Search for the Chiral Magnetic Effect in Au+Au collisions at $\sqrt{s_{NN}}$= 200 GeV

Jagbir Singh, for the STAR Collaboration

Panjab University, Chandigarh, India

Email: jagbir@rcf.rhic.bnl.gov

Abstract

Experimental searches for Chiral Magnetic Effect (CME) in heavy-ion collisions have been going on for a decade, but there is no conclusive evidence for its existence. A new technique, Sliding Dumbbell Method(SDM), is used to search event-by-event back-to-back charge separation [1]. The charge separation distribution for each collision centrality is divided into 10 percentile bins to get sample enriched in CME-like events. γ- correlator is obtained for 10 percentile bins for each collision centrality for data as well as background. The collision centrality dependence of CME fraction (f_{CME}) in the observed Δγ- correlator will be presented.

Introduction

- In non-central heavy-ion collisions, the strong magnetic field (B~10^{15} T) created by the fast moving nuclei induces an electric field along the axis of magnetic field which results in charge separation perpendicular to the reaction plane as shown in Figure 1. This phenomenon of charge separation is known as CME [2].
- Event-by-event study of charge separation is one of the obseravables to investigate the CME.
- The charge separation effect has been investigated both at RHIC and LHC using the CME sensitive γ-correlator [3,4].

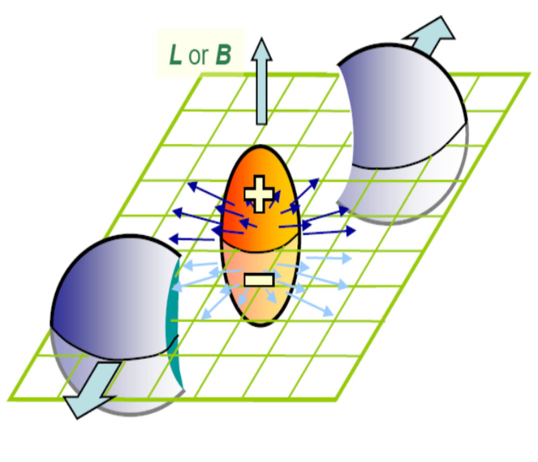

Figure 1: Schematic view of charge separation along magnetic field direction.

Experimental Setup

- The STAR (Solenoidal Tracker at RHIC) detector shown in Figure 2 at RHIC consists of various sub detectors, each specializing in detecting certain types of particles or characterizing their motion.
- The large acceptance of the STAR detector makes it well suited for event-by-event characterizations of heavy-ion collisions.

The Solenoidal Tracker at RHIC (STAR)

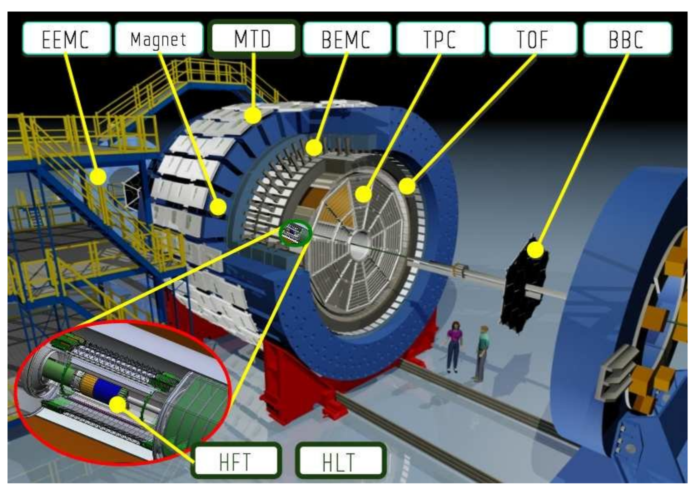

Figure 2: Layout of sub detectors of the STAR experiment.

