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 (BES) program is to search for the signatures of the QCD critical point in heavy-ion collisions. Local density fluctuations near the QCD critical point exhibit strong intermittency which is revealed as the scale (power-law) dependence of scaled factorial moments on phase-space resolution. The scaling exponent can be extracted from the intermittency analysis of scaled factorial moments. The energy dependence of the scaling exponent could be used to search for the signature of the QCD critical point. In this poster, we report the first measurement of intermittency for charged particles in Au + Au collisions from the STAR experiment in the first phase of RHIC BES. Scaled factorial moments (up to the sixth order) for charged particles within $|\eta|$ <0.5 at $\sqrt{s_{NN}}$ = 7.7-200 GeV are presented. We find that 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, also it decreases from mid-central to the most central Au + Au collisions. The physics of observed non-monotonic behavior needs to be understood with more theoretical and model inputs.

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

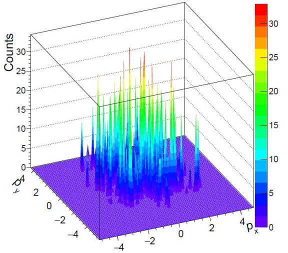
Introduction and Analysis Techniques

- Experimental observation of **local**, **power-law density fluctuations** → Intermittency analysis in transverse momentum space (critical opalescence in ion collisions) by use of scaled factorial moments, $F_q(M)$, defined as:

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

N. G. Antoniou *et al.*, PRL 97, 032002 (2006);
T. Anticic *et al.*, (NA49 Coll.), Eur. Phys. J. C 75, 587 (2015).

where M^D is the number of equal-size cells in which the D-dimensional space is partitioned, q is the order of moments, n_i is the multiplicity in the *i*-th cell, < > denotes averaging over events.



Strong local density fluctuations from the CMC model. J. Wu *et al.*, PLB 801, 135186 (2020).

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

$$F_q(M)\propto F_2(M)^{\beta_q},\ \ \beta_q\propto(q-1)^{\nu}.$$

R. C. Hwa *et al.*, PRL 69, 741 (1992);
R. C. Hwa *et al.*, PRC 85, 044914 (2012).

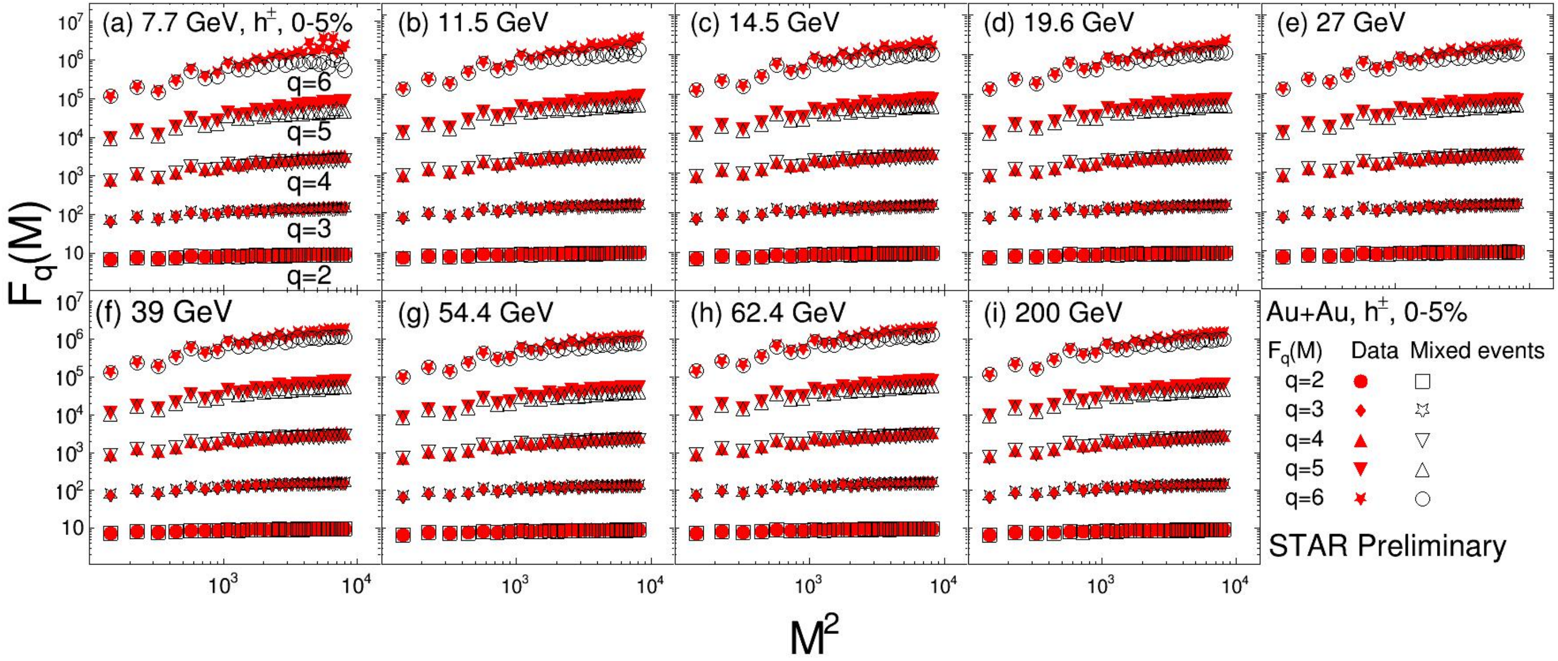
- The energy dependence of ν could be used to search for the signature of the critical point.

