Extraction of CMW fraction with event shape engineering in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV at RHIC

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Abstract

The Chiral Magnetic Wave (CMW), induces electric quadrupole moment in quark-gluon plasma produced in heavy-ion collisions, which leads to the difference between elliptic flow of positively and negatively charged particles [1]. The charge-dependent elliptic flow as a function of the charge asymmetry (A_{ch}) serves as an important tool in the search for the CMW. Event Shape Engineering technique, which differentiates between the background and the CMW signal, is used to study charge asymmetry dependence of the elliptic flow.

Introduction

- Chiral Magnetic Wave (CMW) is a combined effect of Chiral Magnetic Effect (CME) and Chiral Separation Effect (CSE) [1]. These effects arise due to the interaction of chiral and electric charges with magnetic field produced by spectator protons.

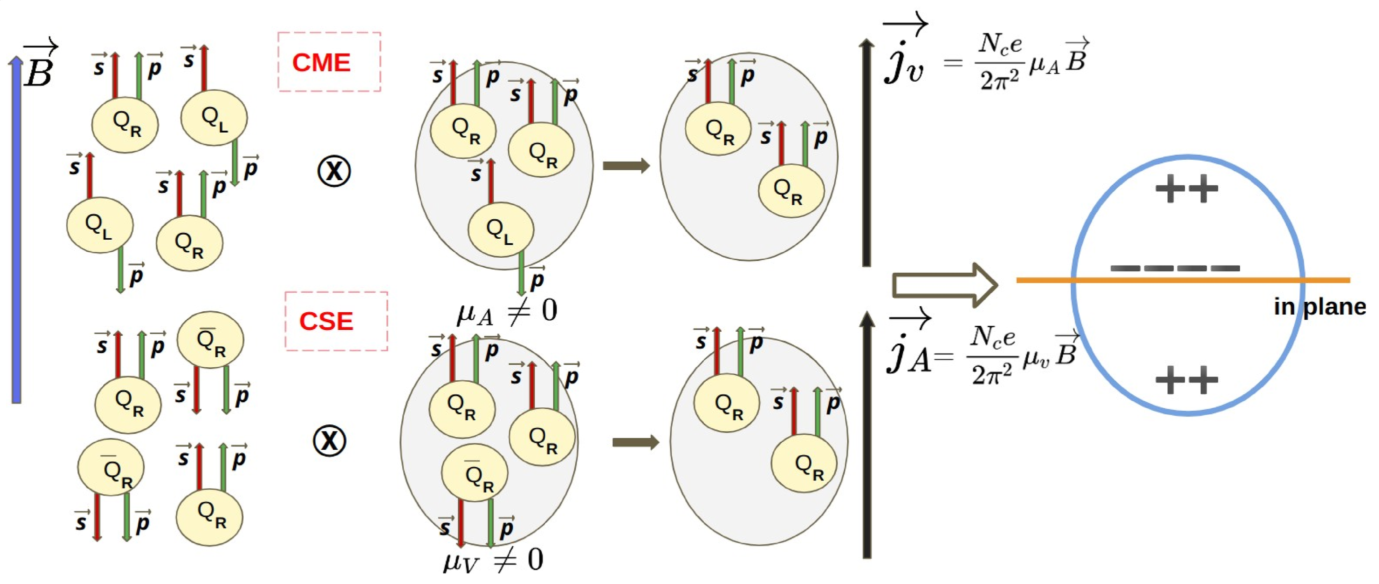


Figure 1: Illustration of Chiral Magnetic Effect (top) and Chiral Separation Effect (bottom), coupling between these two generates CMW, which induces electric quadrupole moment in the collision system.

- The "poles" ("equator") of the collision system acquire additional positive (negative) charge because of the electric quadrupole induced due to CMW, which leads to difference between elliptic flow of positively and negatively charged particles [2].

$$v_2^{\pm} \approx v_2 \mp rA_{ch}/2 \quad \Rightarrow \quad \Delta v_2 = v_2^- - v_2^+ \approx rA_{ch}$$

where $A_{ch} = (N_+ - N_-)/(N_+ + N_-)$ is the charge asymmetry of the collision system, v_2 is the elliptic flow and parameter "r" encodes the strength of the electric quadrupole due to the CMW.

