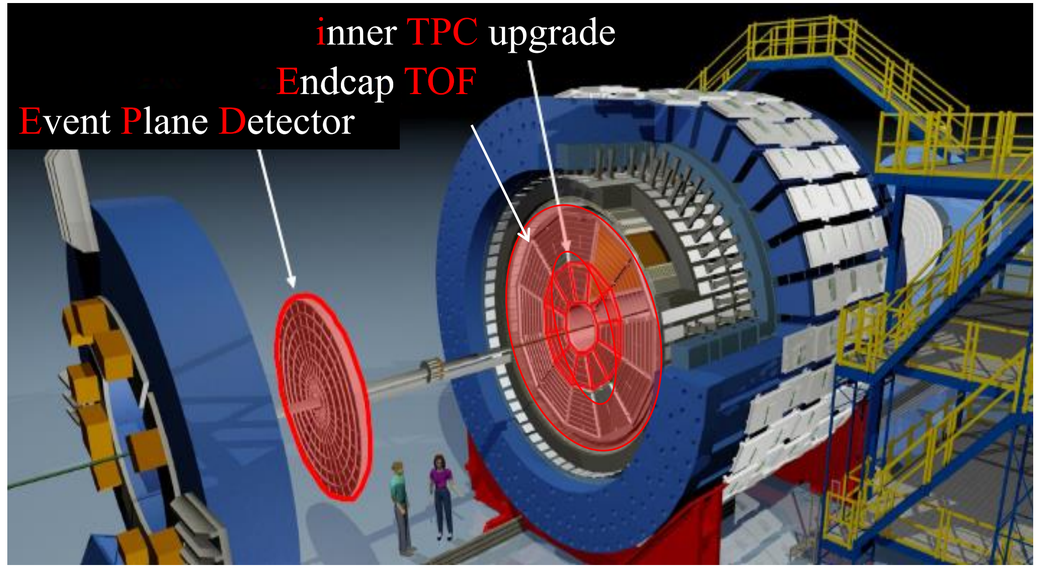
STAR Highlights

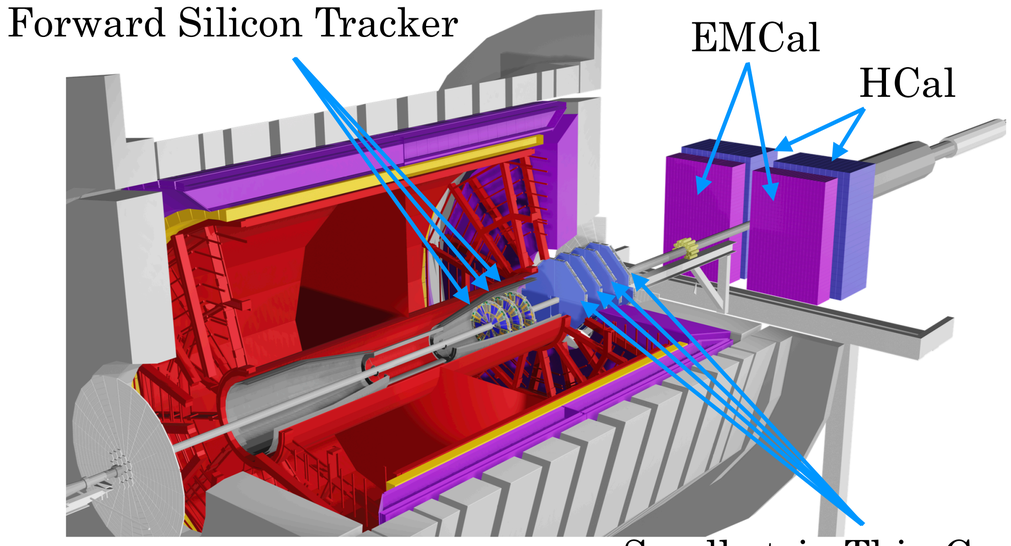
Takafumi Niida for the STAR Collaboration

筑波大学
University of Tsukuba

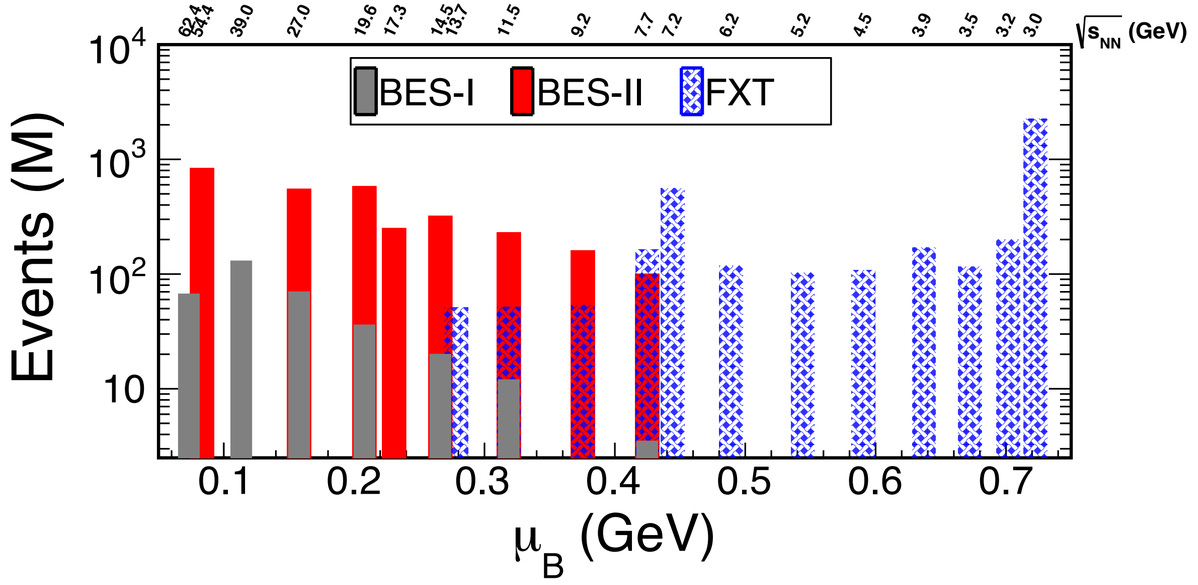
Supported in part by
U.S. DEPARTMENT OF ENERGY | Office of Science

STAR experiment





- Beam Energy Scan II was successfully completed with desired performance of BES-II detector upgrade (iTPC, eTOF, EPD)
  - 8 energies for 7.7 - 54.4 GeV (collider mode)
  - 12 energies for 3.0 - 13.7 GeV (fixed-target mode)
- Run-2022 p+p 508 GeV with STAR Forward Upgrade was successfully completed

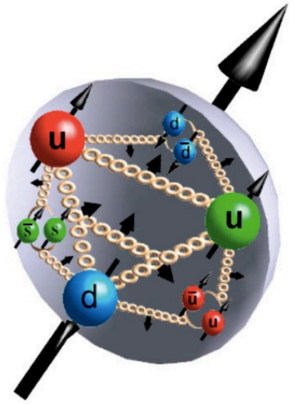


Outline

- Cold QCD/spin physics
- Hot QCD and UPC physics
  - Ultra-peripheral collisions
  - Chirality/vorticity
  - Collectivity
  - Hypernuclei
  - Fluctuations
  - Hard probes

A_{LL} with inclusive jets

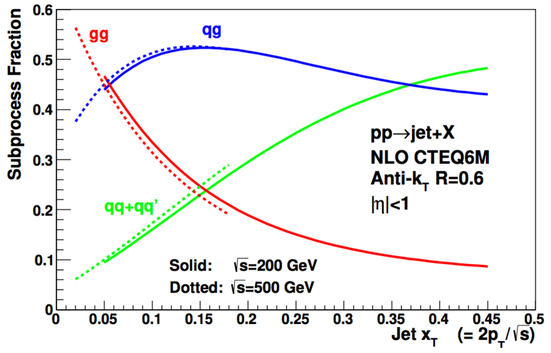
Talk by Jae Nam (6/8)



R.L.Jaffe and A.Manohar, NPB337.509(1990)

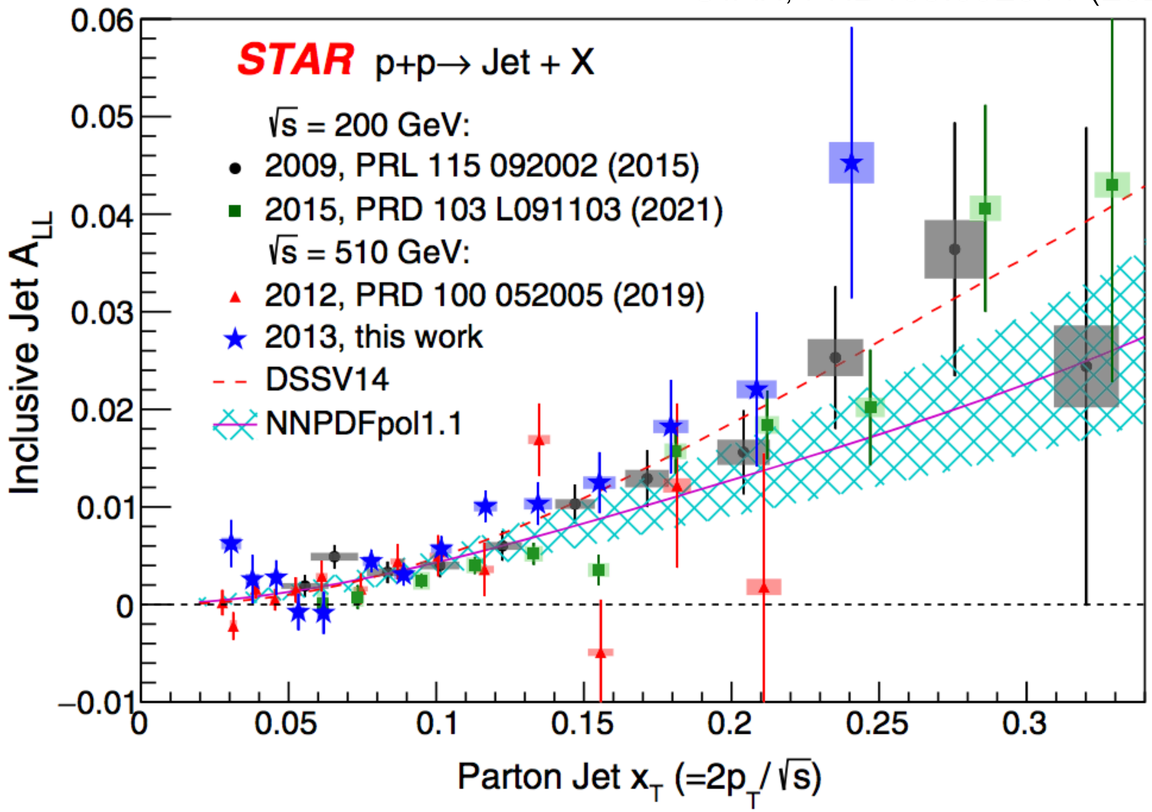
$$S = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L$$

quarks gluons orbital angular momentum



Midrapiidty jets at RHIC originate from qg and gg at low x_T

STAR, PRD105.092011 (2022)

