PROCEEDINGS OF SCIENCE

Two-particle correlations in azimuthal angle and pseudorapidity in Be+Be collisions at SPS energies

Bartosz Maksiak* **for the NA61/SHINE Collaboration**
Warsaw University of Technology, Poland
E-mail: maksiak@if.pw.edu.pl

The NA61/SHINE experiment aims to discover the critical point of strongly interacting matter and study the properties of the onset of deconfinement. These goals are to be achieved by performing a two dimensional phase diagram $(T - \mu_B)$ scan by measurements of hadron production properties in proton-proton, proton-nucleus and nucleus-nucleus interactions as a function of collision energy and system size. In this contribution, the results on two-particle correlations in pseudorapidity and azimuthal angle will be presented for the first time for Be+Be interactions at beam momenta: 20, 30, 40, 75 and 150 GeV/c per nucleon. The NA61/SHINE results will be compared with the already presented results of proton-proton collisions at similar beam momenta as well as to the EPOS model results.

Critical Point and Onset of Deconfinement
7-11 August, 2017
The Wang Center, Stony Brook University, Stony Brook, NY

*Speaker.

PoS(CPOD2017)067

1. Introduction

Two-particle correlations in $\Delta\eta$, $\Delta\phi$ were studied extensively at RHIC and LHC. They allow to disentangle different sources of correlations: jets, flow, resonance decays, quantum statistics effects, conservation laws, etc. The NA61/SHINE experiment is also performing such studies and published results on two-particle correlations in p+p collisions at SPS energies [1, 2]. Those results showed structures that can be connected with resonance decays, momentum conservation and Bose-Einstein correlations.

This paper presents the extension of studies of two-particle correlations in azimuthal angle and pseudorapidity to nucleus-nucleus collisions. The main purpose is to discover correlation structures and their possible sources in Be+Be collisions as well as to look for the differences between correlations in Be+Be interactions and already published p+p results.

2. $\Delta\eta\Delta\phi$ correlations

Correlations are calculated as a function of the difference in pseudorapidity (η) and azimuthal angle (ϕ) between two particles in the same event.

$$\Delta\eta = |\eta_1 - \eta_2|, \qquad \Delta\phi = |\phi_1 - \phi_2|.$$

The uncorrected (*raw*) correlation function is calculated as:

$$C^{raw}(\Delta\eta,\Delta\phi) = \frac{N^{pairs}_{bkg}}{N^{pairs}_{signal}} \frac{S(\Delta\eta,\Delta\phi)}{B(\Delta\eta,\Delta\phi)}, \tag{2.1}$$

where

$$S(\Delta\eta,\Delta\phi) = \frac{d^2N^{signal}}{d\Delta\eta d\Delta\phi}; \quad B(\Delta\eta,\Delta\phi) = \frac{d^2N^{bkg}}{d\Delta\eta d\Delta\phi}$$

are the distributions for signal and background pairs, respectively, measured in the region $0 < \Delta\eta < 3$. The $\Delta\phi$ range is folded, i.e. for $\Delta\phi$ larger than π its value is recalculated as $2\pi - \Delta\phi$. In order to allow a comparison with the RHIC and LHC results the pseudorapidity was calculated in the centre-of-mass (c.m.) system. The transformation from the laboratory system to the c.m. system was performed assuming the pion mass for all produced particles. Measured data was mirrored around the point $(\Delta\eta,\Delta\phi) = (0,0)$. Electrons and positrons were removed by a cut on dE/dx (the energy loss of the particle tracks in the TPC detectors). Only the 5% of the most violent Be+Be collisions were taken into account. The results from Be+Be collisions are not corrected for detector inefficiencies. The study of corrections is currently ongoing.

3. Results

This section presents preliminary results from the analysis of two-particle correlations in azimuthal angle and pseudorapidity in Be+Be collisions. Figures 1, 2, 3, and 4 show energy scan results for pairs of all charged, unlike-charge, positively charged and negatively charged particles, respectively.