Motivation

- Δv_2 for identified particles has already been studied in Au+Au collisions. This difference is found to be proportional to charge asymmetry [3-4].
- Background effects such as local charge conservation (LCC) can also fake the signal.
- We use the Event Shape Engineering (ESE) technique which helps to differentiate background from the CMW signal as suggested by C. Wang et al. [5].
- From Figure 2, it can been seen that for AMPT + quadrupole model, which simulates CMW, slope (r) is independent of $\langle v_2 \rangle$ and has a finite intercept at zero $\langle v_2 \rangle$ whereas for Blast Wave model incropating LCC, it varies linearly with $\langle v_2 \rangle$.
- Therefore, we can use ESE to extract f_{CMW} fraction:

$$f_{CMW} = \frac{b}{a\langle v_2 \rangle + b}$$

where a and b are the slope and the intercept from the linear fit.

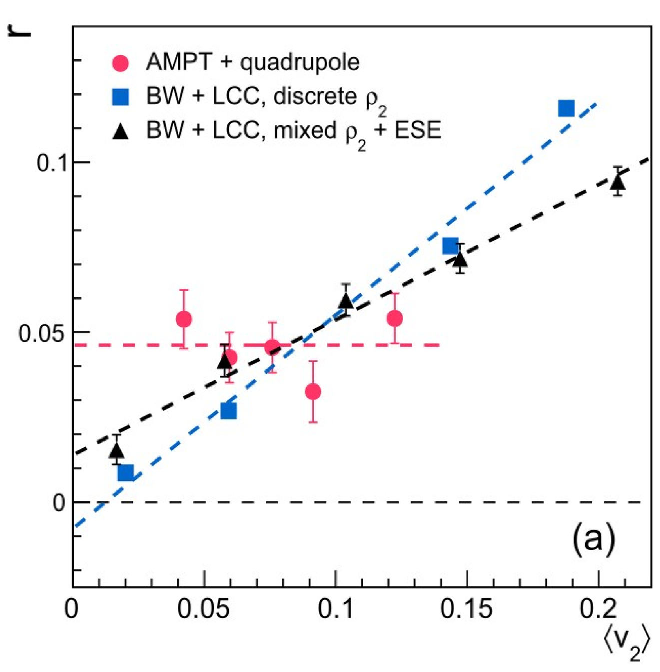


Figure 2: The slope of A_{ch}-Δv_2 as a function of average v_2

Experimental Setup

- TPC: momentum and dE/dx measurements (|η| <1.0 with full azimuthal coverage)
- TOF: particle identification to extended momentum range.
- Collision Type: Au+Au @ 200 GeV
- Data: Data collected in 2011
- Events Analysed: ~ 435 Million
- Trigger: Minimum bias
- Vertex Cut: $|V_z| < 30$ cm
- DCA < 3 cm
- $|\eta| < 1.0$ and $0.15 < p_T < 2.0$ GeV/c

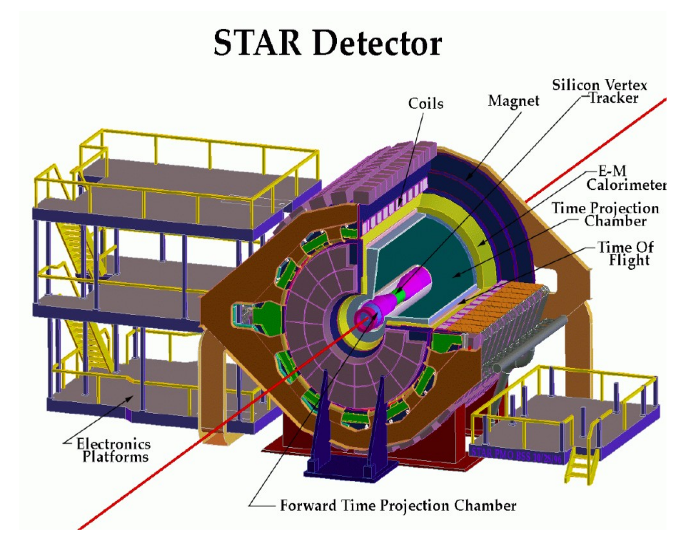


Figure 3: Layout of sub detectors of the STAR experiment.