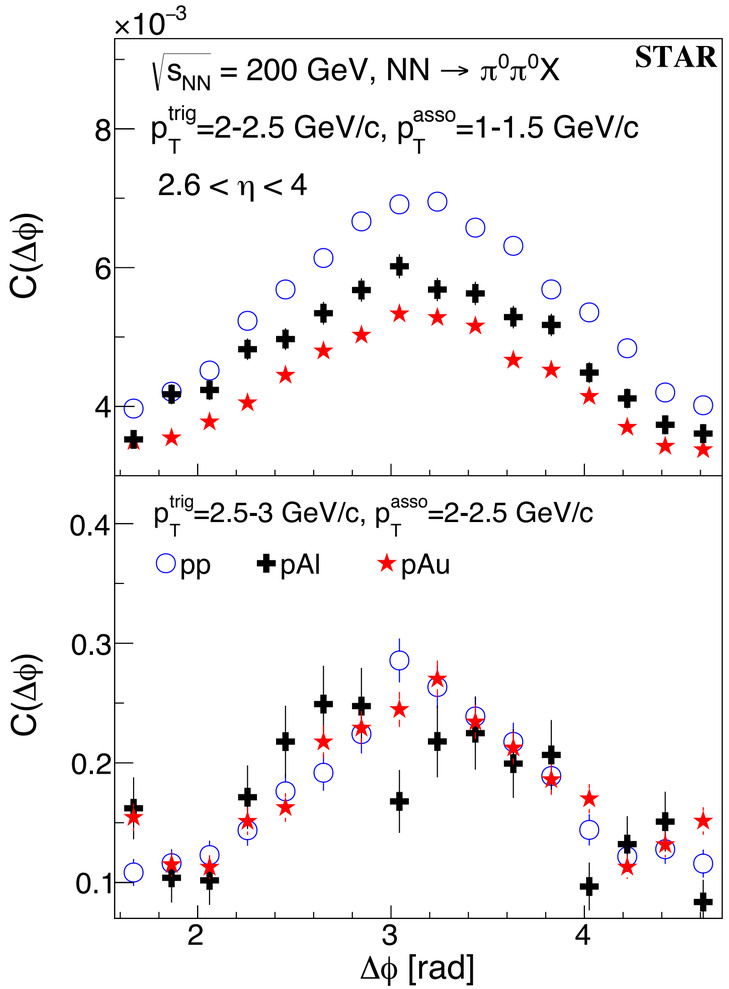


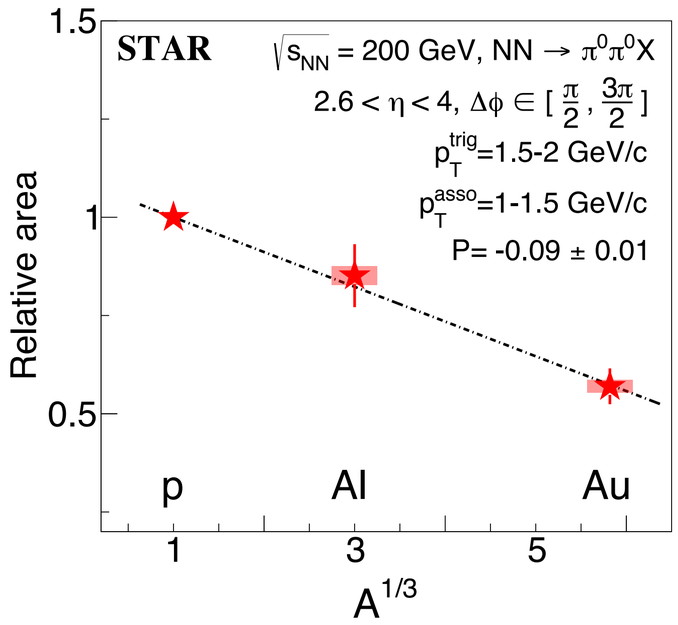
- Longitudinal double spin asymmetry A_{LL} with inclusive jets at midrapidity to probe gluon helicity distribution, extending to lower x by looking at higher energy (510 GeV)
- Improved precision by using the latest datasets (2013/2015)

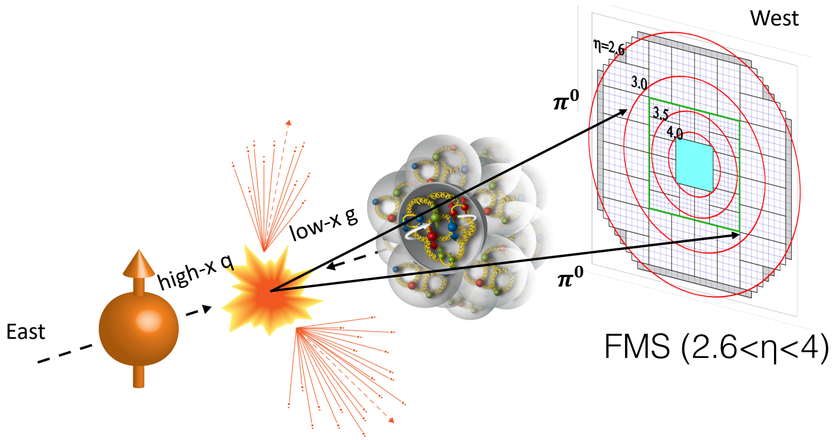
Nonlinear gluon effects in QCD

Talk by Jae Nam (6/8)
Talk by Oleg Eyser (6/8)

STAR, arXiv:2111.10396



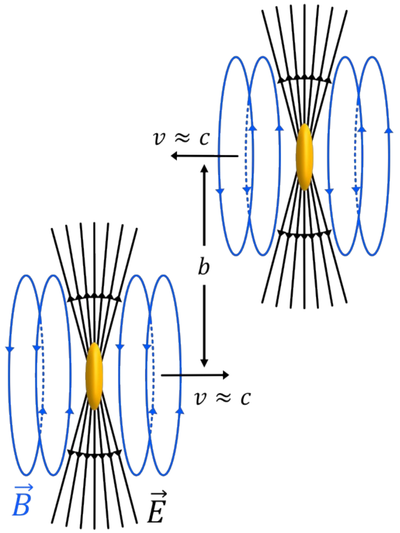


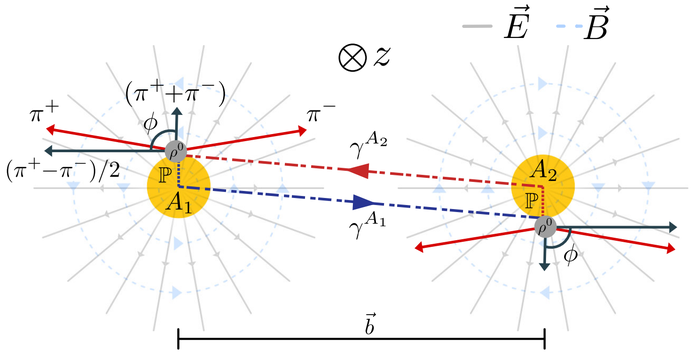


$$Q_s^2 \propto A^{1/3}(1/x)^{\lambda}$$

- Di-π^0 angular correlations at forward rapidity (2.6<η<4) probe high-density gluon field
- Clear suppression of back-to-back pairs in pAl & pAu compared to pp and the relative area scales with $A^{1/3}$, consistent with the expectation from gluon saturation
  - No broadening of the away-side peak

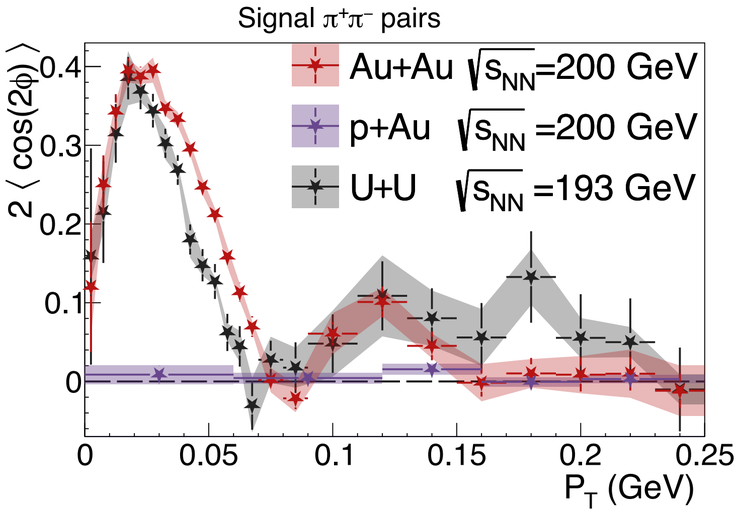
Tomography of nuclei with photon induced process

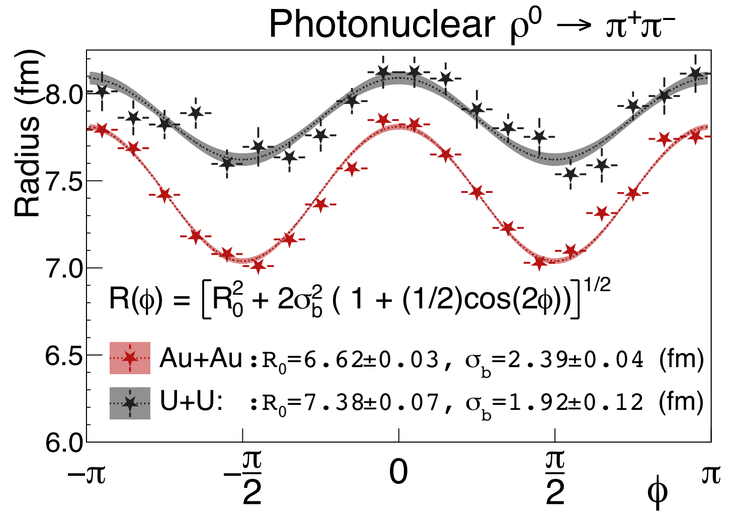




STAR, arXiv:2204.01625

- Transverse linearly polarized photons due to Lorentz contracted EM-field
- Photonuclear production of vector mesons in UPC, e.g. $\gamma\mathbb{P} \rightarrow \rho^0 \rightarrow \pi^+\pi^-$
- Quantum interference with the polarized photons leads to cos(2ϕ) modulation of final state $\pi^+\pi^-$ cf. double slit experiment
- Sensitive to nuclear mass (strong-interaction) radius

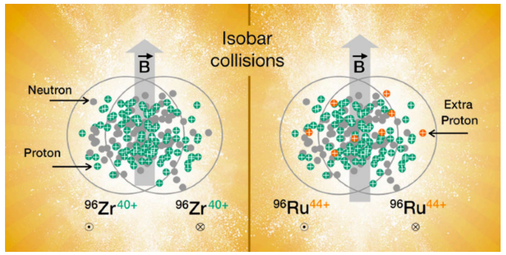


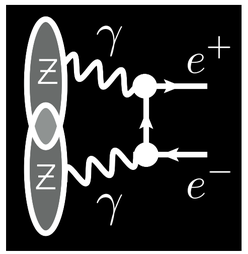


Talk by Nicole Lewis (6/7)

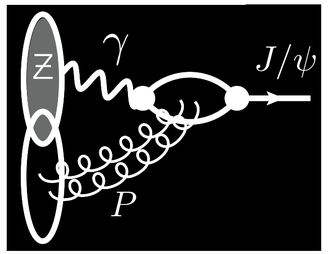
Probing EM-field difference in isobars via γγ/γA reactions

Talk by Nicole Lewis (6/7)

