

$\Lambda(K^0_S)$ -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



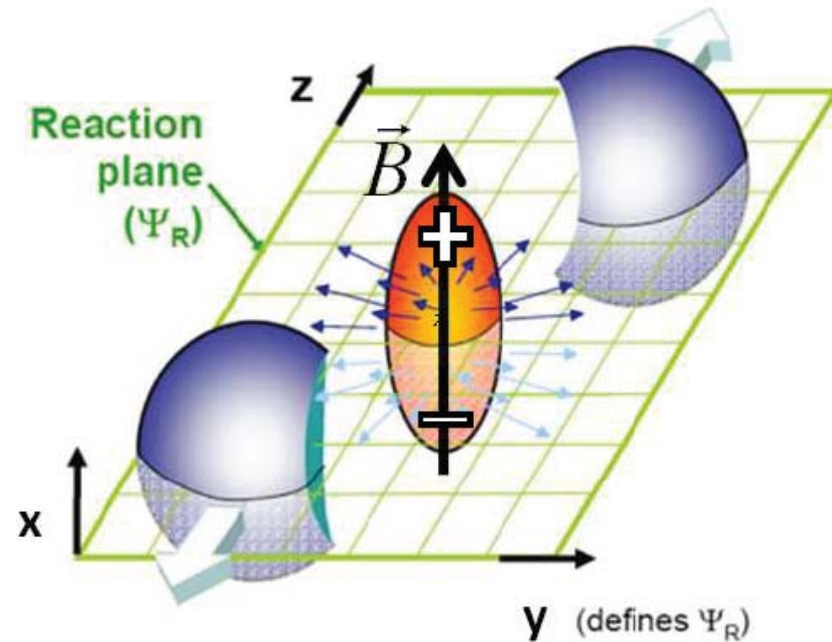
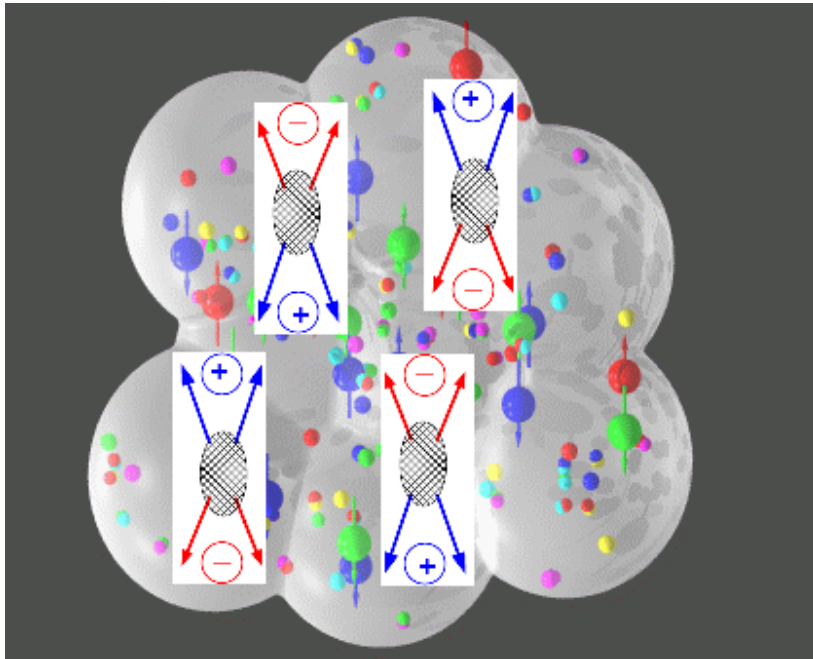
Outline



- Introduction to Chiral Magnetic Effect (CME) and Chiral Vortical Effect (CVE)
- Λ - h^\pm and K_s^0 - 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

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

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



Chiral Magnetic Effect

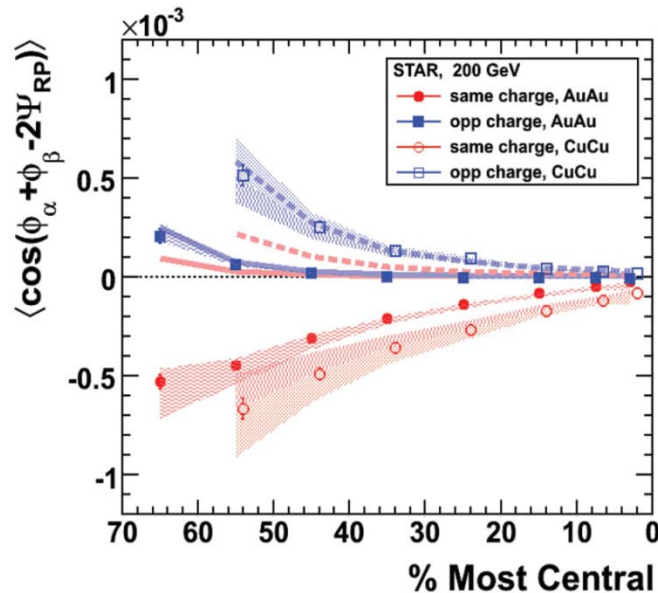


$$\frac{dN_{\pm}}{d\phi} \propto 1 + 2a_{\pm} \cdot \sin(\phi^{\pm} - \Psi_{RP})$$

