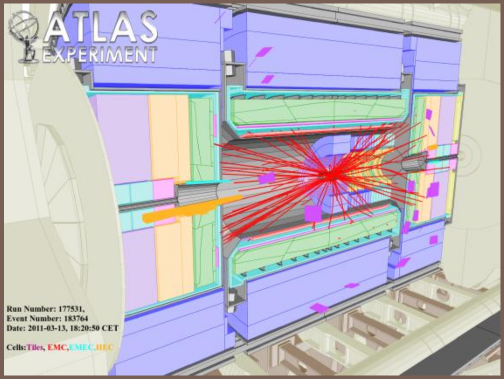
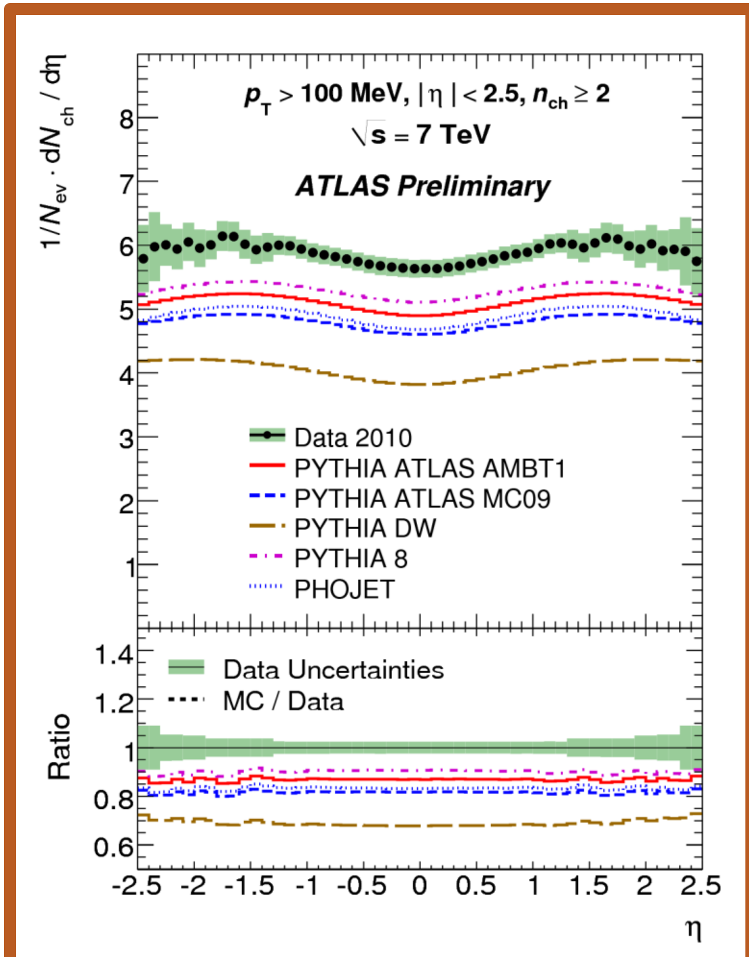


K/Π RATIO AND STRANGENESS SUPPRESSION IN PP COLLISIONS AT THE LHC

S. Lobanov, A. Maevskiy, L. Smirnova

D. V. Scobeltsyn Institute of Nuclear Physics M. V. Lomonosov Moscow State University (SINP MSU), Moscow, Russia

Introduction



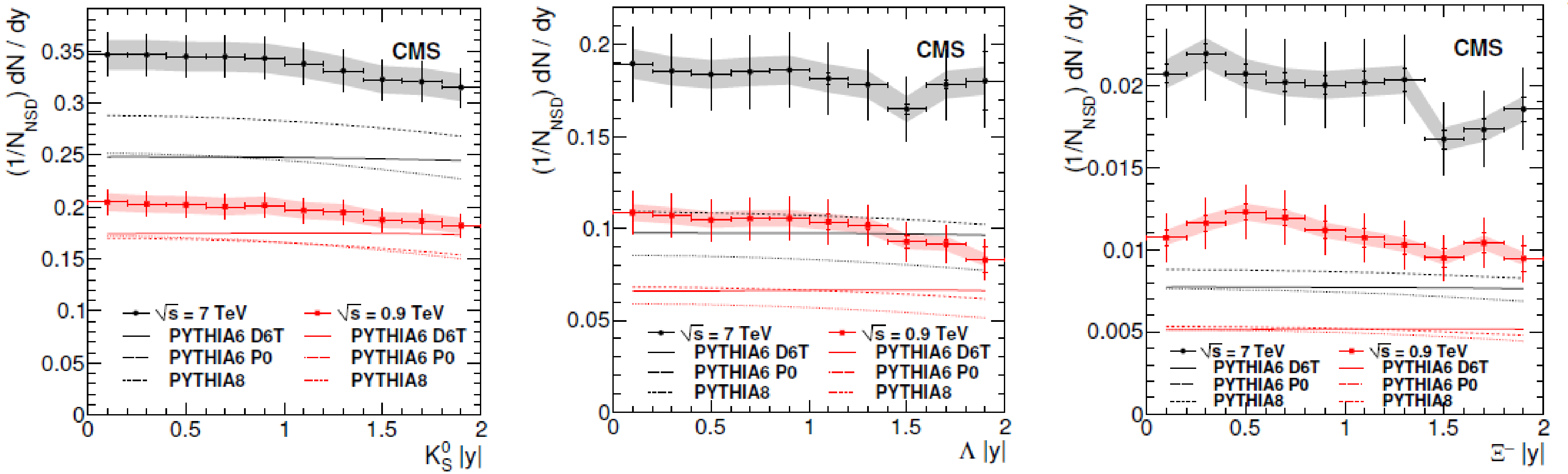
Charged particle multiplicities measurements in pp collisions at 0.9 and 7 TeV at the LHC demonstrate increase in rapidity densities over MC predictions of PYTHIA and PHOJET

It initiated tuning of PYTHIA to reproduce new experimental data

New surprises follow from measurements of strange particle yields

Strange particle measurements at the CMS: (JHEP 05 (2011)064)

