Forward-Backward Multiplicity Correlations with the ALICE experiment in pp collisions at sqrt(s)=0.9, 2.76 and 7 TeV

G. Feofilov
for the ALICE Collaboration

Relativistic Nuclear Physisc and Quantum Chromodynamics
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Outline

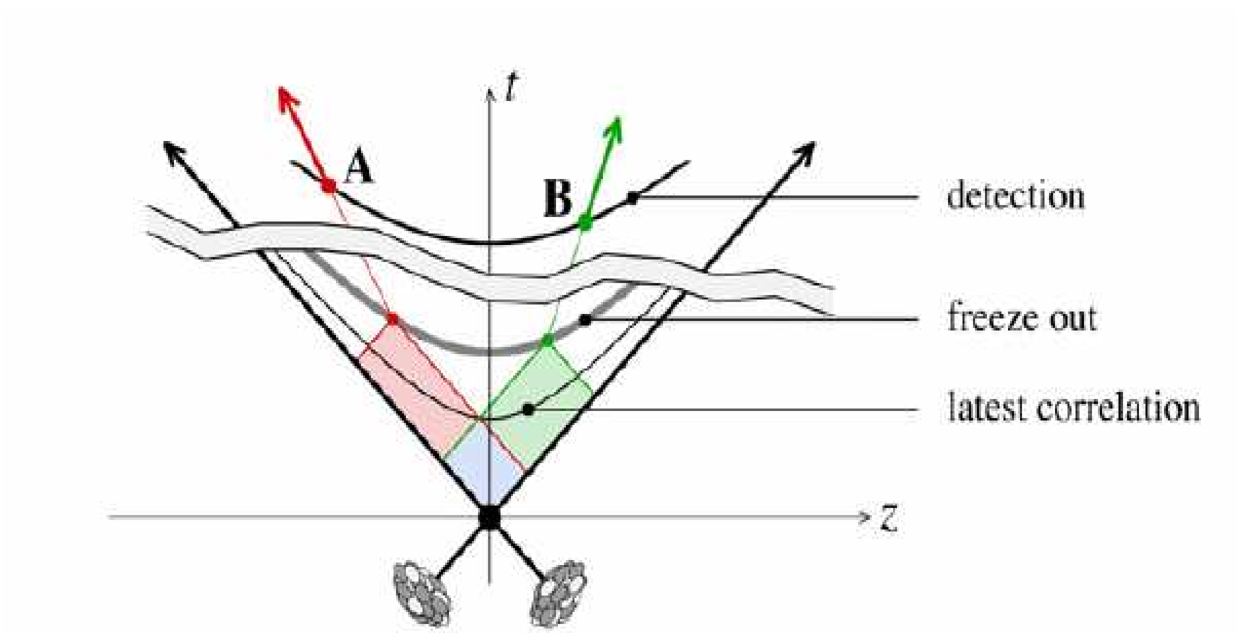
- Introduction: physics motivation
- Experimental method: event and track selection
- Corrections and Systematic errors
- Results and discussion, model comparison
- Conclusions

Experimental study of forward-backward correlations by ALICE:

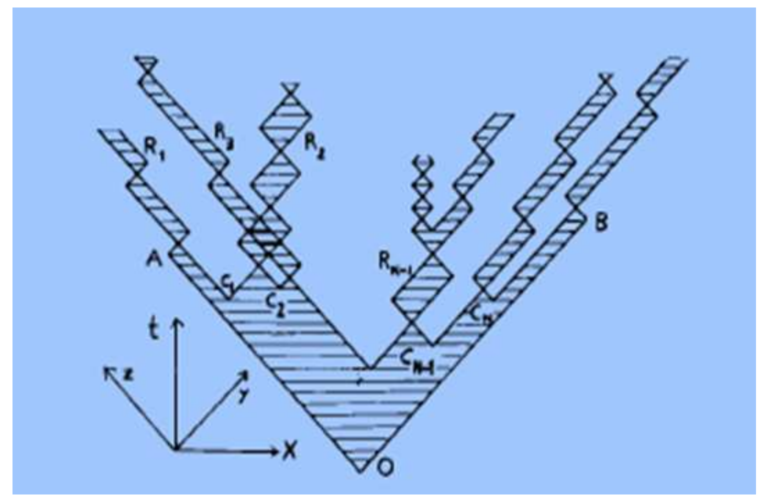
1) “Long-range (forward-backward) pT and multiplicity correlations in ALICE in pp collisions at 900 GeV”, G.Feofilov, for ALICE Collaboration, Proceedings of **The XX International Baldin Seminar** on High Energy Physics Problems "*Relativistic Nuclear Physics and Quantum Chromodynamics*", JINR, October 4-9, **2010, Dubna,** Russia
2) “Long-range (Forward-Backward) pt and Multiplicity Correlations in pp collisions at 0.9 and 7 TeV”, G.Feofilov (for ALICE Collaboration), QM-2011, poster report, Annecy, France.

LRC: a general question WHY? (both for pp and AA)

Causality requires that correlations – if they exist – of Long Range in rapidity between particles (A and B) detected in any type of collisions in separated rapidity intervals must be made very early:



A.Dumitru et al./ Nuclear Physics A 810 (2008) 91-108



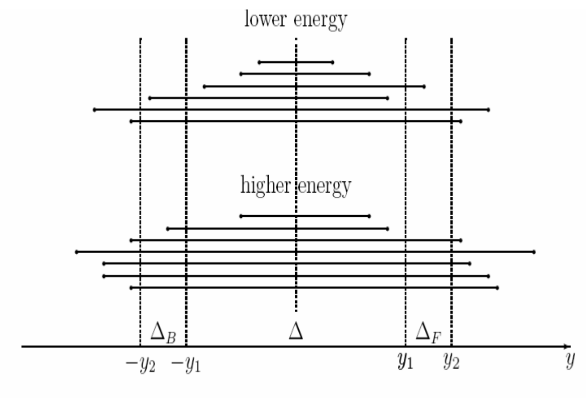
X. ARTRU and G. MENNESS1ER,
“STRING MODEL AND MULTIPRODUCTION”,
Nuclear Physics B70 (1974) 93-115

Theoretical Motivations

- **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 .

