Measurement of Intermittency for Charged Particles in Au + Au Collisions at $\sqrt{s_{NN}}$ = 7.7 - 200 GeV from STAR

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Abstract

One of the main goals of RHIC beam energy scan program is to search for the signature of the QCD critical point in heavy-ion collisions. It is predicted that the local density fluctuations near critical point exhibit power-law scaling, which can be probed with a intermittency analysis of the scaled factorial moments, $F_q(M)$, for charged particles. The power-law behavior of q^{th}-order scaled factorial moments can be expressed as: $F_q(M) \sim (M^2)^{\phi_q}$, where M^2 is the number of equally sized cell in momentum space, and ϕ_q is the intermittency index. The scaling exponent, ν, is related to the critical component and can be derived from the ratio: ϕ_q/ϕ_2. The energy dependence of could be used to search for the signature of the QCD critical point. Such measurement is actively being pursued by the NA49 and NA61 Collaborations in large and small collisions at $\sqrt{s_{NN}}$ = 17.3 GeV. The BES-I data allow STAR to carry out such measurement over a much broader energy range of $\sqrt{s_{NN}}$ = 7.7 - 200 GeV. In this poster, we present the collision-energy and centrality dependence of ν of charged particles in Au + Au collisions measured by the STAR experiment. We find that scaling exponent, ν, decreases as decreasing collision energy and seem to reach a minimum around $\sqrt{s_{NN}}$ = 20 - 30 GeV in 0-5% most central collisions, and it decreases from semi-peripheral to central Au + Au collisions.

Introduction

It is predicted that the local density fluctuations near critical point exhibit power-law scaling, which can be probed with a intermittency analysis of the scaled factorial moments $F_q(M)$[1,2]

$$F_q(M) = \frac{\langle \frac{1}{M^D}\sum_{i=1}^{M^D} n_i(n_i-1)\dots(n_i-q+1)\rangle}{\langle \frac{1}{M^D}\sum_{i=1}^{M^D} n_i\rangle^q}$$

where q is the order of moments, M^D is the number of equally sized cells in which D dimension-space is partitioned, n_i is the particle multiplicity in the i-th cell

For pure 3D Ising critical system, it's predict[1]:

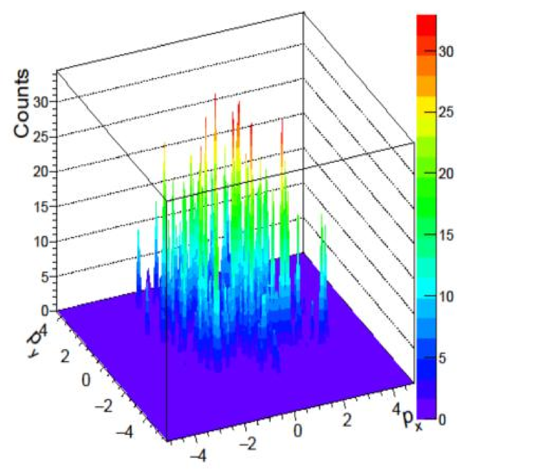
$$F_q(M) \sim (M^2)^{\phi_q} \qquad \phi_q = \frac{5}{6}(q-1)$$

In experiments, even if the $F_q(M)/M$ scaling behaviors is not strictly obeyed, it is possible that[3]:

$$F_q(M) \propto F_2(M)^{\beta_q} \qquad \beta_q = \phi_q/\phi_2$$

The scaling exponent, ν, quantitatively describes all the intermittency indices:

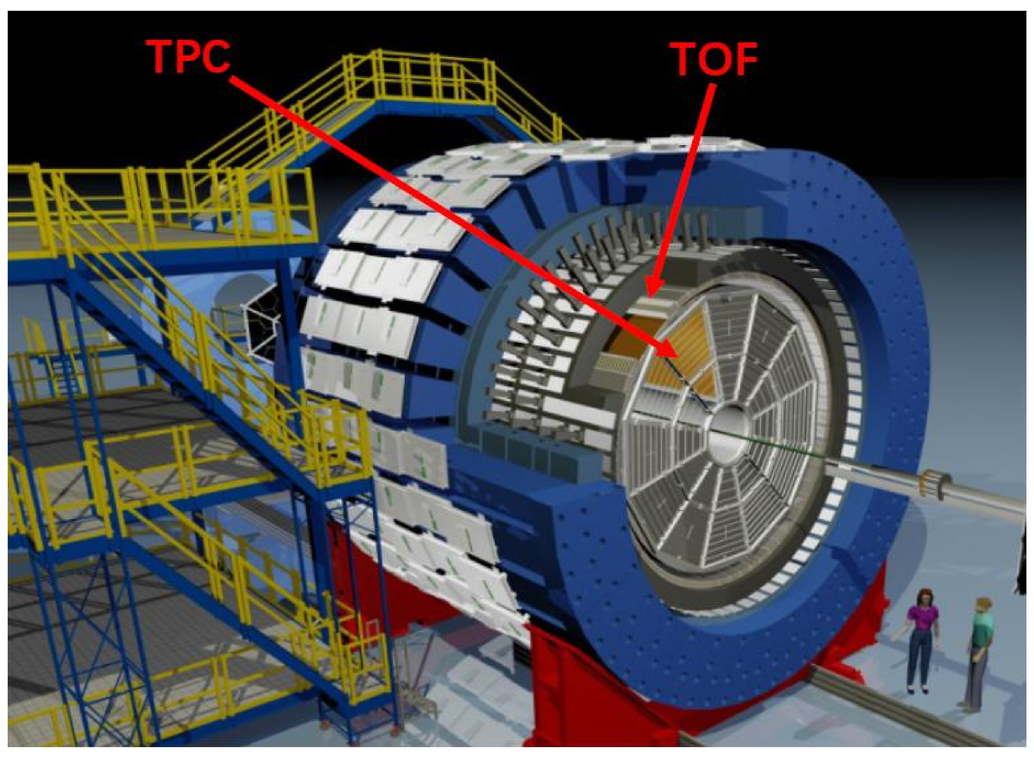
$$\beta_q = (q-1)^{\nu}$$

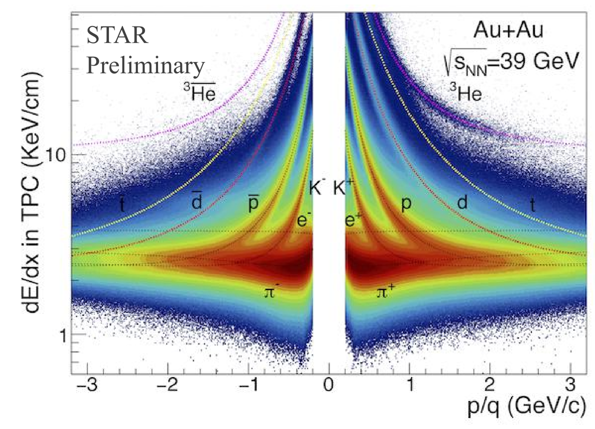


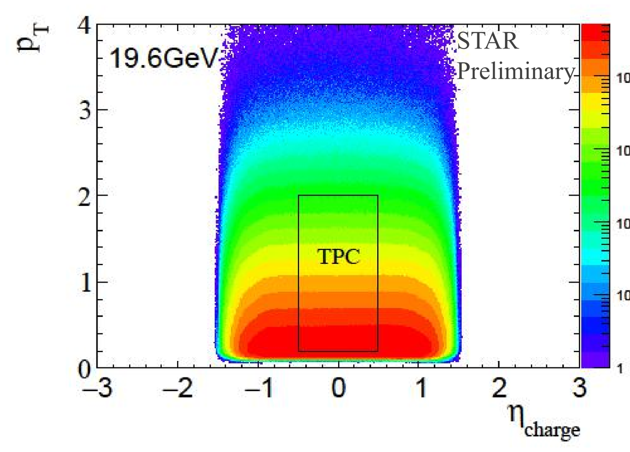
Local strong density fluctuations in transverse momentum space by 3D Ising-Critical model[2].

