Search for Chiral Magnetic Effect with Identified Particles in Au+Au Collisions at √sNN = 39 GeV from RHIC/STAR

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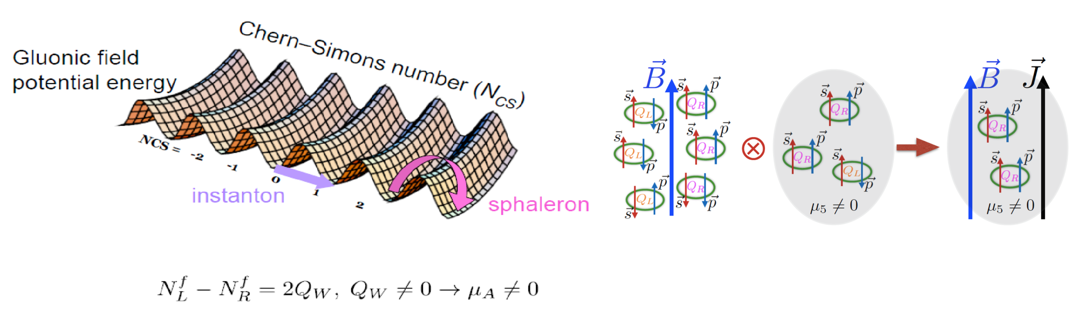
Chirality imbalance could occur in local domains inside the hot nuclear matter formed in high-energy heavy-ion collisions. In the presence of a strong magnetic field, this chirality imbalance will induce an electric charge separation along the magnetic field direction, owing to the chiral magnetic effect (CME) [1]. Previous azimuthal-angle correlation measurements [2] with unidentified charged particles have manifested charge separation signals consistent with the predictions of the CME. But the magnitudes of the background contributions have not been understood. In this poster, we present the correlation results with identified particles (protons, pions and kaons) using STAR data of 39 GeV Au+Au collisions. The results will be compared with those from Au+Au at √sNN = 200 GeV, as well as the published results of unidentified particles at √sNN = 39 GeV.

Motivation

Chiral Magnetic Effect (CME)

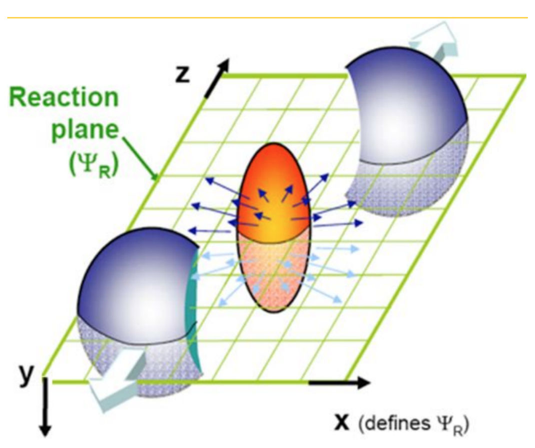


- **Local chiral domains** may be created in heavy-ion collisions on an event-by-event basis. A chiral system bears a non-zero axial chemical potential, μ5.
- In non-central collisions, a strong magnetic field (B ~10^5 T) will be produced. An electric current will be induced in chiral domains along the B field: **Chiral Magnetic Effect** (CME).
- **Charge separation fluctuations** for all charged particles have been experimentally observed.
- For identified particles: Is there an indication of CME?

Observable: γ correlator

$$\frac{dN_{\pm}}{d\phi} \propto 1 + 2a_{\pm}sin(\phi^{\pm} - \Psi_{RP})$$

"Three-point-correlation" observable "γ" to avoid zero value yield by direct measurement of "a".



$$\gamma = \langle cos(\phi_\alpha + \phi_\beta - 2\psi_{RP}) \rangle$$
$$= [\langle v_{1,\alpha} v_{1,\beta}\rangle + B_{in}] - [\langle a_\alpha a_\beta\rangle + B_{out}]$$

