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Recent highlights from the STAR experiment

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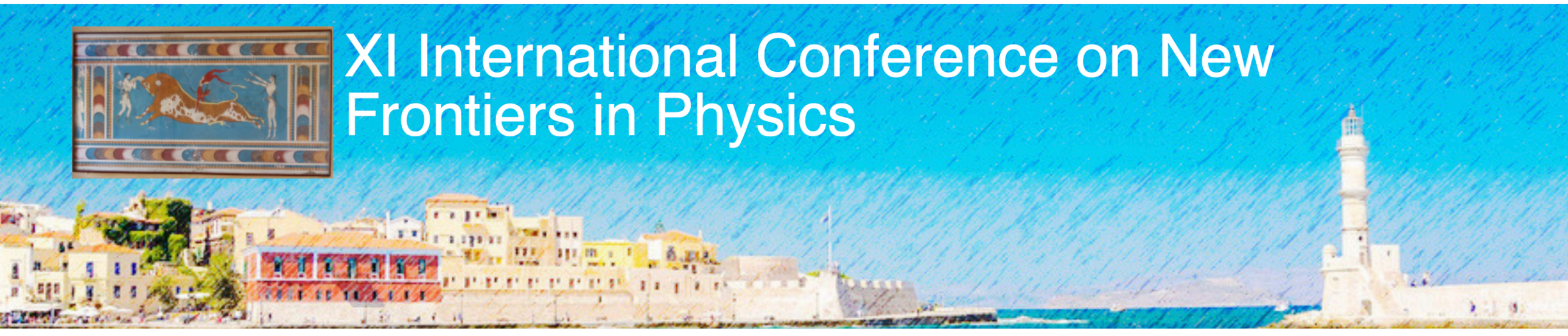
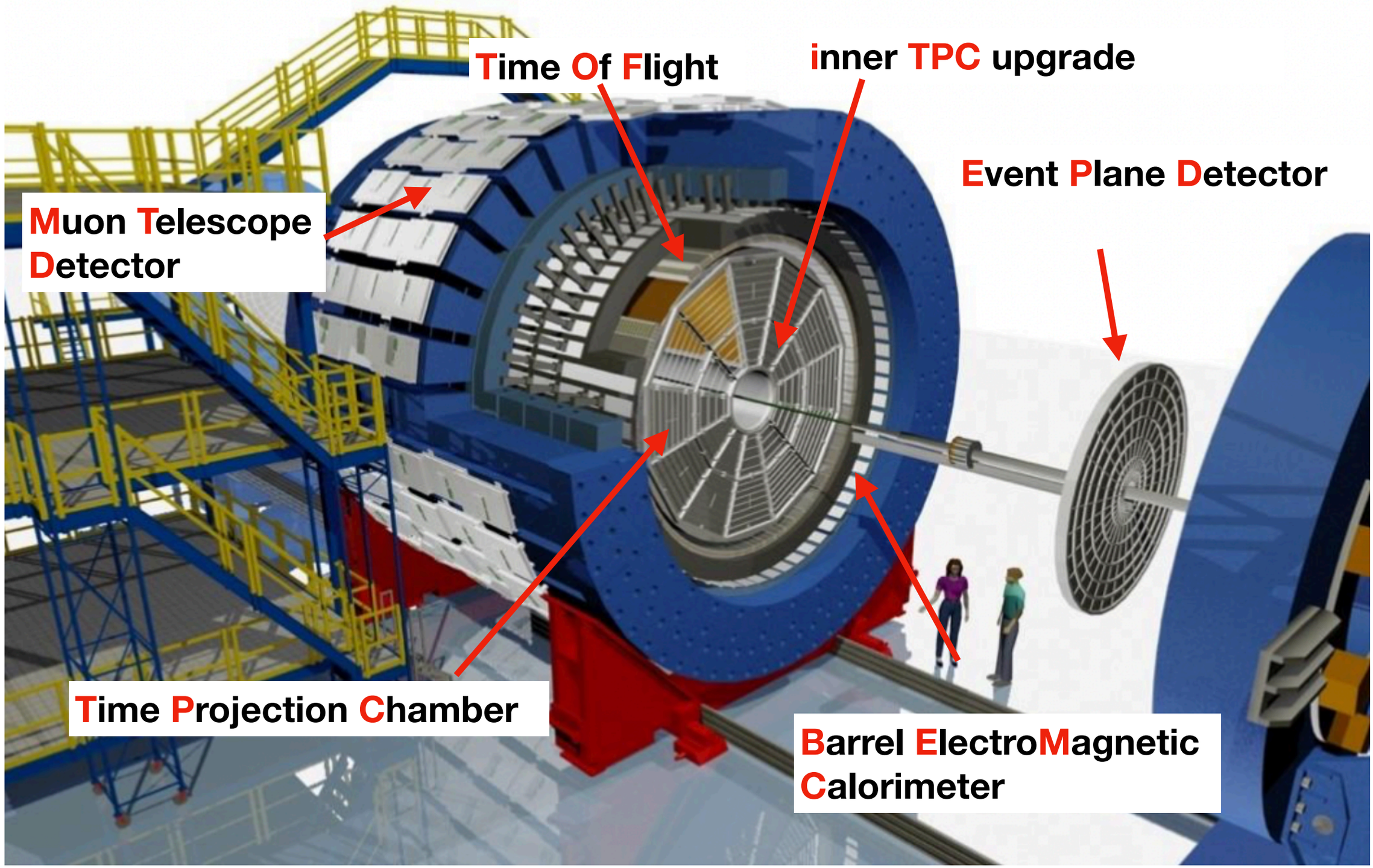


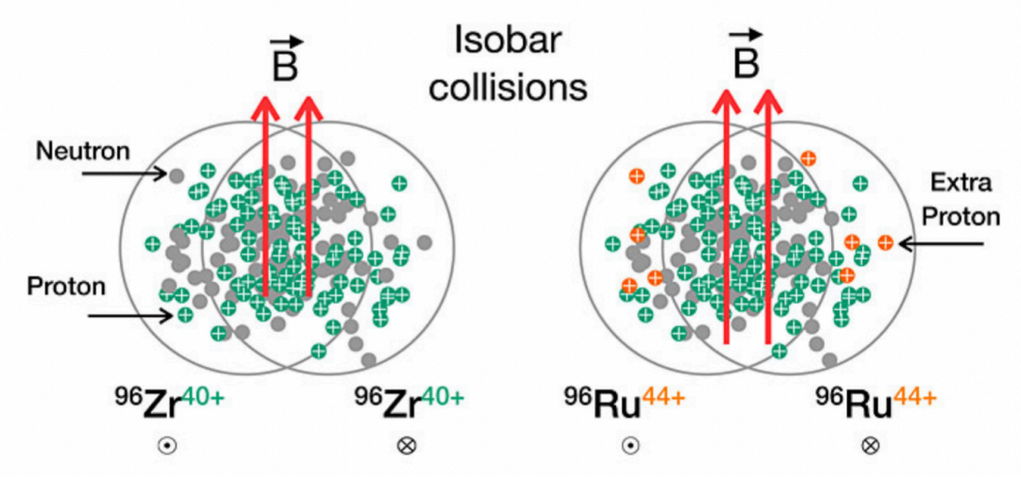
The Solenoidal Tracker at RHIC



Outline

- **Isobar and Au+Au at 200 GeV**
  - CME search and non-flow background
  - nuclear deformation
  - Global and local hyperon polarization
  - J/ψ suppression and elliptic flow
  - Initial EM field and nuclear tomography
- **BES-II results**
  - Elliptic flow of light nuclei
  - Production of light hypernuclei
  - Spin alignment of vector mesons
  - Particle production
- **Upgrade and future program**

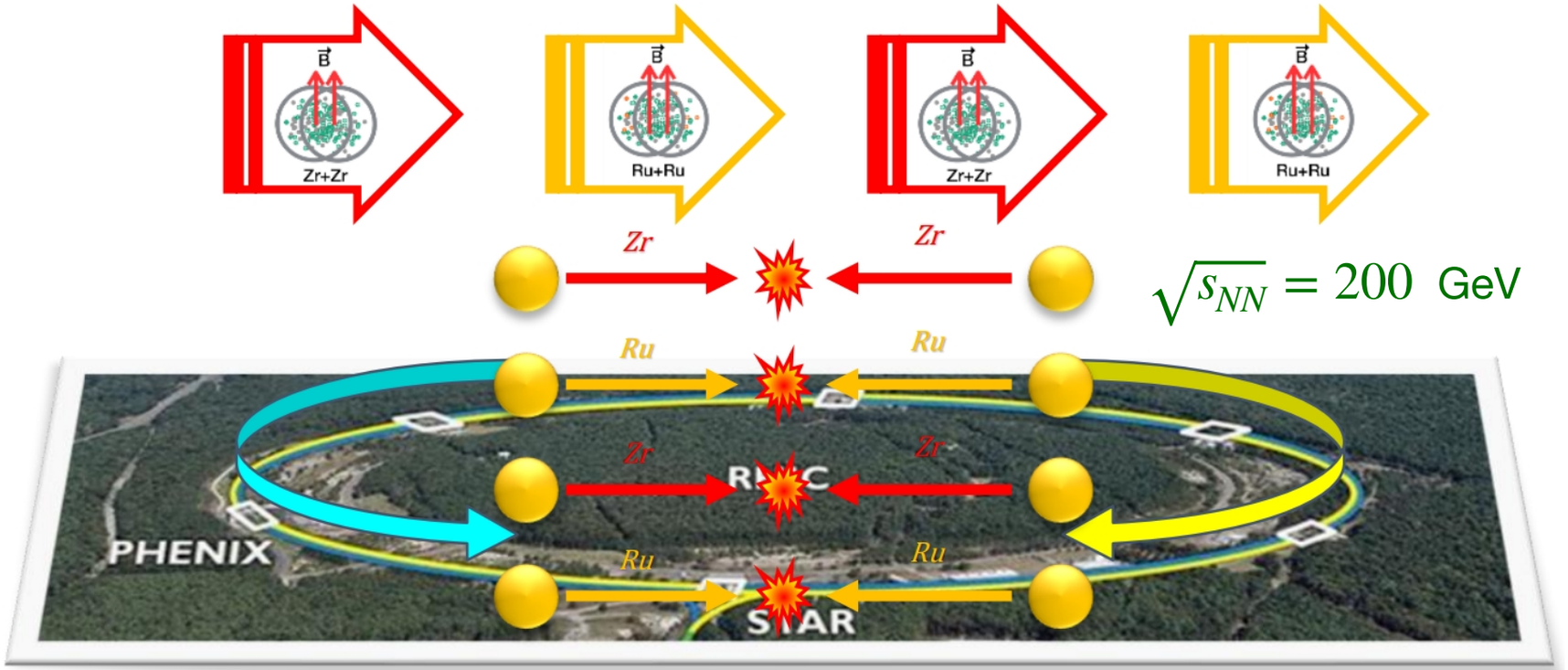
Isobar collisions



Initial B field control:
B-field² in Ru+Ru ~15% larger than in Zr+Zr

Special run to minimize systematics:

- Fill-by-fill switching
- Level luminosity

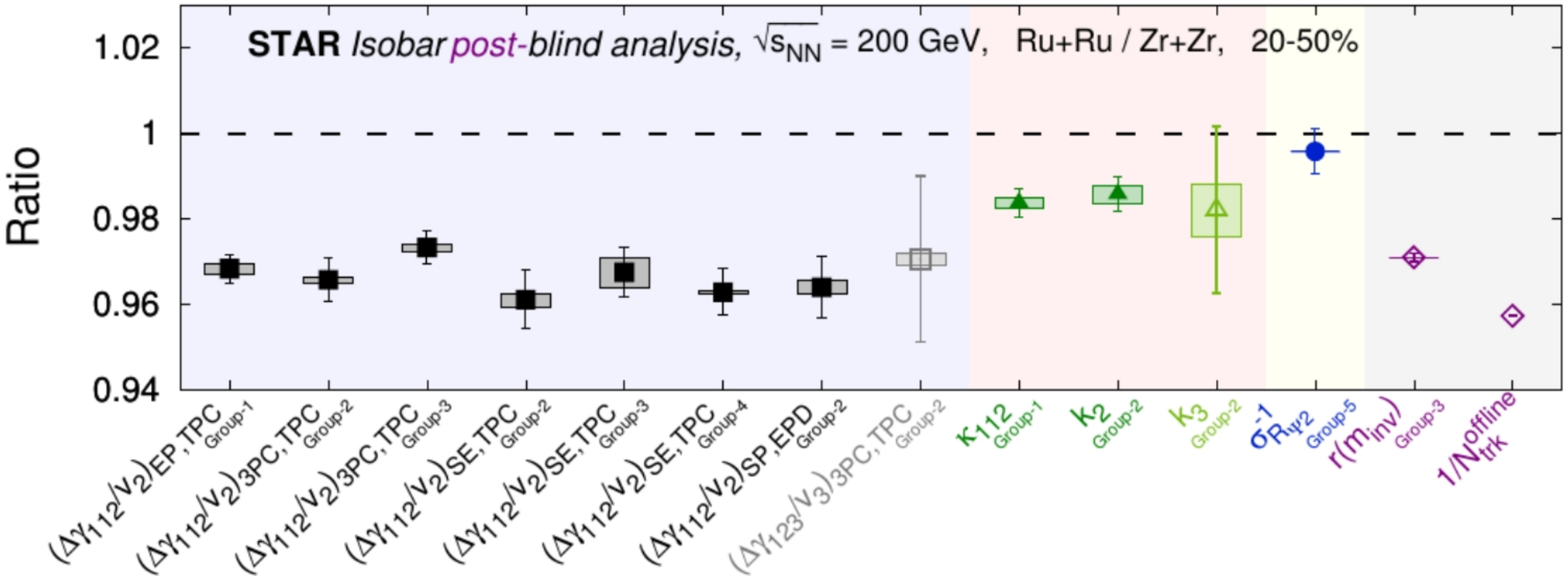


Chiral magnetic effect search

Pre-defined criteria for CME sensitive observable (Blind analysis)

$$\frac{(\Delta\gamma/v_2)_{Ru+Ru}}{(\Delta\gamma/v_2)_{Zr+Zr}} \approx 1 + f_{CME}^{Zr+Zr}[(B_{Ru+Ru}/B_{Zr+Zr})^2 - 1] > 1 \quad \text{(CME signal)}$$

Gang Wang
31/8 12:40



No pre-defined signature of CME is observed in isobar collisions: background not well understood

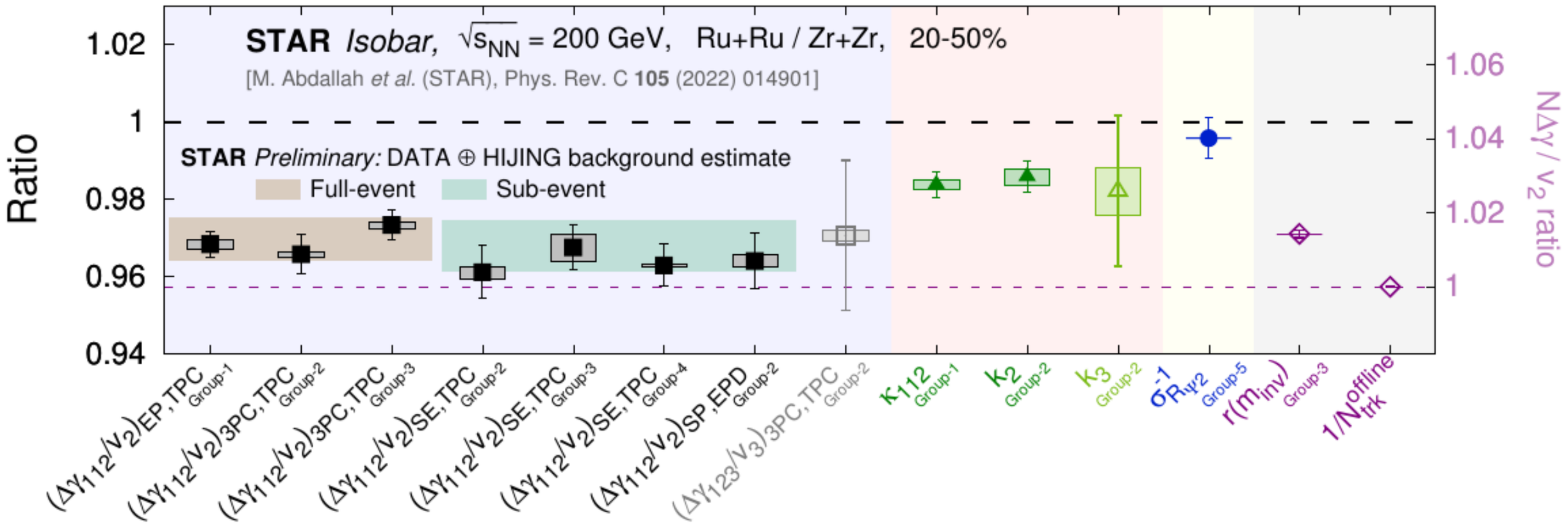
$$\Delta\gamma = \Delta\gamma^{CME} + k\frac{v_2}{N} + \Delta\gamma^{non-flow}$$

CME: non-flow background

- Non-flow background: deviation of CME baseline from unity

$$\Delta\gamma = \Delta\gamma^{CME} + k\frac{v_2}{N} + \Delta\gamma^{non-flow}$$

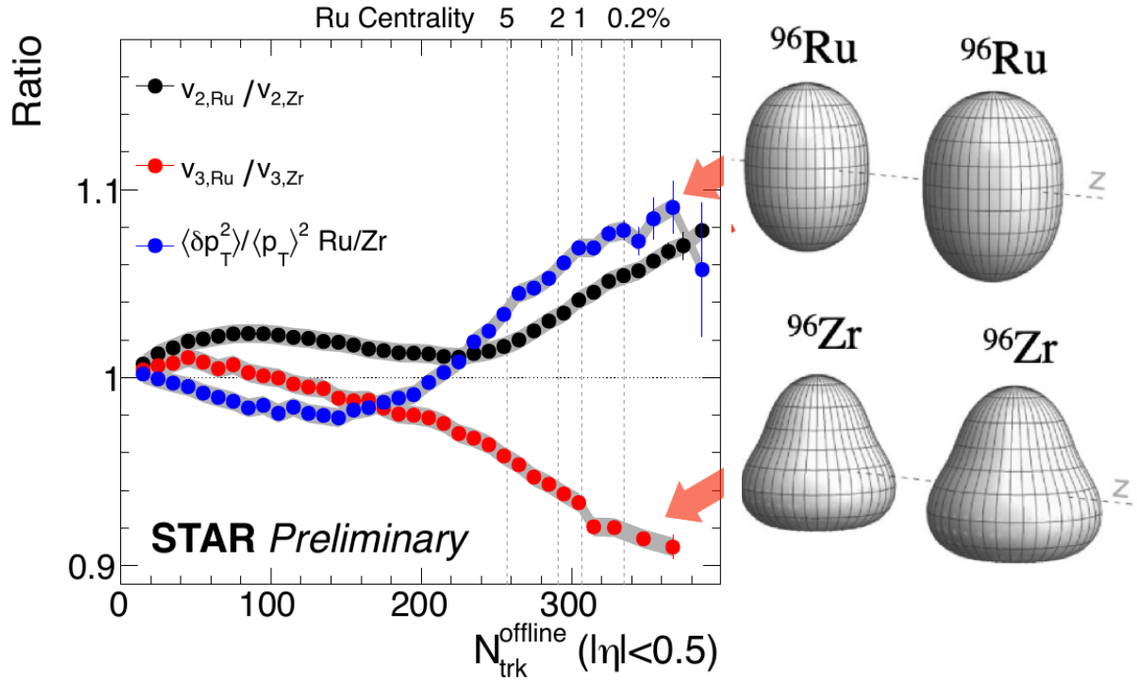
Gang Wang
31/8 12:40



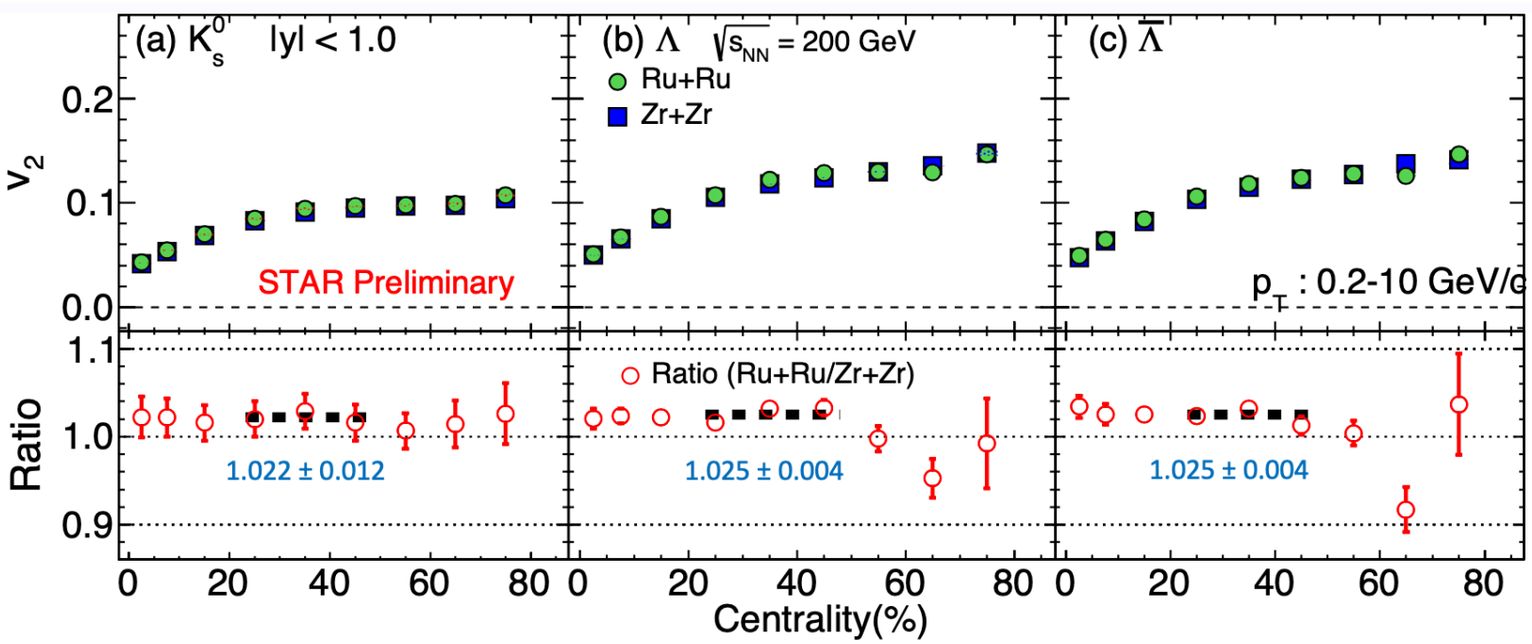
Isobar data consistent with the current estimation of non-flow background within error

