Charge separation in Au+Au collisions at $\sqrt{s_{NN}}$= 200GeV at STAR

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Abstract

We present measurements of event-by-event back-to-back charge separation in Au+Au collisions at $\sqrt{s_{NN}}$= 200 GeV using Sliding Dumbbell Method (SDM). The charge dependent three-particle correlator ($\gamma=\langle\cos(\phi_a+\phi_b-2\Psi_{RP})\rangle$) which is the observable for Chiral Magnetic Effect (CME) [1] is investigated for each centrality interval which is further divided into ten bins depending on the charge separation based on SDM. An attempt is made to get CME enriched sample for each centrality. The background estimation is obtained by reshuffling the charges of particles and also by randomizing the azimuthal angles of particles in an event in which collision centrality dependent flow is also added.

Introduction

- In non-central heavy-ion collisions, the strong magnetic field ($B\sim10^{15}$ 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 [1].
- Event-by-event study of charge separation is one the obseravables to investigate the CME.
- The charge separation effect has been investigated both at RHIC and LHC using γ-correlator ($\langle\cos(\phi_\alpha + \phi_\beta - 2\Psi_{RP})\rangle$) which is CME observable [2,3].

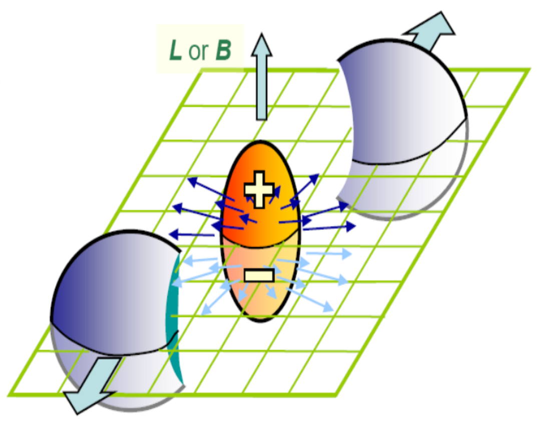

Figure 1: Schematic view of charge separation along magnetic field direction.

Experimental Setup

- The STAR (Solenoidal Tracker at RHIC) detector shown in Figure 2 at RHIC consists with various sub detectors. The main of them are Time Projection Chamber (TPC) and Time of Flight (TOF), 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)

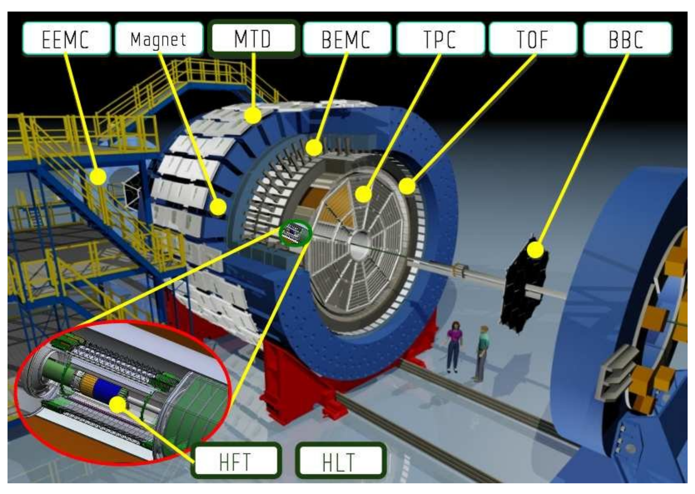

Figure 2: Layout of sub detectors of the STAR experiment.

Data set : Au+Au 200GeV $|\eta| < 1.0$

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 **$\Delta\Phi=90^\circ$** dumbbell in steps of **$\delta\Phi=1^\circ$** while calculating, $Db_\pm$ (defined below) for each region to extract the maximum value of **$Db_\pm$** in each event.

$$Db_\pm = \frac{N_+^{forw}}{N_+^{forw}+N_-^{forw}} + \frac{N_-^{back}}{N_+^{back}+N_-^{back}}$$

- N_+^{forw} and N_-^{forw} (N_+^{back} and N_-^{back}) are the numbers of positively and negatively charged particles on the forward (backward) side of the dumbbell.

