Correlation between heavy flavour production and multiplicity in pp collisions at high energy in the multi-pomeron exchange model

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in collaboration with
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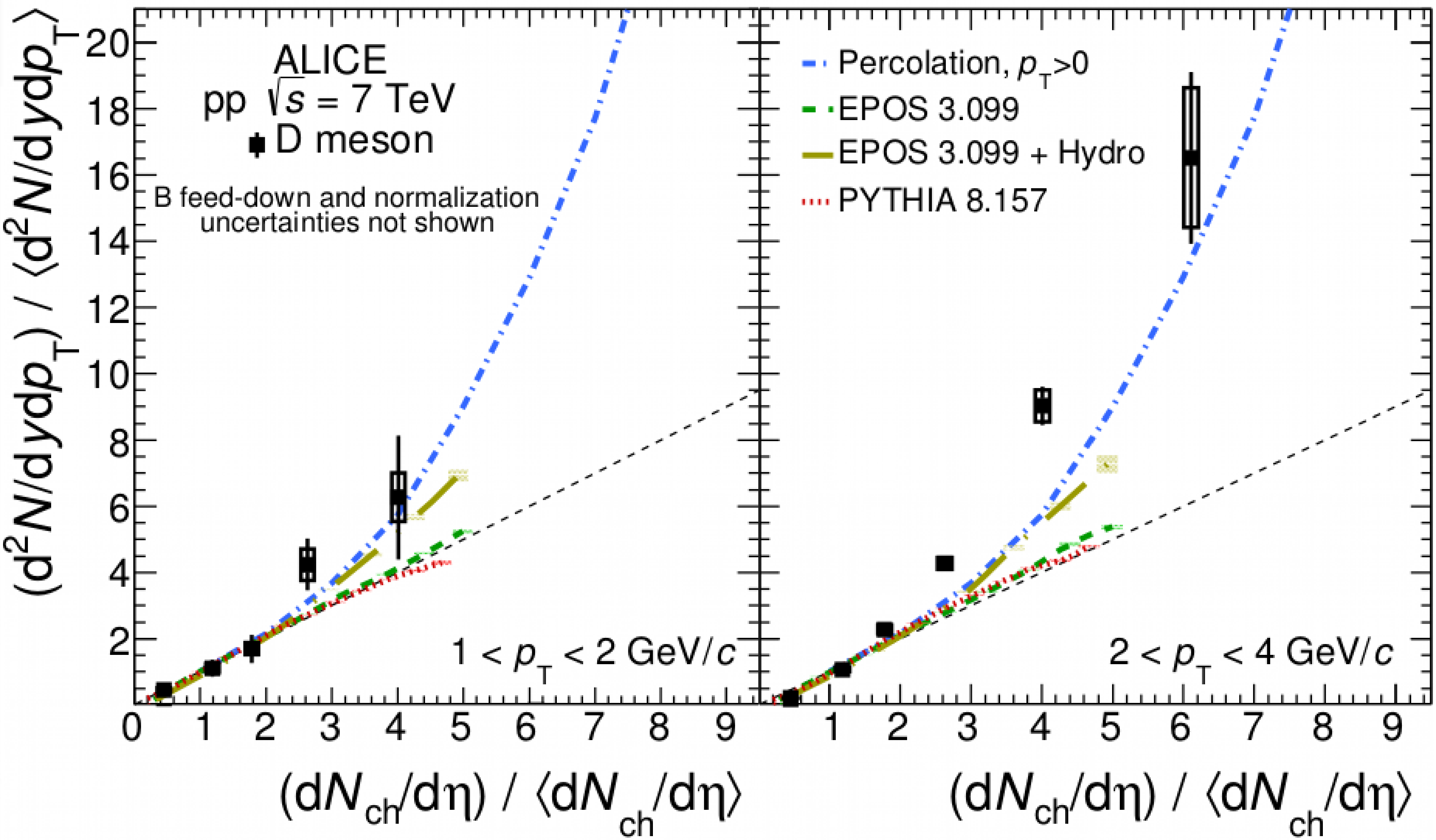
Outline:

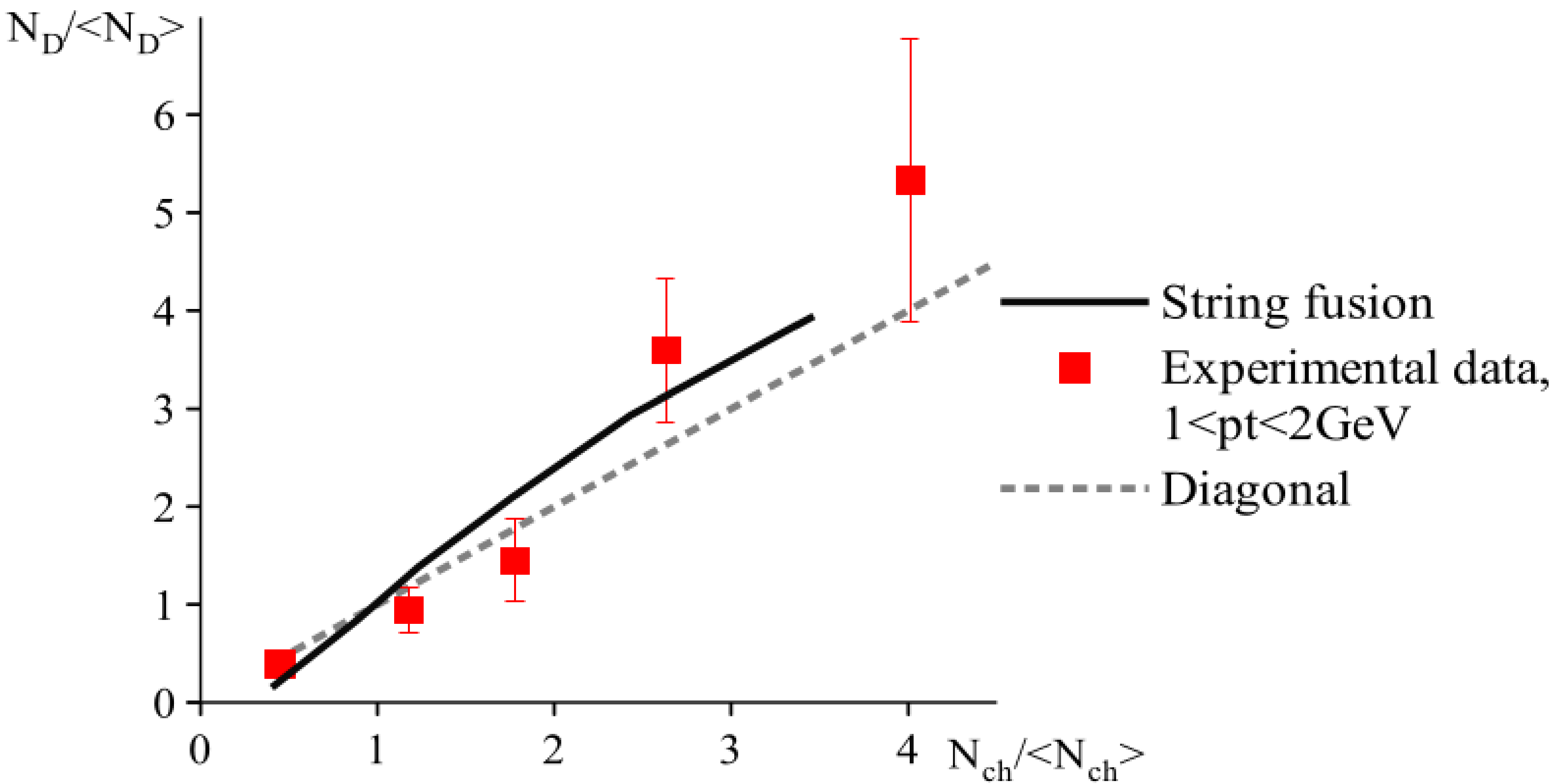
- Some experimental results for multiplicity dependent charm production
- Effective pomeron exchange model (EPEM)
- p_t-N_{ch} correlations
- Particles differentiation in Schwinger mechanism
- Results for pp collisions
- Extension for p-Pb collisions