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

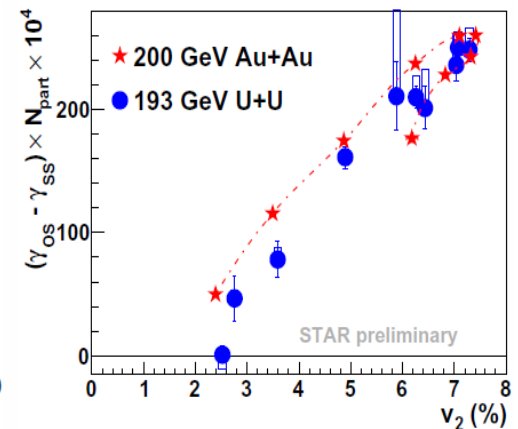
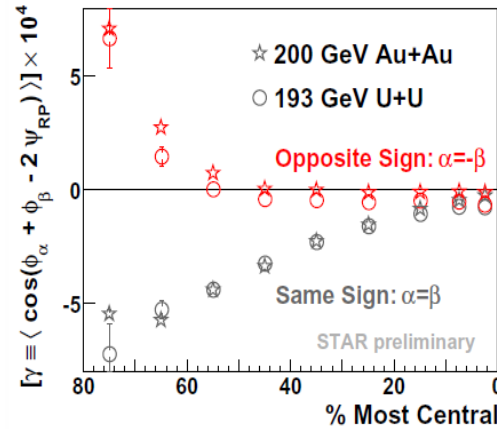
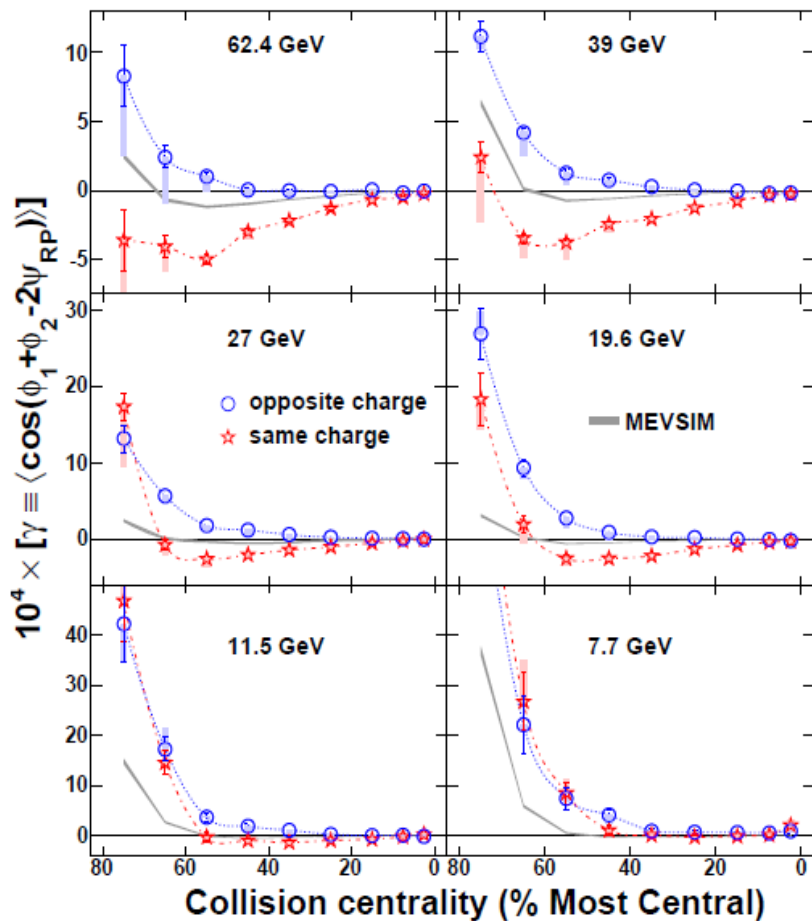
Non-flow/non-parity effects: largely cancel out

P-even quantity: still sensitive to charge separation

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



Chiral Magnetic Effect



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

STAR, subm. to PRL (arXiv:1404.1433)



Chiral Vortical Effect



Parity Odd Domain

-- Parity Odd Domain

Magnetic Field

-- Fluid Vorticity



Chiral Magnetic Effect
(Electric Charge)

-- Chiral Vortical Effect
(Baryon Number)



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

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

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



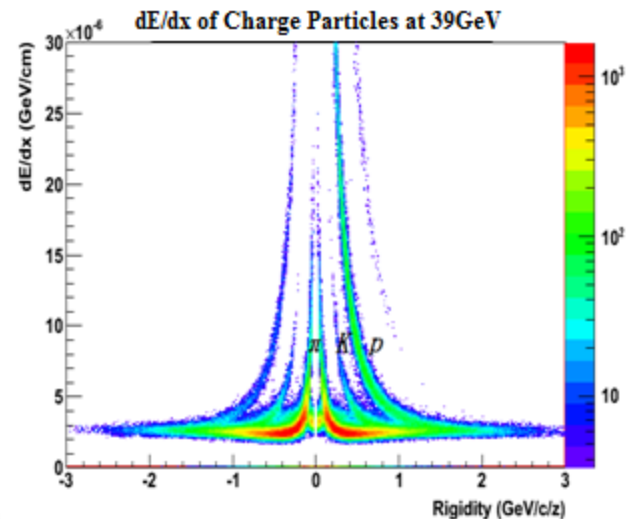
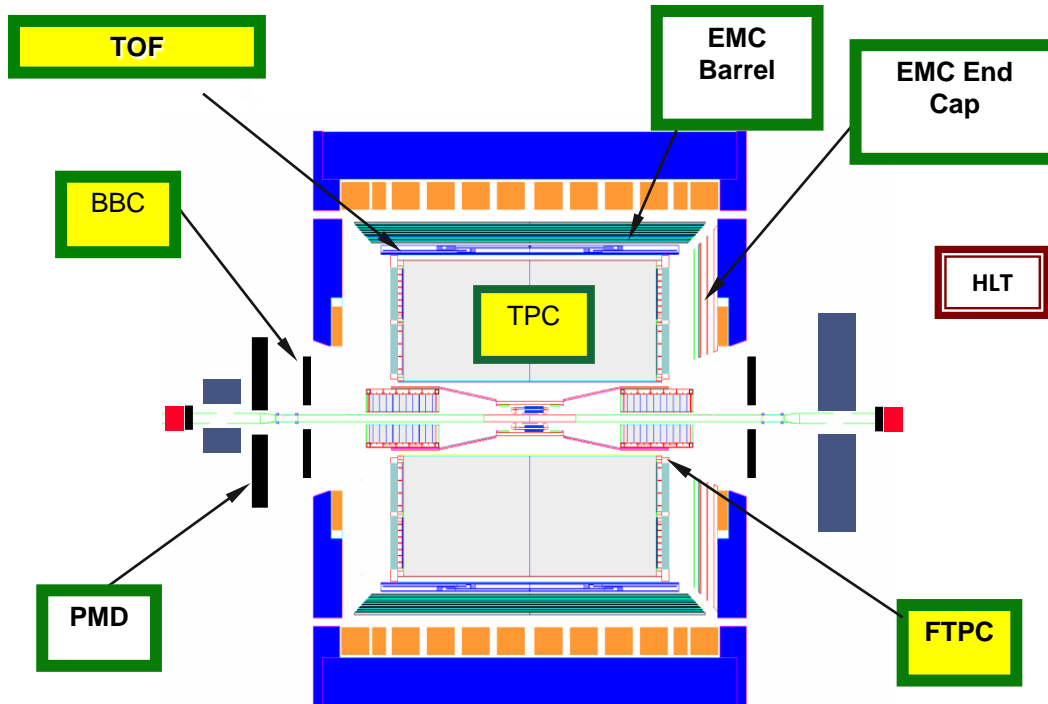
STAR Detector