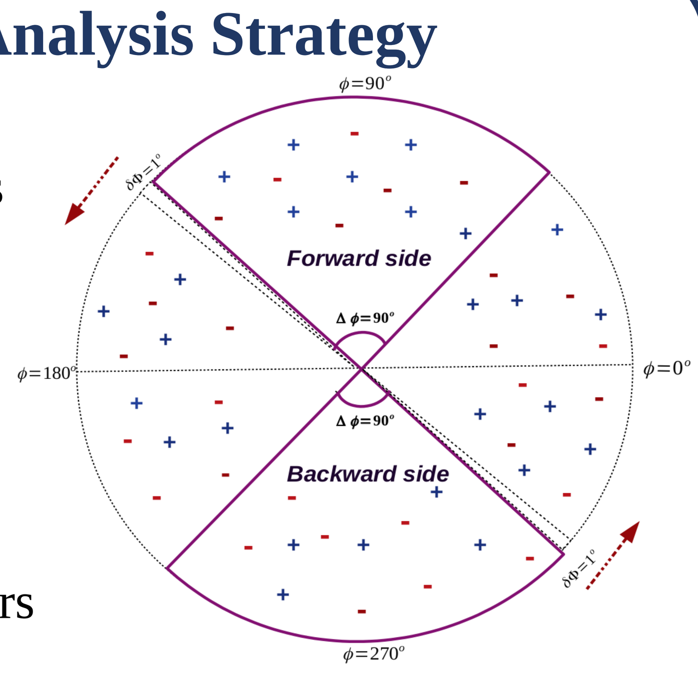

Figure 3: The Dumbbell of $\Delta\Phi=90^\circ$.

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

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

- **$Pos_{ex}^{forw} = N_+^{forw} - N_-^{forw}$** ($Neg_{ex}^{back} = N_-^{back} - N_+^{back}$) is positive (negative) charge excess on the forward (backward) side of the dumbbell.
- For background estimation two methods are used:

1.) The charges of particles are reshuffled keeping θ and Φ same in an event.

2.) Randomising the azimuthal angle of particles keeping the multiplicity of positive and negative particles same as in data. Flow is added to the randomly distributed events in order to increase background. The azimuthal angle is modified as: **$\Phi = \varphi - v_2\sin(2\varphi)$**, where φ is randomised azimuthal angle [4-5].

Results

- Figure 4 shows Db_{asy}, $Db_\pm$ & N distribution vs φ_{Db} for one event while sliding the dumbbell with 1 degree.
- Comparison of $Db_\pm^{max}$ distributions for different centralities is shown in Fig. 5.
- Figure 6 shows Δγ (γ_{opp}-γ_{same}) vs collision centrality for different $Db_\pm^{max}$ values. Top $Db_\pm^{max}$ bins show enhanced value of Δγ. This allows one to select CME-enriched sample.

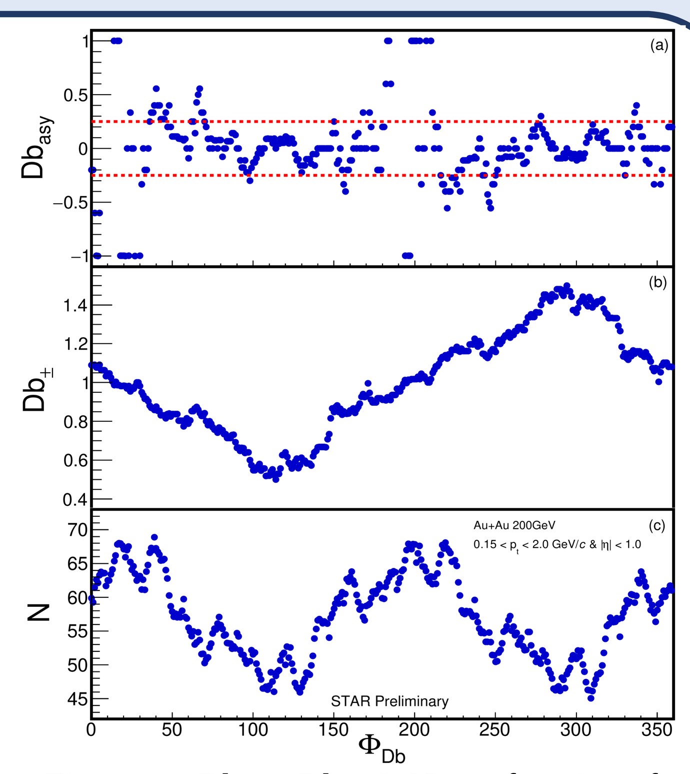

Figure 4 : Db_{asy}, $Db_\pm$ & N as a function of φ_{Db} .

