STAR measurements on charge-dependent correlations at 27 GeV and implications on search for the Chiral Magnetic Effect at lower collision energies

Subikash Choudhury[1] for the STAR collaboration

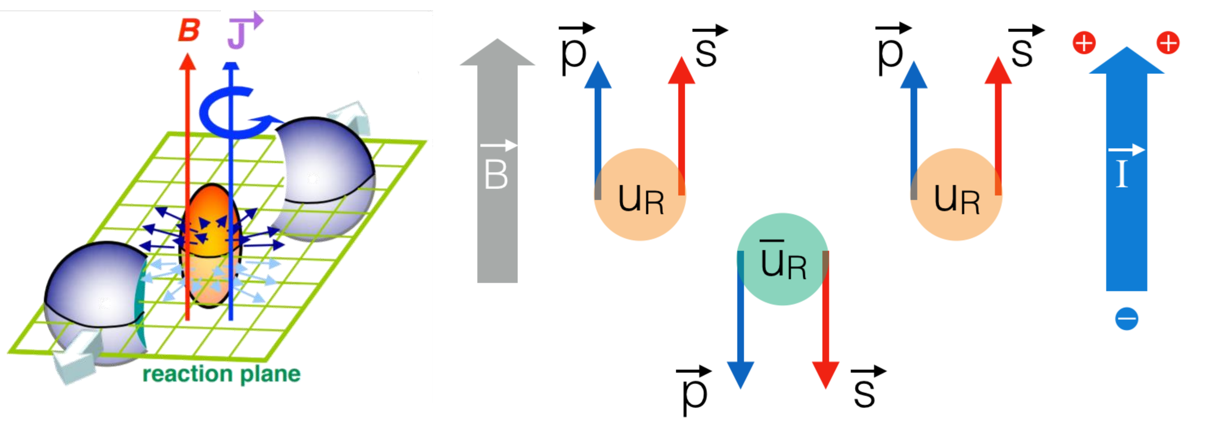
[1]Key Laboratory for Nuclear Physics and Ion-Beam Applications (MOE) and Institute of Modern Physics, Fudan University, Shanghai, China

Abstract

The observability of the Chiral Magnetic Effect (CME) in heavy-ion collisions has been argued to strongly depend on collision energy because of the variations in the lifetime of magnetic field, the domain size of chiral charge and also on the possibility of formation of a medium with deconfinement and chiral symmetry restoration. In this poster we present an analysis of high statistics data of Au + Au collisions at $\sqrt{s_{NN}}$= 27 GeV taken by STAR in the year 2018 with the newly installed Event Plane Detector (EPD). At 27 GeV, the rapidity of the colliding beam (Y_{beam} = 3.4) falls in the acceptance of EPD (2.1< |η|<5.1). Therefore, we use the inner half of EPD (|η|>Y_{beam}) to measure the plane enriched with the spectator protons that generate (and highly correlated to) B-field. Similarly, we use the outer half of EPD (|η| < Y_{beam}) to measure the plane of the produced particles that flows and is weakly correlated to the B-field. Here, we present results on the charge separation across two such planes.

Introduction

- CME search at the LHC and the top RHIC energy indicates dominance of background – what happens at lower collision energy?
- Isobar collision at RHIC likely to provide the decisive test at the top RHIC energy
- CME search with RHIC Beam Energy Scan-I data is limited by statistics and large uncertainties in the determination event-plane
- In this study we show how the Au+Au 27 GeV data collected in year 2018 at RHIC with a pair of new Event-plane detector provide unique opportunity to search for CME at lower energies using the charge dependent azimuthal correlation



CME is driven by chirality imbalance in the hot QCD medium and manifest itself as charge separation along the directions of B-field due to spectators – its observability varies with collision energy

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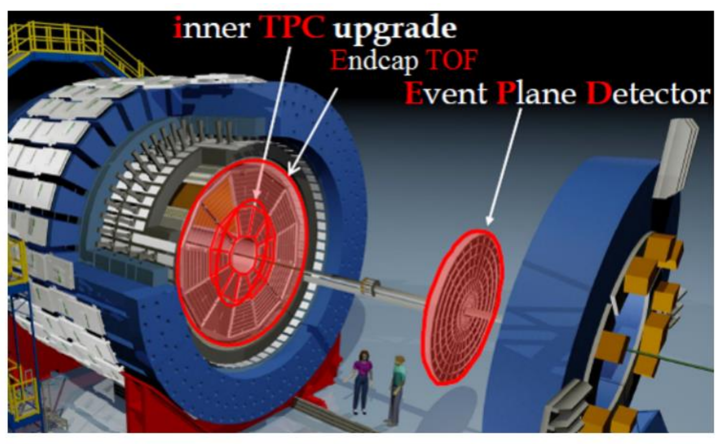
STAR Detector



