Deuteron Electro-Disintegration Experiment (E12-10-003)

Hall C Winter Collaboration Meeting Jan 13-14 2025

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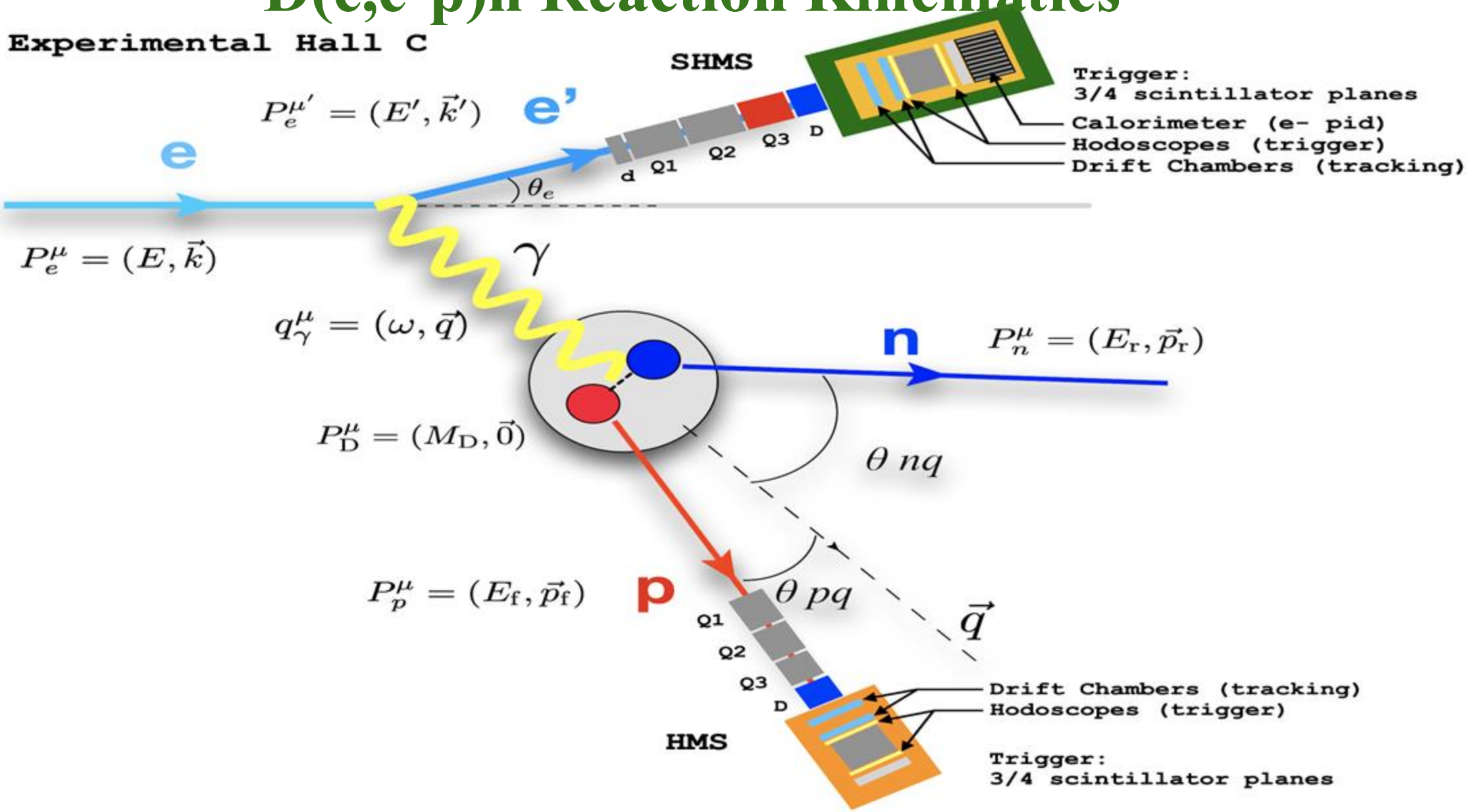
OUTLINE

1. Motivation
1. Kinematics
1. SIMC/DATA Comparison
1. HMS Momentum Check
1. Summary

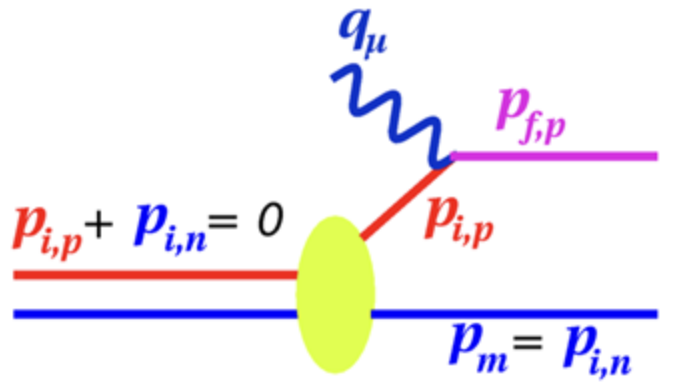
Motivation

- Ideal system to study NN potential.
- Study Deuteron at short ranges (< 1fm).
- Extract D(e,e’p)n cross-section beyond 500 MeV/c missing momentum at high/low Q2
- Extract momentum distributions (not an observable) from cross sections.

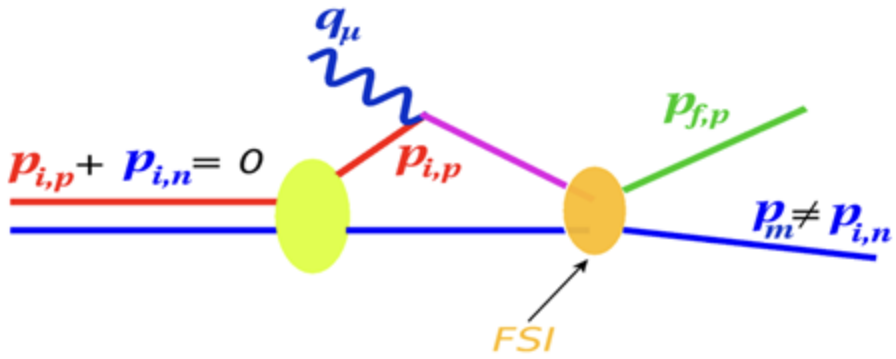
D(e,e'p)n Reaction Kinematics



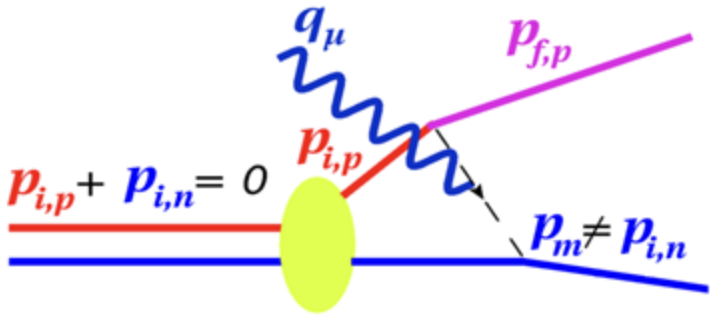
D(e,e'p)n Interactions



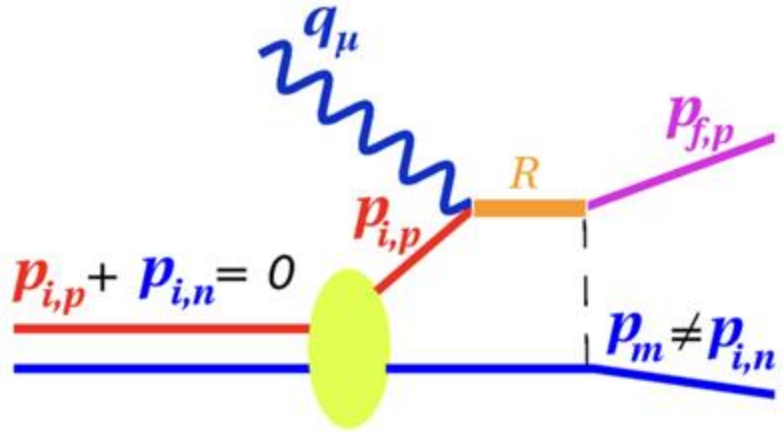
Plane Wave Impulse Approximation (PWIA)



Final State Interactions (FSI)

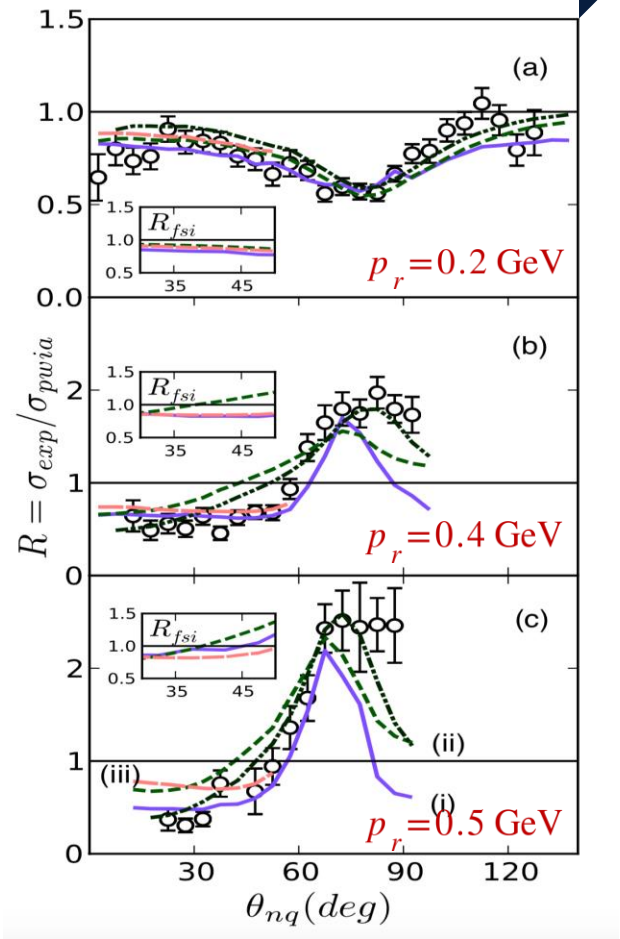


Meson-Exchange Currents (MEC)



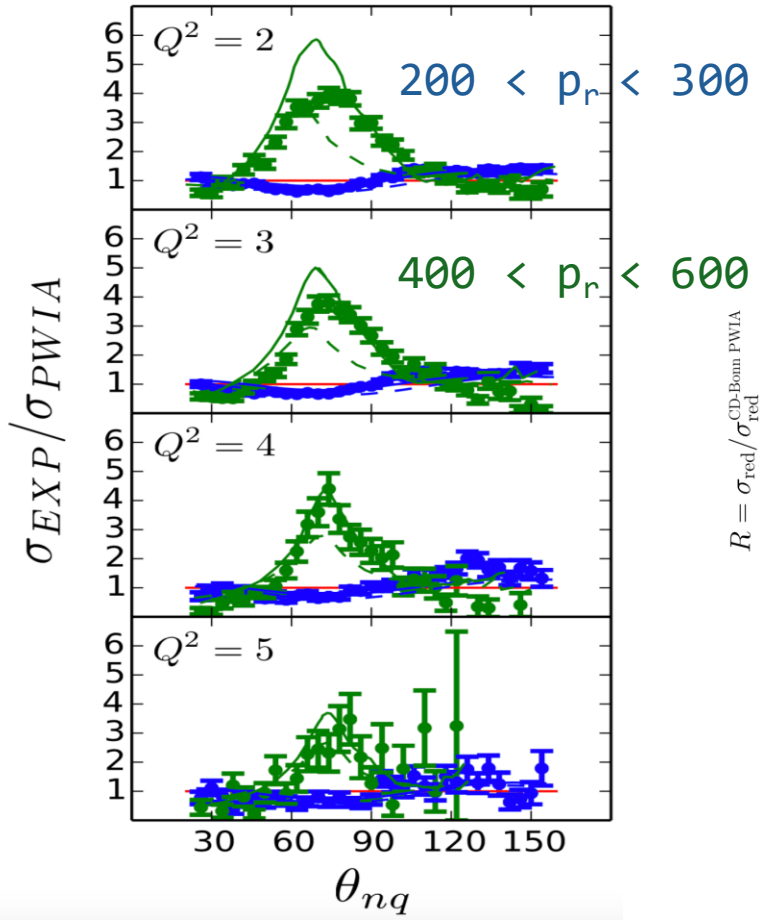
Isobar Configurations (IC)

Hall A Experiment (E01-020)



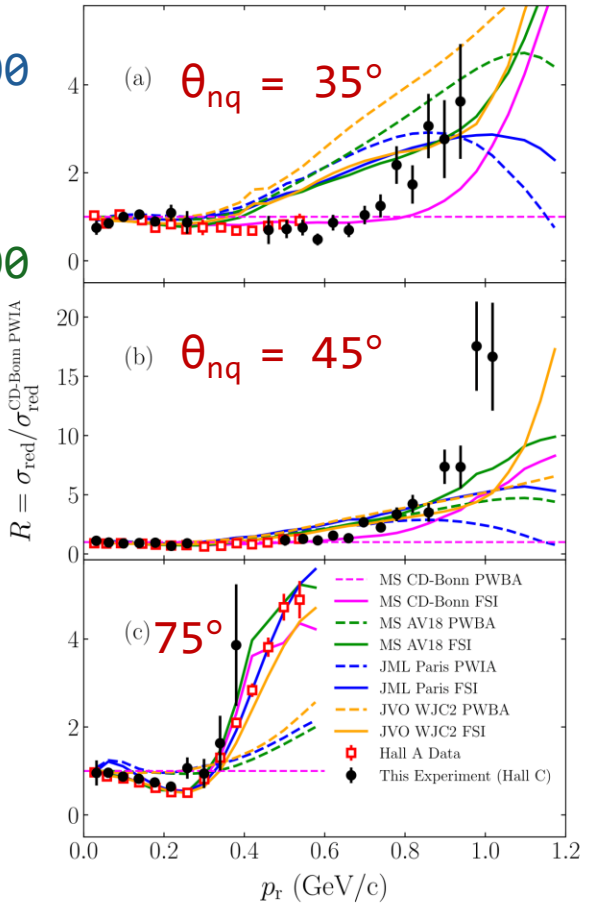
W. U. Boeglin et al. (2011)
10.1103/PhysRevLett.107.262501

Hall B Experiment (CLAS)



K. S. Egiyan et al. (2007)
10.1103/PhysRevLett.98.262502

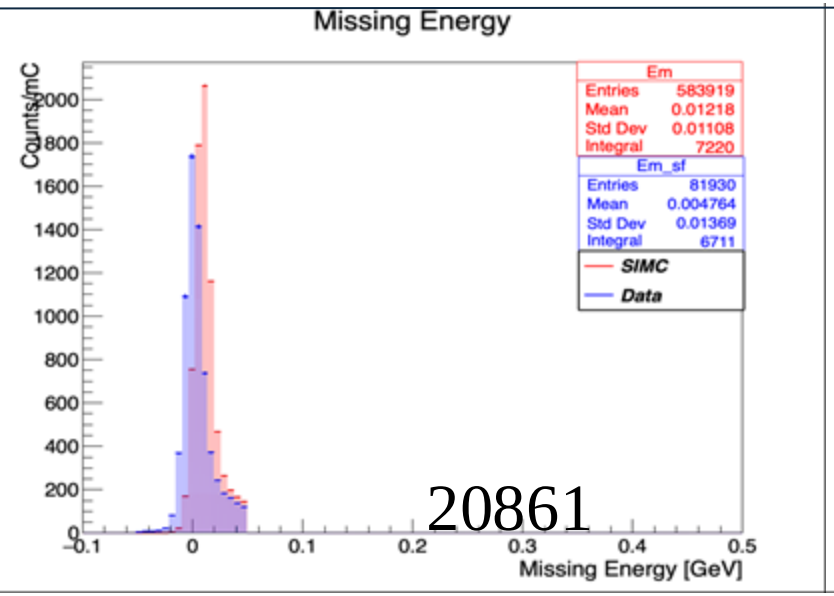
Hall C Experiment (E12-10-003)

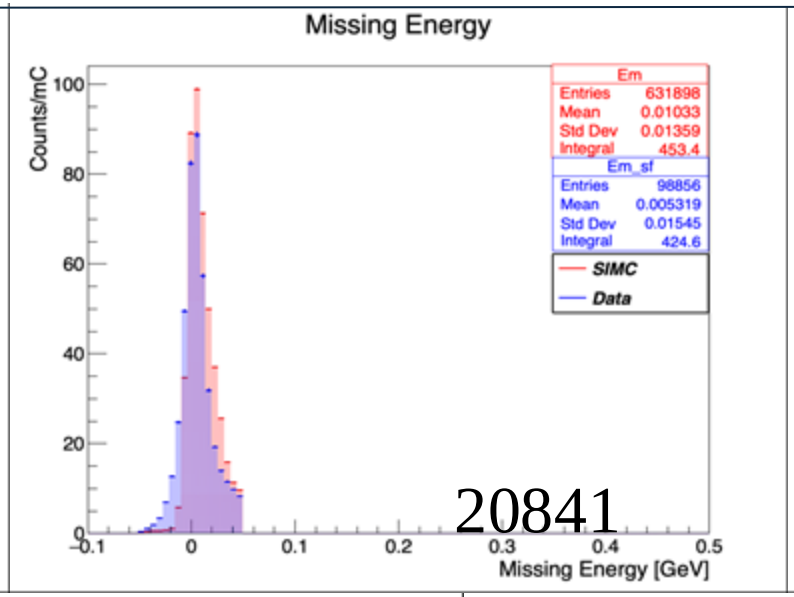


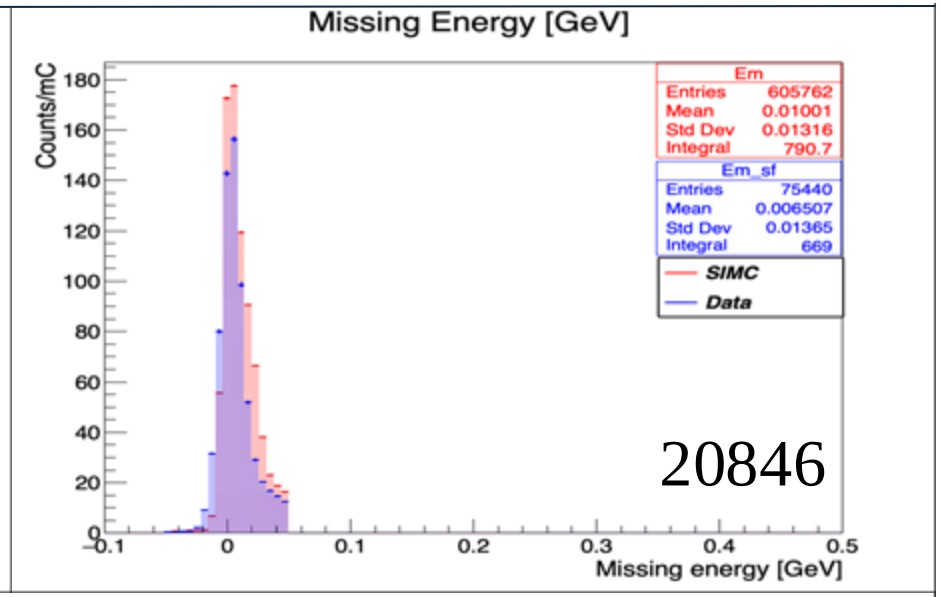
C. Yero et al. (2020)
10.1103/PhysRevLett.125.262501

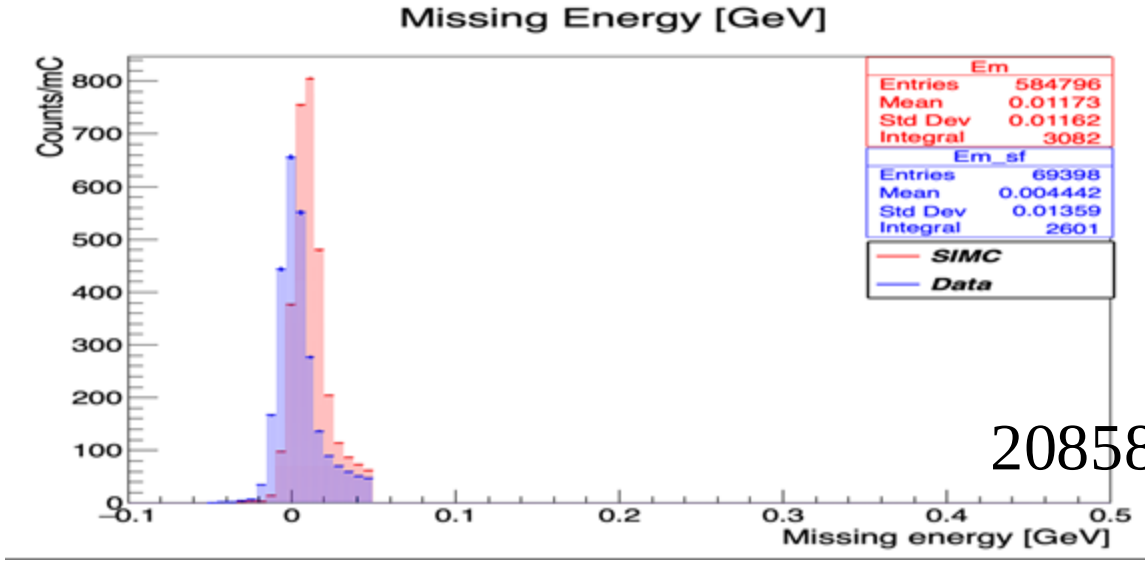
E12-10-003
H(e,e’p) Analysis:
SIMC and Data Comparison

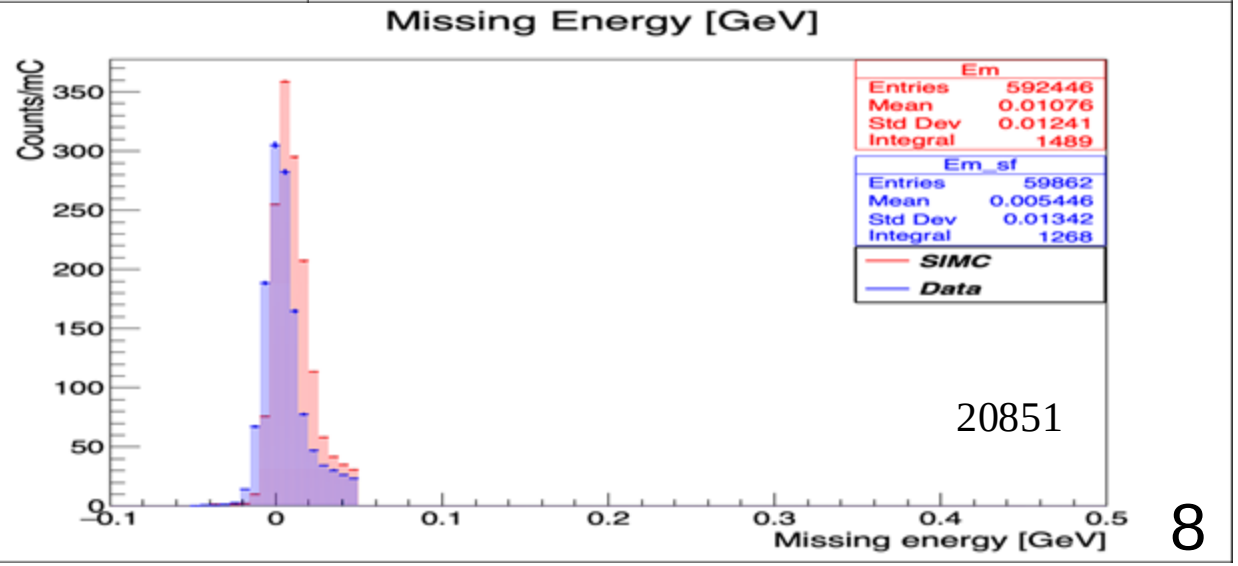
SIMC/DATA Comparison: CUTS APPLIED
Missing Energy cut, Emcut<0.05 and >-0.05





