Measurement of Sixth-Order Cumulant of the Net-Proton Multiplicity Distributions in Au+Au Collisions at $\sqrt{s_{NN}}$ = 54.4 and 200 GeV at the STAR Experiment

Toshihiro Nonaka, for the STAR Collaboration

Central China Normal University

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. It is predicted by Polyakov loop extended (PQM) model that the sixth-order cumulant ratio (C_6/C_2) of net-baryon distribution becomes negative if freeze-out is close to the crossover phase transition. In this poster, acceptance and centrality dependence of C_6/C_2 of net-proton multiplicity distributions are presented for Au+Au collisions at $\sqrt{s_{NN}}$ = 54.4 and 200 GeV. Those results are compared with the hadron transport model and lattice QCD calculations.

Motivation

Smooth crossover at small μ_B predicted by Lattice QCD

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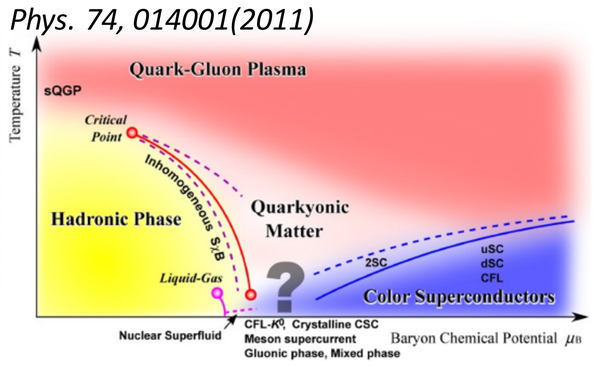
No direct experimental evidence for the crossover phase transition

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



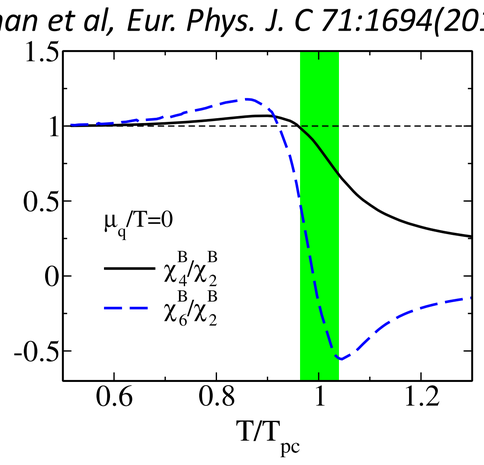
$C_6 < 0$ (net-baryon or net-charge) predicted at the crossover

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

⇓

C_6/C_2 of net-proton distribution is measured at $\sqrt{s_{NN}}$ = 54.4 and 200 GeV (550 and 900 M events) in the STAR experiment to find the evidence of the crossover phase transition

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



Results at 200 GeV are compared with LQCD baryon number susceptibility ratio, χ^6_B/χ^2_B, at T = 160 MeV μ_B = 0 MeV.
Two caveats should be kept in mind :

- μ_B~20 MeV at 200 GeV.
- Acceptance is not considered in LQCD calculations.

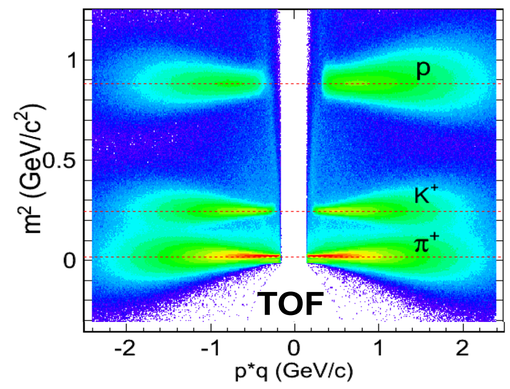
A. Bazavov et al, Phys. Rev. D 054504(2017)
S. Borsanyi, et al, JHEP 1810 205 054504(2018)

