The 18th International Conference on
Strangeness in Quark Matter (SQM 2019)
10-15 June 2019, Bari (Italy)

Recent results on Light Flavor from STAR

Jie Zhao (for the STAR collaboration)
June 11 2019

Purdue University

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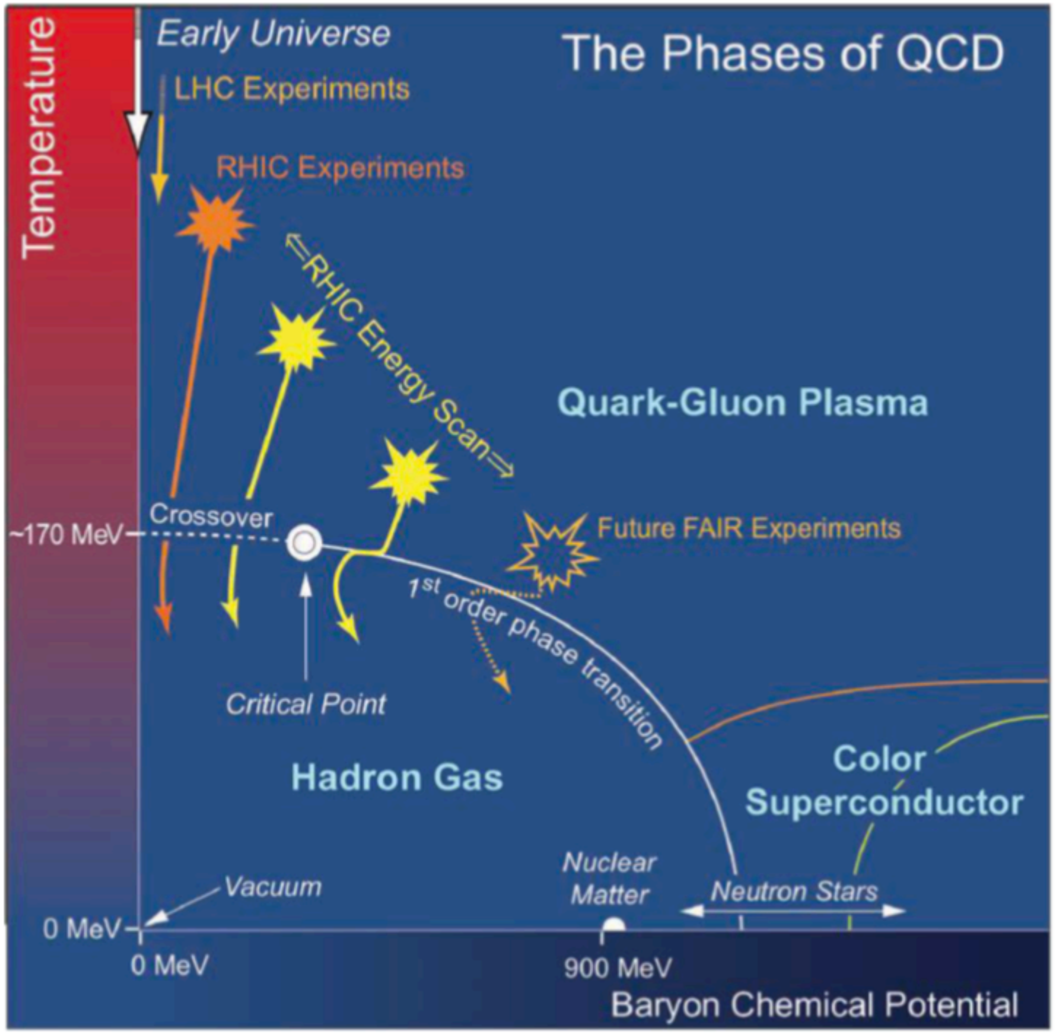
Introduction



RHIC Top Energy

p+p, p+Al, p+Au, d+Au, 3He+Au, Cu+Cu, Cu+Au, Ru+Ru, Zr+Zr, Au+Au, U+U

- QCD at high energy density/temperature
- Properties of QGP, EoS

Beam Energy Scan

Au+Au $\sqrt{S_{NN}}$= 7.7-62 GeV

- QCD phase transition
- Search for the critical point
- Turn-off of QGP signatures

Fixed-Target Program

Au+Au $\sqrt{S_{NN}}$= 3.0-7.7 GeV

- High baryon density regime with μ_B~420-720 MeV

Outline

- **Initial conditions:** flow results
- **Phase transition and critical point:**

  v_1, net fluctuations, deuteron, triton, strangeness
- **Hypertriton**
- **Medium effect and dynamics:**

  K^{*0} and ϕ, low-p_T dilepton
- **Chirality, vorticity and polarization effects:**

  Λ polarization, CME

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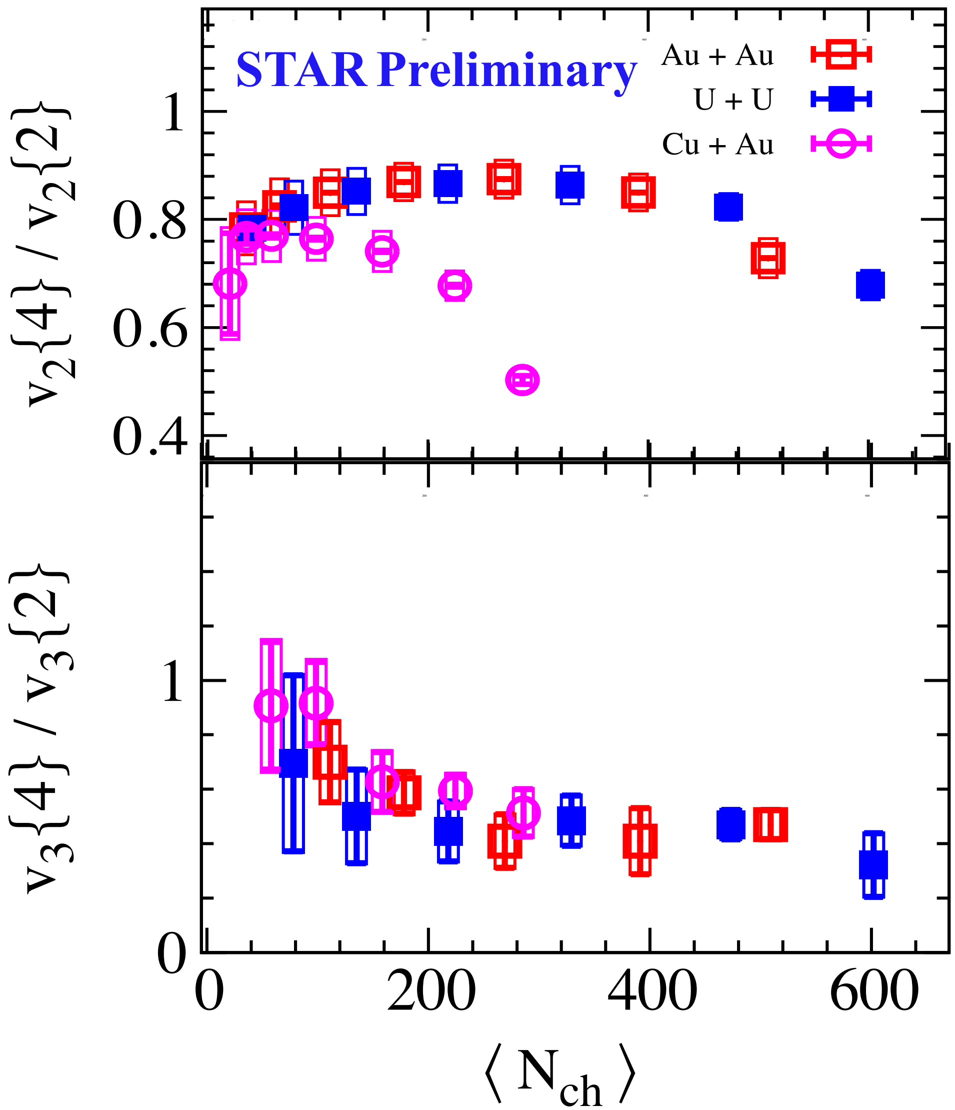
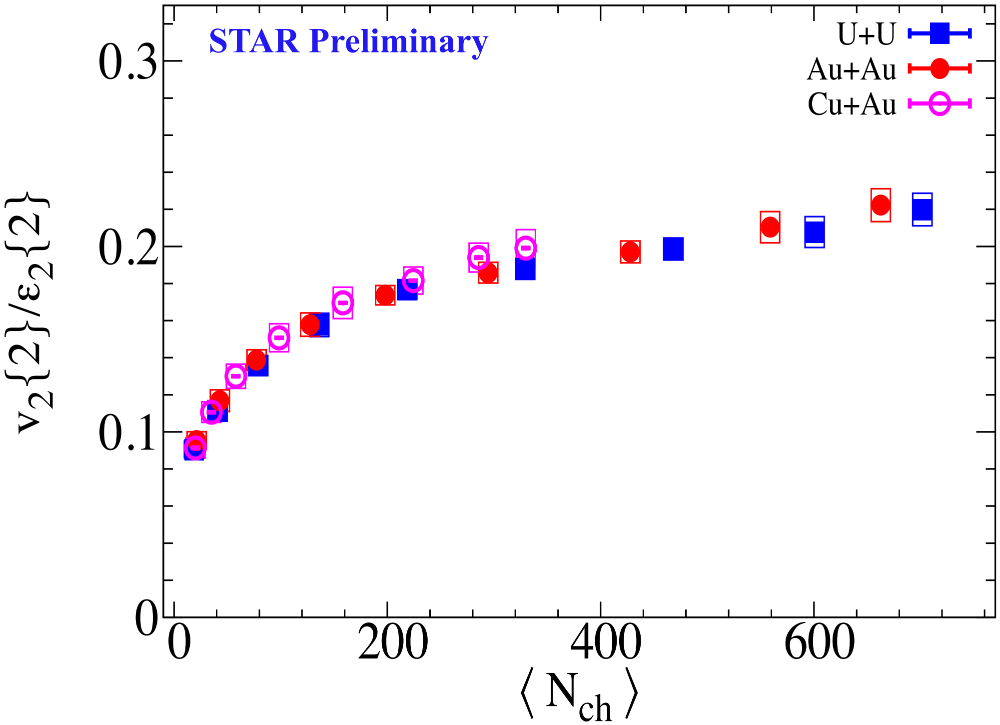
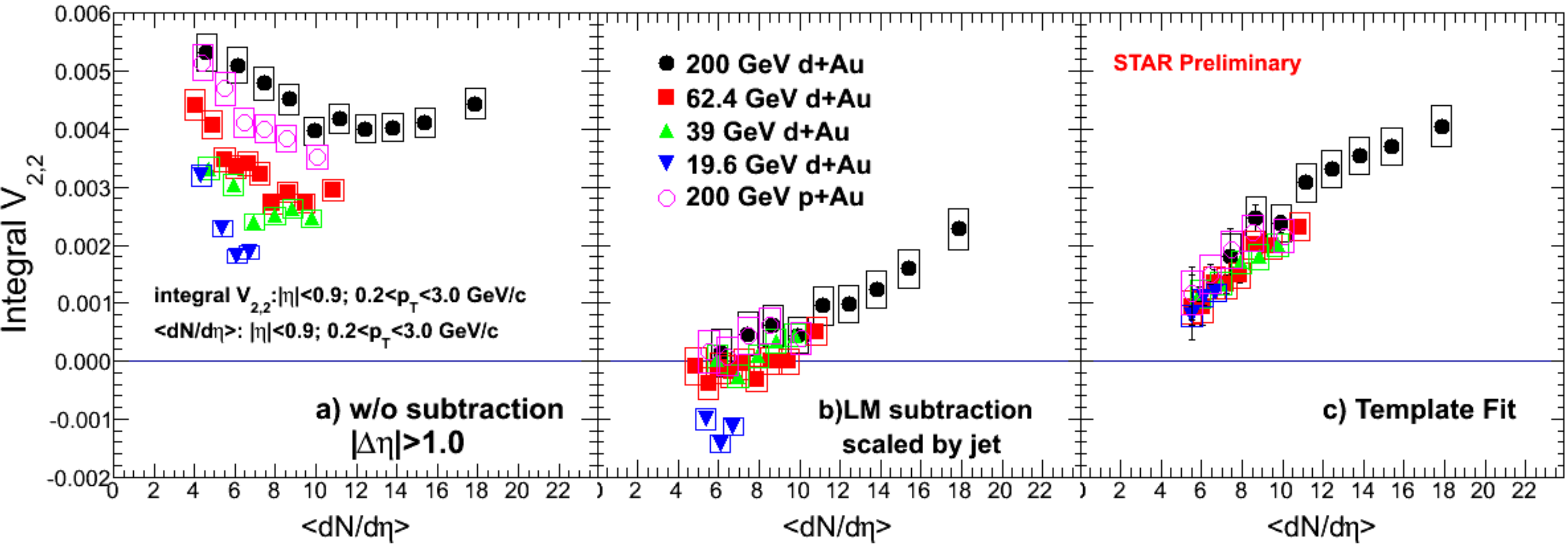
Flow and Fluctuations in Multiple Systems





