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# Probing Spin Hall Effect in Heavy-Ion collisions via $\Lambda$ spin polarization @ 7.7 GeV

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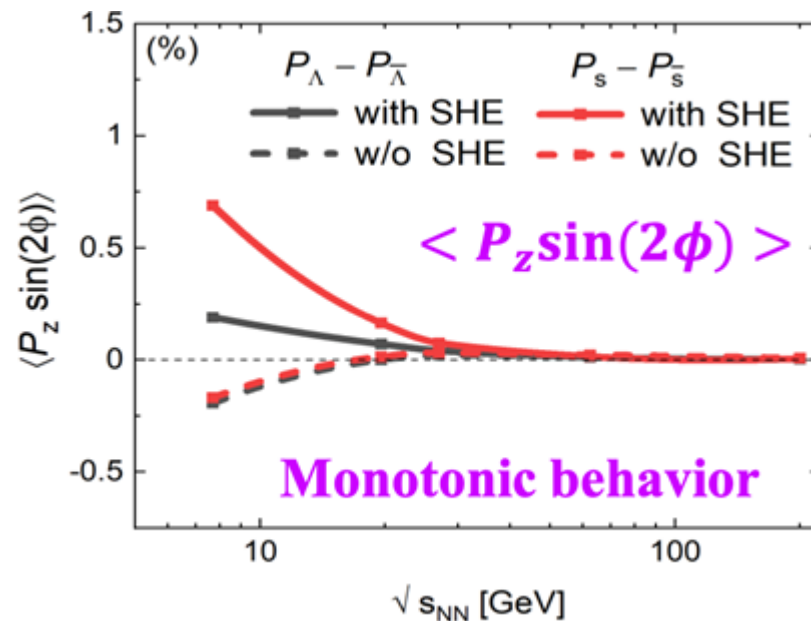
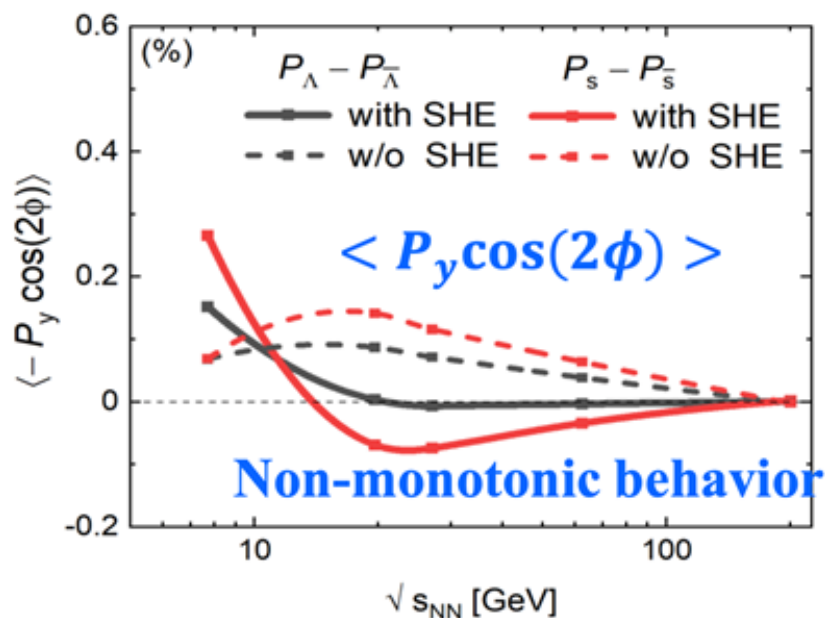
STAR FCV Meeting, Jan. 12, 2022

# Outline

- **Data analysis**
- **Global polarization for  $\Lambda$**
- **Local polarization for  $\Lambda$**
- **Summary**

# 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

**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 I: Data analysis

## Dataset and analysis details

**Au+Au 7.7 GeV, BES-II, fast offline**

### Event Cuts

- Vertex:  $|V_z| < 70$  cm  
 $|V_r| < 2$  cm
- All HLT data
- Pile-up rejection using nTofMatch and Refmult correlation
- Centrality taken from Zuowen Liu's [presentation](#)
- Bad run rejected following Vipul's [presentation](#)

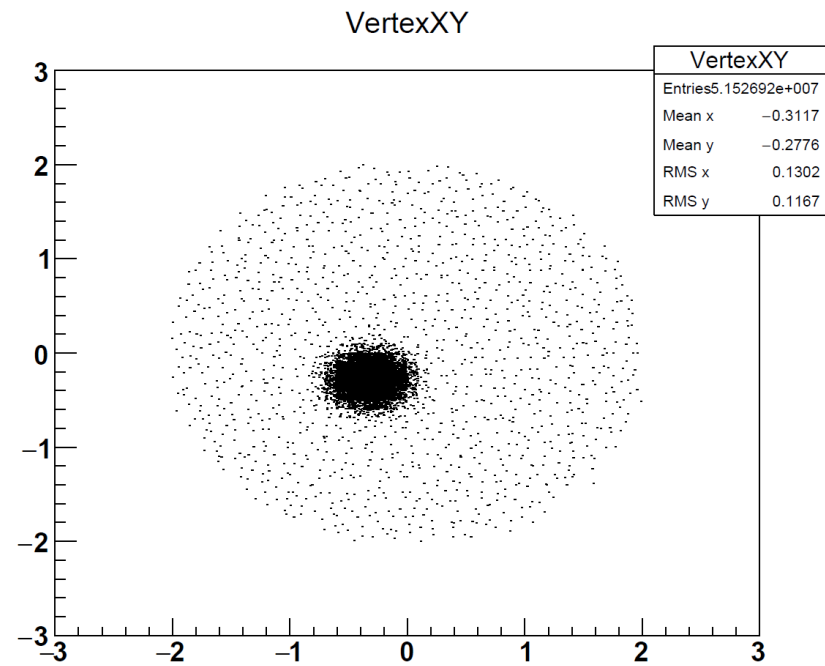
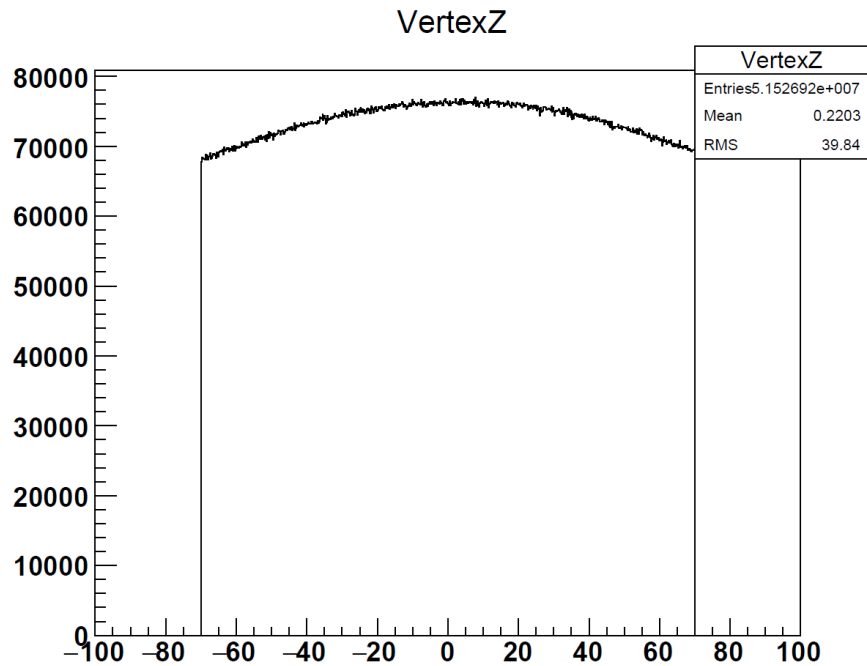
### Single track Cuts

