



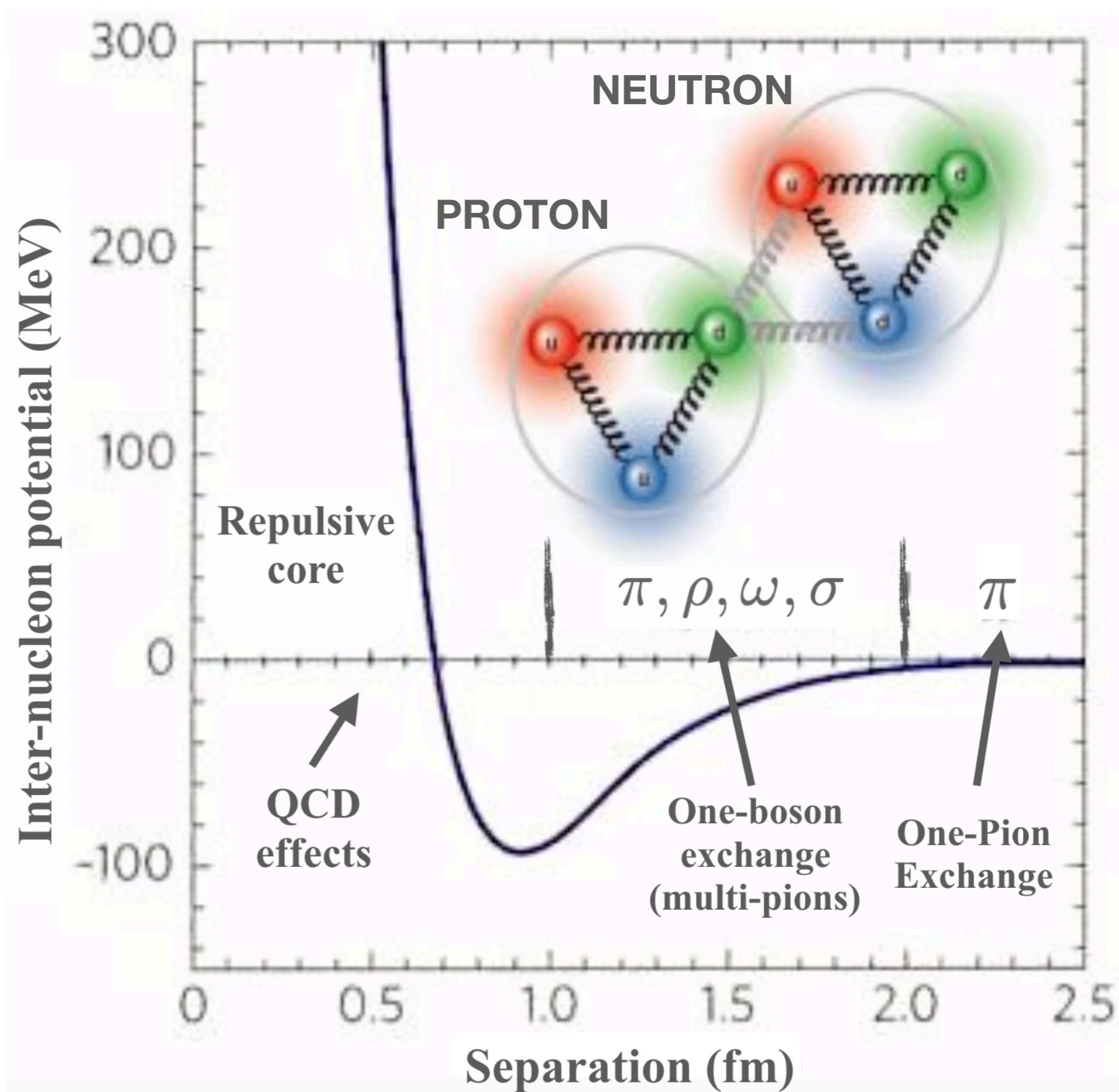
D(e,e'p)n Cross Section Measurements at Very High Missing Momenta and Large Q^2

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

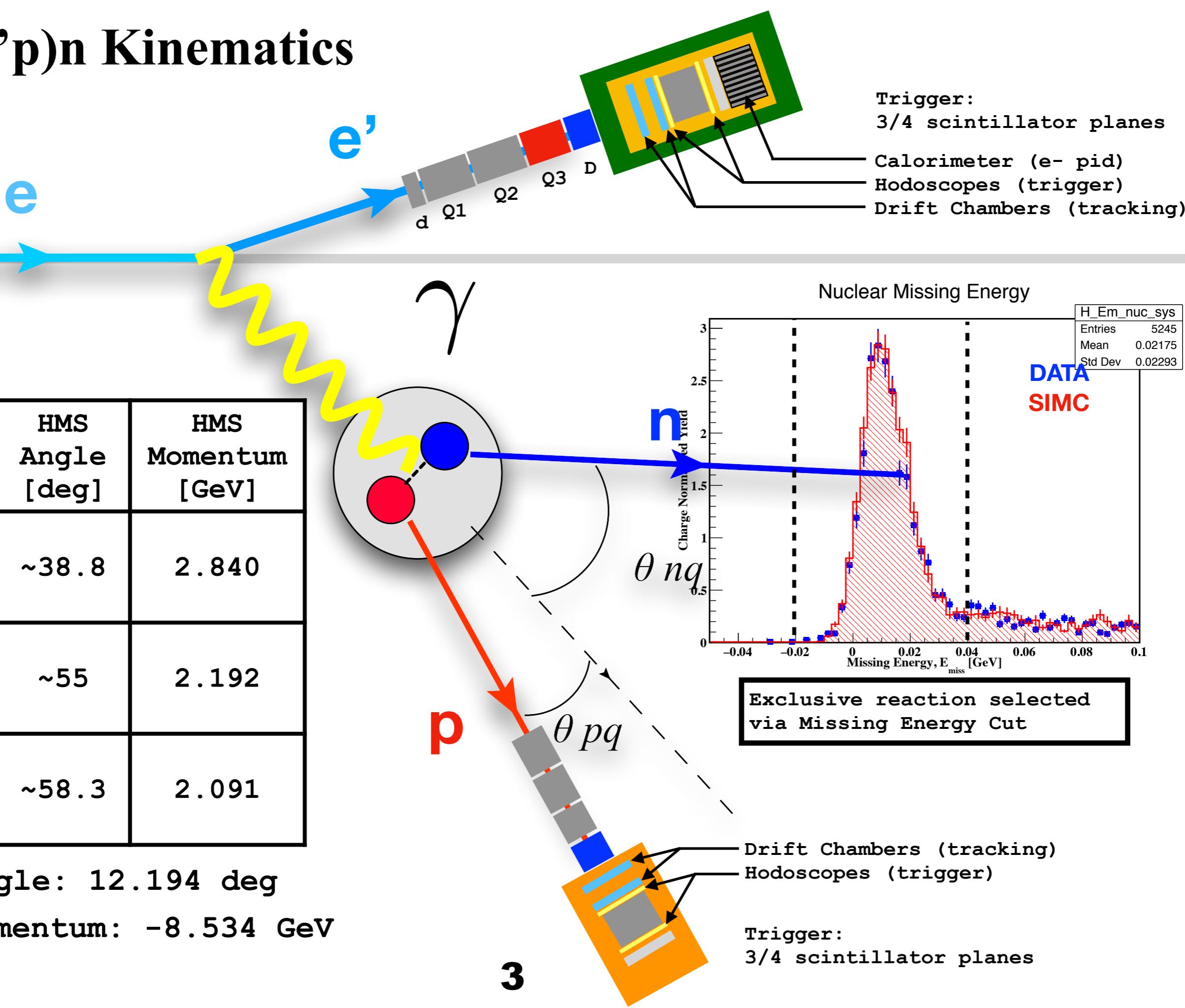
Carlos Yero

Motivation

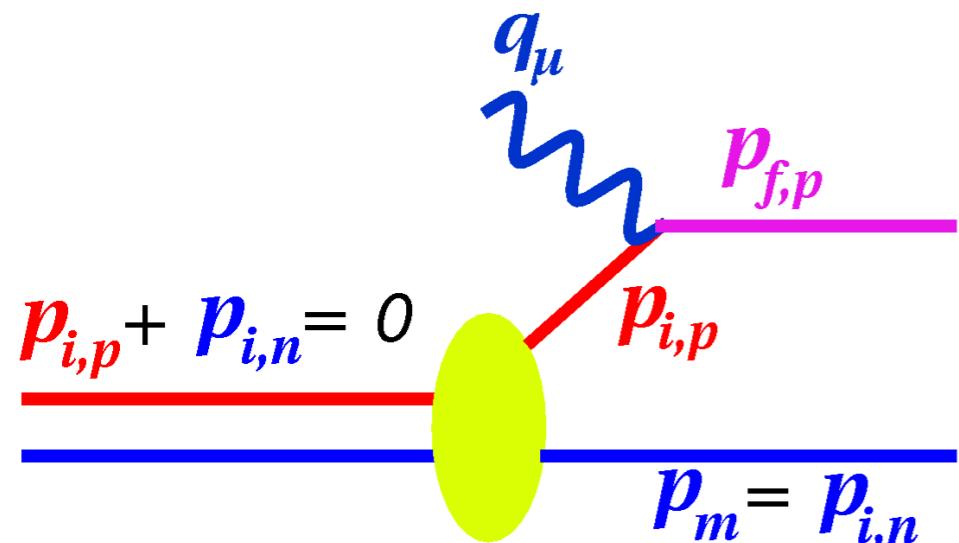
- Deuteron is the simplest np bound state: starting point to study nuclear force (or NN potential)
- Understand the short range structure by probing high momentum tails
- At short ranges, np start overlap: overlap is directly related to SRCs in $A > 2$ nuclei
- Extract momentum distributions beyond 500 MeV/c recoil momenta at PWIA kinematics



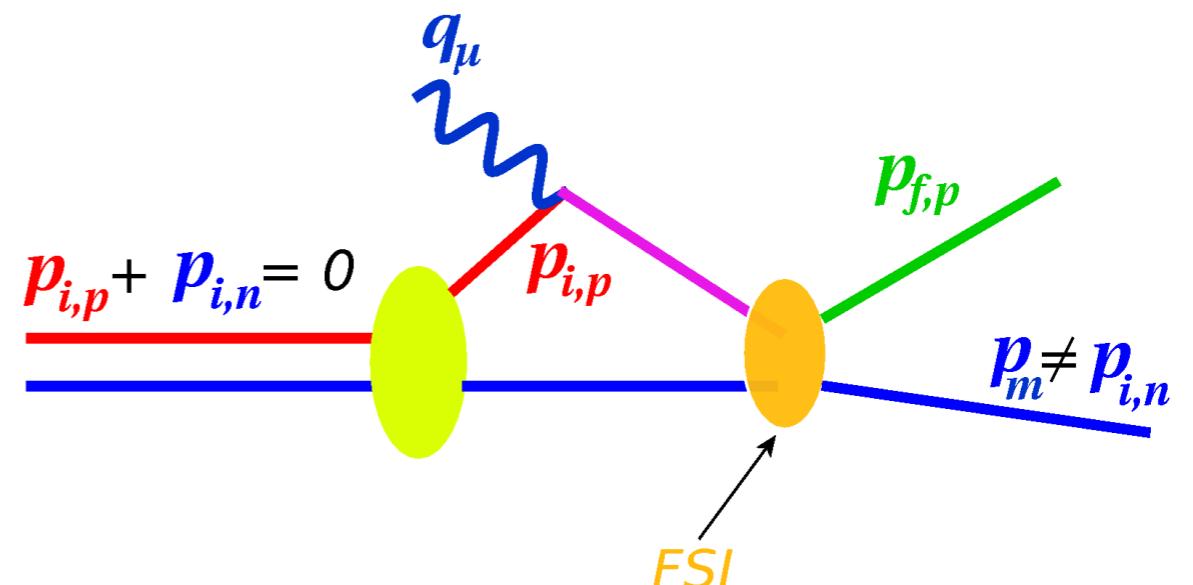
D(e,e'p)n Kinematics



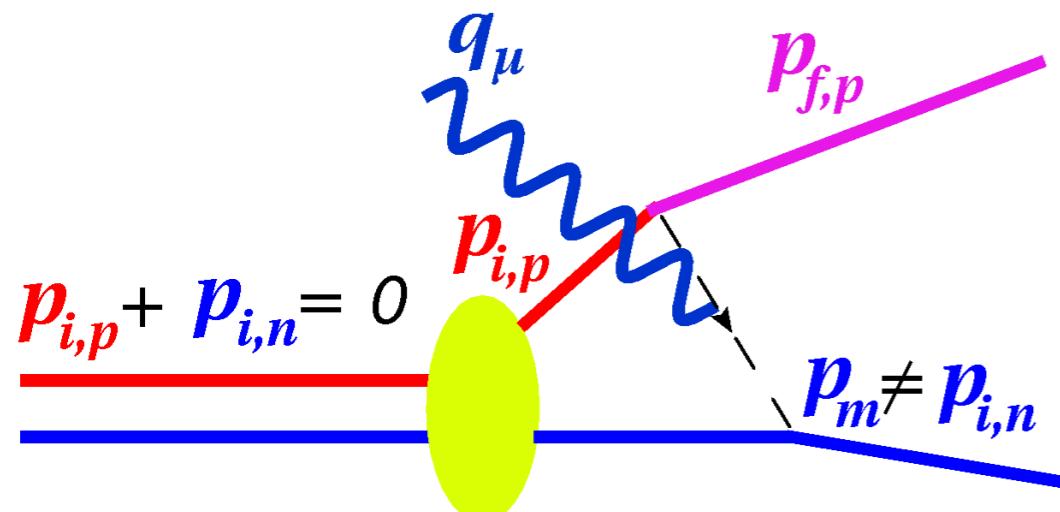
D(e,e'p)n Feynman Diagrams



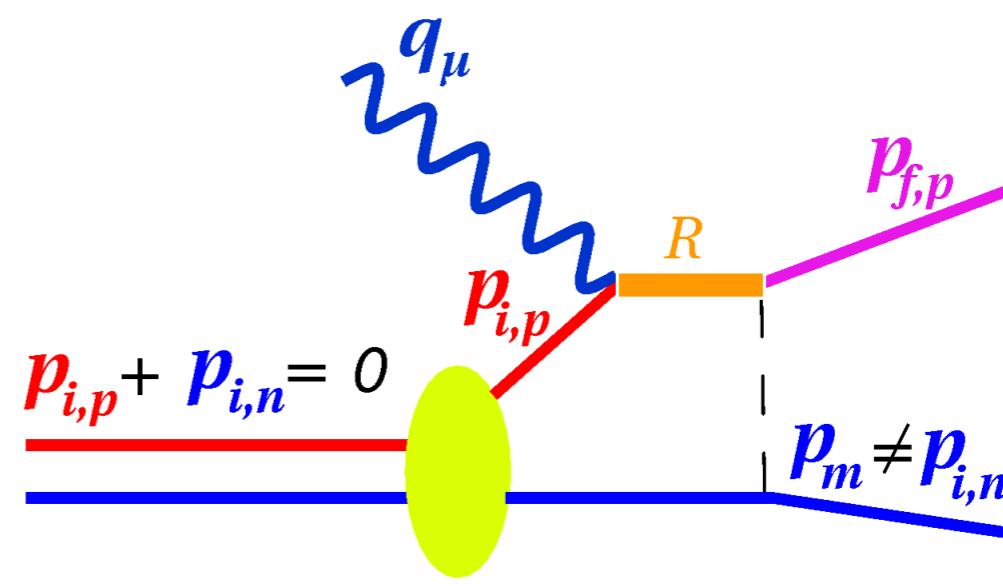
(a) Plane Wave Impulse Approximation (PWIA)



(b) Final State Interactions (FSI)

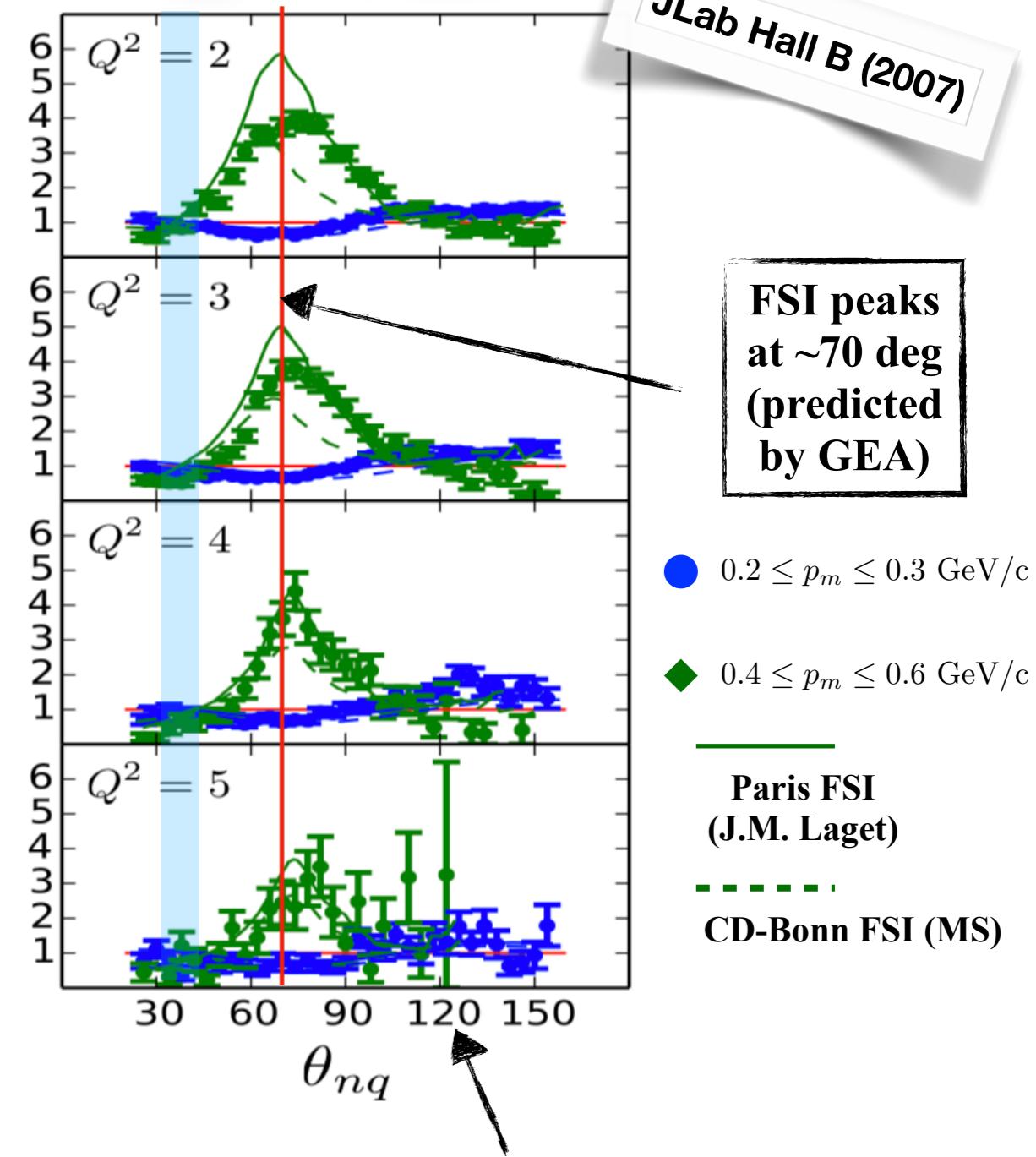
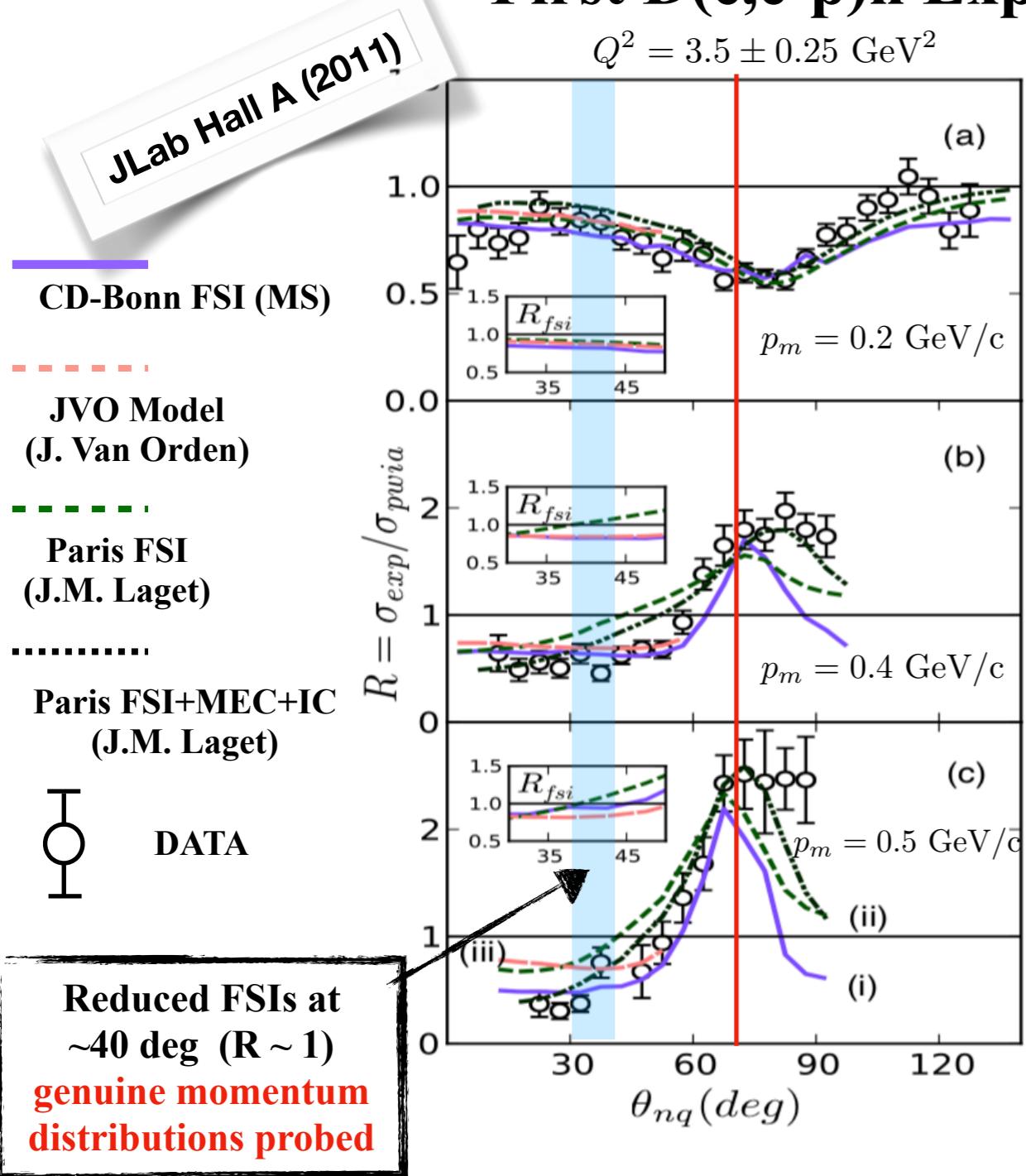


(c) Meson-Exchange Currents (MEC)



(d) Isobar Configurations (IC)

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



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

**Reduced FSIs at ~120 deg ($R \sim 1$),
But ICs are significant**

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-necessary 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.



Optimize SHMS delta matrix



Used sieve data to optimize Y_{tar}



Determined spectrometer kinematics offsets

Details can be found in documentation

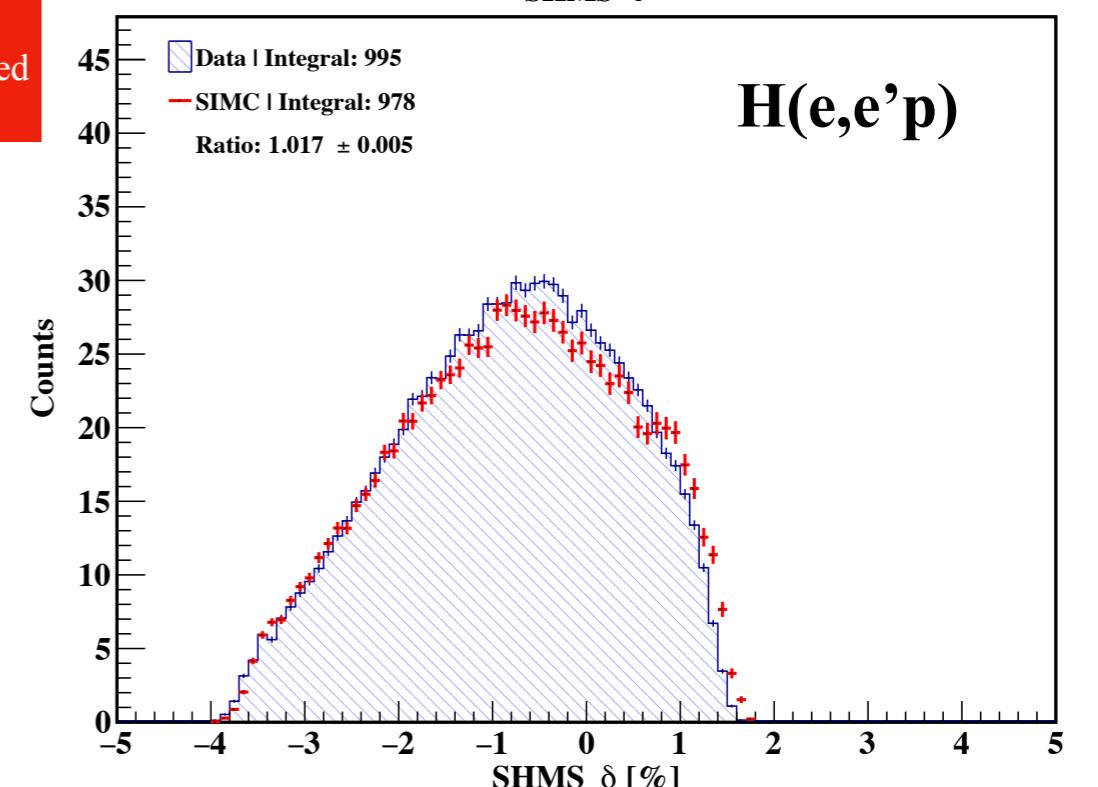
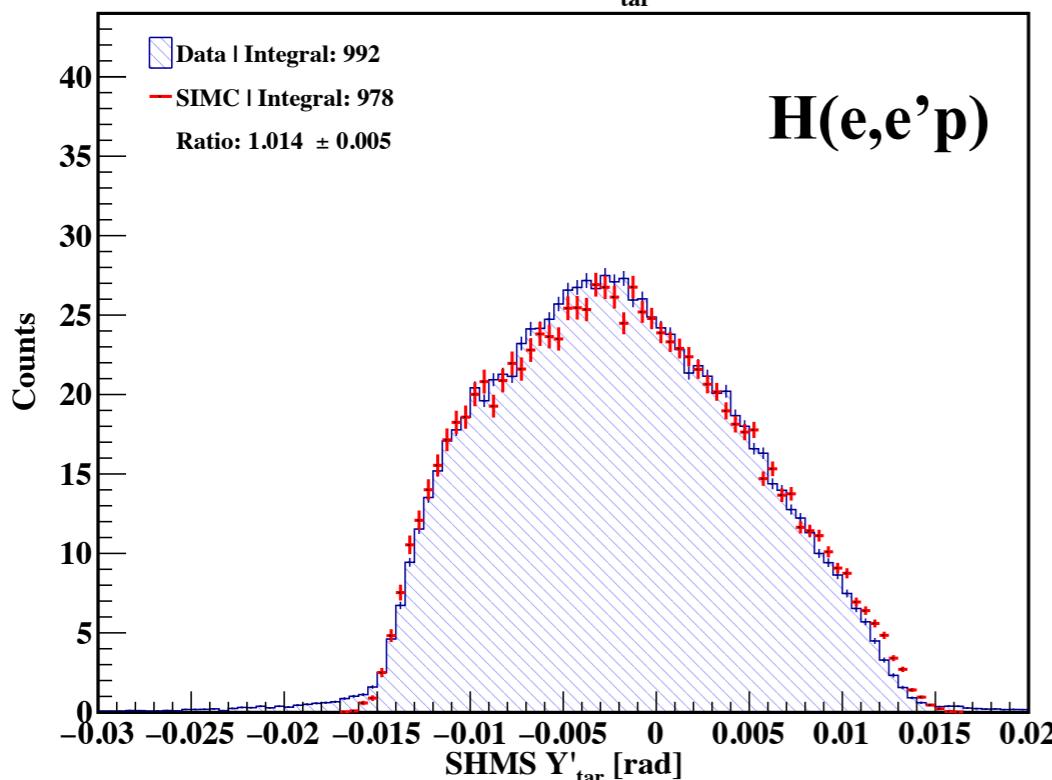
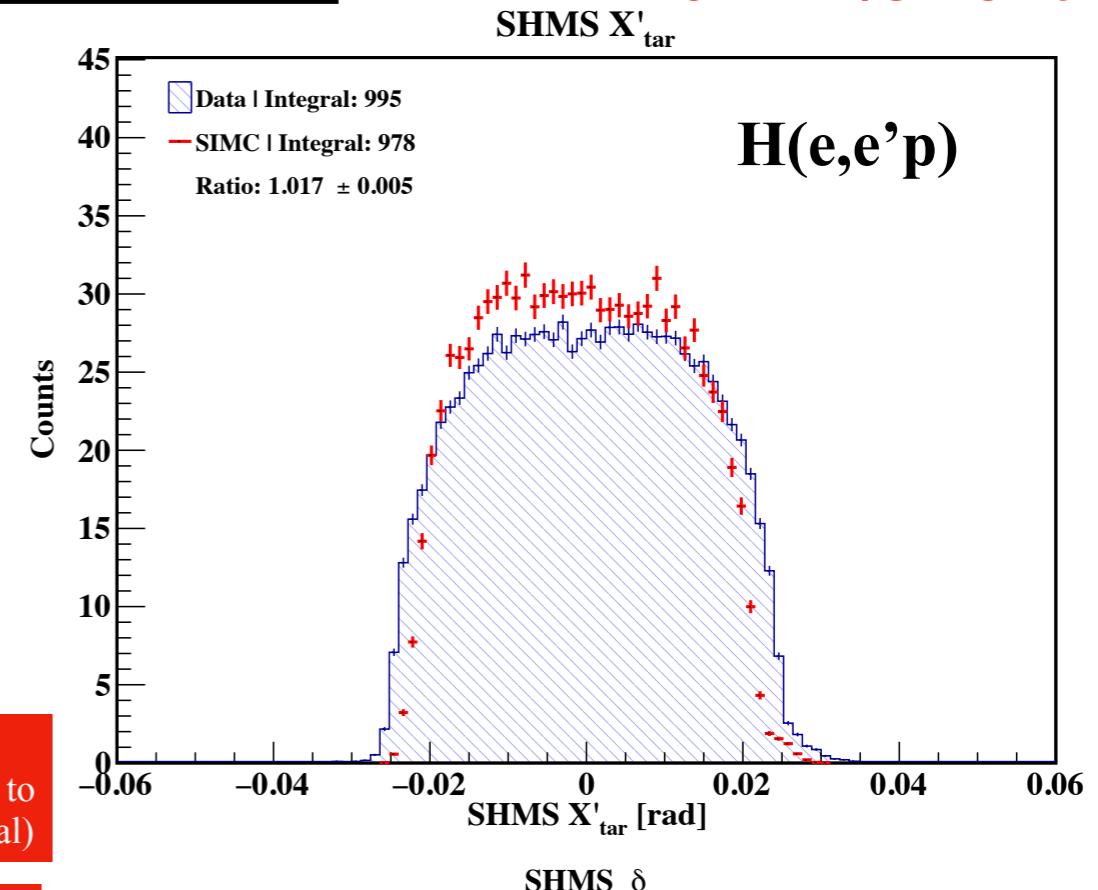
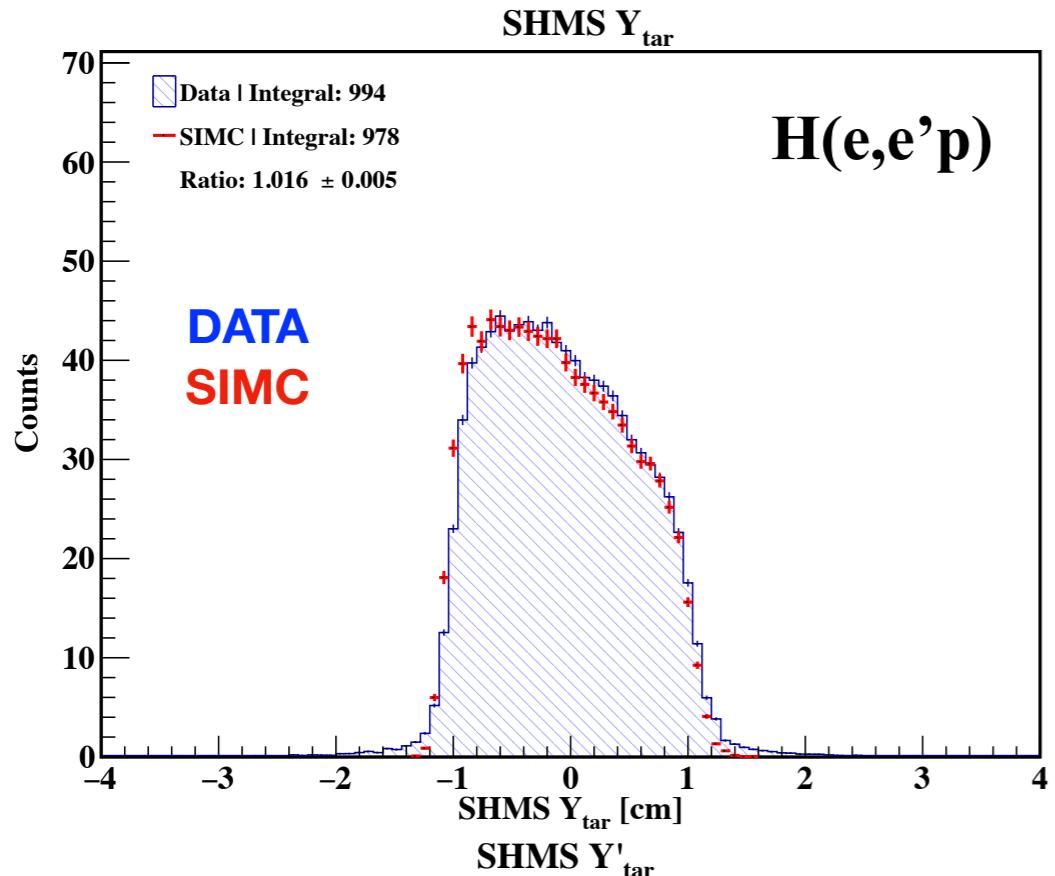
HALLC DOC-DB LINK

