$\Lambda(K^0_S)$-h and Λ-p Azimuthal Correlations with Respect to the Reaction Plane and Searches for CME and CVE

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for STAR Collaboration

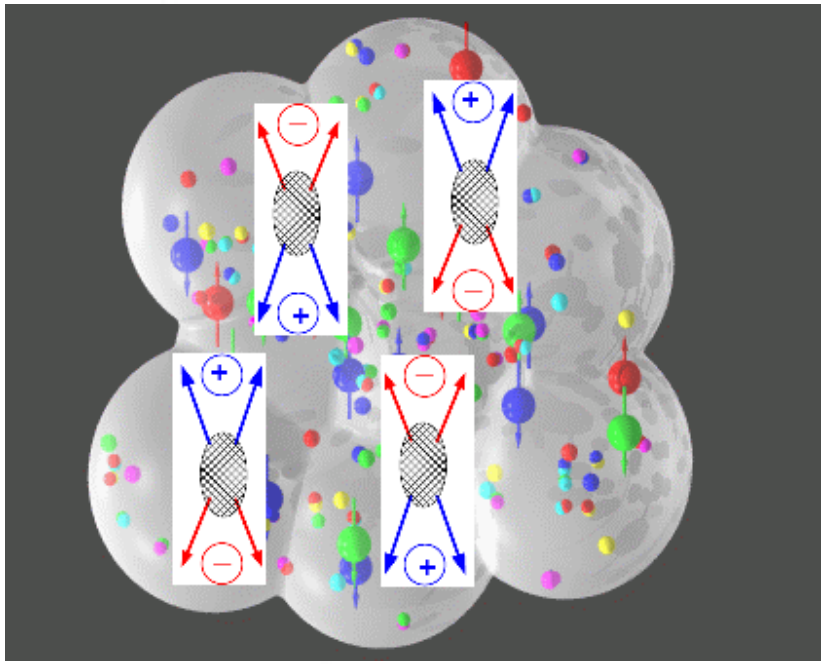
XXIV QUARK MATTER
DARMSTADT 2014

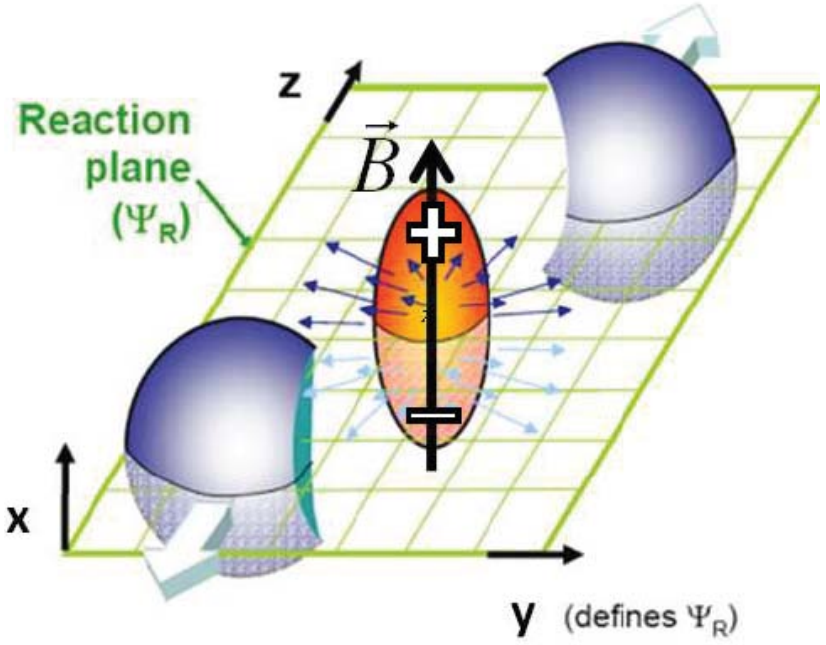
UCLA BRUINS

Outline

- Introduction to Chiral Magnetic Effect (CME) and Chiral Vortical Effect (CVE)
- Λ–$h^{\pm}$ and K^0_S–$h^{\pm}$ correlations and implications on searches for CME
- Λ–$p^{\pm}$ correlations, to search for CVE

Chiral Magnetic Effect





- Parity Odd Domain + Chiral Magnetic Effect

  → Electric Charge Separation across RP

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

- D. Kharzeev. Phys. Lett. B **633**:260 (2006).
- D. Kharzeev, L. McLerran, H. Warringa. Nucl. Phys. A **803**:227 (2008).

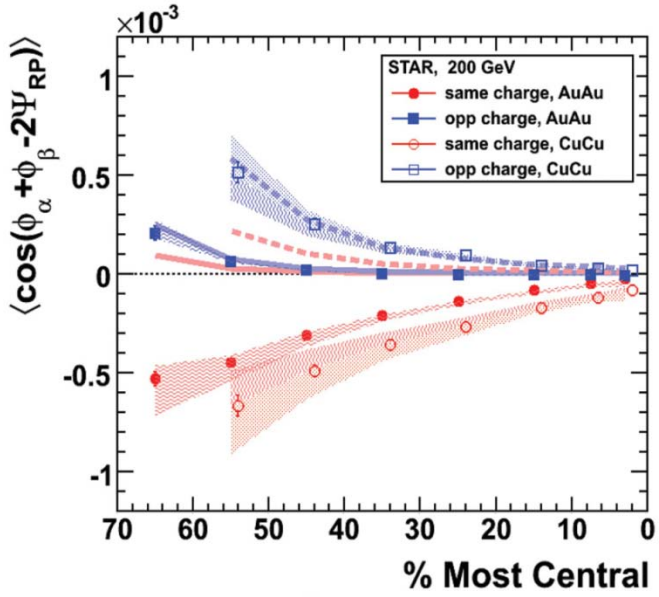
Chiral Magnetic Effect

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

A direct measurement of the *P*-odd quantity *"a"* should yield *zero*.

