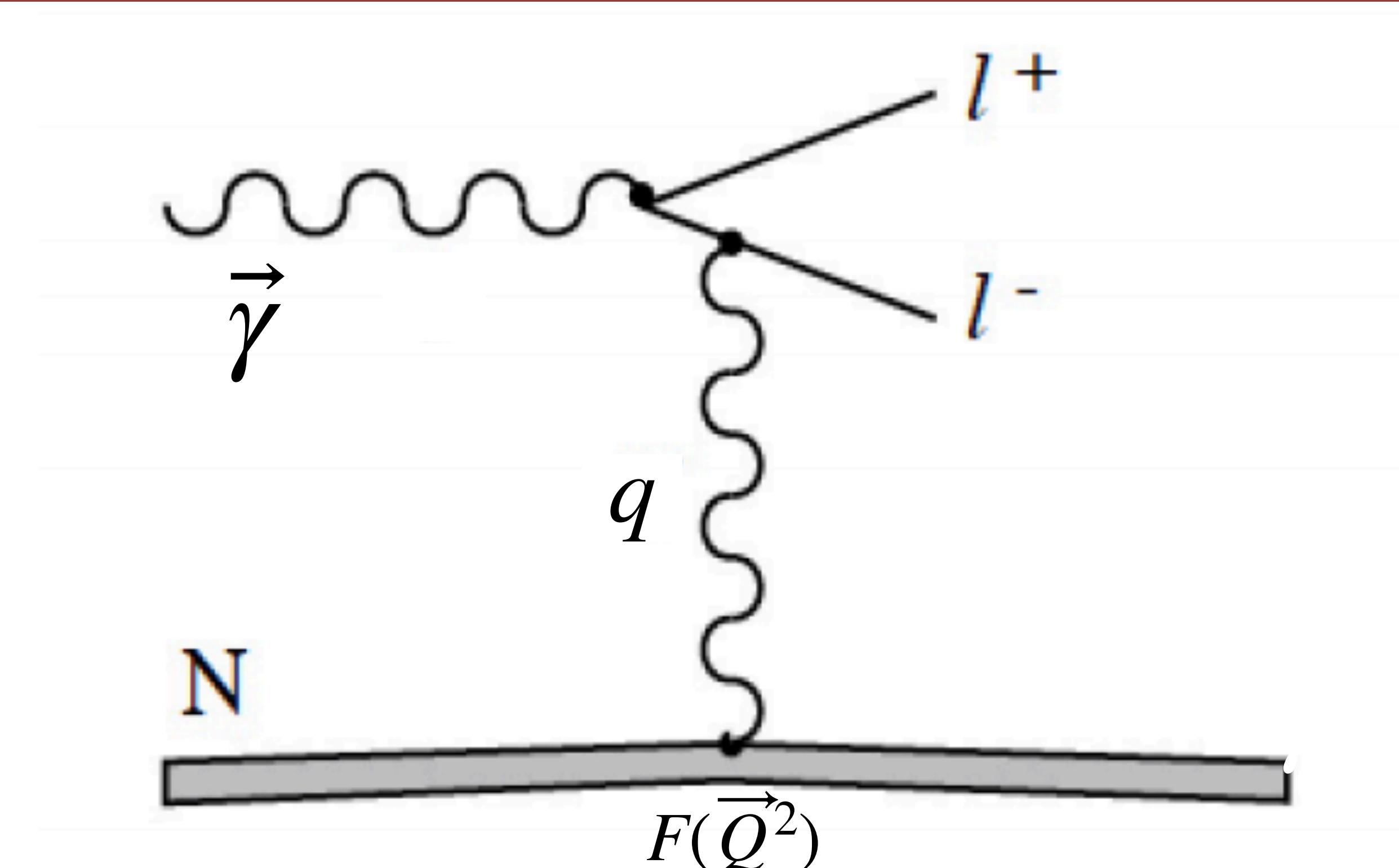


Using Bethe Heitler Pairs as a Polarimeter in GlueX



Andrew Schick

BLTWG Meeting, Tuesday, March 30 2021

Use Bethe-Heitler pairs to measure linear photon polarization.

$$\begin{aligned} d\sigma &= \left(\frac{1 + \mathcal{P}}{2} \right) d\sigma_{||} + \left(\frac{1 - \mathcal{P}}{2} \right) d\sigma_{\perp} \\ &= \left(\frac{d\sigma_{||} + d\sigma_{\perp}}{2} \right) + \mathcal{P} \left(\frac{d\sigma_{||} - d\sigma_{\perp}}{2} \right) \end{aligned}$$

\uparrow \uparrow
 $d\sigma_0$ $d\sigma_1$
Unpolarized Polarized

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$$d\sigma_1 \sim P_{\gamma} |\vec{J}_T|^2 \cos(2\phi_{J_T}) \quad (\text{Bakmaev, 2008})$$

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$$d\sigma_1 \sim P_\gamma |\vec{J}_T|^2 \cos(2\phi_{J_T}) \quad (\text{Bakmaev, 2008})$$

$$\vec{J}_T = \frac{\vec{p}_1}{p_1^2 + m^2} + \frac{\vec{p}_2}{p_2^2 + m^2} = \frac{\vec{p}_1}{c_1} + \frac{\vec{p}_2}{c_2}$$

\vec{p}_1, \vec{p}_2 are the lepton's transverse momenta

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Bakmaev's formulation is really only valid at very large t

Can we find a similar reduction in Heitler's born approximation formulation?

$$d\sigma = \frac{Z^2}{137} \frac{e^4}{4\pi^2} \frac{p_+ p_- dE_+ d\Omega_+ d\Omega_-}{k^3 q^4} \left\{ \frac{(\boldsymbol{\epsilon} \cdot \mathbf{p}_+)^2 (q^2 - 4E_-^2)}{(E_+ - p_+ \cos\theta_+)^2} + \frac{(\boldsymbol{\epsilon} \cdot \mathbf{p}_-)^2 (q^2 - 4E_+^2)}{(E_- - p_- \cos\theta_-)^2} - \frac{2(\boldsymbol{\epsilon} \cdot \mathbf{p}_+) (\boldsymbol{\epsilon} \cdot \mathbf{p}_-) (q^2 + 4E_+ E_-)}{(E_+ - p_+ \cos\theta_+) (E_- - p_- \cos\theta_-)} + \frac{k^2 [p_+^2 \sin^2\theta_+ + p_-^2 \sin^2\theta_- + 2p_+ p_- \sin\theta_+ \sin\theta_- \cos(\varphi_+ - \varphi_-)]}{(E_+ - p_+ \cos\theta_+) (E_- - p_- \cos\theta_-)} \right\}$$

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$$d\sigma_1 \sim |\vec{J}_T|^2 \cos(2\phi_{J_T}), \quad \vec{J}_T = f_1 \vec{p}_1 + f_2 \vec{p}_2$$

Can we find a similar reduction in Heitler's born approximation formulation?

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$$\vec{J}_T = \frac{2E_2}{E_1 - p_1 \cos \theta_1} \vec{p}_{1T} + \frac{2E_2}{E_2 - p_2 \cos \theta_2} \vec{p}_{2T}$$

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$$d\sigma = d\sigma_0 + P_\gamma d\sigma_1$$

$$d\sigma_0 = \frac{d\sigma_{||} + d\sigma_{\perp}}{2} = k \left[- \left| \vec{J}_T \right|^2 + \left| \vec{K}_T \right|^2 + 2E_0^2 \frac{\left| \vec{p}_{1T} + \vec{p}_{2T} \right|^2}{(E_1 - p_1 \cos \theta_1)(E_2 - p_2 \cos \theta_2)} \right]$$

$$d\sigma_1 = \frac{d\sigma_{||} - d\sigma_{\perp}}{2} = k \left[- \left| \vec{J}_T \right|^2 \cos 2\phi_{J_T} + \left| \vec{K}_T \right|^2 \cos 2\phi_{J_T} \right]$$

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$$d\sigma = d\sigma_0 + P_\gamma d\sigma_1$$

$$d\sigma_0 = \frac{d\sigma_{||} + d\sigma_{\perp}}{2} = k \left[- \left| \vec{J}_T \right|^2 + \left| \vec{K}_T \right|^2 + 2E_0^2 \frac{\left| \vec{p}_{1T} + \vec{p}_{2T} \right|^2}{(E_1 - p_1 \cos \theta_1)(E_2 - p_2 \cos \theta_2)} \right]$$

$$d\sigma_1 = \frac{d\sigma_{||} - d\sigma_{\perp}}{2} = k \left[- \left| \vec{J}_T \right|^2 \cos 2\phi_{J_T} + \left| \vec{K}_T \right|^2 \cos 2\phi_{J_T} \right]$$

$$d\sigma = \frac{Z^2}{137} \frac{e^4}{4\pi^2} \frac{p_+ p_- dE_+ d\Omega_+ d\Omega_-}{k^3 q^4} \left\{ \frac{(\boldsymbol{\epsilon} \cdot \mathbf{p}_+)^2 (q^2 - 4E_-^2)}{(E_+ - p_+ \cos \theta_+)^2} \right. \\ \left. + \frac{(\boldsymbol{\epsilon} \cdot \mathbf{p}_-)^2 (q^2 - 4E_+^2)}{(E_- - p_- \cos \theta_-)^2} - \frac{2(\boldsymbol{\epsilon} \cdot \mathbf{p}_+)(\boldsymbol{\epsilon} \cdot \mathbf{p}_-)(q^2 + 4E_+ E_-)}{(E_+ - p_+ \cos \theta_+)(E_- - p_- \cos \theta_-)} \right. \\ \left. + \frac{k^2 [p_+^2 \sin^2 \theta_+ + p_-^2 \sin^2 \theta_- + 2p_+ p_- \sin \theta_+ \sin \theta_- \cos(\varphi_+ - \varphi_-)]}{(E_+ - p_+ \cos \theta_+)(E_- - p_- \cos \theta_-)} \right\}.$$

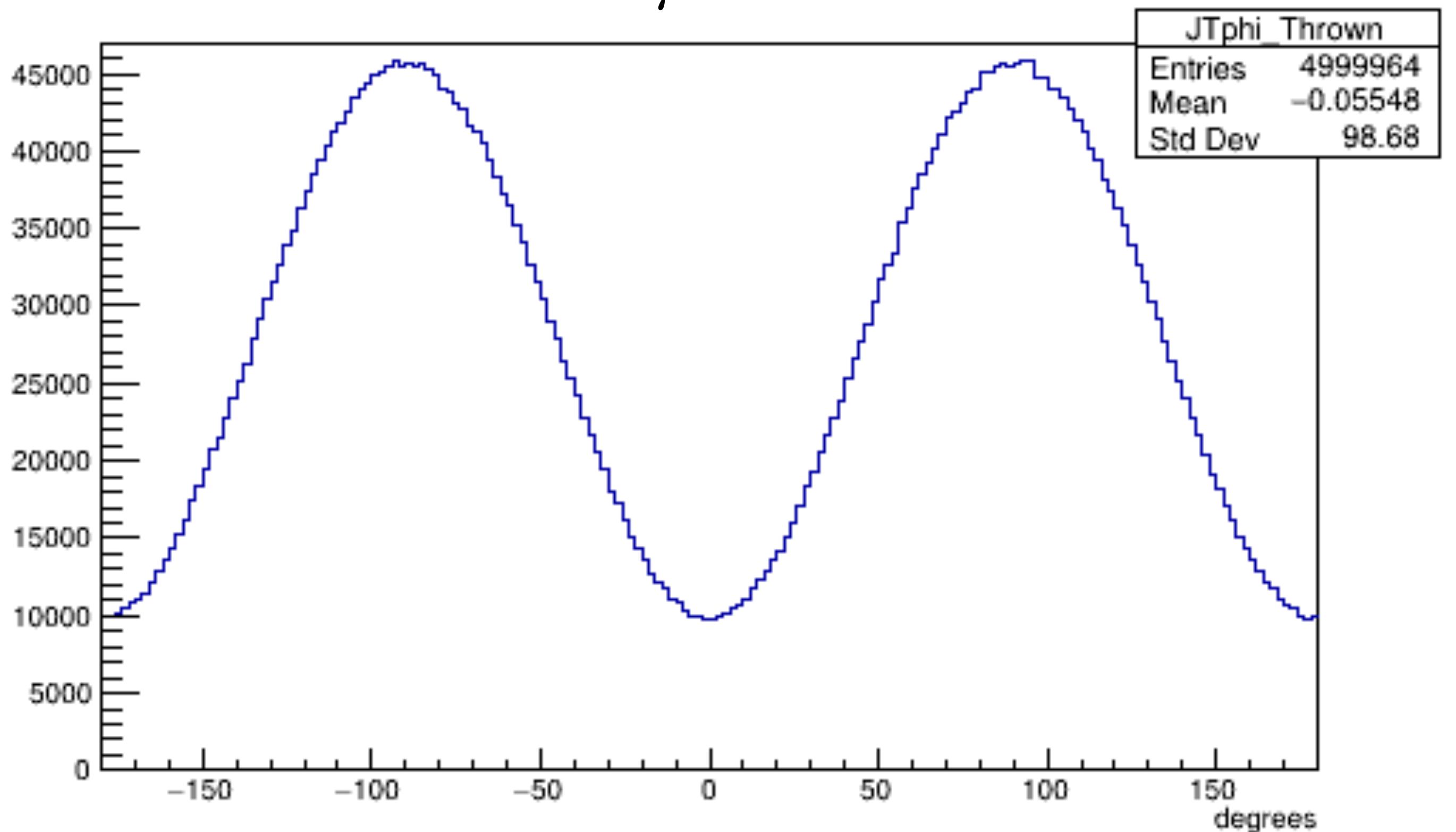
$\boldsymbol{\epsilon}$ is a unit vector in the direction of polarization of the incident photon.

Generally, $\left| \vec{J}_T \right|^2 \gg \left| \vec{K}_T \right|^2$

$$d\sigma = d\sigma_0 + P_\gamma d\sigma_1$$

$$d\sigma_1 \sim \left| \vec{J}_T \right|^2 \cos 2\phi_{J_T}$$

$$P_\gamma = 1$$



MC with BH Cross-Section

$$\begin{aligned} d\sigma = & \frac{Z^2}{137} \frac{e^4}{4\pi^2} \frac{p_+ p_- dE_+ d\Omega_+ d\Omega_-}{k^3 q^4} \left\{ \frac{(\mathbf{\epsilon} \cdot \mathbf{p}_+)^2 (q^2 - 4E_-^2)}{(E_+ - p_+ \cos\theta_+)^2} \right. \\ & + \frac{(\mathbf{\epsilon} \cdot \mathbf{p}_-)^2 (q^2 - 4E_+^2)}{(E_- - p_- \cos\theta_-)^2} - \frac{2(\mathbf{\epsilon} \cdot \mathbf{p}_+) (\mathbf{\epsilon} \cdot \mathbf{p}_-) (q^2 + 4E_+ E_-)}{(E_+ - p_+ \cos\theta_+) (E_- - p_- \cos\theta_-)} \\ & \left. + \frac{k^2 [p_+^2 \sin^2\theta_+ + p_-^2 \sin^2\theta_- + 2p_+ p_- \sin\theta_+ \sin\theta_- \cos(\varphi_r - \varphi_-)]}{(E_+ - p_+ \cos\theta_+) (E_- - p_- \cos\theta_-)} \right\}. \end{aligned}$$

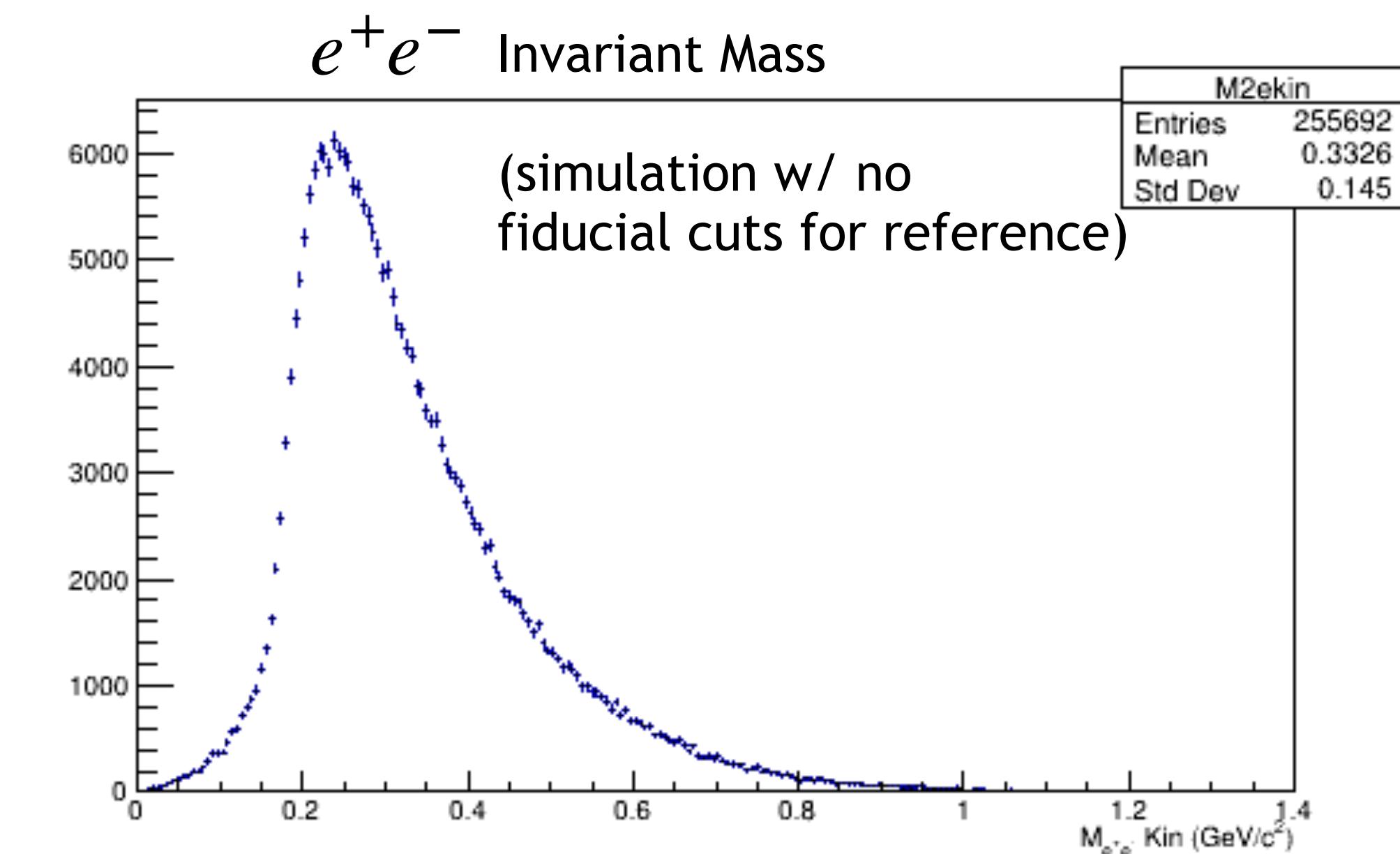
1. Generate e+e- 4 vectors using this cross section

2. Plot ϕ_{J_T} from the 4 vectors

3. Measuring ϕ_{J_T} allows you to infer the beam polarization

2018-01 GlueX data

$\gamma p \rightarrow e^+e^- (p)$ Reaction Filter



Neural Net Cuts:

Neural Net Classification Cuts (NN1, NN2 < 0.2)

Fiducial Cuts:

$8.2 \text{ GeV} < E_\gamma < 8.8 \text{ GeV}$

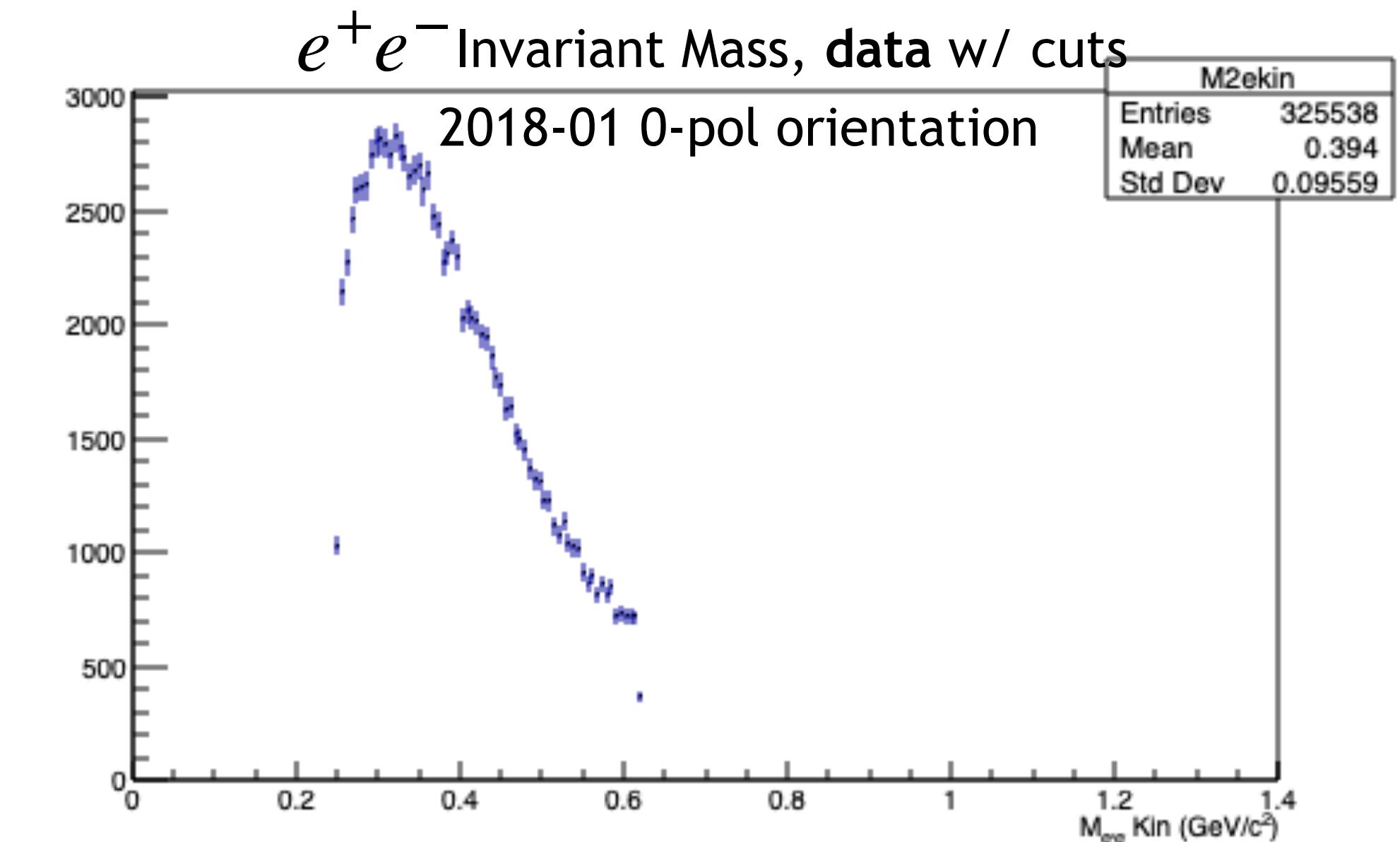
$0.25 \text{ GeV} < W_{ee} < 0.621 \text{ GeV}$

Both tracks have hits in the TOF

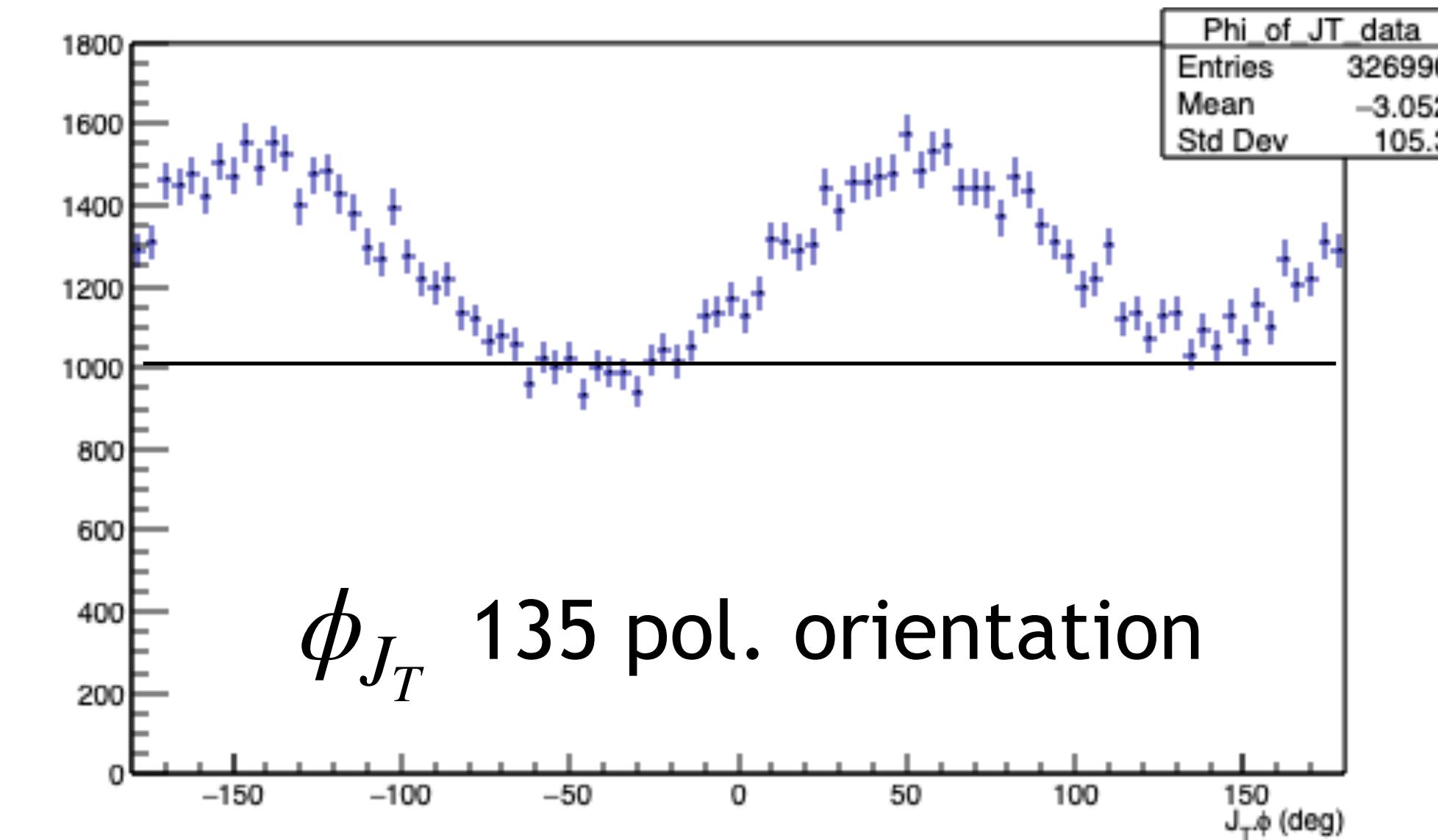
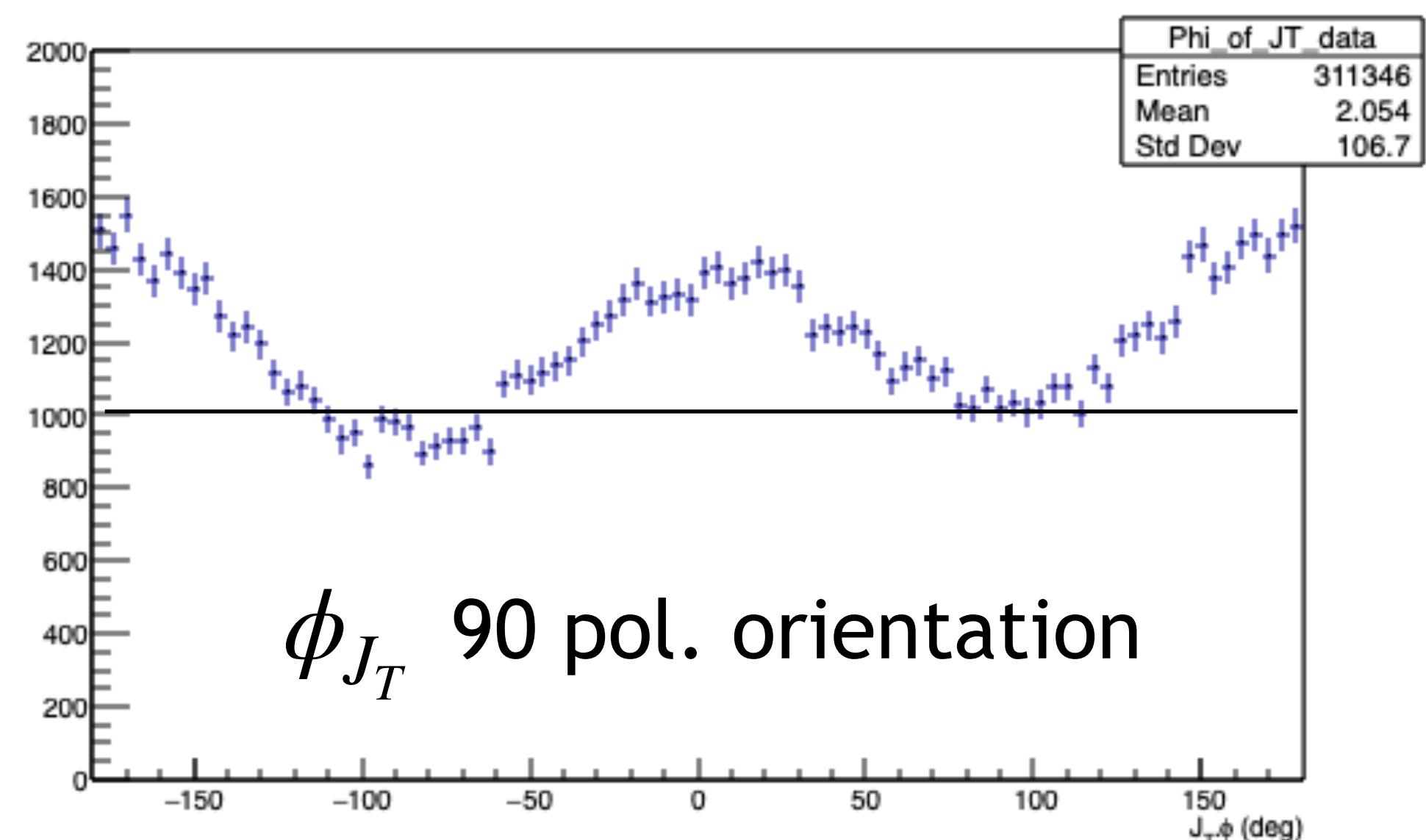
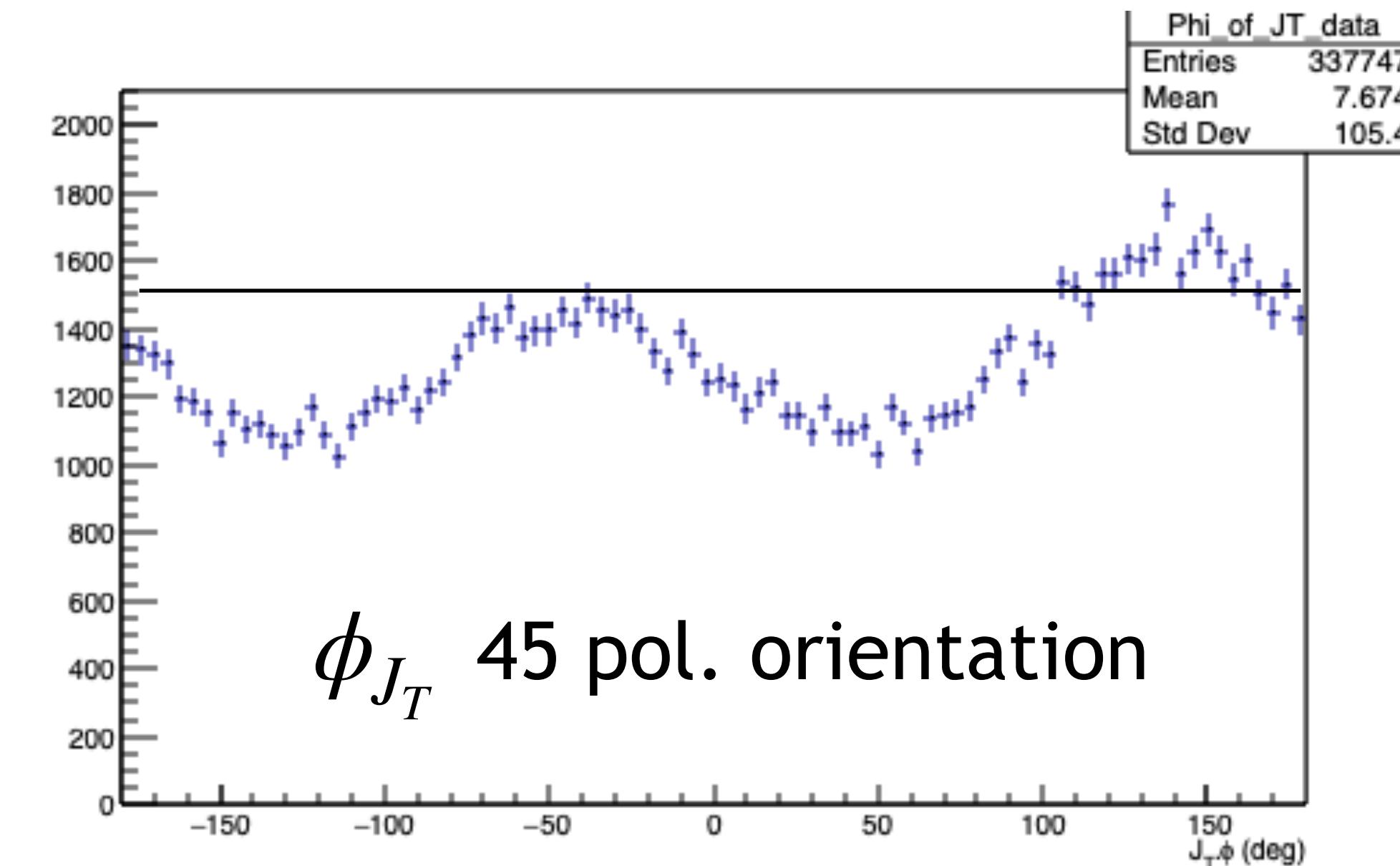
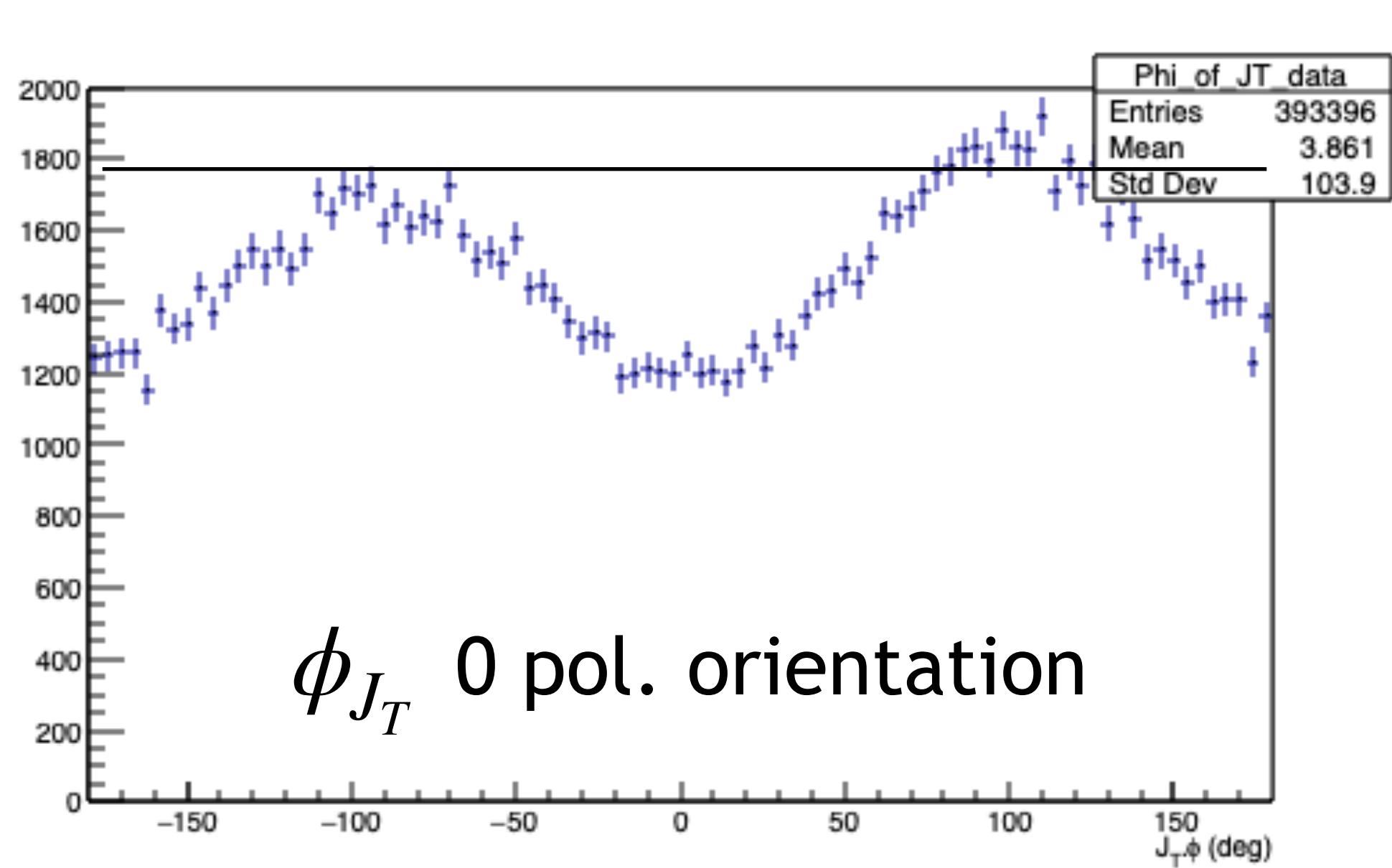
$\theta_1, \theta_2 > 1.5 \text{ deg}$

