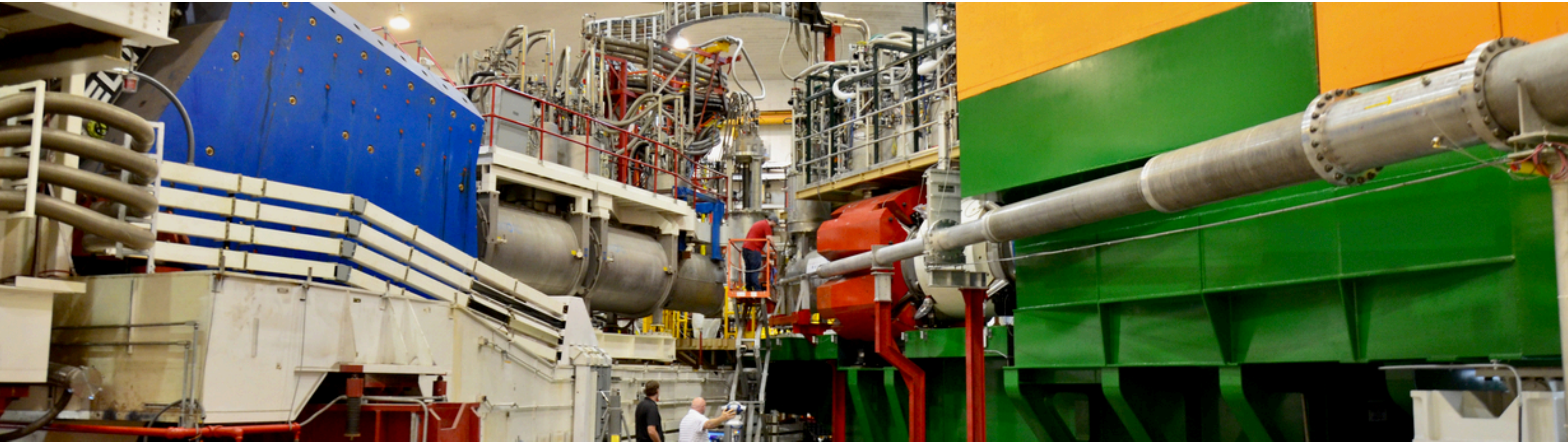


D(e,e'p)n Cross Section Measurements at Very High Missing Momenta and Large Q^2

Hall C Post-Doctoral Fellow Application: April 13, 2020

Carlos Yero

Jefferson Lab
Exploring the Nature of Matter

FIU

Hall-C

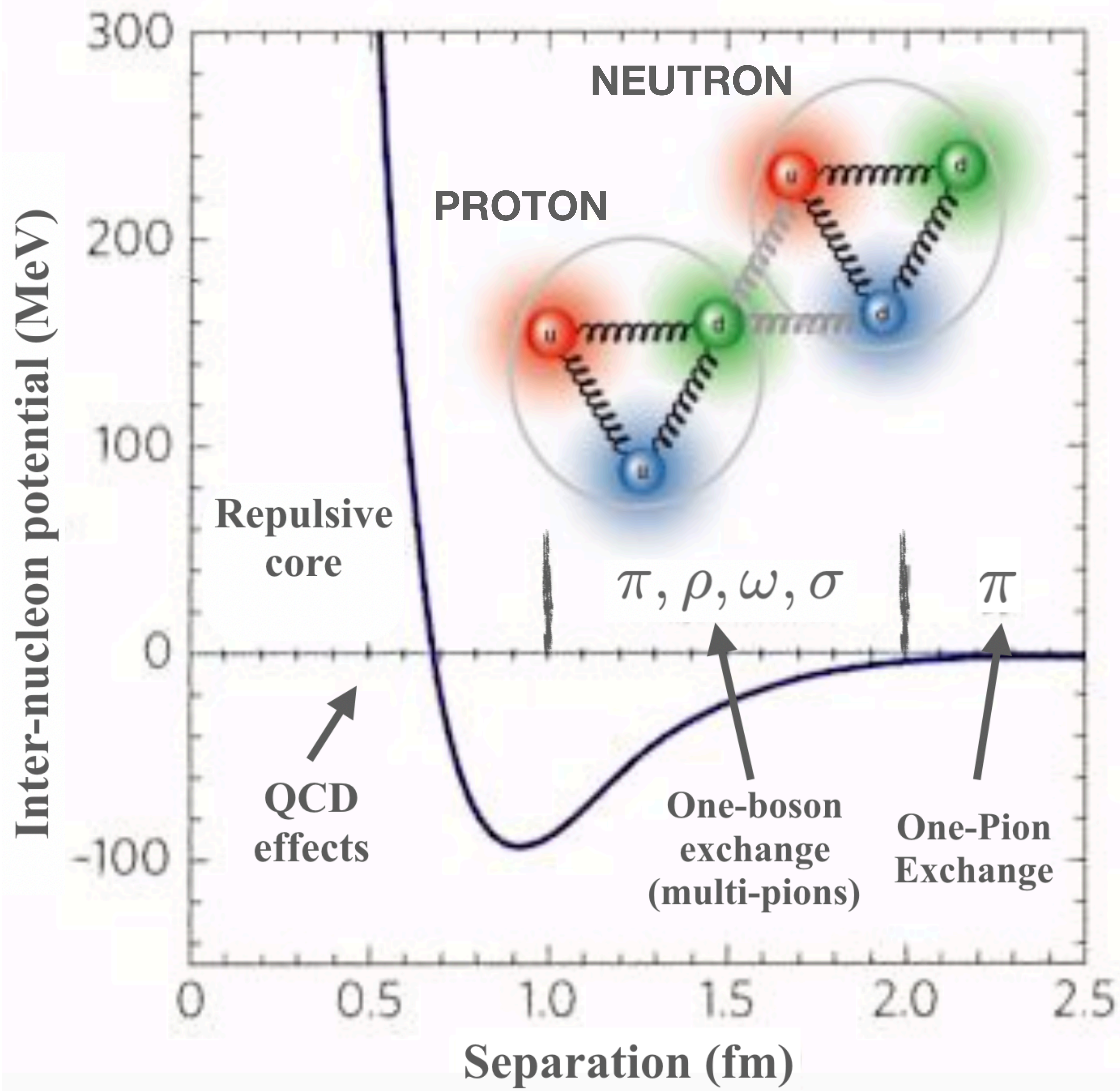
Motivation

- ☑ Deuteron is the simplest np bound state: starting point to study nuclear force (or NN potential)

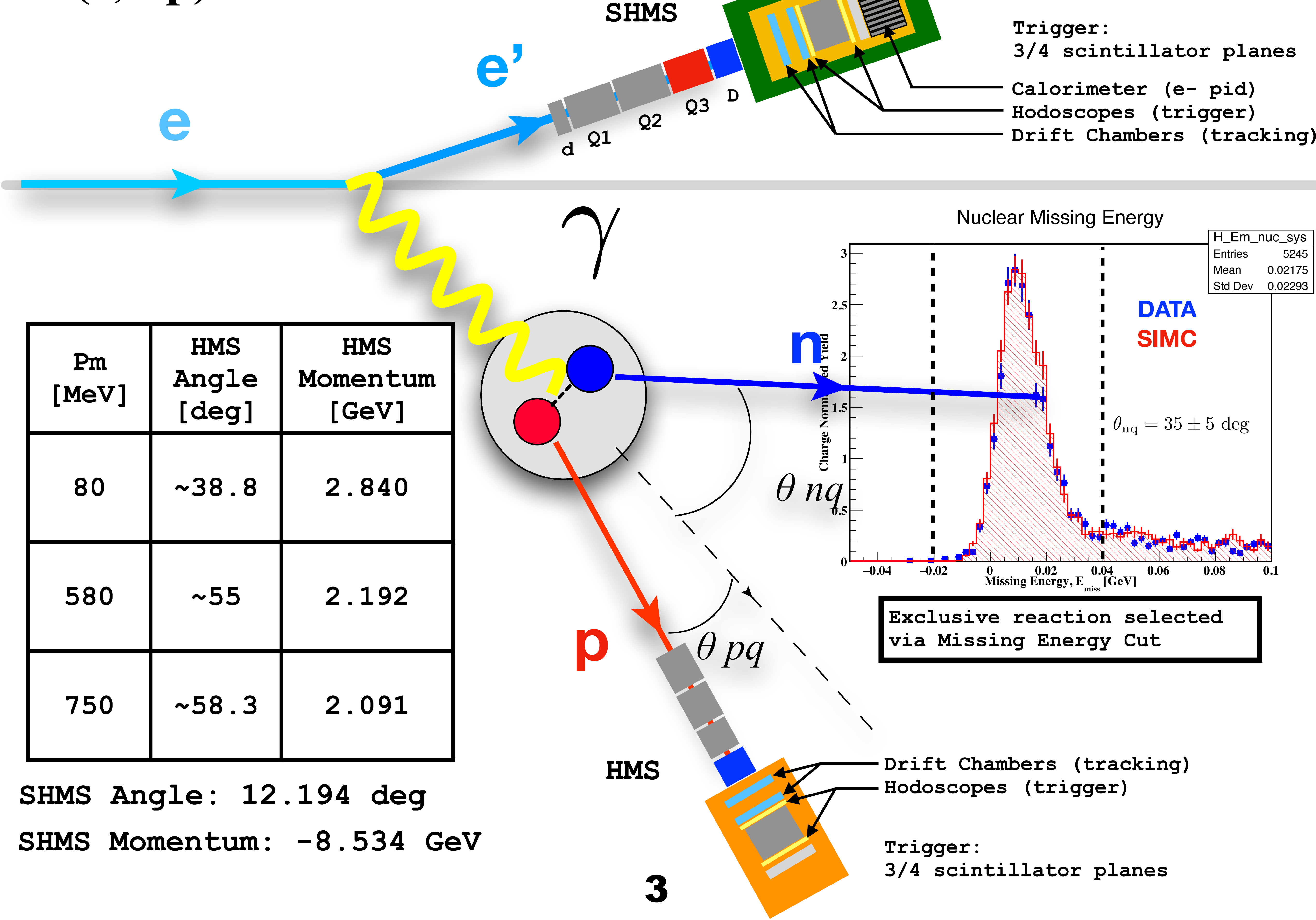
- ☑ Understand the short range structure by probing high momentum tails

- ☑ At short ranges, np start overlap: overlap is directly related to SRCs in A>2 nuclei

- ☑ Extract momentum distributions beyond 500 MeV/c recoil momenta at PWIA kinematics



D(e,e'p)n Kinematics



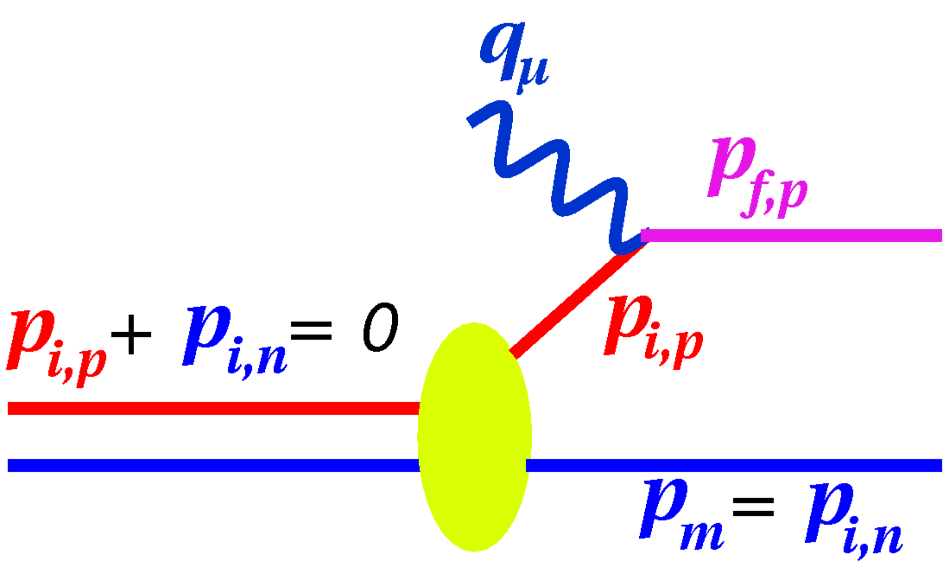
Pm [MeV]	HMS Angle [deg]	HMS Momentum [GeV]
80	~38.8	2.840
580	~55	2.192
750	~58.3	2.091

Exclusive reaction selected via Missing Energy Cut

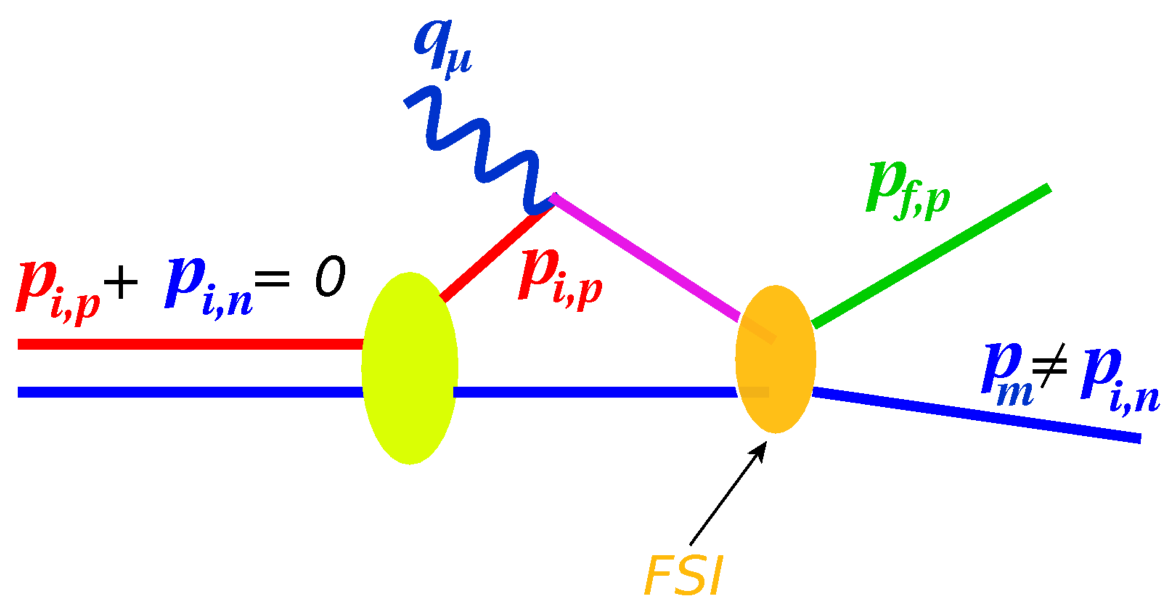
SHMS Angle: 12.194 deg

SHMS Momentum: -8.534 GeV

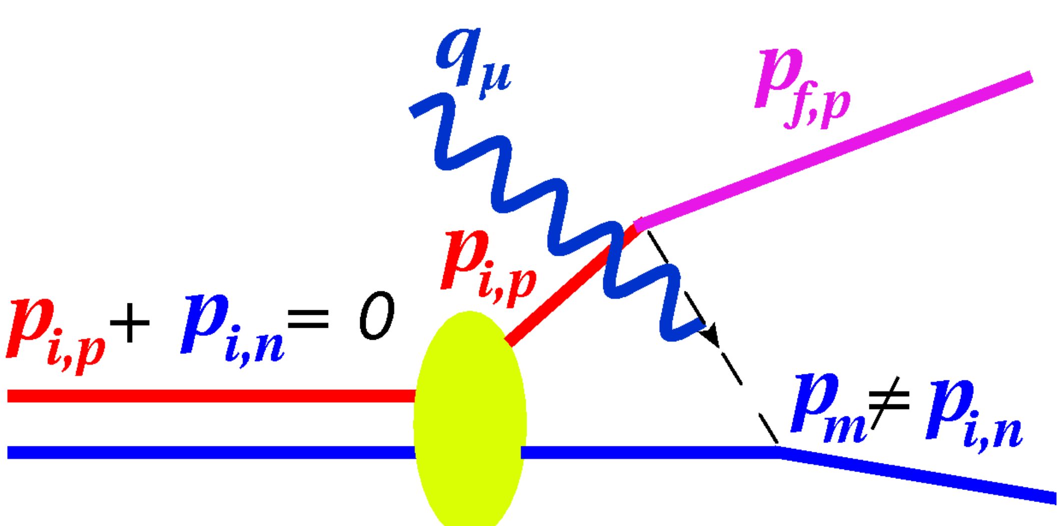
D(e,e’p)n Feynman Diagrams



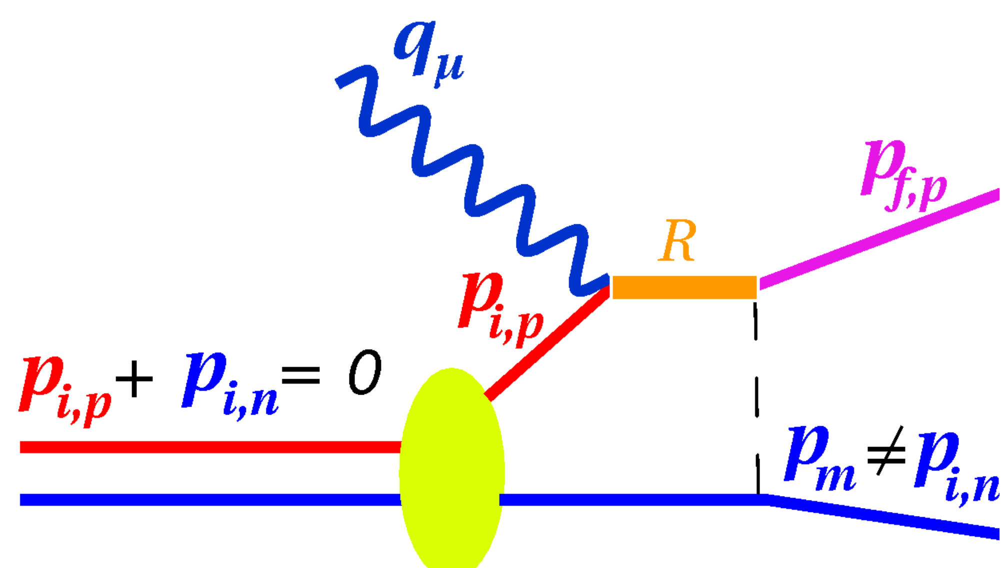
(a) Plane Wave Impulse Approximation (PWIA)



(b) Final State Interactions (FSI)



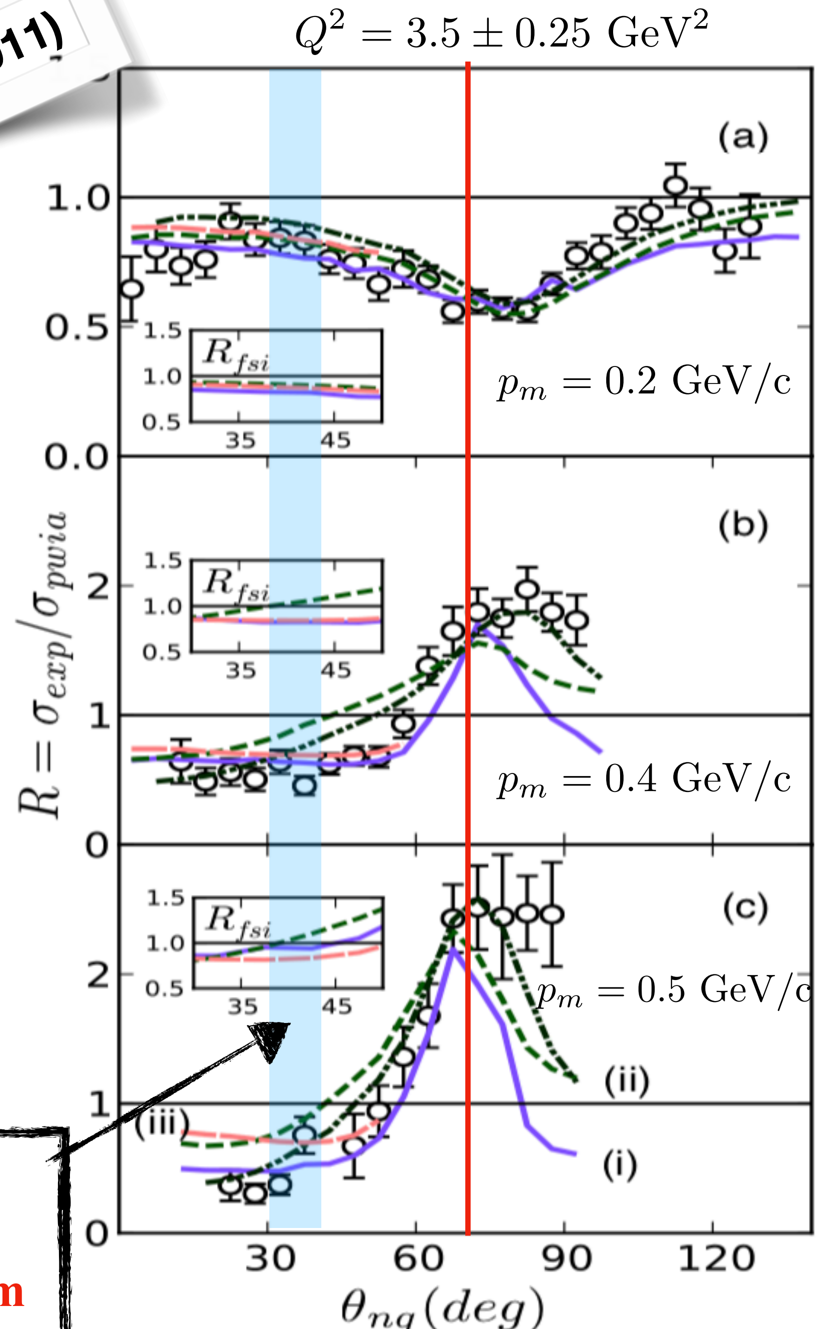
(c) Meson-Exchange Currents (MEC)



(d) Isobar Configurations (IC)

First D(e,e'p)n Experiments at: $Q^2 > 1\ \mathrm{GeV}^2$

JLab Hall A (2011)



CD-Bonn FSI (MS)

JVO Model (J. Van Orden)

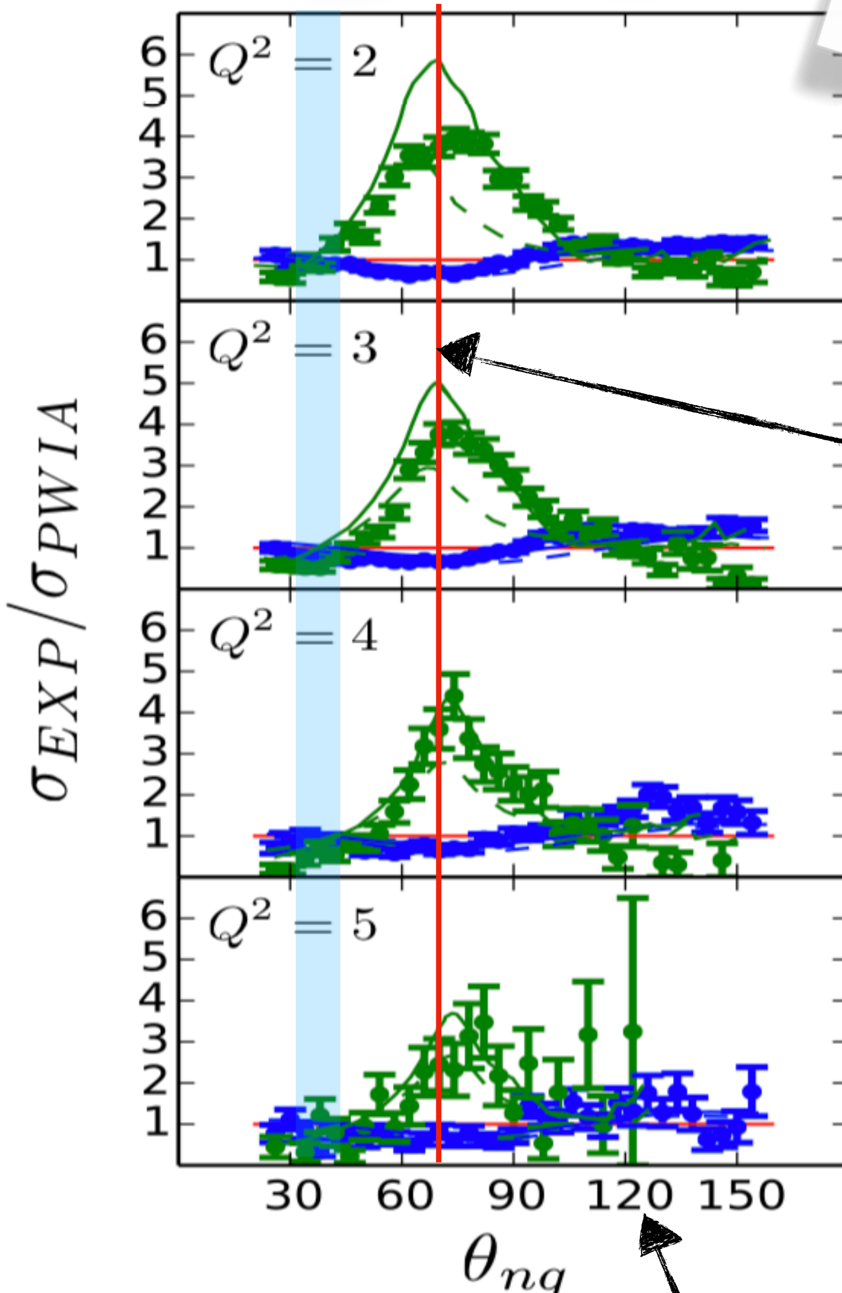
Paris FSI (J.M. Laget)

Paris FSI+MEC+IC (J.M. Laget)

DATA

Reduced FSIs at ~40 deg (R ~ 1)
genuine momentum distributions probed

JLab Hall B (2007)



FSI peaks at ~70 deg (predicted by GEA)

$0.2 \leq p_m \leq 0.3$ GeV/c

$0.4 \leq p_m \leq 0.6$ GeV/c

Paris FSI (J.M. Laget)

CD-Bonn FSI (MS)

Reduced FSIs at ~120 deg (R ~ 1),
But ICs are significant

Plots Reference:
W.U.Boeglin and M. Sargsian
Int.J.Mod.Phys. E24 (2015) no.03, 1530003

Data Analysis of the E12-10-003 Commissioning Experiment at Hall C

See Backup Slides for first steps in general analysis:

1. Set reference times cuts
2. Set detector time window cuts
3. Perform detector calibrations

SHMS Optics Optimization for E12-10-003 Using H(e,e'p) Elastics

The SHMS optics optimization work done for the D(e,e'p)n experiment can be found at Hall C Document Database

Optics Optimization for the D(e,e'p)n Experiment (E12-10-003)

Carlos Yero

July 29, 2019

1 Introduction

The commissioning of the HMS/SHMS optics took place on the 2017-18 run period and underwent multiple revisions of the reconstruction matrix elements for both spectrometers during that period.[3, 4] This document presents the optics optimization checks and procedures done on the High Momentum Spectrometer (HMS) and superHMS (SHMS) for the Deuteron Electro-Disintegration Commissioning Experiment (E12-10-003) on April 2018. At the time, this experiment also served as part of the general optics commissioning as during data-taking, it was found that the SHMS Q3 magnet had an un-ncecessary correction in the matrix elements. As a result, the data for this experiment is divided into two sections. Only the section after the fix in the SHMS optics was used in the optimization procedure.

The problem of optics optimization can be approached in different ways, depending on the circumstances of the experiment. In this particular experiment, a series of H(e,e'p) elastic runs were taken at different configurations such as to cover the entire HMS momentum range in the D(e,e'p)n reaction kinematics. The original and corrected H(e,e'p) kinematics are summarized below.

Run	HMS Angle [deg]	HMS Momentum [GeV]	SHMS Angle [deg]	SHMS Momentum [GeV]
3288	37.338	2.938	12.194	8.7
3371	33.545	3.48	13.93	8.7
3374	42.9	2.31	9.928	8.7
3377	47.605	1.8899	8.495	8.7

Table 1: Original H(e,e'p) Elastic Kinematics in E12-10-003.

Run	HMS Angle [deg]	HMS Momentum [GeV]	SHMS Angle [deg]	SHMS Momentum [GeV]
3288	37.338	2.9355	12.194	8.5342
3371	33.545	3.4758	13.93	8.5342
3374	42.9	2.3103	9.928	8.5342
3377	47.605	1.8912	8.495	8.5342

Table 2: Corrected H(e,e'p) Elastic Kinematics in E12-10-003.

Spec	$\delta\theta$[rad]	$\delta\phi$[rad]	X'_{tar}-offset[rad]	Y'_{tar}-offset[rad]
HMS	0.0	1.521×10^{-3}	2.852×10^{-3}	9.5×10^{-4}
SHMS	0.0	0.0	0.0	0.0

Table 3: Spectrometer Offsets determined from H(e,e'p) Elastic Run 3288 in E12-10-003. See Section 4 of this document for more information.

Since this is a coincidence experiment, the spectrometers are highly correlated which makes the optics optimization more complicated, as changes in one spectrometer can affect the other. Based on the kinematics, it was determined to focus on the HMS first, as the momentum is well below the Dipole saturation (~5 GeV), and the optics are much better understood from the 6 GeV era.

1

- **Optimize SHMS delta matrix**
- **Used sieve data to optimize Ytar**
- **Determined spectrometer kinematics offsets**

Details can be found in documentation

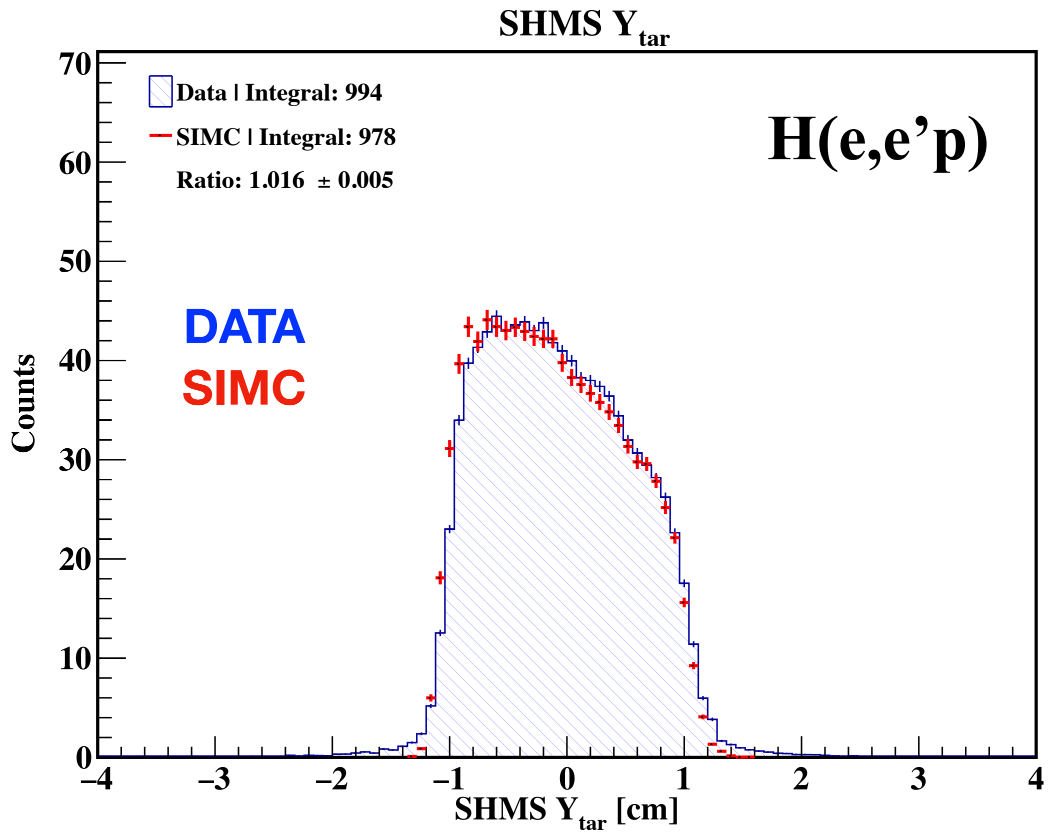
HALLC DOC-DB LINK

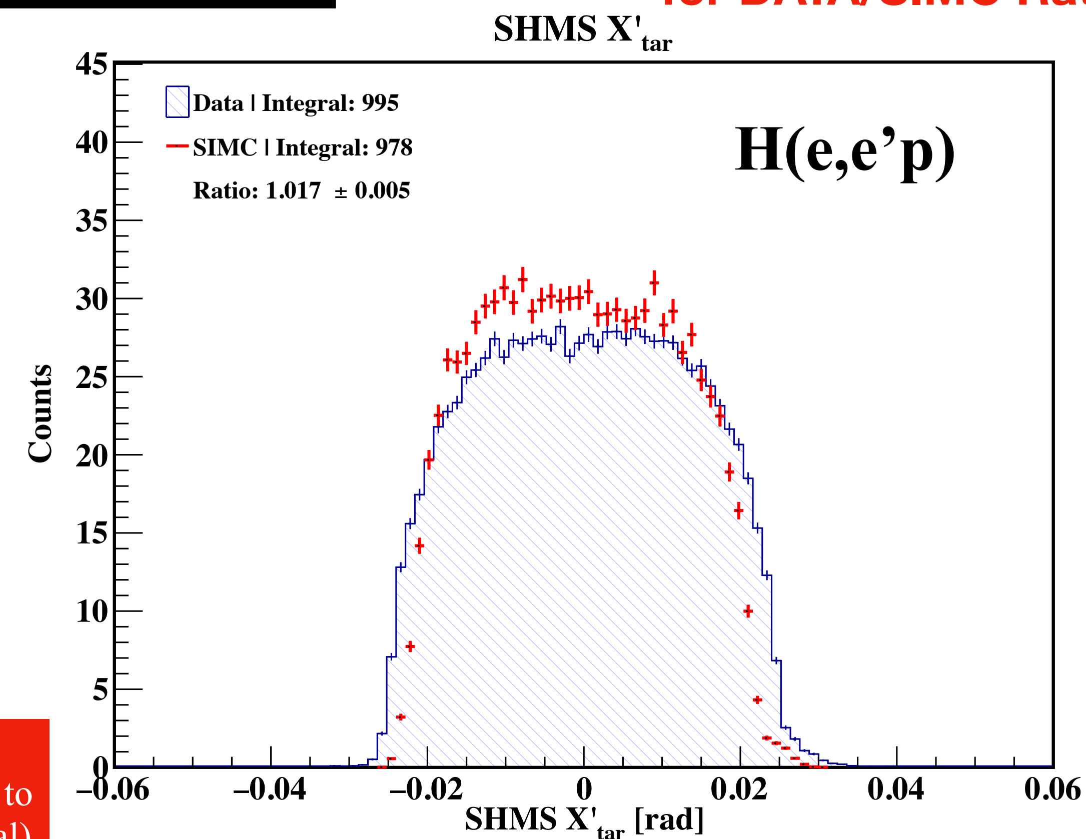
Spectrometer Acceptance
DATA/SIMULATION

(used H(e,e'p) Elastics data taken on D(e,e'p)n Experiment)

SHMS Reconstructed Variables

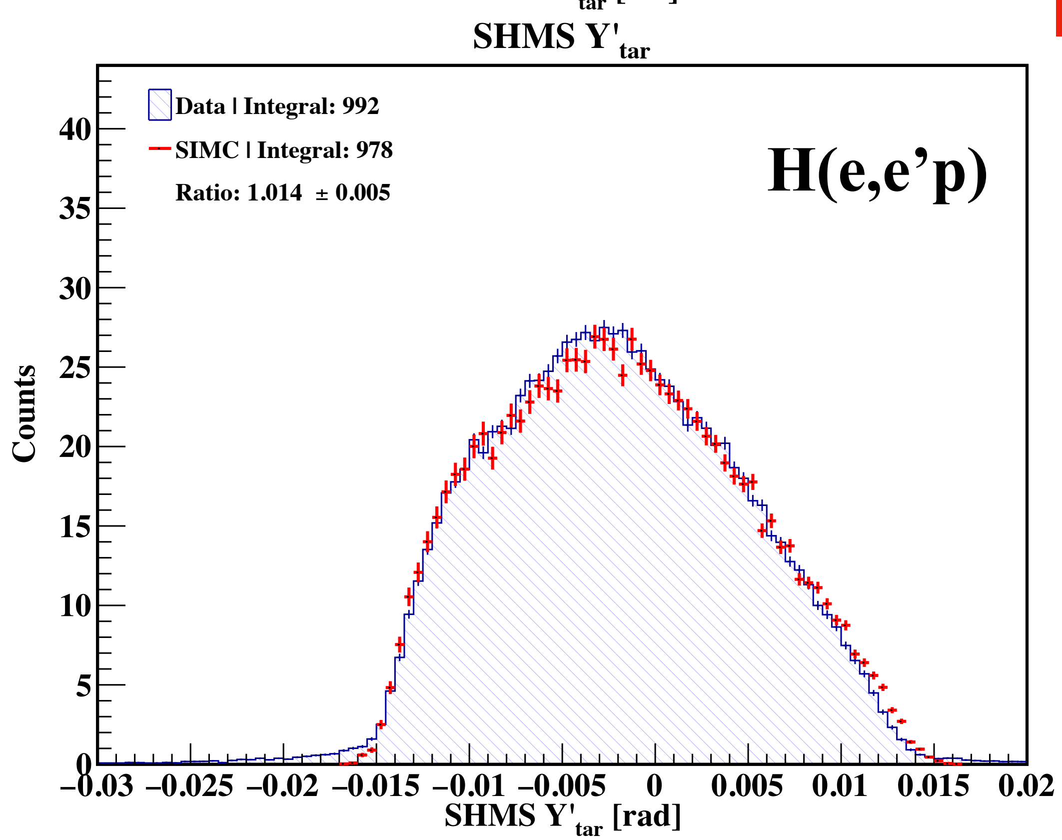
(See Backup Slides for DATA/SIMC Ratio)