We use the Time Projection Chamber (TPC) and Event Plane Detector (EPD)

Analysis Details

We measure the charged dependent azimuthal correlator :

$$\gamma^{\alpha,\beta} \equiv \left\langle \cos\left(\phi_a^\alpha + \phi_b^\beta - 2\psi_{RP}\right)\right\rangle$$

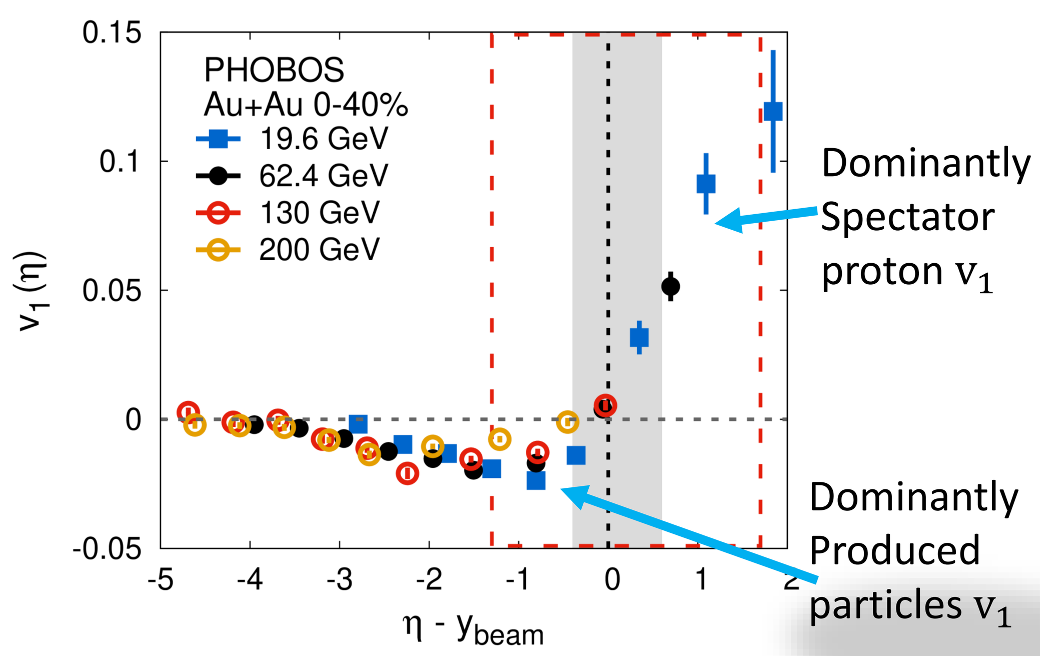
$$\Delta\gamma = \gamma^{\pm,\mp} - \gamma^{++,--}$$

The azimuthal angles of particle "a" and "b" carrying charges are measured by TPC within a range of transverse momentum of 0.2 < pT< 2 GeV and pseudorapidity window of |η|< 0.8

The proxy for the reaction plane angle Ψ_{RP} is done using EPD with 2.1< |η|< 5.1