- **Analysis Techniques**

- Identified charged particles including $p,\bar{p}$, $K^{\pm}$, $\pi^{\pm}$ within $|\eta|$ <0.5. Kinematic cuts $0.2<p_T<1.6$ (GeV/c) for $K^{\pm}$ and $\pi^{\pm}$, $0.4<p_T<2.0$ GeV/c for p and $\bar{p}$.
- Two dimensional phase space (p_x-p_y) is partitioned into M^2 equal-size cells.
- Centrality determination: charged particles multiplicity ($0.5<|\eta|<1$) excluding particles of interest ($|\eta|<0.5$).
- Mixed event method is used to estimate backgrounds: $\Delta F_q(M)=F_q^{data}(M)-F_q^{mix}(M)$.
- Efficiency correction: cell-by-cell method.
- Statistical error: Bootstrap method.

$F_q(M)$ in Central Au + Au Collisions

$|\eta| < 0.5$, $0.2 < p_T(K^\pm, \pi^\pm) < 1.6$ (GeV/c), $0.4 < p_T(p, \bar{p}) < 2.0$ (GeV/c)



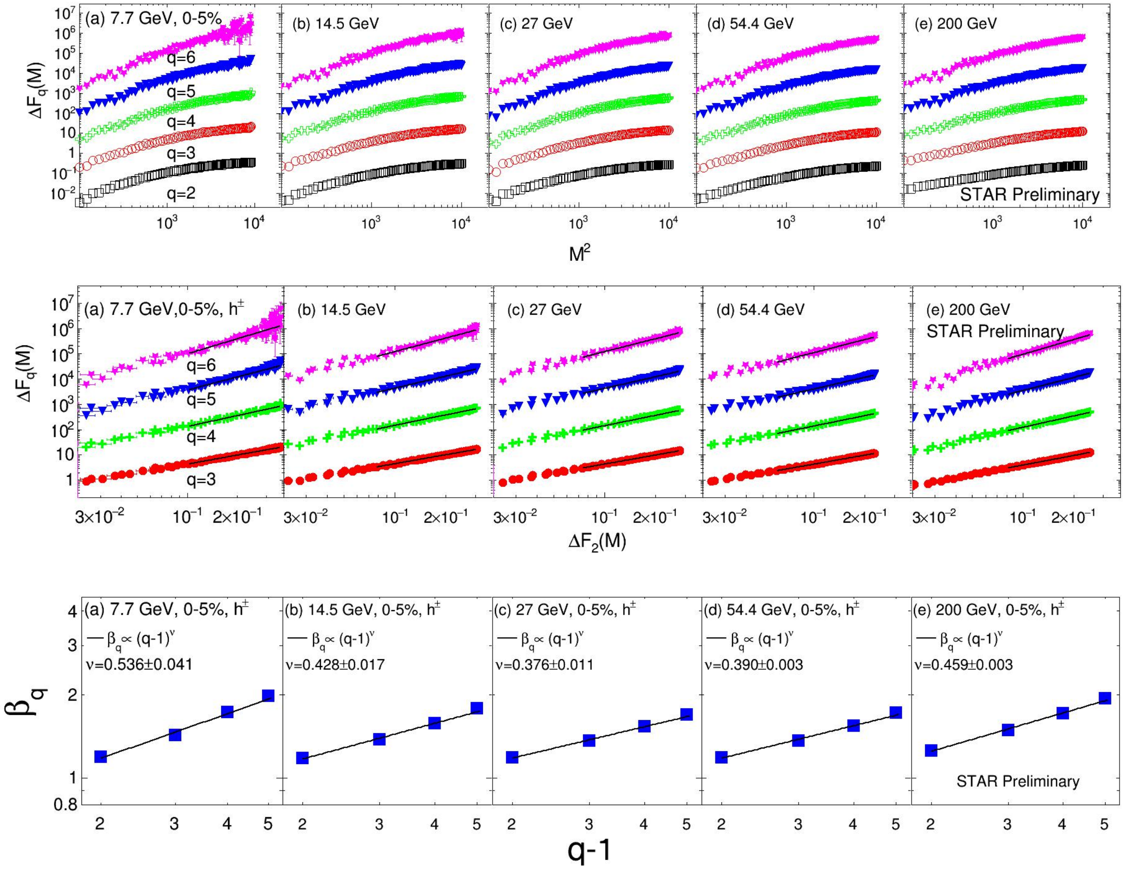
➢ The calculations of $F_q(M)$ were performed in the $M^2 \in [1^2,\ 100^2]$ and up to sixth order ($q = 2 - 6$). Statistical uncertainties are shown but smaller than maker size.

