SCALING TRENDS IN P+P COLLISIONS FROM SPS TO LHC

General Characteristics of pp-collisions at LHC

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in collaboration with

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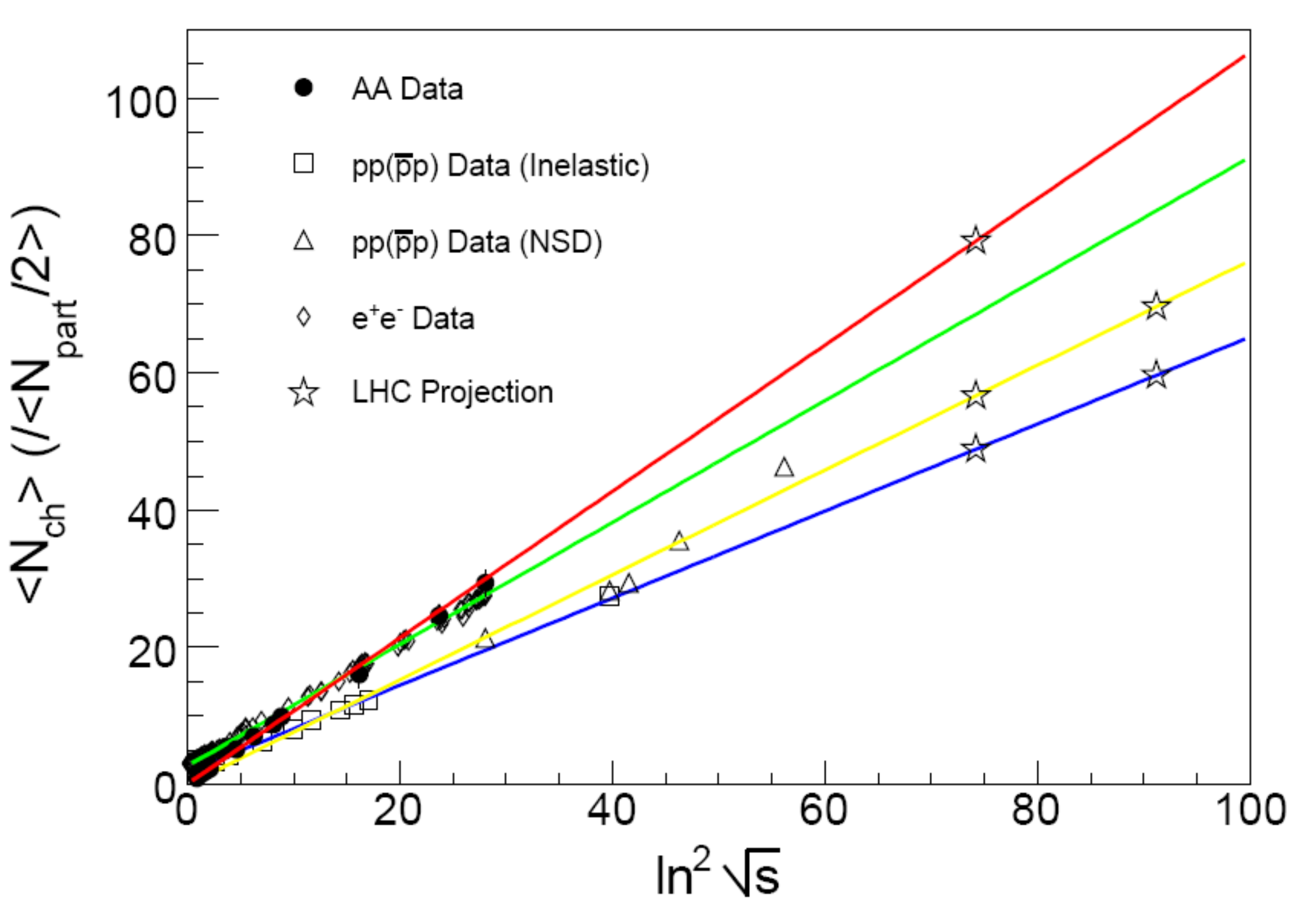
SQM2015, Dubna, 07-11.07.2015

MOTIVATION: EXPERIMENTAL RESULTS

W. Busza, JPG 35 (2008) 044040



Predictions for LHC

inelastic pp :

N_{ch}=60 ±10 (14TeV)

N_{ch}=49 ± 8 (5.5TeV)

NSD pp :

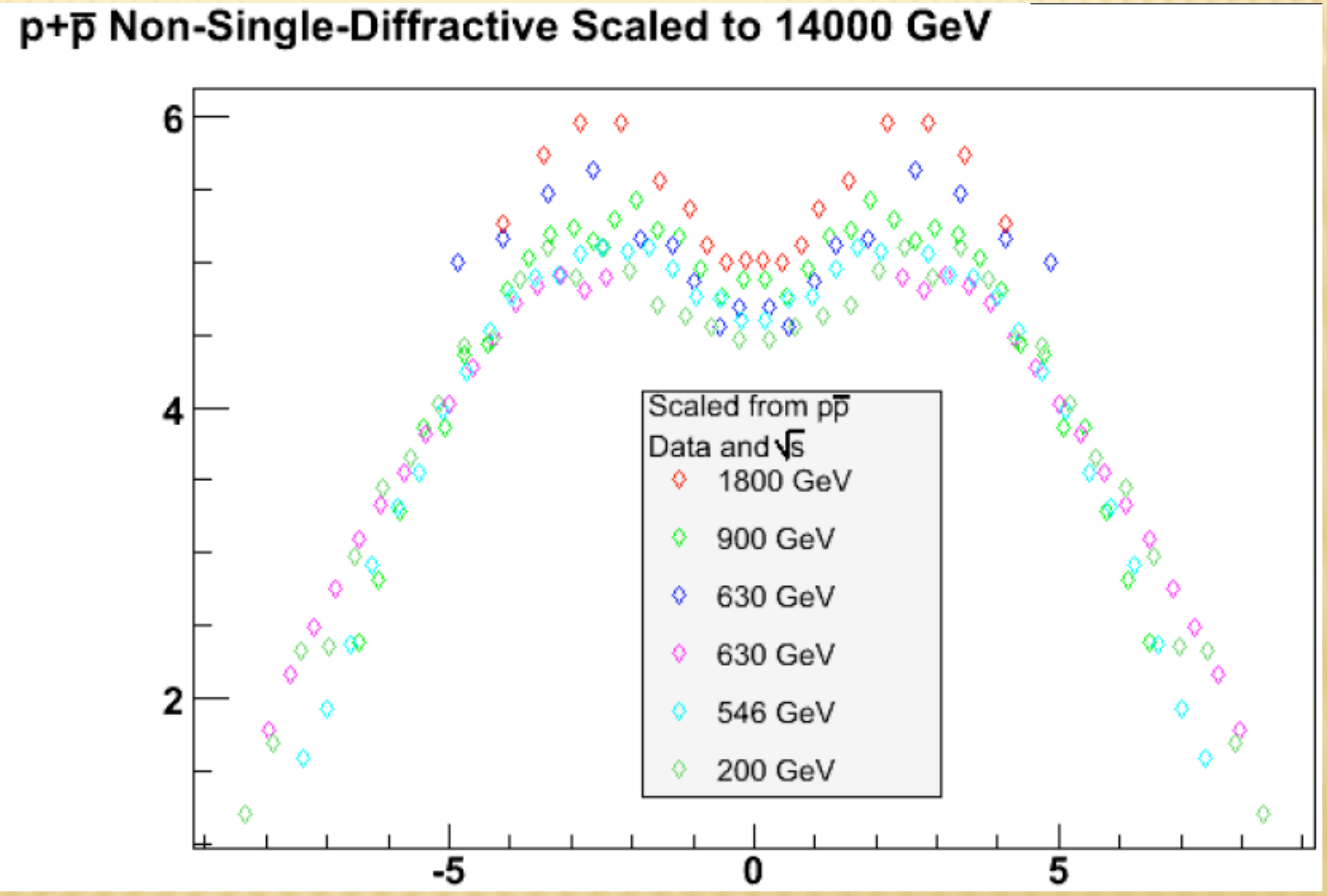
N_{ch}=70 ± 8 (14 TeV)

N_{ch}=57 ± 7 (5.5TeV)

