Multiplicity fluctuations of identified hadrons in heavy-ion collisions from the beam energy scan at FAIR.

Bushra Ali, Anuj Chandra and Shakeel Ahmad
Department of Physics, Aligarh Muslim University, Aligarh-202002, INDIA

Investigation based on the energy and system size dependence of fluctuations of identified charged hadrons is expected to help search the critical point(CP) of strongly interacting matter and may reveal the properties of onset of de-confinement[1,2]. Such studies would also indicate whether nucleus-nucleus(AA) collisions may be treated as the superposition of independent nucleon-nucleon(AA) collisions[3]. Analyses of experimental data on AA collisions, if carried out in limited phase space, may provide useful information on the dynamical fluctuation and may be used as a mean to explore the possibility of QGP formation.

The multiplicity fluctuations may be ex-

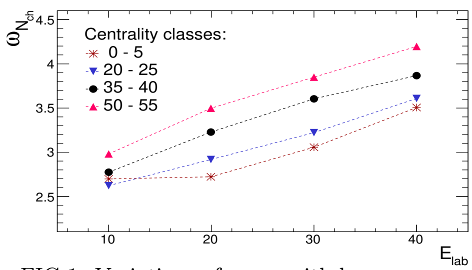

FIG.1: Variations of $\omega_{N_{ch}}$ with beam energy.

amined in terms of the scaled variance of multiplicity distributions(MD), which is defined as $\omega = \left(\sigma^2 / < N_{ch} >\right)$, where N_{ch} is the mean charged particle multiplicity, while σ denotes the dispersion of the MD. ω is regarded as the quantitative measure of particle momentum fluctuations. It is an intensive quantity and does not depend on the volume of the system within grand canonical ensemble or on the number of sources within model of independent sources, like wounded nuclear model. The value of ω will be zero in the absence of fluctuations in MDs and unity for Poisson MD. However, there are several reasons other than CP and onset of deconfinement which cause the fluctuations in MD, it is, therefore, required to carry out a systematic study of energy dependence of fluctuations in the frame work of theoretical models[4]. The present study is based on the analysis of Monte Carlo simulations in the frame work of URQMD model corresponding to FAIR energies; viz, E_{lab} = 10, 20, 30 and 40A GeV. The number of events in each sample is 5.0×10^6. The pseudorapidity and momentum range considered are $-1.0 \le \eta \le 1.0$ and $0.2 \le p_T \le 2.0$ GeV/c respectively.

Variations of scaled variance for all charged

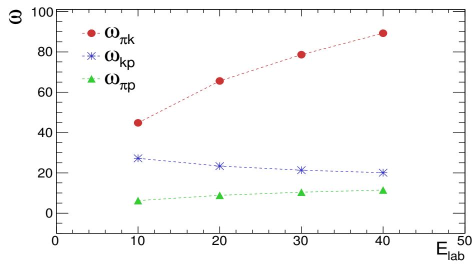

FIG. 1: Beam energy dependence of $\omega_{N_{ch}}$ for all charged hadrons with.

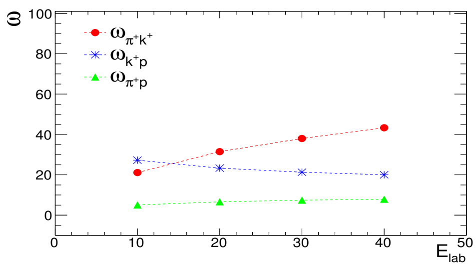

FIG. 2: Same plot as in FIG.2 but for positively charged hadrons.

hadrons, $\omega_{N_{ch}}$ with incident energy for various centrality classes are shown in FIG.1. It is noted that $\omega_{N_{ch}}$ increases with increasing centrality and beam energy. For centrality class $\geq$ 25% the increase in the value of $\omega_{N_{ch}}$ with energy exhibits a linear trend. A weaker dependence of $\omega_{N_{ch}}$ on beam energy for central collisions, in comparison to that in semi-central and peripheral collisions may also be noticed in the figure. These findings are in close agreement with those reported for pp collisions by NA61 collaboration[1].

