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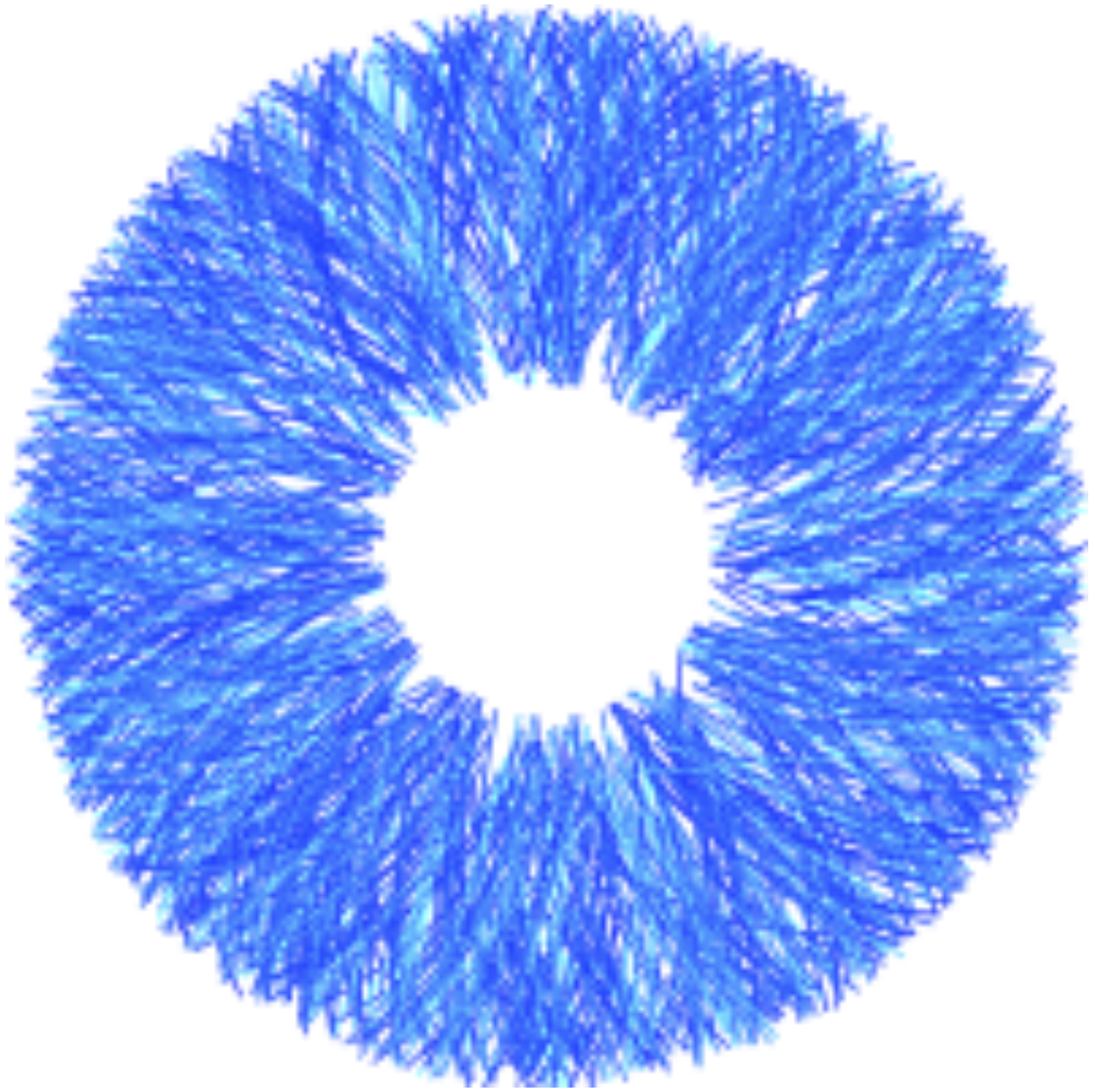
MARIA STEFANIAK FOR THE STAR COLLABORATION

INVESTIGATION OF PARTICLE ANTIPARTICLE ELLIPTIC FLOW DIFFERENCE

OUTLINE

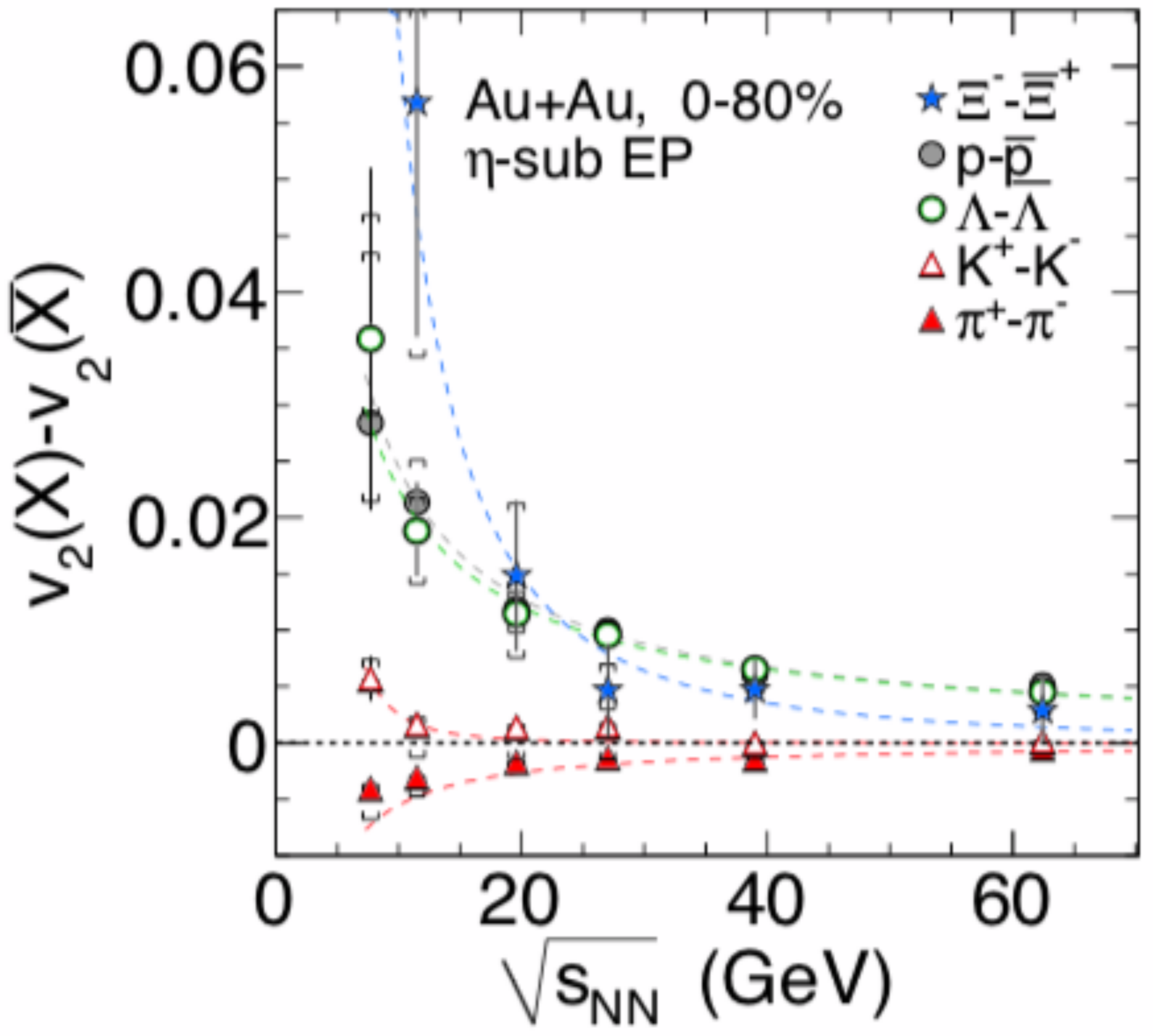
- Motivation
- Analysis methods
- Results
- Conclusions



MOTIVATION

Differences between particle and antiparticle elliptic flow had been observed by the STAR collaboration.

STAR Collaboration: Phys. Rev. C 88 (2013) 14902



STAR Collaboration: Phys. Rev. C 88 (2013) 14902

- Difference of protons - antiprotons elliptic flow increases with decreasing collision energy

Various theoretical scenarios of possible sources of this observations are available

MOTIVATION

Difference between proton and antiproton elliptic flow:

Phys. Rev. Lett. 112, 012301 (2014)

1. **Mean field**: impacts oppositely the quarks and antiquarks.

