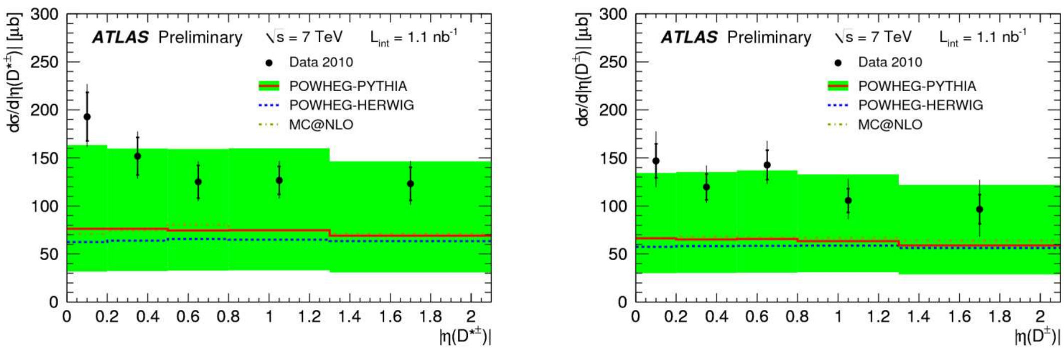

Figure 4: Pseudorapidity densities for $D^{\star+}$ (top) and D^{+} (bottom) in pp interactions at 7 TeV, measured in ATLAS experiment [6].

3. Kaon p_T spectra comparison

The increase of $K^{\pm}/\pi^{\pm}$ ratio at larger p_T (more 1 GeV/c) follows from the difference in the slopes of p_T spectra of kaons and pions. It is useful to compare experimental data for p_T distributions of neutral and charged kaons. They are expected to be similar, but the methods of particle identification are different. The ALICE experiment demonstrates similarity of p_T spectra of charged and neutral kaons (Fig.13 from [5]). The parametrization of these spectra have the slopes n = 6.08±0.2±0.4 for $K^{\pm}$ and 6.6±0.3 for K_s^0 [5], the same within the large experimental uncertainties. The average p_T value for K_s^0 in pp collisions at 0.9 TeV are the same in ALICE and CMS experiments [4]. But the slope of p_T spectra of K_s^0 in CMS is much larger: n = 7.79±0.07±0.26 [4]. It is similar to $\pi^{\pm}$ spectra slope in ALICE in pp collisions at 0.9 TeV [5]. So, with CMS data there is no increase in K/π ratio for large p_T. It means that the experimental situation in observation

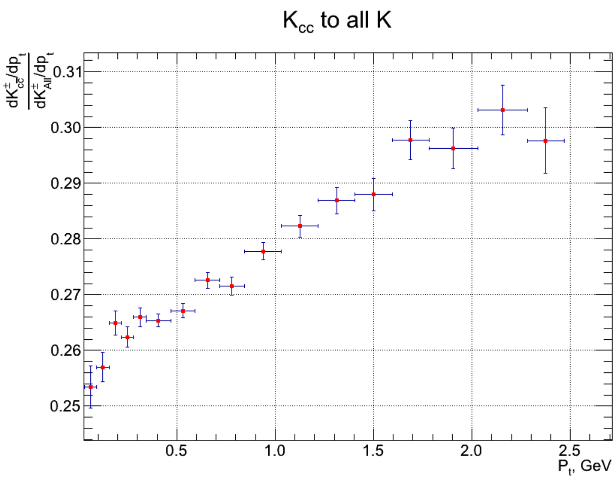

Figure 5: Ratio of $K^{\pm}$ p_T spectra for events with c-quark to same spectra for all events.

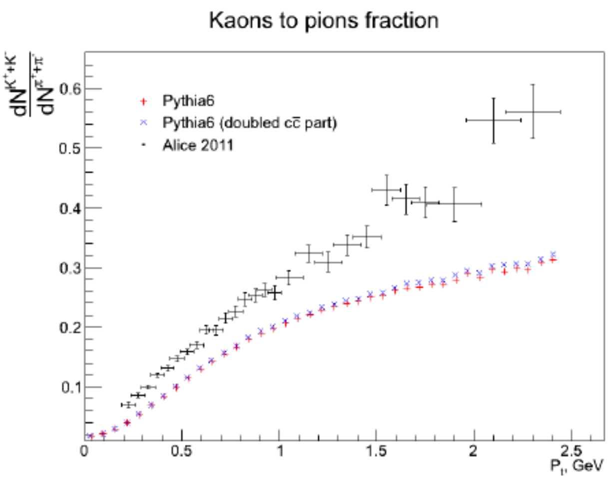

Figure 6: Ratio of $K^{\pm}$ p_T spectrum to $\pi^{\pm}$ p_T spectrum from ALICE experiment ($\sqrt{s}$ = 0.9 TeV) and simulations results with PYTHIA CSC tunes and with two times increased cross section of c-quark production ($\sqrt{s}$ = 7 TeV).

of the effect is not clear.