➢ $F_q^{data}(M)$ are larger than $F_q^{mix}(M)$ at large M^2 region.

$$\Delta F_q(M) = F_q^{data}(M) - F_q^{mix}(M)$$

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

$|\eta| < 0.5,\ 0.4 < p_T(p,\bar{p}) < 2.0$ (GeV/c), $0.2 < p_T(K^{\pm},\pi^{\pm}) < 1.6$ (GeV/c)



$$\Delta F_q(M) = F_q^{data}(M) - F_q^{mix}(M)$$

$$\Delta F_q(M) \propto (M^2)^{\phi_q},\ M \to \infty$$

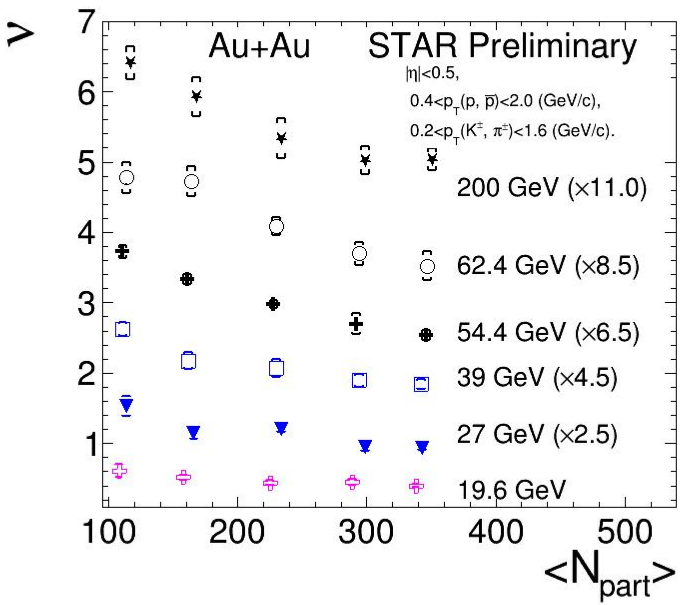
$$\Delta F_q(M) \propto \Delta F_2(M)^{\beta_q},\ M \to \infty$$

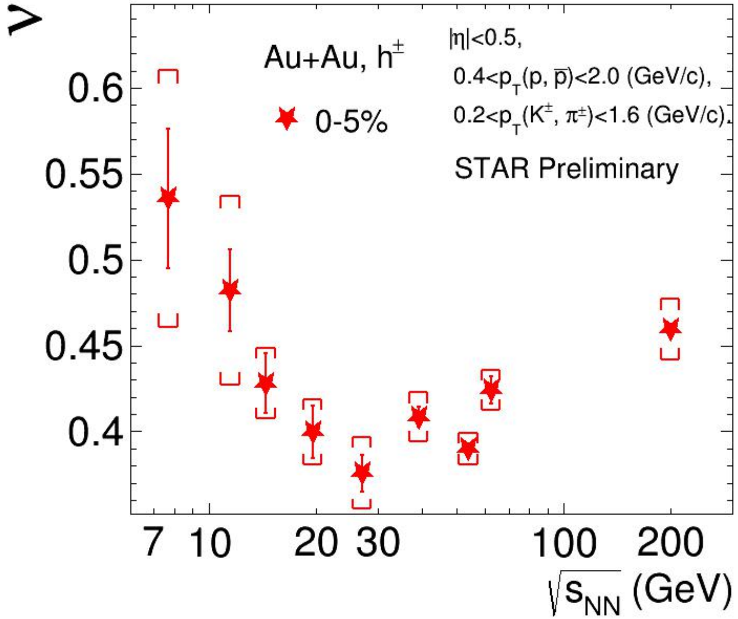
$$\beta_q \propto (q-1)^{\nu}$$

- All orders of $\Delta F_q(M)$ rise with increasing M^2, but can not be fitted well by scaling function of $\Delta F_q(M) \propto (M^2)^{\phi_q}$. Scaling behavior of $\Delta F_q(M) \propto (M^2)^{\phi_q}$ is observed but not strong.
- Clear scaling behaviors of $\Delta F_q(M) \propto \Delta F_2(M)^{\beta_q}$ are visible with $\beta_6 > \beta_5 > \beta_4 > \beta_3$.
- Clear scaling behaviors of $\beta_q \propto (q-1)^{\nu}$ are visible in Au + Au collisions at $\sqrt{s_{NN}}$ = 7.7-200 GeV.

Energy and Centrality Dependence of ν

$$\Delta F_q(M) \propto \Delta F_2(M)^{\beta_q}$$
$$\beta_q \propto (q-1)^{\nu}$$





- Scaling exponent vs. centrality: decreases from mid-central (30-40%) to the most central (0-5%) Au + Au collisions.
- Scaling exponent vs. collision energy: non-monotonic behavior in the most central (0-5%) collisions.
- Model studies and theory inputs are need to understand the baseline, and the observed energy and centrality dependence.