- Ratio of $v_n\{4\}/v_n\{2\}$ is sensitive to flow fluctuations. The ratio for elliptic flow depends on collision system while that for triangular flow is independent
- $v_2\{2\}$ scales with $\varepsilon_2\{2\}$ - similar viscous effect in these collisions

Collectivity in Small Systems



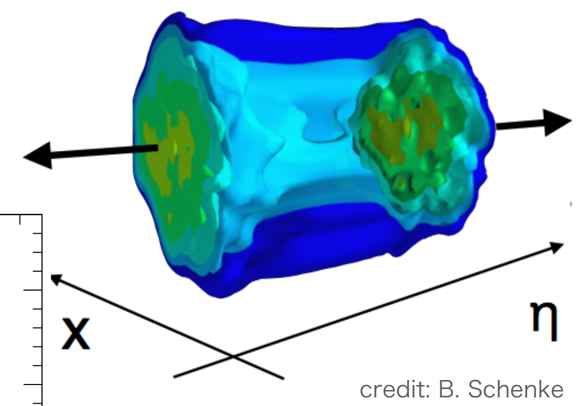
- Different $V_{2,2}$ from different methods to correct for non-flow background in p/d+Au collisions, positive v_2 at high multiplicity
- v_2 from subtraction method is negative at lower collision energies
- v_2 from template fit increases with multiplicity
- Initial state effect vs. final state effect? Hydrodynamics or anisotropic escape?

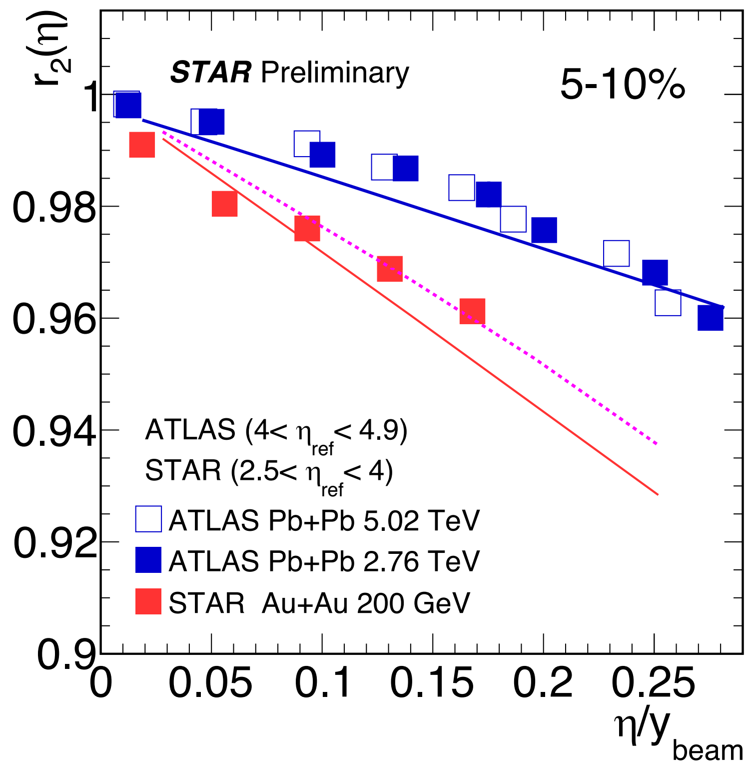
Longitudinal Flow Decorrelation

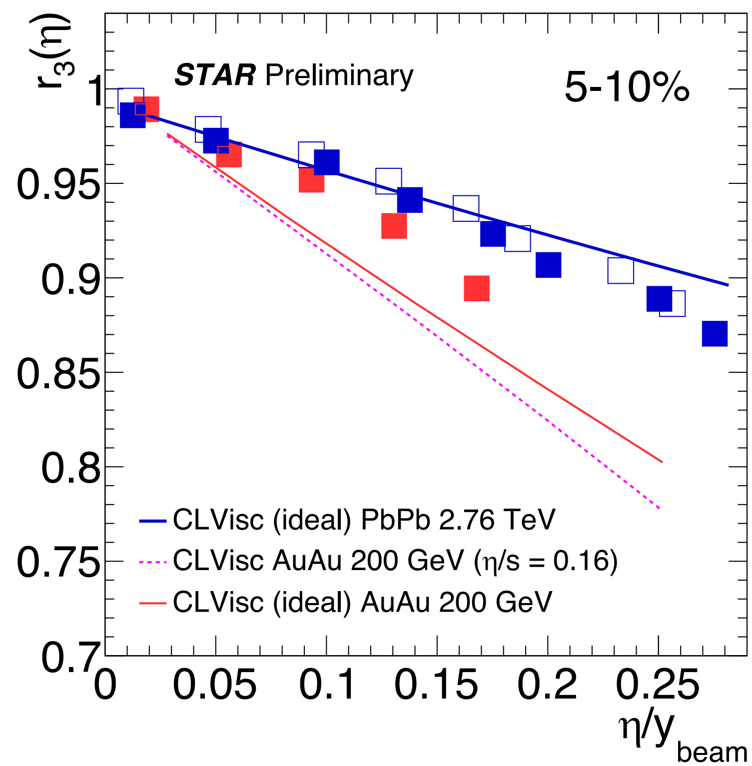
CMS Collaboration, Phys. Rev. C 92 (2015) 034911

$$r_n(\eta) = \frac{\langle v_n(-\eta)v_n(\eta_{\rm ref})\cos n(\Psi_n(-\eta)-\Psi_n(\eta_{\rm ref}))\rangle}{\langle v_n(\eta)v_n(\eta_{\rm ref})\cos n(\Psi_n(\eta)-\Psi_n(\eta_{\rm ref}))\rangle}$$

Evolution of the QGP in (3+1)D







- Stronger longitudinal flow decorrelation at RHIC than at LHC
- Hydrodynamic calculations can not simultaneously describe LHC and RHIC

