Event-Shape-Engineering study of D^0 meson elliptic flow in Au+Au collisions at 200 GeV

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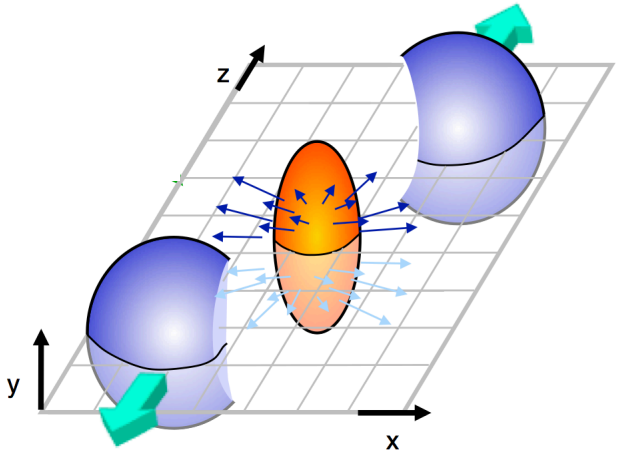
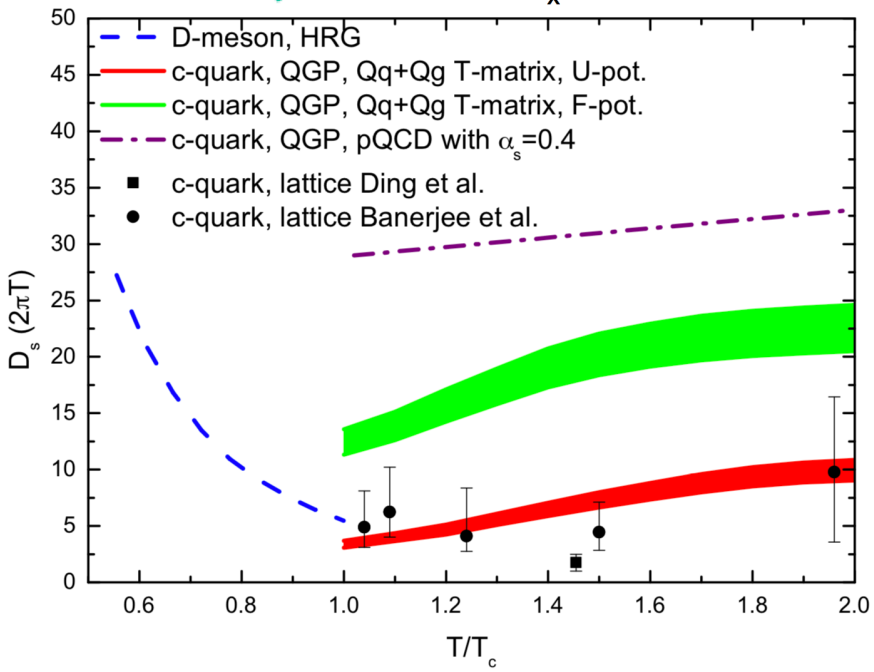
Heavy Quark in QGP

- Elliptic flow (v_2) – second order Fourier coefficient of the azimuthal distribution.

$$E\frac{d^3N}{dp^3} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}(1 + \sum_{n=1}^{\infty} 2v_n \cos(2(\phi - \psi_n)))$$

- Heavy quarks are produced mostly from initial hard scattering. When transporting through QGP, they have a longer thermalization time due to their large masses than light quarks.
- D^0 v_2 , sensitive to charm quark diffusion coefficient in QGP.

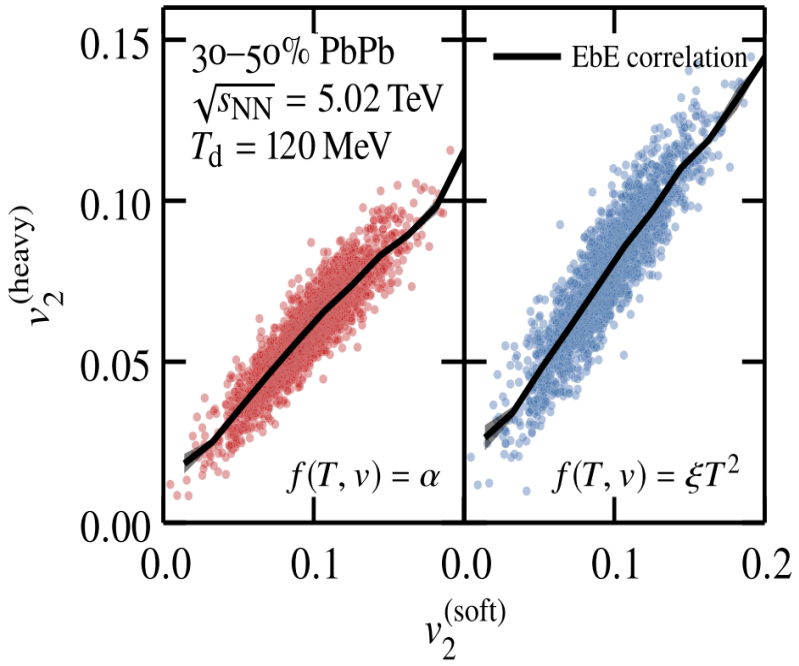


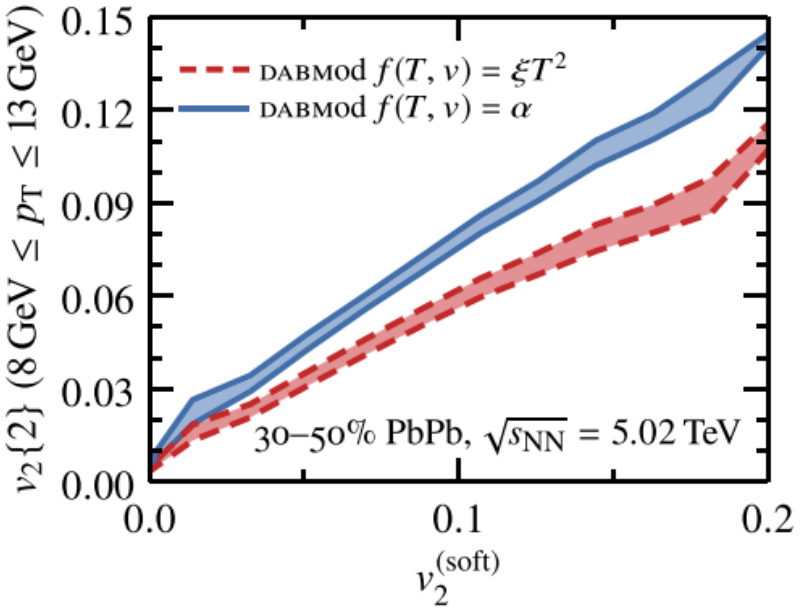


Y. Akiba, et al., arXiv:1502.02730

Light and heavy flavor hadron v_2 correlation

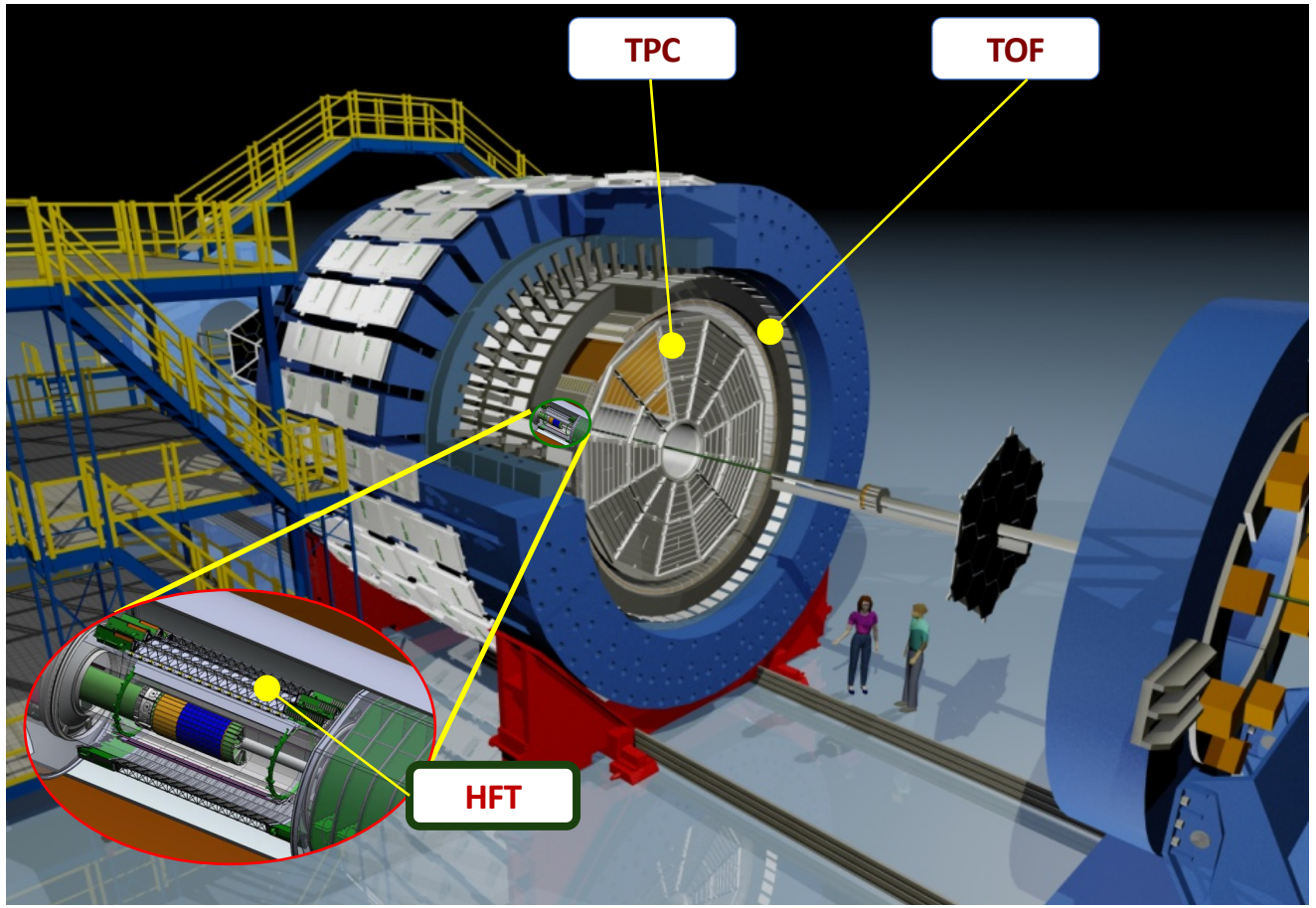
- Event-by-event correlation between D^0 v_2 and light flavor hadron v_2 depends on the energy loss model for charm quark in QGP
- Event-Shape-Engineering(ESE) study of D^0 meson v_2, provides a new observable that could further constrain the charm quark interactions with the QGP

