Onset of Partonic Collectivity in Heavy-Ion Collisions at RHIC

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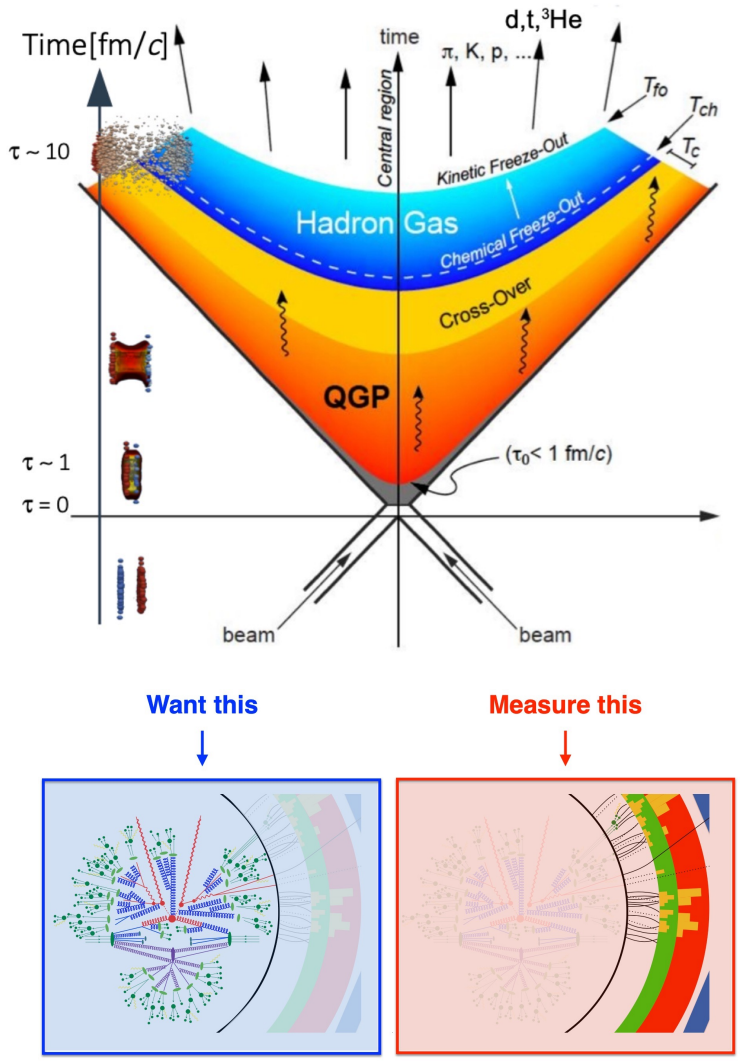
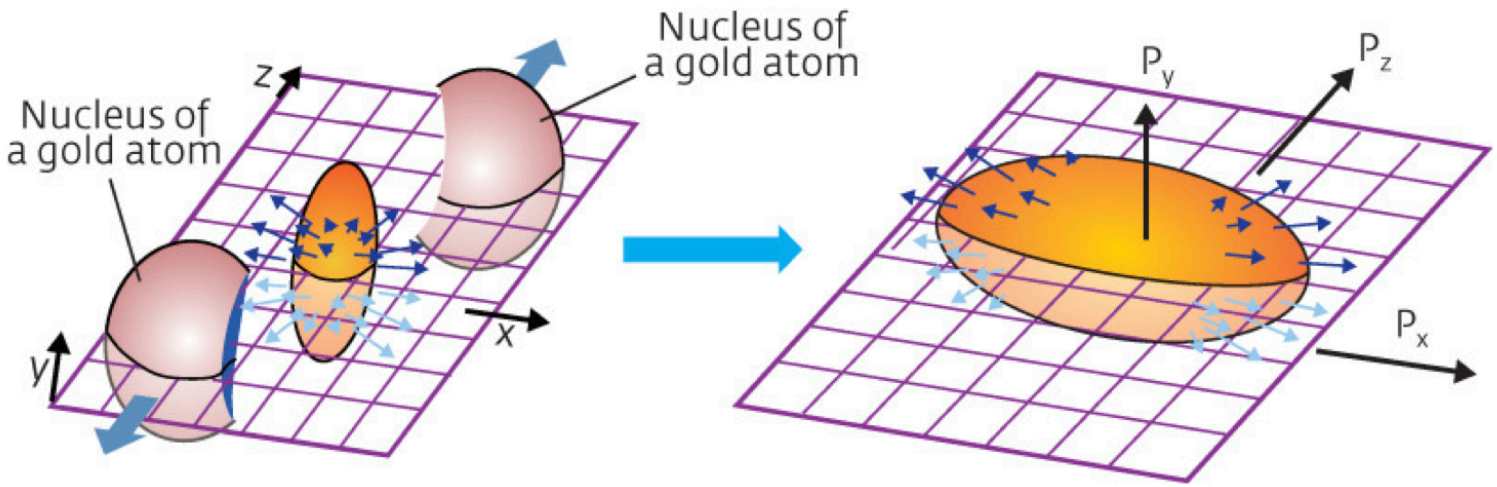
Outline

- Motivation
- p_T Dependence of v_2
- Energy Dependence of NCQ Scaling
- Summary and Outlook

