# Charge-asymmetry dependence of kaon elliptic flow in Au+Au collisions at $\sqrt{s_{NN}} = 27$ GeV from STAR

Keenan Cabrera (for the STAR Collaboration)

UCLA and Oregon State University

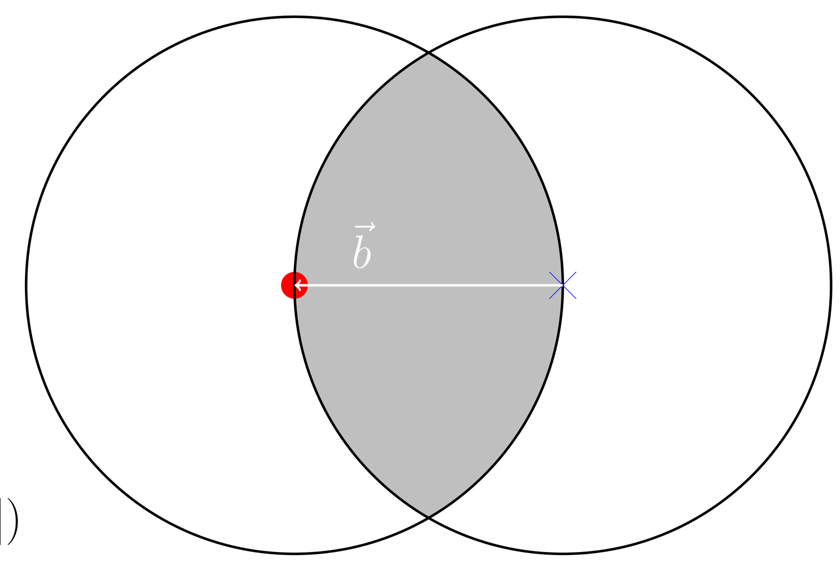
## Abstract

Theory predicts that a chiral magnetic wave (CMW) at finite baryon density can induce a charge-asymmetry dependence of elliptic flow ($v_2$) of particles produced in heavy-ion collisions. STAR has observed that pion $\Delta v_2$ exhibits a linear dependence on charge asymmetry with a positive slope in Au+Au collisions from 27 to 200 GeV [1]. This is consistent with the CMW picture. At lower collision energies, it was found that the charge-asymmetry integrated $v_2$ for negative pions is higher while for kaons, the positive charge is favored. Therefore, an observation of the same positive linear dependence of kaon $v_2$ difference on charge asymmetry will provide a further test on the CMW predictions in heavy-ion collisions. In this work, we present the kaon elliptic flow measurements as a function of charge asymmetry for Au+Au collisions at $\sqrt{s_{NN}} = 27$ GeV.

## Introduction and Theory

### Elliptic Flow ($v_2$)

- Because the quark-gluon plasma created in non-central collisions isn't spherically symmetric, the plasma does not expand uniformly. $v_2$ is a measure of this anisotropy of expansion.
- Characterized by the second order Fourier coefficient in the expansion of the azimuthal distribution of particles with respect to the event plane.
  - $E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T\, dp_T dy}\left(1 + \sum_{n=1}^{\infty} 2v_n \cos\left[n\left(\phi - \Psi_r\right)\right]\right)$
  - $v_2 = \langle cos\left[2\left(\phi - \Psi_{RP}\right)\right]\rangle$