ν specifies the properties of scaling and characterizes in the collision system[3]. The energy dependence of ν could be used to search for the signature of the critical point.

STAR Detector and Particle Identification

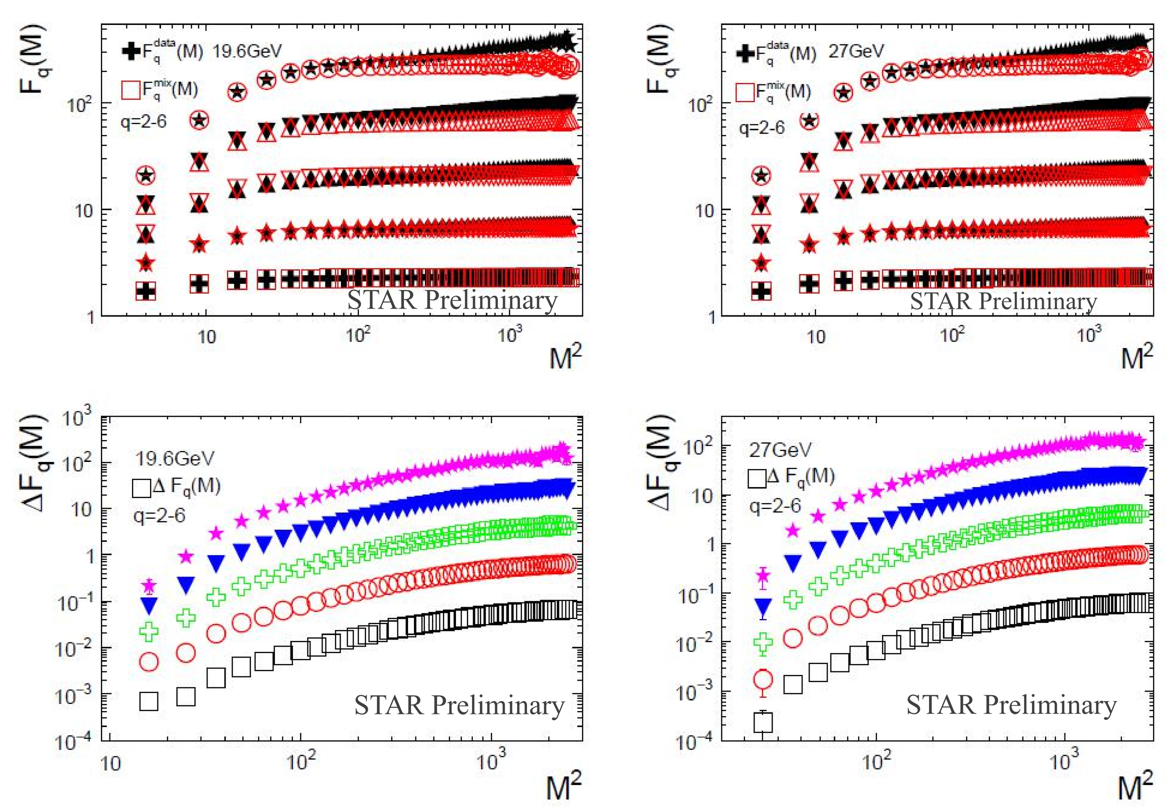






- Excellent Particle Identification
- Large, Uniform Acceptance at Midrapidity

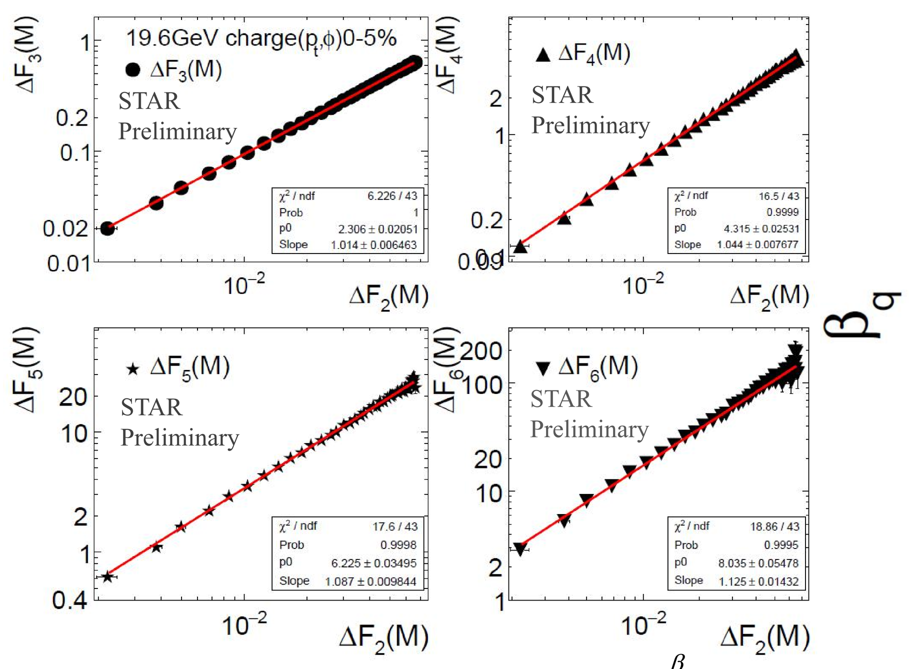