Rapidity densities for K^0_s, Λ and Ξ at 0.9 and 7 TeV

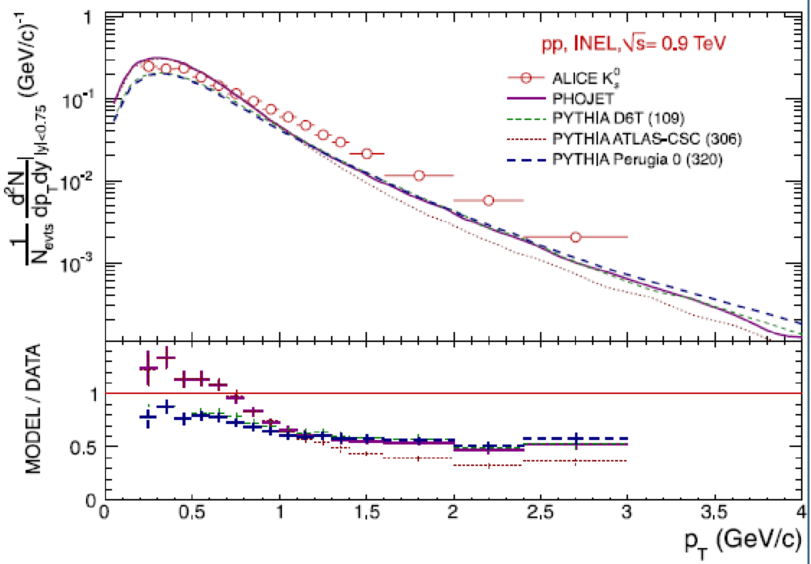


Large underestimations of strange particle yields, increased with collision's energy

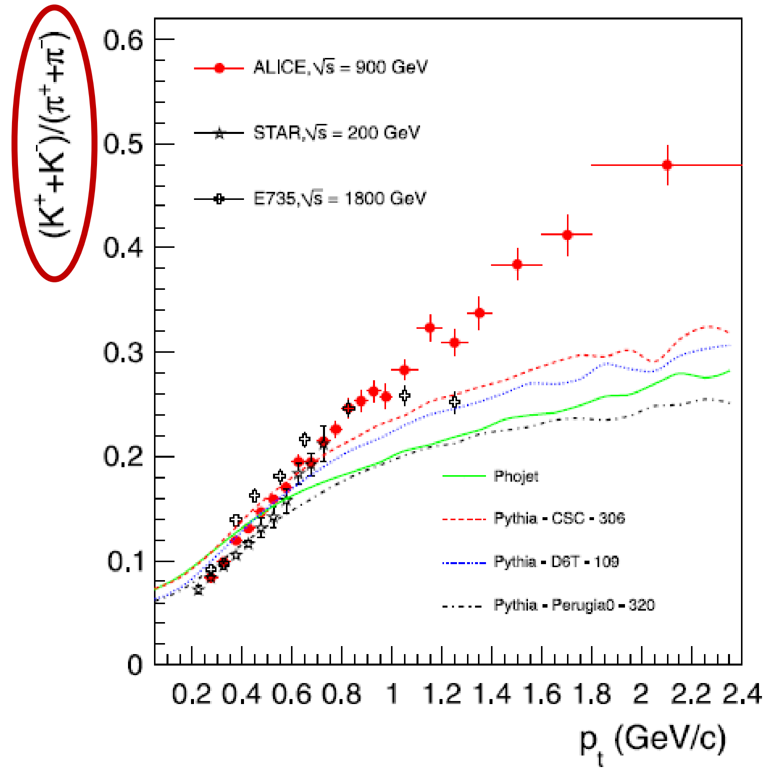
Strange particle measurements at the ALICE: (Eur. Phys. J. C 71 (2011) 1594, 1655)

$1/N_{ev}\,(d^2N/dydp_t)$

Fig. 15 Comparison of the transverse momentum differential yield for the K^0_S particles for INEL pp collisions with PHOJET and PYTHIA tunes 109, 306 and 320