Today:

(1) Color string fusion phenomenon: M.A.Braun and C.Pajares,

Phys. Lett. B287 (1992) 154; Nucl. Phys. B390(1993) 542, 549;

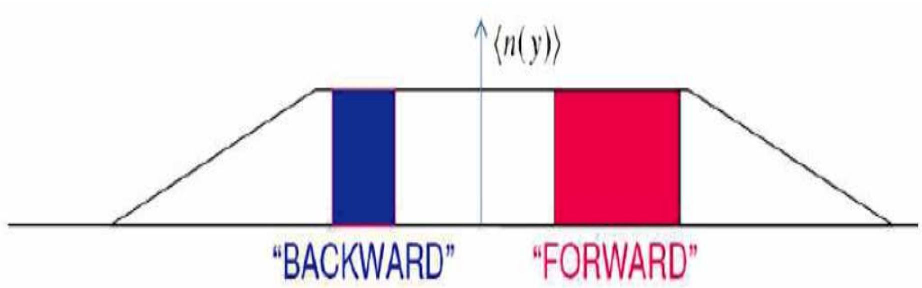
(2) Color Glass Condensate and Glasma flux tubes: see e.g. L.McLerran, Nucl.Phys.A699,73c(2002)

…both (1) and (2) are defining the initial conditions before the QGP and predicting the LRC – but in a different way!

(see N.S.Amelin et al. Phys. Rev. Lett., 73 (1994) 2813).

Forward-Backward (Long Range) Correlations:

for observables measured in two non-overlapping intervals in pseudorapidity space

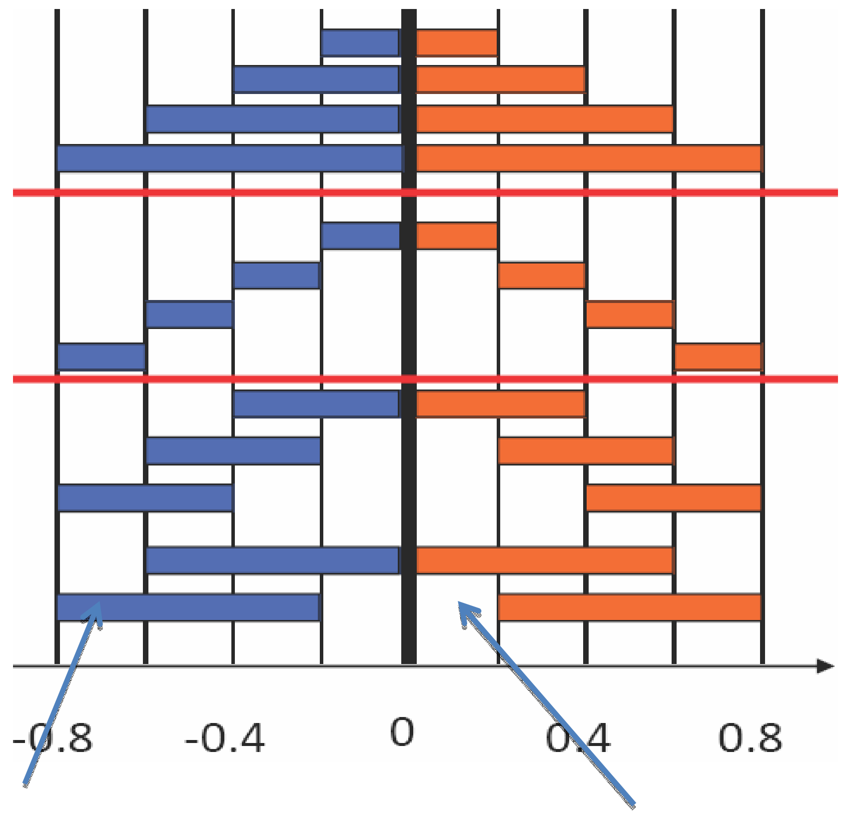


$\delta\eta_B$ η *gap* $\delta\eta_F$

n_B n_F

n_B, n_F – the event multiplicity in the BACKWARD and FORWARD pseudorapidity windows

Configurations of pseudorapidity intervals in our study:



$\delta\eta B$ η *gap* $\delta\eta F$

Pseudorapidity region here is limited to $|\eta|<0.8$

Two methods of calculation of multiplicity correlation coefficient *b*

- **Linear regression** [1]: $\langle \boldsymbol{n_B} \rangle_{n_F} = a + b * \boldsymbol{n_F}$
- **Correlator** [2]: $$b = \frac{\langle N_f N_b \rangle - \langle N_f \rangle \langle N_b \rangle}{\langle N_f^2 \rangle - \langle N_f \rangle^2} = \frac{D_{bf}^2}{D_{ff}^2}$$

[1] UA5 Collaboration, Z.Phys,C-Particles and Fields 37,191-213 (1988)
[2] A.Capella et al.,Phys.Rep. 236,225(1994)

The first early experimental indications of LRC (1988)

Charged particle correlations in $\bar{p}p$ coll at c.m. energies of 200, 546 and 900 Ge

