Measurement of Sixth Cumulant of the Net-Proton Multiplicity Distributions in Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV at the STAR Experiment

Toshihiro Nonaka, for the STAR Collaboration
University of Tsukuba, CiRfSE

Quark Matter 2017

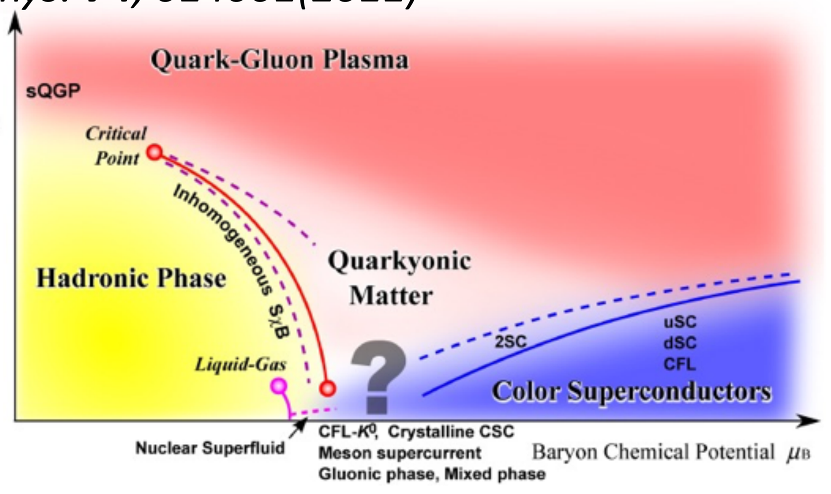
Lattice QCD calculation predicts the phase transition at small μ_B is the smooth crossover. Experimentally, however, there is still no direct evidence for the phase transition. The sixth order cumulant (C_6) is predicted to probe the phase transition, that will be negative at the phase transition. In this poster, the sixth order cumulant (C_6) of net-proton multiplicity distribution has been measured at the extended p_T region ($0.4 < p_T < 2.0$ GeV/c) with efficiency correction in Au+Au collisions in $\sqrt{s_{NN}}$ = 200 GeV. Centrality, p_T and rapidity dependence of C_6/C_2 are presented.

Motivation

Smooth crossover at small μ_B predicted by Lattice QCD

Experimentally no evidence for the phase transition

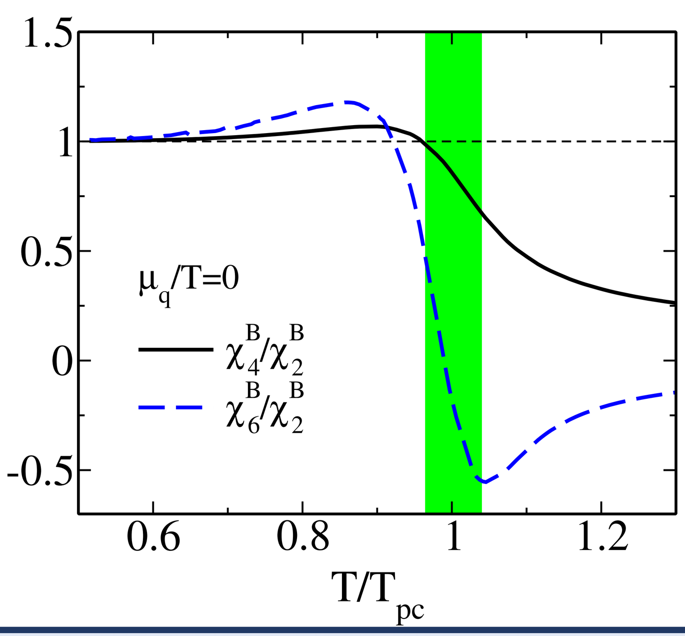
K. Fukushima and T. Hatsuda, Rept. Prog. Phys. ***74****, 014001(2011)*



$C_6 < 0$ (net-baryon or net-charge) predicted at the phase transition

$$\frac{C_6}{C_2} = \frac{\chi_6}{\chi_2}$$ → Cumulant ratio directly connected to the susceptibility