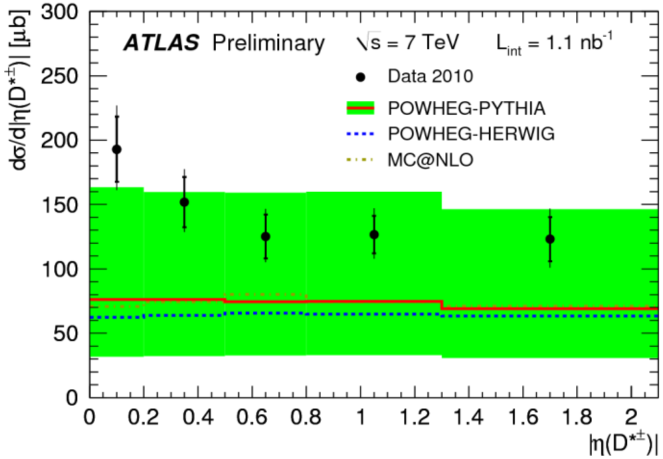


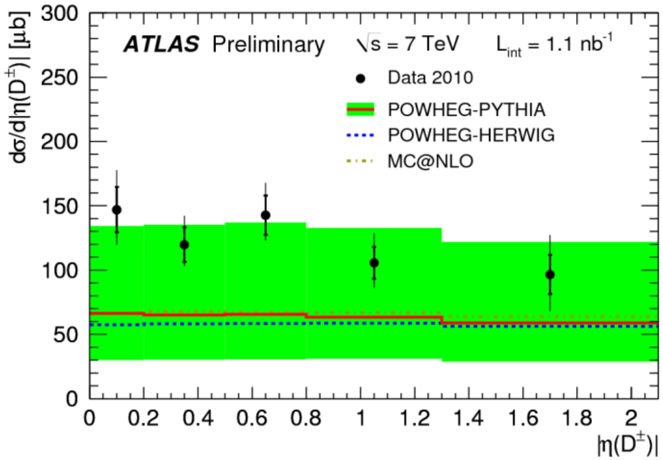
Eur. Phys. J. C (2011) 71:1655



pp collisions at 0.9 TeV, |y| < 0.8

The role of cc-pairs production





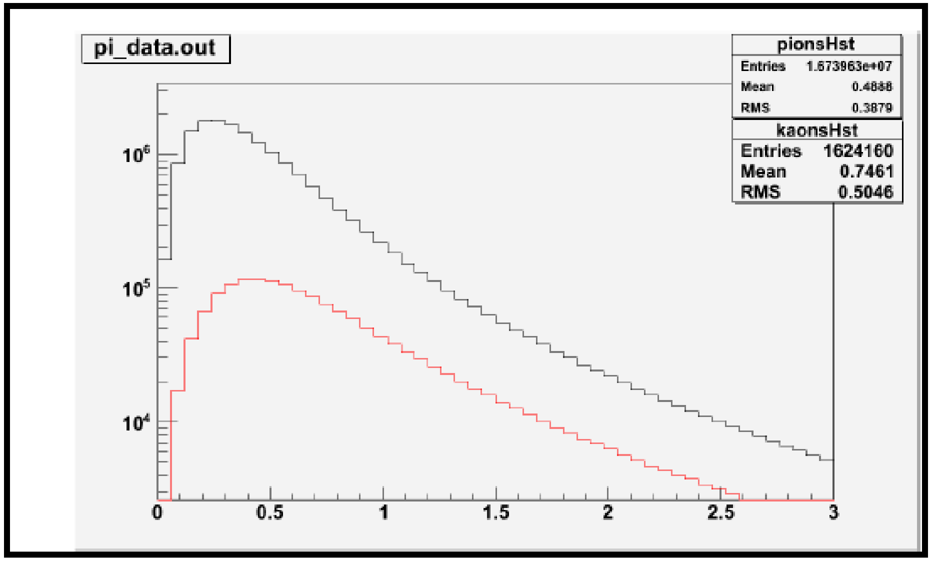
ATLAS measurements of D^{*+} and D^{+} -mesons production at 7 TeV demonstrate agreement with PYTHIA within the large theoretical uncertainties (ATL-CONF-2011-017)

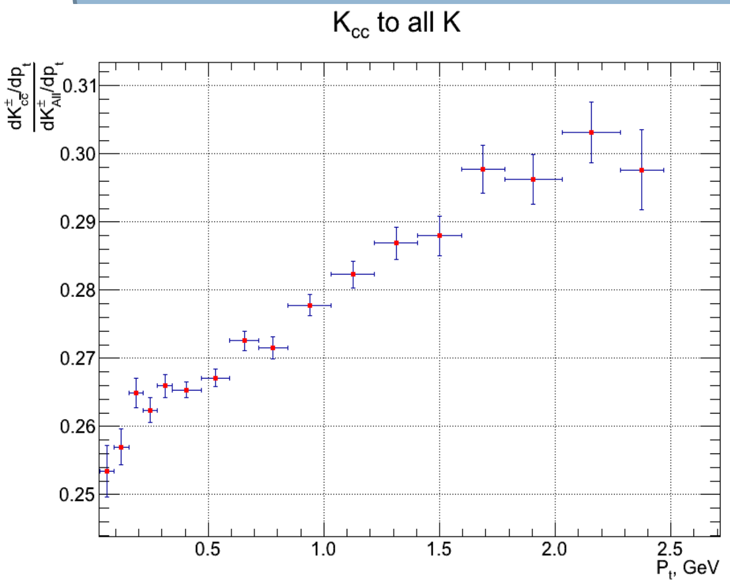
As the c-quark decays dominantly with K-meson production it is interesting to estimate the possible role of the increase of cc-production in K-meson pt spectra - > next slide

The role of cc-pairs production in kaon p_t spectra

$K^{\pm}$ - meson p_t spectra in pp collisions at 7 TeV in all events (blue) and in events with c-quark (red)

Ratio of these spectra: (cc-events)/(all events)





PYTHIA 6 with "CSC" ATLAS tunes

The role of cc-pairs production in kaon p_t spectra

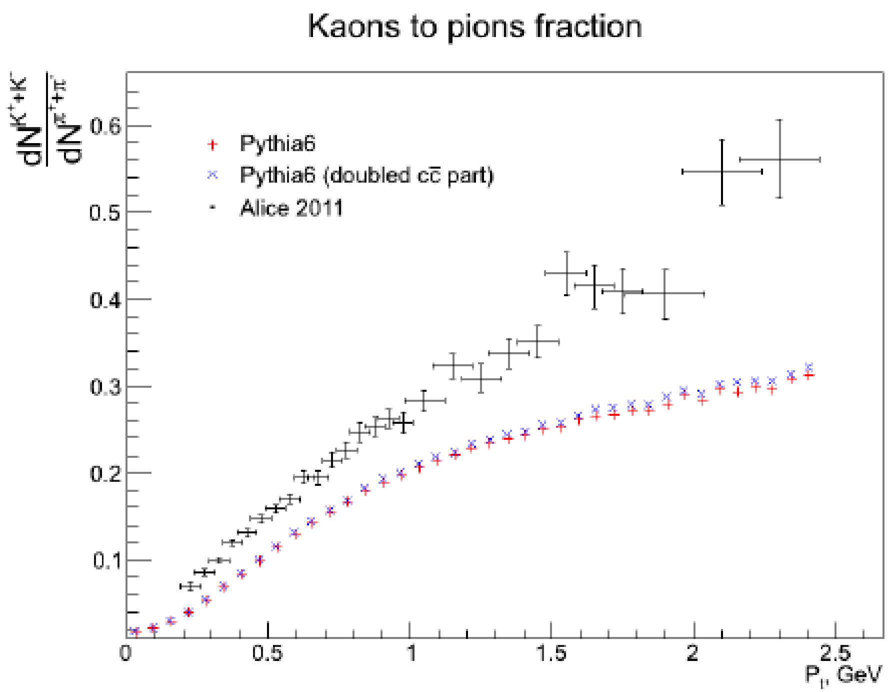


Fig.8. Ration of $K^{\pm}$-mesons to $\pi^{\pm}$-mesons in dependence on pt from ALICE experiment [18] for pp collisions at center-of-mass energy 0.9 TeV in comparison with simulation results with PYTHIA "CSC" tunes and with two times increased cross section of c-quark production.

Multiplying cc-pairs production in PYTHIA does not improve agreement with $K^{\pm}/\pi^{\pm}$, measured by ALICE