Data set : Au+Au 200GeV — |η| < 1.0

Trigger: Minimum bias — 0.15 GeV/c < p_t < 2.0 GeV/c

Sliding Dumbbell Method (SDM) & Analysis Strategy

- In this method the whole azimuthal plane is scanned by sliding the **ΔΦ=90°** dumbbell in steps of **δΦ=1°** while calculating, $Db_\pm$ (defined below) for each region to extract the maximum value of **$Db_\pm$ ($Db_\pm^{max}$)** in each event.

$$Db_\pm = \frac{N_+^a}{N_+^a + N_-^a} + \frac{N_-^b}{N_+^b + N_-^b}$$

- N_+^a and N_-^a (N_+^b and N_-^b) are the numbers of positively and negatively charged particles on one side i.e., "a" (other side i.e., "b") of the dumbbell.

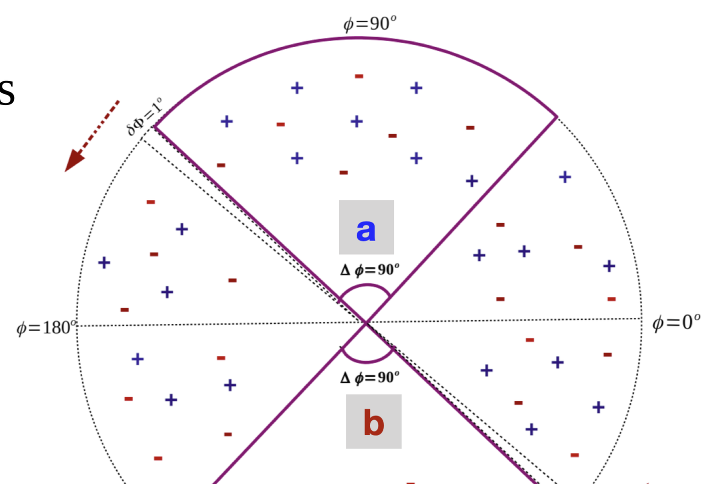

Figure 3: The Dumbbell of ΔΦ=90°.

- For each event the maximum value of $Db_\pm$ (with $|Db_{asy}| < 0.25$) is obtained, where:

$$Db_{asy} = \frac{Pos_{ex}^a - Neg_{ex}^b}{Pos_{ex}^a + Neg_{ex}^b}$$

$Pos_{ex}^a = N_+^a - N_-^a$ ($Neg_{ex}^b = N_-^b - N_+^b$) is positive (negative) charge excess on the side "a" (side "b") of the dumbbell.

- For background estimation we used the following:

Charge Reshufffle : The charges of particles are reshuffled keeping θ and Φ same in an event to get statistical background.

- The γ- correlator is defined as:

$$\gamma = \langle \cos(\phi_a + \phi_b - 2\Psi_{RP}) \rangle \sim (v_{1,a} v_{1,b} - a_a a_b) = \langle \cos(\phi_a + \phi_b - 2\phi_c) \rangle / v_{2,c}$$

- Fractional dumbbell charge separation (f_{DbCS}) is defined as:

