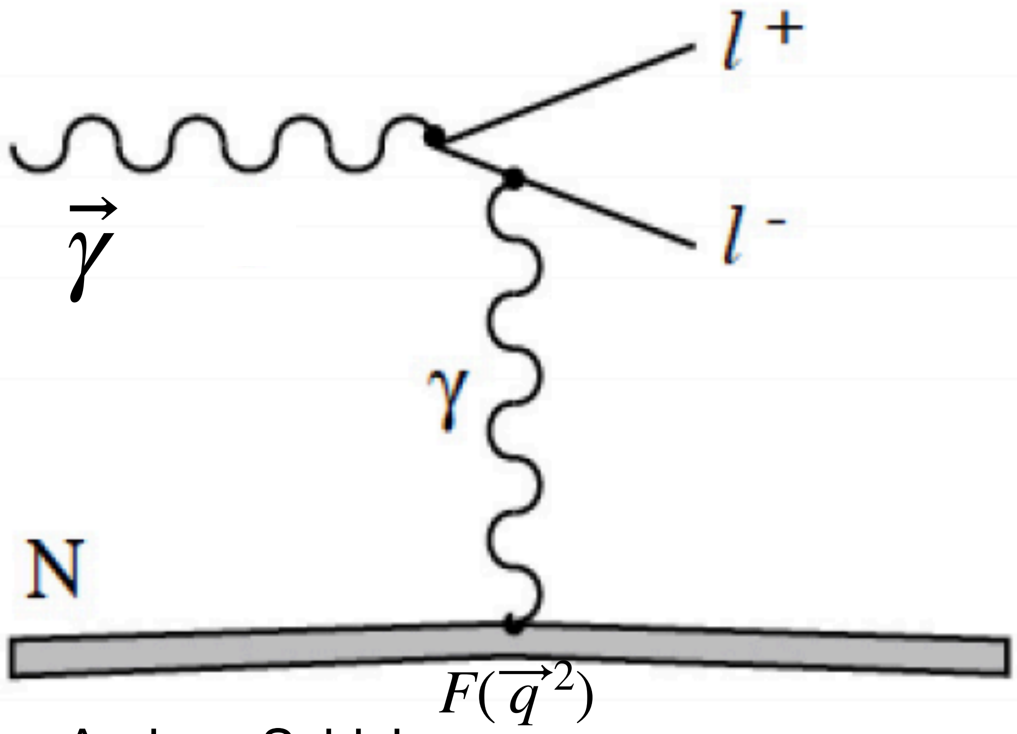
University *of* Massachusetts Amherst

MENP

Yield Asymmetry in Bethe-Heitler Study

$$\gamma \mathrm{p} \rightarrow e^+ e^- (\mathrm{p})$$



Andrew Schick

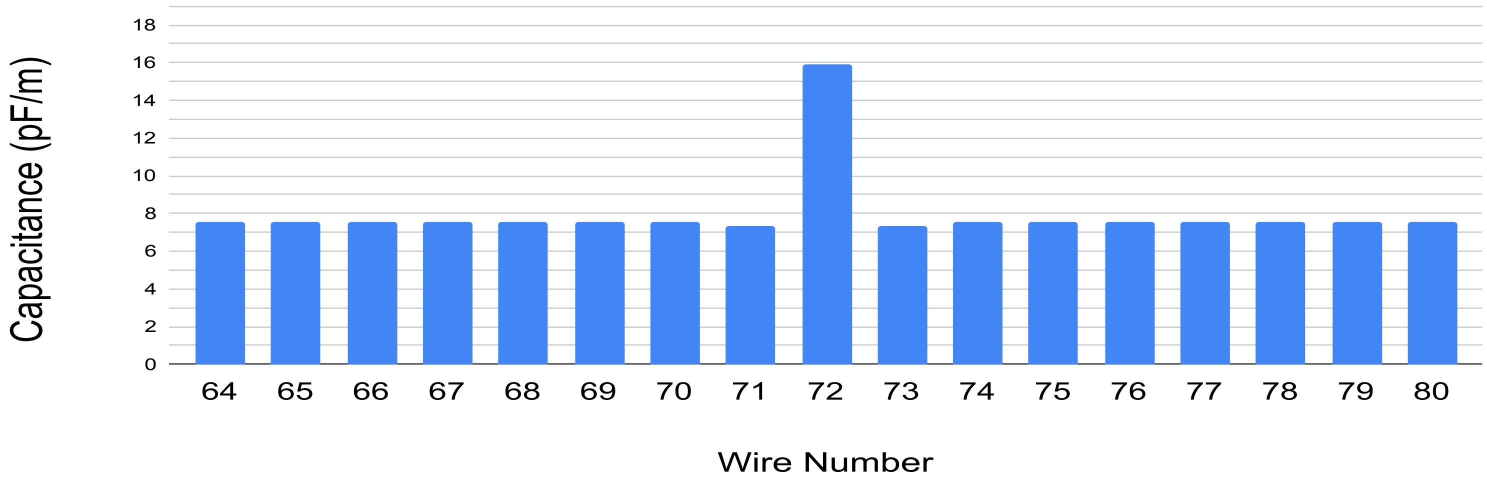
Wednesday, October 8 2019

Overview of Slides

- Quick Garfield update from 2 weeks ago
- TOF issue
- Objective 2: Using BH pairs as a polarimeter
- Objective 3: Towards a proton charge radius measurement
- Missing Mass squared data and MC comparison