Pt spectra for $K^{\pm}$ can be checked by comparison with K0s spectra

ALICE & CMS data

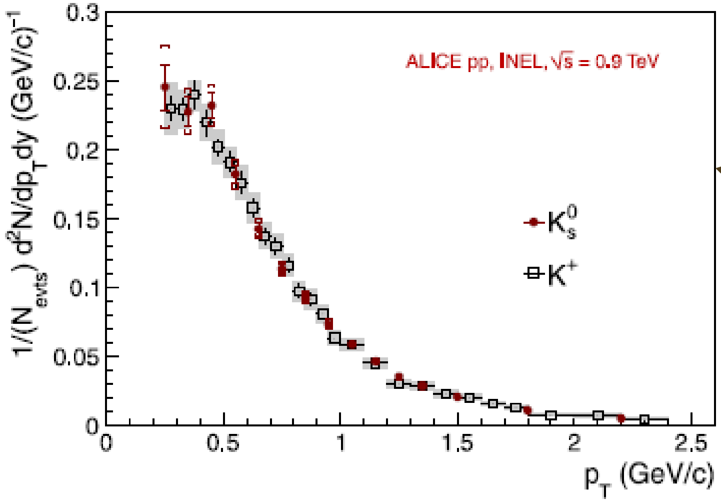
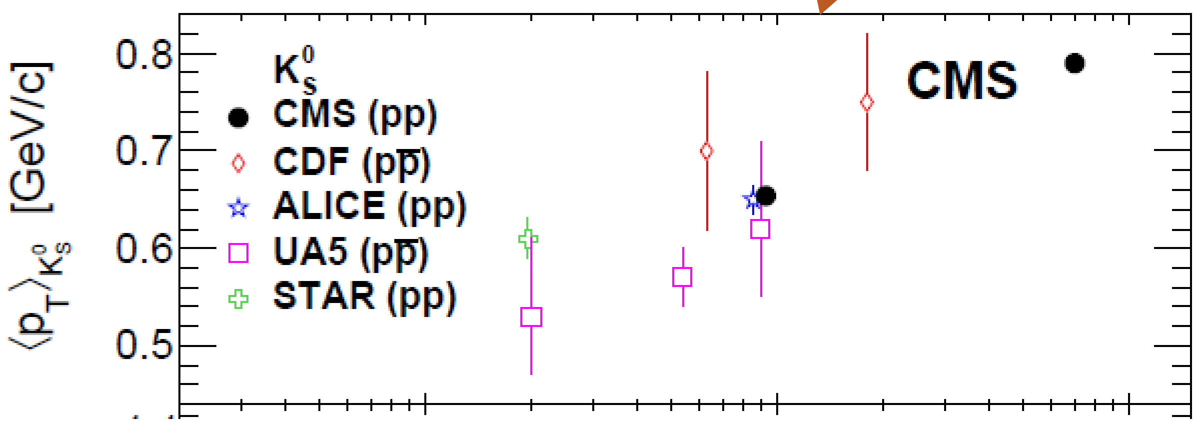


Fig. 13 Comparison of the corrected yields as a function of p_T for K^0_S (*circle*) and charged kaons (K^+) (*open squares*), identified via energy loss in the TPC and ITS, and via time of flight in the TOF. The points

K+ and K0s spectra are similar, but not in logarithmic scale, so not for large p_T

$\langle p_T \rangle$ for K^0_s in ALICE and CMS are similar for pp collisions at 0.9 TeV



ALICE & CMS data: slopes of p_t spectra for Kaons

ALICE 0.9 TeV

Table 5 Results of the Lévy fits to combined positive and negative spectra. See text and the caption of Table 4 for details on the systematic errors

Particle	dN/dy	C (GeV)	n	$\langle p_t \rangle$ (GeV/c)	χ^2/ndf
$\pi^+ + \pi^-$	$2.977 \pm 0.007 \pm 0.15$	$0.126 \pm 0.0005 \pm 0.001$	$7.82 \pm 0.06 \pm 0.1$	$0.404 \pm 0.001 \pm 0.02$	19.69/30
$K^+ + K^-$	$0.366 \pm 0.006 \pm 0.03$	$0.160 \pm 0.003 \pm 0.005$	$6.08 \pm 0.2 \pm 0.4$	$0.651 \pm 0.004 \pm 0.05$	8.46/24
$p + \bar{p}$	$0.162 \pm 0.003 \pm 0.012$	$0.184 \pm 0.005 \pm 0.007$	$7.5 \pm 0.7 \pm 0.9$	$0.764 \pm 0.005 \pm 0.07$	15.70/21

K^0_s — $7.79 \pm 0.07 \pm 0.26$ — CMS 0.9 TeV

Mesons	K^0_S	325 ± 4	117.6/14	168 ± 5	6.6 ± 0.3	10.8/13

There is a question to experiments!

ALICE 0.9 TeV

K-meson yields and strangeness suppression

- K/π ratio depends on strangeness suppression factor λ
- The λ value is measured and calculated by different methods
- The possibility of λ increase was demonstrated in

G.Boequet et al. Phys.Lett.B 366, 447 (1996) [1]

A.Wroblewski, Acta Phys.Pol. B16 (1985) 379

- New Mc generators constructed to include the increase of λ with energy: Hai-Yan Long et al. Phys.Rev.C 84, 0349 (2011), arXiv:1103.2618v1 [hep-ph]
- We estimated factor λ from K/π ratio at y=0 and ration of integrated K and π multiplicities for IyI< 2 at the LHC

K/π ratio and strangeness suppression

[1] UA1 Collab., Phys. Lett. B366 (1996) 447

In terms of λ we can express the K/π ratio as:

$$\frac{2K^0_S}{\pi^\pm} = \frac{12\lambda + 3\lambda^2}{31 + 12\lambda + 3\lambda^2 + \gamma(\frac{16}{3} + 4\lambda + \frac{8}{3}\lambda^2)} \quad \text{where } \gamma = \frac{4+4\lambda+\lambda^2}{5+5\lambda+3\lambda^2+\lambda^3}$$

[1] V. V. Anisovich et al. Nucl. Phys. B55(1973)455
V. V. Anisovich et al. Phys. Lett. B52(1974)217.

$$K/\pi \text{ ratio } \left(\frac{2K^0_S}{\pi^\pm}\right)_{UA1} = 0.094 \pm 0.005\ (stat) \pm 0.004\ (syst)$$

$$\lambda_{UA1} = 0.29 \pm 0.02\ (stat) \pm 0.01\ (syst)$$

Extrapolating to the LHC center of mass energy of 14 TeV

$$f(\sqrt{s}) = a + b \cdot ln(\sqrt{s})$$ ($\sqrt{s}$ is in GeV units)

$$K/\pi \simeq 0.107 \pm 0.030 \text{ and } \lambda = 0.31 \pm 0.05$$

К/π estimation from ALICE, CMS and ATLAS data

- CMS Collab., V.Khachatryan et al. PRL 105, 022002 (2010)
- ALICE Collab., Eur. Phys. J. C (2011) 71: 1655
- CMS PAS QCD-10-007
- K.Aamodt et al., ALICE Collab., Eur. Phys. J. C (2011) 71: 1594
- ATLAS Collab., New J. Phys 13:053033, 2011