Energy dependence of particle multiplicities

MOTIVATION: EXPERIMENTAL RESULTS

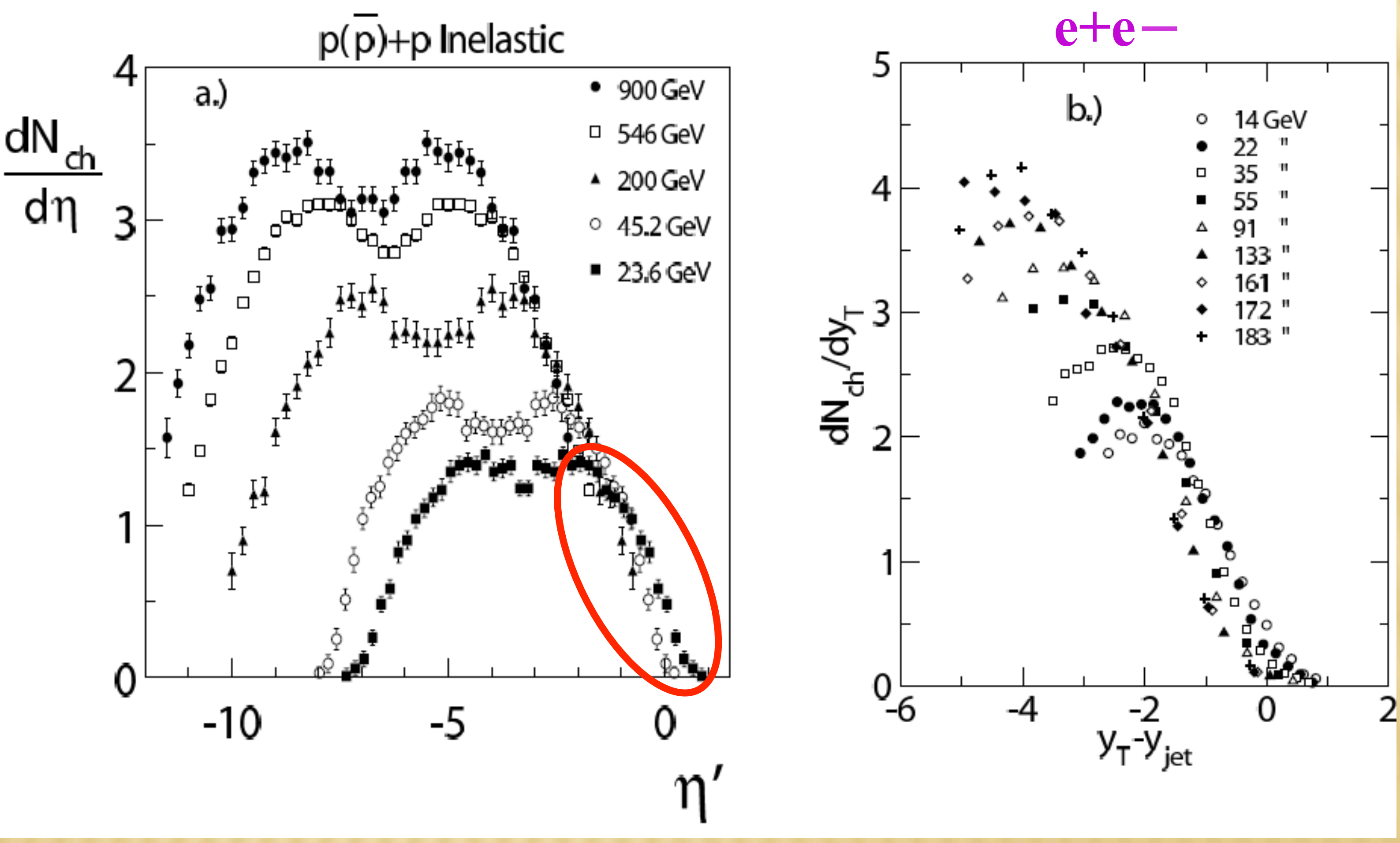
W. Busza, JPG 35 (2008) 044040



Extrapolation of NSD pp data to LHC using ln√s scaling of the width and height of the distribution

MOTIVATION: EXPERIMENTAL RESULTS

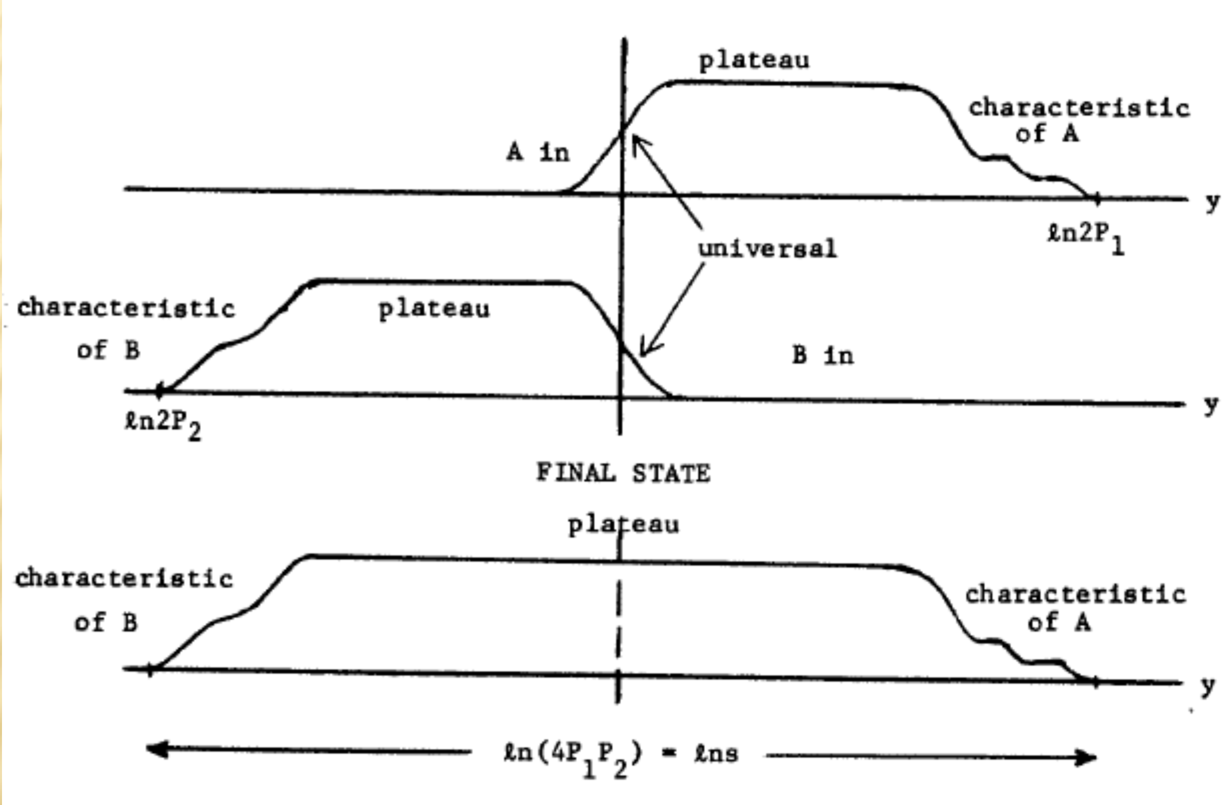
W. Busza, JPG 35 (2008) 044040



Example of extended longitudinal scaling in different reactions

HYPOTHESIS OF FEYNMAN SCALING

R. Feynman, PRL 23 (1969) 1415; also in "Photon-hadron interactions"



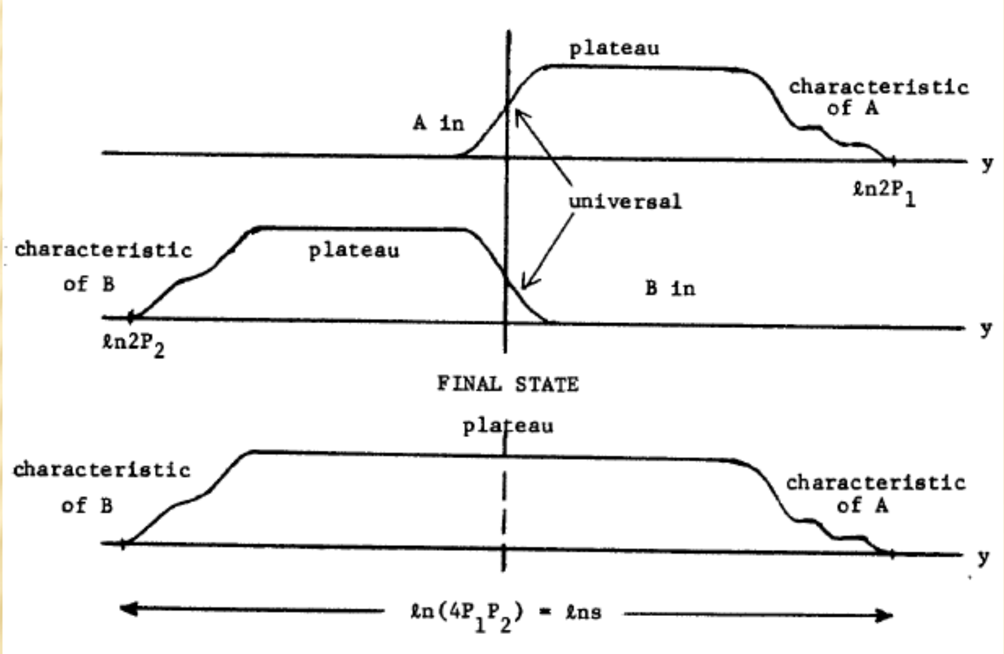
Basic assumption: scaling of inclusive spectra within the whole kinematically allowed region of x_F (or c.m. y)

In addition: existence of central area $-x_0 \le x_F \le x_0$, where $x_0 \approx (0.1-0.2)$ is assumed.

In terms of rapidity

$$-\ln[x_0\sqrt{s}/m_T] \le y^* \le \ln[x_0\sqrt{s}/m_T]$$

CONSEQUENCES OF FEYNMAN SCALING



(1) Logarithmic rise of the central rapidity region with energy

$$(\Delta y^*) \approx 2\ln(x_0\sqrt{s}/m_T)$$

(2) Fragmentation regions are fixed

$$(\Delta y^*) \approx \ln(1/x_0)$$

(3) Main contribution to mean multiplicity comes from the central area

$$\langle n \rangle : \ \ln(x_0\sqrt{s}/m_T)$$

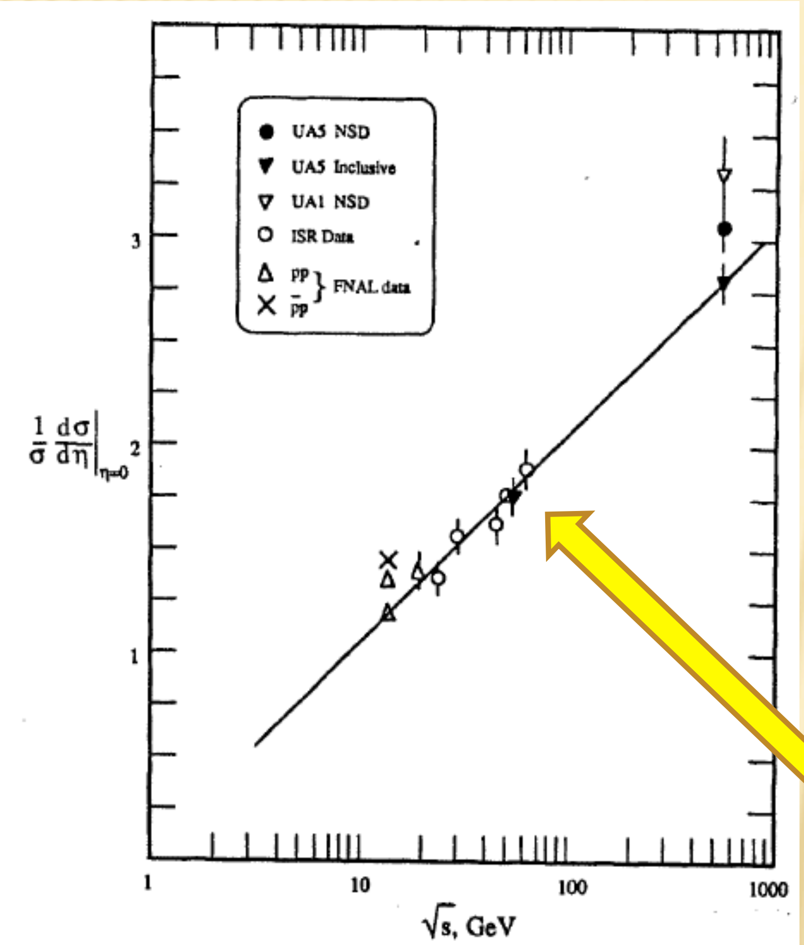
(4) In the central area particle density does not depend on energy and rapidity