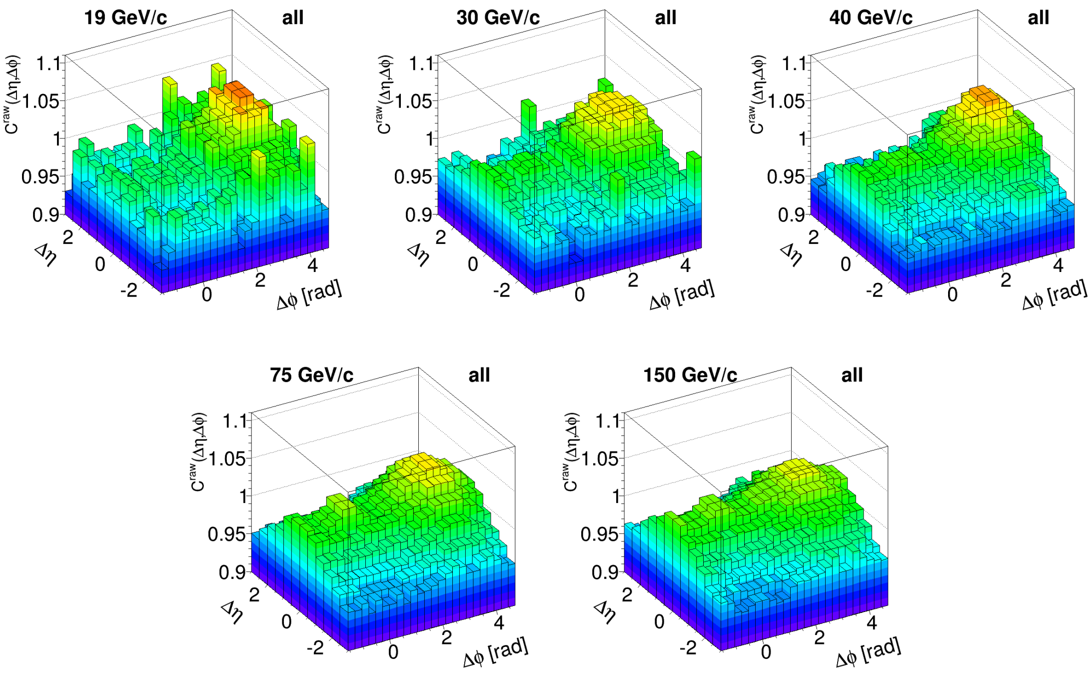

Figure 1: Results on two-particle correlations in $\Delta\eta\Delta\phi$ in Be+Be collisions presented for five beam momenta per nucleon. Pairs of particles of all charges.