Our estimation К/π = 0.15±0.01 at 0.9 and 7 ТэВ from ALICE and CMS data

К/π = 0.12 and 0.15 at 0.9 and 7 ТэВ from ALICE and ATLAS data

K/π ratio energy dependence

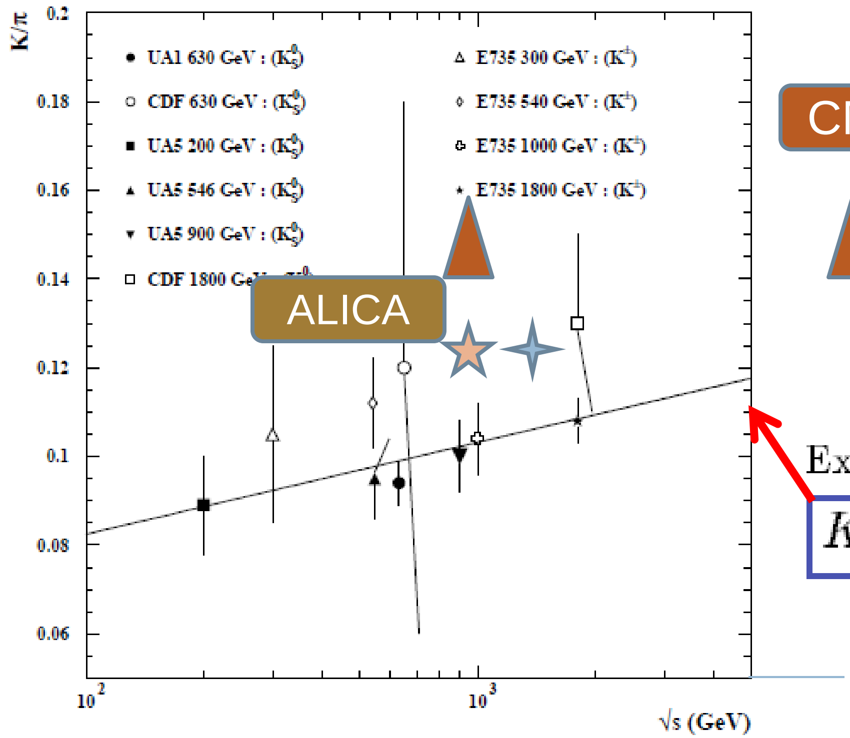


Figure 2: K/π ratio at different center of mass energies for: a) K^0_S : $K/\pi = 2K^0_S/\pi^+$, b) K^+ : $K/\pi = (K^+ + K^-)/\pi^+$. The line is a fit to UA1, UA5 [8], E735 [8] and CDF [11] data.

Our estimations with CMS, ALICE, ATLAS data

Extrapolating to the LHC center of mass energy of 14 TeV

$$K/\pi \simeq 0.107 \pm 0.030 \text{ and } \lambda = 0.31 \pm 0.05$$

Does it mean decrease of strangeness suppression for higher energy?

K/π ratio increases with increase of collision energy

Strangeness suppression energy evolution

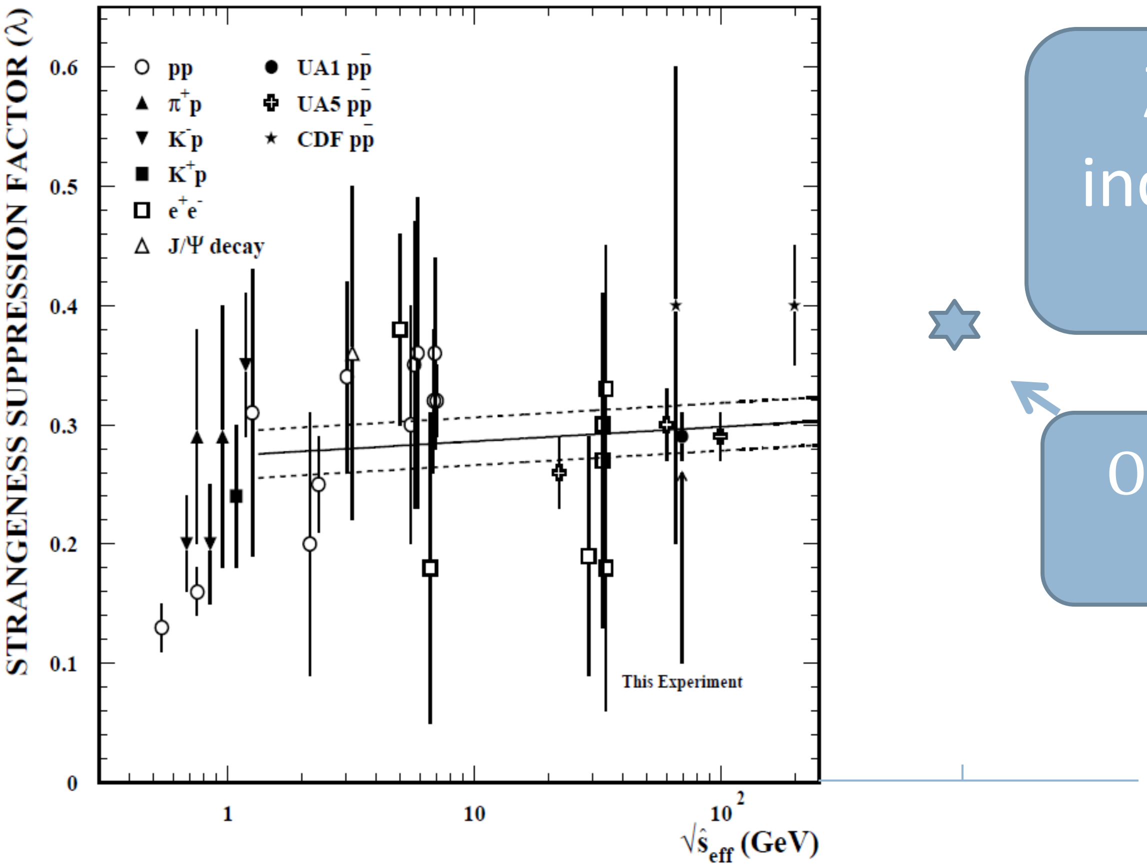


Figure 3: The compilation of the measurements of the strangeness suppression factor as a function of $(\hat{s}_{eff})^{\frac{1}{2}}$ [9, 10, 11]. The solid line is a fit to the data above $(\hat{s}_{eff})^{\frac{1}{2}} = 1.0\ GeV$.

