STAR’s Measurement of Energy and System Size Dependence of K/π Fluctuations at RHIC.

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Abstract. Strangeness enhancement has been predicted to be one of the signatures of the formation of the quark gluon plasma (QGP) and event-by-event fluctuations of strangeness may reveal the nature of such a phase transition. We report results for K/π fluctuations from Cu+Cu at \( \sqrt{s_{NN}} = 62.4 \) and 200 GeV and Au+Au collisions at \( \sqrt{s_{NN}} = 62.4, 130 \) and 200 GeV using the STAR detector at the Relativistic Heavy Ion Collider. We compare our results with the results observed in central Pb+Pb collisions at SPS energies at \( \sqrt{s_{NN}} = 6.3, 7.6, 8.8, 12.3, \) and 17.3 GeV. We observe the fluctuation strength measured at the highest SPS energy point by the NA49 collaboration in Pb+Pb collisions is similar to our results in Cu+Cu and Au+Au collisions. We also compare our results with HIJING, a statistical hadronization model and a multi-phase transport model.

1. Introduction

Quantum Chromodynamics (QCD) predicts a transition of normal hadronic matter to a new state of matter at sufficient high temperature or energy density. This new state of matter is known as Quark Gluon Plasma (QGP). Event-by-event fluctuations in global observables is considered to be one of the signatures of QGP phase transition. The nature of this phase transition may also be revealed in the fluctuations of global observables. Kapusta [1] et al, predicted that fluctuations in kaon to pion ratio may reveal the nature such a phase transition. NA49 recently reported the measurement of strangeness production at several beam energies lower than RHIC(200 GeV). A "horn" like discontinuity in \( K^+/\pi^- \) ratio and continuity in \( K^-/\pi^- \) ratio observed in Pb+Pb collisions has generated lot of excitement to study strangeness fluctuations event wise [2]. In the present talk, we report STAR’s measurement of \( K/\pi \) fluctuations on an event-by-event basis for Cu+Cu collision at 62.4 and 200 GeV and for Au+Au collision at 62.4, 130 and 200 GeV.

2. Measures

Event-by-event fluctuations consist of mainly two components, the statistical fluctuations arising due to finite number statistics of particle production and the
dynamical component due to particle production mechanism. So it's necessary to remove the statistical fluctuations from the total fluctuations to get the dynamical component of fluctuations. We have used two measures to quantify the dynamical fluctuation strength. In first case, the statistical part is being estimated by constructing mixed events. The mixed events are being constructed taking one particle from each real event randomly keeping the multiplicity of the mixed events same as real events. We use a measure, $\sigma_{\text{dyn}, K/\pi}$ as:

$$\sigma_{\text{dyn}, K/\pi} = \sqrt{\sigma_{\text{data}}^2 - \sigma_{\text{mixed}}^2}$$

where $\sigma_{\text{data}}$ is the width of the $K/\pi$ distribution of real data and $\sigma_{\text{mixed}}$ that of mixed events. Then $\sigma_{\text{dyn}, K/\pi}$ is divided by Mean of $K/\pi$ distribution of real data and multiplied by 100 to get the percentage of fluctuation strength. However the variable $\sigma_{\text{dyn}}$ may be problematic at lower multiplicities, so we use another measure, $\nu_{\text{dyn}, K/\pi}$ defined as:

$$\nu_{\text{dyn}, K/\pi} = \frac{< N_K (N_K - 1)>}{< N_K >^2} + \frac{< N_\pi (N_\pi - 1)>}{< N_\pi >^2} - 2 \frac{< N_K N_\pi >}{< N_K > < N_\pi >}$$

where, $N_K$ and $N_\pi$ are the number of kaons and pions in an event. The average is being done over large number of event sample being analyzed. The variable $\nu_{\text{dyn}, K/\pi}$ is assumed to be independent of tracking efficiencies and was first used in STAR Collaboration for net charge fluctuation study.[3]