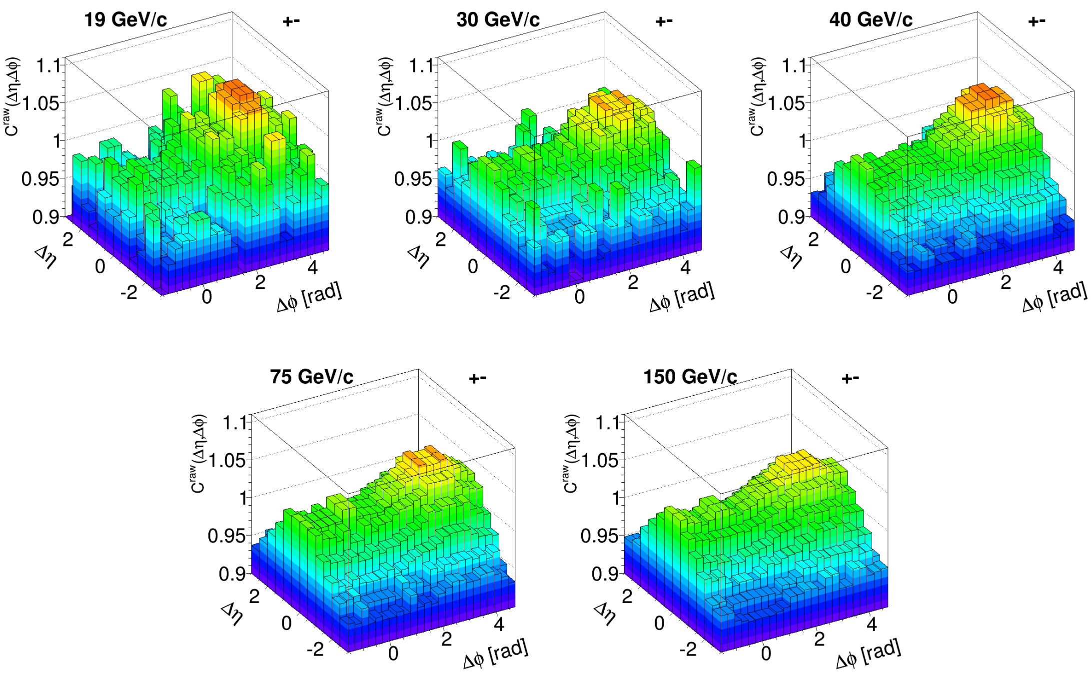

Figure 2: Results on two-particle correlations in $\Delta\eta\Delta\phi$ in Be+Be collisions presented for five beam momenta per nucleon. Unlike-charge pairs of particles.

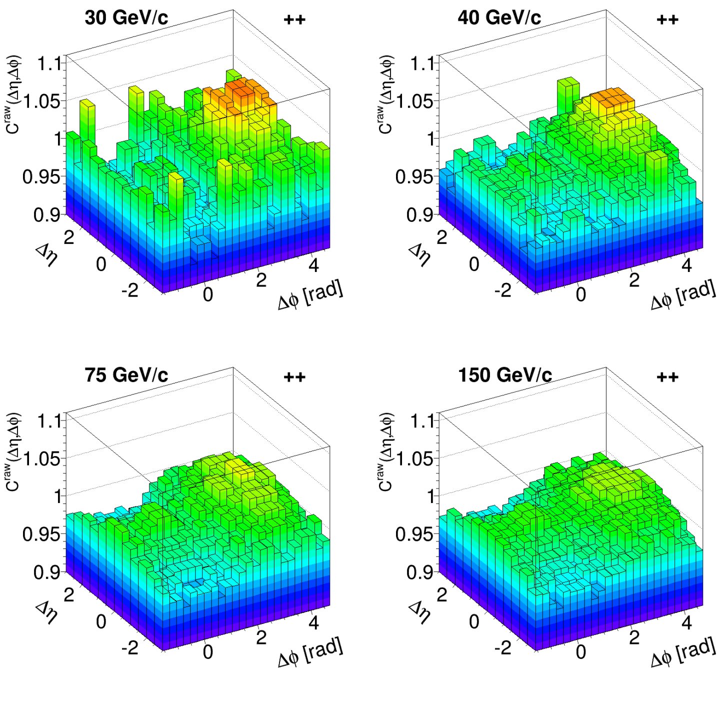

Figure 3: Results on two-particle correlations in $\Delta\eta\Delta\phi$ in Be+Be collisions presented for four beam momenta per nucleon (19*A* GeV/c was omitted due to low statistics). Positively charged pairs of particles.

