Global polarization of hyperons in Au+Au collisions at $\sqrt{s_{NN}}$ = 27 GeV in the STAR experiment

Egor Alpatov (for STAR Collaboration)

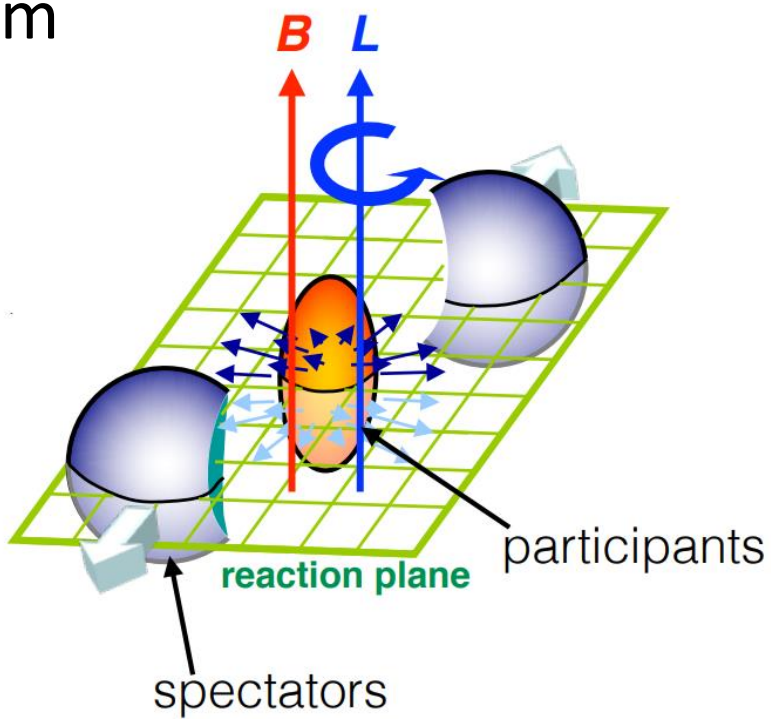
National Research Nuclear University MEPhI

Outline:

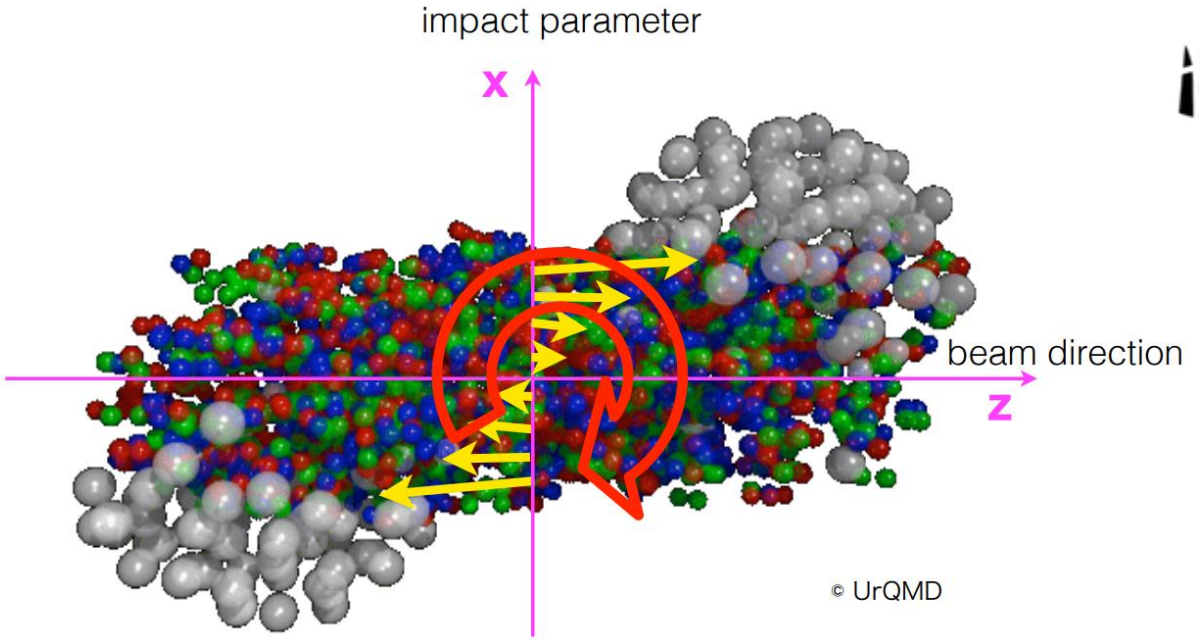
- Introduction
- Global hyperon polarization
- Motivation
- The STAR experiment
- Hyperon polarization measurements
- Results
- Conclusions

Introduction

- The Quark-Gluon Plasma (QGP) formed in non-central nuclear-nuclear collisions is associated with large orbital angular momentum, that leads to vorticity in the medium
- Spin-orbit coupling aligns spin directions of produced particles with the direction of vorticity
  - -Z.-T. Liang and X.-N. Wang, PRL94, 102301 (2005)
  - S. A. Voloshin, arXiv:nucl-th/0410089
- Another possible source of particle polarization is magnetic field, created in non-central collisions in the initial stage
  - -D. Kharzeev, L. McLerran, and H. Warringa, Nucl.Phys.A803, 227 (2008)
  - -McLerran and Skokov, Nucl. Phys. A929, 184 (2014)