UA5 Collaboration

Z. Phys. C – Particles and Fields 37, 191–213 (1988)

$$<n_B>_{n_F} = a+b*n_F$$

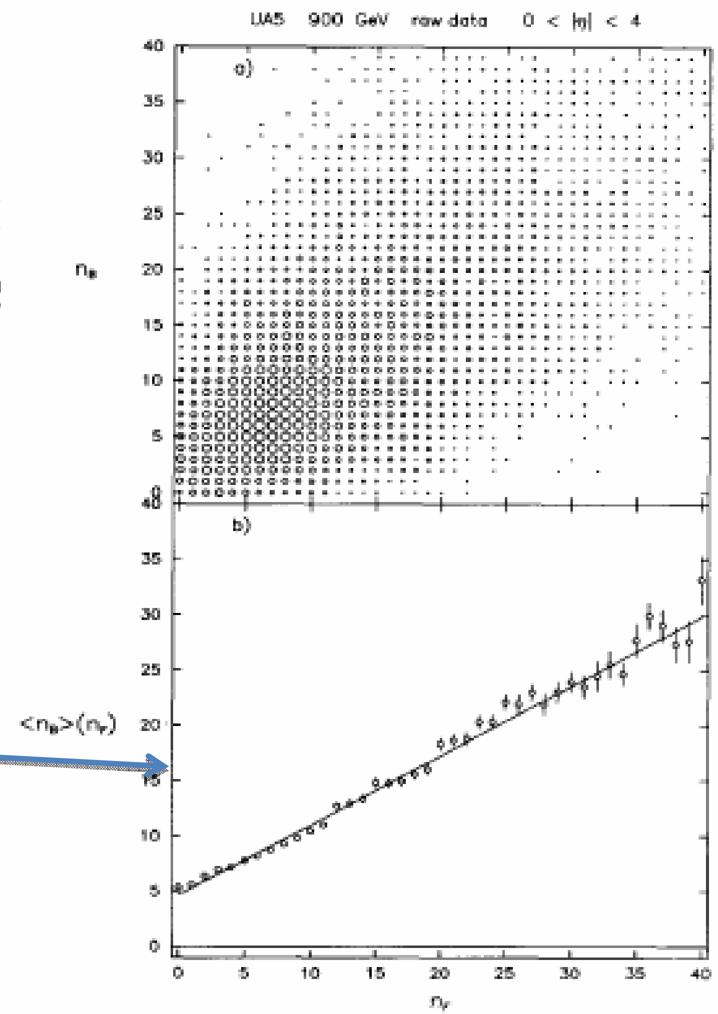
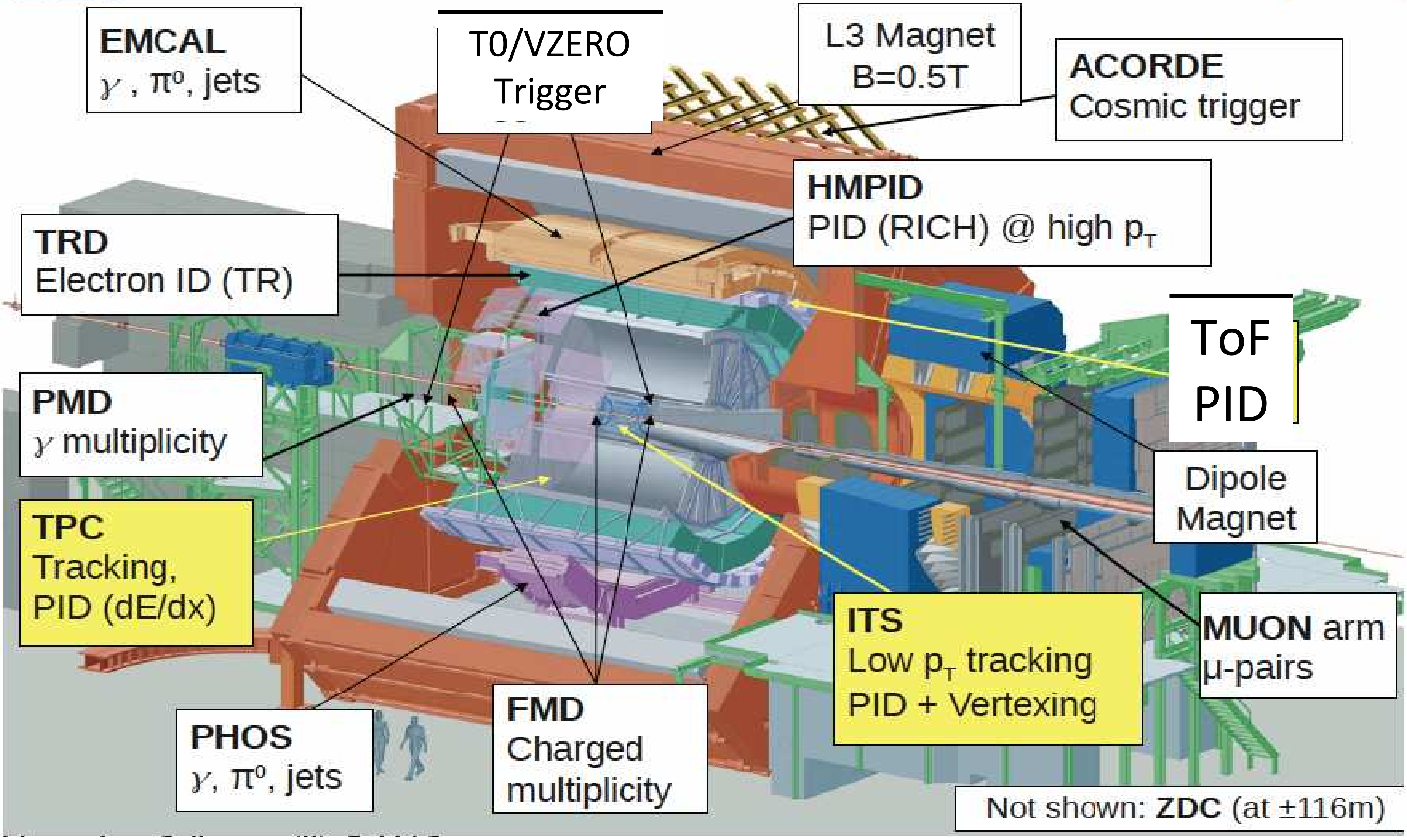


Fig. 12. a shows as a scatter plot (the circle area is proportional to the number of events) the backward multiplicity n_B versus the forward multiplicity n_F for raw data in the η range $0<|\eta|<4$ at 900 GeV. In **b** the average backward multiplicity $\langle n_B \rangle$ as function of the forward multiplicity n_F is plotted for the same data sample. The straight line shows the result of a least squares fit assuming a linear function

A Large Ion Collider Experiment



K. Aamodt et al. (ALICE), JINST, 3 , S08002 (2008)

Tracking of charged particles in ALICE

Detectors involved:

Inner Tracking System (ITS) and
Time Projection Chamber (TPC)

Track Selection

"Soft" p_T region **0.3-1.5 GeV/c**

$|\eta|$ region: {-0.8,+0.8}

Event Selection/vertexing

|Vz|(max) 5 cm

Collision energies and number of events:

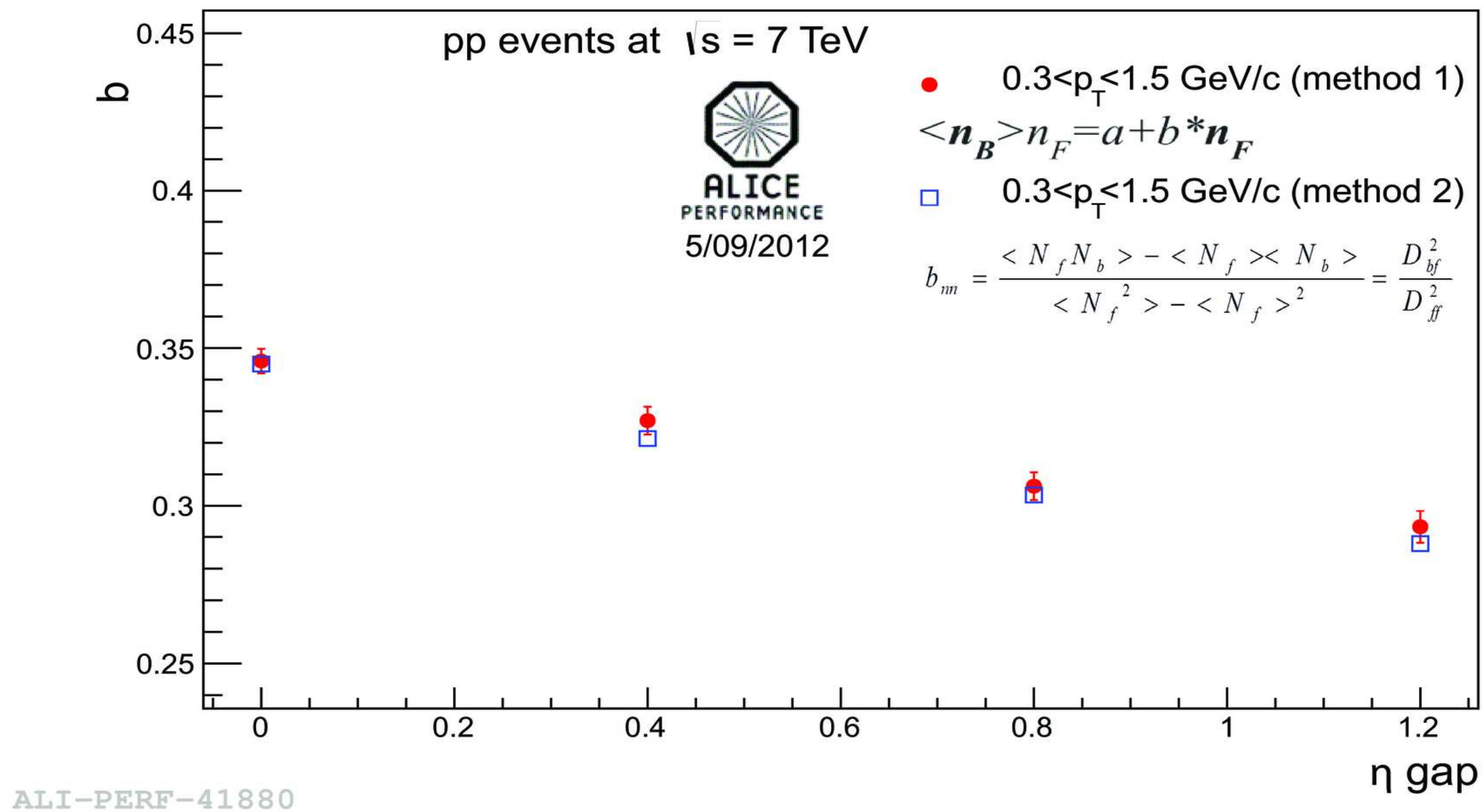
900 GeV Runs 2 mln

2.76 TeV Runs 10 mln

7TeV Runs 6.5 mln

Two alternative methods of *b* calculation

$\delta\eta = 0.2$



Good agreement is obtained

What has to be checked?

Factors that may influence the event multiplicity and correlations:

- Event and track selection criteria
  - vertex and track cuts criteria were varied between certain values
- Possibility of pile-up
  - runs with high luminosities were checked
- Methods of analysis and procedures of corrections
  - various alternative procedures and methods

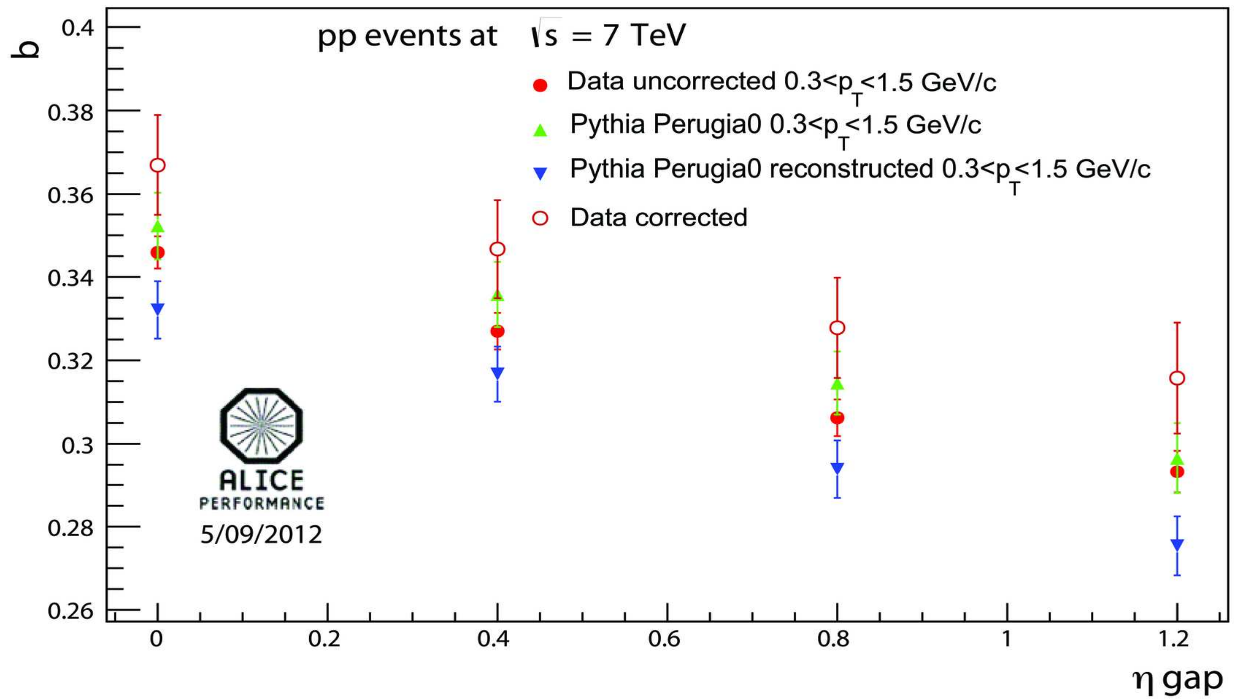
Two alternative procedures of corrections of b and of systematic error estimates

