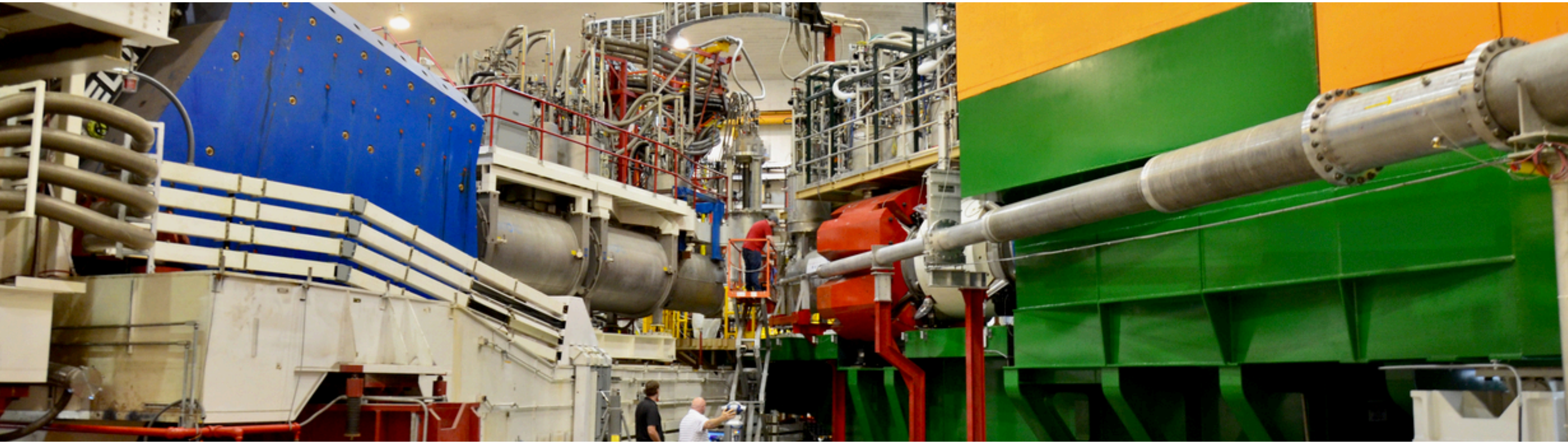


Deuteron Electro-Disintegration At Very High Missing Momenta

(E12-10-003)

Carlos Yero

Spokespeople: Drs. Werner Boeglin and Mark Jones

April 11, 2019

Jefferson Lab
Exploring the Nature of Matter

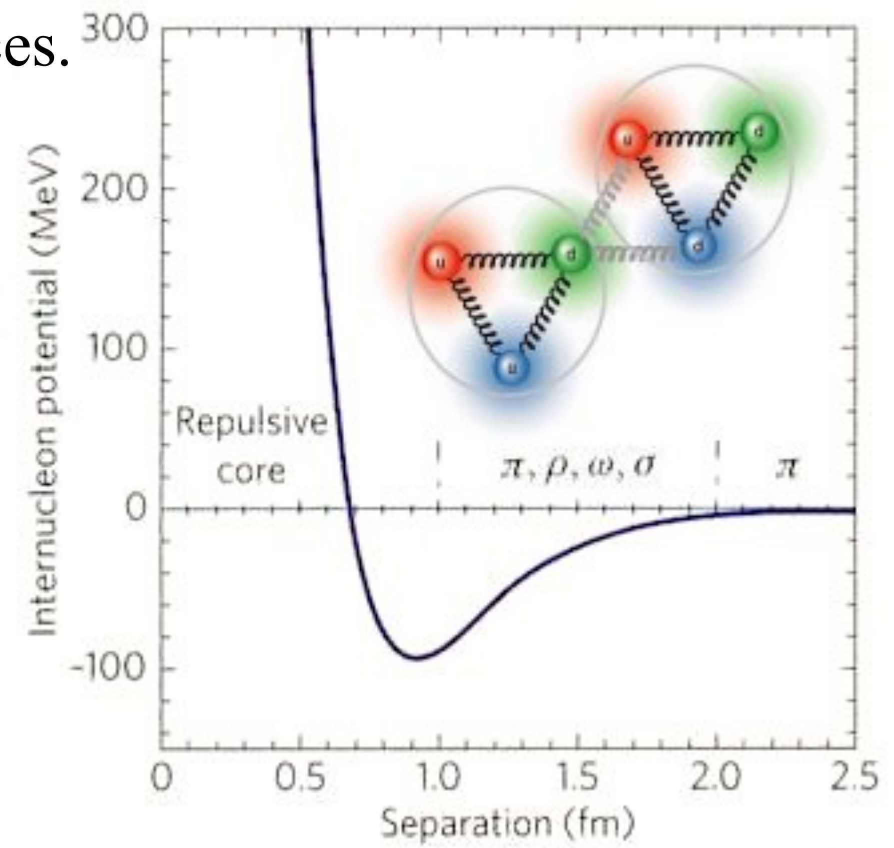
FIU

Hall-C

Motivation

- ☑ Study Deuteron at short ranges (< 1fm).

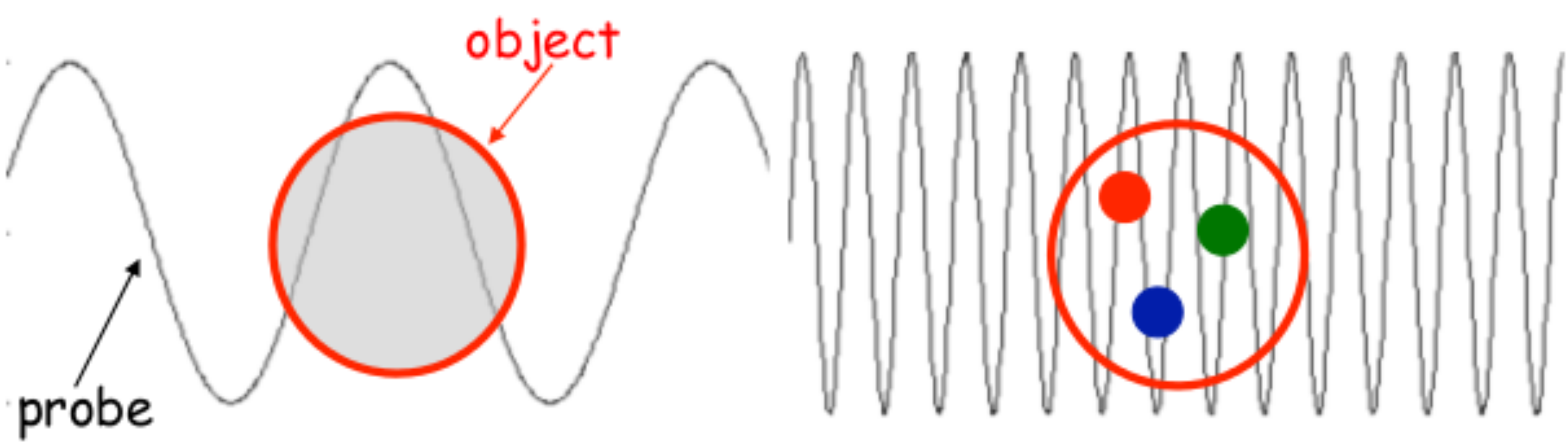
  High momentum transfers probe the Deuteron at smaller distances. Smaller inter-nucleon distances enables one to access the high momentum components of nucleons



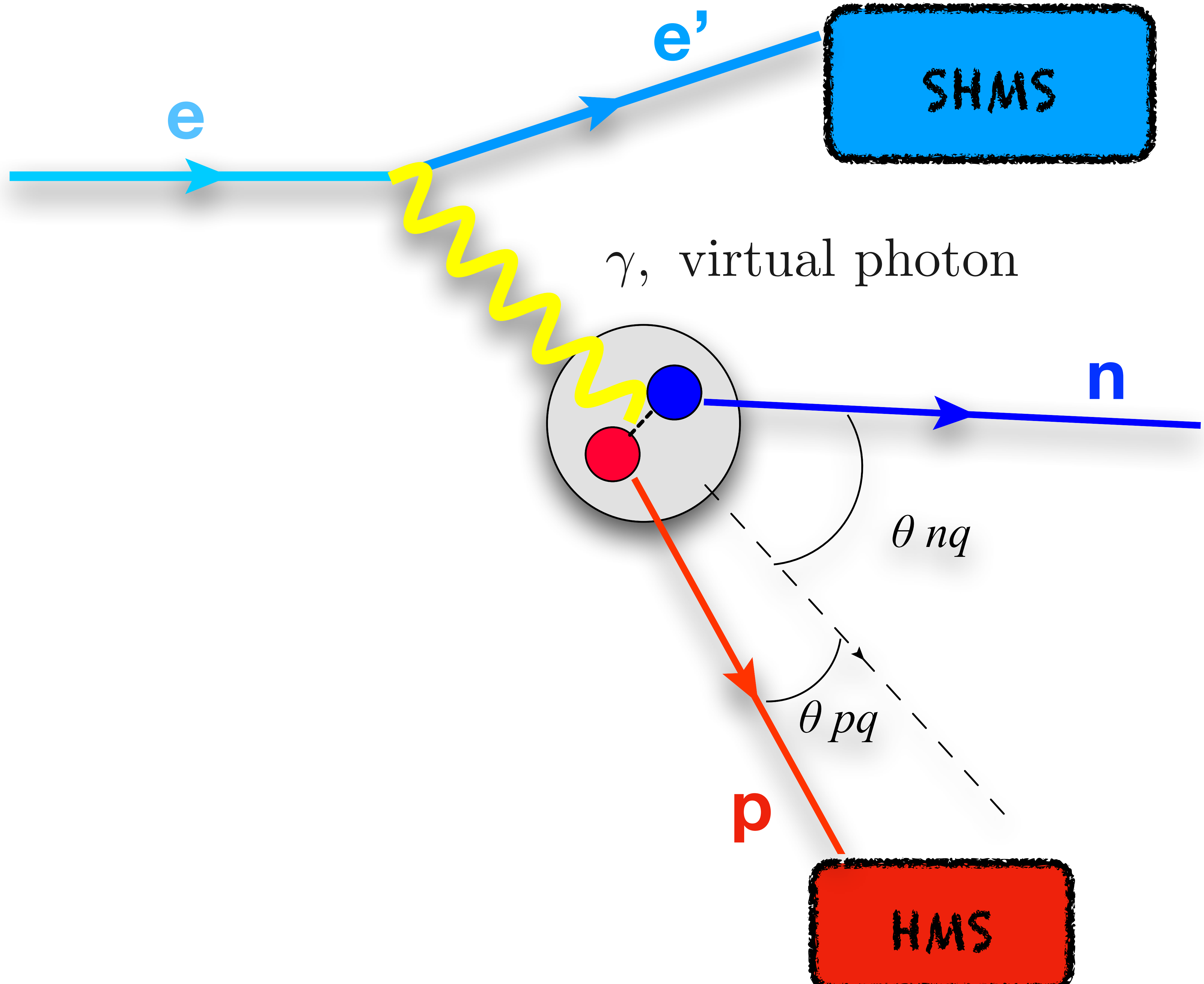
- ☑ **First time measurements of high missing momentum at large Q2**

- ☑ Extract D(e,e'p)n cross-section beyond 500 MeV/c missing momentum at high Q2

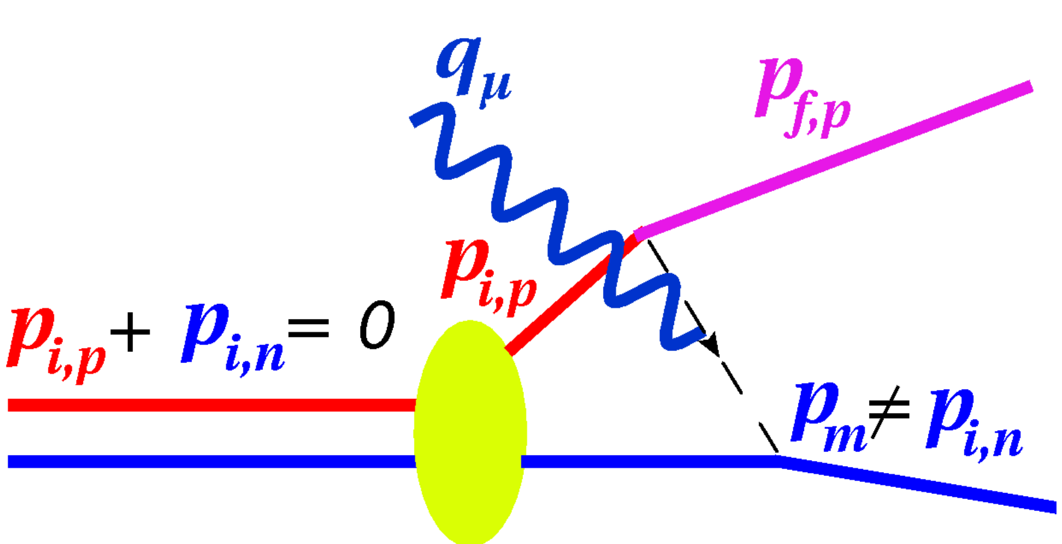
- ☑ Extract momentum distributions (not an observable) from cross sections.