Data Set

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

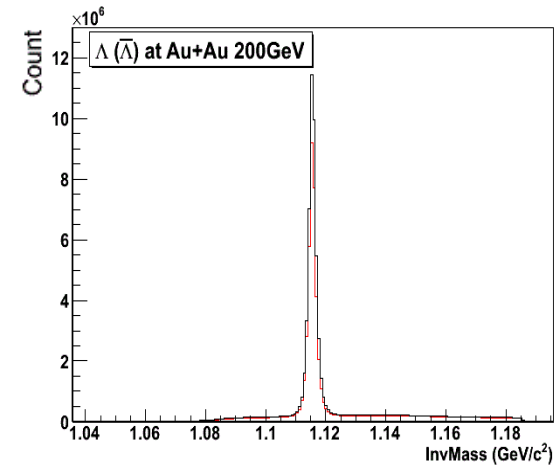
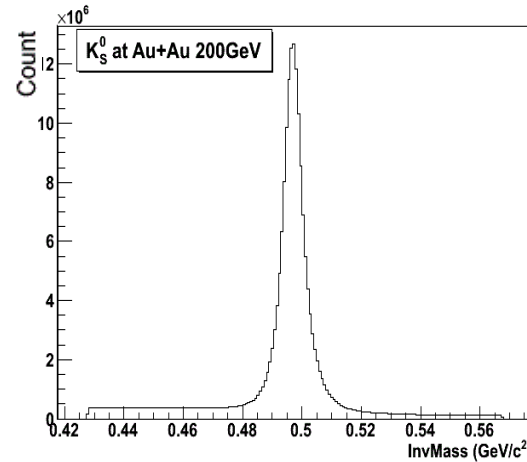
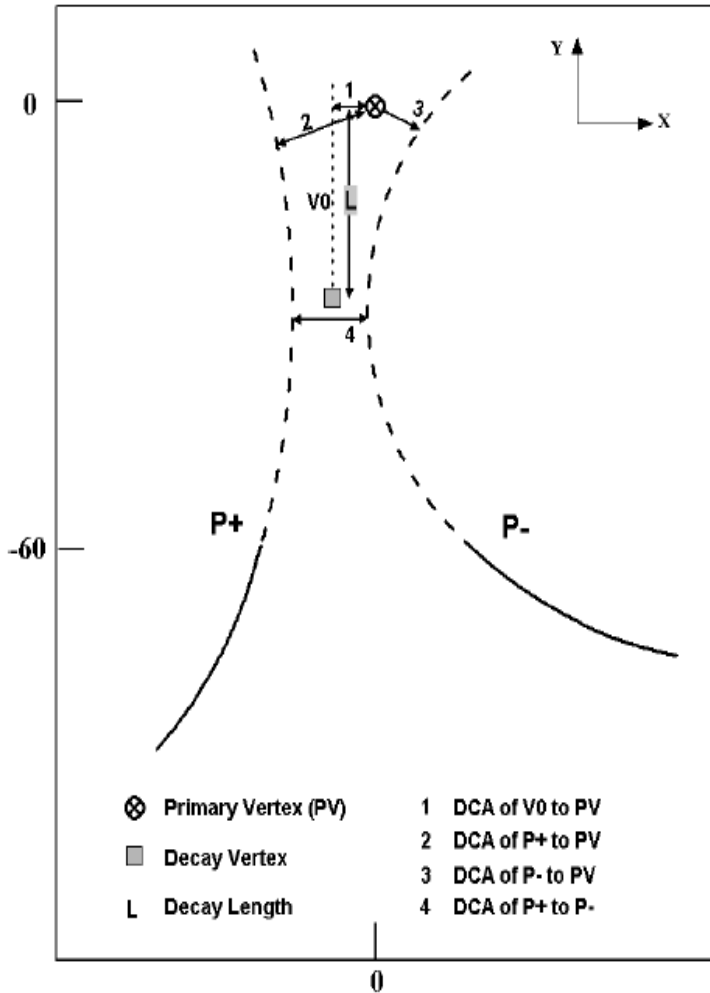
Run11, Au+Au collisions at $\sqrt{s_{NN}} = 200\text{GeV}$, about 480 million events.



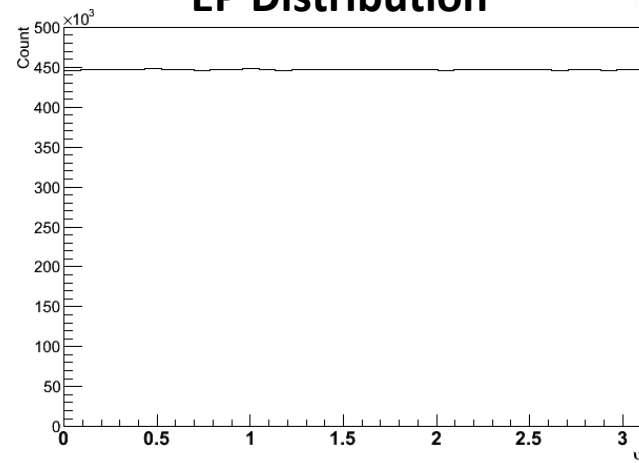
- STAR Detector System in Run 10 and Run 11.



