Δη dependence of net-charge fluctuations in Au+Au collisions from the Beam Energy Scan at the STAR experiment

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Abstract

The fluctuations of conserved quantities in a finite phase space rapidity window (Δη), like the net-charge, are predicted to be one of the most sensitive signals of the QGP formation and phase transition [1].

In this study, D-measure and 1st to 4th order cumulant ratios are calculated in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7, 11.5, 14.5, 19.6, 39, 62.4, and 200 GeV during Beam Energy Scan in 2010, 2011 and 2014. We will report Δη, centrality and energy dependence of the net-charge fluctuation, and discuss an energy dependence of the fluctuation as a function of Δη and possible information from the QGP phase transition.

Introduction

- Relation between moments and cumulants

$$M = C_1 \quad \sigma^2 = C_2 \quad S = \frac{C_3}{(C_2)^{3/2}} \quad \kappa = \frac{C_4}{(C_2)^2}$$

Cumulant ratios (Independent of volume)

$$\frac{\sigma^2}{M} = \frac{C_2}{C_1} \quad S\sigma = \frac{C_3}{C_2} \quad \kappa\sigma^2 = \frac{C_4}{C_2}$$

D-measure

$$D = 4\frac{C_2}{\langle N_{ch} \rangle}$$

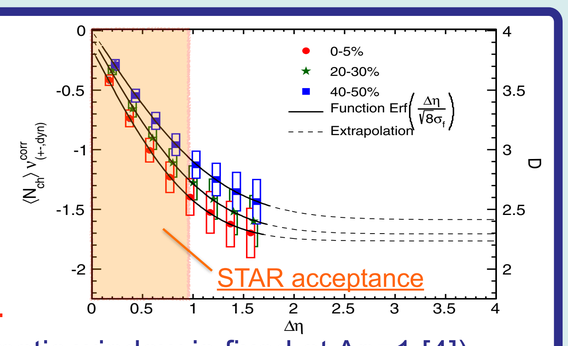
2nd order cumulant of net-charge

total multiplicity in finite acceptance

Theoretically

D=3-4 (Hadron fluctuation)
D=1-1.5 (QGP fluctuation) [2]

- D-measure is observed to decrease with Δη in LHC-ALICE experiment at 2.76TeV Pb-Pb collisions [3].
  → Signal of phase transition?
- Δη dependence of net-charge fluctuations are extremely important.



(In recent net-charge paper in STAR, kinematic window is fixed at Δη=1 [4])

STAR detector

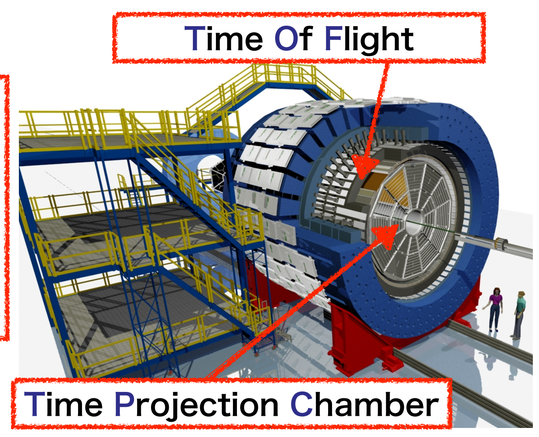
- **Time Projection Chamber (TPC)**

$0.5 < |\eta| < 1$ …used to define centrality (Refmult2)

$|\eta| < 0.5$ …used to calculate net-charge fluctuations

$0.2 < p_T < 2.0$ GeV/c

→ Using different kinematic window to avoid auto-correlation.



- **Time Of Flight (TOF)** … used to remove pile-up events

Analysis method

- **Centrality Bin Width Correction**

$$\sigma = \frac{\sum_r n_r \sigma_r}{\sum_r n_r}$$

σ at r^{th} multiplicity

number of events in r^{th} multiplicity

→ Applied to address the effect of variation of the volume within a wide centrality bin

- **Charge conservation correction**

$$D_{corr} = \overset{\star}{D} = \overset{\circ}{D} + 4\frac{\langle N_{ch} \rangle}{\langle N_{total} \rangle}$$