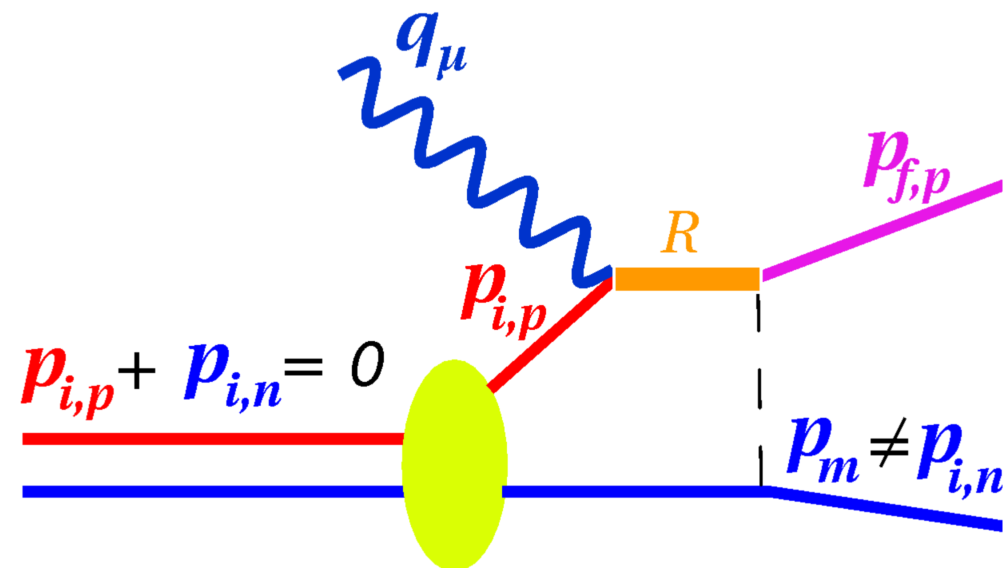
D(e,e'p)n Reaction Kinematics



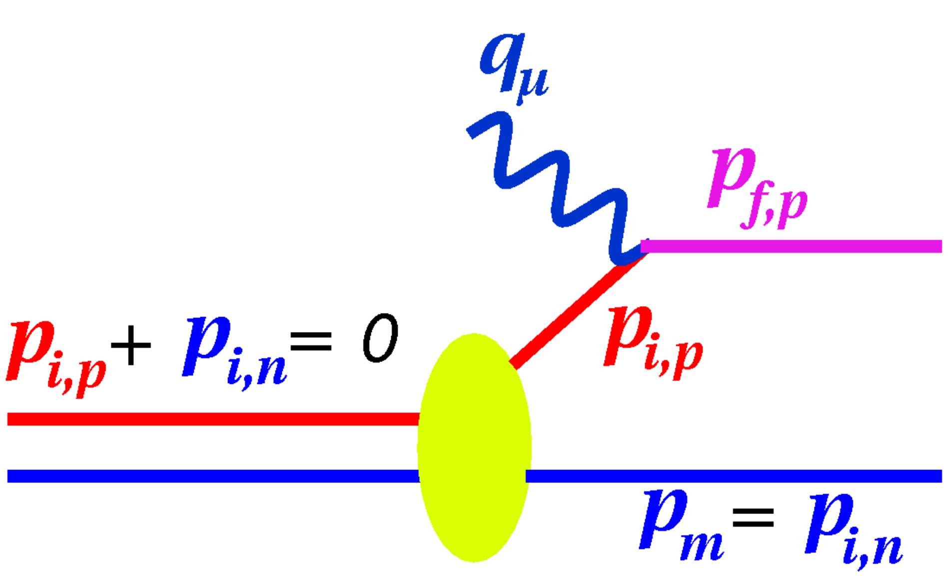
D(e,e’p)n Interactions



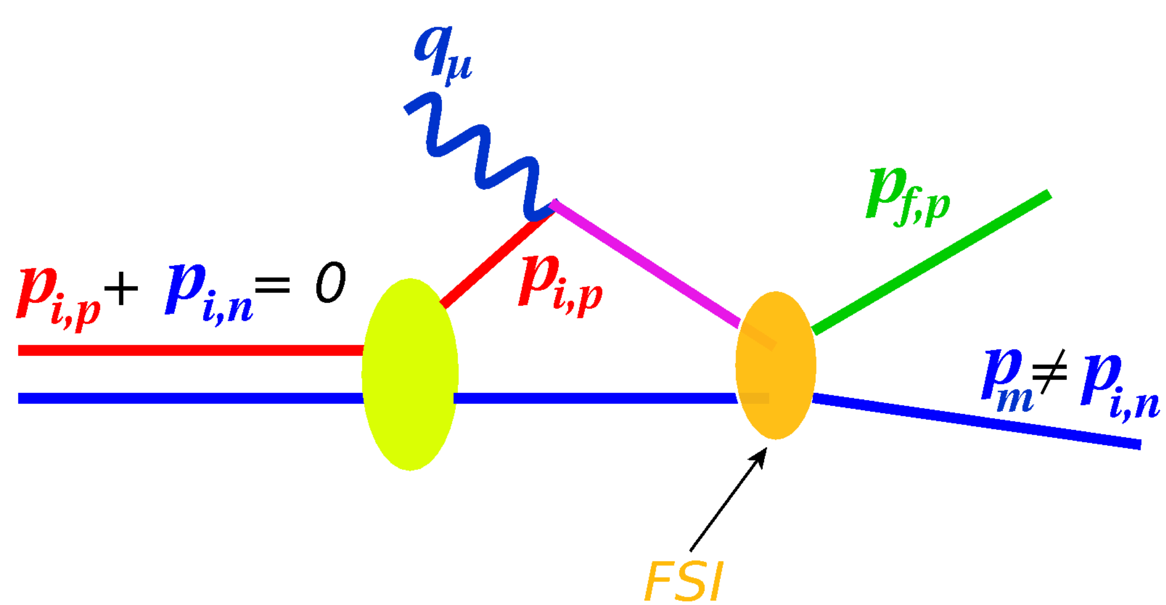
Meson-Exchange Currents (MEC)



Isobar Configurations (IC)



Plane Wave Impulse Approximation (PWIA)



Final State Interactions (FSI)

Deuteron Momentum Distribution

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

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

ep off-shell cross section

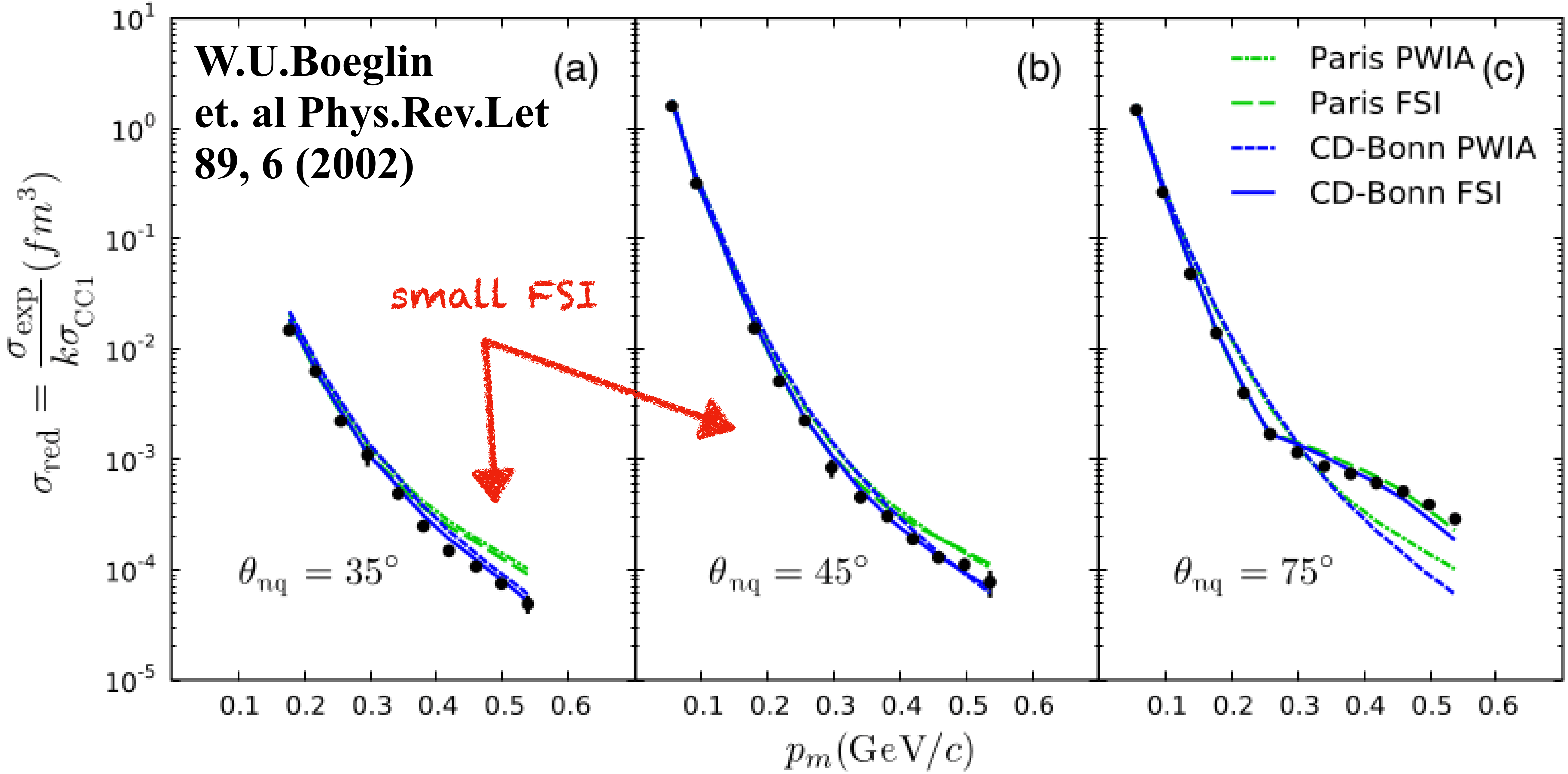
electron scatters off a bound proton within the nucleus; usually, de Forest σ_{cc1} or σ_{cc2} is prescribed

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

Experimental Support for D(e,e'p)n at Hall C

Previous D(e,e'p)n data from Hall A at $Q^2 = 3.25$ GeV^2



- ☑ E12-10-003 Experiment at Hall C focused at $\theta_{nq} \sim 40^o$ and $p_m \geq 500$ MeV/c at $Q^2 = 4.25$ GeV^2