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



EP Distribution

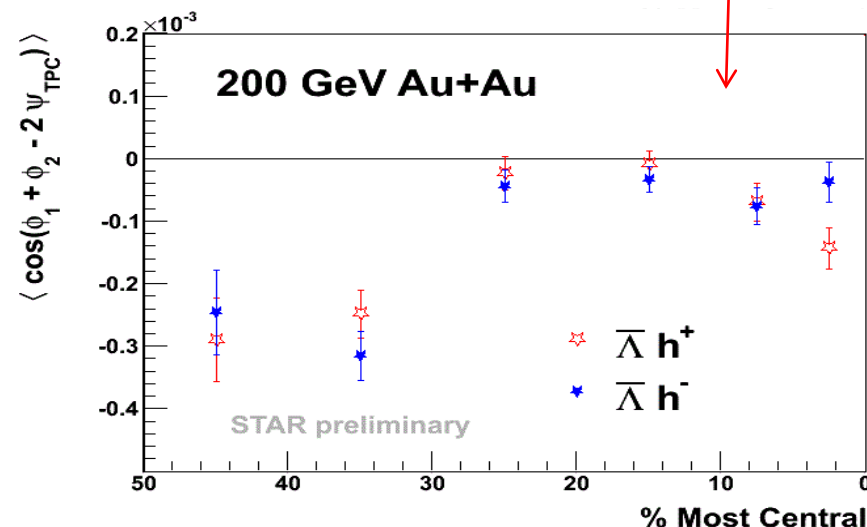
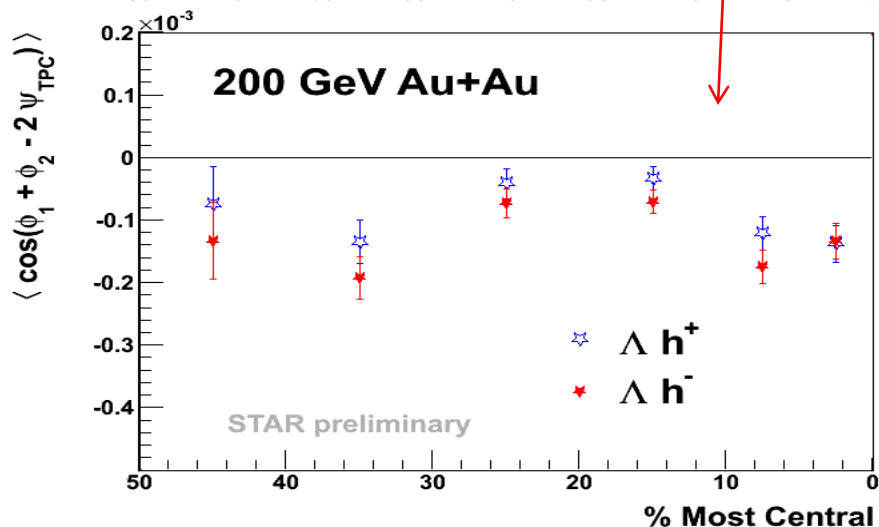
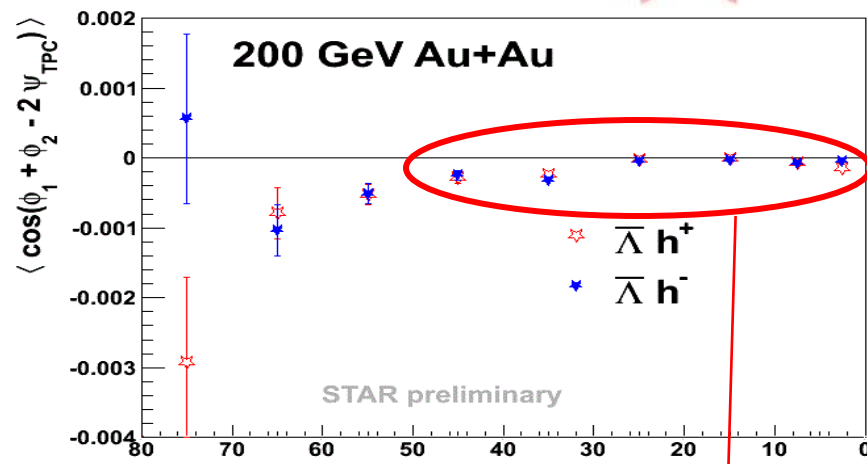
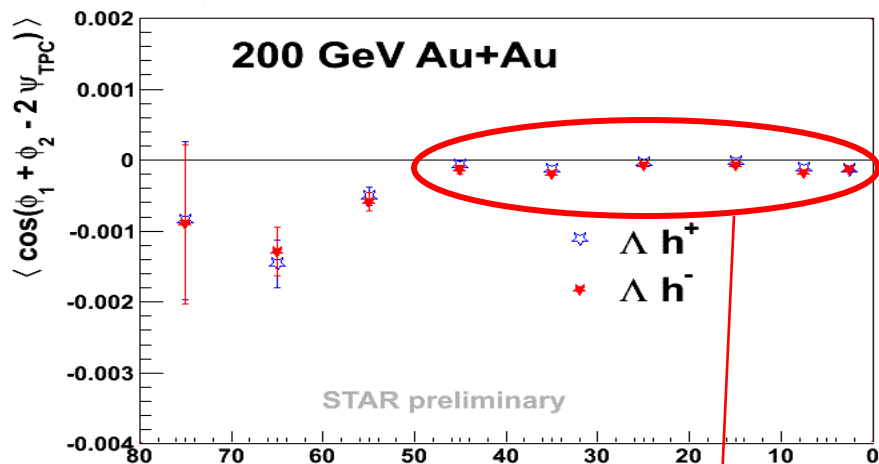


Shifting method used to flatten the EP distribution.

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



Λ - h^\pm at Au+Au 200GeV

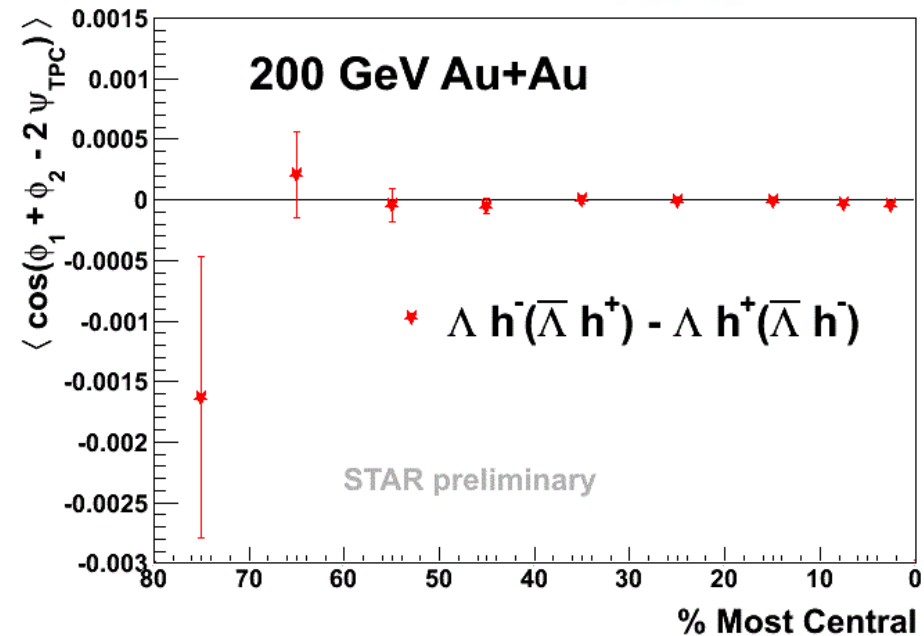
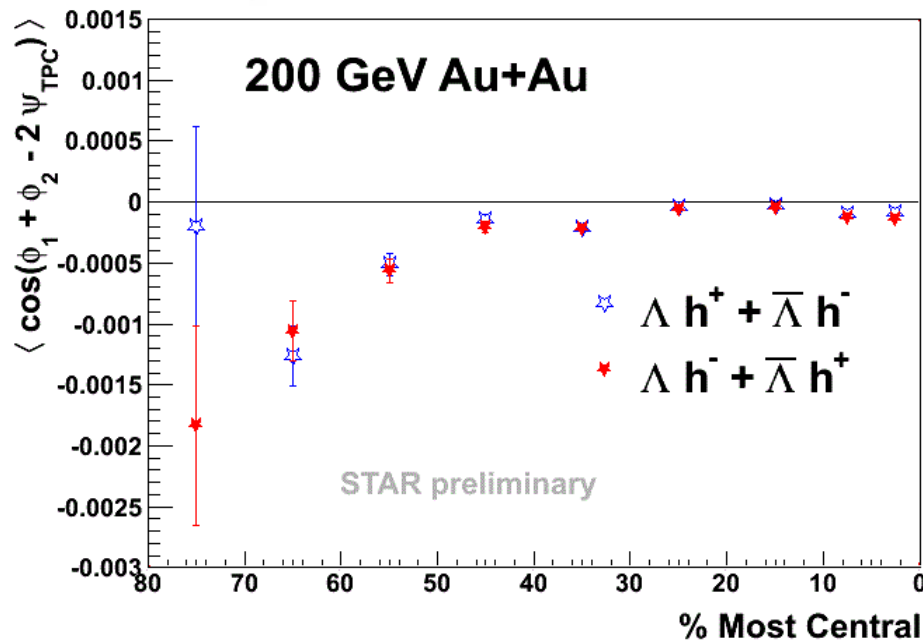


