Long-range (Forward-Backward) p_t and Multiplicity Correlations in *pp* collisions at 0.9 and 7 TeV

G.Feofilov (St.Petersburg State University), *for the ALICE Collaboration*

QUARK MATTER ANNECY 2011

Abstract

Long-range rapidity and azimuthal correlations (LRC) of charged particles are a sensitive tool to study the initial conditions for the Quark Gluon Plasma (QGP) formation [1],[2],[3]. Measured in separated pseudorapidity intervals, these correlations, if they exist, mainly p_t-Nch and p_t-p_t, could be the indication in case of *pp* collisions of processes like color string fusion[2] or glasma flux tubes formation[3]. The event-by-event analysis of the long-range Forward-Backward (FB) Nch-Nch, p_t-Nch and p_t-p_t correlations has been performed on data of the ALICE experiment obtained in the pp runs at 0.9 and 7 TeV pp collision energies. The following observables were defined: p_t (the average transverse momentum in the event) and Nch (the event multiplicity of charged particles). Two pseudorapidity intervals (the "forward" and the "backward" windows) of the variable width from 0.2 to 0.8 rapidity units were chosen. Correlations were studied as a function of the width of these windows and on the gap between them, as well as for the different configurations of four π/2 *azimuth* sectors relevant to these windows. Methods for separating the short-range correlations and to measure the long-range correlations strength in the limited acceptance of the ALICE central barrel (-0.8, 0.8) are discussed. Results are compared to the Model with independent emitters (strings) [4] and show a behaviour compatible with the LRC phenomena for these *pp* collisions.

References

[1] Abramovskii V. A., Gedalin E. V., Gurvich E. G., Kancheli O. V. , JETP Lett., vol.47, 337-339 , 1988.

[2] M.A.Braun, C.Pajares, Phys.Lett. B287 (1992) 154; Nucl.Phys. B390 (1993) 542; Eur.Phys.J. C16 (2000) 349; N.S.Amelin, N.Armesto, M.A.Braun, E.G.Ferreiro, C.Pajares, Phys.Rev.Lett. 73 (1994) 2813; M.A.Braun, C.Pajares, V.V.Vechernin, Phys.Lett. B493 (2000) 54; Internal Note/FMD, ALICE-INT-2001-16, CERN, Geneva (2001) 13p.; M.A.Braun, R.S.Kolevatov, C.Pajares, V.V.Vechernin, Eur.Phys.J. C32 (2004) 535; V.V.Vechernin, R.S.Kolevatov, Phys. of Atom.Nucl. 70 (2007) 1797; 1809.

[3] L.McLerran, "The Color Glass Condensate and the Glasma", Proceedings of the International School of Subnuclear Physics, Subnuclear Series, Vol. 45, 2010.

[4] V.V. Vechernin, R.S. Kolevatov, hep-ph/0304295 (2003); Vestnik SPbU, ser.4, no.2, 12(2004); V.V. Vechernin, arXiv:1012.0214, 2010.

[5] 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)

[6] G.Feofilov (for ALICE Collaboration), "Experimental Studies of Long-Range Forward-Backward p_t and Multiplicity Correlations at ALICE", Report at XVI International Baldin Seminar on High Energy Physics Problems, Dubna, Russia, June 10-15, 2002.

Systematic errors:

It is shown that the use of the normalized observables in study of n-n and p_t-n correlation functions provides the unbiased results in the region $0.3 < p_t < 1.5$ GeV/c

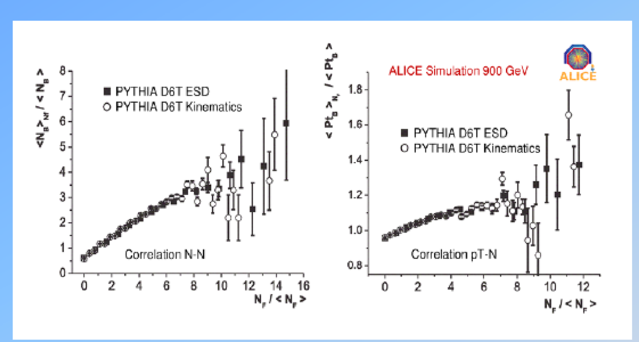


Fig.1. n-n and p_t-n long-range correlations in normalized observables in *pp* collisions at 900 GeV. Pythia-D6T results – with the influence of the experimental setup (reconstructed - open points) and without one(simulated - black points).
Forward η window (-0.8 – 0.0) , backward η window (0.0 – 0.8) .

