Long-Range Multiplicity Correlation in pp-collisions at ALICE at the LHC

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Reported by G.Feofilov , at Baldin ISHEPP XIX, JINR, Dubna, 30.09. 2008

Contents

- Motivation (theory and experiment)
- Long-range multiplicity correlation and collectivity effects in PYTHIA
- Comparison to Experimental Data and Predictions for ALICE
- Conclusions

Motivation(theory)

Investigations of the charged particles long-range multiplicity correlations, measured for well separated rapidity intervals, can give us information on the number of emitting centers and hence on the fusion of colour strings[1].

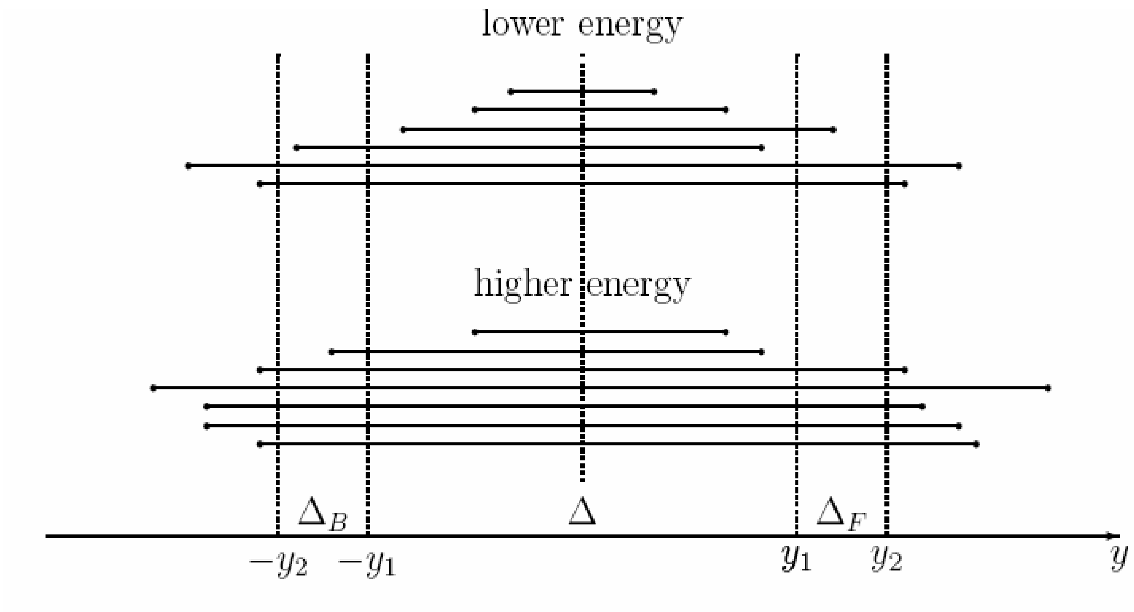
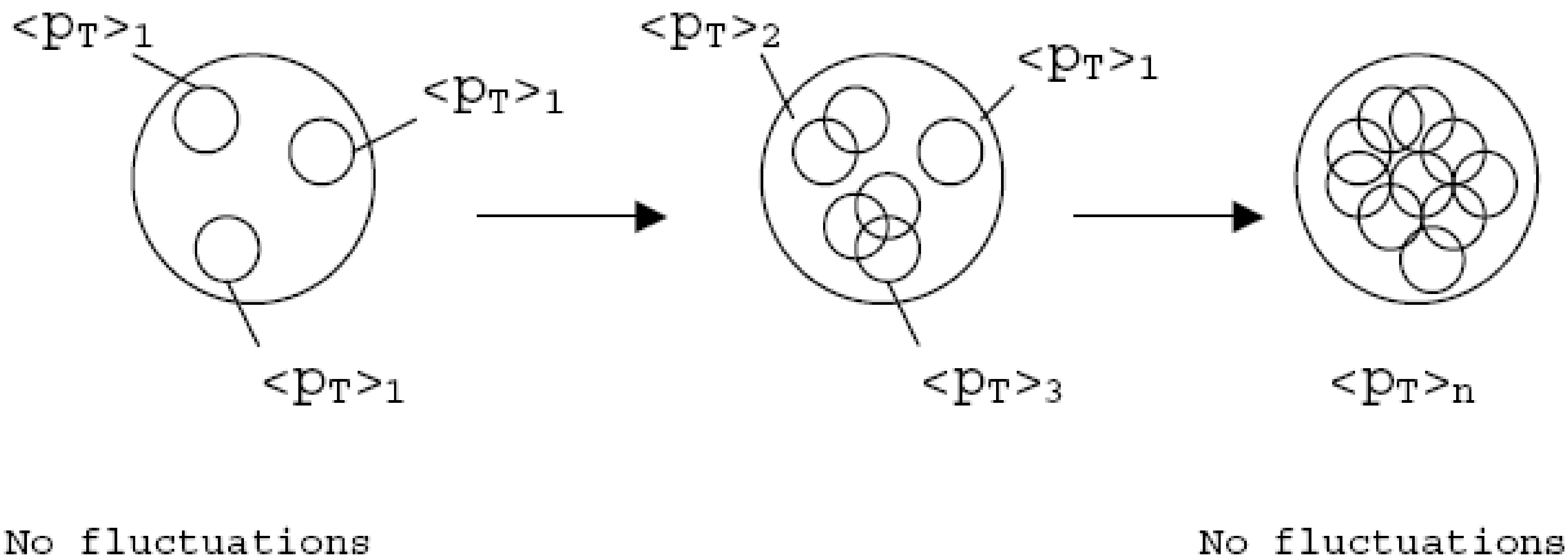


Fig.1. Quark-gluon strings and schematics for studies of Long-Range Correlations[1]

[1] M.A.Braun, C.Pajares and V.V.Vechernin, Low pT Distributions in the Central Region and the Fusion of Colour Strings, Internal Note/FMD ALICE-INT-2001-16

“Percolating color strings approach''.

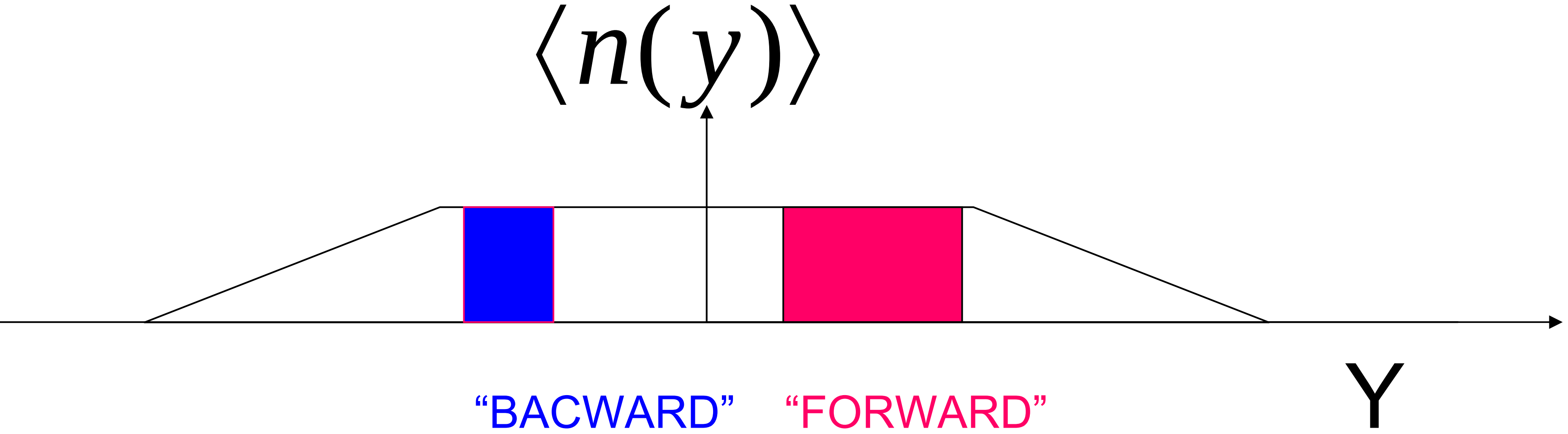
With growing energy and/or atomic number of colliding particles, the number of strings grows and they start to overlap, forming clusters.[3]



[3] **M.A.Braun and C.Pajares, Eur. Phys. J. {\bf C16} (2000) 349.**
M.A.Braun,R.S.Kolevatov,C.Pajares.V.V.Vechernin, ''Correlations between multiplicities and everage transverse momentum in the percolating color strings approach'', Eur.Phys.J.C.32.535-546(2004)
N/Armesto, C/Saldago, U/Wiedemann// PRL94 (2005) 022002.
C. Pajares // arXiv:hep-ph/0501125v1 14 Jan 2005

Long-Range Correlations (LRC)

CORRELATIONS BETWEEN OBSERVABLES MEASURED IN TWO RAPIDITY INTERVALS



LRC observable in the present study: *MULTIPLICITY of the charged particles*

For each event:

***1) the event mean multiplicity* in two rapidity (or pseudorapidity) intervals** (usually called “backward” and “forward”)**:**

$$n_B \, , \, n_F$$

Event-by-event:

We define *the mean value of the observable in one rapidity interval* at the given value of another observable in the second rapidity interval

$$\langle n_B \rangle_{n_F}$$

n-n - the correlation between the charged particle multiplicities in “backward” and “forward” rapidity intervals

Usually: Correlation coefficients are defined (for **absolute** values of observables) as :

$$\langle n_B \rangle_{n_F} = a_{nn} + \beta_{nn} n_F$$

Here the strength of the correlation is measured by the coefficient β_{nn}

Correlation coefficients (for **normalized** observables):

$$\frac{\langle n_B \rangle_{n_F}}{\langle n_B \rangle} = a_{nn}{}^{N} + \beta_{nn}{}^{N} \frac{n_F}{\langle n_F \rangle}$$

Motivation (experiment, collectivity effects in PbPb collisions at 158 AGeV, NA49 data at SPS)

$$\Delta y_B \in (-0.29, 0.33),\ \Delta y_F \in (0.91, 2.0).$$

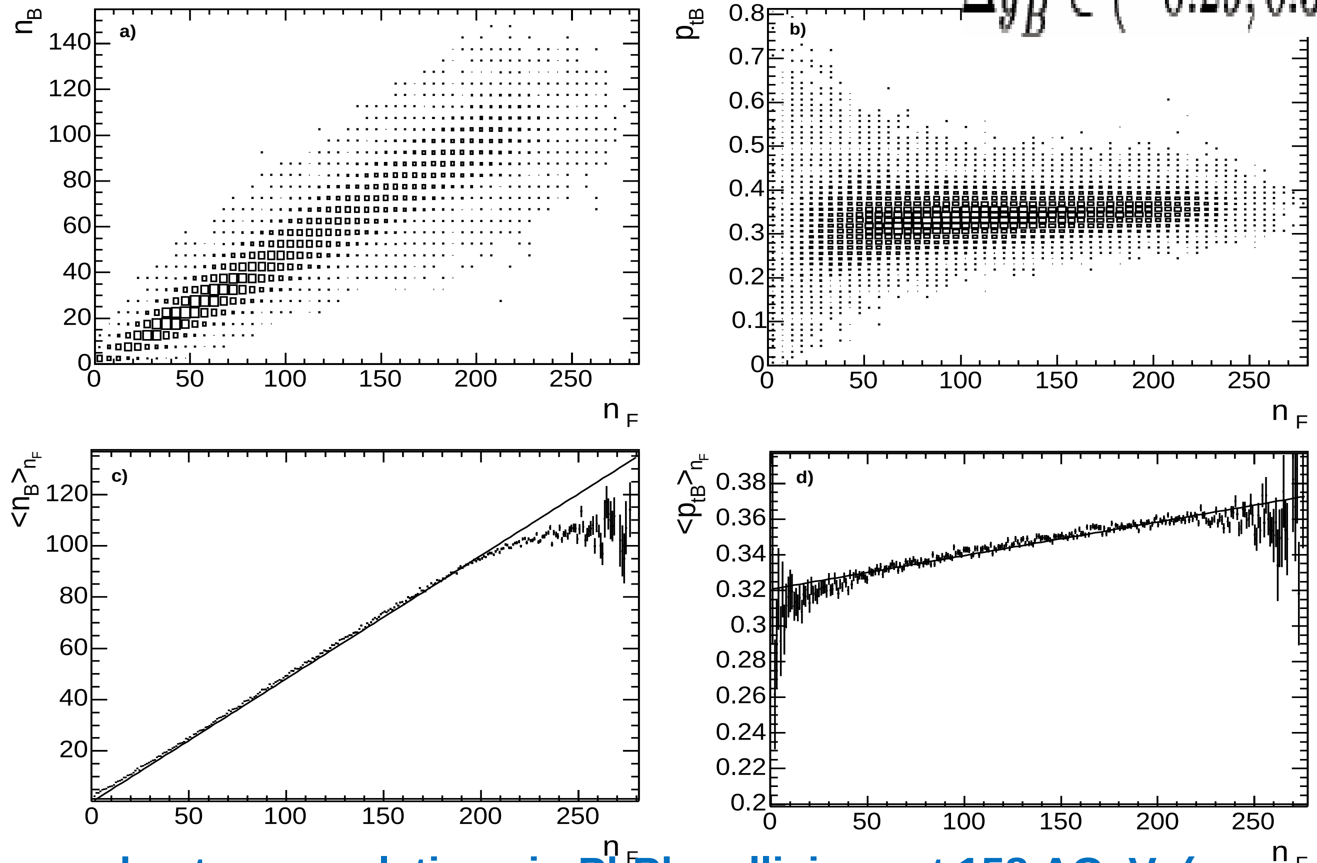


Fig.2. n-n and p_t-n correlations in PbPb collisions at 158 AGeV (examples of Min.bias data , 2 rapidity intervals [3]:

[3] NA49 collab. and Feofilov G.A., Kolevatov R.S.,Kondratiev V.P., Naumenko P.A. ,Vechernin V.V., “Long-Range Correlations in PbPb Collisions at 158 AGeV”. In: Relativistic Nuclear Physics and Quantum Chromodynamics, Proc. XVII Internat. Baldin Seminar on High Energy Physics Problems, vol.1, JINR, Dubna, 2005, 222-231

Motivation, experiment: collectivity effects in AuAu at $\sqrt{sNN}$ =200 GeV [4]

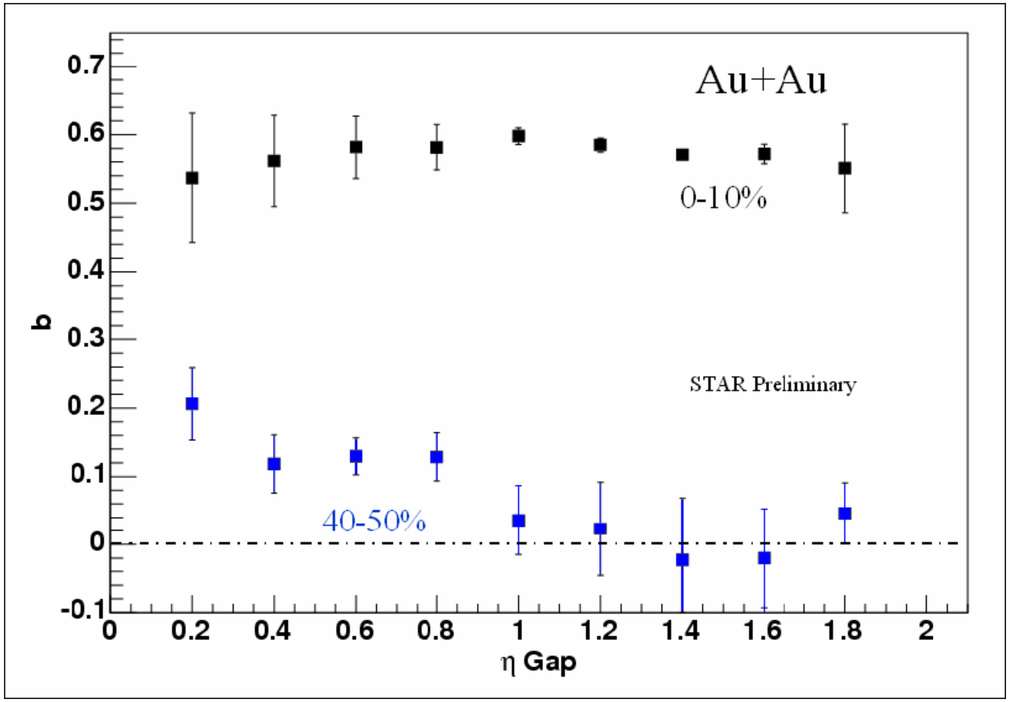


Fig.3. n-n correlation strength for AuAu data, as a function of rapidity gap (Au+Au at $\sqrt{sNN} = 200$ GeV, [4].)

[4] **Terence J Tarnowsky (for the STAR Collaboration), "Energy and System-Size Dependence of Long-Range Multiplicity Correlations from the STAR Experiment", arXiv:0711.1175v1 [nucl-ex] 7 Nov 2007, report at Critical Point and Onset of Deconfinement 4th International Workshop, July 9013 2007, GSI, Darmstadt, Germany**

Collectivity effects in pp and ppbar collisions?