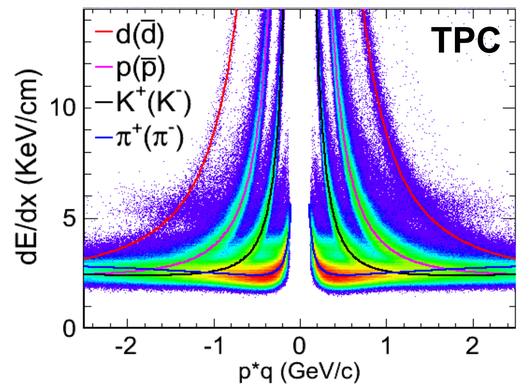
Analysis techniques

X. Luo and N. Xu : Nucl. Sci. Tech. 28, 112 (2017)

❑ Proton identification

- Large and uniform acceptance with full azimuthal coverage (|η|<1.0).
- At low p_T region (0.4 < p_T < 0.8 GeV/c) dE/dx measured in 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 autocorrelation.

❑ Centrality bin width correction

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

❑ Efficiency correction

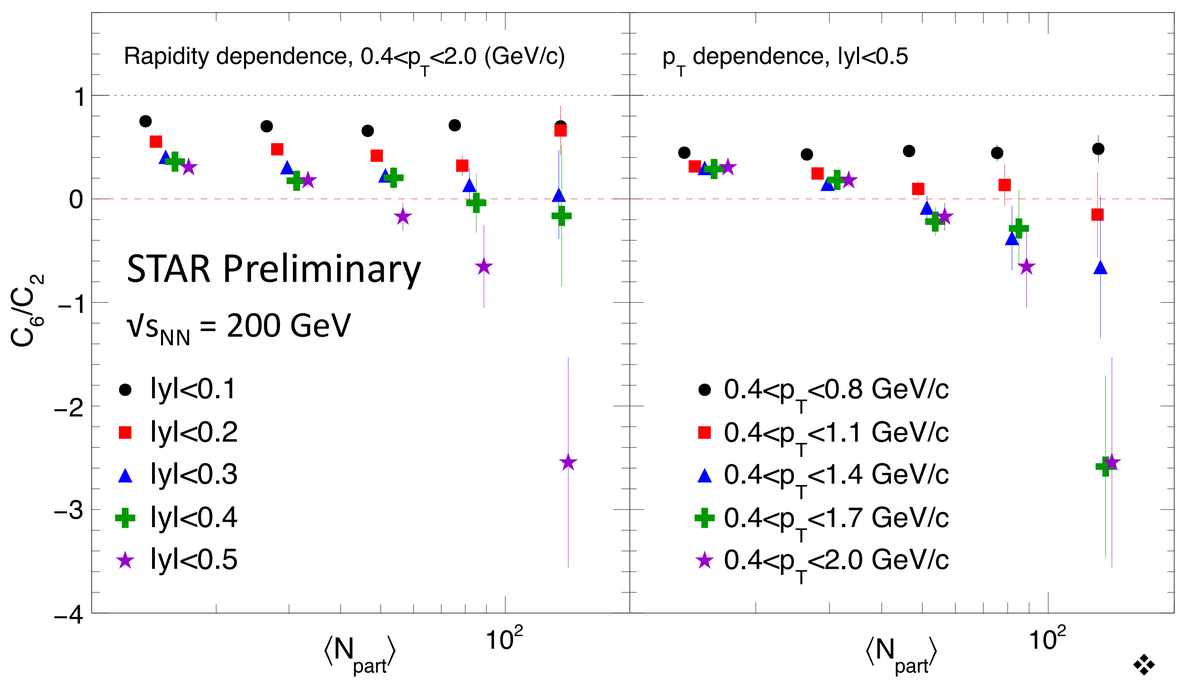
- Formulas applied assuming efficiencies follow binomial distribution.