Long-Range Rapidity *Multiplicity* Correlations in the Model with Independent Emitters[4]

In the framework of the model with independent emitters the following formula for the correlation coefficient b_{nn}^{rel} was obtained:
[V.V. Vechernin, R.S. Kolevatov, hep-ph/0304295 (2003); Vestnik SPbU, ser.4, no.2, 12 (2004)]

$$b_{nn}^{rel} = \frac{\kappa \overline{\mu}_F}{\kappa \overline{\mu}_F + 1},$$

where the κ is the ratio of two scaled variances:

$$\kappa = \frac{V_N}{V_{\mu_F}}, \qquad V_N = \frac{D_N}{\langle N \rangle}, \qquad V_{\mu_F} = \frac{D_{\mu_F}}{\overline{\mu}_F},$$

$\langle N \rangle$ and $D_N = \langle N^2 \rangle - \langle N \rangle^2$ - the mean number of emitters and the E-by-E variance of the number of emitters.
$\overline{\mu}_F$ and $D_{\mu_F} = \overline{\mu_F^2} - \overline{\mu}_F^2$ - the mean multiplicity produced by *one* emitter in the *forward* window and the corresponding variance.
For example, for Poisson distributions $V_N = V_{\mu_F} = 1$ and $\kappa = 1$.

Clear that *the $\overline{\mu}_F$ depends on the acceptance of the forward rapidity window.*
For the forward window in the plateau region one can assume

$$\overline{\mu}_F = \mu_{0F} \Delta y_F \Delta\varphi_F / 2\pi$$

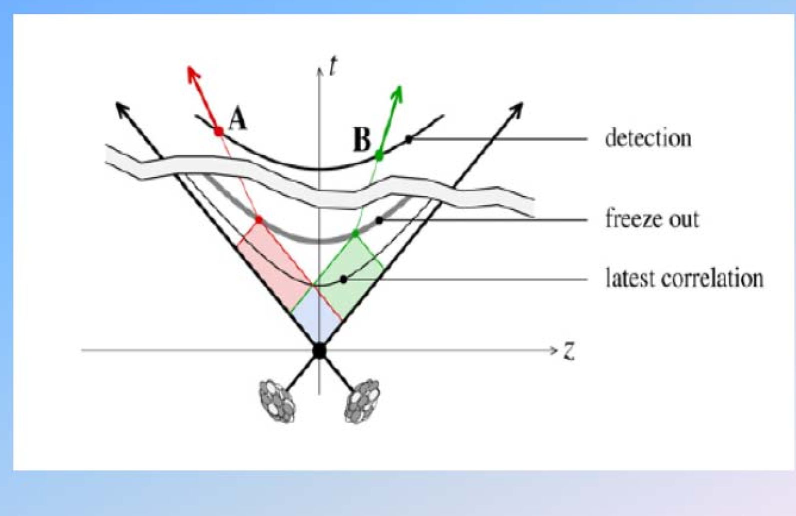
where μ_{0F} is the average multiplicity produced by *one* emitter in the *forward* window per a *unit* of rapidity. Then we have for the correlation coefficient:

$$b_{nn}^{rel} = \frac{\kappa\mu_{0F}\, \Delta y_F \Delta\varphi_F/2\pi}{\kappa\mu_{0F}\, \Delta y_F \Delta\varphi_F/2\pi + 1} = \frac{a\, \Delta y_F \Delta\varphi_F/2\pi}{a\, \Delta y_F \Delta\varphi_F/2\pi + 1}$$