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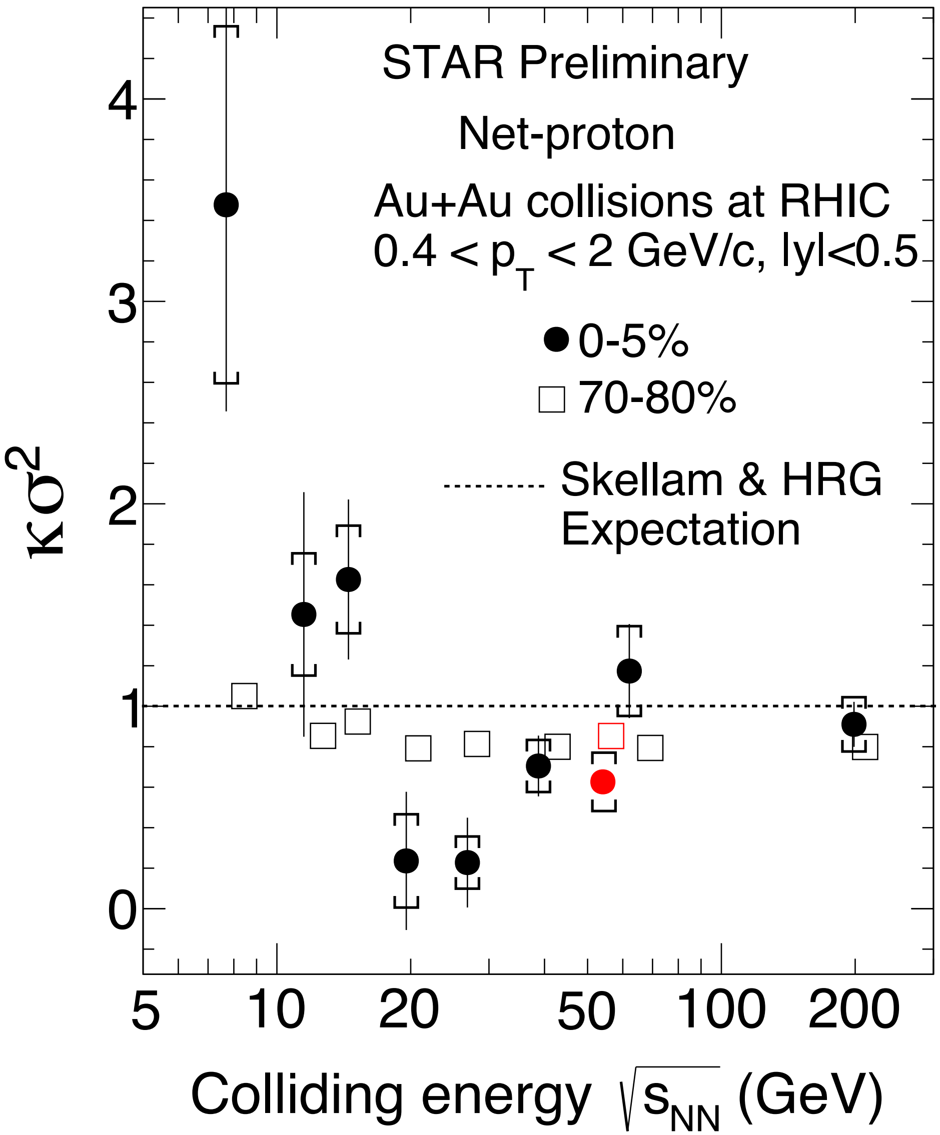
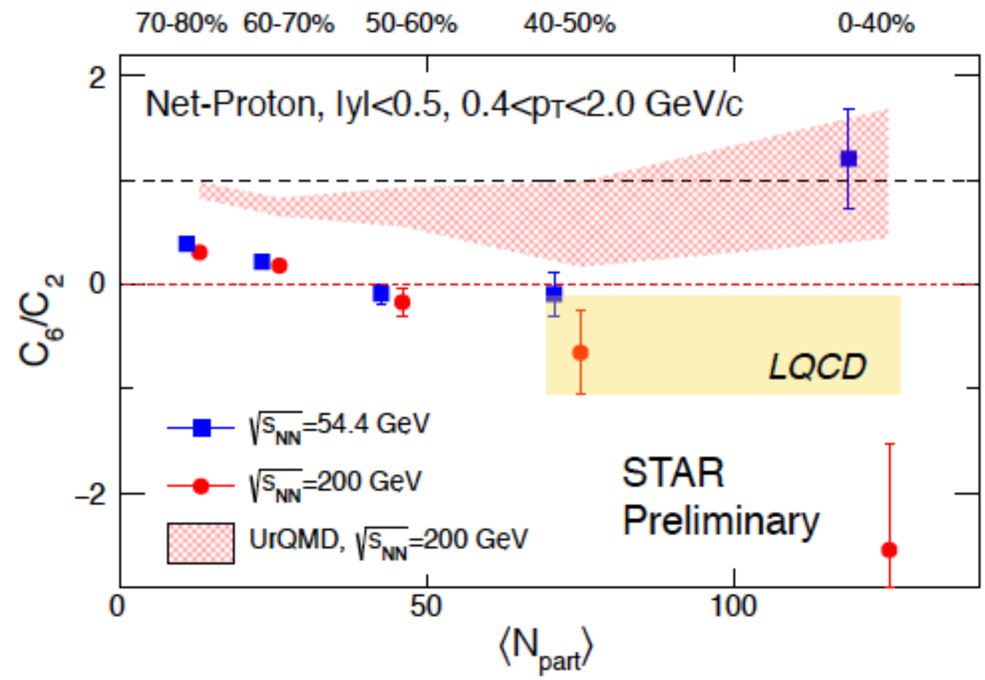
Higher moments





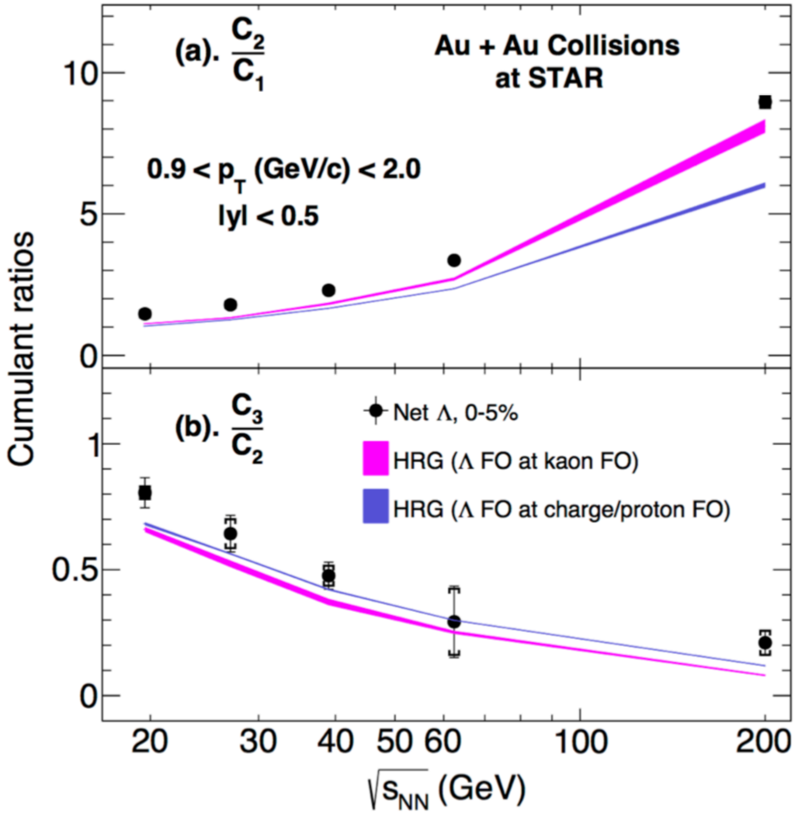
Ashish Pandav's talk

Mapping the **freeze-out curve** and probing the possible **critical point** through fluctuations of conserved quantum numbers:

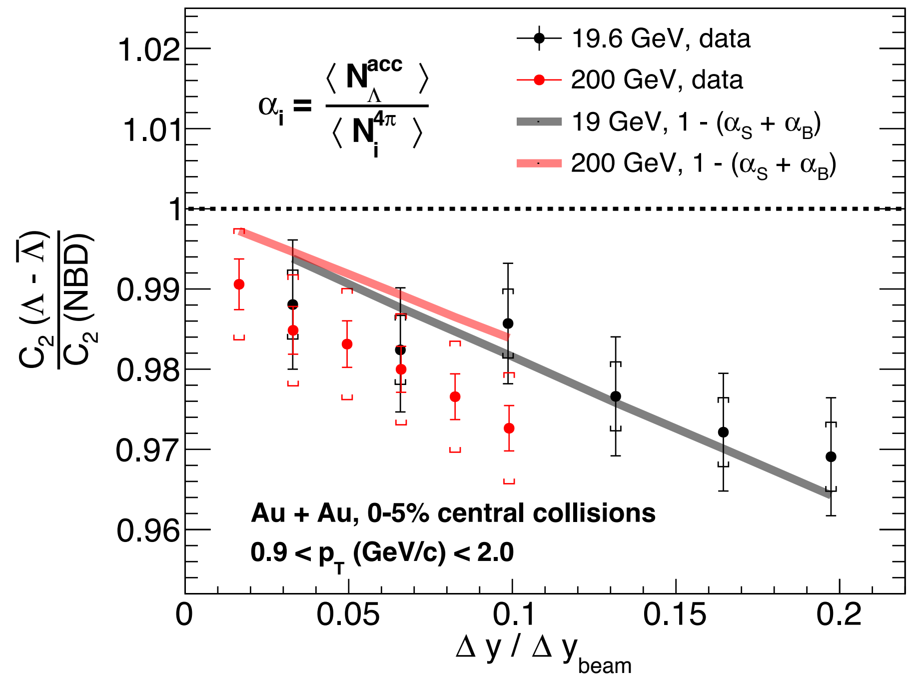
New measurements of net-proton cumulants for Au+Au collisions at $\sqrt{s_{NN}}$ = 54.4 GeV

The C_6/C_2 for central Au+Au collisions at 54.4 GeV is positive while that for 200 GeV is negative (with large uncertainties). These have consequences vis-à-vis chiral criticality in QCD.

Higher moments of Net-Λ distributions



Rene Bellwied's talk



Net-Lambda fluctuations provide a more complete strangeness proxy together with net kaons and compare with HRG predictions for sequential hadronization

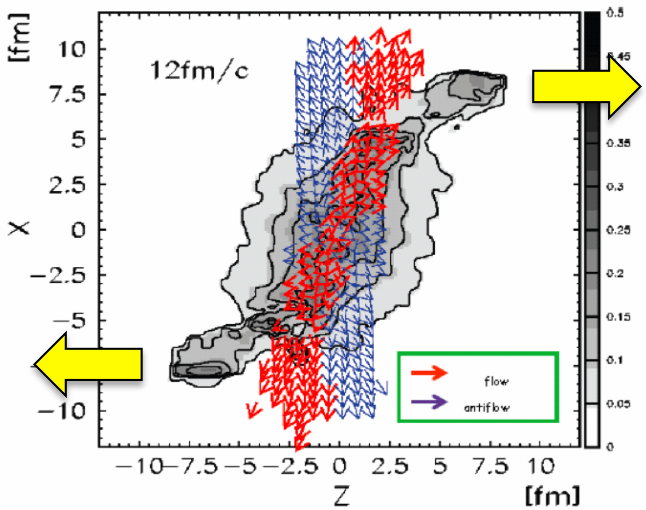
The net-Lambda cumulant ratios can be described by the latest HRG model, no non-monotonic behavior vs. energy

The net-Lambda variance vs. y: small deviations from NBD for larger rapidity coverage, could be attributed to the effect of baryon number and strangeness conservation

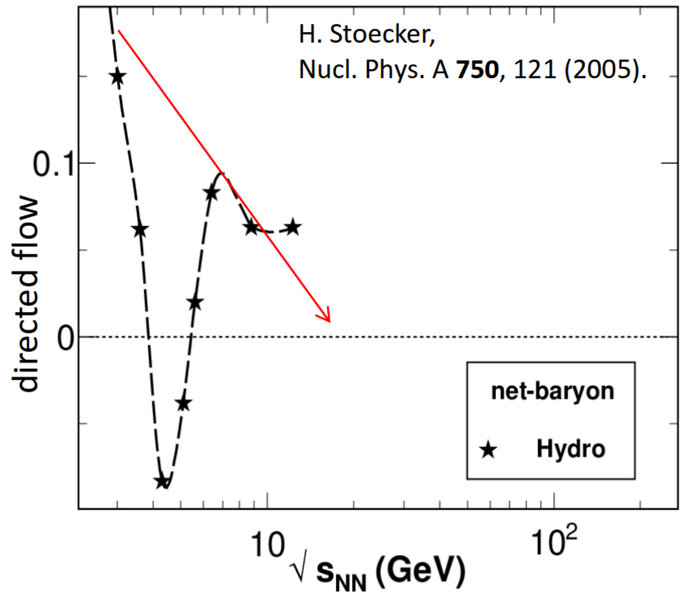
works if B and S conservation are treated additive

