

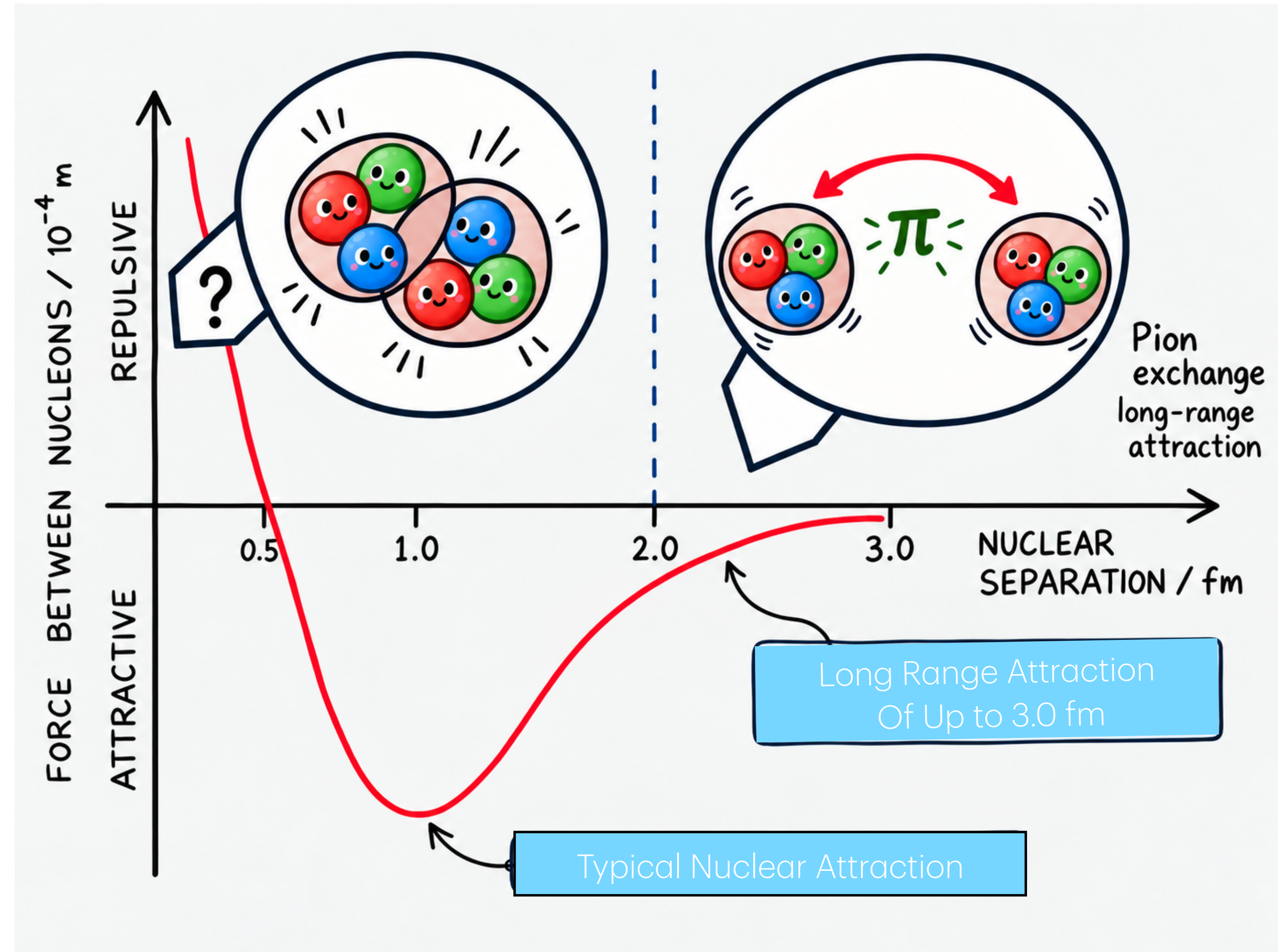
EXPLORING THE NUCLEAR REPULSIVE CORE VIA DEUTERON ELECTRO-DISINTEGRATION AT HIGH-MOMENTUM TRANSFERS (Q^2) [E12-10-003]

Pramila Pokhrel
Advisor: Dr. Carlos Yero
Catholic University of America



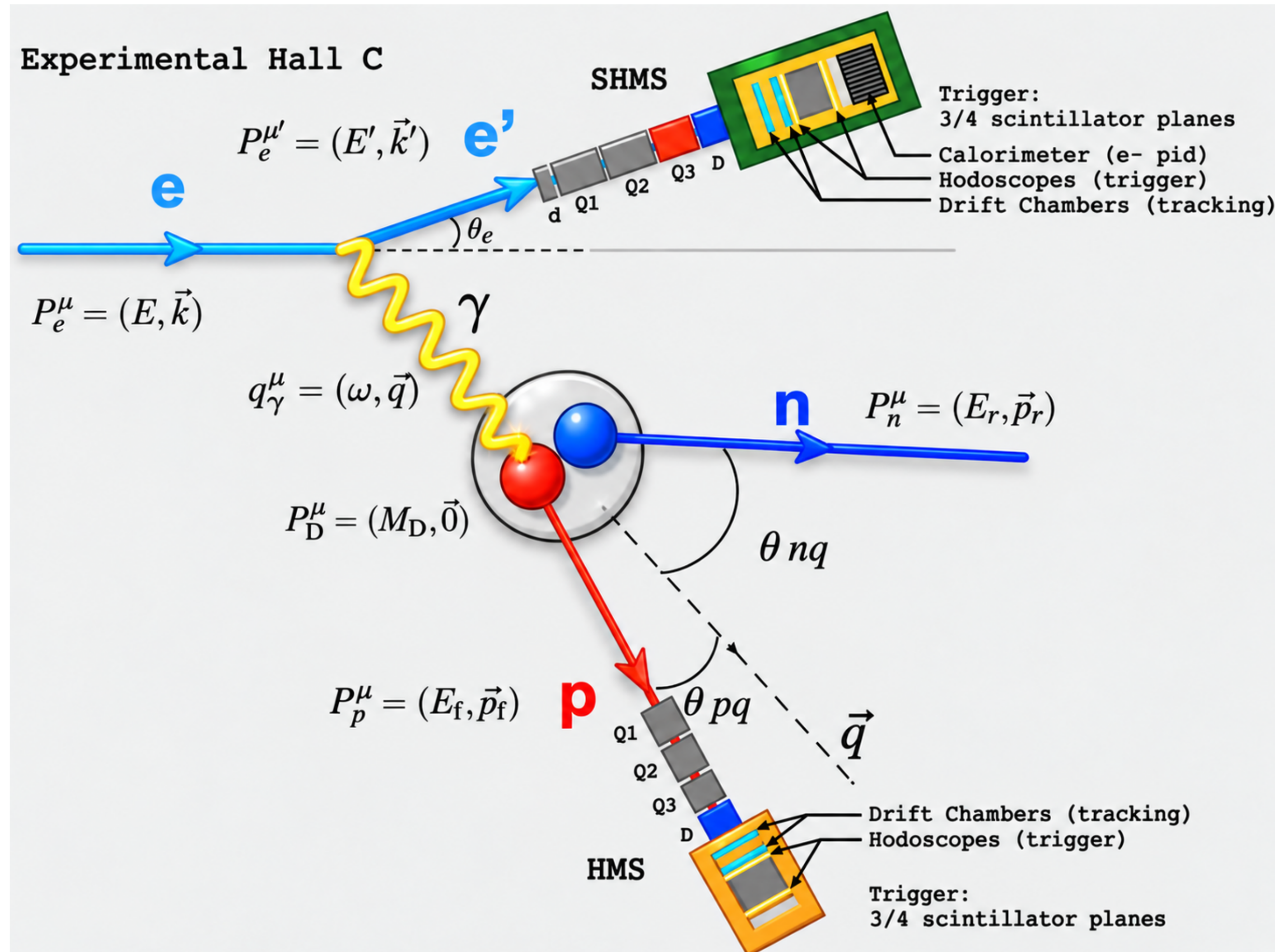
Motivation: Deuteron Break-up Experiment

- Effective tools for exploring **nuclear structure** and determining cross sections
- Ideal system to study **Nucleon-Nucleon (NN)** potential.
- Study Deuteron at **short ranges** ($< 1\text{fm}$).
- Extract $D(e,e'p)n$ cross-section beyond 500 MeV/c Recoil momentum at **high four momentum transfer (Q^2)**

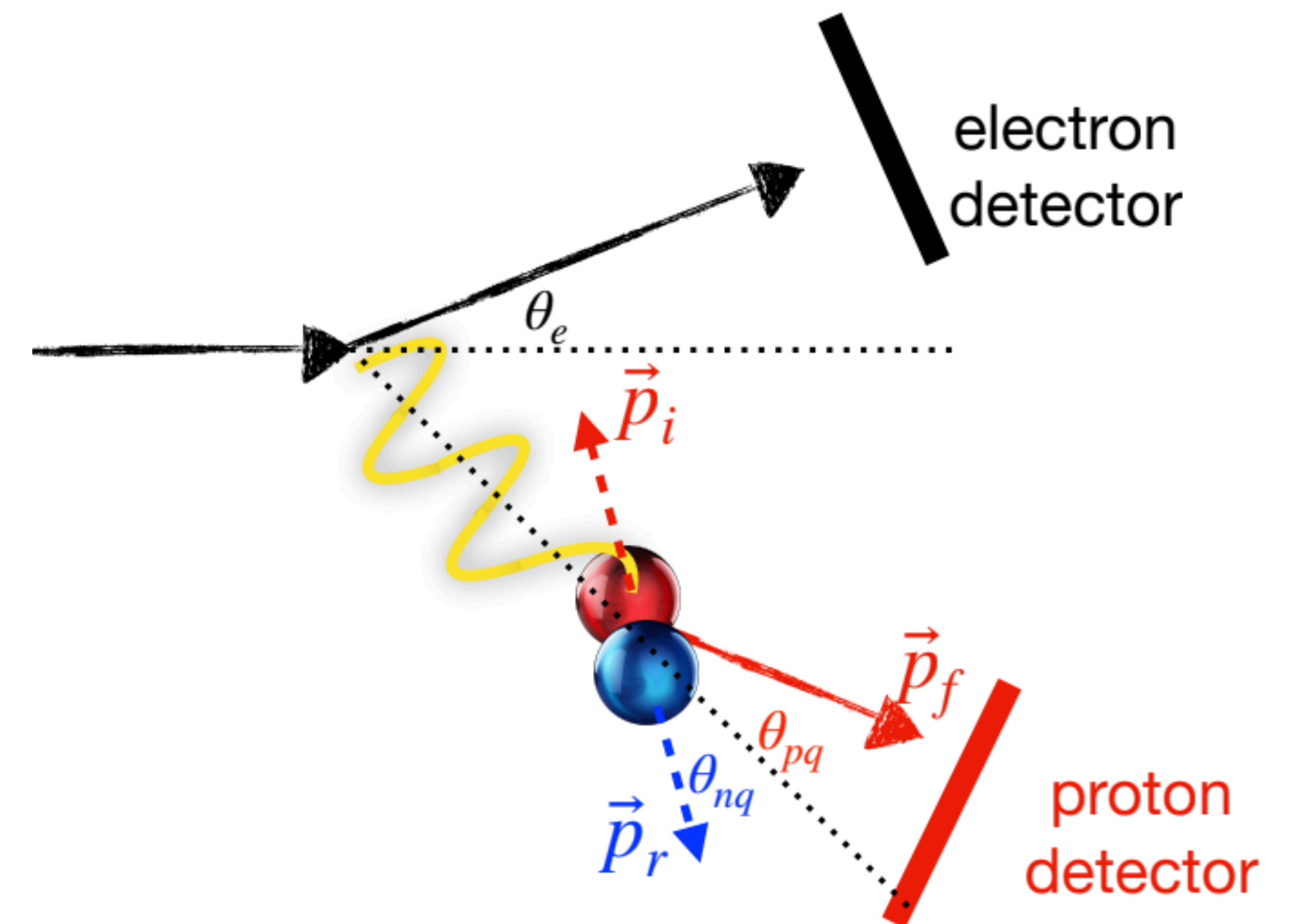


www.openai.com

D(e,e'p)n Kinematics



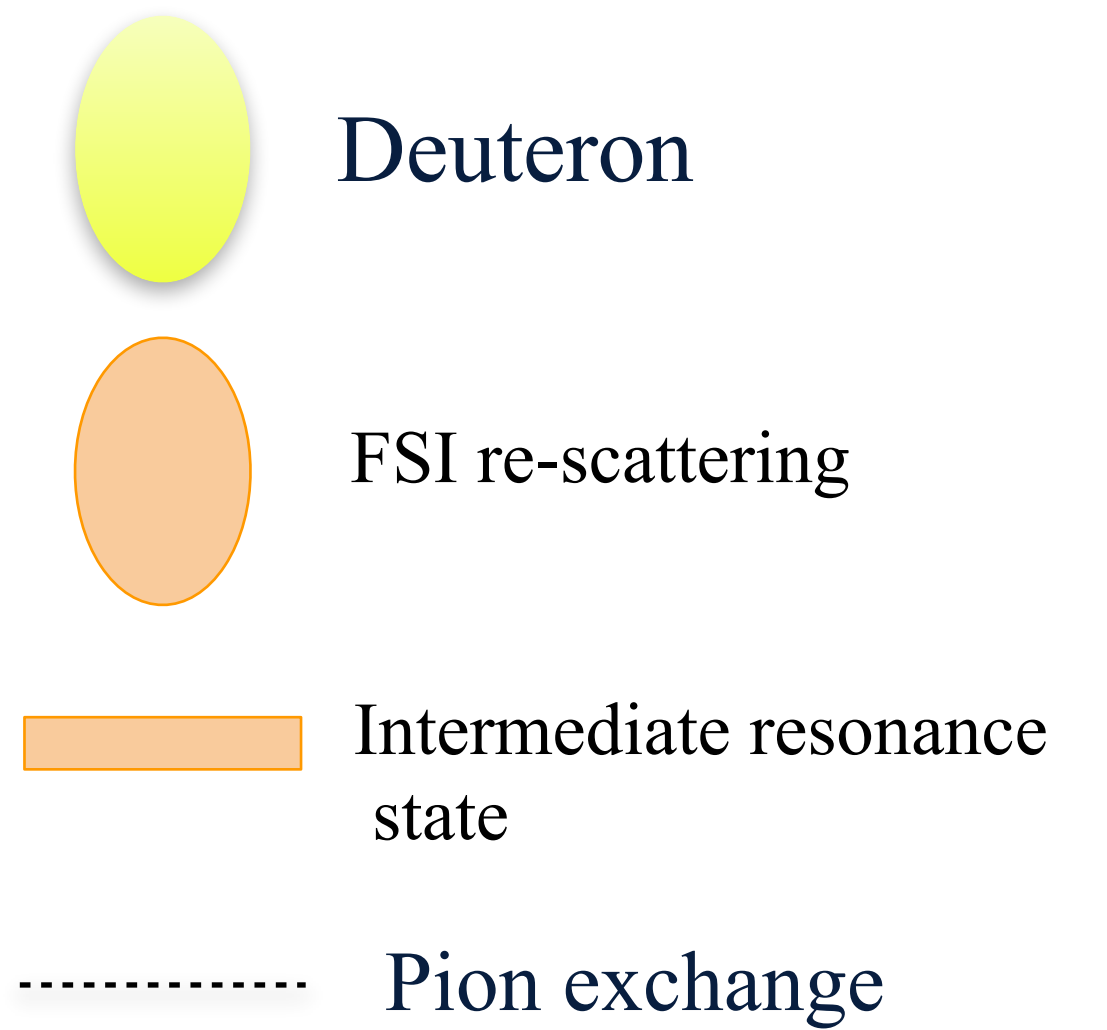
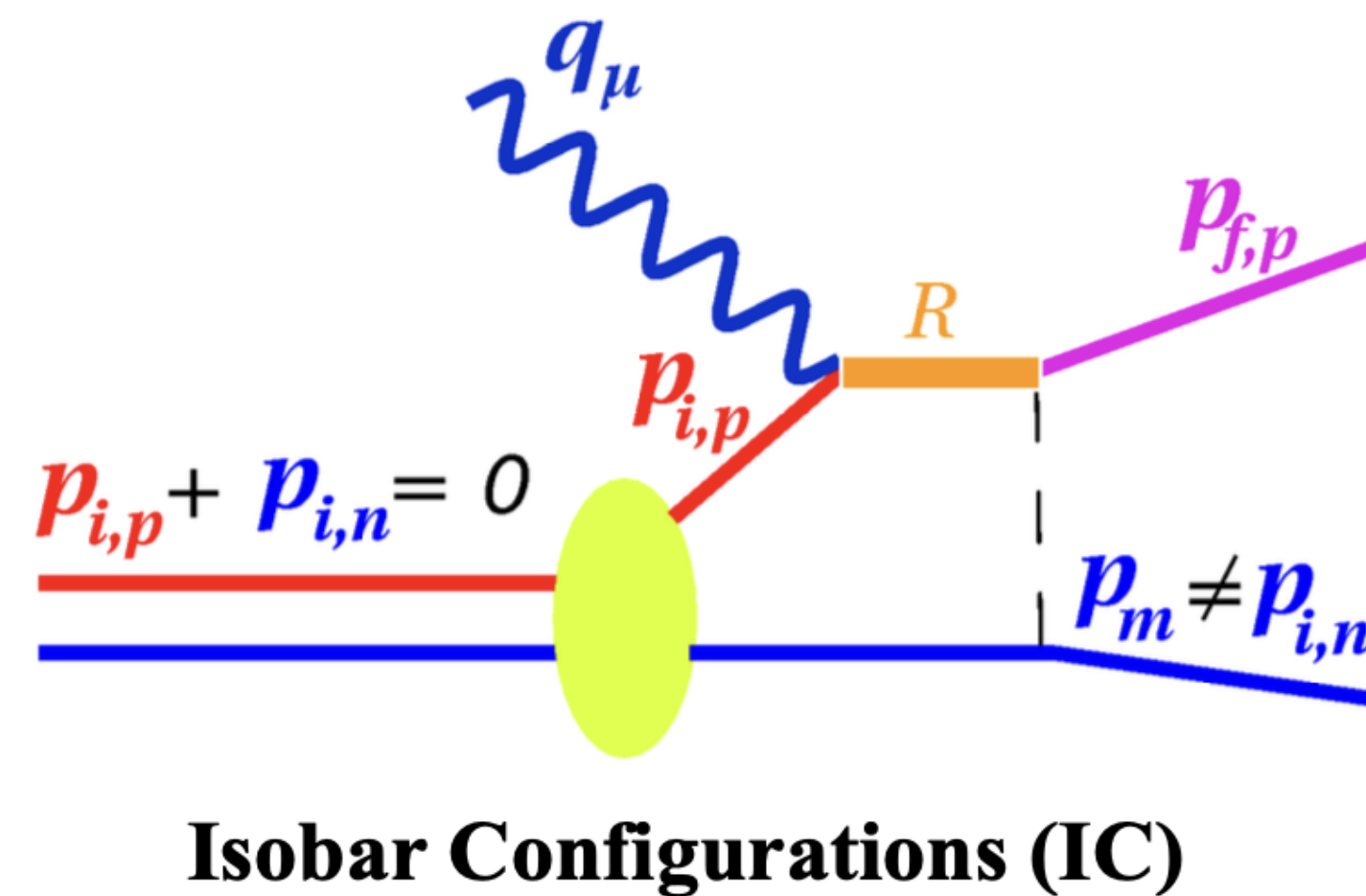
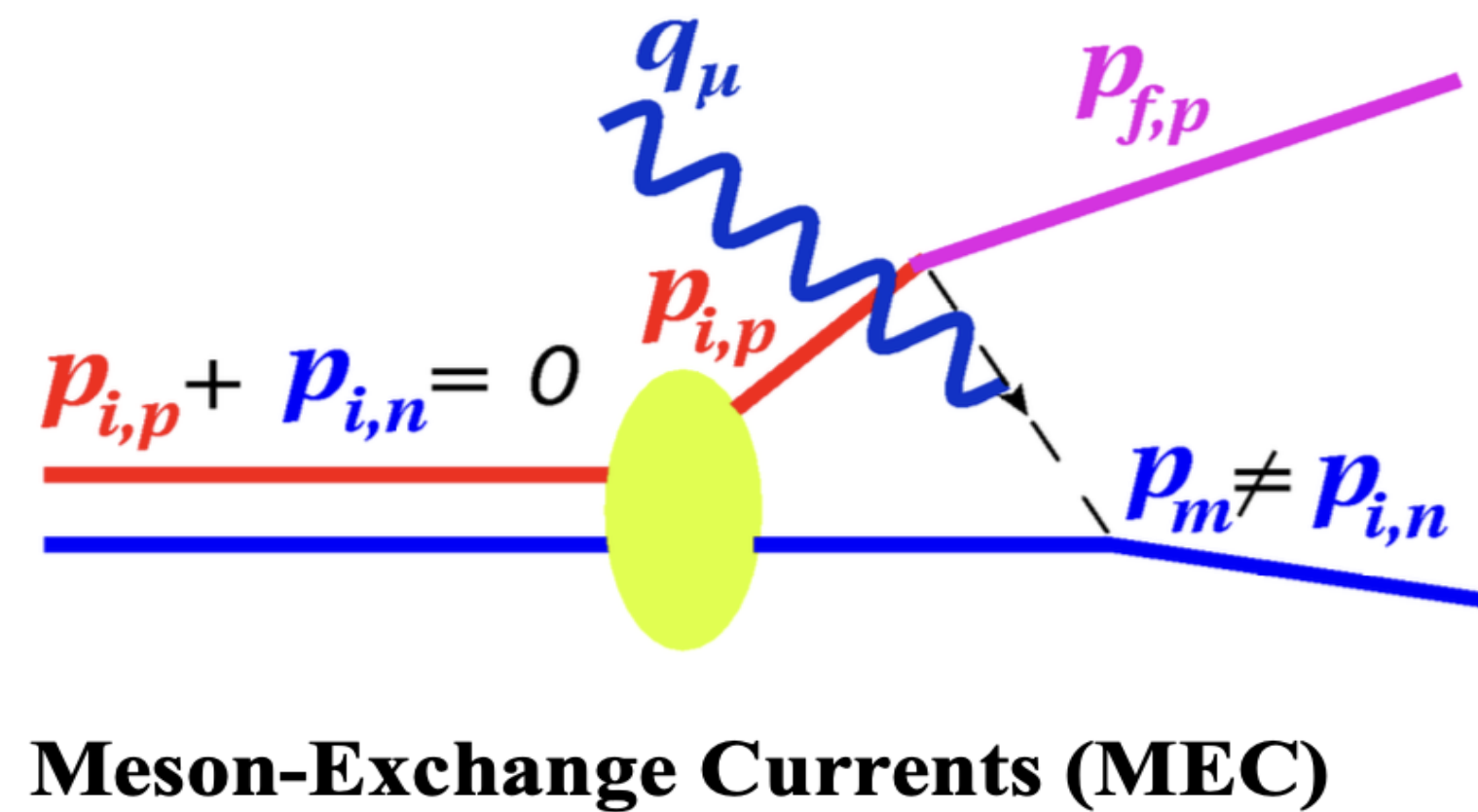
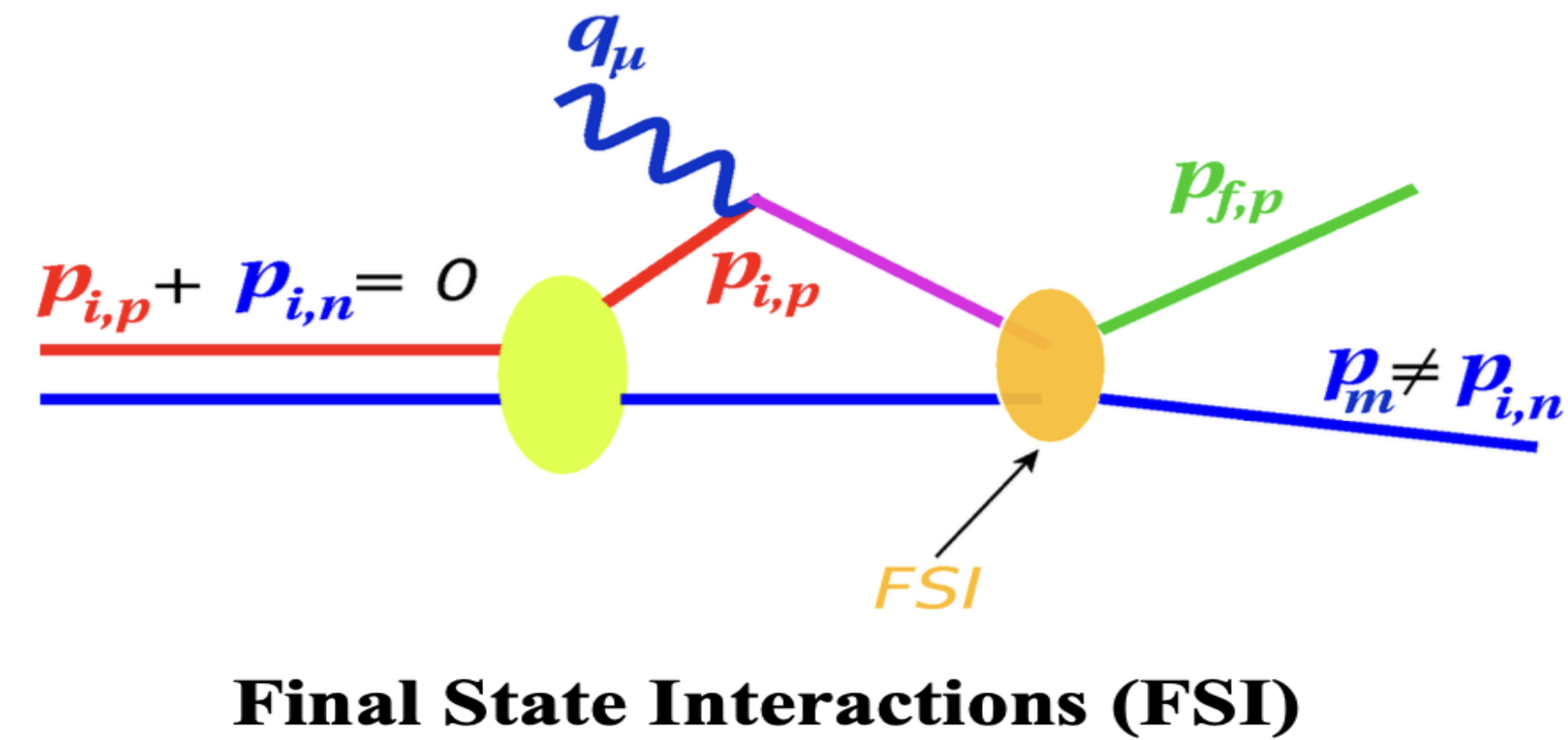
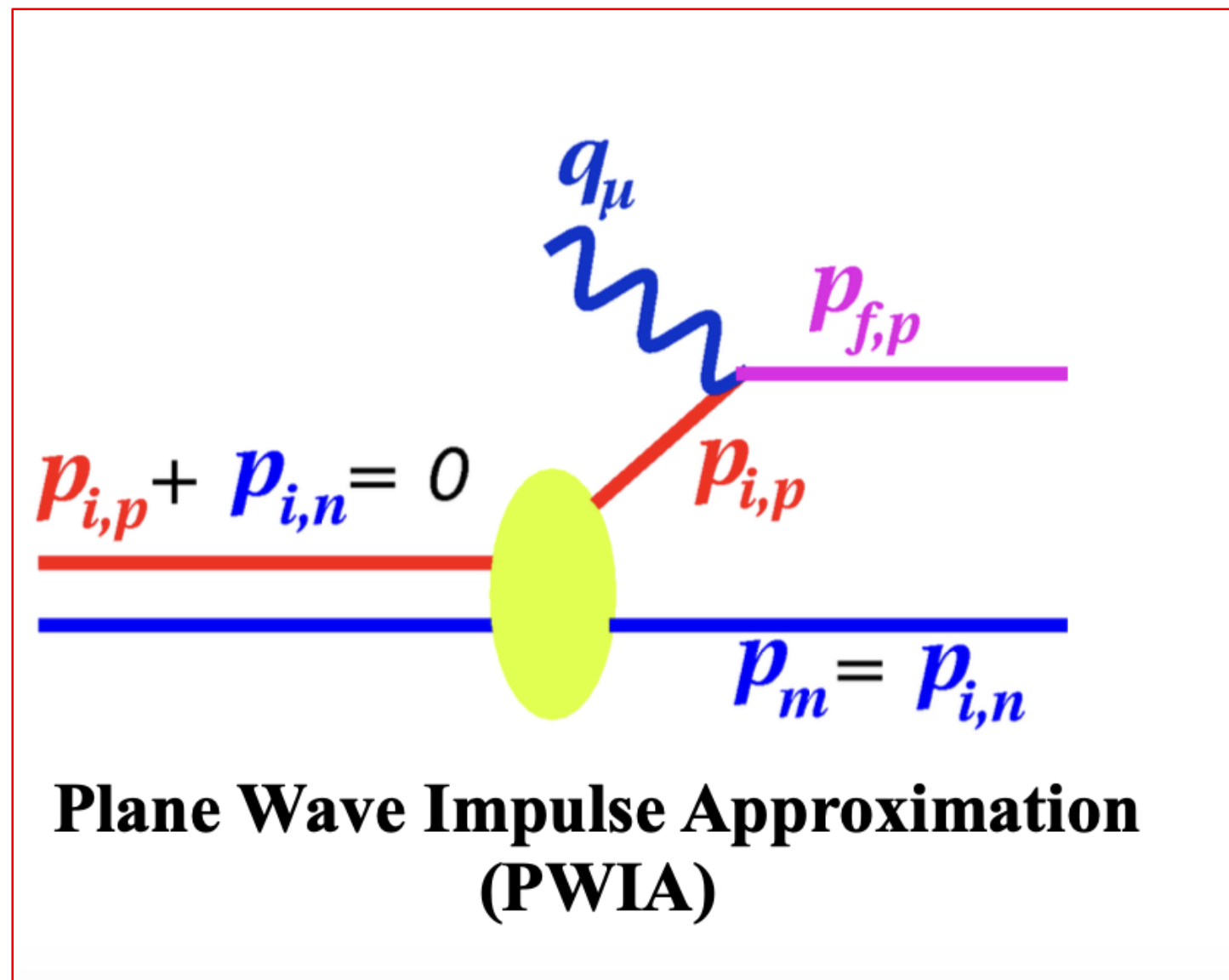
Feynman Diagram of D(e,e'p)n Interaction