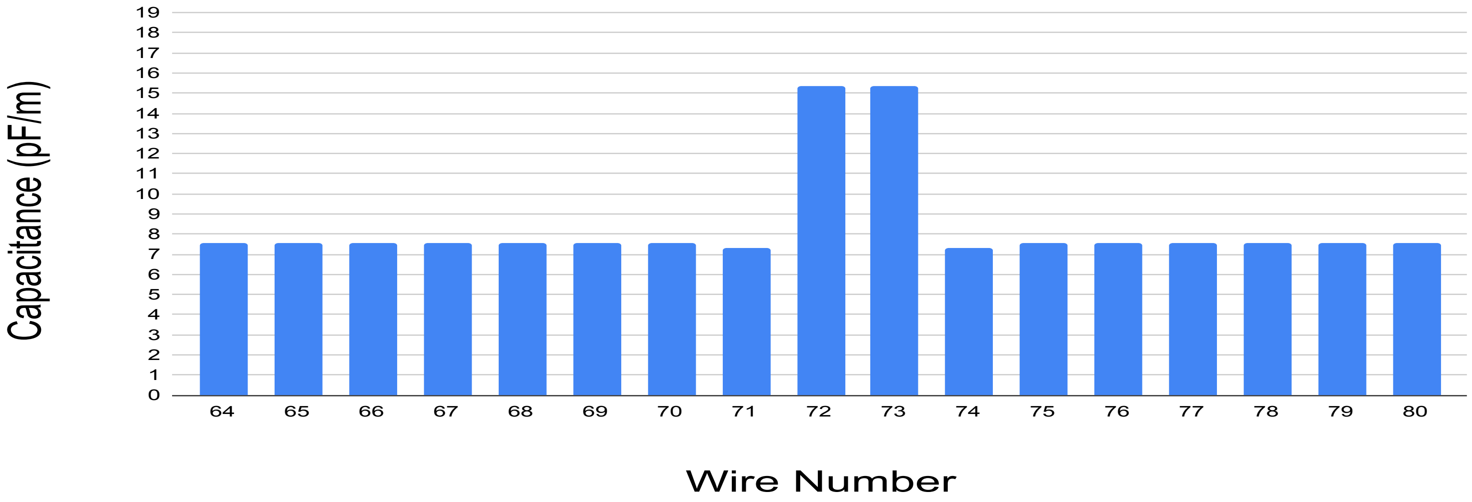
Capacitance vs Wire Number

1 Carbon Tube



Capacitance vs Wire Number

2 Carbon Tubes



Objectives of the BH Analysis:

1. Use Bethe-Heitler pair production for verification of normalization in the Charged Pion Polarizability experiment.

2. Extract the polarization signal of the BH pairs. *Measure the yield asymmetry.*

3. Measure the form factor/charge radius of the proton.

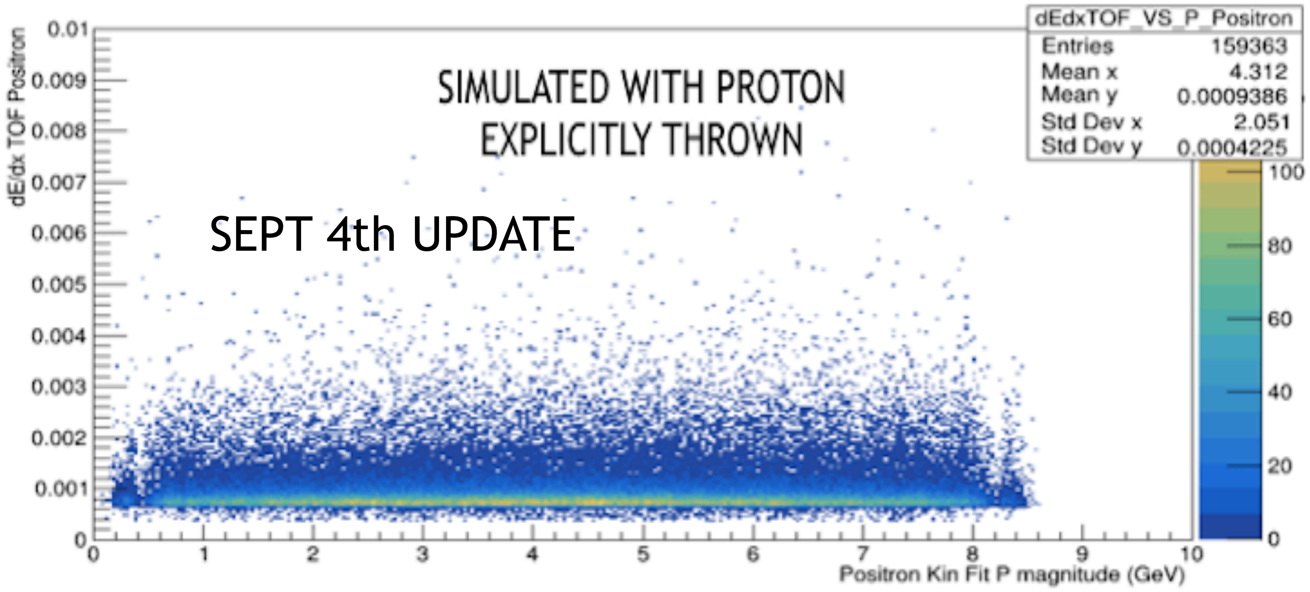
Cuts for γp $\rightarrow e^+e^-$(p)