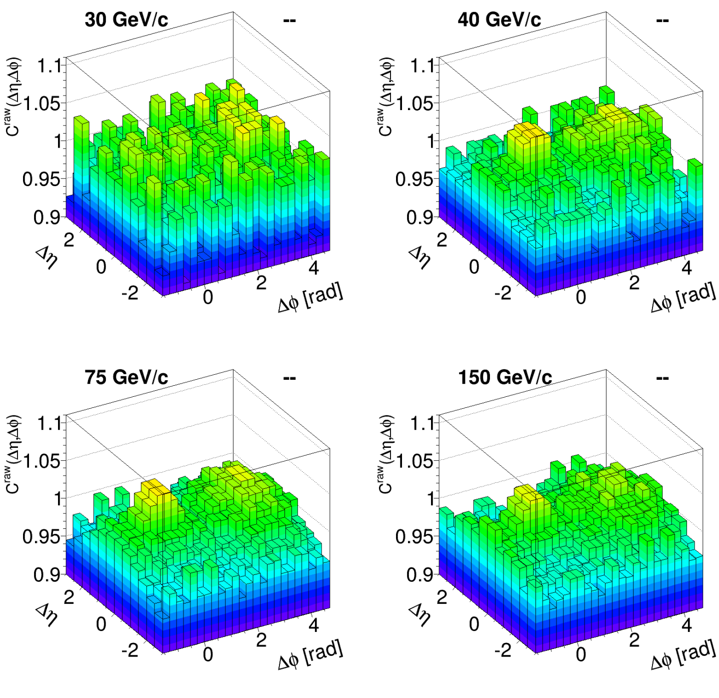

Figure 4: Results on two-particle correlations in $\Delta\eta\Delta\phi$ in Be+Be collisions presented for four beam momenta per nucleon (19*A* GeV/c was omitted due to low statistics). Negatively charged pairs of particles.

Two main structures are visible in the correlation results from central Be+Be collisions. The most prominent is a maximum at $(\Delta\eta, \Delta\phi) = (0, \pi)$ probably due to resonance decays and momentum conservation. The away-side enhancement is the highest in pairs of unlike-charged particles and weaker in like-charge pairs. This indicates that the largest contribution comes from correlations of particles with opposite charge, suggesting that it is due to resonances decaying back to back into two unlike-charge particles. In pairs of positively charged particles this enhancement is lower due to the lower number of resonances decaying into two positively charged particles (e.g. Δ^{++}). For pairs of negatively charged particles it is hardly visible because the multiplicity of produced double-negatively charged resonances, decaying into two negatively charged particles, is very low.

Another, well-visible structure is a small maximum at $(0,0)$ which is present for all charge combinations. For unlike-charge pairs its most probable source is Coulomb attraction. In like-charge pairs it is probably due to quantum statistics. A difference in its height between pairs of positively and negatively charged particles can be observed. A probable explanation is that for negatively charged particles the most frequently produced are negative pions. These are bosons obeying Bose-Einstein statistics which gives the enhancement. In positively charged pairs of particles however, the most abundantly produced particles are positively charged pions (bosons) and protons (fermions). The latter following Fermi-Dirac statistics. Correlations for pairs of positively charged particles is therefore an interplay of two effects: enhancement for bosons and suppression for fermions. Correlations for positively charged particles still show an enhancement but lower than correlations of negatively charged particles with no significant admixture of fermions.

4. Comparisons

In this section, the new measurements in Be+Be collisions are compared to calculations using the EPOS model [3] and to results from p+p interactions already published by the NA61/SHINE experiment [2].

4.1 Comparison with EPOS

Correlations in central Be+Be collisions were compared to results from the EPOS model. Note that EPOS generated results are presented in full (4π) acceptance, whereas experimental data are shown in an acceptance similar to the one for p+p data [4]. A comparison for pairs of unlike-charge and negatively charged particles is presented in Figs. 5 and 6, respectively. An additional comparison of the charge dependence of the correlations for 40*A* GeV/c beam momentum is shown in Fig. 7.

EPOS reproduces most of the features of the measured data quite well qualitatively. As in real data, the away-side enhancement is the most pronounced at lower beam momenta. The differences between charge combinations are also reproduced by the EPOS model. However, EPOS does not produce the peak at (0,0). This is due to the lack of implementation of short-range correlations, like quantum statistics and Coulomb interactions, in the model. As a result, correlations in the (0,0) region are almost flat for the EPOS model.