Multiplicity dependent charge production in pp



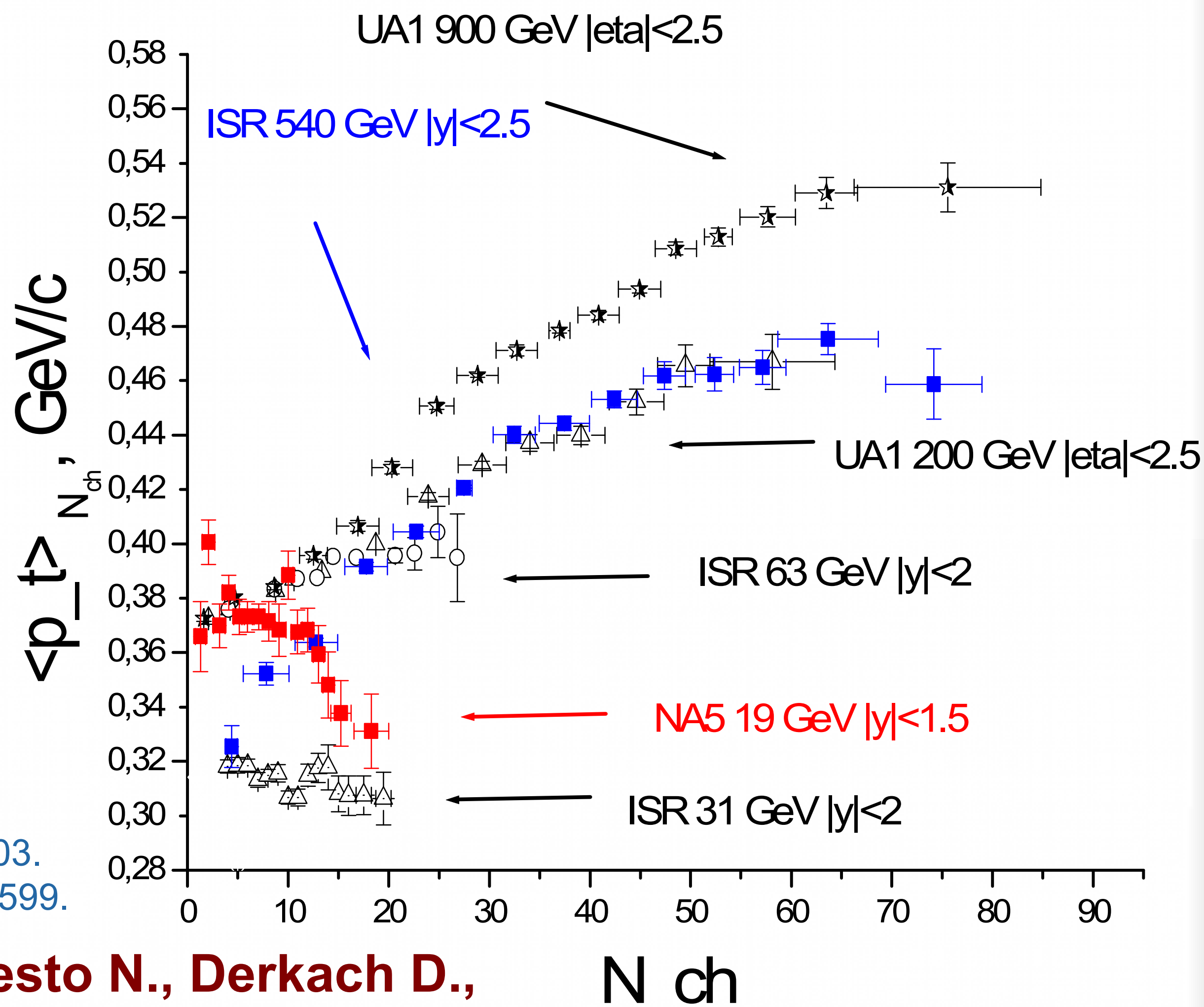
J. Adam, et al (ALICE Collaboration) JHEP 09 (2015) 148, arXiv:1505.00664 [nucl-ex]
Percolation: E. Ferreiro and C. Pajares, arXiv:1501.03381 [hep-ph] (2015)
EPOS: K. Werner, et al, Phys.Rev. C89 (2014) 064903, arXiv:1312.1233 [nucl-th]; see also B. Guiot, J. Phys.: Conf. Ser. 805,012002 (2017)
Pythia 8: T. Sjostrand, et. al. Comput.Phys.Commun. 178 (2008) 852–867, arXiv:0710.3820 [hep-ph].

Multiplicity dependent charge production in pp



V. Kovalenko, V. Vechernin, “Correlation between heavy flavour production and multiplicity in string fusion approach”, 5th International Conference on New Frontiers in Physics ICNFP2016; to be published in EPJ Web of Conferences

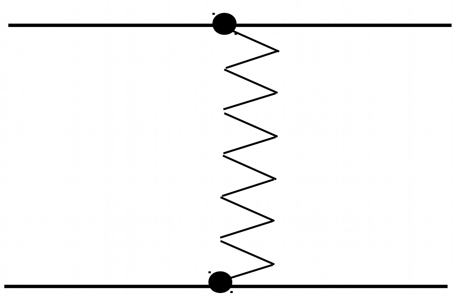
Experimentally Observed p_t-N_{ch} correlations in pp and ppbar collisions:



NA49 collab. arXiv:hep-ex/0311009.
ABCDHW Collaboration, Phys. Lett. 132B (1983) 463.
UA1 collab., Nucl Phys 335B (1990) 261.
F.Abe et.al, Phys.Rev.Lett. 61 (1988) 1819.
C.De Marzo et al. Phys. Rev. 29D (1984) 363.
V.V. Aivazyan et al., Phys.Lett. 209B (1988) 103.
T. Alexopoulos et al., Phys. Lett. 336B (1994) 599.

Compilation of data in: Armesto N., Derkach D., Feofilov G., Phys. Atom. Nucl. 71, 2087 (2008)

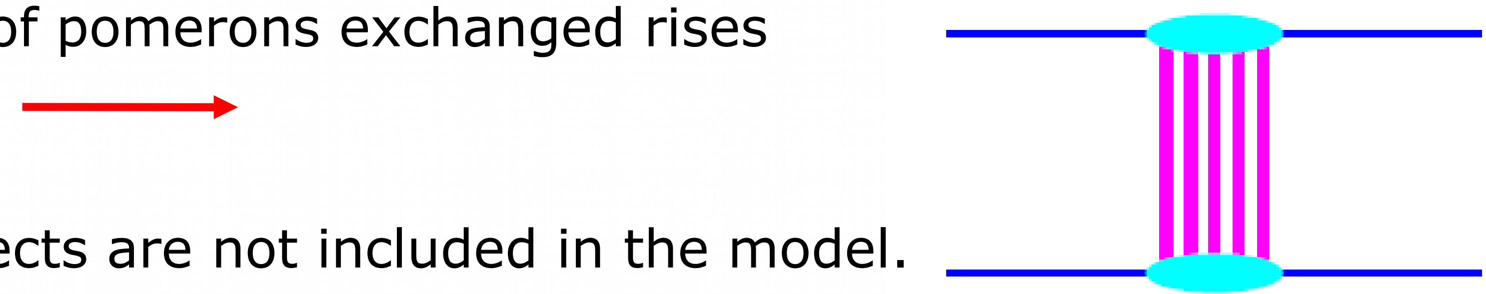
Classical Multi-Pomeron Exchange Model (Regge-Gribov approach)



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

It can be considered as a pair of strings.

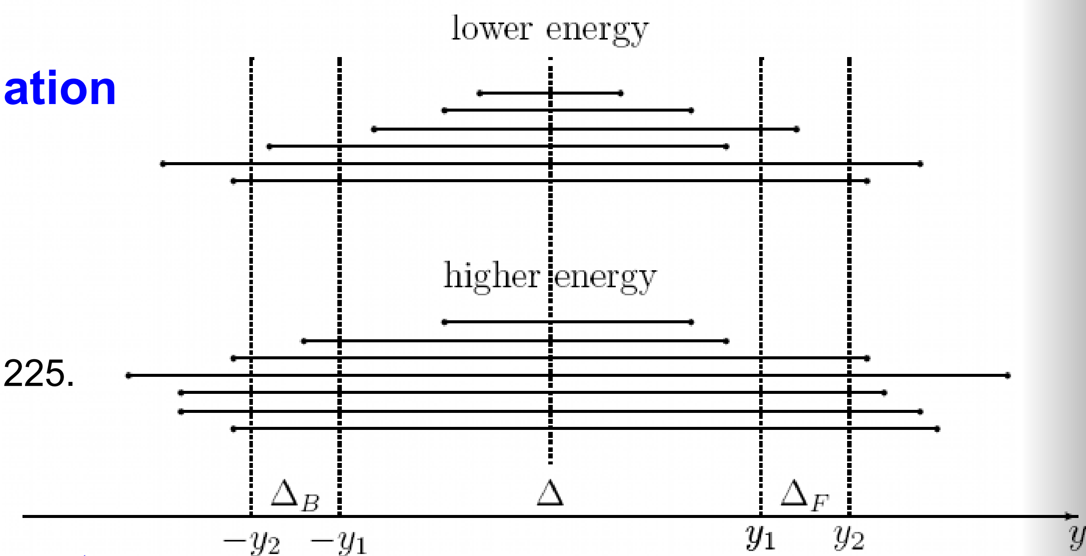
The number of pomerons exchanged rises with energy.