Motivation – Elliptic Flow





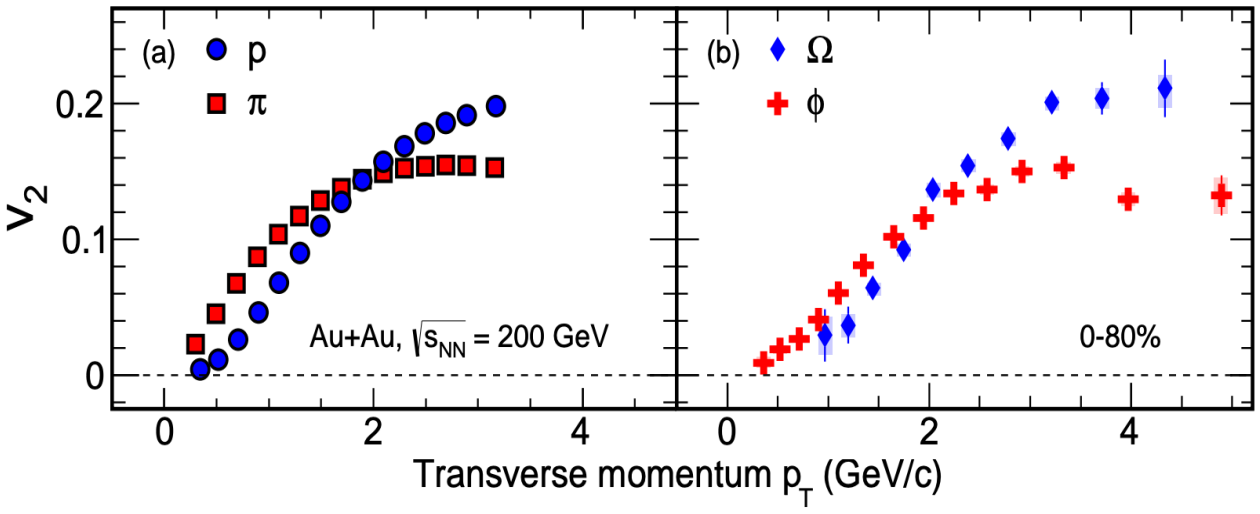
$$\frac{dN}{d(\phi-\Psi)} \sim 1+\sum_{n=1}^{\infty} 2v_n \cos(n(\phi-\Psi))$$

- Elliptic flow: $v_2 = \langle \cos 2(\phi - \Psi) \rangle$
- v_2 can reflect the degree of freedom: partonic vs. hadronic

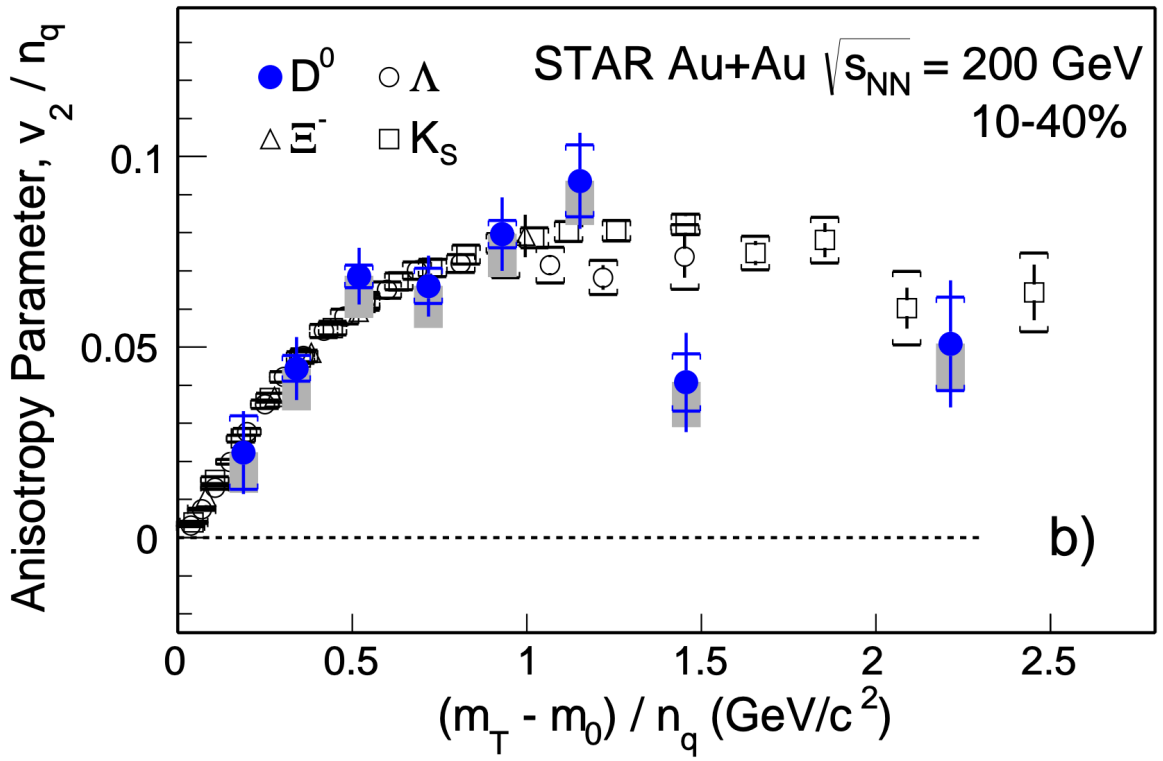
S. A. Bass *et al.*, Prog. Part. Nucl. Phys. **41**, 255 (1998).

Motivation – NCQ Scaling at 200 GeV

STAR: Phys. Rev. Lett. **116**, 062301 (2016)



STAR: Phys. Rev. Lett. **118**, 212301 (2017)