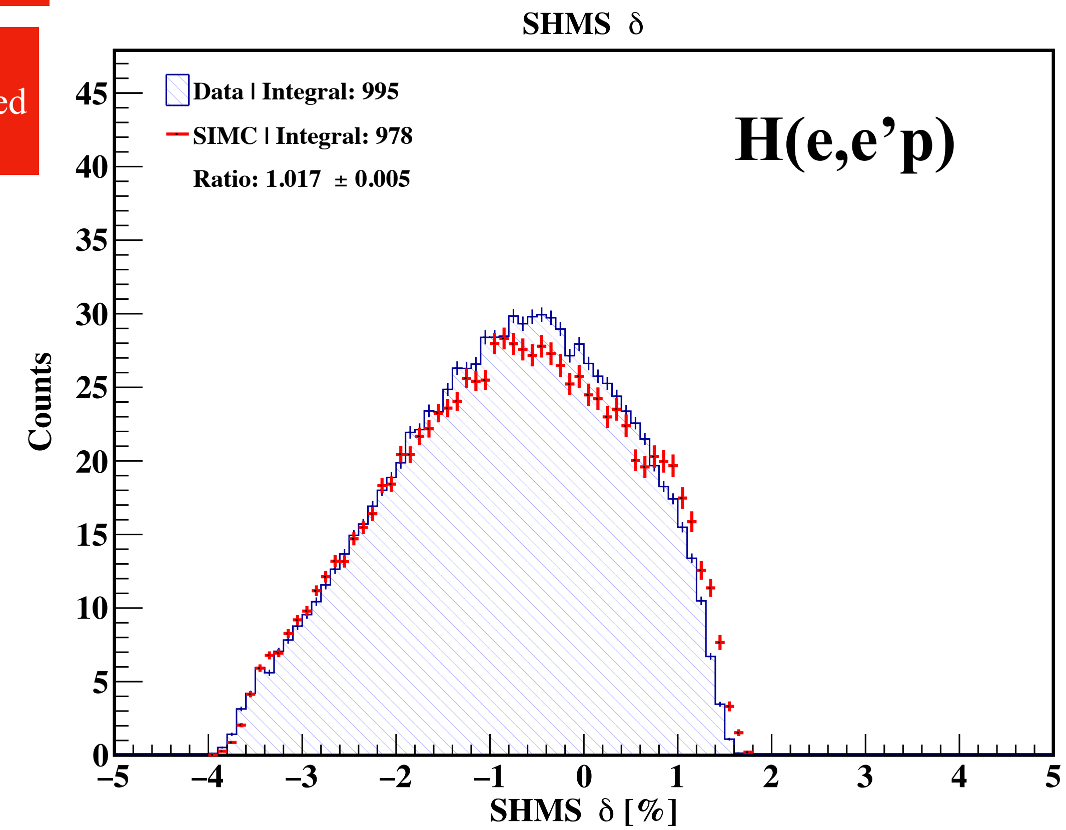




We know the H(e,e'p) cross section to 97 +/- 0.3 % (statistical)

Elastic form factors error is NOT accounted for in SIMC

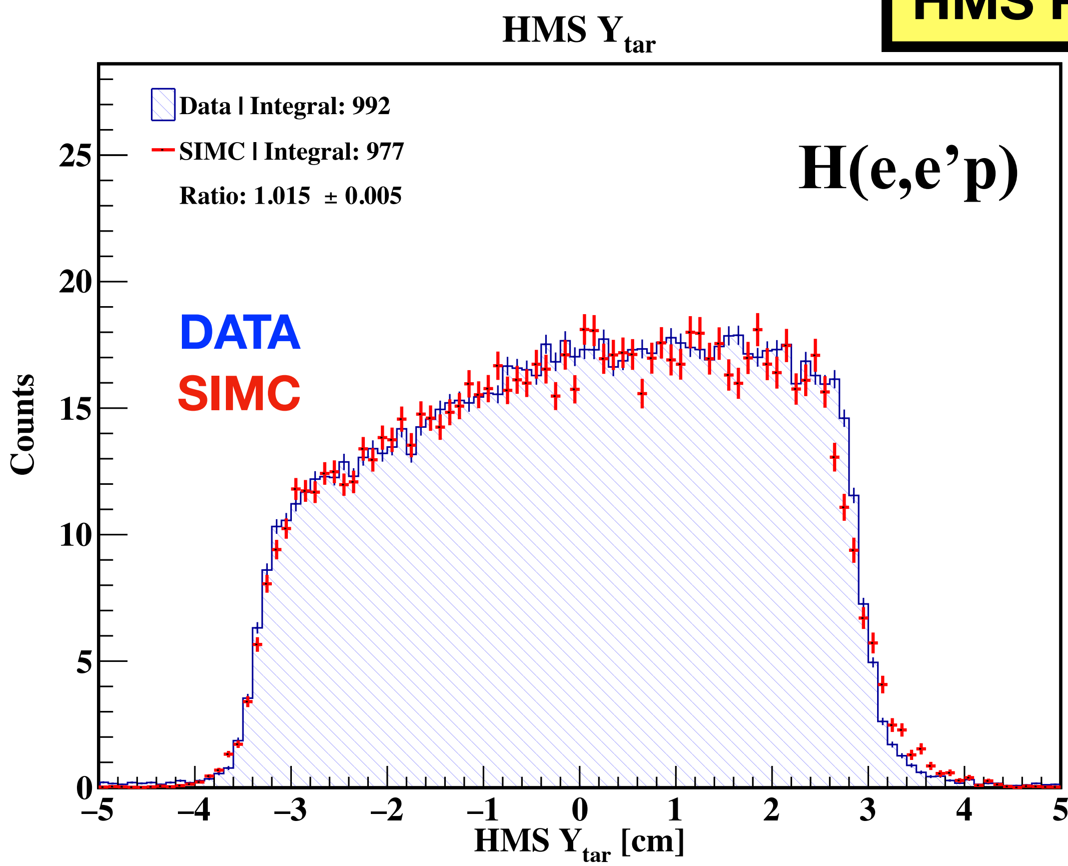


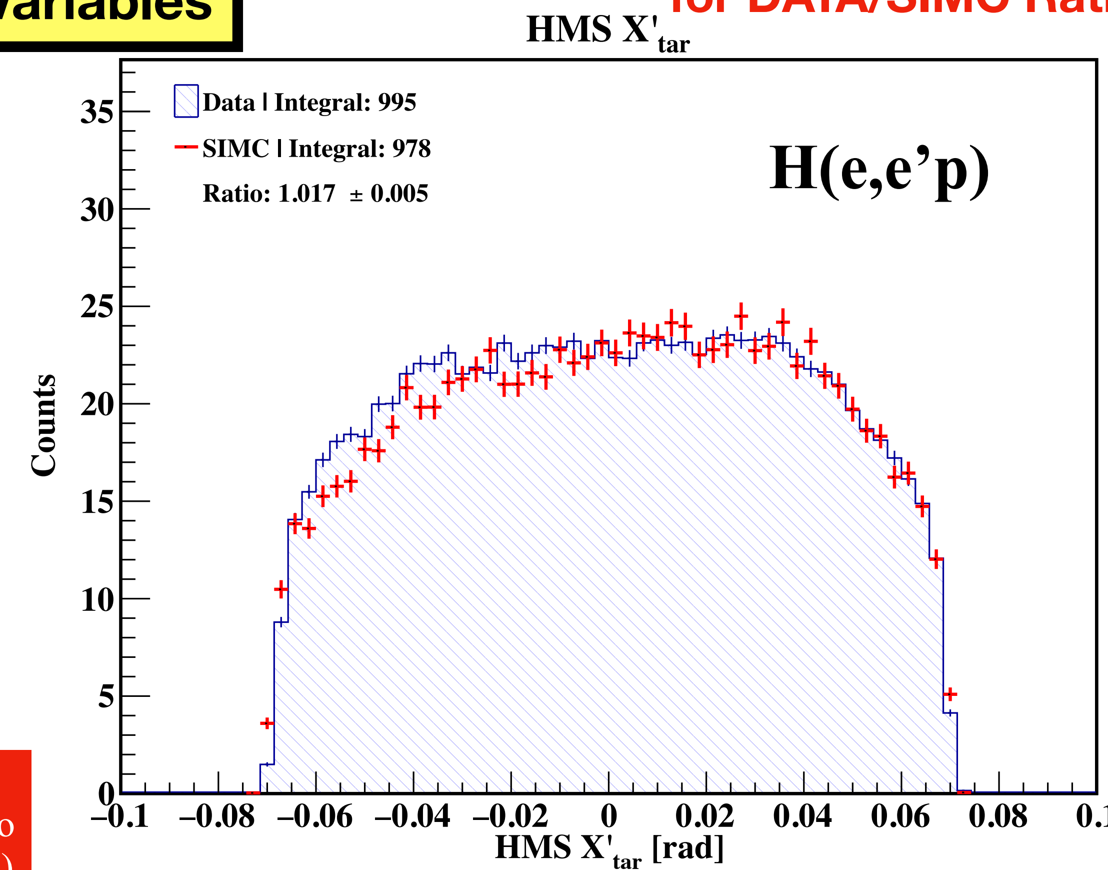


Spectrometer Acceptance
DATA/SIMULATION
(used H(e,e'p) Elastics data taken on D(e,e'p)n Experiment)

HMS Reconstructed Variables

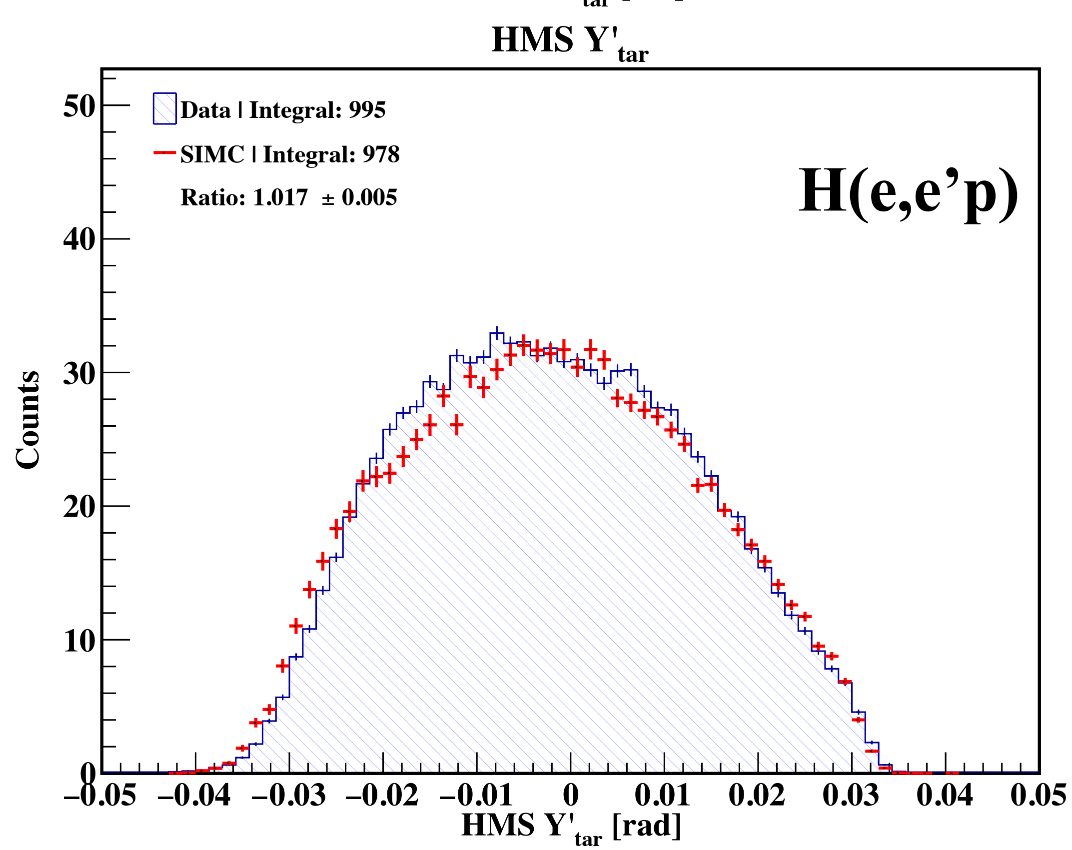
(See Backup Slides for DATA/SIMC Ratio)

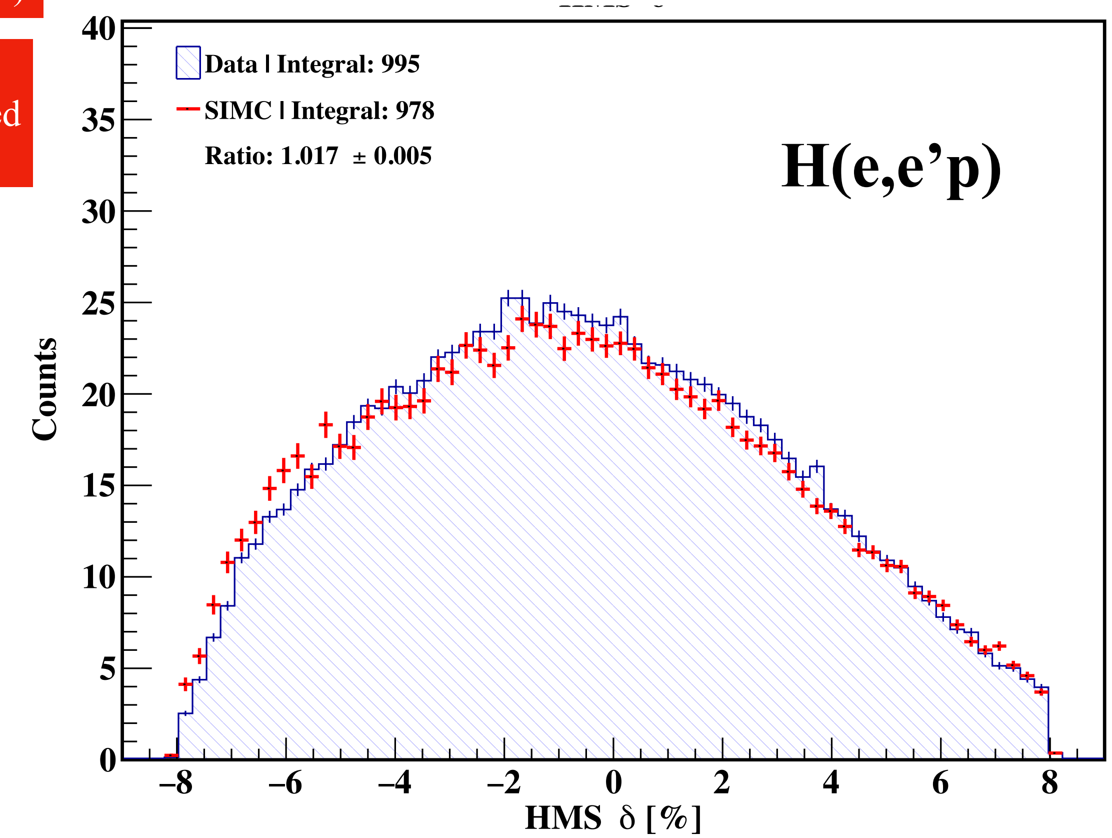




We know the H(e,e'p) cross section to 97 +/- 0.3 % (statistical)

Elastic form factors error is NOT accounted for in SIMC

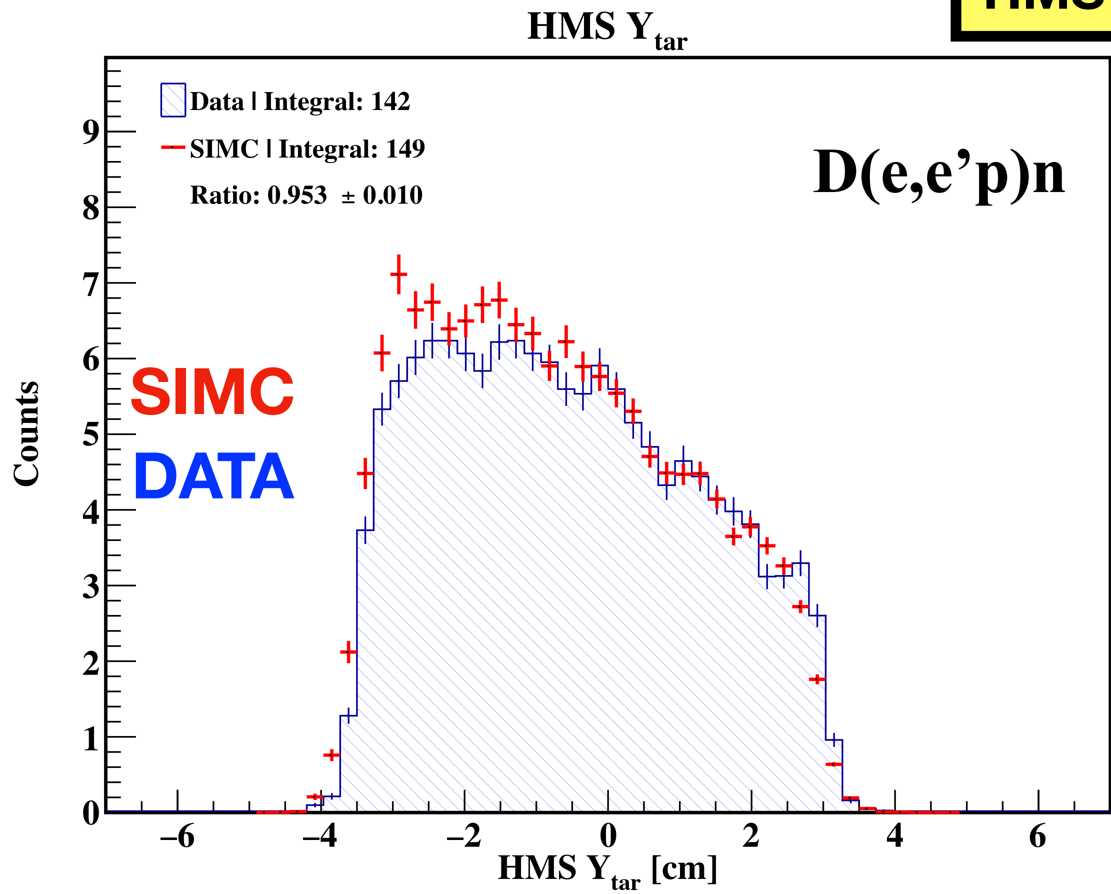


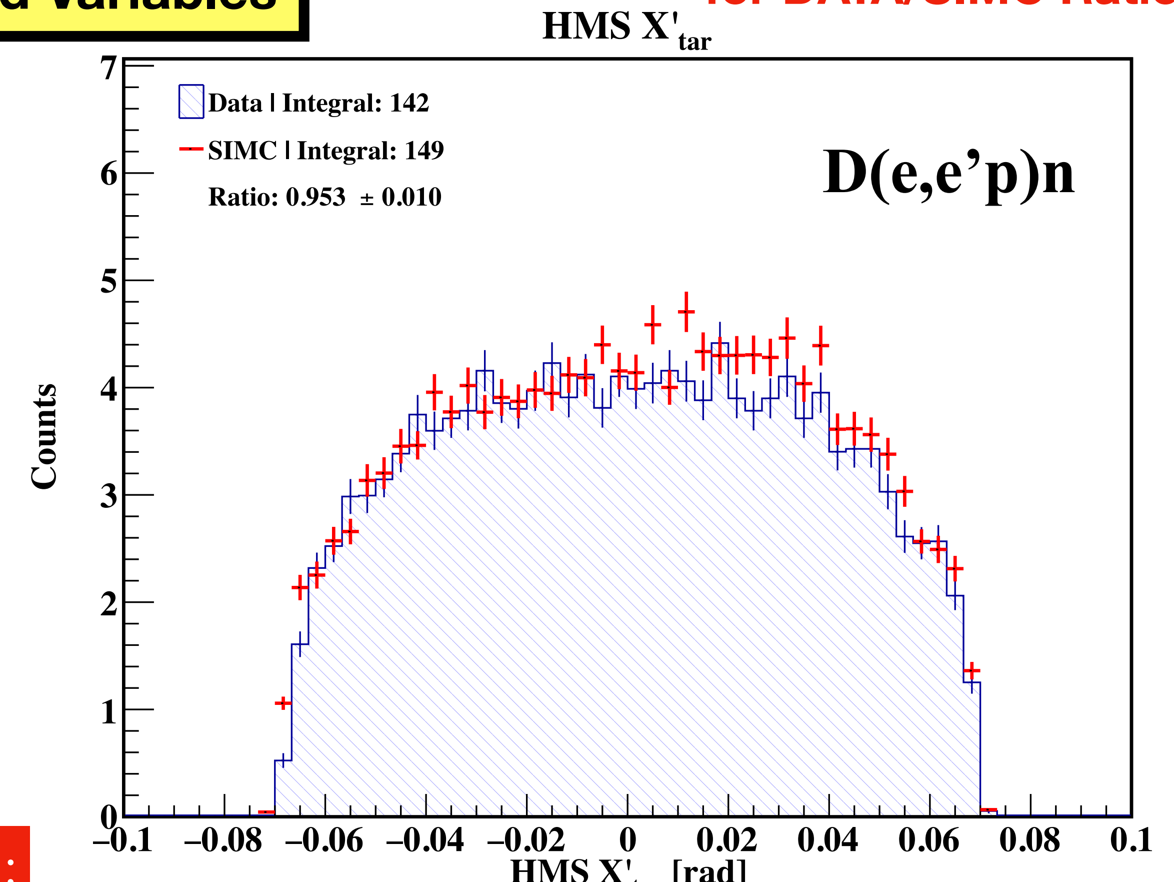


Spectrometer Acceptance
Checks on D(e,e’p)n using 80 MeV setting

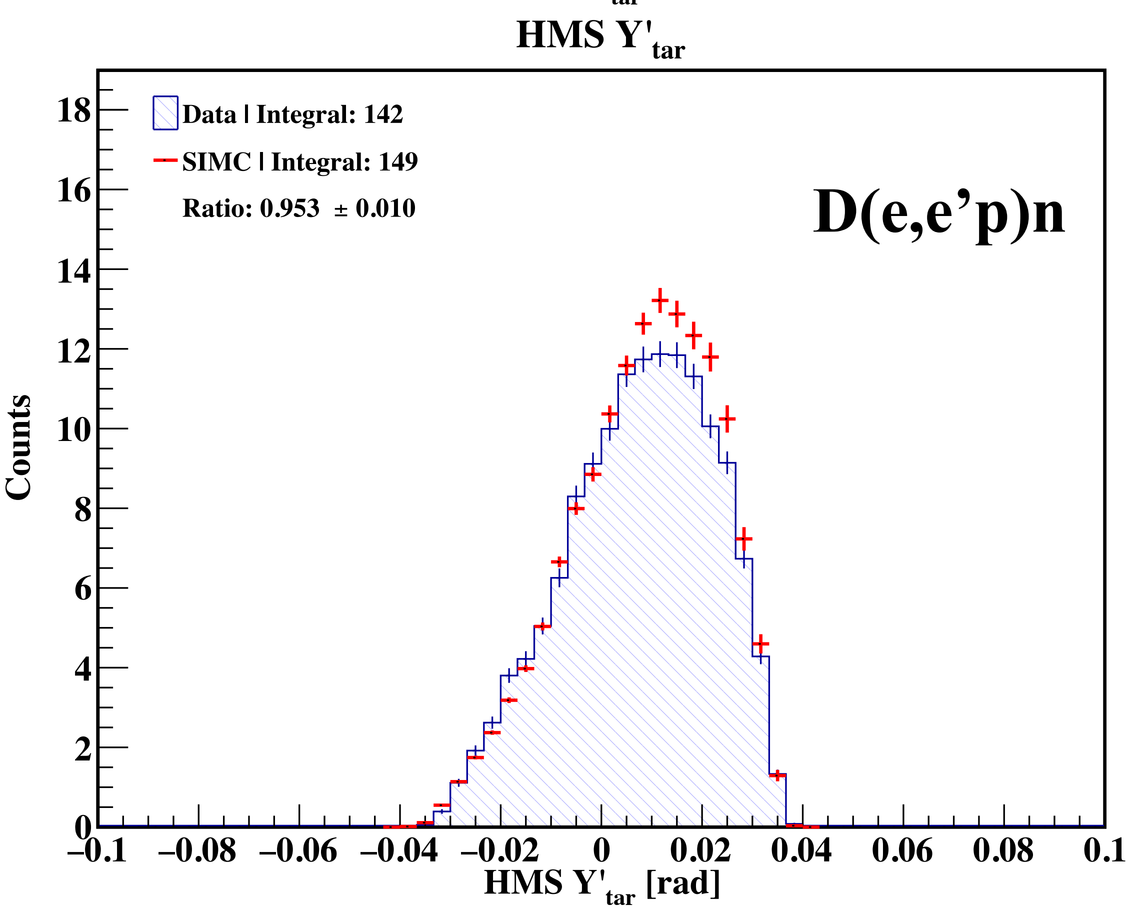
HMS Reconstructed Variables

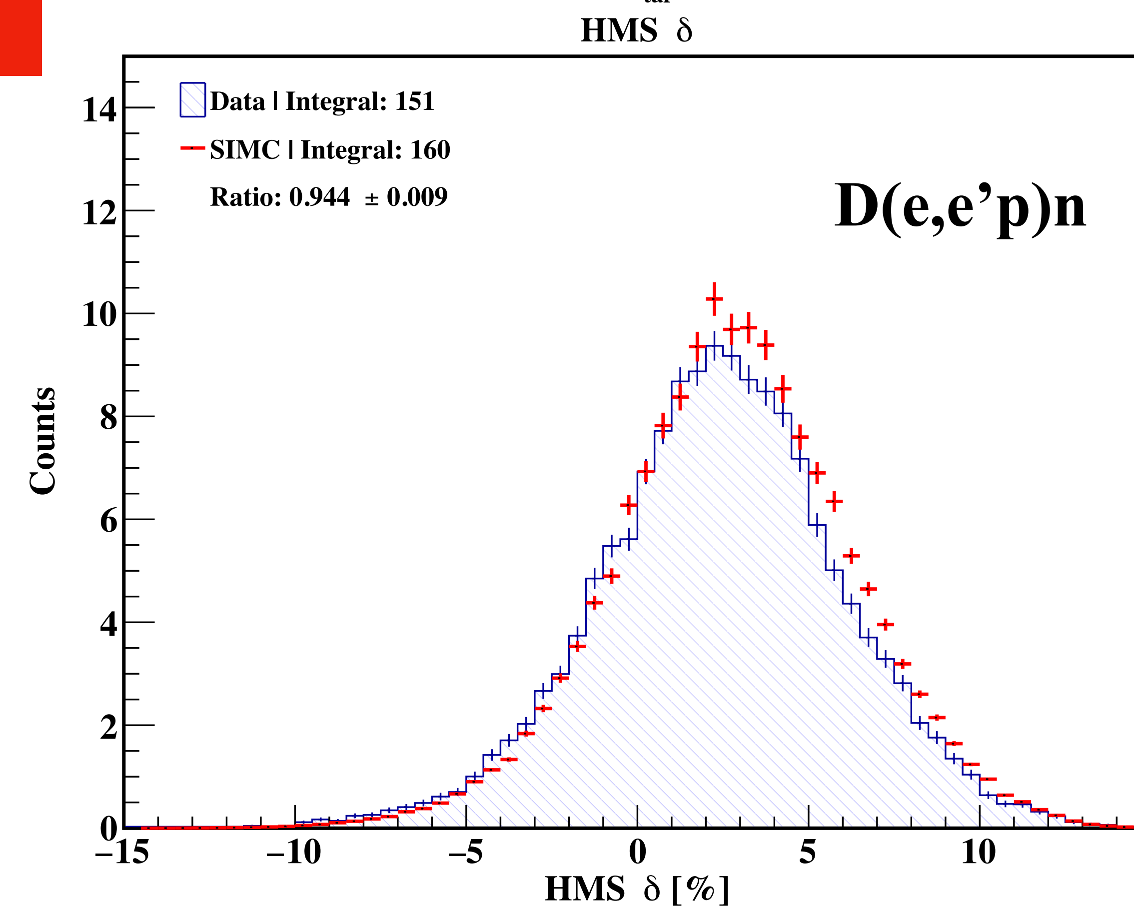
(See Backup Slides for DATA/SIMC Ratio)





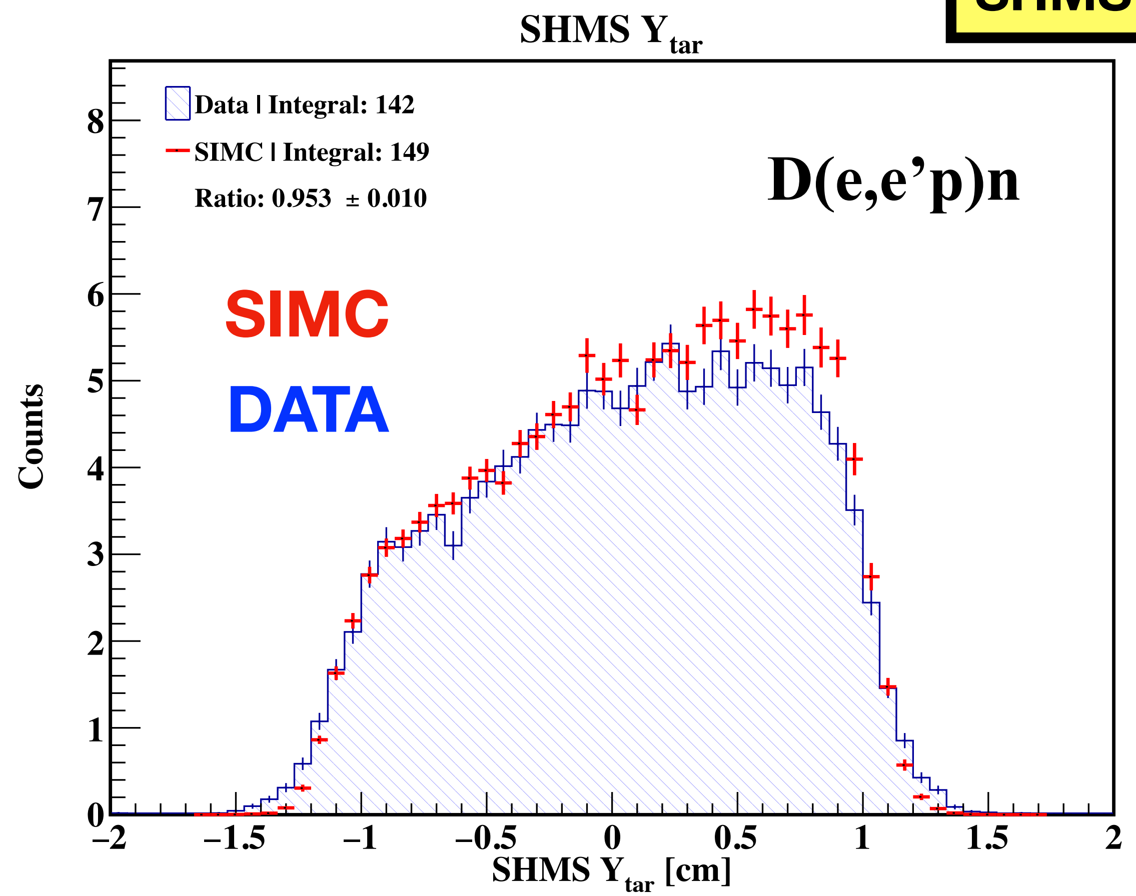
SIMC Model: Laget FSI

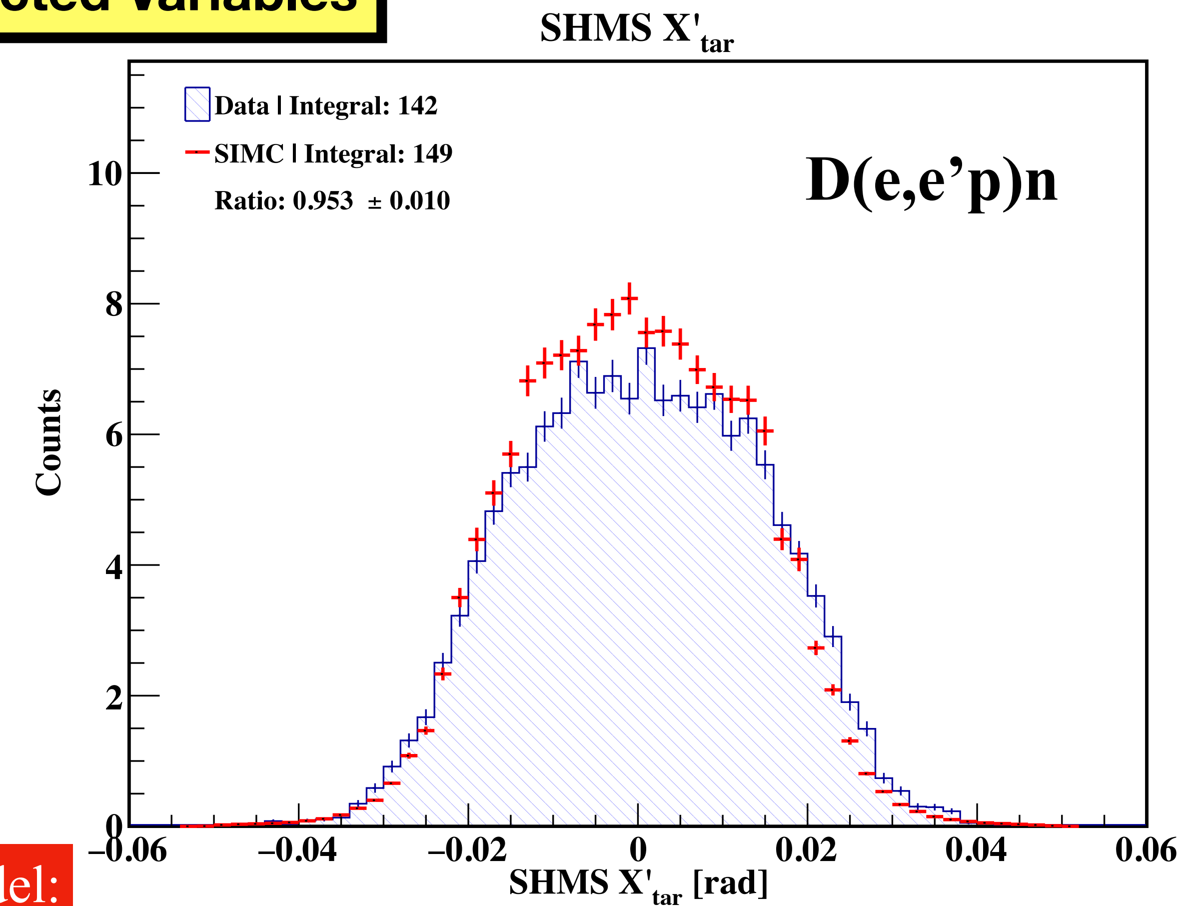




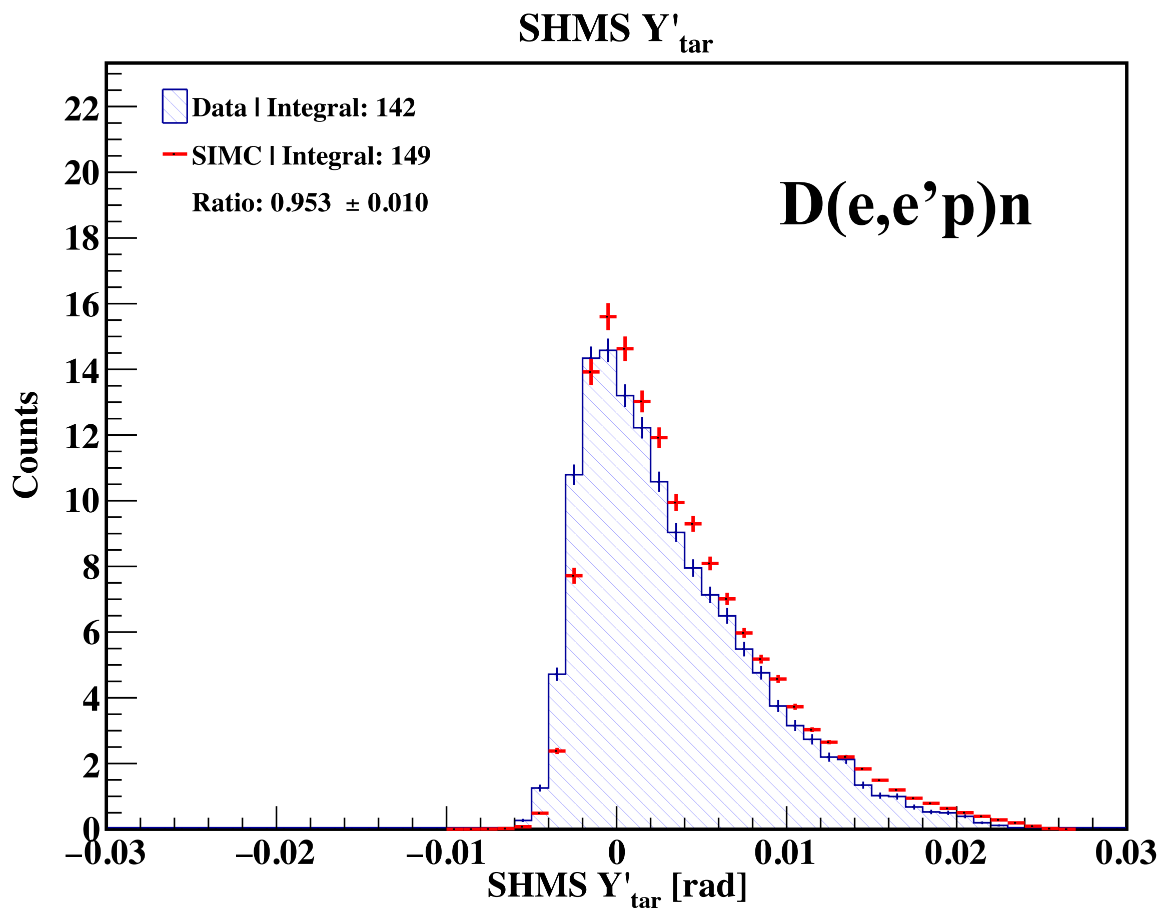
Spectrometer Acceptance
Checks on D(e,e'p)n using 80 MeV setting