$F_q(M)/M$ Scaling in 0-5% Most Central Collisions



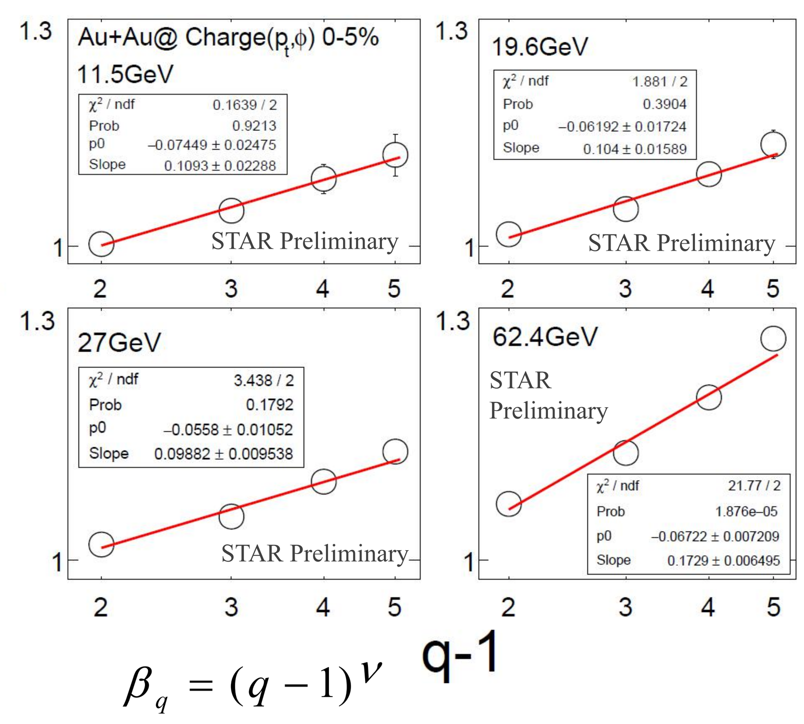
$$\Delta F_q(M) = F_q^{data}(M) - F_q^{mix}(M)$$
$$q = 2\text{-}6$$

- Mixed events method are used to subtract background.
- $F_q(M)$ values rise with increasing M^2, but can not fit a strict scaling behavior in the whole M^2 range in 0-5% central Au + Au collisions at $\sqrt{s_{NN}}$ = 7.7 – 200 GeV.