PWIA Interaction

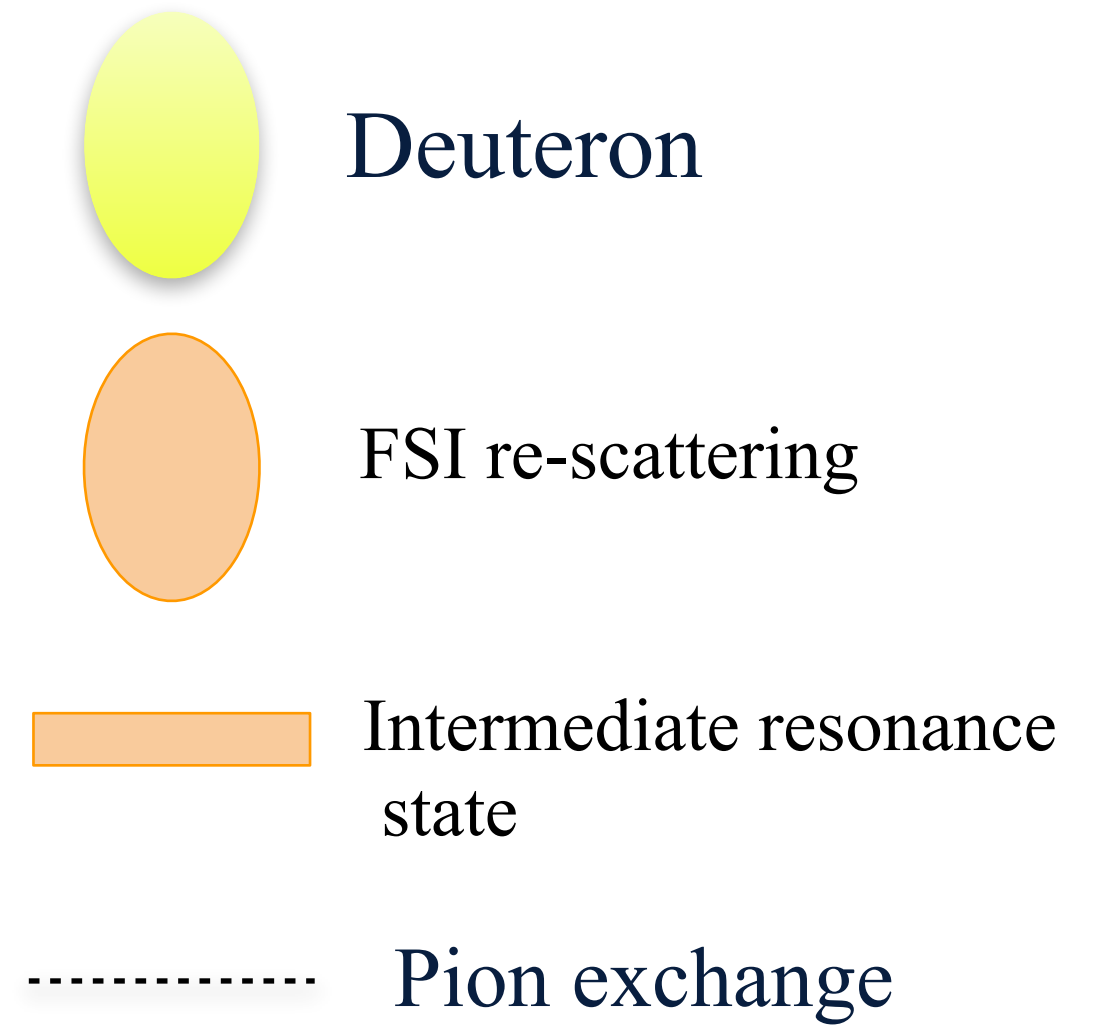
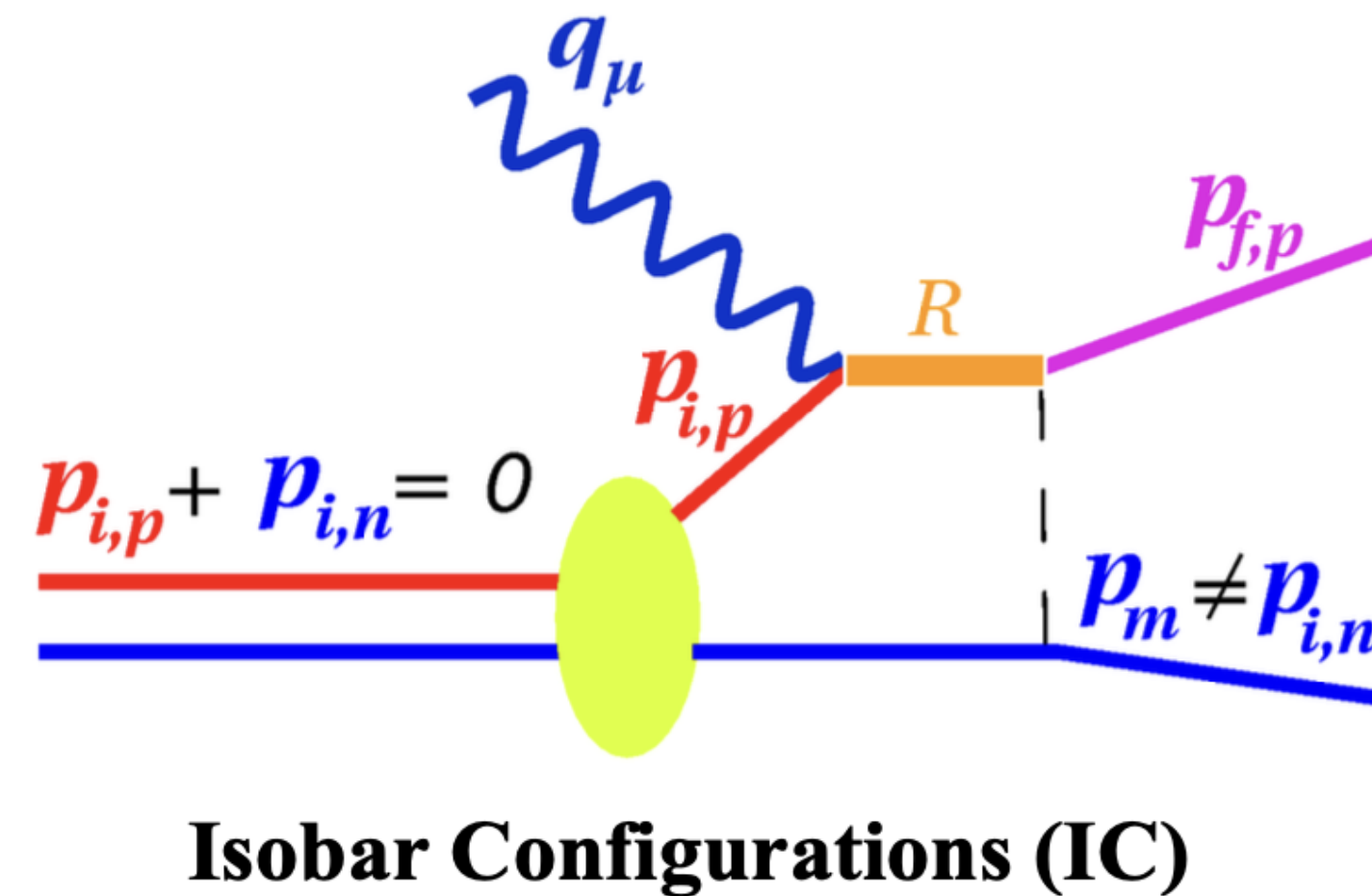
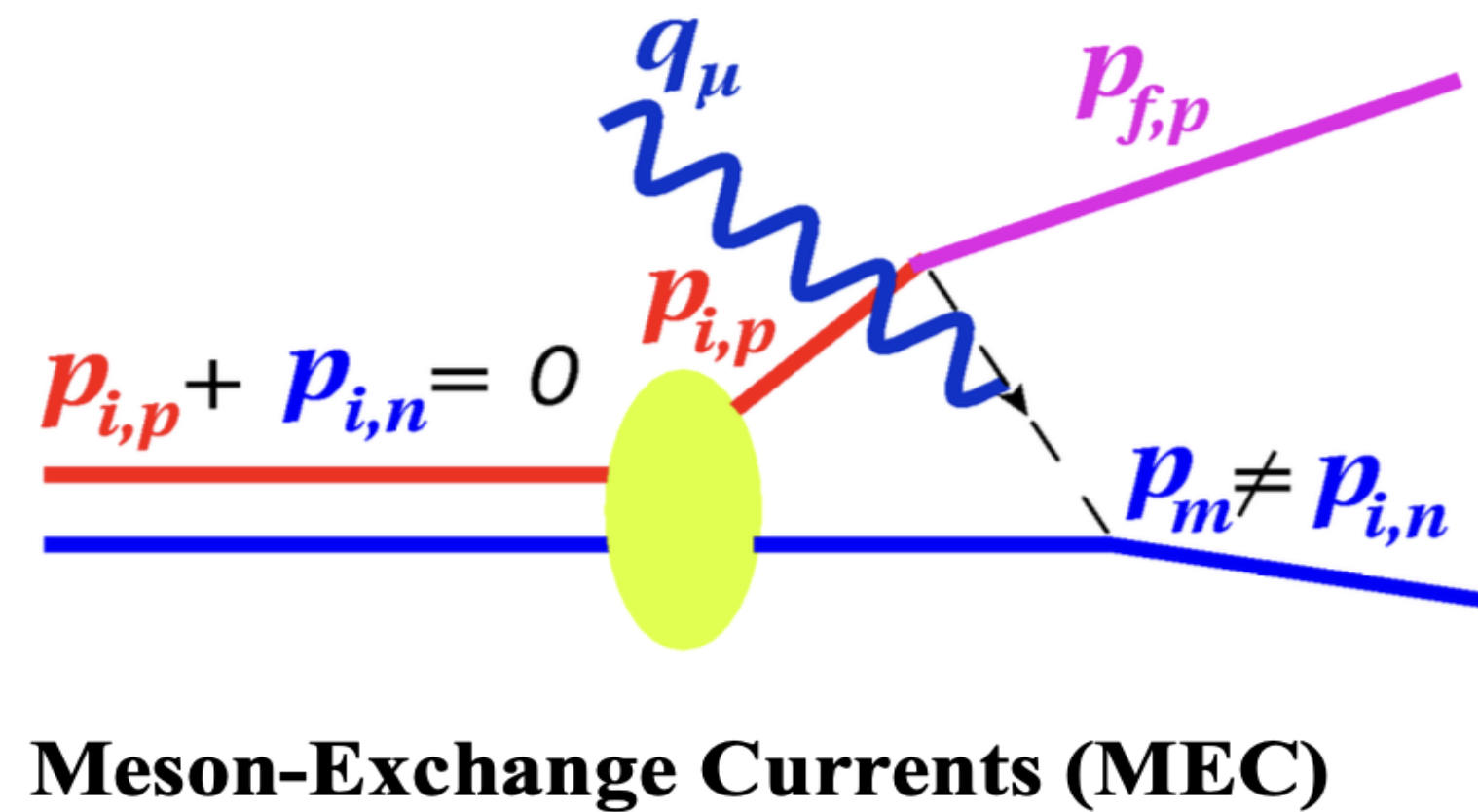
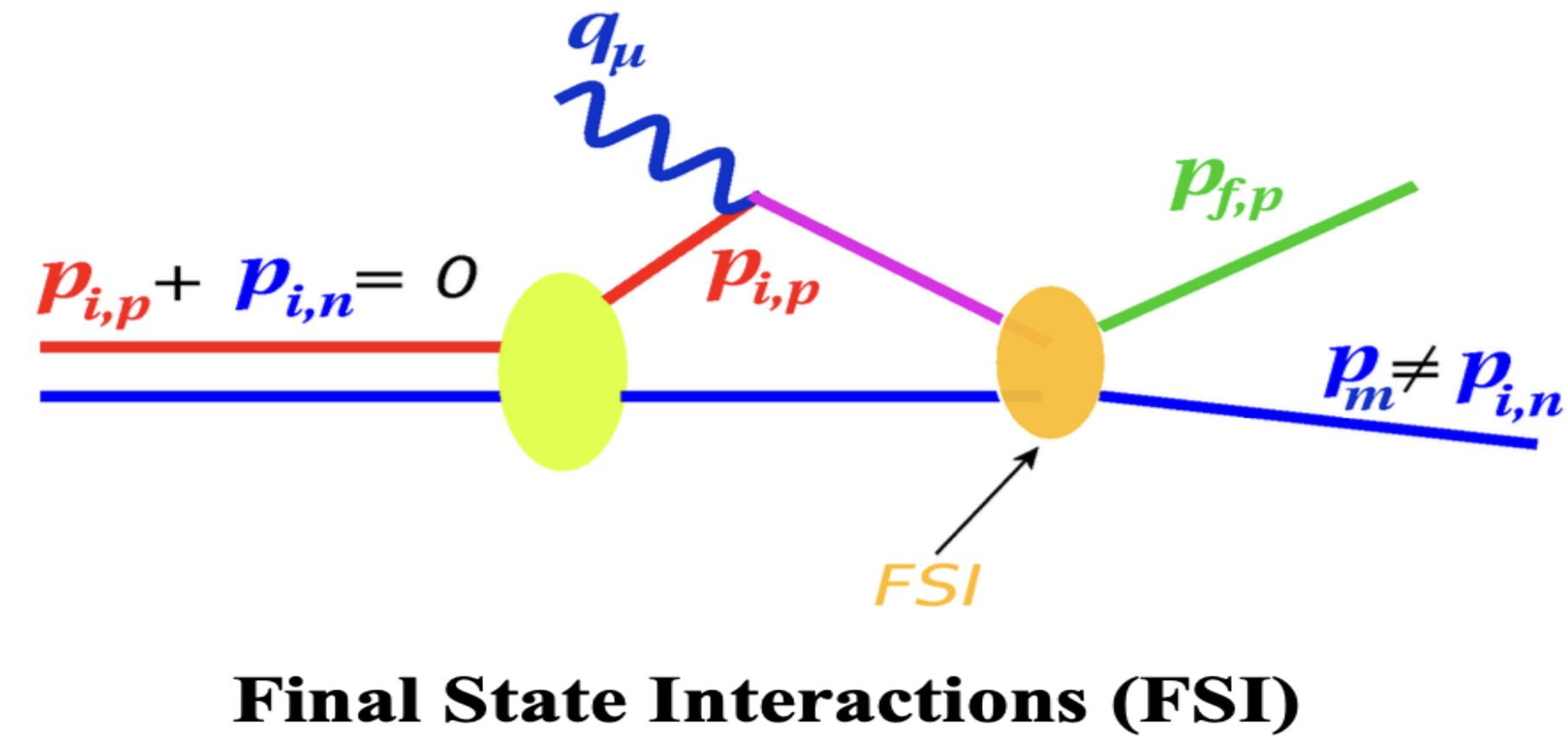
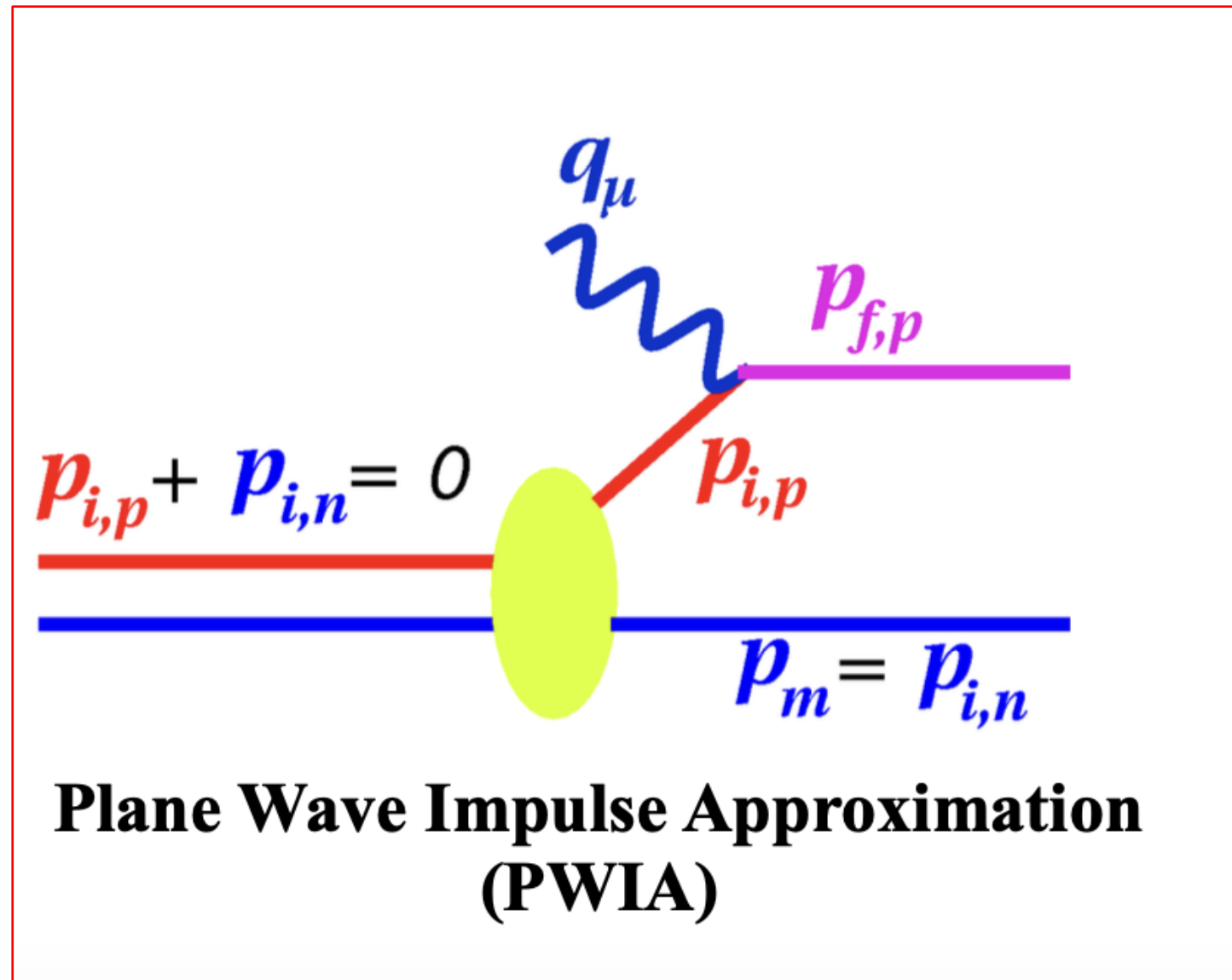
p.c.Yero [Thesis](#)

D(e,e'p)n Interactions



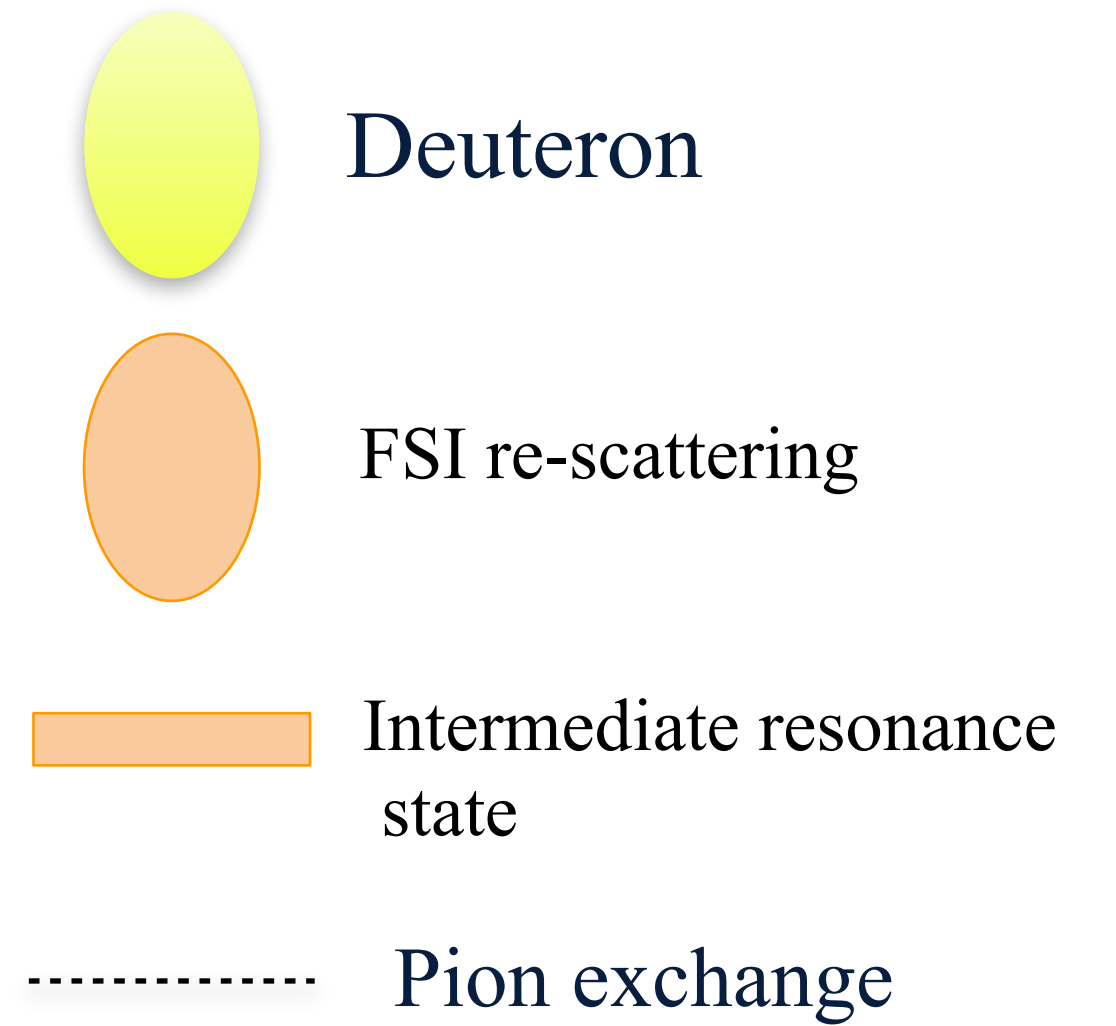
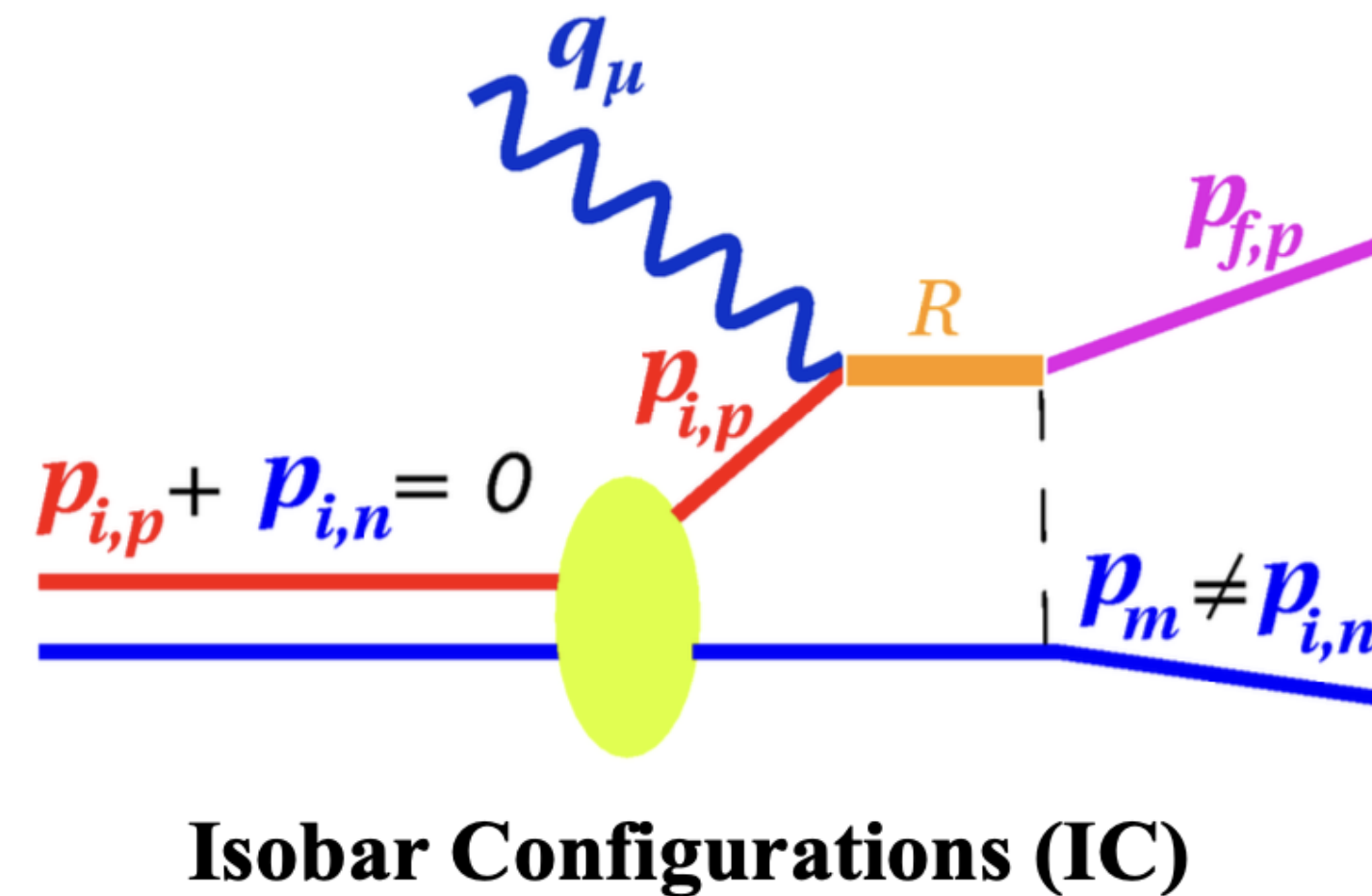
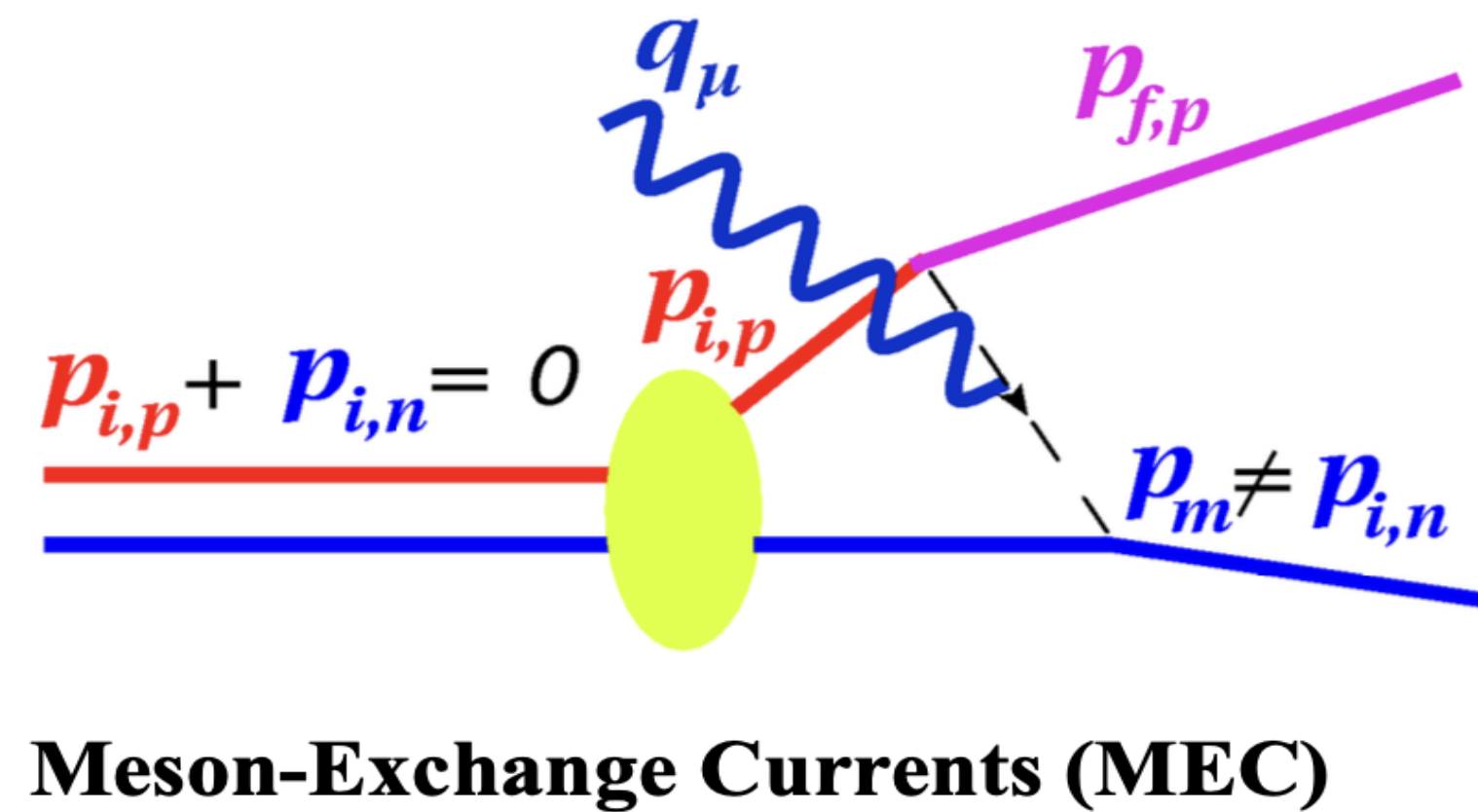
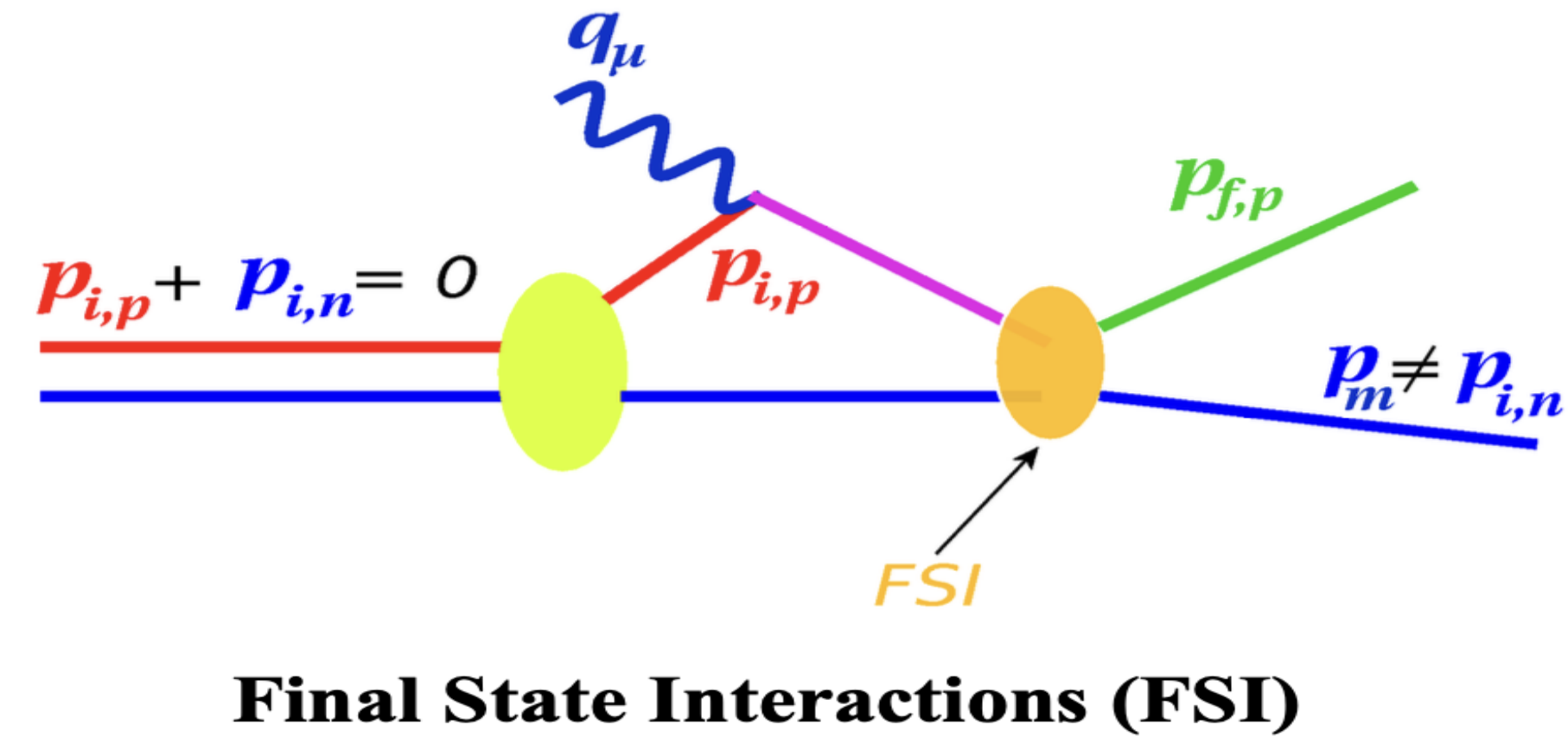
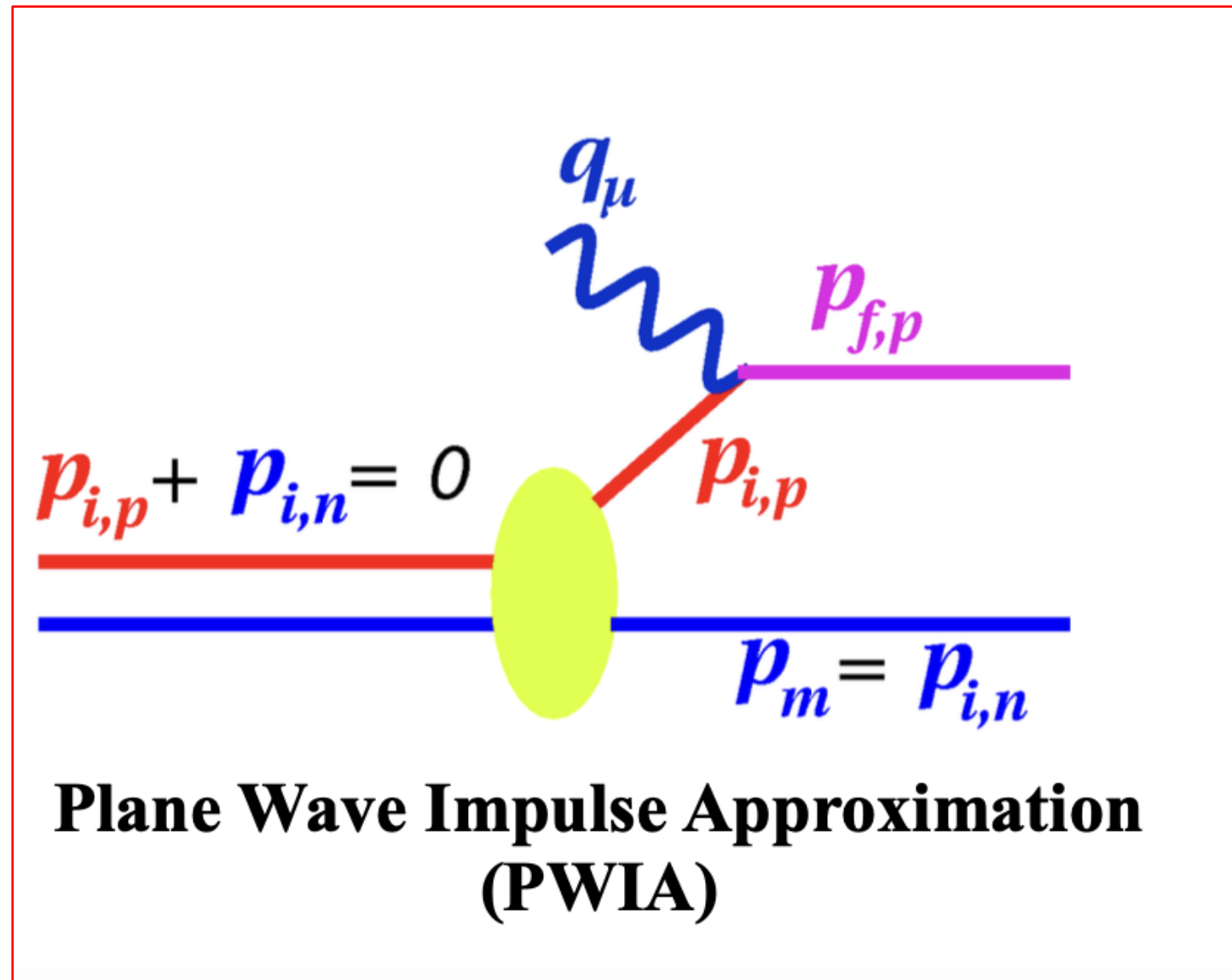
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D(e,e'p)n Interactions