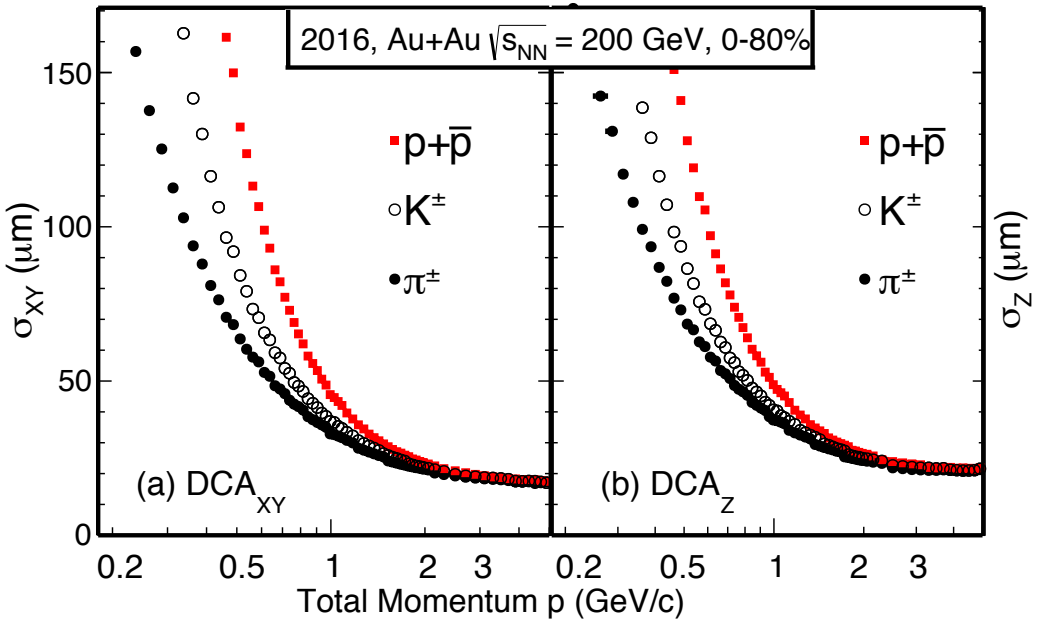




C. A. G. Prado, et al. Phys. Rev. C 96 (2017) no.6, 064903

STAR Detector



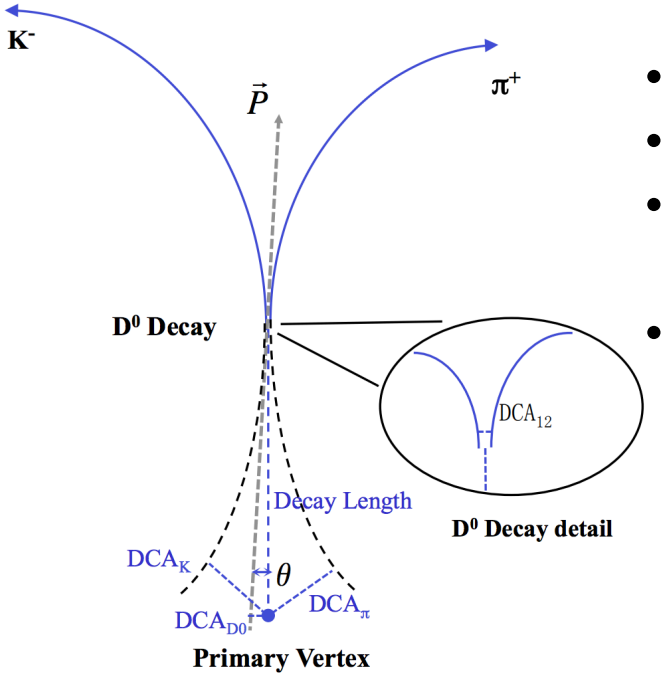


- TPC: Tracking , PID (dE/dx)
- TOF: PID (1/ β)
- HFT: Operation 2014 – 2016
  - Utilizing MAPS

  Excellent track pointing resolution

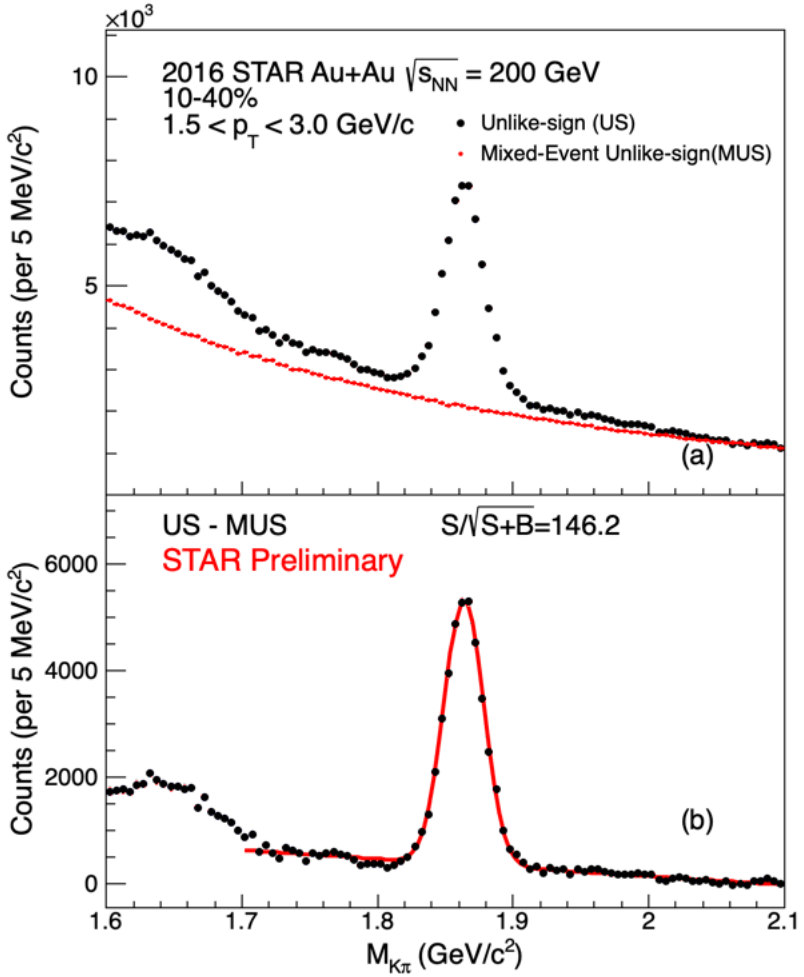
  35 **μm** at p = 1GeV/c

D^0 topological reconstruction with HFT



- $D^0(\bar{u}c)$, $\overline{D^0}$ $(u\bar{c})$,
- Decay channel: $D^0 \rightarrow K^- + \pi^+$
- $c\tau$: 120 **μm**

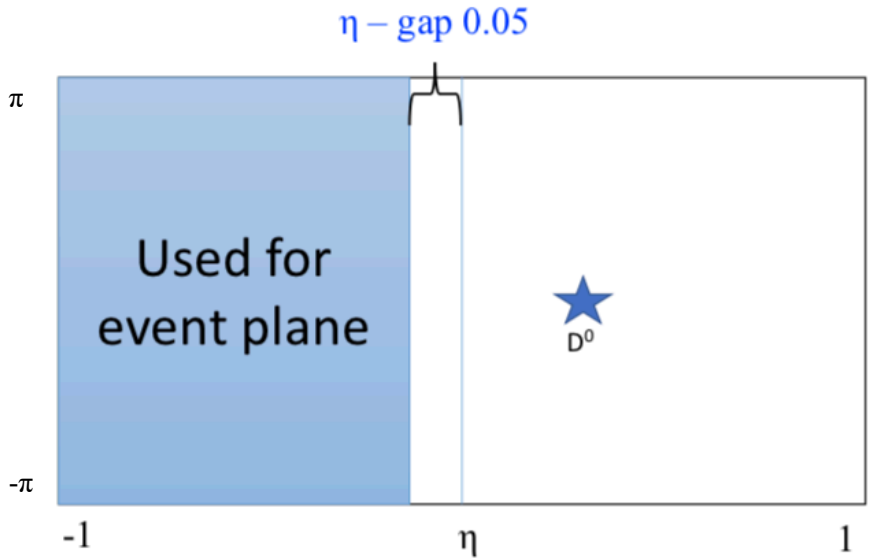
- Rectangular cut method from TMVA package for optimizing cuts on topological variables. Done separately for each p_T, centrality bin.