S. Voloshin, PRC 70 (2004) 057901

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



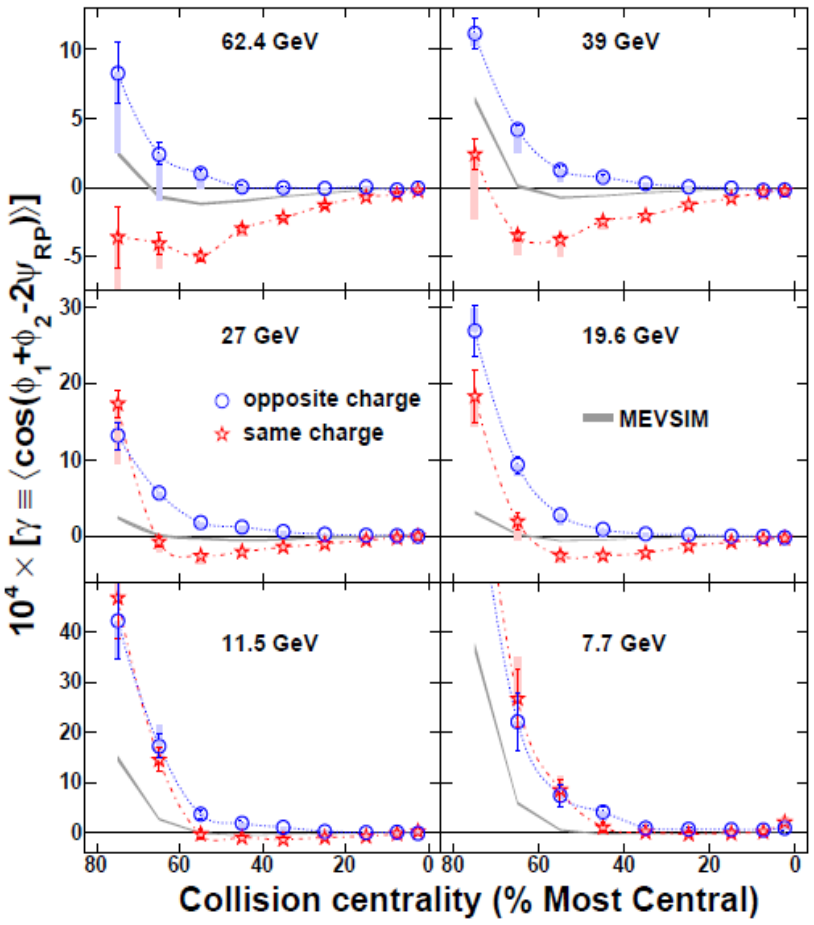
Directed flow: expected to be the same for SS and OS

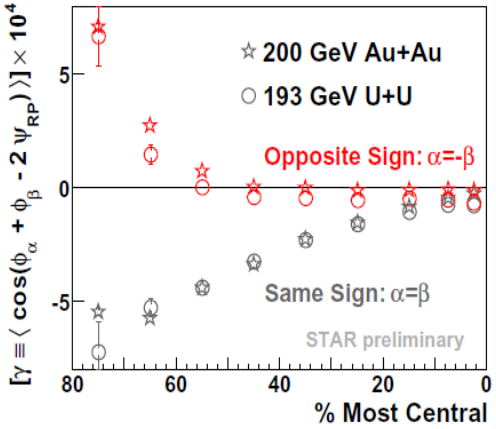
Non-flow/non-parity effects: largely cancel out

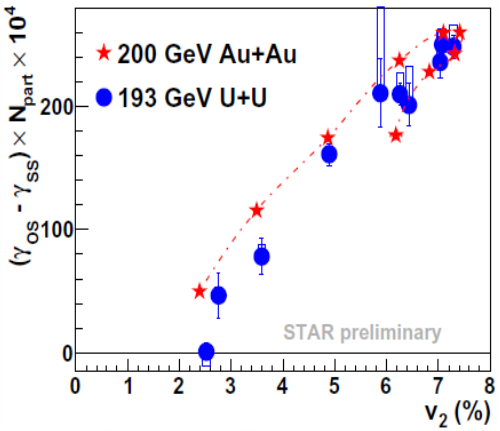
P-even quantity: still sensitive to charge separation

Phys. Rev. Lett. 103 (2009) 251601 (STAR)

Chiral Magnetic Effect







STAR, subm. to PRL (arXiv:1404.1433)

- The signal disappears when:
  - the beam energy is down to ~7.7GeV
  - the magnetic field from spectators is greatly suppressed
- Does the signal disappear in neutral-charged-particle correlations?

Chiral Vortical Effect

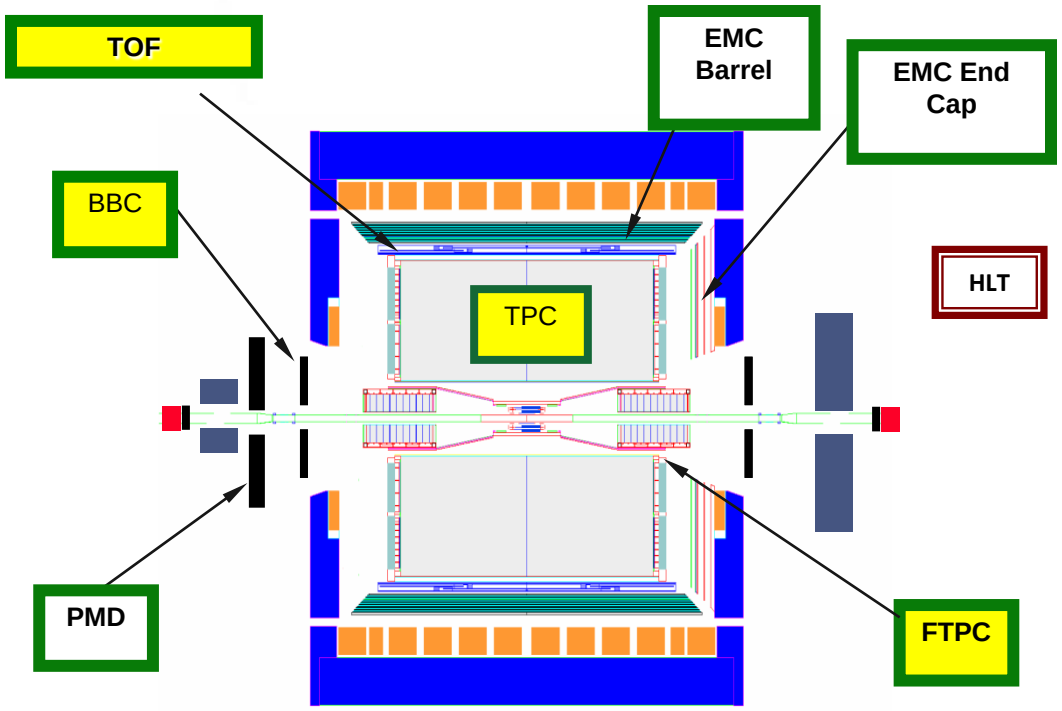
Parity Odd Domain	--	Parity Odd Domain
Magnetic Field	--	Fluid Vorticity
↓		↓
Chiral Magnetic Effect	--	Chiral Vortical Effect
(Electric Charge)	--	(Baryon Number)

D. Kharzeev, D. T. Son, PRL 106 (2011) 062301

$$\langle \cos(\phi_{\Lambda} + \phi_{\mathrm{p}} - 2\Psi_{RP}) \rangle$$

Measure the Λ–$\mathrm{p}^{\pm}$ to search for the Chiral Vortical Effect.