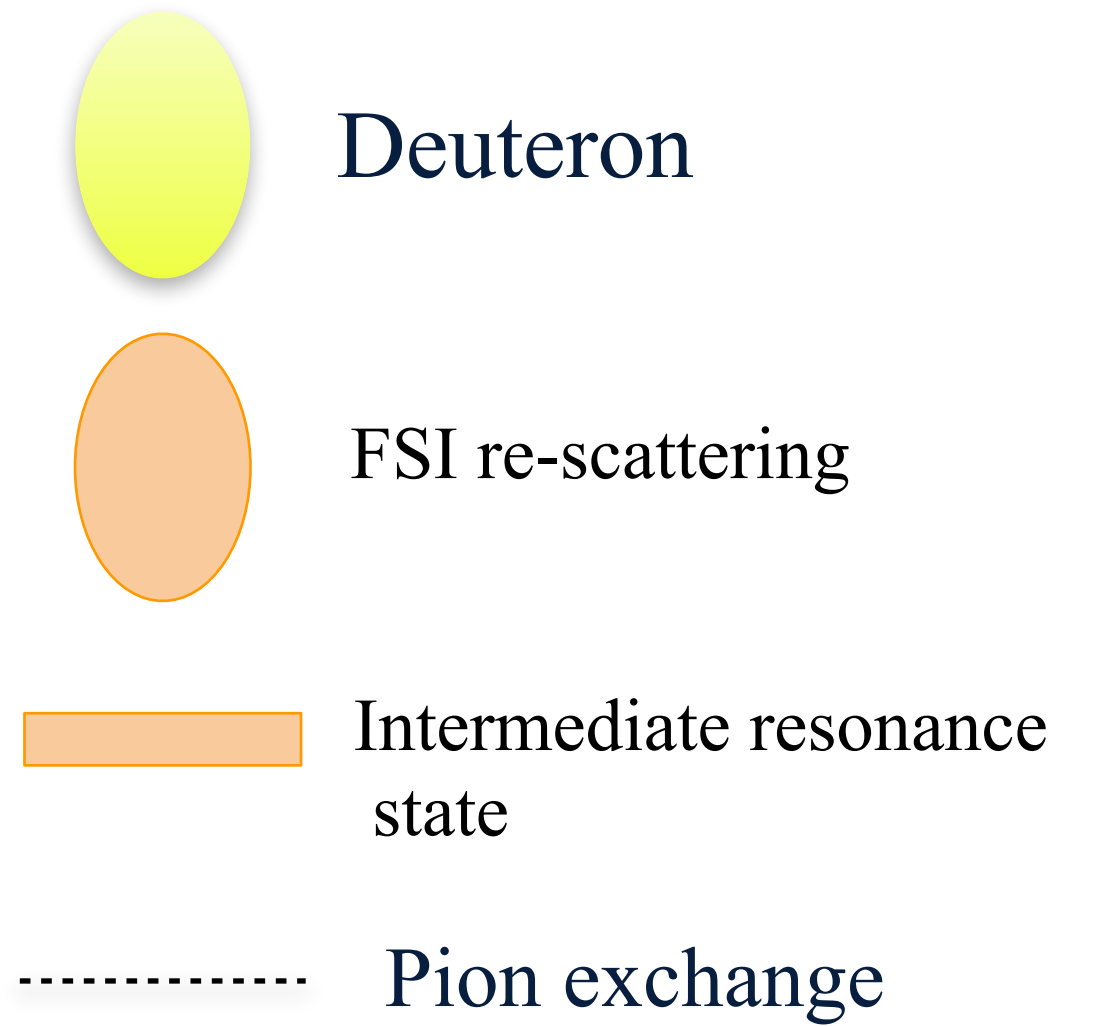
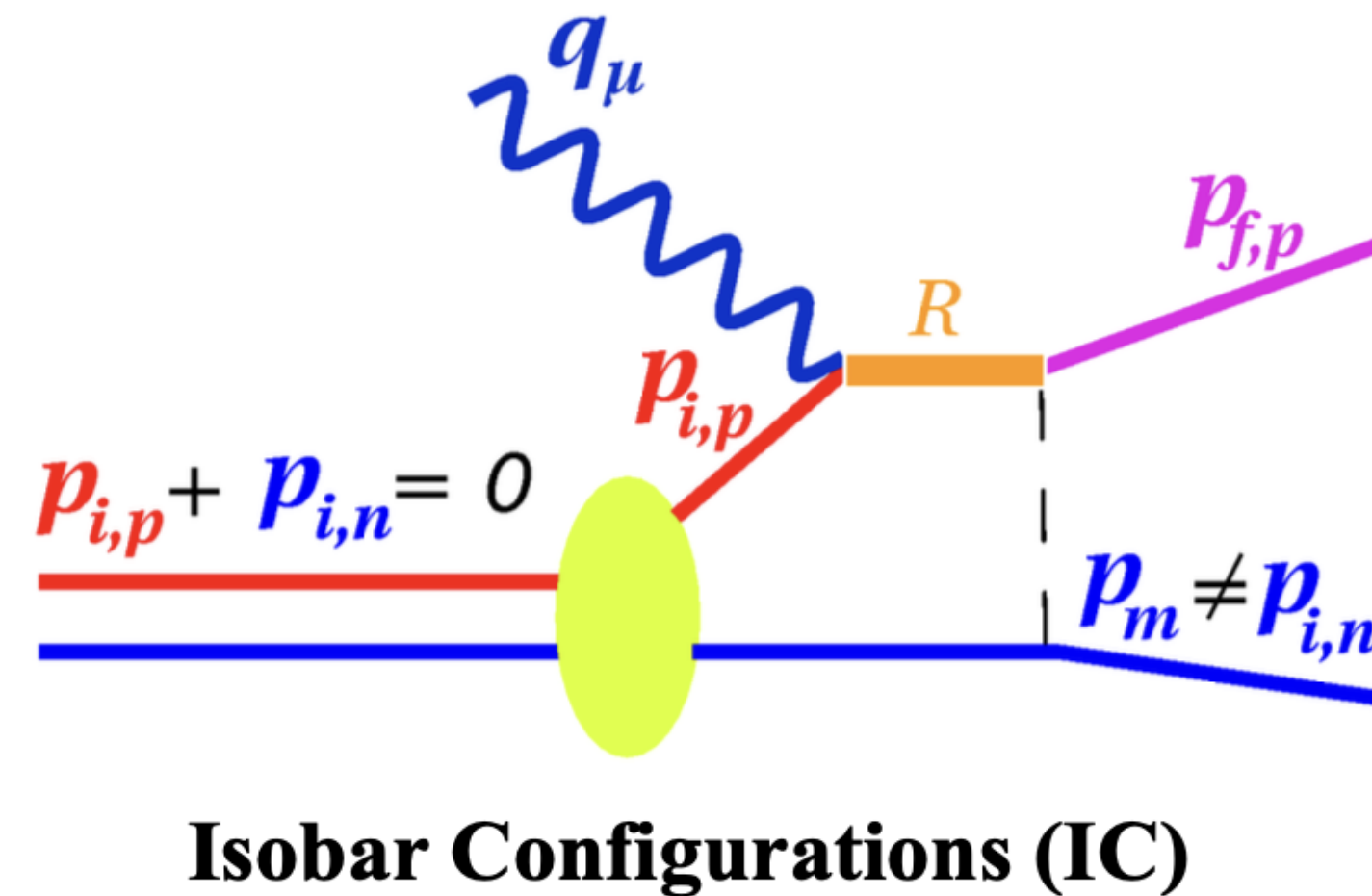
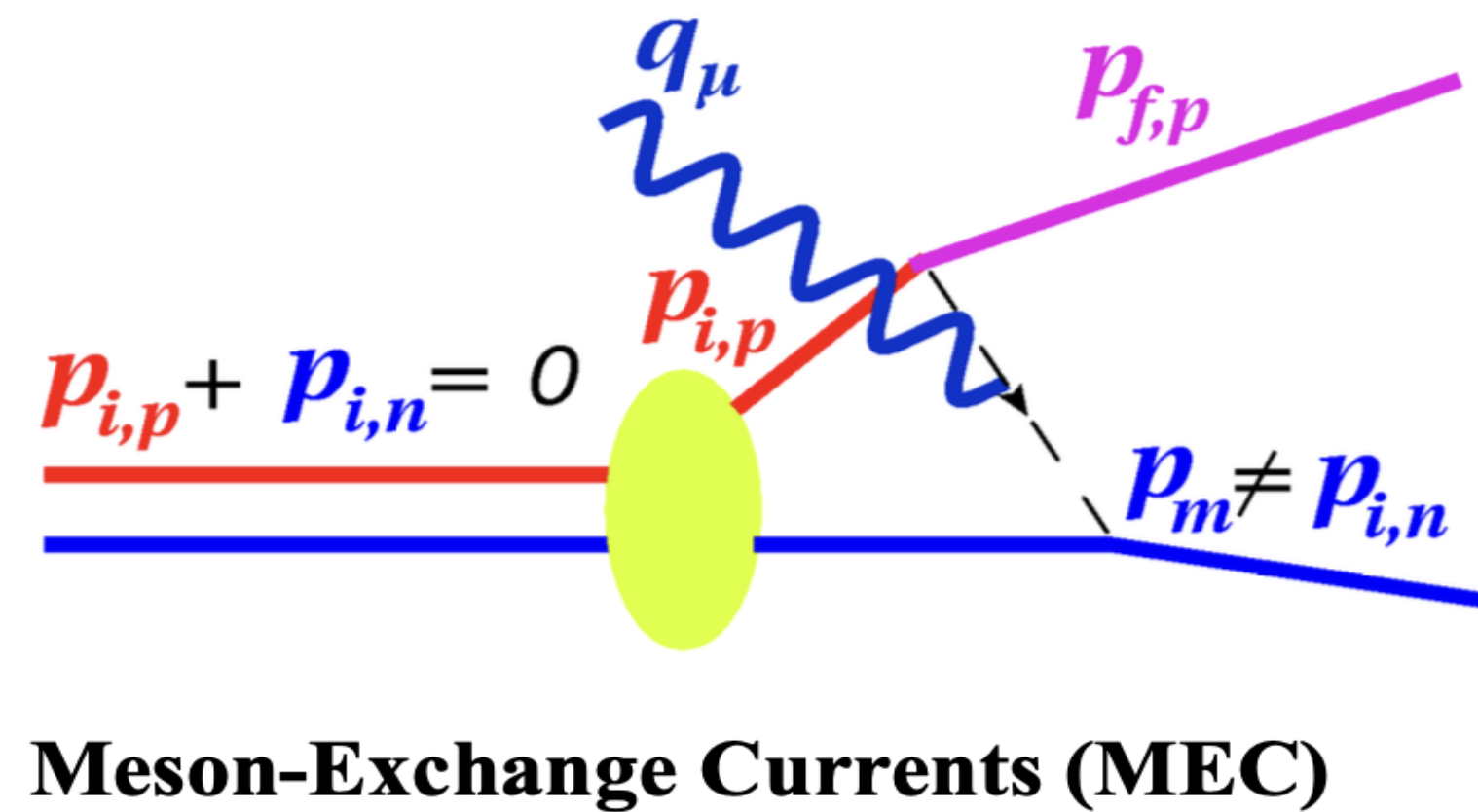
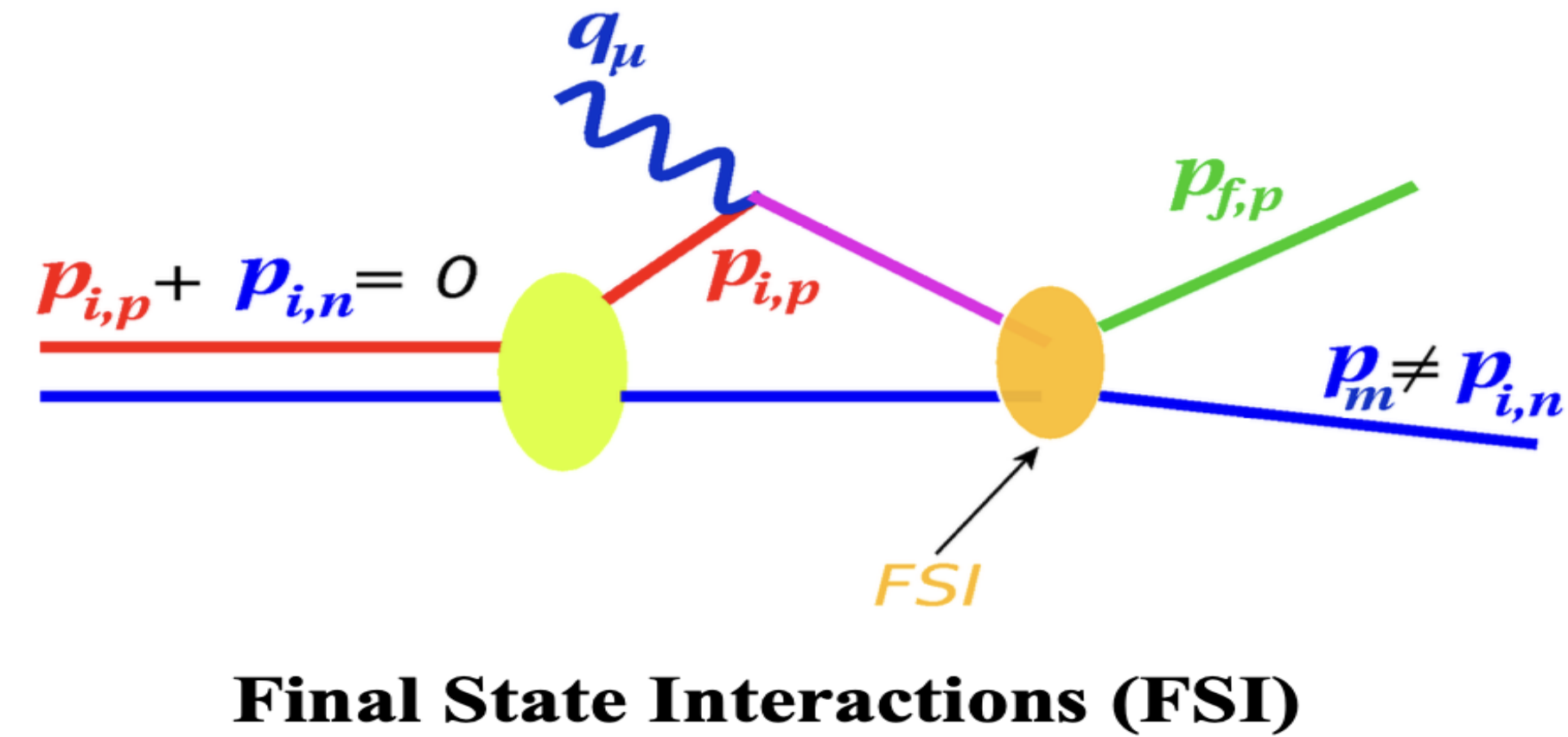
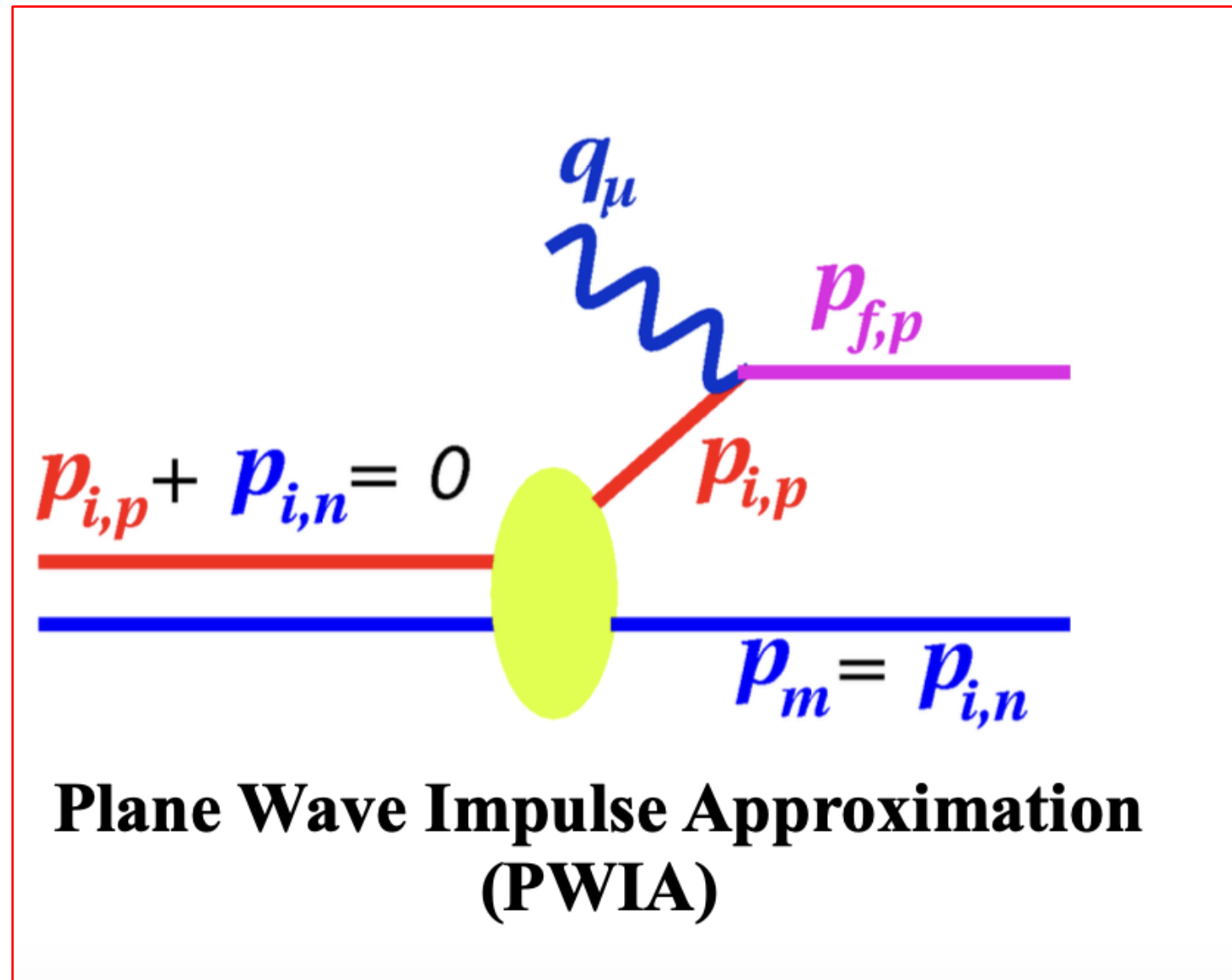
p.c.Yero [Thesis](#)

D(e,e'p)n Interactions



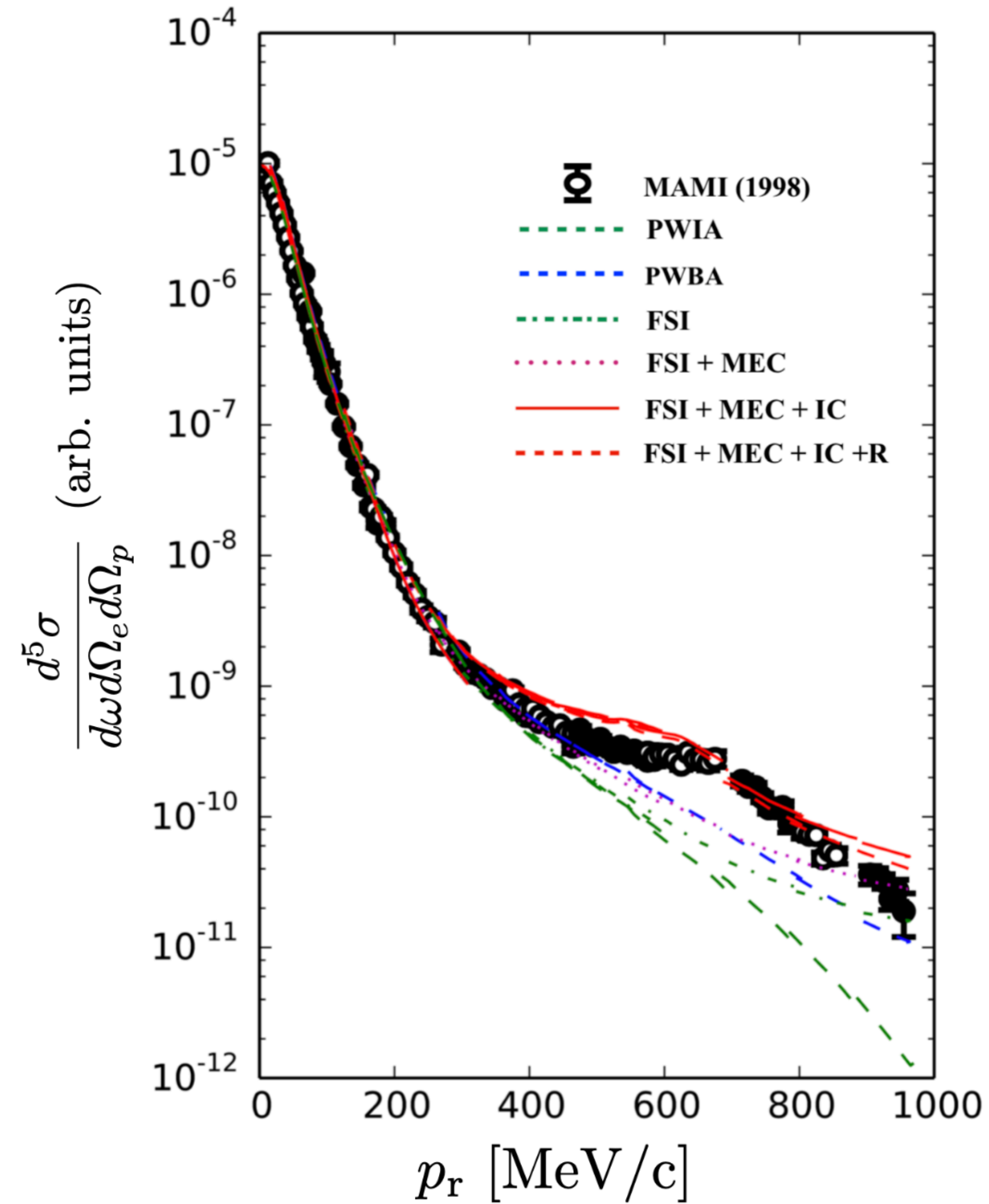
p.c.Yero [Thesis](#)

D(e,e'p)n Interactions



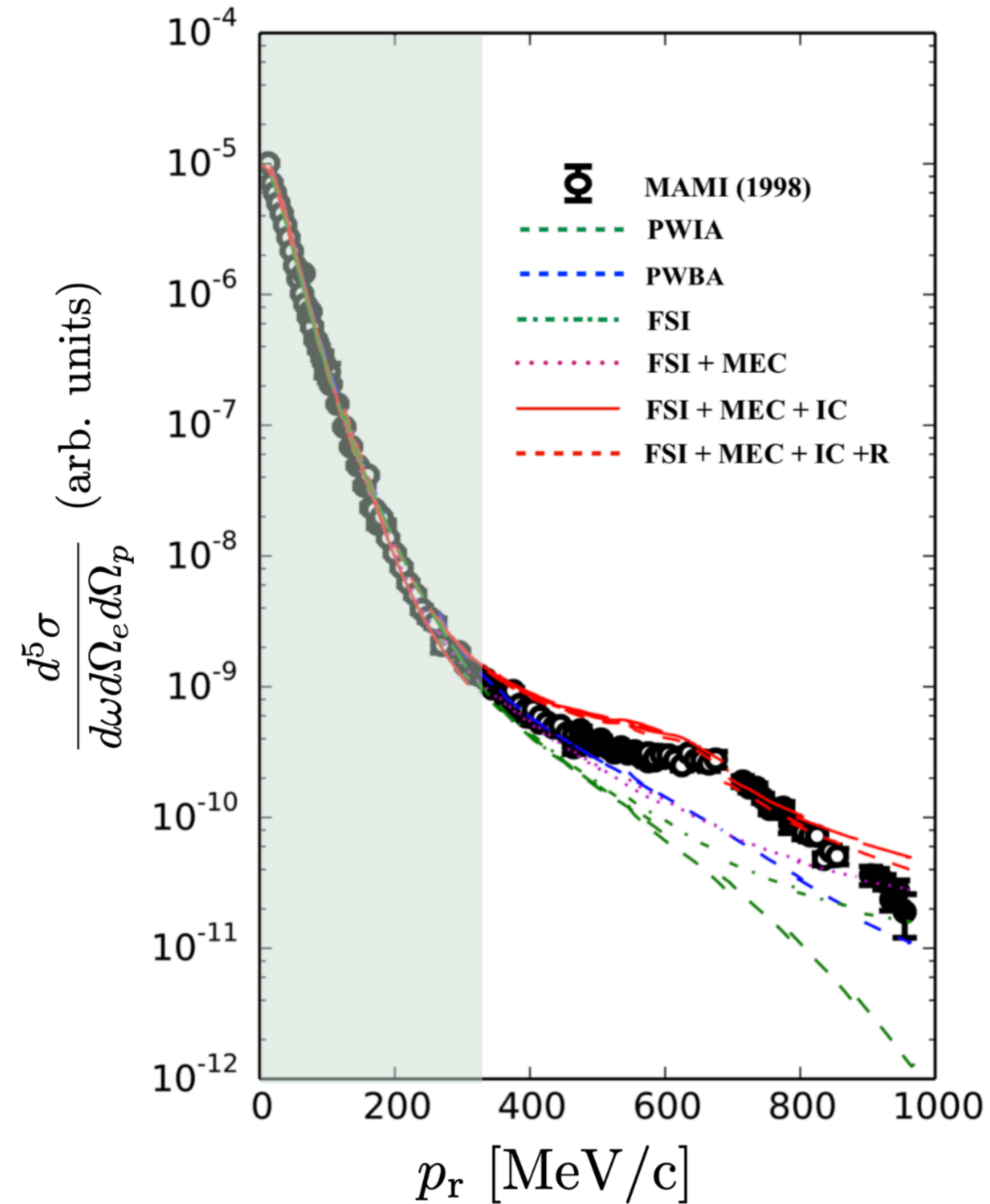
p.c.Yero [Thesis](#)