4. The K/π ratio and strangeness suppression

The K/π production ratio depends on the strangeness suppression factor λ. The value of factor λ is measured and calculated by different methods. It is considered as constant in energy range which was studied by Orava [8]. There are analyses of experimental data which accept the decrease of strangeness suppression with increase of energy of particle collisions [9, 10]. That means the larger values of λ. New MC event generators are developed where λ is energy dependent [11]. We

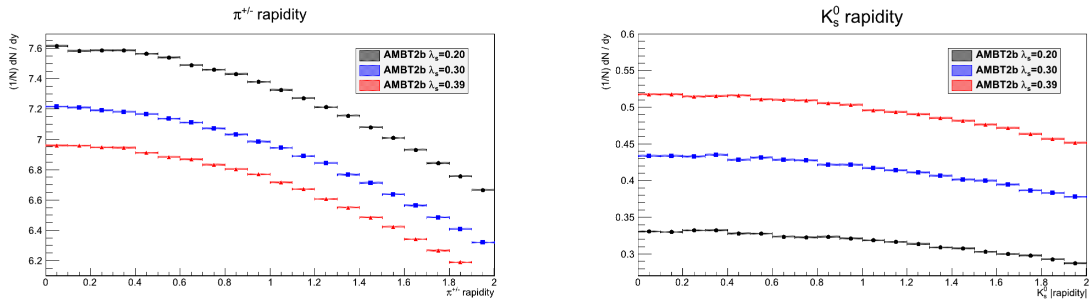

Figure 7: Rapidity densities for K_s^0 and $\pi^{\pm}$, calculated with PYTHIA AMBT2b, $\sqrt{s} = 7$ TeV.

estimated factor λ from new LHC measurements of K/π production ratio at $y = 0$ and integrated multiplicities of kaons and pions for $|y| < 2$.

The analysis is based on the data for K/π ration, collected and measured by UA1 Collaboration [9]. They used the measurements of K/$h^{\pm}$ and $\Lambda/h^{\pm}$ ratios for range of pseudorapidity $|\eta| < 2.5$. In terms of λ they express the K/π ration as

$$\frac{2K_s^0}{\pi^{\pm}} = \frac{12\lambda + 3\lambda^2}{31 + 12\lambda + 3\lambda^2 + \gamma(\frac{16}{3} + 4\lambda + \frac{8}{3}\lambda^2)} \tag{4.1}$$

where

$$\gamma = \frac{4 + 4\lambda + \lambda^2}{5 + 5\lambda + 3\lambda^2 + \lambda^3}.$$

From their measurements at energy $\sqrt{s}$ = 630 GeV they found λ = 0.29±0.02±0.01 in agreement of previous measurements [8] and UA5 and CDF experiments. They made energy dependence fitting for λ values and found the predictions for K/π ratio 0.107±0.030 and λ = 0.31±0.05 at the LHC energy collisions 14 TeV.

From LHC data, published in [1 – 5], we found estimation for K/π ratio value 0.15±0.01 from ALICE and CMS, the same for pp collisions at 0.9 and 7 TeV, and K/π ratio estimations as 0.12 and 0.15 from ALICE and ATLAS data for 0.9 and 7 TeV, correspondingly, for central region $|\eta| < 2.5$. That is much higher values for K/π ratio than predicted in [9]. The estimation of λ with the same formula gives λ = 0.39 in agreement with ATLAS measurements of λ from D-mesons reconstruction at 7 TeV [6], where λ = 0.35±0.07±0.03. With that reason we made simulation of kaons and pions in pp collisions at 7 TeV with new minimum bias tunes for PYTHIA6 (AMBT2b) to see how it changes the production yields for kaons and pions and K/π ratio in dependence on particle pt. The calculations were fulfilled with different values of factor λ to estimate the possible contribution of smaller suppression of strange quarks at the LHC energies.

5. PYTHIA 6.4 with AMBT2b simulation

Transverse momentum and rapidity distributions for $\pi^{\pm}$, $K^{\pm}$ and K_s^0 were calculated using PYTHIA 6.4 with AMBT2b (new ATLAS tune for soft QCD, [12]) for $\sqrt{s} = 7$ TeV and $|y| < 2$ for different values of strangeness suppression factor λ (0.20, 0.30 and 0.39). The rapidity spectra for $\pi^{\pm}$ and K_s^0 are presented on Fig.7. The ratio of K_s^0 and $\pi^{\pm}$ p_T spectra shown on Fig. 8. The result is that the K/π ratio from Fig. 3 is not reproduced in Fig. 8.

