Event-by-Event study of charge separation effect with ALICE

Anjali Sharma for ALICE Collaboration*
Department of Physics, Panjab University, Chandigarh, India

1. Introduction

In the QCD deconfined phase region, QCD vacuum can possess metastable domains which leads to P/CP violations [1]. These P/CP odd domains along with the presence of non-zero magnetic field in heavy-ion collisions leads to charge separation in the produced particles [2]. Voloshin and others [3] proposed an experimental observable (γ) related to 3- particle correlator as defined in Eq. 1 to measure the charge separation.

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

Here $\phi_{a/b/c}$ are azimuthal angles of particles "a" ,"b" and "c", ψ_{RP} is the reaction plane angle (angle between impact parameter vector and beam axis) and $v_{2,c}$ is elliptic flow of the third particle "c". The angled brackets denote an average over the particles within the event and over all the analyzed events in a given sample.

STAR, ALICE and CMS investigated the Chiral Magnetic Effect using γ correlator [4–7]. In this cintribution, we will search the localized event-by-event back-to-back charge separation, with the background effects estimated by a new technique called Sliding Dumbbell Method (SDM).

2. Analysis Details

A. Sliding Dumbbell Method

The ultimate manifestation of the Chiral Magnetic effect is the separation of charged hadrons along the direction of the initial magnetic field. This back-to-back charge separation can easily be checked on event-by-event basis by using Sliding Dumbbell Method in which sum of positive charge fraction (Db_+) of particles on one side and negative charge fraction (Db_-) on oppposite side is calculated as depicted in the fig.1.

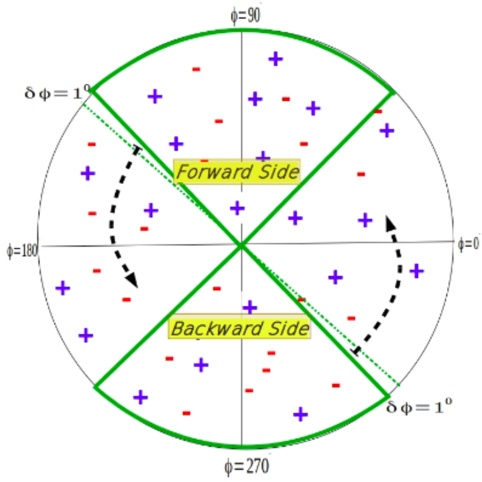

FIG. 1: Pictorial discription of SDM

Fraction $Db_\pm$ is defined as:

$$Db_\pm = Db_+ + Db_- \\ = \frac{N_+^{forw}}{N_+^{forw} + N_-^{forw}} + \frac{N_-^{back}}{N_+^{back} + N_-^{back}} \quad (2)$$

where N_+^{forw} and N_-^{forw} are the number of positively and negatively charged particles on the forward side of dumbbell, respectively whereas N_+^{back} and N_-^{back} are the number of positively and negetively charged particles backward side of dumbbell, respectively. The whole azimuthal plane in an event is then scanned by sliding a dumbbell of $\Delta\phi = 90^0$ in

*Electronic address: anjali.sharma@cern.ch

steps of $\delta\phi = 1^0$ while calculating the fraction $Db_\pm$ to extract the maximum value of $Db_\pm$ in each event. If the charged particles are uniformly distributed then the value of each fraction in Eq. 2, will be equal to 0.5 and the sum will be 1, but due to statistical fluctuations the value of each fraction can be different. Hence, $Db_\pm$ will not be equal to 1 and the maximum possible value of the fraction is 2 in case of complete charge separations.

The maximum value of $Db_\pm$ in each event is extracted with asymmetry $|Db_{asy}| < 0.25$. Here Db_{asy} is defined as:

$$Db_{asy} = \frac{(Pos_{ex}^{forw} - Neg_{ex}^{back})}{(Pos_{ex}^{forw} + Neg_{ex}^{back})} \qquad (3)$$

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. Thus obtained $Db_\pm^{max}$ distributions are then sliced into ten $Db_\pm^{max}$ bins. After slicing, 3- particle correlators for different charge combinations (same sign and opposite sign), are calculated for each $Db_\pm^{max}$ bin for each centrality. 3- particle correlators, $v_2\{2\}, v_2\{4\}$ are calculated using Q - cumulant method [5]. For background, we have used charge reshuffle method, in which we are reshuffling the charges of the particles randomly keeping ϕ and θ same. Reshuffling the charges randomly is expected to kill the charge dependent correlations.

B. Data set, Event and track cuts

ALICE Pb-Pb data at center of mass energy $\sqrt{s_{\rm NN}} = 5.02$ TeV is used for this analysis. Minimum bias events with vertex in the z-direction within $|V_z| <$ 10cm from interaction point are analyzed. Charged particle tracks measured with $0.2 < p_T < 5$ GeV/c and $-0.8 < \eta < 0.8$ with the distance of closest approach (DCA) to the primary-vertex less than 3.2 cm is used. The tracks with at least 70 hits in the Time Projection Chamber used in track reconstruction.

3. Results and Discussion

$Db_\pm^{max}$ distributions for different centralities have been studied and these distributions have sliced into ten bins. γ correlator for same sign charge pairs and opposite sign charge pairs is calculted for each ten bins in each centrality. Along with this, $\Delta\gamma = \gamma_{OS} - \gamma_{SS}$ is also obtained and its variation with centrality will be presented. Along with $\Delta\gamma$ for data, we have also calculated $\Delta\gamma$ for charge reshuffle as background. This study will provide a new approach to estimate background effect of CME and thus might show a new possibility to extract the CME fraction in the future studies.

References

[1] D. Kharzeev, R. D. Pisarski and M. H. G. Tytgat, Phys. Rev. Lett. **81**, 512 (1998).
[2] D. Kharzeev, Phys. Lett. B **633**, 260 (2006).
[3] Sergei A. Voloshin, Phys.Rev. C **70**, 057901 (2004).
[4] B. I. Abelev *et al.* STAR Collaboration, Phys. Rev. C **81**, 54908 (2010).
[5] B. Abelev *et al.* ALICE Collaboration, Phys. Rev. Lett. **110**, 012301 (2013).
[6] S. Achraya *et al.* ALICE Collaboration, Phys. Lett. B **777**, 151-162 (2018).
[7] V. Khachatryan *et al.* CMS Collaboration , Phys.Rev.Lett. **118**, 122301 (2017).