Previous Experiments



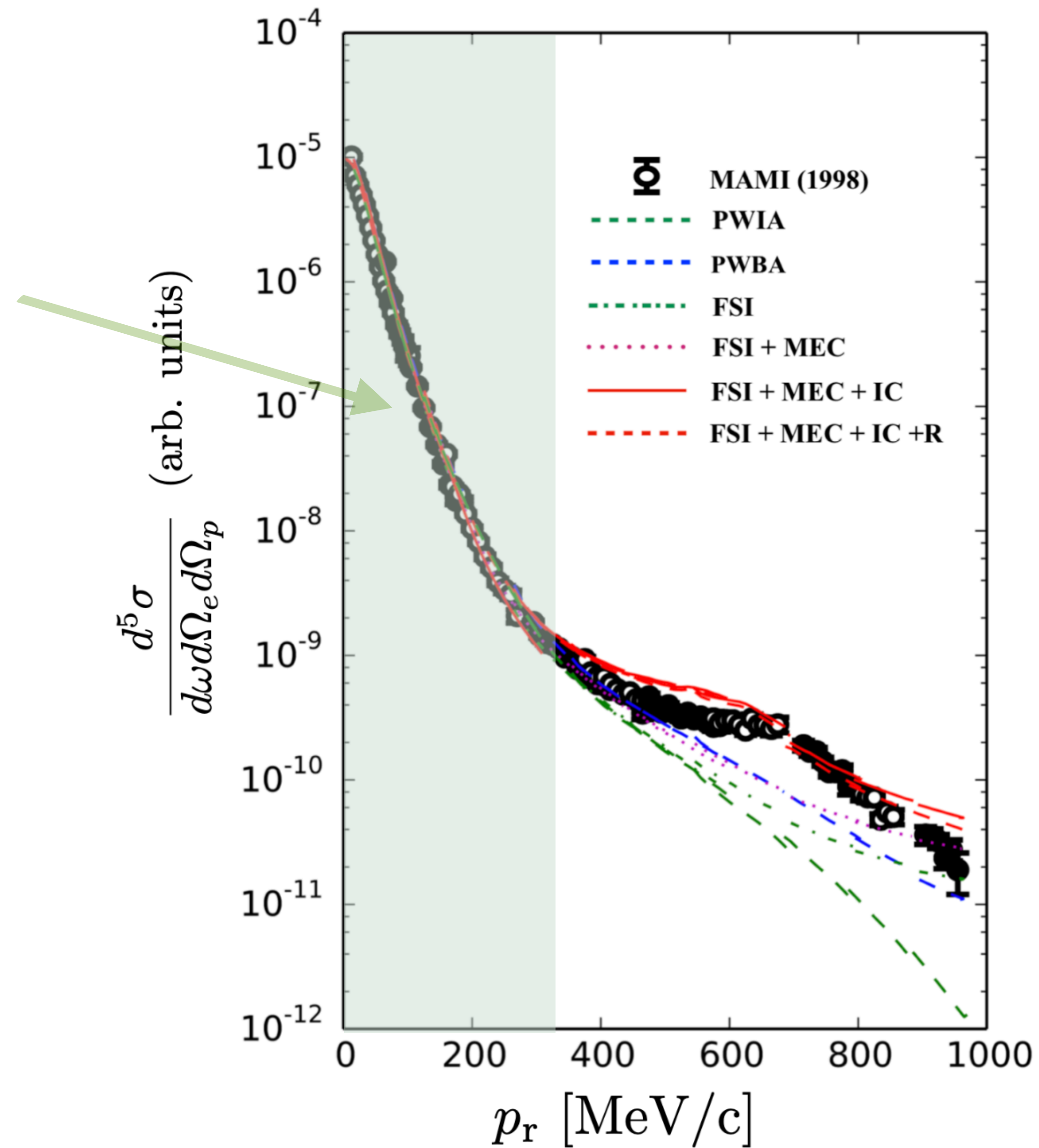
Blomqvist, Boeglin *et al.*, PLB 424 33 (1998)

Previous Experiments



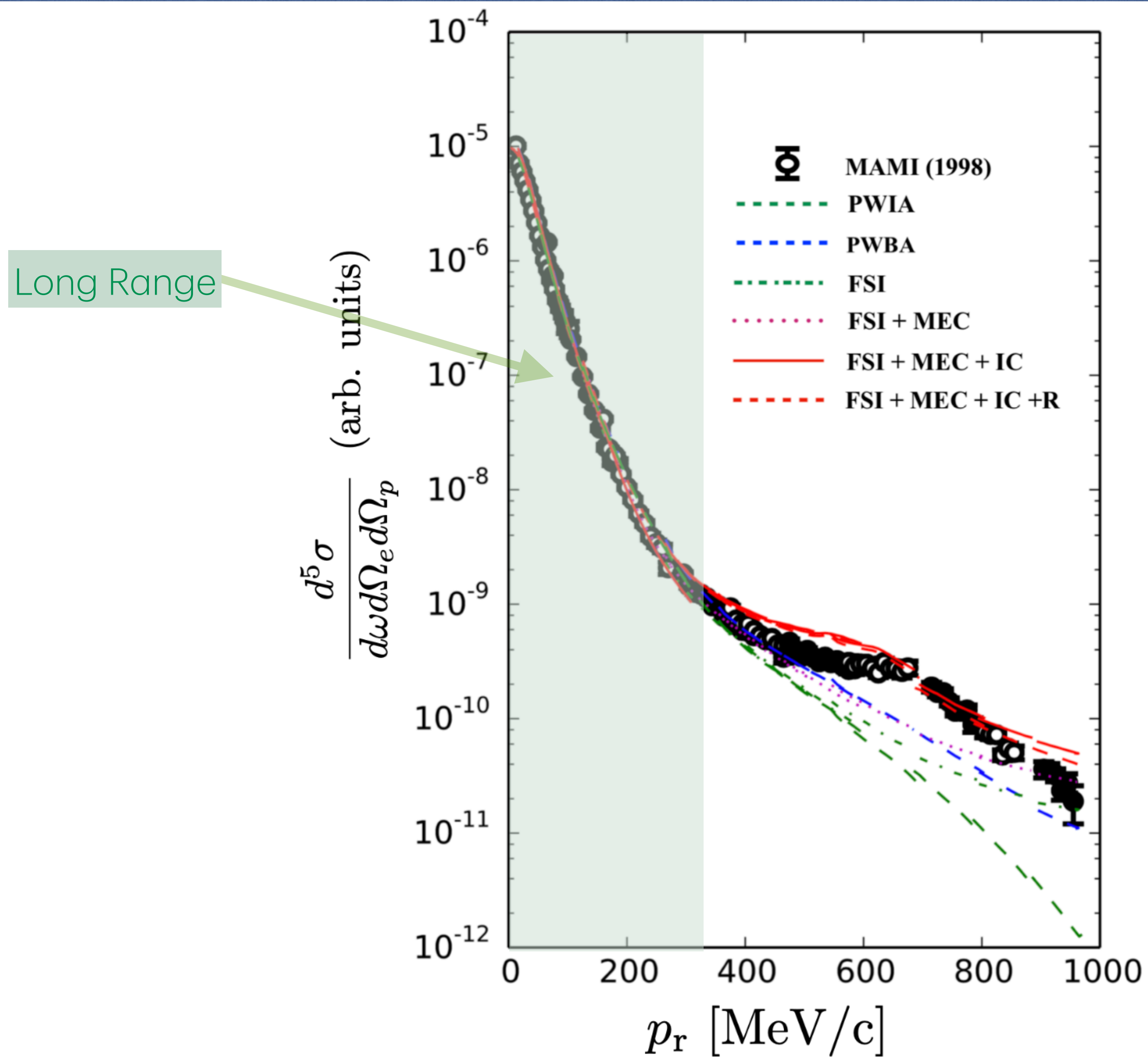
Blomqvist, Boeglin *et al.*, PLB 424 33 (1998)

Previous Experiments



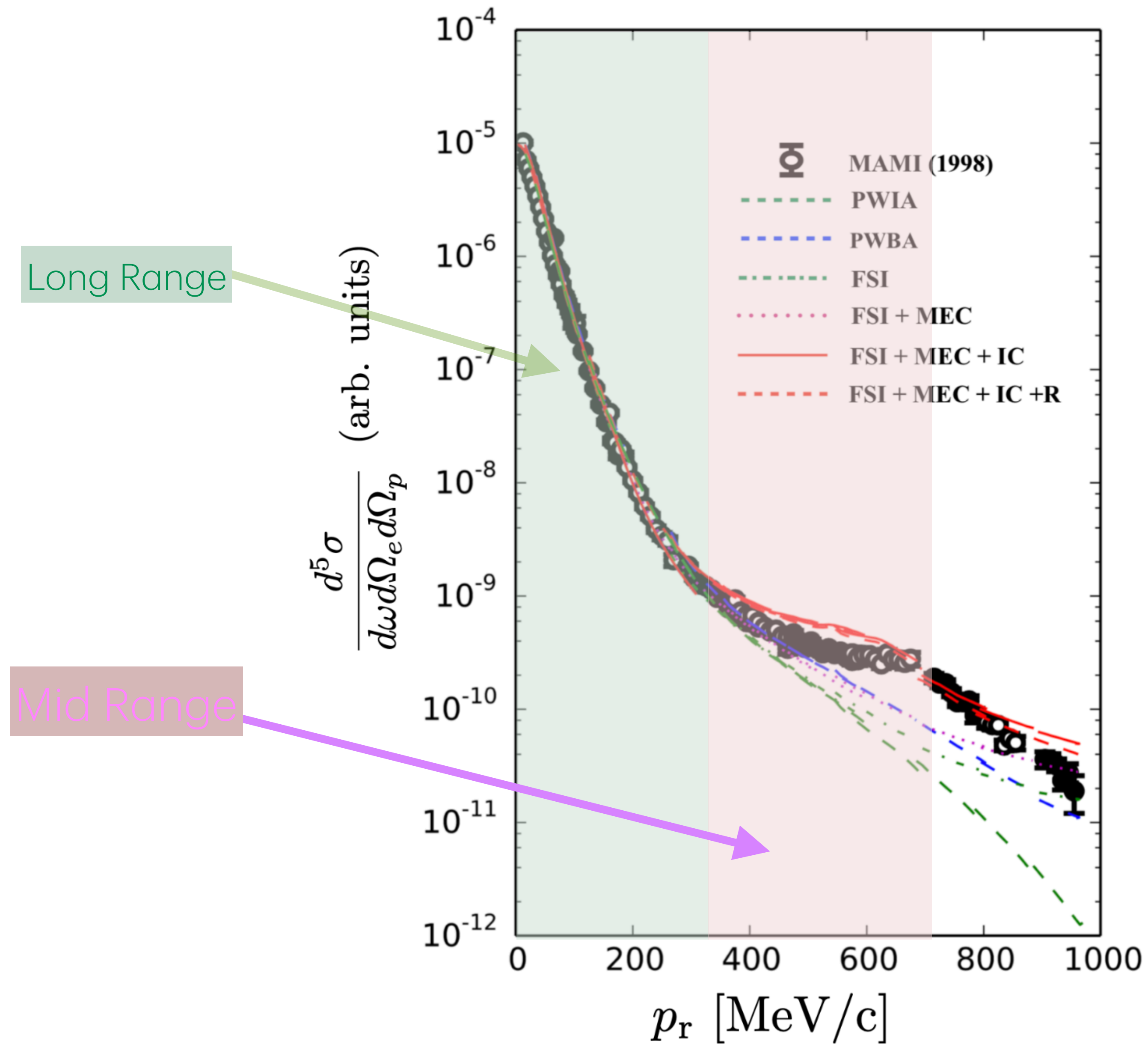
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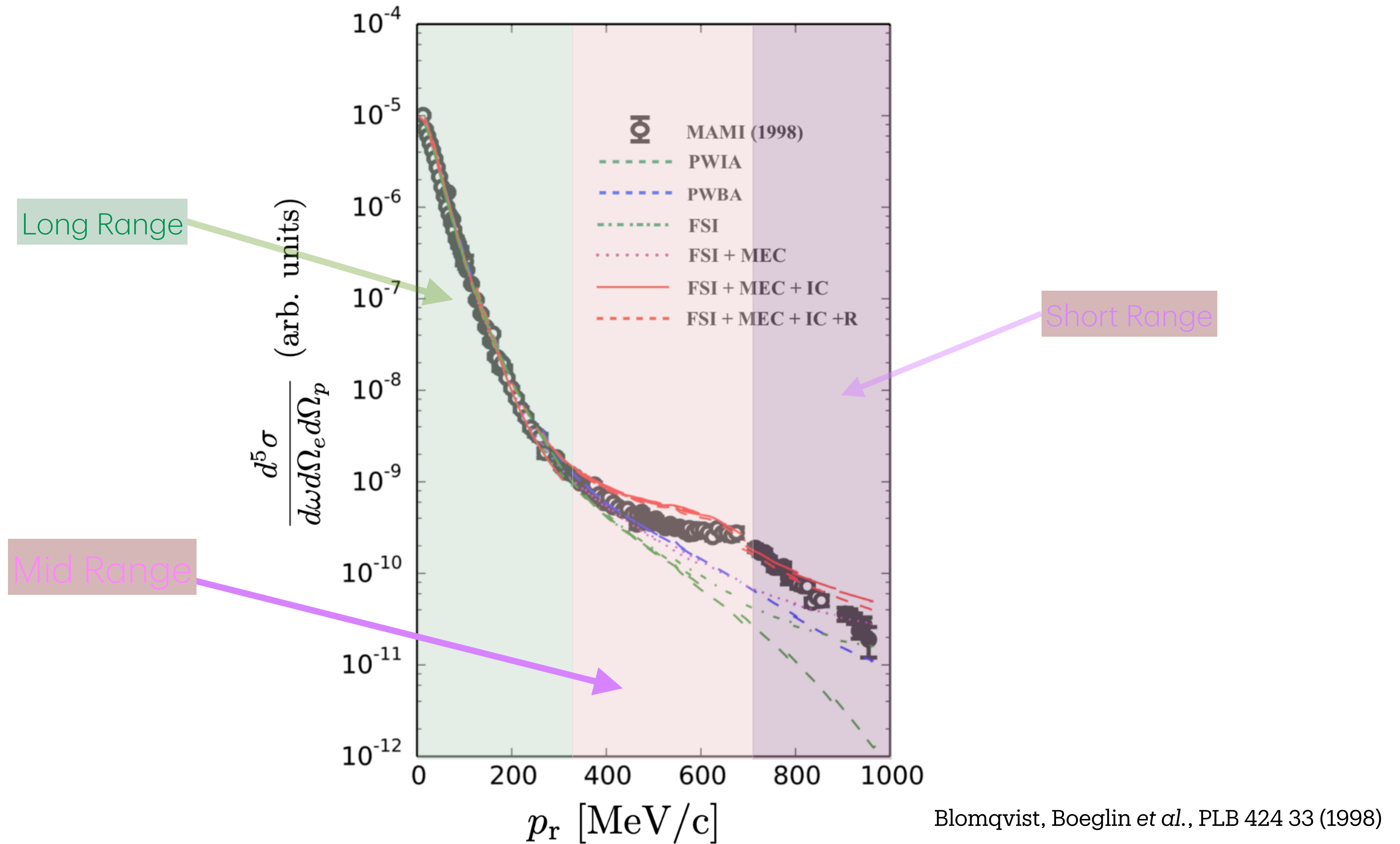
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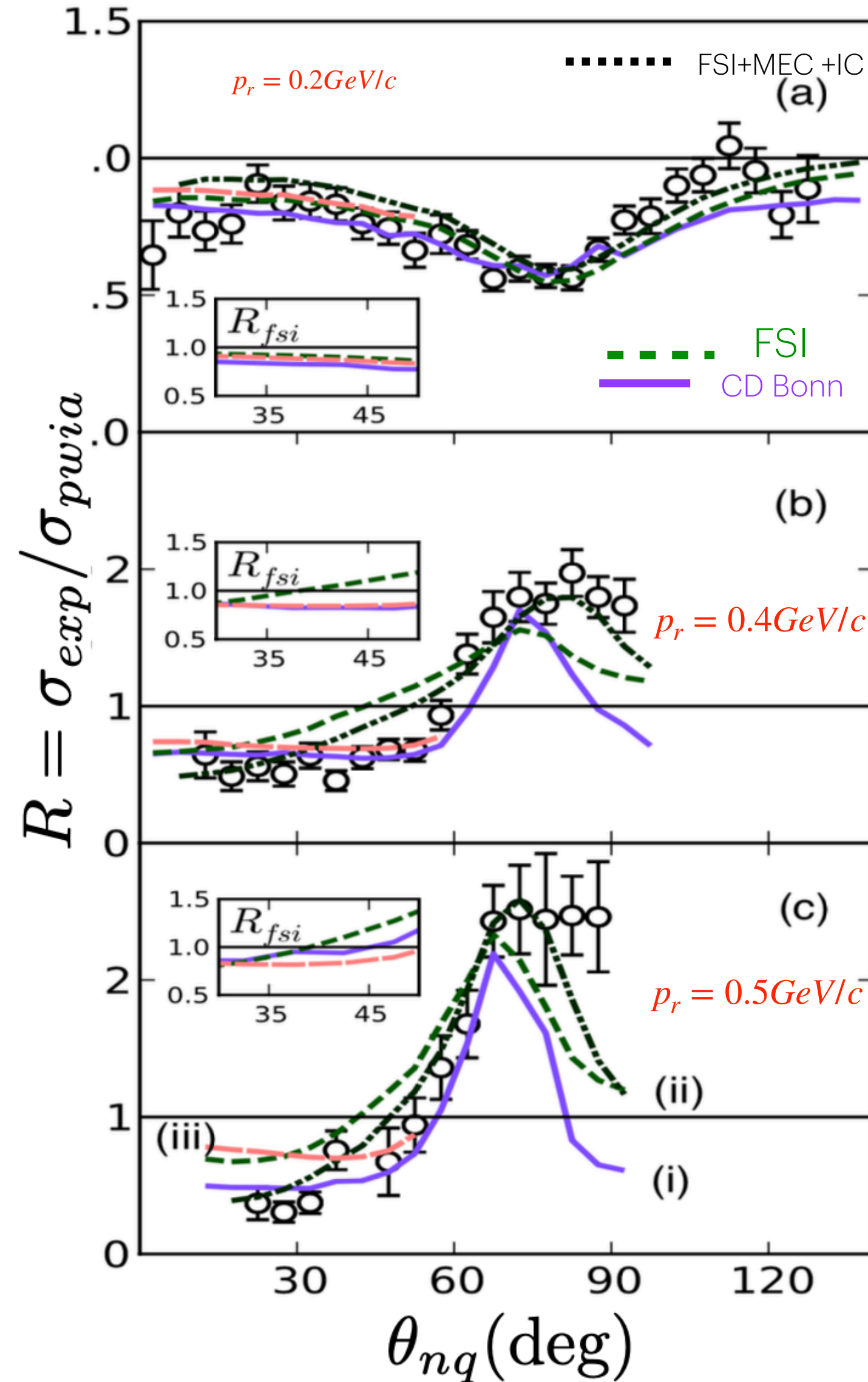
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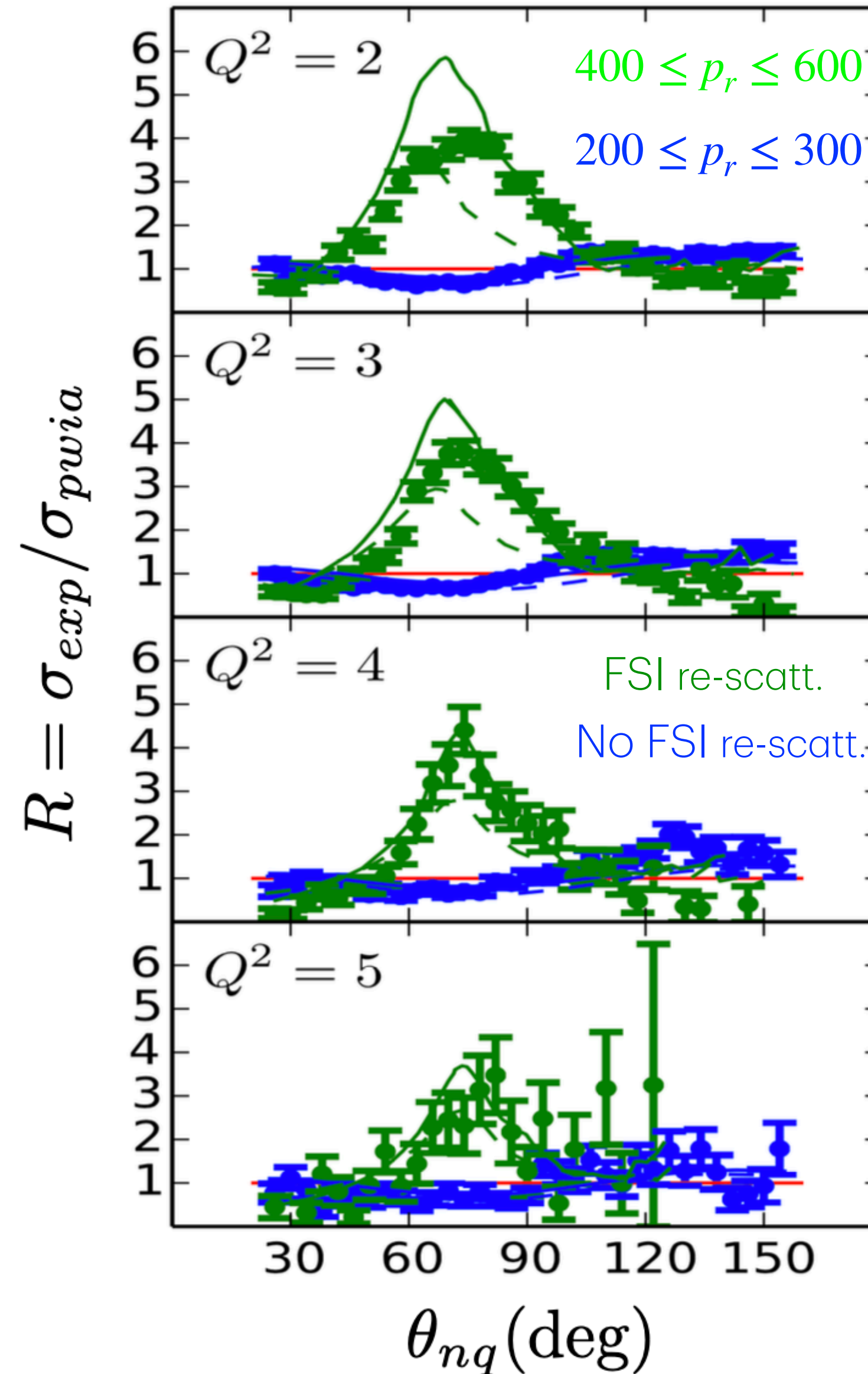


Hall B (CLAS) EXP

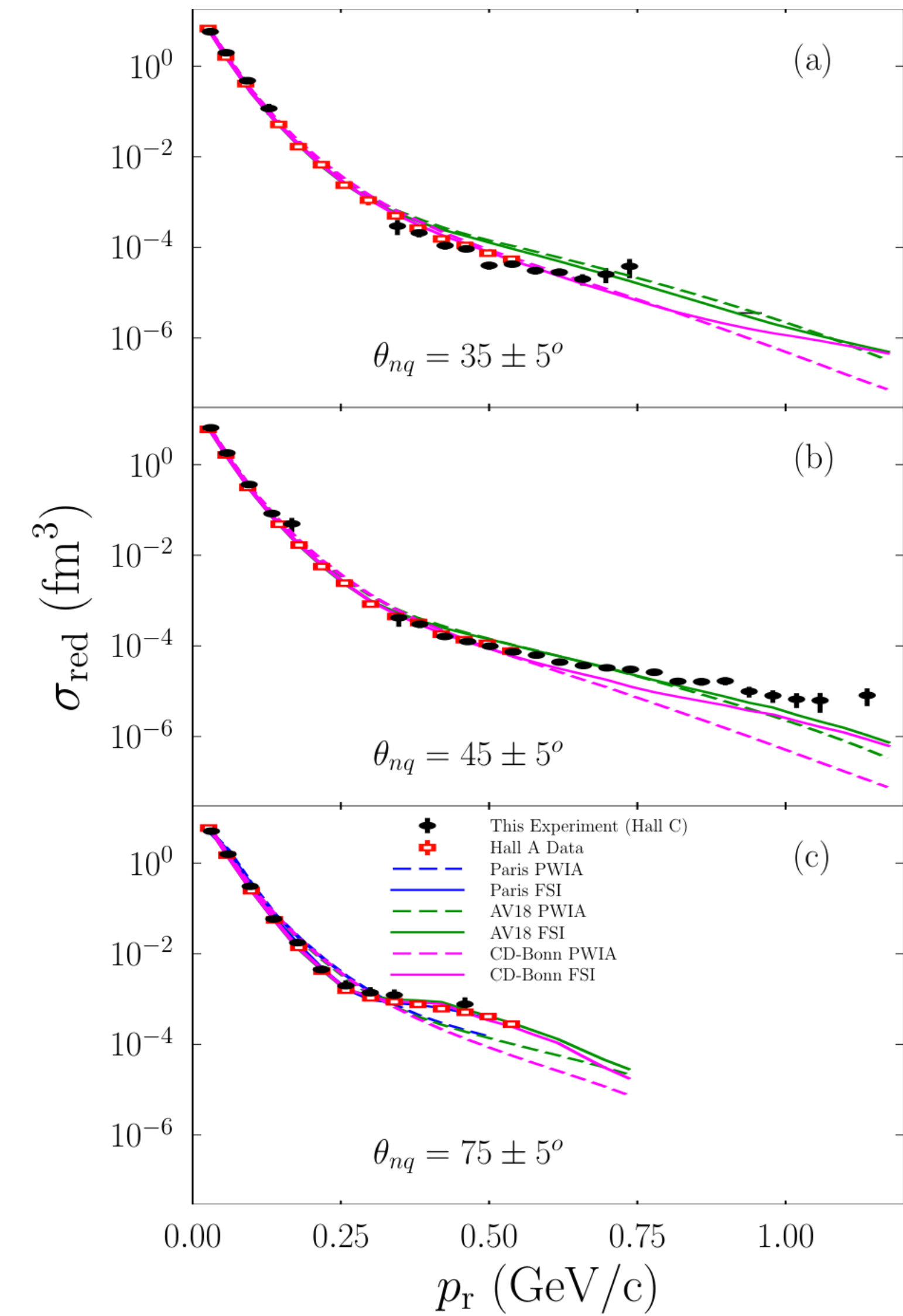
W. U. Boeglin et al. (2011)
10.1103/PhysRevLett.107.262501