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

Theoretical Motivation: Color string formation and decay



- **2-stage scenario of color string formation and decay:**
- **A.Capella, U.P.Sukhatme, C.--I.Tan and J.Tran Thanh Van,**
  Phys. Lett. **B81** (1979) 68; Phys. Rep.,236(1994) 225.
- **A.B.Kaidalov K.A.Ter-Martirosyan** ,
  Phys.Lett., **117B**(1982)247.

Do these color strings interact and what is the signal?

- **Abramovskii V. A., Gedalin E. V., Gurvich E. G., Kancheli O. V.** ,
  JETP Lett., vol.47, 337-339 , 1988 .
- **Color string fusion phenomenon**:
- **M.A.Braun and C.Pajares**,
  Phys. Lett. {\bf B287} (1992) 154;\\ Nucl. Phys. {\bf B390} (1993) 542, 549;

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]:

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

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

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

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

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]:

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

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

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

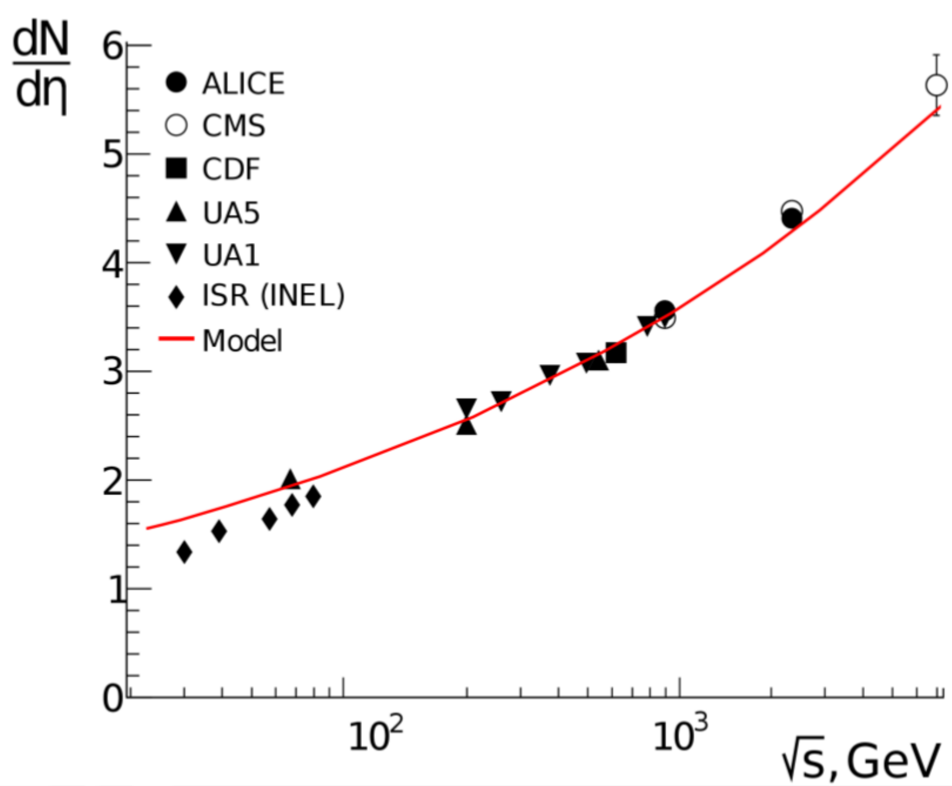
Distribution of N_{ch} and particles over p_t

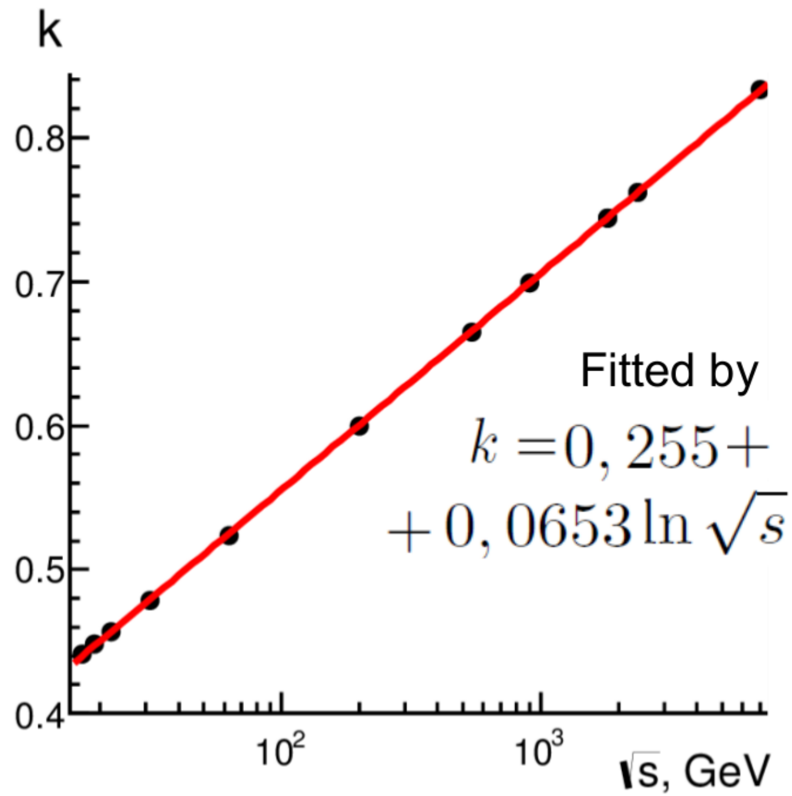
$\rho(N_{ch}, p_t) =$	Probability distribution
$= \frac{C_w}{z} \sum_{n=1}^{\infty} \frac{1}{n} \left(1 - \exp(-z) \sum_{l=0}^{n-1} \frac{z^l}{l!} \right) \times$	Probability of production of *n* pomerons
$\times \exp(-2nk\delta) \frac{(2nk\delta)^{N_{ch}}}{N_{ch}!} \times$	Poisson distribution of the charged particles from 2*n* string
$\times \frac{1}{n^{\beta} \cdot t} \exp\left(-\frac{\pi p_t^2}{n^{\beta} t} \right)$	Modified Schwinger mechanism