Nuclear deformation

New ways to constrain nuclear deformation of the colliding nuclei



Priyanshi Sinha
Extended online session

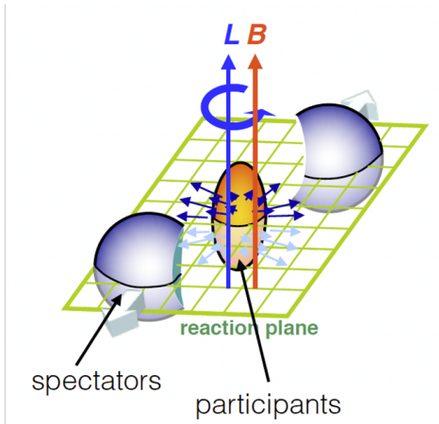


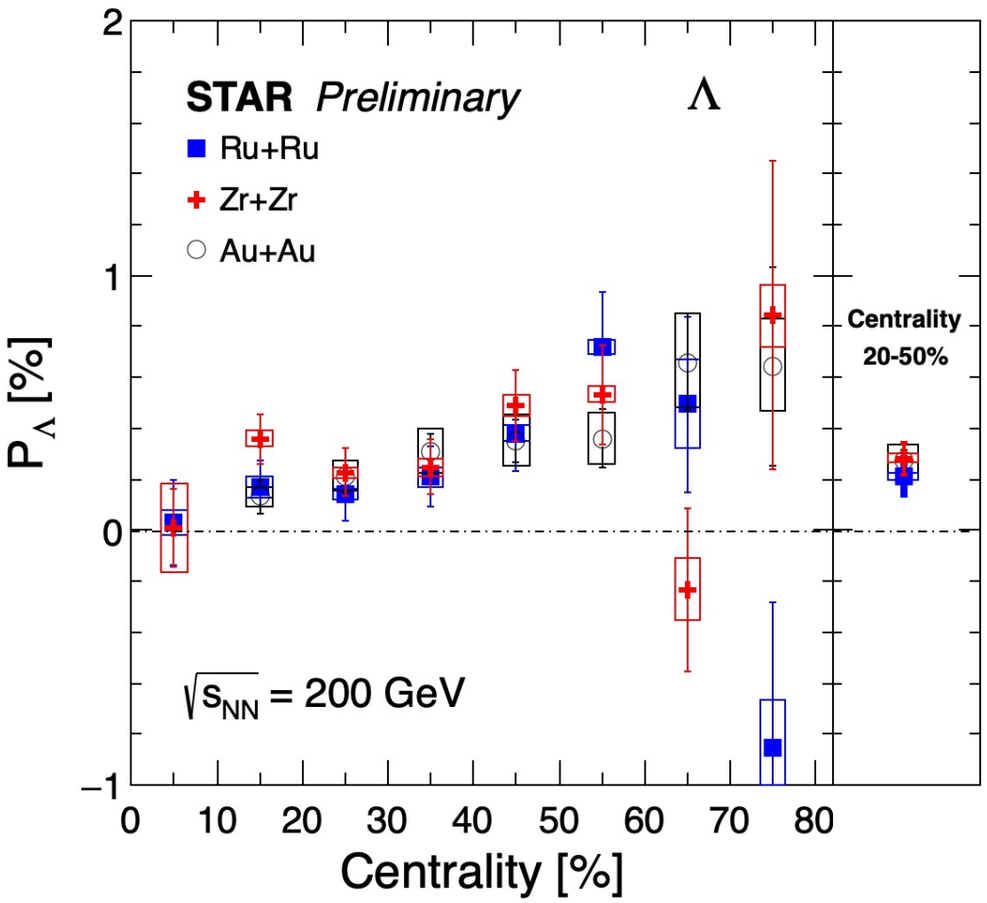
- 2% deviate from unity at central and mid-central collisions
  - →Indicate larger nuclear deformity in Ru than in Zr nucleus

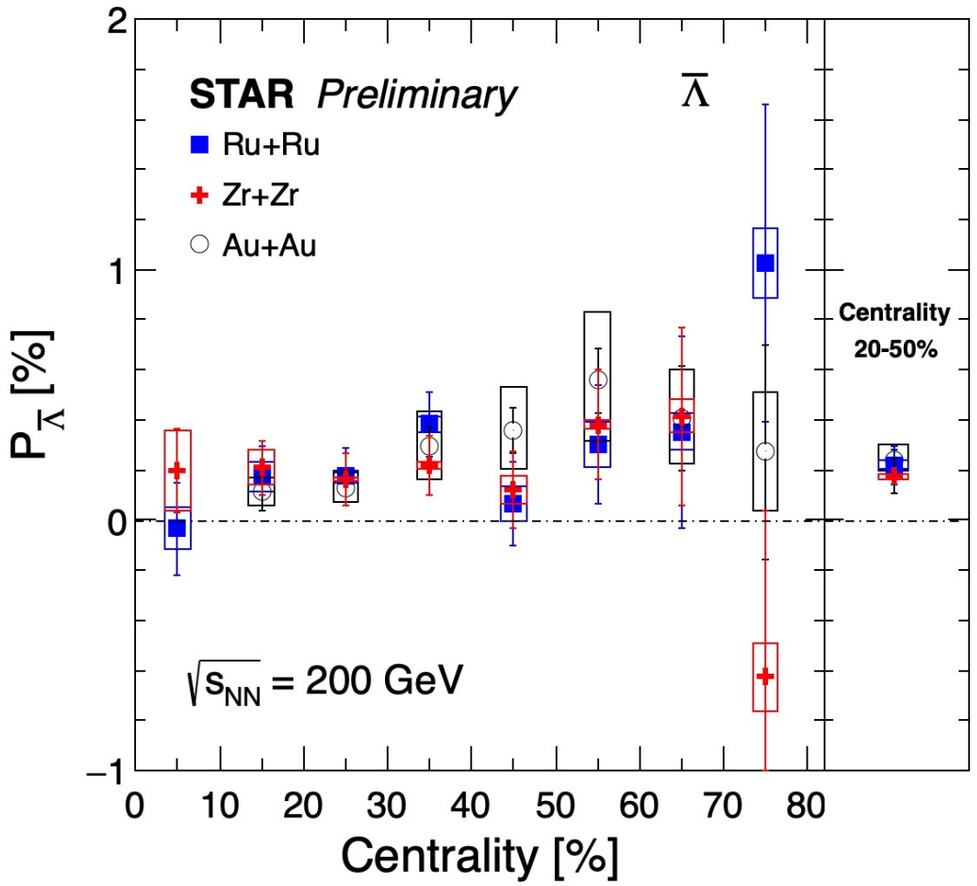
Global hyperon polarization

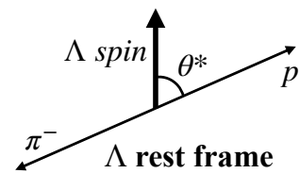
Orbital angular momentum → Lead to global polarization

$$P_\Lambda = \frac{8}{\pi \alpha_\Lambda} \frac{1}{A_0} \frac{\langle sin(\Psi_1 - \phi_p^*) \rangle}{Res(\Psi_1)}$$







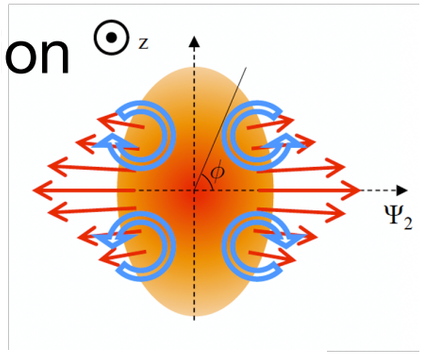


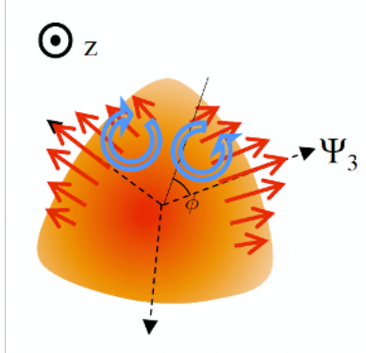
- Global polarization of Λ and $\bar{\Lambda}$ are consistent between isobar and Au+Au collisions
- No collision system size dependence for a give centrality is observed

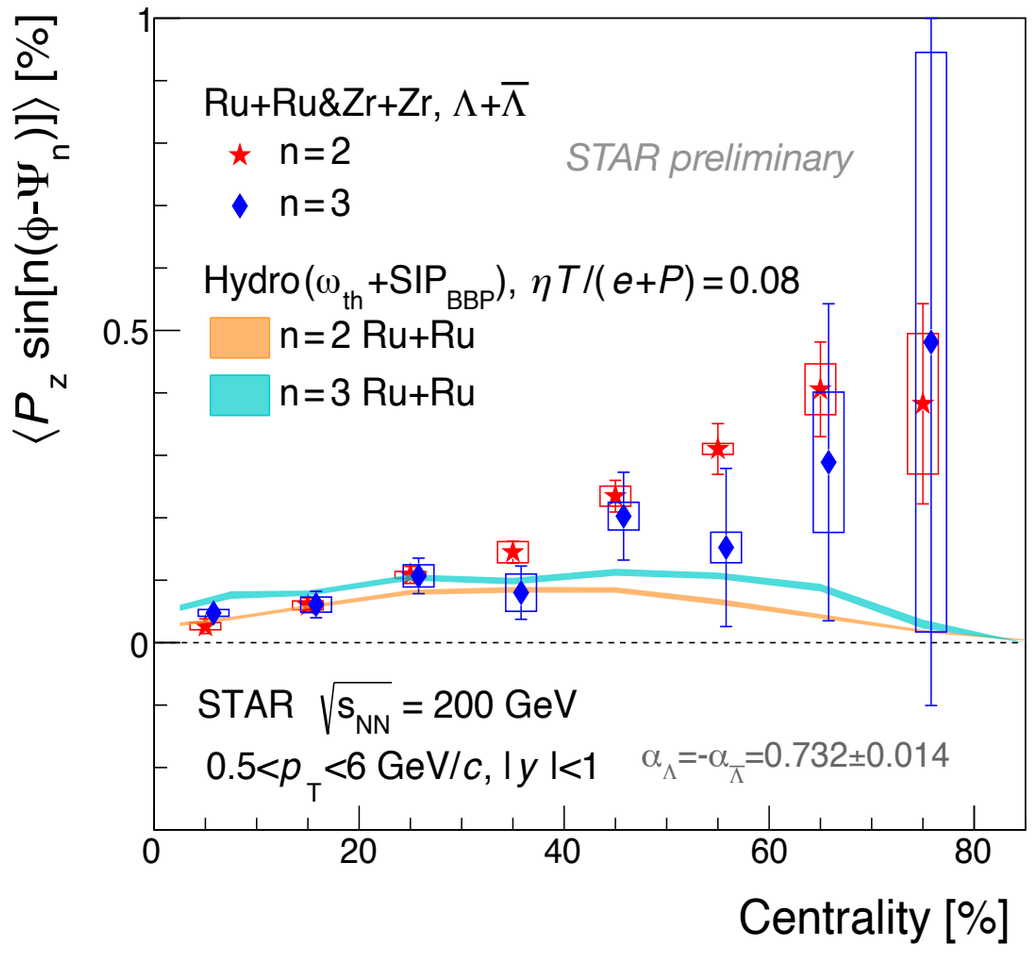
Local hyperon polarization

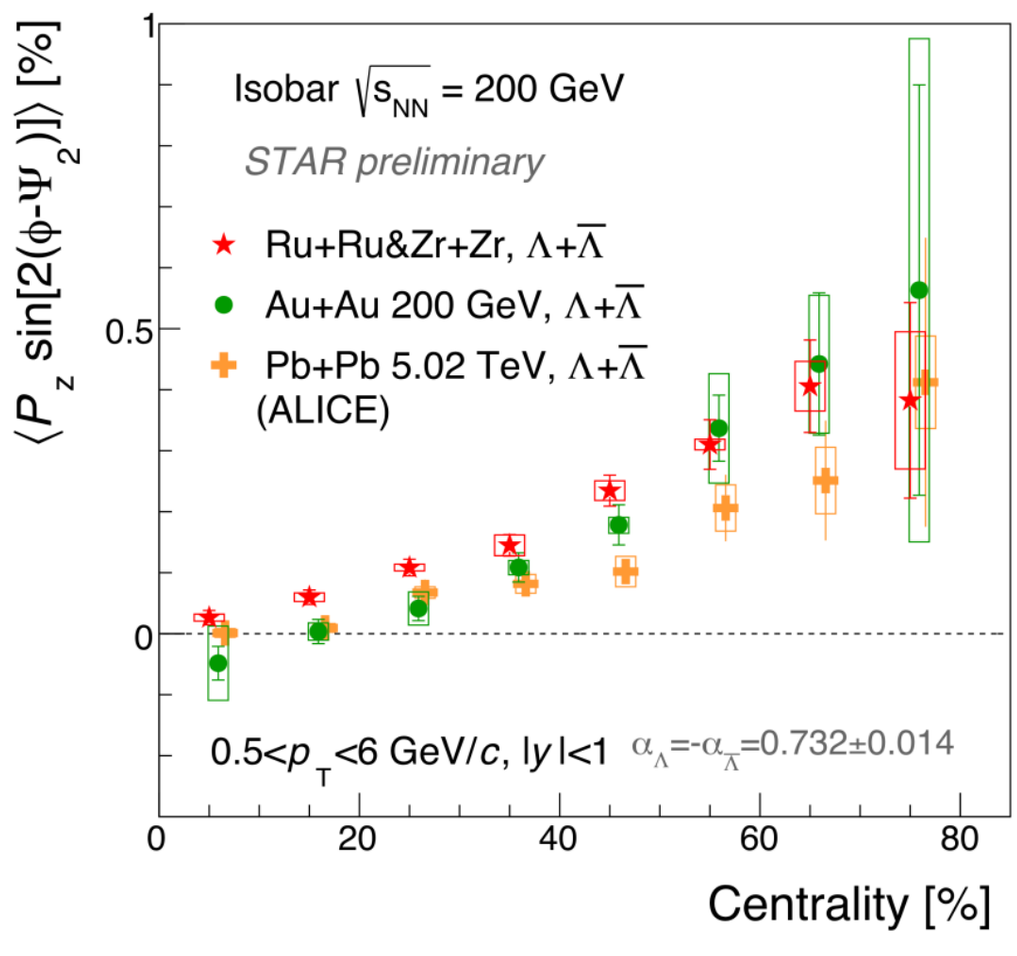
Local vorticity results in polarization along the beam direction

