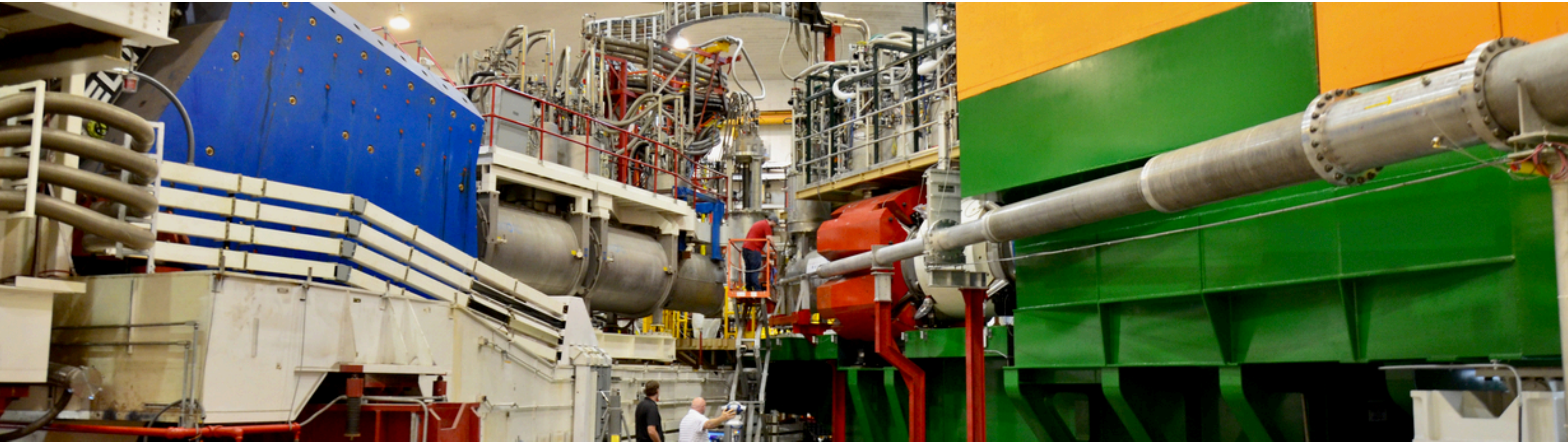


Update on the D(e,e'p)n Commissioning Experiment and Outlook

Hall A/C Joint Collaboration Meeting, June 27-28, 2019

Carlos Yero

Spokespeople: Drs. Werner Boeglin and Mark Jones

Jefferson Lab
Exploring the Nature of Matter

FIU

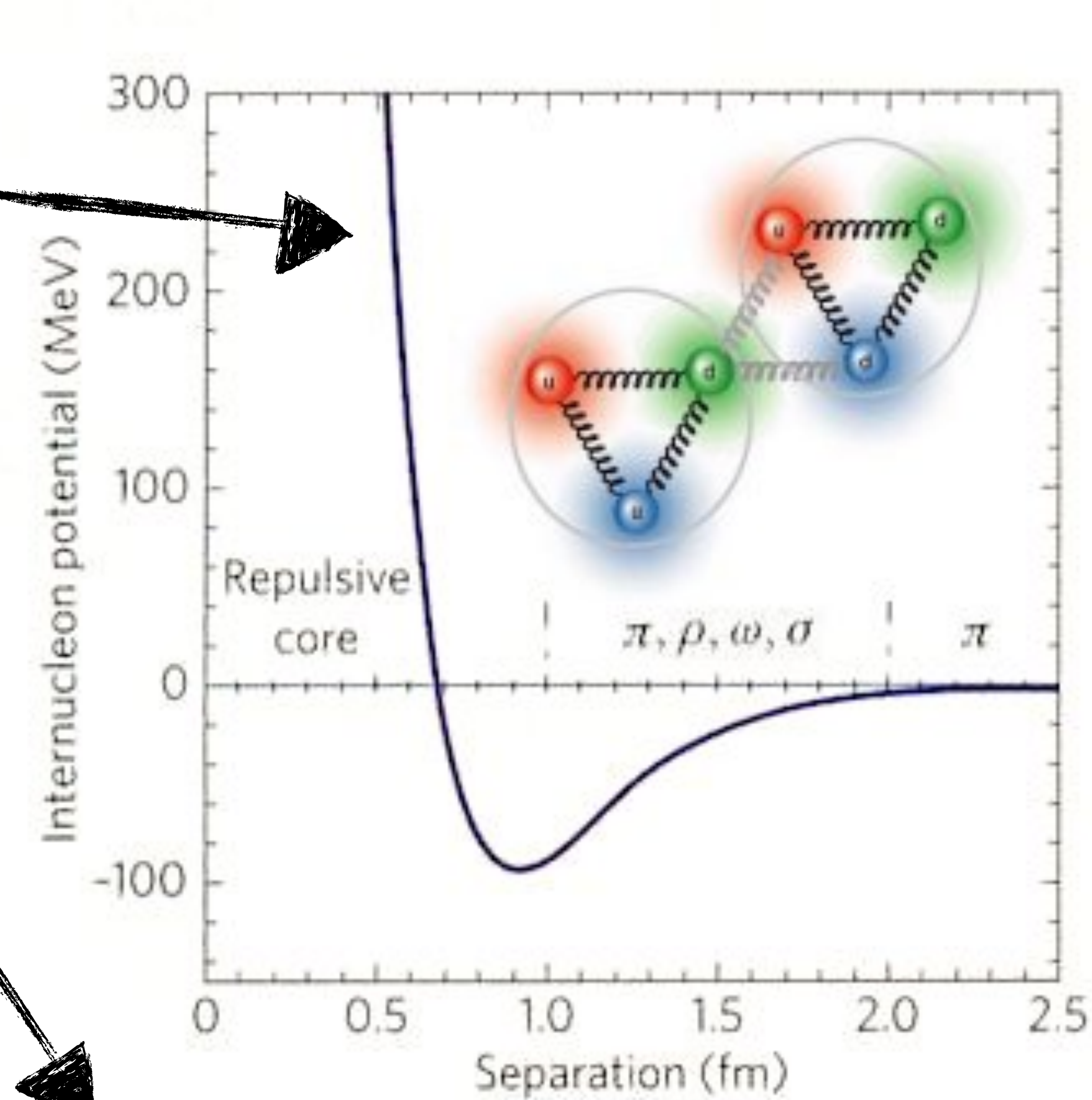
Hall-C

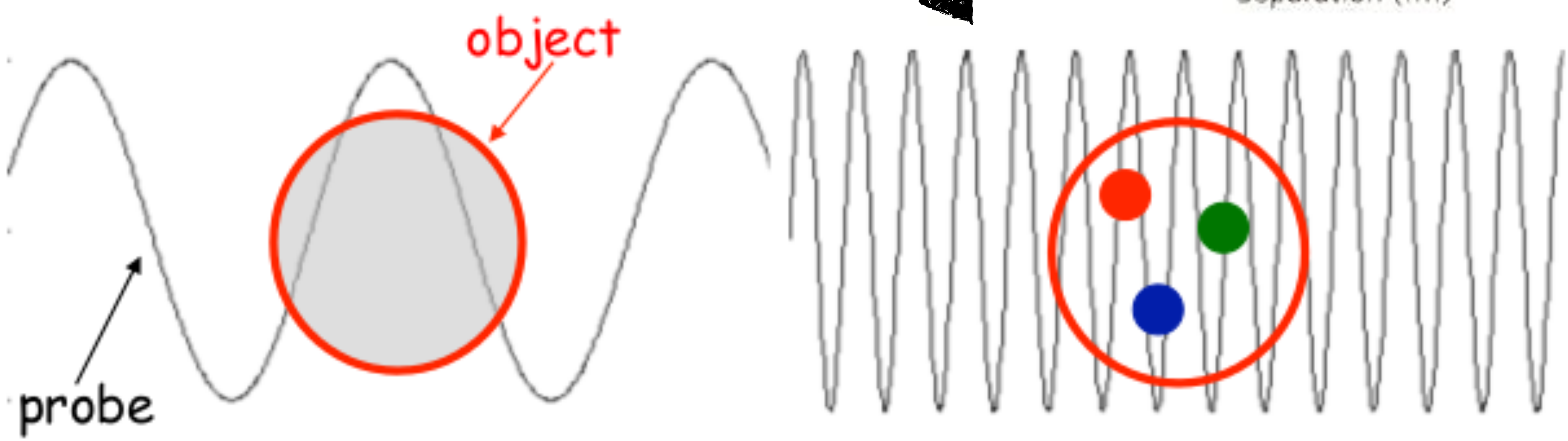
Motivation

- Understand the short range structure of the Deuteron by probing its high momentum tails

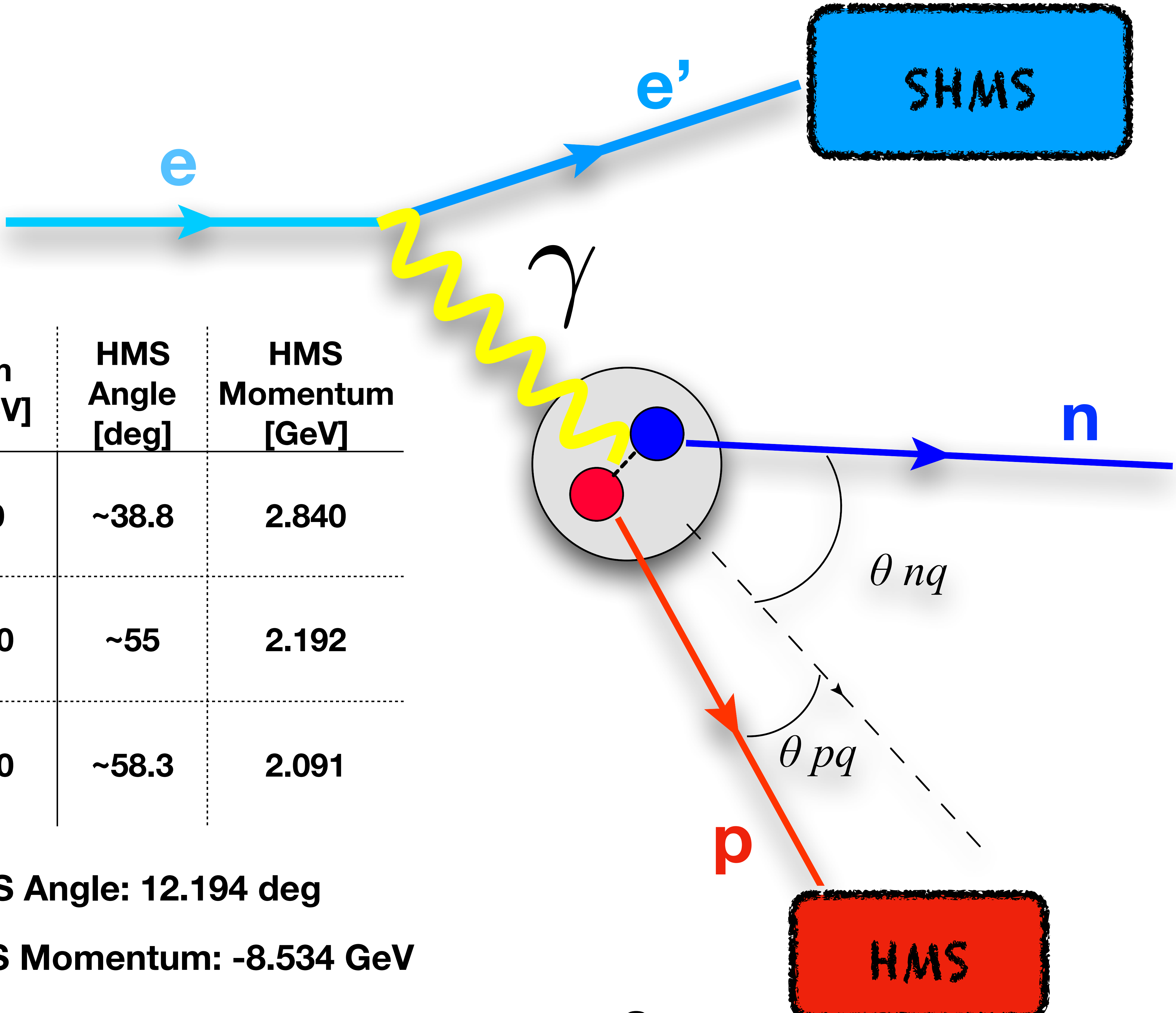
- Use D(e,e’p)n reaction to probe sub-fermi distances using high momentum transfer (Q2)