3

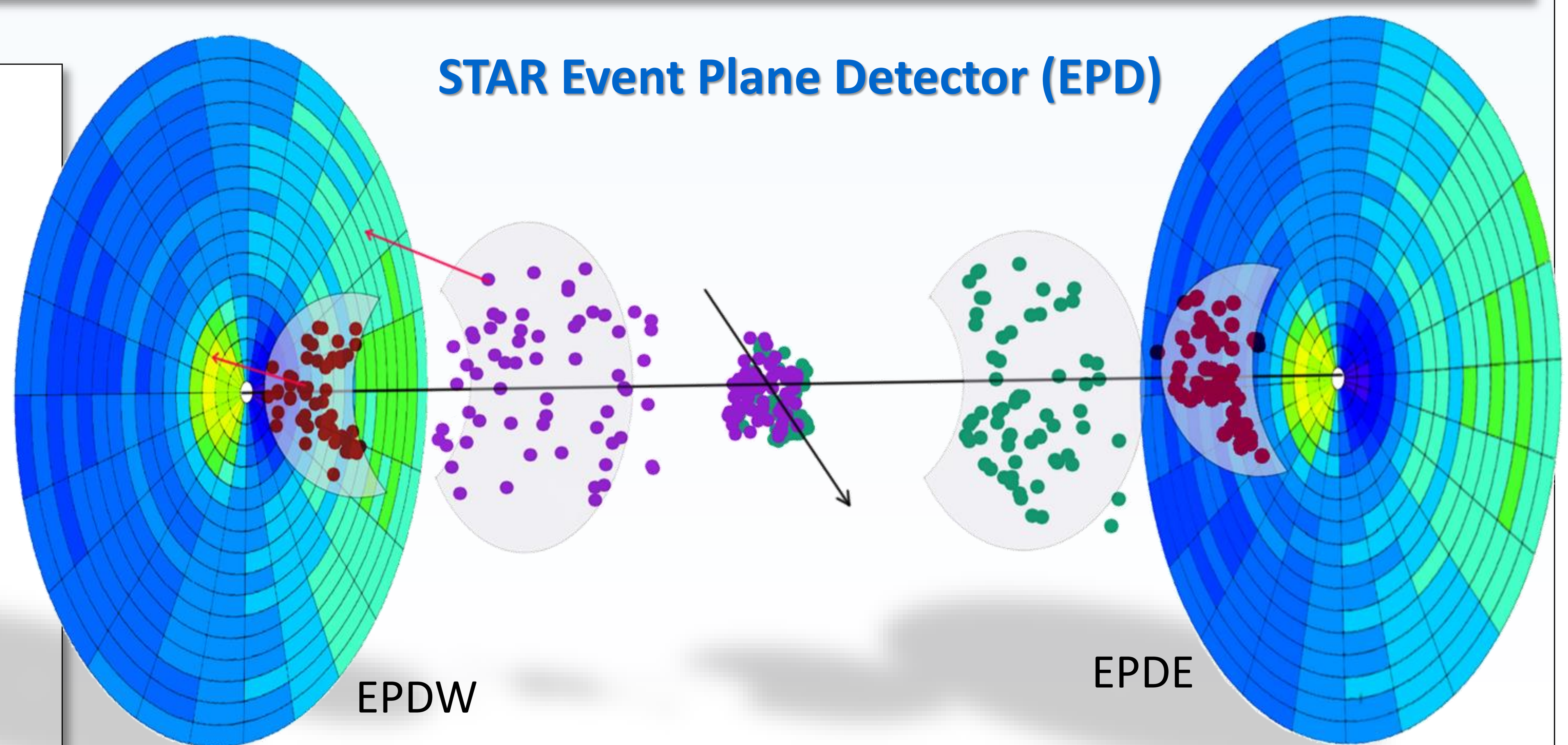
Sign change of v_1 at beam rapidity



The sign change of v_1 indicates transition from participants to spectator rich regions

2

STAR Event Plane Detector (EPD)



STAR Event Plane Detector is one key upgrade for RHIC Beam Energy Scan-II
A dedicated detector to measure event-plane angle with improved resolution
Two highly segmented EPDs (east & west) cover a pseudorapidity of 2.1< |η|< 5.1

- Inner half of EPD → Spectator protons that generate & highly correlated to B-field
- Outer half of EPD → Participants that flows and weakly correlated to B-field