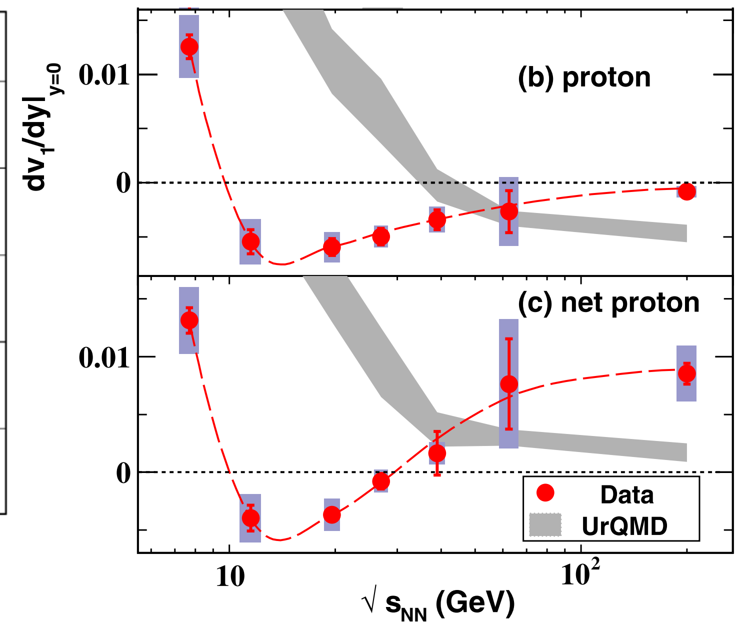
Directed Flow (v_1)

STAR, Phys. Rev. Lett. 112 (2014) 162301



J. Brachmann et al., PRC 61, 24909 (2000).



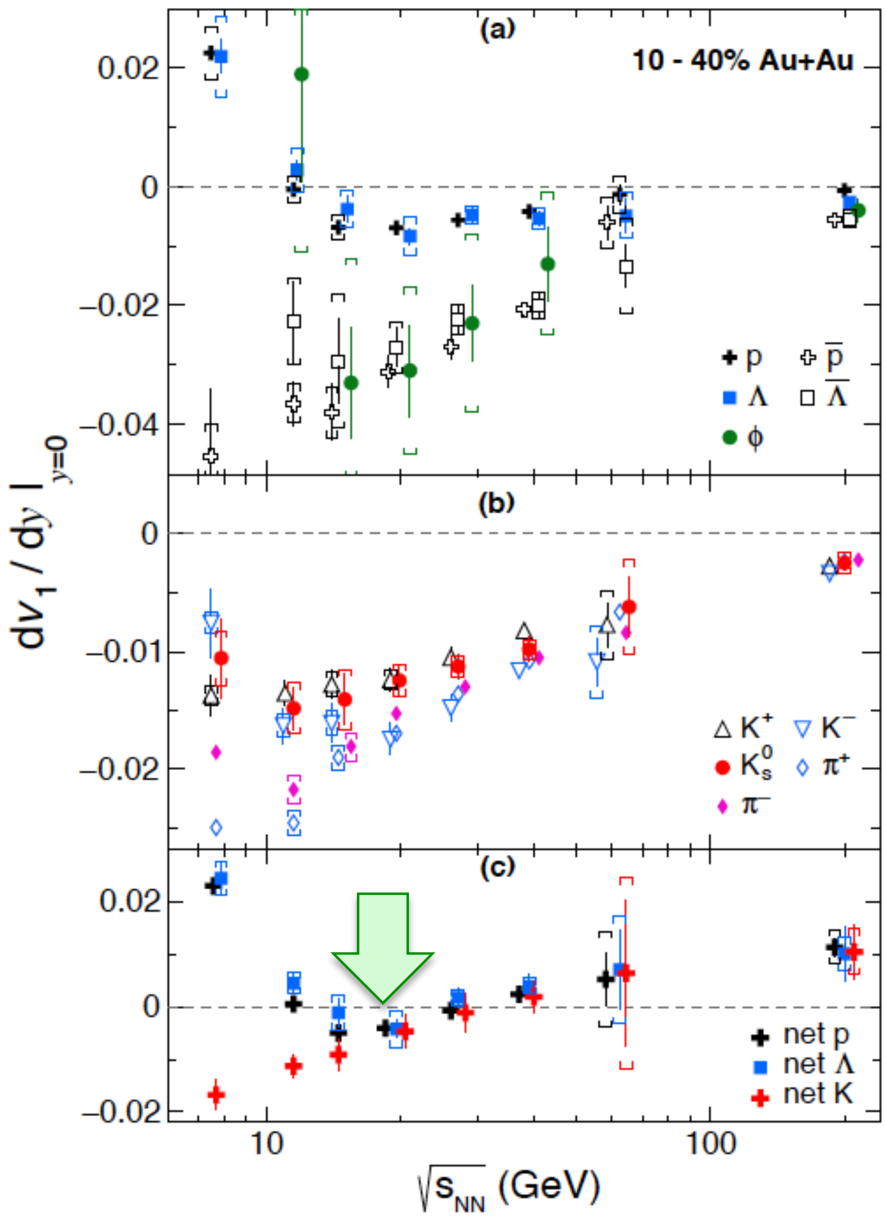


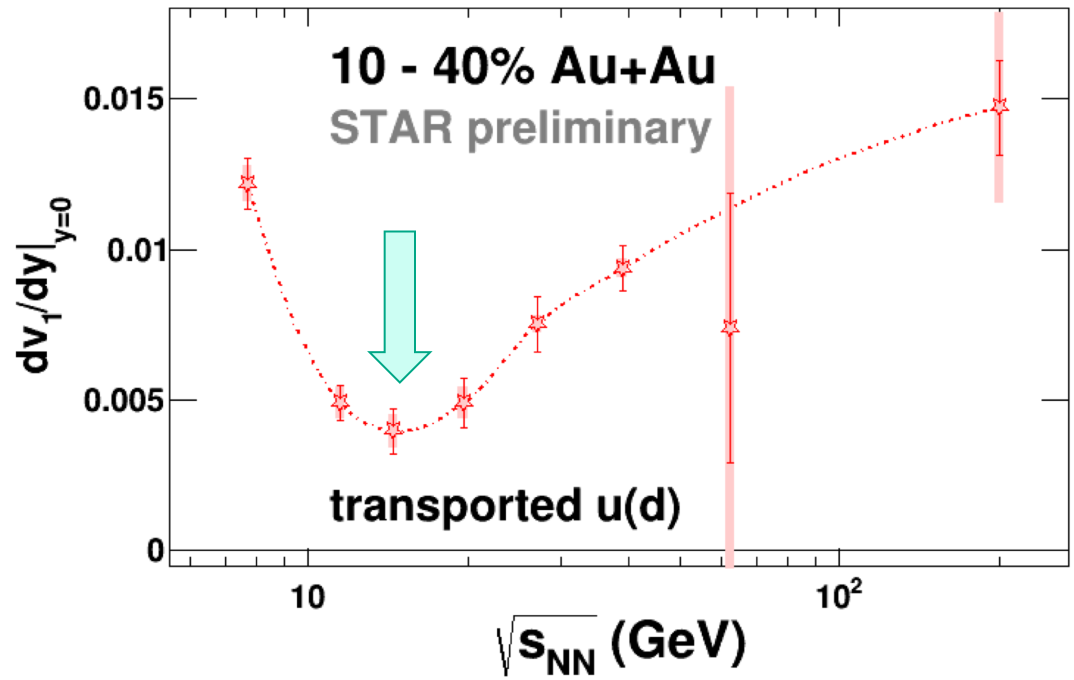
Probe of the softening of the Equation of State

- strong softening: consistent with the 1st-order phase transition
- weaker softening: more likely due to crossover

