Probing the QCD critical point by higher moments of the net-charge and net-proton multiplicity distribution in STAR Experiment

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Introduction

At high temperature and/or high baryonic chemical potential (μ_B) the hadronic mater transit to QCD matter, where color degrees of freedom play important role, known as quark gluon plasma (QGP). Figure 1 shows a schematic QCD phase diagram in terms of temperature and chemical potential. Lattice QCD calculations reveal, close to $\mu_B = 0$, a cross over from hadronic state to a state where the relevant degree of freedom is partonic. At large μ_B, the transition from hadronic to partonic degrees of freedom is speculated to be the first order phase transition. In the QCD phase diagram, the end point of the first order phase transition is called as QCD critical point (CP). The characteristic signature for the CP is the divergence of the thermodynamic susceptibilities of conserved quantities like net-charge, net-baryon, net-strangeness [1] and the correlation length(ξ)[2]. These quantities are related to the higher moments (such as mean(M), standard deviation(σ), skewness(S) and kurtosis(κ)) of the event-by-event distribution of the above conserved quantities. The variance, skewness and kurtosis are related to ξ^2, $\xi^{4.5}$ and ξ^7[2] respectively. The presence of the CP is expected to lead to non-monotonic behavior of the above higher moments and their products as a function of the beam energy [2].

The Beam Energy Scan (BES) program has been undertaken at the Relativistic Heavy Ion Collider (RHIC), at BNL, to search for the QCD critical point (CP) and the phase boundary. In BES program, STAR experiment have taken data of Au+Au collisions at $\sqrt{s_{NN}} = 39$, 27, 19.6, 11.5 and 7.7 GeV. Along with BES energies STAR experiment also have taken data of Au+Au collisions at 200 and 62.4 GeV, which covers the baryon chemical potential ranging from 20 MeV to 410 MeV [4] in the QCD phase diagram.

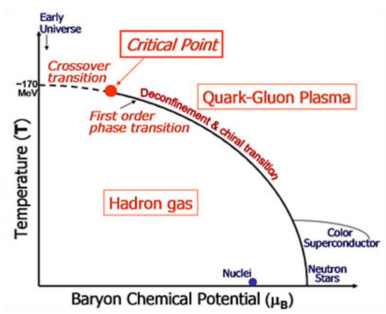

FIG. 1: A schematic QCD phase diagram representing hadronic and QCD matter in termes temperature and baryonic chemical potential.

Analysis Details and Results

The STAR experiment provides the excellent particle identification and large uniform acceptance for the event-by-event fluctuation analysis. The Time Projection Chamber (TPC) is the main tracking device. Particle identification capability is enhanced by using the Time of Flight (TOF) detector. The TPC detector covers full azimuthal angle and ±1.8 unit of pseudo-rapidity (η). For the centrality selection, uncorrected charged particles multiplicity measured within $0.5 < |\eta| < 1.0$ from the TPC is utilized to avoid auto-correlation effect in the net-charge higher moments calculation. To get the average number of participant ($< N_{part} >$) for each centrality,

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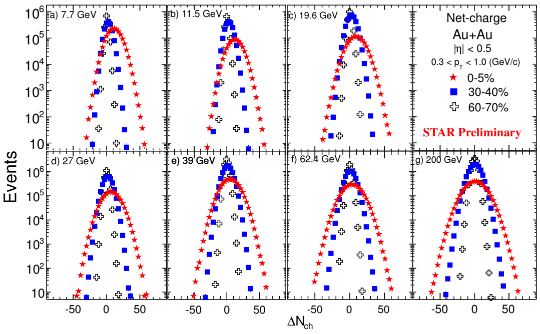

FIG. 2: The event-by-event net-charge multiplicity distributions for three centrality bins of Au+Au collisions at colliding energies from 7.7 to 200 GeV.

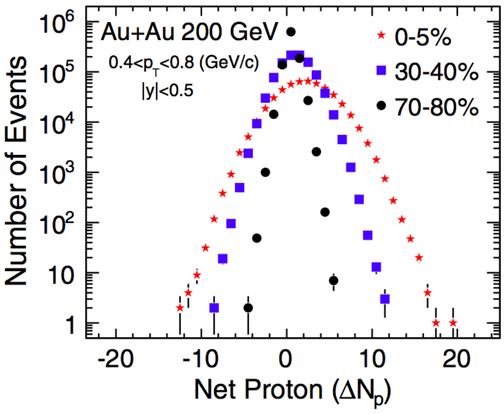

FIG. 3: The event-by-event net-proton multiplicity distribution for three centrality bins of Au+Au collisions at colliding energy 200 GeV[5].

monte carlo Glauber model calculation is done.

We report on the STAR BES results of the higher moments of net-charge, net-proton distribution and the products of their higher moments for Au+Au collisions at $\sqrt{s_{NN}}$ ranging from 7.7 to 200 GeV. The charged particles in the transverse momentum $0.3 < p_T < 1.0$ GeV/c and $|\eta| < 0.5$ region are measured. Figure 2 shows the uncorrected net-charge multiplicity distribution for the Au+Au collisions at various colliding energies for three centrality bins. The protons and anti-protons are measured in rapidity ($|y| < 0.5$) and transverse momentum ($0.4 < p_T < 0.8$ GeV/c). Figure 1 shows the uncorrected net-proton multiplicity distribution for the Au+Au collisions at 200 GeV colliding energies for three centrality (based on uncorrected charged particles multiplicity measured within $0.5 < |\eta|$) bins. The energy dependence of the $S\sigma$, $\kappa\sigma^2$ and σ^2/M of the net-charge and net-proton multiplicity distribution will be compared with the Hadron Resonance Gas model[4] and Poisson expectation.

References

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