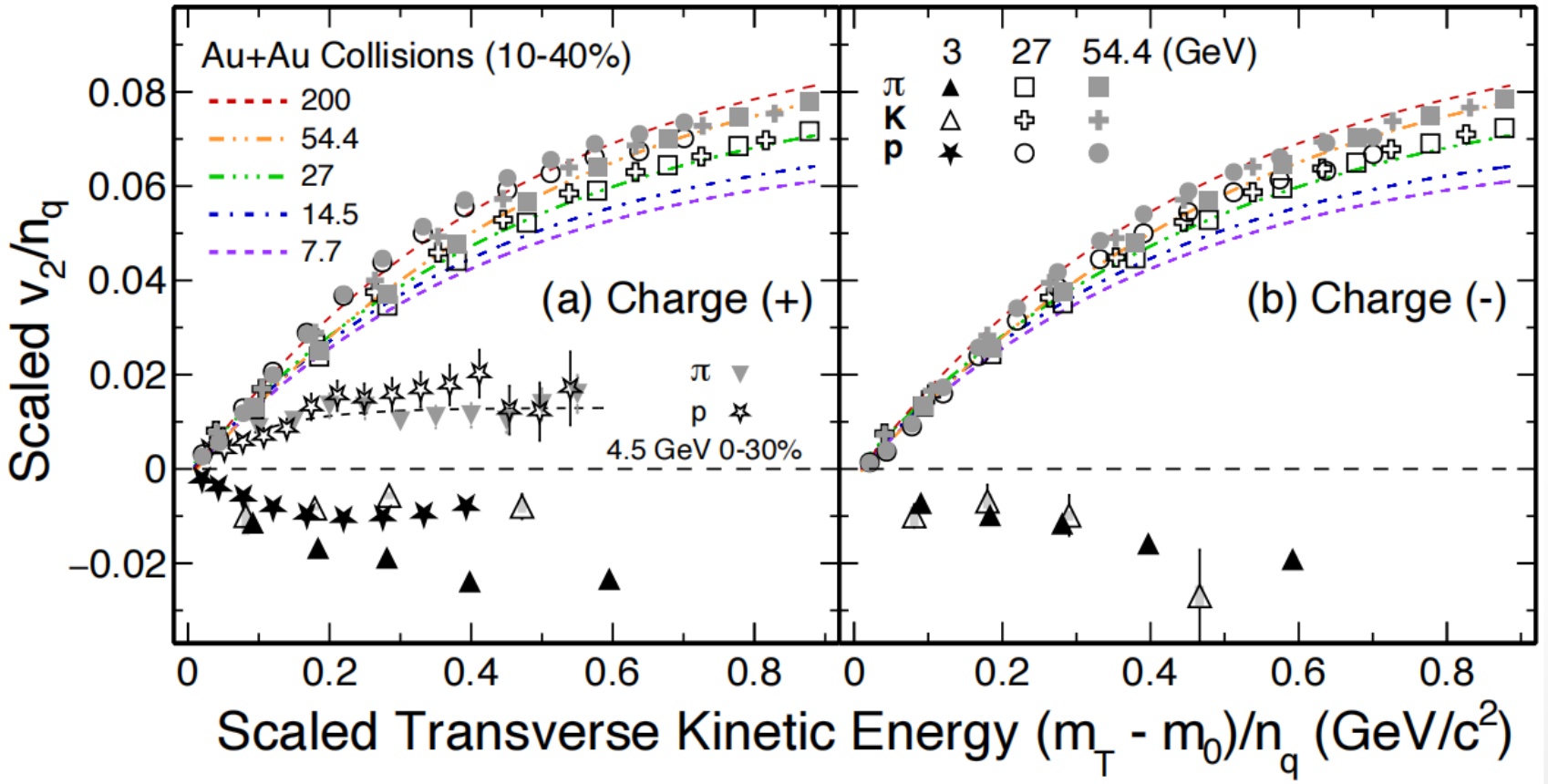


➢ Au + Au collisions 200 GeV: **partonic collectivity**

Motivation – NCQ Scaling at 3 GeV

STAR Collaboration, Phys. Lett. B 827 (2022) 137003

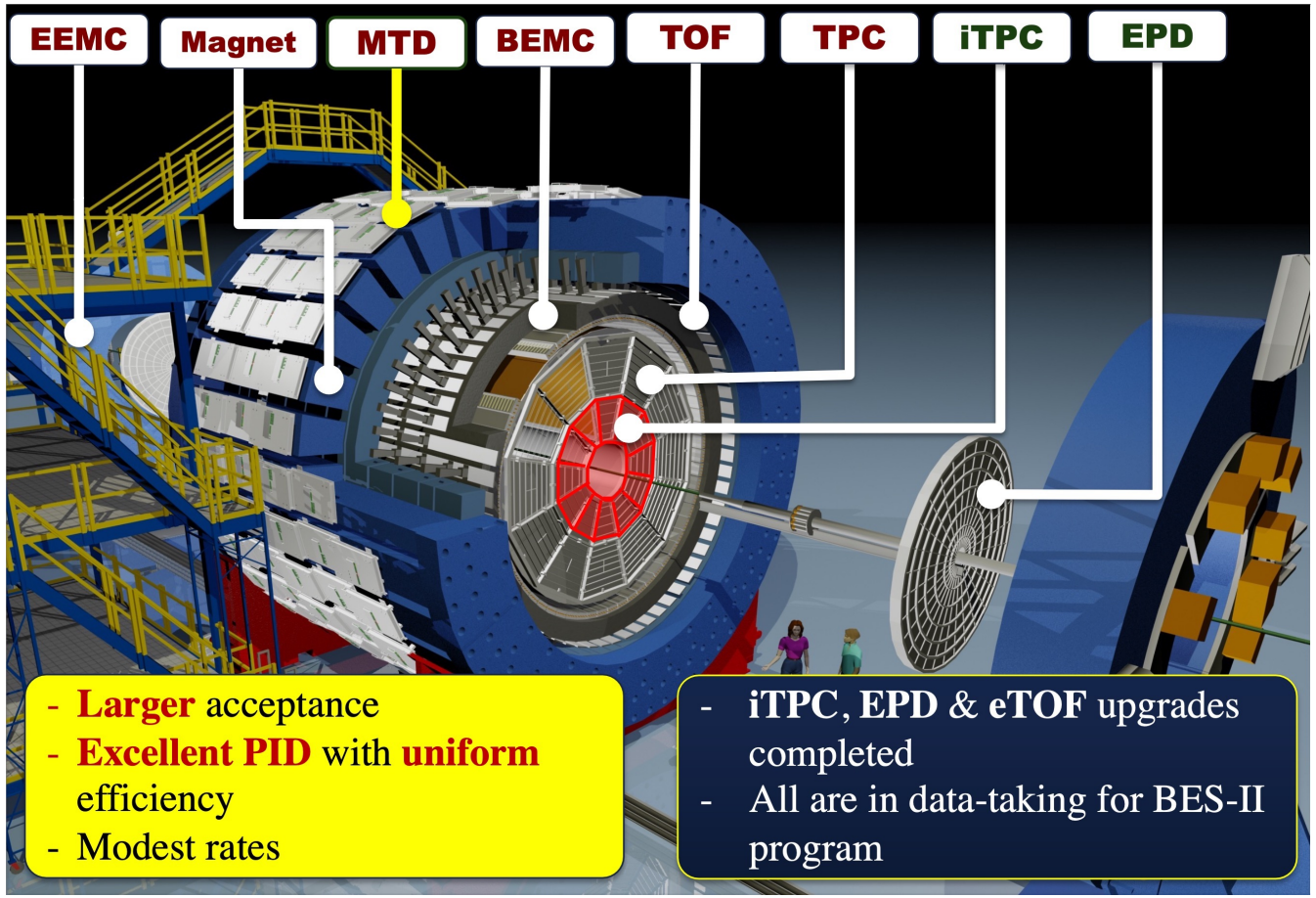
STAR Collaboration, Phys. Rev. C 103 (2021) 034908