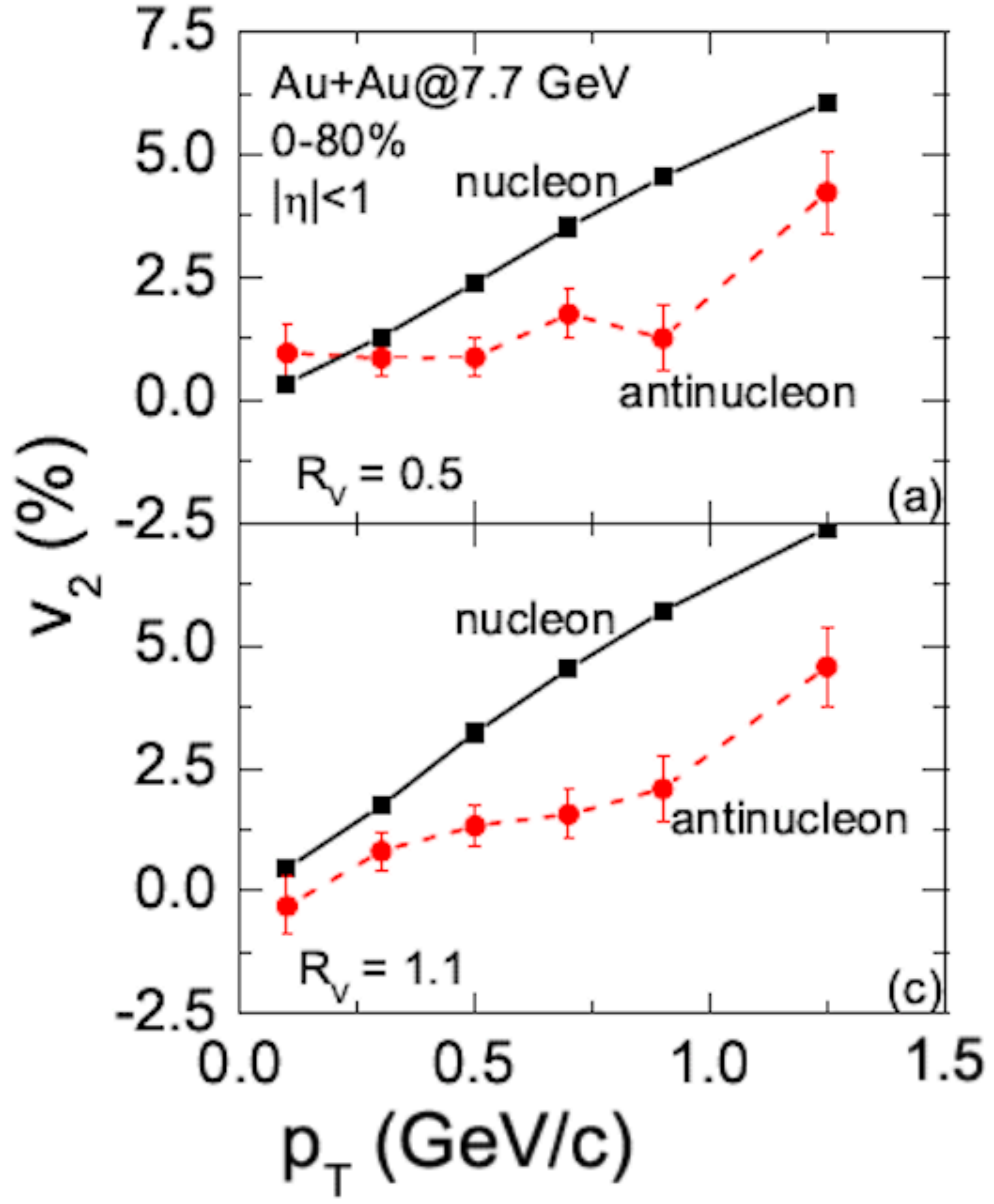
MEAN FIELD

QUARKS

ANTIQUARKS

INCREASE FLOW

DECREASE FLOW



model used: AMPT and 3-flavor Nambu-Jona-Lasinio model

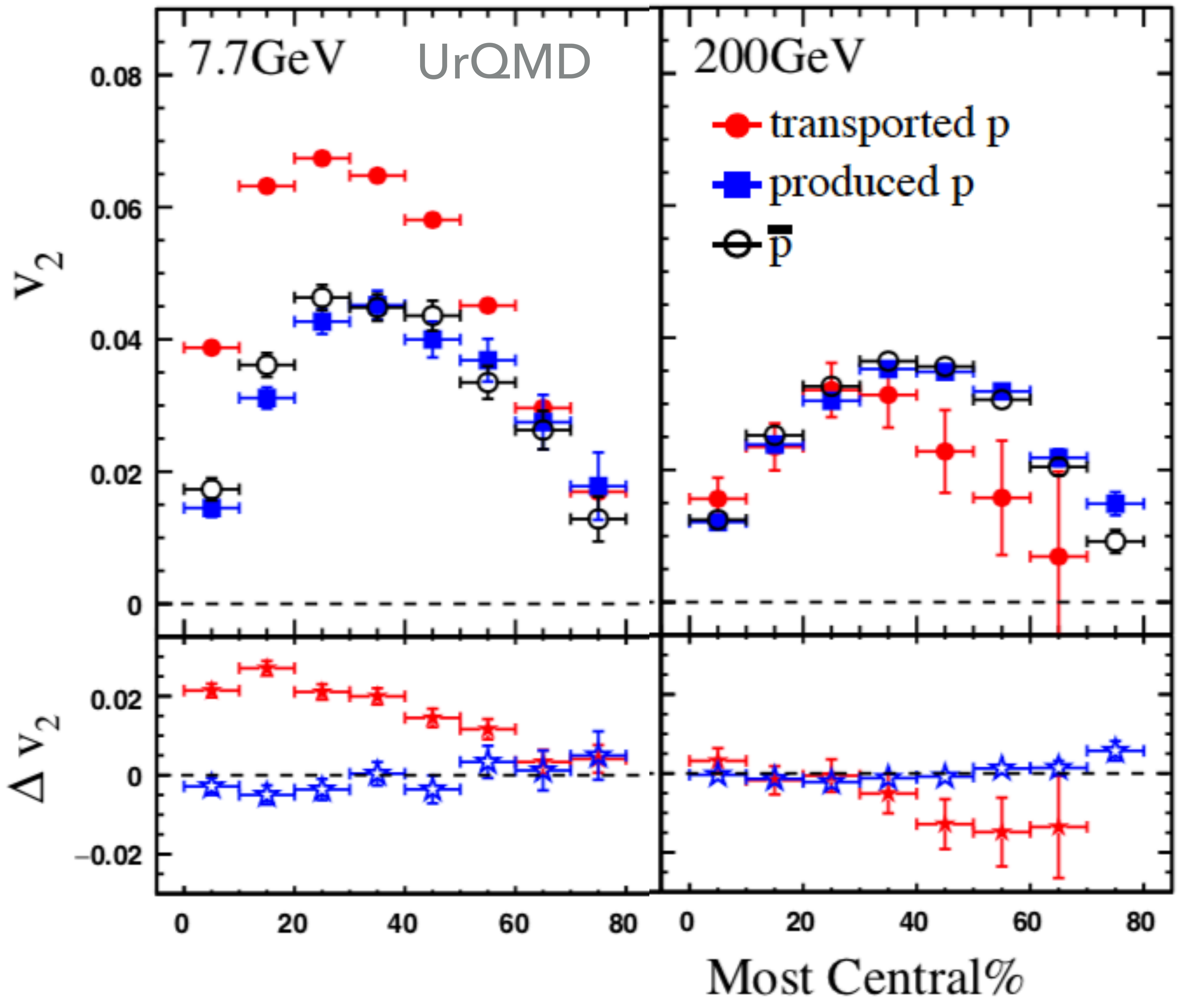
MOTIVATION

Difference between proton and antiproton elliptic flow:

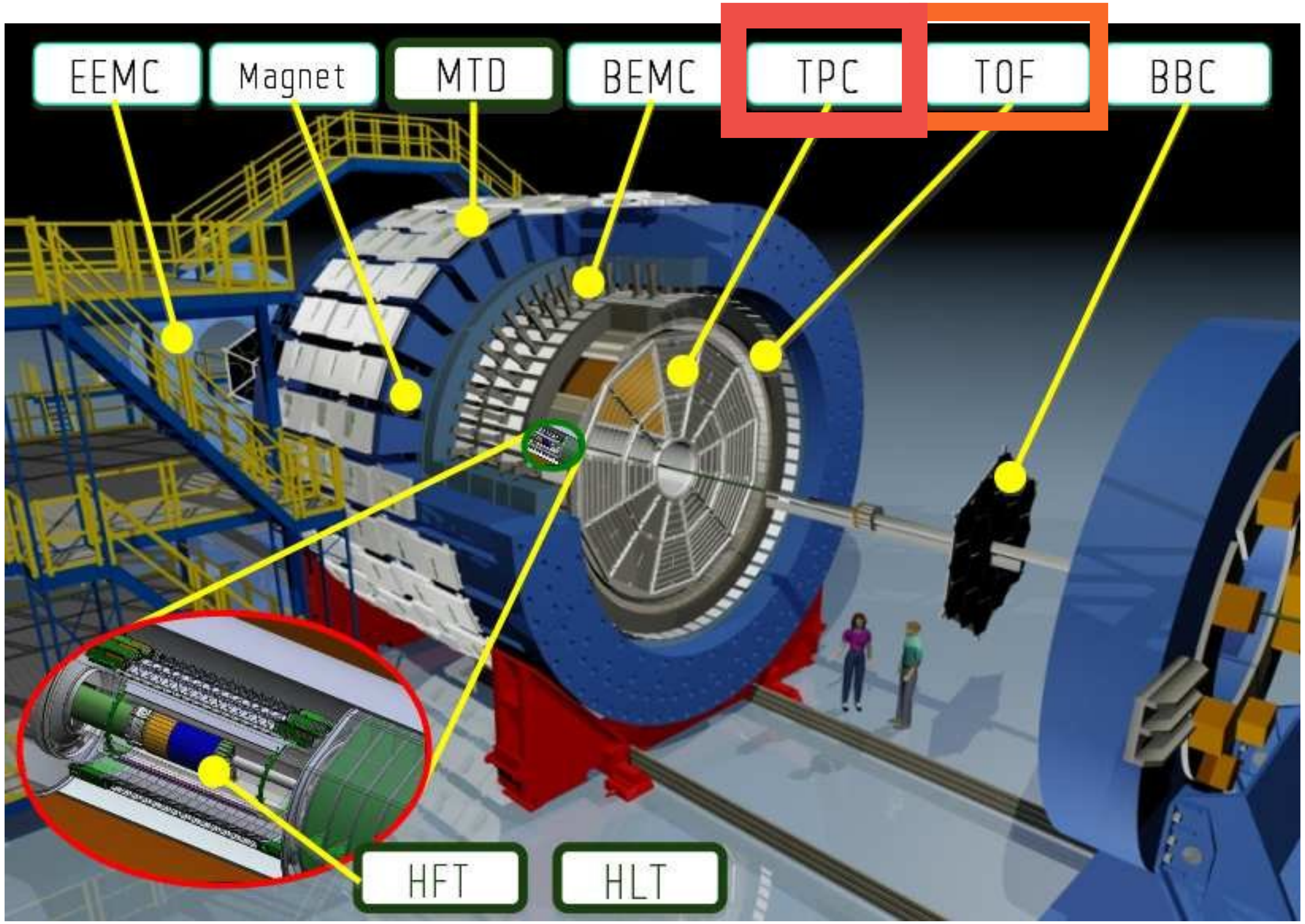
2. Transported vs. **produced protons**:

- Transported protons have stronger positive correlation than produced
- Both produced protons and antiprotons have similar flow - origin from same part of evolution
- **Transported quarks go through all evolution process** of transformation of initial geometry eccentricities to anisotropy in momentum, **produced go through only a part of this scenario**
- Transported quarks suffer more scatterings
- Energy dependence can be explained by **nuclear stopping**

Biao Tu: Chin.Phys. C43 (2019) no.5, 054106



THE SOLENOIDAL TRACKER AT RHIC



Time Projection Chamber

Tracking charged particles with:

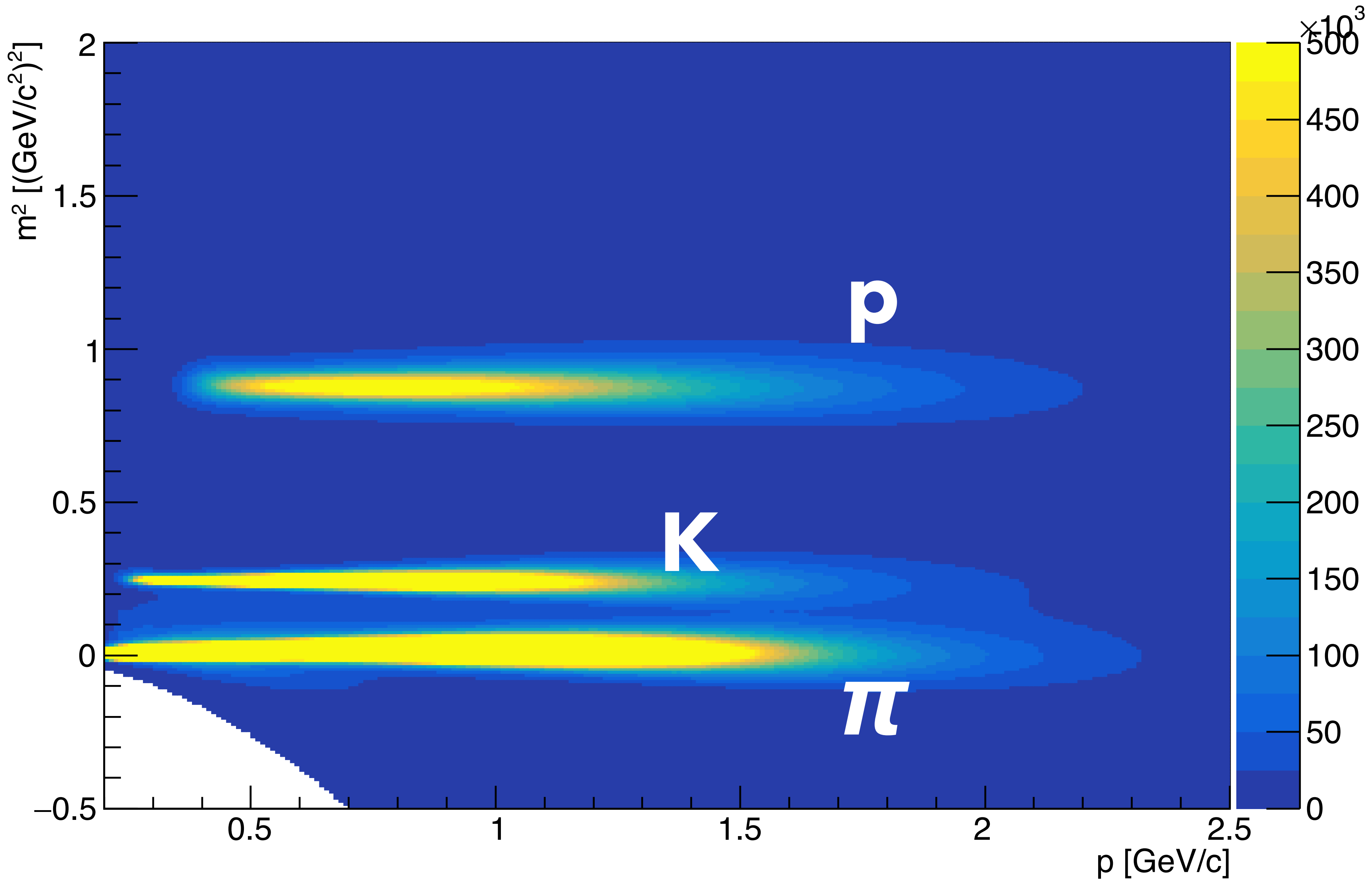
- Full azimuthal coverage
- $|\eta|<1$ coverage
- Particle Identification

Time-Of-Flight

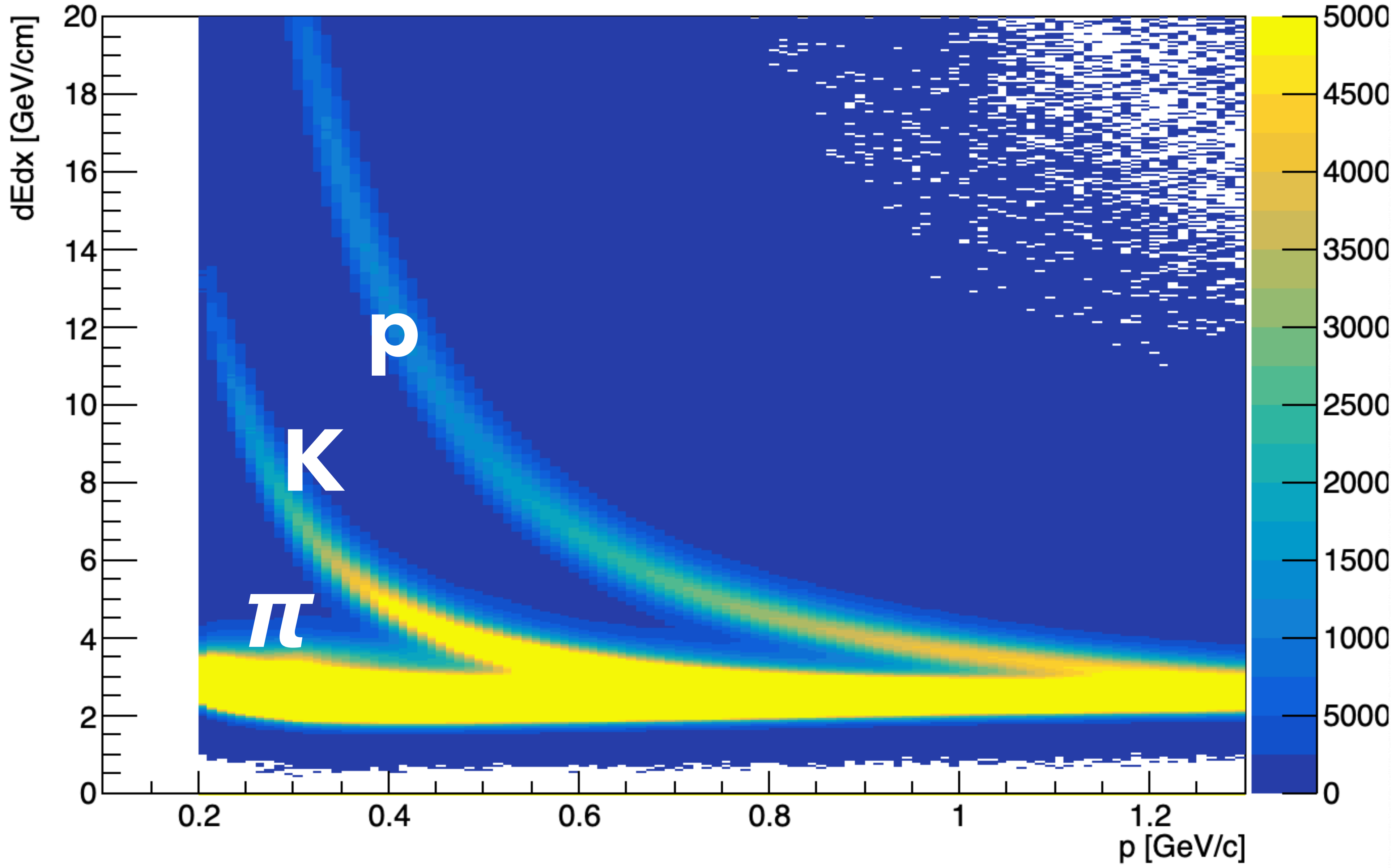
- Particle identification (high momentum)

THE SOLENOIDAL TRACKER AT RHIC

TOF information



TPC information



For particle identification used information from:

- Time-Of-Flight
- Time Projection Chamber detectors

ANALYSIS METHOD: TWO-PARTICLE CORRELATIONS

- 2-particle correlations (2PC) are obtained by averaging over all unique combinations in each event and then over all events:

$$\langle\langle 2\rangle\rangle_n = \langle\langle e^{in(\phi_1-\phi_2)}\rangle\rangle$$

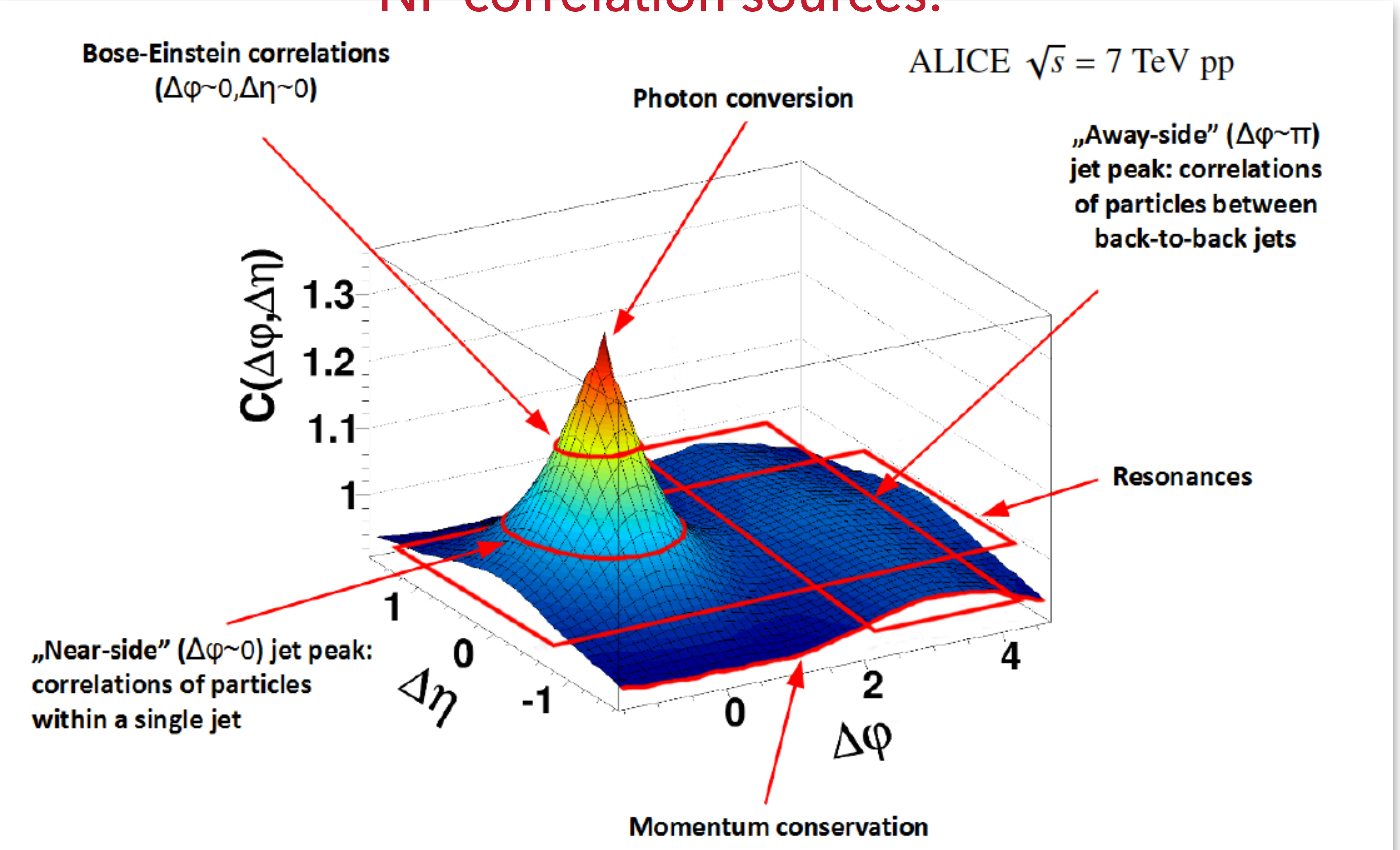
$$c_n\{2\} = \langle\langle 2\rangle\rangle_n$$

