Multi-pomeron exchange model for pp and $p\bar{p}$ collisions at ultra-high energy

E. O. Bodnya[a;b], D. A. Derkach[c], V. N. Kovalenko[a], A. M. Puchkov[a] and G. A. Feofilov[a]

[a] Saint Petersburg State University, Russia
[b] University of California, Berkeley, USA
[c] Oxford University, UK

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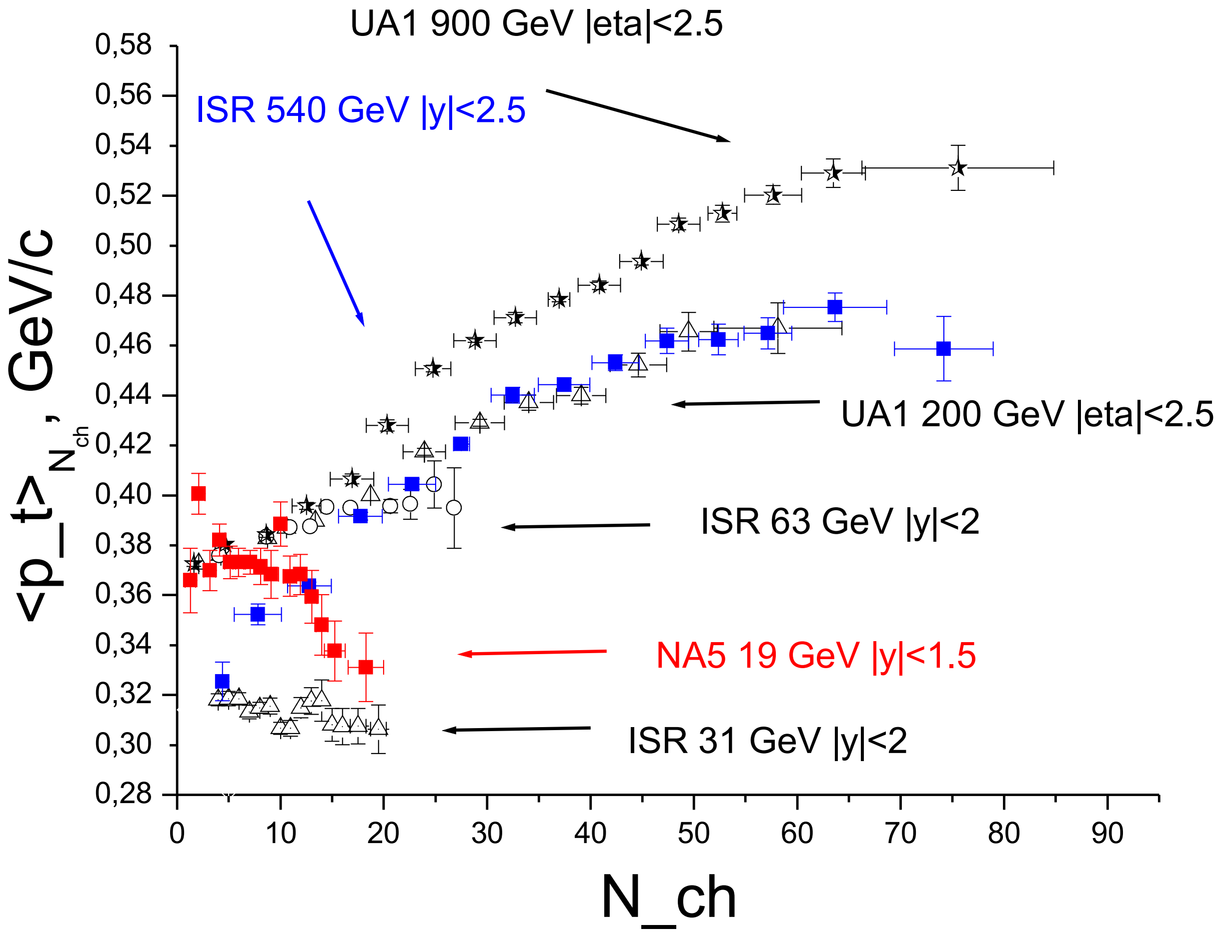
Saint Petersburg, Russia

Experimentally Observed p_t-N_{ch} Correlations



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]:

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

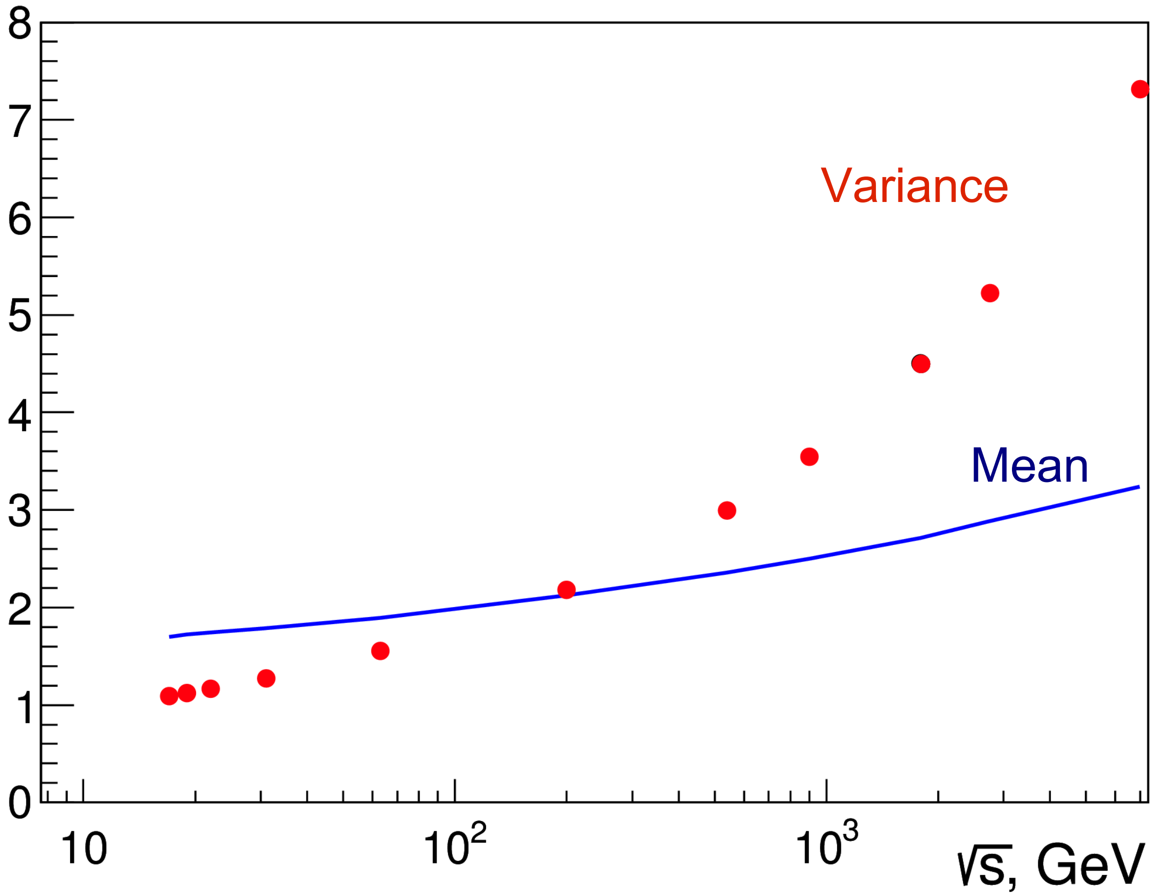
$$\gamma = 1,77\ \mathrm{GeV}^{-2}\,, \quad R_0^2 = 3,18\ \mathrm{GeV}^{-2}\,,$$

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

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

Regge-Gribov multipomeron approach

Mean and variance of the number of pomerons:



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]:

$$\frac{d^2N_{\rm ch}}{dp_T{}^2} \sim \exp\left(\frac{-\pi\left(p_t^2+m^2\right)}{t}\right)$$

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

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

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

Description of transverse momentum

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

$$\frac{d^2N_{\rm ch}}{dp_T{}^2} \sim \exp\left(\frac{-\pi\left(p_t^2+m^2\right)}{n^\beta t}\right)$$

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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

