Correlations with strange particles in a multi-pomeron exchange model

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in collaboration with
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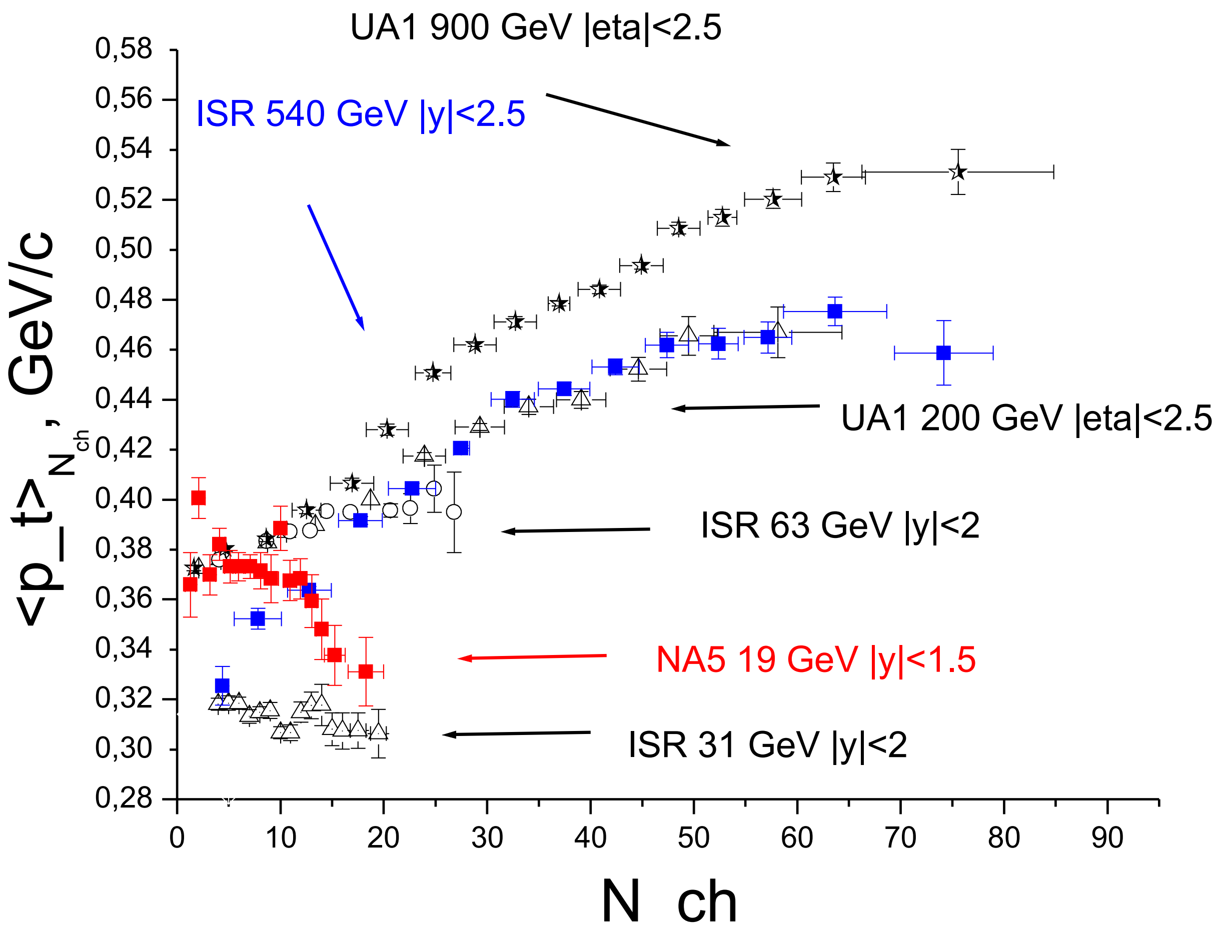
Experimentally Observed p_t-N_{ch} Correlations



summary plot - Armesto N., Derkach D., Feofilov G., Phys. Atom. Nucl. 71, 2087 (2008)

Regge-Gribov multipomeron approach

Probability of production of *n* pomerons

$$w_n = \sigma_n / \sum_{n'} \sigma_{n'},$$

where σ_n – cross section of n cut-pomeron exchange:

$$\sigma_n = \frac{\sigma_{\mathrm{P}}}{nz} \left(1 - e^{-z} \sum_{l=0}^{n-1} \frac{z^l}{l!} \right)$$

Each cut-pomeron corresponds to pair of strings

Regge-Gribov multipomeron approach

$$z = \frac{2C\gamma s^{\Delta}}{R_0^2 + \alpha' \ln(s)}$$

Numerical values of parameters used [1]:

$$\Delta = 0,139\,, \quad \alpha^{'} = 0,21 \text{ GeV}^{-2}\,,$$

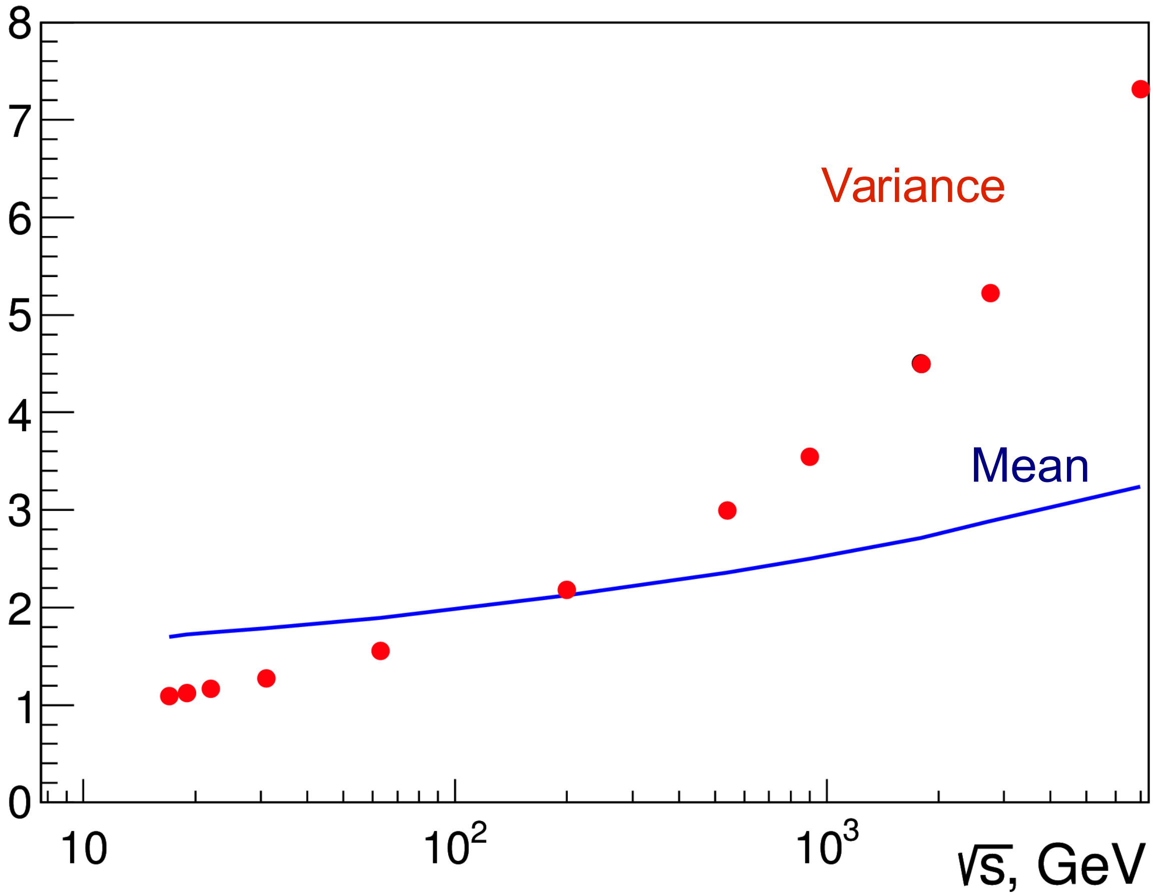
$$\gamma = 1,77 \text{ GeV}^{-2}\,, \quad R_0^2 = 3,18 \text{ GeV}^{-2}\,,$$

$$C = 1,5\,.$$

[1] Lakomov I. A., Vechernin V. V. , PoS (Baldin ISHEPP XXI) 072 (2012)

Regge-Gribov multipomeron approach

Mean and variance of the number of pomerons:



E. Bodnya, D. Derkach, G. Feofilov, V. Kovalenko, and A. Puchkov, PoS (QFTHEP 2013) 060, arXiv:1310.1627 [hep-ph].

Description of multiplicity

Probability for n strings to give N_{ch} particles:

$$P(n, N_{ch}) = \exp(-2nk\delta)\frac{(2nk\delta)^{N_{ch}}}{N_{ch}!},$$

where k – is mean multiplicity per rapidity unit from one pomeron;
δ – acceptance i.e. width of (pseudo-)rapidity interval