Error bars are statistical only.

Protons are excluded from charge hadrons.



Λ - h^\pm at Au+Au 200GeV

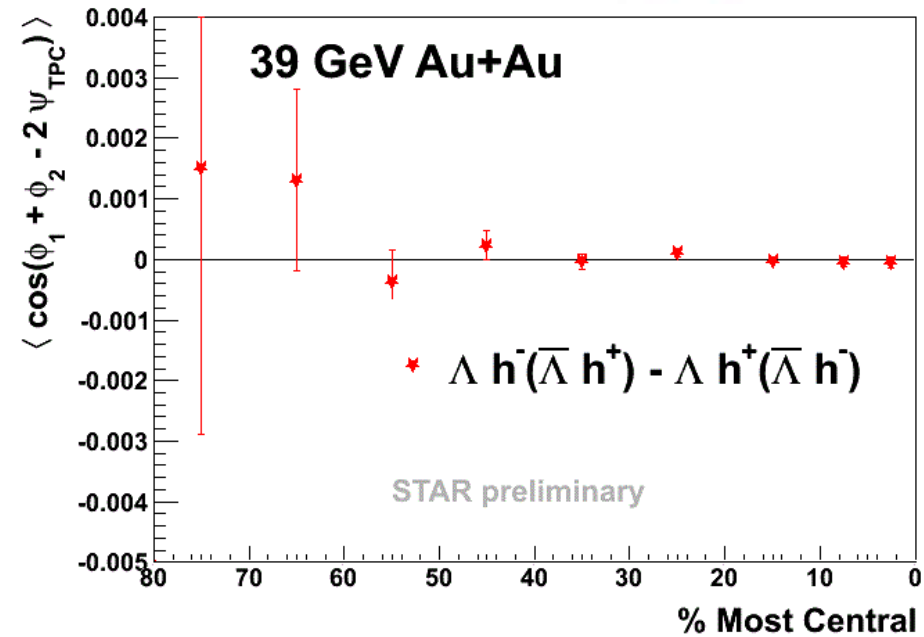
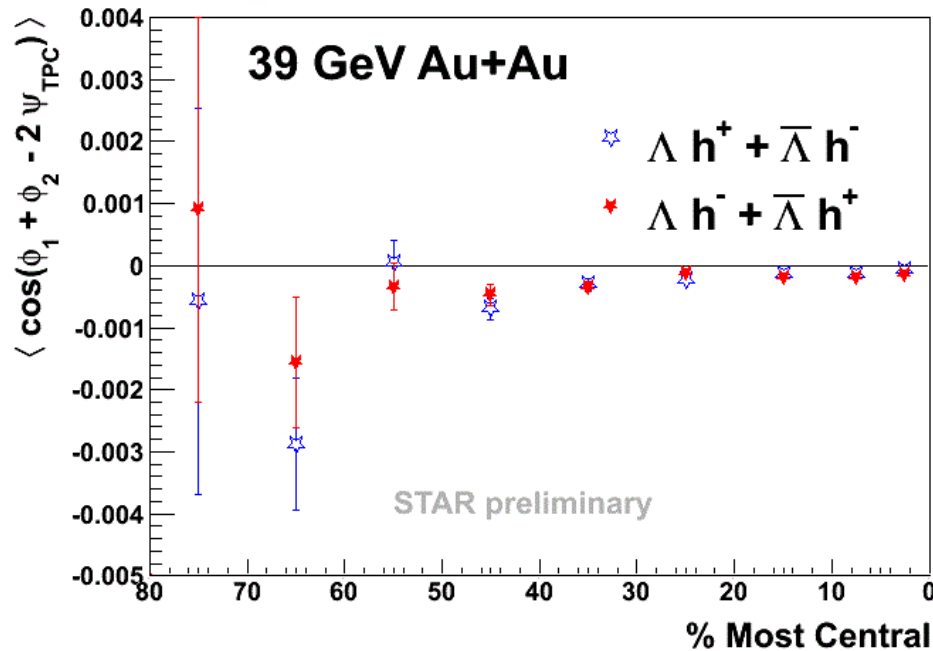


- $\Lambda h^+(\bar{\Lambda} h^-)$ & $\Lambda h^-(\bar{\Lambda} h^+)$ are consistent with each other;
- Assume Λh^+ and $\bar{\Lambda} h^-$ are same sign, Λh^- and $\bar{\Lambda} h^+$ are opposite sign, we can combine them;
- $\Lambda h^+ + \bar{\Lambda} h^-$ & $\Lambda h^- + \bar{\Lambda} h^+$ are consistent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

Error bars are statistical only.