FCAL Elasticity > 0.9

Vertex cut (Window free): $52 < z < 78 \text{ cm}$



$\gamma p \rightarrow e^+e^- (p)$ 2018-01 GlueX data, w/ fiducial+N.N. cuts



$$\frac{Y_{\perp}(\phi) - \frac{N_{\perp}}{N_{\parallel}} Y_{\parallel}(\phi)}{Y_{\perp} + \frac{N_{\perp}}{N_{\parallel}} Y_{\parallel}(\phi)} = \frac{\Sigma \cos 2\phi (P_{\perp} + P_{\parallel})}{2 + \Sigma \cos 2\phi (P_{\perp} - P_{\parallel})}$$

$$N_{\perp} = 311346$$

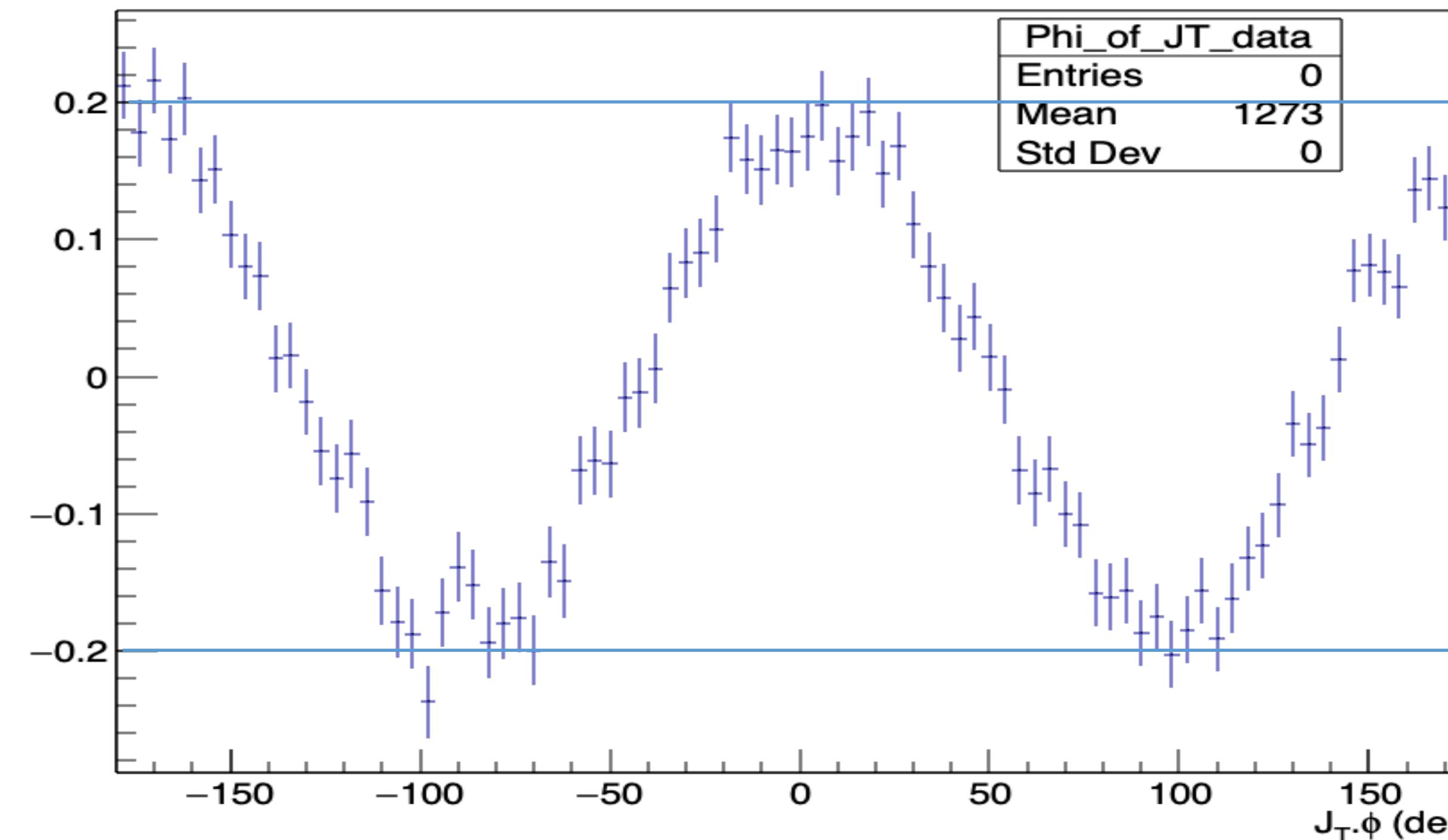
$$N_{\parallel} = 325538$$

$$\frac{N_{\perp}}{N_{\parallel}} = 0.9564$$

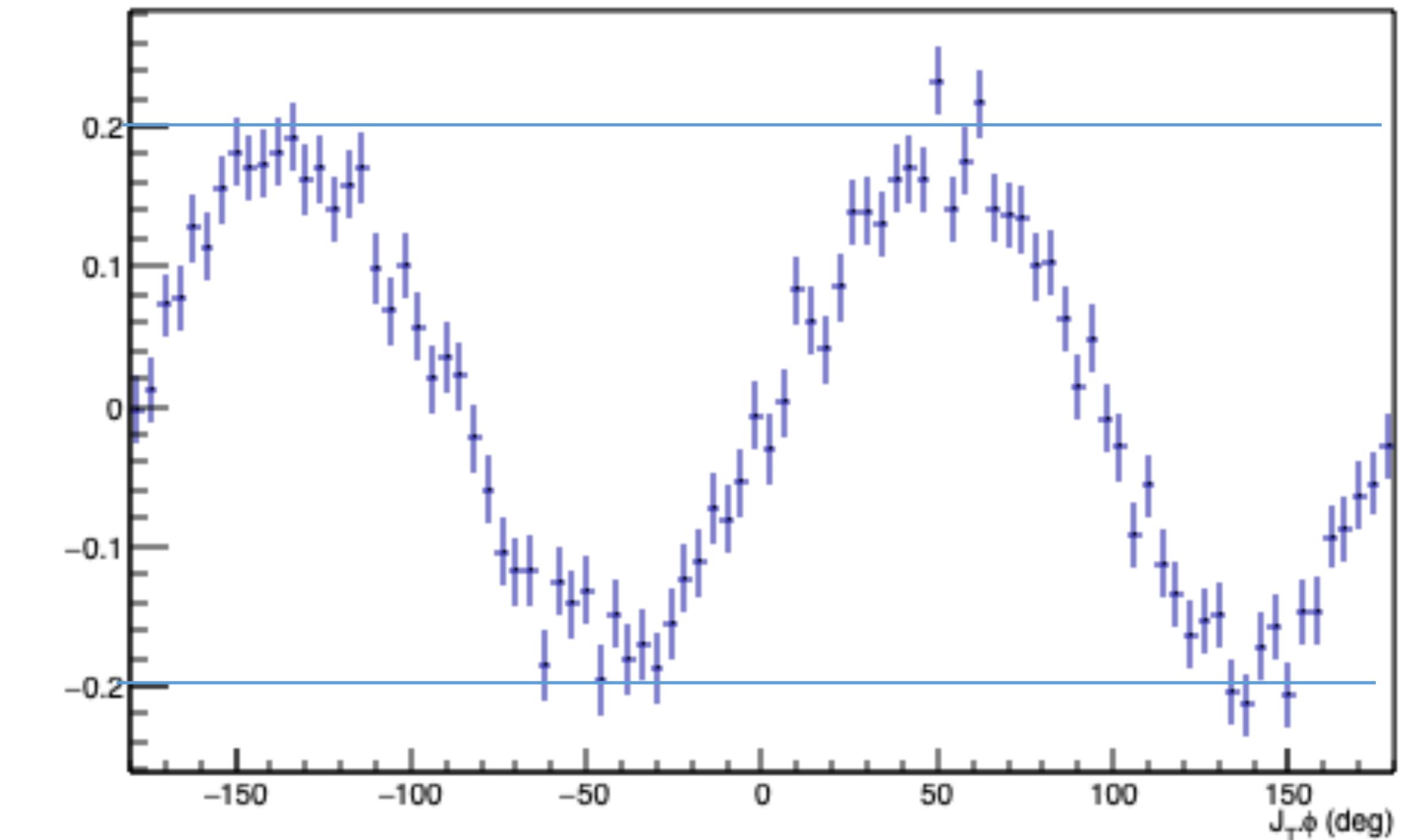
2018-01 GlueX data, $\gamma p \rightarrow e^+e^- (p)$

Yield Asymmetry

0/90 runs



45/135 runs

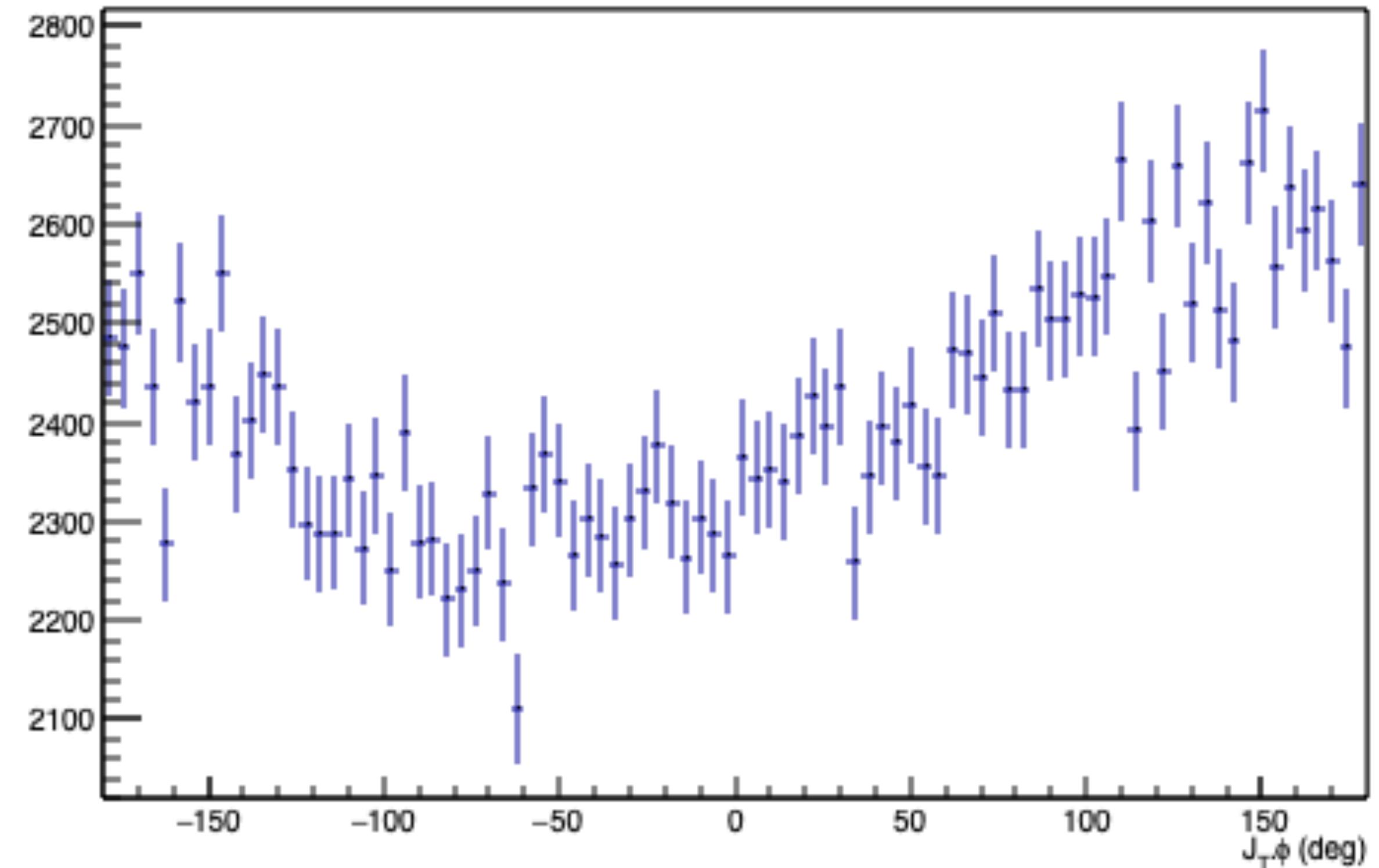
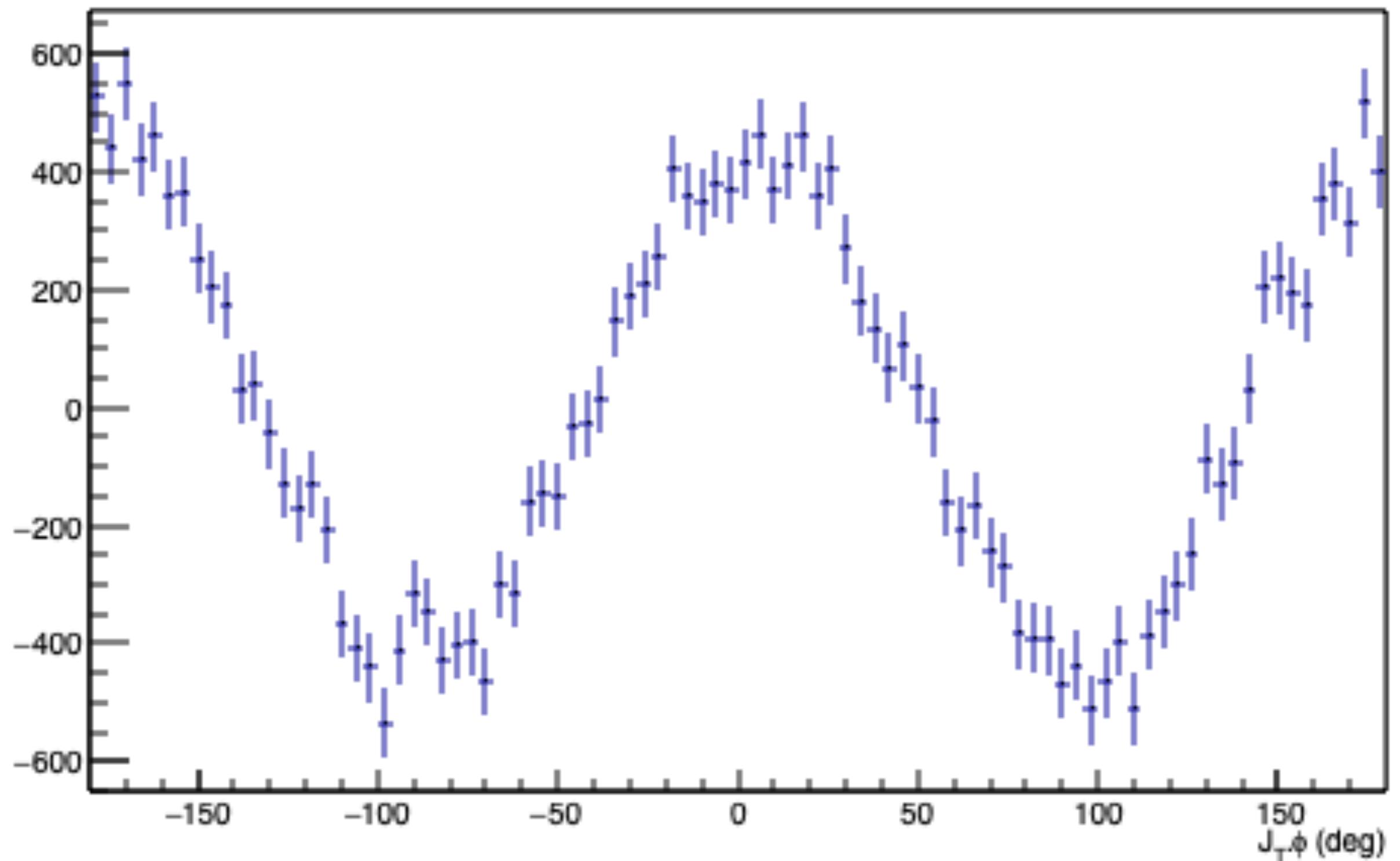


Just Numerator

$$Y_{\perp}(\phi) - \frac{N_{\perp}}{N_{\parallel}} Y_{\parallel}(\phi)$$

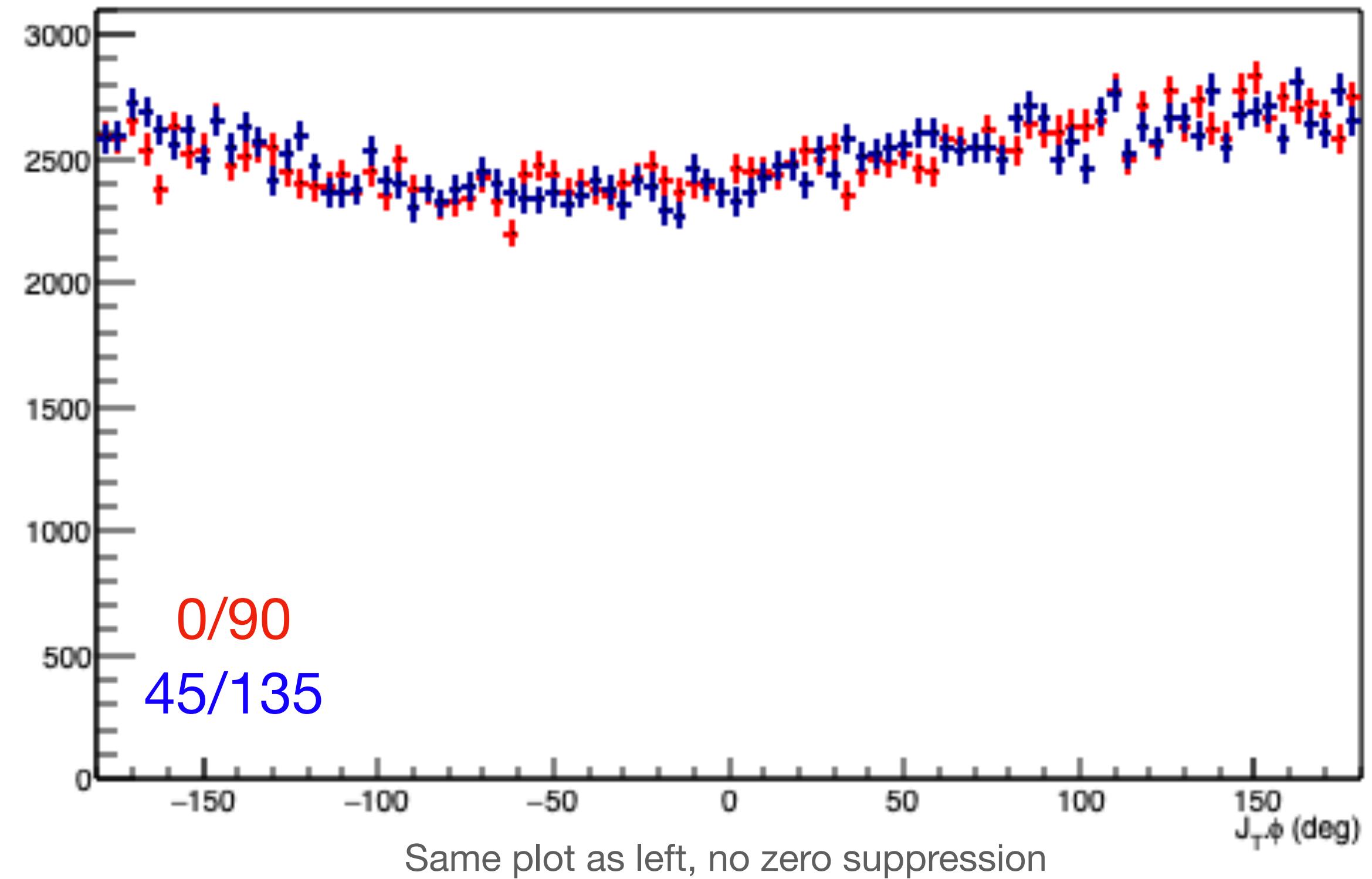
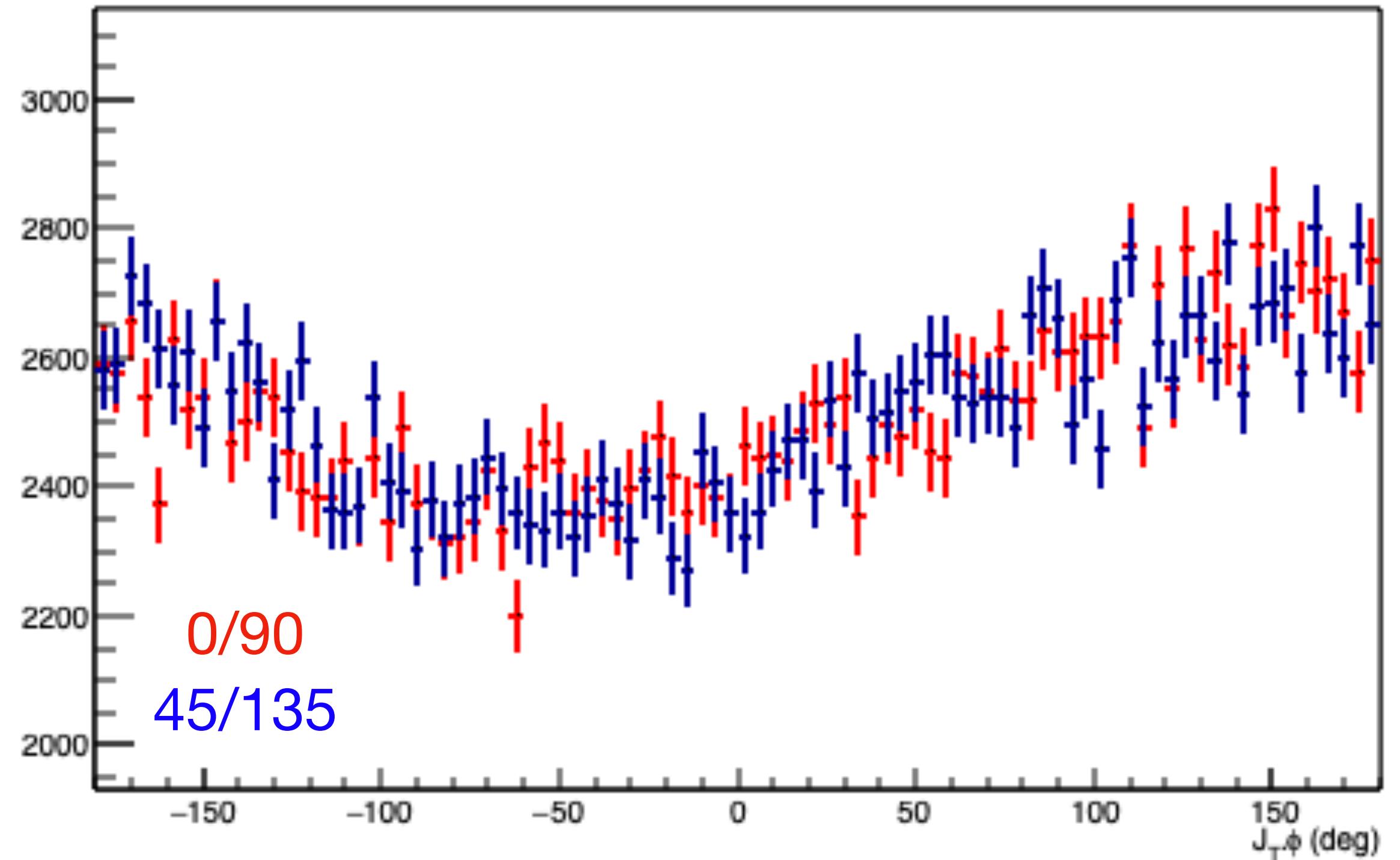
0/90 pol. Orientation**Just Denominator**

$$Y_{\perp}(\phi) + \frac{N_{\perp}}{N_{\parallel}} Y_{\parallel}(\phi)$$



Just Denominator

$$Y_{\perp}(\phi) + \frac{N_{\perp}}{N_{\parallel}} Y_{\parallel}(\phi)$$

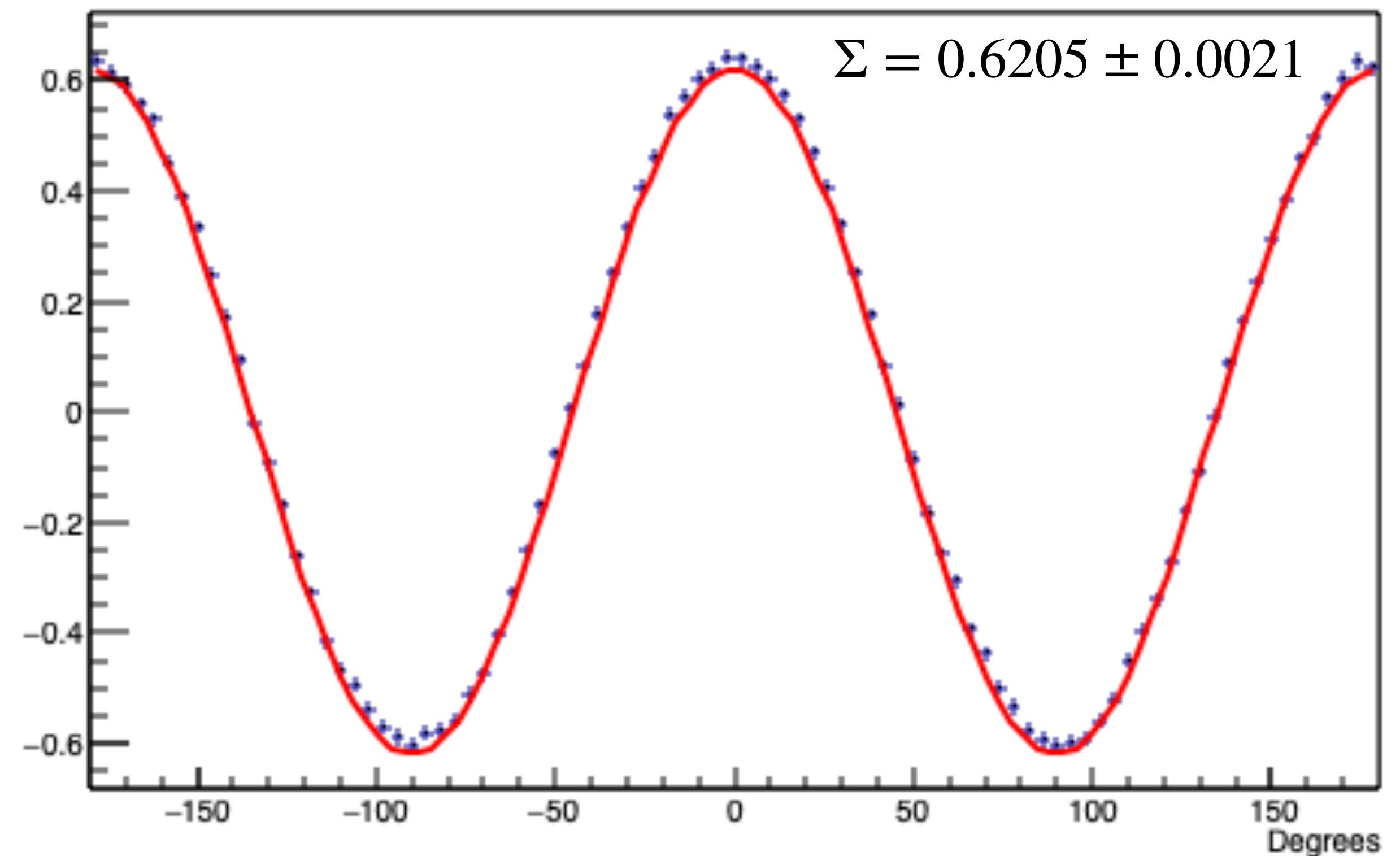


Same plot as left, no zero suppression

$$\frac{Y_{\perp}(\phi) - Y_{\parallel}(\phi)}{Y_{\perp} + Y_{\parallel}(\phi)} = \Sigma \cos 2\phi$$

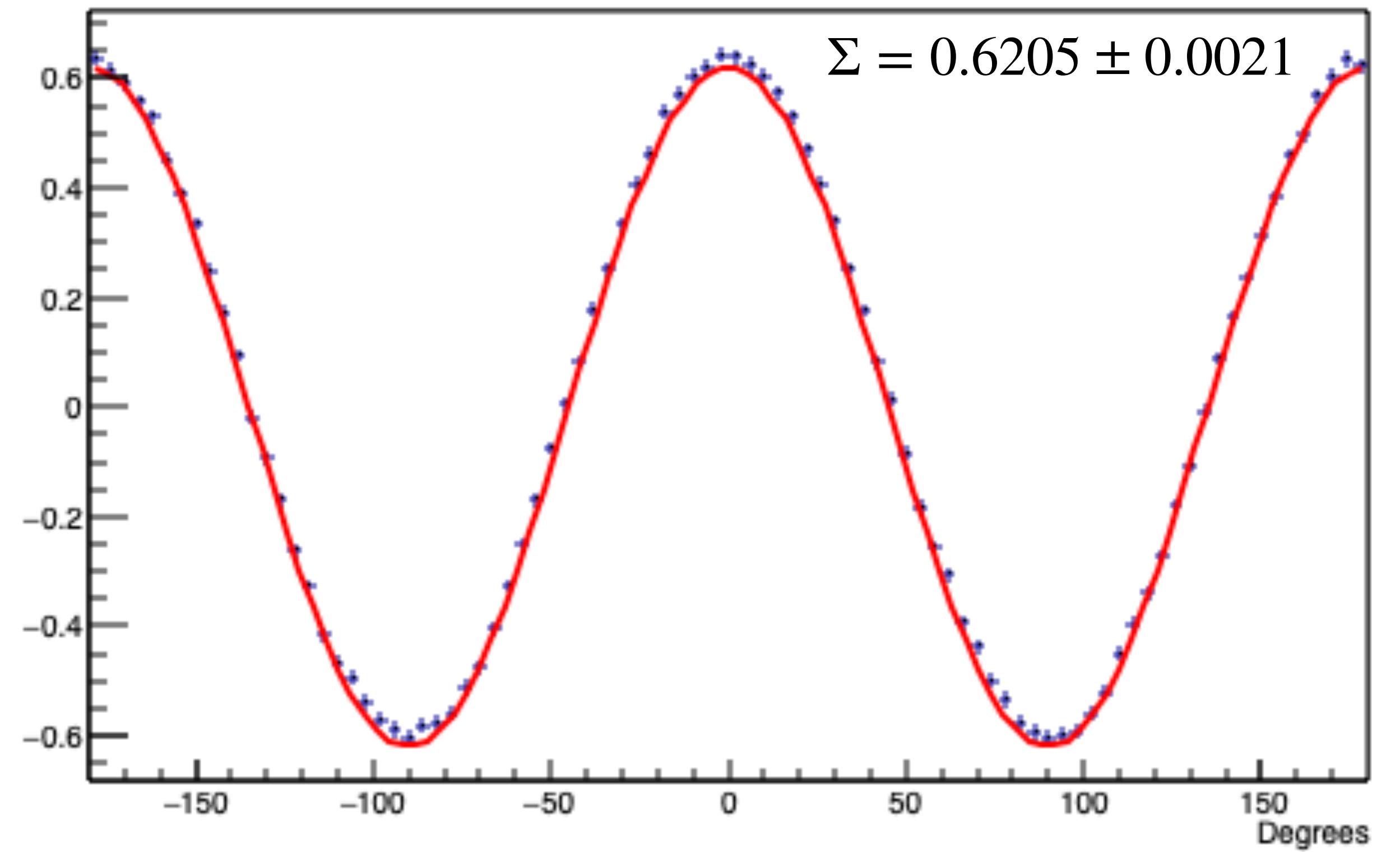
$$\frac{Y_{\perp}(\phi) - \frac{N_{\perp}}{N_{\parallel}} Y_{\parallel}(\phi)}{Y_{\perp} + \frac{N_{\perp}}{N_{\parallel}} Y_{\parallel}(\phi)} = \frac{\Sigma \cos 2\phi (P_{\perp} + P_{\parallel})}{2}$$

Simulated Yield Asymmetry



$$\frac{Y_{\perp}(\phi) - Y_{\parallel}(\phi)}{Y_{\perp} + Y_{\parallel}(\phi)} = \Sigma \cos 2\phi$$

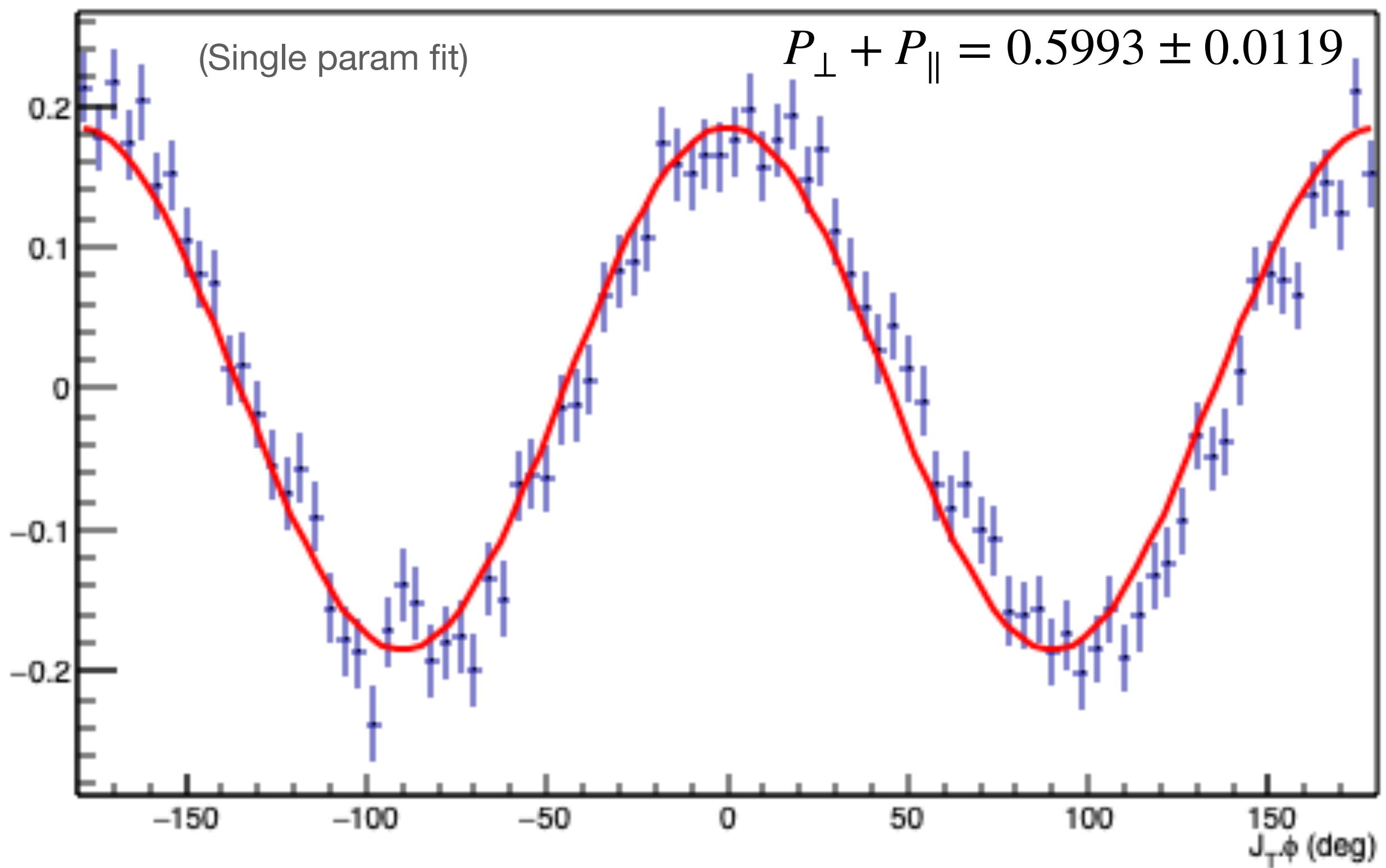
Simulated Yield Asymmetry



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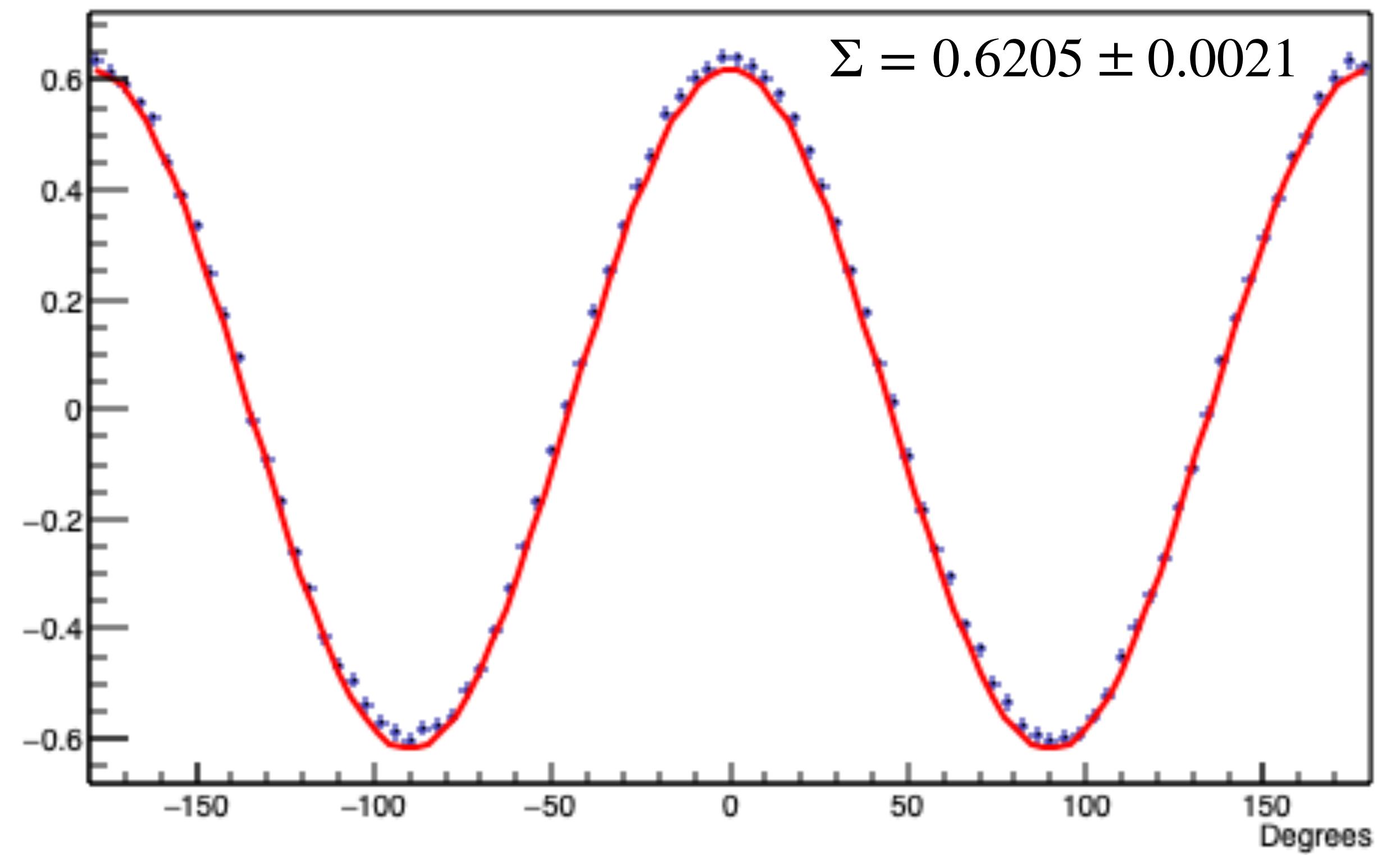
2018-01 Pol = 0 and 90 runs

Data Yield Asymmetry



$$\frac{Y_{\perp}(\phi) - Y_{\parallel}(\phi)}{Y_{\perp} + Y_{\parallel}(\phi)} = \Sigma \cos 2\phi$$

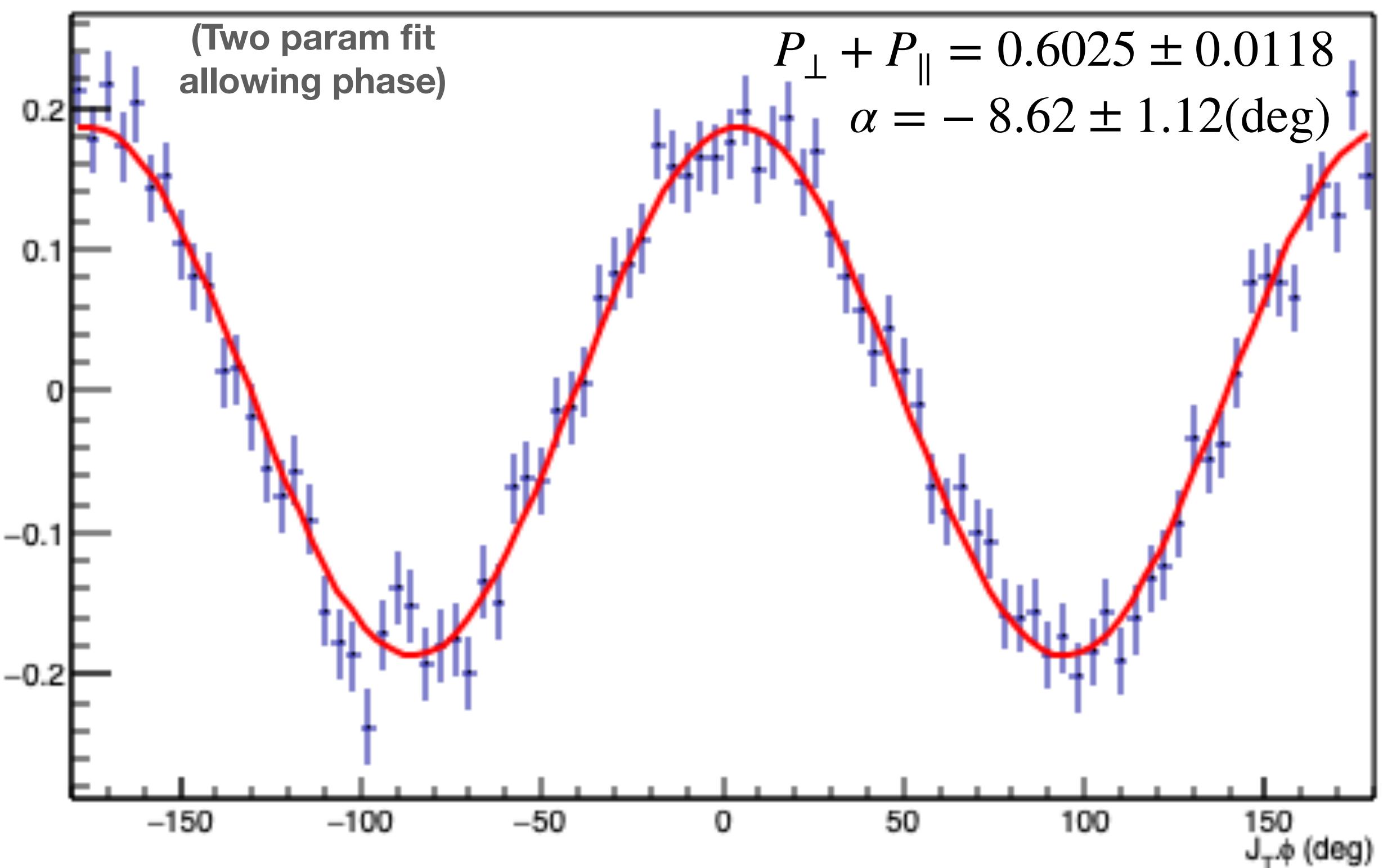
Simulated Yield Asymmetry



$$\frac{Y_{\perp}(\phi) - \frac{N_{\perp}}{N_{\parallel}} Y_{\parallel}(\phi)}{Y_{\perp} + \frac{N_{\perp}}{N_{\parallel}} Y_{\parallel}(\phi)} = \frac{\Sigma \cos(2\phi + \alpha)(P_{\perp} + P_{\parallel})}{2}$$