- $0.15 \text{ GeV}/c < p_T < 10 \text{ GeV}/c$
- No. of TPC hits  $> 15$
- Nhits-TPC/Possible Hits  $\geq 0.52$
- $|\eta| < 1.0$

### 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  $\pi$  and  $p$

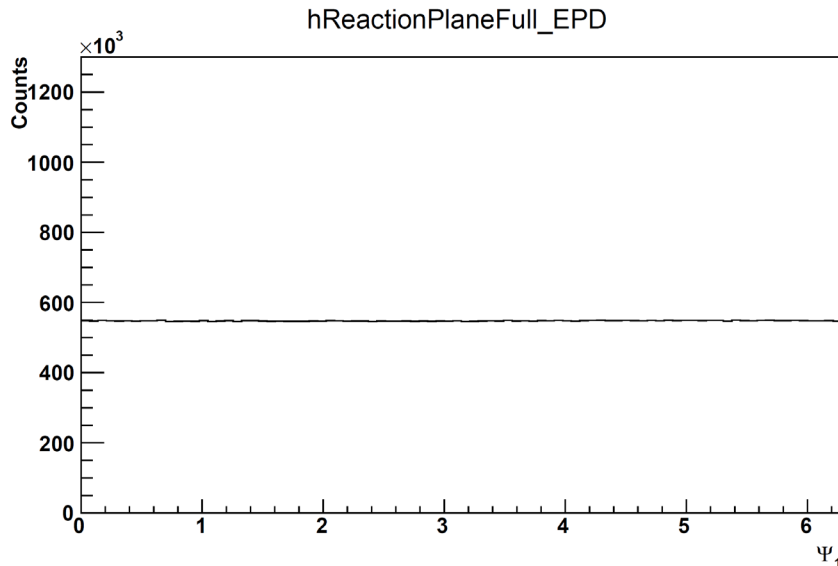
# Part I: Data analysis



## Using STAR Helix method

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

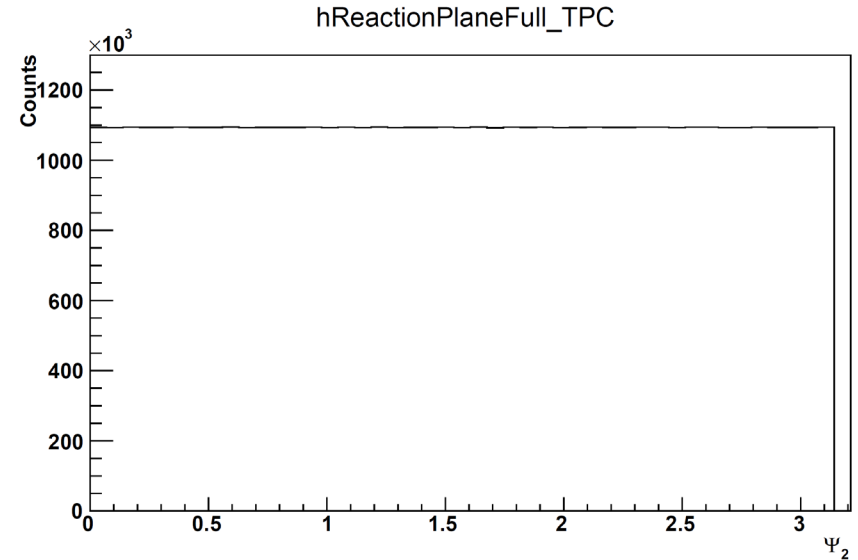
# Part I: Data analysis (event plane calibration)



## EPD Event Plane Cuts

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

Apply phi weights,  $|\eta|$  weights and shift calibrations



## TPC Event Plane Cuts

—  $|p_t| > (0.15 \text{ GeV}/c \ \&\& \ < 2.0 \text{ GeV}/c)$

—  $|\text{DCA}| < 3.0 \text{ cm}$

— No. of TPC hits  $> 15$

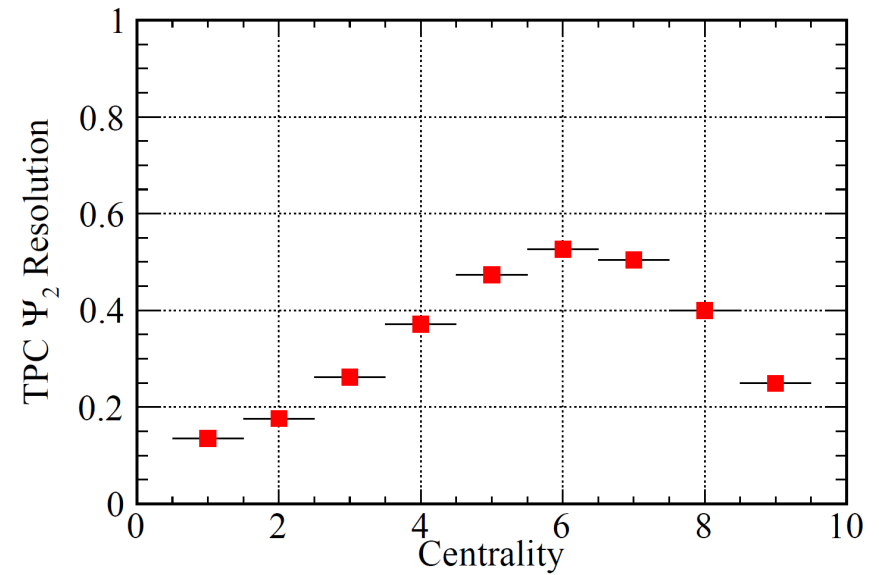
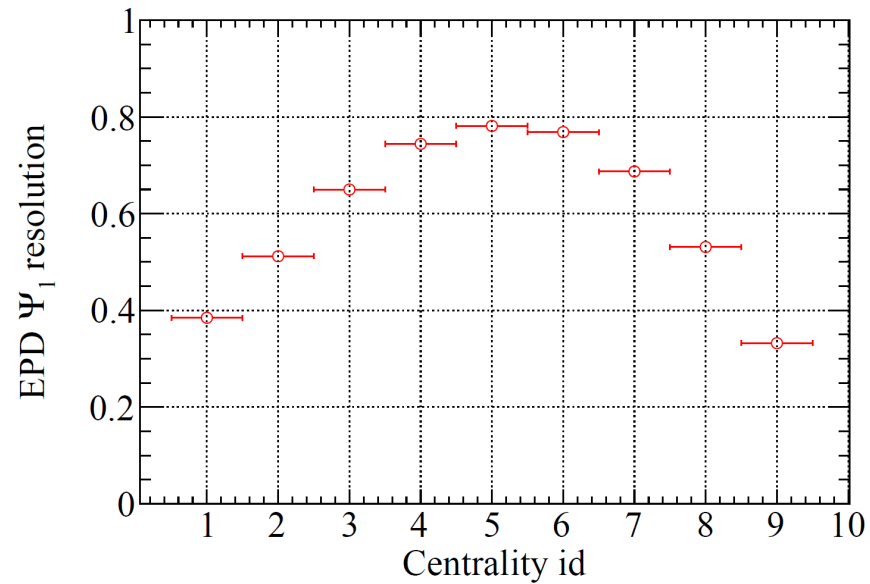
—  $N_{\text{hits-TPC/Possible Hits}} > 0.52$