- **1. MC PYTHIA (Perugia0):**

  MC+GEANT vs True PYTHIA in $0.3<p_T<1.5$ GeV/c interval

- **2. Efficiency corrections using systematics study results**

Procedure 1:
b correction using MC/(MC+Geant)



Note scale! →

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$$b_{corr}=MC/(MC+GEANT)*b_{uncorr}$$

Systematics uncertainties are ~3% using Procedure 1

b correction via MC using correlator

$$b = \frac{<N_f N_b> - <N_f><N_b>}{<N_f^2> - <N_f>^2} = \frac{D_{bf}^2}{D_{ff}^2}$$

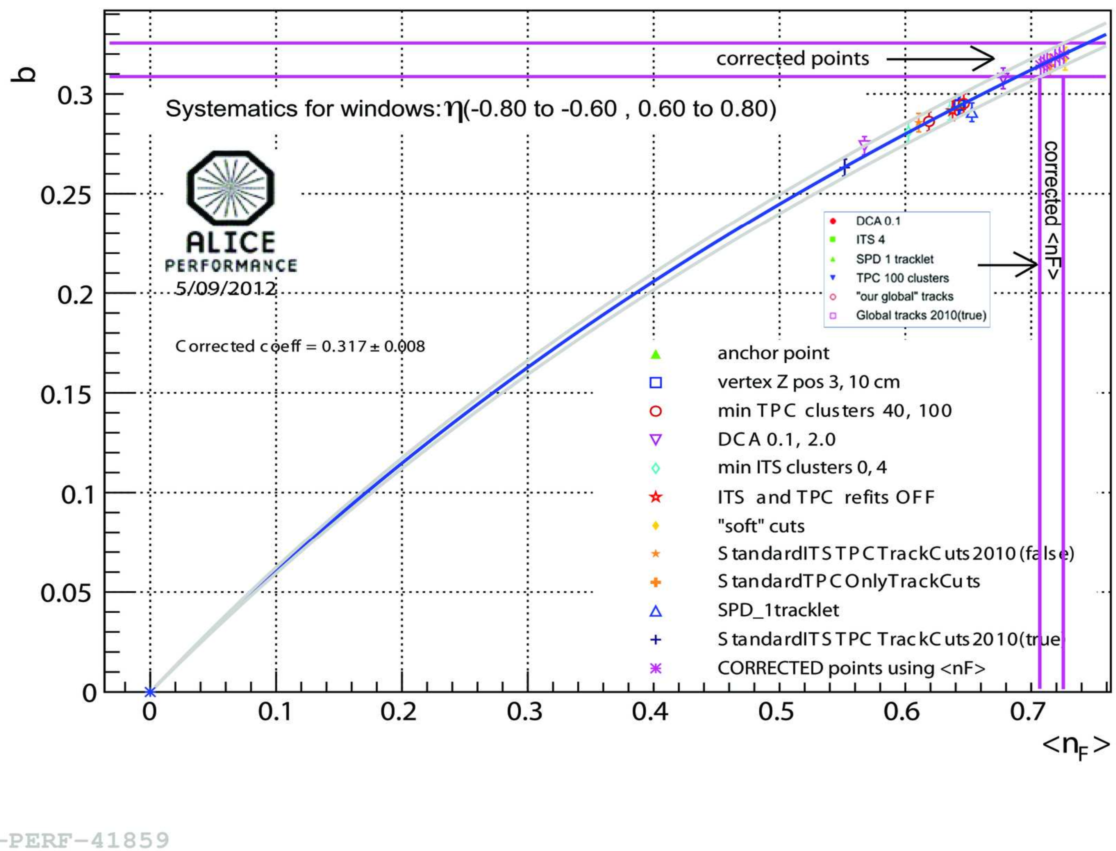
Efficiency is defined as : (MC + Geant)/ MC .
This ratio is done for each quantity like :
$<Nf>_{(MC + Geant)} / <Nf>_{(MC)}$
$<Nb>_{(MC + Geant)} / <Nb>_{(MC)}$
$<NfNb>_{(MC + Geant)} / <NfNb>_{(MC)}$
$<Nf^2>_{(MC + Geant)} / <Nf^2>_{(MC)}$

Each quantity of data is corrected by these factors .
Taking corrected quantities <Nb>,<nF>,<NbNf> “b” is calculated.

Two alternative methods of correction *b* using MC PYTHIA give the same results within 2%