Determination of the parameter k

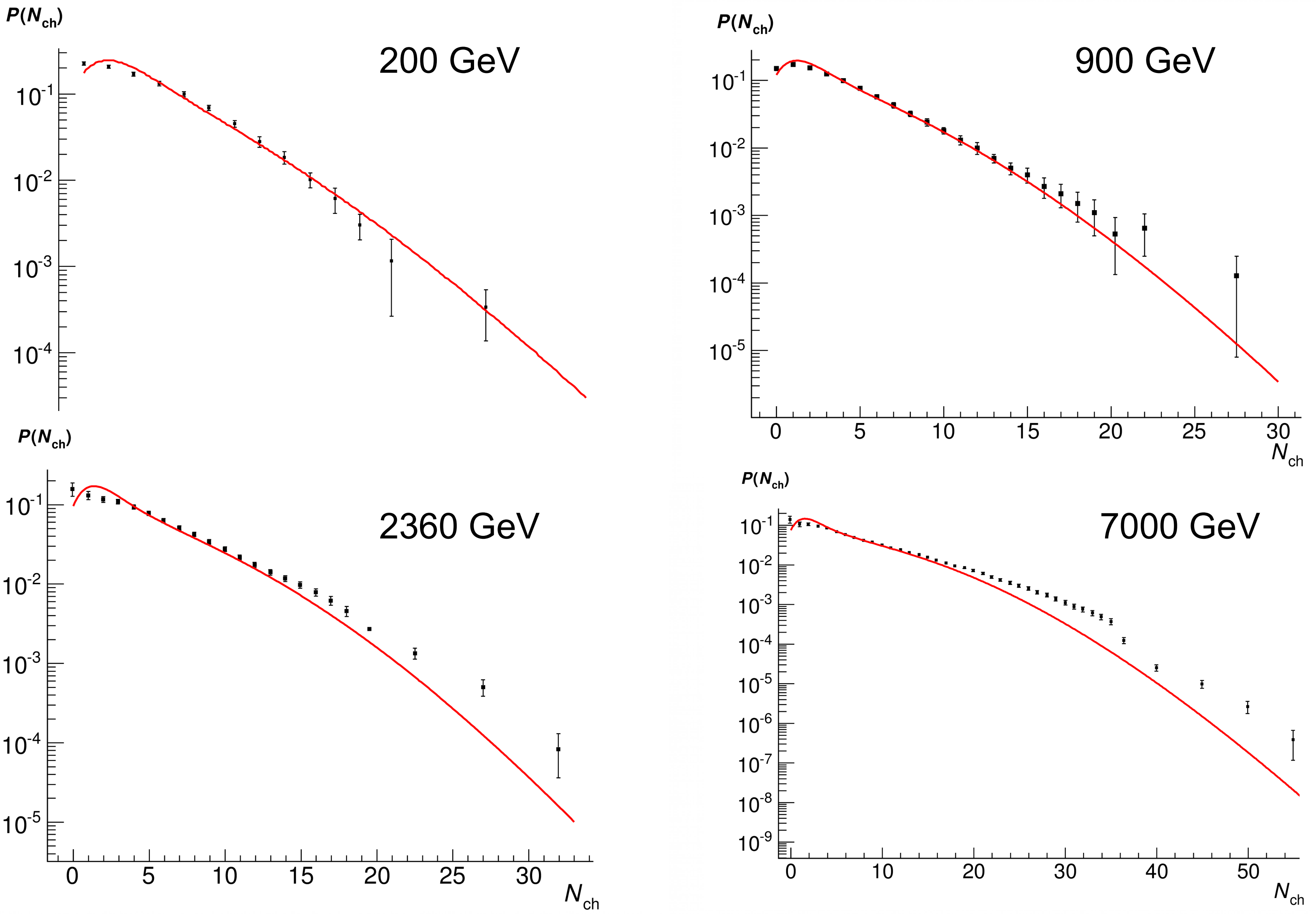
from experimental data on charged multiplicity:

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





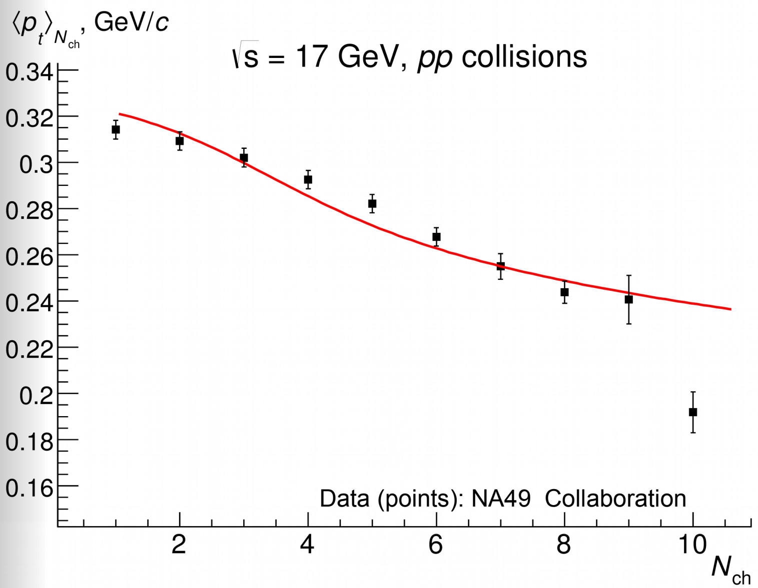
Distribution of N_{ch}

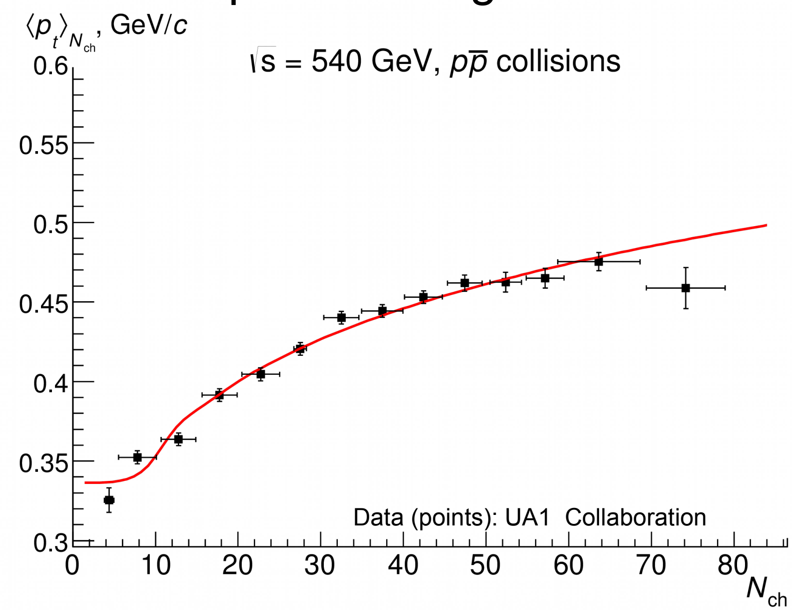


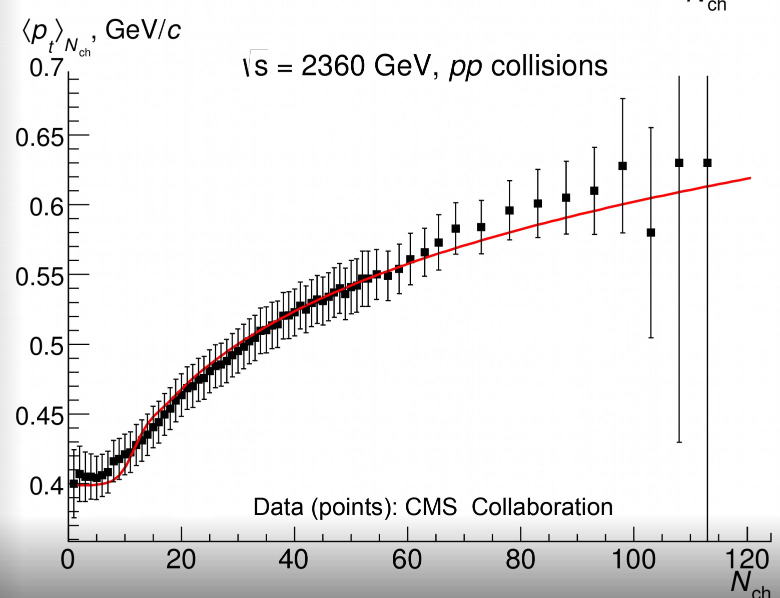
p_t-N_{ch} correlations

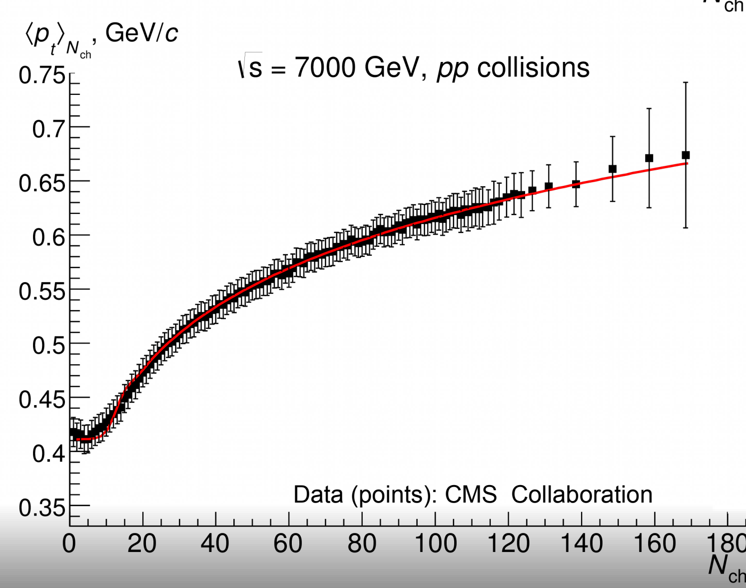
The data on p_t-N_{ch} correlations are analyzed in wide energy region: from 17 GeV to 7 TeV

