Bose-Einstein effects in multiplicity and net-charge correlations in pp collisions using Pythia 8 simulations

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Outline

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Correlation coefficient

Calculation of the correlation coefficient b_{AB}

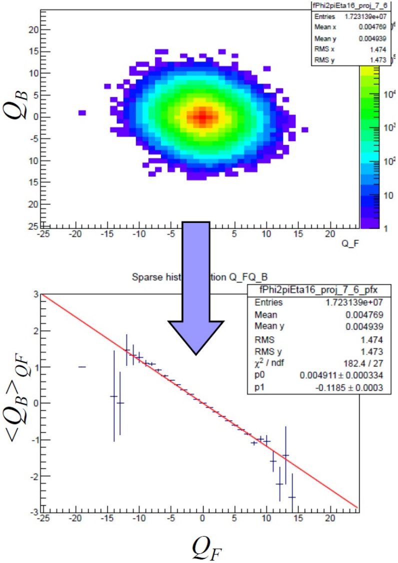
1. Linear regression

$$\langle A \rangle_B = a + b_{AB} B$$

2. Correlation formula

$$b_{AB} = \frac{\langle AB \rangle - \langle A \rangle \langle B \rangle}{\langle A \rangle - \langle A \rangle^2}$$

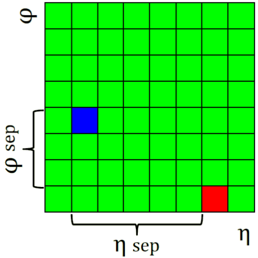
A and B can be any observables

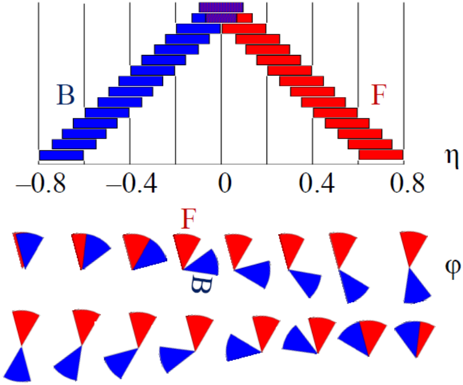


Windows configuration

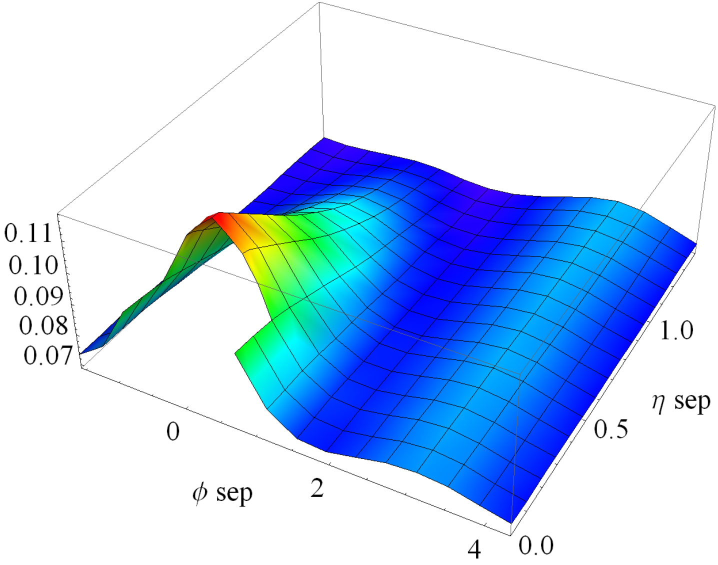
Forward and Backward windows are picked in (η, ϕ)

b is calculated for each configuration and plotted as a function of $(\phi_{sep},\ \eta_{sep})$





N_{ch} : N_{ch} correlation coefficient topology



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Pythia

Pythia is a Monte-carlo program simulating pp and ee collisions at energies larger than 10GeV
It is widely used and thus is well tuned to the modern data

Allows investigation of the influence of various key processes like multiparton interactions, color reconnection, etc. on different observables since you can turn them off

Setup used:
PYTHIA 8.186, Monash 2013 tune, pp, 7TeV
SoftQCD:NonDiffractive=on
HadronLevel:BoseEinstein=on
2.5mln events

Bose-Einstein effects

The BoseEinstein class performs shifts of momenta of identical particles to provide a crude estimate of Bose-Einstein effects.
Results in an enhancement in the correlation function of identical particles by a factor of:

$$f_2(Q) = (1+\lambda*exp[-Q^2R^2])(1+\alpha*\lambda*exp[-Q^2R^2/9])(1-exp[-Q^2R^2/4])$$

$Q^2 = (p_1 + p_2)^2 - (m_1 + m_2)^2$
λ- BE effect strength, default $\lambda = 1$
$R = 1/Q_{ref}$ - effective radius, default $Q_{ref} = 0.2$

First factor pulls particles closer conserving three-momentum,
Second pushes more particles apart ($\alpha < 0$) to restore energy conservation,
Third ensures $f_2(0) = (1 + \lambda)$