$$\rho(y^*, p_T; \sqrt{s}) = \rho(p_T)$$

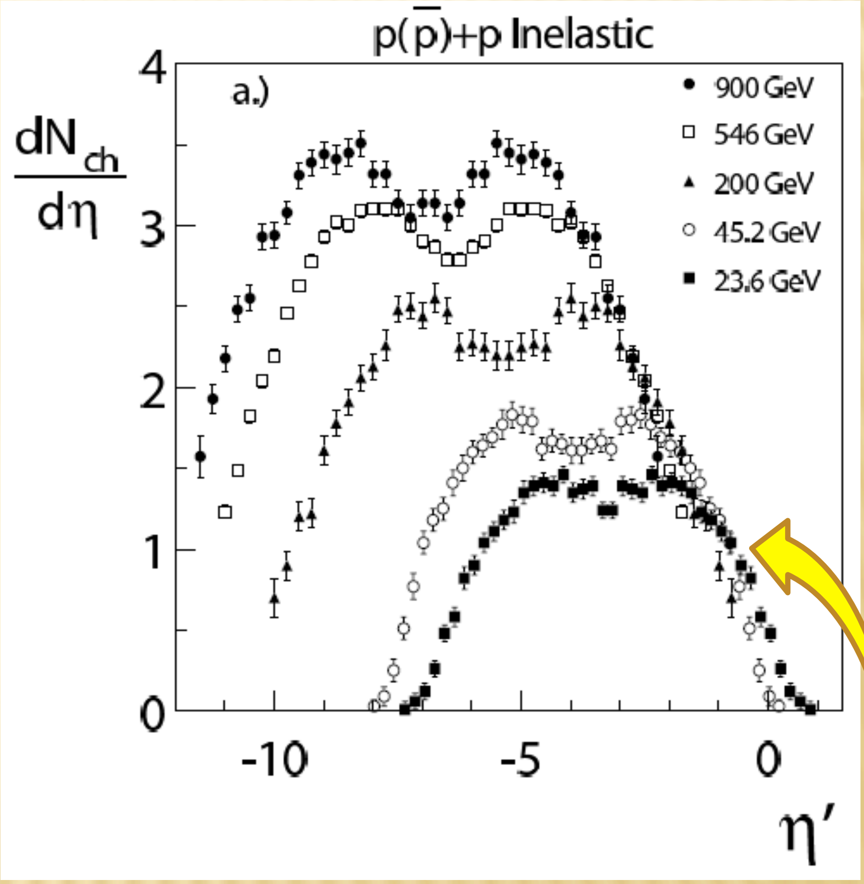
(5) Contribution from the fragmentation regions is energy independent

VIOLATION OF FEYNMAN SCALING

UA5 Collab., Phys. Rep. 154 (1987) 247



W. Busza, JPG 35 (2008) 044040

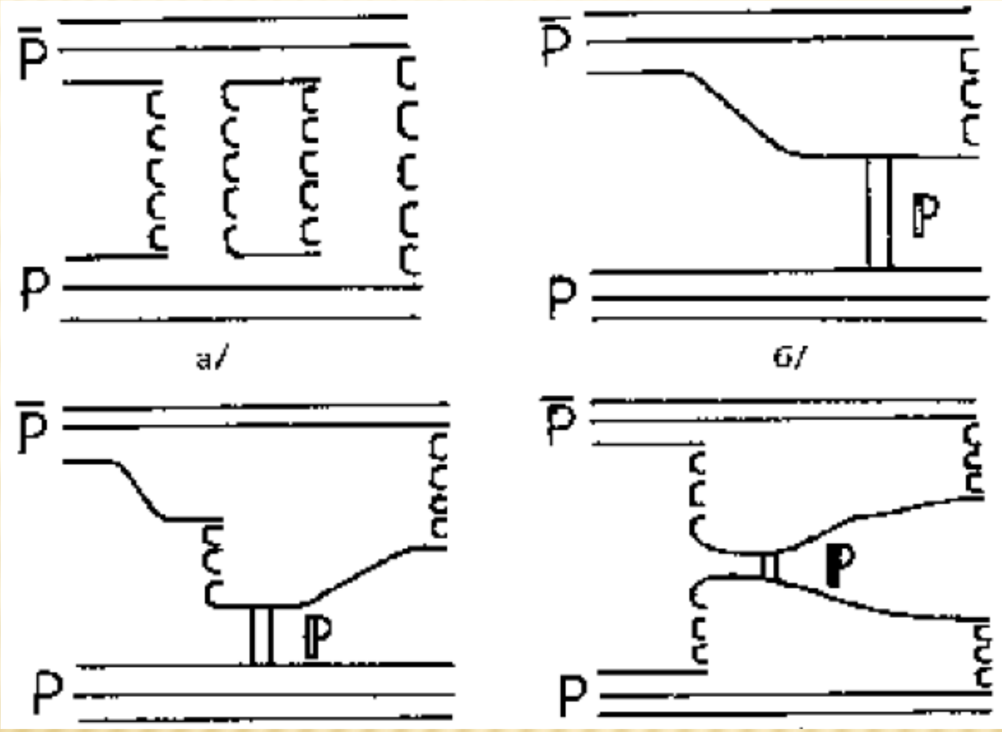


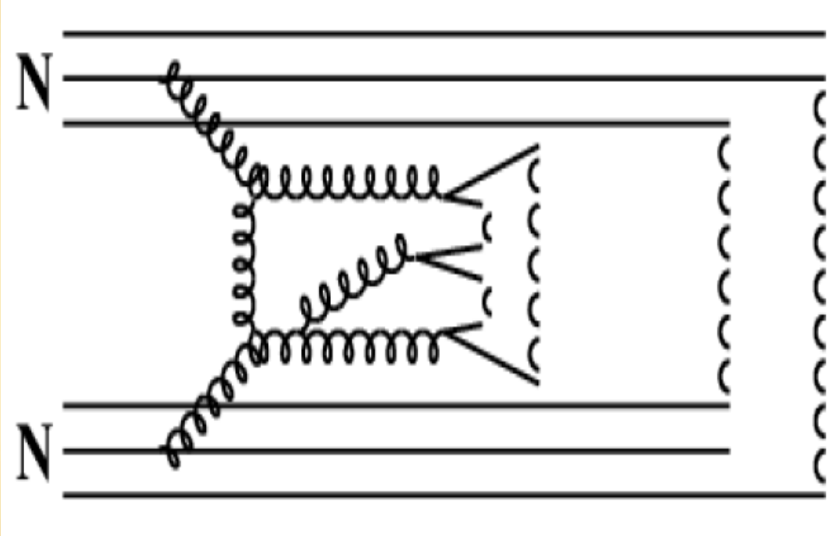
Charged particle pseudorapidity density at h = 0 as a function of √s

Violation of Feynman scaling, but ext. long. scaling holds?!

QUARK-GLUON STRING MODEL

A.B. Kaidalov, K.A.Ter-Martirosyan, PLB 117 (1982)
N.S.Amelin, L.V.Bravina, Sov.J.Nucl.Phys. 51 (1990) 133
N.S.Amelin, E.F.Staubo, L.P.Csernai, PRD 46 (1992) 4873





At ultra-relativistic energies: multi-Pomeron scattering, single and double diffraction, and jets (hard Pomeron exchange)

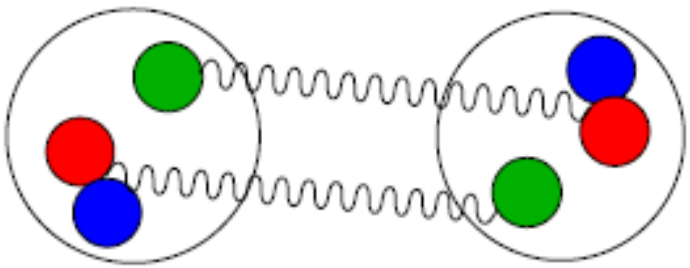
Gribov’s Reggeon Calculus + string phenomenology

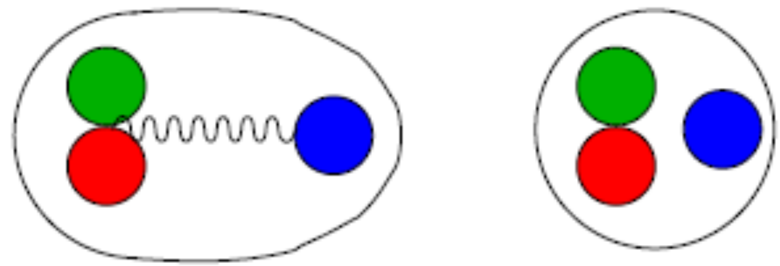
QUARK-GLUON STRING MODEL

two different mechanisms:

- excitation due to exchange of pomerons (color exchange)
- transverse strings

- excitation due to tranfer of momentum to a single parton
- longitudinal string





- n cut pomerons give $2n$ strings

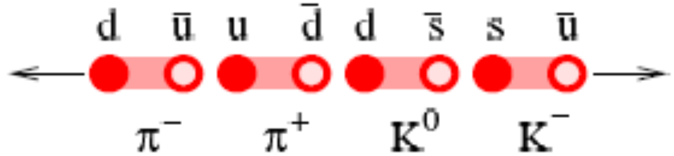
- purely phenomenological process

Excitation of color neutral strings

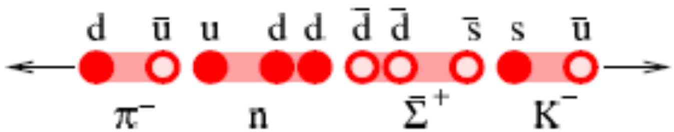
QUARK-GLUON STRING MODEL

Decay of strings - production of mesons and baryons:

- the colorfield between a quark and a antiquark gets “streched”
- a meson (baryon) with some transverse momentum is formed and gets a fraction z of the primordial momentum of the string
- z is generated from the fragmentation function
- the rest of the string either decays further of forms a cluster



production of mesons



production of baryons

Decay of strings and particle production

Predictions for LHC.

