Higher moments of Net Kaon multiplicity distributions at RHIC energies for the search of QCD Critical Point at STAR

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Introduction

The Relativistic Heavy-Ion Collider (RHIC), at Brookhaven National Laboratory, has started its beam energy scan(BES) program by colliding high energy heavy-ions at a centre-of-mass energy $\sqrt{s_{NN}}$ = 7.7-200 GeV, corresponding to baryonic chemical potentials within the range of 20 - 420 MeV. One of the main goals of this beam energy scan program is to locate the critical point which is postulated to lie at the end of the first order phase transition line. Finite temperature lattice QCD calculations at baryon chemical potential $\mu_B = 0$ suggest a crossover above a critical temperature from a system with hadronic degrees of freedom to a system where the relevant degrees of freedom are quarks and gluons[1,2]. Several QCD based calculations find the quark-hadron phase transition to be first order at large μ_B[3,4].

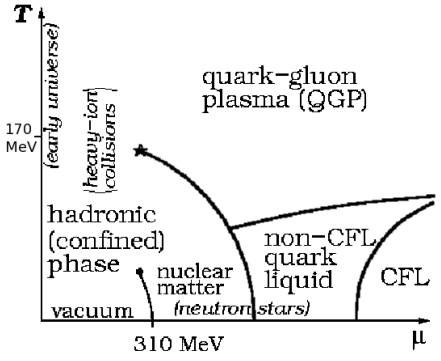

Fig. 1: A schematic diagram of QCD phase representing hadronic phase and quark-gluon phase of matter in terms of temperature(T) and baryonic chemical potential(μ).

In a static, infinite medium, the correlation length (ξ) diverges at the CP[5,6]. ξ is related to various moments of the distributions of conserved quantities such as net baryons, net charge, and net strangeness. Typically variances ($\sigma^2 = \langle(\Delta N)^2\rangle; \Delta N = N - M$;where M is the mean) of these distributions are related to ξ as $\sigma^2 \simeq \xi^2$[7,8]. Finite size and time effects in heavy-ion collisions put constraints on the values of ξ. A theoretical calculation suggests $\xi \simeq 2$, 3 fm for heavy-ion collisions[9]. It was recently shown that higher moments of distributions of conserved quantities, measuring deviations from a Gaussian, have a sensitivity to CP fluctuations that is better than that of σ^2, due to a stronger dependence on ξ. The numerators in skewness ($S = \langle(\Delta N)^3\rangle/\sigma^3$) go as $\xi^{4.5}$ and kurtosis ($\kappa = [\langle(\Delta N)^4\rangle/\sigma^4] - 3$) go as ξ^7[7-9]. A crossing of the phase boundary can manifest itself by a change of sign of S as a function of energy density[10]. Close to the critical point, models predict the net-baryon, net-strangeness and net-charge number distributions to be non-Gaussian and susceptibilities to diverge causing volume independent moment product ($S\sigma$ and $\kappa\sigma^2$) to deviate from being constants. Experimentally measuring event-by-event all produced conserved quantities is very difficult. However, proton, Kaons and charge are measurable for their proxy of the conserved quantities. Event-by-event the net-Kaon multiplicity ($\Delta N_K = N_{K^+} - N_{K^-}$) distribution is measurable for the proxy of the net-strangeness.

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Analysis Details and Results

The STAR(Solenoidal Tracker At RHIC) experiment, provides excellent particle identification and large uniform acceptance. The Time Projection Chamber(TPC) is STAR's primary detector and can track up to $\sim 4\times10^3$ particles per event. For collisions in its center, the TPC covers the full azimuthal angle and an uniform acceptance within pseudo-rapidity region $|\eta| < 1.0$. It can measure particle p_T within the approximate range $0.07 < p_T < 30$ GeV/c. The momentum resolution $\delta p/p$ depends on η and p_T but for most tracks $\delta p_T/p_T \sim 0.02$. The particle identification capability is enhanced by using the Time of Flight (TOF) detector along with the TPC[11].

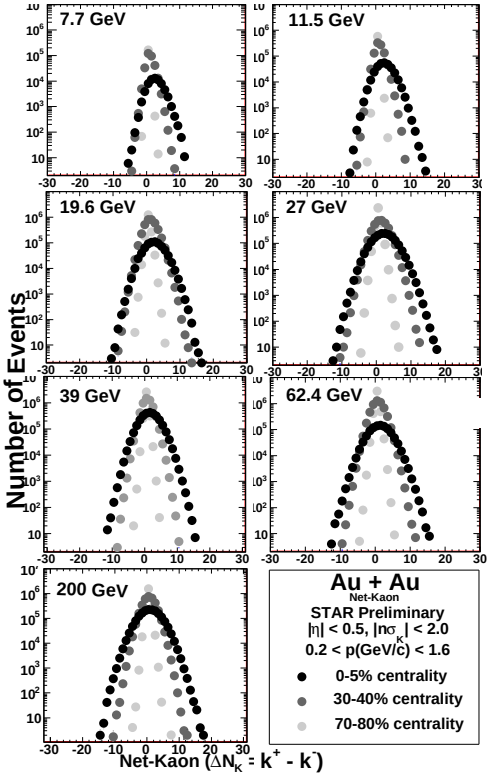

Fig. 2: ΔN_K multiplicity distribution in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7 - 200 GeV for various collision centralities at mid-rapidity ($|\eta| < 0.5$).

Figure2 shows the uncorrected raw net-Kaon ($\Delta N_K = N_{K^+} - N_{K^-}$) multiplicity distribution for various collision centralities from 70-80%, 30- 40%, and 0-5% in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7 - 200 GeV at mid-rapidity ($|\eta| < 0.5$). The positively charged Kaons and negatively charged Kaons are measured in rapidity ($|\eta| < 0.5$) and transverse momentum ($0.2 < p_T < 1.6$ GeV/c), the statistical errors are shown. For centrality selection we have used uncorrected charged particle multiplicity within $0.5 < |\eta| < 1.0$, to avoid the auto correlation.

Here we report the measurements of the various moments (standard deviation (σ), skewness (S) and kurtosis (k)) and their products ($\kappa\sigma^2$, Sσ) of the net Kaon multiplicity measured by the STAR detector at mid-rapidity for Au+Au collisions at $\sqrt{s_{NN}}$ =7.7 to 200 GeV center of mass energies. The energy and centrality dependence of higher moments of net-Kaons and their products (such as Sσ and $\kappa\sigma^2$) will be presented in all BES energies. Theoretical calculation, containing the non-CP physics from the HIJING and AMPT models will be compared to the data.

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