Friman et al, Eur. Phys. J. C (2011) 71:1694



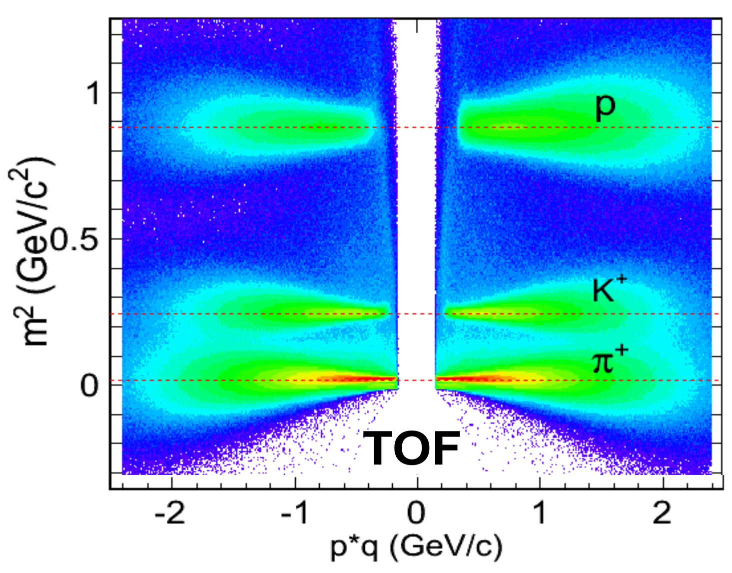
C_6/C_2 of net-proton distribution is measured at $\sqrt{s_{NN}}$ = 200 GeV with STAR detector to find the evidence of the phase transition

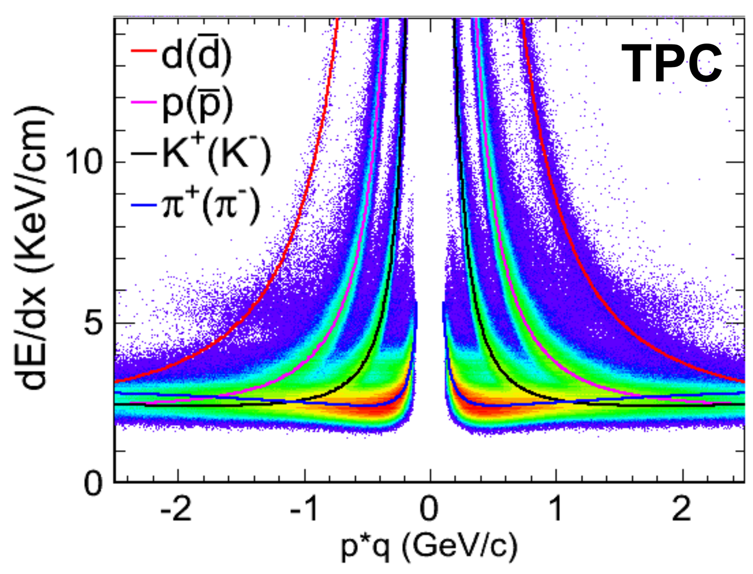
Analysis techniques

X. Luo and N. Xu, arXiv: 1701.02105

Proton identification

- Large and uniform acceptance with full azimuthal angles with $|\eta|<1.0$
- At low p_T region ($0.4 < p_T < 0.8$ GeV/c) dE/dx measured by TPC is used.
- At high p_T region ($0.8 < p_T < 2.0$ GeV/c) combined PID with TOF is implemented.





Centrality determination

- Use charged particles except protons in order to avoid the auto-correlation.

Centrality bin width correction

- Calculate cumulants at each multiplicity bin and average them in one centrality, which leads to the supression of the volume fluctuation.

Statistical errors : Bootstrap

- Make a new distribution by random sampling from the original net-proton distribution and calculate cumulants.
- This procedure is repeated with 300 times, and the statistical errors are taken from the RMS of the cumulants.

Summary

- We present high statistics results of centrality, p_T and rapidity dependence of C_6/C_2 of net-proton multiplicity distributions from $\sqrt{s_{NN}}$ = 200 GeV in Au+Au collisions.
- Results are consistent with zero within 2σ with current statistics.

Efficiency correction

- Calculation cost for efficiency correction become large by power of efficiency bins with formulas based on the factorial moments (Bzdak and Koch, 2016), which is crucial for the sixth order cumulant.
- Nonaka, Kitazawa and Esumi developed a new efficiency correction. Calculation cost increases linearly with the number of efficiency bins.
- In addition to the p_T dependence, acceptance non-uniformity in phi direction are corrected.