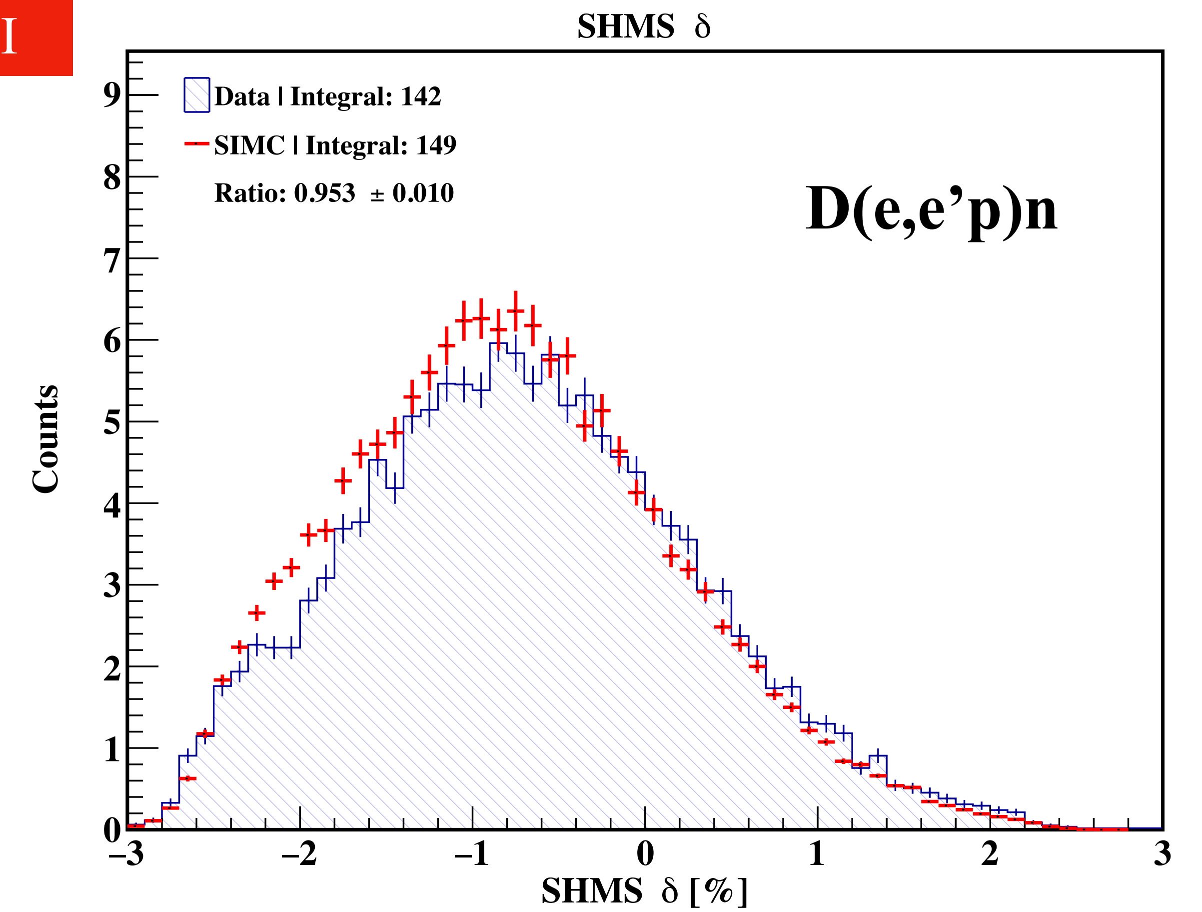
SHMS Reconstructed Variables





SIMC Model: Laget FSI



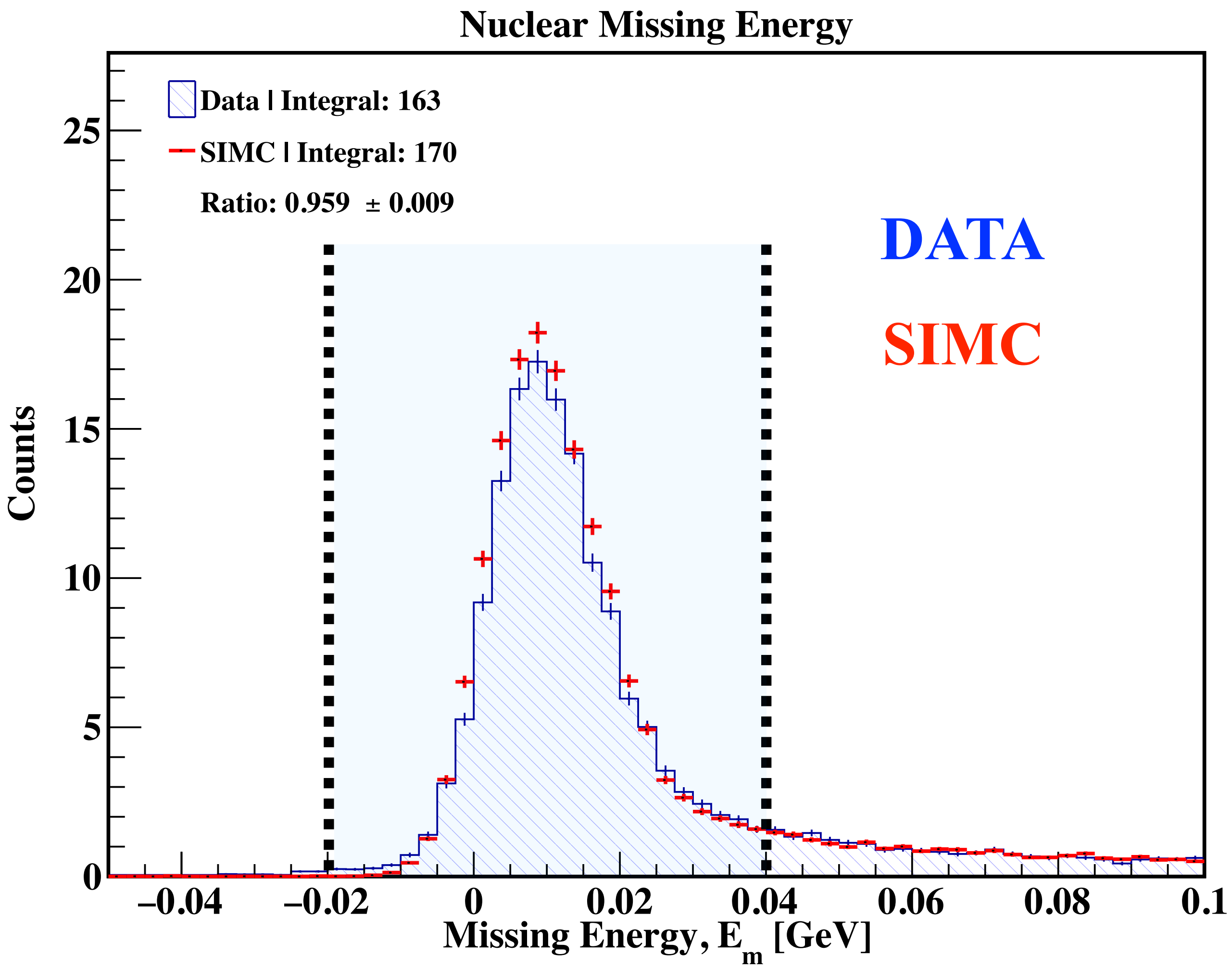


D(e,e’p)n
Data Analysis Cuts

(shown only for 80 MeV setting but are also applied to high missing momentum data)

- **All plots shown have been integrated over all neutron recoil angles**

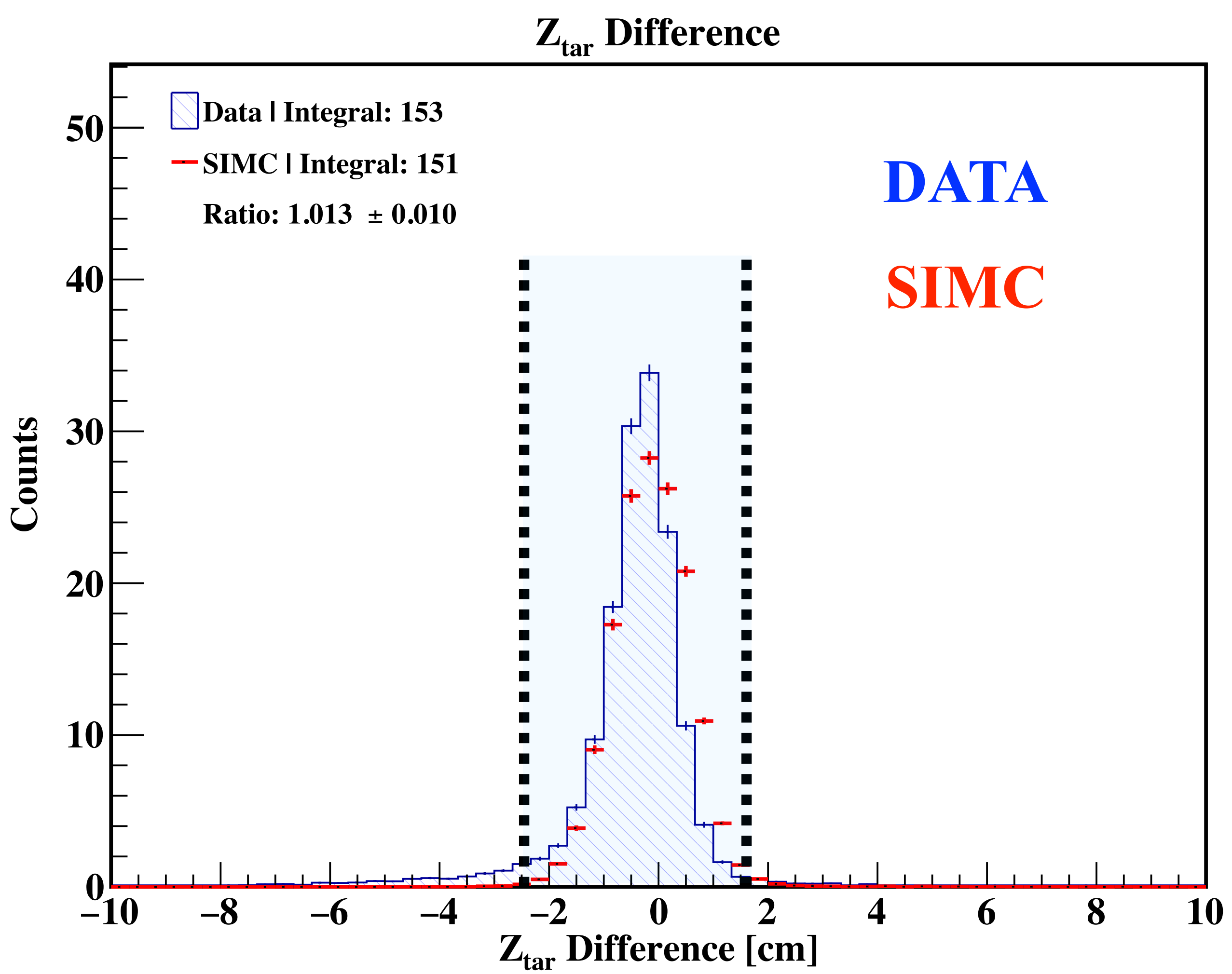
- **Exact cuts are also applied to simulation (except for PID cuts)**



Missing Energy Cut: (-20, 40) MeV

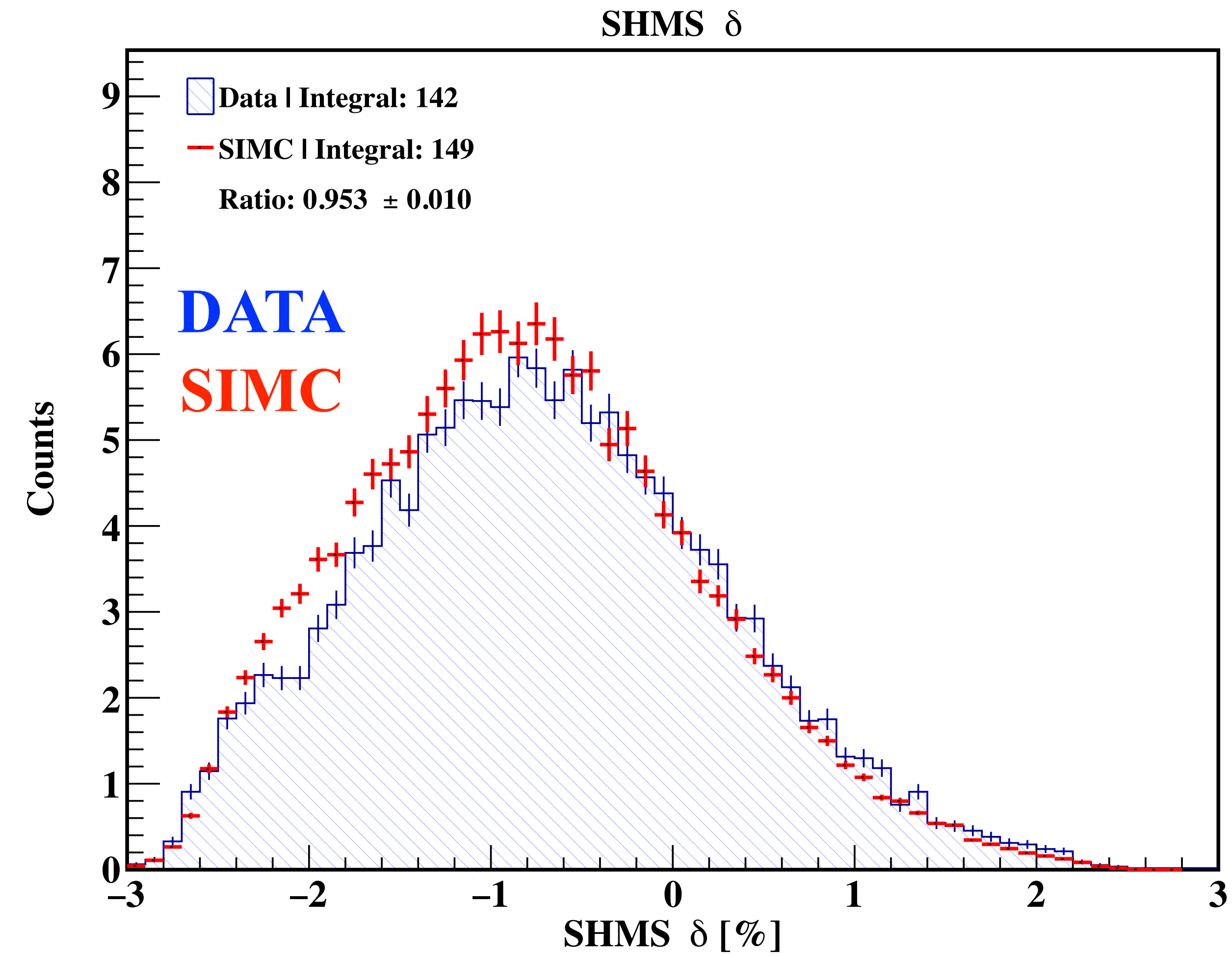
Select true D(e,e'p)n events

$$\underbrace{E_{\mathrm{m}}}_{\substack{\text{Missing energy} \\ \text{is the B.E. of deuteron} \\ (\sim 2.22\text{ MeV})}} = \omega - T_{\mathrm{p}} - \underbrace{T_{\mathrm{r}}}_{\substack{\text{Assume the mass} \\ \text{of the neutron}}}$$



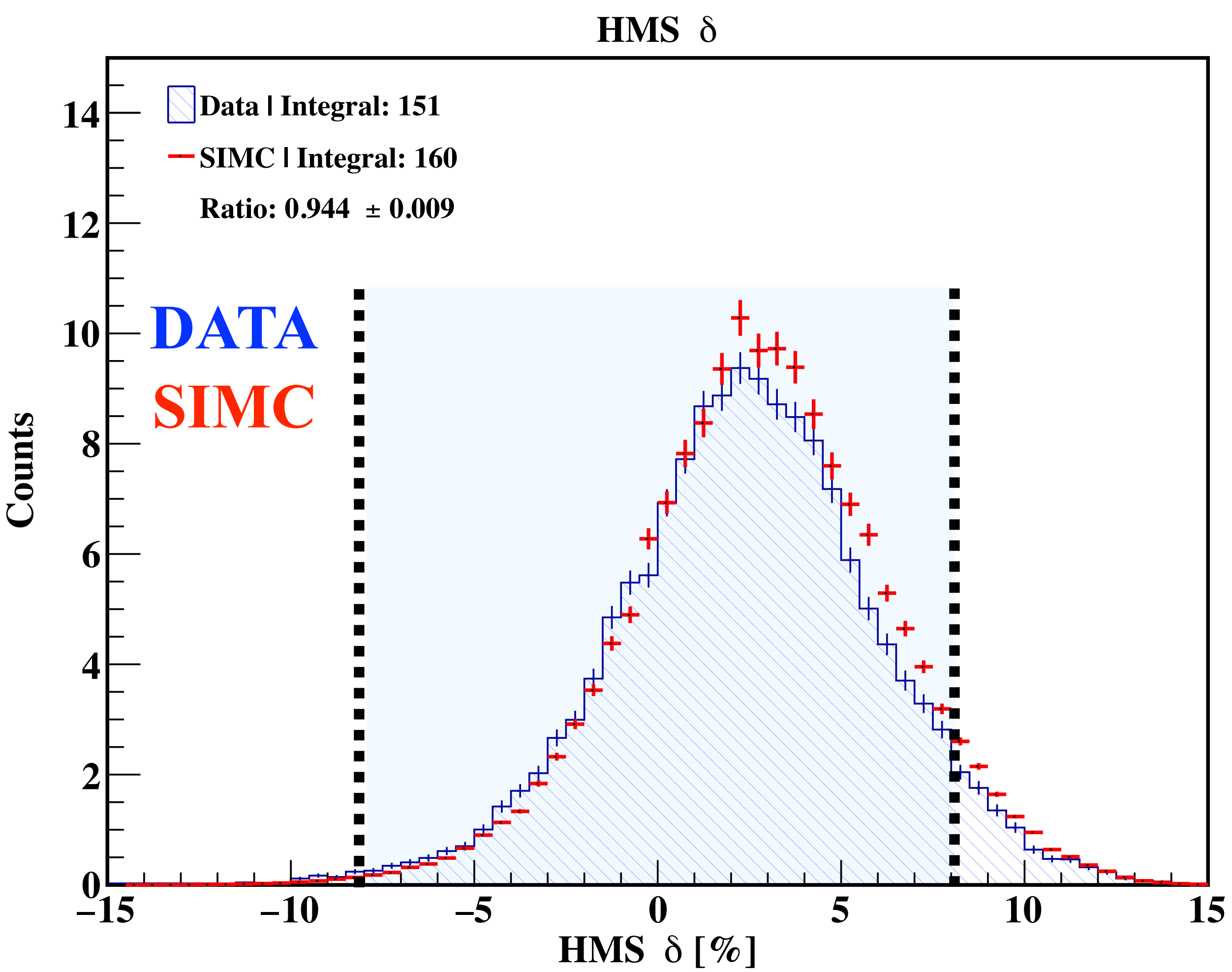
Reconstructed Z vertex difference Cut: +/- 2 cm relative the peak value

require event Z-vertex position to be the same for both HMS and SHMS to select true coincidences and not accidental events



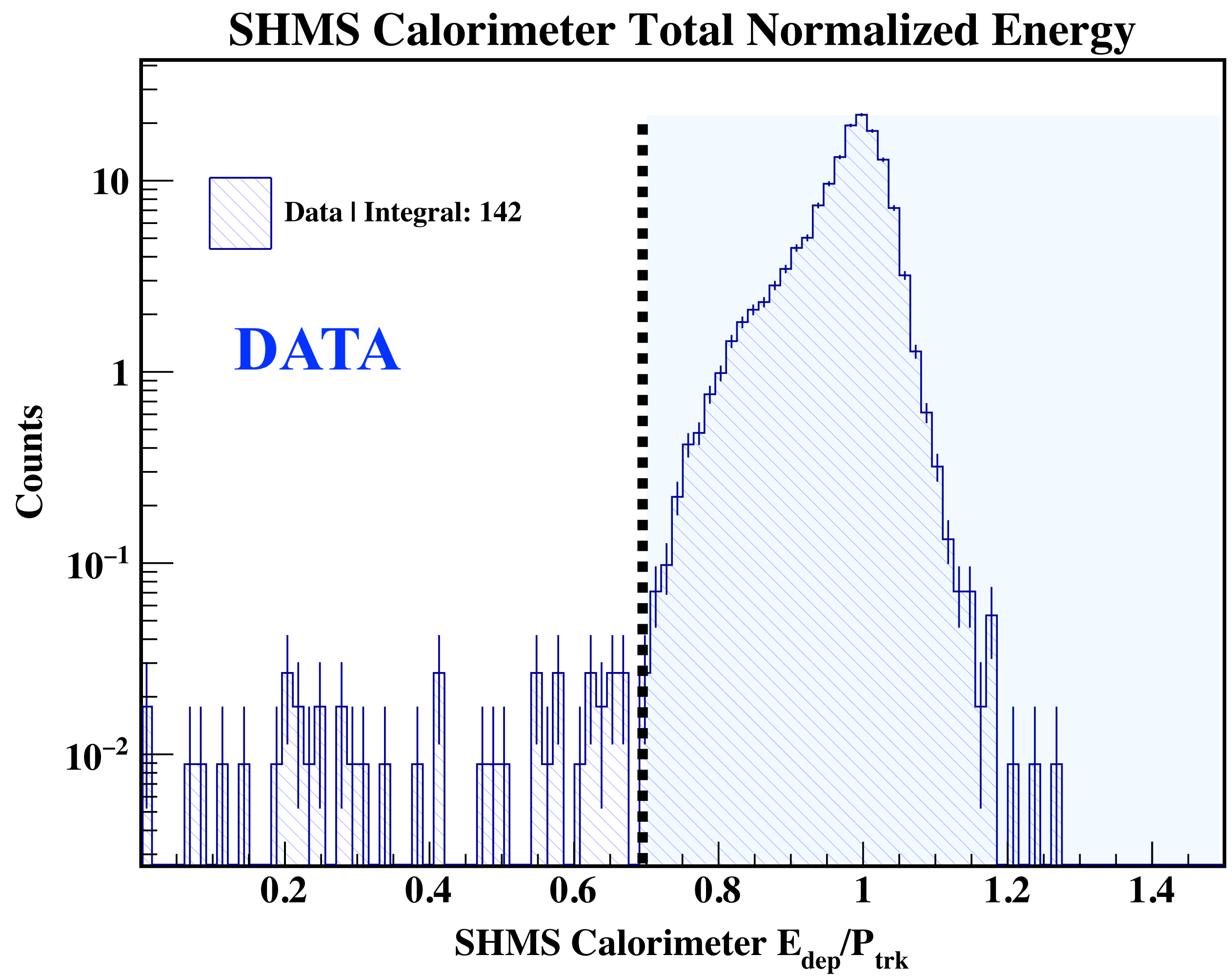
SHMS Delta Acceptance (-3, 3) %

SHMS Delta Acceptance is constrained by the HMS Acceptance to be in the range (-3, 3)%



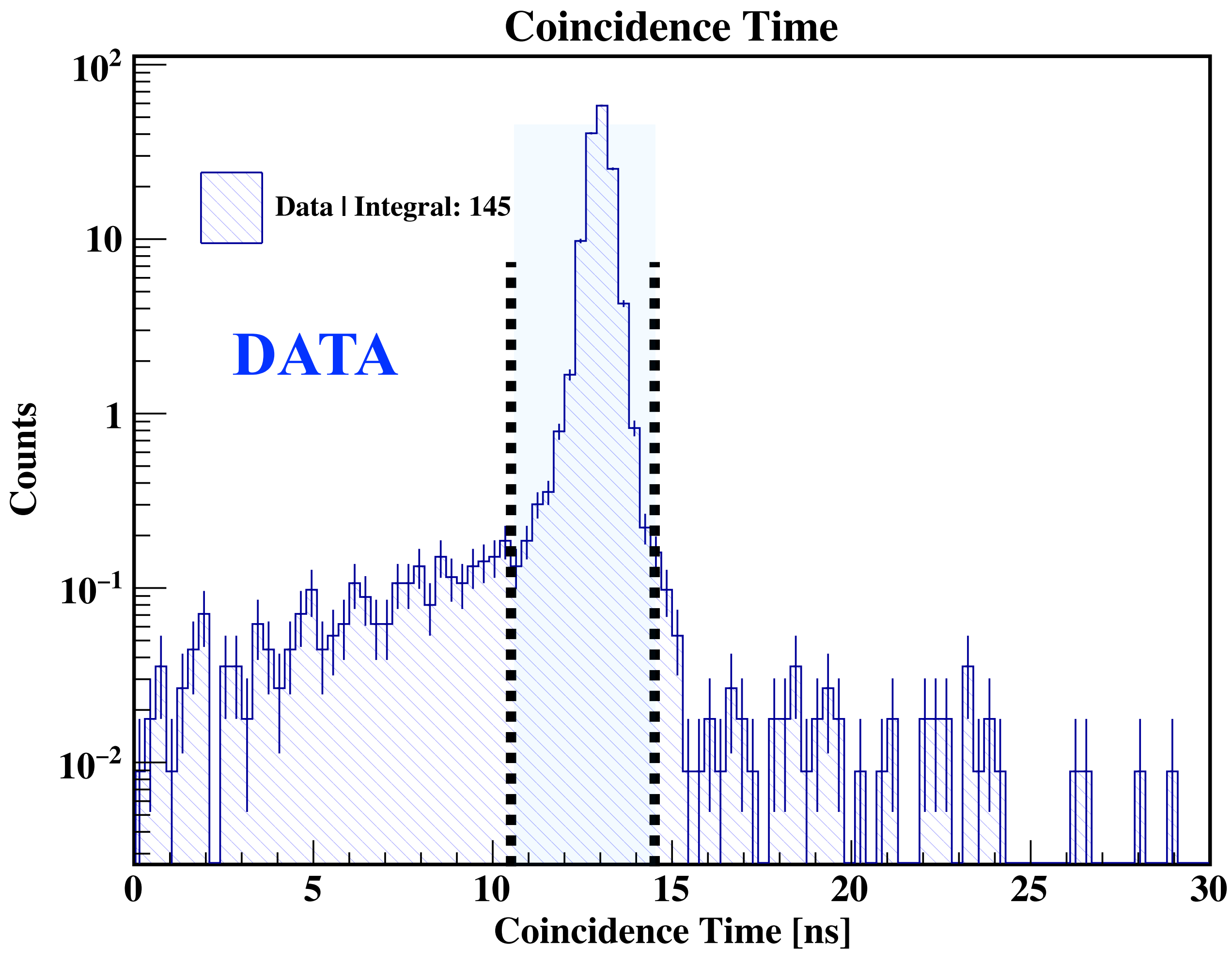
HMS Delta Acceptance Cut: (-8, 8) %

Select HMS acceptance region where Optics Reconstruction is reliable



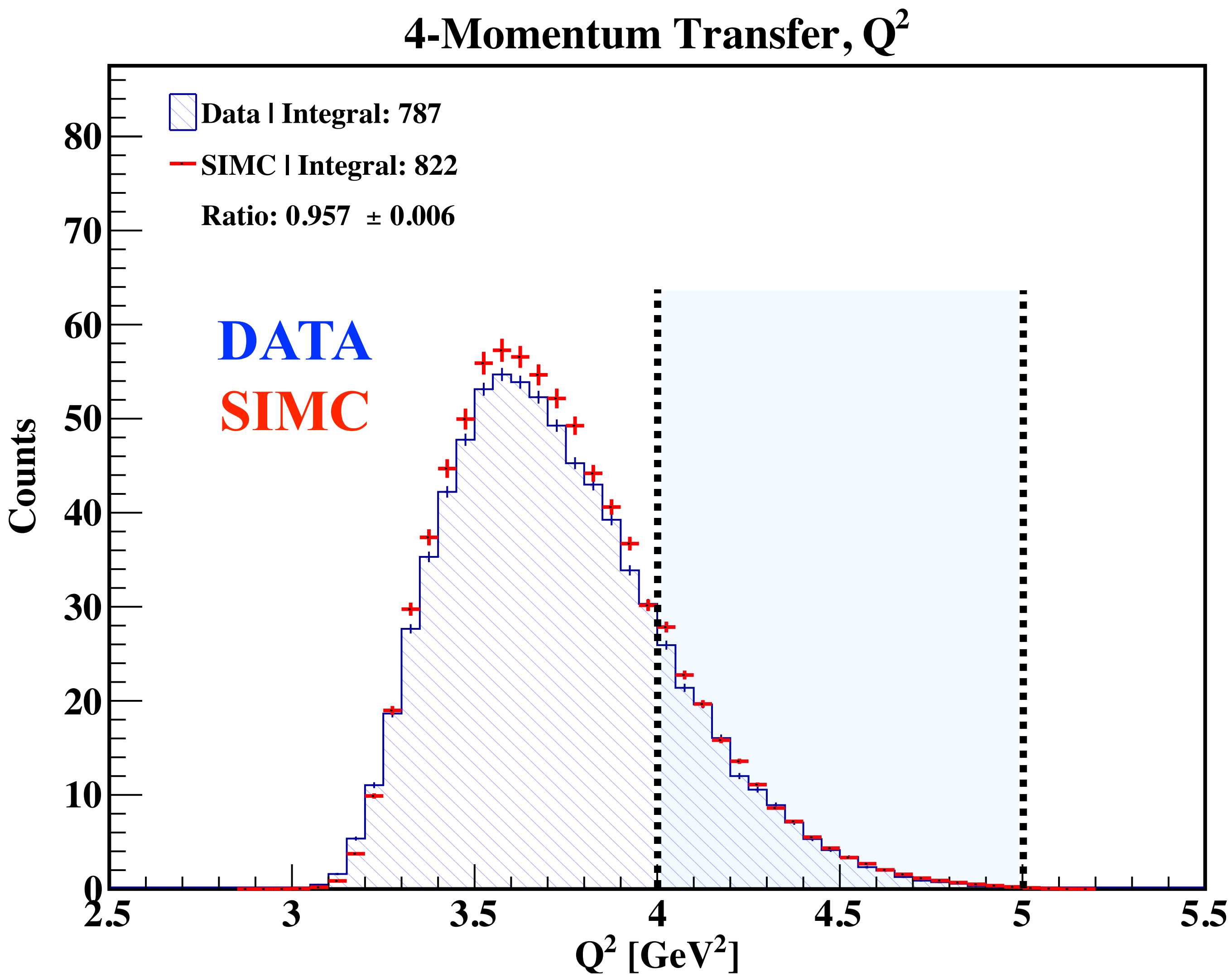
SHMS: Total energy deposited in Calorimeter normalized by the best track
CUT: > 0.7

select true electrons in SHMS and not pions (looks very clean!)



Coincidence Time Cut
CUT: (10.5, 14.5) ns

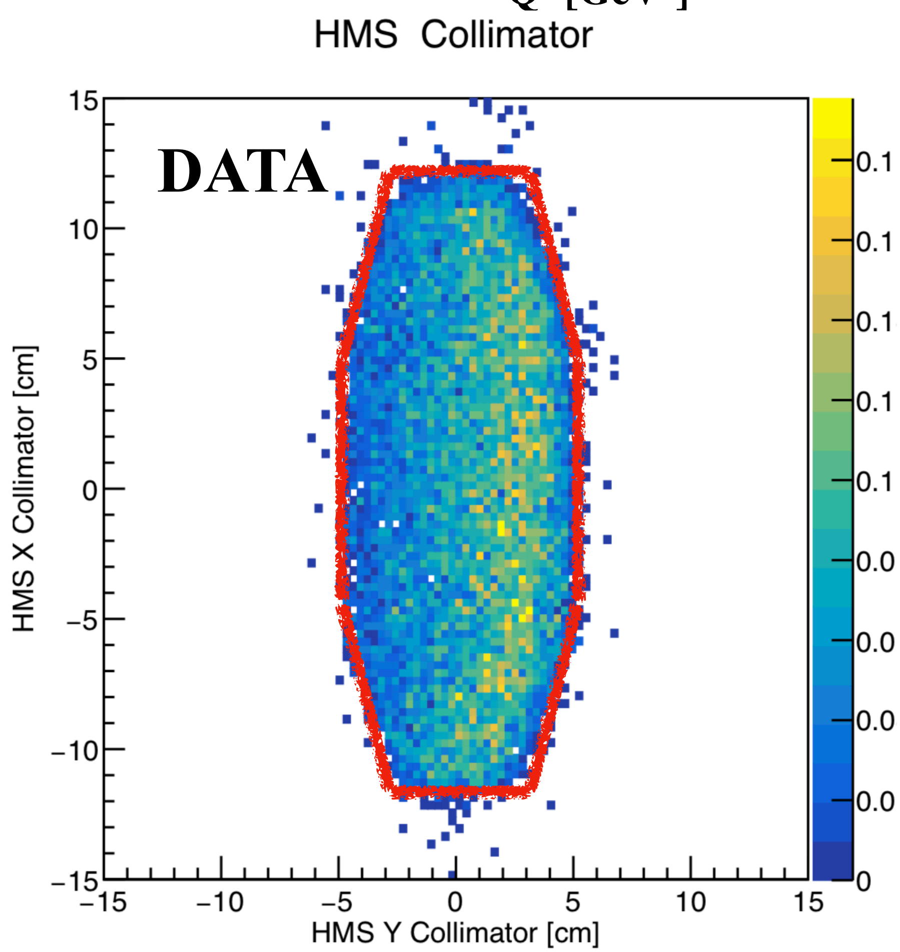
select true electron-proton coincidences



4-Momentum Transfer Cut

CUT: $Q^2 = 4.5 \pm 0.5\ GeV^2$

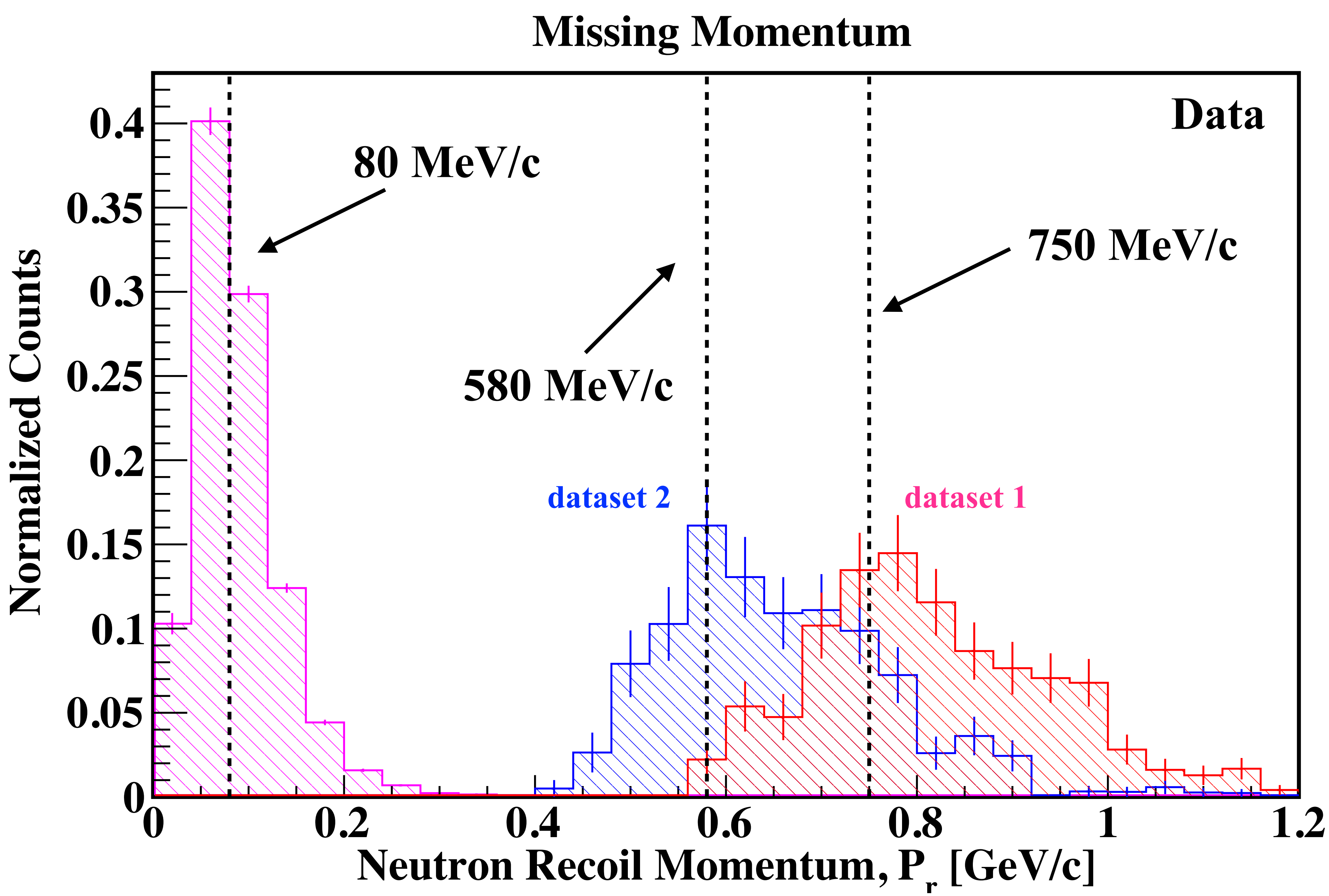
Kinematics cut to select only events with high momentum transfer (as stated on the proposal)



HMS Collimator Cut (Geometrical cut on collimator dimensions)

Select events that passed through collimator and NOT scattered at the edges of the collimator

Extraction of D(e,e'p)n Coincidence Cross Sections at Hall C



Extraction of the D(e,e’p)n Cross Section

$$\bar{\sigma}^{exp} \equiv \frac{Y^{corr}_{data}}{V^{P.S.}}$$

Corrected Data Yield

Phase Space Volume

Radiative Correction

$$Y^{corr}_{data} = \frac{Y^{uncorr}_{data} \cdot f_{rad}}{Q \cdot \epsilon_{tLT} \cdot \epsilon_{htrk} \cdot \epsilon_{etrk} \cdot \epsilon_{tgtBoil} \cdot \epsilon_{pAbs}}$$

Normalize data by total charge

Correct for Inefficiencies

Extraction of the D(e,e'p)n Cross Section

Spectrometer Acceptance (or Phase Space) Definition

$$V^{P.S.} = \frac{N_f}{N_{acc}} \mathcal{J}_{corr} \rightarrow \frac{N_f}{N_{acc}} \equiv \frac{\mathcal{L}}{N_{gen}} d\omega d\Omega_e d\Omega_p$$