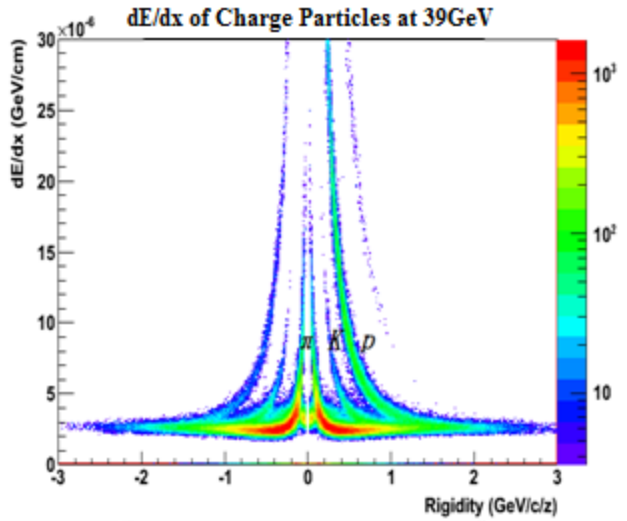
STAR Detector



Data Set

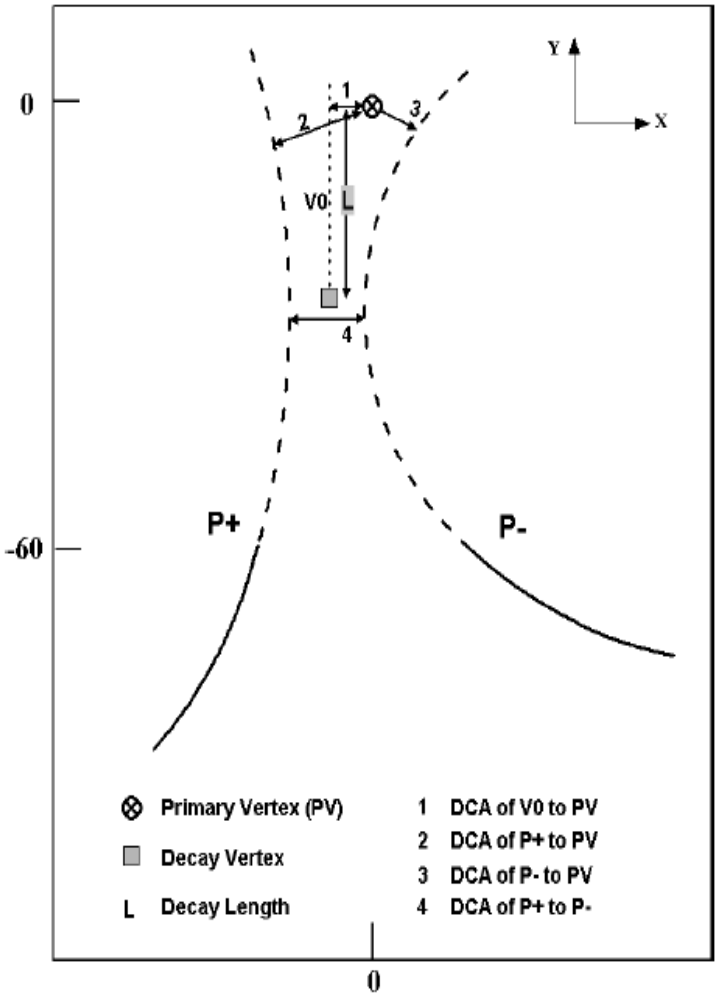
Run10, Au+Au collisions at $\sqrt{s_{NN}}$ = 39GeV, about 130 million events.

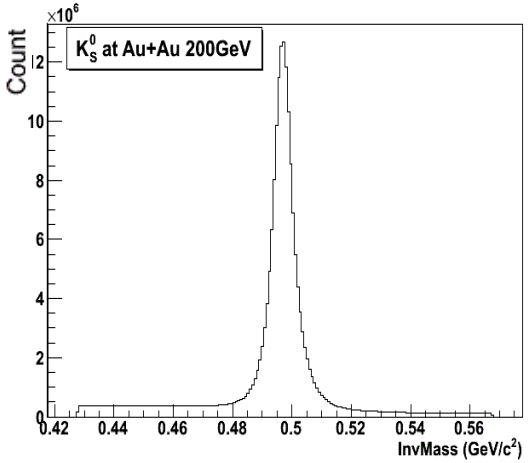
Run11, Au+Au collisions at $\sqrt{s_{NN}}$ = 200GeV, about 480 million events.

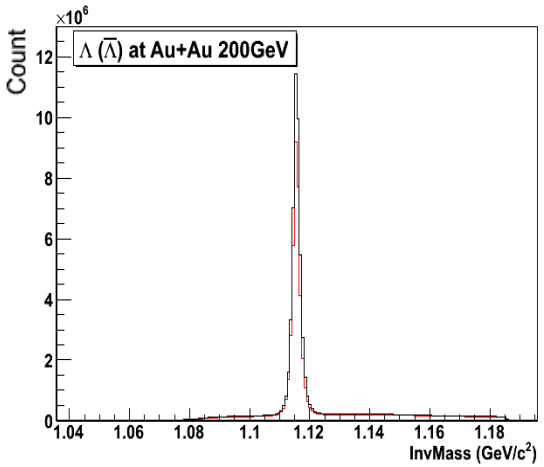


- STAR Detector System in Run 10 and Run 11.