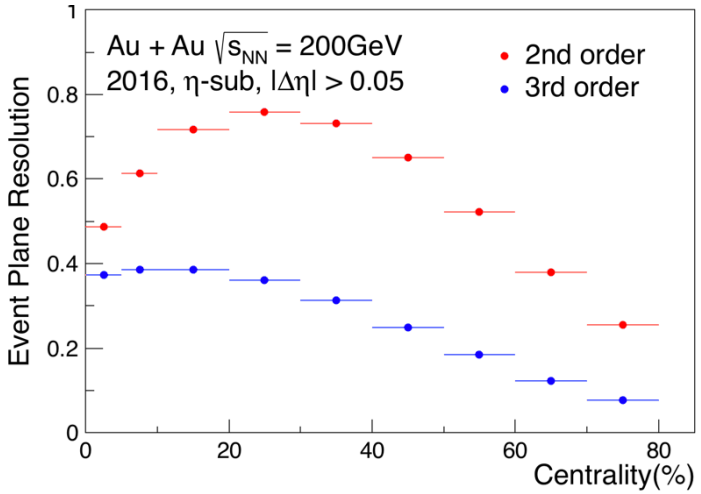


	2010+2011 w/o HFT	2014 w/ HFT
#Event(MB)	1.1 billion	~900 million
Significance per billion events	13	220

STAR: Phys. Rev. Lett. 113, 142301 (2014) STAR: Phys. Rev. Lett. 118, 212301 (2017)

D^0 v_n : event plane method



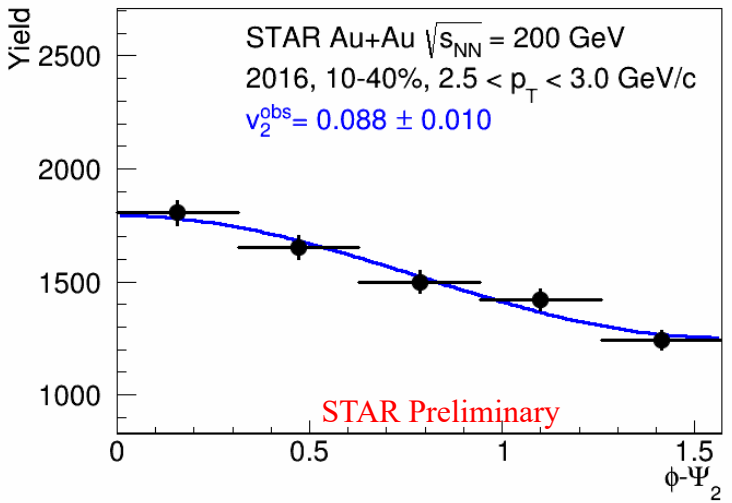


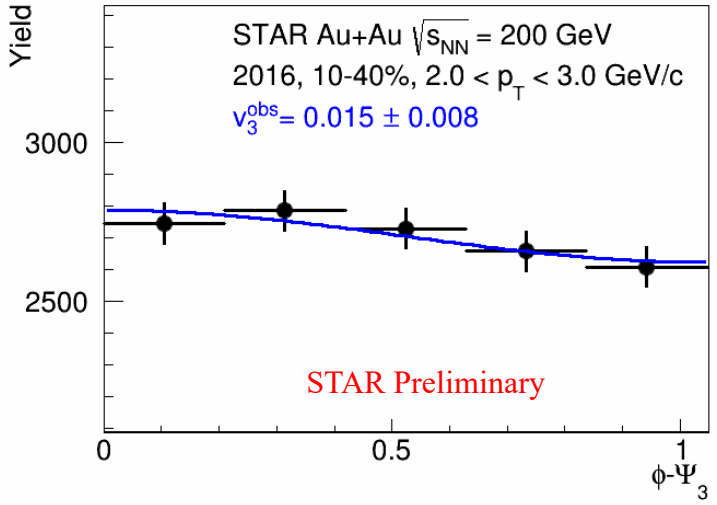
- D^0 v_n measured using η-sub event plane method.
- D^0 yield as a function of $\varphi - \Psi_n$ fit to

$$A(1 + 2v_n^{obs}\cos(n(\varphi - \Psi_n)))$$

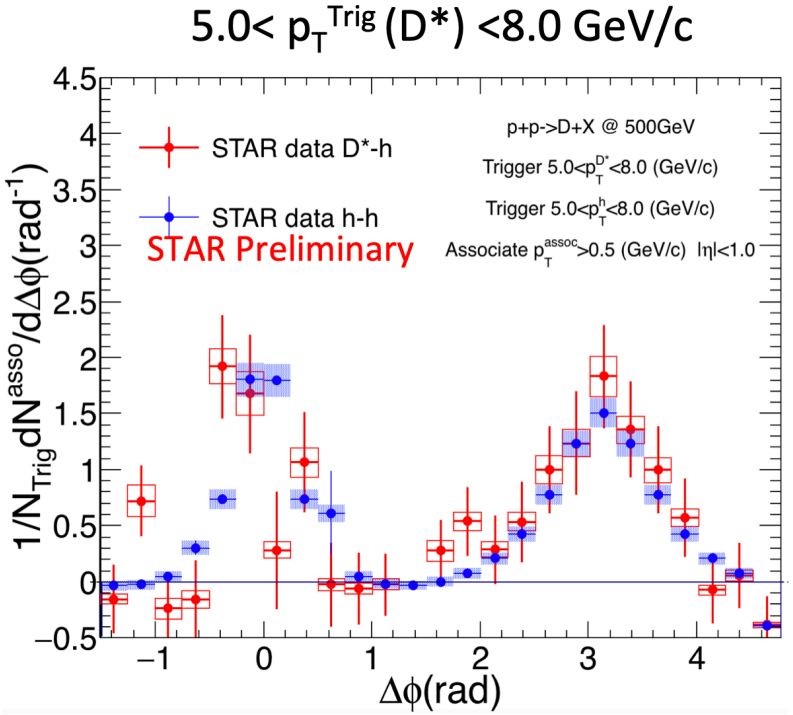
- Results are corrected for event plane resolution.

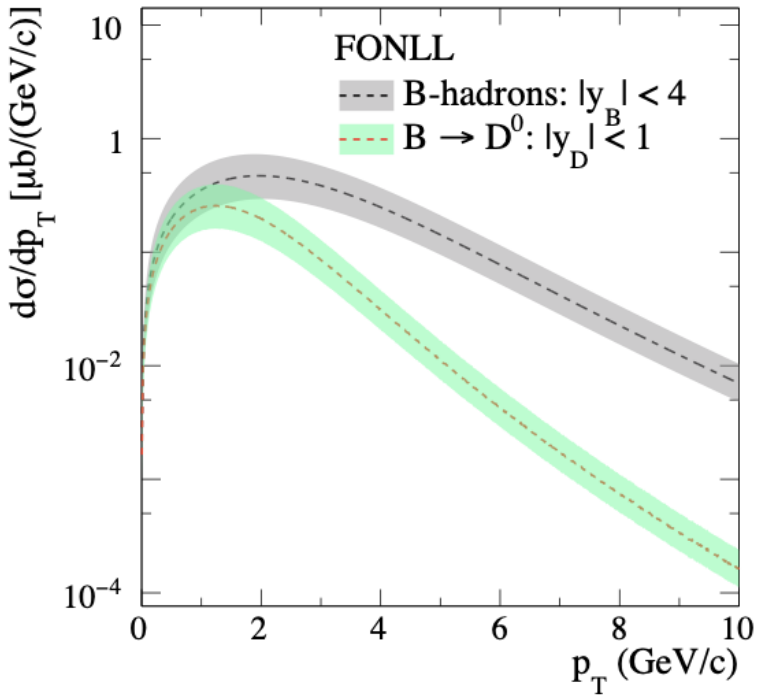
$$v_n = \frac{v_n^{obs}}{E.P.Resolution}$$