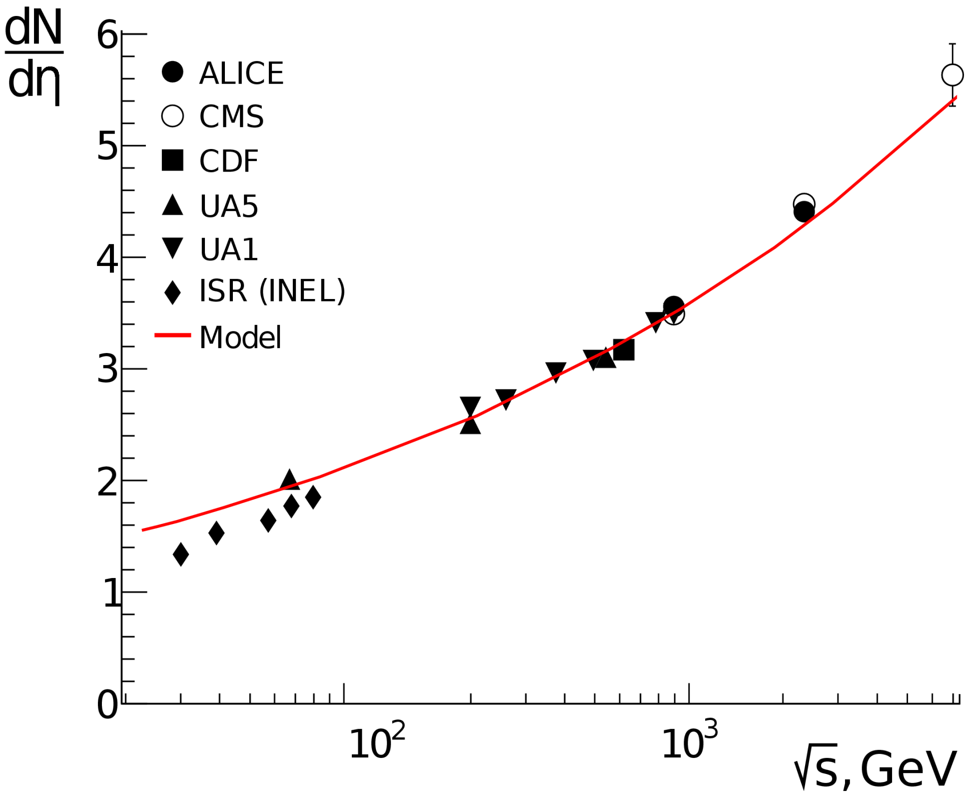
$$\times \frac{1}{n^{\beta} t} \exp\left(-\frac{\pi p_t^2}{n^{\beta} t} \right)$$

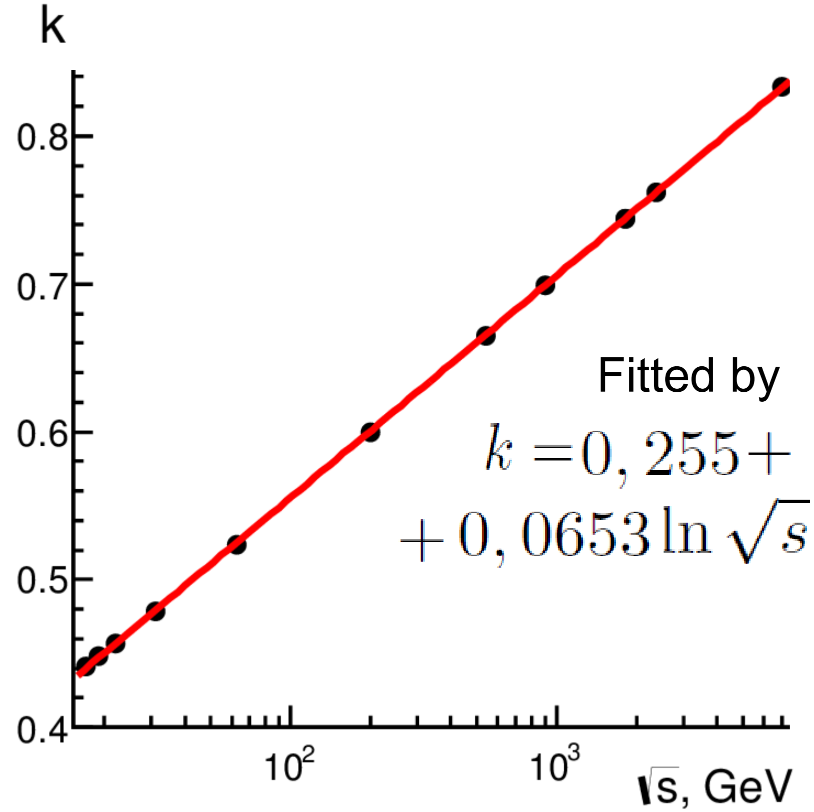
Modified Schwinger mechanism

Determination of the parameter k

from experimental data on charged multiplicity:

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

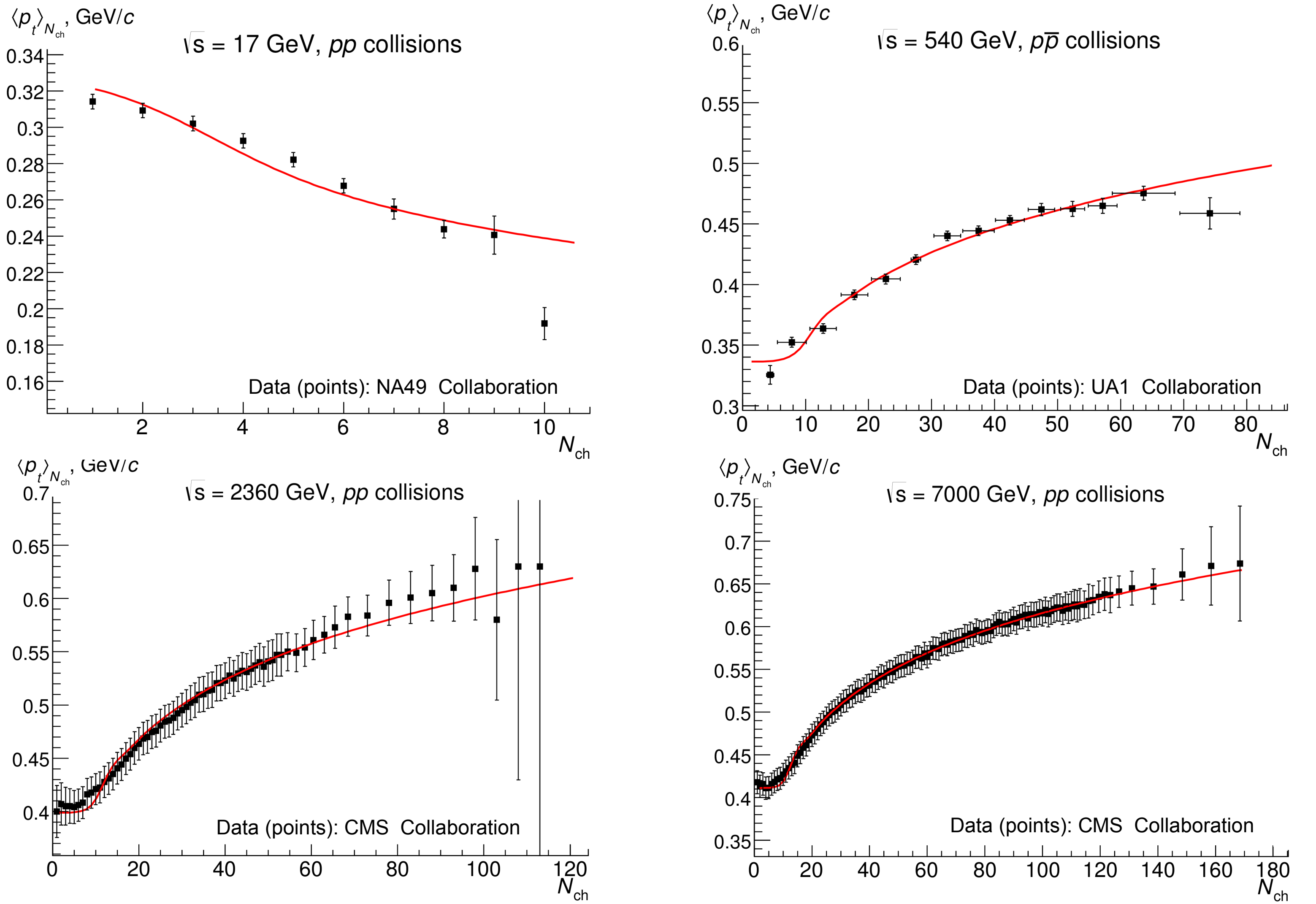




p_t-N_{ch} correlations

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

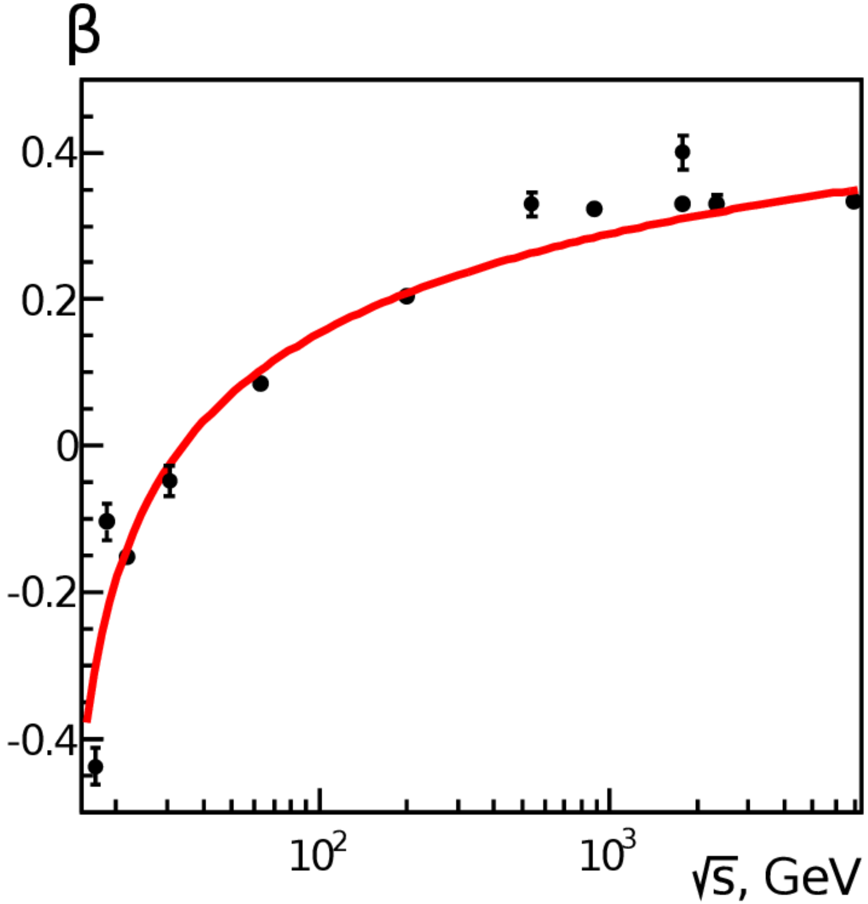
p$\bar{p}$, 1800 GeV

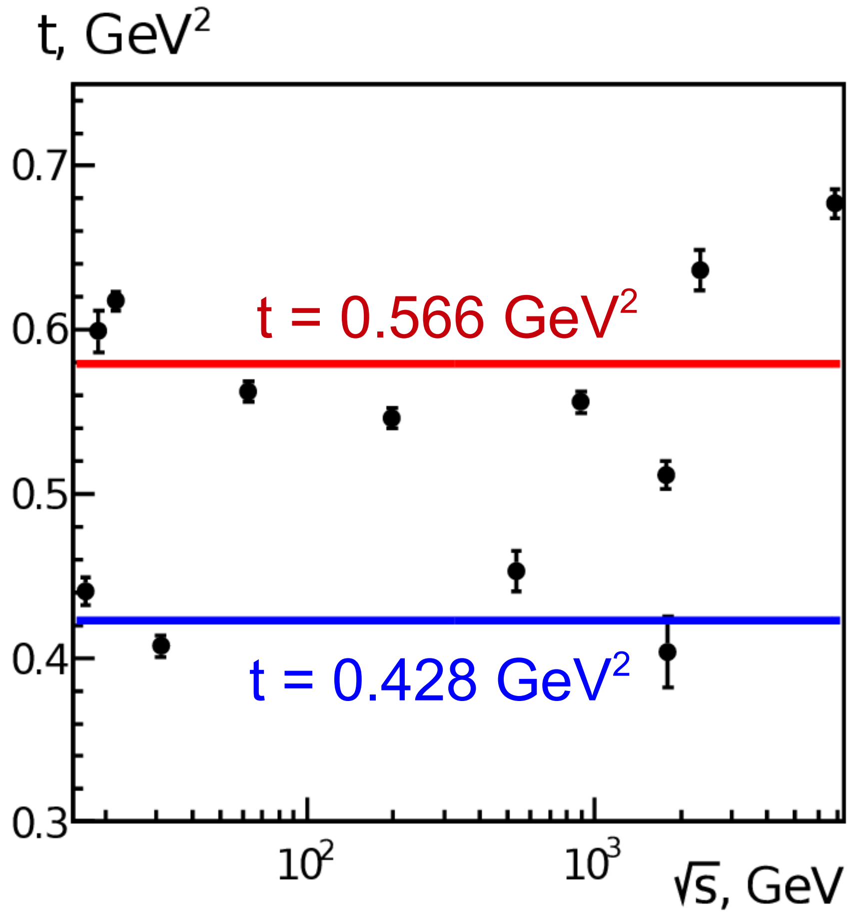
p$\bar{p}$, 1800 GeV

pp, 2360 GeV

pp, 7000 GeV

Dependence of the parameters β and t on collision energy



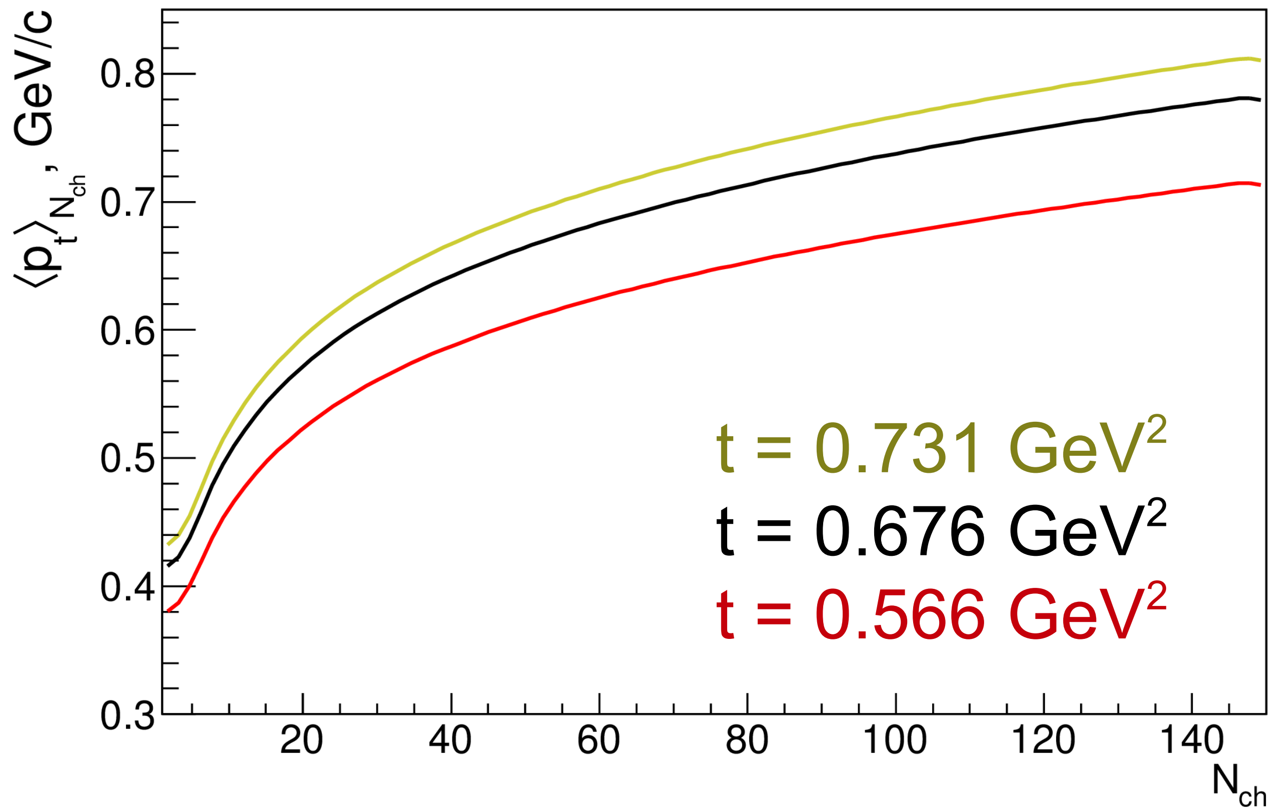


Fitted by

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

LHC predictions at 14 TeV

The predictions are made for several parameter *t* values. The plot should be chosen after specification of experimental data.