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

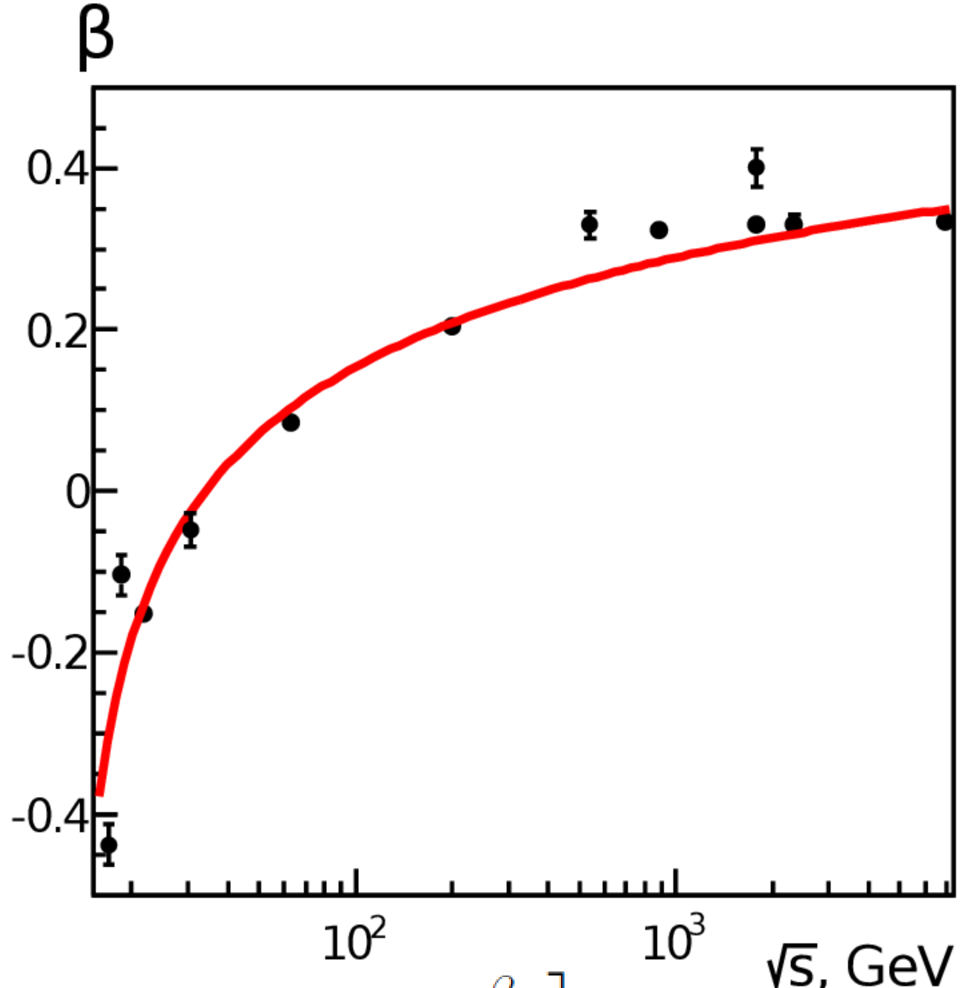
$p\bar{p}$, 1800 GeV

$p\bar{p}$, 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 GeV^2

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: $\rho^0 \rightarrow \pi^+ + \pi^-$, $\rho^\pm \rightarrow \pi^\pm + \pi^0$
  - Best: take all light hadrons and correct for their cascade decays (feed down)

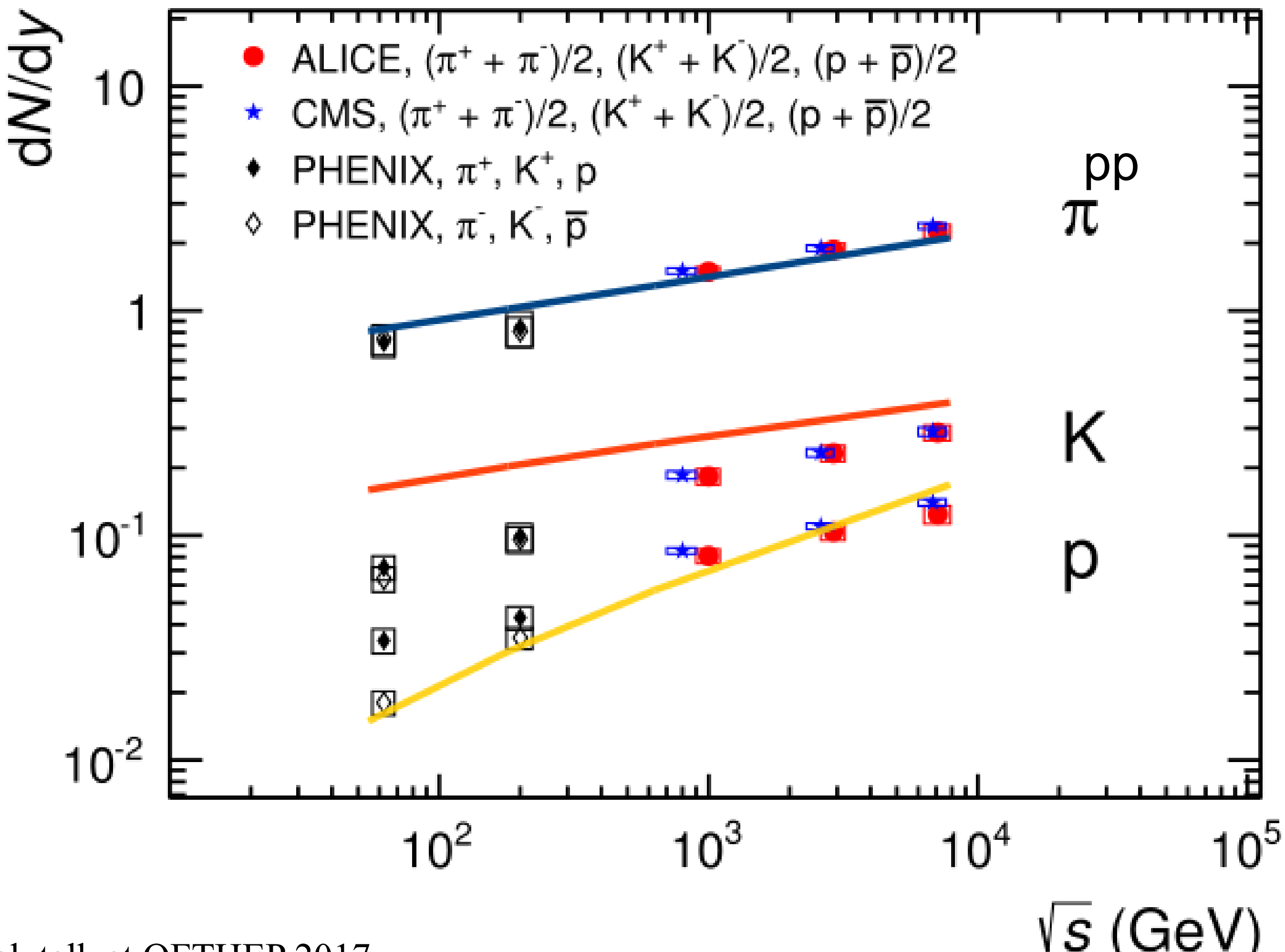
then $$Y_\nu \sim \sum_\mu M_{\mu\nu} \cdot \left(2S_\mu+1\right) \cdot \exp\left(\frac{\pi\left(p_t^2+m_\mu^2\right)}{n^\beta t}\right),$$

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])

