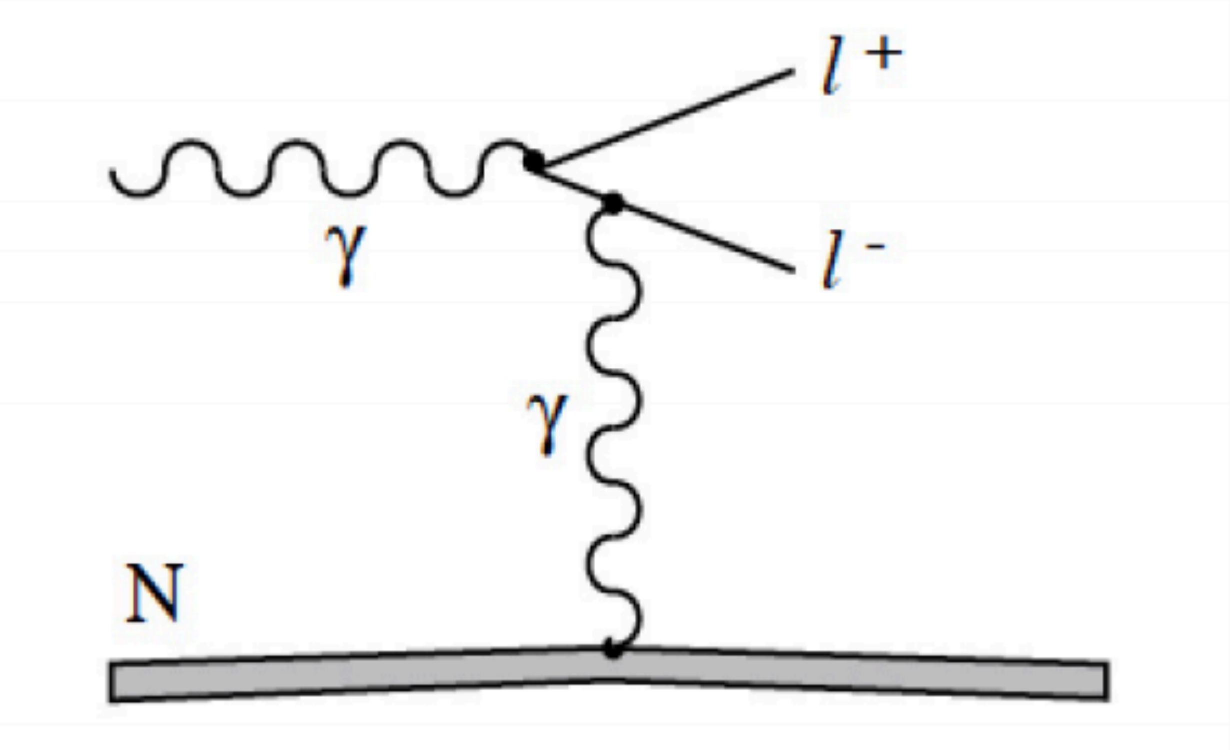
University of Massachusetts Amherst

MENP

2018-01 Run, Bethe-Heitler Study

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



Andrew Schick

Wednesday, September 4 2019

Objectives of the BH Analysis:

1. Use Bethe-Heitler pair production for normalization in the Charged Pion Polarizability experiment. Therefore, developing an analysis suite for BH pairs is necessary.

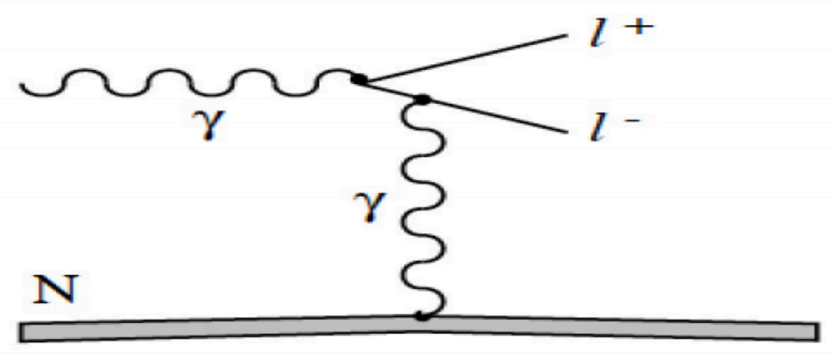
2. We would like to extract the polarization signal of the BH pairs.

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

OBJECTIVES

1. Use Bethe-Heitler pair production for normalization in the Charged Pion Polarizability experiment. Therefore, developing an analysis suite for BH pairs is necessary.

OBJECTIVES



2. Use BH pairs as a polarimeter.

$$\frac{d\sigma_B^c}{dx\, d^2\vec{\Omega}_1\, d^2\vec{\Omega}_2} = \frac{2\alpha^3 Z^2 \omega^4 x^2 (1-x)^2}{\pi^2 (\vec{q}^{\,2})^2} \times [W_{\text{unp}} + P_\gamma W_{\text{pol}} \cos(2\phi)]$$

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

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

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

$$J_S = \frac{1}{\vec{\Omega}_1^2 + m^2} - \frac{1}{\vec{\Omega}_2^2 + m^2}; \qquad \vec{J}_T = \frac{\vec{\Omega}_1}{\Omega_1^2 + m^2} + \frac{\vec{\Omega}_2}{\Omega_2^2 + m^2}$$

$\vec{\Omega}_1$ and $\vec{\Omega}_2$ are the transverse momenta of the leptons.

OBJECTIVES

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

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.

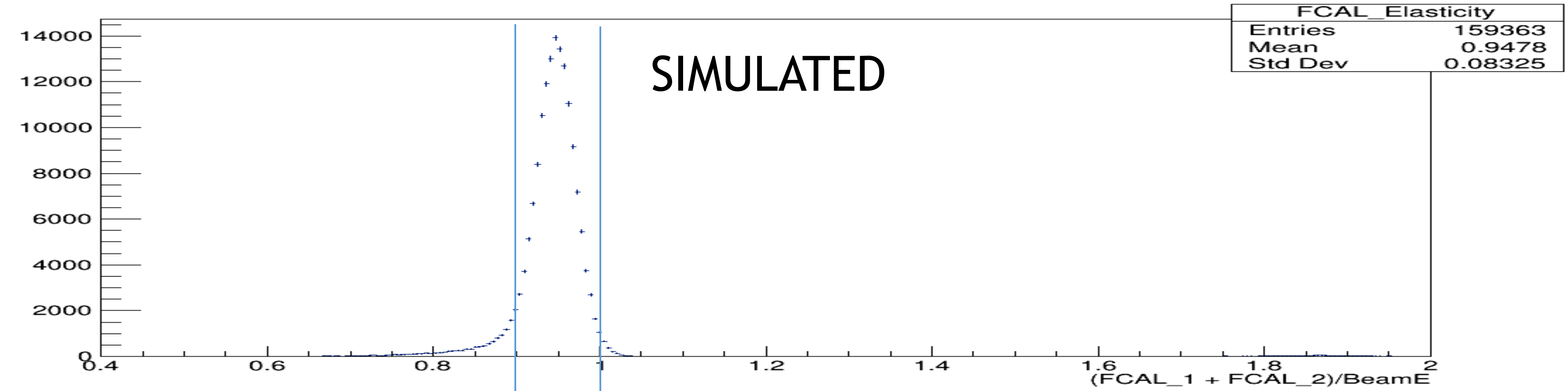
Cuts for γp $\rightarrow e^+e^-$(p)

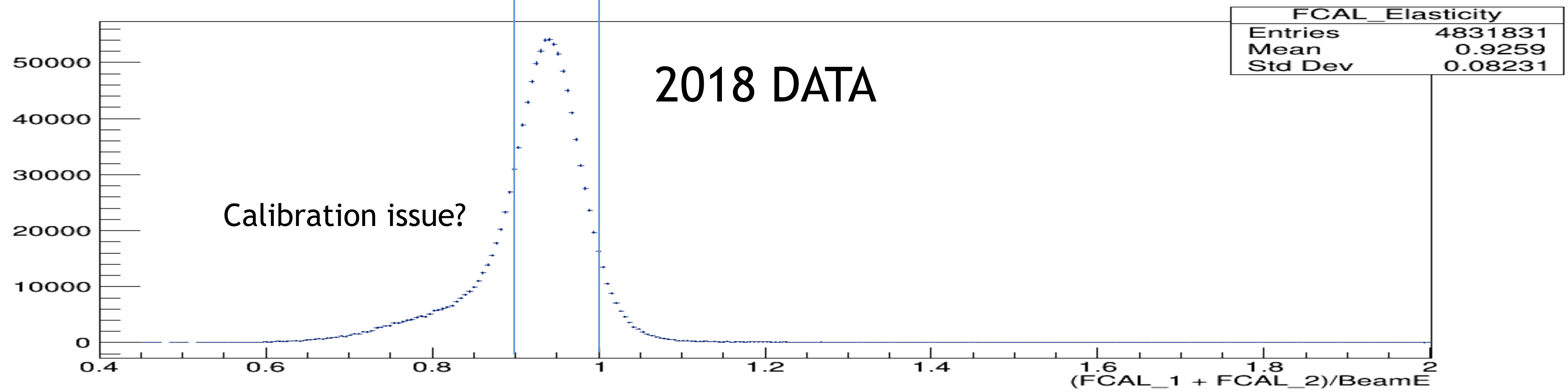
Preselection Cuts

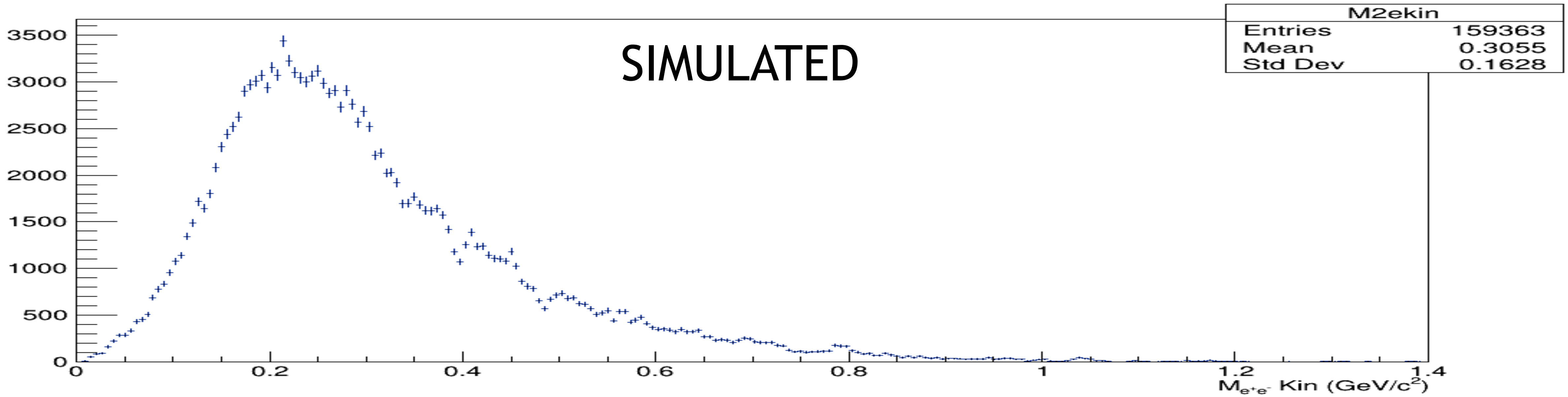
1. Default GlueX cuts: https://halldweb.jlab.org/wiki/index.php/Spring_2017_Analysis_Launch_Cuts
2. Require E/p = 0.7 for electron and positron tracks in FCAL and BCAL

