Measurements of global Λ polarization in Au+Au collisions at STAR

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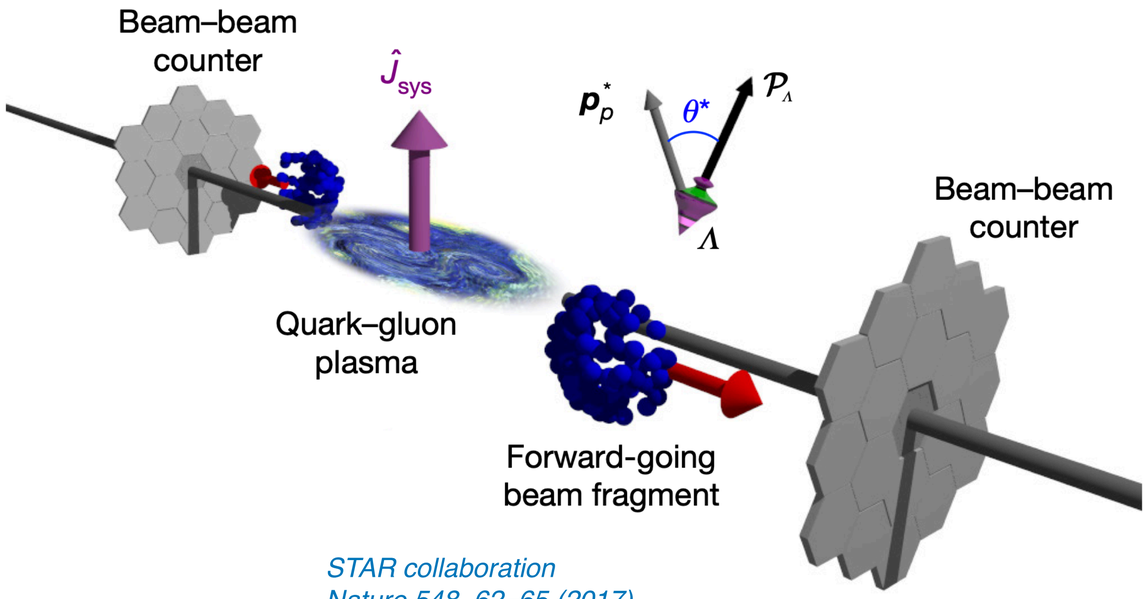
Outline

- Introduction
- Analysis and results
  - BES-II collider mode
  - BES-II Fixed-Target mode
- Summary and outlook

Introduction



STAR collaboration
Nature 548, 62–65 (2017)

$$P_\Lambda = \frac{8}{\pi \alpha_\Lambda R_{EP}^1} < sin(\Psi_{EP,1} - \phi_p^*) >$$

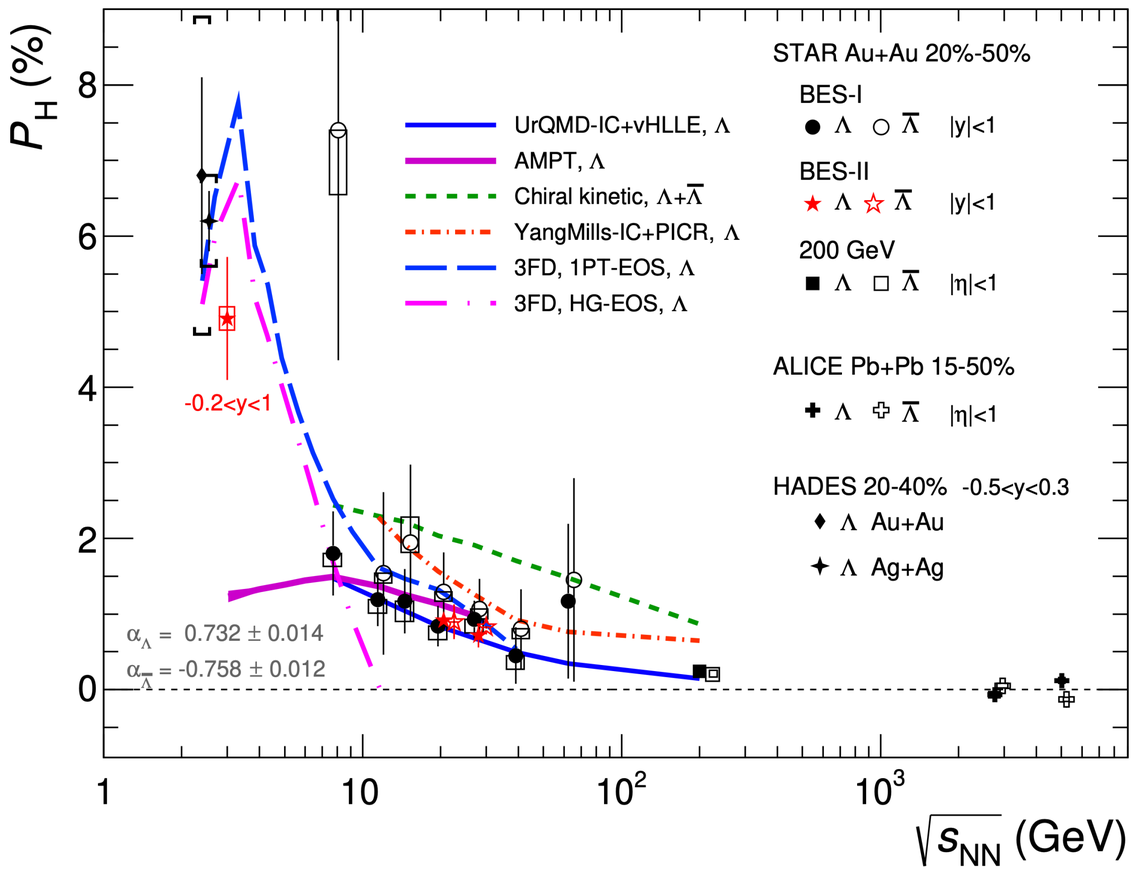
- α_Λ: Λ decay parameter
- $\Psi_{EP,1}$: 1st order event plane
- R_{EP}^1: 1st order event plane resolution
- ϕ_p^* : proton azimuthal angle in Λ rest frame