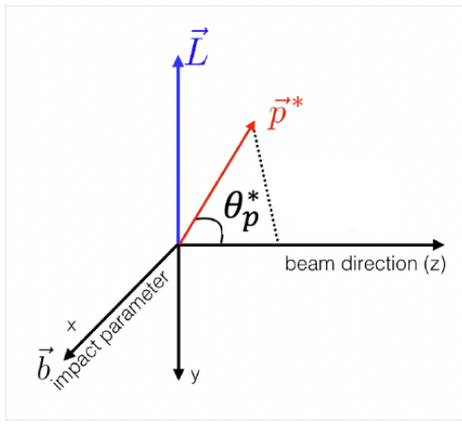
$$P_{z,n} = \langle P_z sin[n(\phi - \Psi_n)] \rangle \qquad P_z = \frac{\langle cos\theta_p^* \rangle}{\alpha_\Lambda \langle (cos\theta_p^*)^2 \rangle}$$







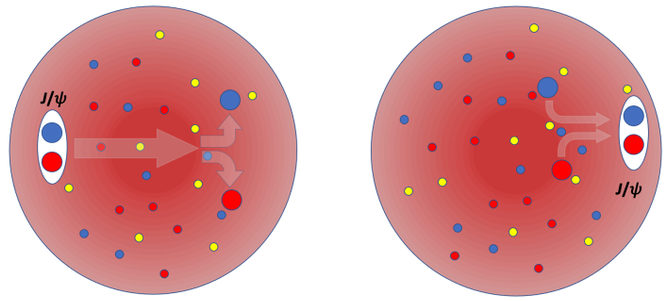




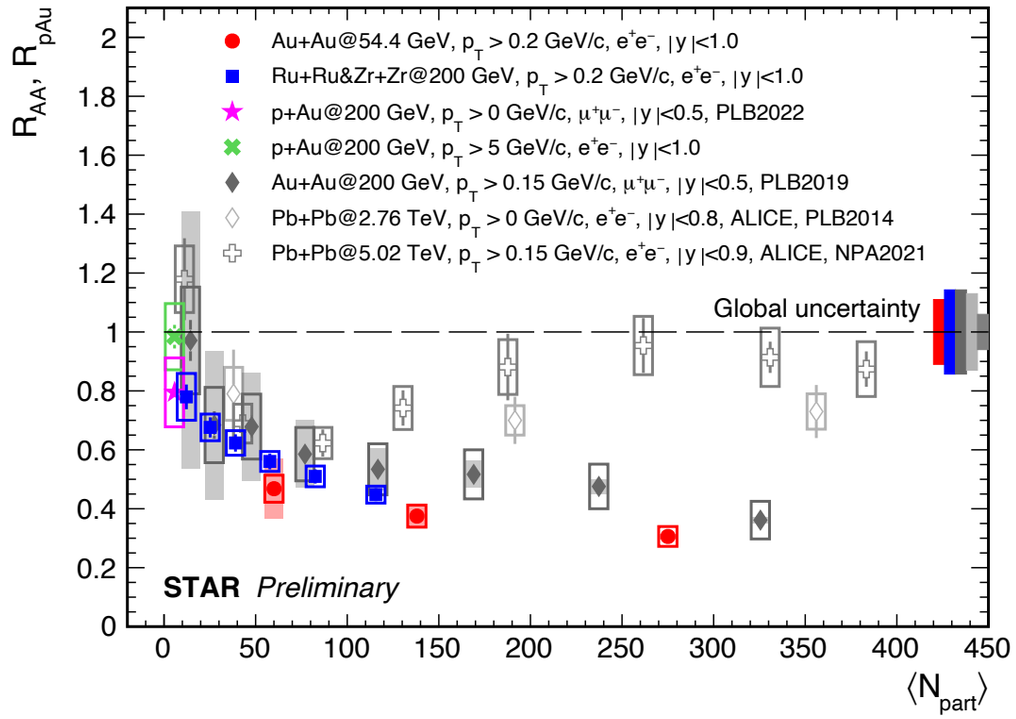
- Comparable second and third order $P_{z,n}$ with centrality →constraint on shear viscosity
- Hint of collision system size dependence of $P_{z,2}$

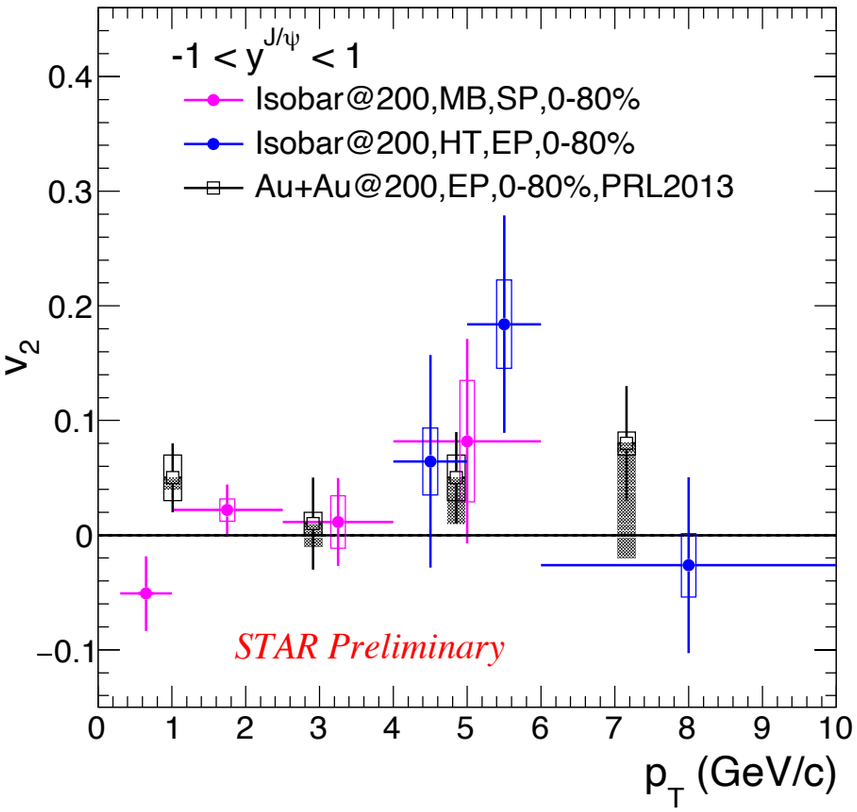
J/ψ R_{AA} and v_2 in isobar collisions

Dissociation vs regeneration effects



Barbara Trzeciak
8/9 15:30

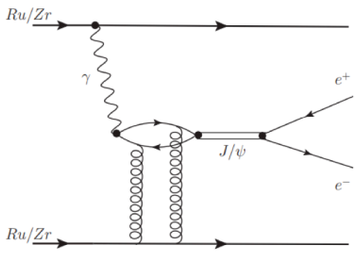




- No significant collision system and energy dependence at similar $\langle N_{part} \rangle$ at RHIC
- v_2 is consistent with zero at 2% precision level at low-p_T range
  - Small regeneration or/and small charm quark flow

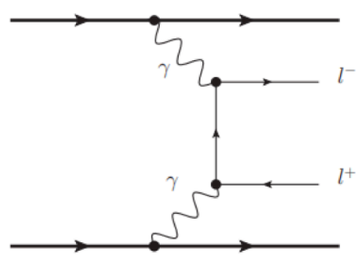
Initial electromagnetic field

The photon-induced production (J/ψ and e^+e^-) is sensitive to initial EM field



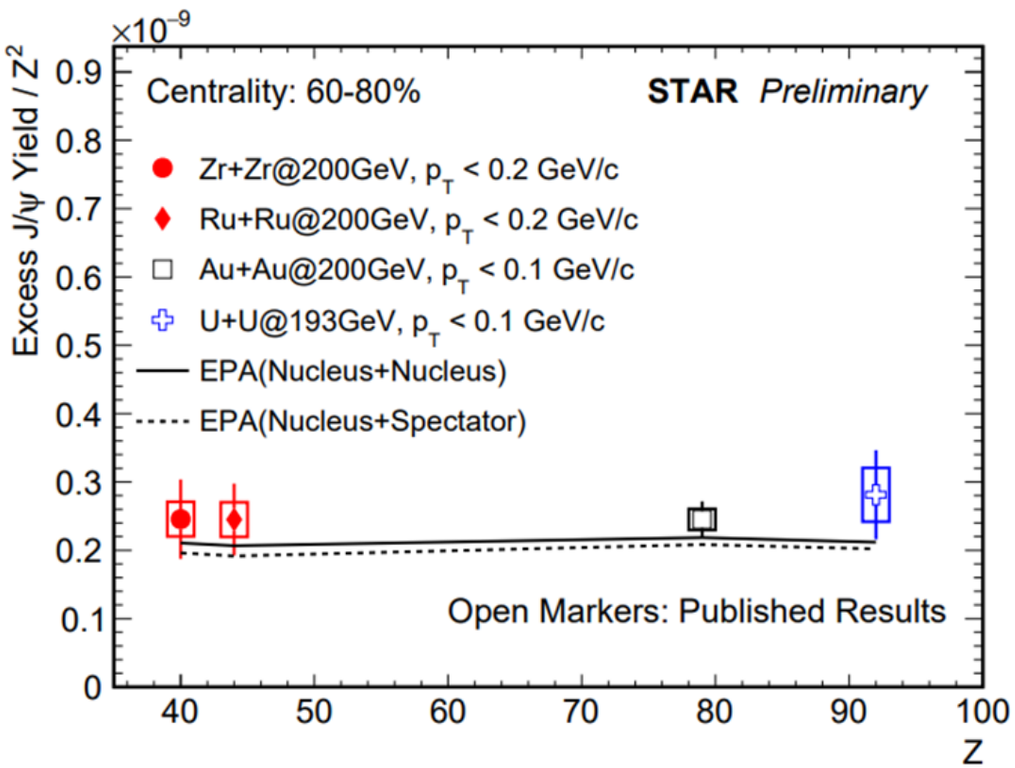
$\gamma + \mathrm{A} \rightarrow J/\psi + \mathrm{A}$

