LONG-RANGE (FORWARD-BACKWARD) Pt AND MULTIPLICITY CORRELATIONS IN ALICE IN pp COLLISIONS AT 900 GEV

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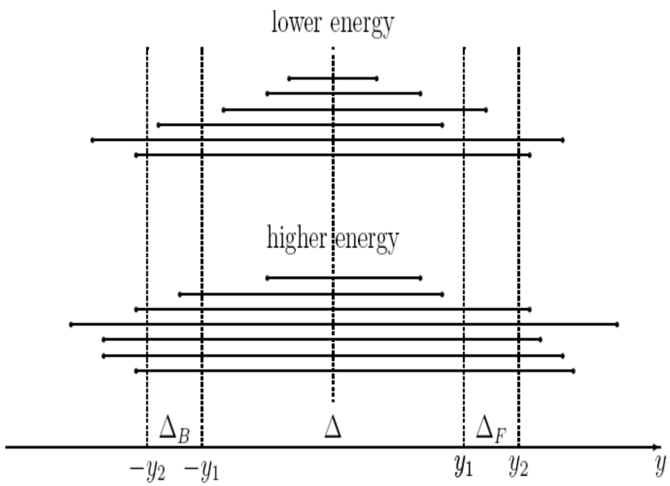
(http://relnp.jinr.ru/ishepp/)

Outline

- Motivation: Long-Range "Forward-Backward" correlations (FB) – WHY?
- pp@900GeV FB correlations analysis
- Systematic errors
- Results and discussion
- Conclusions and outlook

Motivation: Theory

Color string formation and decay



"Founding Fathers":

A two-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. {\bf 236} (1994) 225.
  A.B.Kaidalov, Phys. Lett., **116B**(1982)459;
  A.B.Kaidalov K.A.Ter-Martirosyan ,Phys.Lett., **117B**(1982)247.

Do these color strings interact and what is the signal? (*Long-range azimutal correlations*, *growth of <p_t>* *and* *elliptic flow* --- were predicted for AA and pp --- in 1988 (!):

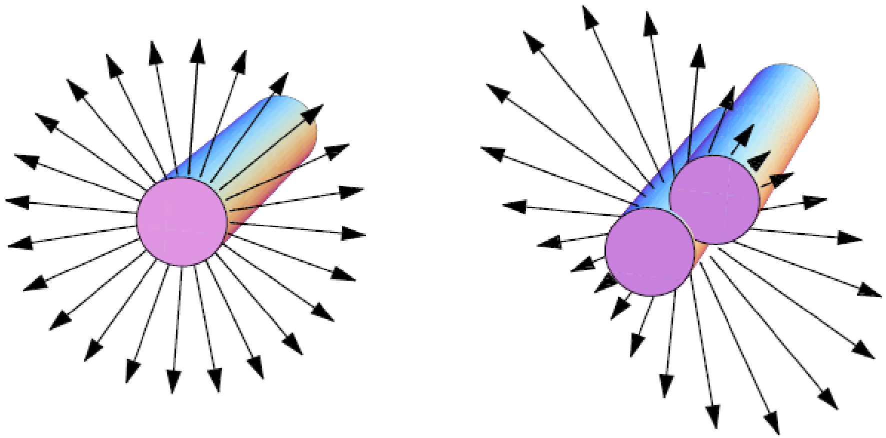
- Abramovskii V. A., Gedalin E. V., Gurvich E. G., Kancheli O. V. , Long-range azimuthal correlations in multiple-production processes at high energies, JETP Lett., vol.47, 337-339 , 1988 (!)

Color string fusion phenomenon:

- M.A.Braun and C.Pajares, Phys. Rev. Lett. {\bf 85} (2000) 4864; M.A.Braun and C.Pajares, Phys. Lett. {\bf B287} (1992) 154;\\ Nucl. Phys. {\bf B390} (1993) 542, 549;\\
- N.S.Amelin, M.A.Braun and C.Pajares, Phys. Lett. {\bf B306} (1993) 312;\\ Z.Phys. {\bf C63} (1994) 507.
- **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

Motivation: more of Theory

This old concept *of interacting chromoelectric tubes [1]* may be illustrated by some nice figure from the quite recent paper [2] :



"Fig. 1. Sketch of the one and two flux tubes configurations considered. On the left a single flux tube elongated in space-time rapidity generates azimuthally symmetric flow. On the right a configuration with two strings leads to an **azimuthally asymmetric flow** in the transverse plane" [2].

[1] Abramovskii V. A., Gedalin E. V., Gurvich E. G., Kancheli O. V. , Long-range azimuthal correlations in multiple-production processes at high energies, JETP Lett., vol.47, 337-339 , 1988

[2] Piotr Bozek, "**Observation of the collective flow in proton-proton Collisions**", arXiv://0911.2392v2 [nucl-th] 22 Jan 2010

…more…

Motivation: more of Theory

Collectivity in pp collisions:

Elliptic flow (*v2) in pp collisions at the LHC*

At Large Hadron Collider energy, the expected large multiplicities suggest the presence of collective behavior even in *pp collisions (see, for example, [1])*

The elliptic flow signal in high-multiplicity p-p collisions at the LHC looks to be measurable with standard techniques [2]

[1] S. K. Prasad, Victor Roy, S. Chattopadhyay, and A. K. Chaudhuri , "**Elliptic flow (*v2) in pp collisions at energies available at the CERN Large Hadron Collider:*** **A hydrodynamical approach". Phys.Rev.C 82, 024909(2010)**

[2] Jorge Casalderrey-Solana1 and Urs Achim Wiedemann1, "**Eccentricity fluctuations make flow measurable in high multiplicity p-p collisions"** , CERN-PH-TH/2009-226, arXiv:0911.4400 [hep-ph]

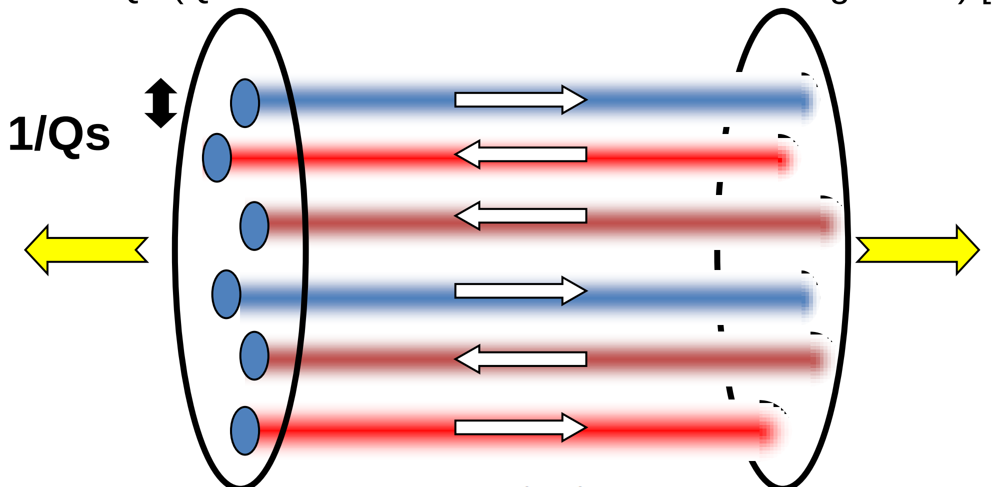
…more…

…more…

Motivation: more of Theory

The glasma flux tubes

The glasma just after the collision is made of color electric and magnetic flux tubes extending in the longitudinal direction with their diameters of the order of 1/Qs (Qs is the saturation scale of the colliding nuclei).[1]



$$E^z = ig[\alpha_1^i, \alpha_2^i]$$
$$B^z = ig\epsilon^{ij}[\alpha_1^i, \alpha_2^j].$$