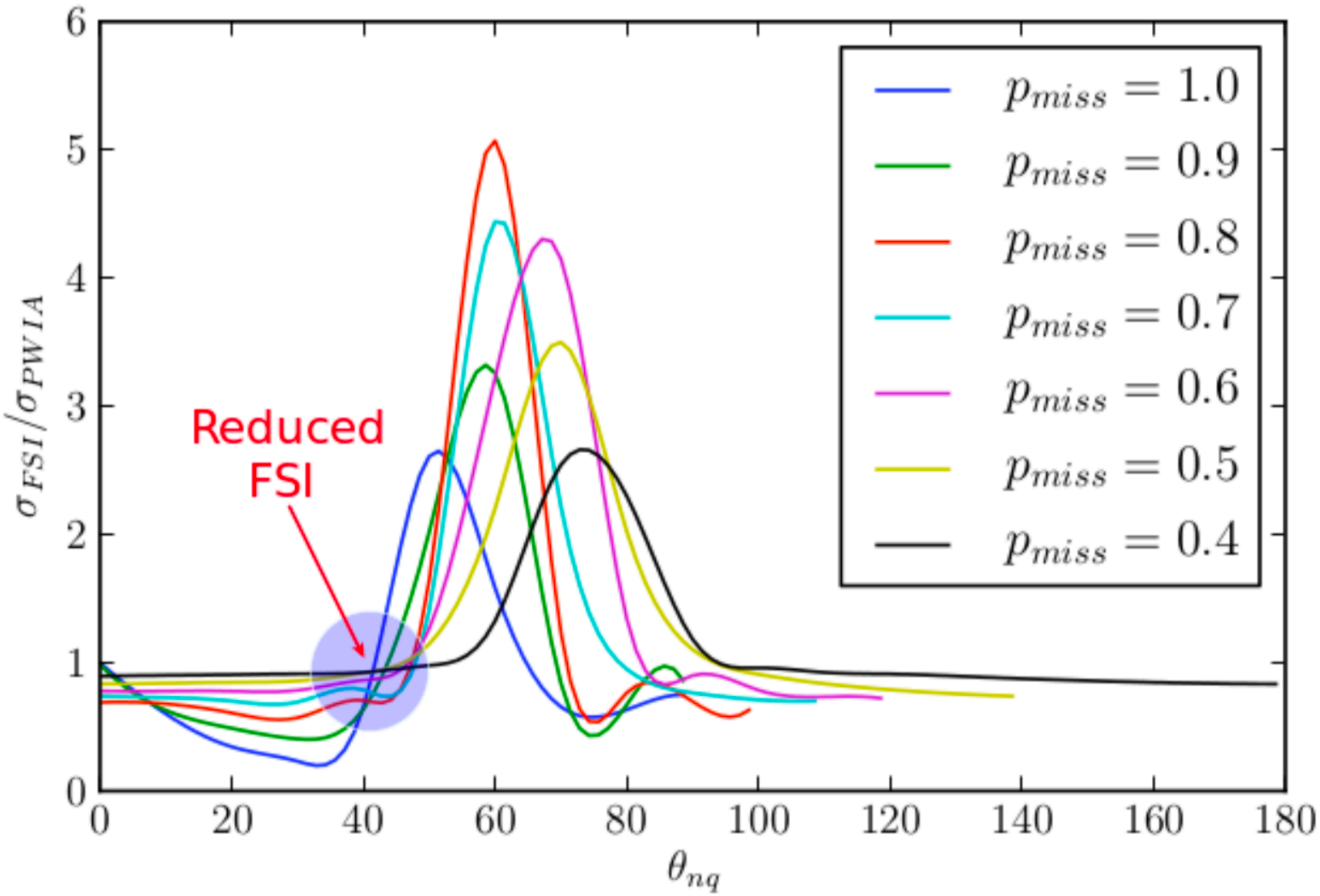
- ☑ Greater sensitivity of deuteron momentum distribution to different NN potential models (e.g. CD-Bonn, Paris, Laget, etc.)

D(e,e'p)n (E12-10-003) Theoretical Background

D(e,e'p)n Kinematics

$E_e = 11$ GeV
$Q^2 = 4.25\ (\mathrm{GeV/c})^2$
$x_{B_j} = 1.35$
$p_m = 0.5 - 1.0$ GeV/c
$\theta_{nq} = 35^\circ - 40^\circ$

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

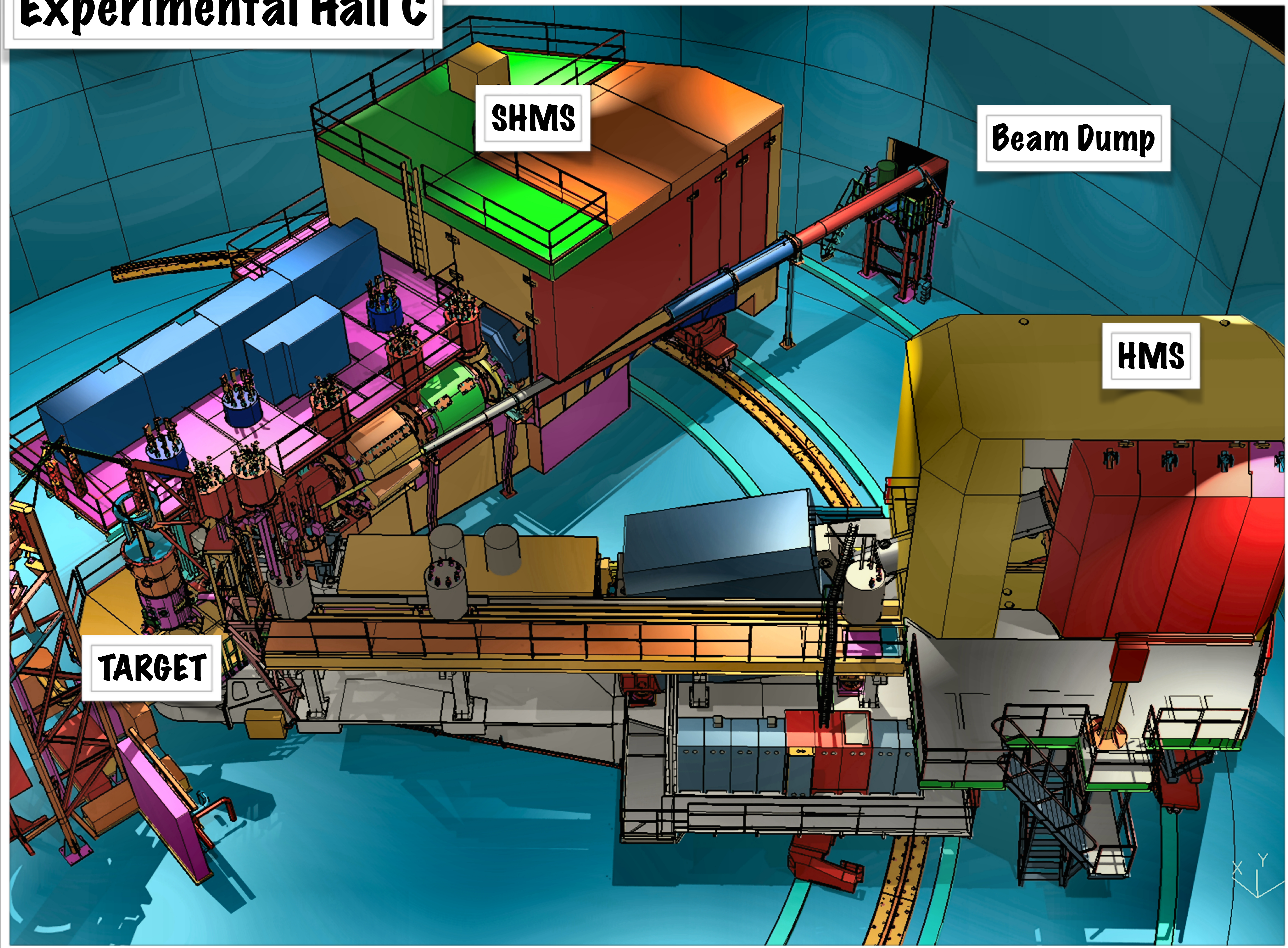


Theoretical Calculation by: M. Sargsian

E12-10-003

Deuteron Break-Up Experiment Background

Experimental Hall C



Experiment Time Line (Year 2018)

April 3 April 5 April 9

Carbon Hole
1 H(e,e'p) Elastic
Proton Absorption
Al. Dummy

D(e,e'p)n: Pm=80 MeV
D(e,e'p)n: Pm=580 MeV

NOT YET ANALYZED!

1 H(e,e'p) Elastic
1 D(e,e'p)n : 80 MeV

D(e,e'p)n : 580 MeV
D(e,e'p)n : 750 MeV

D(e,e'p)n : 580 MeV
D(e,e'p)n : 750 MeV

H(e,e'p) Elastics

D(e,e'p)n : 750 MeV

Spectrometer Moved!

Analyze data sets separately

SHMS Q3 Un-Necessary Optics Correction Removed.

ANALYZED

D(e,e'p)n Kinematics

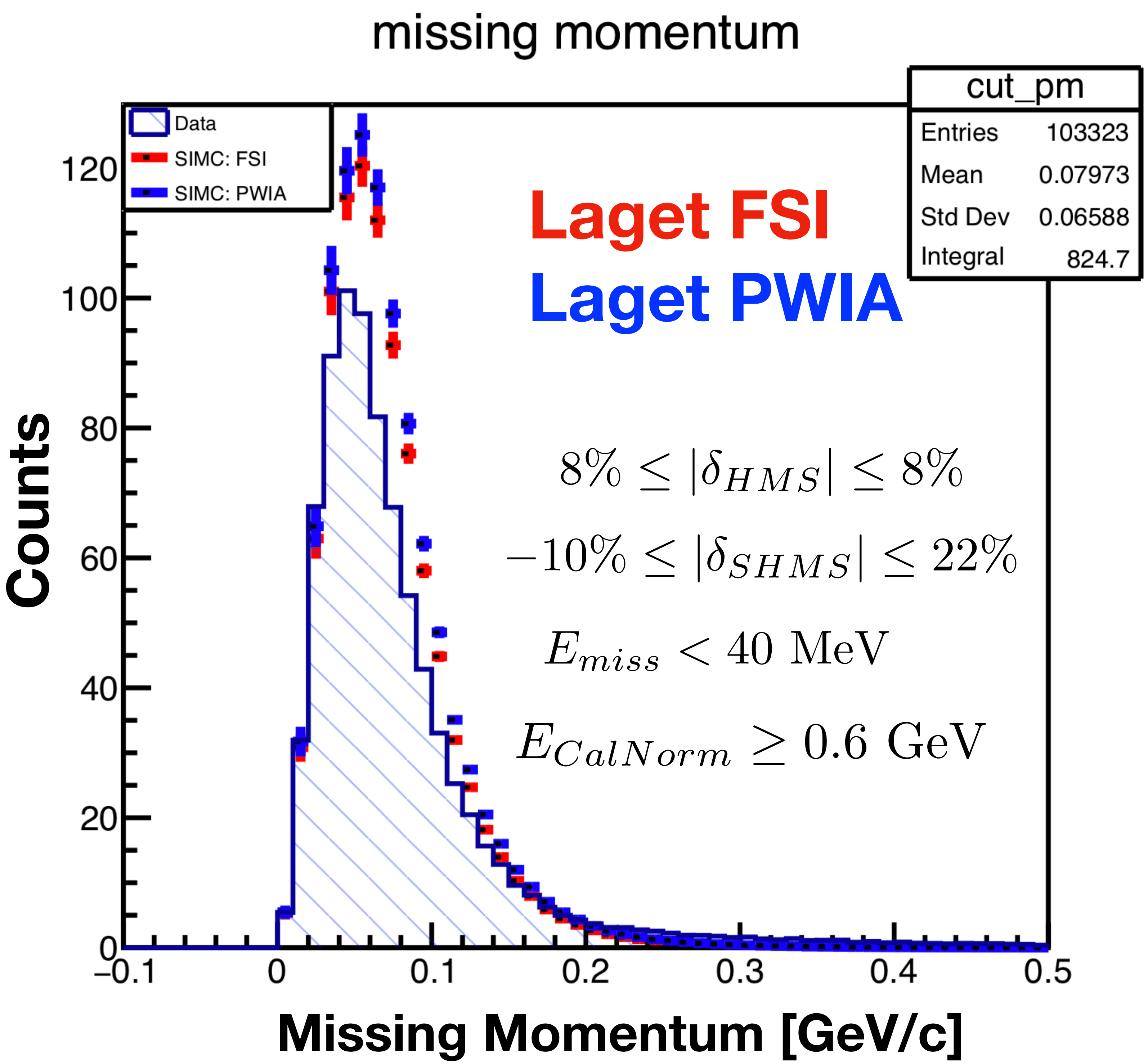
Pmiss [MeV]	SHMS Momentum [GeV]	SHMS Angle [deg]	HMS Momentum [GeV]	HMS Angle [deg]	Beam Energy [GeV]
80	-8.7	~12.2	2.844	~37.3	10.6005
580	-8.7	~12.2	2.194	~55	10.6005
750	-8.7	~12.2	2.091	~58.4	10.6005

- ☑ **The 80 MeV central setting serves as a cross-check with other existing data to make sure the spectrometer is well understood.**

- ☑ **NO previous measurements exist at the high missing momentum settings, hence the need to check reproducibility of data with the 80 MeV setting.**

D(e,e'p)n: 80 MeV Setting

This low missing momentum setting serves as the control for the 580 / 750 MeV settings.