M : # of efficiency bins
n : # of particles
p : efficiency
a : electric charge

$$q_{(r,s)} \equiv \sum_{i=1}^{M} \frac{a_i^r}{p_i^s} n_i.$$

→ Nonaka, Kitazawa and Esumi : in preparation

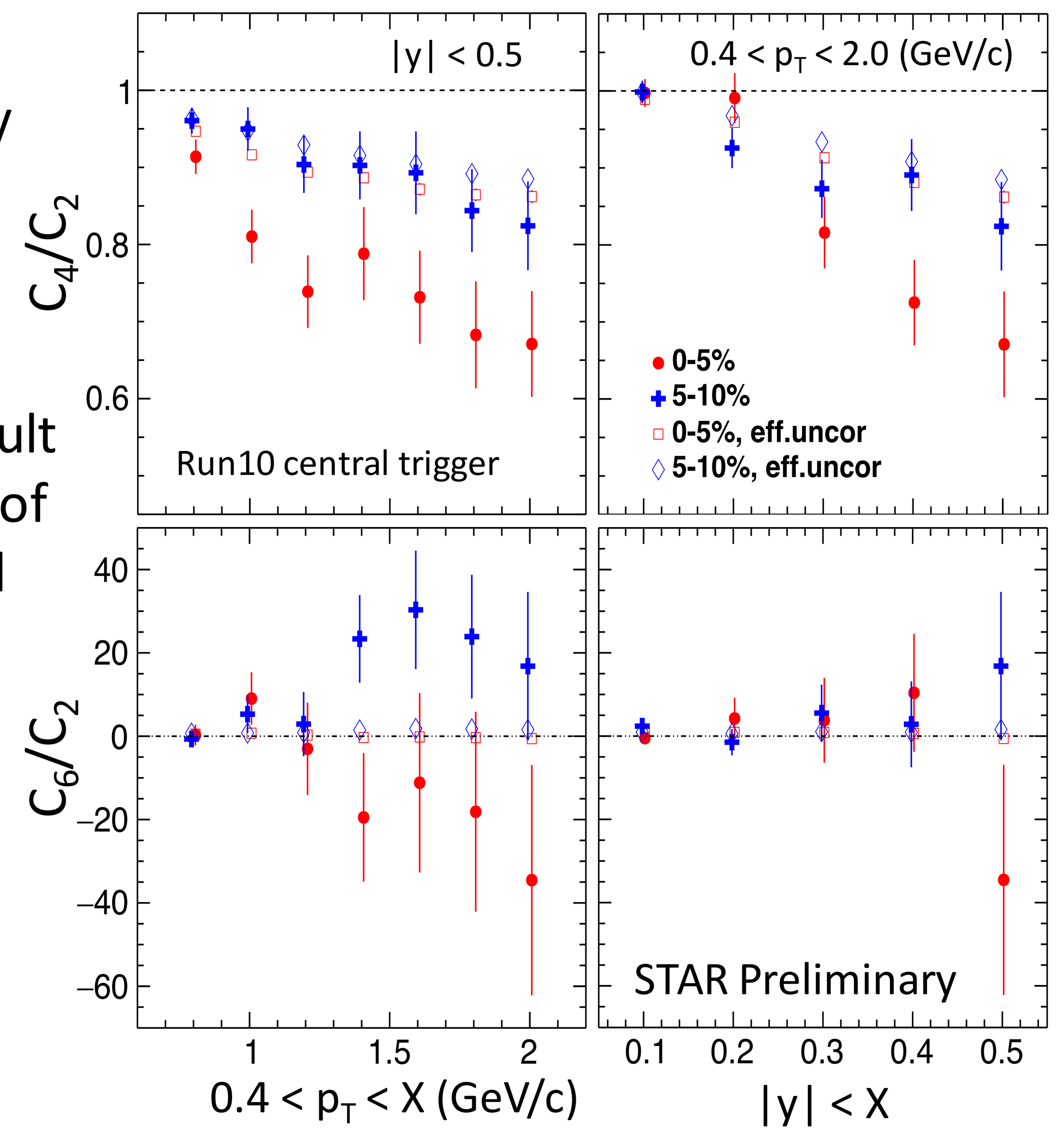
$$\begin{aligned}
\langle Q^6\rangle_c = {} & \langle q_{(1,1)}^6\rangle_c - 15\langle q_{(1,1)}^4 q_{(2,2)}\rangle_c + 15\langle q_{(1,1)}^4 q_{(2,1)}\rangle_c - 90\langle q_{(1,1)}^2 q_{(2,2)} q_{(2,1)}\rangle_c \\
& +40\langle q_{(1,1)}^3 q_{(3,3)}\rangle_c + 45\langle q_{(2,2)}^2 q_{(1,1)}^2\rangle_c + 20\langle q_{(1,1)}^3 q_{(3,1)}\rangle_c - 60\langle q_{(1,1)}^3 q_{(3,2)}\rangle_c \\
& +45\langle q_{(1,1)}^2 q_{(2,1)}^2\rangle_c - 90\langle q_{(1,1)}^2 q_{(4,4)}\rangle_c - 120\langle q_{(3,3)} q_{(2,2)} q_{(1,1)}\rangle_c - 15\langle q_{(2,2)}^3\rangle_c \\
& +15\langle q_{(1,1)}^2 q_{(4,1)}\rangle_c - 60\langle q_{(1,1)} q_{(2,2)} q_{(3,1)}\rangle_c - 60\langle q_{(1,1)}^2 q_{(4,2)}\rangle_c \\
& +120\langle q_{(1,1)} q_{(2,1)} q_{(3,3)}\rangle_c + 180\langle q_{(1,1)}^2 q_{(4,3)}\rangle_c + 45\langle q_{(2,2)}^2 q_{(2,1)}\rangle_c \\
& +180\langle q_{(1,1)} q_{(2,2)} q_{(3,2)}\rangle_c - 45\langle q_{(1,1)}^2 q_{(4,2)}\rangle_c - 45\langle q_{(2,1)}^2 q_{(2,2)}\rangle_c \\