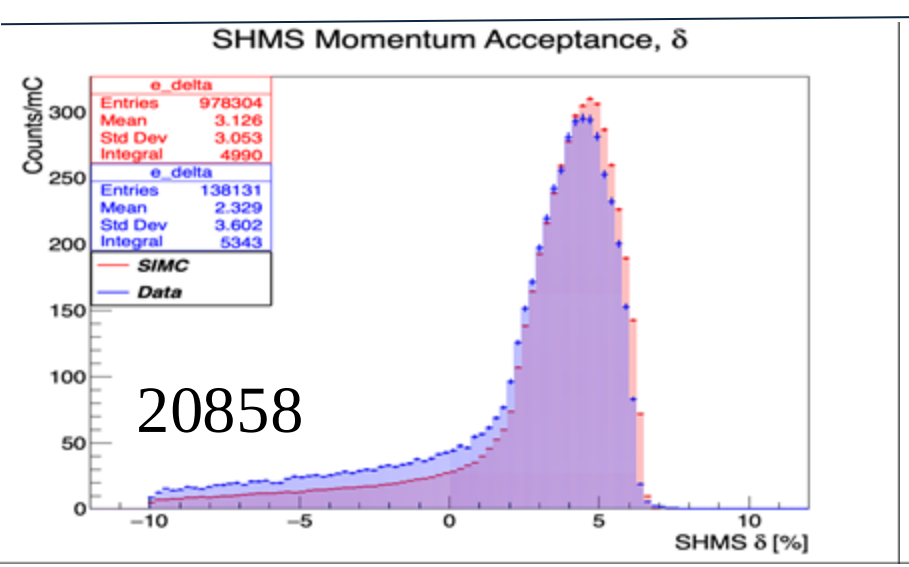


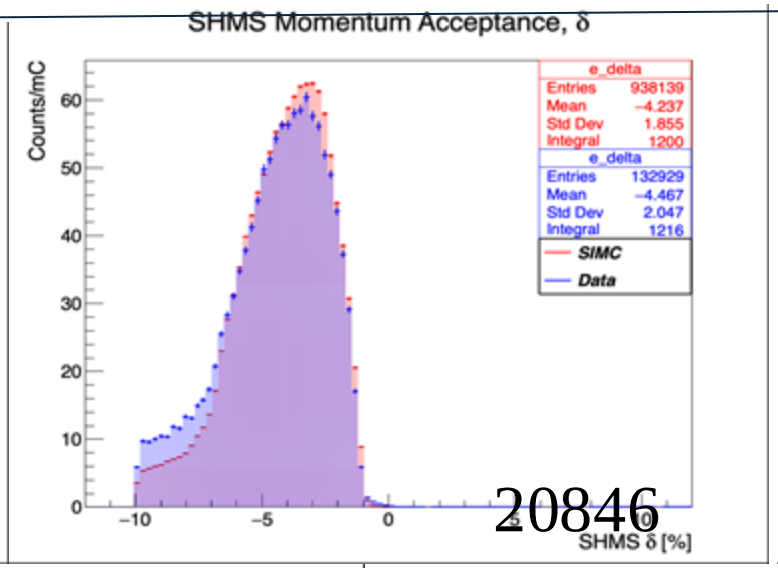


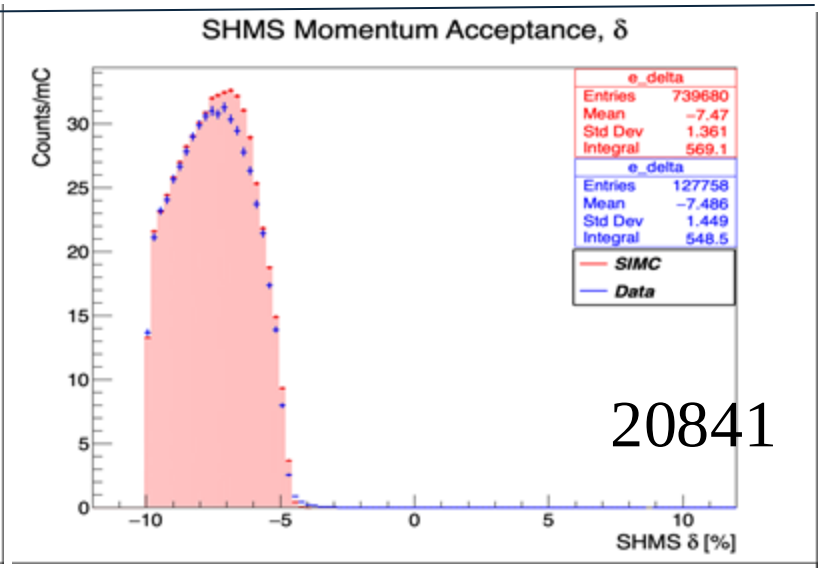


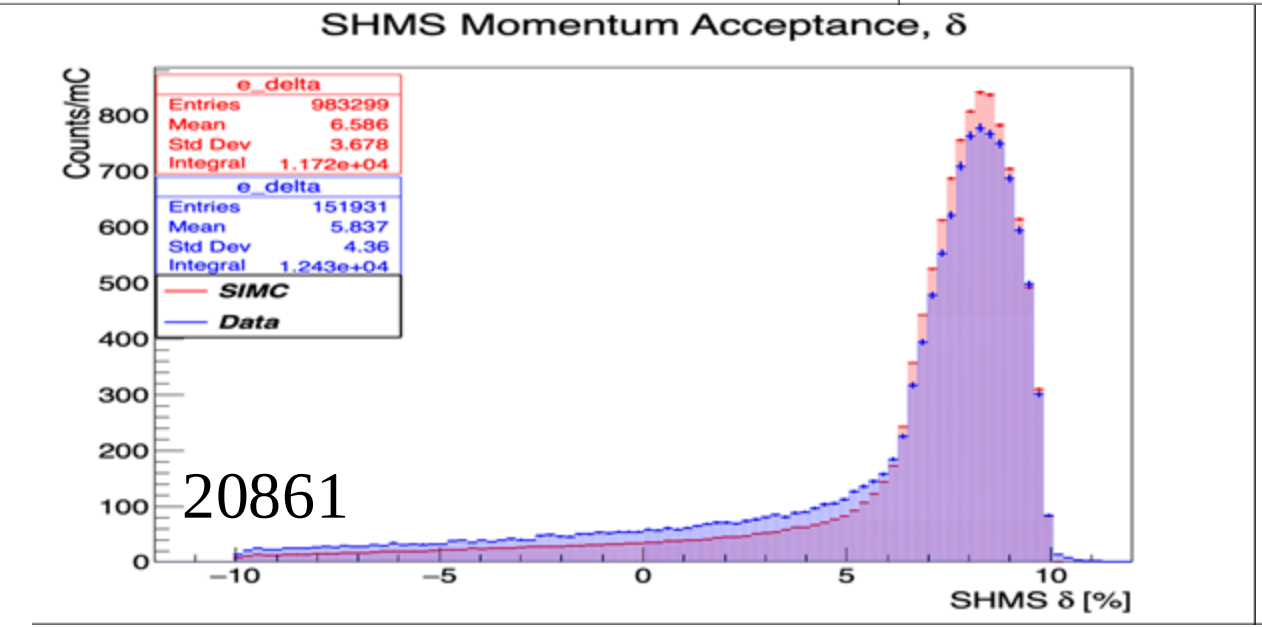
SIMC/DATA Comparison: CUTS APPLIED

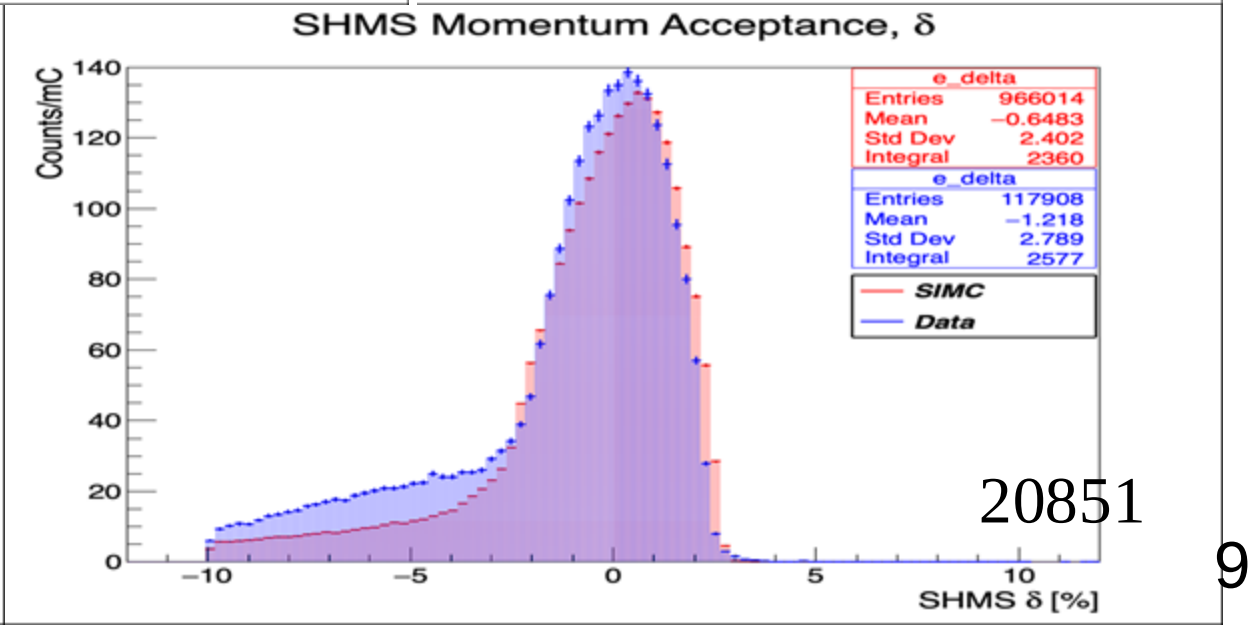
SHMS Momentum Acceptance cut <22 and >-10





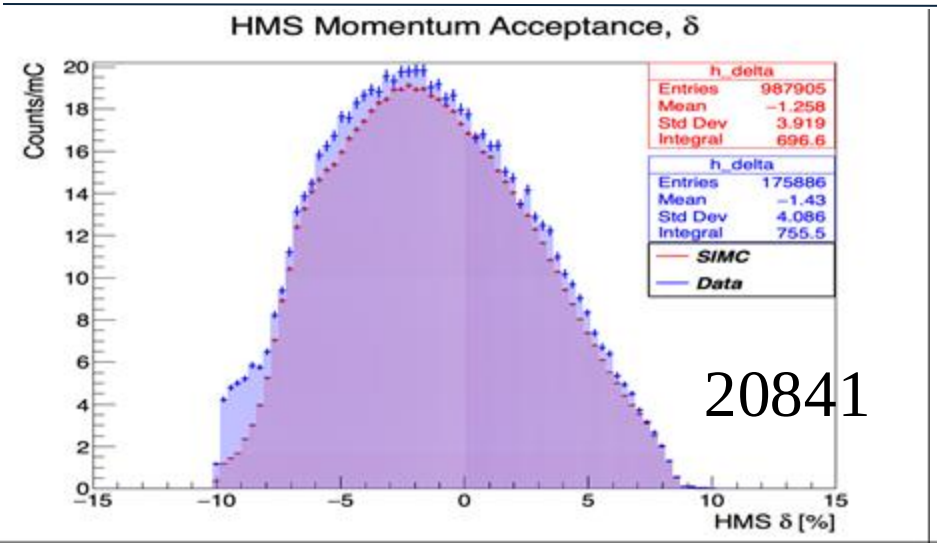






SIMC/DATA Comparison: CUTS APPLIED

HMS Momentum Acceptance cut <10 and >-10



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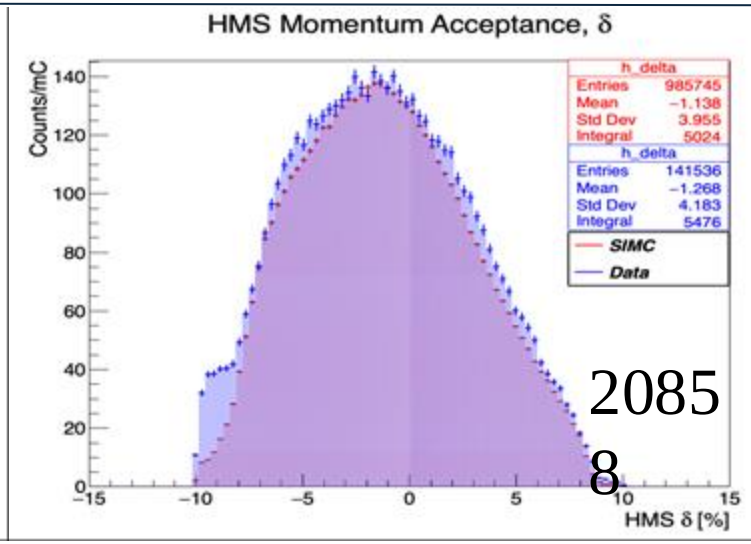

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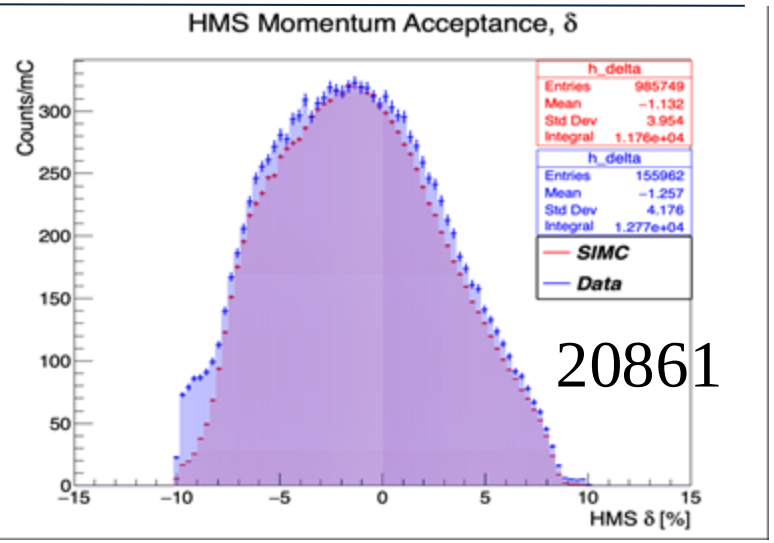
8



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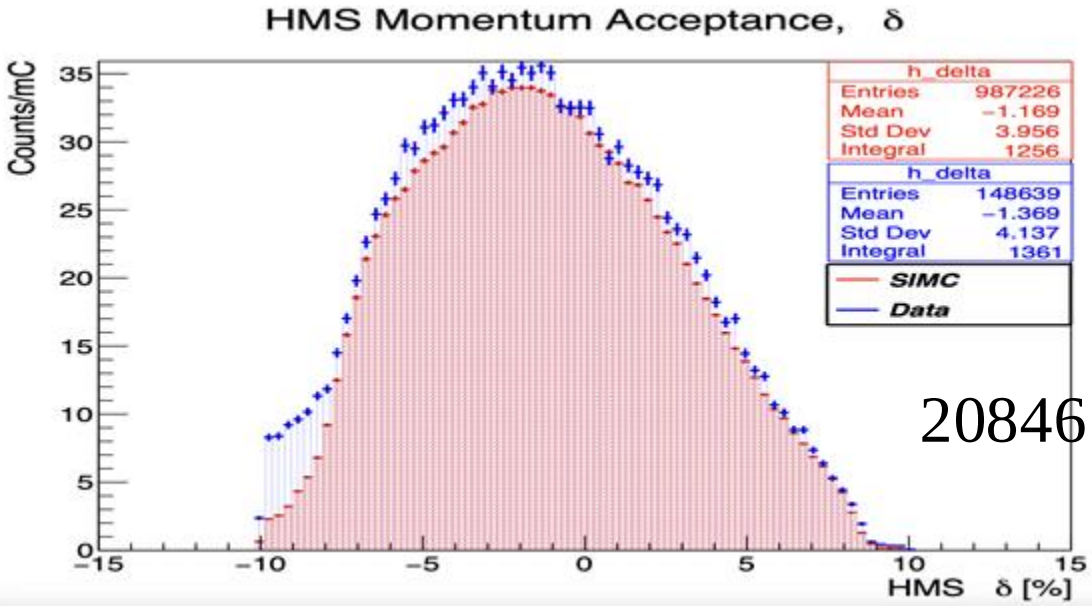

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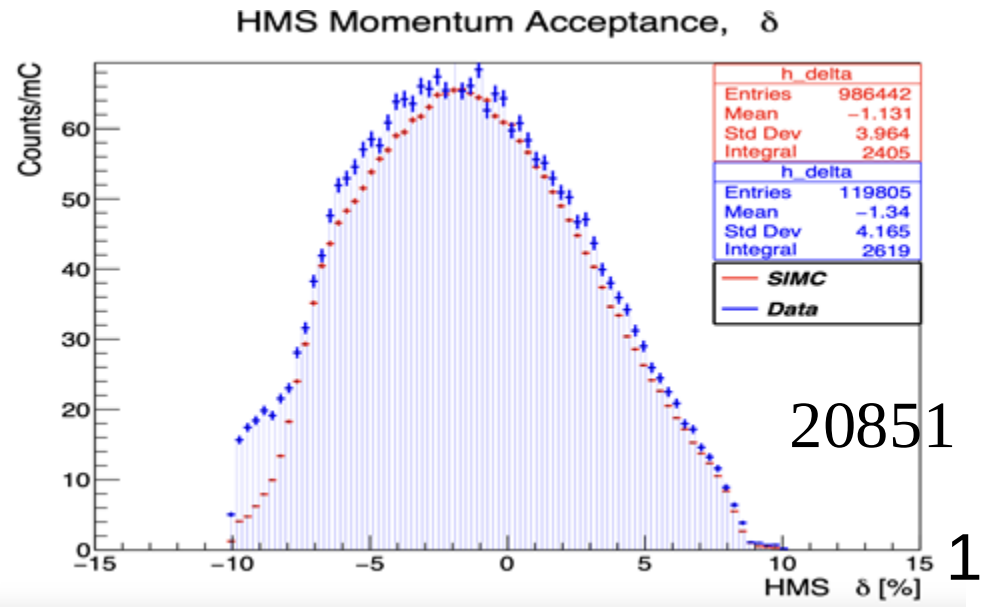

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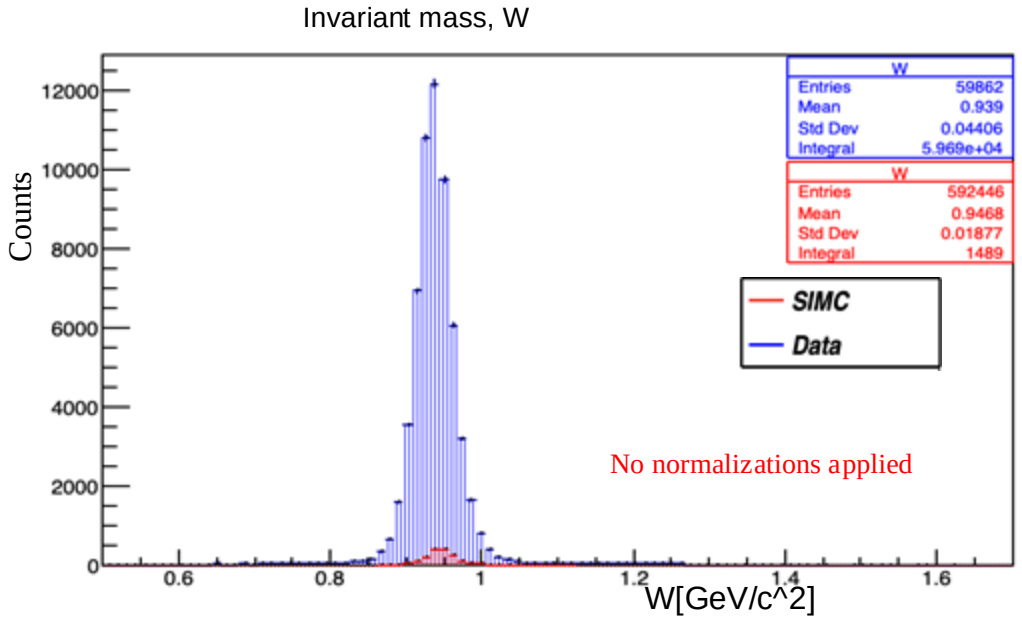
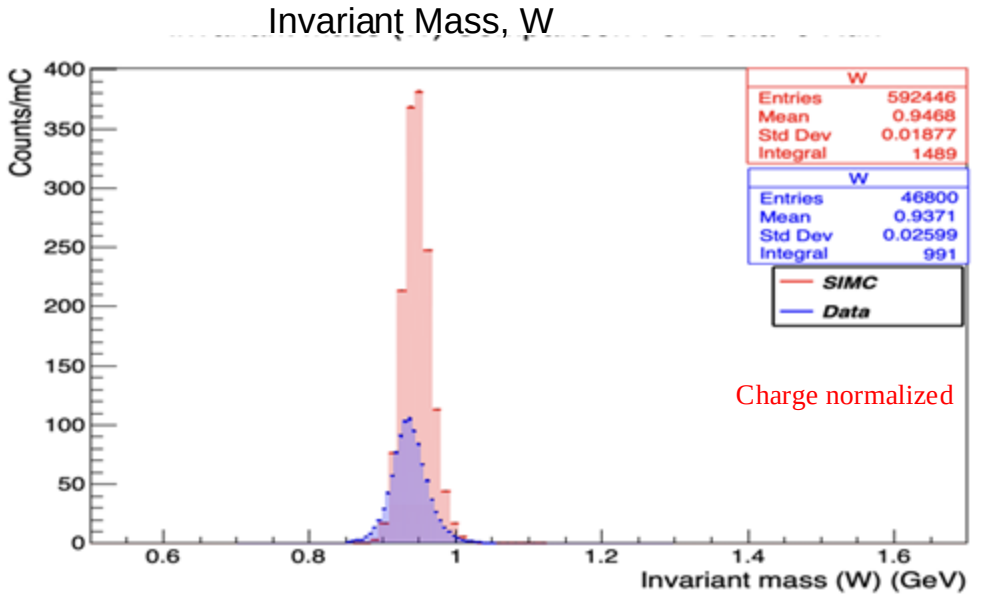
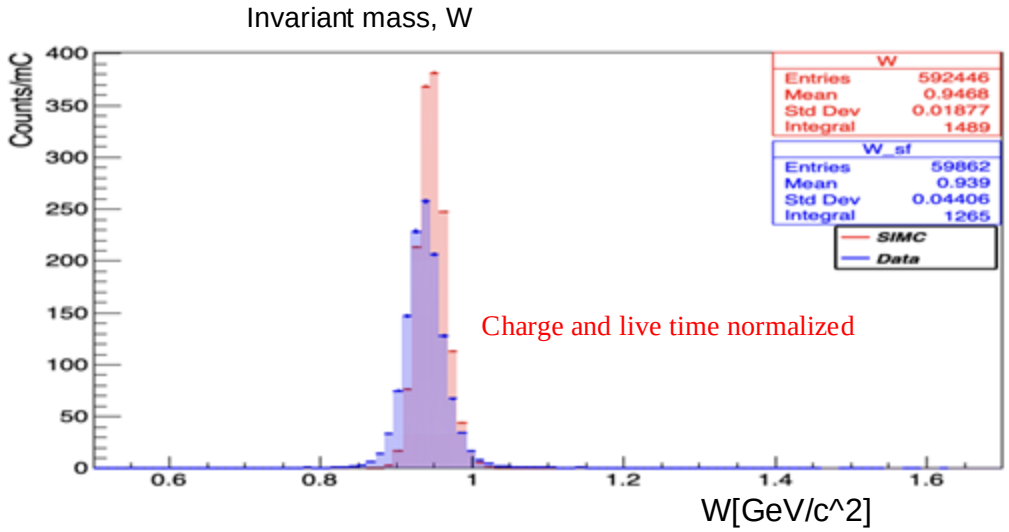
SIMC/DATA Comparison: CUTS APPLIED

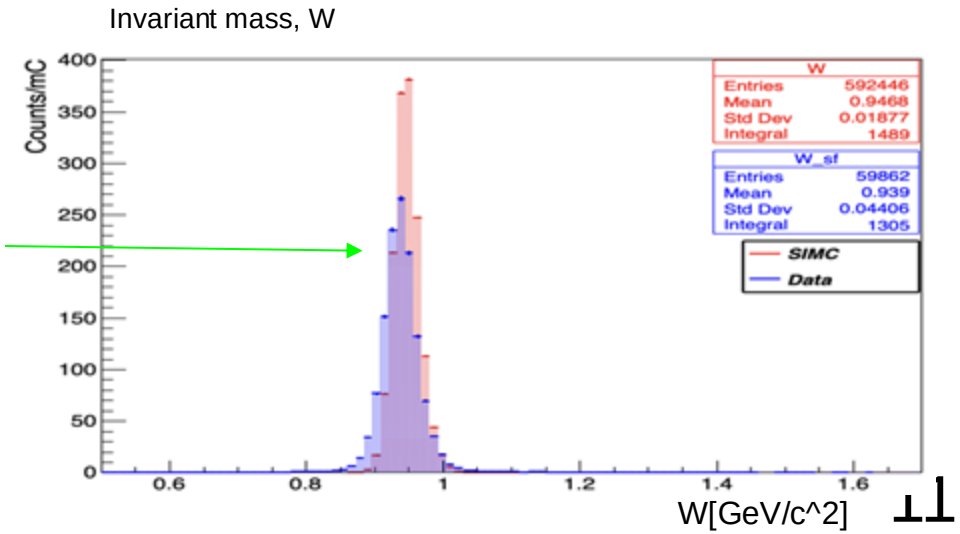
20851







Normalized by charge, live time and tracking efficiencies



E12-10-003
H(e,e’p) Analysis:
HMS Momentum Correction

Heep Analysis: HMS Momentum Corrections and Optimization

$$P_{calc}(E_b, \theta_p) = \frac{2M_p E_b (E_b + M_p)\cos(\theta_p)}{M_p^2 + 2M_p E_b + E_b^2 \sin^2(\theta_p)}$$

$$P_{fr}(E_b, \theta_p, P_{meas}) = \frac{P_{calc}(E_b, \theta_p) - P_{meas}}{Pmeas}$$

