Azimuthal anisotropy in U+U collisions

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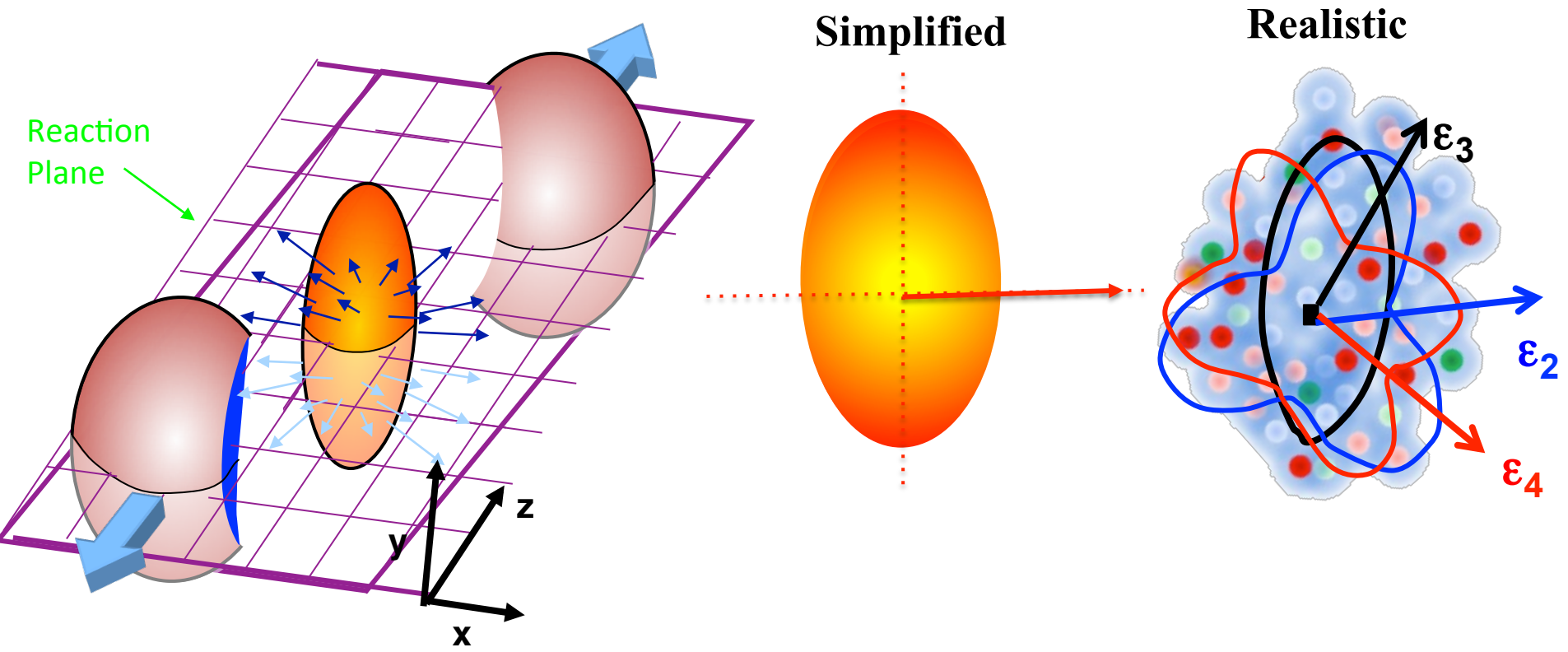
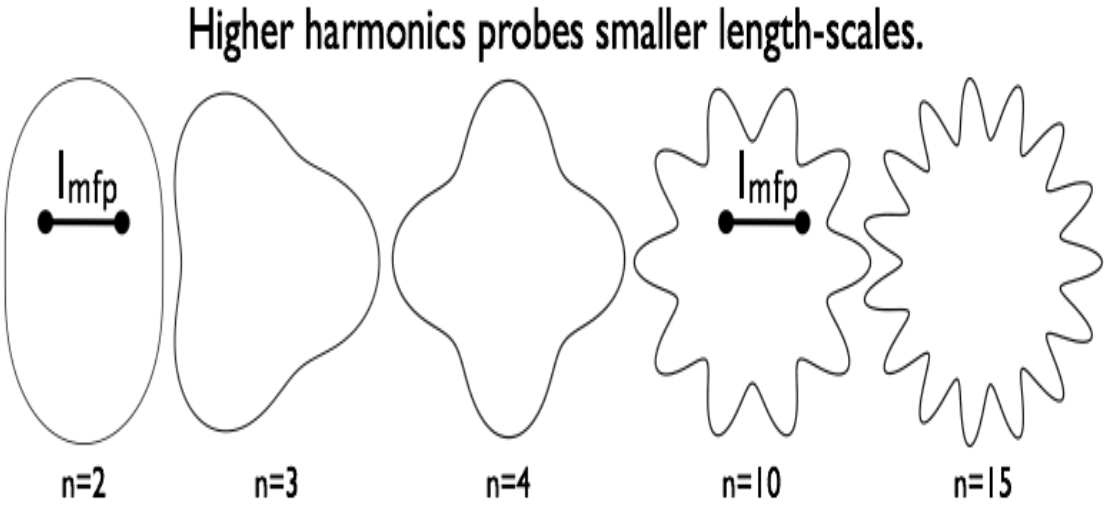
Introduction: Azimuthal Anisotropy



Azimuthal distribution of particles with respect to the symmetry plane

$$\frac{dN}{d\phi} \propto 1 + \sum_{n} 2\mathrm{v}_{\mathrm{n}} \cos n\left(\phi - \psi_{n}\right)$$