$$f_{DbCS} = Db_\pm^{max} - 1$$

Results

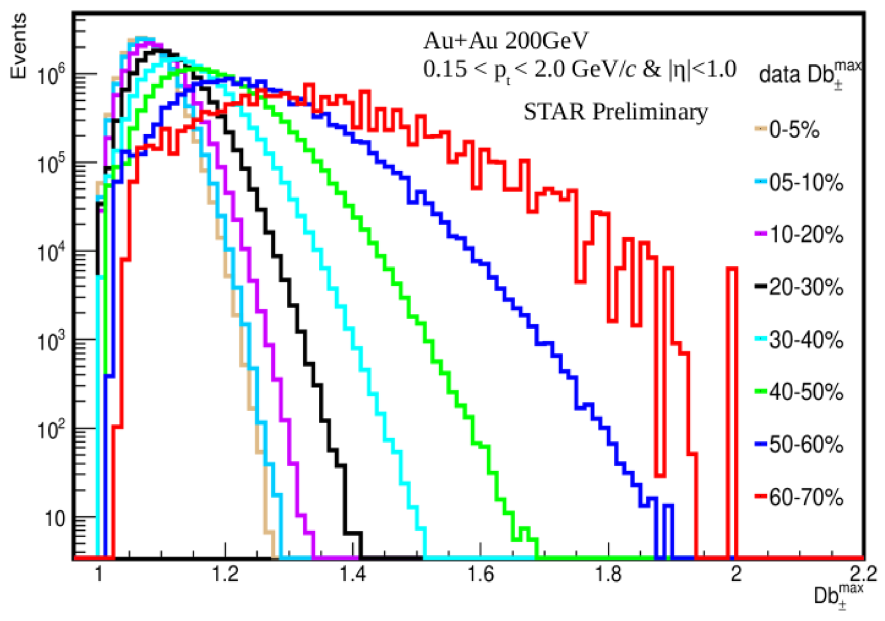

Figure 4 : Comparison of $Db_\pm^{max}$ distributions for Data for different collision centralities.

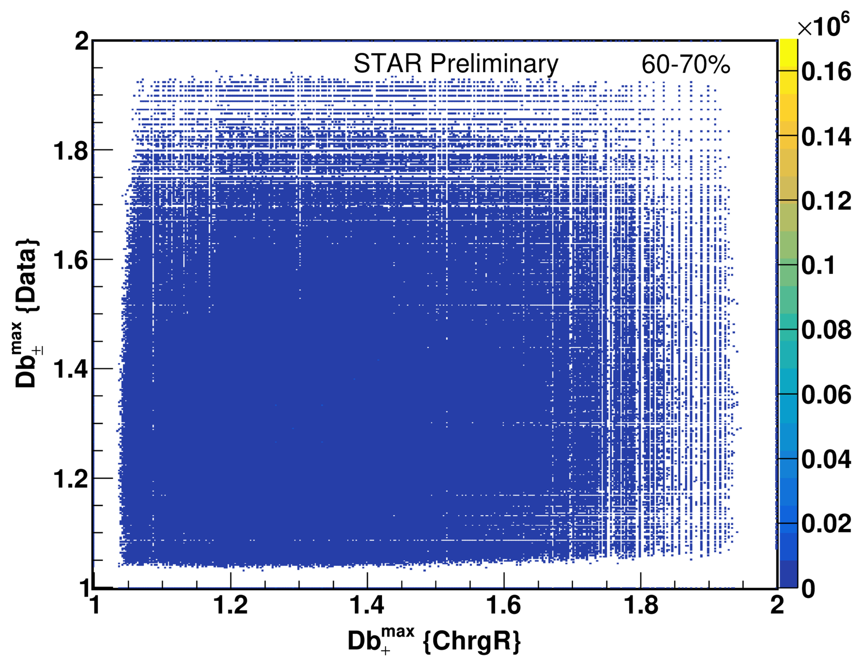

Figure 5 : Scatter plot of $Db_\pm^{max}$ for data vs $Db_\pm^{max}$ for Charge reshuffle background, exhibiting no correlation.