- ☑ **Existing Data @ 80 MeV**
- ☑ **Small FSI**
- ☑ **Existing models are in good agreement with data at low missing momentum**
- ☐ **Data needs to be corrected for proton absorption and radiative effects.**

Extracting the Cross Sections

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

Determined from simulation

$$Y^{data}_{corr.} = \frac{Y^{data}_{uncorr.}}{Q_{tot.} * \epsilon_{LT} * \epsilon^{hms}_{trk} * \epsilon^{shms}_{trk}}$$

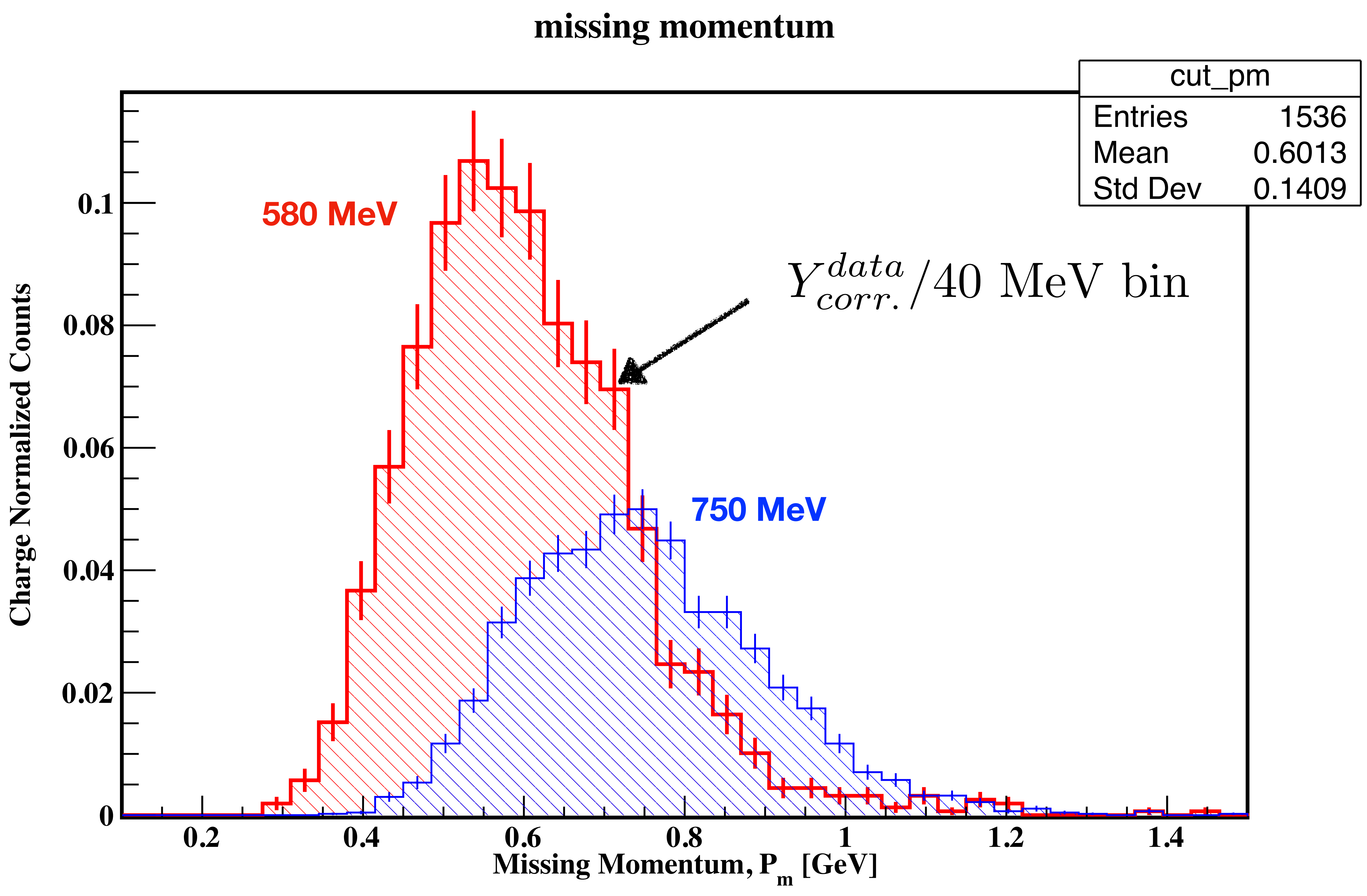
Other corrections still need to be applied..
* Target Boiling
* Radiative corr.
* Proton Absorption

$$V^{P.S.} = \frac{N_{acc.}}{N_{gen.}} \Delta V \text{ , where } \Delta V = \Delta\omega \Delta\Omega_e \Delta\Omega_p$$

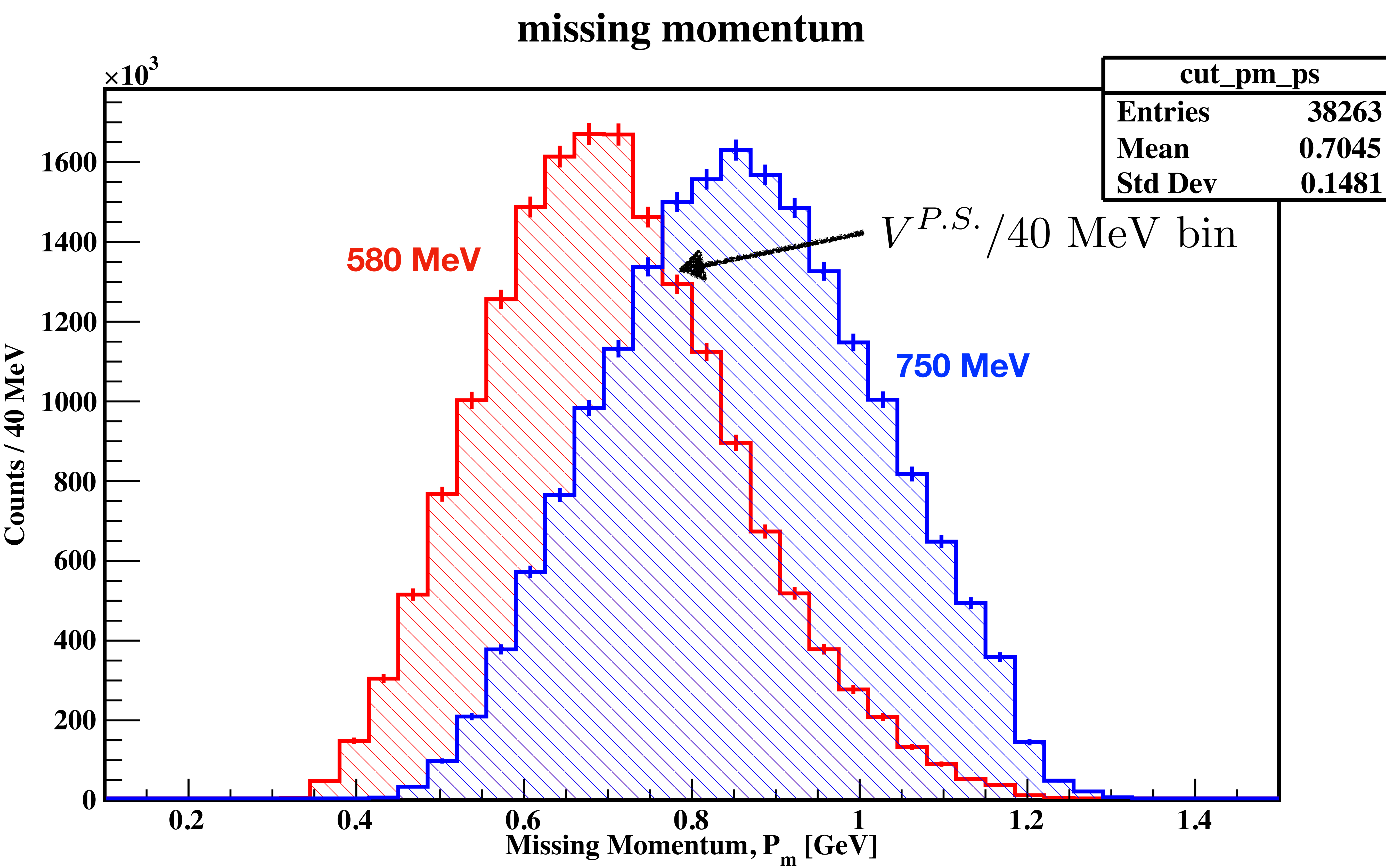
Ratio of accepted to thrown events in spectrometers