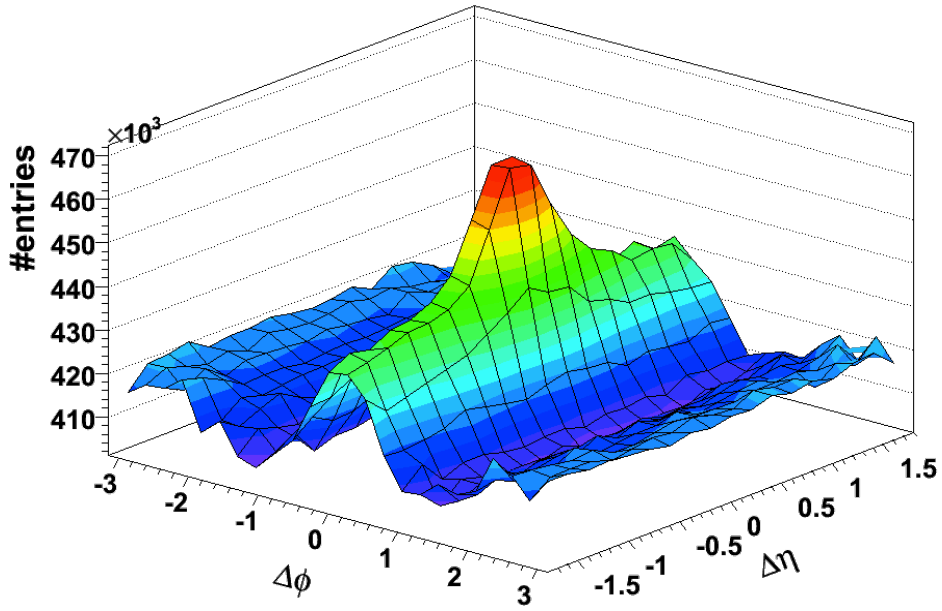
Introduction: Azimuthal Anisotropy



- System evolution
- Ridge Phenomena
- Medium Property:

  eg. η/s
- Constrain the models

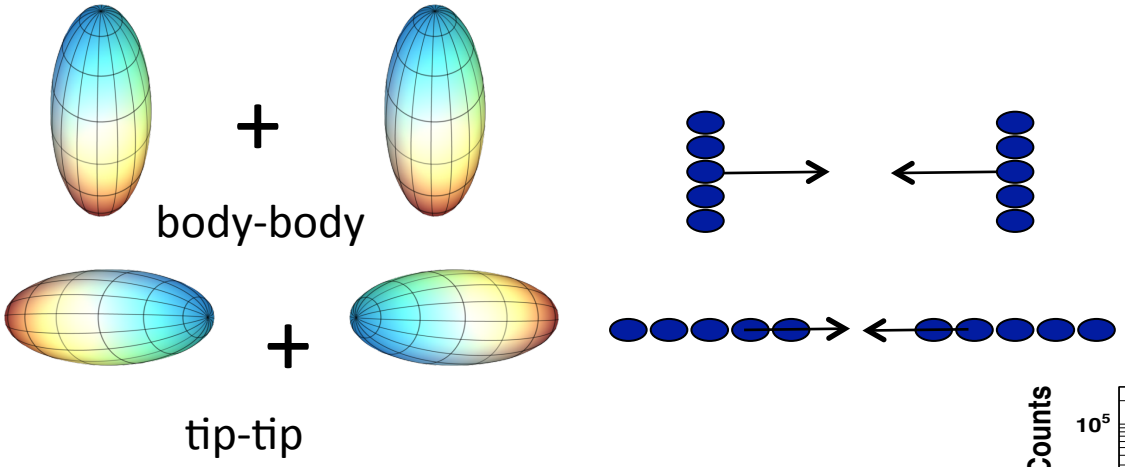
Ridge : long range $\Delta\eta$ correlation at near-side



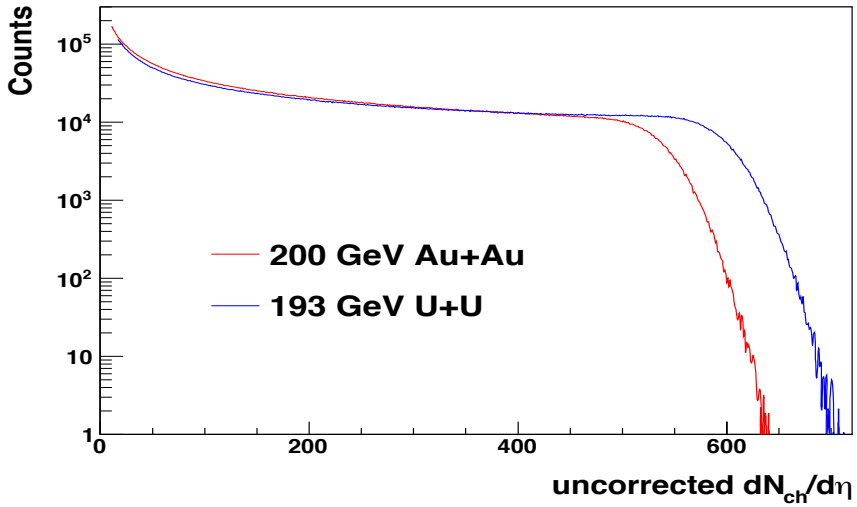
Note:
For most perfect liquid $\eta/s = 1/4\pi$ is the theoretical lower bound.

Motivation

The prolate shape of uranium nuclei provides the possibility to manipulate the initial geometry.