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)



Spectrometer Acceptance DATA/SIMULATION

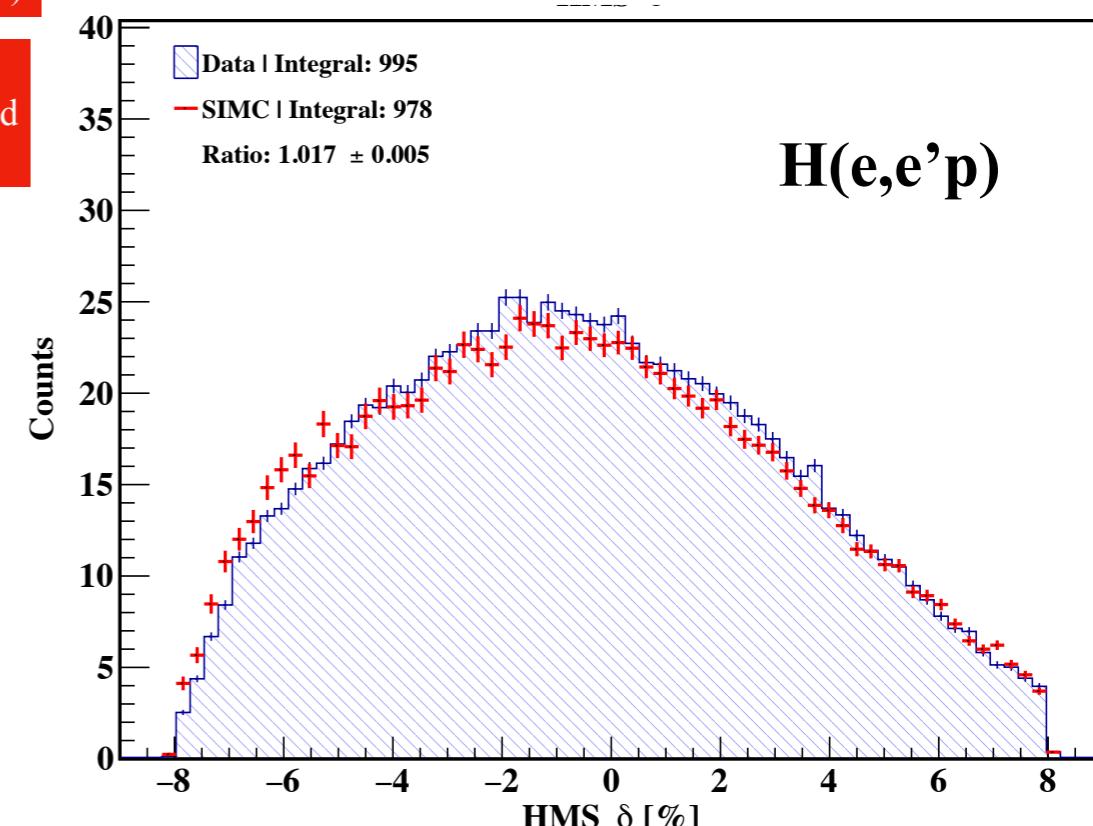
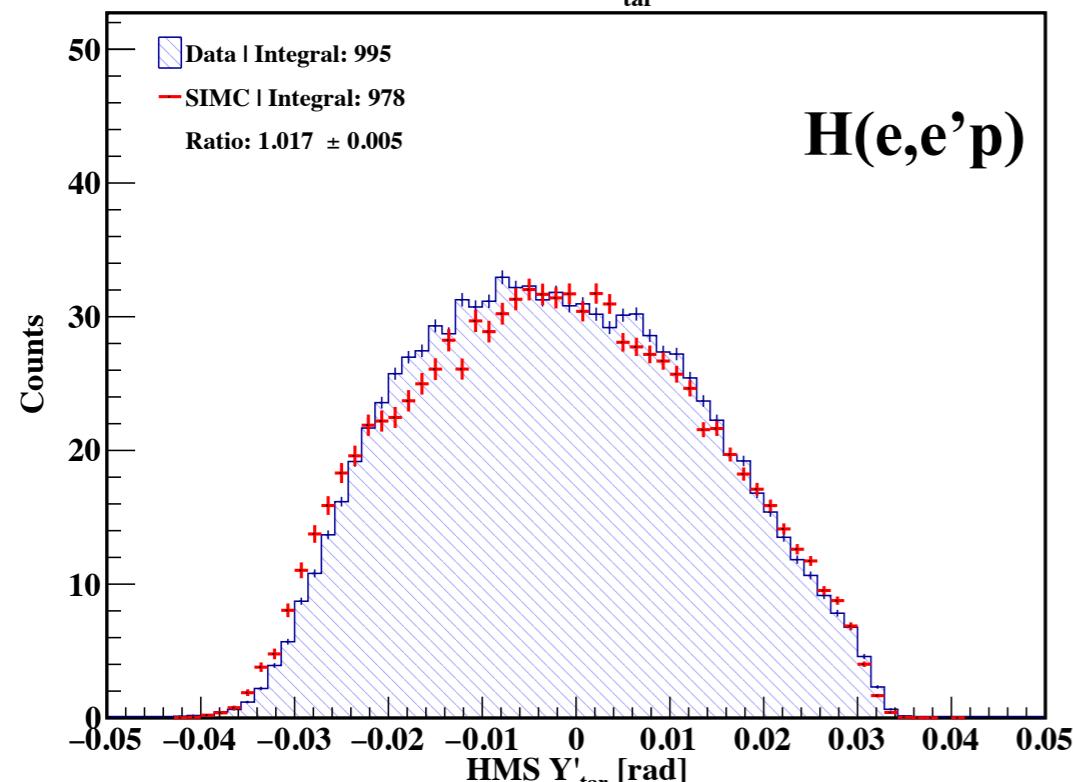
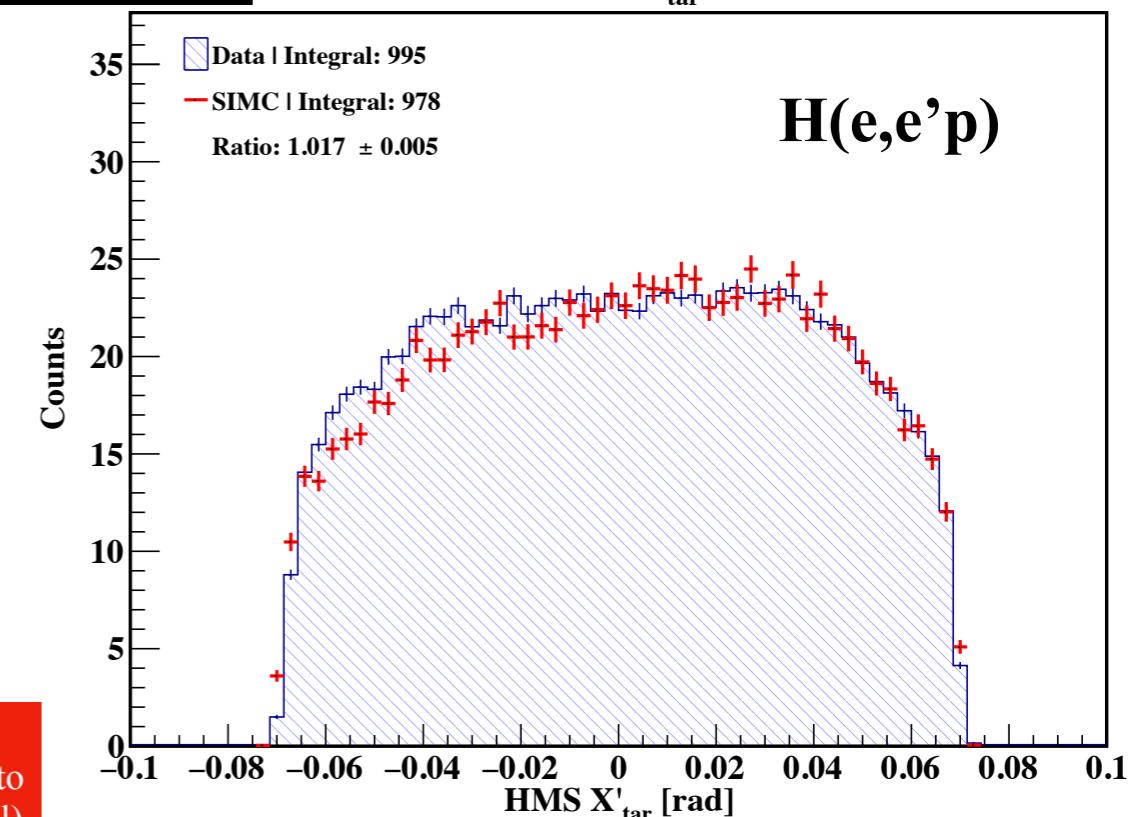
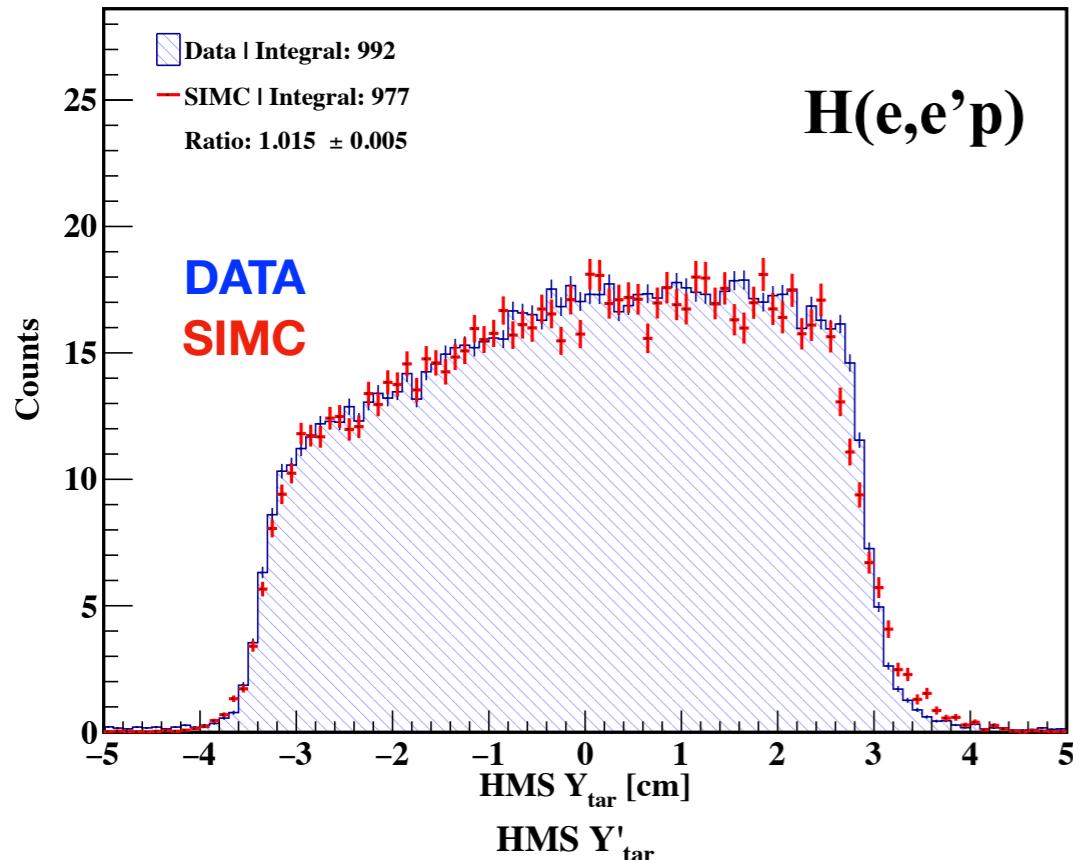
(used H(e,e'p) Elastics data taken on D(e,e'p)n Experiment)

(See Backup Slides
for DATA/SIMC Ratio)

HMS Reconstructed Variables

HMS Y_{tar}

HMS X'_{tar}



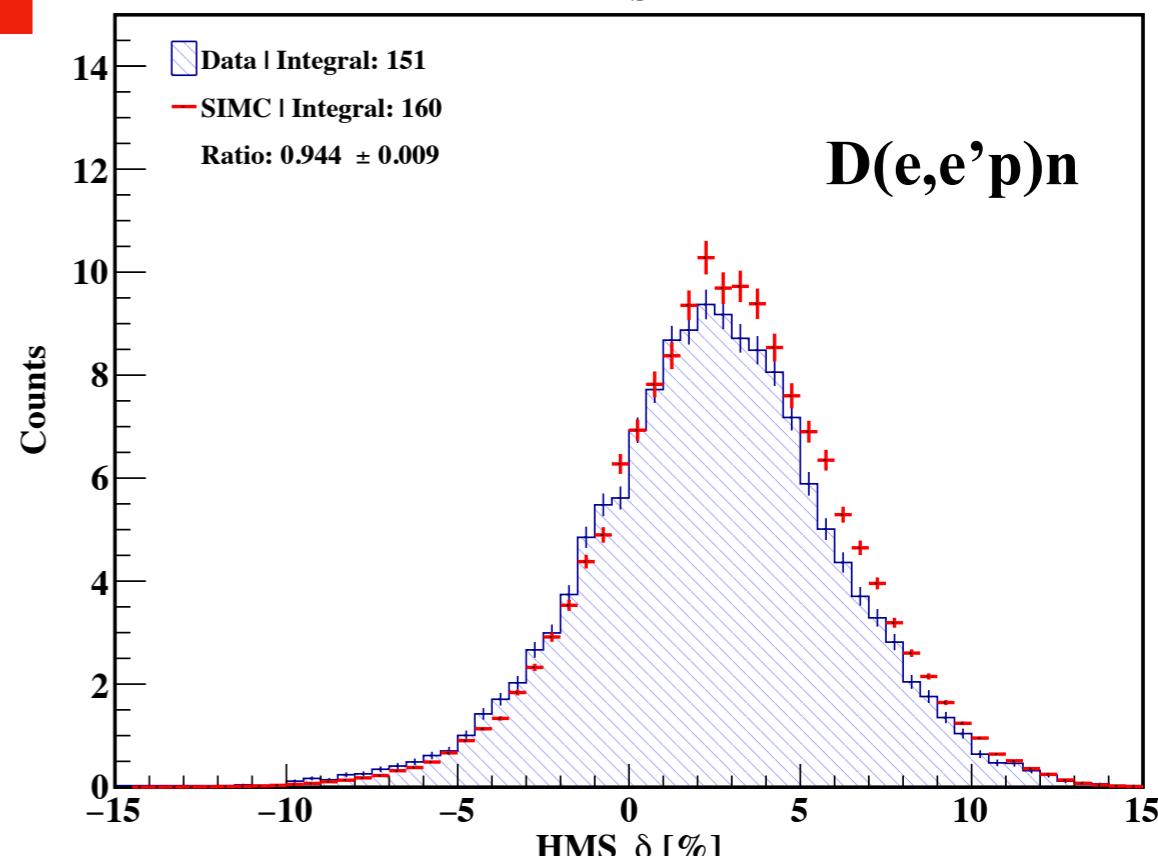
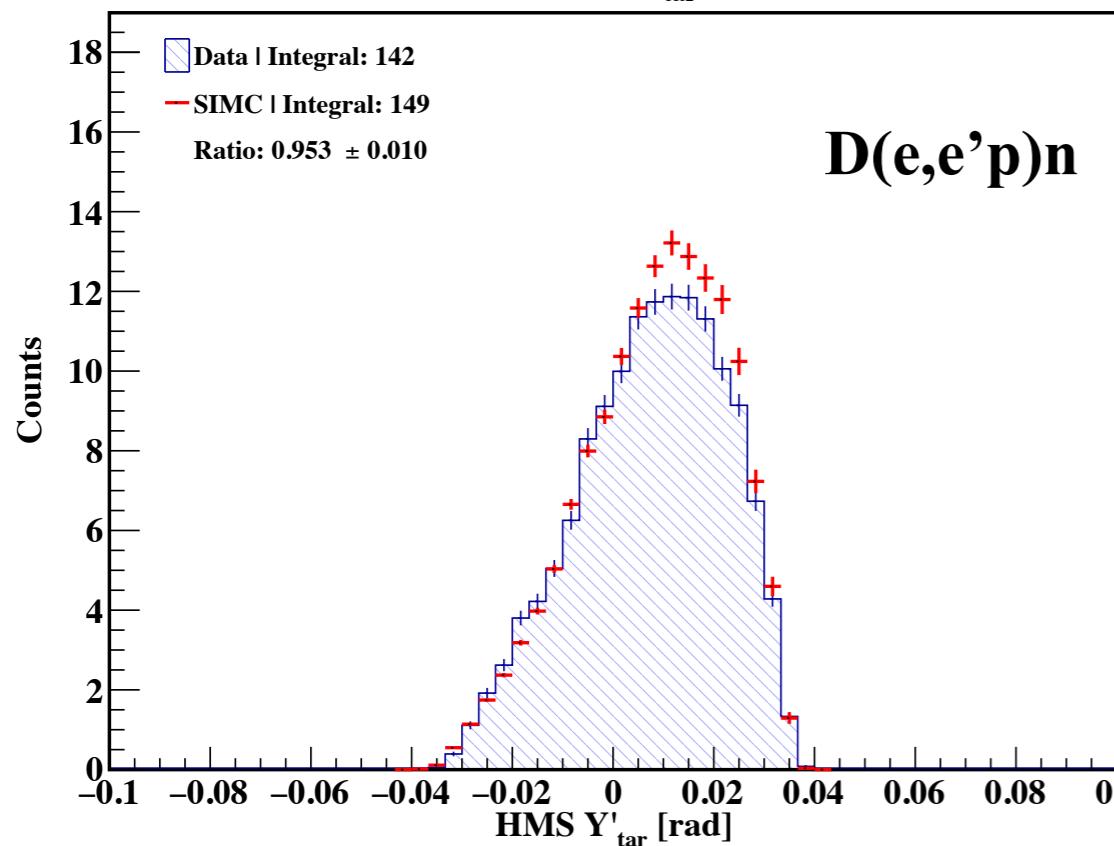
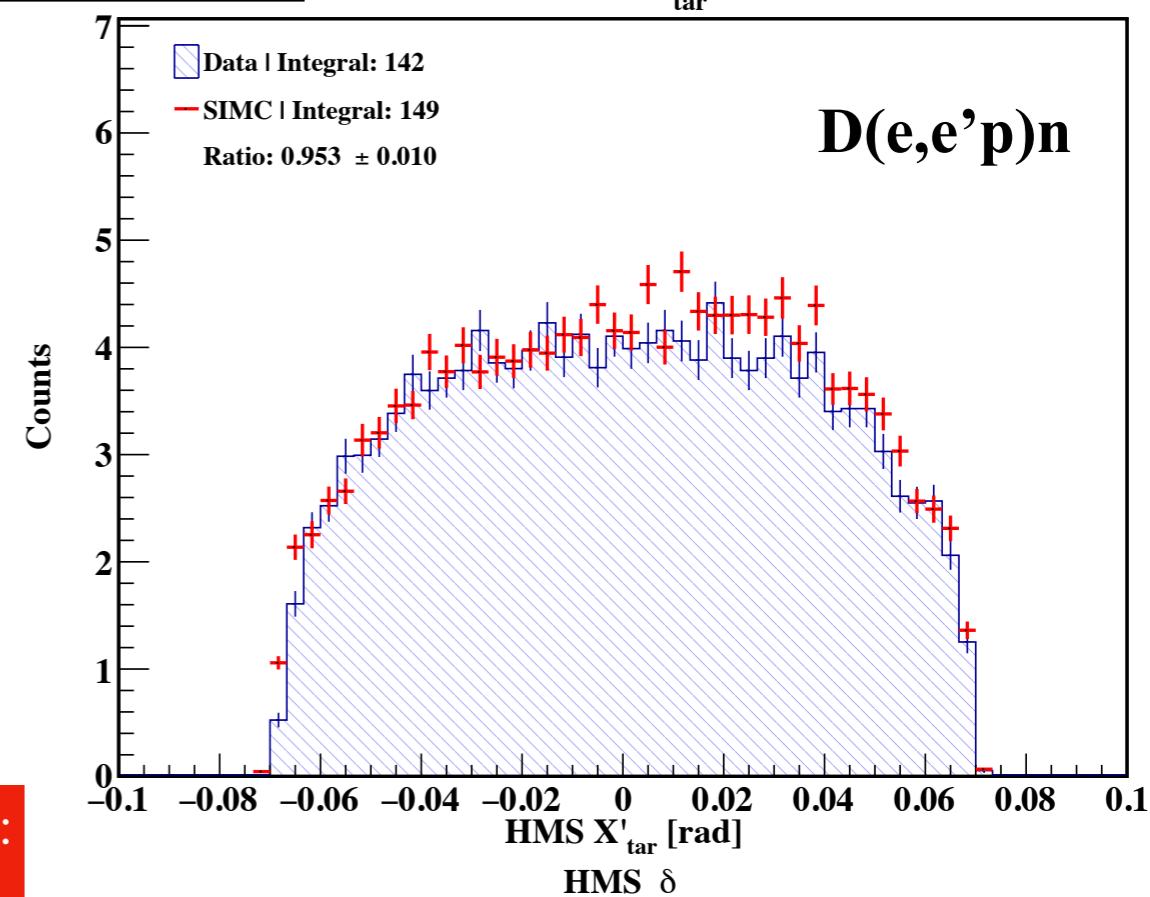
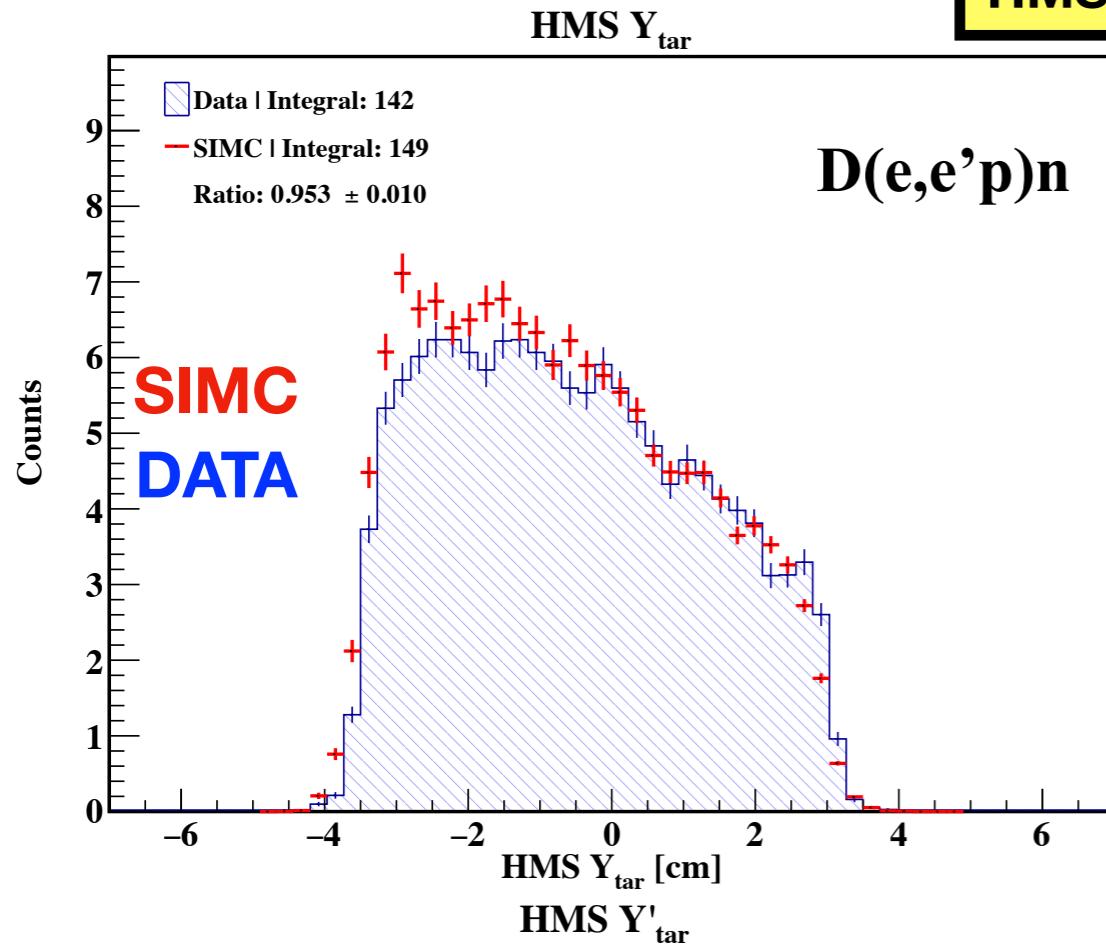
We know the
H(e,e'p) cross section to
 $97 \pm 0.3\%$ (statistical)

Elastic form factors
error is NOT accounted
for in SIMC

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

(See Backup Slides
for DATA/SIMC Ratio)

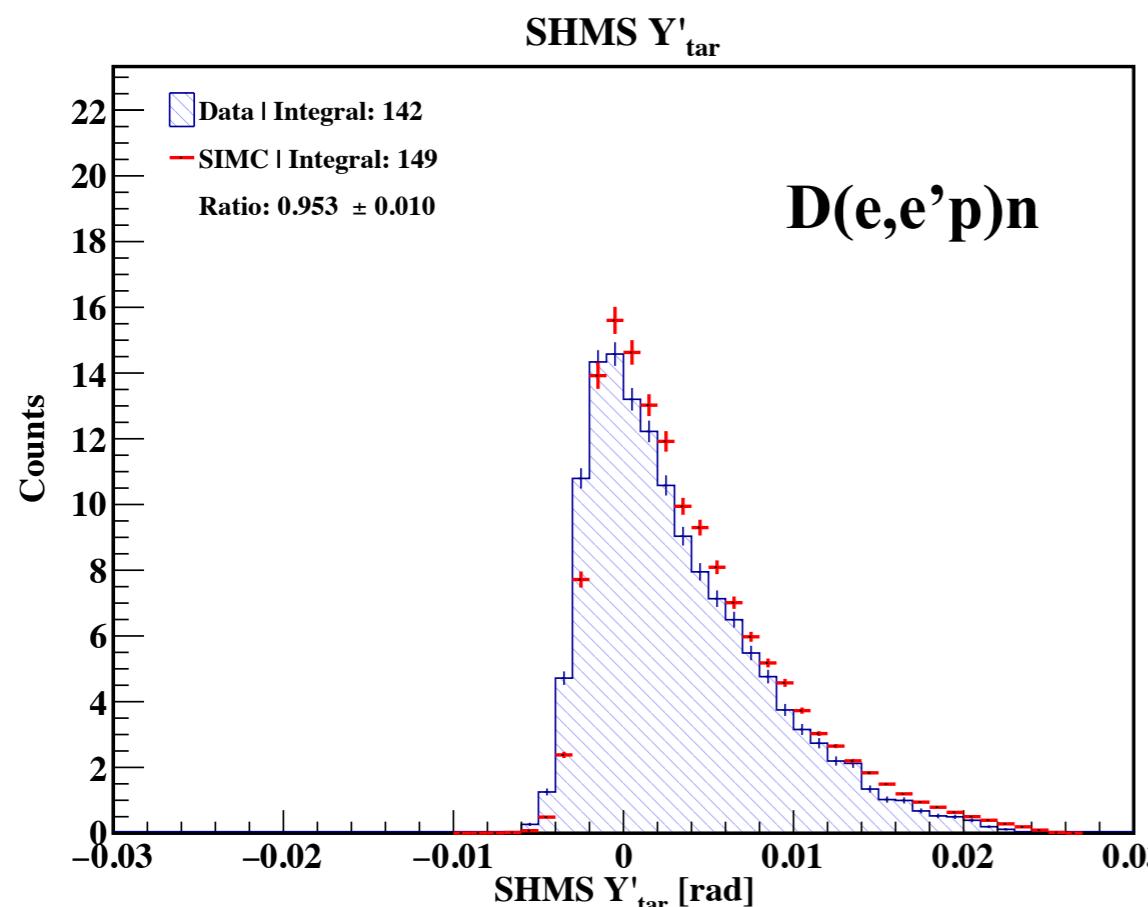
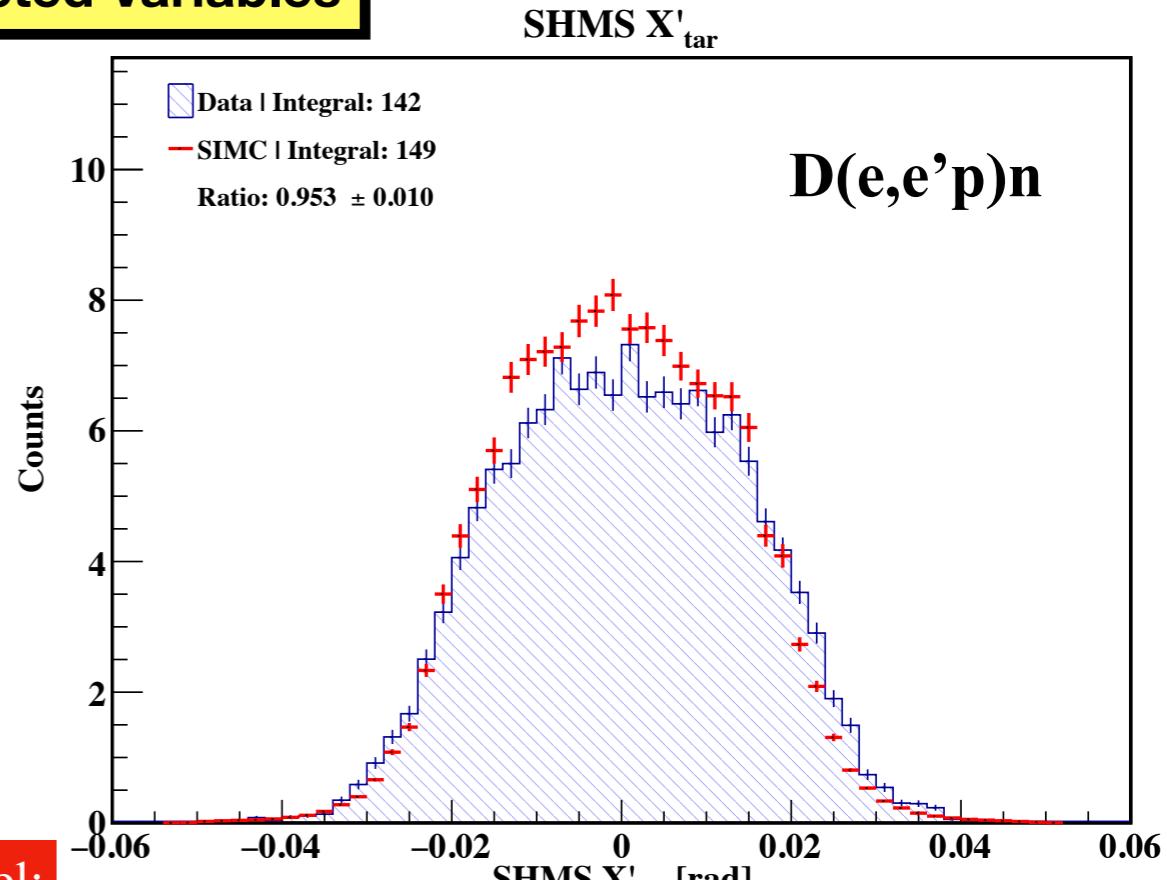
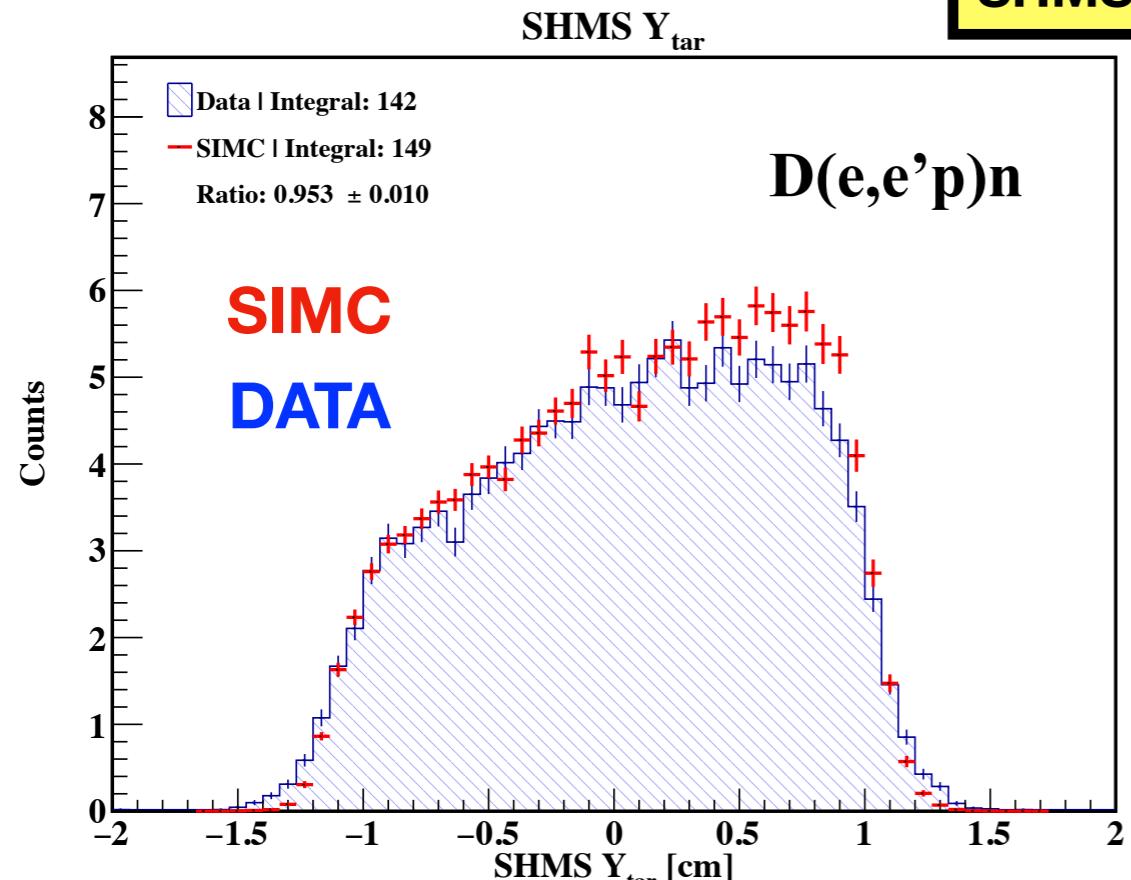
HMS Reconstructed Variables