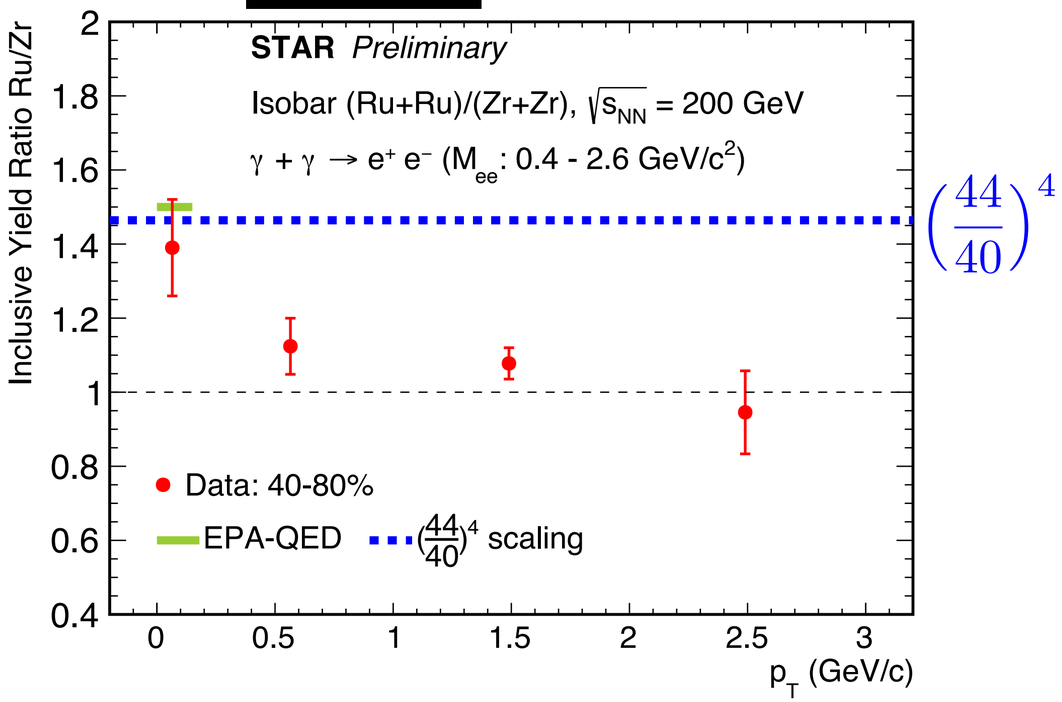




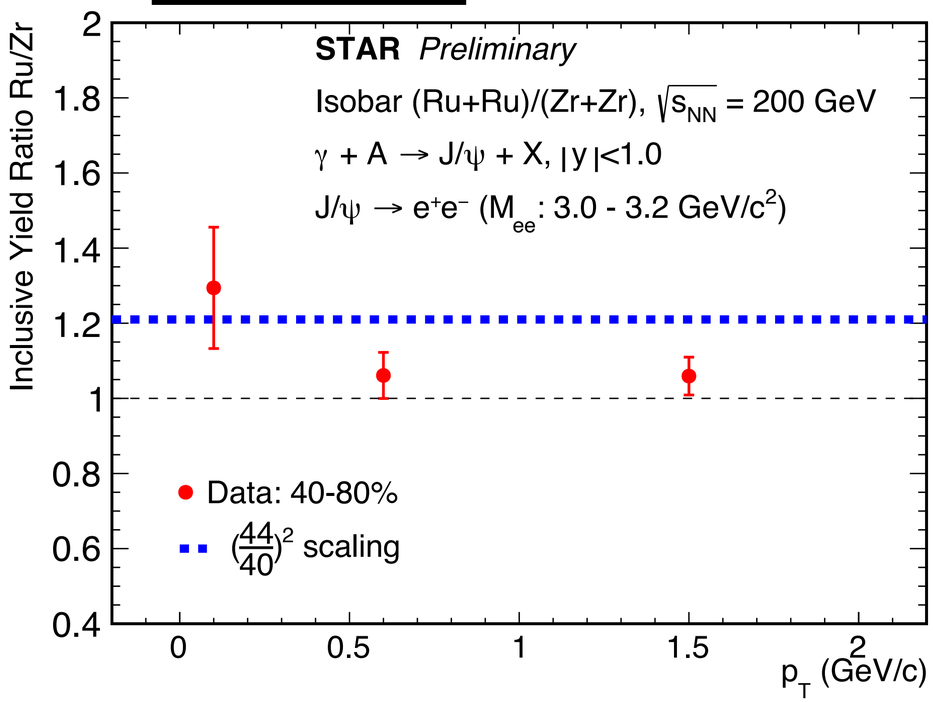
$$\sigma(\gamma\gamma \to e^+e^-) \sim Z^4$$



$$\sigma(\gamma \mathrm{A} \to J/\psi \mathrm{A}) \sim Z^2$$



$$\left(\frac{44}{40}\right)^4$$



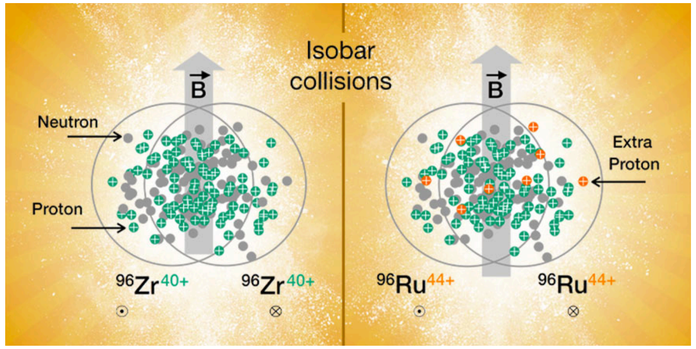
$$\left(\frac{44}{40}\right)^2$$

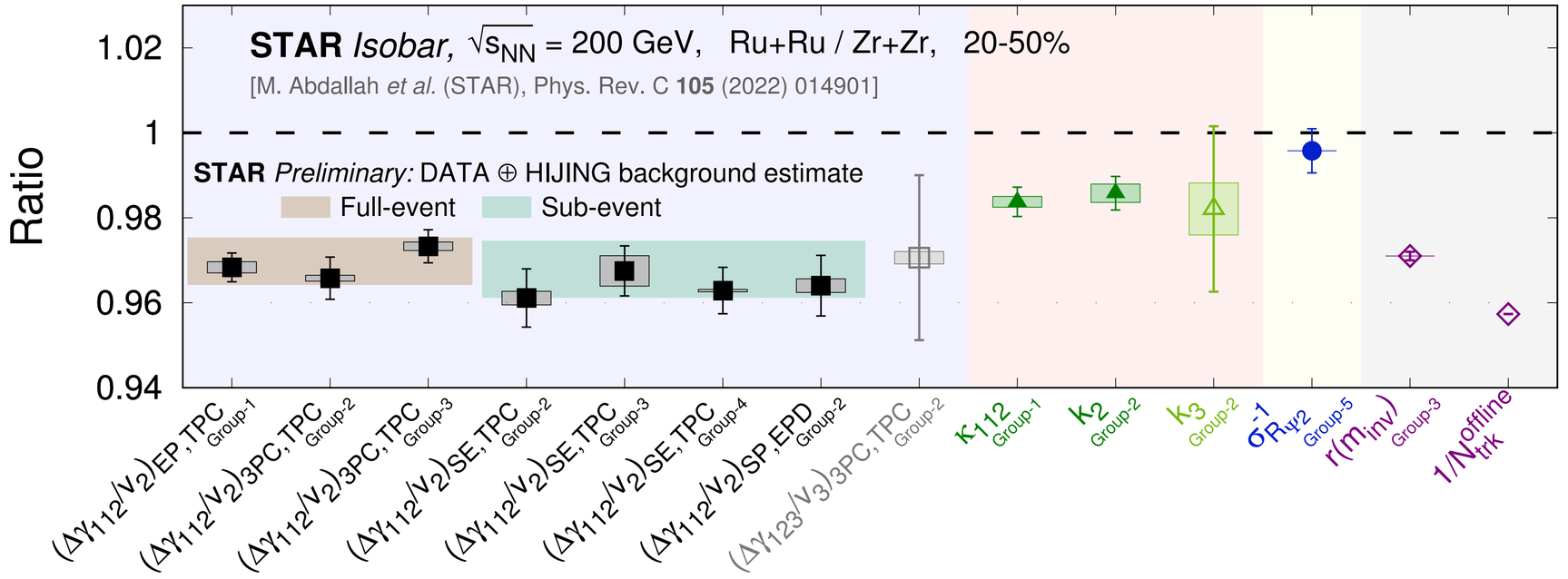
- Dilepton (J/Ψ) production at very low p_T is dominated by γγ (γA) reactions
- The data suggest "Z" scaling due to EM-field difference in isobars as expected

W. Zha et al., PLB789(2019)238

Search for chiral magnetic effect in isobar collisions

STAR, PRC105.014901 (2022)



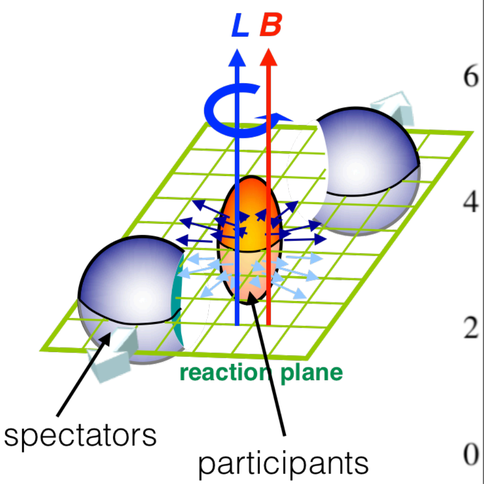


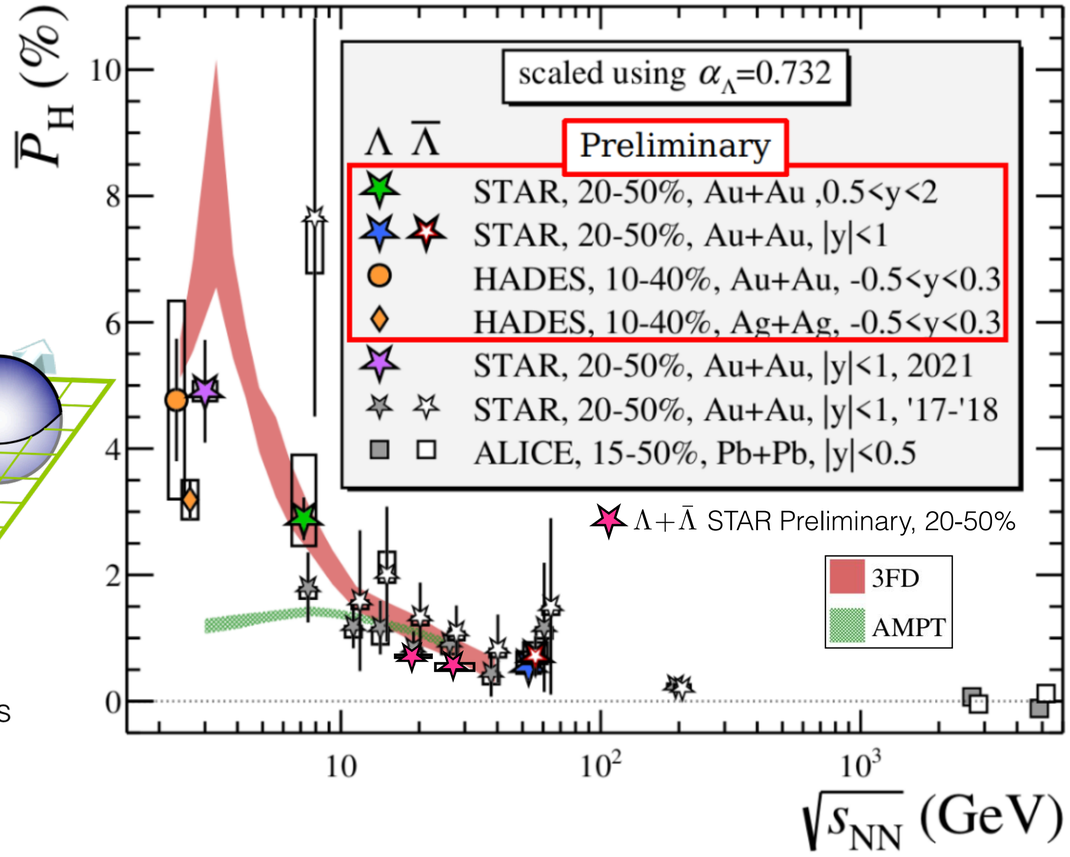
- Precision of 0.4% was achieved but no pre-dfined signature of CME was observed
- Updated estimate of non-flow BG using HIJING, consistent with the data