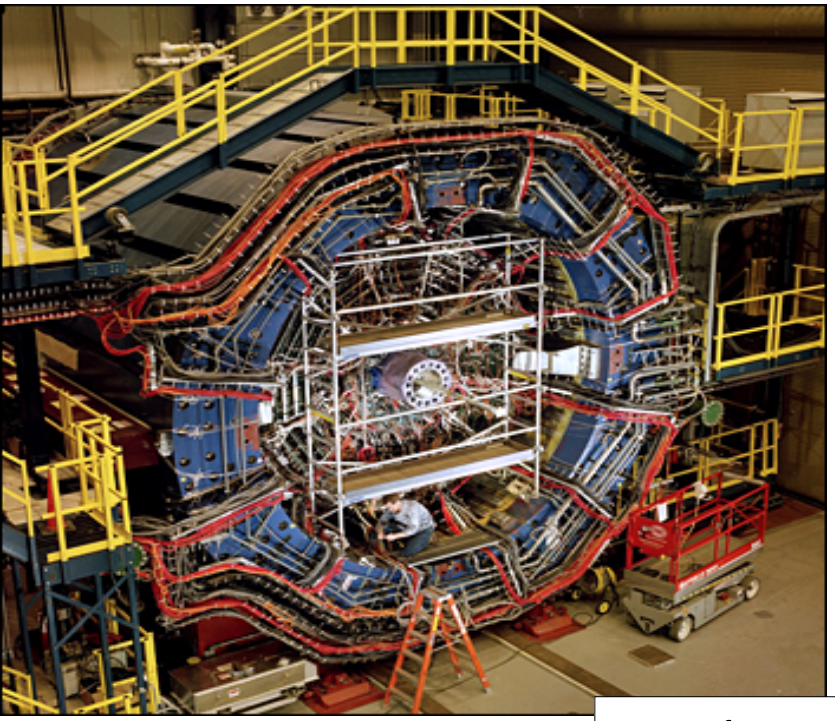


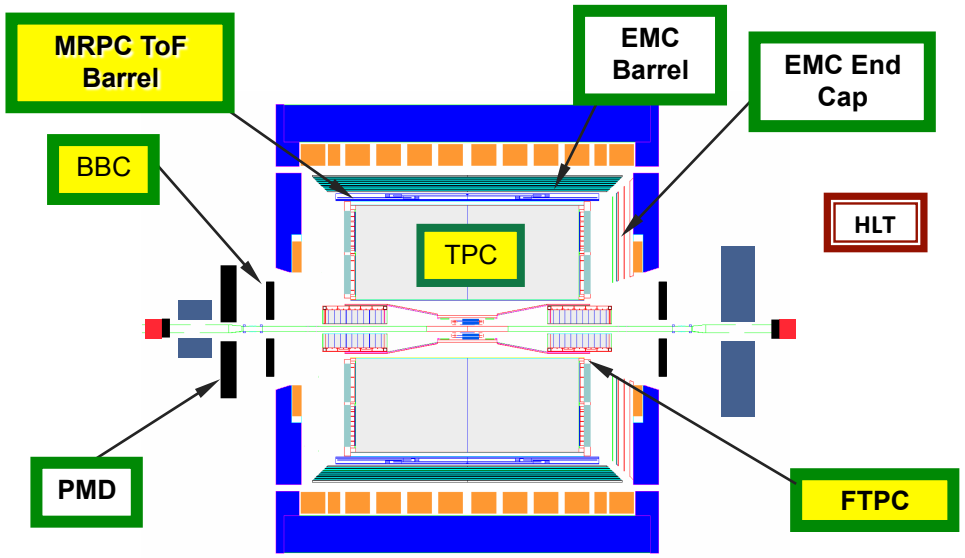
N_{part}	Ncoll	v_2
10	5	large
10	25	small



- Particle production mechanism
- Anisotropic flow
  - Any difference between Au+Au and U+U?
  - Separate body-body and tip-tip in U+U?
- Chiral Magnetic Effects(CME)
  - Does CME disappear at fully overlaped collisions ?.
  - Three-particle correlator signal induced by v_2?
- Path-length dependence of hard probes

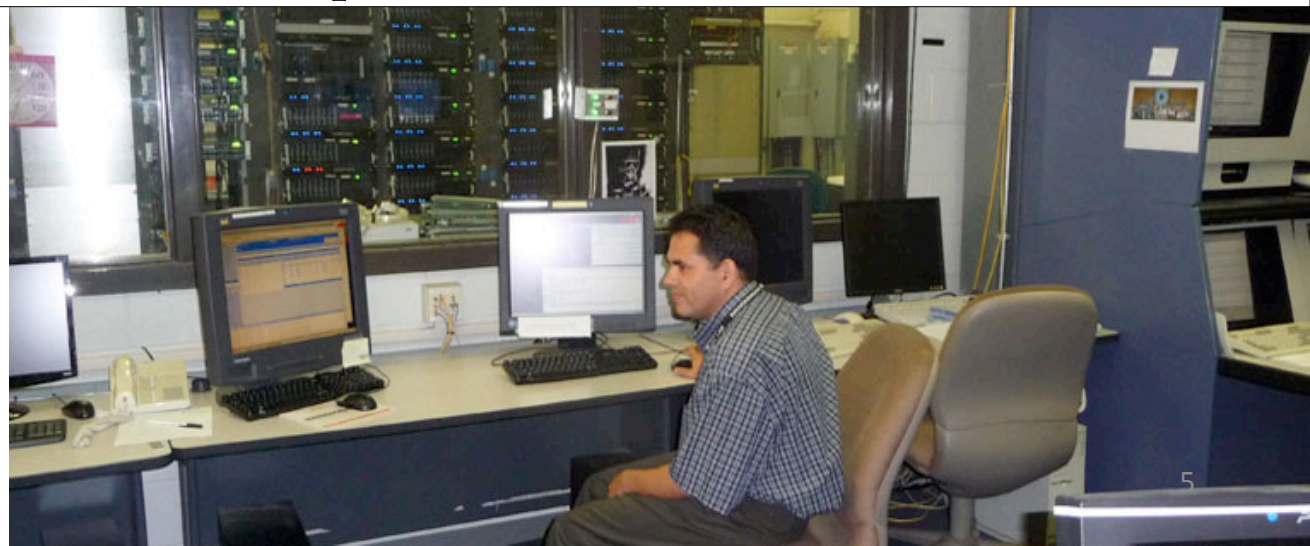
The Solenoidial Tracker At RHIC (STAR)



