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University of Tsukuba
筑波大学

Global polarization of Λ hyperons in Au+Au $\sqrt{s_{\mathrm{NN}}}$ = 7.2 GeV collisions with fixed-target mode at RHIC-STAR experiment

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STAR

QUARK MATTER KRAKÓW 2022

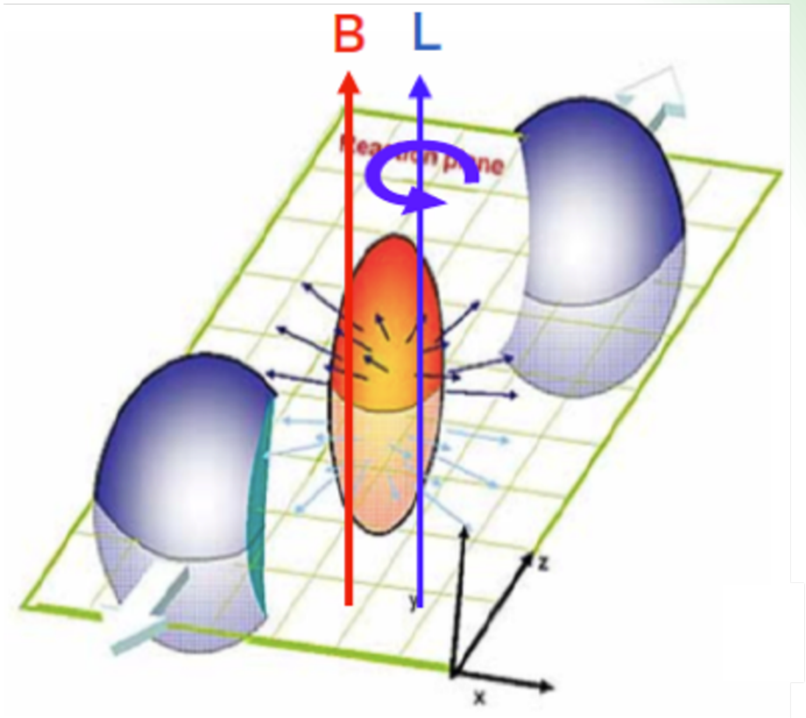
abstract

Non-central heavy-ion collisions produce a large angular momentum that leads to vorticity of the created system. Due to the spin-orbit coupling, spin directions of particles are aligned with the orbital angular momentum of the system. Global polarization of Λ and $\overline{\Lambda}$ hyperons has been measured in Au+Au collisions from $\sqrt{s_{\mathrm{NN}}}$ = 7.7 GeV to 5.02 TeV. The STAR fixed target program provides an opportunity to extend such measurements at even lower energies. In this poster, differential measurements such as centrality, rapidity and transverse momentum dependence of global polarization of Λ hyperons in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 7.2 GeV with the fixed-target configuration is reported.

Vorticity and magnetic field in HIC

✓In non-central collisions…

- The created matter can exhibit strong vorticity.
  -Z.-T.Liang and X.-N. Wang, PRL94, 102301
- The strong magnetic field can appear in the initial state.
  -D. Kharzeev, L. McLerran, and H. Warring, Nucl.Phys.A803, 227 (2008)
  -L.McLerran and V.Skokov, Nucl. Phys. A929, 184 (2014)