Normalization Factor

Accepted Events within spec. Acceptance

Jacobian Correction (convert spec. solid angles to physics angles)

Luminosity

Spectrometer "Solid Angles"

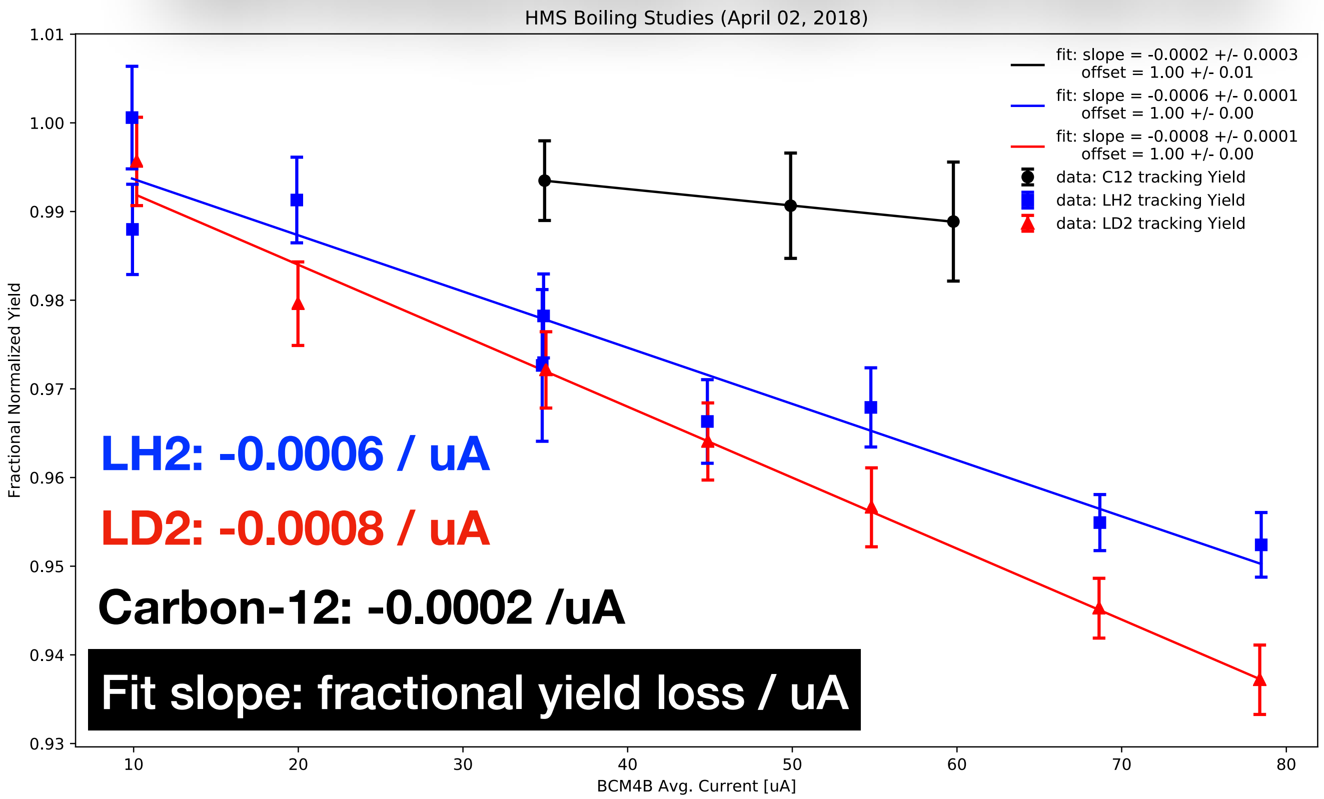
Generated Events

*(See simc.f in SIMC) for definition of luminosity

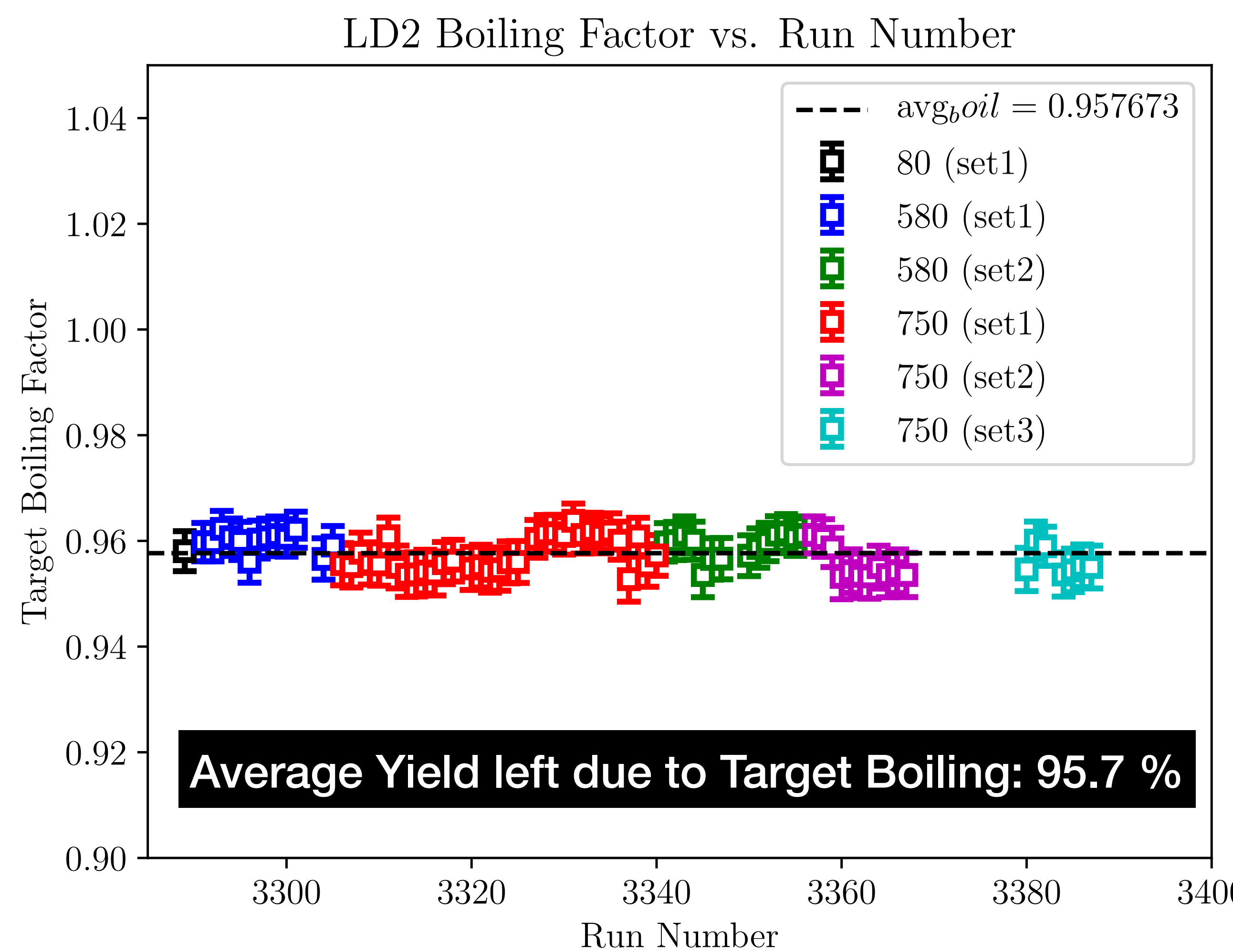
$$Y_{data}^{corr} = \frac{Y_{data}^{uncorr} \cdot f_{rad}}{Q \cdot \epsilon_{tLT} \cdot \epsilon_{htrk} \cdot \epsilon_{etrk} \cdot \epsilon_{tgtBoil} \cdot \epsilon_{pAbs}}$$

See Backup Slides

HMS Boiling Studies (April 2018 data set)



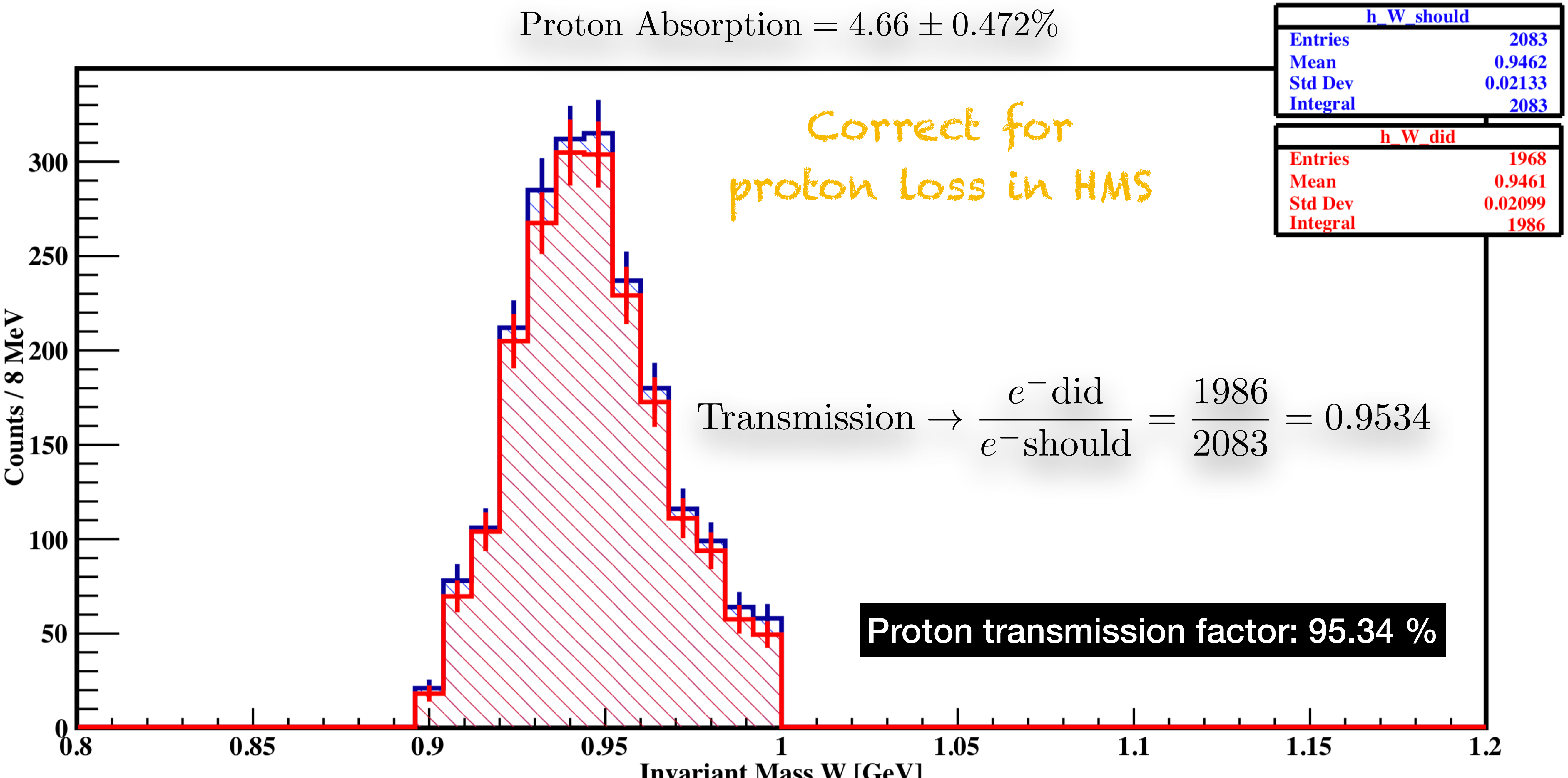
Correct for yield loss due to target boiling



Target Boiling Corrections
See DOC DB Link HERE !

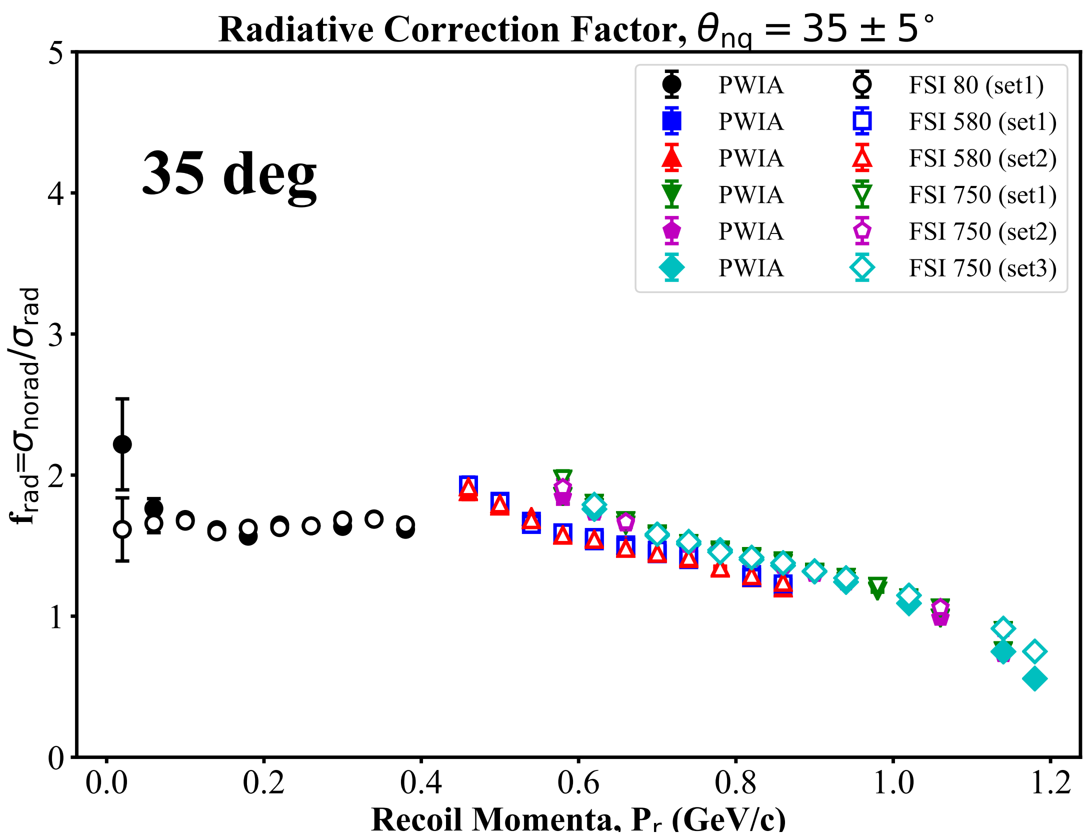
$$Y_{data}^{corr} = \frac{Y_{data}^{uncorr} \cdot f_{rad}}{Q \cdot \epsilon_{tLT} \cdot \epsilon_{htrk} \cdot \epsilon_{etrk} \cdot \epsilon_{tgtBoil} \cdot \epsilon_{pAbs}}$$

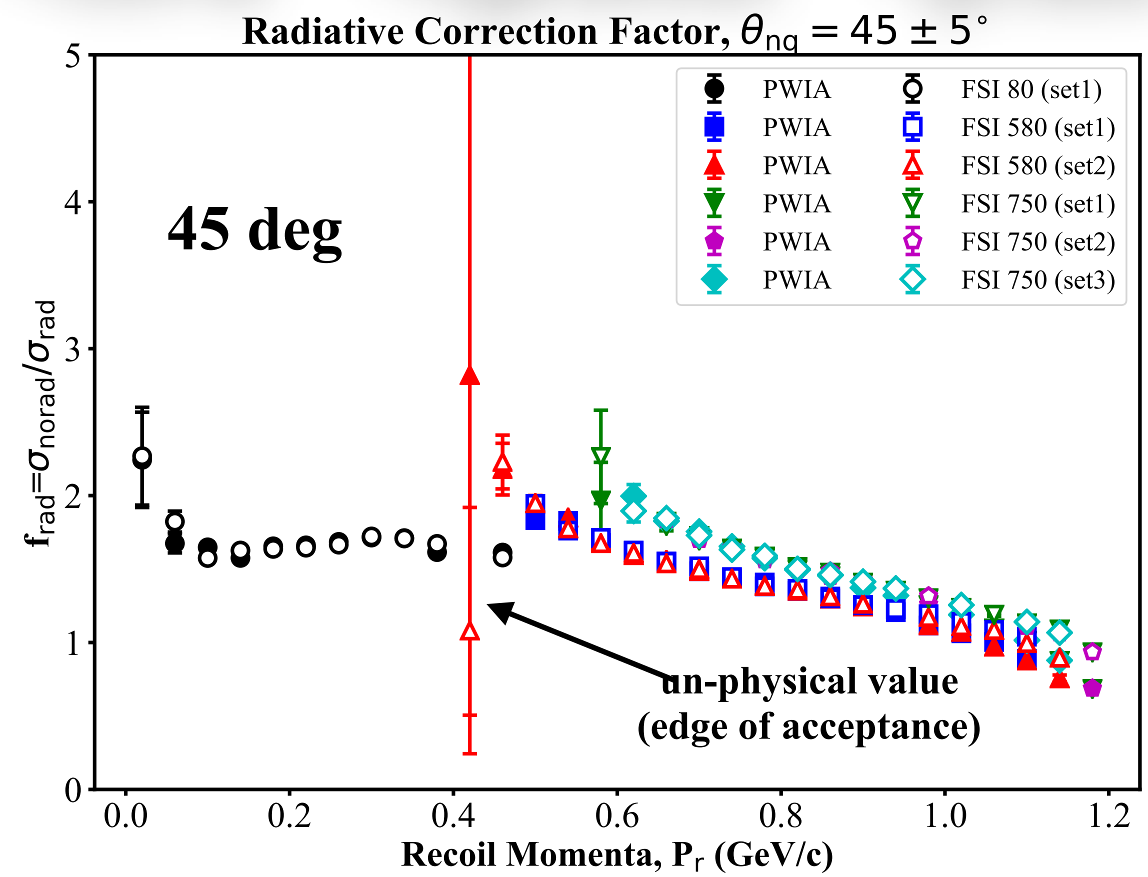
Proton Absorption $= 4.66 \pm 0.472\%$

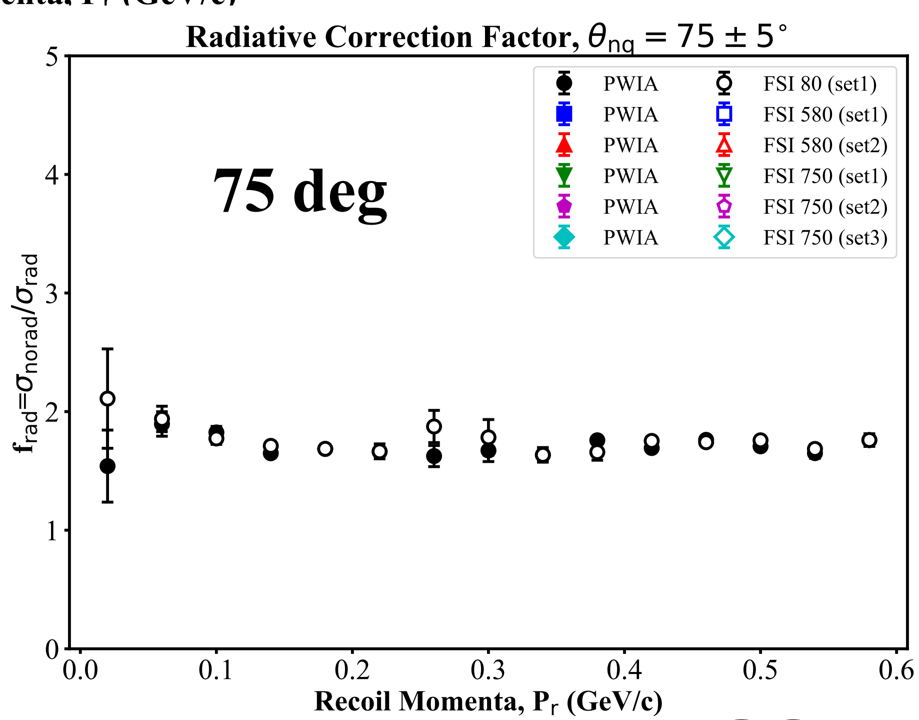


For Full Description of Proton Absorption Analysis, See DOC DB Link HERE !

$$Y_{data}^{corr} = \frac{Y_{data}^{uncorr} \cdot \boxed{f_{rad}}}{Q \cdot \epsilon_{tLT} \cdot \epsilon_{htrk} \cdot \epsilon_{etrk} \cdot \epsilon_{tgtBoil} \cdot \epsilon_{pAbs}}$$







Radiative Correction factor

$$\boxed{f_{\mathrm{rad}}} = \frac{Y_{\mathrm{norad}}^{\mathrm{SIMC}}}{Y_{\mathrm{rad}}^{\mathrm{SIMC}}}$$

D(e,e'p) Momentum Distributions

$$\sigma_{red} \equiv \frac{\sigma^{exp}_{bc}}{K\sigma_{cc1}}$$

Bin-center Corrected Experimental cross sections

Kinematic Factor times deForest ep cross section

Reduced cross section (theoretical momentum distributions in PWIA)

$$K \equiv k \cdot f_{rec} \sim P_f, P_m, q$$

$$\sigma_{cc1} \sim G_{Ep}(Q^2), G_{Mp}(Q^2)$$

J. Arrington, Implications of the discrepancy between proton form factor measurements, Phys. Rev. C **69**, 022201 (2004).

J. Arrington elastic form factor parametrization is used to determine deForest cross-section

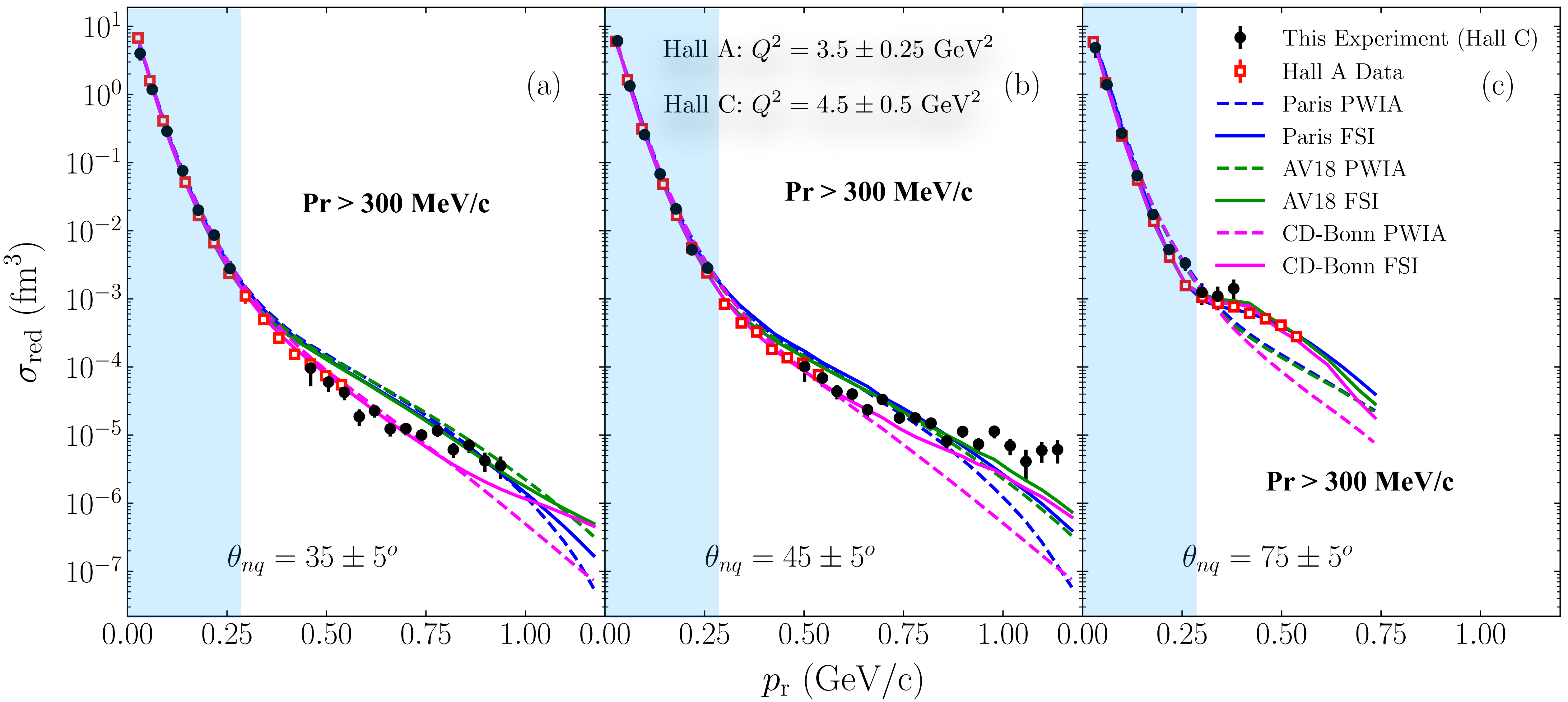
☑ **Division by deForest and kinematic factor removes kinematical dependencies on reduced cross section**

Error Analysis of D(e,e'p)n Coincidence Cross Sections at Hall C

See Backup Slides for Tables and Plots of Statistical/Systematic Errors

D(e,e'p)n Cross Section Experiment Results

D(e,e'p)n Momentum Distributions

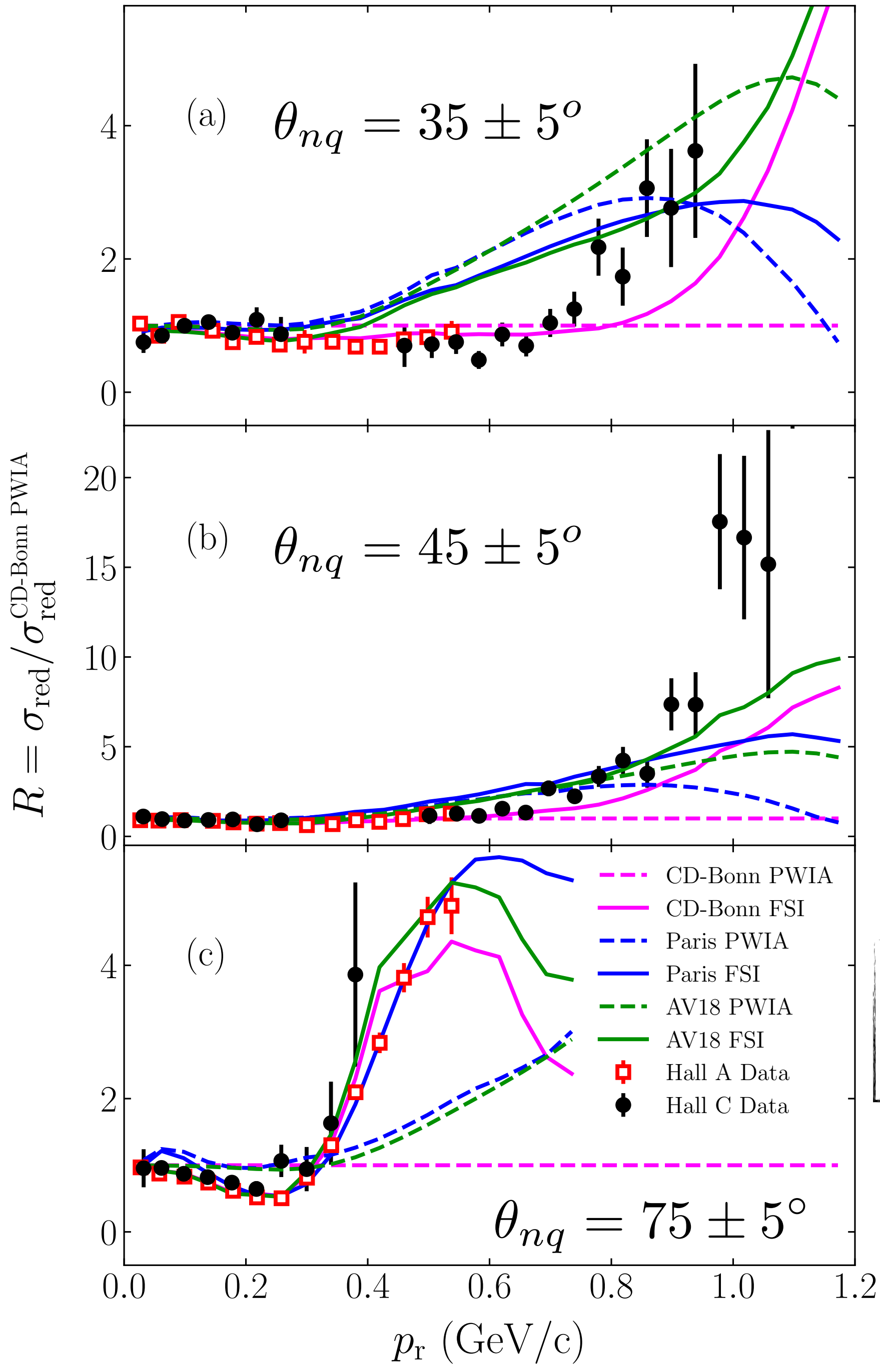


- ☑ Pr < 300 MeV/c, FSIs small and NN dominated by OPEP
- ☑ Pr > 300 MeV/c, CD-Bonn differs from Paris/AV18 models
- ☑ Hall A data agrees with Hall C data well

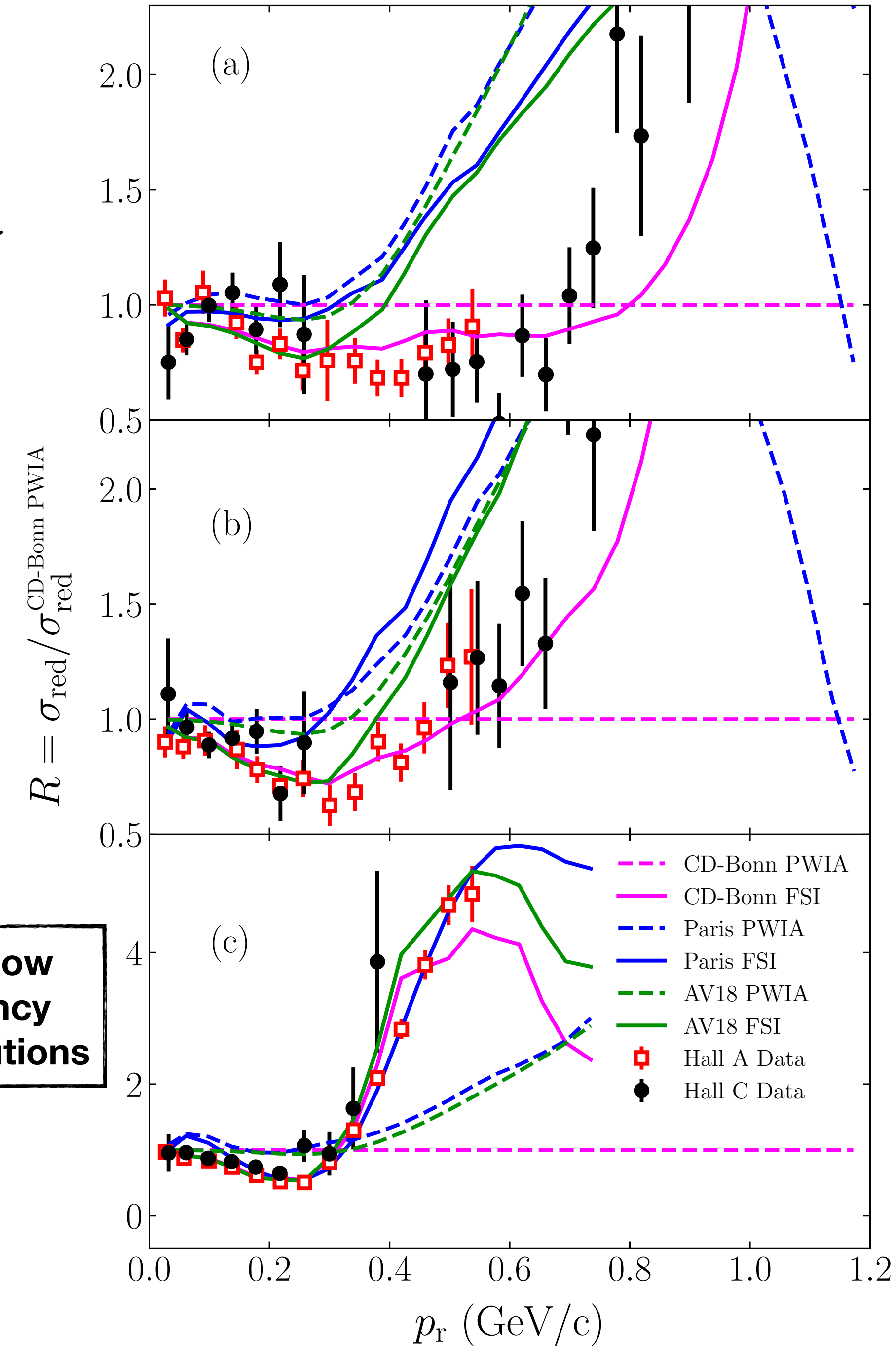
✦ **Paris calculations are done by J.M.Laget** J. Laget, Phys.Lett. **B609**, 49 (2005)

✦ **AV18/CD-Bonn calculations are done by M. Sargsian** M. M. Sargsian, Phys. Rev. **C82**, 014612 (2010)

D(e,e'p)n Ratio to CD-Bonn PWIA



ZOOM



Large FSIs overshadow any model dependency on momentum distributions

- ☑ **Data agrees with CD-Bonn FSI up to Pr~700 MeV/c at 35 and 45 deg**
- ☑ **At Pr ~300 - 700 MeV/c, R ~ 0.5 - 1 —> 35, 45 deg compared to R ~ 2 - 5 —> 75 deg (FSIs largely reduced at smaller angles)**
- ☑ **Pr > 700 MeV/c data is NOT described by any model**

$$\sigma \sim |A_{PWIA} + iA_{FSI}|^2 \sim A_{PWIA}^2 - 2A_{PWIA}A_{FSI} + A_{FSI}^2$$
where $A_{FSI} \sim i|A_{FSI}|$

Approximate cancellation of Scattering Amplitudes leads to reduction in FSI

SUMMARY

- The experiment measured cross sections for the exclusive D(e,e'p)n reaction at $Q^2 = 4.5\ (\mathrm{GeV}/c)^2$ for neutron recoil momentum up to 1.0 GeV/c and neutron recoil angles between 35 to 75 deg
- At large angles ~75 deg, FSIs dominate above 300 MeV/c, and there is virtually no difference between the models due to large FSIs which overshadow the true momentum distributions
- DATA was best described by CD-Bonn potential at smaller recoil angles (35 deg) and recoil momenta up to ~700 MeV/c
- Above 700 MeV/c, NO calculation describes the data

The draft Physics Review Letters (PRL) paper was sent to the Hall C Collaboration for comments/suggestions and has been revised.

Overall, given that this was a 6-day commissioning and statistically limited experiment, it has very interesting results, as no model seems to describe the data above recoil momenta of 700 MeV/c . This discrepancy is worth exploring further in the full experiment.

ADDITIONAL WORK PROJECTS AT HALL C

Prior to carrying out the E12-10-003 experiment at Hall C and completing its analysis, I also . . .

- **Contributed to the refurbishment of the original (6 GeV) HMS Drift Chambers (with E. Pooser)**
- **Set up the Hall C HMS/SHMS hardware electronics trigger from scratch (with E. Pooser and B. Sawatzky)**
- **Set-up the cosmic trigger test bench on the HMS hut to check the 12 GeV HMS Drift Chambers being installed in the detector stack (with B. Pandey)**
- **Wrote a new C++ code to calibrate the Drift Chambers (with the help of M. Jones)**
- **Wrote a new version (in C++) of the Hodoscopes calibration code (with the help of M. Jones, E. Pooser)**
- **Wrote a Coincidence Module C++ class (used in *hcana*) for the Hall C coincidence experimental program (with the help of M. Jones)**

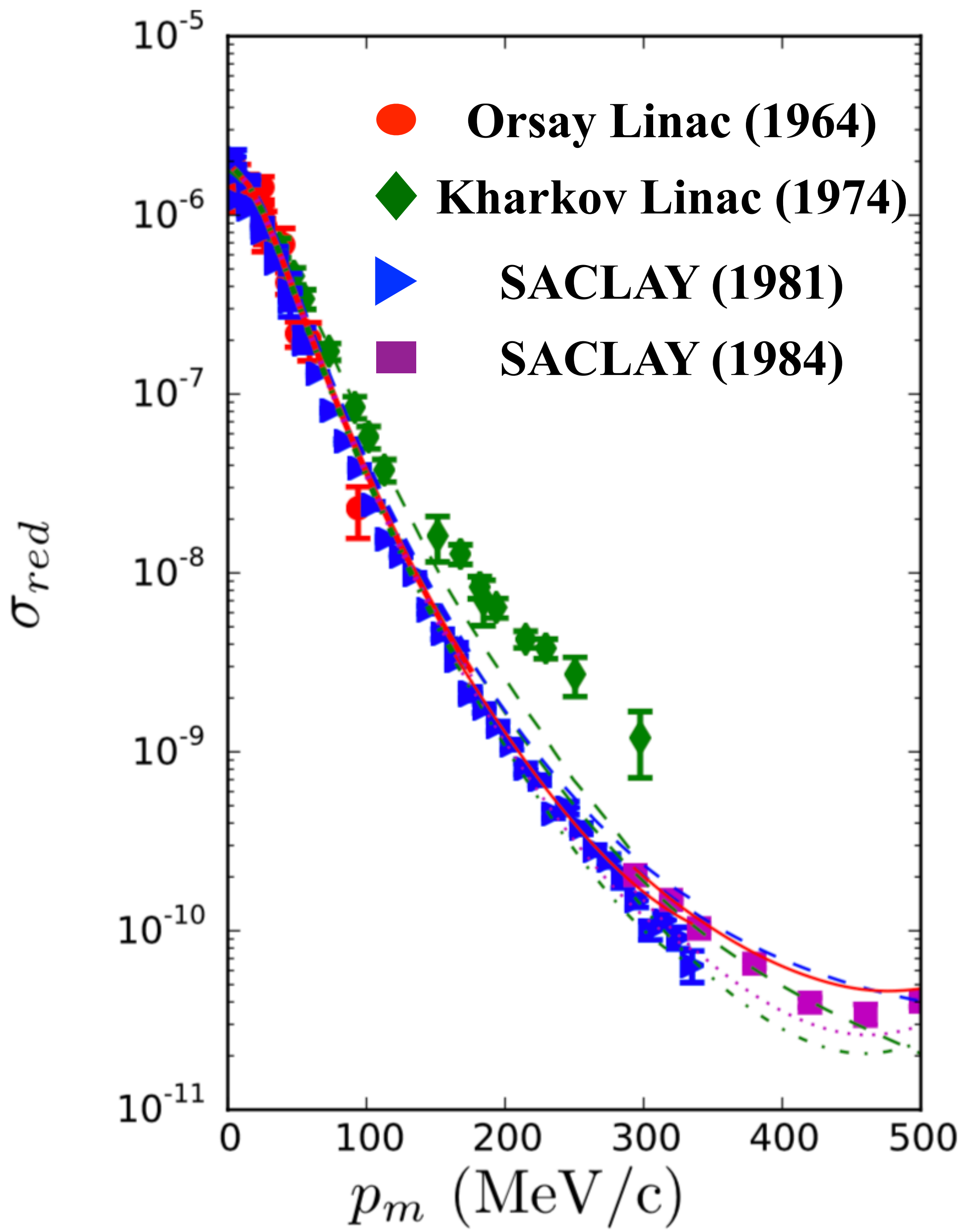
THANK YOU !

