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Institute of Modern Physics, Chinese Academy of Sciences

Update of Spin Hall Effect study with Heavy-Ion collisions

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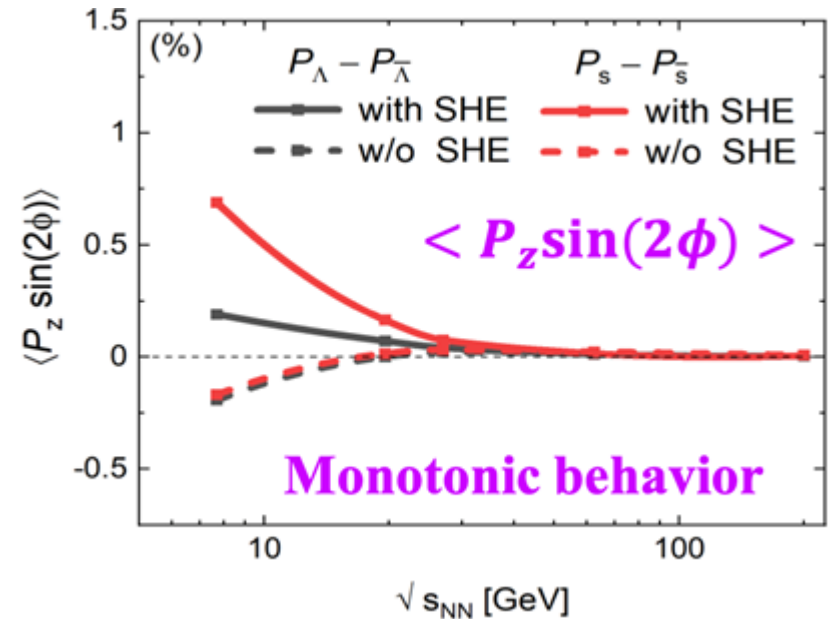
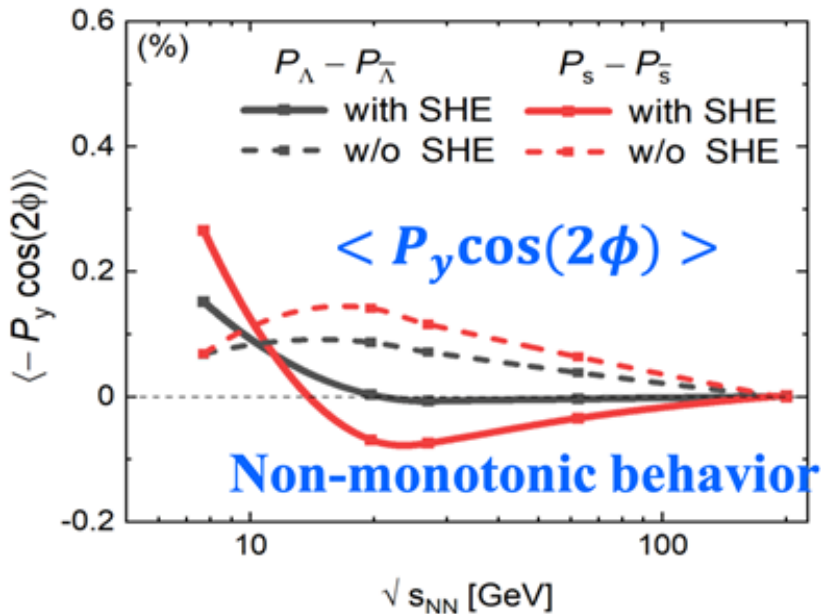
STAR FCV Meeting, May 11, 2022

Outline

- **Motivation**
- **Data analysis for Au+Au @ 27 GeV**
 - **Global polarization for Λ**
 - **Local polarization for Λ**
- **Data analysis for Au+Au @ 19.6 GeV**
 - **Global polarization for Λ**
 - **Local polarization for Λ**
- **Summary**

Part I: Motivation

Baryonic Spin Hall Effect



- B. Fu, L. G. Pang, H. Song, Yi Yin, On-line seminar series III on "RHIC Beam Energy Scan: Theory and Experiment", Nov 23, 2021
- arXiv:2201.12970v1 [hep-ph] 31 Jan 2022

Proposed signature for **SHE**:

$\langle P_y \cos(2\phi) \rangle \rightarrow$ Non-monotonic energy dependence

$\langle P_z \sin(2\phi) \rangle \rightarrow$ Monotonic energy dependence

No investigation of proposed SHE in heavy ion collisions!

Part II

Data analysis for Au+Au @ 27 GeV

Part II: Data analysis (27 GeV)

Dataset and analysis details

**Au+Au @ 27 GeV, BES-II
production=P19ib**

Event Cuts

— Vertex: $|V_z| < 70$ cm
 $|V_r| < 2$ cm

— Trigger ID (610011 || 610011
|| 610021 610031 || 610041||
610051) [**minbias**]

— Pile-up rejection

— Centrality from “StRefMultCorr”

Single track Cuts

— $0.15 \text{ GeV}/c < p_t < 5 \text{ GeV}/c$

— No. of TPC hits > 15

— Nhits-TPC/Possible Hits ≥ 0.52

— $|\eta| < 1.0$

Pion/Proton PID Cuts

— if ToF available

$(1/\beta - 1/\beta_\pi) < 0.03$

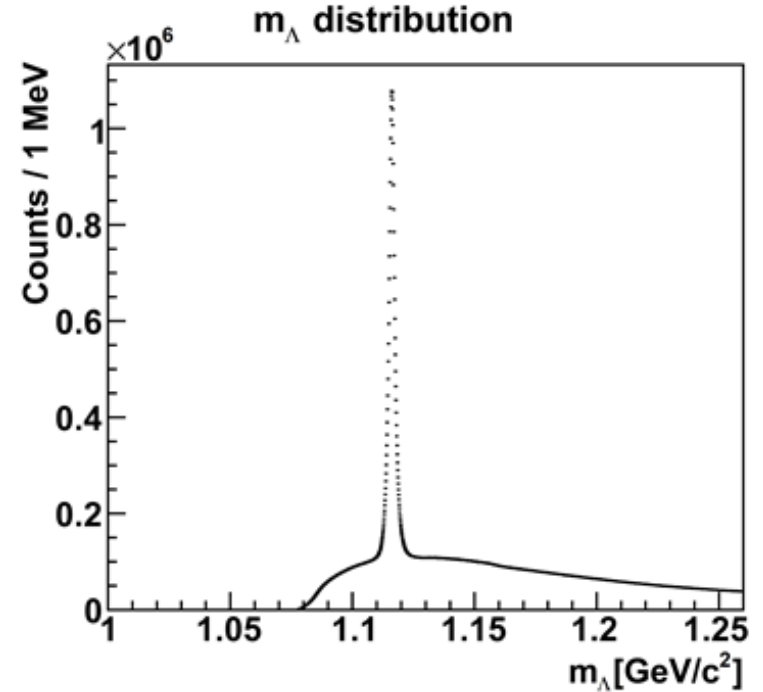
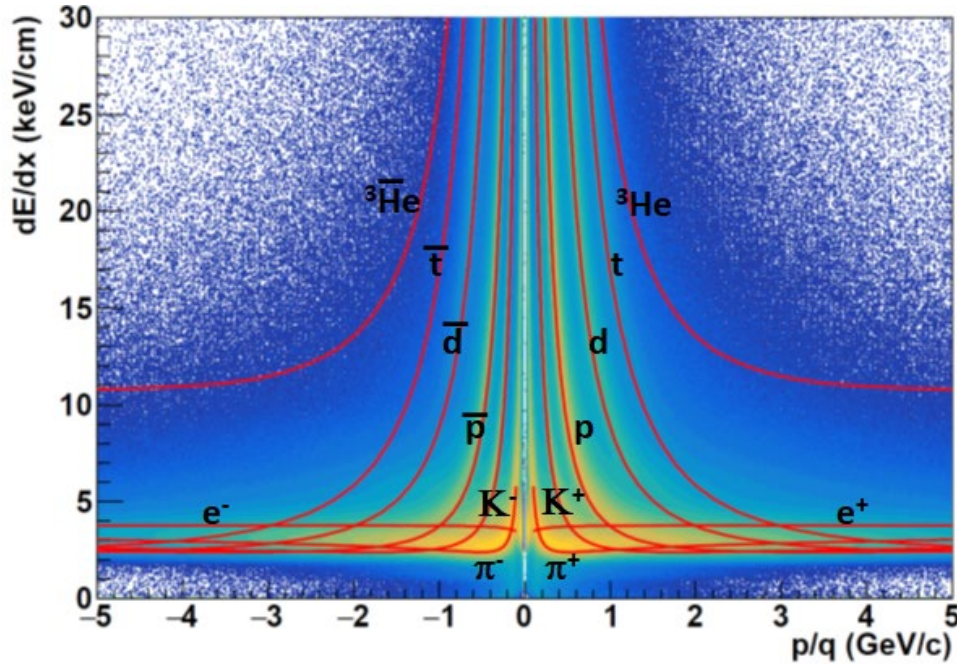
$(1/\beta - 1/\beta_p) < 0.04$

— else use TPC

$|N\sigma| < 3$ for both π and p

No. of events for analysis: ~ 378 M \rightarrow ~ 524 M

Part II: Analysis details (27 GeV)



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

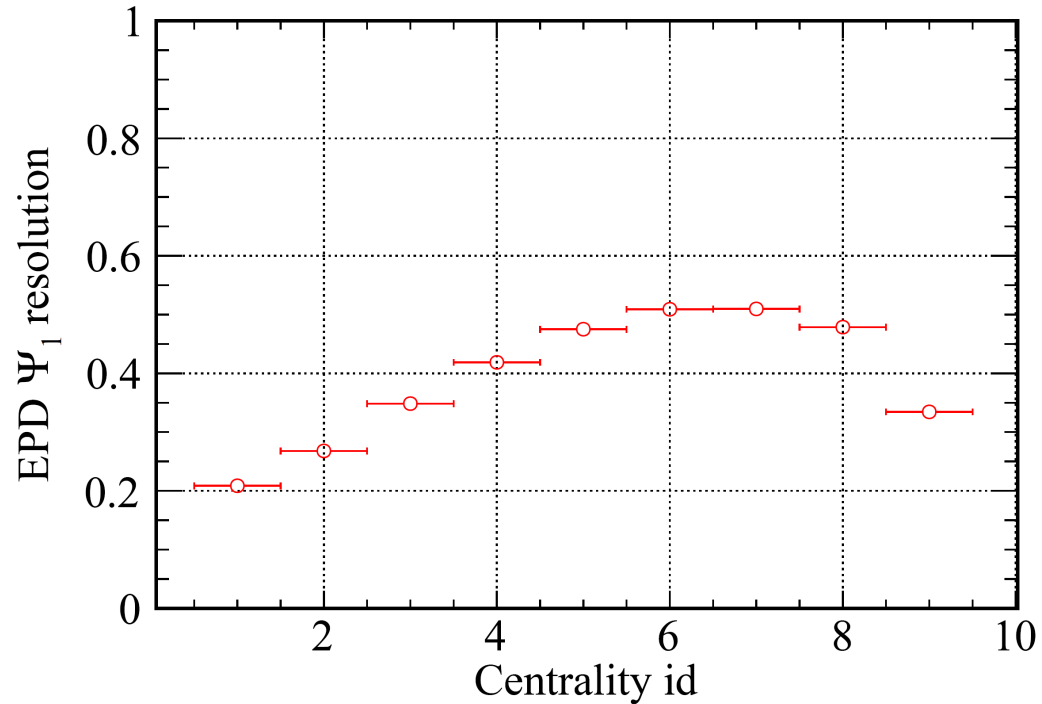
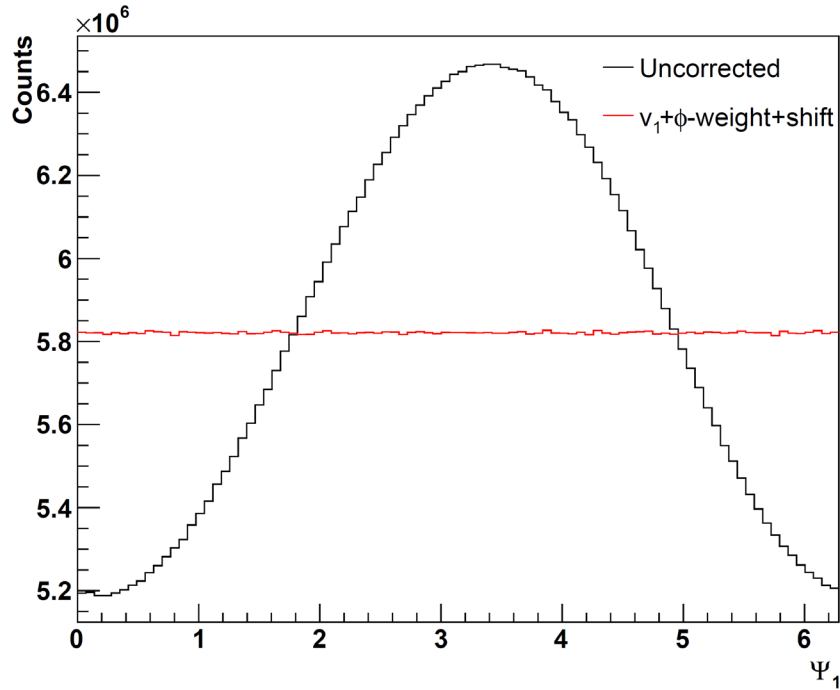
$$\bar{\Lambda} \rightarrow \bar{p} + \pi^+$$