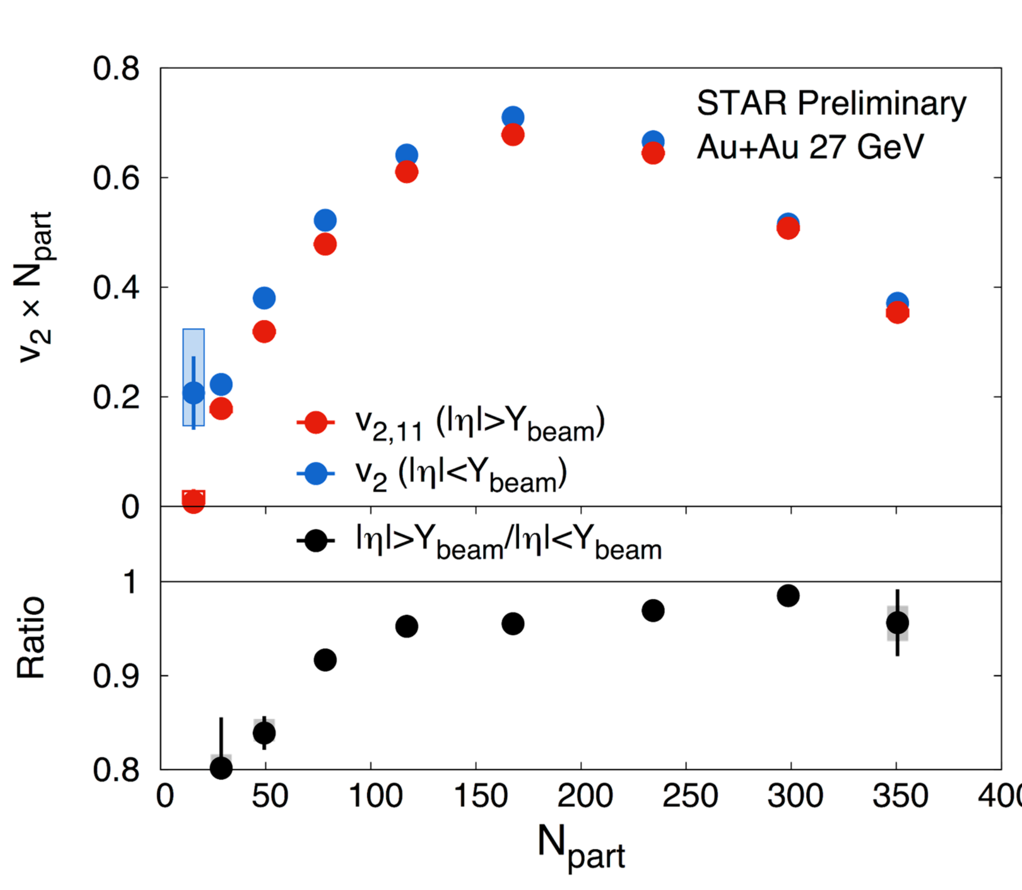
v_2 using inner and outer EPDs

Elliptic anisotropy w.r.to the plane of the produced particles |η|<Y_{beam}

$$v_{2,2} \equiv \left\langle \cos\left(2\phi - 2\psi_2^{|\eta|<Y_{beam}}\right)\right\rangle$$

Elliptic anisotropy w.r.to the plane of the spectator protons |η|>Y_{beam}

$$v_{2,1,1} \equiv \left\langle \cos\left(2\phi - \psi_1^{\eta>Y_{beam}} - \psi_1^{-\eta<-Y_{beam}}\right)\right\rangle$$



Elliptic anisotropy drops significantly w.r.to spectator proton plane due to decorrelation and difference in flow-fluctuations w.r.to two planes.

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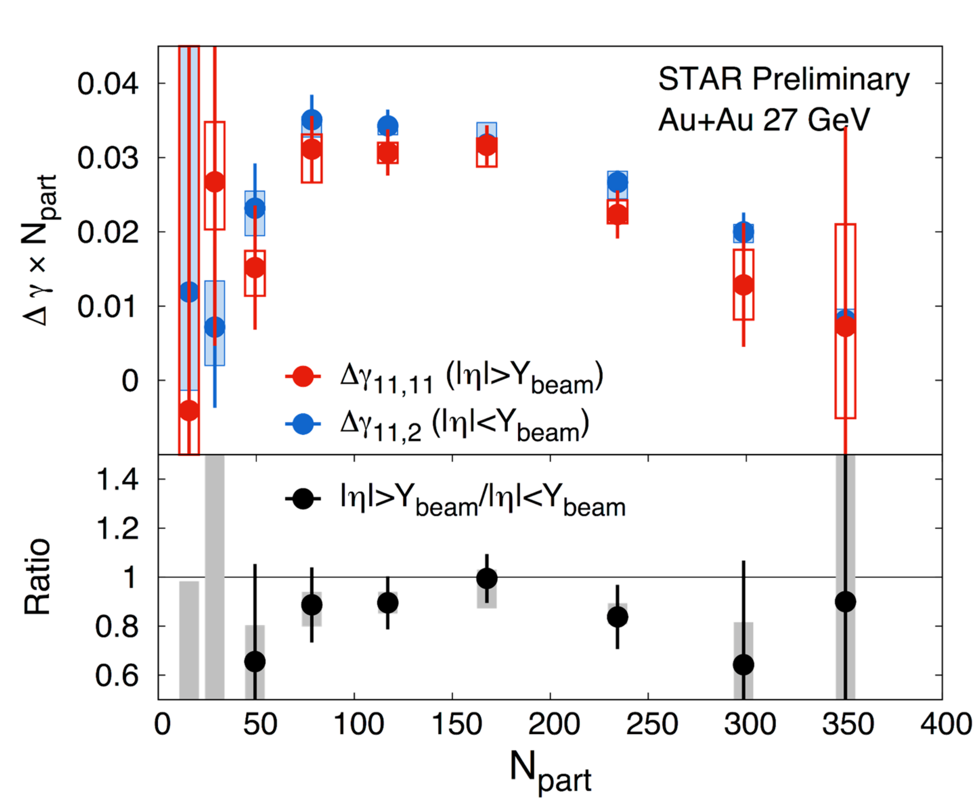
γ-correlators using inner and outer EPDs