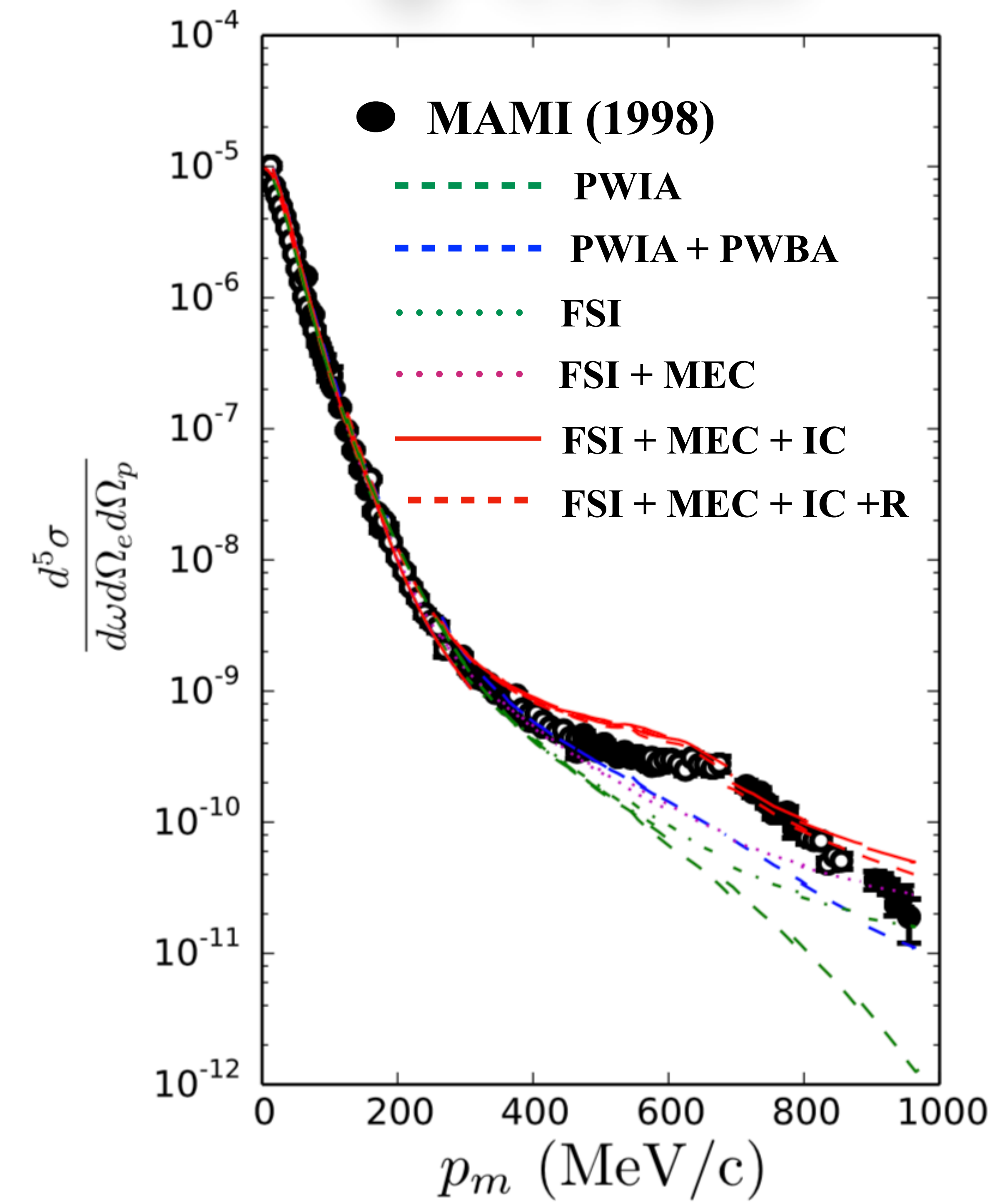

DANGER
FLAMMABLE GAS
KEEP FIRE OR FLAME AWAY
NO SMOKING
THERE IS NO CRYING IN PHYSICS

BACK-UP SLIDES

D(e,e'p) Experiments At $Q^2 < 1\ GeV^2$

Previous D(e,e'p)n Experiments at: $Q^2 < 1\ \mathrm{GeV}^2$





<u>**Theoretical Calculations**</u>
W. Fabian and H. Arenhovel, Nucl.Phys. A258, 461 (1976)

☑ **At Pm>300 MeV/c, FSI+MEC+IC all dominate the cross section**

Plots Reference:
W.U.Boeglin and M. Sargsian Int.J.Mod.Phys. E24 (2015) no.03, 1530003

Error Analysis of D(e,e'p)n Cross Section

NORMALIZATION CORRECTION FACTORS for D(e,e'p)n

Pm	HMS Tracking Efficiency	sHMS Tracking Efficiency	Target Boiling Correction	Proton Absorption Correction	Total Live Time	Total Charge (mC)
80	0.989	0.965	0.958	0.953	0.908	142.140
580 (set 1)	0.990	0.965	0.960	0.953	0.929	1686.830
580 (set 2)	0.987	0.964	0.959	0.953	0.929	1931.770
750 (set 1)	0.988	0.964	0.957	0.953	0.924	5329.490
750 (set 2)	0.989	0.962	0.956	0.953	0.923	1894.010
750 (set 3)	0.989	0.962	0.956	0.953	0.924	1083.700

- **Correction factors were averaged over all runs of individual data sets**

UNCERTAINTY (%) IN NORMALIZATION CORRECTION FACTORS for D(e,e'p)n

Pm	HMS Tracking Efficiency Err.	sHMS Tracking Efficiency Err.	Target Boiling Correction Err.	Proton Absorption Correction Err.	Total Live Time Err.	Total Charge (mC) Err.
80	0.034%	0.040%	0.378%	0.472%	—	—
580 (set 1)	0.396%	0.732%	0.362%	0.472%	—	—
580 (set 2)	0.473%	0.583%	0.369%	0.472%	—	—
750 (set 1)	0.526%	0.689%	0.384%	0.472%	—	—
750 (set 2)	0.467%	0.682%	0.401%	0.472%	—	—
750 (set 3)	0.507%	0.729%	0.397%	0.472%	—	—

** Uncertainty on EDTM and BCM is not finalized. Conservative estimates on the cross section error were made (See next slide)

SYSTEMATIC UNCERTAINTY ON NORMALIZATION

$$\bar{\sigma}^{exp}_{corr} = \bar{\sigma}^{exp}_{uncorr} \cdot f_1 \cdot f_2 \ldots f_i \longrightarrow \left.\frac{d\bar{\sigma}^{exp}_{corr}}{\bar{\sigma}^{exp}_{corr}}\right|_i = \frac{df_i}{f_i}$$

f_i : normalization correction factors
df_i : error in normalization correction factors

	Relative Systematic Error (%) on the Cross Section due to:					
Pm	**HMS Tracking Efficiency**	**sHMS Tracking Efficiency**	**Target Boiling Correction**	**Proton Absorption Correction**	**Total Live Time**	**Total Charge (mC)**
80	0.0344%	0.0413%	0.3948%	0.4951%	3.0%	2.0%
580 (set 1)	0.3999%	0.7586%	0.3766%	0.4951%	3.0%	2.0%
580 (set 2)	0.4786%	0.6041%	0.3842%	0.4951%	3.0%	2.0%
750 (set 1)	0.5329%	0.7155%	0.4013%	0.4951%	3.0%	2.0%
750 (set 2)	0.4719%	0.7089%	0.4196%	0.4951%	3.0%	2.0%
750 (set 3)	0.5127%	0.7584%	0.4150%	0.4951%	3.0%	2.0%

added in quadrature for overlapping Pm bins

Systematic errors that DO NOT vary are added in quadrature to the final result

SPECTROMETER KINEMATIC SYSTEMATIC UNCERTAINTIES on D(e,e'p)n

$\delta\theta_e[mr]$	+/- 0.1659	Uncertainty in SHMS angle
$\delta\theta_p[mr]$	+/- 0.2369	Uncertainty in HMS angle
$\delta E_f/E_f$	+/- 9.132E-04	Uncertainty in SHMS momentum
$\delta E_b/E_b$	+/- 7.498E-04	Uncertainty in Beam Energy
$d\sigma_{exp}$	6.5%	Max. Kin. Systematic Error on Cross Section

Determined from fit to H(e,e'p) coincidence elastic data. (See DOC DB link HERE!)

$$d\sigma^2_{exp} = \left(\frac{d\sigma}{d\theta_e}\delta\theta_e\right)^2 + \left(\frac{d\sigma}{d\theta_p}\delta\theta_p\right)^2 + \left(\frac{d\sigma}{dE_f}\frac{\delta E_f}{E_f}E_f\right)^2 + \left(\frac{d\sigma}{dE_b}\frac{\delta E_b}{E_b}E_b\right)^2 +$$

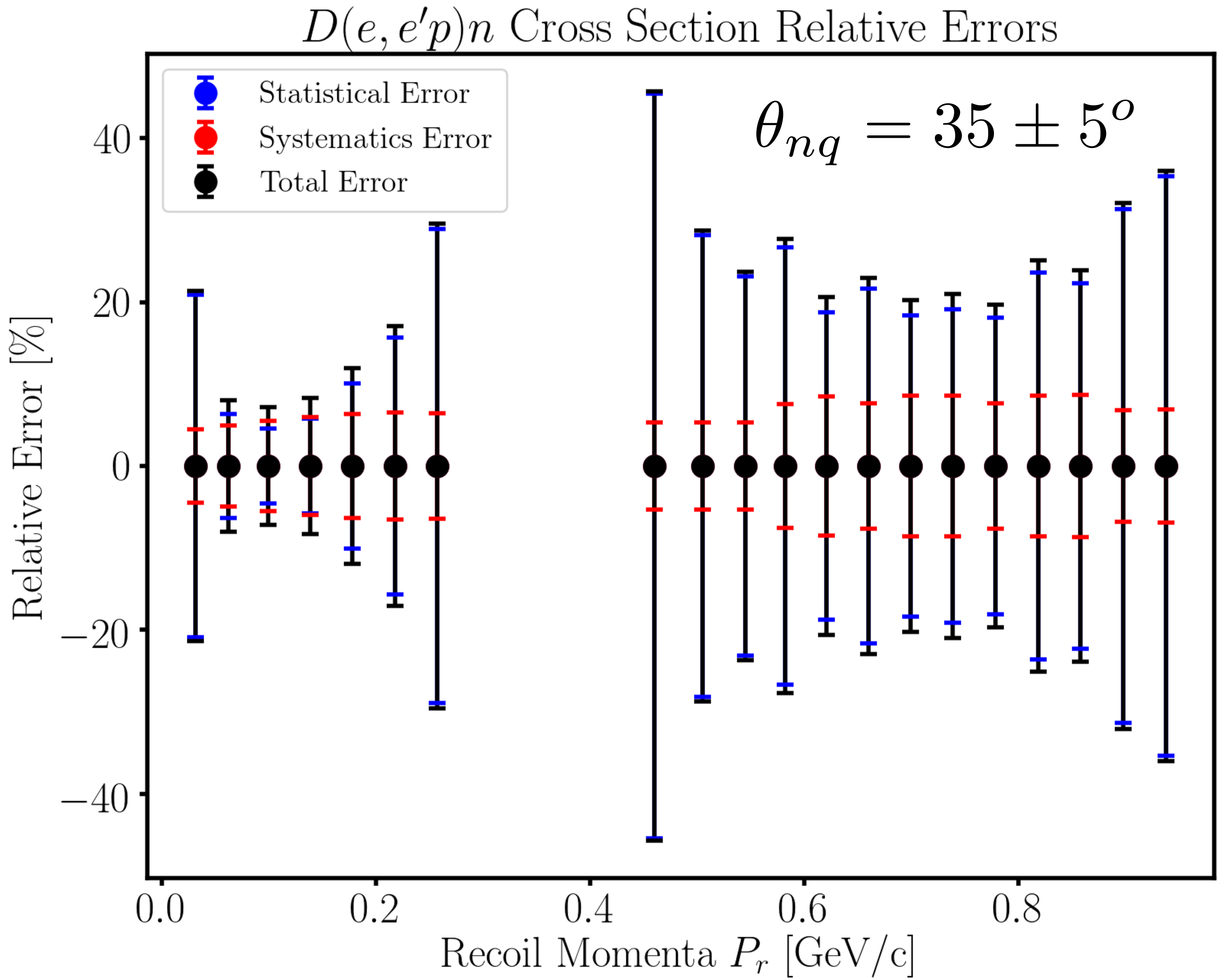
Covariance Errors

Kinematic uncertainties are due to our limited knowledge of the beam, spectrometer momenta and angles Each of these uncertainties affects our knowledge of the cross section, since the cross section depends on these kinematics

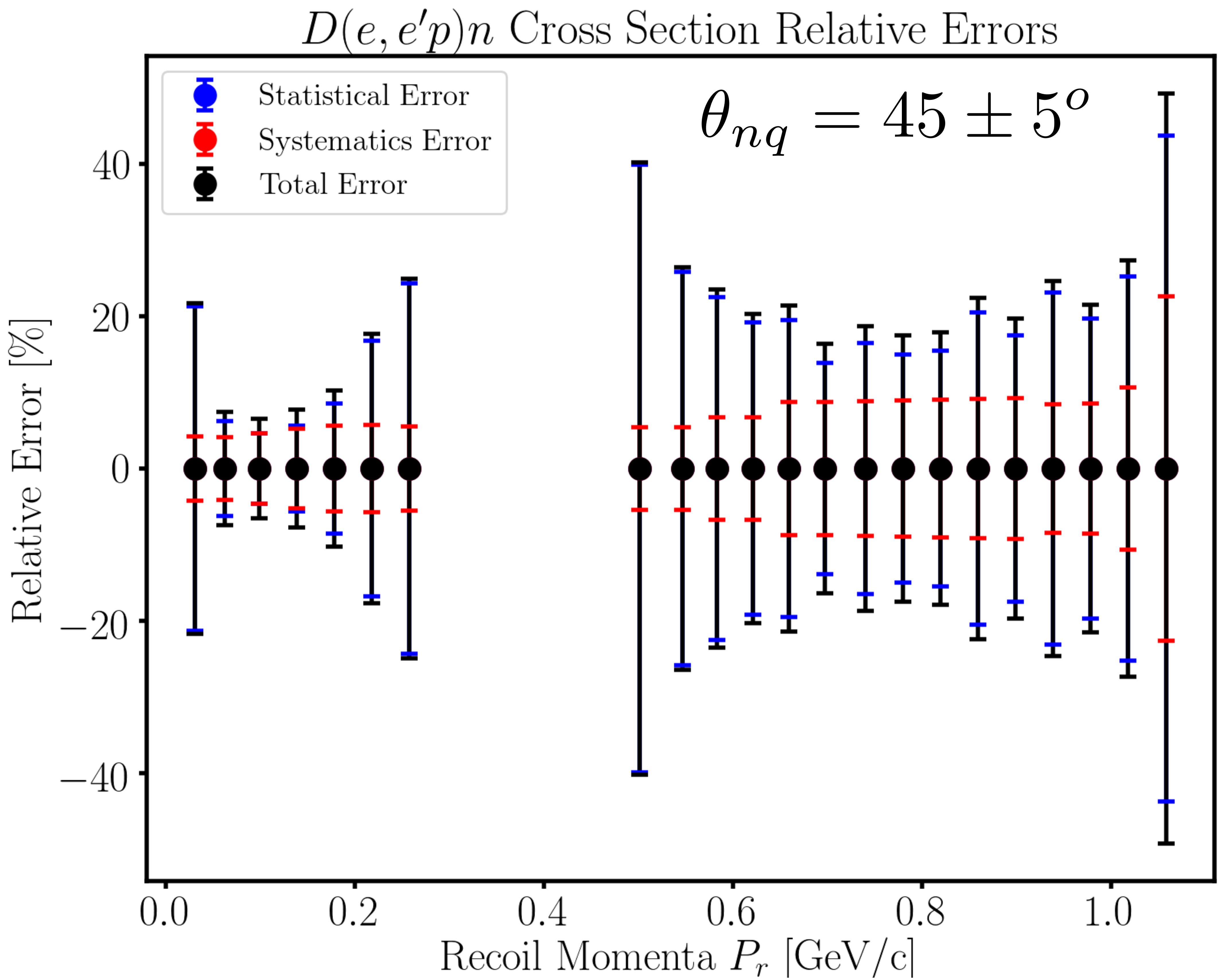
The kinematic uncertainties are point-to-point which means they vary depending for each data point, as each corresponds to a different missing momentum kinematic bin.

The tables of the PWIA Laget Cross section derivatives with respect to the kinematic variables were used

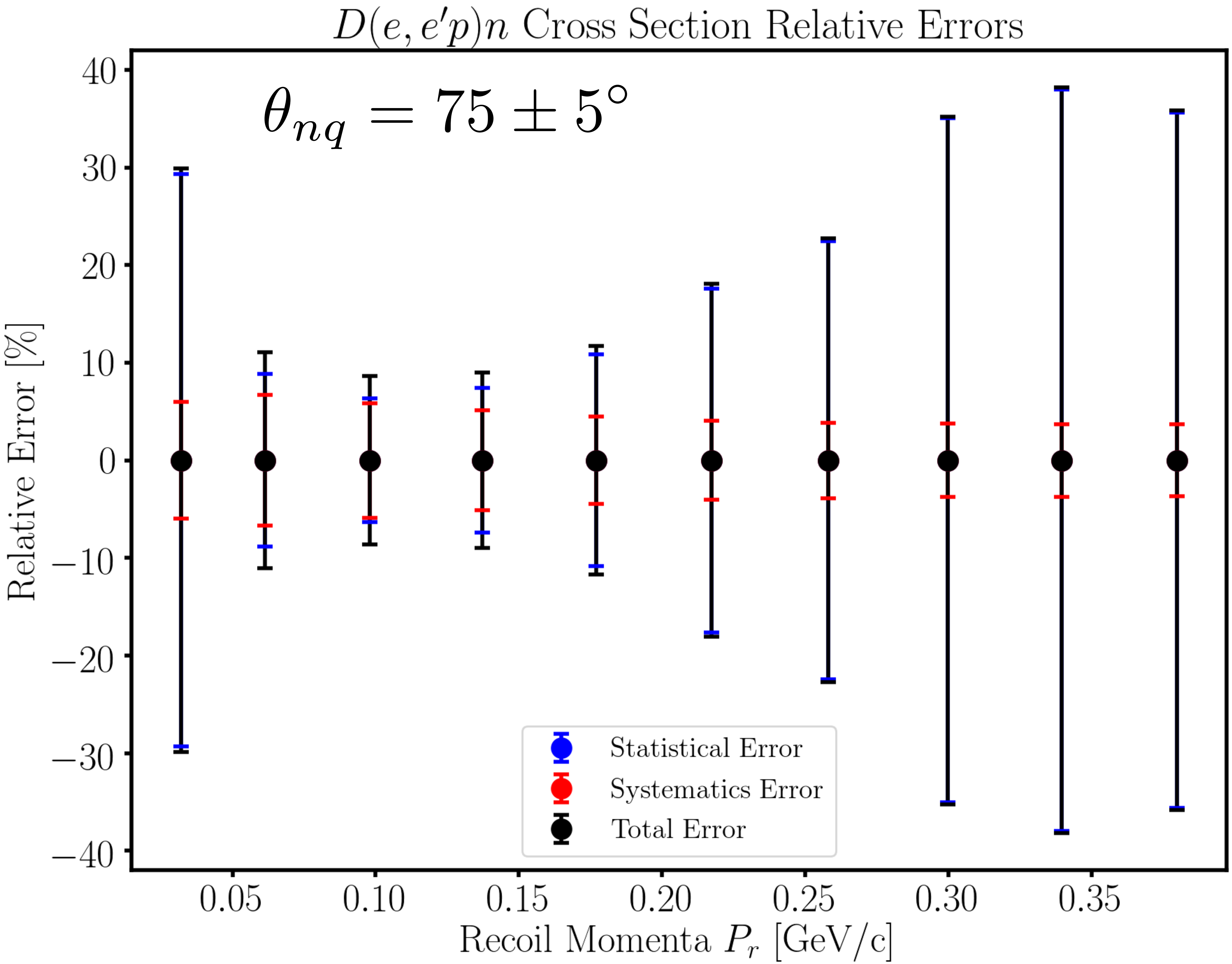
D(e,e’p)n Cross Section Relative Errors Summary Plots



D(e,e'p)n Cross Section Relative Errors Summary Plots



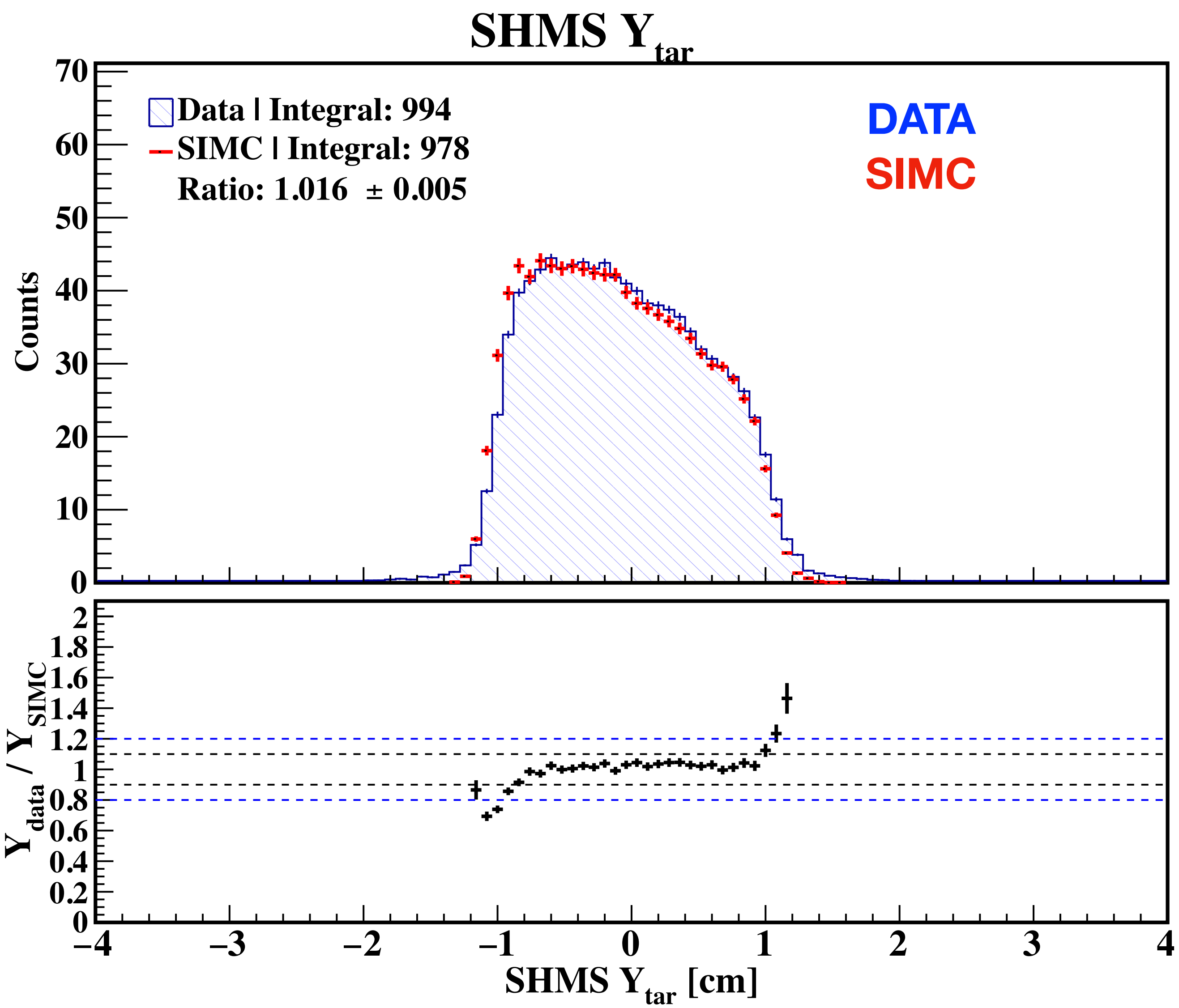
D(e,e’p)n Cross Section Relative Errors Summary Plots

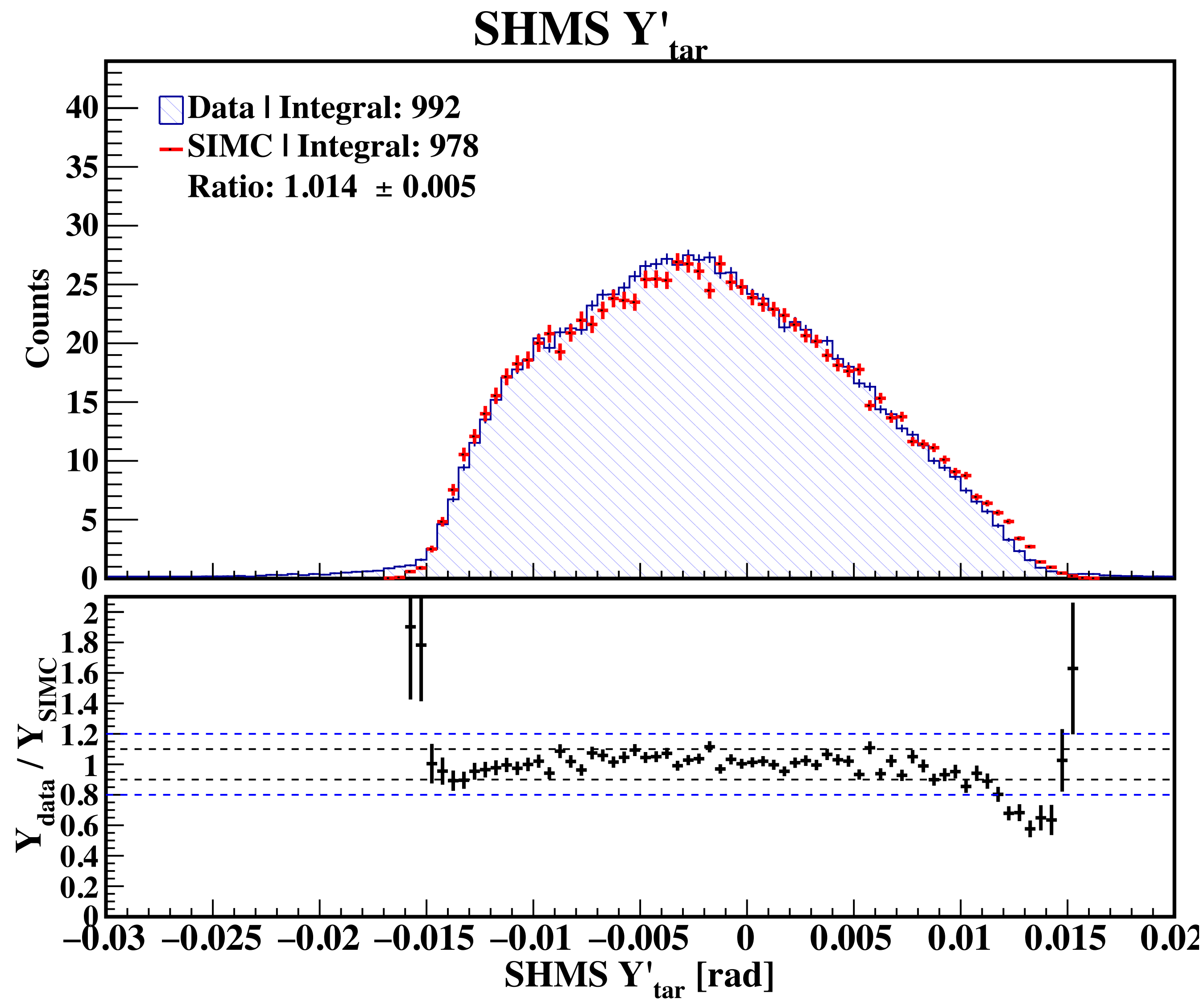


Spectrometer Acceptance
DATA/SIMULATION
(used H(e,e'p) Elastics data taken on D(e,e'p)n Experiment)

SHMS Reconstructed Variables

** Data is fully corrected for inefficiencies



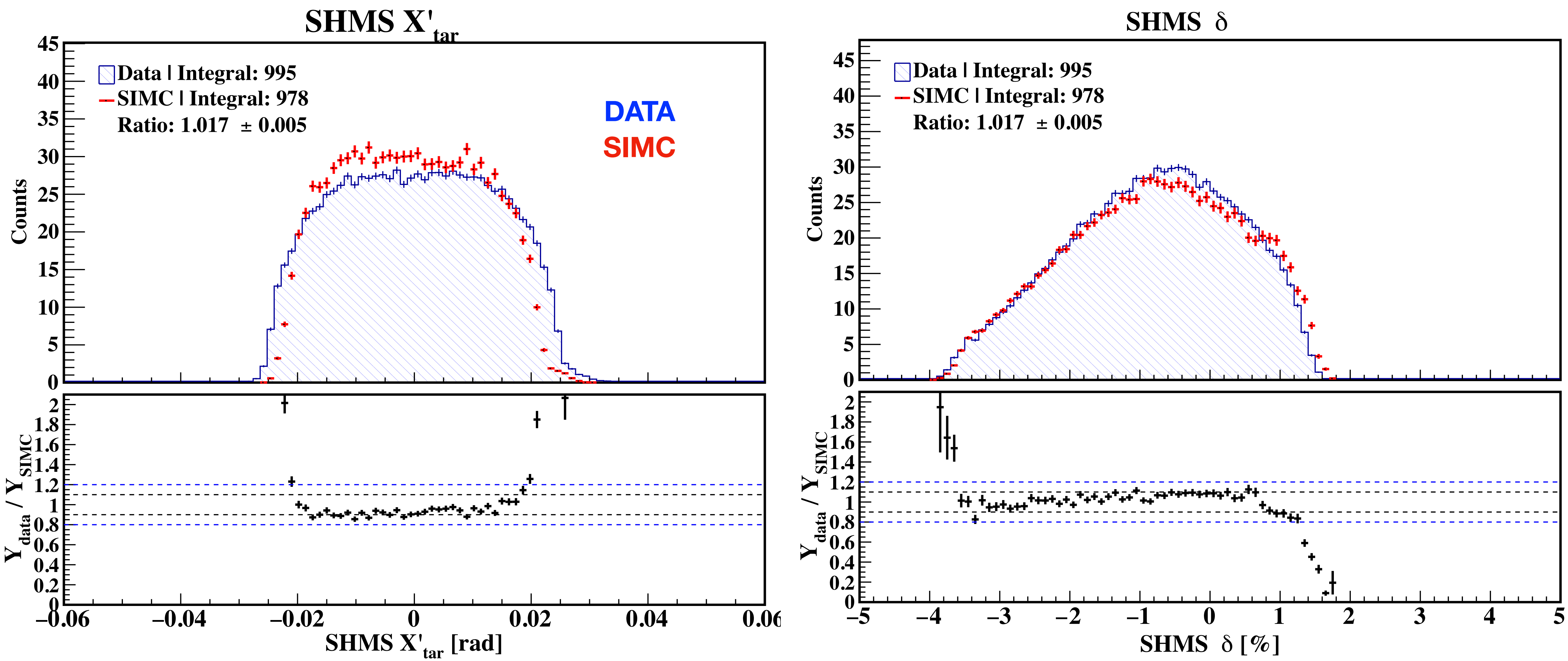


Spectrometer Acceptance
DATA/SIMULATION

(used H(e,e'p) Elastics data taken on D(e,e'p)n Experiment)

SHMS Reconstructed Variables

**** Data is fully corrected for inefficiencies**



Spectrometer Acceptance DATA/SIMULATION

(used H(e,e'p) Elastics data taken on D(e,e'p)n Experiment

HMS Reconstructed Variables

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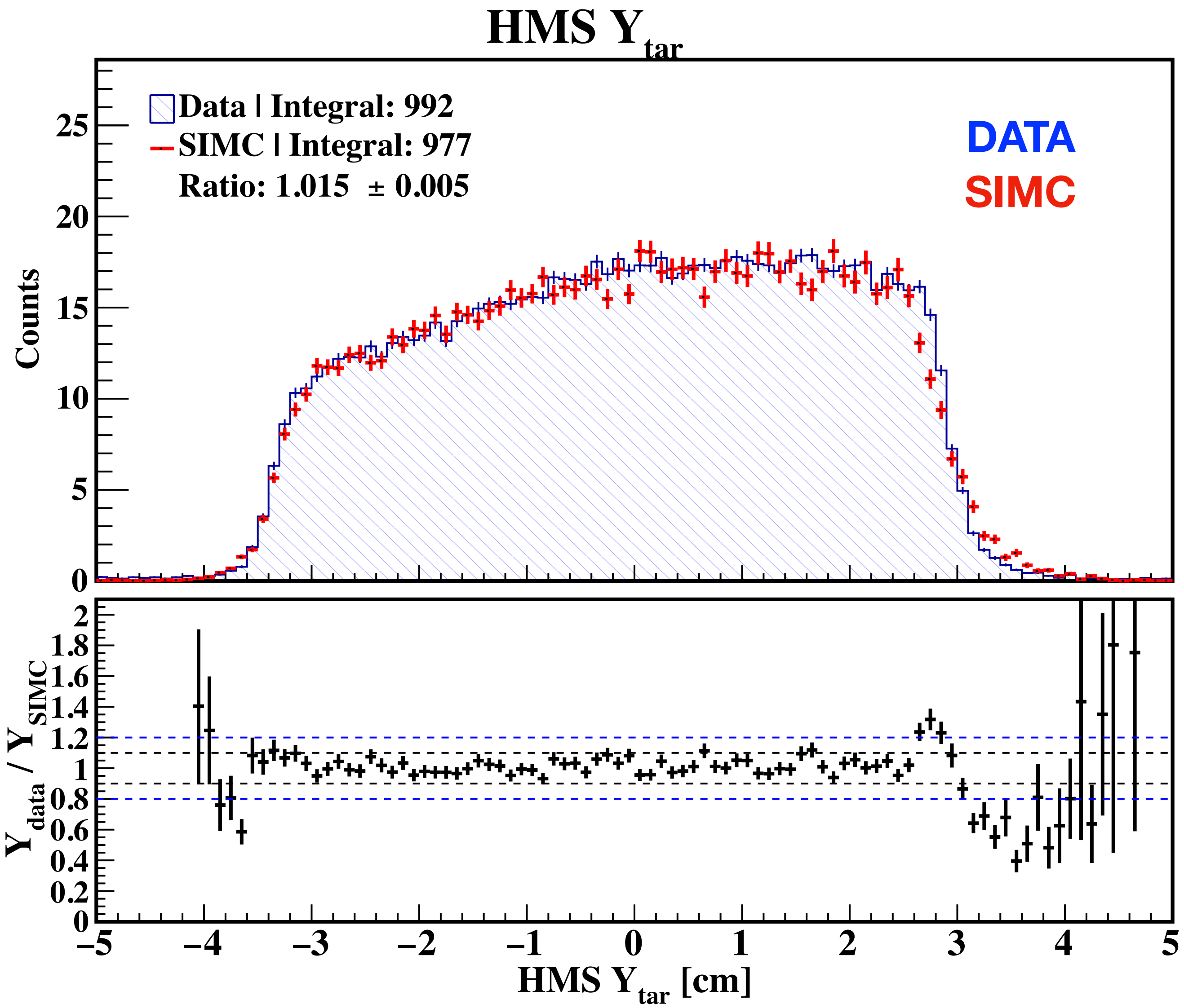