—  $|\eta| < 1.0$

Combined two sub-events  
with  $\eta$ -gap  $\sim 0.1$

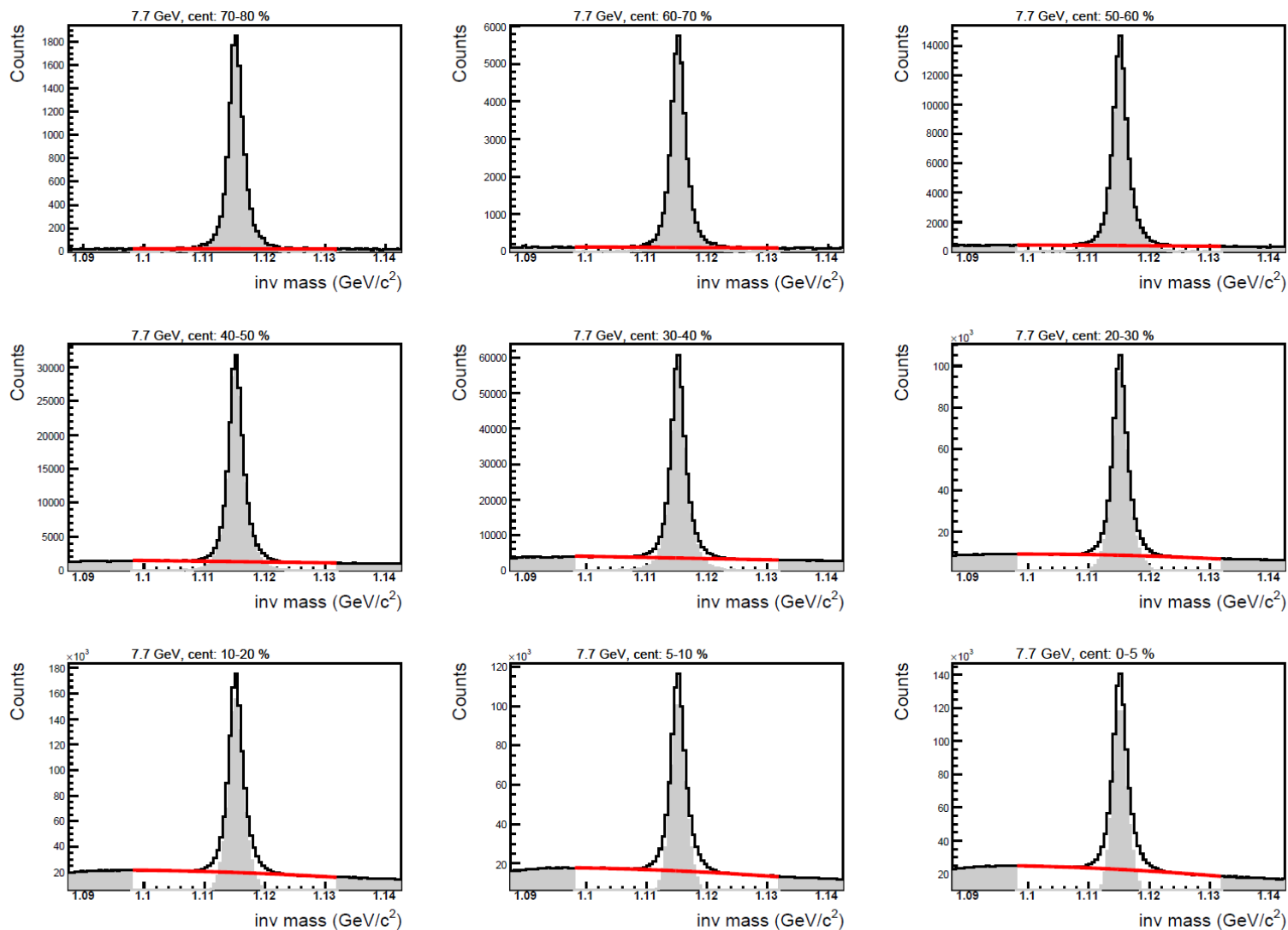
Apply run-by-run and centrality wise re-centering and shift calibrations