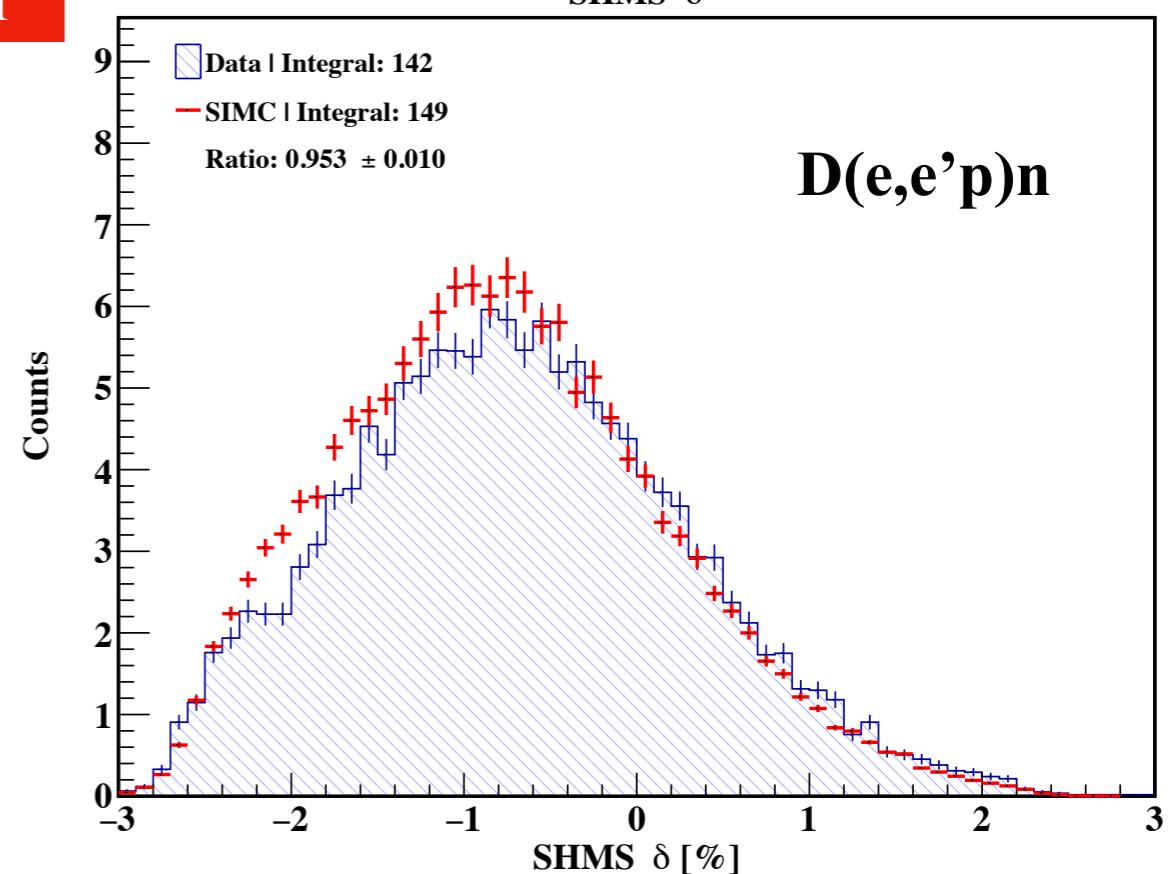
Spectrometer Acceptance

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

SHMS Reconstructed Variables



**SIMC Model:
Laget FSI**



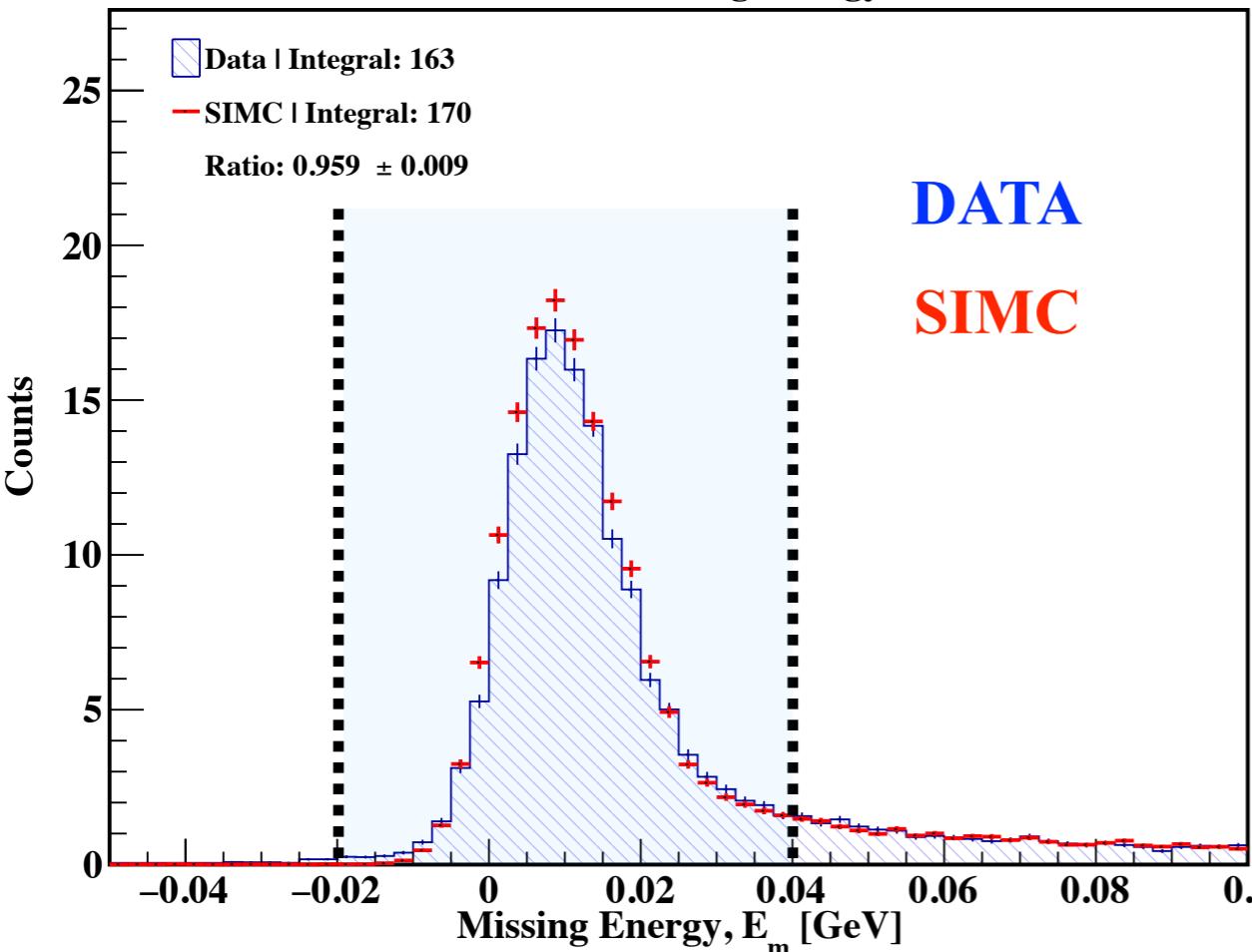
$D(e,e'p)n$

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)

Nuclear Missing Energy



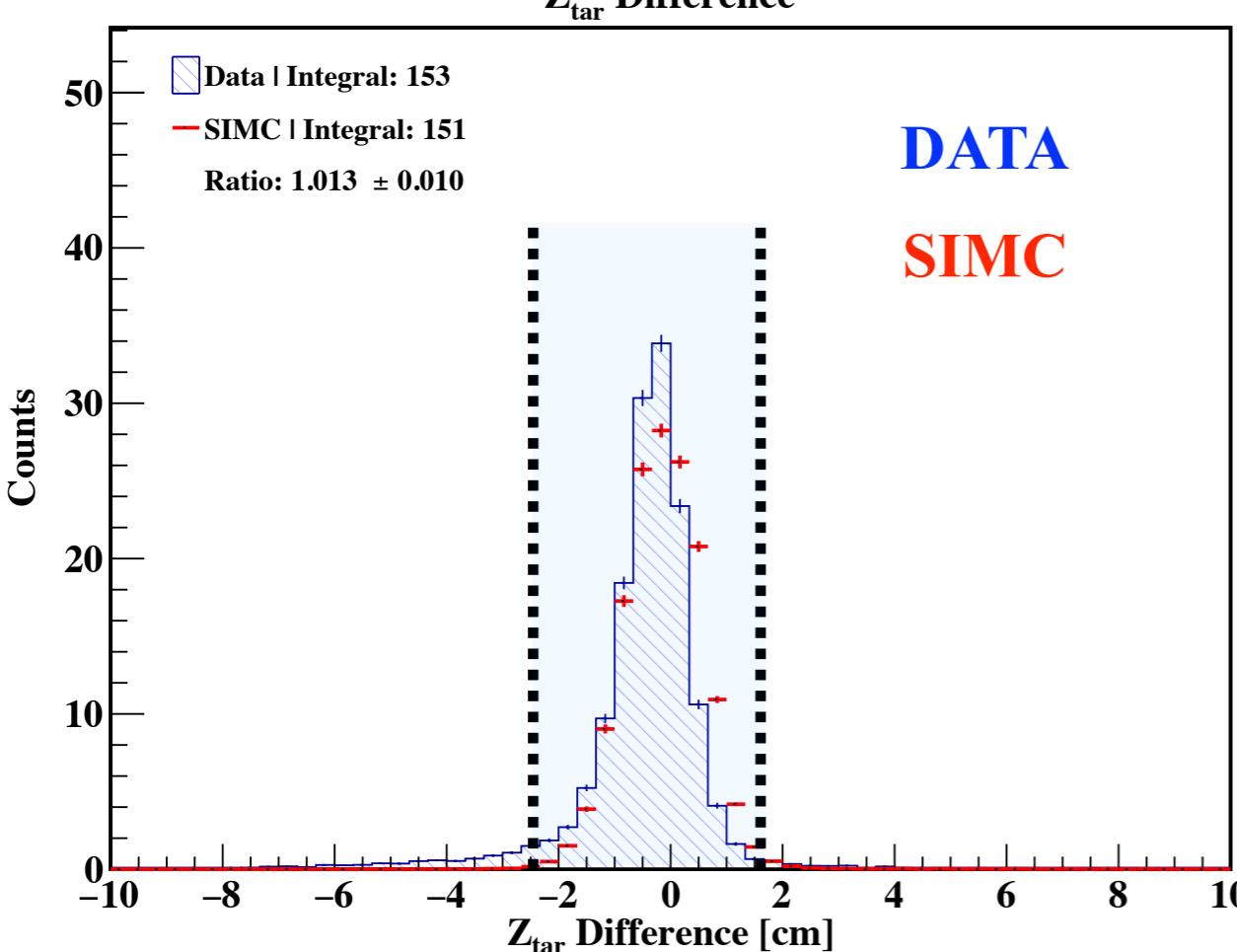
Missing Energy Cut: (-20, 40) MeV

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

$$E_m = \omega - T_p - T_r$$

↑
Missing energy
is the B.E. of deuteron
(~2.22 MeV)

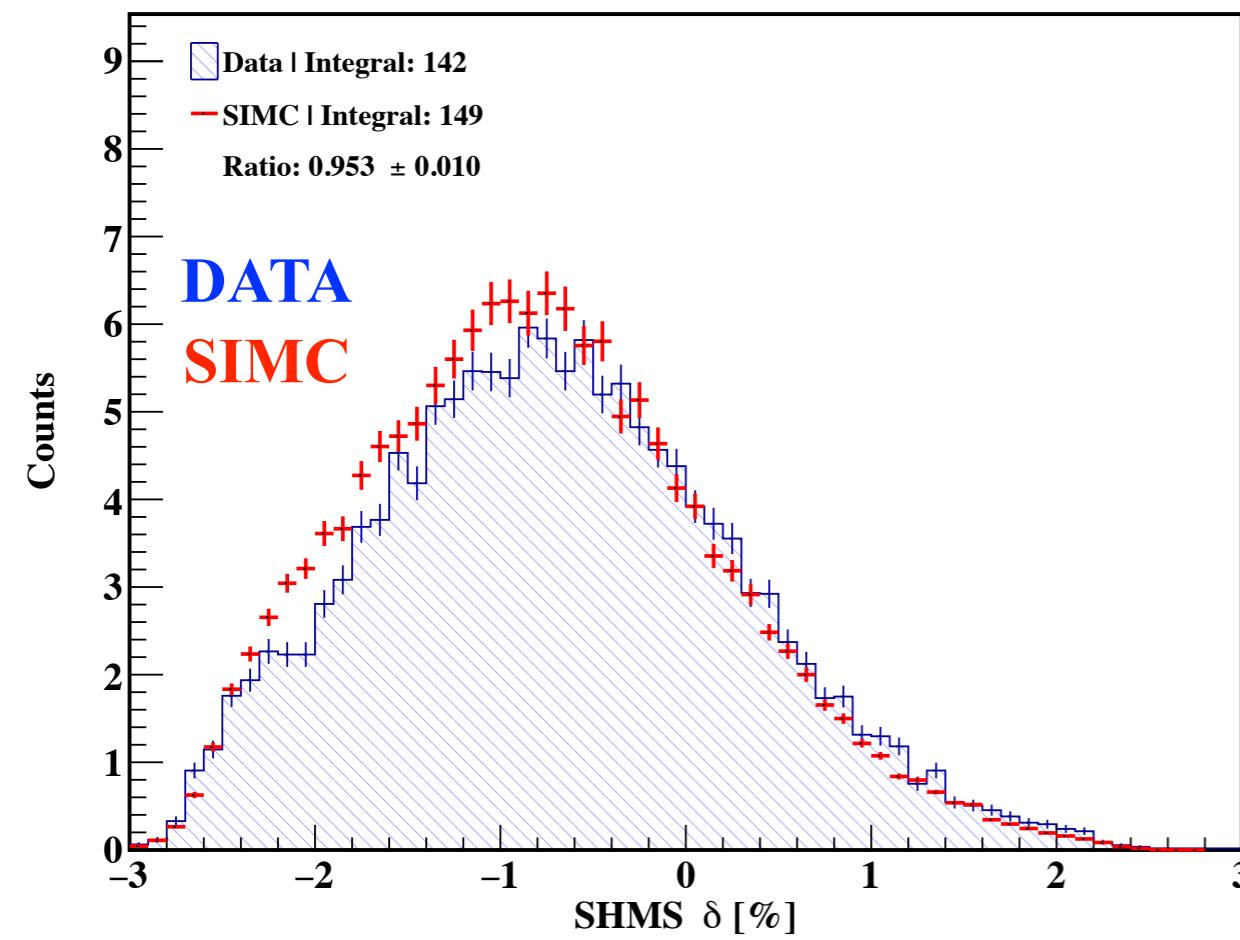
↑
Assume the mass
of the neutron



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

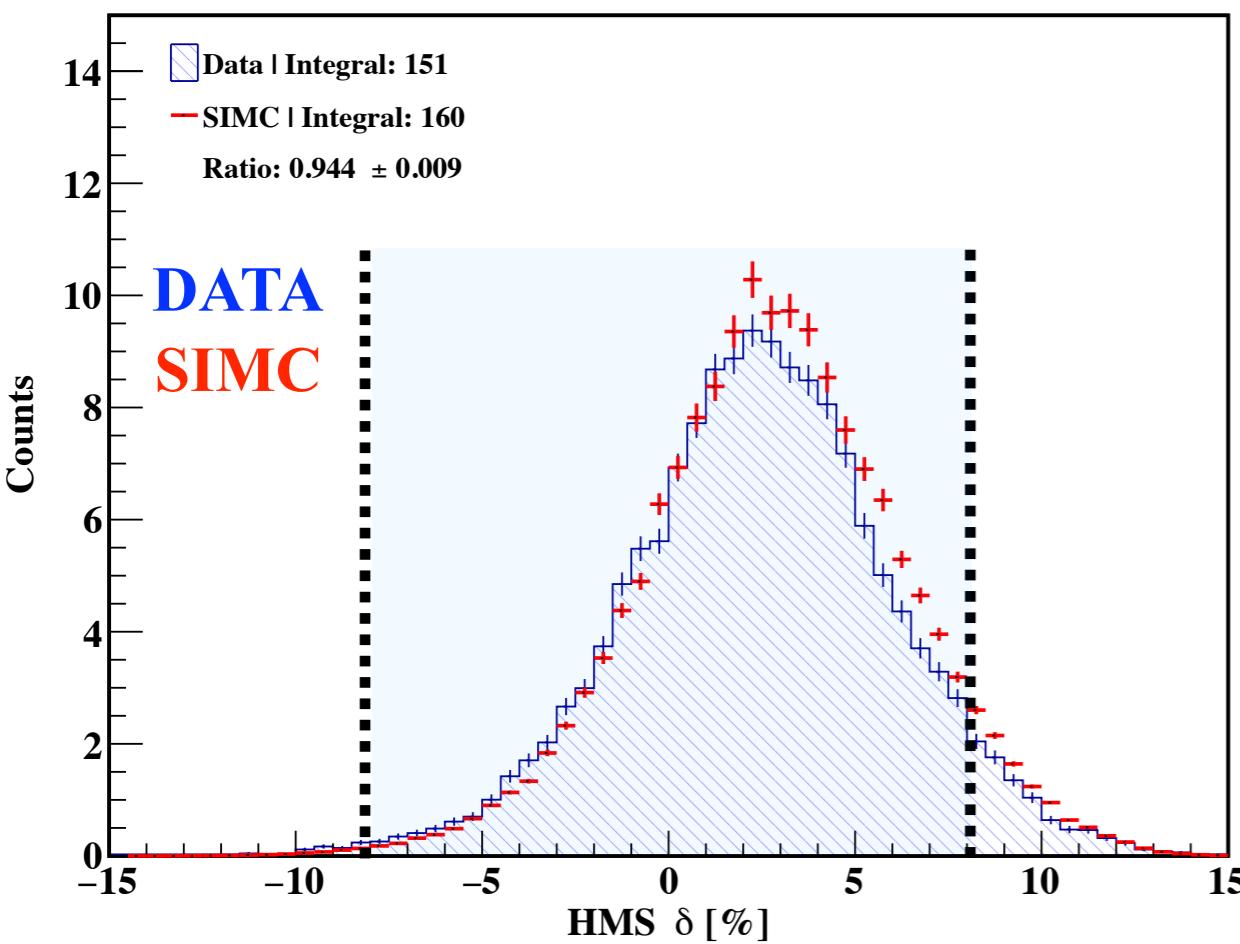
SHMS δ



SHMS Delta Acceptance (-3, 3) %

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

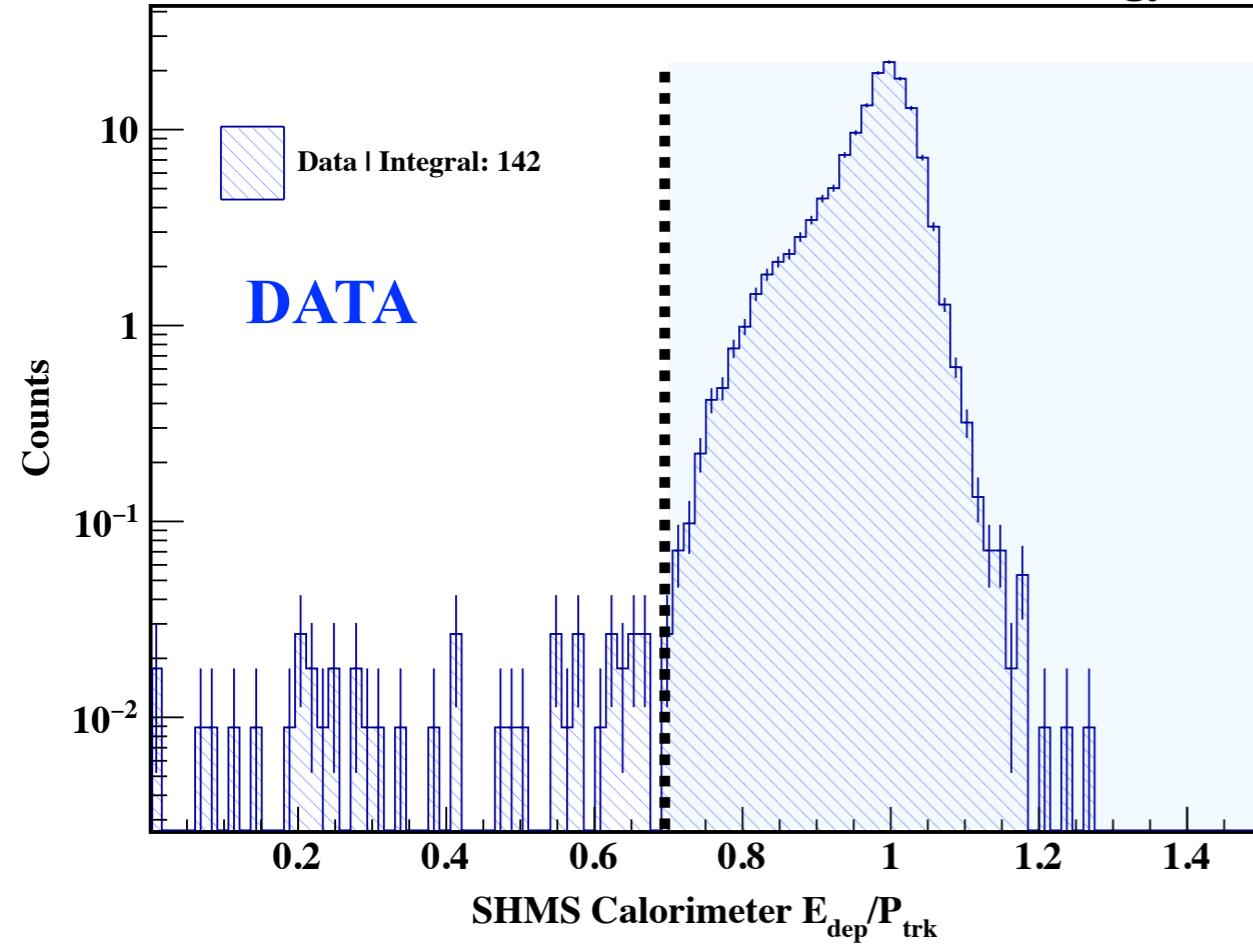
HMS δ



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

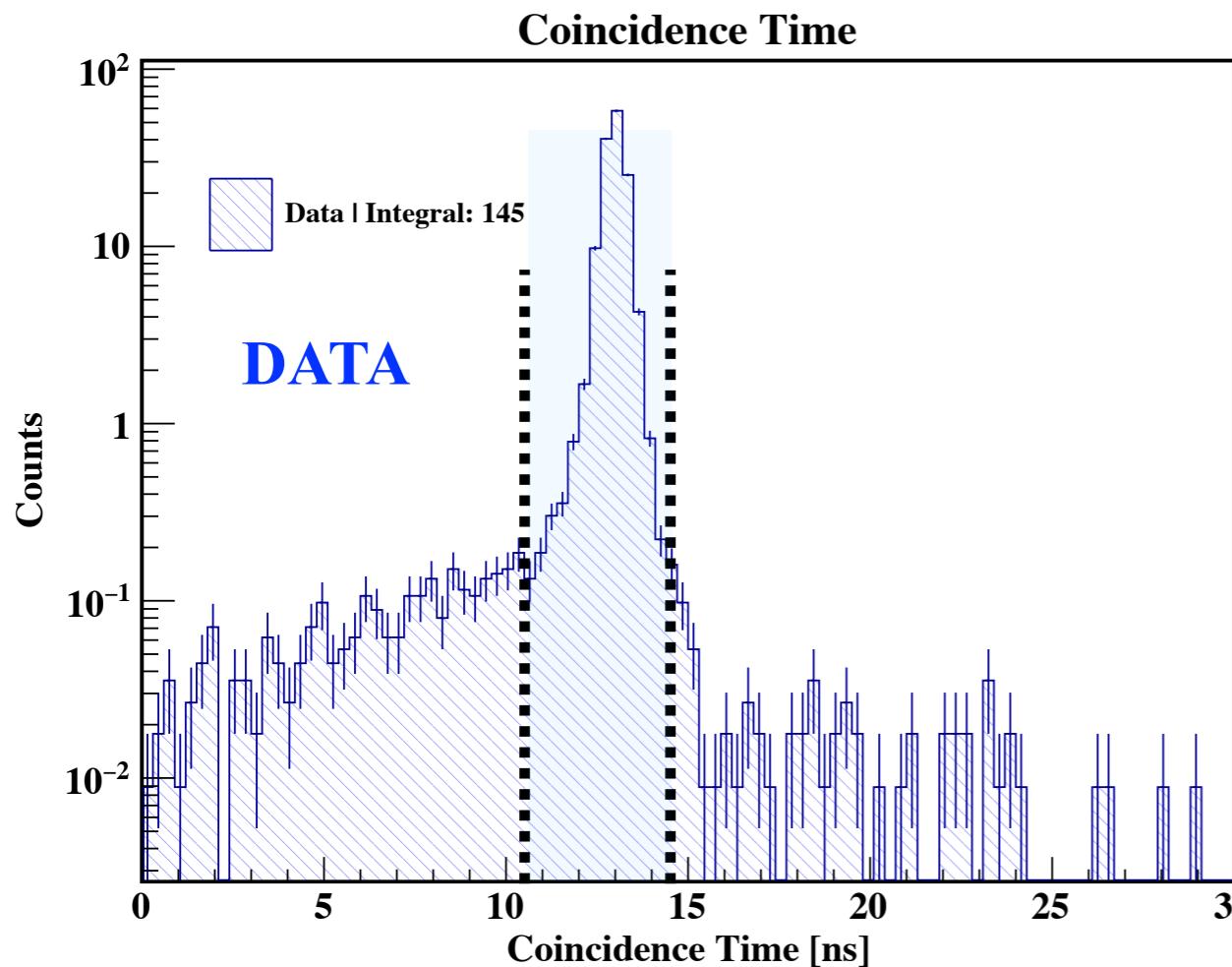
Select HMS acceptance region where Optics Reconstruction is reliable

SHMS Calorimeter Total Normalized Energy



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

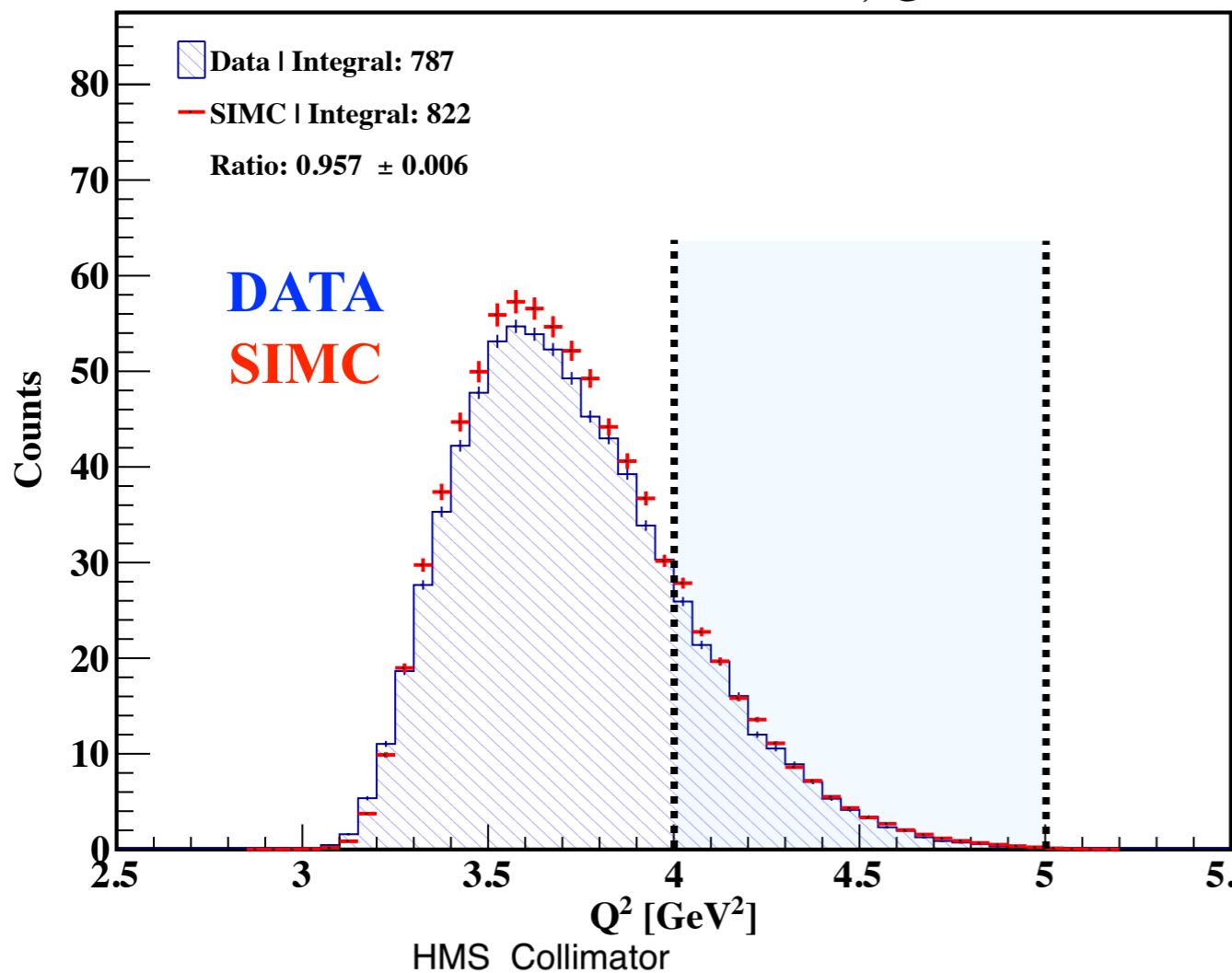
select true electrons in SHMS
and not pions (looks very clean!)