➢ 3 GeV: The hadronic degree of freedom dominated

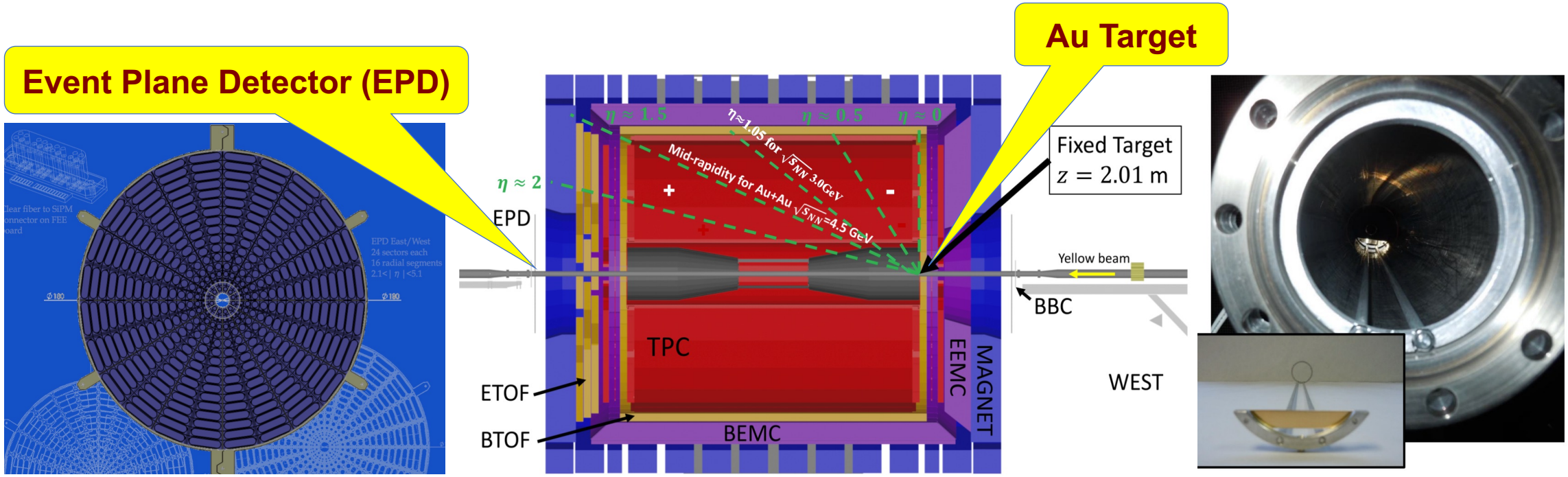
How does the degree of freedom change between 3.0 and 7.7 GeV?

STAR Detector System



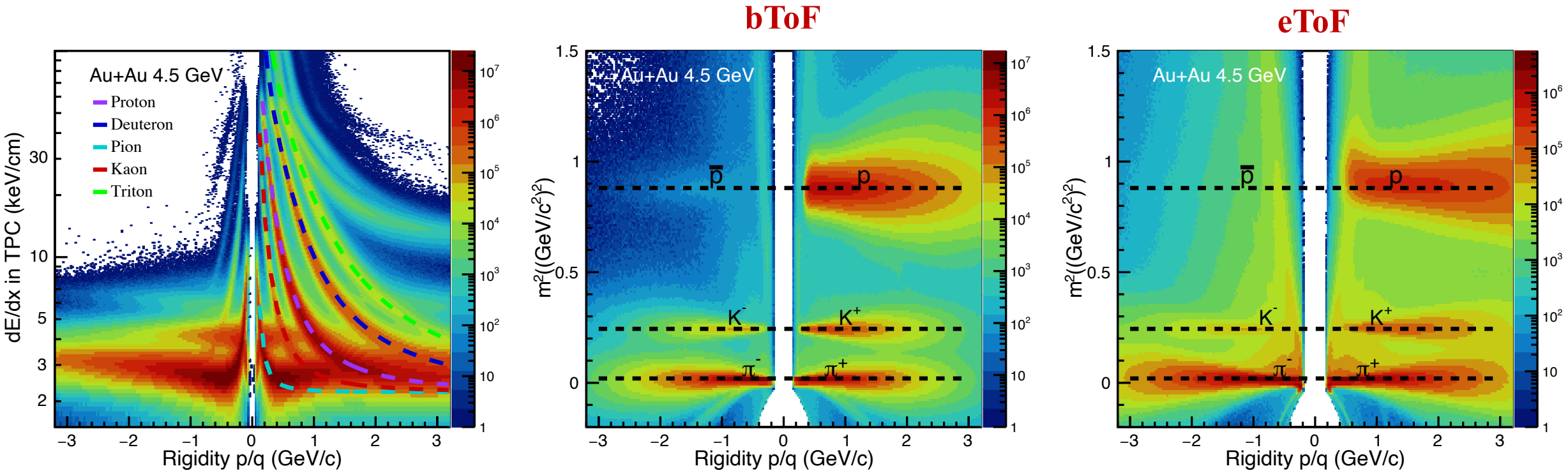
- inner TPC upgrade
  - Improves capability of PID
  - Extends η coverage from 1.0 to 1.5
- Endcap TOF
  - Extends rapidity coverage
  - Improves precision studies of observables rapidity dependence
- Event Plane Detector
  - Allows a better event plane resolution