& -180\langle q_{(1,1)} q_{(2,1)} q_{(3,2)}\rangle_c + 60\langle q_{(1,1)} q_{(2,1)} q_{(3,1)}\rangle_c + 15\langle q_{(2,1)}\rangle_c \\
& +144\langle q_{(5,5)} q_{(1,1)}\rangle_c + 90\langle q_{(4,4)} q_{(2,2)}\rangle_c + 40\langle q_{(3,3)}^2\rangle_c + 6\langle q_{(5,1)} q_{(1,1)}\rangle_c \\
& +15\langle q_{(4,1)} q_{(2,1)}\rangle_c + 10\langle q_{(3,1)}^2\rangle_c - 30\langle q_{(5,2)} q_{(1,1)}\rangle_c - 15\langle q_{(4,1)} q_{(2,2)}\rangle_c \\
& +300\langle q_{(5,3)} q_{(1,1)}\rangle_c + 40\langle q_{(3,3)} q_{(3,1)}\rangle_c + 60\langle q_{(4,2)} q_{(2,2)}\rangle_c - 360\langle q_{(5,4)} q_{(1,1)}\rangle_c \\
& -90\langle q_{(4,4)} q_{(2,1)}\rangle_c - 120\langle q_{(3,3)} q_{(3,2)}\rangle_c - 180\langle q_{(4,3)} q_{(2,2)}\rangle_c \\
& +180\langle q_{(4,3)} q_{(2,1)}\rangle_c + 45\langle q_{(4,2)} q_{(2,2)}\rangle_c + 90\langle q_{(3,2)}^2\rangle_c \\
& -60\langle q_{(3,2)} q_{(3,1)}\rangle_c - 60\langle q_{(4,2)} q_{(2,1)}\rangle_c - 60\langle q_{(5,2)} q_{(1,1)}\rangle_c - 45\langle q_{(4,2)} q_{(2,1)}\rangle_c \\
& -120\langle q_{(6,6)}\rangle_c + 360\langle q_{(6,5)}\rangle_c - 390\langle q_{(6,4)}\rangle_c + 180\langle q_{(6,3)}\rangle_c - 31\langle q_{(6,2)}\rangle_c + \langle q_{(6,1)}\rangle_c.
\end{aligned}$$