- Non-central AA collisions create large angular momentum and magnetic field.
- Non-zero spin particles can be polarized.
- Global polarization is a good probe to study spin degree of freedom.
- Understand properties of fireball under extreme conditions.
- Weak decayed hyperon is easy to measure global polarization. (“Self-analyzing”)

Introduction

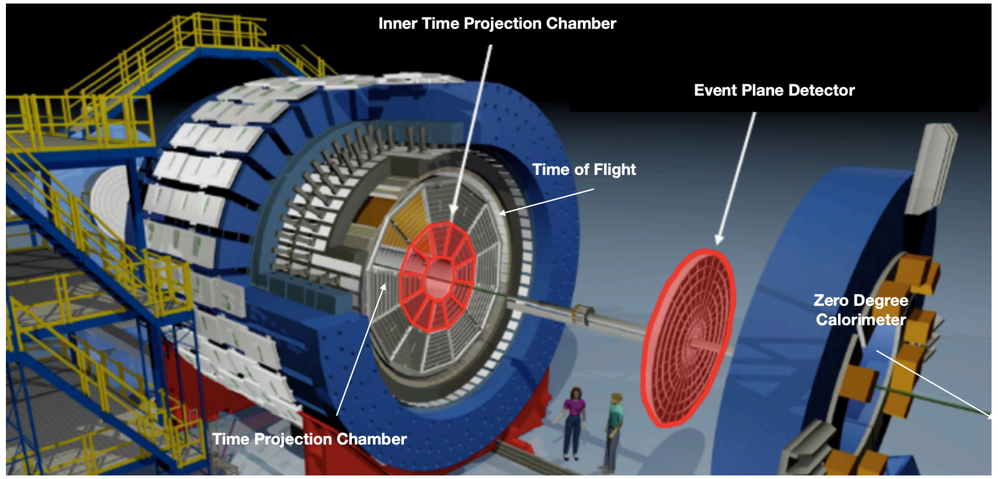
- Theory:
  - Predicted hyperon polarization (P_H) in heavy ion collisions (2005)
- Experiment:
  - ALICE (Pb + Pb collisions)
    - Global $\Lambda, \bar{\Lambda}$ polarization ($P_{\Lambda,\bar{\Lambda}}$) in high temperature region (2020)
  - HADES (Au+Au and Ag+Ag collisions)
    - P_{Λ} in high baryon density region (2022)
  - STAR (Au + Au collisions)
    - First measurements of $P_{\Lambda,\bar{\Lambda}}$ at 62.4 and 200 GeV (2007)
    - First evidence of non-zero $P_{\Lambda,\bar{\Lambda}}$ in BES-I program (2017)
    - Global Λ polarization in high baryon density region (2021)
- Global $\Lambda, \bar{\Lambda}$ polarization in STAR BES-II will be discussed.
  - Improve BES-I $P_{\Lambda,\bar{\Lambda}}$ precision
  - Study P_{Λ} in high baryon density region