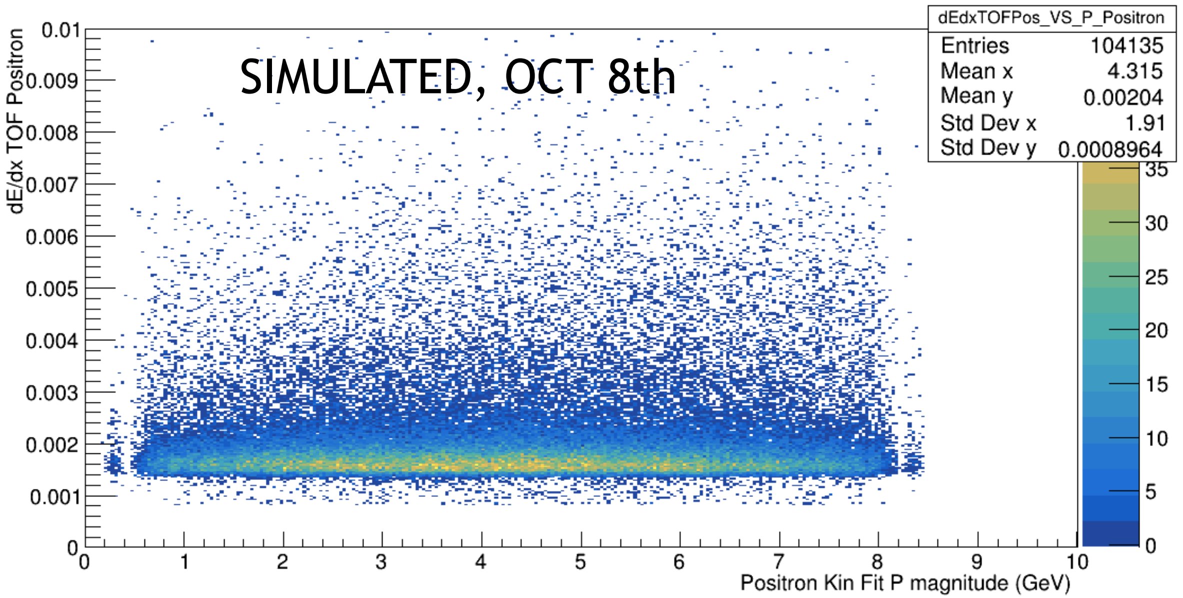
Preselection Cuts

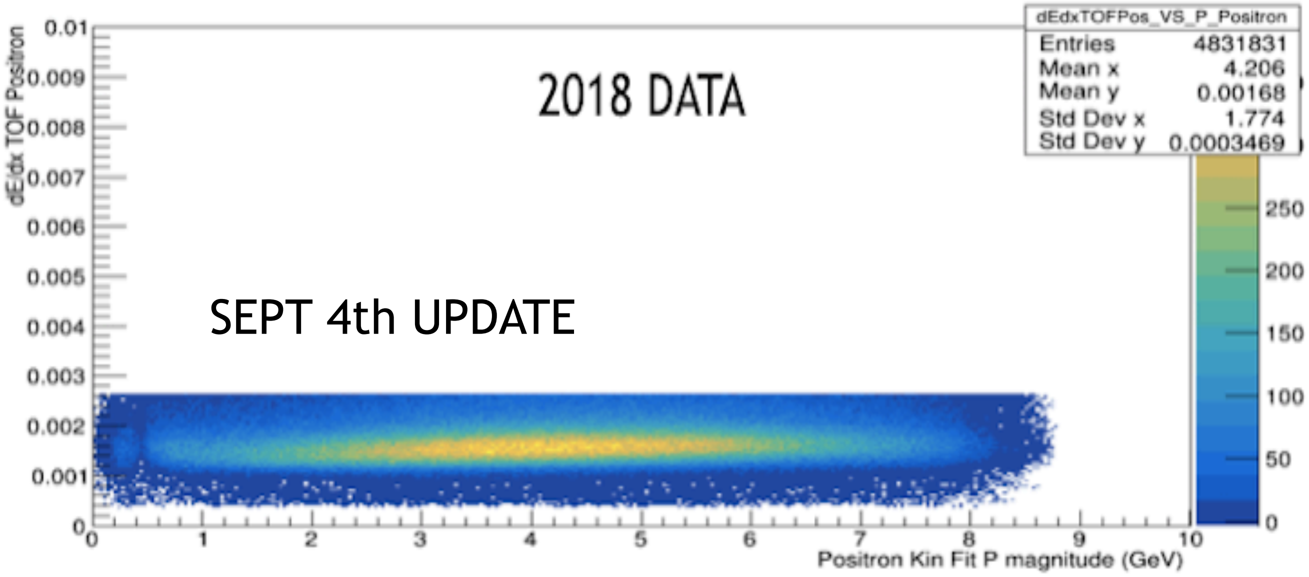
1. Default GlueX cuts: https://halldweb.jlab.org/wiki/index.php/Spring_2017_Analysis_Launch_Cuts
2. Require E/p > 0.7 for electron and positron tracks in FCAL and BCAL

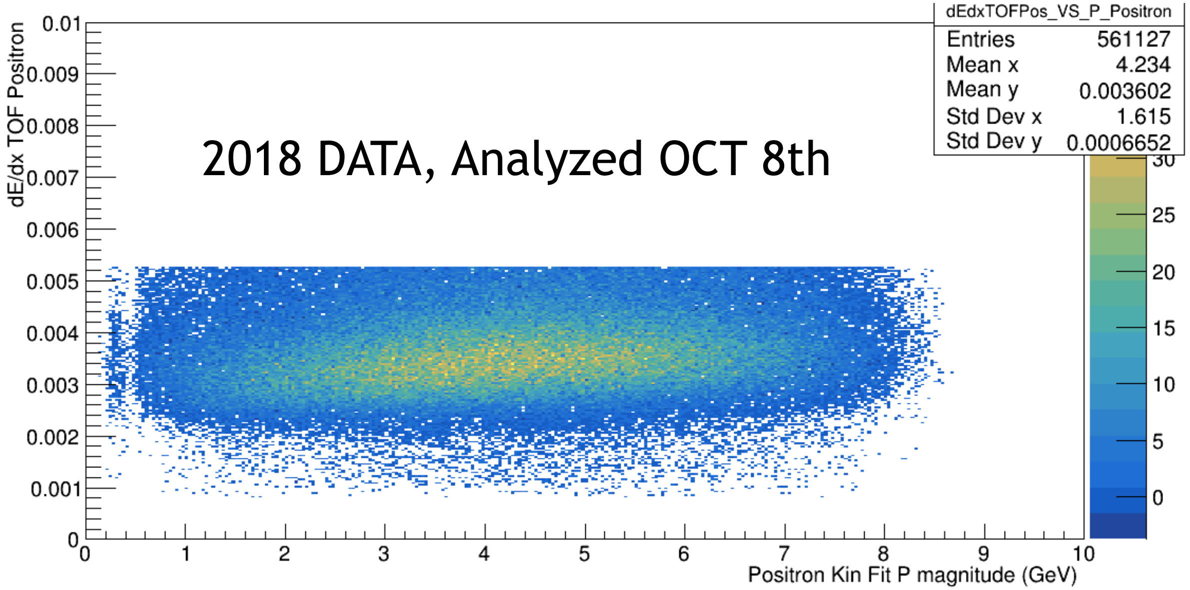
DSelector Cuts

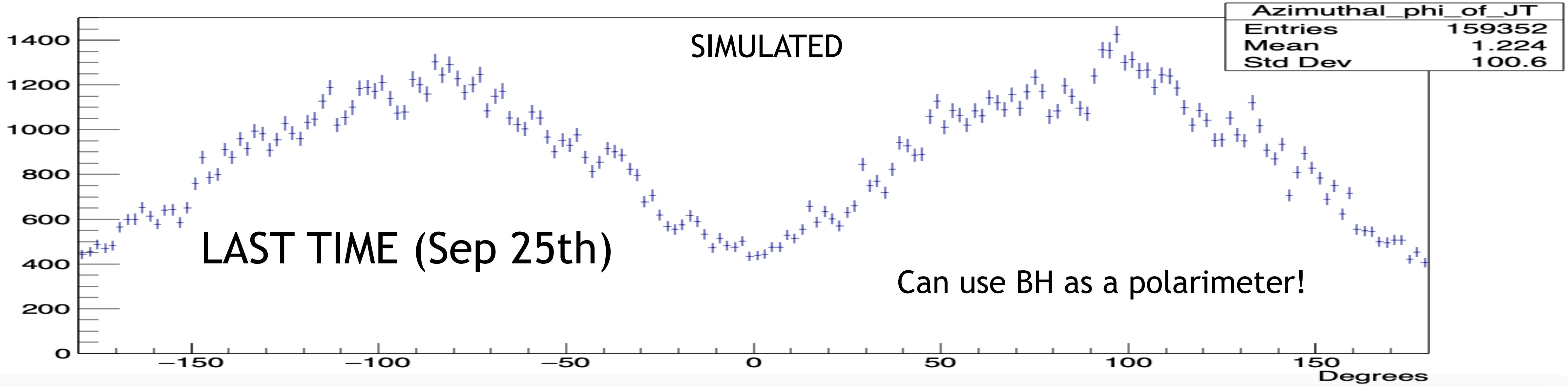
1. Cut on coherent peak: 8.12 < Eγ < 8.88
2. Require both electron and positron tracks have hit in FCAL
3. Require both electron and positron tracks have hit in TOF
4. Require dMinKinFitCL > 10E-6
5. Eliminate events with NumUnusedTracks ≥ 2, (Split up data into 1 unused and 0 unused.) Today we are only looking at **0 unused track events.**
6. Eliminate events with Energy_UnusedShowers > 0
7. TOF dE/dx cut for electron and positron tracks at 3σ
8. FCAL DOCA cut for e+ and e- tracks at 3σ
9. **Cut on** $\frac{E_1}{p_1}$ **and** $\frac{E_2}{P_2}$ **at** $\pm 3\sigma$

