ESE $\Delta\gamma$ as a function of invariant mass in Au+Au collisions at $\sqrt{s_{NN}} = 200\ GeV$

Han-Sheng Li (For the STAR Collaboration)
Purdue University
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STAR

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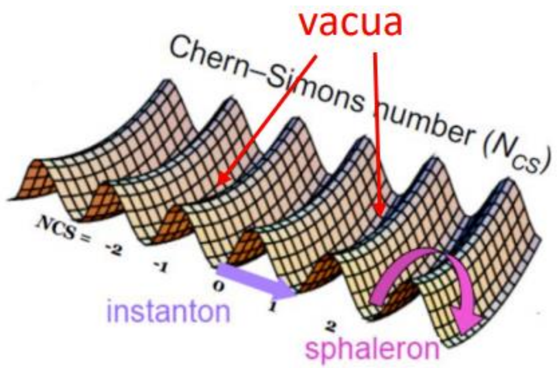
The Chiral Magnetic Effect (CME)

The CME

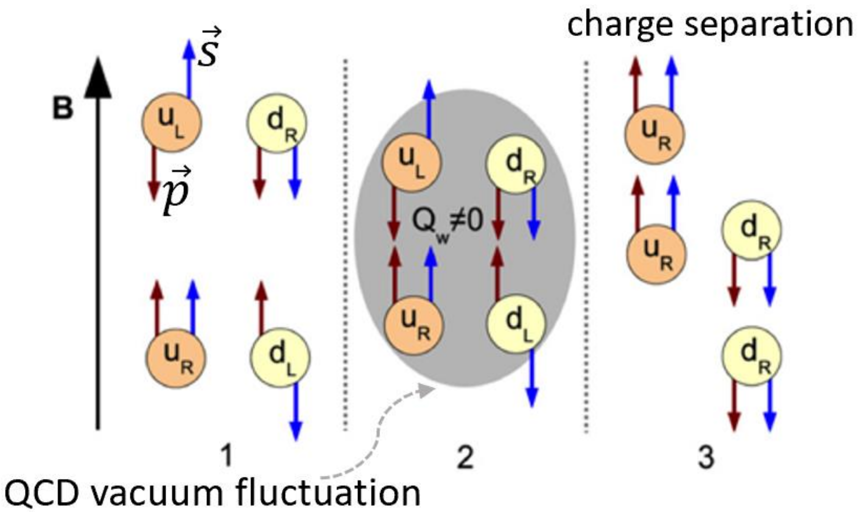
- Non-zero topological charge → Chirality imbalance of fermions
- Strong magnetic field → Spin separation according to charge -> Charge separation

Importance of the CME

- Approximate chiral symmetry restoration
- Local P/CP-violation in strong interaction
- It may resolve the strong CP problem of matter–antimatter asymmetry



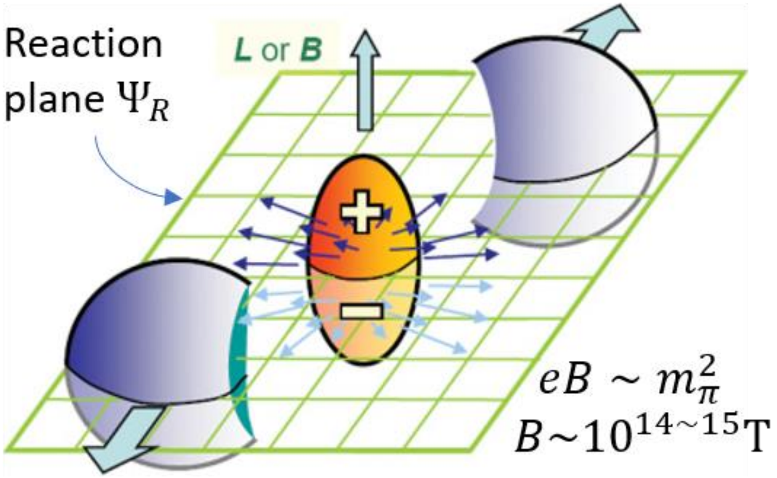
Kharzeev,Pisarski,Tytgat,PRL81(1998)512



Topological charge $Q_w \propto \int \vec{E}_c \cdot \vec{B}_c$

Observables

- **Heavy ion collisions**
  - Deconfined quarks and gluons
  - Strong magnetic field



- **The γ correlator**

$$\gamma_{\alpha\beta} = \langle\cos(\phi_\alpha + \phi_\beta - 2\psi)\rangle = \langle\cos(\phi_\alpha + \phi_\beta - 2\phi_c)\rangle / v_{2,c}$$

$$\Delta\gamma = \gamma_{OS} - \gamma_{SS} \approx b_{bkg} * v_2 + CME$$

Major flow background in $\Delta\gamma$. Intercept more sensitive to CME.