λ has tendency to increase with energy of collisions

Our estimation for 7 ТэВ
Λ = 0.39

ATLAS estimation of λ at 7 TeV from D-mesons measurements (ATL-CONF-2011-017)

The strangeness-suppression factor was calculated as the ratio of the $\sigma_{cc}^{tot}(D_s^{\pm})$ to the sum of $\sigma_{cc}^{tot}(D^{*\pm})$ and that part of $\sigma_{cc}^{tot}(D^{\pm})$ which does not originate from $D^{*\pm}$ decays:

$$\gamma_{s/d} = \frac{\sigma_{cc}^{tot}(D_s^{\pm})}{\sigma_{cc}^{tot}(D^{*\pm}) + \sigma_{cc}^{tot}(D^{\pm}) - \sigma_{cc}^{tot}(D^{*\pm}) \cdot (1 - \mathscr{B}_{D^{*+}\to D^0\pi^+})} = \frac{\sigma_{cc}^{tot}(D_s^{\pm})}{\sigma_{cc}^{tot}(D^{\pm}) + \sigma_{cc}^{tot}(D^{*\pm}) \cdot \mathscr{B}_{D^{*+}\to D^0\pi^+}},$$

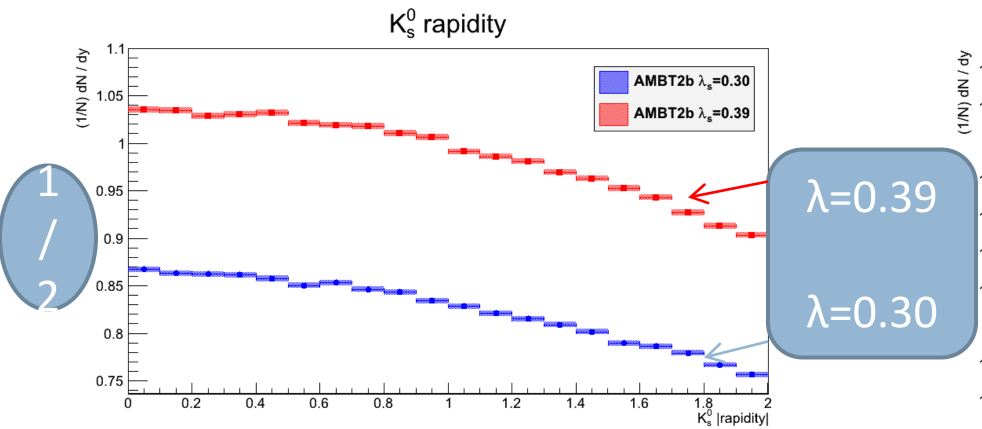
$$\gamma_{s/d} = 0.35 \pm 0.07(\text{stat.})^{+0.03}_{-0.04}(\text{syst.}) \pm 0.03(\text{br.})^{+0.04}_{-0.03}(\text{extr.})$$

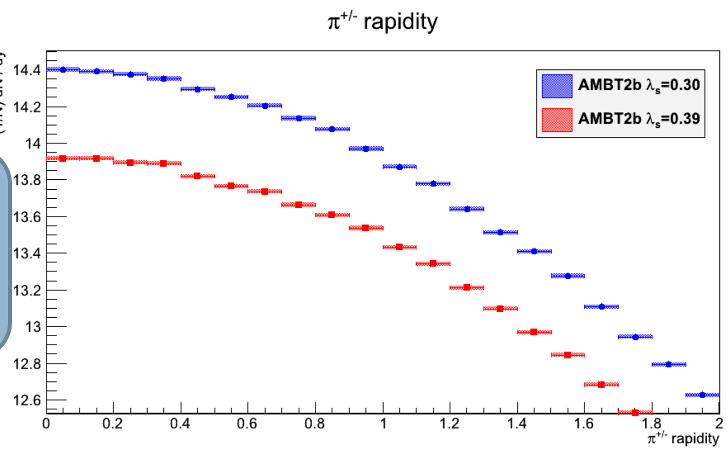
It is not contradict to the larger λ at the LHC

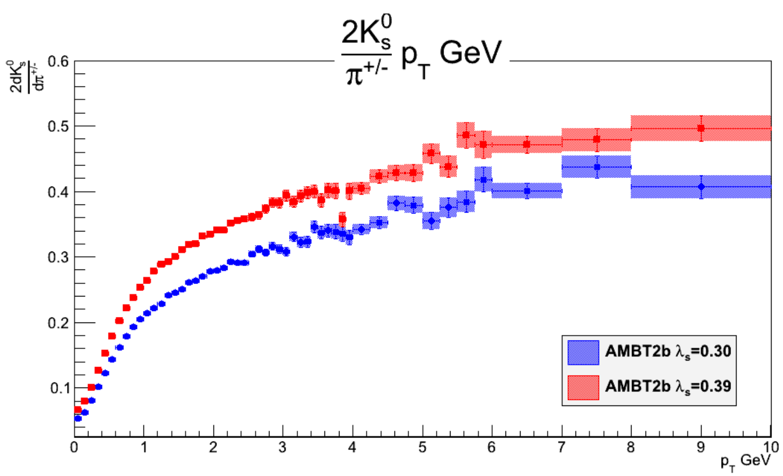
New PYTHIA tunes for soft QCD

- CMS – Z1 tune   R.Field Talk “Strange particles “
- ATLAS – AMBT2 tune   ATL – PUB – 2011-009