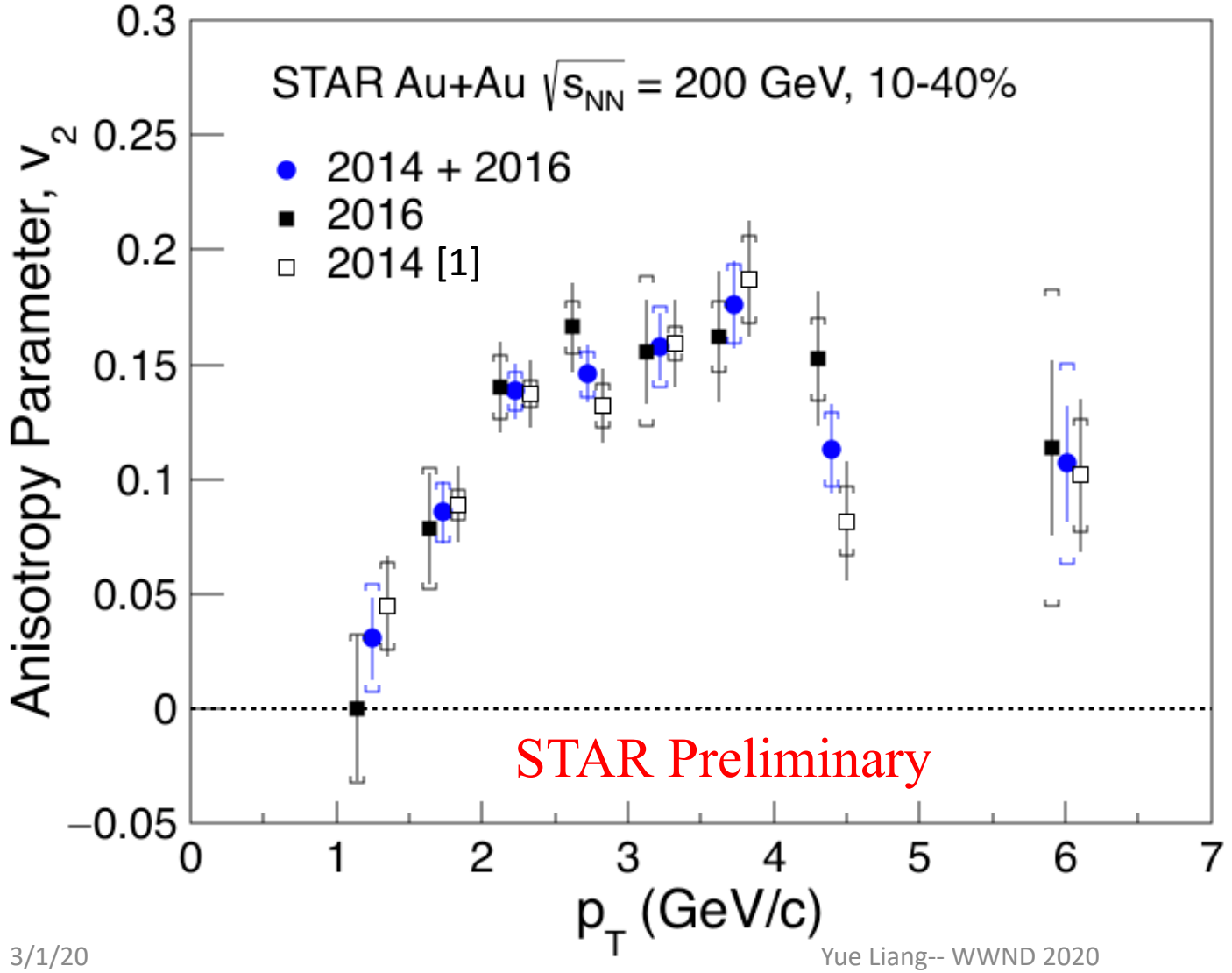
Non-flow and B→ D feed down





- Non-flow estimated from D*-h correlations in p+p 200GeV
- $v_2^{non-Flow} = \frac{<\sum_h \cos(2(\phi_{D^*} - \phi_h))>}{M v_2^h}$ → p+p collision; → Au+Au collision
- B->D feed down is negligible at RHIC energies (< 4%)