**Coincidence Time Cut
CUT: (10.5, 14.5) ns**

select true electron-proton coincidences

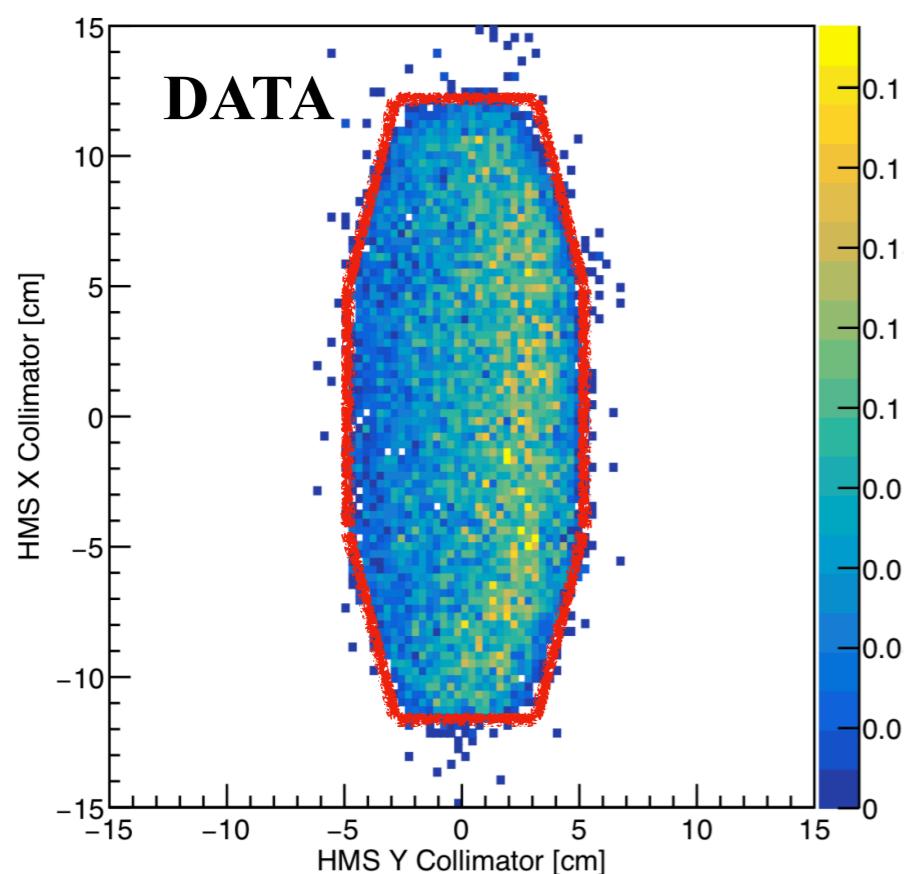
4-Momentum Transfer, Q^2



4-Momentum Transfer Cut

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

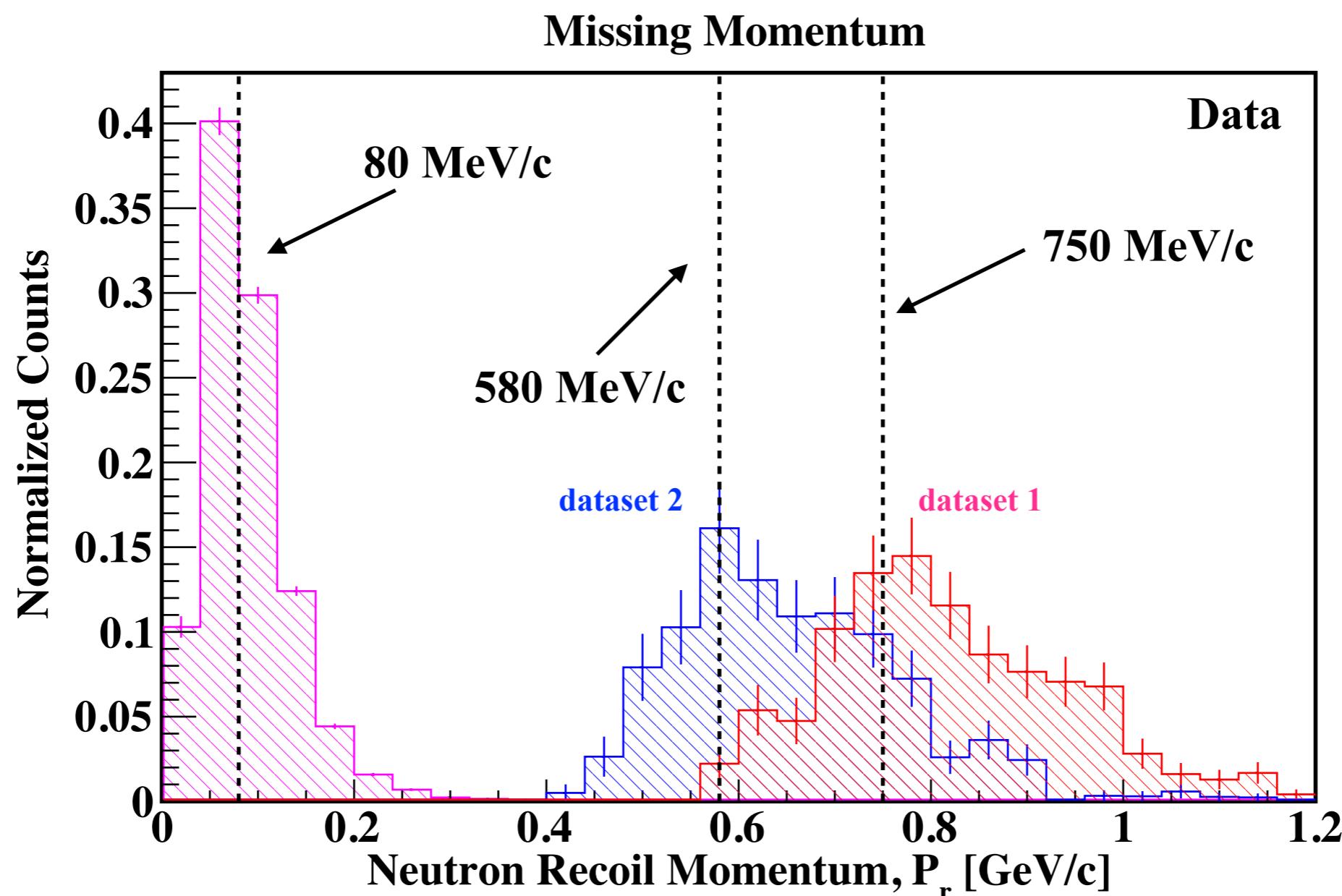
Kinematics cut to select only events with high momentum transfer (as stated on the proposal)



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

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

Corrected Data Yield

Phase Space Volume

Radiative Correction

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

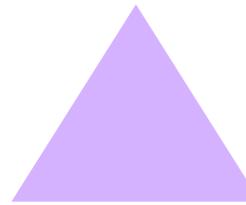
Normalize data by total charge

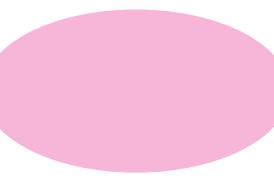
Correct for Inefficiencies

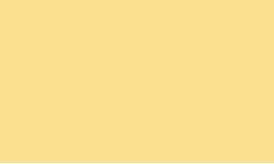
Extraction of the D(e,e'p)n Cross Section

Spectrometer Acceptance (or Phase Space) Definition

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

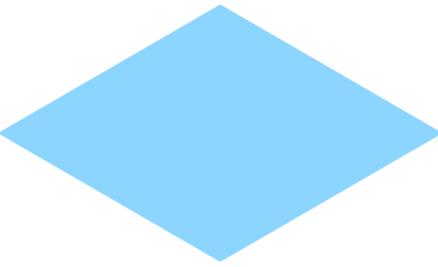
 Normalization Factor

 Accepted Events within
spec. Acceptance

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

 Luminosity

 Spectrometer
"Solid Angles"

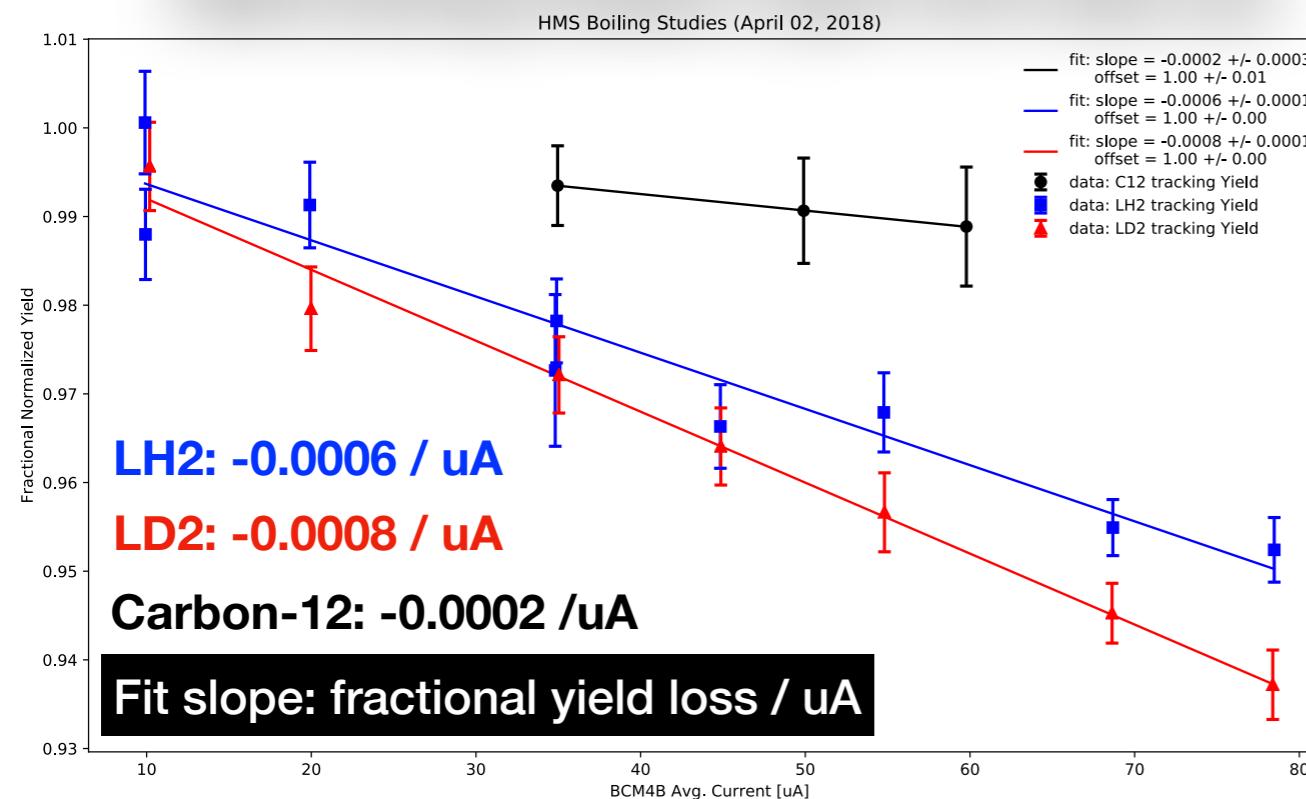
 Generated Events

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

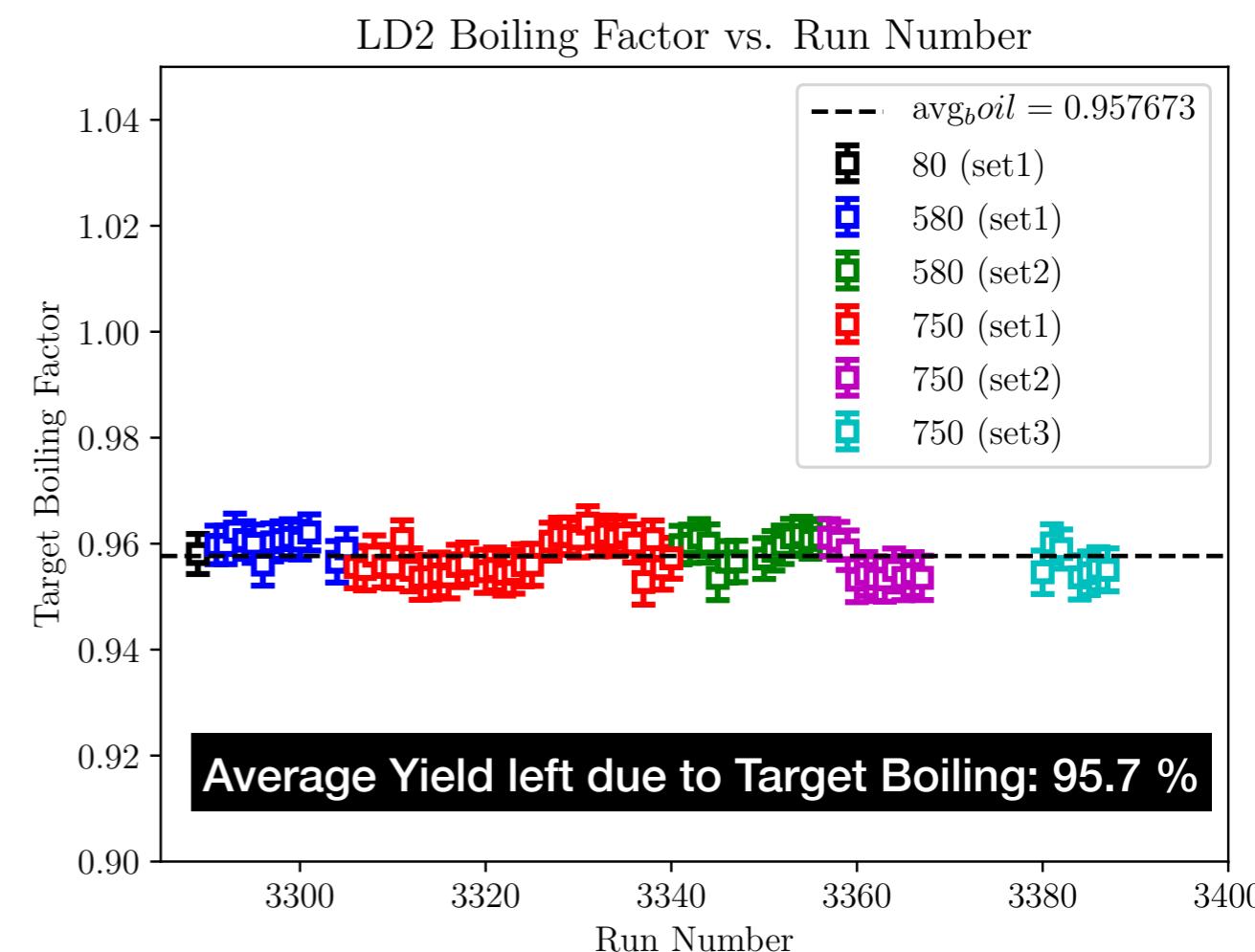
See Backup Slides

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

HMS Boiling Studies (April 2018 data set)



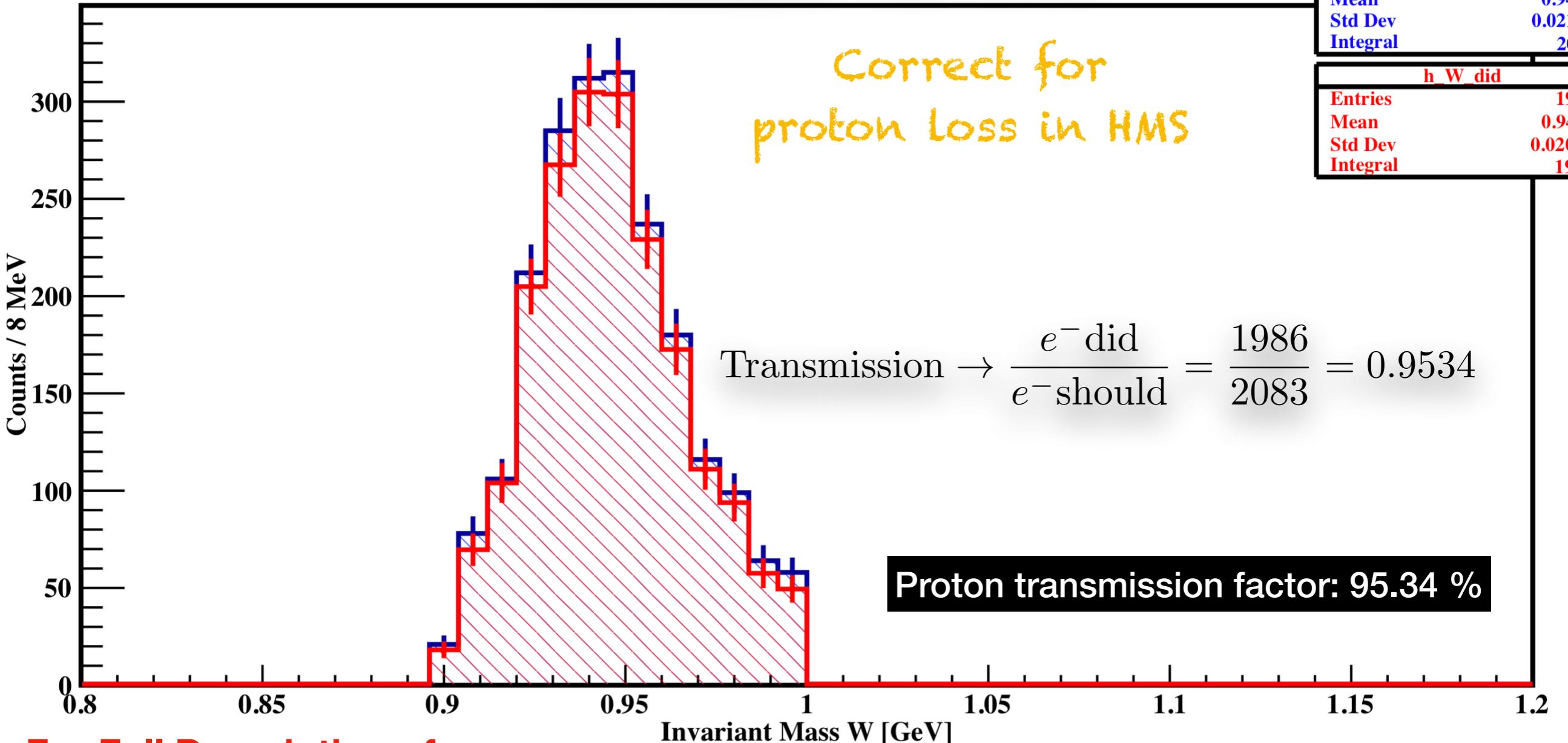
Correct for yield loss due
to target boiling



Target Boiling Corrections
See DOC DB Link [HERE](#) !

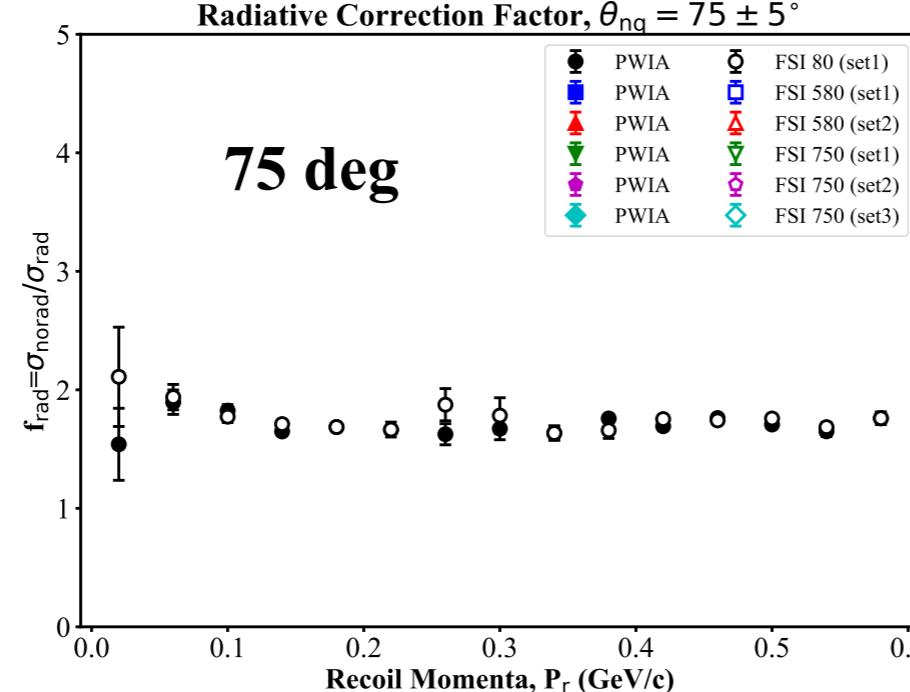
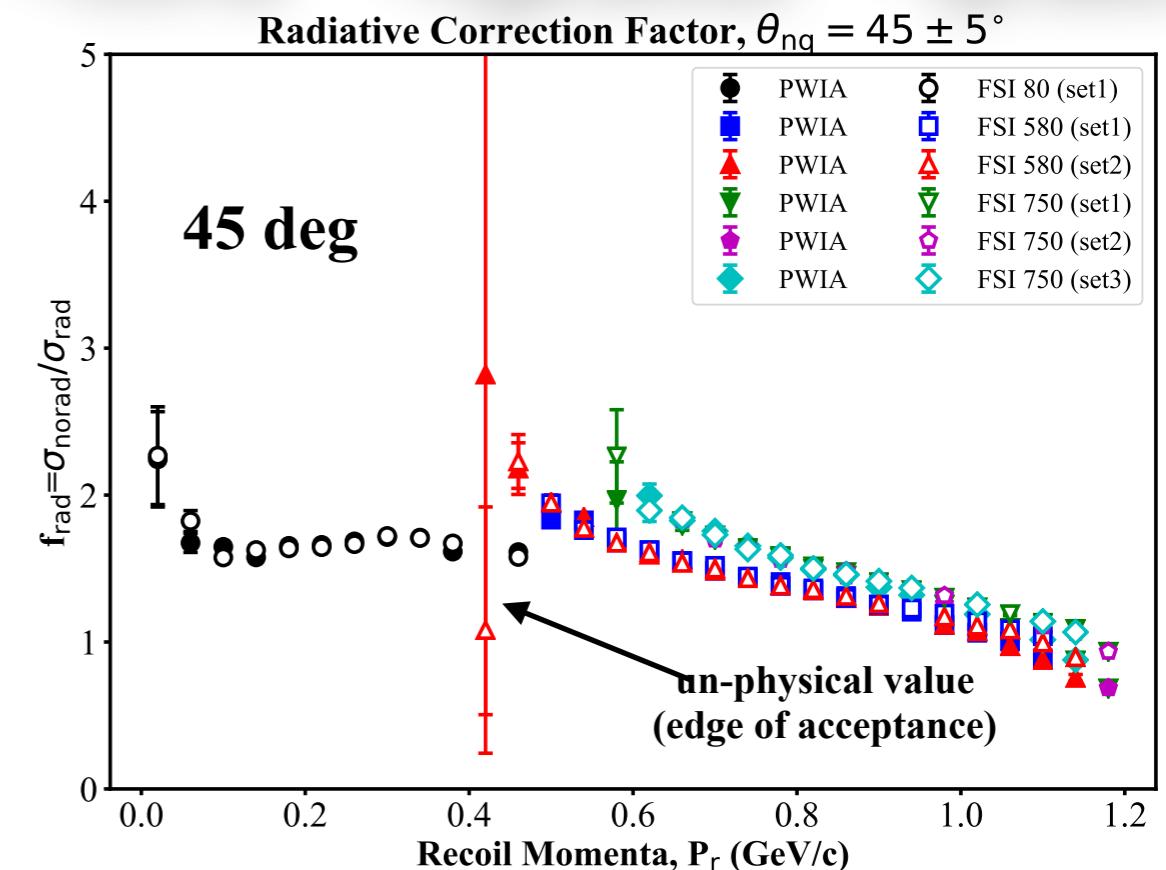
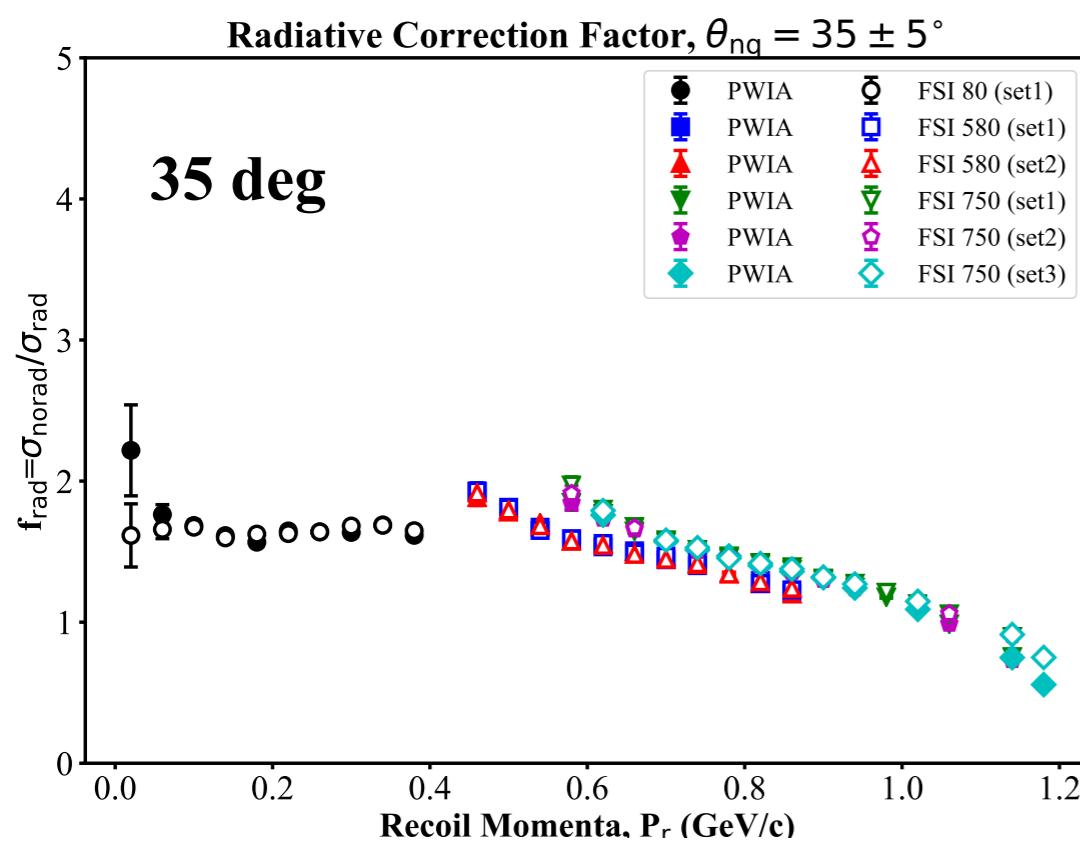
$$Y_{data}^{corr} = \frac{Y_{data}^{uncorr} \cdot f_{rad}}{Q \cdot \epsilon_{tLT} \cdot \epsilon_{htrk} \cdot \epsilon_{etrk} \cdot \epsilon_{tgtBoil} \cdot \epsilon_{pAbs}}$$

Proton Absorption = $4.66 \pm 0.472\%$



For Full Description of
Proton Absorption Analysis,
See DOC DB Link [HERE](#) !

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



Radiative Correction factor

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

D(e,e'p) Momentum Distributions

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

↓

**Reduced cross section
(theoretical momentum distributions in PWIA)**

Bin-center Corrected Experimental cross sections

Kinematic Factor times deForest ep cross section

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

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

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

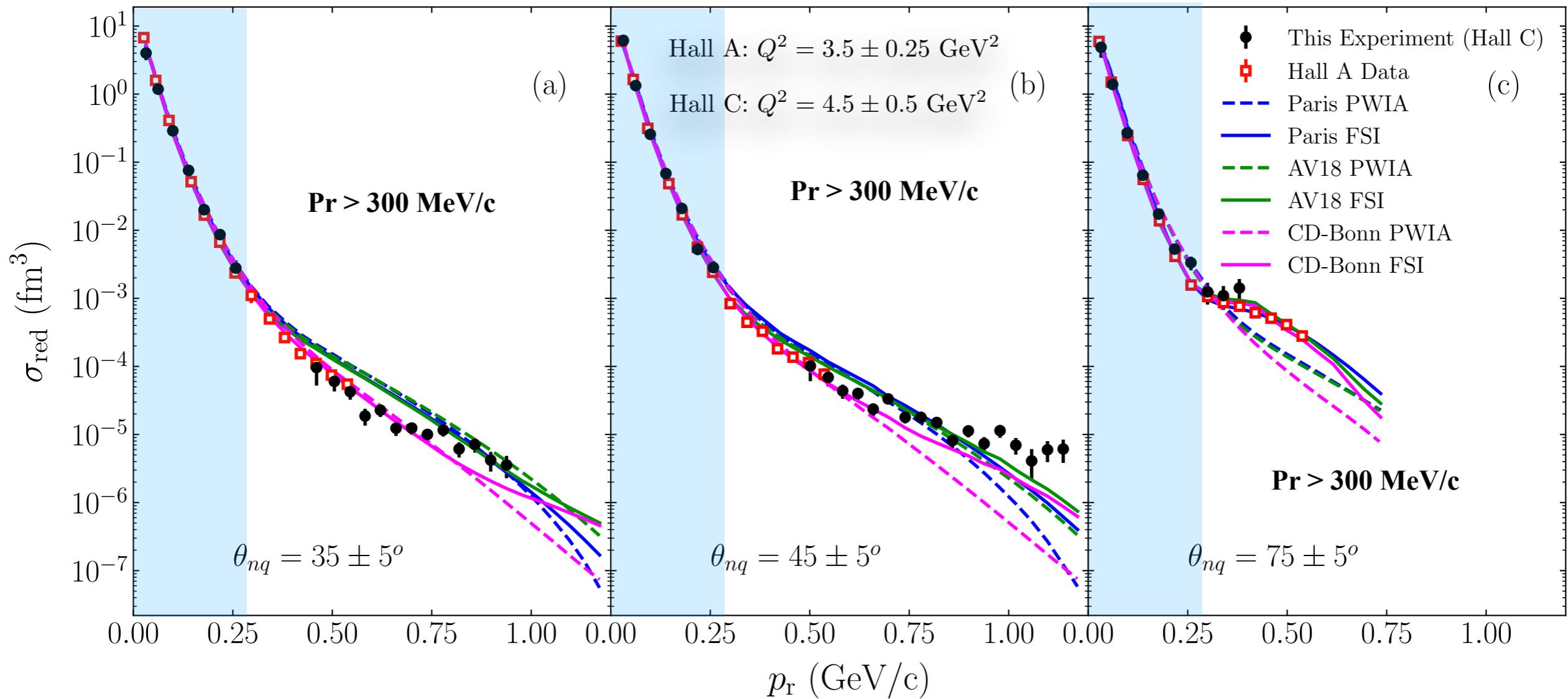
Division by deForest and kinematic factor removes kinematical dependencies on reduced cross section

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

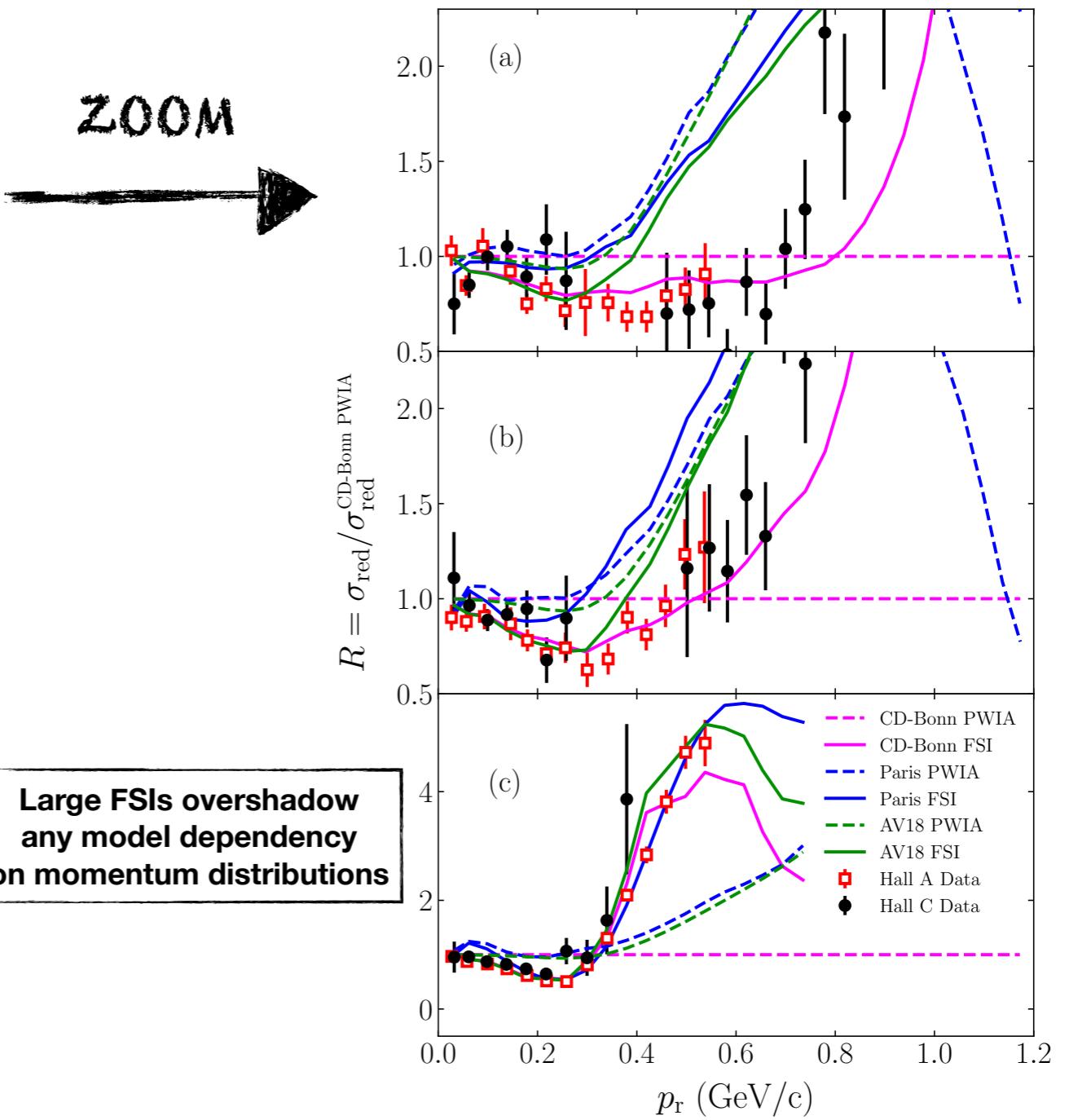
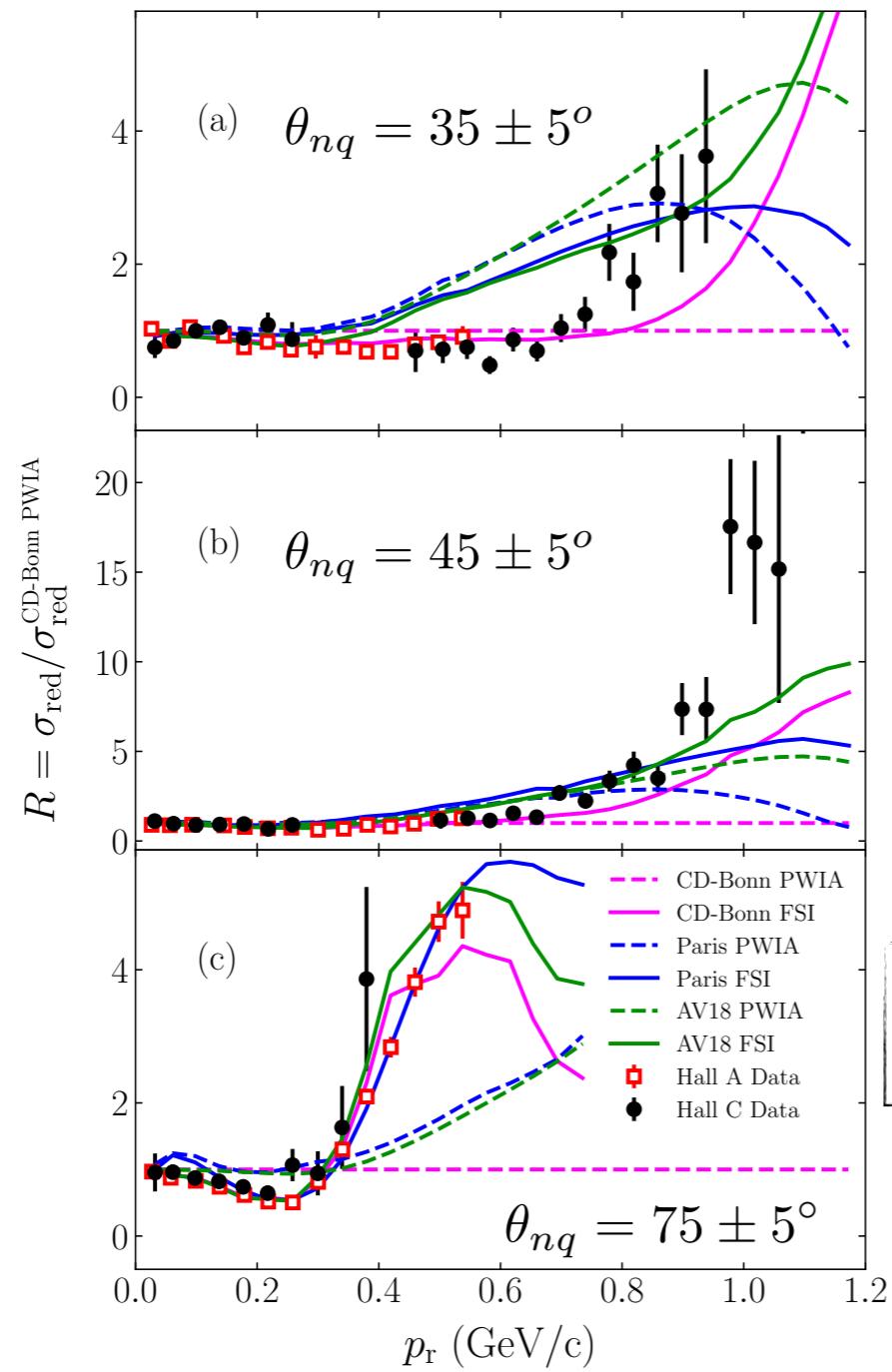
◆ Paris calculations are done by J.M.Laget

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



**Large FSIs overshadow
any model dependency
on momentum distributions**

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

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

where $A_{\text{FSI}} \sim i|A_{\text{FSI}}|$

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 $Q^2 = 4.5 \text{ (GeV/c)}^2$ 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!