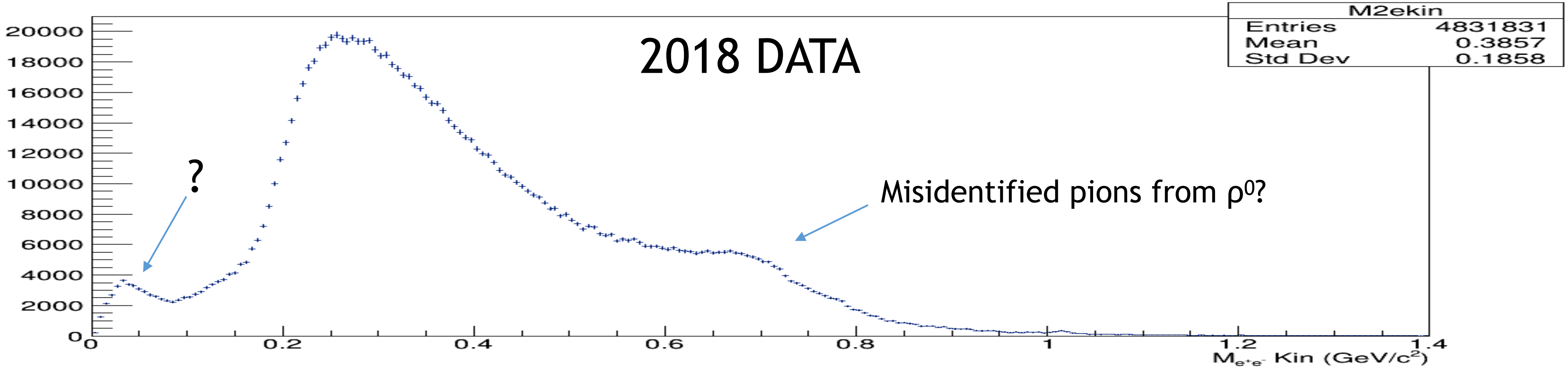
DSelector Cuts

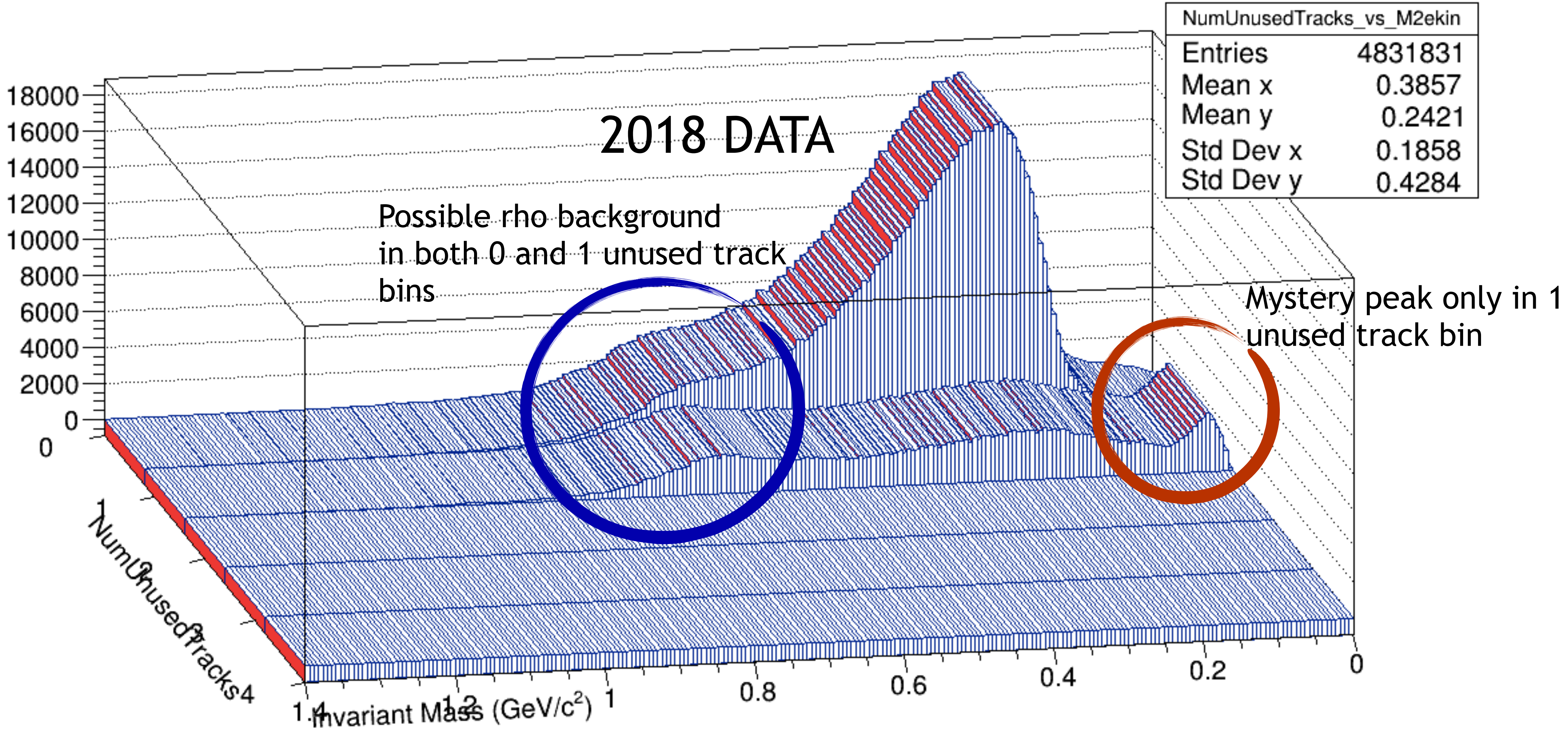
1. Cut on coherent peak: $8.12 < E_\gamma < 8.88$
2. Require both electron and positron tracks have hit in FCAL
3. Require both electron and positron tracks have hit in TOF
4. Require dMinKinFitCL > 10E-6
5. Eliminate events with NumUnusedTracks ≥ 2
6. Eliminate events with Energy_UnusedShowers > 0
7. TOF dE/dx cut for electron and positron tracks at 3σ
8. FCAL DOCA cut for e+ and e- tracks at 3σ


FCAL_Elasticity
Entries 159363
Mean 0.9478
Std Dev 0.08325
SIMULATED
(FCAL_1 + FCAL_2)/BeamE

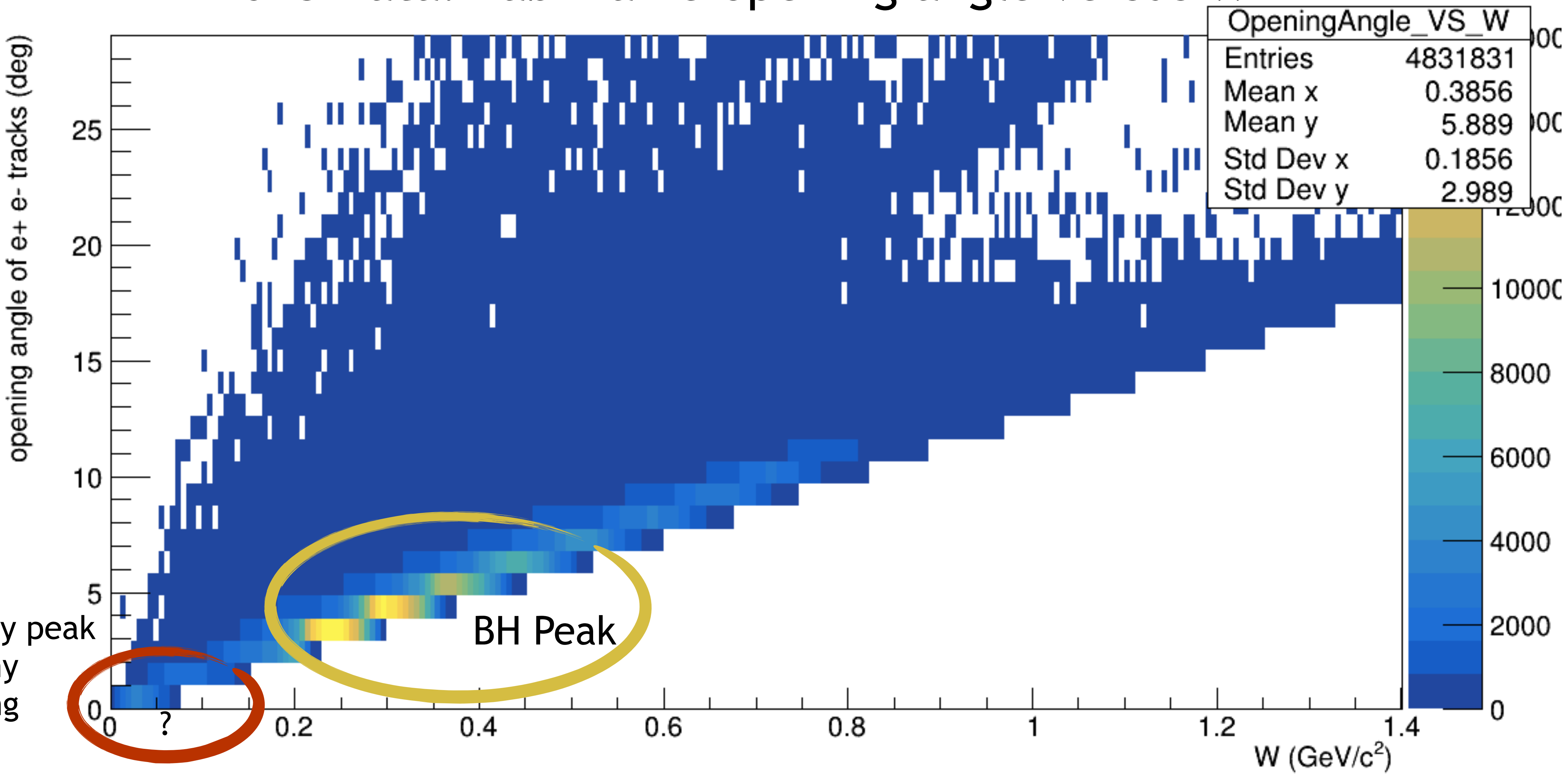

FCAL_Elasticity
Entries 4831831
Mean 0.9259
Std Dev 0.08231
2018 DATA
Calibration issue?
(FCAL_1 + FCAL_2)/BeamE