Vorticity



- In non-central HIC the initial collective longitudinal flow velocity depends on x:

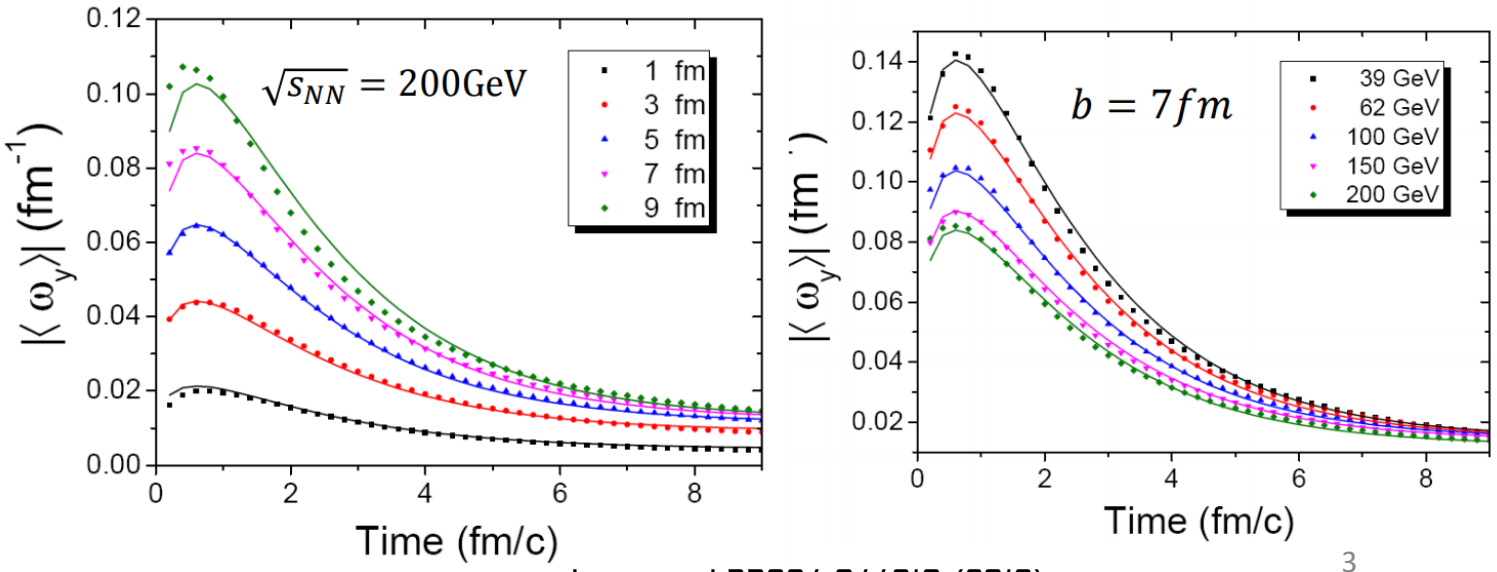
$$\omega_y = \frac{1}{2}(\nabla \times v)_y \approx -\frac{1}{2}\frac{dv_z}{dx}$$

- For small polarization:

Becattini, Karpenko, Lisa, Upsal, Voloshin PRC95.054902 (2017)

$$P_\Lambda \simeq \frac{1}{2}\frac{\omega}{T} + \frac{\mu_\Lambda B}{T}$$

$$P_{\bar{\Lambda}} \simeq \frac{1}{2}\frac{\omega}{T} - \frac{\mu_\Lambda B}{T}$$



Jiang et al,PRC94 044910 (2016)

How to measure global polarization?

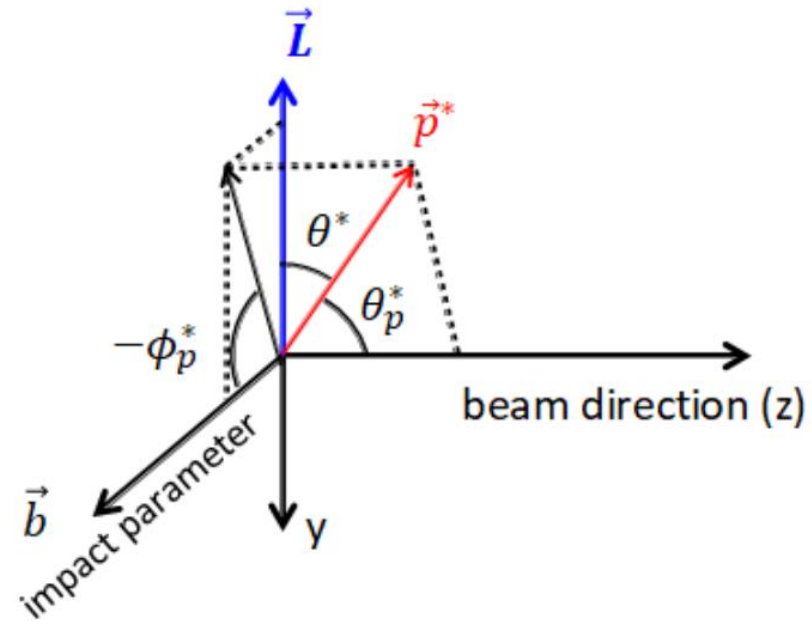
- Hyperons are “self-analyzing” due to weak decay properties:
  - Daughter baryons are preferentially emitted in parent spin direction
- Daughter baryons of hyperons with polarization ($\vec{P}$) follows the distribution:

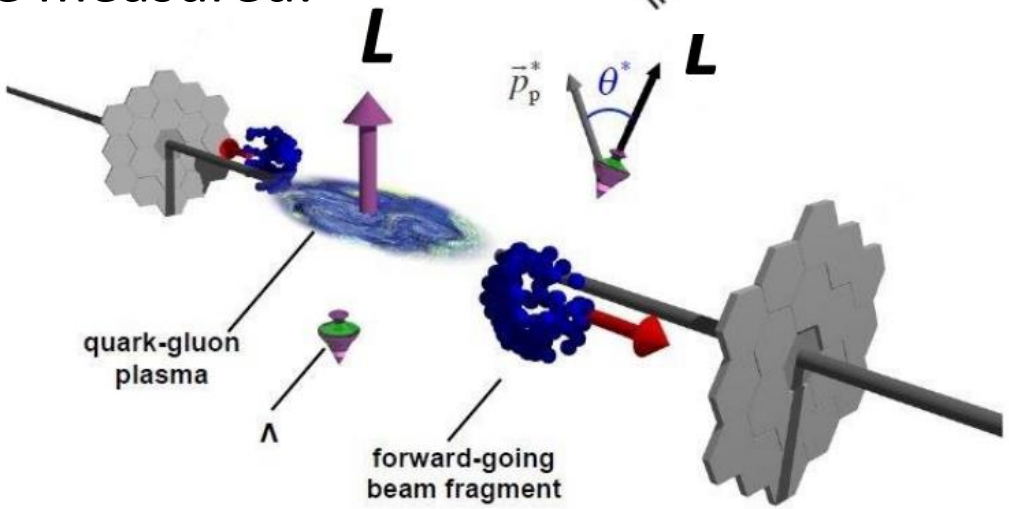
$$\frac{dN}{d\Omega^*} = \frac{1}{4\pi}\left(1 + \alpha_H |\vec{P}| \cdot \widehat{p_b^*}\right) = \frac{1}{4\pi}\left(1 + \alpha_H P \cos\theta^*\right)$$

  - α_H - decay parameter, unique for each hyperon species
  - $\widehat{p_b^*}$ is the daughter baryon momentum in the parent frame
- Projection to the transverse plane can be measured:

$$P_H = \frac{8}{\pi \alpha_H} \frac{\langle \sin(\psi_1 - \varphi_p^*) \rangle}{Res(\psi_1)}$$

  - ψ_1 is the reaction plane angle
  - ψ_1 and it’s resolution $Res(\psi_1)$ can be calculated with spectator’s signal.