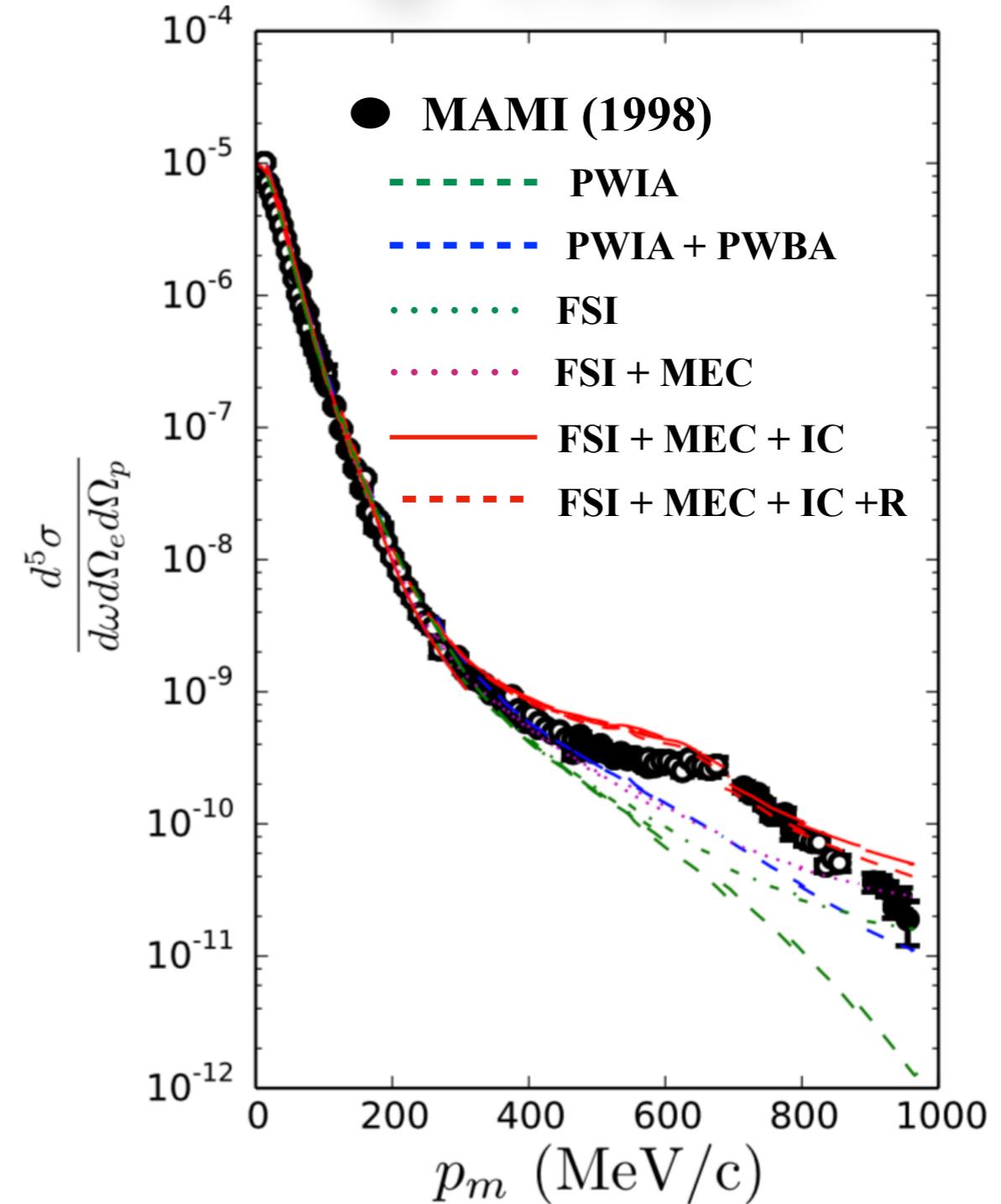
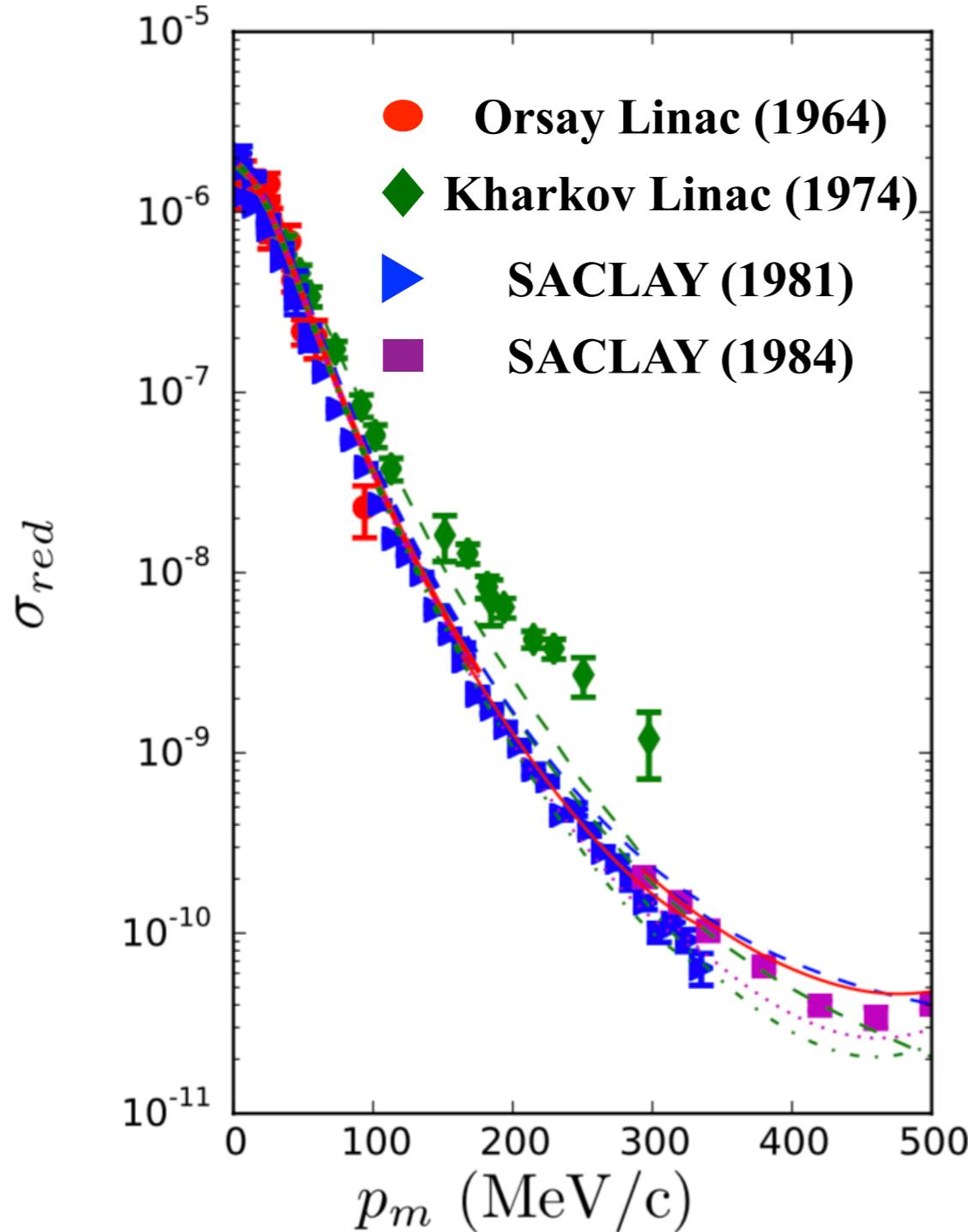


BACK-UP SLIDES

D(e,e'p) Experiments

At $Q^2 < 1 \text{ GeV}^2$

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



Theoretical Calculations

W. Fabian and H. Arenhovel,
Nucl.Phys. A258, 461 (1976)

At $P_m > 300 \text{ MeV}/c$, 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)



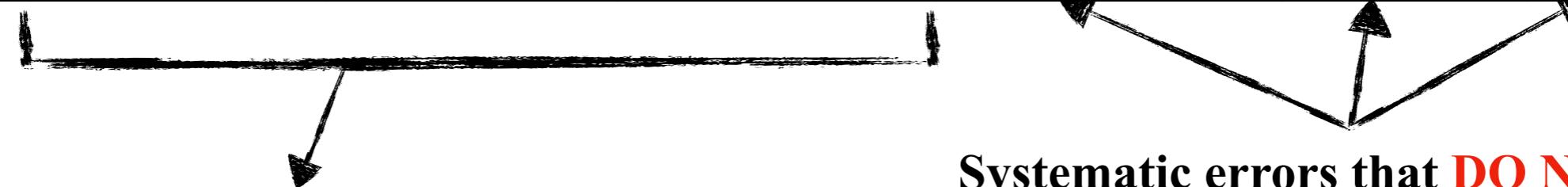
SYSTEMATIC UNCERTAINTY ON NORMALIZATION

$$\bar{\sigma}_{corr}^{exp} = \bar{\sigma}_{uncorr}^{exp} \cdot f_1 \cdot f_2 \dots f_i \longrightarrow \frac{d\bar{\sigma}_{corr}^{exp}}{\bar{\sigma}_{corr}^{exp}} \Big|_i = \frac{df_i}{f_i}$$

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
$\delta\theta_p [mr]$	+/- 0.2369
$\delta E_f / E_f$	+/- 9.132E-04
$\delta E_b / E_b$	+/- 7.498E-04
$d\sigma_{exp}$	6.5%

Uncertainty in SHMS angle

Uncertainty in HMS angle

Uncertainty in SHMS momentum

Uncertainty in Beam Energy

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

← Max. Kin. Systematic
Error on Cross
Section

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

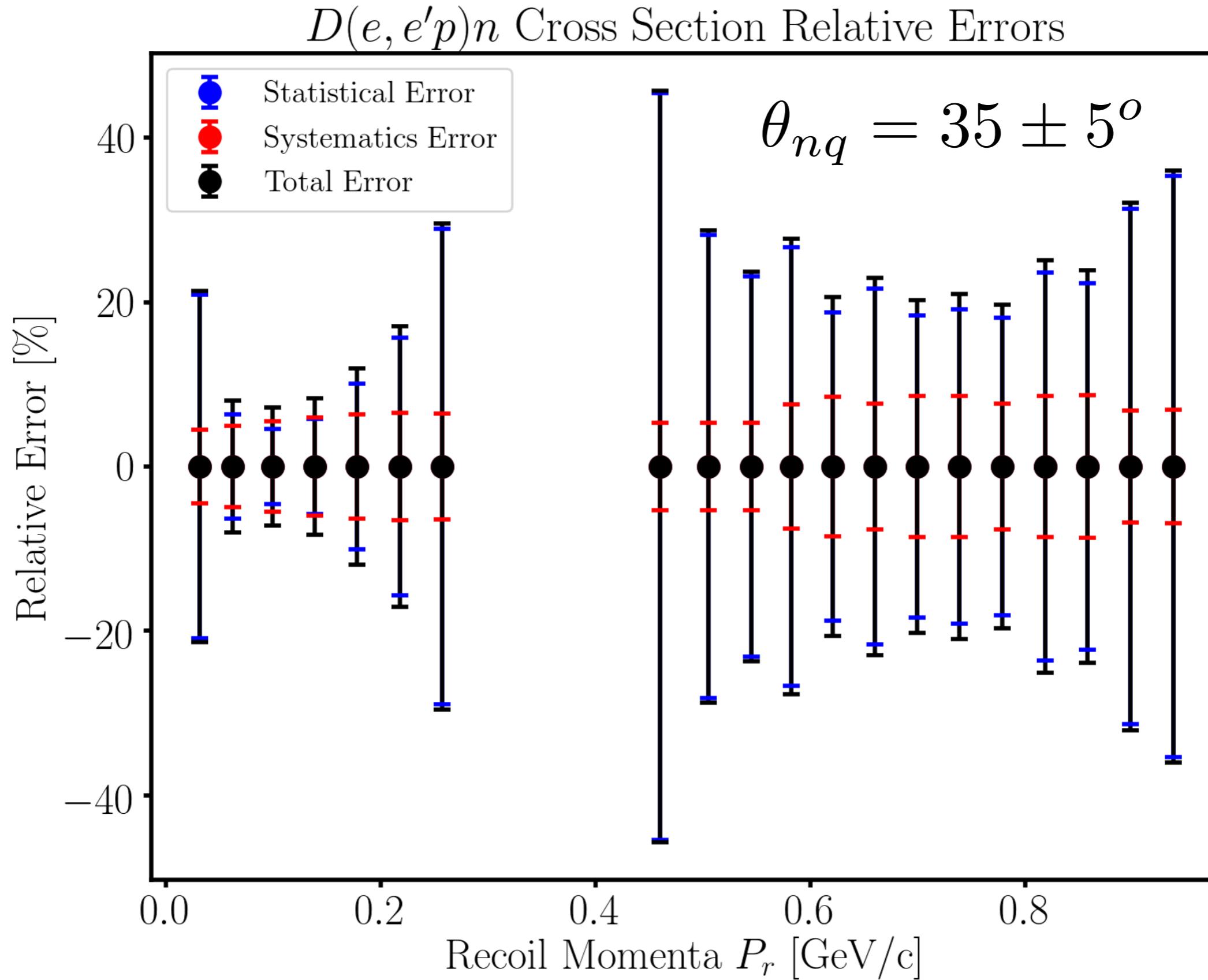
Covariance Errors

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

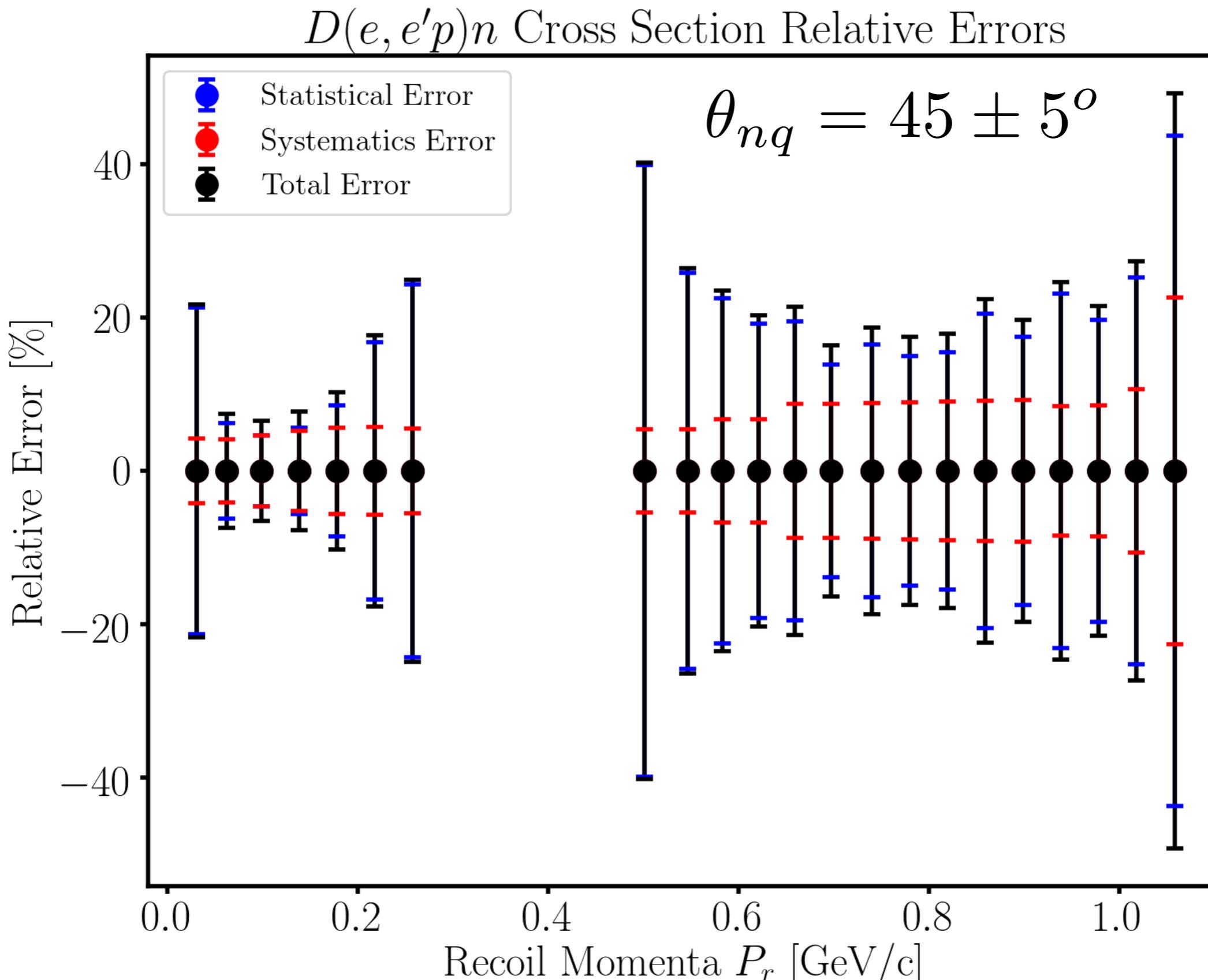
The kinematic uncertainties are point-to-point which means they vary depending for each data point, as each corresponds to a different missing momentum kinematic bin.

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

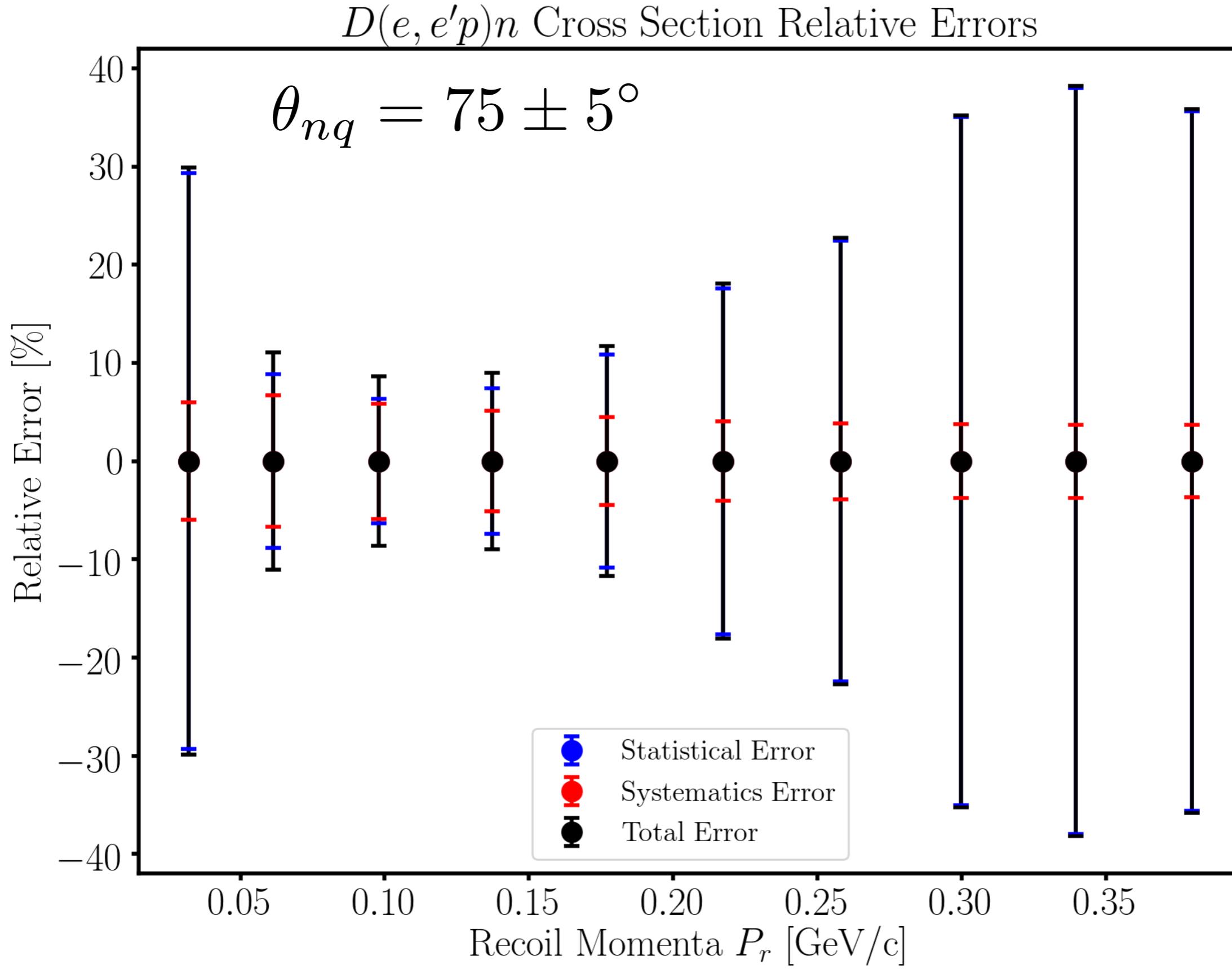
D(e,e'p)n Cross Section Relative Errors Summary Plots



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



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

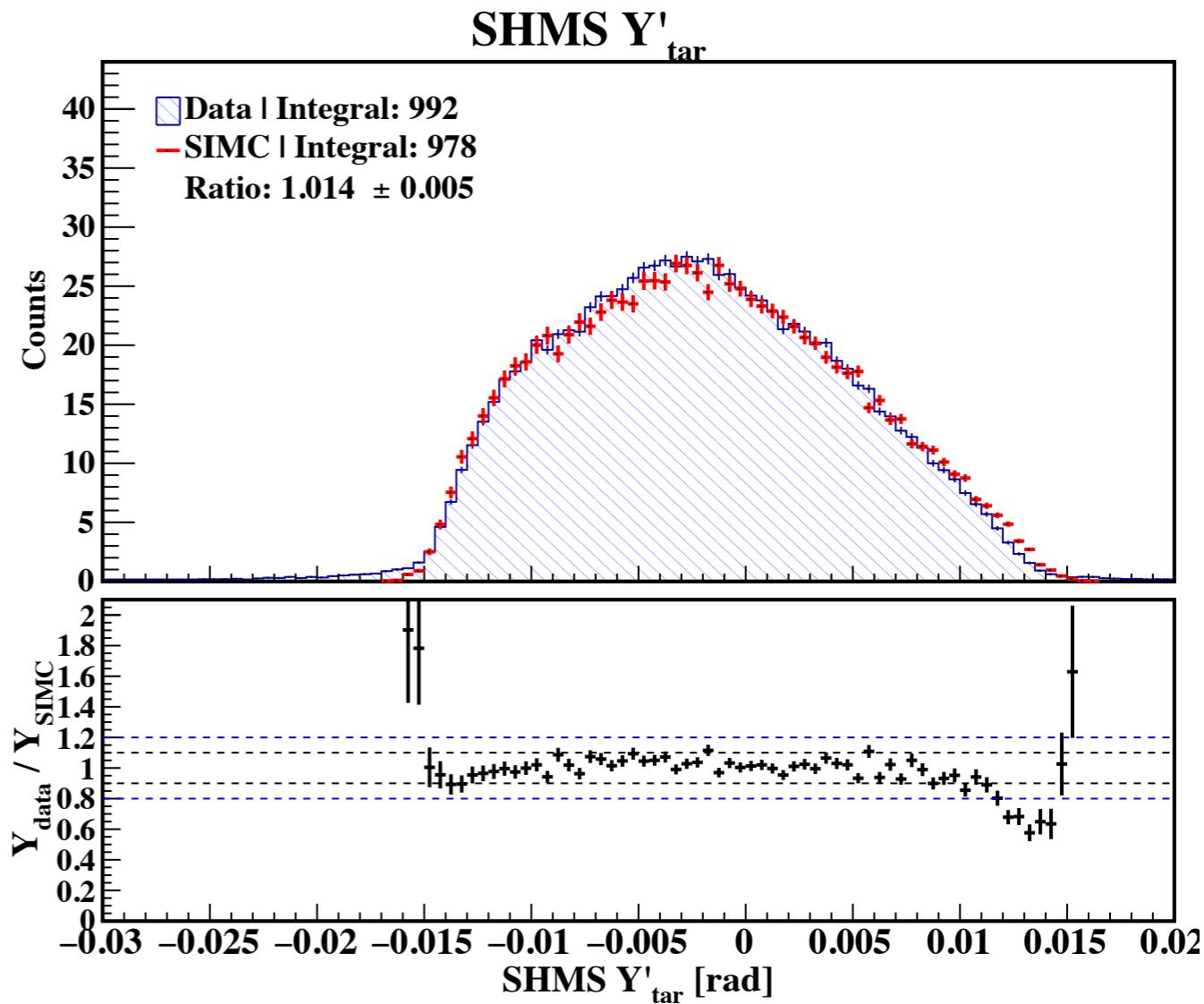
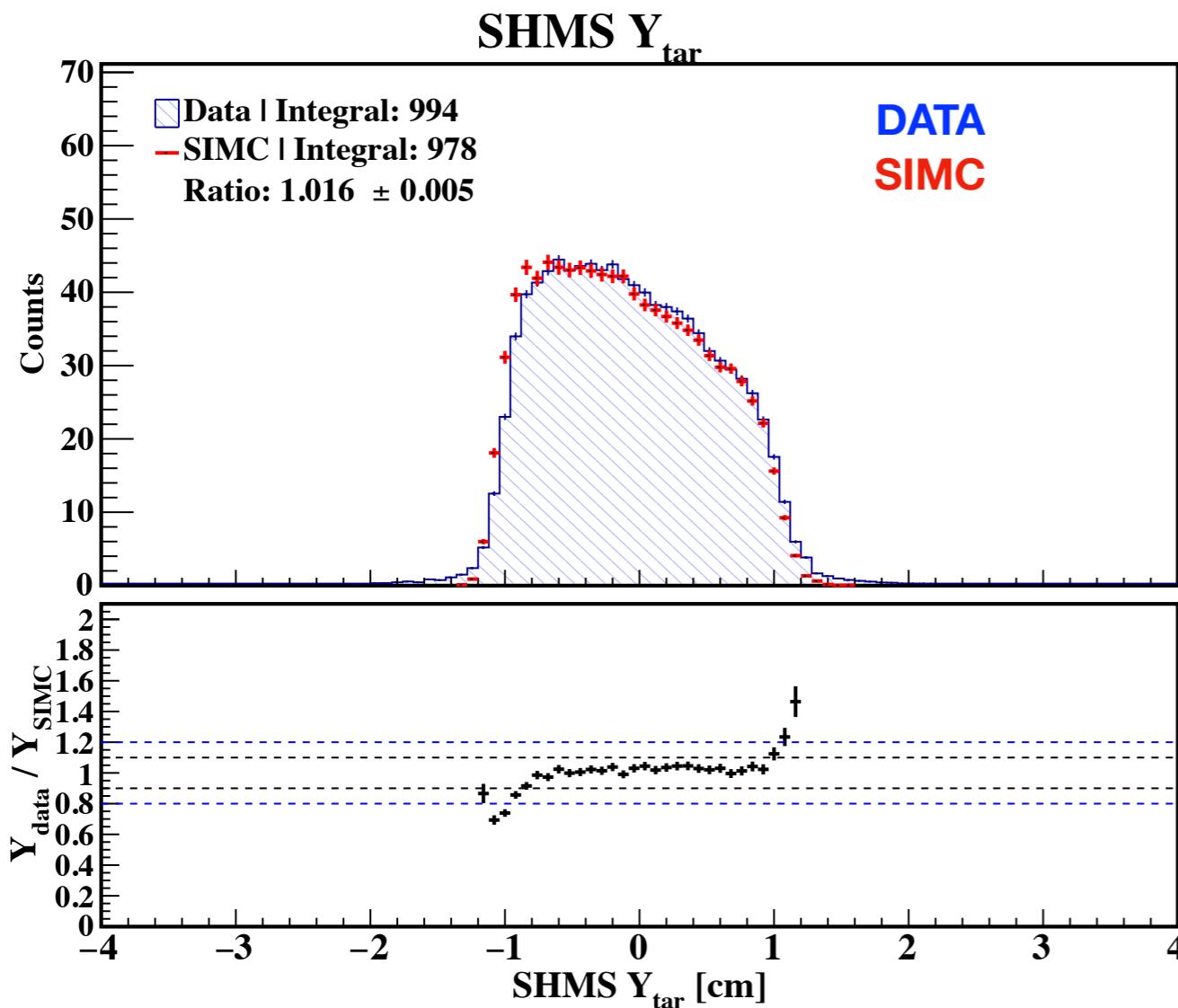