# Part I: Data analysis (Event plane resolution)



# Part II: Global polarization (centrality dependent)

## lambda

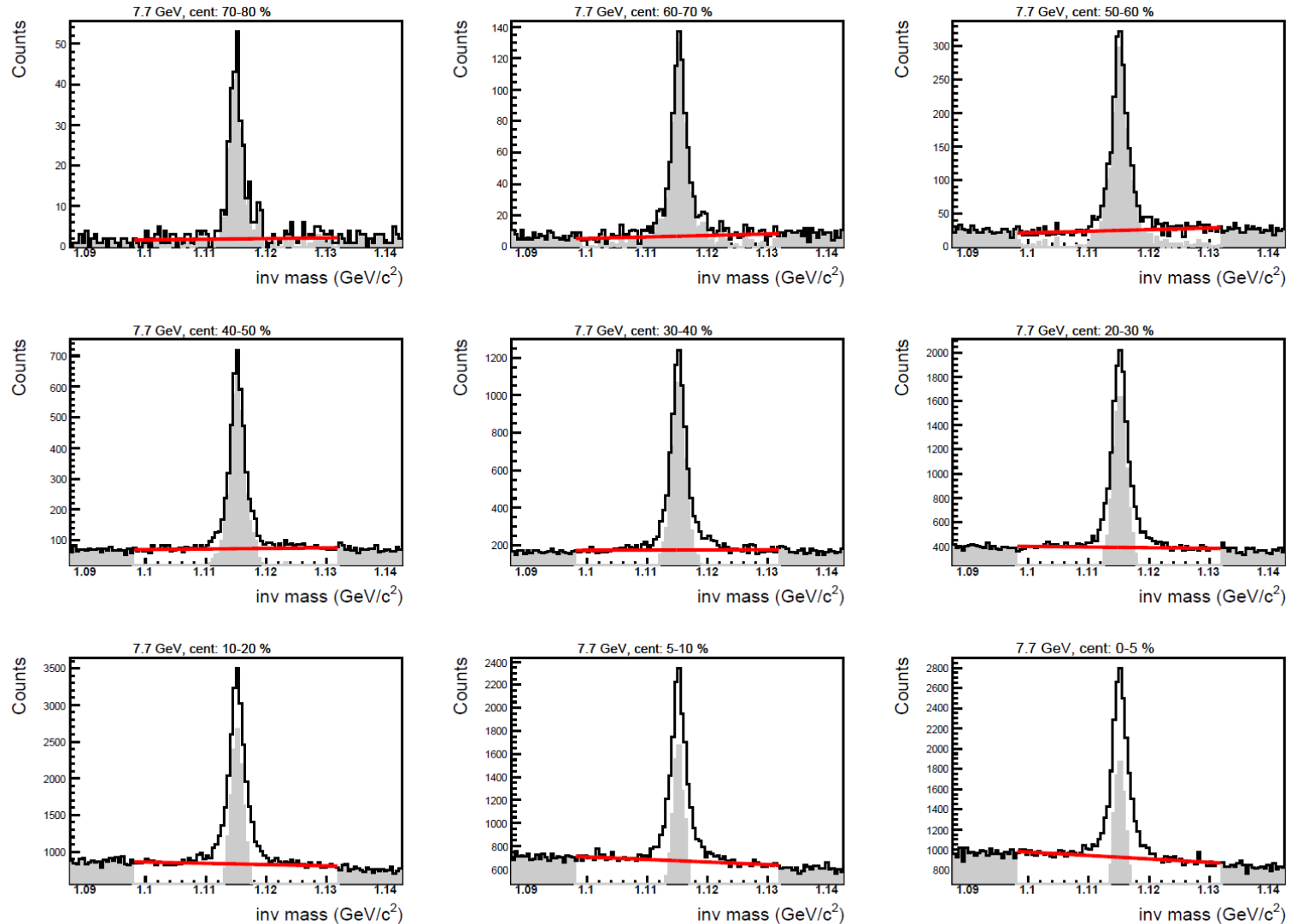


Invariant mass spectra at different centrality



# Part II: Global polarization (centrality dependence)

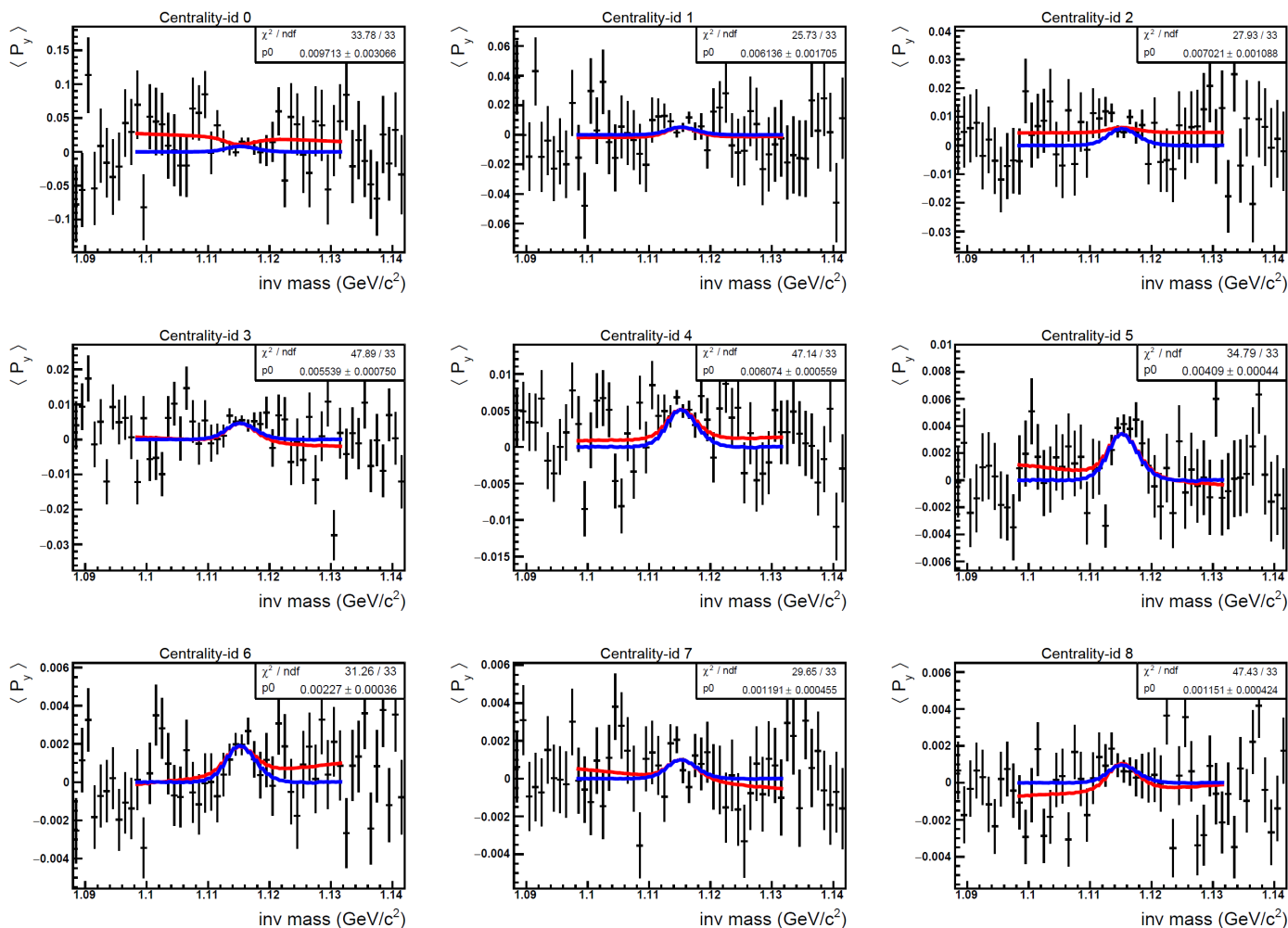
## Anti-lambda



Invariant mass spectra at different centrality

# Part II: Global polarization (centrality dependence)

## lambda



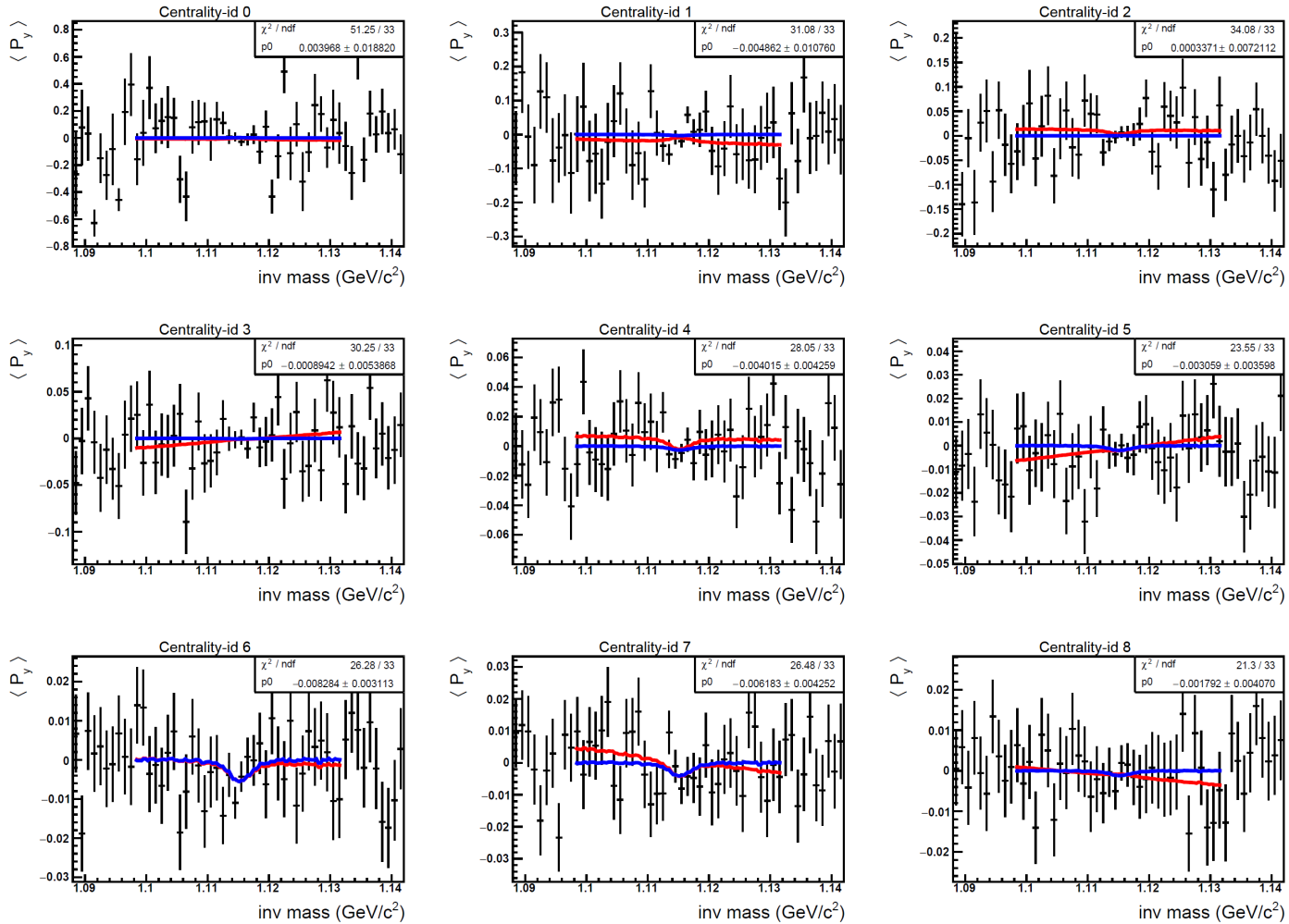