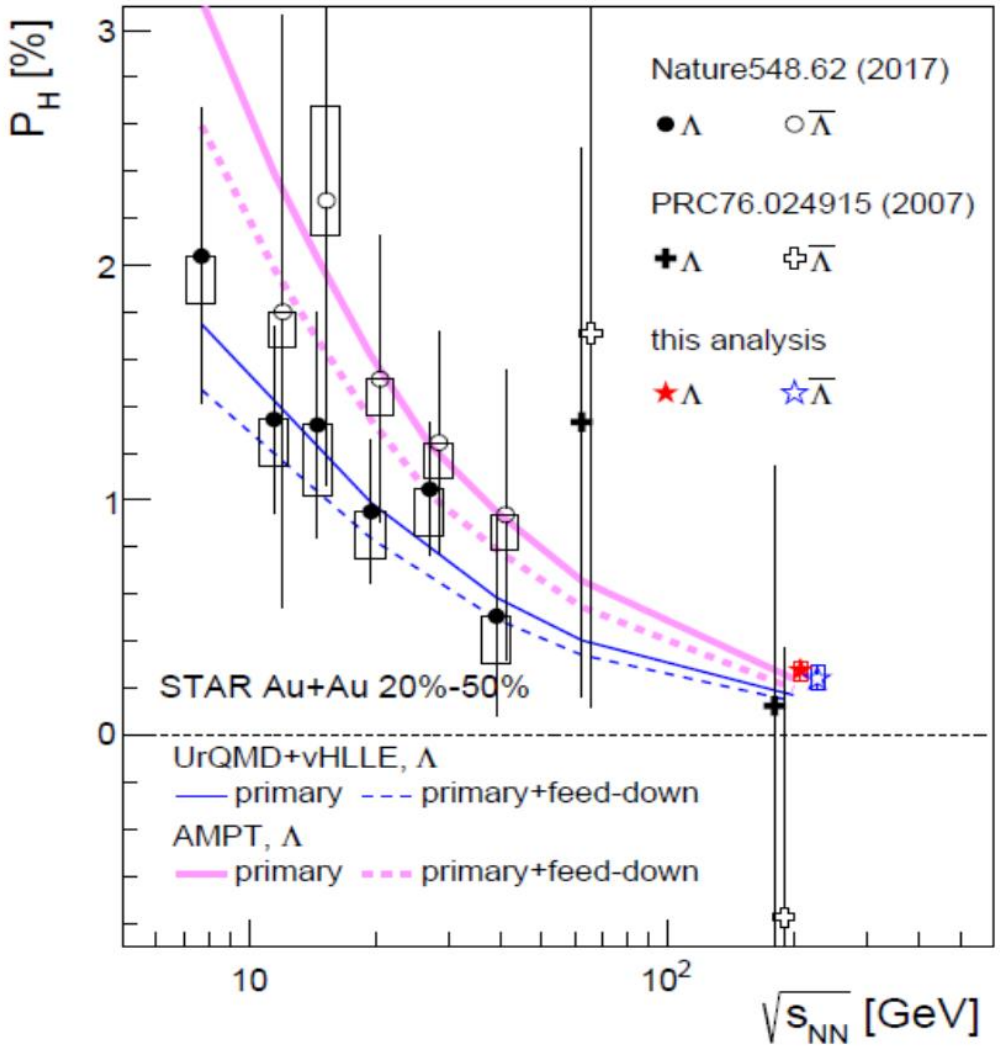




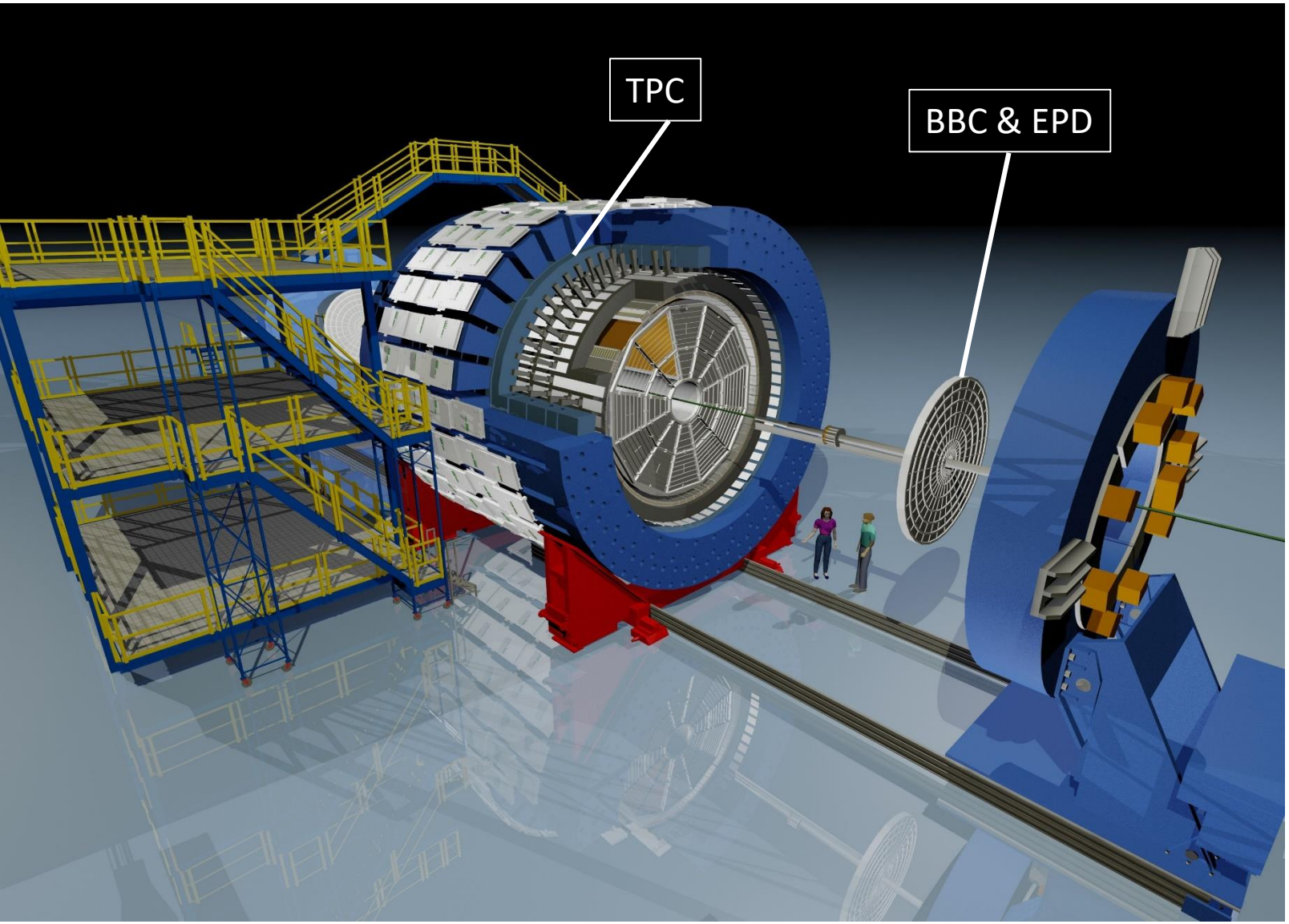
Motivation

- Global polarization of Λ hyperons was measured for $\sqrt{s_{NN}}$ = 7.7-200 GeV at STAR
- P_H decreases with increasing collision energy
- Difference between P_Λ and $P_{\bar{\Lambda}}$ maybe due to B-field effect
- Theoretical calculations can quantitively explain the energy dependence of the Λ polarization, but many of them fail to explain differential measurements
- Nowadays there is a growing interest to measure the global polarization of Λ and $\bar{\Lambda}$ produced from the decays of other particles such as Ξ.
- <u>Ξ polarization may provide new input for global polarization and vorticity studies</u>

STAR PRC 98, 014910 (2018)

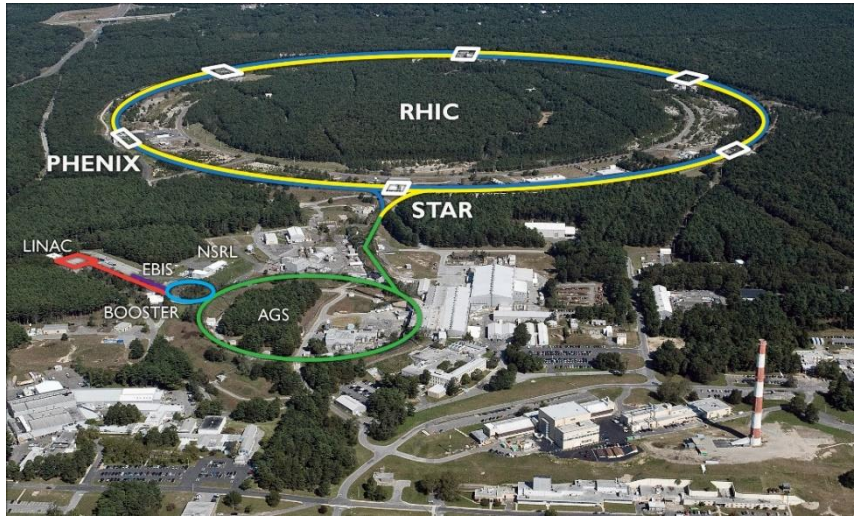


The STAR experiment



Detectors, used in this work:

- **T**ime **P**rojection **C**hamber
  η: [-1, 1]
- **E**vent **P**lane **D**etector
  η:[2.1, 5.1]
- **B**eam-**B**eam **C**ounters
  η: [3.3, 5.0]



Event plane measurement

- Event plane was measured using BBCs and EPDs

$$\Psi_1 = \tan^{-1}\left(\frac{\sum w_i \sin(\phi_i)}{\sum w_i \cos(\phi_i)}\right)$$

where w_i is detector's tile ADC

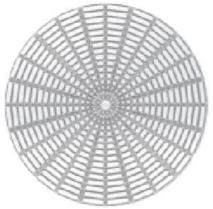
- $Res(\Psi_{1,EPD\ East}) = Res(\Psi_{1,EPD\ West}) = \sqrt{< \cos(\Psi_{1,EPD\ East} - \Psi_{1,EPD\ West}) >}$

- Resolution for east and west detectors combination estimated by two sub-event method A. M. Poskanzer, S. A. Voloshin, PRC58.1671(1998)
- $Res_{EPD} > 1.5\ Res_{BBC}$
- BES 1 results used BBCs event plane

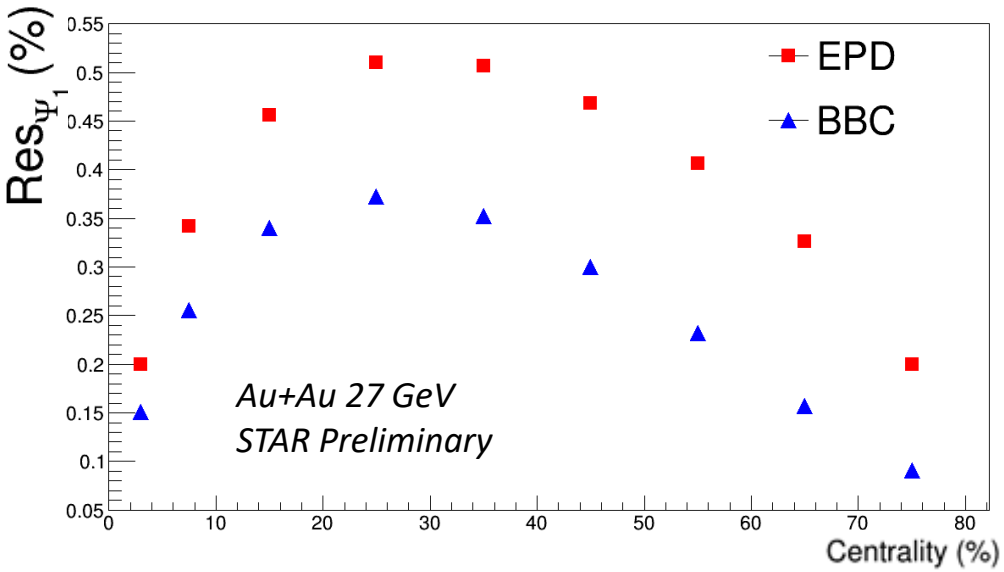
BBC

- 18 (x2) tiles but only 16(x2) photomultiplier tubes
- $|\eta_{BBC}| = 3.3 - 5.0$