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





Kinematics

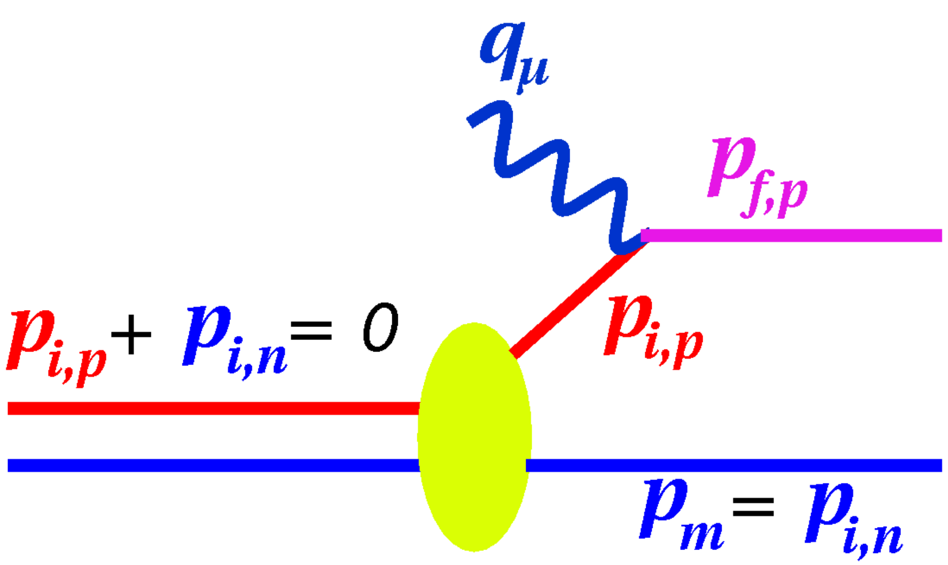


Pm [MeV]	HMS Angle [deg]	HMS Momentum [GeV]
80	~38.8	2.840
580	~55	2.192
750	~58.3	2.091

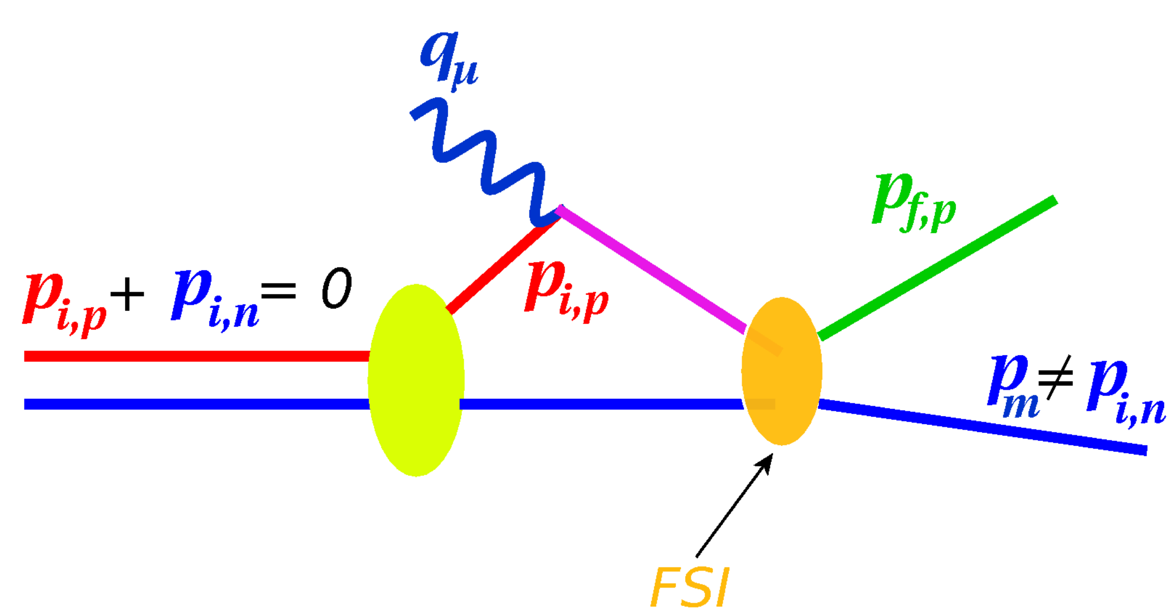
SHMS Angle: 12.194 deg

SHMS Momentum: -8.534 GeV

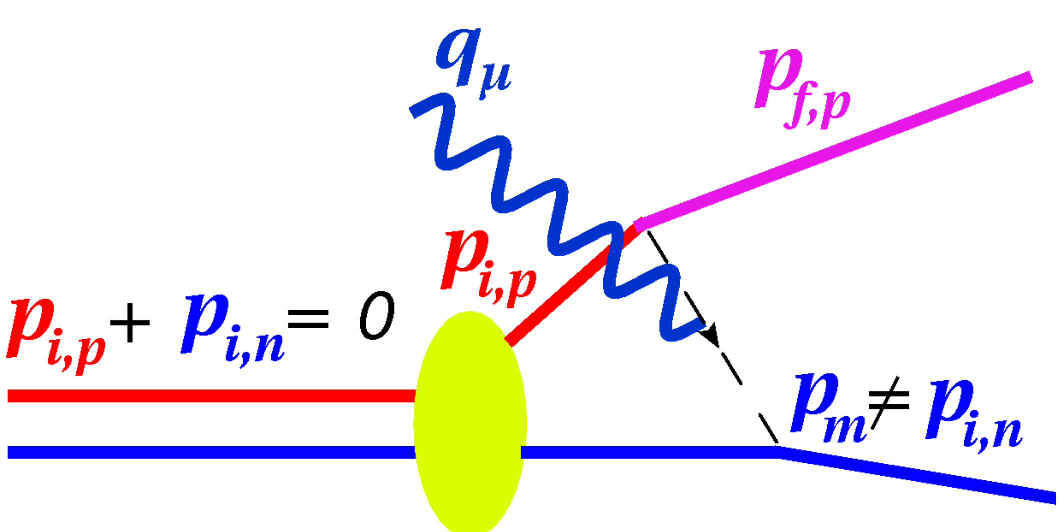
D(e,e'p)n Feynman Diagrams



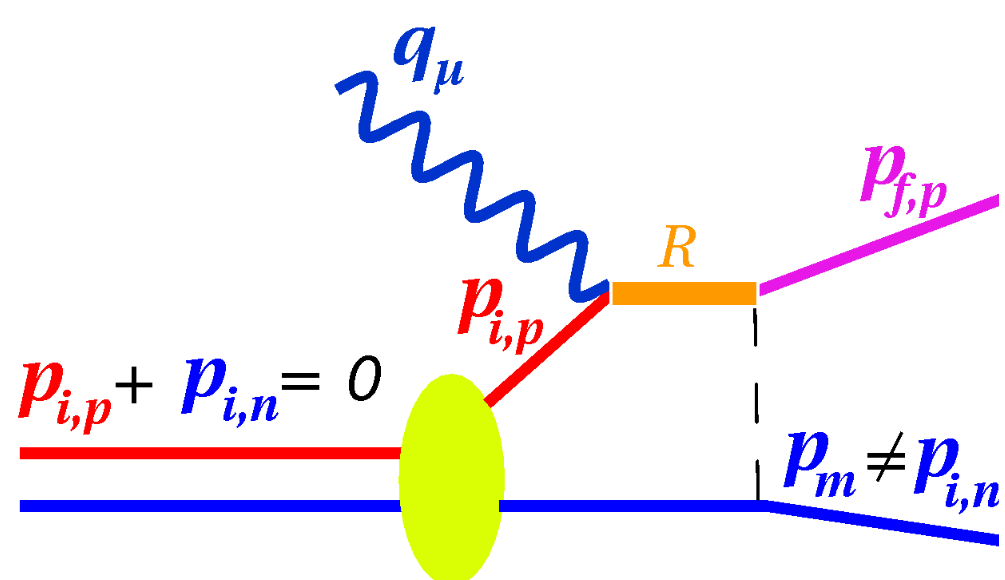
Plane Wave Impulse Approximation (PWIA)



Final State Interactions (FSI)



Meson-Exchange Currents (MEC)



Isobar Configurations (IC)

Deuteron Momentum Distribution

Experiment

Theory

$$\boxed{\sigma_{exp} \equiv \frac{d^6\sigma}{d\omega d\Omega_e dT_p d\Omega_p}} = \boxed{K \cdot \sigma_{ep} \cdot S(E_m, p_m)}$$

$$S(p_m) \approx \sigma_{red} \equiv \frac{\sigma_{exp}}{K\sigma_{ep}}$$

Factorization ONLY possible in PWIA

ep off-shell cross section

electron scatters off a bound proton within the nucleus; usually, de Forest σ_{cc1} or σ_{cc2} is prescribed

Spectral Function, $S(p_m)$

the momentum distribution inside the deuteron is interpreted as the probability density of finding a bound proton with momentum p_i