Talk by Evan Finch (6/10)
Poster by Yicheng Feng

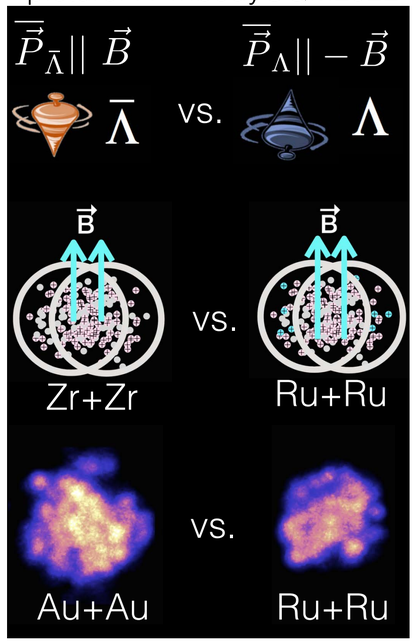
Global polarization

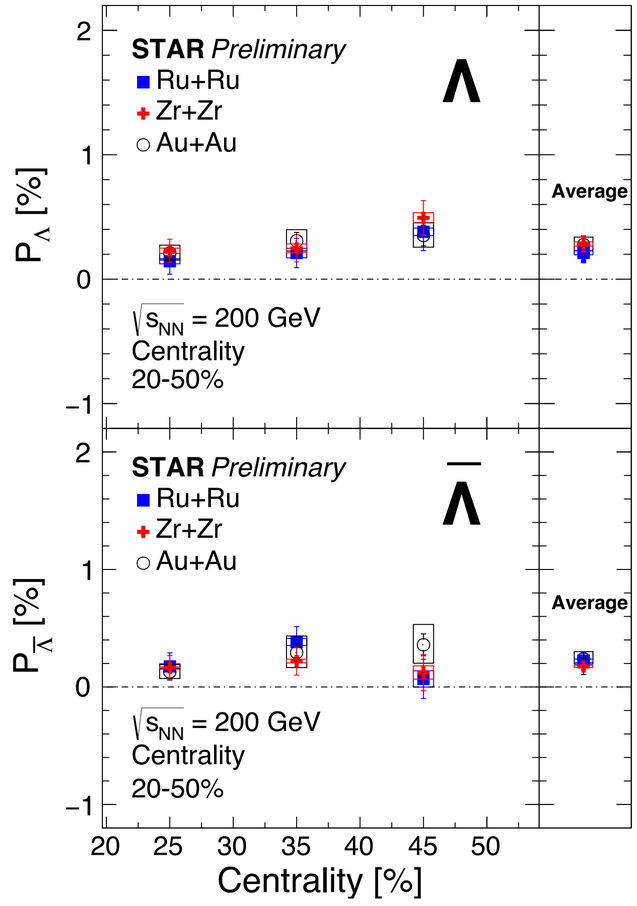
STAR, PRC104.L061901 (2021)
HADES, SQM2021





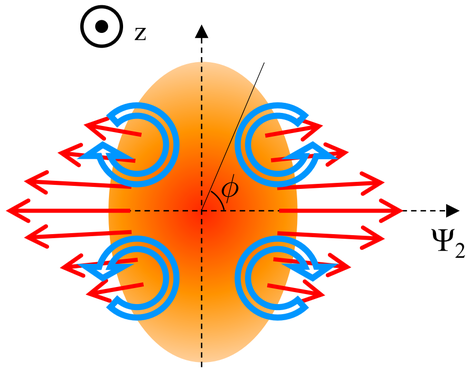
picture: P. Tribedy@QM2022

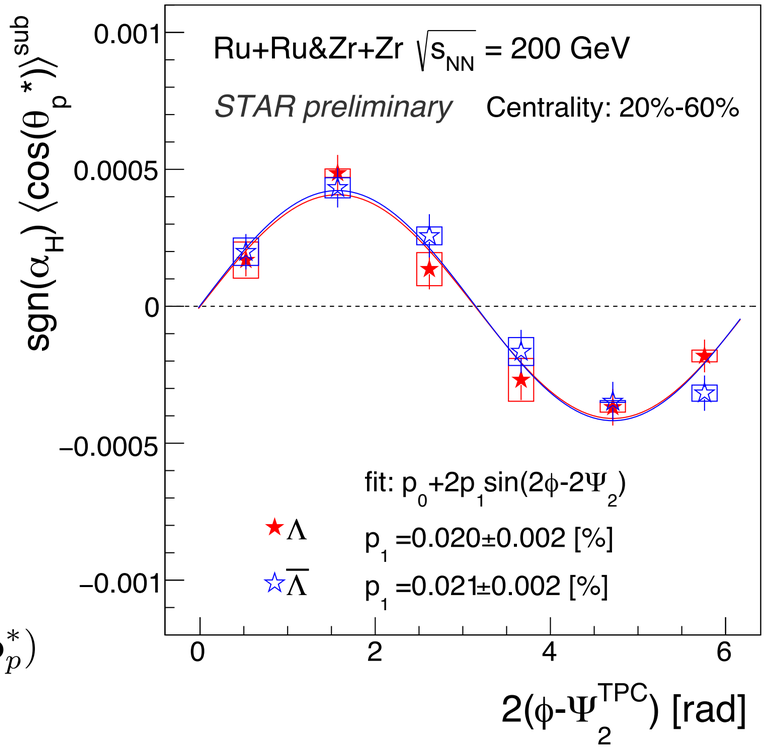


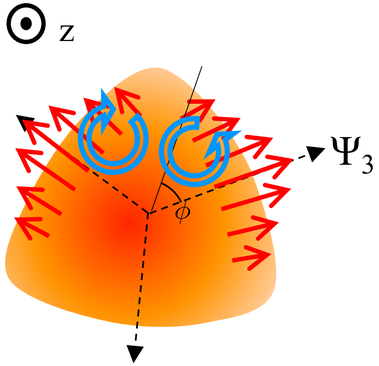


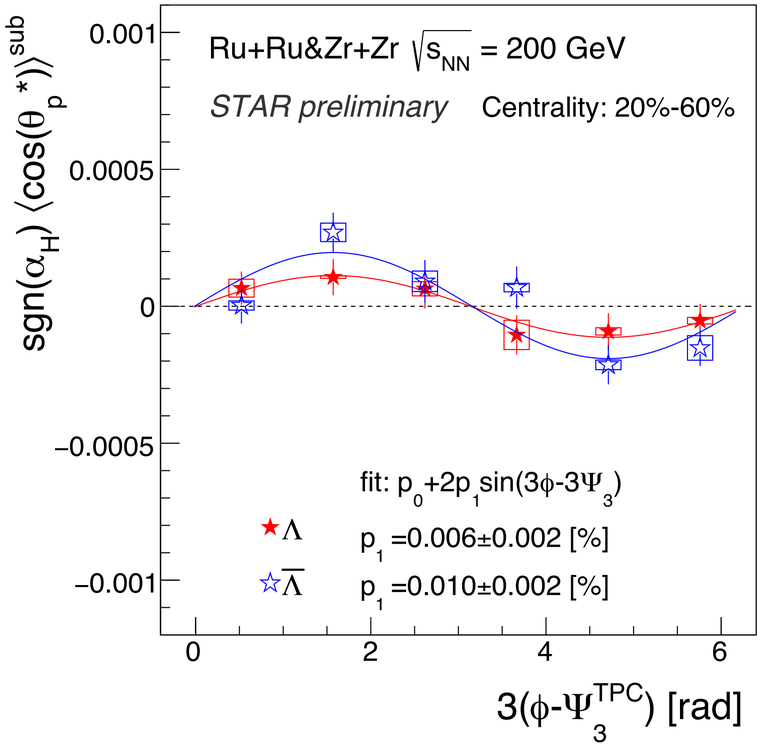
- Still increasing trend down to $\sqrt{s_{NN}}$ = 3 GeV (FXT). Results from BES-II (3, 7.2, 19.6, 27, 54.4 GeV) follow the global trend. More results will come!
- No colliding system size dependence nor splitting between Λ and anti-Λ in isobar collisions

Local polarization in isobar collisions









$$\frac{dN}{d\Omega^*} = \frac{1}{4\pi}(1+\alpha_H \mathbf{P_H}\cdot\mathbf{p}_p^*)$$

$$\langle\cos\theta_p^*\rangle = \int \frac{dN}{d\Omega^*}\cos\theta_p^* d\Omega^*$$

$$= \alpha_H P_z \langle(\cos\theta_p^*)^2\rangle$$

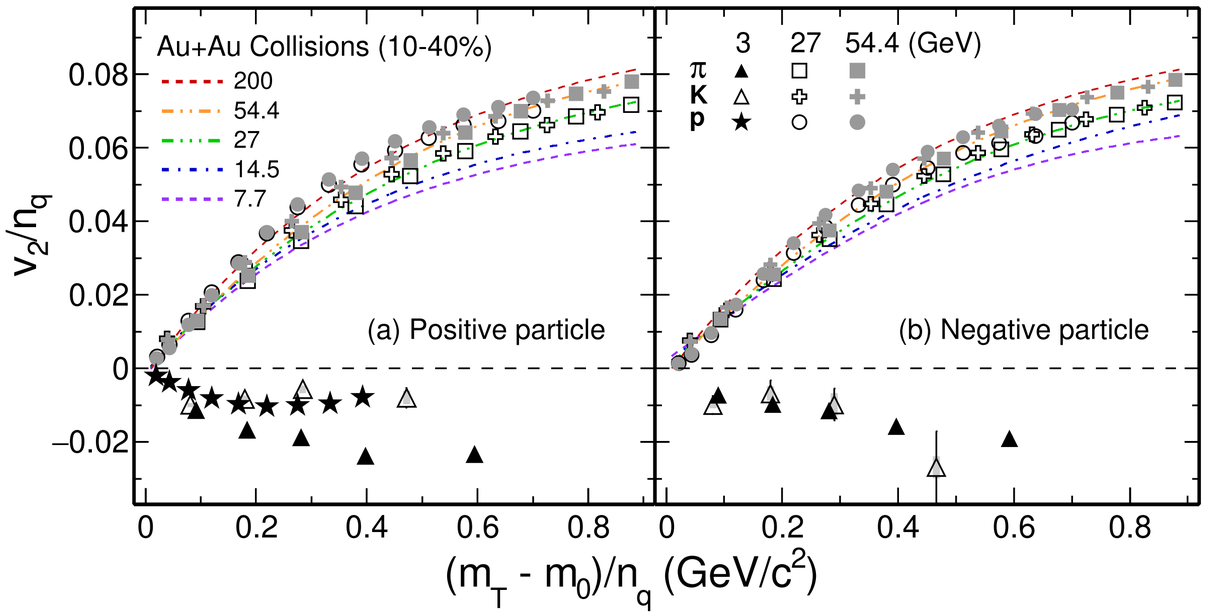
$$\therefore\ P_z = \frac{\langle\cos\theta_p^*\rangle}{\alpha_H\langle(\cos\theta_p^*)^2\rangle}$$