Using STAR Helix method

- Decay length > 3.0 cm
- DCA to prim vertex < 0.8
- DCA between π/p < 0.8
- DCA to p > 0.3
- DCA to π > 1.6
- p & π : $p_t > 0.15$ GeV/c;
- Λ (anti- Λ): $p_t > 0.5$ GeV/c
- $|y_{p-\pi \text{ pair}}| < 1.0$

Part II: Analysis details (27 GeV)

Event plane reconstruction (EPD)



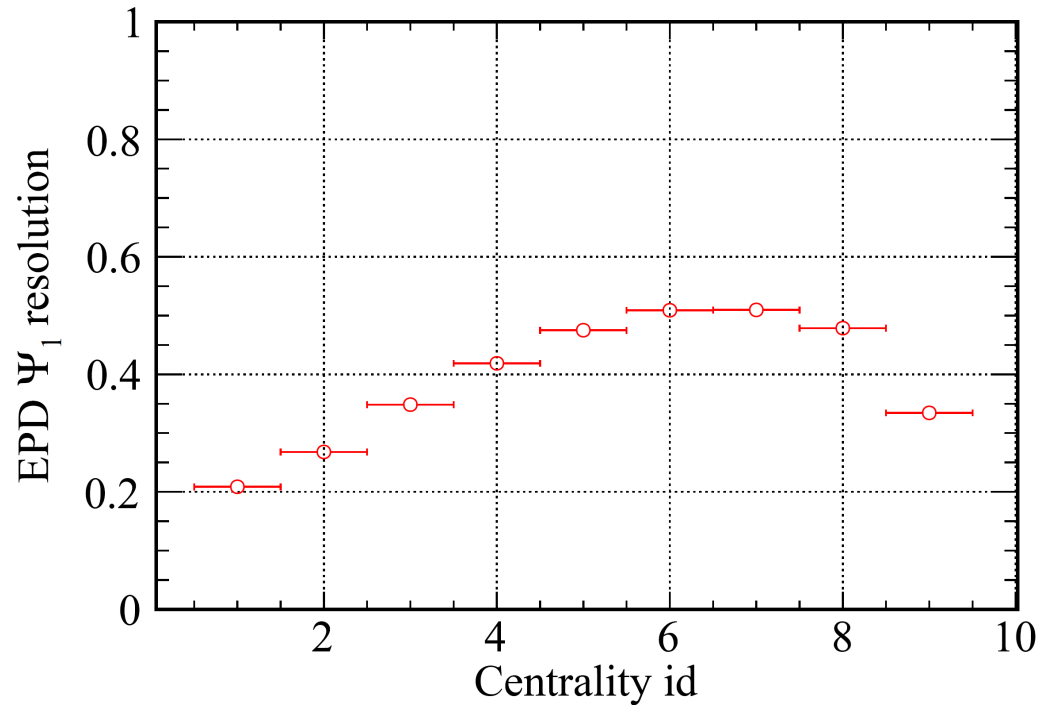
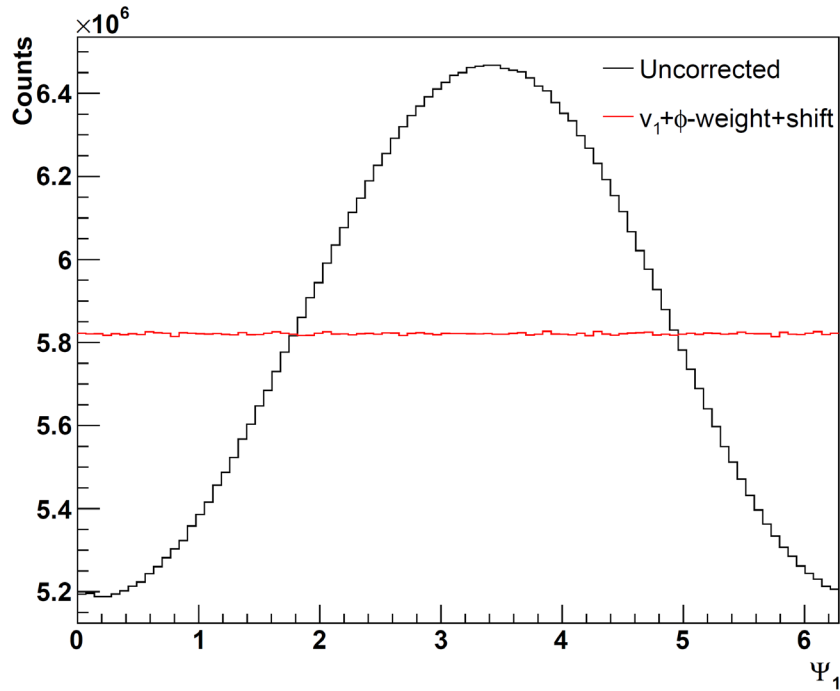
EPD Event Plane Cuts

— Using standard cuts implemented in “StEpdEpFinder” (by Mike Lisa)

Apply phi weights, v_1 weights and shift calibrations

Part II: Analysis details (27 GeV)

Event plane reconstruction (EPD)



EPD Event Plane Cuts

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Part II: Analysis details (27 GeV)

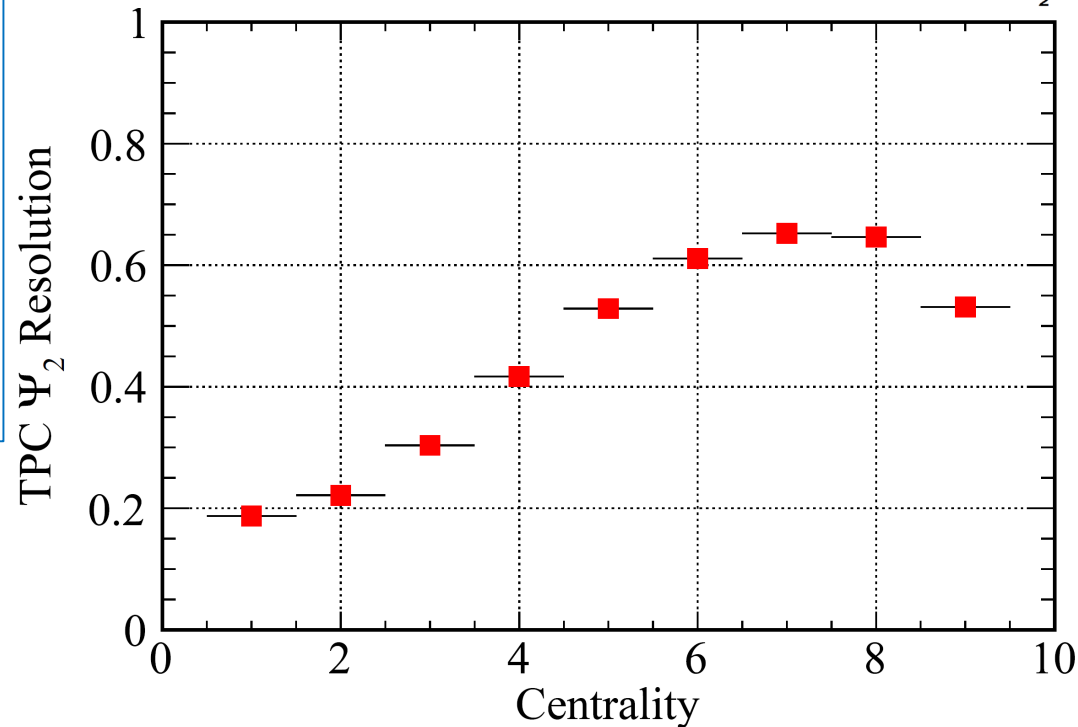
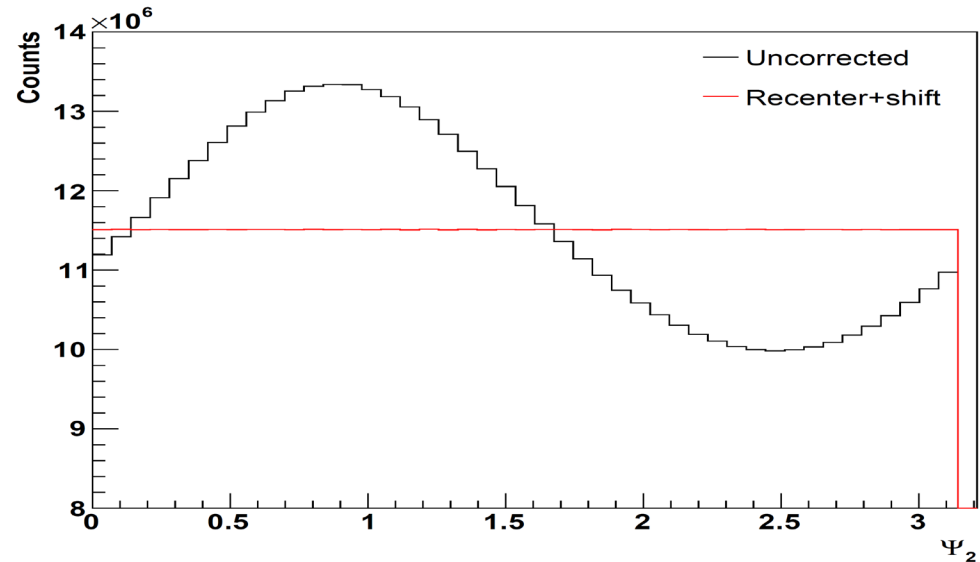
Event plane reconstruction (TPC)