### The Chiral Magnetic Wave

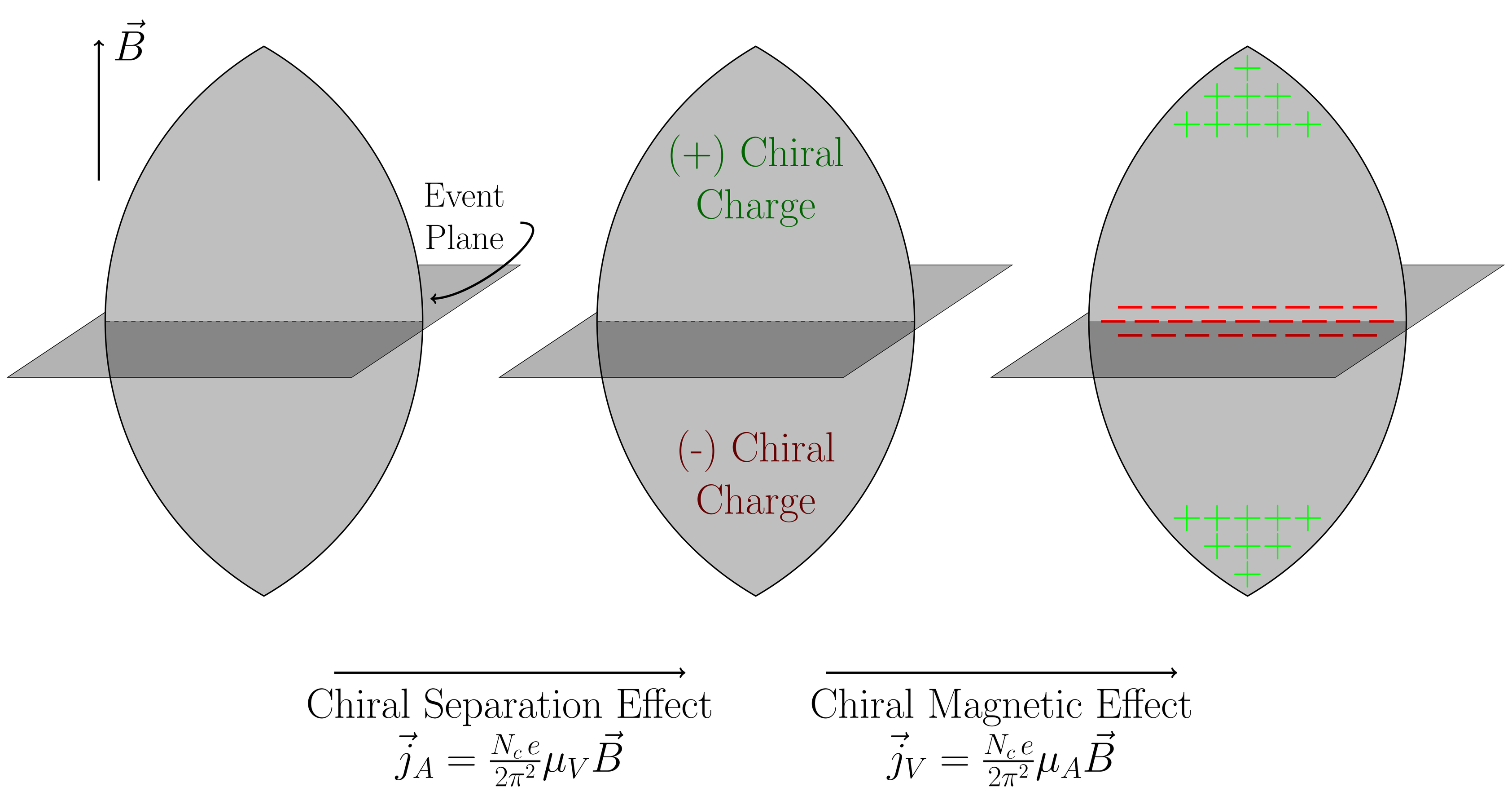



Fig. 2: A basic overview of the chiral magnetic wave effect. The magnetic field shown in the figure is incredibly strong and is created by the fast moving spectator nucleons.