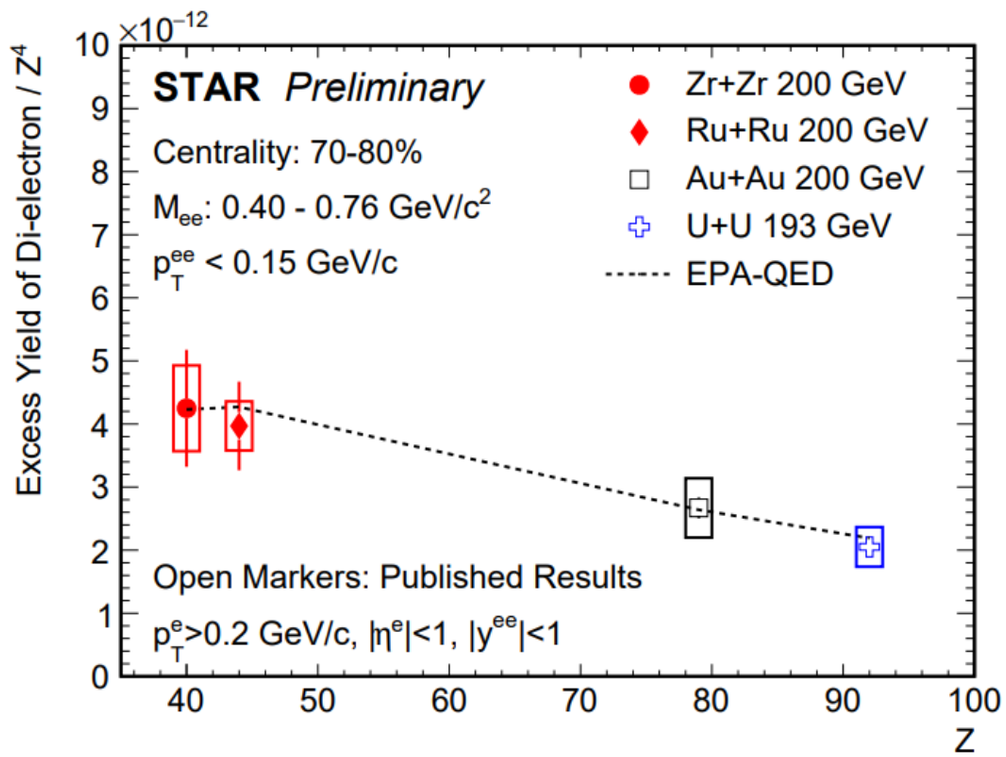
$\sigma(\gamma A \rightarrow J/\psi A) \sim Z^2$



$\gamma + \gamma \rightarrow e^+e^-$

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

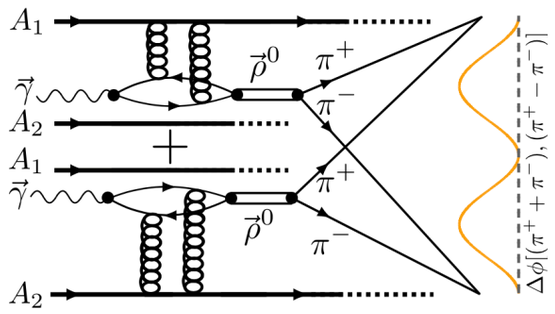




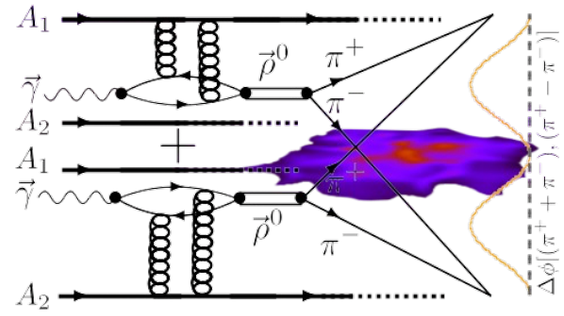
- The Z^2 scaled excess yield of J/ψ is independent of collision system
- e^+e^- excess yield, scaled by Z^4, shows a clear collisions system dependence
  - → impact parameter dependence