EPD

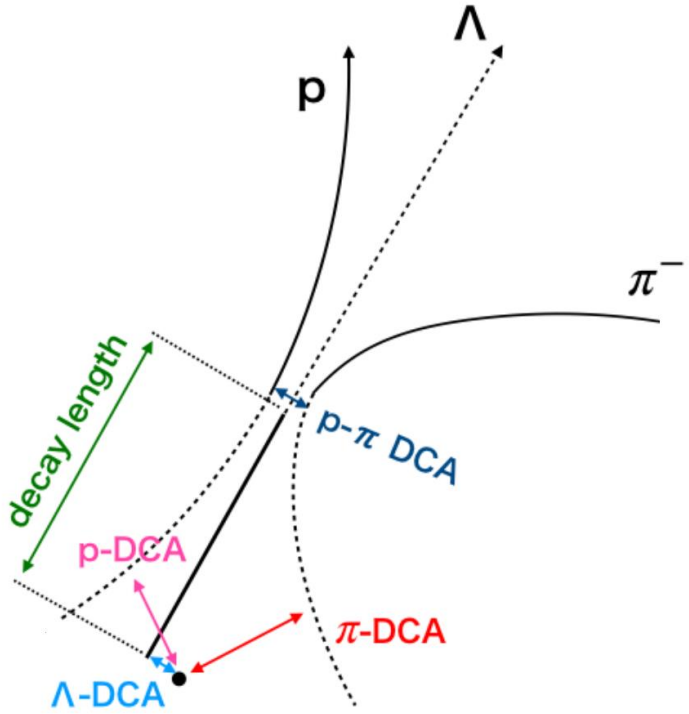


- 372 (x2) tiles and 372(x2) Silicon photomultipliers
- $|\eta_{EPD}| = 2.1 - 5.1$

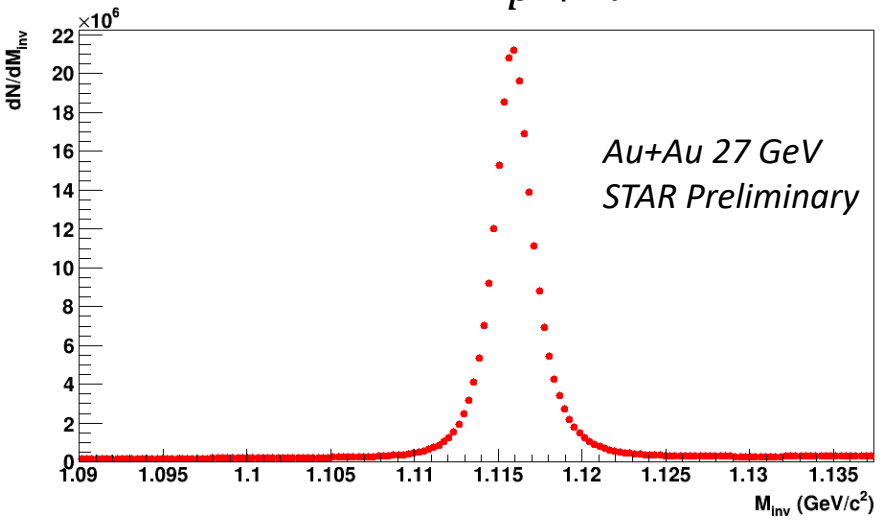


Hyperon reconstruction

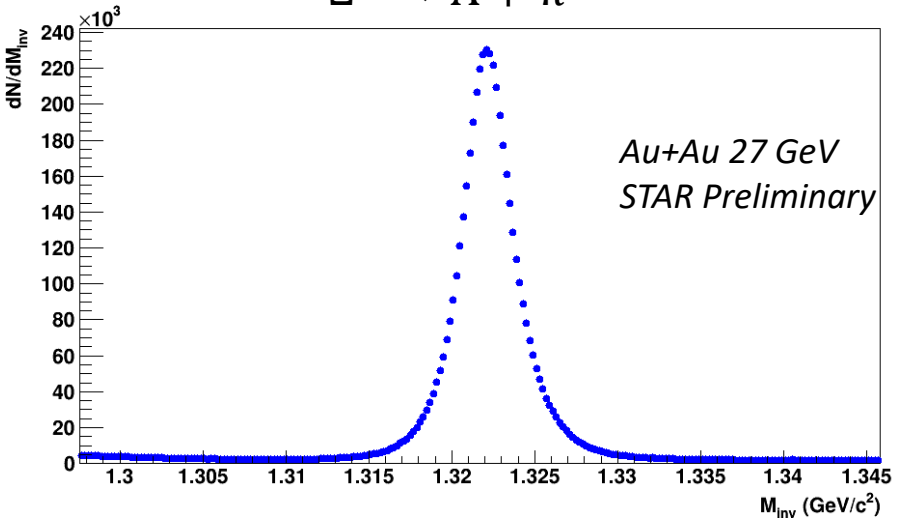
- Hyperon daughters are identified using dE/dx in TPC
- Used topology of decays to reconstruct Lambdas
- Ξ were reconstructed via $\Xi \rightarrow \Lambda + \pi$