Directed Flow of Identified Particles

STAR, Phys. Rev. Lett. **120** (2018) 62301



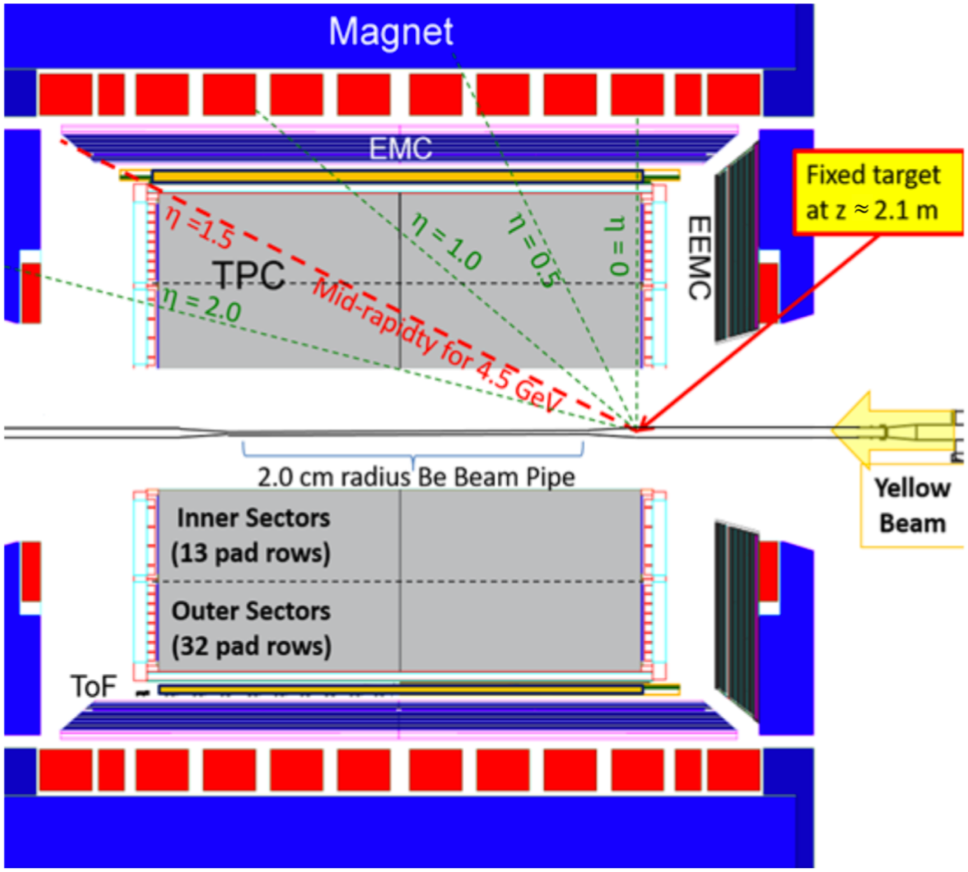


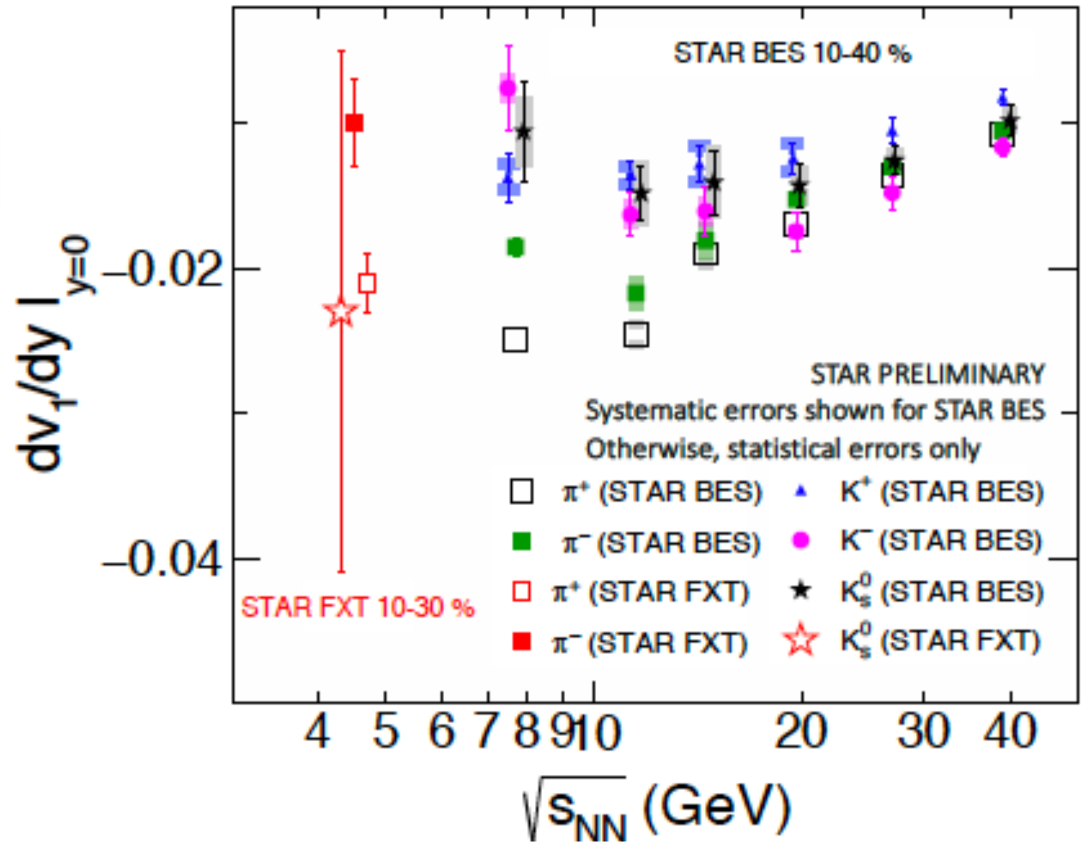
$$(v_1)_{trans.u(d)} = \left[(v_1)_{net\ p} - \left(3 - N_{trans.u(d)}\right)(v_1)_{\bar{u}(\bar{d})}\right]/N_{trans.u(d)}$$

$$N_{trans.u(d)} = 3\left[1 - exp\left(-2\mu_{u(d)}/T_{ch}\right)\right]/\left(1 - r_{\bar{p}/p}\right)$$

- 10 species & 8 energies allow a detailed study of constituent-quark v_1. In most cases, the coalescence picture works for both "produced" particles and "net" particles
- "Transported quark" v_1 has a local minimum at ~14.5 GeV

Fixed-Target Test Run for Au+Au at 4.5 GeV

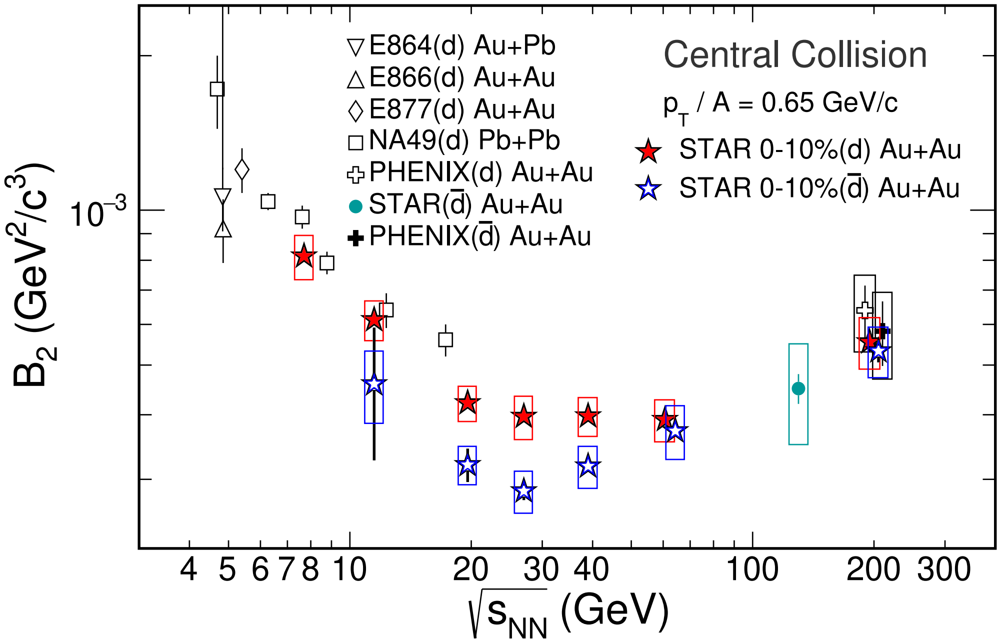


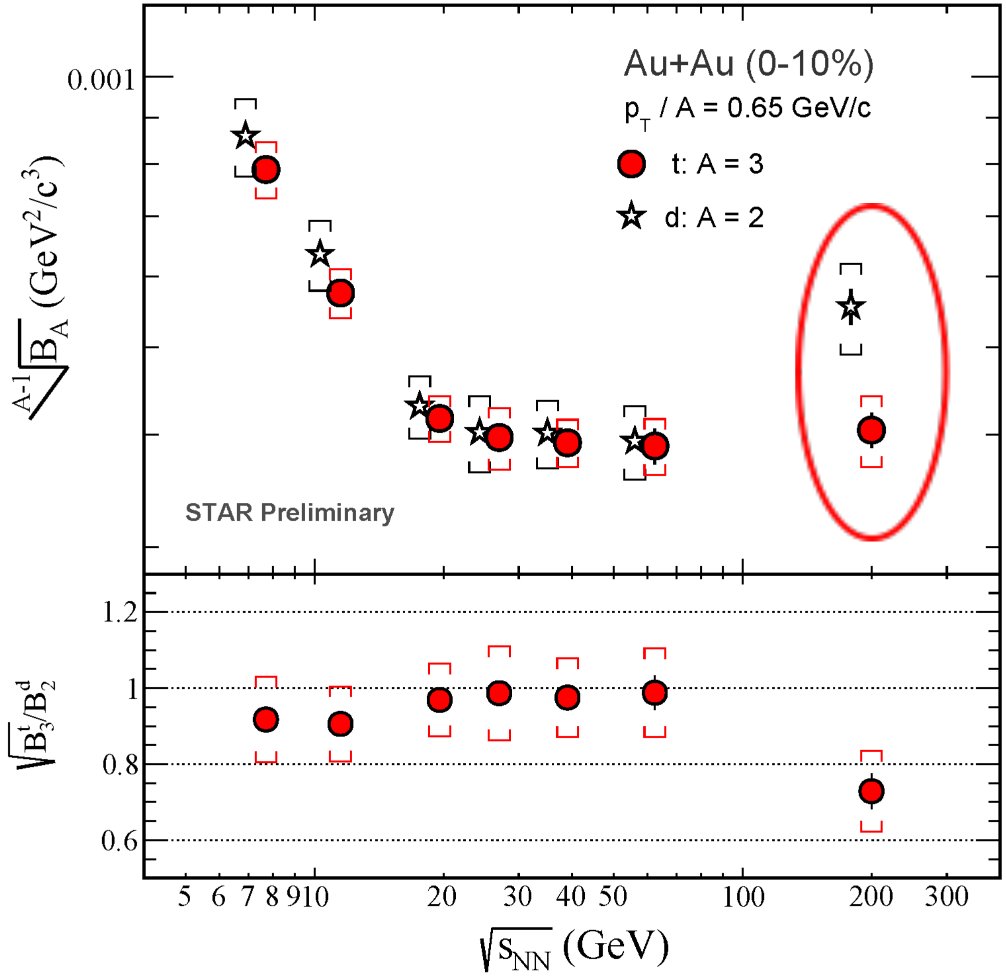


- First π v_1 measurement in this energy range, v_1 slope turning up towards lower energies
- Dedicated FXT runs (3.0-7.7 GeV) in 2019+ to explore high baryon density regime

Coalescence Parameters – B_2 and B_3

STAR, arXiv:1903.11778





$B_2(\bar{d})$ are smaller than that of $B_2(d)$, indicate antibaryon freeze-out at a larger source.

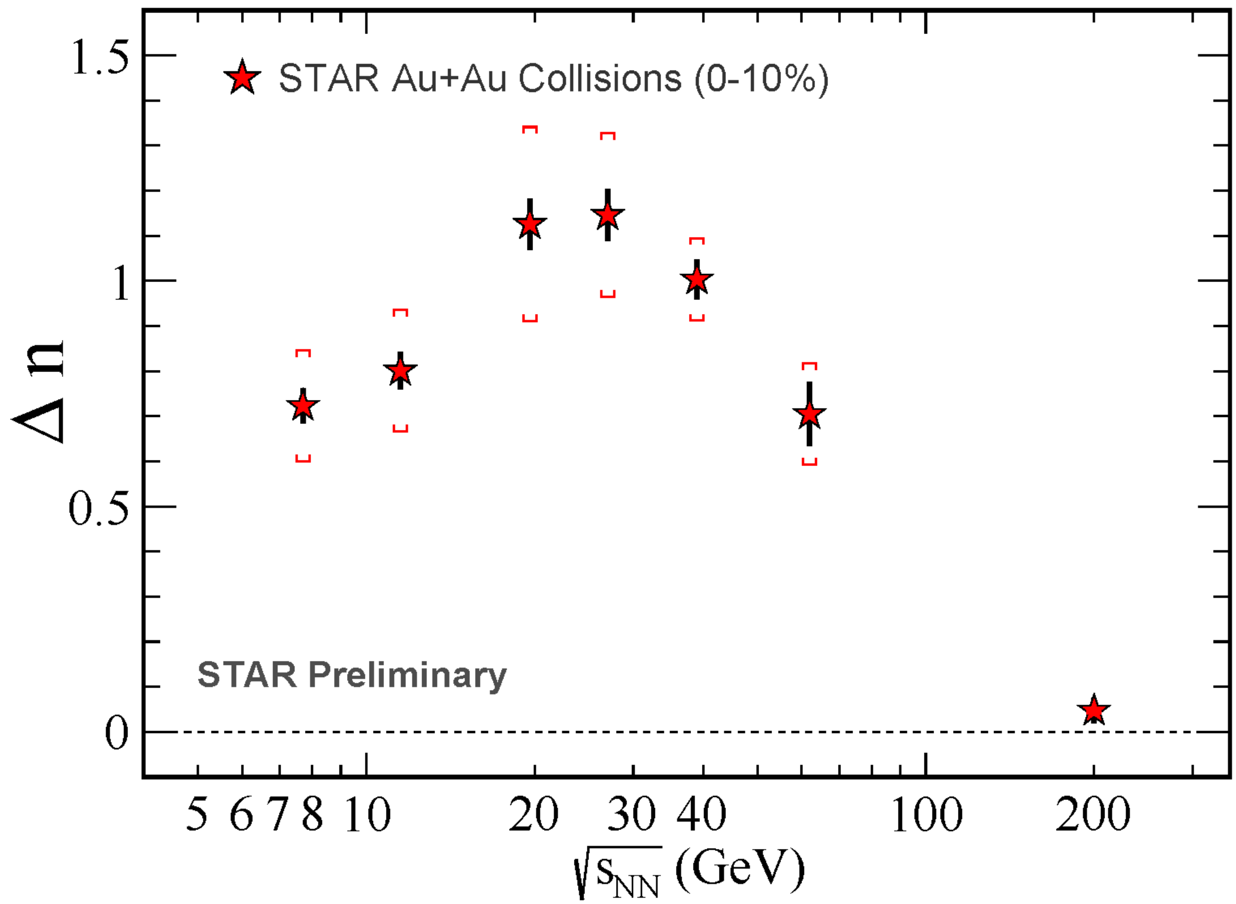
B_2 decreases with collision energy. A minimum at $\sqrt{s_{NN}}$ ~ 20 GeV: change of EOS?!