STAR Fixed Target Program



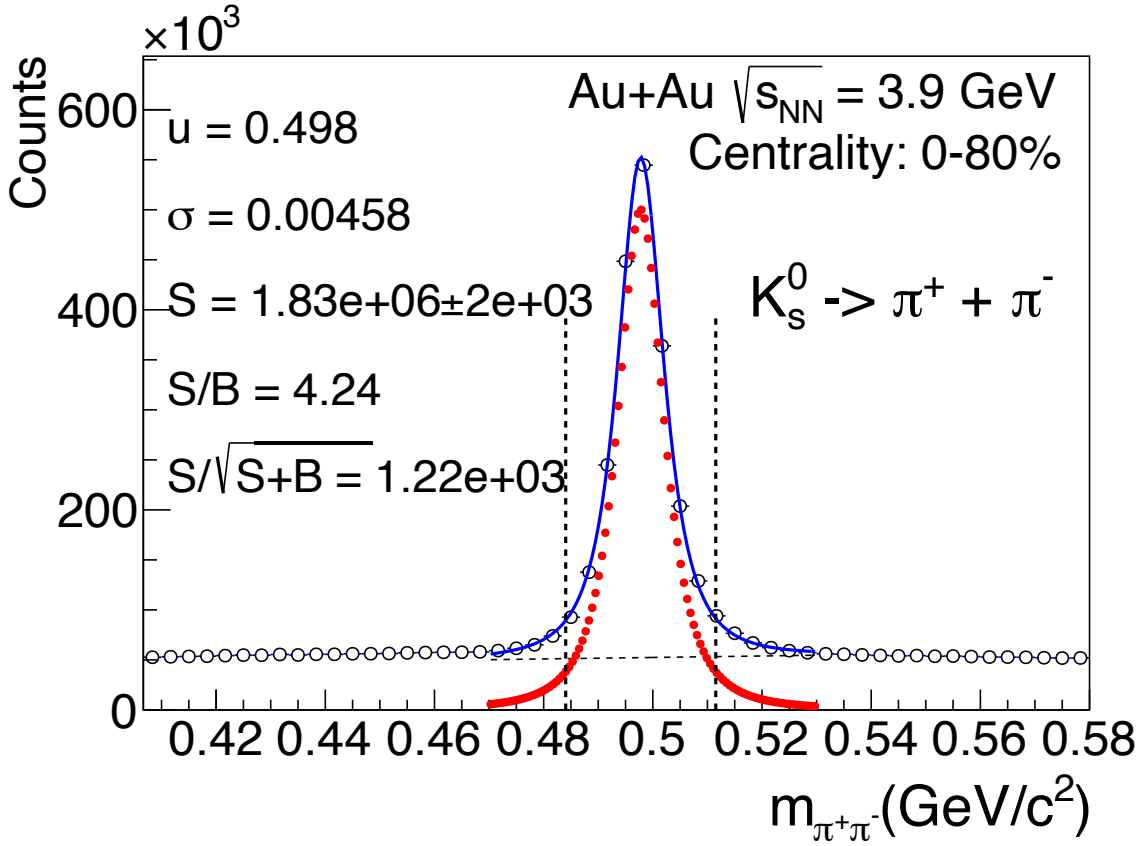
Au+Au (GeV)	3.0	3.2	3.5	3.9	4.5
Baryon chemical potential (~MeV)	750	700	670	635	590
Events analyzed (M)	260	223	107	94	128

