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Differential measurements of global polarization of Λ hyperons in Au+Au collisions at $\sqrt{s_{NN}} = 54.4$ GeV with STAR

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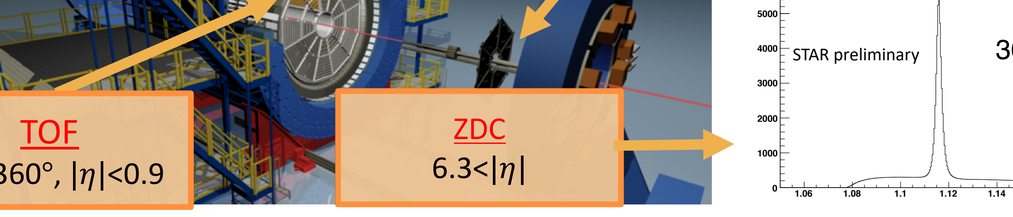
abstract

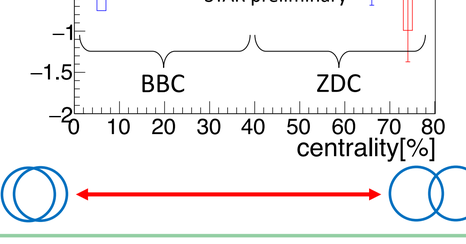
The medium generated by non-central nuclear-nuclear collision would have a large angular momentum. Due to spin-orbit coupling, spin directions of particles formed by recombining quarks from the plasma could reflect the spin direction aligned with the angular momentum of the system. Global polarization is expected to lead to the understanding of the physical properties of QGP because it is caused by the vorticity of the system. Global polarization has been measured from 7.7 GeV to 200 GeV via Lambda hyperon decay. In this poster, various differential studies including different event planes and azimuthal dependences of the global polarization measurements in Au+Au collision at 54.4 GeV which have not been measured yet will be reported.

Motivation

- In non-central collisions :
  - The created matter should exhibit rotational motion [1].
  - The strong magnetic field would appear in the initial state [2][3].



- Polarization due to spin-orbit coupling:
  - Particle and anti-particle's spins are aligned with angular momentum **L**.
- Spin alignment by magnetic field:
  - Particle's spin are aligned with magnetic field, B.
  - Antiparticle's spin is oppositely aligned.

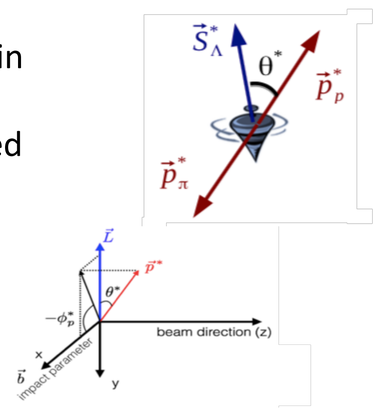


Measurement of the polarization

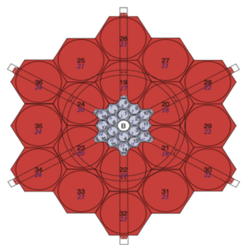
- Daughter proton preferentially decays into the Λ's spin (opposite for anti-Λ)
- The global polarization of Λ hyperons can be measured via the distribution of the azimuthal angle of the hyperon decay baryon [4].

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

Ψ_1 : 1^{st}-order event plane
ϕ_p^* : ϕ of daughter proton in Λ rest frame
α_H : decay parameter ($\alpha_\Lambda = -\alpha_{\bar{\Lambda}} = 0.642 \pm 0.013$)



The STAR detector



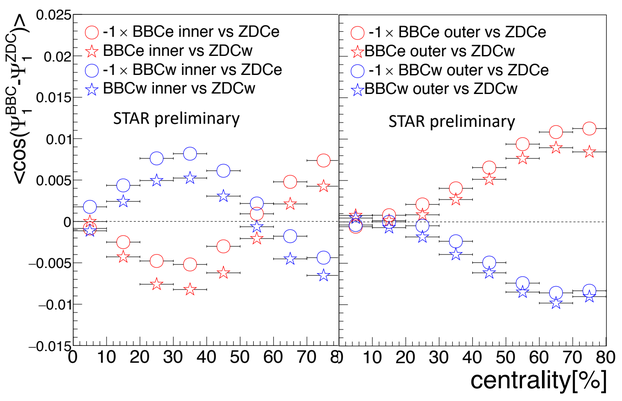
- Charged particles can be identified via specific ionization energy loss in the TPC and mass estimated with the TOF.
- 1st –order event plane was reconstructed by BBC and ZDC.