Spectrometer Acceptance DATA/SIMULATION

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

SHMS Reconstructed Variables

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

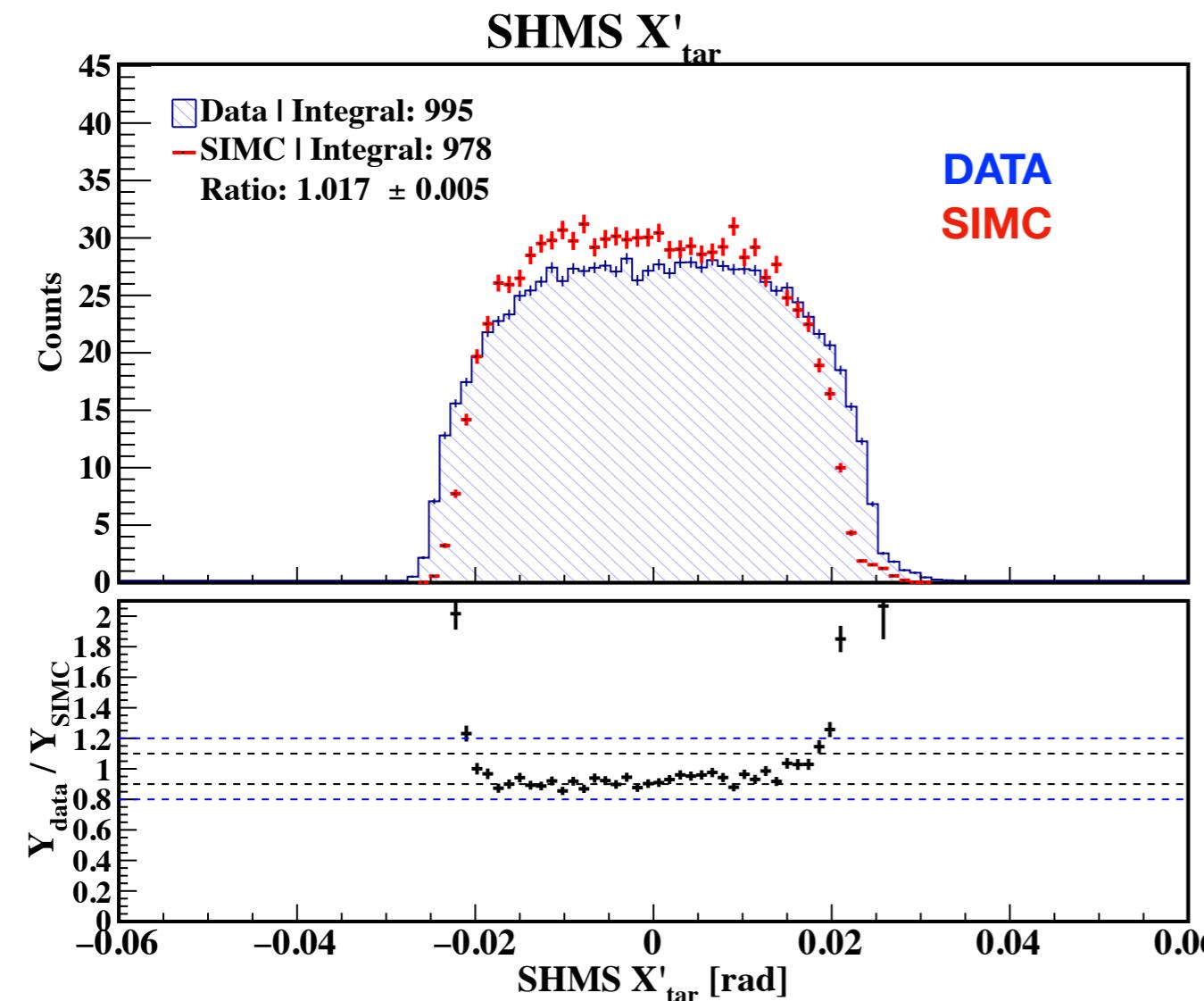


Spectrometer Acceptance DATA/SIMULATION

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

SHMS Reconstructed Variables

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

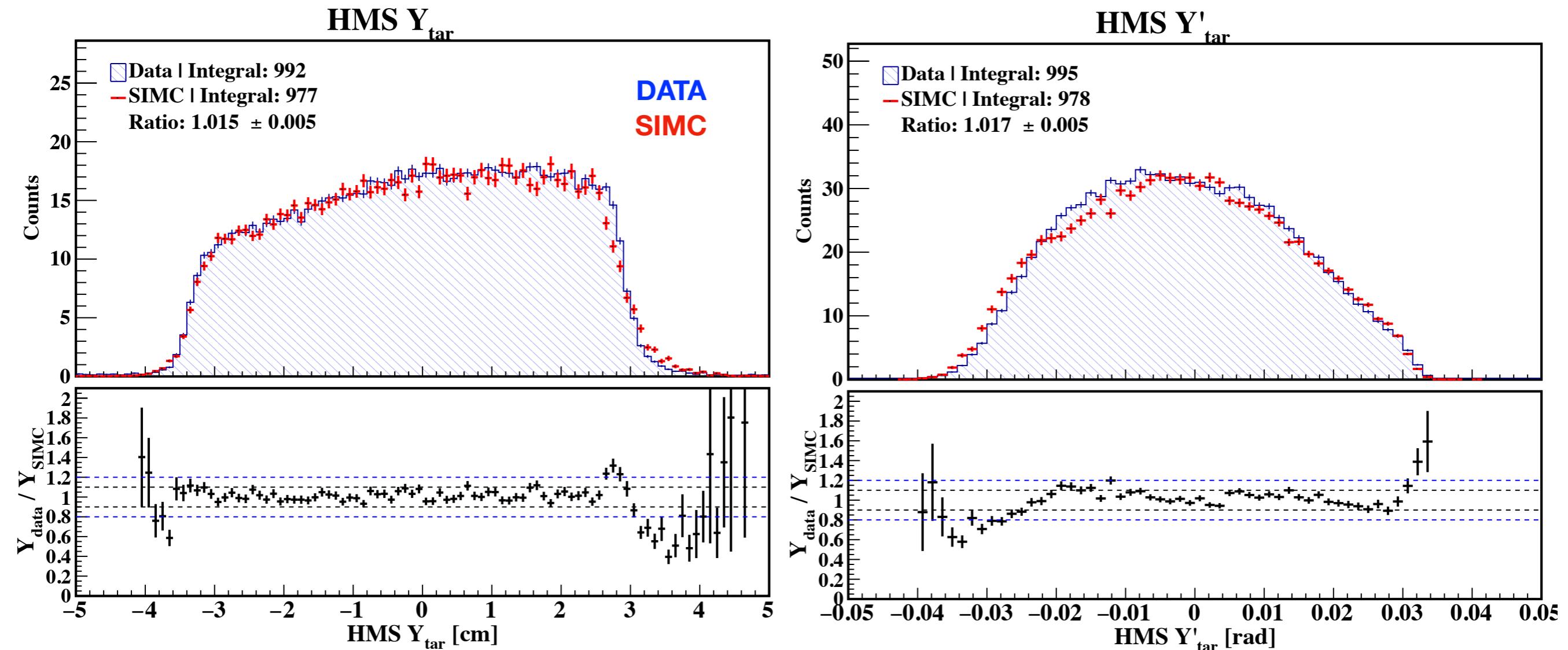


Spectrometer Acceptance DATA/SIMULATION

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

HMS Reconstructed Variables

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

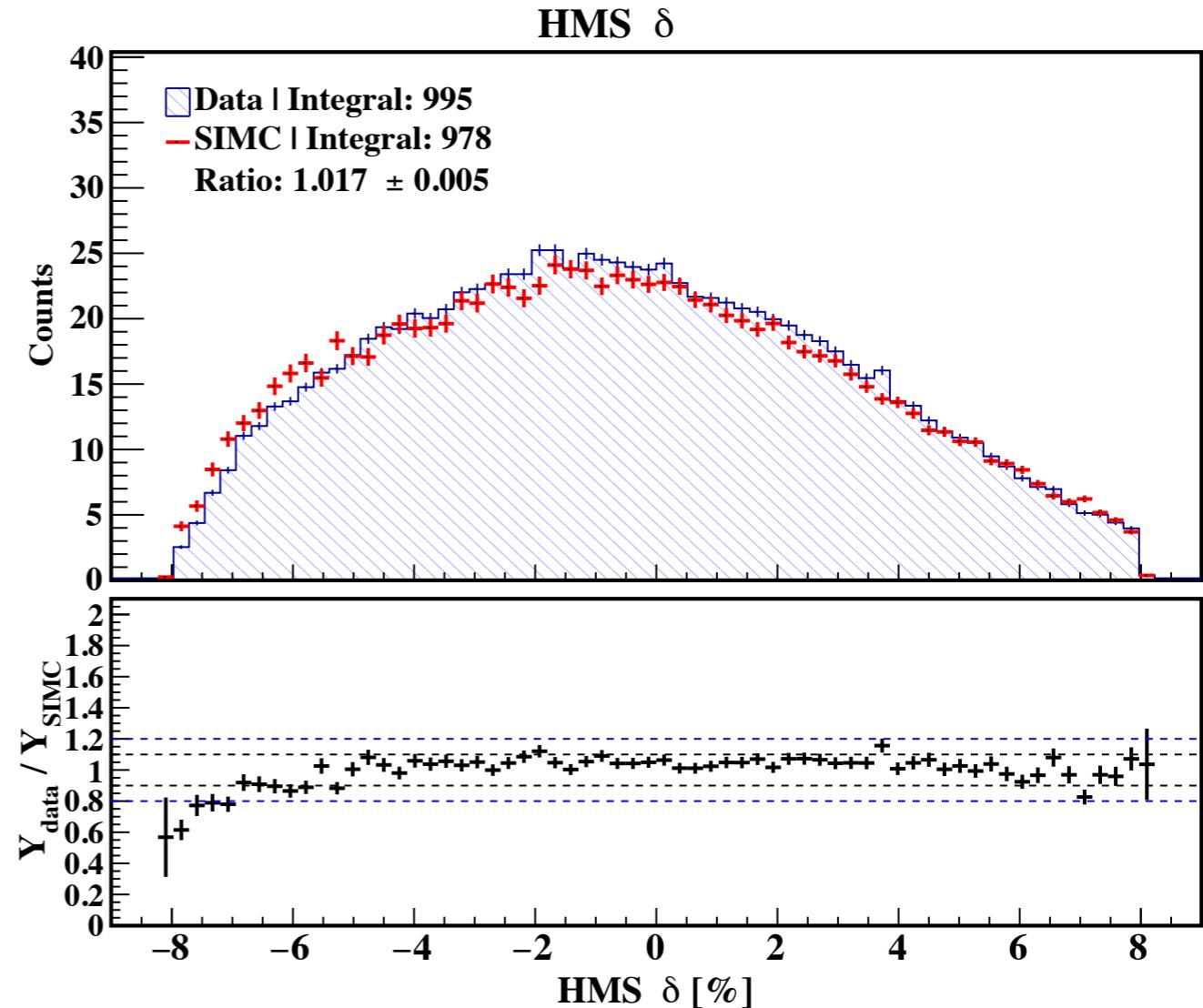
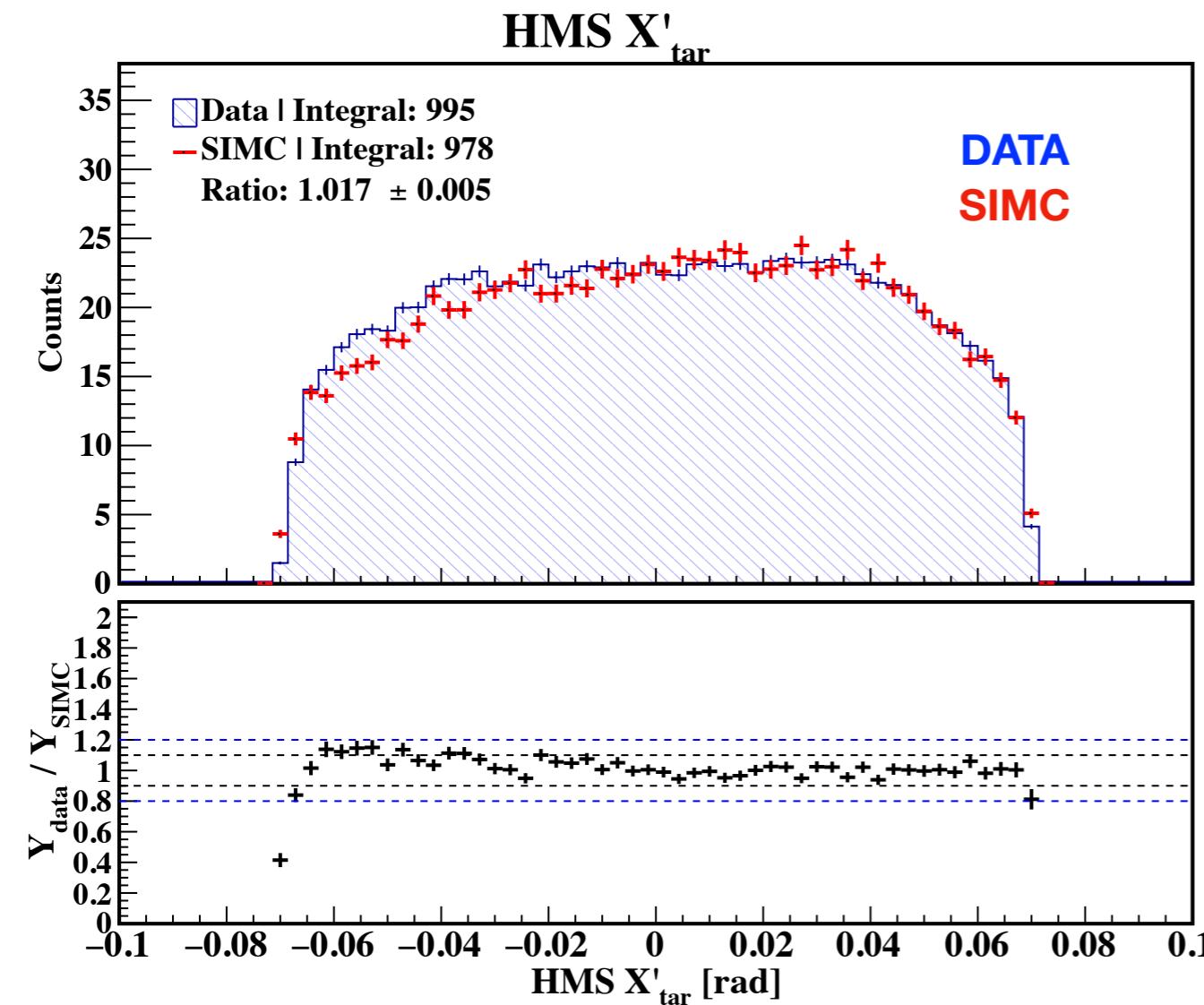


Spectrometer Acceptance DATA/SIMULATION

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

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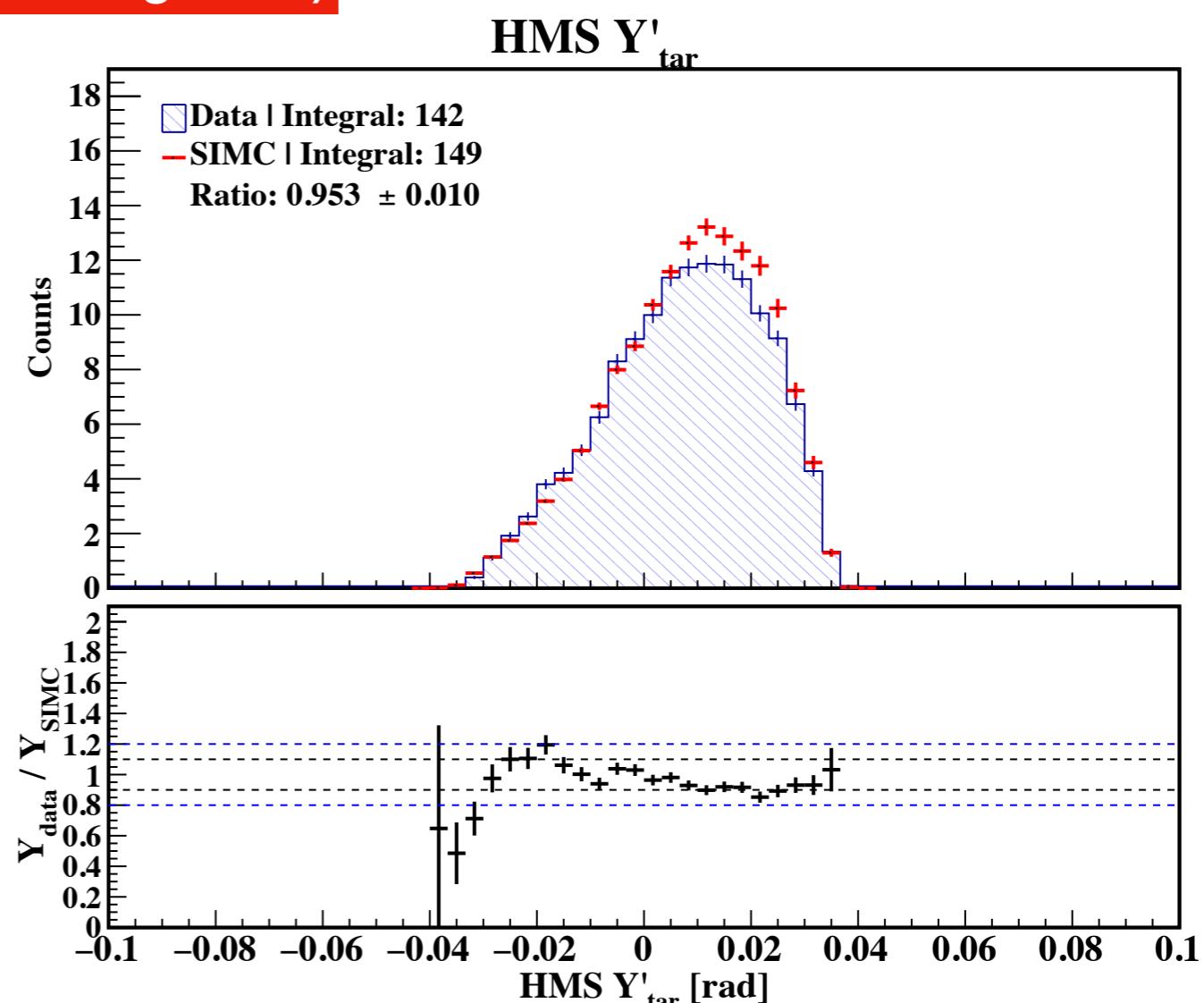
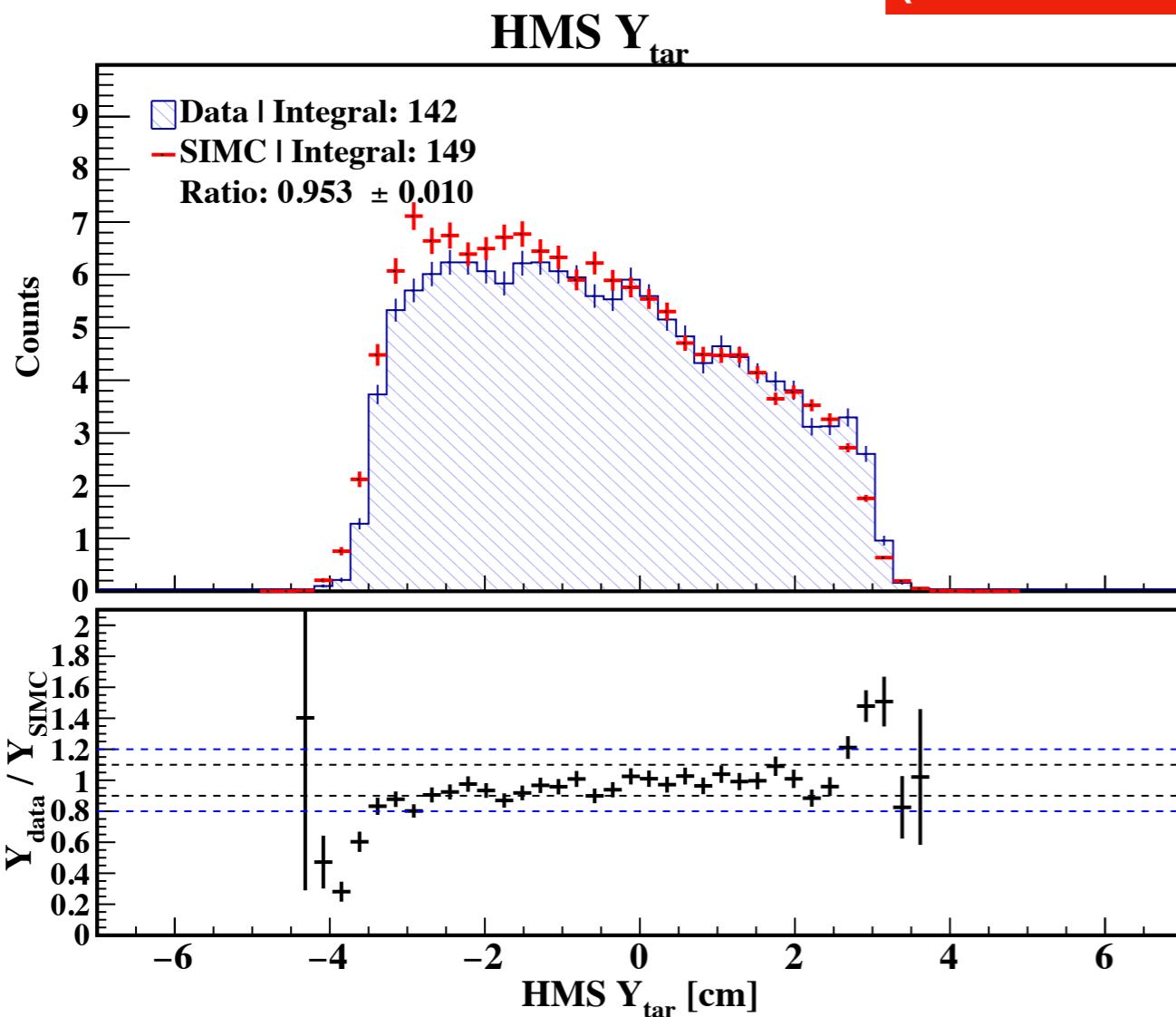


Spectrometer Acceptance Checks on $D(e,e'p)n$ using 80 MeV setting

HMS Reconstructed Variables

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

(SIMC MODEL: Laget FSI)

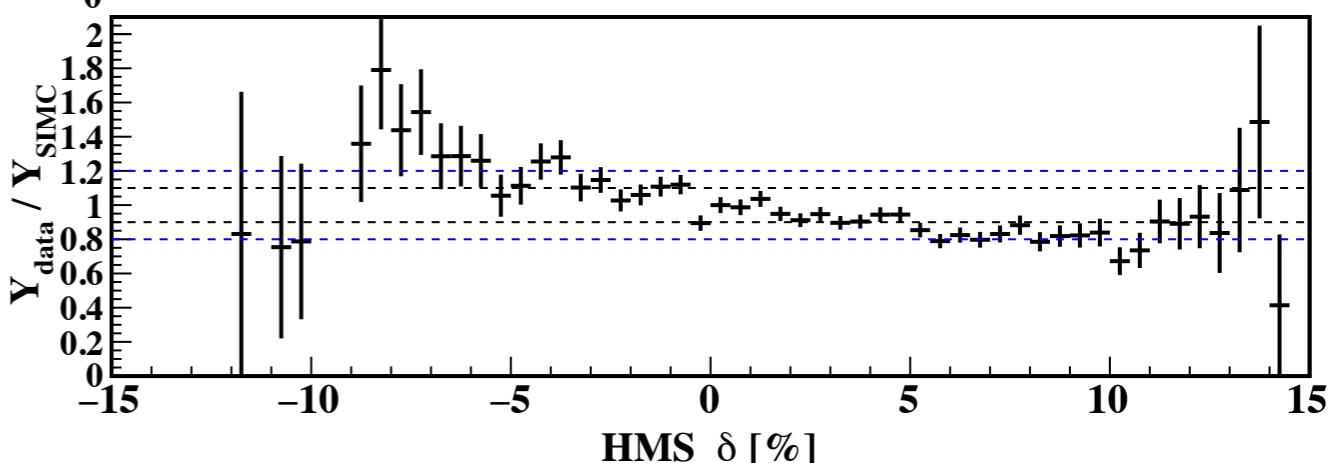
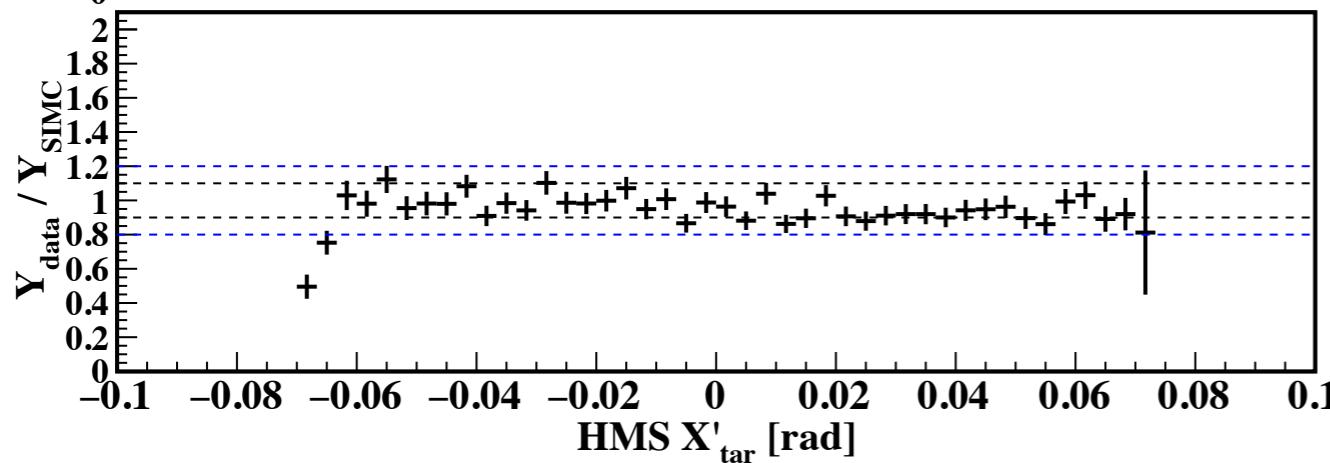
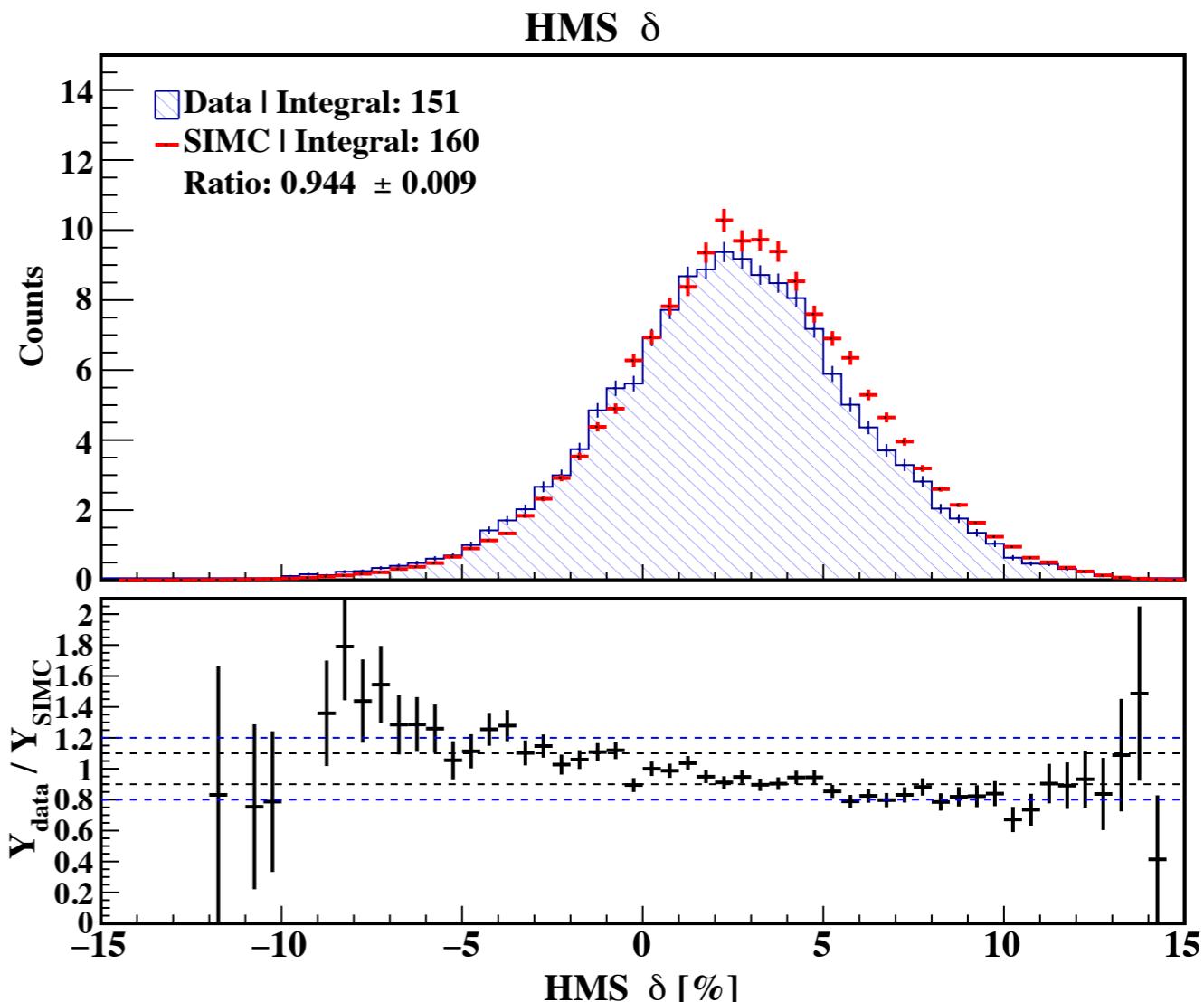
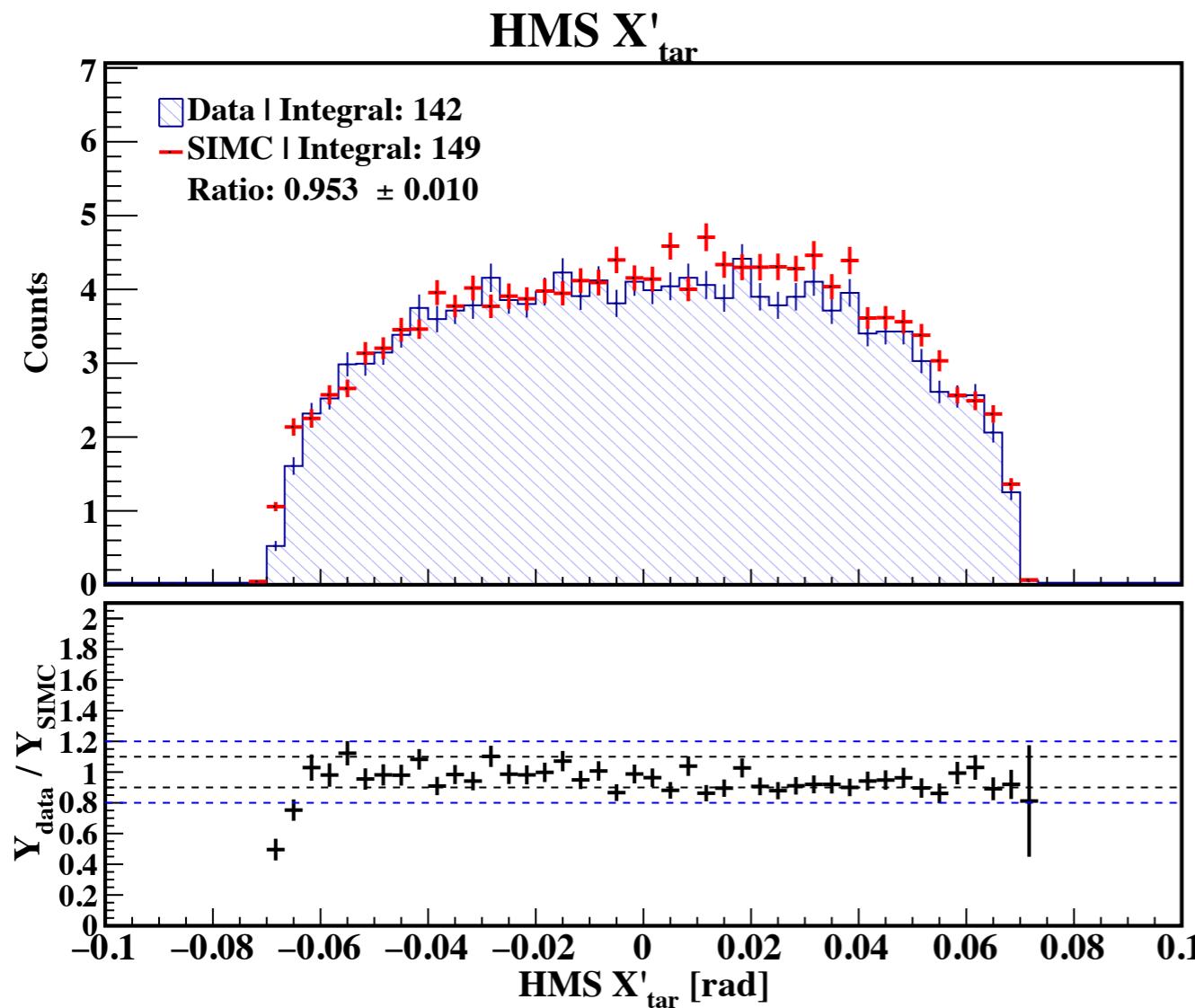


Spectrometer Acceptance Checks on $D(e,e'p)n$ using 80 MeV setting

HMS Reconstructed Variables

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

(SIMC MODEL: Laget FSI)

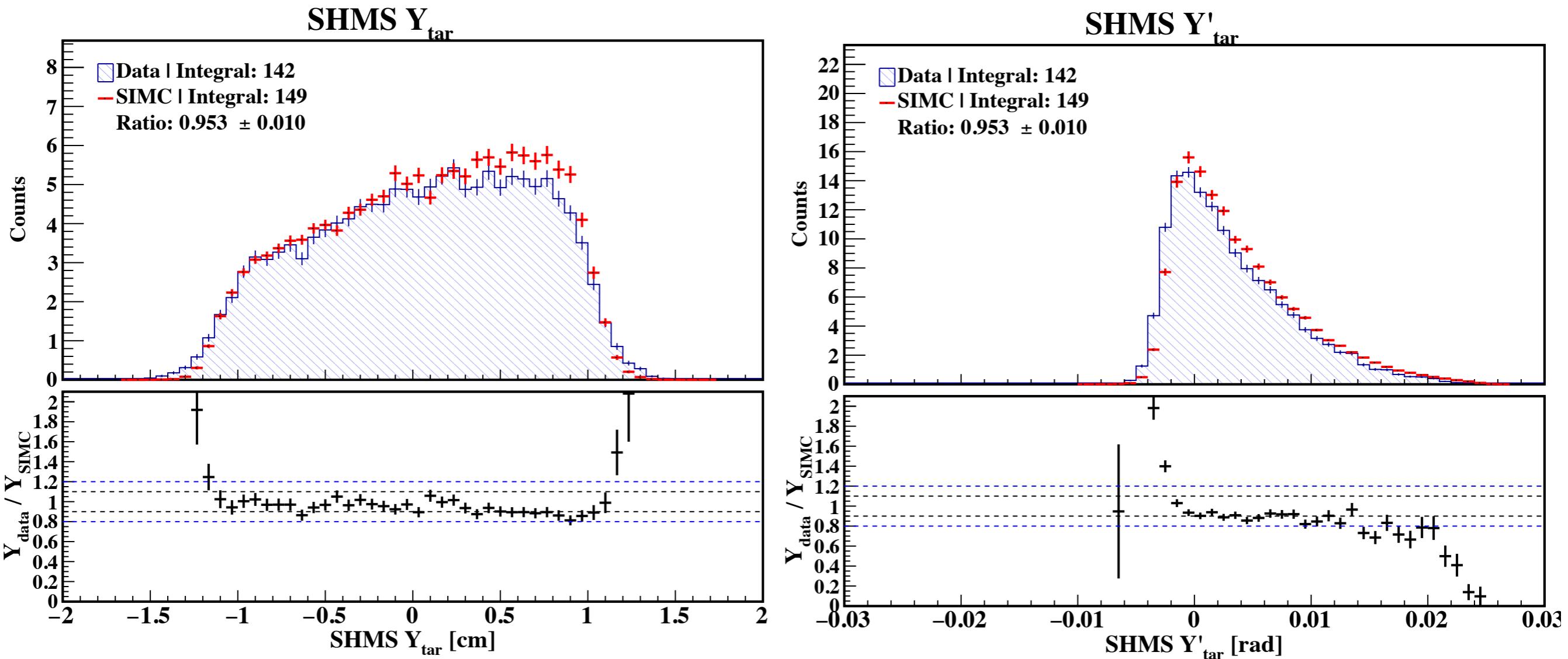


Spectrometer Acceptance Checks on $D(e,e'p)n$ using 80 MeV setting

SHMS Reconstructed Variables

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

(SIMC MODEL: Laget FSI)