7. $\langle n_{ch} \rangle$ $80 \div 100$

8. $\left.\frac{dn_{ch}}{dy}\right|_{y=0}$ $5.5 \div 6.0$

9. Structures in σ_n

10. Strong long-range (in y) correlations

11. Large amount of minijets.

7. QGSM: Predictions for LHC.

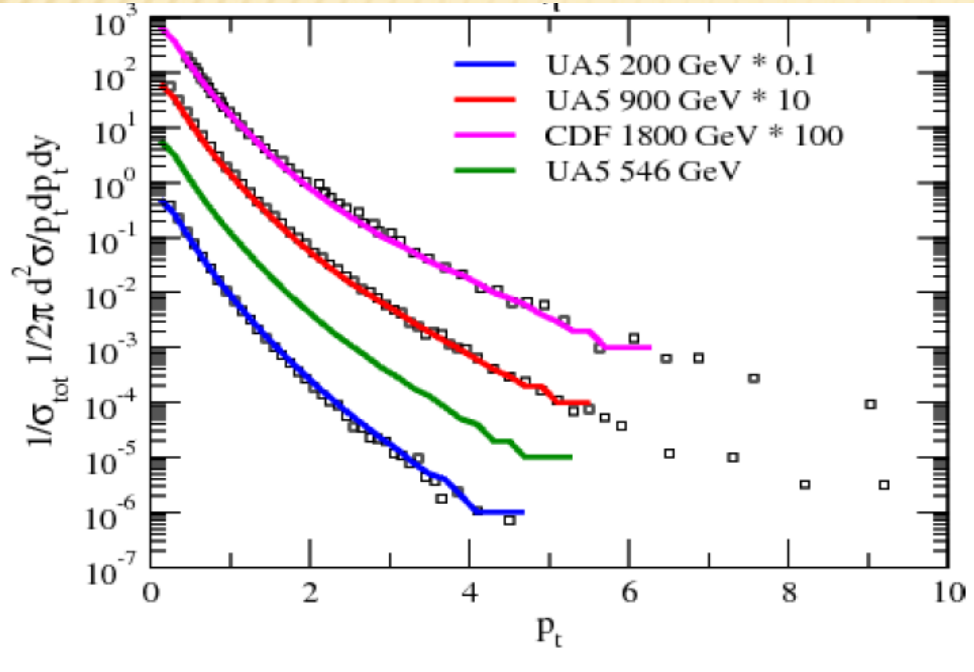
1.	$\sigma^{(tot)}$	103 mb	$(\sigma^{(tot)}(s) \sim \ln^2 \frac{s}{s_0})$
2.	$\sigma^{(el)}$	26 mb	$(\sigma^{(el)}(s) \sim \ln^2 \frac{s}{s_0})$
3.	$B(0)$	21.5 GeV^{-2}	$(B(0) \sim \ln^2 \frac{s}{s_0})$
4.	$\rho = \frac{ReT(0)}{ImT(0)}$	0.11	
5.	σ_{SD}	12÷13 mb	$(\sigma_{SD} \sim \sigma_{DD} \sim \ln \frac{s}{s_0})$
6	σ_{DD}	11÷13 mb	

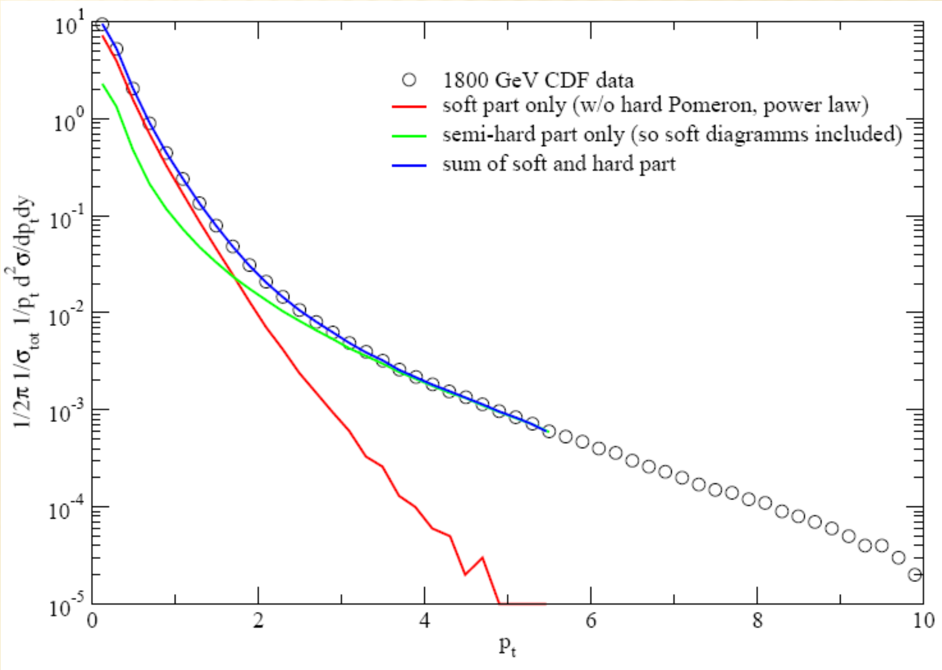
$$\sigma^{(el)} + \sigma_{SD} + \sigma_{DD} = 51\,mb \approx \frac{1}{2}\sigma^{(tot)}$$

RAPIDITY AND P_T SPECTRA: MODEL VS. DATA

Transverse momentum spectra

Hard and soft components

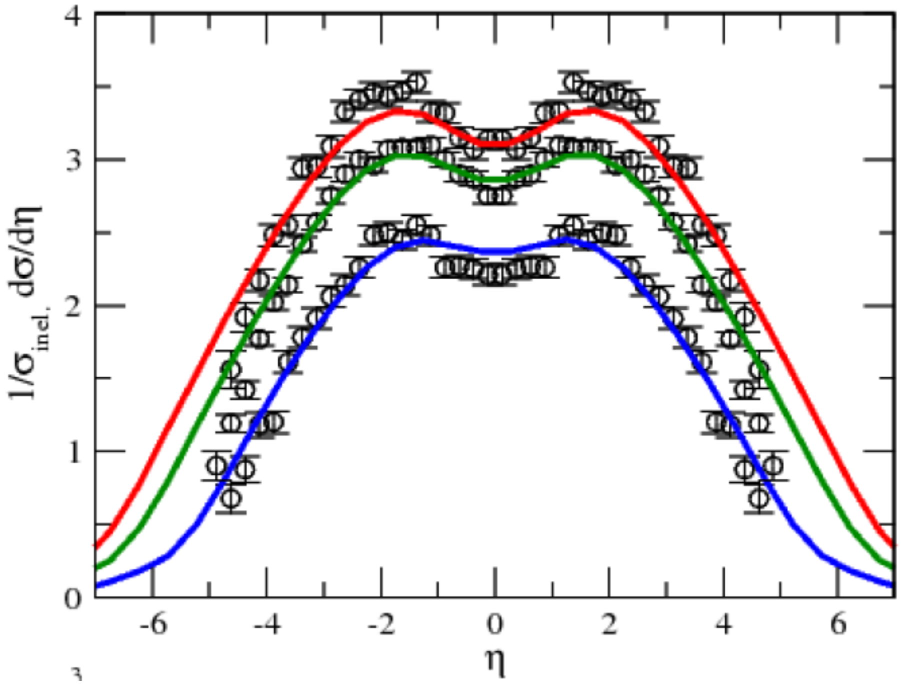




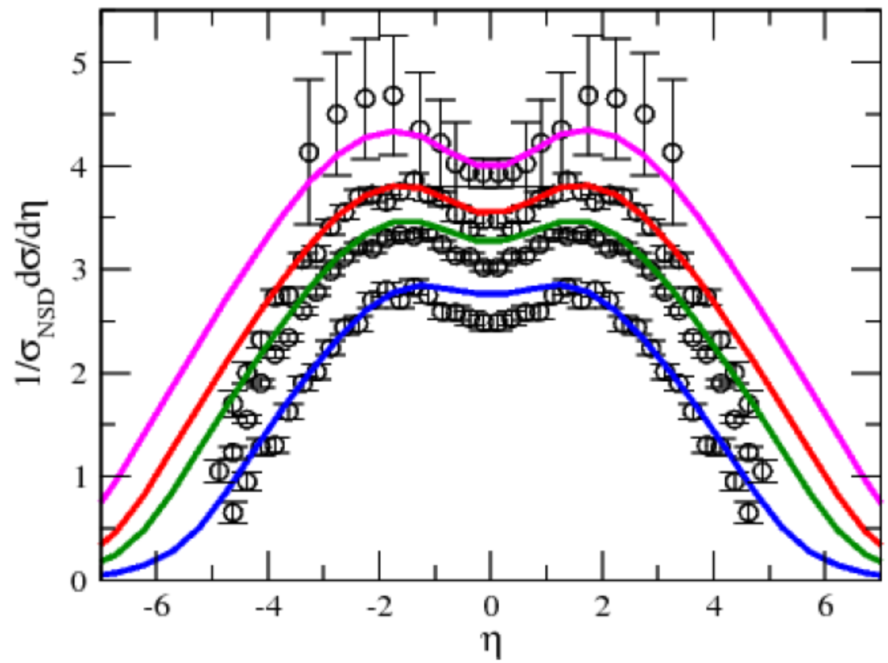
Description of P_t distributions seems to be good