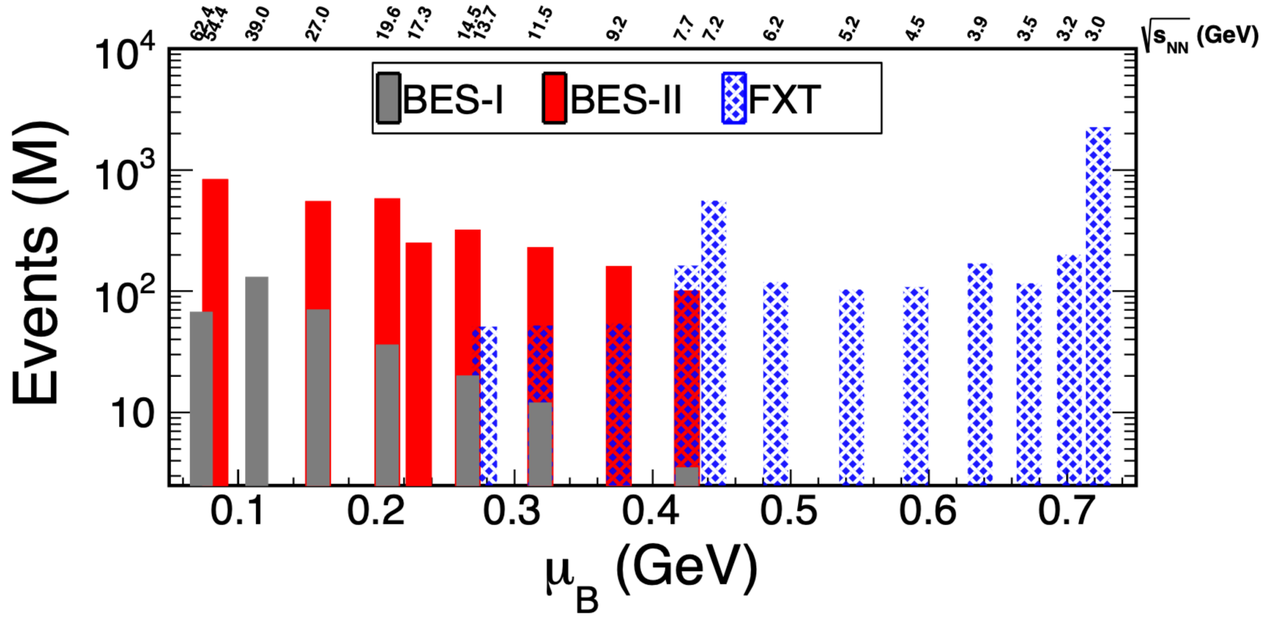
arXiv:2404.11042



- Phys. Rev. Lett 94,102301 (2005)
- STAR
  Phys. Rev. C 76, 024915 (2007)
  Nature 548, 62–65 (2017)
  Phys. Rev. C 104, 061901 (2021)
- ALICE
  Phys. Rev. C 101, 044611 (2020)
- HADES
  Phys. Lett. B 835, 137506 (2022)

Introduction

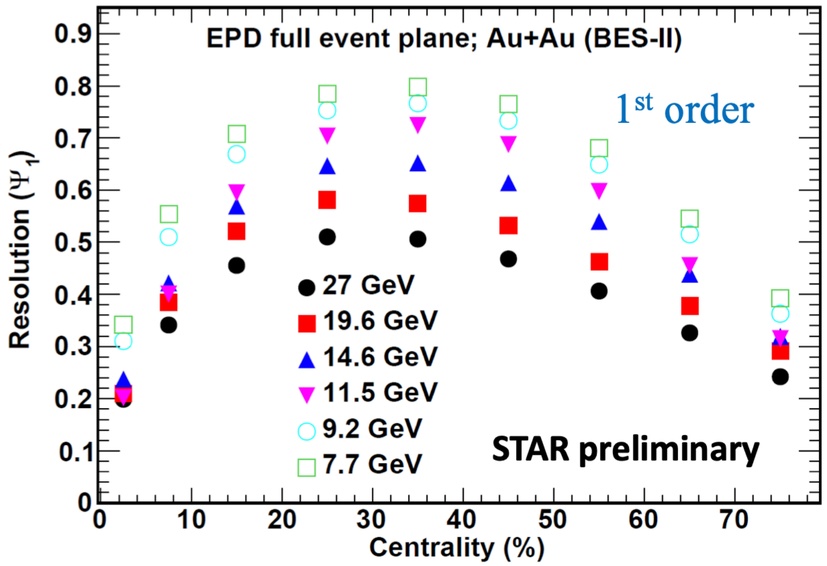




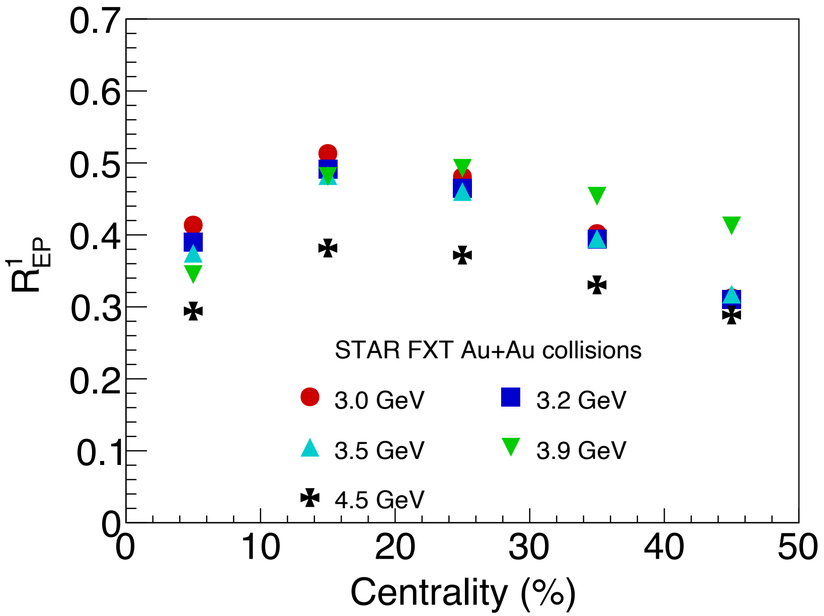
- EPD (Event Plane Detector) is for event plane reconstruction.
- TPC (Time Projection Chamber) and iTPC are for particle identification.
- STAR collects the high statistic data with upgraded detector from BES-II program.
- Good opportunity to study global Λ polarization in a wide energy range.