SIMULATED
M2ekin
Entries 159363
Mean 0.3055
Std Dev 0.1628
$M_{e^+e^-}$ Kin (GeV/c^2)


2018 DATA
M2ekin
Entries 4831831
Mean 0.3857
Std Dev 0.1858
?
Misidentified pions from ρ^0?
$M_{e^+e^-}$ Kin (GeV/c^2)


2018 DATA
Possible rho background
in both 0 and 1 unused track
bins
Mystery peak only in 1
unused track bin
NumUnusedTracks_vs_M2ekin
Entries 4831831
Mean x 0.3857
Mean y 0.2421
Std Dev x 0.1858
Std Dev y 0.4284
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
NumUnusedTracks
Invariant Mass (GeV/c^2)
1.4
1.2
1
0.8
0.6
0.4
0.2
0

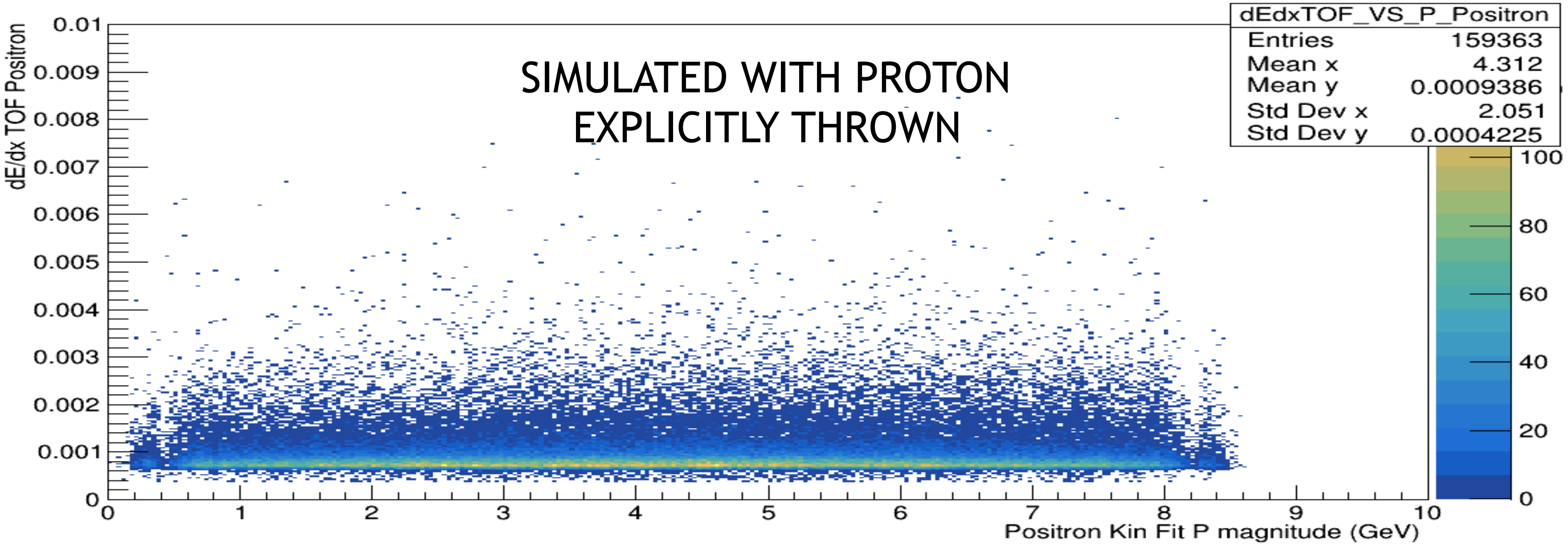
2018 Data: Lab frame opening angle versus W