- 2PC carry flow and non-flow (NF) contribution:

$$c_n\{2\} = v_n^{ab} = v_n(a)v_n(b) + \delta_{NF}$$

short-range | long-range
HBT | momentum conservation
decays | di - jets

NF correlation sources:



Małgorzata Janik PhD thesis

- NF suppression is needed

ANALYSIS METHOD: SUB-EVENTS

$$\langle 2\rangle_{a|b} = \langle e^{in(\phi_1^a - \phi_2^b)}\rangle = \frac{\langle Q_{n,a} Q^*_{n,b}\rangle}{\langle M_a M_b\rangle}$$

Ma/b - multiplicity of particles in sub-event **a/b**

$$Q_{n,o} \equiv \sum_i e^{in\phi_i^o} \quad o = a \text{ or } b$$

calculated only for particles from given sub-event

- The correlations are measured for the pairs of particles coming from different sub-events
- There are no self-correlations
- The non-flow contribution is suppressed

integrated flow harmonics:

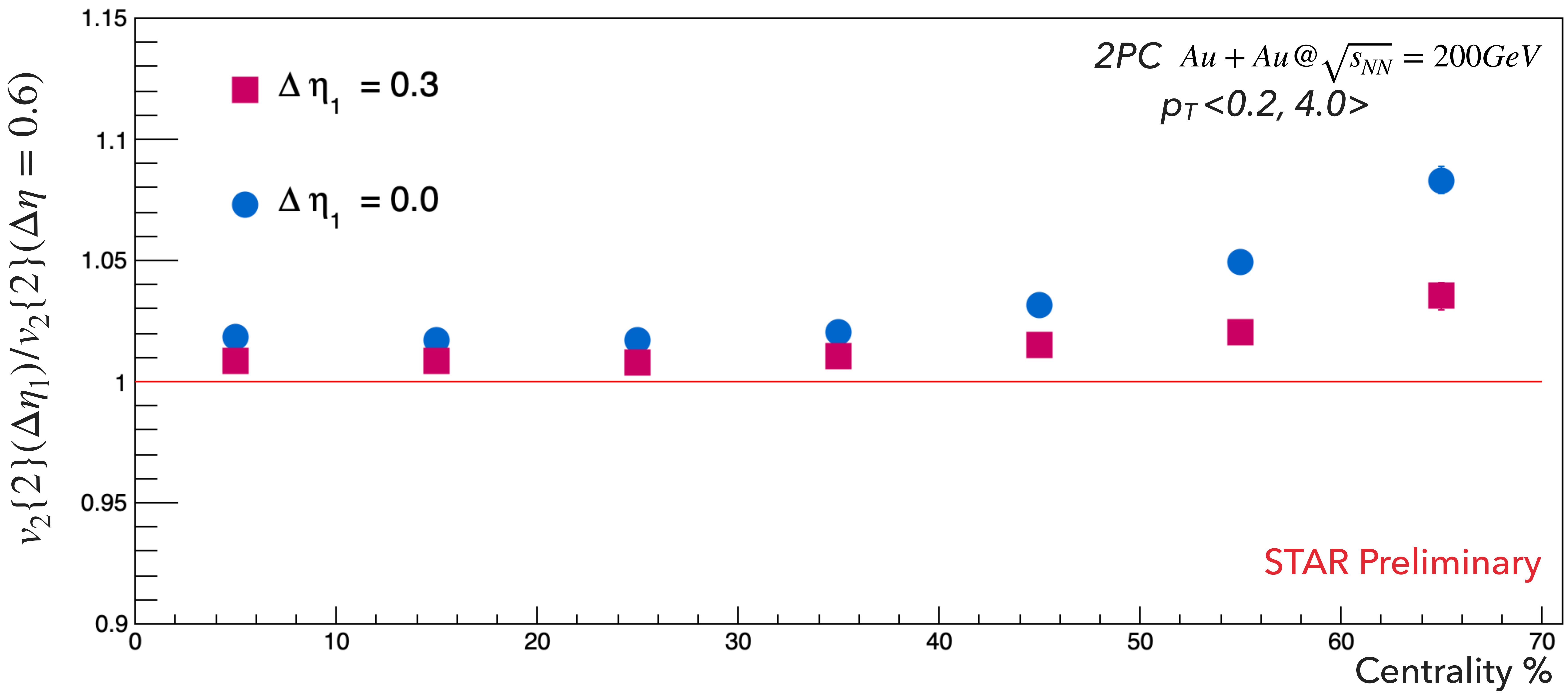
$$v_n\{2\} = \sqrt{c_n\{2\}}$$

p_T (PID) - differential flow harmonics:

$$v_n(p_T) = v_n^2(p_T, p_T^{ref}) / \sqrt{v_n^2(p_T^{ref}, p_T^{ref})}$$

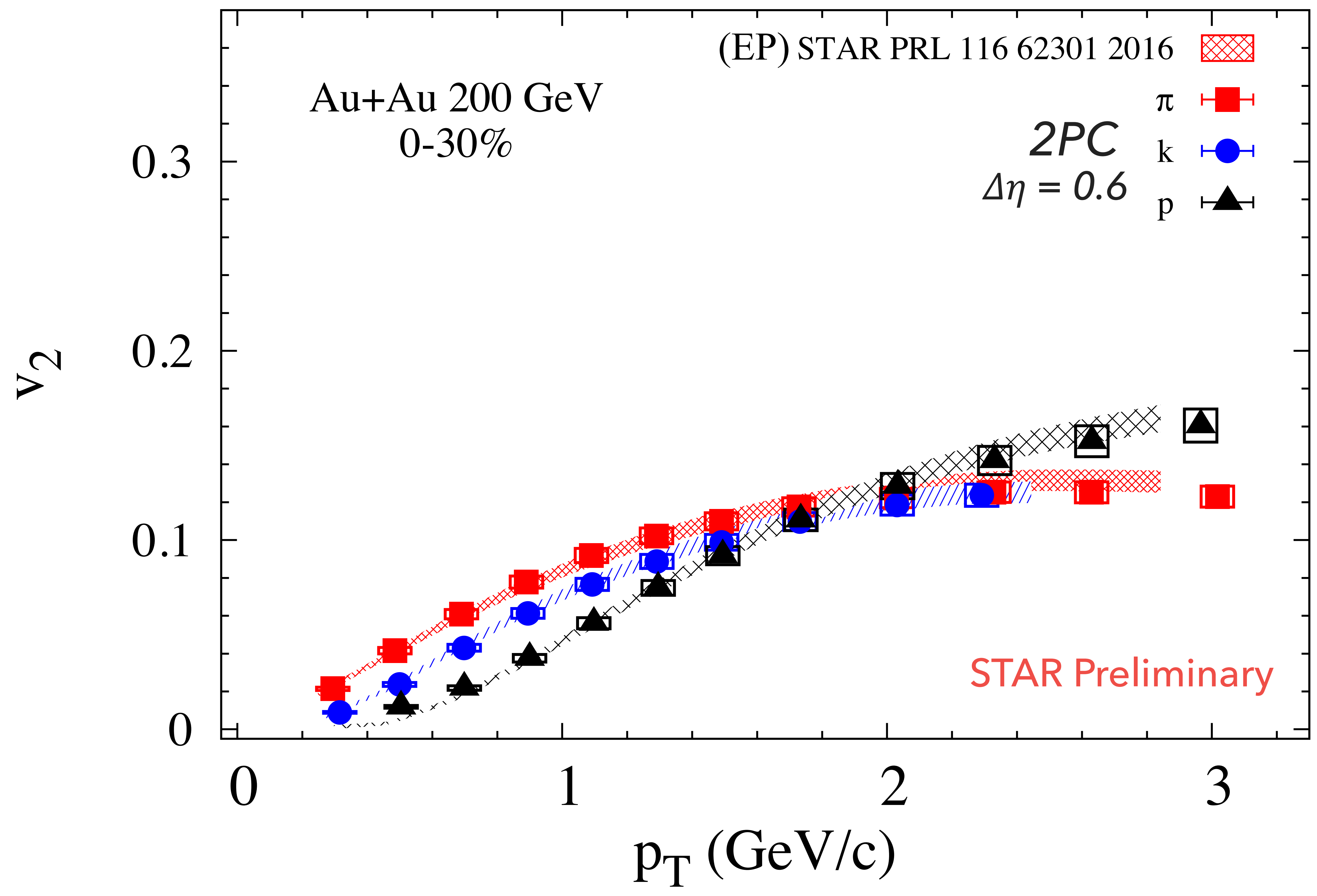
RESULTS

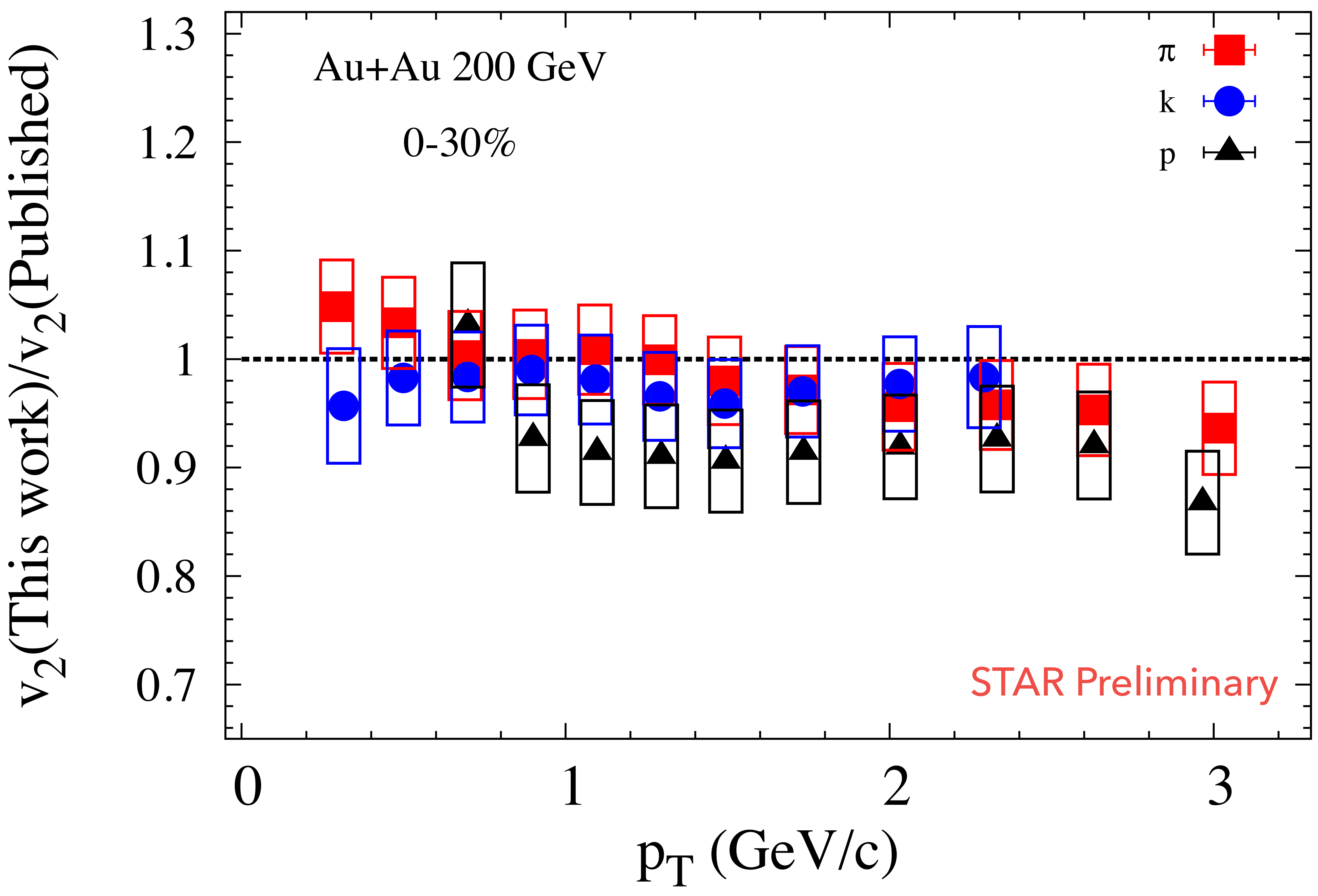
NON-FLOW CONTRIBUTION



Non-flow contribution is suppressed using higher Δη

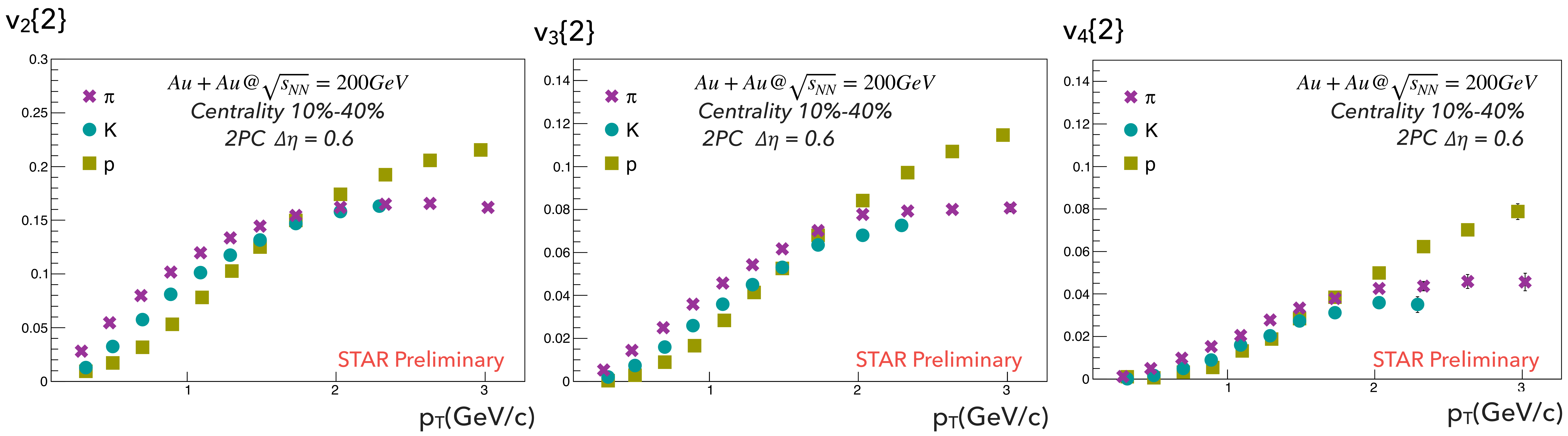
CENTRALITY SELECTION FOR 2-PARTICLE CORRELATIONS





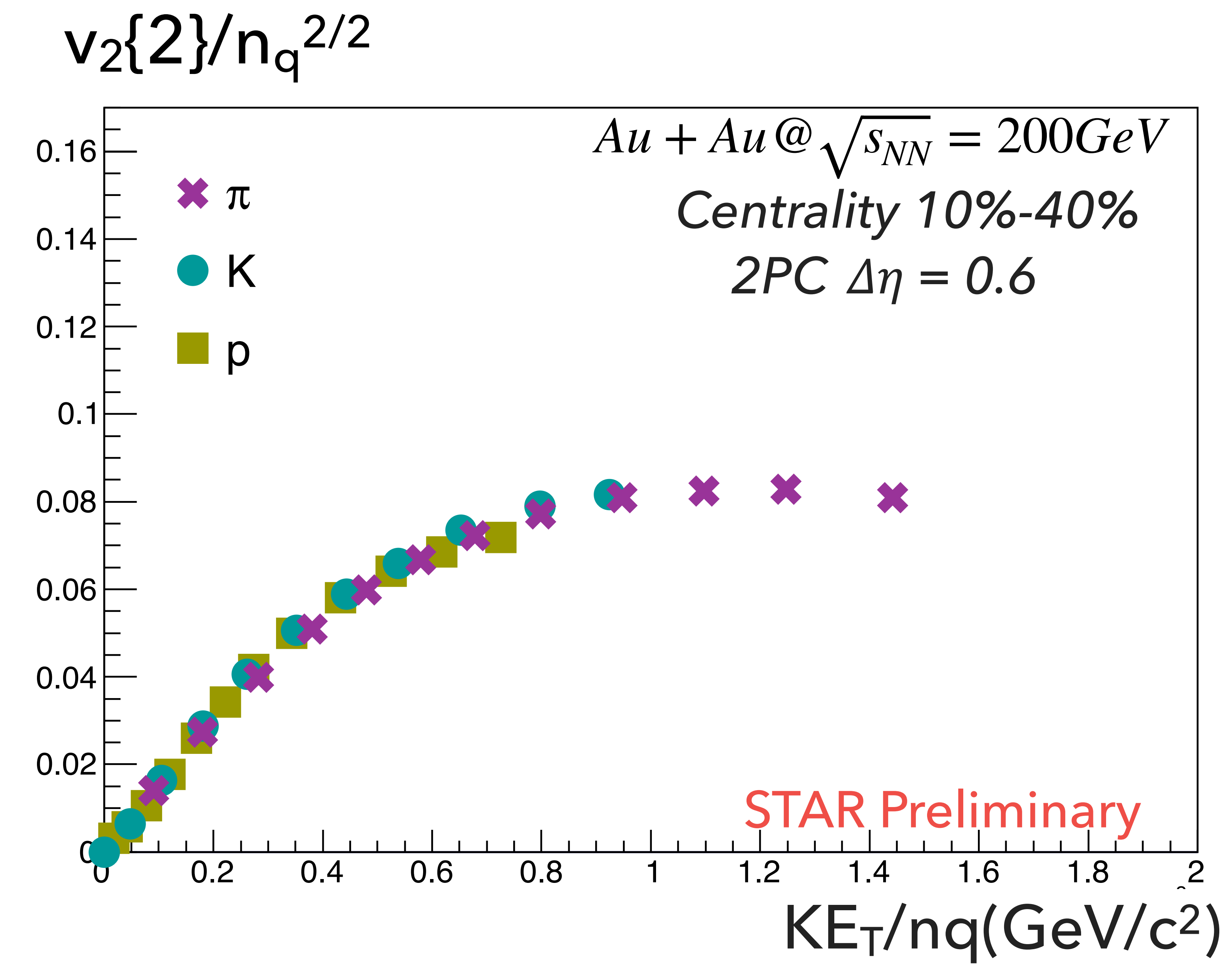
- Good agreement with the STAR published measurements obtained via event-plane method

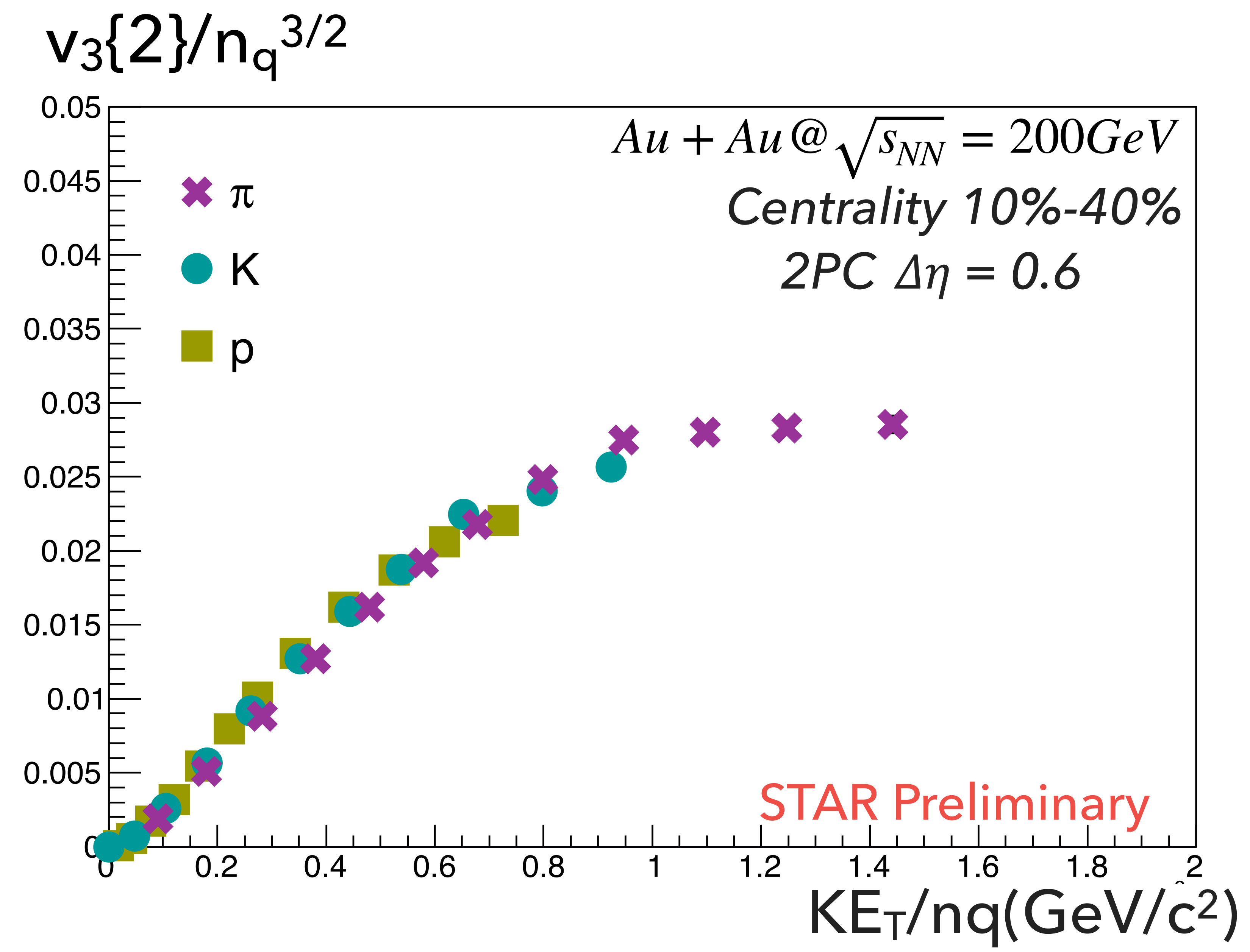
FLOW HARMONICS: $\sqrt{s_{NN}} = 200$ GEV