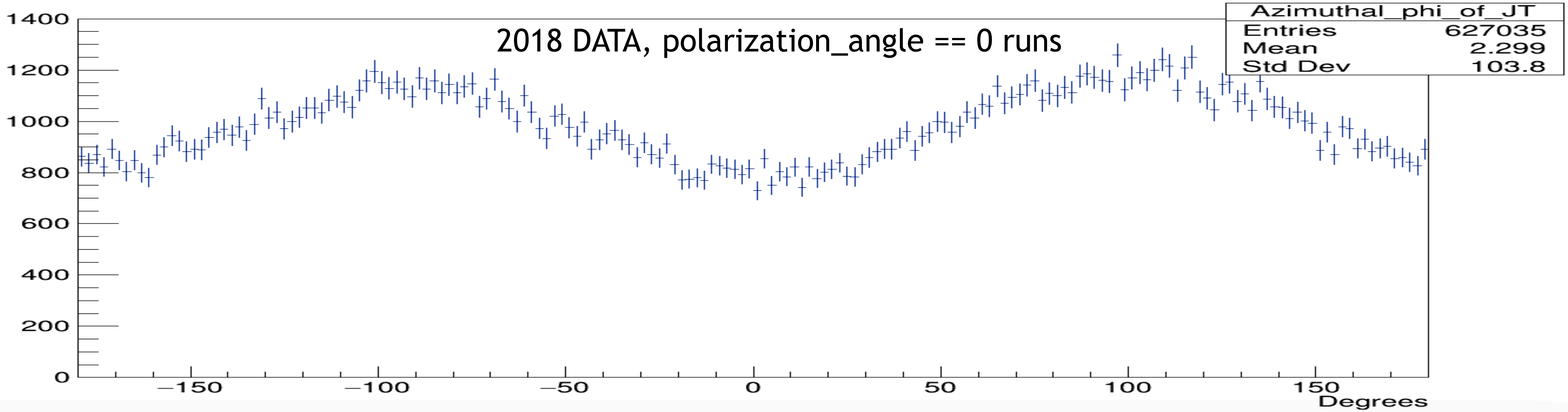

dEdxTOF_VS_P_Positron
Entries 159363
Mean x 4.312
Mean y 0.0009386
Std Dev x 2.051
Std Dev y 0.0004225
SIMULATED WITH PROTON EXPLICITLY THROWN
SEPT 4th UPDATE
dE/dx TOF Positron
Positron Kin Fit P magnitude (GeV)


dEdxTOFPos_VS_P_Positron
Entries 104135
Mean x 4.315
Mean y 0.00204
Std Dev x 1.91
Std Dev y 0.0008964
SIMULATED, OCT 8th
dE/dx TOF Positron
Positron Kin Fit P magnitude (GeV)


dEdxTOFPos_VS_P_Positron
Entries 4831831
Mean x 4.206
Mean y 0.00168
Std Dev x 1.774
Std Dev y 0.0003469
2018 DATA
SEPT 4th UPDATE
dE/dx TOF Positron
Positron Kin Fit P magnitude (GeV)

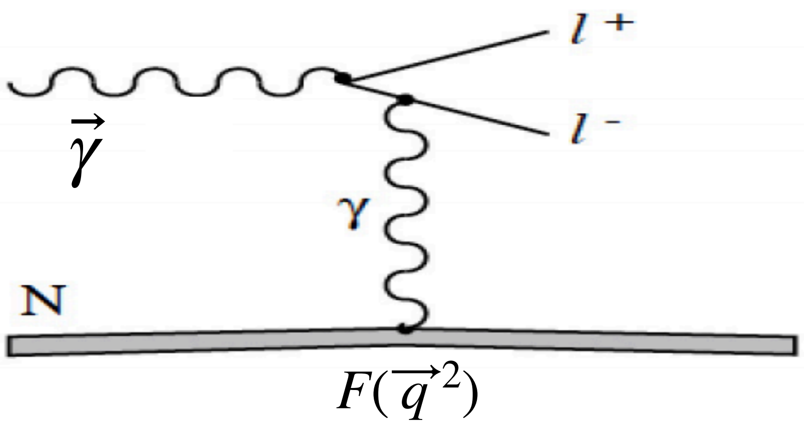

dEdxTOFPos_VS_P_Positron
Entries 561127
Mean x 4.234
Mean y 0.003602
Std Dev x 1.615
Std Dev y 0.0006652
2018 DATA, Analyzed OCT 8th
dE/dx TOF Positron
Positron Kin Fit P magnitude (GeV)


Azimuthal_phi_of_JT
Entries 159352
Mean 1.224
Std Dev 100.6
SIMULATED
LAST TIME (Sep 25th)
Can use BH as a polarimeter!
Degrees


Azimuthal_phi_of_JT
Entries 627035
Mean 2.299
Std Dev 103.8
2018 DATA, polarization_angle == 0 runs
Degrees

OBJECTIVES

2. Use BH pairs as a polarimeter.



$\vec{p}_{t\,1}$ and $\vec{p}_{t\,2}$ are the transverse momenta of the leptons.