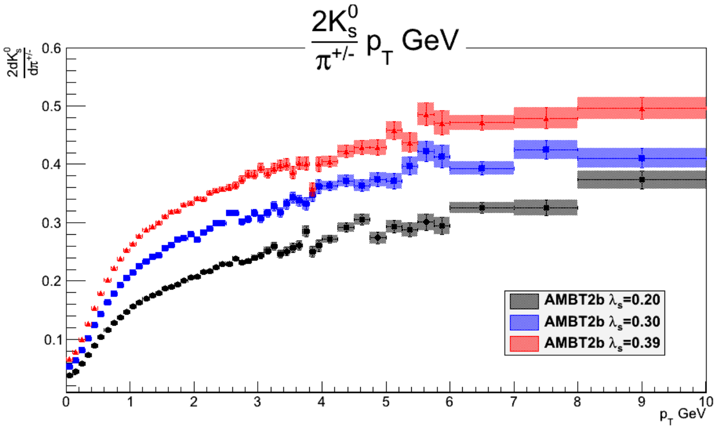

Figure 8: $2K_s^0$ p_T spectrum to $\pi^{\pm}$ p_T spectrum, calculated with PYTHIA AMBT2b ,$\sqrt{s} = 7$ TeV, $|y| < 2$.

	$\lambda_s = 0.20$	$\lambda_s = 0.30$	$\lambda_s = 0.39$
$\pi^{\pm}$	29.10	27.57	26.64
$K^{\pm}$	2.56	3.36	4.04
K_s^0	1.26	1.65	1.98
$2K_s^0/\pi^{\pm}$	0.09	0.122	0.15

Table 1: $\pi^{\pm}$, $K_s^{\pm}$ and K_s^0 multiplicity and $2K_s^0/\pi^{\pm}$ for AMBT2b depending on λ, $\sqrt{s} = 7$ TeV, $|y| < 2$.

Table 1 presents integrated average multiplicities of particles for region $|y| < 2$ and ratio $2K_s^0/\pi^{\pm}$ for pp inelastic interactions at 7 TeV for different values of factor λ. Table 2 shows the rapidity densities at $y = 0$ for these particle distributions. The K/π ratio dependence on λ is demonstrated by these results. The K_s^0 integrated multiplicity and rapidity density at $y = 0$ can be compared with CMS results for 7 TeV [4]: 1.341±0.001±0.097 and 0.346±0.001±0.025, correspondingly. The conclusion is that K_s^0 yields can be reproduced in simulations without increase of λ value.

To compare simulated p_T distributions with CMS results they were fitted by Tsallis functions [13]. Two parameters of these fits are presented in Table 3 for different values of λ. The slope

	$\lambda_s = 0.20$	$\lambda_s = 0.30$	$\lambda_s = 0.39$
$\pi^{\pm}$	7.61	7.21	6.96
$K^{\pm}$	0.67	0.89	1.06
K_s^0	0.33	0.43	0.52

Table 2: $\pi^{\pm}$, $K^{\pm}$ and K_s^0 $\frac{1}{N}\frac{dN}{dy}|_{y=0}$ for AMBT2b depending on λ, $\sqrt{s} = 7$ TeV, $|y| < 2$.

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	T, MeV	n
$\pi^{\pm}$	120.0±0.6	5.51±0.01
$K^{\pm}$	180.0±1.4	5.03±0.02
K_s^0	181.0±1.9	5.07±0.03

$\lambda_s = 0.20$

	T, MeV	n
$\pi^{\pm}$	119.0±0.6	5.51±0.01
$K^{\pm}$	180.0±1.2	5.150±0.018
K_s^0	180.0±1.7	5.15±0.03

$\lambda_s = 0.30$

	T, MeV	n
$\pi^{\pm}$	118.0±0.7	5.48±0.01
$K^{\pm}$	176.0±1.1	5.170±0.017
K_s^0	175.0±1.5	5.14±0.02

$\lambda_s = 0.39$

Table 3: Tsallis parameterization of $\pi^{\pm}$, $K^{\pm}$ and K_s^0 p_T spectra, AMBT2b with different λ_s, $\sqrt{s} = 7$ TeV, $|y| < 2$.

parameter n does not depend on λ and for K_s^0 is smaller than CMS measurements ($n = 6.87 \pm 0.02 \pm 1.1$). The parameter T is also much smaller in simulations compare to CMS result ($T = 220 \pm 1 \pm 3$ MeV).

6. Conclusions

Increase of the cross section of charm production does not improve the simulated K/π ratio dependence on p_T. There are some discrepancy in experimental data for strange particles production in pp collisions at $\sqrt{s} = 0.9$ TeV. Experimental data for integral K/π ratio demonstrate its increase in pp collisins at the LHC energies, or smaller strangeness suppression (following to analysis from previous energy range). New ATLAS tunes for PYTHIA 6.4 can reproduce kaon yields at 7 TeV without special change of λ. New experimental data for identified hadrons are necessary and the analysis of strangeness suppresson should be continued.

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