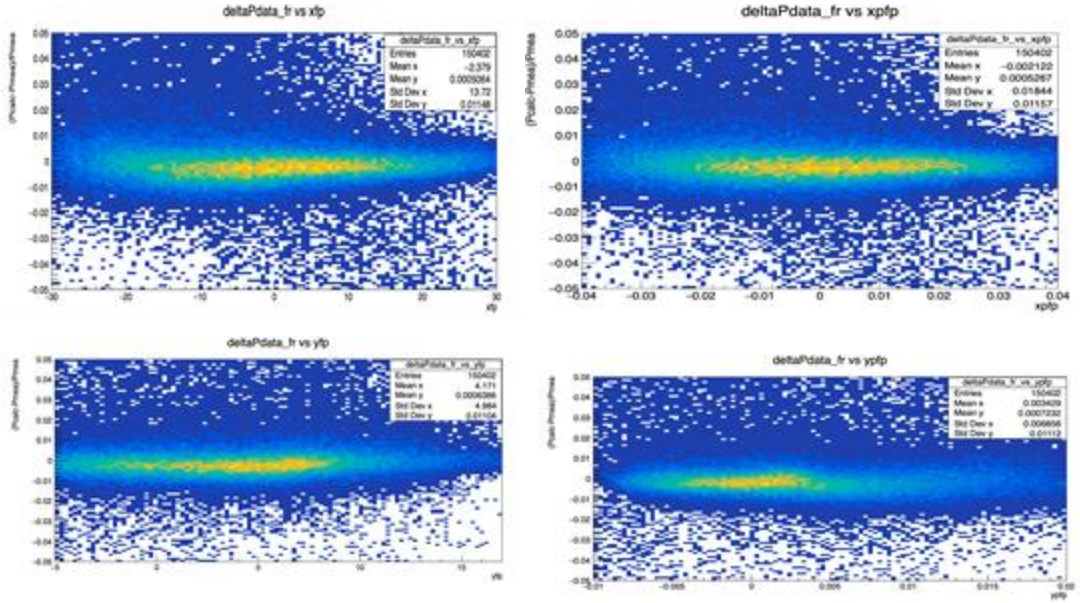
→ Fractional Momentum

H(e,e'p) Elastics Kinematics Used In Optimization Procedure

Run #	HMS Momentum [GeV/c]	HMS angle [deg]	SHMS Momentum [GeV/c]	SHMS angle [deg]	SHMS Delta	HMS Delta Range
20841	3.499	33.344	8.55	14.153	Delta scan -8	
20846	3.145	35.750	8.55	12.940	Delta scan -4	
20851	2.783	38.549	8.55	11.705	Delta scan 0	
20858	2.417	41.812	8.55	10.435	Delta scan+4	
20861	2.048	45.667	8.55	9.125	Delta scan+8	

Correlation check

20851



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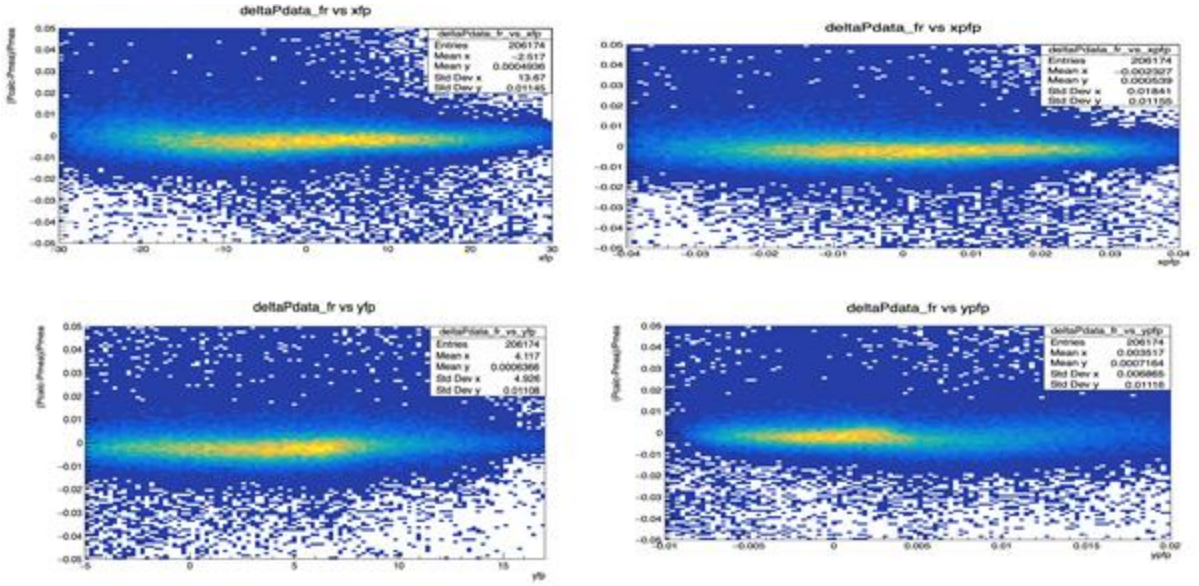

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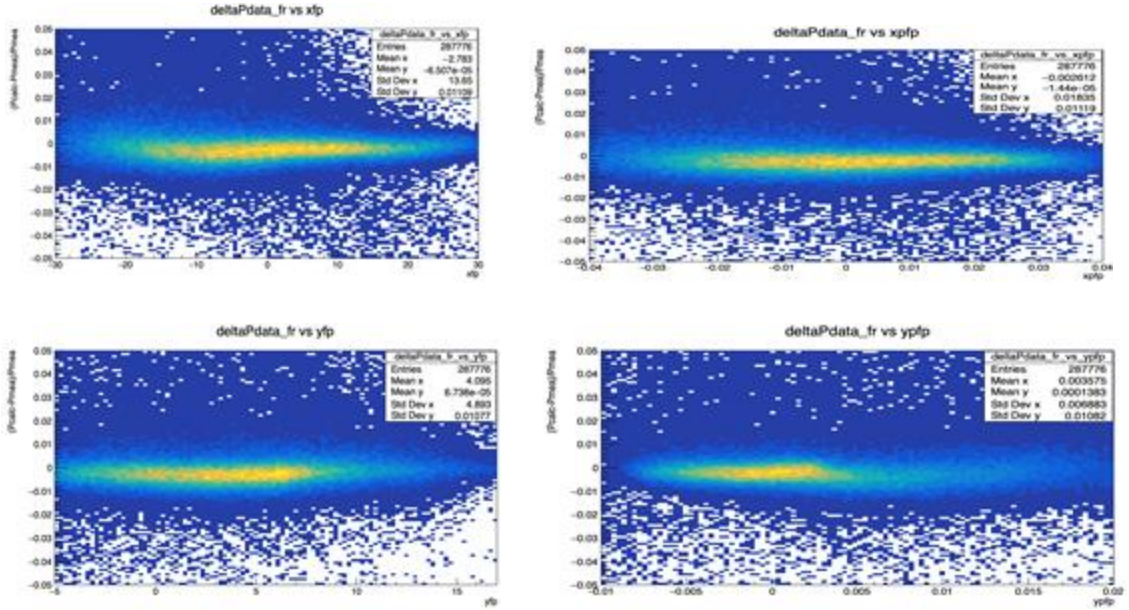

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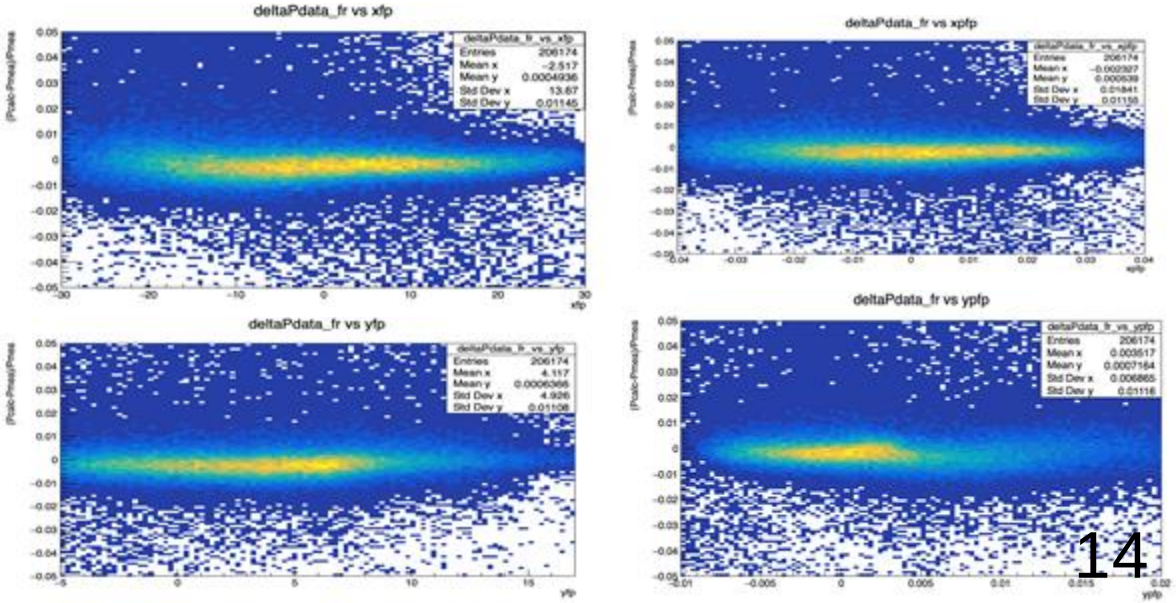
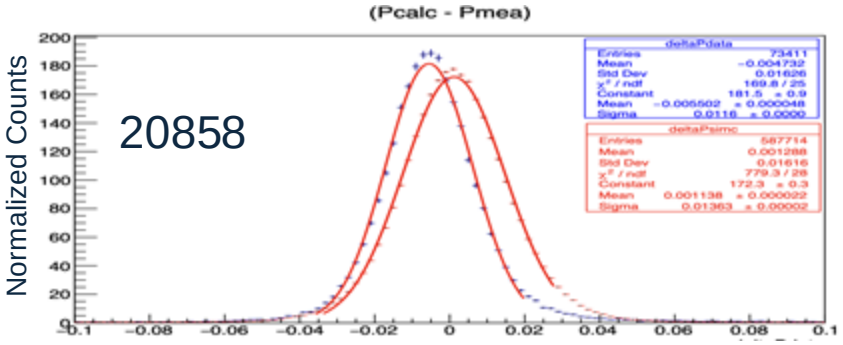
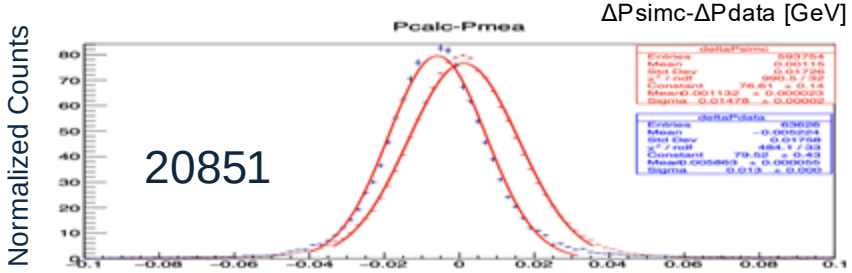
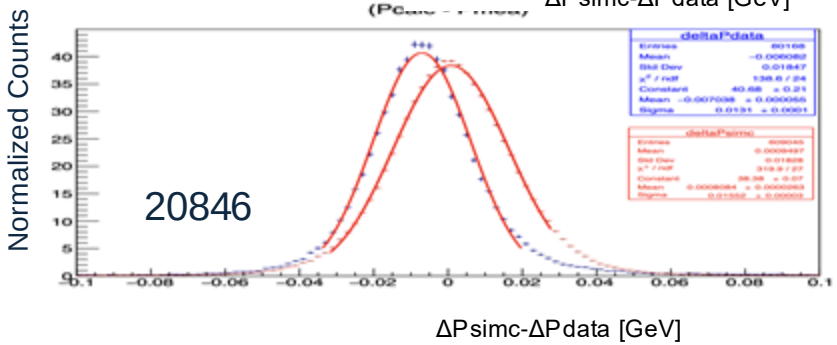
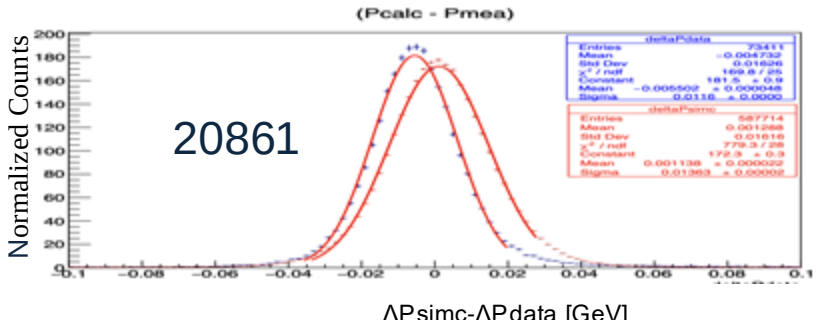


Before Correction

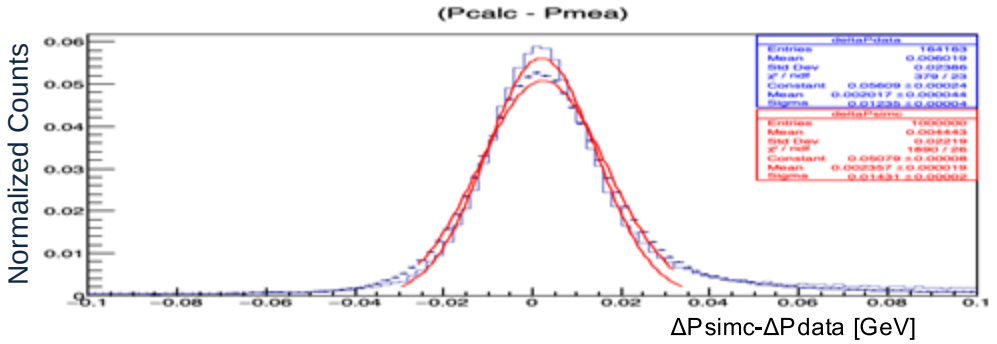


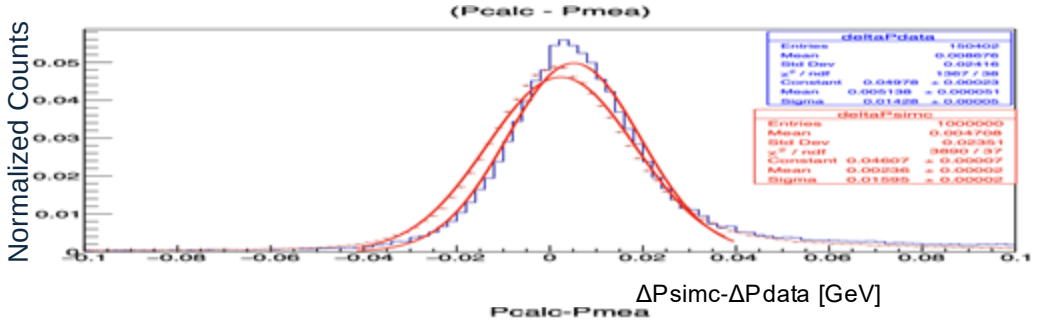


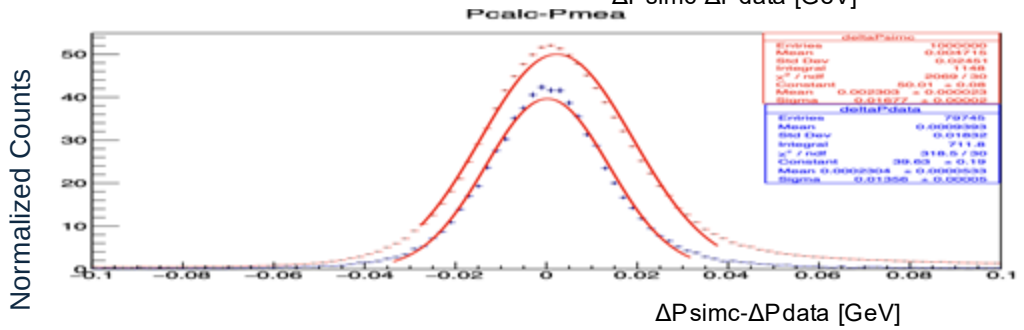


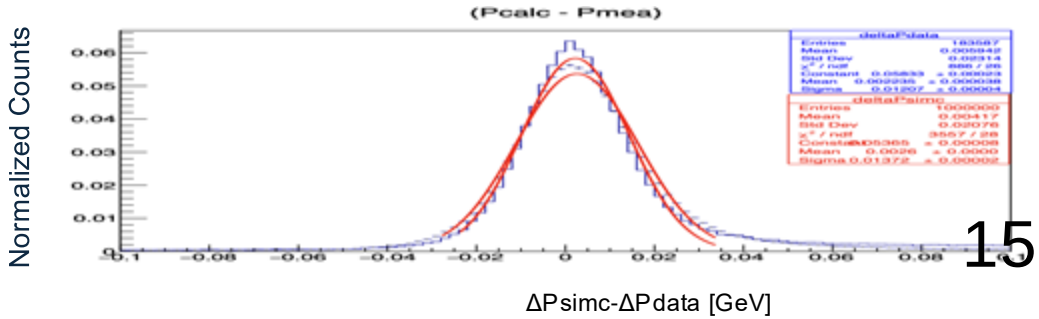


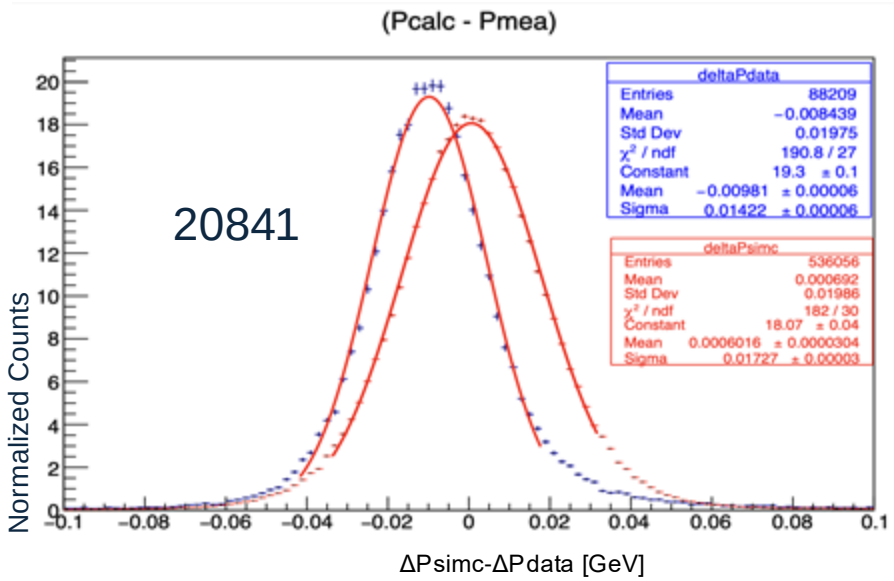
After Correction

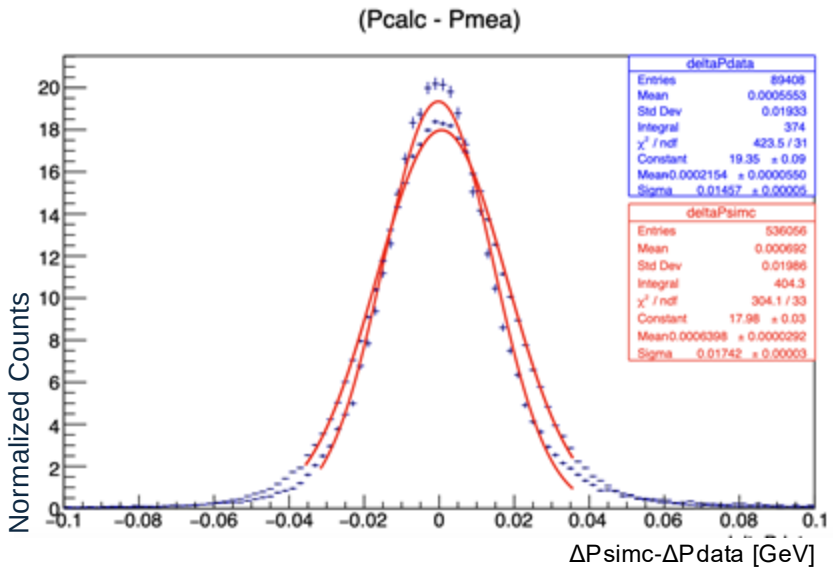




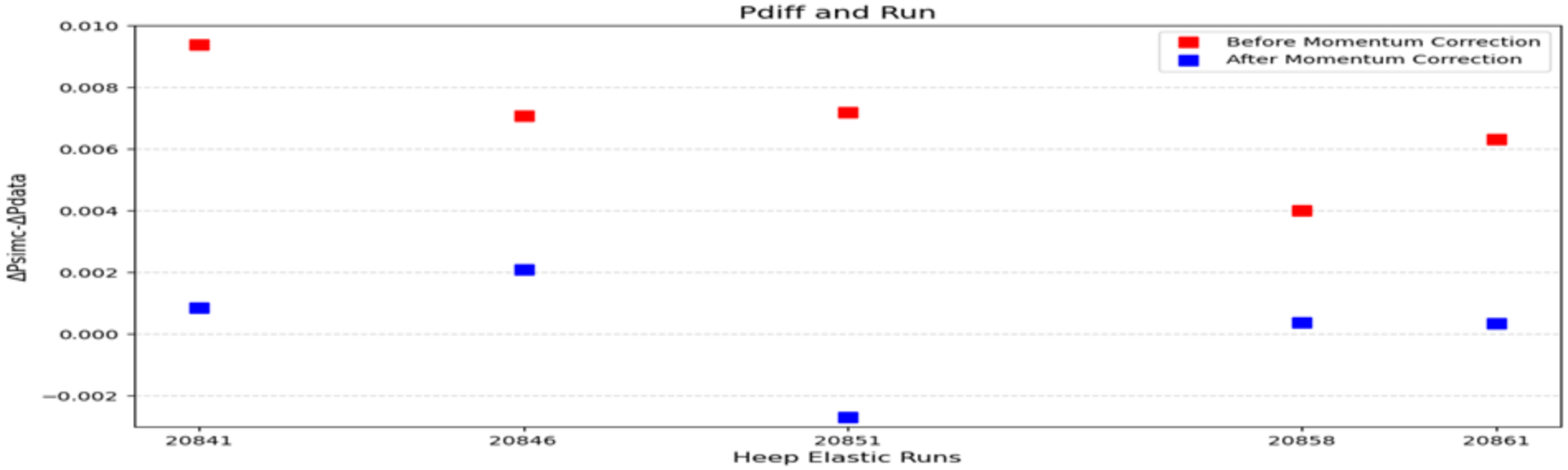








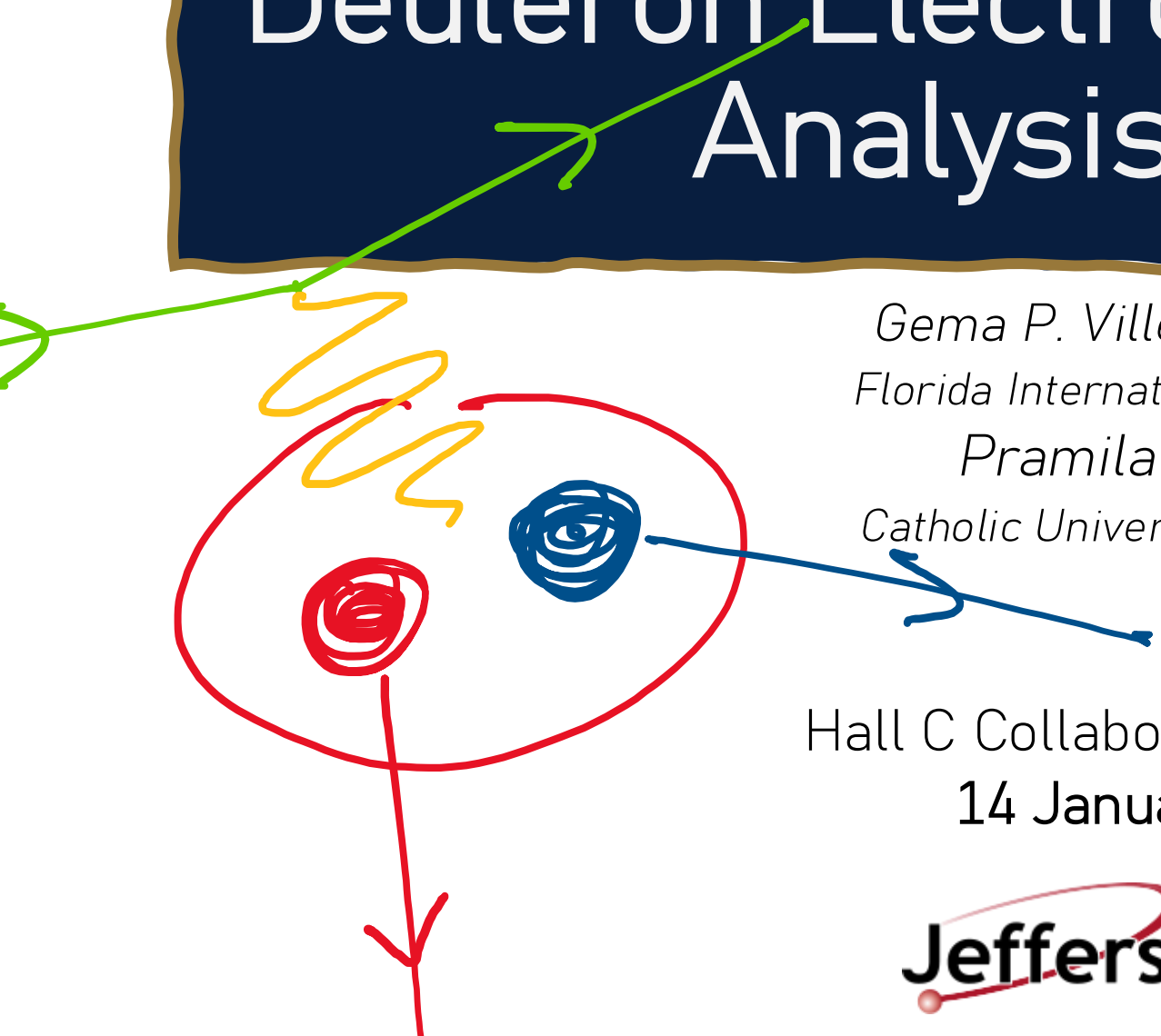
HMS Momentum Before and After Correction