Event plane resolution

BES-II Collider mode



BES-II Fixed-Target mode



- 1st order event plane resolution calculation:
  - BES-II Collider mode → 2 sub-events method (Full East and West EPD)
  - BES-II Fixed-Target mode → 3 sub-events method (East EPD and two TPC sub-events)

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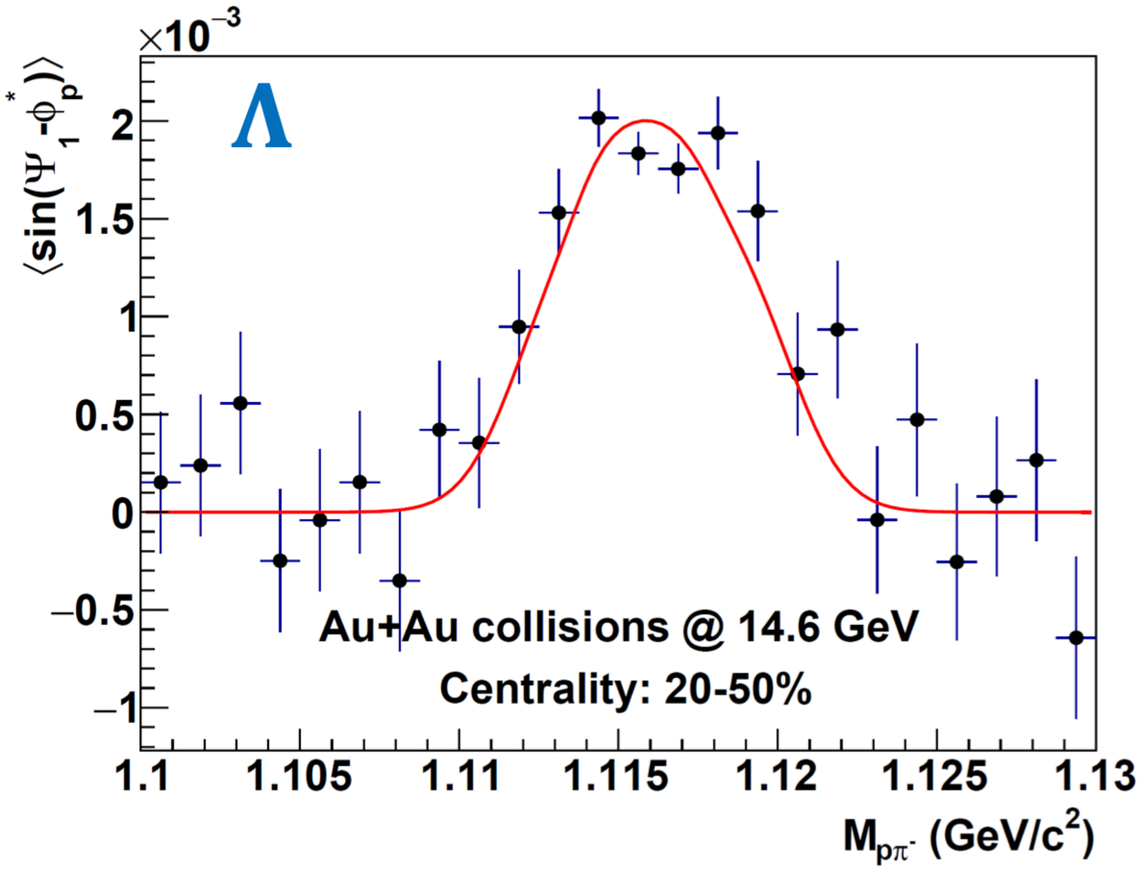
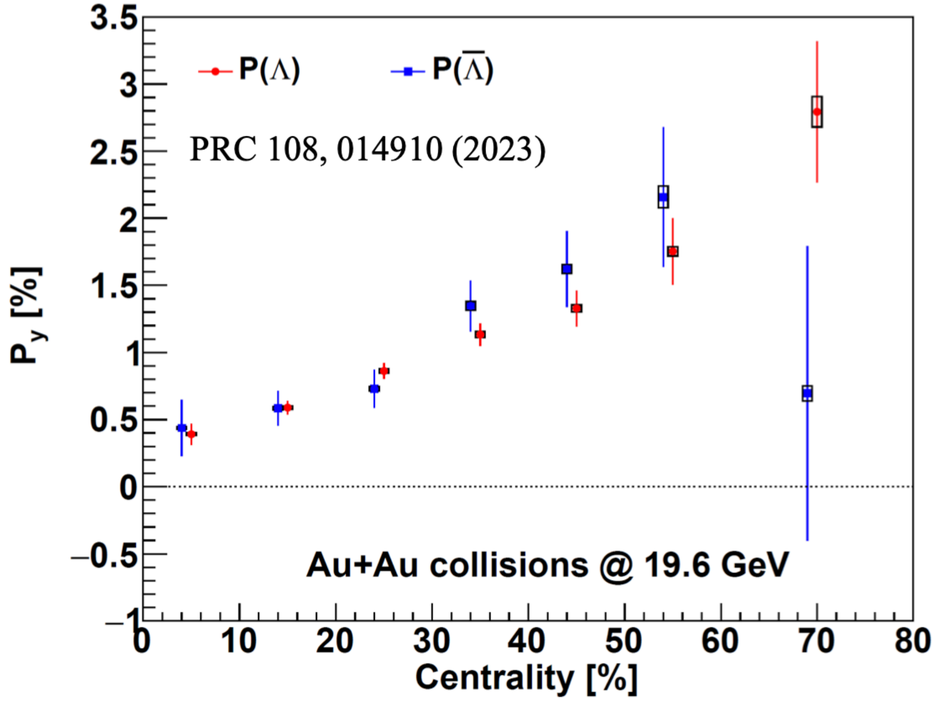
P_Λ signal extraction