total multiplicity over full phase space

- **Efficiency correction**

$$f_{ik} = p_1^i \cdot p_2^k \cdot F_{ik}$$

Efficiencies

Observed factorial moment

True factorial moment

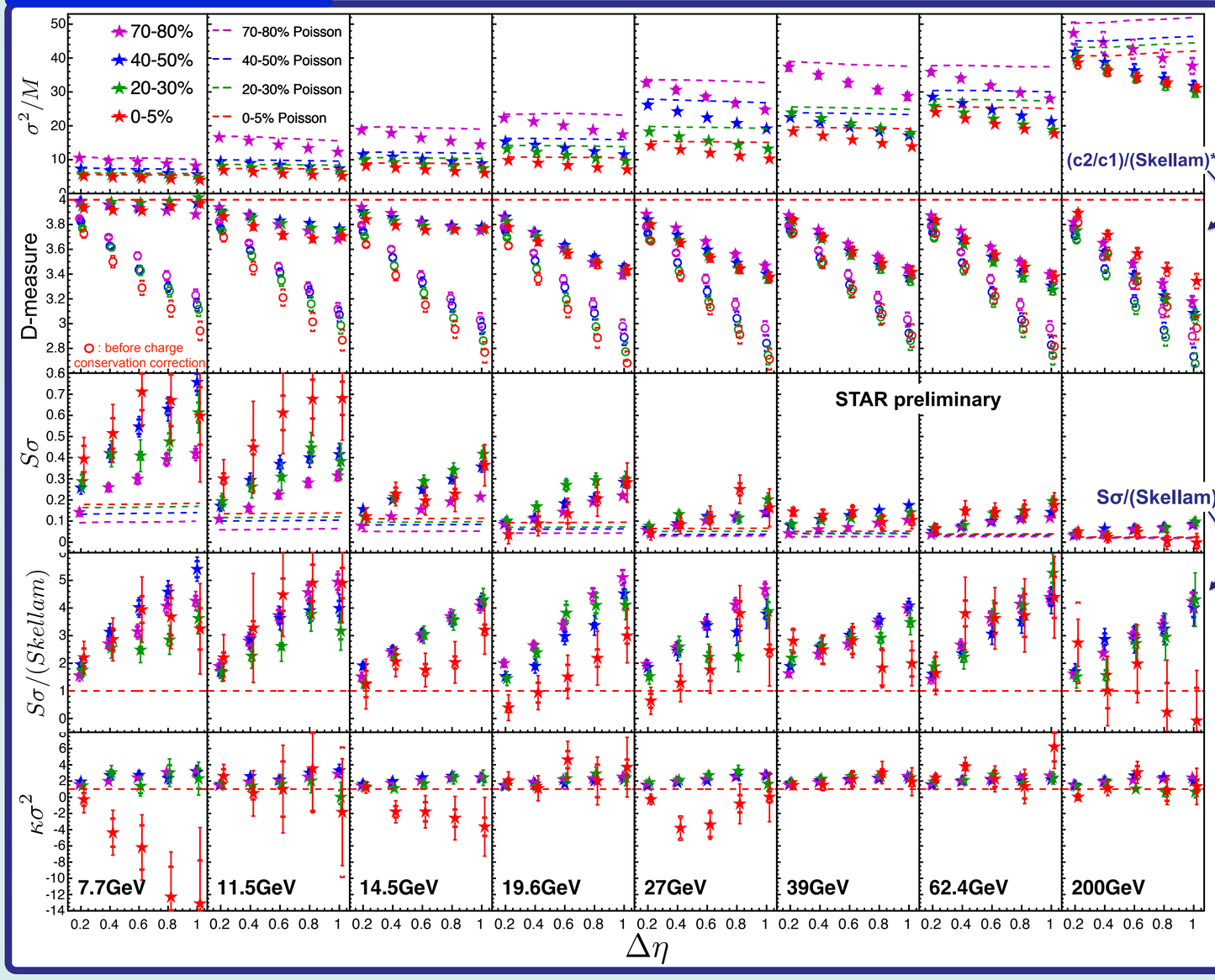
True cumulant

$$\begin{aligned} pK_1 &= c_1 \\ p^2K_2 &= c_2 - n(1-p) \\ &\vdots \end{aligned}$$

Observed cumulant

Efficiency correction has been done for each centrality bin

Results



- **D-measure ($4*c_2/\langle N_{ch} \rangle = 4*(c_2/c_1)/(\text{Skellam})$)**
  - Decrease with Δη for all energies and centralitiy.
  - Approach to baseline after corrections at lower energies, and decrease with beam energies.

→ Consistent with ALICE results

- **σ^2/M (c_2/c_1)**
  - Similar trends were seen to D-measure.
- **$S\sigma$ (c_3/c_2)**
  - Increase with Δη from poisson baseline for all energies.
- **$\kappa\sigma^2$ (c_4/c_2)**
  - Consistent with statistical baseline for all energies.

- **Statistical errors**
  Estimated by Bootstrap (100times)
- **Systematic errors**
  Estimated from uncertainty in the efficiency, dca cut, nFitpoints, and nhitsdedx.

Summary

- Δη dependence of net-charge fluctuations (from 1st to 4th order) is measured in Au+Au collisions at BES energies.
- Results of D-measure are consistent with ALICE results.
- $\kappa\sigma^2$ is consistent with poisson baseline for all energies.

Outlook & Reference

- Compare with simulation results.

[1] M.A.Stephanov, Phys. Rev. Lett. 102, 032301 (2009)
[2] S. Jeon and V. Koch, Phys. Rev. Lett. 85, 2076 (2000)
[3] B. Abelev et al.(ALICE Collaboration), Phys. Rev. Lett 110, 152301 (2013)
[4] L. Adamczyk et al. (STAR Collaboration) Phys. Rev. Lett. 113, 092301 (2014)

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