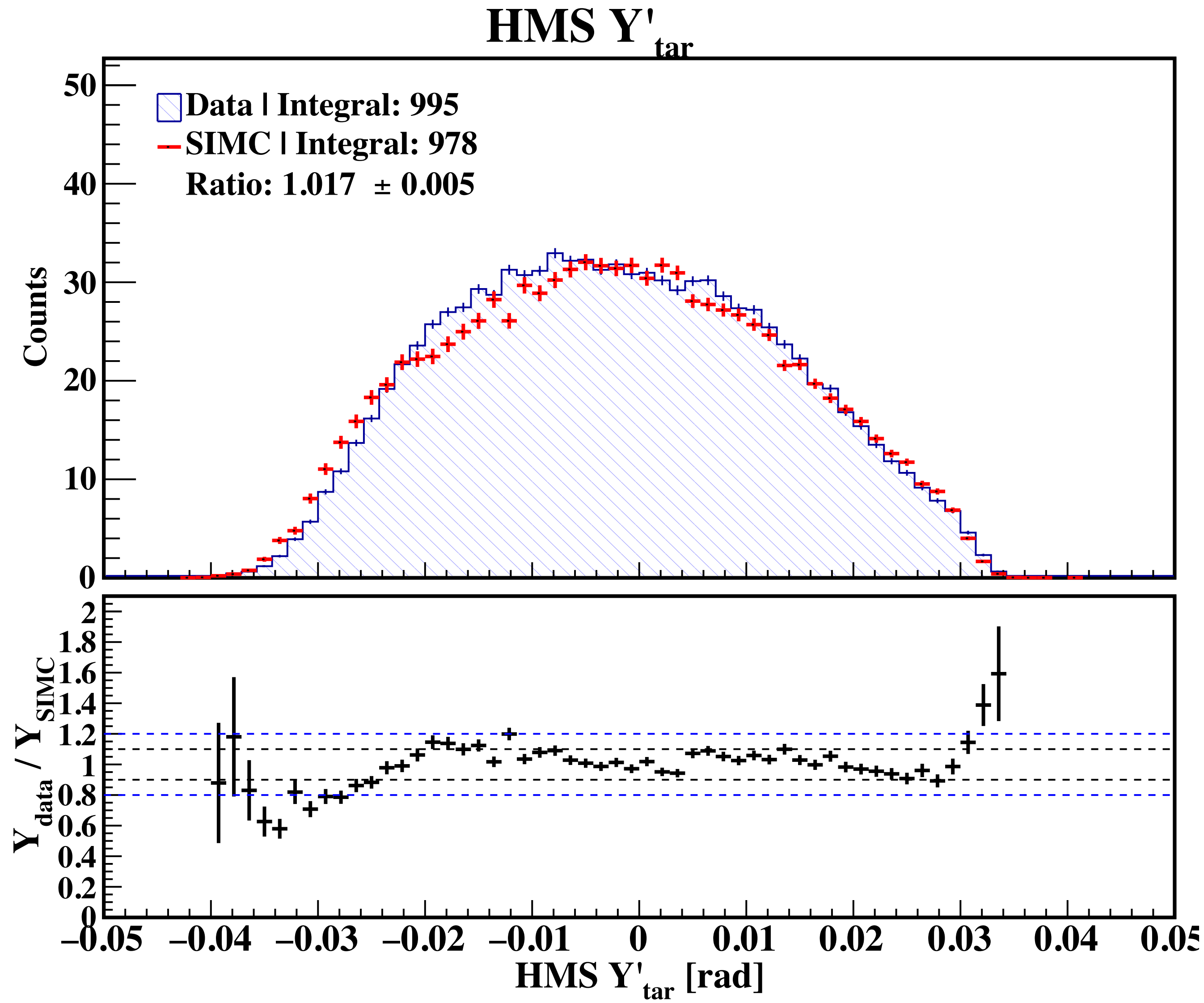

Spectrometer Acceptance
DATA/SIMULATION

(used H(e,e'p) Elastics data taken on D(e,e'p)n Experiment

HMS Reconstructed Variables

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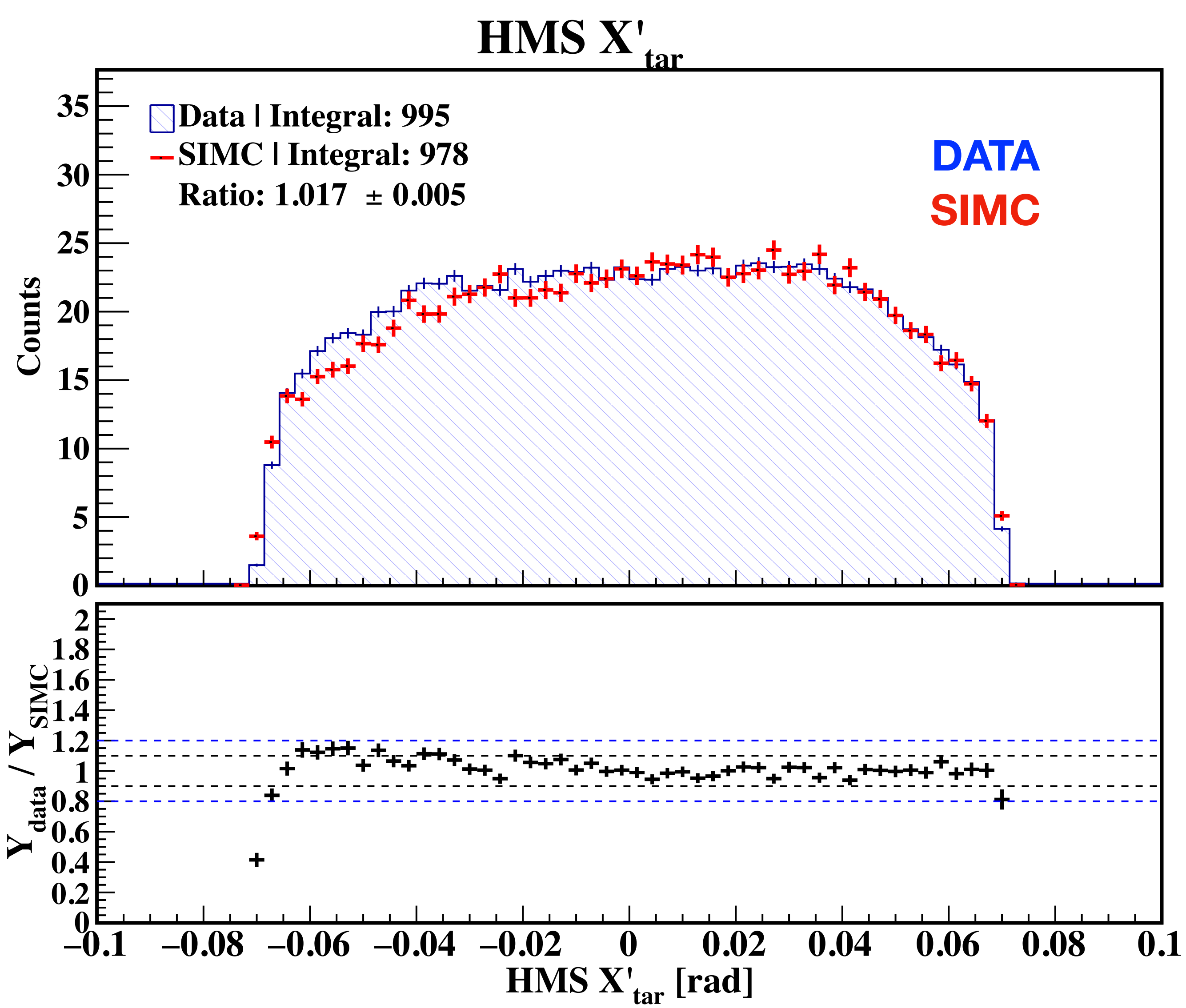
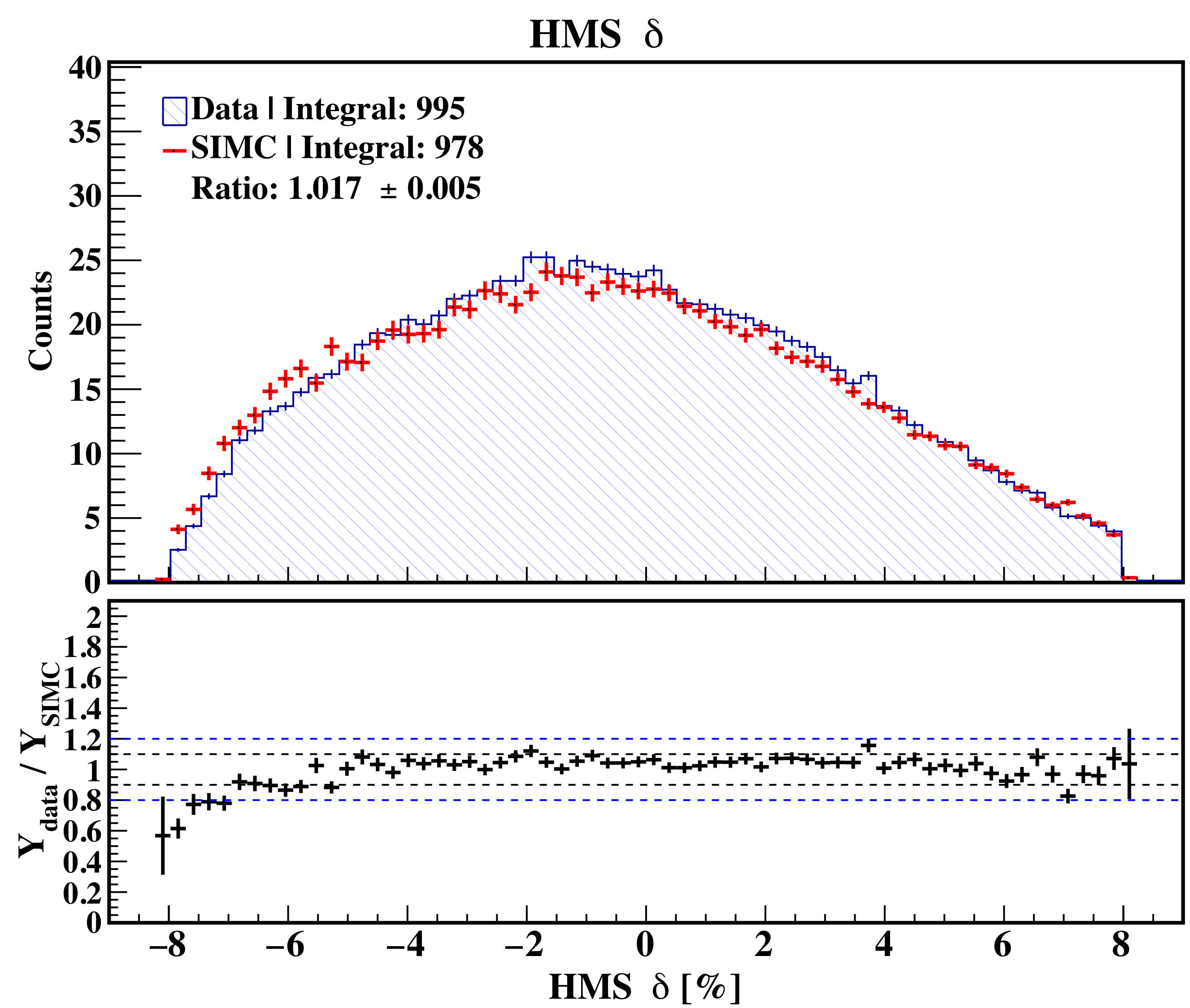




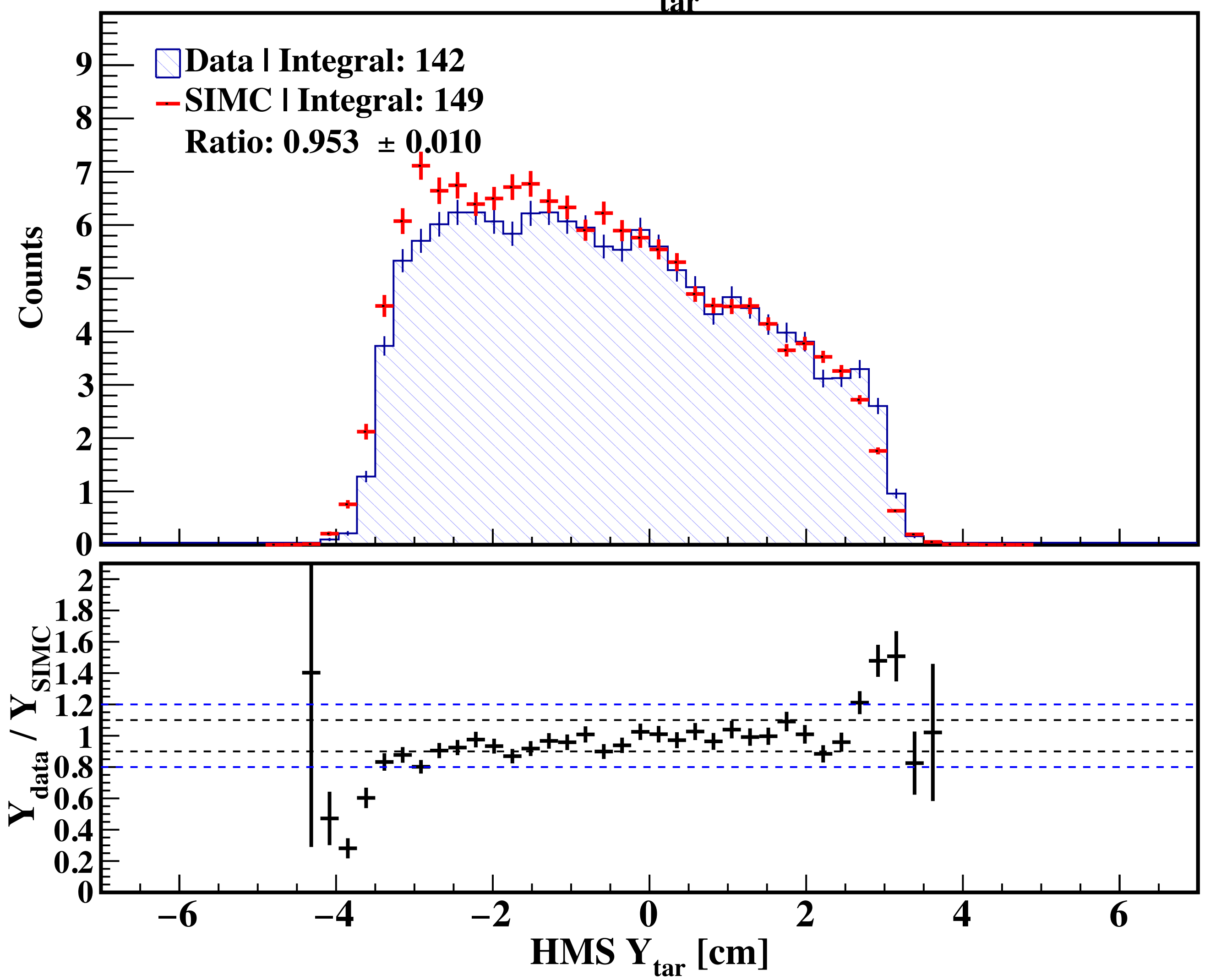
Spectrometer Acceptance
Checks on D(e,e’p)n using 80 MeV setting

HMS Reconstructed Variables

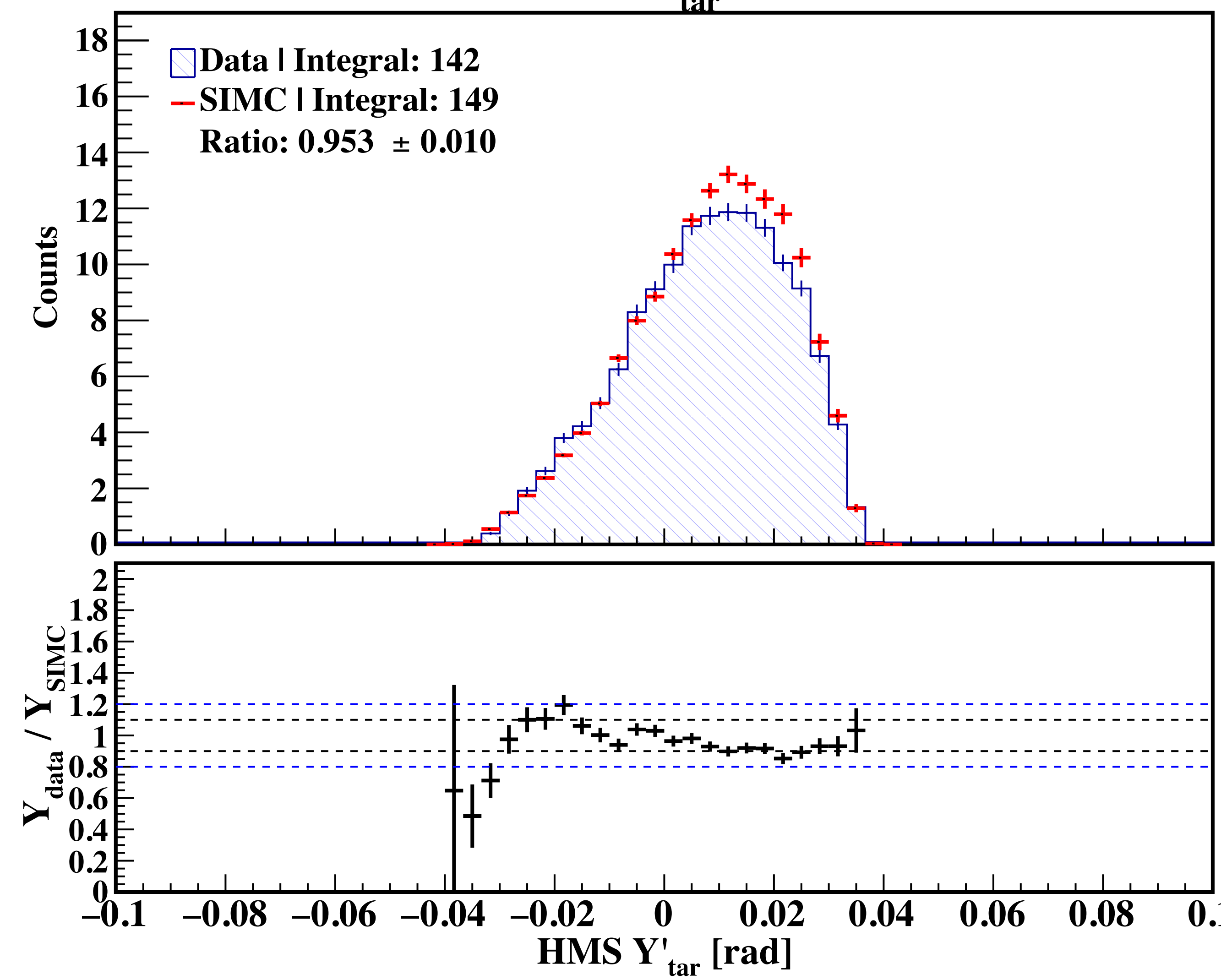
** Data is fully corrected for inefficiencies

(SIMC MODEL: Laget FSI)

HMS Y_{tar}



HMS Y'_{tar}

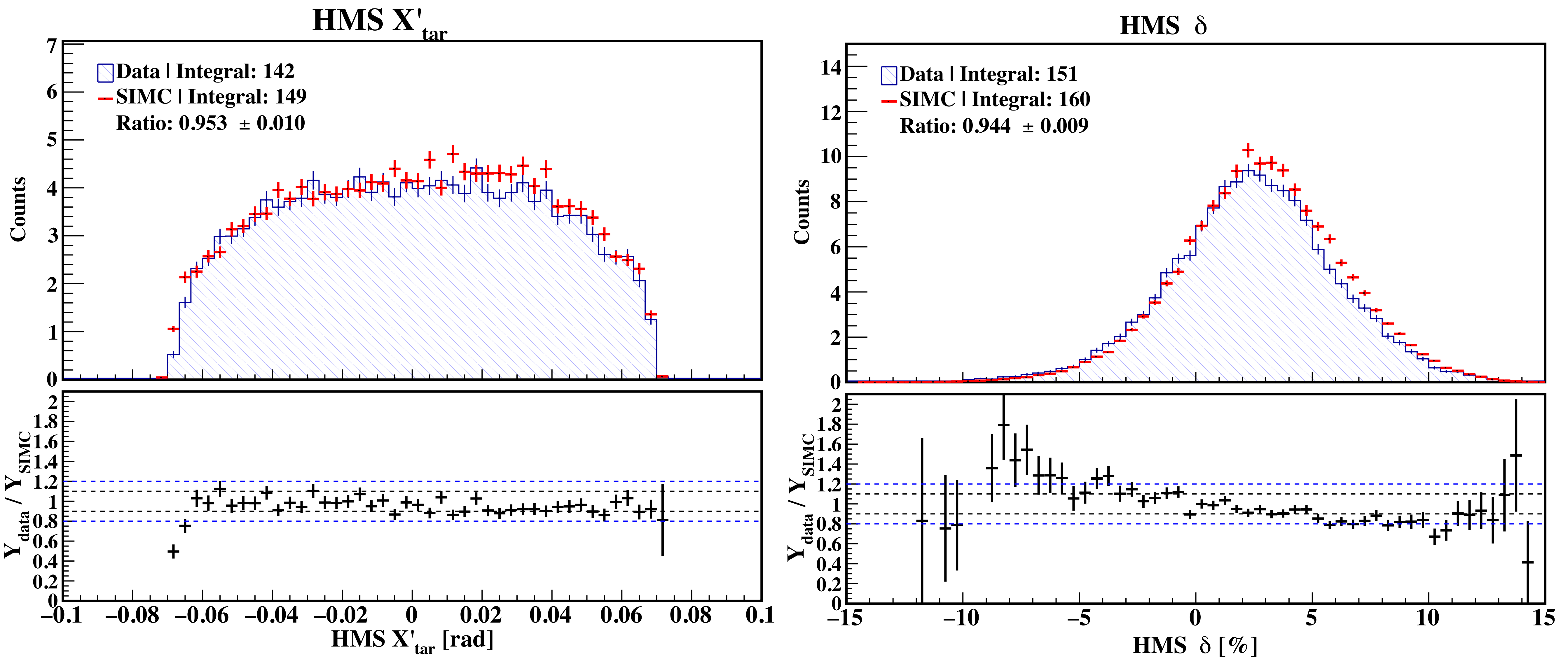


Spectrometer Acceptance
Checks on D(e,e'p)n using 80 MeV setting

HMS Reconstructed Variables

** Data is fully corrected for inefficiencies

(SIMC MODEL: Laget FSI)

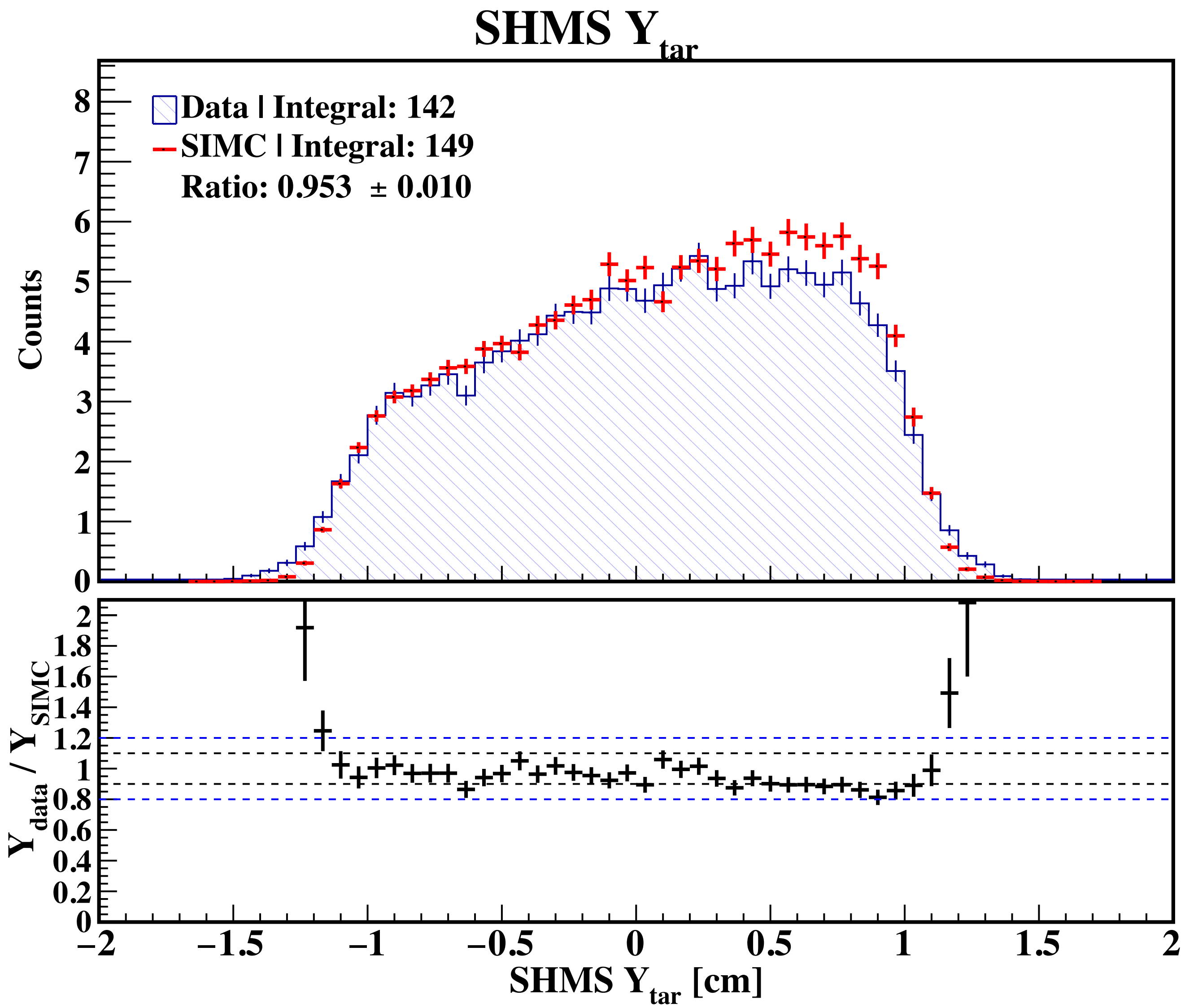


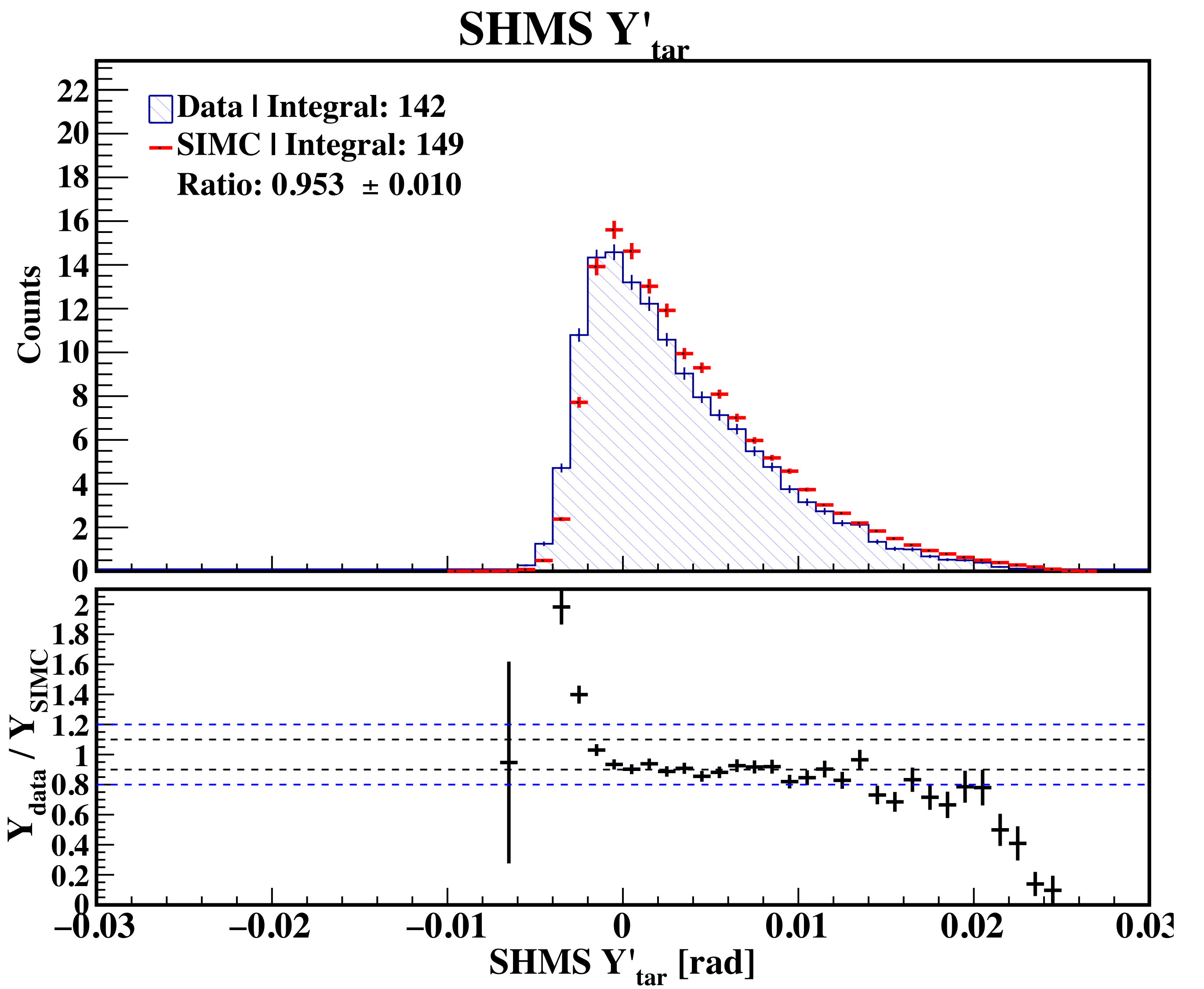
Spectrometer Acceptance
Checks on D(e,e'p)n using 80 MeV setting

SHMS Reconstructed Variables

** Data is fully corrected for inefficiencies

(SIMC MODEL: Laget FSI)



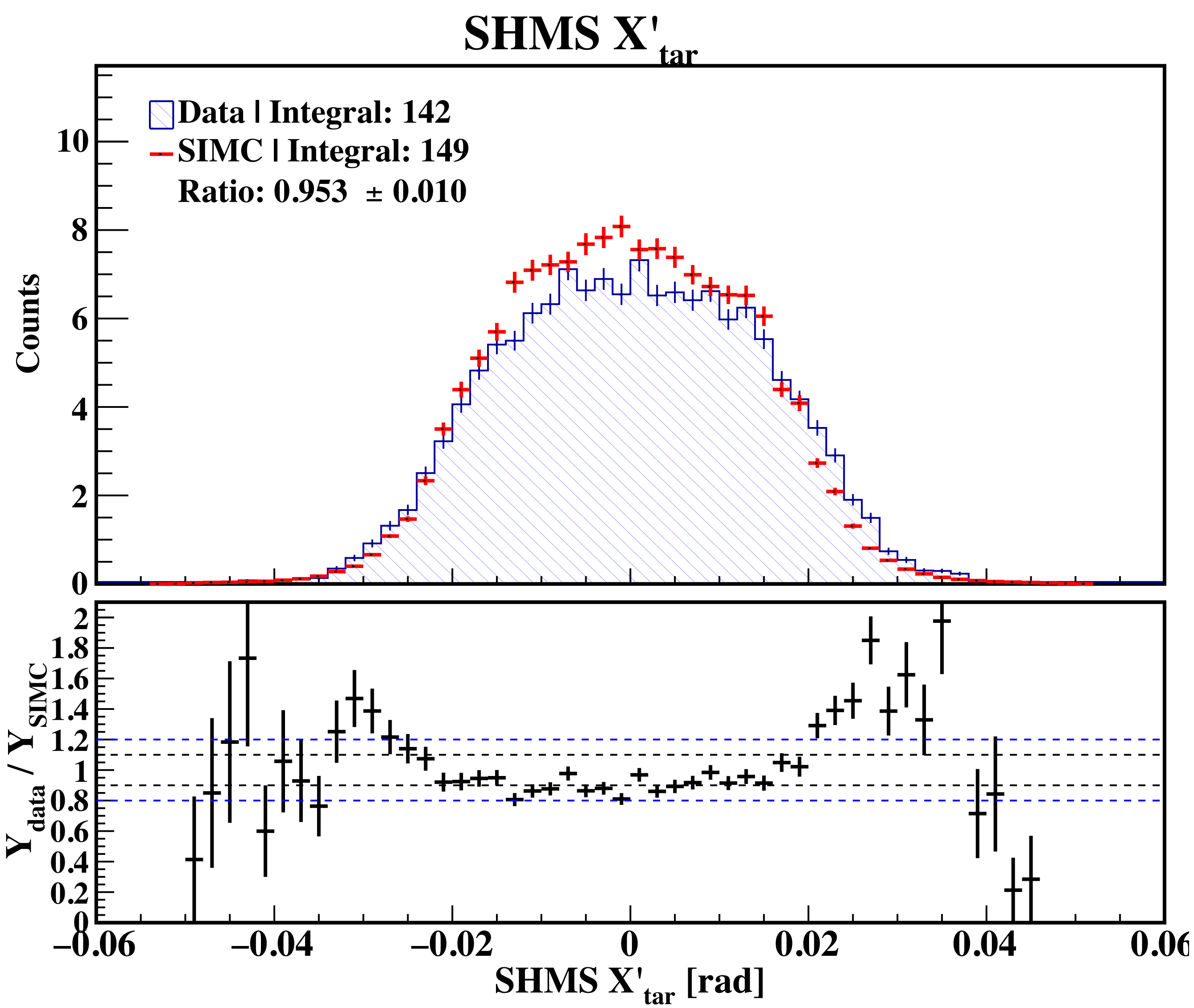


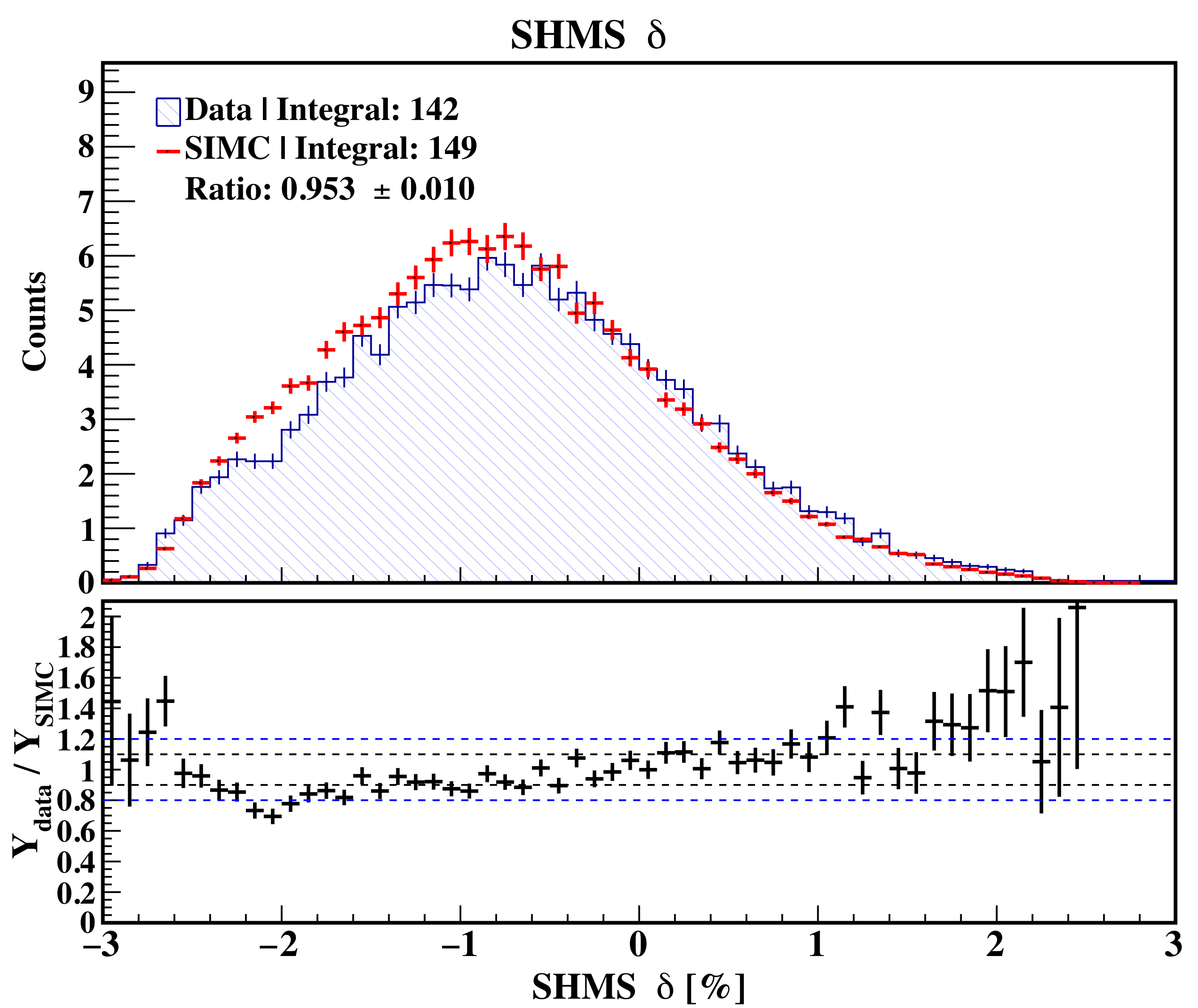
Spectrometer Acceptance
Checks on D(e,e'p)n using 80 MeV setting

SHMS Reconstructed Variables

** Data is fully corrected for inefficiencies

(SIMC MODEL: Laget FSI)

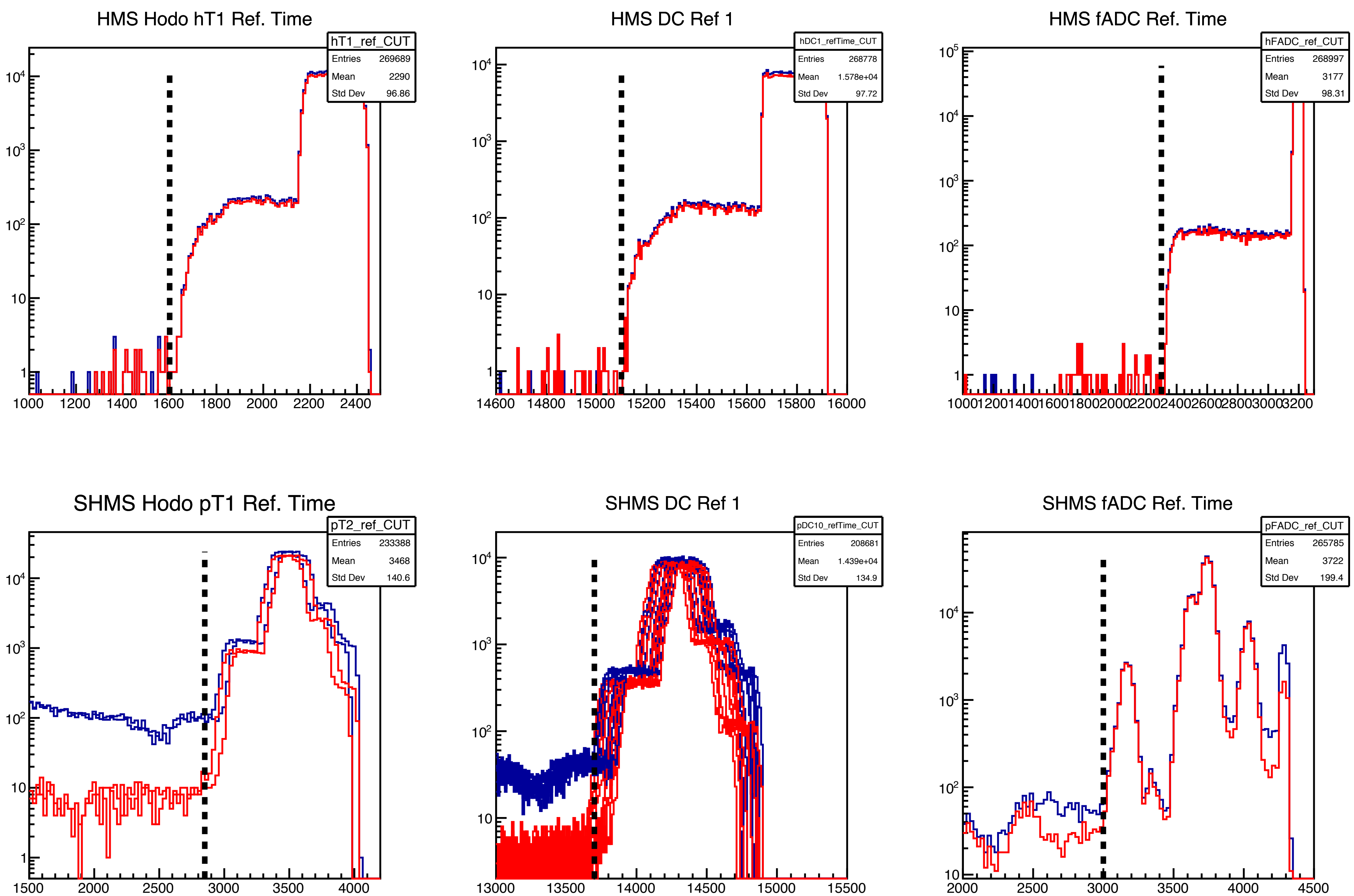




Hall C Experimental Analysis
on
D(e,e'p)n

Reference Time Cuts

☑ **Correct reference time (copy of the trigger) must be chosen so that the ADCs/TDCs subtract the correct reference time (to the right of the cut dashed line)**