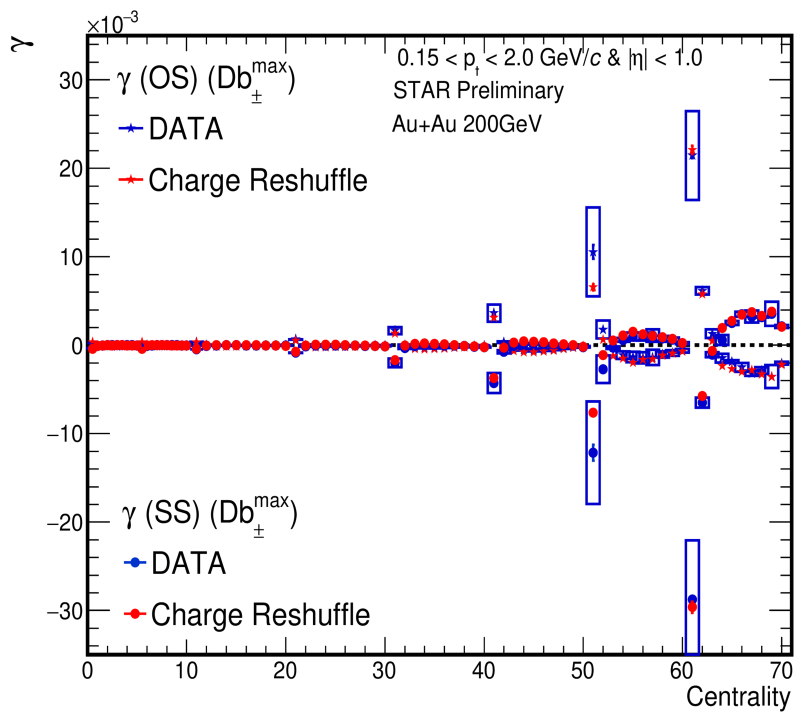

Figure 6 : γ (OS & SS) vs collision centrality for different percentile of $Db_\pm^{max}$ showing larger magnitude for top $Db_\pm^{max}$ for each collision centrality.

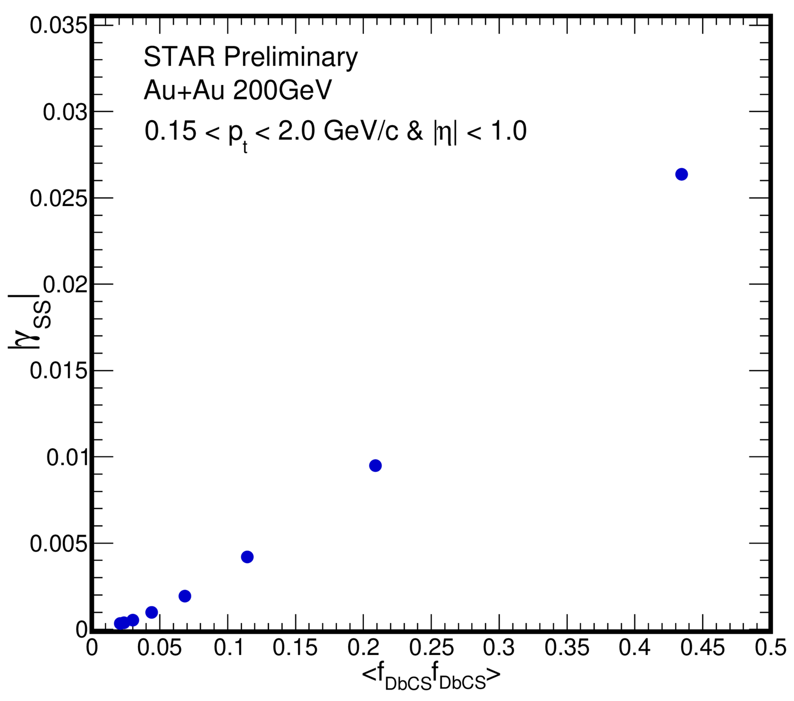

Figure 7 : $|\gamma_{SS}|$ vs $\langle f_{DbCS}^2 \rangle$ for top 10 percentile of $Db_\pm^{max}$ seems to exhibit linear dependence.