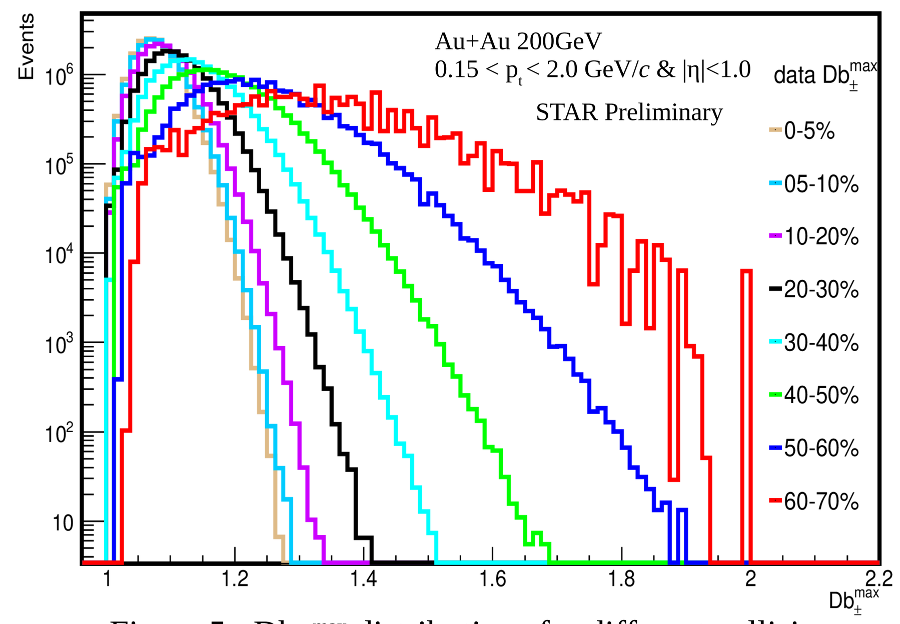

Figure 5 : $Db_\pm^{max}$ distributions for different collision centrality.

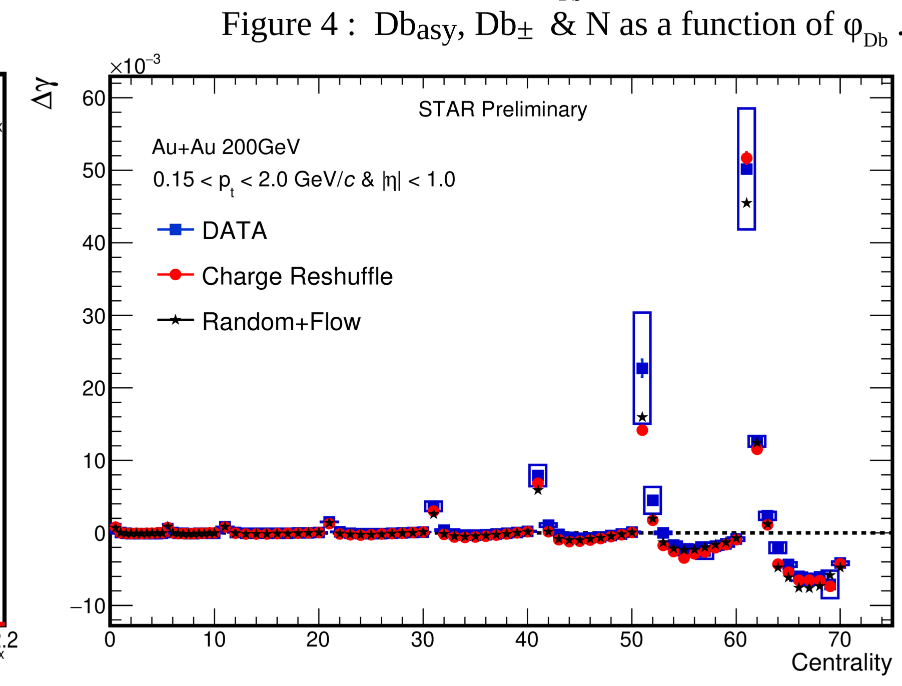

Figure 6 : Δγ vs collision centrality as a function of $Db_\pm^{max}$.