B_2 and $\sqrt{B_3}$ are consistent within uncertainties except 200 GeV.

Neutron Density Fluctuation

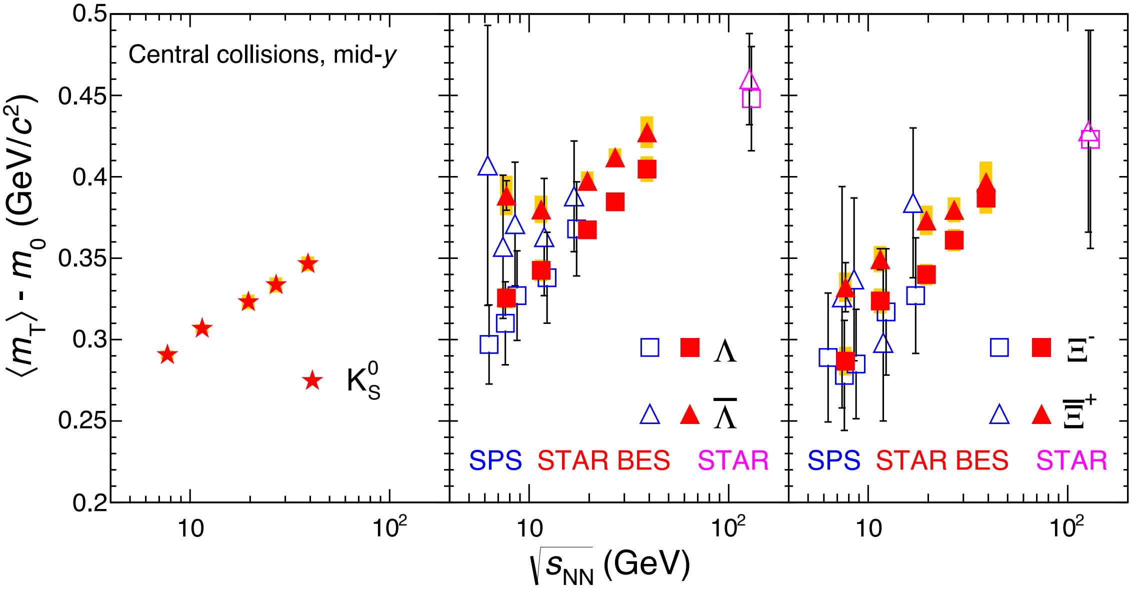
K. J. Sun, L. W. Chen, C. M. Ko, Z. Xu, Phys. Lett. B774, 103 (2017).
K. J. Sun, L. W. Chen, C. M. Ko, J. Pu, Z. Xu, Phys. Lett. B781, 499 (2018).

$$N_t \cdot N_p / N_d^2 = g(1 + \Delta n)$$



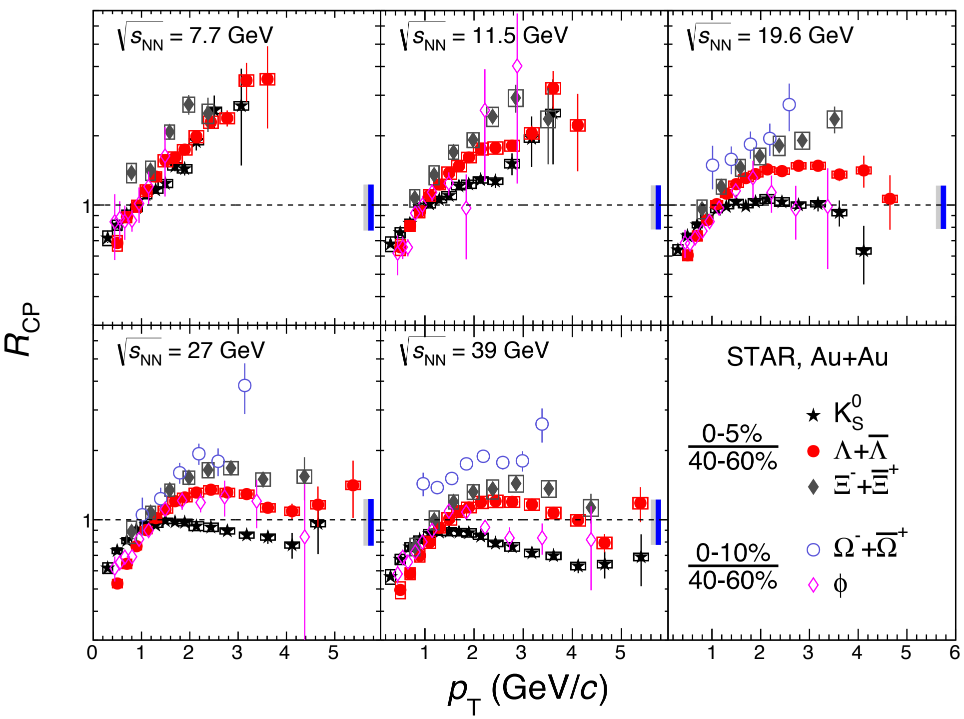
➢ Neutron density fluctuation, Δn, shows a non-monotonic behavior on collision energy. Peak ~ 20 GeV

Strange hadron production



$\langle m_T \rangle - m_0$ of antibaryons and baryons significantly deviate from each other towards lower collision energies, especially for anti-Λ and Λ.

STAR, arXiv:1906.03732



- The K^0_s R_{cp} no suppression for p_T 3.5 GeV and particle type independence at <= 11.5 GeV.
- Partonic energy loss effect less significant at low energies. The cold nuclear matter effect take over?
- Further investigation of the deconfinement phase transition below 19.6 GeV

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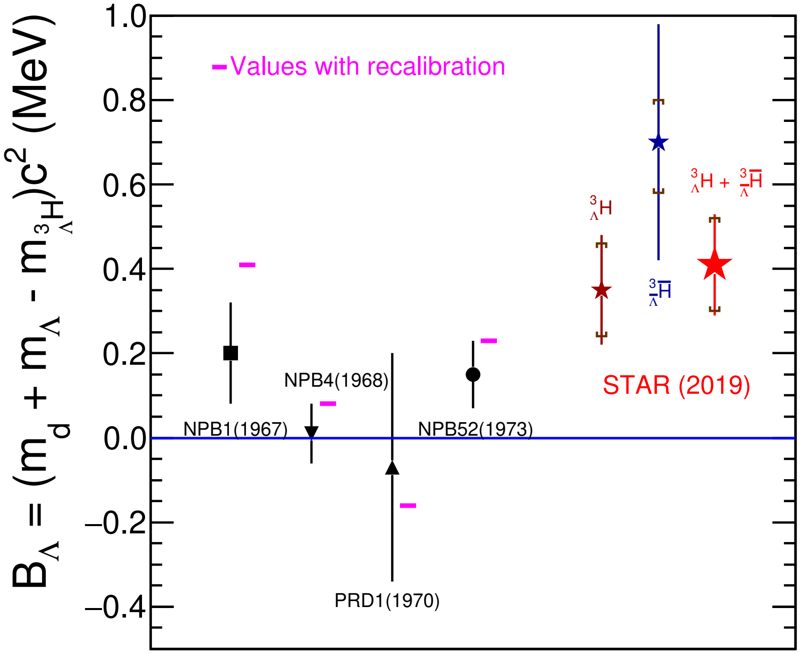
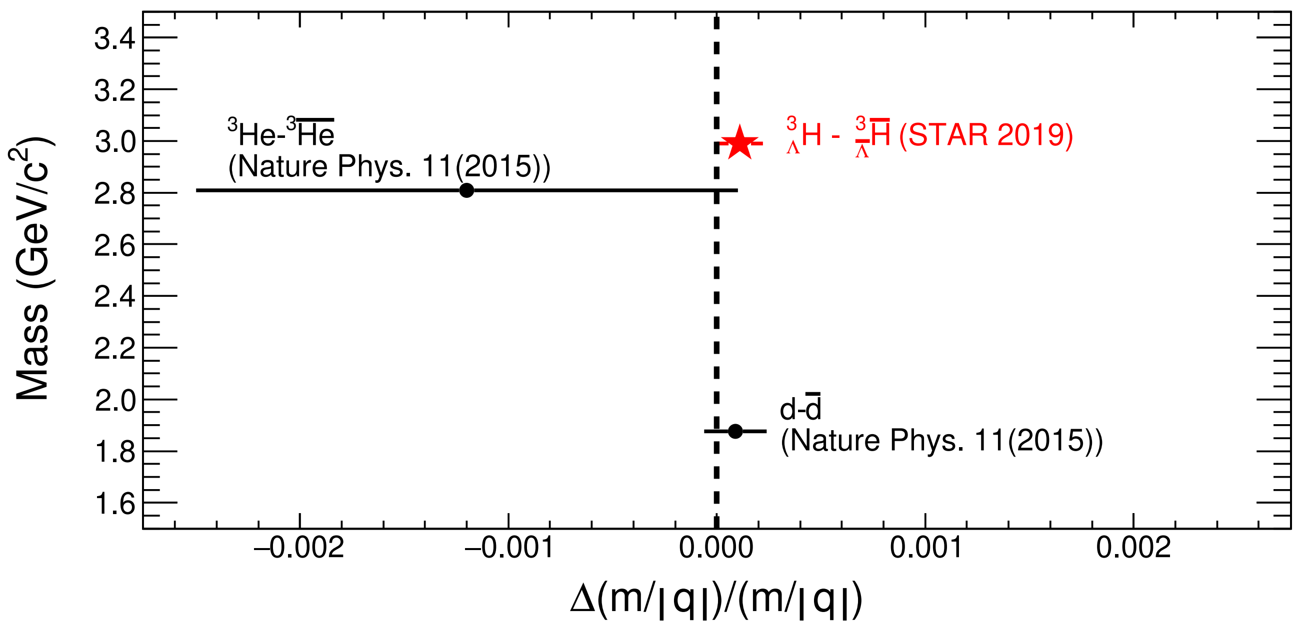
(Anti-)Hypertriton Masses