TPC Event Plane Cuts

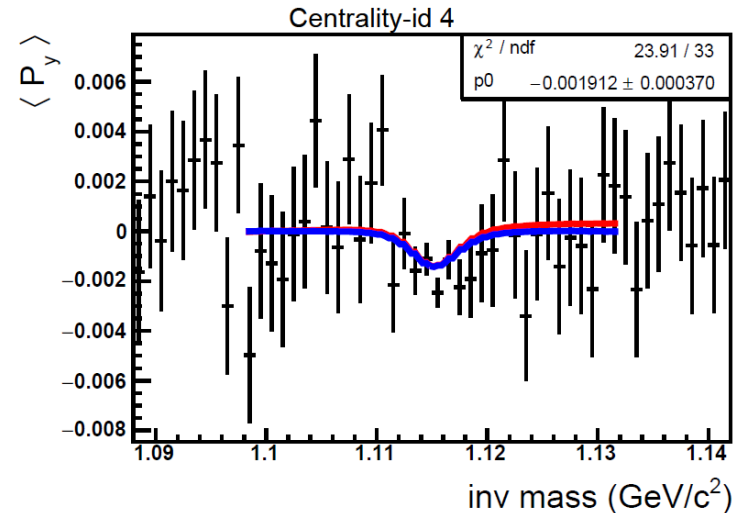
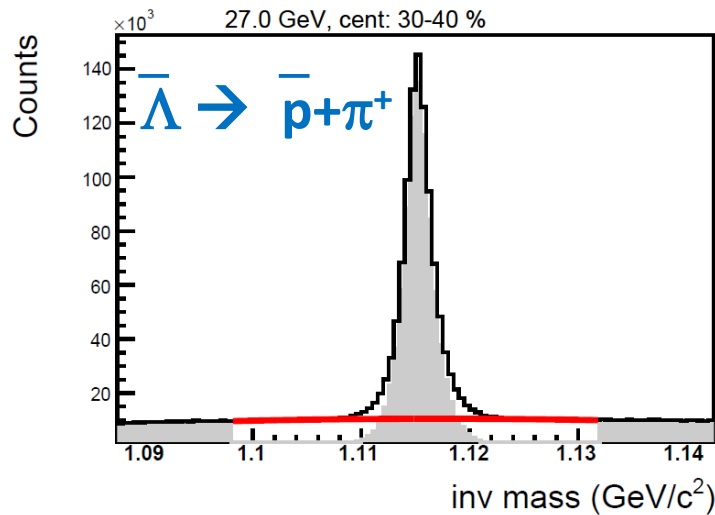
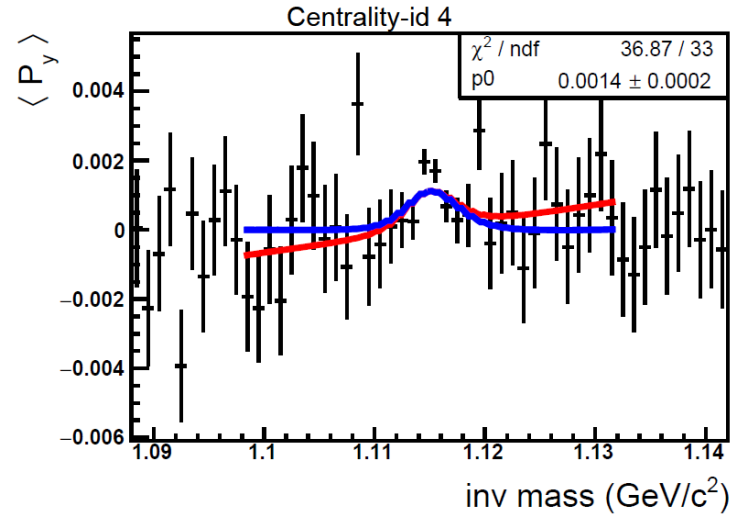
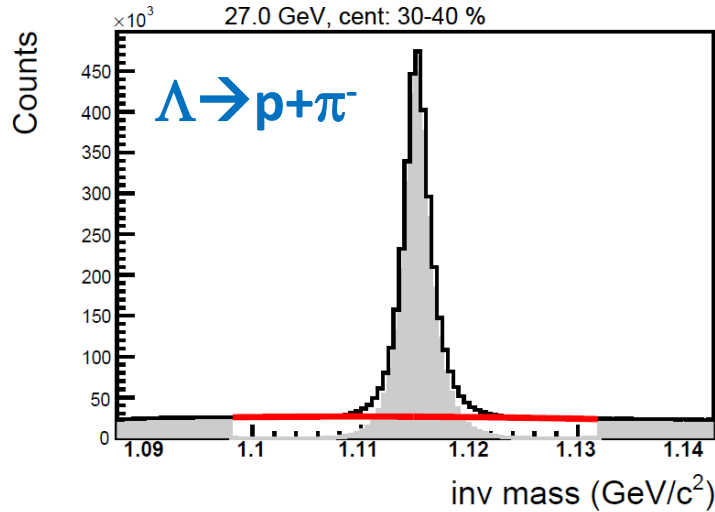
- $|\mathbf{p}_t| > (0.15 \text{ GeV}/c \ \&\& \ < 2.0 \text{ GeV}/c)$
- $|\text{DCA}| < 3.0 \text{ cm}$
- No. of TPC hits > 15
- $\text{Nhits-TPC/Possible Hits} > 0.52$
- $|\eta| < 1.0$

Combined two sub-events with η -gap
 ~ 0.1

Apply run-by-run and centrality wise
re-centering and shift calibrations



Part II: Global polarization (27 GeV)

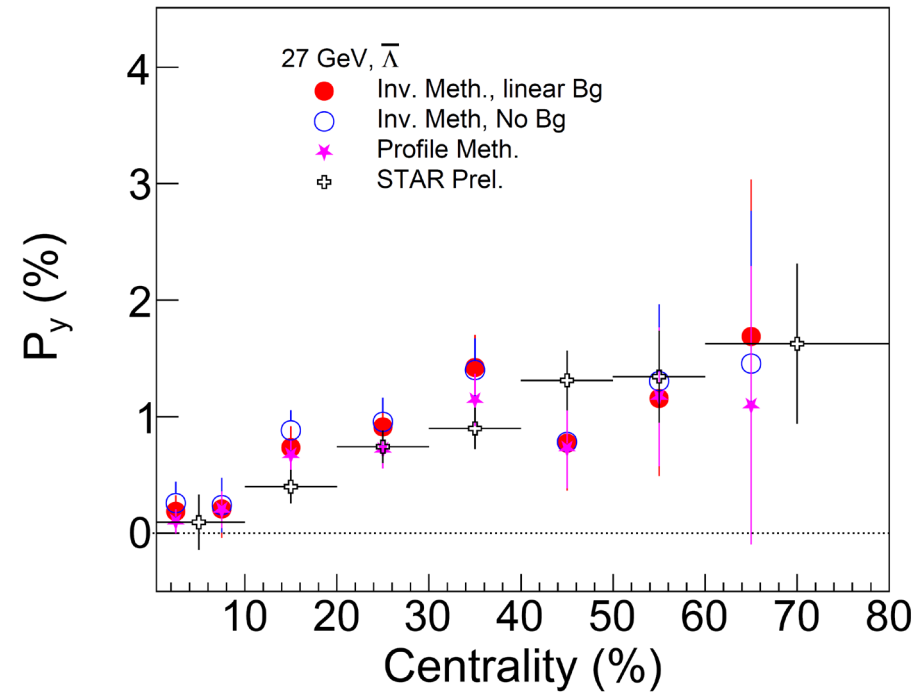
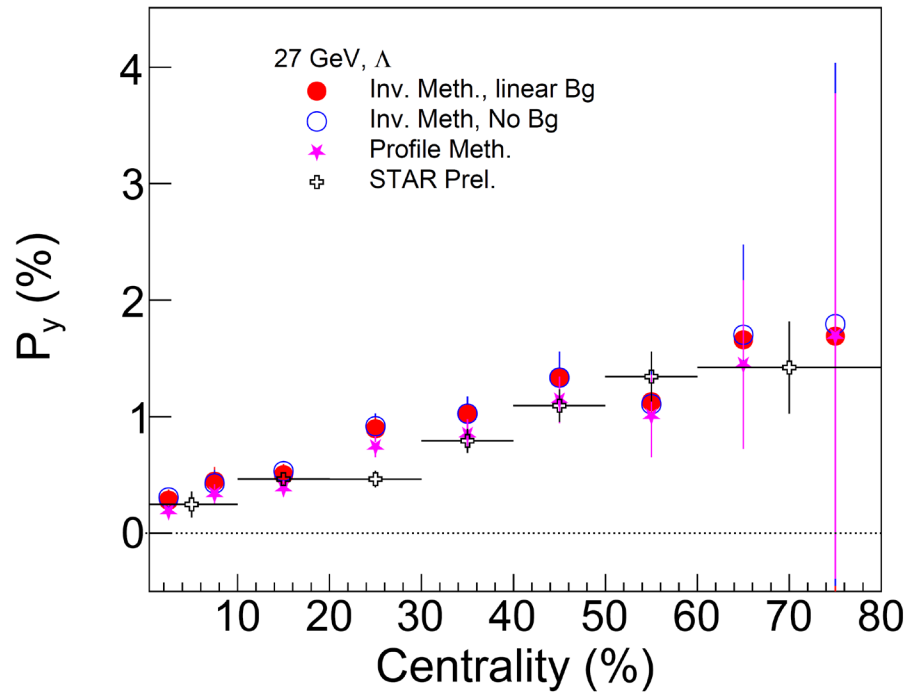


$$\langle \sin(\Delta\phi) \rangle^{\text{obs}} = (1 - f^{\text{Bg}}(M_{\text{inv}})) \langle \sin(\Delta\phi) \rangle^{\text{Sg}} + f^{\text{Bg}}(M_{\text{inv}}) \langle \sin(\Delta\phi) \rangle^{\text{Bg}}$$

$$\Delta\phi = \psi_1 - \phi_p^*$$

Blue: w/o bkg; Red: with bkg ($\alpha + \beta M_{\text{inv.}}$)

Part II: Global polarization (27 GeV)

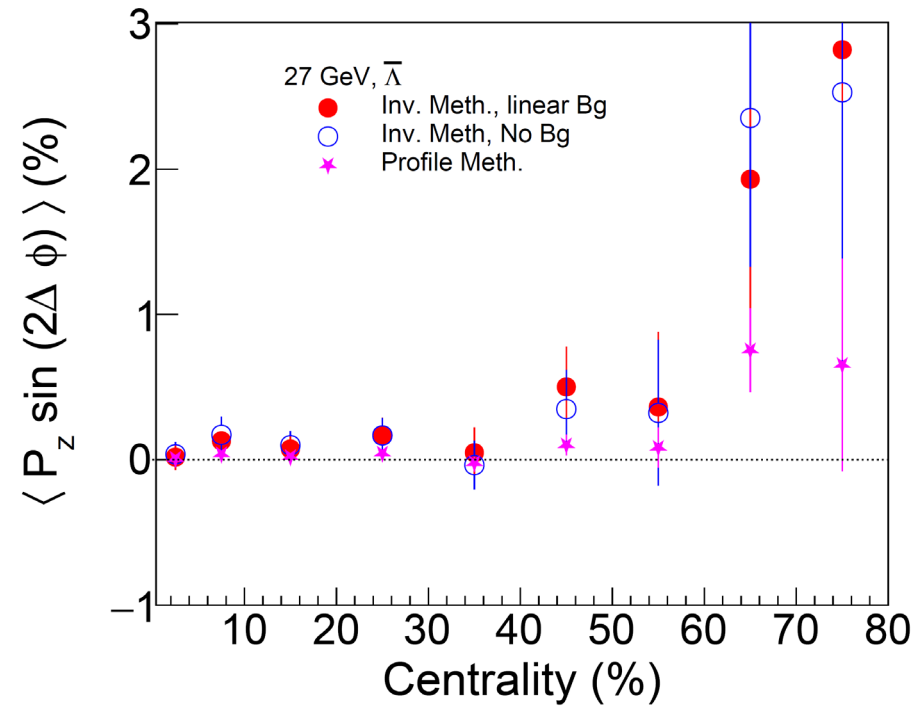
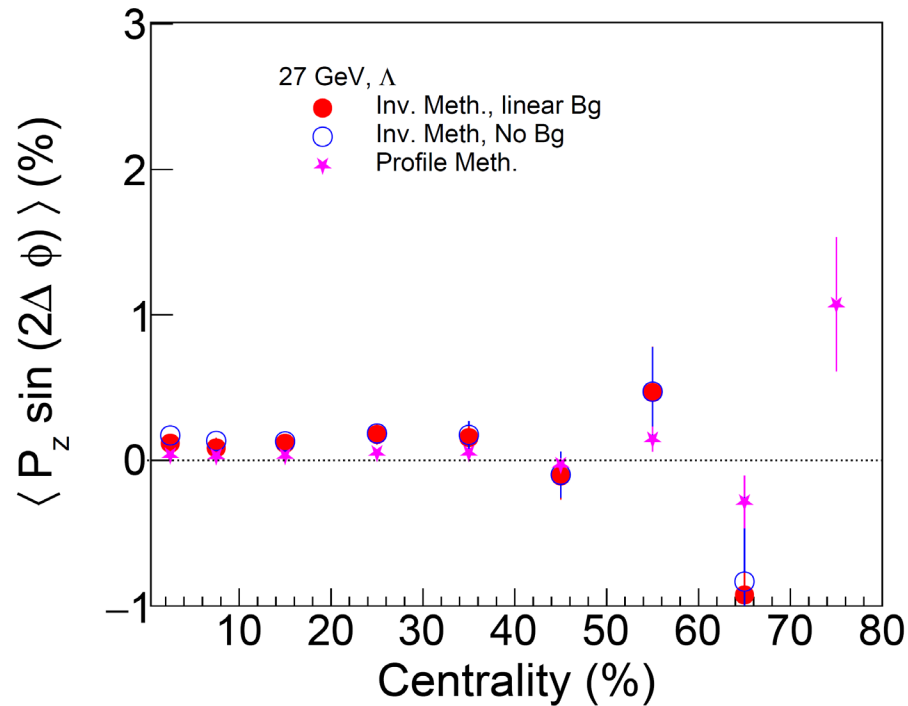


