



C_7 and C_8 of Net-proton Distributions in Heavy-Ion Collisions at RHIC-STAR



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Outline

1. Motivation
2. Analysis
3. Results

Abstract

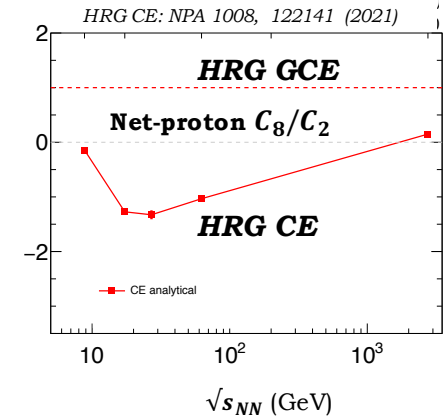
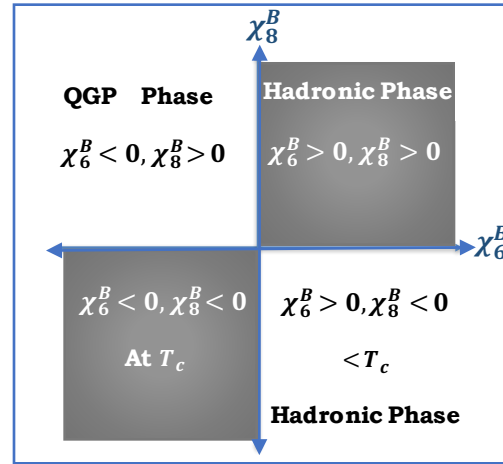
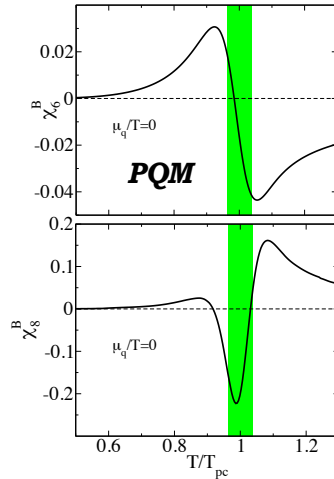
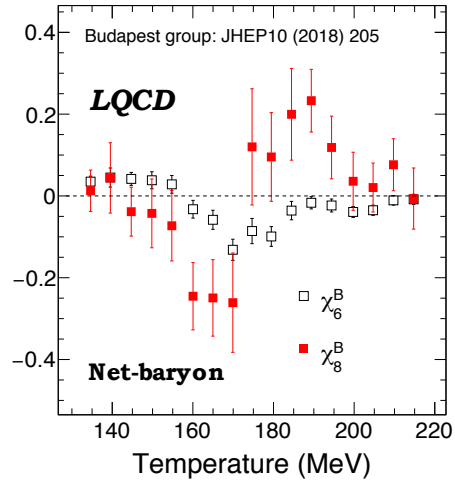
Higher-order cumulants of net-proton distributions are sensitive to the phase structure of the QCD phase diagram. Lattice QCD and QCD-based model calculations indicate that the signs of sixth and eighth order cumulants have different combinations in the hadronic phase, partonic phase, and near the transition temperature.

We report the first measurements of seventh and eighth order cumulants of net-proton distributions in the high statistics Au+Au collisions at $\sqrt{s_{NN}} = 54.4$ and 200 GeV. The measurements are performed at mid-rapidity $|y| < 0.5$ within $0.4 < p_T < 2.0$ GeV/c using the Time Projection Chamber and Time-of-Flight detector. The signs of the measured sixth, seventh, and eighth order cumulants will be contrasted to those expected from the lattice QCD and QCD-based models. The ratios of the measured cumulants will also be compared with those obtained from the thermal models.



Motivation

Goal: Identification of O(4) chiral criticality on the phase boundary.



LQCD: JHEP10 (2018) 205, PRD101, 074502 (2020), PQM: EPJC71, 1694(2011), FRG: PRD104, 094047 (2021)

C_5, C_6, C_7, C_8 (Hyper-order cumulants) < 0 and $|C_8| > |C_6|$, $|C_7| > |C_5|$ from LQCD, FRG, PQM – more sensitive probes for crossover.