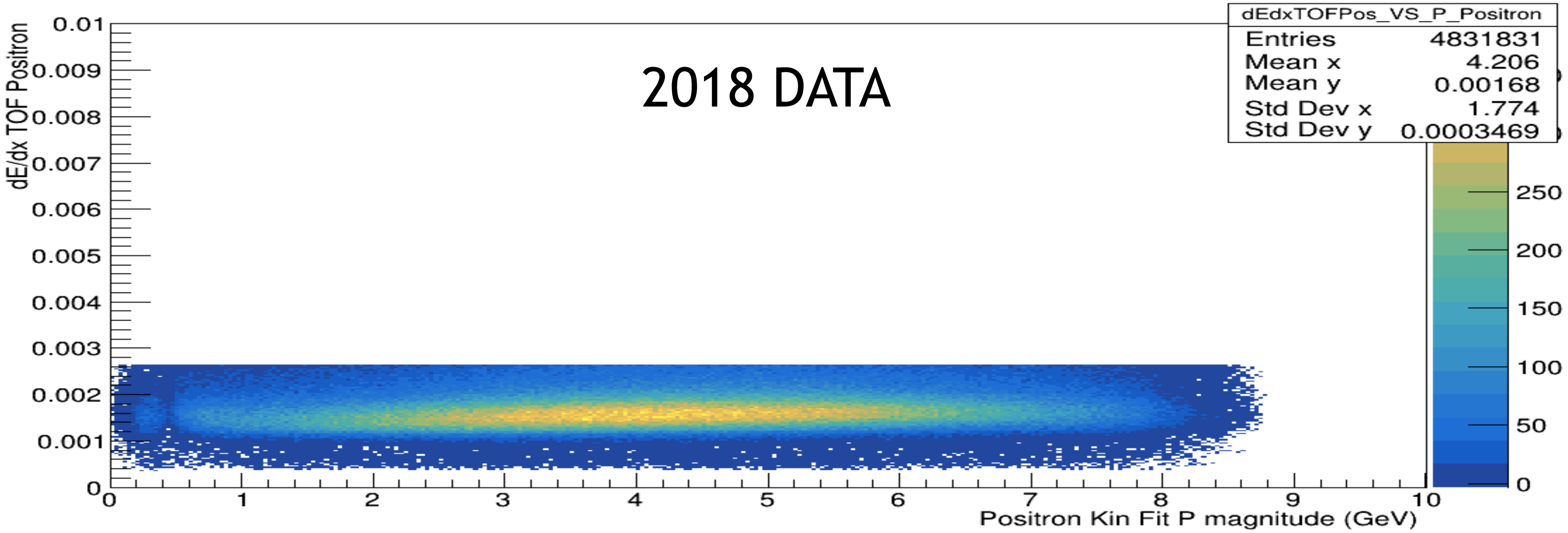


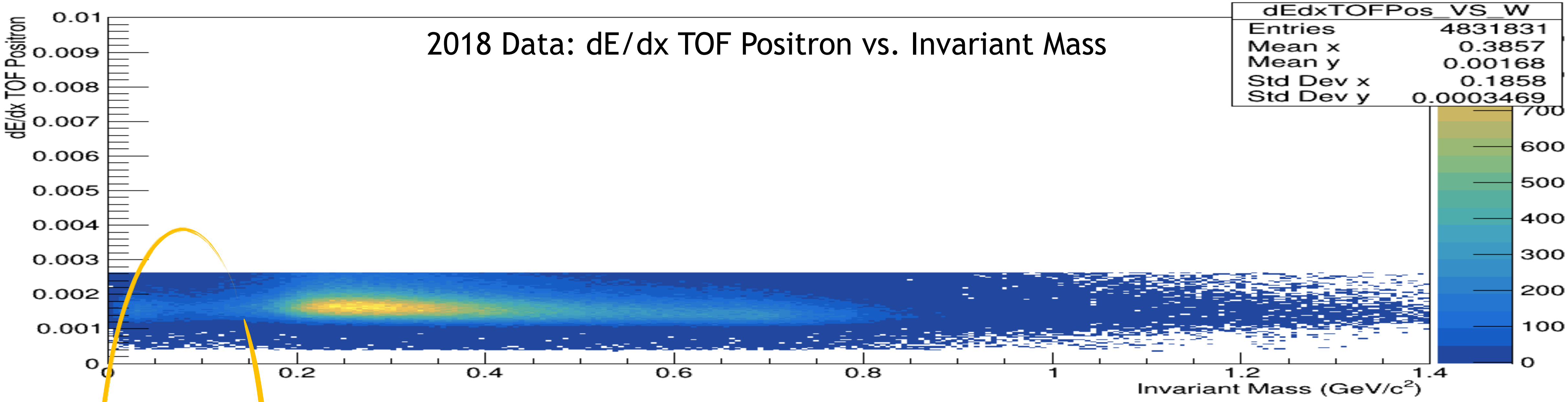
Mystery peak has tiny opening angle

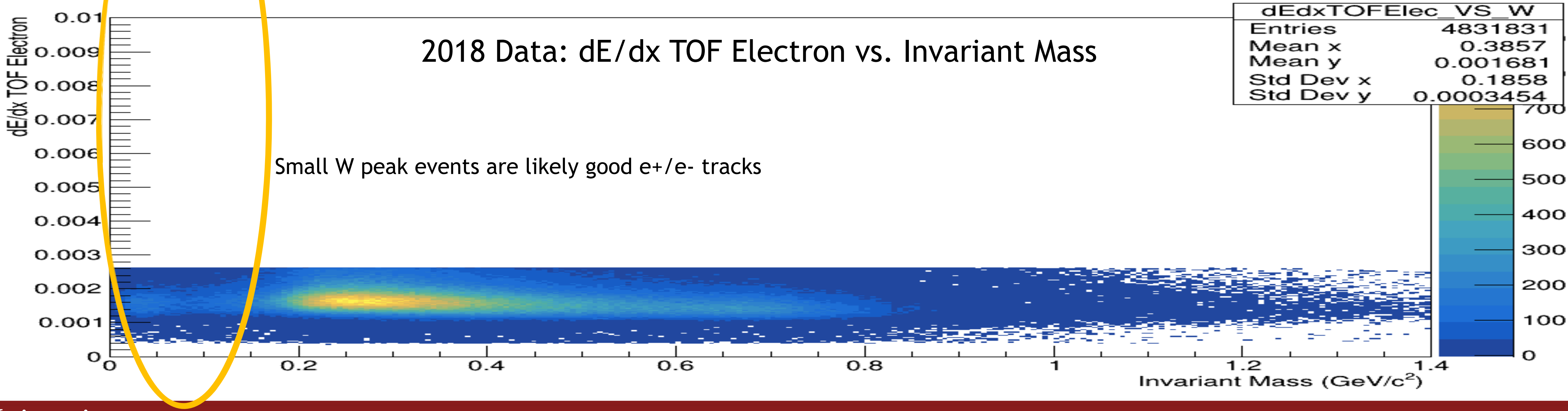
Proton Mis-ID?

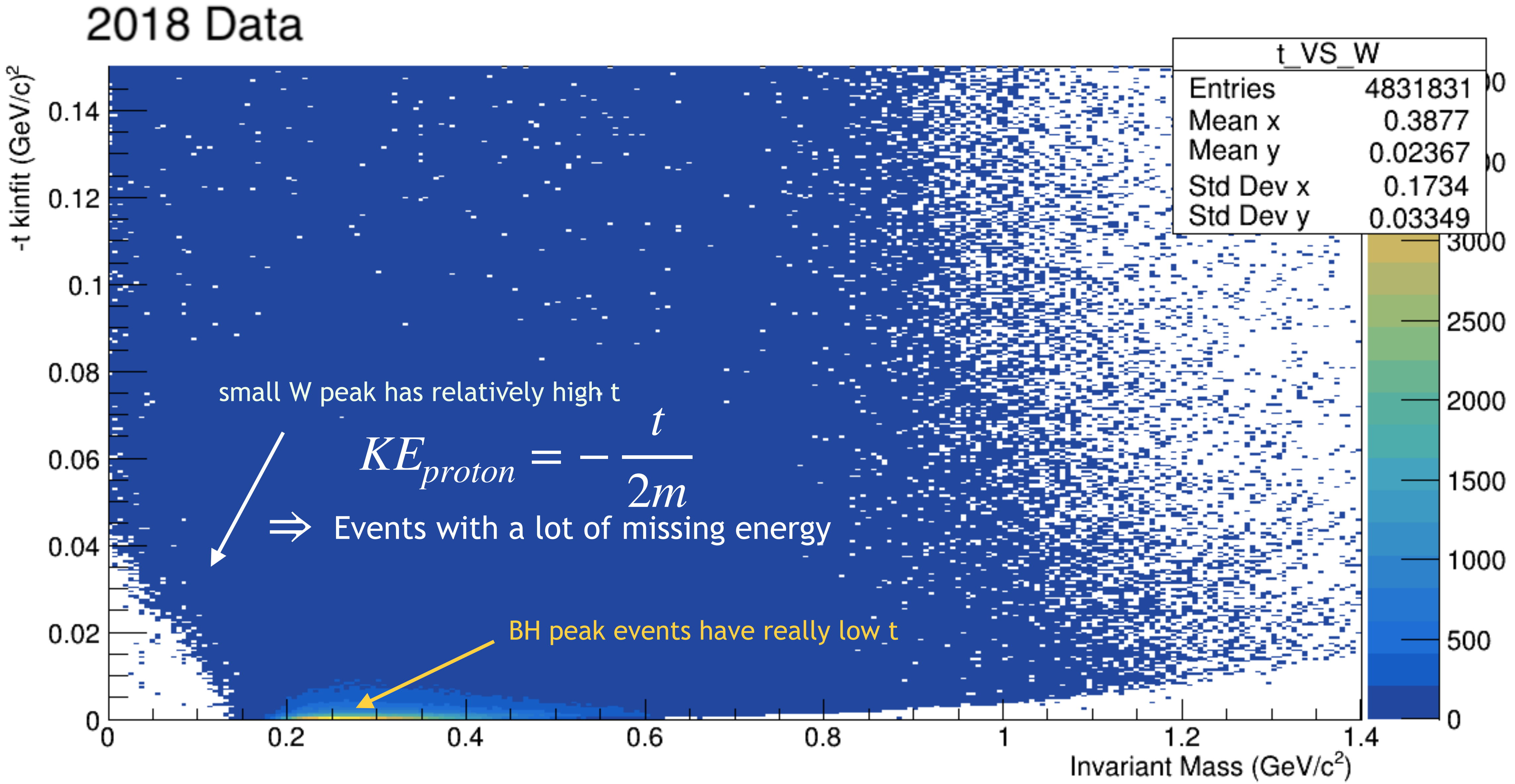
- Calibration is off between MC and DATA
- Otherwise, dE/dx for positron looks mostly independent of momentum





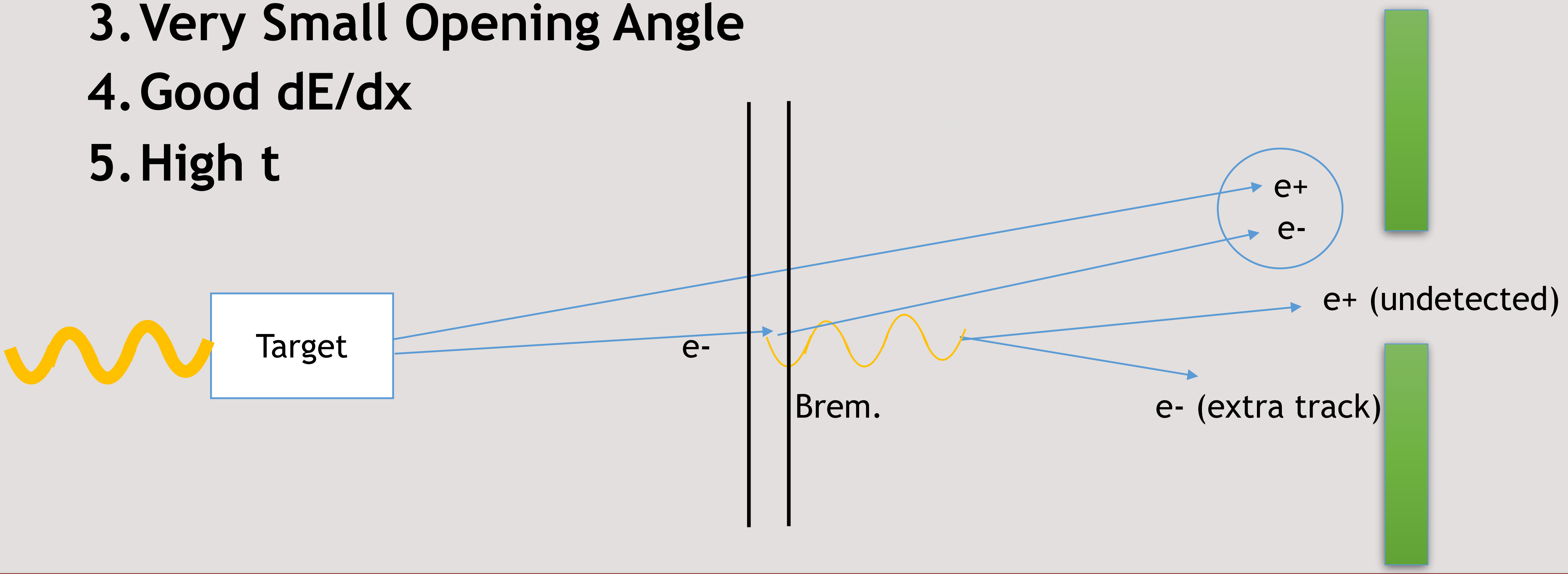

2018 Data: dE/dx TOF Positron vs. Invariant Mass
dEdxTOFPos_VS_W
Entries 4831831
Mean x 0.3857
Mean y 0.00168
Std Dev x 0.1858
Std Dev y 0.0003469
dE/dx TOF Positron
Invariant Mass (GeV/c²)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0.2
0.4
0.6
0.8
1
1.2
1.4
700
600
500
400
300
200
100
0


2018 Data: dE/dx TOF Electron vs. Invariant Mass
dEdxTOFElec_VS_W
Entries 4831831
Mean x 0.3857
Mean y 0.001681
Std Dev x 0.1858
Std Dev y 0.0003454
Small W peak events are likely good e+/e- tracks
dE/dx TOF Electron
Invariant Mass (GeV/c²)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0.2
0.4
0.6
0.8
1
1.2
1.4
700
600
500
400
300
200
100
0


2018 Data
t_VS_W
Entries 4831831
Mean x 0.3877
Mean y 0.02367
Std Dev x 0.1734
Std Dev y 0.03349
-t kinfit (GeV/c)^2
Invariant Mass (GeV/c^2)
small W peak has relatively high t
$$KE_{proton} = -\frac{t}{2m}$$
$\Rightarrow$ Events with a lot of missing energy
BH peak events have really low t
0 0.02 0.04 0.06 0.08 0.1 0.12 0.14
0 0.2 0.4 0.6 0.8 1 1.2 1.4
0 500 1000 1500 2000 2500 3000

Need explanation that satisfies:

1. **Small Invariant Mass**
2. **One Extra (Unused) Track**
3. **Very Small Opening Angle**
4. **Good dE/dx**
5. **High t**



