Search for QCD Critical Point: Recent Results from STAR BES-I Program and Status of BES-II

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Introduction

The QCD phase diagram, commonly characterized by temperature (T) and baryon chemical potential (μ_B), displays two key phases: quark-gluon plasma and hadronic phase [1]. Lattice QCD (LQCD) calculations show that quark-hadron transition at low μ_B is a crossover [2]; while at large μ_B, QCD based models predict a first order phase transition [3] that ends with a critical point (CP). Cumulants (C_n) of event-by-event net-proton distribution (as a proxy of conserved quantity net-baryon) are proposed as sensitive observables to the QCD phase structure [4]. They are related to the correlation length (ξ) of the system and thermodynamic susceptibilities of conserved charges [4]. A non-monotonic collision energy ($\sqrt{s_{NN}}$) dependence of C_4/C_2 serves as an experimental signature of CP [4]. Furthermore, LQCD and functional renormalization group (FRG) model predict negative C_6/C_2 during crossover transition [9].

Analysis details

Measurements are done for Au+Au collisions at collision energies from 200 - 7.7 GeV in the first phase of the beam energy scan (BES-I) program and at 3.0 GeV in the fixed target (FXT) program at RHIC, covering a wide range of μ_B from 20 - 750 MeV. (Anti-)protons are selected within transverse momentum (p_T) coverage of $0.4 < p_T < 2.0$ GeV/c and rapidity (y) coverage of $|y| < 0.5$. At 3.0 GeV, protons are selected within $-0.5 < y < 0$. Collision centrality is determined by the charge particle multiplicity distribution within pseudorapidity (η) range $|\eta| < 1$ (for 3 GeV, $0 < \eta < 2$) excluding protons and anti protons to avoid autocorrelation. Cumulants and cumulant ratios are centrality bin width corrected [5] and detector efficiency corrected [6]. Bootstrap method is used to estimate statistical uncertainty, while systematic uncertainties for C_n is obtained by varying criteria for track reconstruction, particle identification (PID) and reconstruction efficiencies.

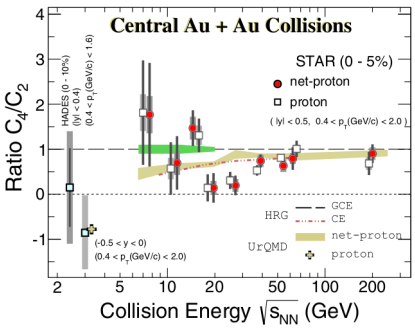

FIG. 1: Collision energy dependence of C_4/C_2 from top 0-5% Au+Au collisions at RHIC [10]. Vertical black and gray bars are the statistical and systematic uncertainties, respectively. Results from HRG [7] and UrQMD are also shown.

Results and Discussion

Figure 1 shows collision energy dependence of C_4/C_2 for 0-5% central Au+Au collisions. The observed non-monotonic trend for net-proton C_4/C_2 in the range 7.7 - 27 GeV [11, 12] can not be described by the non-CP models UrQMD and HRG. However, C_4/C_2 at 3.0 GeV can be described by UrQMD model [13]. Figure 2 depicts the collision en-

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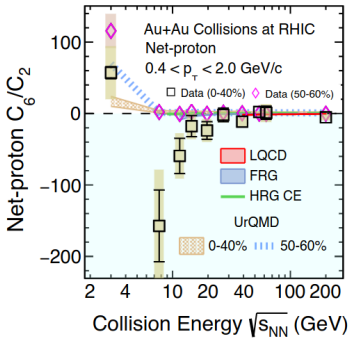

FIG. 2: Collision energy dependence of C_6/C_2 for net-proton from 0-40% (squares) and 50-60% (diamonds) Au+Au collisions at RHIC [15]. The bars and bands on the data points represent statistical and systematic uncertainties, respectively. Results are also shown for LQCD [8], FRG [9], HRG and UrQMD models.

ergy dependence of net-proton C_6/C_2. For 0-40% centrality collisions C_6/C_2 is progressively negative from higher to lower collision energy up to 7.7 GeV, followed by a large positive value at 3 GeV [14, 15]. LQCD and FRG models, which include quark-hadron crossover transition, also show progressively decreasing negative values for C_6/C_2 in the range 200 - 7.7 GeV. The peripheral 50-60% C_6/C_2 data and UrQMD remains always non-negative.

Beam Energy Scan Phase II

The phase II of the BES program (BES-II) at RHIC has collected 10 - 20 times larger statistics than BES-I within the collision energy $\sqrt{s_{NN}}$ = 7.7 - 19.6 GeV in collider mode [16]. Figure 3 compares event statistics for BES-II with BES-I. It now includes two more energies $\sqrt{s_{NN}}$ = 9.2 and 17.3 GeV in collider mode for their strategic relevance to CP search. Furthermore, STAR fixed-target program explores the QCD phase diagram up to μ_B = 750 MeV. Upgrades to the STAR detector, including installation of the inner chambers of the TPC (iTPC), addition of the eTOF and the event plane detector, have expanded pseudo-rapidity coverage from $|\eta| < 1.0$ to 1.5, have improved PID and centrality definition for fluctuation measurements [16]. Acceptance dependence study of C_4/C_2 with extended rapidity coverage offered by iTPC is important for CP search. For this regard, results from BES-II are highly anticipated, and the analysis process is ongoing.

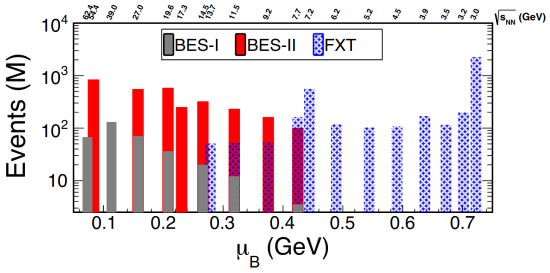

FIG. 3: Event statistics of Au+Au collisions for all collision energies from BES-I and BES-II are shown.

Acknowledgments

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