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]

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

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]:

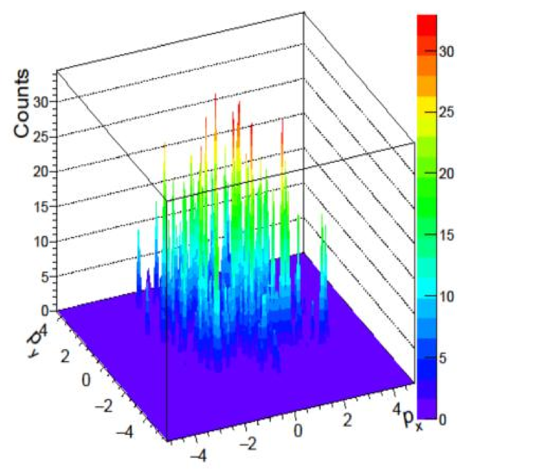
$$F_q(M) \sim (M^2)^{\phi_q} \qquad \phi_q = \frac{5}{6}(q-1)$$

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:

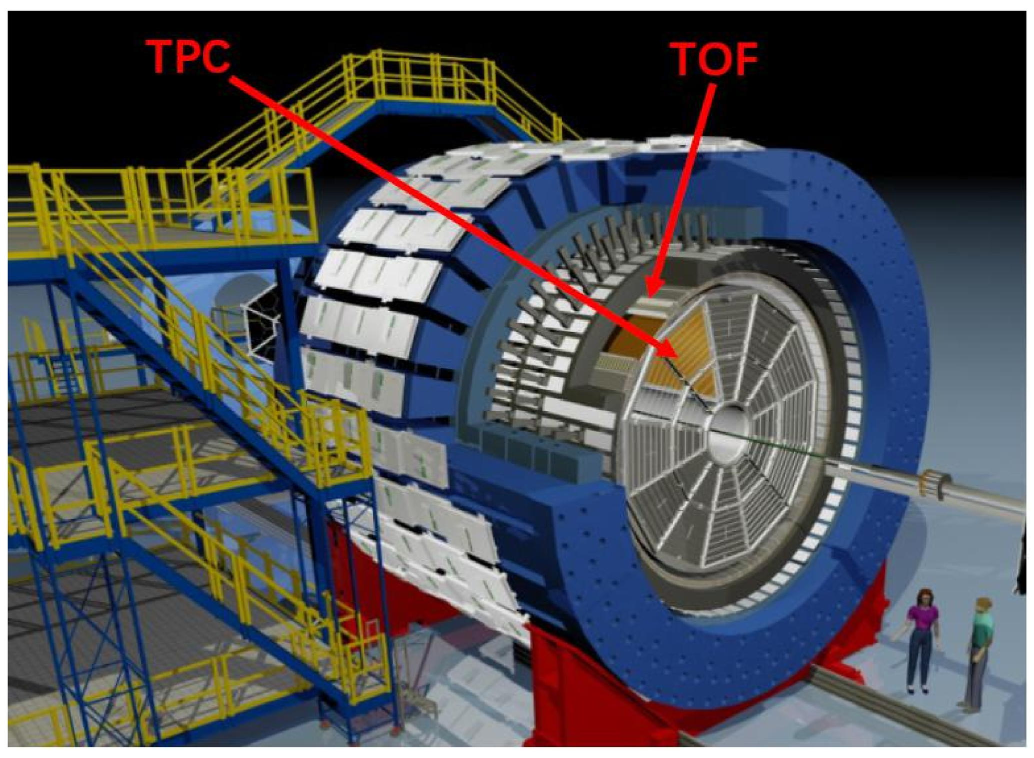
$$\beta_q = (q-1)^{\nu}$$

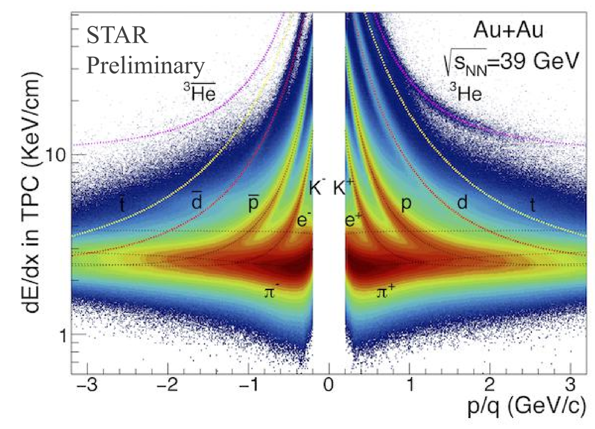


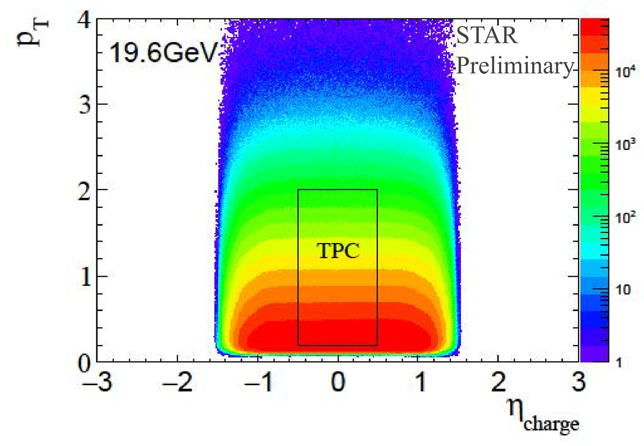
Local strong density fluctuations in transverse momentum space by 3D Ising-Critical model[2].