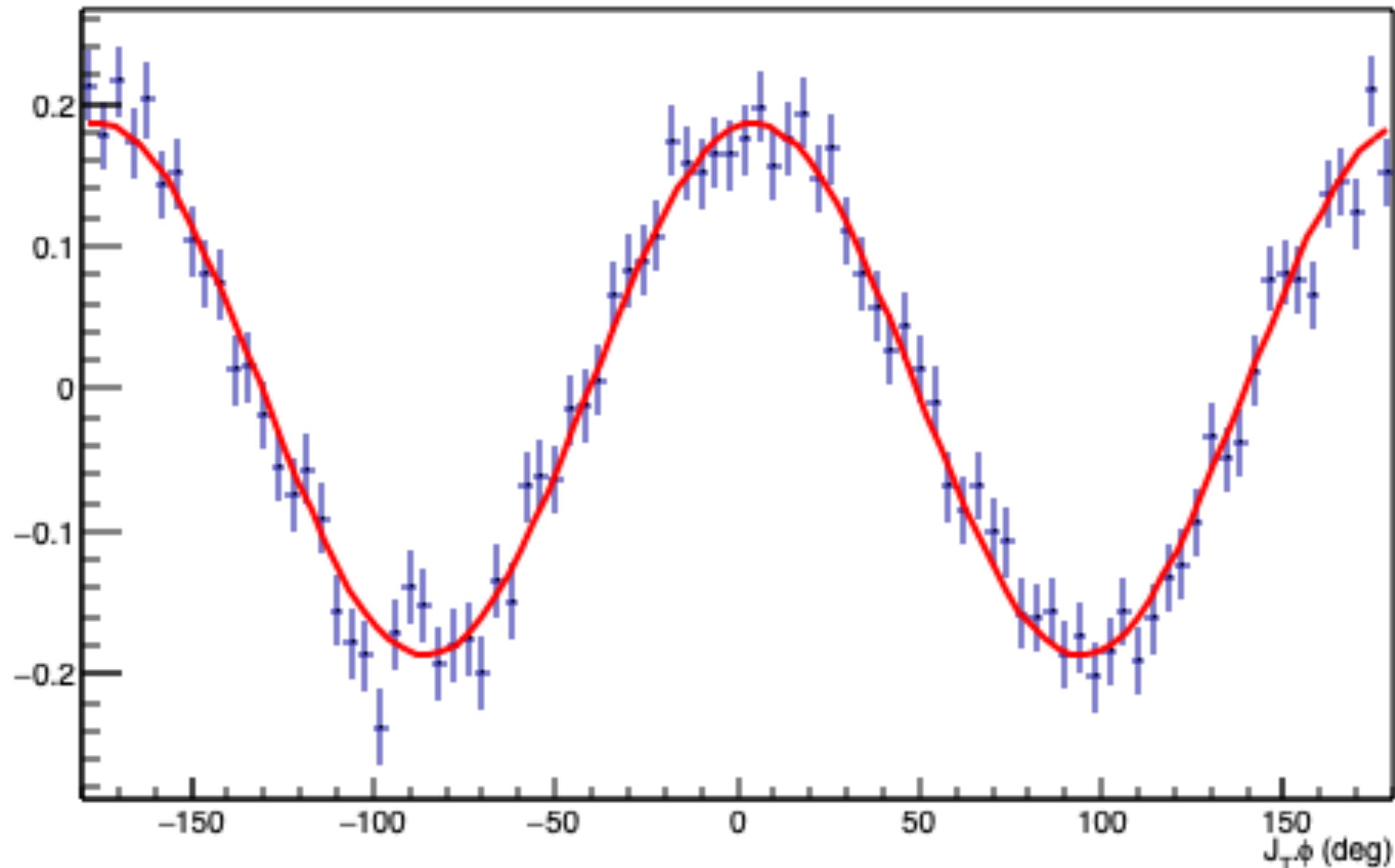
2018-01 Pol = 0 and 90 runs

Data Yield Asymmetry



$$\frac{Y_{\perp}(\phi) - \frac{N_{\perp}}{N_{\parallel}} Y_{\parallel}(\phi)}{Y_{\perp} + \frac{N_{\perp}}{N_{\parallel}} Y_{\parallel}(\phi)} = \frac{\Sigma \cos(2\phi + \alpha)(P_{\perp} + P_{\parallel})}{2 + \Sigma \cos(2\phi + \alpha)(P_{\perp} - P_{\parallel})}$$

0 and 90 Yield Asymmetry



$$P_{\perp} + P_{\parallel} = 0.6025 \pm 0.011 \quad \alpha = -8.62 \pm 1.12(\text{deg})$$

$$P_{\perp} - P_{\parallel} = 0.0091 \pm 0.0737$$

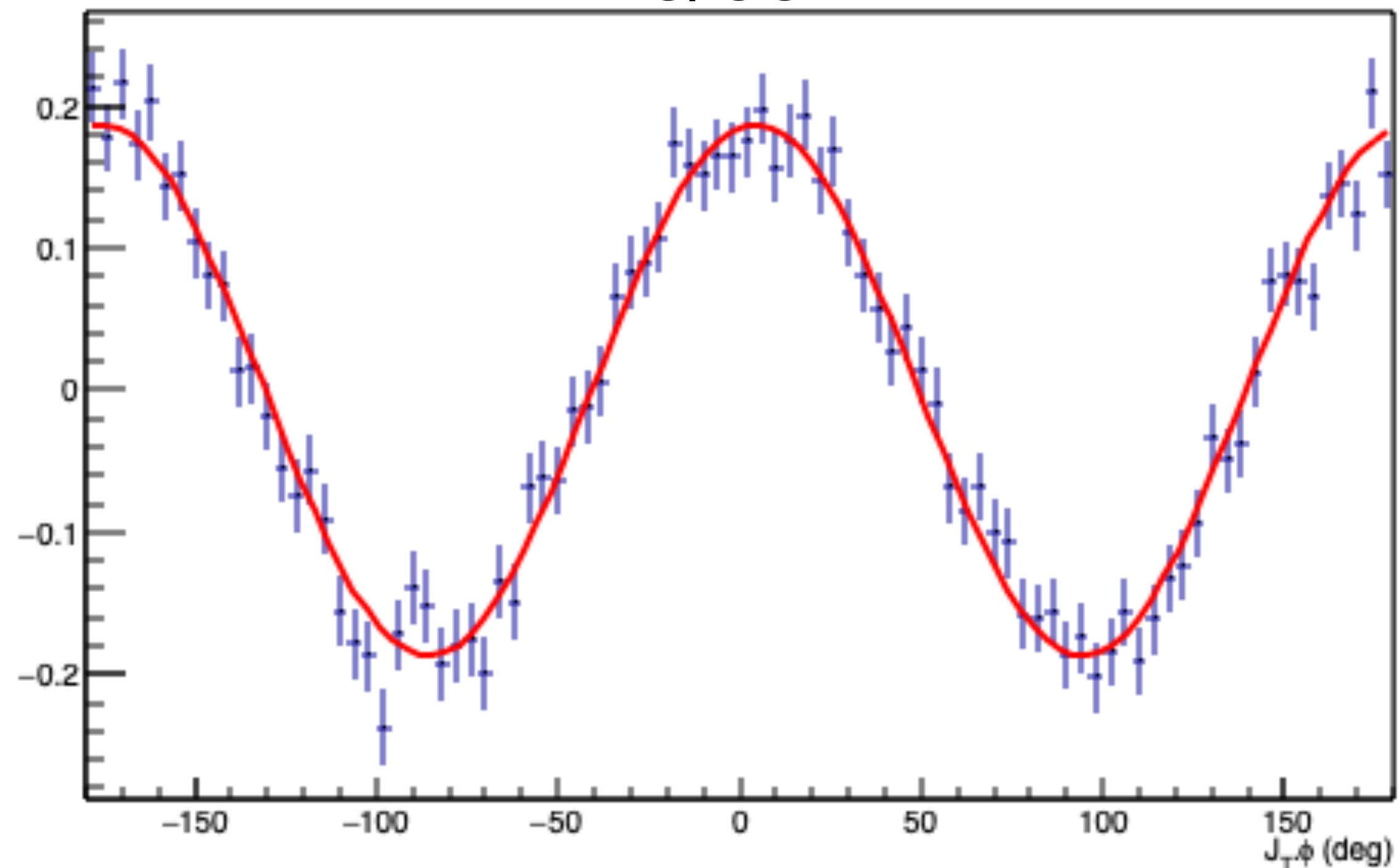


Nothing to be gained from trying to fit $(P_{\perp} - P_{\parallel})$. It is effectively 0.

2018-01 GlueX data, $\gamma p \rightarrow e^+e^- (p)$, ϕ_{J_T} Yield Asymmetry

$$\frac{Y_\perp(\phi) - \frac{N_\perp}{N_\parallel} Y_\parallel(\phi)}{Y_\perp + \frac{N_\perp}{N_\parallel} Y_\parallel(\phi)} = \frac{\Sigma \cos(2\phi + \alpha)(P_\perp + P_\parallel)}{2}$$

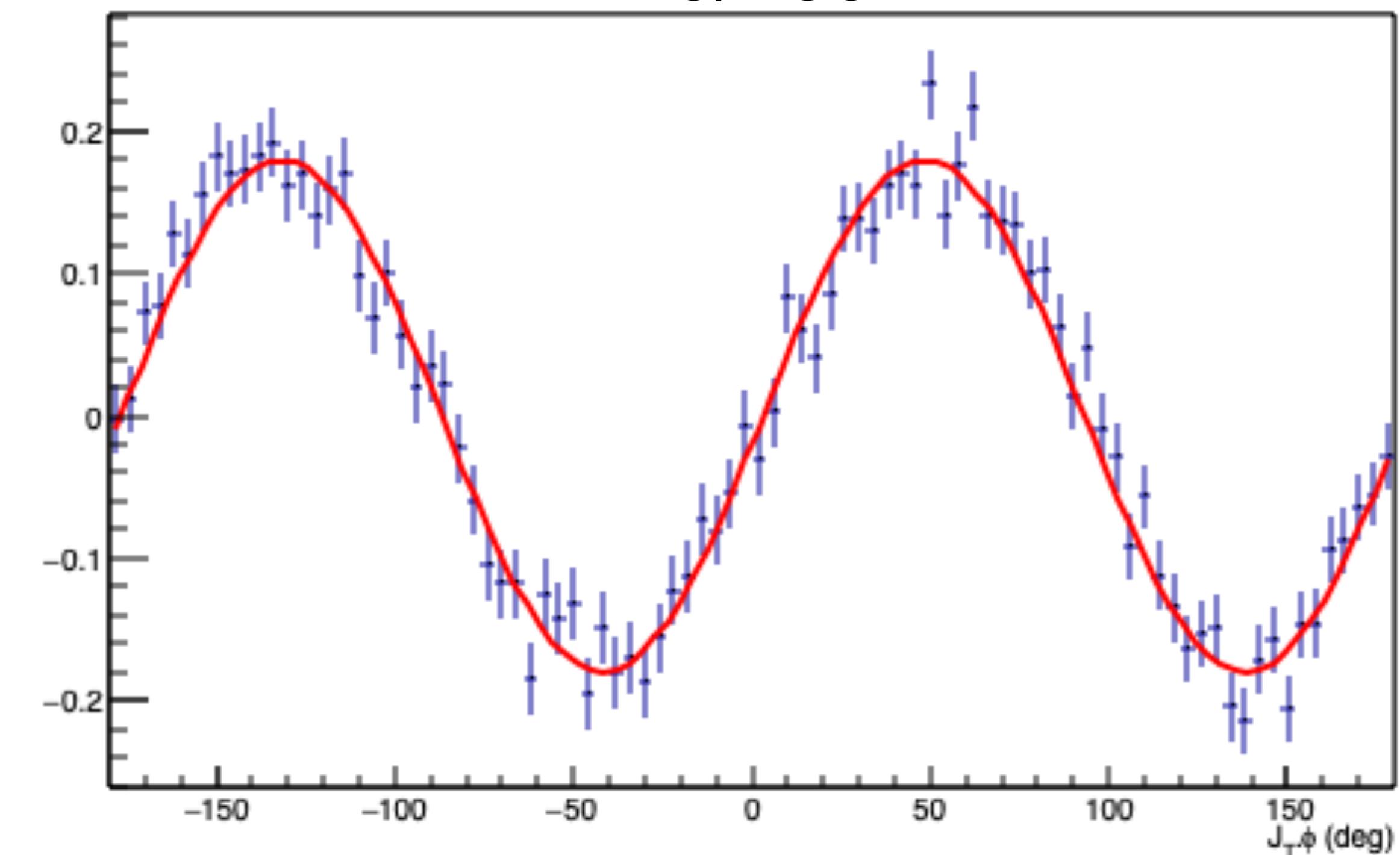
0/90



$$P_\perp + P_\parallel = 0.6025 \pm 0.0118$$

$$\alpha = -8.62 \pm 1.12(\text{deg})$$

45/135



$$P_\perp + P_\parallel = 0.5789 \pm 0.0116$$

$$\alpha = 83.53 \pm 1.14(\text{deg})$$

SUMMARY SO FAR

TPOL expected polarization for energy range $8.2 < E_\gamma < 8.8$ $\bar{\mathcal{P}}_\gamma = 0.3399 \pm 0.0125$

Chisq method: Measured with ϕ of J_T , pol 0 config runs $\mathcal{P}_\gamma = 0.2860 \pm 0.0016$

Yield asymmetry method: Average polarization
between 0 and 90 runs: $\frac{\mathcal{P}_\perp + \mathcal{P}_\parallel}{2} = 0.3013 \pm 0.0060$

Yield asymmetry method: Average polarization
between 45 and 135 runs: $\frac{\mathcal{P}_\perp + \mathcal{P}_\parallel}{2} = 0.2895 \pm 0.0058$

Backup Slides

TPOL Value for the BH events

Polarization values for E_gamma between 8.2 and 8.8 GeV	
Beam orientation	Polarization
0 degrees:	0.3420 +/- 0.0063
45 degrees:	0.3474 +/- 0.0065
90 degrees:	0.3478 +/- 0.0063
135 degrees:	0.3517 +/- 0.0065

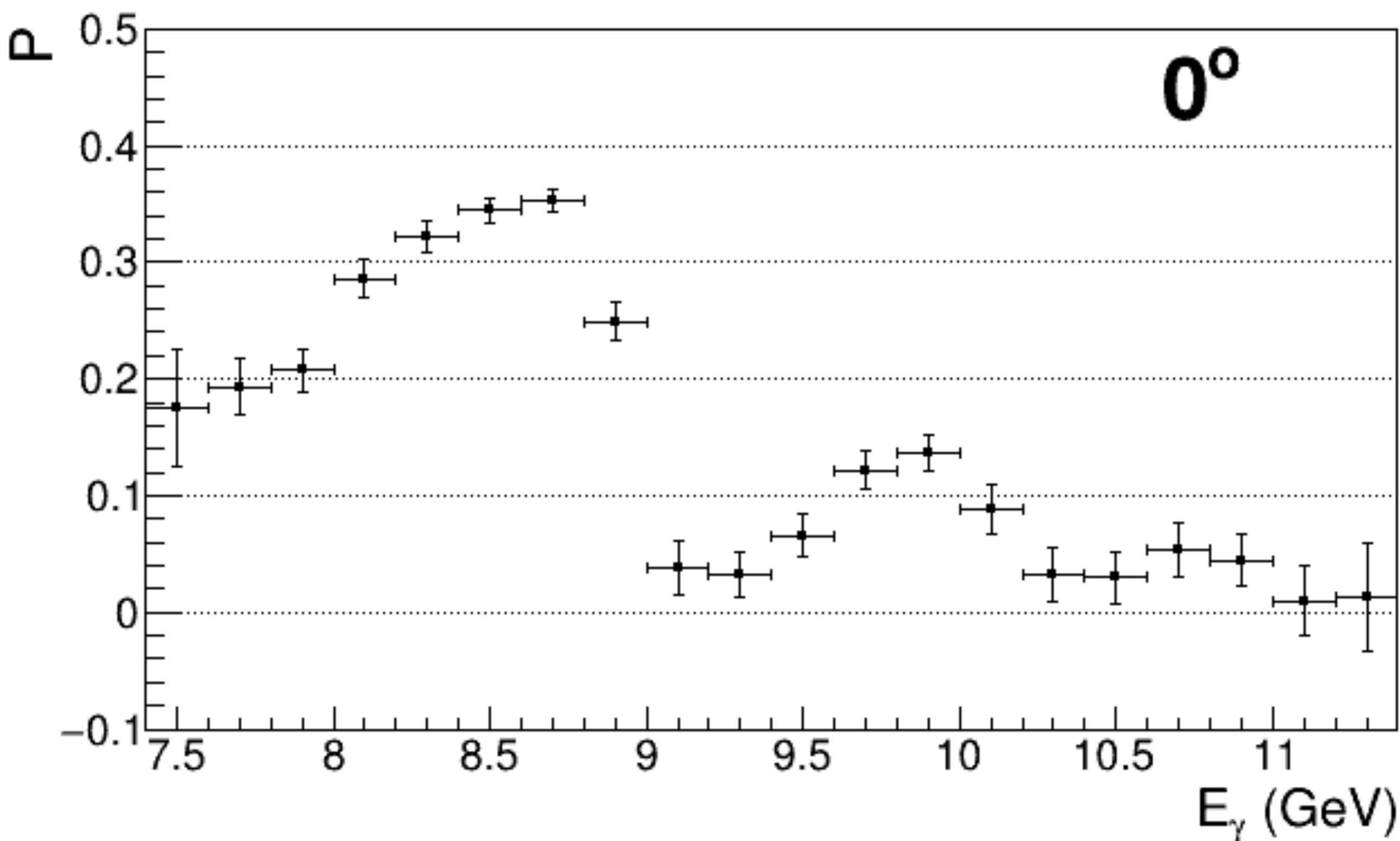
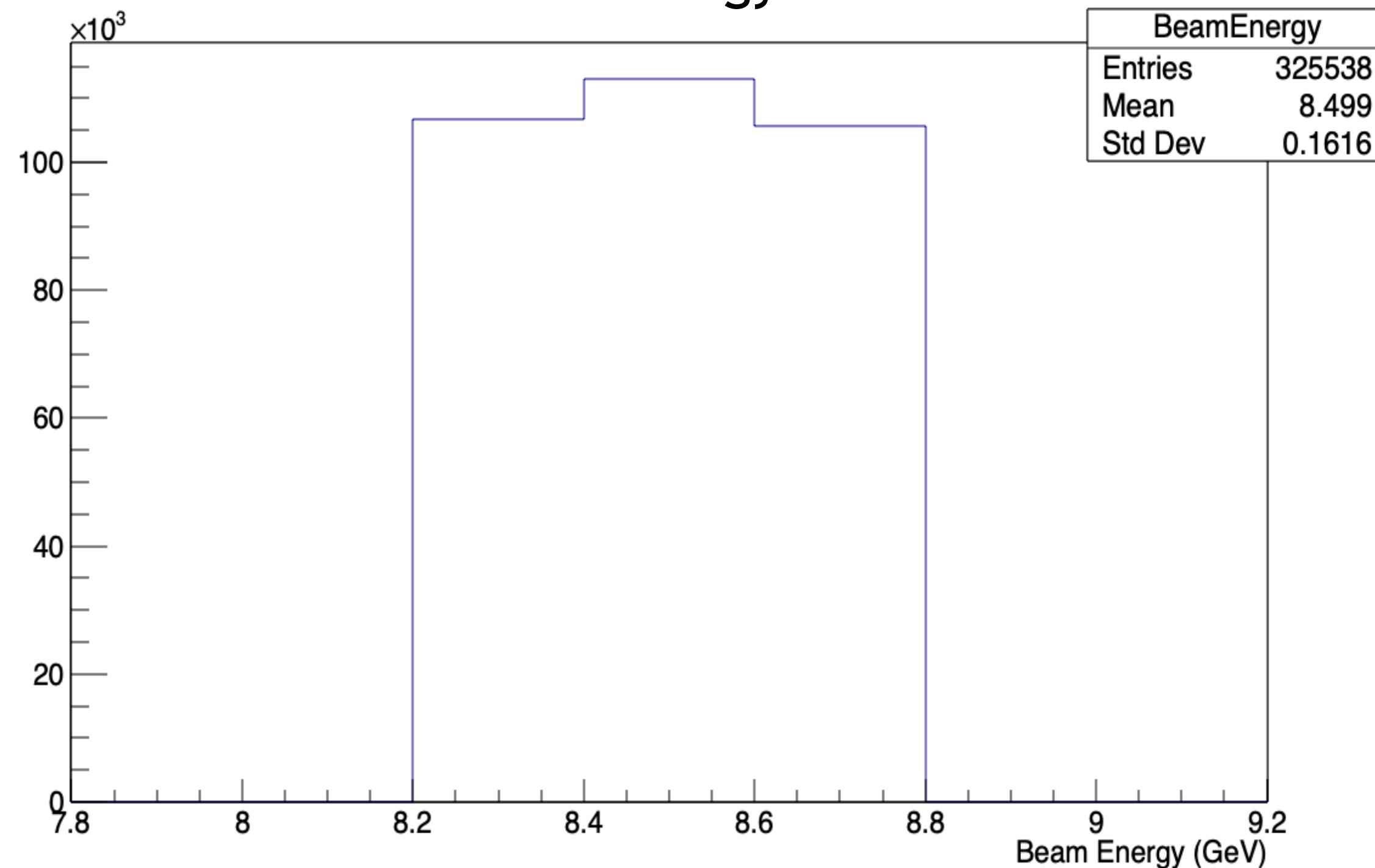


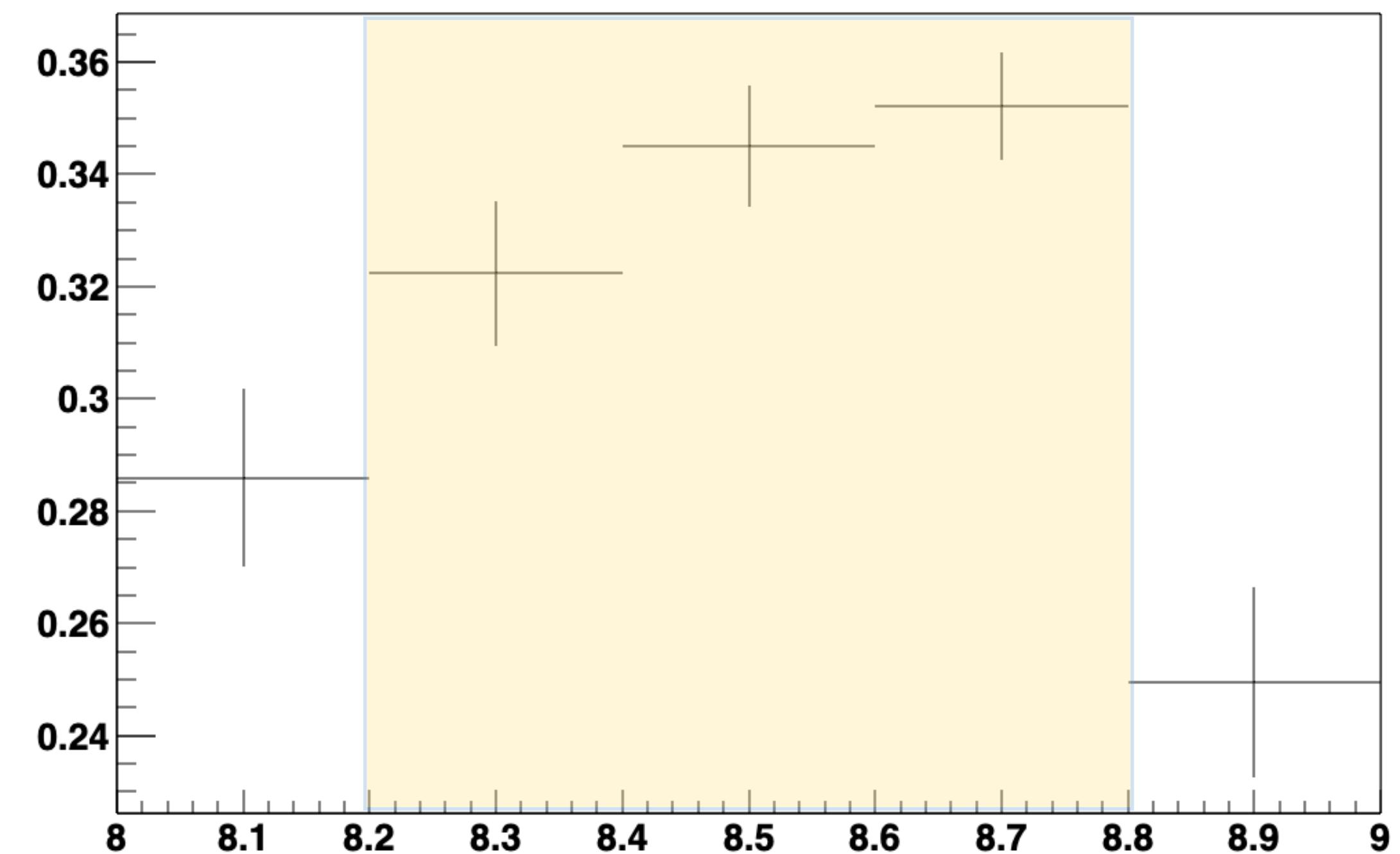
Table 1

8.3	106740
8.5	113046
8.7	105752

Bethe-Heitler Data Beam Energy



8.2 to 8.8 Energy range



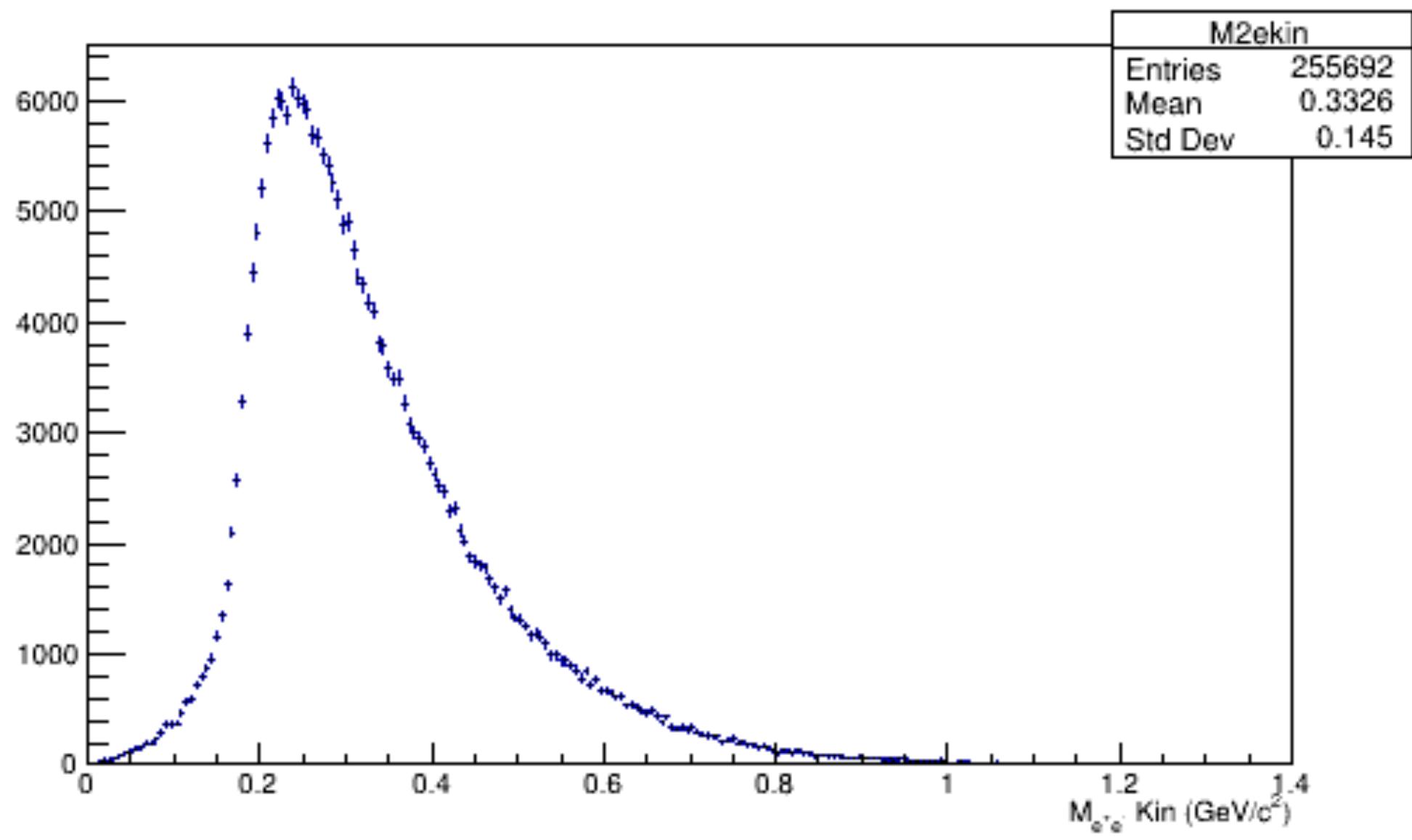
$$8.2 < E_\gamma < 8.8$$

$$\bar{\mathcal{P}}_\gamma = 0.3399 \pm 0.0125$$

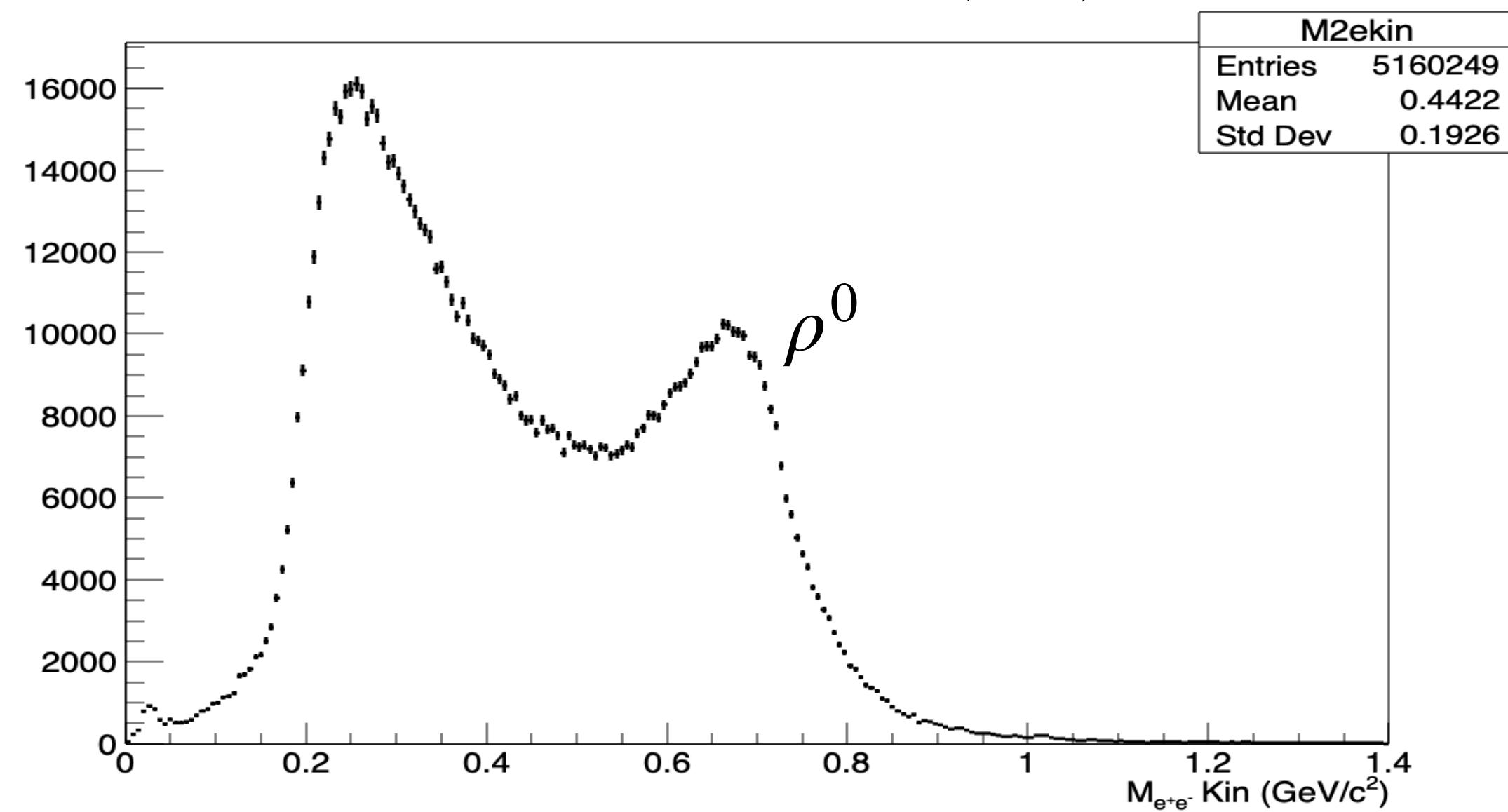
BH Event Selection w/ Neural Nets

Analyzing data

e^+e^- Invariant Mass (simulation)



e^+e^- Invariant Mass (data)



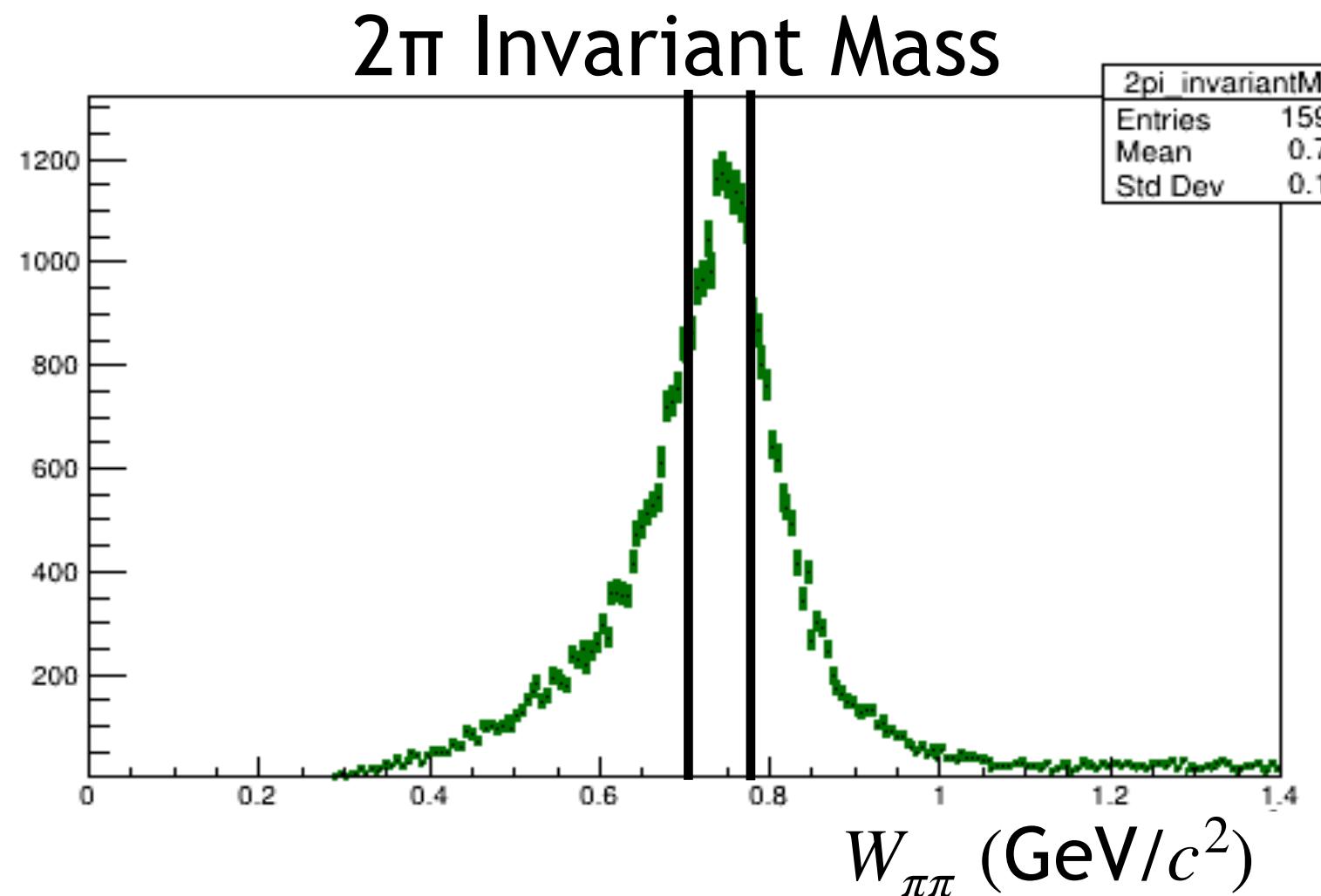
e/π separation using Machine Learning

- ROOT's TMVA package
- Two multi-layer perceptron neural nets—one for e+/π+ separation, and one for e-/π-
 - Classify single tracks as e^\pm or π^\pm , but only keep for analysis events where *both* tracks pass as e+/e-, or π+/π-
- π+/π- signal training using GlueX 2018-01 ρ^0 data with $\gamma p \rightarrow \pi^+\pi^-p$ reaction filter, $700 \text{ MeV} < W_{\pi\pi} < 770 \text{ MeV}$
- e+/e- background training using Bethe-Heitler Monte Carlo, $\gamma p \rightarrow e^+e^-(p)$ reaction filter