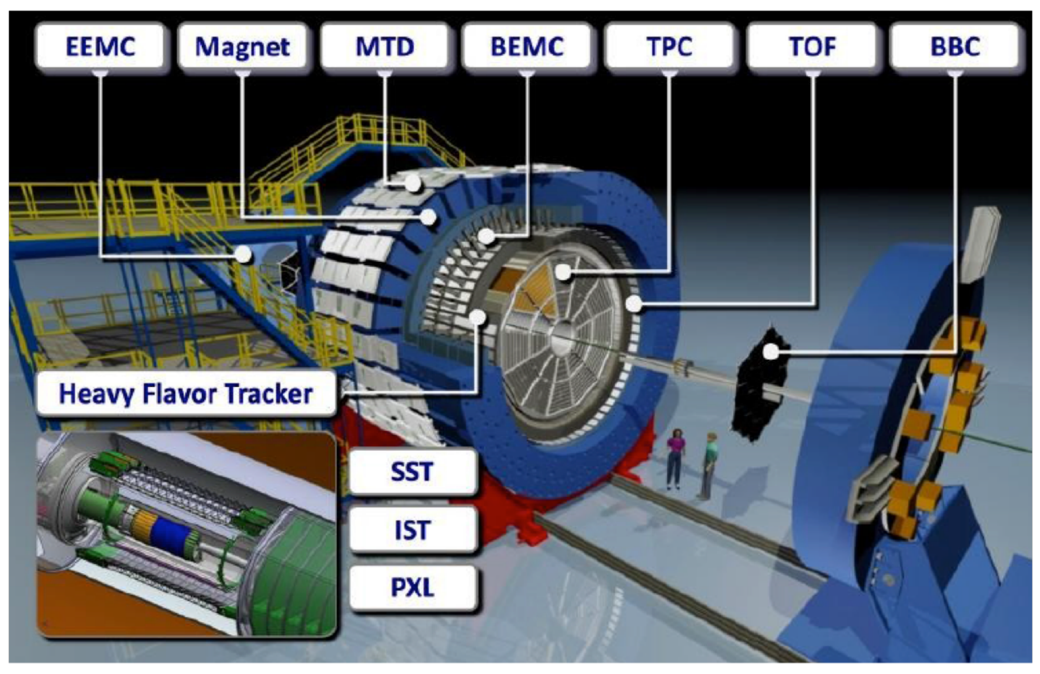
P-even quantity: still sensitive to separation effect, i.e., different for "same sign" and "oppo sign"

Directed flow: baseline unrelated to the magnetic field

Background Contribution: suppressed to a level close to the magnitude of v2

Experimental Approach

Solenoidal Tracker At RHIC (STAR)



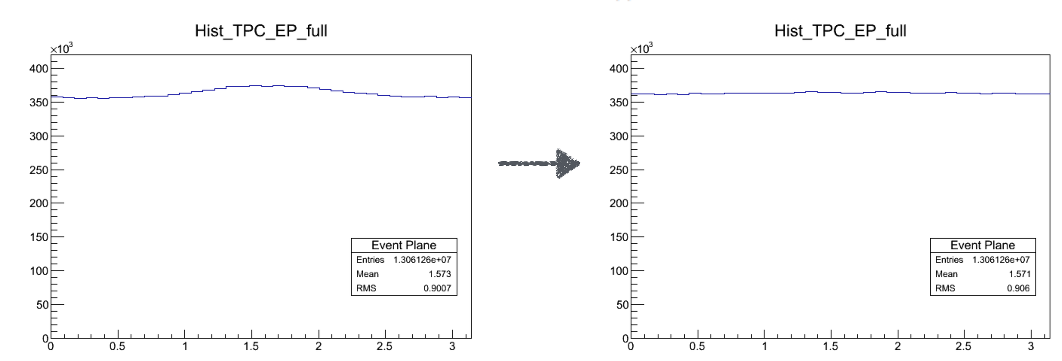
- Data of Au+Au at 39 GeV 200 GeV were collected by STAR detector in RHIC run 2010.
- Particle Identification:
  - **Time Projection Chamber**(TPC) dE/dx is used for proton/pion/kaon identification;
  - **Time of Flight** (TOF) detector provides mass information used for particle identification.