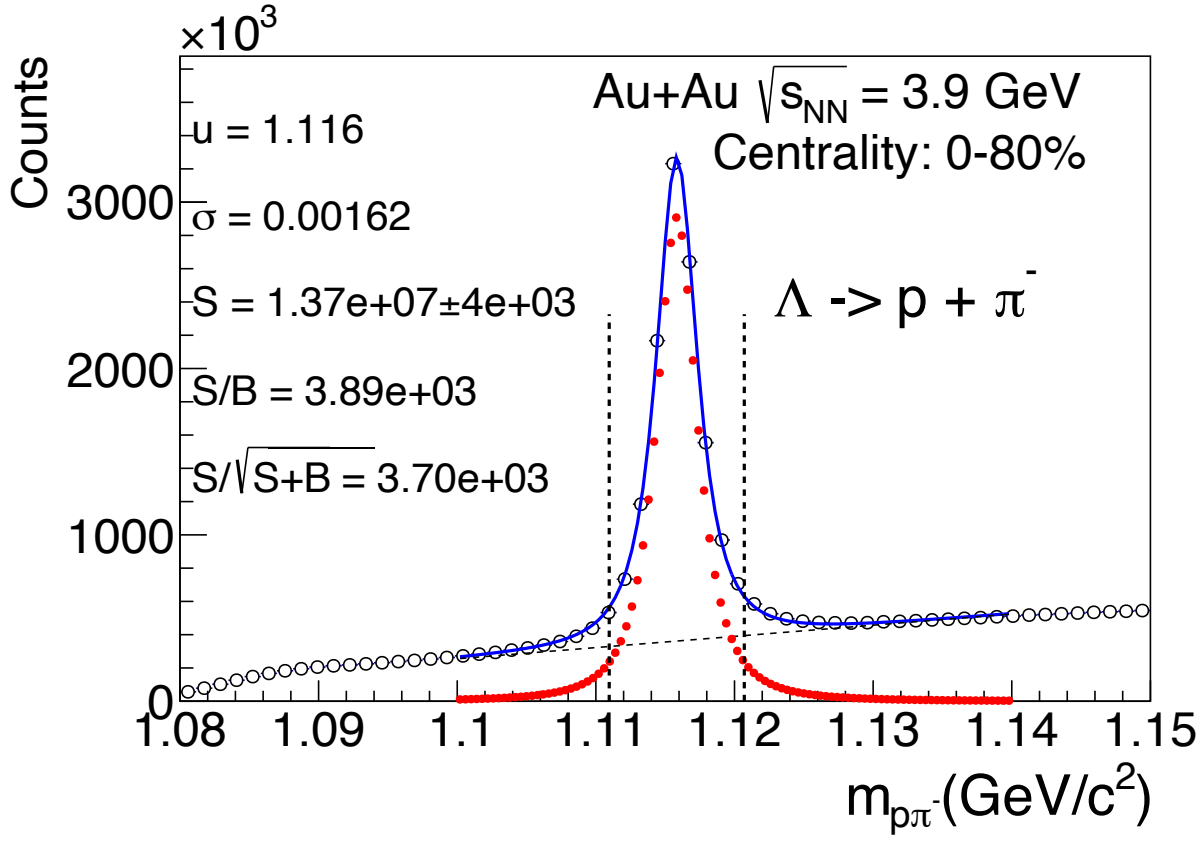
Particle Identification



- Good capability of particle identification (PID) based on TPC and TOF
- Extend the phase space coverage by TOF