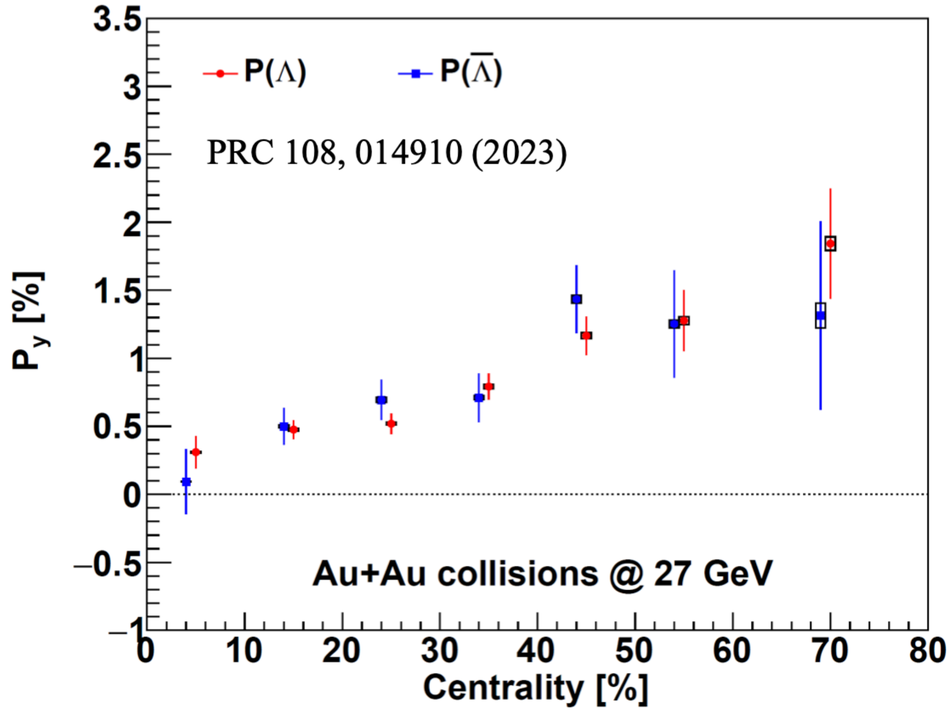


$$P_\Lambda = \frac{8}{\pi \alpha_\Lambda R^1_{EP}} < sin(\Psi_{EP,1} - \phi^*_p) >$$

- In collider mode dataset,
  - Polarization can be extracted by invariant mass method
  - $f(m_{inv}) = \frac{S}{S+B} * P_{\Lambda,signal} + \frac{B}{S+B} * P_{\Lambda,bkg}$