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

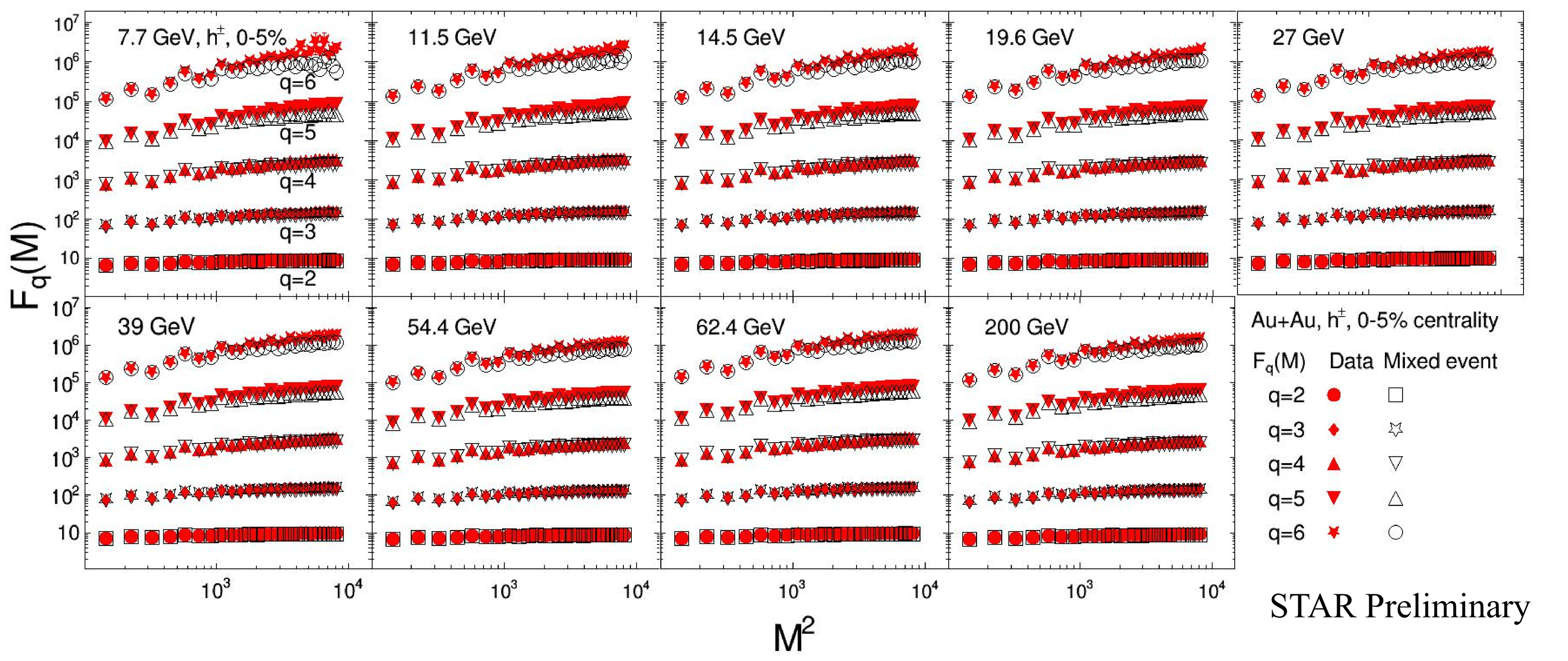