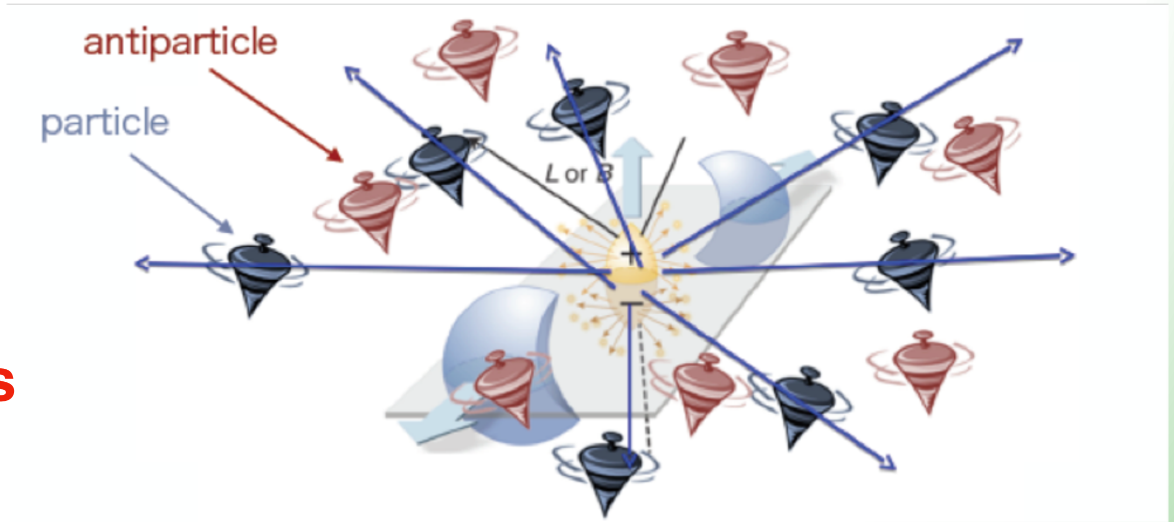
Global polarization

✓Polarization due to the spin-orbit coupling:

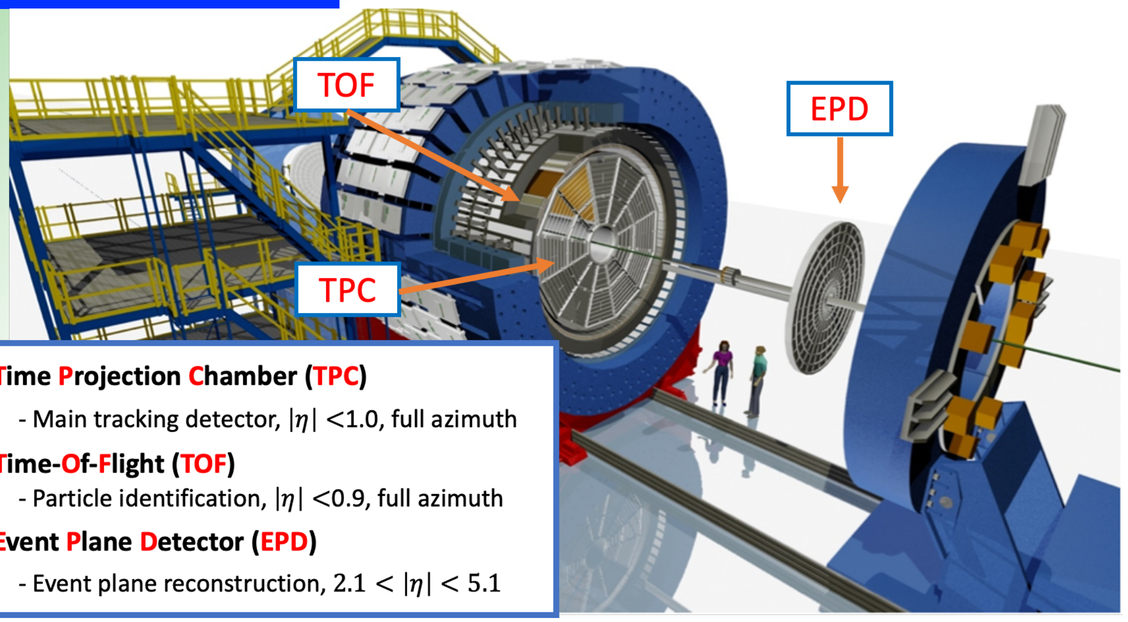
- **Particle and anti-particle's spins are aligned with angular momentum, L.**