$$a = \kappa\mu_{0F} - \text{the only theory parameter}$$

So the multiplicity correlation coefficient b_{nn}^{rel} even *defined for scaled variables* nevertheless depends through μ_F on the acceptance of the *forward* rapidity window Δy_F, $\Delta\varphi_F$ and does not depend on the acceptance of the backward one Δy_B, $\Delta\varphi_B$.
This is because the regression procedure is being made by the forward window. One can find the physical discussion of this phenomenon in ref.:
V.V. Vechernin, R.S. Kolevatov, hep-ph/0304295 (2003); Vestnik SPbU, ser.4, no.2, 12 (2004).
V.V. Vechernin, arXiv:1012.0214, 2010

Causality requires that correlations of Long Range in rapidity must be made very early: (A.Dumitru et al./ Nuclear Physics A 810 (2008) 91-108).



Long-range correlation (LRC) studies are made for *pp* collisions at 0.9 and 7 TeV in ALICE between observables measured in two different, separated pseudo-rapidity intervals $\delta\eta_F$ and $\delta\eta_B$, which are conventionally referred to as forward(F) and backward(B) windows. Correlations between two main dynamical variables, the multiplicity of charged particles (n) and the mean transverse momentum (p_t) in *the given event* are investigated using the information obtained in these two windows, the event mean p_t is defined as:

$$p_t \equiv \frac{1}{n}\sum_{i=1}^{n} |\mathbf{p}_{ti}|, \quad \text{for particles with} \quad \eta_i \in \delta\eta; \quad i = 1, ..., n. \qquad (1)$$

Here p_{ti} and η_i are correspondingly the transverse momentum and the pseudo-rapidity of the i-th particle measured in the given event in the defined pseudo-rapidity interval. Three major types of long-range correlations between various observables were proposed for to be measured in ALICE at the LHC [5, 6]:

Types of correlations:

1. n_B-n_F - the correlation between charged particle multiplicities in backward (B) and forward (F) rapidity windows (n-n correlation).
2. p_{tB}-n_F - the correlation between the event mean transverse momentum in the backward rapidity window and the charged particle multiplicity in the forward window (p_t-n correlation)..
3. p_{tB}-p_{tF} - the correlation between the event mean transverse momenta in backward and forward rapidity windows. (p_t-pt correlation).

$$p_{tF} \equiv \frac{1}{n_F}\sum_{i=1}^{n_F} |\mathbf{p}_{tF}^i| \qquad p_{tB} \equiv \frac{1}{n_B}\sum_{i=1}^{n_B} |\mathbf{p}_{tB}^i|$$

To analyze these correlations we introduce the correlation functions and study the linear regression in scaled (relative) variables:

$$\frac{\langle n_B \rangle_{n_F}}{\langle n_B \rangle} = a_{nn} + b_{nn}\frac{n_F - \langle n_F \rangle}{\langle n_F \rangle} \qquad \frac{\langle p_{tB} \rangle_{p_{tF}}}{\langle p_{tB} \rangle} = a_{pp} + b_{pp}\frac{p_{tF} - \langle p_{tF} \rangle}{\langle p_{tF} \rangle}$$

Event and track selection

For LRC analysis only a most flat efficiency p_t region **0.3-1.5 GeV/c** is used

900 GeV Runs: 118506,118558,118556, 118560

7TeV MB: 126158

7TeV Bins: 126158,126097, 126090, 126088, 126082, 126081, 126078, 126073, 126008, 126007, 126004, 125855, 125851, 125850, 125849, 125848, 125847, 125844, 125843, 125842, 125633, 125632, 125630

Track Selection – Quality cuts	
Number of TPC clusters	80
$\chi^2/N_{TPCclusters}$	4
Number of ITS clusters	2
dca_z	0.3 cm
dca_{xy}	0.3 cm
kITSrefit	Yes
Min Nclusters ITS	2
kTPCrefit	Yes