PYTHIA 6.4 with AMBT2B simulation



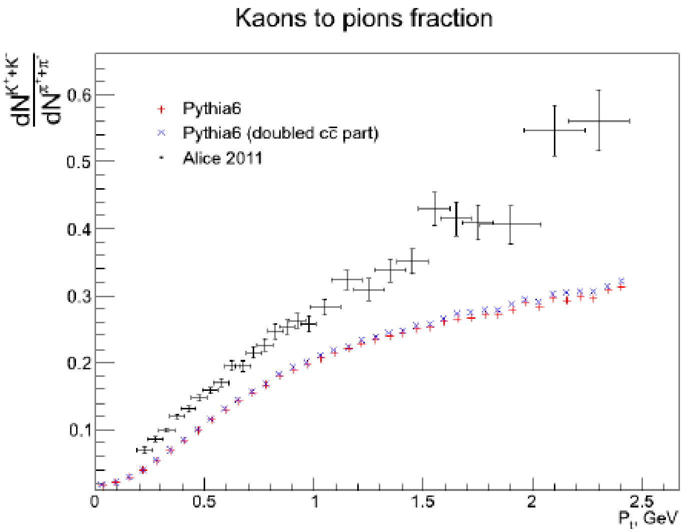




Meson yields depends on λ

for pp collisions at 7 TeV

PYTHIA 6.4 with AMBT2B simulation



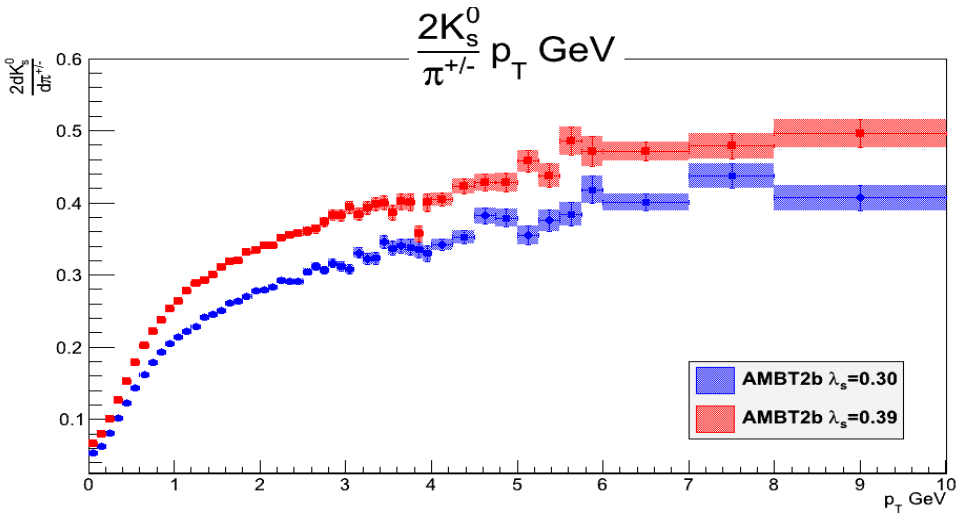


Fig.8. Ration of $K^{\pm}$-mesons to $\pi^{\pm}$-mesons in dependence on pt from ALICE experiment [18] for pp collisions at center-of-mass energy 0.9 TeV in comparison with simulation results with PYTHIA "CSC' tunes and with two times increased cross section of c-quark production.

K/π ratio dependence on p_T is not as measured by ALICE again

PYTHIA 6.4 with AMBT2B simulations

for pp collisions at 7 TeV

	Λs =0.30 <N> for lyl < 2	Λs=0.39 <N> for IyI < 2	Λs=0.20 <N> for IyI < 2
π±	27.54	26.64	29.10
K±	3.36	4.04	2.56
K0s	1.65	1.98	1.26
2K0s/π±	0.122	0.15	0.09

CMS <K0s> = 1.333 ± 0.002stat. ± 0.112 syst. For IyI < 2

New ATLAS tunes for PYTHIA 6.4 can reproduce <K0s> measured by CMS and K/π ratio with standard λ <~ 0.3

Parameterization of CMS data

Particle	$\sqrt{s}$ (TeV)	C	T (MeV)	n	χ^2/NDF
K^0_S	0.9	$0.776 \pm 0.002 \pm 0.042$	$187 \pm 1 \pm 4$	$7.79 \pm 0.07 \pm 0.26$	19/21
Λ	0.9	$0.395 \pm 0.002 \pm 0.041$	$216 \pm 2 \pm 11$	$9.3 \pm 0.2 \pm 1.1$	32/21
Ξ^-	0.9	$0.043 \pm 0.001 \pm 0.006$	$250 \pm 8 \pm 48$	$10.1 \pm 0.9 \pm 4.7$	19/19
K^0_S	7	$1.329 \pm 0.001 \pm 0.062$	$220 \pm 1 \pm 3$	$6.87 \pm 0.02 \pm 0.09$	50/21
Λ	7	$0.696 \pm 0.002 \pm 0.058$	$292 \pm 1 \pm 10$	$9.3 \pm 0.1 \pm 0.5$	128/21
Ξ^-	7	$0.080 \pm 0.001 \pm 0.012$	$361 \pm 7 \pm 72$	$11.2 \pm 0.7 \pm 4.9$	21/19

Table 2. Results of fitting the Tsallis function to the data. In the C, T, and n columns, the first uncertainty is statistical and the second is systematic. The parameter values and χ^2/NDF are obtained from fits to the data with only the

$$\frac{1}{N}\frac{dN}{dp_T} = C p_T \left[1 + \frac{\sqrt{p_T^2 + m^2} - m}{nT}\right]^{-n}$$

	T, GeV	n
$\pi^{\pm}$	$1.42\times10^{-1}\pm5.05\times10^{-5}$	$6.76\pm4.58\times10^{-3}$
$K^{\pm}$	$1.52\times10^{-1}\pm1.55\times10^{-4}$	$4.86\pm5.92\times10^{-3}$
K^0_s	$1.54\times10^{-1}\pm2.23\times10^{-4}$	$4.90\pm8.56\times10^{-3}$
Λ	$1.54\times10^{-1}\pm5.77\times10^{-4}$	$4.07\pm 1.39\times10^{-2}$

Таблица 2: Tsallis fit parameters for AMBT2b with $\lambda_s = 0.30$

0-10 GeV/c

For Pt in range 1-10 GeV/c n= 5.51 for pions and 5.03 for kaons – not a real difference

Conclusions

- Increase of the cross section of charm production does not improve the simulated K/π ratio dependence on pt
- There are some discrepancy in experimental data for strange particles production in pp collisions at 0.9 TeV
- Experimental data for integral K/π ratio demonstrate its increase in pp collisions at the LHC energies, or smaller strangeness suppression (following to analysis from previous energy range)
- New tunes for PYTHIA 6.4 can reproduce main features of strange particle without special increase of λ
- New experimental data for identified hadrons are necessary and the analysis of strangeness suppression should be continued

Parameterization of ALICE data

 Eur. Phys. J. C (2011) 71: 1594

Table 5 Summary of the parameters extracted from the fits to the measured transverse momenta spectra using p_T exponential (1) and Lévy (2) functional forms and including point-to-point systematic uncertainties

Particles		p_T exponential (1)		Lévy (2)		
		T (MeV)	χ^2/NDF	T (MeV)	n	χ^2/NDF
Mesons	K^0_S	325 ± 4	117.6/14	168 ± 5	6.6 ± 0.3	10.8/13
	ϕ	438 ± 31	1.3/2	164 ± 91	4.2 ± 2.5	0.6/1

$$\frac{d^2N}{dy\,dp_T} = A \times p_T \times e^{-\frac{p_T}{T}} \quad (1)$$

$$\frac{d^2N}{dy\,dp_T} = \frac{(n-1)(n-2)}{nT[nT+m(n-2)]} \times \frac{dN}{dy} \times p_T \times \left(1 + \frac{m_T - m}{nT}\right)^{-n} \quad (2)$$

where $m_T = \sqrt{m^2 + p_T^2}$. The p_T exponential has two parameters: the normalization A and the inverse slope parameter T. The Lévy function [Eq. (2)], already used at lower