$$\langle \sin(\Delta\phi) \rangle^{\text{obs}} = (1 - f^{Bg}(M_{\text{inv}})) \langle \sin(\Delta\phi) \rangle^{\text{Sg}} + f^{Bg}(M_{\text{inv}}) \langle \sin(\Delta\phi) \rangle^{\text{Bg}}$$

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

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

# Part II: Global polarization (centrality dependence)

## Anti-lambda

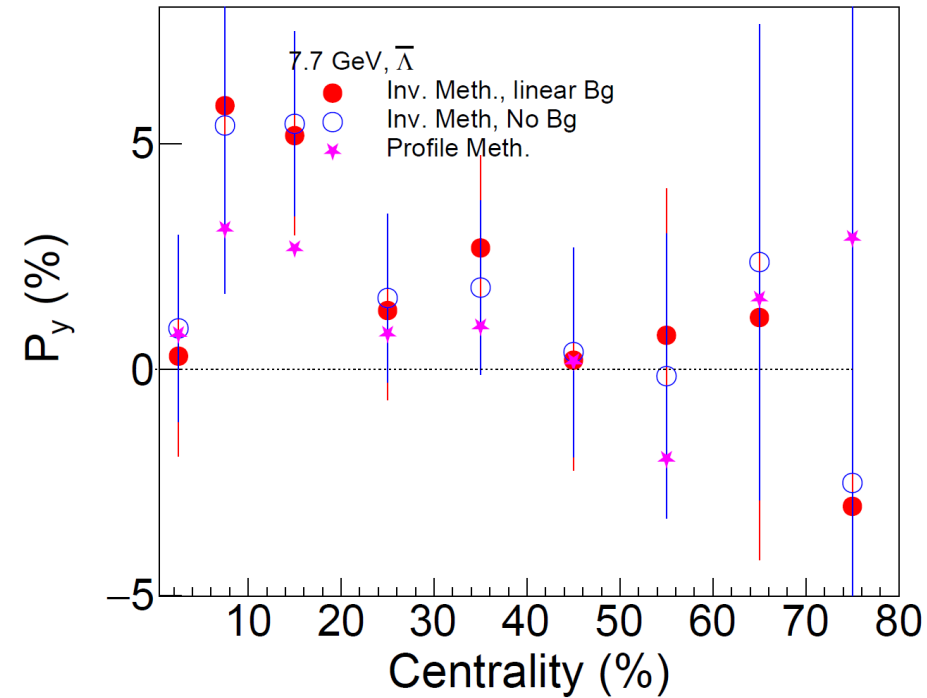
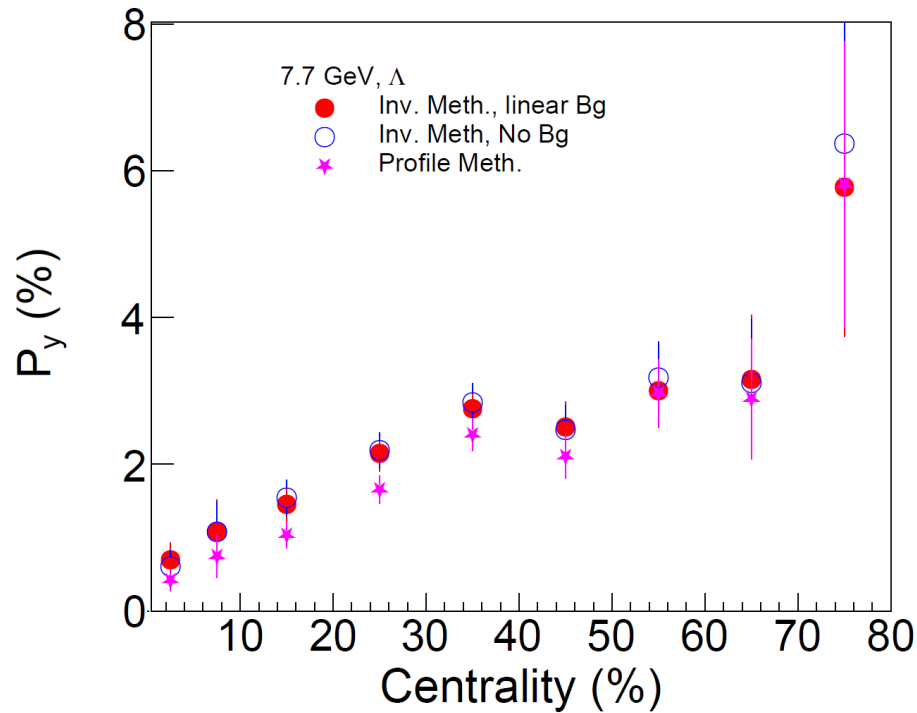


