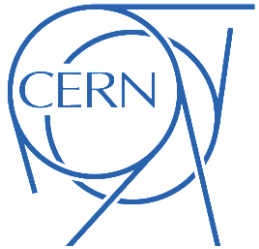
Energy scan of correlations in p+p and Be+Be collisions from NA61/SHINE

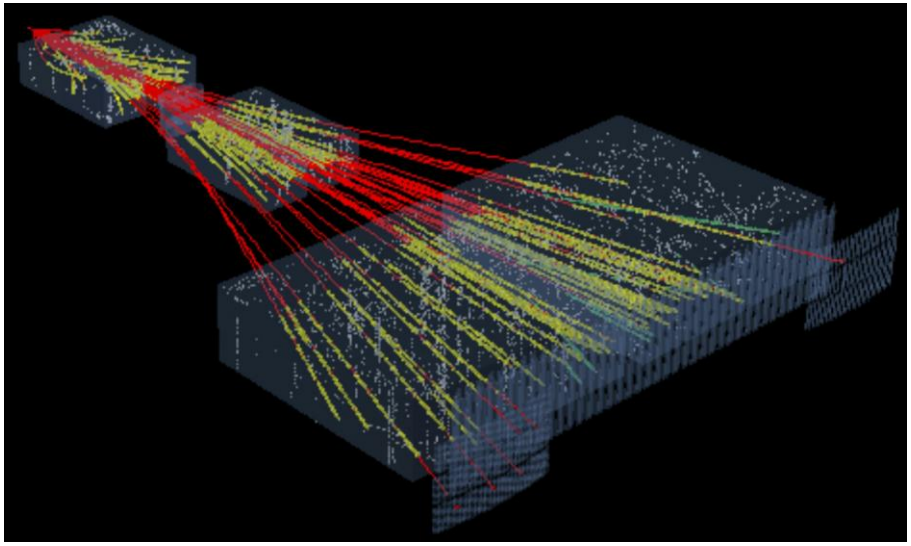
Andrey Seryakov
for the NA61/SHINE collaboration
seryakov@yahoo.com

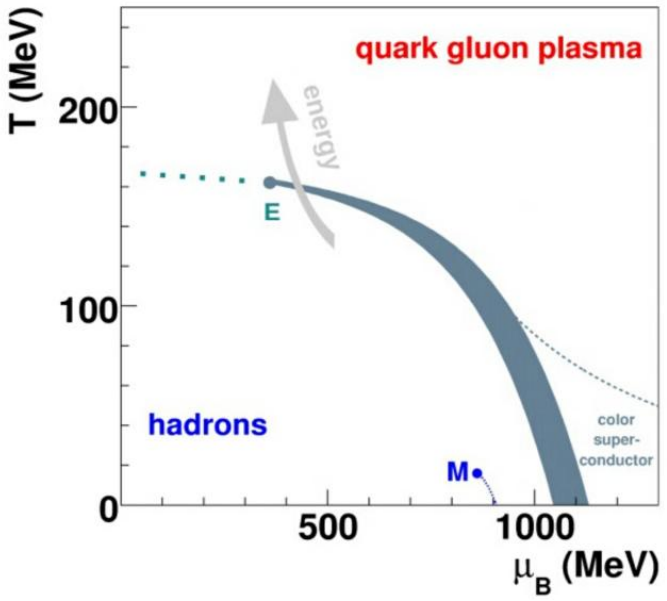
Laboratory of Ultra-High Energy Physics
St. Petersburg State University

6-11/07/2015
Dubna, Russia



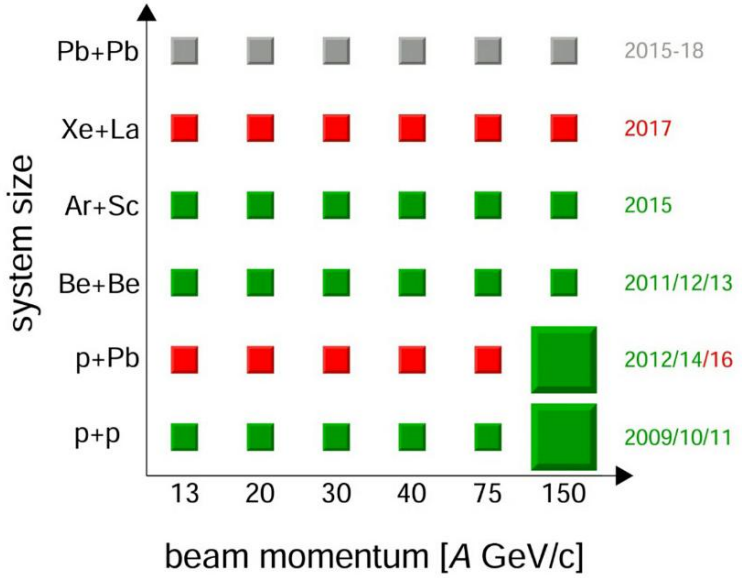

NA61/SHINE – unique multipurpose facility:
hadron production in h+p, h+A, A+A
at 13*A* - 150*A* GeV/c
LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
CMS
ALICE
LHC 27 km





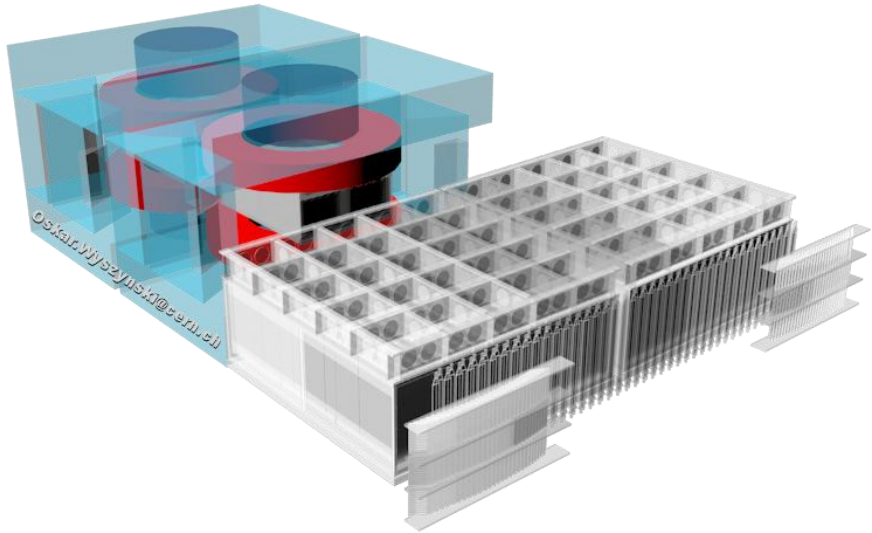
The NA61/SHINE program on strong interactions:

- Study of the phase transition
- Search for the critical point



Outline

- Introduction
- Two-particle correlations $C(\Delta\eta, \Delta\varphi)$
  in p+p 20 – 158 GeV/c ($\sqrt{s_{NN}}$ = 6.3−17.3 GeV)
- Pseudorapidity correlations b
  in Be+Be 150*A* GeV/c ($\sqrt{s_{NN}}$ = 16.8 GeV)

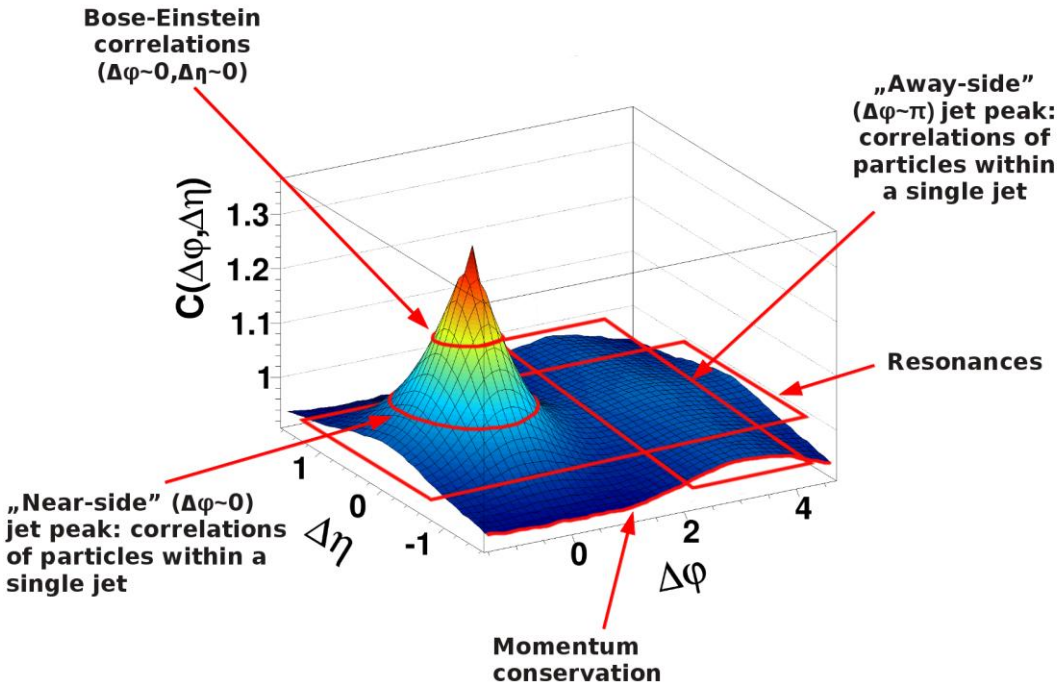


Two-particle correlations: motivation

Two-particle correlations in $\Delta\eta, \Delta\varphi$

- Studied at RHIC and LHC.

- Allow to disentangle different sources of correlations:
  - ❖ Jets
  - ❖ Flow
  - ❖ Resonance decays
  - ❖ Quantum statistic effects
  - ❖ Conservation laws



The motivation

To study correlations and their sources at the SPS-energies

Two-particle correlations: definition

Correlations are calculated by finding the difference in pseudo-rapidity and azimuthal angle between two particles in the same event.

$\Delta\eta = |\eta_1 - \eta_2|$ transformed from LAB to CMS assuming pion mass
$\Delta\varphi = |\varphi_1 - \varphi_2|$

The azimuthal angle is folded (to improve statistics):
if $\Delta\varphi > \pi$ then $\Delta\varphi = 2\pi - \Delta\varphi$

$$C(\Delta\eta, \Delta\varphi) = \frac{N_{mixed}^{pairs}}{N_{data}^{pairs}} \frac{S(\Delta\eta, \Delta\varphi)}{M(\Delta\eta, \Delta\varphi)}$$