$F_q(M)/F_2(M)$ Scaling in 0-5% Most Central Collisions



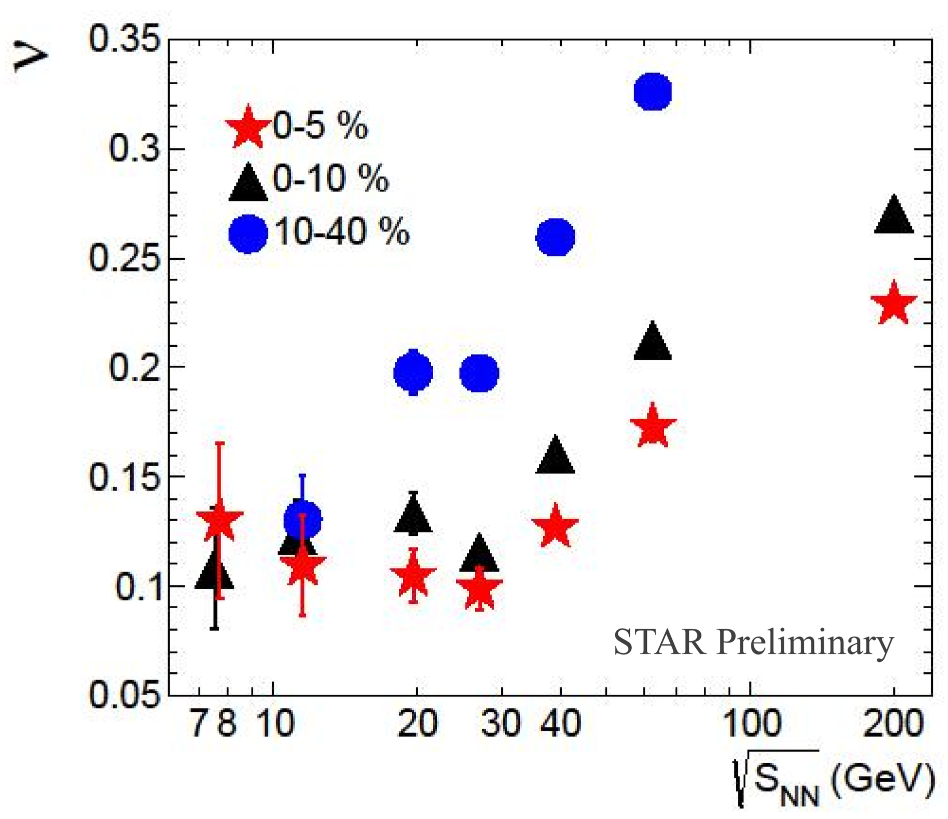
$$\Delta F_q(M) \propto \Delta F_2(M)^{\beta_q}$$