Theoretical Background for D(e,e'p)n

D(e,e'p)n Kinematics

$E_e = 11$ GeV

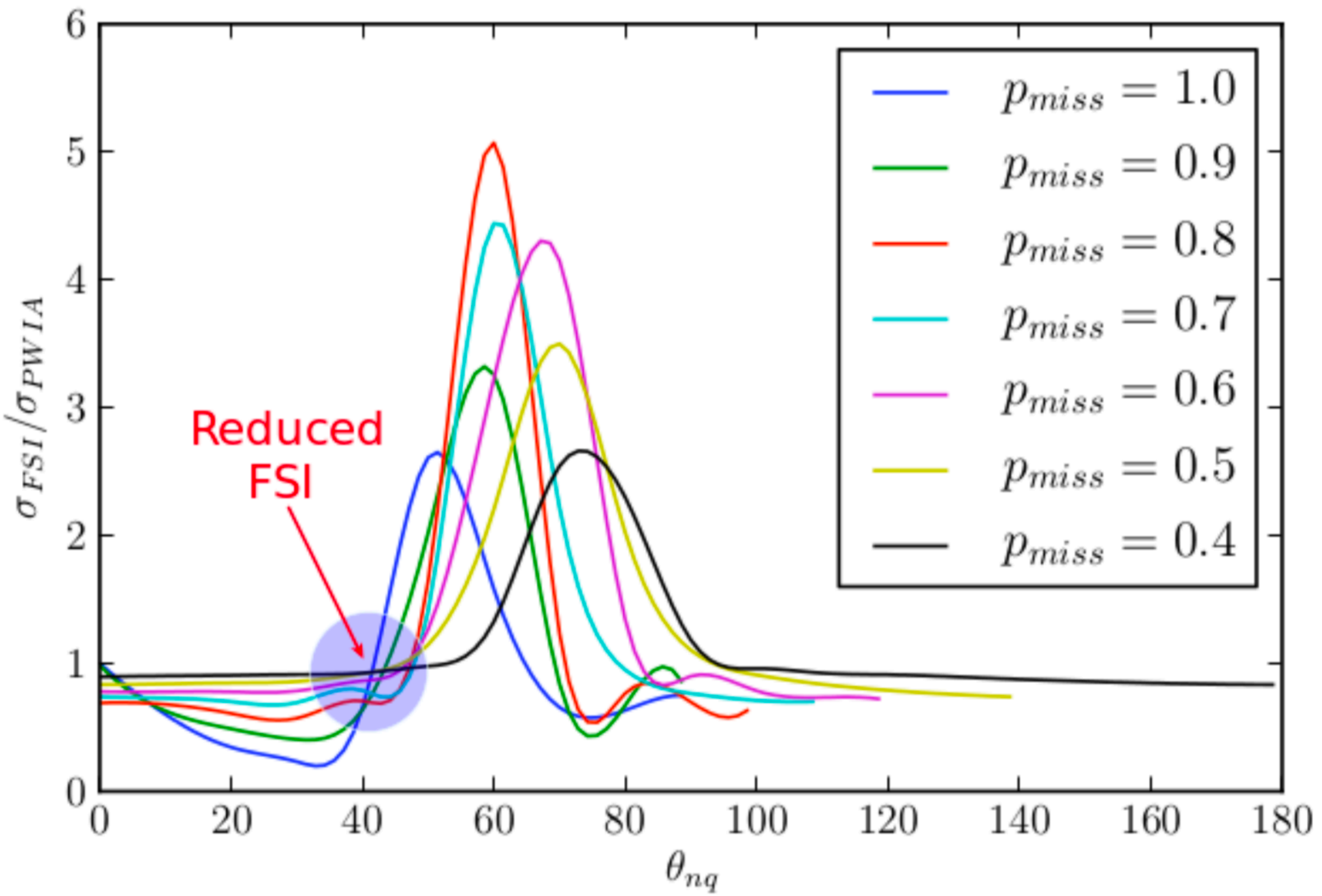
$Q^2 = 4.25$ (GeV/c)^2

$x_{B_j} = 1.35$

$p_m = 0.5 - 1.0$ GeV/c

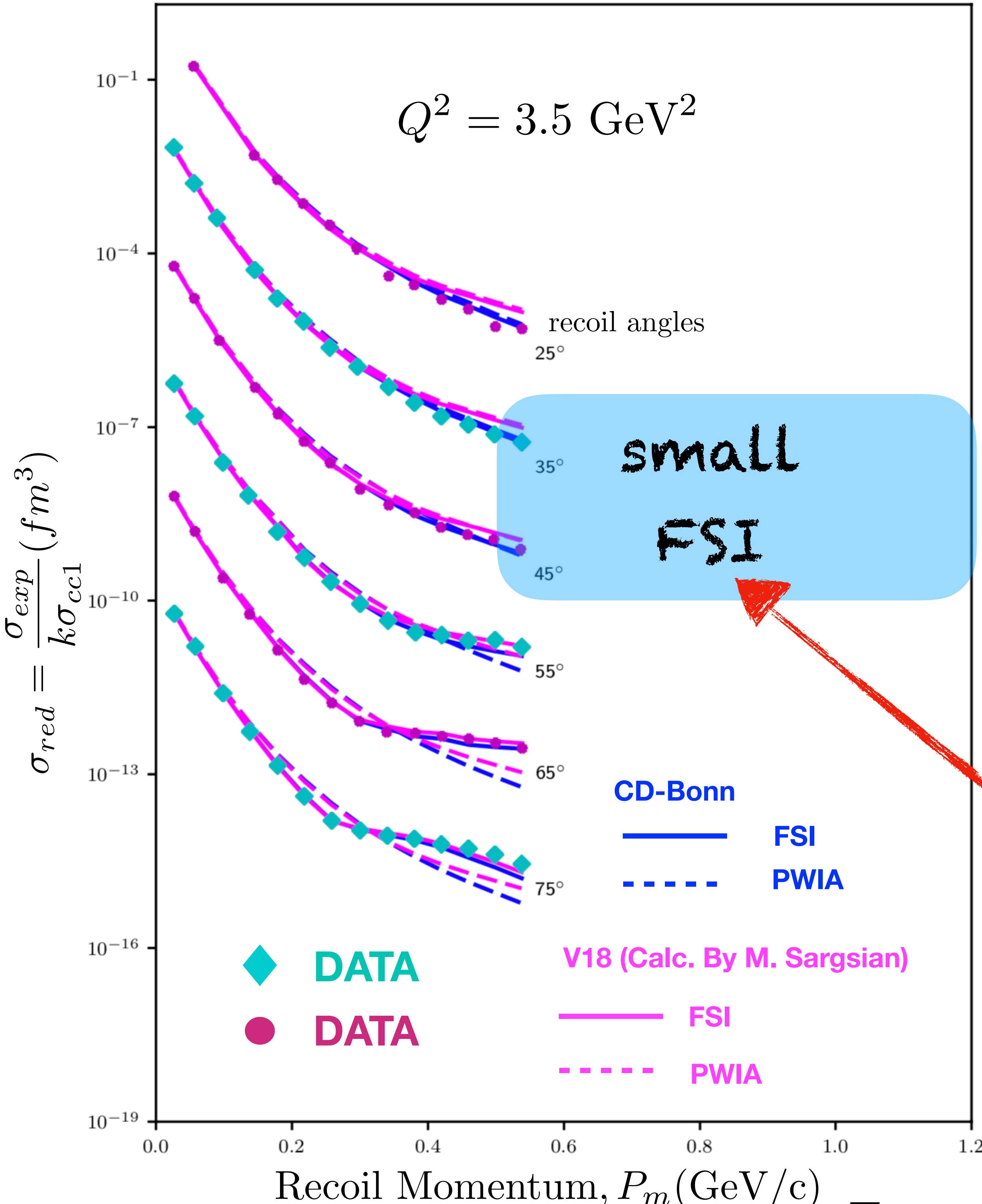
$\theta_{nq} = 35° - 40°$

W.U. Boeglin *et. al*
Int.J.Mod.Phys. E24
(2015) no.03, 1530003



Theoretical Calculation by: M. Sargsian

Previous Hall A Measurement of D(e,e'p)n

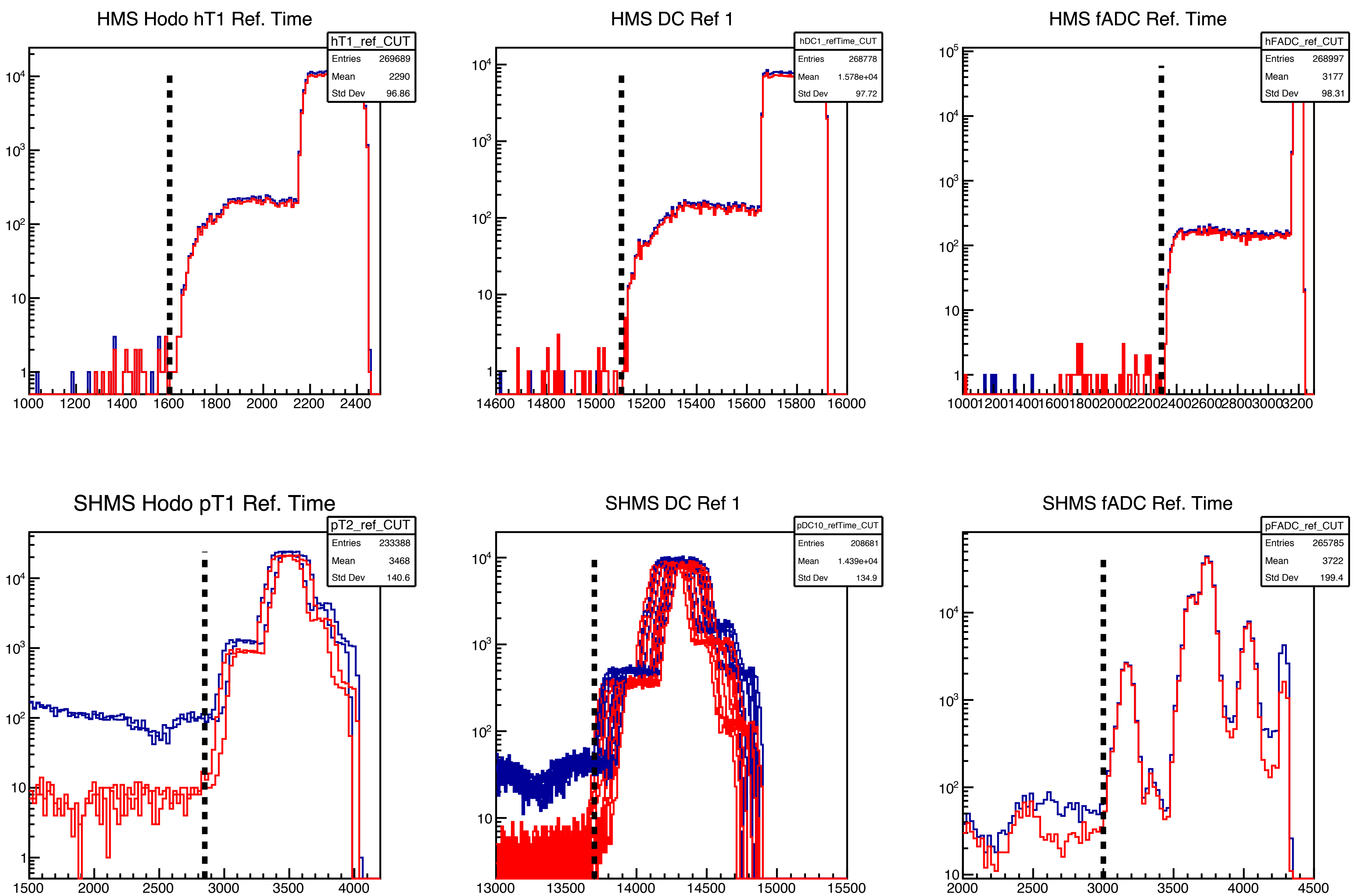


- Momentum Distribution at various recoil angles are scaled relative to the 25 deg. setting
- At recoil angles 40 +/- 5 deg, is a kinematic region of interest as FSI are suppressed
- Deuteron Momentum Distribution becomes accessible at small FSI
- This experiment focuses on recoil angles ~ 40 deg at recoil momenta beyond 500 MeV/c where FSI are small