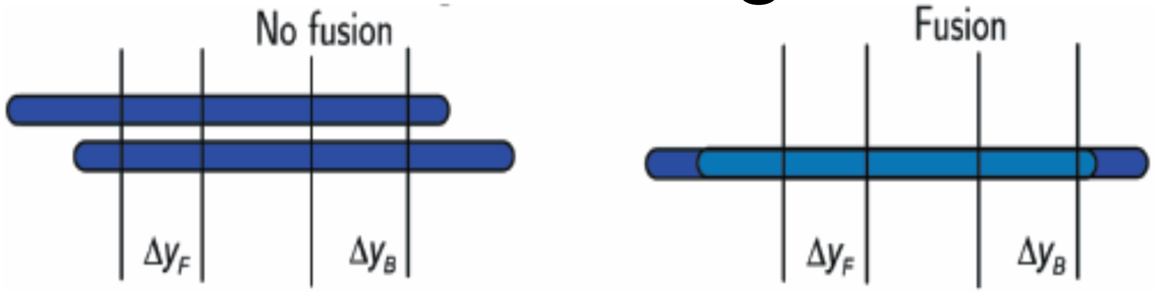


$t = 0.731$ GeV^2 – parabola fit applied

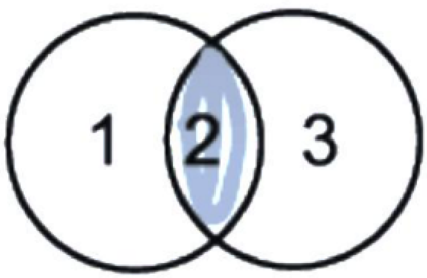
$t = 0.676$ GeV^2 – as at 7 TeV

$t = 0.566$ GeV^2 – averaged over all experimental data

relation to String Fusion



S_p – area, where p strings are overlapping



$$\langle n \rangle_p = \mu_0 \frac{S_p}{\sigma_0} \sqrt{p} \quad \langle p_t^2 \rangle_p = \overline{p^2} \sqrt{p}$$

$$\mu = \mu_0 \sqrt{\eta}, \quad p_t^2 = p_0^2 \sqrt{\eta} \quad \Rightarrow \quad \frac{p_t^2}{\mu} = \frac{p_0^2}{\mu_0}$$

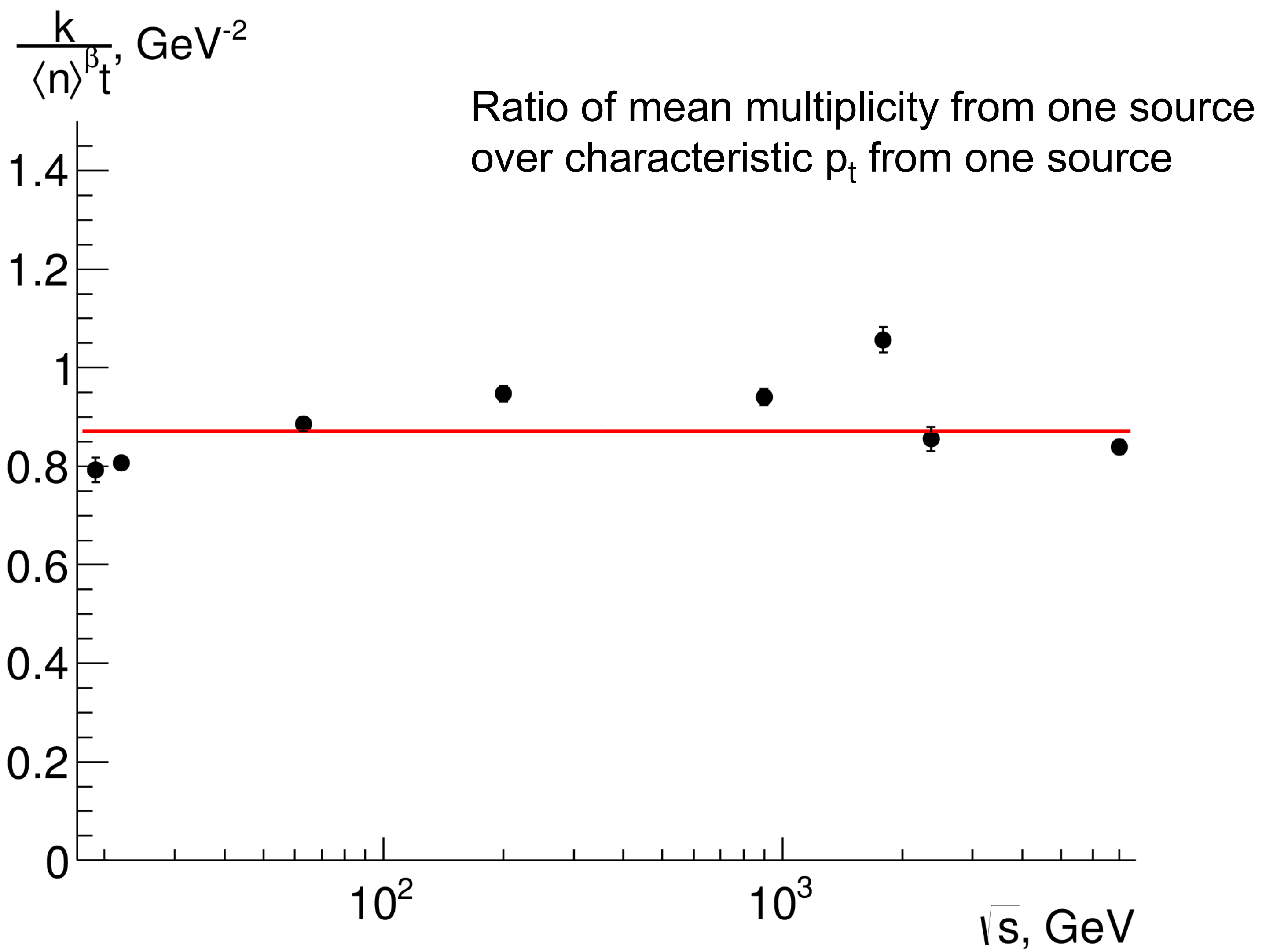
independently on energy

$$\frac{k}{\langle n \rangle^{\beta} t}$$

– mean multiplicity from one source

– characteristic transverse momentum from one source

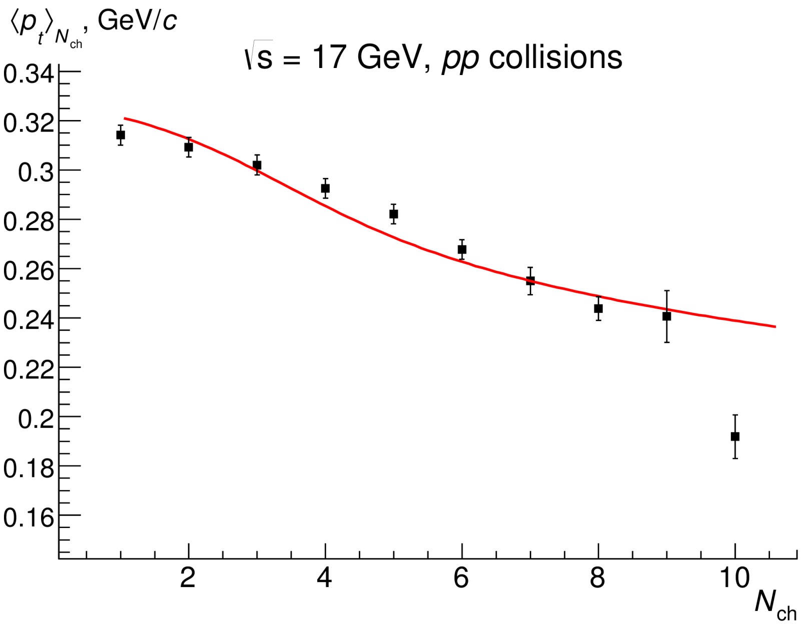
relation to String Fusion



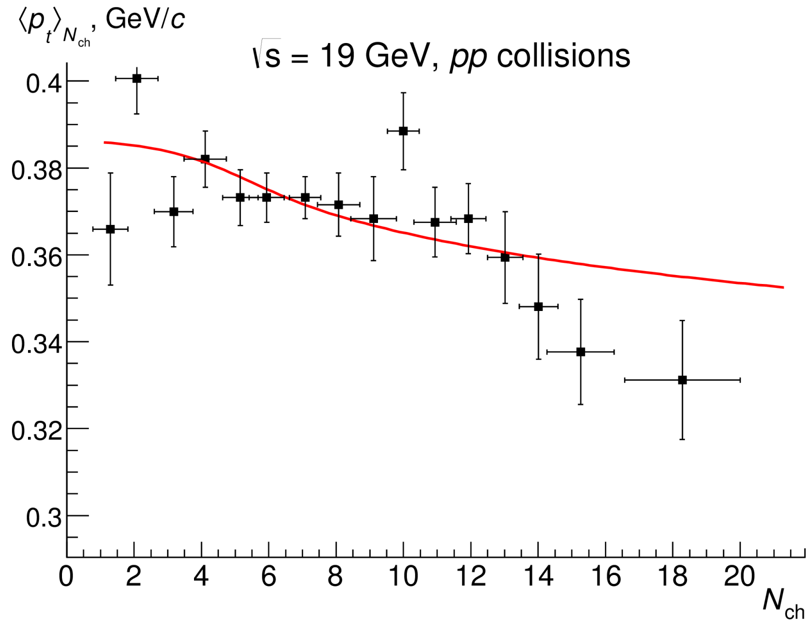
Conclusions

- Experirmental results on p_t-N_{ch} correlation are studied in a wide energy range and model parameters are obtained:
  - Logarithmic growth of mean multiplicity from one pomeron (k) with energy is obtained
  - Smooth growth of parameter β, accounting string collectivity
  - The parameter t is found to be constant.
  - Numerical agreement with string fusion model
- predictions for p_t-N_{ch} correlation behavior at the collision energy of 14 TeV have been made