Event Plane Reconstruction

- **Shifting method** is used to make corrections to the event plane.

$$\frac{dN}{d\psi} = \frac{a_0}{2} + \sum_n (a_n \cos n\psi + b_n \sin n\psi) \qquad A_n = -\frac{2}{n}\cdot\frac{b_n}{a_0} = -\frac{2}{n}\langle \sin n\psi \rangle$$

$$\frac{dN}{d\psi} = \frac{dN}{d\psi'}\cdot\frac{d\psi'}{d\psi} = \frac{a_0}{2}\cdot\Big(1+\sum_n(-n\cdot A_n \sin n\psi + n\cdot B_n \cos n\psi)\Big) \qquad B_n = -\frac{2}{n}\cdot\frac{a_n}{a_0} = \frac{2}{n}\langle \cos n\psi \rangle$$

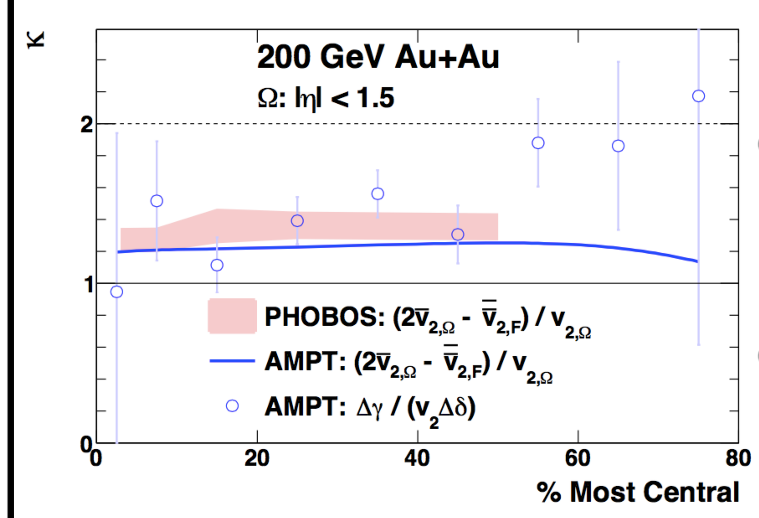


Flow Background

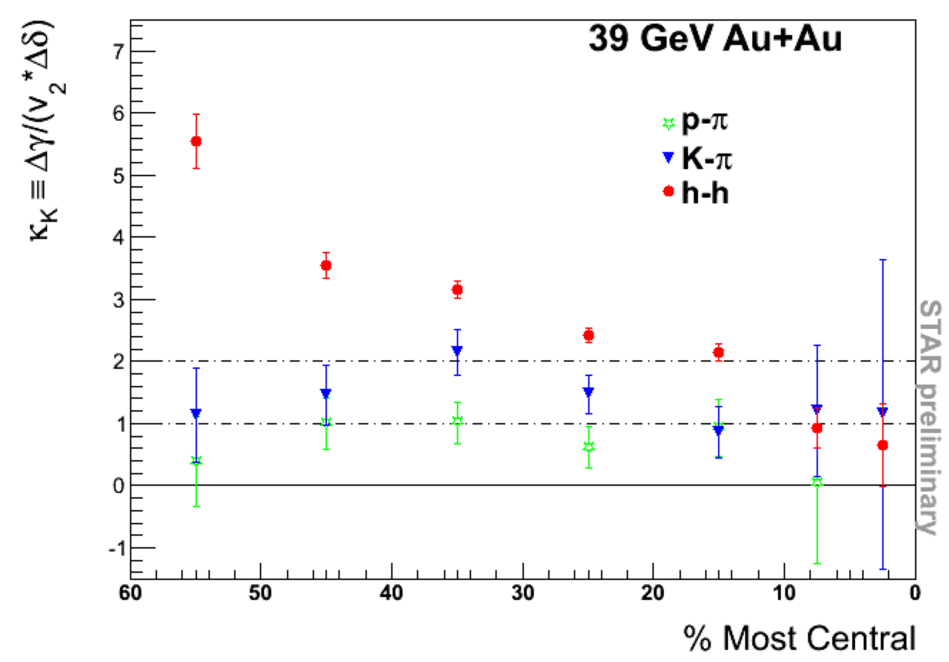
- Correlation signal is contaminated with the **background contributions** due to collective motion of the collision system (flow)
  - elliptic flow coupled with transverse momentum conservation (TMC), local charge conservation (LCC) and also decay of the clusters.
- H: background-subtracted correlator, CME contributions