SUMMARY

- HMS Momentum for Heep studied.
- SIMC/DATA Yields currently being studied

Deuteron Electro-disintegration Analysis Update

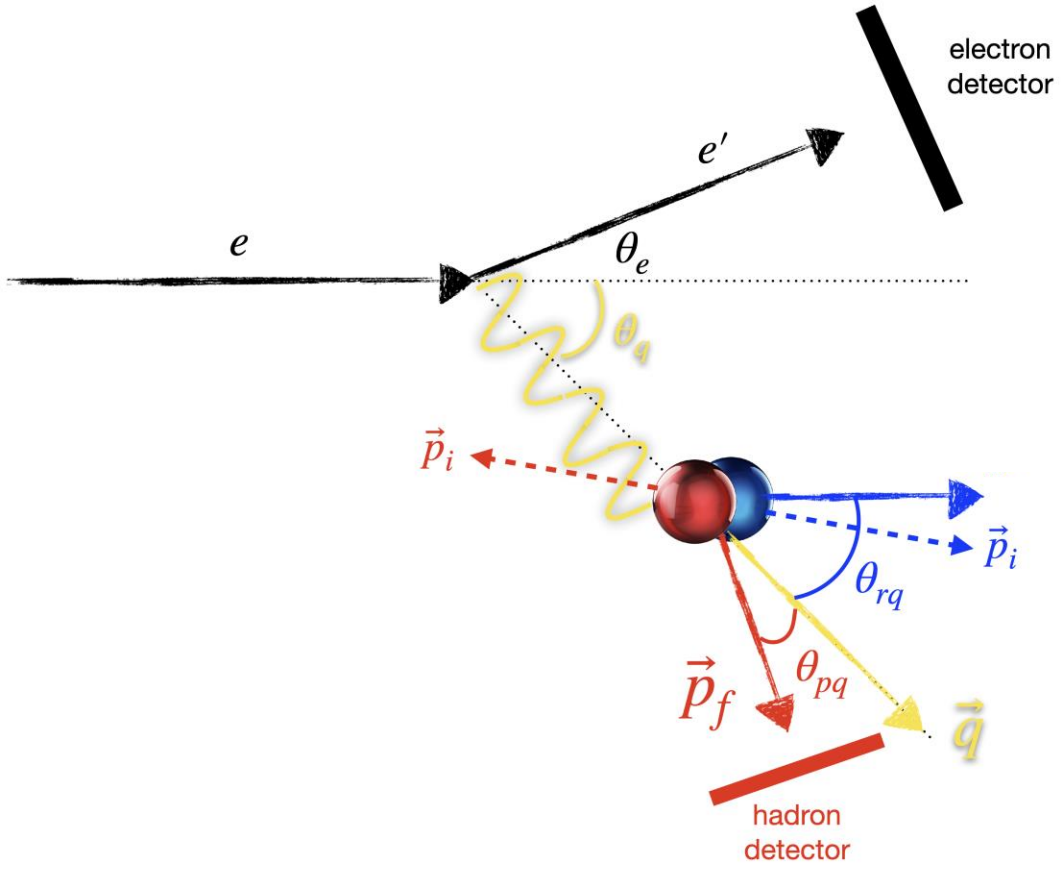


Gema P. Villegas Minyety
Florida International University
Pramila Pokhrel
Catholic University of America

Hall C Collaboration Meeting
14 January 2025

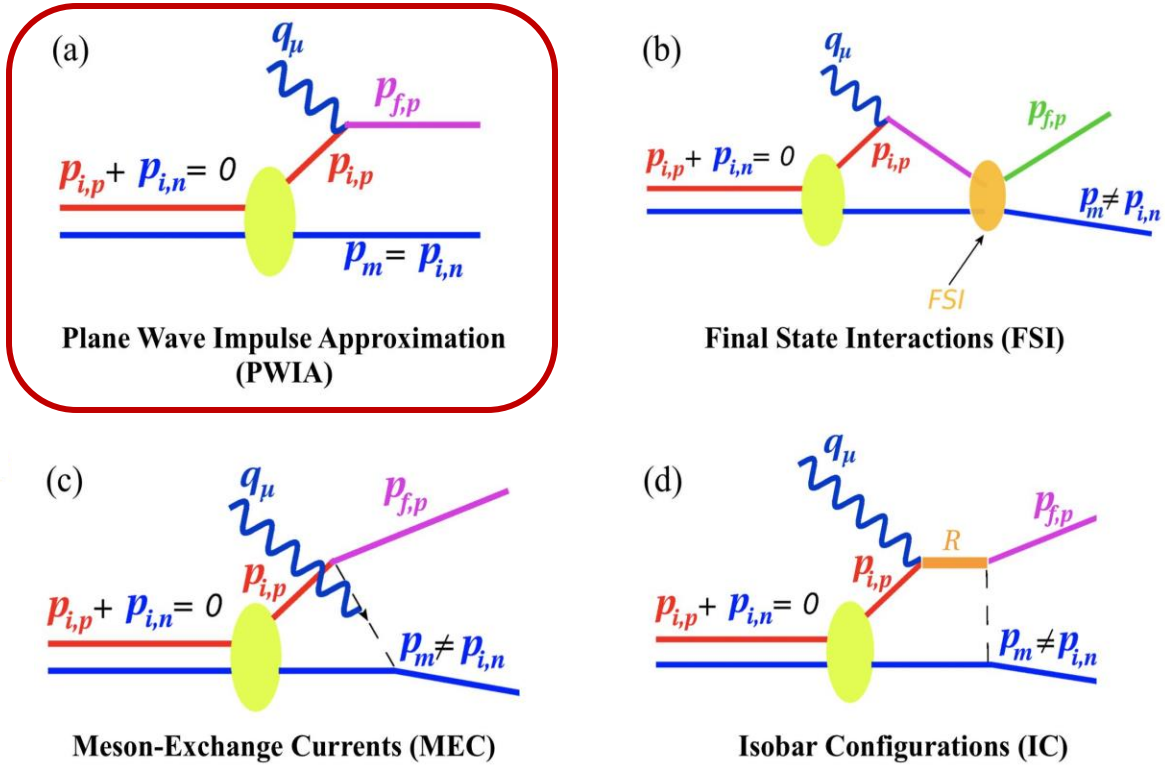
Jefferson Lab Hall C FIU

Brief Overview of D(e,e'p)n



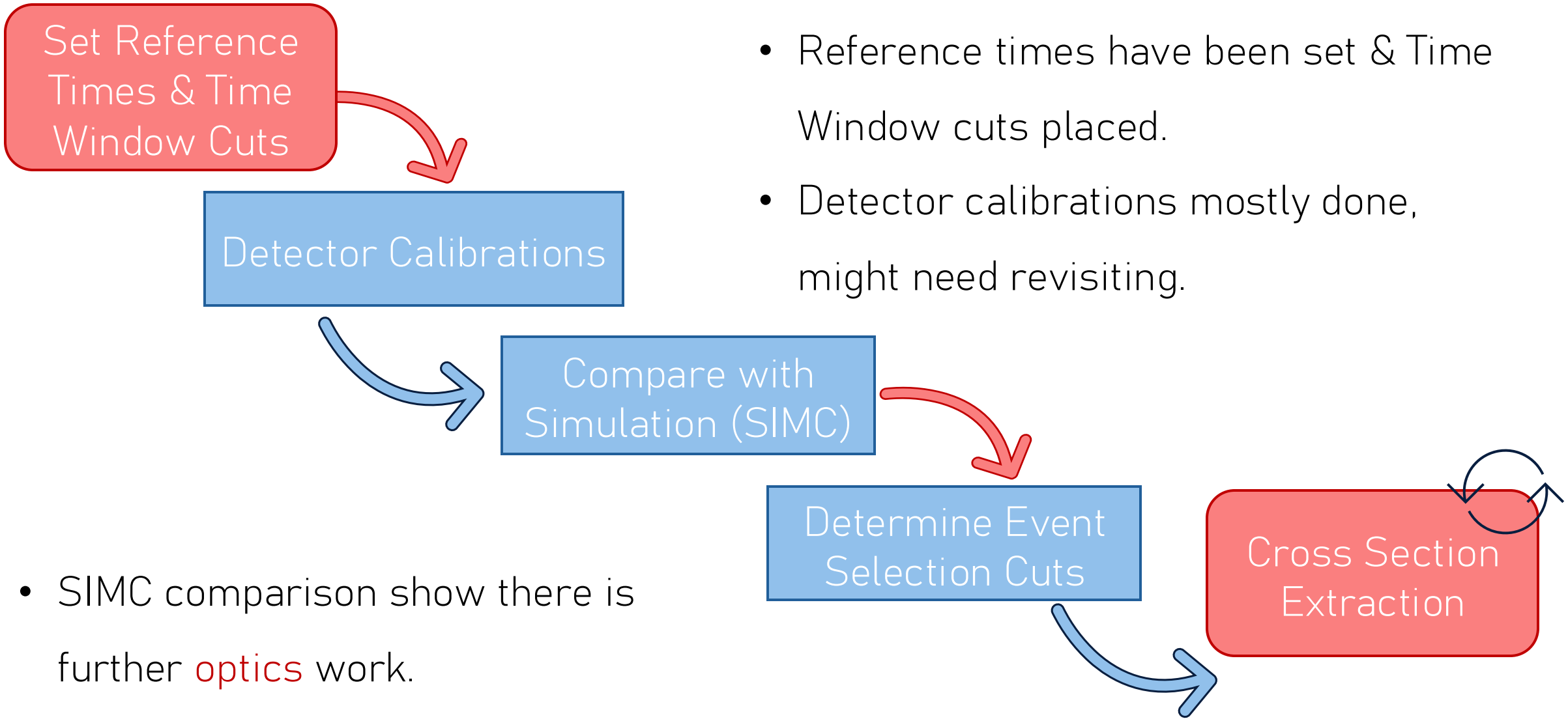
C. Yero, p. c.

C. Yero. (2020). Thesis



(b), (c), and (d) are suppressed in the kinematic window used

Analysis Procedure

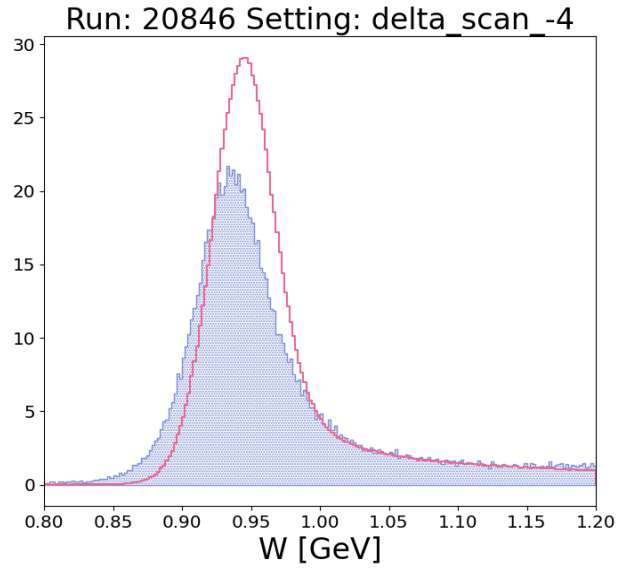


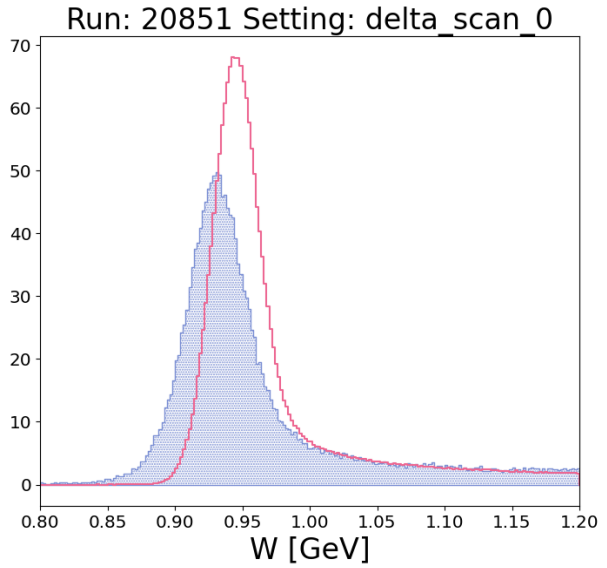
- Reference times have been set & Time Window cuts placed.
- Detector calibrations mostly done, might need revisiting.

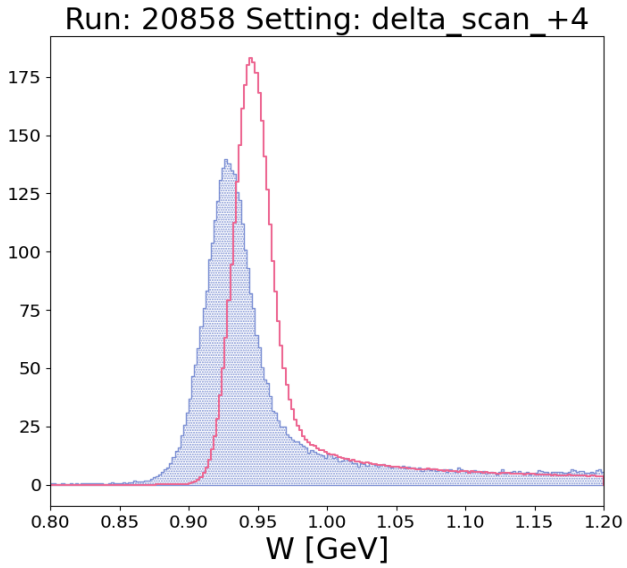
- SIMC comparison show there is further optics work.

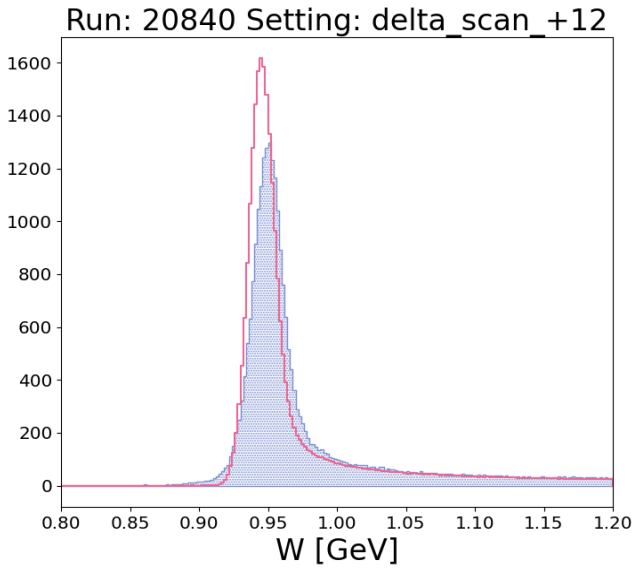
SIMC-H(e,e'p) Comparison

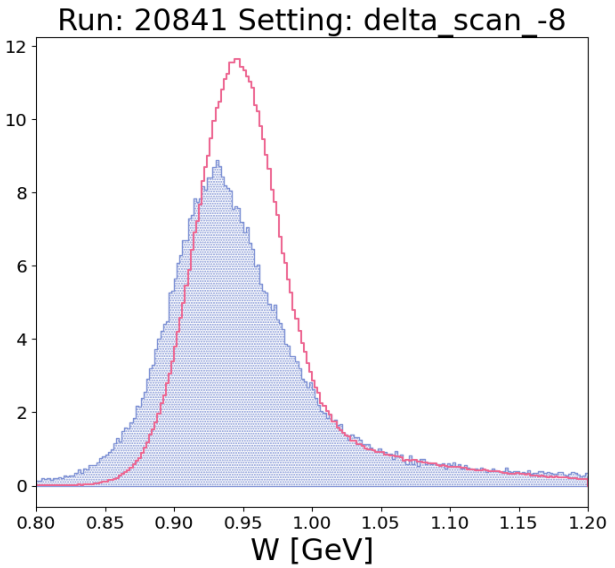
Hydrogen Elastics

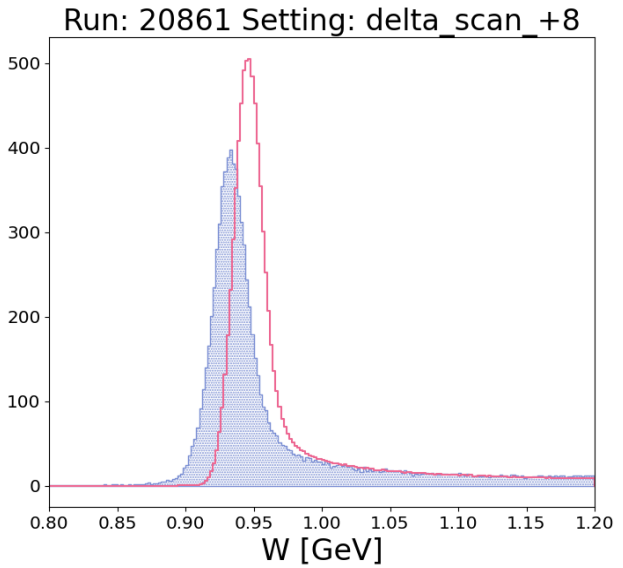












Angle and Momentum Offset Determination

- Determining offsets in angle then in momentum, based on SIMC comparison
- Method was developed by C. Yero for Café

Definitions

calculated (e-) momentum

$$k_{f,calc}(E_b,\theta_e) = \frac{M_p E_b}{M_p + 2E_b \sin^2(\theta_e/2)}$$

measured (e-) momentum

$$k_{f,meas} = P_0\left(\frac{\delta_{shms}}{100} + 1\right)$$

calculated (proton) momentum

$$P_{f,z} = E_b - k_f \cos(\theta_e)$$

$$P_{f,x} = -k_f \sin(\theta_e)$$

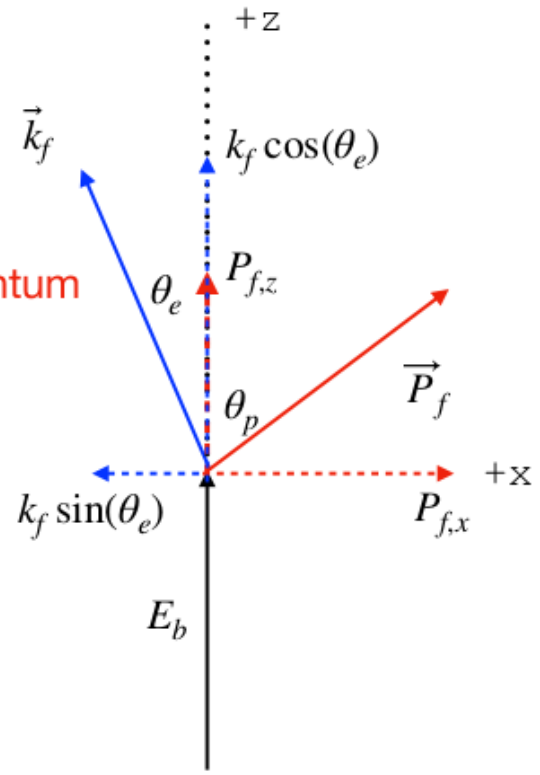
$$P_{f,calc}(E_b,\theta_e) = \sqrt{P_{f,x}^2 + P_{f,z}^2}$$

measured (proton) momentum

$$P_{f,meas} = P_0\left(\frac{\delta_{hms}}{100} + 1\right)$$

calculated (proton) angle

$$\theta_{p,calc}(E_b,\theta_e) = \tan^{-1}\frac{P_{f,x}}{P_{f,z}}$$



calculated-measured:

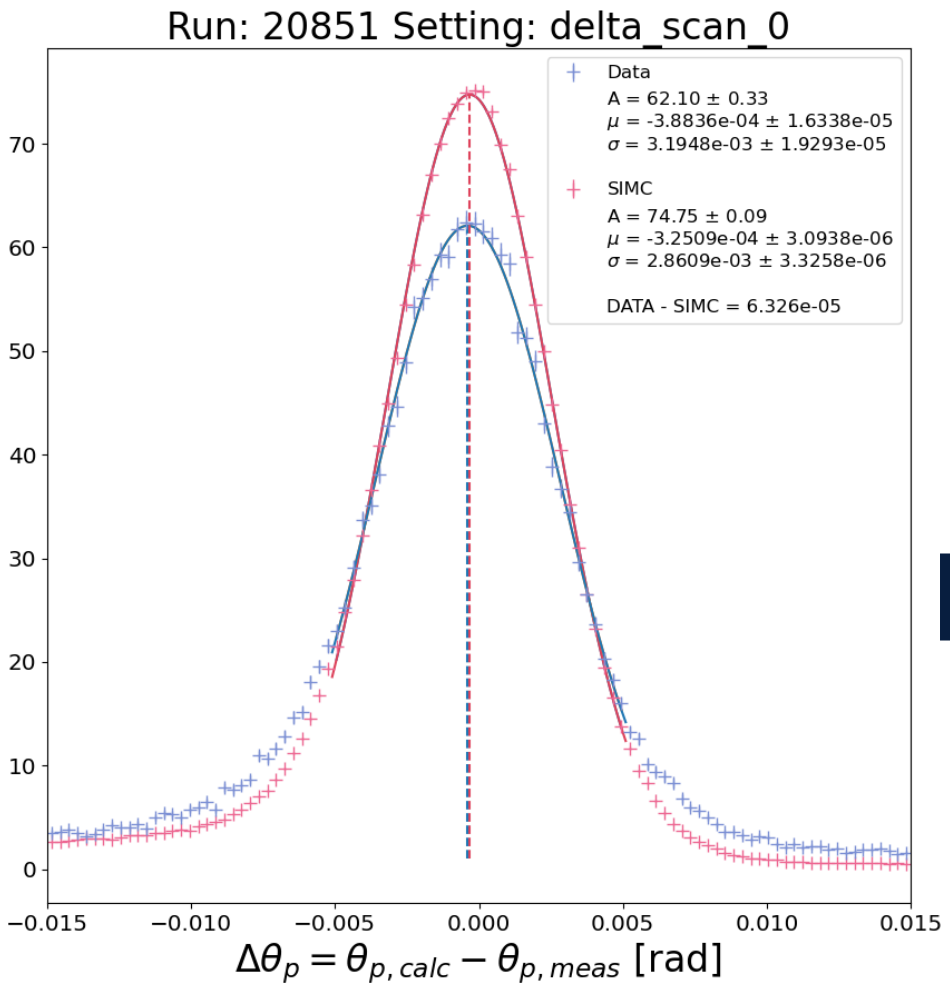
$$dk_f = k_{f,calc} - k_{f,meas}$$

$$dP_f = P_{f,calc} - P_{f,meas}$$

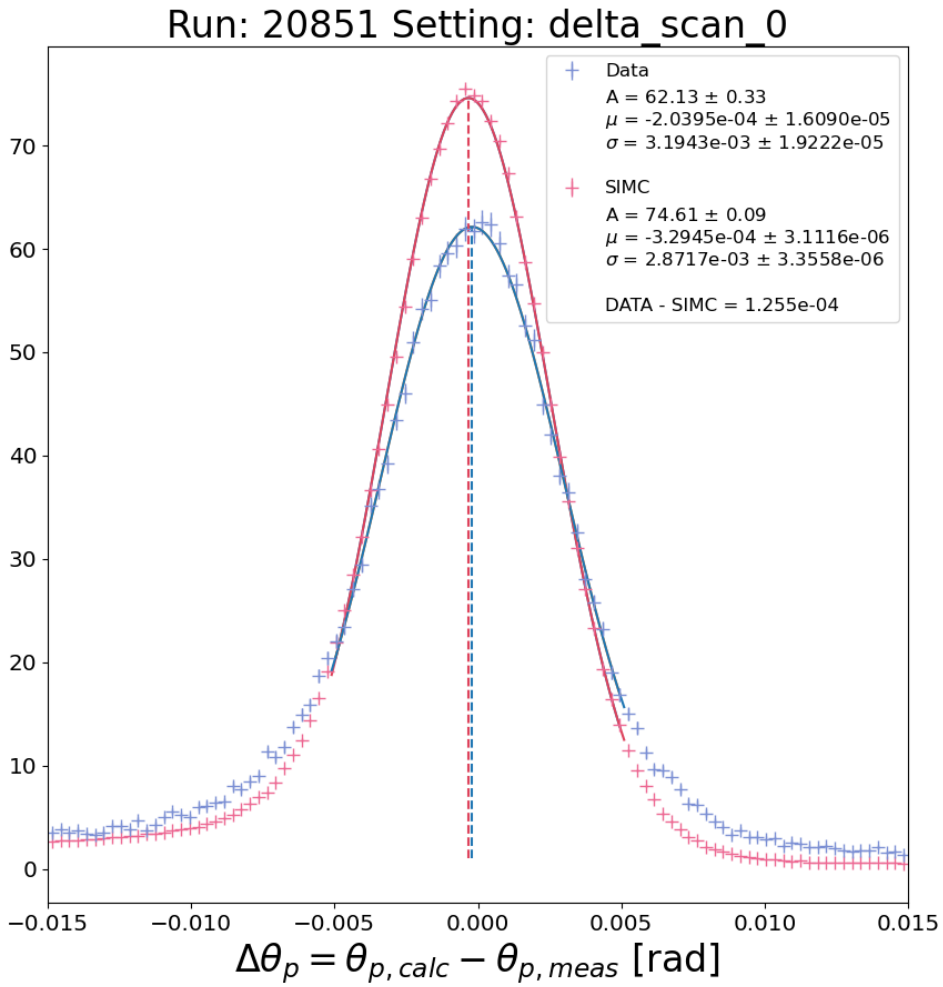
$$d\theta_p = \theta_{p,calc} - \theta_{p,meas}$$

Angle and Momentum Offset Determination

Old Offset = 2.0e-04 [rad]