- Clear Ψ_2 dependence as seen in Au+Au at 200 GeV
- First measurement relative to the 3rd-order event plane Ψ_3!
  - Similar pattern to the 2nd-order, indicating v_3-driven polarization

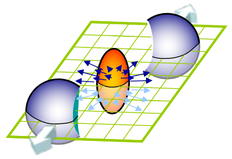
Collectivity at $\sqrt{s_{NN}}$ = 3 GeV

Talk by Xionghong He (6/7)

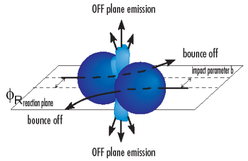
STAR, PLB827(2022)137003



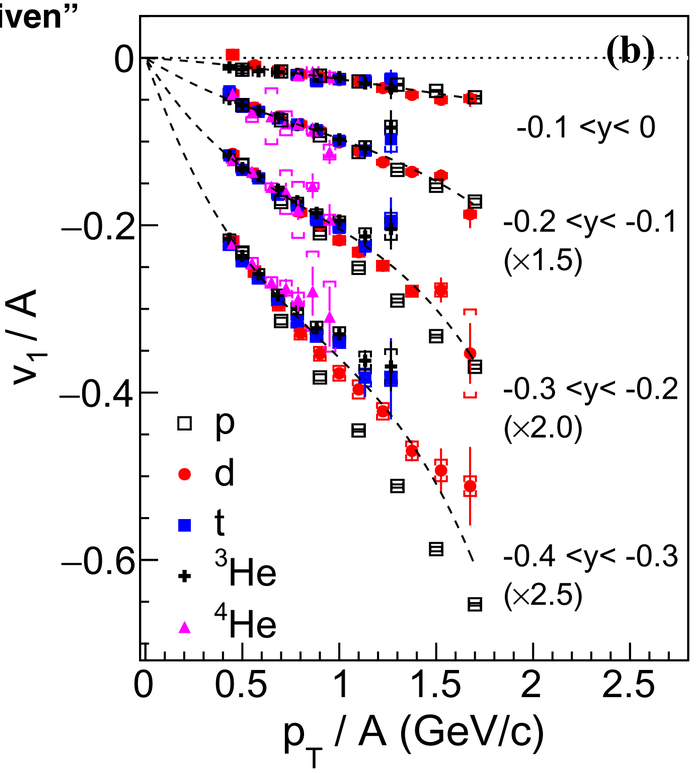
"pressure-gradient driven"



"squeeze-out"



STAR, PLB827(2022)136941

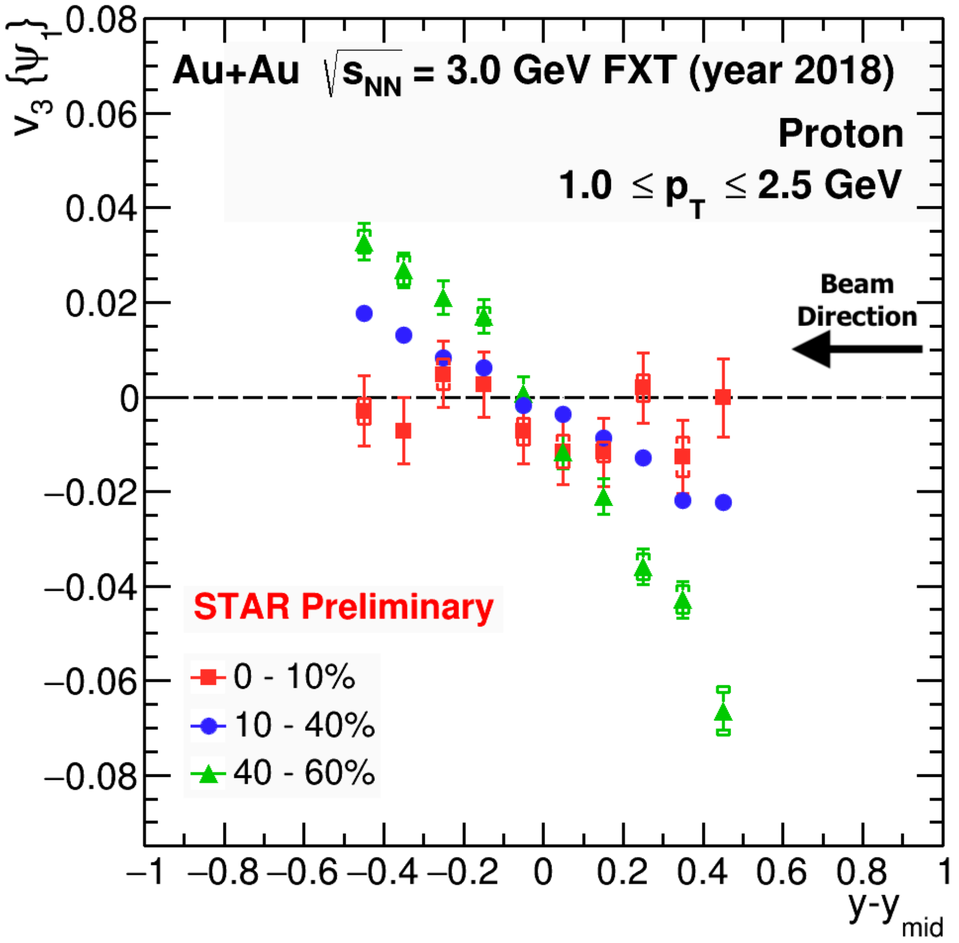


- At 3 GeV, NCQ scaling is absent with negative v_2 which is described by hadronic transport with baryonic interactions
- Atomic mass number (A) scaling of light nuclei v_1 is observed, consistent with nucleon coalescence picture

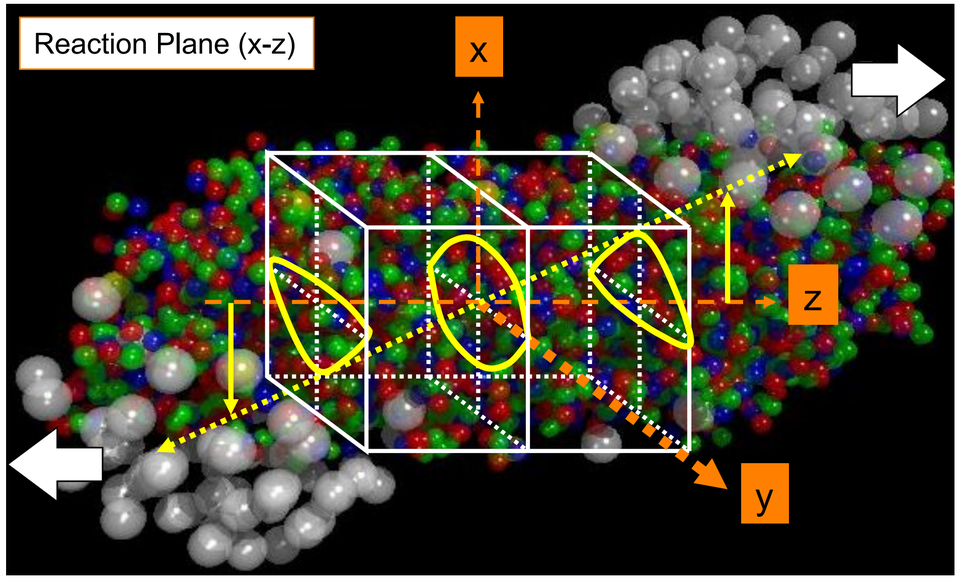
$$v_n^A(p_T, y)/A \approx v_n^p(p_T/A, y).$$

Rapidity-odd v_3 w.r.t. Ψ_1

Talk by Xionghong He (6/7)



picture: S. Esumi@WWND2011

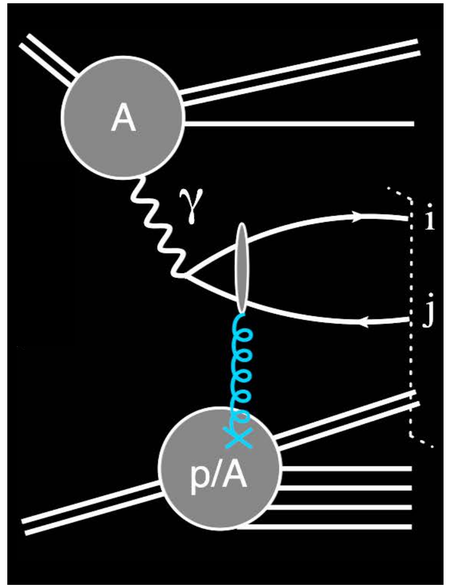


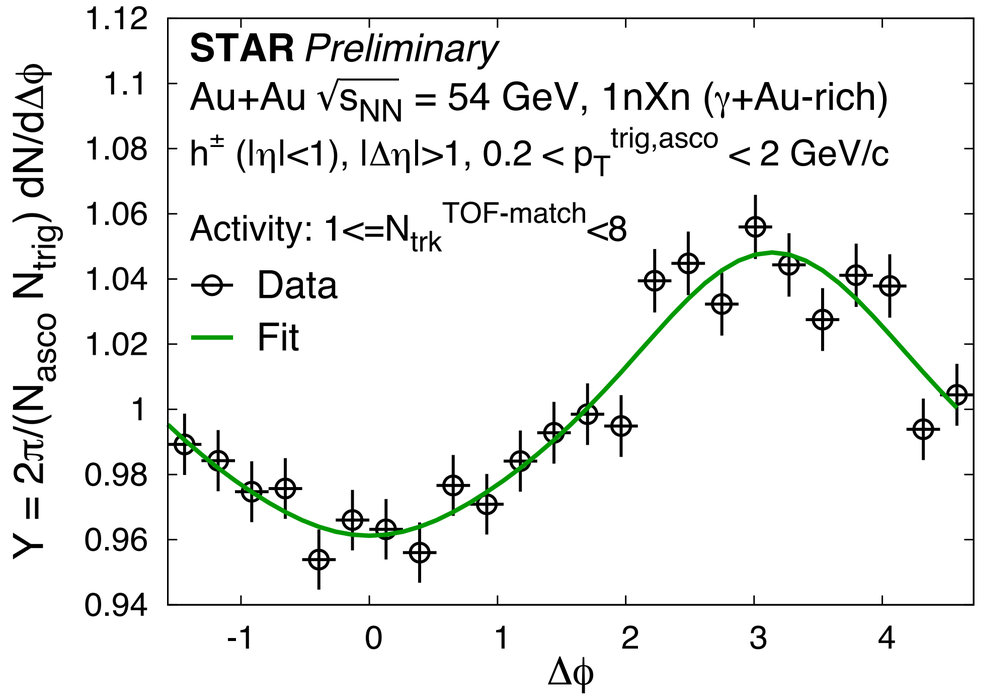
- First measurement of rapidity-odd v_3 with respect to the first-order event plane at $\sqrt{s_{NN}}$ = 3 GeV, indicating a correlation between v_1 and v_3
- Sensitive to the 3D initial geometry and EOS

