Search for the chiral magnetic effect with the ALICE experiment

Md Rihan Haque[1]
(for the ALICE Collaboration)
[1]National Institute of Science Education and Research (NISER), Odisha - 752050, INDIA*

Introduction

Relativistic heavy-ion collisions create a hot and dense medium of quarks and gluons named Quark–Gluon Plasma (QGP). The nonzero axial chemical potential in this QGP, induced by the chiral anomaly with an imbalance of left-and right-handed quarks, can produce an electric current along the magnetic field $\vec{B}$ created by the spectator protons. This current manifests itself as a charge separation along the direction of $\vec{B}$. This phenomenon is known as the chiral magnetic effect (CME) [1]. To measure the CME in heavy-ion collisions, angular correlations of charged particle are used. One such observable is a three–particle correlator given by

$$\gamma_{\rm mn} = \langle \cos({\rm m}\varphi_\alpha - {\rm n}\varphi_\beta - ({\rm m}-{\rm n})\Psi_{|{\rm m}-{\rm n}|})\rangle \quad (1)$$

where, φ is the azimuthal angle, and subscripts α, β correspond to the charge of the particle. The quantity $\Psi_{|{\rm m}-{\rm n}|}$ is called event plane (EP) angle which is estimated with the azimuthal distributions of selected particles in an event. Previous measurements in Au-Au collisions at $\sqrt{s_{\rm NN}}$ = 200 GeV by STAR [3] and in Pb–Pb collisions at $\sqrt{s_{\rm NN}}$ = 2.76 TeV by ALICE [5] shows that the magnitude of $\gamma_{1,-1}$ is of similar order, despite the fact that the difference of collision energies are more than 10 times.

While $\gamma_{1,-1}$ is sensitive to the CME, it also carries a lot of background correlations which needs to be quantified. A recent measurement from ALICE using event shape engineering (ESE) techniques gave an estimate of the CME fraction to be 26—33% at 85–95% confidence interval [5].

In this presentation, we report recent results of three—particle correlations relative to the 2$^{\rm nd}$, 3$^{\rm rd}$ and 4$^{\rm th}$ order EP for charged particles in Pb–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV. Following a novel data driven background approach, we estimate an upper limit of the CME fraction to be 15% (23%) at 95% (99.7%) confidence level in the centrality interval 0–40% of Pb–Pb collisions at LHC.

Experiment and Dataset

The main tracking devices of the ALICE detector are the Inner Tracking System (ITS) [6] and the Time Projection Chamber (TPC) [7]. A set of forward detectors, the V0 scintillator arrays [8], were used in the trigger logic and for the determination of the collision centrality. A detailed description of ALICE and its sub-detectors can be found in [6] and their performance in [9].

The analysis is performed using Pb–Pb events collected in 2010 and in 2015 at a centre-of-mass energy of $\sqrt{s_{\rm NN}}$ = 2.76 and 5.02 TeV, respectively. Events are analysed if the z–coordinate of the primary vertex (V_z) resides within ±10 cm from the nominal interaction point. The collision centrality is estimated from the amplitude measured by the V0 detectors as explained in [10]. Charged particles reconstructed by both TPC and the ITS are used for analysis, with pseudorapidity η and transverse momentum $p_{\rm T}$ ranges of $|\eta| <$ 0.8 and $0.2 < p_{\rm T} < 5.0$ GeV/c, respectively.

Results and Discussion

The measurements of the three–particle correlator $\gamma_{1,-1}$(Eq. 1) for same-sign and opposite-sign charged particle pairs are presented in Fig. 1. The results for same-sign

*Electronic address: rihan.h@niser.ac.in

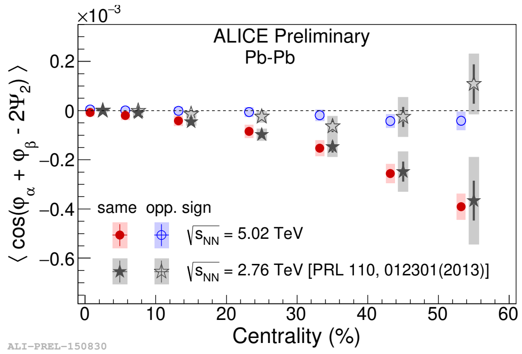

FIG. 1: $\gamma_{1,-1}$ for SS and OS charged pairs as function of centrality(%) in Pb–Pb collisions at $\sqrt{s_{\rm NN}}$ = 2.76 and 5.02 TeV. The vertical line (band) on each markers corresponds to the statistical (systematic) uncertainty.

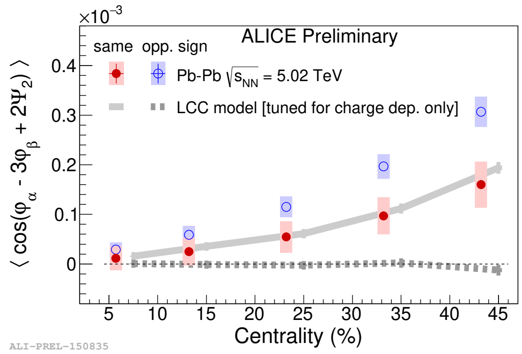

FIG. 2: $\gamma_{1,3}$ for SS and OS charged pairs as function of centrality(%) in Pb–Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV. The vertical line (band) on each markers corresponds to the statistical (systematic) uncertainty. Solid (dotted) lines corresponds to the LCC model prediction.

(SS) and opposite-sign (OS) charged particle pairs in Pb–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV are shown by solid and empty circles. The results of $\gamma_{1,-1}$ from Pb–Pb collisions at $\sqrt{s_{\rm NN}}$ = 2.76 TeV for SS and OS charged particle pairs are also shown as solid and empty stars. In Fig. 1, we observe that the magnitudes of $\gamma_{1,-1}$ for SS and OS are similar for the two collision energies. The results are also consistent with measurement by STAR Collaboration at RHIC at $\sqrt{s_{\rm NN}}$ = 200 GeV [4]. Figure 2 presents the mixed harmonic correlator $\gamma_{1,3}$ measurements by ALICE. The thick solid (dotted) lines in Fig. 2 correspond to $\gamma_{1,3}$ as predicted by a Blast-wave (BW) inspired Local Charge Conservation (LCC) model [11]. The LCC model uses the BW parameters (e.g. radial flow and its azimuthal modulation, initial spacial anisotropy) obtained from the fit to the experimentally measured flow and $p_{\rm T}$-spectra, as input. In Fig. 2, we observe that the simplistic LCC model cannot reproduce the measurements. The mixed ($\gamma_{1,3}$, $\gamma_{1,-2}$) and higher harmonic ($\gamma_{2,-2}$) three–particle correlators are sensitive to the background correlations, which are also present in $\gamma_{1,-1}$. We estimate an upper limit of the CME fraction to be 15% (23%) at 95% (99.7%) confidence level for the centrality interval 0–40% of Pb–Pb collisions at LHC. Detailed methodology will be discussed in the presentation.

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