Cuts for Training Samples

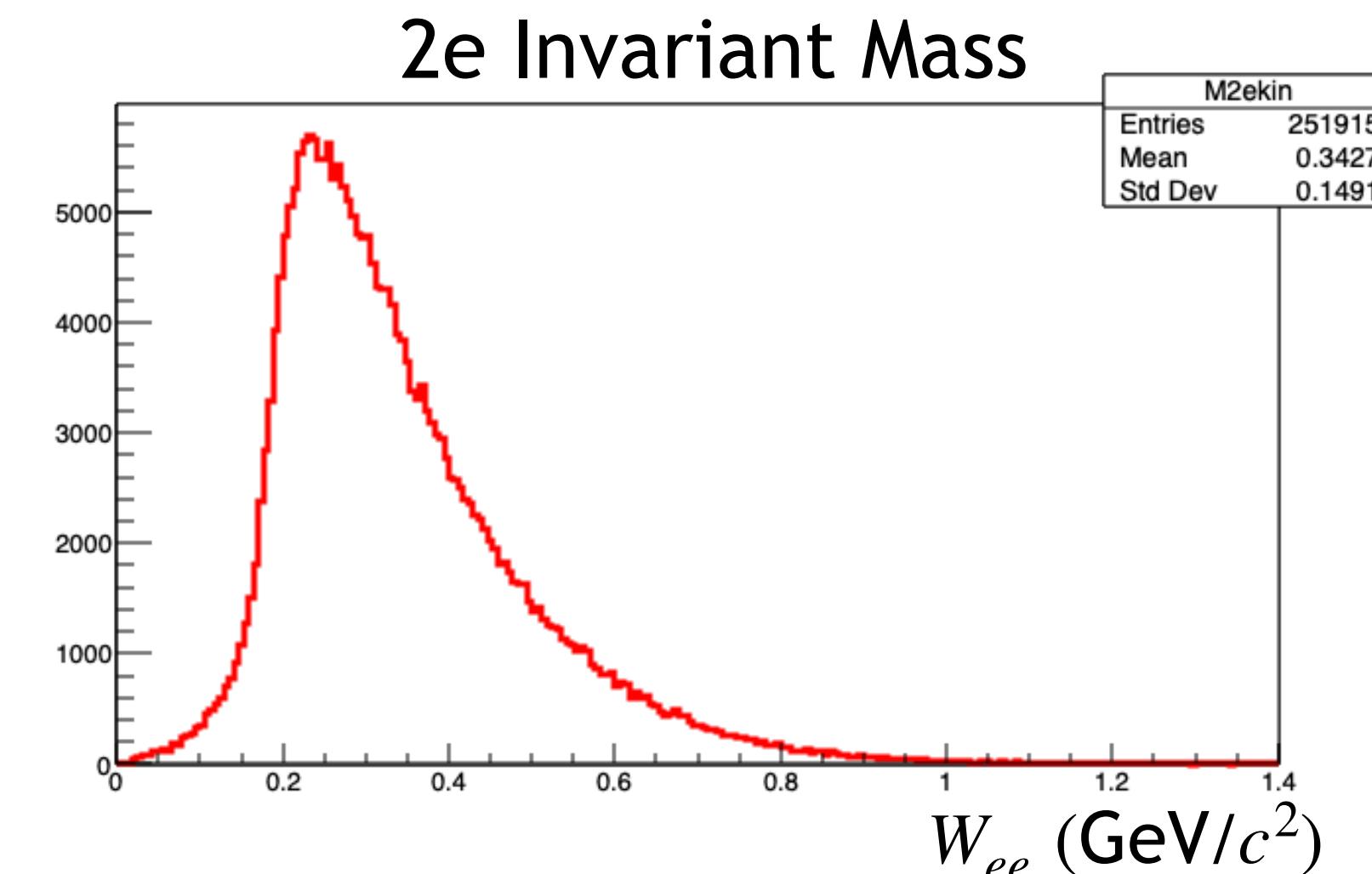
ρ^0 DATA, $\gamma p \rightarrow \pi^+ \pi^- p$ (signal)

- Default GlueX analysis launch cuts
- $8.11 \text{ GeV} < E_\gamma < 8.88 \text{ GeV}$
- TOF $dE/dx > 0$ for both tracks
- $700 \text{ MeV} < W_{\pi\pi} < 770 \text{ MeV}$



BH MC, $\gamma p \rightarrow e^+ e^- (p)$ (bkgnd)

- Default GlueX analysis launch cuts
- $8.11 \text{ GeV} < E_\gamma < 8.88 \text{ GeV}$
- TOF $dE/dx > 0$ for both tracks

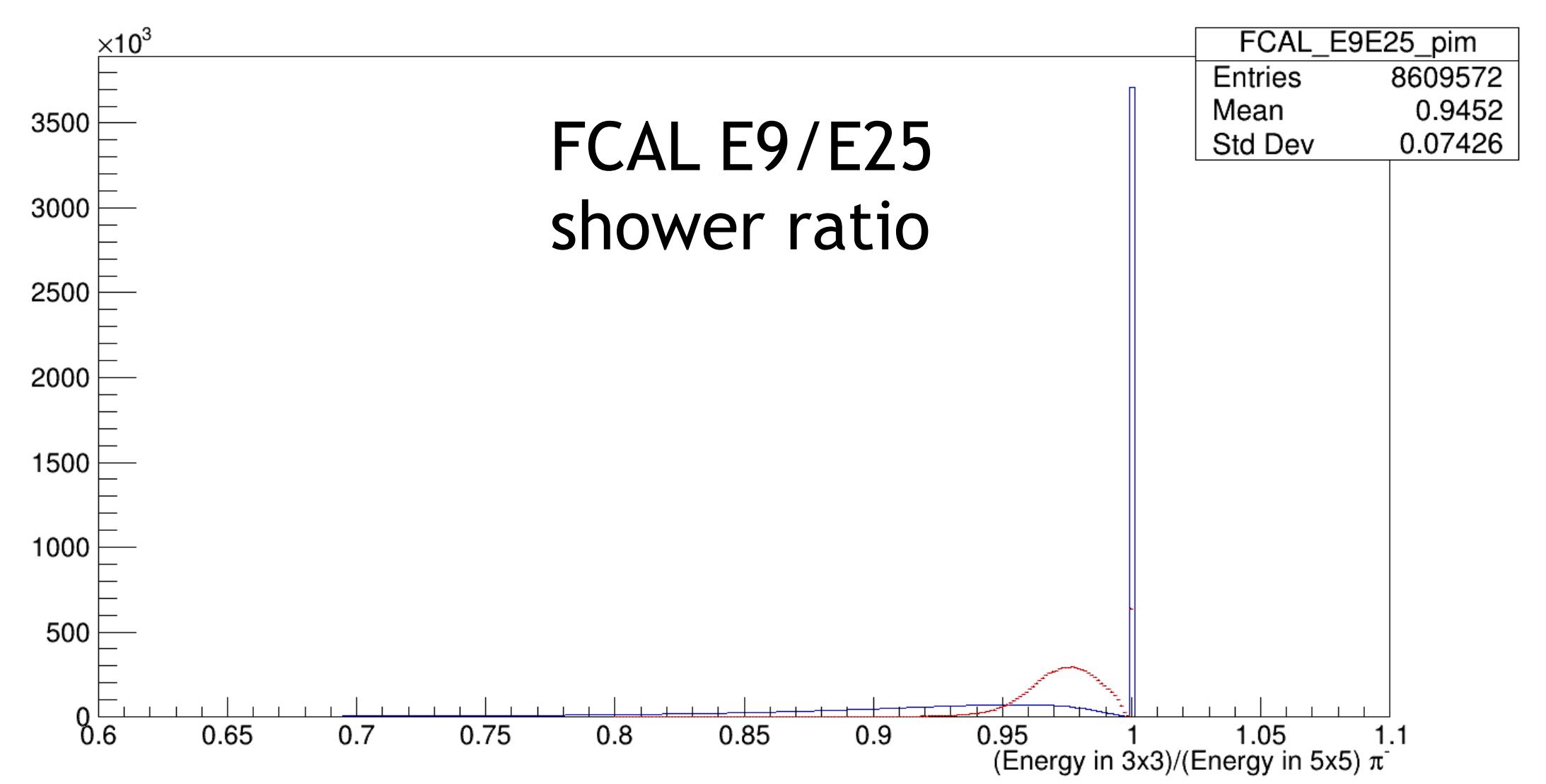
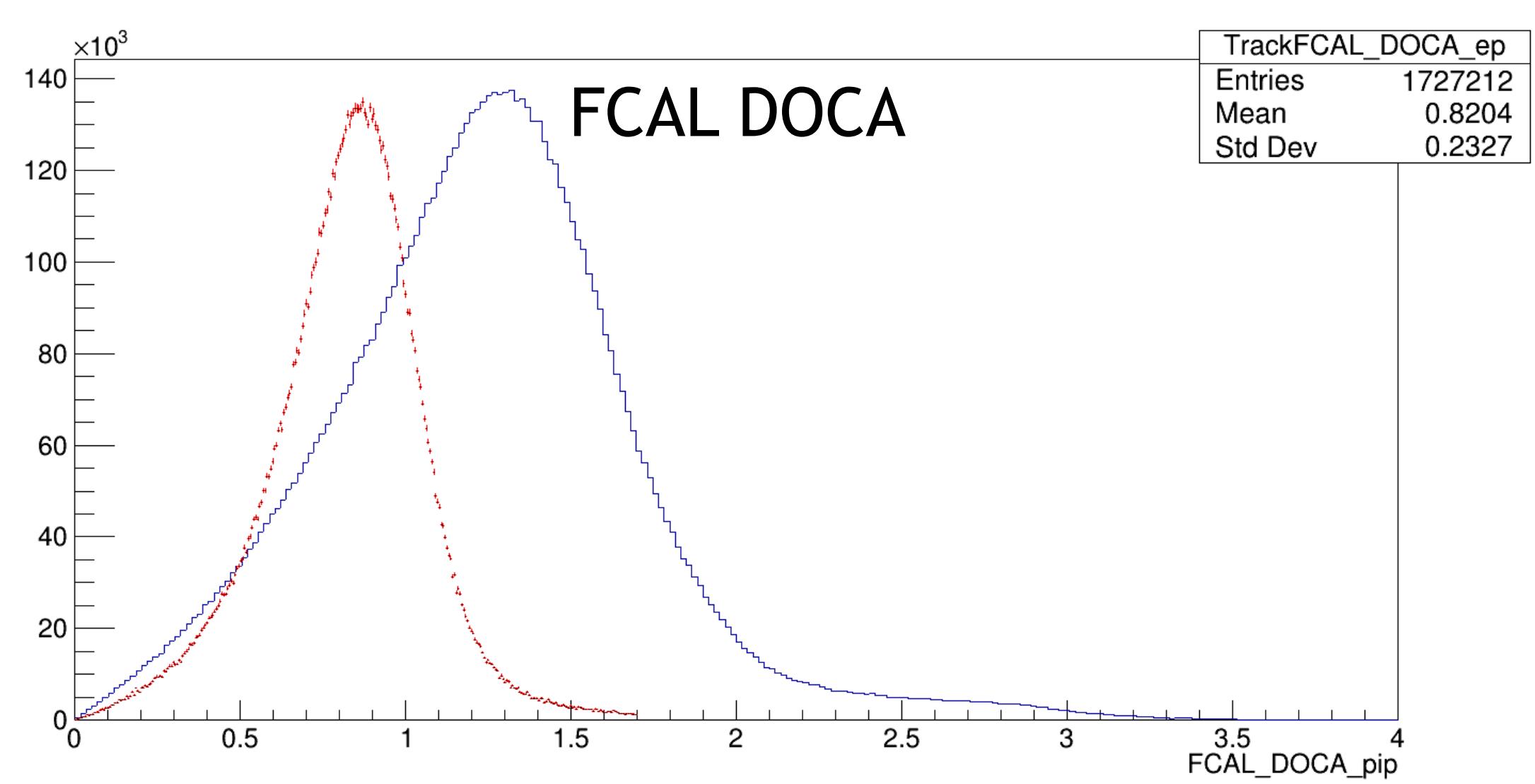
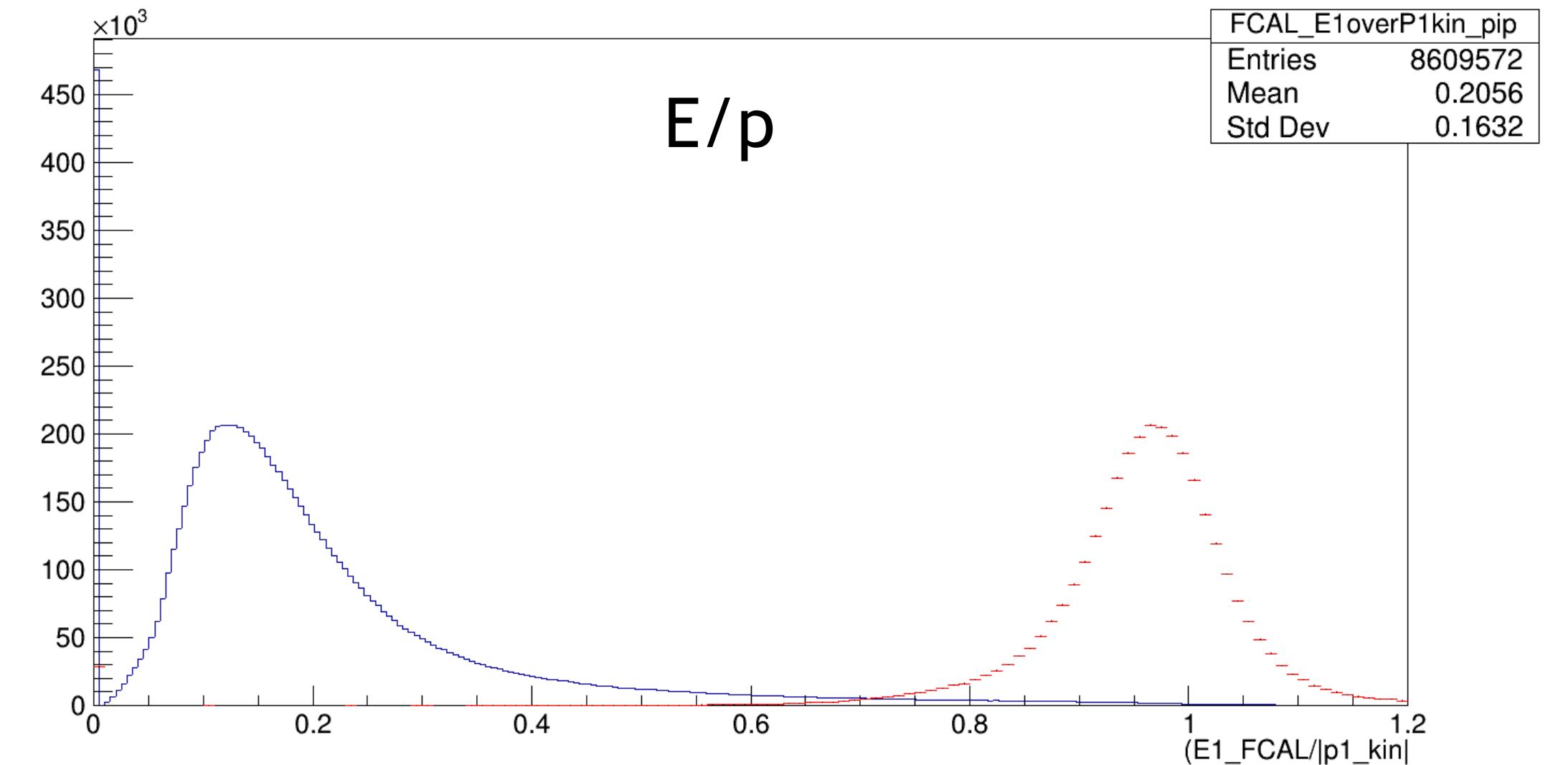


3 Training Variables

Energy deposited by track in FCAL/tracks momentum

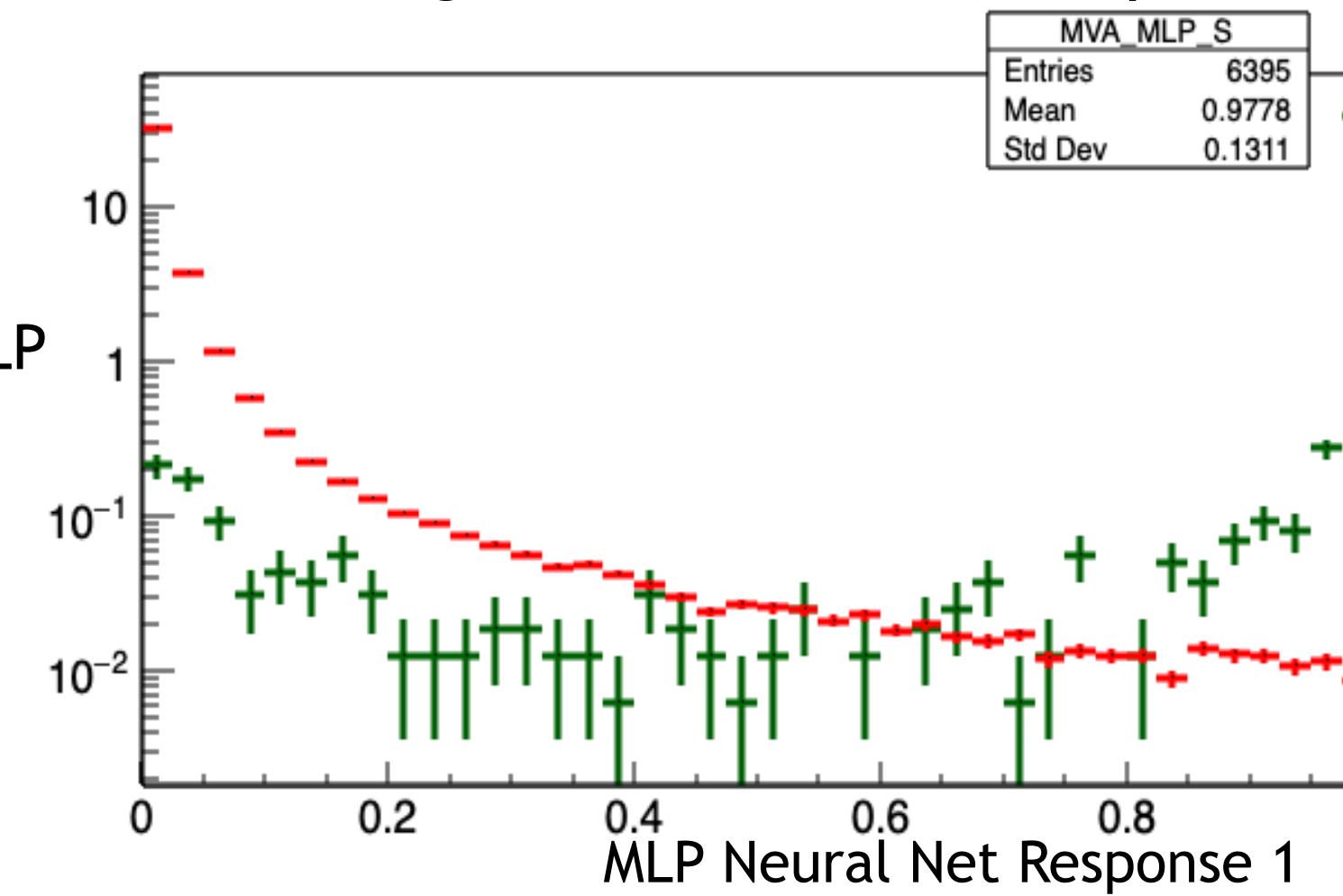
DOCA: Distance between shower centroid and track projection.

E9/E25: Sum of energy deposited in 3x3 grid of FCAL blocks, divided by the sum of energy in a 5x5 grid

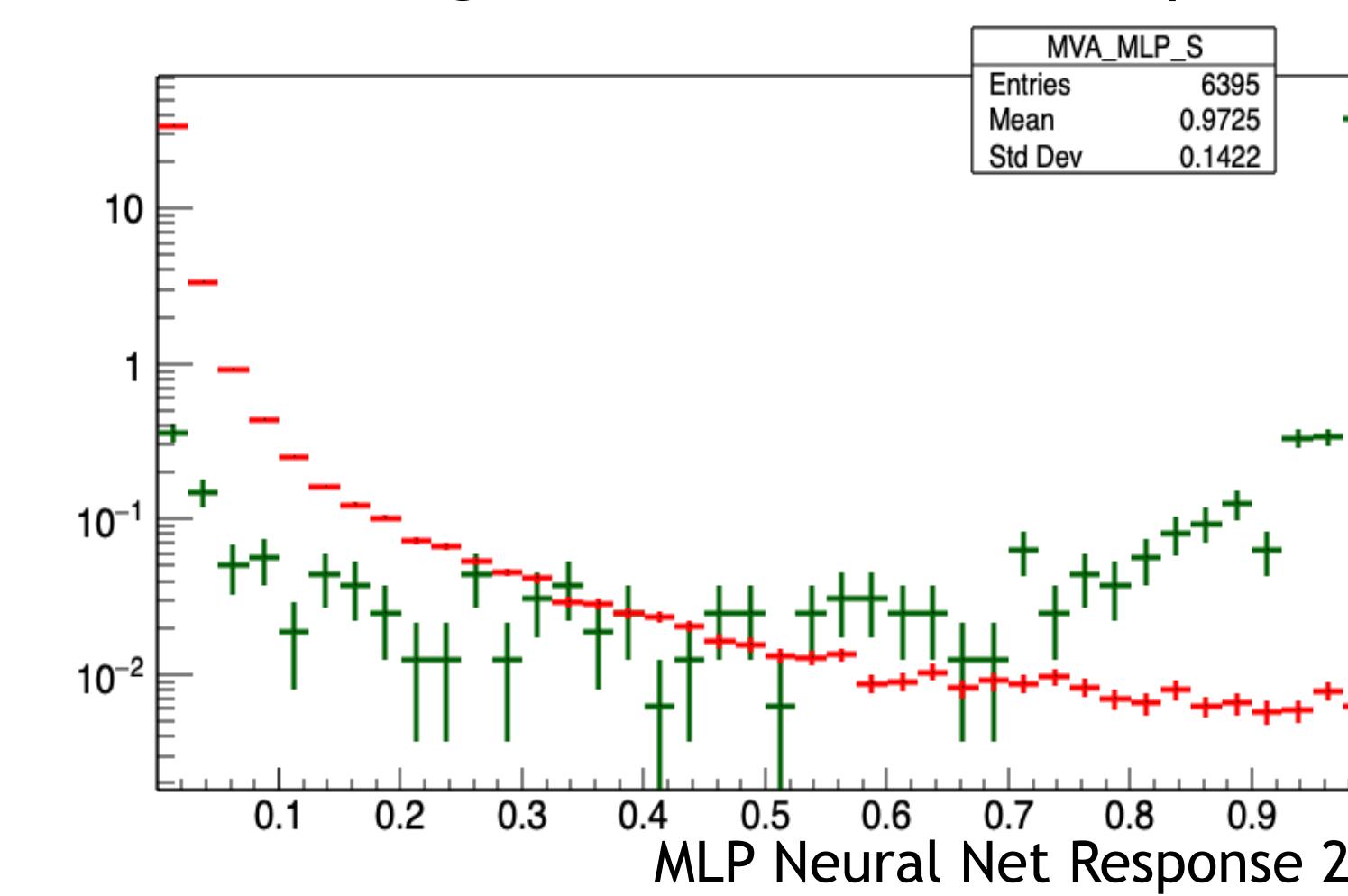


Neural Net Responses from ρ^0 data/BH MC training

Training: π^-/e^- classifier output

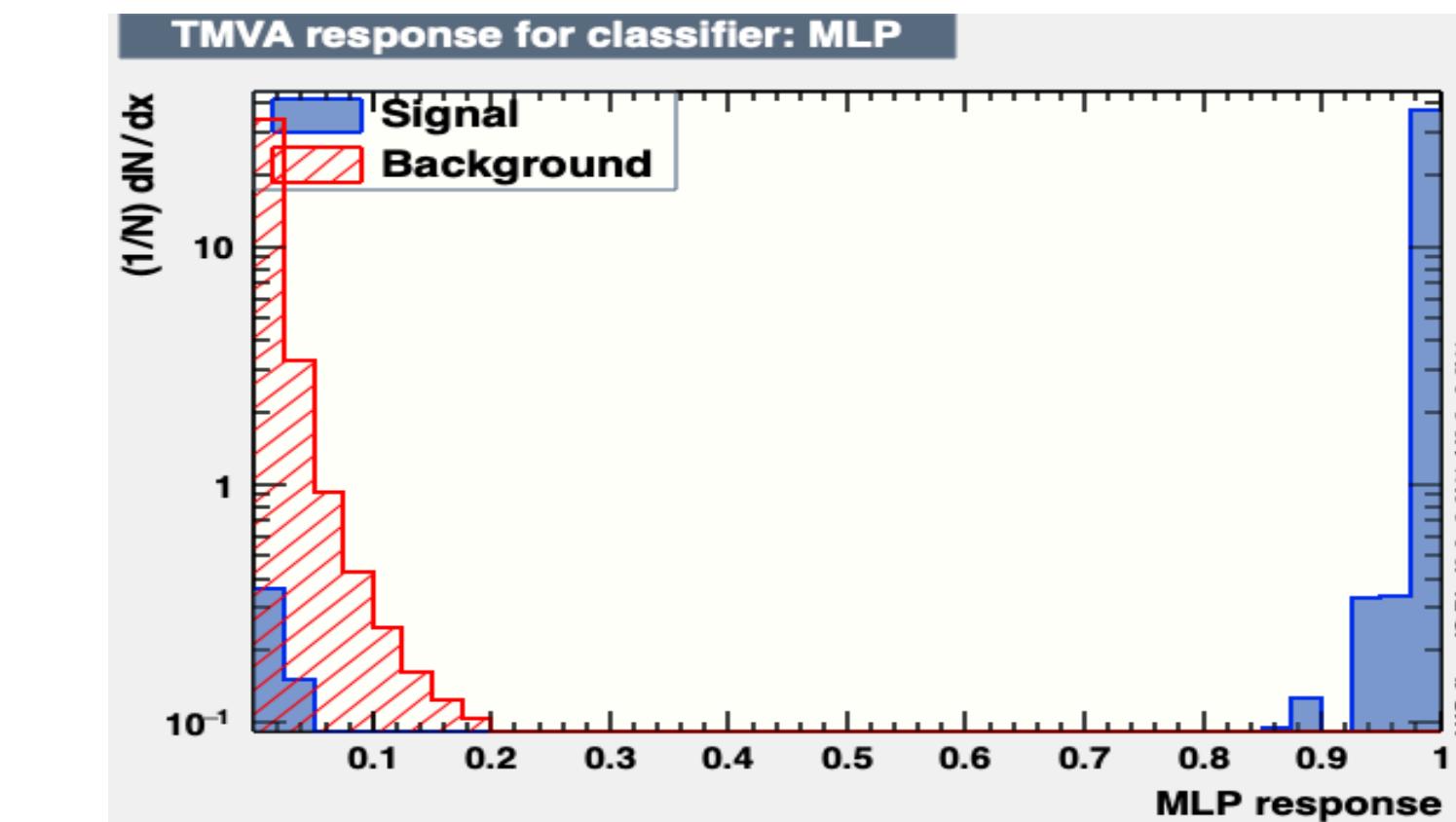
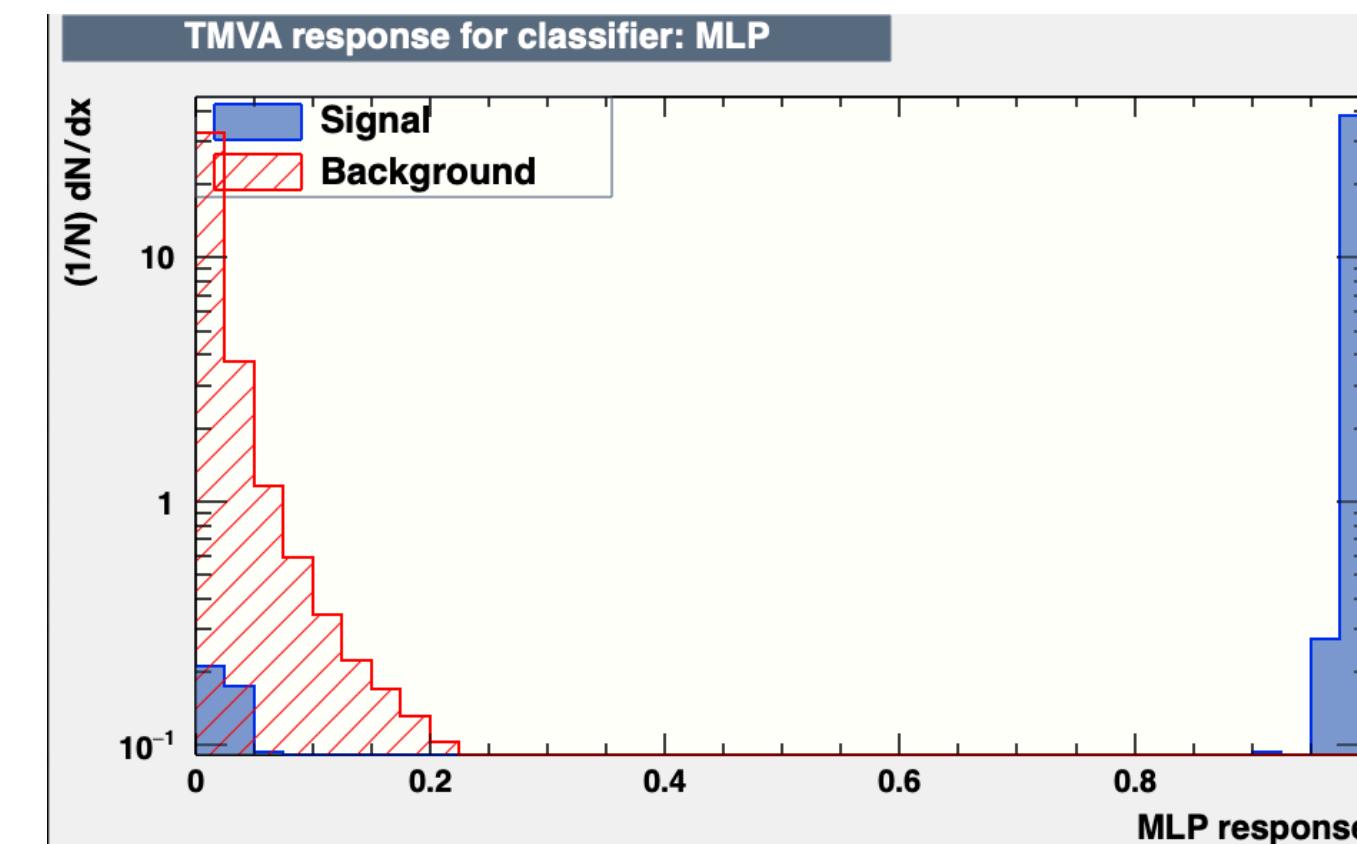


Training: π^+/e^+ classifier output



TOP: User created plot of MLP response on log Y scale to better show $0.2 < \text{NNR} < 0.9$ range.

BOT: TMVA default plot of MLP response on log Y scale

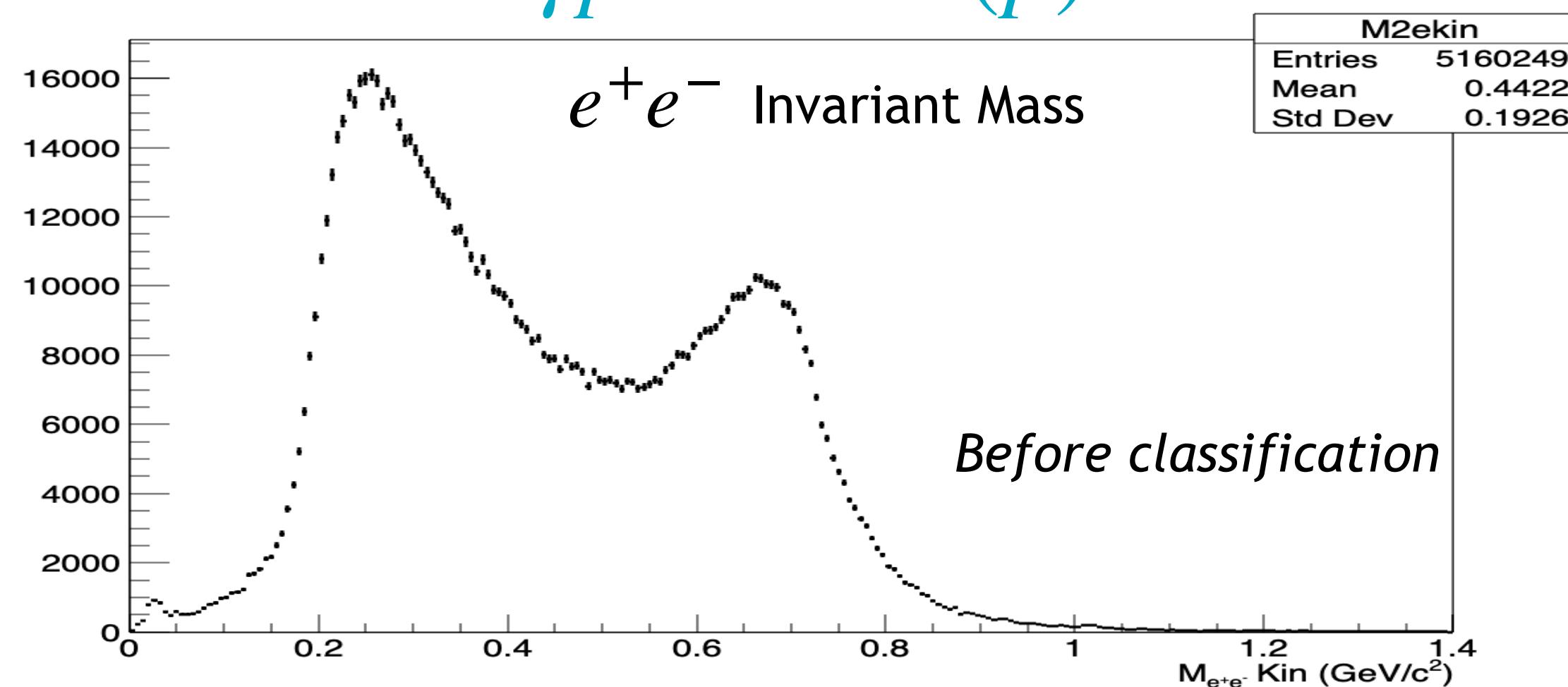


LEFT: 2018 GlueX data containing BH pairs and ρ^0 . Use NN to classify and separate.

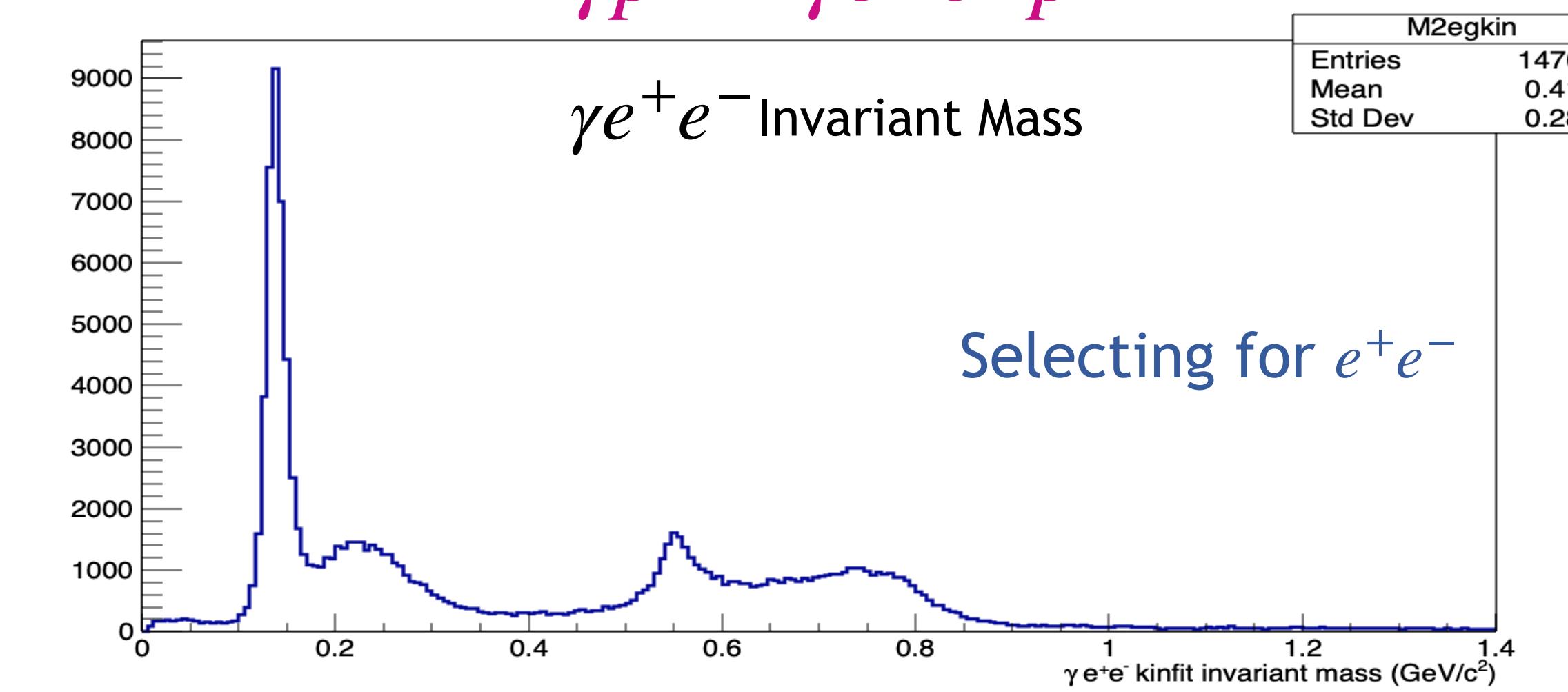
BENCHMARK STUDIES

RIGHT: 2018 GlueX data containing π^0 Dalitz decay. Select for pions and see how many e+e- pairs from π^0 get through.