P. Hillmann et al., J.Phys.G: Nucl. Part. Phys. 45, 085101 (2018)

Search for collectivity in γ+A collisions

picture: P. Tribedy@QM2022





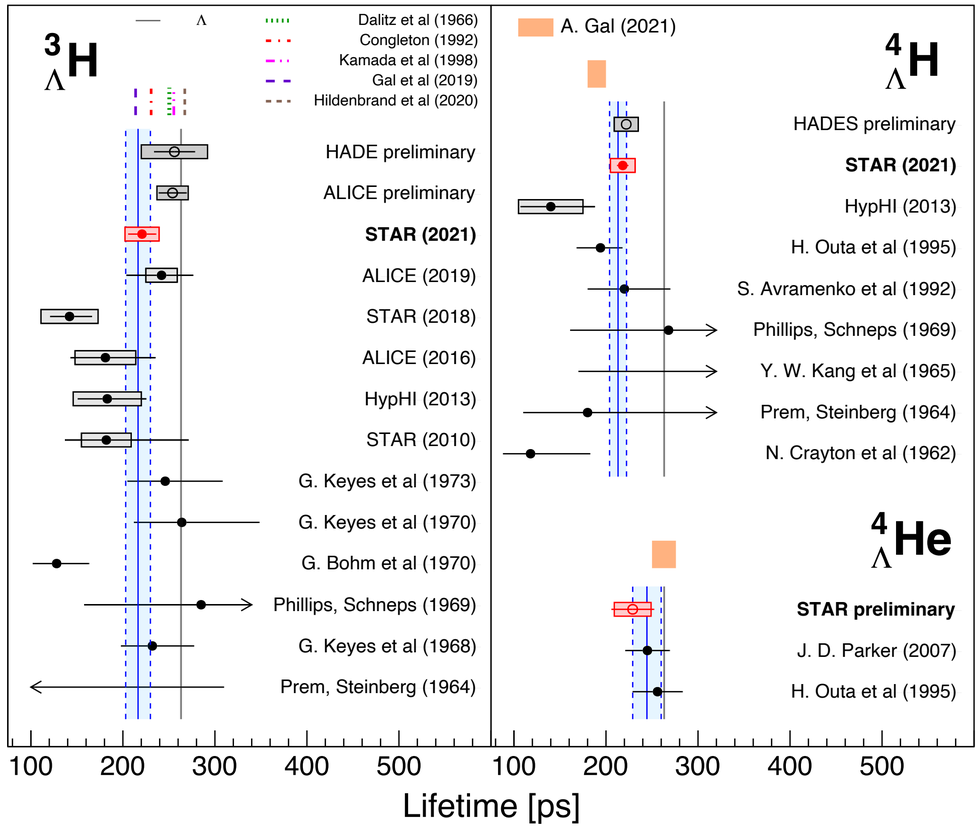
- Dihadron correlations in photon+nucleus process for $\sqrt{s_{NN}}$ = 54.4 GeV Au+Au collisions
- No obvious signature of collectivity (near-side ridge) in the γ+A collisions
- To be further explored at 200 GeV with STAR forward upgrade

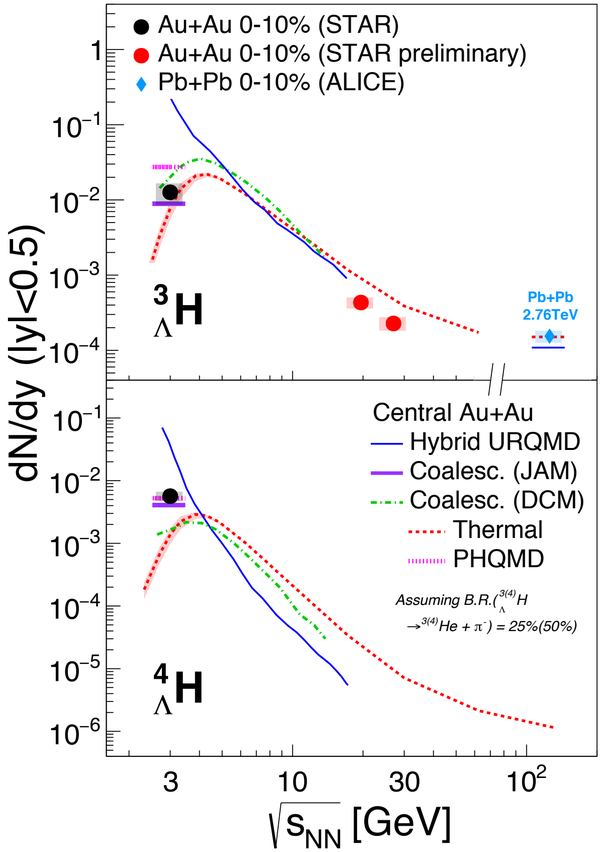
Talk by Nicole Lewis (6/7)

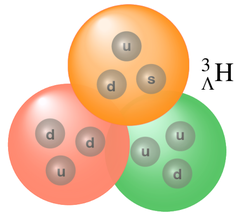
Hypernuclei lifetime and production

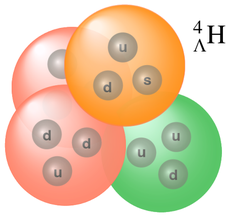
Talk by Xiujun Li (6/7)

STAR, PRL128.202301 (2022)





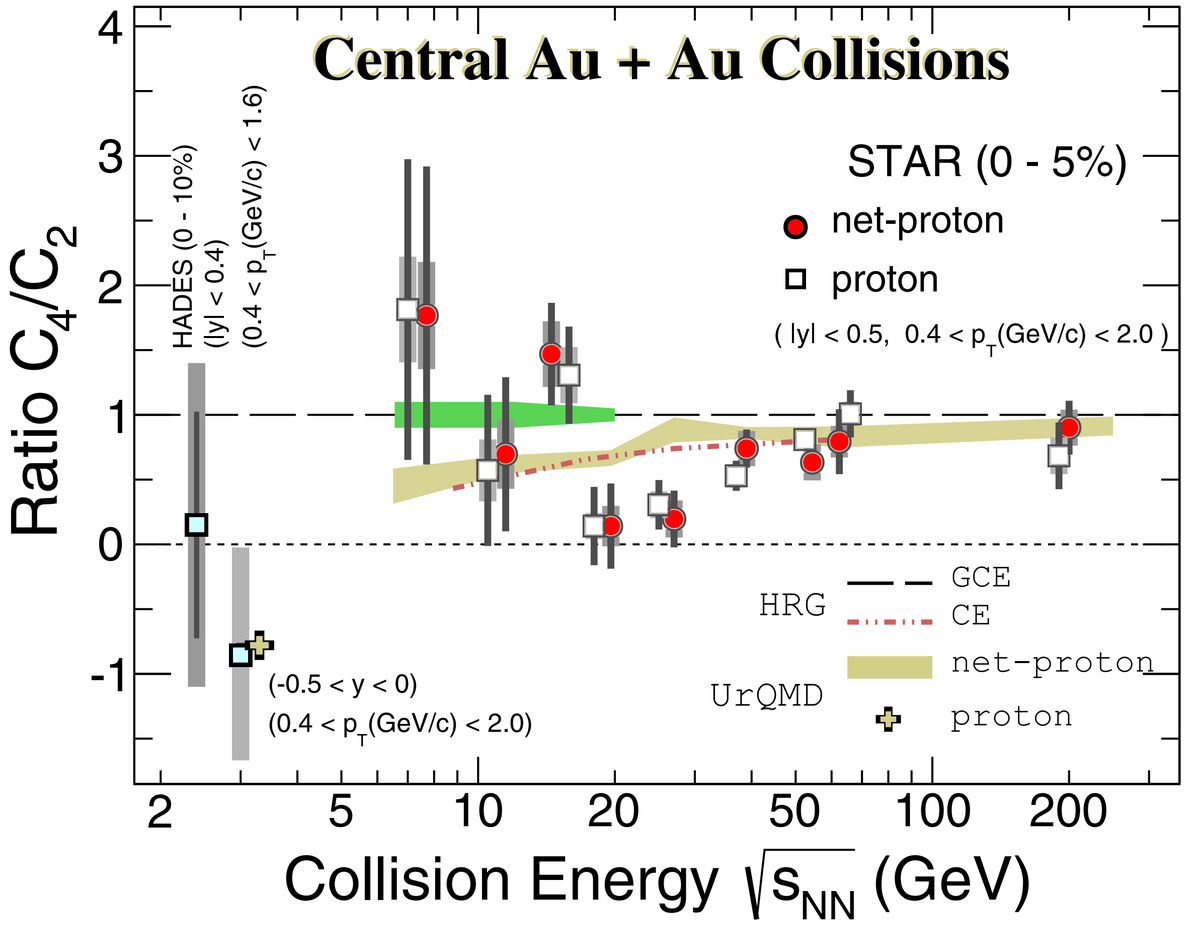




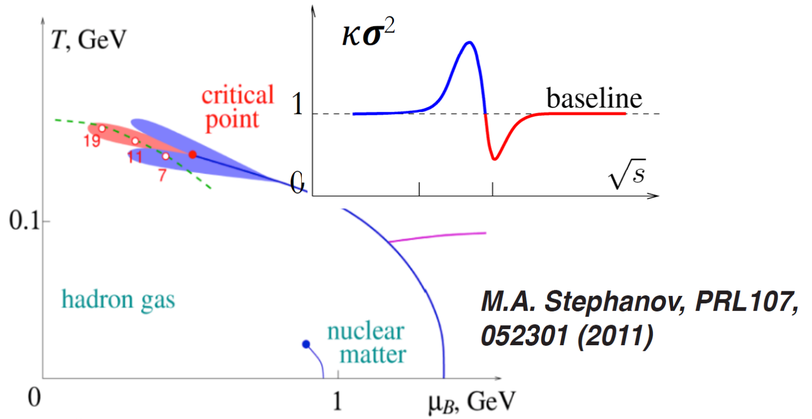
Thermal model/transport models based on coalescence of nucleons capture the trend but not quantitatively

- First measurement of $^{4}_{\Lambda}\mathrm{He}$ lifetime in heavy-ion collisions as well as precise measurements of $^{3}_{\Lambda}\mathrm{H}$ and $^{4}_{\Lambda}\mathrm{H}$ lifetimes; important inputs for understanding YN interaction
- New results at 3 GeV provide constraints on production mechanism of hypernuclei in baryon-rich system

QCD CP search by net-proton fluctuations



STAR, PRL126.092301 (2021)
STAR, PRL128.202303 (2022)