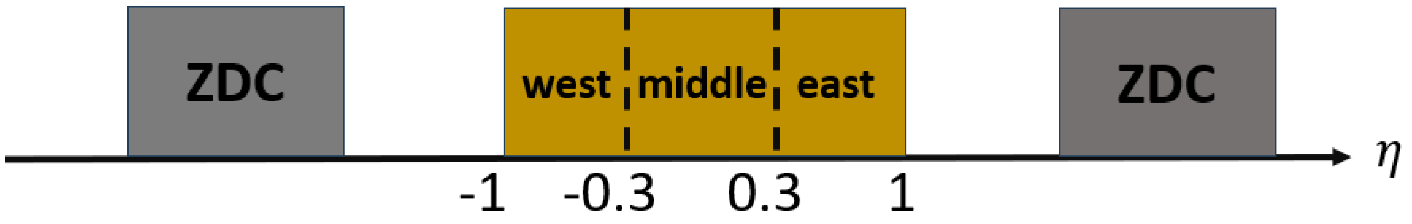
S.A. Voloshin, Phys. Rev. C70(2004)057901

- **Event-shape engineering (ESE)**

Selects events within narrow centrality bins according to the flow vector q_2 in phase space apart from POI's. Select events on dynamical fluctuations of v_2.

ESE Analysis procedure

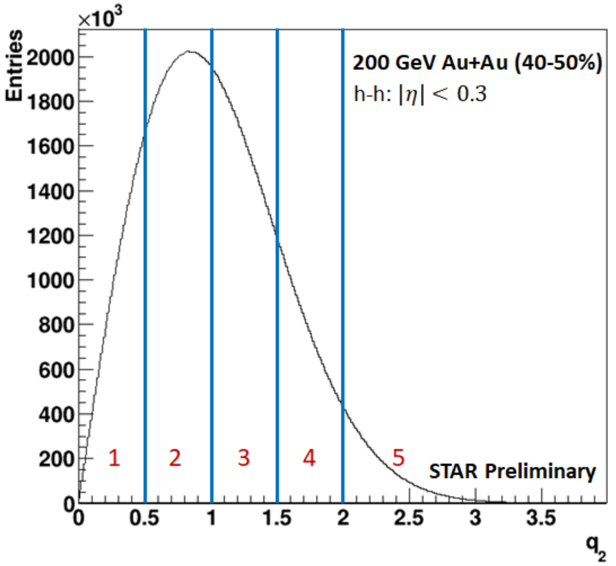
- **Three subevents:** west ($-1 < \eta < -0.3$), middle ($-0.3 < \eta < 0.3$), and east ($0.3 < \eta < 1$)



q_2 calculated from middle subevent and POIs from side subevents

- **The flow vector**

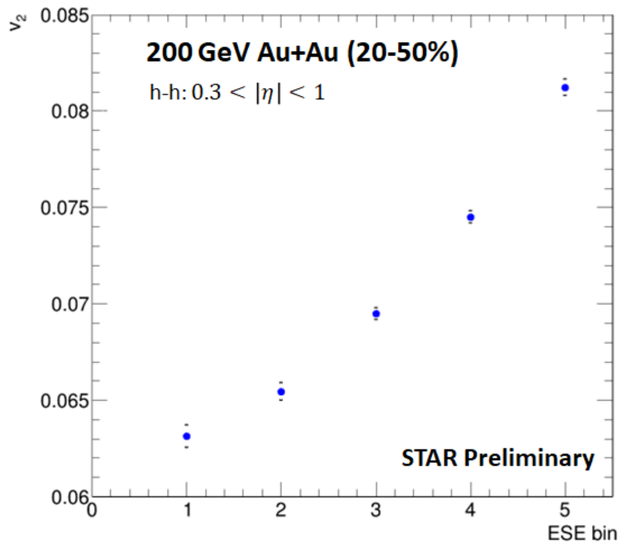
$$q_2 = \sqrt{\left[\left(\sum_i^M cos2\phi_i\right)^2 + \left(\sum_i^M sin2\phi_i\right)^2\right]/M}$$