RAPIDITY AND P_T SPECTRA: MODEL VS. DATA

Inelastic collisions



NSD collisions

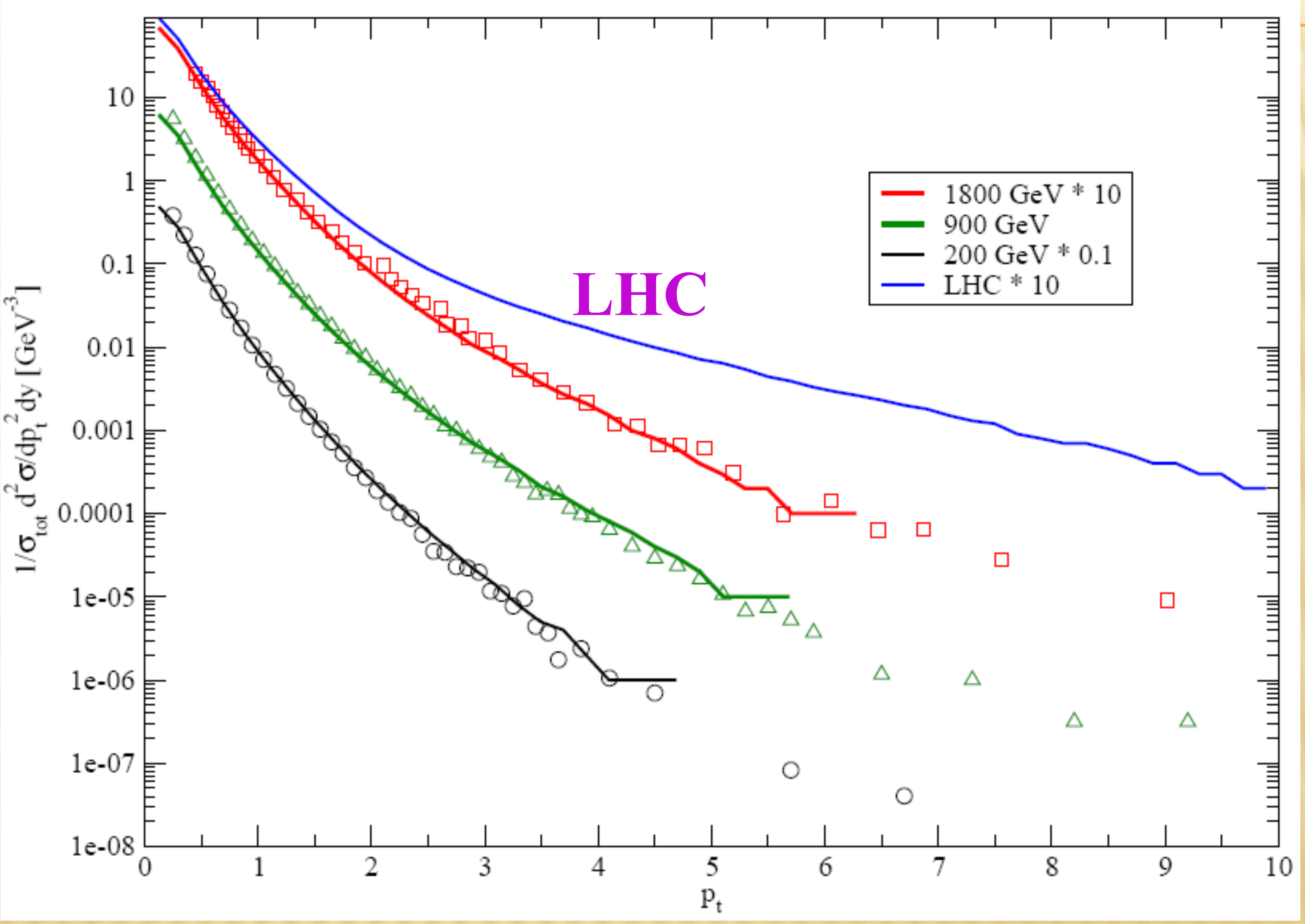


200, 546, 900 GeV

200, 546, 900, 1800 GeV

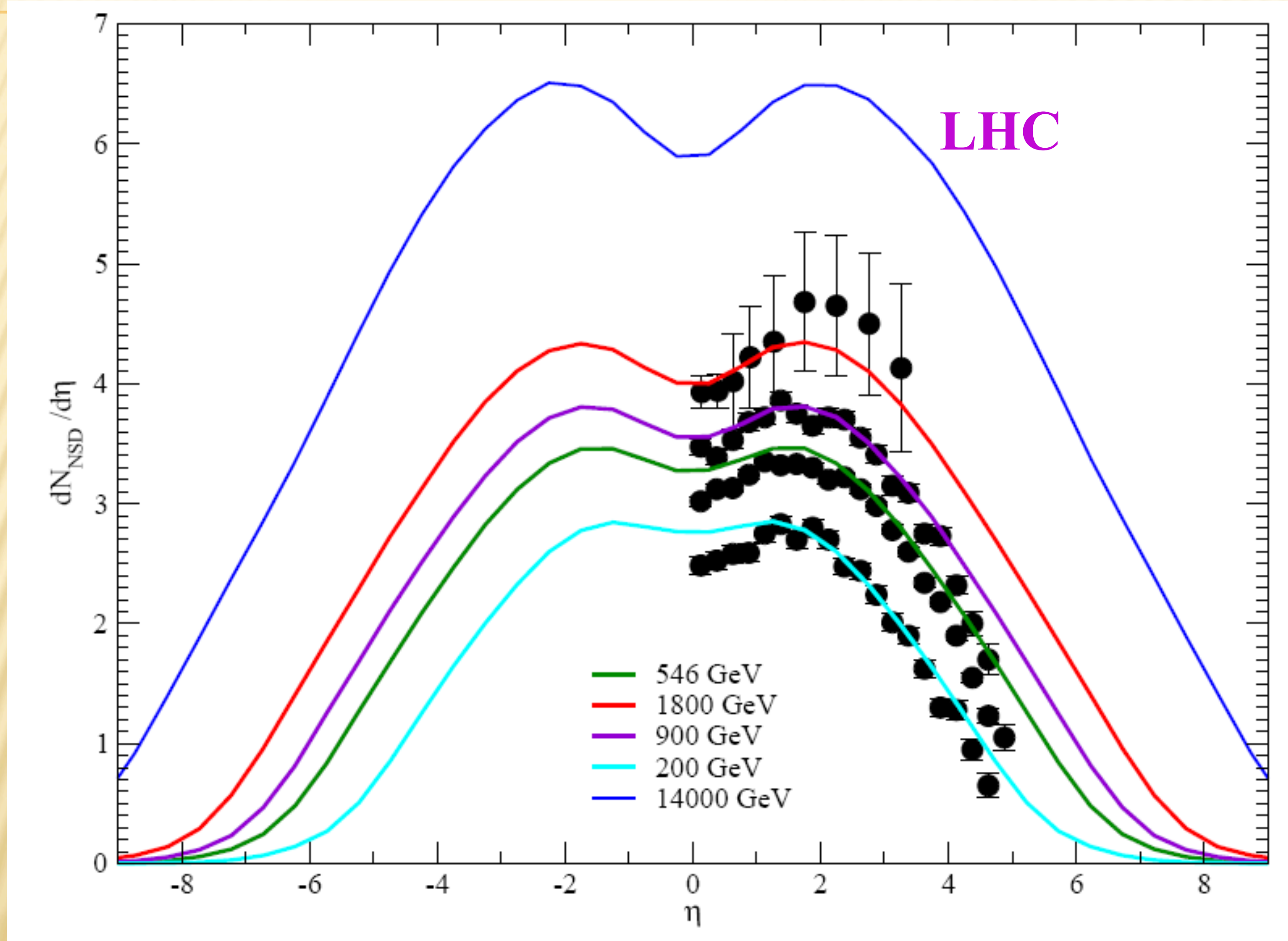
Description of pseudorapidity spectra seems to be good

PREDICTIONS FOR P+P @ LHC



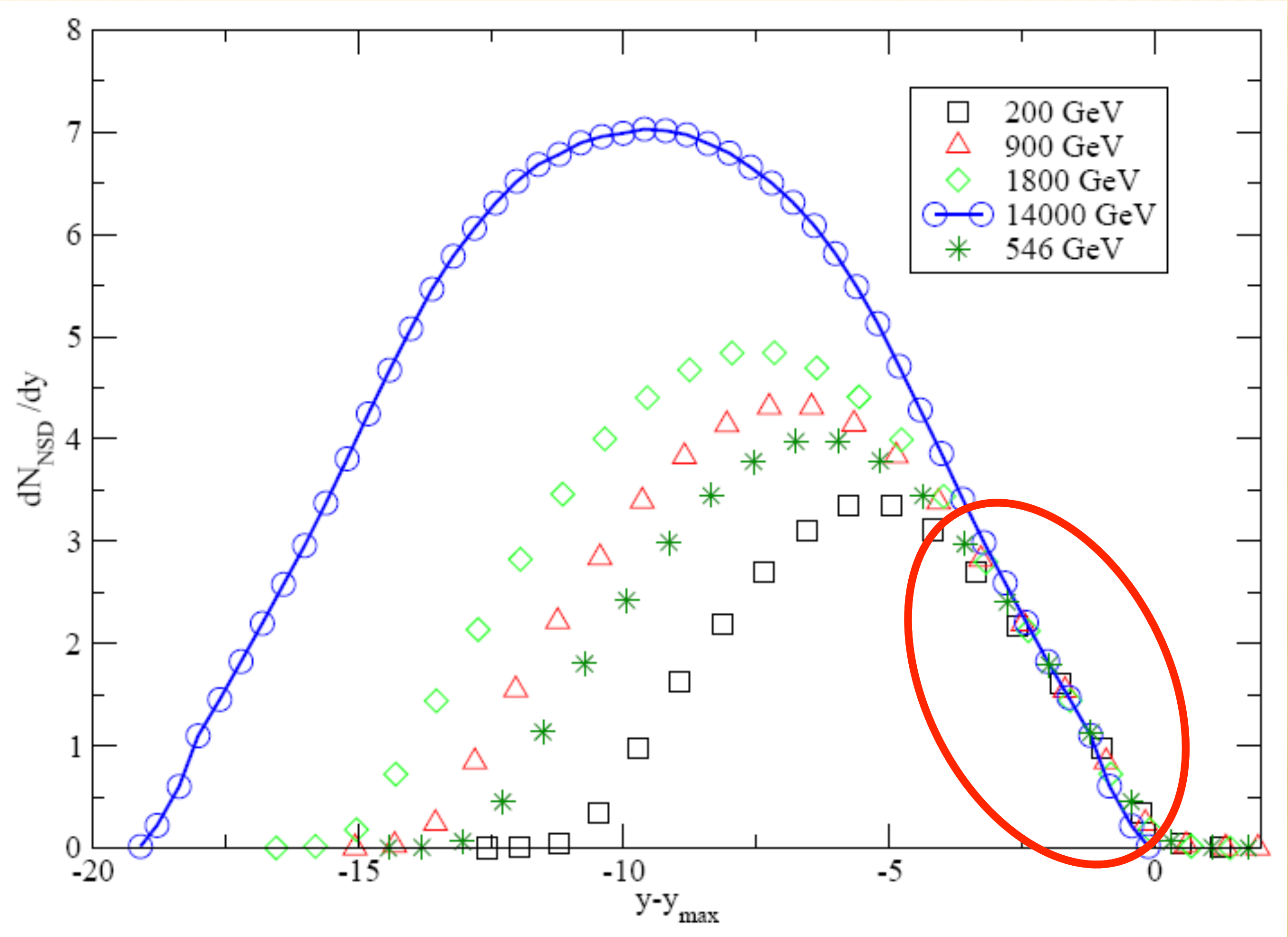
QGSM: transverse momentum distribution of particles