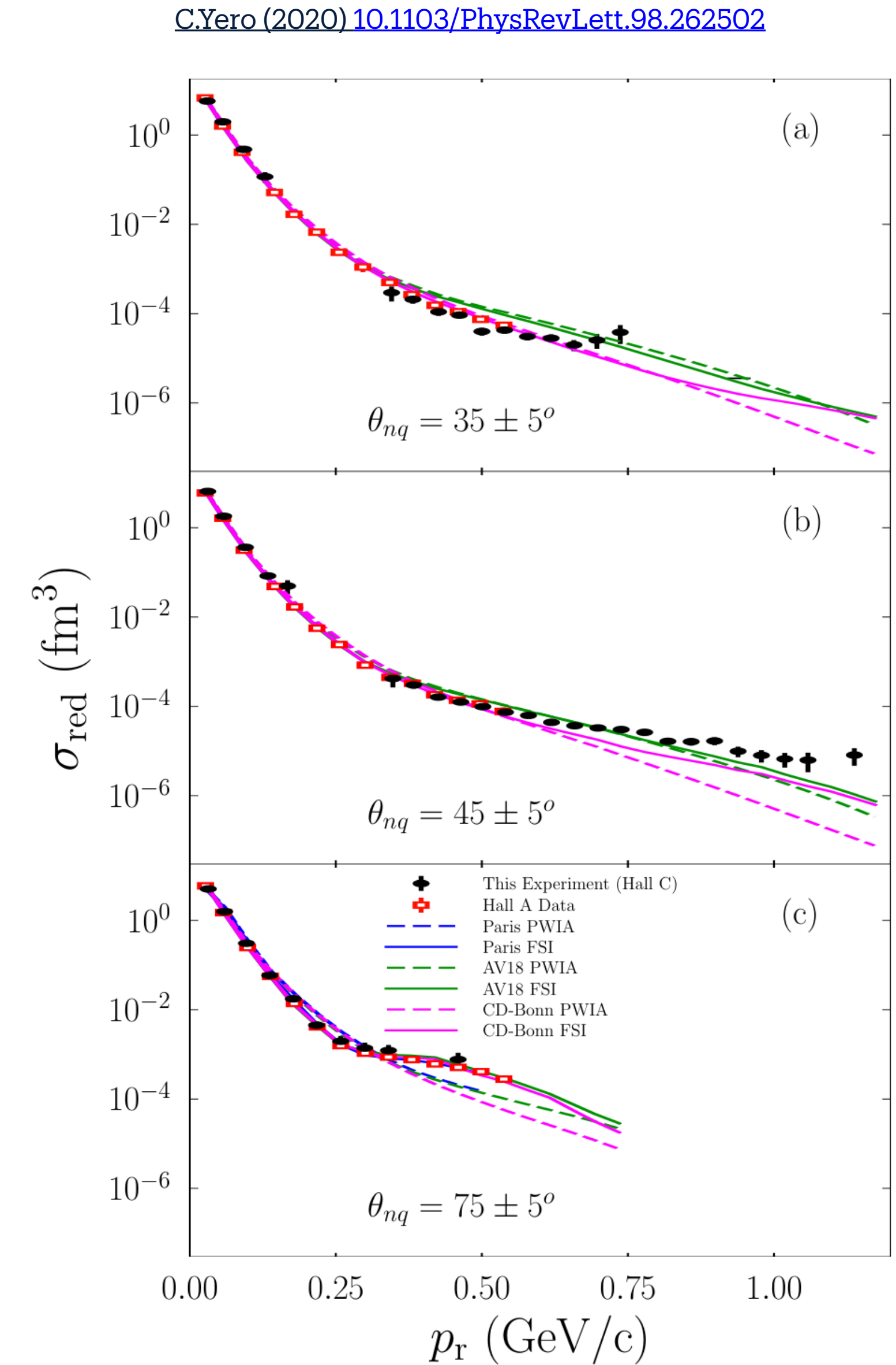
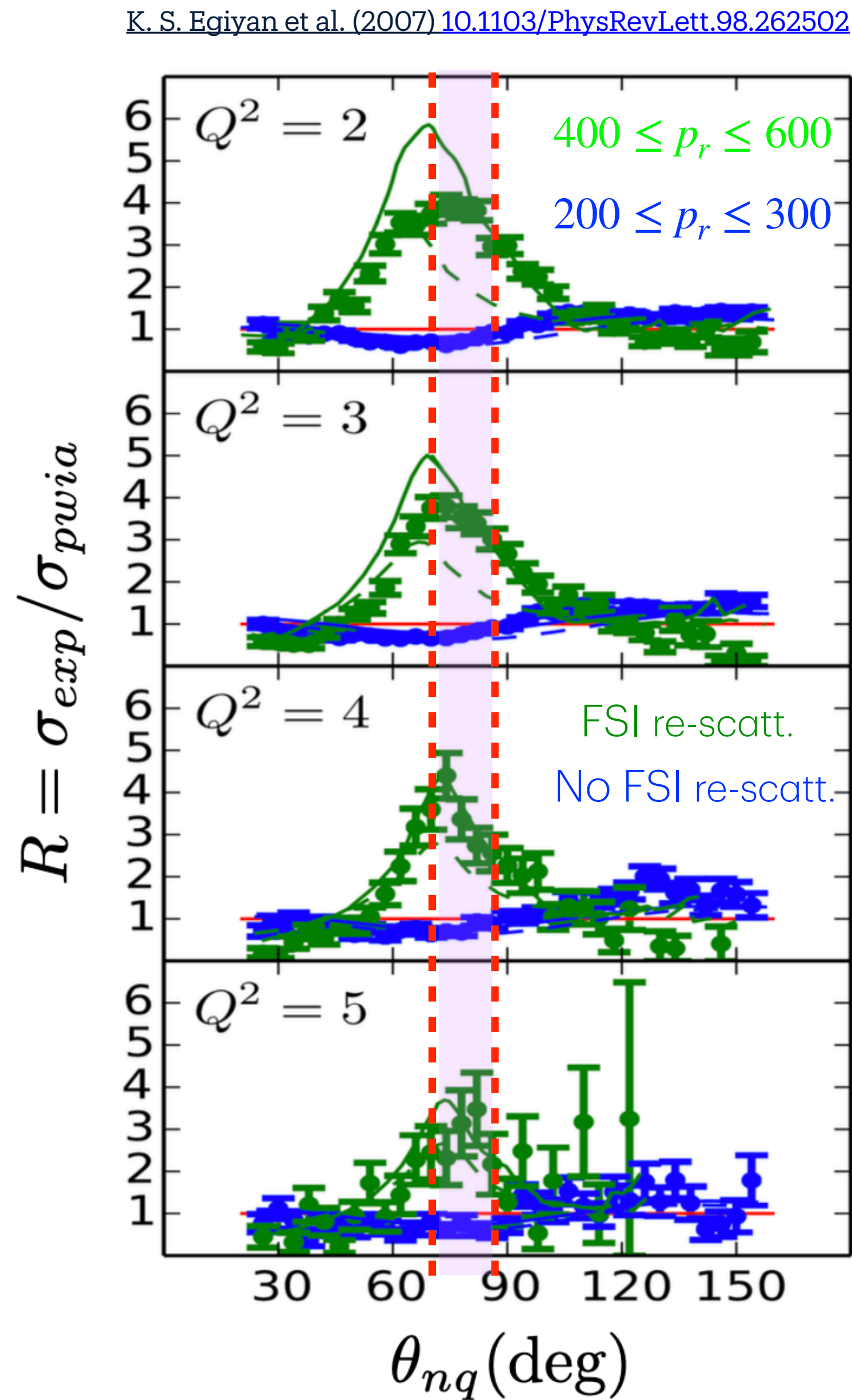
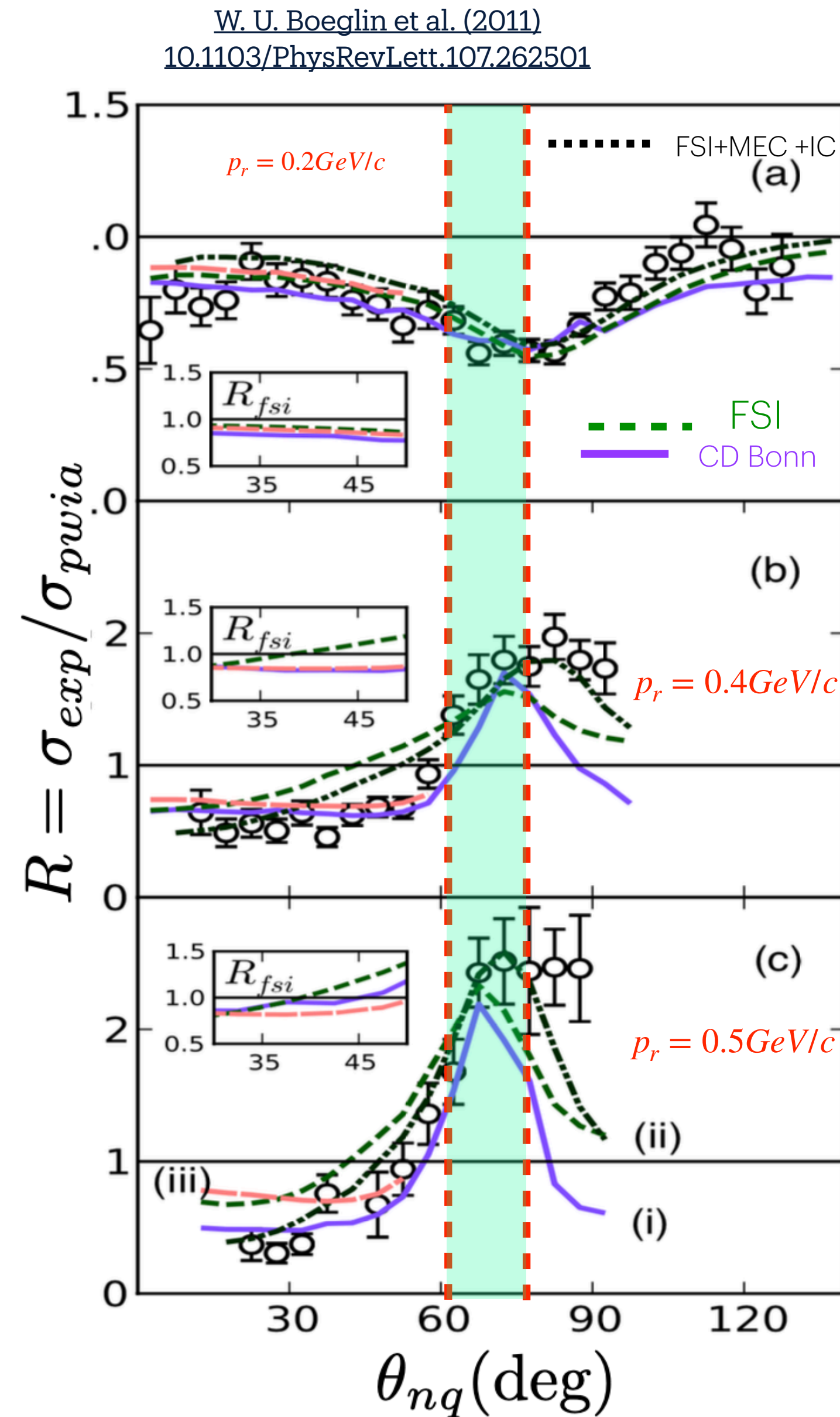
K. S. Egiyan et al. (2007) 10.1103/PhysRevLett.98.262502



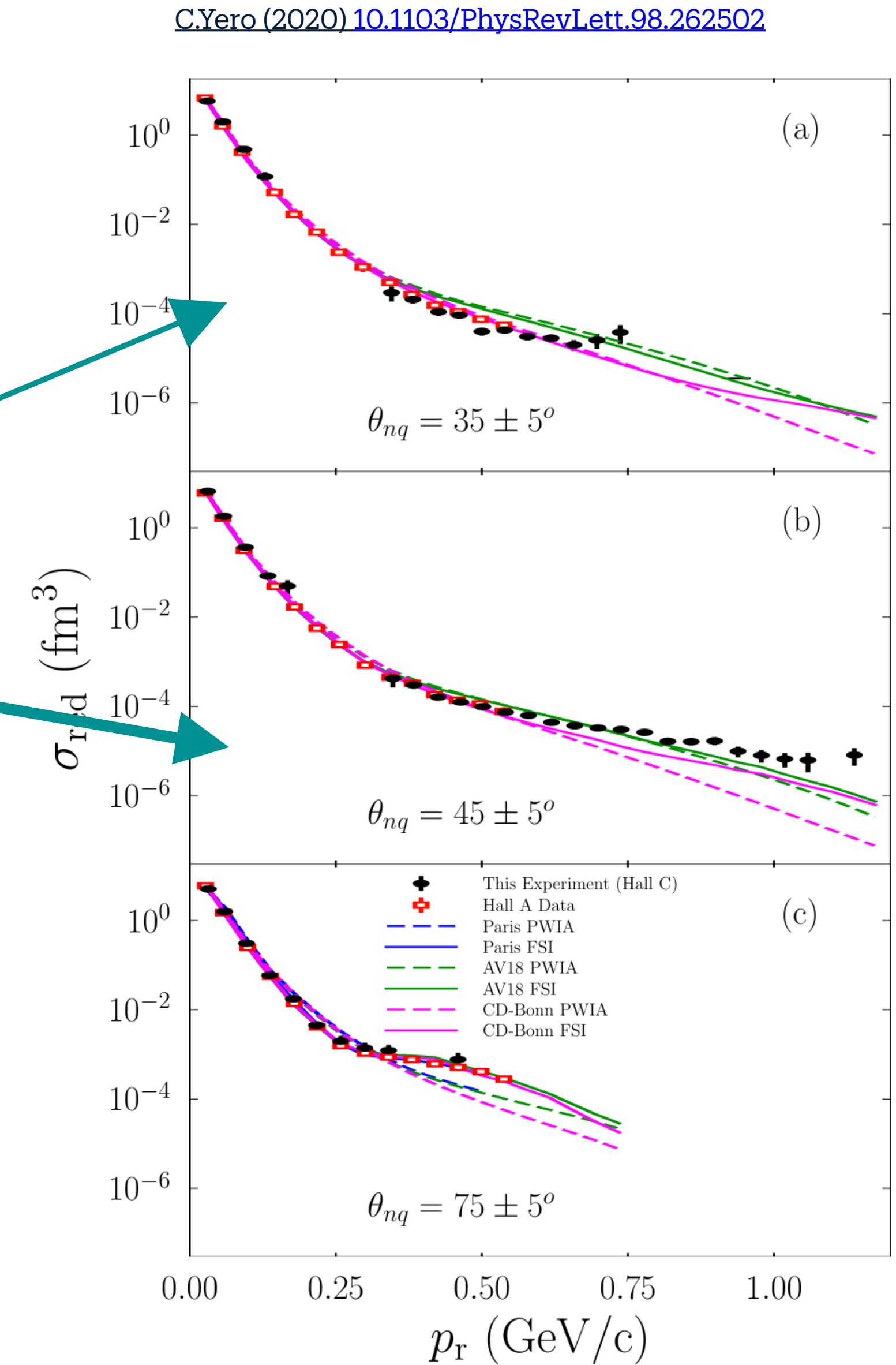
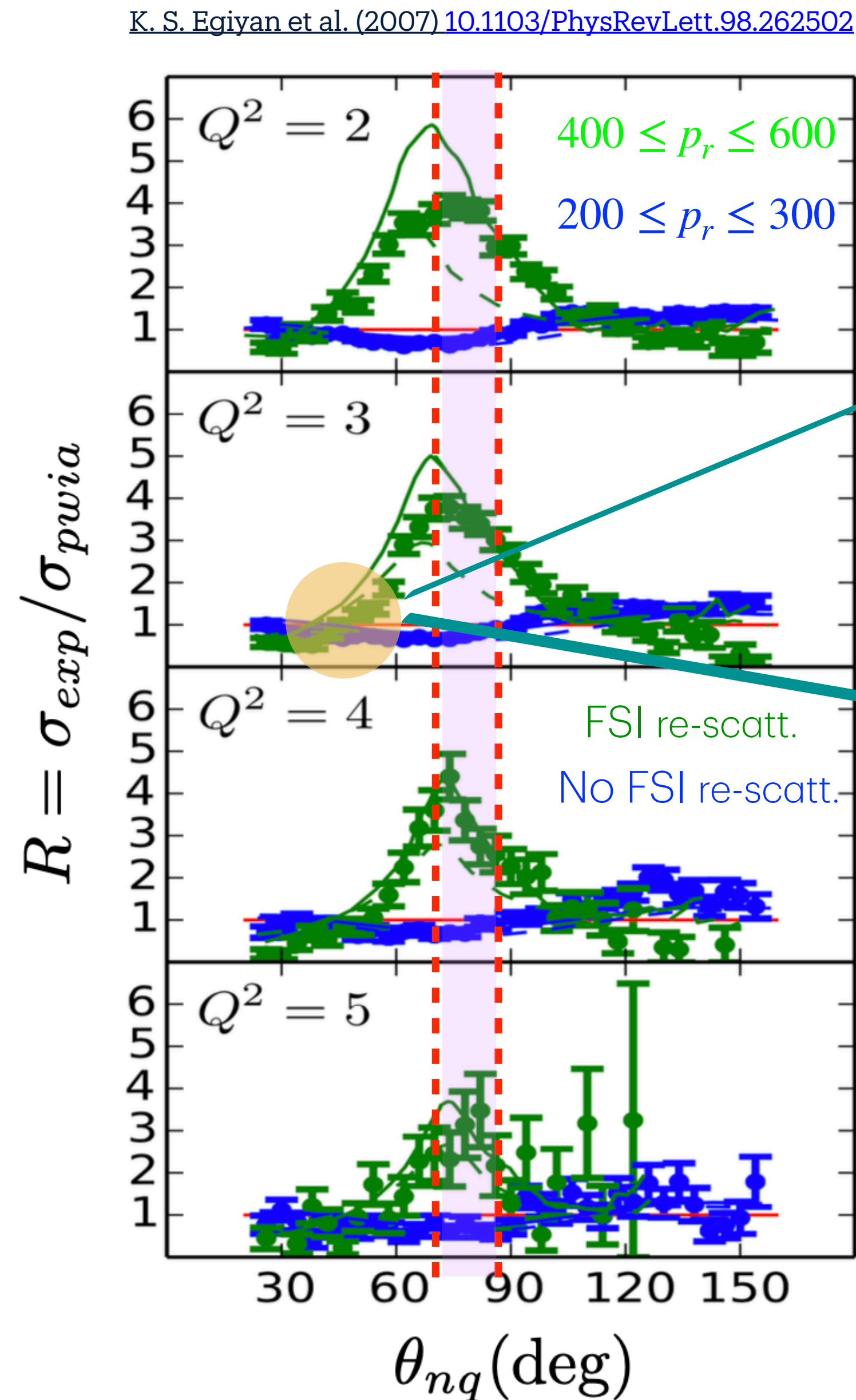
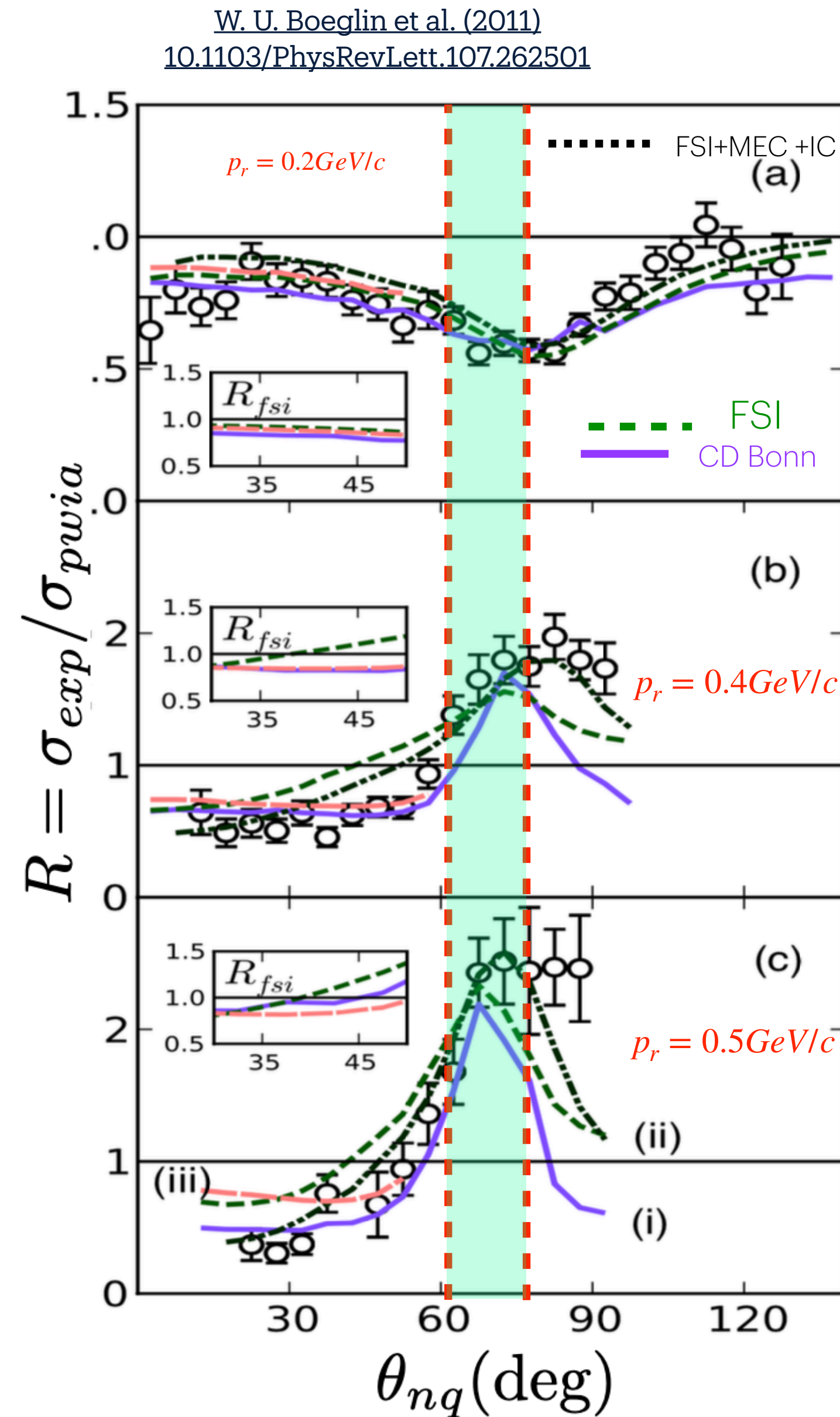
C.Yero (2020) 10.1103/PhysRevLett.98.262502



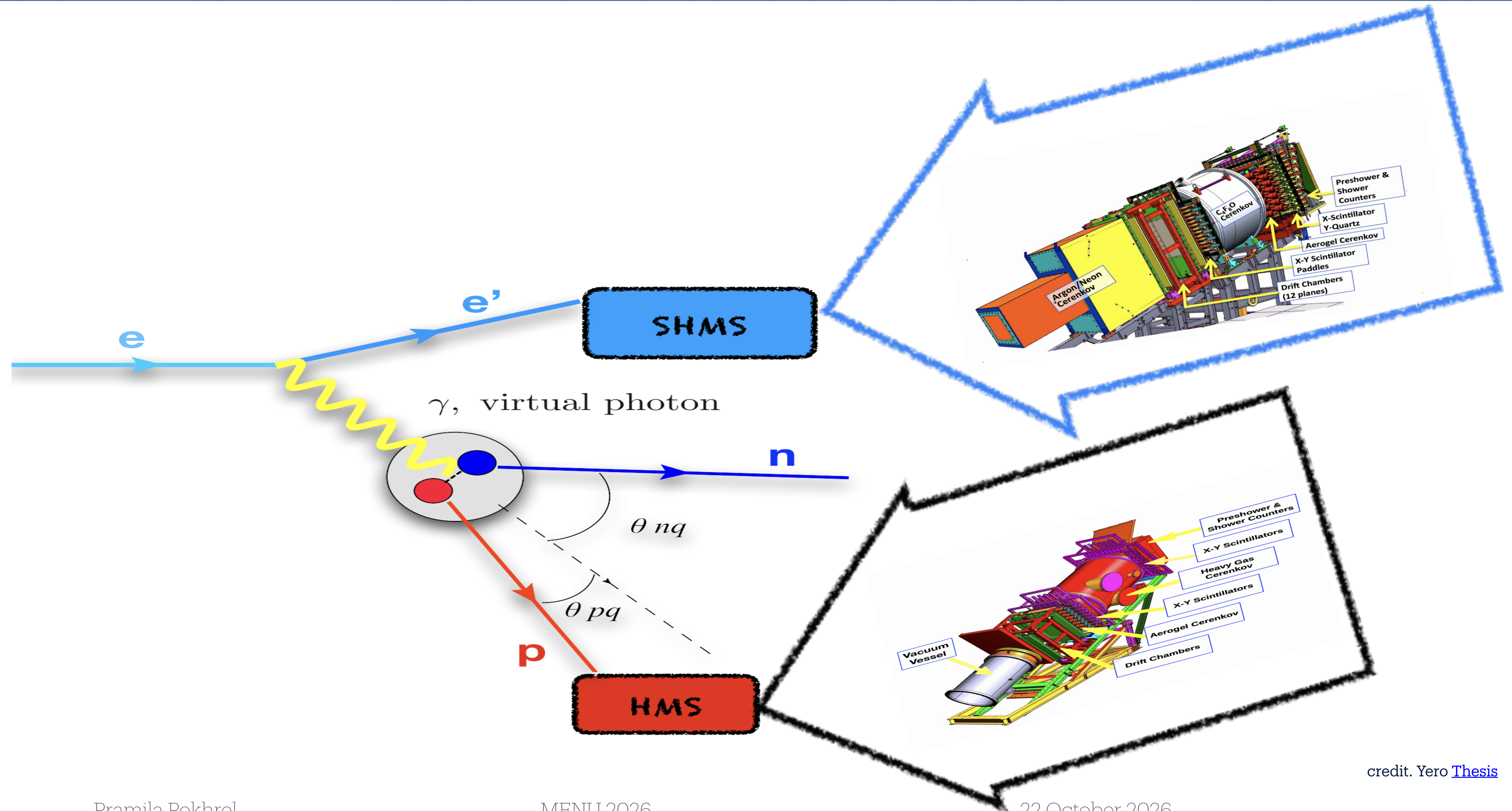
Hall B (CLAS) EXP



Hall B (CLAS) EXP



D(e,e'p)n Experiment Kinematics



credit. Yero [Thesis](#)

Experimental Timeline

- The data acquisition period: **February 24 – March 20, 2023**
- Dedicated H(e,e'p) runs were conducted to map the large delta (δ) acceptance region

H(e,e'p) δ scan

SHMS Delta	HMS Momentum [GeV/c]	HMS angle [°]	SHMS Momentum [GeV/c]	SHMS angle [°]
-8	3.499	33.344	8.55	14.153
-4	3.145	35.750	8.55	12.940
0	2.783	38.549	8.55	11.705
+4	2.417	41.812	8.55	10.435
+8	2.048	45.667	8.55	9.125

- D(e,e'p)n runs: four missing-momentum settings
- Purpose: to cover a wide kinematic region of interest

D(ee'p)n production

Missing Momentum Setting(MeV/c)	HMS Momentum [GeV/c]	HMS angle [°]	SHMS Momentum [GeV/c]	SHMS angle [°]
120	3.0423	38.63	8.55	12.197
580	2.2622	54.96	8.55	12.197
800	2.121	59.39	8.55	12.197
900	2.0474	61.33	8.55	12.197

D(e,e'p)n Cross-Sections

$$Y_{DATA} = \frac{Y_{uncorr} \cdot f_{rad}}{Q \cdot \epsilon_{trk} \cdot \epsilon_{tgt} \cdot \epsilon_{pabs} \cdot \epsilon_{tLT}}$$

Where,

- Radiative Correction Factor
- Charge Normalization
- Tracking Efficiency Correction
- Target Boiling Correction
- Proton Absorption
- Total LiveTime Correction

Data to D(e,e'p)n Cross-Sections

$$\sigma_{theory} \equiv \sigma_{exp} = \frac{d^5 \sigma_{theory}}{dE' \cdot d\Omega_e \cdot d\Omega_p}$$

$$\sigma_{exp} \approx \sigma_{theory} = K \cdot \sigma_{eN} \cdot f_{rec} \cdot S(\vec{P}_{p,i}, E_m)$$

$$\sigma_{red} = \frac{\sigma_{exp}}{K \cdot \sigma_{eN} \cdot f_{rec}} \equiv S(p_i) \approx \rho_m(P_i)$$

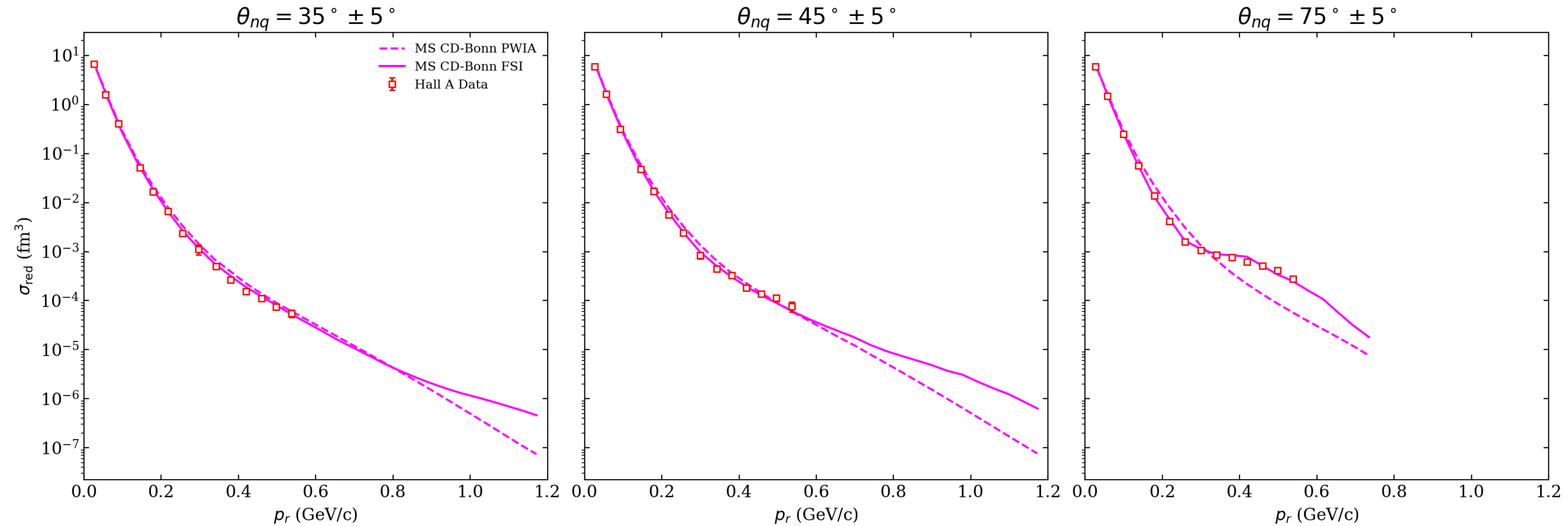
The momentum
Distribution in
PWIA

- The reduced cross-section in PWIA is expressed in terms of :
 - K : the Kinematic factor
 - σ_{eN} : the cross-section of the electron scattering of a bound nucleon
 - f_{rec} : the recoil factor
 - $S(p_i)$: the Spectral function