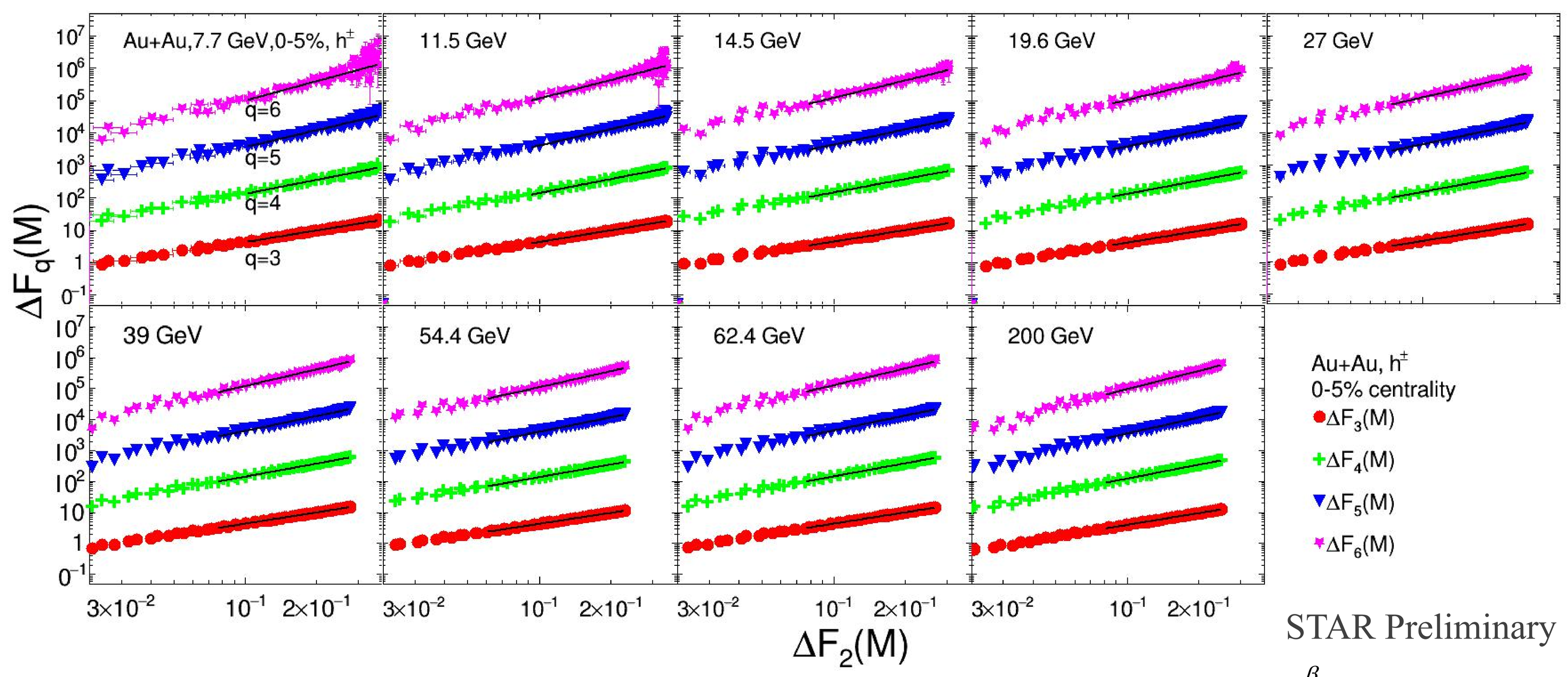
- Excellent Particle Identification
- Large, Uniform Acceptance at Midrapidity