Method & Analysis Strategy

- A_{ch} distribution is divided into 6 bins having approximately equal number of events.

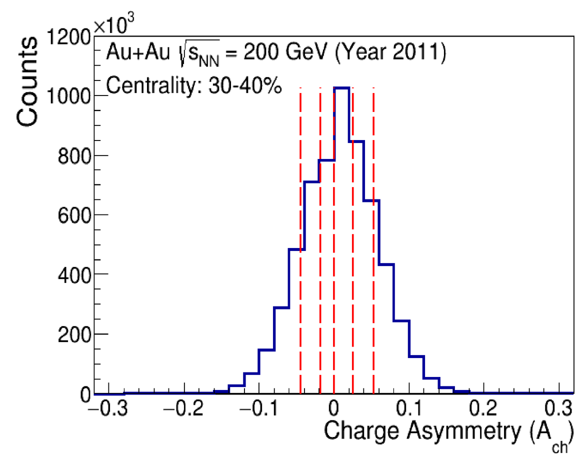


Figure 4: A_{ch} distribution.

- Trivial dependence of v_n on A_{ch} due to difference in nonflow correlations between like-sign and unlike-sign pairs is eliminated by taking positively and negatively charged particles separately as reference particles in flow calculation [6].

$$v_2^h = (v_2\{2;h^+\} + v_2\{2;h^-\})/2$$

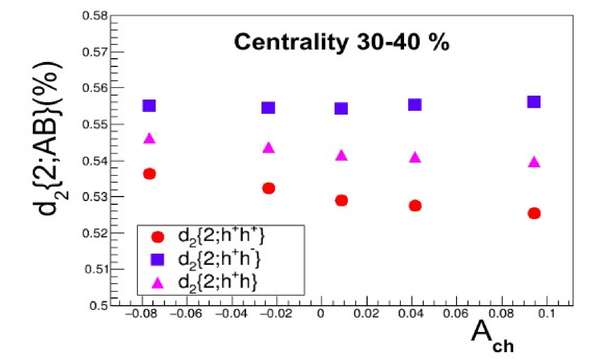


Figure 5: The two-particle cumulants $d_2\{2\}$ between charged hadron and all charged hadrons (h), positive charges (h^+), and negative charges (h^-), respectively.

Event Shape Engineering (ESE):

- In ESE [7] different initial eccentricities for a given centrality are selected using the flow vector:

$$q_2 = \frac{|Q_2|}{\sqrt{M}}$$

where M is the multiplicity and Q_2 is defined as:

$$Q_{2,x} = \sum_i^M \cos(2\varphi_i), \quad Q_{2,y} = \sum_i^M \sin(2\varphi_i)$$

- q_2 distribution is divided into 10 bins having approximately equal numbers of events.
- Slope (r) of Δv_2 versus A_{ch} is calculated for each q_2 bin.