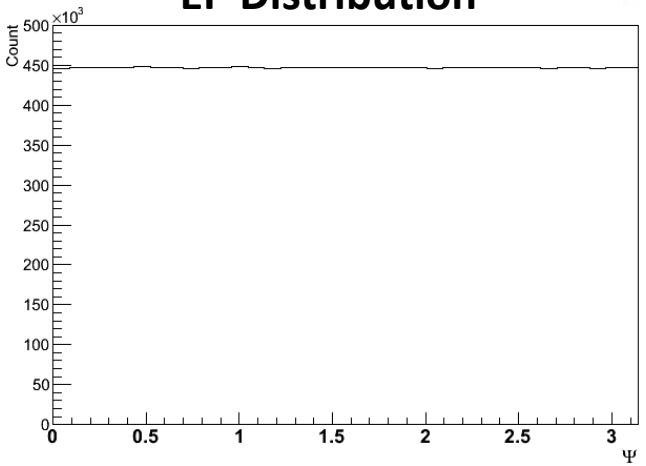
$\Lambda(K^0_S)$ and Event Plane







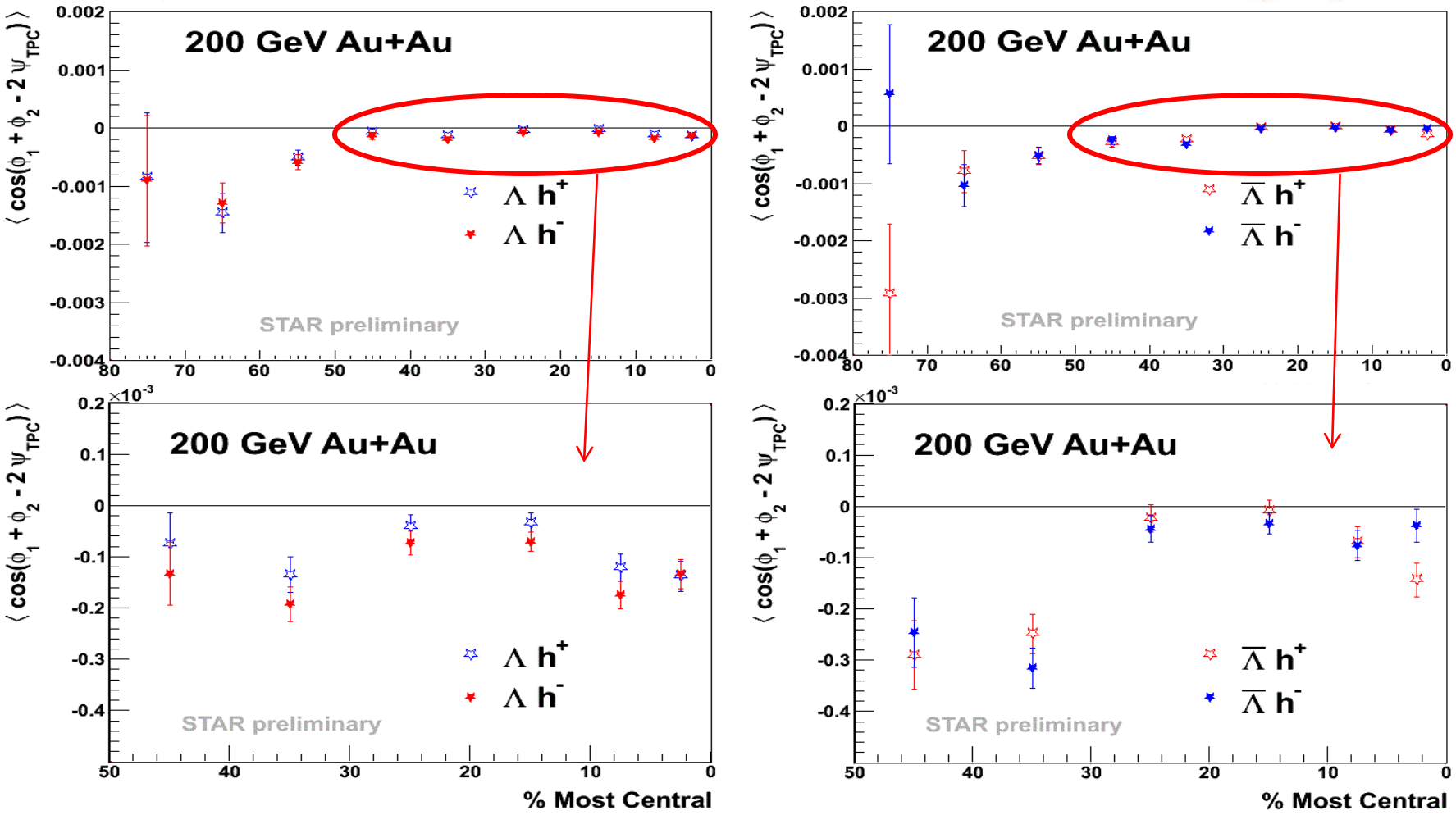
EP Distribution



Shifting method used to flatten the EP distribution.