- **elliptic anisotropy flow**

$$v_2 = \sqrt{\langle cos2(\phi_{c_1} - \phi_{c_2})\rangle}$$ (cumulant method)

c_1 from east subevent, c_2 from west subevent



$\Delta\gamma$ vs. v_2 in ESE bins

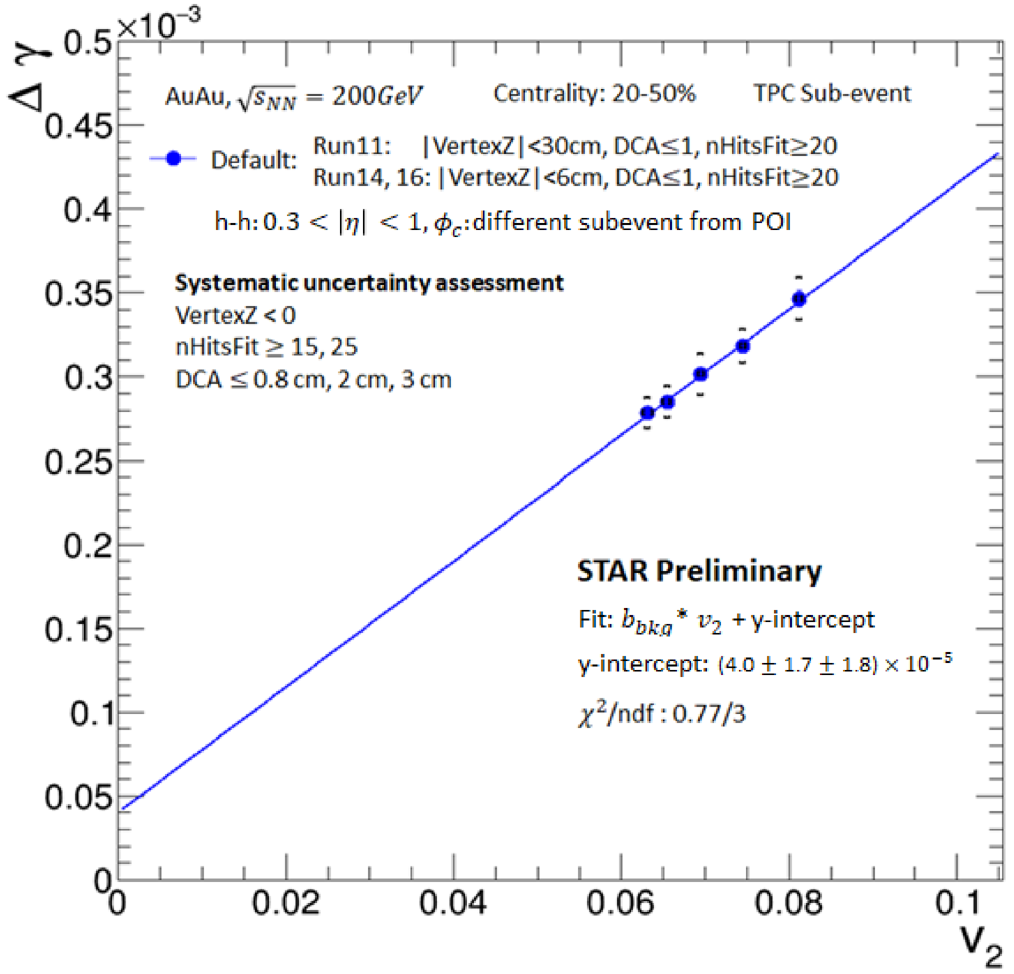
- AuAu200GeV (Run 2011+2014+2016)
  - 2.1 B min-bias events

- $\Delta\gamma = \gamma_{OS} - \gamma_{SS}$
  - $\gamma_{OS} = \langle \cos(\phi_\alpha^\pm + \phi_\beta^\mp - 2\phi_c) \rangle / v_2$

    $\gamma_{SS} = \langle \cos(\phi_\alpha^\mp + \phi_\beta^\mp - 2\phi_c) \rangle / v_2$