Fig. 1. The color electric and magnetic flux tubes just after the collision. The transverse size of the flux tube is of the order of 1/Qs.[1]

[1] Hirotsugu Fujii, Kazunori Itakura , "Expanding color flux tubes and instabilities", arXiv:0803.0041, 4 June 2008

…more…

Motivation: more of Theory

C.Pajares, **"STRING PERCOLATION AND THE GLASMA",** report at **"The first heavy ion collisions at the LHC - HIC10", see:** http://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=75549

- Large similarities between CGC and percolation of strings
- For pp at the LHC the same phenomena as for AuAu at RHIC
- Percolation parameter η_{crit}=1.15 both
  for PbPb at sqrt(s)=20 GeV
  AND for pp at sqrt(s)=6TeV at the LHC (!)

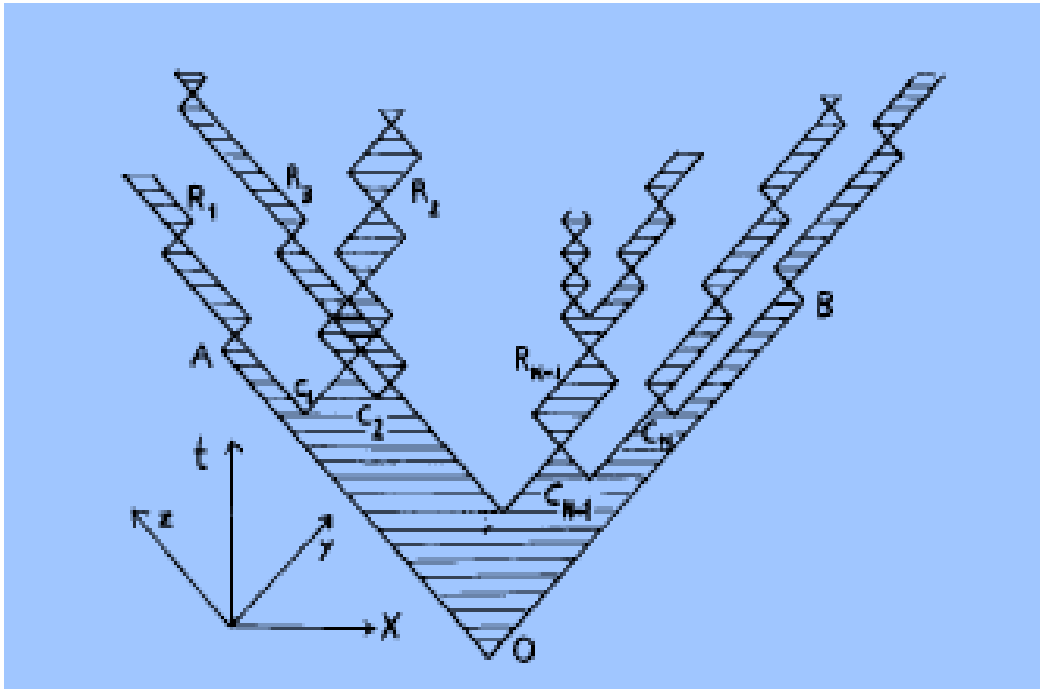
The characteristic feature of ALL these approaches is the prediction of the Long-Range Correlations that could be measured:

$$\langle n_B n_F \rangle - < n_B >< n_F >$$

Motivation

Space-Time 2D picture of string formation and decay into 2nd and etc. generation of resonances or particles [1]

[1] X. ARTRU and G. MENNESS1ER,
"STRING MODEL
AND
MULTIPRODUCTION",
Nuclear Physics B70 (1974) 93-115



Measurement of the **Long-Range "Forward-Backward"** **<n>-n , <pt>-n and <pt>-pt** correlations using the data in separated pseudorapidity intervals is ***a model independent method*** to reveal the presence of the **collective effects**, relevant to ***the early stages*** of hadronic matter formation both in pp and AA collisions

…more…

Motivation: experiment

Real LRC in ppbar collisions 0.3-1.8 TeV[1]

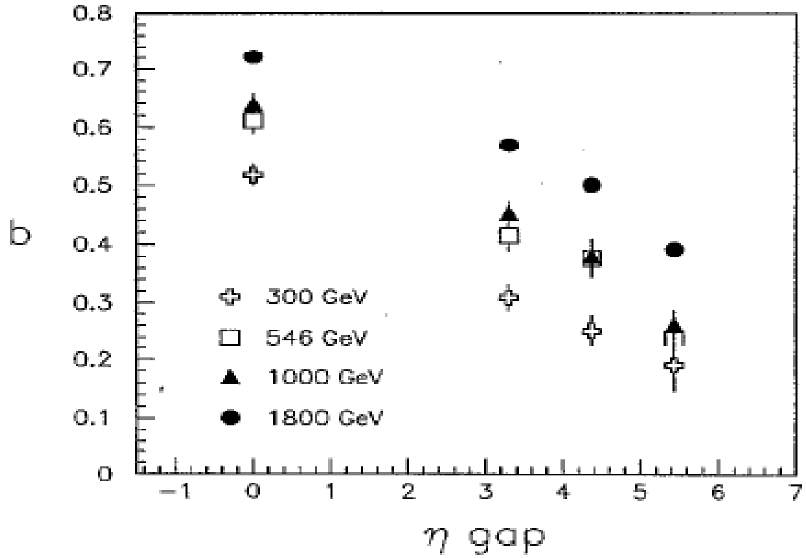


Fig. 2. Correlation coefficient as a function of central η gap.