Procedure 2:
b correction using systematics curve

Example of *b* calculation* pp@7TeV, $\delta\ \eta$ =0.2



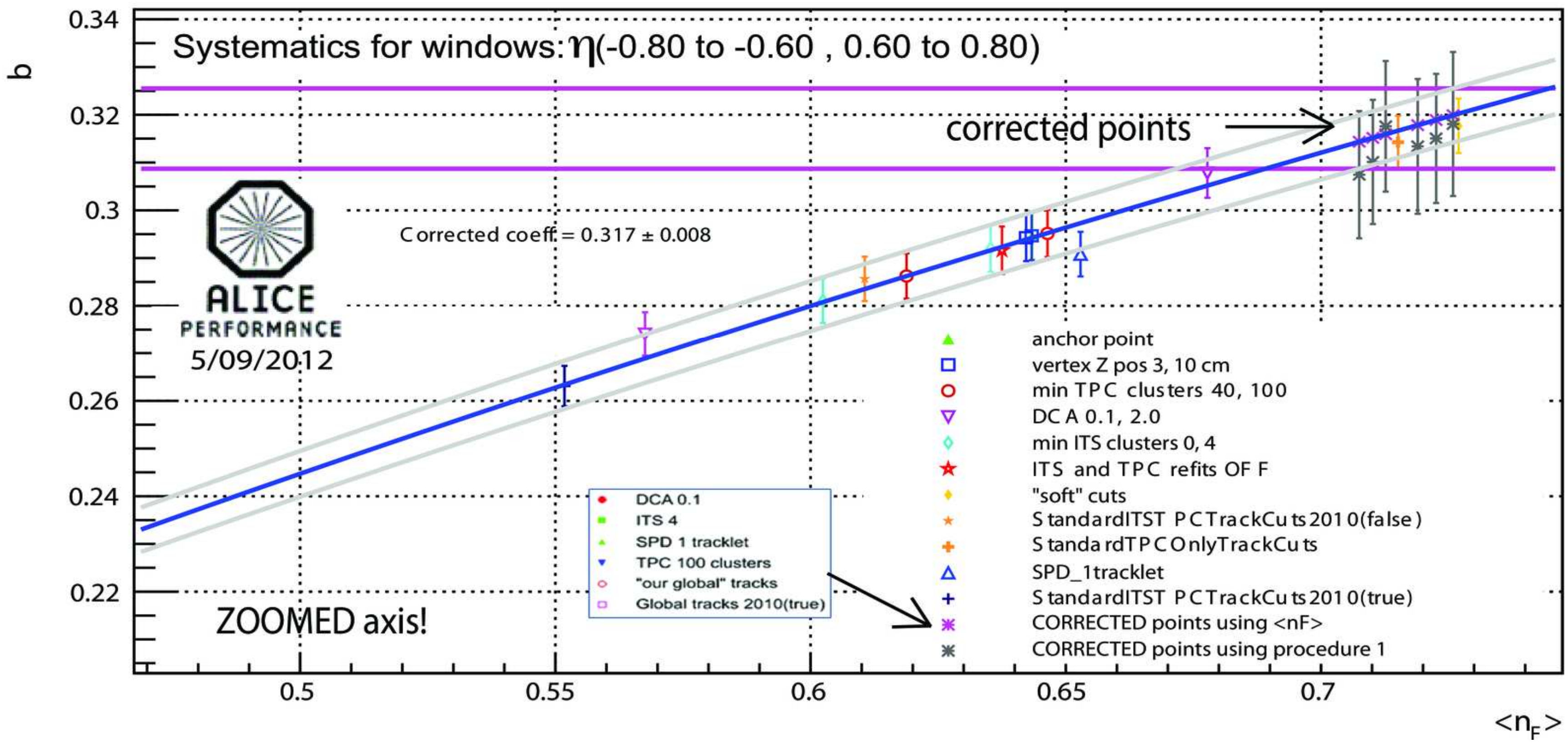
On this plot several corrected points are shown!

for fit function, see:* **M.A. Braun, R.S. Kolevatov, C. Pajares, V.V. Vechernin, Eur. Phys. J. C32, 535 (2004). V.V. Vechernin, arXiv:1012.0214, 2010

ZOOMED: Corrections both for *b* and for <Nf> using MC and comparison :

Example of *b* calculation

pp@7TeV, $\delta\,\eta = 0.2$

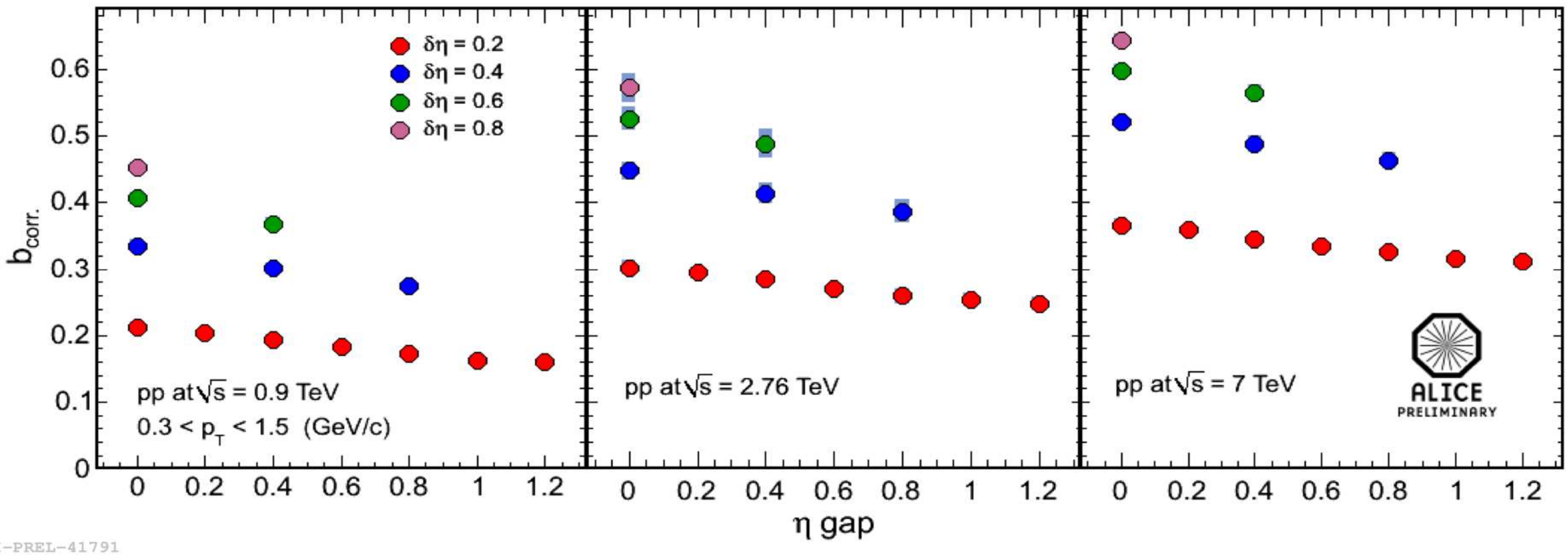


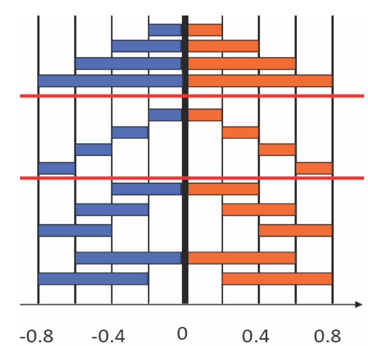
Two alternative procedures of correction - (1) using systematics curve and (2) via MC PYTHIA correction - give the same results within 2-4%