Motivation, theory: $\langle p_t \rangle_{Nch}$*-*$N_{ch}$ correlation and collectivity effects in pp and ppbar collisions at 17-1800 GeV [5]

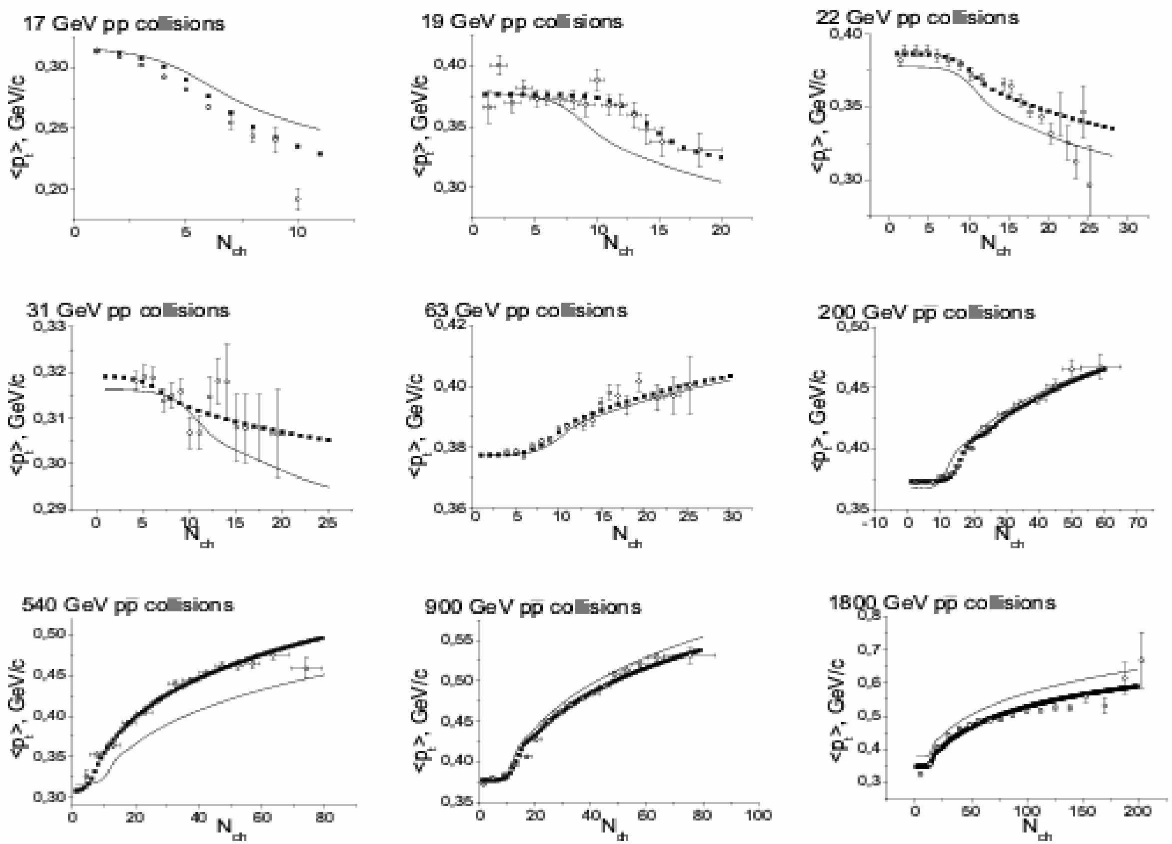


Fig.4. Experimental data and model [5]

[5] N. Armesto, D. Derkach, G. Feofilov , “Multi-Pomeron exchange model with the account of string fusion”, ALICE Internal Note/PHY/2006 -31

Motivation : collectivity effects in pp experiment, charged particle multiplicity correlation

(ppbar collisions 0.3-1.8 TeV", [2])

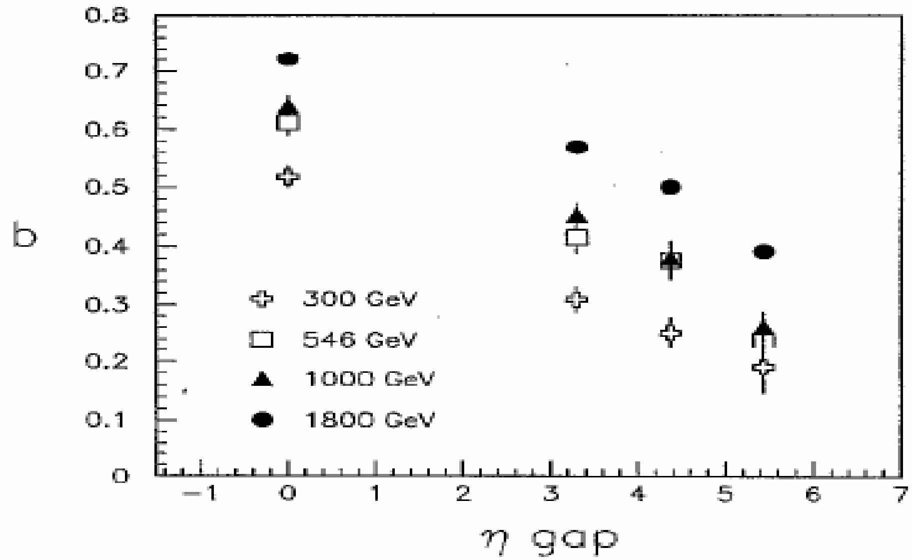


Fig. 2. Correlation coefficient as a function of central η gap.

[2] E735 Collaboration, "Charged particle multiplicity correlations in ppbar collisions at 0.3-1.8 TeV", Physics Letters B 353 (1995) 155-160

Collectivity effects in PYTHIA and Long-Range multiplicity correlation

PYTHIA 6.3

Collectivity in PYTHIA

Model of multiple interactions

Parameters	Description
MSUB(91)	Elastic Scattering
MSUB(92)	Single Diffraction AB -> XB
MSUB(93)	Single Diffraction AB -> AX
MSUB(94)	Double Diffraction
MSUB(95)	Low Pt Production
MSUB(96)	Semihard QCD
PARP(85) D=33% in v6.325	**“Colour correlations” -** probability that an additional interaction in the multiple interaction formalism gives two gluons, with colour connections to ‘nearest neighbours’ in momentum space
PARP(86) D=66% in v6.325	**“Gluon-gluon string formation” -** probability that an additional interaction in the multiple interaction formalism gives two gluons, either as described in PARP(85) or as a closed gluon loop. Remaining fraction is supposed to consist of quark–antiquark pairs

T. Sjöstrand, **“Monte Carlo Generators”,** European School of High-Energy Physics 2006, Aronsborg, Sweden, 27 June 2006

Torbjörn Sjöstrand, Leif Lönnblad, Stephen Mrenna, Peter Skands, **“PYTHIA 6.3 Physics and Manual”,** hep-ph/0308153, LU TP 03–38, August 2003

Final PYTHIA parameters were tuned using $\langle p_t \rangle_{Nch}$-$N_{ch}$ correlation data:

(report by A.Asryan at CERN, PWG2 31.03.08)

Values of parameters

Results are based on fitting of experimental data on **Pt-N correlations** in p-p and p-pbar collisions from 17 to 1800 GeV.

In PYTHIA version 6.4 and higher these values of parameters are set as default. See also R. Fields' studies in http://www.phys.ufl.edu/~rfield/cdf/

Energy, GeV / PYTHIA Parameters	17	31	200	540	900	1800
MSUB(91) Elastic scattering	0	0	**1**	**1**	**1**	**1**
MSUB(92) Single diffraction	1	1	**1**	**1**	**1**	**1**
MSUB(93) Single diffraction	1	1	**1**	**1**	**1**	**1**
MSUB(94) Double diffraction	1	1	**1**	**1**	**1**	**1**
MSUB(95) Low pt production	0	0	**1**	**1**	**1**	**1**
MSUB(96) Semihard QCD	1	1	**1**	**1**	**1**	**1**
PARP(85) Gluon string fusion	90%	90%	**90%**	**90%**	**90%**	**90%**
PARP(86) Gluon string formation	95%	95%	**95%**	**95%**	**95%**	**95%**

Calculations (no fits!) and discussion: Collectivity effects in PYTHIA, Comparison to experiment and predictions for ALICE