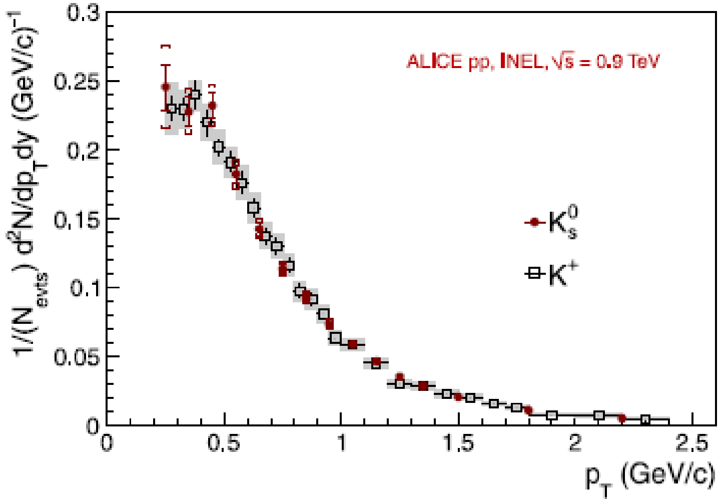


Fig. 13 Comparison of the corrected yields as a function of p_T for K^0_S (*circle*) and charged kaons (K^+) (*open squares*), identified via energy loss in the TPC and ITS, and via time of flight in the TOF. The points

Parameterization of ALICE data

Table 5 Results of the Lévy fits to combined positive and negative spectra. See text and the caption of Table 4 for details on the systematic errors

Particle	dN/dy	C (GeV)	n	$\langle p_t \rangle$ (GeV/c)	χ^2/ndf
$\pi^+ + \pi^-$	$2.977 \pm 0.007 \pm 0.15$	$0.126 \pm 0.0005 \pm 0.001$	$7.82 \pm 0.06 \pm 0.1$	$0.404 \pm 0.001 \pm 0.02$	19.69/30
$K^+ + K^-$	$0.366 \pm 0.006 \pm 0.03$	$0.160 \pm 0.003 \pm 0.005$	$6.08 \pm 0.2 \pm 0.4$	$0.651 \pm 0.004 \pm 0.05$	8.46/24
$p + \overline{p}$	$0.162 \pm 0.003 \pm 0.012$	$0.184 \pm 0.005 \pm 0.007$	$7.5 \pm 0.7 \pm 0.9$	$0.764 \pm 0.005 \pm 0.07$	15.70/21

The combined spectra shown in Fig. 14 are fitted with the Lévy (or Tsallis) function (see e.g. [26, 27])

$$\frac{d^2N}{dp_t dy} = p_t \frac{dN}{dy} \frac{(n-1)(n-2)}{nC(nC + m_0(n-2))} \left(1 + \frac{m_t - m_0}{nC}\right)^{-n} \quad (2)$$

with the fit parameters C, n and the yield dN/dy. This function gives a good description of the spectra and has been

$$\frac{1}{N}\frac{dN}{dp_T} = Cp_T \left[1 + \frac{\sqrt{p_T^2 + m^2} - m}{nT}\right]^{-n}$$

CMS <pt>

Table 3: Average p_T in units of MeV/c obtained from the appropriate dN/dp_T distribution as described in the text. Results from PYTHIA 6 with tune D6T are also given. In each data column, the first uncertainty is statistical and the second is systematic.

Particle	$\sqrt{s} = 0.9$ TeV Data	$\sqrt{s} = 0.9$ TeV MC (D6T)	$\sqrt{s} = 7$ TeV Data	$\sqrt{s} = 7$ TeV MC (D6T)
K^0_S	$654 \pm 1 \pm 8$	580	$790 \pm 1 \pm 9$	757
Λ	$837 \pm 6 \pm 40$	750	$1037 \pm 5 \pm 63$	1071
$\Xi-$	$971 \pm 14 \pm 43$	831	$1236 \pm 11 \pm 72$	1243

ALICE <pt>

Eur. Phys. J. C (2011) 71: 1594 Page 19 of 24

Table 6 Rapidity and p_T ranges, $\langle p_T \rangle$, corrected yields and extrapolated fraction at low p_T using the Lévy function (2)

Particles		$\|y\|$	p_T range (GeV/c)	$\langle p_T \rangle$ (GeV/c)	dN/dy (INEL)	Extrapolation (%)
Mesons	K^0_S	<0.75	[0.2–3.0]	$0.65 \pm 0.01 \pm 0.01$	$0.184 \pm 0.002 \pm 0.006$	$12 \pm 0.4 \pm 0.5$
	ϕ	<0.60	[0.7–3.0]	$1.00 \pm 0.14 \pm 0.20$	$0.021 \pm 0.004 \pm 0.003$	$48 \pm 18 \pm 7$
Baryons	Λ	<0.75	[0.6–3.5]	$0.86 \pm 0.01 \pm 0.01$	$0.048 \pm 0.001 \pm 0.004$	$36 \pm 2 \pm 4$
	$\overline{\Lambda}$	<0.75	[0.6–3.5]	$0.84 \pm 0.02 \pm 0.02$	$0.047 \pm 0.002 \pm 0.005$	$39 \pm 3 \pm 4$
	$\Xi^- + \overline{\Xi}^+$	<0.8	[0.6–3.0]	$0.95 \pm 0.14 \pm 0.03$	$0.0101 \pm 0.0020 \pm 0.0009$	$35 \pm 8 \pm 4$

ALICE & CMS data: slope of p_t spectra

ALICE 0.9 TeV

Table 5 Results of the Lévy fits to combined positive and negative spectra. See text and the caption of Table 4 for details on the systematic errors

Particle	dN/dy	C (GeV)	n	$\langle p_t \rangle$ (GeV/c)	χ^2/ndf
$\pi^+ + \pi^-$	$2.977 \pm 0.007 \pm 0.15$	$0.126 \pm 0.0005 \pm 0.001$	$7.82 \pm 0.06 \pm 0.1$	$0.404 \pm 0.001 \pm 0.02$	19.69/30
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K^0s — $7.79 \pm 0.07 \pm 0.26$ — CMS 0.9 TeV

Mesons	K^0_S	325 ± 4	117.6/14	168 ± 5	6.6 ± 0.3	10.8/13

ALICE 0.9 TeV

Conclusions abstract

- 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 predictions for strange particle spectra are calculated and presented with new ATLAS tunes and with different parameters of strangeness suppression.