Summary of systematic errors

sources	0.9 TeV	2.76 TeV	7 TeV
TPC Clusters	3.0 %	0.13 %	0.7%
ITS Clusters	1.9 %	--------	1.4 %
DCA	1.5 %	1.8 %	1.0 %
VertexZ	1.1 %	1.0 %	0.7 %
Procedure(method)	4.0 %	4.2 %	2.8 %
Pile up	1 %	< 1%	<1 %
Total	4.5 %	4.2 %	3 %

Results: Correlation strength vs. η gap and for different η bin-widths.

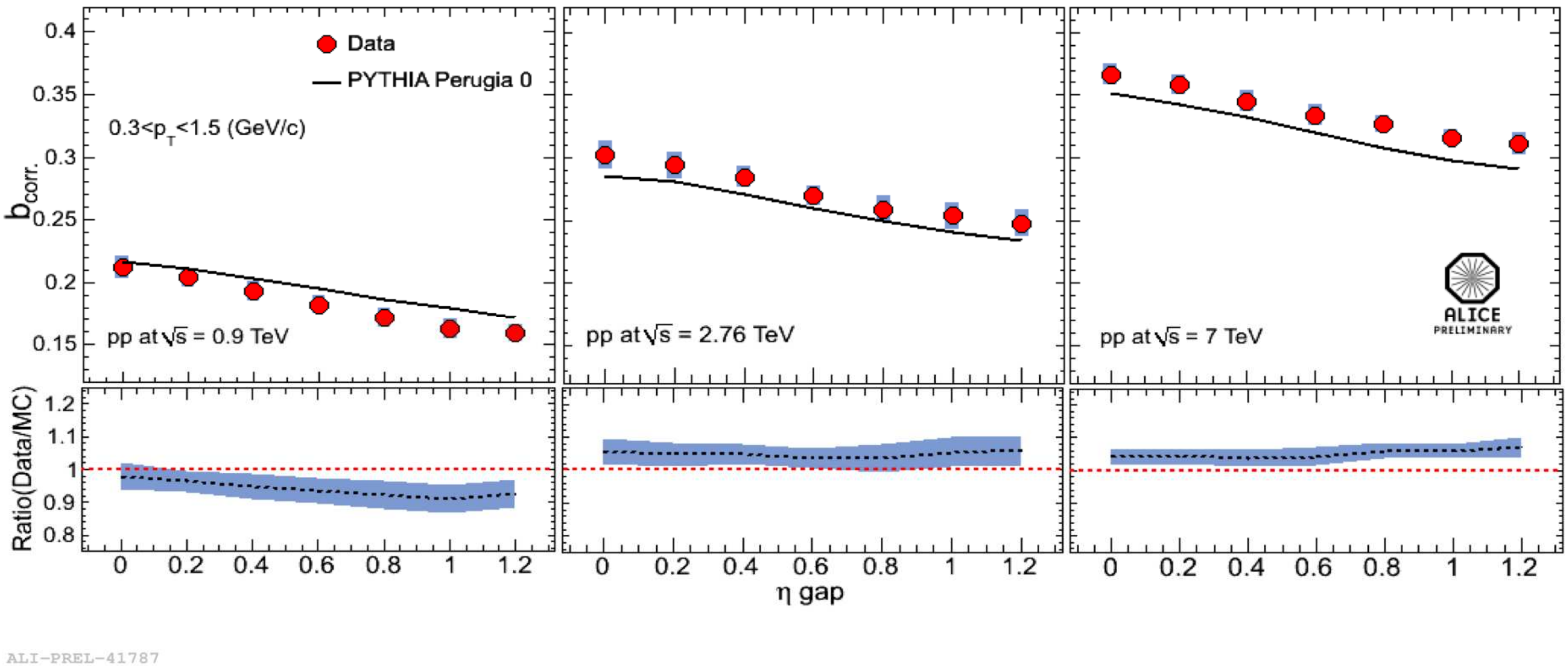




- *b* increases with increasing $\delta\ \eta$ bin-width

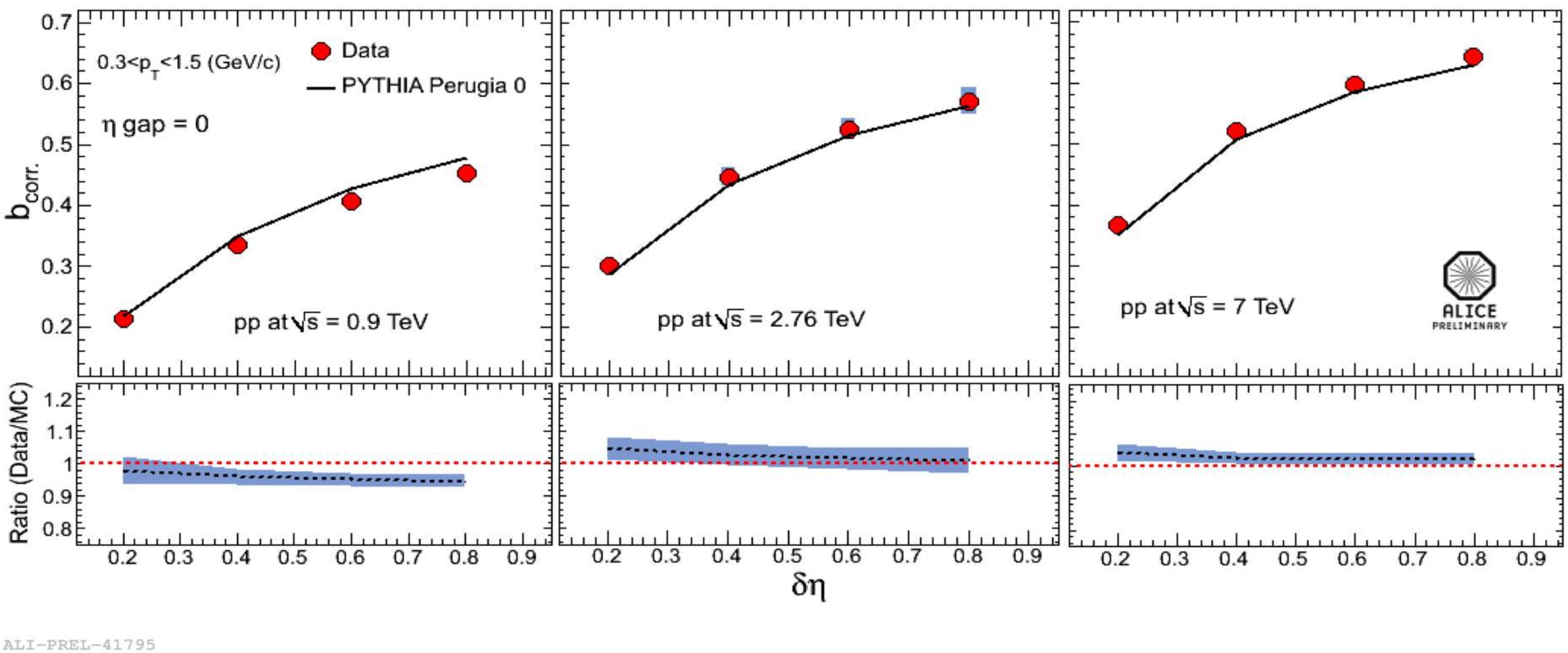
Results: Correlation strength vs. η gap and