$$\gamma \equiv \langle\langle \cos(\phi_\alpha + \phi_\beta - 2\Psi_{RP})\rangle\rangle$$
$$\delta \equiv \langle\langle \cos(\phi_\alpha - \phi_\beta)\rangle\rangle$$
$$H^\kappa = (\kappa v_2 \delta - \gamma)/(1+\kappa v_2).$$

$$\boxed{\kappa_K \equiv \Delta\gamma/(v_2{}^*\Delta\delta)}$$



- **Baseline:** κ estimated to be (1.2,1.4) for three methods [3].
- Indication of signal if higher than baseline: κ that forces ΔH = 0
- κ might be different for different particle pairs: different possible implications



- Inconclusive to claim a charge-separation signal in proton-pion or in kaon-pion because signal + background is consistent with background at this level of precision.

Identified Particle Analysis

Cuts

- Event

VertexZ (cm)	(-30,30)

- Particles

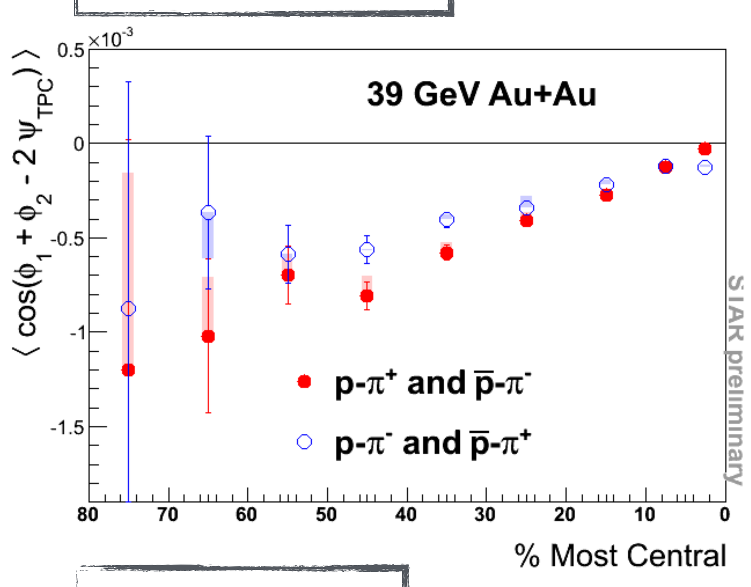
Eta	(-1,1)	
Dca (cm)	Kaon	< 1
	Pion	< 2
	Proton	< 1
Tof	β	> 0
	Ylocal	(-1.8,1.8)

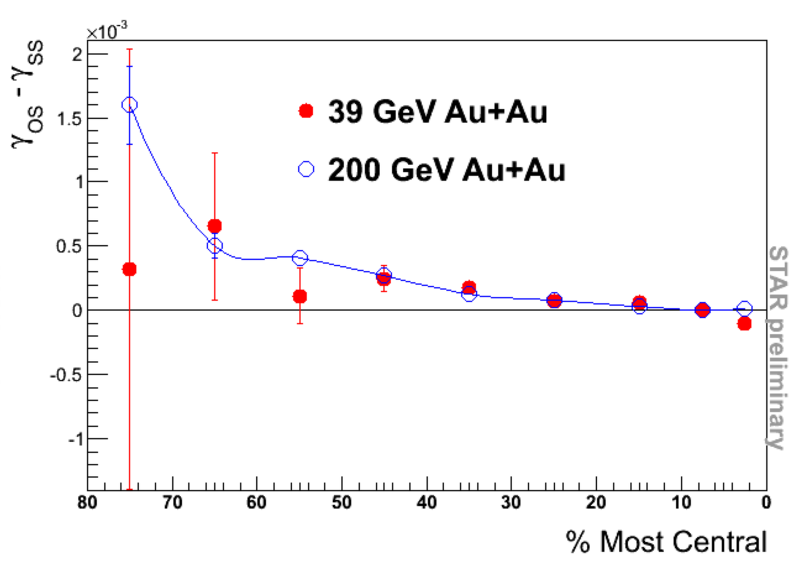
- Identified Particles

Mass² (GeV²/c⁴)	Proton	(0.8, 1)
	Pion	(0.01, 0.1)
	Kaon	(0.2, 0.35)
pT (GeV/c)	Proton	> 0.4
	Pion	> 0.15
	Kaon	> 0.2
P (GeV/c)	Proton	< 2
	Pion	< 1.6
	Kaon	< 1.6
nSigma of Proton		(-2, 2)
nSigma of Kaon		(-2, 2)
nSigma of Pion		(-2, 2)