Probability to have N_{ch} particles in a given event:

$$\mathscr{P}(N_{ch}) = \sum_{n=1}^{\infty} w_n P(n, N_{ch})$$

Mean charged multiplicity:

$$\langle N_{ch}\rangle(s) = \sum_{N_{ch}=0}^{\infty} N_{ch}\mathscr{P}(N_{ch}) = 2\langle n\rangle \cdot k \cdot \delta$$

Description of transverse momentum

Schwinger mechanism of particles production from one string [2]:

$$\left.\frac{dN_{\text{ch}}}{dy\,d^2p_T}\right|_{y=0} \sim \exp\left(\frac{-\pi\left(p_t^2+m^2\right)}{t}\right)$$

p_t-N_{ch} correlation function in the model is calculated as:

$$\langle p_t\rangle_{N_{ch}}(s) = \frac{\int\limits_0^\infty \rho(N_{ch},p_t)p_t^2\,dp_t}{\int\limits_0^\infty \rho(N_{ch},p_t)p_t\,dp_t}$$

[2] Schwinger J. Phys. Rev. 1951. Vol. 82, P. 664 – 679

Description of transverse momentum

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[2] Schwinger J. Phys. Rev. 1951. Vol. 82, P. 664 – 679

Distribution of N_{ch} and particles over p_t

$$\rho(N_{ch}, p_t) =$$

Probability distribution

$$= \frac{C_w}{z} \sum_{n=1}^{\infty} \frac{1}{n} \left(1 - \exp(-z) \sum_{l=0}^{n-1} \frac{z^l}{l!} \right) \times$$

Probability of production of n pomerons

$$\times \exp(-2nk\delta) \frac{(2nk\delta)^{N_{ch}}}{N_{ch}!} \times$$

Poisson distribution of the charged particles from $2n$ string

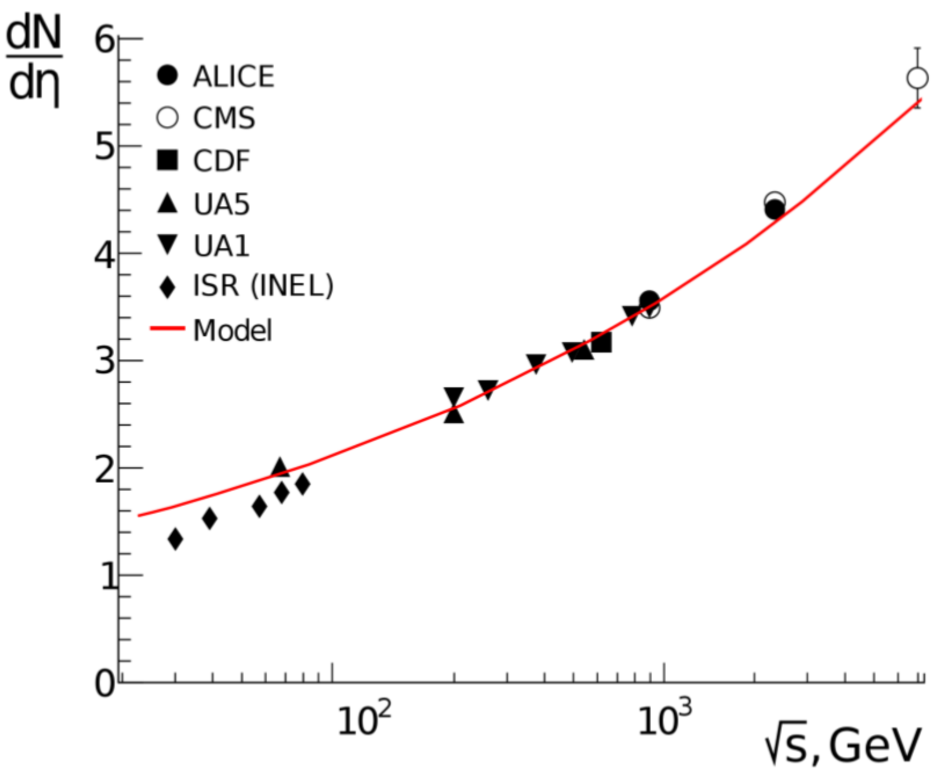
$$\times \frac{1}{n^{\beta} t} \exp\left(-\frac{\pi p_t^2}{n^{\beta} t} \right)$$

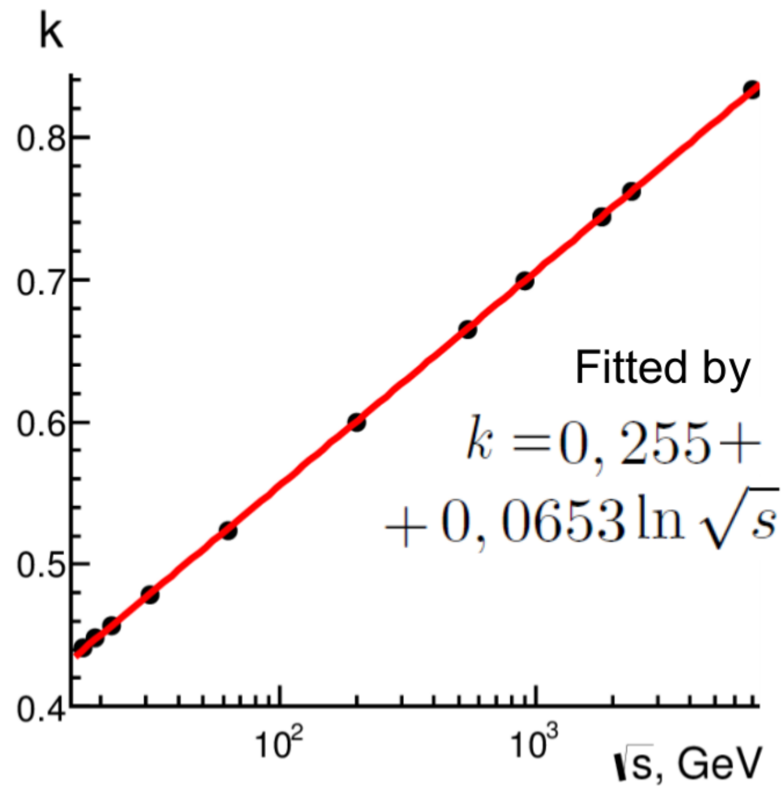
Modified Schwinger mechanism

Determination of the parameter k

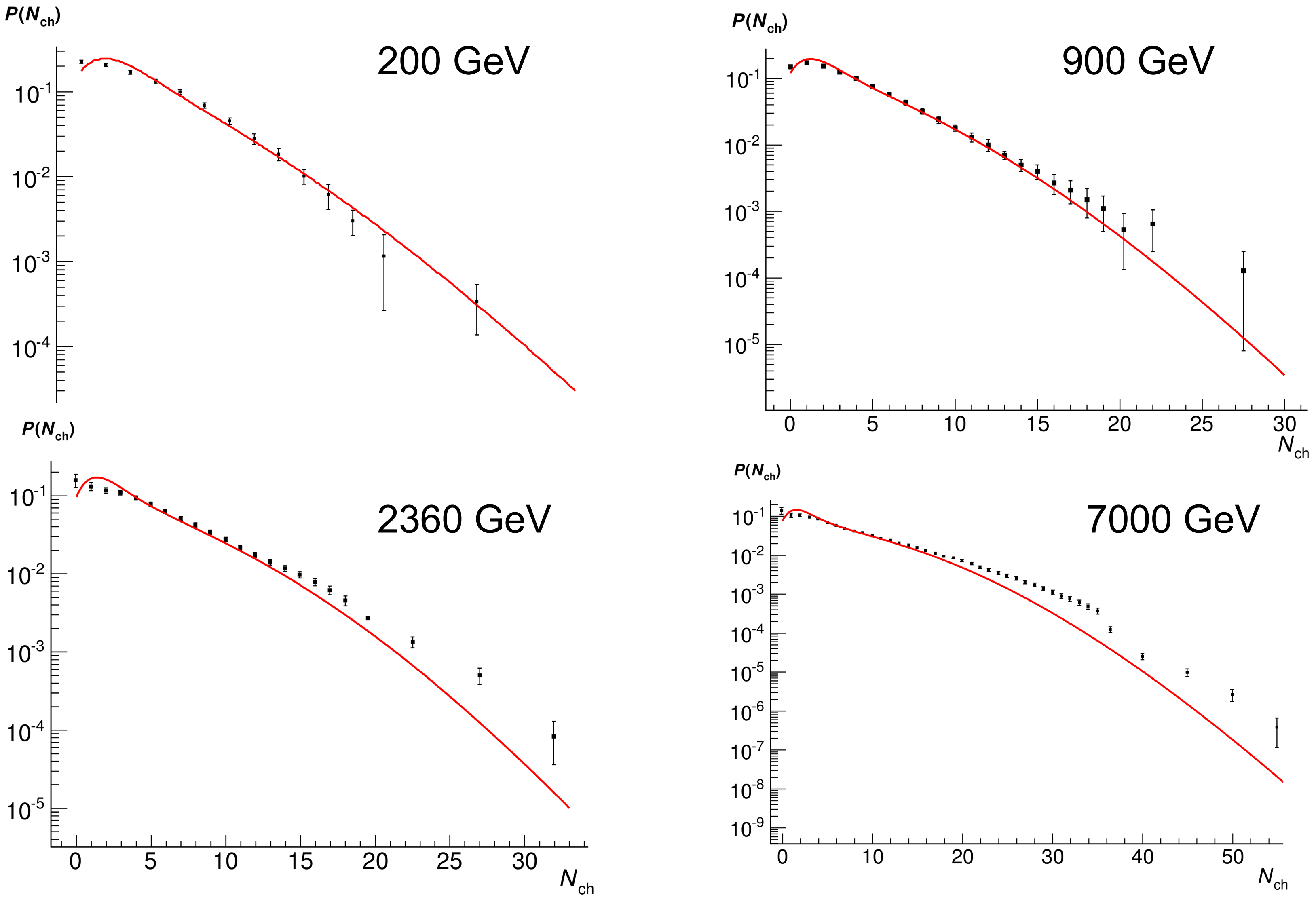
from experimental data on charged multiplicity:

$$\langle N_{ch}\rangle(s) = \sum_{N_{ch}=0}^{\infty} N_{ch}\mathscr{P}(N_{ch}) = 2\langle n\rangle \cdot k \cdot \delta$$





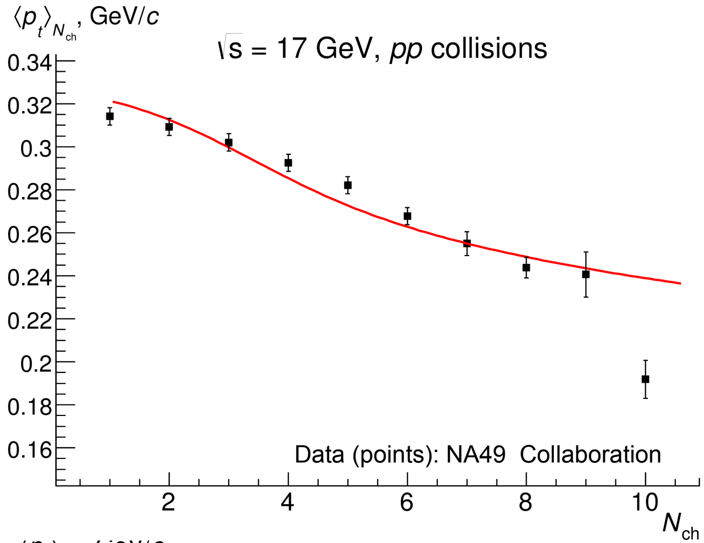
Distribution of N_{ch}

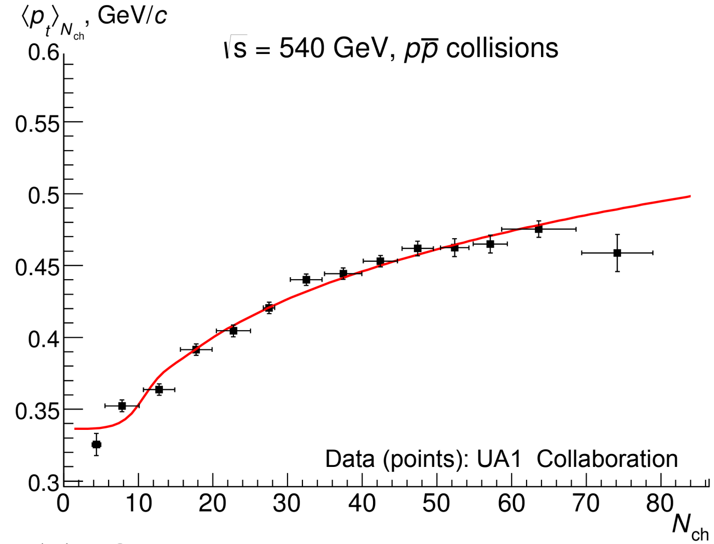


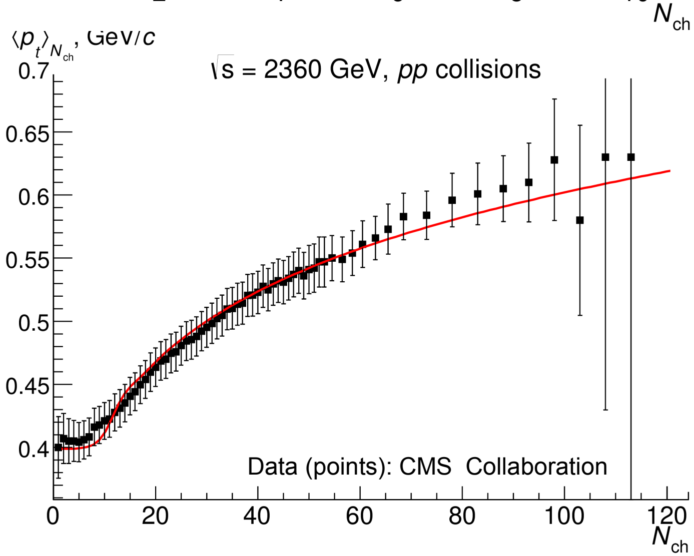
p_t-N_{ch} correlations

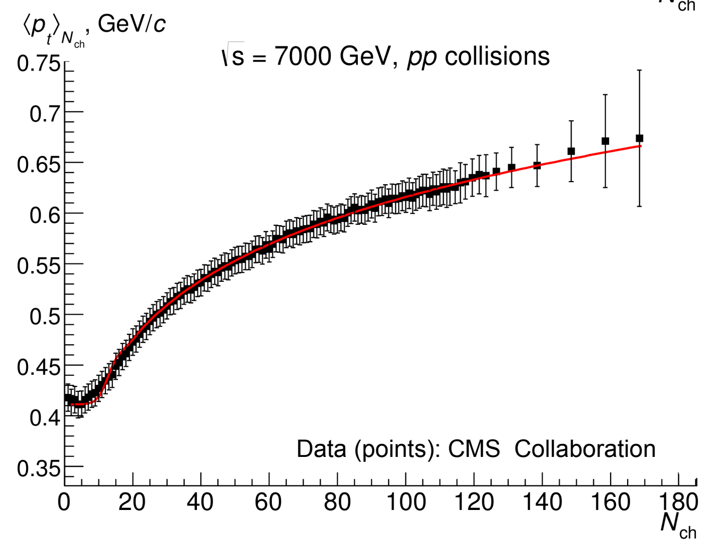
The data on p_t-N_{ch} correlations are analyzed in wide energy region: from 17 GeV to 7 TeV

Values of the parameters β and t are obtained. Examples of fitting:









pp, 17 GeV

pp, 19 GeV

pp, 22 GeV

pp, 31 GeV

pp, 63 GeV

$p\bar{p}$, 200 GeV

$p\bar{p}$, 540 GeV

$p\bar{p}$, 900 GeV

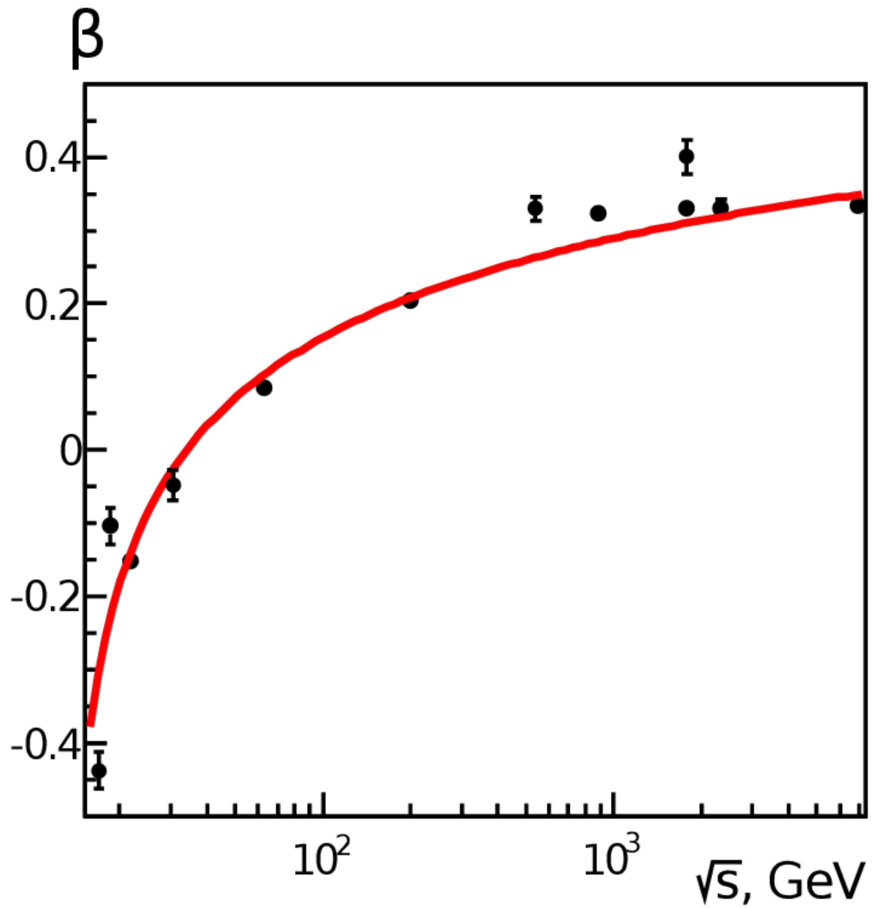
$p\bar{p}$, 1800 GeV

$p\bar{p}$, 1800 GeV

pp, 2360 GeV

pp, 7000 GeV

Dependence of the parameters β and t on collision energy



Fitted by

$$\beta = \beta_0 \left[1 - \left(\ln\sqrt{s} - \beta_2\right)^{-\beta_1}\right]$$