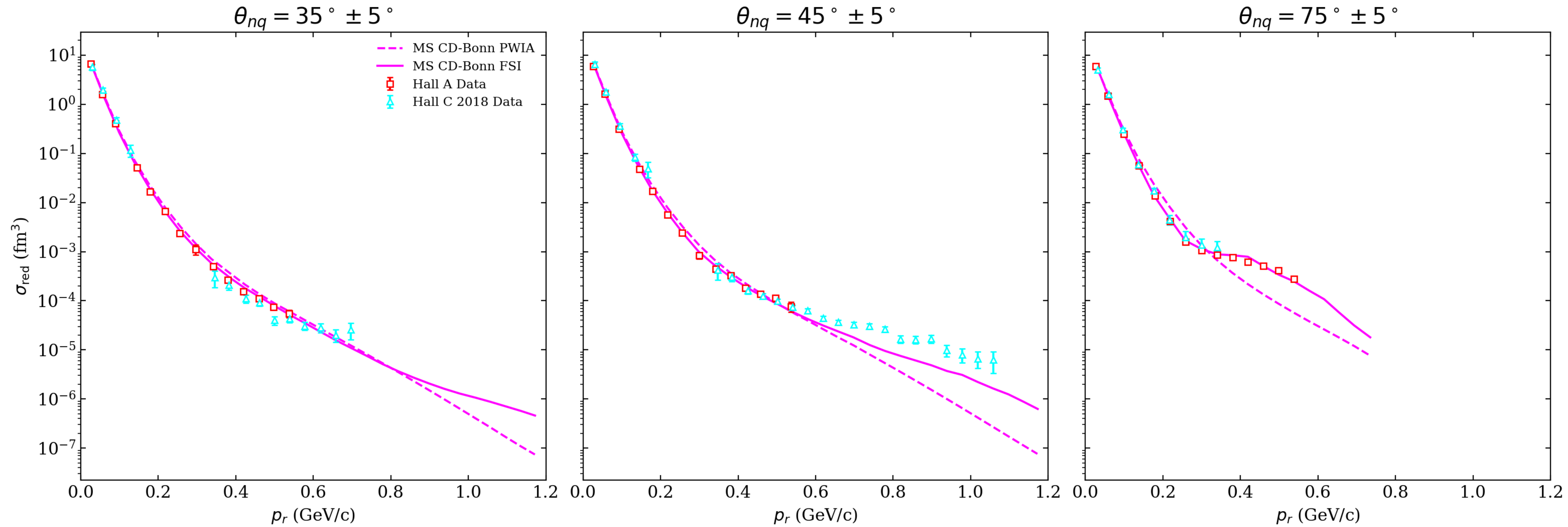
Preliminary Cross-section Results

$$Q^2 = 3.5 \pm 0.5 \text{ GeV}^2$$

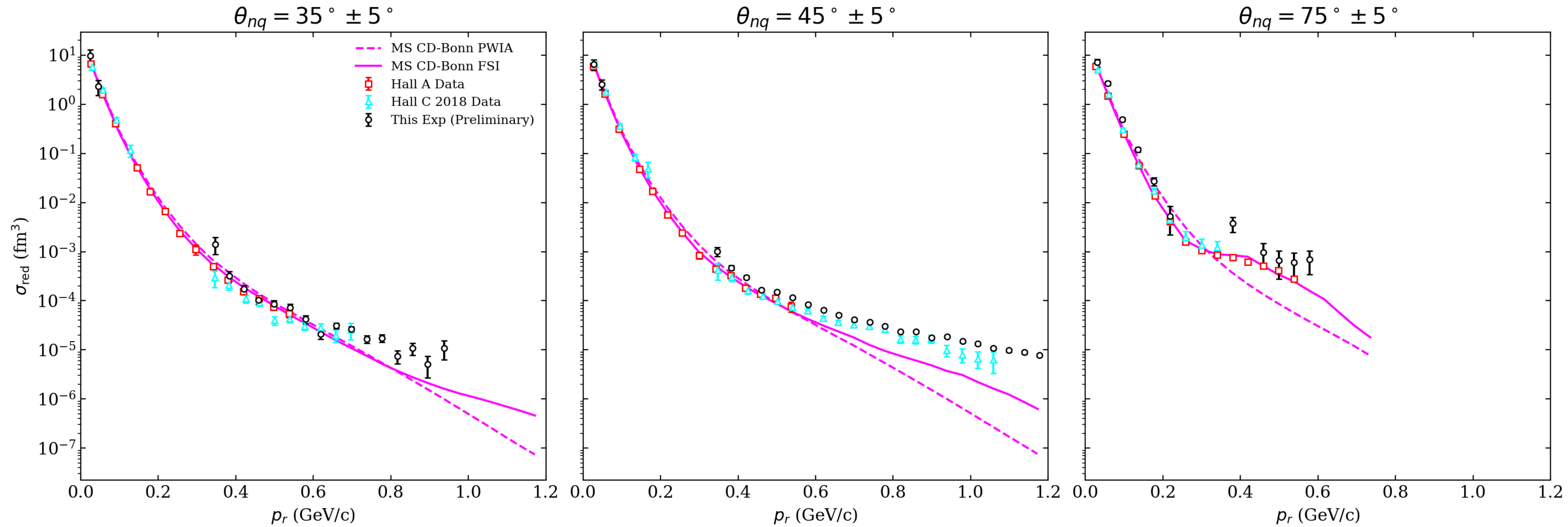
PRELIMINARY CROSS-SECTIONS



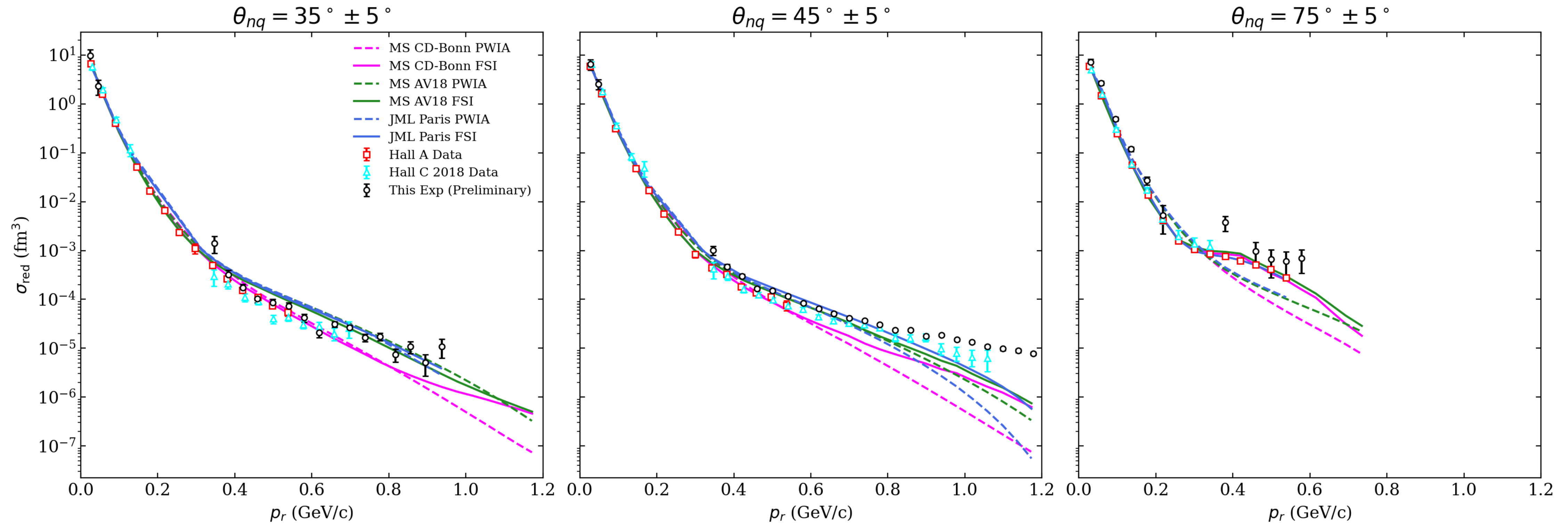
PRELIMINARY CROSS-SECTIONS



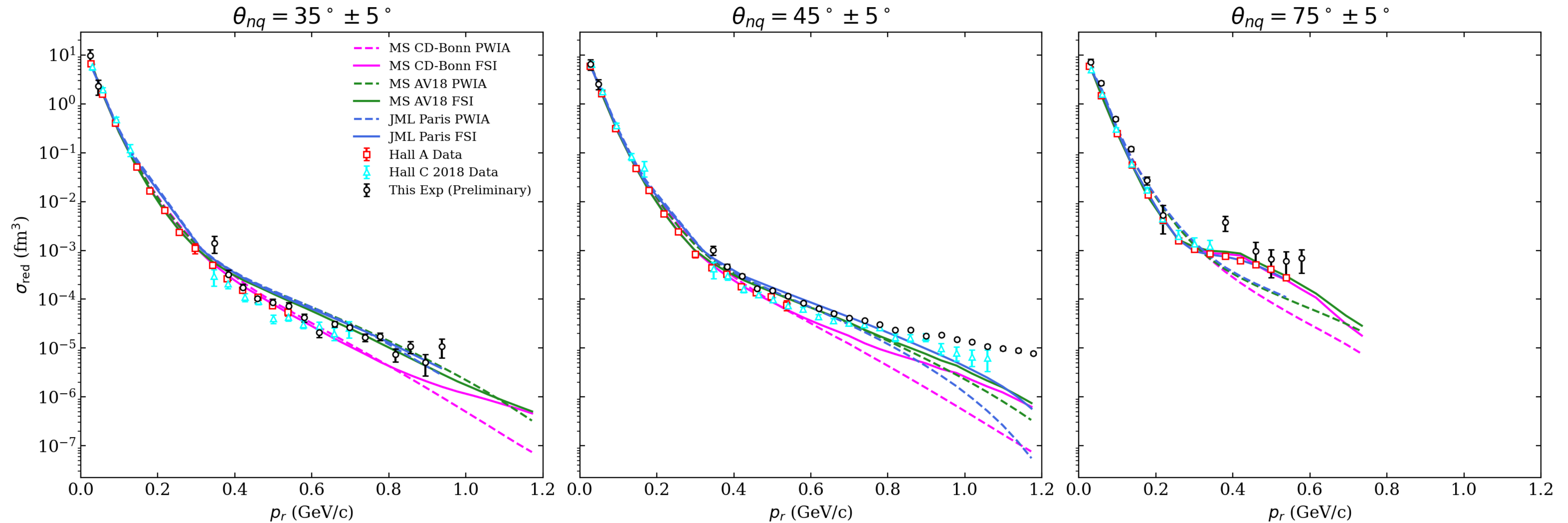
PRELIMINARY CROSS-SECTIONS



Discrepancy in the Data and the Models

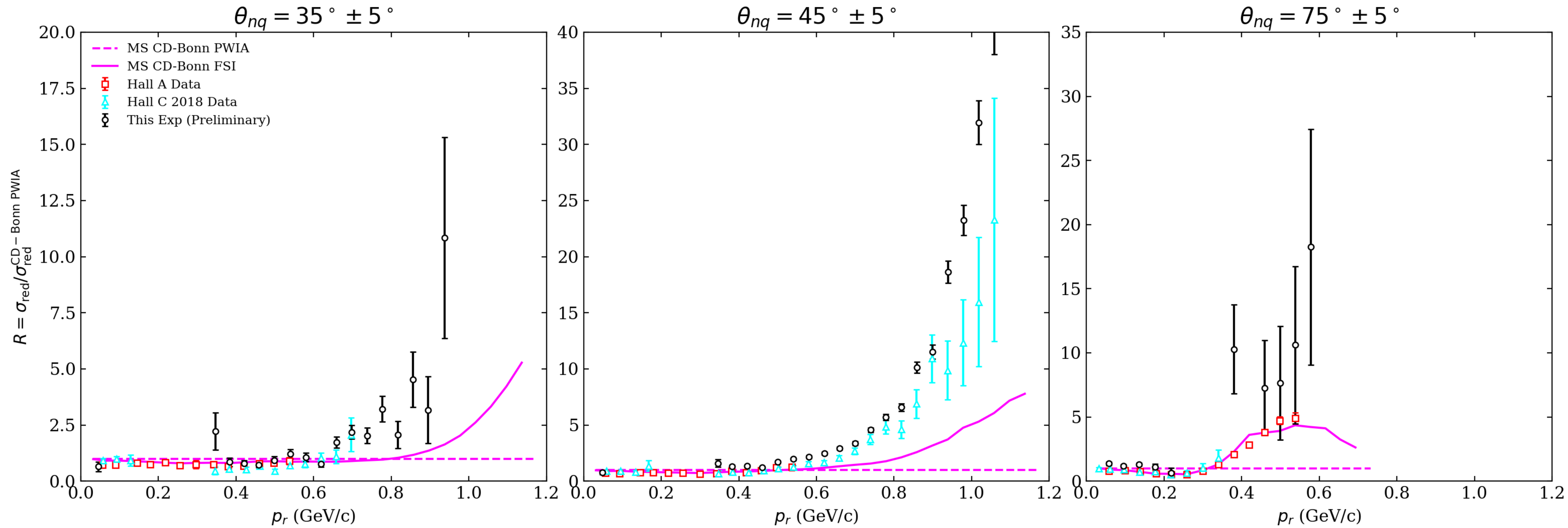


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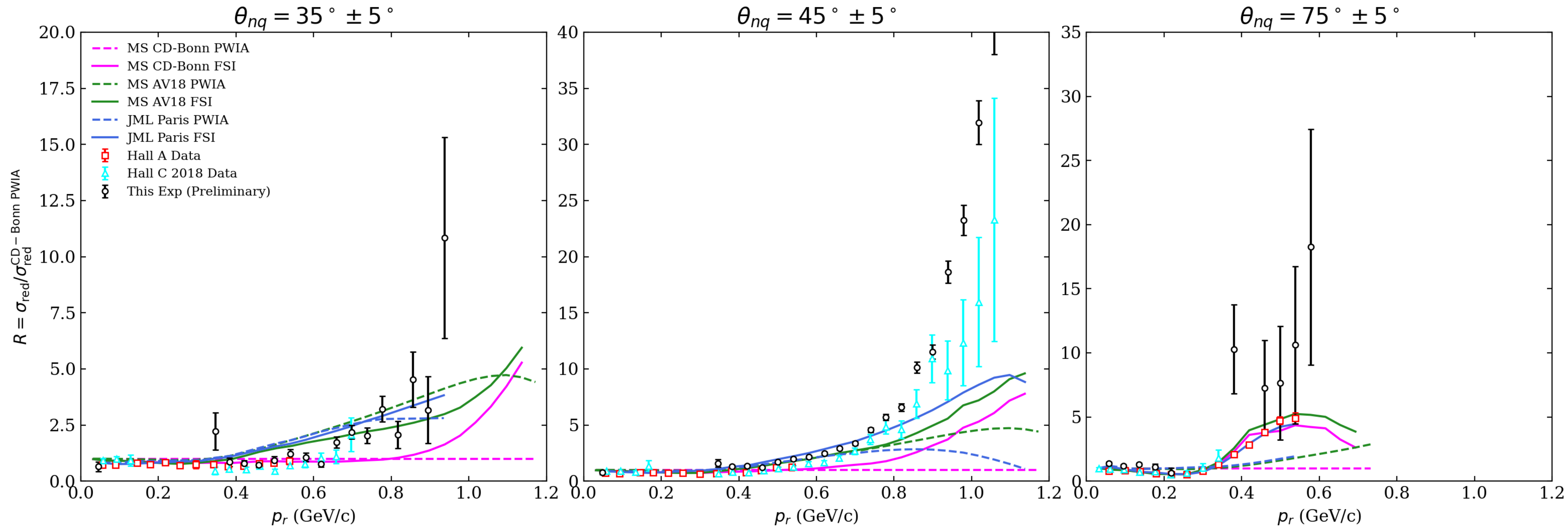


- Hall C experiment reproduces results from previous Hall A.
- At $p_m > 0.3 \text{ GeV}/c$ (For $\theta_{nq} = 75$), a bump indicates FSI.
- Data is best reproduced by CD-Bonn up to $700 \text{ MeV}/c$, above $700 \text{ MeV}/c$ no calculation describes the data ($\theta_{nq} = 35, 45$)
- No data trend produce the data above $750 \text{ MeV}/c$.

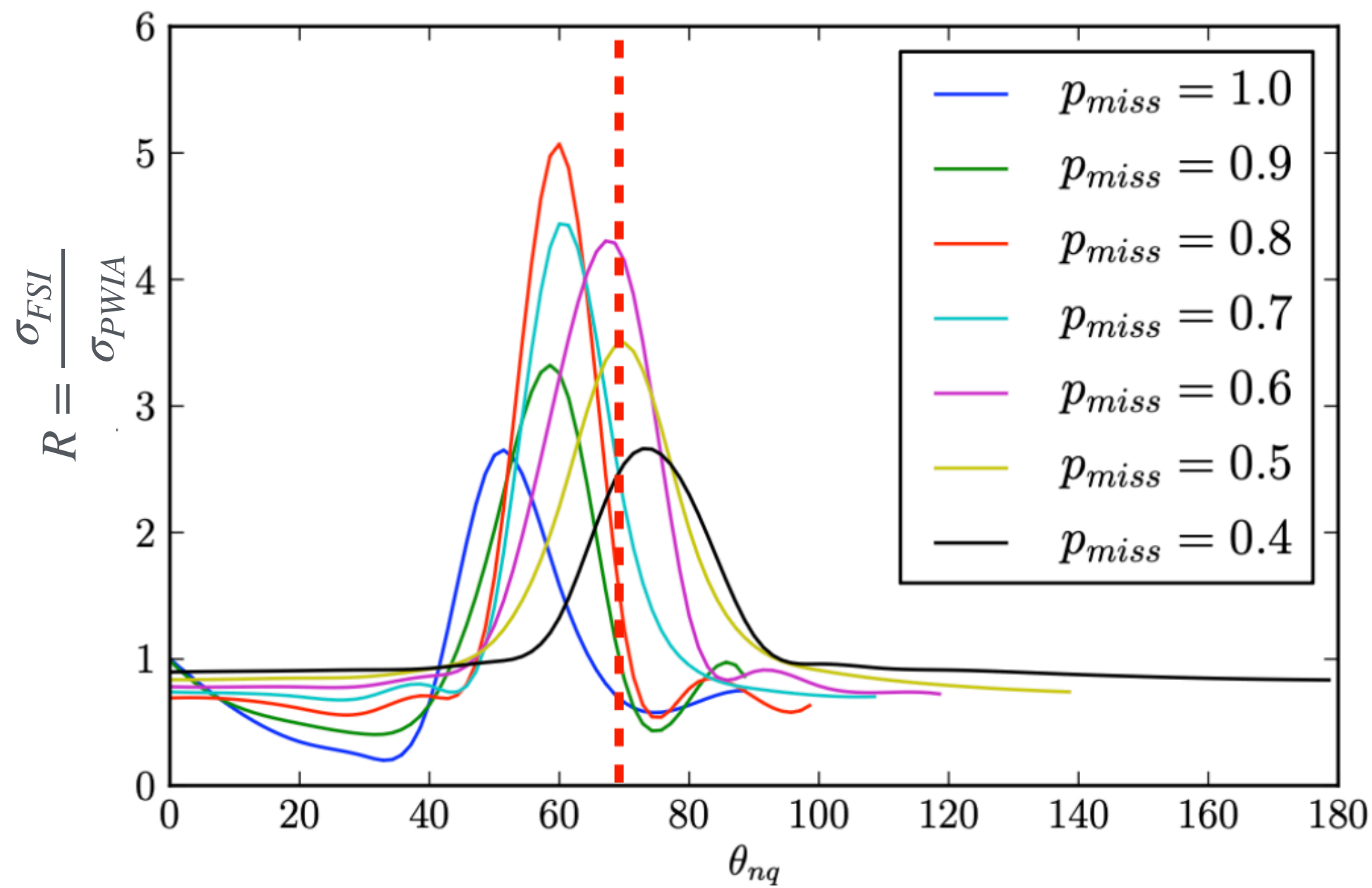
PRELIMINARY CROSS-SECTIONS



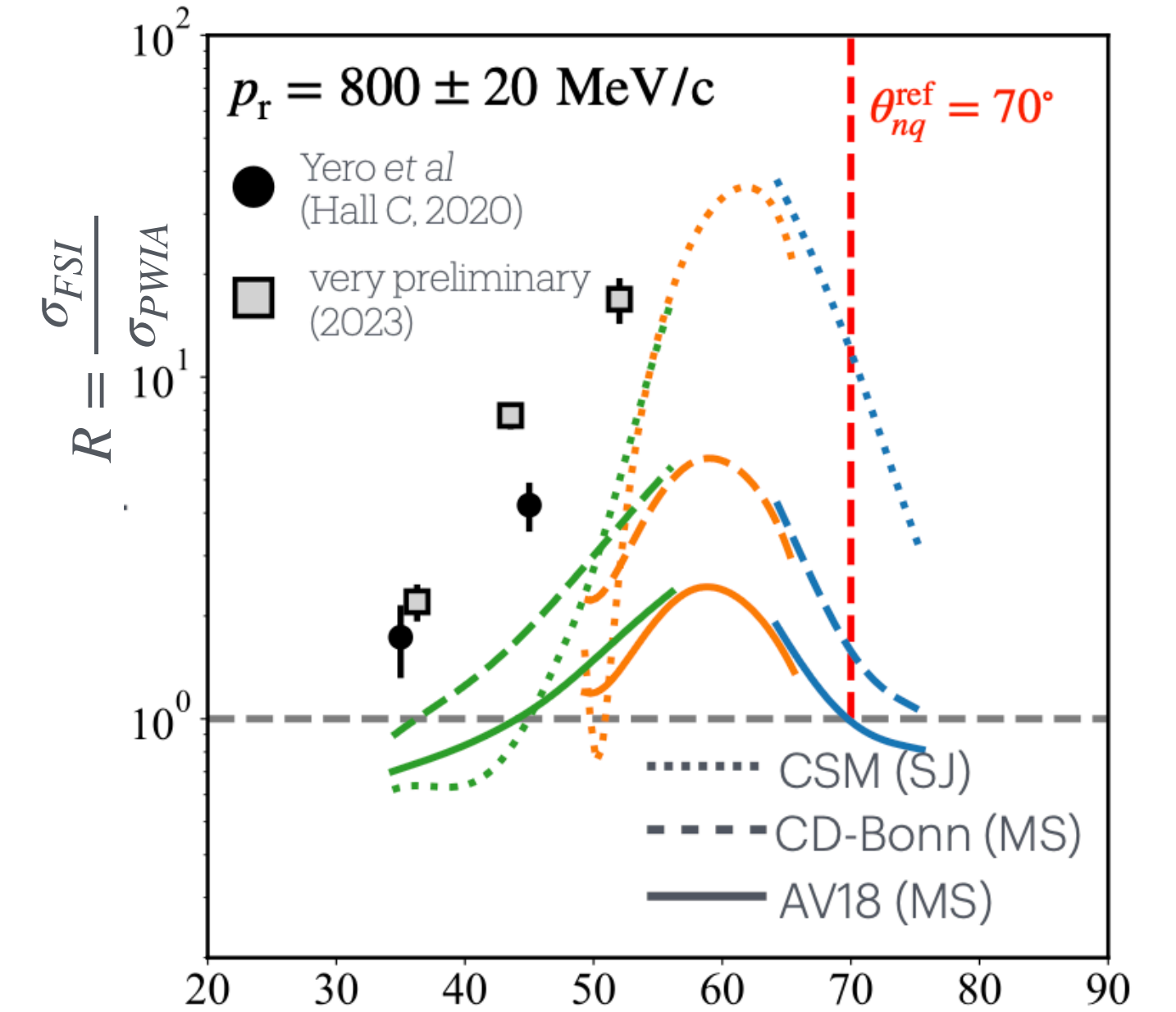
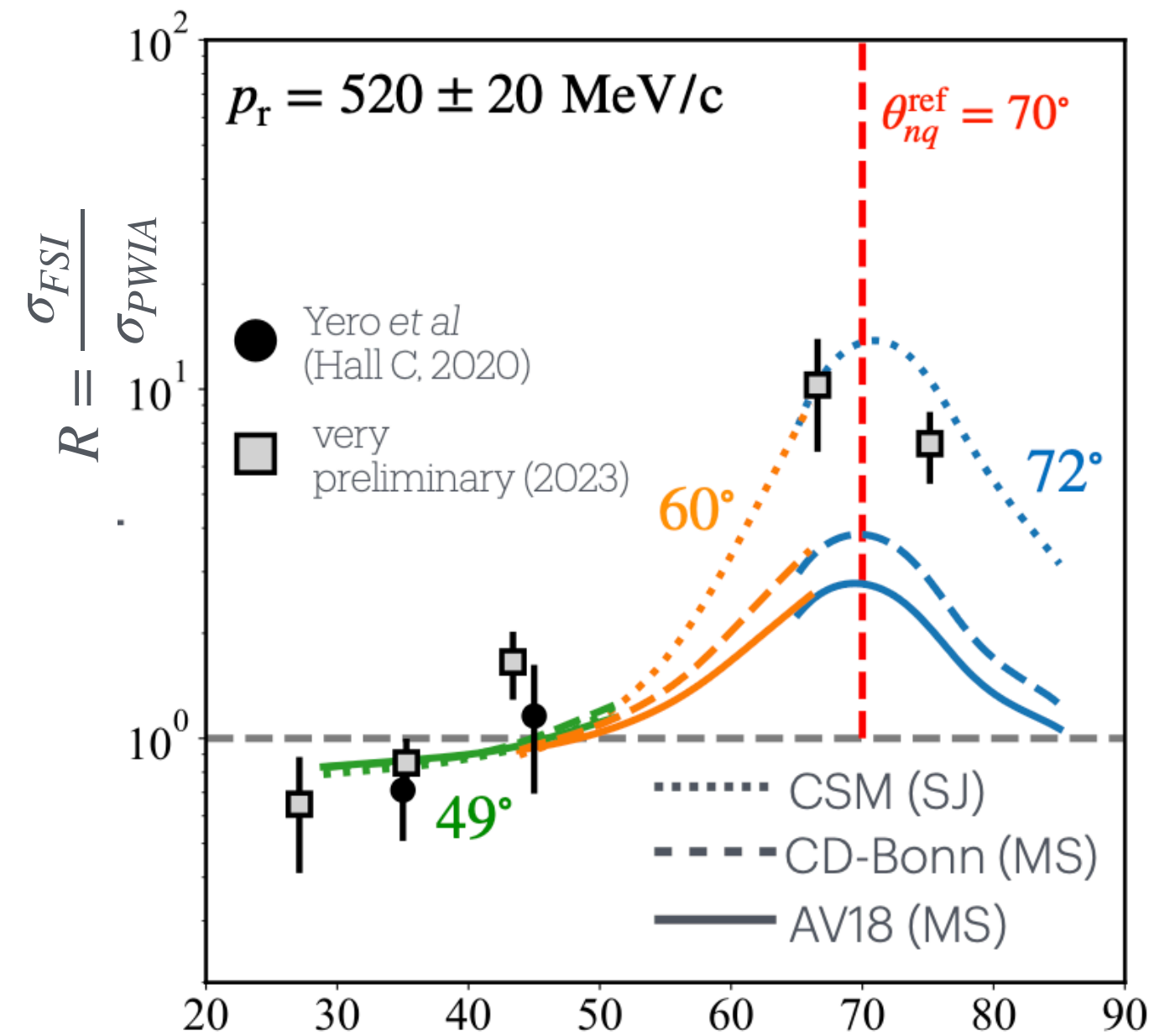
PRELIMINARY CROSS-SECTIONS



FSI Studies at the Nuclear Core



IJMP E Vol. 24, No. 03, 1530003 (Boeglin & Sargsian, 2015)



Plot Courtesy to C. Yero

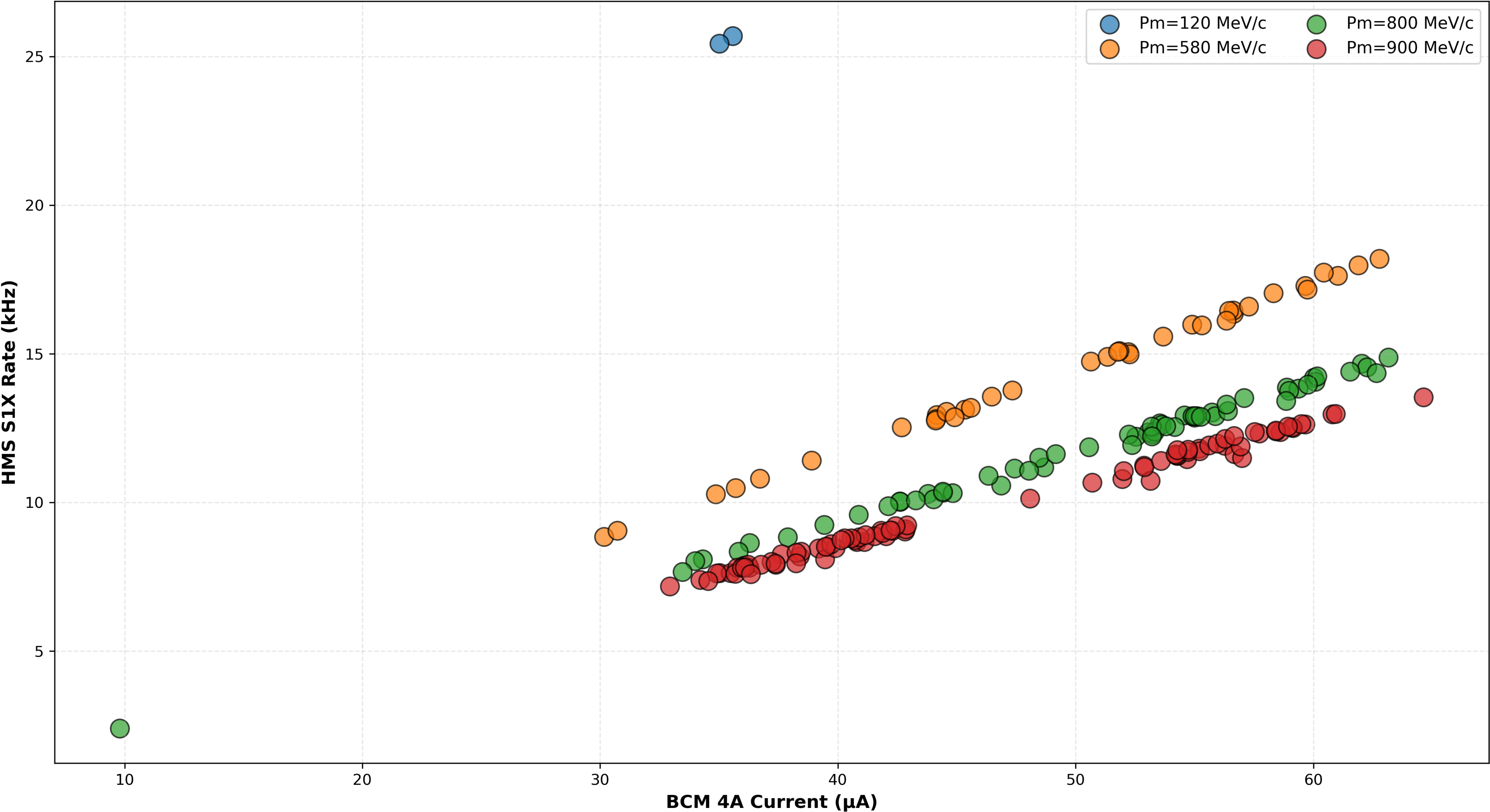
- The peak of the reduced cross-section moves to lower neutron recoil angle (θ_{nq}) with higher missing momentum.
- Existing experimental data provide limited coverage neutron recoil angle (θ_{nq}) at high missing momentum.
- The recently approved Experiment (PR 12-26-009) , FSI Studies at the Nuclear core aims to investigate this intriguing behavior and improve our understanding of FSI at high Pm.

SUMMARY

- The most recent deuteron electro-disintegration experiment was successfully conducted in 2023.
- Preliminary analysis indicates **good agreement** with previous experimental results, while a significant discrepancy with theoretical predictions persists around a missing momentum of 700 MeV/c.
- Possible reasons for the theory-data discrepancy :
 - Contributions from non-nucleonic degree of freedom at very short distances
 - Relativistic effects not fully accounted for in conventional deuteron models
 - FSI not well understood at very high missing momentum
- To further investigate the role of FSI and resolve these discrepancies, a new experiment, **PR12-25-003**, has been proposed and approved.