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)**



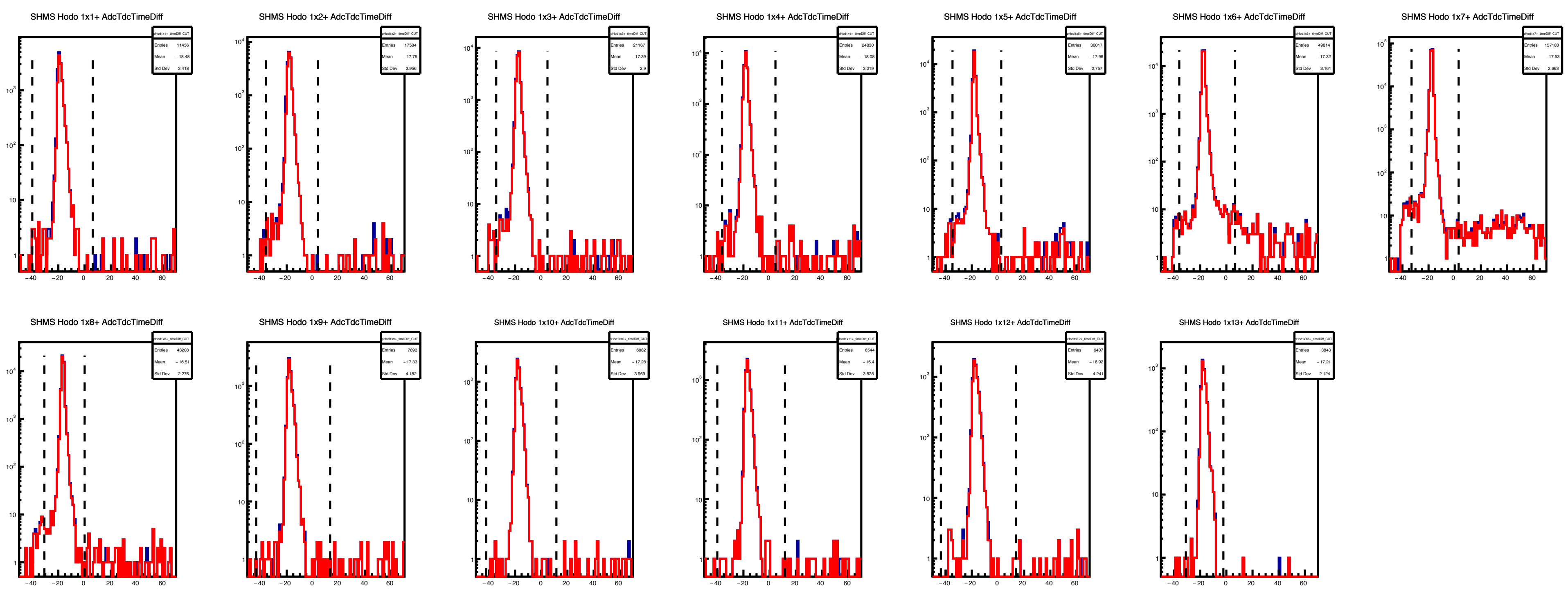
HMS Reference Times

SHMS Reference Times

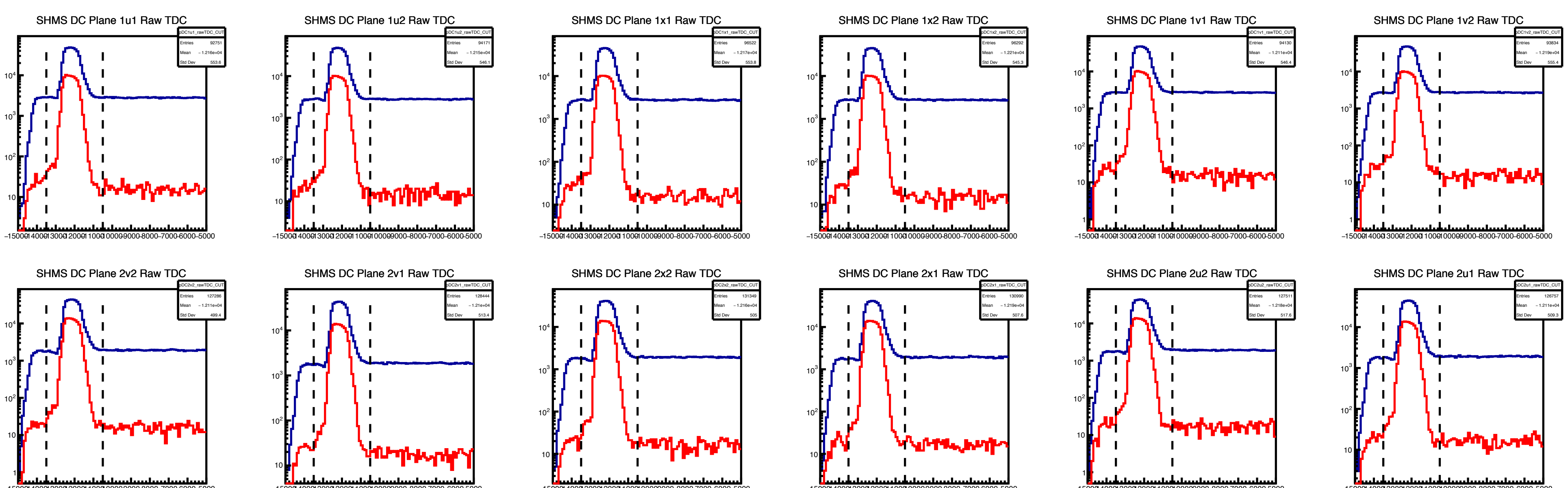
TDC Time Window Cuts

☑ 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

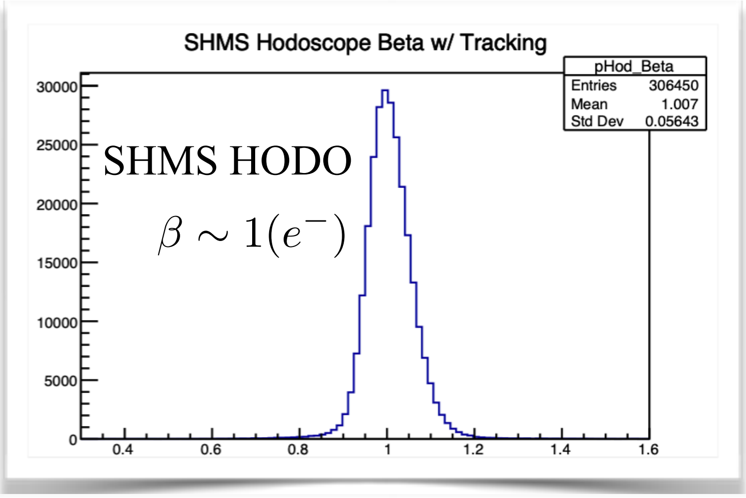


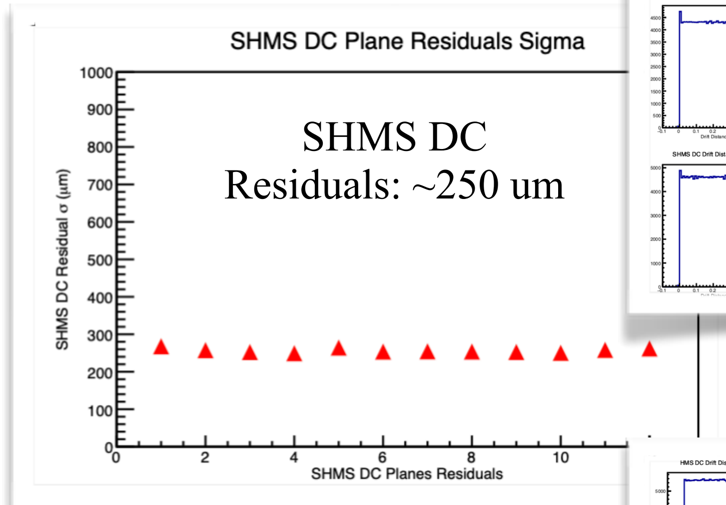
SHMS Hodoscope 1X+ (ADC-TDC) Time Difference