STAR, arXiv:1904.10520



- Excellent S/B with HFT, precise determination of the binding energy:

  $m_d + m_\Lambda - m^3_\Lambda = 0.44 \pm 0.10\ (\text{stat.}) \pm 0.15\ (\text{syst.})$ MeV

- Providing insight on Hyperon-Nucleon interaction, thus neutron star structure
- The mass difference between ${}_\Lambda{}^3H$ and anti-${}_\Lambda{}^3H$

  $(\Delta m/m)_\Lambda{}^3H = (1.0 \pm 0.9\ (\text{stat.}) \pm 0.7\ (\text{syst.})) \times 10^{-4}$

  is the first test of the CPT symmetry in the light hypernuclei sector

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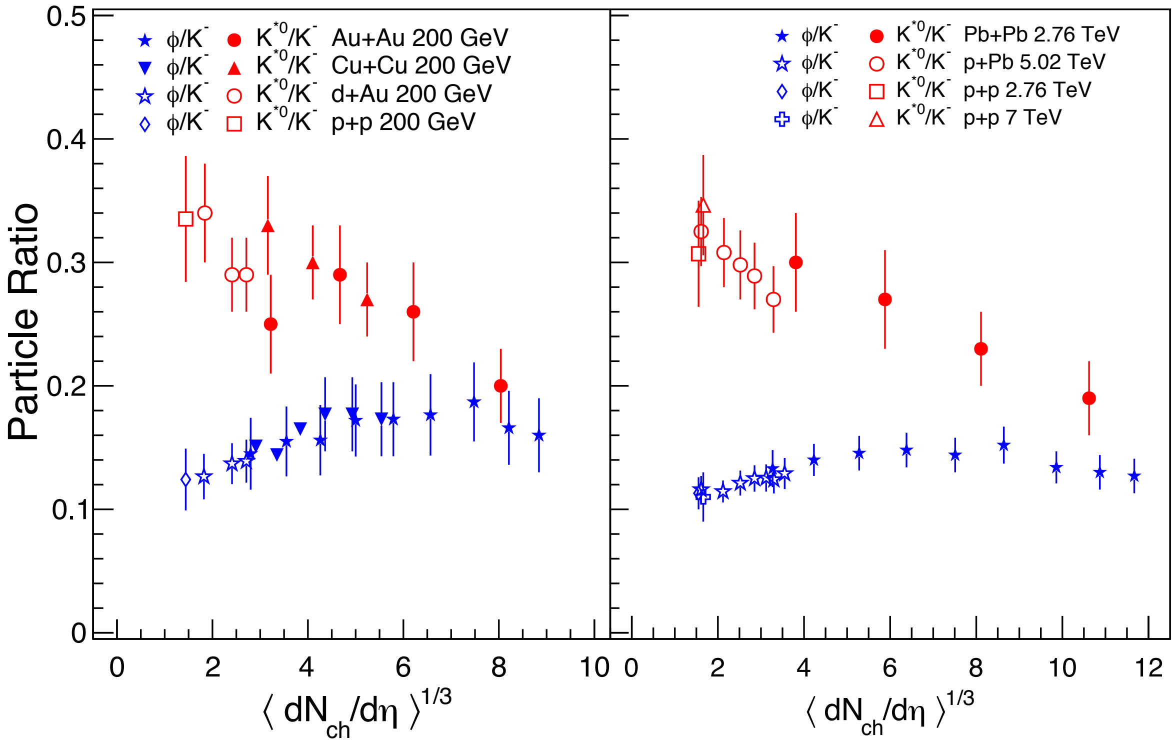
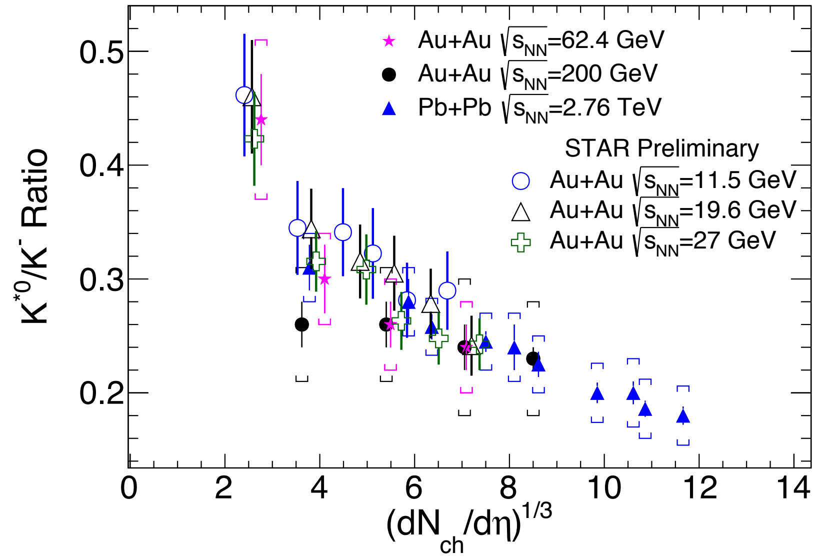
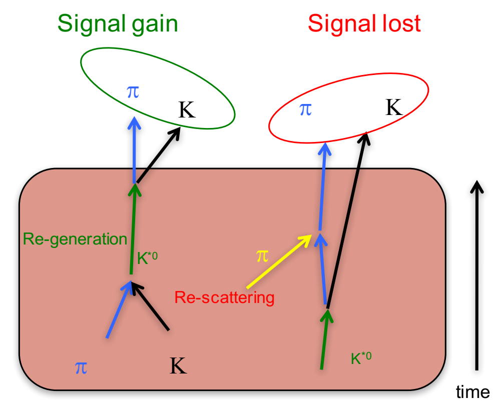
K^{*0} and ϕ resonance production







K^{*0}/K^- decreases with centrality

ϕ/K^- ratio is independent of centrality

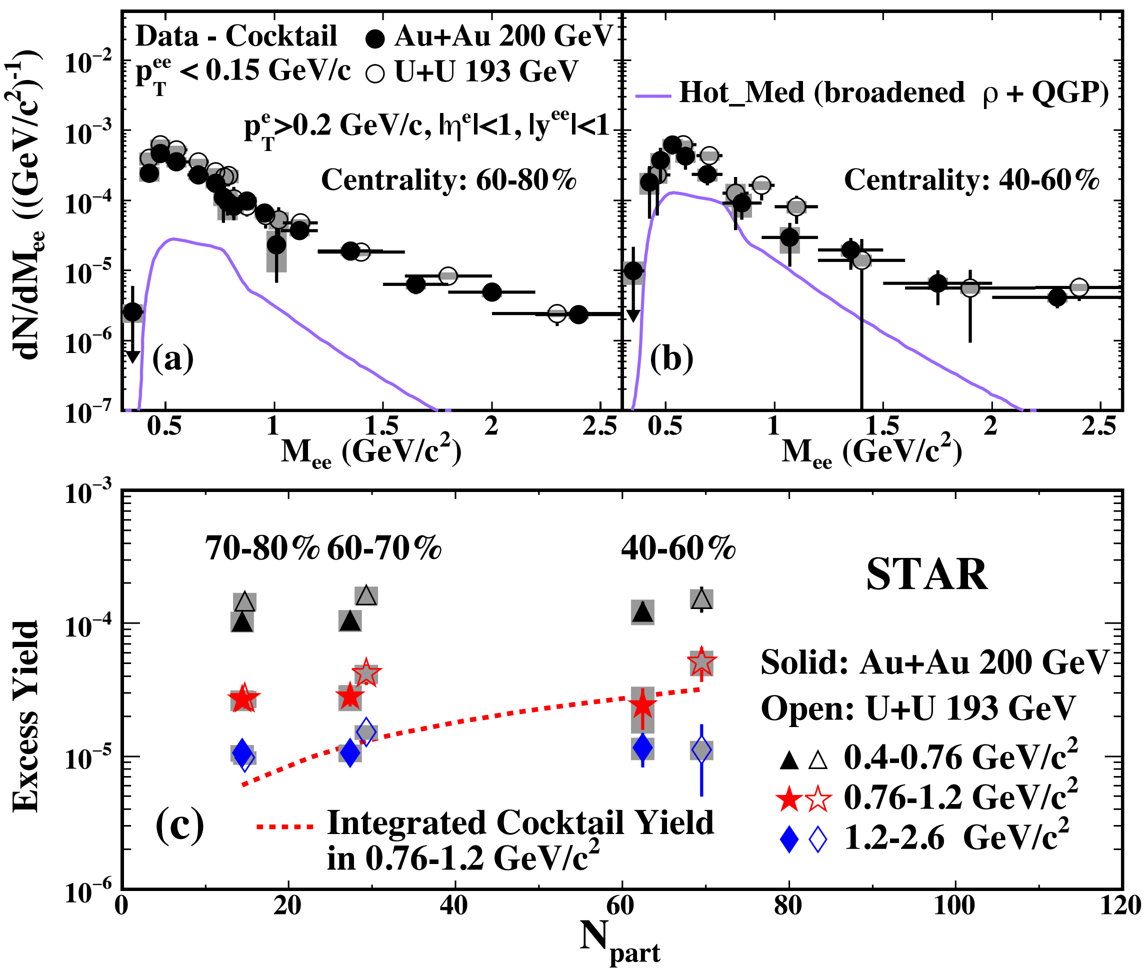
Small hadronic interaction cross section for ϕ

- Dominance of hadronic re-scattering at RHIC and LHC
- More re-scattering in central collisions

Md. Nasim's talk

Low-p_T e^+e^- enhancement

STAR, PRL 121 (2018) 132301
R. Rapp, PRC 63 (2001) 054907



Can not be explained by in -medium broadened ρ model

Compared to hadronic production, excess yield exhibits a much weaker centrality dependence

Need additional source(s)

Initial magnetic field?
May provide insights on the chiral effects?