BACKUP SLIDES

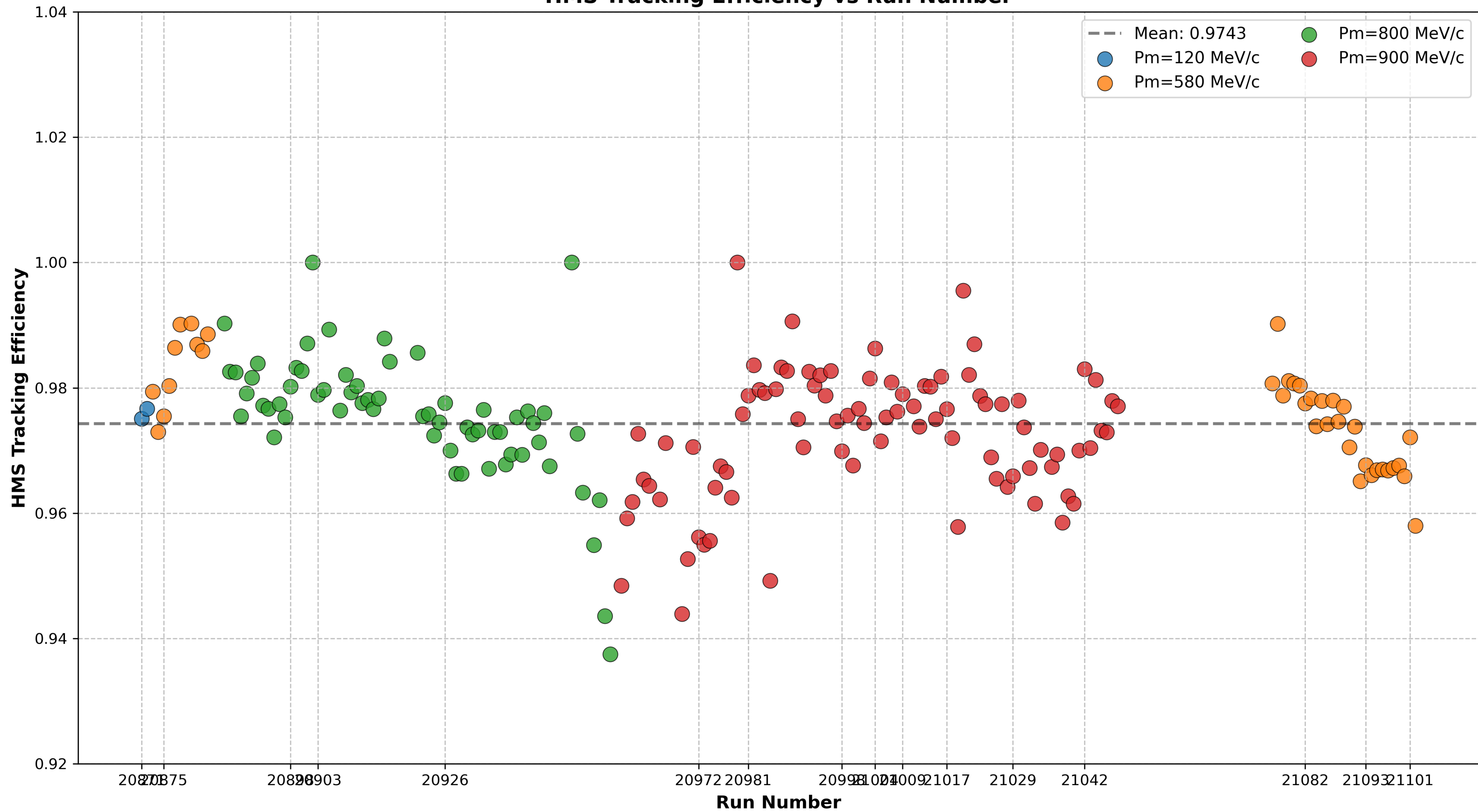
HMS S1X Rate vs BCM 4A Current (by PM Setting)



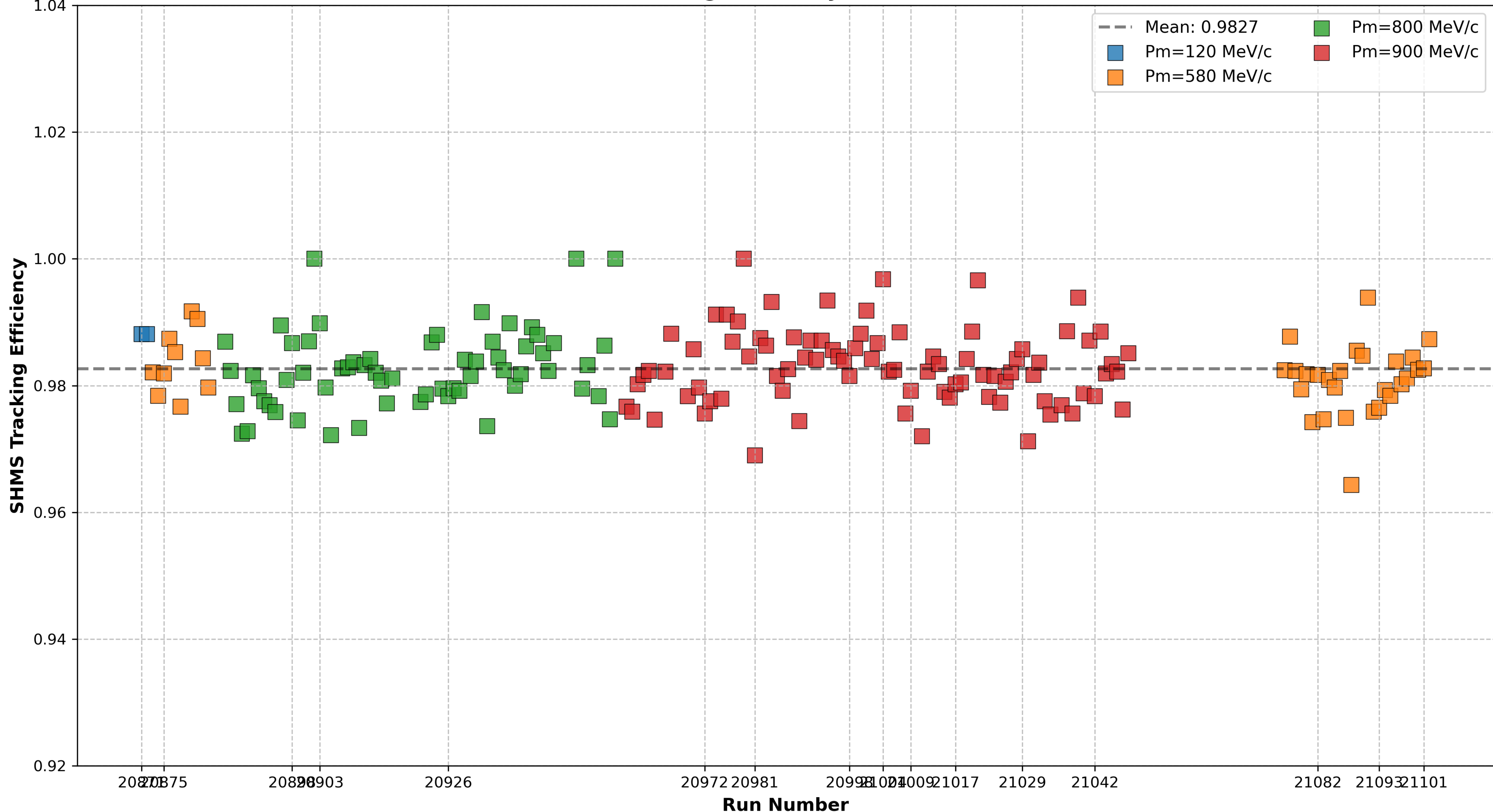
Live Time vs Run Number (All Runs)



HMS Tracking Efficiency vs Run Number

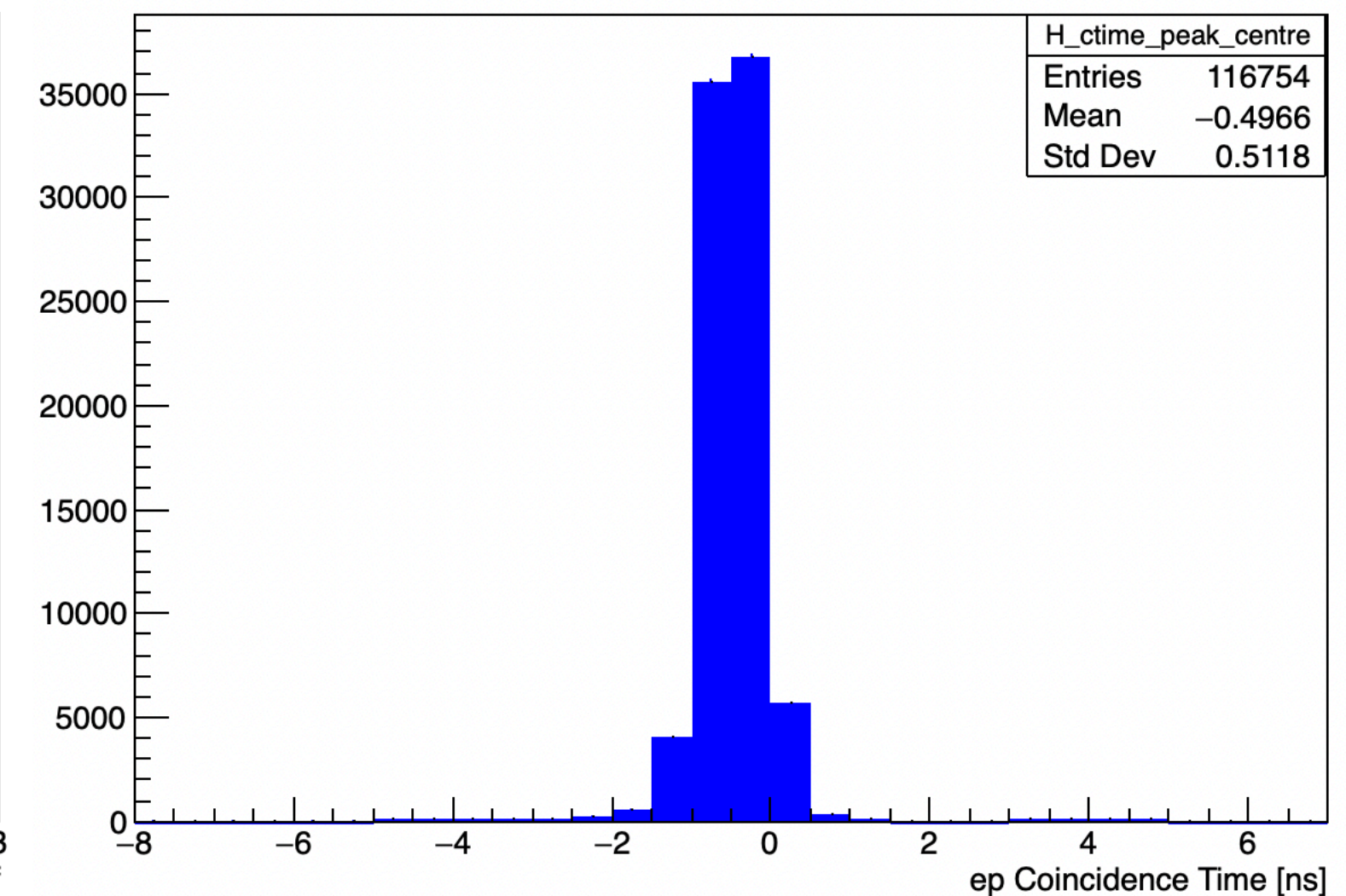
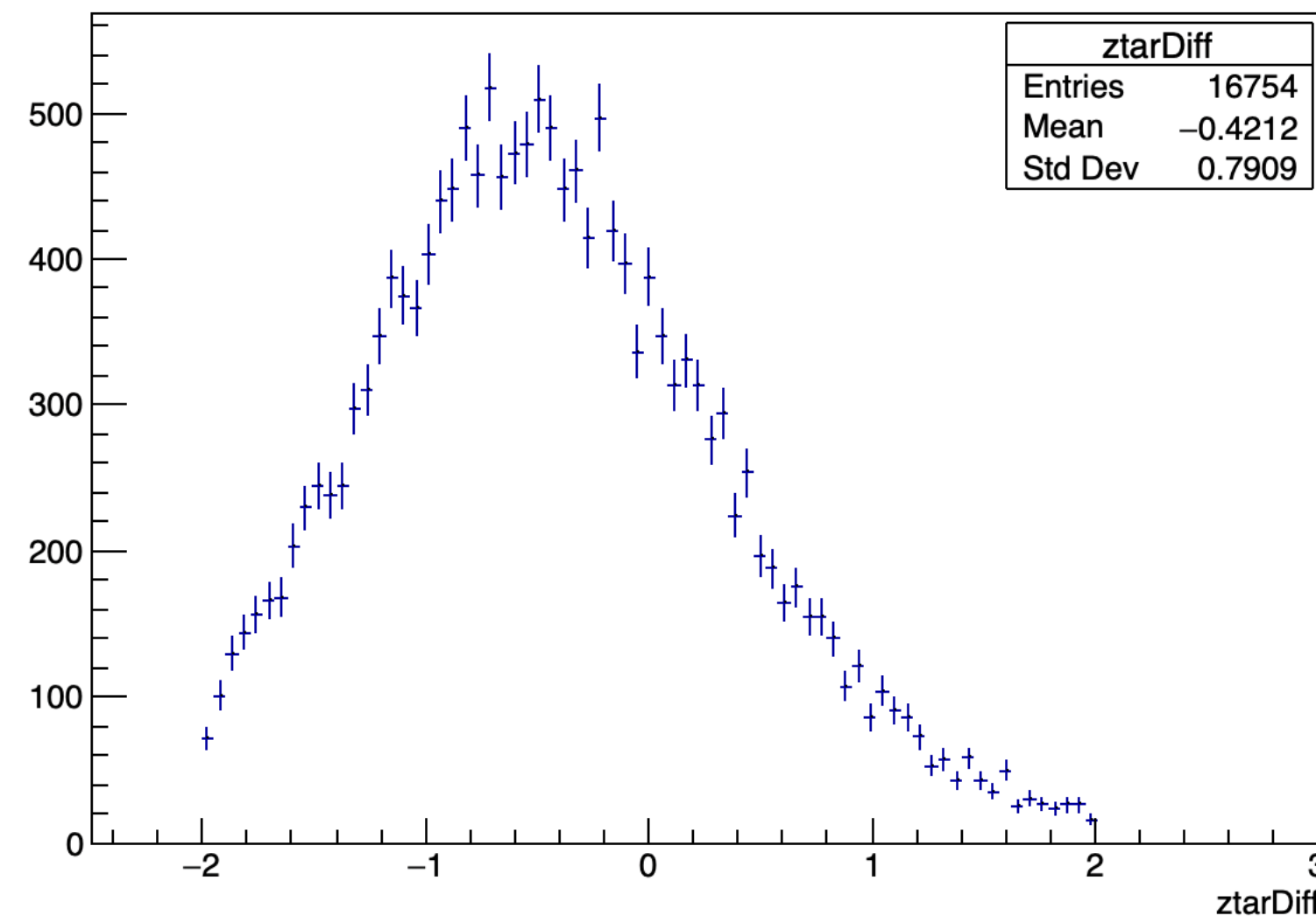
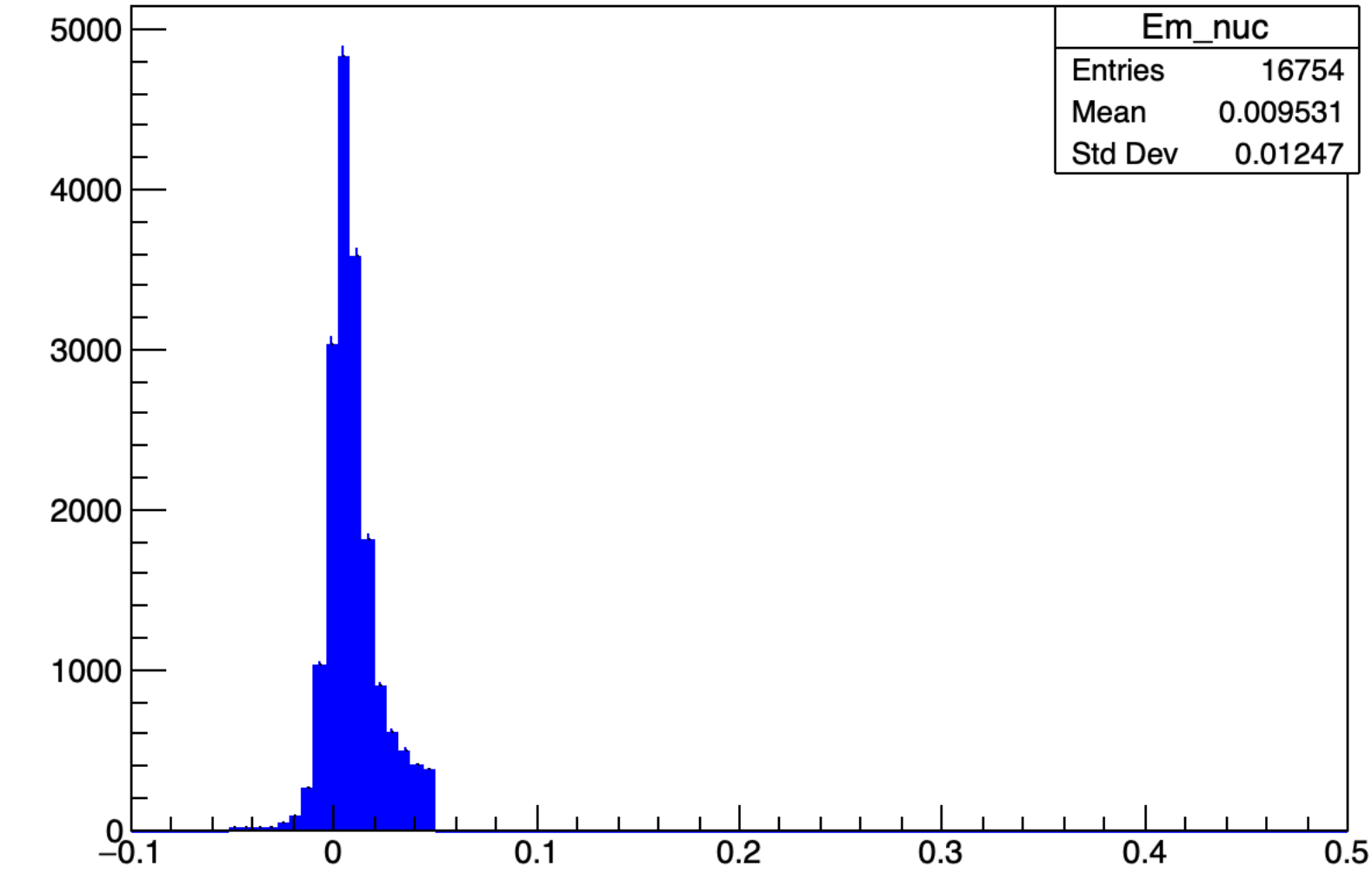
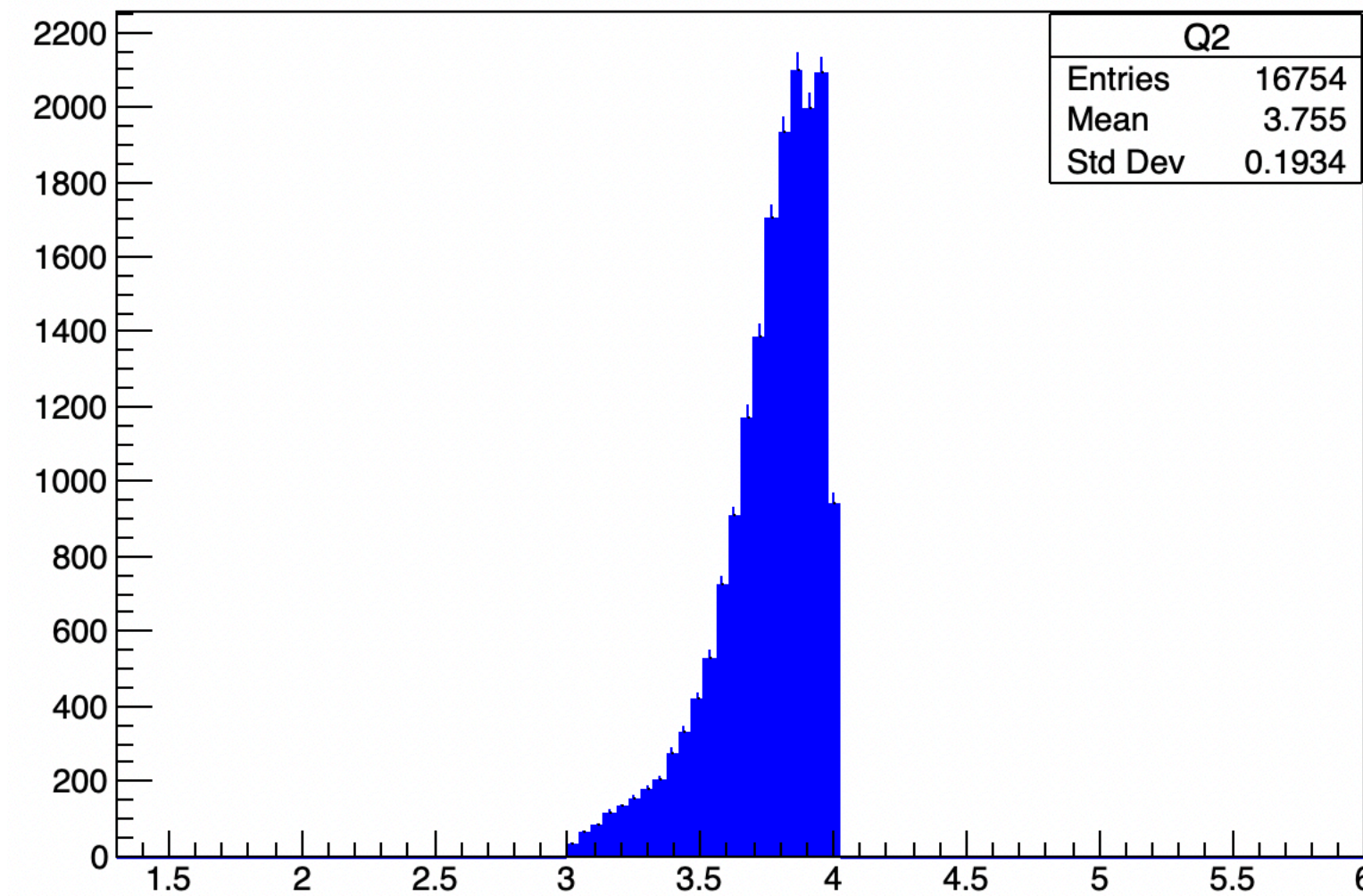


SHMS Tracking Efficiency vs Run Number



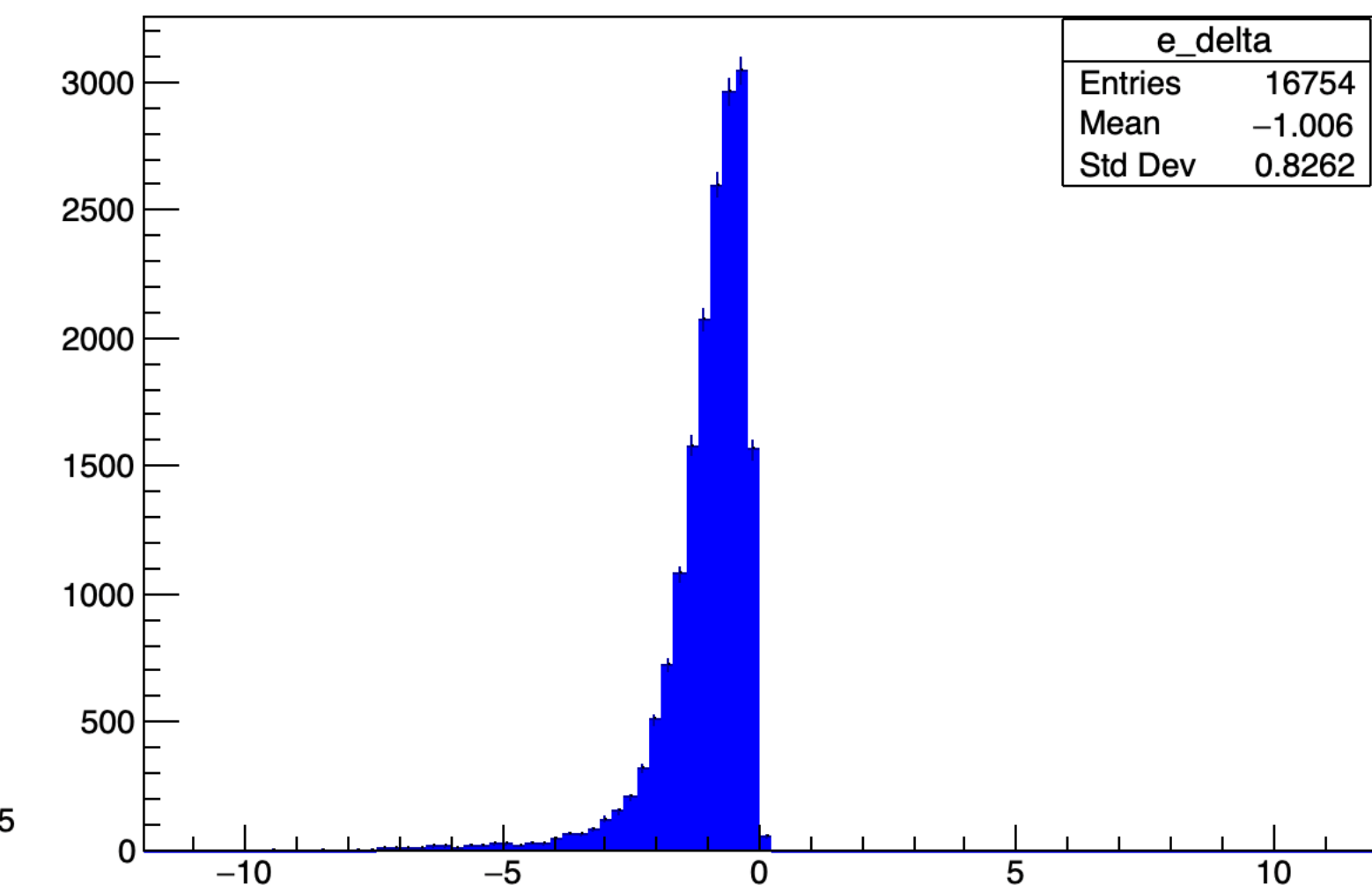
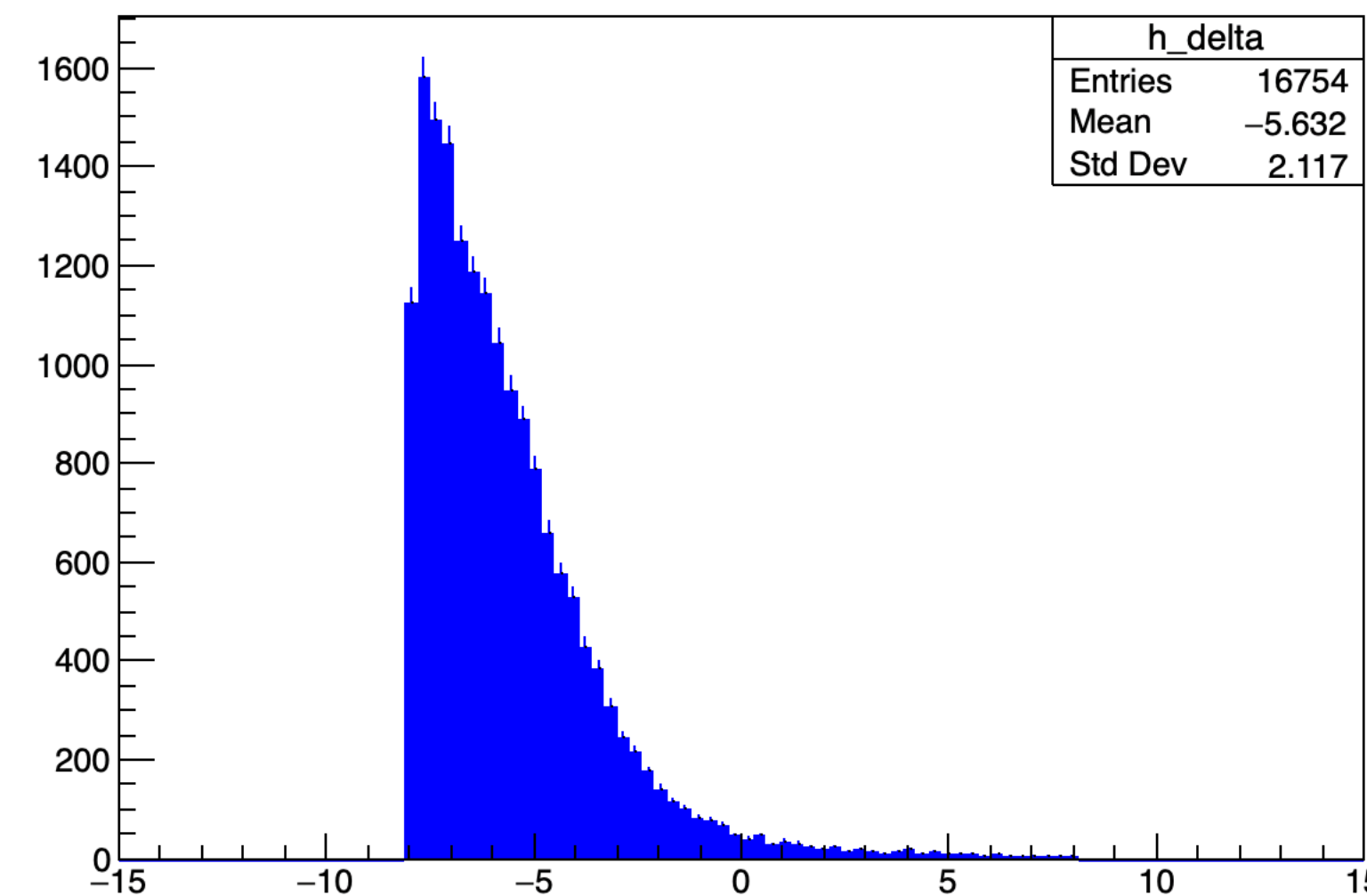
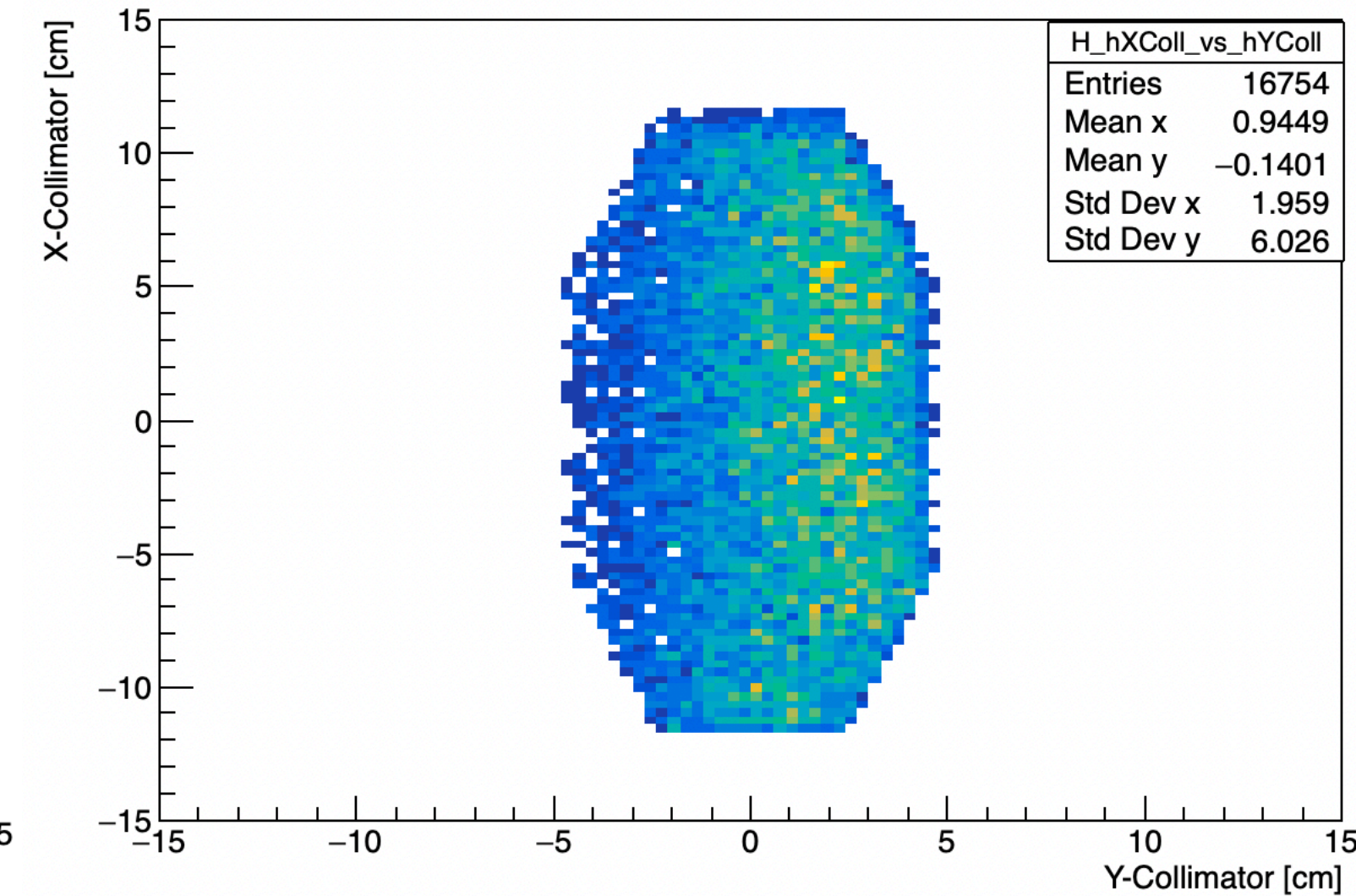
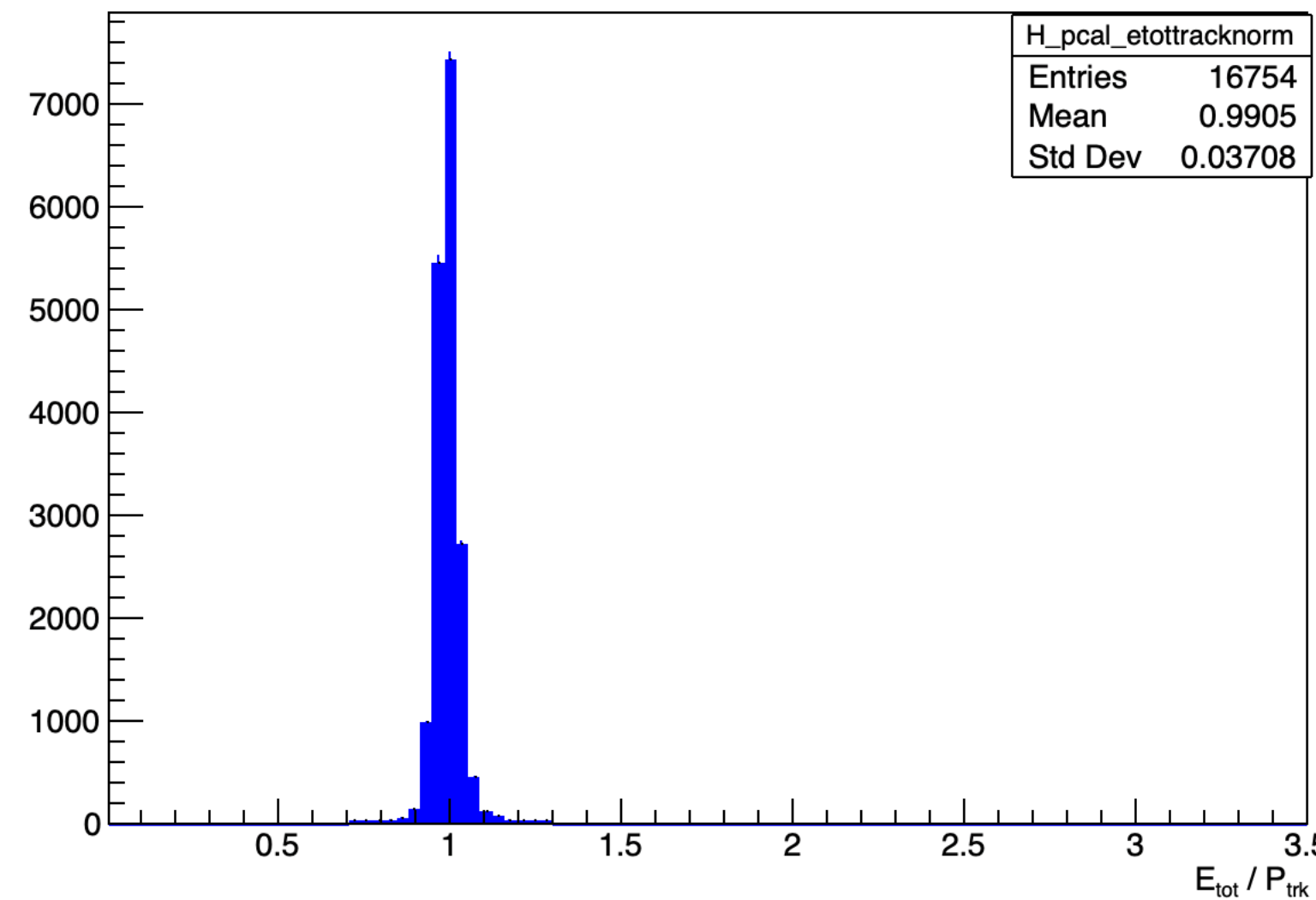
Event Selection Cuts