Spectrometers Phase Space Volume

Data Set Charge Normalized Missing Momentum Yield

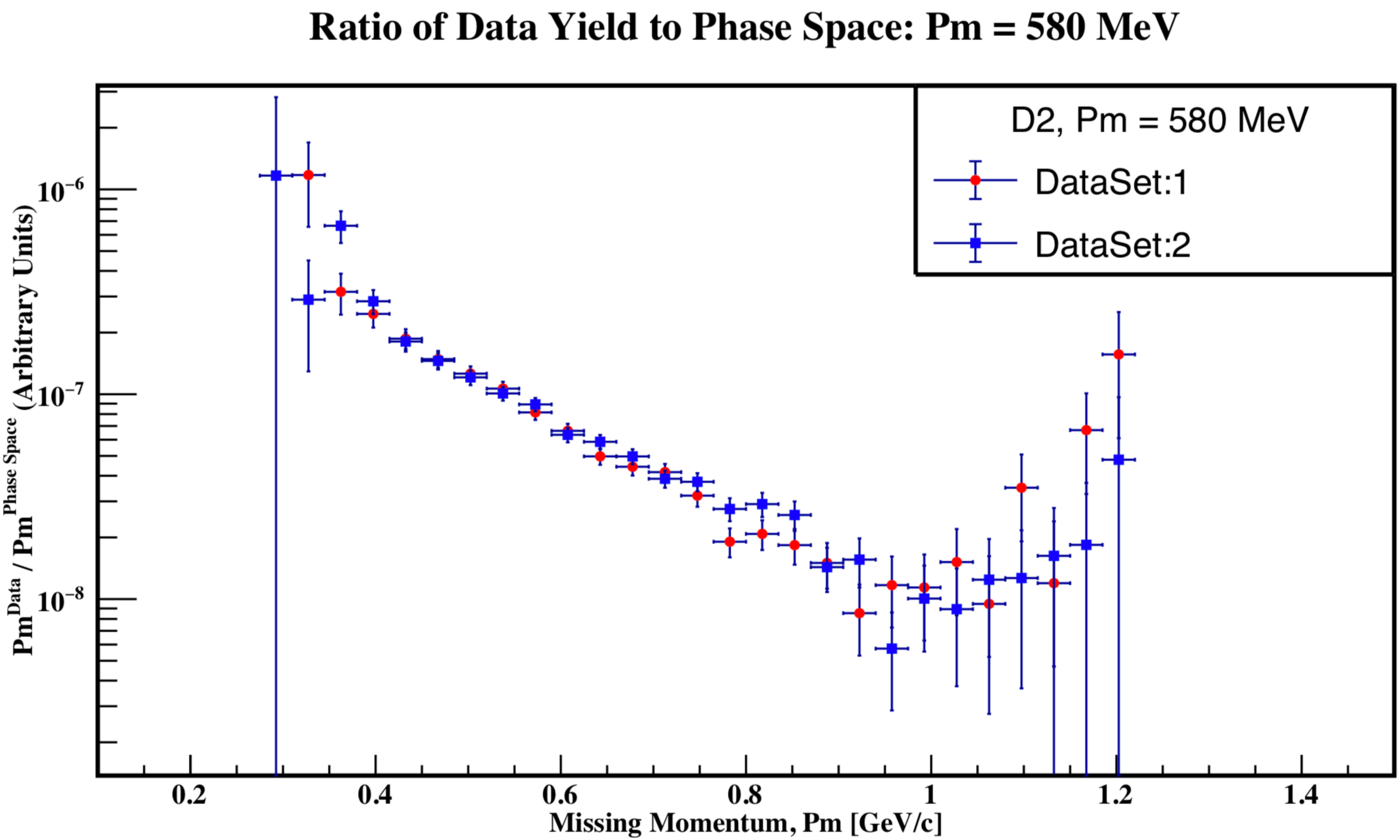


Missing Momentum Phase Space from SIMC



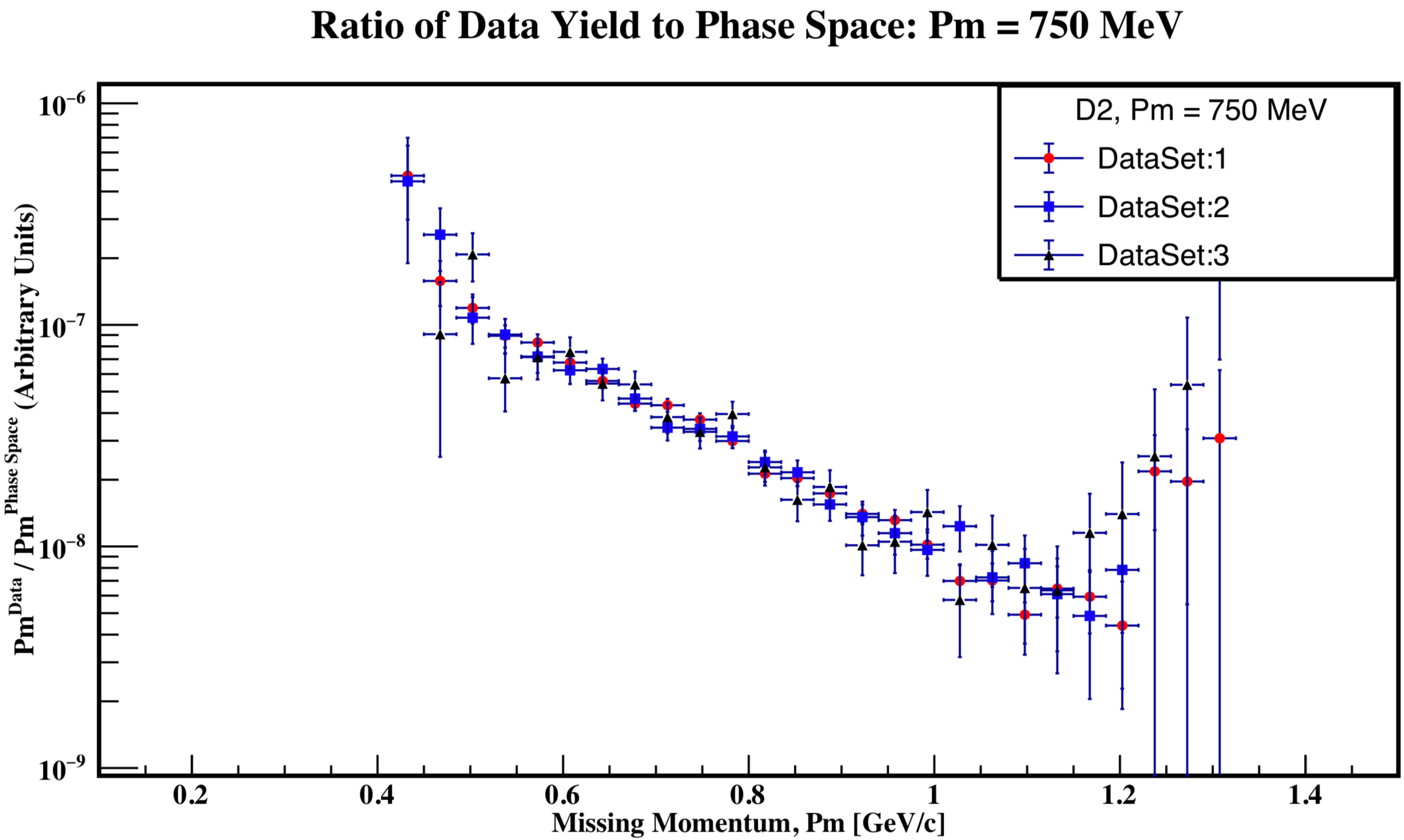
D(e,e'p)n Cross Sections

- Good agreement between the two 580 MeV data sets
- Data sets can be combined

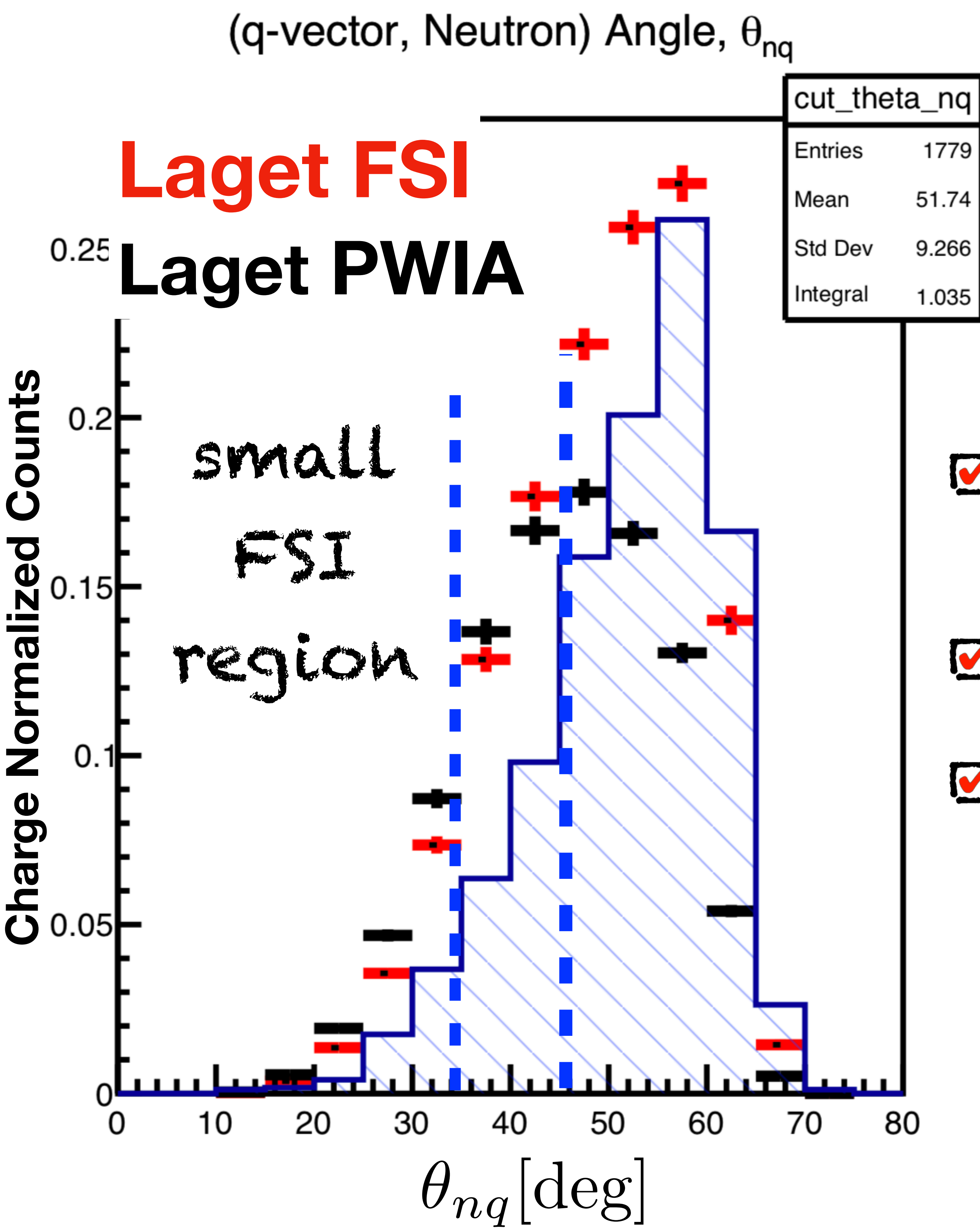


D(e,e'p)n Cross Sections

- ☑ Good agreement between the three 750 MeV data sets
- ☑ Data sets can be combined



Selecting Small FSI Region

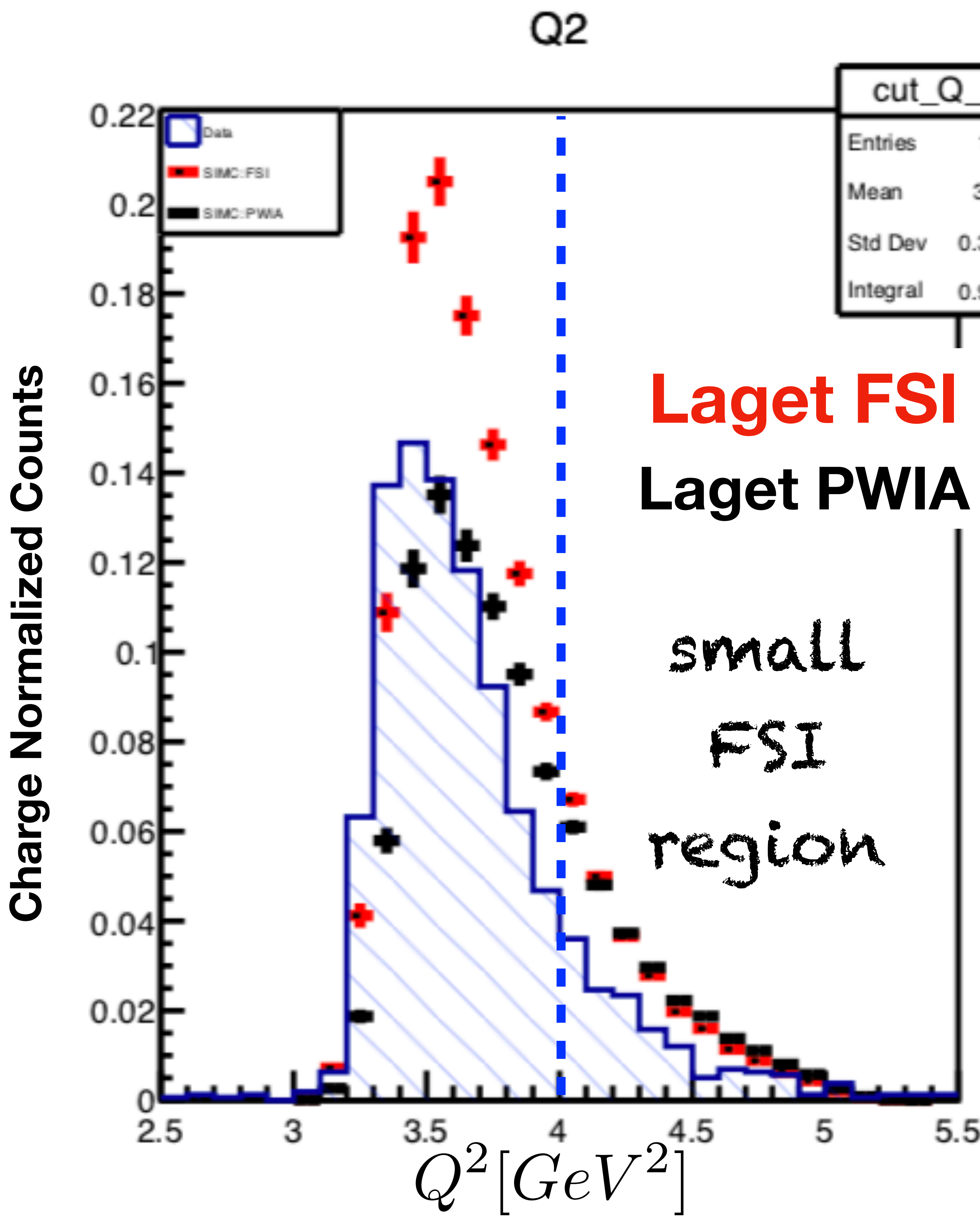


FSI ~ PWIA at:

$$35^o \leq \theta_{nq} \leq 45^o$$

- ☑ **Kinematic region of interest at high missing momentum**
- ☑ **FSI contributions are small**
- ☑ **Deuteron Momentum Distribution can be extracted**