$\gamma p \rightarrow e^+e^- (p)$



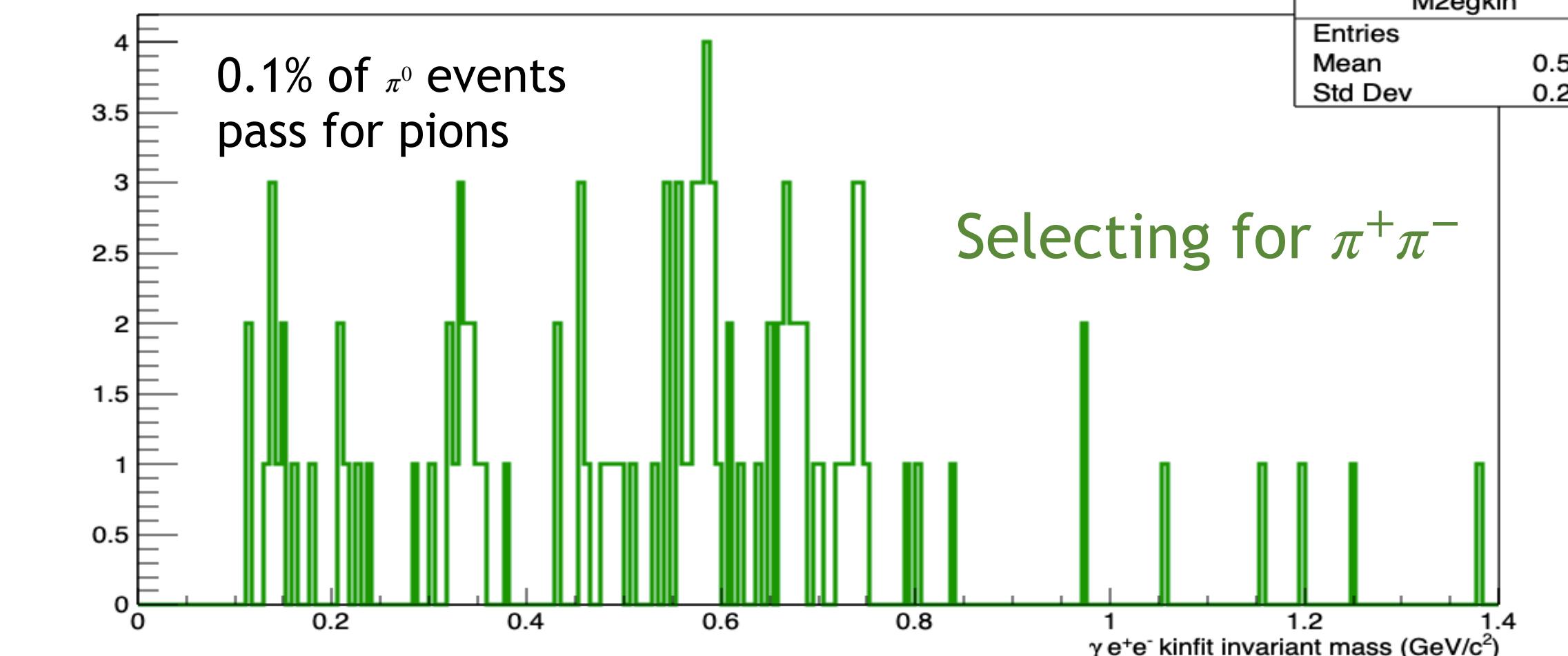
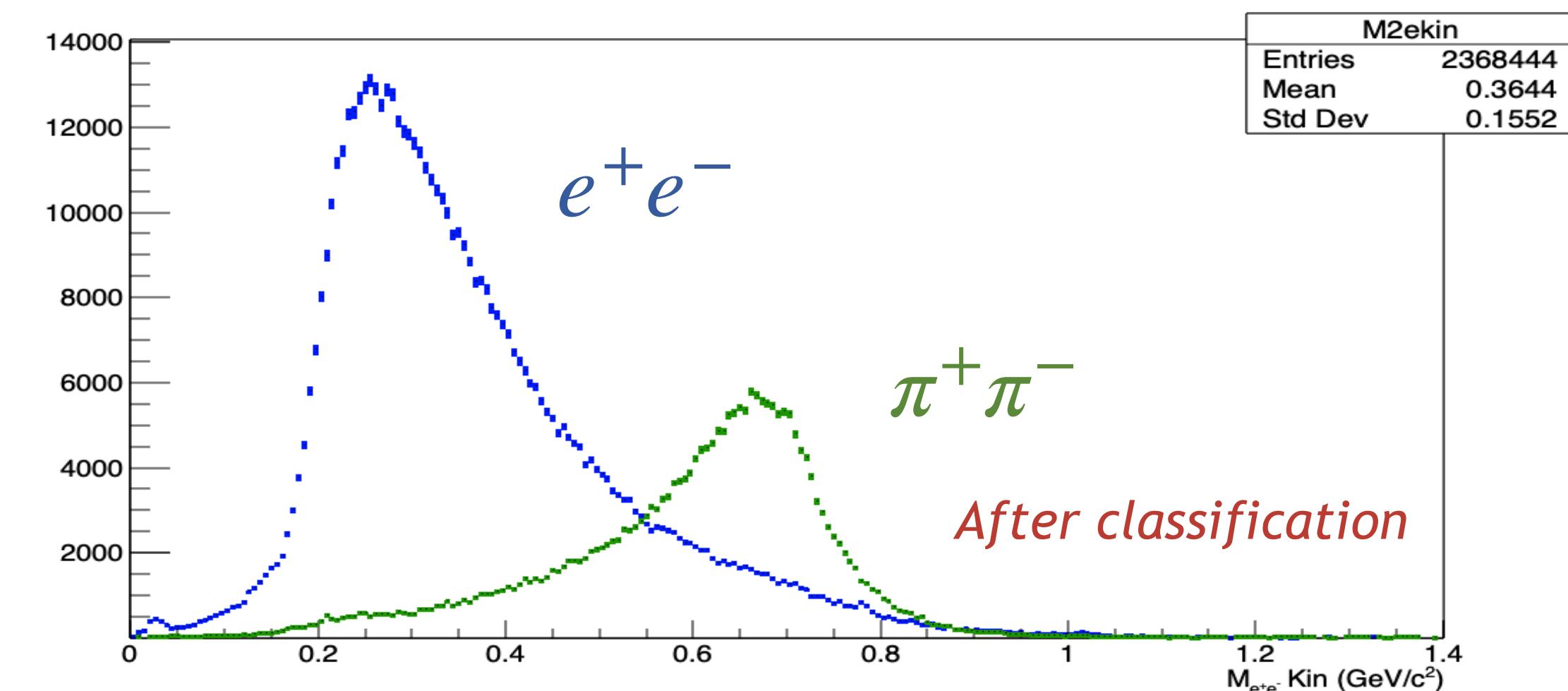
$\gamma p \rightarrow \gamma e^+e^- p$



e^+e^-

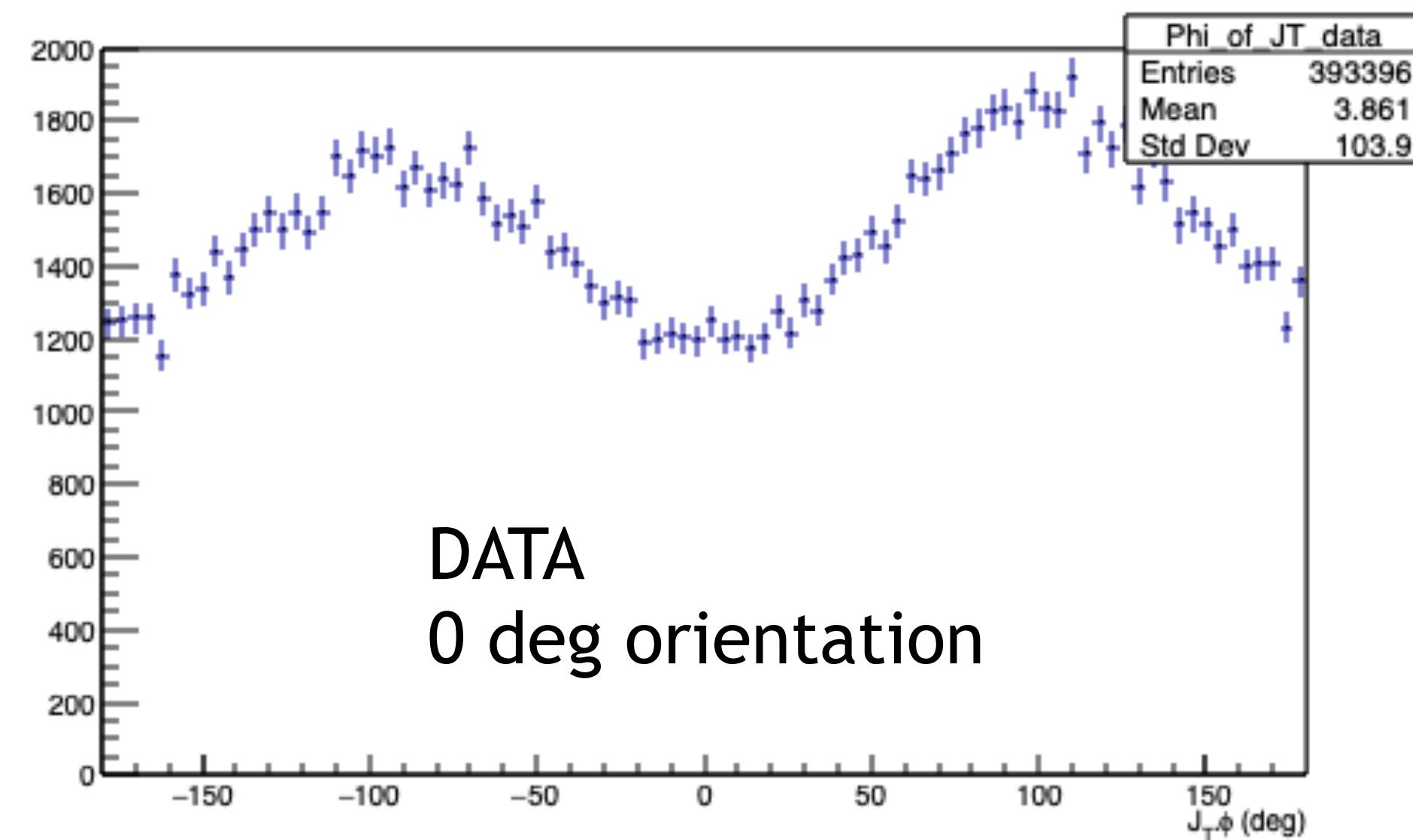
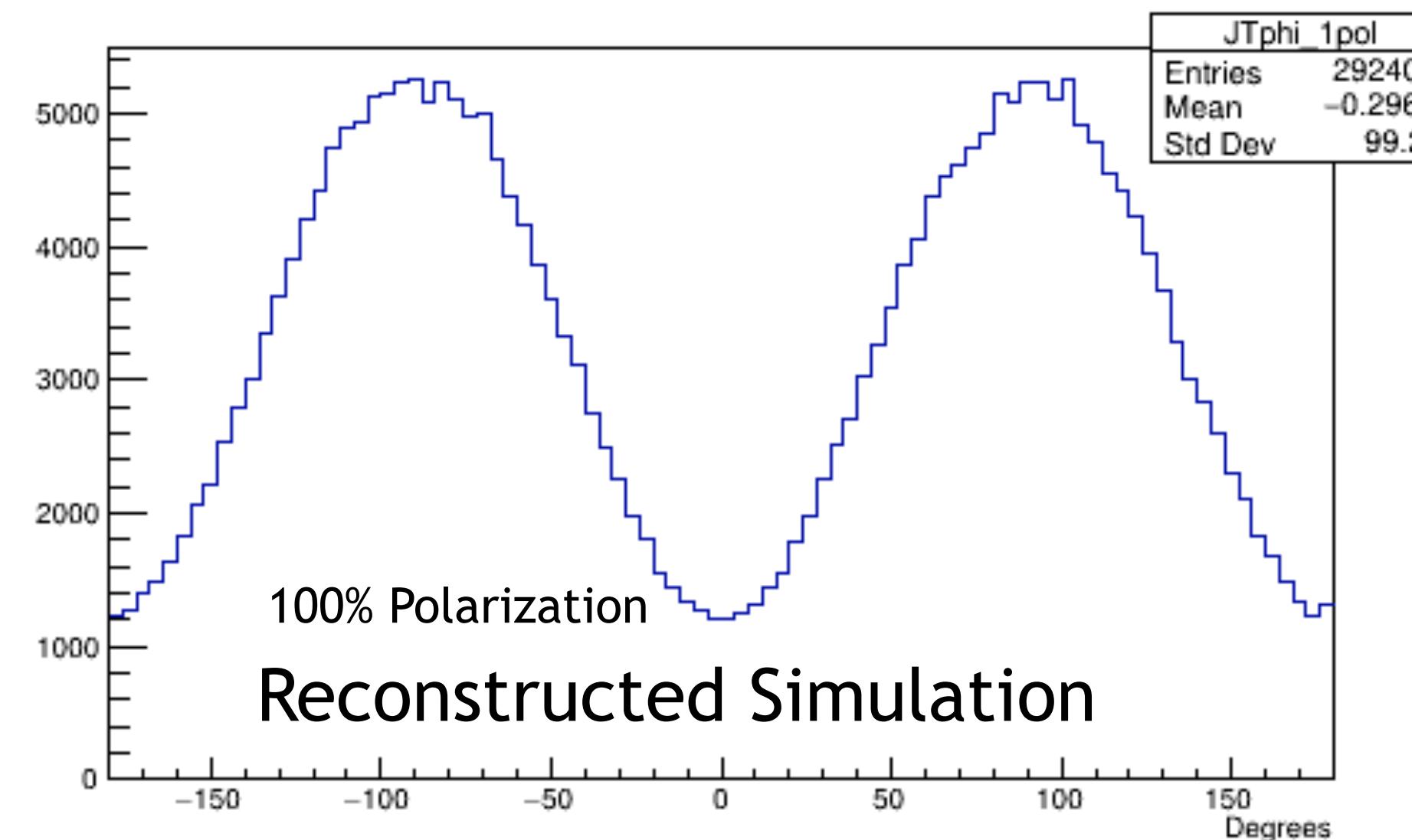
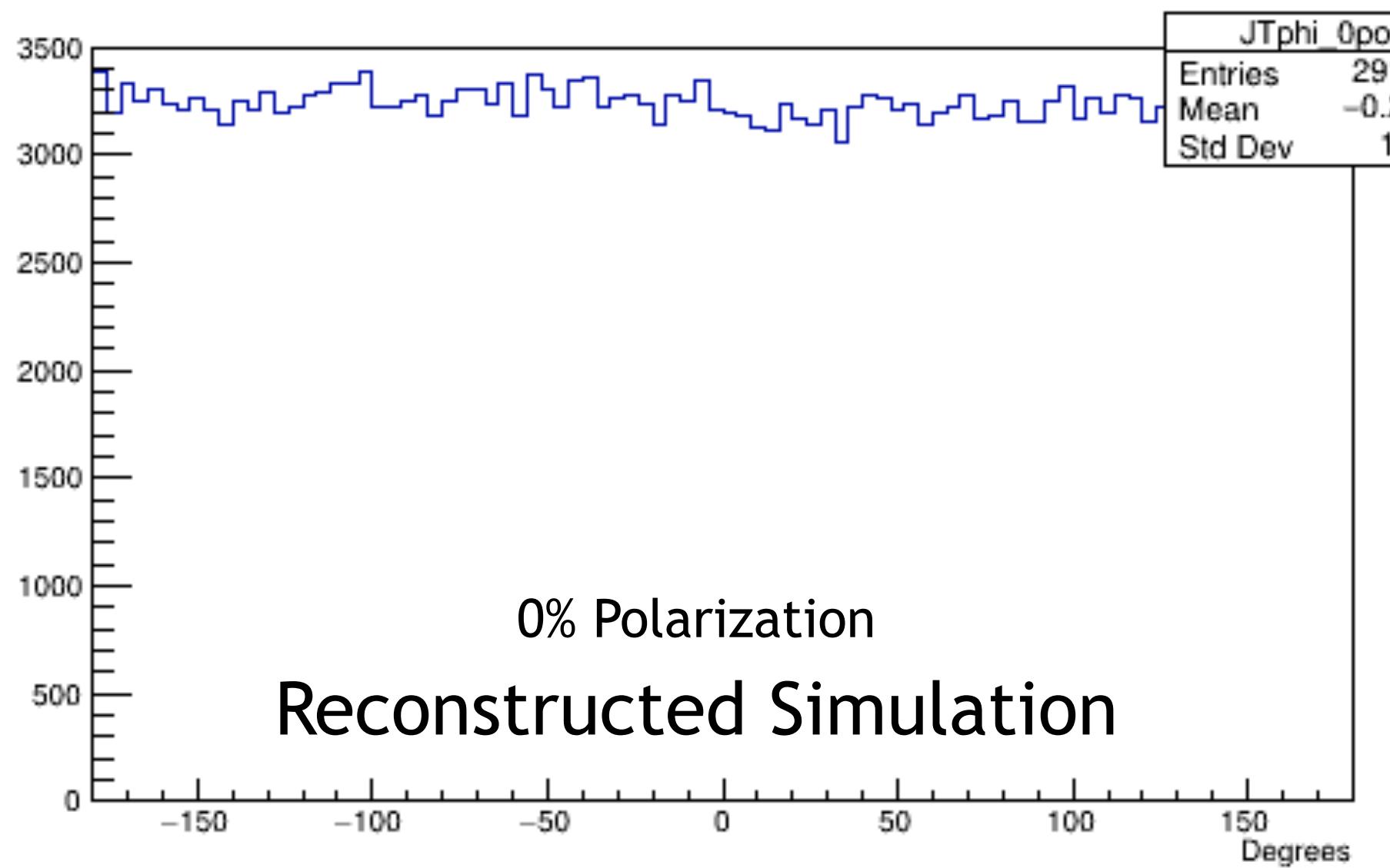
$\pi^+\pi^-$

After classification

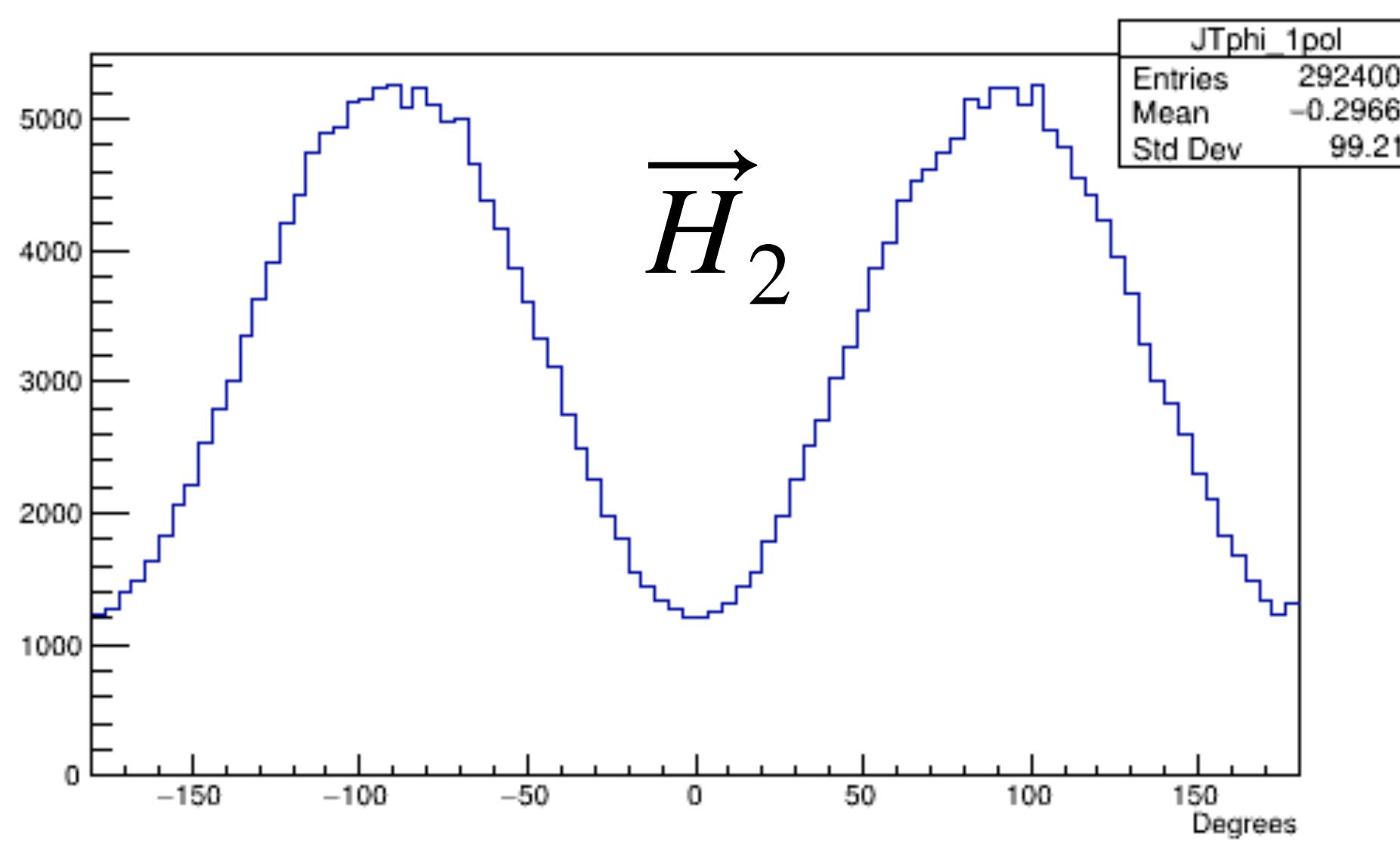
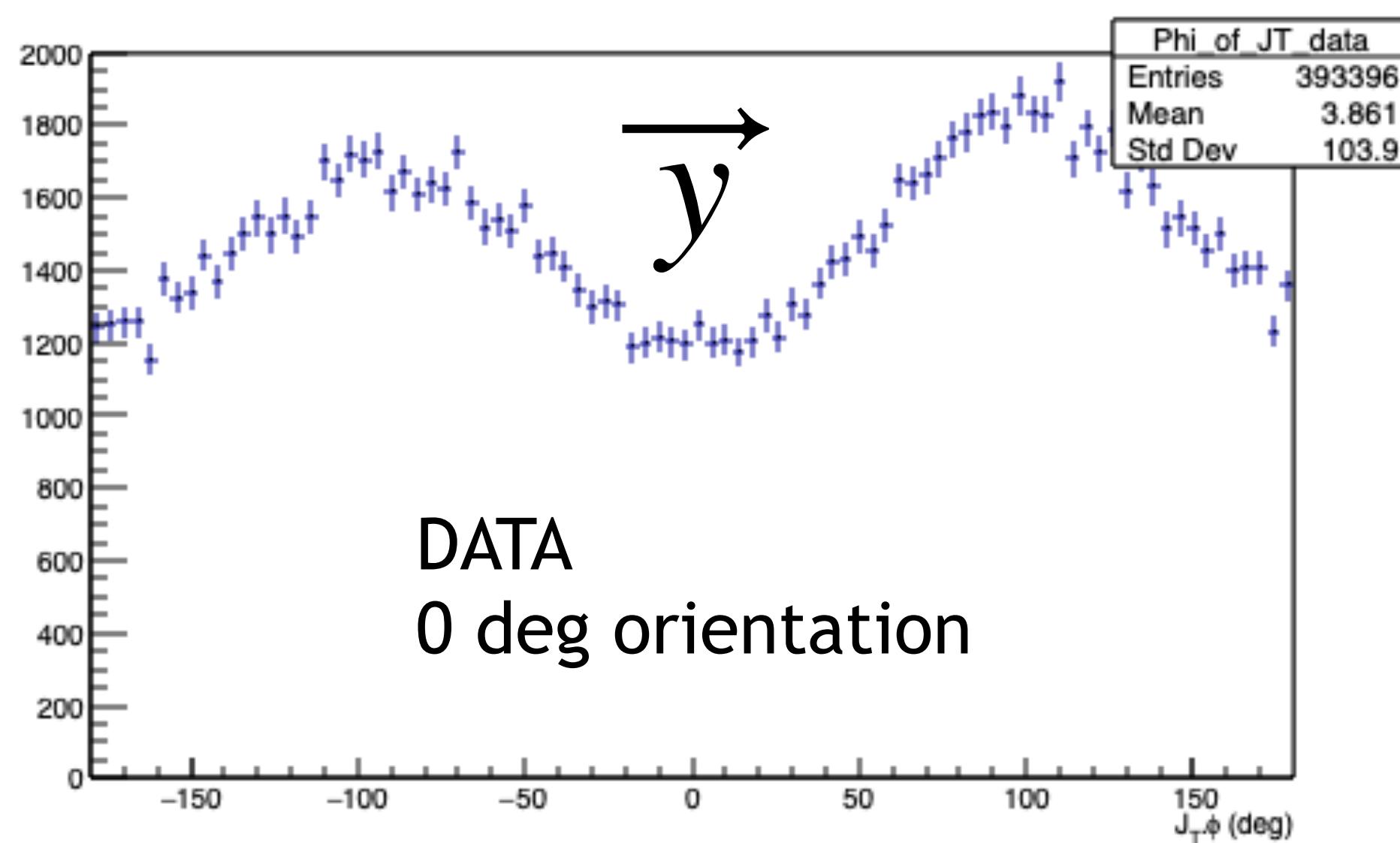
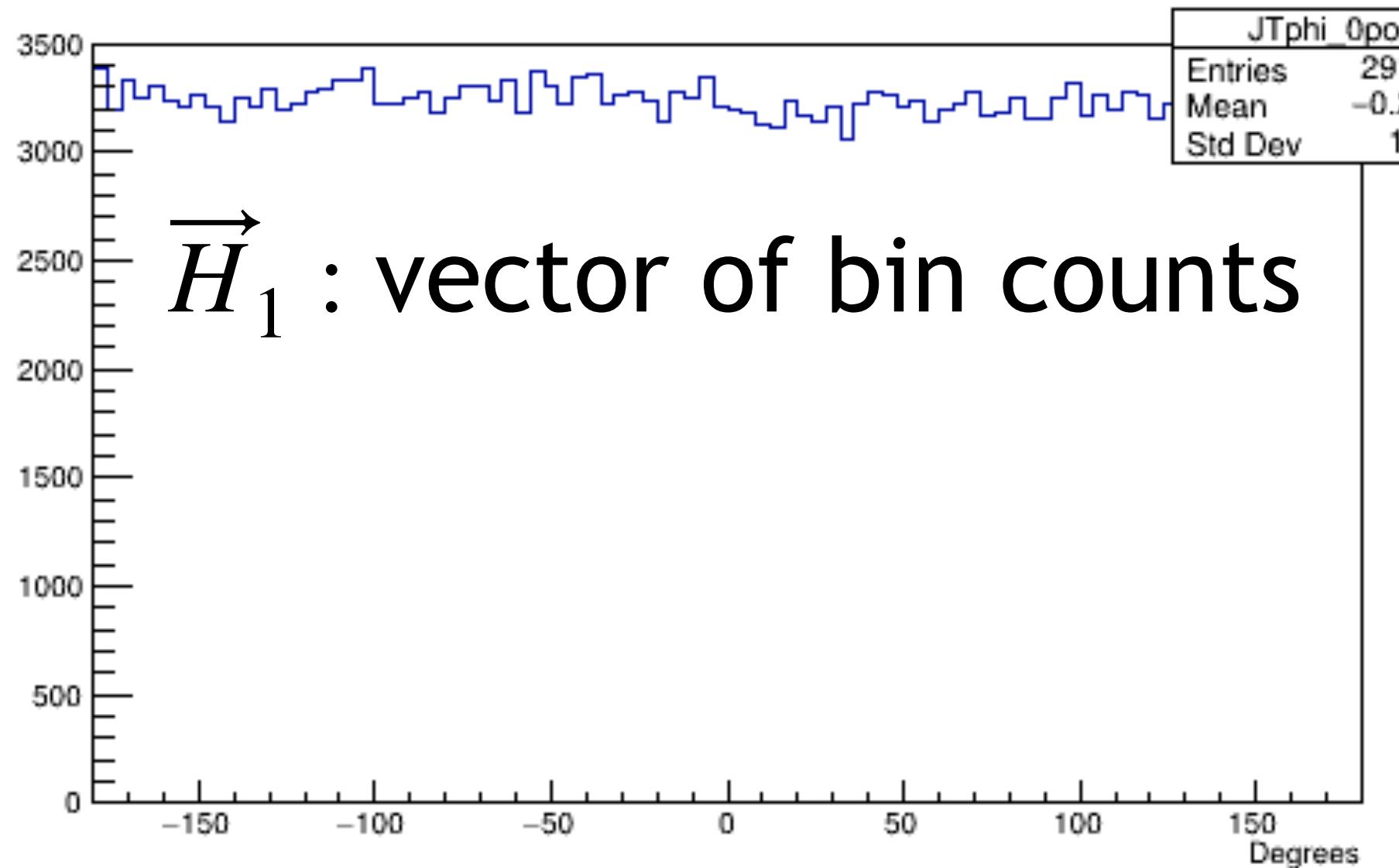


Same neural net and cut on NN response used in both studies

Early Attempts to measure the polarization (January 2021)



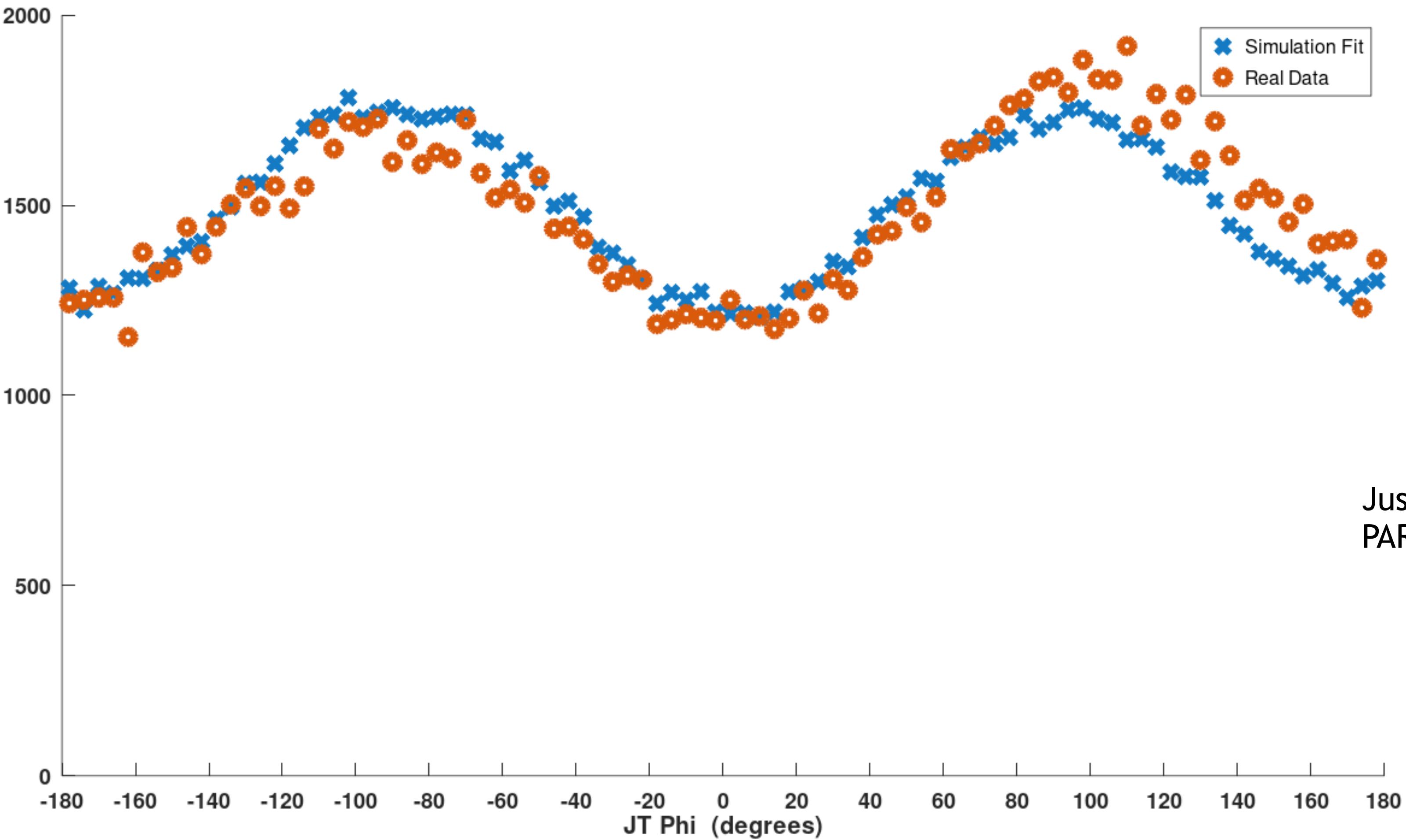
Neural Net Cut:
NN1,NN2 < 0.2
Fiducial Cuts Require:
 $8.12 < E_\gamma < 8.88 \text{ GeV}$
 FCAL Elasticity > 0.9
 $\Theta_1, \Theta_2 > 1.5 \text{ deg}$
 $0.25 \text{ GeV} < W < 0.621 \text{ GeV}$



$$J(\vec{\theta}) = \frac{1}{2}(\theta_1 \vec{H}_1 + \theta_2 \vec{H}_2 - \vec{y})^2$$

find $\vec{\theta}$ such that $J(\vec{\theta})$ is minimized
(gradient descent)

$$\min[J(\vec{\theta})] = \min\left[\frac{1}{2}(\theta_0 \vec{H}_0 + \theta_1 \vec{H}_1 - \vec{y})^2\right] \Rightarrow \vec{\theta} = [0.2773, \ 0.1111]$$



0deg Pol: orientation

$$P_\gamma = \frac{\theta_1}{\theta_0 + \theta_1} = \frac{0.1111}{0.3883} = 0.2860$$

Justin's Paper: PERP: $0.382 \pm 0.008(\text{stat.}) \pm 0.006(\text{syst.})$
PARA: $0.440 \pm 0.009(\text{stat.}) \pm 0.007(\text{syst.})$

$$\begin{matrix} 0.2773 \\ 0.1111 \end{matrix}$$

$$\sigma_{\theta_0}^2 = \frac{1}{\sum_i H_i^0 H_i^0 / J_i} \quad \sigma_{\theta_1}^2 = \frac{1}{\sum_i H_i^1 H_i^1 / J_i} \quad P_\gamma = \frac{\theta_1}{\theta_0 + \theta_1} = \frac{0.1111}{0.3883} = 0.2860$$

$$\sigma_0^2 = 1.3053 \times 10^{-6} \quad \sigma_1^2 = 1.2014 \times 10^{-6}$$

Denominator first: $f = A + B$ $\sigma_f = \sqrt{\sigma_A^2 + \sigma_B^2 + 2\sigma_{AB}}$

$$\sigma_d^2 = \sigma_0^2 + \sigma_1^2 = 1.3053 \times 10^{-6} + 1.2014 \times 10^{-6} = 2.5067 \times 10^{-6}$$

Numerator is just: $\sigma_n = \sigma_1$

$$f = \frac{A}{B} \quad \sigma_f \approx |f| \sqrt{\left(\frac{\sigma_A}{A}\right)^2 + \left(\frac{\sigma_B}{B}\right)^2 - 2\frac{\sigma_{AB}}{AB}}$$

$$\sigma \approx \left| \frac{\theta_1}{\theta_0 + \theta_1} \right| \sqrt{\left(\frac{\sigma_1}{\theta_1}\right)^2 + \left(\frac{\sigma_d}{\theta_0 + \theta_1}\right)^2} = \left| 0.2860 \right| \sqrt{\frac{1.2014 \times 10^{-6}}{0.2773^2} + \frac{2.5067 \times 10^{-6}}{0.3883^2}} = 0.0016241$$

$$P_\gamma = 0.2860 \pm 0.0016$$

$$P_\gamma = \frac{\theta_1}{\theta_0 + \theta_1} = \frac{0.1111}{0.3883} = 0.2860$$

Error associated with P_γ is given by

$$\sigma_{P_\gamma}^2 = \left[\frac{\partial P_\gamma}{\partial \theta_0} \sigma_{\theta_0} \right]^2 + \left[\frac{\partial P_\gamma}{\partial \theta_1} \sigma_{\theta_1} \right]^2$$

$$\sigma_{\theta_0}^2 = \frac{1}{\sum_i H_0^{(i)} H_0^{(i)} / y^{(i)}} = 1.3053 \times 10^{-6}$$

$$\sigma_{\theta_1}^2 = \frac{1}{\sum_i H_1^{(i)} H_1^{(i)} / y^{(i)}} = 1.2014 \times 10^{-6}$$

$$\frac{\partial P_\gamma}{\partial \theta_0} = -\frac{\theta_1}{(\theta_0 + \theta_1)^2} = -\frac{0.1111}{(0.3883)^2} = -0.7369 \quad \left(\frac{\partial P_\gamma}{\partial \theta_0} \right)^2 = 0.5430$$

$$\frac{\partial P_\gamma}{\partial \theta_1} = \frac{1}{\theta_0 + \theta_1} - \frac{\theta_1}{(\theta_0 + \theta_1)^2} = \frac{1}{0.3883} - 0.7369 = 1.8384 \quad \left(\frac{\partial P_\gamma}{\partial \theta_1} \right)^2 = 3.3797$$

$$\sigma_{P_\gamma}^2 = \left[\frac{\partial P_\gamma}{\partial \theta_0} \sigma_{\theta_0} \right]^2 + \left[\frac{\partial P_\gamma}{\partial \theta_1} \sigma_{\theta_1} \right]^2 = (0.5430) \cdot (1.3053 \times 10^{-6}) + (3.3797) \cdot (1.2014 \times 10^{-6}) = 4.7691 \times 10^{-6}$$

$$\sigma_{P_\gamma} = 0.0021$$

Polarization values for E_gamma between 8.2 and 8.8 GeV	
Beam orientation	Polarization
0 degrees:	0.3420 +/- 0.0063
45 degrees:	0.3474 +/- 0.0065
90 degrees:	0.3478 +/- 0.0063
135 degrees:	0.3517 +/- 0.0065

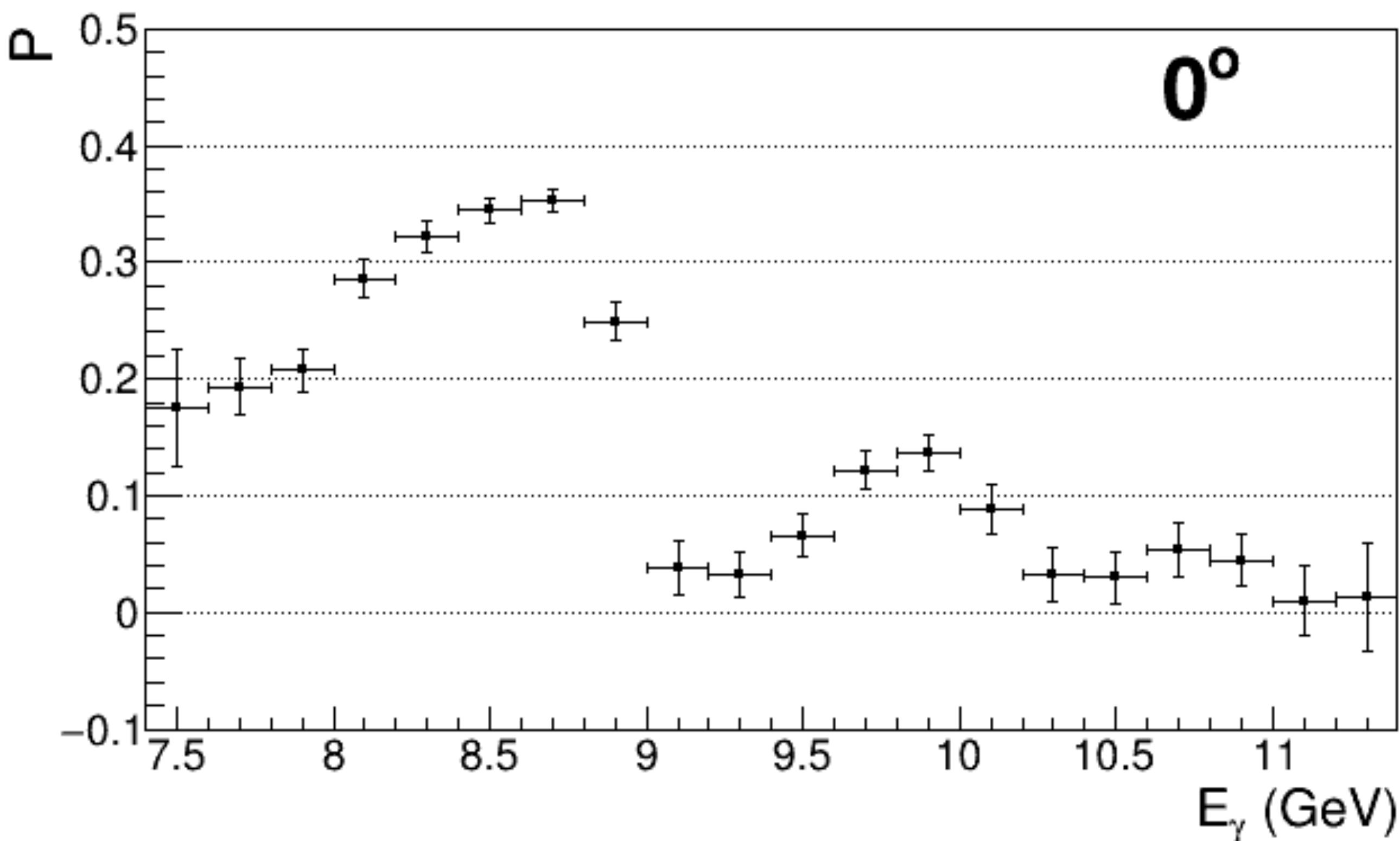
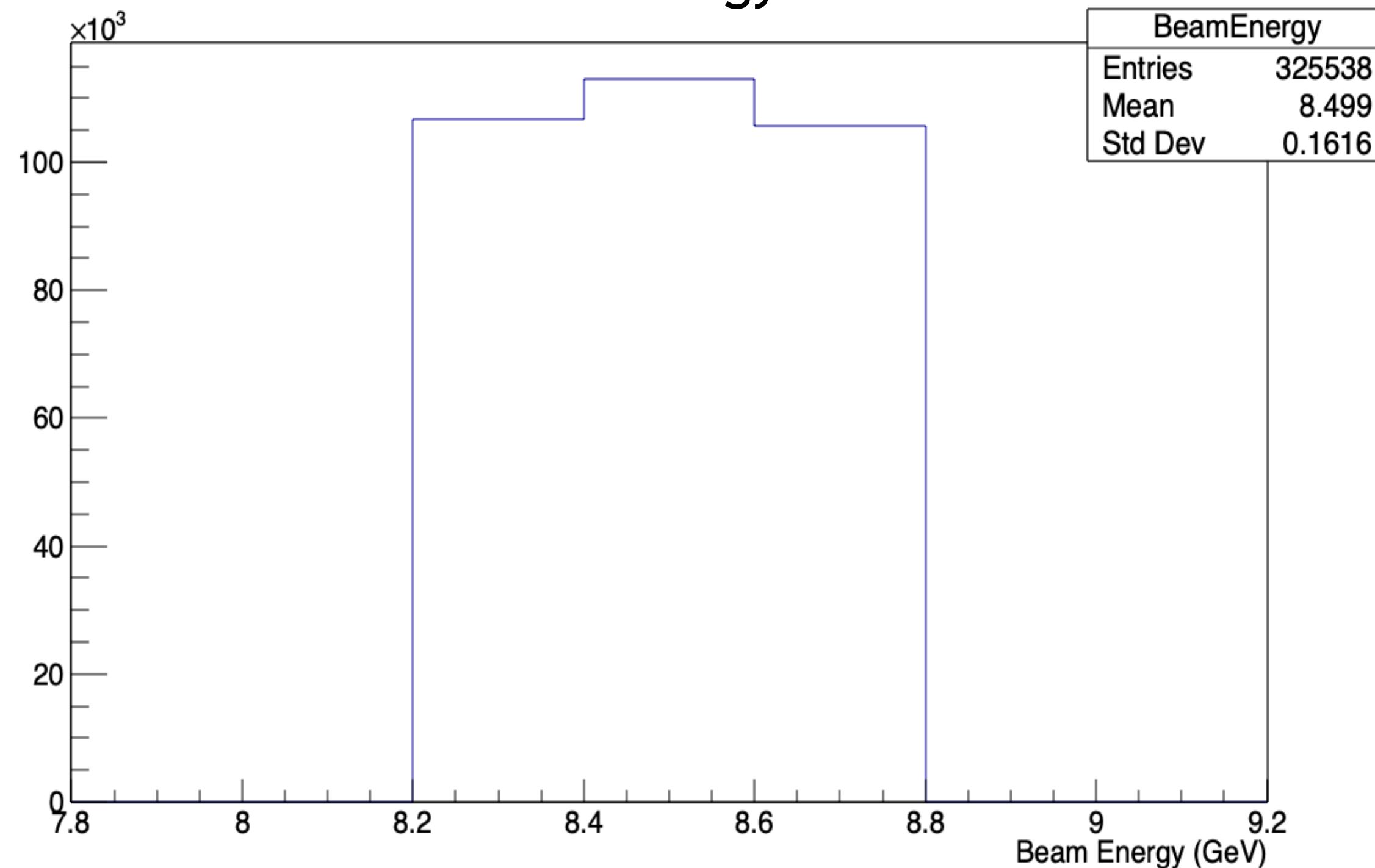