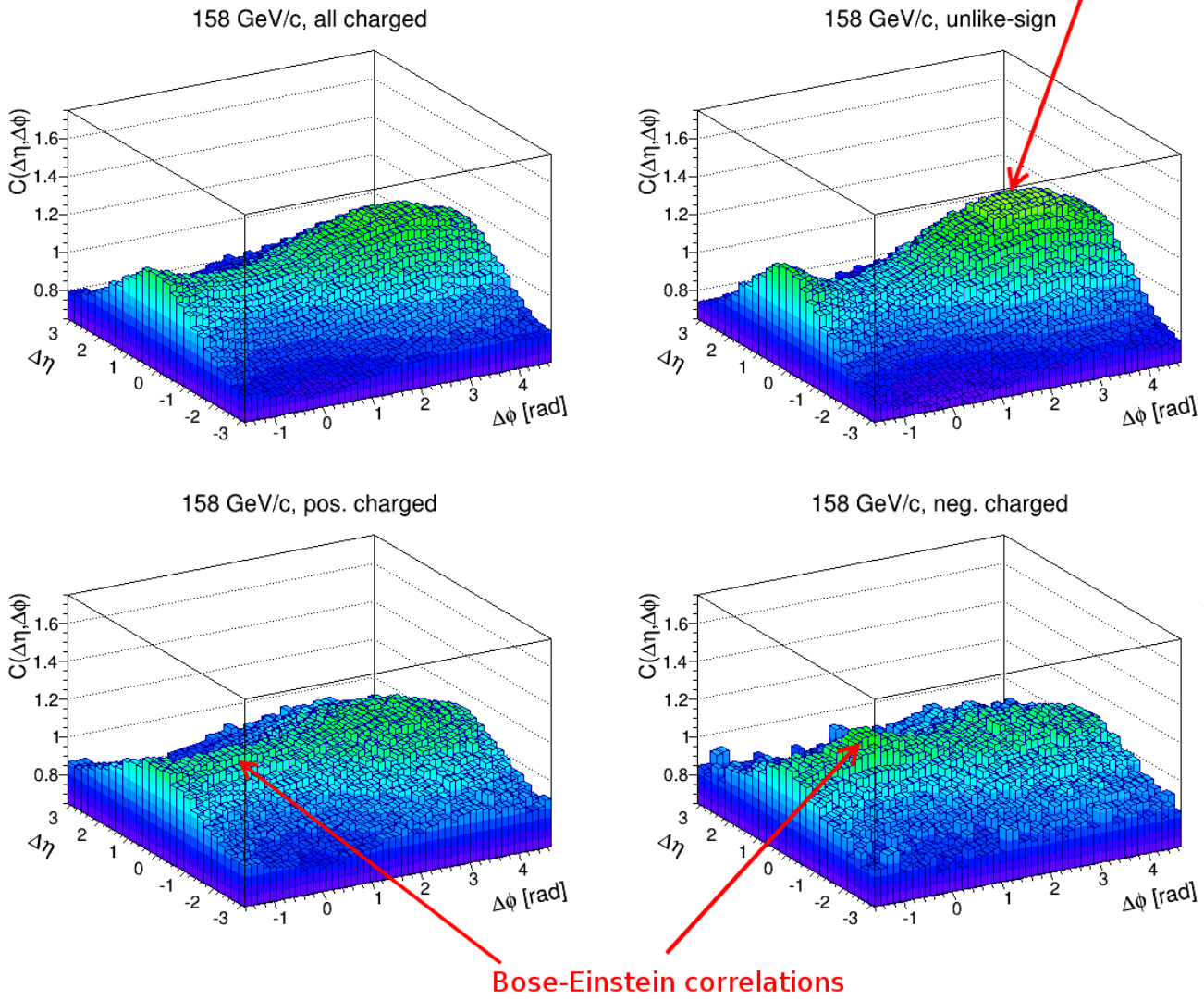
$$S(\Delta\eta, \Delta\varphi) = \frac{d^2 N^{signal}}{d\Delta\eta d\Delta\varphi}; \qquad M(\Delta\eta, \Delta\varphi) = \frac{d^2 N^{mixed}}{d\Delta\eta d\Delta\varphi}$$

Correlation function ratio is calculated and normalized in restricted region: $0 < \eta < 3$
Event and track cuts were chosen to select only inelastic interactions with particles produced in strong and EM processes within the NA61/SHINE acceptance.
The results are corrected on detector effects: tracking inefficiencies, trigger bias (see backup).

Two-particle correlations: results

NA61/SHINE **preliminary**

p+p 158 GeV/c



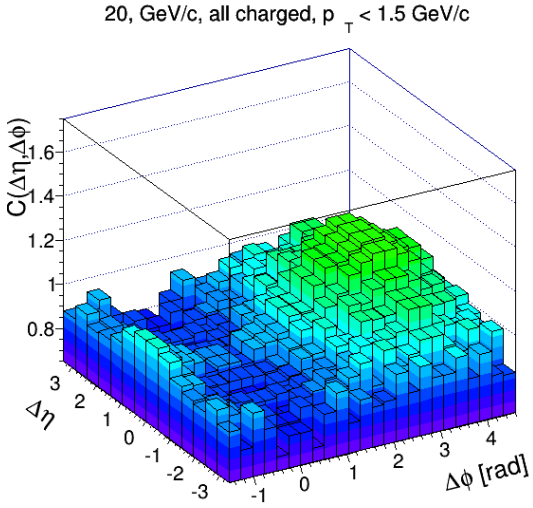
- Maximum at $(\Delta\eta, \Delta\varphi) = (0, \pi)$ probably resonance decays and momentum conservation.
  - The strongest in unlike-sign pairs,
  - still visible in positively charged pairs (Δ^{++}decay)
  - non-visible in negatively charged (almost no double-negative resonances).

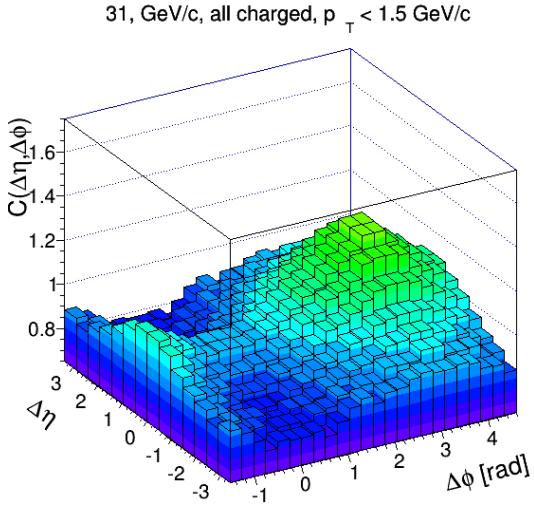
- An enhancement at (0; 0) - probably Coulomb or quantum statistics effects.
  - Not strong in unlike-sign pairs,
  - clearly visible in same charge pairs.

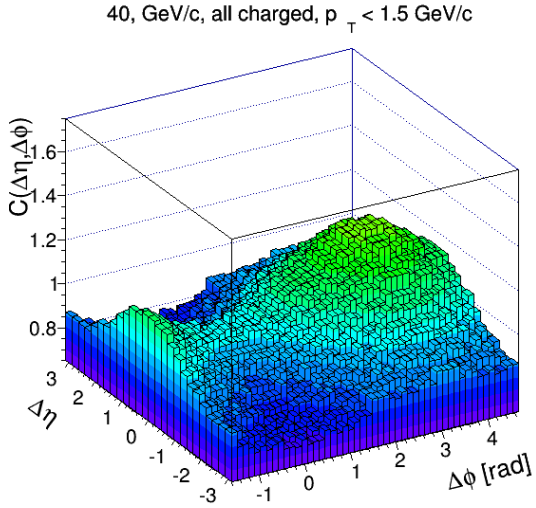
B.Maksiak [for the NA61/SHINE collaboration], PoS(CPOD2014)055

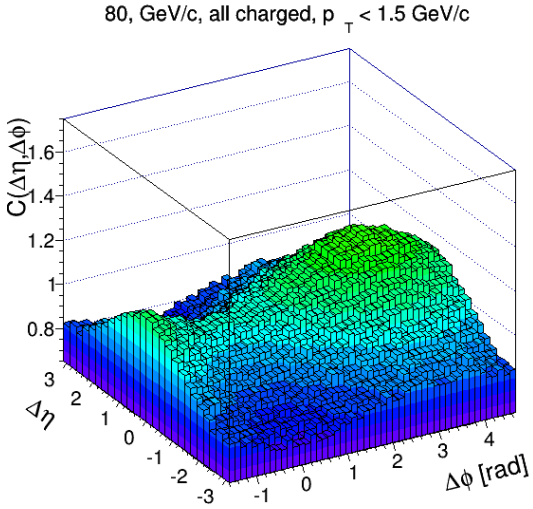
Two-particle correlations: energy dependence

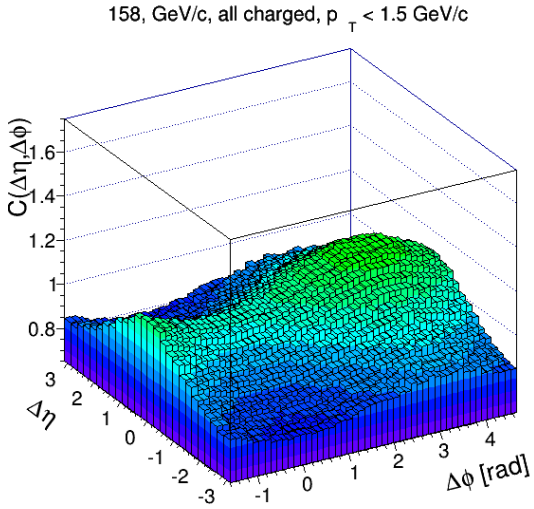
NA61/SHINE **preliminary**











The enhancement “saddle” at (0,0) rises with increasing beam momentum

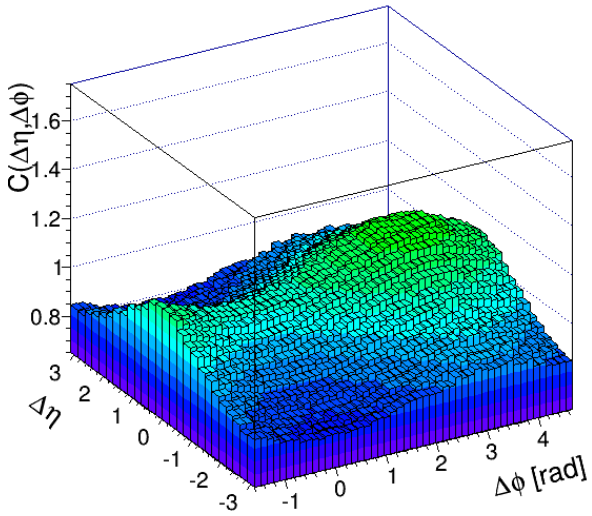
B.Maksiak [for the NA61/SHINE collaboration], PoS(CPOD2014)055

Two-particle correlations: EPOS 1.99 vs data

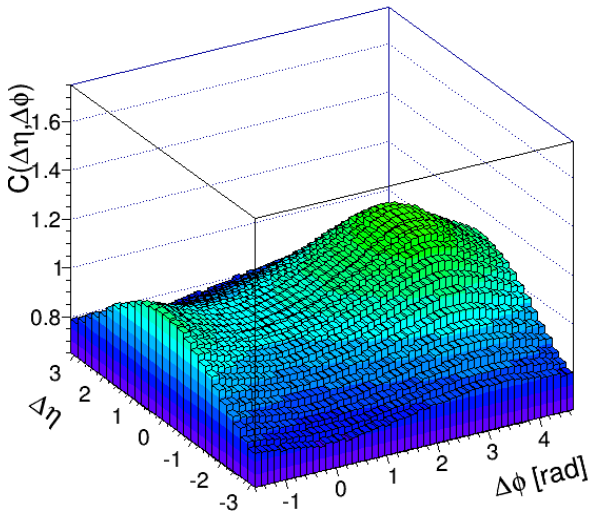
NA61/SHINE **preliminary**

p+p 158 GeV/c all charged

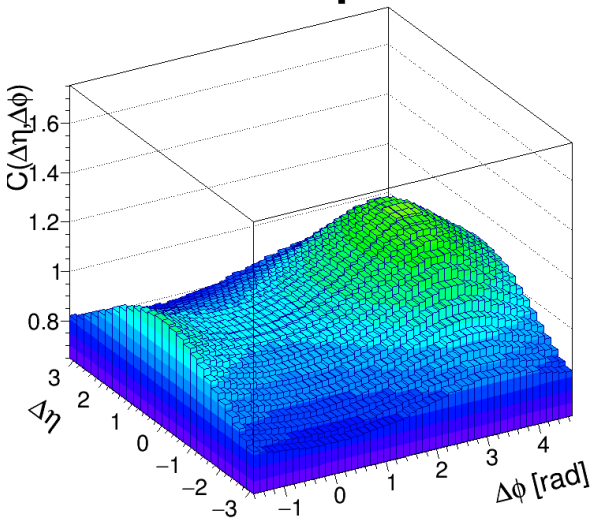
NA61/SHINE



EPOS:
NA61 acceptance



EPOS:
4π acceptance



- Qualitative agreement with EPOS data
- NA61 acceptance affects weekly results

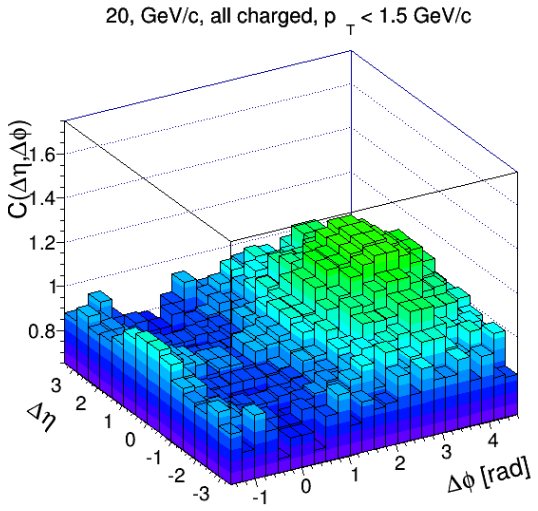
B.Maksiak [for the NA61/SHINE collaboration], PoS(CPOD2014)055