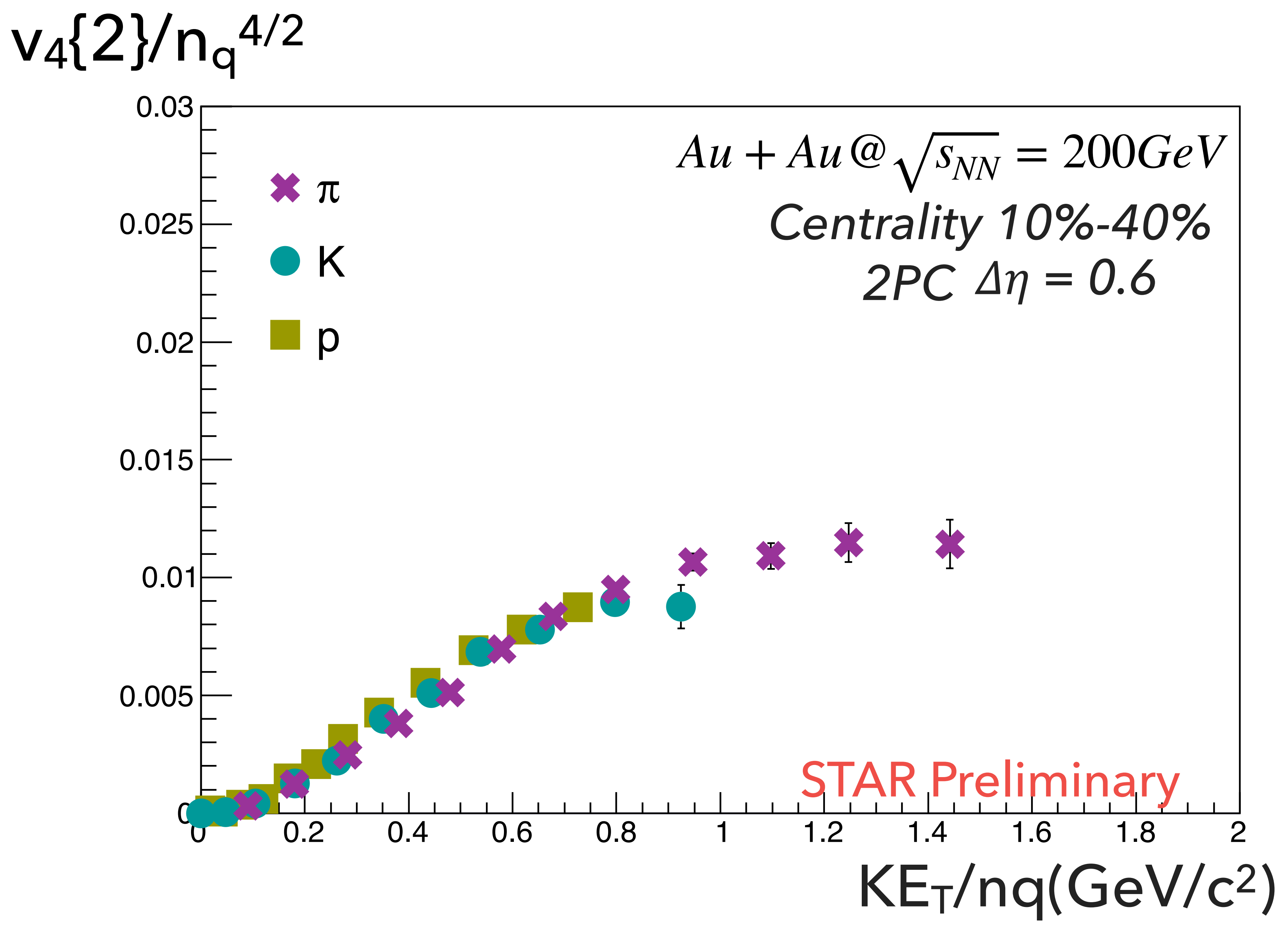


- **The expected mass ordering**

FLOW HARMONICS : NCQ(KE_T)-SCALING $\sqrt{S_{NN}} = 200$ GEV

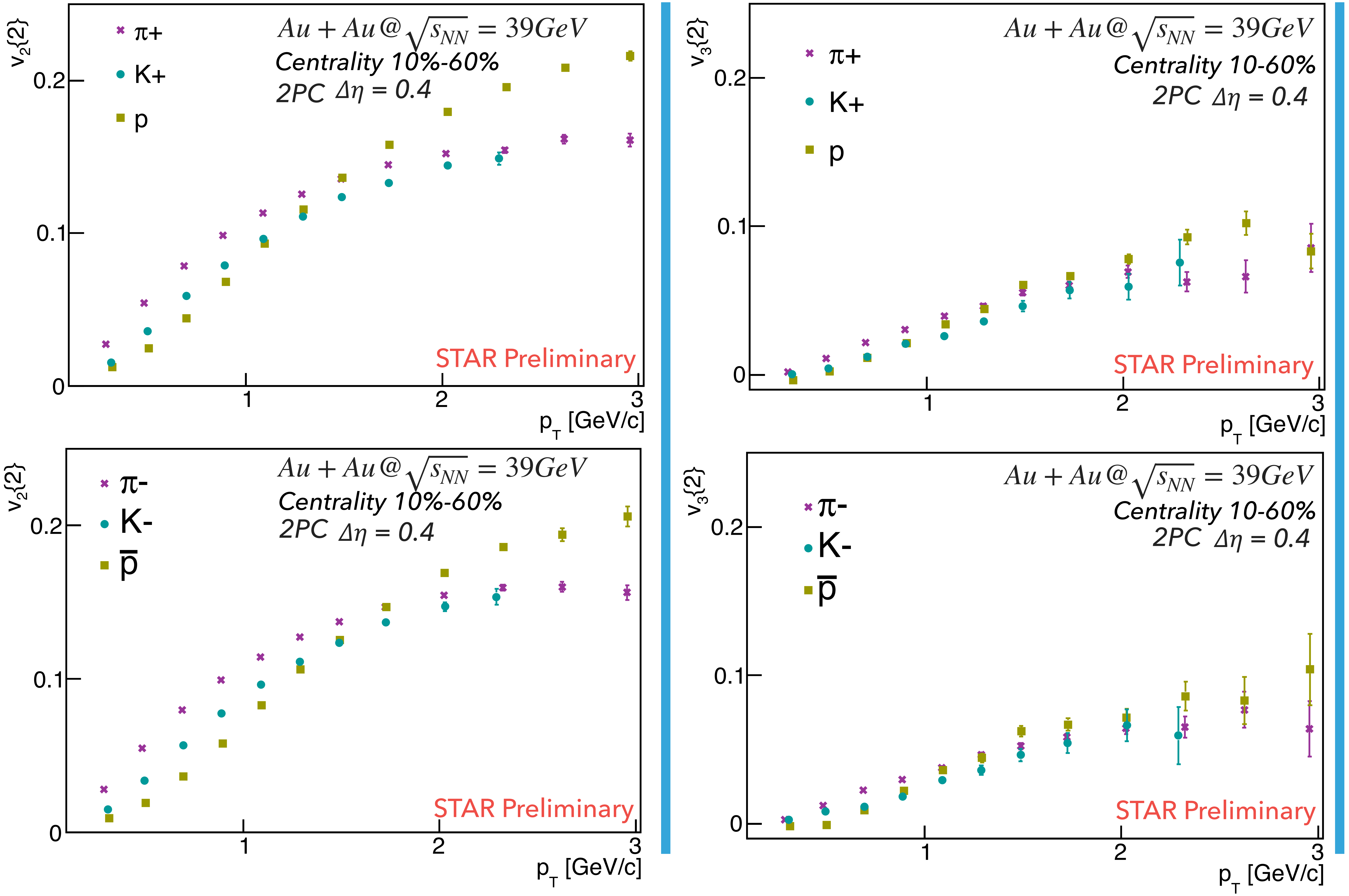






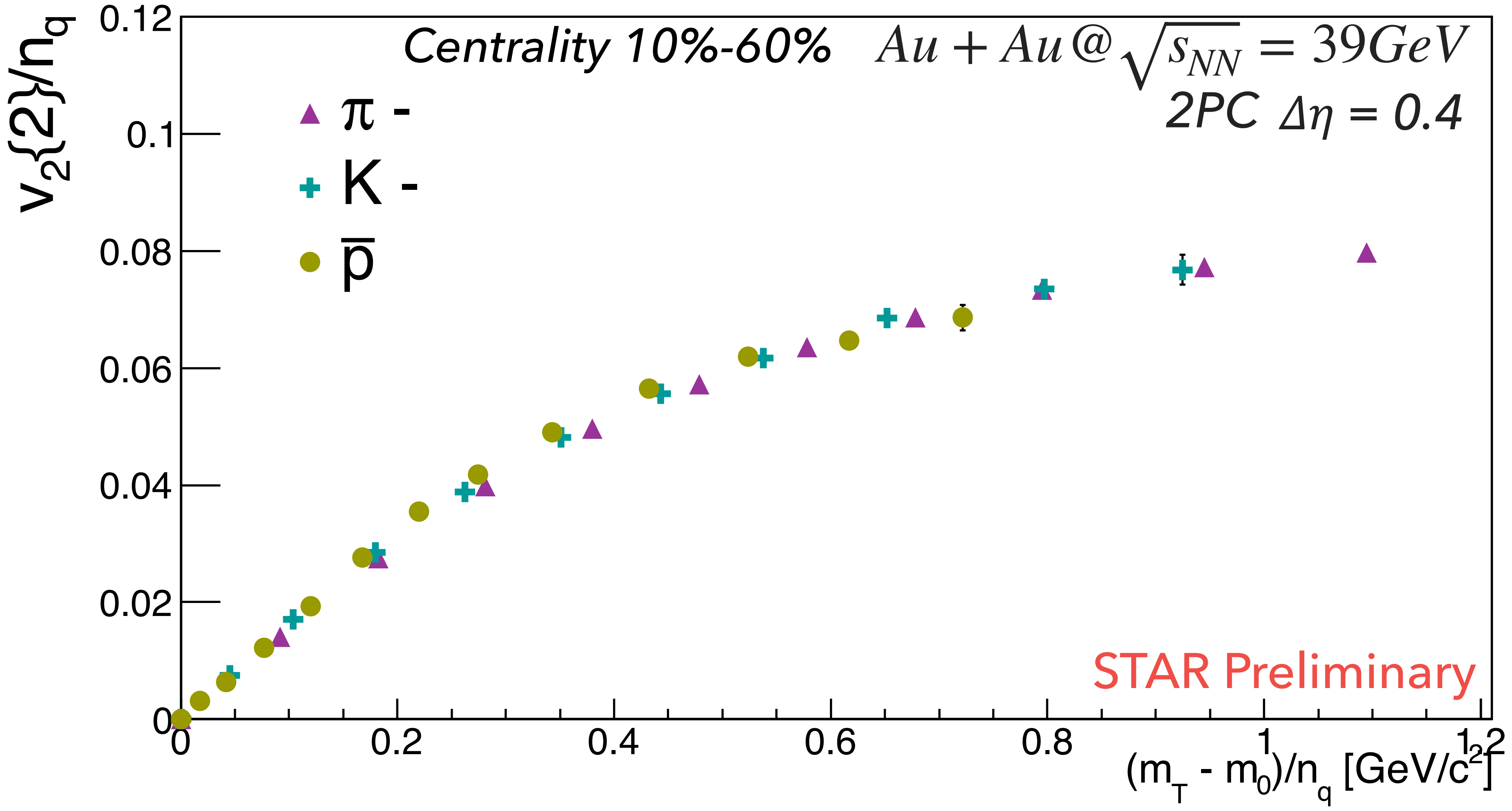
- **$v_n\{2\}/n_q^{n/2}$ scales with KE_T/nq**