Particle Identification

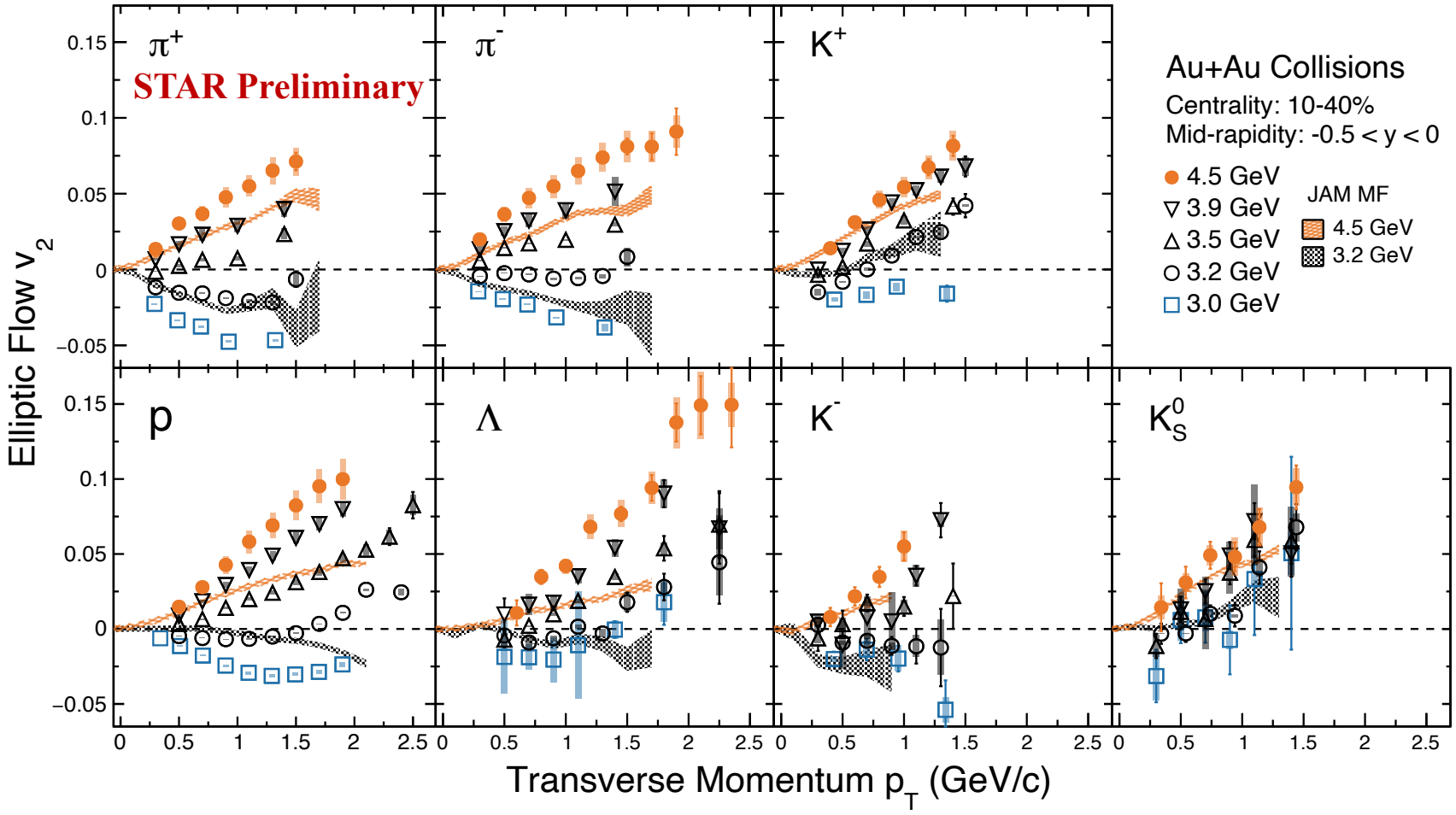




- Decayed particles are reconstructed by KF(Kalman Filter) particle package

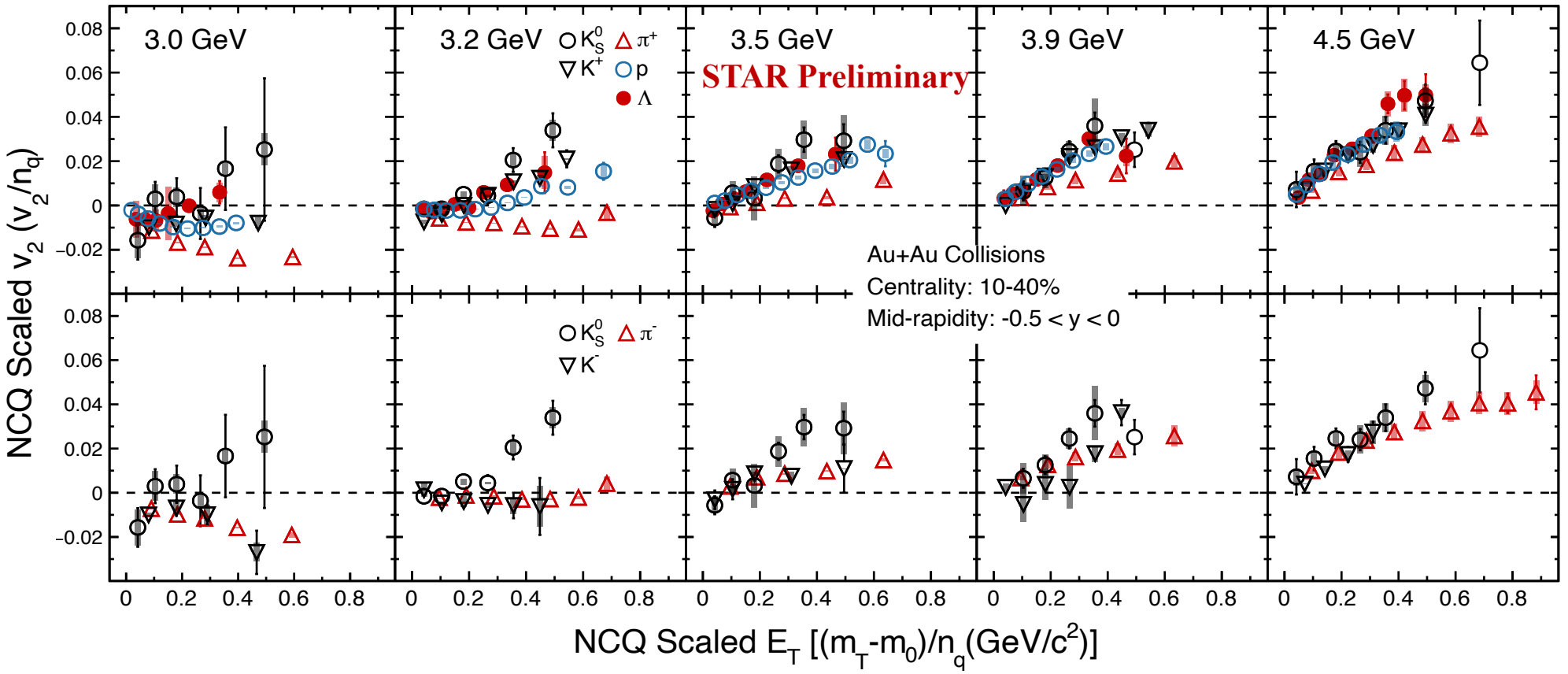
A. Banerjee, I. Kisel and M. Zyzak, Int. J. Mod. Phys. A 35, 2043003 (2020)

p_T Dependence of v_2 at 3 – 4.5 GeV



- $v_2(p_T)$ changes from negative to positive between 3 GeV and 4.5 GeV: Shadowing effect
- JAM2 mean-filed qualitatively describe the 3.2 GeV data (π^+, K^+, K_s^0) while underestimate 4.5 GeV data