Centrality dependence of P_Λ

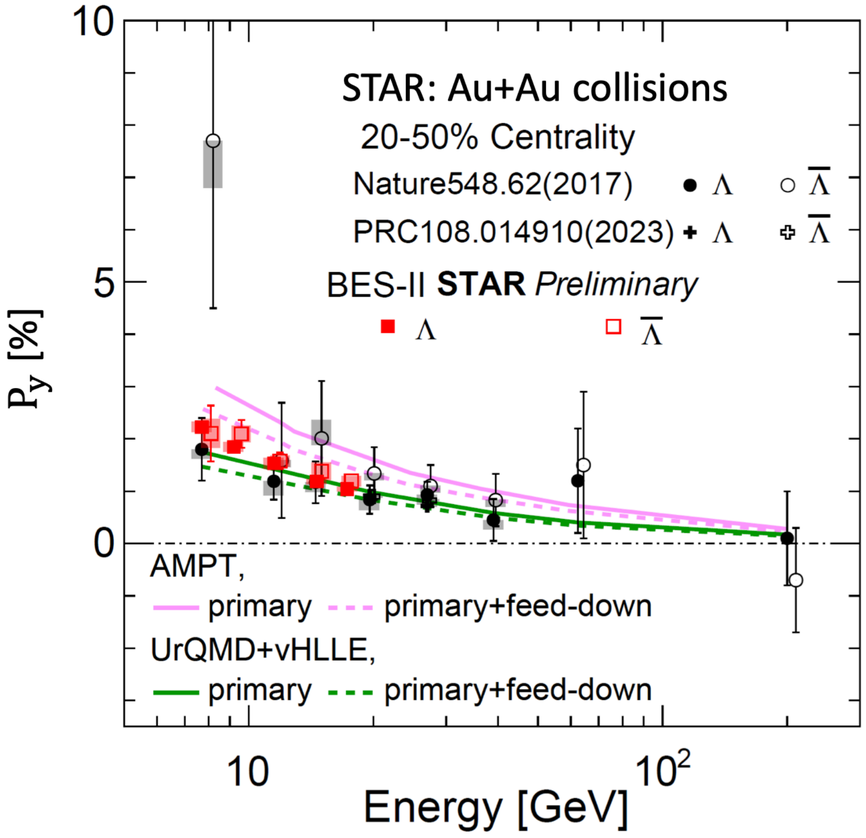


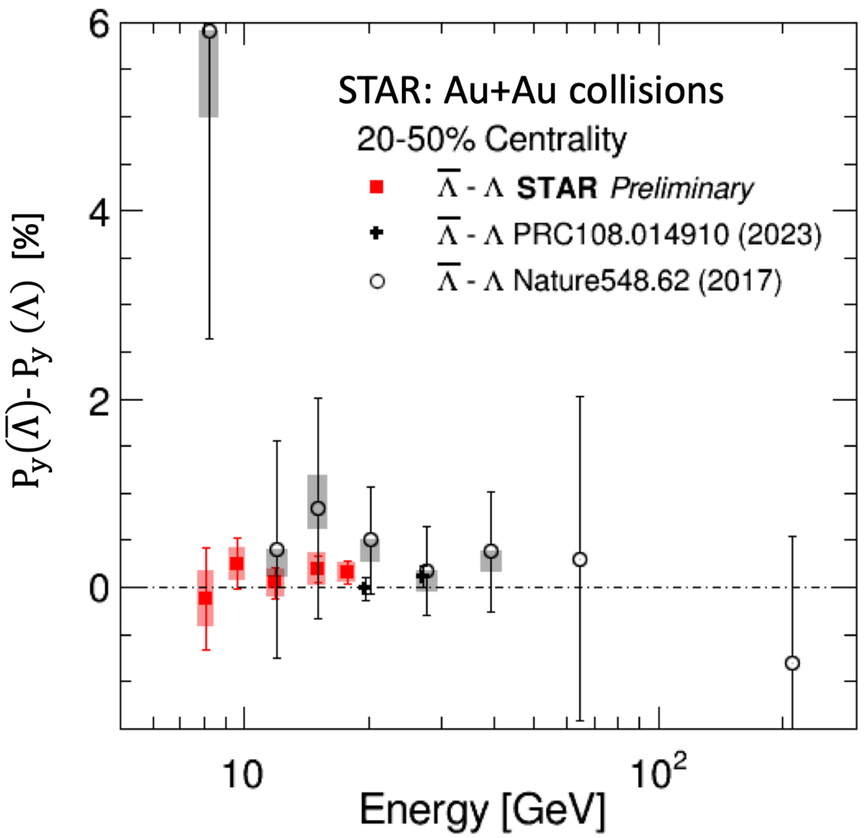


- Clear centrality dependence of Λ, $\overline{\Lambda}$ global polarization is observed.
- Λ, $\overline{\Lambda}$ global polarization are consistent within uncertainty.

• Phys. Rev. C 108,014910 (2023)

Energy dependence of P_Λ





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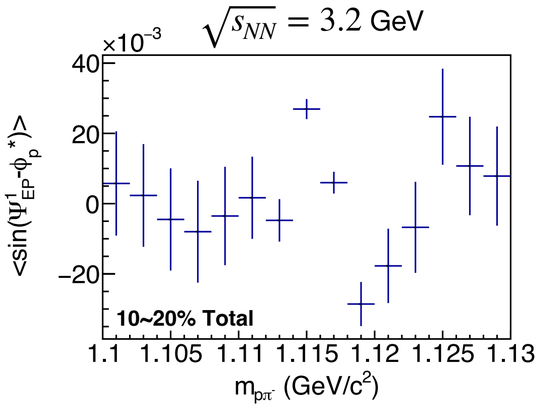
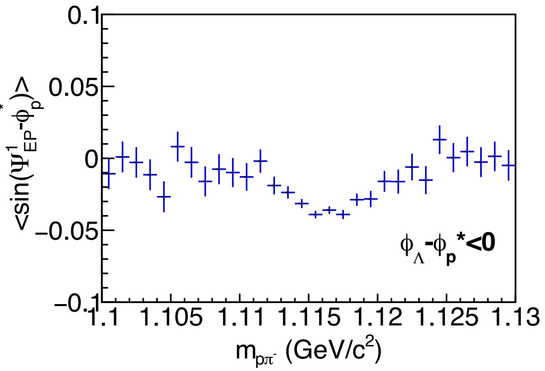
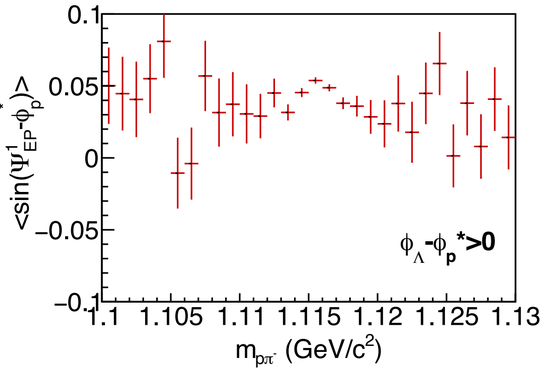
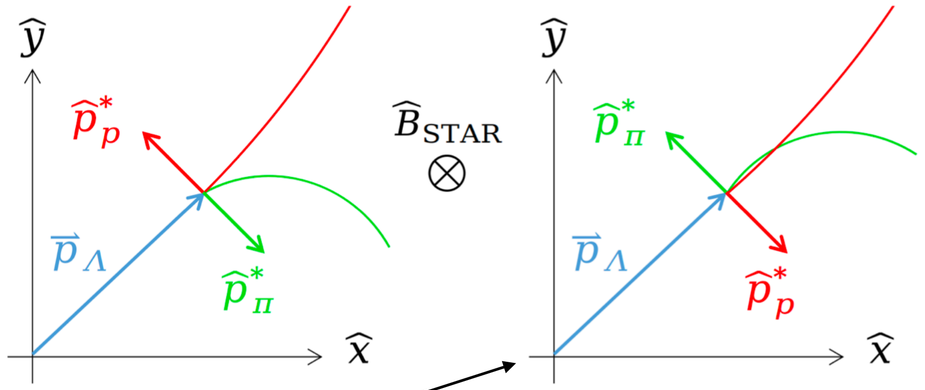
Generalized invariant mass method