$\Lambda-h^\pm$ at Au+Au 39GeV

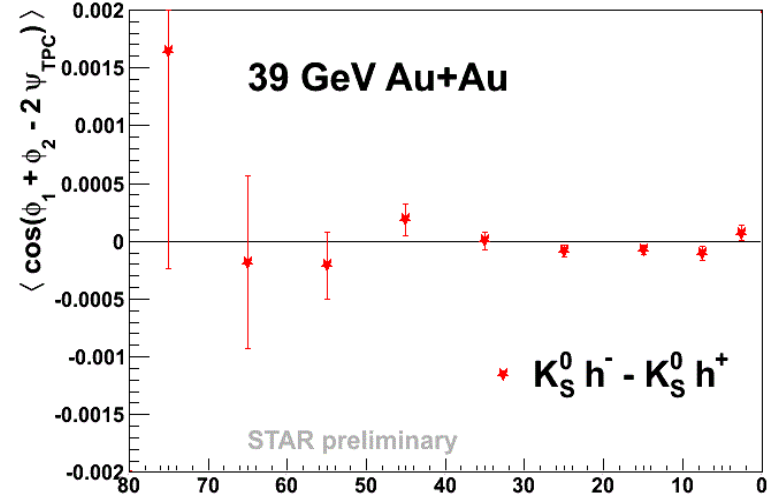
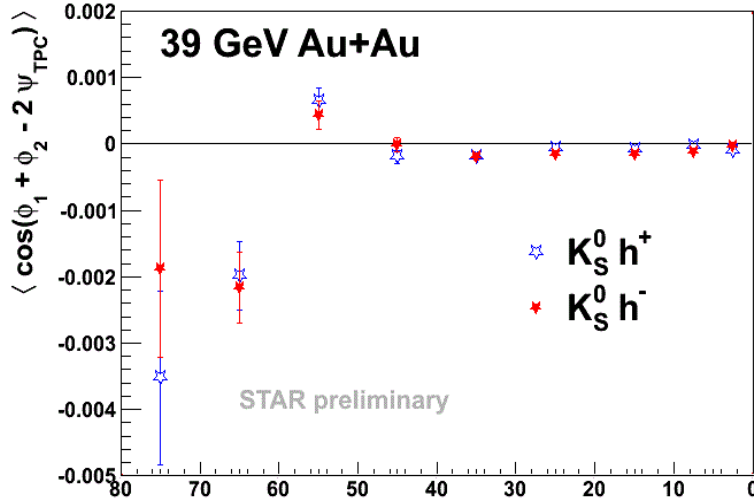
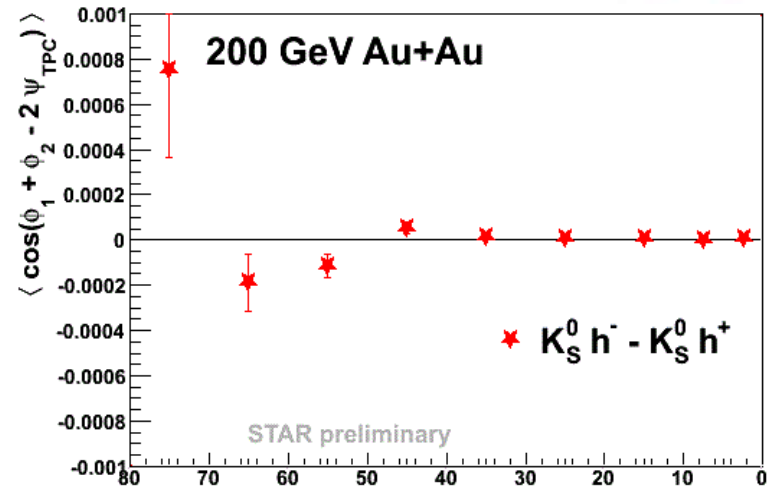
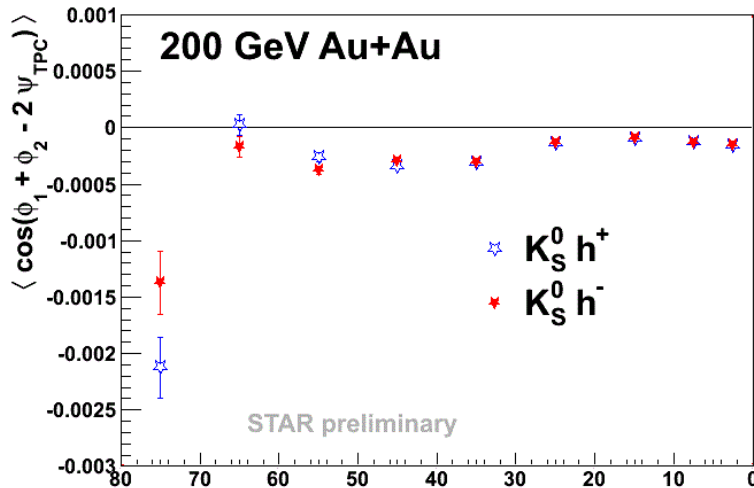


- At Au+Au 39GeV, $\Lambda h^+ + \bar{\Lambda} h^-$ & $\Lambda h^- + \bar{\Lambda} h^+$ also show a consistent behavior.

Error bars are statistical only.