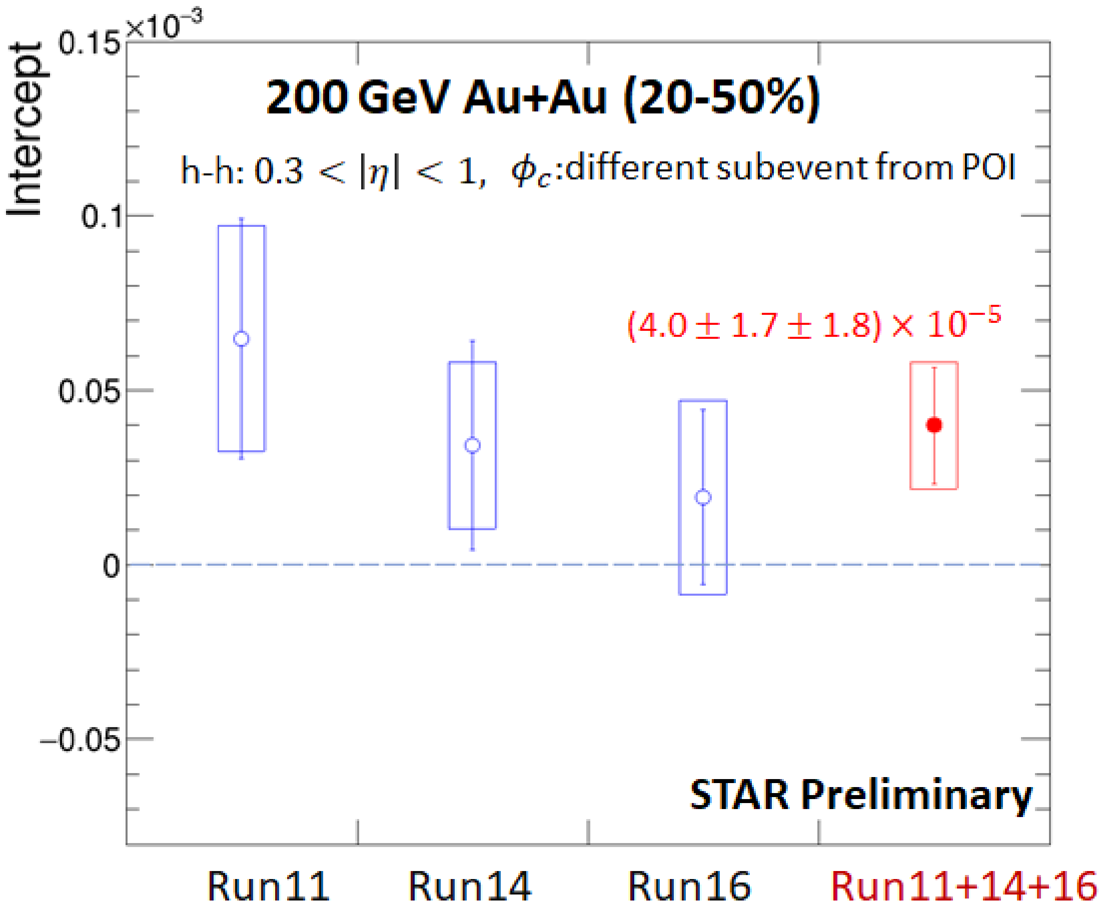
    POI (α, β) from east subevent, c from west subevent; and vice versa.

- **$\Delta\gamma$ vs. v_2 using five ESE bins**
  - $\Delta\gamma = b_{bkg} * v_2 + CME(intercept)$