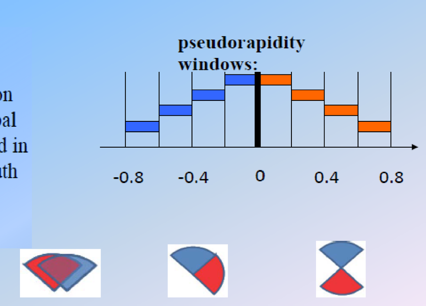
Event Selection	
Trigger selection	Yes
Reconstructed vertex	Yes
Number of contributors	> 1
|Vz|(max)	5 cm

Long-range n-n, pt-n and pt-pt correlations in separated pseudorapidity and azimuth sectors

η– gap between the pseudorapidity windows

Δϕ - azimuth sectors

One can also look for a same phenomenon using event-by-event correlations of global observables such as Nch and p_t measured in windows separates by rapidity and azimuth angle.



Comparison with Model of Independent Emitters :

n-n correlations in ALICE pp@7TeV data vs. η gap between windows for various widths of the pseudorapidity windows δη and for azimuth sectors configurations

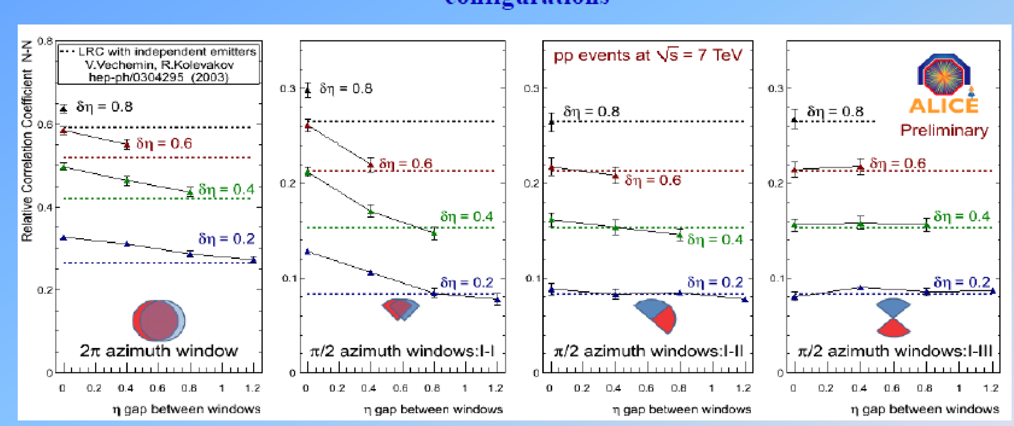
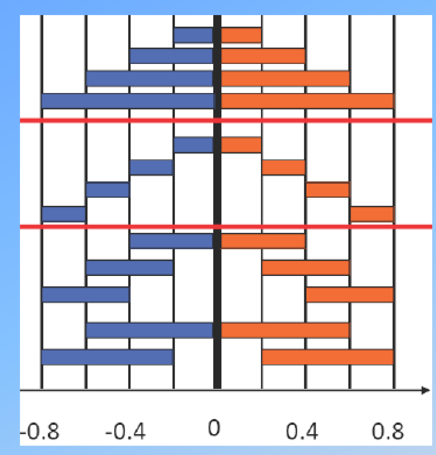