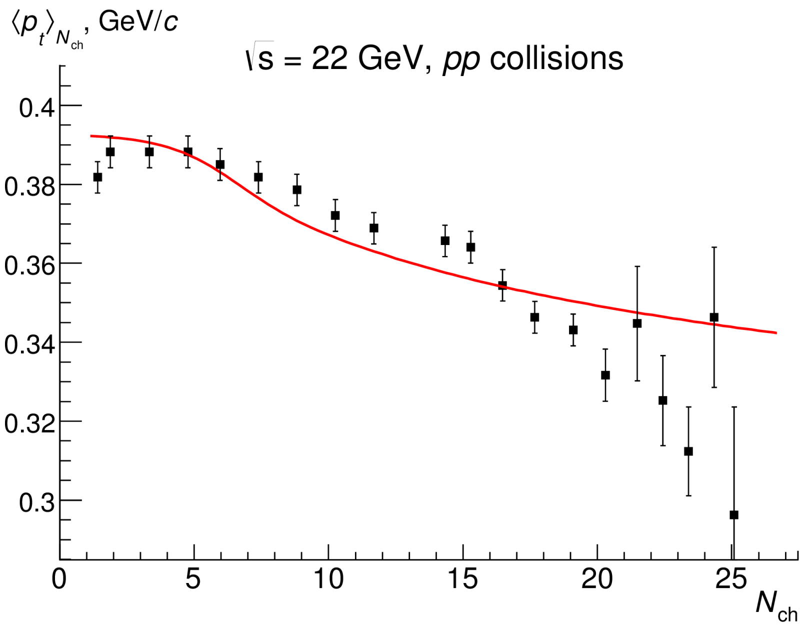
Backup slides



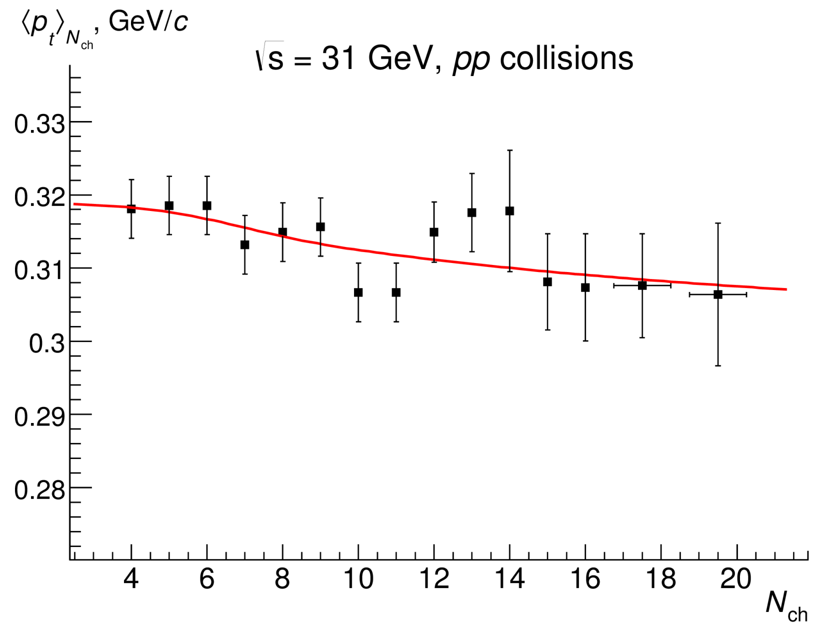
$\langle p_t \rangle_{N_{ch}}$, GeV/$c$
$\sqrt{s}$ = 17 GeV, pp collisions
N_{ch}



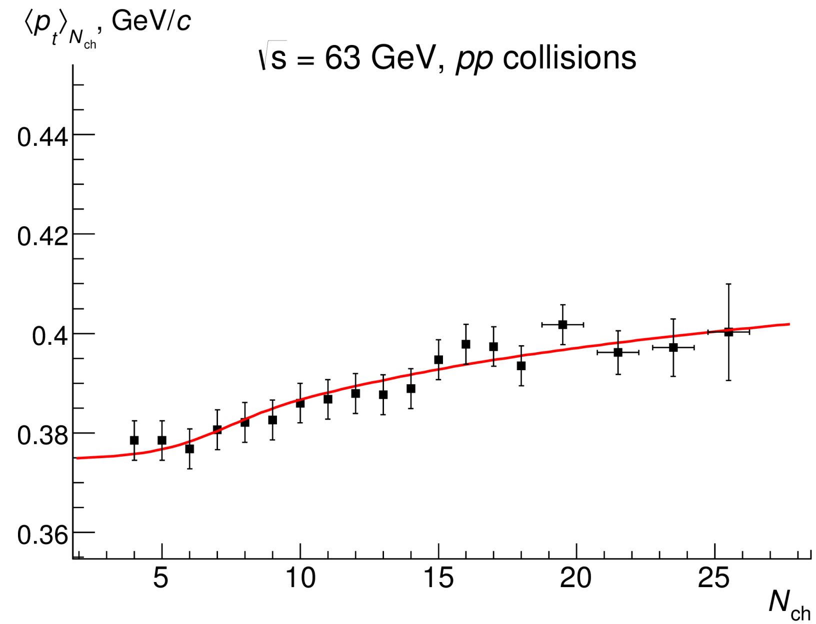
$\langle p_t \rangle_{N_{ch}}$, GeV/$c$
$\sqrt{s}$ = 19 GeV, pp collisions
N_{ch}

