Investigation of forward-backward correlation in hybrid UrQMD-hydro at 10 AGeV Au+Au collisions

Somen Gope,* Supriya Das, and Saikat Biswas
Department of Physical Sciences, Bose Institute, Kolkata-700091, INDIA

Introduction

The investigation of Quark-Gluon Plasma (QGP) is vital for understanding the fundamental characteristics of matter under extreme conditions, providing valuable insights into the early universe and the dynamics of the strong nuclear force. Furthermore, the energy density in the Compressed Baryonic Matter (CBM) experiment at the future Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany, is anticipated to reach the critical value of energy density, potentially inducing a phase transition (PT) from hadronic matter to QGP [1]. Various observables, including forward-backward correlation, can indicate the existence of such a phase transition.

In high-energy nuclear collisions, initial fluctuations cause collective behavior and correlations. Short-range correlations are limited to narrow rapidity ranges, while long-range correlations span wider gaps and are crucial for understanding early-stage dynamics and phase transitions [2].

Relativistic viscous hydrodynamic models have proven highly effective in describing the characteristics of the hot and dense matter created in heavy-ion collisions [3]. Therefore, hydrodynamic models are well-suited for such studies. This study aims to investigate the forward-backward correlation of produced particles in Au+Au collisions at 10 AGeV energy using the hybrid UrQMD-hydro event generator [4].

Mathematical Formalism

To calculate the forward-backward multiplicity correlation in rapidity or pseudorapidity (for higher energies) space, we define forward and backward zones with respect to the central rapidity and y_{gap} is the distance between forward and backward zones. Mathematically, the correlation coefficient (b_{corr}) is represented by the formula:

$$b_{corr} = \frac{\langle N_F N_B \rangle - \langle N_F \rangle \langle N_B \rangle}{\langle N_F^2 \rangle - \langle N_F \rangle^2} \qquad (1)$$

where, N_F and N_B are the multiplicities in forward and backward zones respectively [3, 5].

Results

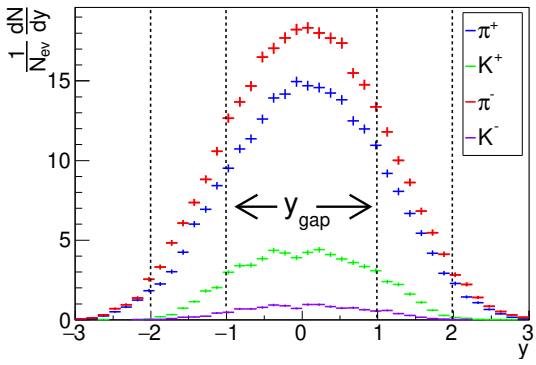

FIG. 1: Rapidity spectra of identified π^+, π^-, K^+, and K^- produced in minimum bias (MB) Au+Au collisions at 10 AGeV using UrQMD-hydro (default) generated data.

The analysis begins with data of 40 K events using the hybrid UrQMD-hydro model for 10 AGeV minimum bias Au+Au collisions. This analysis focuses on rapidity space, where the rapidity spectra for identified pions and kaons are plotted using the mentioned Monte Carlo (MC) data. Fig. 1 shows the rapidity spectra of identified pions and kaons.

*Electronic address: somengope30@jcbose.ac.in

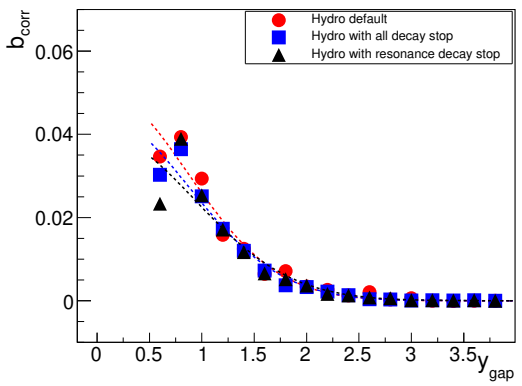

FIG. 2: y_{gap} vs. b_{corr} for all charged particles produced in 10 AGeV Au+Au collisions.

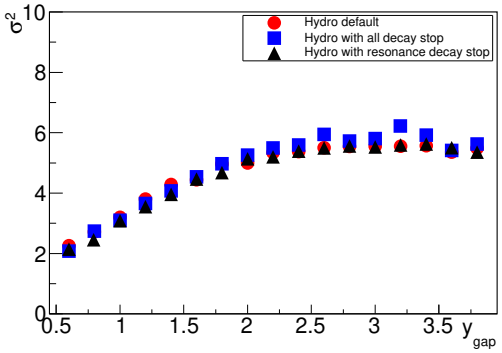

FIG. 3: y_{gap} vs. σ^2 for all charged particles produced in minimum bias 10 AGeV Au+Au collisions.

b_{corr} is calculated using `equation 1`. In Fig. 2, b_{corr} is plotted as a function of y_{gap} for three different data sets, each generated by varying specific parameters to observe changes in the values of correlation length (λ) or collision dynamics. The first data set was generated using the hybrid UrQMD-hydro model without altering any parameters. The 2^{nd} and 3^{rd} data sets were generated by stopping meson-meson and meson-baryon scattering and resonance decays, and by stopping only resonance decays, respectively. The plot y_{gap} vs. b_{corr} is fitted using the `equation 2` to find the values of the parameter δ, and δ is related to λ as $\lambda = 2\delta/\sqrt{\pi}$.

$$b_{corr} \propto \exp\left(-\frac{y_{gap}^2}{\delta^2}\right) \qquad (2)$$

The correlation length λ and parameter δ for all three sets of data are listed in `table 1`. The listed values indicates there is existance correlations in the UrQMD-hydro generated data at 10 AGeV Au+Au collisions. The contribution of correlations coming from long range correlation.

Research indicates that the value of variance (σ^2) signifies the presence of long-range correlation. The detailed formulation of σ^2 is derived in [5]. In the absence of such correlations, σ^2 equals unity. Fig. 3 shows the plot of y_{gap} vs σ^2. The results suggest that long-range correlations are present in the UrQMD-hydro generated data.

TABLE I: Values of δ and λ for three different sets of data.

Systems	δ	λ
Data with default mode	1.24 ± 0.06	1.40
Data with resonance decays stop	1.31 ± 0.11	1.48
Data with all decays stop	1.21 ± 0.06	1.37

Acknowledgments

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