✓Spin alignment by magnetic field:

- **Spin direction of particles and anti-particles are aligned in opposite direction due to the opposite signs of their magnetic moments.**



STAR detector



- **Time Projection Chamber (TPC)**
  - Main tracking detector, $|\eta| < 1.0$, full azimuth
- **Time-Of-Flight (TOF)**
  - Particle identification, $|\eta| < 0.9$, full azimuth
- **Event Plane Detector (EPD)**
  - Event plane reconstruction, $2.1 < |\eta| < 5.1$

- Charged particles can be identified via specific ionization energy loss in the TPC and mass estimated with the TOF.
- First-order event plane was reconstructed by EPD.

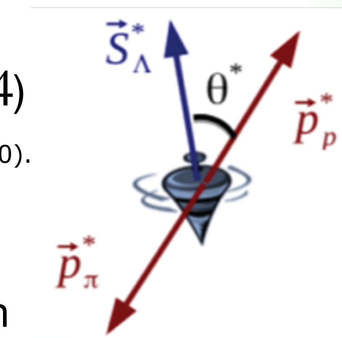
Measurement of the polarization

✓ Daughter proton preferentially decays along the Λ's spin (opposite for anti-Λ).

$$\Lambda \rightarrow p + \pi^-$$ (BR:63.9%, $c\tau$~7.9cm)

✓ Polarization can be measured via the distribution of the azimuthal angle of the daughter proton (in the Lambda rest frame).

$$P_H = \frac{8}{\pi \alpha_H} \frac{\langle \sin(\Psi_1 - \phi_p^*) \rangle}{Res(\Psi_1)}$$



α_H : decay parameter ($\alpha_\Lambda = 0.732 \pm 0.014$)

P.A. Zyla et al. (PDG), Prog. Theor. Exp. Phys.2020, 083C01 (2020).

Ψ_1 : 1^{st}-order event plane

ϕ_p^* : azimuthal angle of the daughter proton in the Λ's rest frame

Event plane reconstruction

- **First order event plane**

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

First,
$w_i^{TPC} = \eta - y^{mid}$ $w_i^{EPD} =$ nMip

Second,
$w_i = \langle \cos(\phi^A - \Psi_1) \rangle$ A : pion or proton

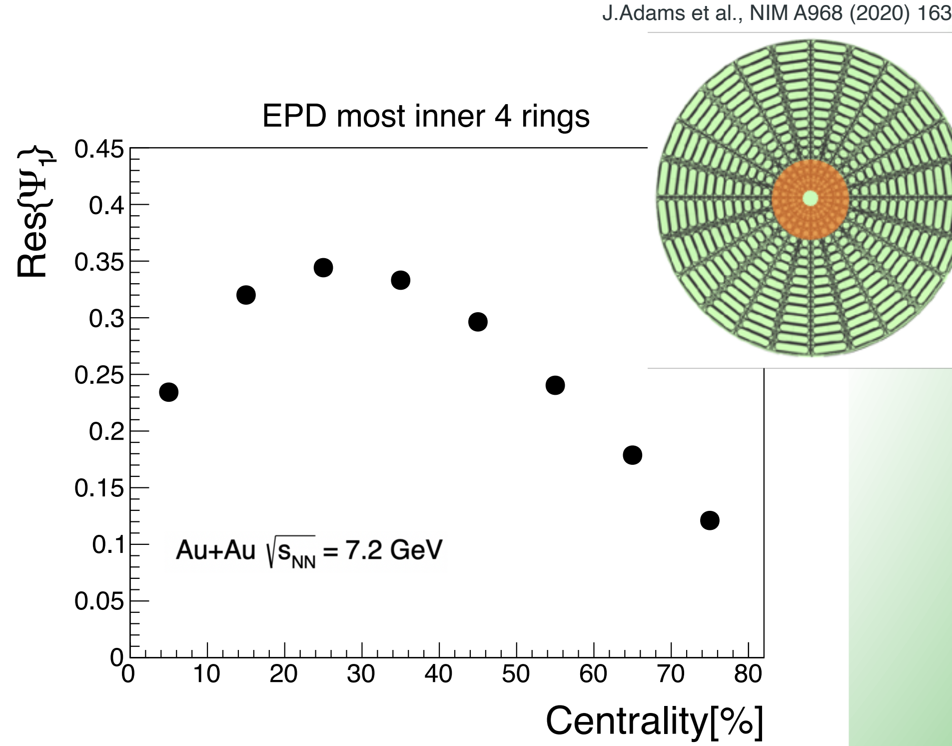
✓ Event plane resolution was calculated by 3-subevent method.