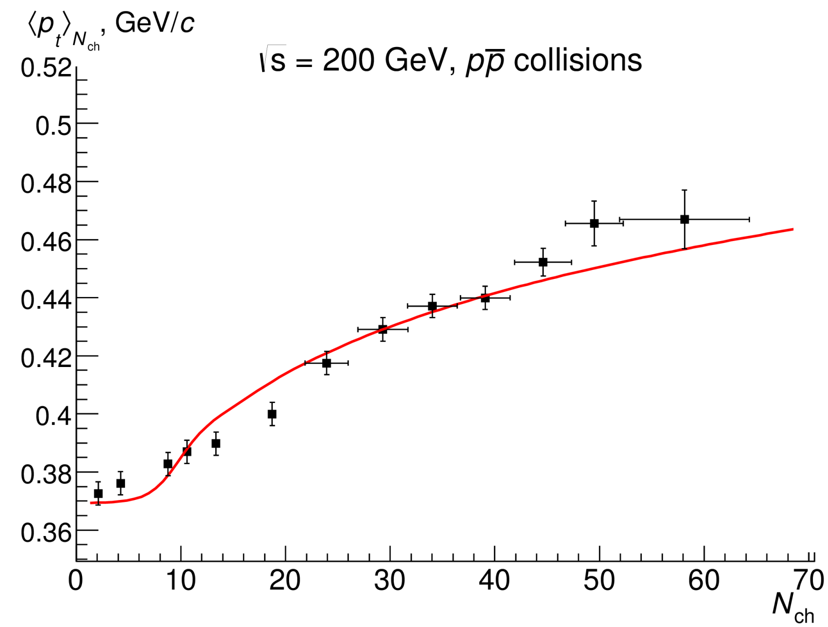


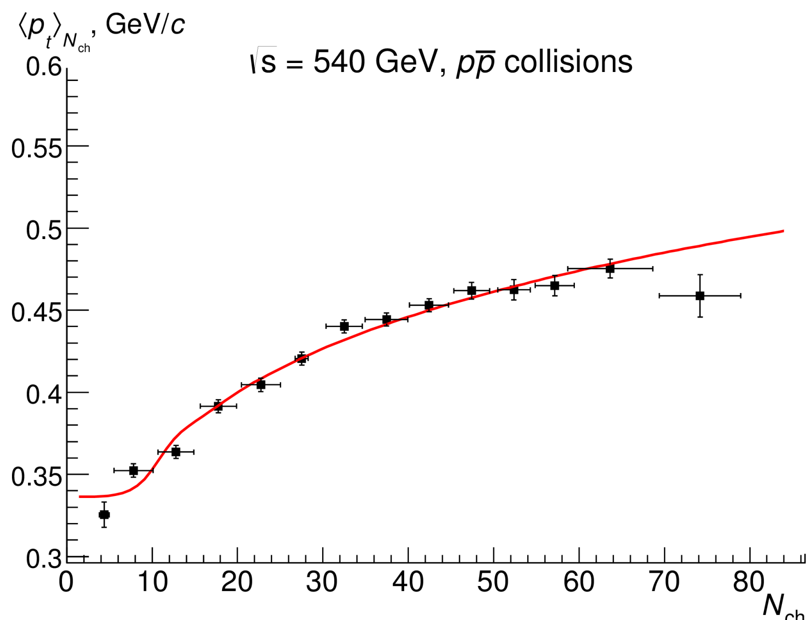
$\langle p_t \rangle_{N_{ch}}$, GeV/$c$
$\sqrt{s}$ = 22 GeV, pp collisions
N_{ch}

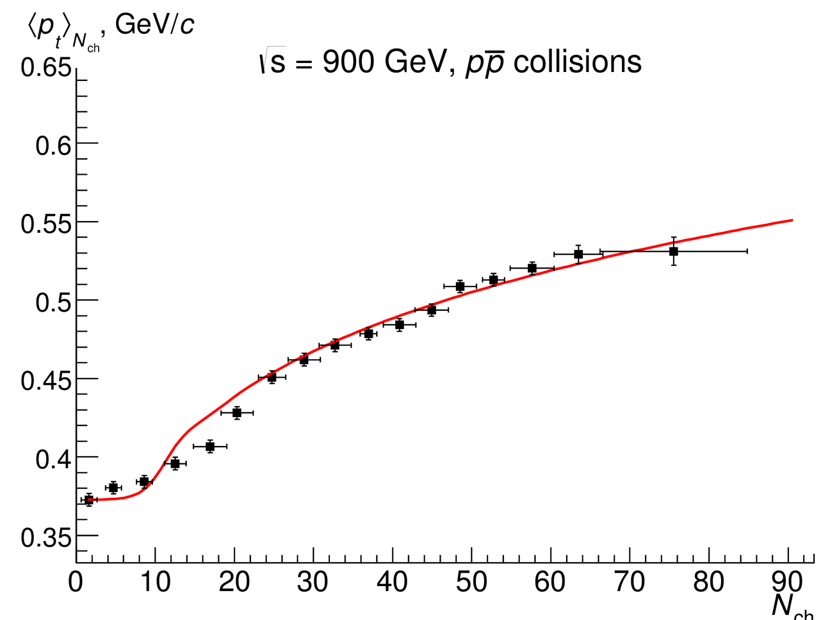


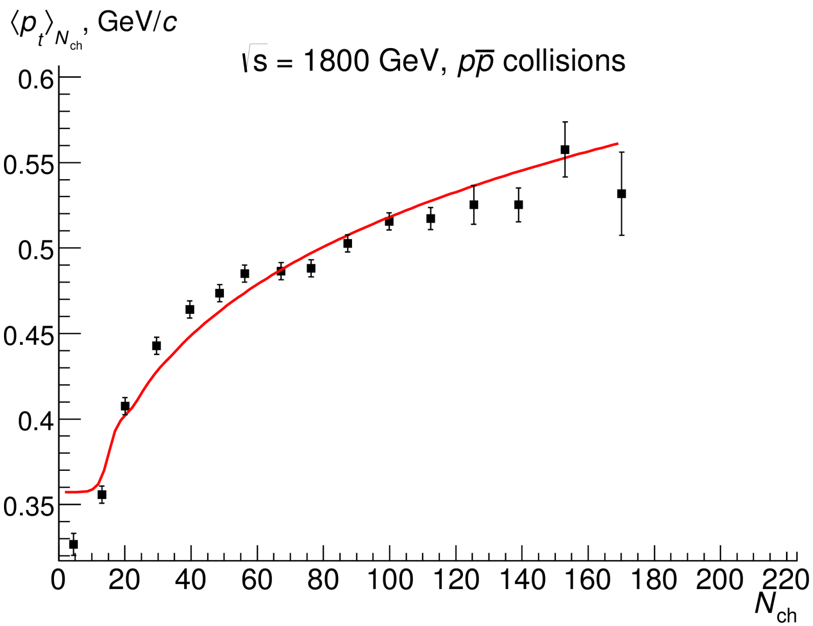
$\langle p_t \rangle_{N_{ch}}$, GeV/$c$
$\sqrt{s}$ = 31 GeV, pp collisions
N_{ch}

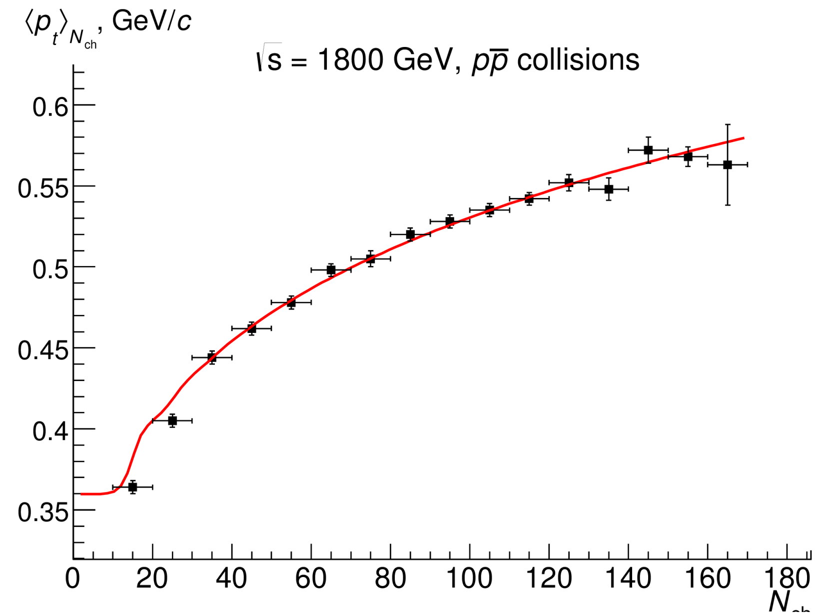

⟨p_t⟩_N_ch, GeV/c
√s = 63 GeV, pp collisions
0.44
0.42
0.4
0.38
0.36
5
10
15
20
25
N_ch

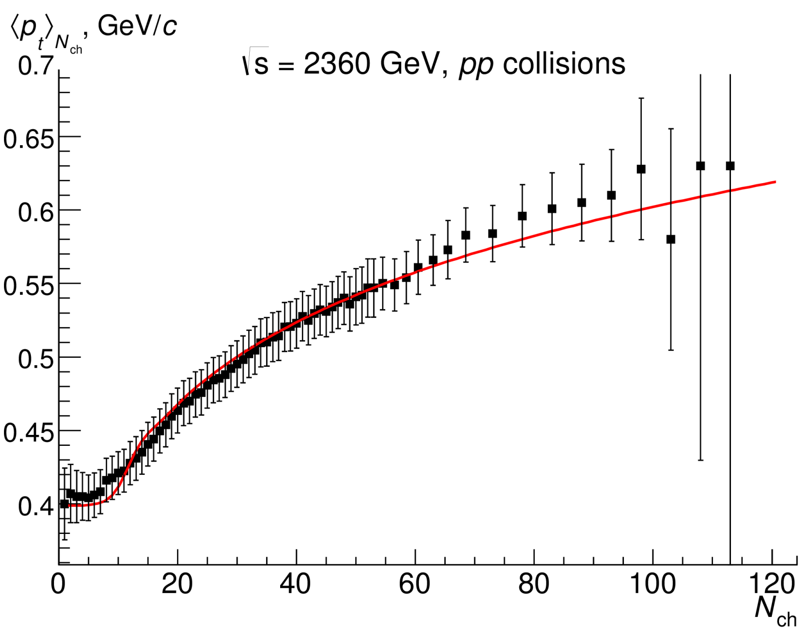

⟨p_t⟩_N_ch, GeV/c
√s = 200 GeV, pp̄ collisions
0.52
0.5
0.48
0.46
0.44
0.42
0.4
0.38
0.36
0
10
20
30
40
50
60
70
N_ch