E877, Phys. Rev. C 56 (1997) 3254

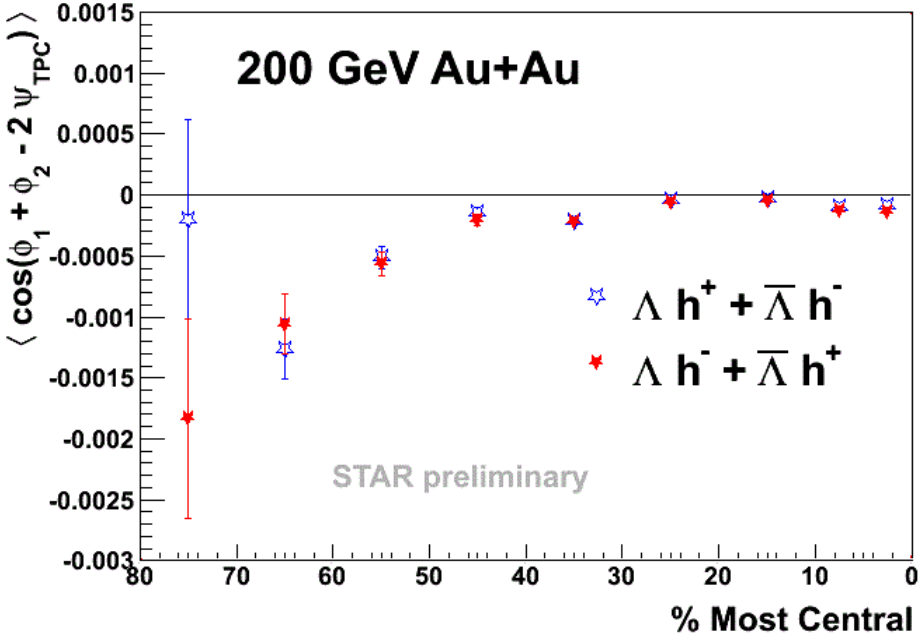
Λ–$h^{\pm}$ at Au+Au 200GeV

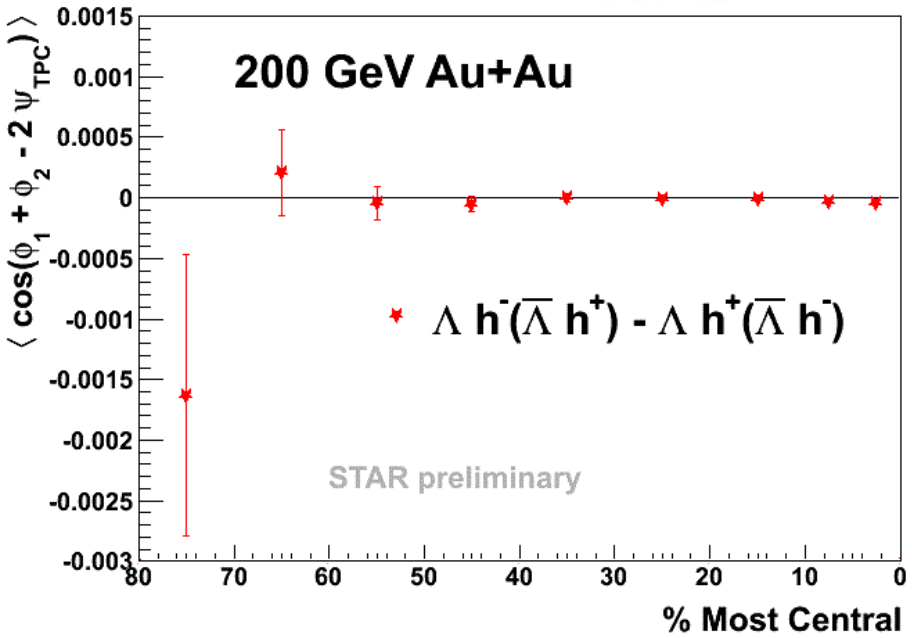


Error bars are statistical only.

Protons are excluded from charge hadrons.

Λ–h$^{\pm}$ at Au+Au 200GeV

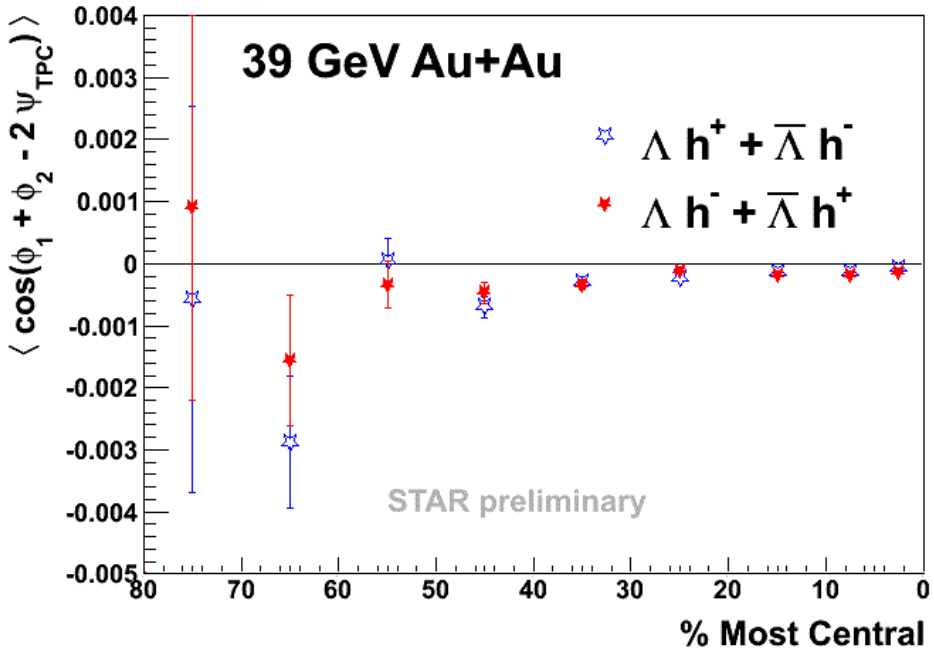


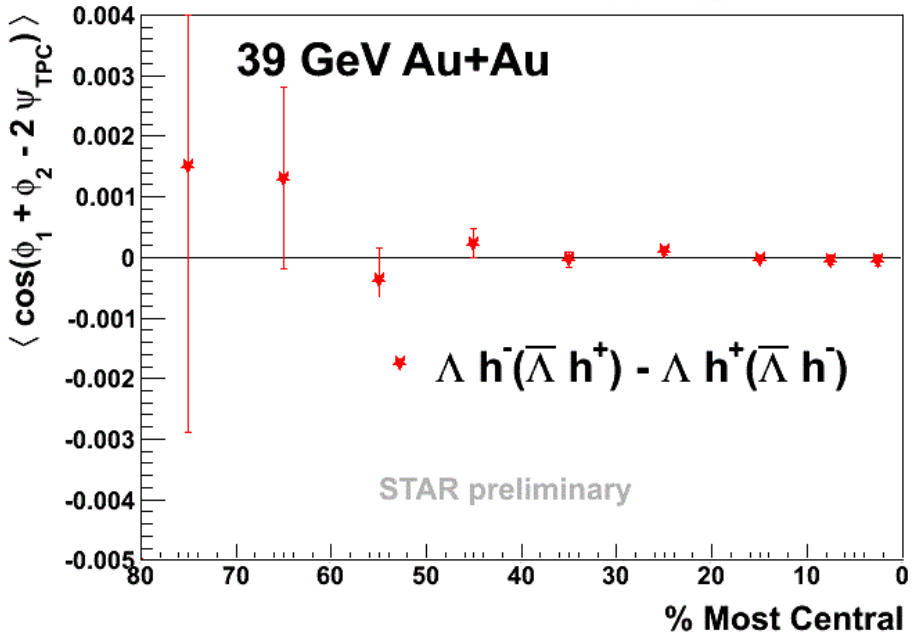


- $\Lambda h^+(\bar{\Lambda} h^-)$ & $\Lambda h^-(\bar{\Lambda} h^+)$ are consistent with each other;
- Assume Λh^+ and $\bar{\Lambda} h^-$ are same sign, Λh^- and $\bar{\Lambda} h^+$ are opposite sign, we can combine them;
- $\Lambda h^+ + \bar{\Lambda} h^-$ & $\Lambda h^- + \bar{\Lambda} h^+$ are consistent with each other.