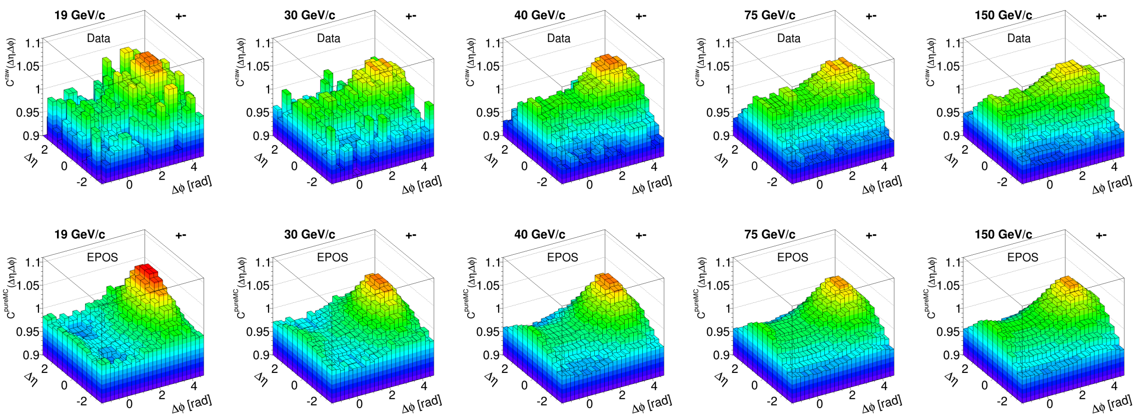

Figure 5: Comparison of results from central Be+Be collisions of NA61/SHINE (top row) and obtained from the EPOS model (bottom row). Results for unlike-charge particles. EPOS results are within full acceptance. Beam momenta are per nucleon.

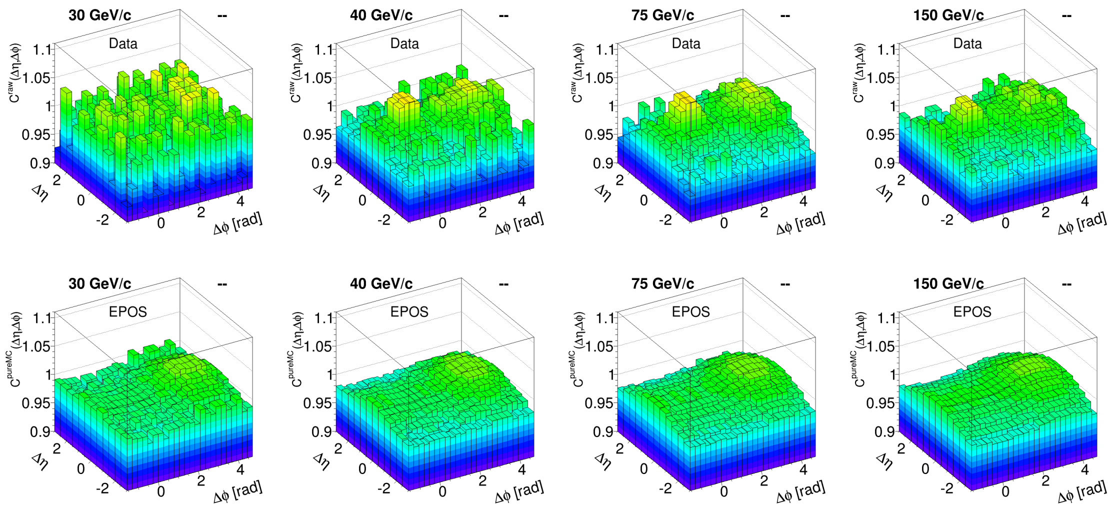

Figure 6: Comparison of results from central Be+Be collisions of NA61/SHINE (top row) and obtained from the EPOS model (bottom row). Results for negatively charged particles. EPOS results are within full acceptance. Beam momenta are per nucleon.

4.2 Comparison with results from p+p collisions

Correlations in Be+Be collisions are compared to results from p+p interactions [2] in Fig 8. It needs to be mentioned that correlations in Be+Be are generally much weaker than in p+p collisions due to higher combinatorical background diluting the correlation signal. This is evident from the comparison with the same vertical scales in Be+Be and p+p correlations presented in Fig. 8 (middle and right panels). Structures in correlations are readily visible with the vertical scale range $(0.9, 1.1)$ (see Fig. 8, left panel) while they are not apparent with the vertical scale range $(0.5, 1.6)$ used for p+p interactions.