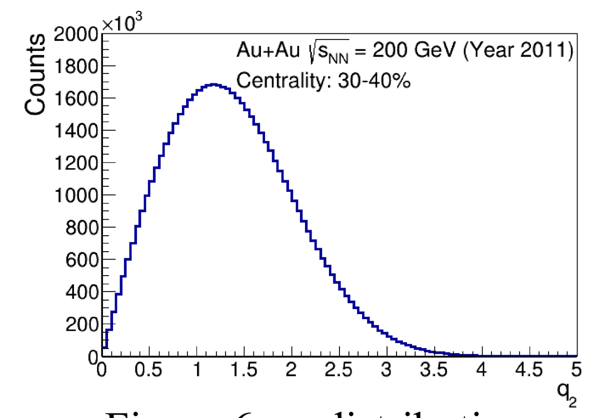
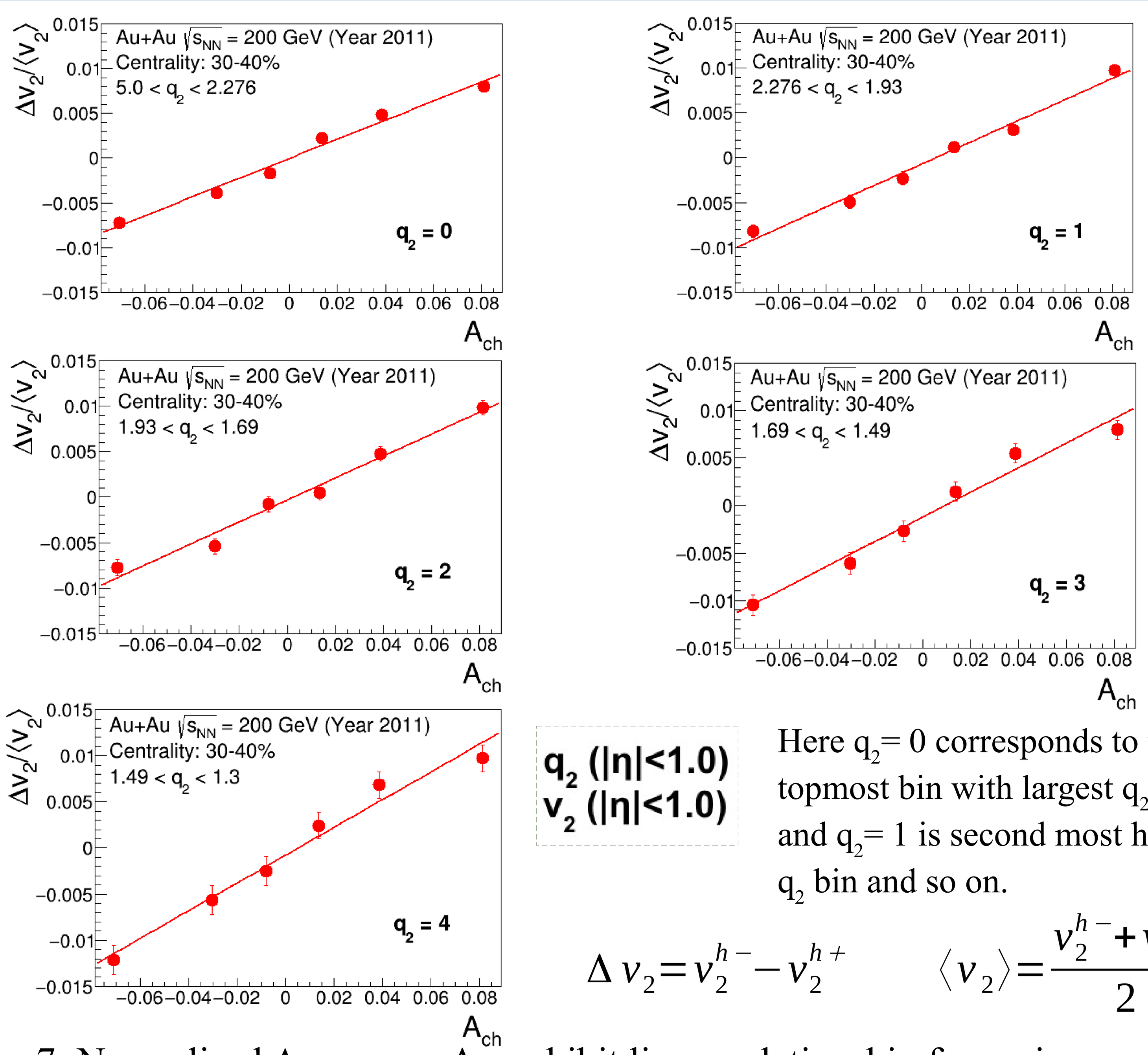


Figure 6: q_2 distribution

Results

Normalised Δv_2 versus A_{ch} for top 5 q_2 bins



q_2 (|η|<1.0)
v_2 (|η|<1.0)

Here q_2= 0 corresponds to the topmost bin with largest q_2 value and q_2= 1 is second most highest q_2 bin and so on.

$$\Delta v_2 = v_2^{h-} - v_2^{h+} \qquad \langle v_2 \rangle = \frac{v_2^{h-} + v_2^{h+}}{2}$$

- Figure 7: Normalised Δv_2 versus A_{ch} exhibit linear relationship for various q_2 bins. All errors are statistical only.

Summary

- Normalised Δv_2 shows linear relationship with charge asymmetry.
- First measurements of ESE approach look promising to reduce the background.
- Further studies are underway for the extraction of f_{CMW} and to come to any conclusion.

References:

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