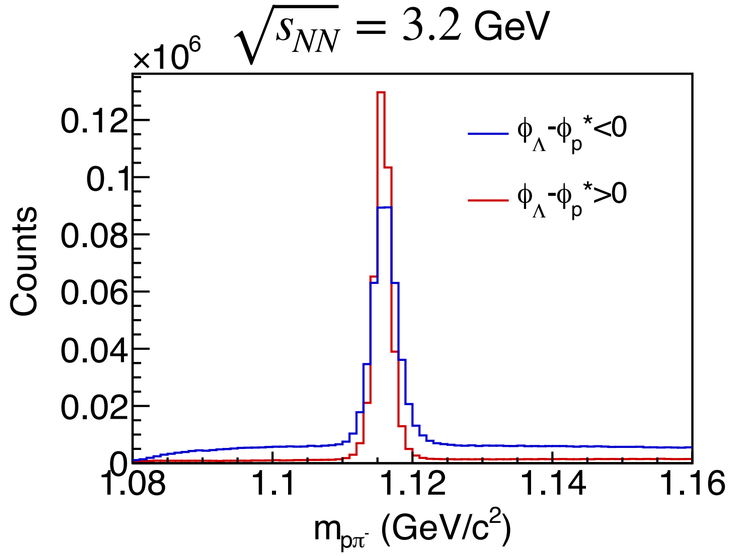






- In Fixed-target mode, method should be updated due to Λ v_1 and asymmetric detector acceptance.



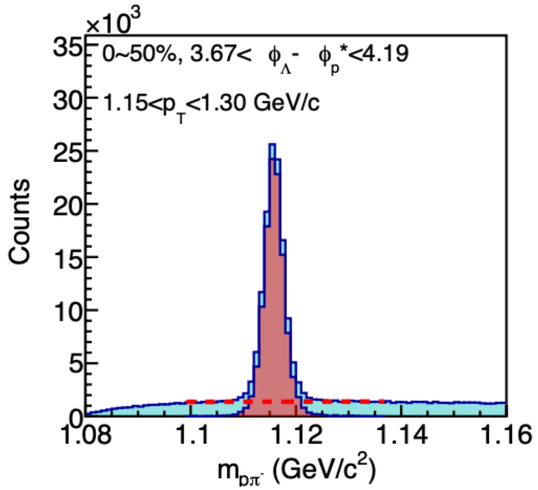


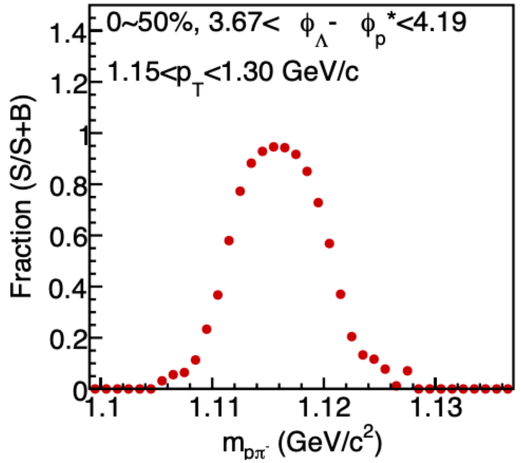
- ϕ_Λ has correlation with Ψ_1.
- Generalized invariant mass method should be used in FXT analysis.
  - $$\frac{8}{\pi\alpha_\Lambda}\frac{1}{R_1} < sin(\Psi_1 - \phi_p^*) >_{observed} = p_\Lambda^{real} + c \cdot sin(\phi_\Lambda - \phi_p^*)$$

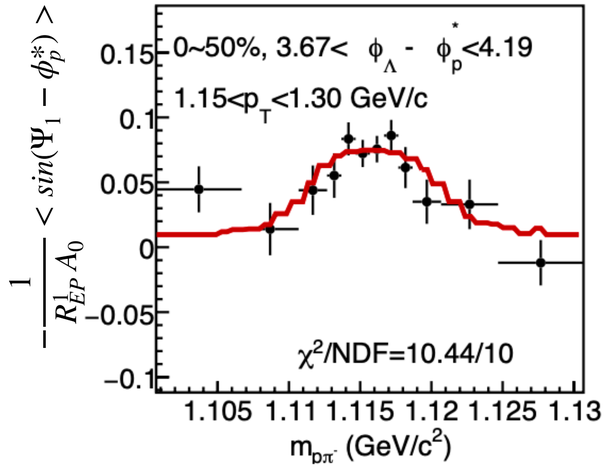
Phys. Rev. C 104, 061901 (2021)

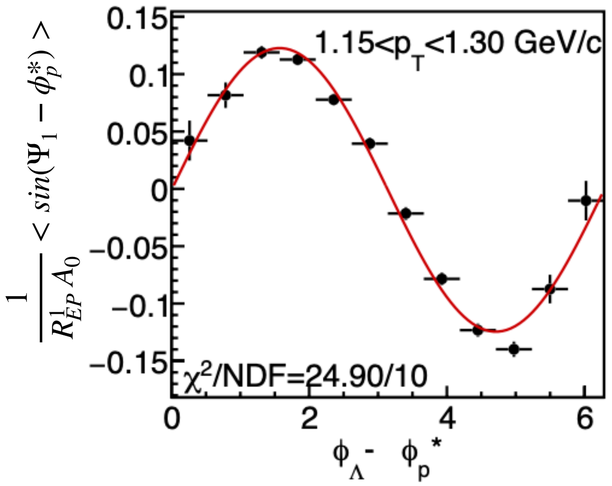
P_Λ signal extraction (FXT)