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$0.5 \text{ GeV}/c < p_t < 5.0 \text{ GeV}/c; |\eta| < 1.0; \alpha(\Lambda) = 0.732$

P_y for lambda and anti-lambda increase with centrality, the trend mostly consistent with the previous STAR measurements

Part II: Local polarization (27 GeV)



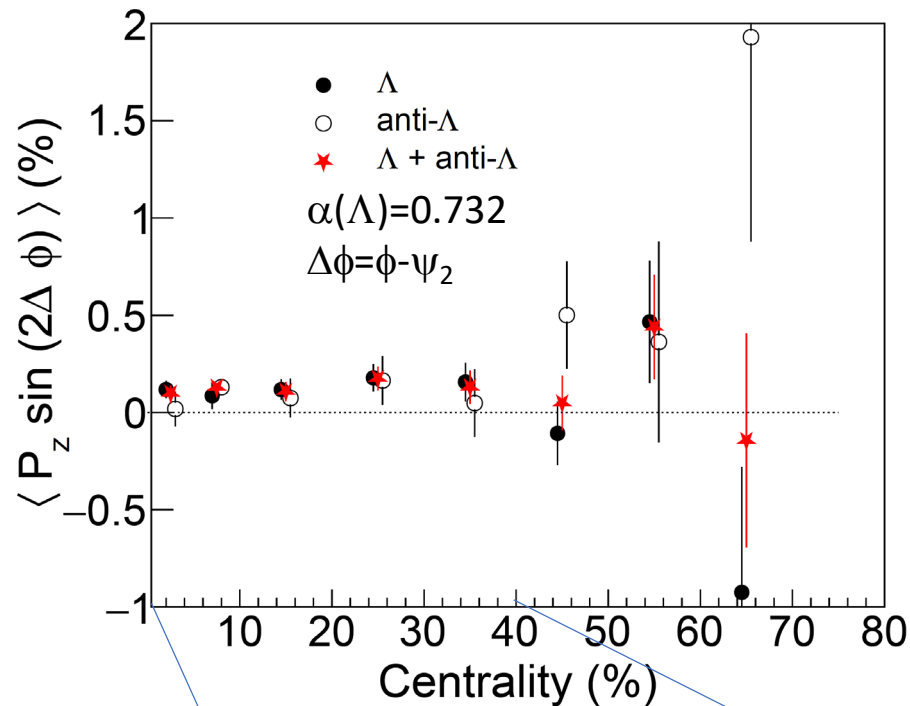
$$P_z = \frac{\langle \cos\theta_p^* \rangle}{\alpha_H \langle (\cos\theta_p^*)^2 \rangle}$$

$$0.5 \text{ GeV}/c < p_t < 5.0 \text{ GeV}/c; |\eta| < 1.0$$

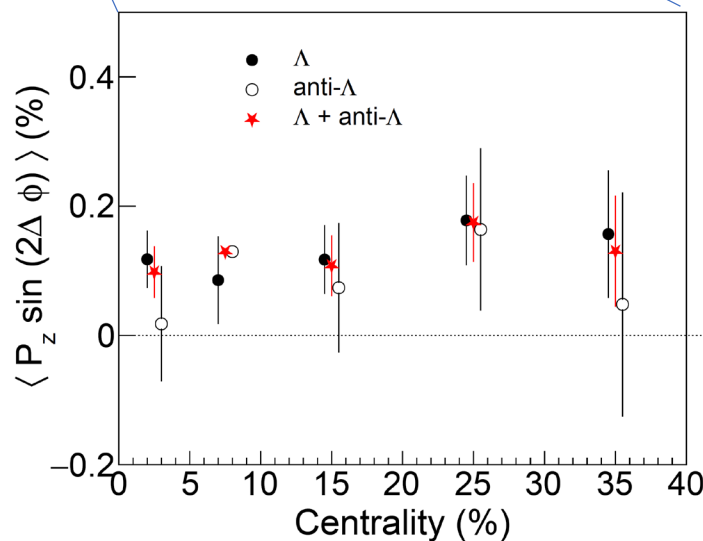
$$\alpha(\Lambda) = 0.732; \Delta\phi = \phi_\Lambda - \psi_2$$

For profile method, bkg is included, it will be corrected later.

Part II: Local polarization (27 GeV)



$p_t \in (0.5, 5.0)$ GeV/c
 $|\eta| < 1.0$



Part III

Data analysis for Au+Au @ 19.6 GeV

Part III: Data analysis (19.6 GeV)

Dataset and analysis details

**Au+Au @ 19.6 GeV, BES-II
production=P21ic**

Event Cuts

- Vertex: $|V_z| < 70$ cm
 $|V_r| < 2$ cm
- Trigger ID (640002 || 640012
|| 640022 || 640032)
[minbias-hltgood]
- Pile-up rejection
- Centrality from “StRefMultCorr”

Single track Cuts

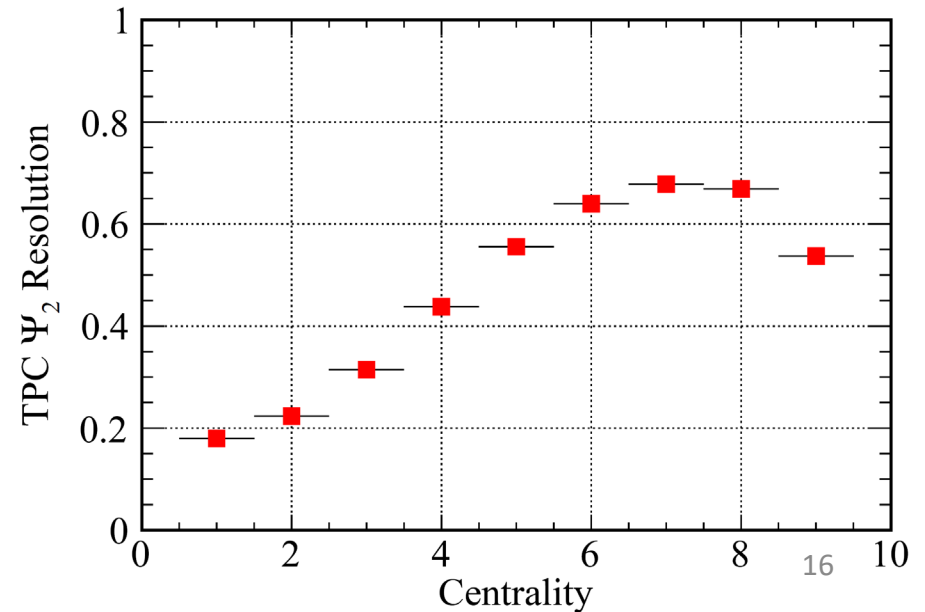
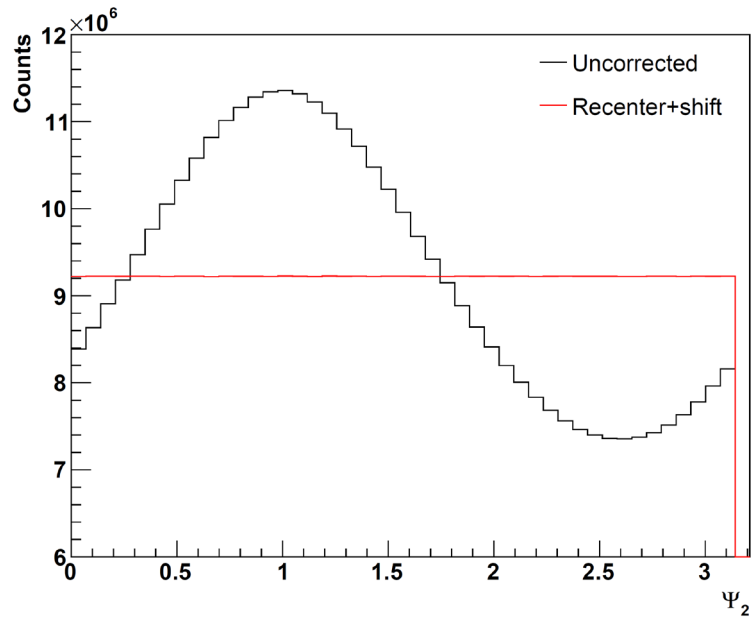
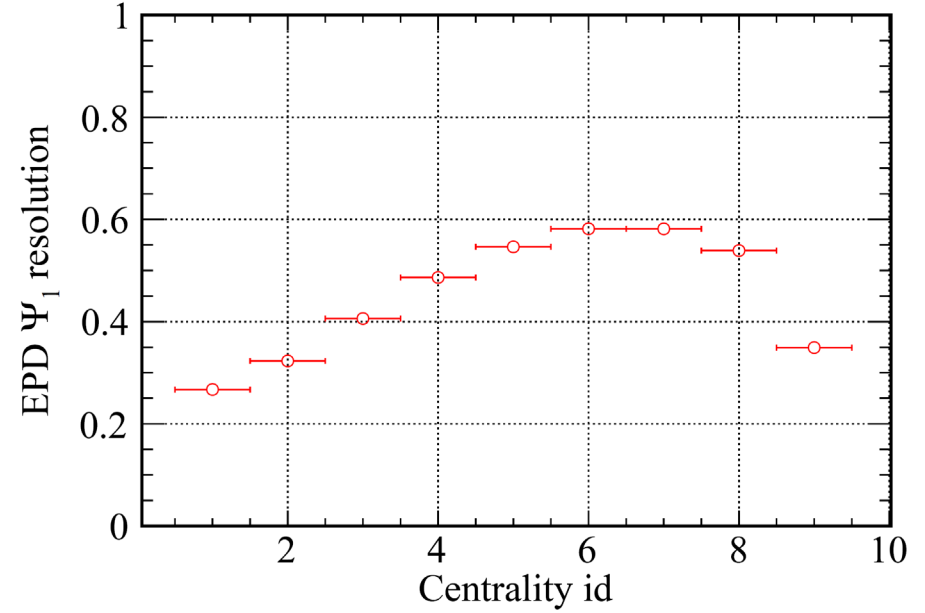
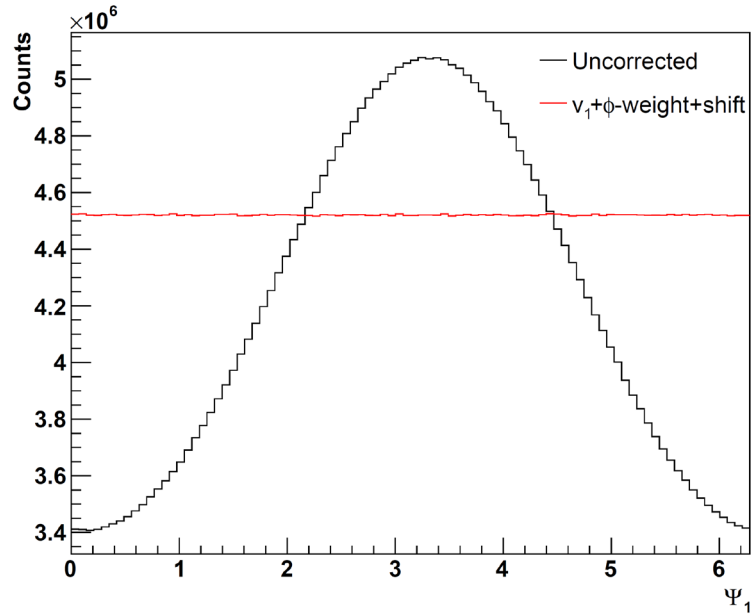
- $0.15 \text{ GeV}/c < p_t < 5 \text{ GeV}/c$
- No. of TPC hits > 15
- Nhits-TPC/Possible Hits ≥ 0.52
- $|\eta| < 1.5$