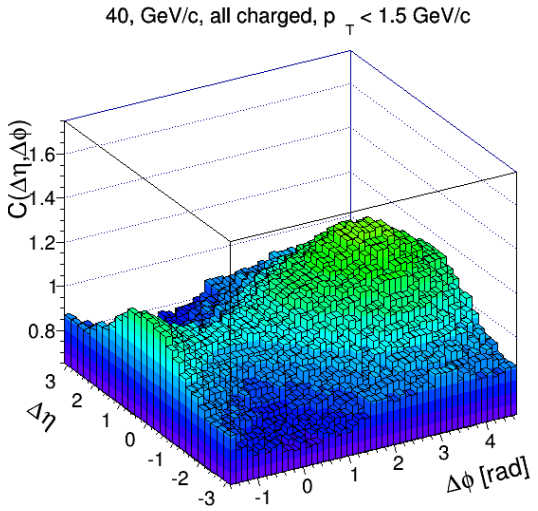
Two-particle correlations: summary

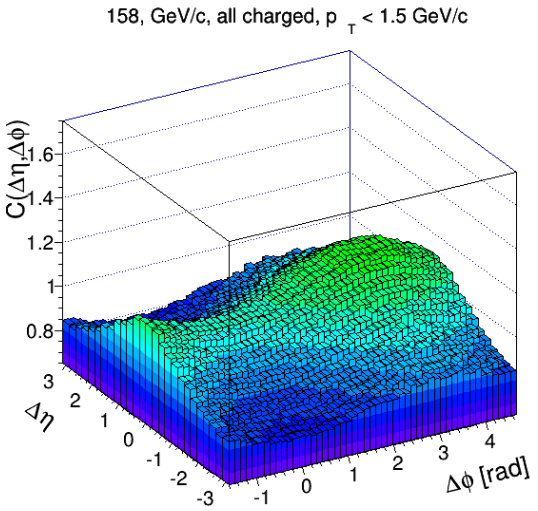
- Two-particle correlations in $\Delta\eta\Delta\varphi$ in inelastic p+p collisions at beam momenta 20-158 GeV/c ($\sqrt{s_{NN}}$ = 6.3−17.3 GeV) were measured.

- p+p data shows structures coming mainly from resonance decays, conservation laws, quantum statistics and Coulomb interactions.

- C(0; 0) increases with energy.
- C(0; π) decreases with energy.







B.Maksiak [for the NA61/SHINE collaboration], PoS(CPOD2014)055

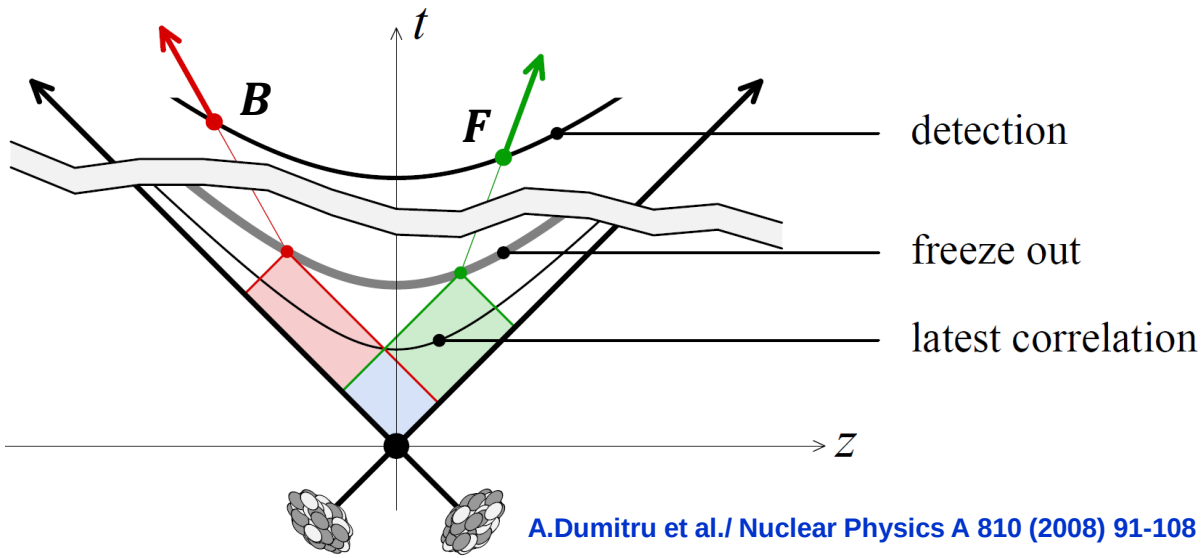
Pseudorapidity correlations: motivation

Long-range pseudorapidity correlations between particles are expected to be sensitive to the early stage of heavy ion collisions

- Color string fusion phenomenon (SFM)
  M.A.Braun and C.Pajares (see Phys. Lett. B287 (1992) 154; Nucl. Phys. B390 (1993) 542, 549);
- Color Glass Condensate (CGC) and Glasma flux tubes
  L.McLerran, Nucl.Phys.A699,73c(2002)

However many other effects could play role in pseudorapidity correlations:

- Jets
- Flow
- Resonance decays
- Quantum statistic effects
- Conservation laws



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

Pseudorapidity correlations: definition

$\boldsymbol{B}$ – an observable in “backward” pseudorapidity windows
$\boldsymbol{F}$ – an observable in “forward” pseudorapidity windows

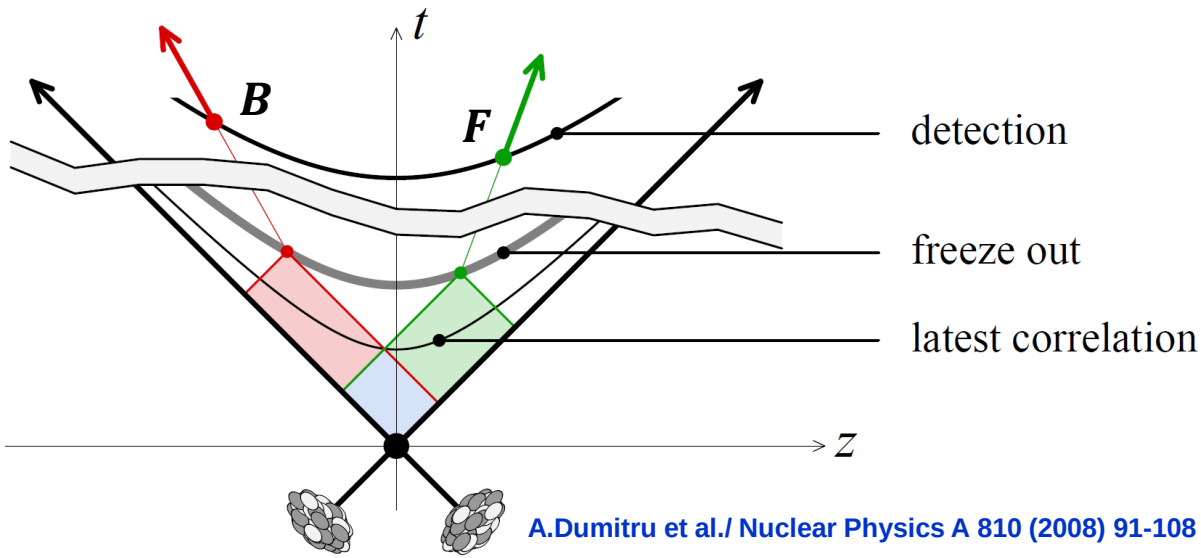
$$\boldsymbol{b[B,F]} = \frac{\langle \boldsymbol{BF} \rangle - \langle \boldsymbol{B} \rangle \langle \boldsymbol{F} \rangle}{\langle \boldsymbol{F^2} \rangle - \langle \boldsymbol{F} \rangle^{\boldsymbol{2}}}$$

To reduce trivial correlations du to variation of volume

$B \to B/\langle B \rangle = B_{rel}$

$F \to F/\langle F \rangle = F_{rel}$

$$\boldsymbol{b_{rel}[B,F]} = b[B,F]\,\langle F \rangle / \langle B \rangle$$



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

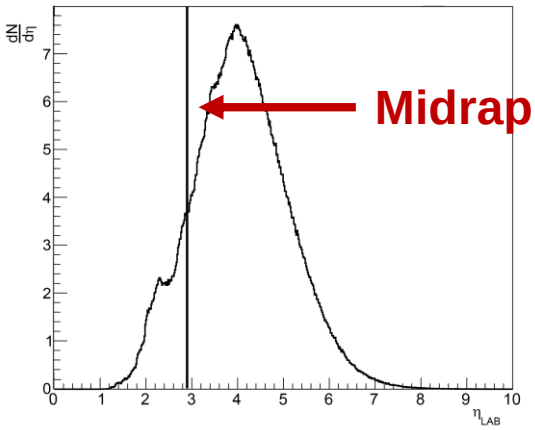
Possible selections of **B** and **F**:

- $N_B N_F$ - the correlation between charged particle multiplicities
- $Pt_B N_F$ - the correlation between the event mean transverse momentum (B) and multiplicity (F)
- $Pt_B Pt_F$ - the correlation between the event mean transverse momenta
- $\Delta Q_B \Delta Q_F$ - the correlation between the event net charges in B and F

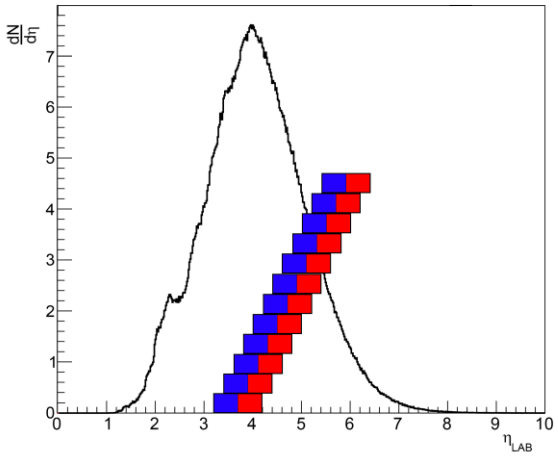
Pseudorapidity correlations: windows selection

Results for:

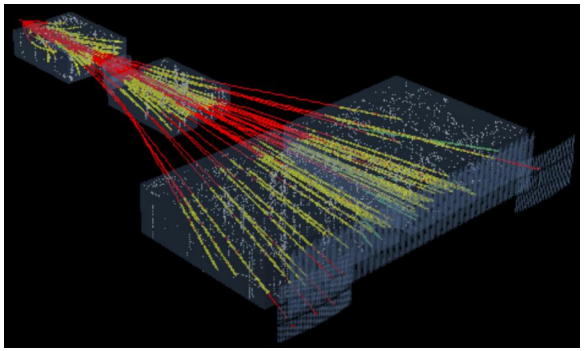
Pseudorapidity



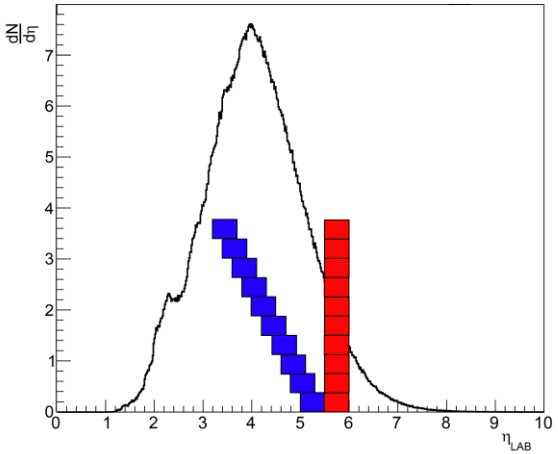
connected windows



- x-axis: $\frac{\eta_F+\eta_B}{2}$ (windows connection point)
- window length: 0.5



disconnected windows

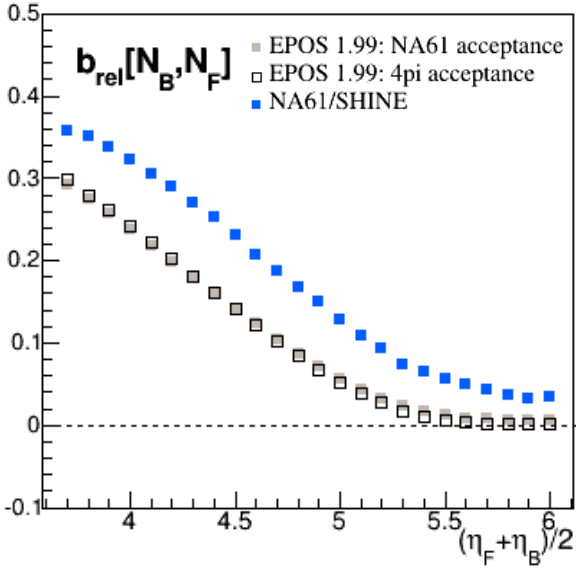


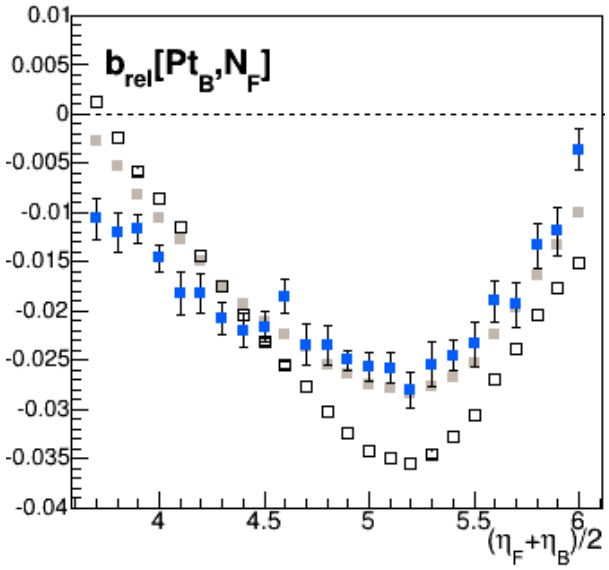
- x-axis: $\eta_F - \eta_B$ (distance between windows)
- window length: 0.5

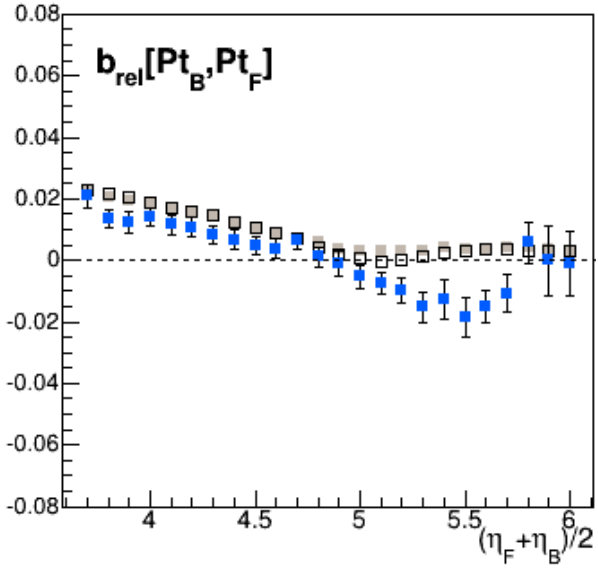
Pseudorapidity correlations: results
Be+Be 150A GeV/c 0-20% centrality

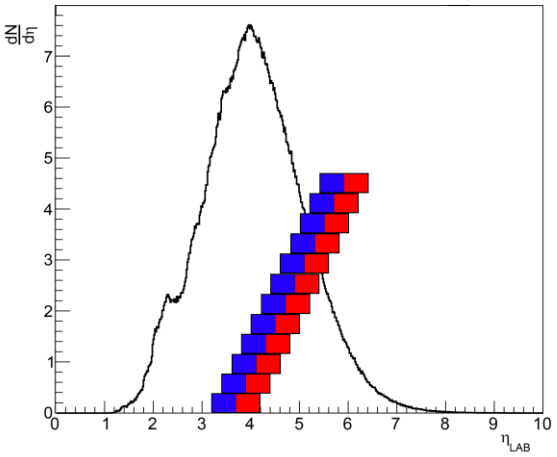
NA61/SHINE **preliminary**

Connected windows









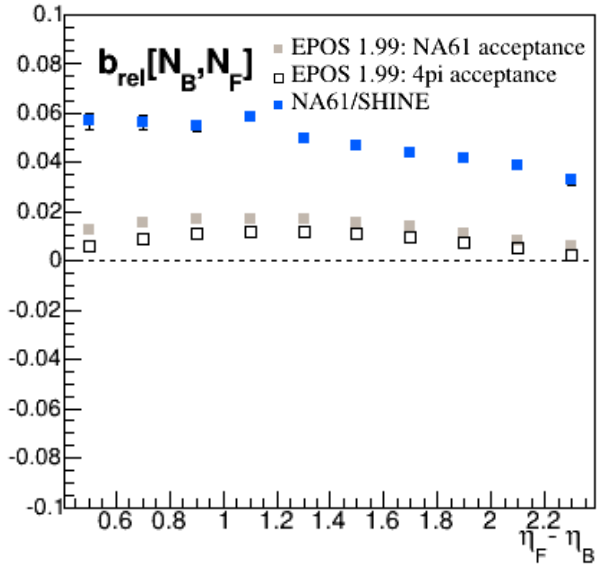
- Strong dependence on the windows position
- EPOS 1.99 describe the data qualitatively

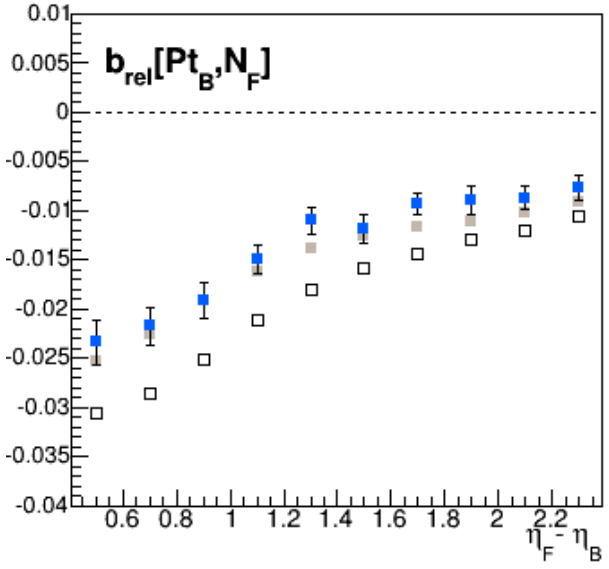
Event and track cuts were chosen to select only inelastic interactions with particles produced in strong and EM processes within the NA61/SHINE acceptance.
The results are corrected on detector effects: tracking inefficiencies, trigger bias.
The results are preliminary, only statistical errors are shown

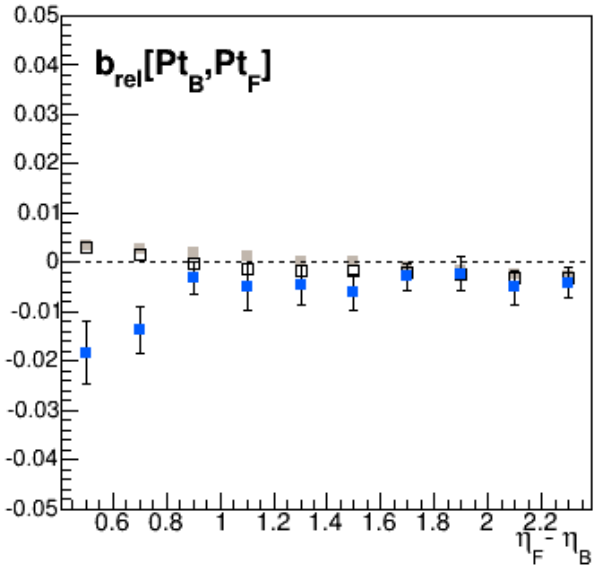
Pseudorapidity correlations: results
Be+Be 150A GeV/c 0-20% centrality

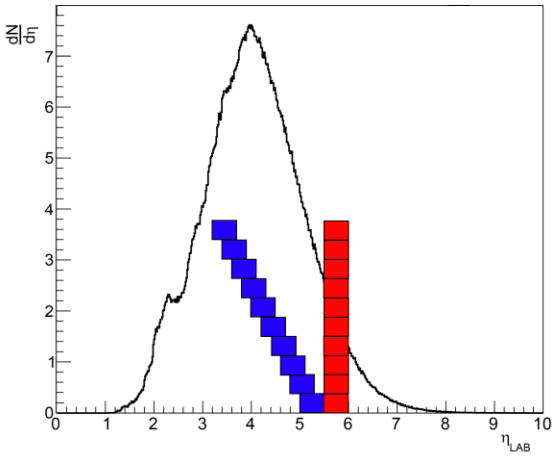
NA61/SHINE **preliminary**

Disconnected windows







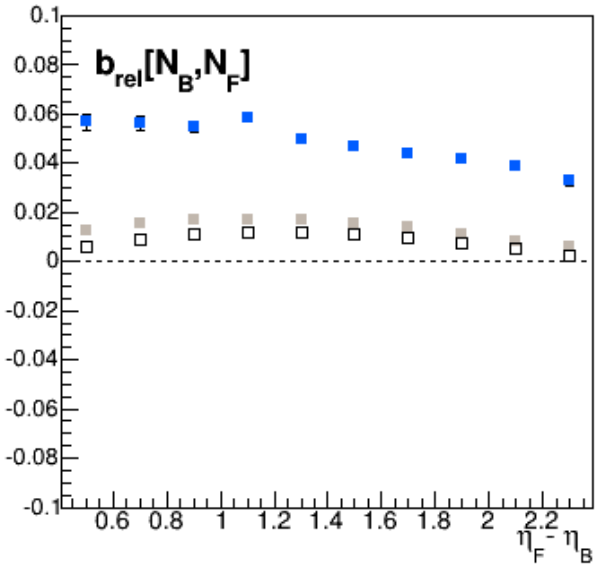


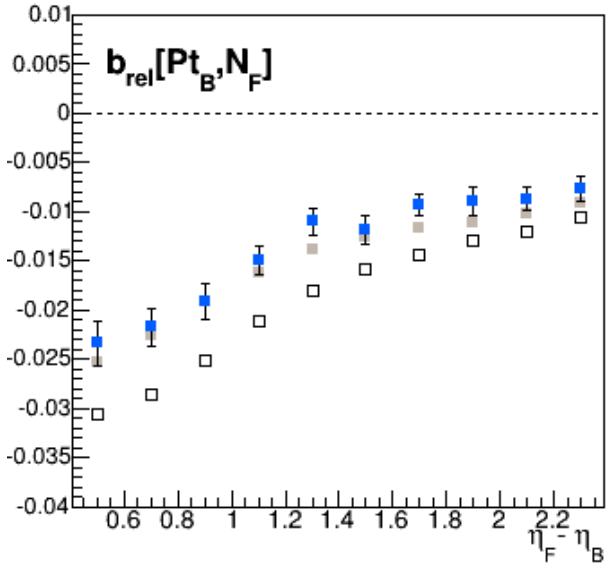
- Strong dependence on the windows position
- EPOS 1.99 describe the data qualitatively