$P_\gamma =$ photon polarization; $x =$ energy fraction carried by e^+

$$\frac{d\sigma_B^c}{dx\, d^2\vec{p}_{t\,1}\, d^2\vec{p}_{t\,2}} = \frac{2\alpha^3 Z^2 \omega^4 x^2 (1-x)^2}{\pi^2 (\vec{q}^{\,2})^2} \times [W_{\text{unp}} + P_\gamma W_{\text{pol}} \cos(2\phi)] \times | F_{\text{nuclear}}(\vec{q}^{\,2}) - F_{\text{atomic}}(\vec{q}^{\,2}) |^2$$

$$W_{\text{unp}} = [x^2 + (1-x)^2] | \vec{J}_T |^2 + m^2 | J_S |^2 ; \qquad W_{\text{pol}} = -2x(1-x) | \vec{J}_T |^2$$

$$J_S = \frac{1}{\vec{p}_{t\,1}^{\,2} + m^2} - \frac{1}{\vec{p}_{t\,2}^{\,2} + m^2}; \qquad \vec{J}_T = \frac{\vec{p}_{t\,1}}{p_{t1}^2 + m^2} + \frac{\vec{p}_{t\,2}}{p_{t2}^2 + m^2}$$

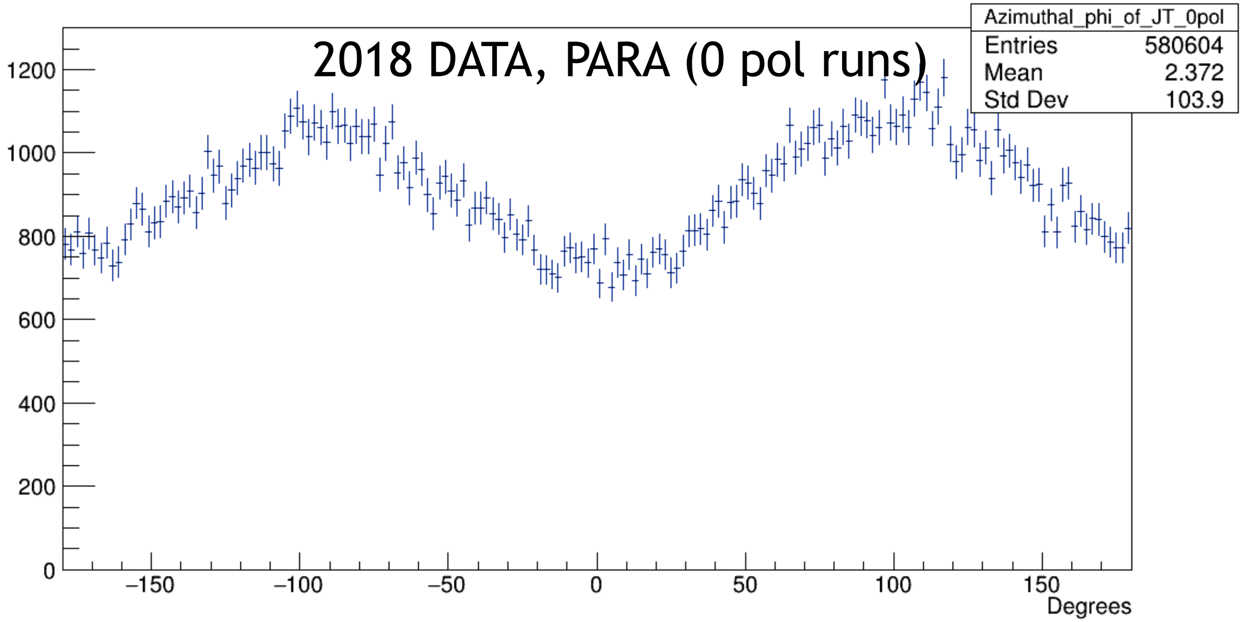
2. Use BH pairs as a polarimeter —> Extract the yield asymmetry

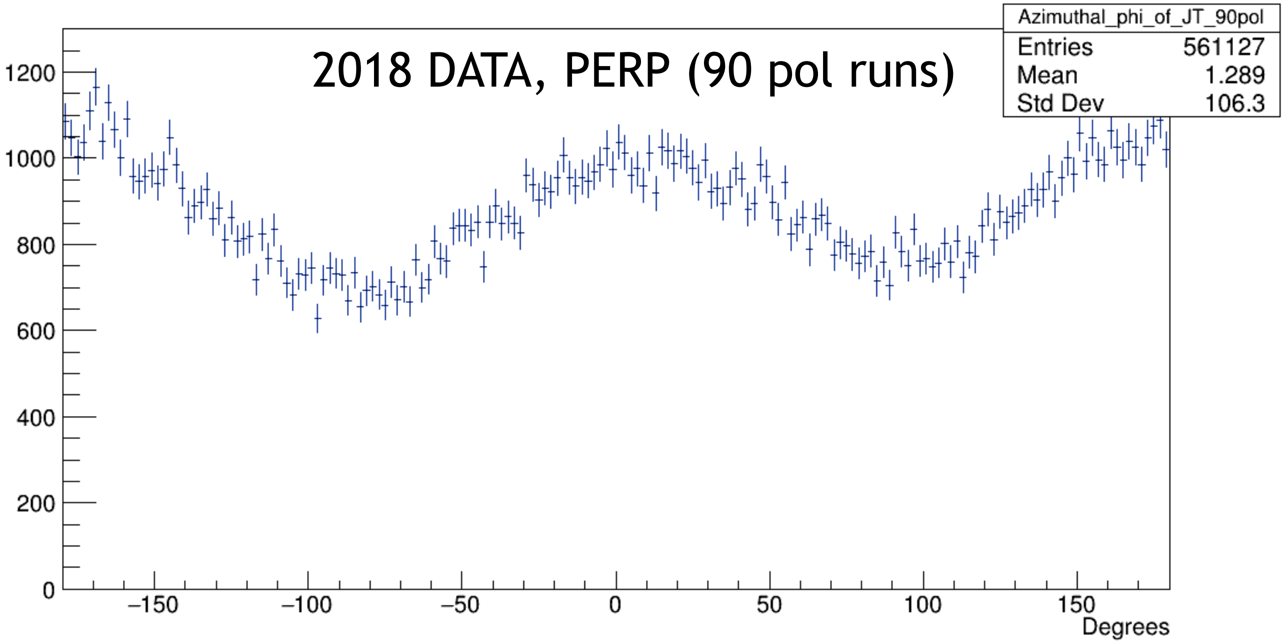
ϕ is angle between the polarization direction and $\vec{J}_T$

$$\vec{J}_T = \frac{\vec{p}_{t1}}{p_{t1}^2 + m^2} + \frac{\vec{p}_{t2}}{p_{t2}^2 + m^2}$$

$$\frac{d\sigma_B^c}{dx\, d^2\vec{p}_{t1}\, d^2\vec{p}_{t2}} = \frac{2\alpha^3 Z^2 \omega^4 x^2 (1-x)^2}{\pi^2 (\vec{q}^{\,2})^2} \times [W_{\mathrm{unp}} + P_\gamma W_{\mathrm{pol}} \cos(2\phi)] \times |F_{\mathrm{nuclear}}(\vec{q}^{\,2}) - F_{\mathrm{atomic}}(\vec{q}^{\,2})|^2$$

PARA and PERP runs are 90 degrees out of phase => $\cos 2(\phi + \pi/2) = -\cos 2\phi$