$F_q(M)$ (up to sixth order) in Central Au + Au Collisions



- The calculations of $F_q(M)$ were performed in the $M^2 \in [1^2, 100^2]$ and up to sixth order ($q = 2\sim6$).
- $F_q^{data}(M)$ are larger than $F_q^{mix}(M)$ at large M^2 region. $\Delta F_q(M) = F_q^{data}(M) - F_q^{mix}(M)$

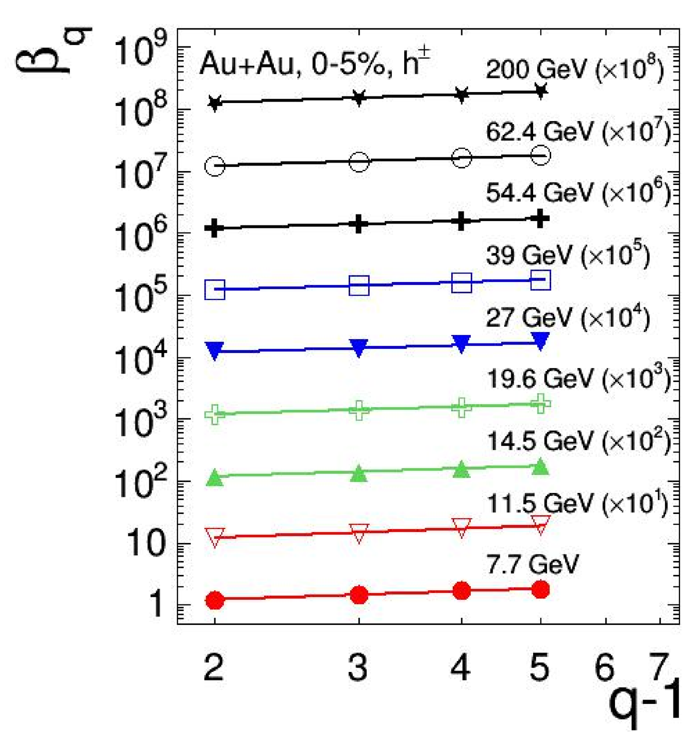
$\Delta F_q(M)$ / $\Delta F_2(M)$ Scaling in Central Au + Au Collisions

