Cumulant ratios of conserved quantities at FAIR energy in the UrQMD model

S. Ghosh, P. Mali, and A. Mukhopadhyay*
Department of Physics, University of North Bengal, Siliguri, Darjeeling 734013

One of the major physics goals of the Compressed baryonic Matter (CBM) experiment to be held at the Facility for Antiproton and Ion Research (FAIR) is to investigate the characteristics of the hot and dense intermediate fireballs that are presumably created in high-energy nucleus-nucleus (AB) collisons. As the experimental data on CBM experiment are still awaited, simulation study can help us understand the characteristics of the baryon-rich hadronic/partonic matter present in the fireball [1]. Observables like the cumulants of net-charge distribution are proportional to the correlation length and thermodynamic susceptibility of the system [2]. It is seen that the negative binomial distribution (NBD) can suitably describe the multiplicity distribution [3]. A deviation from the Poisson distribution (PD) increases with increasing acceptance [4]. We here report some preliminary results of a simulation study on the cumulant ratios of the multiplicity distributions of conserved quantities. Out of a million min. bias Au+Au events generated by the UrQMD code [5] at $E_{\rm lab} = 30A$ GeV, only the 0-10% most central events are taken for our analysis. Cumulants $C_{n,N}$ of order n and multiplicity N are defined as

$$C_{1,N} = \langle N \rangle \,, \; C_{2,N} = \left\langle (\delta N)^2 \right\rangle ,$$
$$C_{3,N} = \left\langle (\delta N)^3 \right\rangle ,$$
$$C_{4,N} = \left\langle (\delta N)^4 \right\rangle - 3 \left\langle (\delta N)^2 \right\rangle^2 \qquad (1)$$

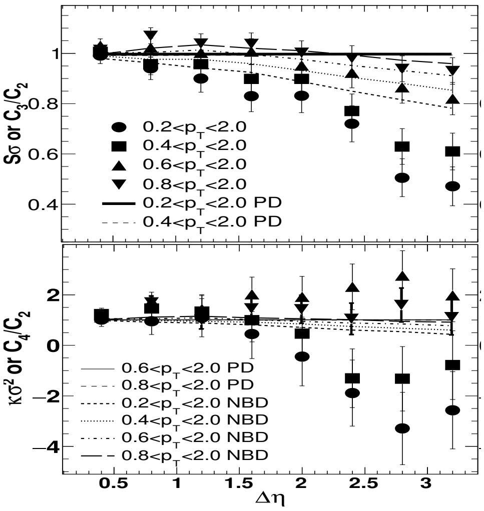

FIG. 1: $\Delta\eta$ dependence of net-proton cumulant ratios.

where $\delta N = N - \langle N \rangle$ is the deviation from the mean value $\langle N \rangle$. Once we have these definitions, the moments of the distribution can be denoted as,

$$M = C_{1,N}, \quad \sigma^2 = C_{2,N},$$
$$S = \frac{C_{3,N}}{(C_{2,N})^3/2}, \quad \kappa = \frac{C_{4,N}}{(C_{2,N})^2} \qquad (2)$$

The cumulant ratios are constructed to eliminate the trivial volume dependence

$$S\sigma = \frac{C_{3,N}}{C_{2,N}}, \quad \kappa\sigma^2 = \frac{C_{4,N}}{C_{2,N}} \qquad (3)$$

In FIG.1 we plot the cumulant ratios for the net-proton distribution against $\Delta\eta$ at different p_T range. The cumulants are modified for the auto-correlation effect [6]. The

---

*Electronic address: amphys@nbu.ac.in

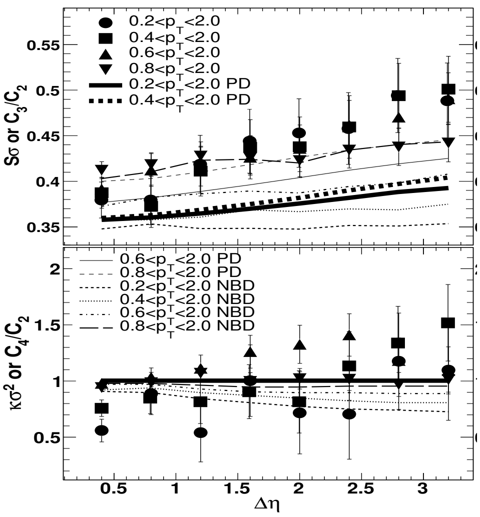

FIG. 2: $\Delta\eta$ dependence of net-kaon cumulant ratios.

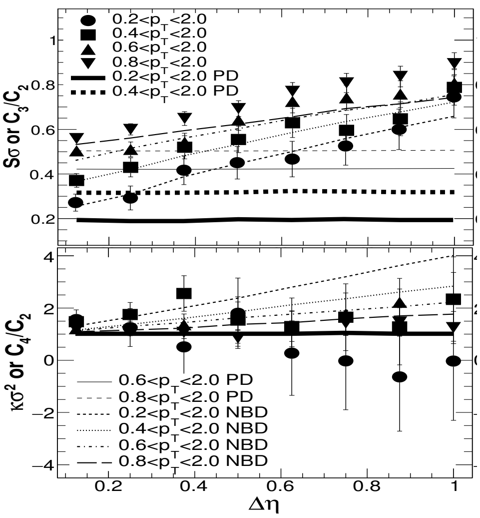

FIG. 3: $\Delta\eta$ dependence of net-charge cumulant ratios.

statistical uncertainties are calculated by using the Delta theorem. The $\Delta\eta = |\eta - \eta_0|$ windows are chosen symmetrically about the centroid η_0 of the overall η-distribution. At FAIR energy the antiproton yeild is quite low as the proton production is largely influenced by the effect of baryon stopping. So the observed decreasing trend in the ratio C_3/C_2 at higher acceptance is almost similar to that of [4]. On most ocassions this ratio remains below unity. However C_4/C_2 ratios are sometimes higher than unity. NBD appears to be a better approximation than the Poisson baseline. In FIG.2 the $S\sigma$ values show an increasing trend with increasing $\Delta\eta$ for the net-kaon distribution. Deviations from both NBD and Poisson expectation are observed, particularly at large acceptances. In FIG.3 we plot the C_n ratios of net-charge distribution as a function of $\Delta\eta$. The C_3/C_2 ratio gradually increases with higher acceptance. However, at high p_T values C_3/C_2 shows a decreasing trend. From all the plots it is evident that at smaller $\Delta\eta$ we see a better compatibility between the simulated result and the NBD prediction and/or Poisson baseline. In conclusion we can say that the acceptance dependence of the C_n ratios are better described by the NBD. At higher acceptance however the cumulant ratios deviate from both the NBD and Poisson expectation significantly. Possibly the effect of global conservation principle comes into the picture. A definite conclusion in this regard however requires more involved analysis of both the simulation and experimental data.

References

[1] CBM Collaboration, Compressed Baryonic Matter Experiment: Technical Status Report, GSI, Darmstadt (2005).
[2] C. Zhou et al, arXiv: 1703.09114v2 [nucl.ex] (2017).
[3] T. J Tarnosky and G. D. Westfall, Phys. Lett. B 724 (2013) 51.
[4] S. He and X. Luo, Phys. Lett. B 774 (2017) 623.
[5] S. A. Bass et al, Prog. Part. Nucl. Phys. 41 (1998) 255.
[6] X. Luo, J. Xu, B. Mohanty and N. Xu, J. Phys. G 40 (2013) 105104.
[7] X. Luo, J. Phys. G 39 (2012) 025008.