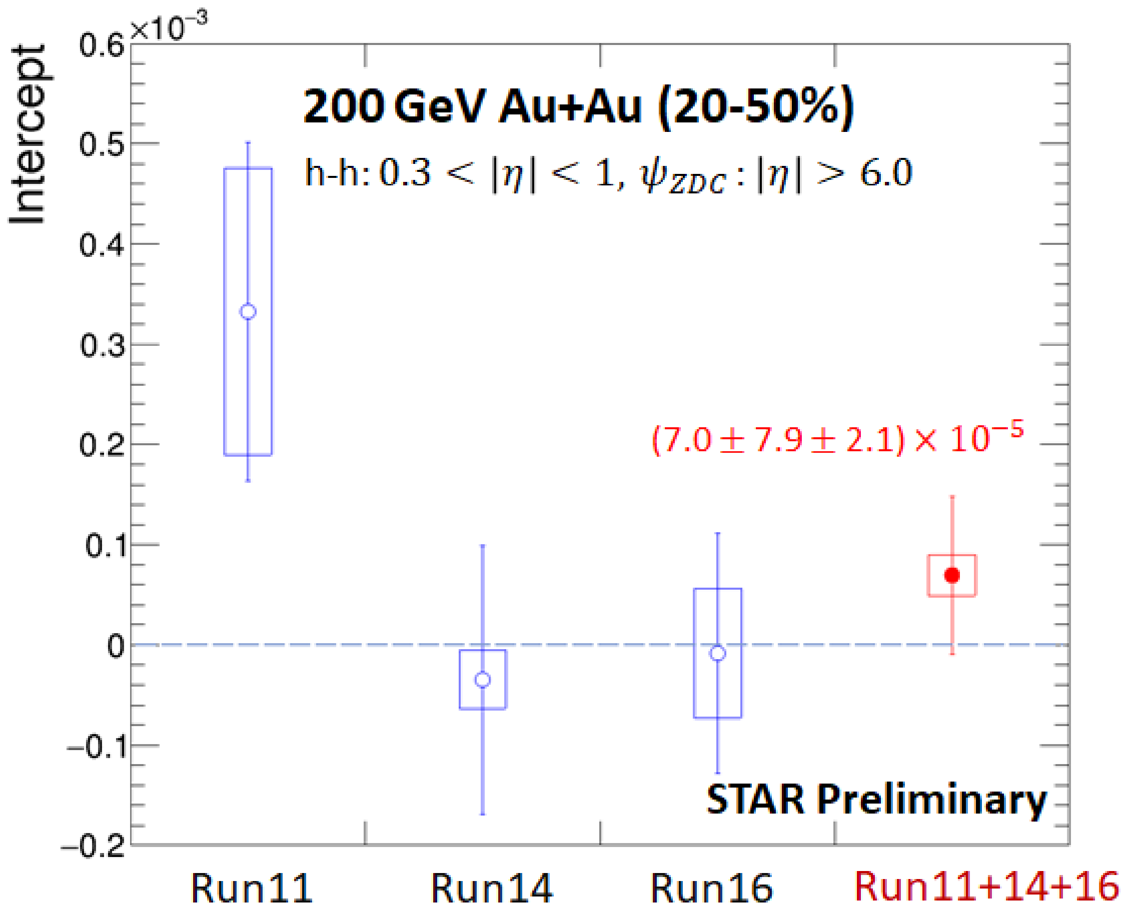
Variation of Intercept in Run year

- **POI from one side sub-event, c particle from the other sub-event**



- The intercept has a significance of about 1.5σ
- Nonflow effects: v_2 nonflow, three-particle correlations

- **POI from one side sub-events, EP from ZDC**



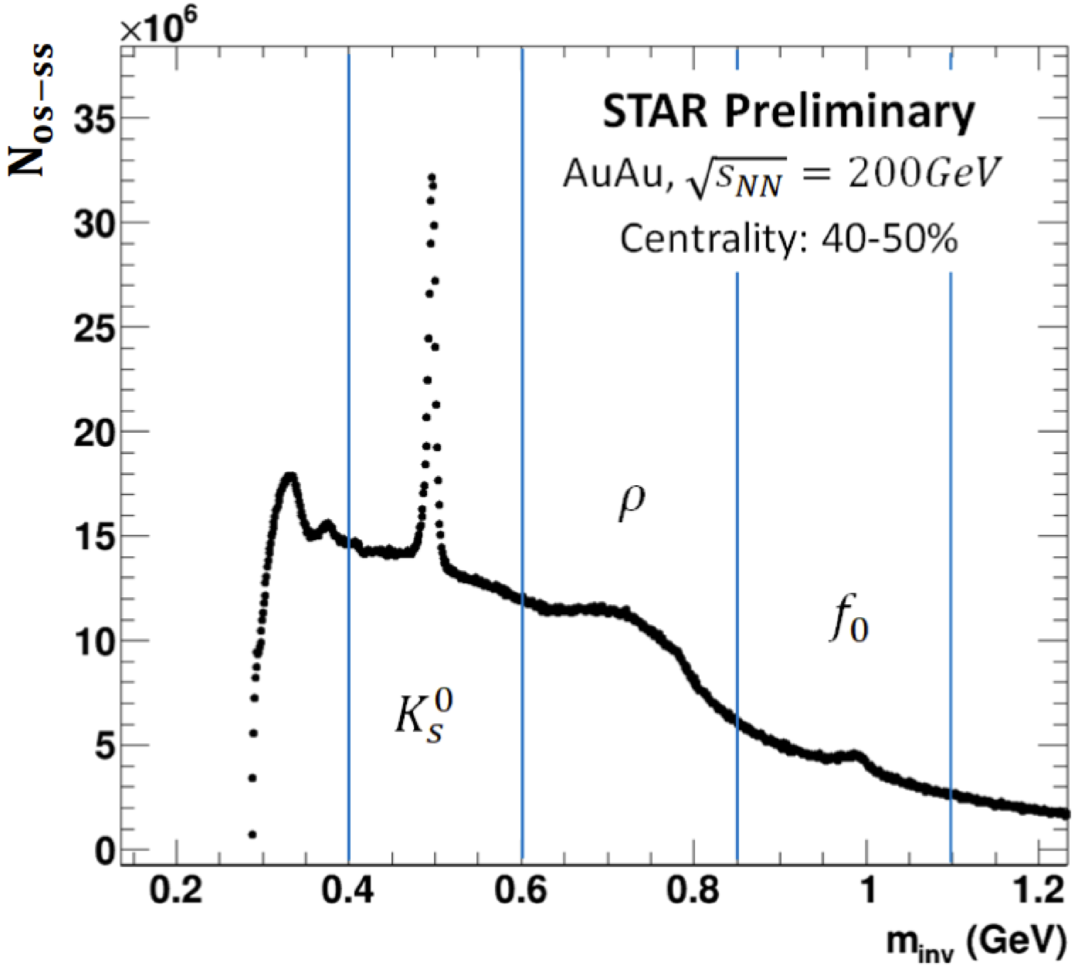
- ZDC significantly suppress non-flow effects but poor event plane resolution