Error bars are statistical only.

Λ–h$^{\pm}$ at Au+Au 39GeV

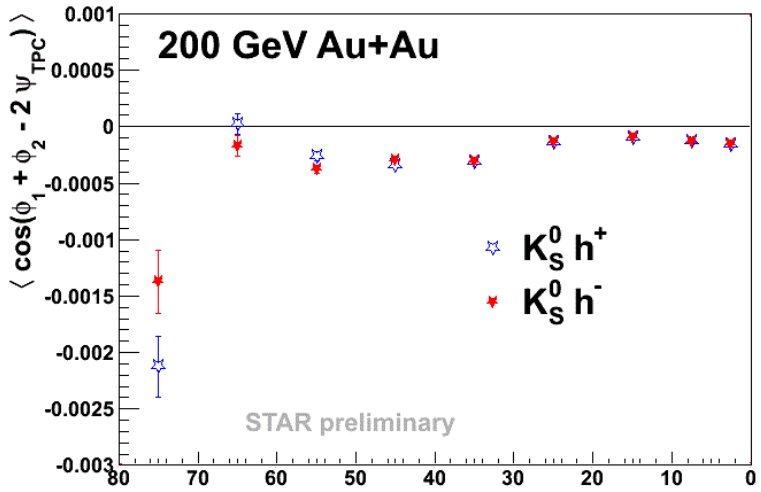


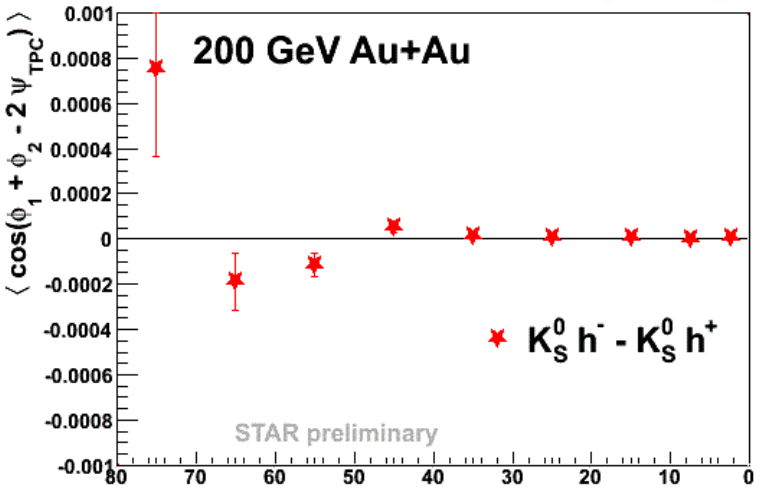


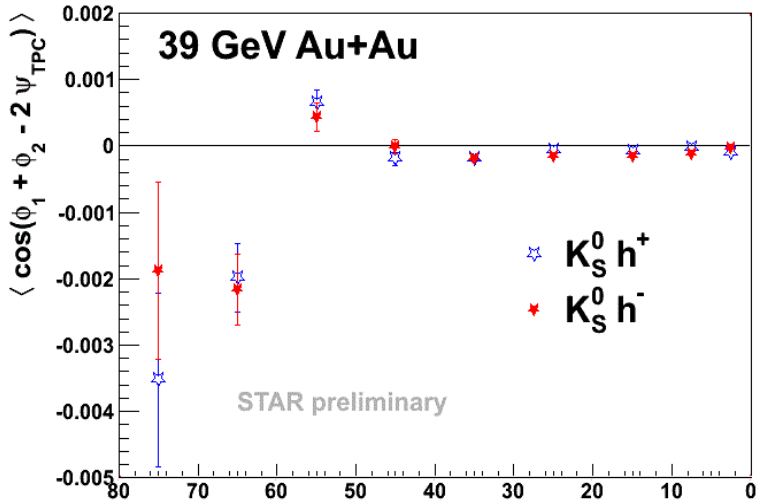
- At Au+Au 39GeV, $\Lambda h^+ + \overline{\Lambda} h^-$ & $\Lambda h^- + \overline{\Lambda} h^+$ also show a consistent behavior.

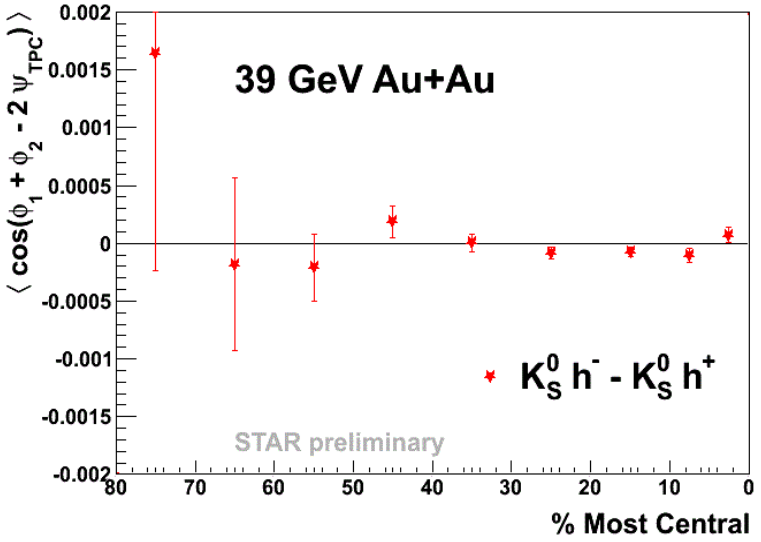
Error bars are statistical only.