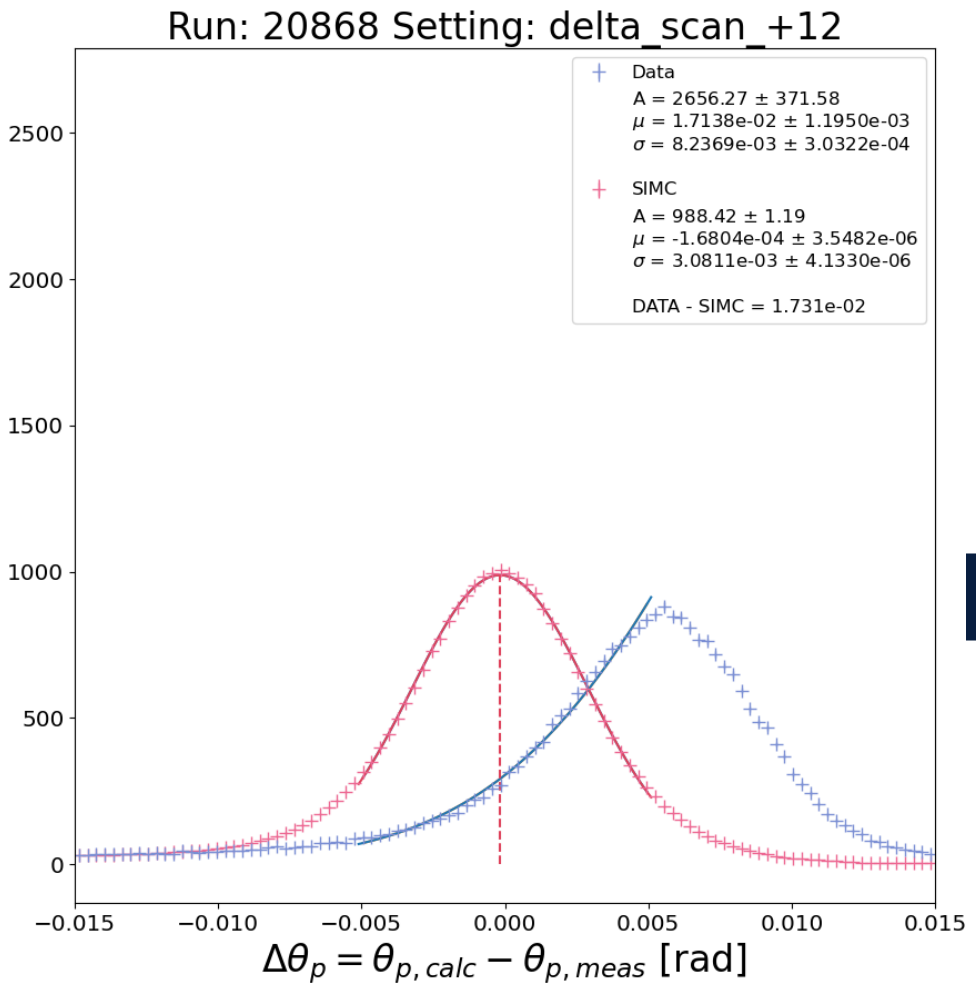


New Offset = 2.81e-04 [rad]

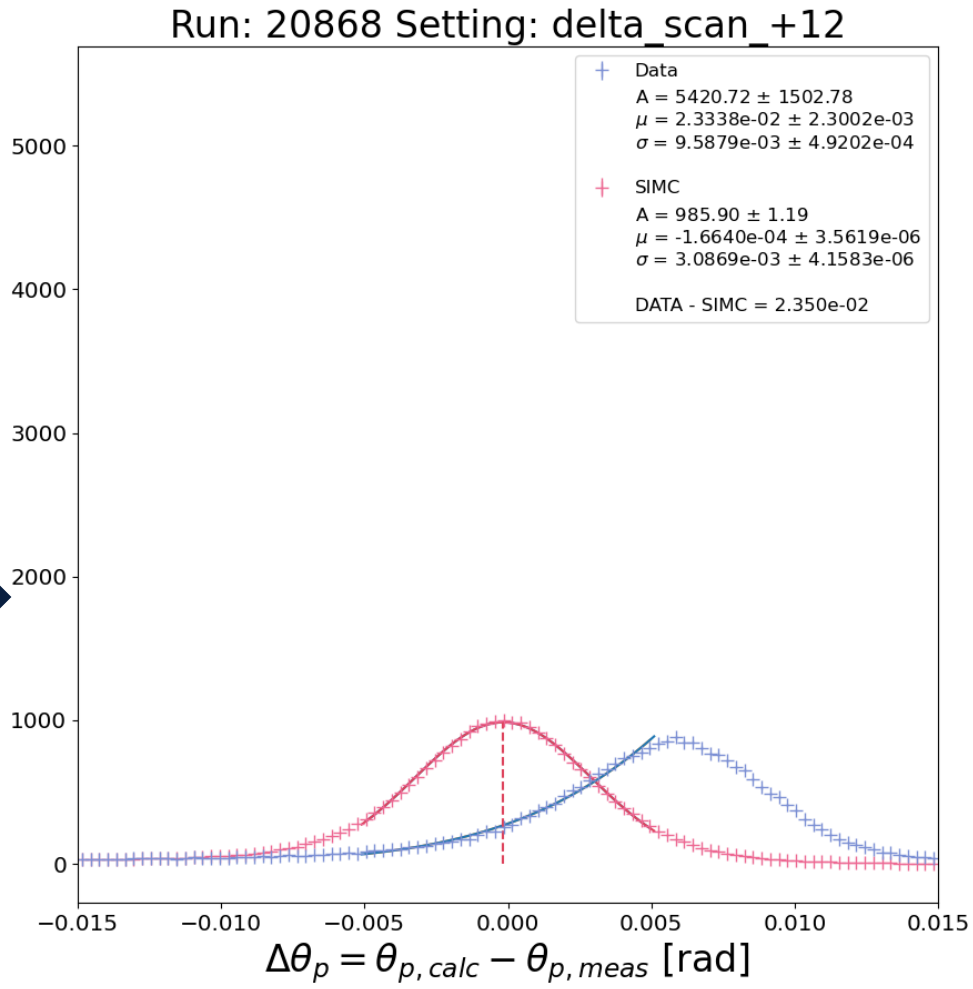


Angle and Momentum Offset Determination

Old Offset = 2.0e-04 [rad]

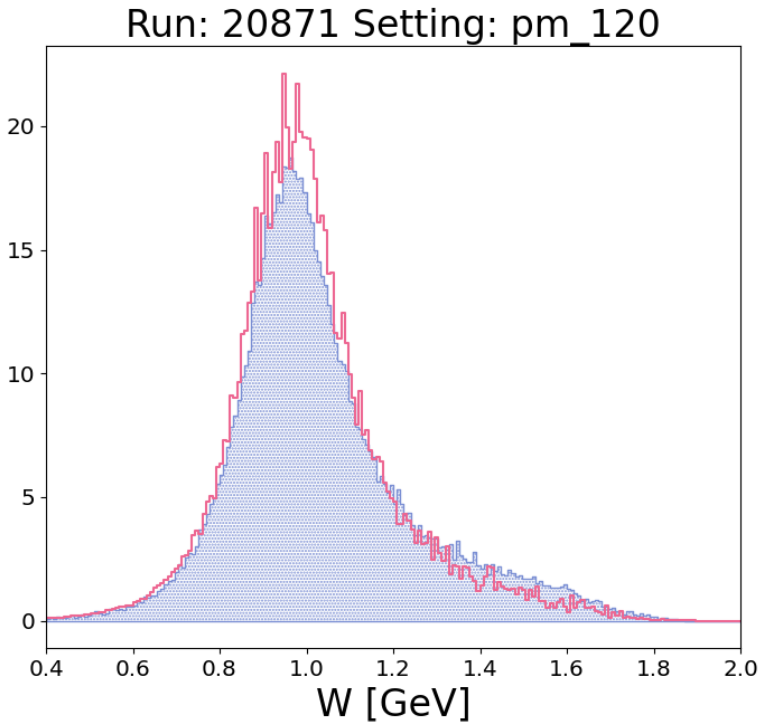


New Offset = 2.81e-04 [rad]



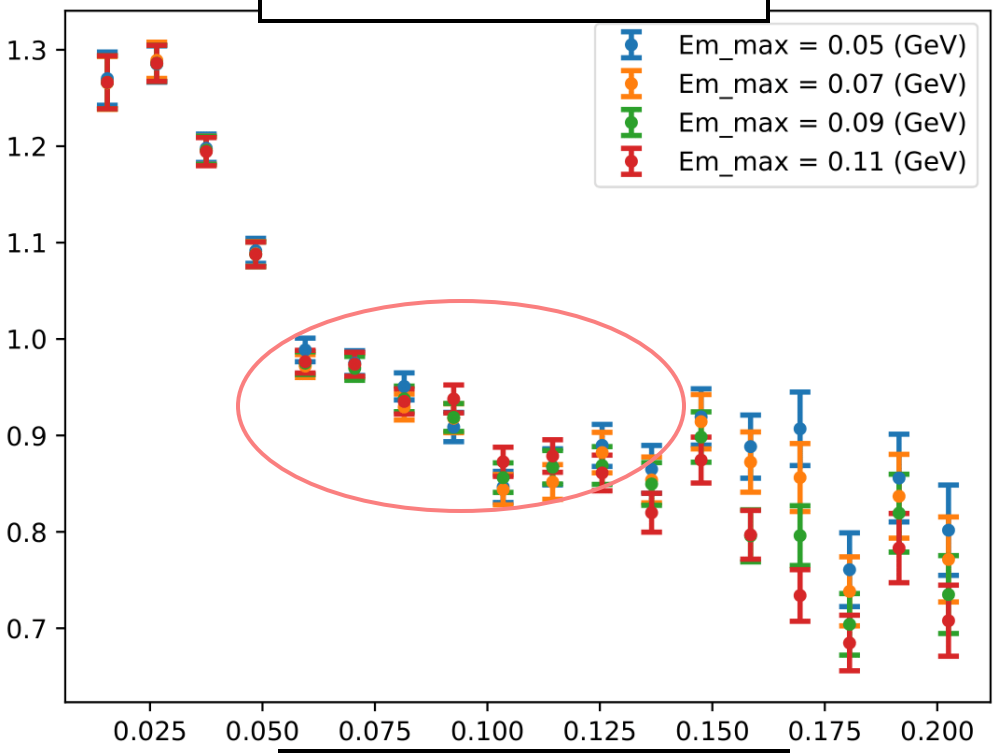
Low Momentum Run (120 MeV) Yield Ratios

- Some calibrations done
- CaFe optics matrix



Yield Ratios for 20871

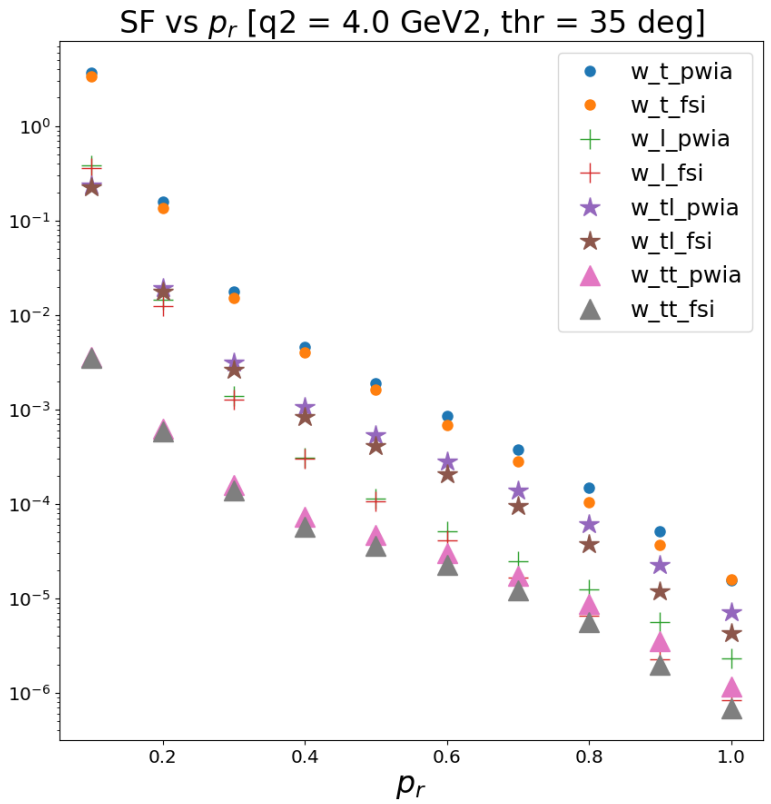
$$\frac{Y_{\text{exp}}}{Y_{\text{SIMC}}}$$

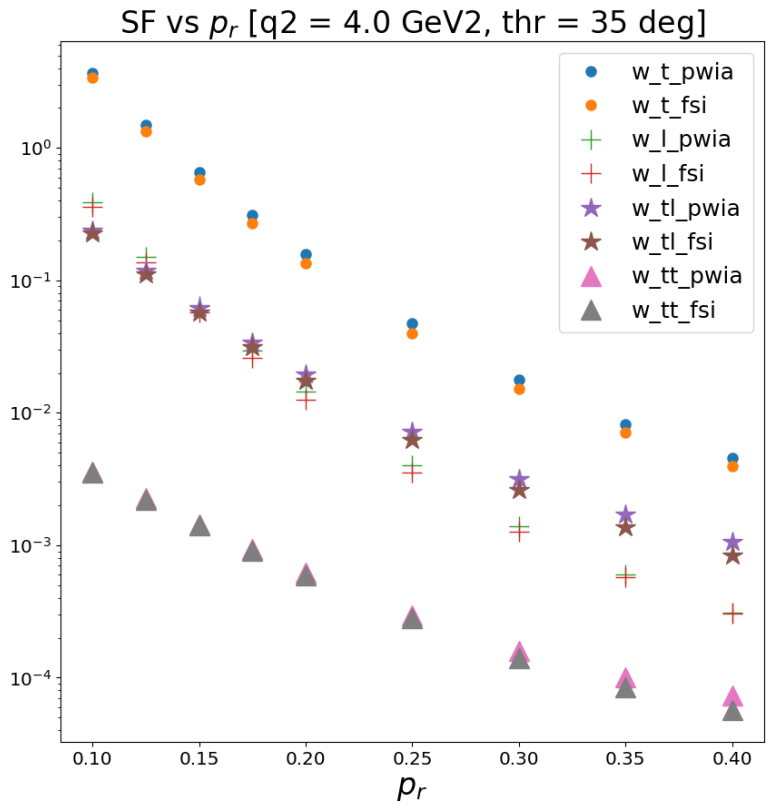


Pm [GeV]

Incorporating MS Models in SIMC

- Choose kinematic variable that SF vary the most
- Choose and test interpolating function and bin size
- Extend to other kinematics
- Create a grid





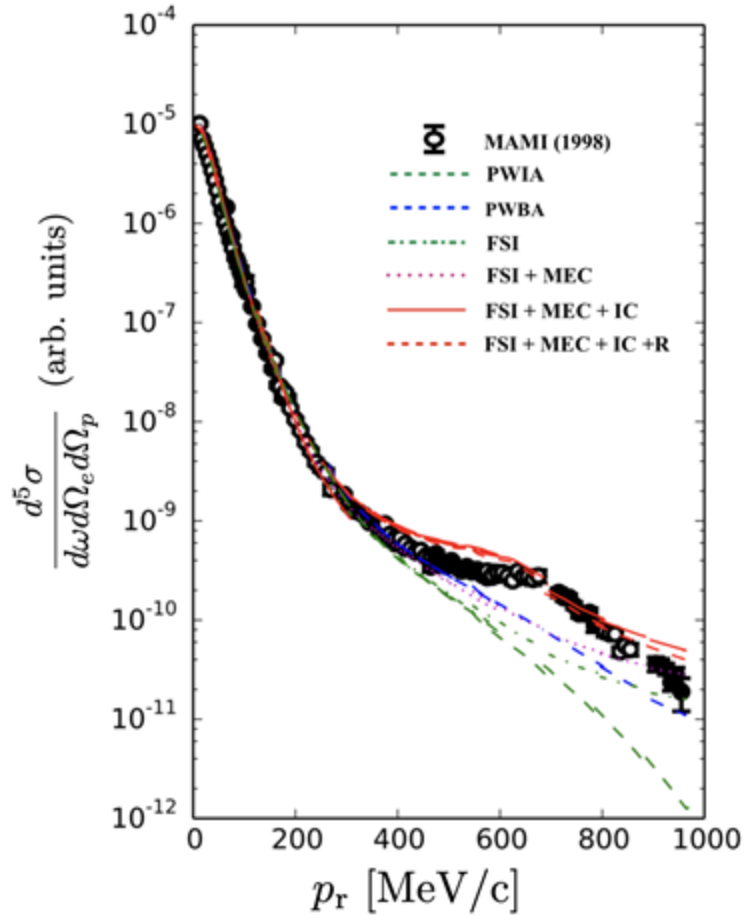
SUMMARY

- We are making progress: Optics, Offset determination, Detector calibrations need fine tuning.
- Interested to see how changing the Laget cross section from SIMC will affect our yields.
- Looking forward to finishing analysis by the end of the year!

BONUS SLIDES

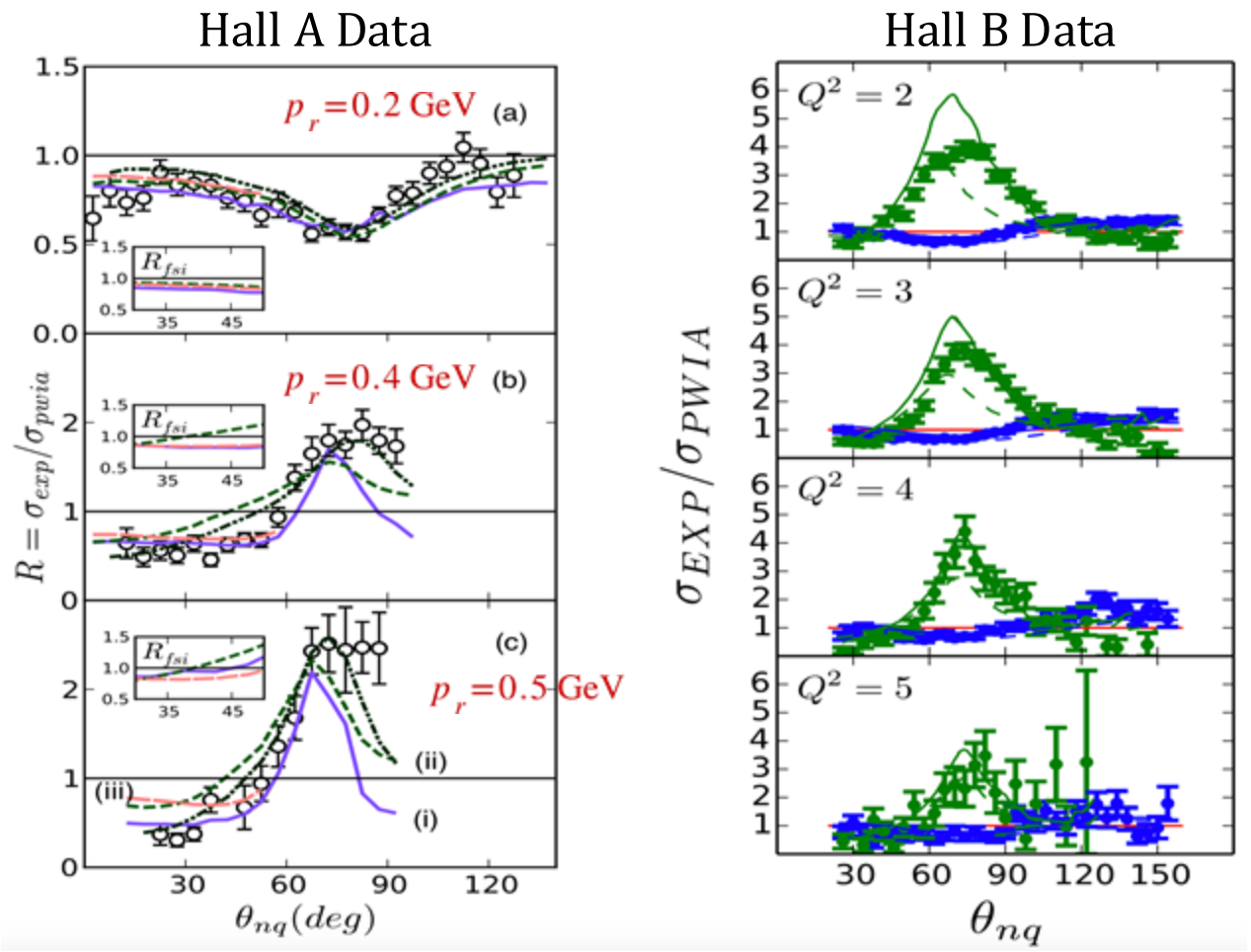
Previous Work

A)



MAMI (1995)

B)



W. Boeglin and M. Sargsian. (2015). DOI

SIMC Weighted Yield Calculation:

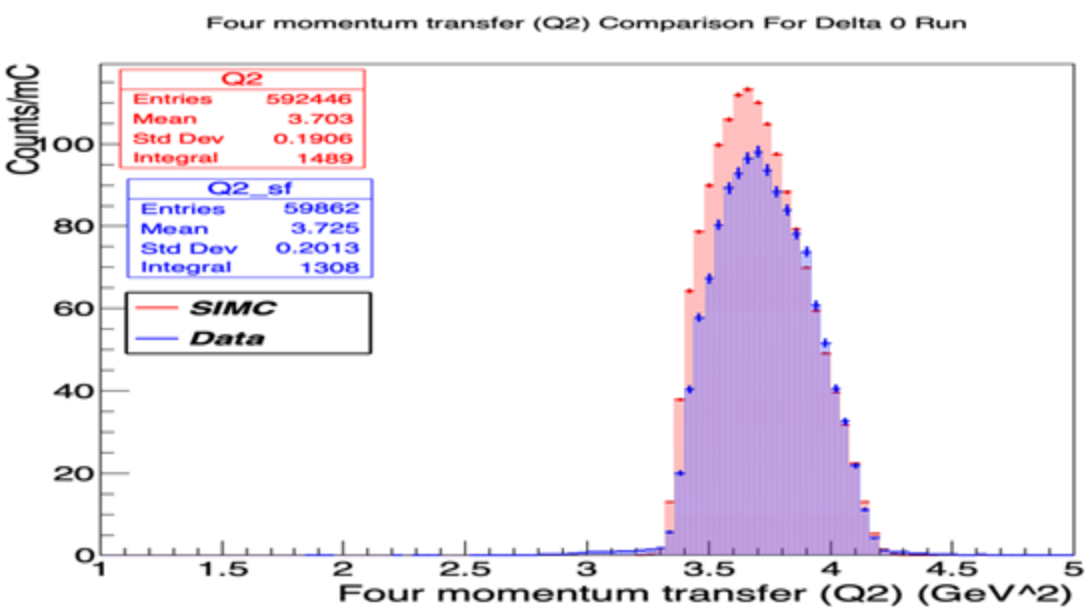
$$Y^{Corr} = Y^{Uncorr} * \text{FullWeight}$$

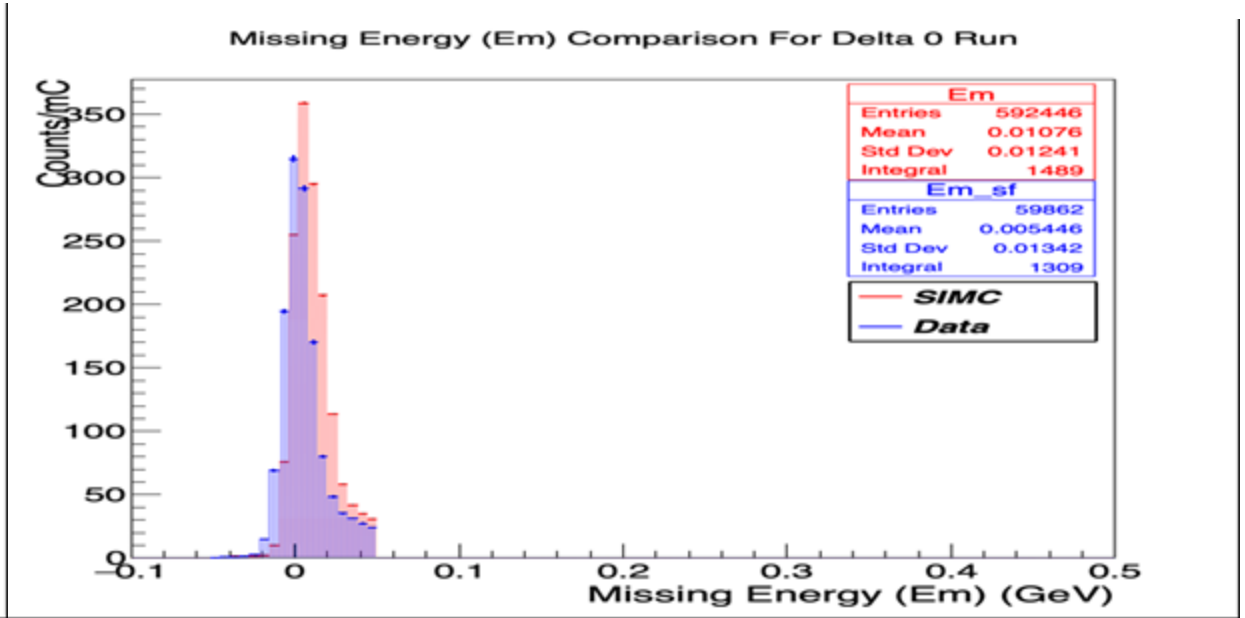
$$\text{Full Weight} = \frac{N_{norm} * \sigma_{weight} * Q_{charge} * \epsilon_{trk}^{(e)} * \epsilon_{trk}^{(h)} * L.T.}{\text{entries}}$$

