Constraining the Chiral Magnetic Effect in heavy ion collisions using AMPT model

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Introduction

D. Kharzeev [1] proposed the possibility of strong P and CP violation in ultra relativistic heavy ion collisions. The emission of positive and negative charged particles in opposite directions and perpendicular to the reaction plane (defined by impact parameter and beam direction) leads to the signal of P and CP violation. The imbalance of charged particles associated with the strong magnetic field (B $\sim 10^{15}$ T) would exhibit the charge separation in the direction of magnetic field, known as Chiral Magnetic Effect (CME) [2]. Many high energy experiments investigated the CME at different center of mass energies at RHIC (Relativistic Heavy Ion Collider) in STAR $\sqrt{s_{\rm NN}}$ = 7.7-200 GeV [3] and at LHC (Large Hadron Collider) in ALICE $\sqrt{s_{\rm NN}}$ = 2.76 TeV [4] and CMS at $\sqrt{s}$ = 5.02 TeV [5]. Voloshin introduced the multi particle correlator, $\langle \cos(\phi_a + \phi_b - 2\psi_{RP}) \rangle \equiv \langle \cos(\phi_a + \phi_b - 2\phi_c) \rangle / v_2$ for the measurement of charge separation [6]. Here, ϕ_a, ϕ_b and ϕ_c are the azimuthal angles of charged particles a, b, c, and ψ_{RP} is the reaction plane angle. v_2 represents the elliptic flow of particle c.

The simulation study of the multi particle correlator (γ) is performed for different charge combinations, opposite sign (OS) (+ -) and same sign (SS) (++, - -) charge pairs at 2.76 TeV using AMPT model.

A Multi Phase Transport Model

The simulation study plays a crucial role in understanding the theoretical predictions of different physics topics in relativistic heavy ion collisions. AMPT (A Multi Phase Transport Model) is a Monte Carlo event generator and it contains four basic parts: the initial conditions, partonic interactions, hadronization process and hadronic rescattering. The explanation of these processes can be found in ref. [7]. The AMPT generated Pb-Pb events at 2.76 TeV have been analyzed for different centralities from 20-70%. The charged particles are selected with p_T range 0.2 < p_T <5.0 GeV/c and pseudo rapidity interval $\eta < |0.8|$.

Analysis Method

In this analysis, the Sliding Dumbbell Method is used [8] to study localized charge separation on event-by-event basis. One expects the excess of positive charged particles on one side of the dumbbell and negative charged particles on the other side of the dumbbell showing charge separation effect perpendicular to the reaction plane. The observable is defined as,

$$Db_{+-} = \frac{N_{+}^{left}}{(N_{+}^{left} + N_{-}^{left})} + \frac{N_{-}^{right}}{(N_{+}^{right} + N_{-}^{right})} \tag{1}$$

where N_{+}^{left} and N_{-}^{left} are the positive and negative charged particles on left side of the dumbbell whereas N_{+}^{right} and N_{-}^{right} are the positive and negative charged particles on right side of the dumbbell. The fraction Db_{+-} is estimated by sliding the window of fixed size $\Delta\phi = 40^\circ$ by 1° over the full azimuth and maximum of Db_{+-} is selected in each event. The Db_{+-}^{max} distribution is plotted for each centrality. For general case, the distribution peaks around 1 and for the CME, distribution shifts toward higher Db_{+-}^{max} value. Further, the Db_{+-}^{max} distribution is divided into 10 bins with highest (lowest) Db_{+-}^{max} value corresponds to 0-10% (90-100%) and analyzed the three particle correlator in

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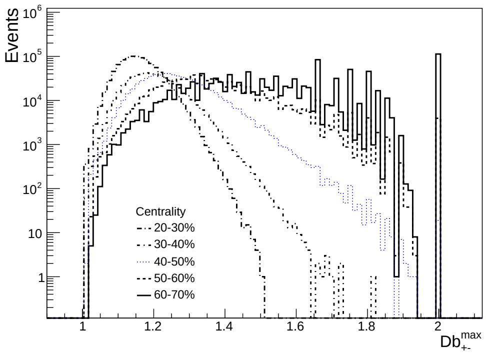

FIG. 1: Db^{max}_{+-} distribution obtained using sliding dumbbell for 20-70% centrality interval.

each Db^{max}_{+-} bin as a function of centrality. To estimate the background contribution, the charges of particles are reshuffled over the azimuthal plane keeping θ, ϕ same and the results are compared with those obtained using AMPT without charge reshuffle.

Results

AMPT generated Pb-Pb events at $\sqrt{s_{\rm NN}} =$ 2.76 TeV are analyzed and the distributions of Db^{max}_{+-} are displayed in FIG. 1 and the three particle correlator is estimated in different Db^{max}_{+-} bins. FIG. 2 shows the comparison of AMPT data points with those obtained by reshuffling the charges, it is observed that both agree within the statistical uncertainties as expected since there is no CME signal in the AMPT generated events. The SS charge pairs have negative values for each centrality in each Db^{max}_{+-} bin showing strong correlation while the OS charge pairs are positive and have no correlation. The difference of OS and SS charge pairs are also positive for all centralities. It is observed that the reshuffle of charges in each event exhibit similar trend as AMPT without charge reshuffle.

References

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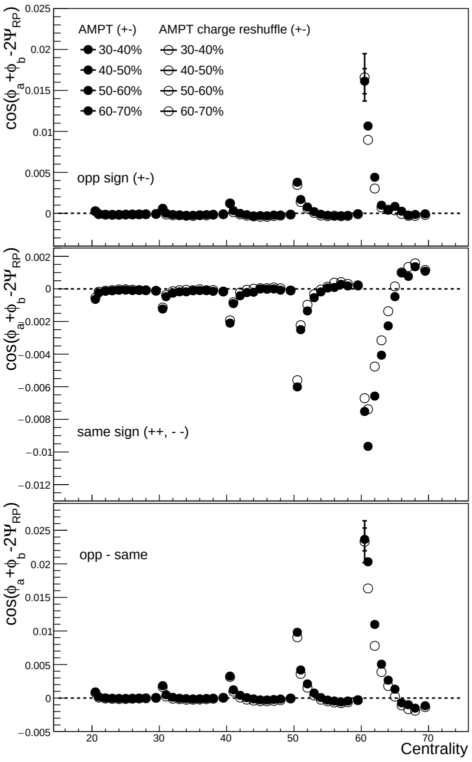

FIG. 2: The three particle correlator for same sign (++, - -) (top) and opposite sign (+-) (middle) and the difference of opp and same sign (bottom) charge pairs as a function of Db^{max}_{+-} bins for each collision centrality.

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