Study of event-by-event charge separation in Au+Au collisons at $\sqrt{s_{NN}}$ = 200 GeV using AMPT

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Introduction

In the view of the theoretical studies, it has been proposed that some metastable states leading to the local parity violation, may be created in the ultra-relativistic heavy-ion collisions [1]. The interplay between the strong magnetic field (B $\sim 10^{15}$ T) and the deconfined state created in such collisions leads to the separation of positively and negatively charged particles along the axis of magnetic field. This phenomenon of the charge separation along the axis of magnetic field and perpendicular to the reaction plane is known as Chiral Magnetic Effect (CME)[2]. The multiparticle correlator $\langle\cos(\phi_\alpha + \phi_\beta - 2\Psi_{\rm RP})\rangle$ has been proposed for the observation of charge separation [3]. Here, ϕ_α, ϕ_β represent the azimuthal angles of the particles α, β and $\Psi_{\rm RP}$ is the reaction plane angle.

Measurement Technique

We are investigating event-by-event charge separation using Sliding Dumbbell Method (SDM), where we calculate the observable $\mathrm{Db}_\pm$, which is defined as:

$$Db_\pm = \frac{N_+^{forw}}{(N_+^{forw} + N_-^{forw})} + \frac{N_-^{back}}{(N_+^{back} + N_-^{back})}. \quad (1)$$

N_+^{forw} and N_-^{forw} are the numbers of positively and negatively charged particles on the forward side of the dumbbell respectively. N_+^{back} and N_-^{back} are the numbers of positively and negatively charged particles on the backward side of the dumbbell respectively. The whole azimuthal plane is scanned by sliding the $\Delta\phi$ =60° dumbbell in the steps of $\delta\phi$ =1° and calculating the observable $\mathrm{Db}_\pm$ for each $\Delta\phi$ region to extract the maximum value of $\mathrm{Db}_\pm$. For each event the maximum value of $\mathrm{Db}_\pm^{max}$ along with the condition that asymmetry (asy) < 0.25 is obtained, where asy can be defined as follows:

$$asy = \frac{Pos_{ex} - Neg_{ex}}{Pos_{ex} + Neg_{ex}} \quad (2)$$

Here, Pos_{ex}= N_+^{forw} − N_-^{forw} denote the excess of positive charges on the forward side of the dumbbell and Neg_{ex}= N_-^{back} − N_+^{back} is the excess of negative charges on the backward side of the dumbbell. The $\mathrm{Db}_\pm^{max}$ distributions corresponding to different centrality intervals are obtained and further sliced into different groups depending upon the highest (0-10%) and lowest (90-100%) $\mathrm{Db}_\pm^{max}$ values. Two and three particle correlators for both same-sign and opposite-sign charged pairs are investigated as a function of centrality and $\mathrm{Db}_\pm^{max}$ binning. The background is estimated by reshuffling the charges of particles keeping θ and ϕ same. The results obtained by charge reshuffle are compared with those obtained from the simulated events.

Analysis Details

The AMPT (String melting On)∼ 2 million events for Au + Au collision at the center of mass energy $\sqrt{s_{NN}}$ = 200 GeV are generated [4]. The tracks in the pseudorapidity region $|\eta| < 1.0$ and transverse momentum range $0.15 < p_T < 2.0$ GeV/c in each event are used for the analysis.

Results and Discussions

The $\mathrm{Db}_\pm^{max}$ distribution for the 50-60% central events is presented in Figure 1. The solid curve is for the AMPT simulated data and the dotted curve is for the charge reshuffle. It has been observed that the

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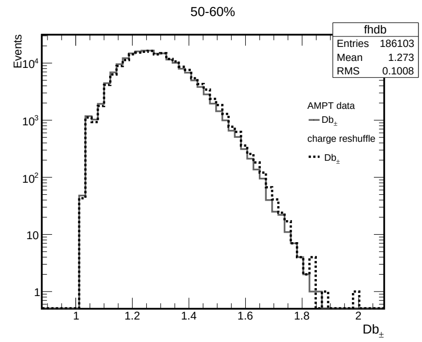

FIG. 1: Distributions of $\mathrm{Db}_{\pm}^{max}$ for 50-60% central events for AMPT simulated data (solid curve) and charge reshuffle (dotted curve).

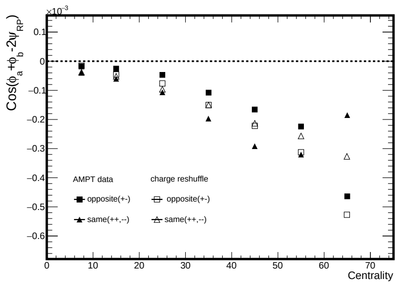

FIG. 2: Three-particle correlator for same and opposite-sign charged pairs of both AMPT simulated data (closed symbols) and charge reshuffle (open symbols) as a function of centrality.

distributions agree within statistical errors.

Figure 2 shows the three particle correlator of same-sign and opposite-sign charged pairs as a function of centrality for both AMPT simulated data and charge reshuffle. The closed symbols are for the AMPT simulated data and open symbols are for the charge reshuffle. It is seen that the correlation for the same and opposite-sign charged pairs is negative. Also, it has been observed that the correlation for oppositely charged pairs is relatively smaller than for the same-sign charged pairs and the correlation increases as we go from the central to the peripheral collisions. However, the correlation in charge reshuffle appears to be same for both same and opposite charged pairs. The $\gamma_{opp-same}$ correlator for each centrality interval, which is further divided into ten different groups depending upon the $\mathrm{Db}_{\pm}^{max}$ values is shown in figure 3. It has been seen that the particles are strongly correlated for the top $\mathrm{Db}_{\pm}^{max}$ bins.

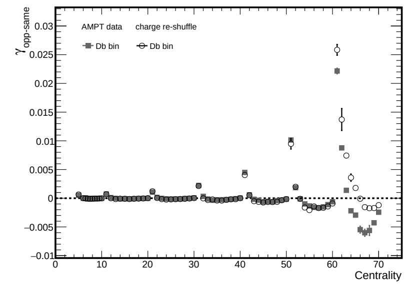

FIG. 3: The centrality dependence of $\gamma_{opp-same}$ corresponding to different $\mathrm{Db}_{\pm}^{max}$ values.

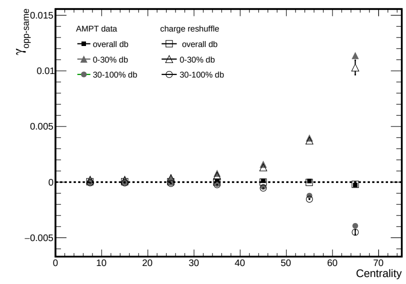

FIG. 4: γ correlator for both AMPT data (closed symbols) and charge reshuffle (open symbols) as a function of centrality corresponding to 0-30% and 30-100% $\mathrm{Db}_{\pm}^{max}$ bins.

Figure 4 displays the γ correlator as a function of centrality, corresponding to the 0-30% and 30-100% $\mathrm{Db}_{\pm}^{max}$ bins in each centrality. The closed symbols are for AMPT simulated data and the open symbols are for the charge reshuffle. It has been observed that the charge reshuffle is coinciding with the AMPT simulated data results even for the top 30% $\mathrm{Db}_{\pm}^{max}$ bins in each centrality interval. As there is no signal of CME or charge separation expected in AMPT model so both the AMPT simulated data and the charge reshuffle exhibiting the similar trend. Further the results will also be presented for the events sample having initial CME signal introduced by flipping the charges of some particles.

References

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