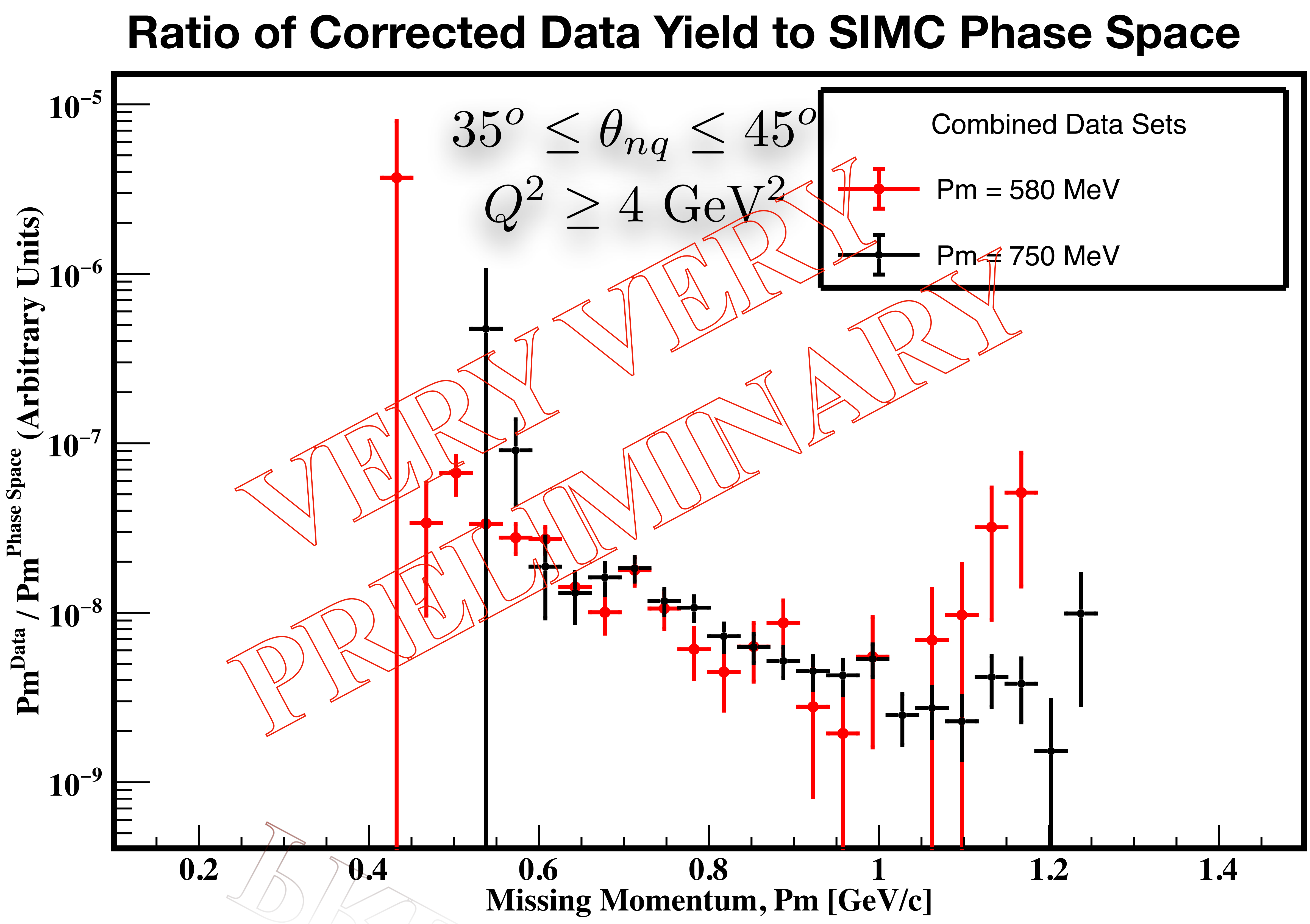
Selecting Small FSI Region



FSI ~ PWIA at:

$$Q^2 \geq 4 \text{ GeV}^2$$

Selecting Small FSI Region



Extraction of Momentum Distributions

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

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

Momentum Distribution

$$K = \frac{E_p P_p}{(2\pi)^3}$$

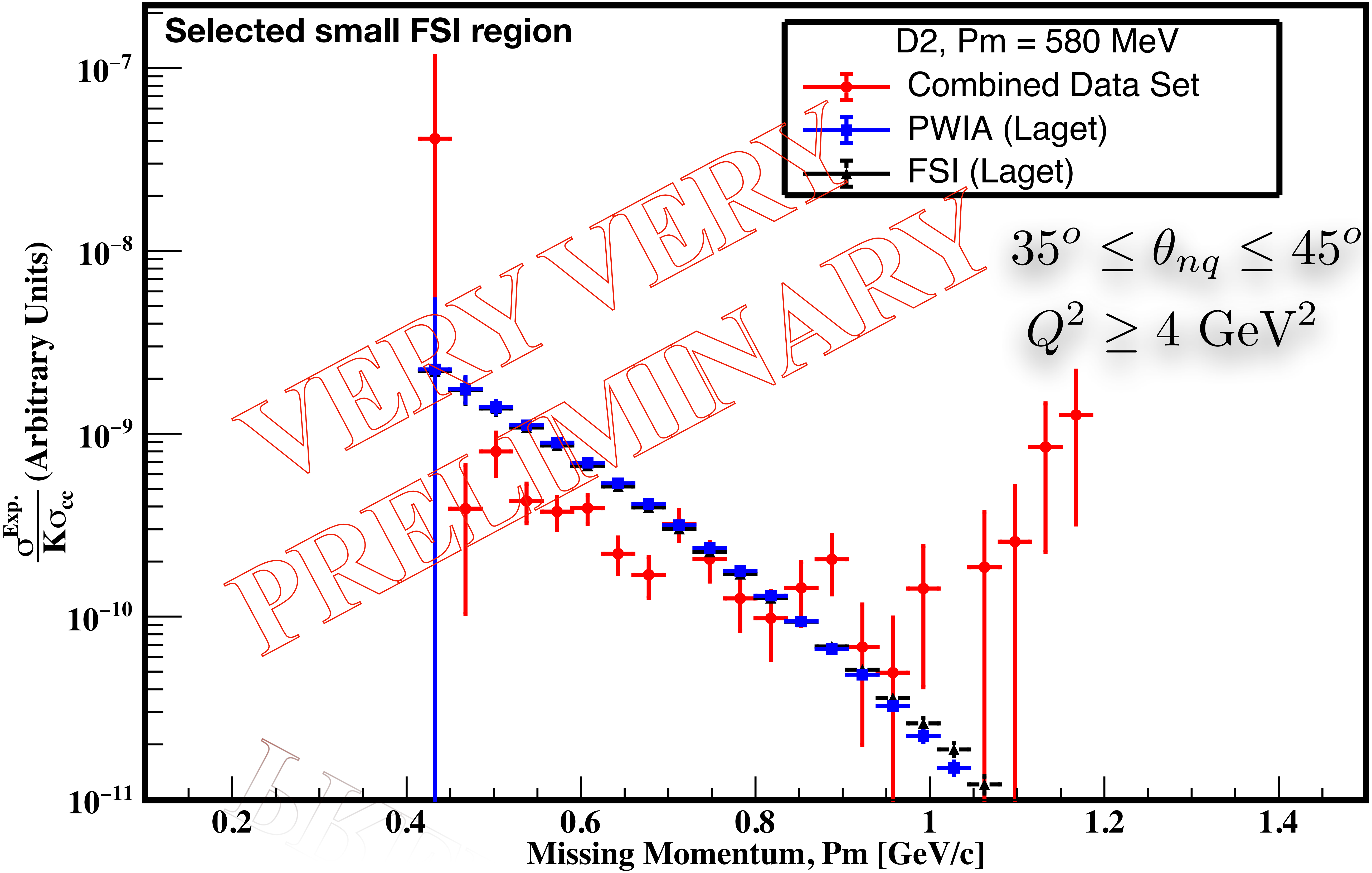
Kinematic Factor. (See Hari Khanal's Thesis)

$$\sigma_{ep} \rightarrow \sigma_{\mathrm{cc1\ or\ cc2}}$$

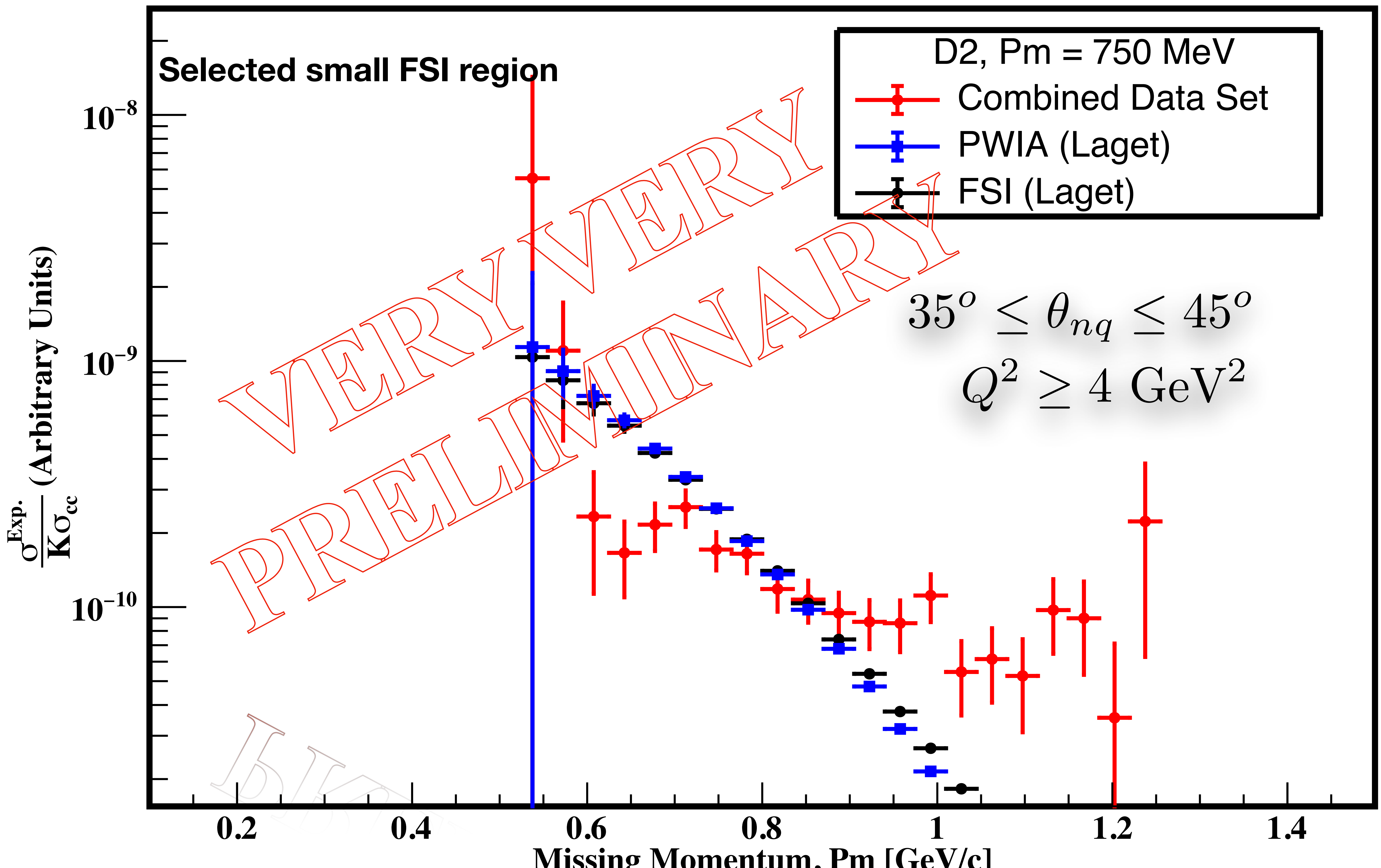
Off-shell electron-proton cross-section (from SIMC)

- ☑ **Only in PWIA (small FSI) is factorization possible**
- ☑ **Small FSI region has been selected in experiment (See previous slides)**

Reduced Cross Sections: Pm = 580 MeV



Reduced Cross Sections: Pm = 750 MeV



Summary

- ☑ The 80 MeV setting between data / simulation comparison looks OK
- ☑ Agreement of 580 / 750 MeV cross section data in the overlap region
- ☐ Data needs radiative, proton absorption, and target boiling corrections before extracting the final cross sections
- ☐ Systematic Uncertainties need to be studied

Acknowledgements

I would like to thank Drs. Werner Boeglin and Misak Sargsian for their significant contributions to the Deuteron experiment and theory.