$$\beta_q = (q-1)^{\nu}$$

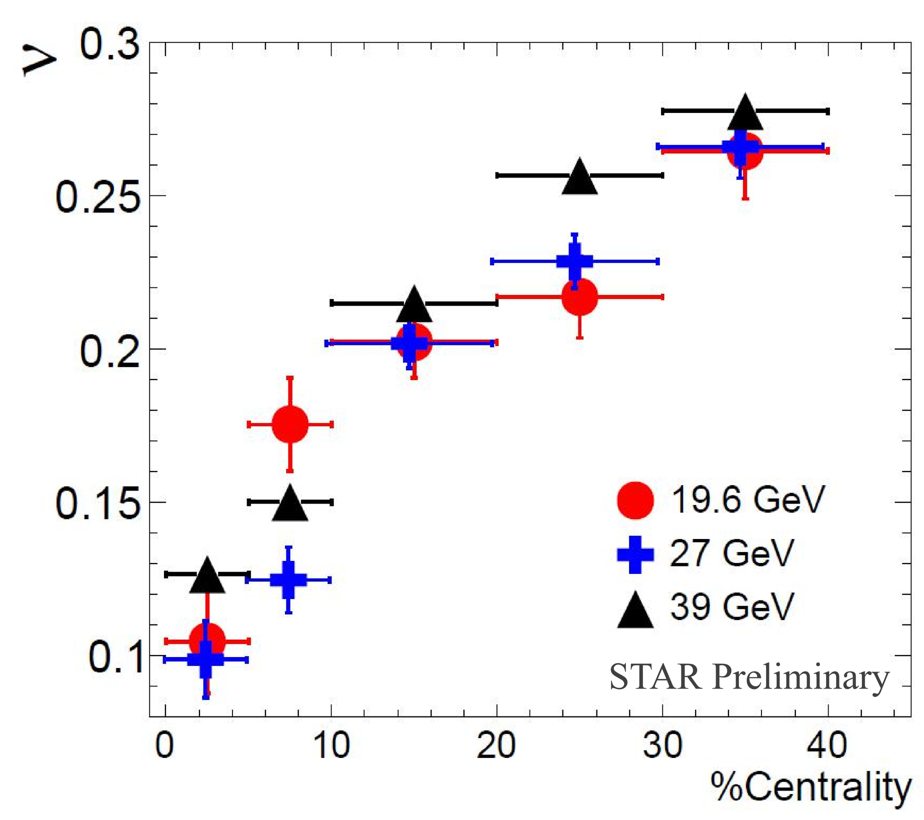
$F_q(M)/F_2(M)$ scaling behaviors are found in central Au + Au collisions at $\sqrt{s_{NN}}$ = 7.7 - 200 GeV with $\beta_6 > \beta_5 > \beta_4 > \beta_3$

Energy Dependence of ν in Au + Au Collisions



Scaling exponent, ν, decreases with decreasing collision energy and seems to reach a minimum around $\sqrt{s_{NN}}$ = 20 - 30 GeV, indicating a change in the equation of state. However, ν decreases with decreasing collision energy in 10-40% central Au + Au collisions at $\sqrt{s_{NN}}$ = 11.5 – 62.4 GeV.

Centrality Dependence of ν in Au + Au collisions



Scaling exponent, ν, decreases from semi-peripheral to central Au + Au collisions at $\sqrt{s_{NN}}$ = 7.7 - 200 GeV.

Moreover, influence of detection efficiency on ν is found to be small. This is because both the definition of the scaled factorial moment and the subtraction of mixed events can cancel the efficiency effect.

Summary:

- We report the intermittency of charged particles in Au + Au collisions at RHIC/STAR BES-I energies.
- $F_q(M)/M$ scaling is not valid in the whole space, however, $F_q(M)/F_2(M)$ scaling is found to be valid at all energies. Scaling behaviors are observed in central Au + Au collisions at BES-I energies.
- Scaling exponent, ν, decreases from semi-peripheral to central Au + Au collisions at $\sqrt{s_{NN}}$ = 7.7 - 200 GeV.
- Scaling exponent, ν, decreases with decreasing collision energy and seem to reach a minimum around $\sqrt{s_{NN}}$ = 20 - 30 GeV, indicating a change in the equation of state, however ν decreases with decreasing collision energy in 10-40% central Au + Au collisions at $\sqrt{s_{NN}}$ = 11.5 – 62.4 GeV.

References

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[2] N. G. Antoniou, PRL 97, 032002(2006).
[3] Rudolph C. Hua and M. T. Nazirov, PRL, Volume 69, Number 5(1992); Rudolph C. Hua and C. B. Yang, PRC 85, 044914(2012).

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The STAR Collaboration
drupal.star.bnl.gov/STAR/presentations

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