L. Lönnblad, T. Sjöstrand, *"Modelling Bose-Einstein correlations at LEP 2"*, 1997, arXiv:hep-ph/9711460

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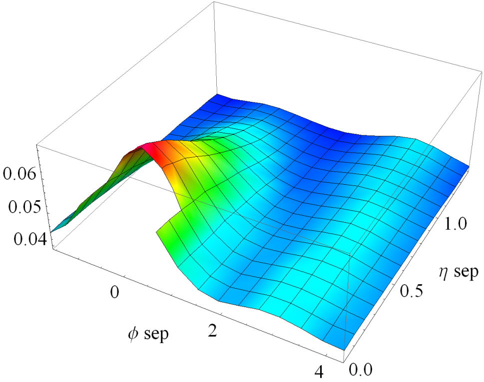
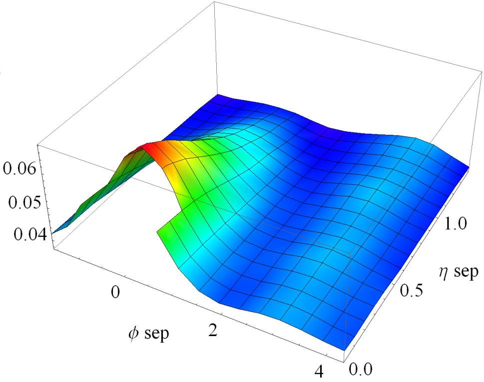
N+N- correlation coefficient topology

BE off

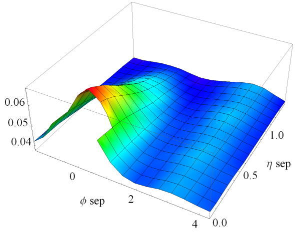


BE on



N+N- correlation coefficient topology

BE on



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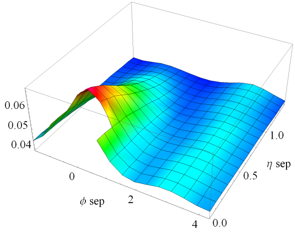
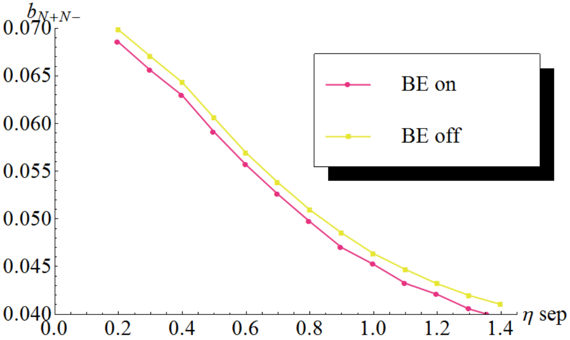


Slice at $\phi_{sep} = 0$



N+N+ correlation coefficient topology

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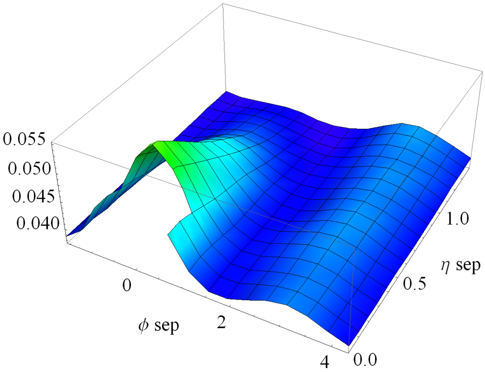

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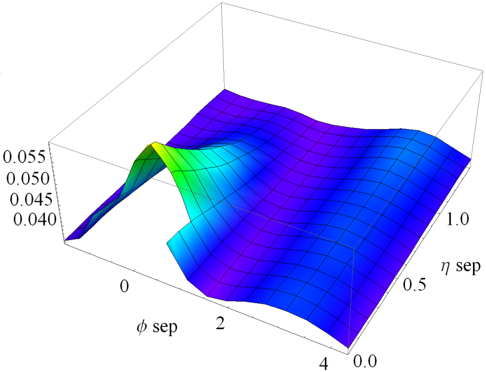
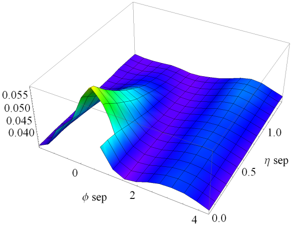


N+N+ correlation coefficient topology

BE on



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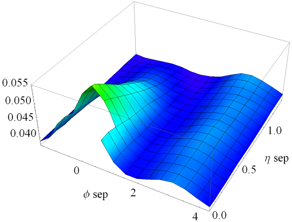