I would also like to give many thanks to Dr. Mark Jones, who has helped me immensely in data analysis.

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The Nuclear Regulatory Commission (NRC) graduate fellowship grant No: NRC-HQ-84-14-G-0040 to FIU

The Department of Energy (DOE) grant DE-SC0013620 to FIU

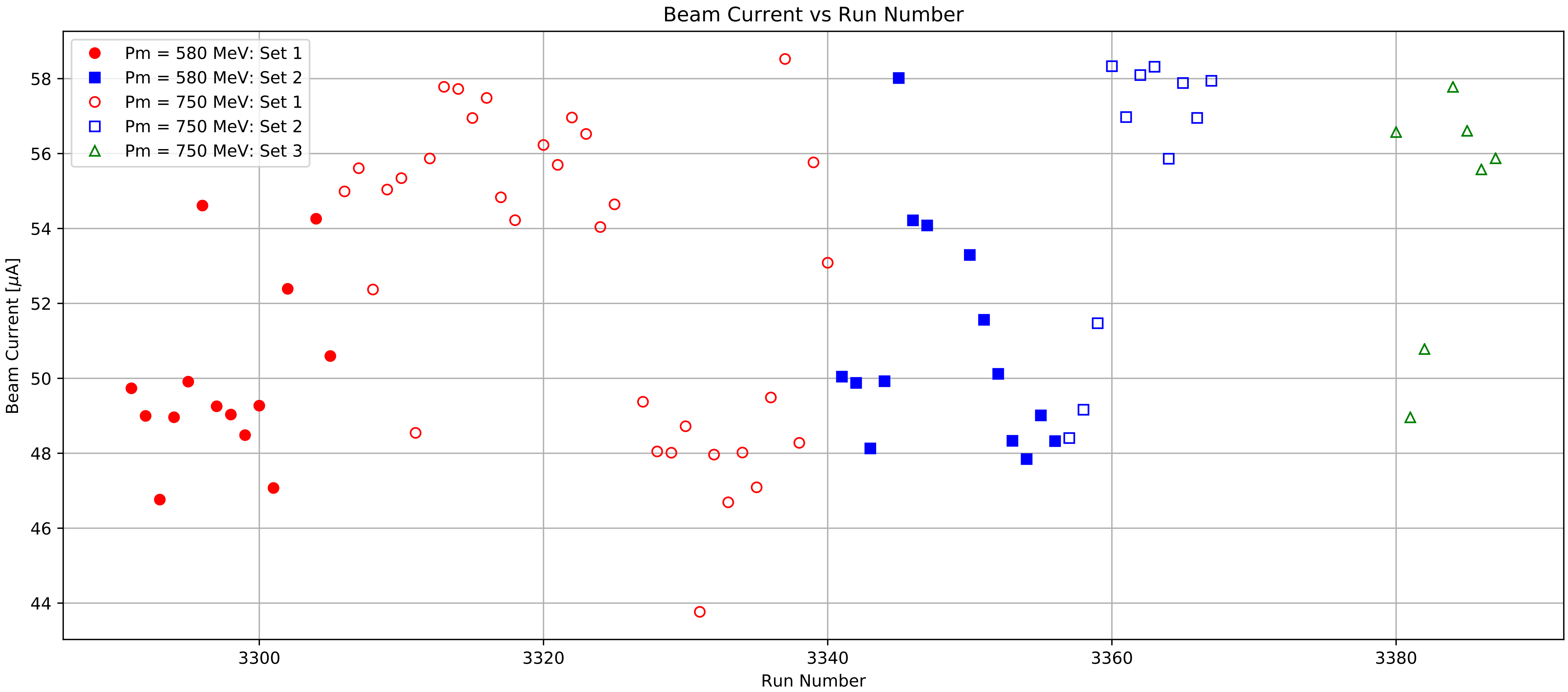
Thank You !

Questions ?