$K_S^0-h^\pm$ at Au+Au 39 and 200 GeV



Error bars are statistical only. % Most Central

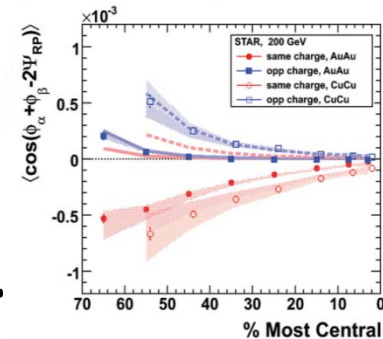
% Most Central



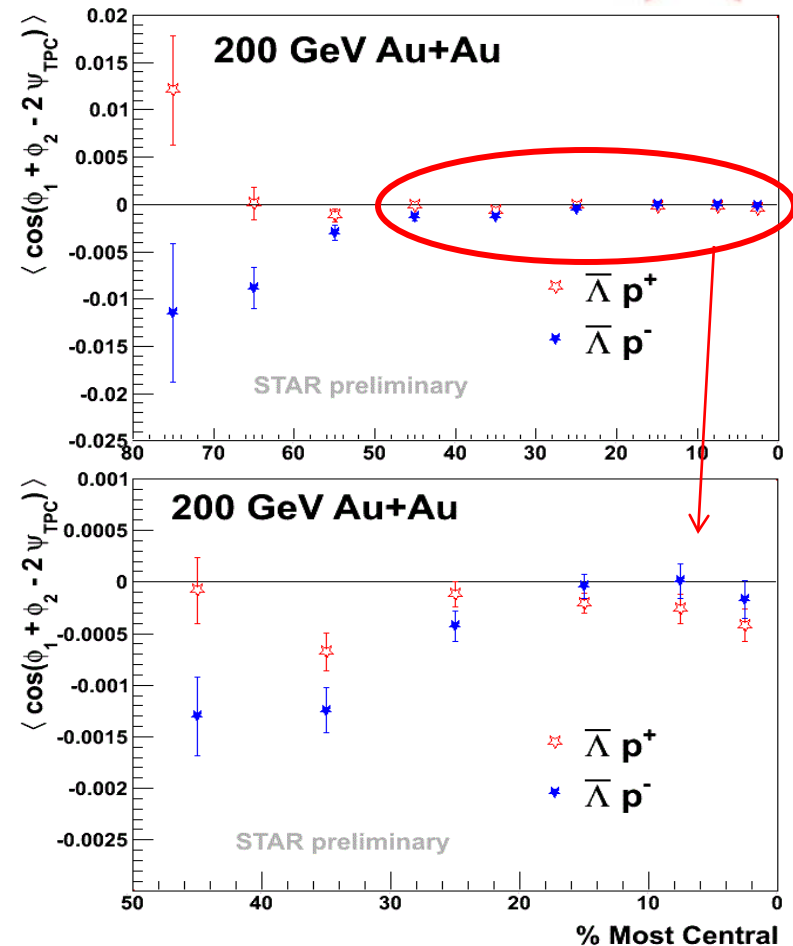
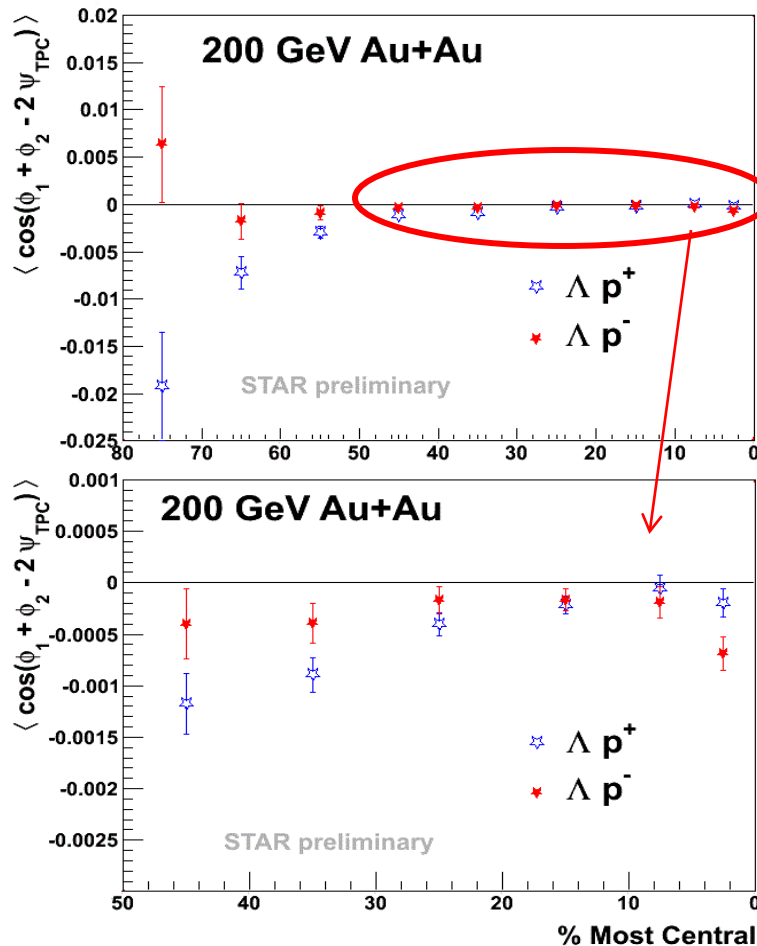
Summary I



- $\Lambda-h^\pm$ and $K_s^0-h^\pm$ 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 $\Lambda-h^\pm$ and $K_s^0-h^\pm$ provides a charge-independent background study for the CME.



Λ - p^\pm at Au+Au 200GeV

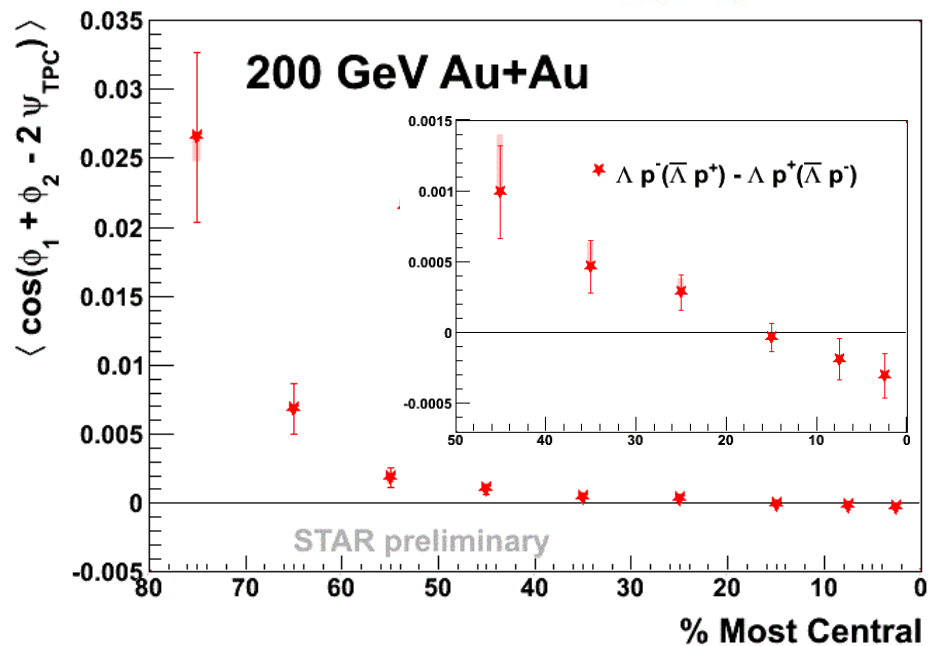
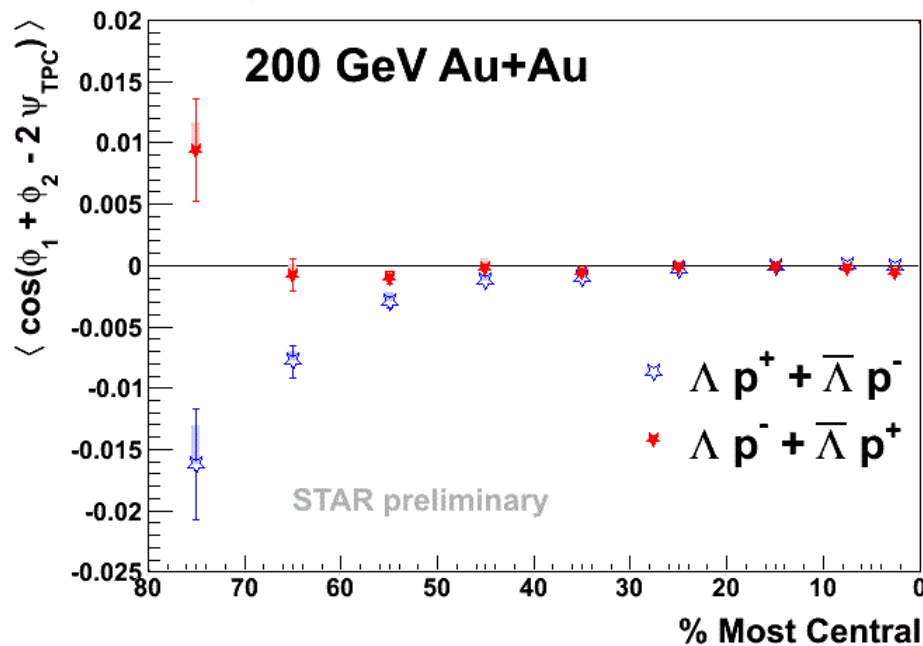