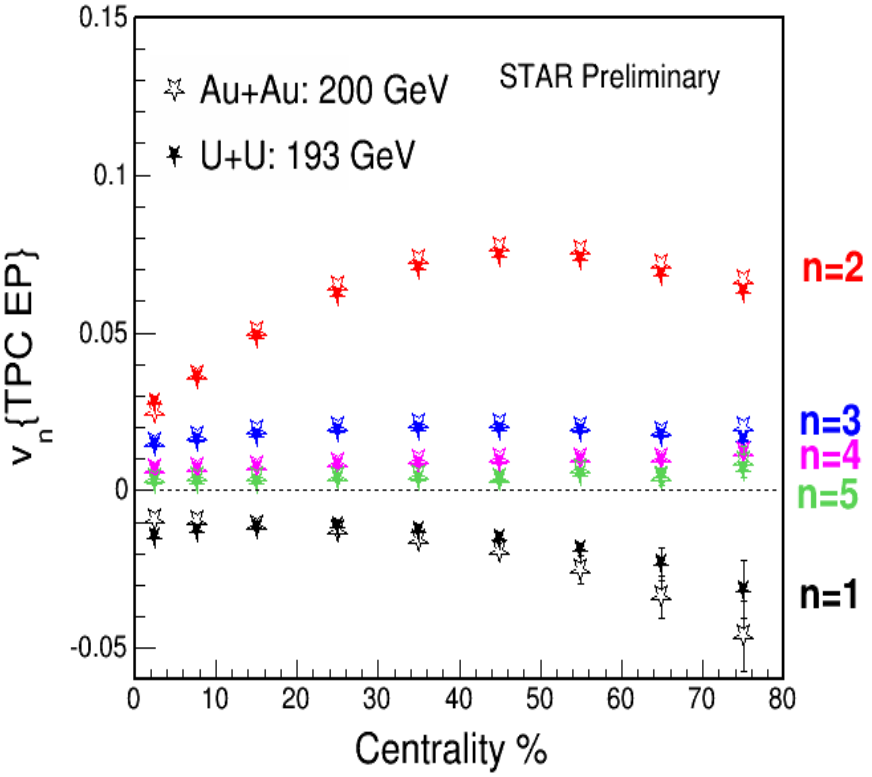


Uniform acceptance in $-1 < \eta < 1$ & 2π in azimuth

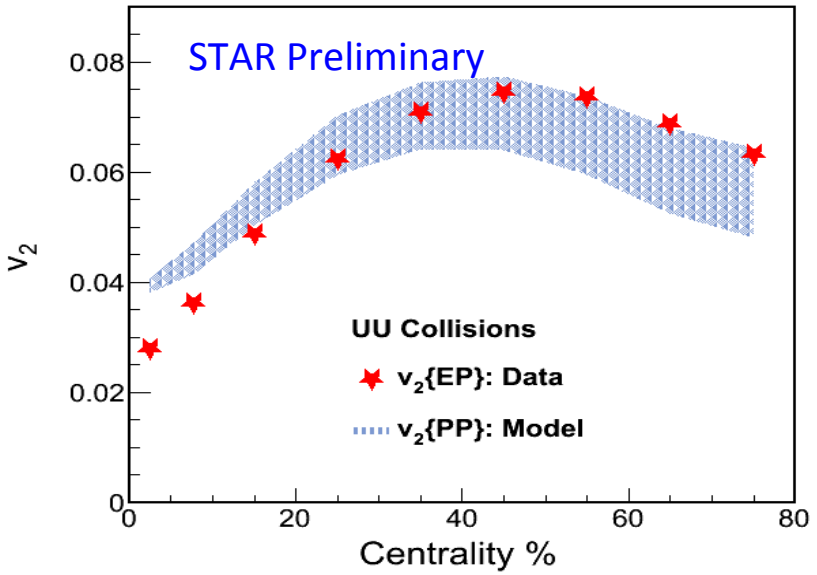
STAR is composed of 57 institutions from 12 countries, with a total of 533 collaborators