A. M. Poskanzer and S. A. Voloshin, Phys. Rev. C 58, 1671 (1998).

$$Res(\Psi_1^A) = \sqrt{\frac{\langle \cos([\Psi_1^A - \Psi_1^B]) \rangle \langle \cos([\Psi_1^A - \Psi_1^C]) \rangle}{\langle \cos([\Psi_1^B - \Psi_1^C]) \rangle}}$$

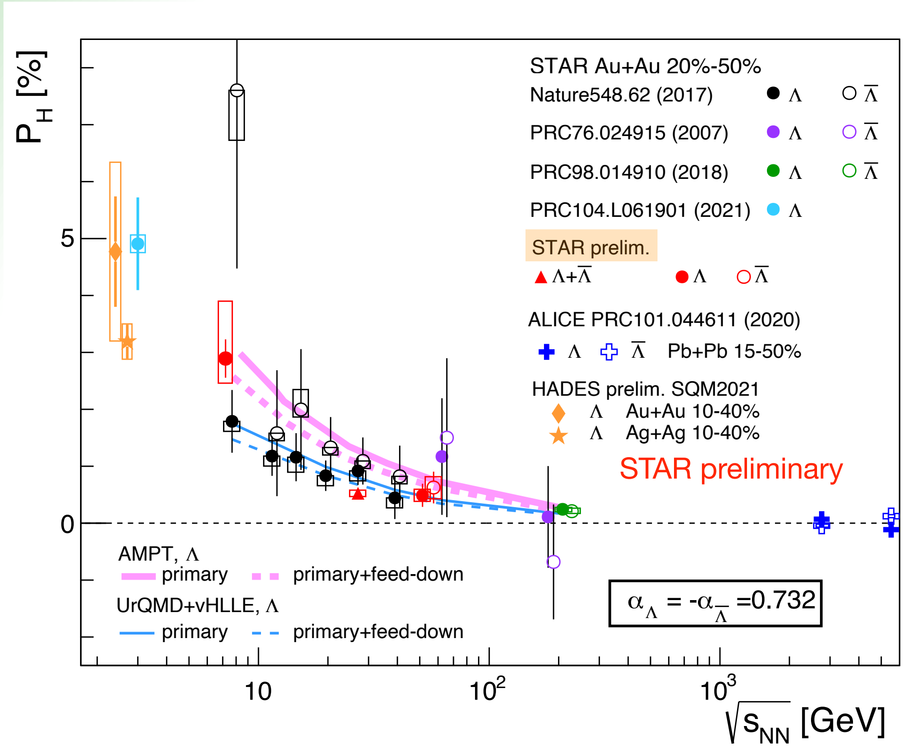
A : EPD most inner 4 rings
B : TPC ($-0.5 < \eta < 0$)
C : TPC ($-1.5 < \eta < -1.0$)