$$\langle \sin(\Delta\phi) \rangle^{\text{obs}} = (1 - f^{\text{Bg}}(M_{\text{inv}})) \langle \sin(\Delta\phi) \rangle^{\text{Sg}} + f^{\text{Bg}}(M_{\text{inv}}) \langle \sin(\Delta\phi) \rangle^{\text{Bg}}$$

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

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

# Part II: Global polarization (centrality dependence)



$$\bar{P}_{\Lambda} = \frac{8}{\pi\alpha_{\Lambda}} \frac{1}{R_{EP}^{(1)}} \langle \sin(\psi_1 - \phi_p^*) \rangle$$

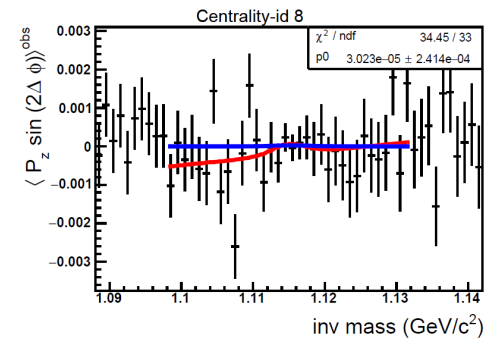
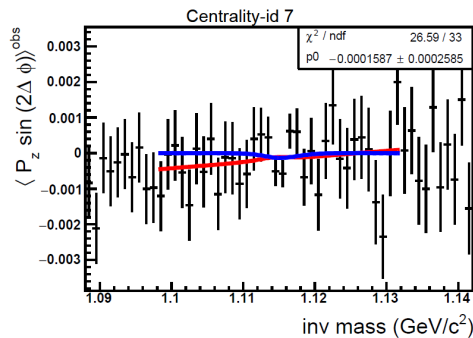
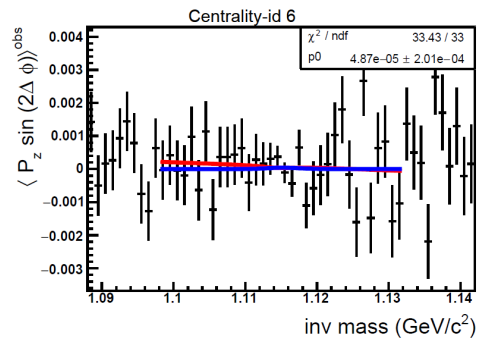
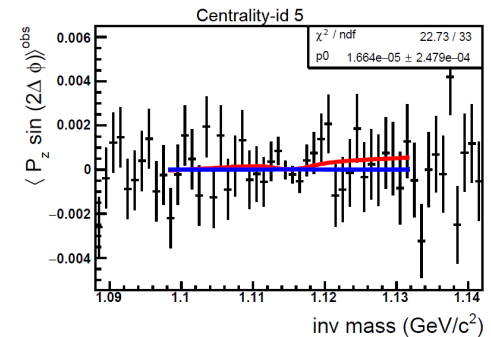
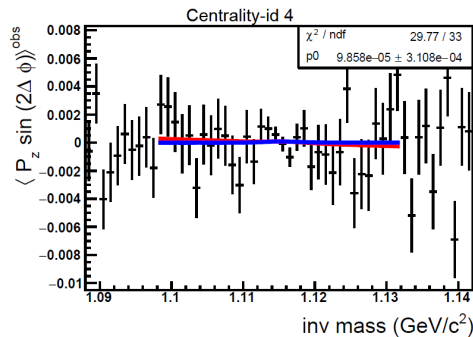
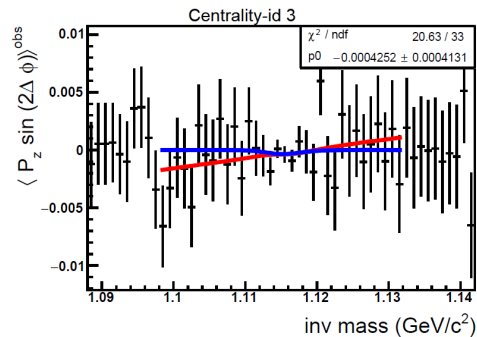
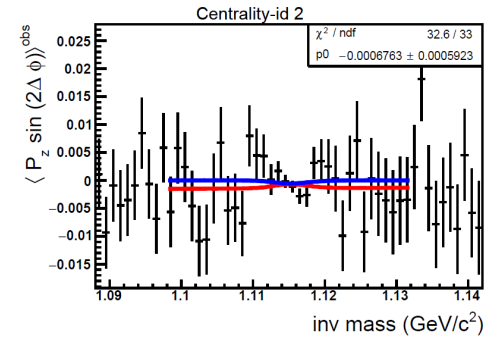
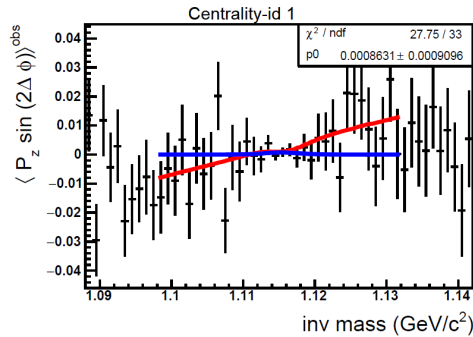
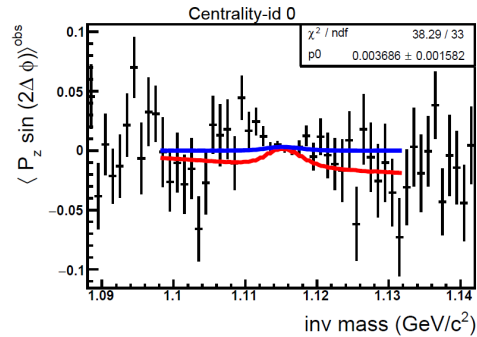
$\alpha_{\Lambda}$ :  $\Lambda$ 's decay parameter