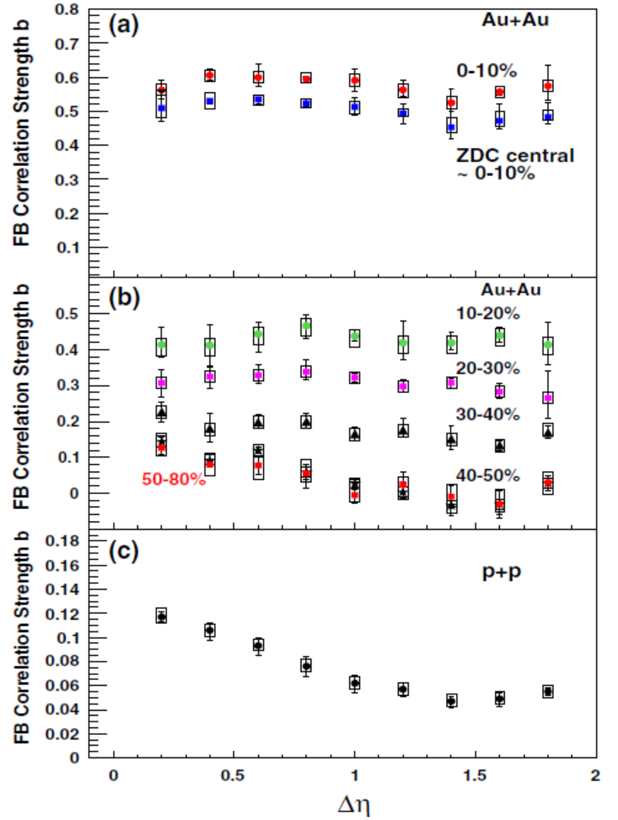


FIG. 1 (color online). (a) FB correlation strength for 0–10%(circle) and ZDC based centrality (square) (b) FB correlation strength for 10–20, 20–30, 30–40, 40–50 and 50–80% (square)Au +Au and (c) for p + p collisions as a function of at 200 GeV. [2]

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

[3] STAR Collab., "Growth of Long Range Forward-Backward Multiplicity Correlations with Centrality in Au +Au Collisions at 200 GeV" PRL 103, 172301 (2009)

Motivation: experiment - **the 1st detailed study of LRC in PbPb collisions at 158 AGeV [3])**,

2 rapidity intervals: $\Delta y_B \in (-0.29, 0.33),\ \Delta y_F \in (0.91, 2.0).$

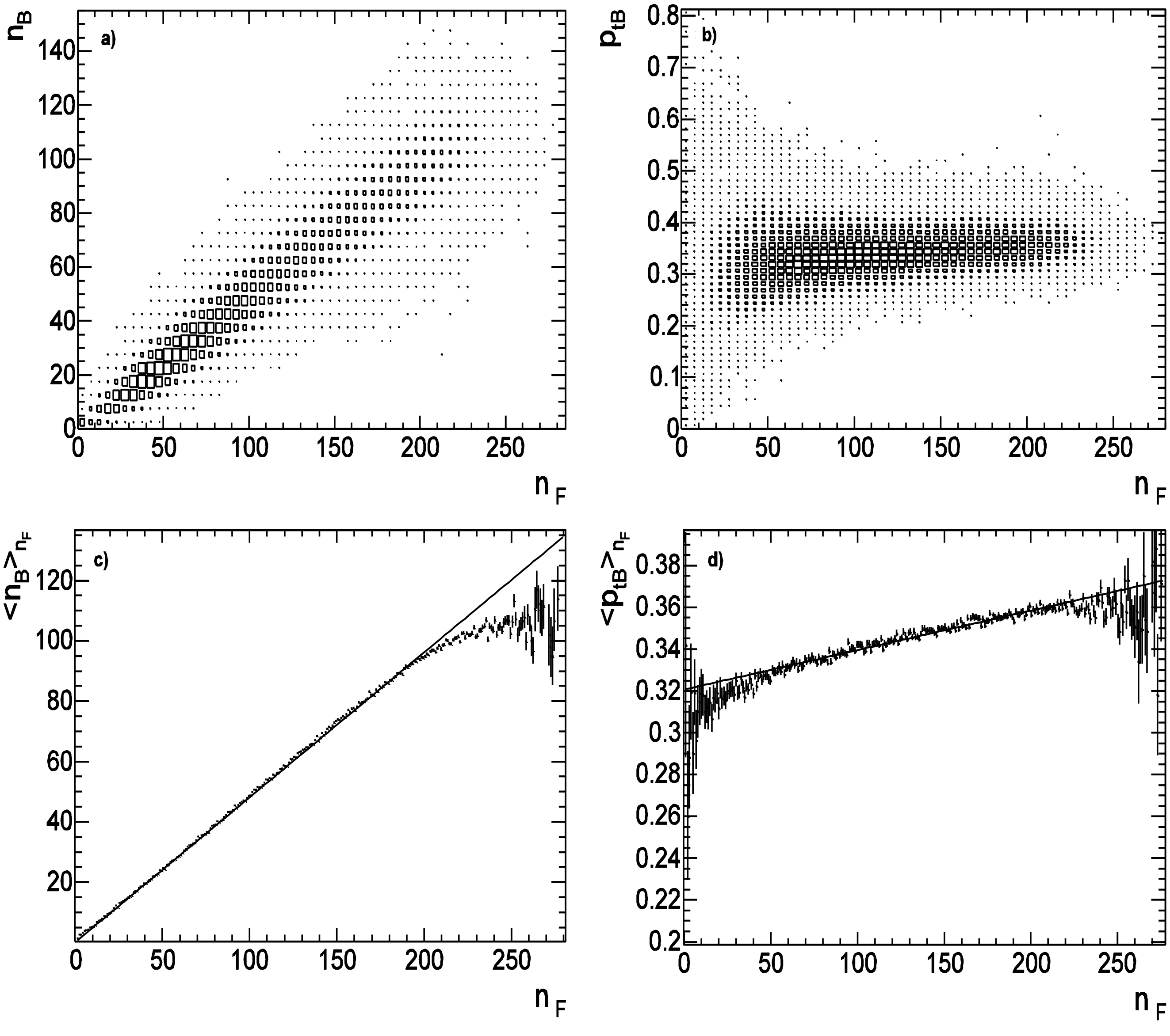
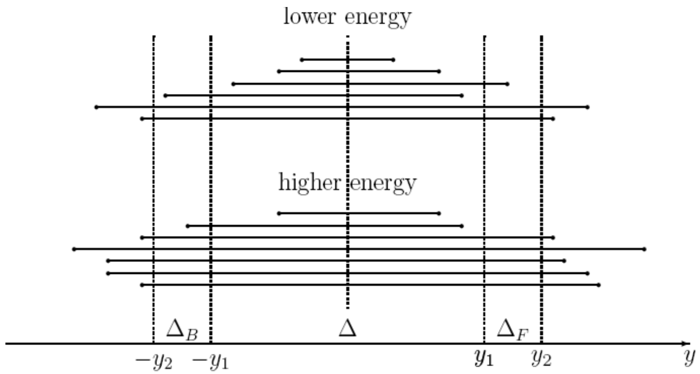


Fig.2. n-n and p_t-n correlations in PbPb collisions at 158 AGeV (example of Min.bias data) , [3]:

[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 (Presented by G,Feofilov (for NA49 Collaboration and SPbSU), ISHEPP-XVII, JINR,Dubna, 27 Sept.-02 Oct. 2004)

Motivation:

- We continue studies of Long-range {Forward-Backward) correlations proposed for ALICE[1,2] as a tool to search for colour string fusion phenomenon that might be reached in the high energy nucleus-nucleus collisions and lead to the formation of the QGP.
- Term “Forward-Backward” correlations (“FB”) refers here to the limited rapidity coverage ($-0.9 < \eta < 0.9$) of the ALICE central tracking system used in this first study .