Particles multiplicities

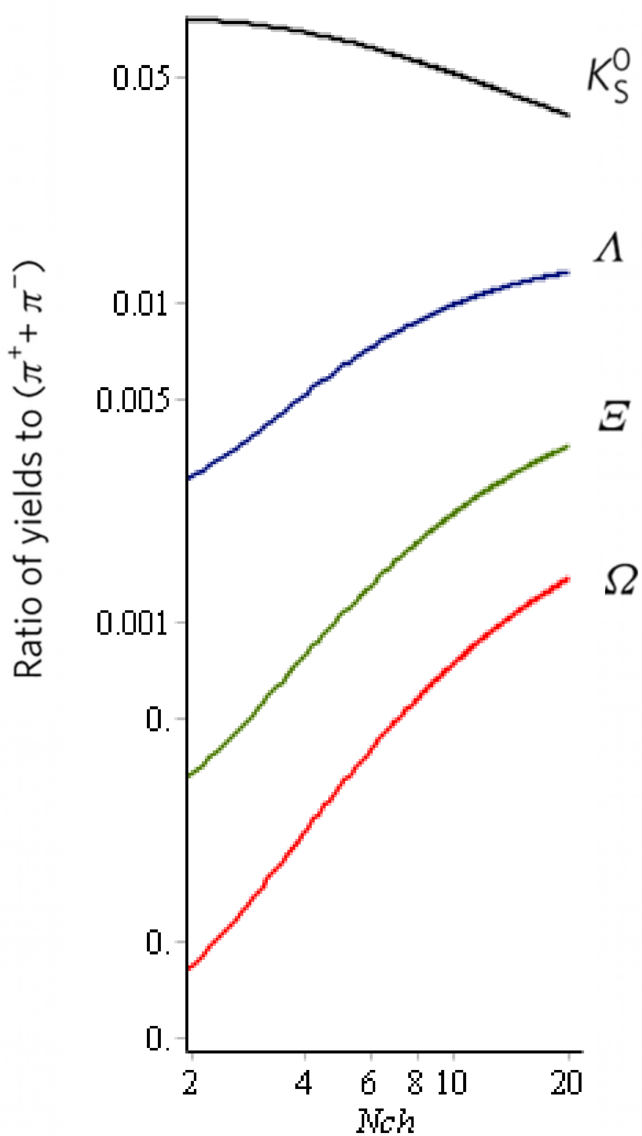
- Energy dependence of the charged proton, kaon and proton multiplicities

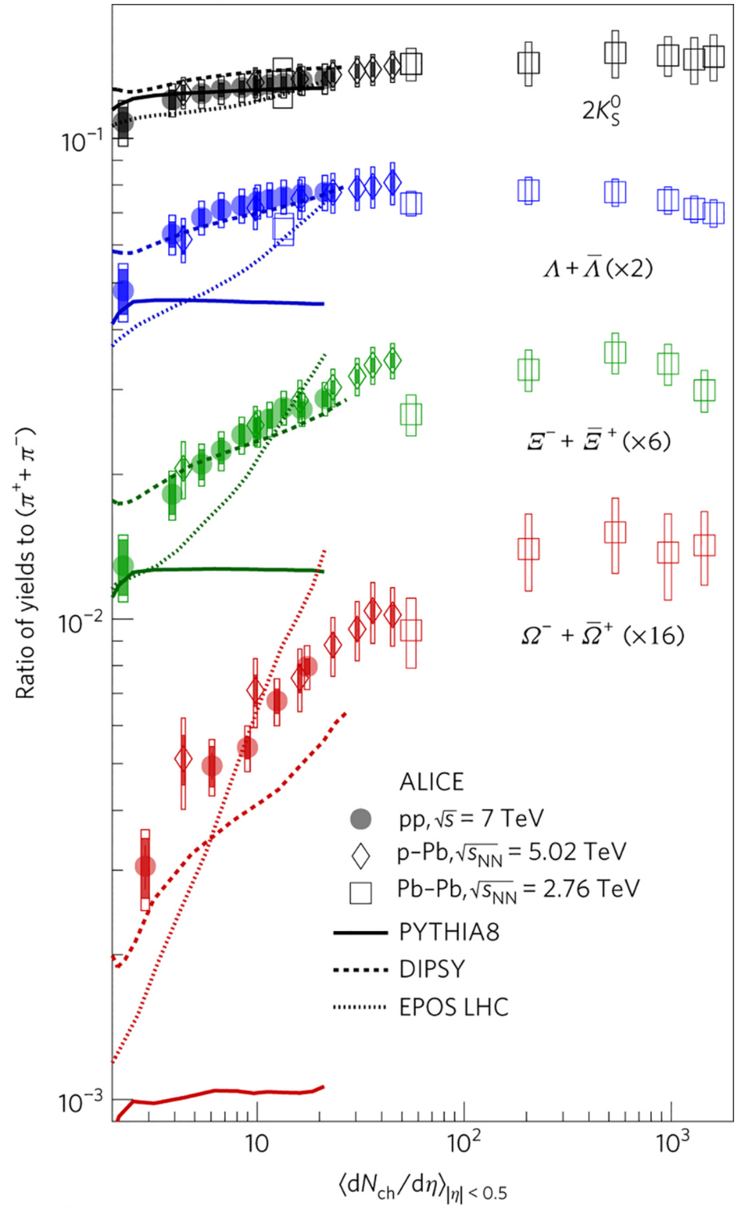


V. Kovalenko, et al, talk at QFTHEP 2017, http://qfthep.sinp.msu.ru/talks2017/1498738291_QFTHEP-2017_Kovalenko_V.pdf

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

Multi-strange production





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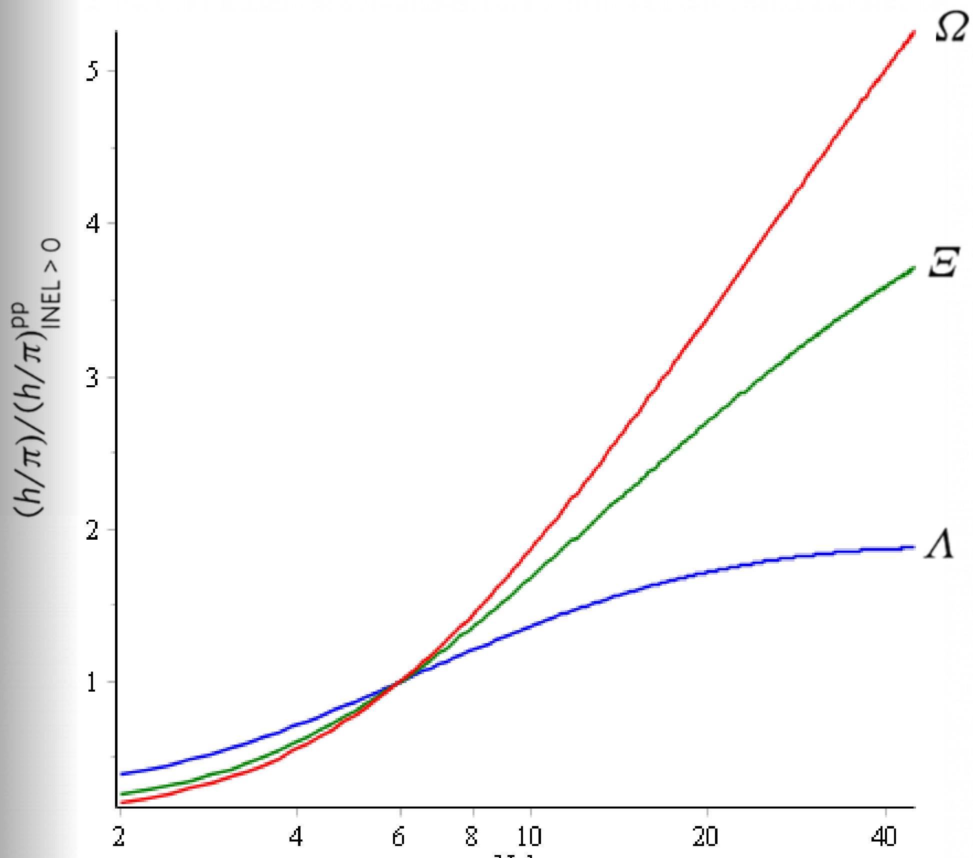
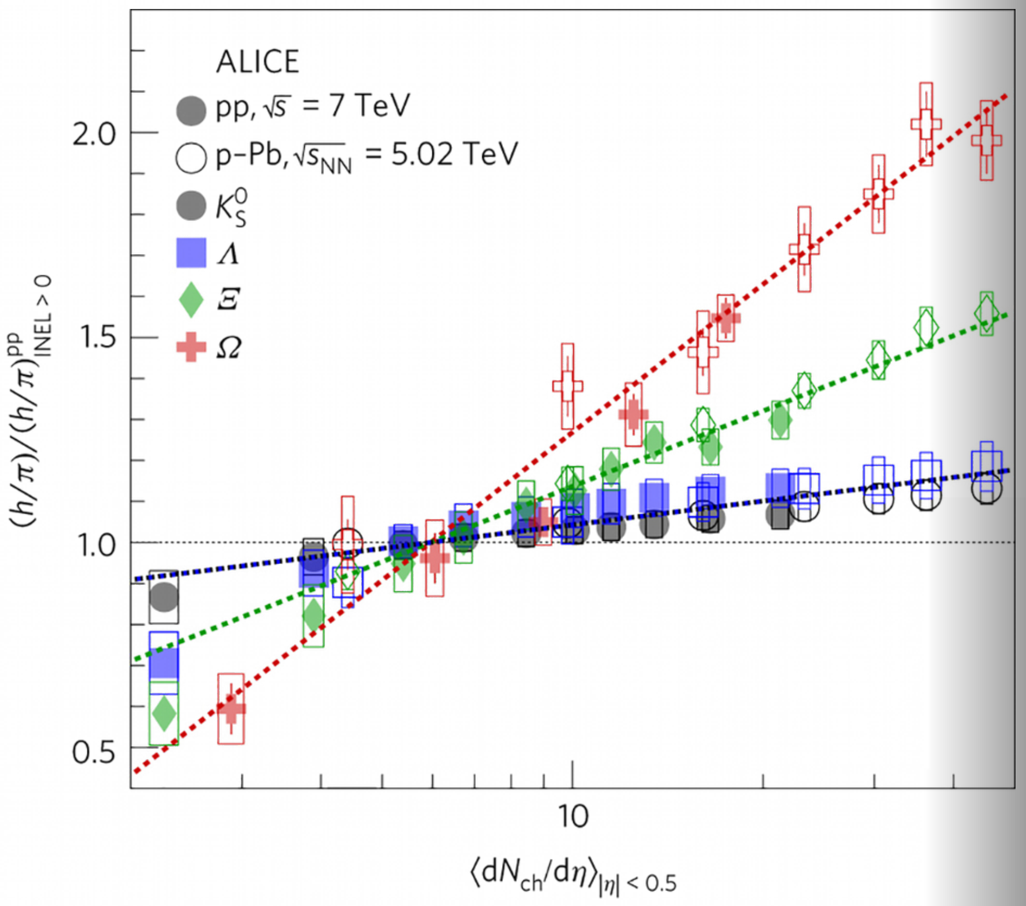
J. Adam, et al (ALICE Collaboration), Nature Physics 13, 535–539 (2017), arXiv:1606.07424 [nucl-ex]