J.Adams et al., NIM A968 (2020) 163970



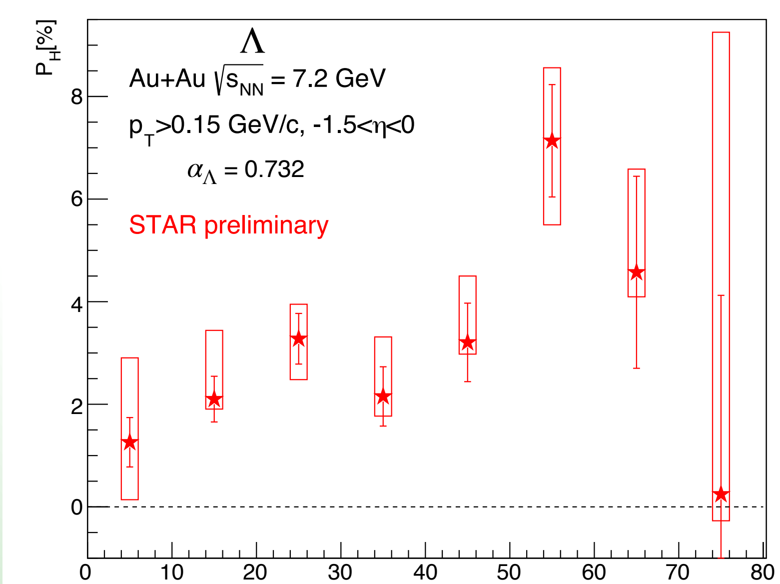
Global polarization in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.2 GeV

‣ Collision energy dependence



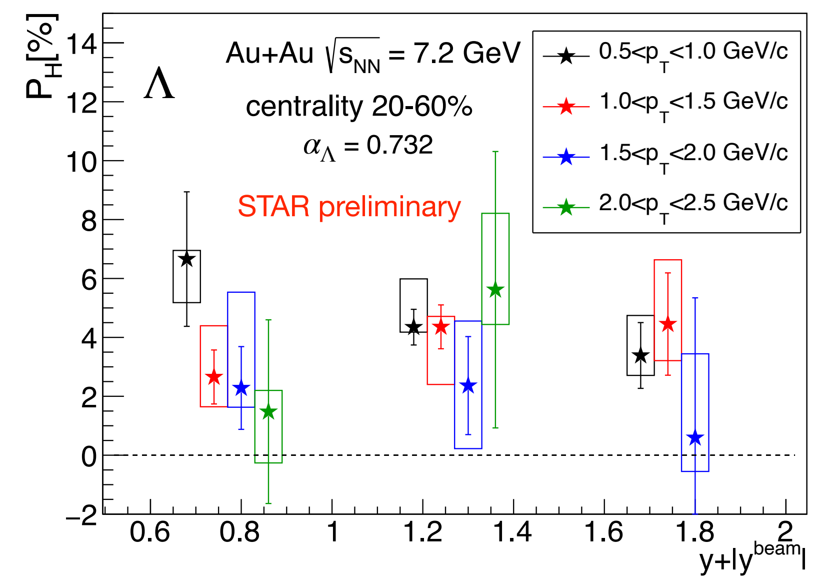
✓ The increasing trend with the decrease of collision energy persists down to 2.4 GeV.

‣ Centrality dependence



✓ Tend to Increase in more peripheral collisions.