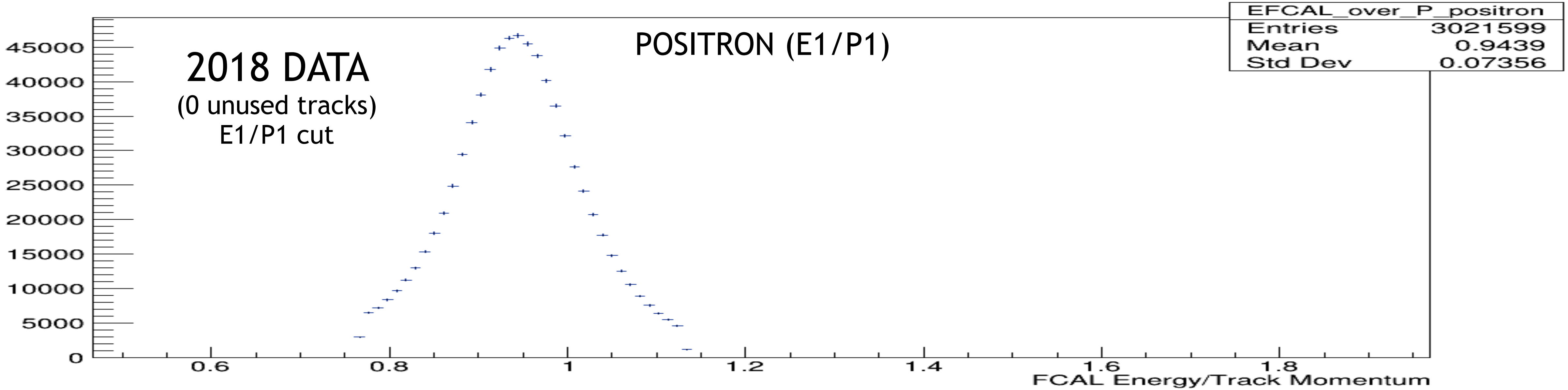
Split Up Analysis Into “No Unused Track” and “One Unused Track” channels.

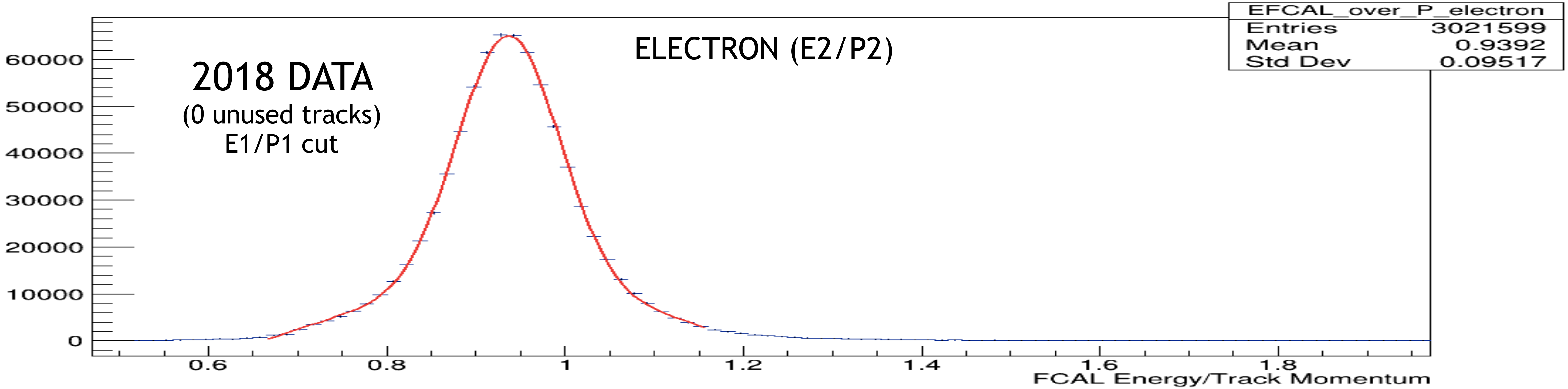
1. Cut on $\frac{E_1}{p_1}$ at $\pm 3\sigma$ (p1 is kinematic, not measured)

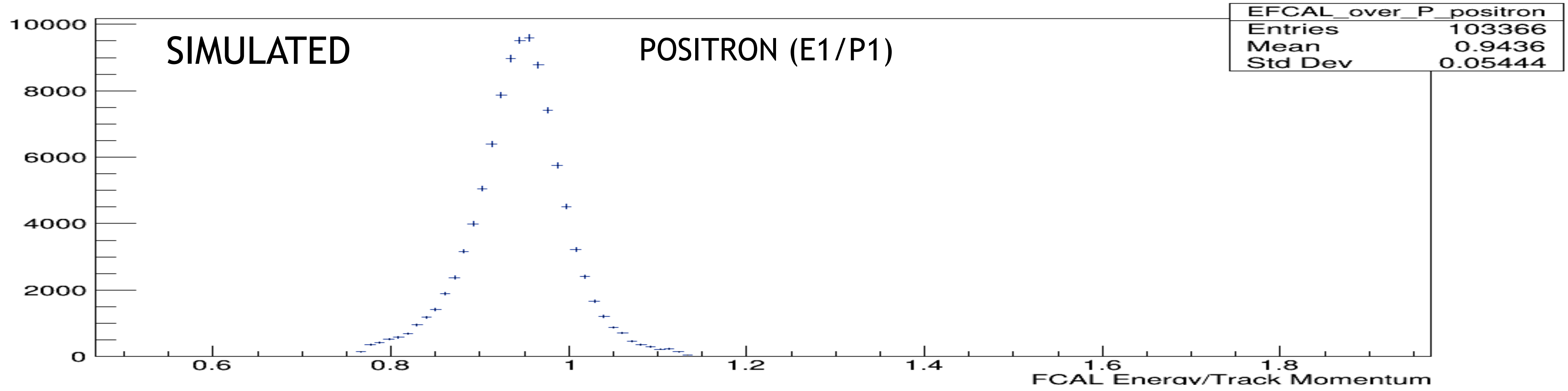
   We’ll look at some plots with this cut applied.

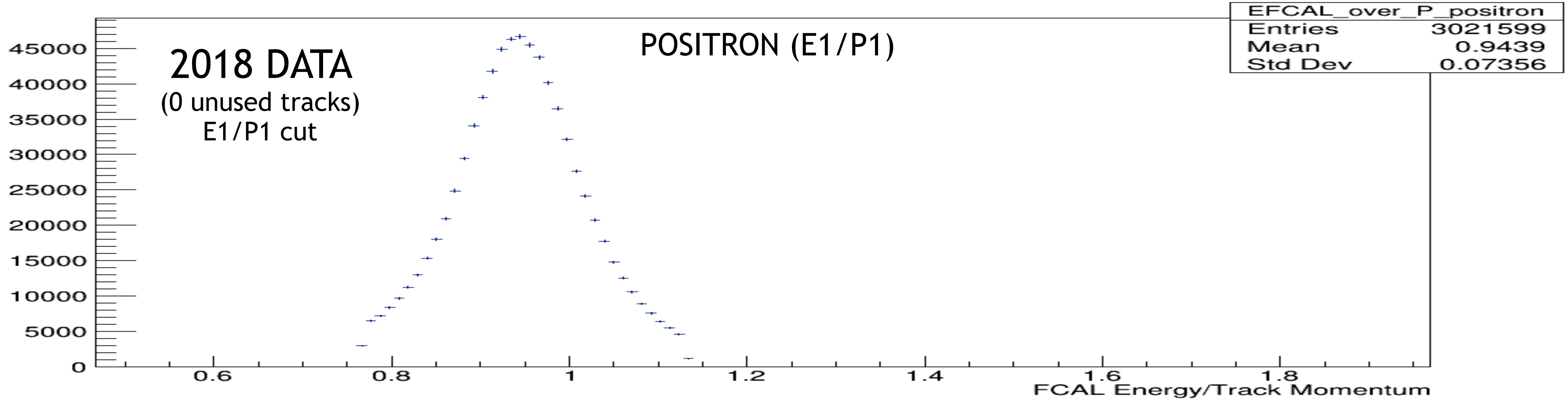
2. Fit $\frac{E_2}{P_2}$ (p2 is kin. not meas.) and subtract background

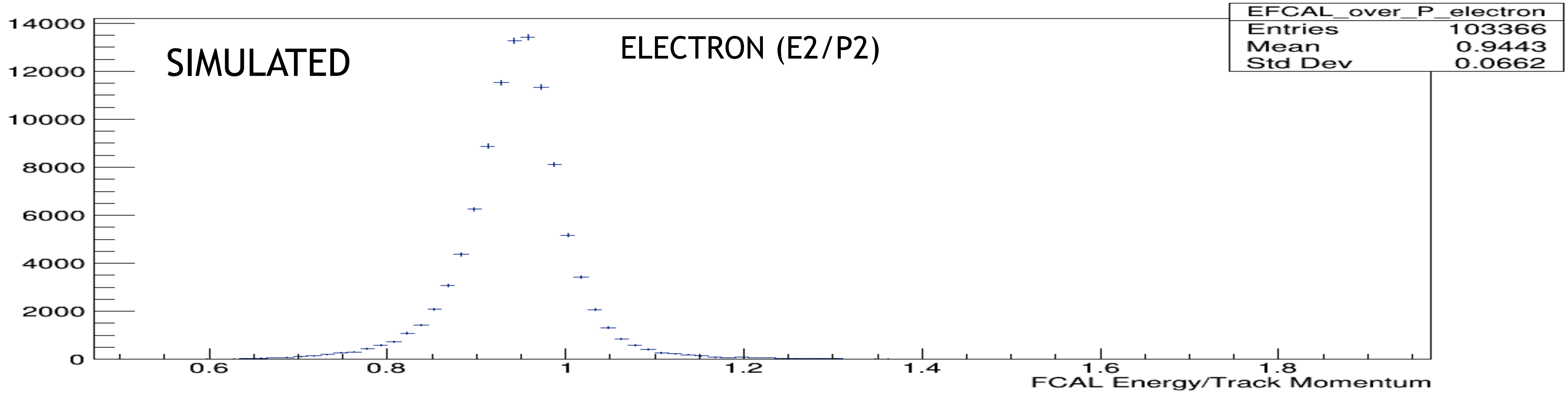
   Not yet implemented. Still need to carve time away to learn how to properly fit.