3. Particle Identification and track selection

The data analyzed were measured using Time Projection Chamber (TPC) detector in STAR experiment located inside solenoidal magnetic field. The particle identification is based on specific energy loss ($dE/dx$)[4] measured in the TPC. In order to precisely identify a particle, we define $N\sigma_X = \log \left( \frac{dE/dx}{B_X} \right) / \sigma_X$[5] for each particle where, X can be any particle type ($\pi^\pm, K^\pm$ etc.), $B_X$ is the expected mean $dE/dx$ of particle X, and $\sigma_X$ is the $dE/dx$ resolution of the TPC. In the present analysis, all tracks within $-1 < \eta < 1$ and $200 < pt < 600$ MeV/c are selected. We select a particle to be pion if $N\sigma_\pi < 2$ and $N\sigma_K > 2$, similarly for kaon is selected if $N\sigma_K < 2$ and $N\sigma_\pi > 2$. For removing electron contamination, we give a tighter cuts on electron. A particle is called electron, if $N\sigma_e < 1$.

4. Results and discussion

We have shown the $K/\pi$ distribution for Cu+Cu collision at 200 GeV in Figure 1 (a). The filled circle in the figure corresponds to real data and the solid line corresponds to mixed events. Using the width of this $K/\pi$ distributions, $\sigma_{\text{dyn}, K/\pi}$ is calculated. The measured $\sigma_{\text{dyn}, K/\pi}$ is shown in figure 1(b) for Cu+Cu 62.4 GeV and Cu+Cu 200 GeV. Also shown in the figure is the $\sigma_{\text{dyn}, K/\pi}$ for Au+Au collisions at 62.4, 130 and 200 GeV. We observe the measured dynamical fluctuation strength is independent of collision energy. It is seen that the $\sigma_{\text{dyn}, K/\pi}$ is similar for Cu+Cu and Au+Au collisions. We have
Figure 1: The $K/\pi$ ratio distribution for (a)Cu+Cu 200 GeV. The filled circles are from the data and the solid histogram corresponds to mixed events. The errors shown here are statistical only. (b) The measured $\sigma_{\text{dyn},K\pi}$ for Cu+Cu and Au+Au collision. The errors shown here for Au+Au and Cu+Cu are both statistical and systematic. Also shown in the figure is the comparison with the measurement of NA49 Collaboration.

Figure 2: (a) The measured $\nu_{\text{dyn},K\pi}$ for Cu+Cu, Au+Au collisions. The errors shown for Cu+Cu collision includes statistical and systematic. However for Au+Au, only statistical errors shown. Systematic error for Au+Au is about 17.6%. (b) The scaled $\nu_{\text{dyn},K\pi}$ is compared to Corresponding results from HIJING and AMPT model calculations.
compared our results with the measurement of NA49 collaboration\cite{6}. The fluctuations strength measured at the highest SPS energy by NA49 collaboration in Pb+Pb collisions is similar to our results in Cu+Cu and Au+Au collisions within the present level of precision of measurement. The figure 1(b) also includes the predictions of Statistical Hadronization(SH) model\cite{7}. The SH model predictions for non-equilibrium scenario are consistent with our measurement at higher energy points, however they under predict the data at lower energies. In case of equilibrium scenario with fitted parameter,\( \gamma_q = 1 \), the SH model under predicts our results at all energies. The figure 2(a) shows the measured \( \nu_{dyn,K\pi} \) for Cu+Cu and Au+Au collisions. Figure 2(a) also shows the comparison with NA49 measurement by using the relation \( \sigma_{dyn,K\pi} = \sqrt{\nu_{dyn,K\pi}} \). Its observed that the measured \( \nu_{dyn,K\pi} \) is similar to Cu+Cu and Au+Au collisions and independent of collision energy. We have also compared our results with model predictions mainly for HIJING model and A Multi Phase Transport model(AMPT)\cite{8}. AMPT model uses HIJING as initial particle production in addition to hadronic evolution(multiple re-scattering). The track selection in HIJING and AMPT were done within same kinematic cuts as real data. The comparison of experimental results and the HIJING and AMPT predictions have been shown in the figure 2(b). we observe that the HIJING over predicts the experimental results, however the AMPT predictions are in better agreement with data.

5. Summary

We have measured \( K/\pi \) fluctuation for Cu+Cu collisions at 62.4 and 200 GeV and for Au+Au collisions at 62.4,130 and 200 GeV. The measured fluctuation strength is observed to be independent of system size and energy. Our preliminary results are similar in comparison to top SPS energy measurements. HIJING model over predicts the experimental results however AMPT model is in better agreement with the data.

6. References

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