2. Use BH pairs as a polarimeter —> Extract the yield asymmetry

ϕ is angle between the polarization direction and $\overrightarrow{J}_T$

$$\overrightarrow{J}_T = \frac{\overrightarrow{p}_{t\,1}}{p_{t_1}^2 + m^2} + \frac{\overrightarrow{p}_{t\,2}}{p_{t_2}^2 + m^2}$$

$$\frac{d\sigma_B^c}{dx\, d^2\overrightarrow{p}_{t\,1}\, d^2\overrightarrow{p}_{t\,2}} = \frac{2\alpha^3 Z^2 \omega^4 x^2 (1-x)^2}{\pi^2 (\overrightarrow{q}^{\,2})^2} \times [W_{\rm unp} + P_\gamma W_{\rm pol} \cos(2\phi)] \times |F_{\rm nuclear}(\overrightarrow{q}^{\,2}) - F_{\rm atomic}(\overrightarrow{q}^{\,2})|^2$$

PARA and PERP runs are 90 degrees out of phase => $\cos 2(\phi + \pi/2) = -\cos 2\phi$

$$Y_{||}(\phi) \propto N_{||}[\sigma_0 A(\phi)(1 - P_{||}\Sigma \cos 2\phi)] \qquad Y_{\perp}(\phi) \propto N_{\perp}[\sigma_0 A(\phi)(1 + P_{\perp}\Sigma \cos 2\phi)]$$

2. Use BH pairs as a polarimeter —> Extract the yield asymmetry

ϕ is angle between the polarization direction and $\vec{J}_T$

$$\vec{J}_T = \frac{\vec{p}_{t1}}{p_{t1}^2 + m^2} + \frac{\vec{p}_{t2}}{p_{t2}^2 + m^2}$$

$$\frac{d\sigma_B^c}{dx\, d^2\vec{p}_{t1}\, d^2\vec{p}_{t2}} = \frac{2\alpha^3 Z^2 \omega^4 x^2 (1-x)^2}{\pi^2 (\vec{q}^{\,2})^2} \times [W_{\text{unp}} + P_\gamma W_{\text{pol}} \cos(2\phi)] \times |F_{\text{nuclear}}(\vec{q}^{\,2}) - F_{\text{atomic}}(\vec{q}^{\,2})|^2$$

PARA and PERP runs are 90 degrees out of phase => $\cos 2(\phi + \pi/2) = -\cos 2\phi$

$$Y_{||}(\phi) \propto N_{||}[\sigma_0 A(\phi)(1 - P_{||}\Sigma \cos 2\phi)] \qquad Y_\perp(\phi) \propto N_\perp[\sigma_0 A(\phi)(1 + P_\perp \Sigma \cos 2\phi)]$$

$$Y_\perp(\phi) - \frac{N_\perp}{N_{||}} Y_{||}(\phi) = N_\perp \sigma_0 A(\phi) \Sigma \cos 2\phi (P_\perp + P_{||})$$

$$Y_\perp + \frac{N_\perp}{N_{||}} Y_{||}(\phi) = N_\perp \sigma_0 A(\phi)[2 + \Sigma \cos 2\phi (P_\perp - P_{||})]$$

2. Use BH pairs as a polarimeter —> Extract the yield asymmetry

ϕ is angle between the polarization direction and $\vec{J}_T$

$$\vec{J}_T = \frac{\vec{p}_{t\,1}}{p_{t_1}^2 + m^2} + \frac{\vec{p}_{t\,2}}{p_{t_2}^2 + m^2}$$

$$\frac{\mathrm{d}\sigma_B^c}{\mathrm{d}x\,\mathrm{d}^2\vec{p}_{t\,1}\,\mathrm{d}^2\vec{p}_{t\,2}} = \frac{2\alpha^3 Z^2 \omega^4 x^2 (1-x)^2}{\pi^2 (\vec{q}^{\,2})^2} \times [W_{\mathrm{unp}} + P_\gamma W_{\mathrm{pol}} \cos(2\phi)] \times |F_{\mathrm{nuclear}}(\vec{q}^{\,2}) - F_{\mathrm{atomic}}(\vec{q}^{\,2})|^2$$

PARA and PERP runs are 90 degrees out of phase => $\cos 2(\phi + \pi/2) = -\cos 2\phi$

$$Y_{\parallel}(\phi) \propto N_{\parallel}[\sigma_0 A(\phi)(1 - P_{\parallel}\Sigma\cos 2\phi)] \qquad Y_{\perp}(\phi) \propto N_{\perp}[\sigma_0 A(\phi)(1 + P_{\perp}\Sigma\cos 2\phi)]$$

$$Y_{\perp}(\phi) - \frac{N_{\perp}}{N_{\parallel}} Y_{\parallel}(\phi) = N_{\perp}\sigma_0 A(\phi)\Sigma\cos 2\phi(P_{\perp} + P_{\parallel})$$

$$Y_{\perp} + \frac{N_{\perp}}{N_{\parallel}} Y_{\parallel}(\phi) = N_{\perp}\sigma_0 A(\phi)[2 + \Sigma\cos 2\phi(P_{\perp} - P_{\parallel})]$$