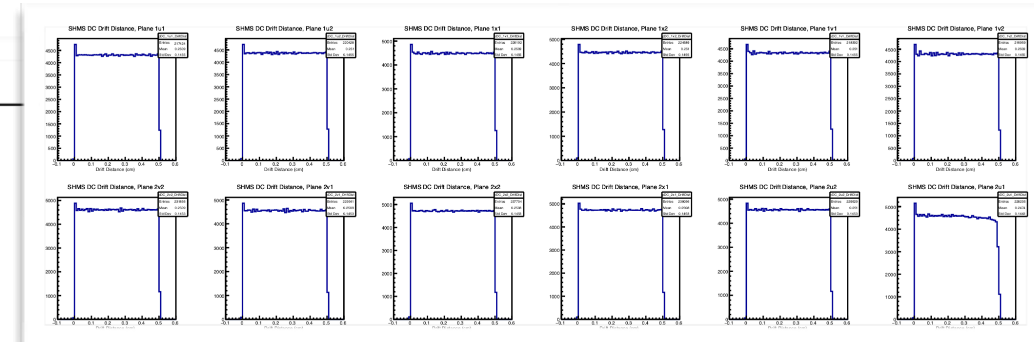


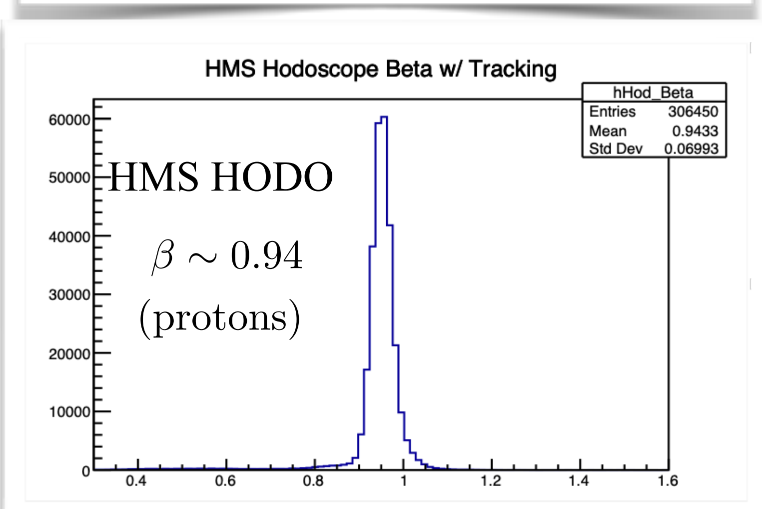
SHMS Drift Chambers Raw TDC Time

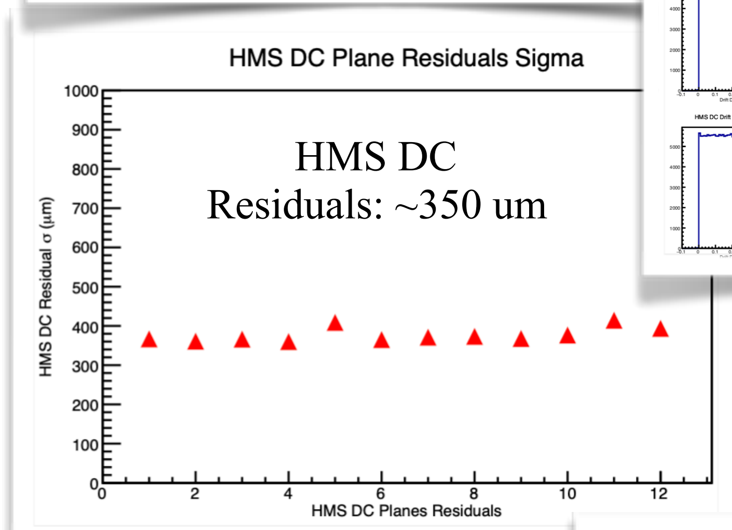
Detector Calibrations

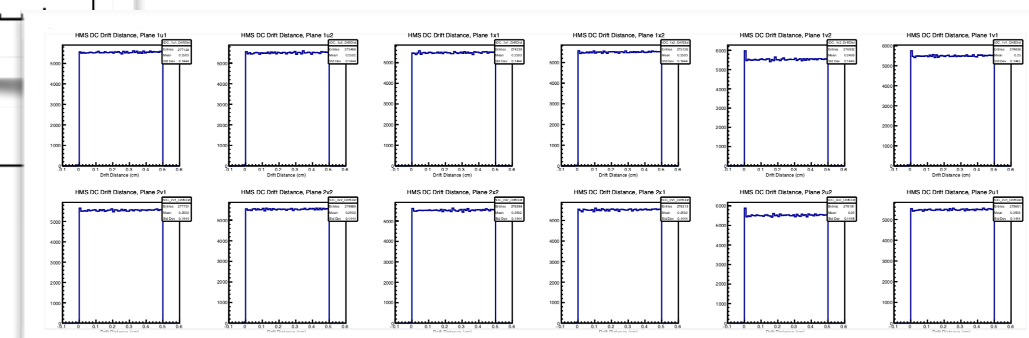


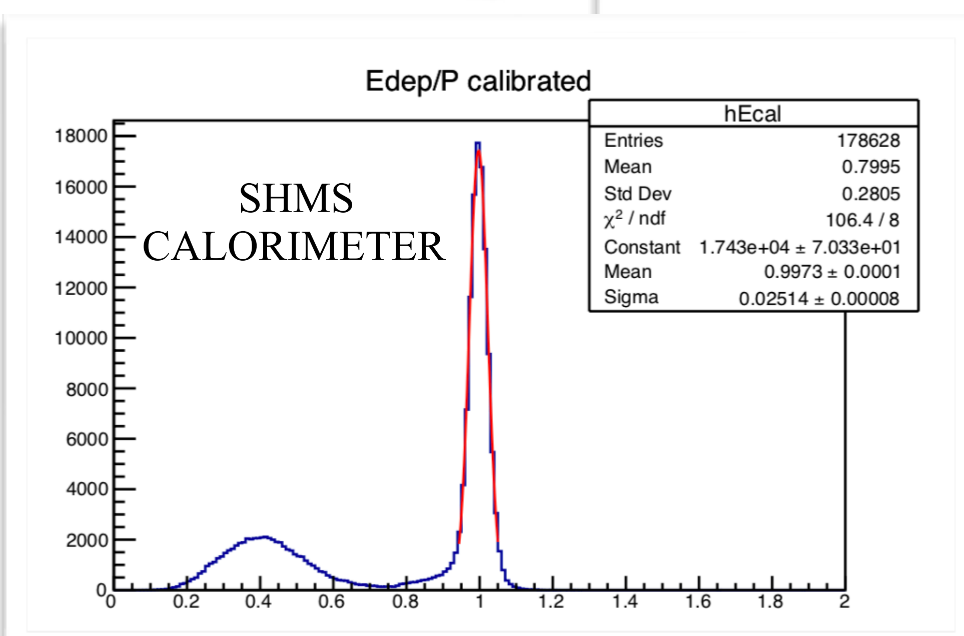


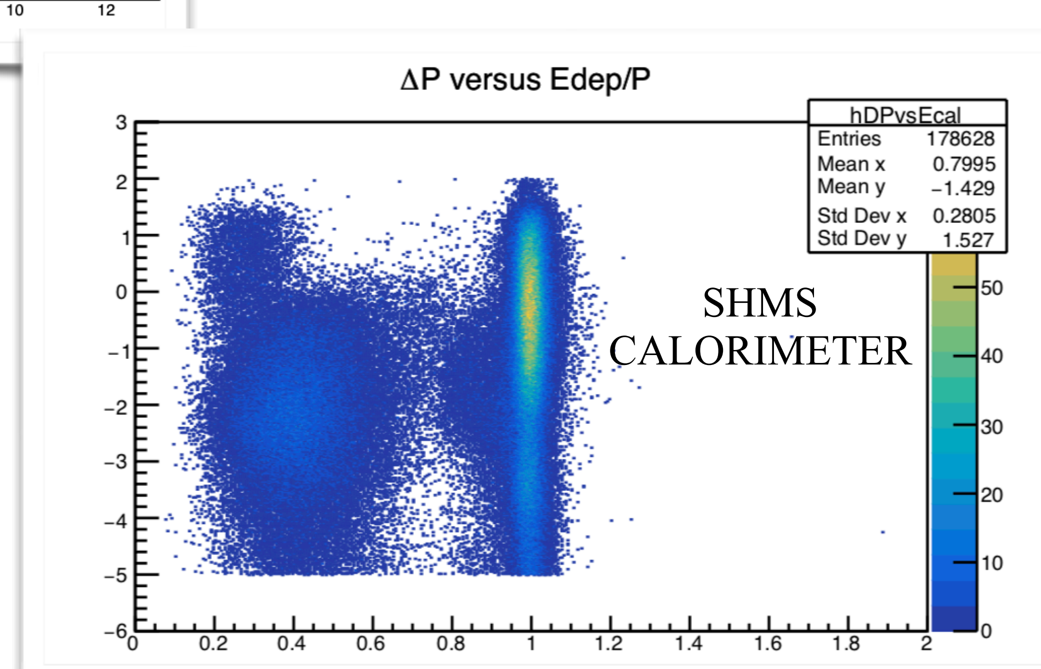




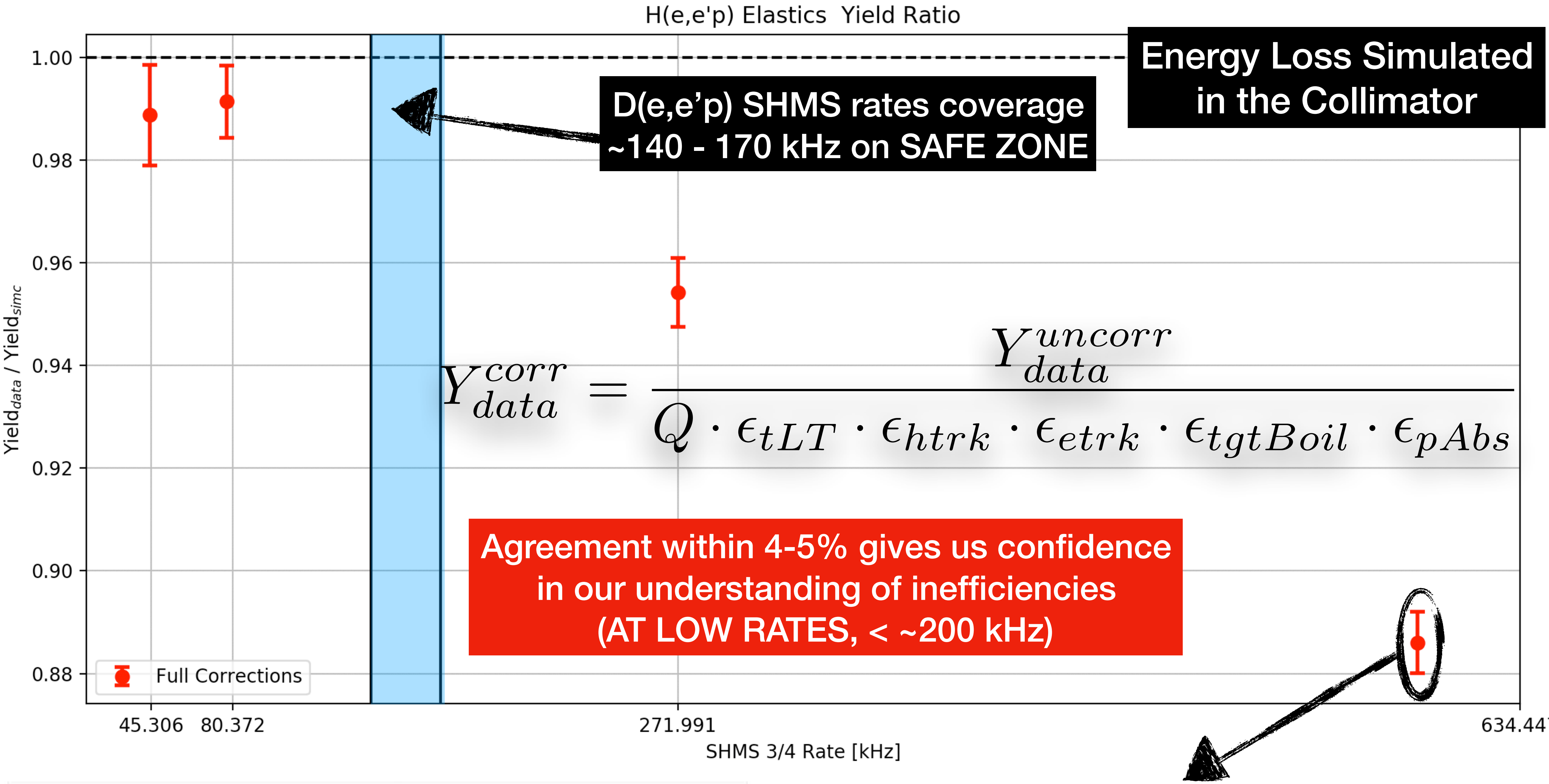








H(e,e'p) Yield Ratio Check



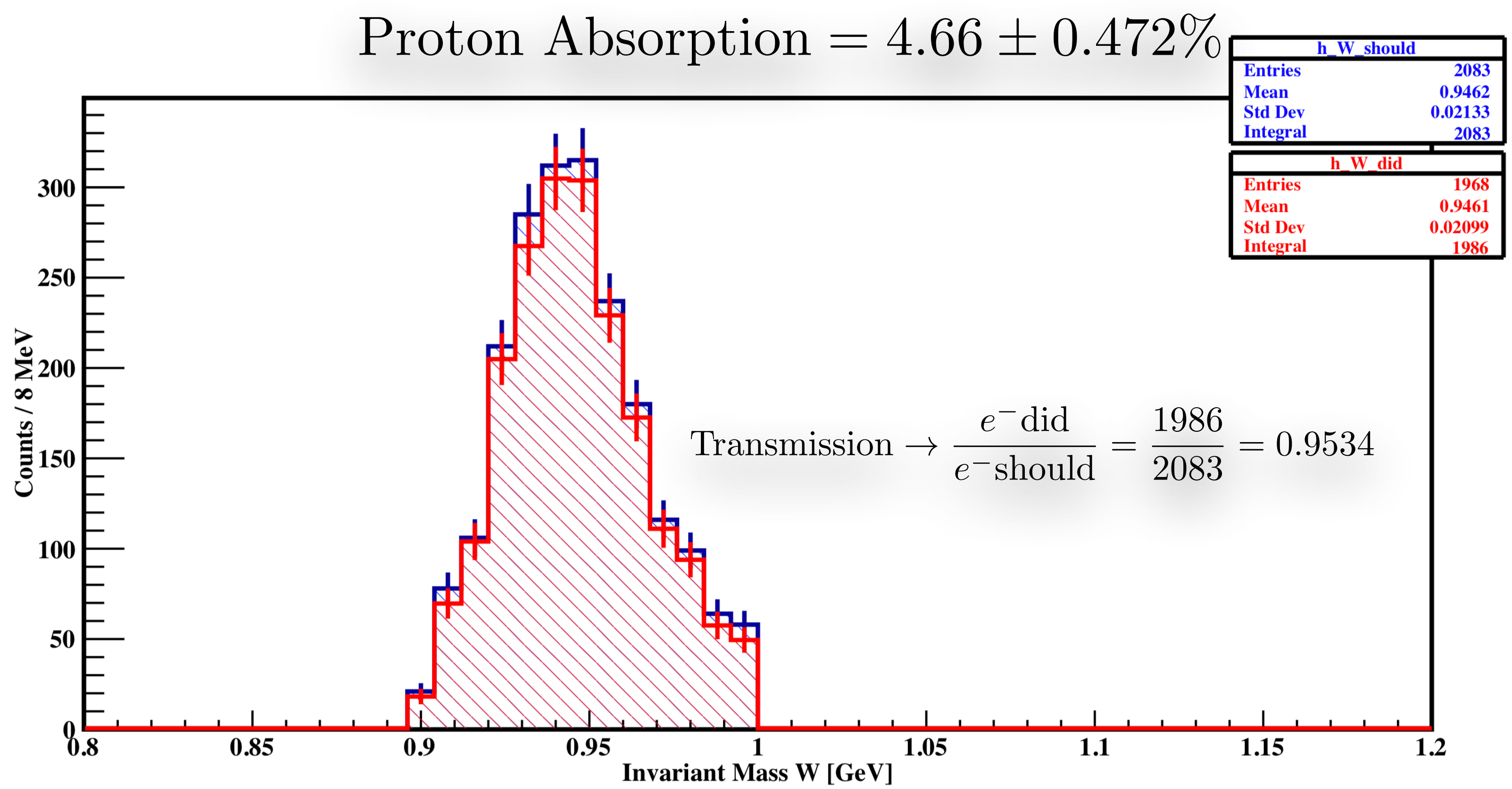
$$Y_{data}^{corr} = \frac{Y_{data}^{uncorr}}{Q \cdot \epsilon_{tLT} \cdot \epsilon_{htrk} \cdot \epsilon_{etrk} \cdot \epsilon_{tgtBoil} \cdot \epsilon_{pAbs}}$$

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

NOT Understood:

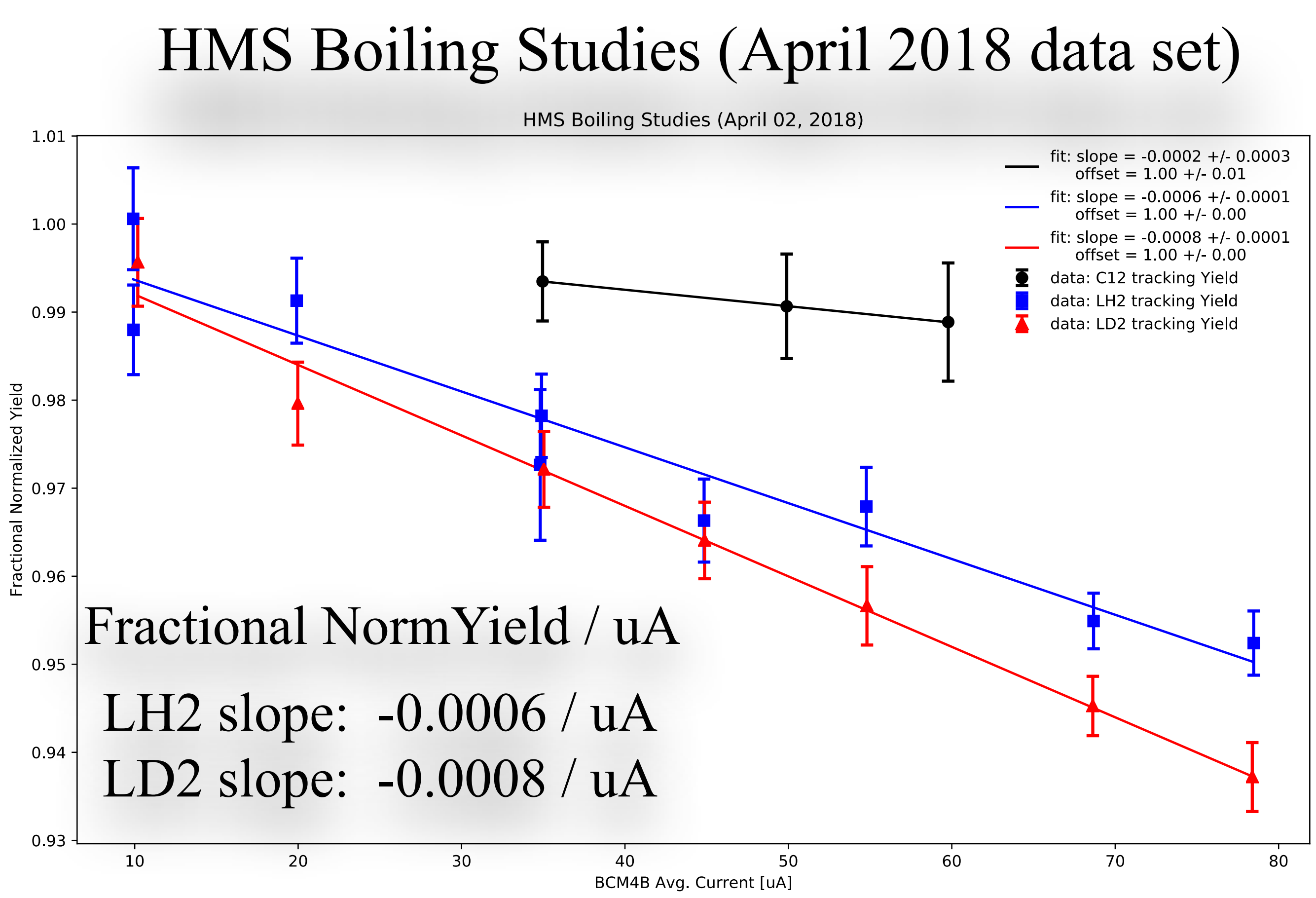
* How does the tracking algorithm perform at high rates?
* How well are Form Factors known at these low Q2 (1.9, 2.5) GeV2

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 !

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

frc = Ysimc_norad / Ysimc_rad

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

Correct for Inefficiencies

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

*(See simc.f in SIMC)

Normalization Factor

Accepted Events

Jacobian Correction to solid angles

Luminosity

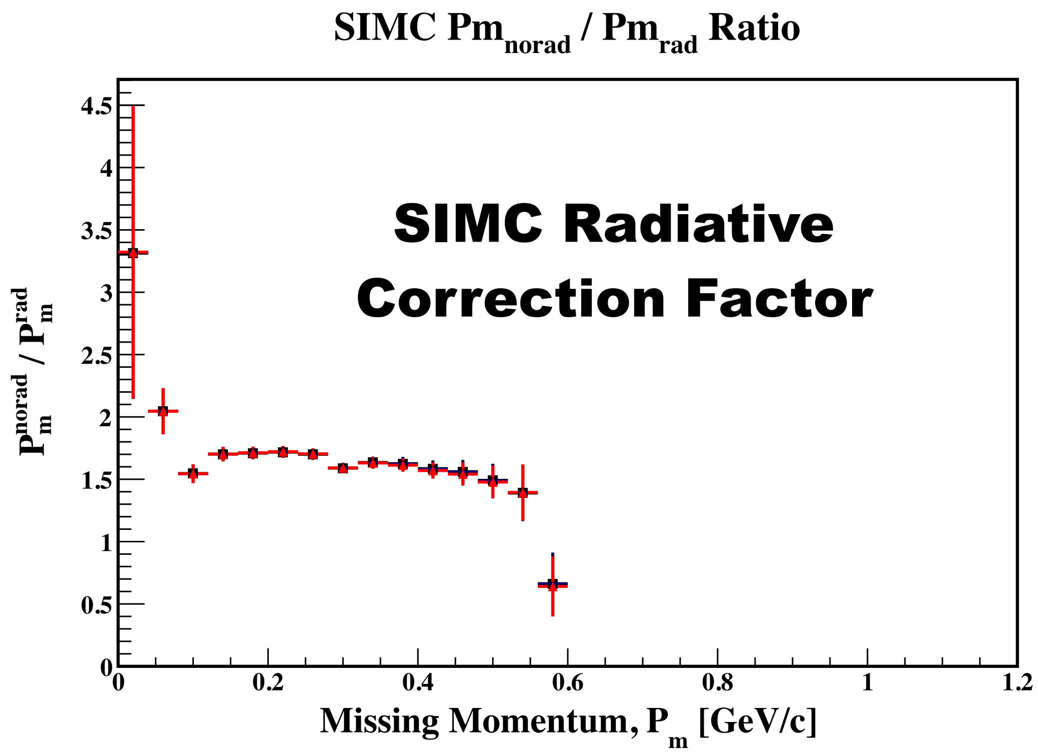
Spectrometer "Solid Angles"

Generated Events

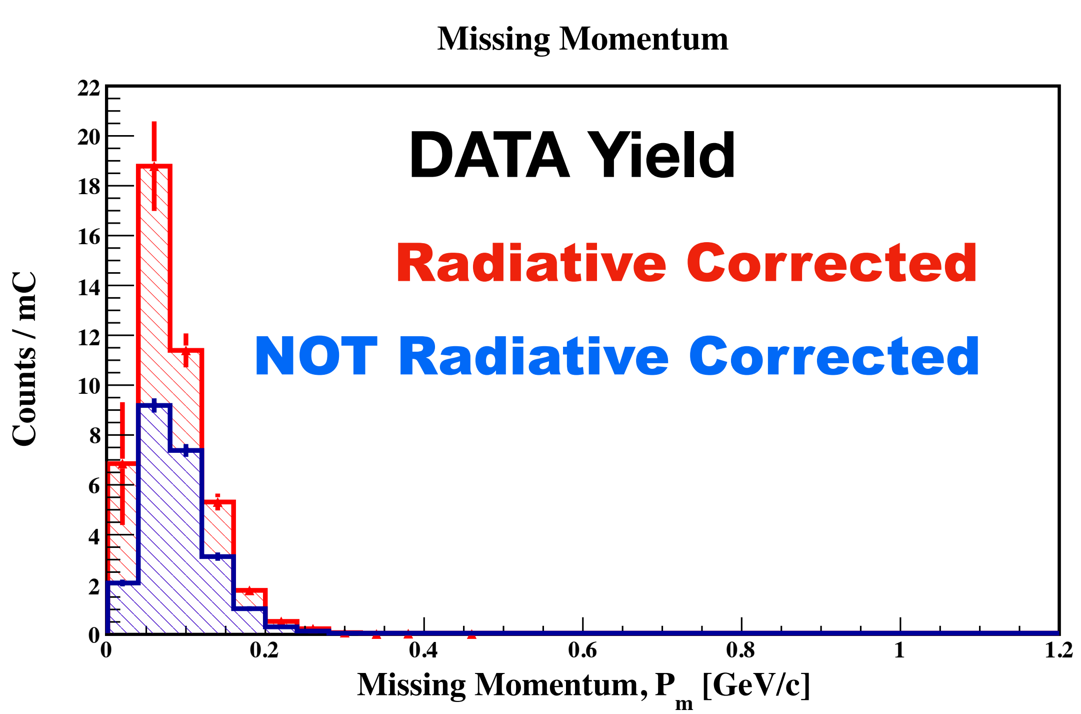
Extraction of the D(e,e'p)n Cross Section

- Decide which kinematic variable to bin (or store) the cross section.
  (I choose to store the cross section in missing momentum bins)

- Only apply radiative corrections to the relevant variable chosen
  (No need for unnecessary histograms)