Pion/Proton PID Cuts

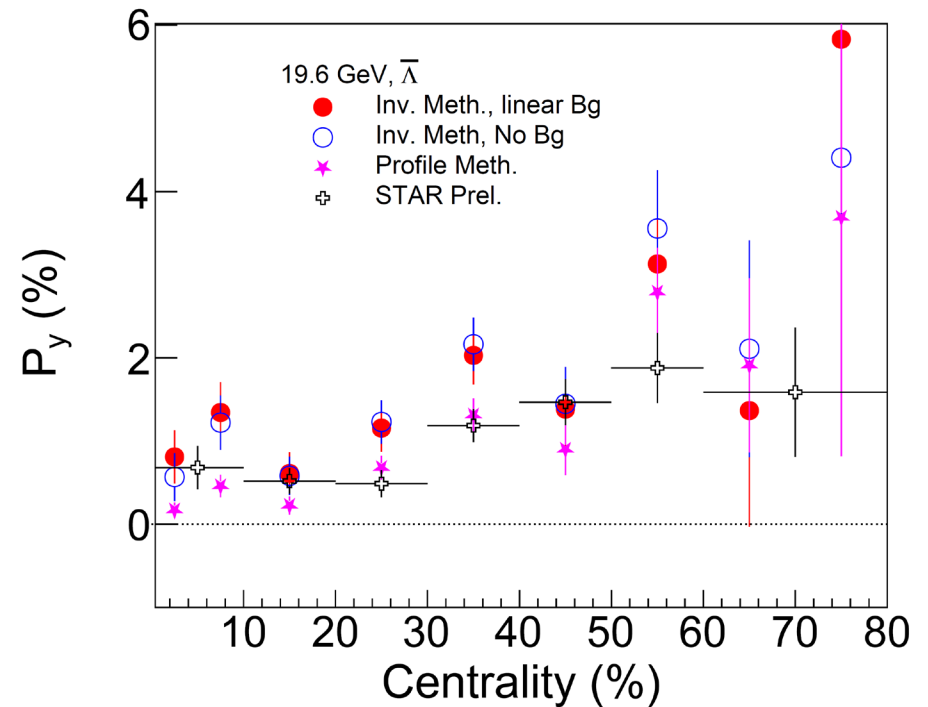
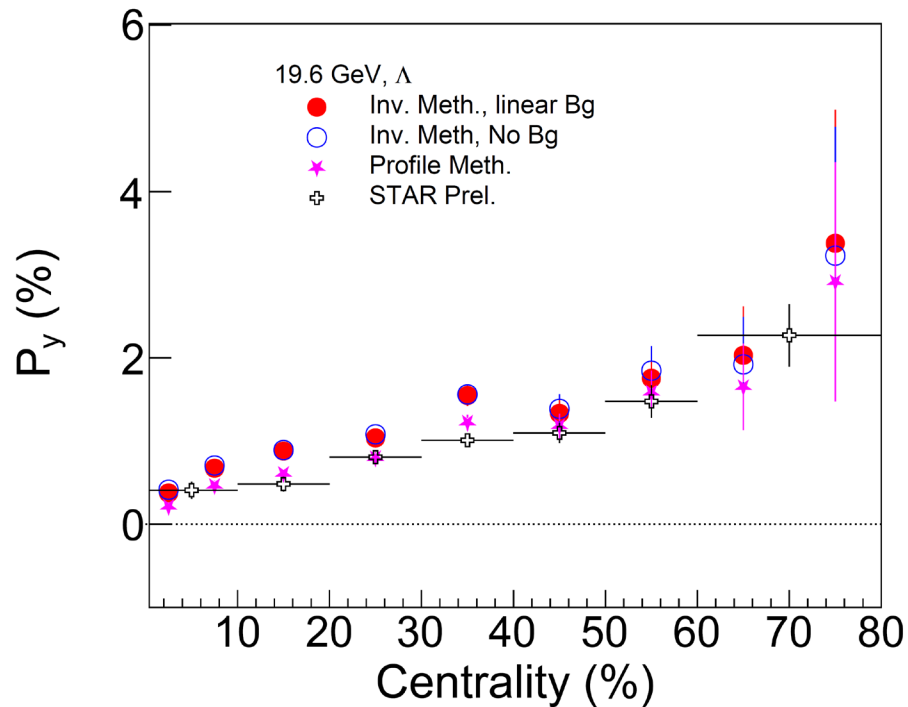
- if ToF available
 $(1/\beta - 1/\beta_\pi) < 0.03$
 $(1/\beta - 1/\beta_p) < 0.04$
- else use TPC
 $|N\sigma| < 3$ for both π and p

No. of events for analysis: ~ 418 M

Part III: Global polarization (19.6 GeV)



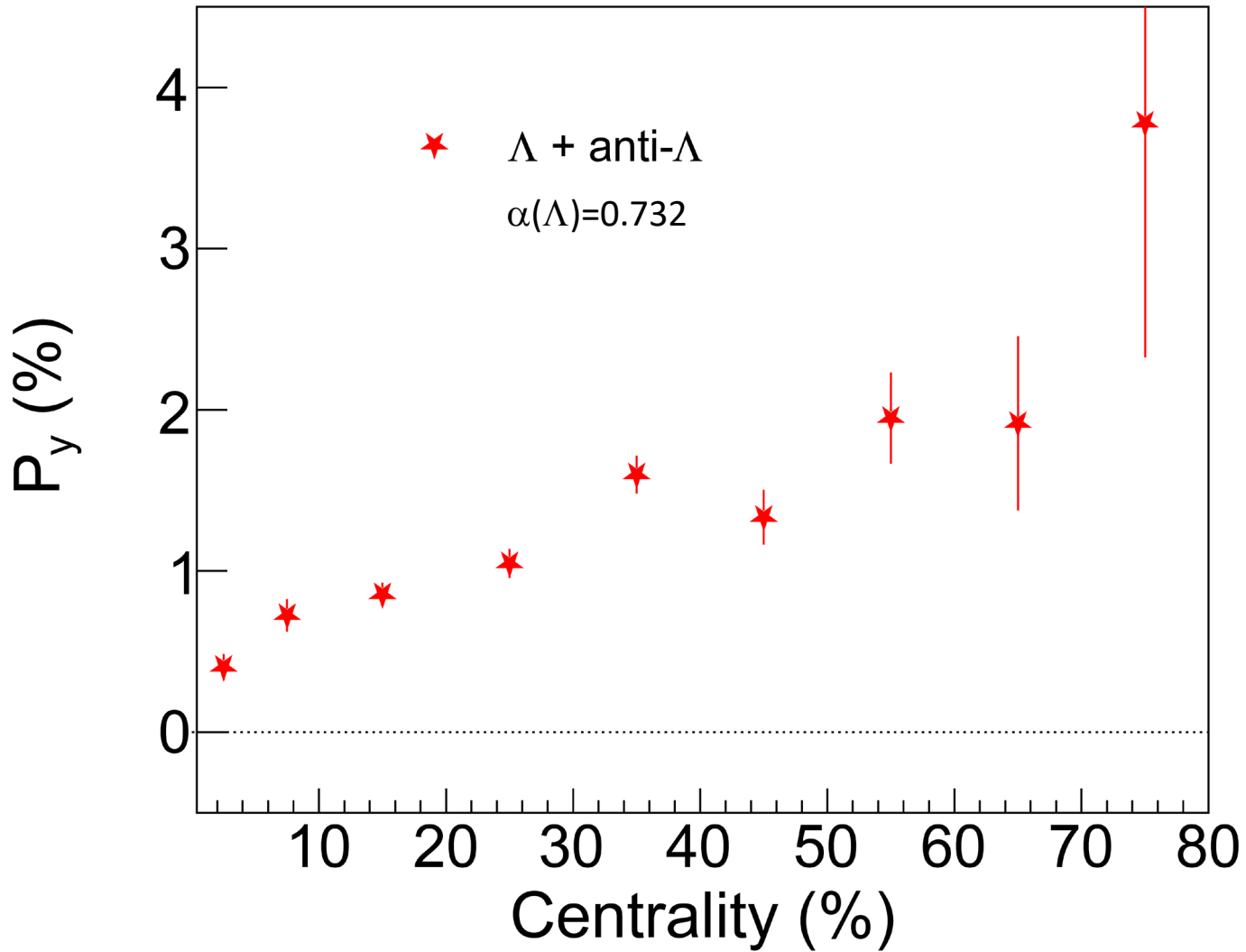
Part III: Global polarization (19.6 GeV)