$\Lambda \rightarrow p + \pi^-$



$\Xi^- \rightarrow \Lambda + \pi^-$



Signal extraction

- The data was fitted with the following equation:

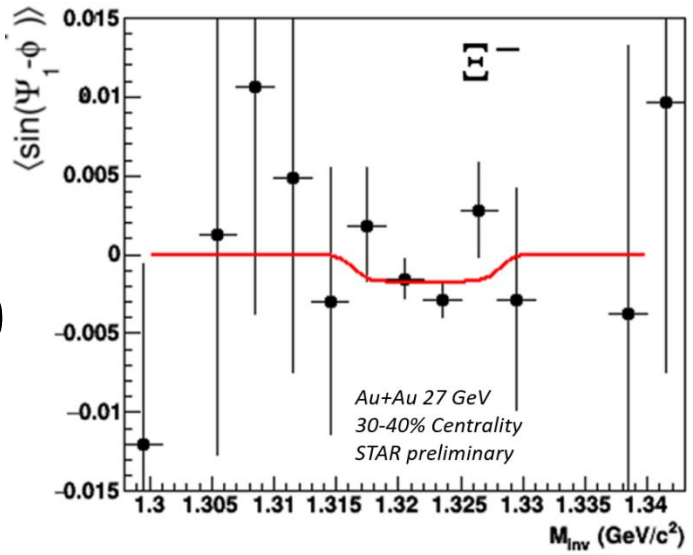
$$\langle \sin(\Delta\varphi) \rangle^{obs} = \left(1 - f^{Bg}(M_{inv})\right) \langle \sin(\Delta\varphi) \rangle^{Sg} + f^{Bg}(M_{inv}) \langle \sin(\Delta\varphi) \rangle^{Bg}$$

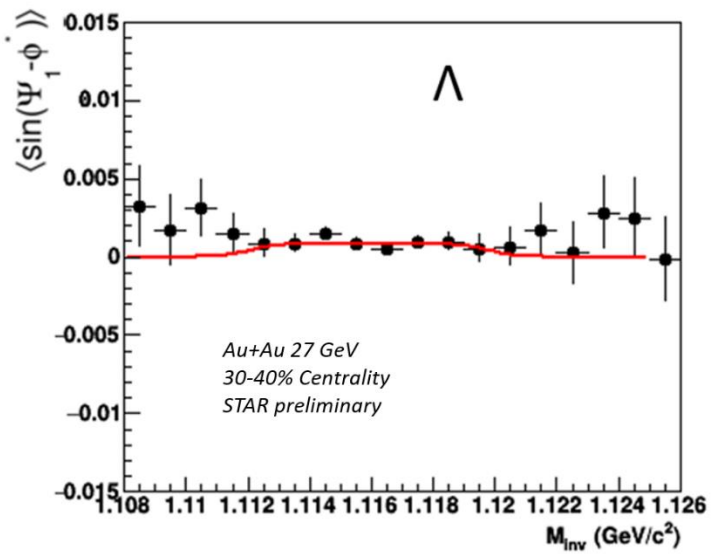
$$\Delta\varphi = \Psi_1 - \varphi_p^*$$

$f^{Bg}(M_{inv})$ is background fraction

- $f^{Bg}(M_{inv})$ is taken from the invariant mass distribution fit
- Assumption: background signal = 0
- Signal is scaled after extraction:

$$\boldsymbol{P_H = \frac{8}{\pi \alpha_H} \frac{\langle sin(\psi_1 - \varphi_p^*) \rangle}{Res(\psi_1)}}$$