Comparison of correlations for different charge combinations are shown at 150A/158 GeV/c

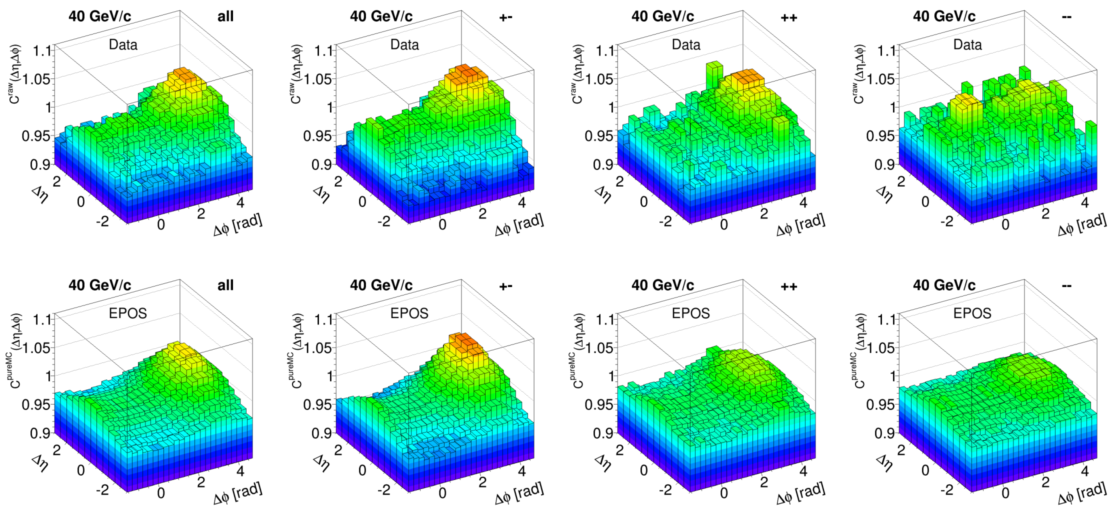

Figure 7: Comparison of charge dependence of correlations from central Be+Be collisions of NA61/SHINE (top row) and obtained from the EPOS model (bottom row). Results are presented for 40*A* GeV/c beam momentum. EPOS results are within full acceptance.

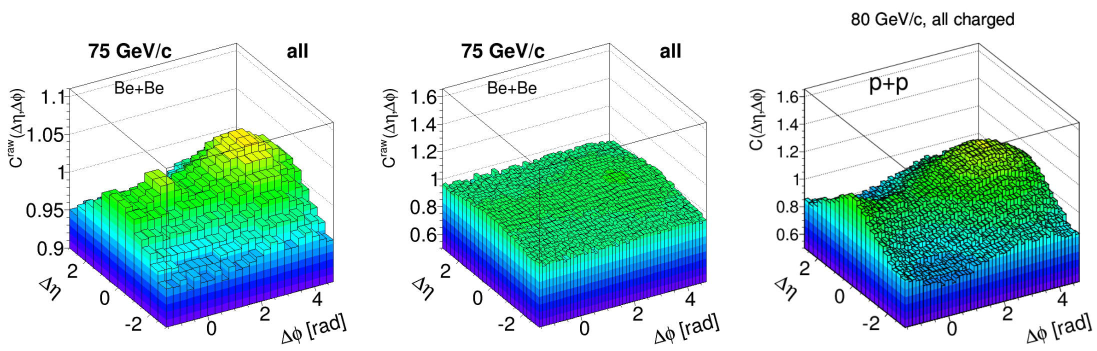

Figure 8: Comparison of correlations in Be+Be collisions at 75*A* GeV/c and p+p interactions [2] at 80 GeV/c. Left and middle plots show the same data but using different vertical scales.

beam momentum in Fig. 9 using vertical scales tuned to present the structures with similar magnitudes. Although correlations is Be+Be are generally weaker than in p+p, the structures appearing in both systems are similar and show a maximum at the away-side and a small enhancement at the near-side. However, in Be+Be collisions the peak around $(\Delta\eta,\Delta\phi) = (0,0)$ is more prominent with respect to the rest of correlation landscape.