Multi-strange production

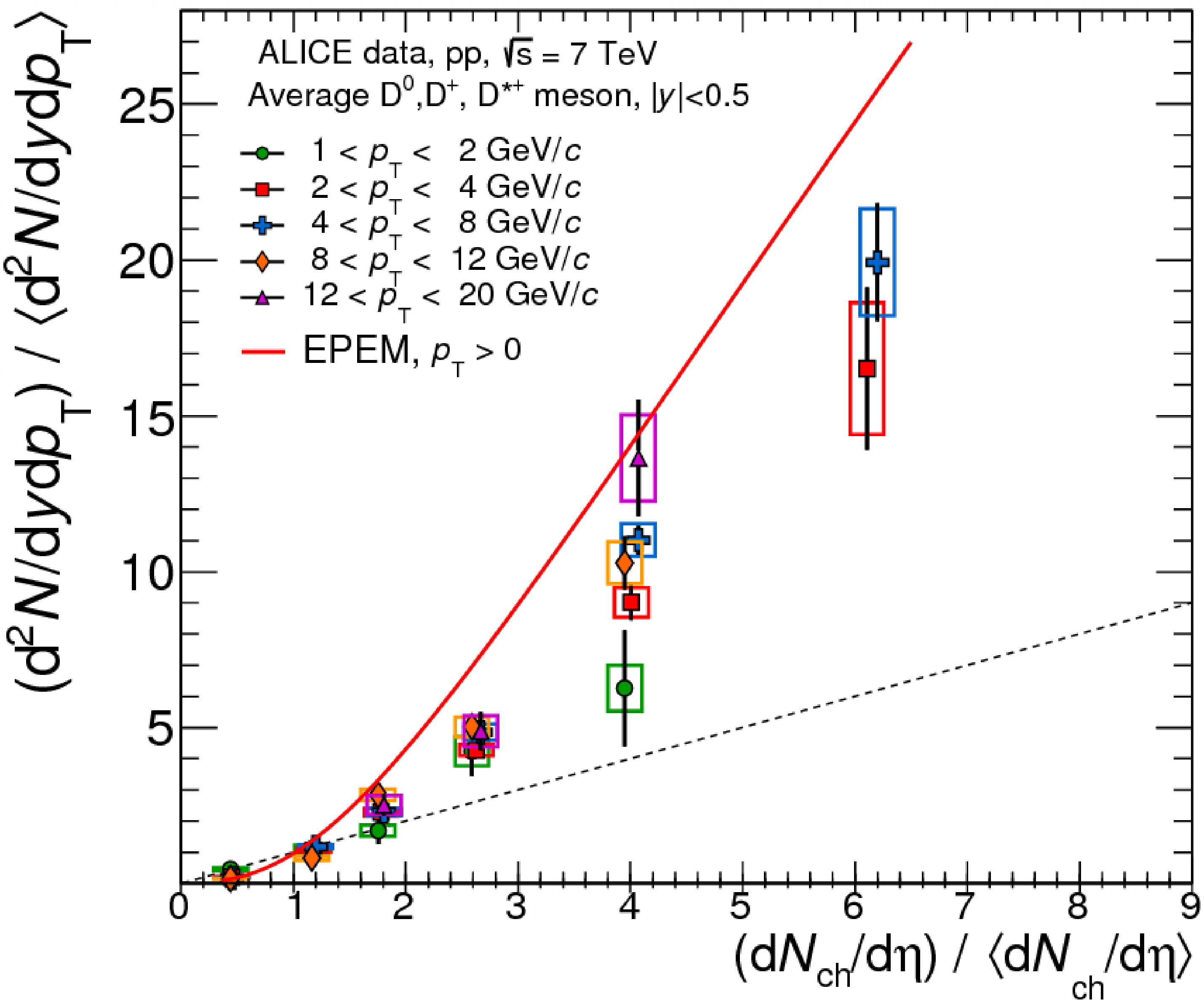




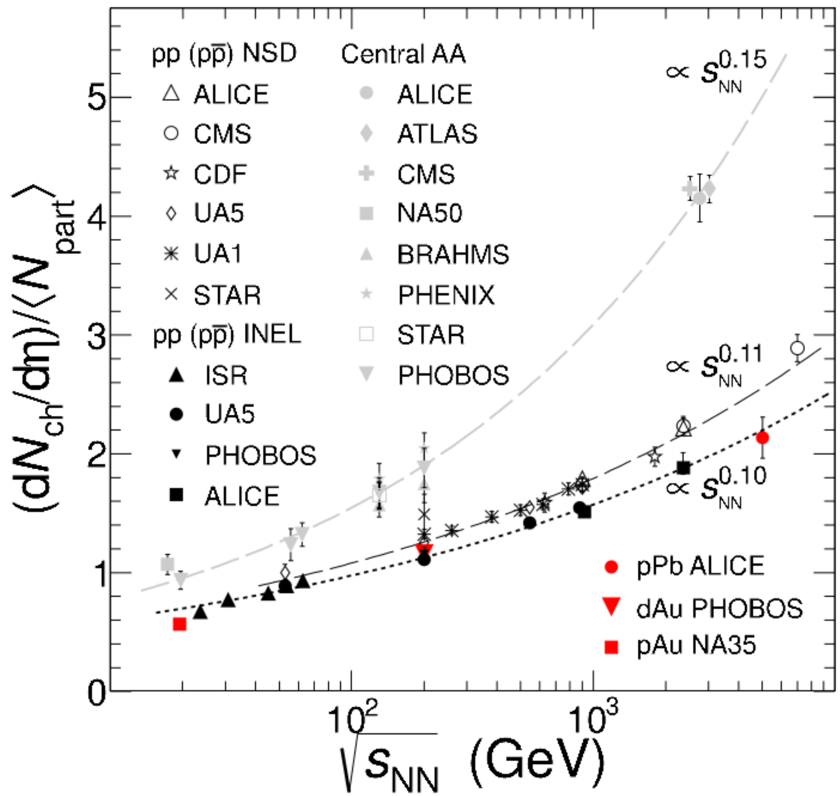
V. Kovalenko, et al, talk at QFTHEP 2017, http://qfthep.sinp.msu.ru/talks2017/1498738291_QFTHEP-2017_Kovalenko_V.pdf