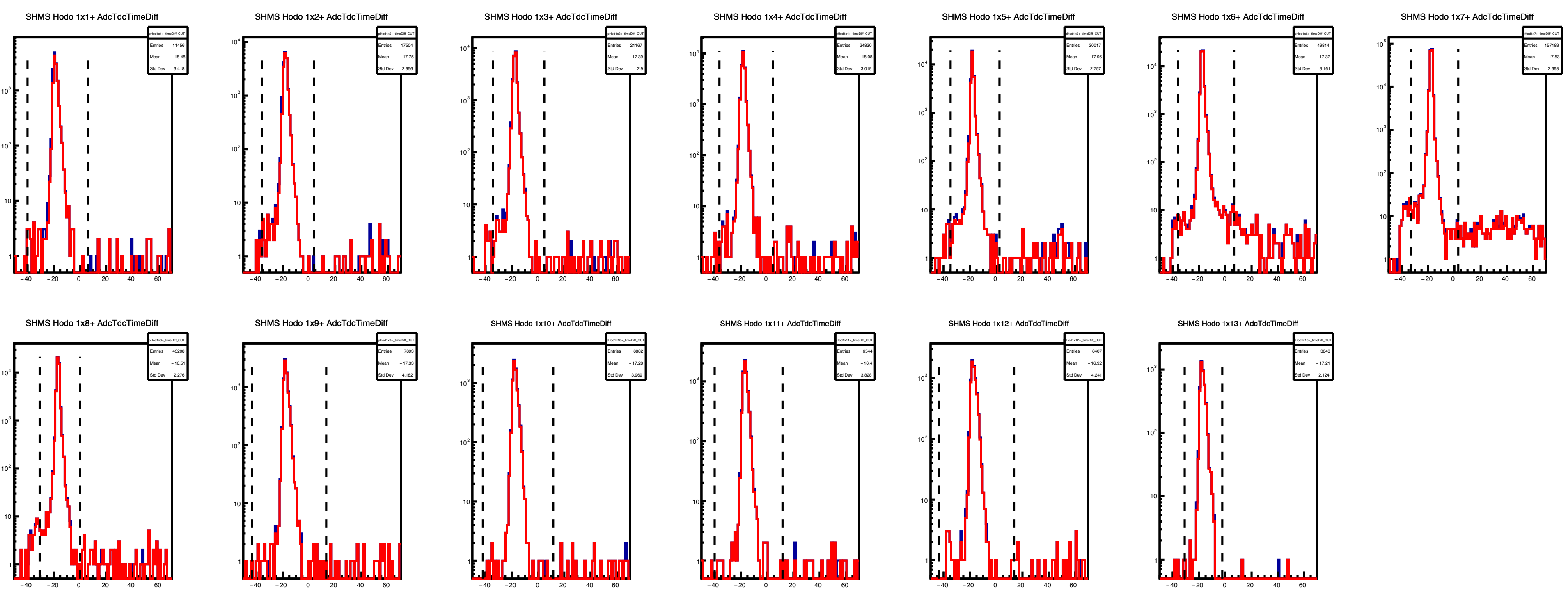
HMS Reference Times

SHMS Reference Times

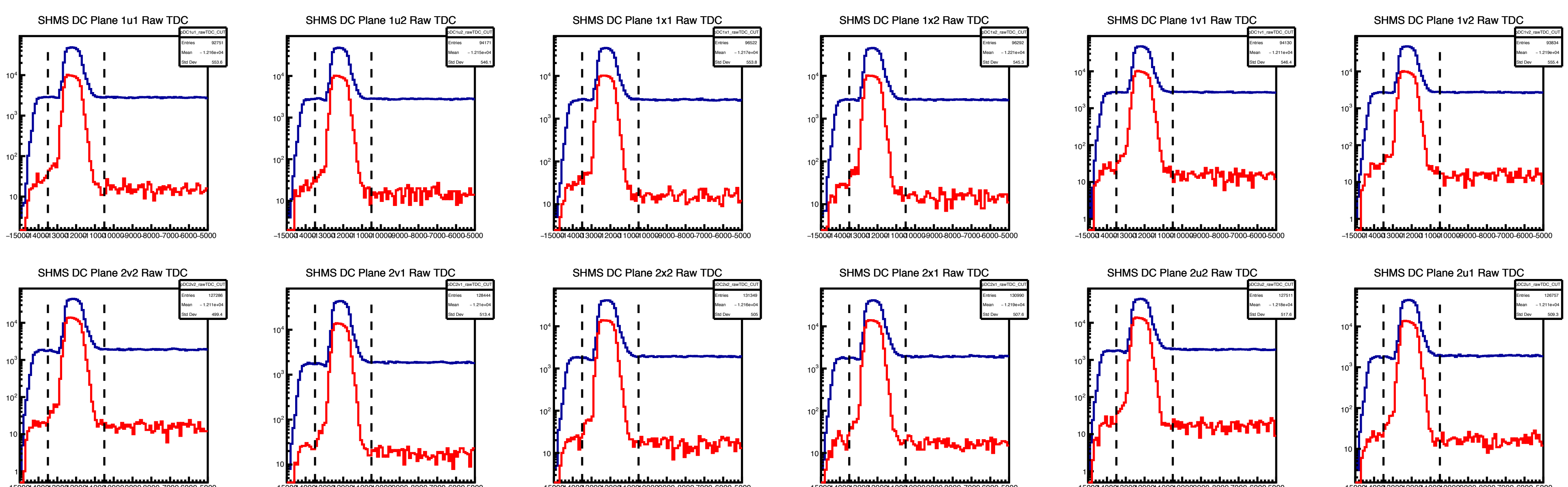
TDC Time Window Cuts

☑ **A time window cut MUST be made around the main signal peak to reduce background from possible out-of-time events.** **(Specially on the DCs)**

Legend: No Mult. Cut Multiplicity==1

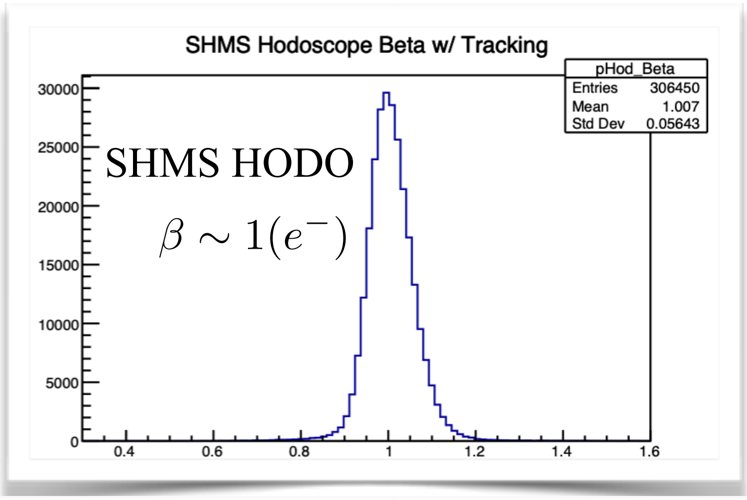


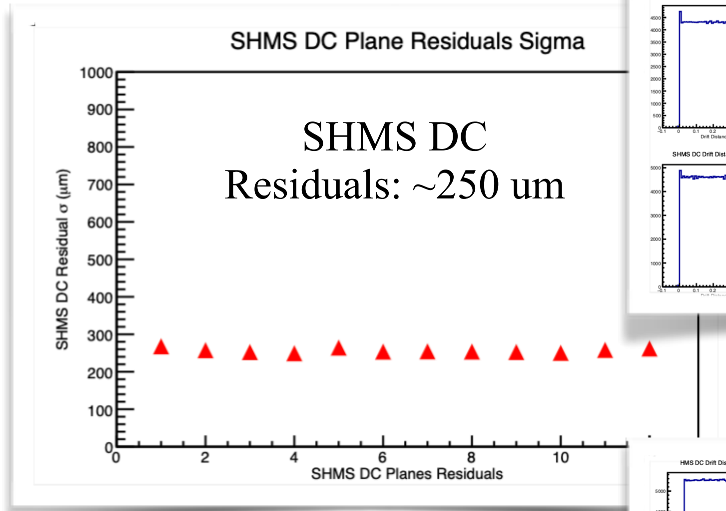
SHMS Hodoscope 1X+ (ADC-TDC) Time Difference

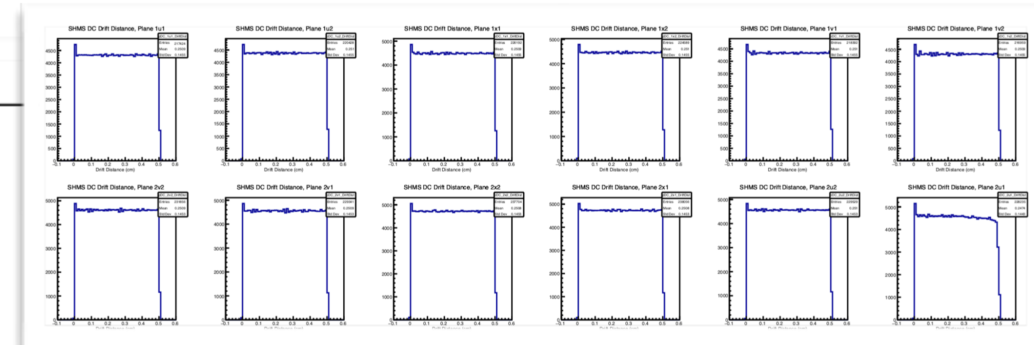


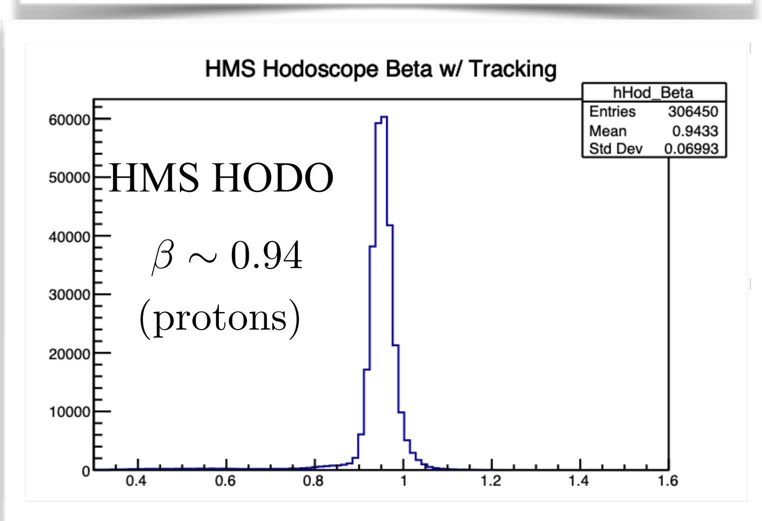
SHMS Drift Chambers Raw TDC Time

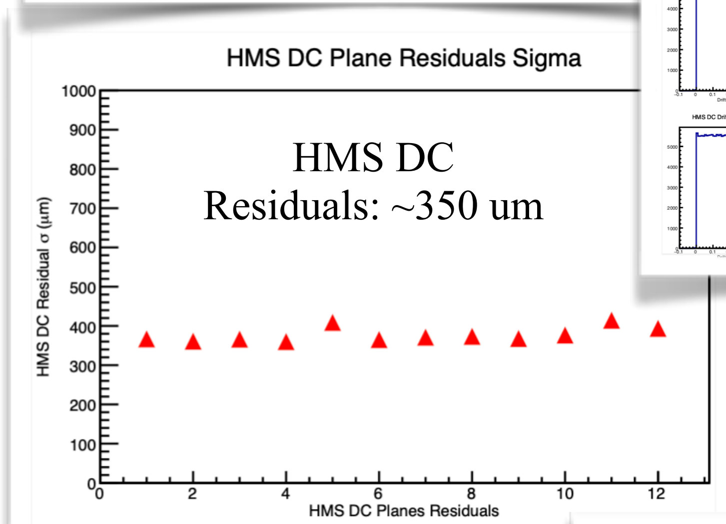
Detector Calibrations

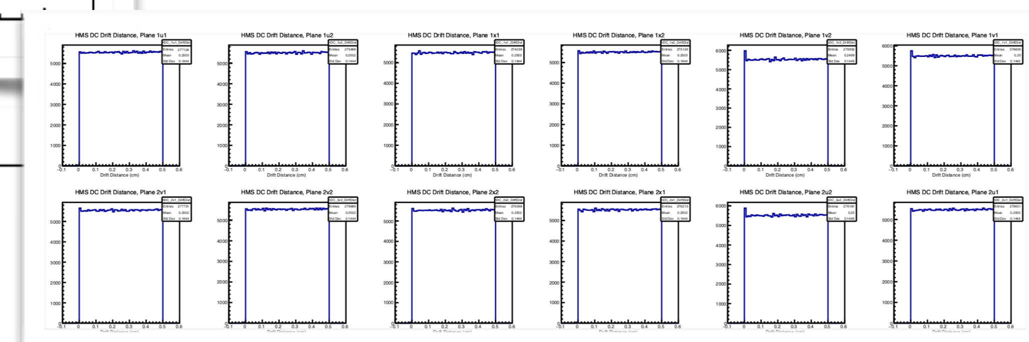


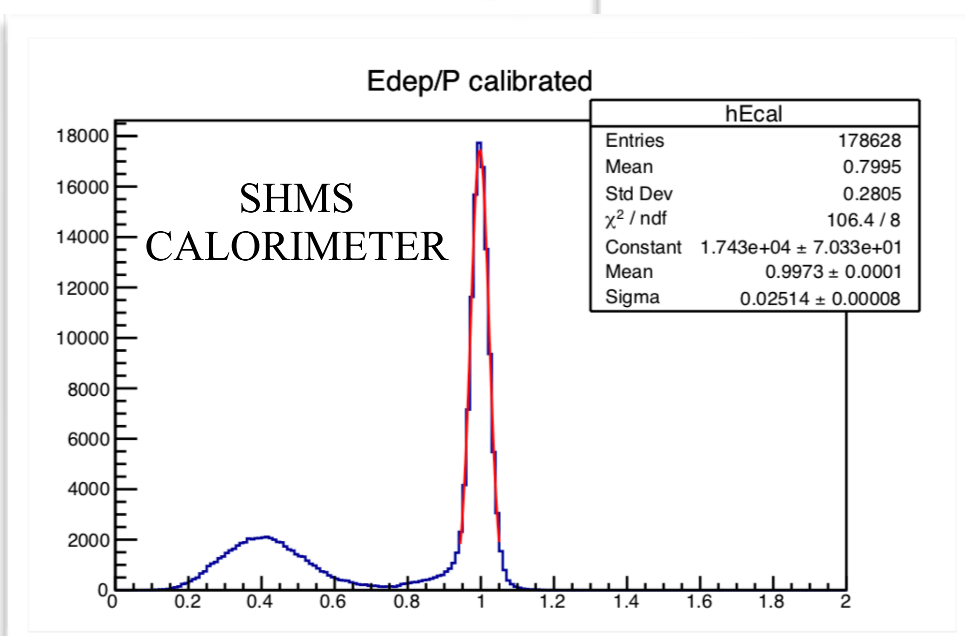


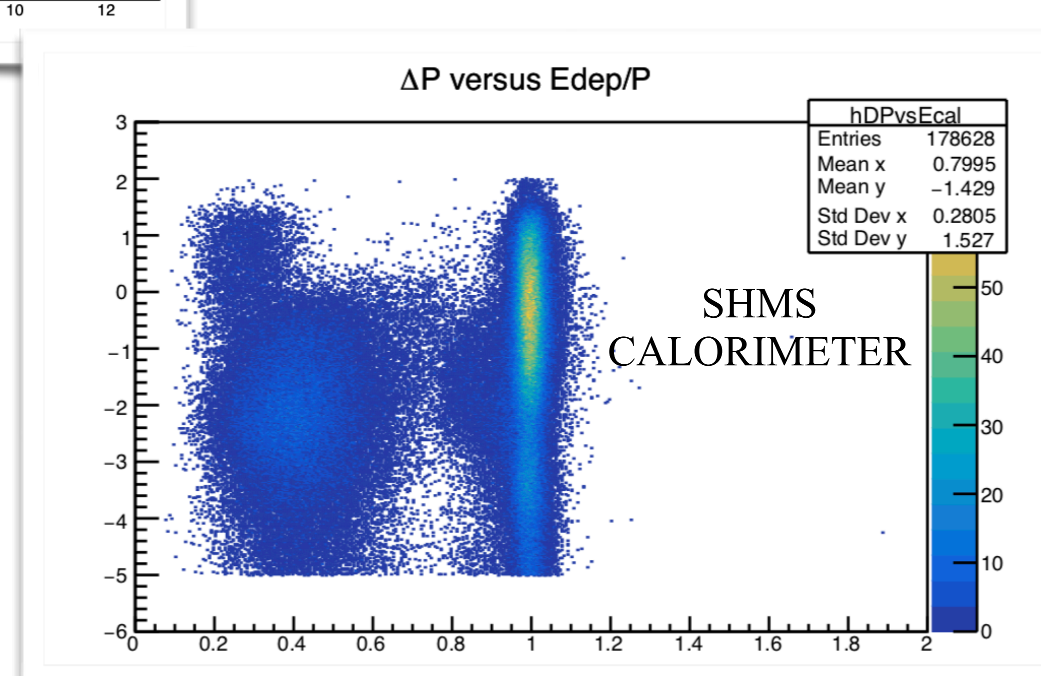




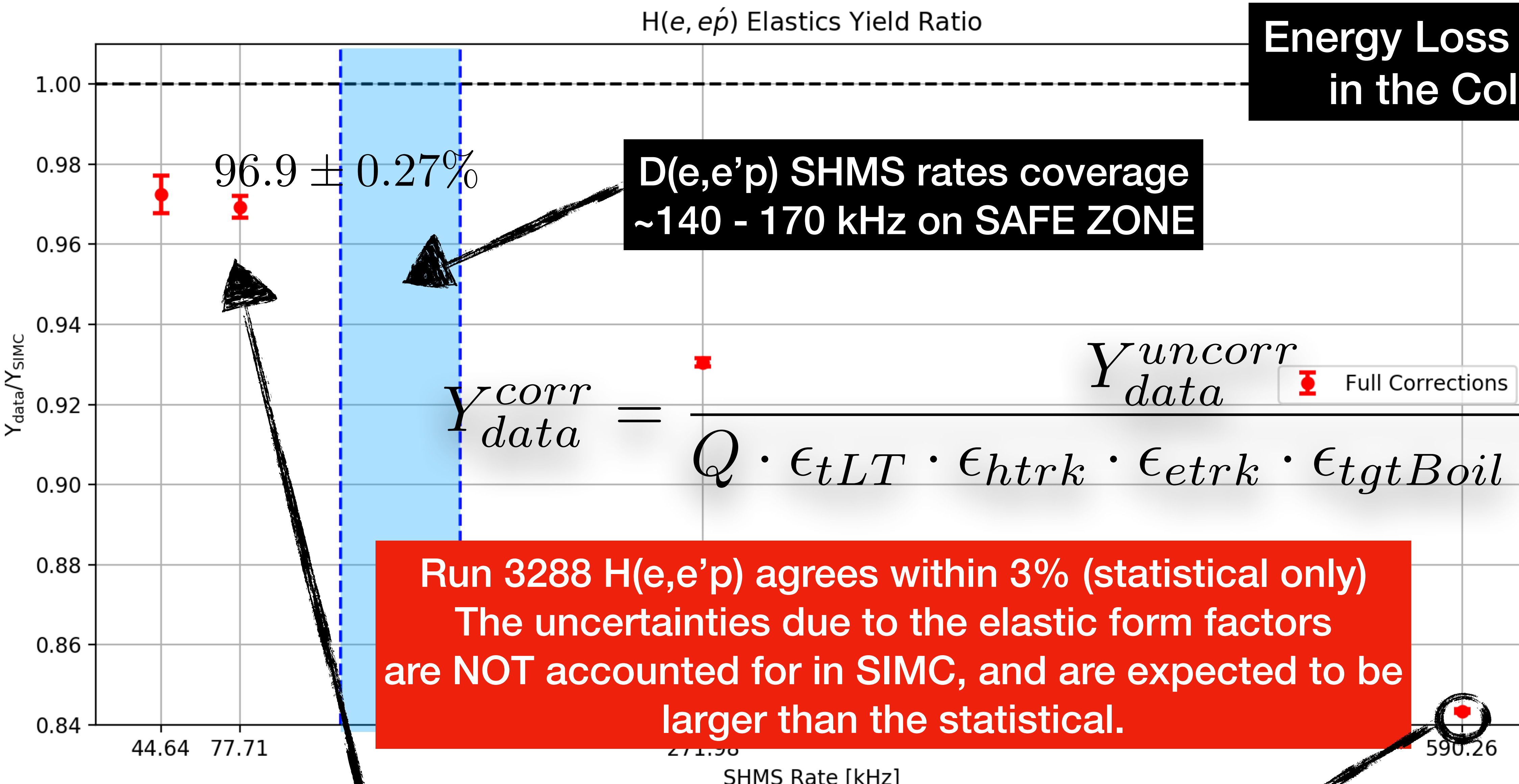








H(e,e'p) Yield Ratio Check



Energy Loss Simulated in the Collimator

D(e,e'p) SHMS rates coverage
~140 - 170 kHz on SAFE ZONE

$$Y^{corr}_{data} = \frac{Y^{uncorr}_{data}}{Q \cdot \epsilon_{tLT} \cdot \epsilon_{htrk} \cdot \epsilon_{etrk} \cdot \epsilon_{tgtBoil} \cdot \epsilon_{pAbs}}$$

Run 3288 H(e,e'p) agrees within 3% (statistical only)
The uncertainties due to the elastic form factors
are NOT accounted for in SIMC, and are expected to be
larger than the statistical.

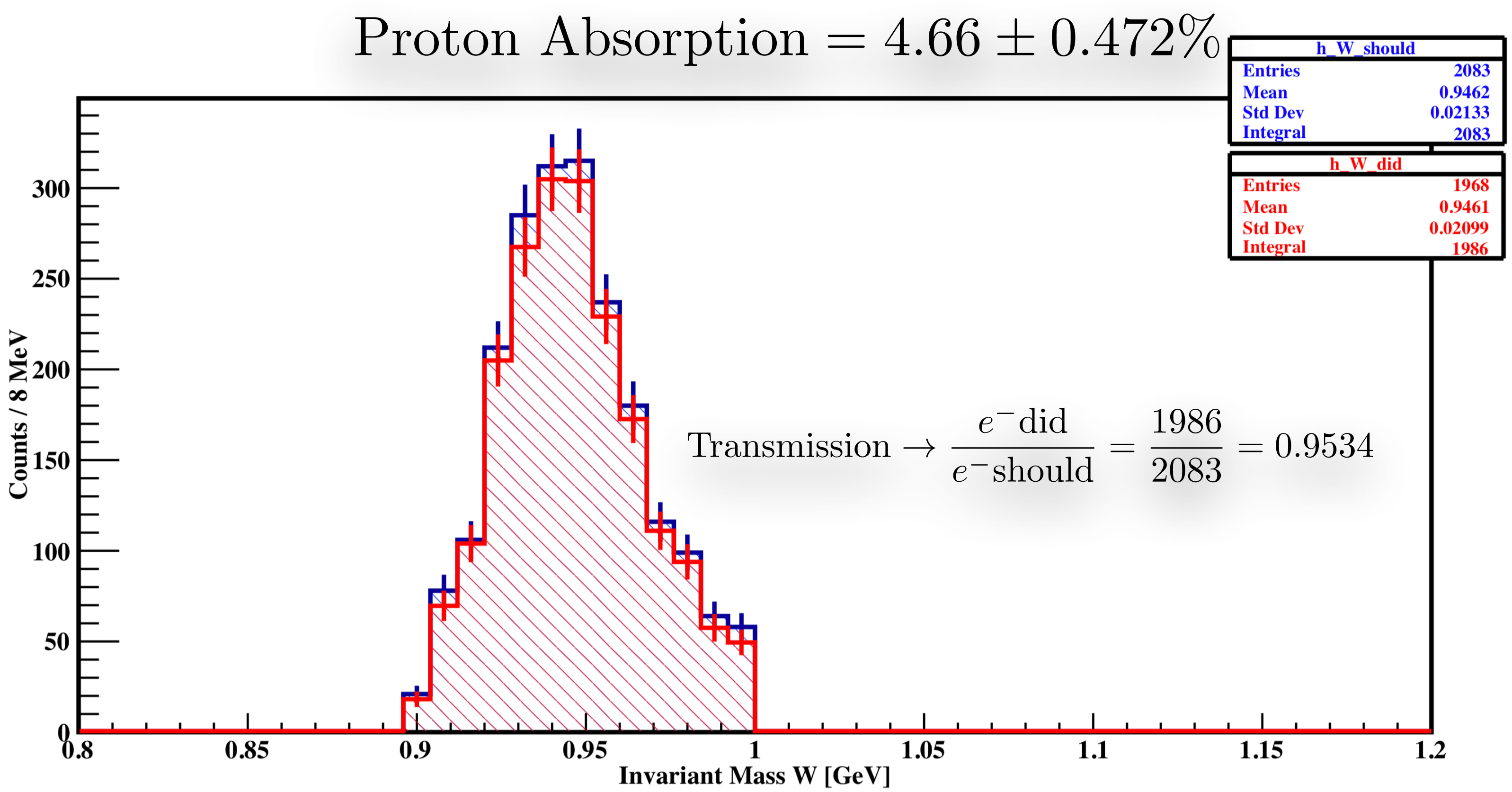
Spectrometer acceptance is studied in detailed for this run (3288), due to its proximity to the D(e,e'p)n 80 MeV kinematics

NOT Understood:

* How does the tracking algorithm perform at very high rates?

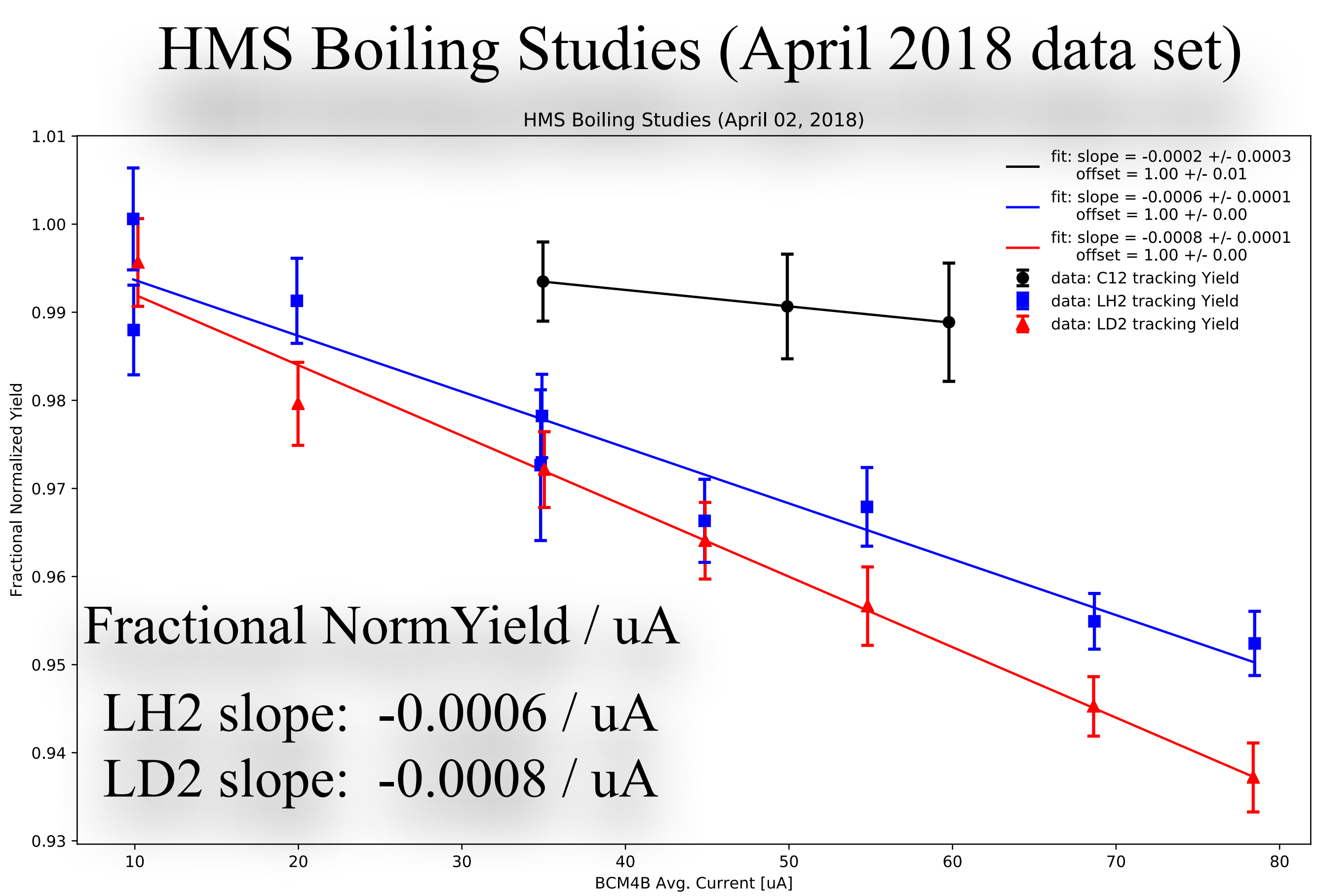
The general cuts applied were:
|HMS Delta| < 8 % SHMS Delta: (-10, 22) %
Inv. Mass W : (0.85, 1.05), HMS Coll. Cut

Results of p-Absorption and Target Boiling Corrections to the Data Yield



For Full Description of Proton Absorption Analysis, See DOC DB Link HERE !

(ONLY relevant for coincidence experiments)

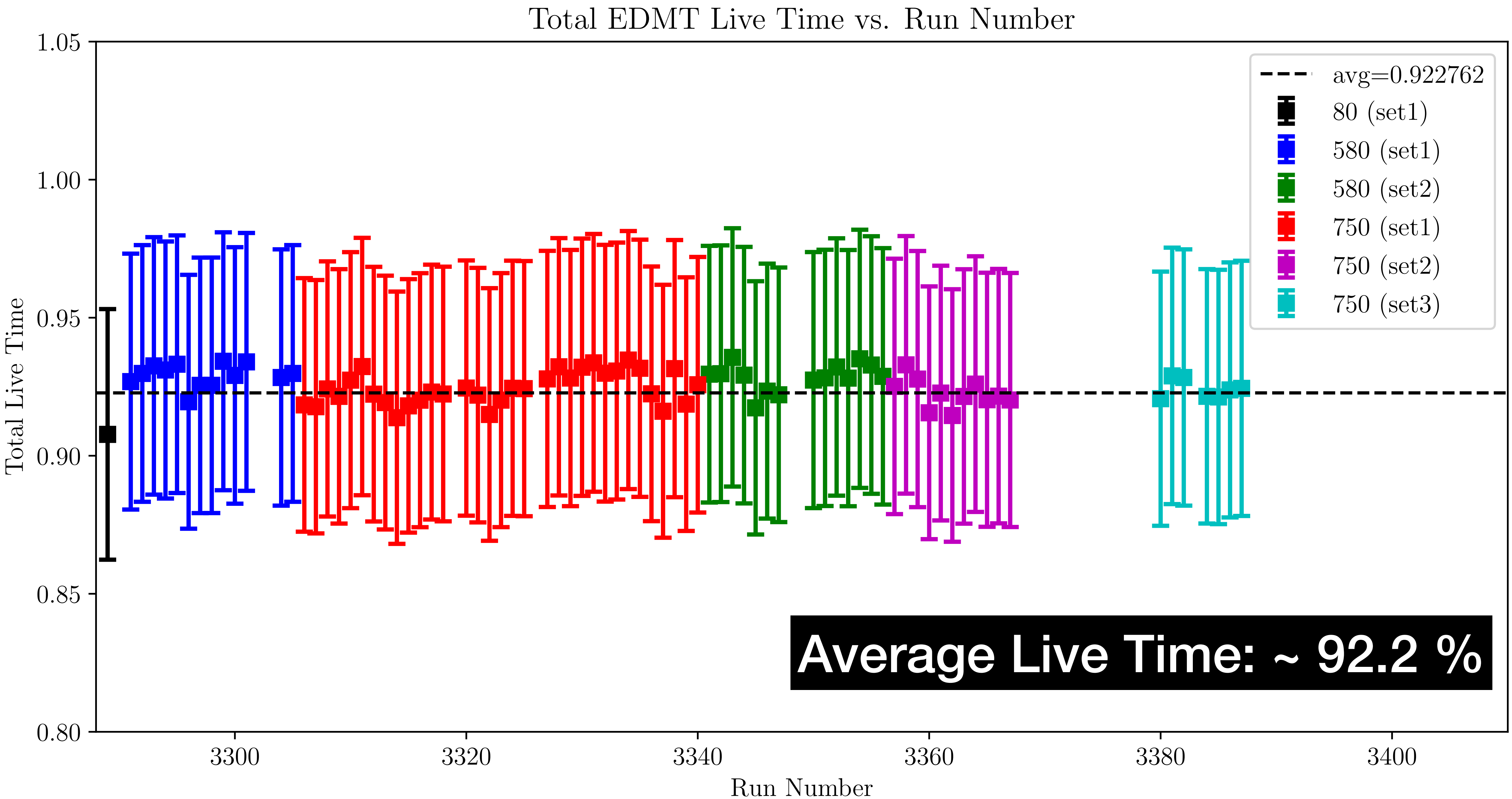


For Full Description of Target Boiling Corrections See DOC DB Link HERE !