More stronger $\sqrt{s_{NN}}$ dependence predicted for C_8 than C_6 .

Sign of C_6 and C_8 together sensitive to hadronic phase, QGP phase and T_c .

Test of thermal model: Non-monotonic $\sqrt{s_{NN}}$ dependence of C_8/C_2 - HRG CE.

Analysis Details

Collision system and energy	Au+Au at $\sqrt{s_{NN}} = 54.4$ and 200 GeV
Collision centrality	70-80%, 60-70%, 50-60%, 40-50%, 0-40%
Centrality selection	Using charged particle multiplicity excluding protons
Charged Particle Selection	Protons and antiprotons to construct net-protons

PID Detector	Transverse Momentum Range(p_T)	Rapidity
TPC	0.4 to 0.8 GeV/c	$ y < 0.5$
TPC+TOF	0.8 to 2.0 GeV/c	$ y < 0.5$

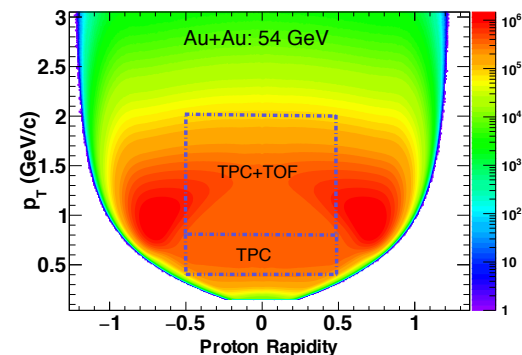
Suppress Volume Fluctuation:
Centrality Bin Width Correction

$$C_n = \sum_r w_r C_{n,r}$$

where $w_r = n_r / \sum_r n_r$, $n=1,2,3,4\dots$
Here, n_r is no. of events in r^{th} multiplicity bin

Finite Detection Efficiency:
Efficiency Correction:
Binomial model for detector response.

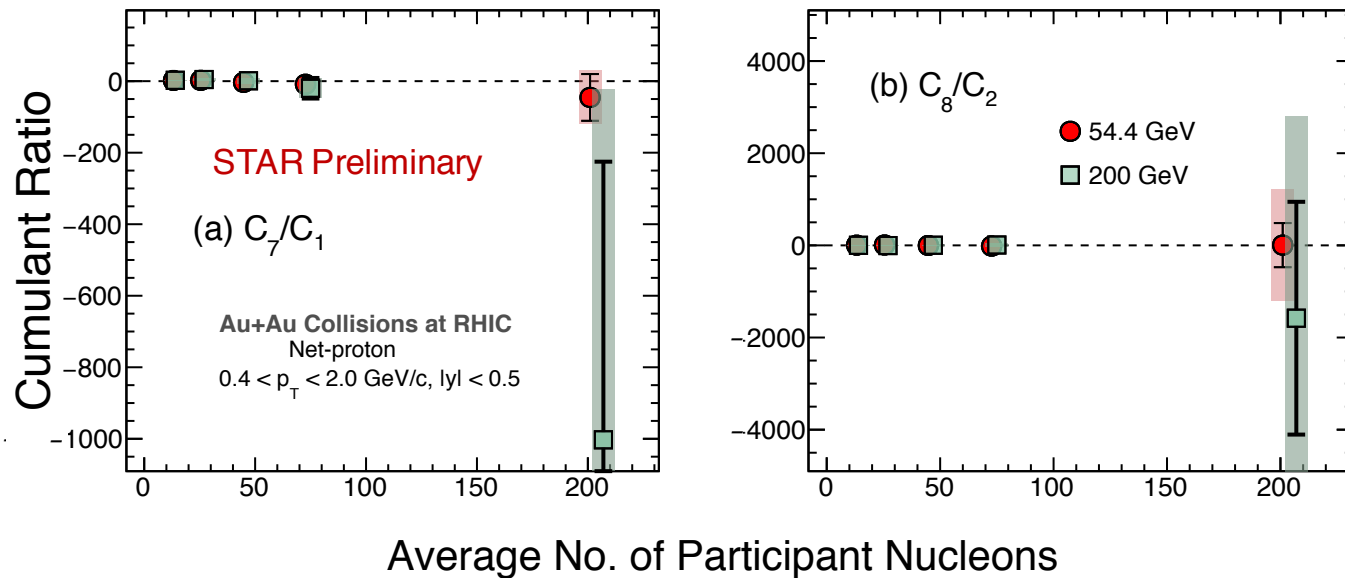
X. Luo et al, J.Phys. G 40, 105104(2013)
T. Nonaka et al, Phys. Rev. C 95, (2017)064912
A.Pandav et al, Nucl. Phys. A 991, (2019)121608