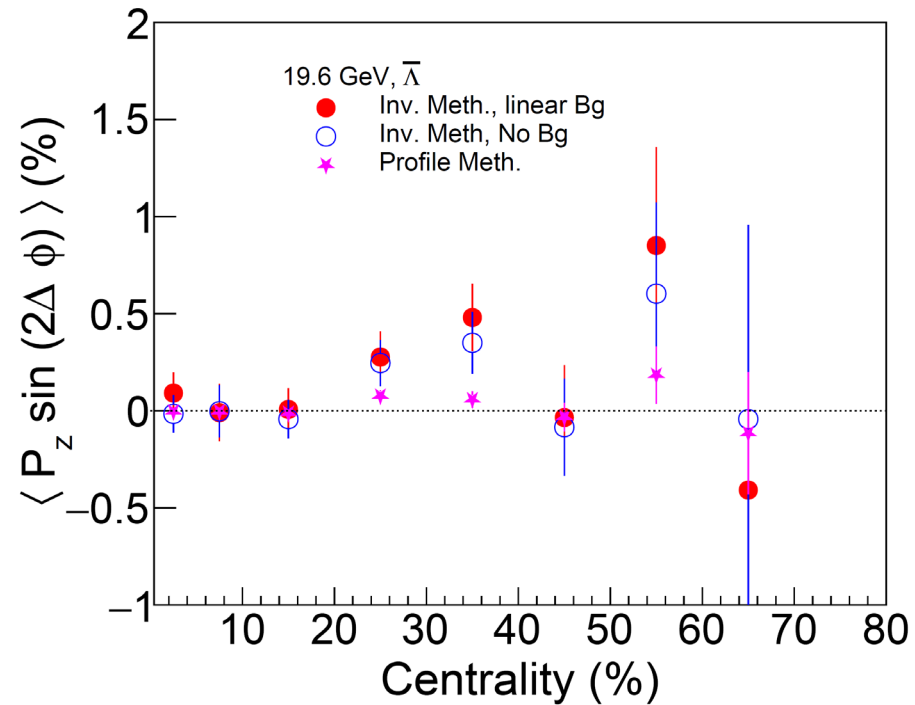
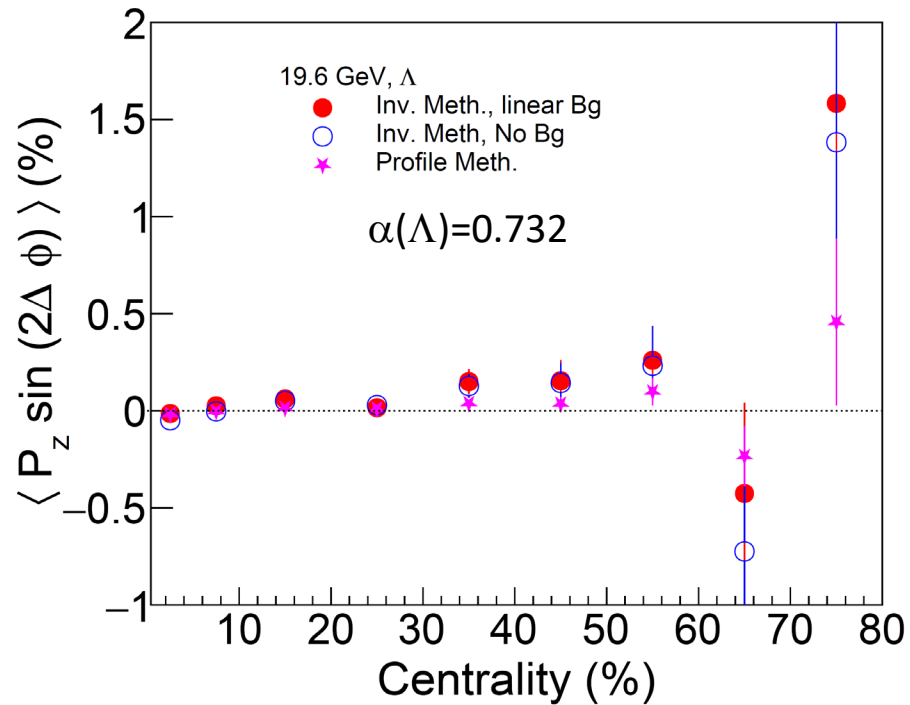
Joey Adams, STAR Collaboration Meeting-FCV PWG, May 2022

For profile method, bkg is included, it will be corrected later.

Part III: Global polarization (19.6 GeV)

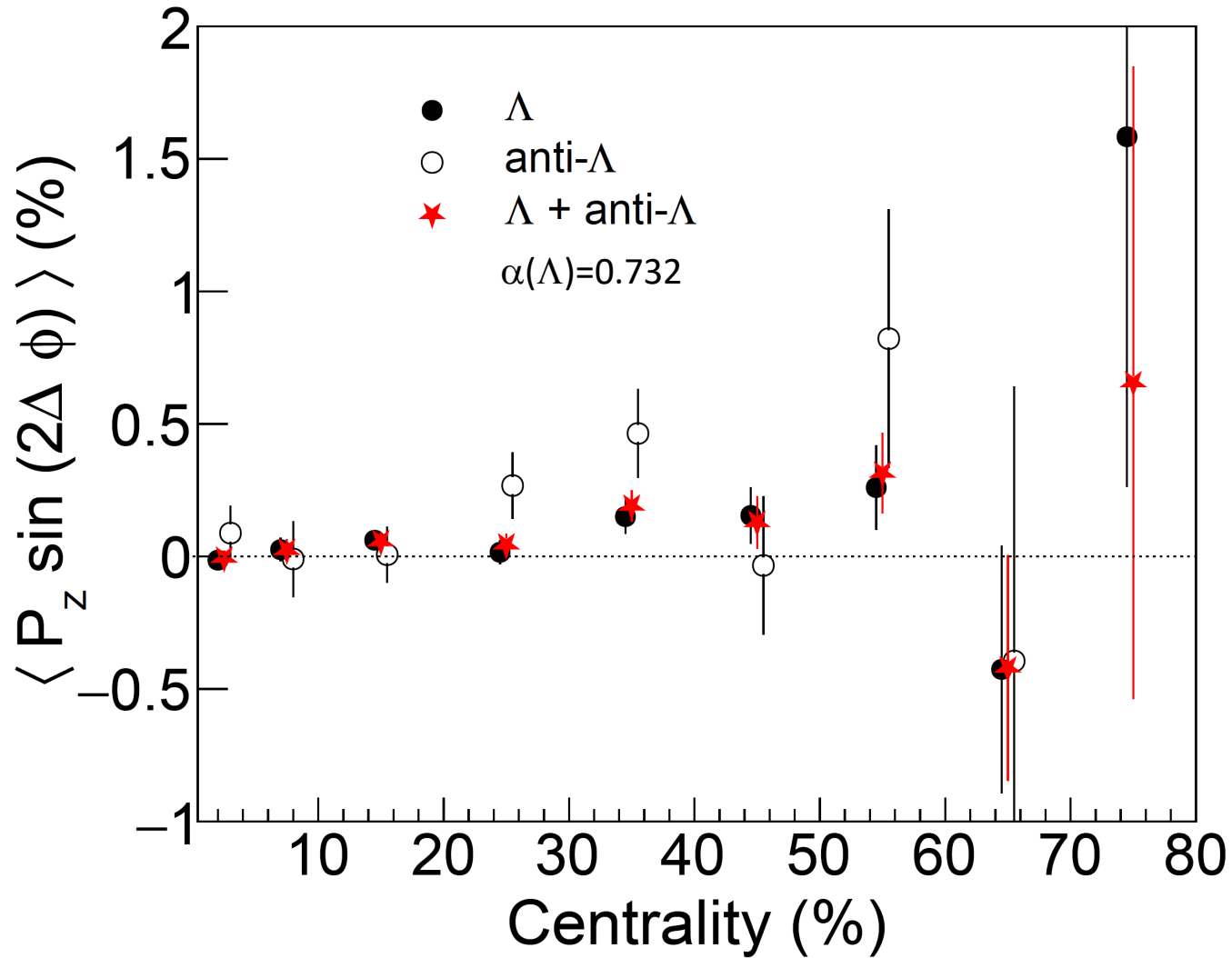


Part III: Local polarization (19.6 GeV)



For profile method, bkg is included, it will be corrected later.

Part III: Local polarization (19.6 GeV)



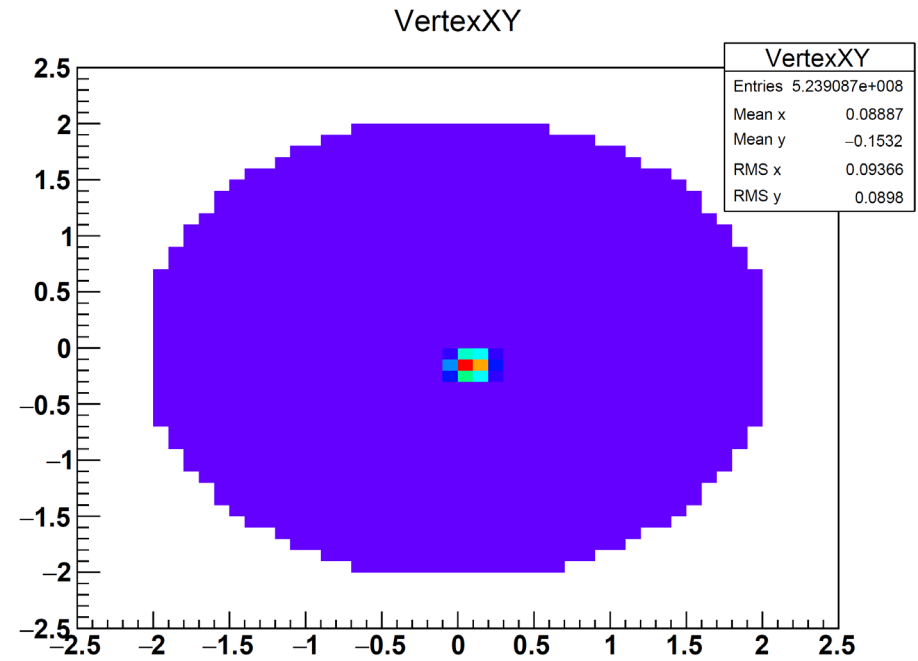
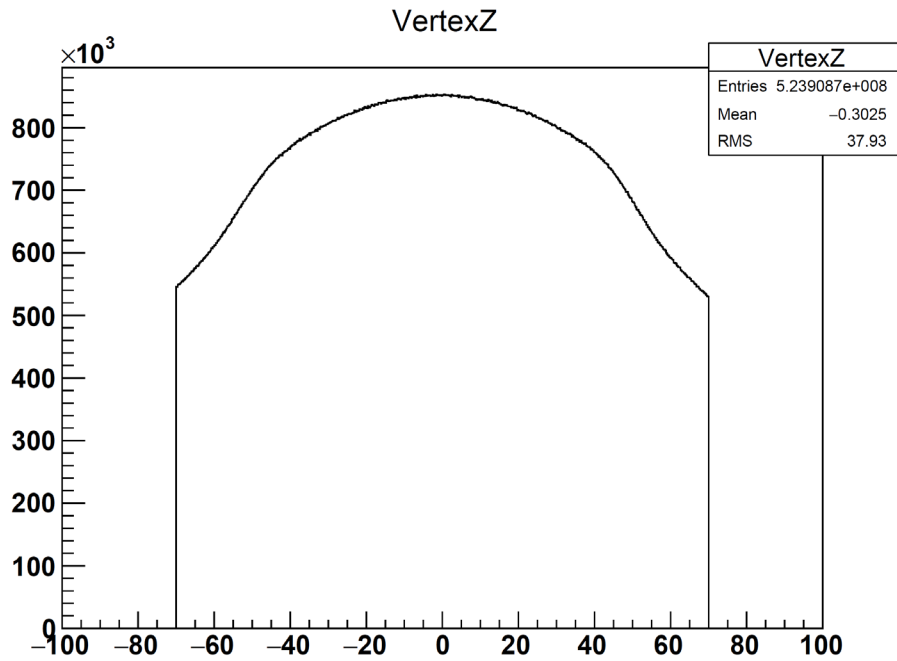
Summary

- Centrality dependent global and local polarization of Λ are studied without efficiency correction for Au+Au @ 27 and 19.6 GeV
- The trend of Λ 's global polarization is consistent with the STAR preliminary one for Au+Au@27 GeV and 19.6 GeV

Next steps

- Extraction of $\langle P_x \sin(2\phi) \rangle$ and $\langle P_y \cos(2\phi) \rangle$
- Systematic error estimation for local polarization
- Continue to analysis the BES-II Au+Au collisions data at lower energies (14.6 GeV and 7.7 GeV et al.) to search SHE signal