- Db_{CME} is calculated for positive values of Δγ (Δγ > 0). Figure 7 (top) shows Db_{CME} vs centrality, where different points for different centralities have different no. of $Db_\pm^{max}$ bins exhibiting CME signal:

$$Db_{CME} = (\Delta\gamma_{data} - \Delta\gamma_{background})/\Delta\gamma_{data}$$

- The f_{CME} is calculated using:

$$f_{CME} = Db_{CME} * f_{nevt}$$

where f_{nevt} is the fraction of events exhibiting CME signal.

- Figure 7 (bottom) shows estimated CME fraction (f_{CME}) vs collision centrality, which is approximately ~5-7% for 10-60% centrality. The f_{CME} from data is compared with different CME-injected samples of AMPT .

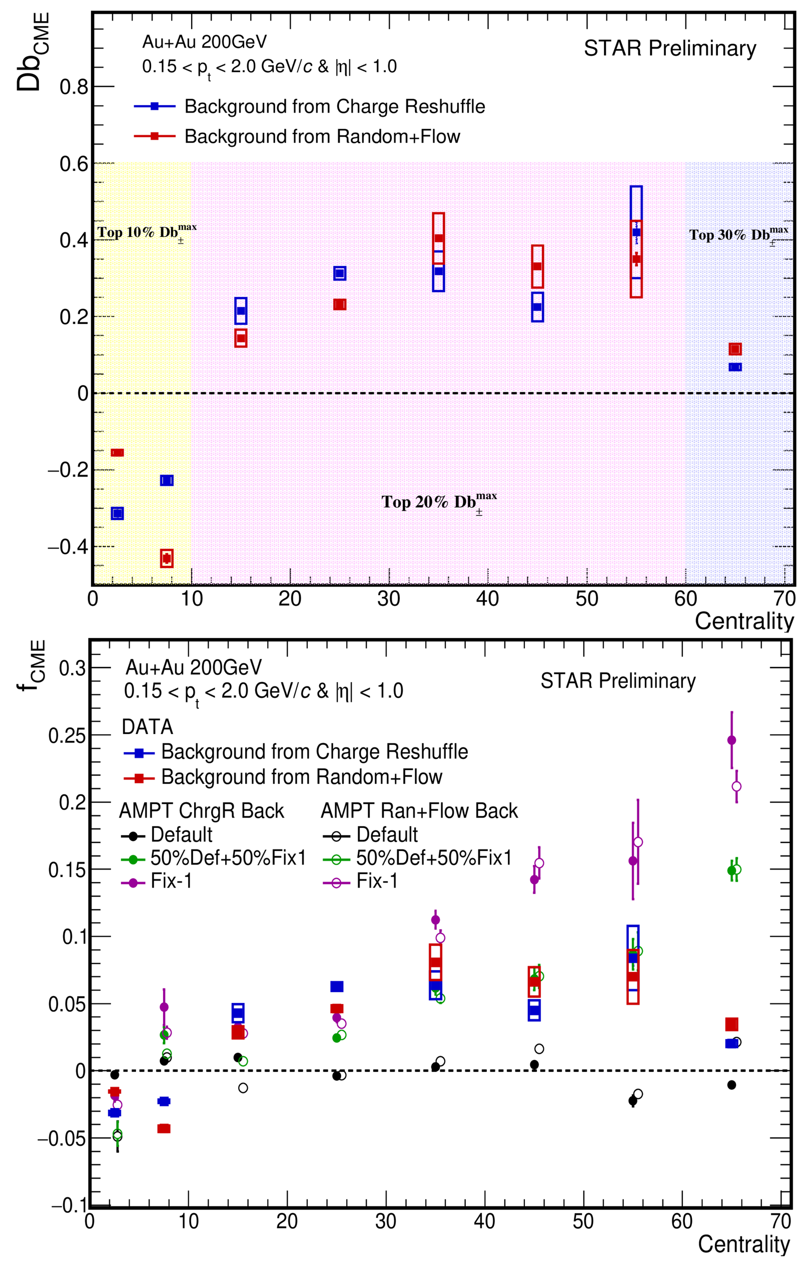

Figure 7 : Top: Db_{CME} vs collision centrality for different $Db_\pm^{max}$ bins. Bottom : f_{CME} vs collision centrality.

Summary

- The f_{CME} obtained using two different methods of background construction agree within uncertainties.
- The f_{CME} is aproximately ~5-7% for 10-60% collision centralities. It is observed that f_{CME} (data) matches with f_{CME} obtained from AMPT with CME signal injected.
- Using SDM it is possible to select CME enriched sample.

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