Error bars are statistical only.

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



Λ - p^\pm at Au+Au 200 GeV



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*

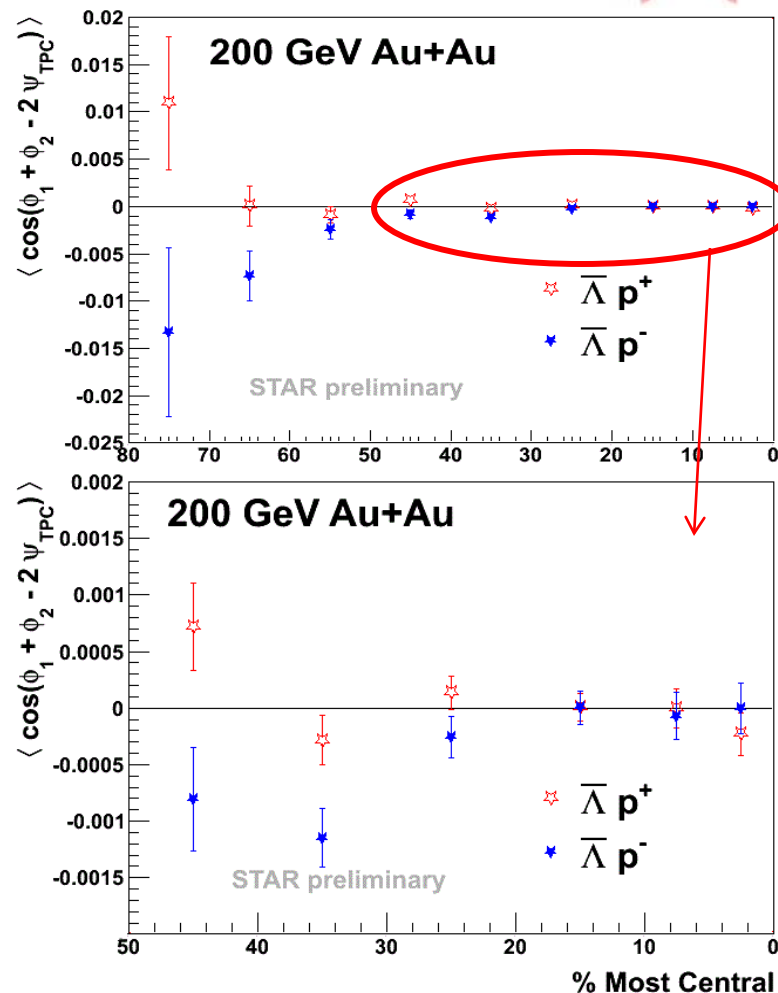
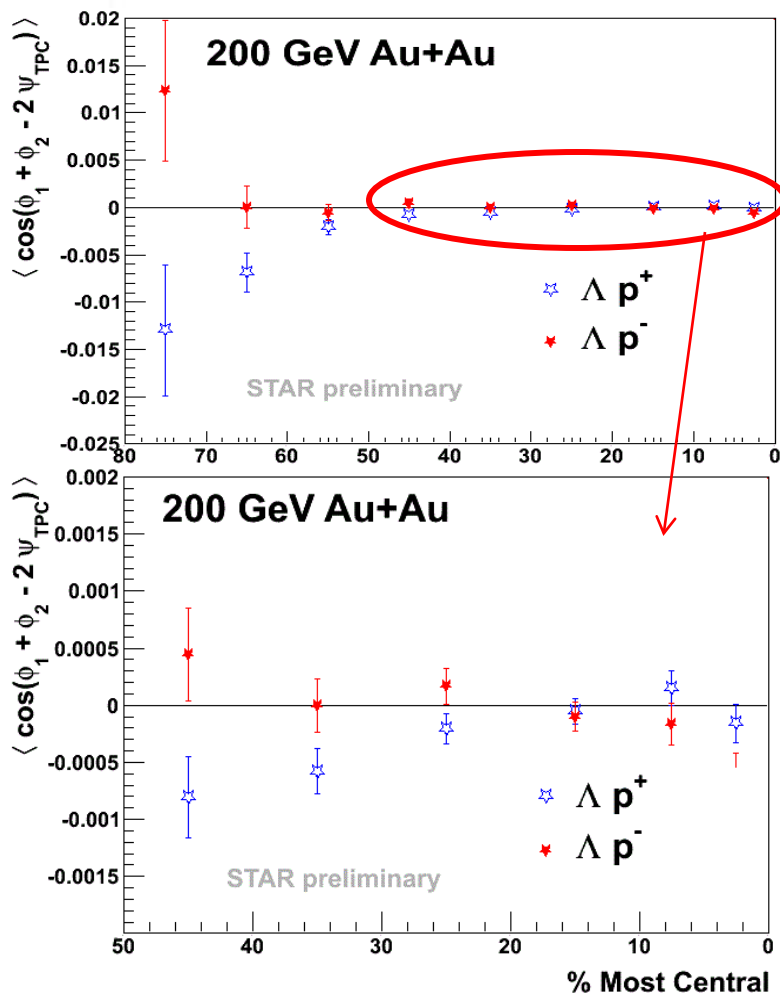
May 20, 10:00am, QCD phase diagram1



Back Up



Λ - p^\pm at Au+Au 200GeV



Results with HBT effect excluded.

Error bars are statistical only.