$\phi_p^*$ : the azimuthal angle of the daughter proton in  $\Lambda$  rest frame

Lambda:  $P_y$  increase with centrality  
 Anti-lambda: the statistics is not sufficient

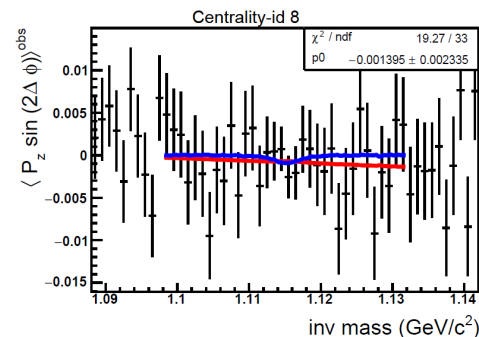
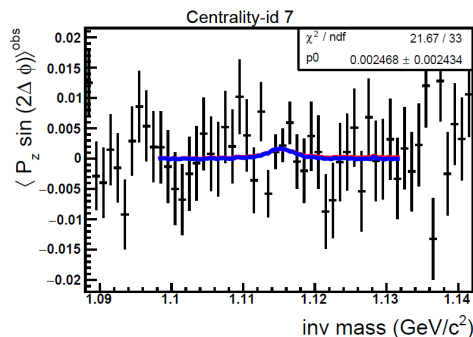
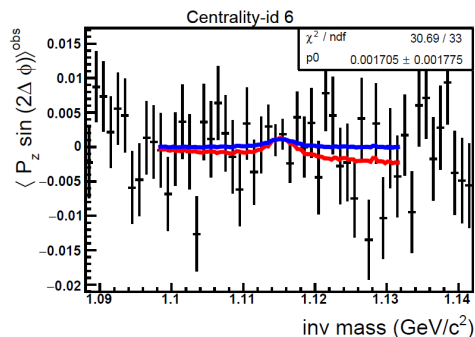
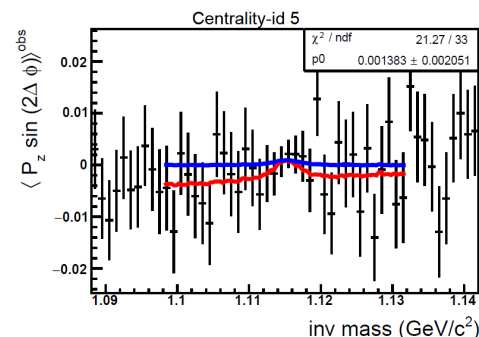
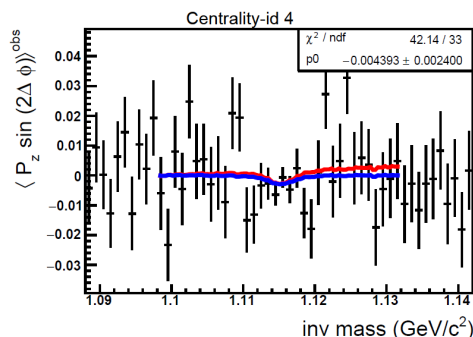
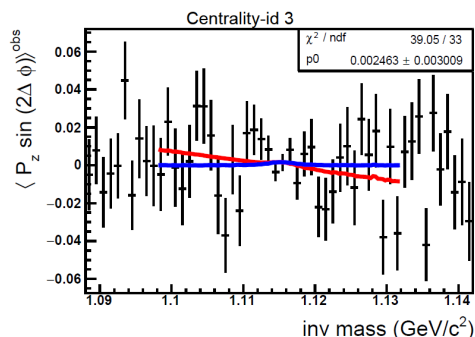
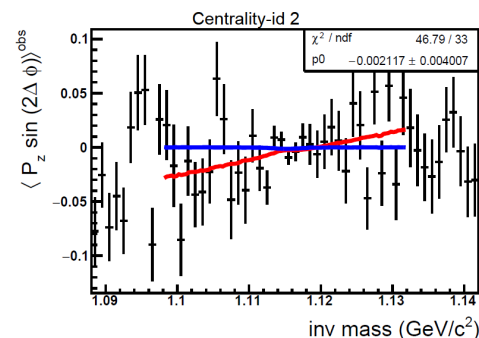
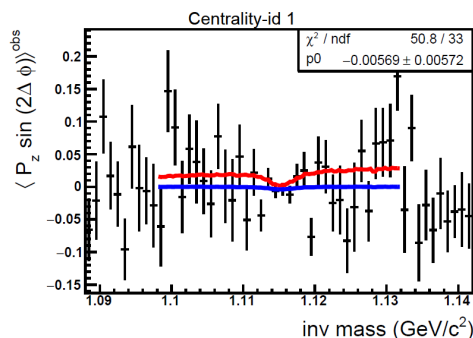
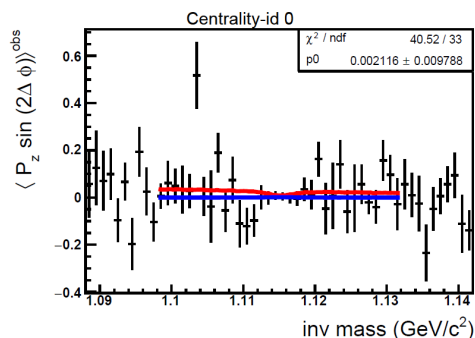
# Part III: Local polarization (centrality dependence)