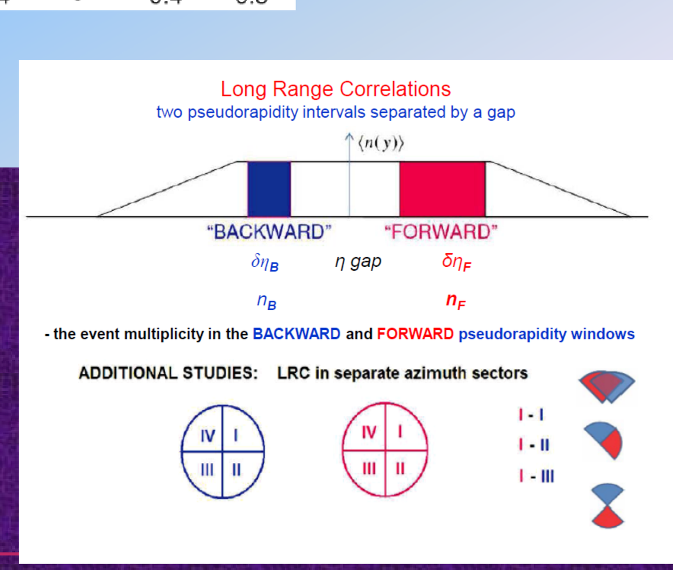
Fig.6. The comparison of n-n long-range correlations (data points) with the Model of independent emitters [4] (horizontal dotted lines) for different configurations of backward and forward azimuth windows at the model parameter a=1.8. Widths of the pseudorapidity windows δη are shown near the relevant data sets (lines are to guide the eye).

Selection of the Forward and Backward pseudorapidity windows



δη – the width of the Forward and Backward pseudorapidity windows

η– gap between the pseudorapidity windows



pp@0.9 TeV minbias LHC Data

p_T cuts $(0.3 < p_T < 1.5$ GeV/c)

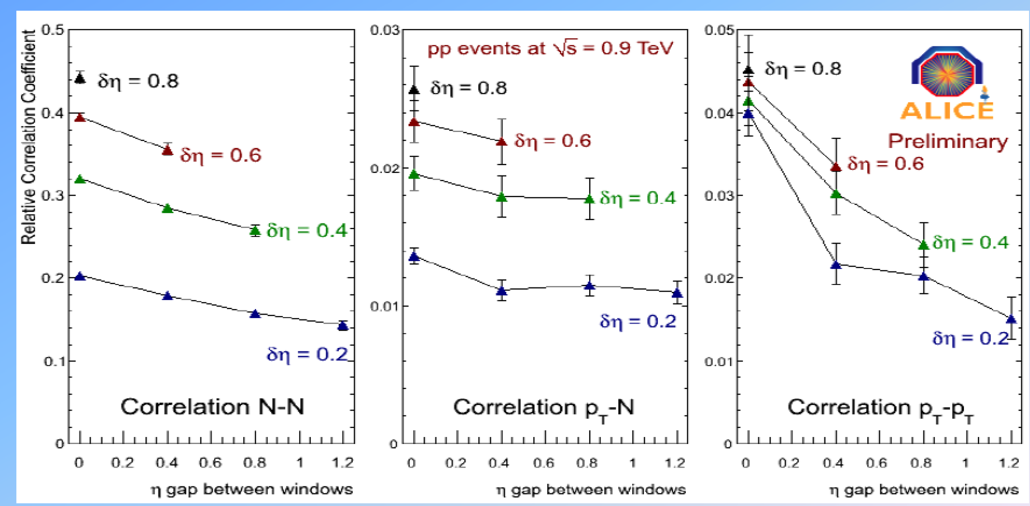


Fig.2. The dependence of long-range n-n, pt-n and pt-pt correlations on the η gap between windows in *pp* collisions at 0.9 TeV, measured for different widths δη of the observation windows. Normalized observables. Lines are to guide the eye.

pp@7 TeV minbias LHC Data

p_T cuts $(0.3 < p_T < 1.5$ GeV/c)