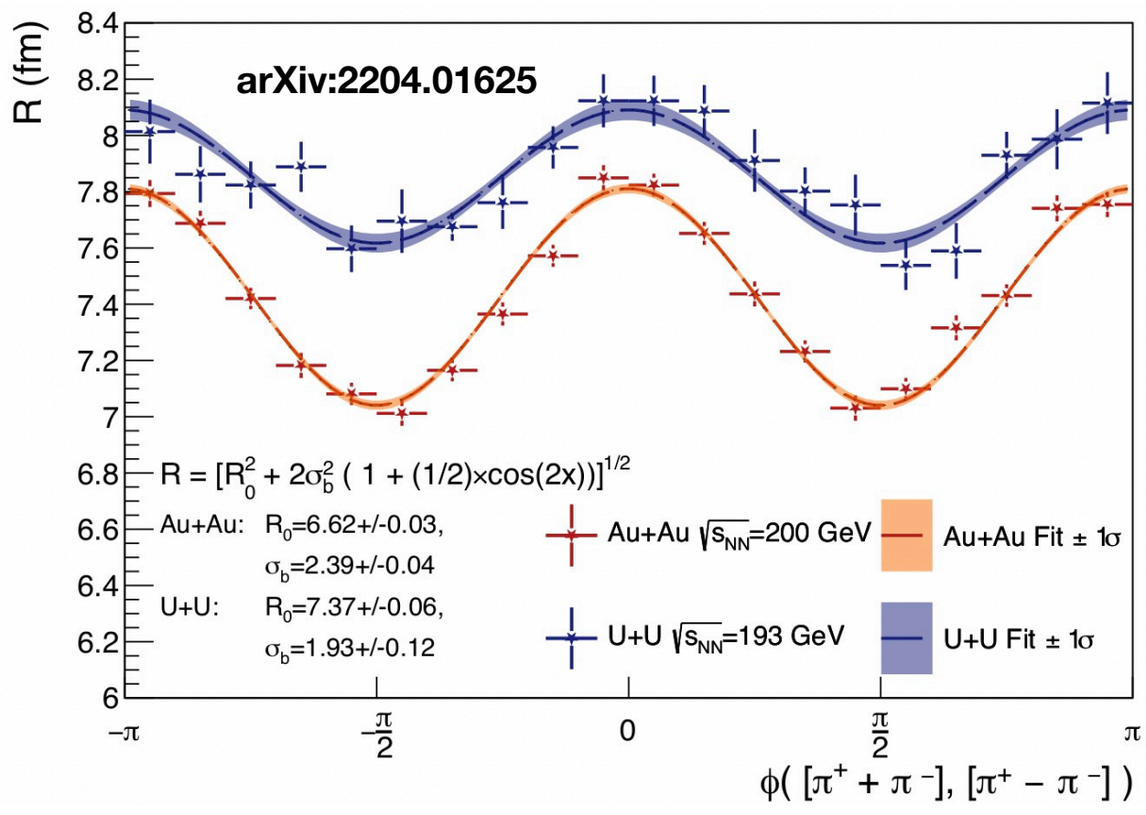
Nuclear tomography

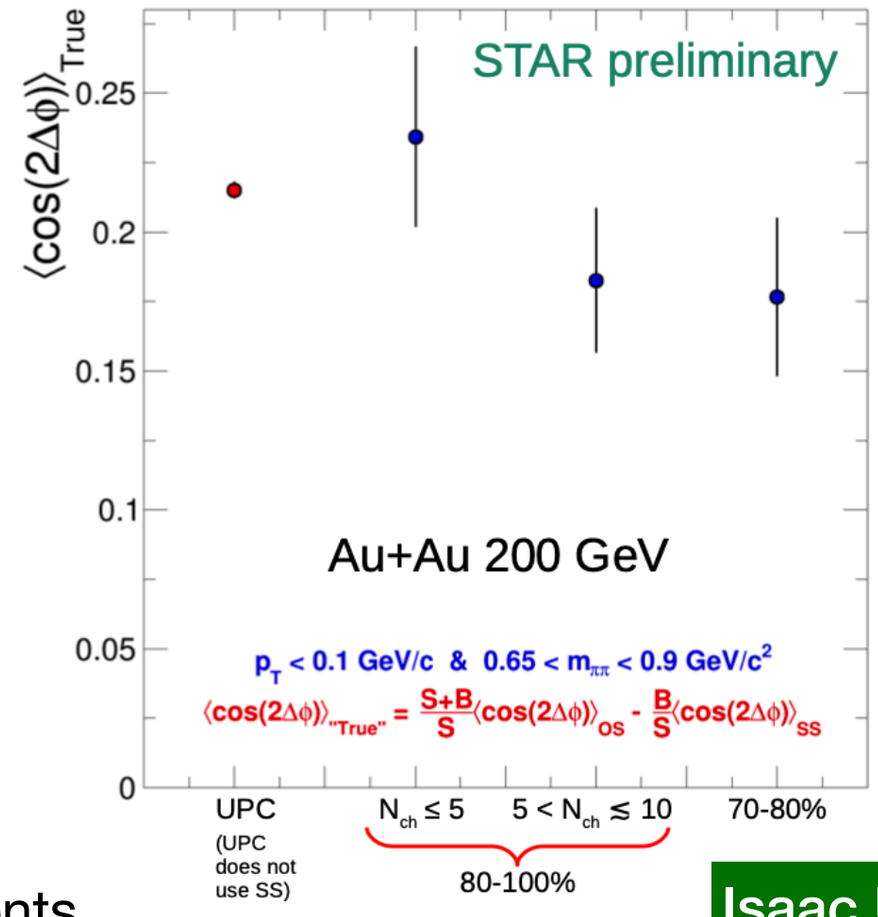
UPC



non-UPC



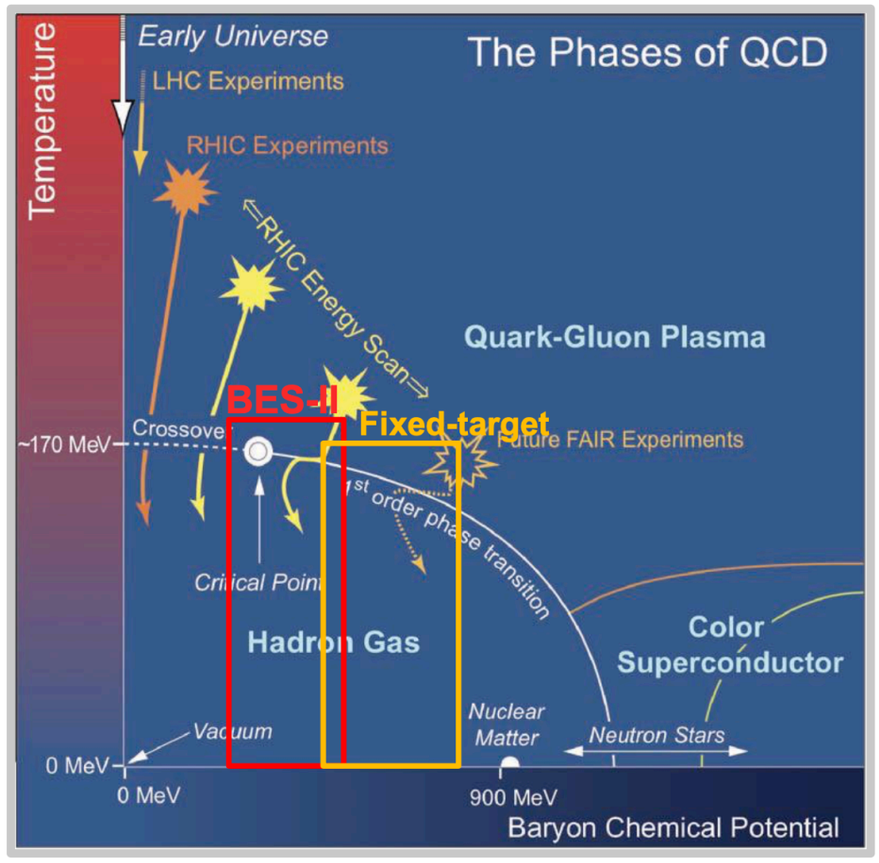




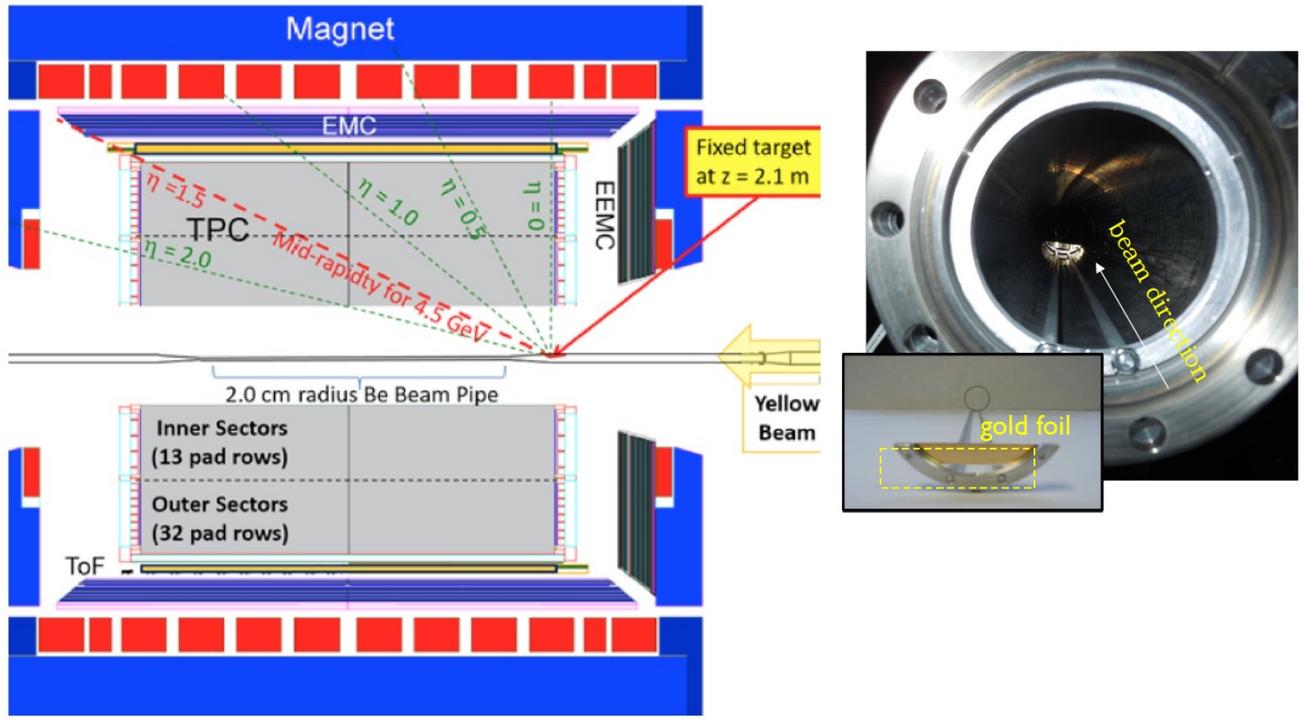
- Strong modulation in Au+Au and U+U UPC events
  →Excellent tool for measuring nuclear size
- Interference survives hadronic interactions in a peripheral HIC

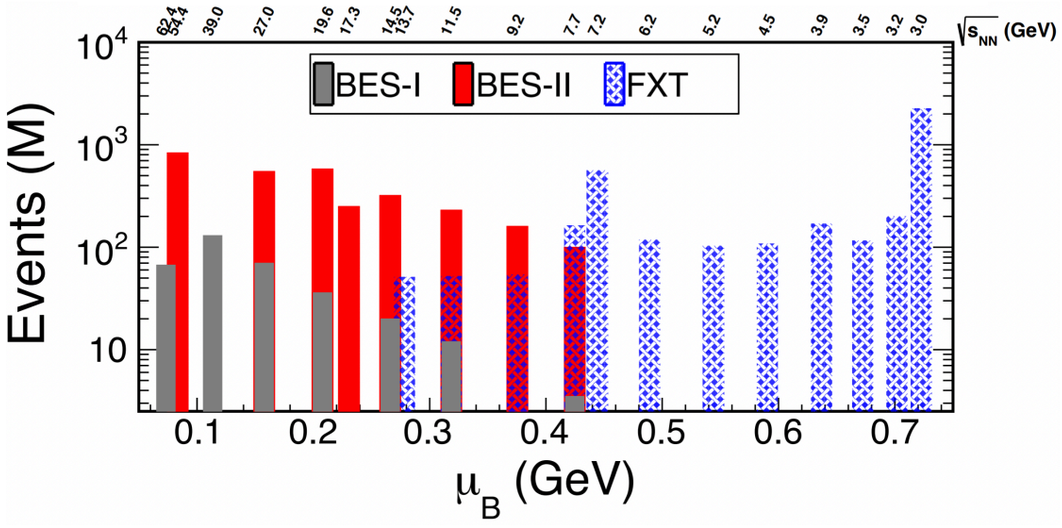
Isaac Upsal 8/9 9:00

BES-II and fixed-target program



Fixed target



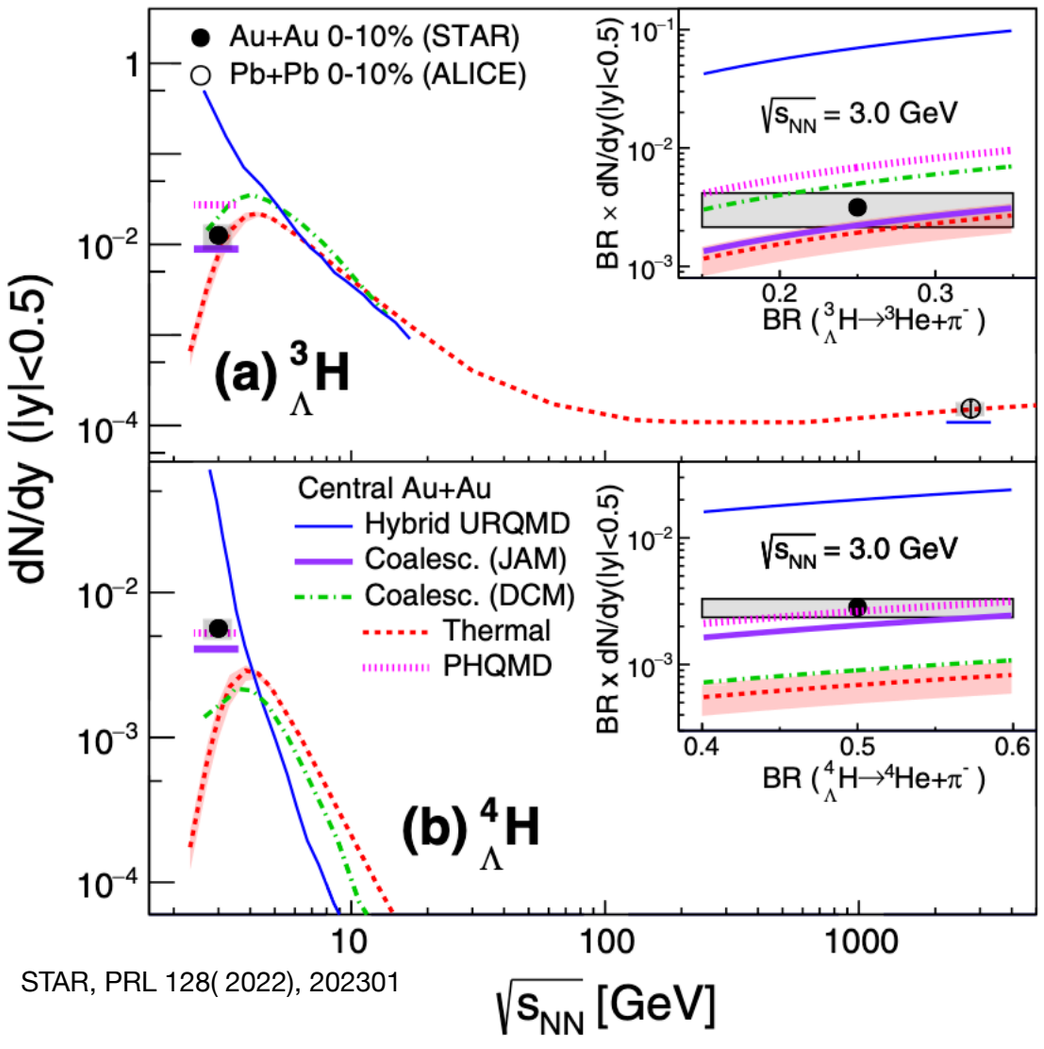


Beam Energy Scan II completed

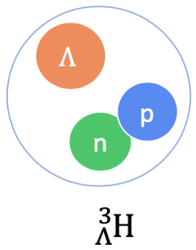
- RHIC BES-II: greatly enhance the statistics
- BES-II: precisely map the QCD phase diagram
  - Signs of 1st order phase transition, QCD critical point, signature on QGP turn-off, et.al
- Fixed-target program: $\sqrt{s_{NN}}$ = 3 - 13.7 GeV

Production of light hypernuclei

Hyperon-Nucleon (Y-N) interaction→ EOS of neutron stars and the hadronic phase of heavy-ion collisions