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

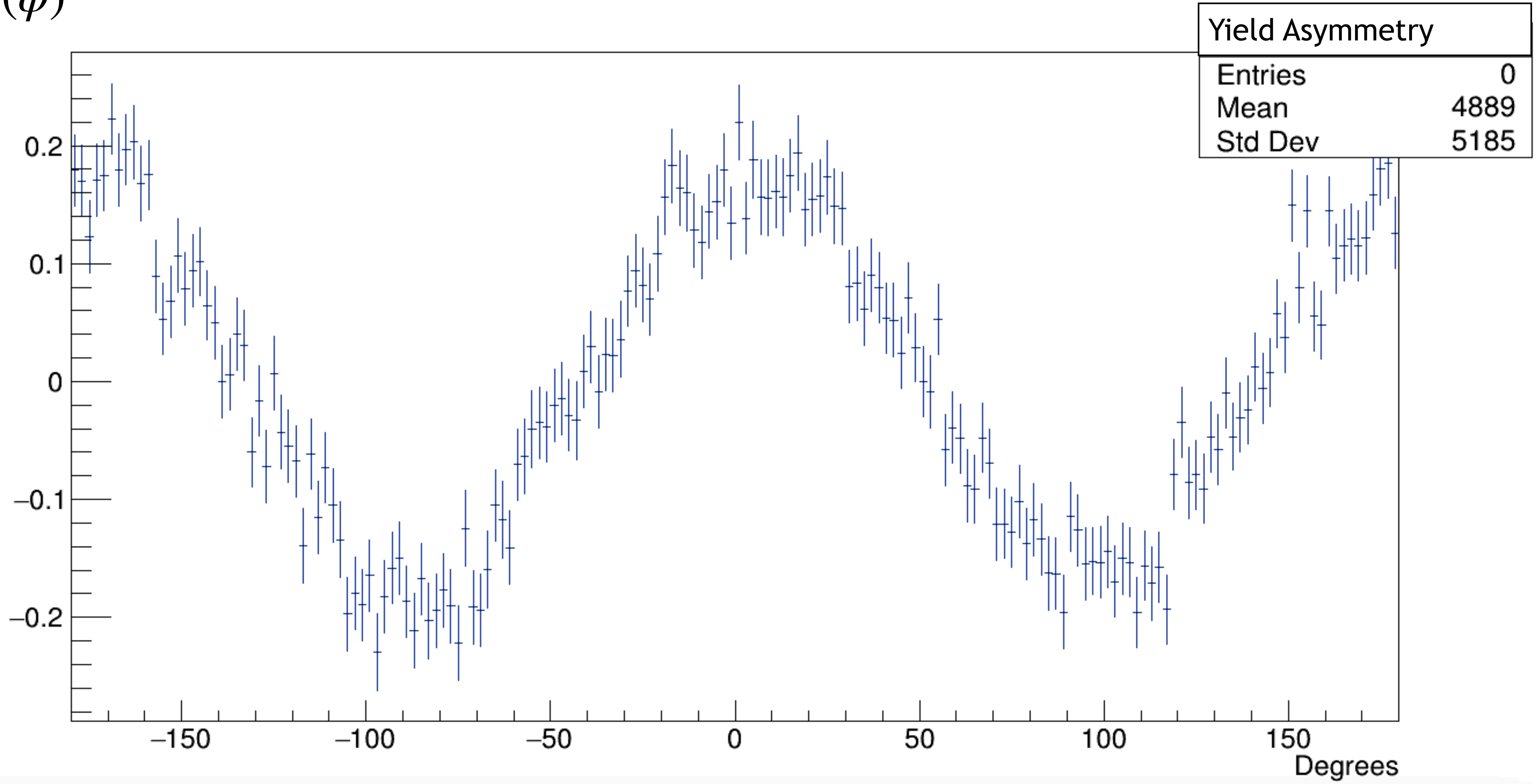
Pol = 0 and 90 runs

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

$$N_\perp = 833565$$

$$N_\parallel = 862412$$

$$\frac{N_\perp}{N_\parallel} = 0.96655$$



OBJECTIVES

3. Measure the form factor/charge radius of the proton.

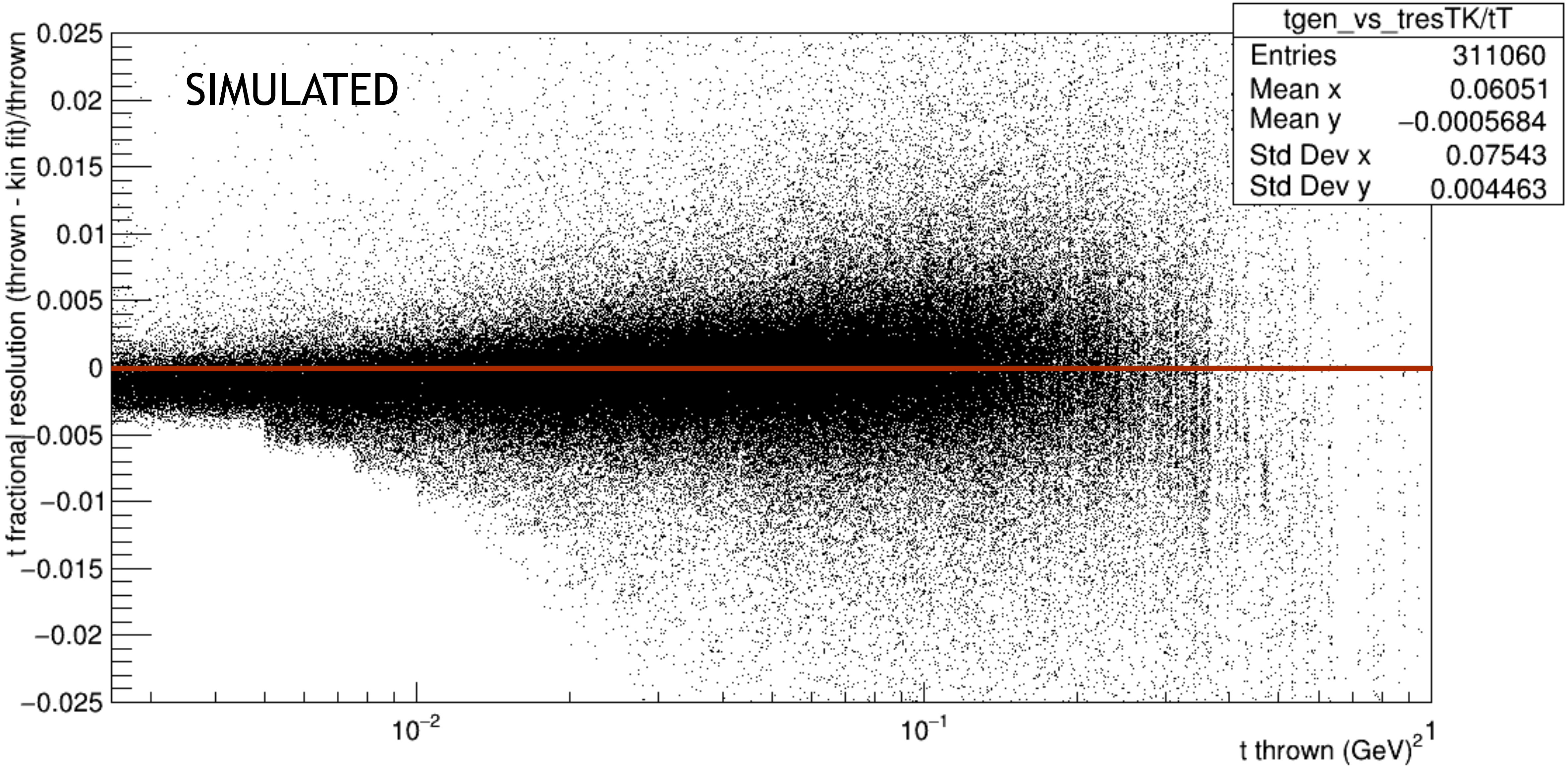
$$\frac{d\sigma_B^c}{dx\, d^2\overrightarrow{p_t}_1\, d^2\overrightarrow{p_t}_2} \propto |F_{\text{nuclear}}(\overrightarrow{q}^2) - F_{\text{atomic}}(\overrightarrow{q}^2)|^2$$