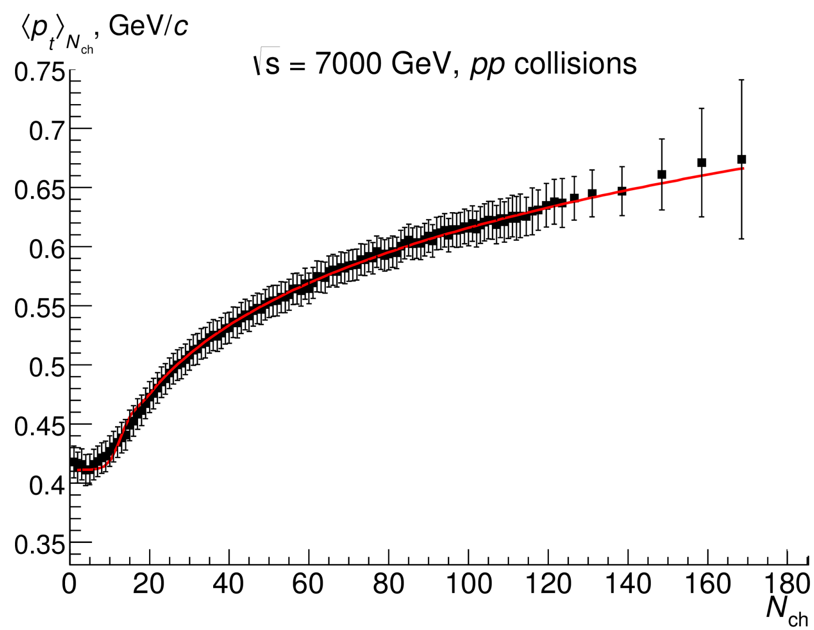

⟨p_t⟩_N_ch, GeV/c
√s = 540 GeV, pp̄ collisions
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0
10
20
30
40
50
60
70
80
N_ch


⟨p_t⟩_N_ch, GeV/c
√s = 900 GeV, pp̄ collisions
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0
10
20
30
40
50
60
70
80
90
N_ch

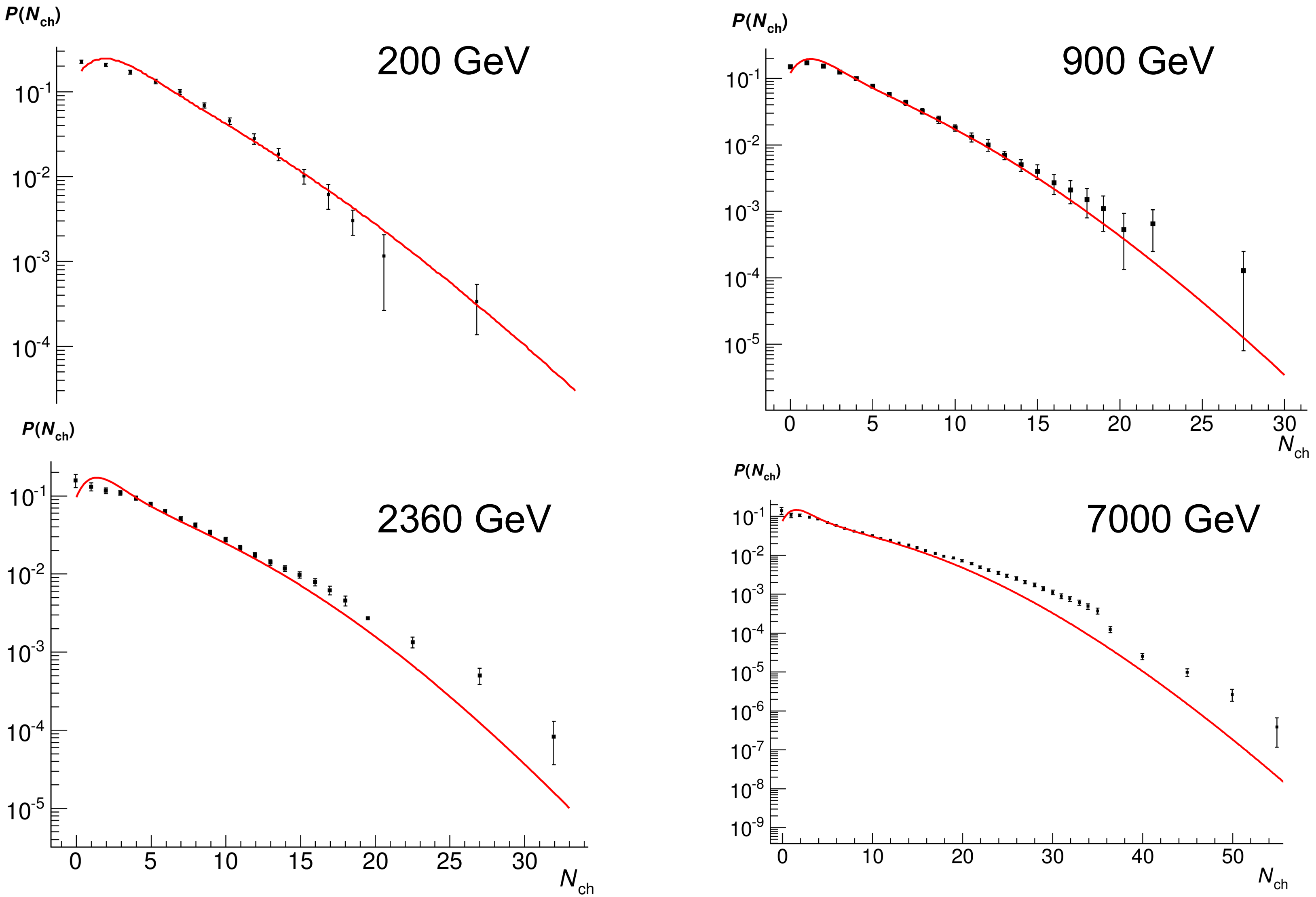

⟨p_t⟩_{N_ch}, GeV/c
√s = 1800 GeV, pp̄ collisions
0.6
0.55
0.5
0.45
0.4
0.35
0 20 40 60 80 100 120 140 160 180 200 220
N_ch


⟨p_t⟩_{N_ch}, GeV/c
√s = 1800 GeV, pp̄ collisions
0.6
0.55
0.5
0.45
0.4
0.35
0 20 40 60 80 100 120 140 160 180