- The CMW is "a gapless collective excitation of QGP in the presence of [an] external magnetic field that stems from the interplay of Chiral Magnetic (CME) and Chiral Separation Effects (CSE)" [2].
- The CMW induces an electric quadrapole moment in the QGP that favors the elliptic flow of negative hadrons ($v_2^- > v_2^+$).
- In the presence of a CMW effect, the difference in elliptic flow between negative and positive hadrons is predicted to exhibit a linear dependence with positive slope on charge asymmetry $A_{ch} = \frac{N_+ - N_-}{N_+ + N_-}$.

**The goal of this investigation is to determine the presence of the CMW effect by analysis of kaons. If we can determine that $v_2(K^-) - v_2(K^+) = \Delta v_2$ exhibits a positive linear dependence on $A_{ch}$, this is strong support for the effect.**

### Experiment

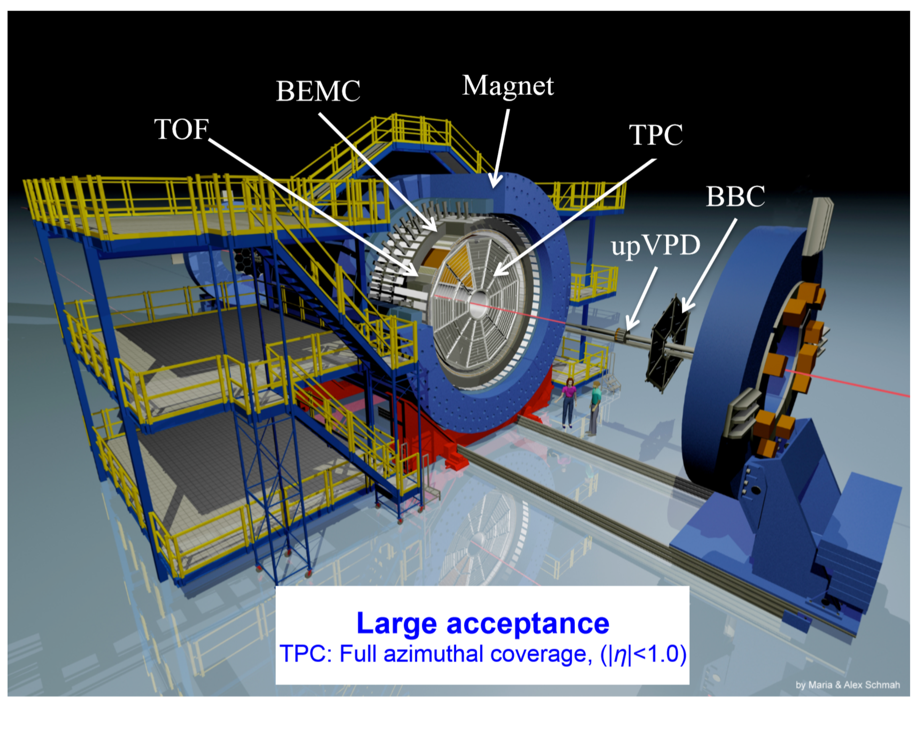



Fig. 3: A computer-generated cross section of the detector.

- Data for Au + Au collisions were collected by the STAR Detector at RHIC
- Kaon Identification
  - The TPC (Time Projection Chamber) measures the ionization energy loss per unit arc length ($\frac{dE}{dx}$), which is used to identify kaons [3,4].
  - To further increase purity, the ToF (Time of Flight) detector is used to calculate the mass squared of detected particles, allowing further identification of Kaons [3,4].

## Results

$\Delta v_2$ is first determined using two different methods:

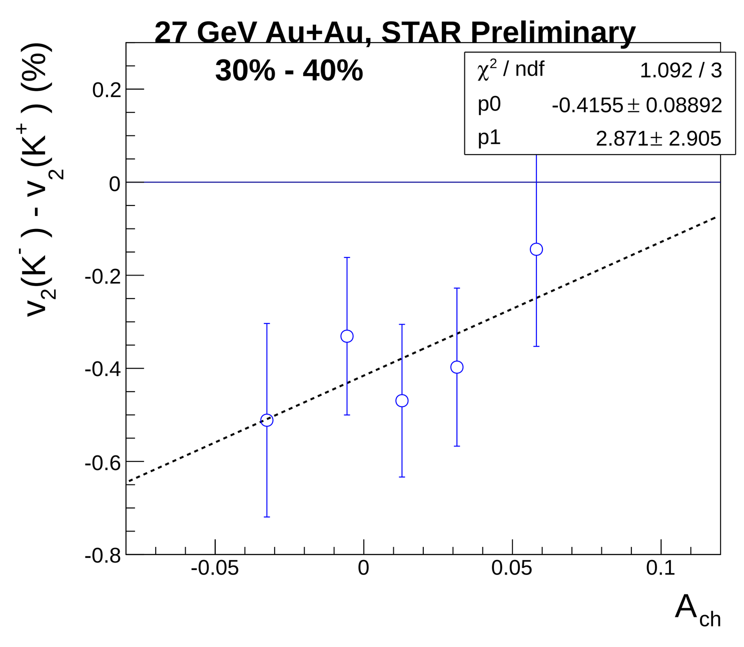



Fig. 4: Fitting Method: $\Delta v_2$ determined by fitting a plot of $\Delta v_2$ vs $p_T$ with a constant fit.

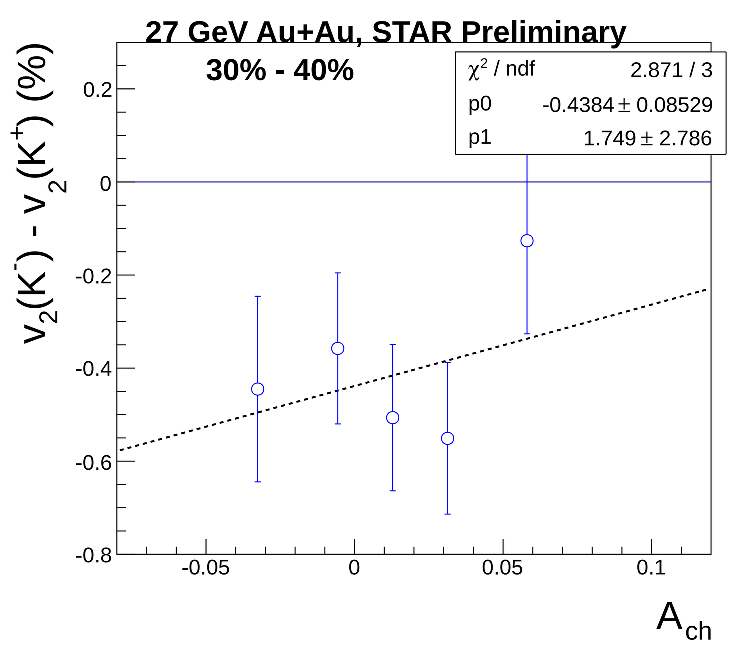



Fig. 5: Integral Method: $\Delta v_2$ determined by finding the difference between $p_T$-integrated $v_2$.

The fit parameters from the integral method are then plotted as a function of centrality, with the discrepancy between this and first method included in the systematic errors.