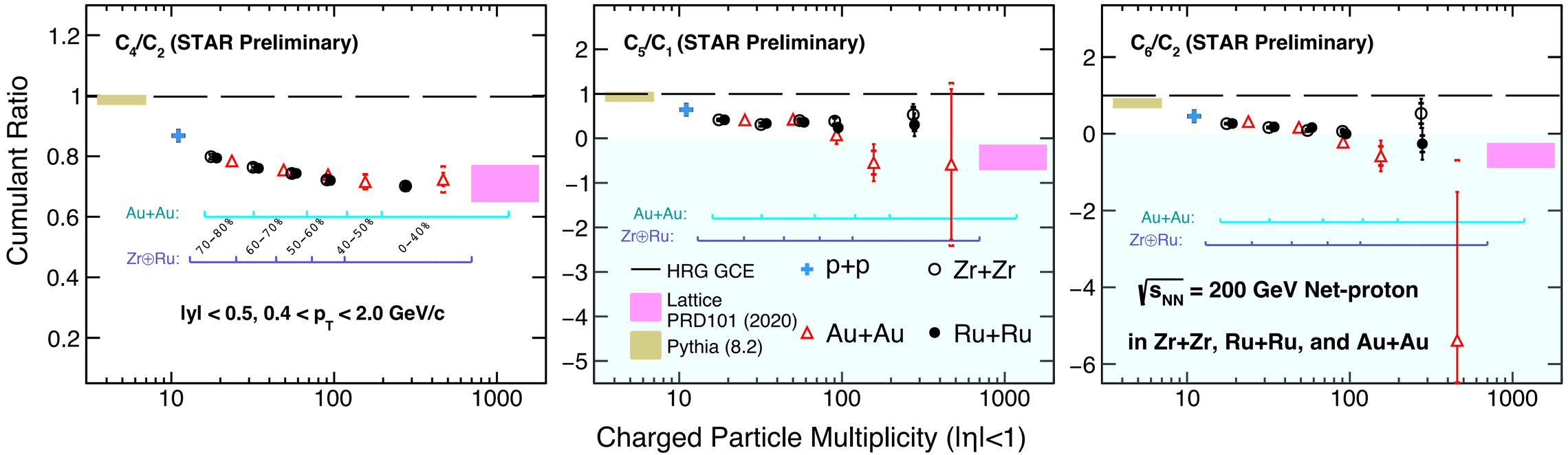


- Non-monotonic energy dependence observed (~3σ)
- New result at 3 GeV, consistent with baryon number conservation (UrQMD), implies that CP could exist only at $\sqrt{s_{NN}}$ > 3 GeV, if any
- More precise results from BES-II will come!

Talk by Ashish Pandav (6/7)

Search for the chiral crossover

- New results of net-proton fluctuations in isobar collisions
- Higher order cumulant ratios decrease with multiplicity from p+p to Ru+Ru&Zr+Zr and then to Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV, approaching LQCD calculations that predict crossover of thermalized medium near $\mu_B = 0$

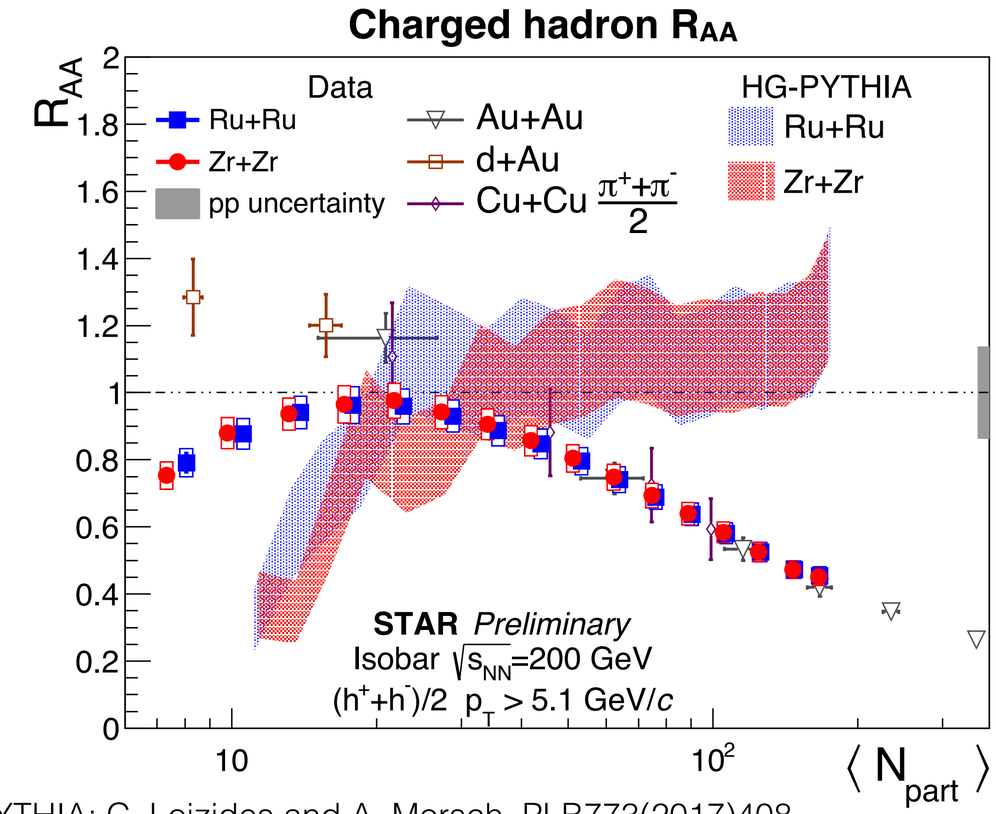


STAR, PRL127.262301 (2021)

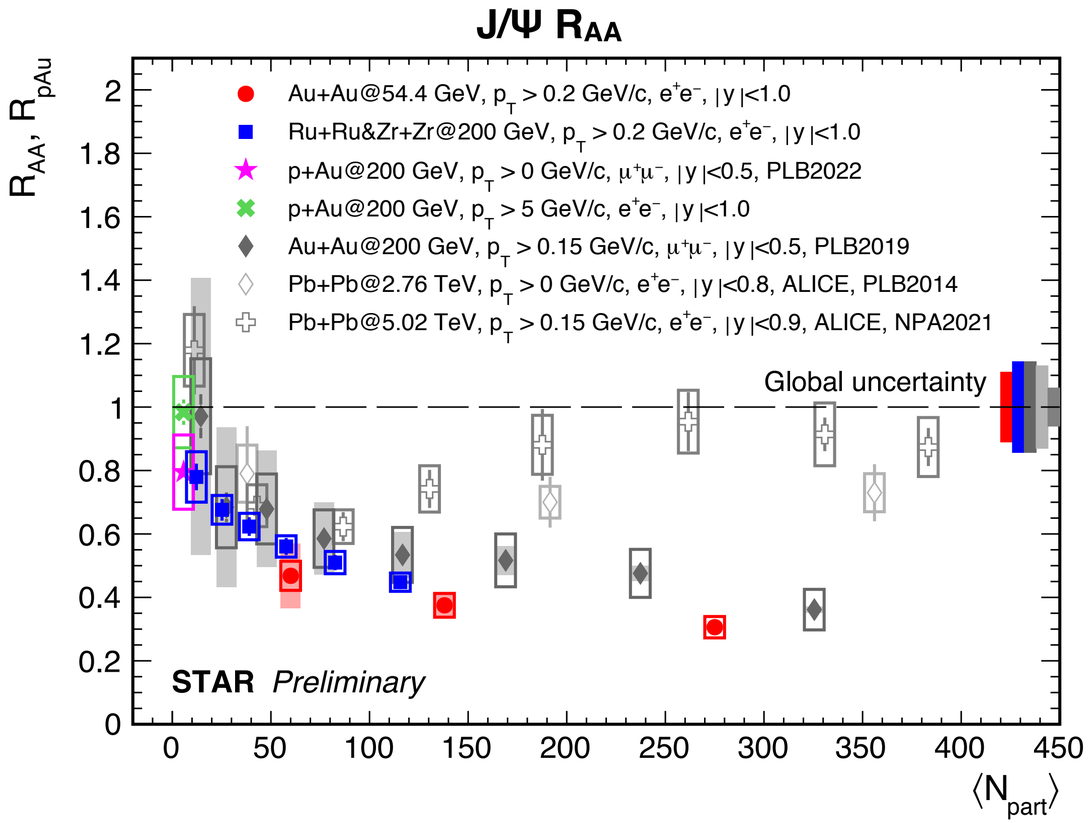
Talk by Ashish Pandav (6/7)

Hadron suppression in isobar collisions

Talk by Sooraj Radhakrishnan (6/8)



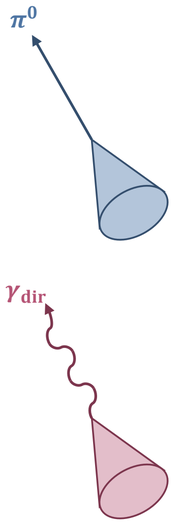
HG-PYTHIA: C. Loizides and A. Morsch, PLB773(2017)408

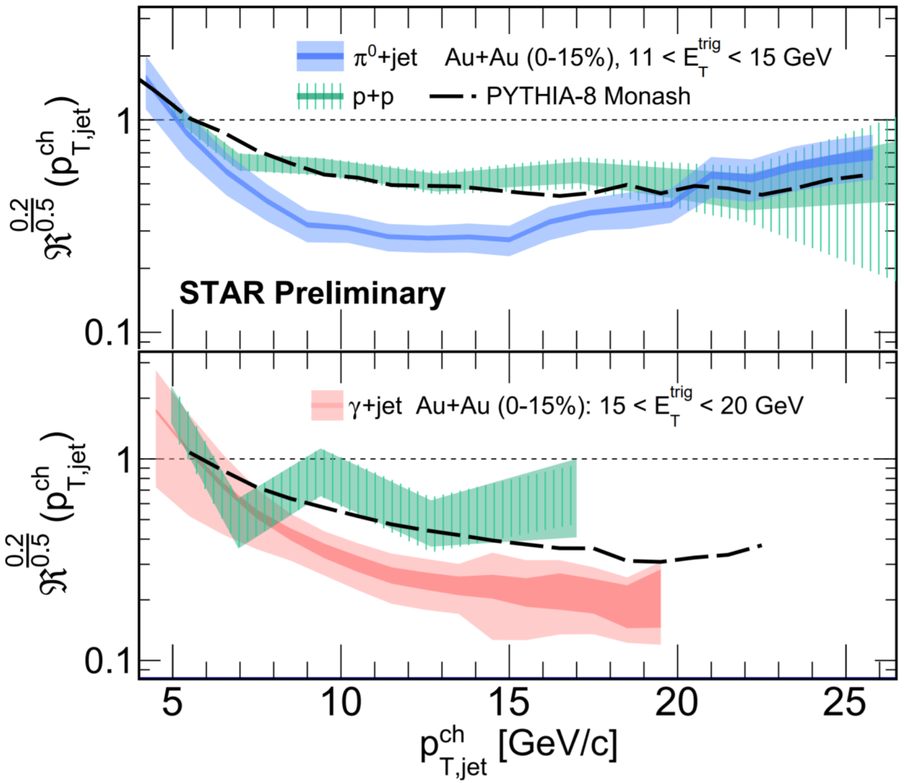


- Same R_{AA} of charged hadrons for a given N_{part} regardless of collision system; possible centrality bias in peripheral events
- Similarly, J/Ψ R_{AA} vs. N_{part} in isobars is comparable to that in Au+Au