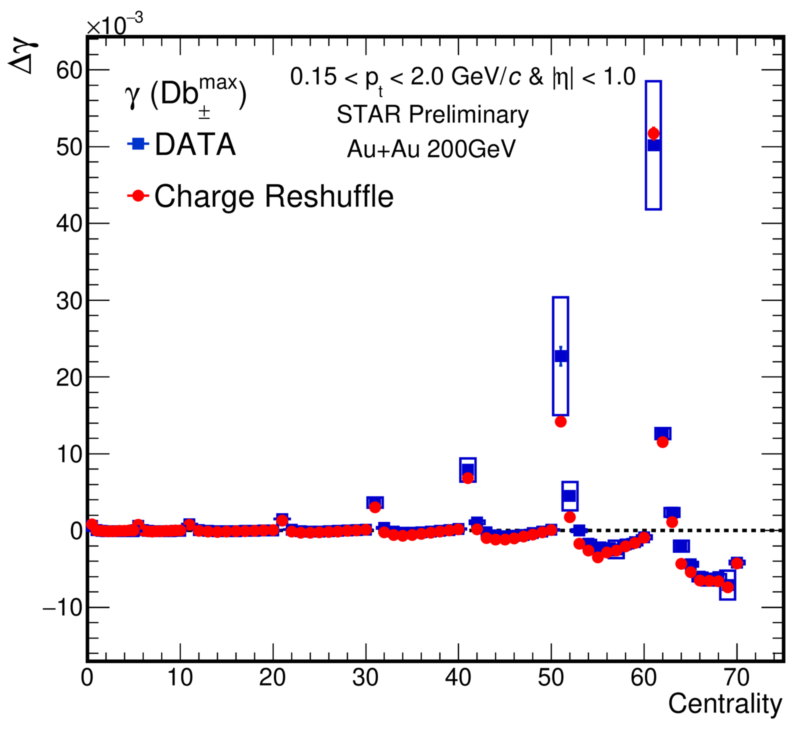

Figure 8 : Δγ vs collision centrality for different percentile of $Db_\pm^{max}$ which shows larger value of Δγ for top $Db_\pm^{max}$ bins.

- The f_{CME} is calculated using:

$$f_{cme} = \frac{\sum_{i=1}^{i=N} W_i \delta\gamma}{\sum_{i=1}^{N} W_i} \qquad \delta\gamma = (\Delta\gamma_{data} - \Delta\gamma_{bkg})/\Delta\gamma_{data}$$

where W_i *is number of events in the particular bin.*

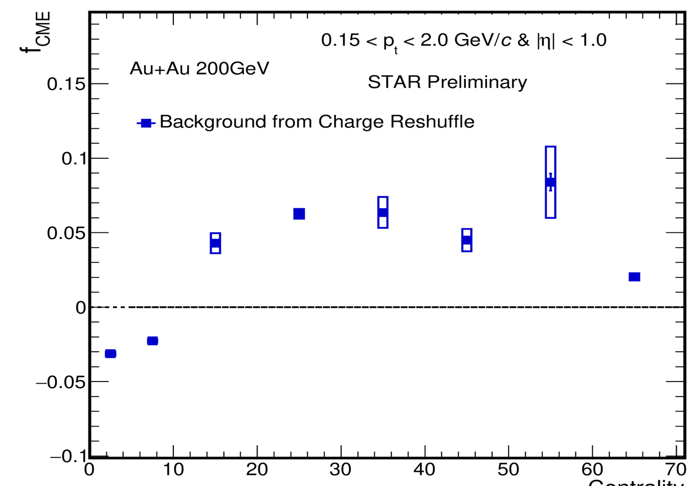

Figure 9 : f_{CME} vs collision centrality.

Summary

- Using SDM it is possible to select CME enriched sample.
- $|\gamma_{SS}| \sim |\gamma_{OS}|$ for top $Db_\pm^{max}$ bins as expected for CME-like sample.
- $|\gamma_{SS}|$ varies linearly with the average of square of the fractional dumbbell charge separation ($\langle f_{DbCS}^2 \rangle$) for top 10% of $Db_\pm^{max}$.
- The f_{CME} is aproximately ~5-7% for 10-60% collision centralities.
- We are working on improving the f_{CME} calculations. At present we have considered the charge reshuffle background which kills not only CME-like correlation but also correlations amongst produced particles. So, we are working on the correlated background which can be added to charge reshuffle background to get f_{CME}.

References:

[1] J. Singh, A. Attri, M. M. Aggarwal, DAE Symp.Nucl. Phys.64, 830-831 (2020) "https://inspirehep.net/files/64a853a890393602047fc34aa8e8c2da"

[2] S.A.Voloshin, Phys. Rev. C 70, (2004) 057901.

[3] B. I. Abelev et al., (STAR Collaboration), Phys. Rev. C 81, (2010) 054908.

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