PREDICTIONS FOR P+P @ LHC



QGSM: pseudorapidity distribution of particles

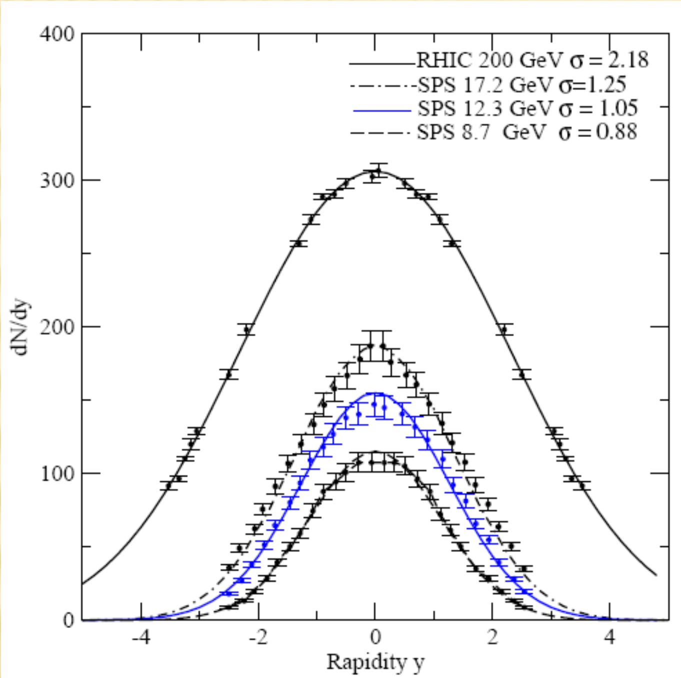
PREDICTIONS FOR P+P @ LHC

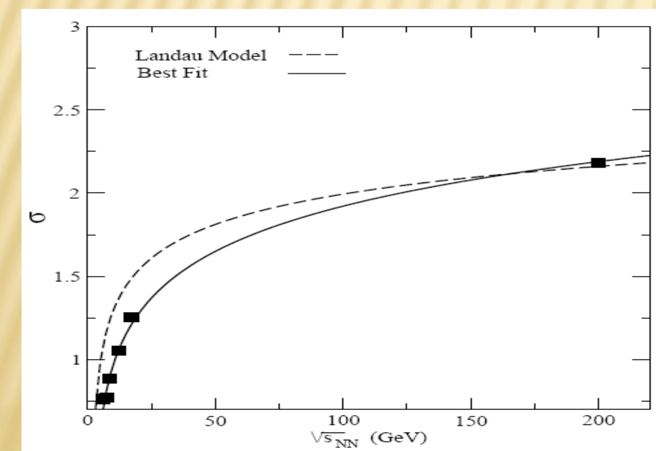


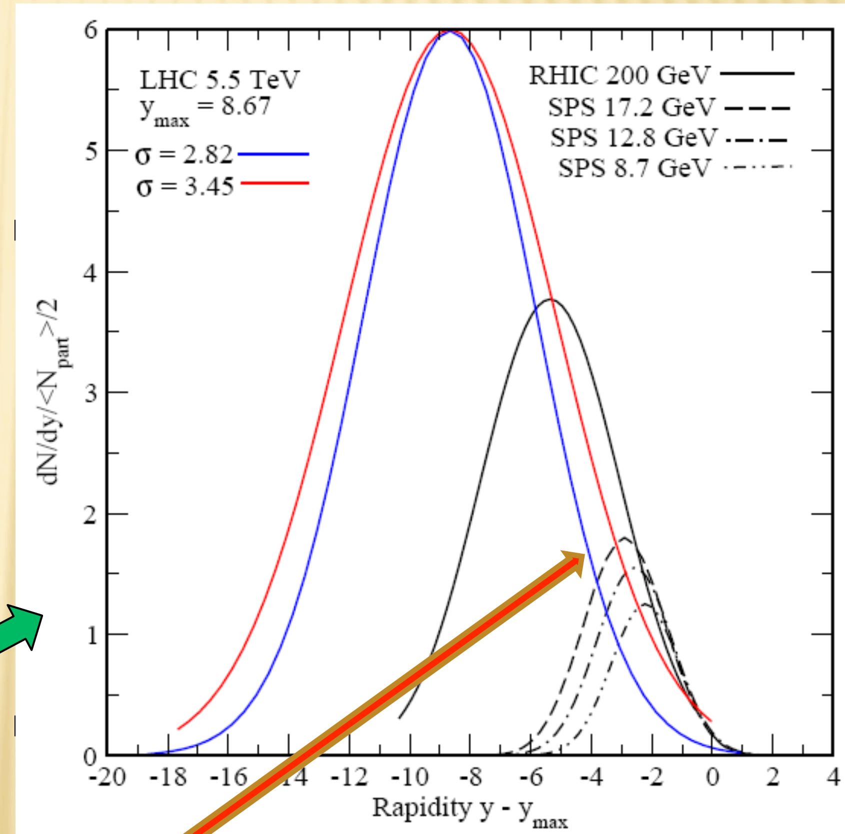
QGSM: extended longitudinal scaling in p+p collisions holds

VIOLATION OF ELS IN A+A AT LHC?

J. Cleymans, J.Struempfer, L.Turko, PRC 78 (2008) 017901







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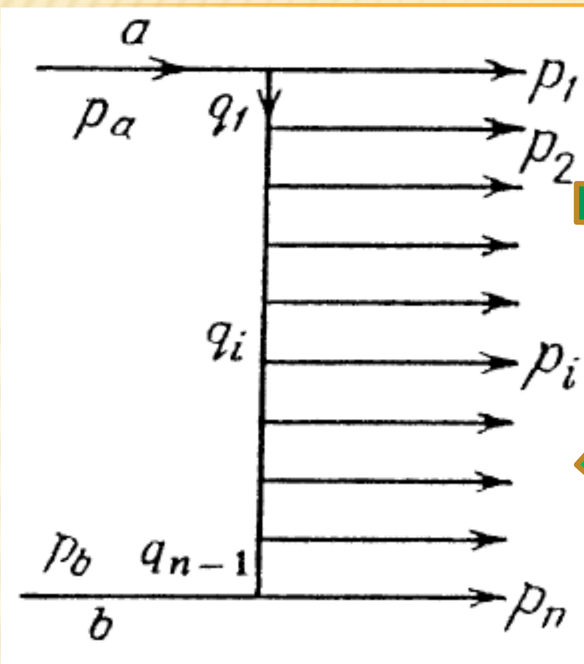
Statistical thermal model: ELS will be violated in A+A @ LHC. What about p+p ?

WHY SCALING HOLDS IN THE MODEL?



Short range correlations

Correlation function

$$C(y_i, y_j) \propto \exp\{-\lambda(y_i - y_j)\}$$

Particles are uncorrelated if

$$y_i - y_j \equiv \Delta y \ ? \ \ 1$$

Consider now inclusive process

$$1 + 2 \rightarrow i + X$$

Particle inclusive cross section

$$f_i = \frac{d^2\sigma(y_1 - y_i, y_i - y_2, p_{iT}^2)}{dy_i d^2 p_{iT}}$$

$$x_F^{(i)} \equiv \frac{p_{i\text{P}}}{p_{\text{P}}^{\max}} \approx \exp\{-(y_1 - y_i)\}$$

In the fragmentation region of particle 1

$$y_1 - y_i \approx 1\,,\; y_i - y_2 \approx y_1 - y_2 \ ? \ \ 1$$

Inclusive density

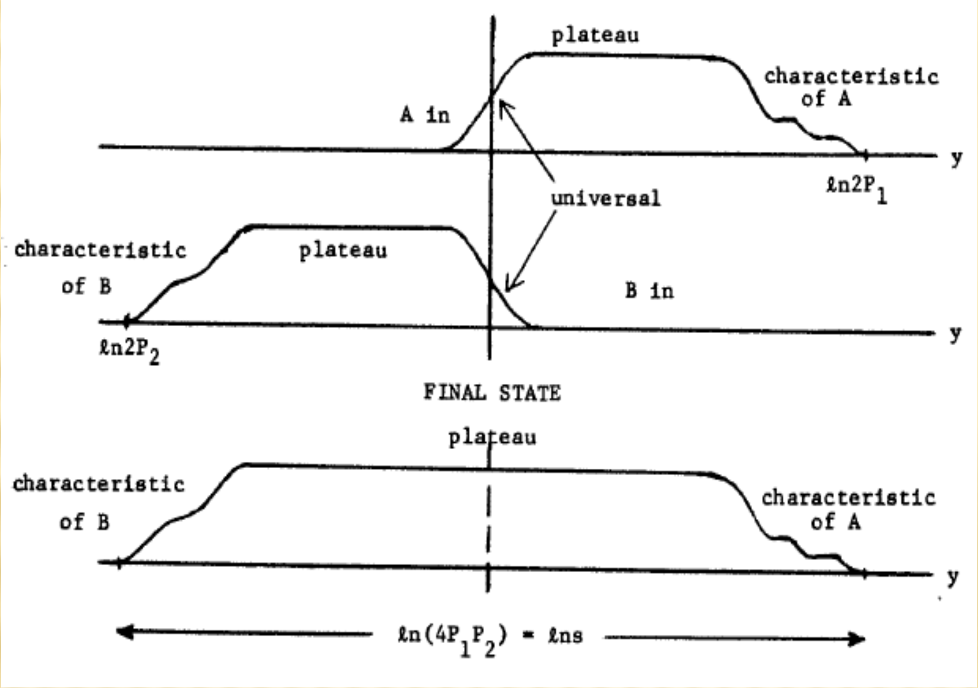
therefore

$$n_i = \psi(x_F^{(i)}, p_{iT}^2) \quad \Longleftrightarrow \quad \text{n}_i = f_i / \sigma_{inel} = \phi(y_1 - y_i, p_{iT}^2)$$

In string models both FS and ELS holds in the fragmentation regions

KOBA-NIELSEN-OLESEN (KNO) SCALING

Z.Koba, H.B.Nielsen, P.Olesen, NPB 40 (1972) 317



They claim that if Feynman scaling holds, then the multiplicity distribution is independent of energy except through the variable