comparison to PYTHIA (Perugia 0)



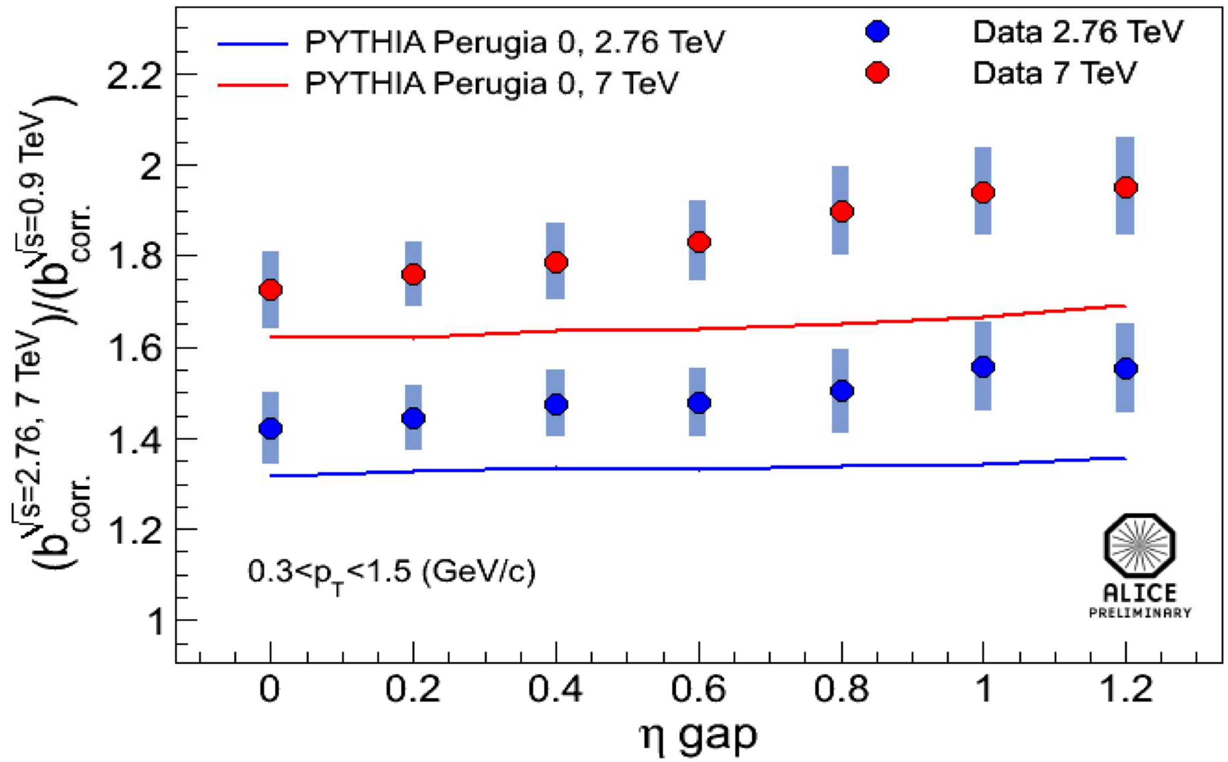
- Correlation strength with η – gap for three different energies is presented . Shaded region represent the systematic errors.
- Correlation strength increases with $\sqrt{s}$.
- **PYTHIA overestimates b at lowest energy and underestimates b at highest energy**

Results: Correlation strength vs. bin width ($\delta\ \eta$) for η gap=0 and comparison to PYTHIA Perugia 0



- Correlation strength is plotted with bin width ($\delta\ \eta$) for all the energies.
- b increases with increasing bin-width and shows a tendency to saturate for higher bin-width.
- PYTHIA (black line) shows similar trend as data.

Results: Ratio of correlation strength *b* at 7 TeV and 2.76 TeV wrt 0.9 TeV vs. η gap



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Red Points = Ratio between values of $b_{corr.}$ *at* 7TeV and 0.9 TeV

Blue Point = Ratio between values of b_{corr} at 2.76 TeV and 0.9 TeV

(δ η bin-width = 0.2)

Conclusions

- Strong non-linear dependence of the Forward-Backward multiplicity correlation coefficient value on the width of the pseudorapidity windows is observed in the region of $|\eta|<0.8$.

- The general growth of the Forward-Backward multiplicity correlations strength with energy is obtained in pp collisions study in ALICE at 0.9, 2.76 and 7 TeV

- The first comparison with the PYTHIA Perugia-0 calculations on the dependence of the correlation strength on the collision energy,the width and the position of pseudorapidity windows
show that the experimental data impose new constraints on the theoretical models.