K^0_S–$h^{\pm}$ at Au+Au 39 and 200GeV





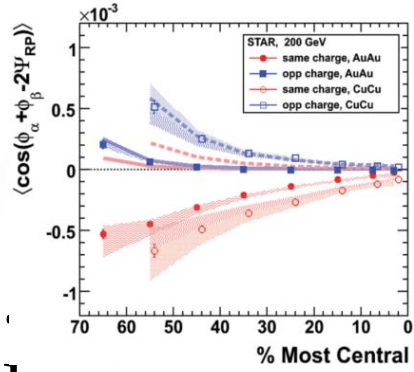




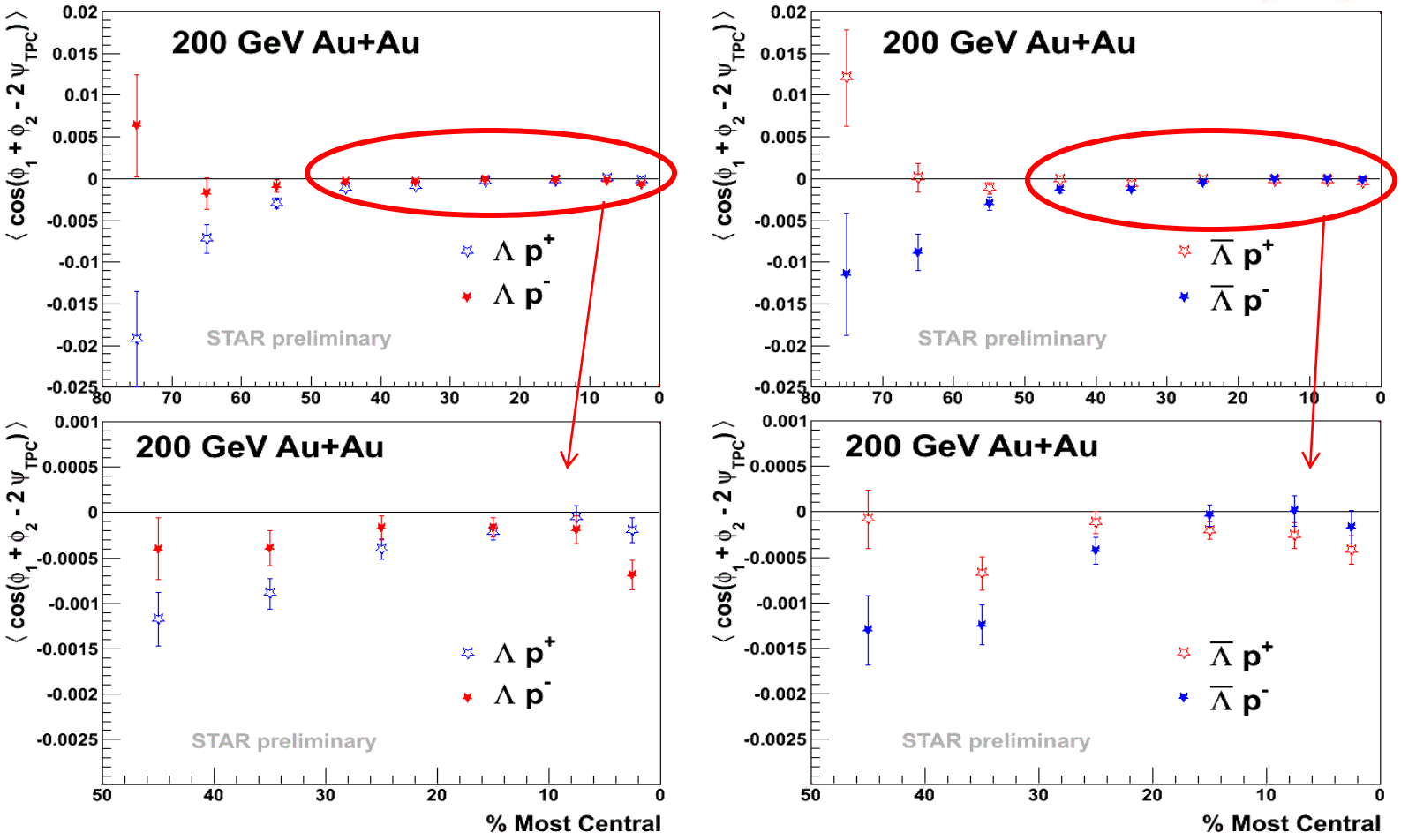
Error bars are statistical only.

Summary I

- Λ–$h^{\pm}$ and K^0_S–$h^{\pm}$ correlations show no charge-separation-like effects w.r.t. reaction plane.
- The charge separation observed in charged hadron correlation relies on electric charges of correlated hadrons.
- In search for CME, Λ acts like a neutral particle: s quarks appear to fully participate in the chiral dynamics, just like u and d quarks.
- The measurement of Λ–$h^{\pm}$ and K^0_S–$h^{\pm}$ provides a charge-independent background study for the CME.