[1] P.A.Bolokhov, M.A.Braun, G.A.Feofilov, V.P.Kondratiev, V.V.Vechernin, Internal Note/PHY.ALICE-INT-2002-20(2002)16p;

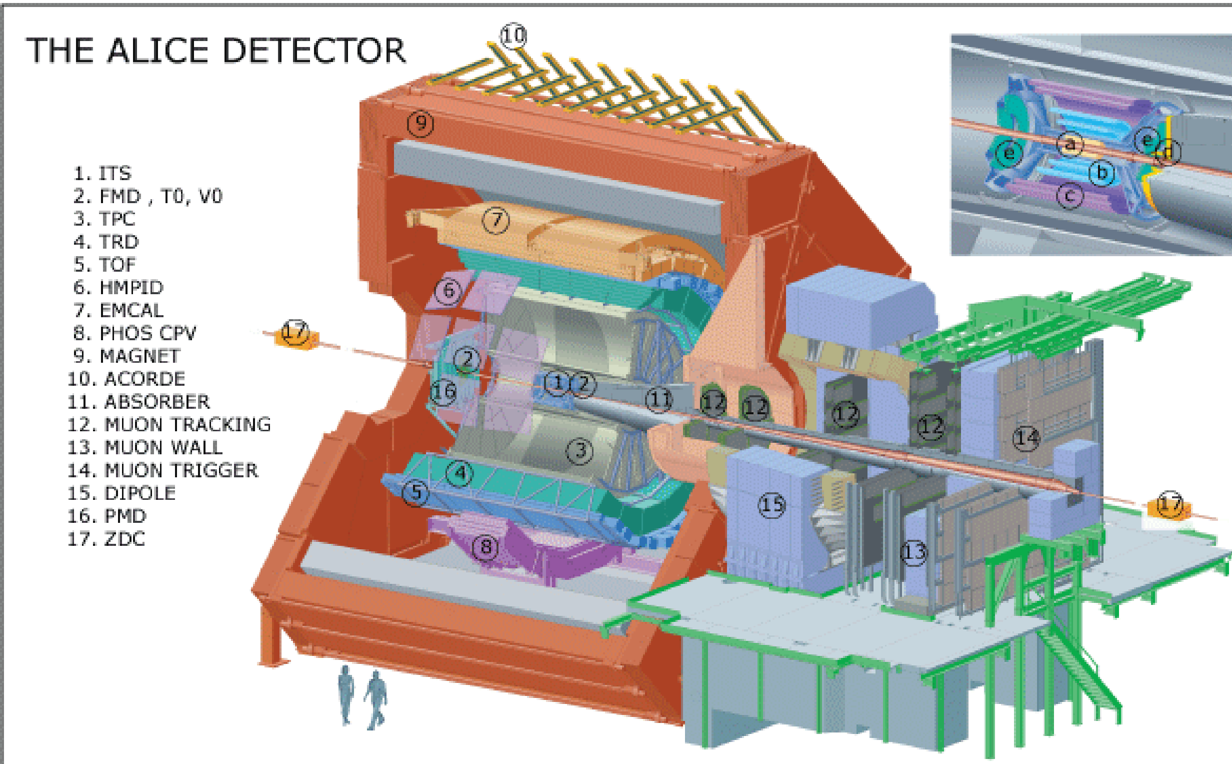
[2] ALICE collaboration “ALICE: Physics Performance Report, Volume II”, J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295-2040 (Section: 6.5.15 - Long-range correlations, p.1749)

ALICE at the LHC

http://iopscience.iop.org/0954-3899/30/11/001/

ALICE Technical Paper

http://iopscience.iop.org/1748-0221/3/08/S08002



- ALICE is a *dedicated heavy-ion* detector:
- Soft (100MeV) to hard (>100GeV) physics
- **Soft physics: low p_T cut-off (~100 MeV):**
  => Low magnetic field: 0.2-0.5 T & Low material budget: about 7% for the ITS, below 13% Xo up to the end of the TPC)

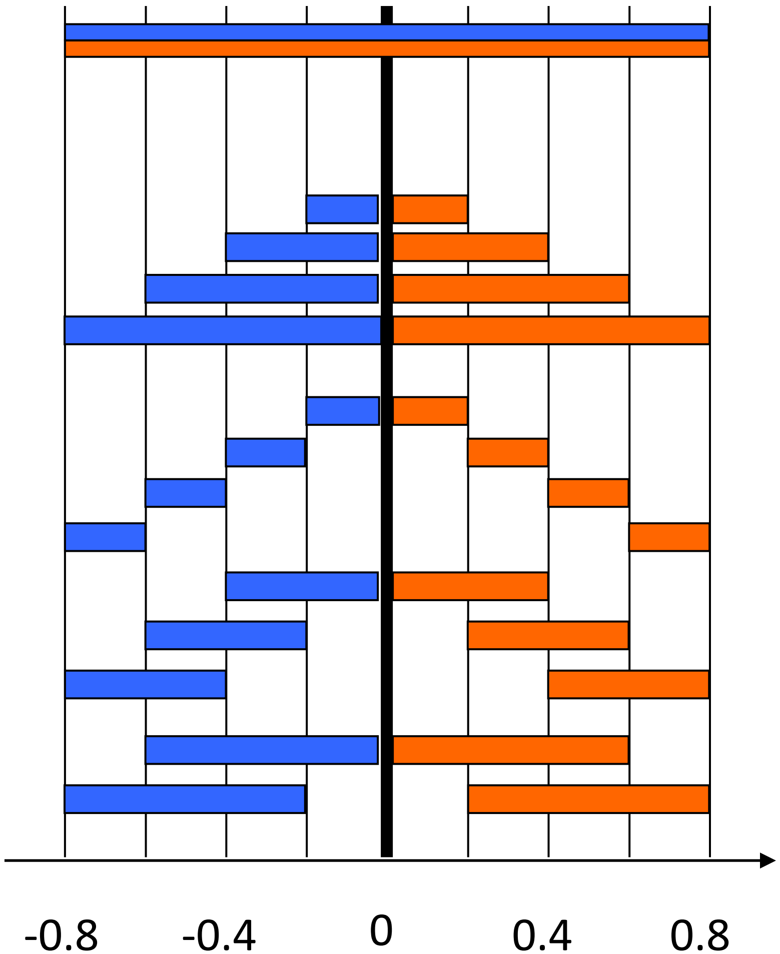
- Multiplicity
  - charged (barrel+FMD): ($-5.03 < \eta < 3.68$)
  - photons in PMD ($-2.3 < \eta < -3.7$)
- Forward muon arm ($2.4 < \eta < 4.0$)
  - absorber, dipole magnet
  - tracking and trigger chambers
- Trigger, timing, luminosity:
  - ZDC, V0, T0, CRT
- Central Barrel ($-0.9 < \eta < 0.9$)
  - tracking, PID (ITS, TPC, TRD, TOF)