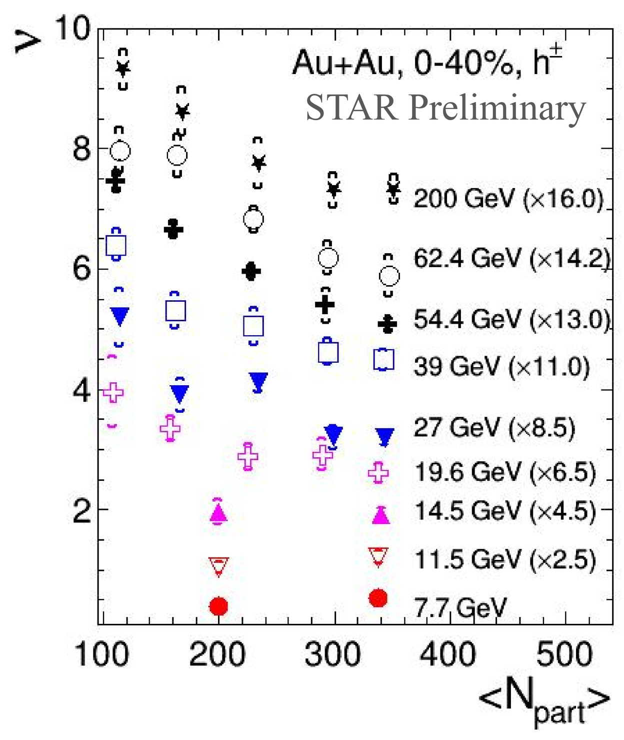


$$\Delta F_q(M) \propto \Delta F_2(M)^{\beta_q}$$

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

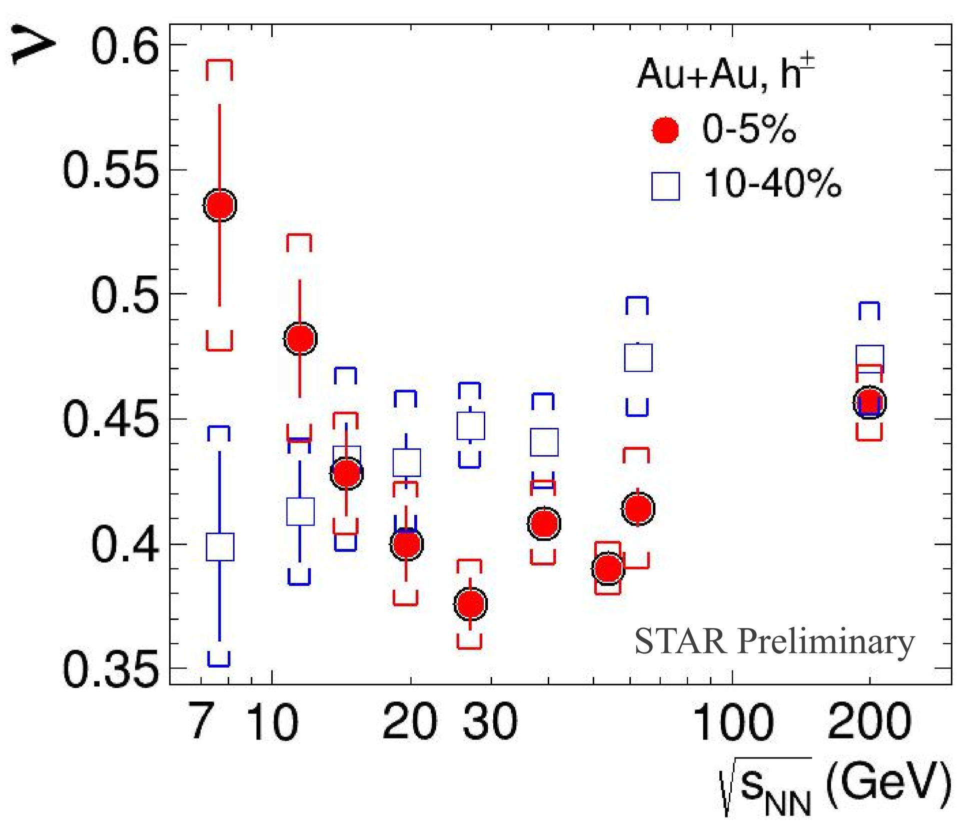
β_q/q Scaling and Centrality Dependence of ν





- Clear β_q/q scaling behaviors are visible in central Au + Au collisions at $\sqrt{s_{NN}}$ = 7.7-200 GeV.
- Scaling exponent, ν, decreases from mid-central (30-40%) to the most central (0-5%) Au + Au collisions.

Energy Dependence of ν in Au + Au collisions



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

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

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

- Scaling exponent exhibits a non-monotonic behavior on collision energy and seems to reach a minimum around $\sqrt{s_{NN}}$ = 20-30 GeV in the most central collisions.
- In 10-40% central collisions, ν monotonically increases with increasing collision energy at $\sqrt{s_{NN}}$ = 7.7 – 200 GeV.

Summary:

- We report the first measurement of intermittency for charged particles in Au + Au collisions at $\sqrt{s_{NN}}$ = 7.7 - 200 GeV measured by STAR experiment in the first phase of RHIC beam energy scan.
- A clear $\Delta F_q(M)/\Delta F_2(M)$ scaling (power-law) behavior is visible in central Au + Au collisions at $\sqrt{s_{NN}}$ = 7.7 - 200 GeV. β_q can be extracted from $\Delta F_q(M)/\Delta F_2(M)$ scaling.
- In 10-40% central collisions, scaling exponent, ν, monotonically increases with increasing collision energy. More importantly, ν exhibits a non-monotonic energy dependence with a minimum around $\sqrt{s_{NN}}$ = 20-30 GeV in the most central Au + Au (0-5%) collisions.

References

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[3] R. C. Hwa, M. T. Nazirov, Phys. Rev. Lett. 69, 741 (1992); R. C. Hwa, C. B. Yang, Phy. Rev. C 85, 044914 (2012).

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