t = 0.566 GeV²

Particle differentiation

- Schwinger mechanism of particle production:

$$Y_\nu \sim \exp\left(\frac{\pi\left(p_t^2+m_\nu^2\right)}{n^\beta t}\right)$$

  - Naive approach: take only major particles: pions, kaons, protons
  - Better: include rho-meson: decays into pions: $\rho^0 \to \pi^+ + \pi^-$, $\rho^\pm \to \pi^\pm + \pi^0$
  - Best: take all light hadrons and correct for their cascade decays (feed down)

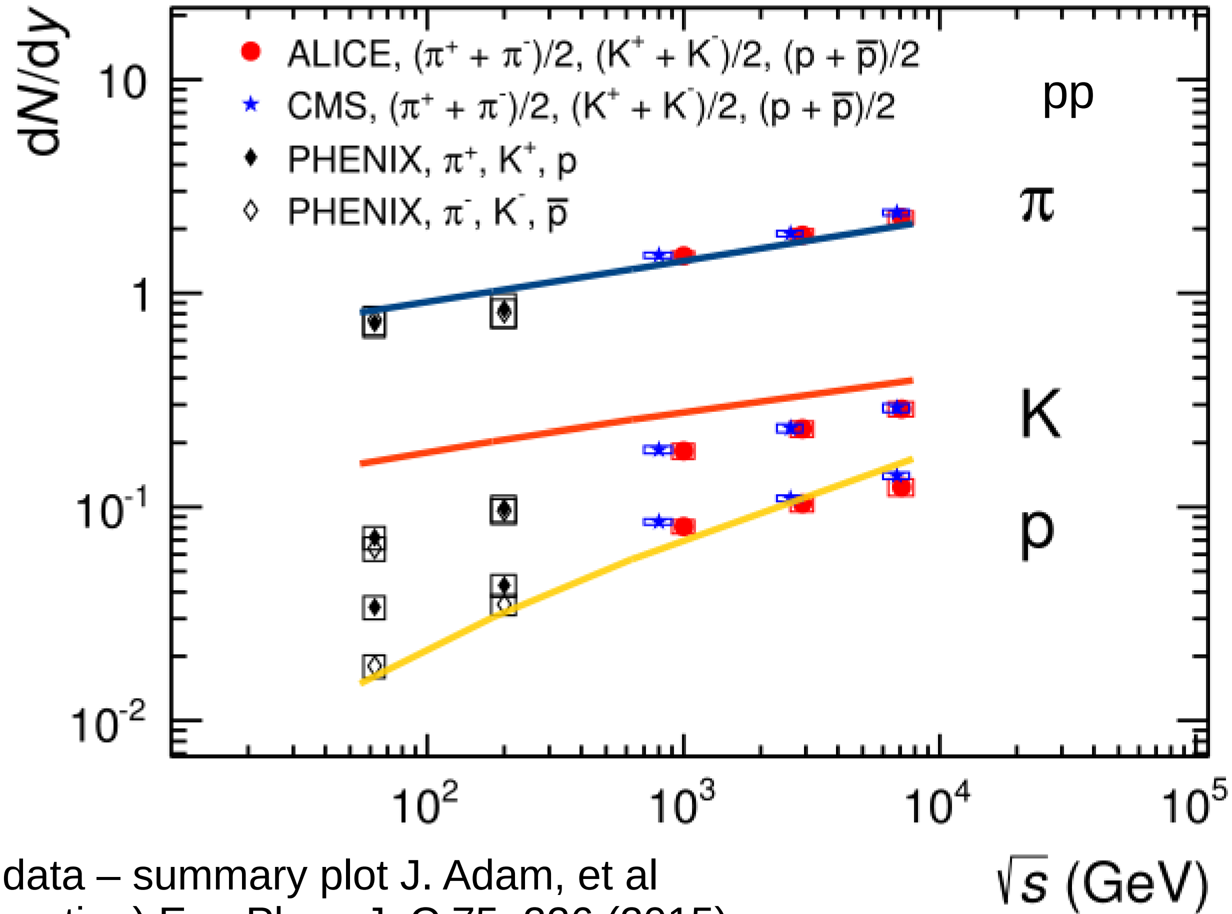
then $$Y_\nu \sim \sum_\mu M_{\mu\nu} \cdot \left(2 S_\mu + 1\right) \cdot \exp\left(\frac{\pi\left(p_t^2+m_\mu^2\right)}{n^\beta t}\right),$$

where S_μ – spin of particle type μ
$M_{\mu\nu}$ – effective branching ration matrix, i.e. the yield of particles from cascade decays of a particle μ

- The mass spectrum and the effective branching ration is extracted from Therminator 2 particle decayer (M. Chojnacki, et al, Comput. Phys. Commun. 183, 746 (2012), arXiv:1102.0273 [nucl-th]

Results:

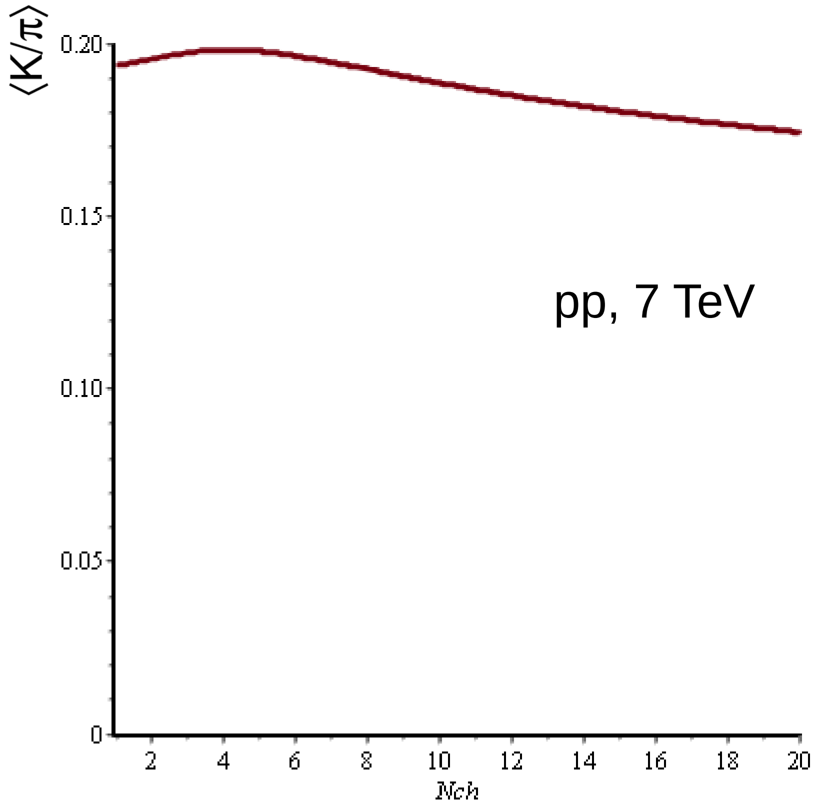
- Energy dependence of the charged proton, kaon and proton multiplicities



Experimental data – summary plot J. Adam, et al (ALICE collaboration) Eur. Phys. J. C 75, 226 (2015)

Results:

- Kaon over pion ratio as a function of multiplicity



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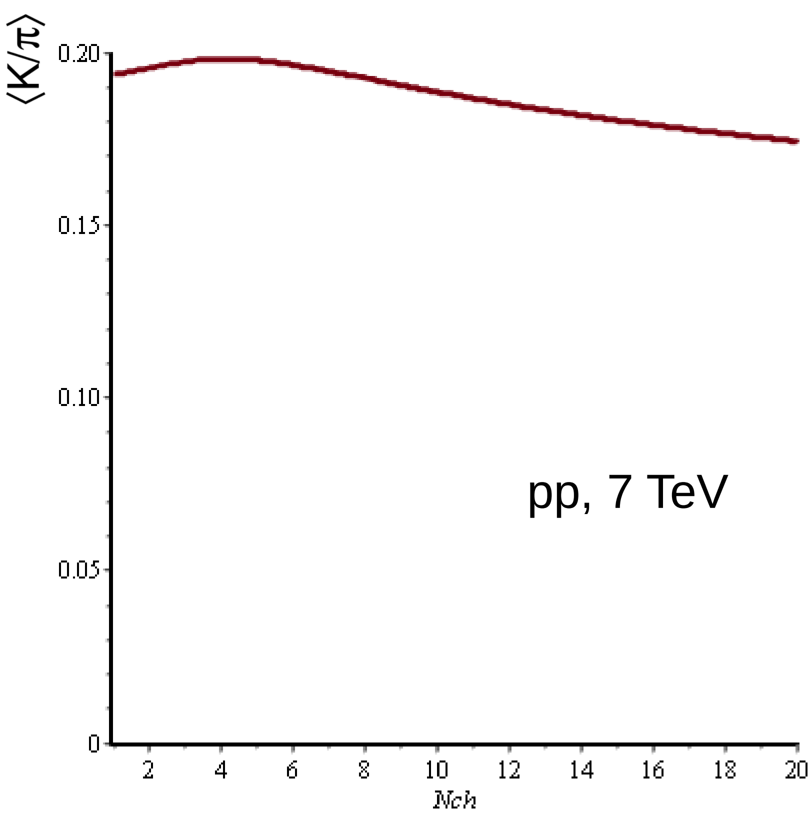

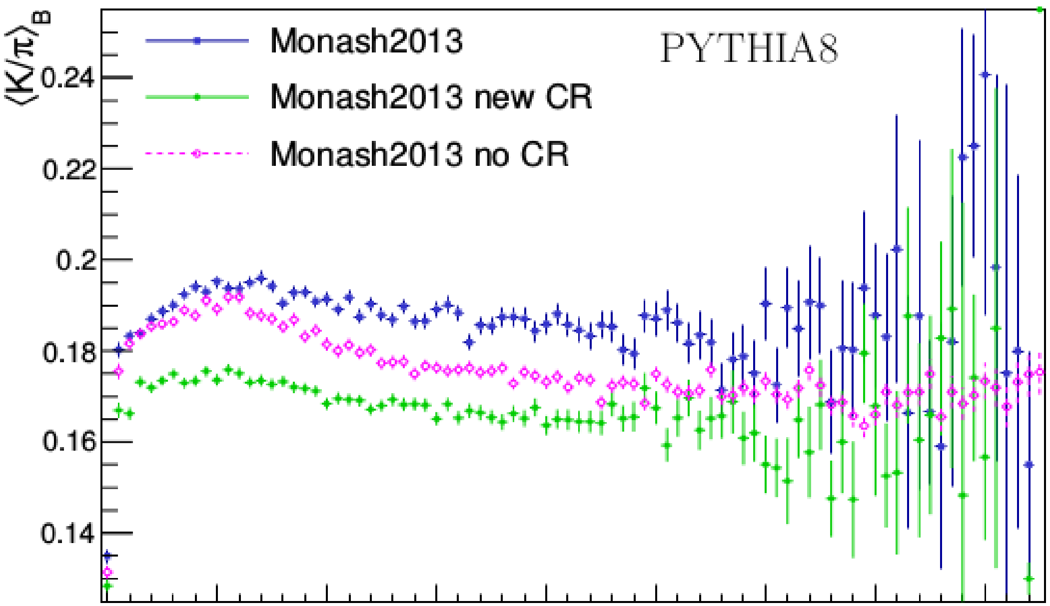

Igor Altsybeev, et al, J. Phys. Conf. Ser. 668, 012034 (2016), arXiv:1510.02080 [hep-ph] (supplementary)

Results:

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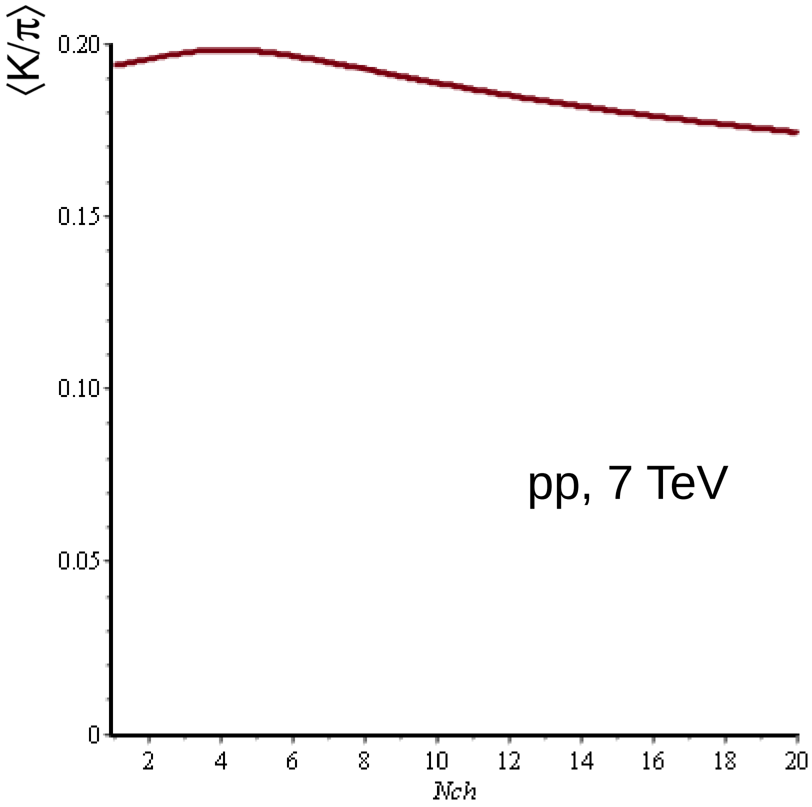
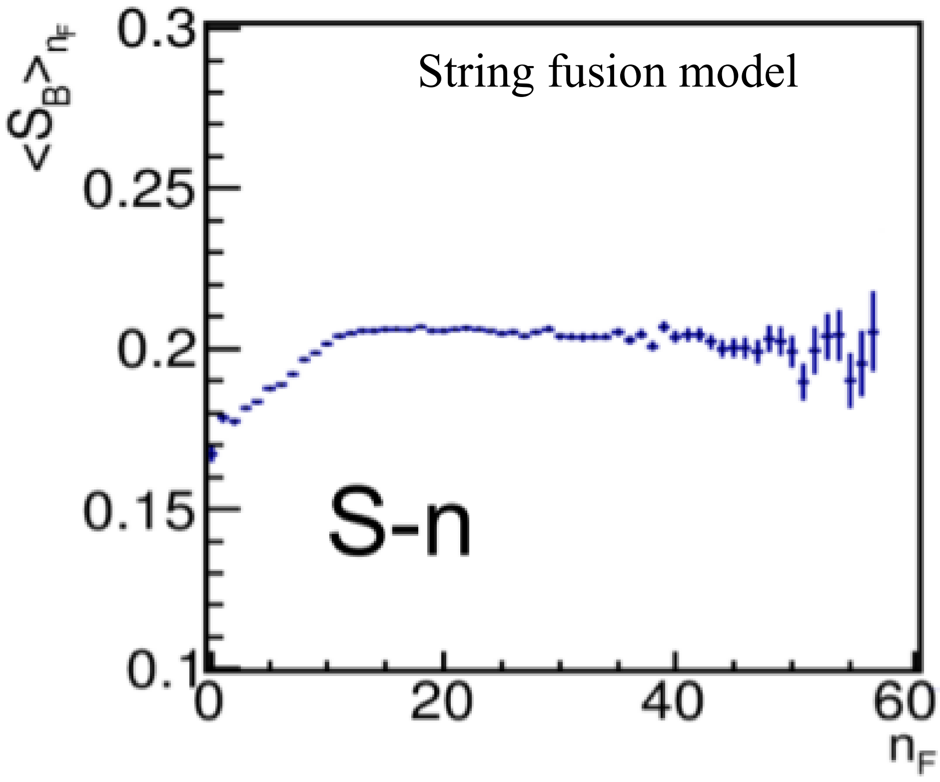
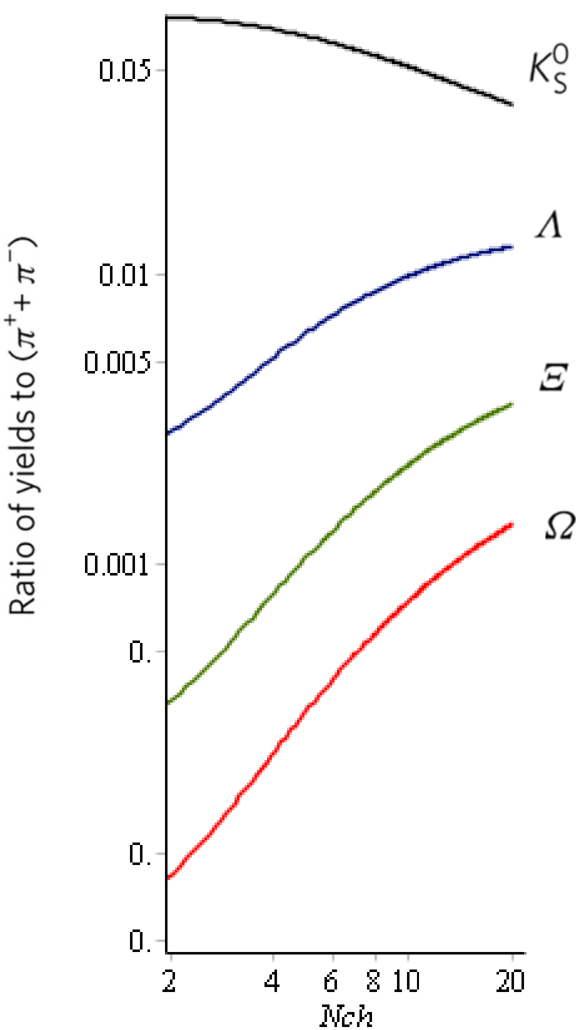
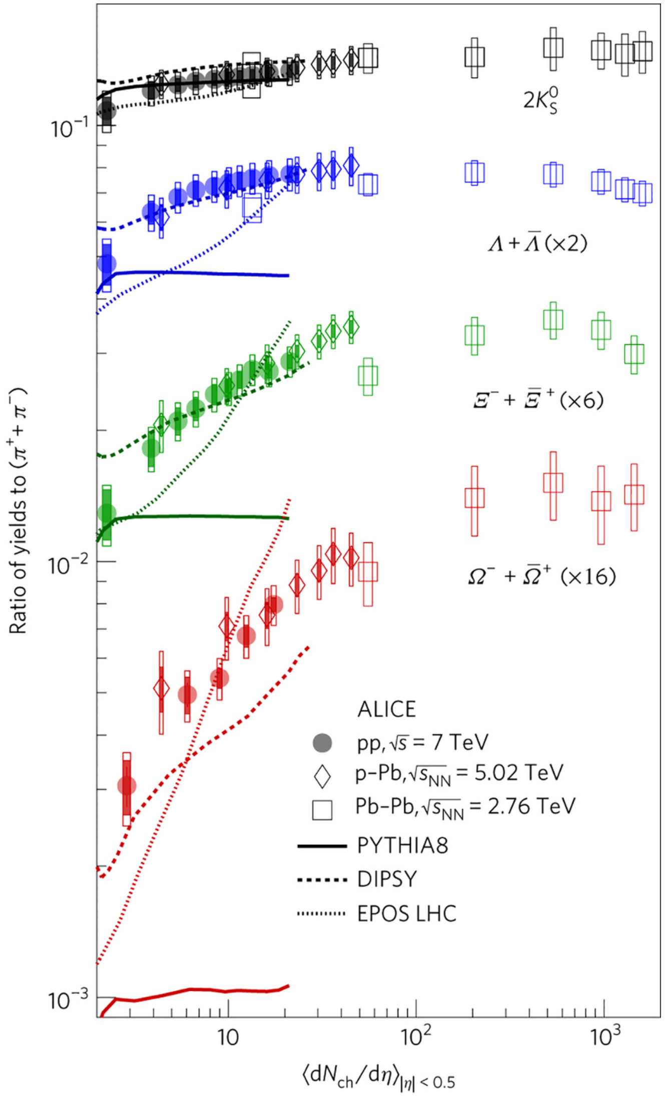