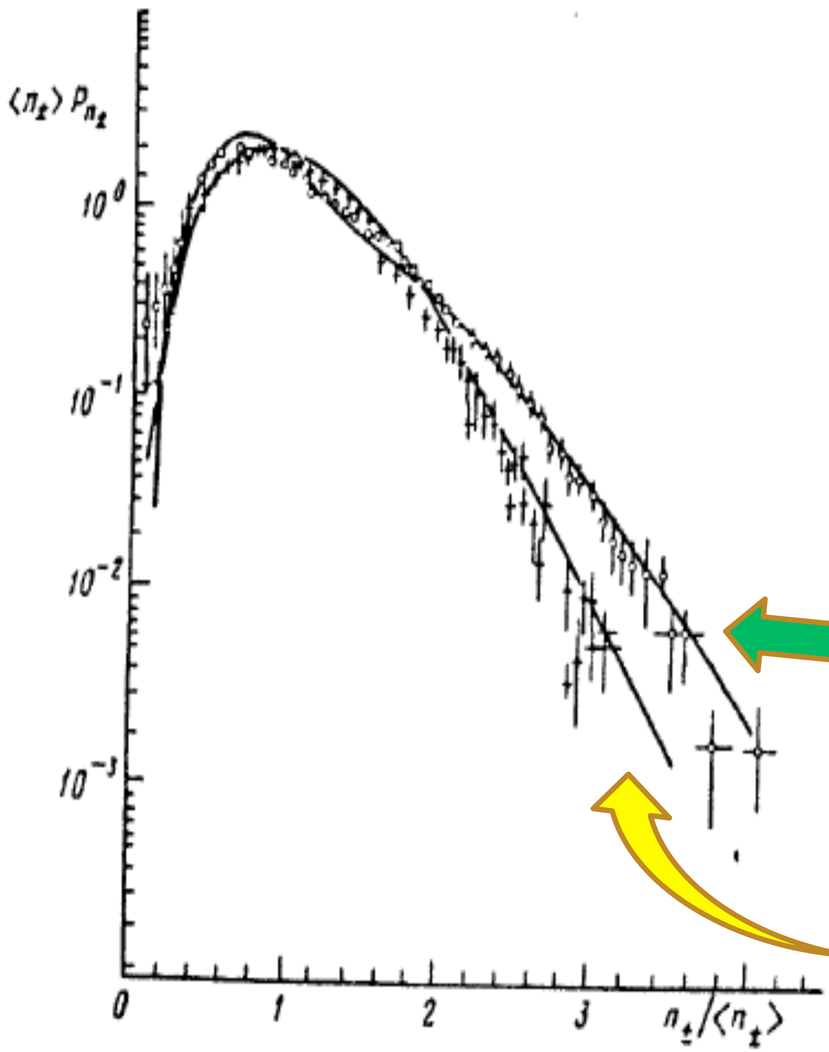
$$z = n / \langle n \rangle$$

$$P_n(s) = \frac{\sigma_n(s)}{\sigma_{tot}(s)} = \frac{1}{\langle n \rangle} \Psi\left(\frac{n}{\langle n \rangle} \right)$$

Experimental data: KNO scaling holds in *hh* collisions up to √s = 53 GeV (ISR)

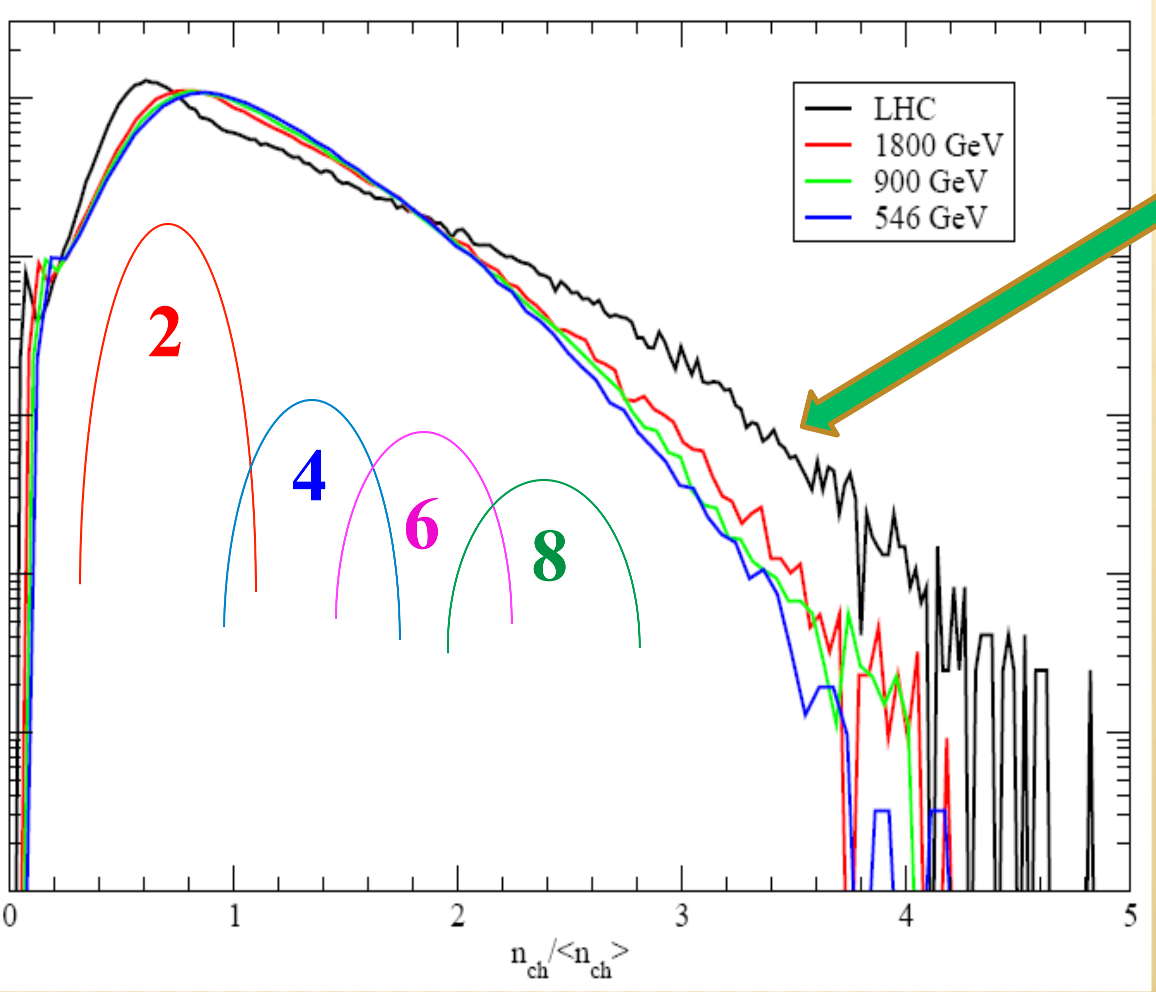
VIOLATION OF KNO SCALING

A.B.Kaidalov, K.A.Ter-Martirosyan, PLB 117 (1982) 247
UA5 Collaboration, Phys. Rep. 154 (1987) 247
N.S.Amelin, L.V.Bravina, Sov.J.Nucl.Phys. 51 (1990) 133



Charged-particle multiplicity distributions in the KNO variables in nondiffractive antiproton-proton collisions at $\sqrt{s}$ = 546 GeV and 53 GeV

VIOLATION OF KNO SCALING AT LHC

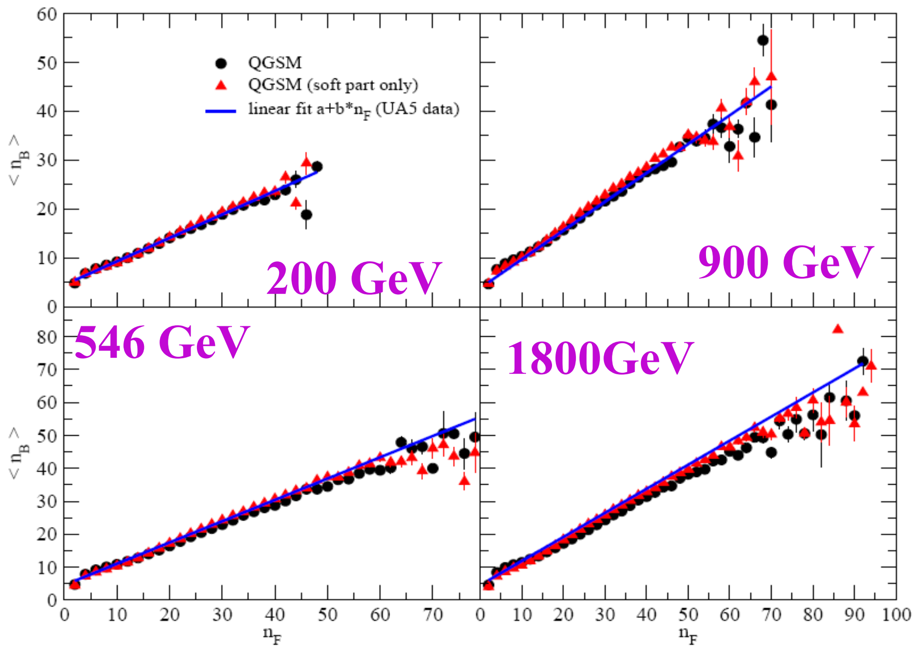


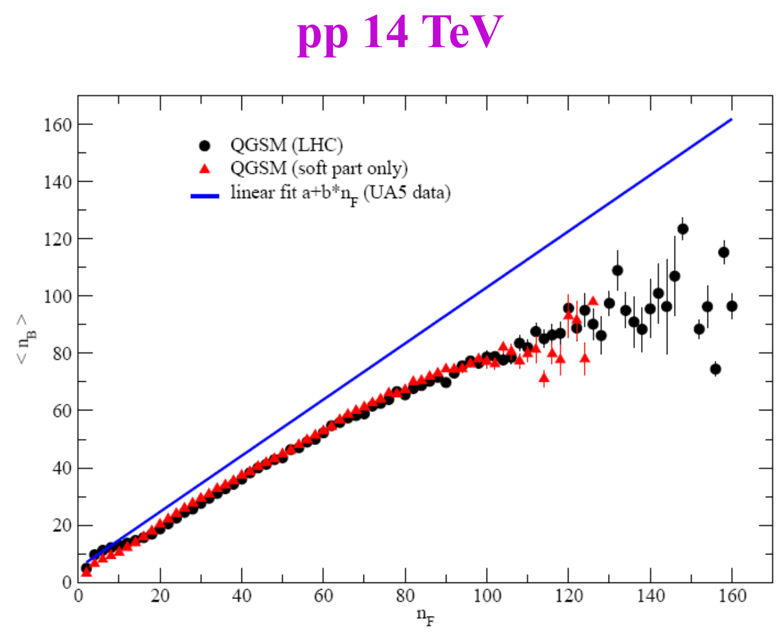
High-multiplicity tail is pushed up, whereas maximum of the distribution is shifted towards small values of z

At energies below 100 GeV different contributions overlap strongly, whereas at higher energies – more multi-string processes