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

Results: open charm



Extension for p-Pb collisions

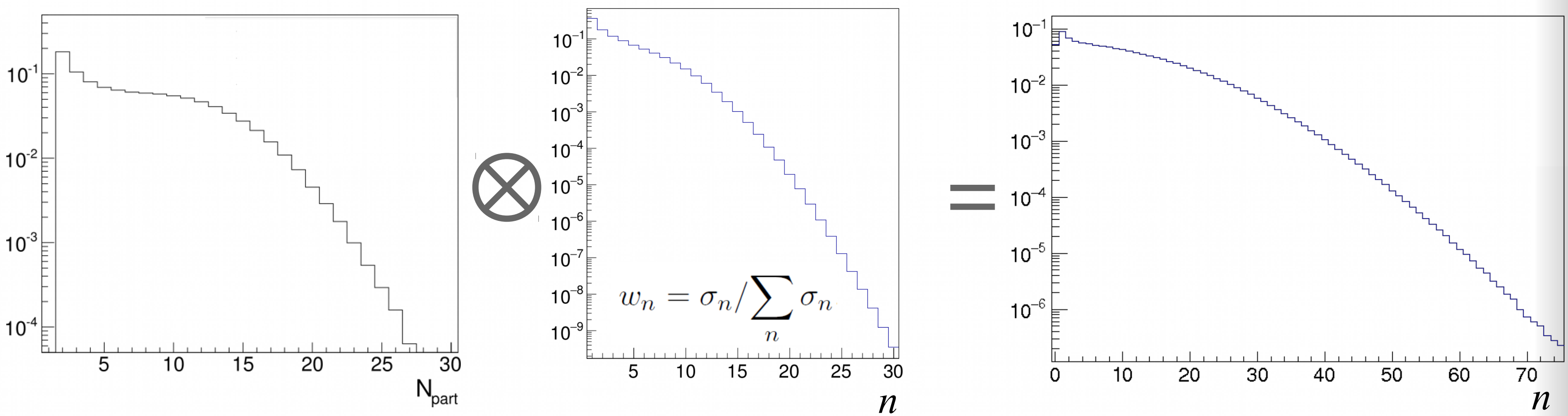


For each participant pair one emits n pomerons with a probability w_n

Experimental data – summary plot B. Abelev, et al (ALICE Collaboration) Phys. Rev. Lett. 110 (2013) no.3, 032301

Extension for p-Pb collisions

Probability of production of *n* pomerons obtained as a convolution of Npat distributiuon and the distribution of n pomerons from pp



Min. bias multiplicity:

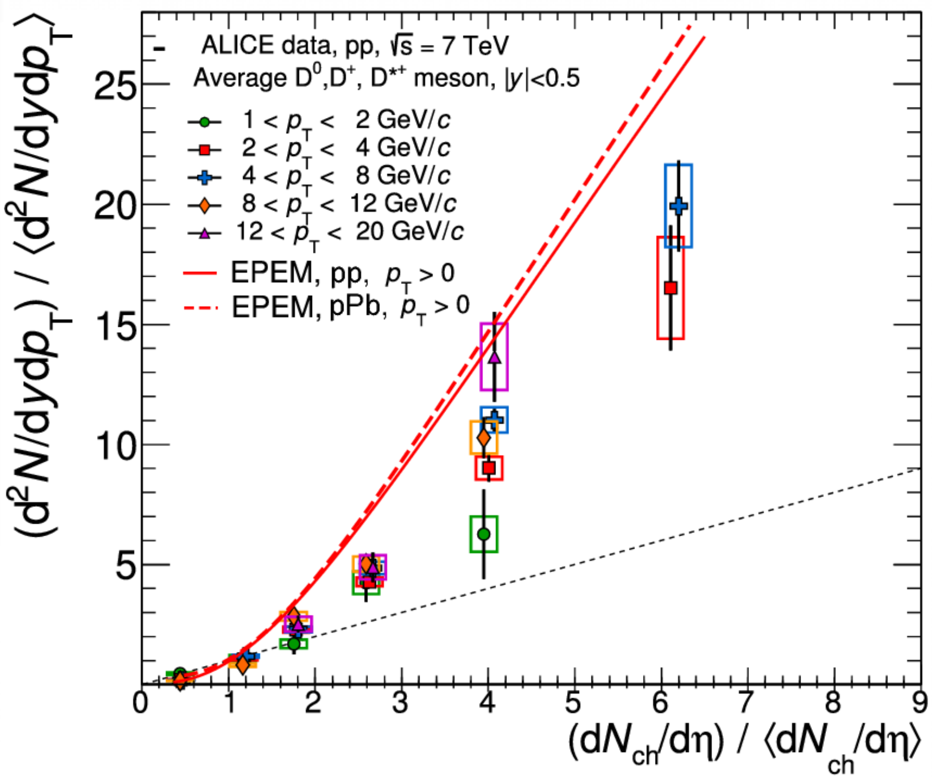
experiment

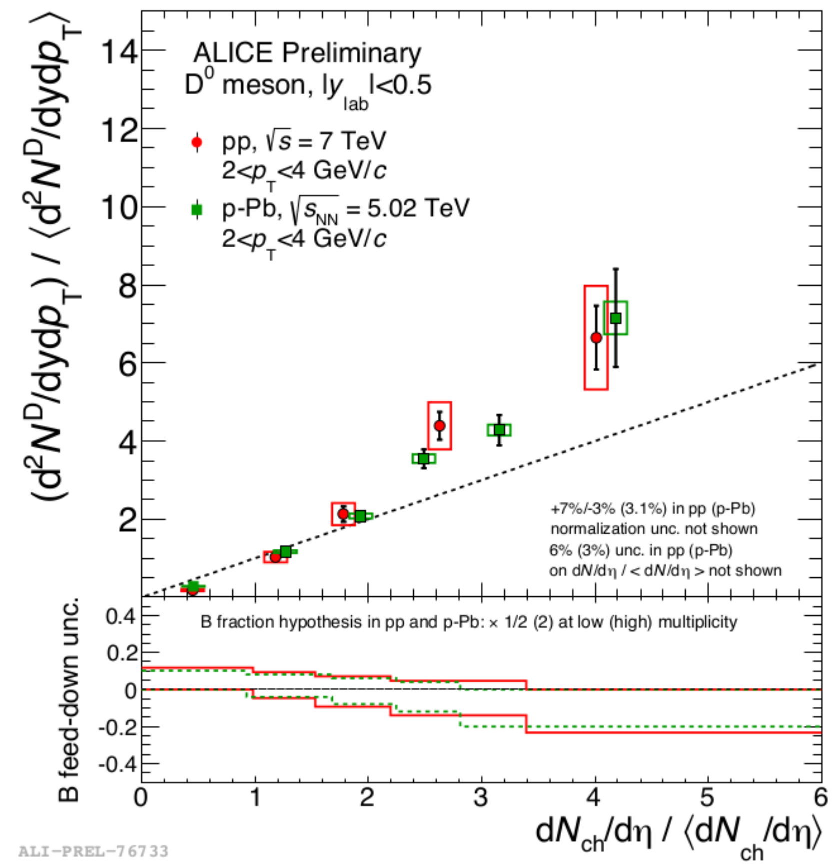
$$\langle dN/d\eta \rangle = 16.81 \pm 0.71$$

model

$$\langle dN/d\eta \rangle = 17.8$$

Results for p-Pb collisions





Riccardo Russo (for the ALICE Collaboration),
Nucl. Phys. A 931 (2014) 552-557

Conclusions

- A generalization of the multi-pomeron exchange model with effective account of interaction between strings is proposed allowing for the production of charm particles in the Schwinger mechanism.
- The model parameters are determined by experimental data on p_t-N_{ch} correlation
- No additional parameters for particle differentiation is introduced.
- The accounting of the cascade resonances decays considerably enables to describe pion, kaon and proton multiplicities in a wide energy range
- The multiplicity dependence of D meson yields is calculated
- The results are in a qualitative agreement with experimental data
- The model extended for the description of p-Pb collisions; it predicts similar yield of open charm as in pp collisions at same multiplicity, which is consistent with experimental data

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