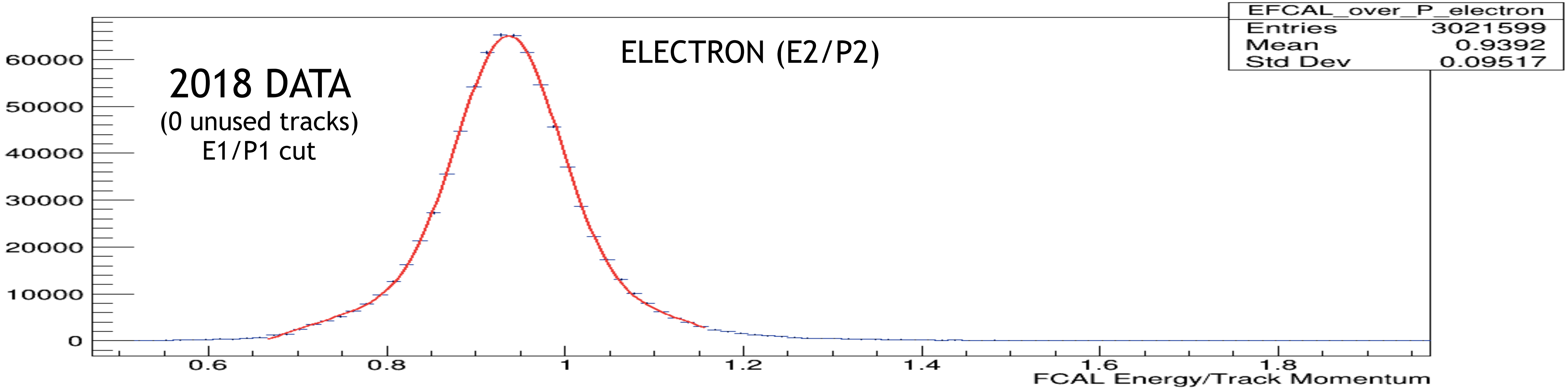

EFCAL_over_P_positron
Entries 3021599
Mean 0.9439
Std Dev 0.07356
POSITRON (E1/P1)
2018 DATA
(0 unused tracks)
E1/P1 cut
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0.6
0.8
1
1.2
1.4
1.6
1.8
FCAL Energy/Track Momentum

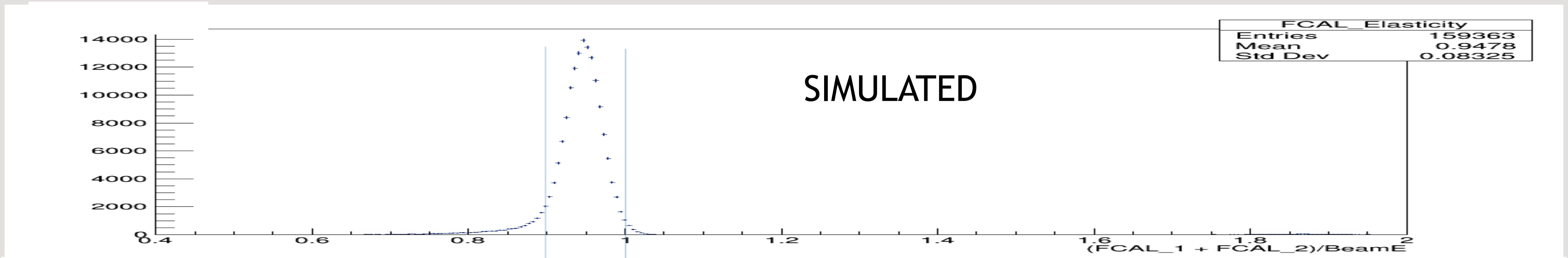

EFCAL_over_P_electron
Entries 3021599
Mean 0.9392
Std Dev 0.09517
ELECTRON (E2/P2)
2018 DATA
(0 unused tracks)
E1/P1 cut
60000
50000
40000
30000
20000
10000
0
0.6
0.8
1
1.2
1.4
1.6
1.8
FCAL Energy/Track Momentum


SIMULATED
POSITRON (E1/P1)
EFCAL_over_P_positron
Entries 103366
Mean 0.9436
Std Dev 0.05444
10000
8000
6000
4000
2000
0
0.6
0.8
1
1.2
1.4
1.6
1.8
FCAL Energy/Track Momentum


2018 DATA
(0 unused tracks)
E1/P1 cut
POSITRON (E1/P1)
EFCAL_over_P_positron
Entries 3021599
Mean 0.9439
Std Dev 0.07356
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0.6
0.8
1
1.2
1.4
1.6
1.8
FCAL Energy/Track Momentum


SIMULATED
ELECTRON (E2/P2)
EFCAL_over_P_electron
Entries 103366
Mean 0.9443
Std Dev 0.0662
FCAL Energy/Track Momentum


2018 DATA
(0 unused tracks)
E1/P1 cut
ELECTRON (E2/P2)
EFCAL_over_P_electron
Entries 3021599
Mean 0.9392
Std Dev 0.09517
FCAL Energy/Track Momentum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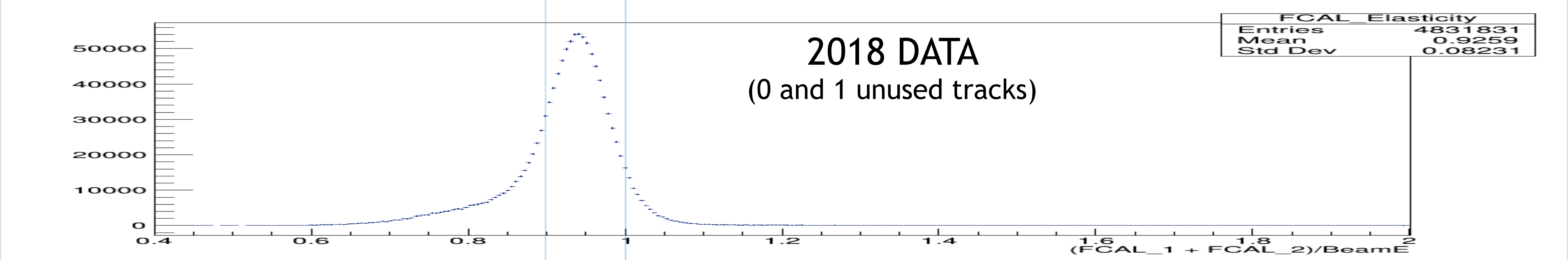
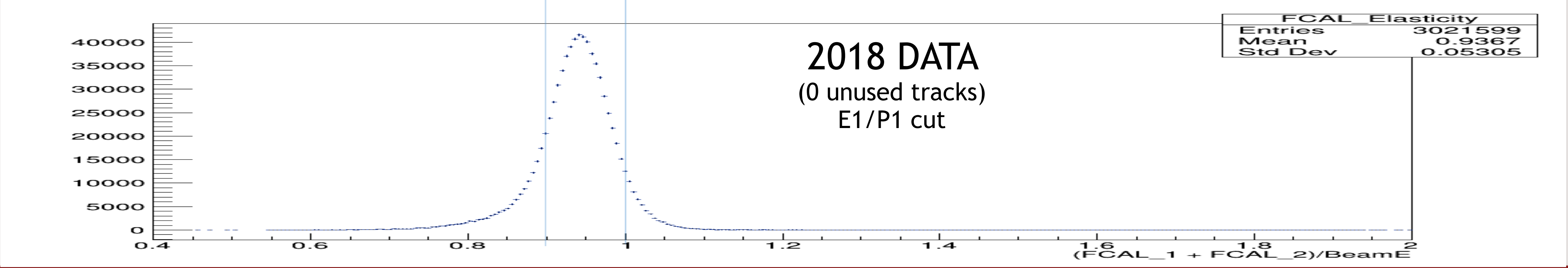
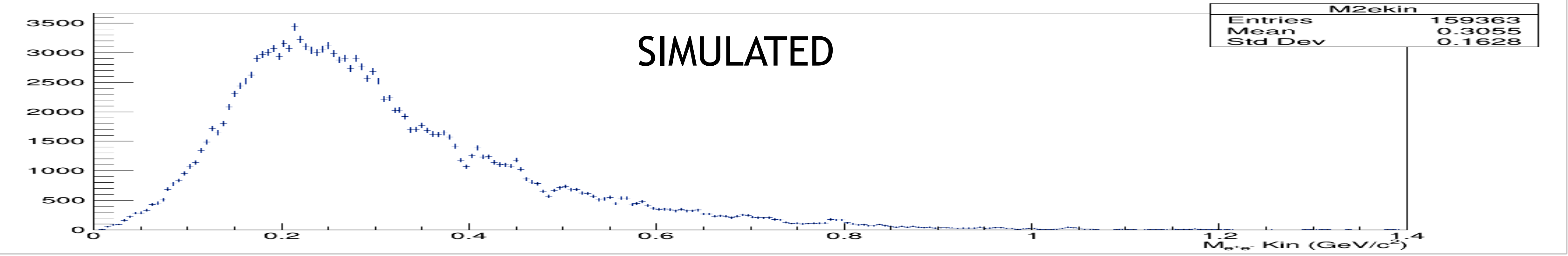
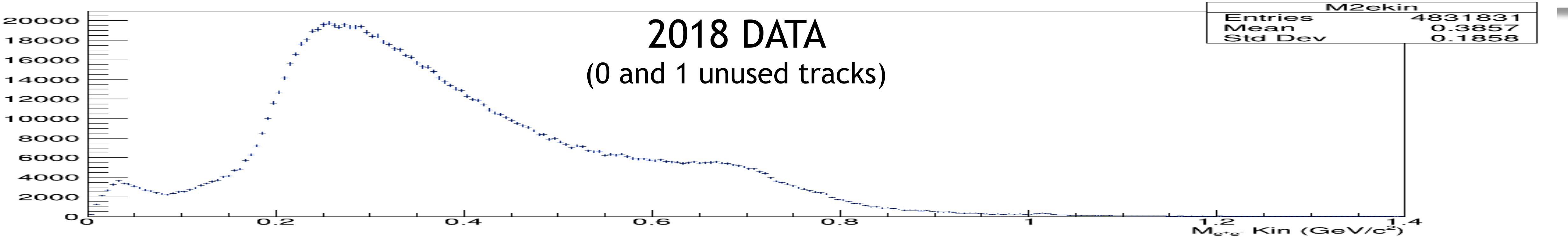
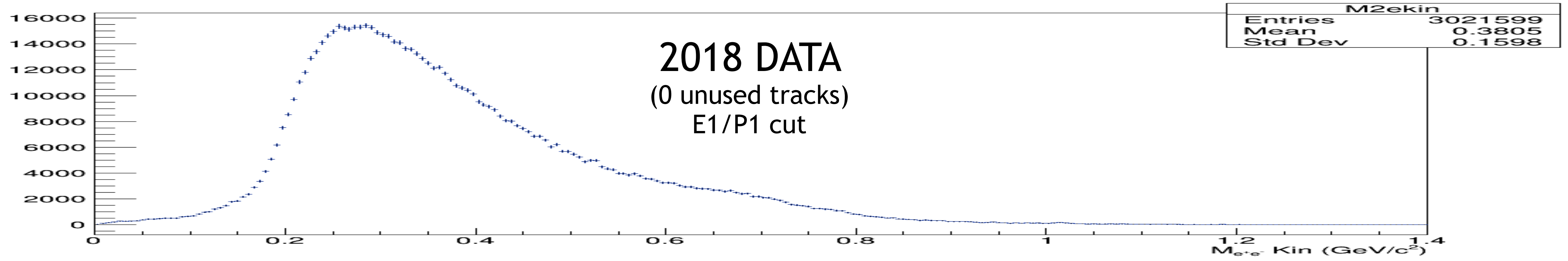