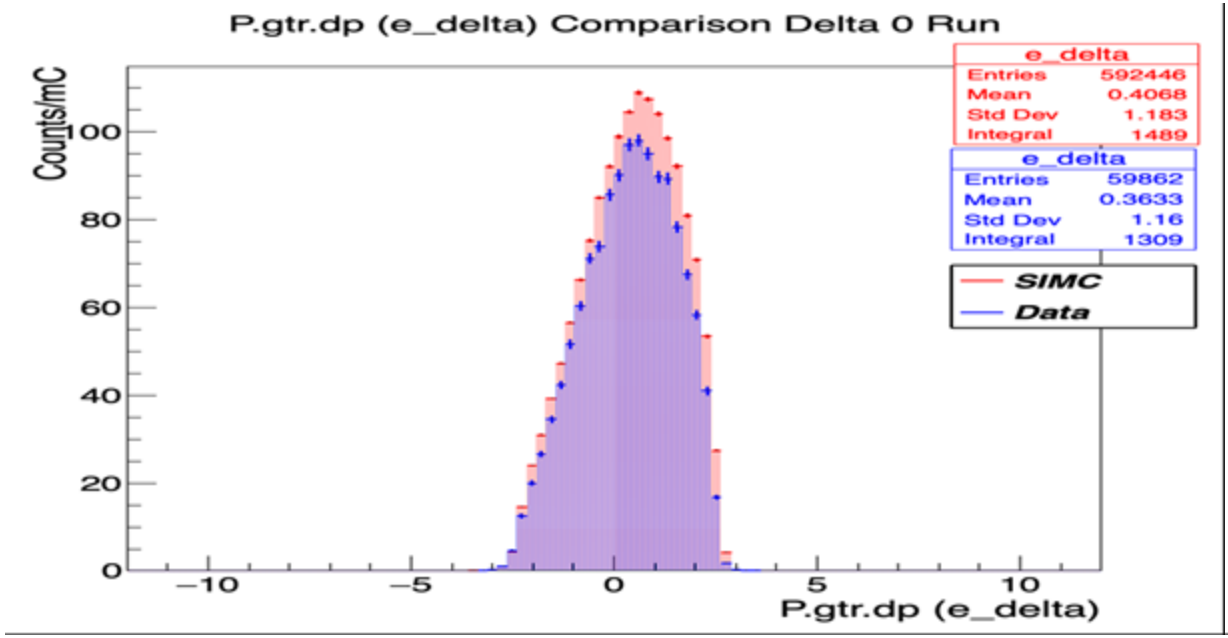
Data Yield Calculation:

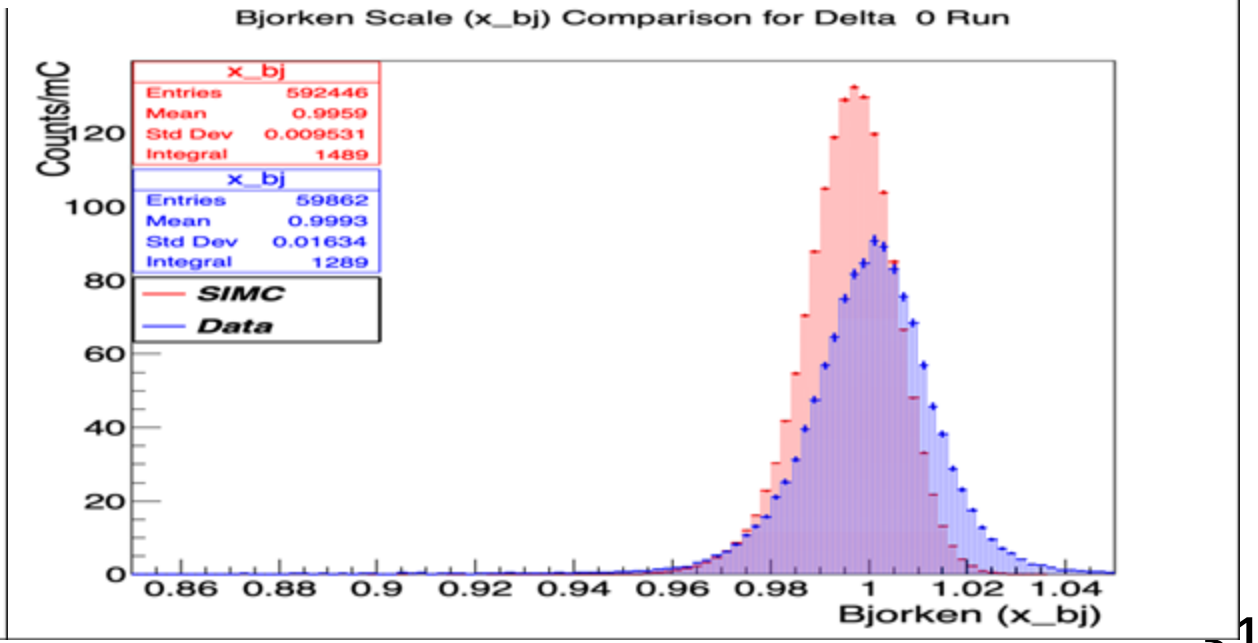
$$Y_{corr} = \frac{Y_{uncorr} \cdot f_{rad}}{\epsilon_{etrk} \cdot \epsilon_{htrk} \cdot \epsilon_{tgt.Boil} \cdot \epsilon_{pTrk} \cdot \epsilon_{tLT} \cdot Q_{tot}}$$

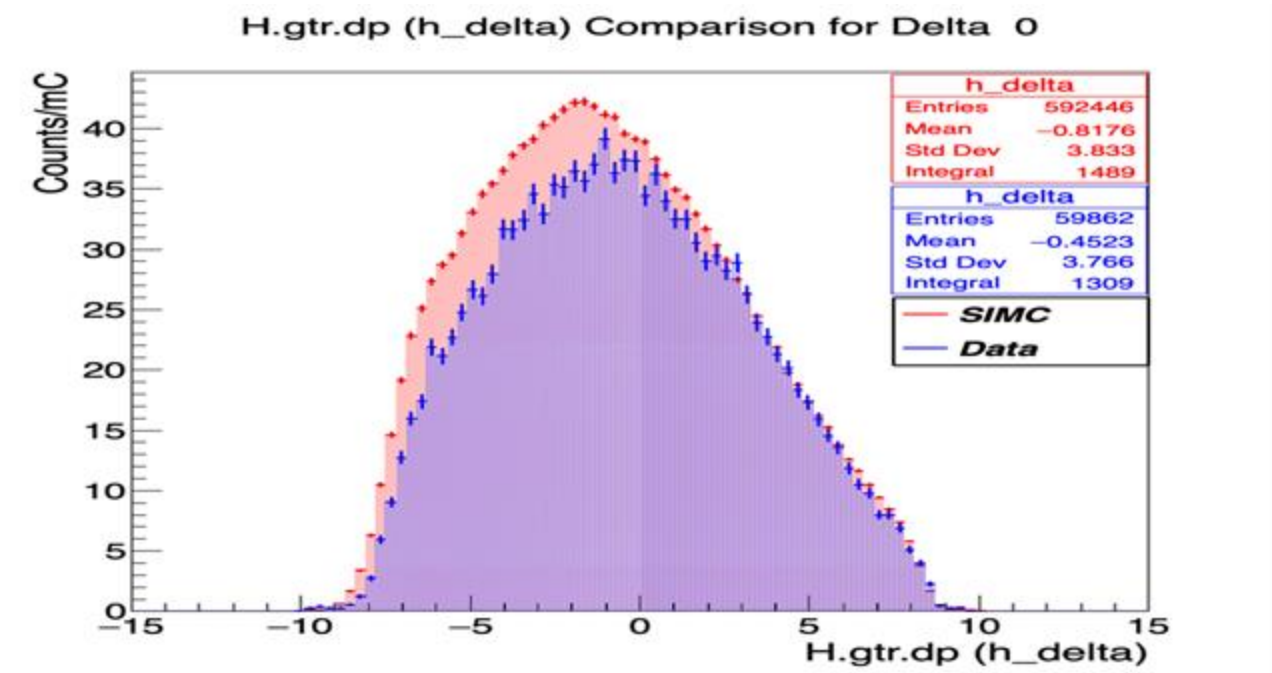
Other Kinematics Parameters

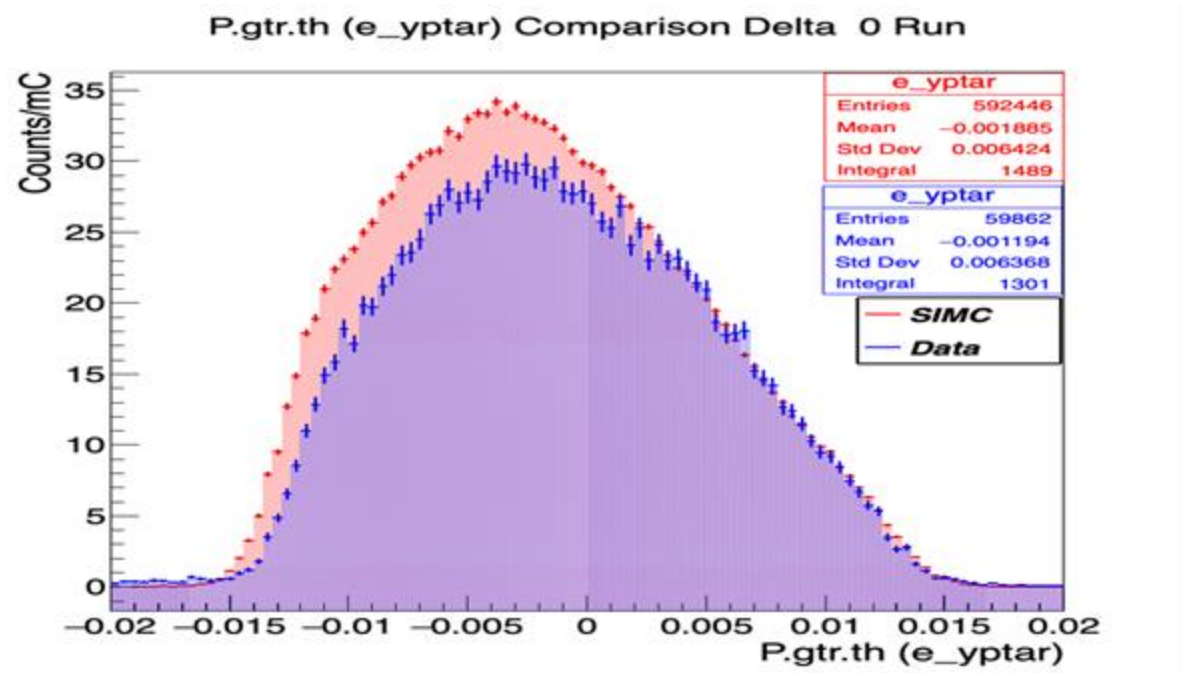


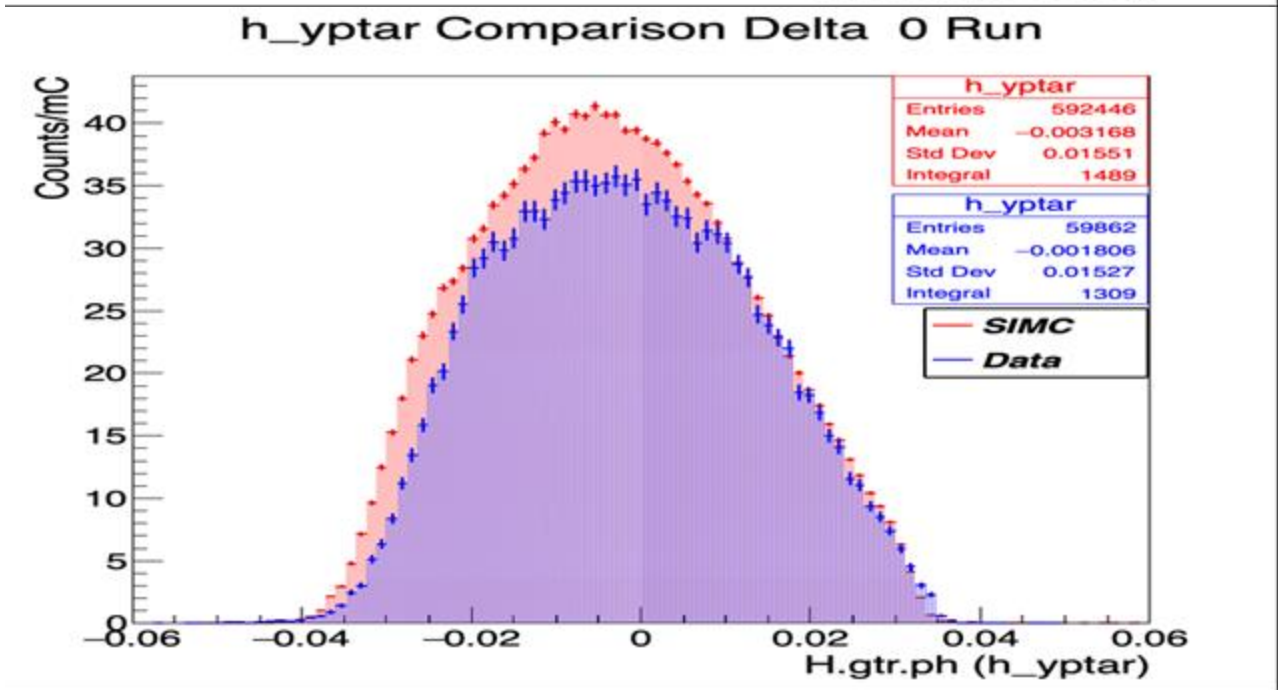


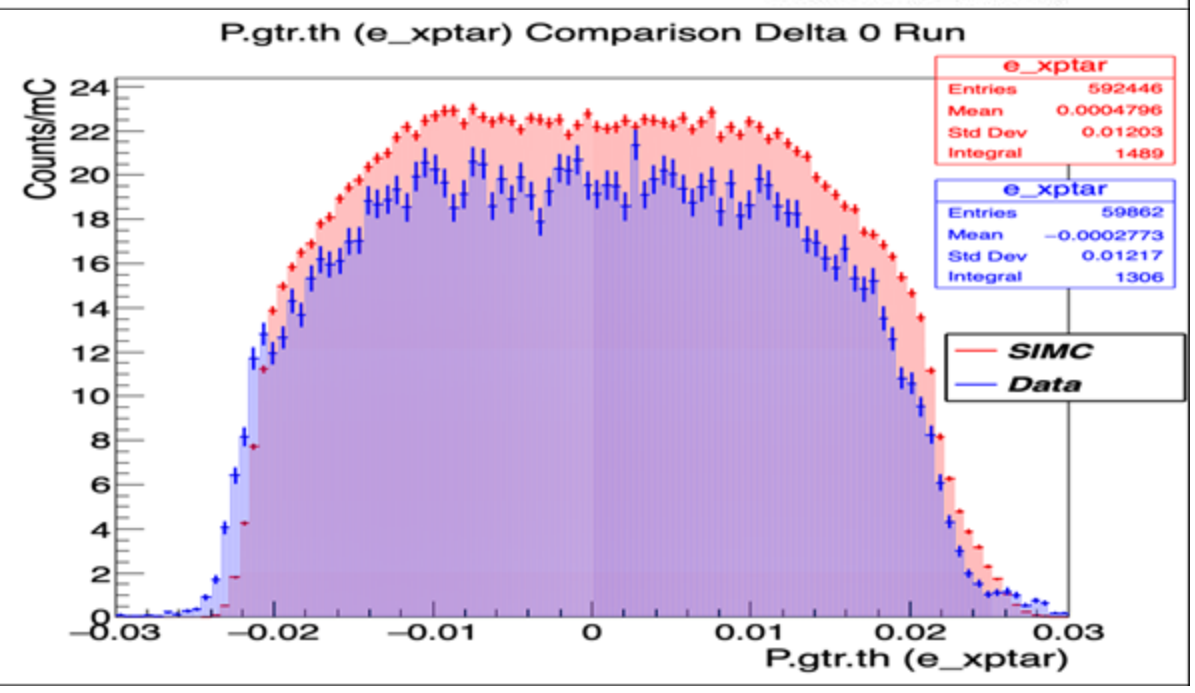





H.gtr.dp (h_delta) Comparison for Delta 0
Counts/mC
H.gtr.dp (h_delta)
h_delta
Entries 592446
Mean −0.8176
Std Dev 3.833
Integral 1489
h_delta
Entries 59862
Mean −0.4523
Std Dev 3.766
Integral 1309
SIMC
Data


P.gtr.th (e_yptar) Comparison Delta 0 Run
Counts/mC
P.gtr.th (e_yptar)
e_yptar
Entries 592446
Mean −0.001885
Std Dev 0.006424
Integral 1489
e_yptar
Entries 59862
Mean −0.001194
Std Dev 0.006368
Integral 1301
SIMC
Data

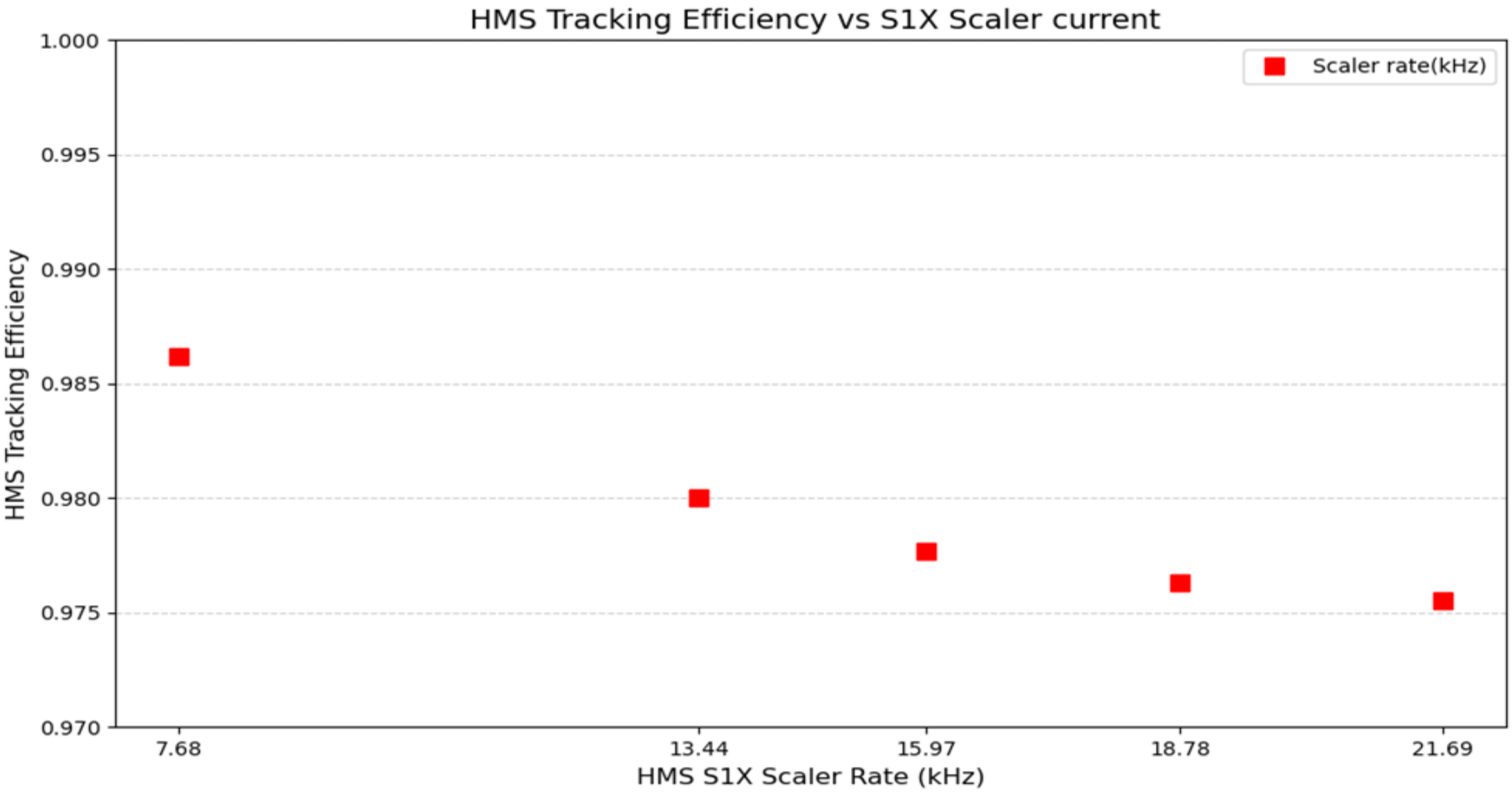

h_yptar Comparison Delta 0 Run
Counts/mC
H.gtr.ph (h_yptar)
h_yptar
Entries 592446
Mean −0.003168
Std Dev 0.01551
Integral 1489
h_yptar
Entries 59862
Mean −0.001806
Std Dev 0.01527
Integral 1309
SIMC
Data


P.gtr.th (e_xptar) Comparison Delta 0 Run
Counts/mC
P.gtr.th (e_xptar)
e_xptar
Entries 592446
Mean 0.0004796
Std Dev 0.01203
Integral 1489
e_xptar
Entries 59862
Mean −0.0002773
Std Dev 0.01217
Integral 1306
SIMC
Data

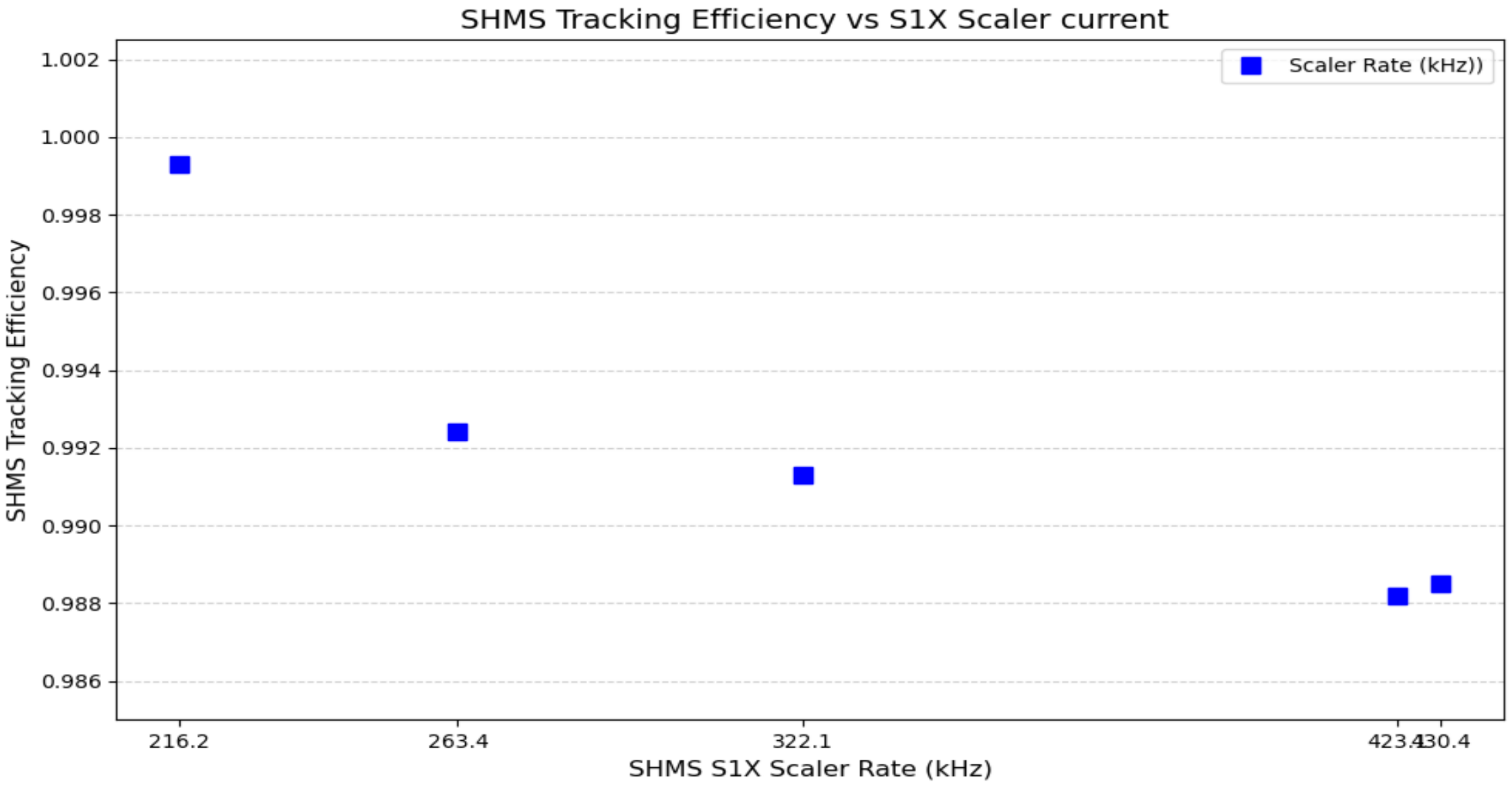
SIMC/DATA Comparison

Run	BCM4A Charge(mC)	Total live time correction for trigger 6	HMS Tracking Efficiency	SHMS Tracking Efficiency	Data Yield
20851	47.2262	0.9993 +/-0.0002	0.9777+/-0.0005	0.9913 +/- 0.0003	1306
20846	112.7961	0.9997+/- 0.0001	0.9763+/- 0.0005	0.9924 +/- 0.0002	689
20841	240.4688	0.9997 +/- 0.0001	0.9755 +/- 0.0004	0.9928 +/- 0.0002	369.7
20858	26.7272	0.9983 +/- 0.004	0.9800 +/- 0.0004	0.9885 +/- 0.0006	2685
20861	12.5527	0.9980 +/-0.0006	0.9862 +/- 0.0003	0.9882 +/- 0.0003	5904