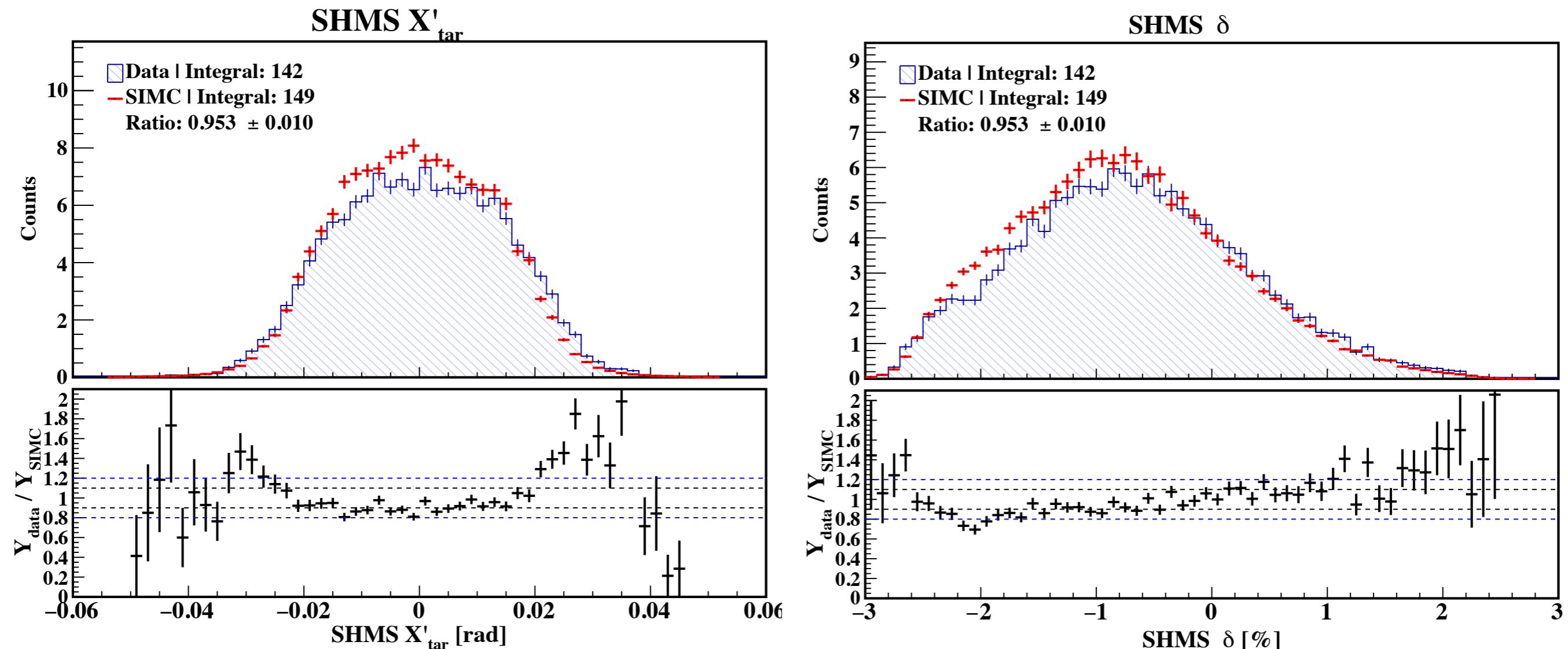


Spectrometer Acceptance Checks on $D(e,e'p)n$ using 80 MeV setting

SHMS Reconstructed Variables

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

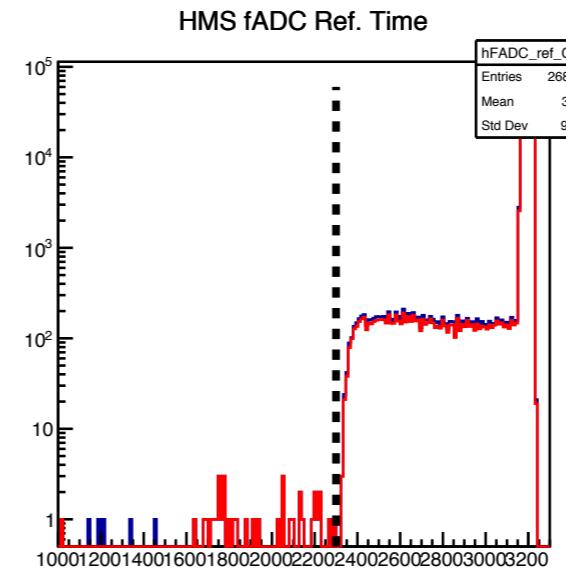
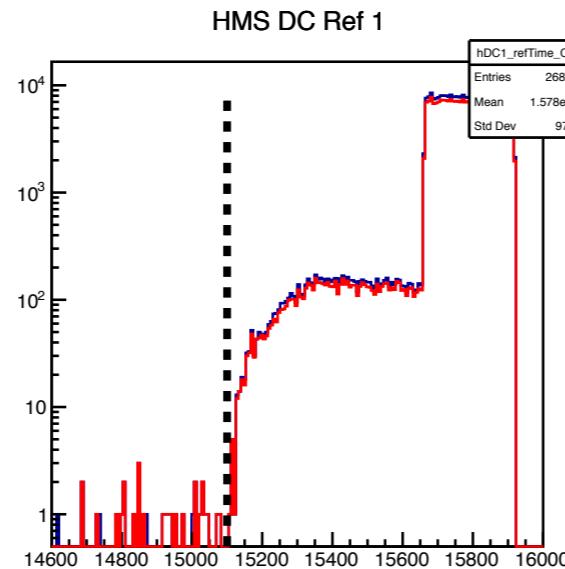
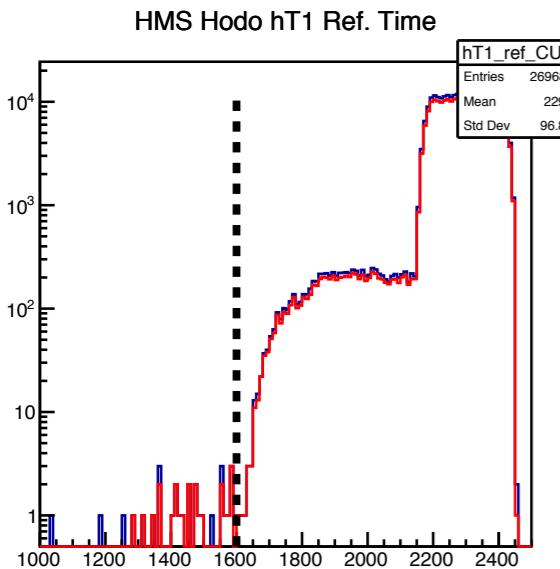
(SIMC MODEL: Laget FSI)



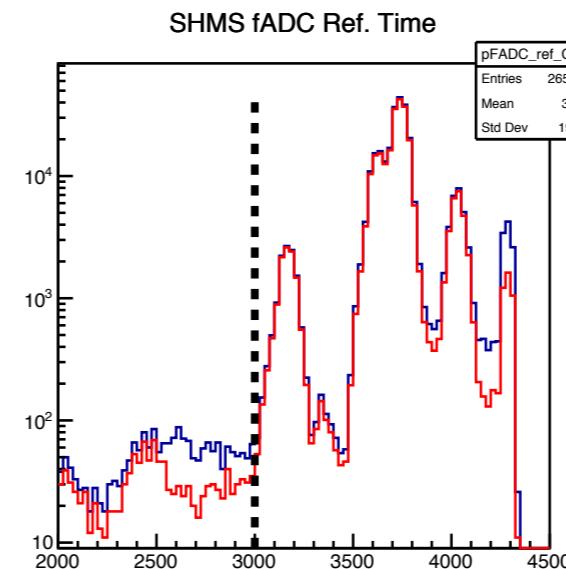
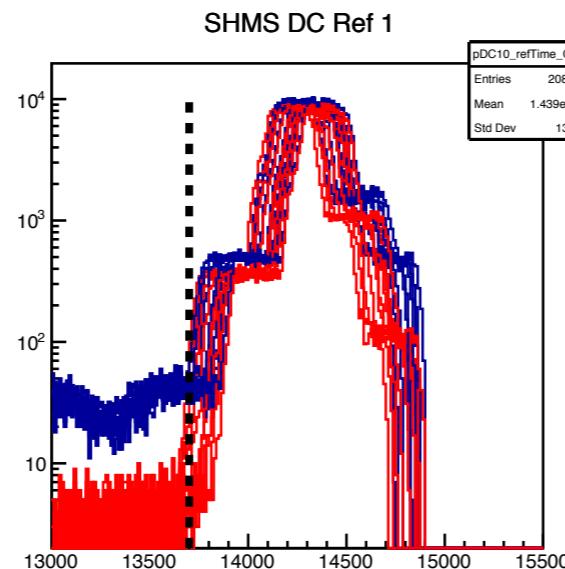
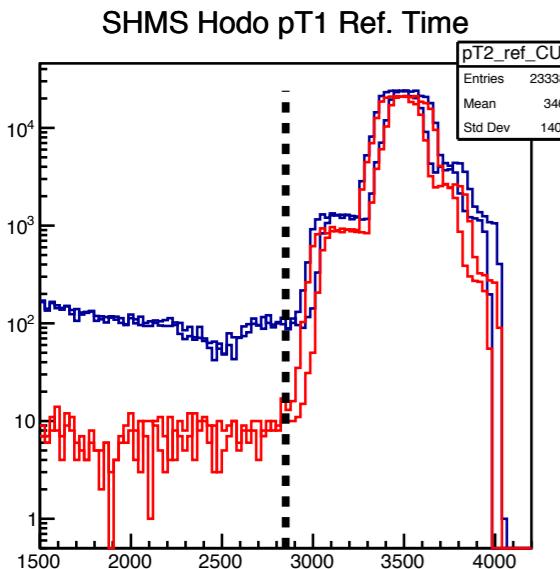
Hall C Experimental Analysis
on
 $D(e,e'p)n$

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

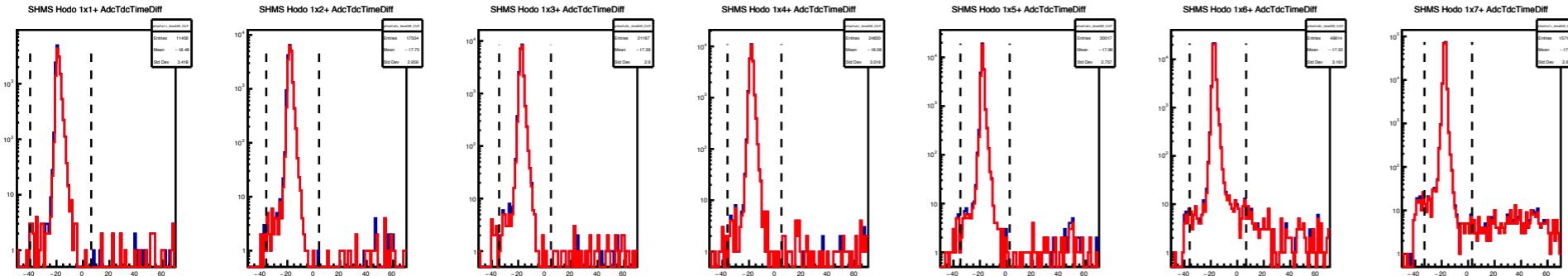


SHMS
Reference Times

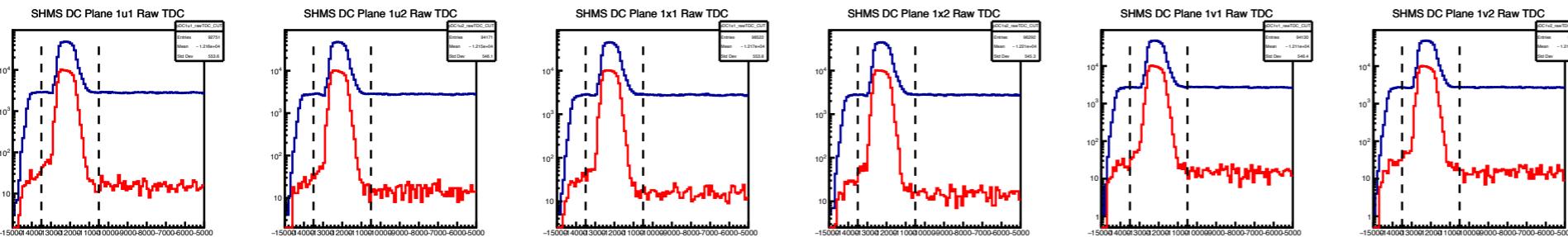
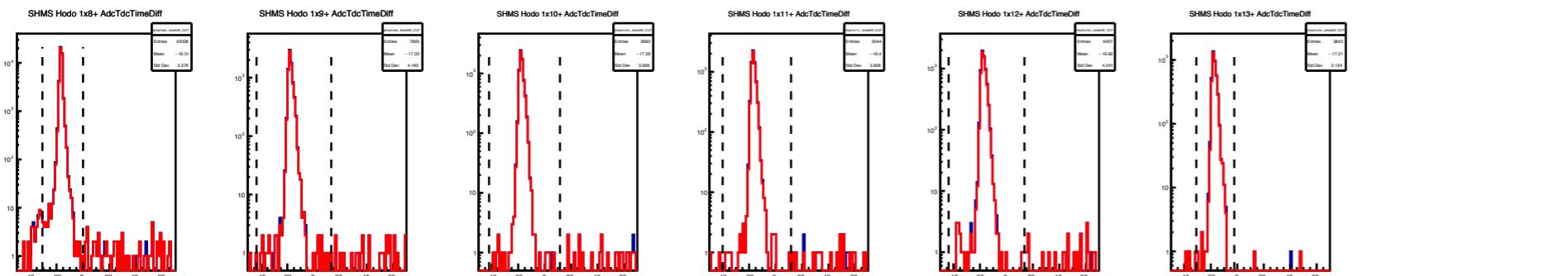
TDC Time Window Cuts

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)

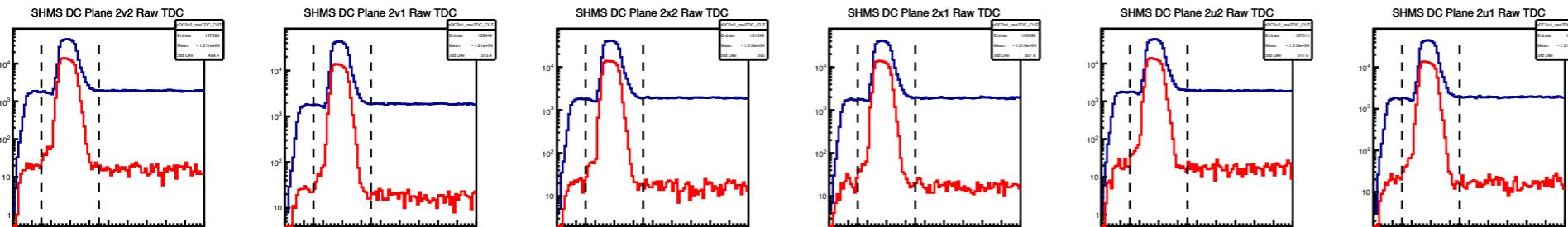
Legend: No Mult. Cut Multiplicity==1



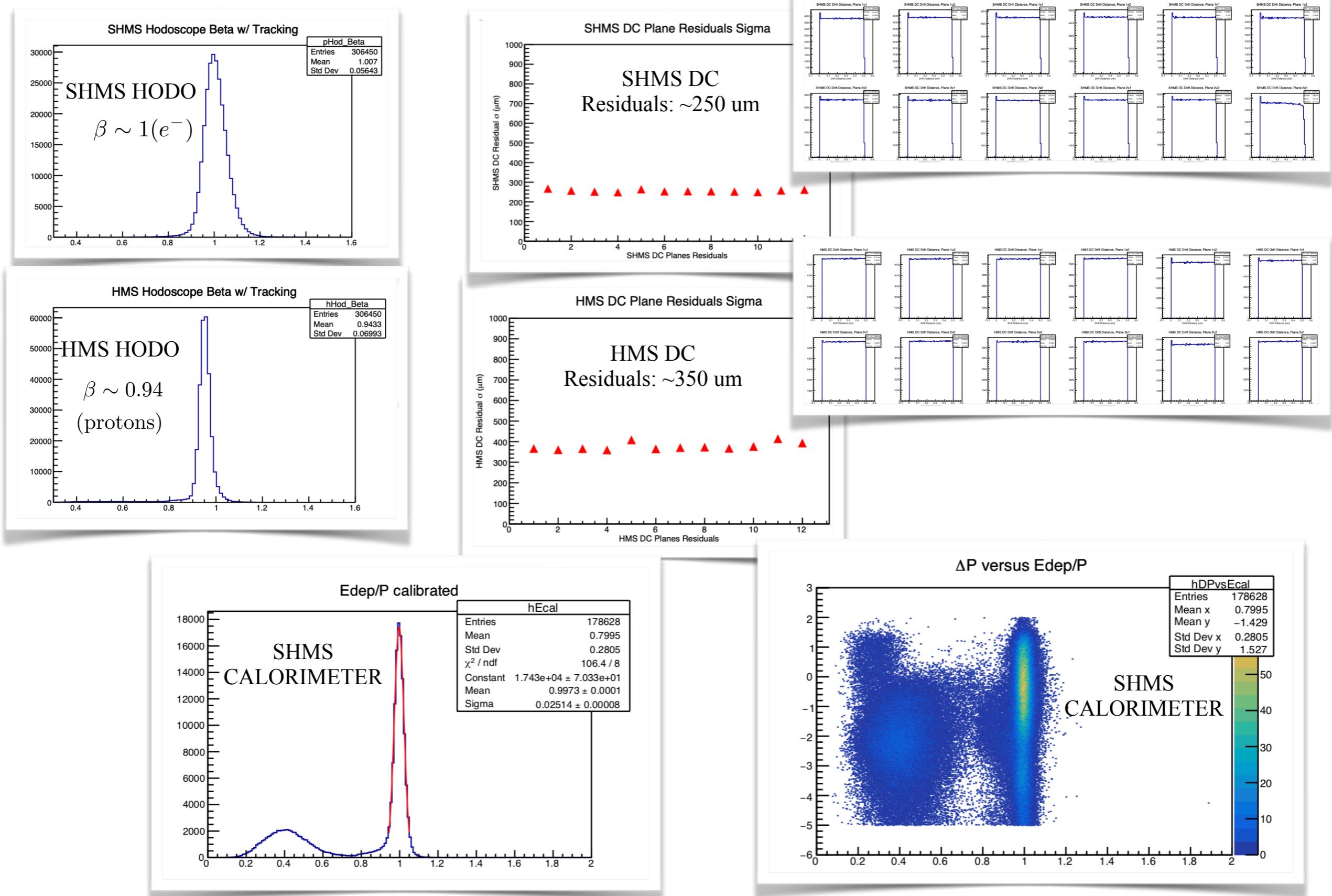
SHMS
Hodoscope 1X+
(ADC-TDC) Time
Difference



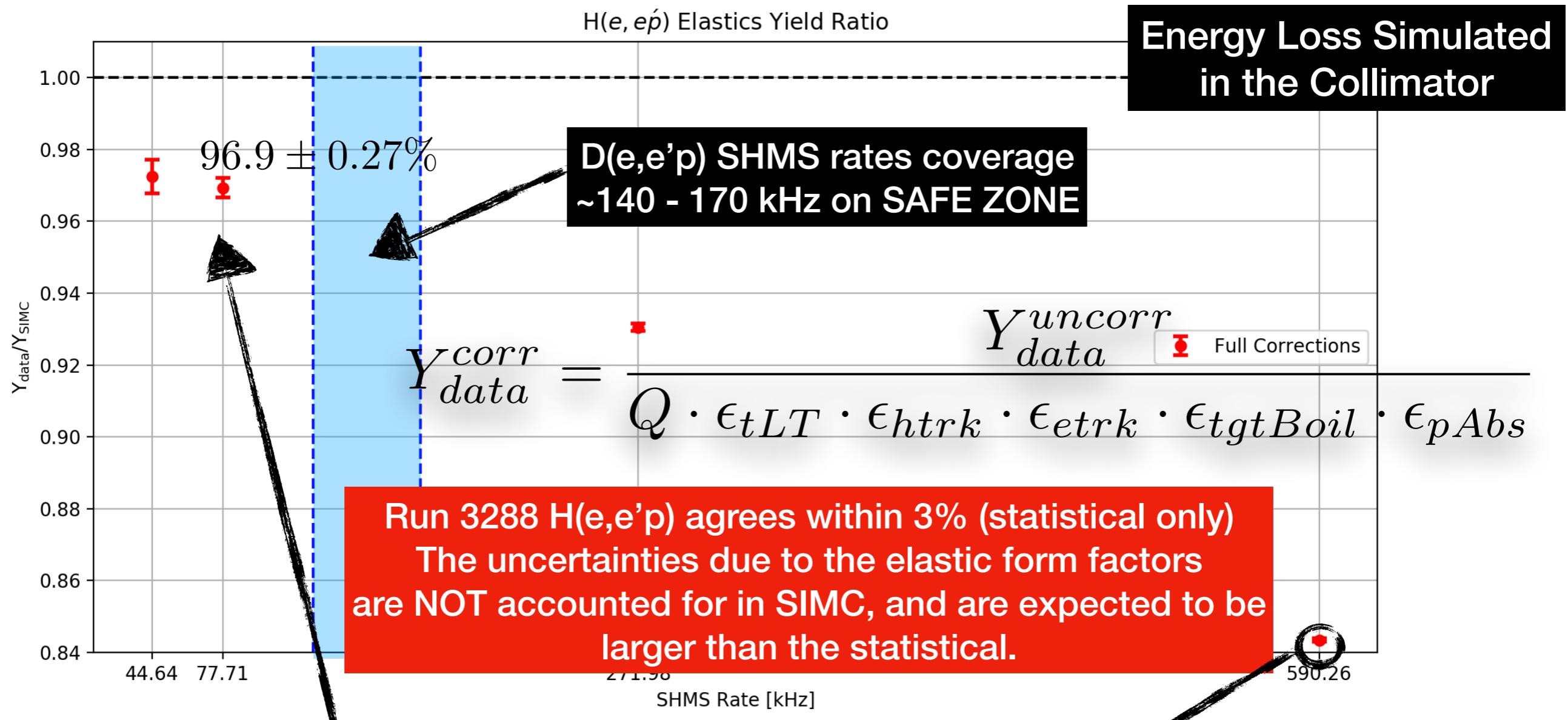
SHMS
Drift Chambers
Raw TDC Time



Detector Calibrations



H(e,e'p) Yield Ratio Check



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

The general cuts applied were:

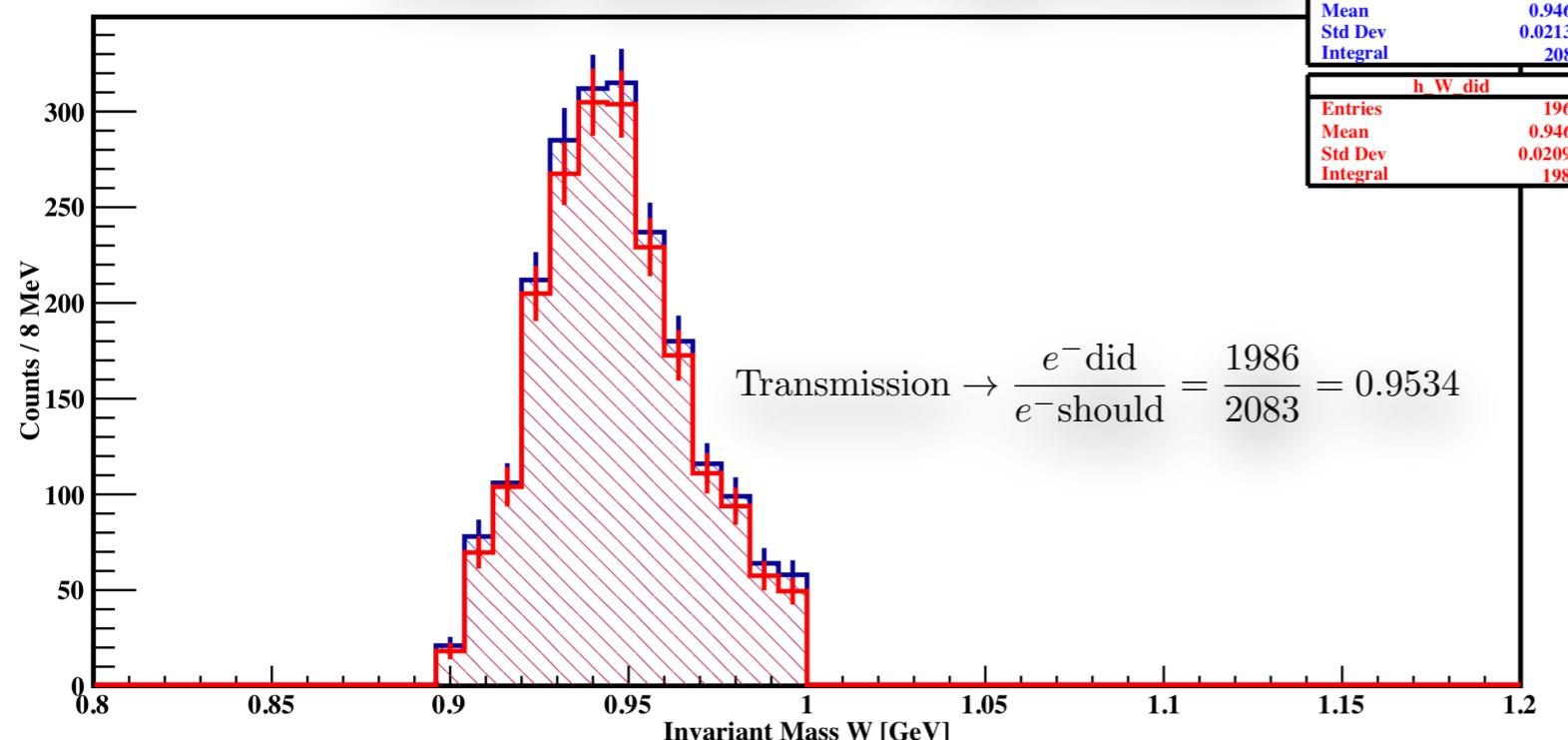
|HMS Delta| < 8 % SHMS Delta: (-10, 22) %

Inv. Mass W : (0.85, 1.05), HMS Coll. Cut

NOT Understood:
 * How does the tracking algorithm perform at very high rates?

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

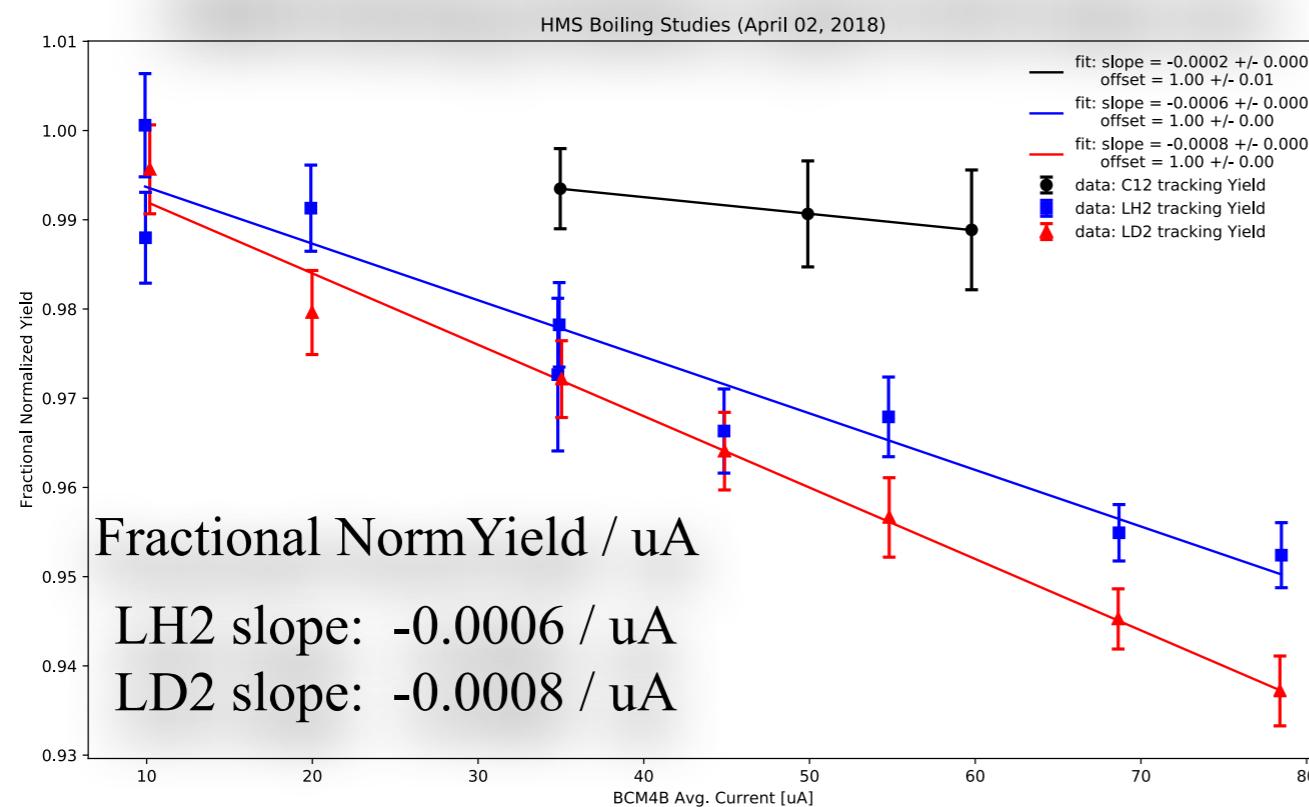
Proton Absorption = $4.66 \pm 0.472\%$



For Full Description of
Proton Absorption Analysis,
See DOC DB Link [HERE !](#)

(ONLY relevant for coincidence experiments)

HMS Boiling Studies (April 2018 data set)

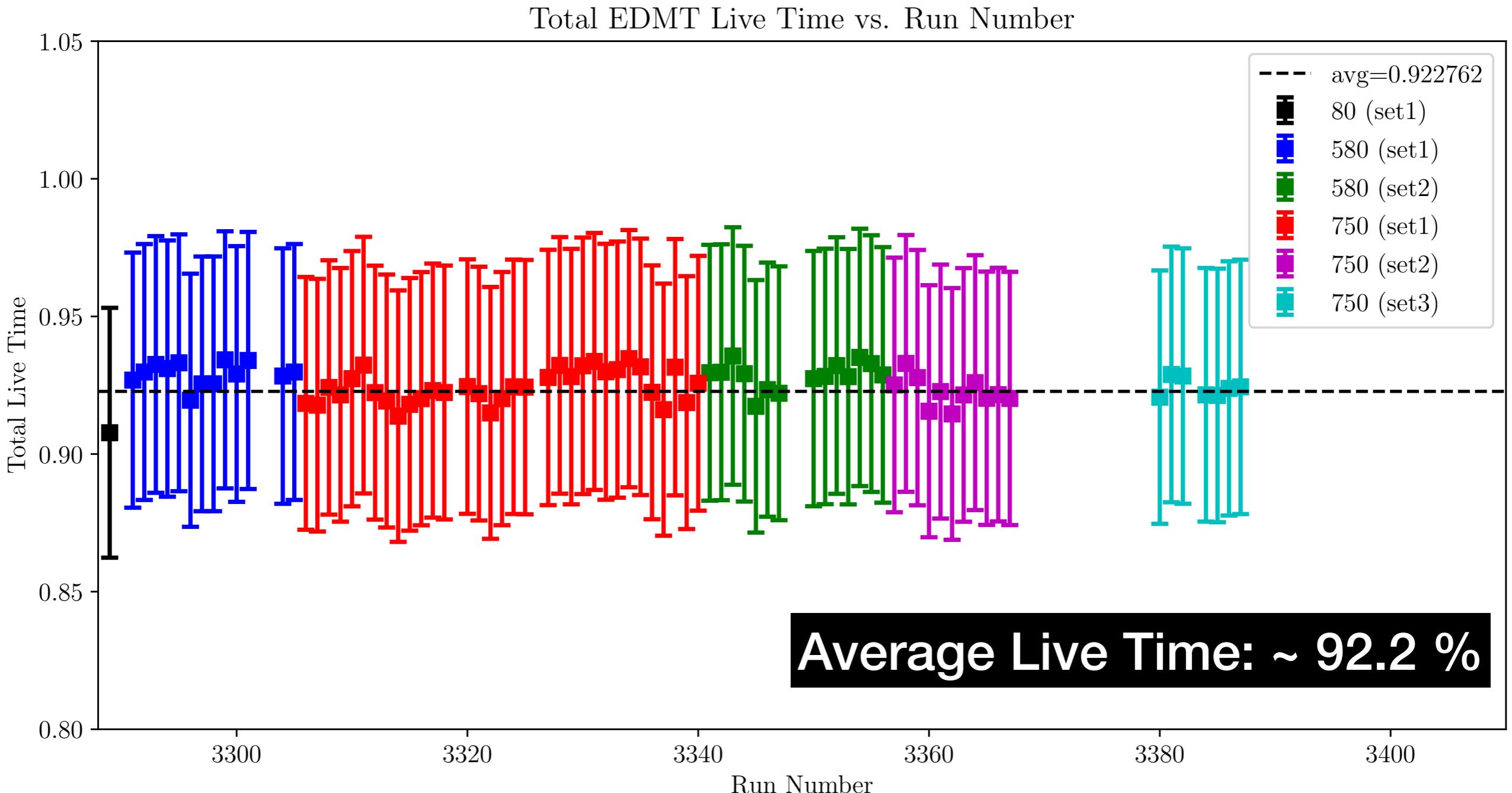


For Full Description of
Target Boiling Corrections
See DOC DB Link [HERE !](#)

Efficiencies and Correction Factors

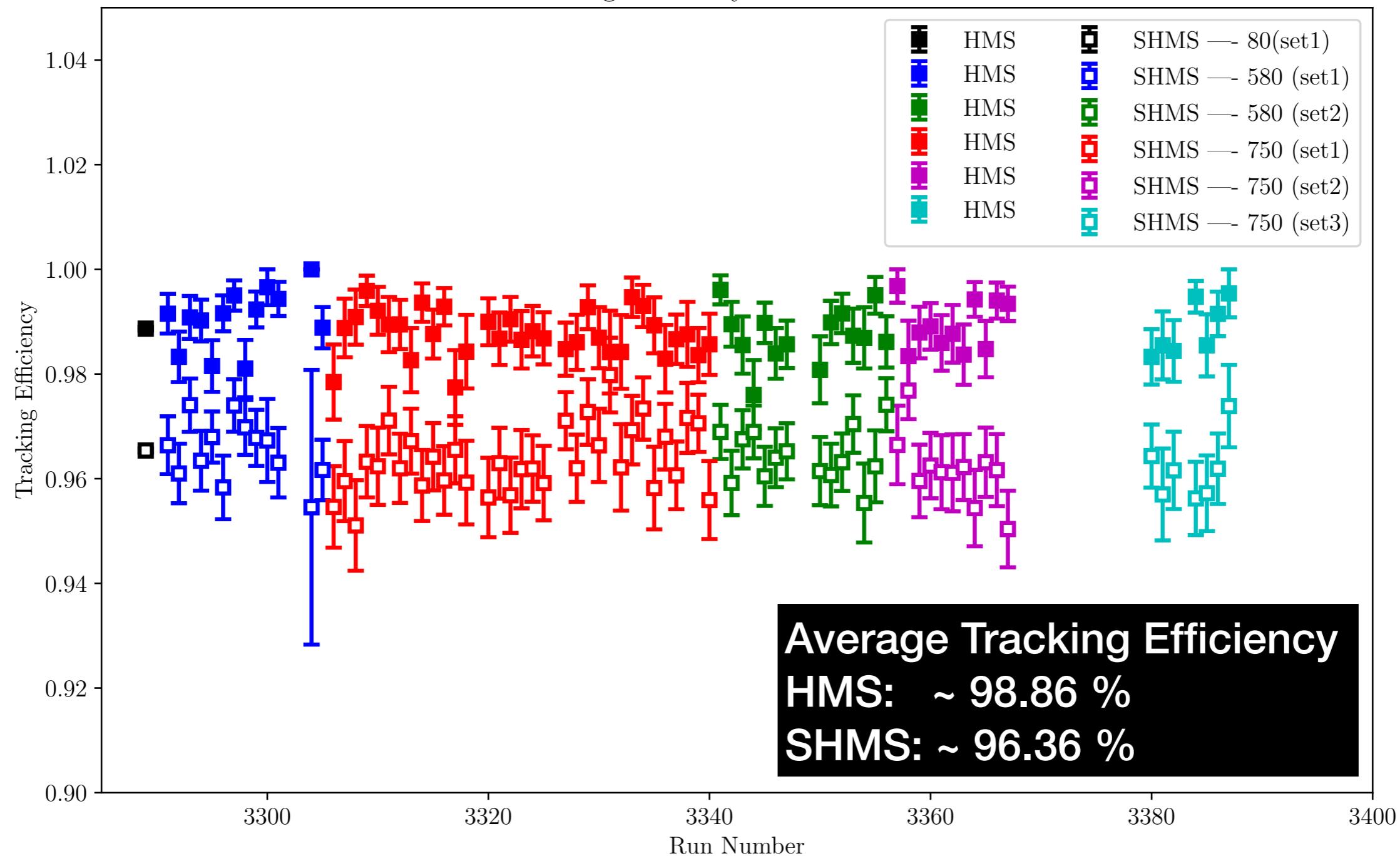
$$Y_{data}^{corr} = \frac{Y_{data}^{uncorr} \cdot f_{rad} \cdot f_{bc}}{Q \cdot \epsilon_{tLT} \cdot \epsilon_{htrk} \cdot \epsilon_{etrk} \cdot \epsilon_{tgtBoil} \cdot \epsilon_{pAbs}}$$