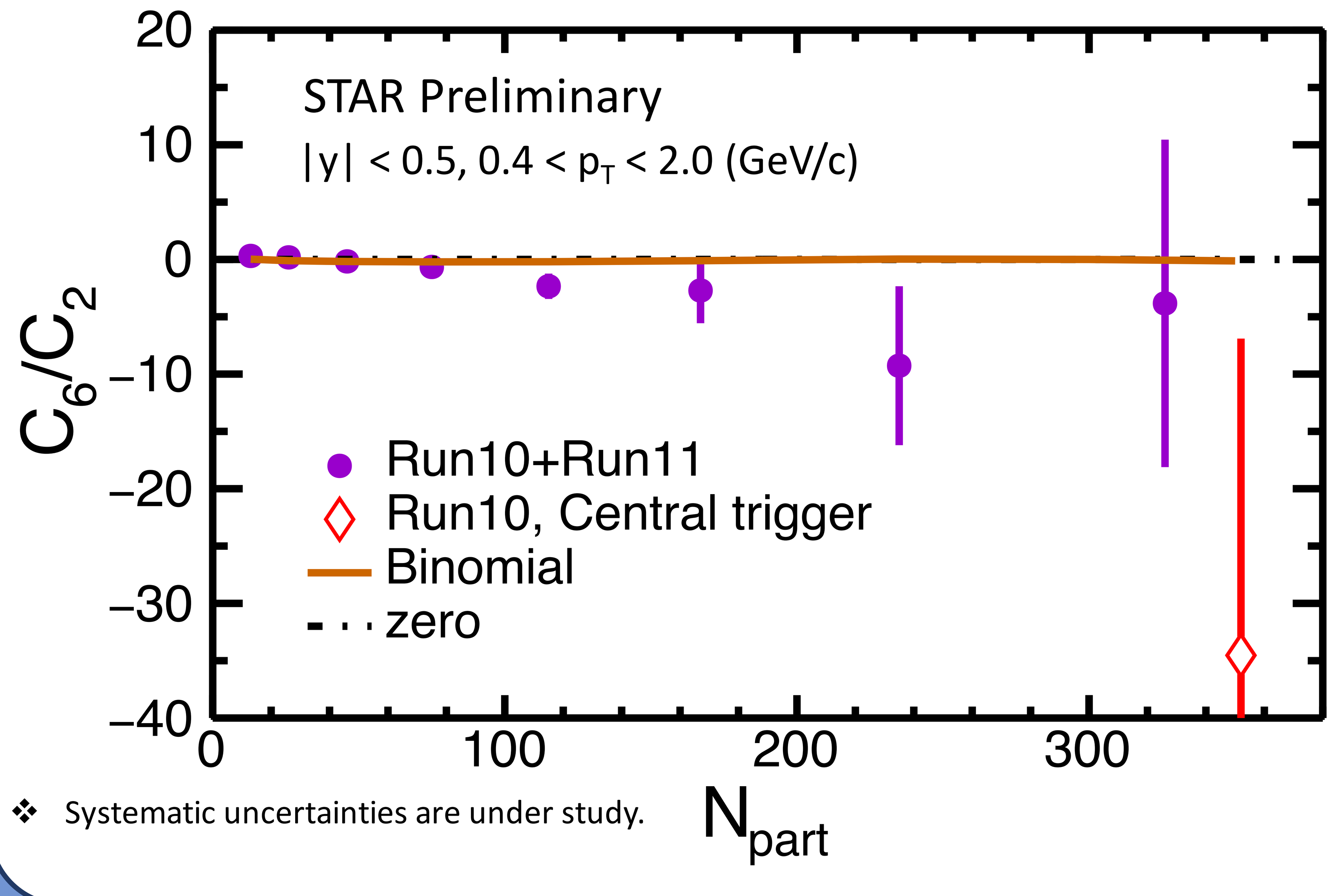
Results

- (Right plot) p_T and rapidity dependence of C_4/C_2 and C_6/C_2 at central collisions.
- (Bottom plot) Merged result of centrality dependence of C_6/C_2 between Run10 and Run11.

✓ Used statistics

	0-10%	10-80%
Run10	~160M	~200M
Run11	~50M	~450M





❖ Systematic uncertainties are under study.

Toshihiro Nonaka
tnonaka@rcf.rhic.bnl.gov

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

CiRfSE
筑波大学
University of Tsukuba