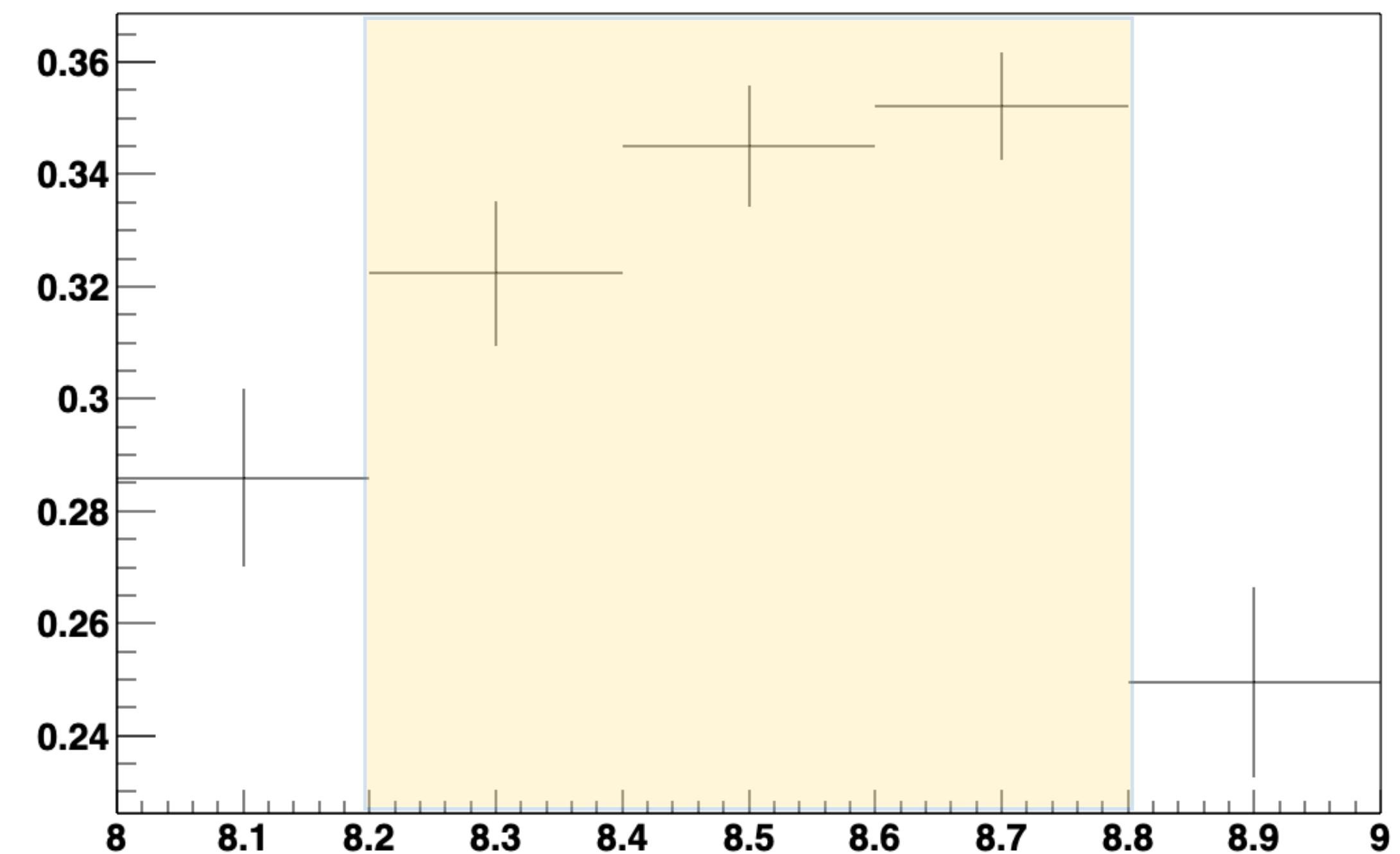
Table 1

8.3	106740
8.5	113046
8.7	105752

Bethe-Heitler Data Beam Energy



8.2 to 8.8 Energy range



$$8.2 < E_\gamma < 8.8$$

$$\bar{\mathcal{P}}_\gamma = 0.3399 \pm 0.0125$$

SUMMARY SO FAR

TPOL expected polarization for energy range $8.2 < E_\gamma < 8.8$

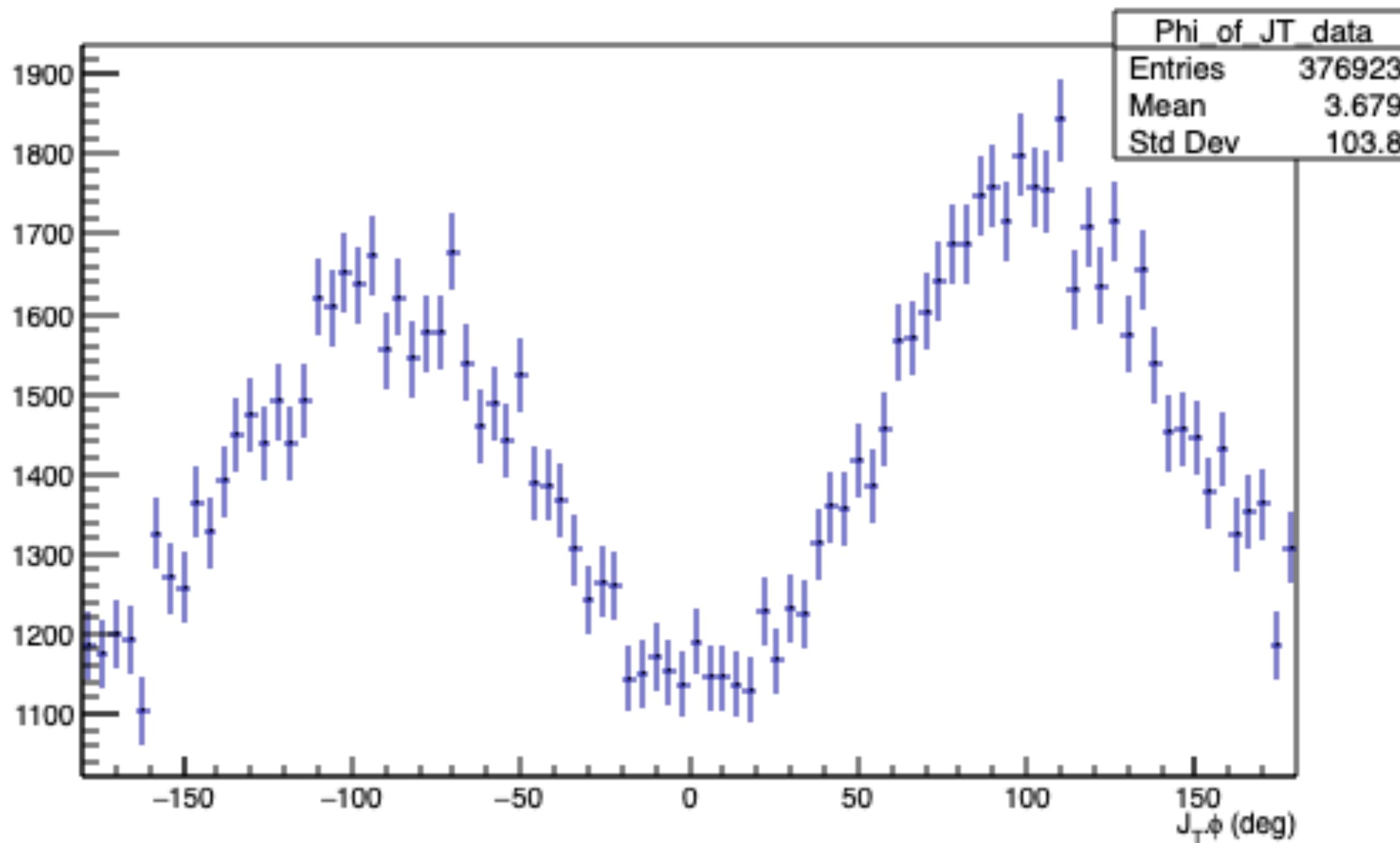
$$\bar{\mathcal{P}}_\gamma = 0.3399 \pm 0.0125$$

Chisq method: Measured with ϕ of J_T , pol 0 config runs

$$\mathcal{P}_\gamma = 0.2860 \pm 0.0016$$

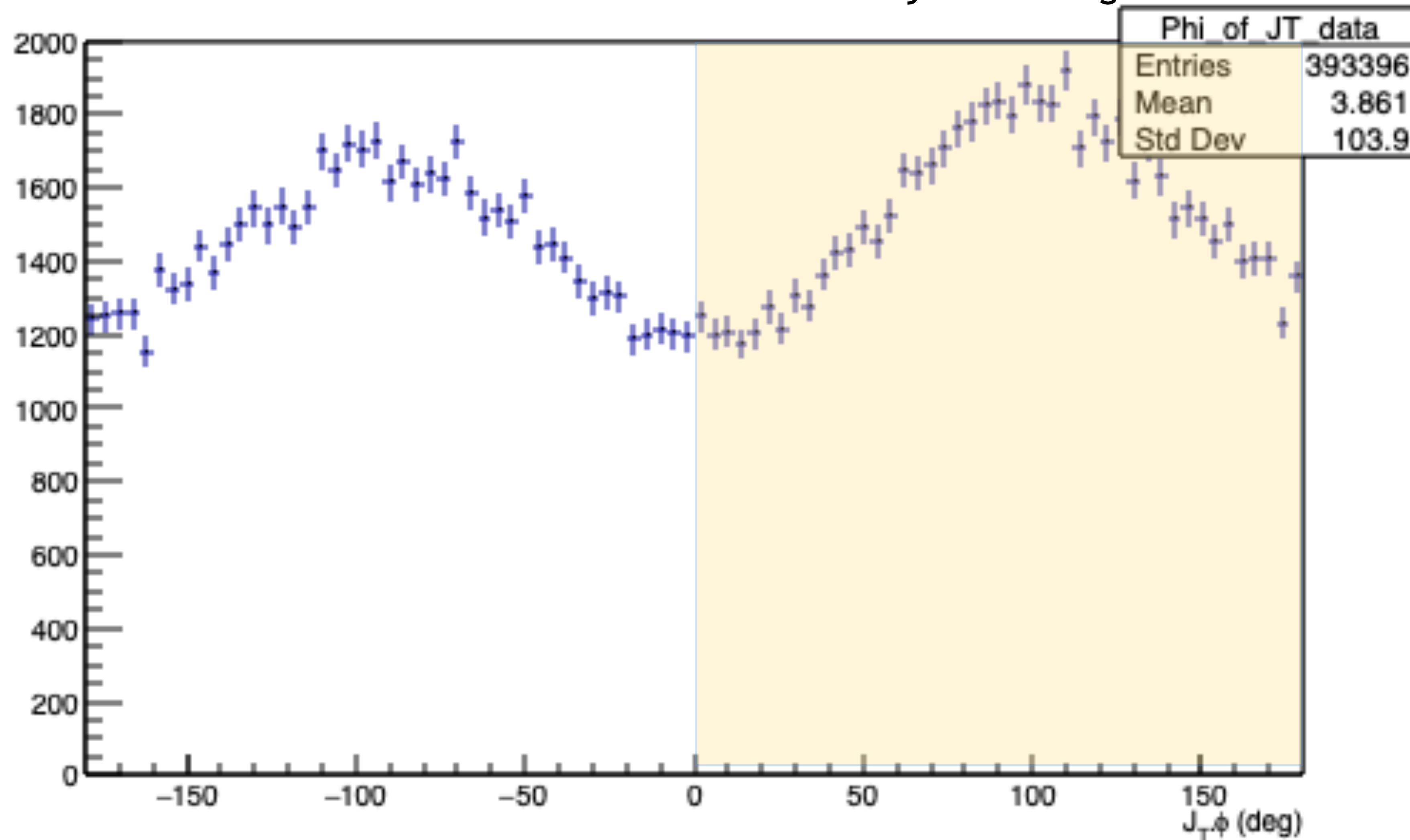
Yield asymmetry method: Average polarization between 0 and 90 runs:

$$\frac{\mathcal{P}_\perp + \mathcal{P}_\parallel}{2} = 0.2996 \pm .0060$$



Tighter cut on invariant mass ($300 \text{ MeV} < W < 500 \text{ MeV}$) does not fix asymmetry. This is likely due to calibration. Jobs to test this are running now but may be statistics limited. Will submit for new reconstruction of 2018-01 data set.

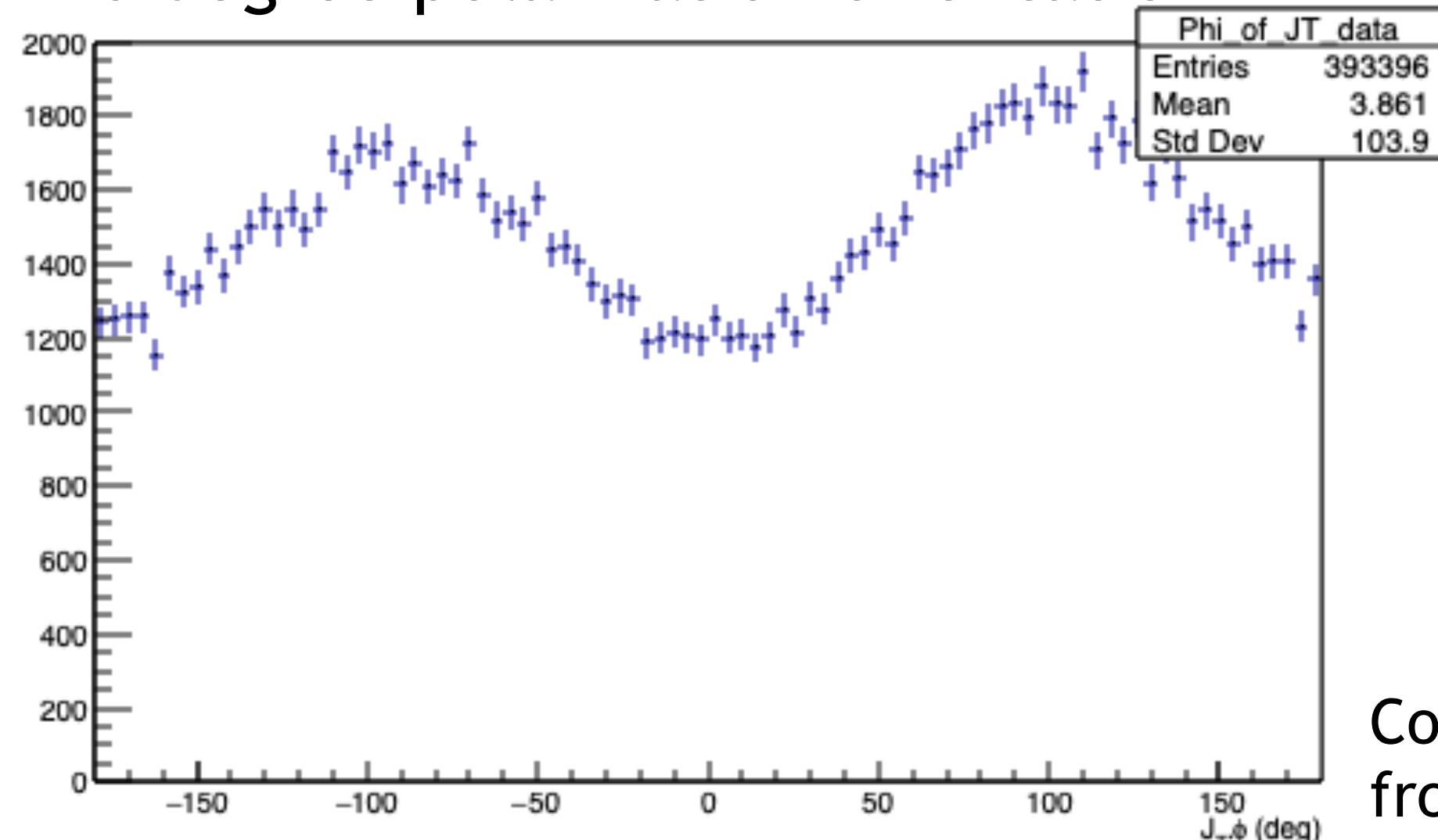
What if I just take right side?



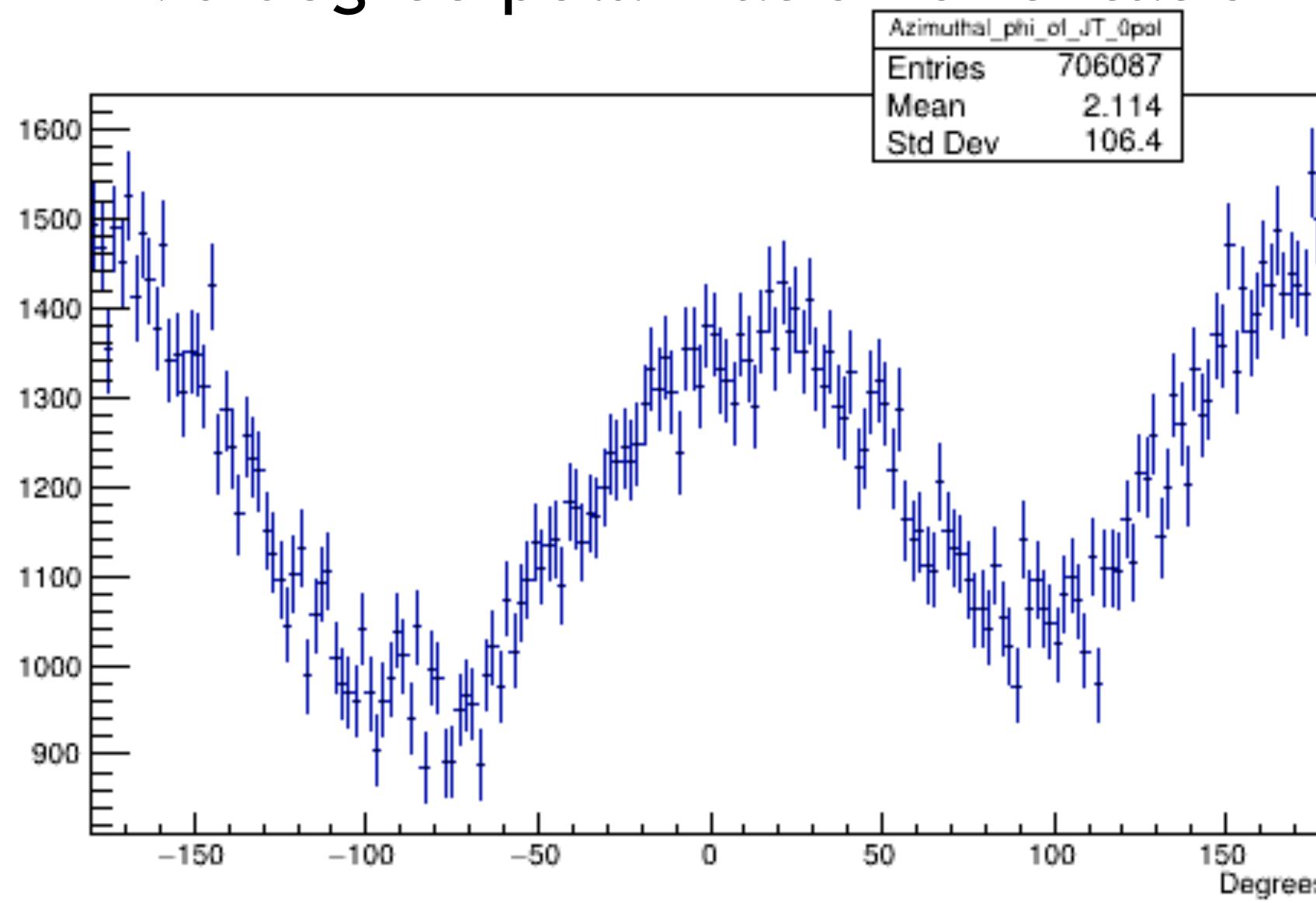
Then I get .30449
for a polarization.

Asymmetric peaks
maybe are part of
the problem, but
not enough to get
results to agree
with tpol.

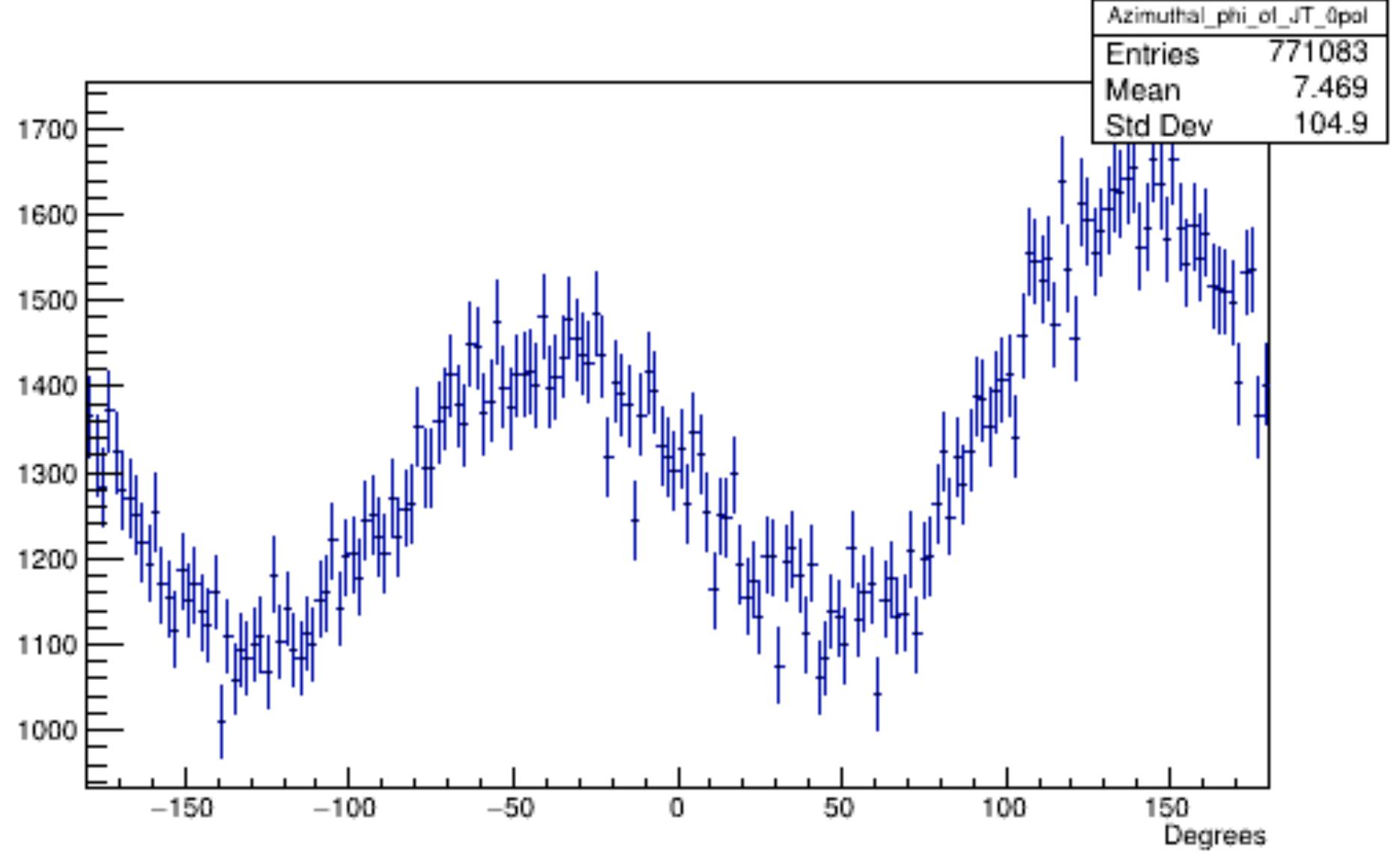
0 degree polarization orientation



90 degree polarization orientation



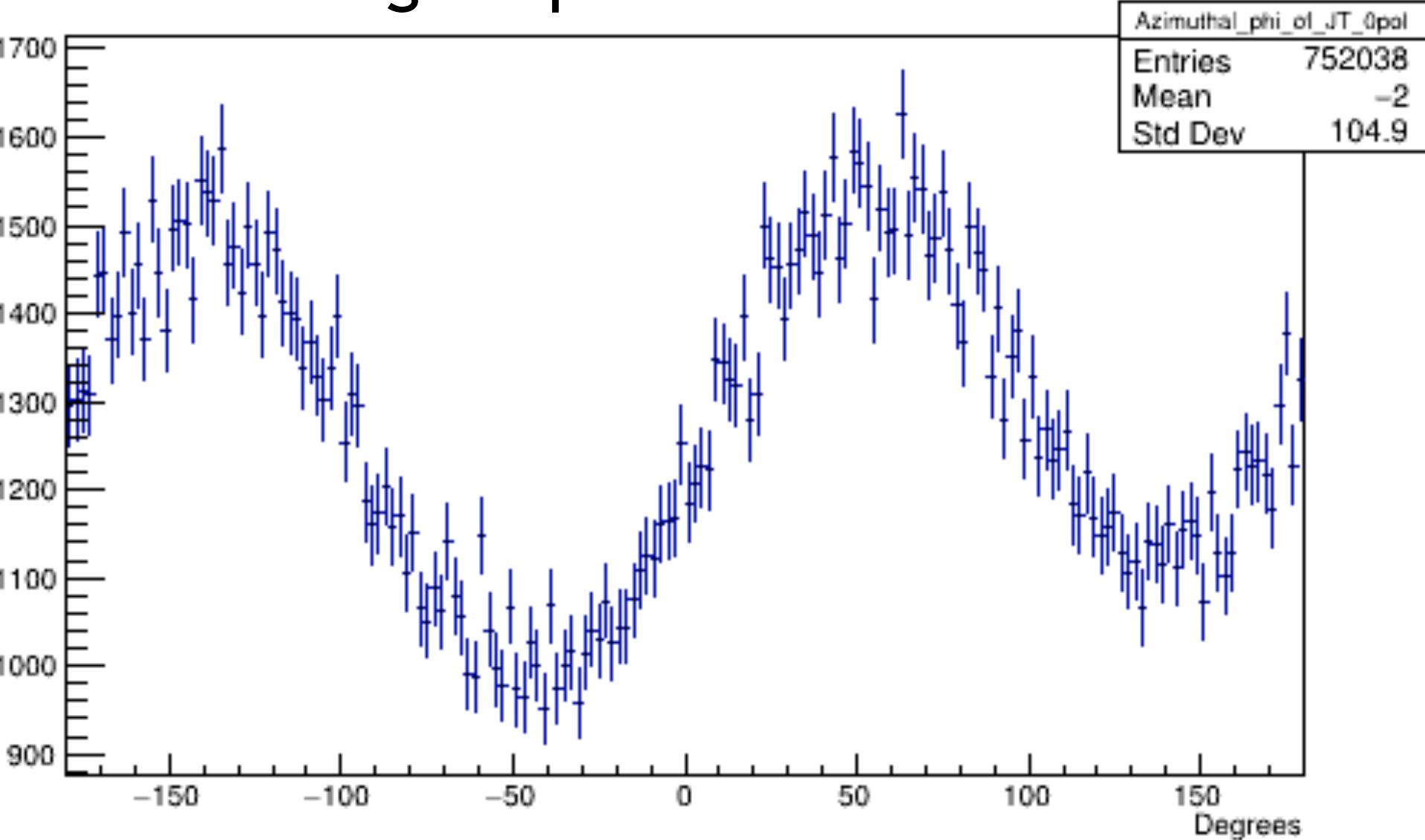
45 degree polarization orientation



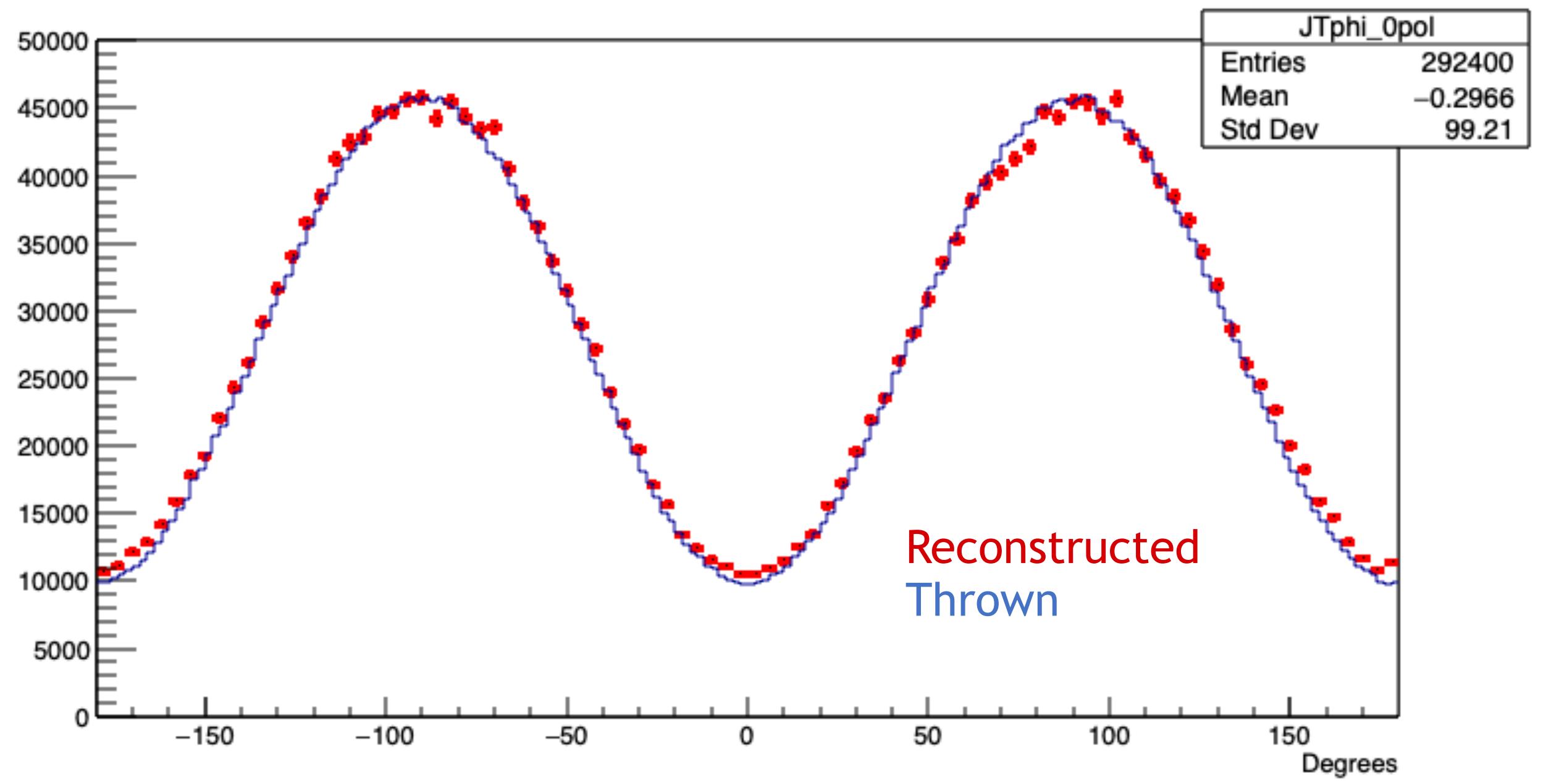
Comparing data
from separate pol.
runs:

All exhibit asymmetry

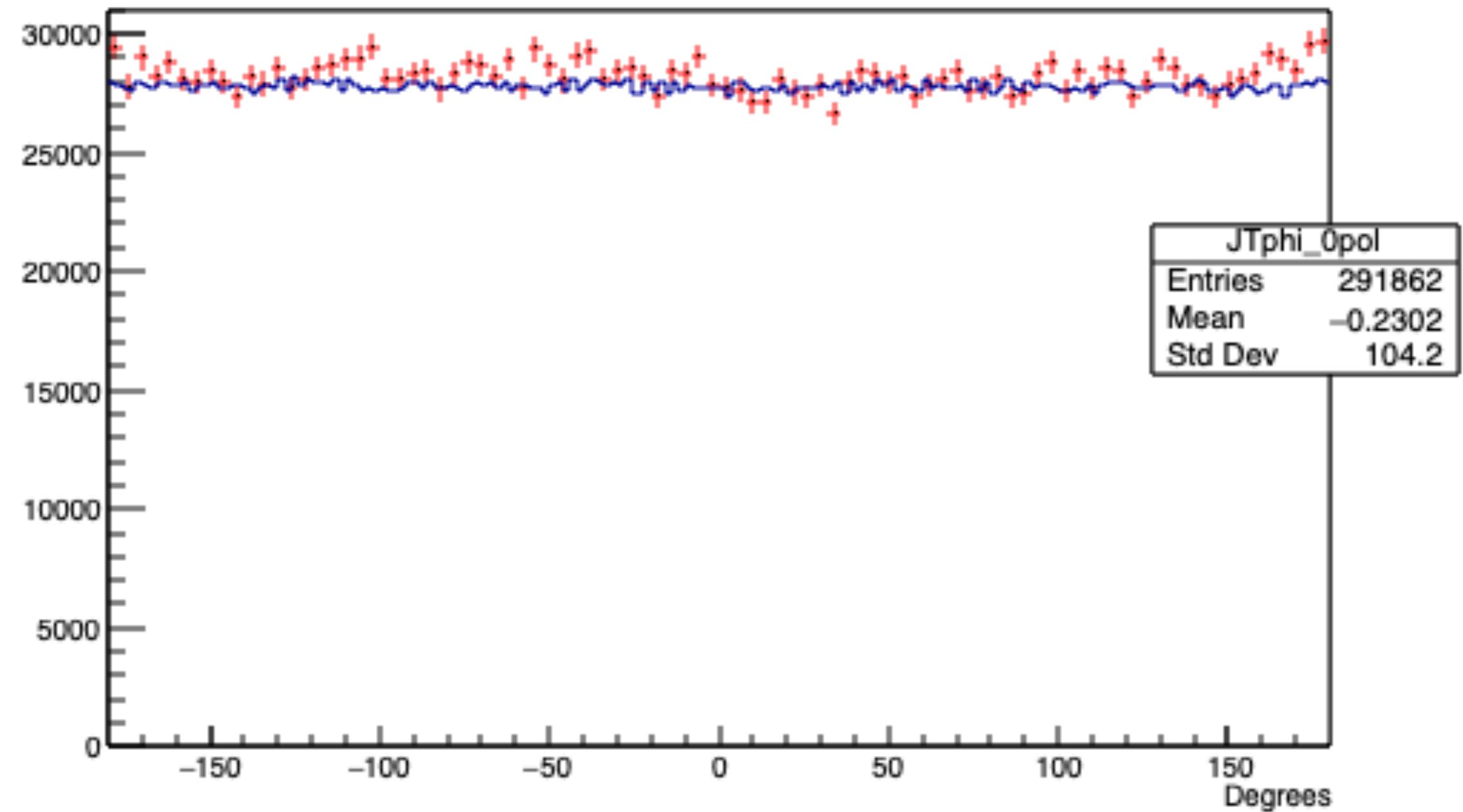
135 degree polarization orientation

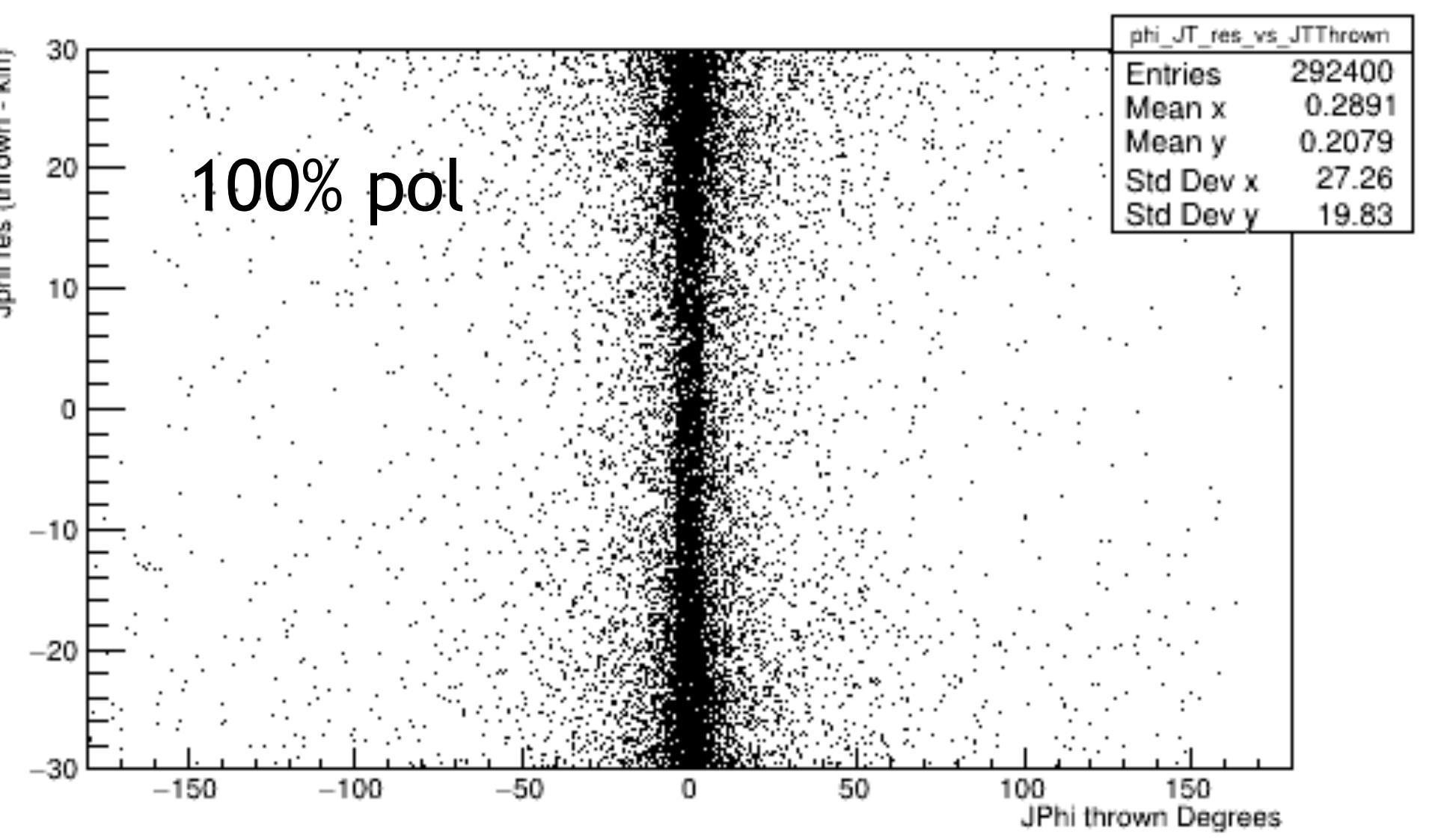
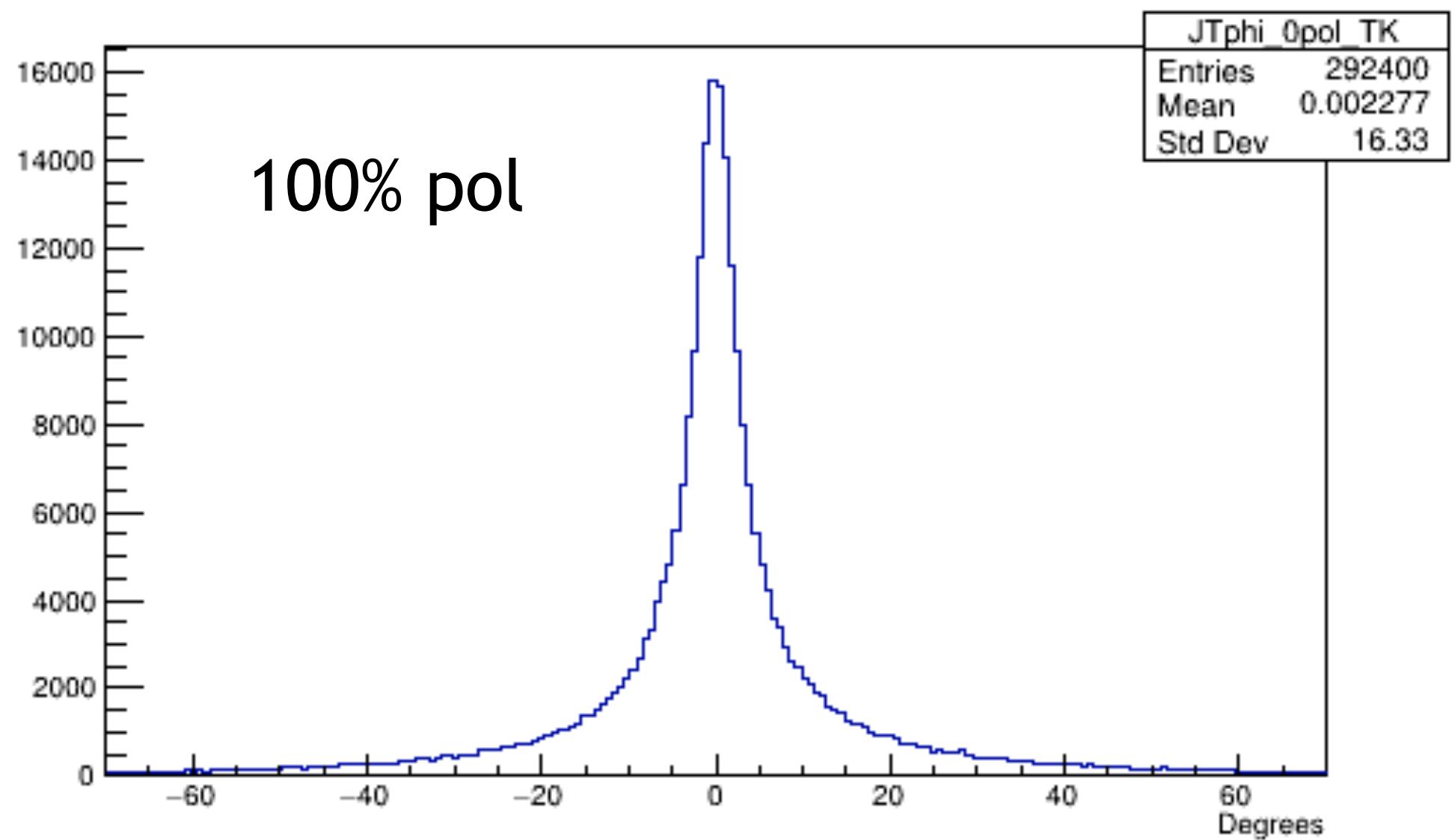
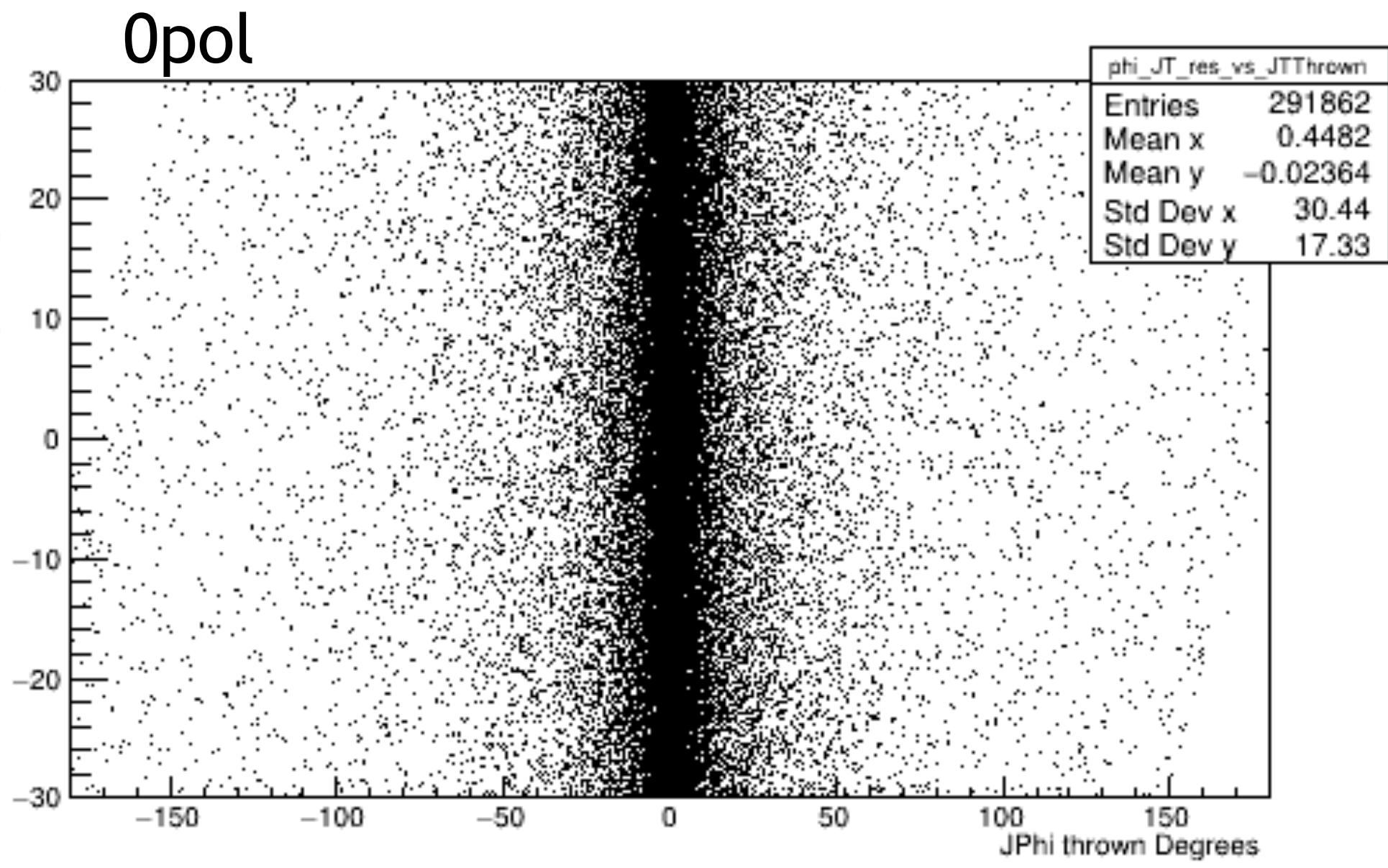
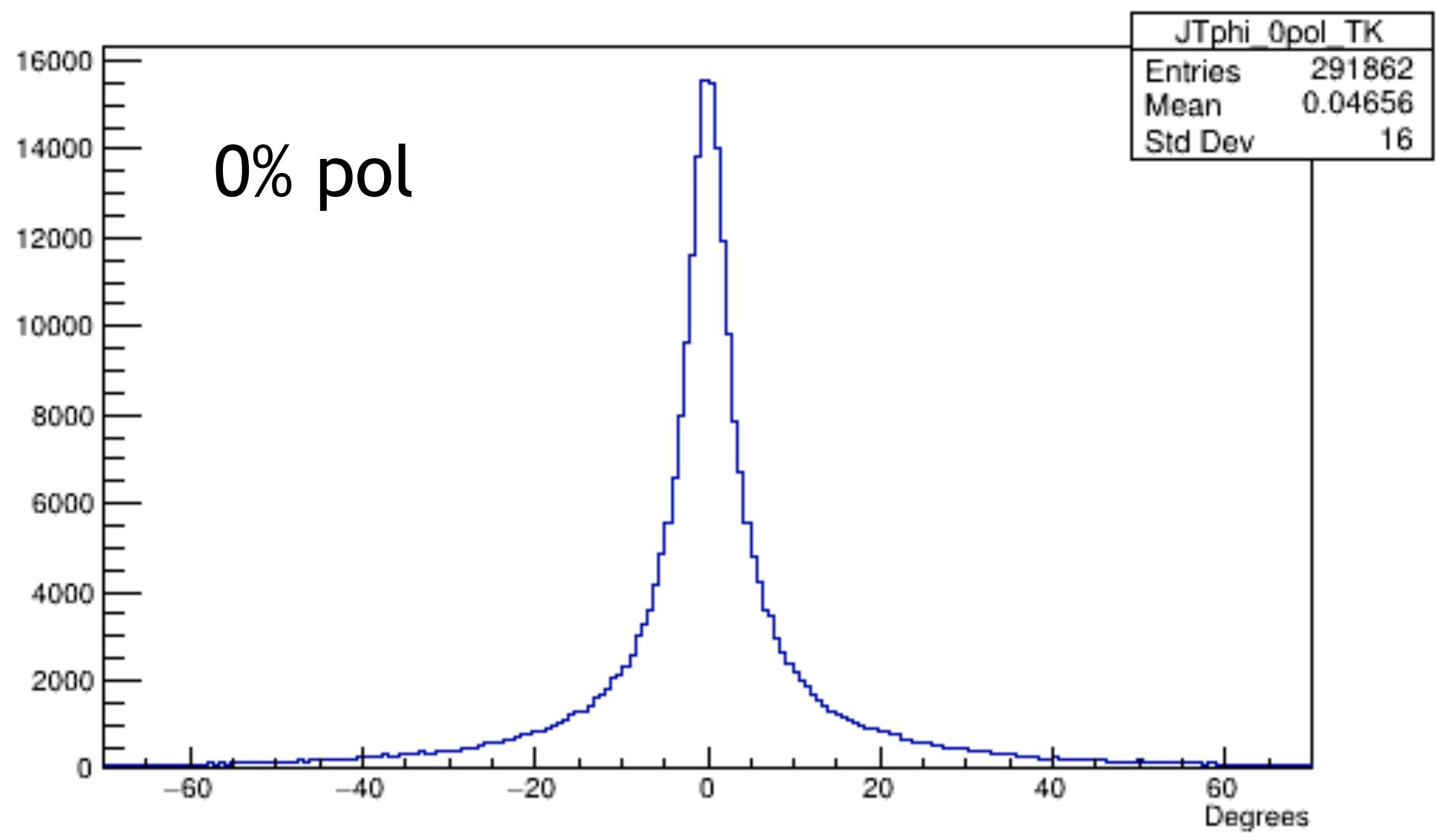


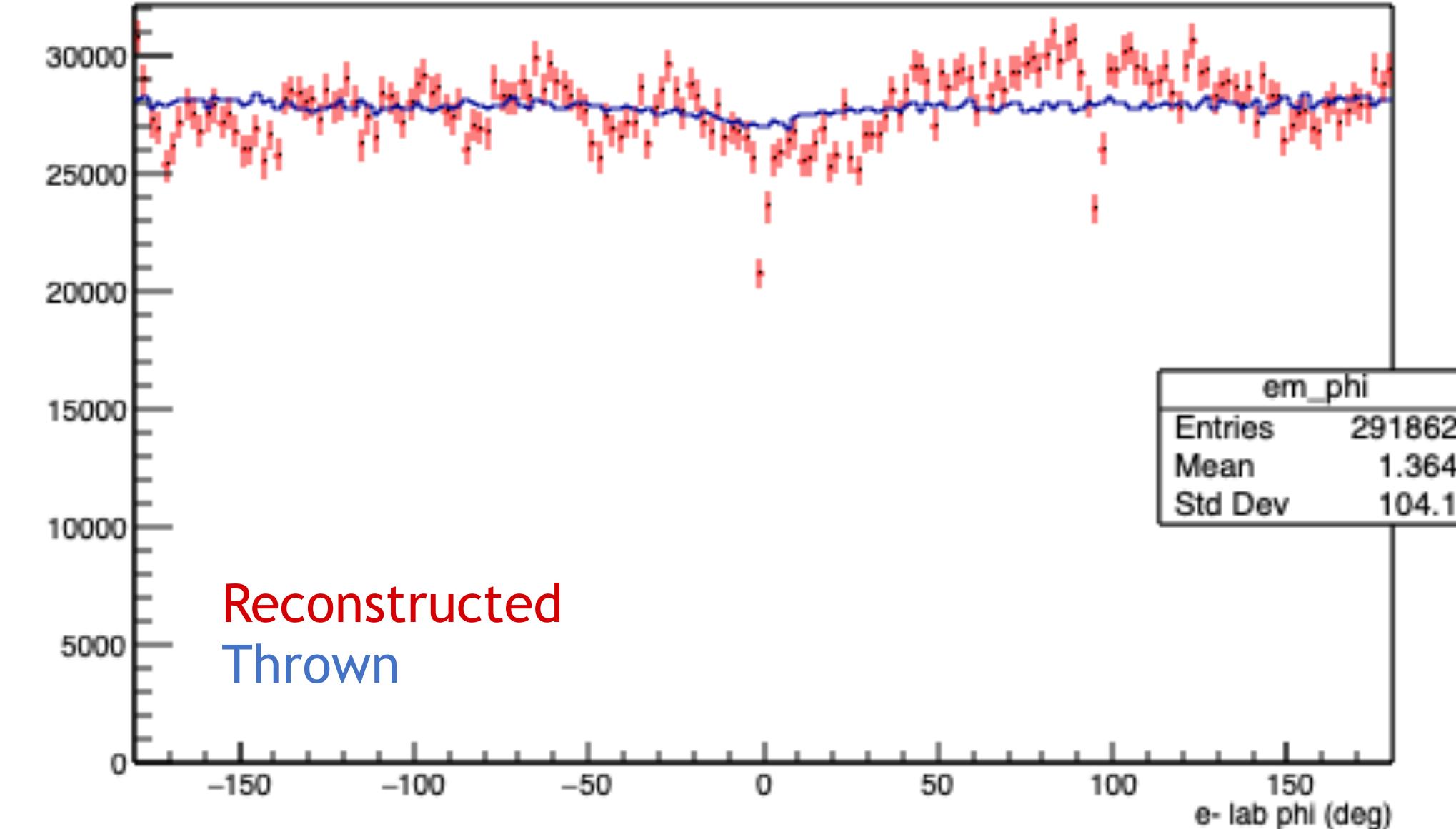
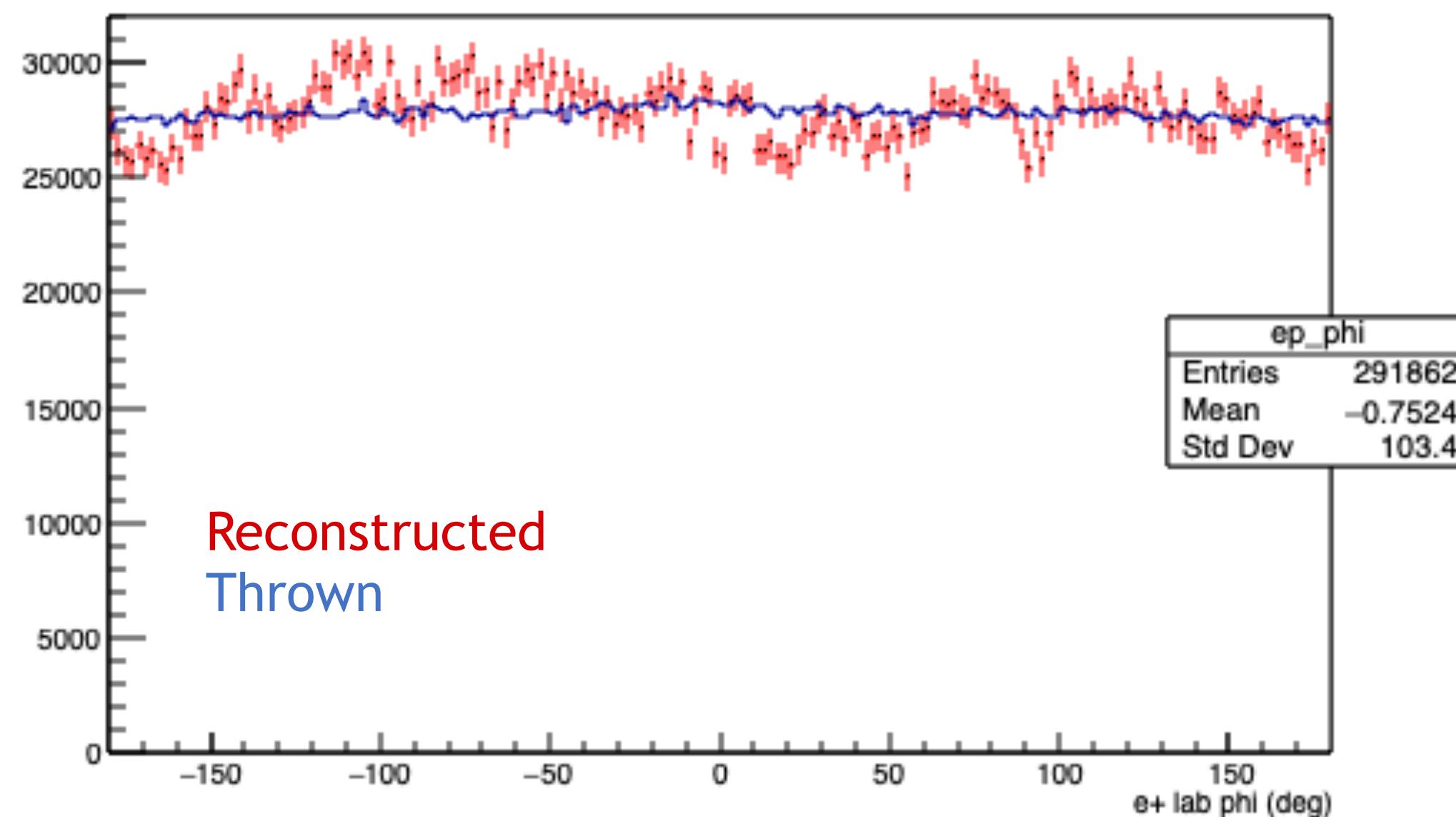
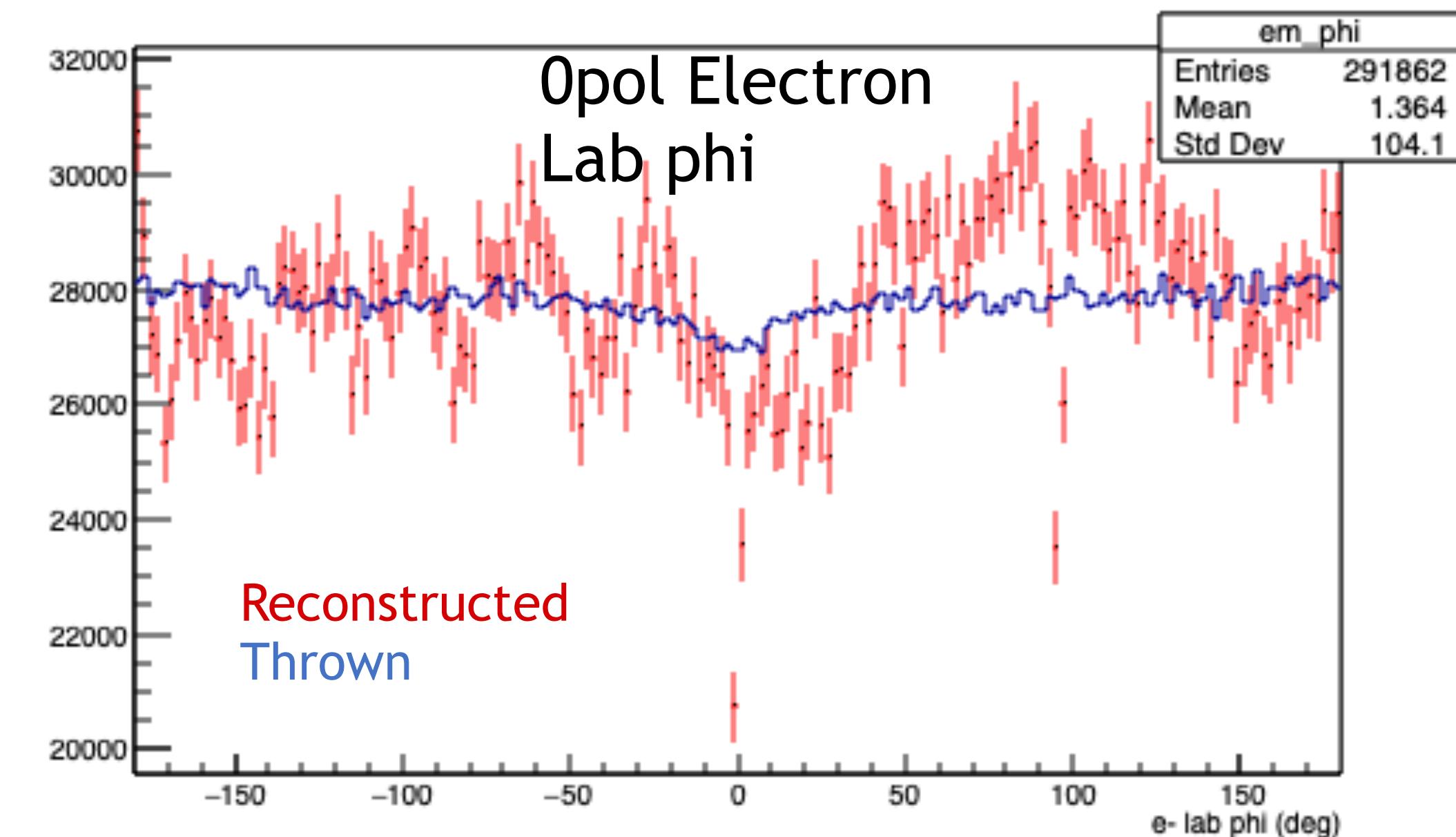
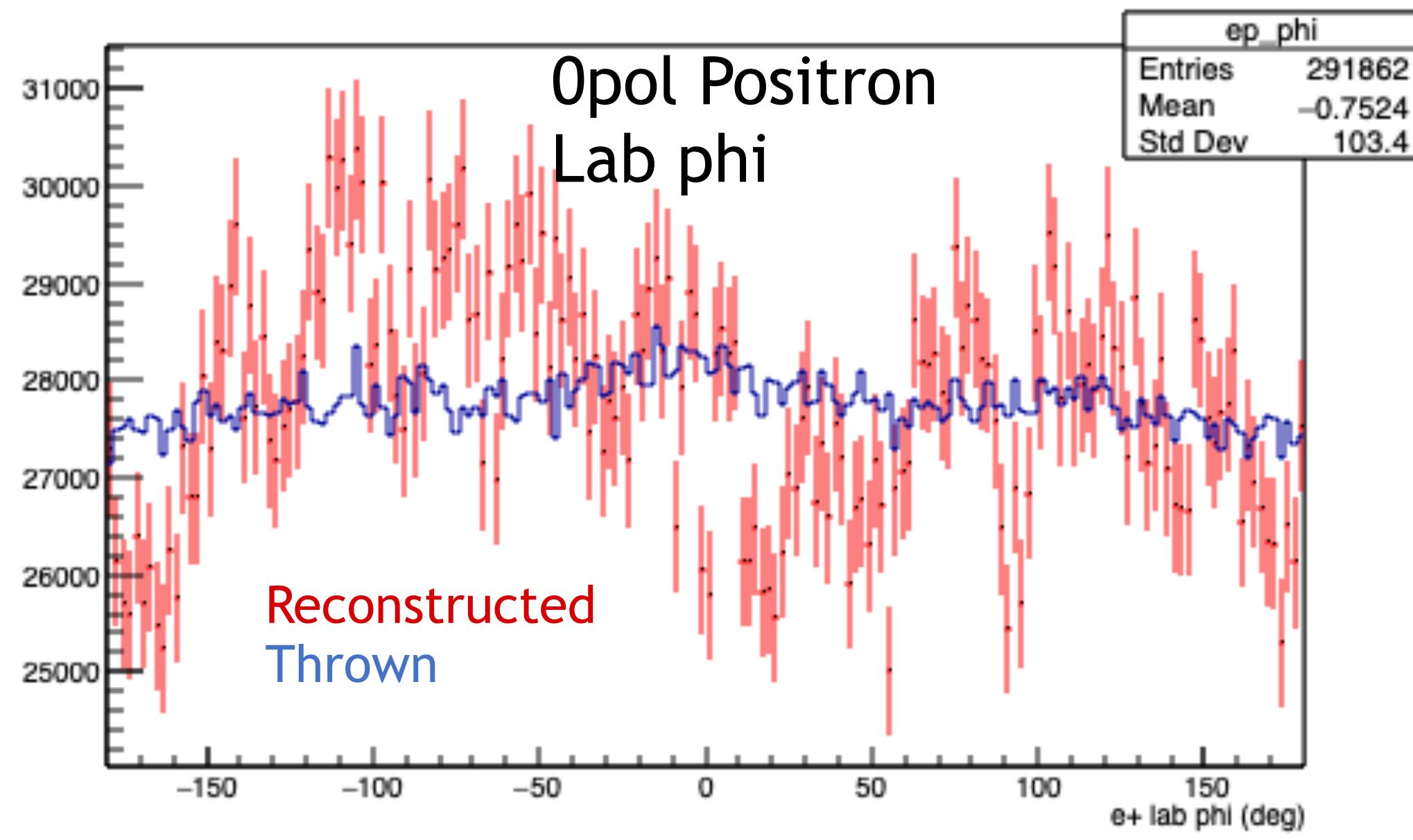
100% pol
phi of JT