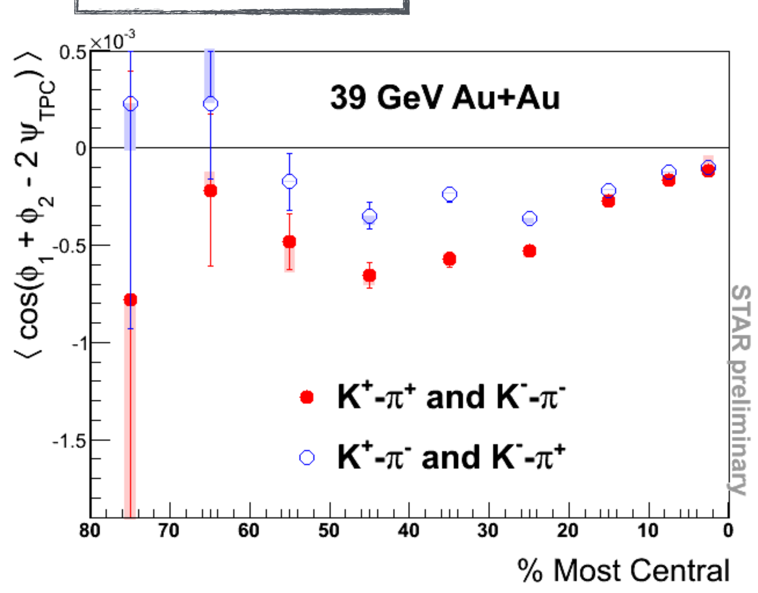
- Opposite sign signal is above the same sign signal, and the the signal is smaller for more central collisions.

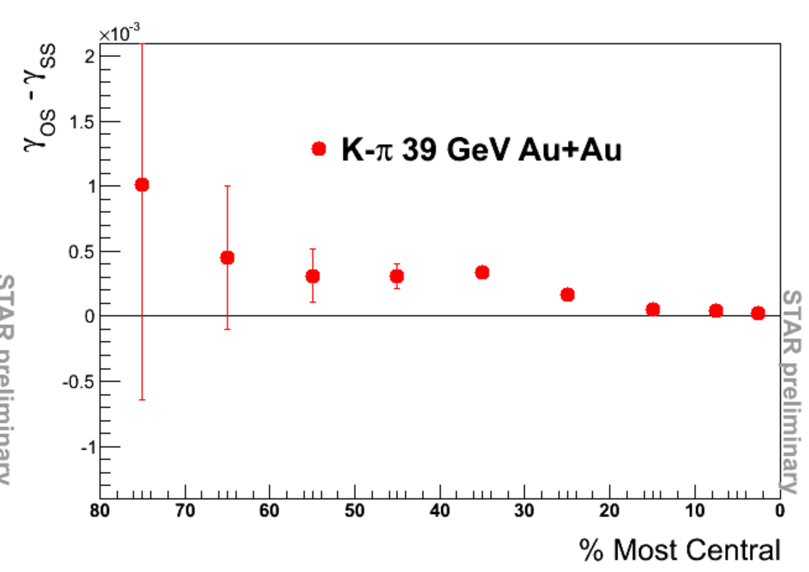
Proton-Pion





Kaon-Pion





Summary

- **Identified particle results for p-π and K-π behave as expected: Opposite sign signal is above the same sign signal, and the the signal is smaller for more central collisions.**
- **Inconclusive to claim a charge-separation signal in p-π or K-π because the normalized signal + background value is compatible with background at this level of precision.**

References

[1]D. Kharzeev, Phys. Lett. B **633** (2006) 260.
[2]L. Adamczyk et al., Phys. Rev. Lett. **113** (2014) 052302.
[3]arXiv:1608.03205 [nucl-th].

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