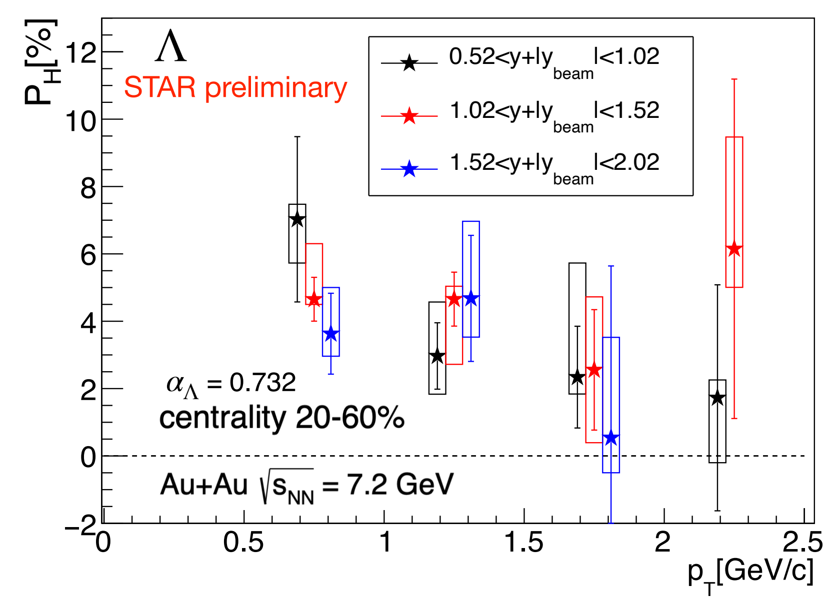
‣ Rapidity dependence



✓ The result does not show significant rapidity dependence within our acceptance.

✓ Polarization in large rapidity region can be explored in the future with iTPC and forward upgrade(2023+2025).

‣ p_T dependence



✓ No significant p_T dependence seen in data.

Summary and Outlook

‣ Summary

✓**We presented measurements of Λ global polarization in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.2 GeV from STAR in fixed target mode.**

- Positive polarization is observed.
- Λ polarization increases at lower collision energies.
- Increasing trend towards peripheral collisions as expected.
- No significant dependence on rapidity and p_T observed.

‣ Outlook

✓Measurement of anti-Λ polarization at 7.2 GeV.

✓Measurement global polarization with higher statistics.

- Completed the data taking of BES II + FXT.
- $\sqrt{s_{NN}}$ = 7.2 GeV : 155M(2018)
  → 155M(2018) + 317M(2020) + 88.6M(2021).

2018	Start	Stop	Good	Target	Status
27 GeV	May 10th	June 17th	555 M	700 M	Final
3.0 FXT	May 30th	June 4th	258 M	100 M	Final
7.2 FXT	June 11th	June 12th	155 M	none	Final
2019	**Start**	**Stop**	**Good**	**Target**	
19.6 GeV	Feb 25th	April 3rd	478 M	400 M	Preliminary
14.6 GeV	April 4th	June 3rd	324 M	310 M	Post-prod QA
3.9 FXT	June 18th	June 18th	52.7 M	50 M	Produced
3.2 FXT	June 28th	July 2nd	200.6 M	200 M	Post-prod QA
7.7 FXT	July 8th	July 9th	50.6 M	50 M	Produced
200 GeV	July 11th	July 12th	138 M	140 M	*March ?*
2020	**Start**	**Stop**	**Good**	**Target**	**Status**
11.5 GeV	Dec 10th	Feb 24th	235 M	230 M	*Summer?*
7.7 FXT	Jan 28th	Jan 29th	112.5 M	100 M	Produced
4.5 FXT	Jan29th	Feb 1st	108 M	100 M	Produced
6.2 FXT	Feb 1st	Feb 2nd	118 M	100 M	Produced
5.2 FXT	Feb 2nd	Feb 3rd	103 M	100 M	Produced
3.9 FXT	Feb 4th	Feb 5th	117 M	100 M	Produced
3.5 FXT	Feb 13th	Feb 14th	115.6 M	100 M	Produced
9.2 GeV	Feb 24th	Sep 1st	161.8 M	160 M	*Summer?*
7.2 FXT	Sep 12th	Sep 14th	317 M	None	
2021	**Start**	**Stop**	**Good**	**Target**	**Status**
7.7 GeV	Jan 31st	May 1st	100.9 M	100 M	*May?*
3.0 FXT	May 1st	June 28th	2103 M	2.0 B	
9.2 FXT	May 6th	May 6th	53.9 M	50 M	
11.5 FXT	May 7th	May 7th	51.7 M	50 M	
13.7 FXT	May 8th	May 8th	50.7 M	50 M	
17.3 GeV	May 25th	June 7th	256.1 M	250 M	
7.2 FXT	June 3rd	July 3rd	88.6 M	None	