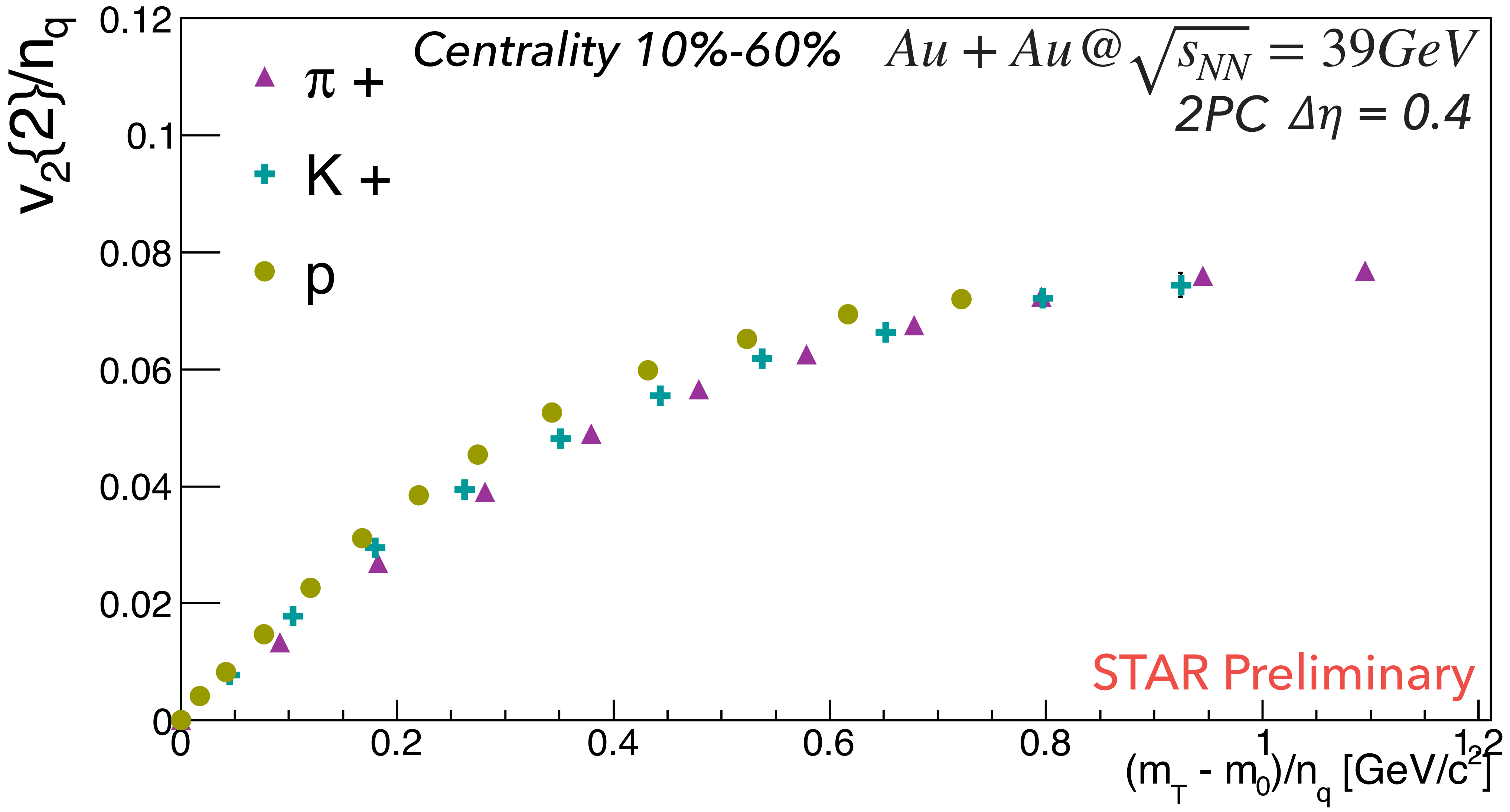
FLOW HARMONICS: P_T-DIFFERENTIAL MEASUREMENT AT $\sqrt{S_{NN}} = 39$ GEV



- The presented elliptic and triangular flow show the expected mass ordering

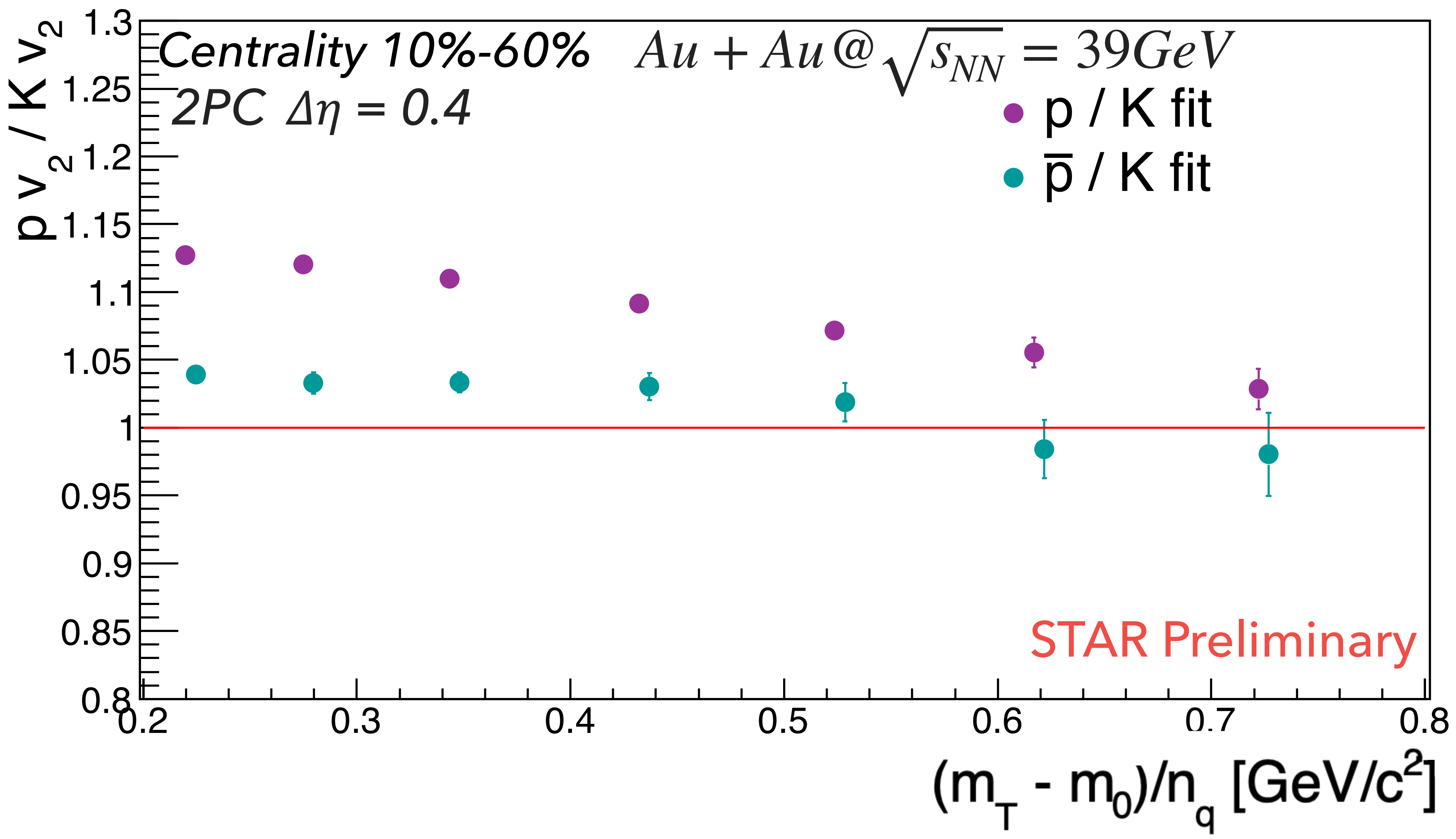
NCQ(KE_T)– SCALING: ELLIPTIC FLOW





Mean field scenario:

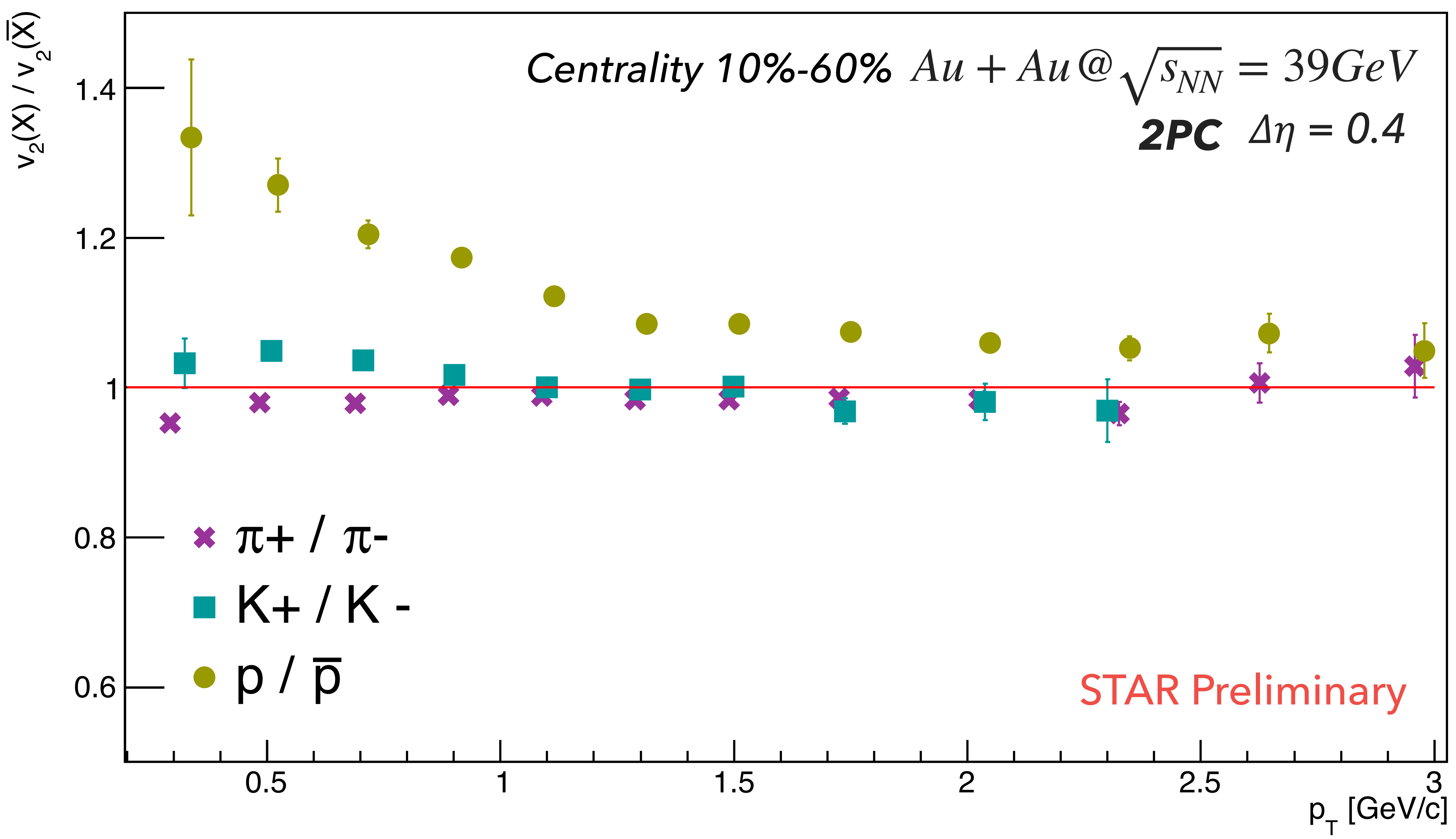
- Expected proton and antiproton violate NCQ(KE_T) scaling in the same magnitude (but opposite sign)



- Protons break the NCQ(KE_T) scaling

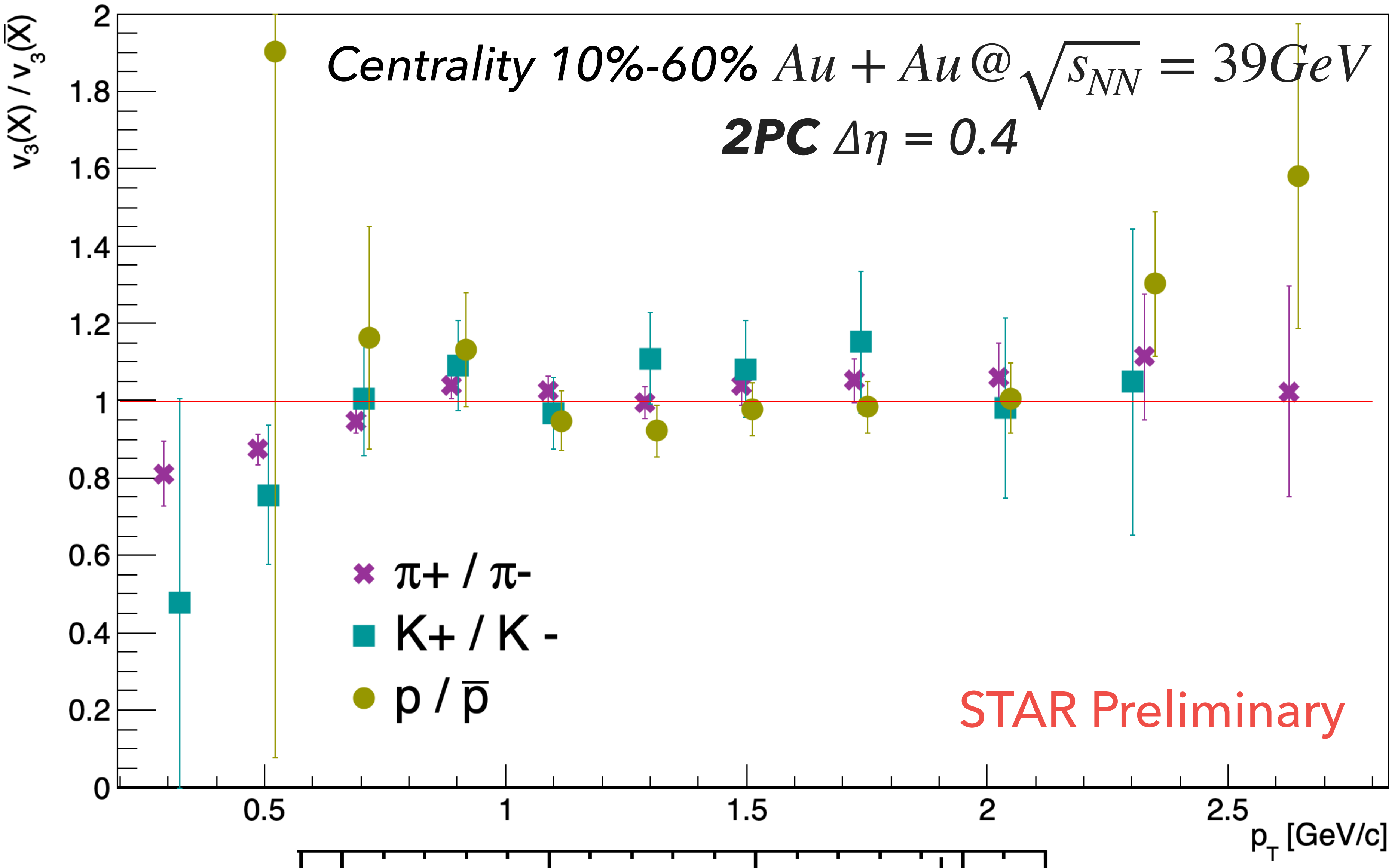
- ***Does the mean field scenario valid?***

PARTICLE AND ANTIPARTICLE ELLIPTIC FLOW DIFFERENCE

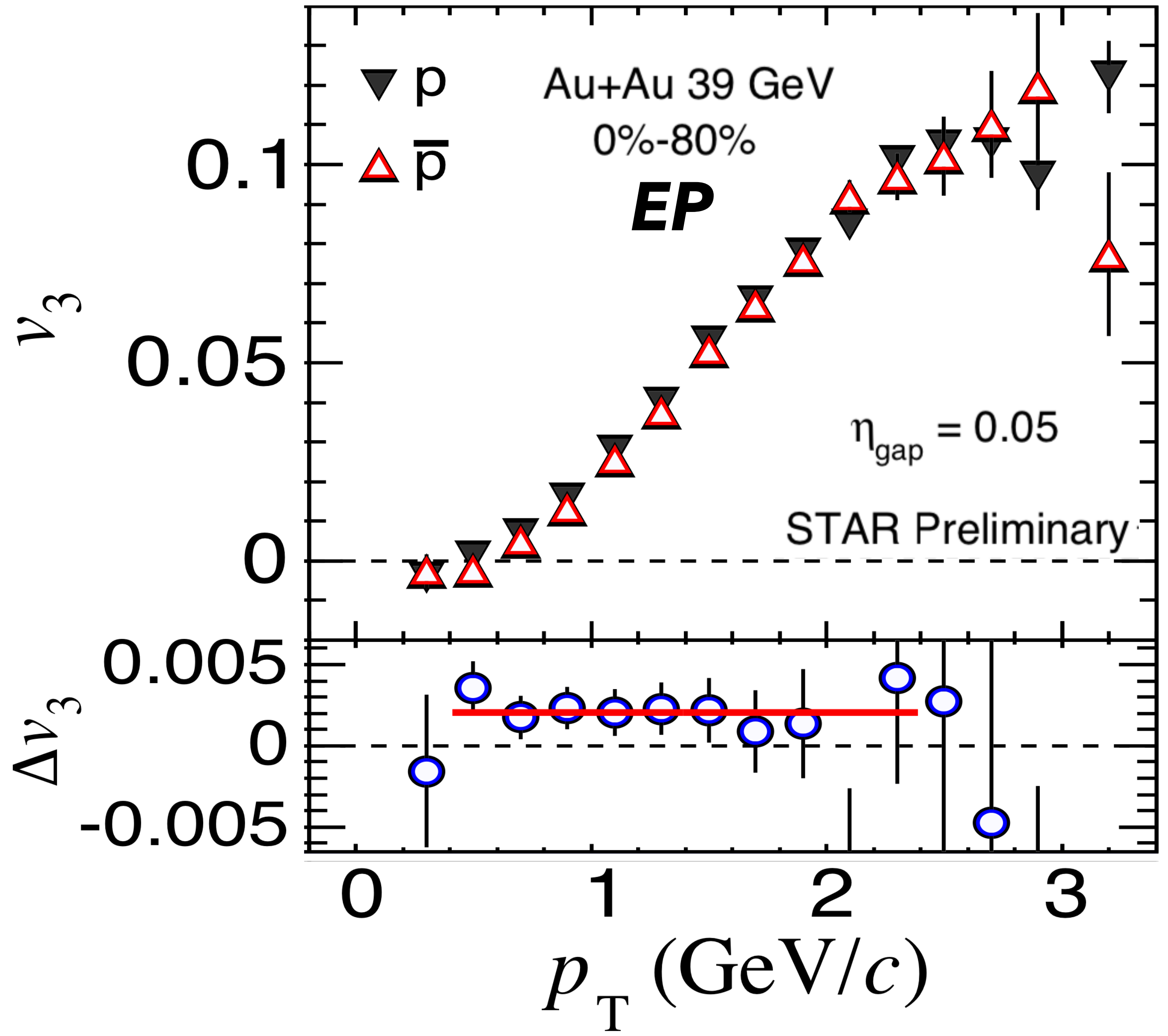


- Negligible difference between v_2 of mesons and antimesons
- Strong p_T dependance of the proton/antiproton v_2

PARTICLE AND ANTIPARTICLE TRIANGULAR FLOW DIFFERENCE



- No vital differences within uncertainties between particles and antiparticles of the fluctuation-driven triangular flow



- Differences between v_3 for protons and antiprotons is more visible using event-plane method and smaller *Δη*

Xu Sun, PhD Thesis

SUMMARY

- For both $\sqrt{s_{NN}}$ = 39 GeV and $\sqrt{s_{NN}}$ = 200 GeV mass ordering of triangular flow
- No significant difference in the particle/antiparticle triangular flow for $\sqrt{s_{NN}}$ = 39 GeV
- *Mean field* as a reason of the proton/antiproton difference in v_2 is not validated with NCQ(KE_T)-scaling

Thank you for attention