In the 1st analysis here we used the information only from the central ALICE detector systems: ITS and TPC

Detector	Acceptance (η, ϕ)
ITS layer 1,2 (SPD)	$\pm 2, \pm 1.4$
ITS layer 3,4 (SDD)	$\pm 0.9, \pm 0.9$
ITS layer 5,6 (SSD)	$\pm 0.97, \pm 0.97$
TPC	± 0.9 at r=2.8 m

‘Forward-Backward” correlations dependence on η gap and on η window size

η windows in central barrel



Analysis

General:

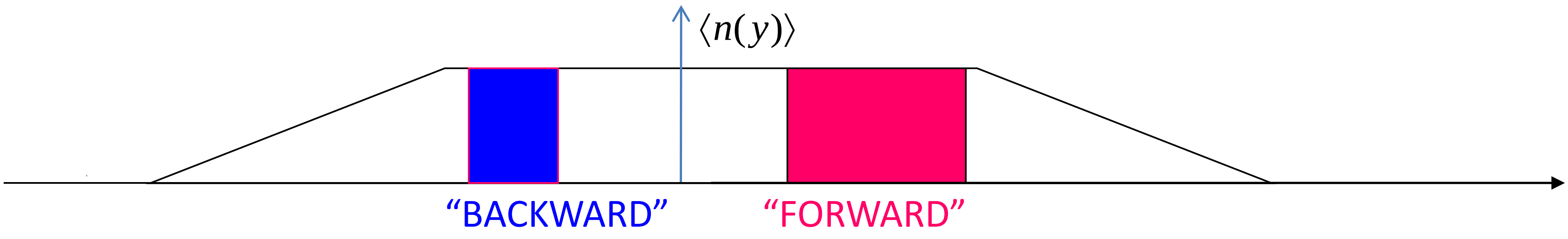
study of **<n>-n ,<pt>-n and <pt>-pt** correlation coefficient dependences on η windows size and positions.

Now: only ITS+TPC data

Future plans: to include the FMD as multiplicity detector for **<n>-n and <pt>-n** correlations. So that charged particle multiplicity and long-range correlations will be measured in a larger rapidity domain ($-3.4 < \eta < 5.1$).

Forward-Backward/Long-Range Correlations:

2 rapidity intervals separated by gap



For each event:

1) ***the event mean multiplicity*** **in BACKWARD or FORWARD rapidity windows:**

$$n_B, n_F$$

2) ***the event mean transverse momentum*** **for BACKWARD and FORWARD rapidity windows:**

$$p_{tB} = \frac{1}{n_B}\sum_{i=1}^{n_B} p_{tB}{}^{i} \qquad p_{tF} = \frac{1}{n_F}\sum_{i=1}^{n_F} p_{tF}{}^{i}$$

Event-by-event:

We define ***the mean value of the observable in one rapidity window*** **at the given value of another observable in the second window(regression), for example:**

$$\langle p_{tB}\rangle_{n_F} \quad or \quad \langle n_B\rangle_{n_F} \quad or \quad \langle p_{tB}\rangle_{p_{tF}}$$

Types of correlations:

1. **<n>-n** - the correlation between the event mean charged particle multiplicity in one rapidity interval and the charged particle multiplicity in another interval
2. **<pt>-n** - the correlation between the event mean transverse momentum in one rapidity interval and the charged particle multiplicity in another interval.
3. **<pt>-pt** - the correlation between the event mean transverse momentum obtained in the backward (B) rapidity window
   and the event mean transverse momentum in the forward (F) rapidity window

Usually:
Correlation coefficients are defined
– in the region where some linearity exists -
for the **absolute** values of observables as:

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

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

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

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

Systematic errors:

Potential major sources of systematic errors that could systematically shift the values of the correlation coefficients :

--- the event selection cuts

--- track selection criteria and track quality criteria values

---- Event Multiplicity and particle type multiplicity

---- PID Efficiency

The analysis was done using the standard ALICE Event Summary Data (ESD). It is based on pp simulated data (Pythia LHC10a8 production). We compare the calculations of Long-range correlation coefficients with the influence of the whole experimental setup and data reconstruction chain (ESD) and without this influence (Kinematics)

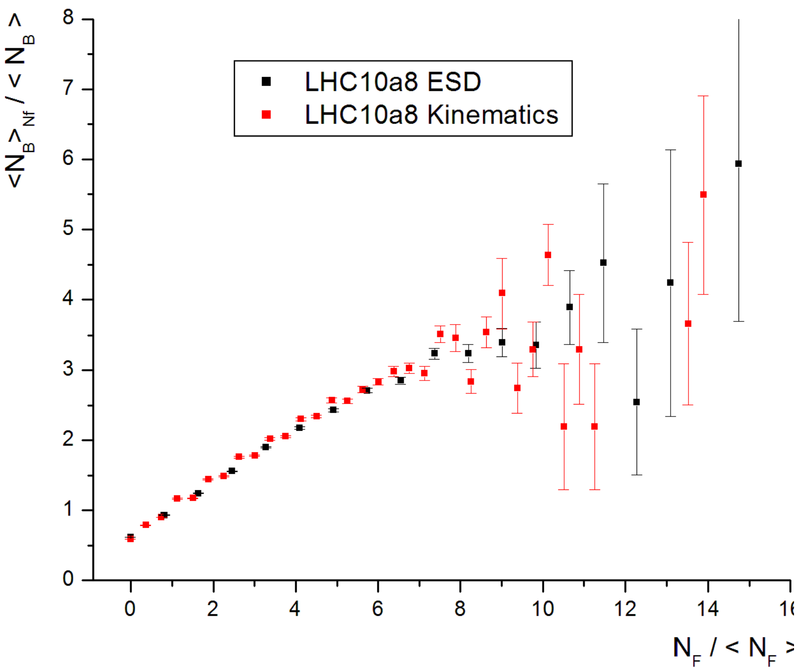
It appears that **the use of the normalized observables** in study of: **<n>-n and <pt>-n** correlation functions **provides the unbiased results** in the region of interest (Pt cut: $0.3 < Pt < 1.5$),

see the next slide:

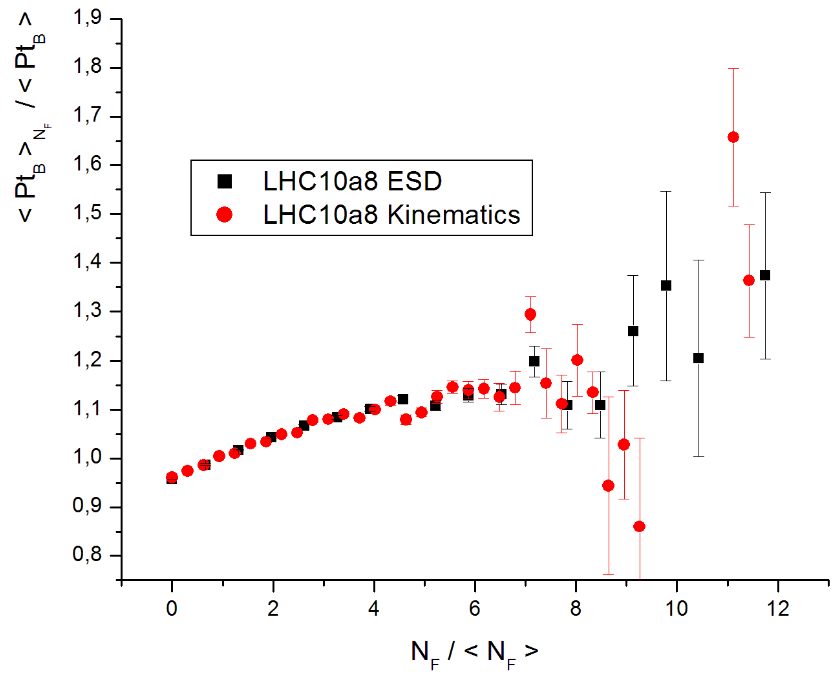
Comparison of simulated and reconstructed PYTHIA data in the framework of ALICE experimental setup in terms of FB correlations

Comparison of Kinematics and ESD in Pythia LHC10a8 production in terms of FB correlations: **<n>-n** **and** **<pt>-n** correlation functions **in normalized** observables.
Forward η window (-0.8 – 0.0) Backward η window (0.0 – 0.8)
Pt cut (0.3 < Pt < 1.5), Kinematics events are triggered together with ESDs.

N-N correlation



Pt-N correlation

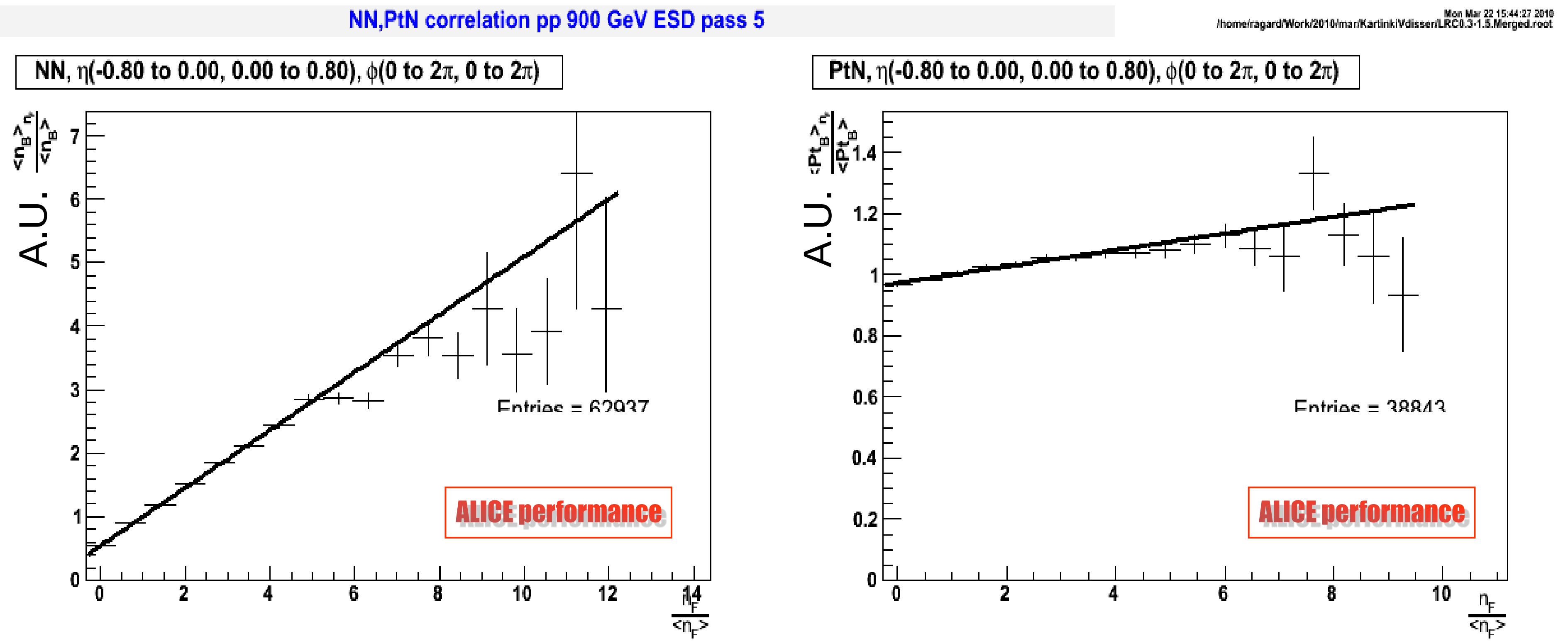


The first experimental results on FB correlations in ALICE in pp collisions at 900 GeV

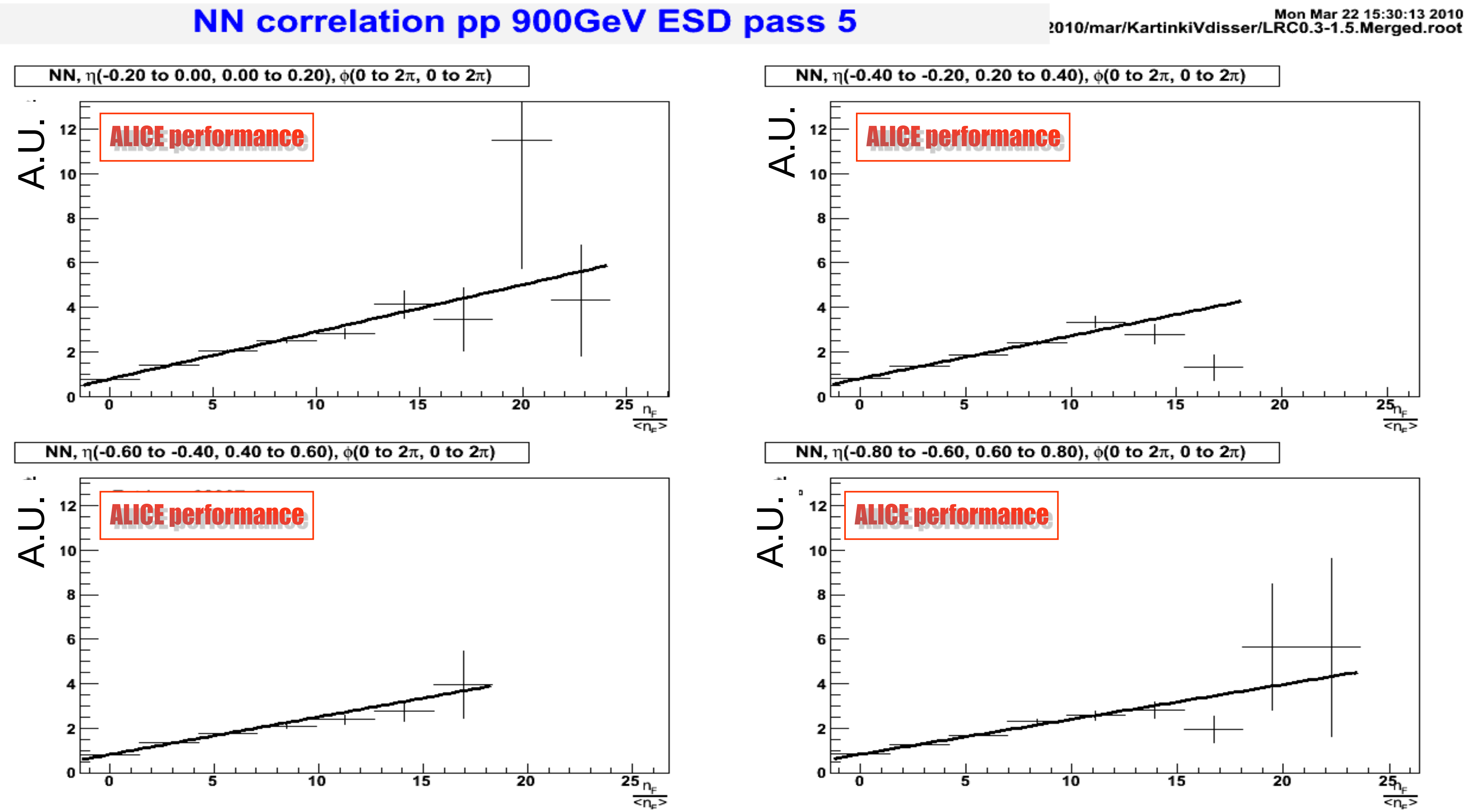
The 1st analysis of BF **<n>-n and <p_t>-n** correlations in pp@900GeV: "B"{-0.8, 0.0}, "F"{0.0, 0.8}.