SIMC/DATA Comparison: CUTS APPLIED

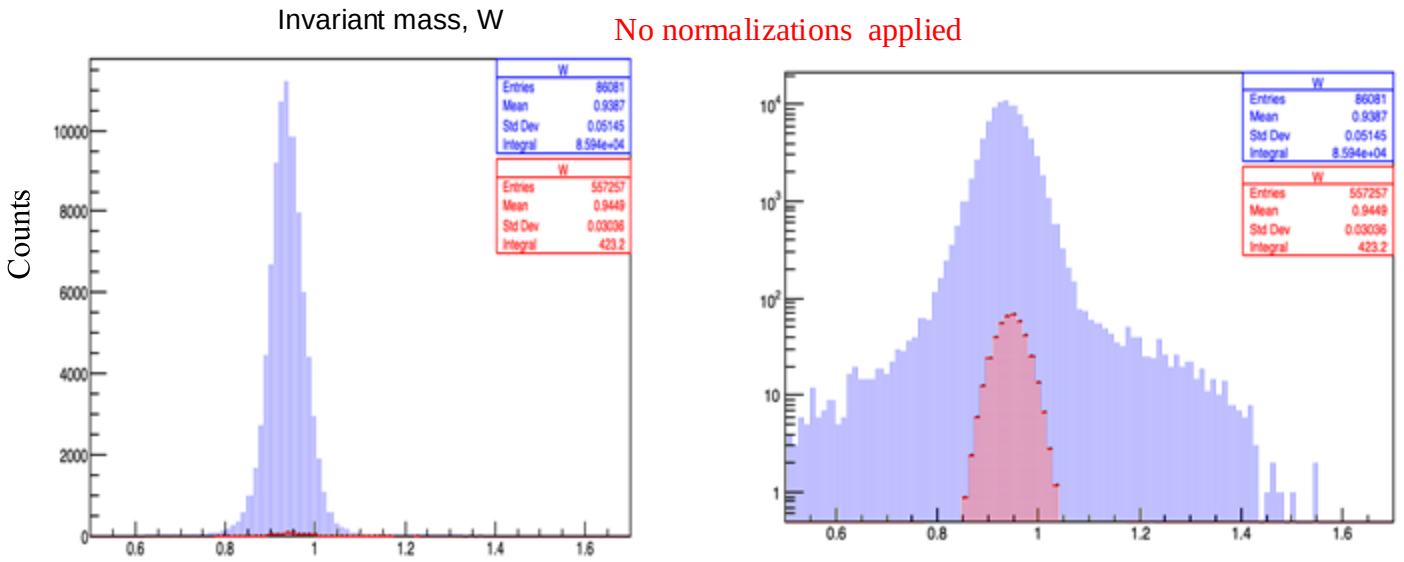


SIMC/DATA Comparison: CUTS APPLIED

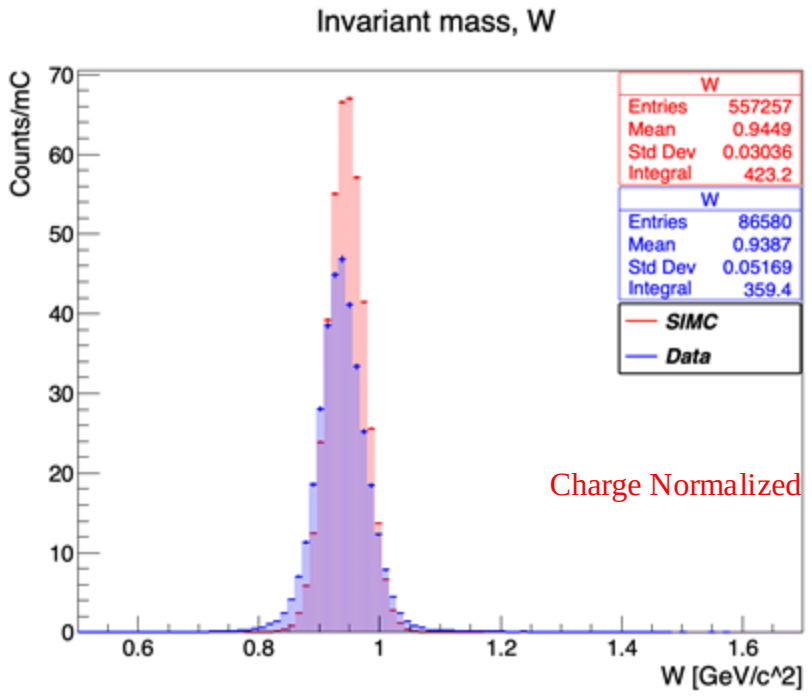


SIMC/DATA Comparison: CUTS APPLIED

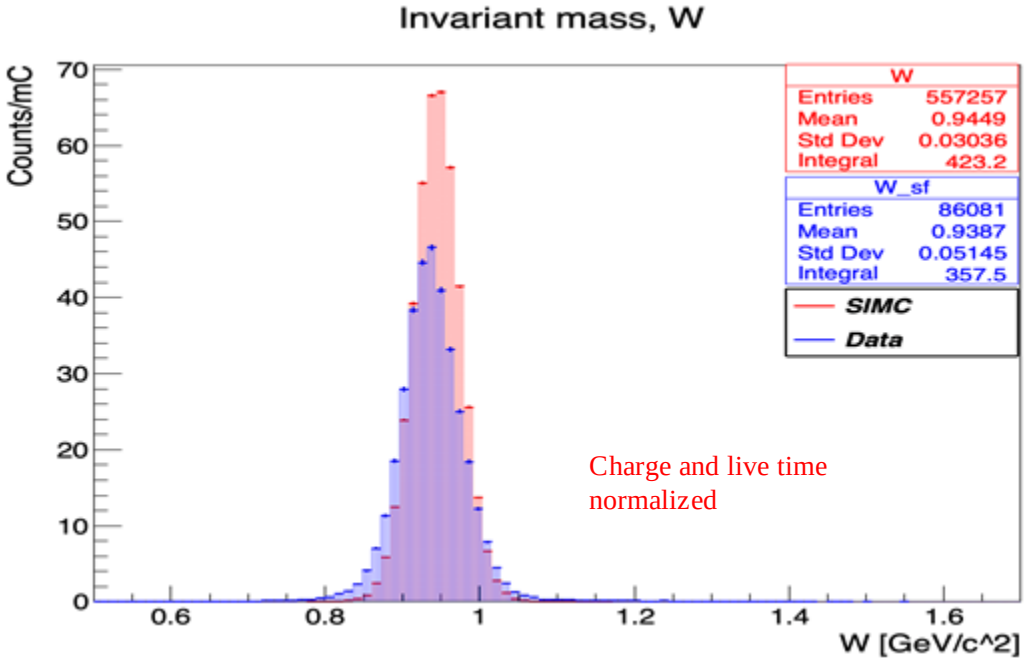
20841



No normalizations applied

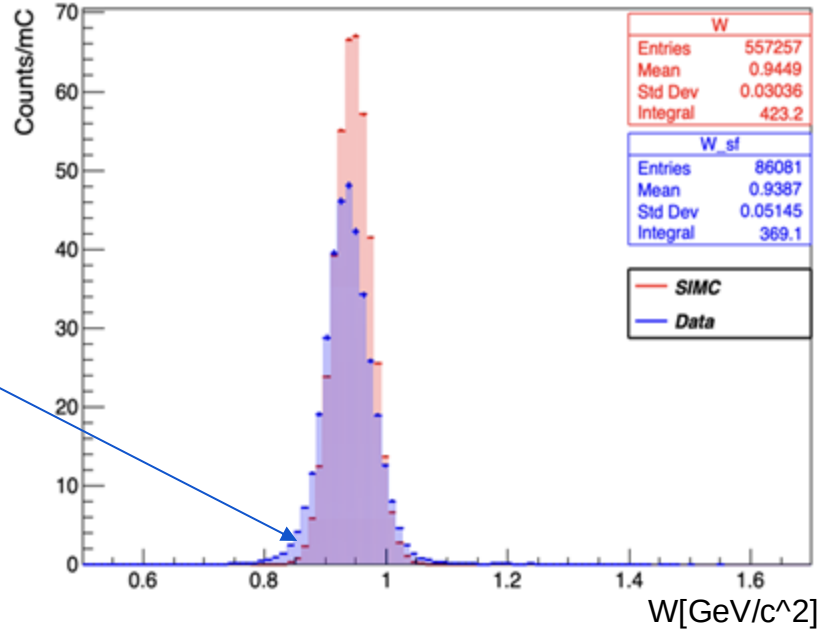


Charge Normalized



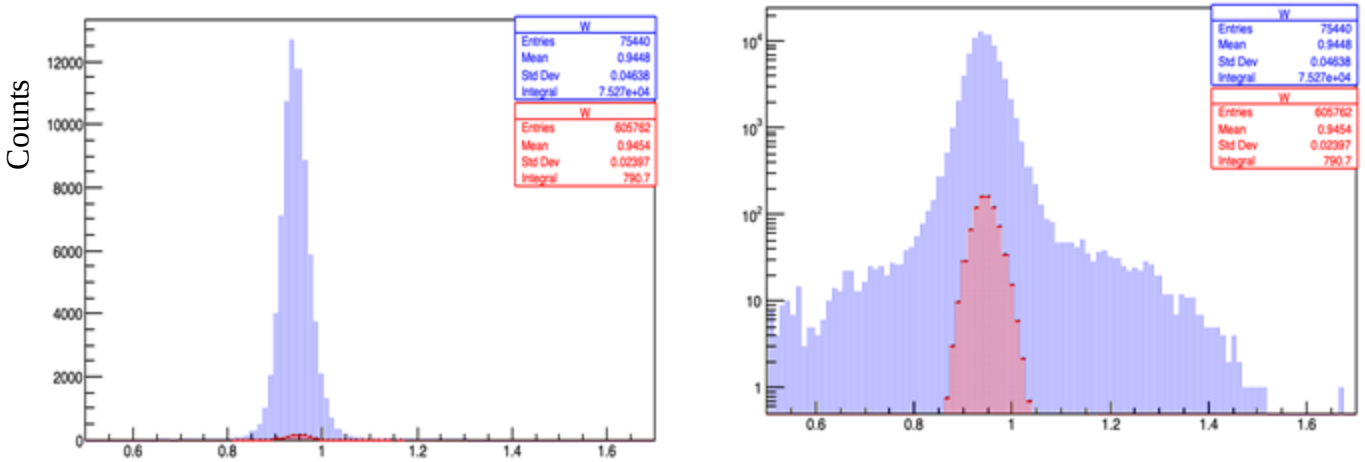
Charge and live time normalized

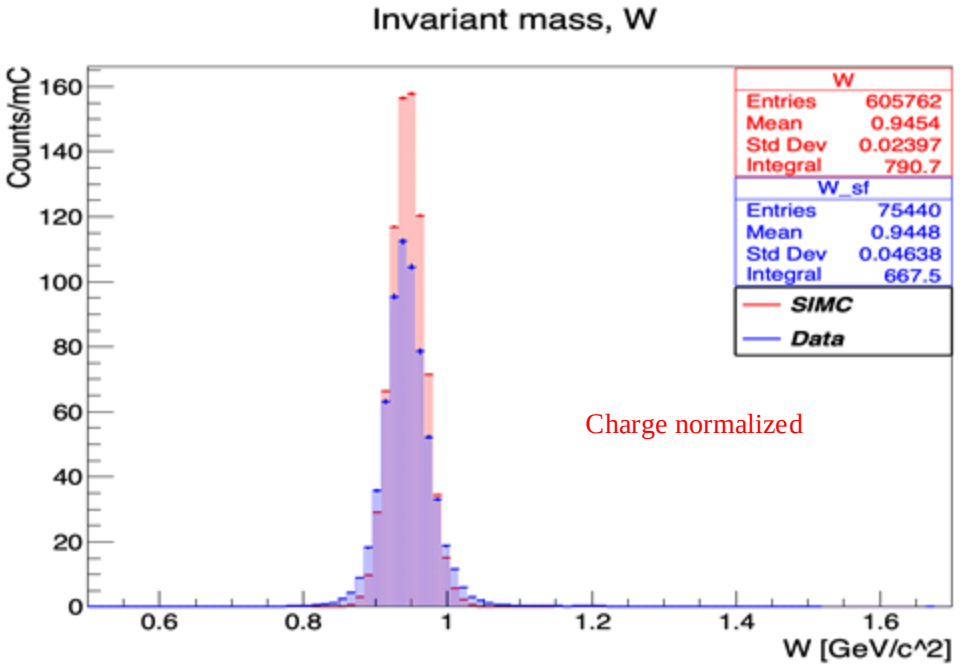
Data Normalized by charge, live time and tracking efficiencies

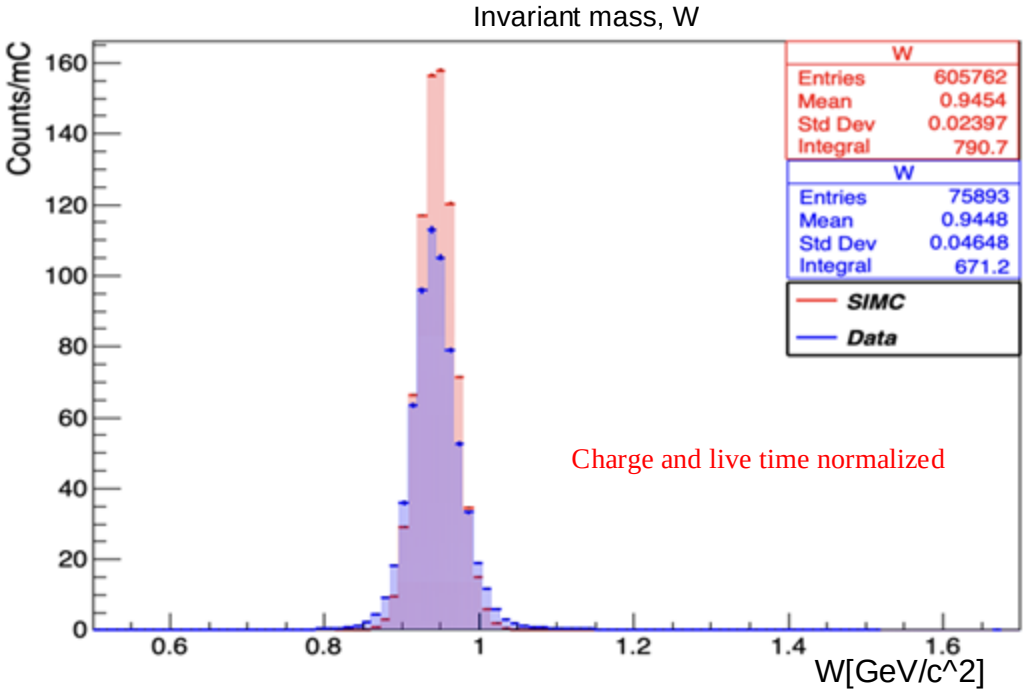


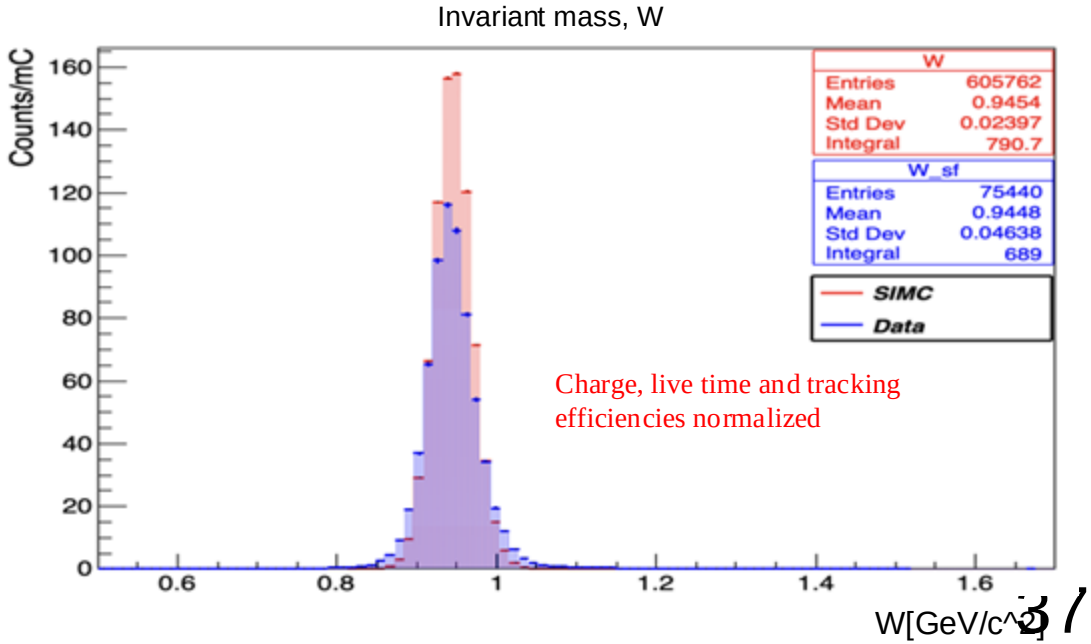
20846

No normalizations applied

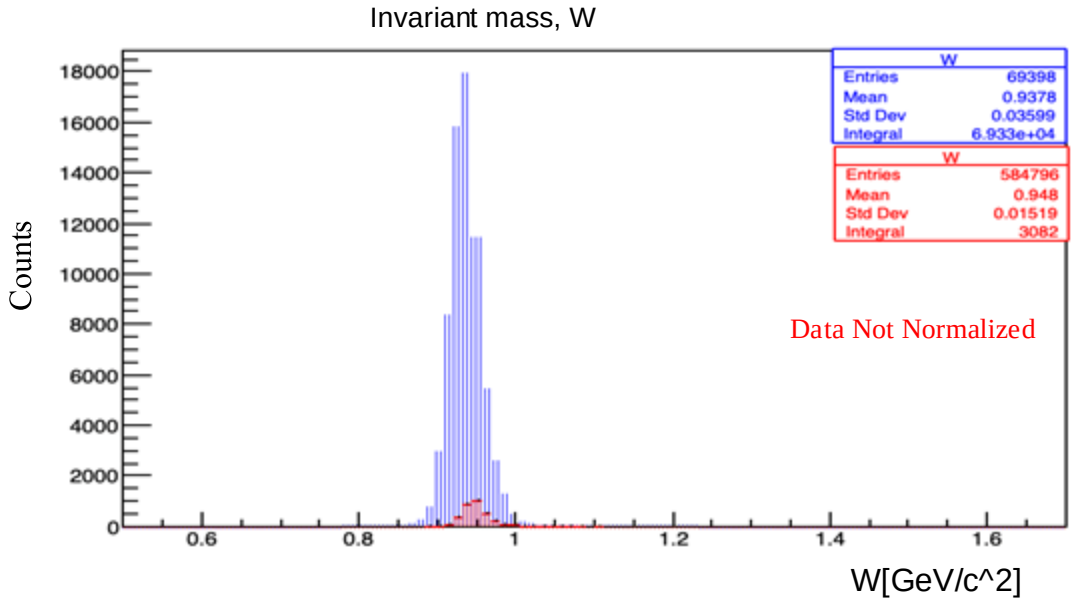


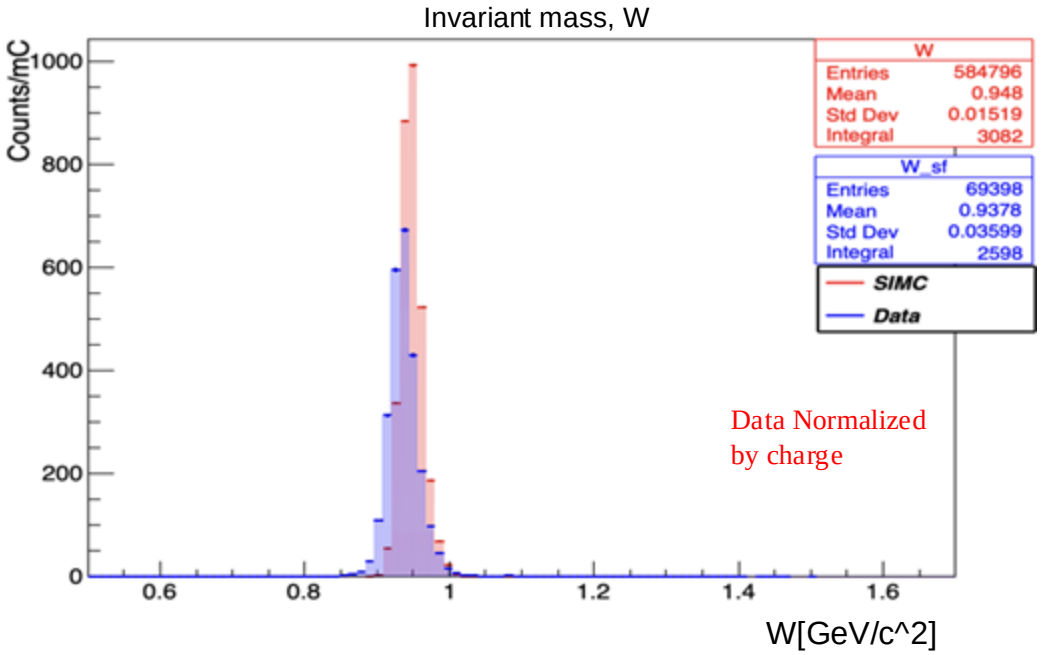


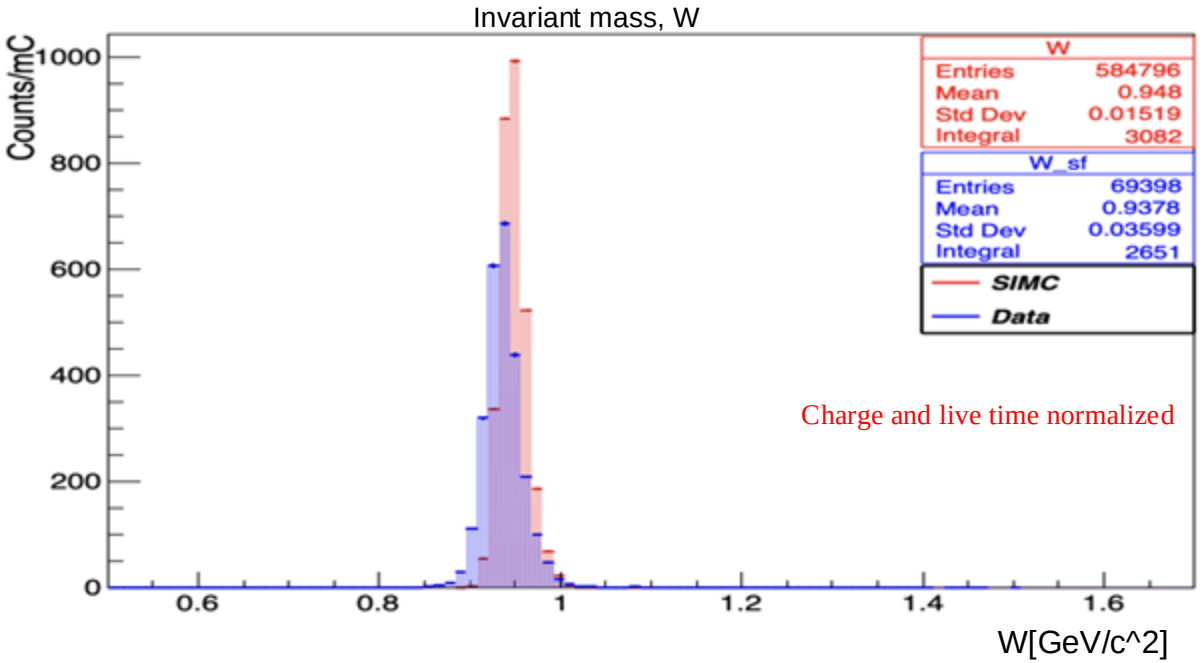


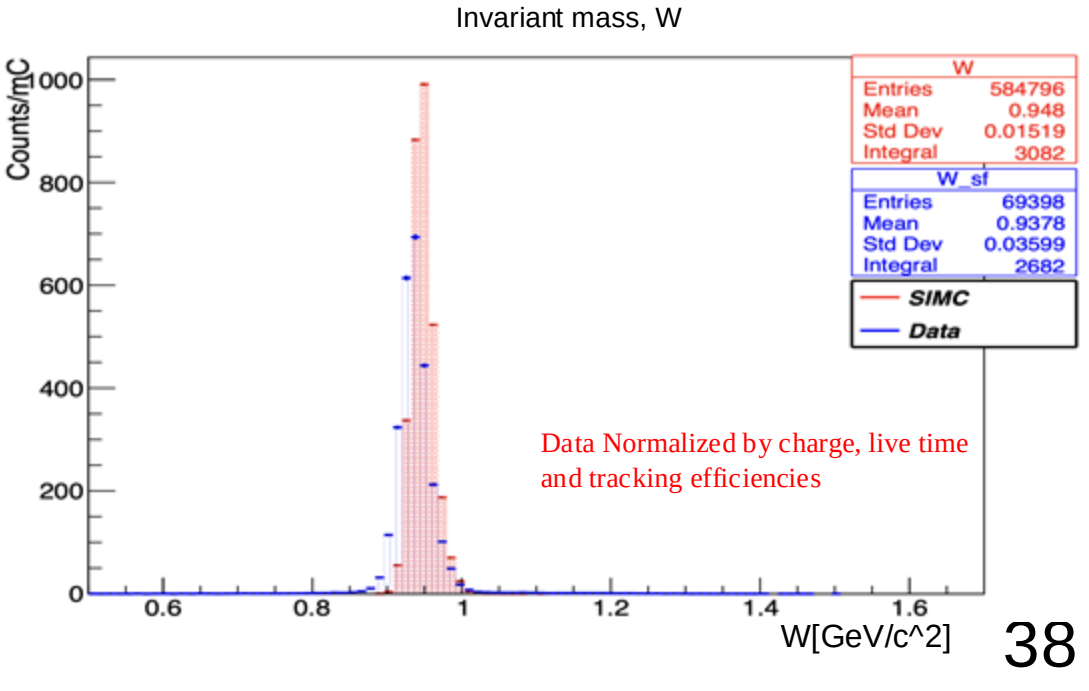


20858

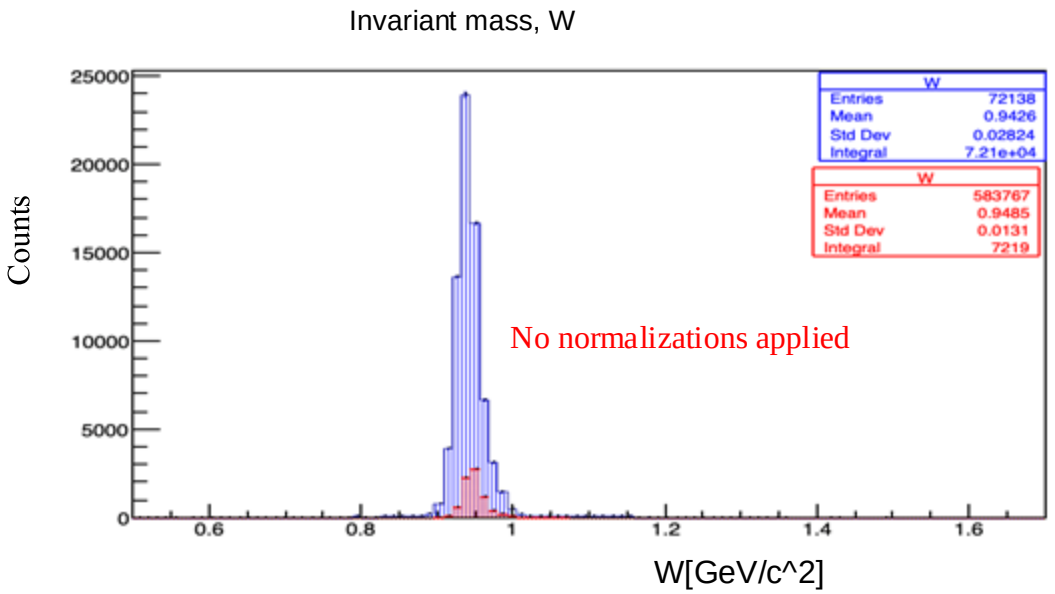

Invariant mass, W
Counts
W
Entries 69398
Mean 0.9378
Std Dev 0.03599
Integral 6.933e+04
W
Entries 584796
Mean 0.948
Std Dev 0.01519
Integral 3082
Data Not Normalized
W[GeV/c^2]