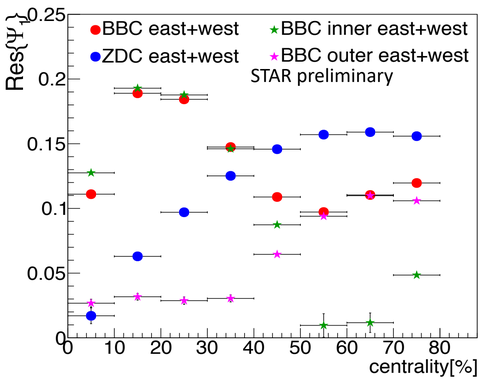
Event plane reconstruction

- **The contribution of spectator only in the central collision of BBC inner ring (3.9 < |η| < 5.0) is observed.**
  - Beam rapidity is ~ 4 in Au+Au collisions at 54.4 GeV.

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

Inner ring : 1-6 for the tile number (3.9 < |η| < 5.0)
Outer ring : 7-18 for the tile number (3.3 < |η| < 3.9)





- Calculate the resolution by 2-subevent method.

$$\text{Res}\{\Psi_A\} = \text{Res}\{\Psi_B\} = \sqrt{\langle \cos(\Psi_A - \Psi_B) \rangle}$$ [5]

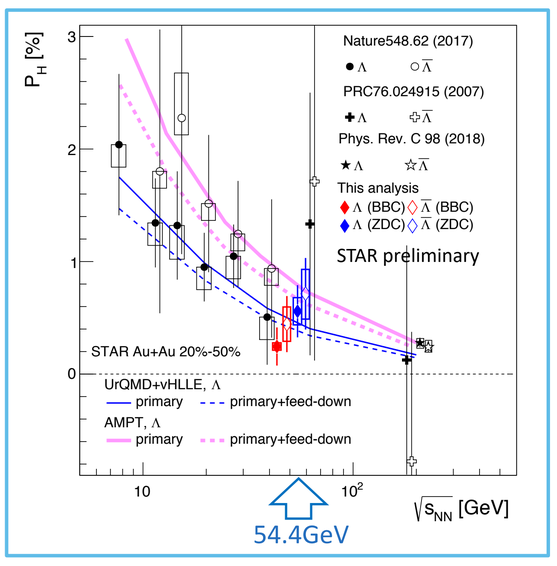
- In peripheral collisions the event plane resolution of ZDC is better than that of BBC.

Global polarization in Au+Au collisions at $\sqrt{s_{NN}}$ = 54.4 GeV

Energy dependence of Λ global polarization.

- Observed positive $\Lambda(\bar{\Lambda})$ global polarization.
- New data of 54.4 GeV (~570 millions) follow global trend of the energy dependence.
- The results agree with model calculations within uncertainties. (UrQMD+vHLLE [6], AMPT [7])
- There is no significant difference between Λ and $\bar{\Lambda}$.
- The results obtained from ZDC is slightly higher than those from BBC.

$P_H^{BBC}(\Lambda) = 0.245 \pm 0.170\,(\text{stat}) \pm {}^{0.033}_{0.033}(\text{sys})$ $\quad P_H^{ZDC}(\Lambda) = 0.558 \pm 0.232(\text{stat}) \pm {}^{0.121}_{0.121}(\text{sys})$
$P_H^{BBC}(\bar{\Lambda}) = 0.444 \pm 0.250\,(\text{stat}) \pm {}^{0.152}_{0.153}(\text{sys})$ $\quad P_H^{ZDC}(\bar{\Lambda}) = 0.714 \pm 0.318\,(\text{stat}) \pm {}^{0.217}_{0.225}(\text{sys})$



Centrality dependence of Λ global polarization.

- Polarization might increase from central to peripheral collisions.
  - According to the AMPT model, ω_y is larger in more peripheral collisions [8].

Systematic uncertainty

- Background P_H assumption ~ 20%.
- Difference between methods for signal P_H extraction ~ 12%.
- Uncertainty from the decay parameter : ~ 2.0% for Λ, ~ 9.6% for $\bar{\Lambda}$.

Summary & Outlook

- Global polarization of Λ hyperons is measured using BBC and ZDC in Au+Au collisions at $\sqrt{s_{NN}}$ = 54.4 GeV.
  - **Positive polarization is observed and agrees with model calculations.**
  - No significant difference between Λ and anti-Λ.
  - Centrality dependence may be observed.

Outlook : Calculate Λ global polarization using TPC event plane.
- TPC : |η| < 1.0, BBC : 3.3 < |η| 5.0, ZDC : 6.3 < |η|

Reference

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