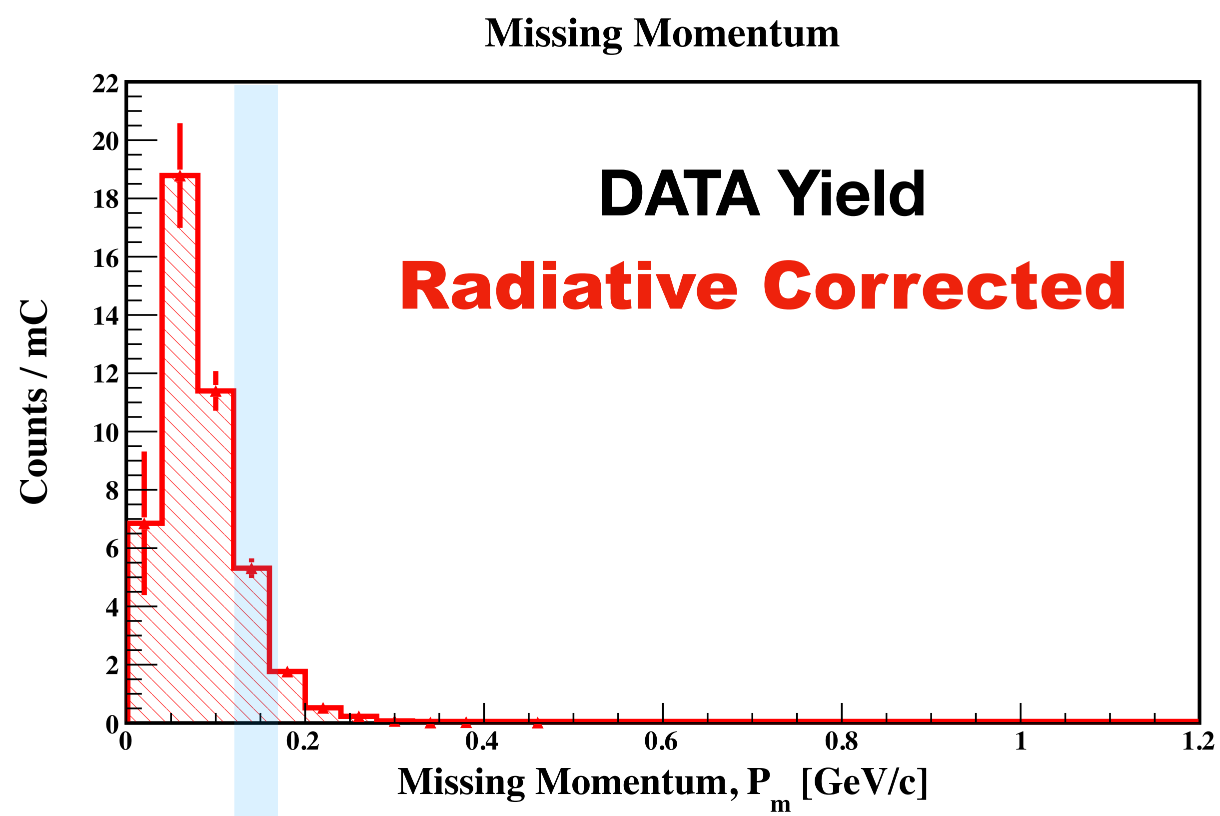


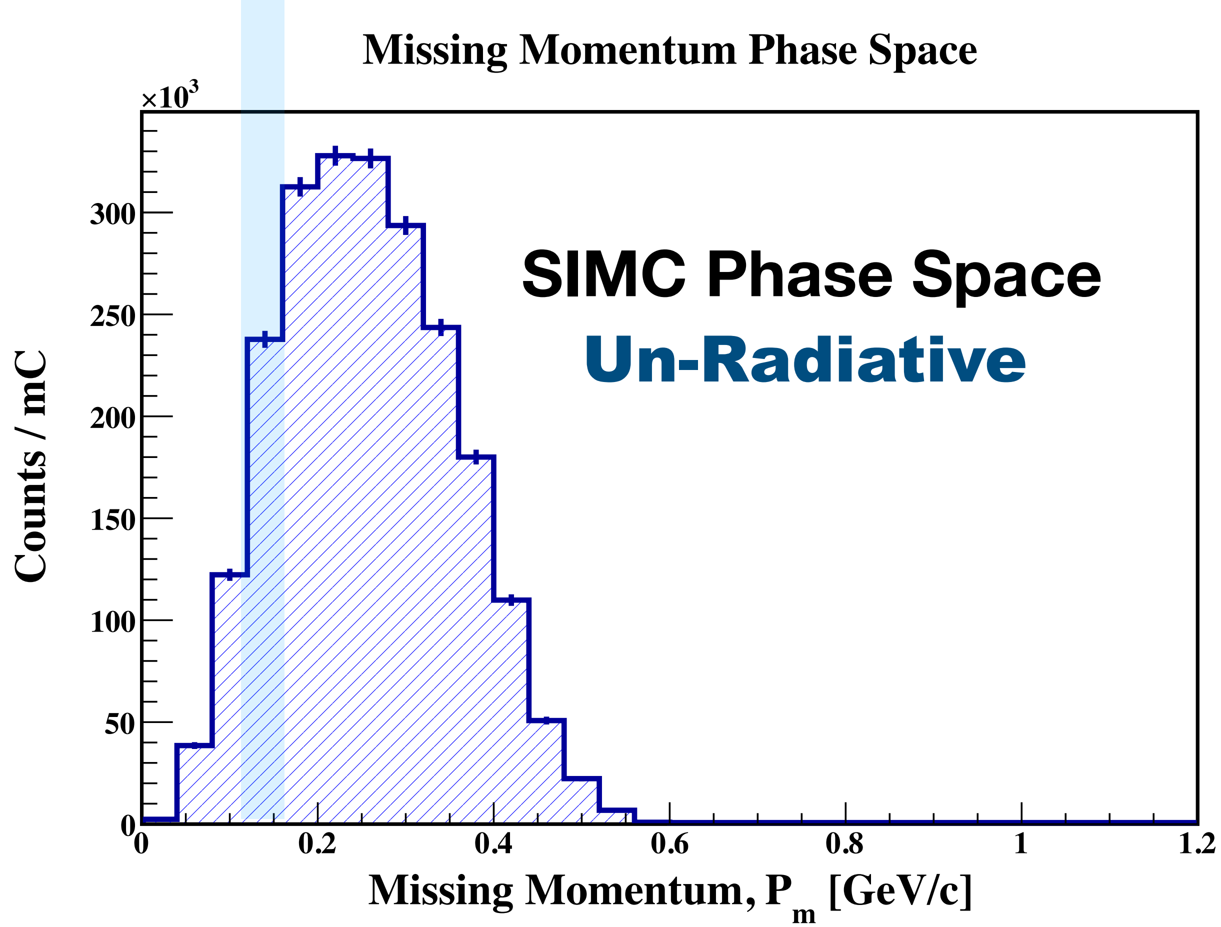
- Take ratio between non-rad to rad SIMC Yield to get correction factor bin by bin.

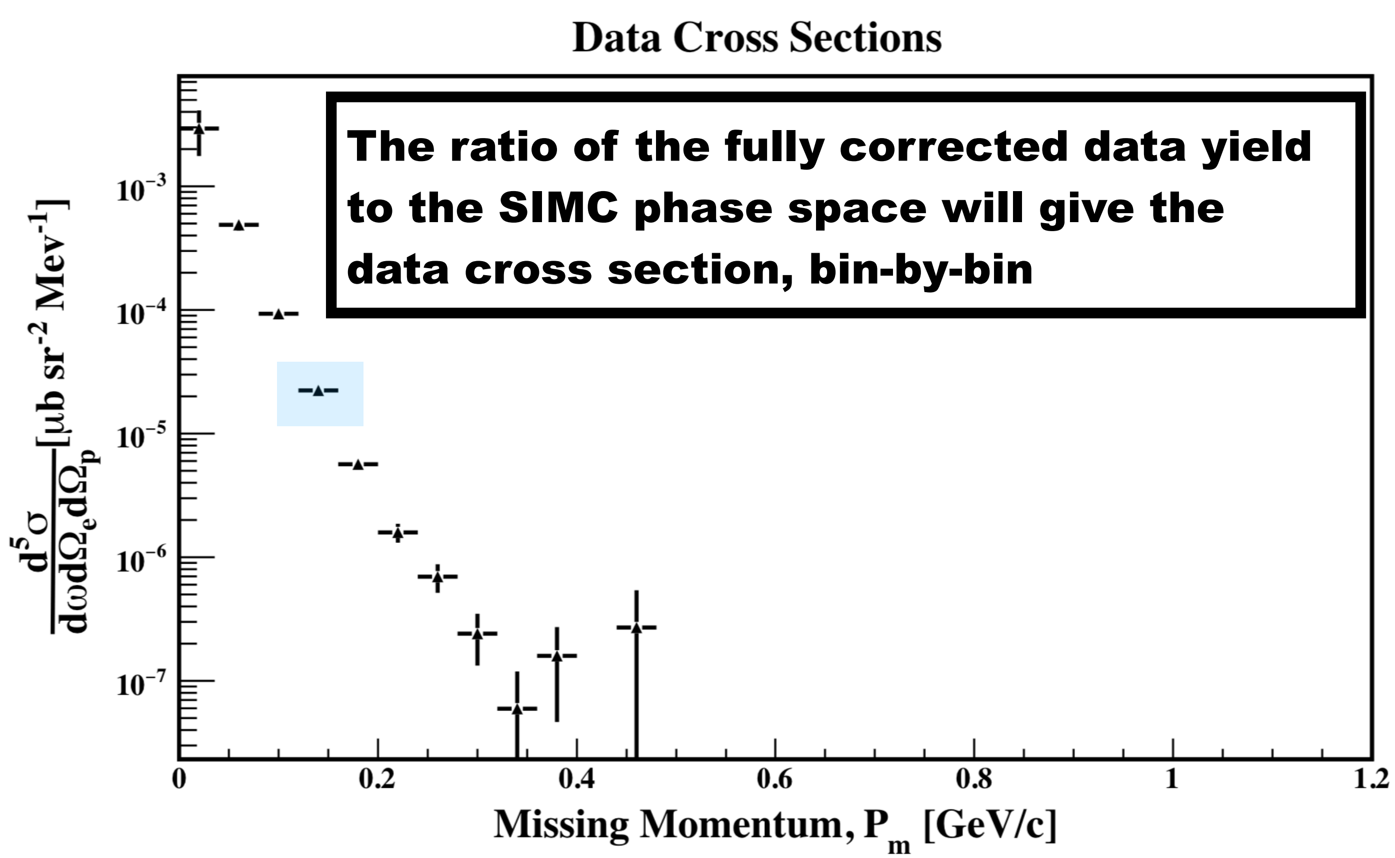


- Multiply the radiative correction factor by the un-radiative data yield to get the corrected data yield bin-by-bin.

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



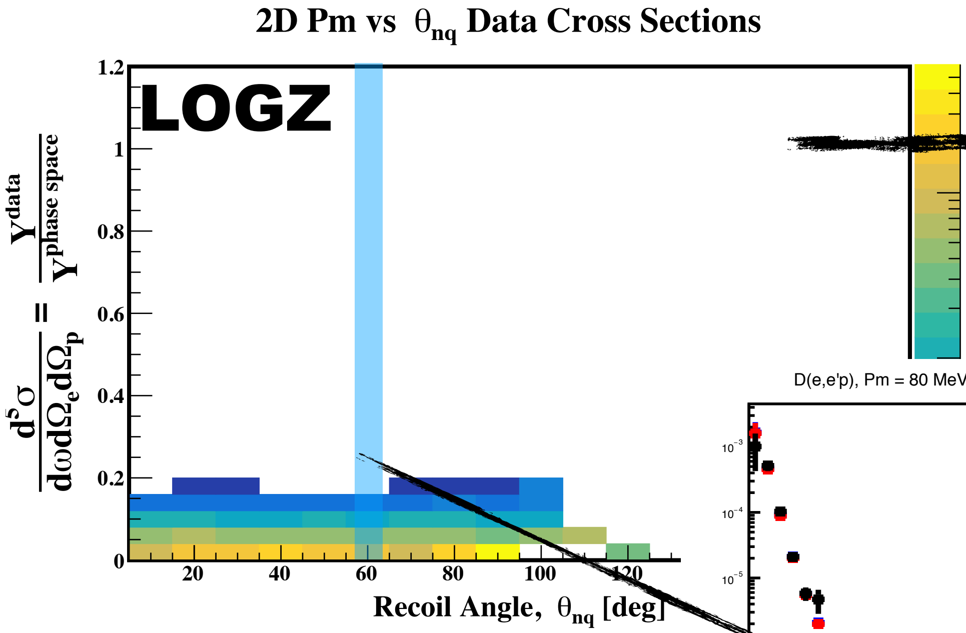




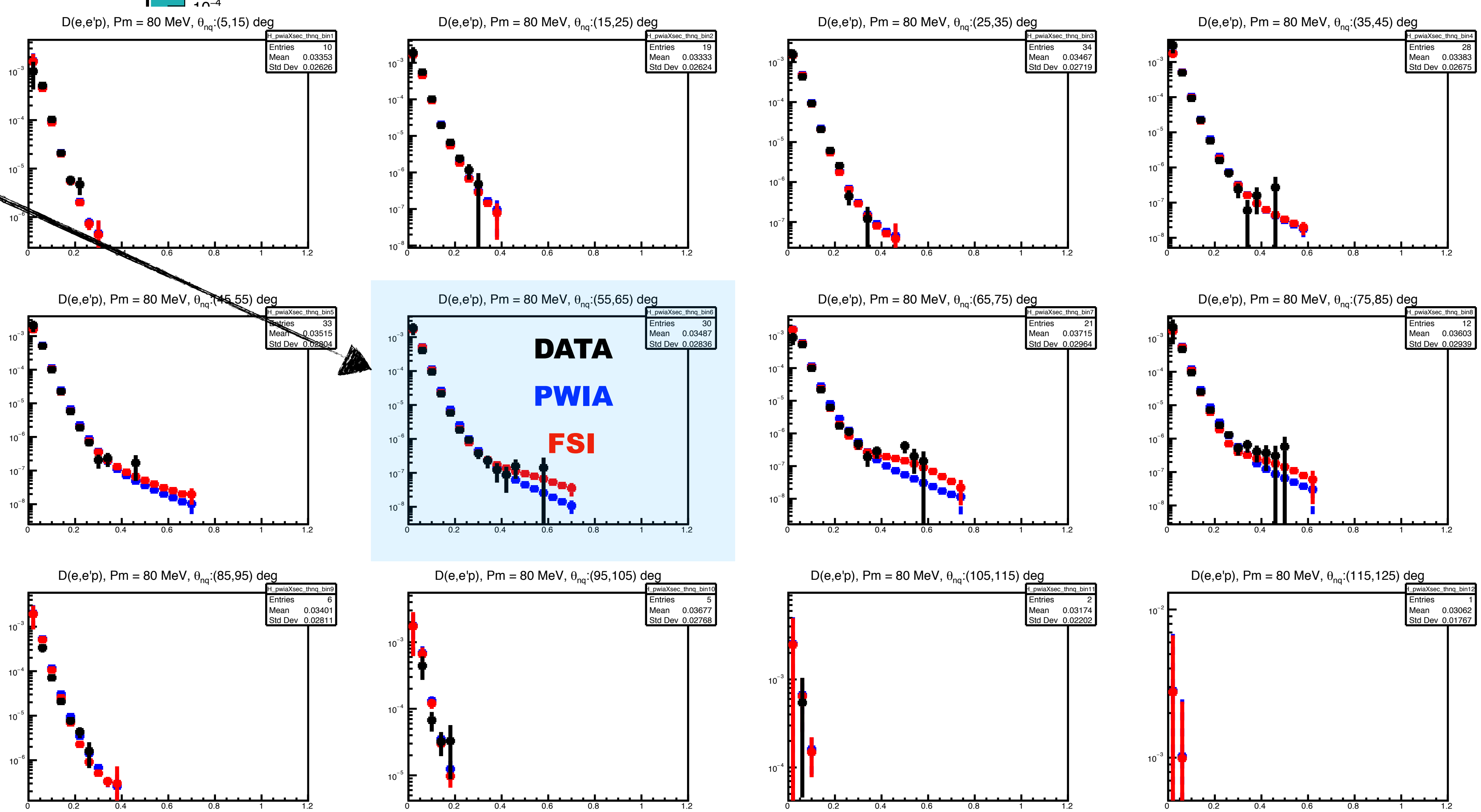
Extraction of the D(e,e’p)n Cross Section

❖ **Often it is useful to calculate the cross section in bins of other kinematic variable in addition to the missing momentum.**

e.g. say I wanted to get the cross section in different recoil angle bins.