V. Kovalenko, et al, J. Phys. Conf. Ser. 66, 012065 (2016), arXiv:1509.06696 [hep-ph]

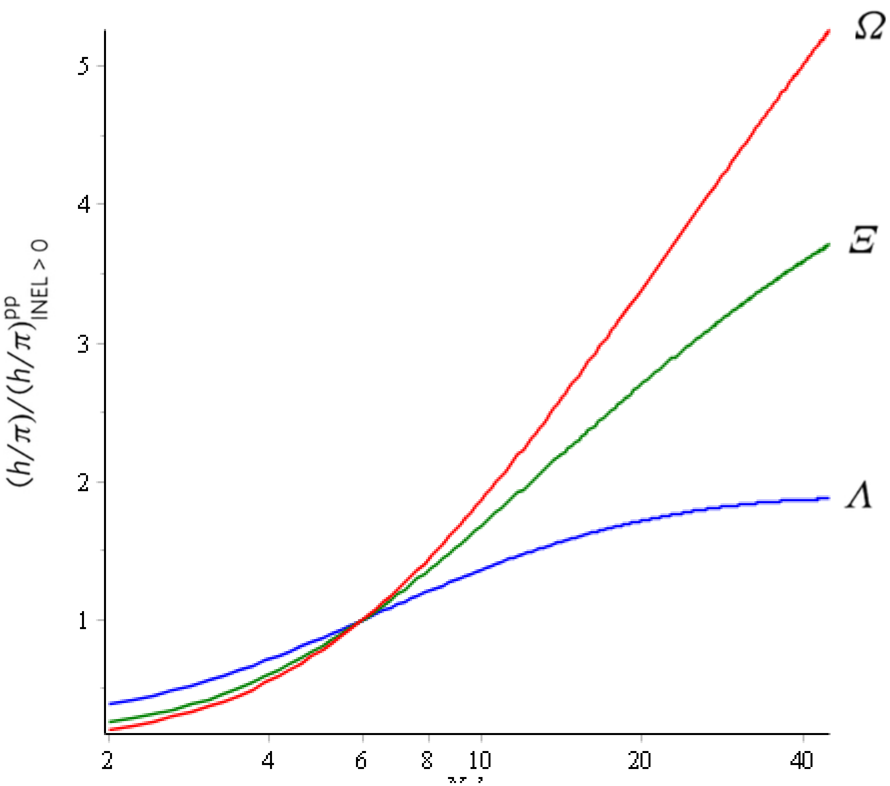
Results: multi-strange

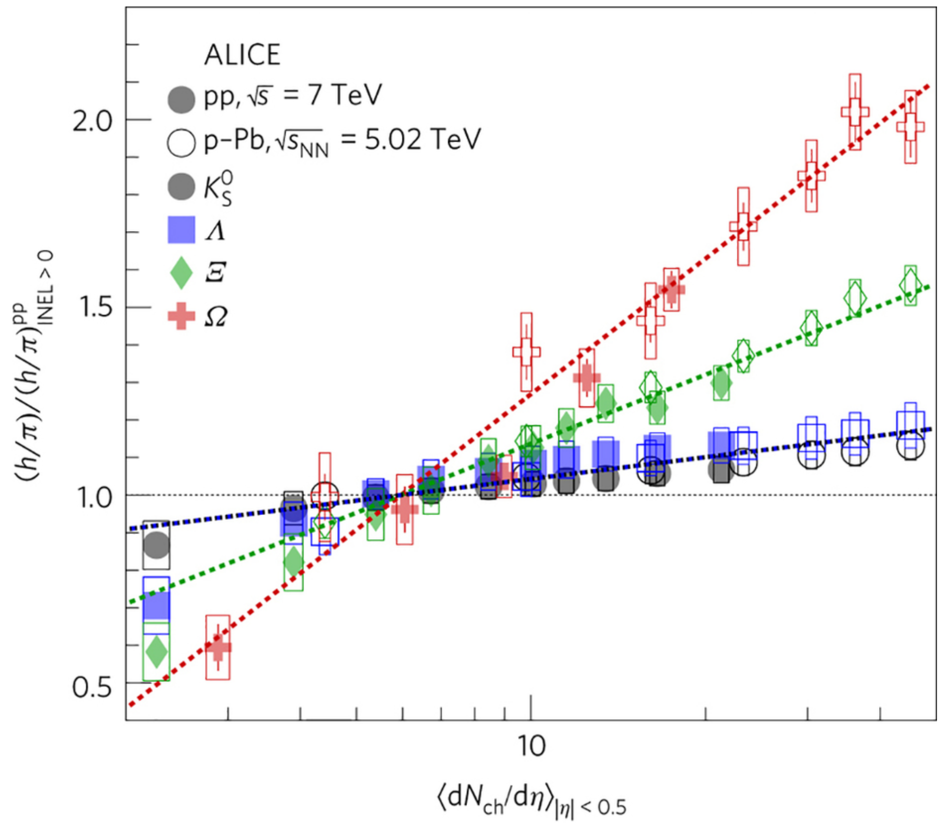




J. Adam, et al (ALICE Collaboration), Nature Physics 13, 535–539 (2017), arXiv:1606.07424 [nucl-ex]

Results: multistrange





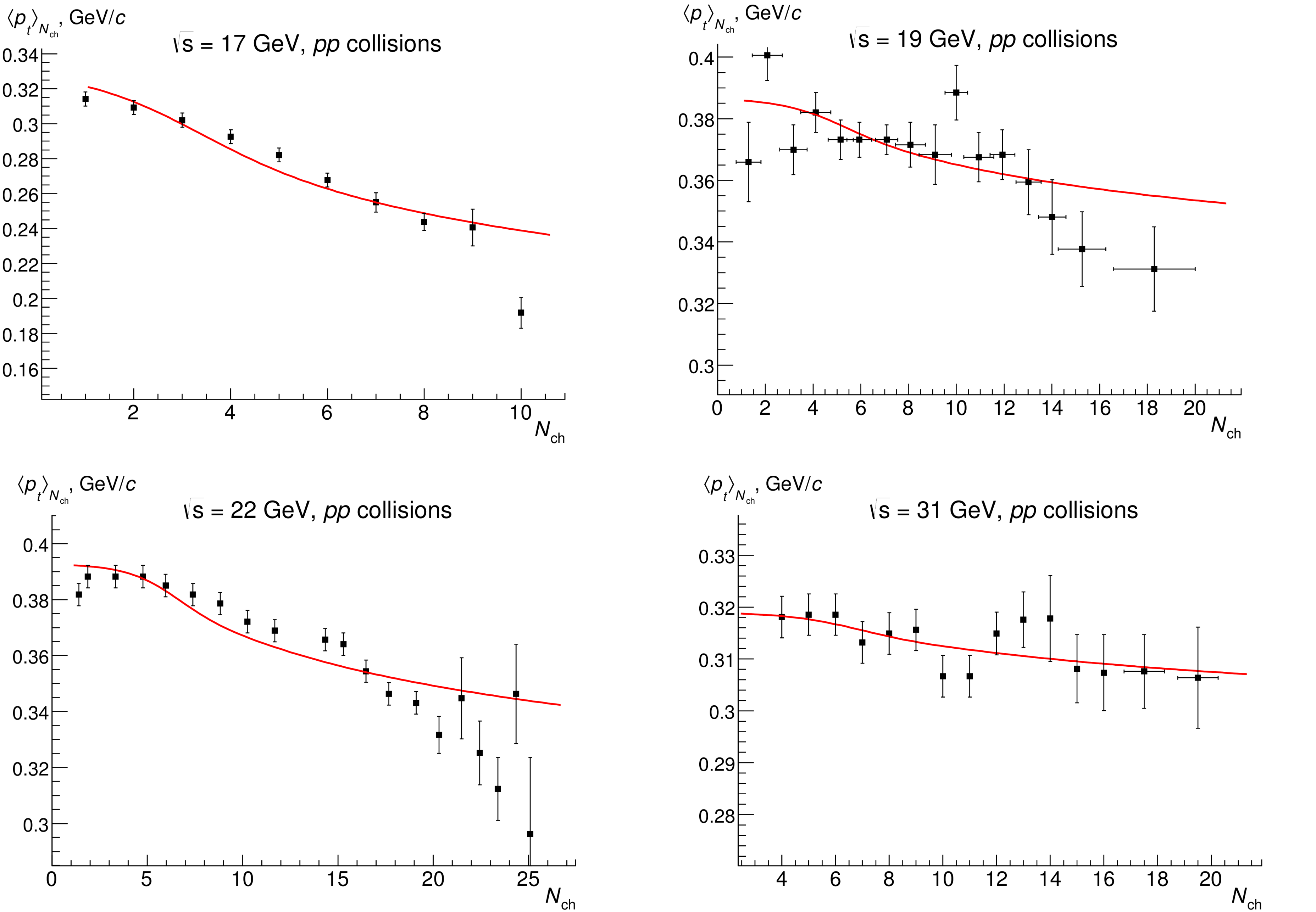
J. Adam, et al (ALICE Collaboration), Nature Physics 13, 535–539 (2017), arXiv:1606.07424 [nucl-ex]

Conclusions

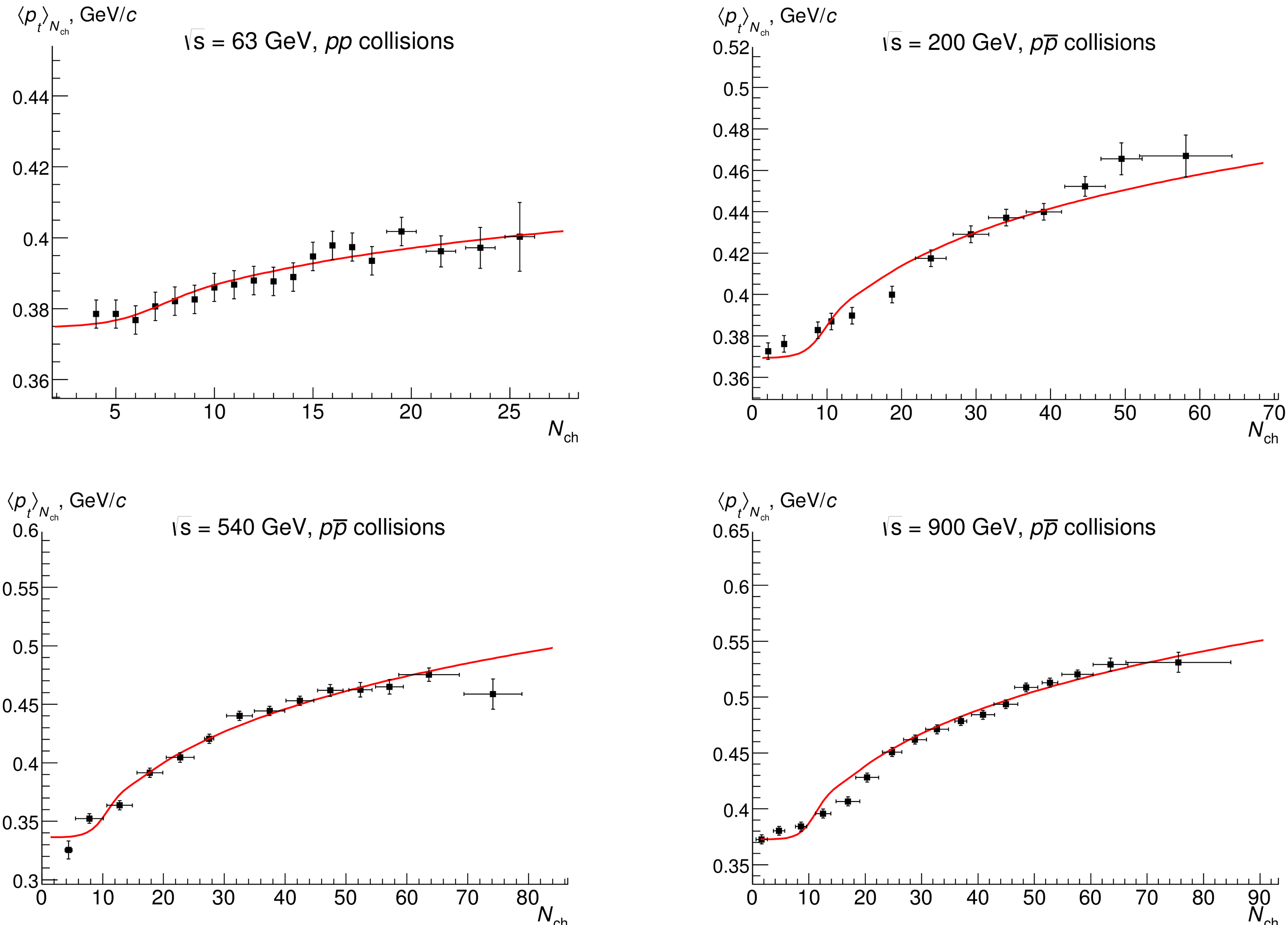
- A generalization of the multi-pomeron exchange model with effective account of interaction between strings is proposed allowing for the production of strange particles in the Schwinger mechanism.
- The model parameters are determined by experimental data on pt-Nch correlation
- No additional parameters for particle differentiation is introduced.
- The accounting of the cascade resonances decays considerably improve the agreement of pion, kaon and proton multiplicities with experimental data in a wide energy range
- The model predicts non-trivial dependence of K/pi ratio with the multiplicity of charged particles in pp collisions
- The results on multiplicity dependence of multi-strange hadron yields in a qualitative agreement with experimental data