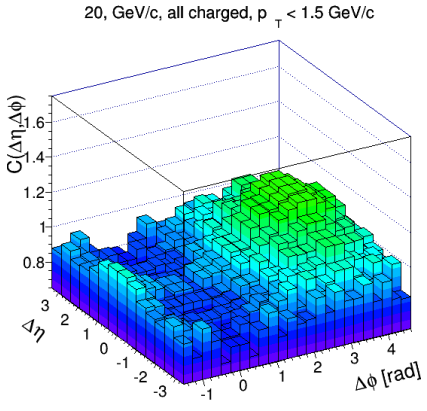
Event and track cuts were chosen to select only inelastic interactions with particles produced in strong and EM processes within the NA61/SHINE acceptance.
The results are corrected on detector effects: tracking inefficiencies, trigger bias.
The results are preliminary, only statistical errors are shown

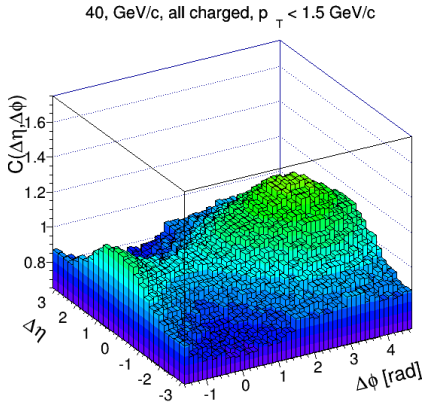
Pseudorapidity correlations: summary

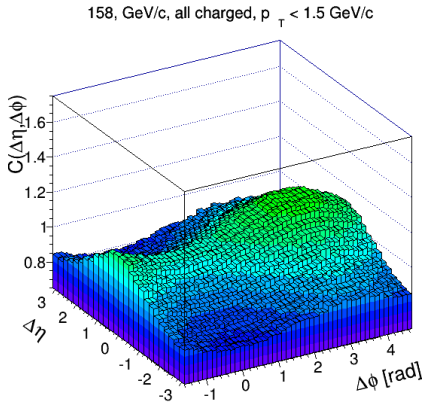
- Pseudorapidity correlations in inelastic Be+Be collisions at beam momenta 150*A* GeV/c ($\sqrt{s_{NN}}$ = 16.8 GeV) were measured.
- Results are strongly dependent on the position and the distance between the windows
- Long-range multiplicity and event-mean transverse momentum correlations are observed.





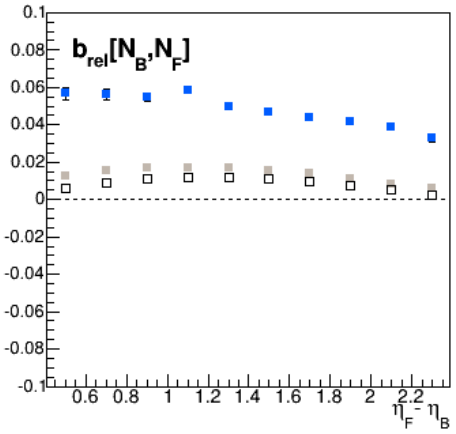


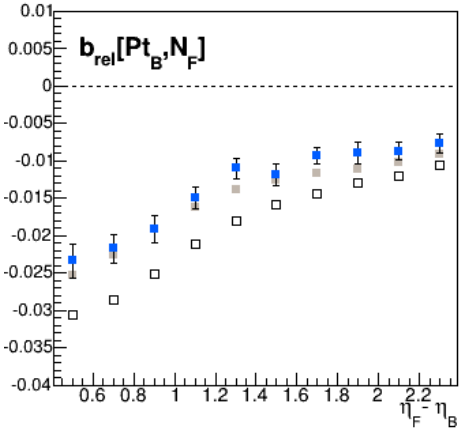




Thank you!

serykov@yahoo.com

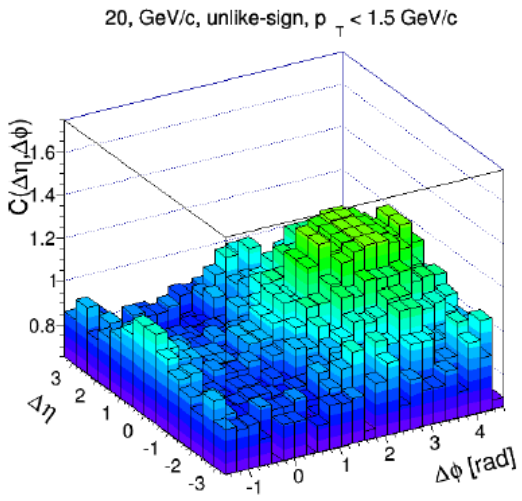


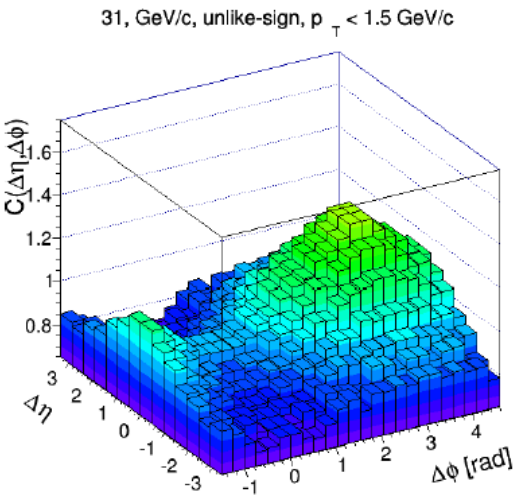


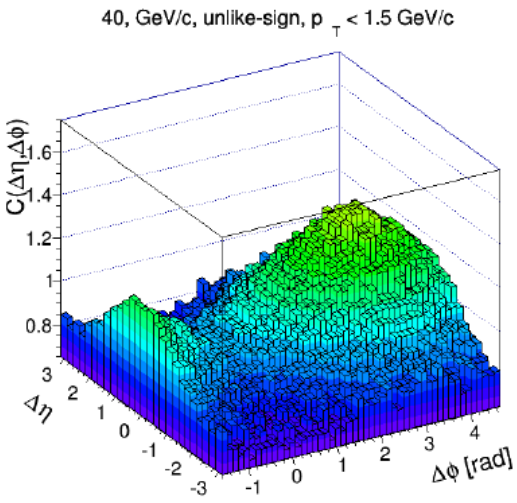
Two-particle correlations: energy dependence

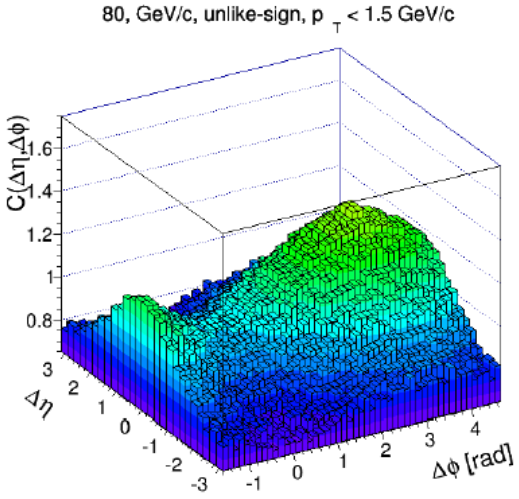
NA61/SHINE **preliminary**

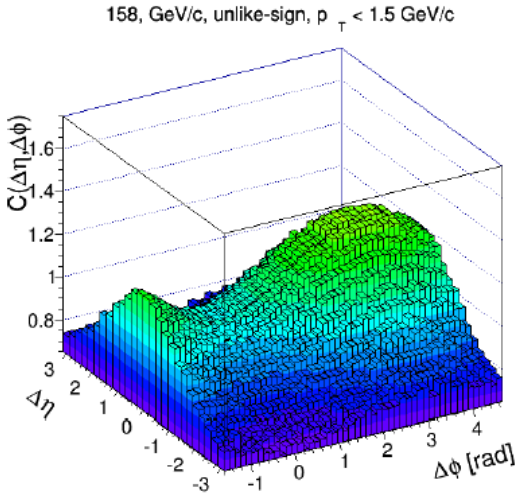
Unlike-sign charges







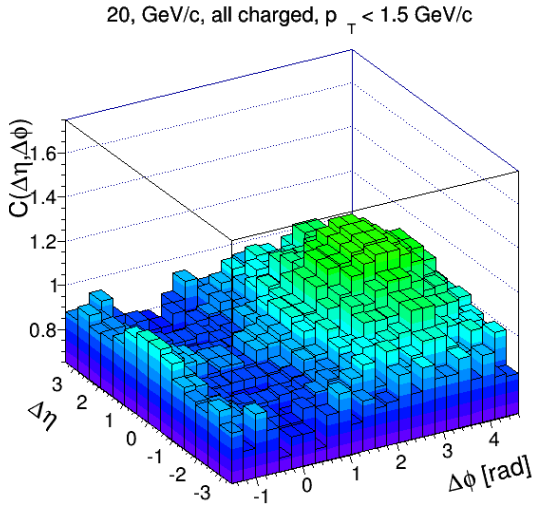


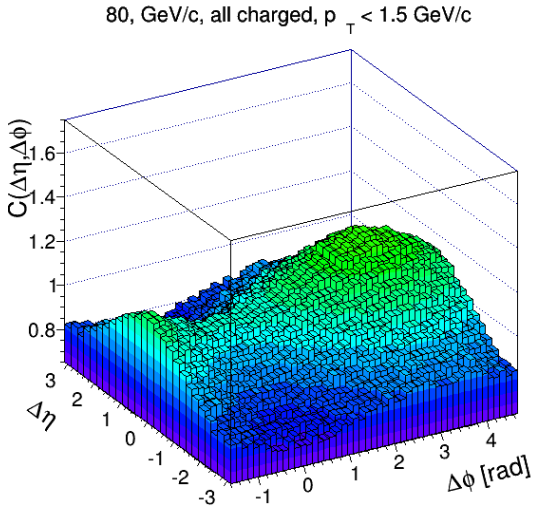


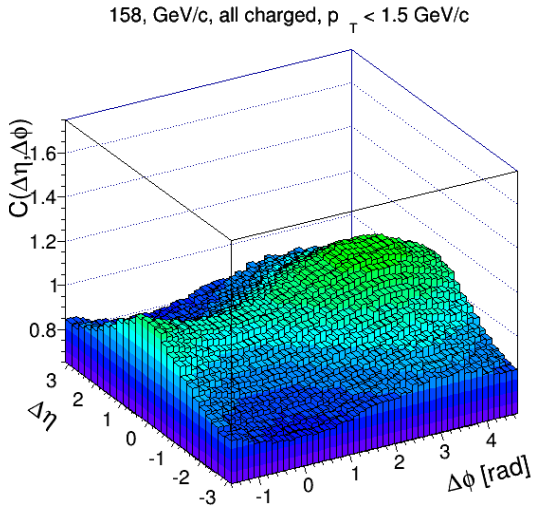
The enhancement “saddle” at (0,0) rises, like in previous slide, with increasing beam momentum