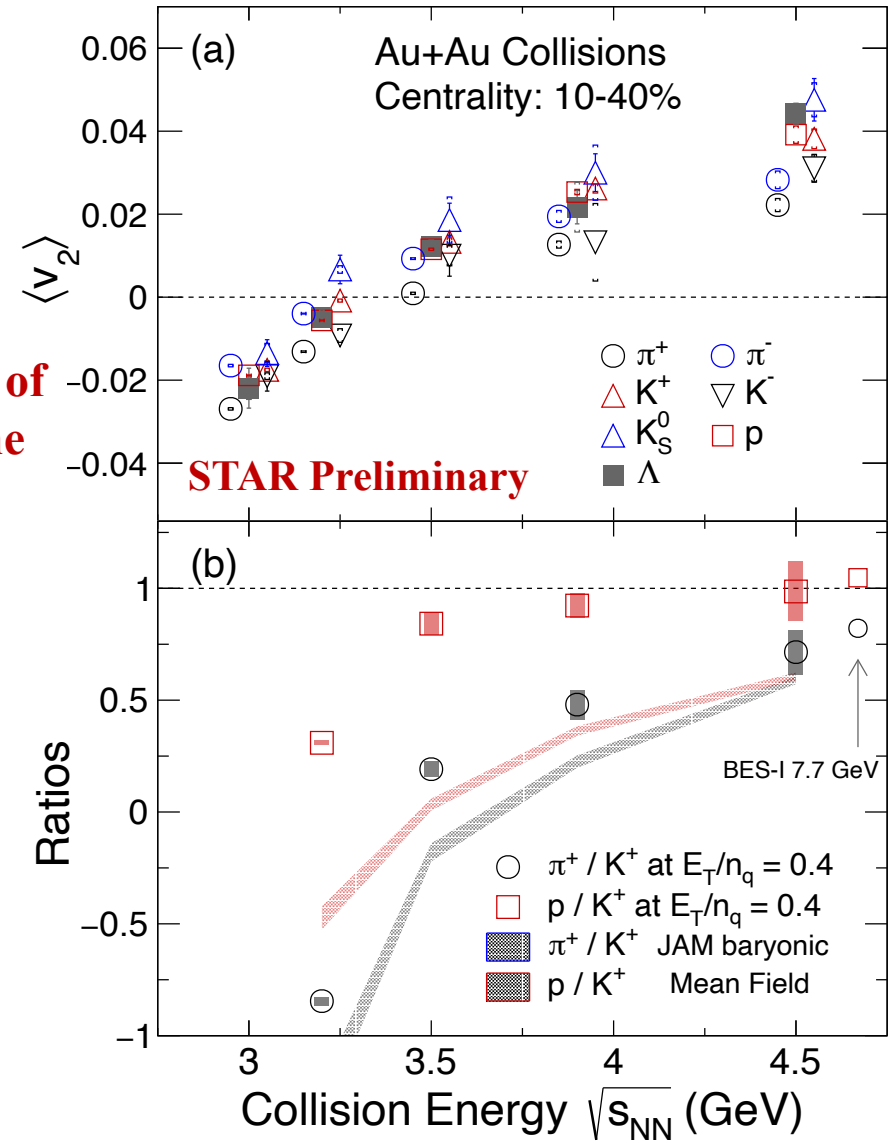
NCQ scaling of v_2 at 3 – 4.5 GeV



- NCQ scaling completely breaks below 3.2 GeV : Hadronic interactions
- NCQ scaling becomes better gradually from 3.2 to 4.5 GeV

  → Partonic interactions become more important

Energy dependence of $\langle v_2 \rangle$



Out of plane

In-plane expansion

- Negative to positive flow: 3- 4.5 GeV
- NCQ scaled v_2 ratio of p/K^+ close to unity at 3.9 and 4.5 GeV, while deviating largely from 1 at 3.2 GeV.

Summary and Outlook

- The v_2 of the particles changes from negative to positive around 3.2 GeV.

  ⟶ Shadowing effect diminishes

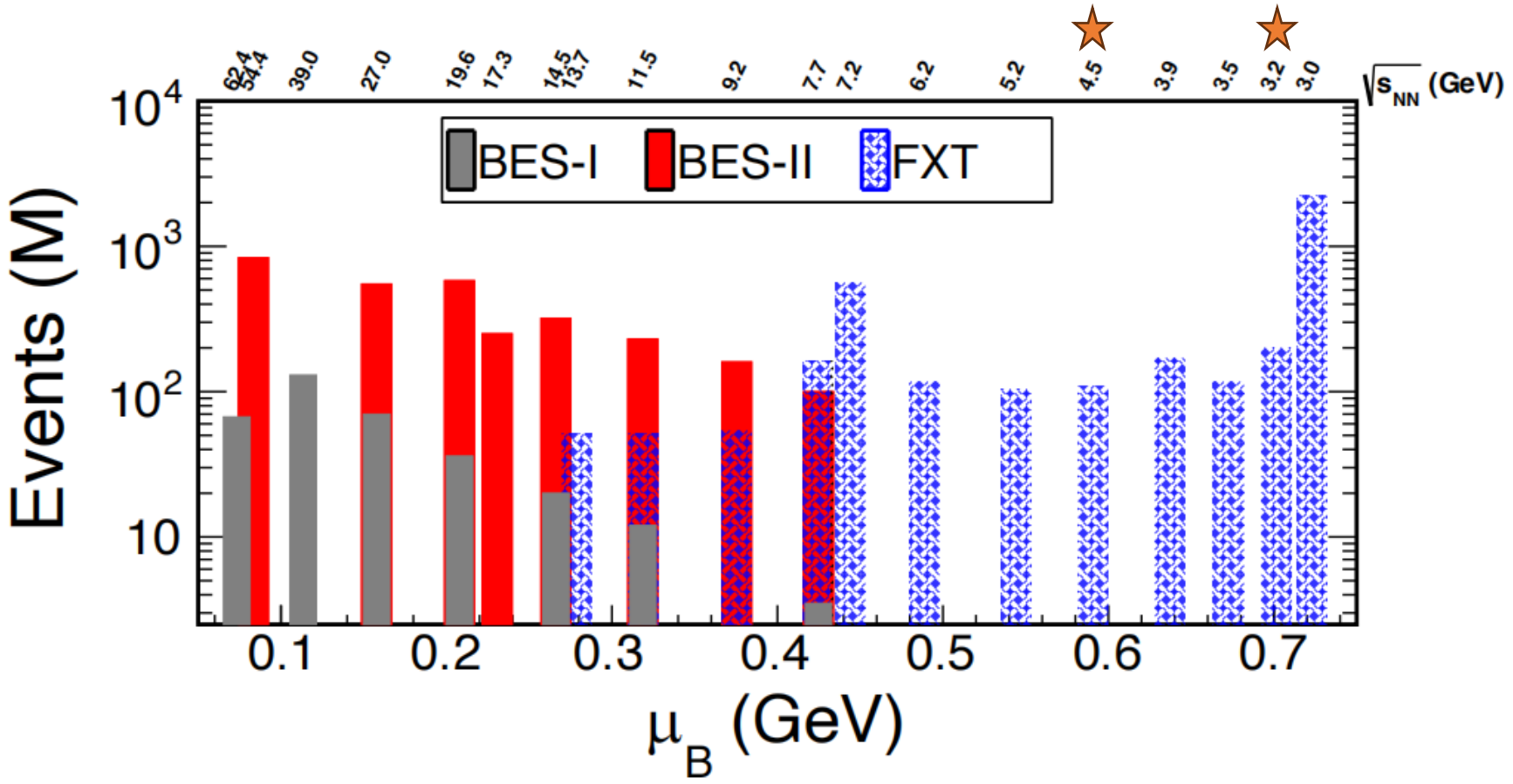
- JAM calculations reproduce the p_T dependence of v_2 at 3.2 GeV

  ⟶ Hadronic interactions dominant

- NCQ scaling breaks totally at 3 and 3.2 GeV, gradually restoring from 3.2 to 4.5 GeV

  ⟶ Dominance of partonic interactions at 4.5 GeV

Summary and Outlook



- Higher statistics, better detector performance and more energy points in BES-II
- Explore the QCD phase diagram

Thank you for your attention!