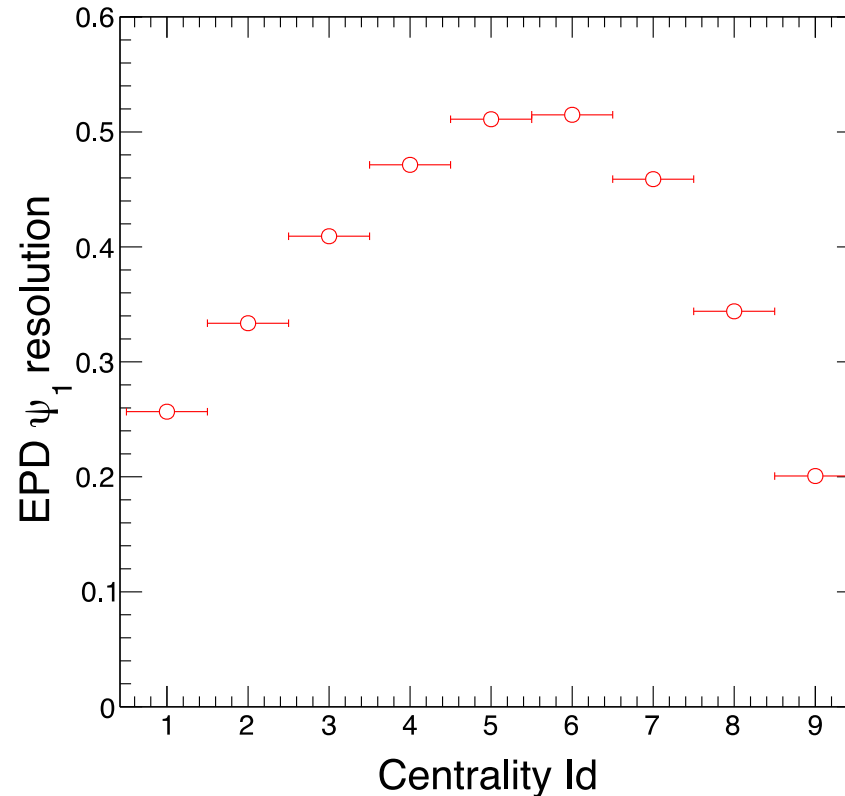
Thank you for your attention!



update vertex distribution

Part II: Analysis details

Event plane reconstruction (EPD)



EPD Event Plane Cuts

— Using standard cuts implemented in “StEpdEpFinder” (by Mike Lisa)

Apply phi weights, v1 weights and shift calibrations

2021.12.15

Part II: Analysis details

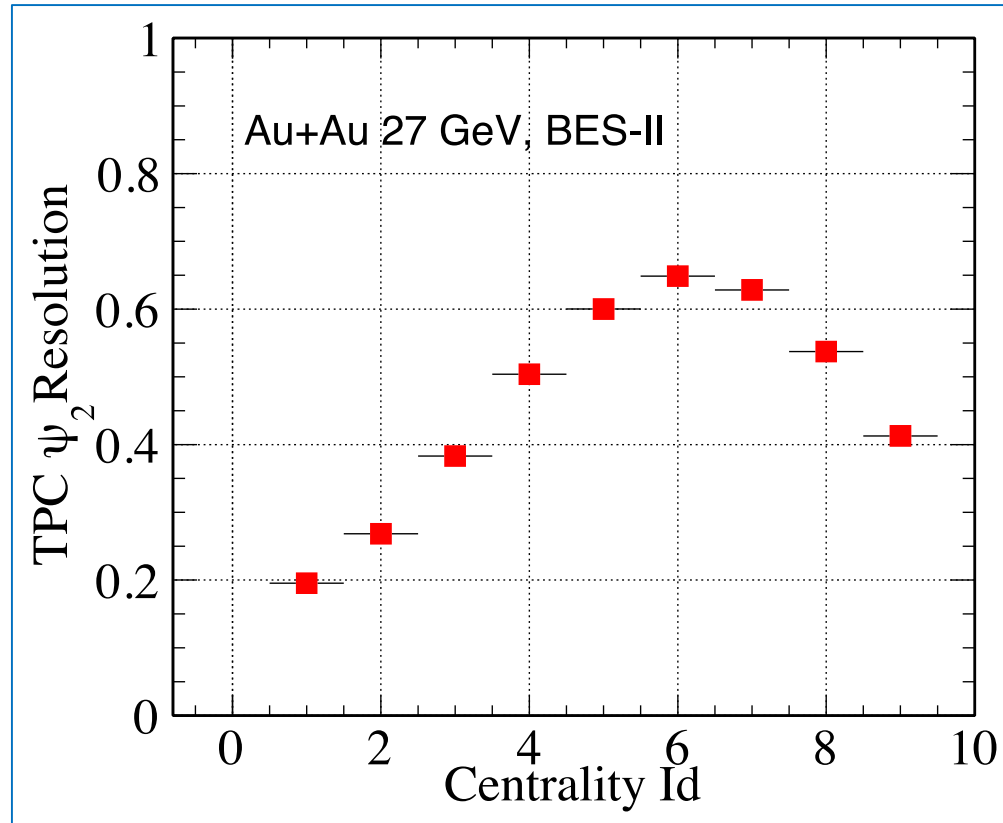
Event plane reconstruction (TPC)

TPC Event Plane Cuts

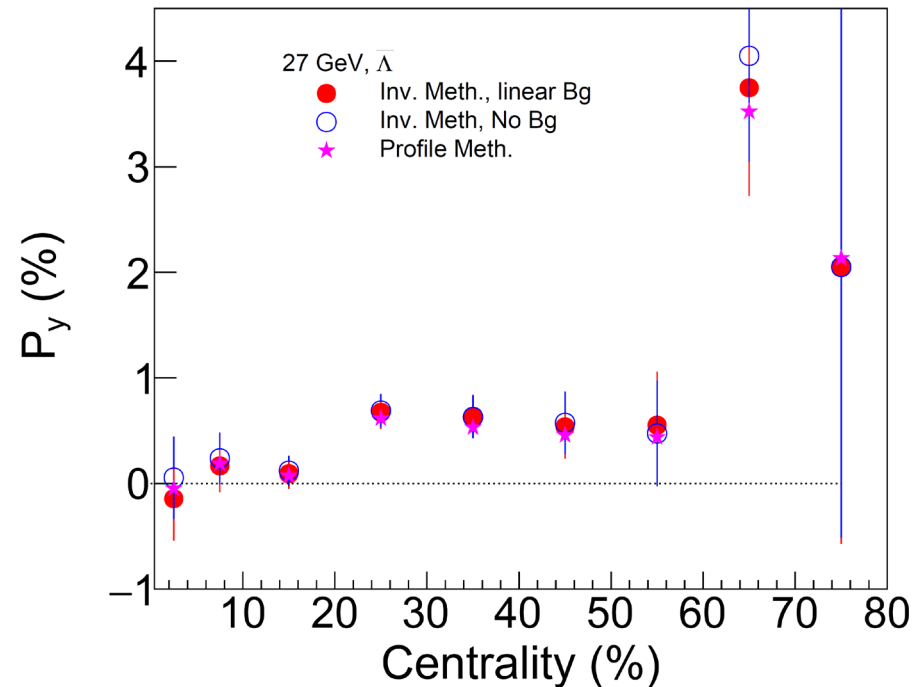
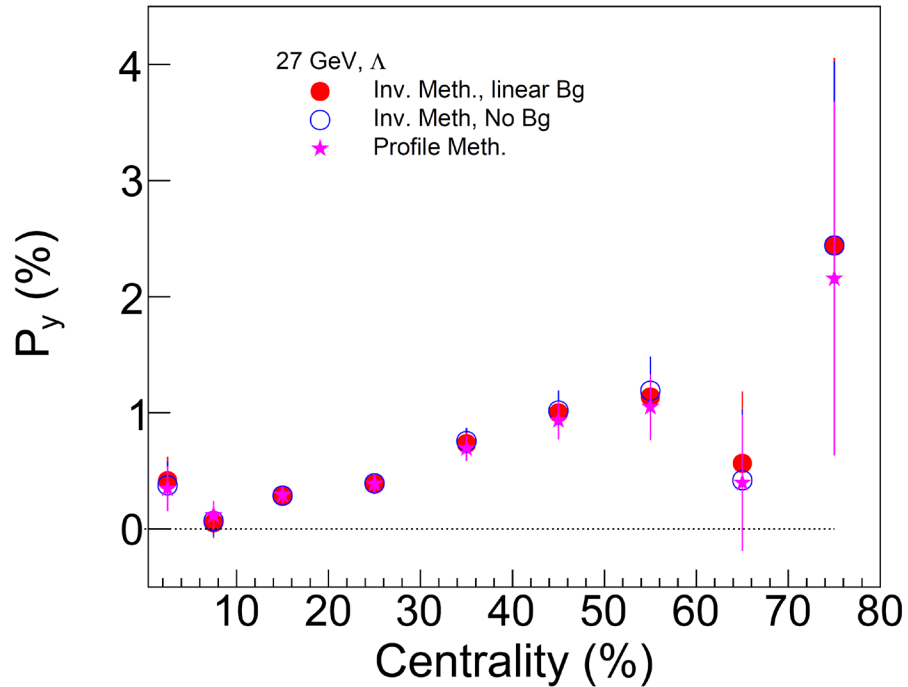
- $|\mathbf{p}_t| > (0.15 \text{ GeV}/c \ \&\& \ < 2.0 \text{ GeV}/c)$
- $|\text{DCA}| < 3.0 \text{ cm}$
- No. of TPC hits > 15
- $N_{\text{hits-TPC/Possible Hits}} > 0.52$
- $|\eta| < 1.0$

Combined two sub-events with η -gap
 ~ 0.1

Apply run-by-run and centrality wise
re-centering and shift calibrations

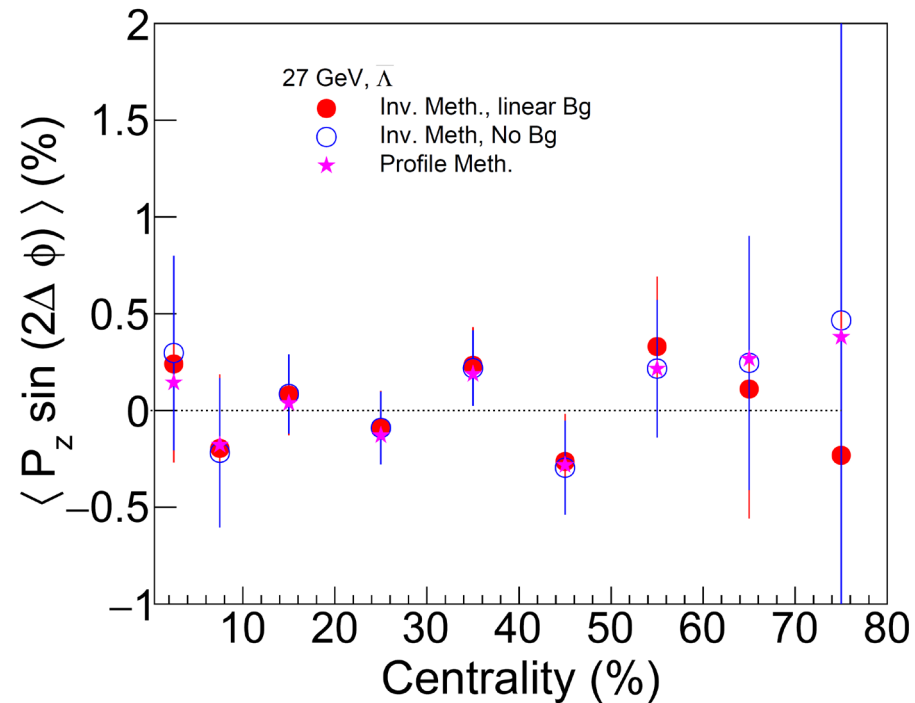
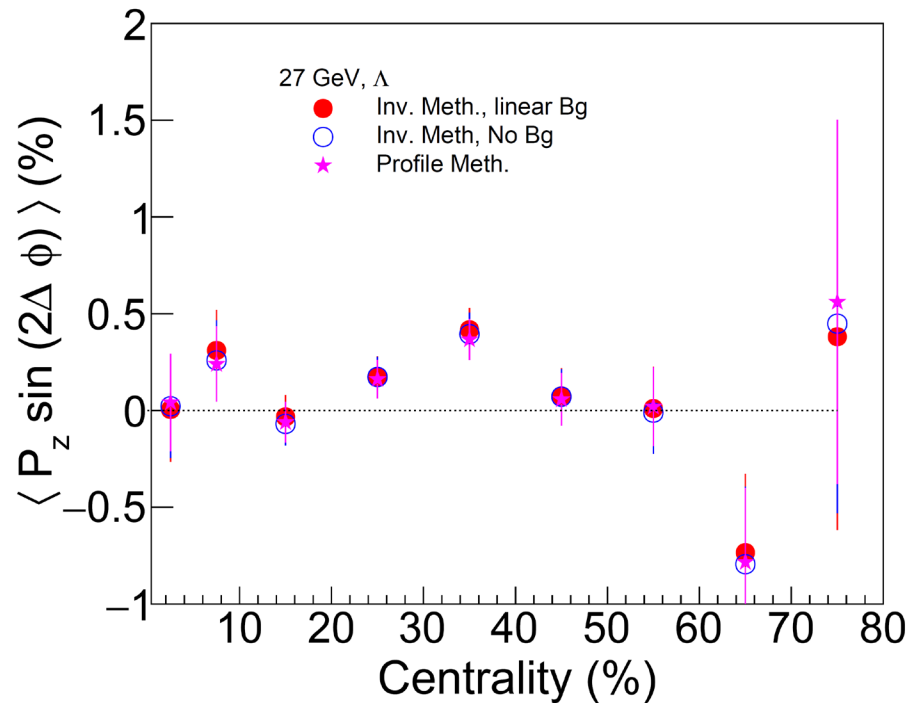