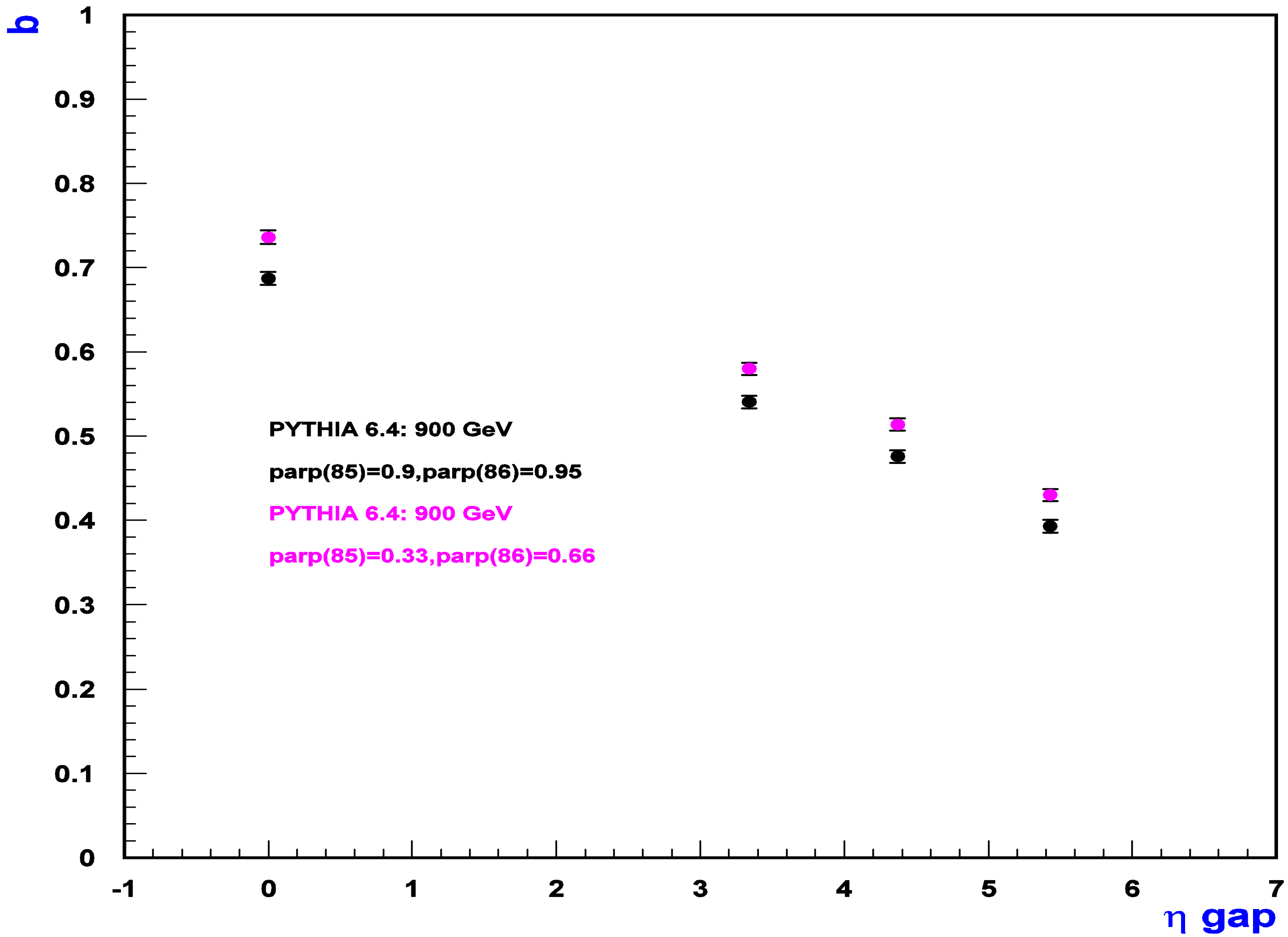


Fig.7. **PYTHIA:** The n-n correlation strength for pp collisions, as a function of rapidity gap for ppbar at $\sqrt{sNN}$ *= 900 for 2 sets of collectivity parameters : 0.33,0.63} (pink circles), 0.9, 0.95(black circles)*

Long-range multiplicity correlation in ppbar collisions from 0.3-1.8 TeV:

PYTHIA 6.4 and experiment E735. Physics Letters B 353 (1995) 155-160)

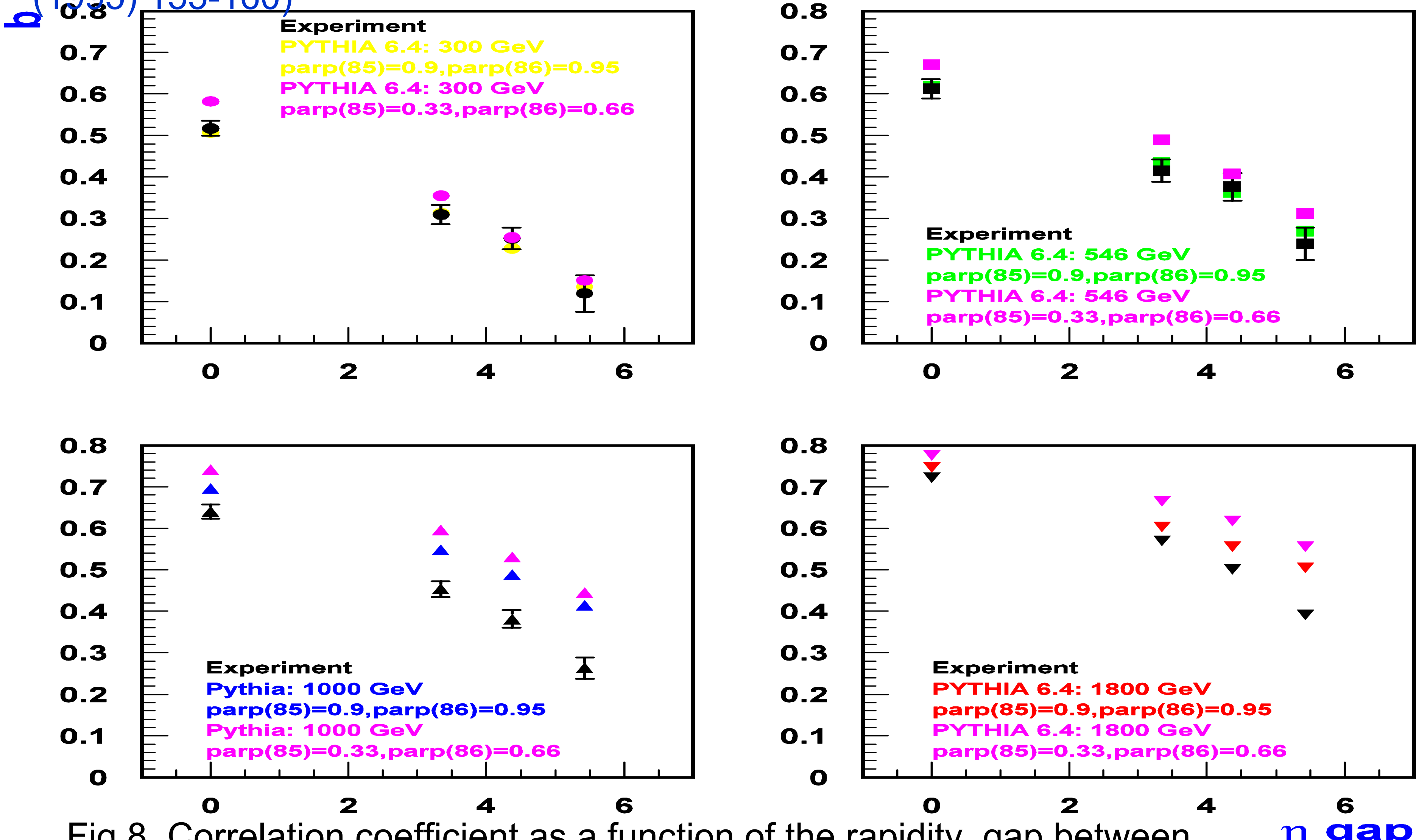


Fig.8. Correlation coefficient as a function of the rapidity gap between two rapidity intervals ("backward" and "forward" intervals of 0.2 units).

Long-range multiplicity correlation in ppbar collisions from 0.3-1.8 TeV: **PYTHIA 6.4 and experiment** (E735 Physics Letters B 353 (1995) 155-160)