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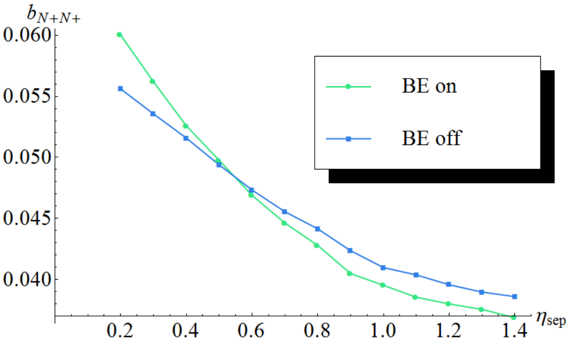
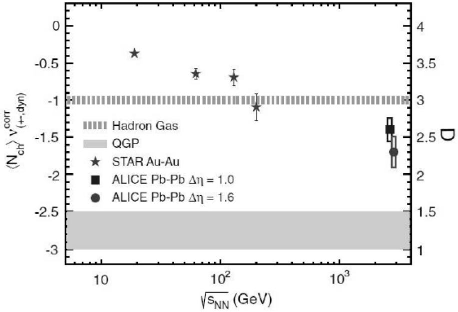


Outline

Why net-charge

$Q = N_+ - N_-$
$\langle Q \rangle = 0$
$D \sim \langle Q^2 \rangle - \langle Q \rangle^2$
Strongly depend on state of the matter, when particles are produced



Experimental net-charge fluctuations vs QGP and hadron gas predictions

B. Abelev et al. (ALICE Collaboration), Net-charge fluctuations in Pb- Pb collisions at $\sqrt{S_{NN}} = 2.76$ TeV, Phys. Rev. Lett. 110 (2013) 152301, [1207.6068 [nucl-ex]]

Connection of b_{QQ} with b_{NN}

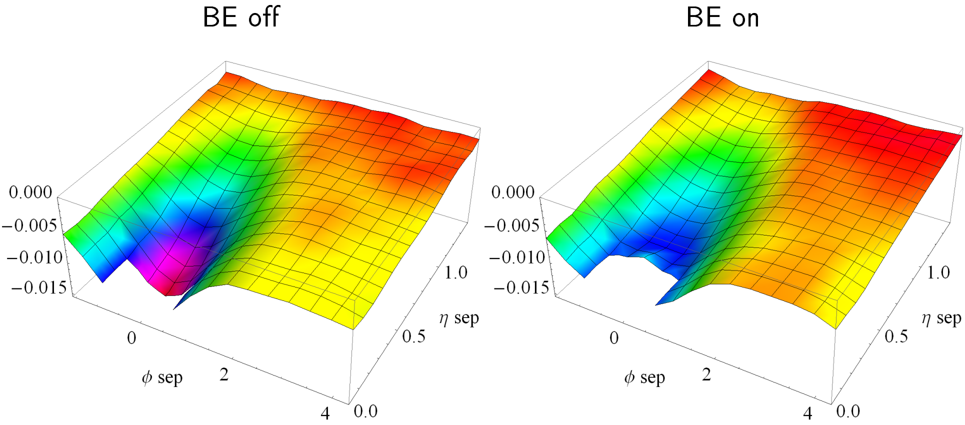
$$b_{QQ} = \frac{\langle Q_B Q_F \rangle - \langle Q_B \rangle \langle Q_F \rangle}{\langle Q_F^2 \rangle - \langle Q_F \rangle^2} = \frac{\langle (p_B - m_B)(p_F - m_F) \rangle - \langle p_B - m_B \rangle \langle p_F - m_F \rangle}{\langle (p_F - m_F)^2 \rangle - \langle p_F - m_F \rangle^2} =$$

$$= \frac{2Cov(p_F, p_B) - 2Cov(p_F, m_B)}{2D(p_F) - 2Cov(p_F, m_B)} = (b^{F-B}_{N+N+} - b^{F-B}_{N+N-}) \frac{1}{1 - b^{F-F}_{N+N-}}$$

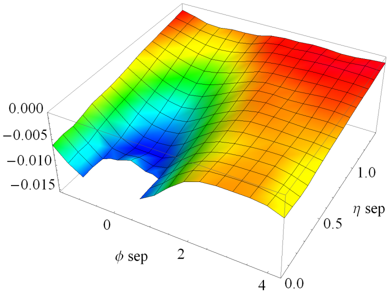
If b^{F-F}_{N+N-} is small,
Q Q correlation is generally the difference between N+N+ and N+N-

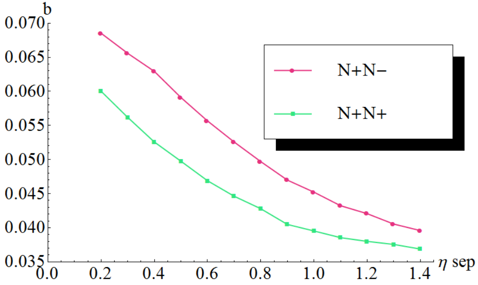
And $b^{F-F}_{N+N-} \approx 0.05$.

QQ correlation coefficient topology



QQ correlation coefficient topology





$b_{QQ} \approx (b_{N+N+} - b_{N+N-})$, hence the bump

Conclusions

- Effects of Bose-Einstein statistics has a significant influence on net-charge correlations in short-range region
- Difference in the behavior of correlation coefficient for like- and unlike-sign multiplicity results in a bump in net-charge correlations

Thank you for attention