Azimuthal Anisotropy: Centrality dependence

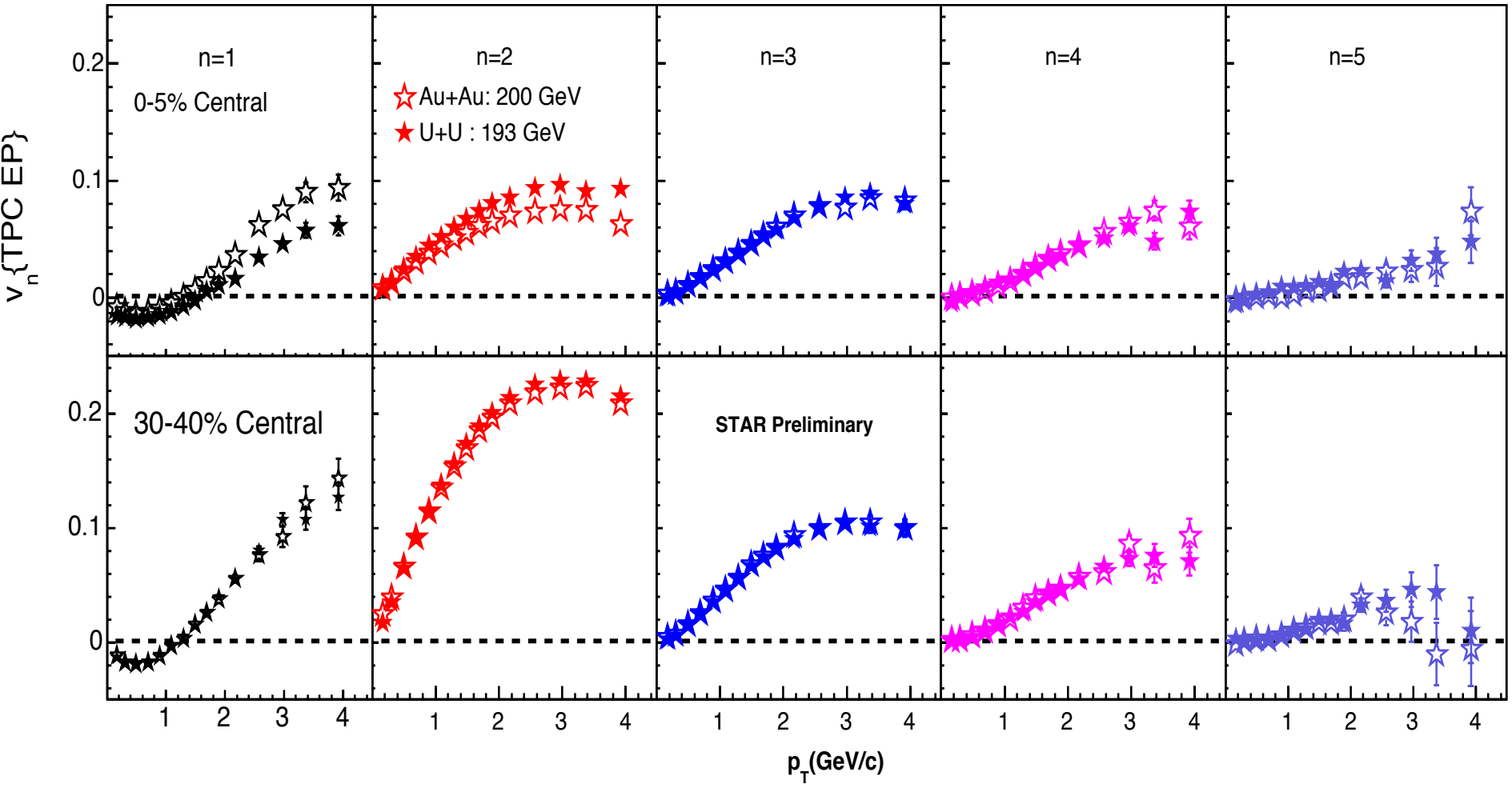


H. Masui et. al, Phys. Lett. B 679, 440(2009)



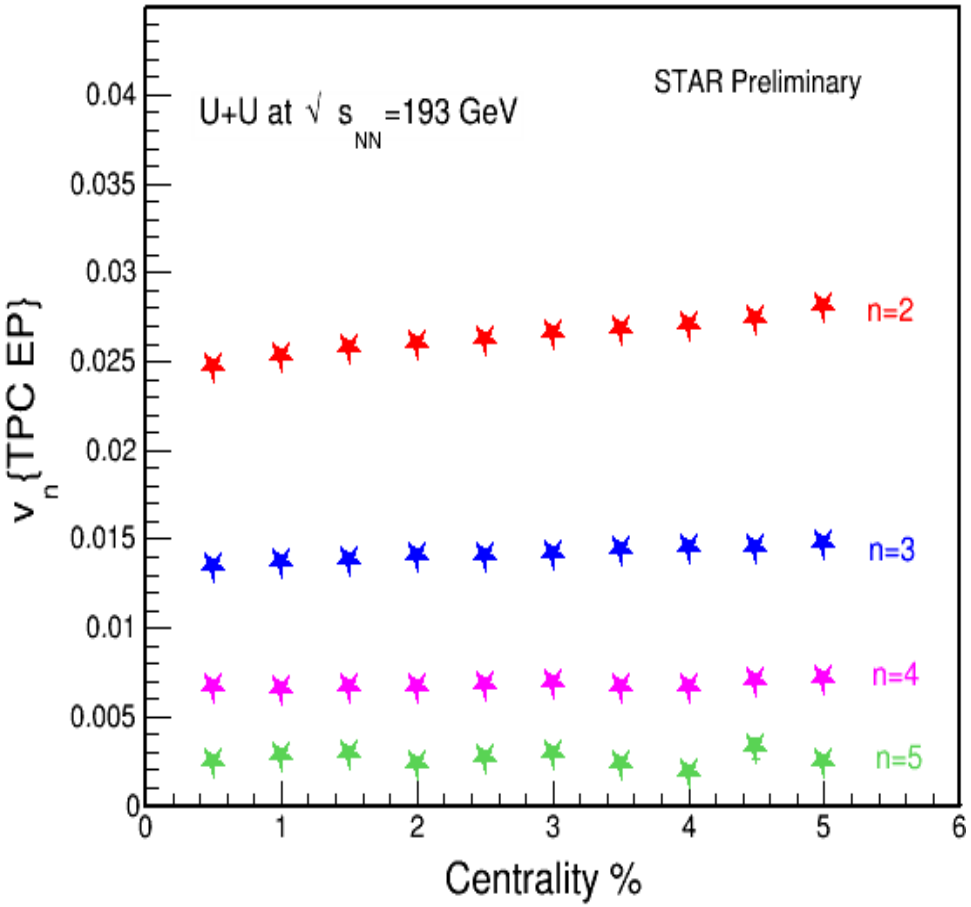
- v_n integrated in $0.15<p_T<2$ GeV/c.
- Centrality dependence is week for all other harmonics except n=2
- v_2 in U+U central collisions is not as large as predicted based on MC Glauber based approach

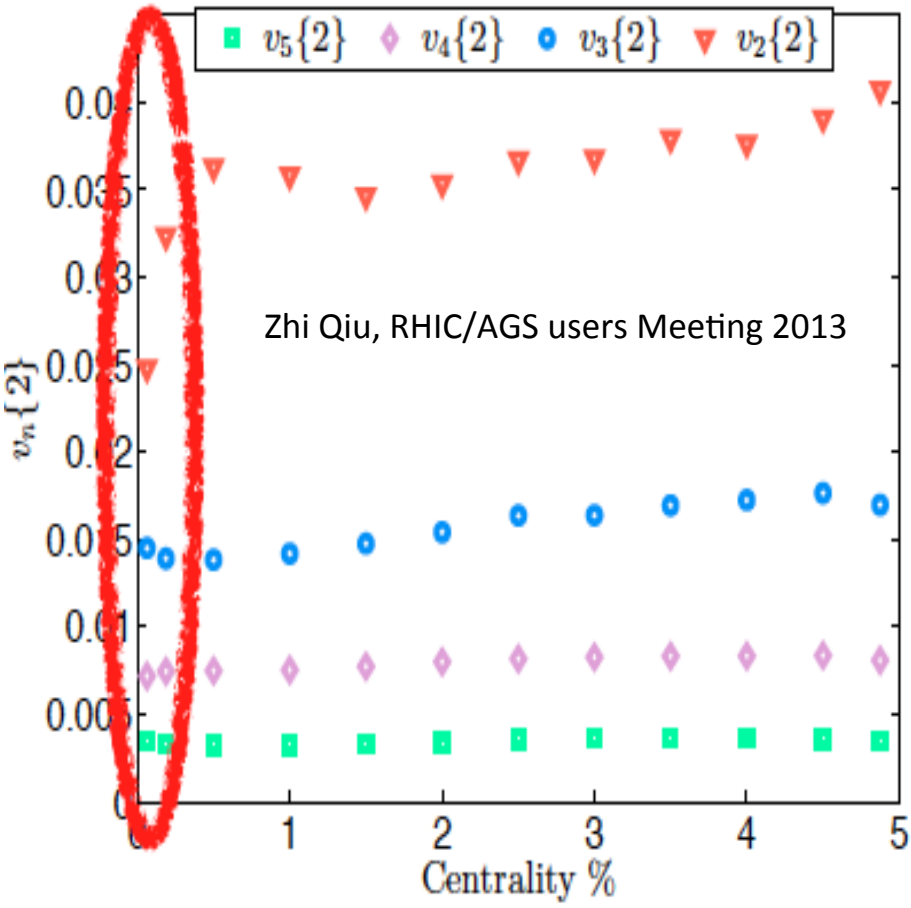
Azimuthal Anisotropy: pT dependence



- v_1 crosses zero above $p_T > 1.2$ GeV/c
- $v_n(p_T)$ for U+U collisions is similar to that of Au+Au Collisions except n=1 and 2 at central collisions