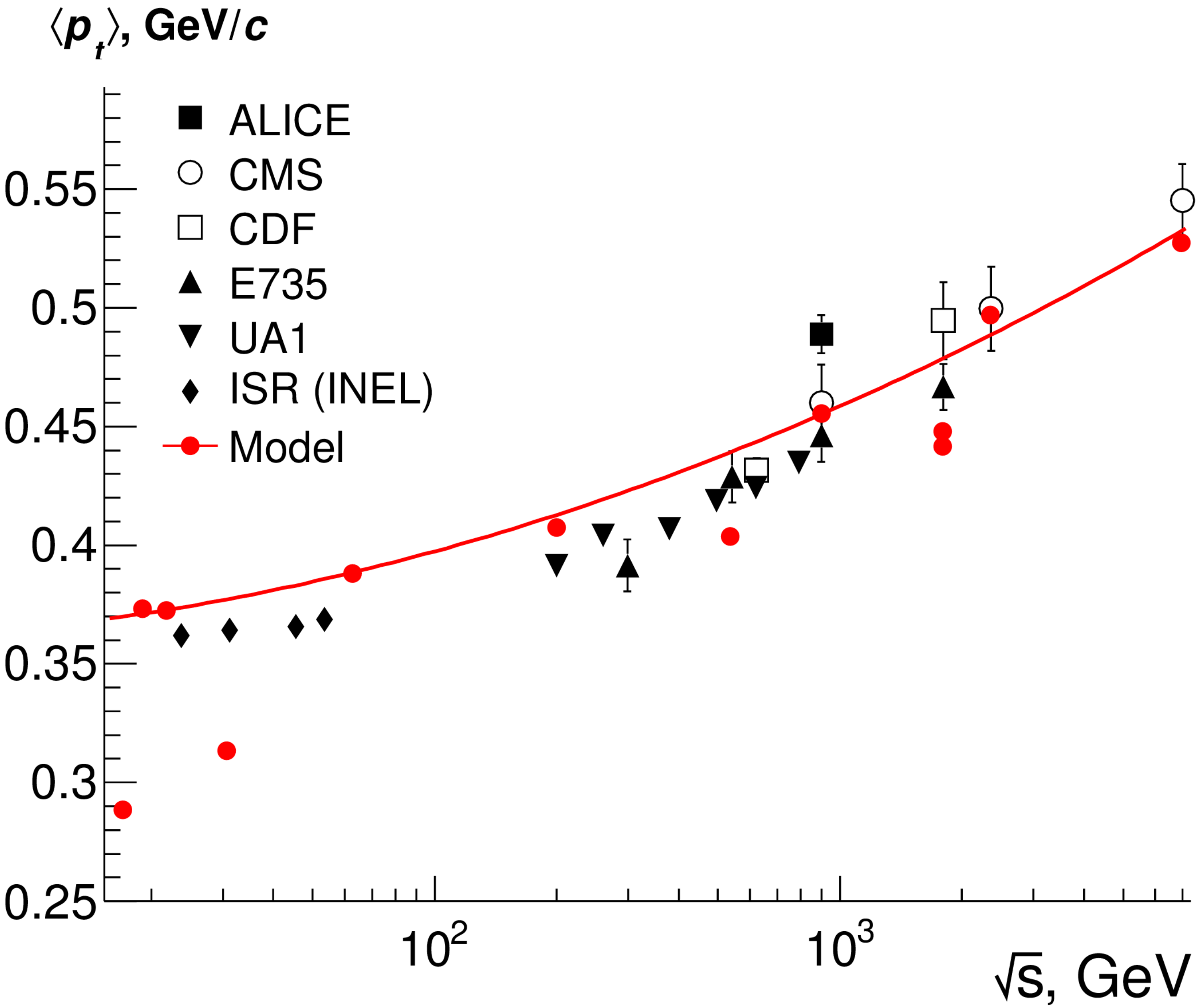

⟨p_t⟩_{N_ch}, GeV/c
√s = 2360 GeV, pp collisions
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0 20 40 60 80 100 120
N_ch


⟨p_t⟩_{N_ch}, GeV/c
√s = 7000 GeV, pp collisions
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0 20 40 60 80 100 120 140 160 180
N_ch

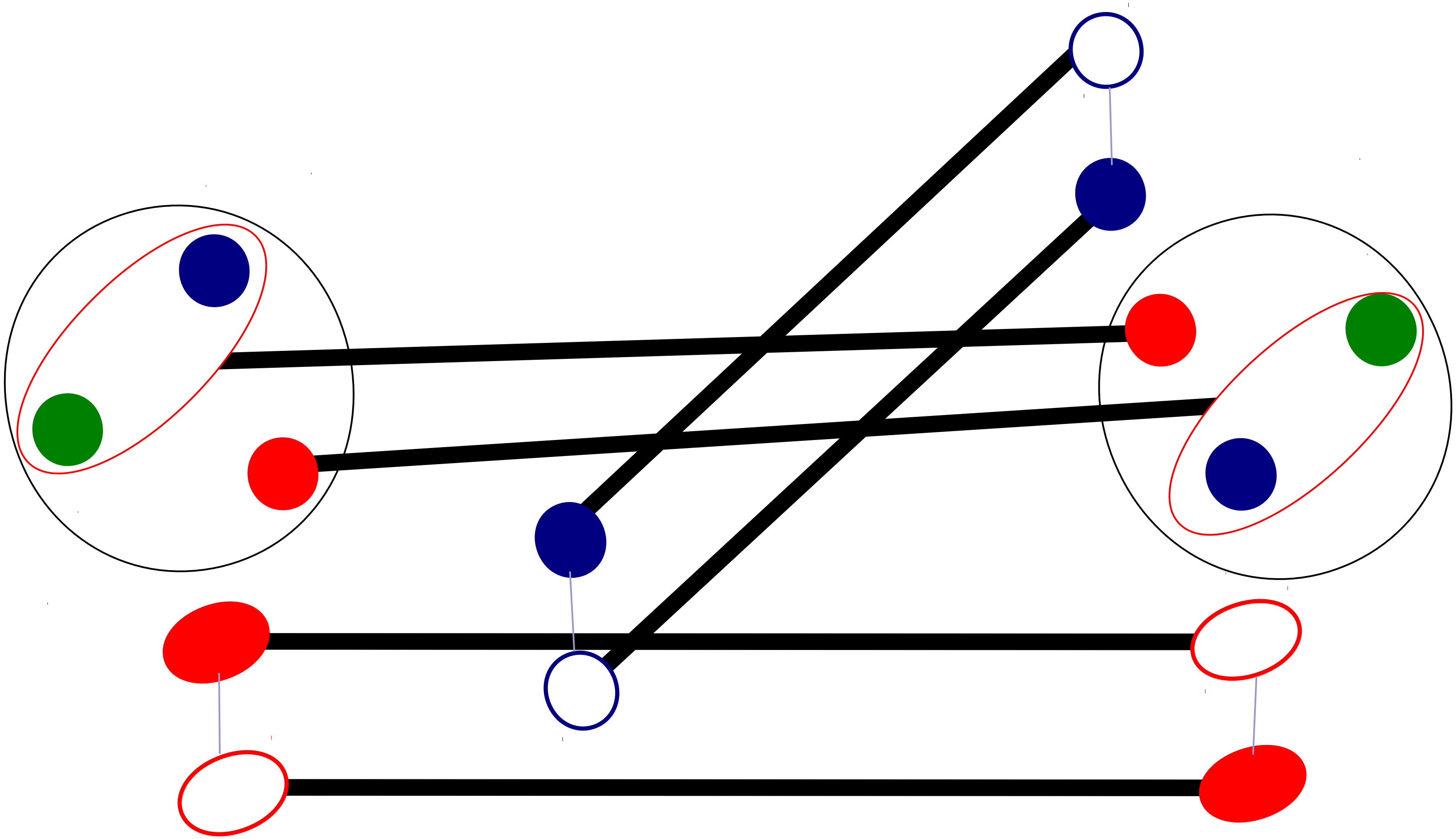
Distribution of N_{ch}



Mean transverse momentum

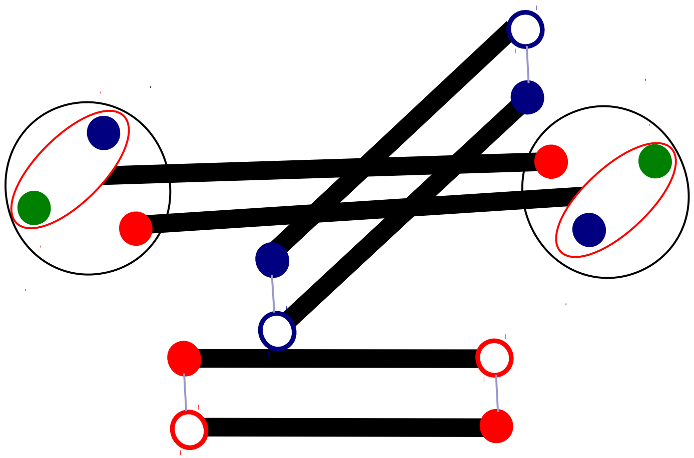


String Formation



[2] A. B. Kaidalov and K. A. Ter-Martirosyan, Phys. Lett. B 117 (1982) 247

String Formation



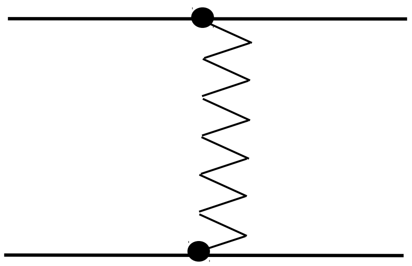
- Collective effects are observed.
- Possible solution – string interactions. [3]

[3] M. A. Braun and C. Pajares, Phys. Lett. B 287 (1992) 154; Nucl. Phys. B 390 (1993) 542, 549

Experimentally Observed p_t-N_{ch} Correlations. Features

Experimentally Observed p_t-N_{ch} Correlations. Features

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

Classical Multi-Pomeron Exchange Model

$$\frac{dN}{d^2 p_T} = \sum_n w_n P(n, N_{ch}) g(p_t)$$

w_n normalized cross section of simultaneous production of n-pomeron showers

$P(n, N_{ch})$ probability for $2n$ strings to give N_{ch} particles after hadronization

$g(p_t)$ transverse momentum distribution for particles coming from a single string

A. B. Kaidalov, K. A. Ter-Martirosyan Phys. Lett. 11B (1982) 247

Parameters

Classical model parameters:

t – average string tension

k – mean number of particles produced per unit rapidity by one string

Modificated model parameter:

β - efficient string collective coefficient