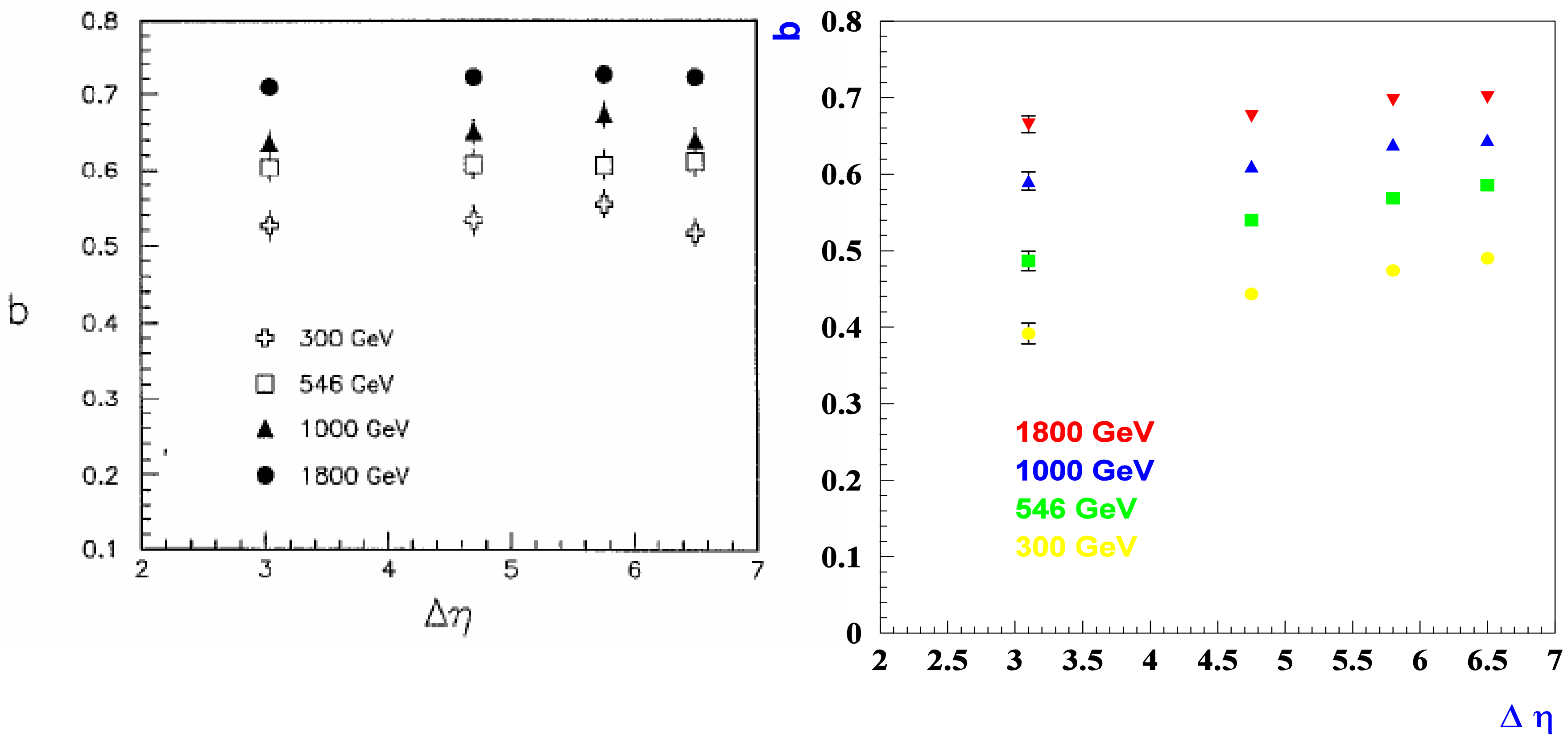


Fig. 9. Correlation coefficient as a function of the 2 rapidity interval width. There is no gap between the "forward" and "backward" regions.

Experiment : left figure, PYTHIA: right

Predictions for ALICE:
pp-collisions at 10 TeV

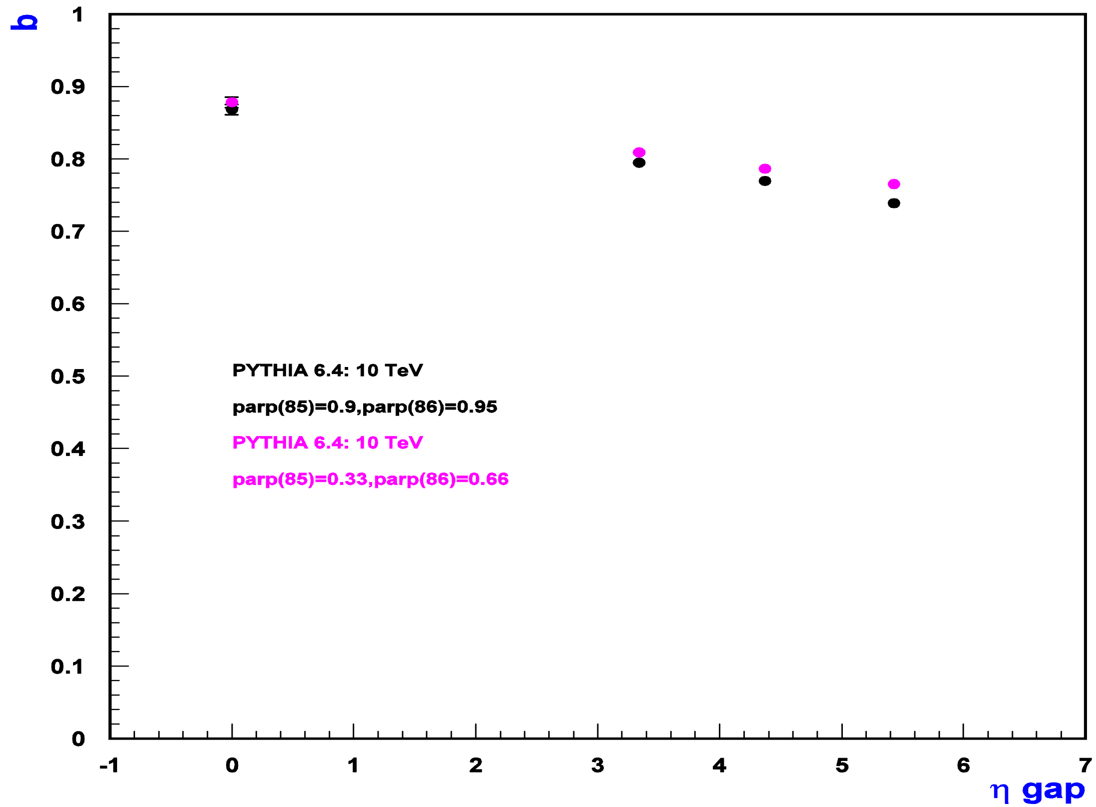
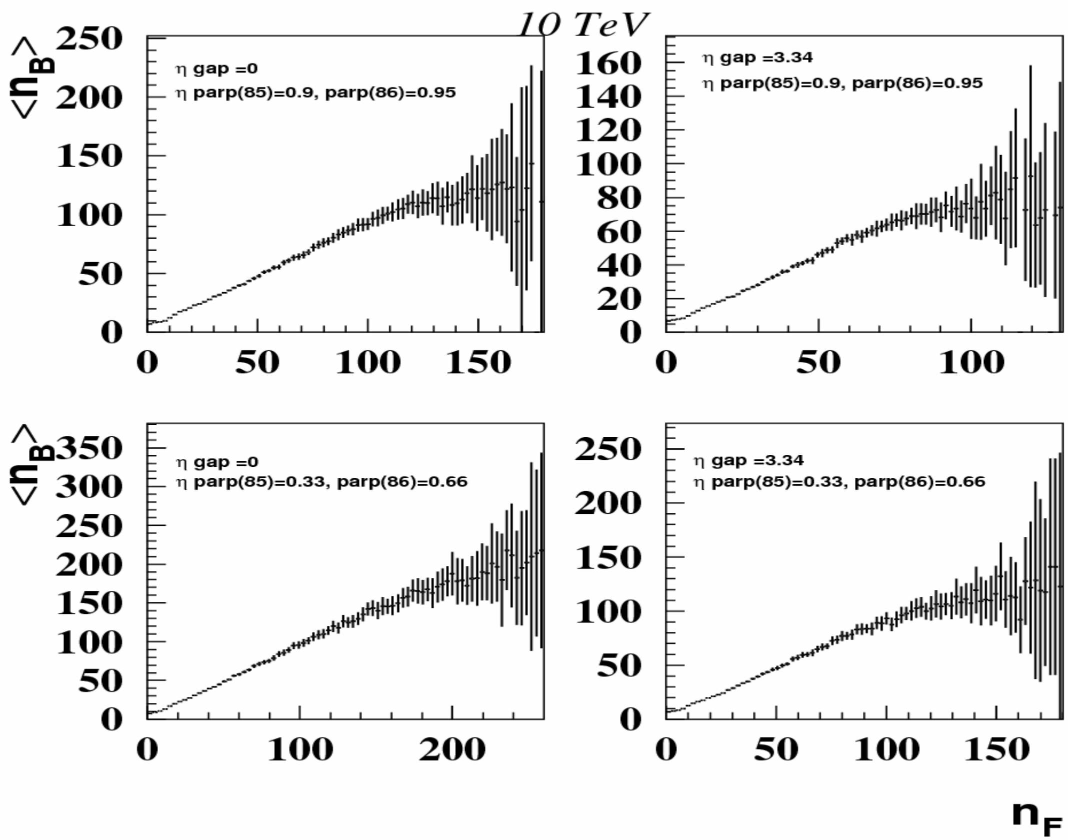


Fig.10. The n-n correlation strength for pp data, as a function of rapidity gap for pp collisions at *√sNN = 10 TeV at ALICE for 2 sets of collectivity parameters : 0.33,0.63} (pink circles), 0.9, 0.95(black circles)*

Predictions for ALICE: Collectivity and "Saturation" effects in long-range multiplicity correlation



In case of large collectivity parameter set, the "plato" observed in multiplicity correlation is expected to start earlier and to have lower value: at the level of <nB>~120 in vs. <nB>~170 (see left column for 0 gap). Similar is the result for the gap=3.4 units(right column)

Fig.11. **Collectivity and "Saturation" effect in long-range multiplicity correlation: PYTHIA predictions for ALICE,** pp collisions at √*sNN = 10 TeV for 2 sets of collectivity parameters : 0.33,0.63} (lower raw), 0.9, 0.95(upper raw) . Figures are for 2 values of rapidity gap: 0 (left column) and 3.34 (right column). Backward and forward rapidity intervals are of 0.2 units of rapidity*

Observation of “Saturation” effects in long-range multiplicity correlation in PbPb collisions at 158 AGeV [3].

$\Delta y_B \in (-0.29, 0.33), \Delta y_F \in (0.91, 2.0)$.