Invariant mass distribution

- **Mass windows**
  - Low mass: mass ($\pi^+\pi^-$) < 0.4 GeV
  - K_s^0 region: 0.4 GeV < mass ($\pi^+\pi^-$) < 0.60 GeV
  - ρ region: 0.6 GeV < mass ($\pi^+\pi^-$) < 0.85 GeV
  - f_0 region: 0.85 GeV <mass ($\pi^+\pi^-$) < 1.1 GeV
  - High mass: 1.1 GeV < mass ($\pi^+\pi^-$)

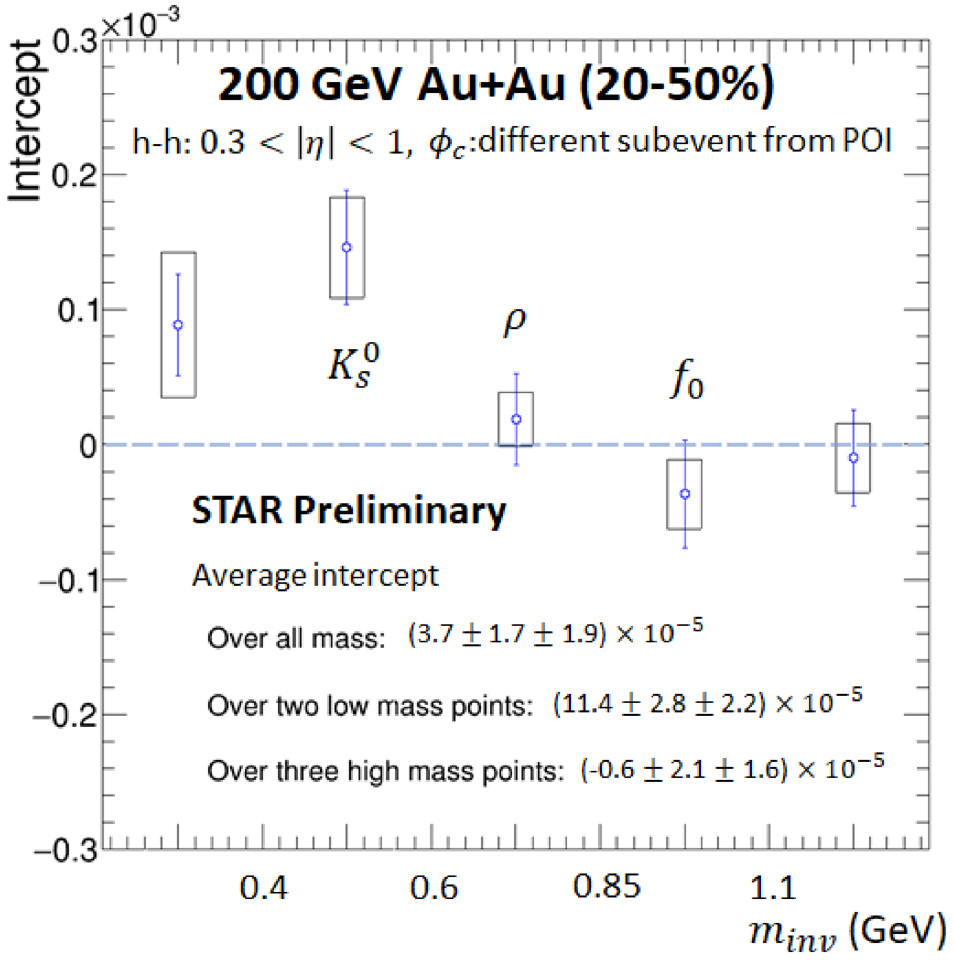
- **Repeat ESE analysis for pairs within each inv mass window**

- **Data binned in POI (α,β) pair inv. mass; All other aspects of analysis identical to inclusive ESE.**