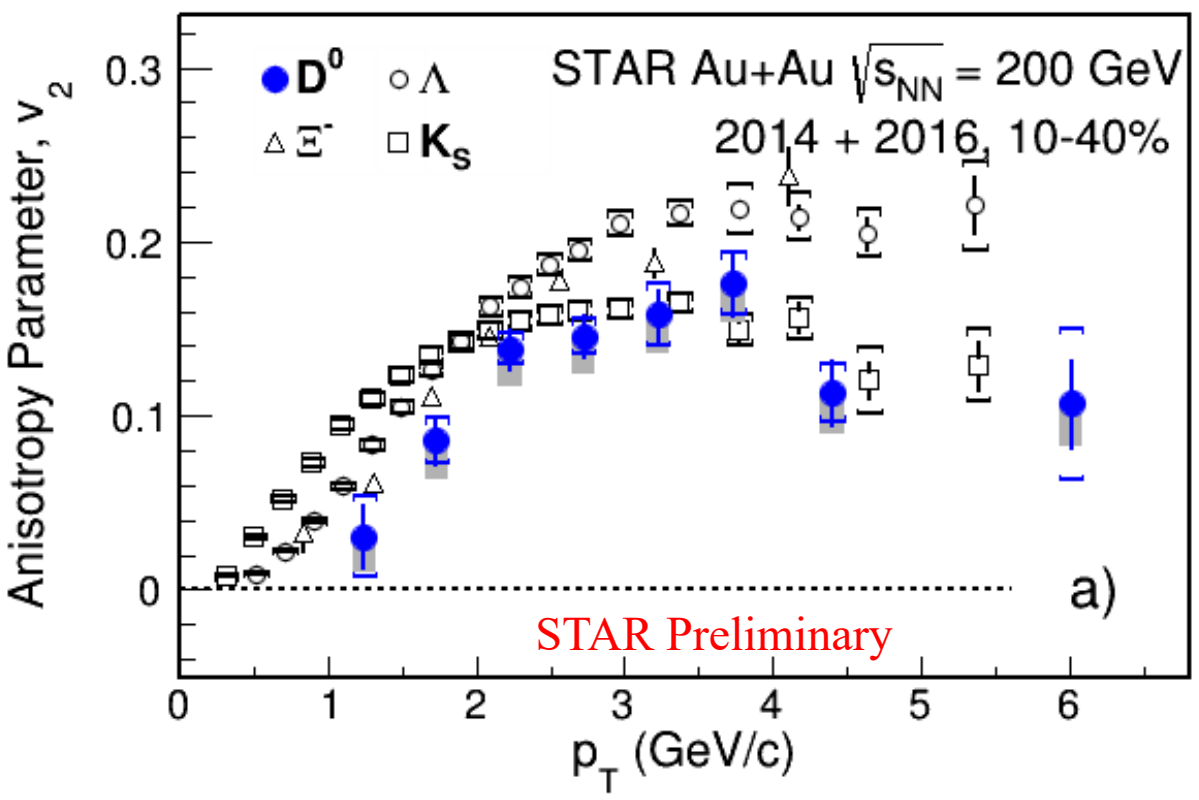
D^0 v_2 from 2014 and 2016

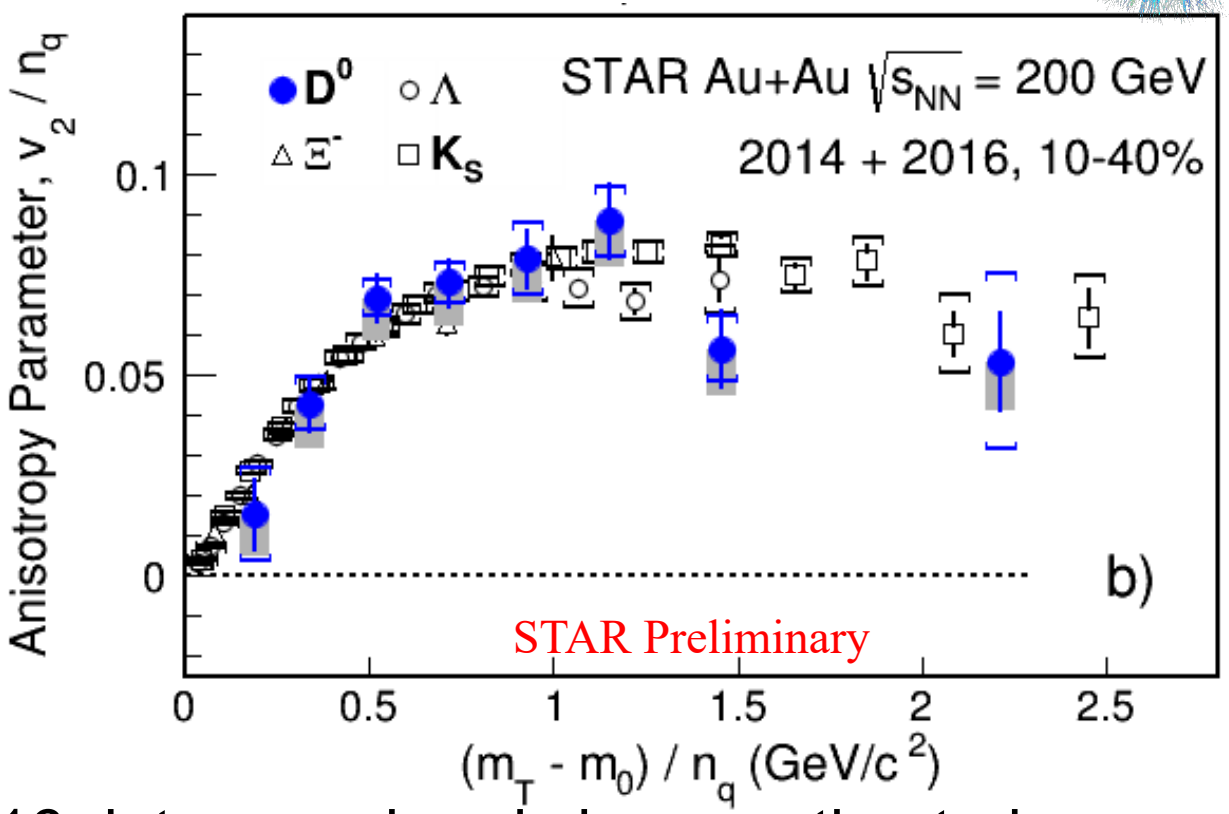


- 2016 and 2014 D^0 v_2 are consistent
- Improved precision from combined two years of data
- Non-flow uncertainty not shown in this plot

[1]STAR, Phys. Rev. Lett. 118, 212301 (2017)

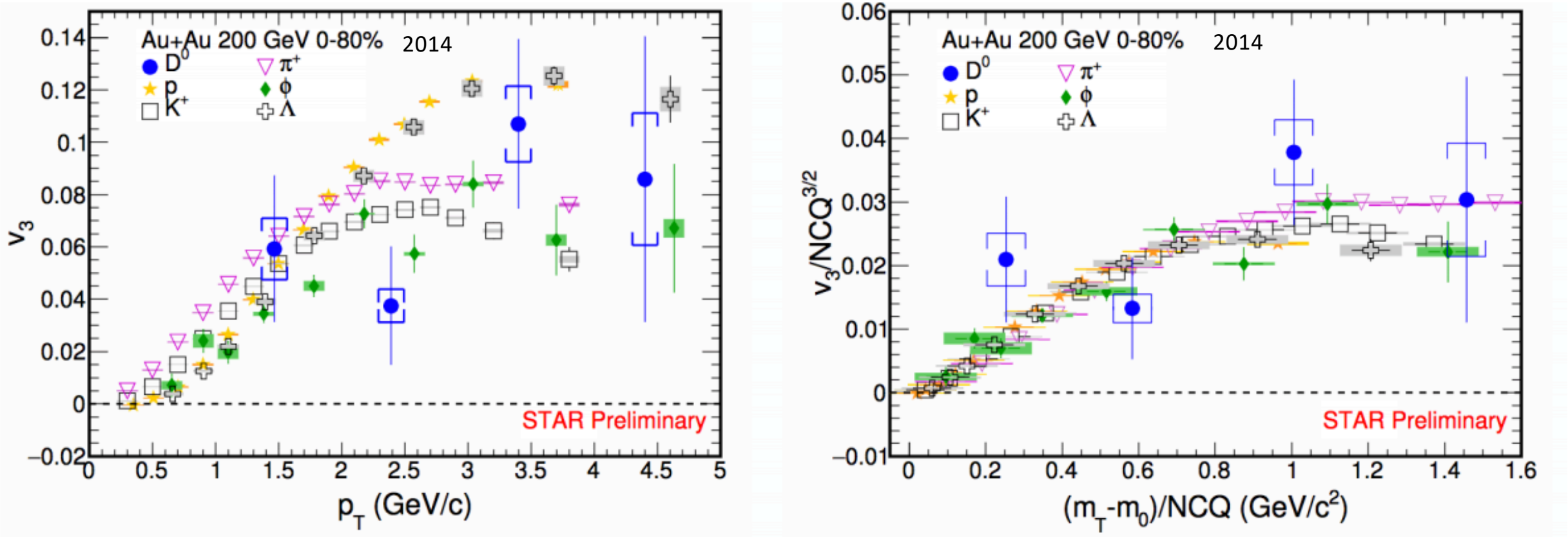
D^0 v_2 comparison with light flavor hadrons





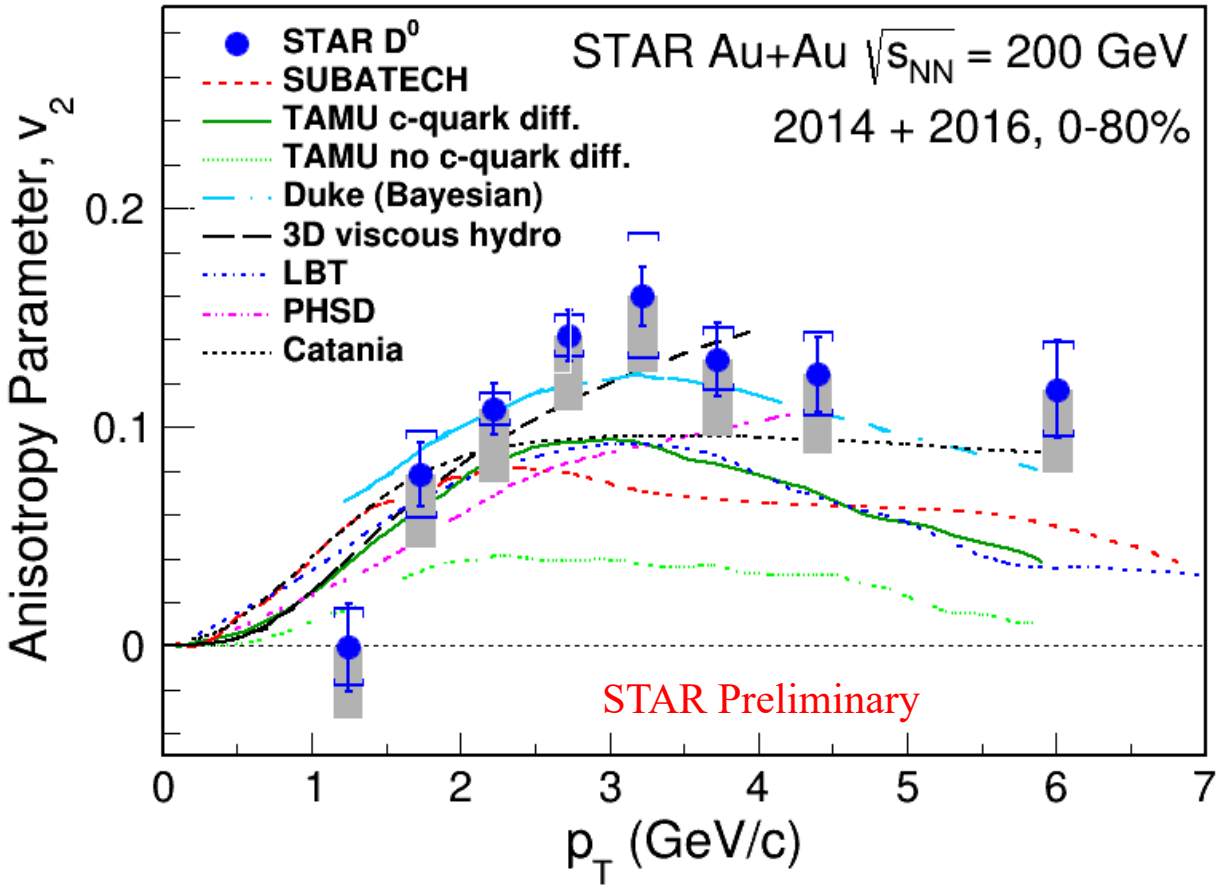
- D^0 v_2 from combined 2014 + 2016 data, grey band shows estimated uncertainties from non-flow.
- NCQ-scaled D^0 v_2 consistent with light flavor hadrons.
- Suggest charm quarks flow with the QGP.