Dependence of ω, estimated for identified

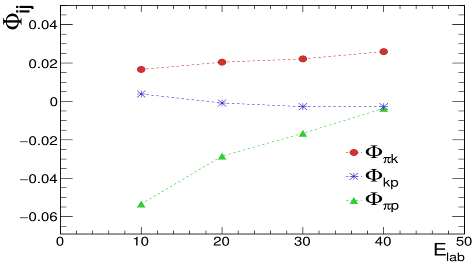

FIG. 3: Dependence of Φ_{ij} on incident energy.

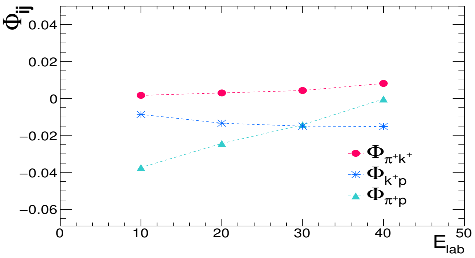

FIG. 4: Variations of Φ_{ij} for positively charged hadrons with incident energy.

hadrons, i.e., ω_π, ω_k and $\omega_{p\bar{p}}$ on beam energy is plotted in FIG.2. It is observed that ω_π increases with energy whereas ω_k and $\omega_{p\bar{p}}$ values are nearly independent of incident energy. The observed linear increase of ω_π and $\omega_{N_{ch}}$ with energy is expected from the KNO scaling predictions[1]. FIG.3 shows the similar plots but for identified charged particles, i.e., π^+, k^+ and $p\bar{p}$. It may be noted from FIG.2 and 3 that $\omega_{\pi^+} \sim 2\omega_\pi$ while $\omega_{k^+} \sim \omega_k$ and $\omega_p \sim \omega_{p+\bar{p}}$. This indicates that the fluctuations of sum of charges (for $k^+ + k^-$ and $p + \bar{p}$) is dominated by k^+ and p. The observed values of ω_k and ω_{k^+} are probably connected to the strangeness conservation which in turn would suggest correlated production of kaons[1]. Significantly smaller values of ω_p and $\omega_{p+\bar{p}}$ may be due to baryon number conservation. The net baryon number in ion-ion collisions would depend on the collision centrality and the fluctuations of $p + \bar{p}$ is dominated by the protons.

It has been suggested[1] that the influence of specific charge conservation on the scaled variance depend on the volume of the system, particle anti-particle ratio, mean multiplicity and masses of the charge carriers. In order to reduce the volume fluctuation effects, an intrinsic measure, $\Phi_{ij} = \frac{\sqrt{\langle n_i\rangle\langle n_j\rangle}}{\langle n_i+n_j\rangle} \times (\sqrt{\Sigma^{ij}} - 1)$, where $\Sigma^{ij} = [\langle n_i\rangle \omega_j + \langle n_j\rangle \omega_i - 2(\langle n_i n_j\rangle - \langle n_i\rangle \langle n_j\rangle)]/\langle n_i + n_j\rangle$; i, j represent two different hadron types. Φ_{ij} is independent of volume and its fluctuation. $\Phi_{ij} = 0$ for independent emission.

Variations of Φ_{ij} for various pairs of hadrons with incident energy for different data sets are displayed in FIG.4. In FIG.5 similar plots for positively charged hadrons are displayed. The following facts may be noted from the figures.

1. A slight increase in the values of $\Phi_{\pi k}$ and $\Phi_{\pi^+k^+}$ and also that values of $\Phi_{\pi k}$ and $\Phi_{\pi^+k^+}$ are positive.
2. $\Phi_{\pi p+\bar{p}}$ and Φ_{π^+p} acquire values < 0 at all energies but the values increase with energy.
3. Values of $\Phi_{kp+\bar{p}}$ and Φ_{k^+p} are independent of energy.

Centrality bin width effects on the scaled variance has also been looked into by examining the dependence of ω on centrality classes by changing the centralities in steps of 2, 5 and 10% bin-width. The findings suggest that for a bin width corresponding to 5% the statistical fluctuations are under control and considering such bins would lead to make remarks on the dynamical fluctuations, is present [4].

References

[1] Maja Maćkowiak-Pawłowska and Andrzej Wilczek and, NA61 coll. *J.Phys.Conf.Ser.* **509** (2014) 012044.

[2] Z. Fodor and S. D. Katz, *J. High Energy Phys.* **0404** (2004) 050.

[3] NA35 coll. *Z. Phys.* **C65** (1992) 347.

[4] Anuj Chandra et al. *Adv. High Energy Phys.* (2019) to be published.