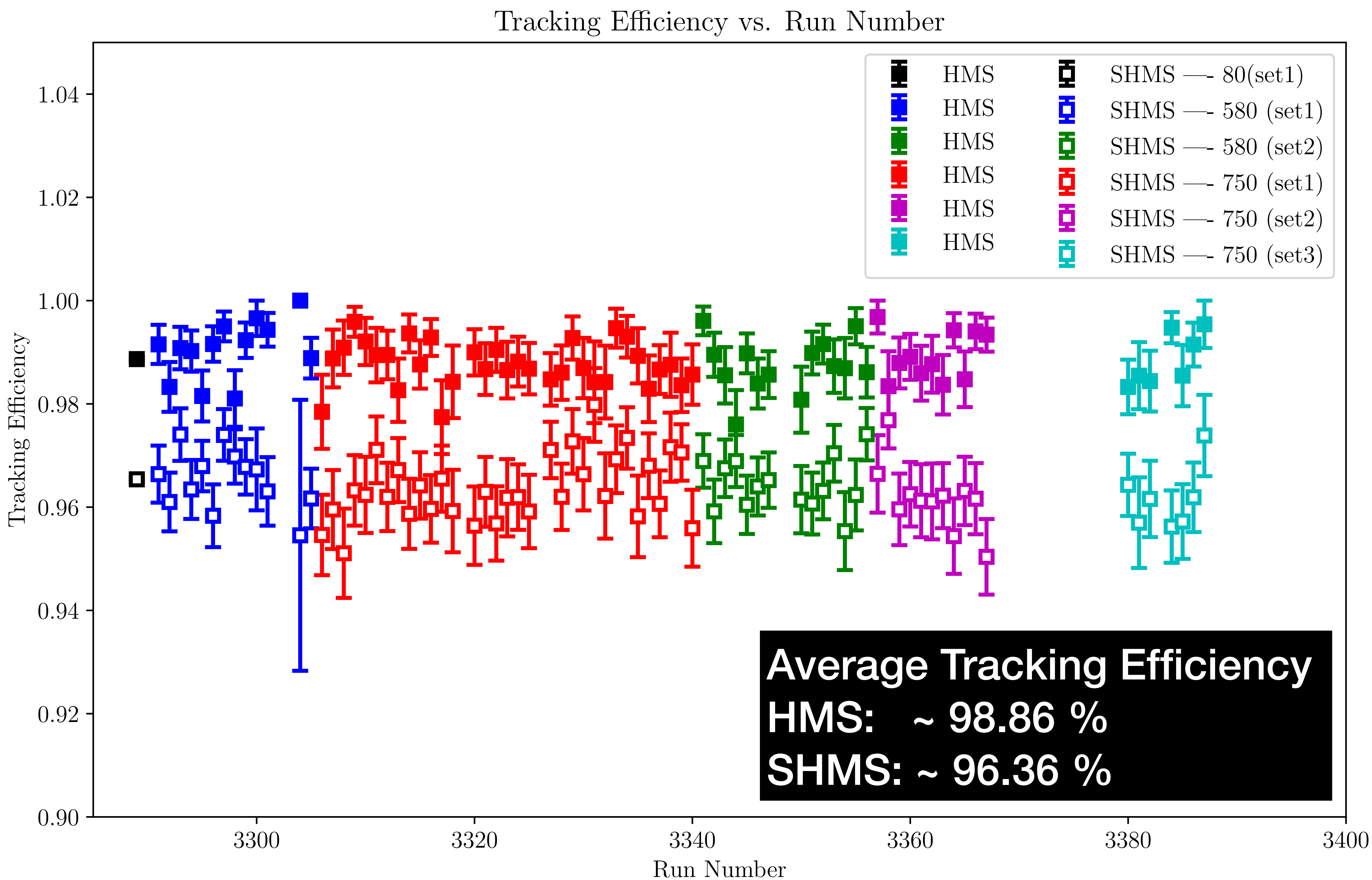
Efficiencies and Correction Factors

$$Y_{data}^{corr} = \frac{Y_{data}^{uncorr} \cdot f_{rad} \cdot f_{bc}}{Q \cdot \epsilon_{tLT} \cdot \epsilon_{htrk} \cdot \epsilon_{etrk} \cdot \epsilon_{tgtBoil} \cdot \epsilon_{pAbs}}$$

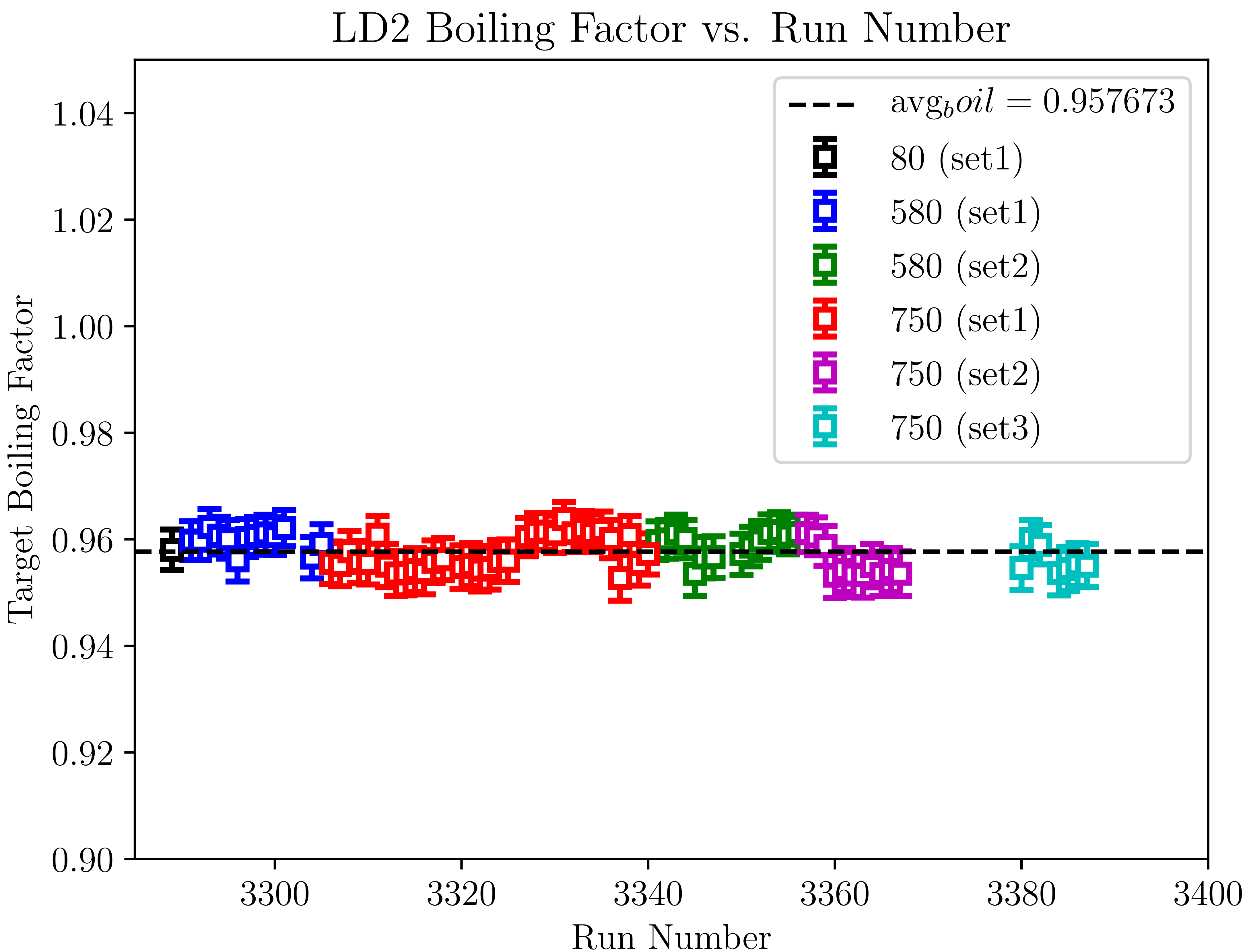
TOTAL EDTM LIVE TIME



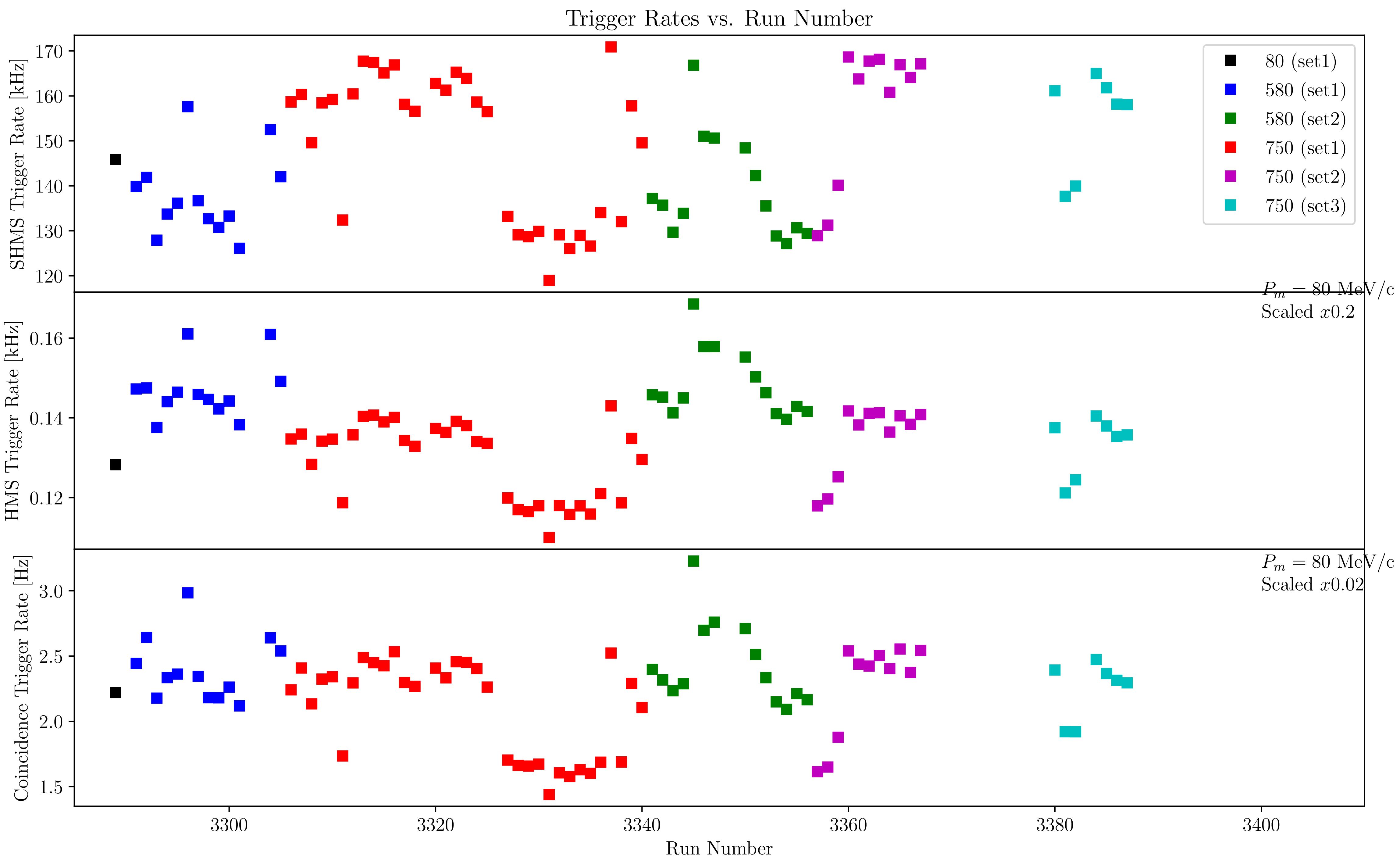
TRACKING EFFICIENCY



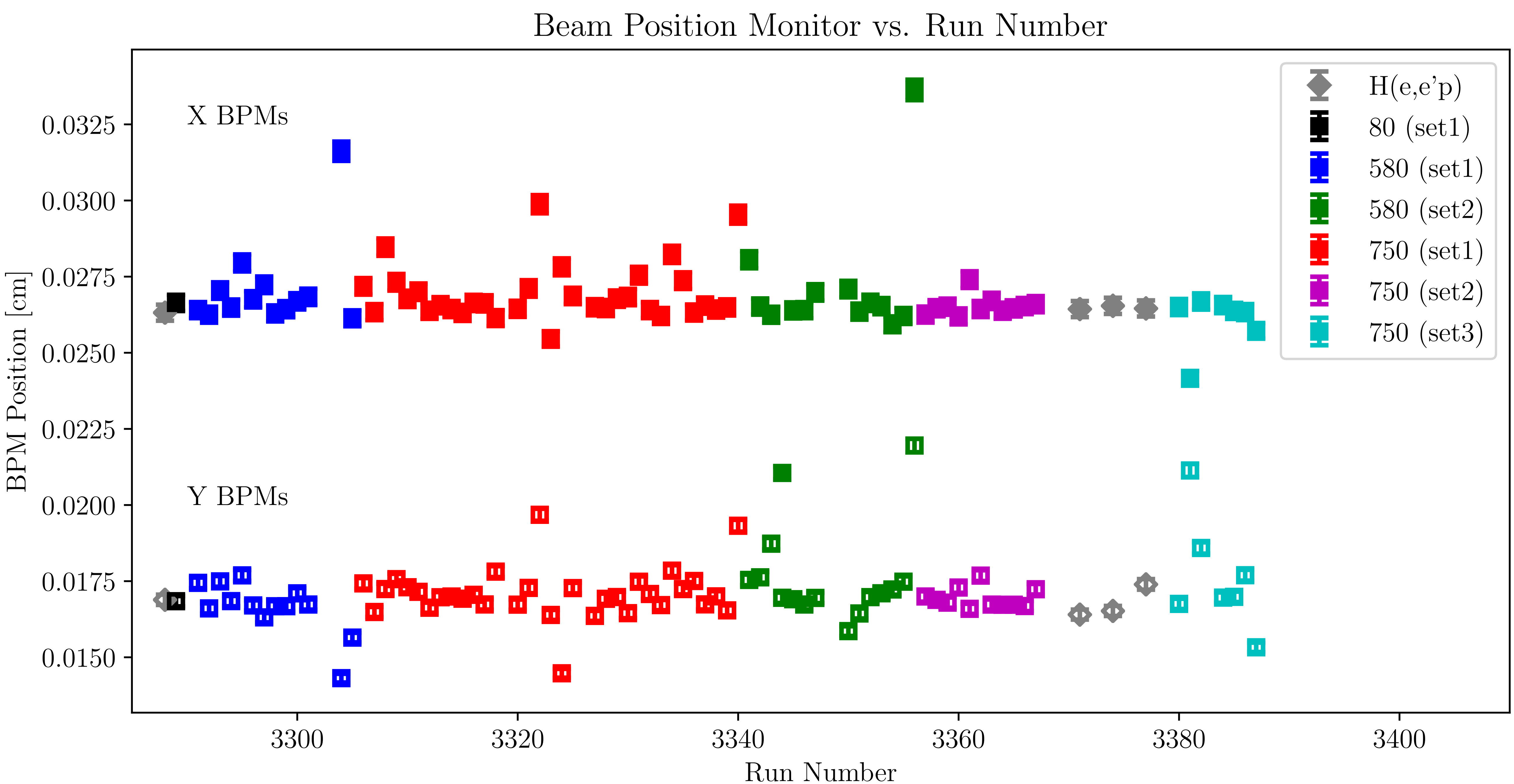
TARGET BOILING FACTOR



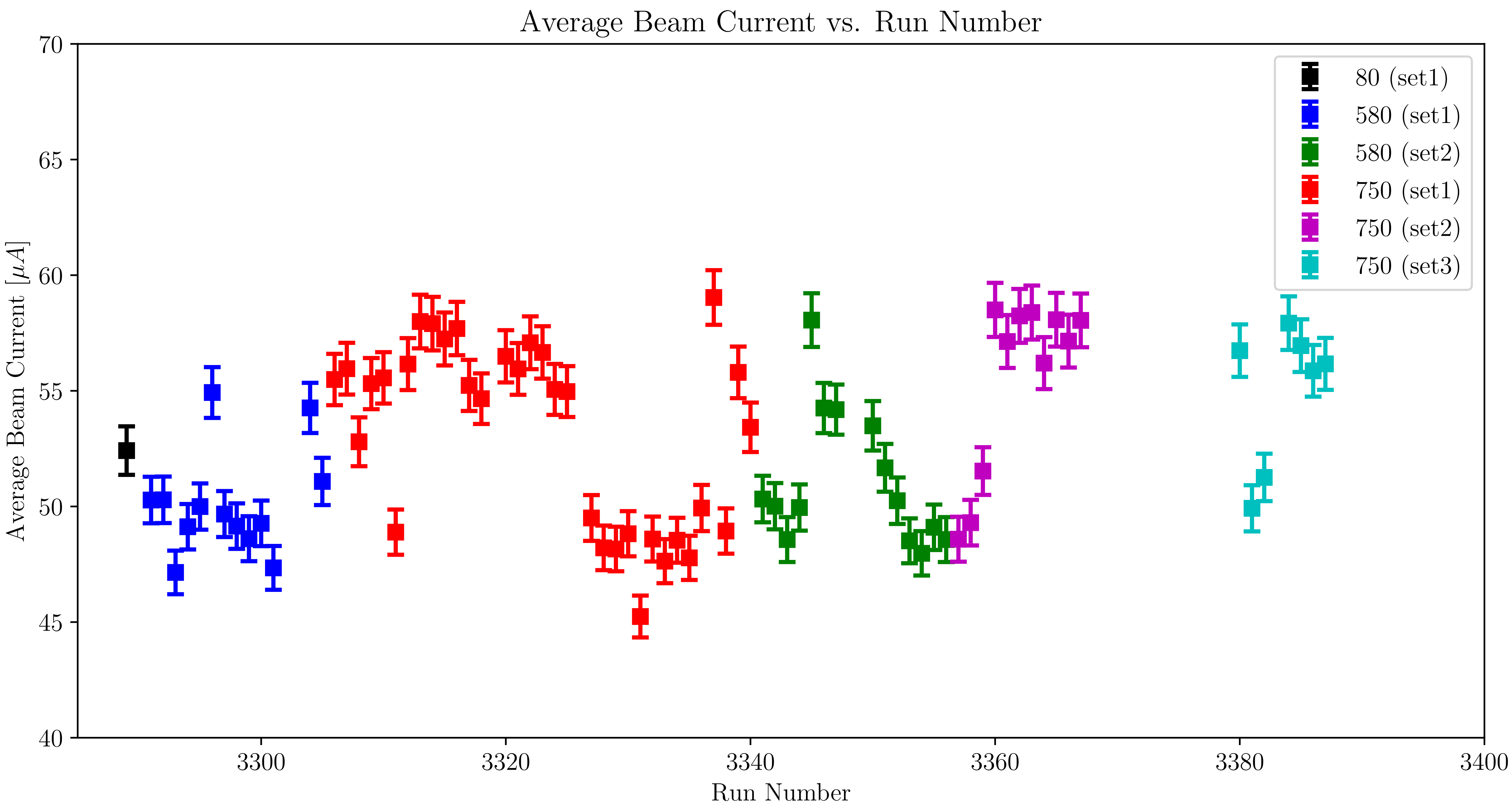
TRIGGER RATES



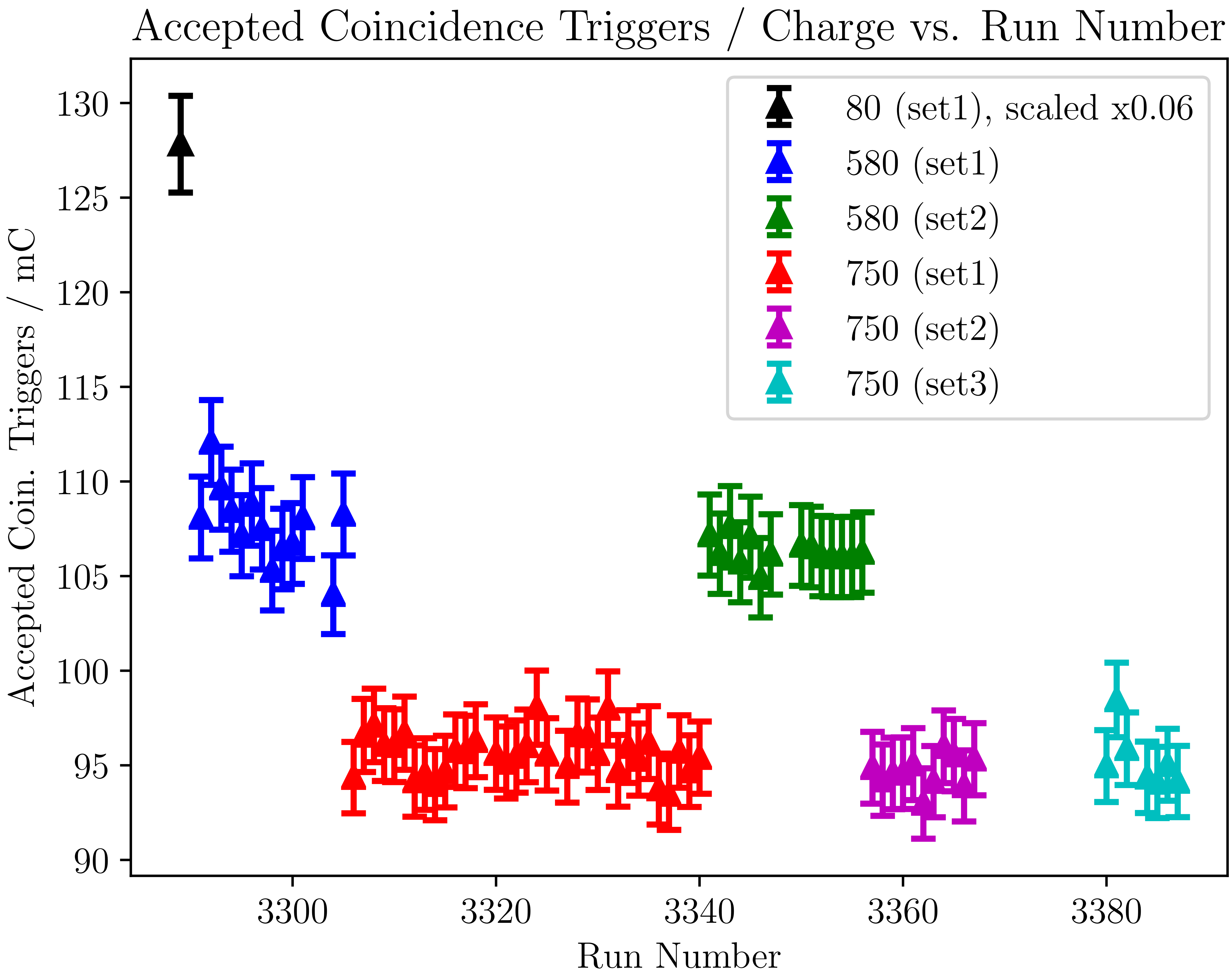
BEAM POSITION MONITORING (BPMs)



AVERAGE BEAM CURRENT



ACCEPTED COUNTS / CHARGE

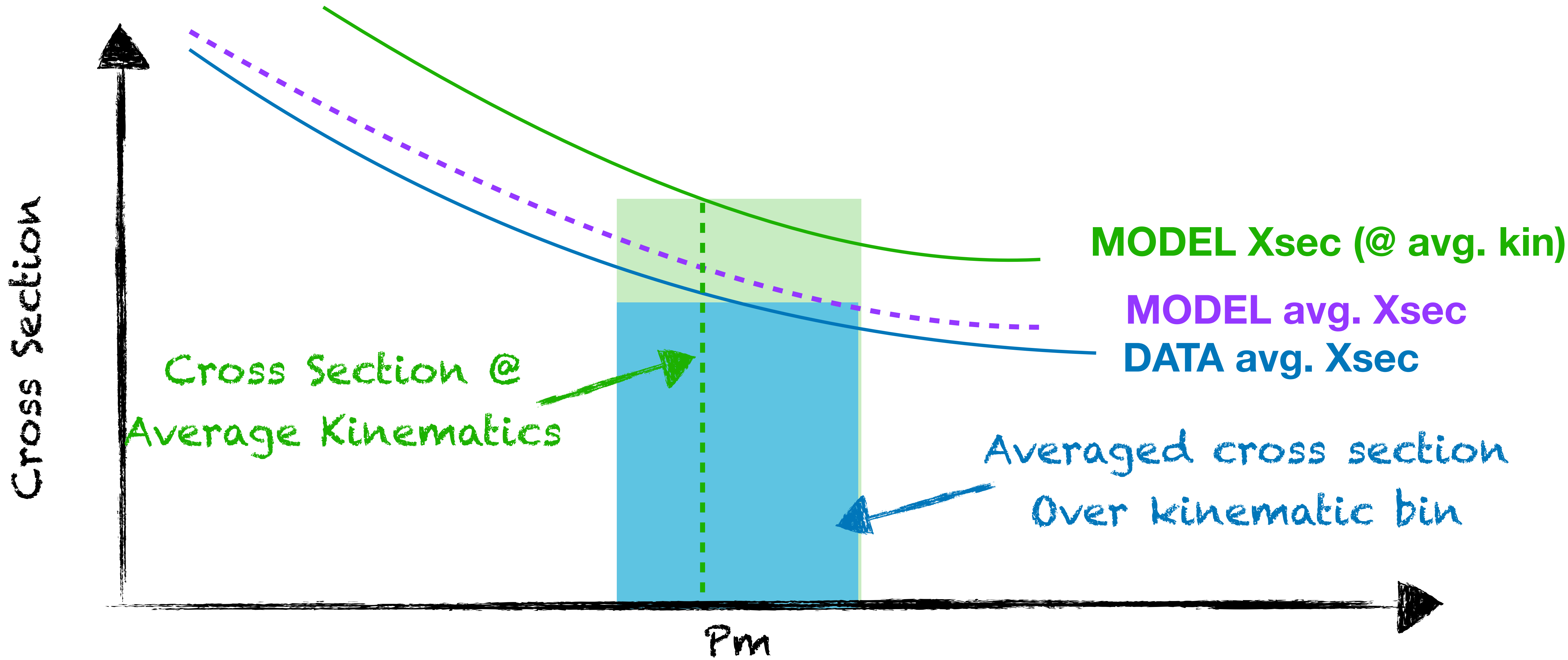


BIN-CENTERING

CORRECTIONS

Bin Centering Corrections

- In reality, the measured data cross section is an average over the kinematic bin in which it is stored.



Model cross section at the averaged kinematic variables

Model average cross section -> simcYield / PhaseSpace

(SIMC Yield does NOT have to be corrected for efficiencies or charge, as it is assumed all efficiencies are 100% and a 1 mC charge is assumed in the input file)

$$f_{bc} = \frac{\sigma^{model}(\bar{E}_b, \bar{Q}^2, \bar{\omega}, \bar{\theta}_{pq}^{cm}, \bar{\phi}_{pq})}{\bar{\sigma}^{model}}$$

Bin-centering correction

Bin Centering Corrections

❖ **Currently, Hall C software does NOT do energy loss corrections, therefore, the average kinematics were calculated from vertex quantities in simulation.**

Kinematic bin (e.g. Pm bin where cross section is stored)

$$\bar{x}_k = \left(\frac{\sum_i w_i x_i}{\sum_i w_i} \right)_k$$

Averaged kinematic variable x over kinematic bin k

Weight times kinematic variable summed over all events

Sum of the weights over all events

Bin Centering Corrections

❖ **Once the averaged kinematics have been calculated, . . .**

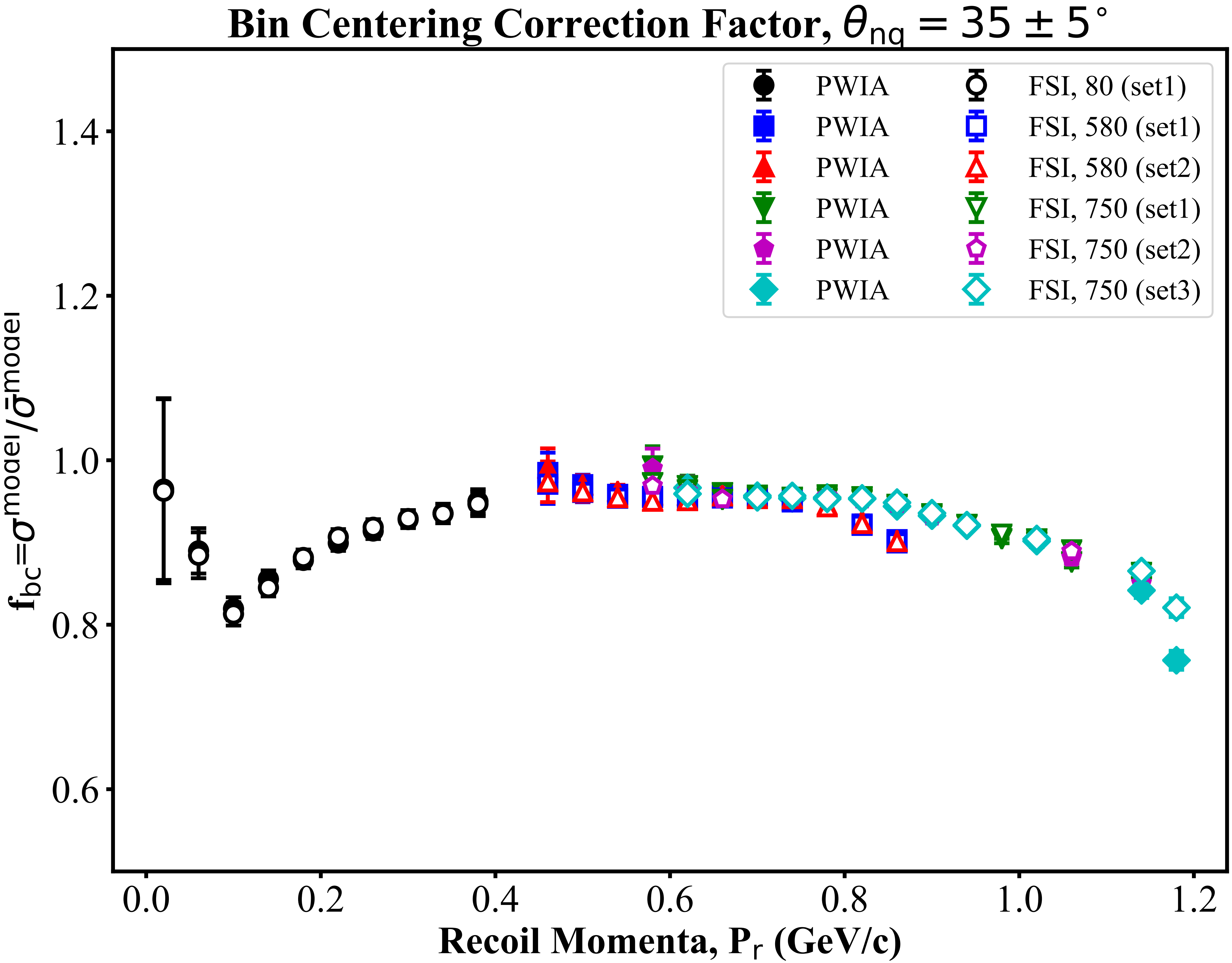
$\bar{x}$: avg. kinematics → **IN** → **Theoretical Model (usually a code that takes the input)** → **OUT** → $\sigma^{model}(\bar{E}_b, \bar{Q}^2, \bar{\omega}, \bar{\theta}_{pq}^{cm}, \bar{\phi}_{pq})$

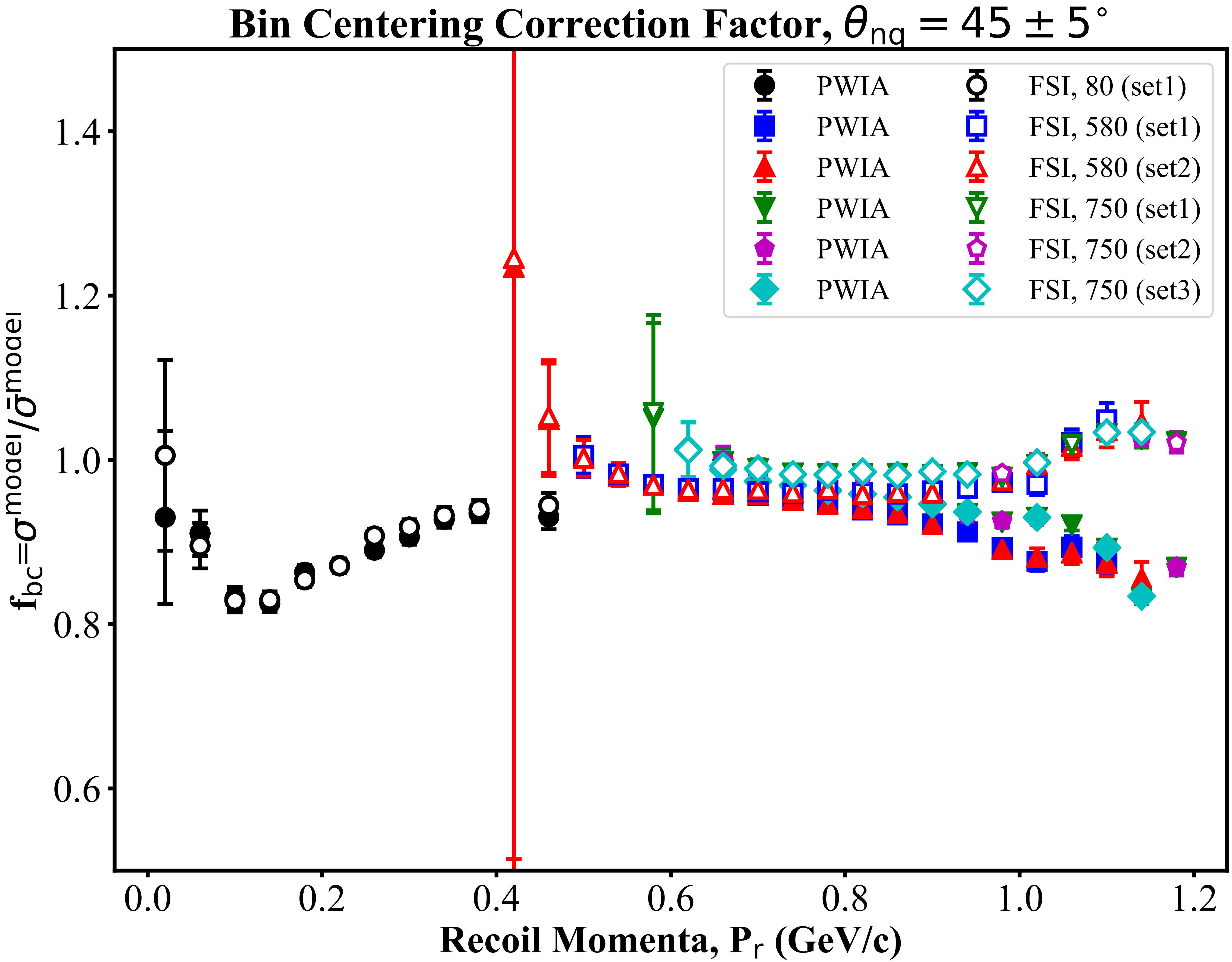
$$\bar{\sigma}^{model} \equiv \frac{Y^{\text{SIMC}}}{V^{P.S.}}$$

→ **Averaged Model Cross Section**
(See Slide 11 for reference)

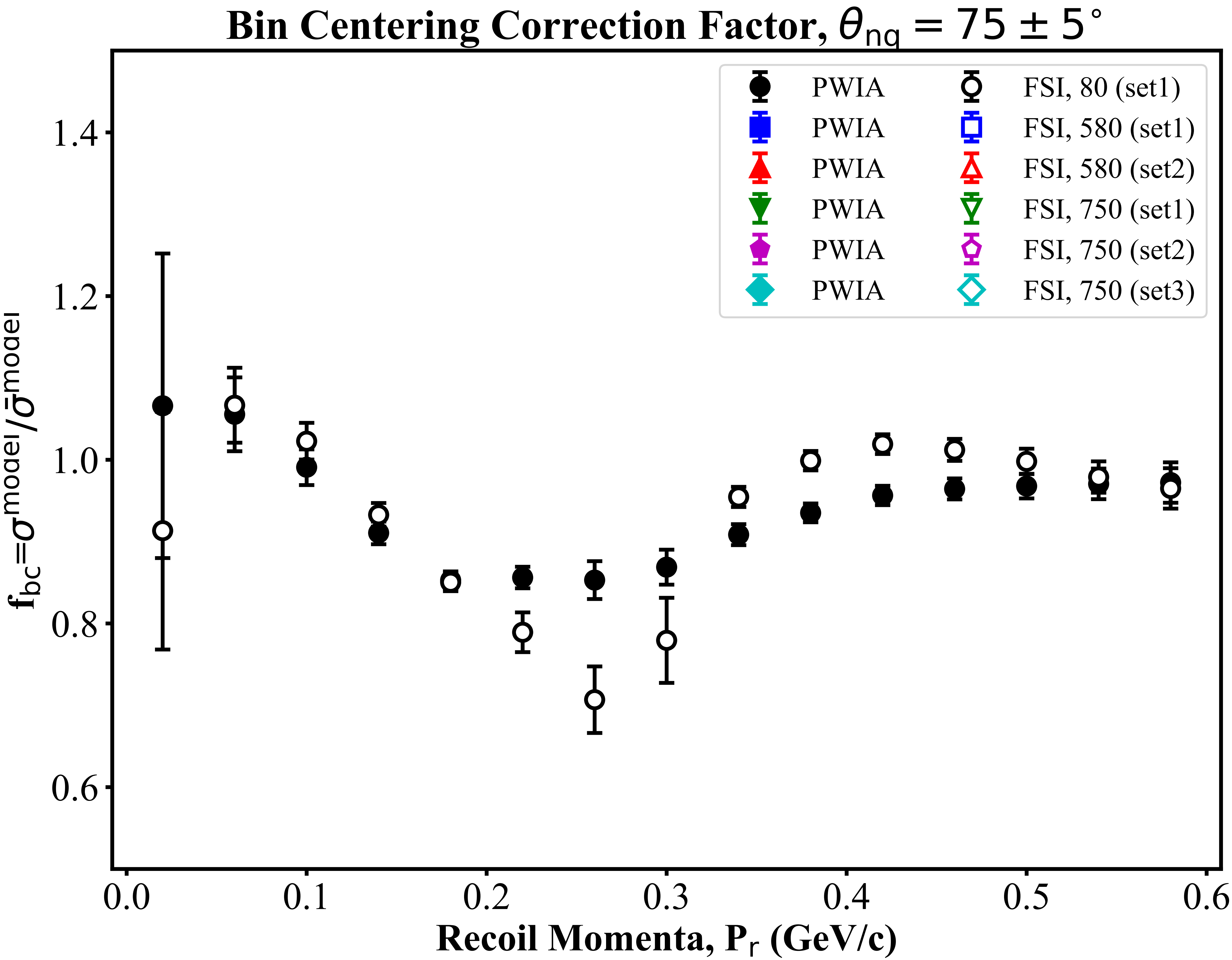
❖ **Correct the data bin-by-bin using the model cross sections ratio . . .**

$$\sigma_{bc}^{exp} = \bar{\sigma}^{exp} \cdot \frac{\sigma^{model}(\bar{E}_b, \bar{Q}^2, \bar{\omega}, \bar{\theta}_{pq}^{cm}, \bar{\phi}_{pq})}{\bar{\sigma}^{model}}$$


Bin Centering Correction Factor, $\theta_{nq} = 35 \pm 5^{\circ}$
PWIA
FSI, 80 (set1)
PWIA
FSI, 580 (set1)
PWIA
FSI, 580 (set2)
PWIA
FSI, 750 (set1)
PWIA
FSI, 750 (set2)
PWIA
FSI, 750 (set3)
$f_{bc}=\sigma^{model}/\bar{\sigma}^{model}$
Recoil Momenta, P_r (GeV/c)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0.6
0.8
1.0
1.2
1.4



Bin Centering Correction Factor, $\theta_{nq} = 45 \pm 5^{\circ}$
$f_{bc} = \sigma^{model} / \bar{\sigma}^{model}$
Recoil Momenta, P_r (GeV/c)
0.6
0.8
1.0
1.2
1.4
0.0
0.2
0.4
0.6
0.8
1.0
1.2
PWIA
FSI, 80 (set1)
PWIA
FSI, 580 (set1)
PWIA
FSI, 580 (set2)
PWIA
FSI, 750 (set1)
PWIA
FSI, 750 (set2)
PWIA
FSI, 750 (set3)


Bin Centering Correction Factor, $\theta_{nq} = 75 \pm 5^{\circ}$
$f_{bc}=\sigma^{model}/\bar{\sigma}^{model}$
Recoil Momenta, P_r (GeV/c)
PWIA
PWIA
PWIA
PWIA
PWIA
PWIA
FSI, 80 (set1)
FSI, 580 (set1)
FSI, 580 (set2)
FSI, 750 (set1)
FSI, 750 (set2)
FSI, 750 (set3)
1.4
1.2
1.0
0.8
0.6
0.0
0.1
0.2
0.3
0.4
0.5
0.6