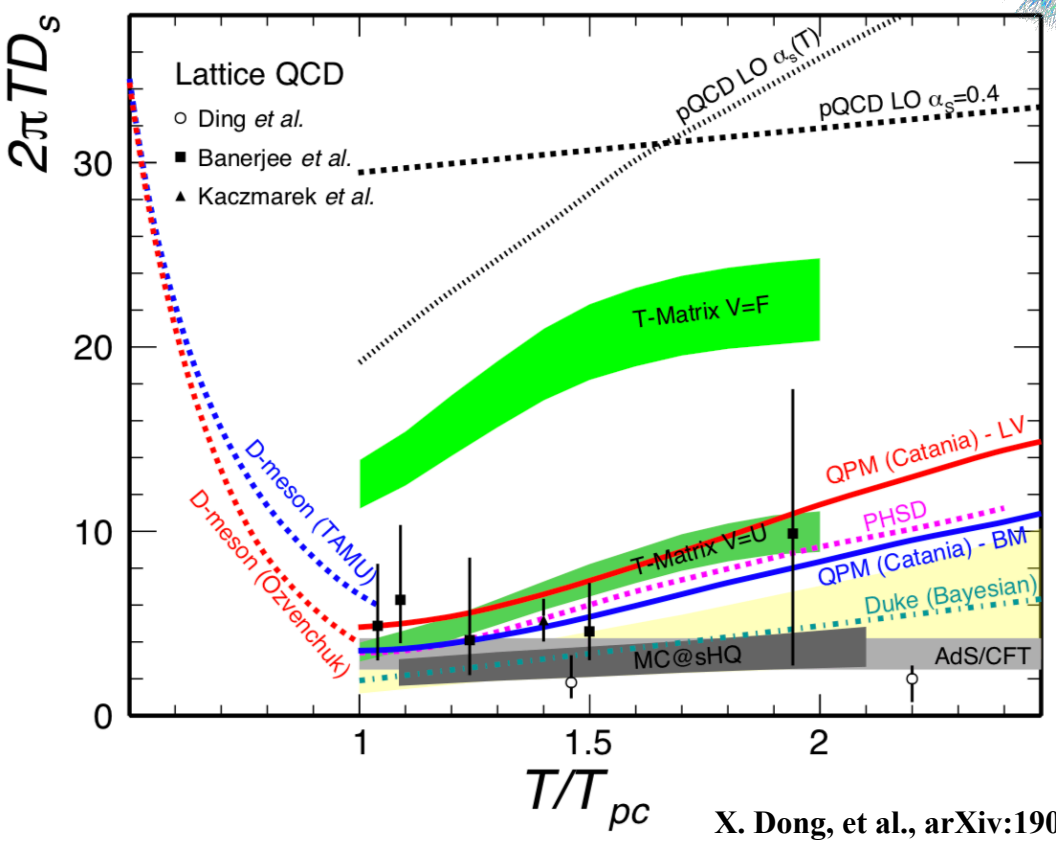
D^0 v_3 comparison with other hadrons



- Non-zero D^0 v_3 values; comparable to light flavor hadron v_3
- NCQ-scaled D^0 v_3 consistent within error bars

D^0 v_2 comparison with Models





X. Dong, et al., arXiv:1903.07709

- Improved precision to constrain the models
- TAMU no c-quark diffusion fails to describe data,
  - Necessity of heavy quark diffusion for charm hadron v_2
- Models describe D^0 v_2 well with $2\pi TD_s$ in the range of 2 – 5 around T_c

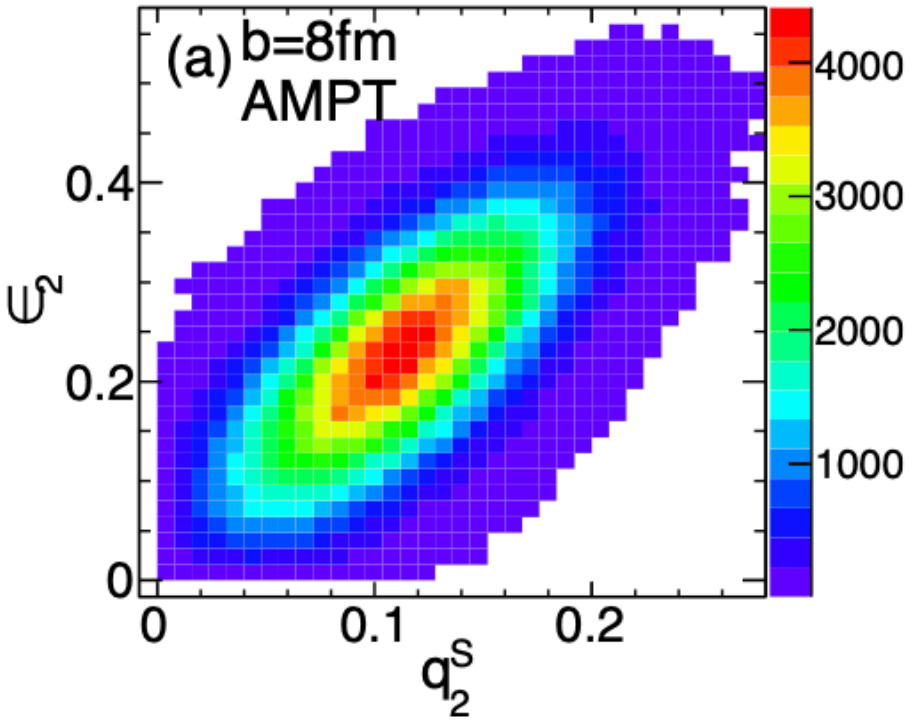
Event-Shape-Engineering (ESE)

- Reduced flow vector q_2 : An experimental observable to select on the initial eccentricity in collisions

$$Q_{2,x} = \sum_i^M \cos(2\phi_i), \quad Q_{2,y} = \sum_i^M \sin(2\phi_i),$$

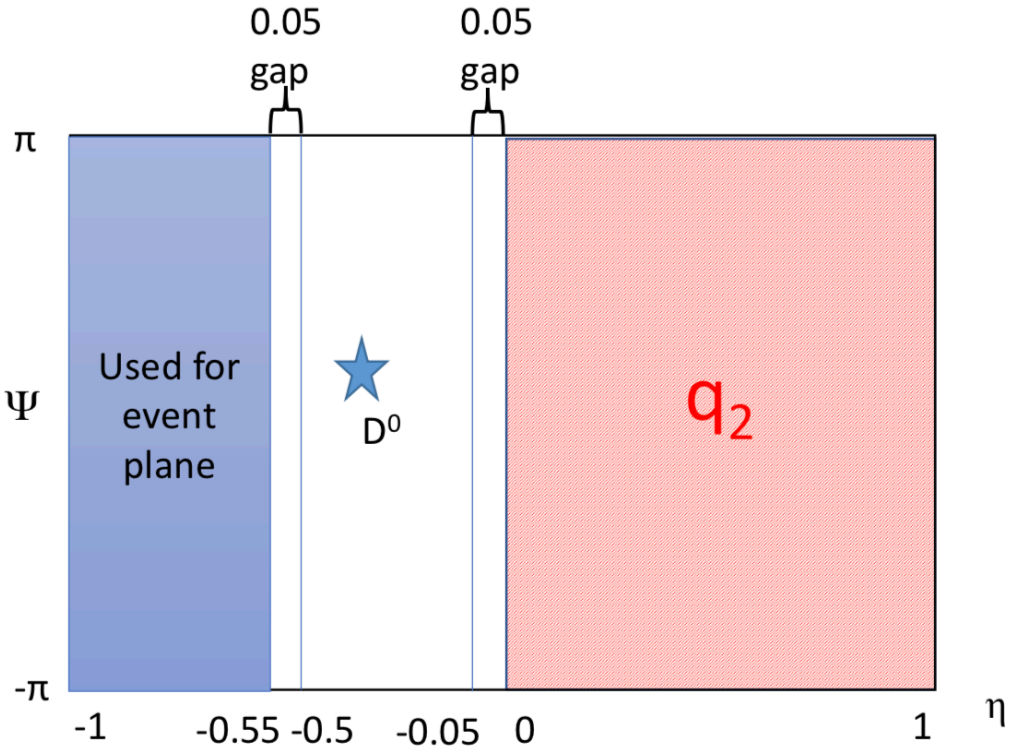
$$q_2 = Q_2 / \sqrt{M}, \qquad \text{M = multiplicity}$$

J. Schukraft, et al., Phys. Lett., B719:394–398, 2013



P. Huo, et al., Phys. Rev. C **90,** 024910 (2014)

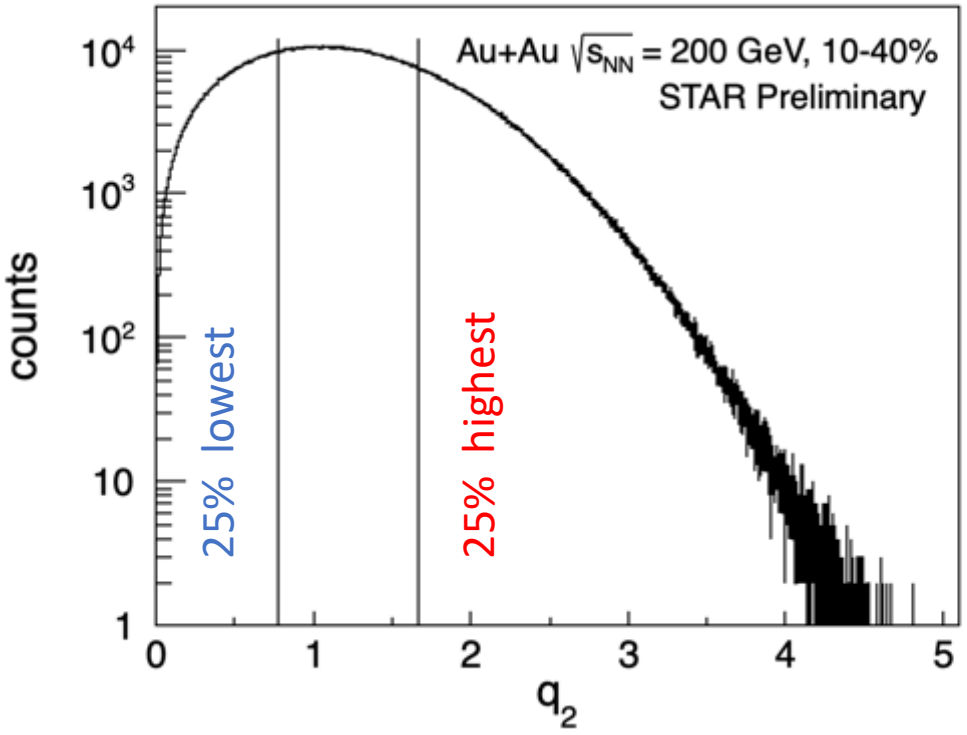
Event-Shape-Engineering(ESE)

