Effect of event pile-up on the higher moments of net-proton multiplicity distribution in heavy-ion collisions.

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Introduction

The measurements of conserved number multiplicity distributions from BES at RHIC have drawn much attention from both the theoretical and the experimental community to map the QCD phase diagram and find out the location of critical end point (CEP) [1]. Recently, preliminary results from STAR experiment on net-proton multiplicity distribution show a large enhancement in the product of higher moments ($\kappa\sigma^2$) values at lower collision energies [2]. Several theoretical studies suggest that, the higher moments start to oscillate in temperature and μ_B plane near the QCD critical point. But the sensitivity of these observables on the multiplicity distribution is the motivation to study the effect of residual event pile-up. Most of the pile-up events are removed using different experimental techniques, however it is difficult to rule-out the possibility of a small fraction of residual pile-up events. The residual pile-up effect has never been considered while studying the cumulants in the experimental data.

In high luminosity heavy-ion collisions, there may be several sources of the background events during a collision, such as, in-time, out-of-time, cavern background, beam halo events, beam gas events. In the experimental situation, several techniques are applied to reduce the background events.

Method and results

The method discussed in this study assumes the proton and anti-proton multiplicities to be Poisson, negative binomial distributions (NBD) or binomial, as different cases of multiplicity distribution. If two collision events happen within a same bunch crossing, it may be difficult to disentangle them and can be misinterpreted as one single event. We have adopted a simple Monte-Carlo approach by generating two independent multiplicity distributions of proton (p) and anti-proton ($\bar{p}$) using the corresponding mean values for (0% 5%) centrality in Au+Au collisions at different center-of-mass energies $\sqrt{s_{NN}}$. A large sample of central physics events has a small fraction of events where two central events are piled-up. For which, in some fraction of the events, the extra proton and anti-proton multiplicities coming from pile-up are added to the original multiplicity distributions for central collisions. Hence, out of all the accumulated events, some events will have higher multiplicities as compared to the usual multiplicity of central col-

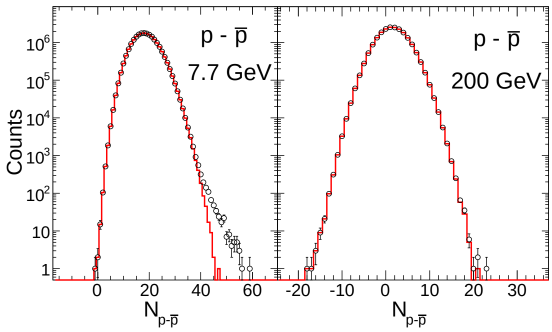

FIG. 1: Net-proton multiplicity distributions are shown with (open symbol) and without (solid line) event pile-up for $\sqrt{s_{NN}}$ = 7.7 GeV and 200 GeV [3].

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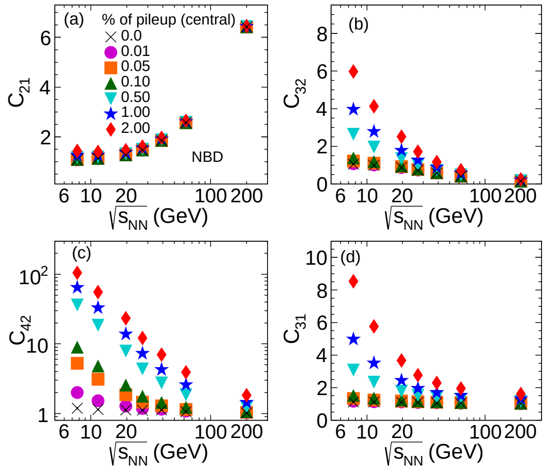

FIG. 2: Variation of cumulant ratios (C_2/C_1, C_3/C_2, C_4/C_2, and C_3/C_1 of net-proton distributions as a function of $\sqrt{s_{NN}}$ for different fraction of pile-up events for central (0% – 5%) Au+Au collisions [3].

lision event.

Figure 1 shows the typical multiplicity distributions for net-proton ($p - \bar{p}$) for two different $\sqrt{s_{NN}}$ = 7.7 and 200 GeV. The multiplicity distributions are compared for without and with inclusion of pile-up events. The effect of event pile-up is more visible in the proton distribution at $\sqrt{s_{NN}}$ = 7.7 GeV as compared to 200 GeV. Since at lower energies the mean number of protons are larger as compared to higher energies, therefore, while mixing a central event with central (or minimum bias) event, the effect is more pronounced. At higher energies, due to small mean multiplicity of p and $\bar{p}$, the effect does not add-up much. However, in experimentally measured p or $\bar{p}$ multiplicity distributions, it is not easy to figure out those events, as the excess is very small. This may look like real event multiplicity which can be seen for $\sqrt{s_{NN}}$ = 200 GeV.

Figure 2 shows the cumulant ratios as a function of $\sqrt{s_{NN}}$ for different fraction of pile-up events. Both the added pile-up multiplicities and the original multiplicities distribution are from the central Au+Au collisions. The C_{32}, C_{42}, and C_{31} ratios show strong dependence on energy and fraction of added pile-up events. The effect of event pile-up on net-proton multiplicity distribution will be more crucial at lower $\sqrt{s_{NN}}$, due to large asymmetry between p and $\bar{p}$ multiplicities. On the other hand, event pile-up effect is not observed at higher collision energies, because the mean multiplicities of both p and $\bar{p}$ are small and comparable. While constructing the net-proton multiplicity distribution, the excess pile-up effect gets neutralize for the high energy collisions, while at lower $\sqrt{s_{NN}}$ it is not the case as the asymmetry between the proton and anti-proton is more. It is to be noted that, the pile-up effect will be more important for net-proton fluctuations as compared to charge particles. Since, at lower energies the asymmetry between protons and anti-proton multiplicities are larger, which is not the case for net-charge.

Summary

In the present work, we have emphasized the importance of residual event pile up for net-proton higher-moment analysis. We try to demonstrate qualitatively, that even a very small fraction of the pile-up events can change the higher cumulants significantly specially at lower center-of-mass energies. This issue is even more important for the fix target experiments like CBM where the collision rates will be even higher. The pile-up have a tendency to increase the ratios of cumulants and are more significant at lower energies. This observation makes it critical to estimate the purity of the measured physics event sample for net-proton multiplicity analysis. It is important to estimate the effect of residual pile up effect before making any conclusion on critical point using higher moments of net-proton multiplicity distributions; as the artifact may lead to a very different conclusion.

References

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