Uncertainties:

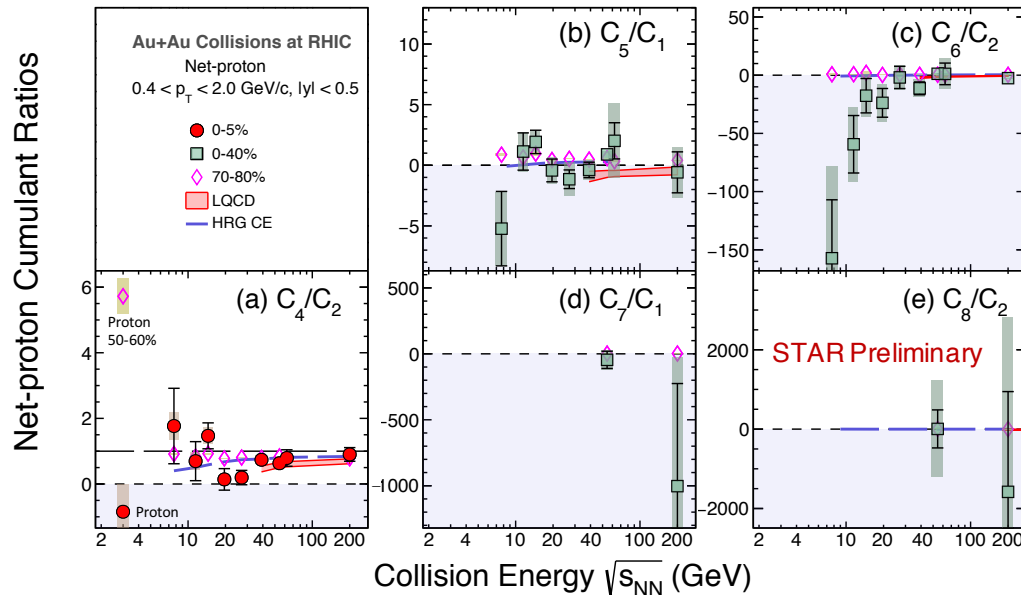
- Statistical: Bootstrap method
- Systematic: Varying track cuts, PID criteria, DCA, efficiency

First Observation of Net-proton C_7 and C_8



- ❑ Collision centrality dependence of C_7/C_1 and C_8/C_2 at 54.4 and 200 GeV are presented.
- ❑ Central 0-40% measurements consistent with zero within uncertainties.
- ❑ Peripheral data close to zero for the two energies.

Summary and Outlook



- ❑ Non-monotonic $\sqrt{s_{NN}}$ dependence of C_4/C_2 observed – consistent with CP expectation.
- ❑ C_5/C_1 (0-40%) fluctuates around zero. C_6/C_2 increasingly negative with decreasing $\sqrt{s_{NN}}$ – consistent with lattice QCD prediction ($\mu_B < 110$ MeV).
- ❑ The new data on C_7/C_1 and C_8/C_2 (0-40%) are consistent with zero within large uncertainties.
- ❑ Peripheral data ≥ 0 for all ratios.

STAR: PRL, 126, 092301 (2021), PRC, 104, 024902 (2021), PRL, 127, 262301 (2021)
LQCD: PRD101, 074502 (2020), HRG CE: NPA 1008, 122141 (2021)

- ❑ Hyper-order cumulants are important observable in the study of QCD phase structure. Combination of signs of hyper-order cumulants are sensitive to hadronic phase, QGP phase and T_c .
- ❑ Current net-proton C_7 and C_8 measurements at 54.4 and 200 GeV are consistent with zero within uncertainties. Measurement at lower energies will be interesting.
- ❑ Measurements with high statistic STAR data (~10 times of current statistics) ongoing.