STAR FXT Au+Au collisions $\sqrt{s_{NN}} = 3.2$ GeV



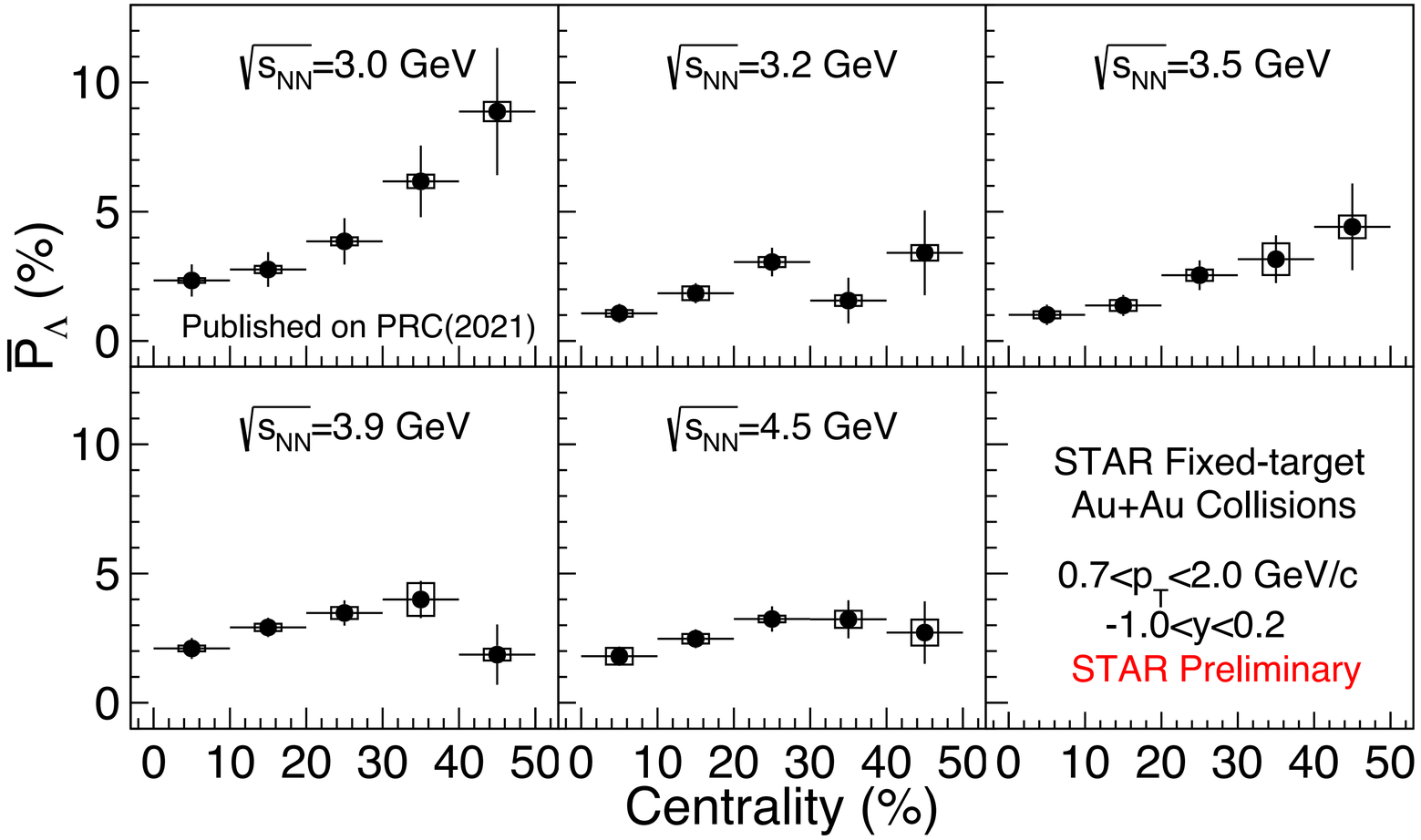






- Use invariant mass method to get the $\frac{1}{R_{EP}^1 A_0} < sin(\Psi_1 - \phi_p^*) >$ value.
  - $f(m_{inv}) = \frac{S}{S+B} * P_{\Lambda,signal} + \frac{B}{S+B} * P_{\Lambda,bkg}$
- Generalized invariant mass method is used to extract the true P_H.
  - $\frac{8}{\pi\alpha_H}\frac{1}{R_{EP,1}}\frac{1}{A_0} < sin(\Psi_1 - \phi_p^*) >_{observe} = p_H^{real} + c \cdot sin(\phi_\Lambda - \phi_p^*)$

Centrality dependence of P_Λ (FXT)



- Clear centrality dependence of P_Λ is observed.

Summary and outlook

- Global $\Lambda, \overline{\Lambda}$ polarization are obtained at BES-II energies in Au+Au collision at STAR@RHIC.
- Global $\Lambda, \overline{\Lambda}$ polarization show the energy dependence at $\sqrt{s_{NN}} = 7.7 \sim 27$ GeV.
- $\Lambda, \overline{\Lambda}$ global polarization are consistent within uncertainty at $\sqrt{s_{NN}} = 7.7 \sim 27$ GeV.
- Centrality dependence of P_{Λ} is observed at $\sqrt{s_{NN}} = 3.0 \sim 4.5$ GeV.

Outlook

- Polarization analysis using STAR FXT datasets is ongoing.

Thanks for your attention!