The intercept vs. invariant mass

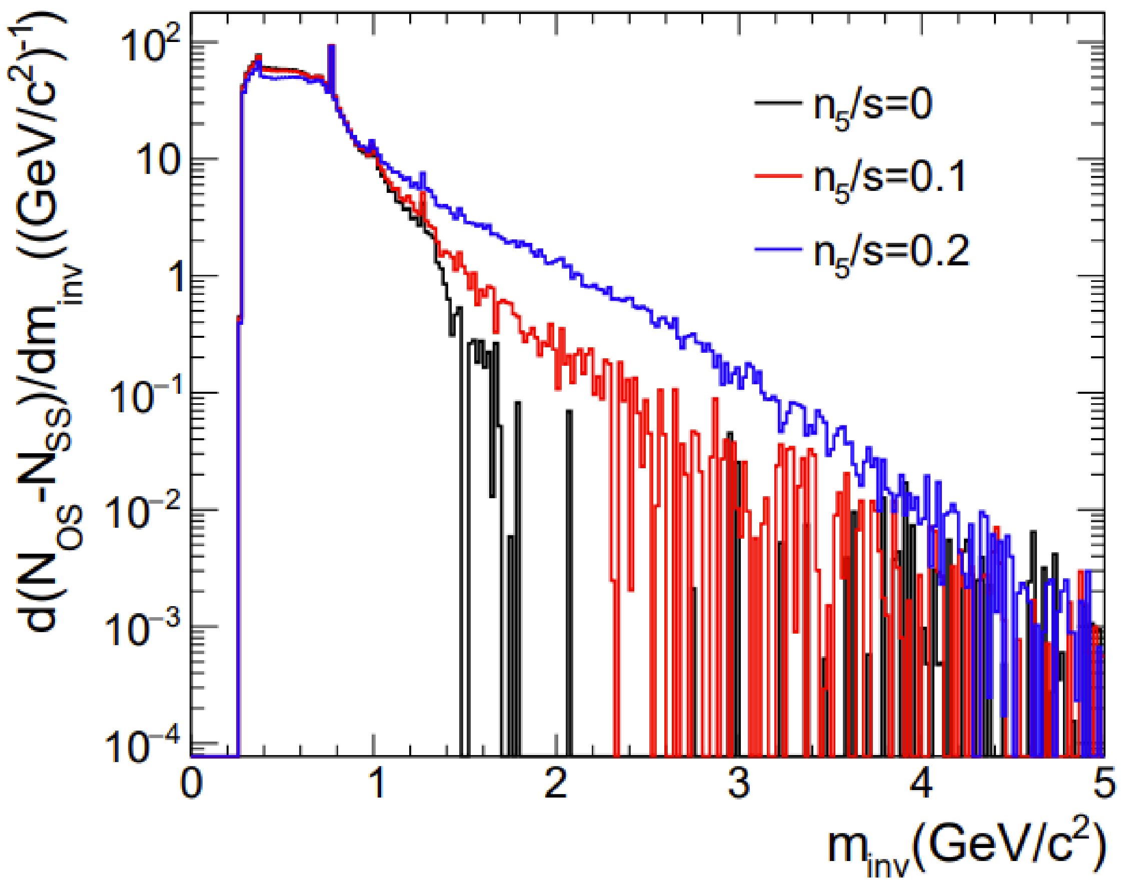
- Low mass region appears to have a larger signal (3σ) than high mass region (consistent with zero)



CME is a low p_T effect and might be stronger in low mass region

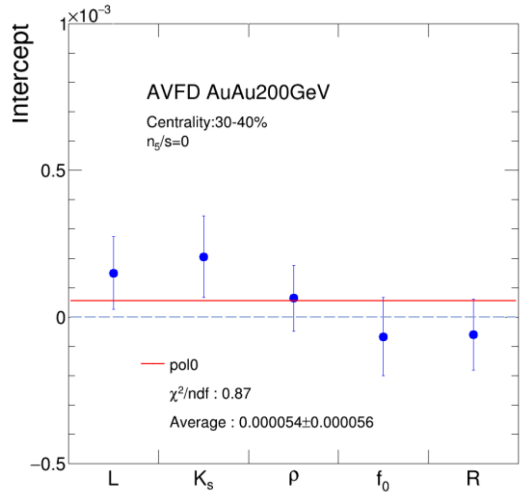
Anomalous-Viscous Fluid Dynamics (AVFD) simulation

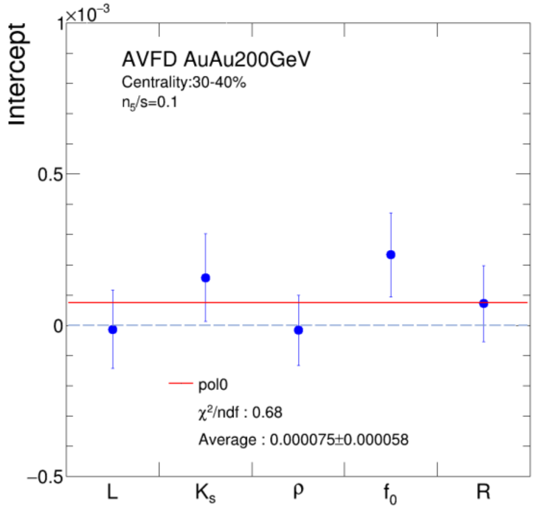
- Invariant mass in various axial current densities
  - Au+Au collisions at 200 GeV were simulated by AVFD
  - 20M events for each data set
  - Centrality: 30-40%