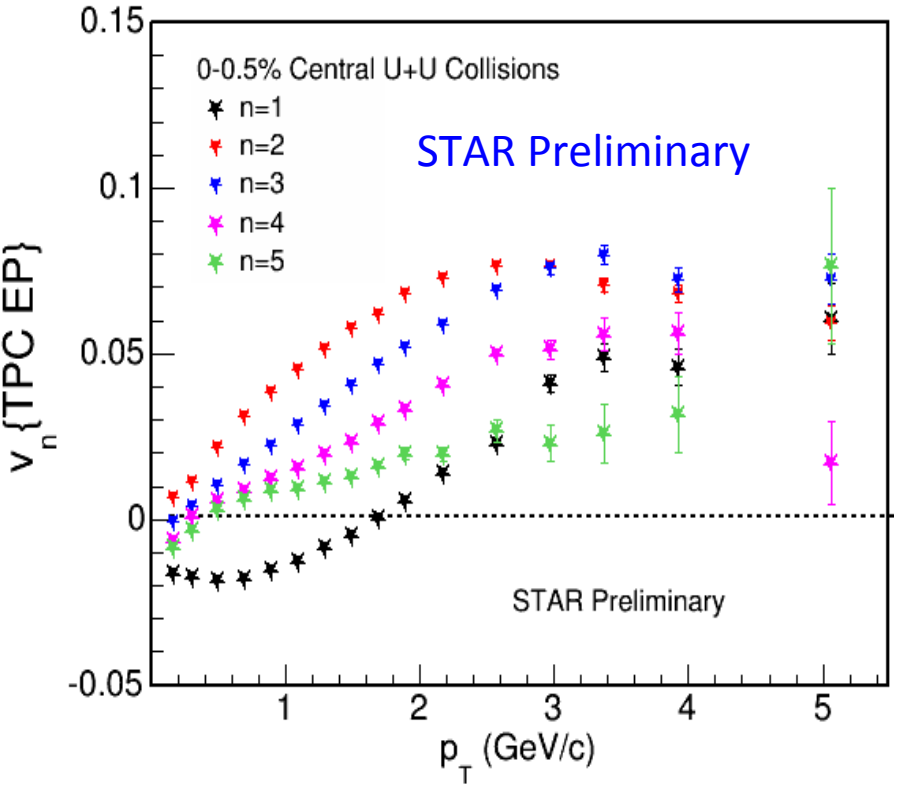
v_n in Central Events

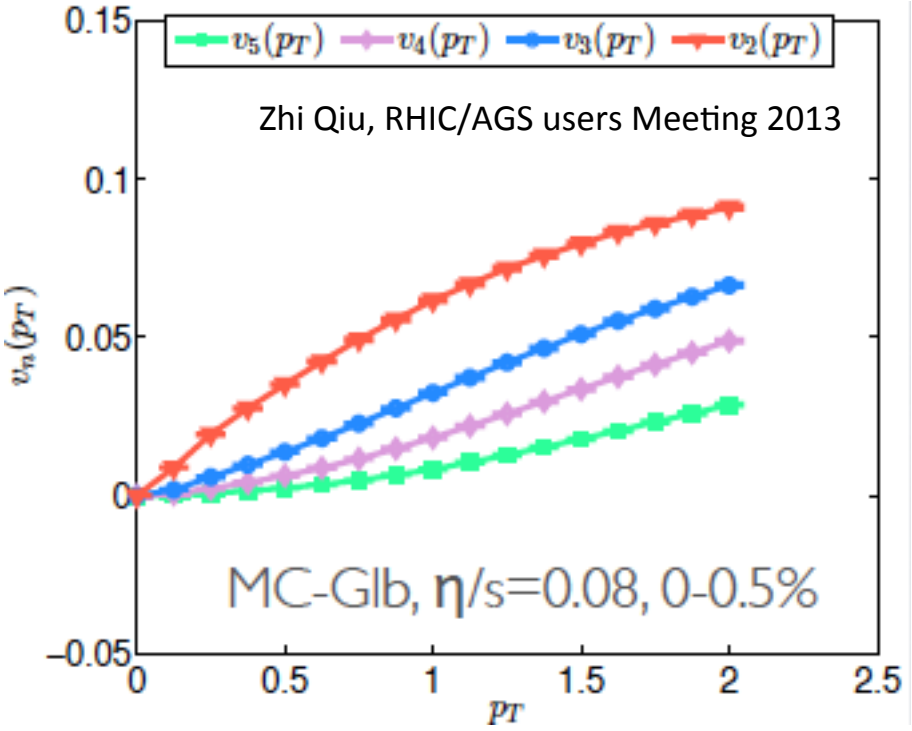




- Centrality is selection is based on track multiplicity at midrapidity.
- p_T ($0.15 < p_T < 2$) integrated v_n: v_2 changes slightly, other harmonics are almost constant
- We do not observe knee structure. Need to go below ~0.5% centrality /or fluctuations mask the knee structure in the data.