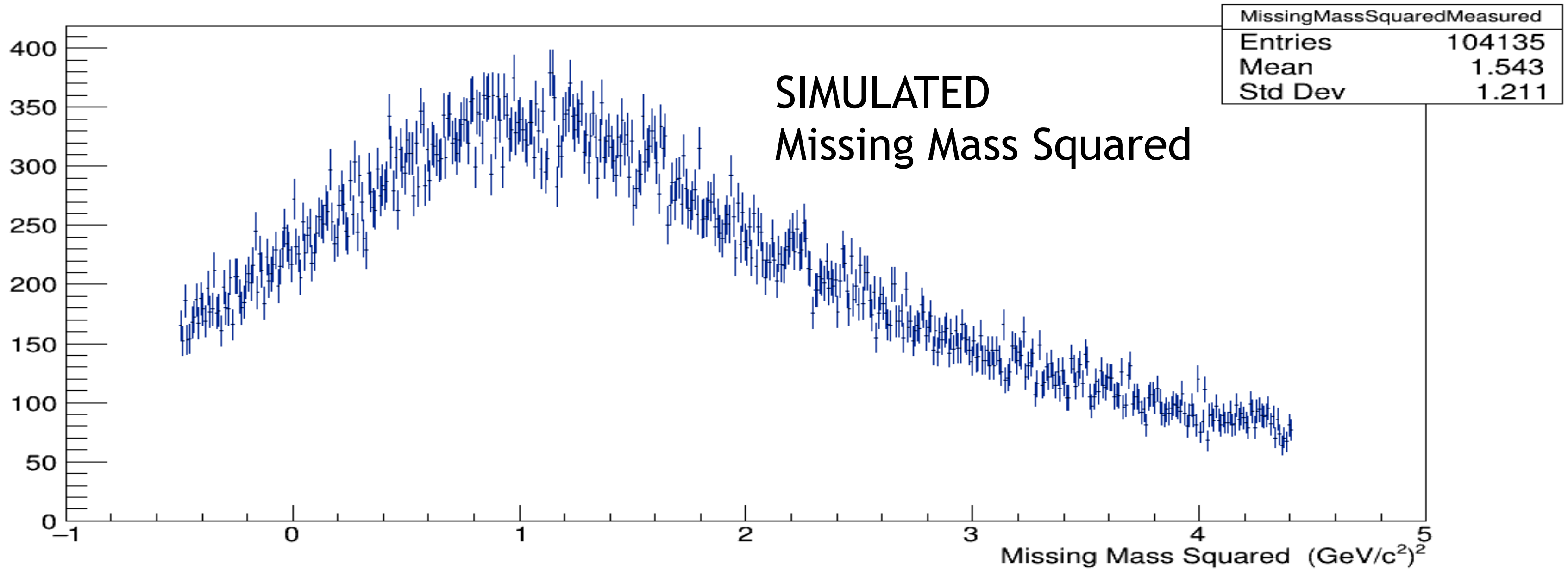
i.) Get t distribution for the data.

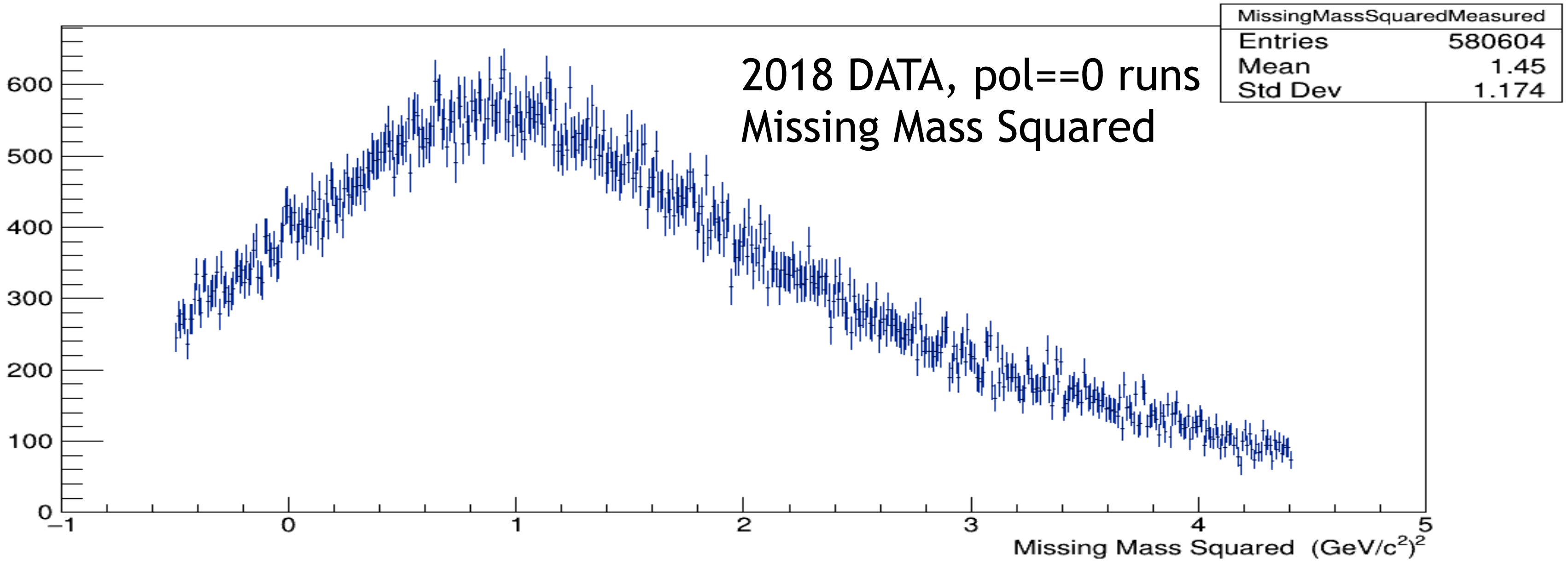
ii.) Do MC with standard dipole form factor and get t distribution.

iii.) Divide data by simulation and look for deviations from standard dipole at really low momentum transfer.

Need to understand MC at low t


SIMULATED
tgen_vs_tresTK/tT
Entries 311060
Mean x 0.06051
Mean y −0.0005684
Std Dev x 0.07543
Std Dev y 0.004463
t fractional resolution (thrown - kin fit)/thrown
0.025
0.02
0.015
0.01
0.005
0
−0.005
−0.01
−0.015
−0.02
−0.025
10⁻²
10⁻¹
1
t thrown (GeV)²


MissingMassSquaredMeasured
Entries 104135
Mean 1.543
Std Dev 1.211
SIMULATED
Missing Mass Squared
Missing Mass Squared (GeV/c²)²


MissingMassSquaredMeasured
Entries 580604
Mean 1.45
Std Dev 1.174
2018 DATA, pol==0 runs
Missing Mass Squared
Missing Mass Squared (GeV/c²)²