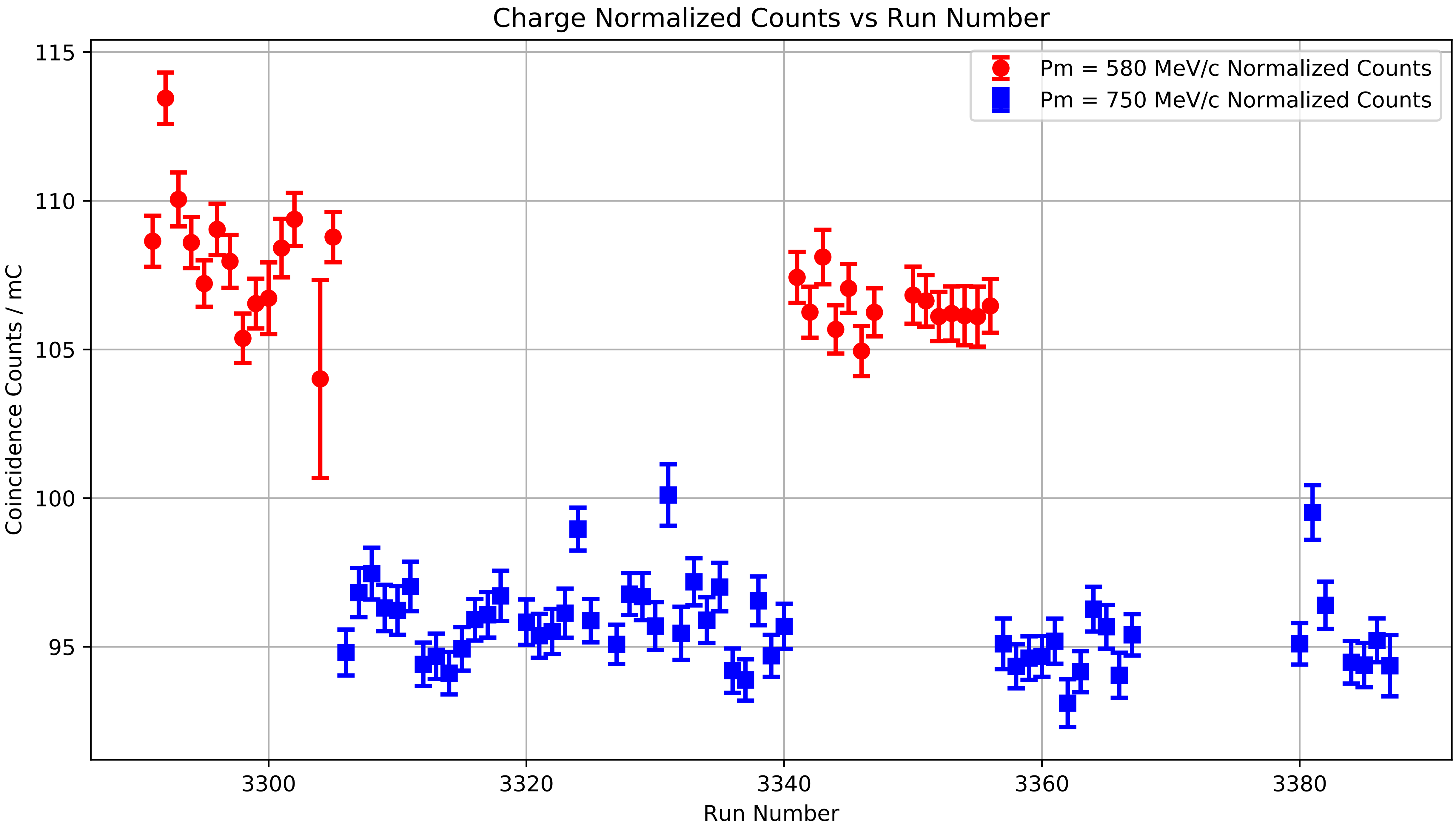
Back-Up Slides

Beam Current

- ☑ **Beam Current ranged from 45 - 60 uA**

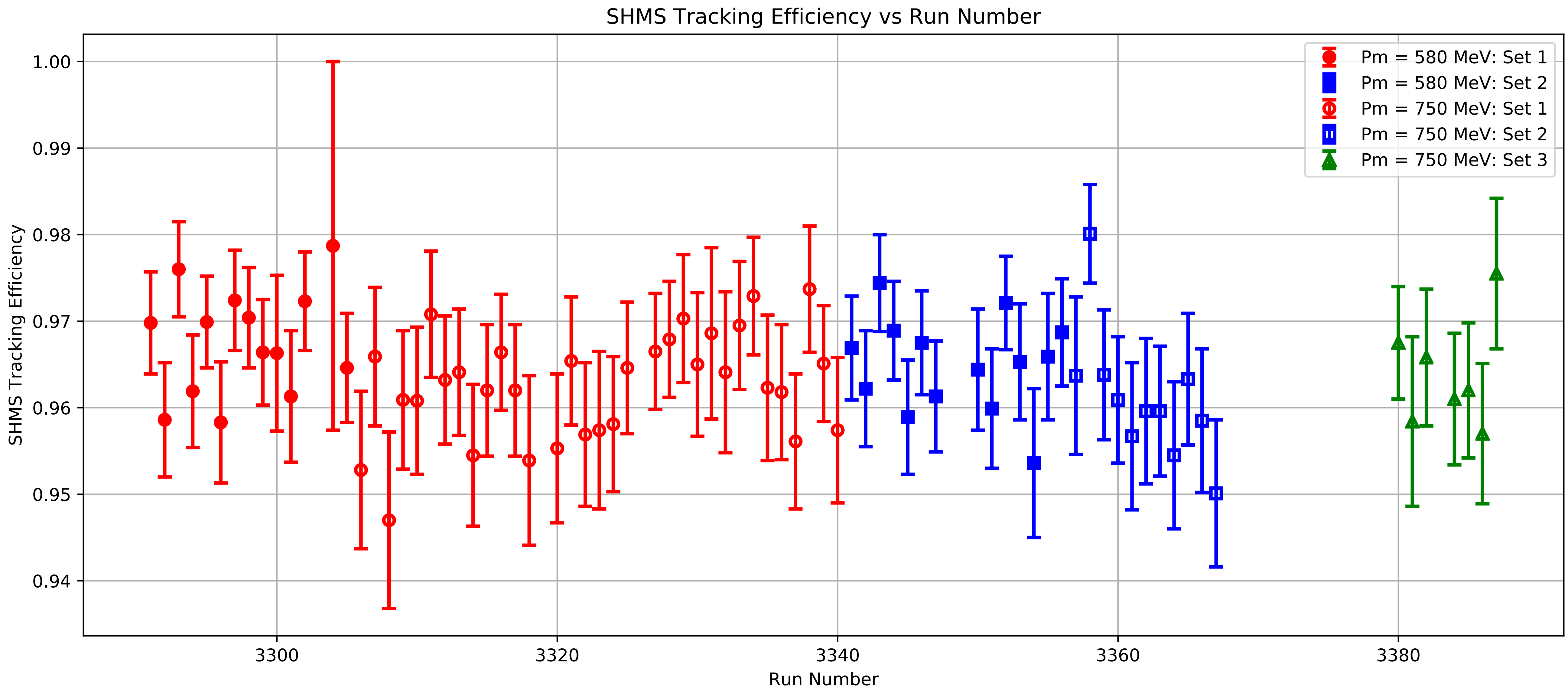


Charge Normalized Counts



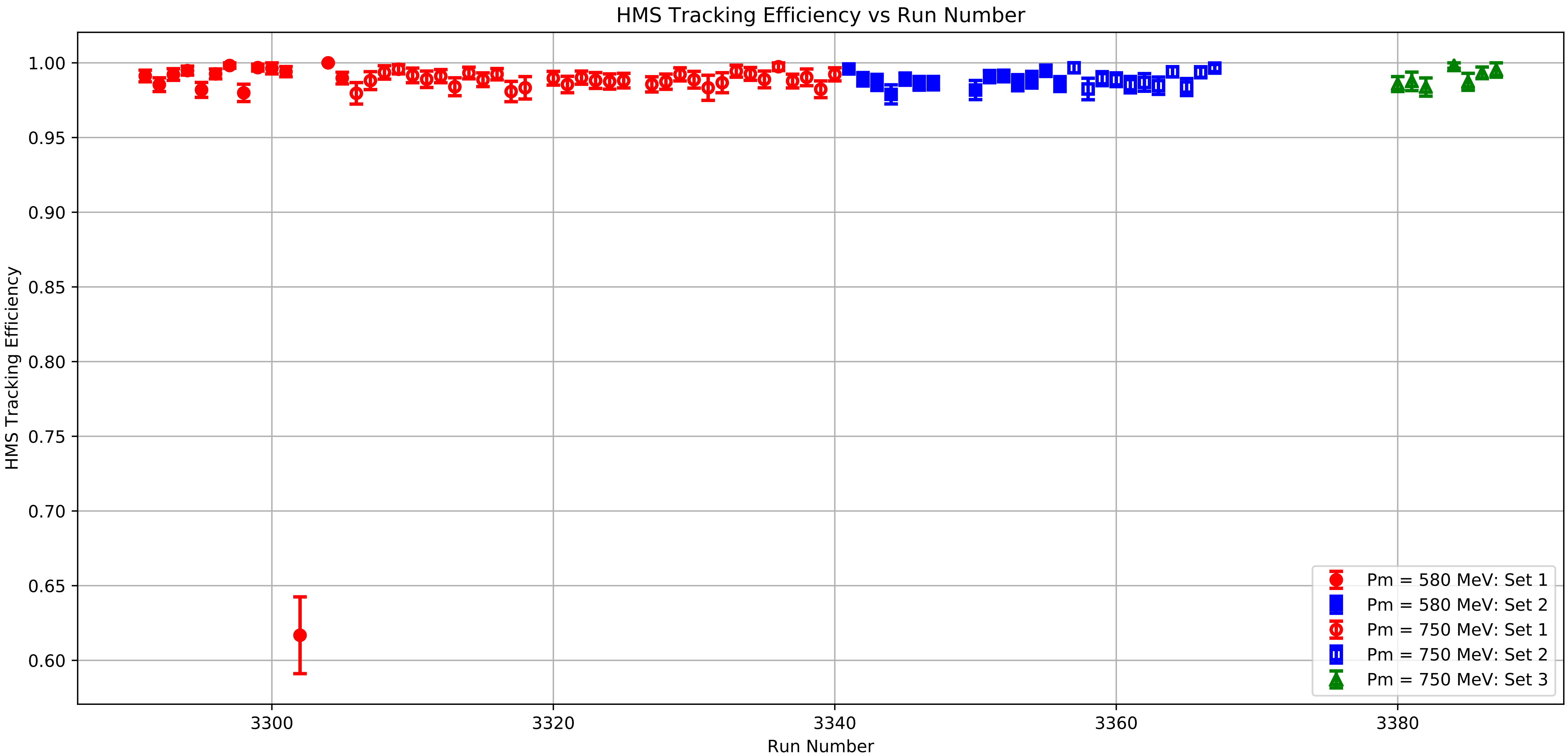
SHMS Tracking Efficiencies

☑ **SHMS electron tracking efficiencies ranged from 95-98 %**



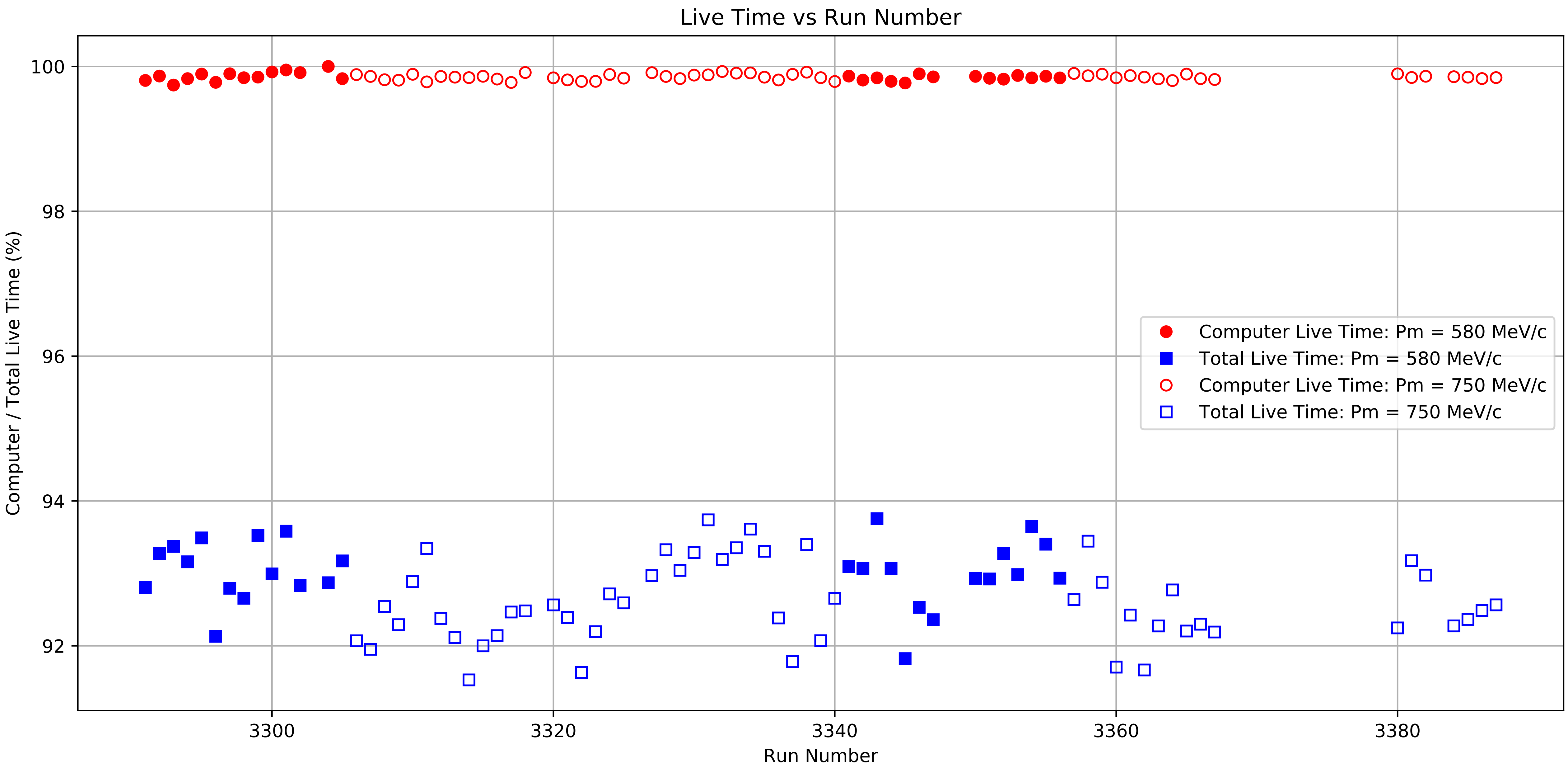
HMS Tracking Efficiencies

☑ **HMS electron tracking efficiencies ranged from 98-99 %**

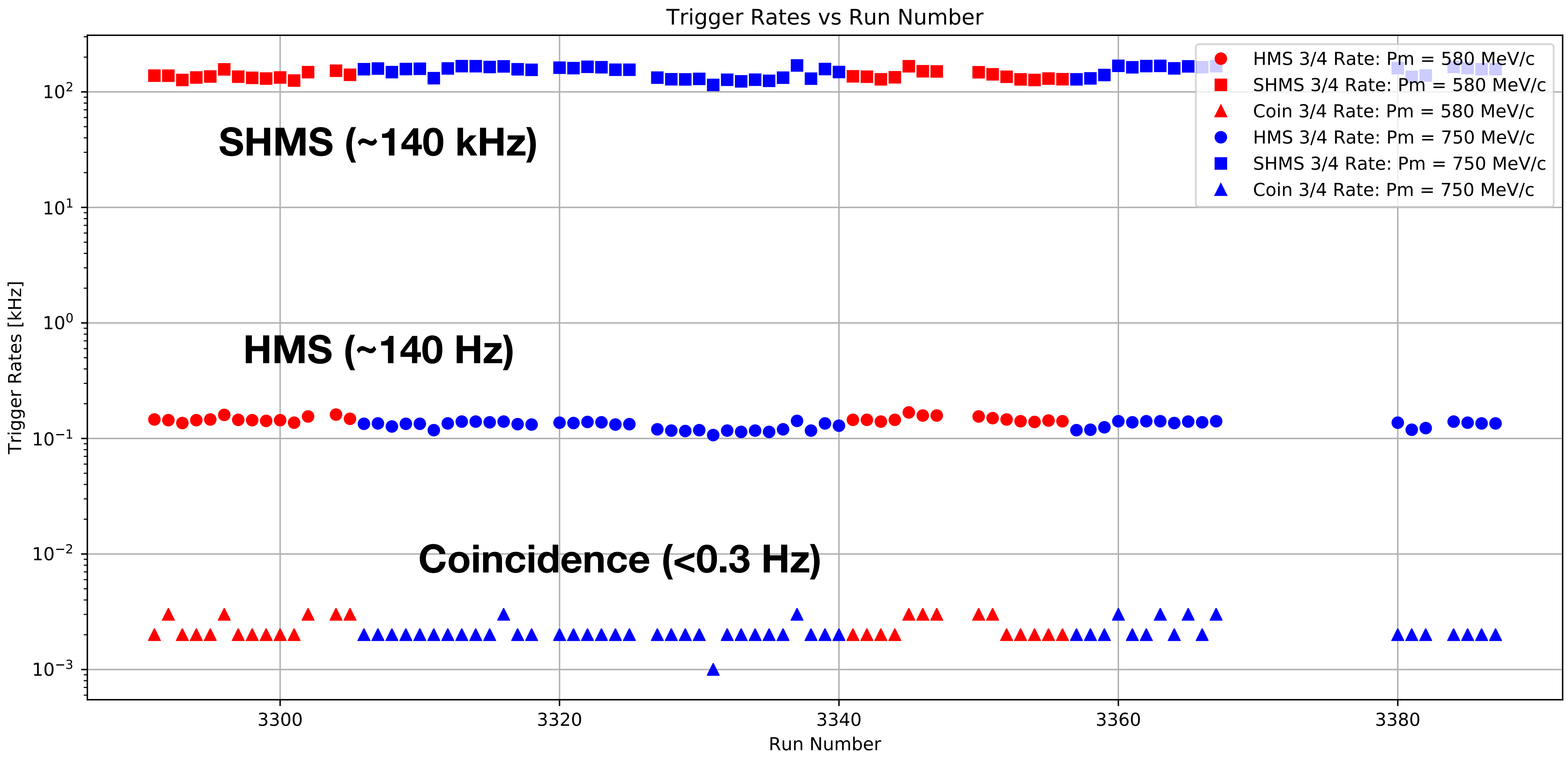


Computer / Total Live Time

- ☑ **Computer Live Time was ~ 98-99%**
- ☑ **Total Live Time was ~92-94% (Due to electronics pile-up at high rates)**



Trigger Rates



Beam Positions (BPMs)