5. Summary

For the first time two-particle correlations were measured by NA61/SHINE in central Be+Be collisions at SPS beam momenta. The results show a prominent enhancement at $(\Delta\eta,\Delta\phi) = (0,\pi)$, mostly visible in pairs of unlike-charge particles and weaker in pairs of like-charge, produced probably due to resonance decays and momentum conservation. Another visible structure is a small maximum at (0,0) appearing in all charge combinations. In pairs of unlike-charge particles

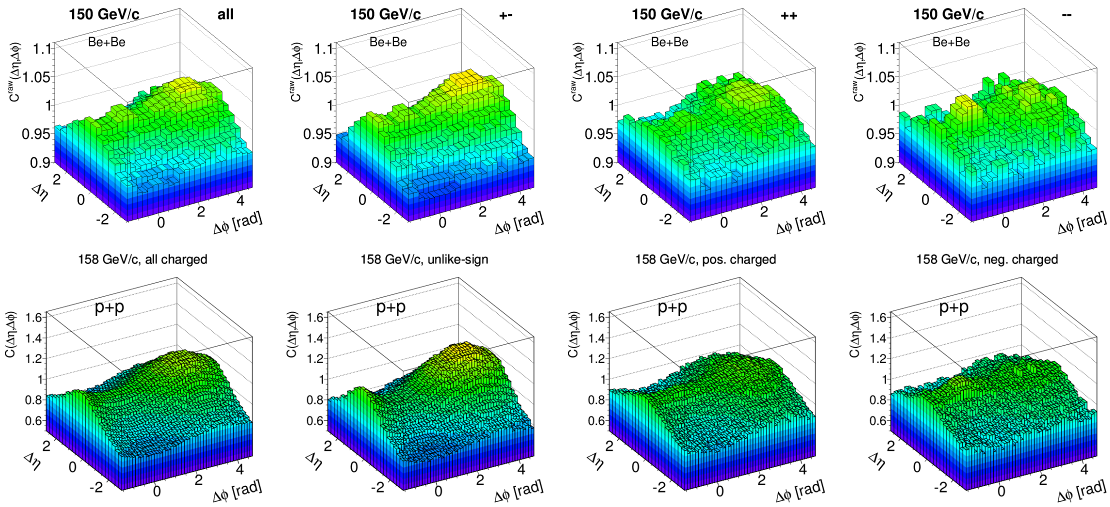

Figure 9: Comparison between Be+Be (top row) and p+p results [2] (bottom row) presented for all charge combinations for beam momentum 150*A* or 158 GeV/c (for Be+Be and p+p, respectively).

it is probably a result of Coulomb attraction, while in pairs of like-charge it may come from an interplay of Bose-Einstein and Fermi-Dirac statistics effects.

Results from the EPOS model calculations are in general similar to the measurements of NA61/SHINE. The only exception is the lack of (0,0) enhancement, since no short-range correlations (quantum statistics, Coulomb interactions) are generated in the model.

Comparing to the smaller system of p+p interactions, the correlations in Be+Be collisions are much weaker due to larger combinatorical background diluting the signal. Qualitatively, the structures in both systems are similar with exception of the peak at (0,0) which is more prominent in the Be+Be system.

Acknowledgments: This work was supported by the National Science Centre, Poland grants 2015/19/N/ST2/01689 and 2015/18/M/ST2/00125.

References

[1] B. Maksiak [for the NA61/SHINE Collaboration], PoS CPOD **2014** (2015) 055 [arXiv:1503.02470 [nucl-ex]].

[2] A. Aduszkiewicz *et al.* [NA61/SHINE Collaboration], Eur. Phys. J. C **77** (2017) no.2, 59 doi:10.1140/epjc/s10052-017-4599-x [arXiv:1610.00482 [nucl-ex]].

[3] K. Werner, F. M. Liu and T. Pierog, Phys. Rev. C **74** (2006) 044902 [hep-ph/0506232].

[4] Particle Population Matrices: Acceptance definitions for two-particle correlations analysis in p+p collisions, https://edms.cern.ch/document/1700774/1.