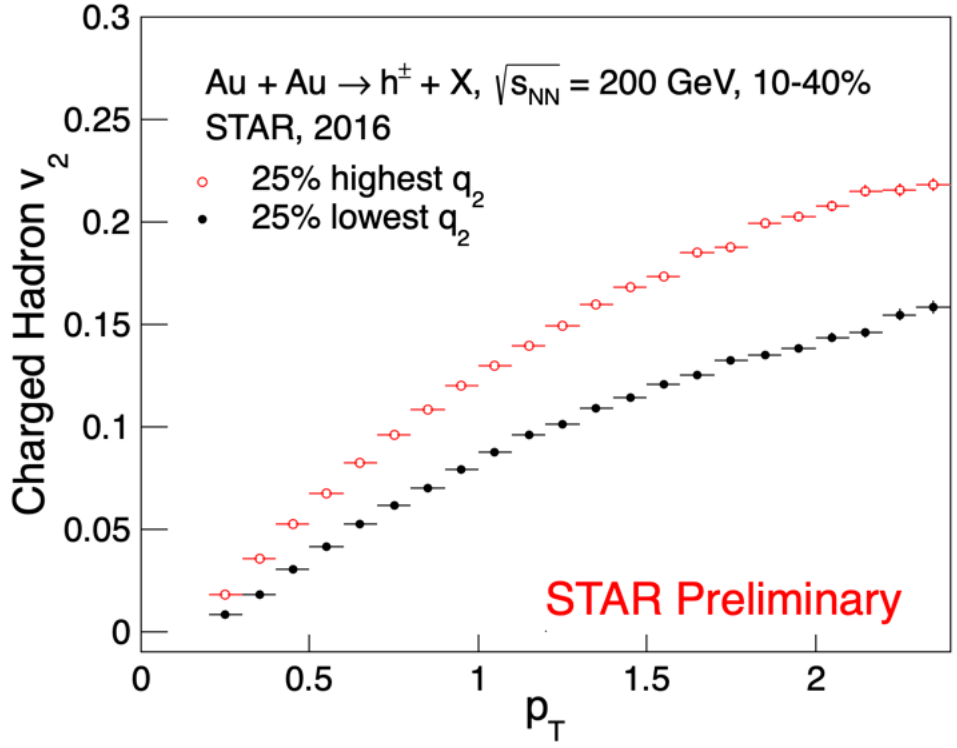


Example of one possible choice, selection are swapped between each other to gain full statistics.

- The event shape analysis is performed with a three-subevent technique.
- η-gap is applied between subevent, to reduce short-range correlation.
- Fixed centrality selection gives fixed average energy density, and q_2 selection allows control of the initial geometry.

Event-Shape-Engineering(ESE)

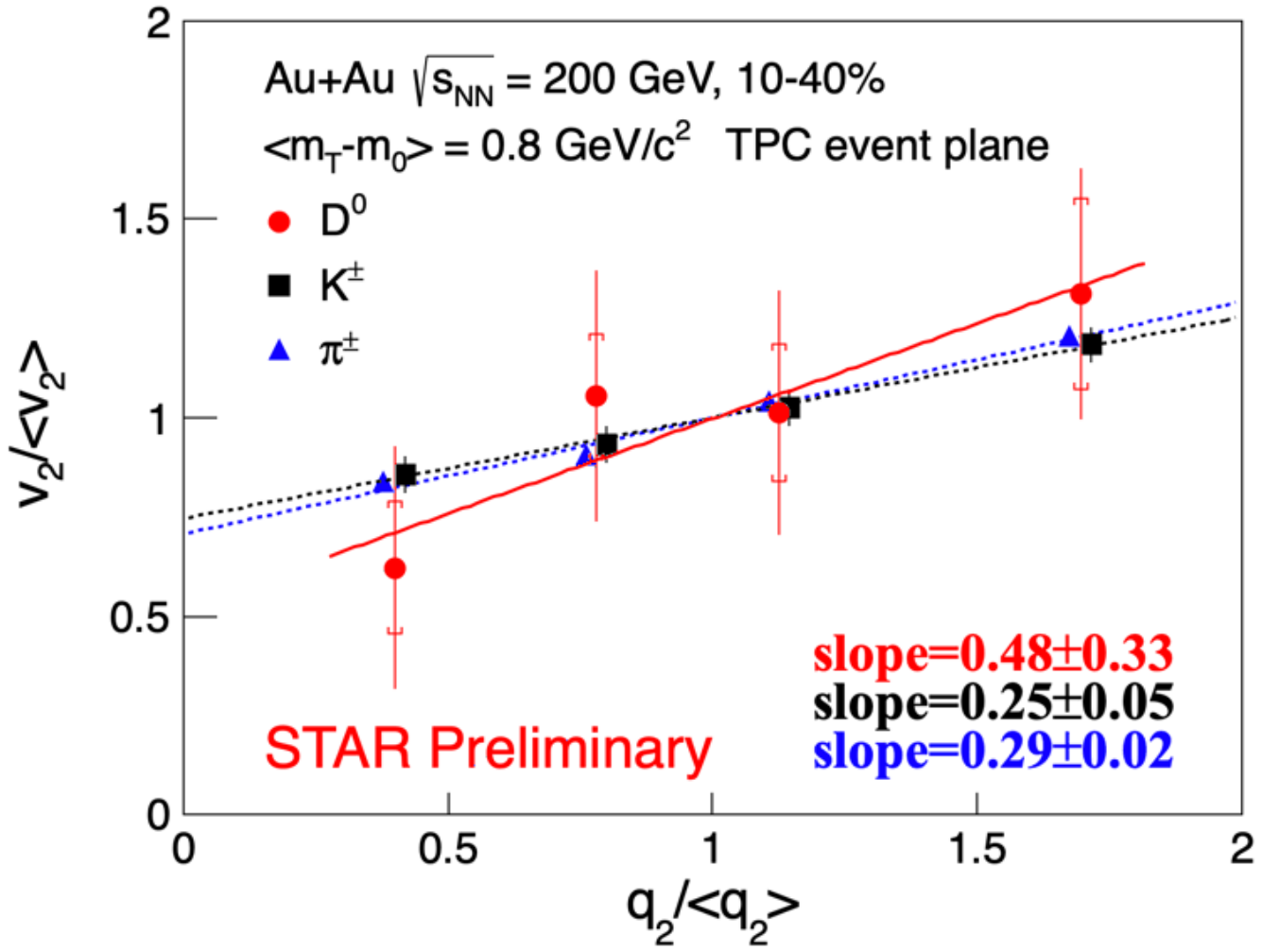




- q_2 classes are determined for each narrow (1%) centrality bin and combined in 10-40% for physics measurement.

ESE study on D^0 v_2

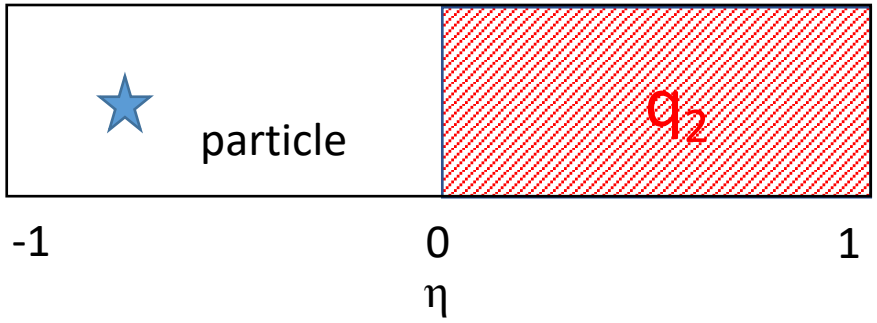
- v_2 vs. q_2 has a linear increasing trend for pions and kaons.
- Hint of increasing trend for D^0 mesons.
- ~1x more events to analyze with 2014 data