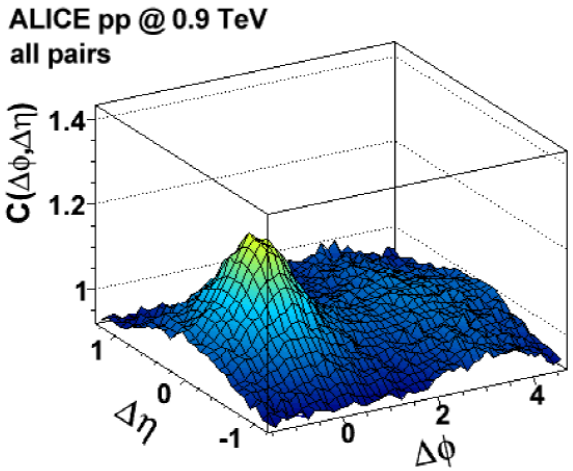
Two-particle correlations: NA61/SHINE vs ALICE

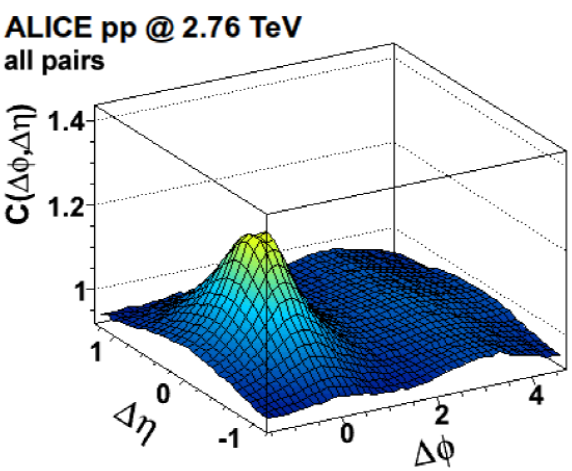
NA61/SHINE **preliminary**

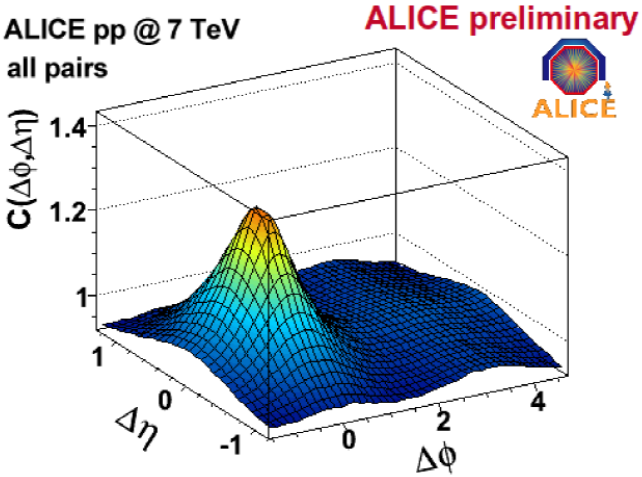








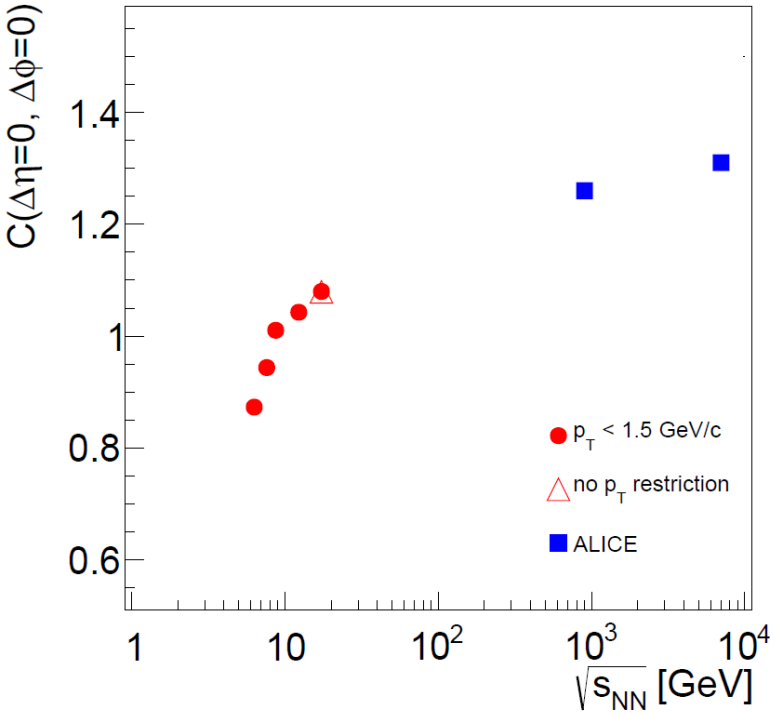


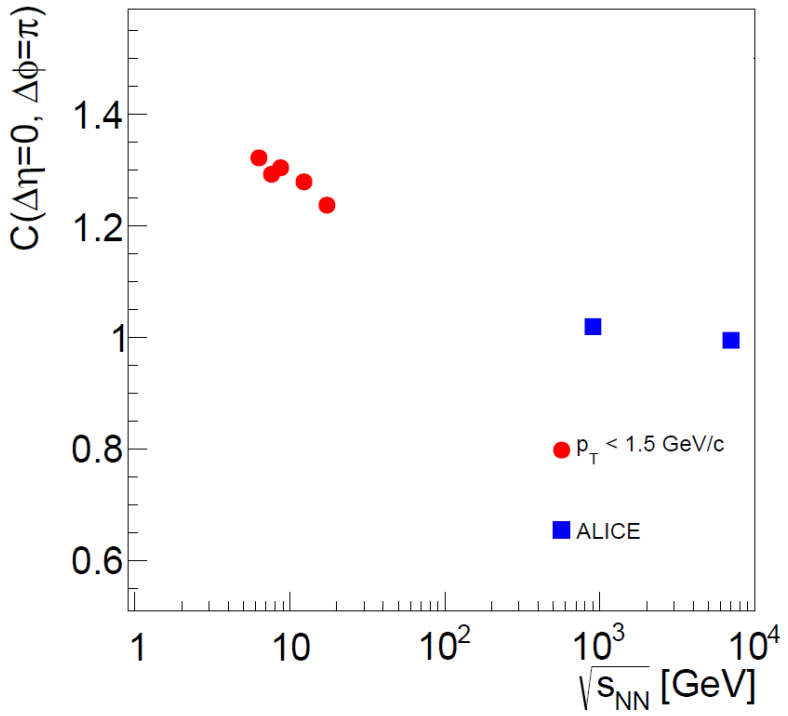


B.Maksiak [for the NA61/SHINE collaboration], PoS(CPOD2014)055

Two-particle correlations: (0,0) (0,π)

NA61/SHINE **preliminary**

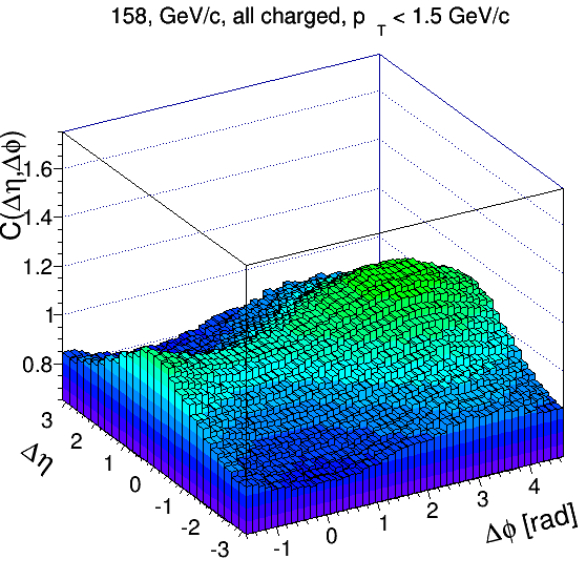


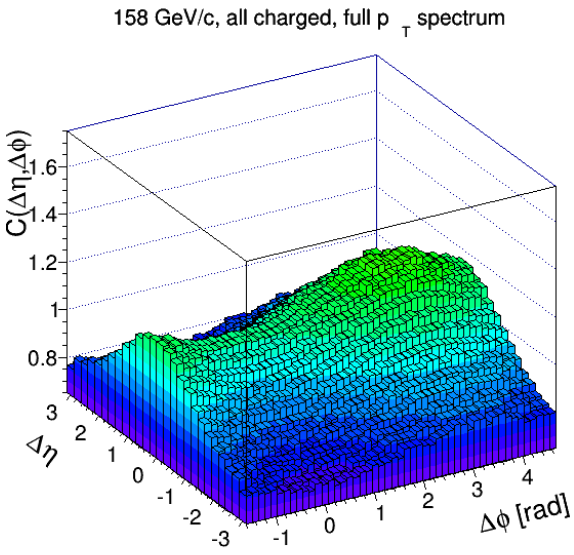


B.Maksiak [for the NA61/SHINE collaboration], PoS(CPOD2014)055

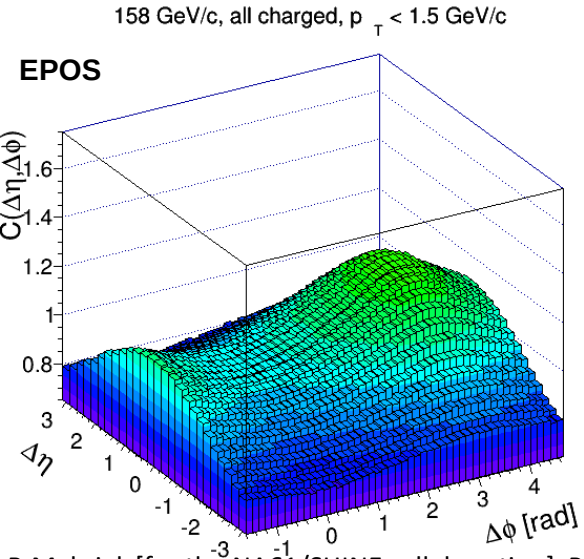
Two-particle correlations: Pt-influence

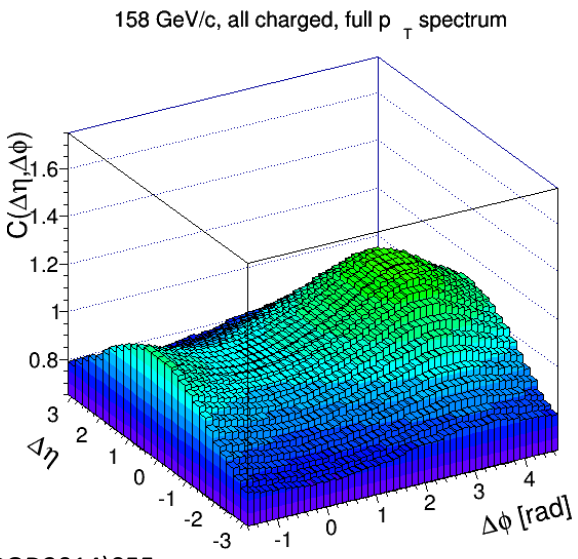
NA61/SHINE **preliminary**





EPOS





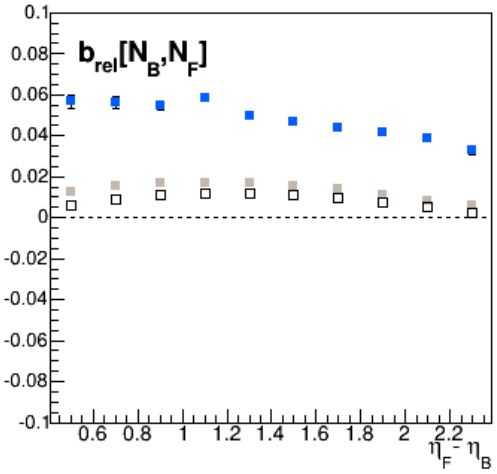
- Data and EPOS are in qualitative agreement.
- Results with and without $p_t < 1.5$ GeV/c cut are similar.
- No jet peak is visible at 158 GeV/c ($\sqrt{s_{NN}}$ = 17.3 GeV)