Part III: Global polarization



$0.5 \text{ GeV}/c < p_t < 5.0 \text{ GeV}/c; |\eta| < 1.0$
 $\alpha(\Lambda) = 0.732; \alpha(\text{anti-}\Lambda) = -0.758$

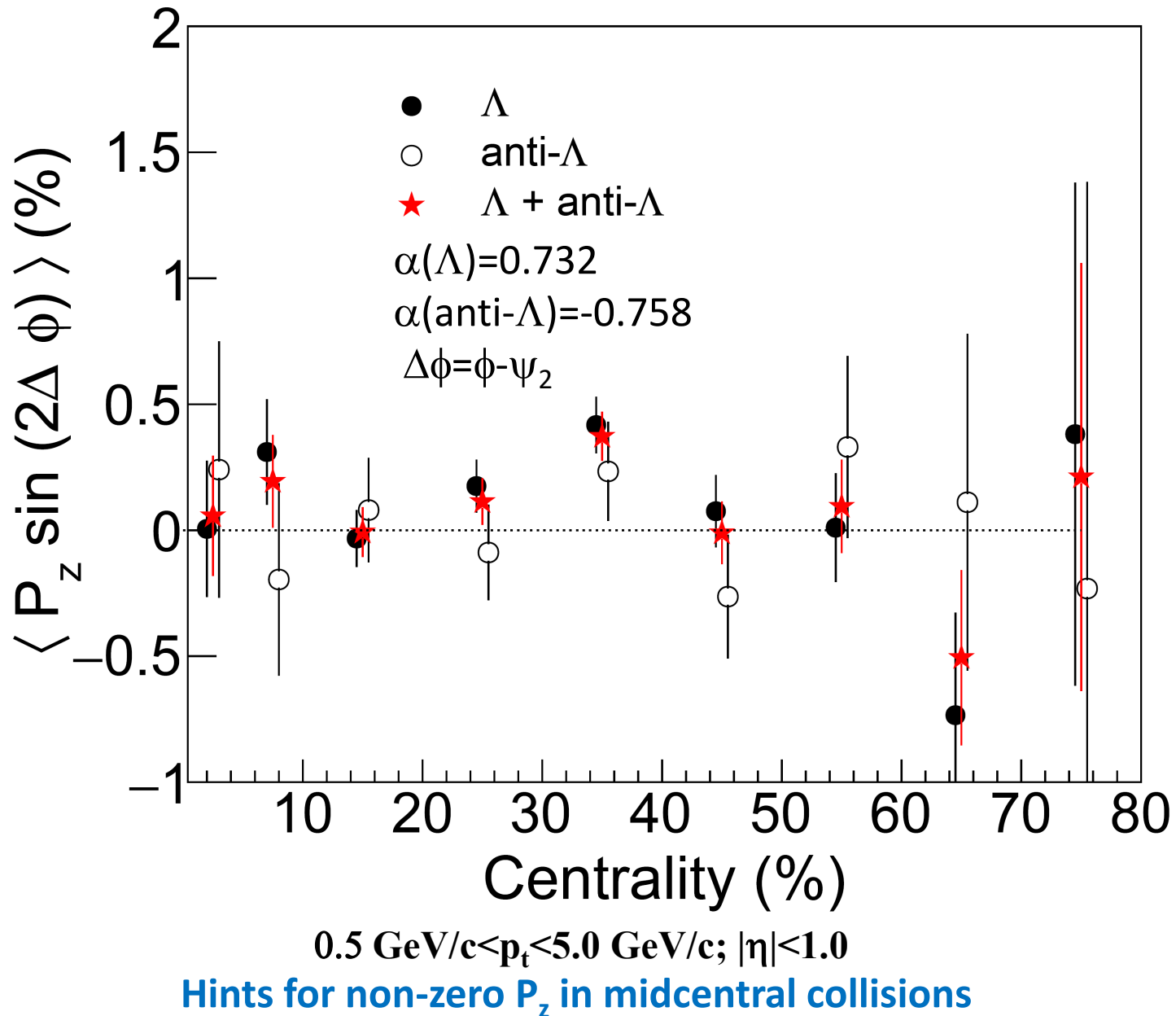
Part IV: Local polarization



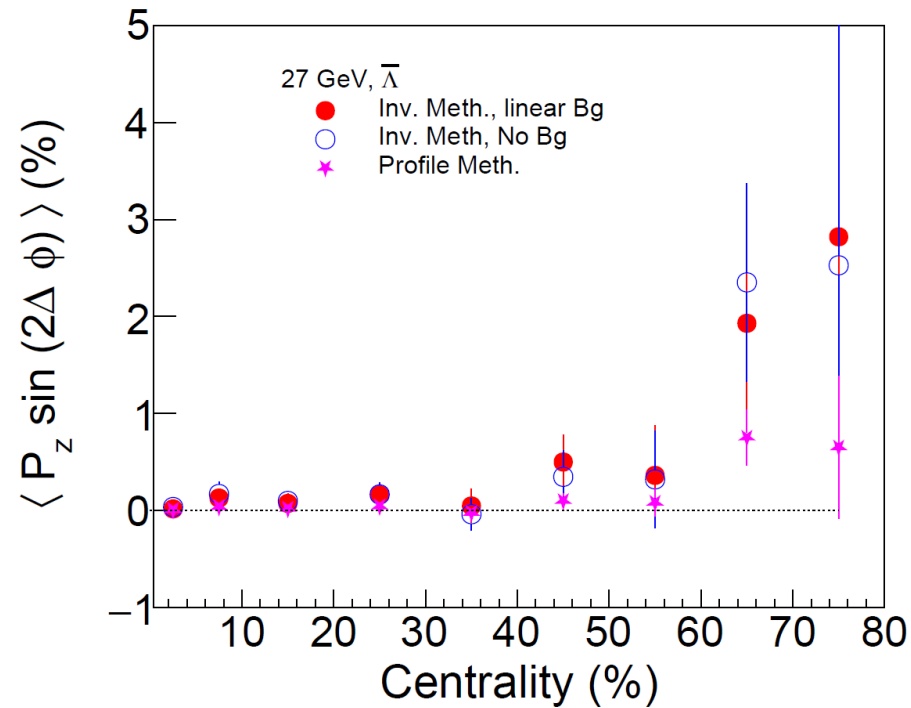
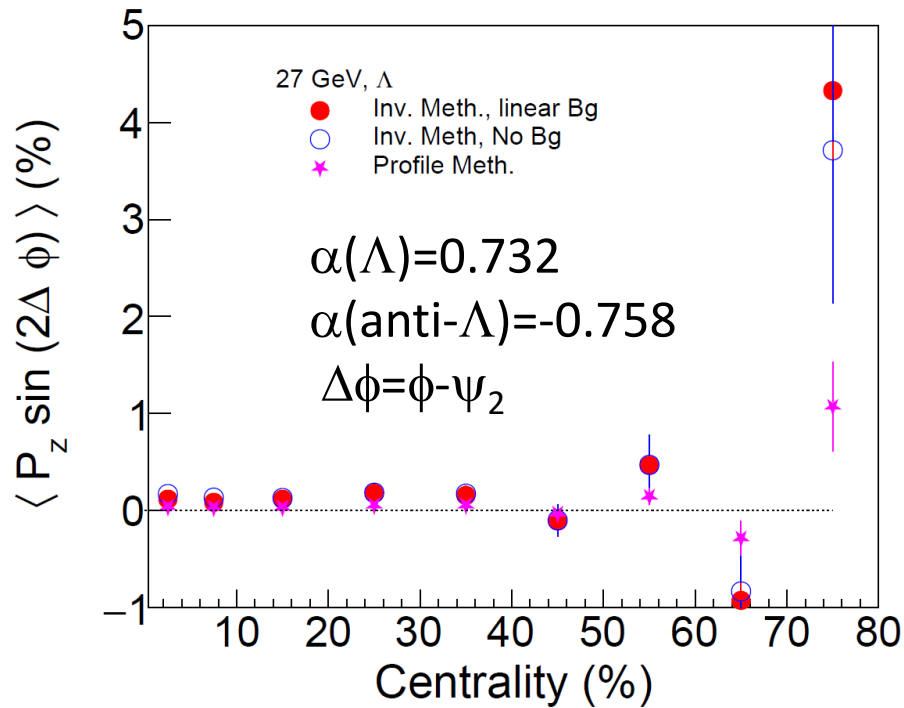
$0.5 \text{ GeV}/c < p_t < 5.0 \text{ GeV}/c; |\eta| < 1.0$
 $\alpha(\Lambda) = 0.732; \alpha(\text{anti-}\Lambda) = -0.758; \Delta\phi = \phi - \psi_2$

Hints for non-zero P_z in midcentral collisions

Part IV: Local polarization

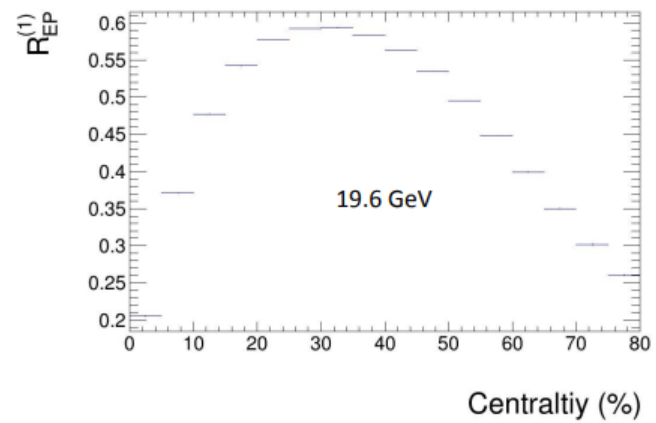
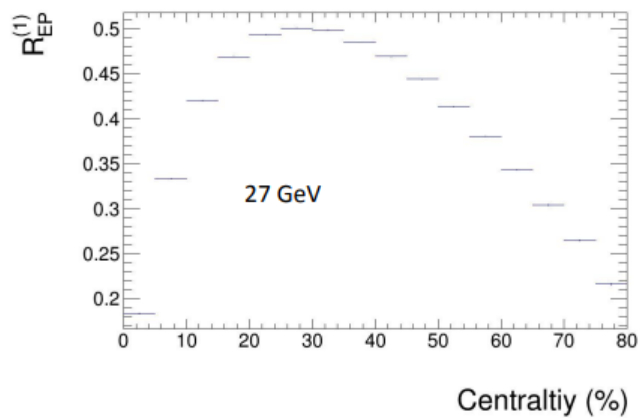


Part IV: Local polarization



Update on 2022.05.09

$0.5 \text{ GeV}/c < p_t < 5.0 \text{ GeV}/c; |\eta| < 1.0$
Hints for non-zero P_z in midcentral collisions



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