pp 900GeV run 104892 pass 5 ESDs : Global tracking, TPC clusters > 80 , Sigma < 3.5. No kink daughters.

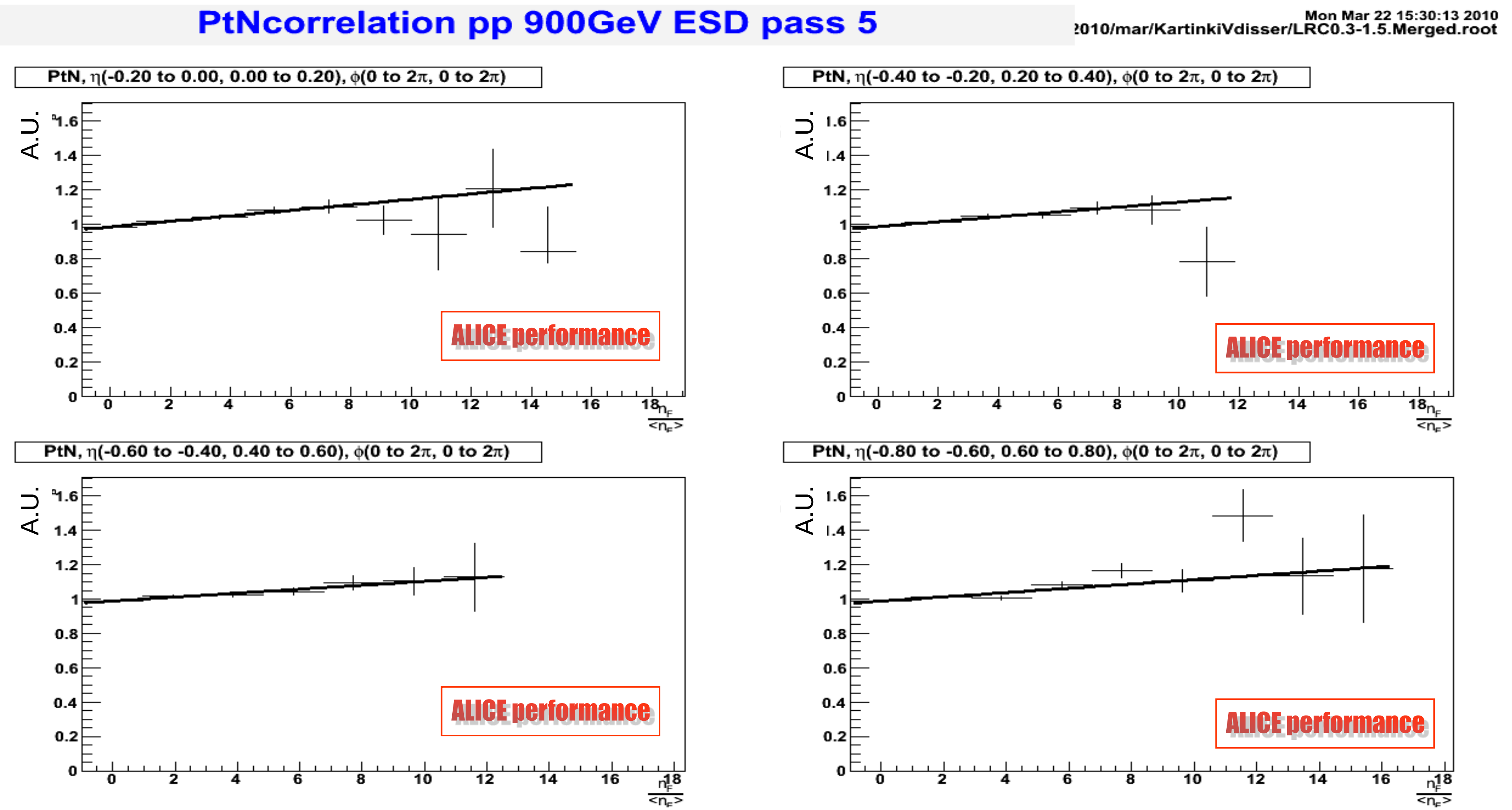
normalized values of observables **p_t cut: (0.3 < P_t < 1.5)**