✓ Efficient formulas : *T. Nonaka et al, Phys. Rev. C. 95.064912*
✓ Track-by-track correction: *X. Luo and T. Nonaka , Phys. Rev. C. 99, 044917 (2019)*

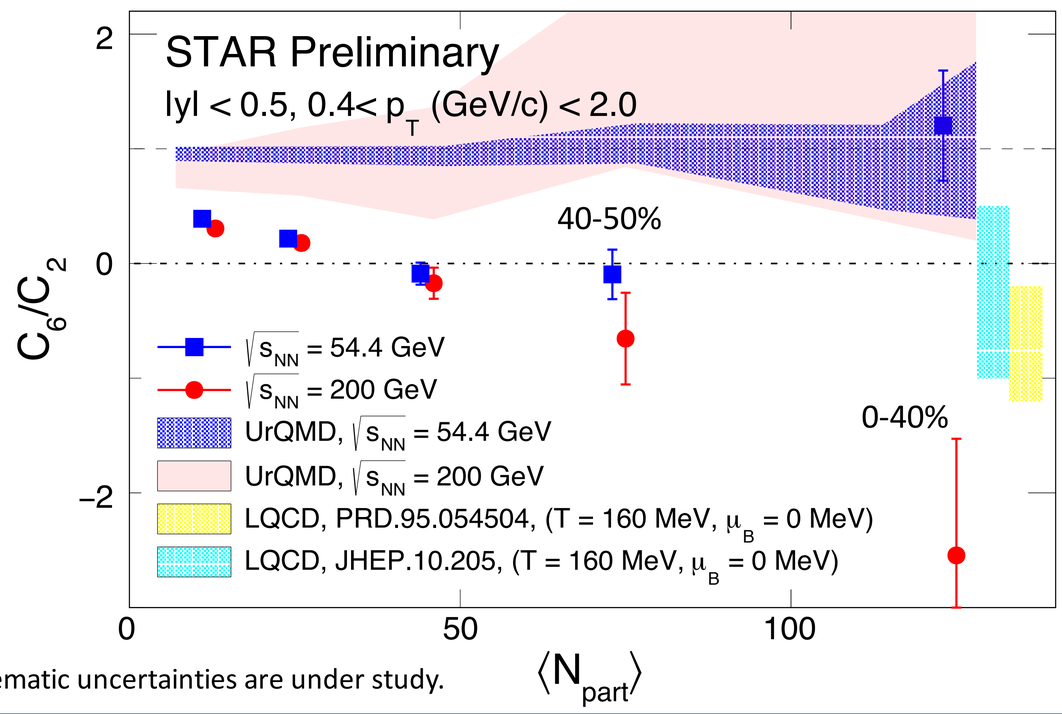
❑ Statistical errors : Bootstrap

Results

- Rapidity and p_T acceptance window dependence of C_6/C_2 at $\sqrt{s_{NN}}$ = 200 GeV for each centrality bin.
- Results show linear decrease with increasing the acceptance.
- The C_6/C_2 becomes negative in central collisions with wide acceptance.



- Centrality dependence of C_6/C_2 at $\sqrt{s_{NN}}$ = 54.4 and 200 GeV.
- The C_6/C_2 values for both the energies are consistent with each other in peripheral collisions, while C_6/C_2>0 at 54.4 GeV and C_6/C_2<0 at 200 GeV in central collisions.
- UrQMD shows C_6/C_2>0 for all centralities.
- Results in 0-40% central collisions at 200 GeV are consistent with LQCD calculations within large uncertainties.



❖ Systematic uncertainties are under study.

Summary

For the first time, we present high statistics results of centrality, p_T and rapidity dependence of C_6/C_2 of net-proton multiplicity distributions from $\sqrt{s_{NN}}$ = 54.4 and 200 GeV in Au+Au collisions. Results show C_6/C_2>0 and <0 at 54.4 and 200 GeV central collisions, respectively.
This is qualitatively consistent with the PQM model prediction while UrQMD shows C_6/C_2>0 for all collision centralities. LQCD calculations are consistent with the data from 0-40% central Au+Au collisions at 200 GeV at RHIC.

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The STAR Collaboration
drupal.star.bnl.gov/STAR/presentations
Toshihiro Nonaka : tnonaka@rcf.rhic.bnl.gov

華中師範大學 CENTRAL CHINA NORMAL UNIVERSITY