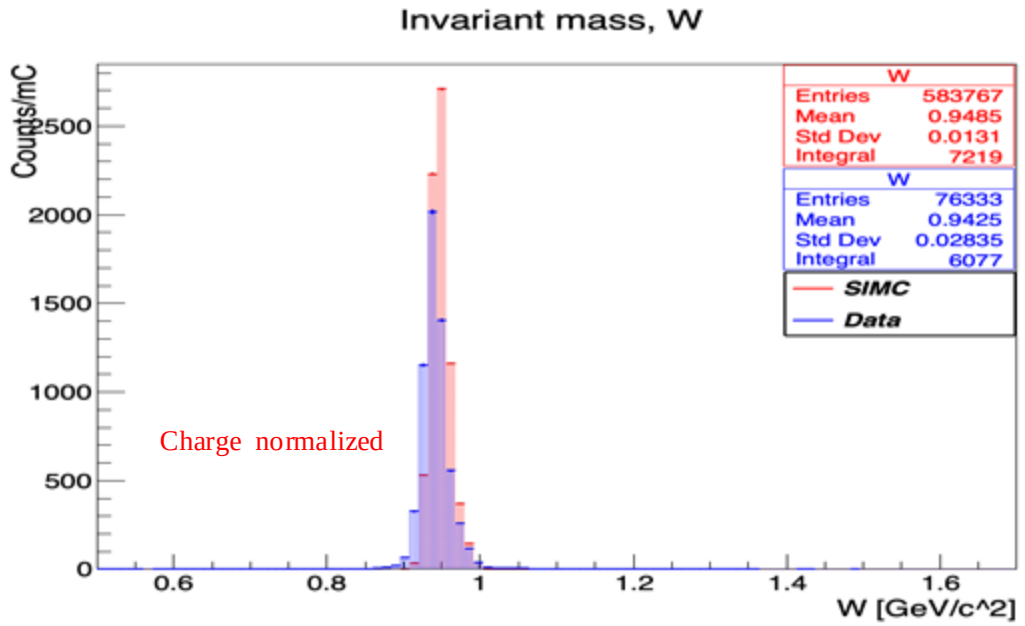

Invariant mass, W
Counts/mC
W
Entries 584796
Mean 0.948
Std Dev 0.01519
Integral 3082
W_sf
Entries 69398
Mean 0.9378
Std Dev 0.03599
Integral 2598
SIMC
Data
Data Normalized by charge
W[GeV/c^2]

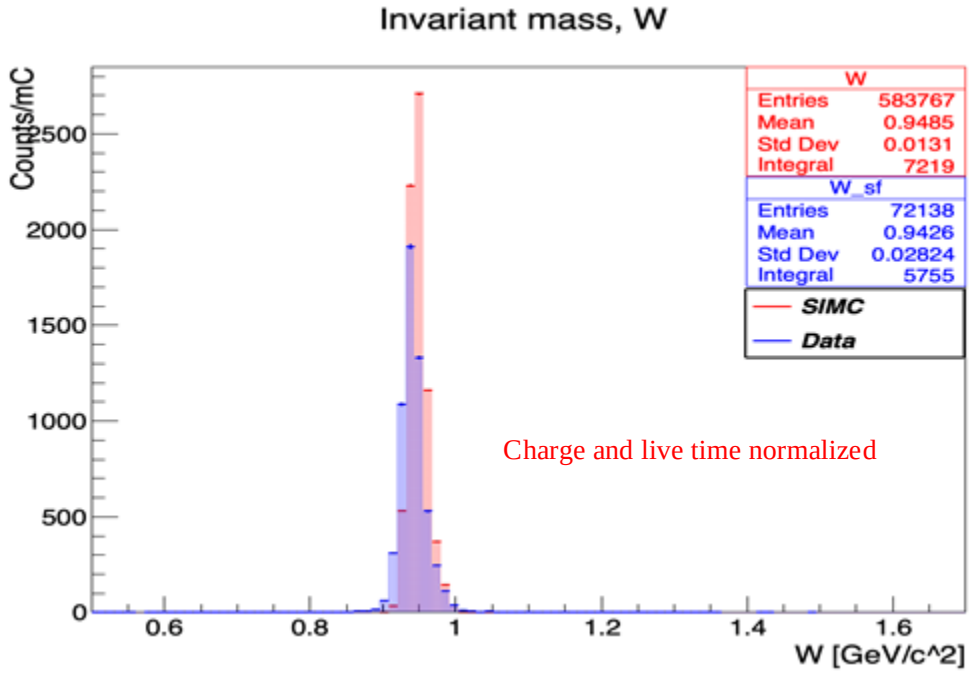

Invariant mass, W
Counts/mC
W
Entries 584796
Mean 0.948
Std Dev 0.01519
Integral 3082
W_sf
Entries 69398
Mean 0.9378
Std Dev 0.03599
Integral 2651
SIMC
Data
Charge and live time normalized
W[GeV/c^2]


Invariant mass, W
Counts/mC
W
Entries 584796
Mean 0.948
Std Dev 0.01519
Integral 3082
W_sf
Entries 69398
Mean 0.9378
Std Dev 0.03599
Integral 2682
SIMC
Data
Data Normalized by charge, live time and tracking efficiencies
W[GeV/c^2]

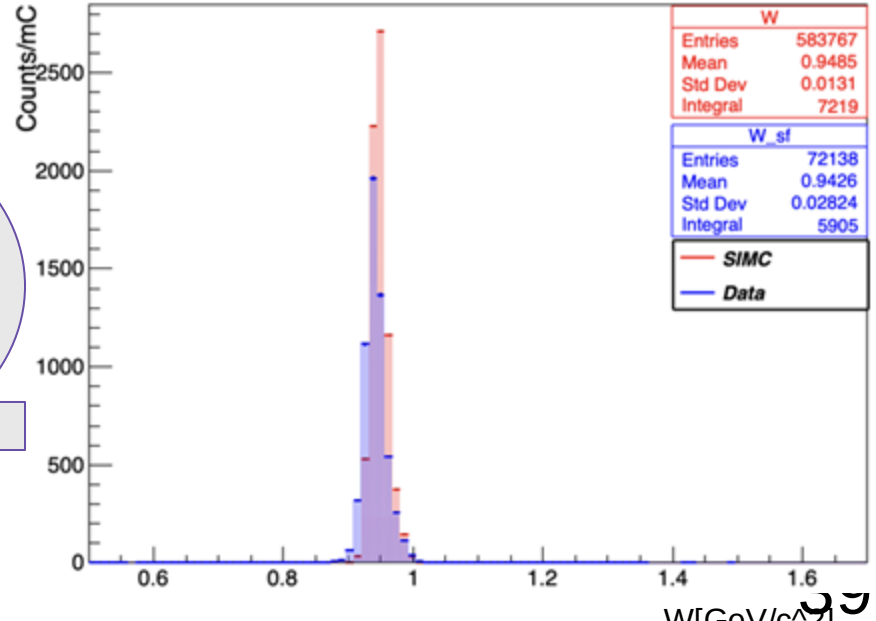
20861







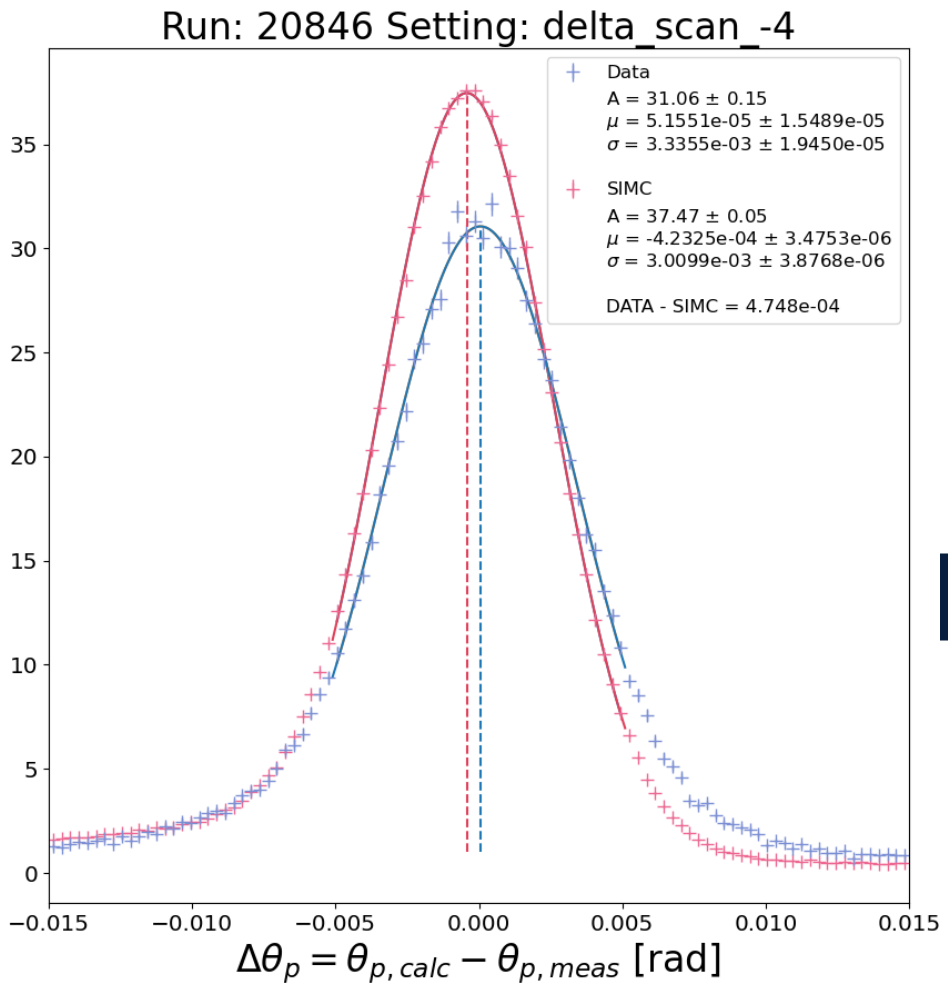
Data Normalized by charge, live time and tracking efficiencies



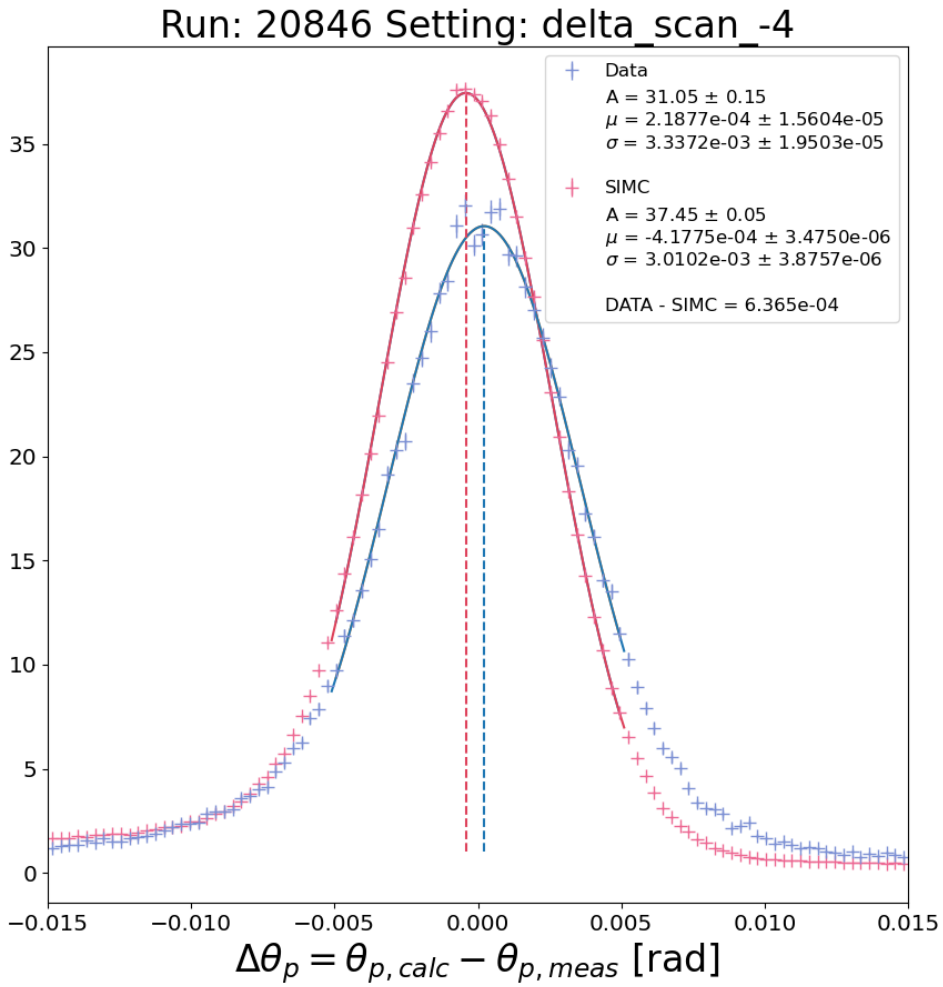
Back-Up Slides

Angle and Momentum Offset Determination

Old Offset = 2.0e-04 [rad]

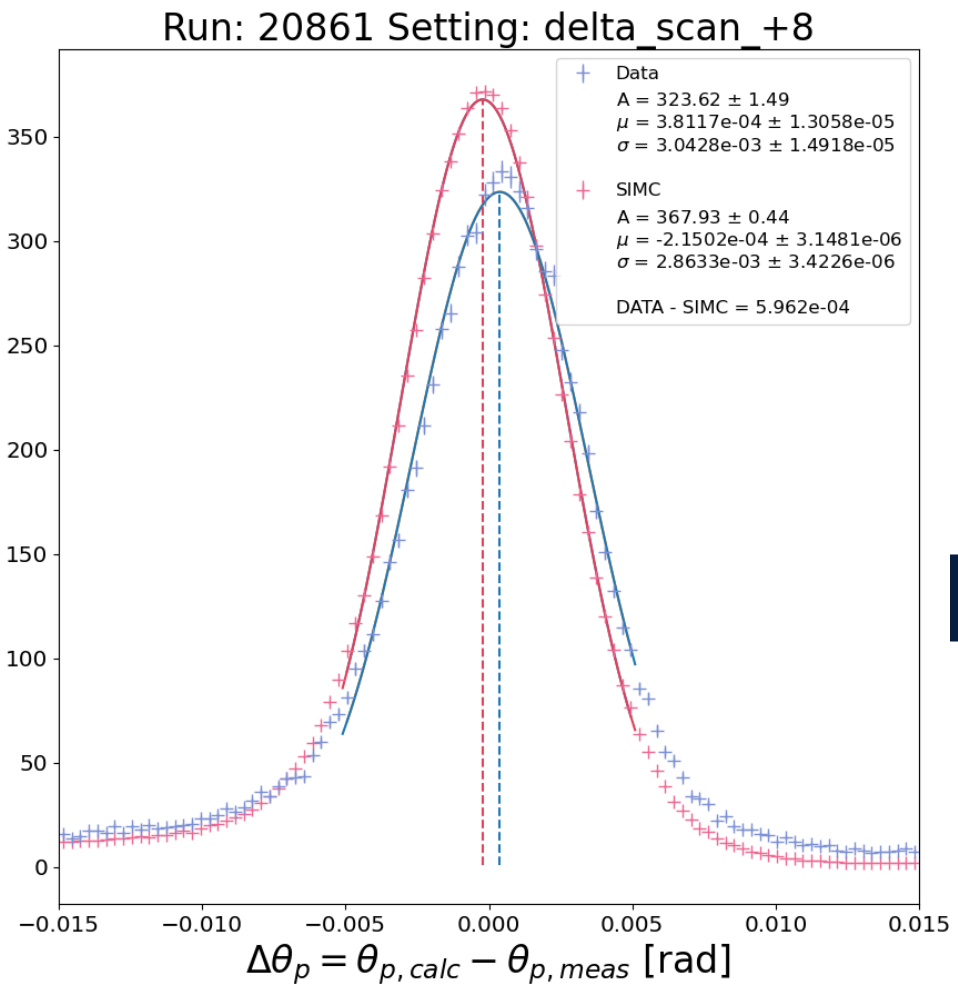


New Offset = 2.81e-04 [rad]

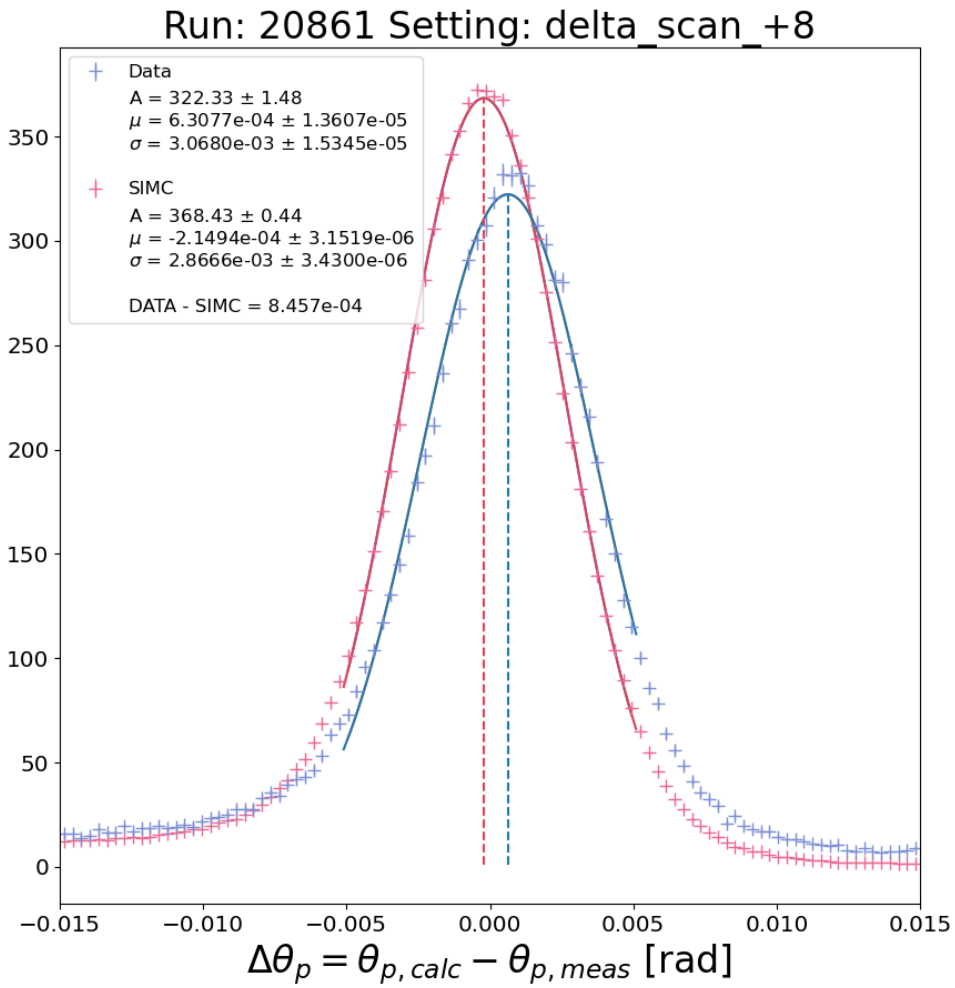


Angle and Momentum Offset Determination

Old Offset = 2.0e-04 [rad]

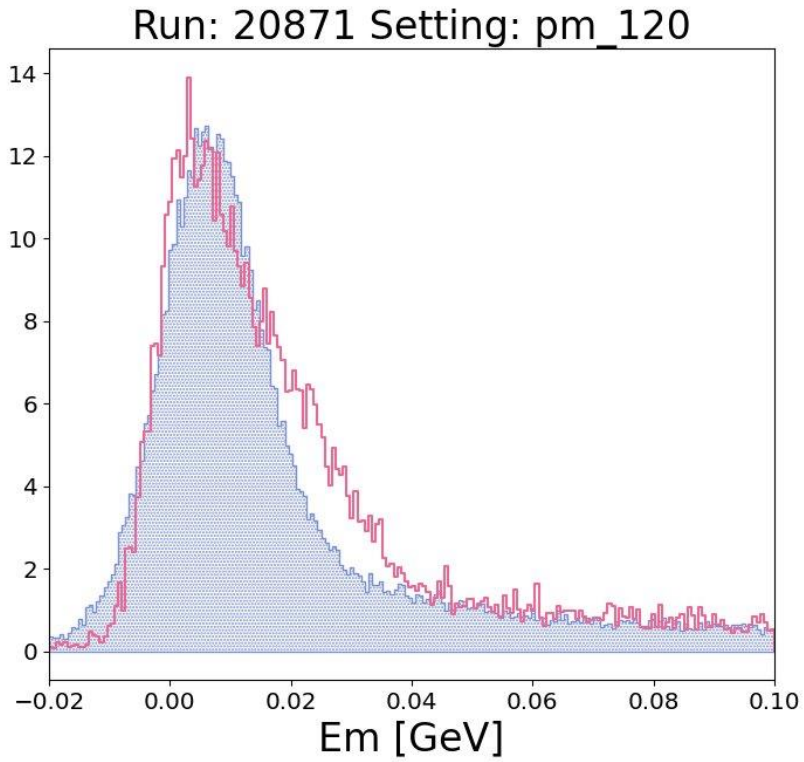


New Offset = 2.81e-04 [rad]



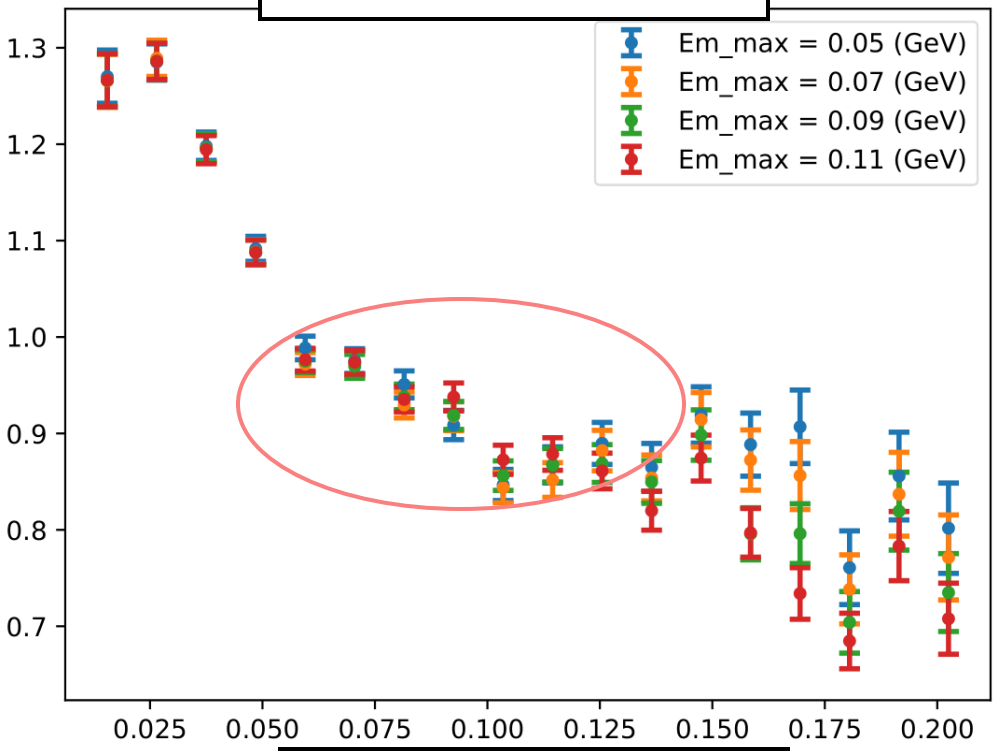
Low Momentum Run (120 MeV) Yield Ratios

- Some calibrations done
- CaFe optics matrix



$$\frac{Y_{\text{exp}}}{Y_{\text{SIMC}}}$$

Yield Ratios for 20871



Pm [GeV]