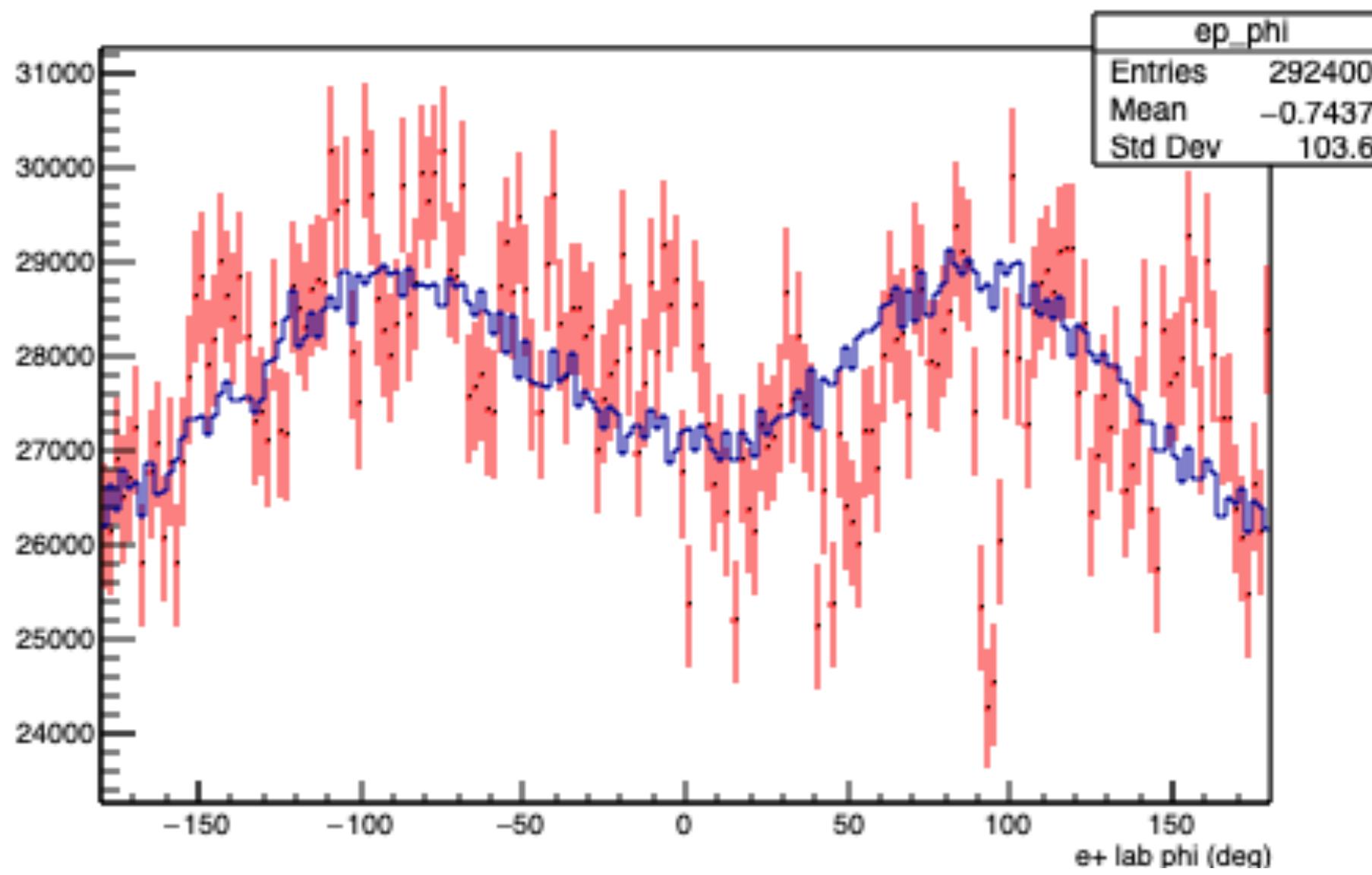
0% pol
phi of JT



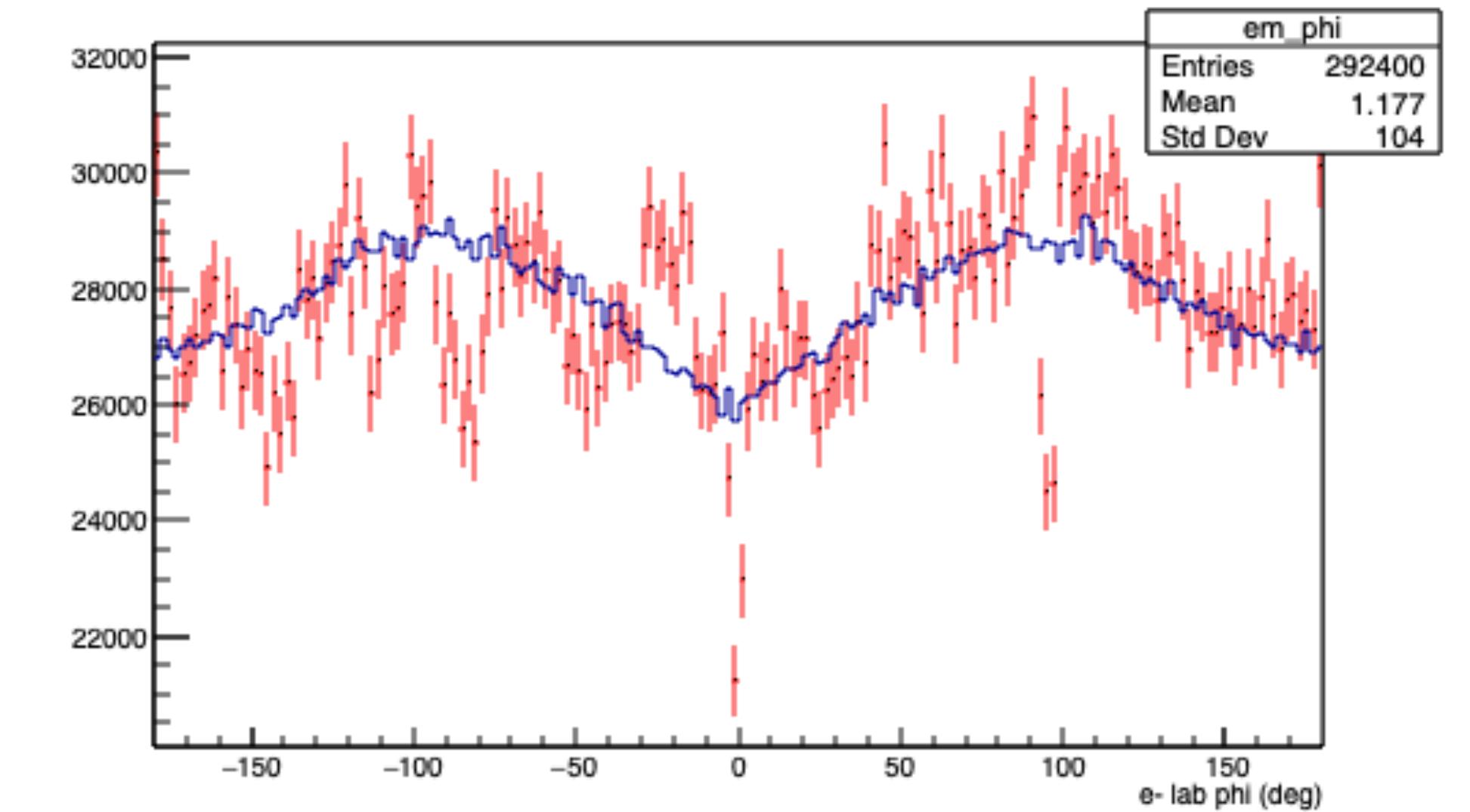




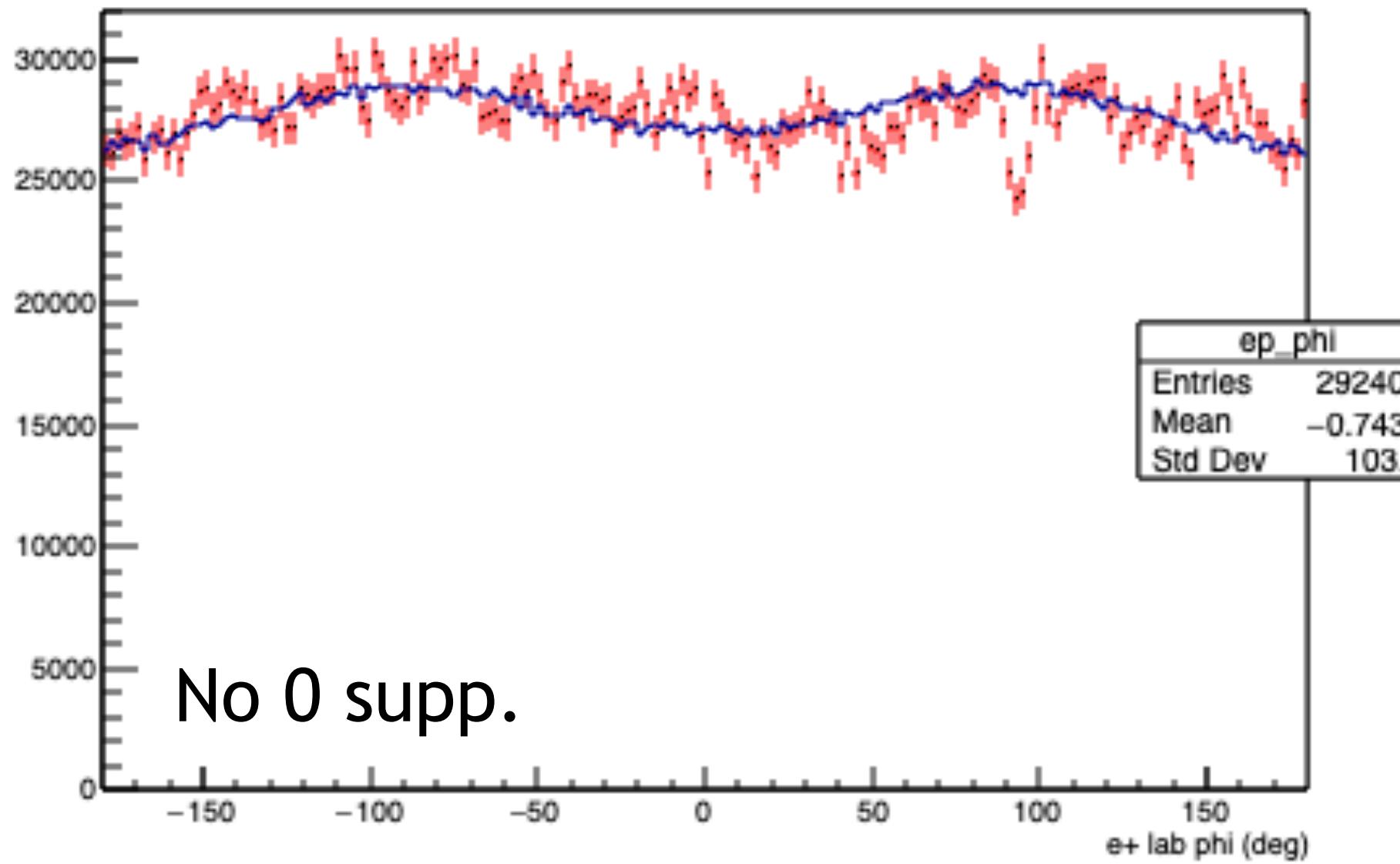
100% pol positron



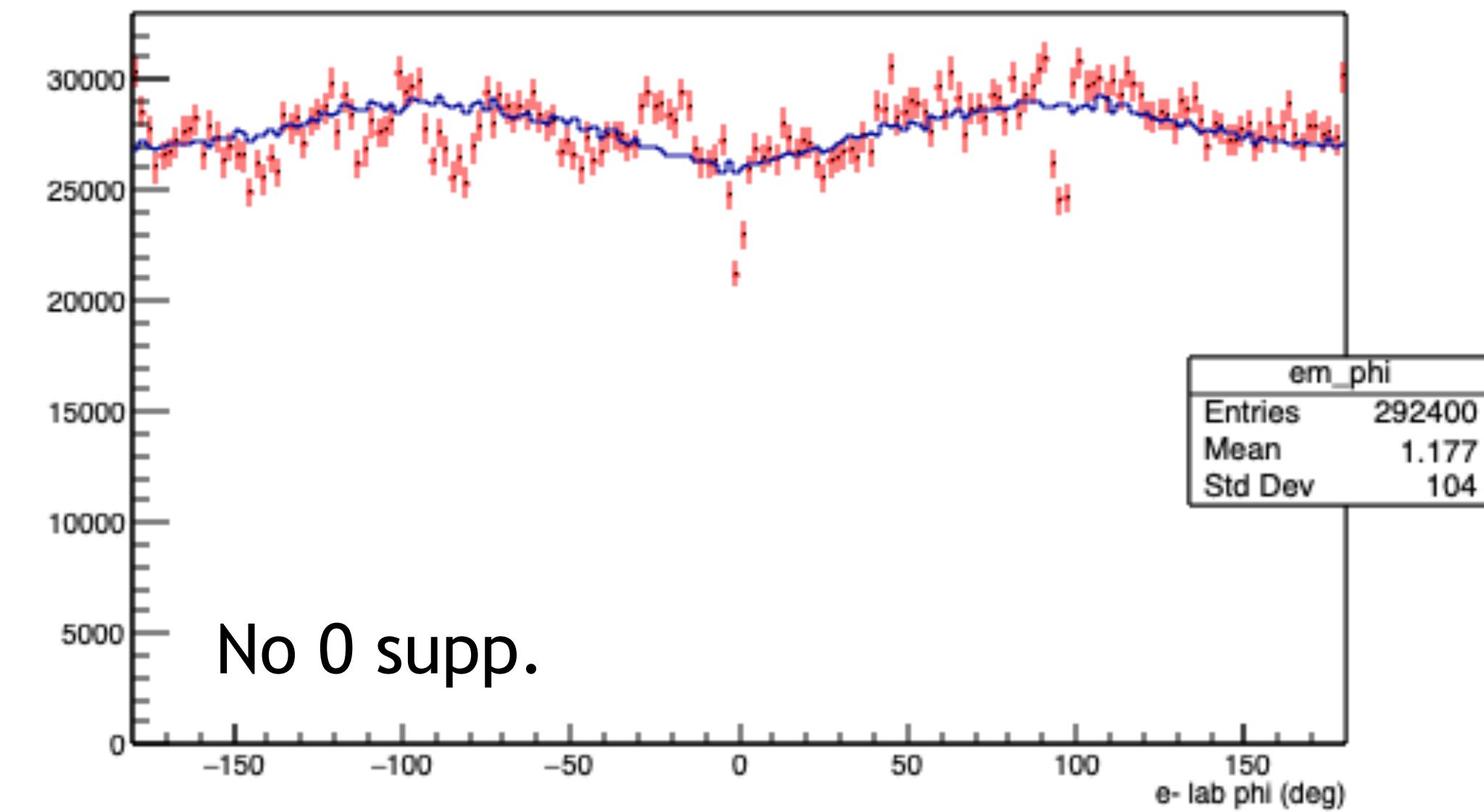
100% pol electron

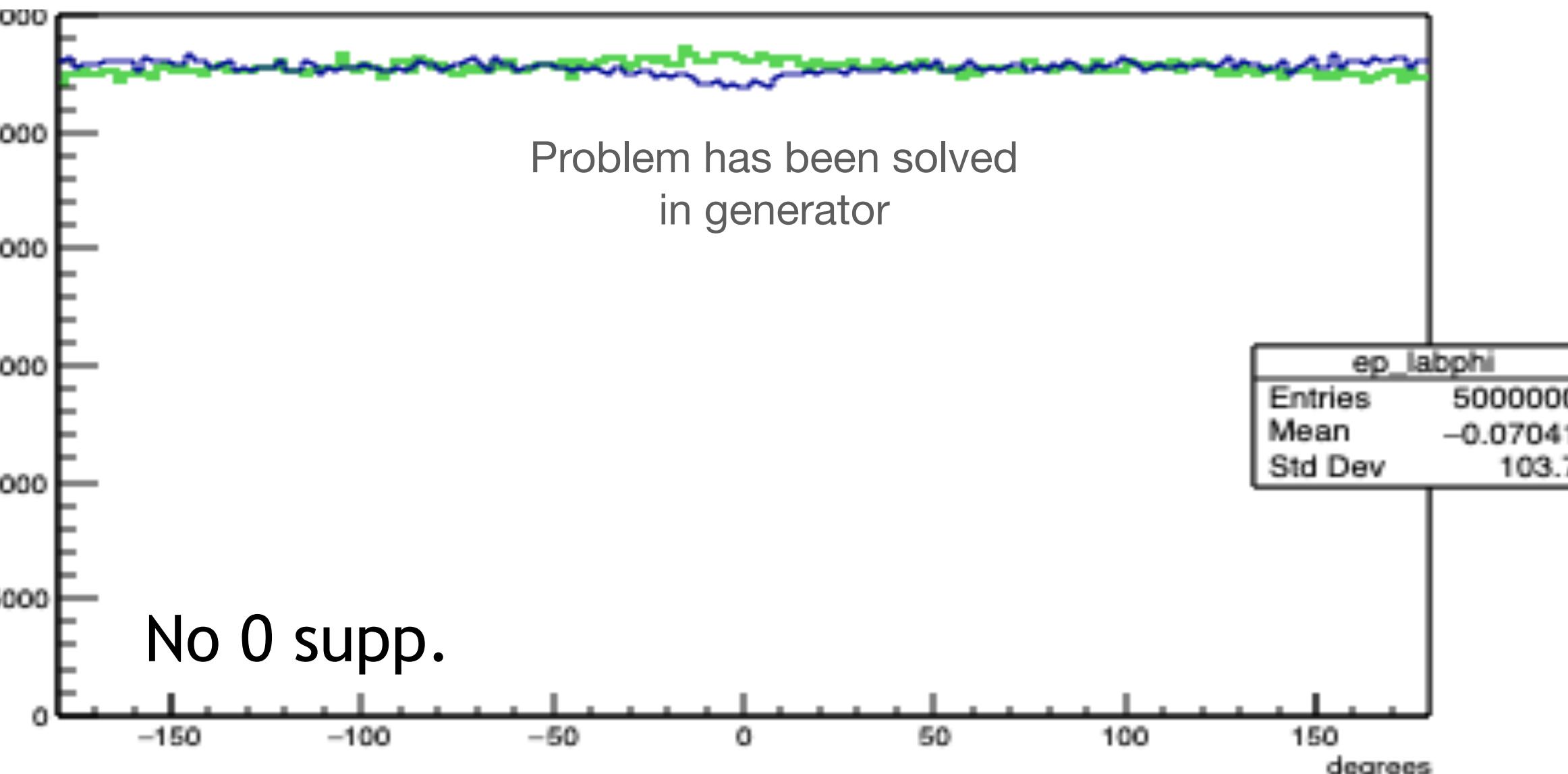
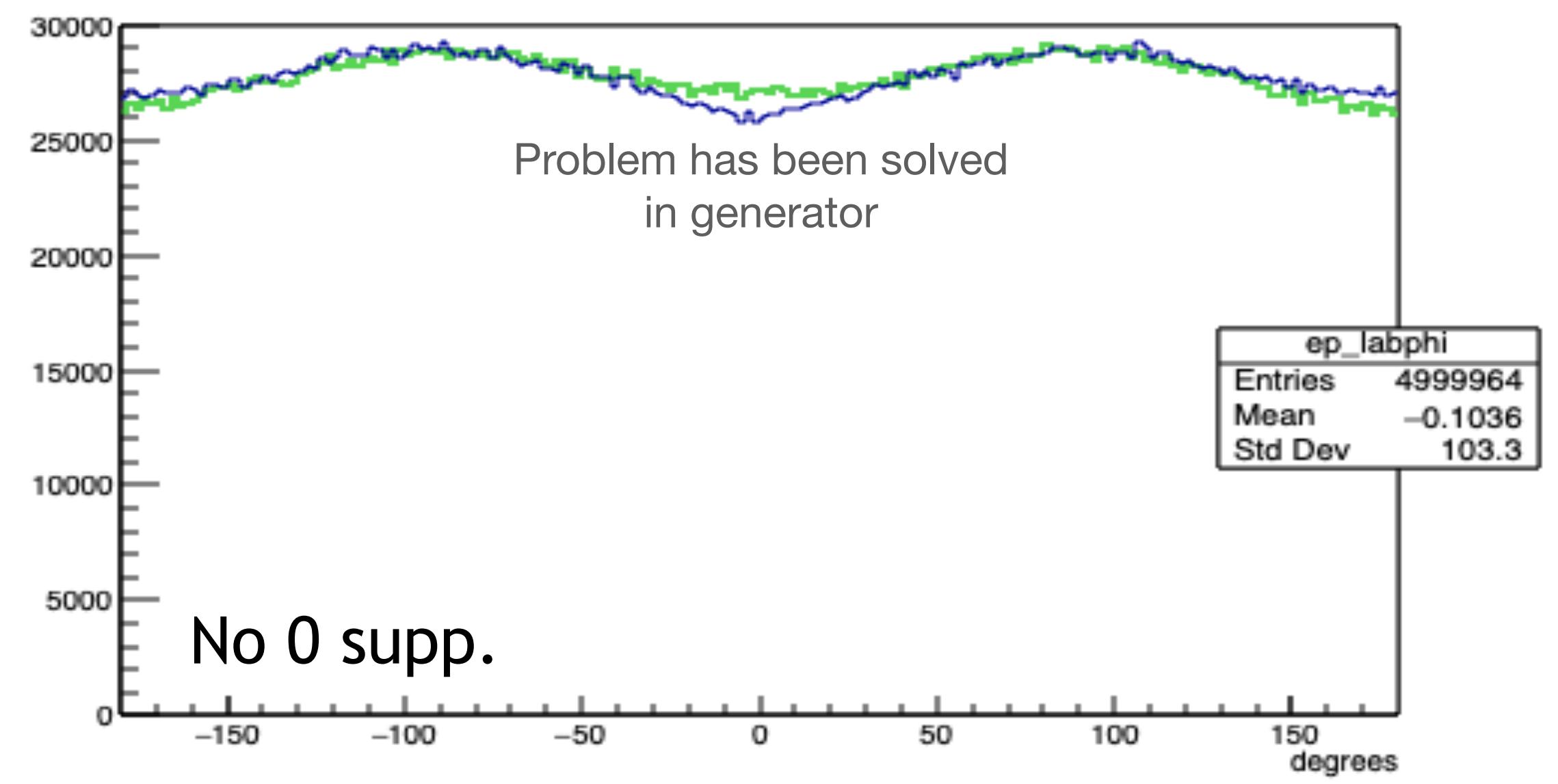
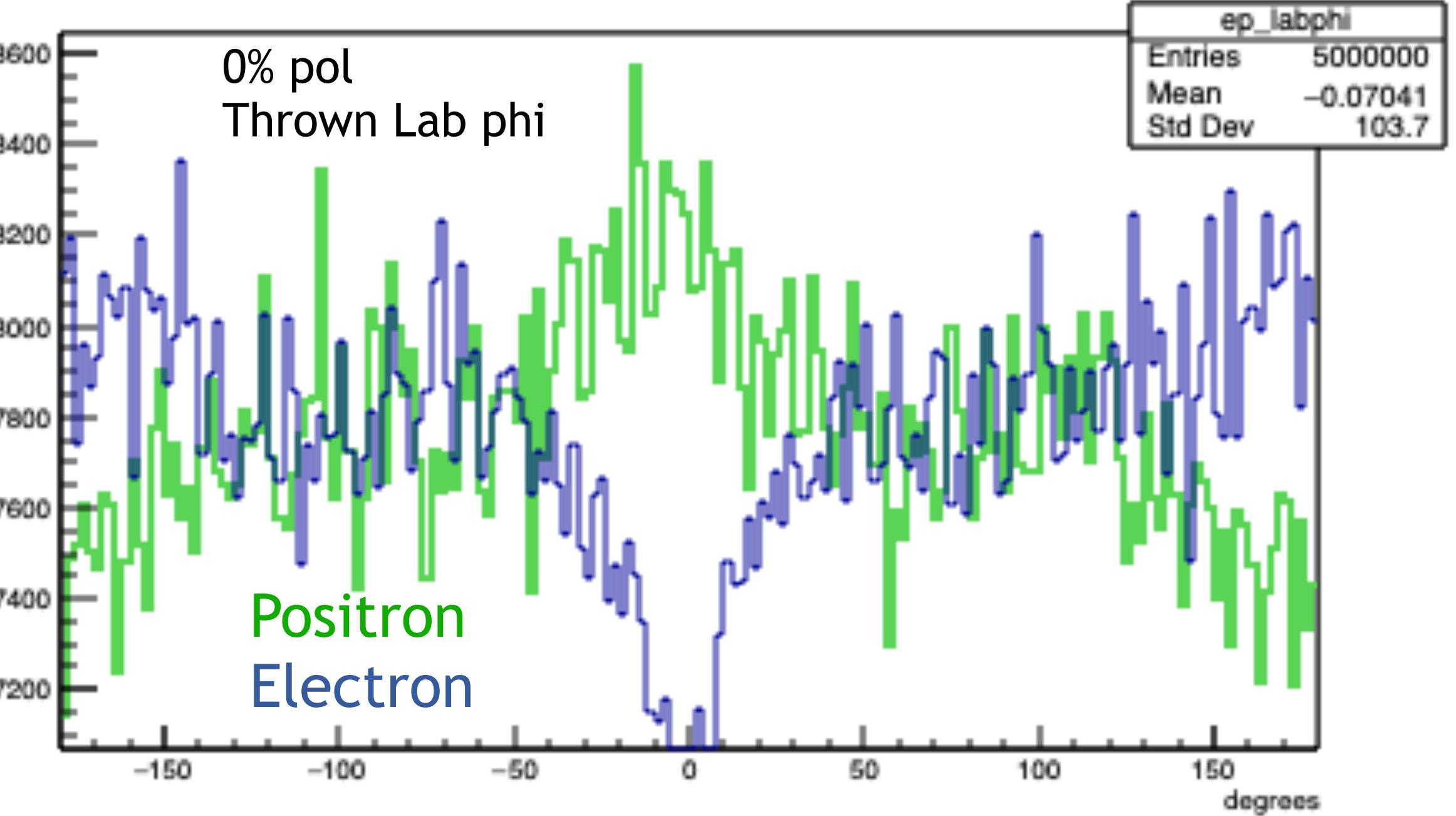
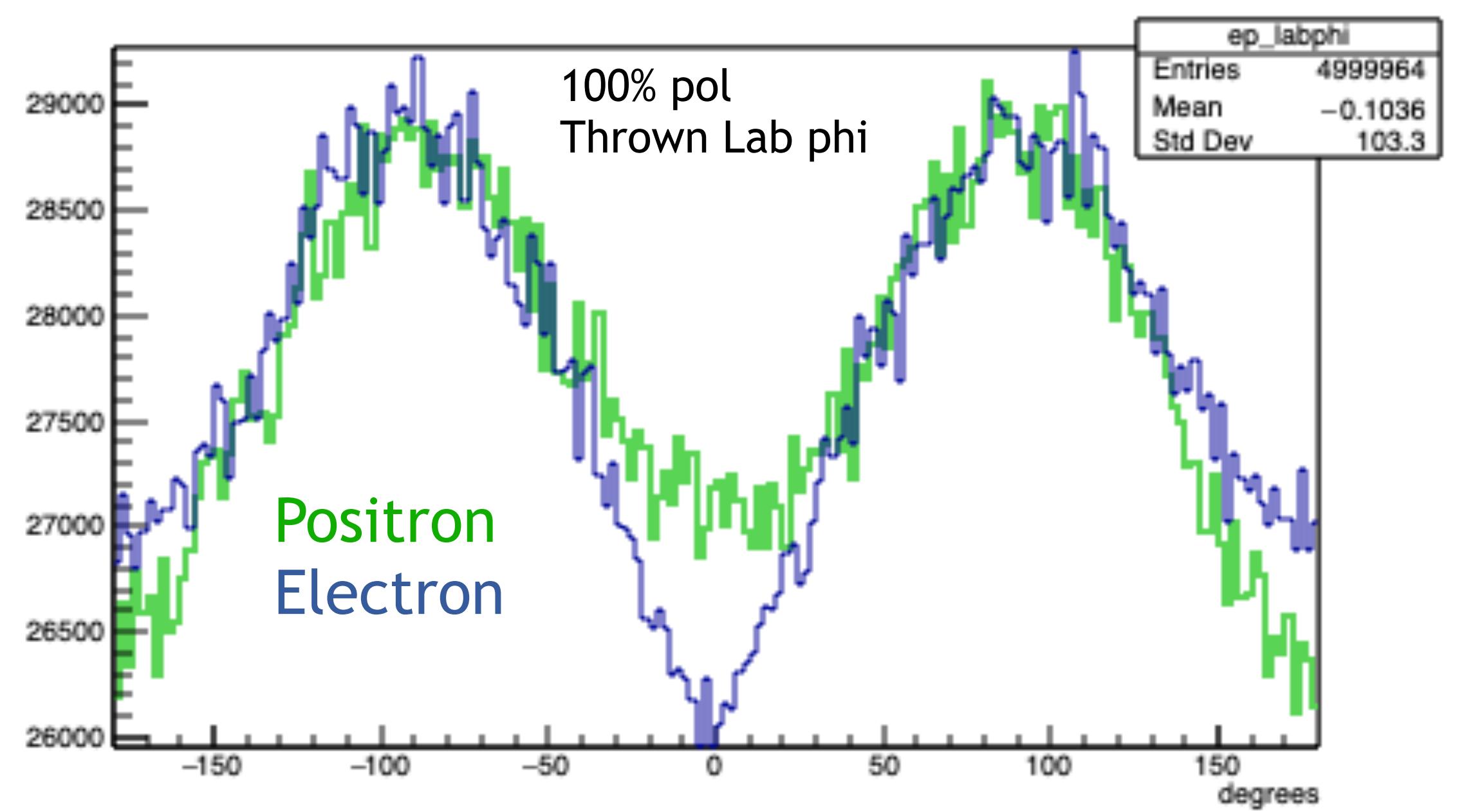


No 0 supp.

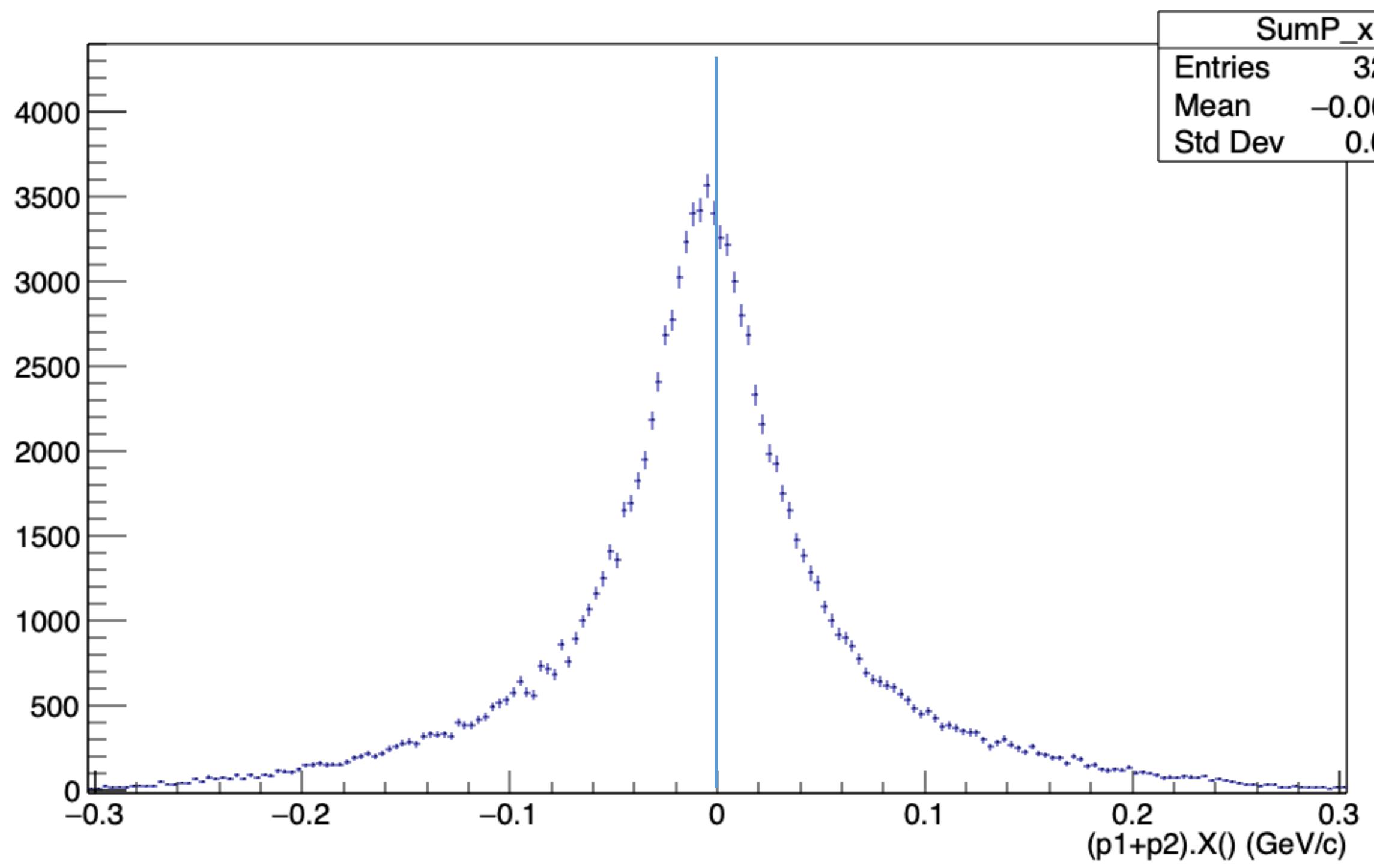


No 0 supp.

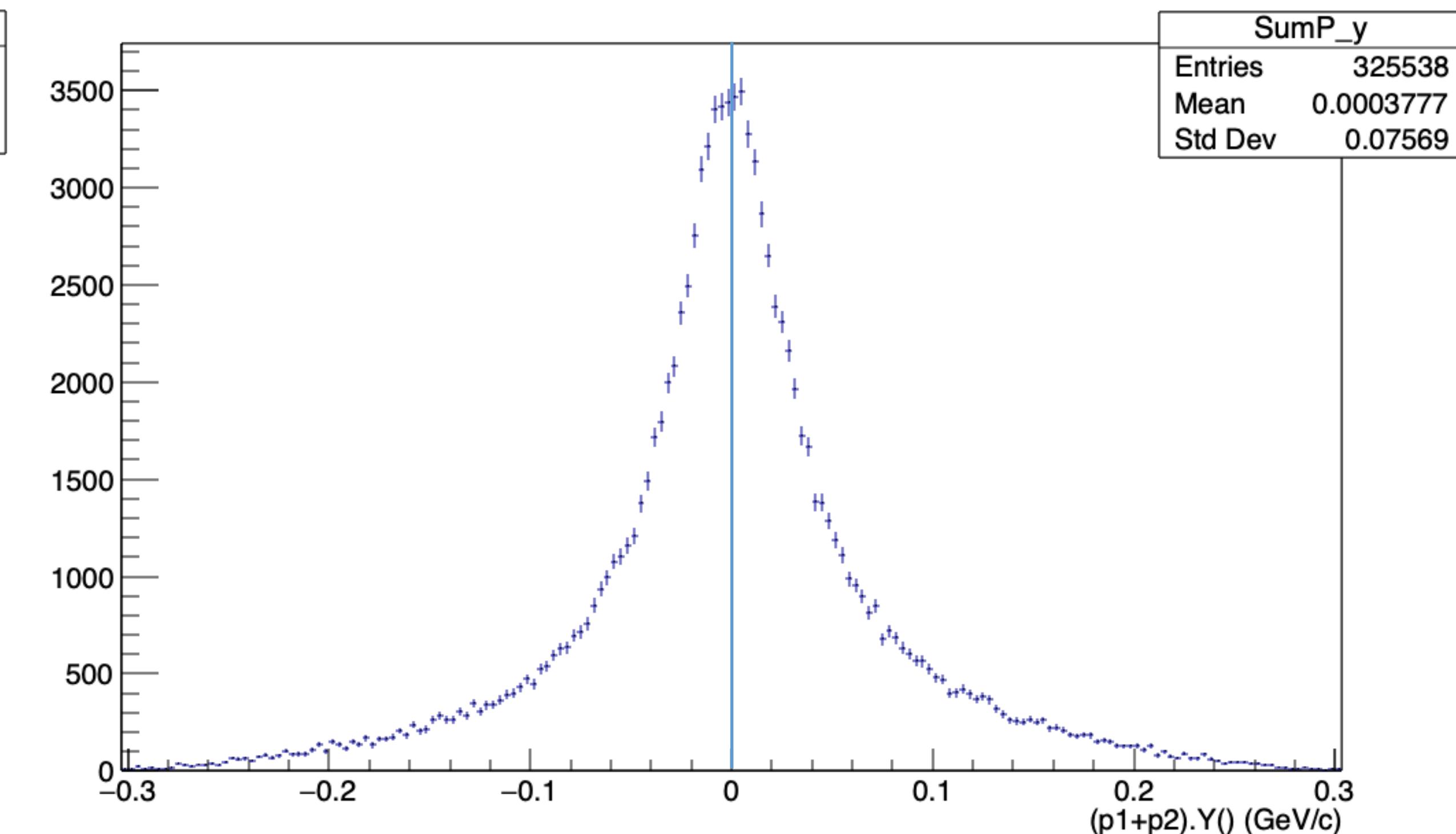




P1 + P2, x component
2018-01 GlueX data

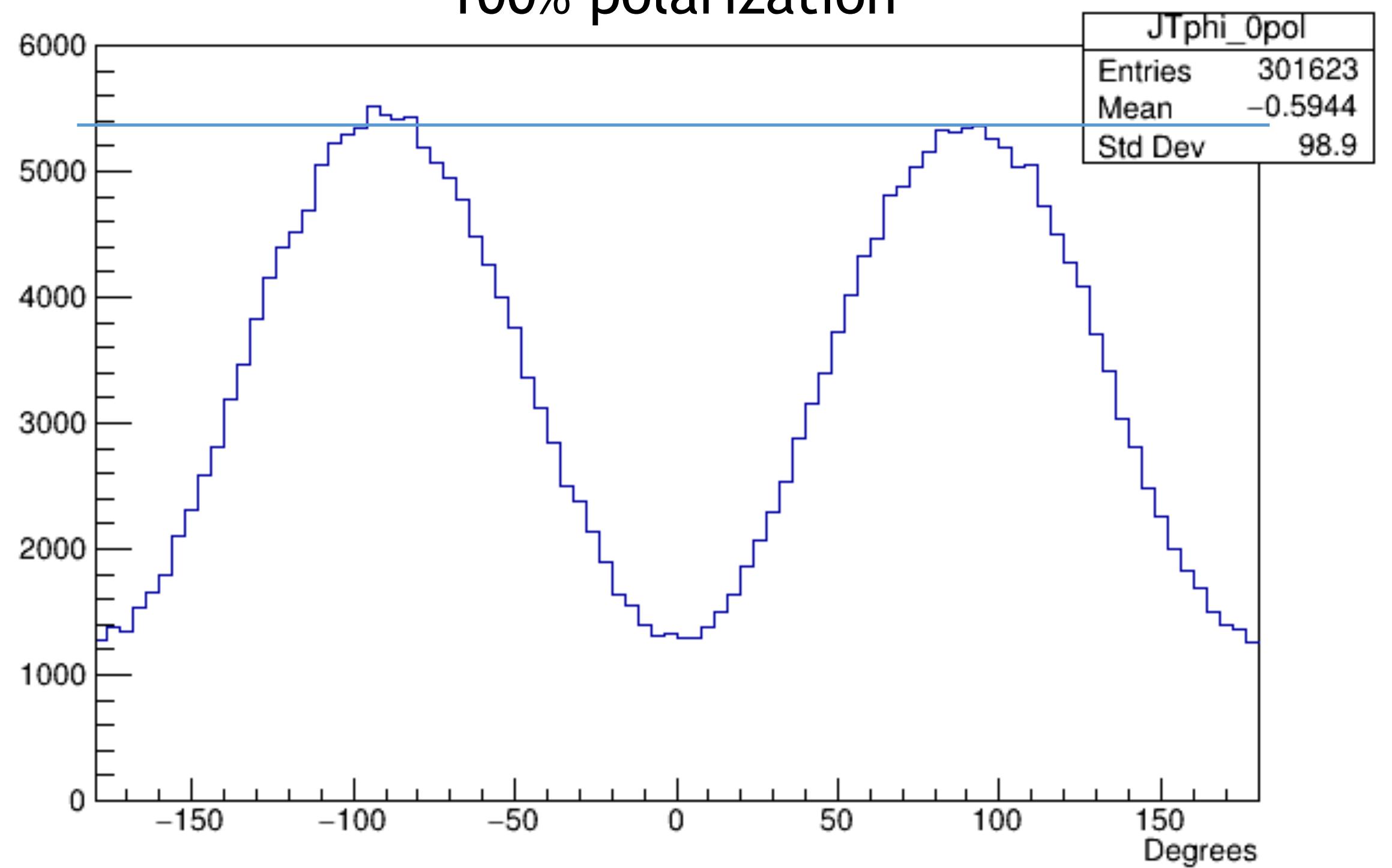


P1 + P2, y component
2018-01 GlueX data

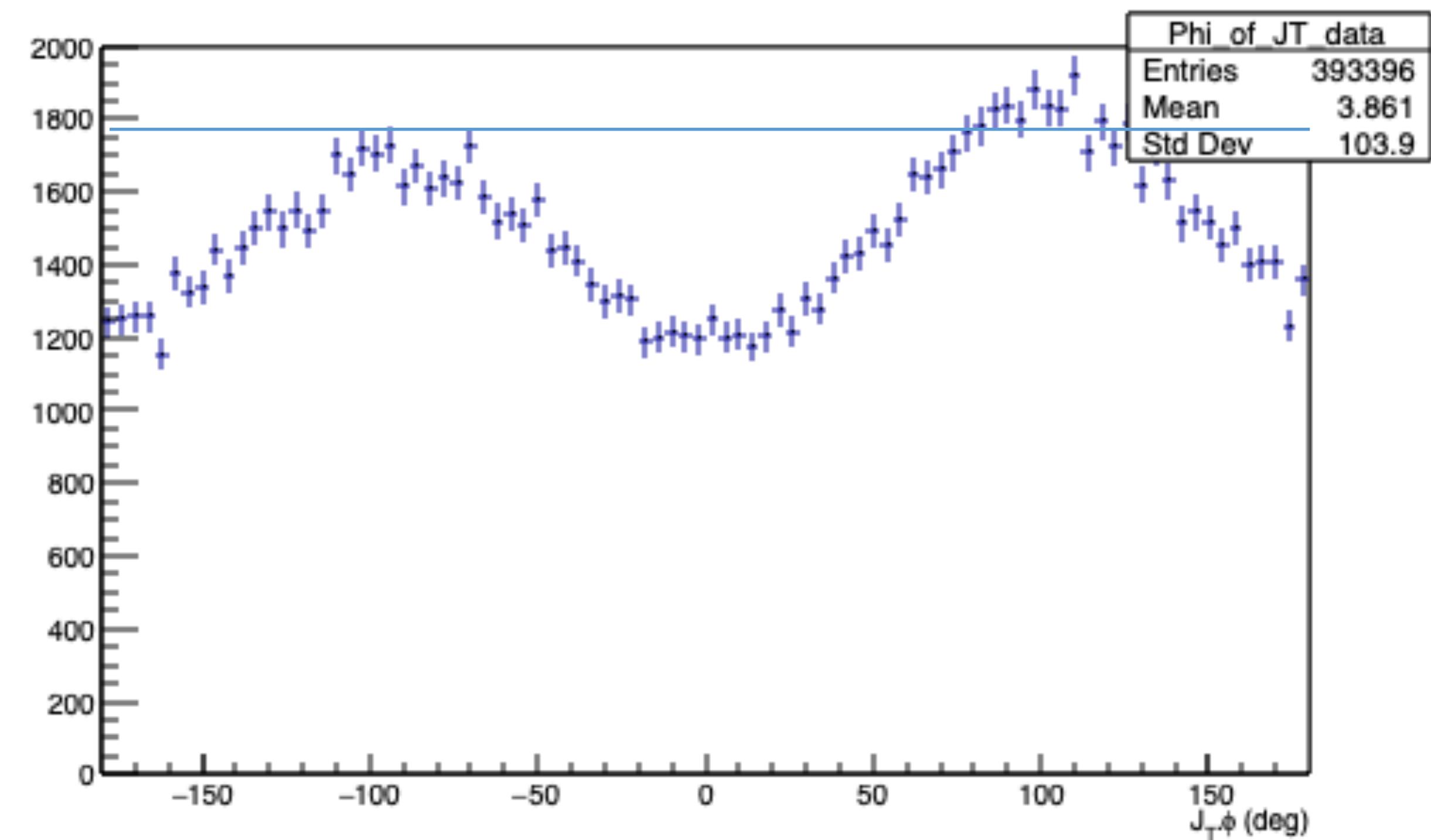


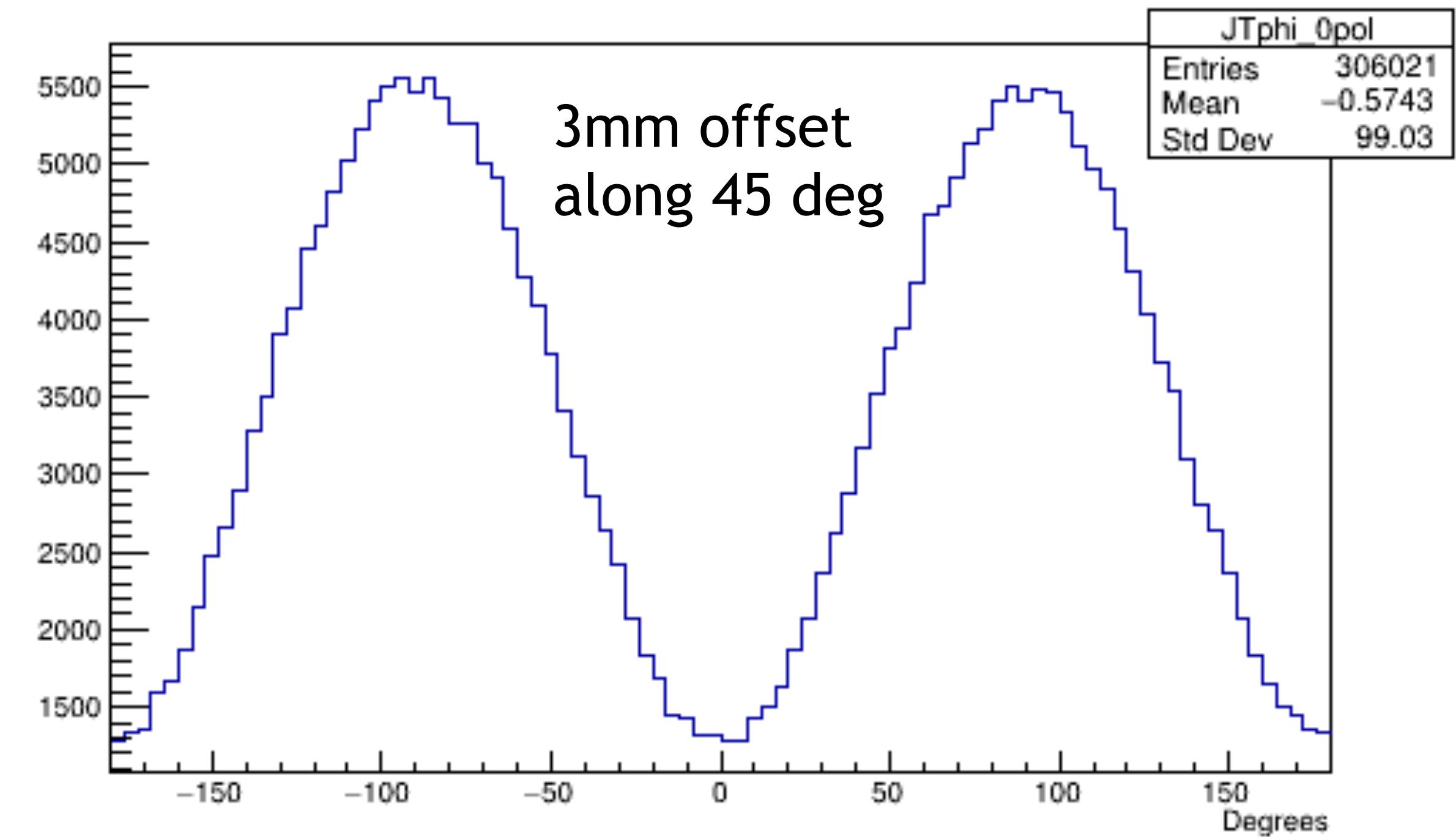
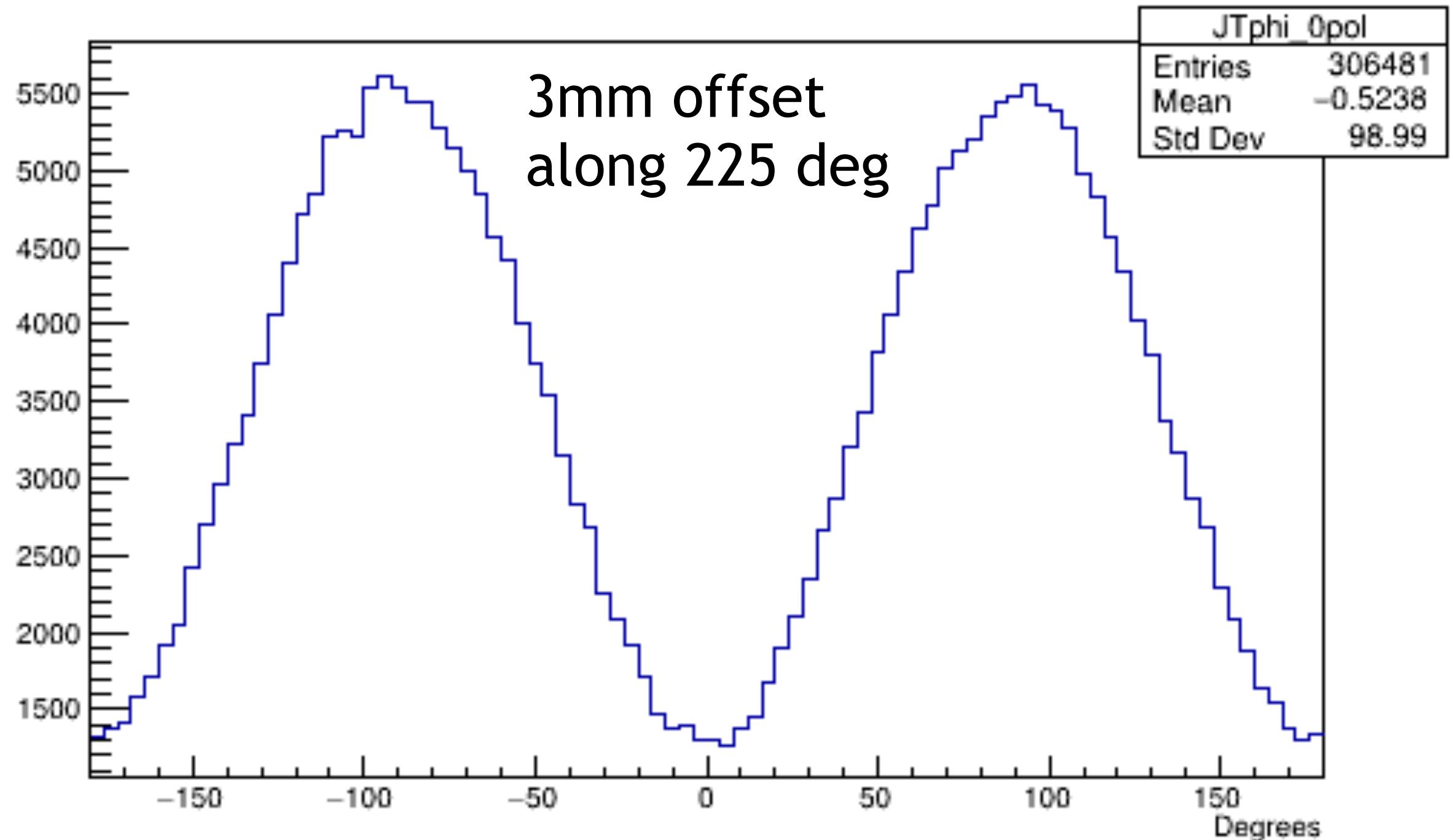
RUNNING SIMULATION WITH THE ELECTRON BEAM OFFSET ON THE COLLIMATOR

SIMULATION WITH ELECTRON BEAM OFFSET
ON COLLIMATOR 1mm along 45 deg
100% polarization



2018-01 DATA
0 deg orientation runs





Does not produce an asymmetry