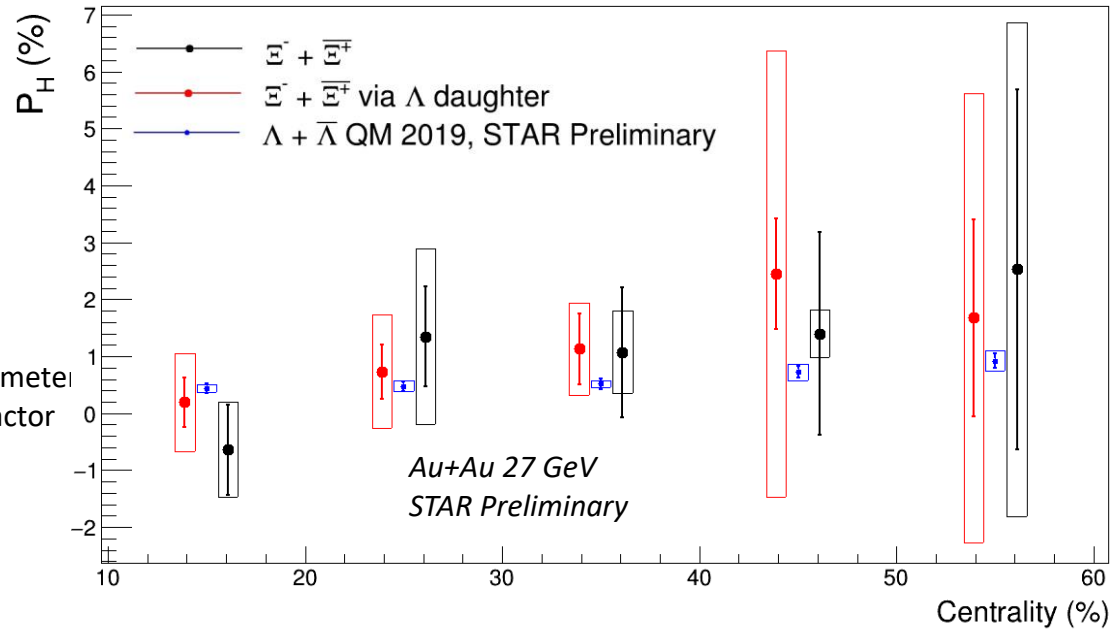


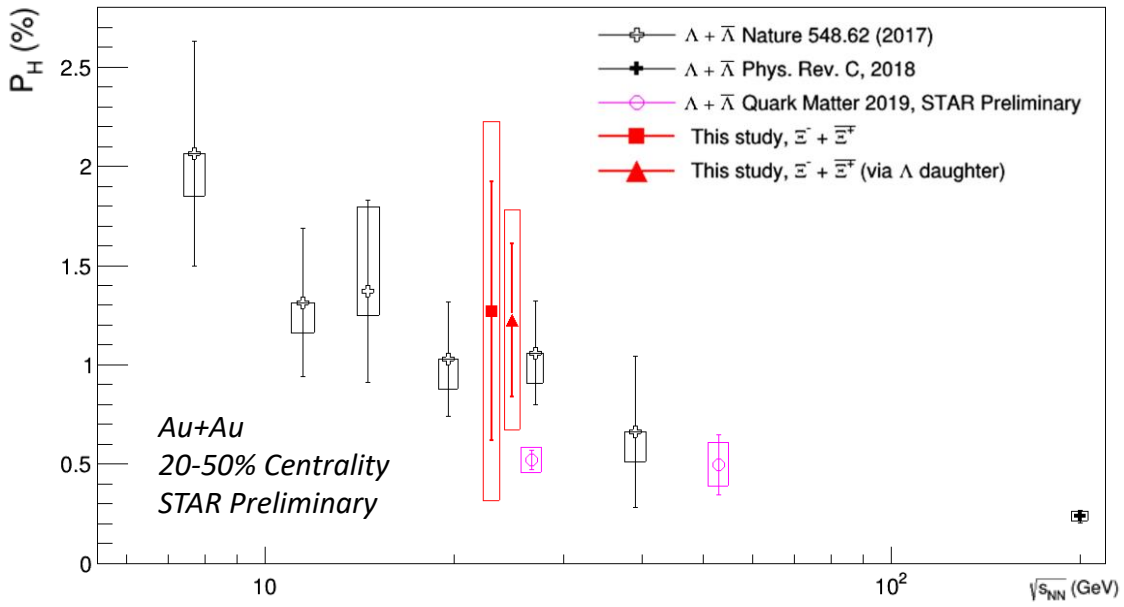


Results

$\alpha_{\Xi^-} = -0.401$
$\alpha_{\bar{\Xi}^+} = 0.401$
$\alpha_{\Lambda} = 0.738$
$\alpha_{\Lambda} = -0.752$
$C_{\Xi\Lambda} = 0.932$

α_H - decay parameter
$C_{\Xi\Lambda}$ - transfer factor
$P_{\Xi} = C_{\Xi\Lambda} P_{\Lambda}$





- Ξ polarization transfers to it's daughter Λ with transfer factor $C_{\Xi\Lambda}$
- Ξ polarization was measured directly and via Λ daughter
- Directly measured P_{Ξ} is comparable with $P_{\Xi\to\Lambda}$
- Weak centrality dependence of Ξ polarization within uncertainties

- P_{Ξ} is consistent with P_{Λ} trend

Results from previous publications were scaled to be consistent with updated decay parameters: Zyla, P.A. and others, Review of Particle Physics
Old $\alpha_{\Lambda} = 0.642$, $\frac{\alpha_{\Lambda\ old}}{\alpha_{\Lambda\ new}} = 0.869$

Conclusions

- We presented first results of $\Xi + \bar{\Xi}$ global polarization measurements in Au+Au collisions at 27 GeV
- Direct polarization measurements are consistent with measurements via Λ daughters
- Ξ polarization is comparable to Λ polarization at 27 GeV within uncertainties
- We are looking forward to continuing this measurements at other energies

Thank you for your attention!