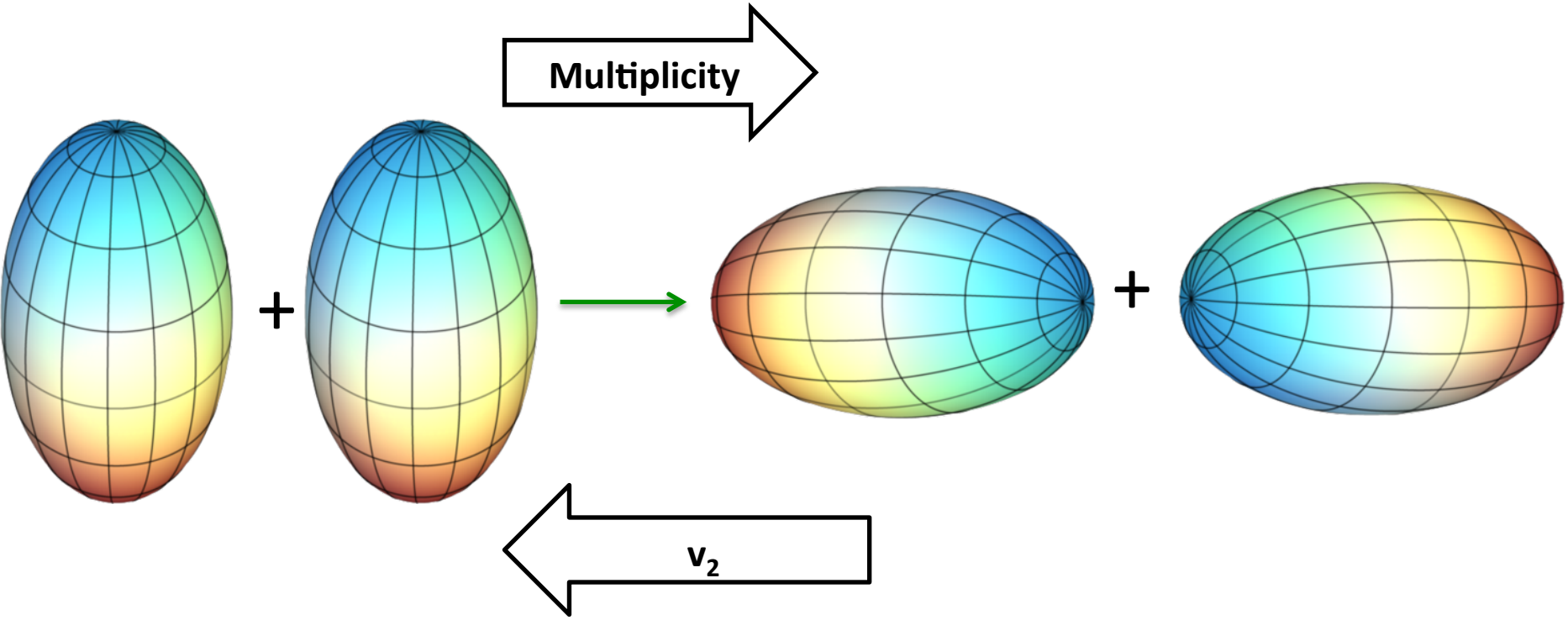
v_n (p_T) in Central Events





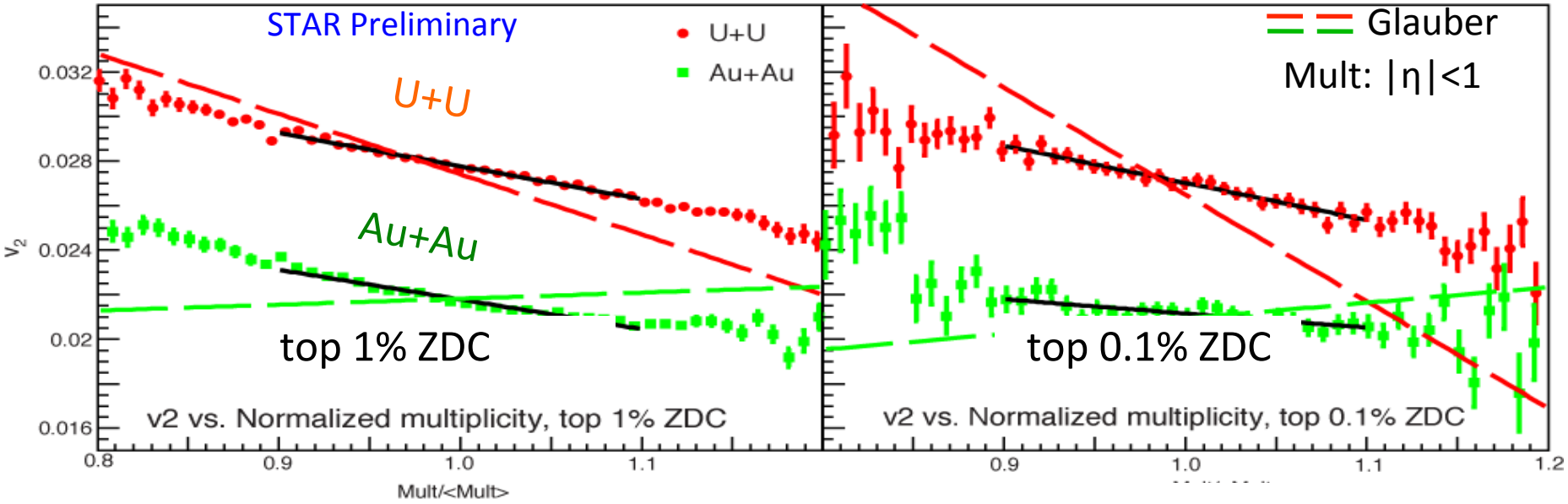
- v_2 is still dominant harmonics at low p_T (< 2 GeV/c) at ultra central(0-0.5%) collisions
- At intermediate p_T (3-5 GeV/c) range, $v_3 \sim v_2$ and $v_1 \sim v_4$ in ultra central collisions
- Results from model calculation show the similar trend to the data. (Model. magnitude is larger)

v_2 slope (v_2 vs dN/dη) in Central Events

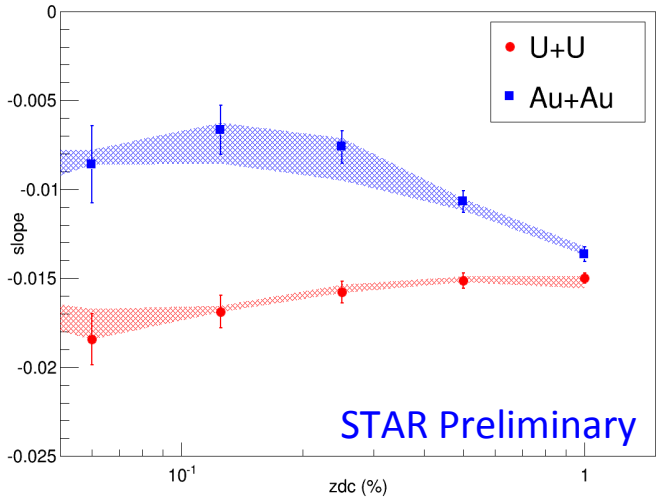


Use slope of v_2 vs dN/dη in U+U to look for correlation between dN/dη and geometry

v_2 (Multiplicity) in Central Events

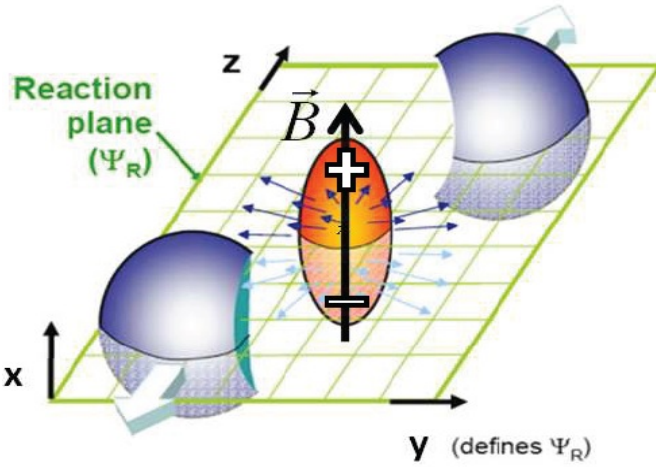


- Centrality selection is based on Zero Degree Calorimeter (ZDC) signal (spectator neutrons)
- Glauber model eccentricities scaled by the ratio of $\langle v_2 \rangle$ and $\langle \varepsilon_2 \rangle$
- U+U slope is weaker than models predicted.
- For tighter cuts, the U+U slope becomes steeper than the Au+Au sample