TOTAL EDTM LIVE TIME



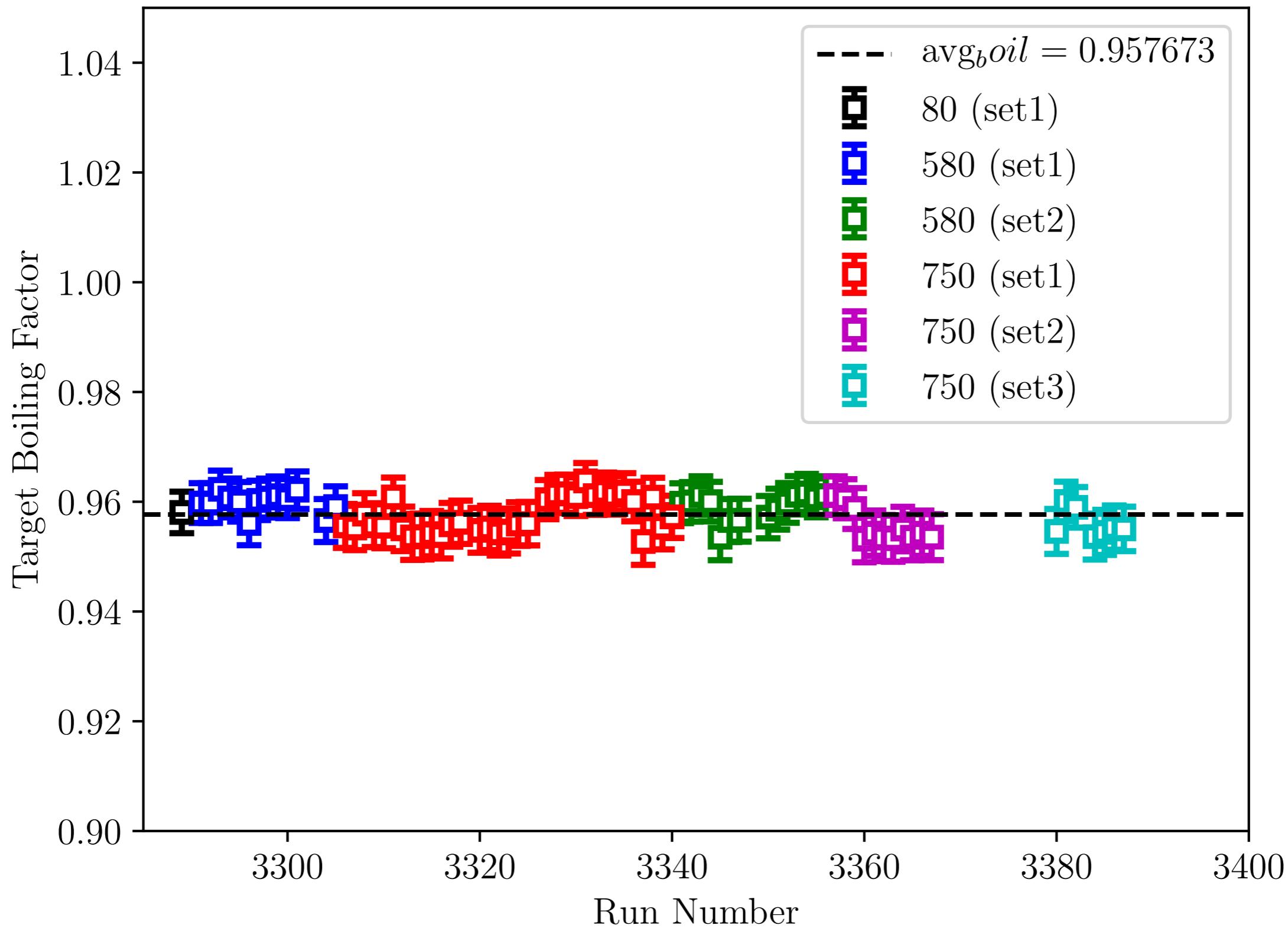
TRACKING EFFICIENCY

Tracking Efficiency vs. Run Number

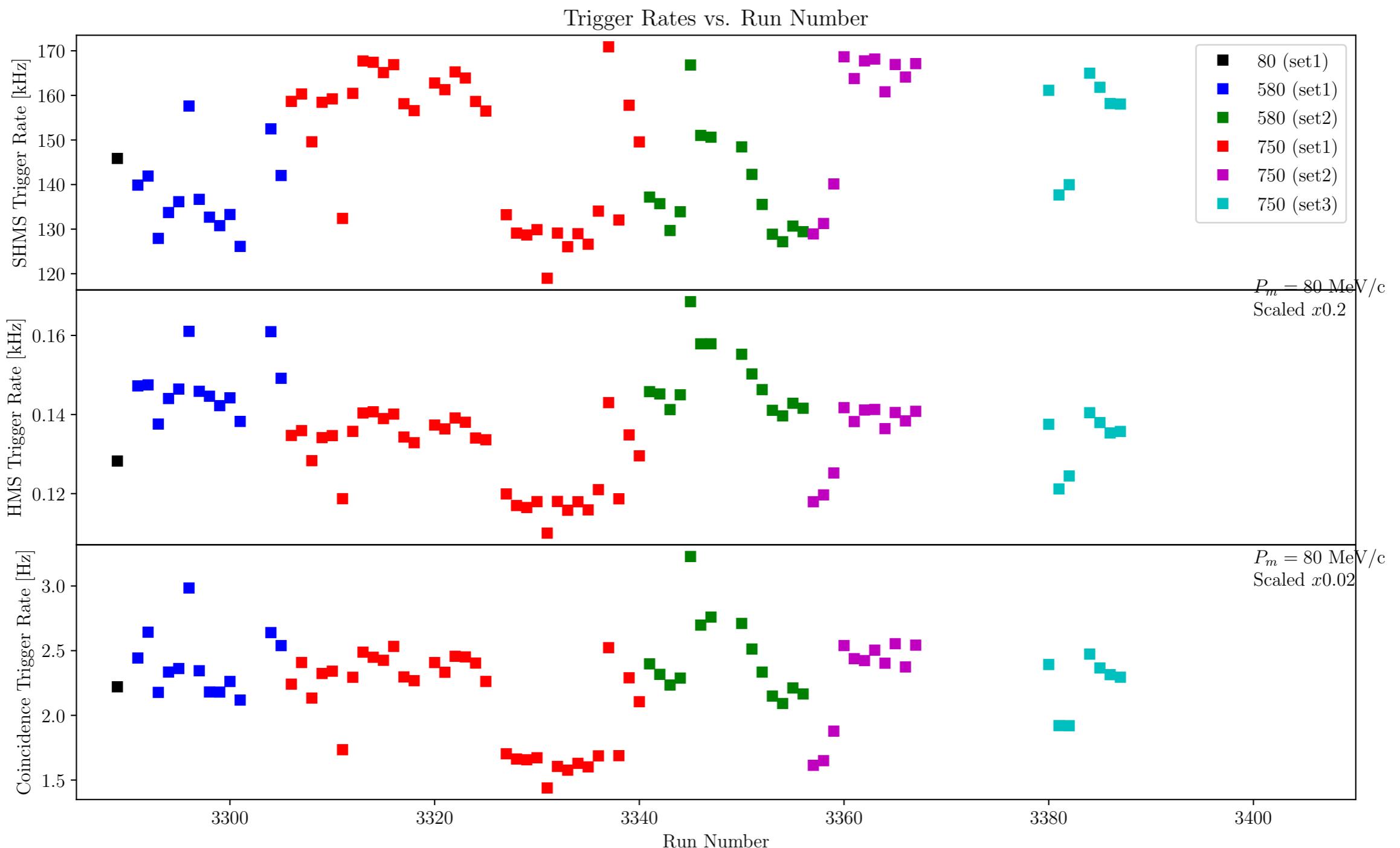


TARGET BOILING FACTOR

LD2 Boiling Factor vs. Run Number

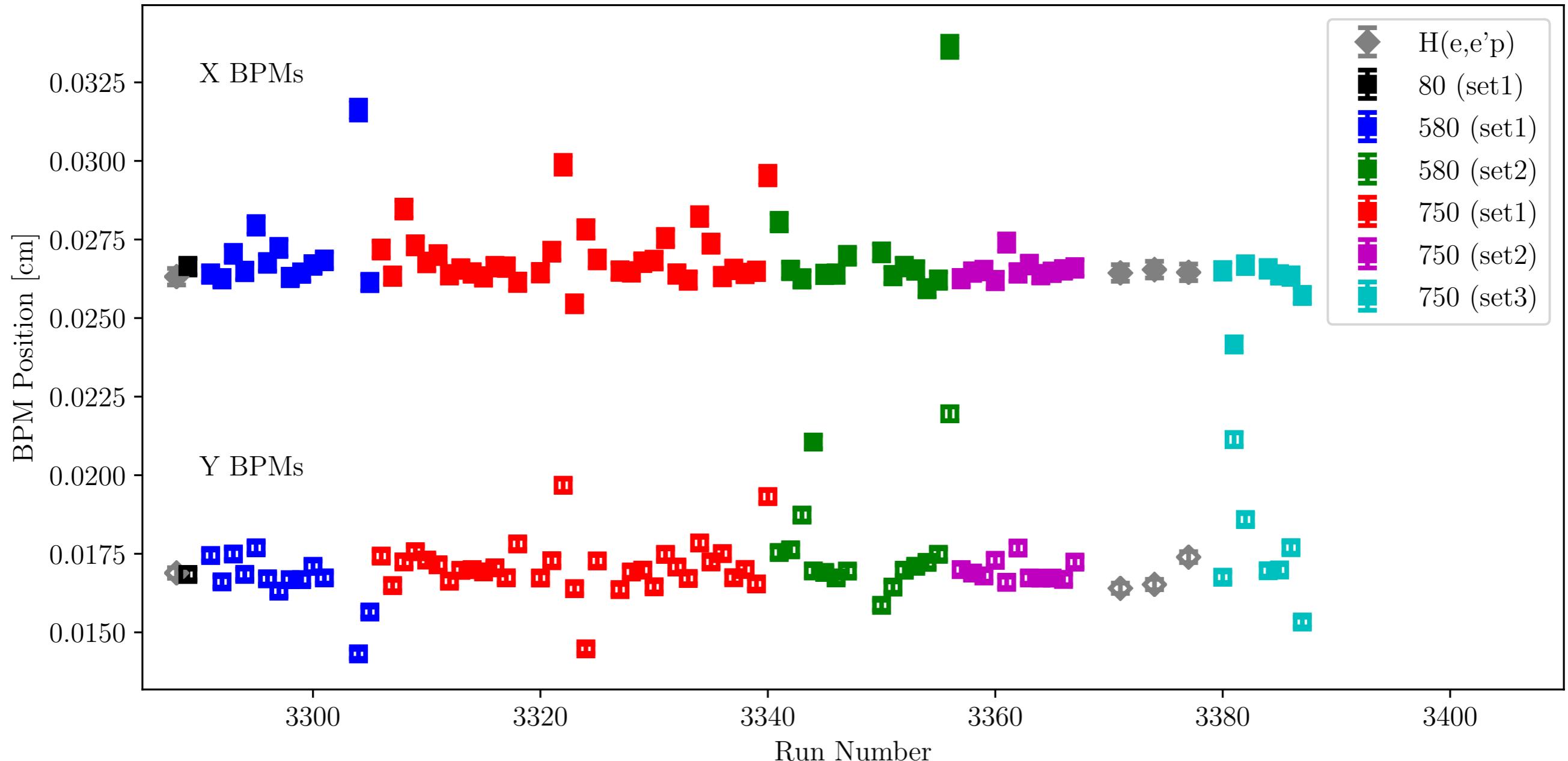


TRIGGER RATES

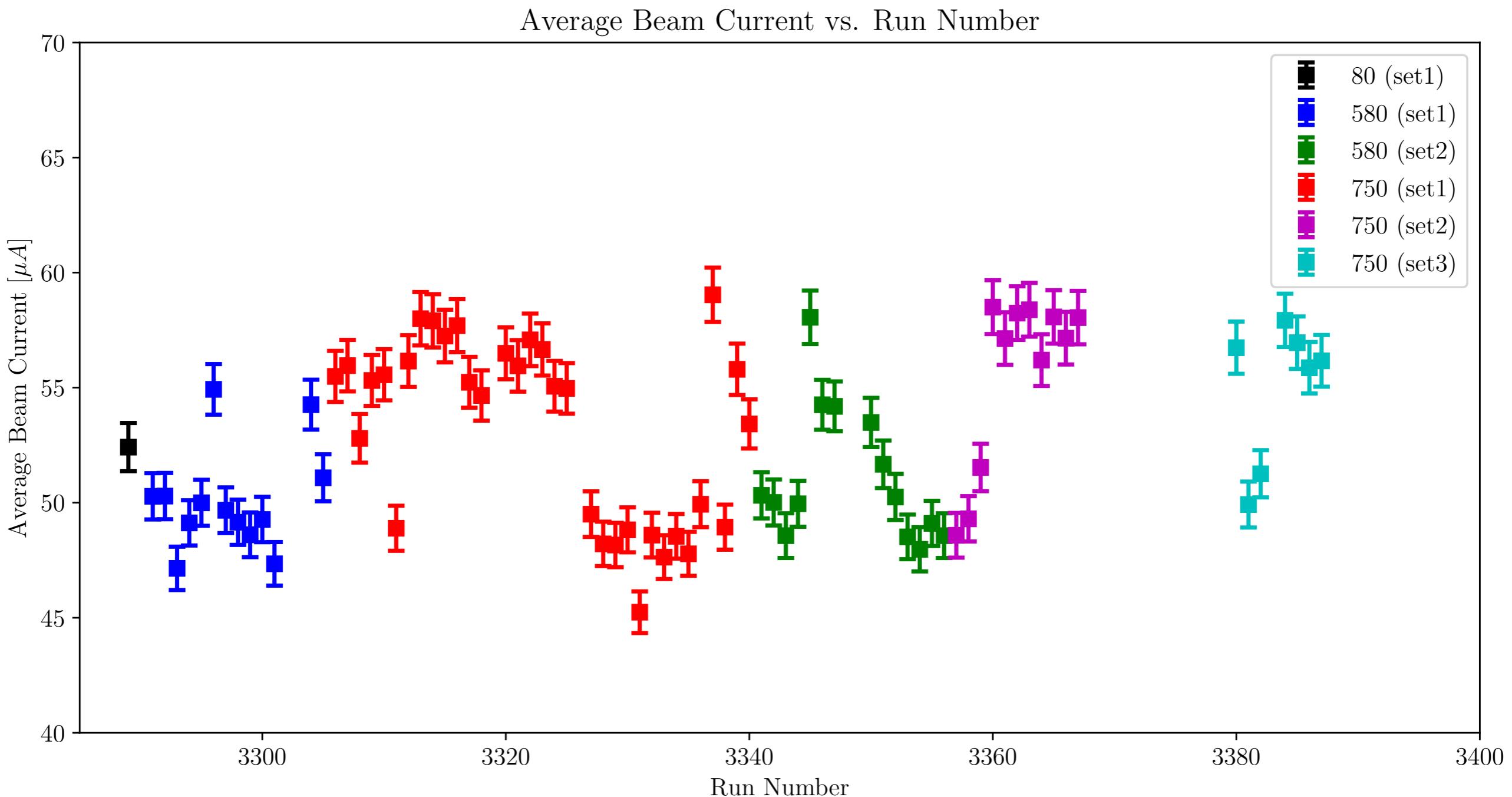


BEAM POSITION MONITORING (BPMs)

Beam Position Monitor vs. Run Number

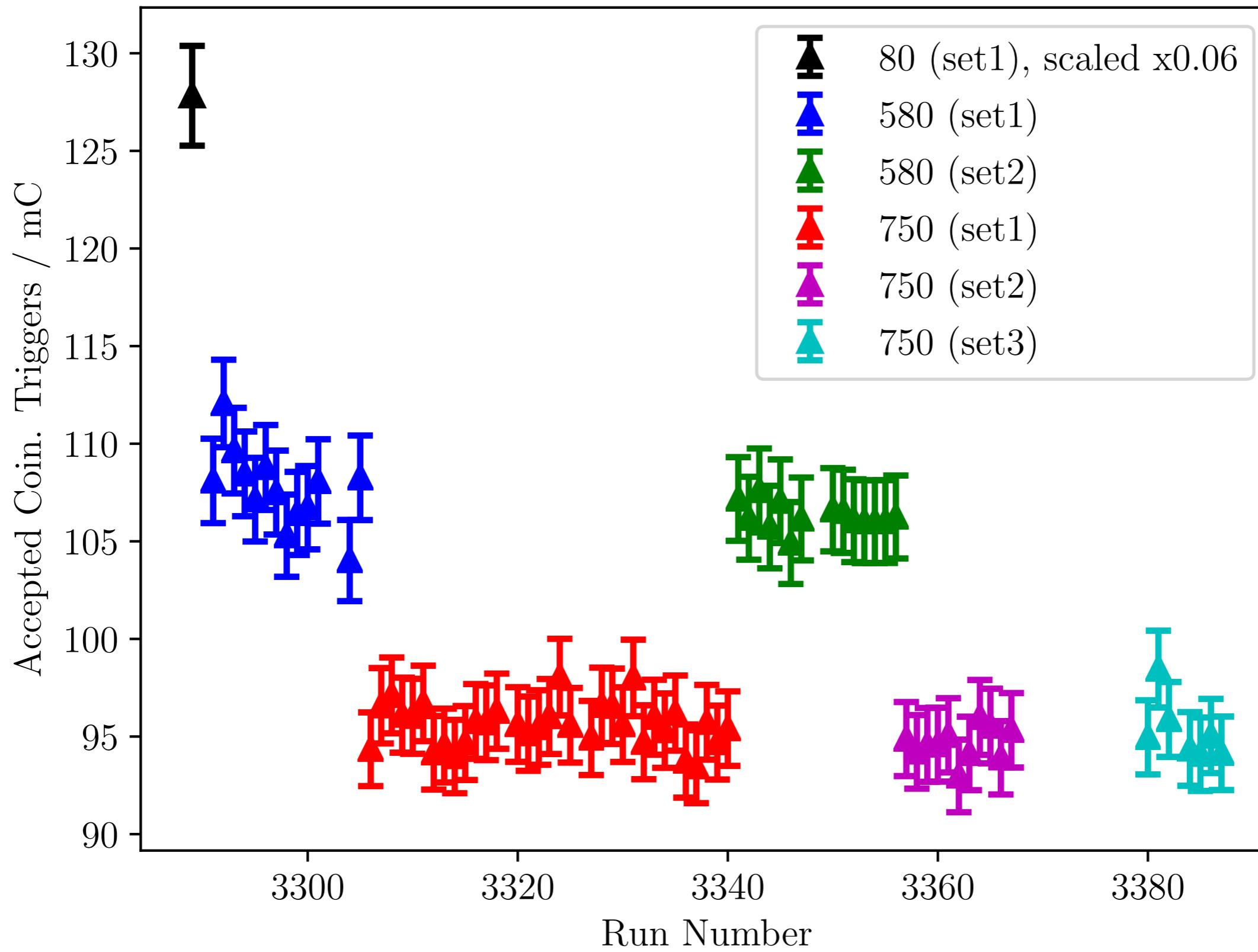


AVERAGE BEAM CURRENT



ACCEPTED COUNTS / CHARGE

Accepted Coincidence Triggers / Charge vs. Run Number

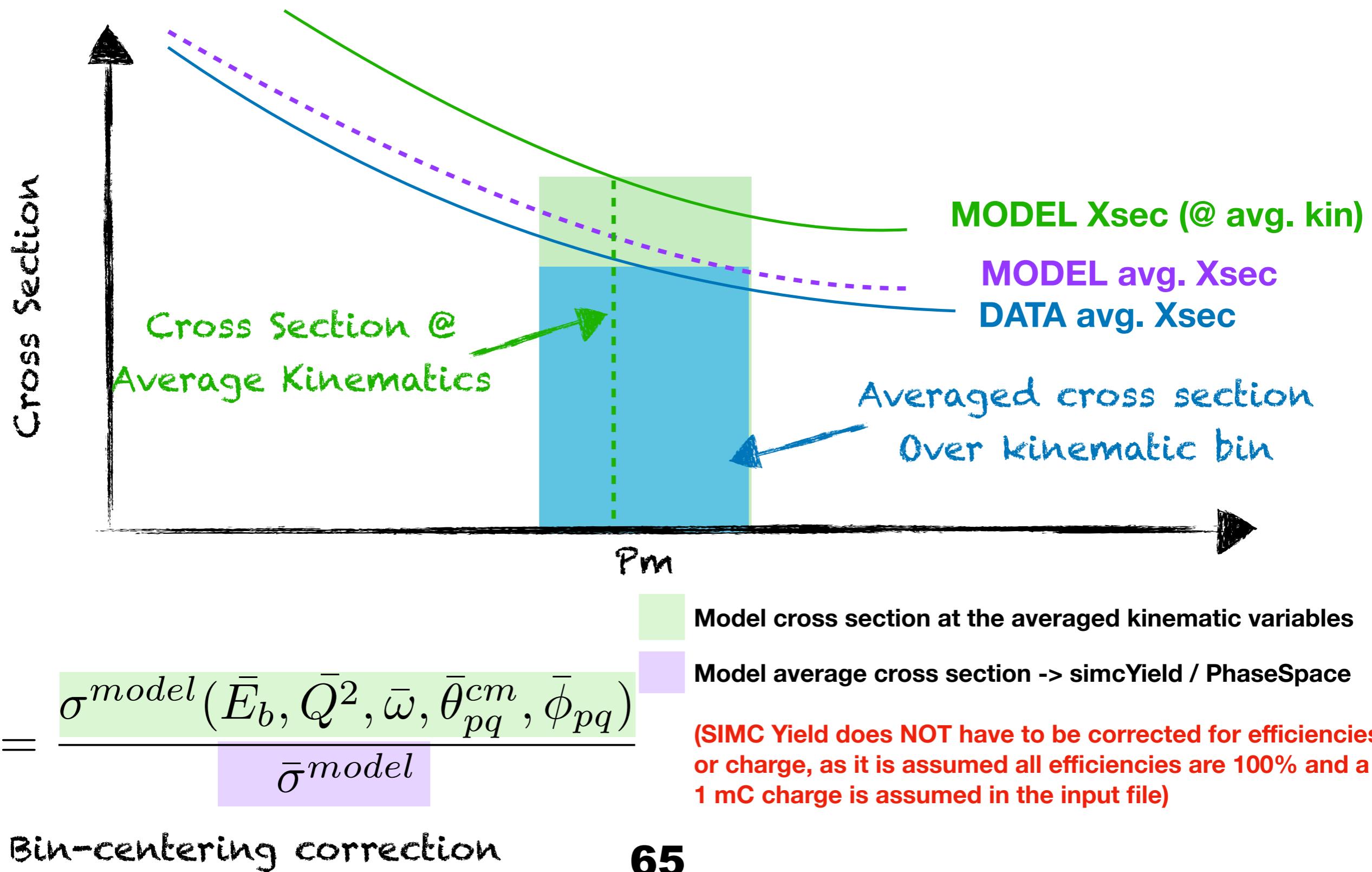


BIN-CENTERING

CORRECTIONS

Bin Centering Corrections

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



Bin Centering Corrections

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

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

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

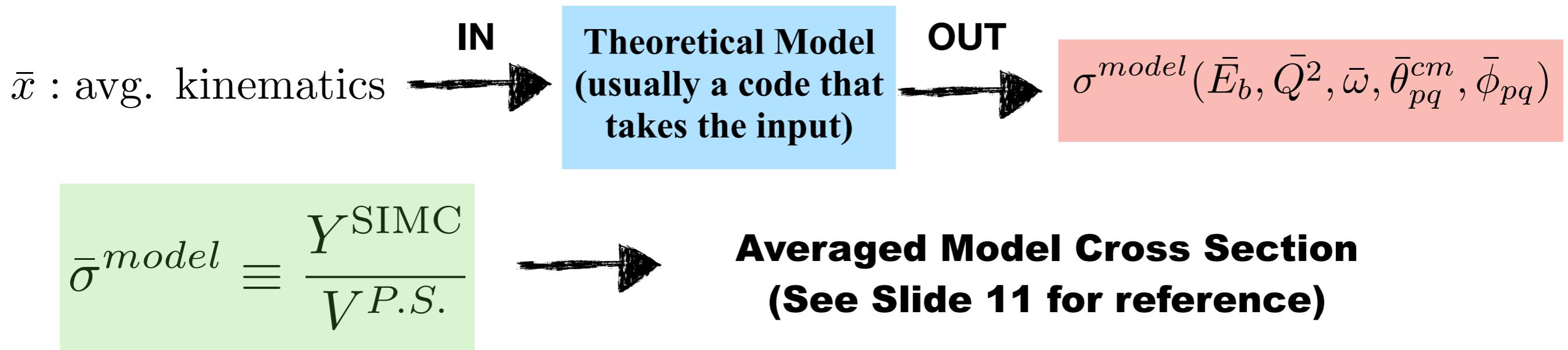
Averaged kinematic variable x over kinematic bin k

Weight times kinematic variable summed over all events

Sum of the weights over all events

Bin Centering Corrections

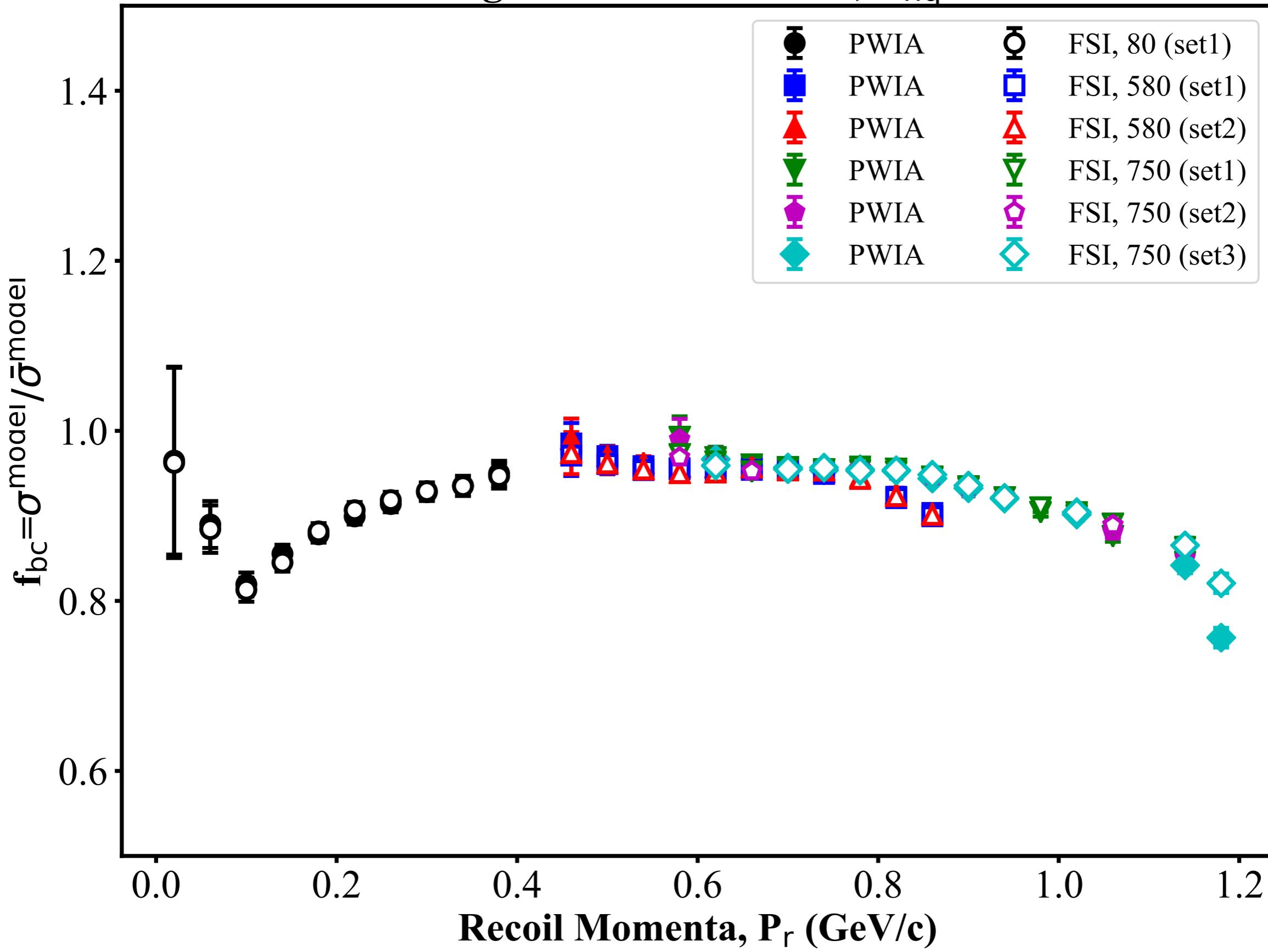
- ❖ Once the averaged kinematics have been calculated, . . .



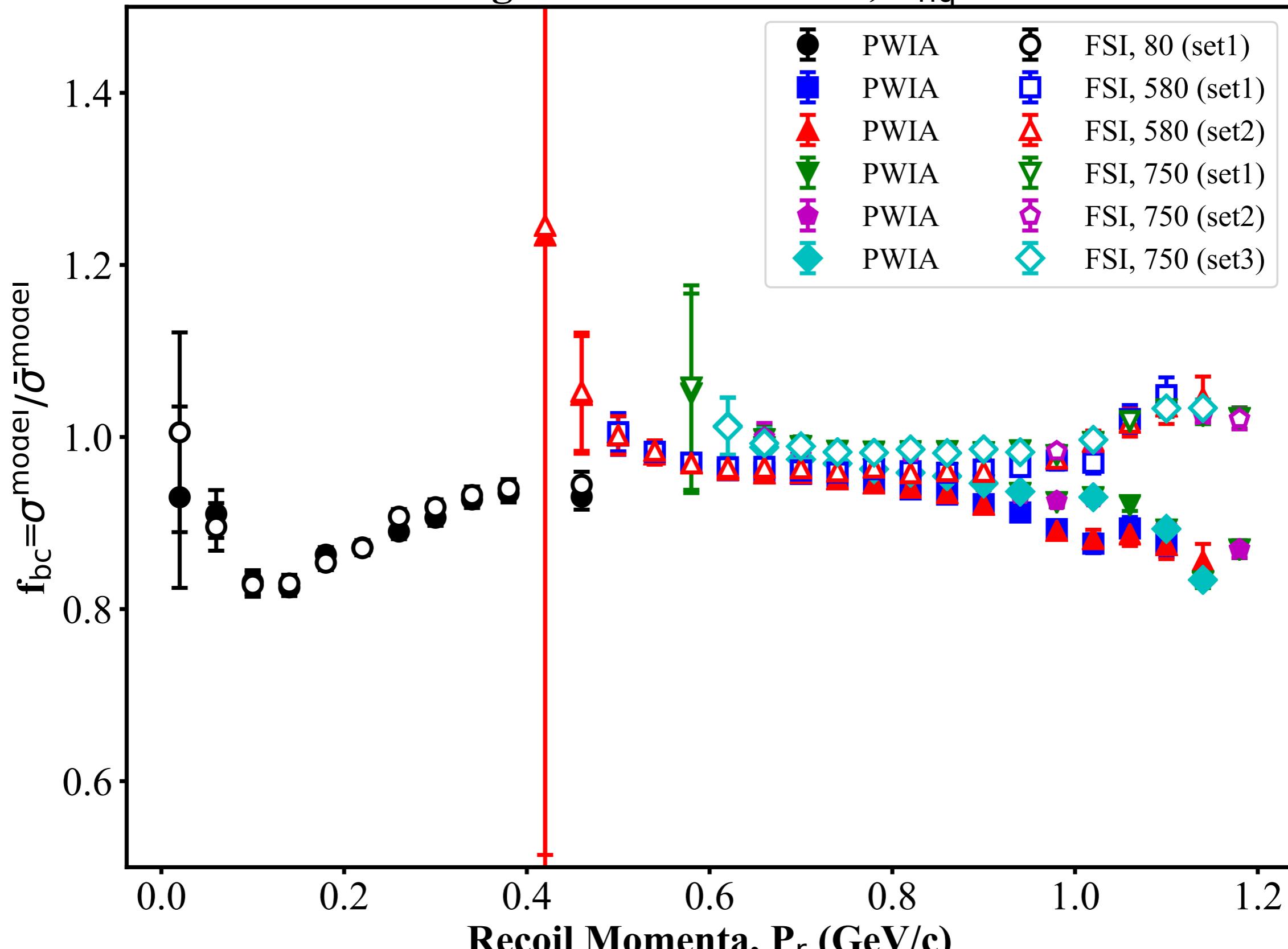
- ❖ Correct the data bin-by-bin using the model cross sections ratio . . .

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

Bin Centering Correction Factor, $\theta_{\text{hq}} = 35 \pm 5^\circ$



Bin Centering Correction Factor, $\theta_{nq} = 45 \pm 5^\circ$



Bin Centering Correction Factor, $\theta_{nq} = 75 \pm 5^\circ$

