Contribution of Stopped Proton Fluctuation in Net-proton Multiplicity Distributions

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Introduction

The QCD inspired models predict a presence of CEP in the QCD phase phase diagram, where the 1^{st} order phase transition and crossover meets in the T-μ_b plane. The recent results on conserved number fluctuations from the beam energy scan program at RHIC have drawn much attention to explore the critical point in the QCD phase diagram. But, the experimentally measured protons for net-proton fluctuations contain contribution from various processes such as secondaries from higher mass resonance decay, production process, and protons from the baryon stopping. Further, these contributions also fluctuate from event to event and can contaminate the dynamical fluctuations due to the critical point. The present work is mainly focused to disentangle the stopped proton fluctuation from the net-proton results measured by STAR experiment.

Method and Results

A Monte-Carlo approach is adopted by taking two independent distributions of proton (p^{incl}) and anti-proton ($\bar{p}$) multiplicities as Binomial distribution. The mean values used in the Binomial distribution of p^{incl} and $\bar{p}$ for $(0\% - 5\%)$ centrality in Au+Au collisions at different $\sqrt{s_{NN}}$ are taken from Ref. [1]. The net-proton multiplicity p^{diff} $(= p^{\mathrm{incl}} - \bar{p})$ distribution is then constructed from independently produced p^{incl} and $\bar{p}$ distributions. For

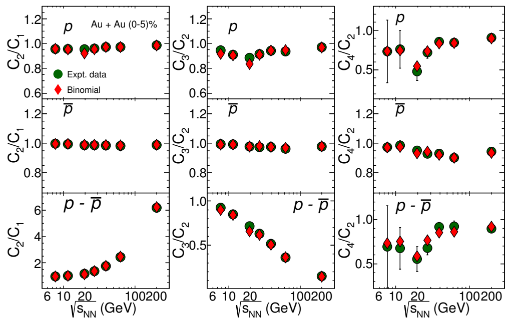

FIG. 1: The comparison between efficiency corrected individual cumulants of inclusive protons (p), anti-protons ($\bar{p}$), and net-protons ($p-\bar{p}$) multiplicity as a function of $\sqrt{s_{NN}}$ in most central Au+Au collisions and the experimental measurements [3].

the proof of principle, we calculate the individual cumulants of measured proton, anti-proton and net-proton multiplicities, which are distributed binomially and compare them with the experimentally measured cumulants as is shown in Fig. 1. Also, by this construction, we get access to the efficiency corrected distributions of protons and anti-protons.

Experimentally, it is not trivial to tag a measured proton originating from stopping or production, hence, the correction for the stopped protons to the net-proton multiplicity distribution can not be applied to the experimental measurement. The fraction of stopped and produced proton contributions in the inclusive proton distribution are estimated by taking the mean number of p^{incl} [1] and p^{stop} [2]. The stopped and produced proton fractions are calculated as: $f^{\mathrm{stop}} = (C_1$ of $p^{\mathrm{stop}}/$ C_1 of $p^{\mathrm{incl}})$ and $f^{\mathrm{prod}} = [(C_1$ of $p^{\mathrm{incl}}-$ C_1 of $p^{\mathrm{stop}})/C_1$ of p^{incl}], respectively.

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The stopped proton and produced proton distributions are constructed on event-by-event basis from the inclusive proton distribution weighted by corresponding $f^{\rm stop}$ and $f^{\rm prod}$ fractions. The resulting $p^{\rm stop}$ and $p^{\rm prod}$ distributions also remain Binomial. These factorized multiplicity distributions along with the anti-proton multiplicity distributions are further used for the study of net-proton fluctuation at various collision energies.

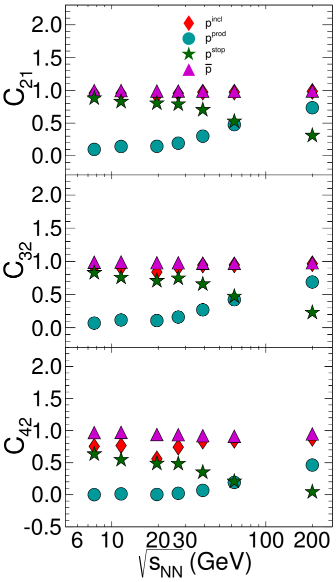

FIG. 2: Collision energy dependence of cumulant ratios (C_2/C_1, C_3/C_2, C_4/C_2, and C_3/C_1) in most central Au+Au collisions obtained from Binomial distributions [3].

Fig. 2 shows the ratios of cumulants for p^{incl}, $p^{\rm prod}$, $p^{\rm stop}$ and $\bar{p}$ separately using the present approach from their respective distributions. Further, using these distributions we construct the cumulants for the difference with inclusive and stopped protons as is shown in Fig. 3. As can be seen from Fig. 3 that after removing the stopped proton fluctuations the C_{32} or Sσ also shows the non-monotonic behavior and it is even more pronounced for $\kappa\sigma^2$. Therefore, the net-proton fluctuation measurements should be corrected for the stopped proton fluctuations.

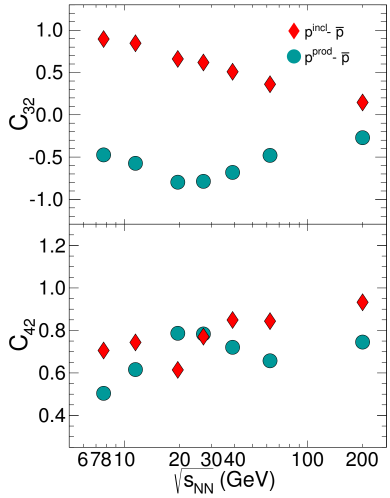

FIG. 3: Variation of cumulant ratios of net-proton multiplicity distributions assuming individual $p^{\rm incl}$ and $\bar{p}$ distributions are Binomial [3].

Summary

In summary, we demonstrate the contribution of stopped proton and produced proton fluctuations in the net-proton higher moments measured by STAR experiment at RHIC. The produced net-proton multiplicity fluctuations using cumulants and their ratios are studied as a function collision energies. After removing the stopped proton contribution from the inclusive proton multiplicity distribution, a non-monotonic behavior is even more pronounced in the net-proton fluctuations around $\sqrt{s_{NN}}$ = 19.6 GeV, both in $S\sigma$ and $\kappa\sigma^2$. The present study will be useful to understand the fluctuations originating due to critical point.

References

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[3] D. K. Mishra *et al.* arXiv:1706.04012 [nucl-th] and references therein