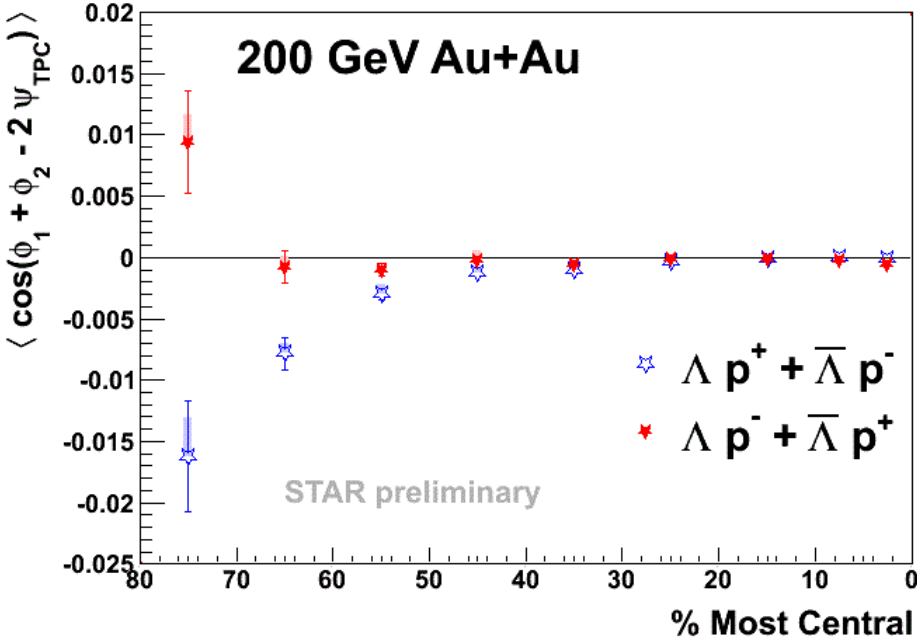
Λ–p$^{\pm}$ at Au+Au 200GeV

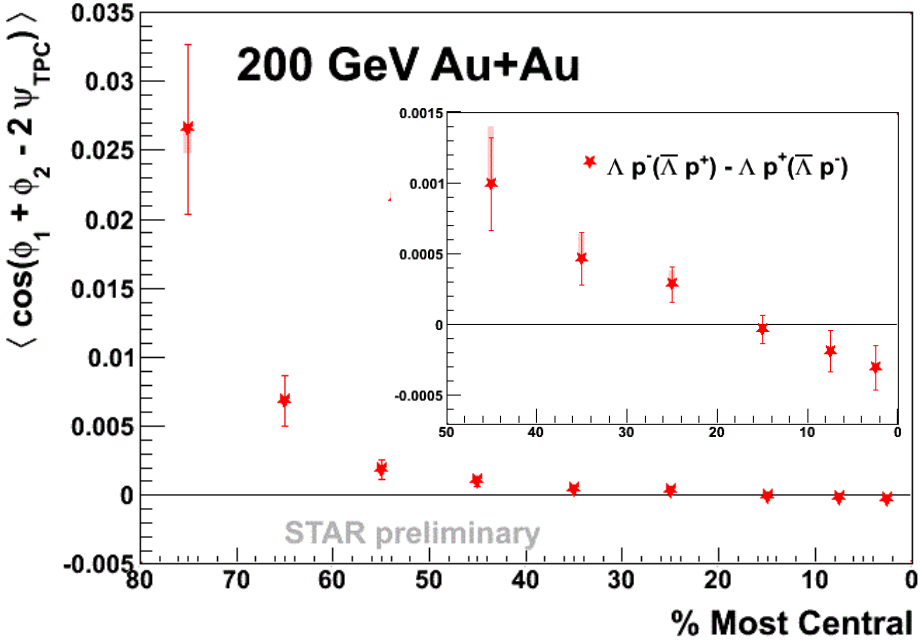


Error bars are statistical only.

Study on systematic errors, particle purity and weak decay contribution is on-going.

Λ–$p^{\pm}$ at Au+Au 200GeV





Error bars are statistical errors; the shadows are the systematic errors due to HBT effect.

- Λp^+ and $\bar{\Lambda} p^-$ (same baryon number) show a similar behavior;
- Λp^- and $\bar{\Lambda} p^+$ (opposite baryon number) show a similar behavior;
- "same B" is systematically lower than "oppo B" in the mid-central and peripheral collisions, consistent with the CVE expectation.

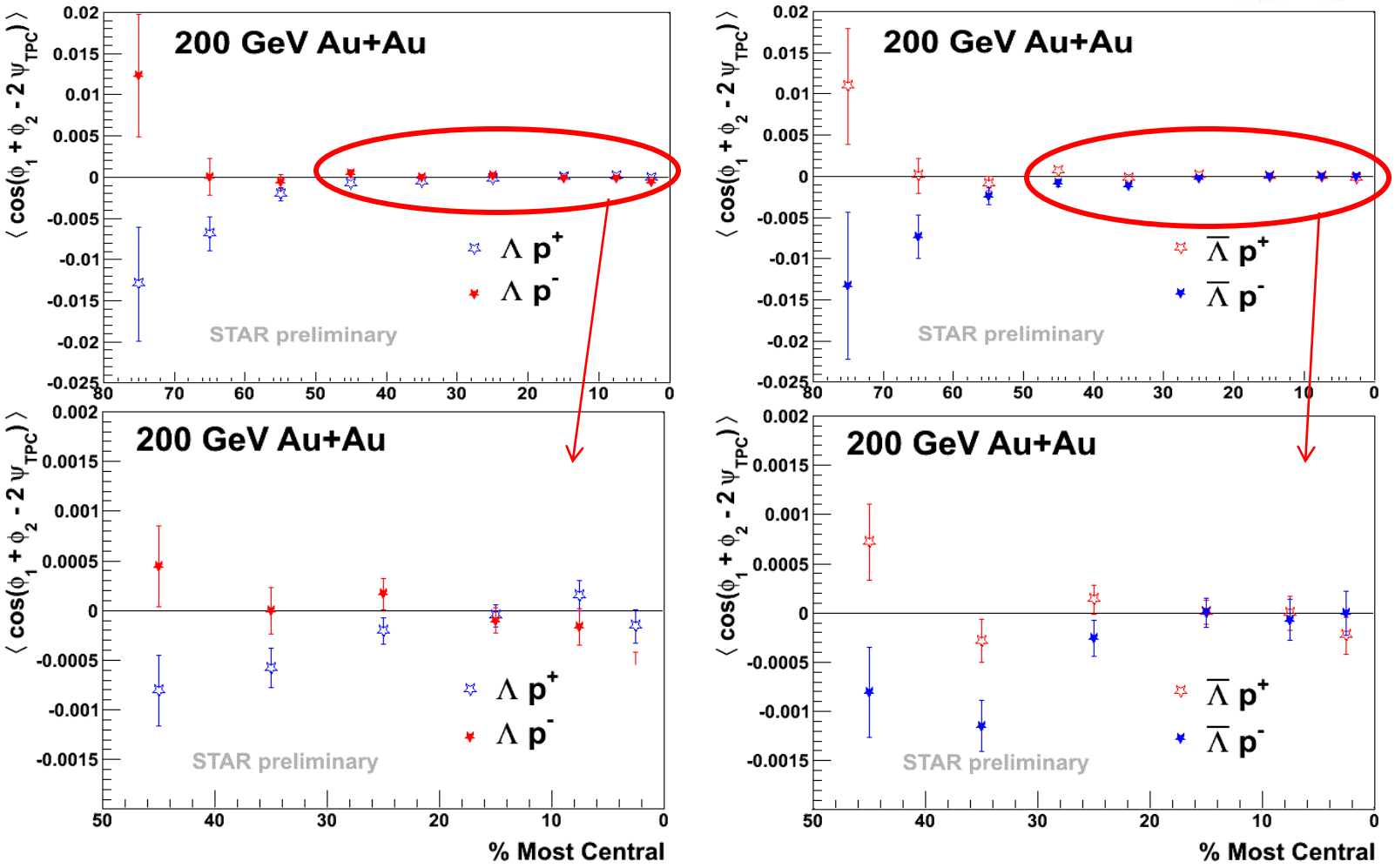
Summary II

- We observe a baryon number dependent Λ–p correlations w.r.t. the reaction plane.
- CVE predicted such baryon number dependent correlations, but more measurements are needed to understand the nature of the correlation.

More LPV results from STAR, please refer to presentation by Qi-Ye Shou, *Charge asymmetry dependence of π/K anisotropic flow in UU and AuAu collisions at RHIC*
May 20, 10:00am, QCD phase diagram1

Back Up

Λ–$p^{\pm}$ at Au+Au 200GeV



Results with HBT effect excluded.

Error bars are statistical only.