- Q2 cut: $3 \leq Q^2 \leq 4$
- Missing Energy Cut (-0.05, 0.05)
- Z-tar cut (-2.0, 2.0)
- Coincidence Time cut (-2.5, 2.5)
- SHMS Calorimeter cut (0.7, 1.3)
- HMS and SHMS Collimator cut
- Acceptance cuts
 - HMS delta (-8, 8)
 - SHMS delta (-10,22)



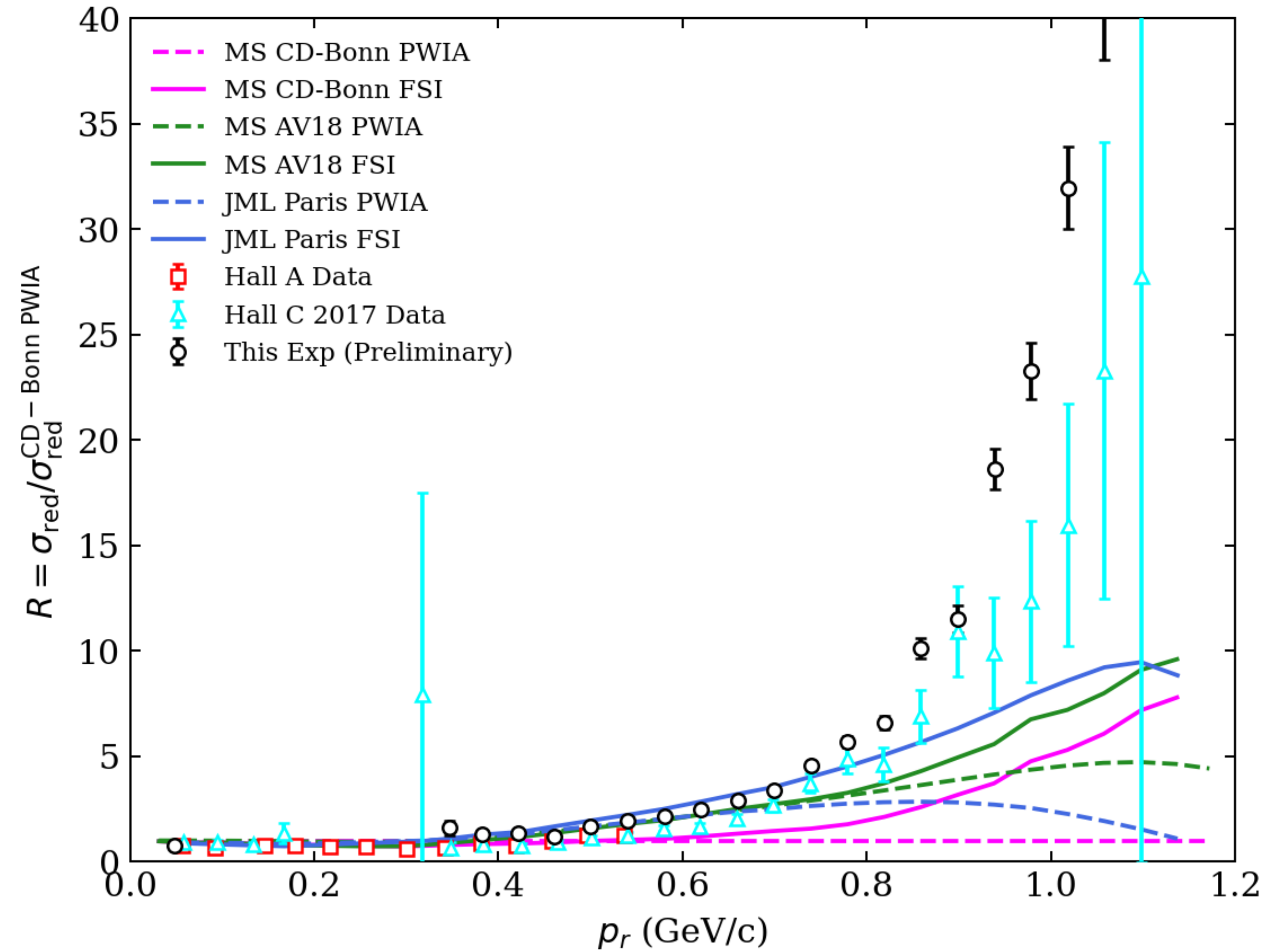
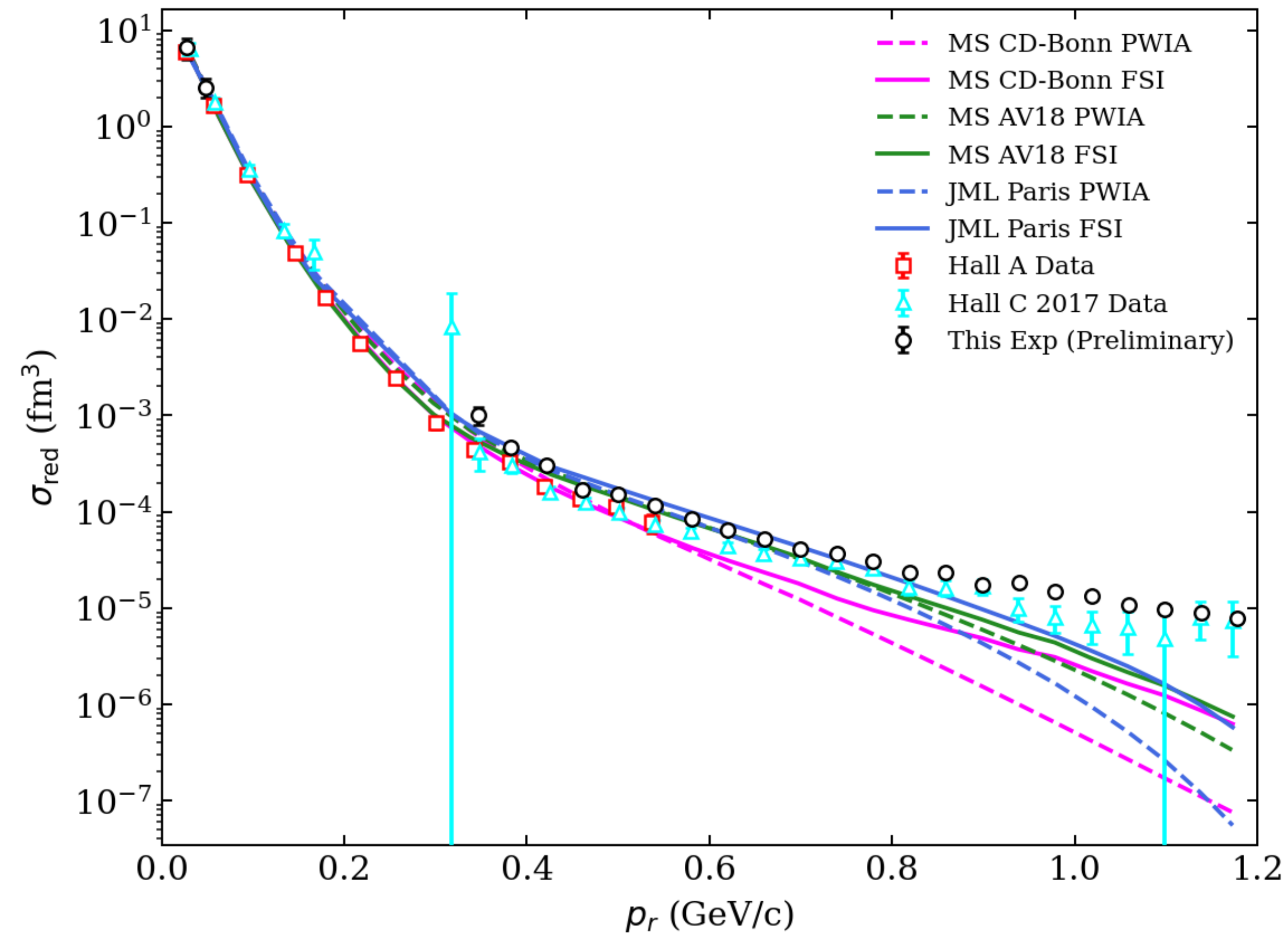
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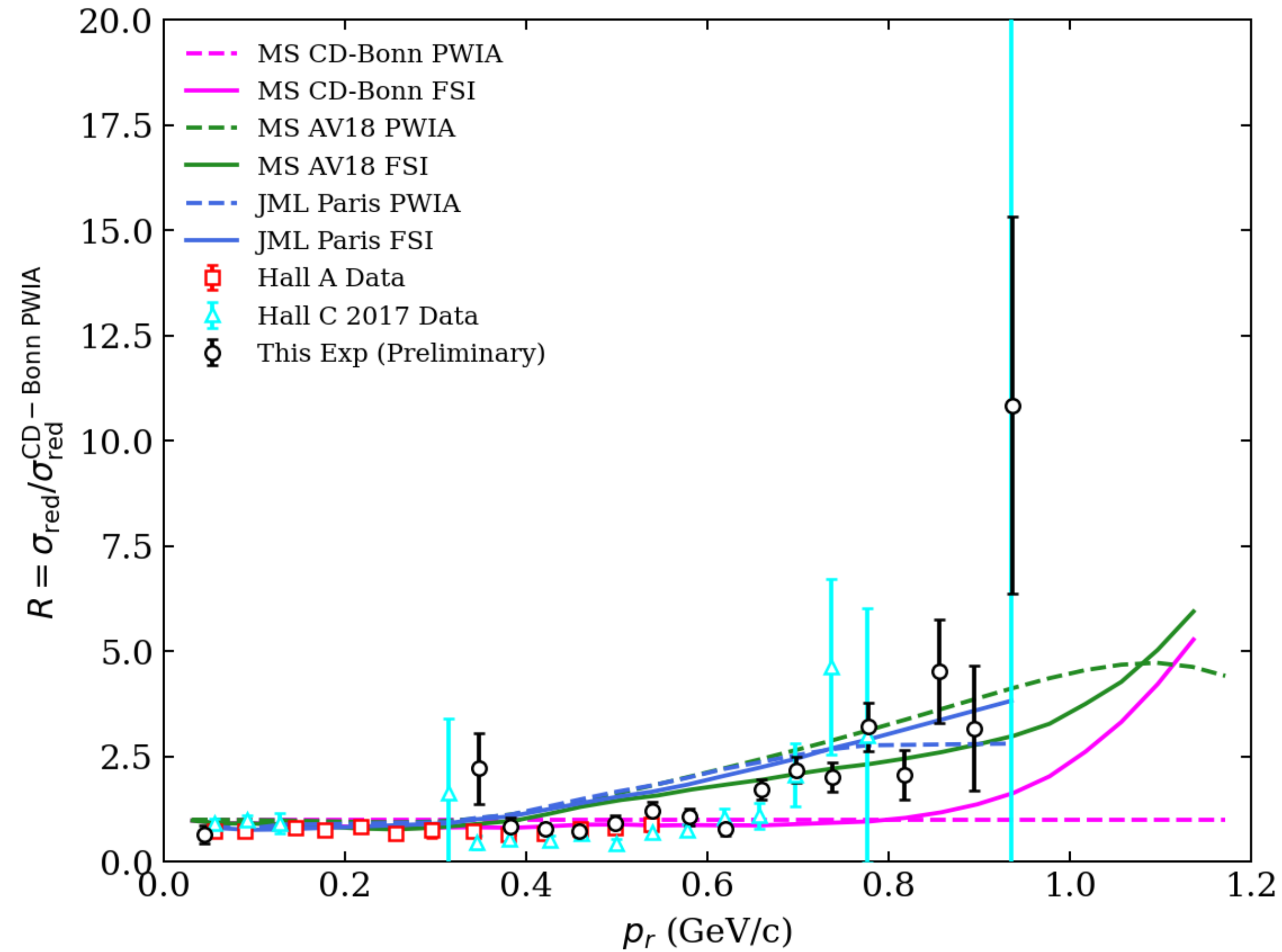
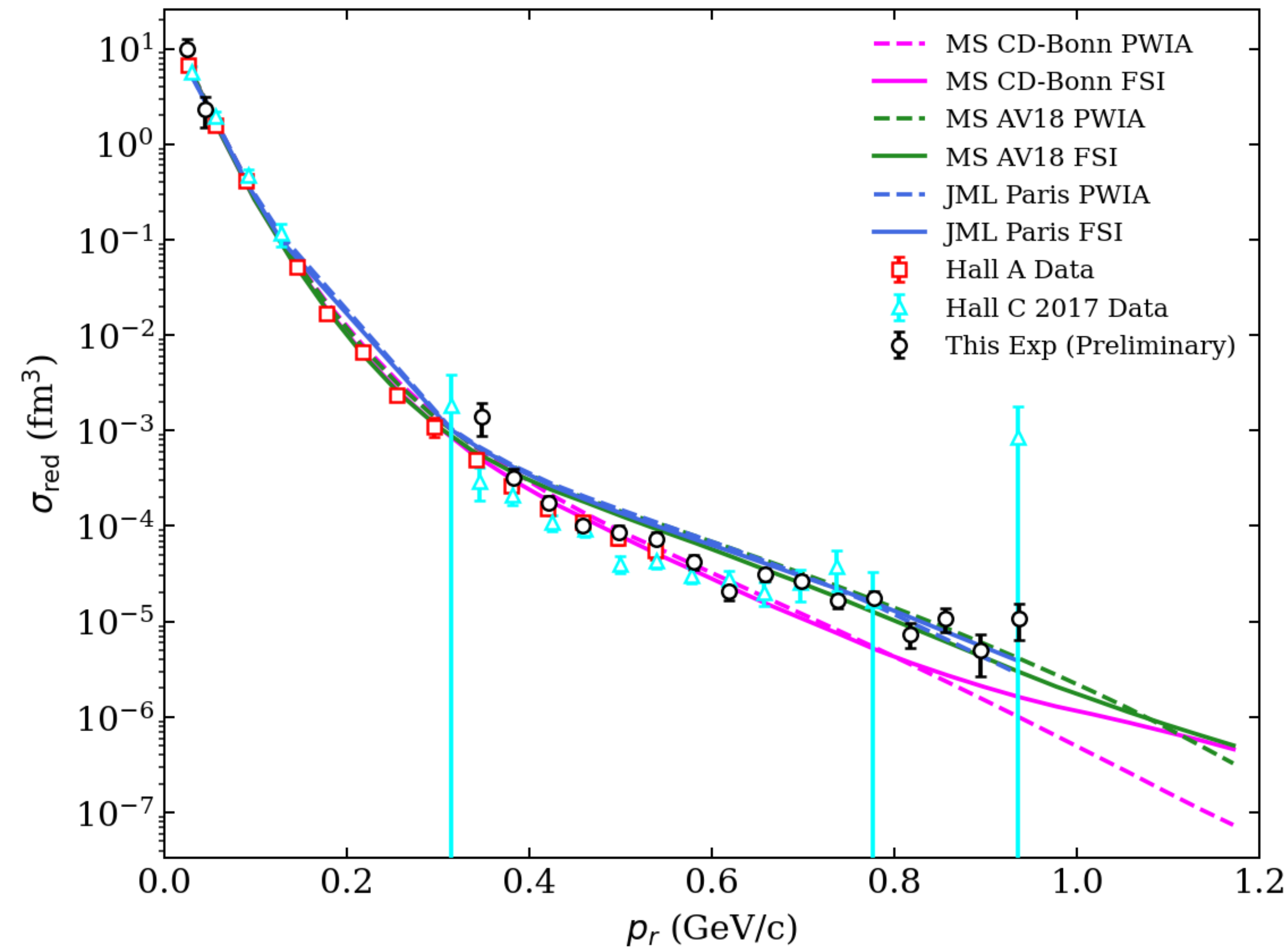
PRELIMINARY CROSS-SECTIONS

Reduced cross section, $\theta_{nq} = 45 \pm 5^\circ$



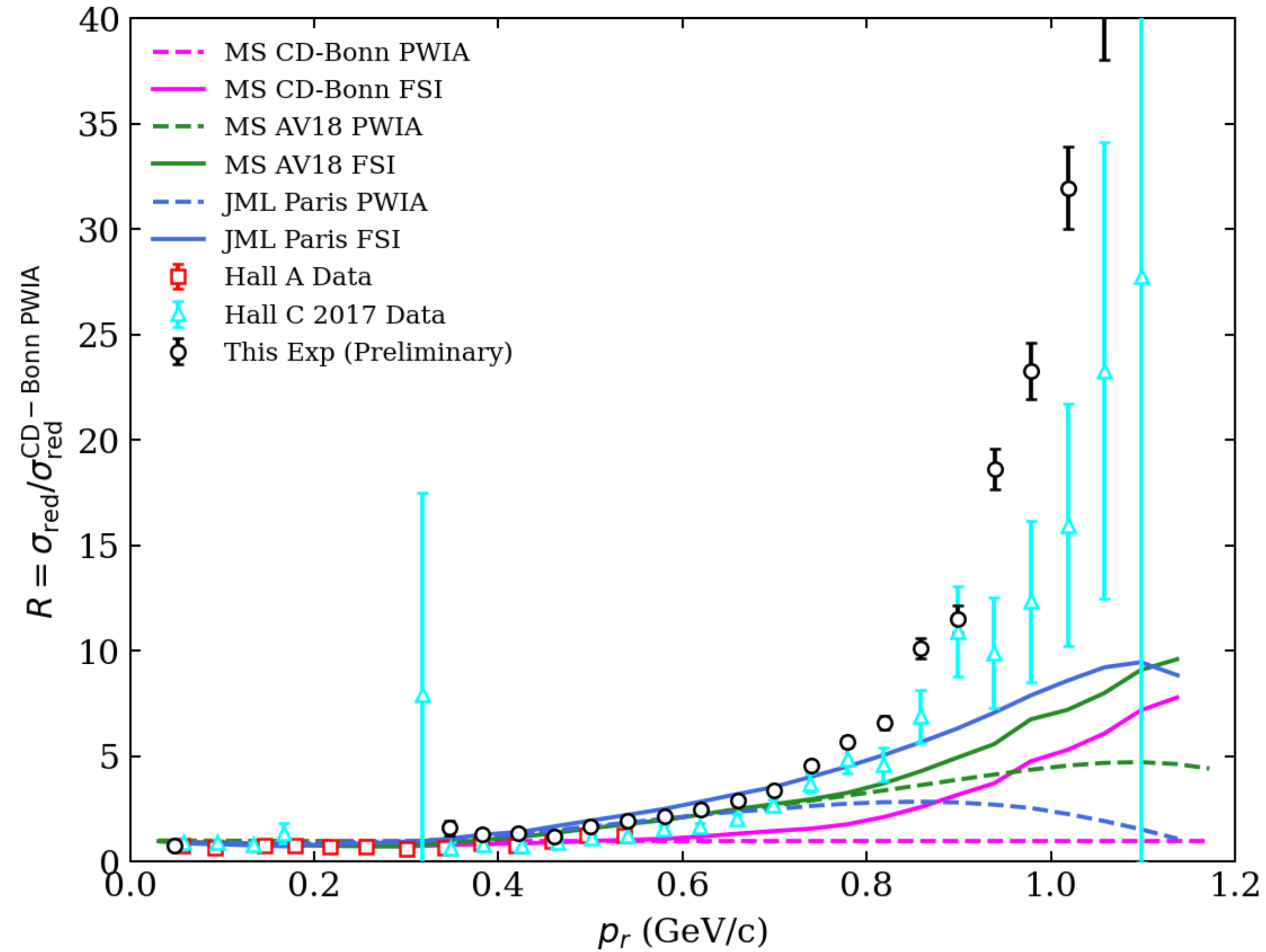
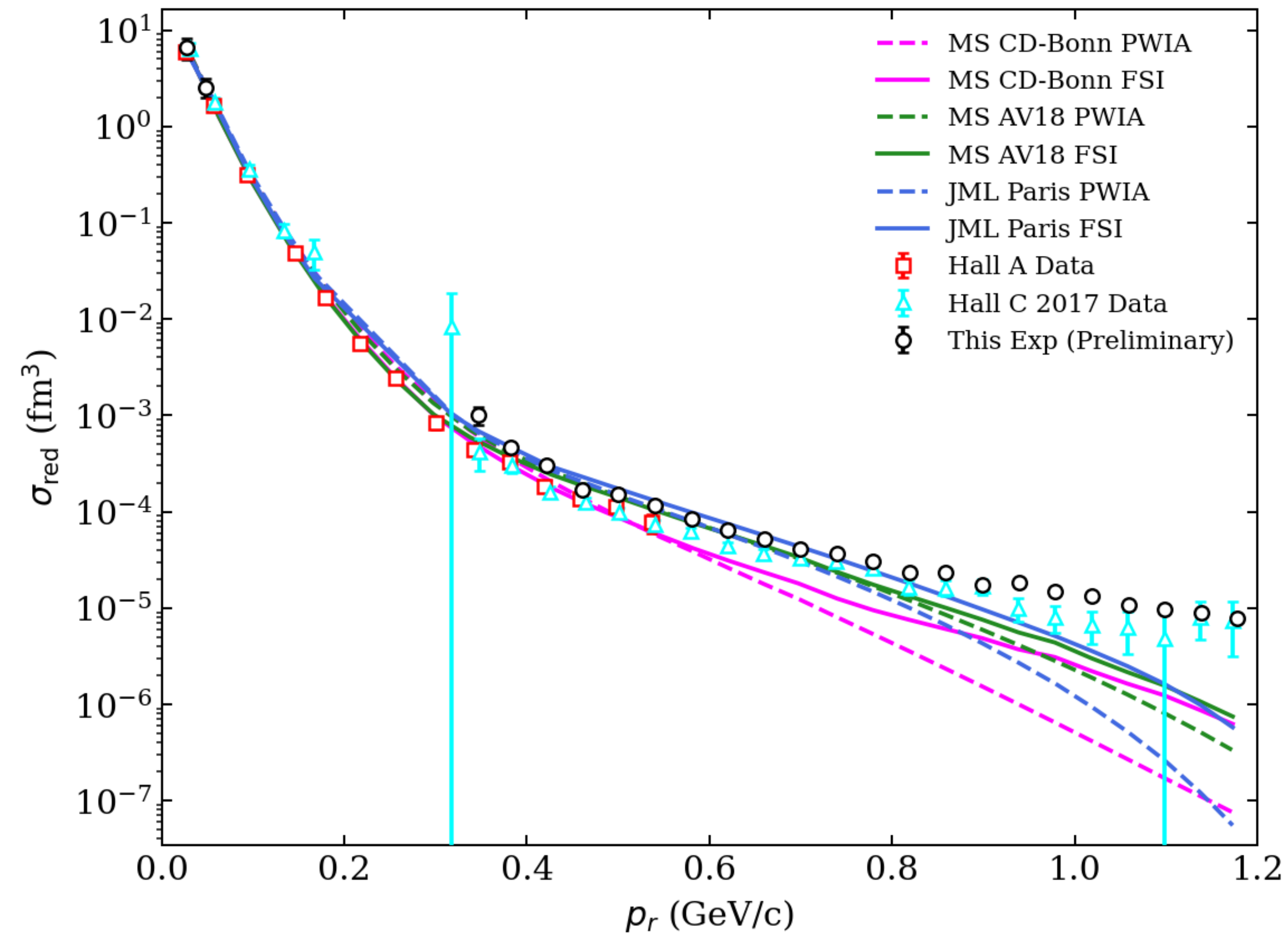
PRELIMINARY CROSS-SECTIONS

Reduced cross section, $\theta_{nq} = 35 \pm 5^\circ$



PRELIMINARY CROSS-SECTIONS

Reduced cross section, $\theta_{nq} = 45 \pm 5^\circ$



PRELIMINARY CROSS-SECTIONS

Reduced cross section, $\theta_{nq} = 75 \pm 5^\circ$