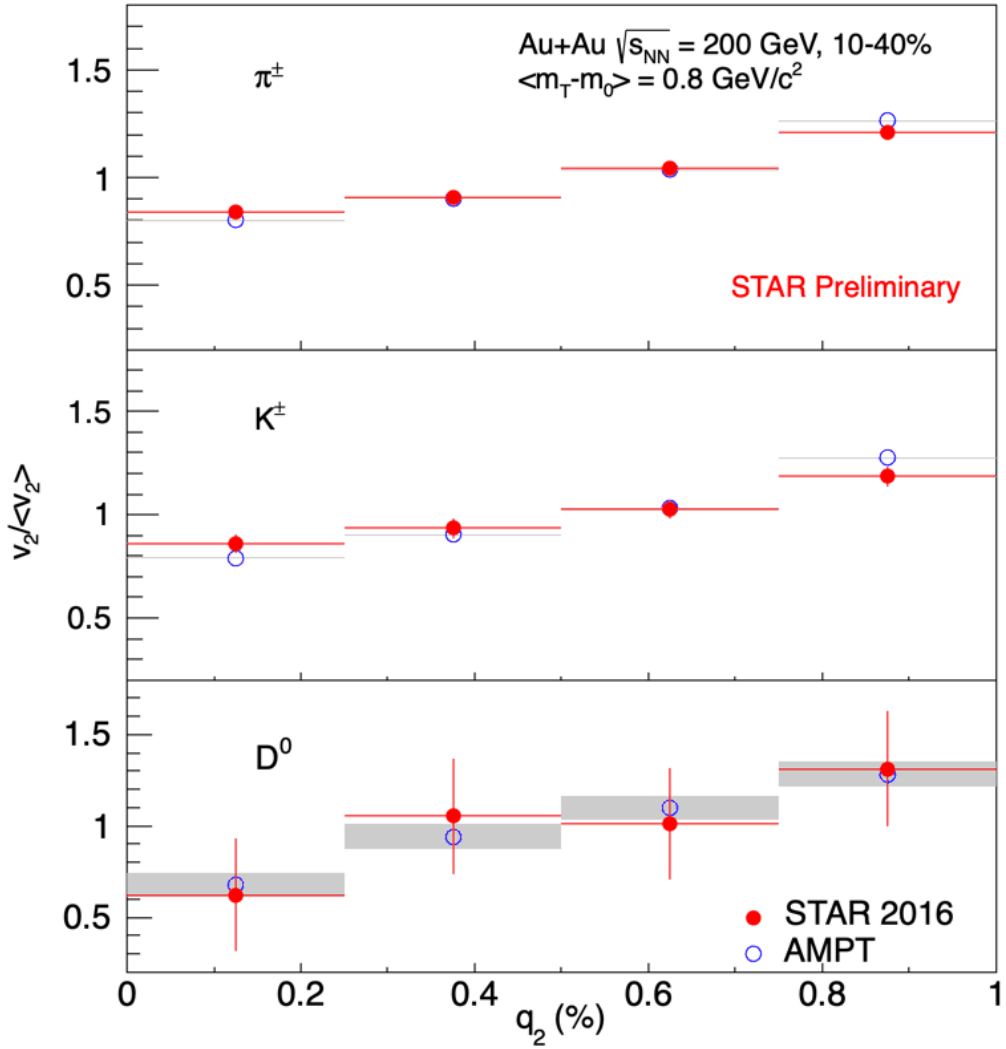
ESE Model study

- A Multi-Phase Transport (AMPT) model is widely used for Relativistic Heavy Ion Collisions.
- Version: [ampt-v1.26t9b-v2.26t9b.zip]

- 3 million AMPT events generated at 200 GeV

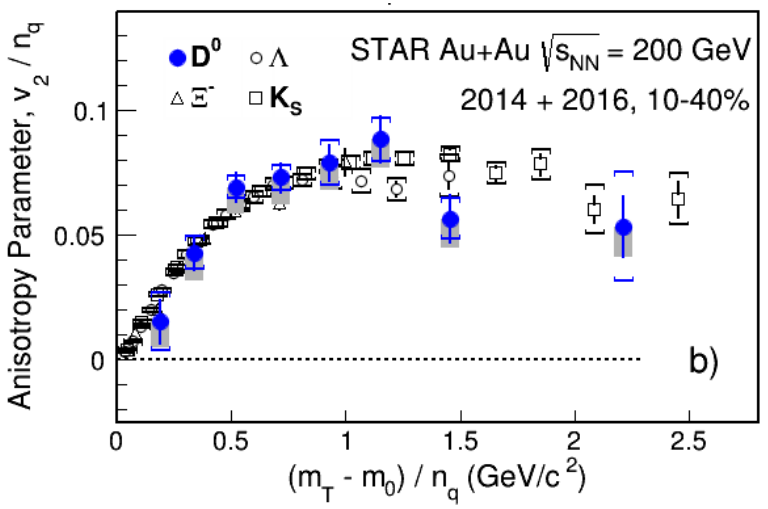


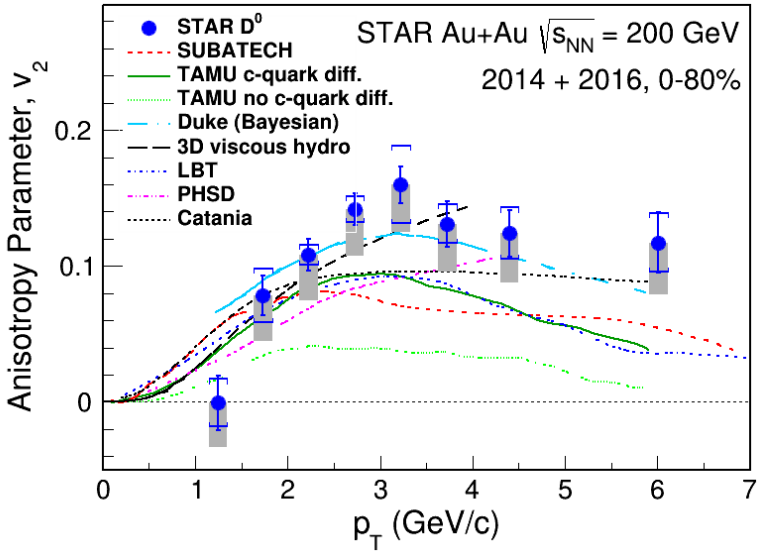
- AMPT model describes data.



Summary and outlook

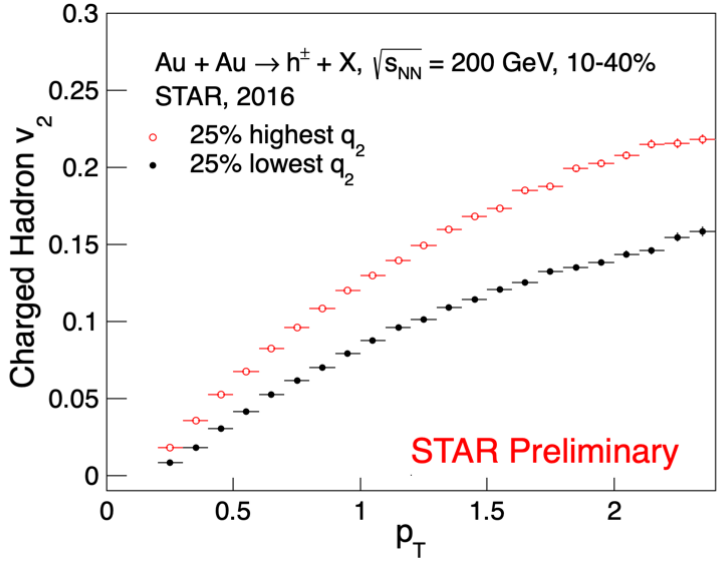
- Improved precision of D^0 v_2 results with combined 2014 and 2016 data.
- D^0 v_2 follows the NCQ scaling with light flavor hadrons.
- D^0 v_2 constrains model calculation. Models with $2\pi TD_s$ in the range of 2 – 5 near T_c describe data.

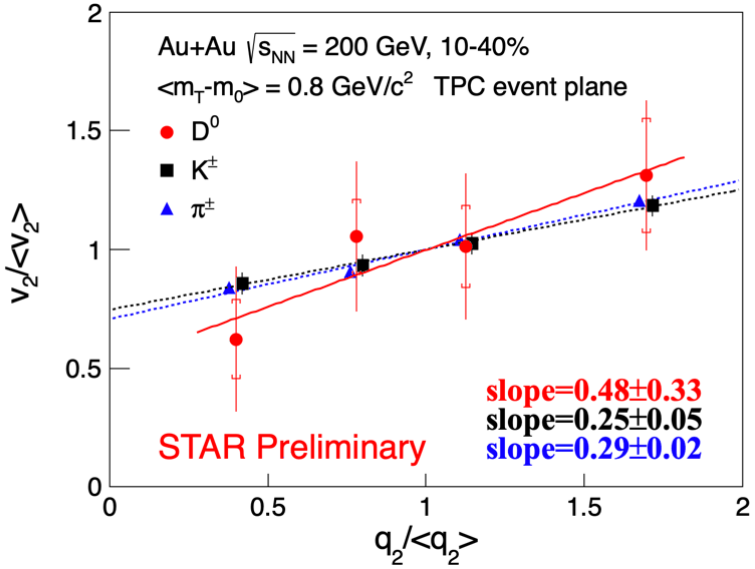




Summary and outlook

- Reduced flow vector q_2 can be used to distinguish events with different initial eccentricity.
- v_2 vs q_2 has a linear increasing trend for pions and kaons. Hint of increasing trend for D^0 mesons observed in 2016 data.
- Future analysis will include the 2014 dataset.





BACK UP