=> Enhancement of high multiplicities

FORWARD-BACKWARD MULTIPLICITY CORRELATIONS

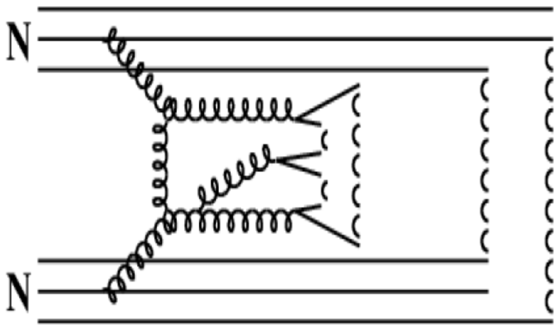




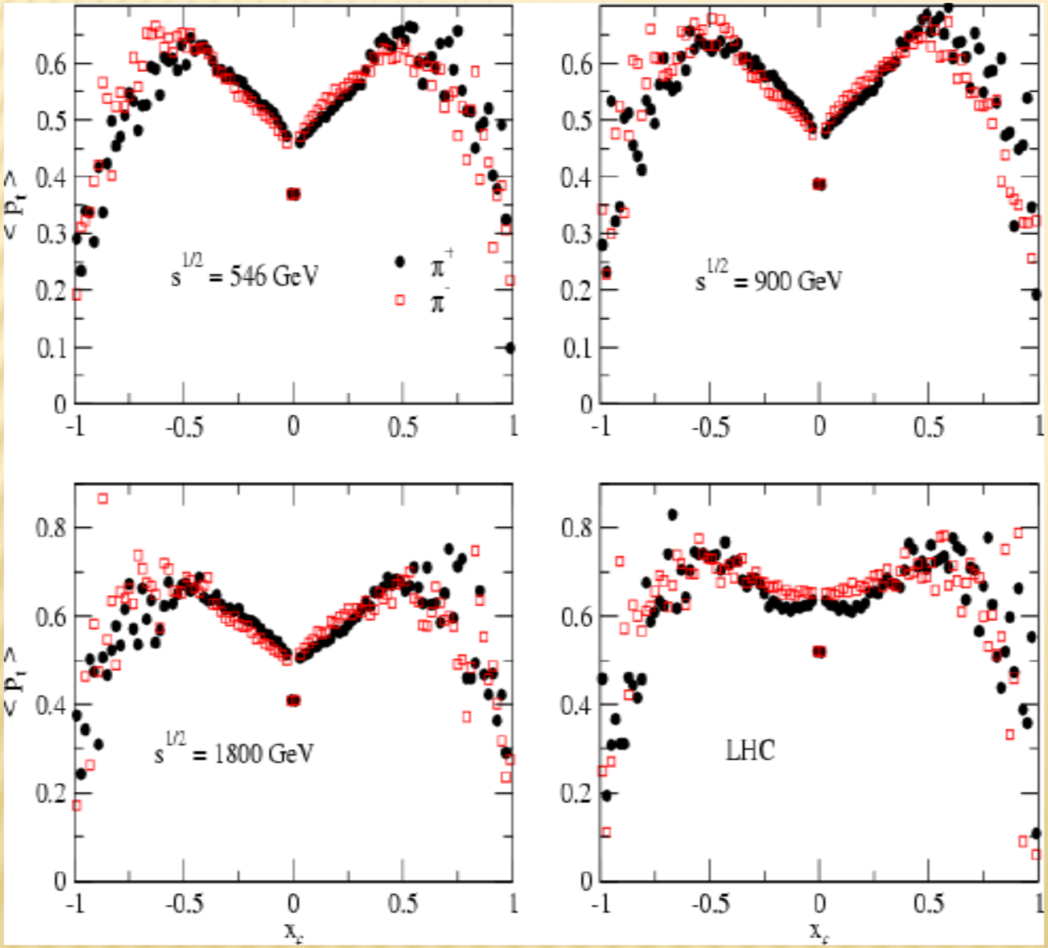
$<n_B(n_F)> = a+bn_F$ is linear with increasing of the slope b with energy due to

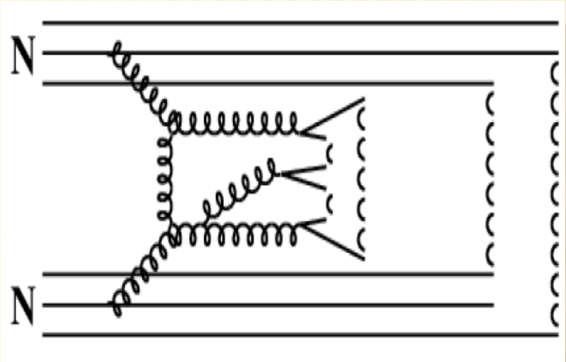
1) Multi-chain diagrams

2) Color exchange type of string excitation



STRONG SEA-GULL EFFECT <PT(XF)>





Sea-gull effect becomes more pronounced with energy

8. Anisotropic flow in pp

Azimuthal anisotropy in relativistic string fragmentation, I

Accepted picture for flow in heavy ion collisions – hydro expansion of QGP. Still, flow in *pp* and light AA is an open question:

? possible reasons for it

? magnitude

? possibility of observation

All the points are linked with each other

⇒ Importance of models as a test-ground for study of possible mechanisms.

Possibility of flow in DPM

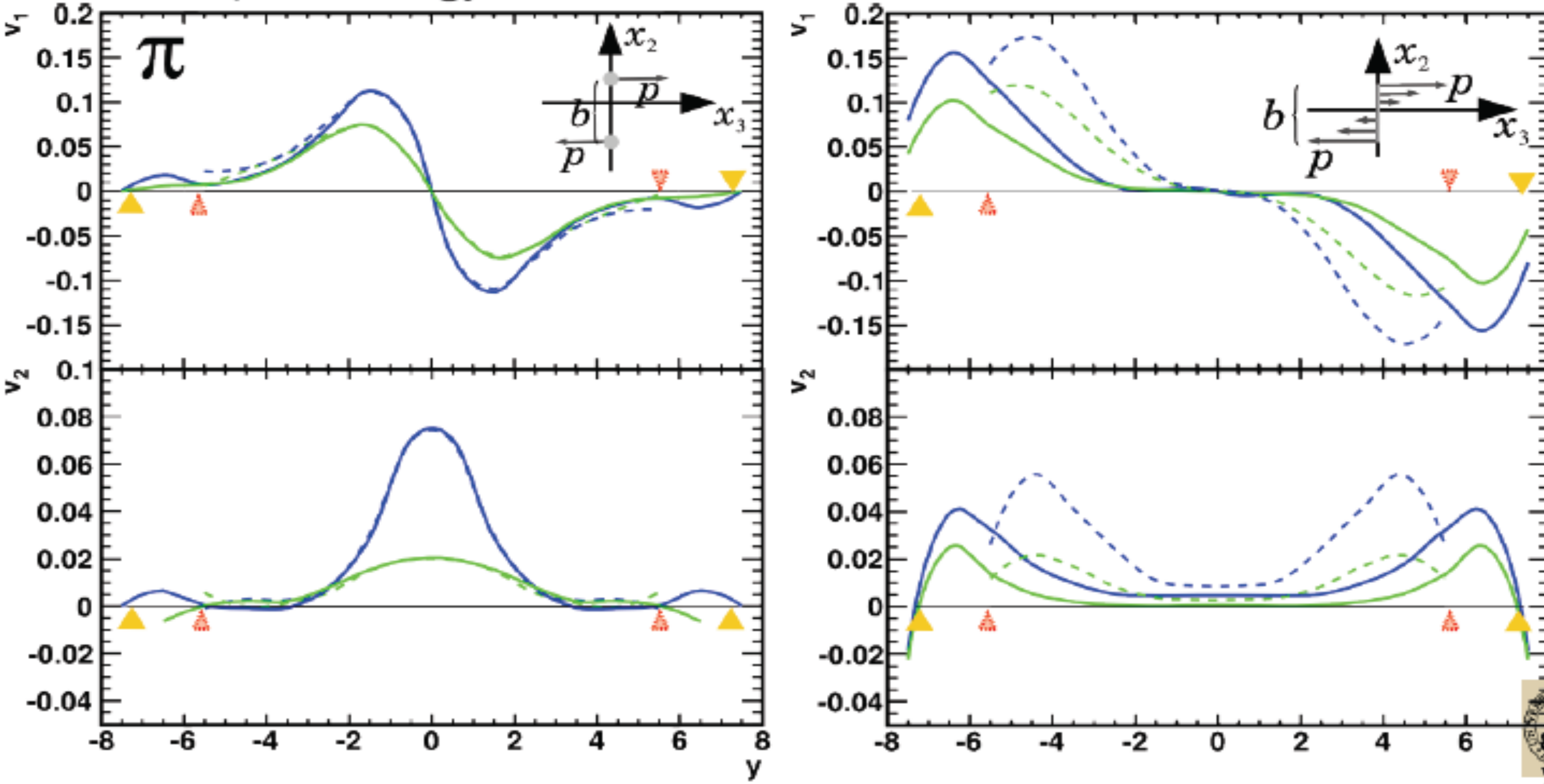
- DPM: final particles come as fragments of *qg* strings, *N* of strings is defined via RFT.
- RFT study (K.Boreskov, A.Kaidalov, O.Kancheli) proposes asimuthal anisotropy.
- Model for $\mathbb{P}$ with transverse separation of its ends – *qg* string → relativistic string with transverse separation of its ends.

8. Anisotropic flow in pp

Azimuthal anisotropy in relativistic string fragmentation, II

Comparatively simple model, only one sort of particles("π-mesons").

But: explicitly observed string dynamics;
explicit energy-momentum conservation.



b = 0.5 fm, 1 fm; s^1/2 = 40 GeV, 200 GeV.

8. Anisotropic flow in pp

Azimuthal anisotropy in relativistic string fragmentation, III

RESULTS:

1. Both v_1 and v_2 present; positive v_2, v_1 comes with the same sign as v_1 in AuAu experiment.
2. Extreme sensitivity to the internal momentum distribution.

Paper R.Kolevatov "On azimuthal anisotropy in fragmentation of classical relativistic string " (arXiv:0912.5377v1 [hep-ph]); submitted to EPJC.

OUTLOOK:

1. Application to *pp* involve $2 \times n$ strings asymmetric in rapidity,
2. Need much deeper understanding of string formation within RFT (see p.2 of the results)

Summary and perspectives

- *Feynman scaling should hold in pp collisions at LHC in the fragmentation regions only*
- *=> Extended longitudinal scaling holds there as well*
- *It would be interesting to check the ELS for pp collisions within the statistical thermal model*
- *KNO scaling is strongly violated at LHC. The origin of the violation is traced to multi-string processes*