Search for Local Parity Violation

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



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

$$\gamma = \left\langle \cos(\phi_\alpha + \phi_\beta - \psi_{RP}) \right\rangle$$

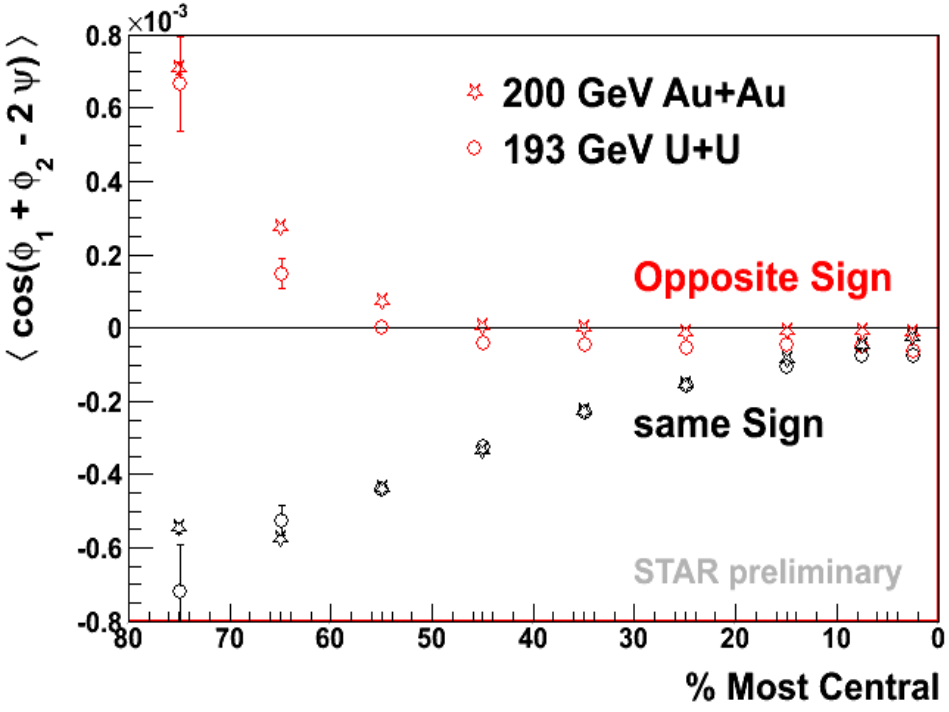
$$= \left[\left\langle v_{1,\alpha} v_{1,\beta} \right\rangle + B_{in} \right] - \left[\left\langle a_\alpha a_\beta \right\rangle + B_{out} \right]$$

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

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

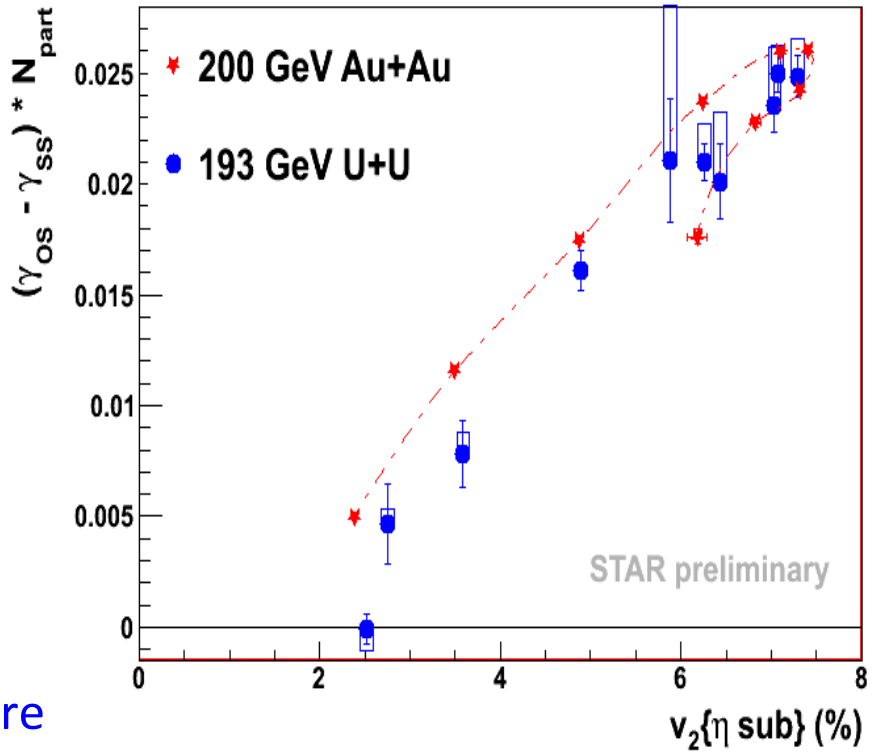
P-even quantity: still sensitive to charge separation

Search for Local Parity Violation



$$\gamma = \langle \cos(\varphi_\alpha + \varphi_\beta - \psi_{RP}) \rangle$$

Consider OS-SS to be the signal.
N_{part} accounts for the dilution



- The difference between OS and SS is still there in U+U, with similar magnitude to Au+Au

- A dedicated trigger with 0-1% spectator neutrons. With the magnetic field suppressed, the charge separation signal disappears while v_2 is still >2%

Summary

- Anisotropic flow

1. For higher harmonics and mid central collisions, v_n{U+U} is similar to v_n{Au+Au}, the difference appears at central collisions(0-5% central) for v_1 and v_2.
2. The U+U v_2 shows a stronger multiplicity dependence for central events.
3. The differences in the slope parameters between Au+Au and U+U increase in more central collision
4. Results from model calculation with low viscosity setting are similar to the data.
5. We do not observe "knee structure" in v_2 vs multiplicity(centrality) in current analysis as predicted by models.

- Chiral Magnetic Effects

An important systematic check for three-particle correlator was carried out in U+U. With the magnetic field suppressed, the charge separation signal disappears while v_2 is still >2%