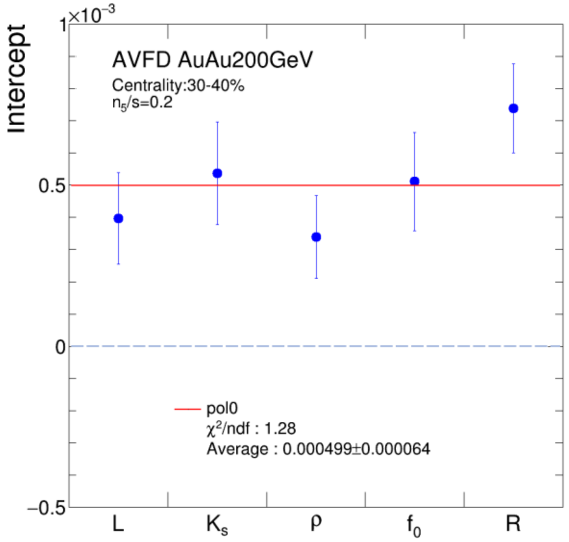


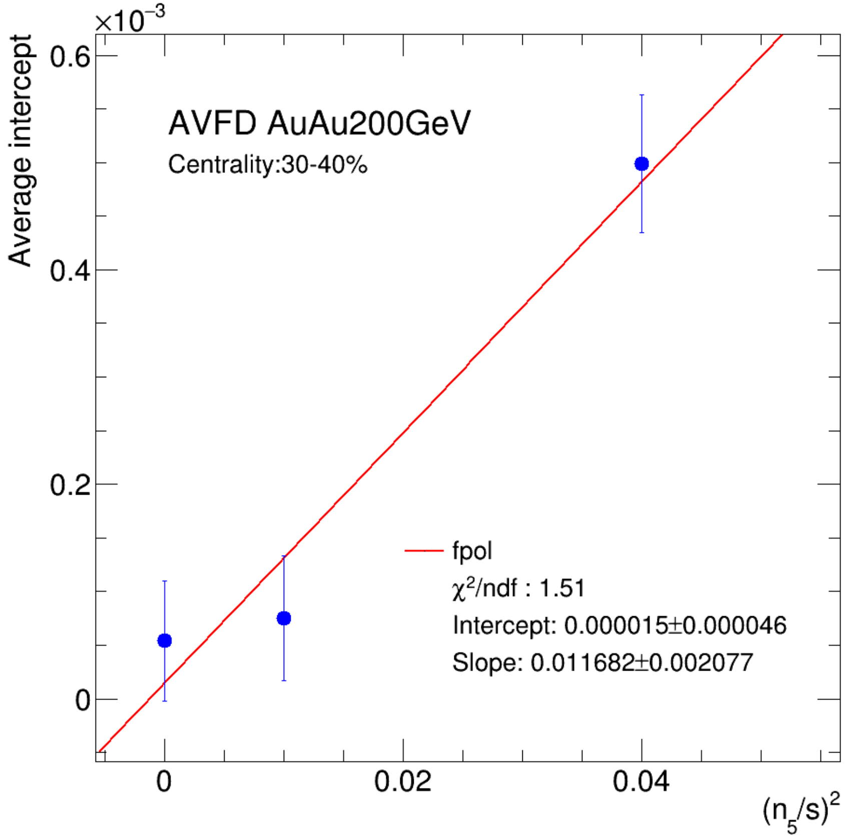
AVFD simulation

- Intercepts are in various axial current densities
  - Participant plane in TPC acceptance









- In the case n_5/s = 0.2, the intercept is positive as expected
- Need more statistics for the simulation

Summary and outlook

- ESE studies performed: inclusive and differential in invariant mass (2.1 B Au+Au events)

- Intercept (sensitive to CME) from inclusive data:
  - TPC sub-event: $(4.0 \pm 1.7 \pm 1.8) \times 10^{-5}$ (1.5σ effect)
  - ZDC sub-event: $(7.0 \pm 7.9 \pm 2.1) \times 10^{-5}$
- Intercept from low/high mass regions (TPC data):
  - mass < 0.6 GeV (low pt): $(11.4 \pm 2.8 \pm 2.2) \times 10^{-5}$ (3σ effect)
  - mass > 0.6 GeV (high pt): $(-0.6 \pm 2.1 \pm 1.6) \times 10^{-5}$

- The AVFD is consistent with expectation

- To be studied: nonflow effects, q_2 dependence of the magnetic field direction

Backup

Systematic uncertainty

- Sources of the systematic uncertainty
  - |VertexZ| < 30 cm or 6 cm (default), VertexZ < 0
  - nHitsFit $\geq$ 20 (default), 15, 25
  - DCA $\leq$ 1 cm (default), 0.8 cm, 2 cm, 3 cm
- The calculation of systematic uncertainty based on the Barlow prescription