Charge separation w.r.to planes of the produced particles |η|<Y_{beam}

$$\gamma_{1,1,2}^{\alpha,\beta} = \left\langle \cos\left(\phi_a^\alpha + \phi_b^\beta - 2\psi_2^{|\eta|<Y_{beam}}\right)\right\rangle$$

Charge separation w.r.to planes of the spectator protons |η|>Y_{beam}

$$\gamma_{1,1,1,1}^{\alpha,\beta} = \left\langle \cos\left(\phi_a^\alpha + \phi_b^\beta - \psi_1^{\eta>Y_{beam}} - \psi_1^{-\eta<-Y_{beam}}\right)\right\rangle$$



No significant difference in the charge separation w.r.to spectator proton & produced particle event planes.

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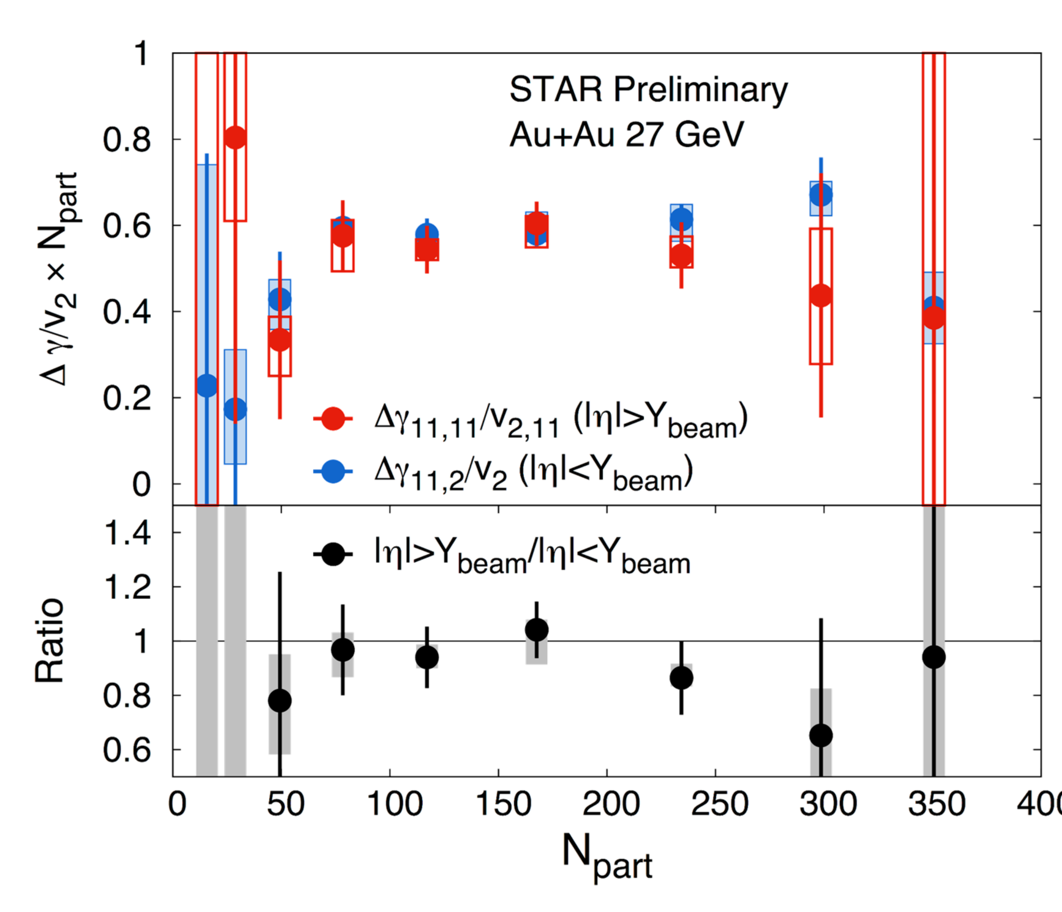
Normalized γ-correlators

Charge separation normalized by elliptic anisotropy w.r.to planes at |η|<Y_{beam} and |η|>Y_{beam}



No significant difference in the scaled charge separation w.r.to spectator proton & produced particle event planes.

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Summary

- We utilized the unique combination of Au+Au 27 GeV data collected by STAR in the year 2018 of RHIC run and the newly installed Event Plane Detector to study charge separation w.r.to spectator proton-plane and event-plane at forward rapidity using the same detector.
- We see no significant difference of charge separation between the two scenarios.
- Our results will put strong constraints on the observability of CME search.

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