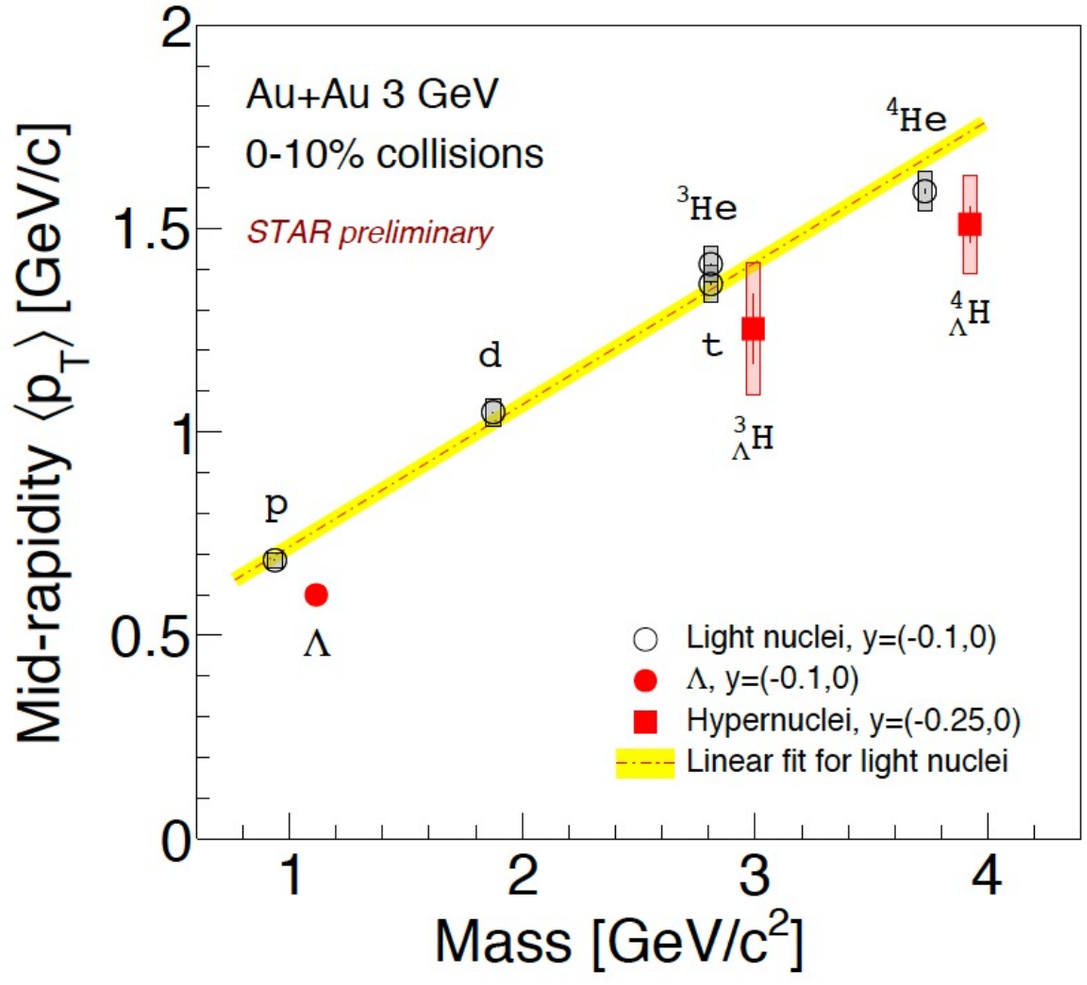


STAR, PRL 128(2022), 202301



$^{3}_{\Lambda}$H

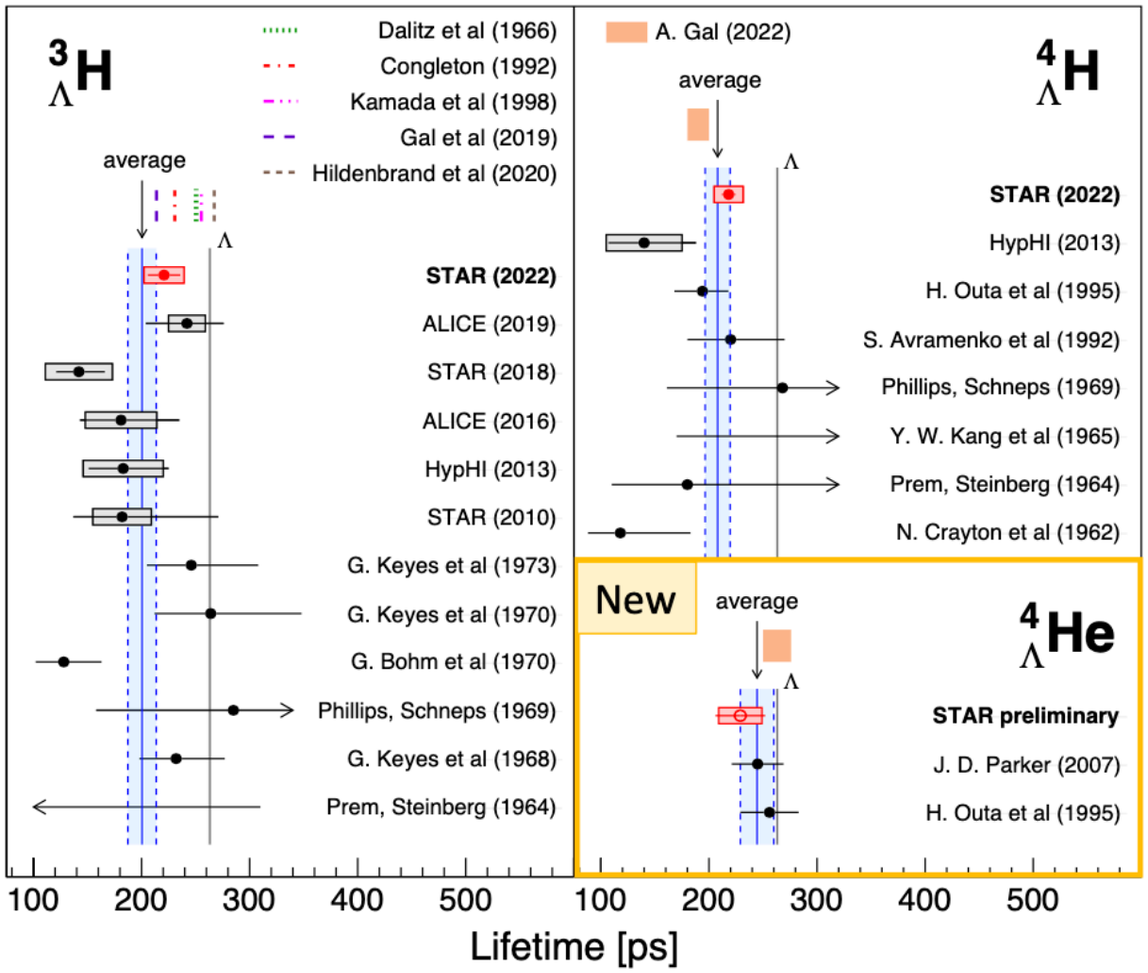
$^{4}_{\Lambda}$H

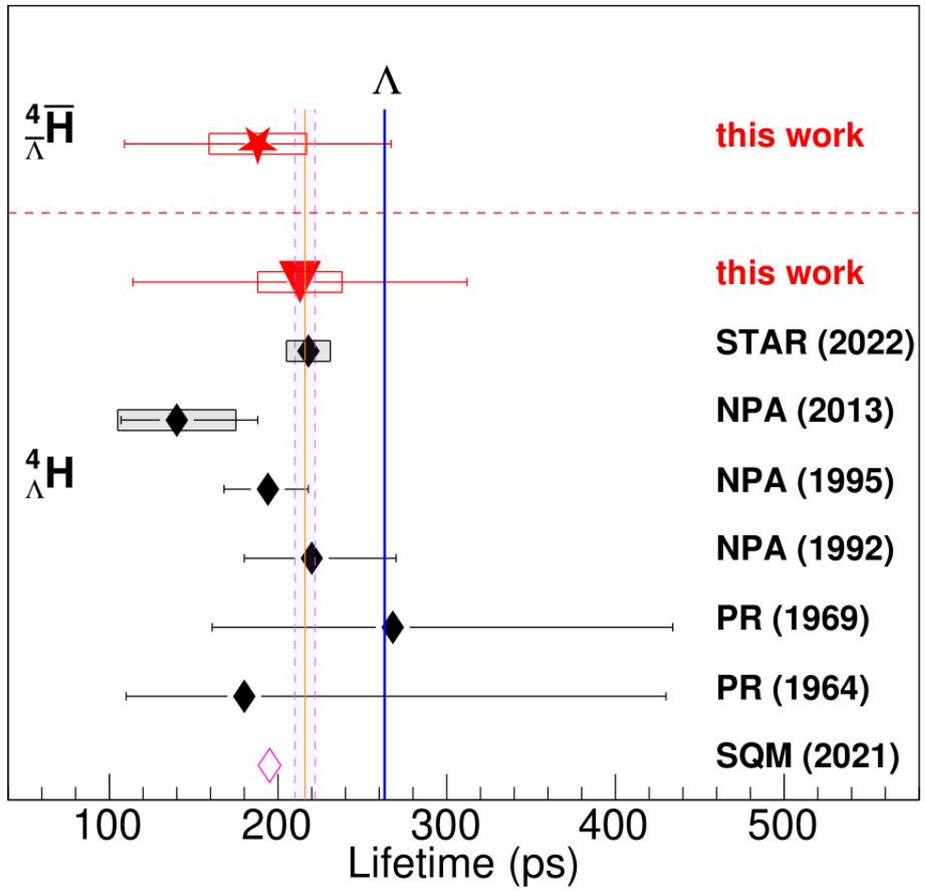


- Data support coalescence of hypernuclei production
- Linear trend for light nuclei and hypernuclei <p_T> reflects dominance of collective radial motion

Lifetimes of hypernuclei

Intrinsic properties of hypernuclei



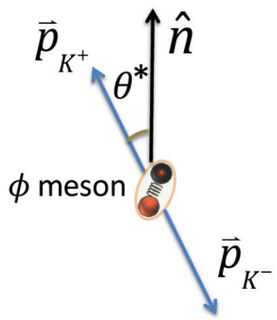


- The first hyperhelium-4 and anti-hyperhelium-4 lifetime measurements in heavy-ion collisions
  - Strong constraints on hypernuclei internal structures

Global spin alignment of vector mesons

Preferential alignment of a particle's spin with respect to the large OAM produced in heavy-ion collisions

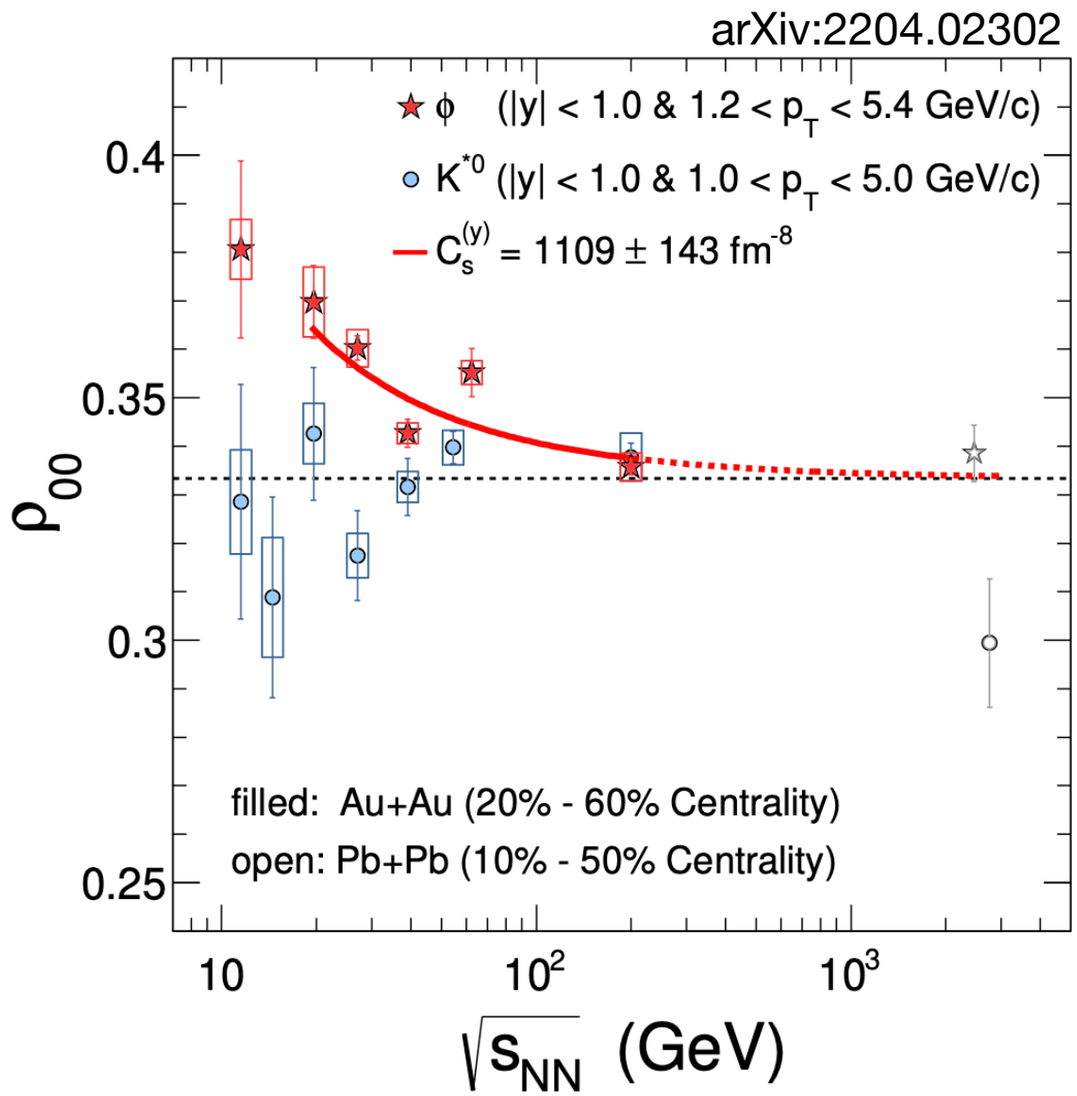
$$\frac{dN}{dcos\theta^*} = N_0 \times [(1-\rho_{00}) + (3\rho_{00}-1)cos^2\theta^*]$$



ρ_{00}: 00th element of the spin density matrix,

$\rho_{00} \neq 1/3$ indicates spin alignment

arXiv:2204.02302

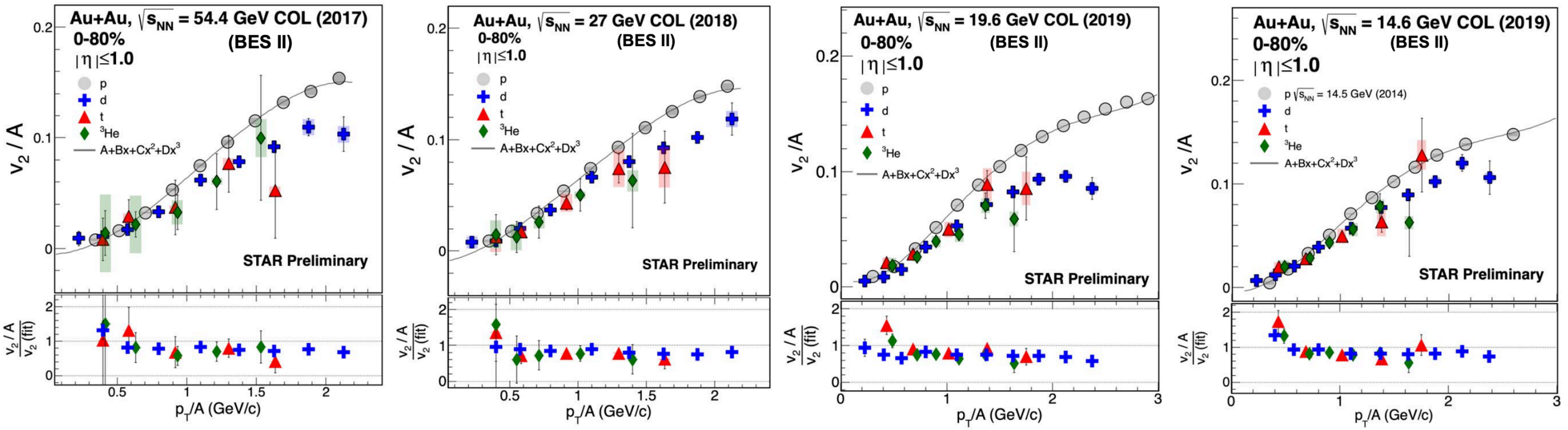


Meson Species	ρ_{00}	Constituent quarks	Mean lifetime (fm/c)	Spin
ϕ	>1/3	$s\bar{s}$	45	1
K^{*0}	~1/3	$d\bar{s}$	4.1	1

- ϕ meson $\rho_{00} > 1/3$ with 5.3σ in BES-II 19.6 GeV Au+Au
- Can be described by vector meson strong force field calculation
  - More inputs needed from theory

Elliptic flow of light nuclei

Light (hyper-)nuclei production: **thermal production** or **final-state coalescence** ?