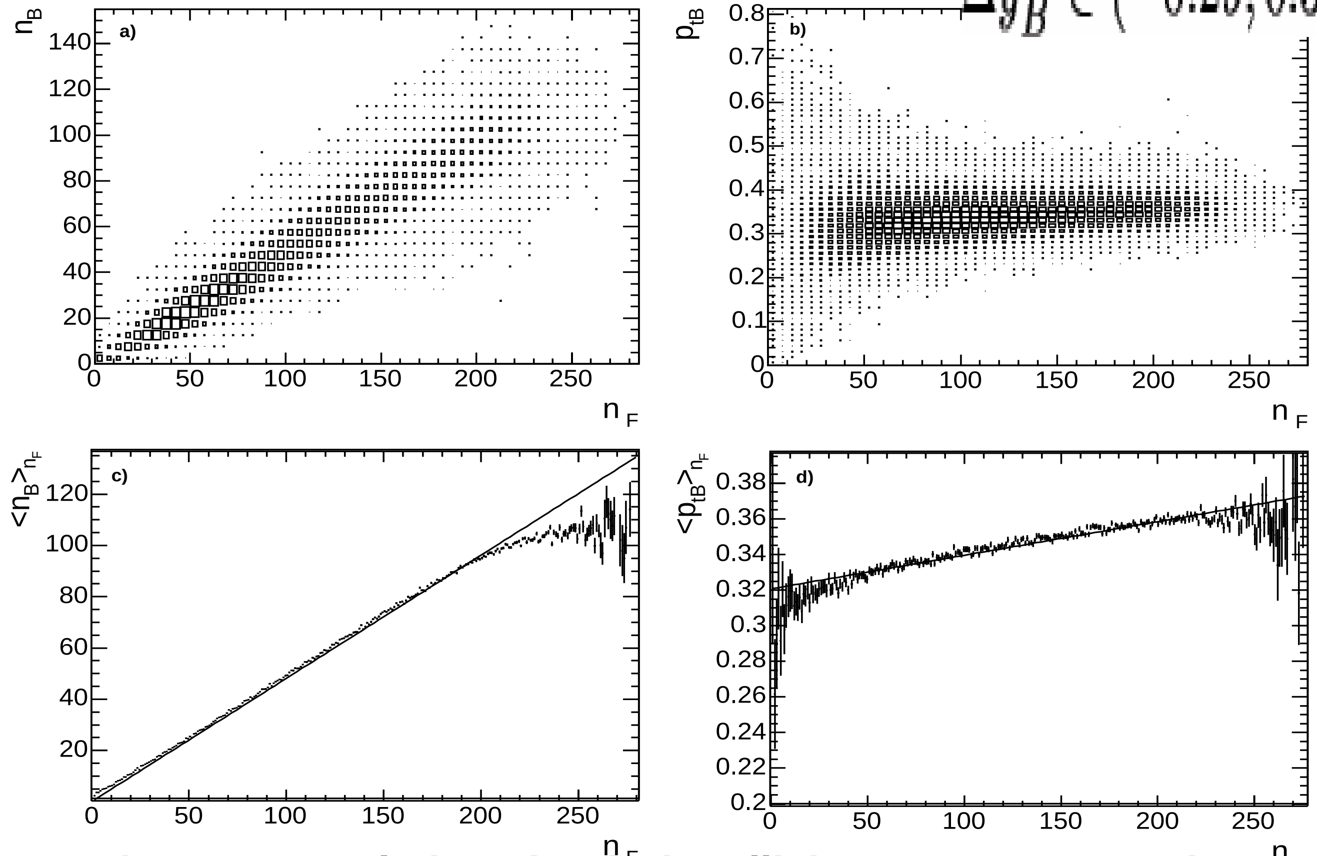
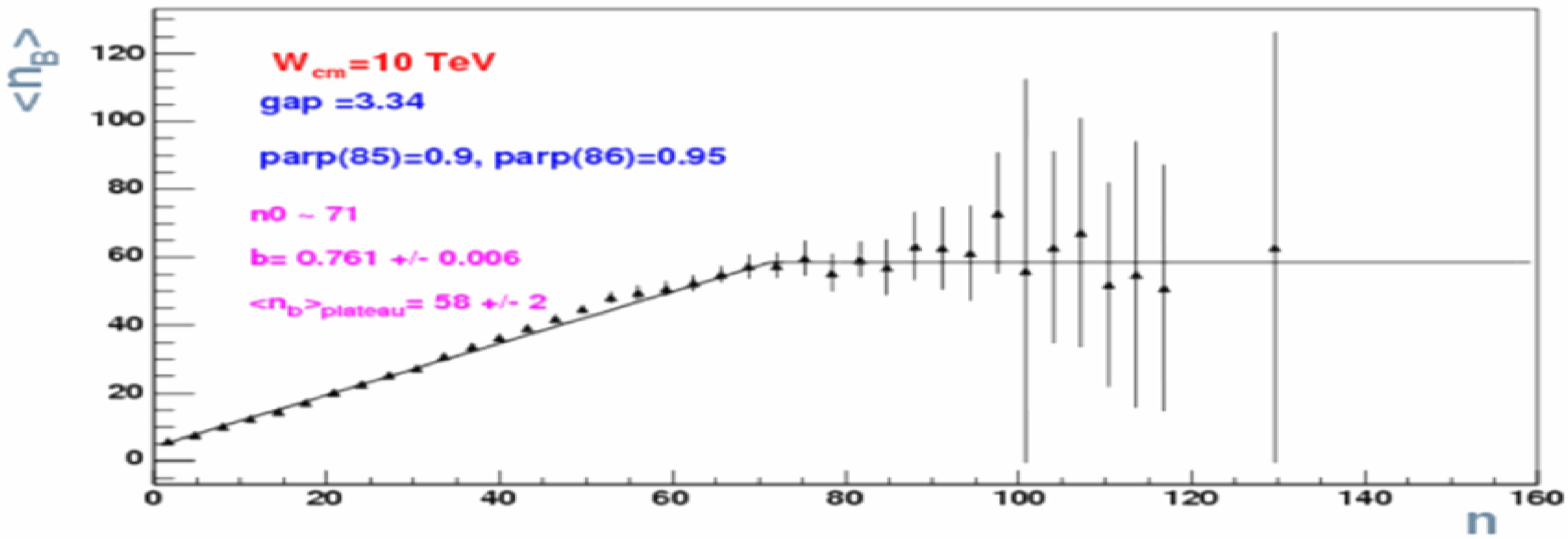


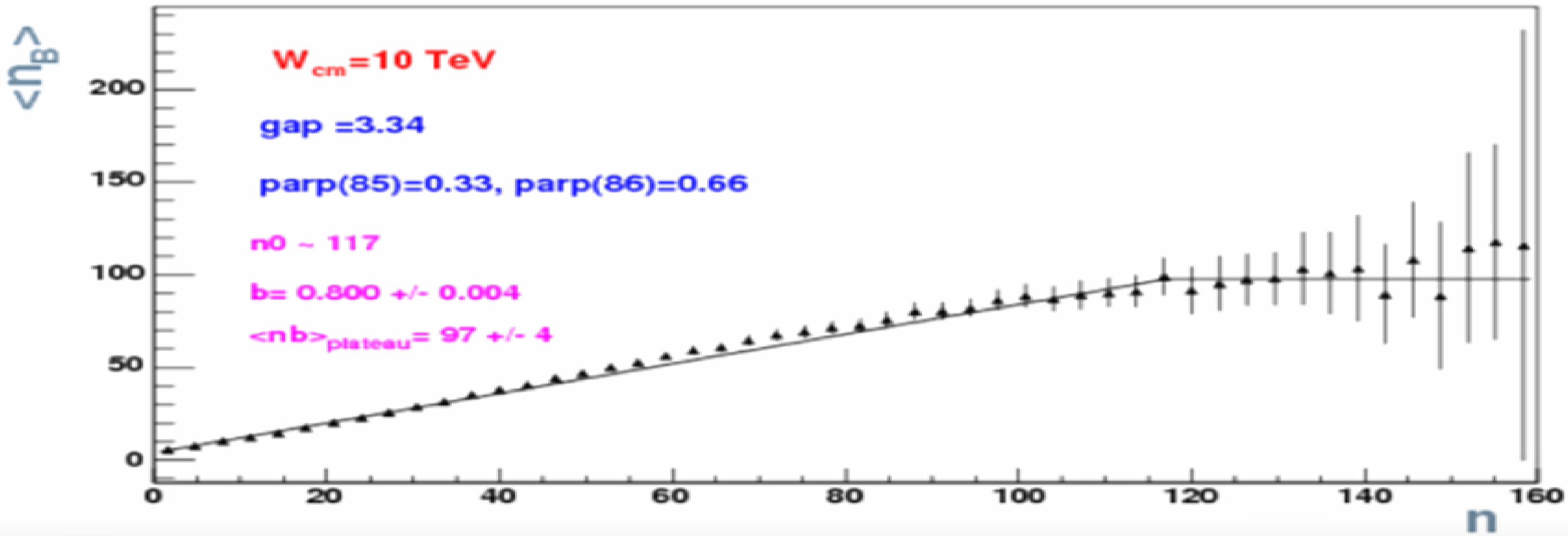
Fig.2. n-n and p_t-n correlations in PbPb collisions at 158 AGeV (examples of Min.bias data , 2 rapidity intervals [3]:

[3] NA49 collab. and Feofilov G.A., Kolevatov R.S.,Kondratiev V.P., Naumenko P.A. ,Vechernin V.V., “Long-Range Correlations in PbPb Collisions at 158 AGeV”. In: Relativistic Nuclear Physics and Quantum Chromodynamics, Proc. XVII Internat. Baldin Seminar on High Energy Physics Problems, vol.1, JINR, Dubna, 2005, 222-231

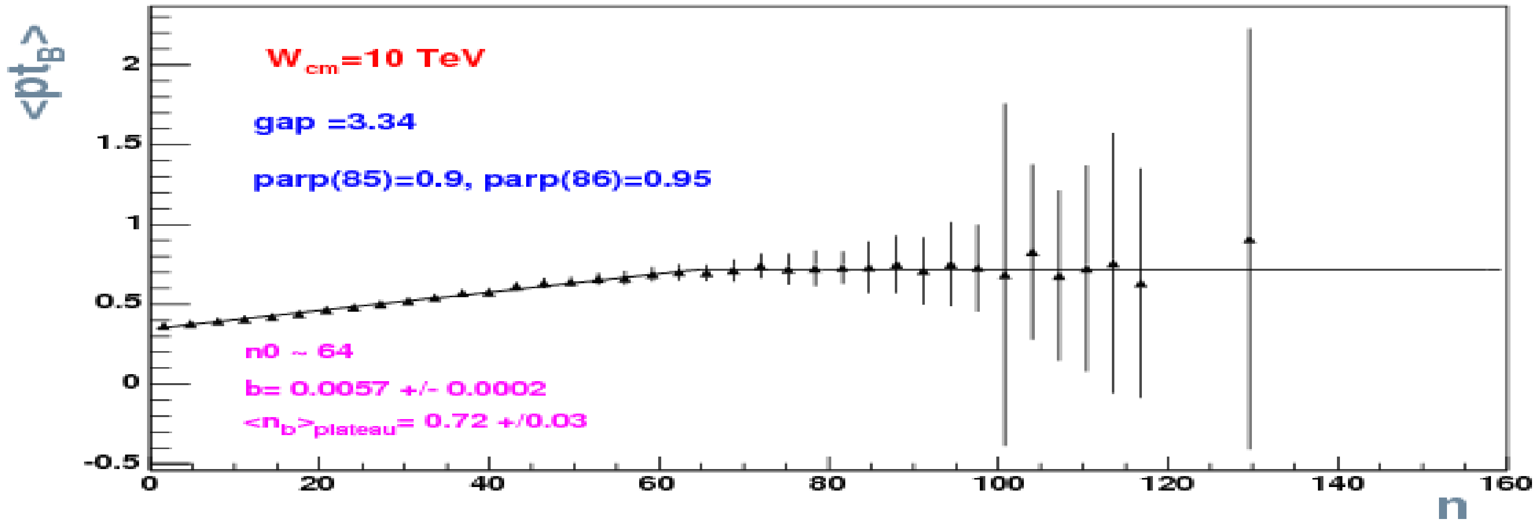
“Saturation” effect in long-range multiplicity correlation and selection of “the very central” events in pp-collisions at the LHC

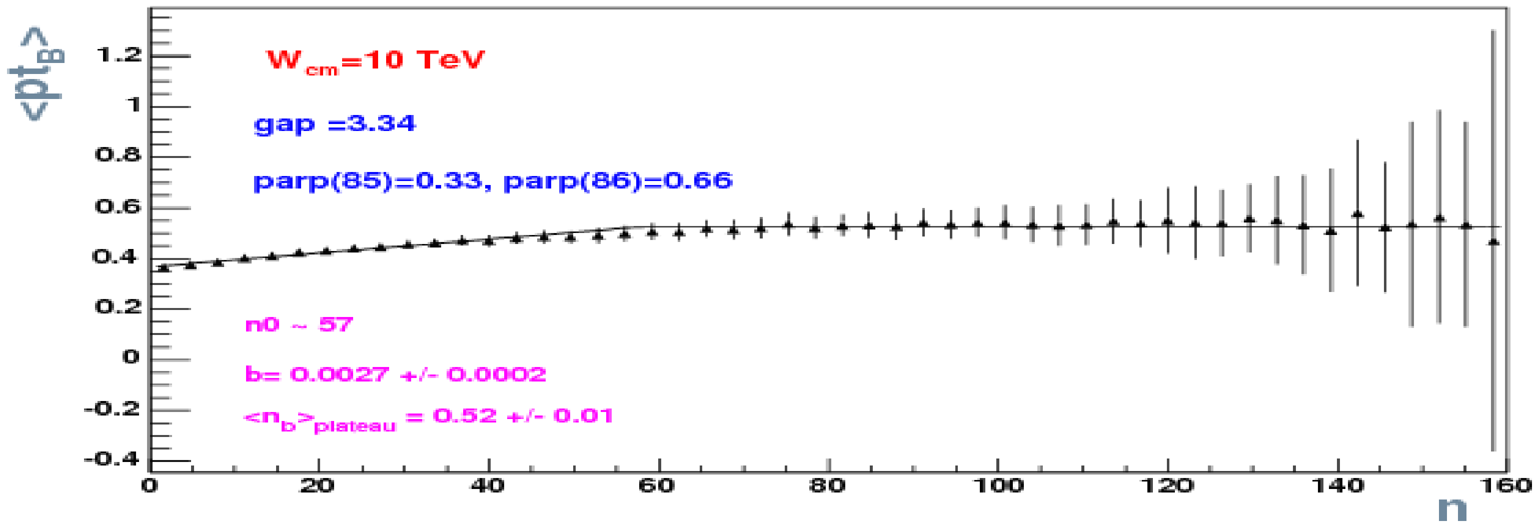


W_{cm}=10 TeV
gap =3.34
parp(85)=0.9, parp(86)=0.95
n0 ~ 71
b= 0.761 +/- 0.006
<n_b>$_{plateau}$= 58 +/- 2
<n_B>
n



W_{cm}=10 TeV
gap =3.34
parp(85)=0.33, parp(86)=0.66
n0 ~ 117
b= 0.800 +/- 0.004
<nb>$_{plateau}$= 97 +/- 4
<n_B>
n

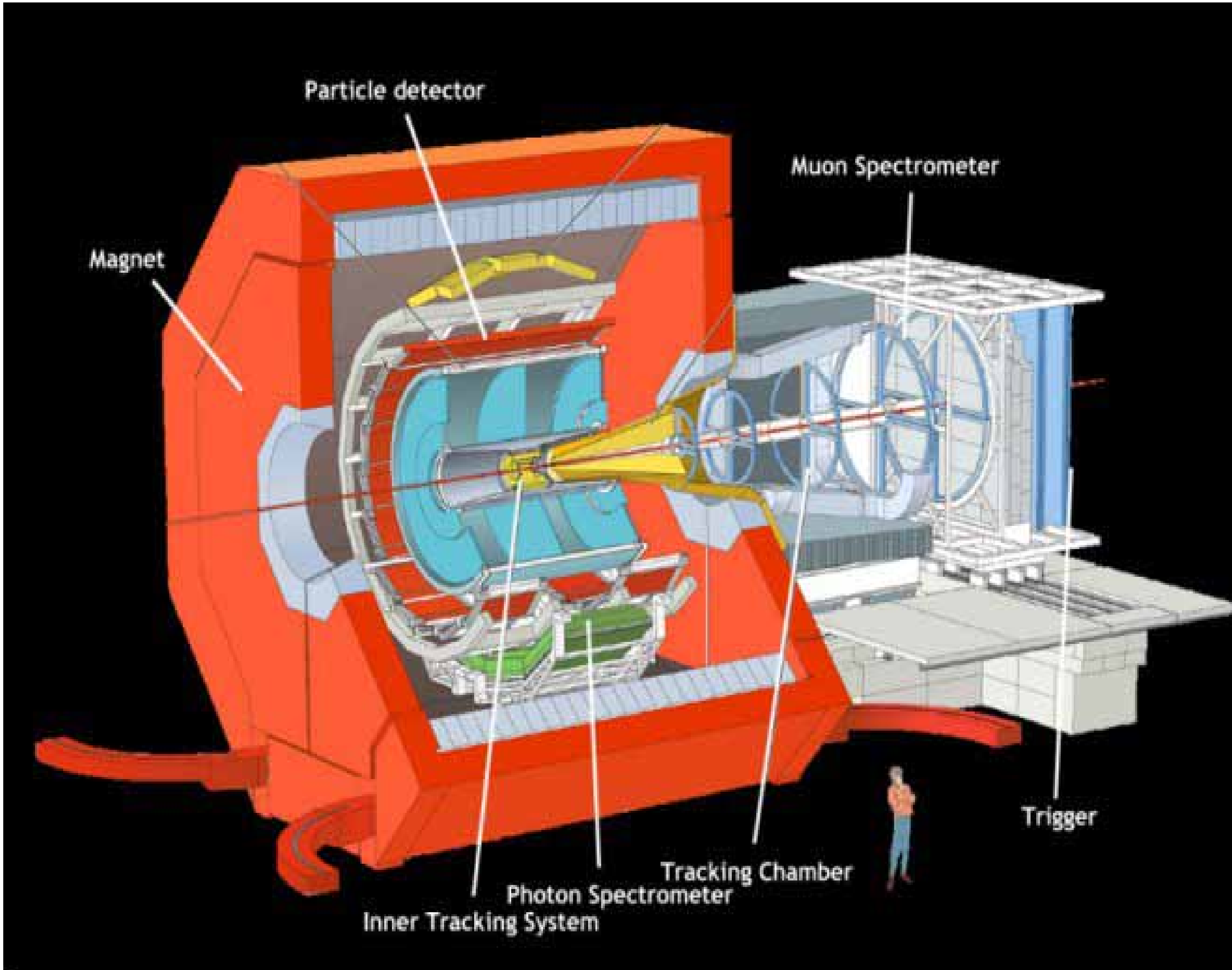

W_{cm}=10 TeV
gap =3.34
parp(85)=0.9, parp(86)=0.95
n0 ~ 64
b= 0.0057 +/- 0.0002
$<n_b>_{plateau}$= 0.72 +/0.03
$<pt_B>$
n