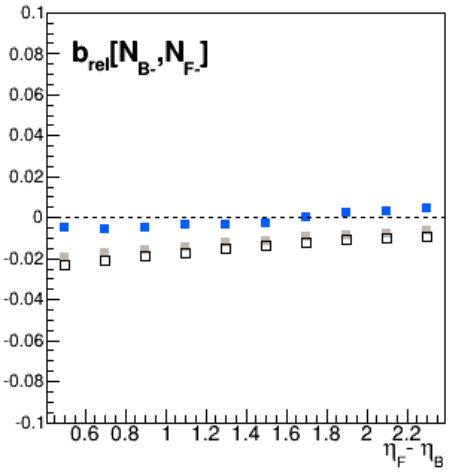
B.Maksiak [for the NA61/SHINE collaboration], PoS(CPOD2014)055

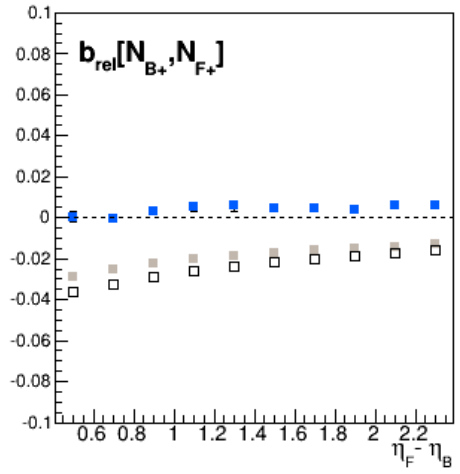
Pseudorapidity correlations: results
Be+Be 150A GeV/c 0-20% centrality

NA61/SHINE **preliminary**

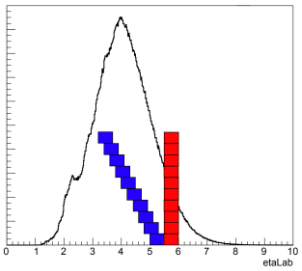
Disconnected windows

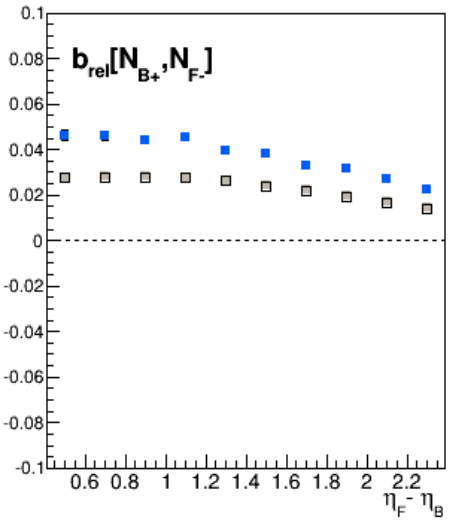


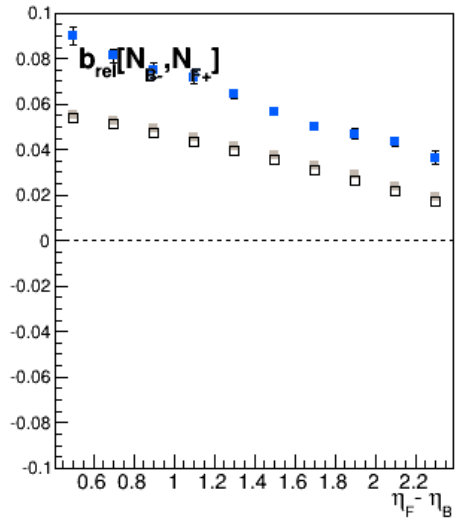




EPOS 1.99: NA61 acceptance
EPOS 1.99: 4pi acceptance
NA61/SHINE



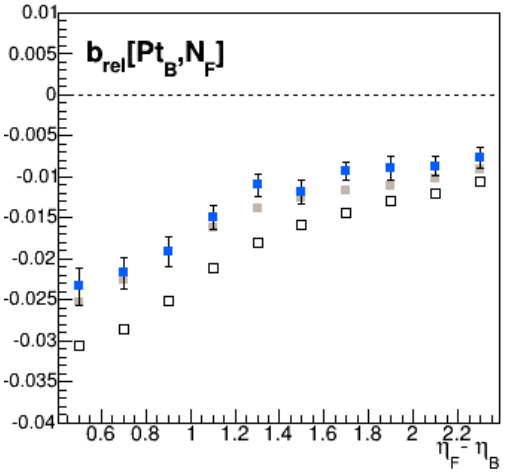


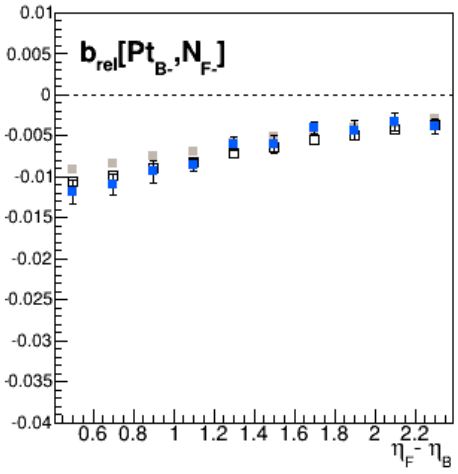


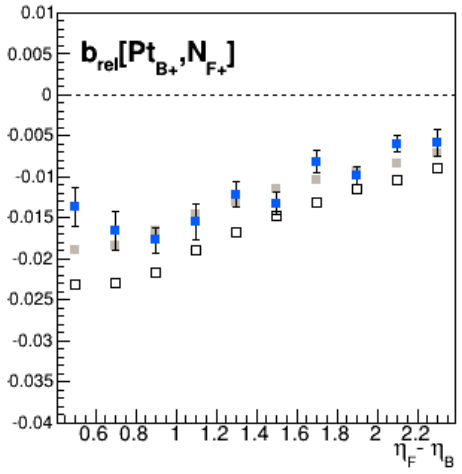
Pseudorapidity correlations: results
Be+Be 150A GeV/c 0-20% centrality

NA61/SHINE **preliminary**

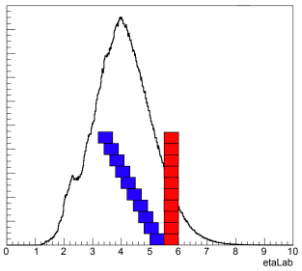
Disconnected windows

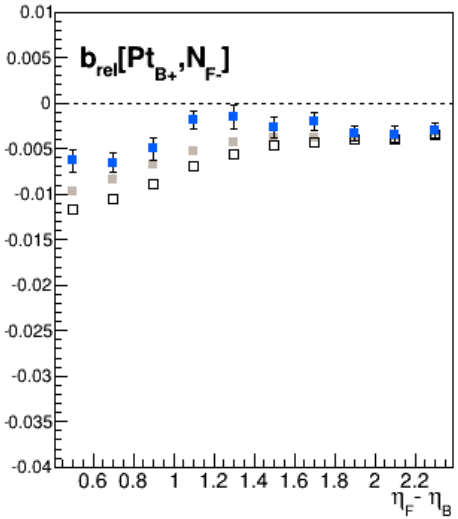


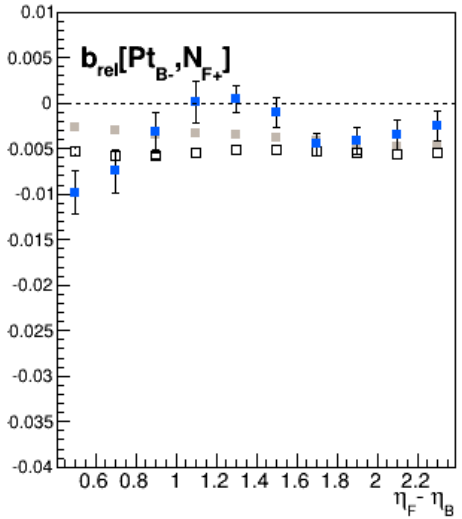




EPOS 1.99: NA61 acceptance
EPOS 1.99: 4pi acceptance
NA61/SHINE



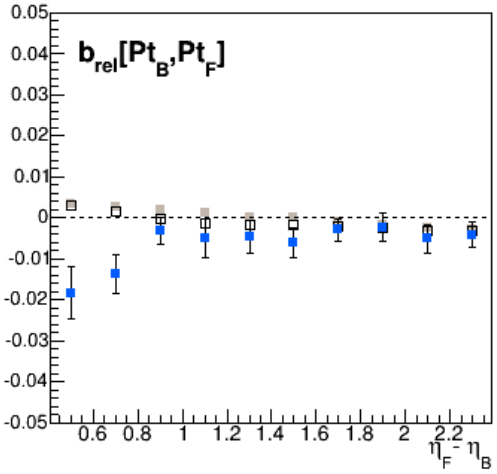


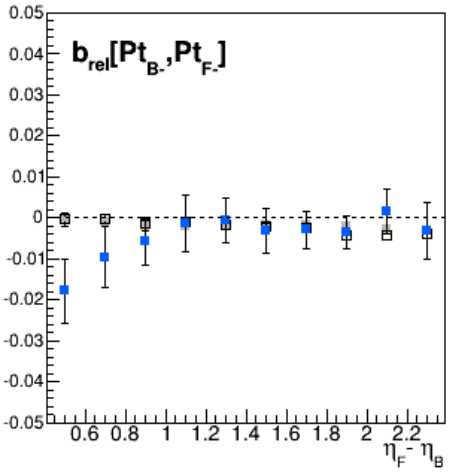


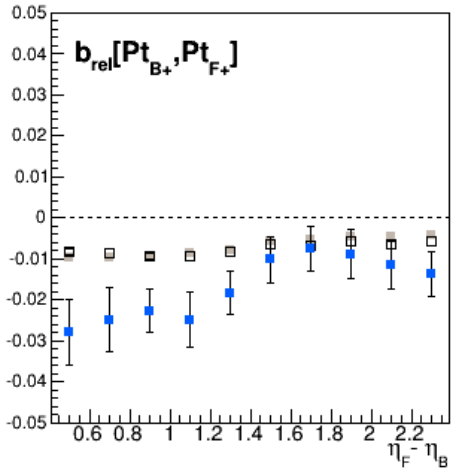
Pseudorapidity correlations: results
Be+Be 150A GeV/c 0-20% centrality