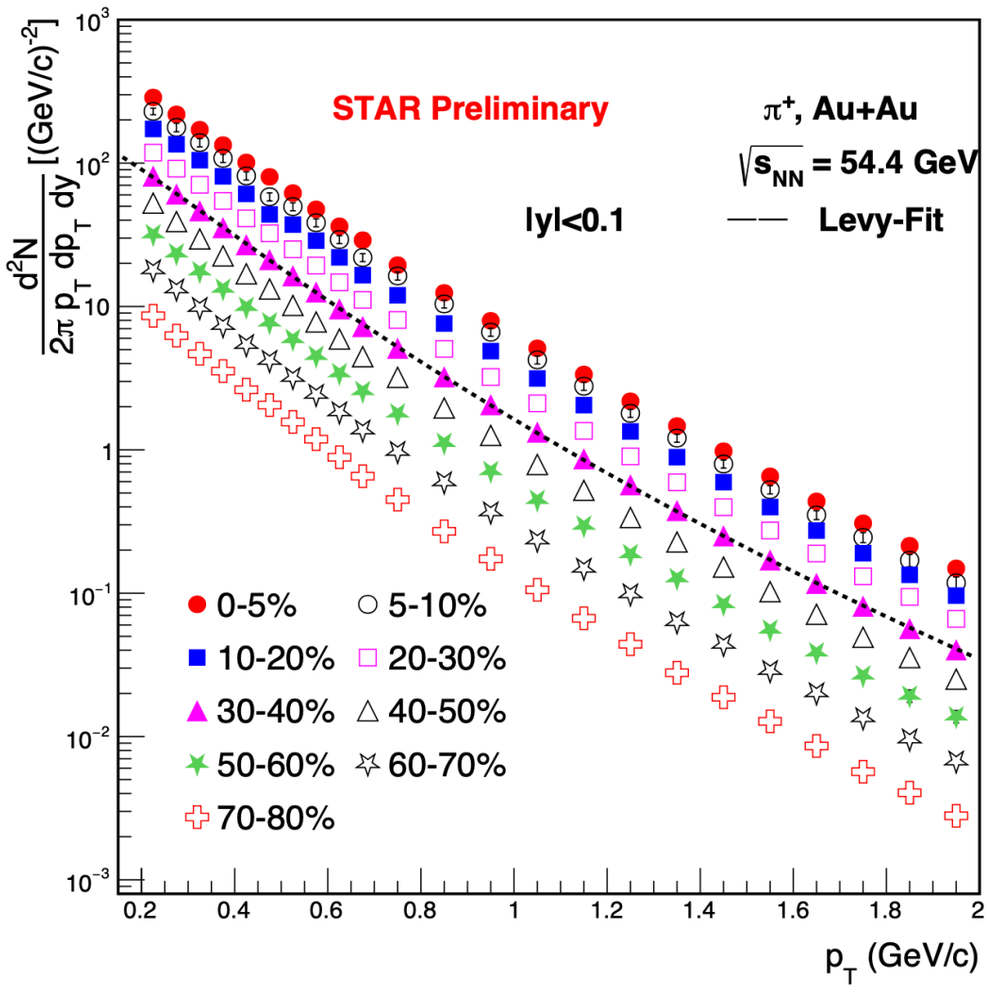


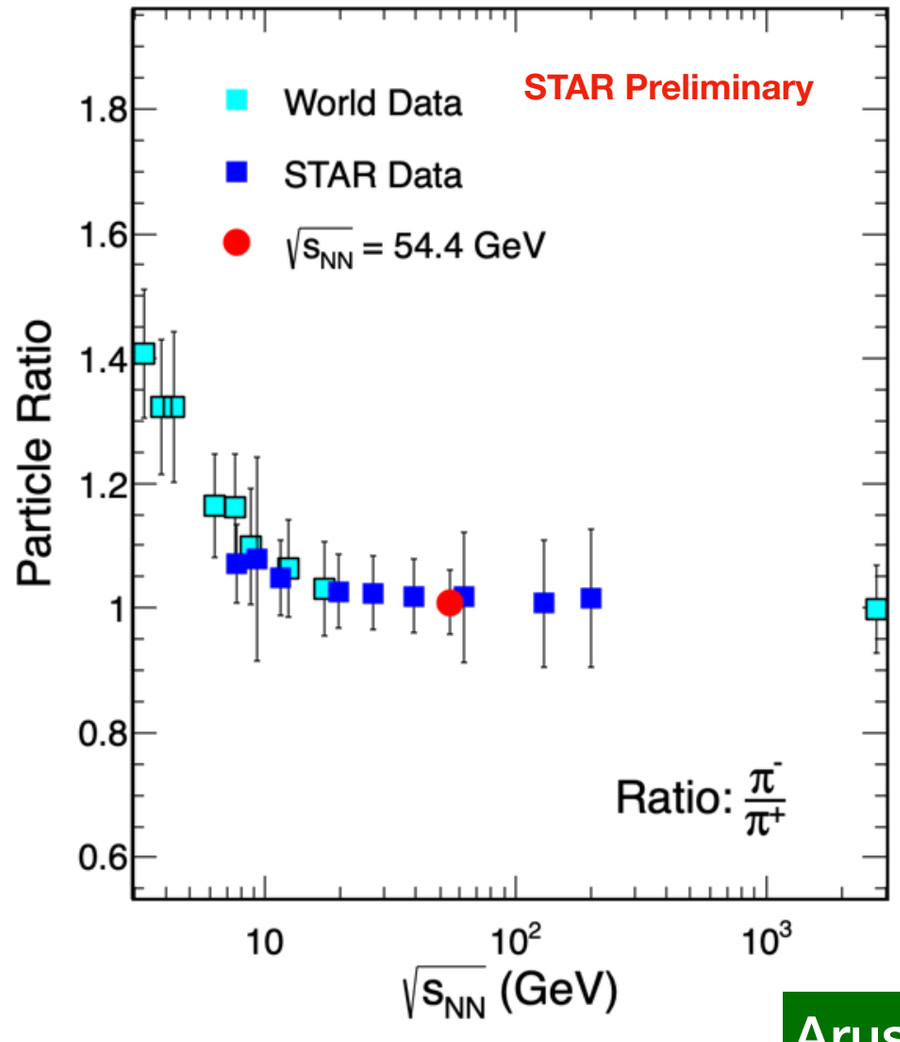
Rishabh Sharma
Extended online session

- ~20% deviation of light nuclei v_2 from mass number scaling at all measured energies

Particle production at 54.4 GeV

Transverse momentum spectra for $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ and particle ratios

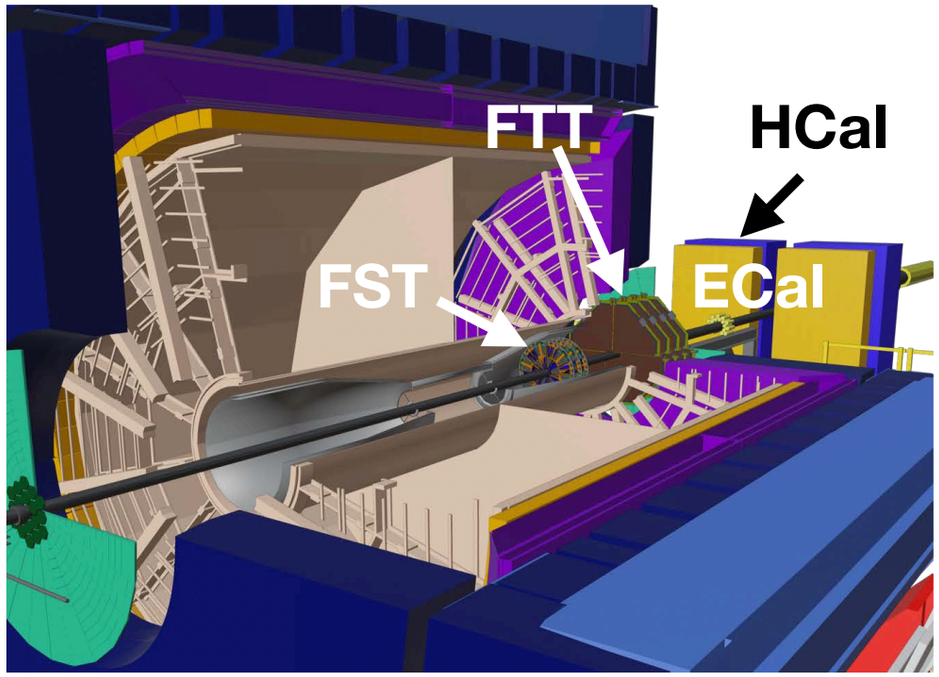




- Particle yield shows a clear centrality dependence
- The particle yield ratio is consistent with world data trend

Arushi Dhamija
8/9 15:30

Forward upgrade and 2023-2025 Runs



- Forward Tracking System (FTS)
  - Forward Silicon Tracker (FST)
  - Forward Small-strip Thin Gap Chambers Tracker (FTT)
- Forward Colorimeter System (FCS)
  - Electromagnetic Calorimeter
  - Hadronic Calorimeter

The STAR Beam Use Request for Run-23-25

The STAR Collaboration

https://drupal.star.bnl.gov/STAR/system/files/STAR_BUR_Runs23_25_2022.pdf

Hot QCD - study the microstructure of QGP Au+Au @200 GeV (2023 & 2025)

- What is the nature of the 3-dimensional initial state?
- What is the precise temperature dependence of viscosity?
- What can charmonium tell us about deconfinement?
- What is the temperature of the medium?
- What are the underlying mechanisms of jet quenching?
- What is the nature of the phase transition near $\mu_B = 0$?
- ...

Cold QCD - equal N-N luminosities in pp and pAu in 2024 essential to optimize several critical measurements

- First look gluon GPD
- Nuclear dependence of PDFs, FF, and TMDs
- Non-linear effects in QCD

Summary

- Selected isobar and BES-II results are shown
- Stay tuned for more results from isobar data and BES-II datasets
- More hot and cold QCD results with 2023-2025 runs

ICNFP STAR talks:

- **Search for the Chiral Magnetic Effect by the STAR Experiment: Wang Gang, Aug 31, 2022, 12:40 AM**
- **Nuclear Tomography with Polarized Photon-Gluon Collisions at STAR: Isaac Upsal, Sep 8,2022, 9:00 PM**
- **Strange hadron production in d+Au collisions at √sNN = 200 GeV using the STAR detector: Ishu Aggarwal, Sep 8, 2022, 15:50PM**
- **Study the production of identified hadrons in Au+Au collisions at √sNN = 54.4 GeV using the STAR detector , Arushi Dhamija, Sep 8, 2022, 15:30PM**
- **Recent heavy-flavor results from STAR, Barbara Trzeciak, Sep 8, 2022, 15:30PM**
- **Search for Hypernuclei in STAR Express Stream with KF particle Package, Ivan Kisel, Sep 8, 2022, 12:10AM**
- **Recent measurements of Hypernuclei in Au+Au Collisions at sqrt(s)=3.0 and 7.2 GeV with the STAR experiment at RHIC, Sonia Kabana, Extended Online-only session**
- **Azimuthal anisotropy of strange and multi-strange hadrons in isobar collisions at √sNN = 200 GeV , Priyanshi Sinha, Extended Online-only session**
- **Elliptic flow of light (anti-)nuclei in Au+Au collisions at √sNN = 14.6, 19.6, 27, and 54.4 GeV using the STAR detector , Rishabh Sharma, Extended Online-only session**