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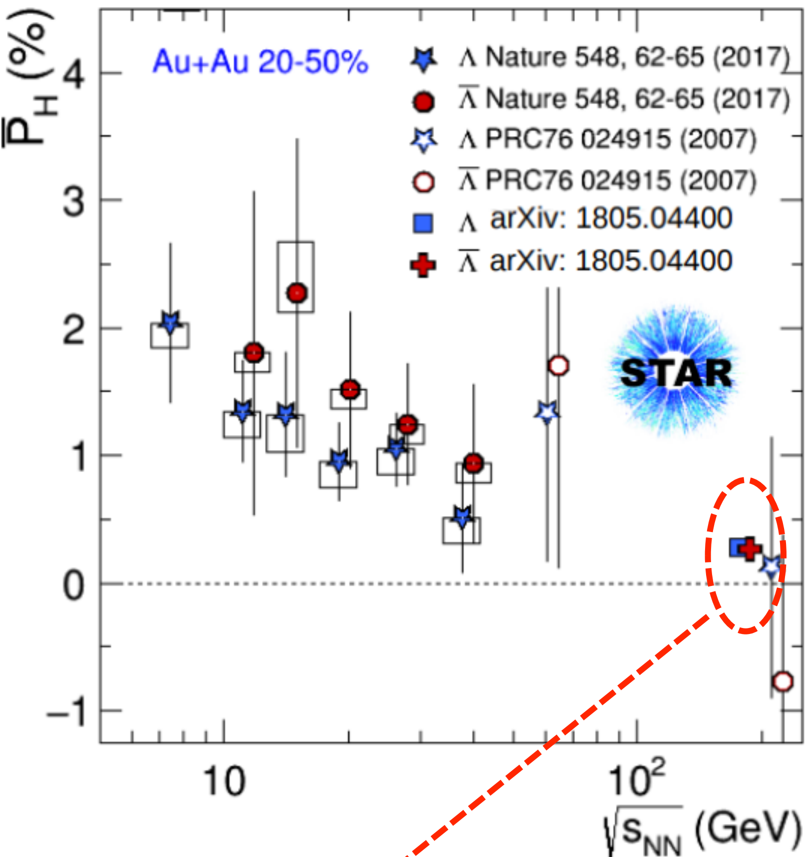
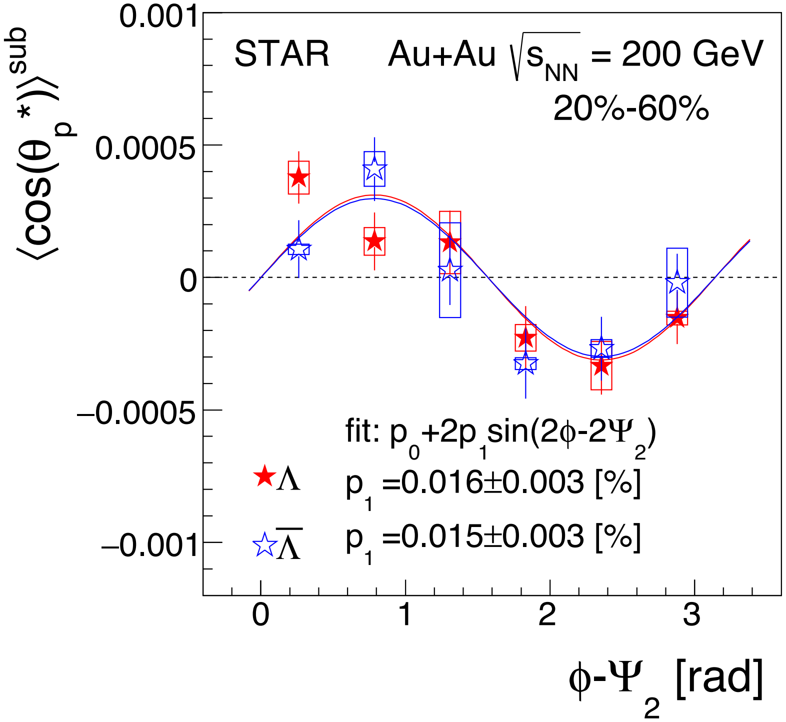
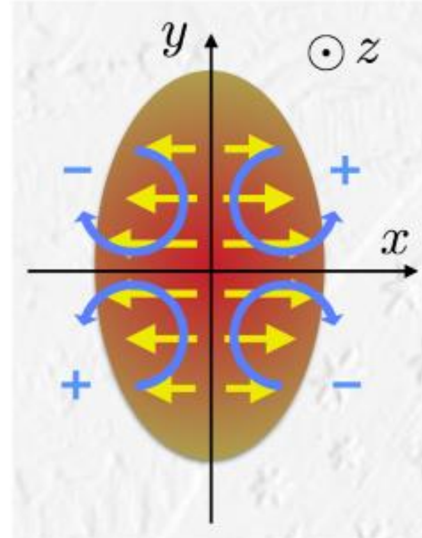
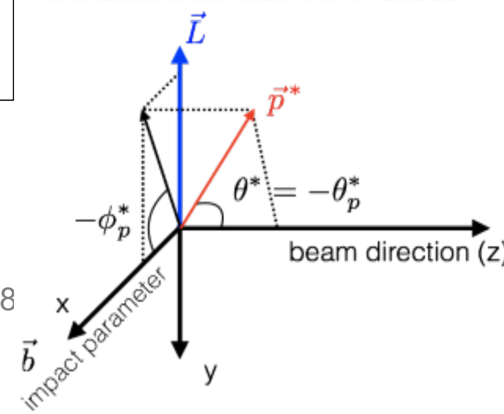
Λ Global and Local Polarization





S. Voloshin, EPJ Web Conf. 17 (2018) 10700
F. Becattini and I. Karpenko, PRL120, 012302 (2018



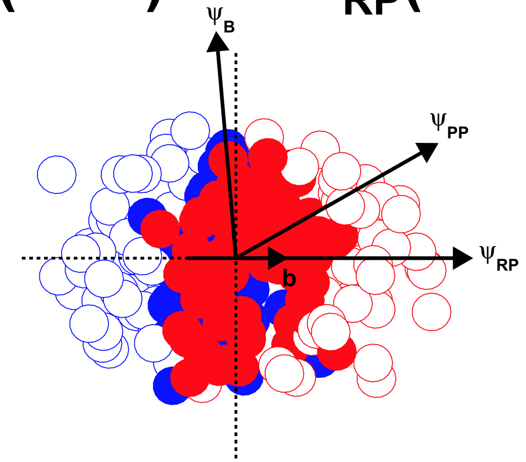


STAR, arXiv:1905.11917

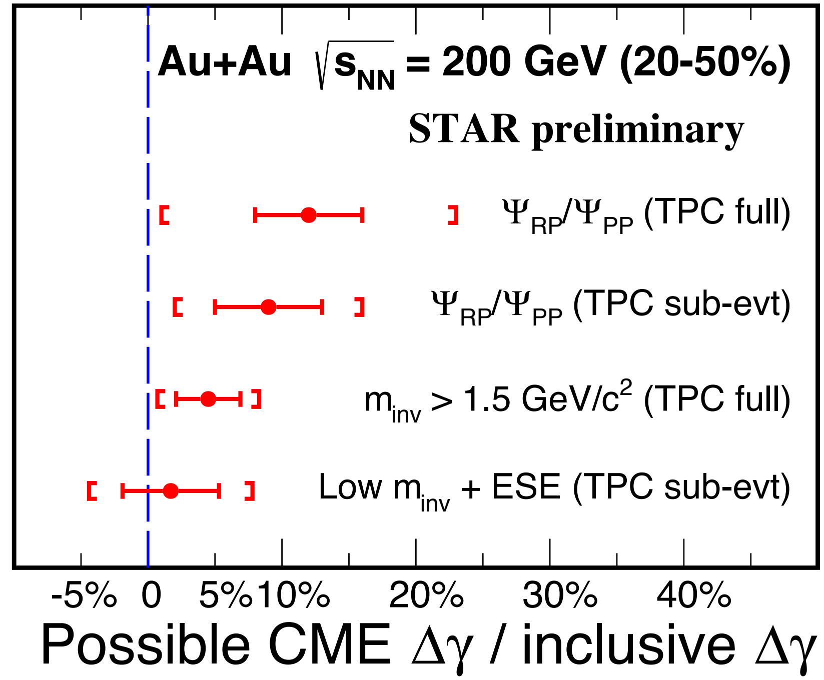
- First observation of finite Λ global polarization at 200 GeV
- First observation of quadrupole structure of Λ local polarization along beam direction

Chiral Magnetic Effect

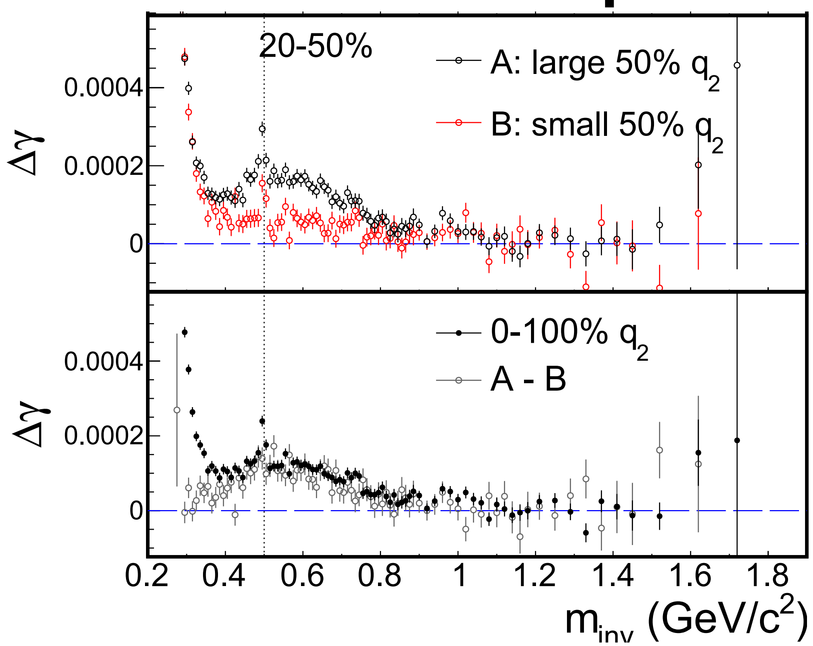
- Ψ_{PP}(TPC) vs. Ψ_{RP}(ZDC)



H-J Xu, *etal*, CPC 42 (2018) 084103
J. Zhao, H. Li, F. Wang, Eur. Phys. J. C (2019) 79:168



- Invariant mass dep. of the Δγ



- Isolate possible CME signal in inclusive Δγ by different methods
- These estimates indicate: possible CME signal is small in inclusive Δγ, within 1-2σ from zero with the current precision

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