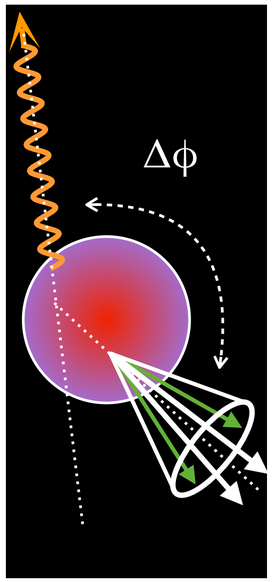
Semi-inclusive π^0/γ+jets

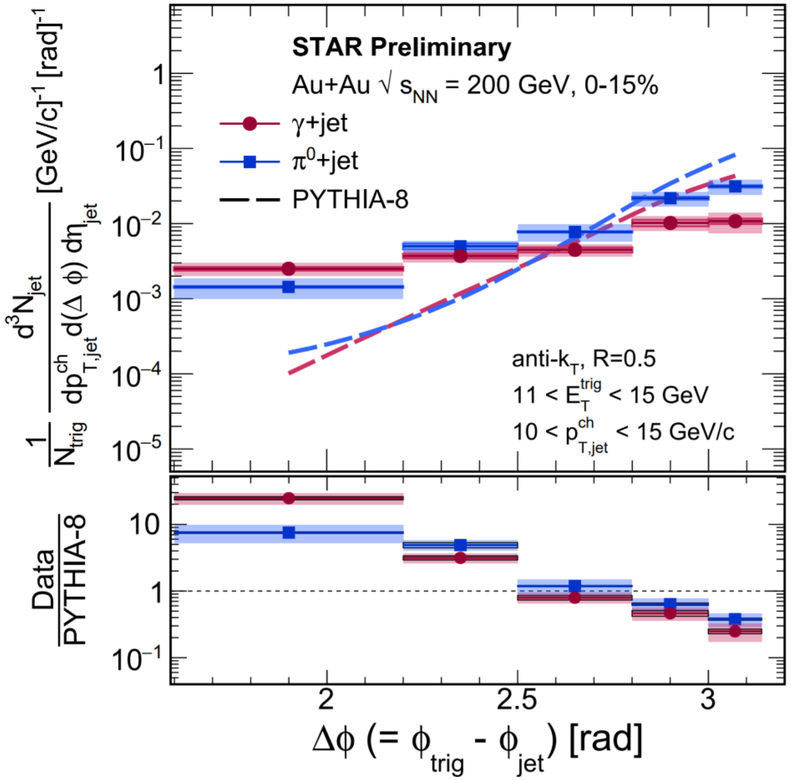
Talk by Sooraj Radhakrishnan (6/8)
Poster by Derek Anderson





picture: P. Tribedy@QM2022



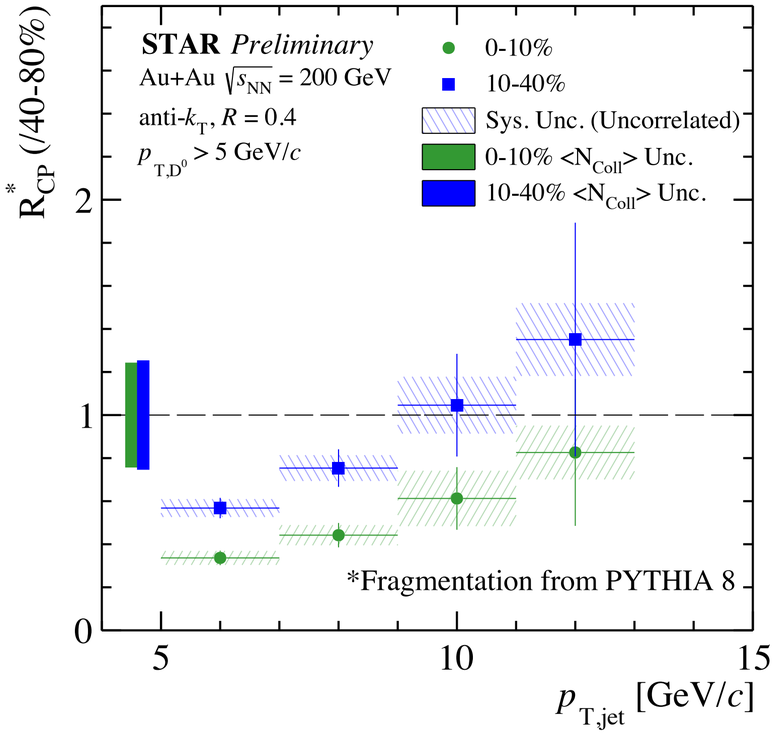


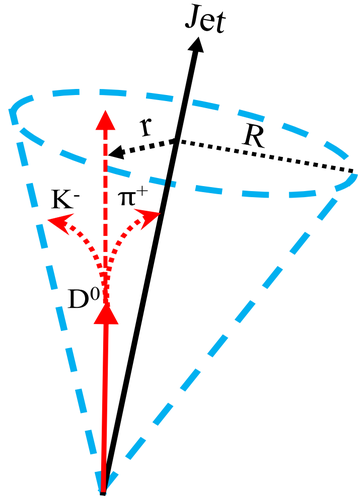
- Ratio of recoil jet yields for R = 0.2 vs. 0.5 in Au+Au is suppressed relative to that in p+p
- Excess at large angle in angular correlation of π^0/γ and jets in Au+Au relative to p+p

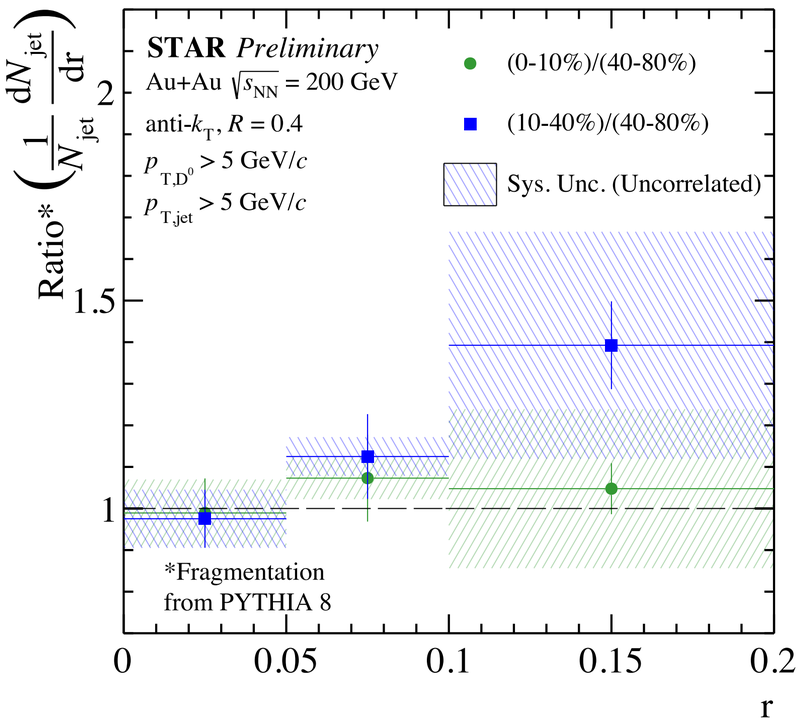
→ Medium-induced broadenings of intra-jet distribution and acoplanarity

Heavy flavor tagged jets

Talk by Sooraj Radhakrishnan (6/8)

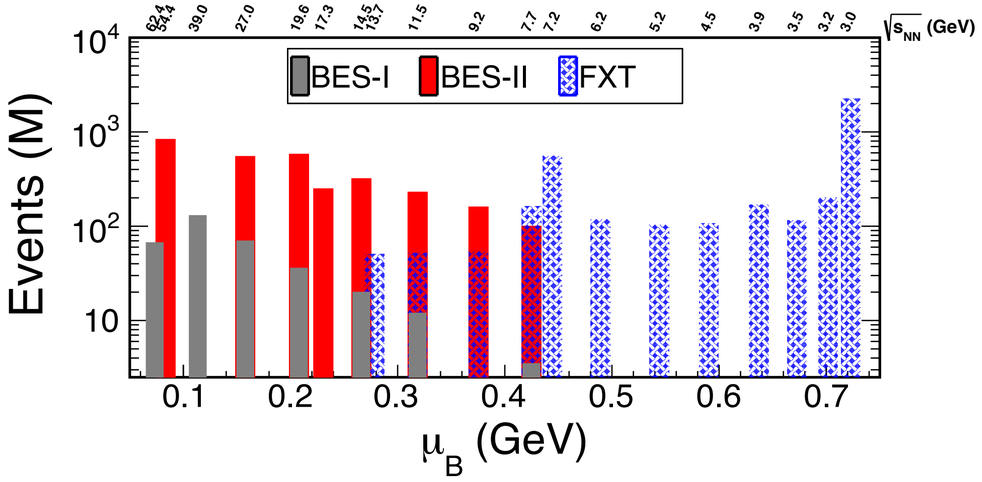




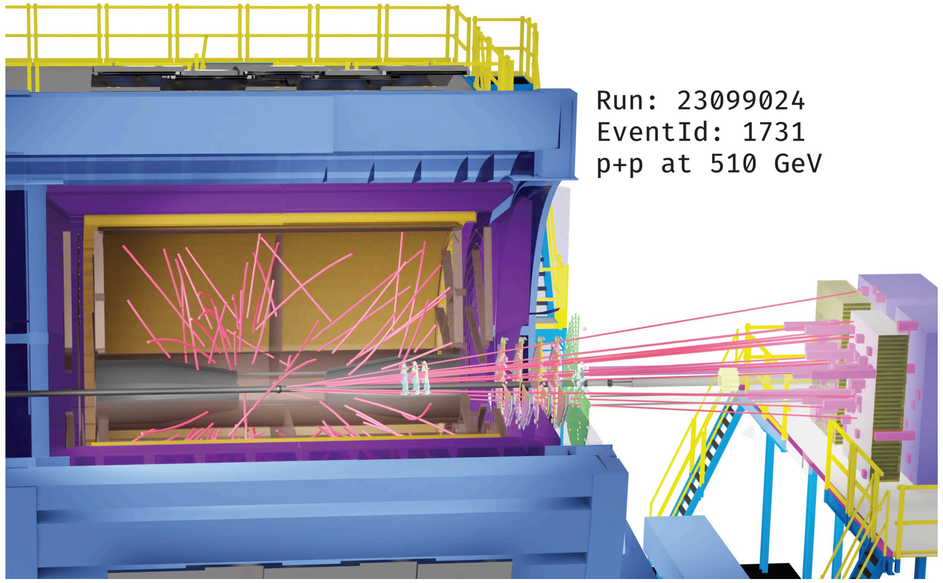


- First measurement of D^0-tagged jets at RHIC
  - R_{cp} shows suppression at low pT
  - Radial profile of D^0 (p_T>5 GeV/c) in jets is consistent with unity. To be explored with low p_T D^0 to study the effect of HF diffusion.

Summary



- Many interesting results from Cold QCD and Hot QCD physics programs at STAR
  - New results from high statistics isobar and BES-II data
  - More results from full BES-II data will come soon



- STAR Forward upgrade subsystems were installed, commissioned, and successfully operated during Run-22
- Many interesting physics with the Forward upgrade in 2023+

Back up