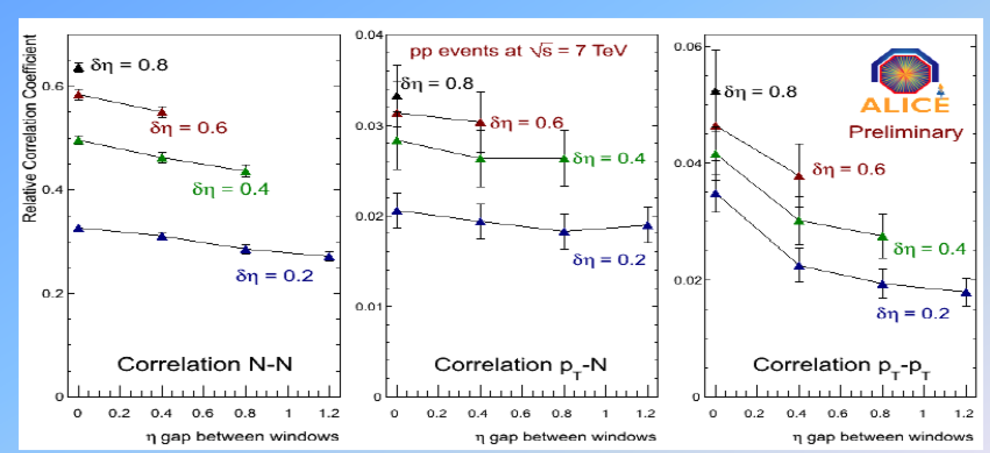


Fig.3. The dependence of long-range n-n, pt-n and pt-pt correlations on the η gap between windows in *pp* collisions at 7TeV, measured for different widths δη of the observation windows. Normalized observables. Lines are to guide the eye.

n-n, p_t-n and p_t-p_t LRC in ALICE pp@7TeV data for various Δϕ azimuthal sectors configurations vs. rapidity gap between windows

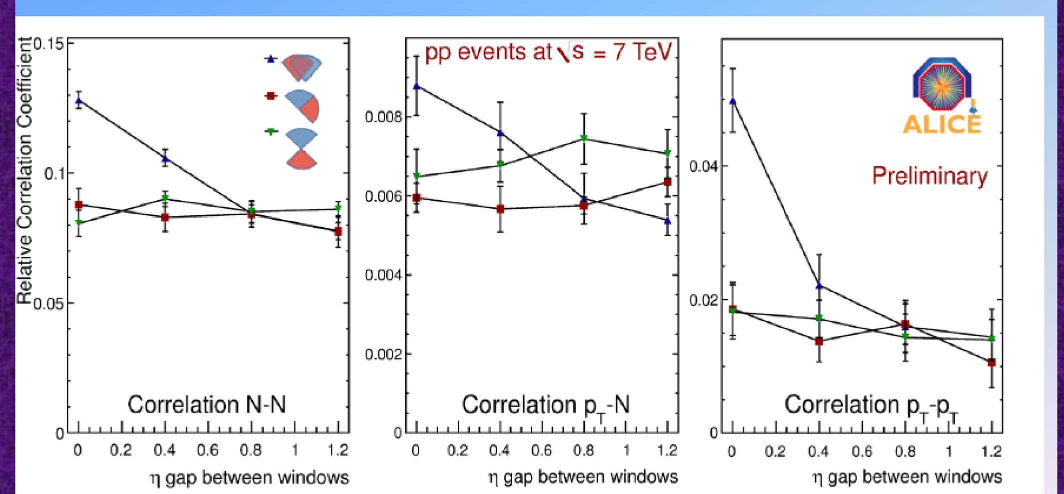


Fig.4. The same as in Fig.3 but for different configurations of backward and forward pi/2 azimuth sectors (for the width of the pseudrapidity windows - δη=0.2). Relative orientations of sectors are marked by color.

Conclusions

→ Noticeable forward-backward *n-n, pt-n and pt-pt correlations are observed in pp collisions* at 900 GeV and 7 TeV with the *gap between pseudo-rapidity windows extended up to 1.2* units.
→ One may see a general growth of correlation coefficients for the results at 7 TeV compared to 0.9 TeV data.
→ It is shown that the use of the normalized observables for selected soft pt region (0.3 GeV/c < pt < 1.5 GeV/c) allows one to obtain the unbiased correlation functions without additional systematic corrections (it is proven by the good agreement of simulated and reconstructed PYTHIA data in the framework of ALICE experimental setup).
→ Analysis of data for different configurations of azimuth sectors provides the method for separating the short-range correlations and to measure the long-range correlations strength in the limited acceptance of the ALICE central barrel (-0.8, 0.8).