FCAL_Elasticity
Entries 4831831
Mean 0.9259
Std Dev 0.08231
2018 DATA
(0 and 1 unused tracks)
(FCAL_1 + FCAL_2)/BeamE

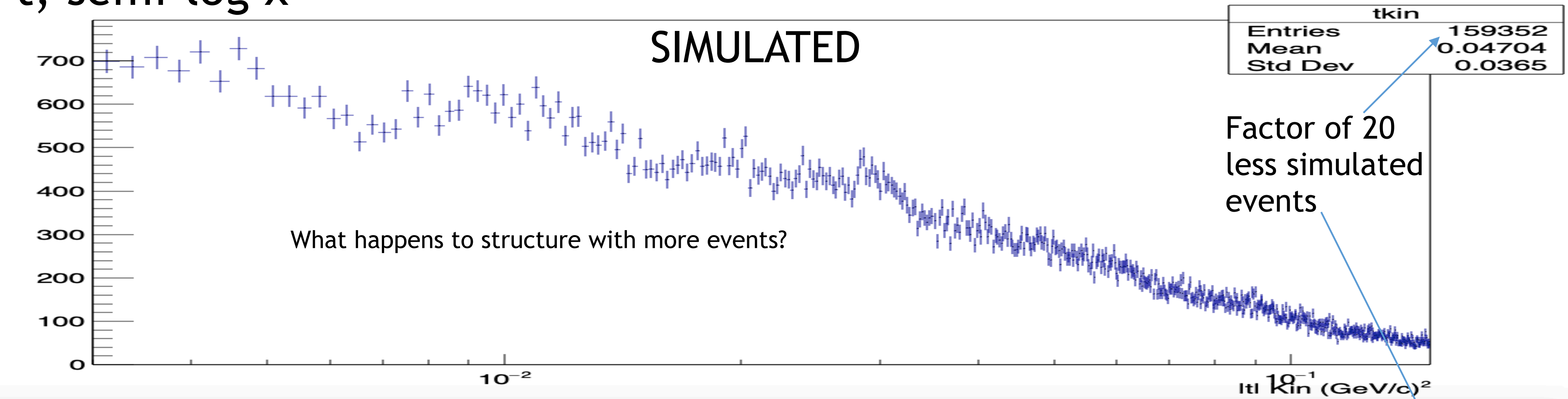

FCAL_Elasticity
Entries 3021599
Mean 0.9367
Std Dev 0.05305
2018 DATA
(0 unused tracks)
E1/P1 cut
(FCAL_1 + FCAL_2)/BeamE


SIMULATED
M2ekin
Entries 159363
Mean 0.3055
Std Dev 0.1628
$M_{e^+e^-}$ Kin (GeV/c^2)


2018 DATA
(0 and 1 unused tracks)
M2ekin
Entries 4831831
Mean 0.3857
Std Dev 0.1858
$M_{e^+e^-}$ Kin (GeV/c^2)

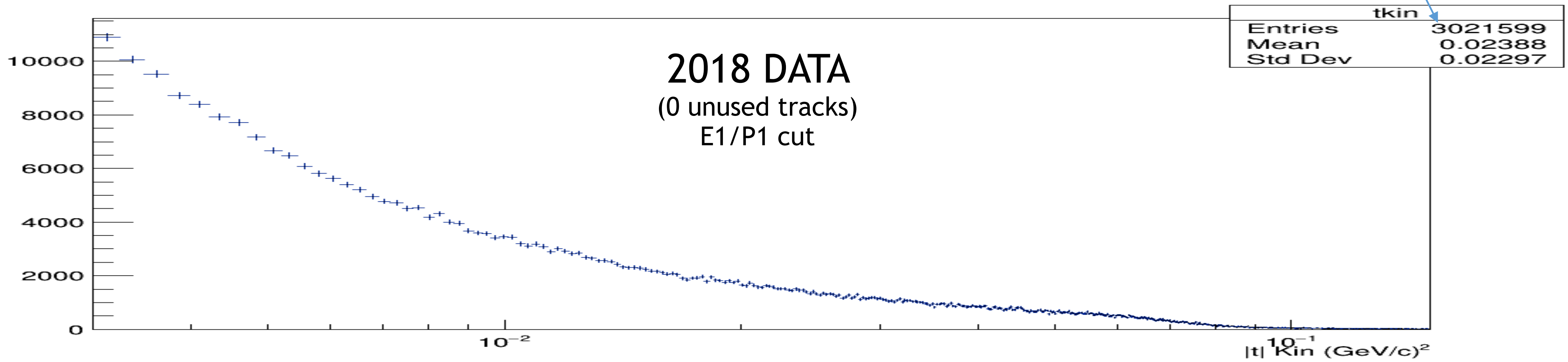

2018 DATA
(0 unused tracks)
E1/P1 cut
M2ekin
Entries 3021599
Mean 0.3805
Std Dev 0.1598
$M_{e^+e^-}$ Kin (GeV/c^2)

-t, semi-log x



What happens to structure with more events?

