System size and beam energy dependence of longitudinal asymmetry

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Introduction

In a collision of two identical heavy nuclei, the number of participating nucleons fluctuates event-by-event due to fluctuations in their positions around the mean nuclear density profile. This results in a shift in rapidity of the participant zone with respect to the nucleon-nucleon centre of mass rapidity [1]. This is known as longitudinal asymmetry characterized by the rapidity shift y_0 [1–4]. The rapidity shift can be measured experimentally from the asymmetry in the energy deposition by the spectator nucleons in the two Zero-Degree Calorimeters (ZDCs). The longitudinal asymmetry is expected to affect the observables more which depend directly on the rapidity, like the charged particle rapidity distribution [2, 3]. In the present work, we have used AMPT model [5] (with string melting (SM)) to investigate the effect of the longitudinal asymmetry on the charged particle rapidity distribution and anisotropic flow parameters from Cu+Cu and Au+Au collisions at $\sqrt{s_{NN}}$= 200 GeV and 62.4 GeV at RHIC [6].

Formalism

The longitudinal asymmetry in participants is defined as, $\alpha_{part} = (A - B)/(A + B)$ and in spectators can be expressed as, $\alpha_{spec} = \frac{(N-A)-(N-B)}{(N-A)+(N-B)} = -\alpha_{part}\frac{A+B}{2N-(A+B)}$ where A and B are the number of participants from two nuclei and N represents the total number of nucleons in each nuclei. The rapidity shift is approximated as [2, 3],

$$y_0 \approx \frac{1}{2} ln \frac{A}{B} \tag{1}$$

This is obtained by assuming $m_0 \ll p$ at RHIC ($m_0/p < 10^{-4}$). It can be expressed in terms of longitudinal asymmetry as,

$$y_0 = \frac{1}{2} ln \frac{1 + \alpha_{part}}{1 - \alpha_{part}}. \tag{2}$$

For small α_{part}, $y_0 \approx \alpha_{part}$. It can also be expressed as,

$$y_0 = \frac{1}{2} ln \frac{(A + B)(1 + \alpha_{spec}) - 2N\alpha_{spec}}{(A + B)(1 - \alpha_{spec}) + 2N\alpha_{spec}}. \tag{3}$$

Effect on the rapidity distribution

The rapidity distribution of chrged particles in the participant zone with rapidity shift y_0 is described by a Gaussian,

$$\frac{dN}{dy} \propto e^{-\frac{(y-y_0)^2}{2\sigma^2}} \tag{4}$$

where, σ is the width of the Gaussian distribution. The ratio of the symmetric and asymmetric distributions can be expanded in a power series of y as [2, 3]

$$\frac{dN/dy|_{sym}}{dN/dy|_{asym}} = \frac{f(y)}{f(y - y_0)} \propto \sum_0^{\infty} c_n(y_0, \sigma) y^n \tag{5}$$

where, c_n are the coefficients of the Taylor expansion. The coefficients of the expansion depend on the shape of the actual rapidity distribution and also on rapidity shift y_0. The dominant linear term in the expansion signifies the magnitude of asymmetry. The coefficients are extracted by fitting the ratio to a third-order polynomial [2, 3]. The width of the distribution decreases with increasing centrality and as a result the slope of c_1 increases.

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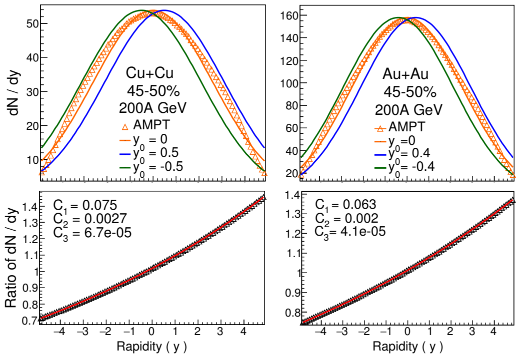

FIG. 1: The $\frac{dN}{dy}$ distributions from Cu+Cu and Au+Au collisions for 45–50% centrality bin [upper panel]. The ratio of the distributions is fitted to a third-order polynomial [lower panel]. These y_0 values are the maximum shift in rapidity. [6]

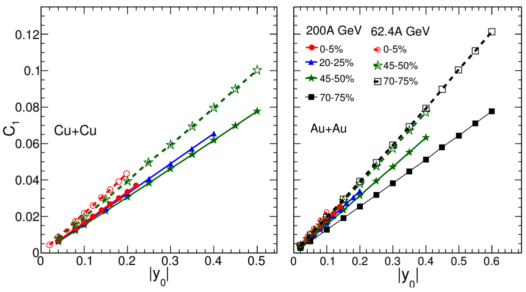

FIG. 2: The dependence of the coefficients c_1 on rapidity shift y_0 from Cu+Cu and Au+Au at $\sqrt{s_{NN}}$ =200 GeV and 62.4 GeV [6].

Effect on flow coefficients

The anisotropic flow parameters of the charged particles are also affected by the rapidity shift. Both the elliptic and the triangular flow parameters are found to decrease when the rapidity shift is included as shown in Fig 3 [6]. However, the effect is more visible for the triangular flow parameter.

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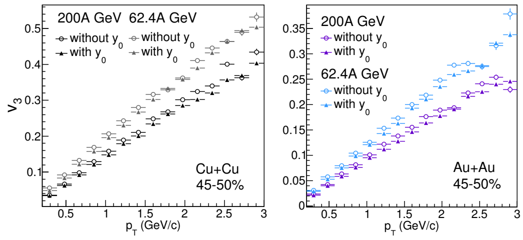

FIG. 3: The effect of y_0 on the p_T dependent flow coefficients v_2 and v_3 from Cu+Cu and Au+Au at $\sqrt{s_{NN}}$ =200 GeV and 62.4 GeV at 45–50% centrality bin [6].

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