A study of forward backward correlations of identified particles in heavy-ion collisions with a strongly intensive quantity Σ

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Introduction

In high-energy hadronic and heavy-ion collisions, particle production is governed by several conservation laws, with the most relevant being the conservation of electric charge, strangeness, and baryon quantum numbers. Two primary approaches commonly used for the phenomenological modeling of particle production are the statistical hadronization model (SHM) and string fragmentation [1, 2]. These conservation laws are handled differently in SHM and string fragmentation models. In SHM, the conservation laws apply within a finite correlation volume, whereas in string fragmentation, quantum numbers are conserved locally. As a consequence, in SHM, the correlation strength between two particles, whether they have the same or opposite quantum numbers, decreases as the correlation volume increases. In contrast, the string fragmentation model shows a strong correlation predominantly between oppositely charged hadrons due to the imposition of conservation laws on each string breaking.

The event-by-event measurements of correlation between different hadron species can be used to probe this difference in the quantum number conservation between these two models. In this work, we use a strongly intensive quantity called Σ [3] which is defined as,

$$\Sigma = \frac{\omega_B\langle N_F\rangle + \omega_F\langle N_B\rangle - 2Cov(N_F, N_B)}{\langle N_F\rangle + \langle N_B\rangle} \tag{1}$$

to study the forward(F)-backward(B) multiplicity correlations between different hadrons.

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Here F and B refers to forward and backward pseudorapidity (η) intervals, symmetrically placed around η=0, $\langle N_{F/B}\rangle$ denotes average particle multiplicity in F/B η-region and $\omega_{F/B}$ stands for scaled variance of particle multiplicity.

To test the sensitivity of this observable to the correlation strength between different particles, we use particles simulated from a model called Ultra relativistic Quantum Molecular Dynamics (UrQMD). UrQMD is basically a hadronic transport model, where particles are produced from resonance decay and fragmentation of excited strings.

Model setup and Analysis

We simulate events for central (0-5%) Pb-Pb collision at $\sqrt{s}$ = 6.27 and 17.3 GeV from UrQMD 3.4 with its default parameter settings. These two energies corresponds to 30 and 158 AGeV respectively, in lab frame. In each event, the produced particles divided into two groups. One with $\eta > 0$ which we call forward (F) going particles and another with $\eta < 0$ which we refer to as backward (B) going particles. While calculating Σ, a subset of F and B going particles are chosen which lie in the η-region ($\Delta\eta$) of 0.25 or its integer multiple.

Results and Discussion

Figure 1 shows the FB correlations between unlike sign pions, kaons and protons as a function of pseudorapidity ($\Delta\eta$) interval for 0-5% most central Pb-Pb collisions at 17.3 GeV or 158 AGeV. Pions and kaons exhibit a significant $\Delta\eta$ dependence with a sharp decrease upto $\Delta\eta$ 1 followed by a saturation. Protons on the other hand, shows no variation with $\Delta\eta$. For pions and kaons, this observed deviation of Σ from unity may partly arise

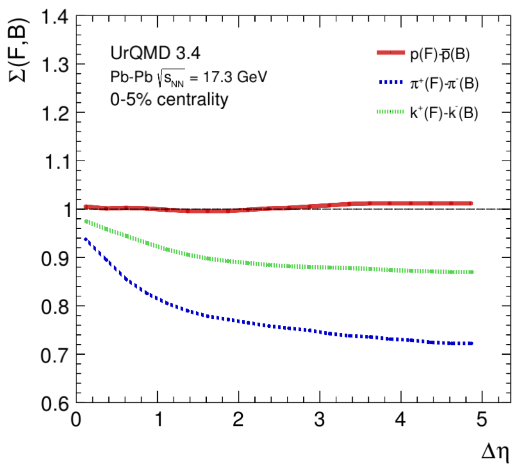

FIG. 1: Pseudorapidity interval ($\Delta\eta$) dependence of FB Correlator Σ for unlike sign pions, kaons and protons in 0-5% central Pb-Pb collisions at $\sqrt{s_{NN}} = 17.3$ GeV

from the resonance decays of $\rho \to \pi^+\pi^-$ and $\phi \to K^+K^-$. As the $\Delta\eta$ interval is broadened more and more decay pairs are accepted giving a positive contribution to $Cov(N_F, N_B)$ in Eq.1 leading to its deviation from unity. Protons however, show no deviation from unity. This could be partly because resonance decay contributions for protons are negligible as no resonances decay to p$\bar{p}$ with a sizeable branching ratio. Also there could be a role of global baryon number conservation. Detailed study on the impact of resonance contribution to FB correlations will be done later.

It may also be noted that in narrower $\Delta\eta$ interval Σ approaches to unity. This is because the phase space distribution of produced particles in small acceptance approaches Poisson limit, where dynamical correlations vanish. In the Poisson limit $\omega_F = \omega_B \to 1$ and $Cov(N_F, N_B)$ approaches to zero resulting in Σ approaching to unity.

We repeat the same analysis at a lower energy of $\sqrt{s_{NN}} = 6.23$ GeV or 30 AGeV in the lab frame. Similar to Fig 1, we plot $\Sigma(F, B)$ as a function $\Delta\eta$ in Fig. 2. It suggests that in UrQMD, the underlying mechanisms of particle productions does not change with the collision energy, atleast in the energy range where this study has been done.

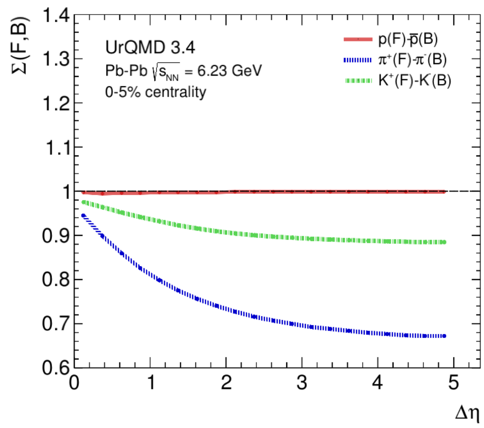

FIG. 2: Pseudorapidity interval ($\Delta\eta$) dependence of FB correlator Σ for unlike sign pions, kaons and protons in 0-5% central Pb-Pb collisions at $\sqrt{s_{NN}} = 6.23$ GeV

References

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