W_{cm}=10 TeV
gap =3.34
parp(85)=0.33, parp(86)=0.66
n0 ~ 57
b= 0.0027 +/- 0.0002
$<n_b>_{plateau}$ = 0.52 +/- 0.01
$<pt_B>$
n

PROPOSALS FOR LONG-RANGE CORRELATION STUDY IN ALICE AT THE LHC [1,2]

[1] see reports by V.Vechernin and G.Feofilov ISHEPP VII, , Dubna, 2002

[2] ALICE collaboration “ALICE: Physics Performance Report, Volume II”, J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295-2040 (Section: 6.5.15 - Long-range correlations, p.1749)


Particle detector
Muon Spectrometer
Magnet
Trigger
Tracking Chamber
Photon Spectrometer
Inner Tracking System

Collectivity effects in pp collisions?

Method: event-by-event measurement of long-range charged particle correlations between such observables as mulplicity and mean transverse momentum defined in two separate rapidity intervals

. The required running condition (detectors, trigger, read-out bandwidth, dead time...) for LRC study during the first pp run at 0.9/10 TeV

Trigger: min-bias

Studies/Detectors:

Rapidity structure of multiplicity-multiplicity LRC: ITS and FMD are sufficient

Rapidity structure of <p_t>-multiplicity LRC: TPC (+ITS) and FMD are needed

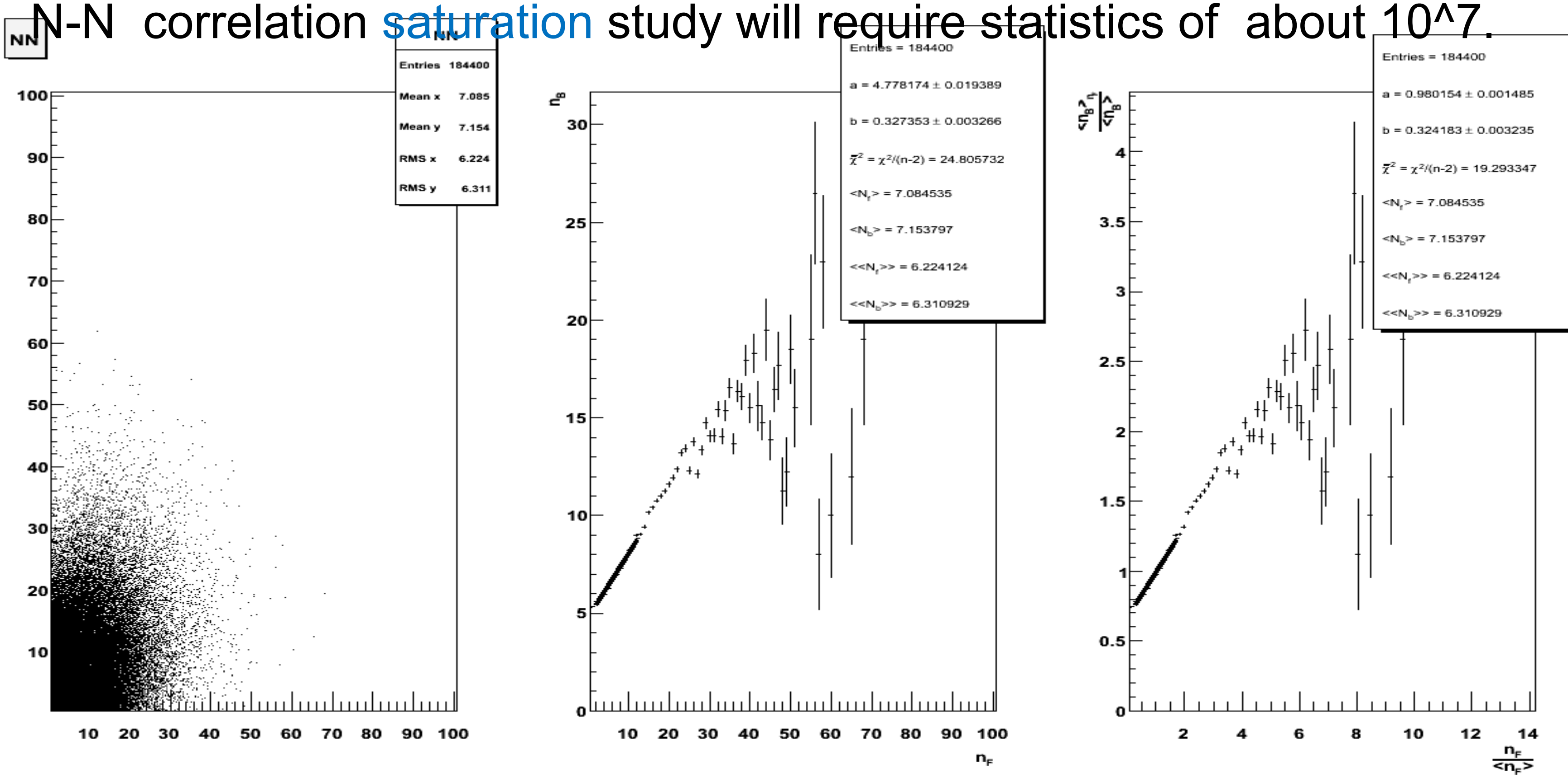
<p_t>-multiplicity correlation at midrapidity: TPC is sufficient

Rapidity structure of <p_t->p_t correlation at midrapidity ($|\eta|<1$) : TPC is sufficient

Example of Long-range n-n correlation, pp 900GeV. Pythia ESD

.

N-N correlation saturation study will require statistics of about 10^7.



Long-range Nch-Nch correlations. Forward rapidity window [1..0] ,
Backward rapidity window [0..-1]. Data from CAF: PDC06 Run 600 – 601
Link : http://aliceinfo.cern.ch/export/sites/default/Offline/Analysis/CAF/v4-04-Rev-07/ESD600_601_900GeV_v2.txt

The feasibility of the measurement in terms of statistics and systematic errors during the first pp run at 0.9/10 TeV in 2008

1). Short 900 GeV min bias pp run is interesting for this analysis to start and to compare to the existing data on multiplicity correlation

N-N correlation : Statistics about 1 - 2 x 10^5 events should be sufficient for the comparison to the existing data at 900 GeV(E735 Collaboration, "Charged particle multiplicity correlations in ppbar collisions at 0.3-1.8 TeV", Physics Letters B 353 (1995) 155-160) ,where about 150000 events data were accumulated

2). 10 TeV min bias run has to provide 2-3 x 10^5 of events for p_t-n correlation coefficient determination (This corresponds to [-1..0], [0..1] rapidity windows).

In a case of smaller windows of 0.2 units of rapidity the minimal required statistics will be 1 - 2 x 10^6 .

N-N correlation saturation: study will require statistics of about 10^7 events.

Conclusions

Long-Range Multiplicity correlation may indicate both in pp and AA high energy collisions to the common nature relevant to the phenomenon of color string fusion:

- The available data on pp and AA collisions show that nn correlation strength is observed to increase both with the collision energy and the system size
- Rapidity flat structure of nn-correlation strength is found in AuAu collisions at 200 GeV, extending to 1.8 units of rapidity
- In case of pp and ppbar collisions the nn-correlation demonstrates the presence of short-range and long-range components.
- Experiment shows considerable Long-Range Multiplicity Correlation up to about 5 units in the case of ppbar collisions at Fermilab
- **PYTHIA 6.4 with new default parameters, defined earlier by fitting to p_t-n correlation data, is found adequate to describe the long-range correlation observed in ppbar collisions at 0.3-1.8 TeV**
- **Collectivity effects in PYTHIA are found to be important in producing the "saturation" in the observed long-range multiplicity correlation**
- **The events relevant to this "saturatied multiplicity " domain are also characterized by the increased value of the <p_t> and could be selected in the experiment as the unique candidates of "the very central" pp-collisions**

Acknowledgemnts

Authors are grateful to **K. Safarik** and **T. Sjöstrand** for permanent interest to these studies and fruitful discussions.

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THANK YOU FOR YOUR ATTENTION!