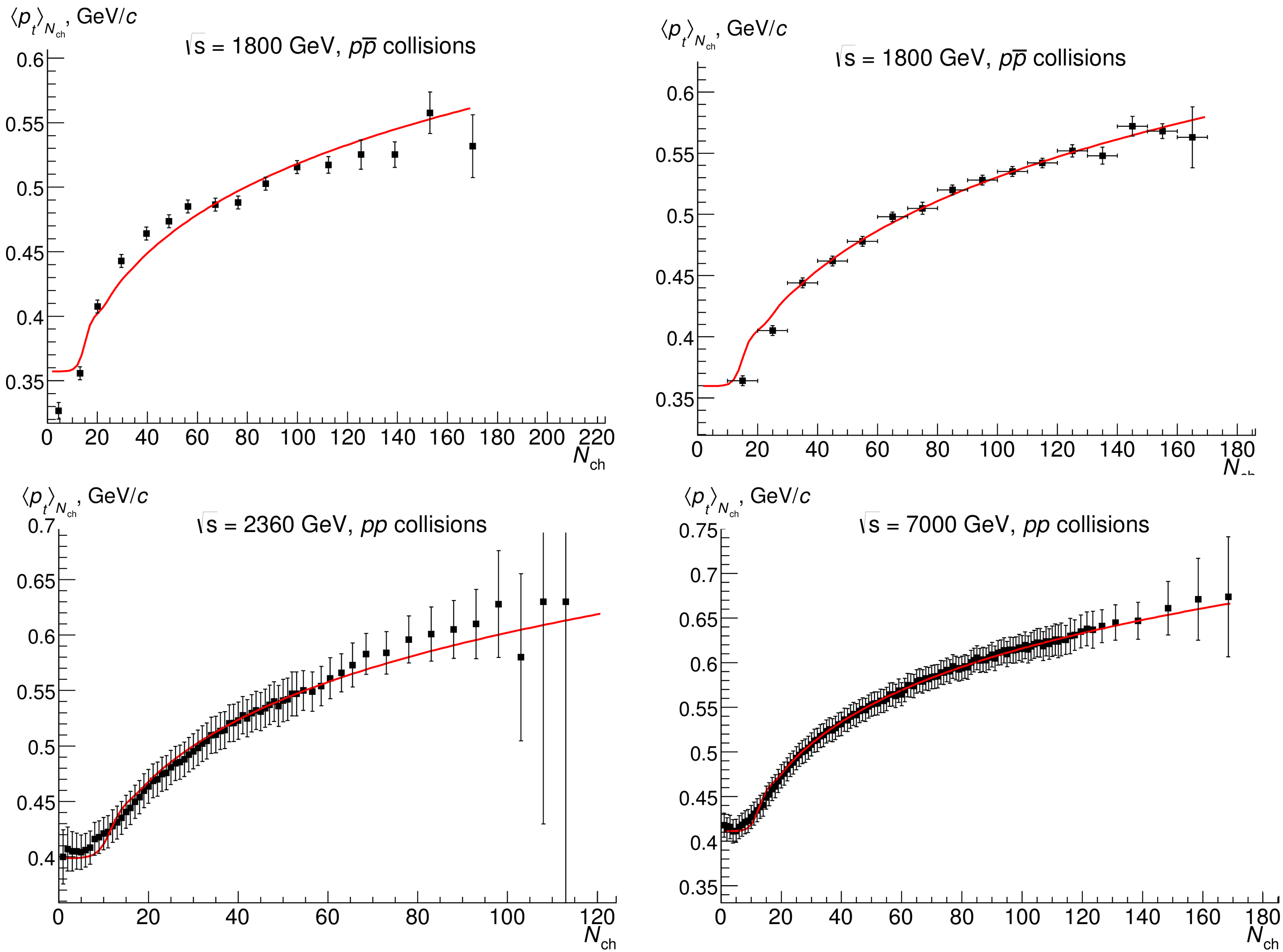
The authors acknowledge Saint-Petersburg State University for a research grant 11.38.242.2015.

Backup slides

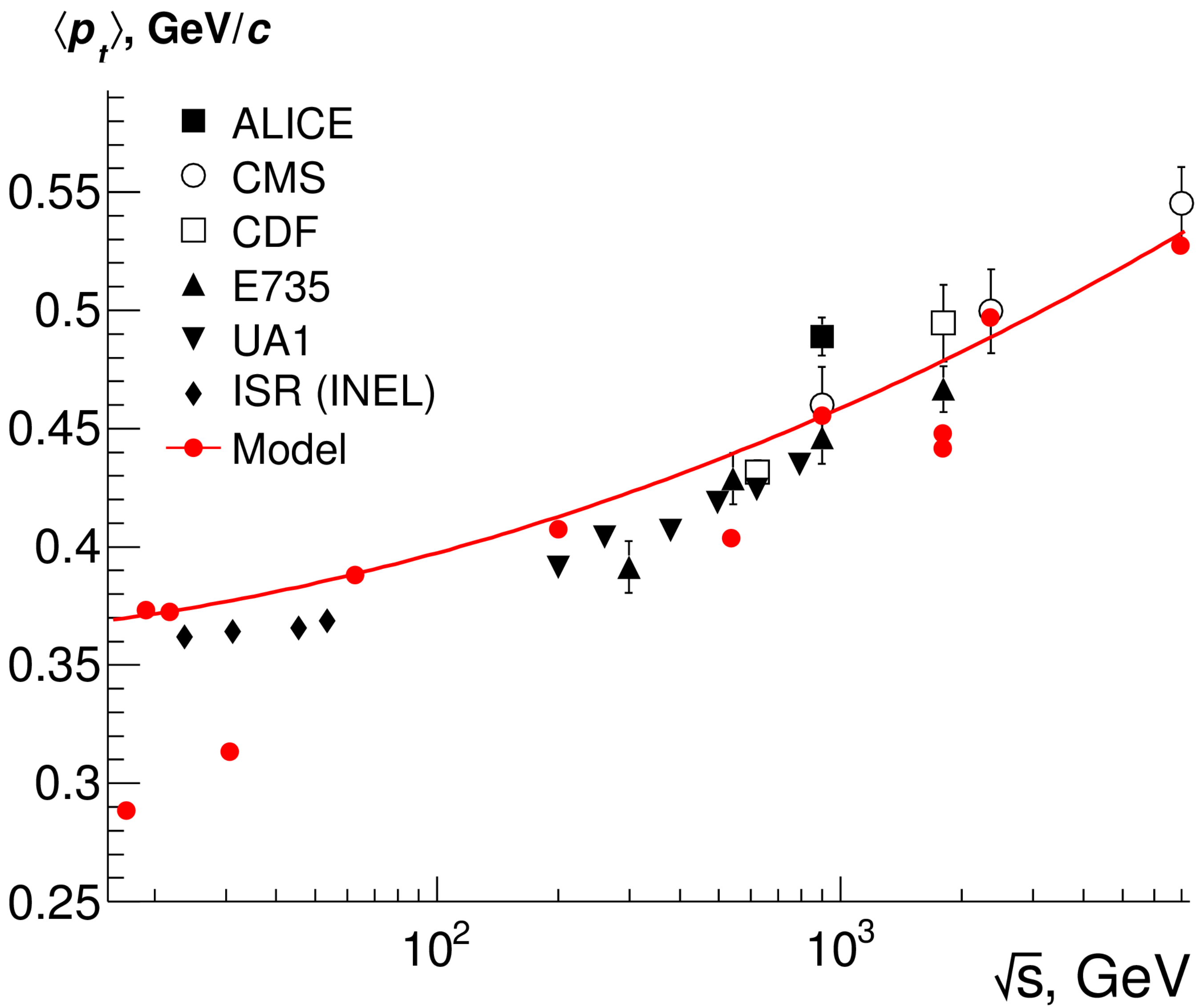


$\langle p_t \rangle_{N_{ch}}$, GeV/$c$
$\sqrt{s}$ = 17 GeV, pp collisions
N_{ch}
$\langle p_t \rangle_{N_{ch}}$, GeV/$c$
$\sqrt{s}$ = 19 GeV, pp collisions
N_{ch}
$\langle p_t \rangle_{N_{ch}}$, GeV/$c$
$\sqrt{s}$ = 22 GeV, pp collisions
N_{ch}
$\langle p_t \rangle_{N_{ch}}$, GeV/$c$
$\sqrt{s}$ = 31 GeV, pp collisions
N_{ch}

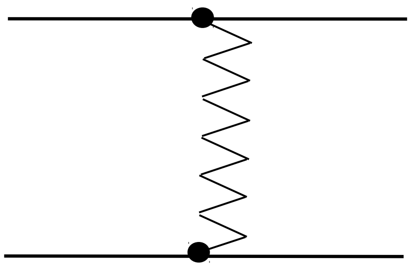

⟨p_t⟩_Nch, GeV/c
√s = 63 GeV, pp collisions
N_ch
⟨p_t⟩_Nch, GeV/c
√s = 200 GeV, pp̄ collisions
N_ch
⟨p_t⟩_Nch, GeV/c
√s = 540 GeV, pp̄ collisions
N_ch
⟨p_t⟩_Nch, GeV/c
√s = 900 GeV, pp̄ collisions
N_ch


⟨p_t⟩_{N_ch}, GeV/c
√s = 1800 GeV, pp̄ collisions
N_ch
⟨p_t⟩_{N_ch}, GeV/c
√s = 1800 GeV, pp̄ collisions
N_ch
⟨p_t⟩_{N_ch}, GeV/c
√s = 2360 GeV, pp collisions
N_ch
⟨p_t⟩_{N_ch}, GeV/c
√s = 7000 GeV, pp collisions
N_ch

Mean transverse momentum



Classical Multi-Pomeron Exchange Model



Pomeron is a virtual particle that is exchanged during the inelastic scatering process with vacuum quantum numbers flow.

It can be considered as a pair of strings.

The number of pomerons exchanged rises with energy.

Collective effects are not included in the model.

A.Capella, U.P.Sukhatme, C.-I.Tan and J.Tran Thanh Van, Phys. Rep.236(1994)225