NA61/SHINE **preliminary**

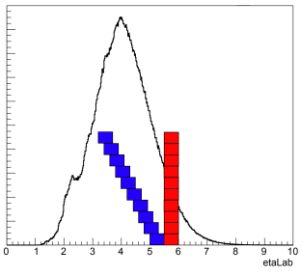
Disconnected windows

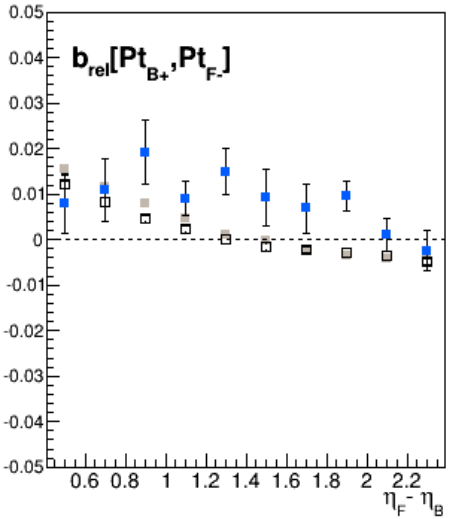


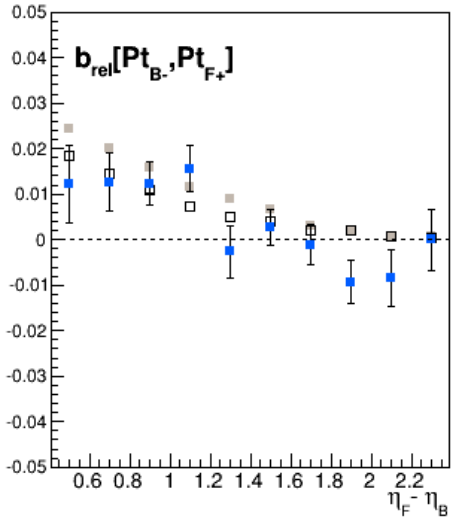




EPOS 1.99: NA61 acceptance
EPOS 1.99: 4pi acceptance
NA61/SHINE



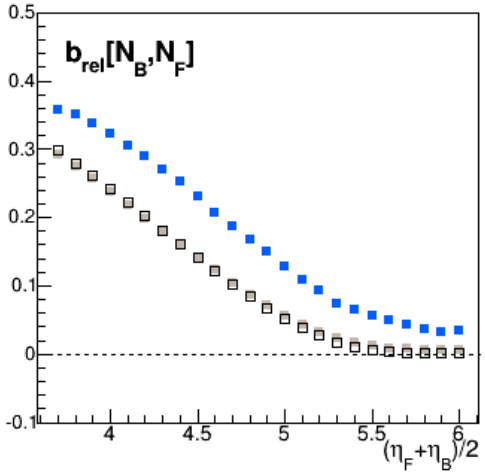


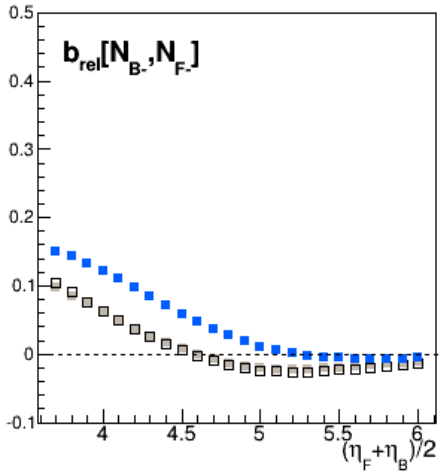


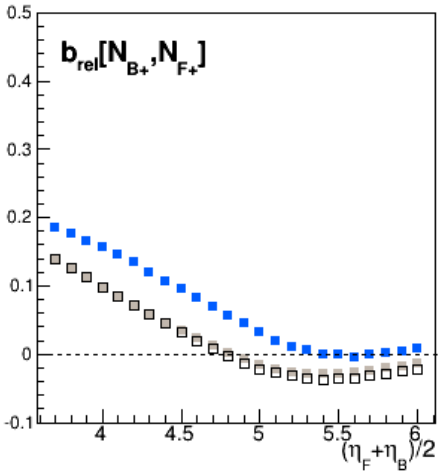
Pseudorapidity correlations: results
Be+Be 150A GeV/c 0-20% centrality

NA61/SHINE **preliminary**

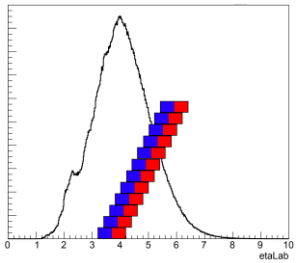
Connected windows

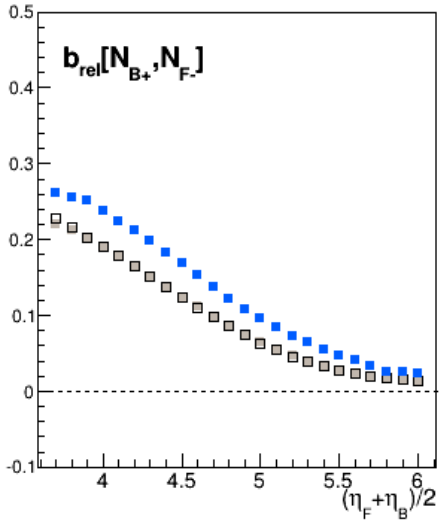


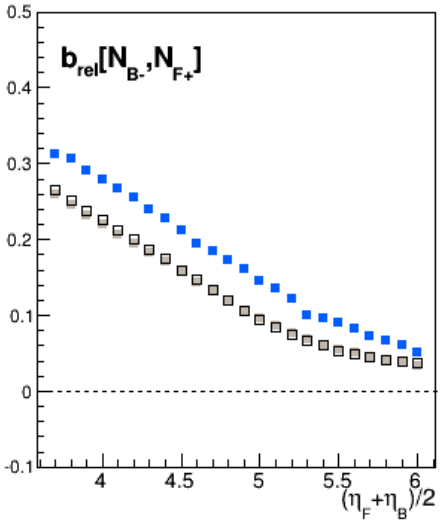




EPOS 1.99: NA61 acceptance
EPOS 1.99: 4pi acceptance
NA61/SHINE



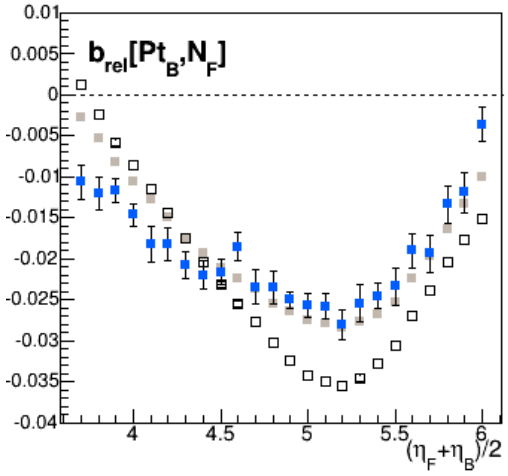


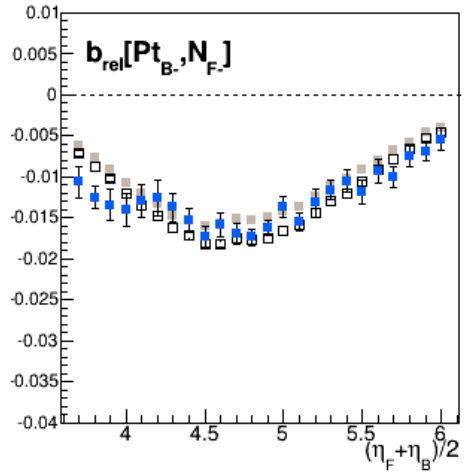


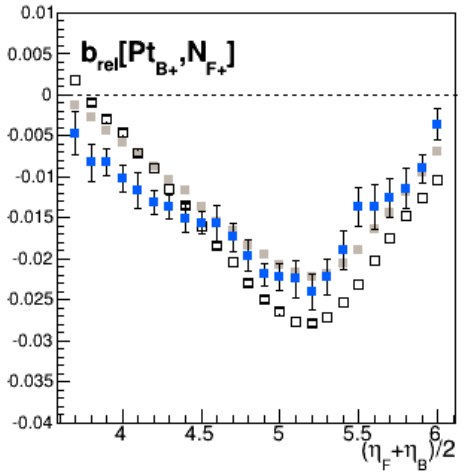
Pseudorapidity correlations: results
Be+Be 150A GeV/c 0-20% centrality

NA61/SHINE **preliminary**

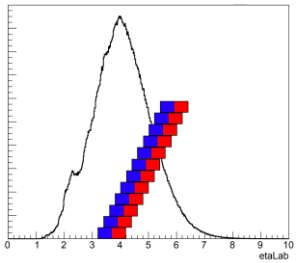
Connected windows

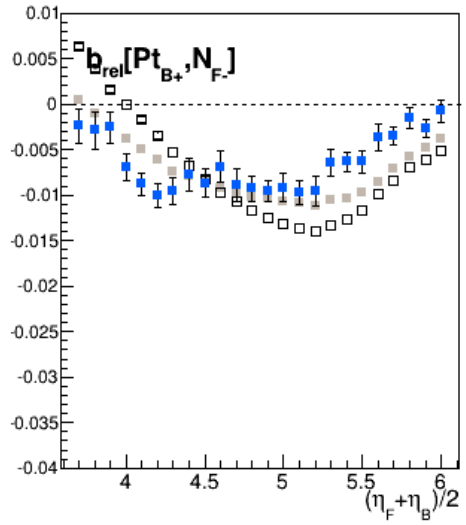


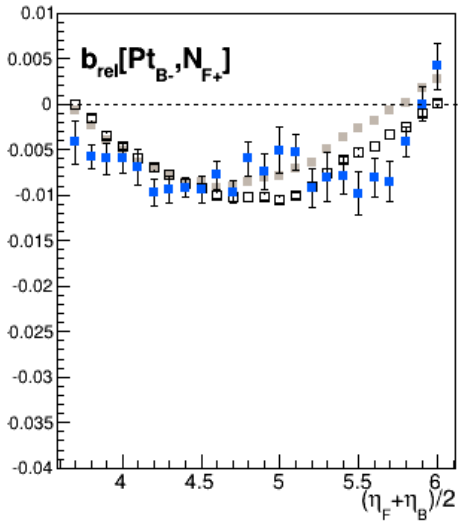




EPOS 1.99: NA61 acceptance
EPOS 1.99: 4pi acceptance
NA61/SHINE



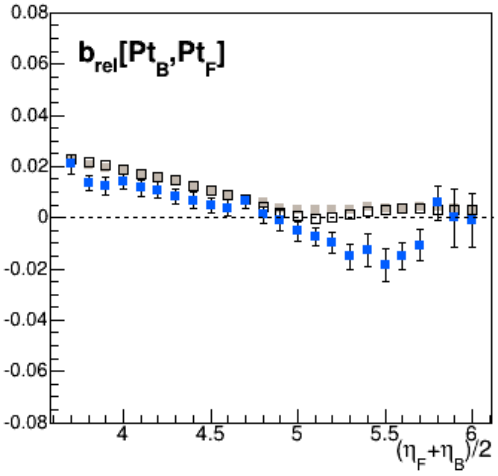


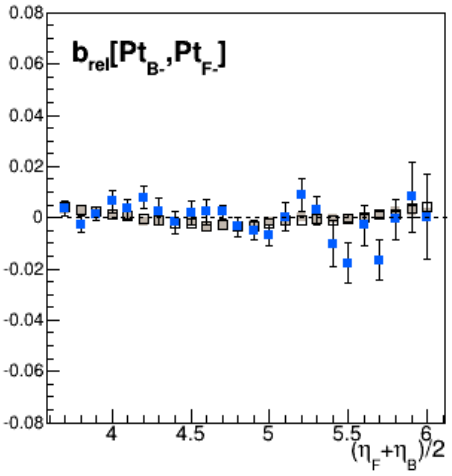


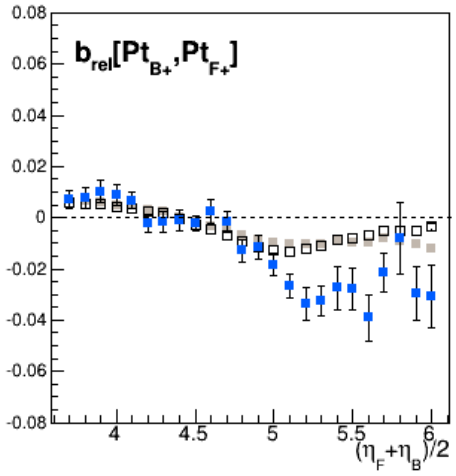
Pseudorapidity correlations: results
Be+Be 150A GeV/c 0-20% centrality

NA61/SHINE **preliminary**

Connected windows







EPOS 1.99: NA61 acceptance
EPOS 1.99: 4pi acceptance
NA61/SHINE