<n>-n "FB" correlation in pp@900GeV: narrow (0.2) windows, η gap dependence

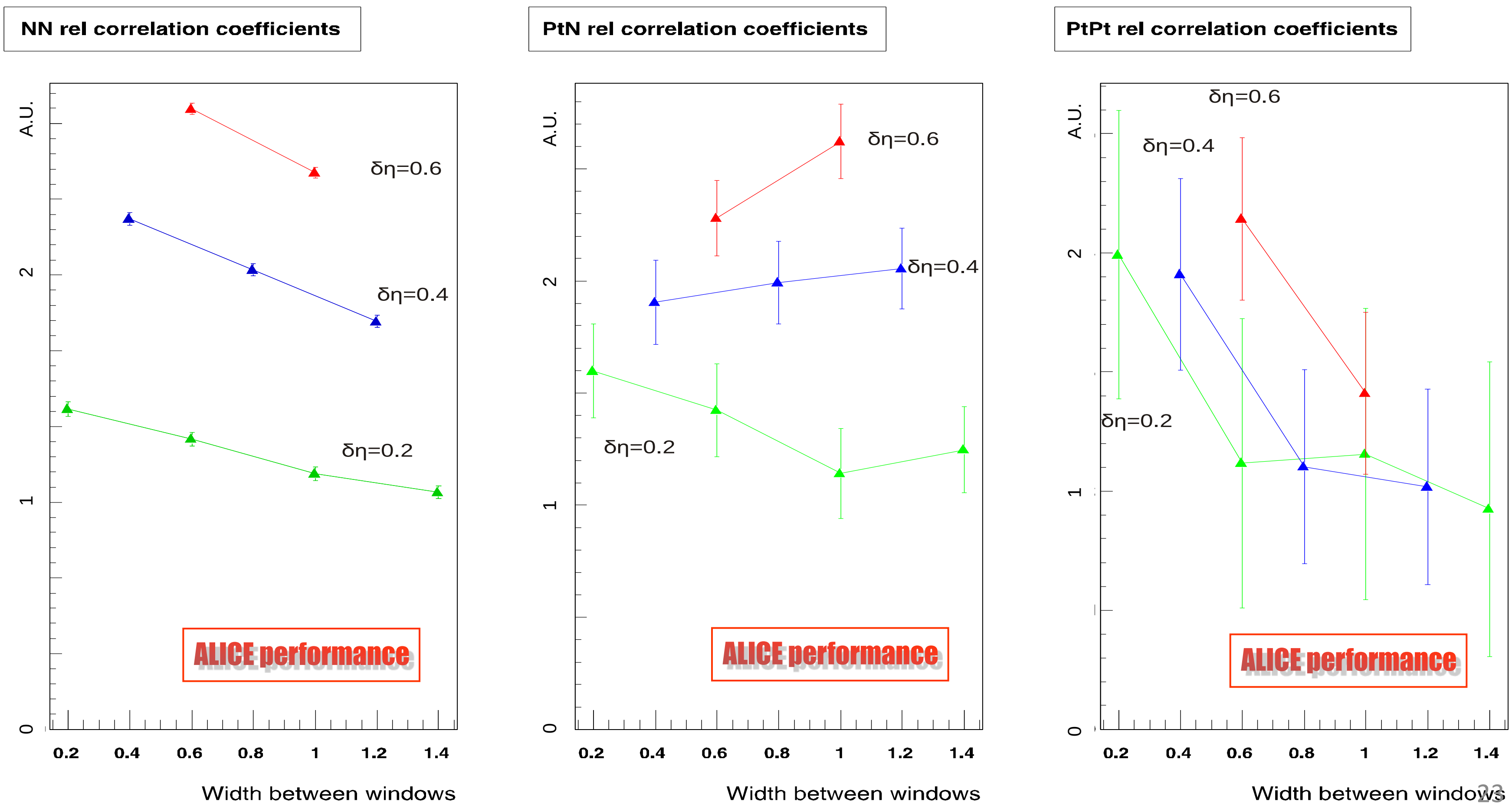


<pt>-n FB correlation in pp@900GeV: narrow (0.2) windows, η gap dependence



<n>-n and <pt>-n FB correlations in pp@900GeV: *η* gap dependence

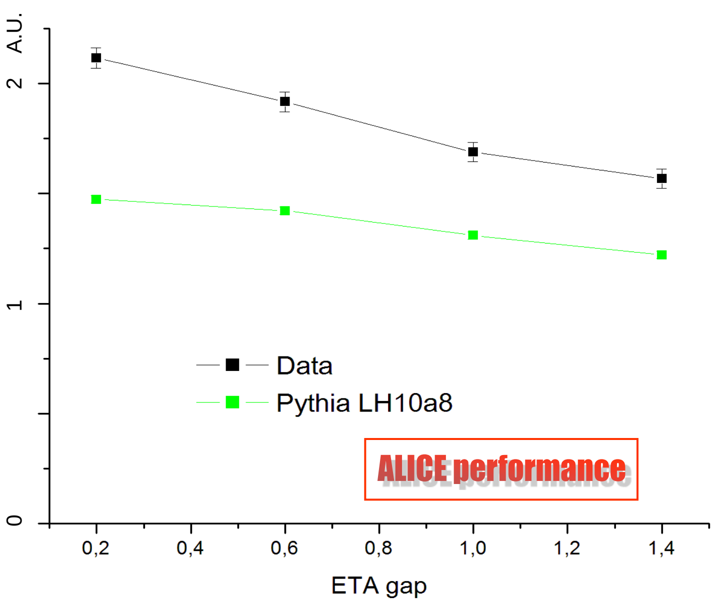
Correlation coefficient dependence on *η* gap between window centers and on the windows size (*δη*).



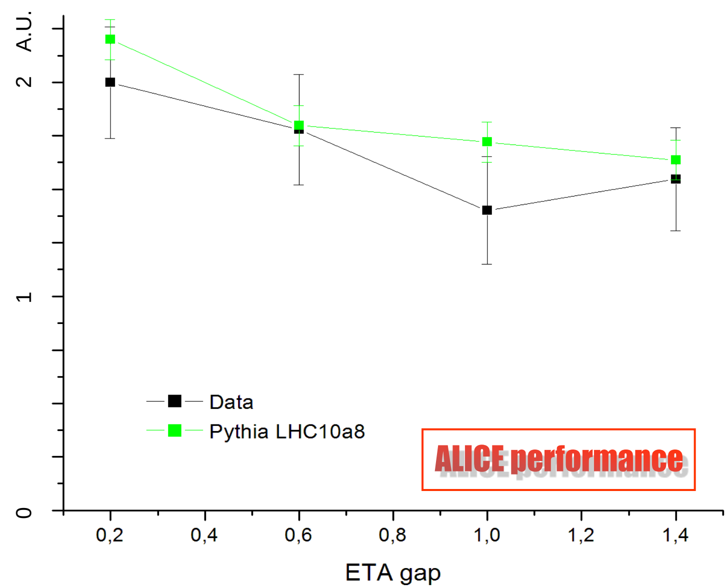
<n>-n and <pt>-n FB correlations in pp@900GeV: η gap dependence

Correlation coefficient dependence on η gap between window centers.
Windows in η: of 0.2 units. Data in comparison with results of Pythia D6T LHC10a8

N-N correlations



Pt-N correlations



Conclusions and outlook

- First analysis of Forward-Backward correlations is completed on pp collisions at 900GeV ALICE ITS+TPC data
- The good agreement of simulated and reconstructed PYTHIA data in the framework of ALICE experimental setup shows that the use of the relative observables for selected "soft" pt region (0.3 GeV/c < pt < 1.5 GeV/c) allows one to obtain the unbiased correlation functions without the additional systematic corrections.
- Noticeable FB/Long-Range **<n>-n ,<pt>-n and <pt>-pt** correlations are observed in pp collisions at 900 GeV with the η gap extented up to 1.4 units of pseudorapidity
- We see also a difference between Pythia D6T and the data
- The work is in progress in expanding the rapidity coverage of the long-range correlation study by adding the SPD ($-2.0 < \eta < 2.0$) and FMD ($-5.03 < \eta < 3.68$) multiplicity information.

Thank you for your attention !