Searching CME using Sliding Dumbbell Method in Pb-Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV using AMPT

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1. Introduction

Chiral imbalance along the magnetic field produced during the heavy-ion collisions causes the charge separation along the magnetic field direction. This phenomena is known as chiral magnetic effect (CME) [1]. Experimental observable (γ) was proposed [2] to measure the charge separation.

$$\begin{aligned}\gamma &= \langle cos(\phi_a + \phi_b - 2\psi_{RP})\rangle \\ &= \langle cos(\phi_a + \phi_b - 2\phi_c)\rangle / v_{2,c}\end{aligned} \quad (1)$$

Here $\phi_{a/b/c}$ are azimuthal angles of particles "a" ,"b" and "c", ψ_{RP} is the reaction plane angle and $v_{2,c}$ is elliptic flow of the third particle "c". The average is taken over the particles within the event and over all the analyzed events in a given sample. We developed a new method to study event-by-event back-to-back charge separation, Sliding Dumbbell Method (SDM), and checked its realibility on AMPT model which will be presented here alongwith the method discription.

2. Analysis Details

A. Sliding Dumbbell Method

Sliding dumbbell method will be used to characterize the events which exhibit enhanced chiral magnetic effect. In SDM, sum ($Db_\pm$) of positive charge fraction (Db_+) on one side of the dumbbell and negative charge fraction (Db_-) on oppposite side of the dumbbell is calculated. For an event, the whole azimuthal plane is investigated by sliding the dumbbell of $\Delta\phi = 90^0$ in steps of $\delta\phi = 1^0$ to get the maximum value of $Db_\pm$. Asymmetry cut $|Db_{asy}| < 0.25$ is applied to extract the maximum value of $Db_\pm$ in each event. Here Db_{asy} is defined as:

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

where, $Pos_{ex}^{forw} = N_+^{forw} - N_-^{forw}$ is positive charge excess in the forward side of dumbbell and $Neg_{ex}^{back} = N_-^{back} - N_+^{back}$ is negative charge excess in the backward side of dumbbell. Obtained distributions of $Db_\pm^{max}$ for each centrality are divided into ten bins and γ correlator is calculated for each bins. Background study is done by reshuffling the charges of particles randomly, hence omitting any charge dependent correlation.

B. Data sets and Selection Criteria

A Multi Phase Transport (AMPT) model [3] is a monte carlo model used for to describe nuclear collisions ranging from center-of-mass energies from about $\sqrt{s_{\rm NN}} = 5$ GeV up to 5500 GeV. We have tested the realibility of the SDM using Pb-Pb events at $\sqrt{s_{\rm NN}} = 2.76$ TeV generated through AMPT String Melting ON with reaction plane angle, $\Psi_{RP} = 0$. CME type signal is externally injected in the AMPT generated events as default AMPT does not have CME. We are analyzing 4 different sets of AMPT events having 1.6M events as listed below:

1. Default AMPT : Default AMPT SM on data having zero CME signal.
2. 1_Fix CME signal : Sample generated by flipping the charges of one +ve and one -ve particles perpendicular to the reaction plane in AMPT generated events.
3. 50% Default + 50% 1_Fix : Sample created by taking 50% events from default

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AMPT and 50% events from 1_Fix signal.

4. 2_Fix CME signal : Same as 1_Fix except charges of two +ve and two -ve particles are flipped here.

Injected CME signal has been kept constant i.e., independent of collision centrality and event multiplicity. Transverse momentum and pseudorapidity track cuts are used as $0.2 < p_T < 5$ GeV/c and $-0.8 < \eta < 0.8$.

3. Results and Discussion

Figure 1 shows the $Db^{max}_{\pm}$ distributions for 4 different AMPT data sets for 40-50% and 50-60% centralities. It can be seen from the figure that data sets with higher injected CME signal have higher $Db^{max}_{\pm}$ values.

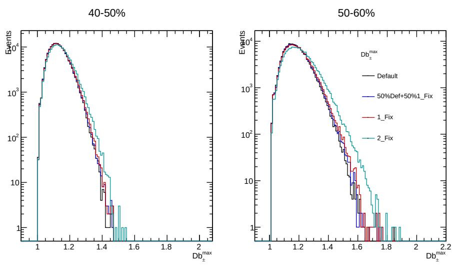

FIG. 1: $Db^{max}_{\pm}$ distributions obtained using the sliding dumbbell method for data and charge reshuffled for 40-50% and 50-60% centrality intervals.

Figure 2 shows the centrality dependence of $\Delta\gamma = \gamma_{OS} - \gamma_{SS}$ for each ten bins. The correlation values become more positive as the signal contribution increases indicating the strong dependence of three particle correlator on the injected signal strength. It is also observed that the number of $Db^{max}_{\pm}$ bins exhibiting positive value of $\Delta\gamma$ are different for different data sets and centralities indicating different no. of events exhibiting CME type effect.

From $\Delta\gamma$, we calculate the fraction of CME by using the following equation for those $Db^{max}_{\pm}$ bins for which $\Delta\gamma_{AMPT} > 0$ where $\Delta\gamma_{AMPT}$ is $\Delta\gamma$ for different sets of AMPT samples.

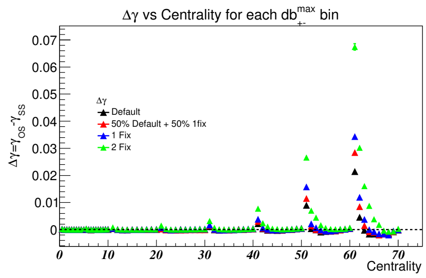

FIG. 2: Centrality dependence of $\Delta\gamma$ for different $Db^{max}_{\pm}$ bins for data and charge reshuffle.

$$f_{CME} = \left(\frac{\Delta\gamma_{AMPT} - \Delta\gamma_{ch.re}}{\Delta\gamma_{AMPT}}\right) * f_{nevt} \quad (3)$$

where f_{nevt} is the fraction of events exhibiting positive value of $\Delta\gamma$ and $\Delta\gamma_{ch.re}$ is $\Delta\gamma$ for charge reshuffle background. Fig.**??** shows the f_{CME} versus collision centrality for different sets of AMPT generated events. We can see from the figure that fraction is almost zero for default AMPT as expected and for different sets of CME injected AMPTs, fraction decreases with increasing collision centrality.

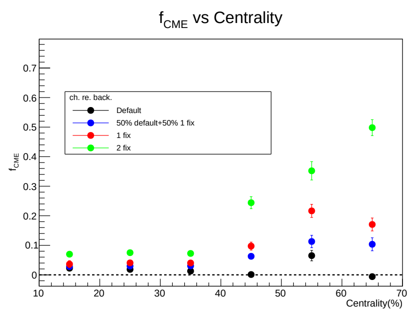

FIG. 3: Centrality dependence of f_{CME}

References

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[3] Zi-Wei Lin *et al.*, Phys. Rev. C **72**, 064901 (2005).