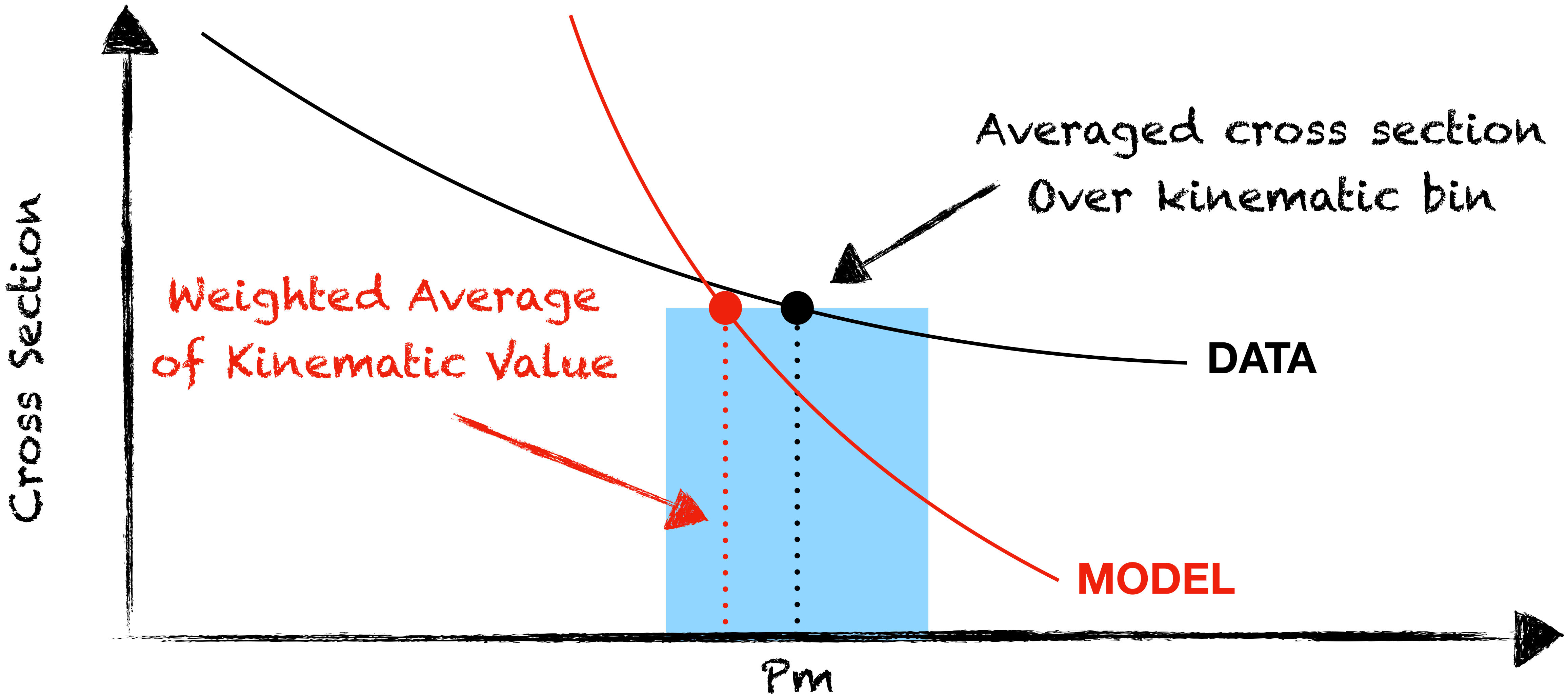


Taking the ratio of data 2D Histo, Pm vs. th_nq fully corrected to SIMC 2D Histo, Pm vs. th_nq weighted by phase space (NOT SO OBVIOUS . . . AT LEAST TO ME.)



Bin Centering Corrections

❖ **In reality, the measured data cross section is NOT the true cross section, but 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

$$f_{bc} = \frac{\sigma^{model}(\bar{E}_b, \bar{k}_f, \bar{\theta}_e, ...)}{\bar{\sigma}^{model}}$$

(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)

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

```
1D Example:  hist1->Fill(Pm, theta_e * FullWeight)
             hist2->Fill(Pm, FullWeight)

Outside EventLoop: hist3->Divide(hist1, hist2); //avg. electron angle
```

Bin Centering Corrections

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

IN **OUT**

$\bar{x} : \bar{E}_b, \bar{k_f}, \bar{\theta}_e, \ldots \longrightarrow$ **Theoretical Model** $\longrightarrow \sigma^{model}(\bar{E}_b, \bar{k_f}, \bar{\theta}_e, \ldots)$

$\bar{\sigma}^{model} \equiv \frac{Y^{\mathrm{SIMC}}}{V^{P.S.}} \longrightarrow$ **Averaged Model Cross Section (See Slide 14 for reference)**

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

$$\sigma_{bc}^{exp} = \bar{\sigma}^{exp} \cdot \frac{\sigma^{model}(\bar{E}_b, \bar{k_f}, \bar{\theta}_e, \ldots)}{\bar{\sigma}^{model}}$$

D(e,e'p) Momentum Distributions

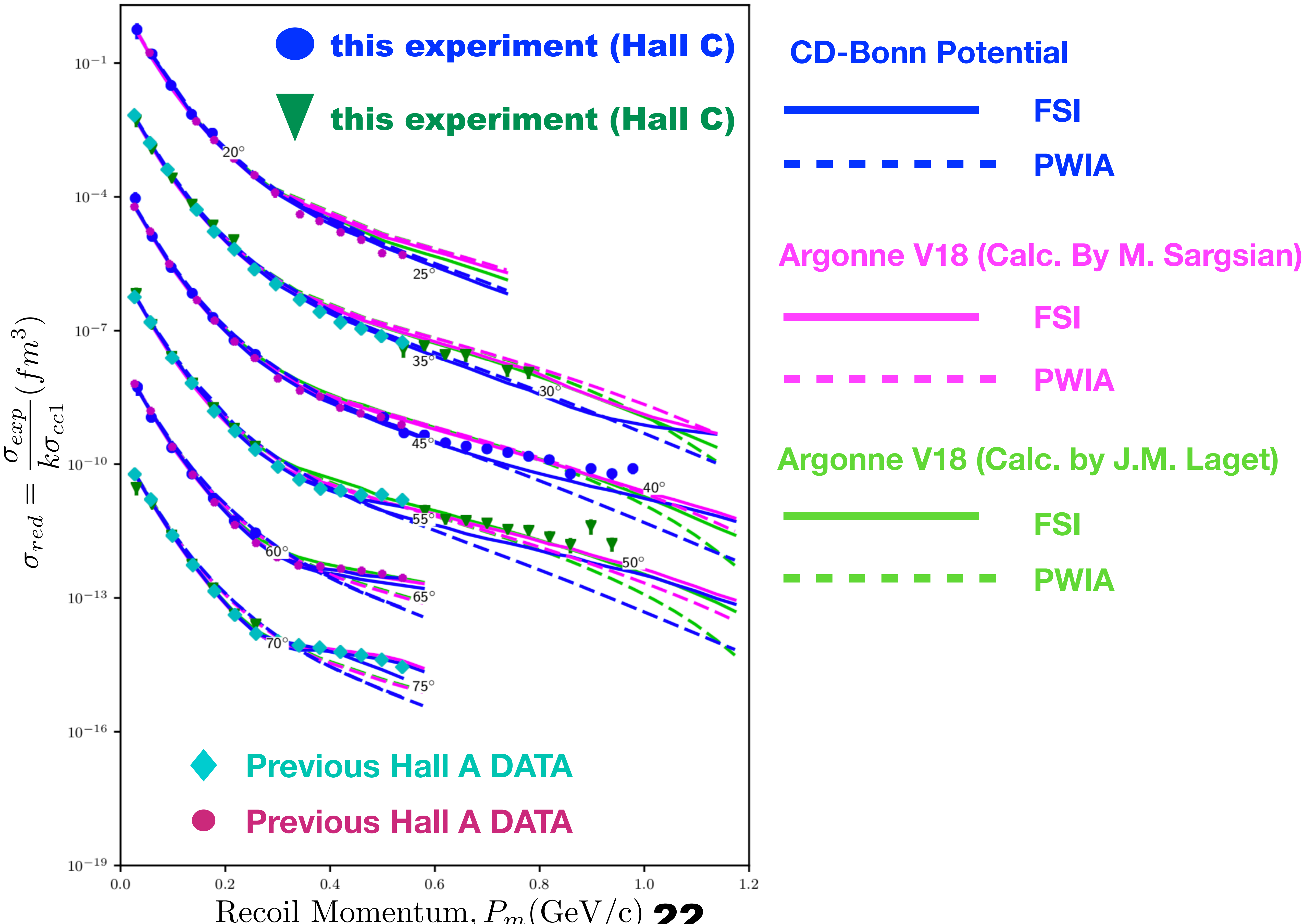
$$\sigma_{red} \equiv \frac{\sigma_{bc}^{exp}}{k\sigma_{cc1}}$$

Fully Corrected Experimental cross sections

Kinematic Factor times deForest cross section

Reduced cross section (momentum distributions in PWIA)

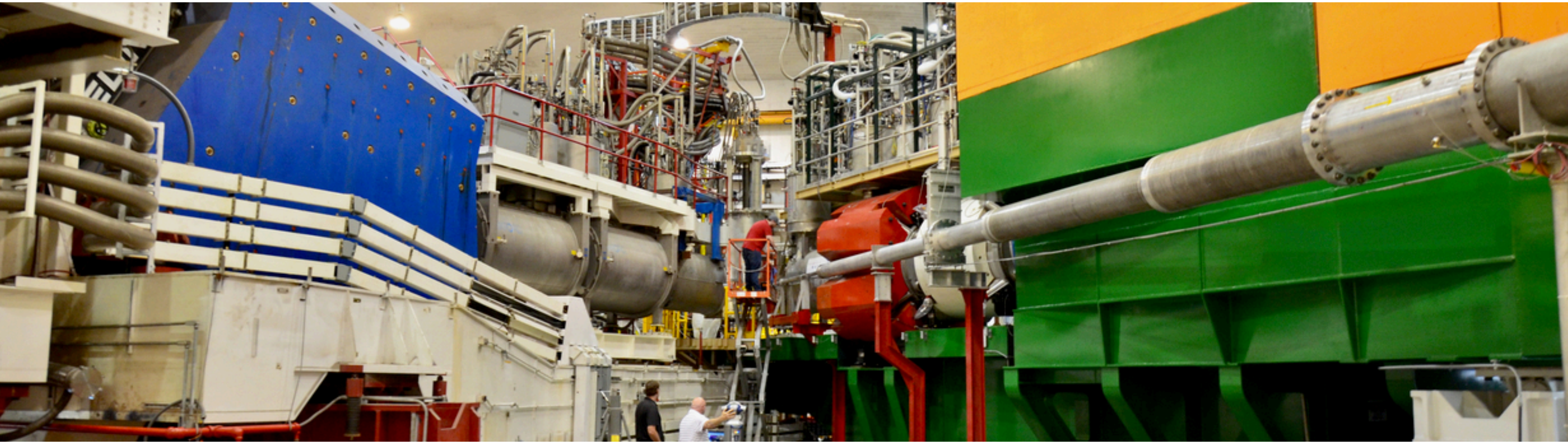
Preliminary Results for this Experiment !



SUMMARY

- This experiment (commissioning) ran for 3 PAC days (6 days total) out of the approved 21 PAC days.
- Preliminary results shows reasonable agreement with previous Hall A data at low recoil momenta
- At high recoil momenta, the data are NOT well described by either models.

Very interesting results at high missing momentum with ONLY 6 days of beam time, as data does NOT seem to be well described by theory in small FSI region ! ! !



THANK YOU !