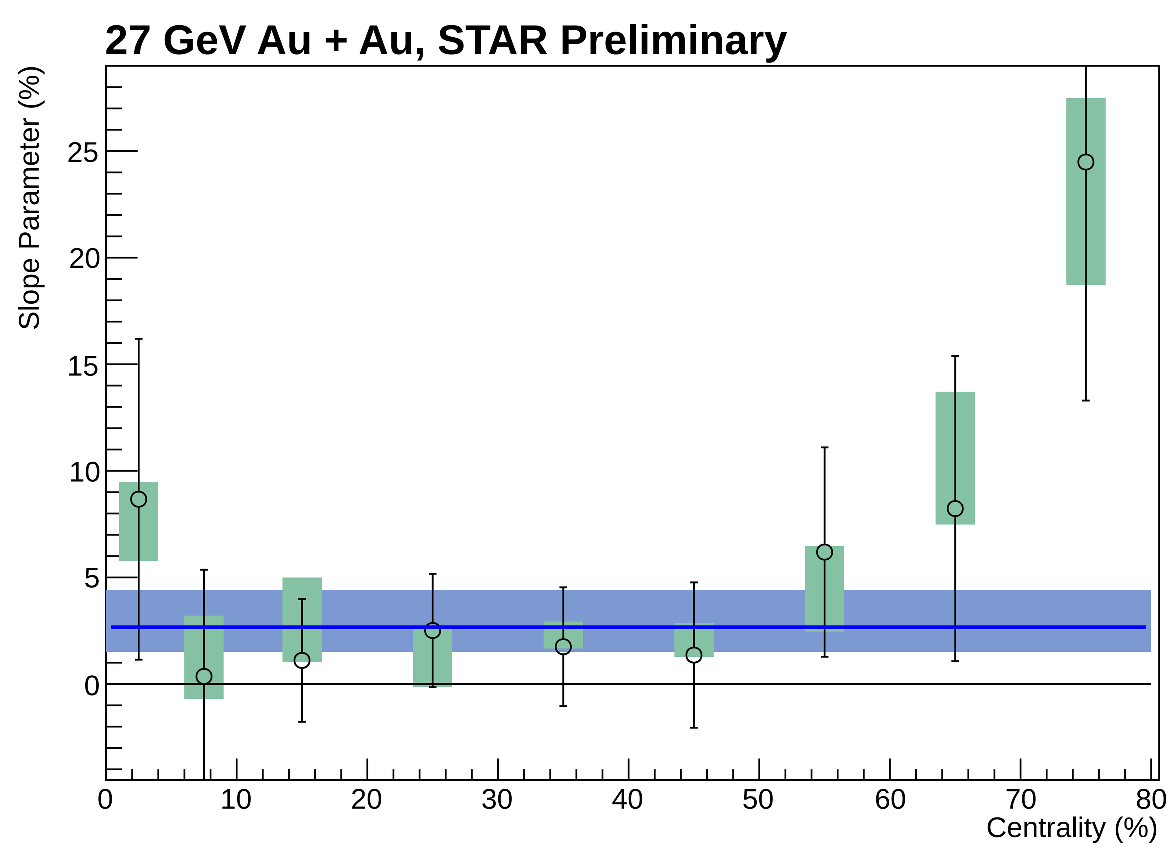



Fig. 6: A plot of the slope parameter as a function of centrality. The error bars are statistical only, while the green shaded boxes indicate the systematic errors. The systematic errors include contributions from tracking efficiency, kaon identification cuts and the difference between the two methods

## Conclusion

- We have carried out the $v_2$ measurements of charged kaons as a function of charge asymmetry in Au+Au collisions at 27 GeV.
- We have determined the presence of a positive linear dependence of $v_2$ difference on $A_{ch}$. This is consistent with the CMW picture.
- Error bars are very large.
- More data is needed to extract a statistically significant result.

## References

**[1]** L. Adamczyk *et al.* (STAR), Phys. Rev. Lett. 114, 252302 (2015), arXiv:1504.02175 [nucl-ex].
**[2]** Y. Burnier, D. E. Kharzeev, J. Liao, and H.-U. Yee, Phys. Rev. Lett. 107, 052303 (2011), arXiv:1103.1307 [hep-ph].
**[3]** K. Ackermann *et al.*, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 499, 624 (2003), the Relativistic Heavy Ion Collider Project: RHIC and its Detectors.
**[4]** M. Anderson *et al.*, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers,Detectors and Associated Equipment 499, 659 (2003), the Relativistic Heavy Ion Collider Project: RHIC and its Detectors.

LaTeX TikZposter