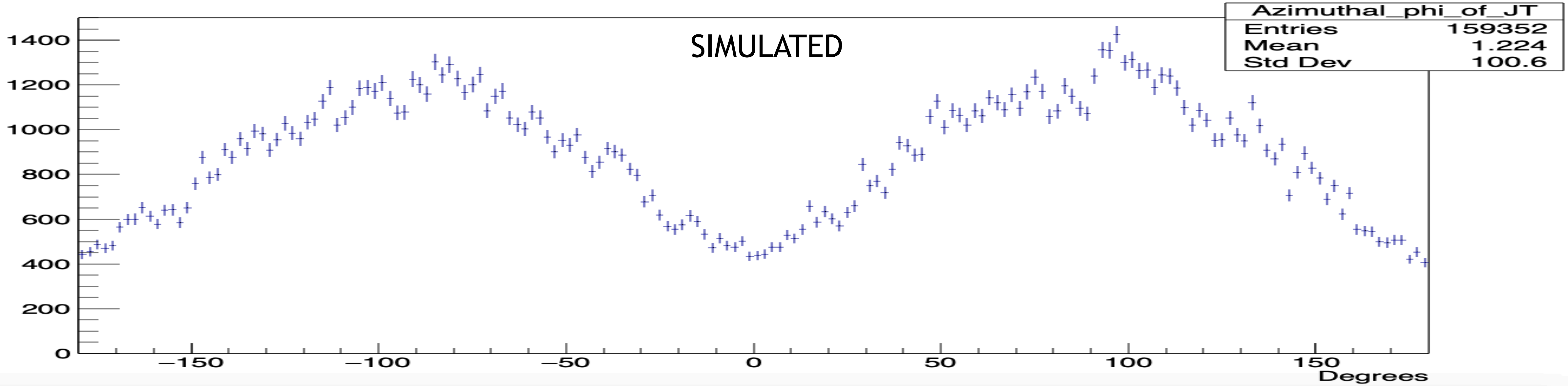
Factor of 20 less simulated events

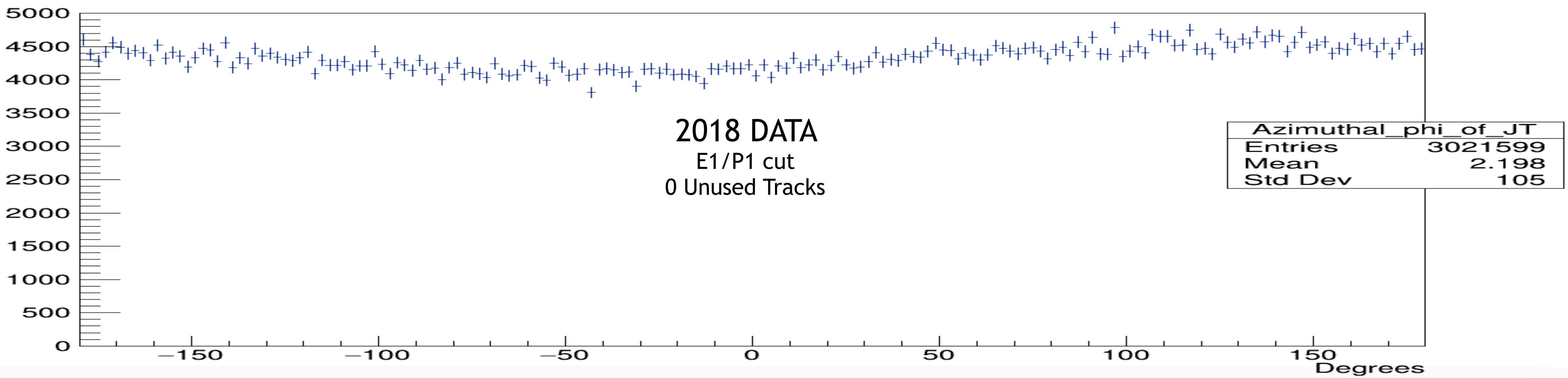


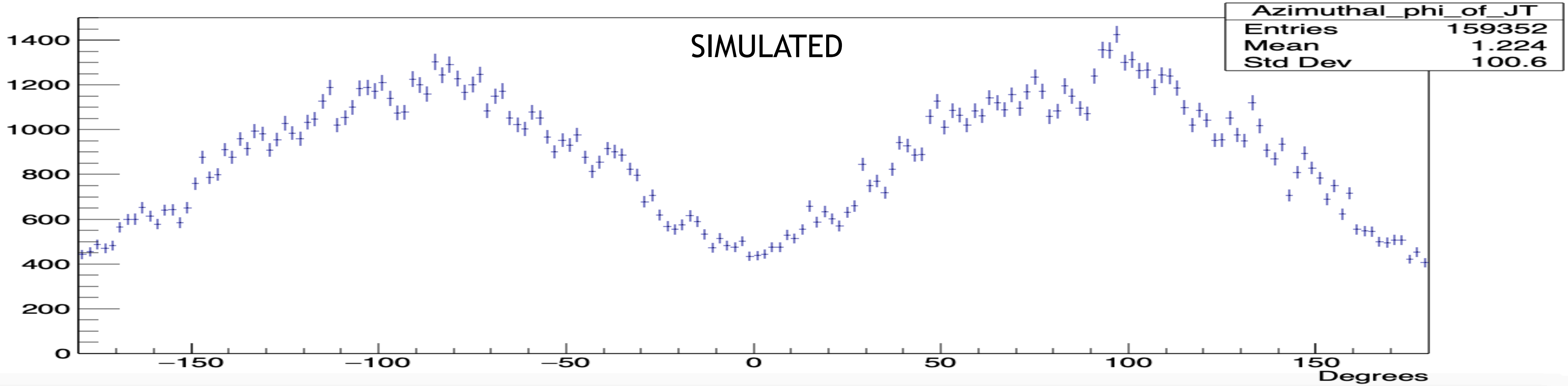
2018 DATA

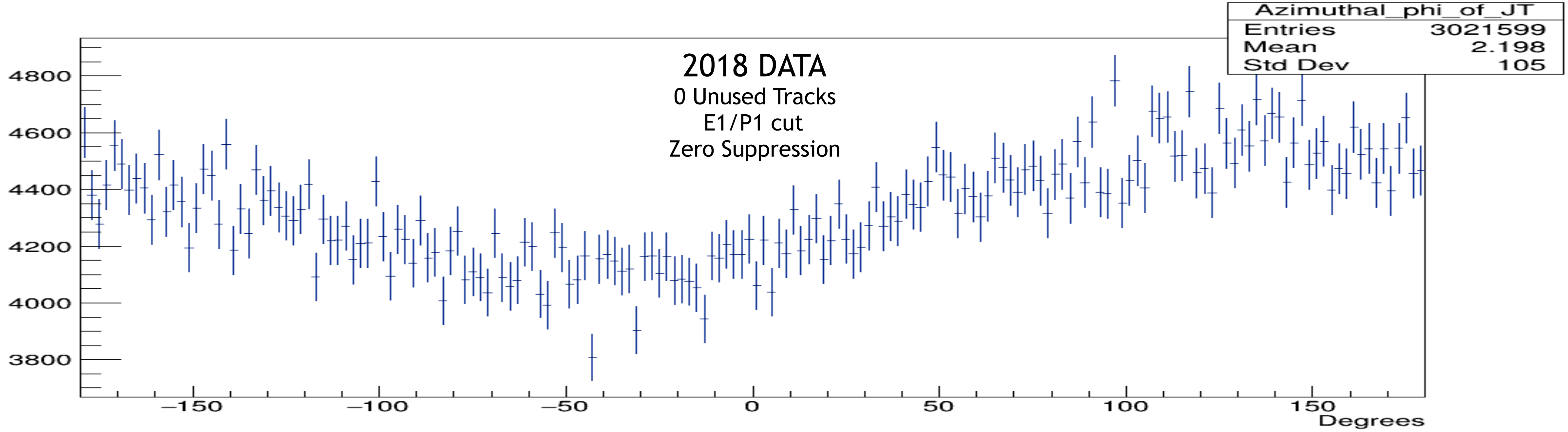
(0 unused tracks)

E1/P1 cut


SIMULATED
Azimuthal_phi_of_JT
Entries 159352
Mean 1.224
Std Dev 100.6
Degrees


2018 DATA
E1/P1 cut
0 Unused Tracks
Azimuthal_phi_of_JT
Entries 3021599
Mean 2.198
Std Dev 105
Degrees


Azimuthal_phi_of_JT
Entries 159352
Mean 1.224
Std Dev 100.6
SIMULATED
1400
1200
1000
800
600
400
200
0
−150
−100
−50
0
50
100
150
Degrees


Azimuthal_phi_of_JT
Entries 3021599
Mean 2.198
Std Dev 105
2018 DATA
0 Unused Tracks
E1/P1 cut
Zero Suppression
4800
4600
4400
4200
4000
3800
−150
−100
−50
0
50
100
150
Degrees

Conclusions

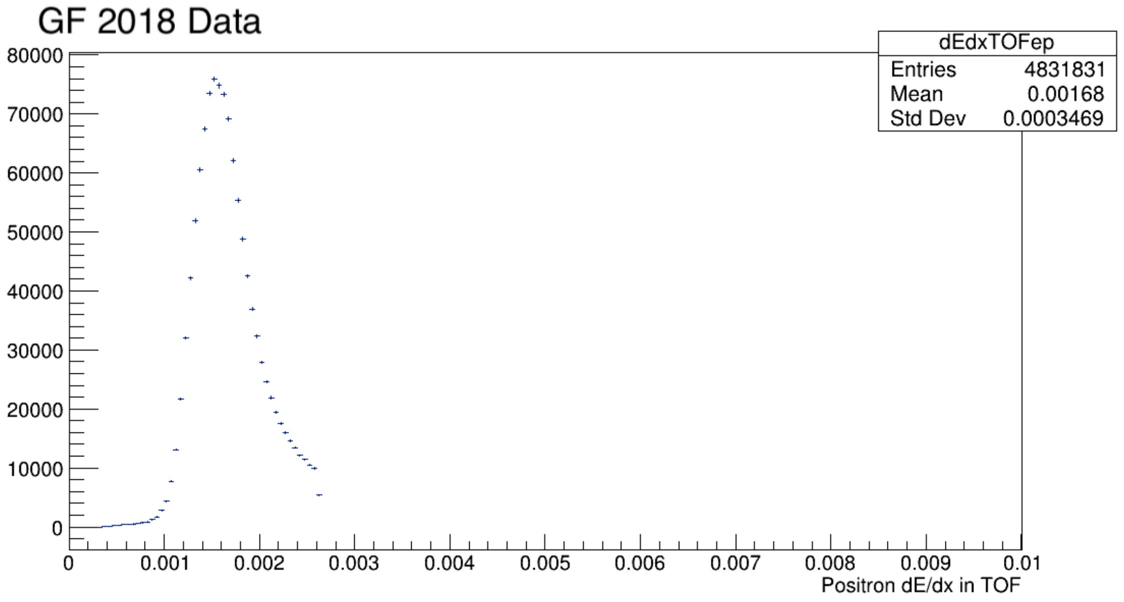
Need to track down discrepancies between MC and data:

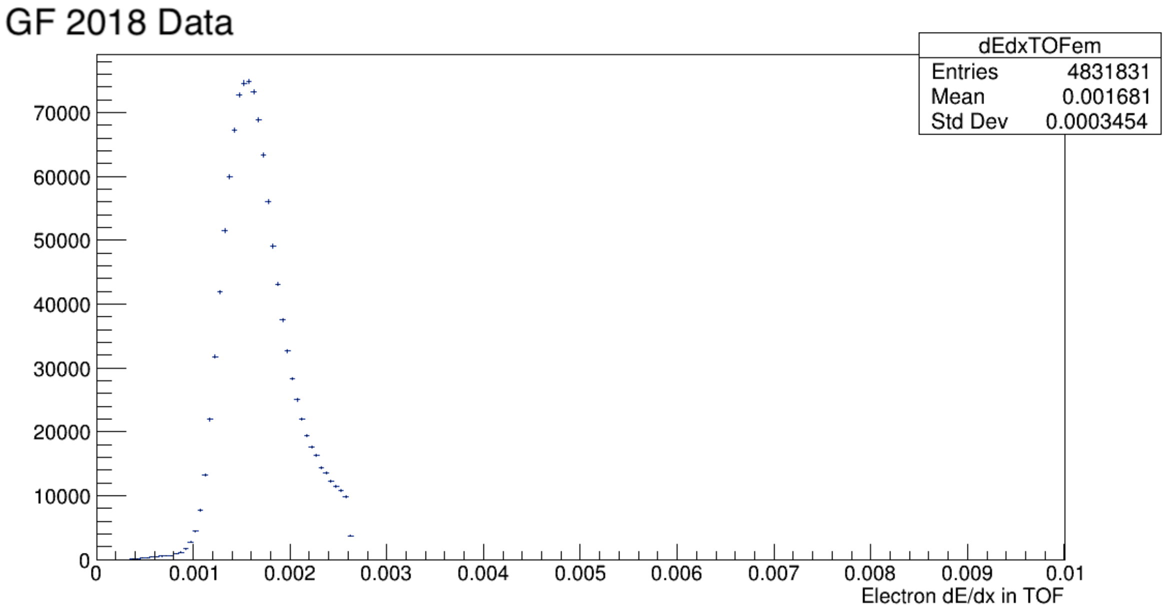
- Widths of peaks -> Calibration issues?
- Why does MC not model the low invariant mass peak?

Have to return to MC to make it as robust as possible:

- Real bremsstrahlung photon distribution
- Tagger Accidentals
- Open up phase space in theta to have very low angle tracks along the beam line
- More events!

Backup Slides


GF 2018 Data
dEdxTOFep
Entries 4831831
Mean 0.00168
Std Dev 0.0003469
80000
70000
60000
50000
40000
30000
20000
10000
0
0 0.001 0.002 0.003 0.004 0.005 0.006 0.007 0.008 0.009 0.01
Positron dE/dx in TOF


GF 2018 Data
dEdxTOFem
Entries 4831831
Mean 0.001681
Std Dev 0.0003454
70000
60000
50000
40000
30000
20000
10000
0
0 0.001 0.002 0.003 0.004 0.005 0.006 0.007 0.008 0.009 0.01
Electron dE/dx in TOF