## lambda

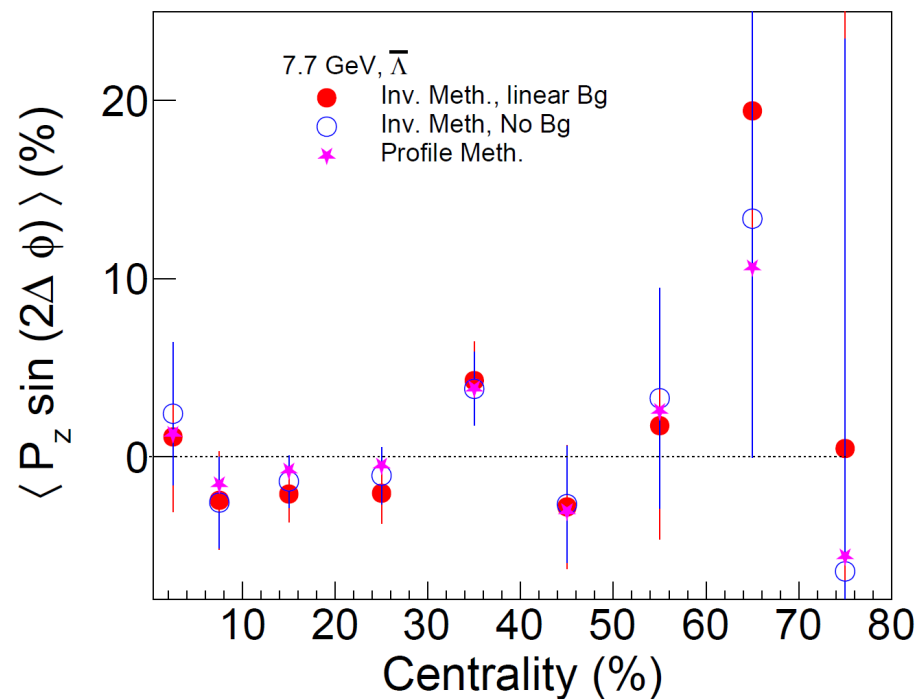
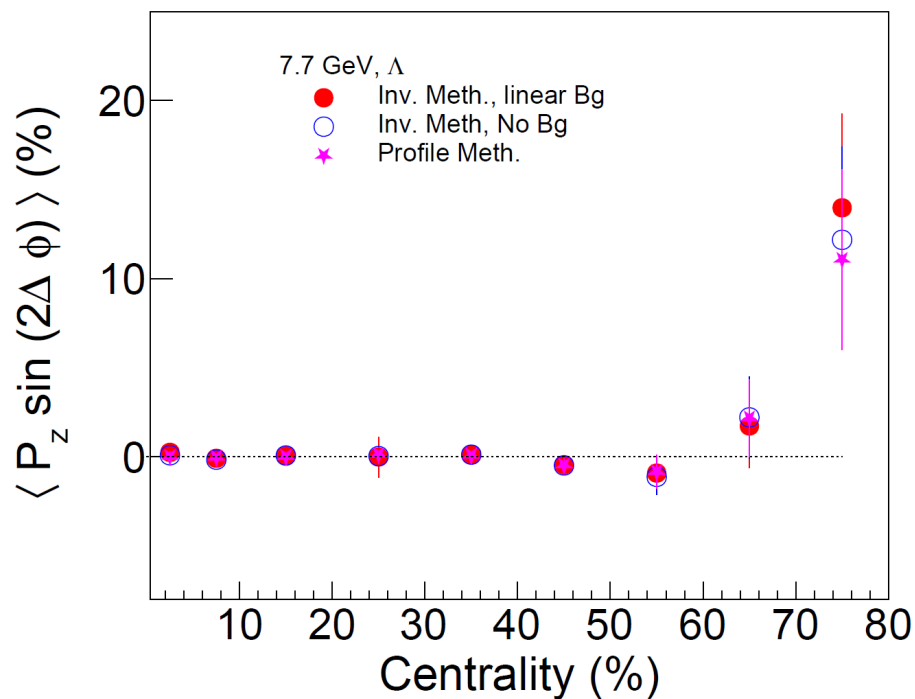


# Part III: Local polarization (centrality dependence)

## Anti-lambda



# Part III: Local polarization (centrality dependence)



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

$\theta^*$ : angle between daughter proton momentum vector in  $\Lambda$  rest frame and polarization direction

# Summary

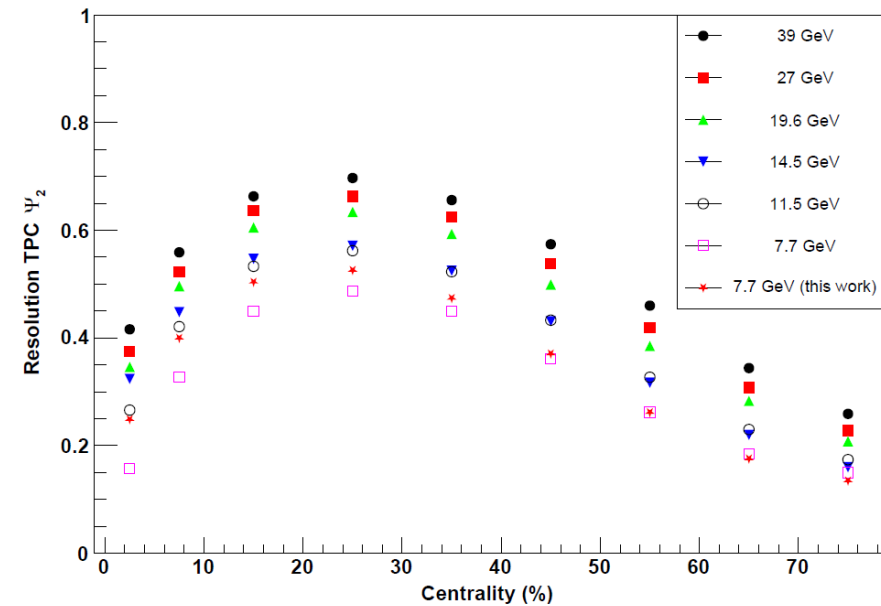
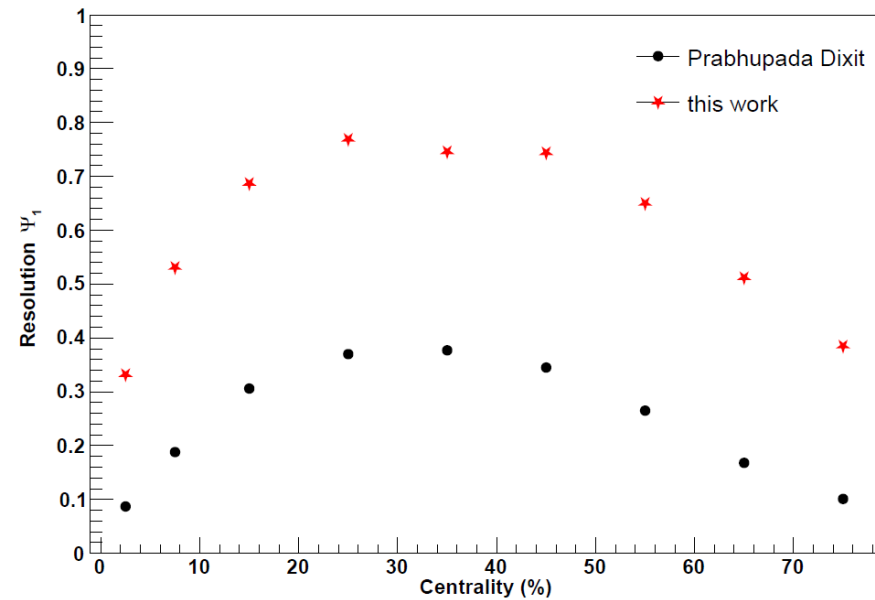
- **EPD & TPC full event plane has been calibrated for fast offline Au+Au @ 7.7 GeV**
- **Centrality dependence of global and local polarization of  $\Lambda$  (anti-  $\Lambda$ ) are studied**

## Next steps

- **Efficiency & acceptance correction**
- **Measurement of  $\langle P_y \cos(2\phi) \rangle$  and  $\langle P_x \sin(2\phi) \rangle$**
- **Continue to analysis the BES-II Au+Au collisions data at 19.6, 14.6 and 7.7 GeV et al. to search SHE signal**

***Thank you for your attention!***





What caused the huge difference between this work and previous results?