PAC 53

(PR12-25-003)

deuteron FSI studies

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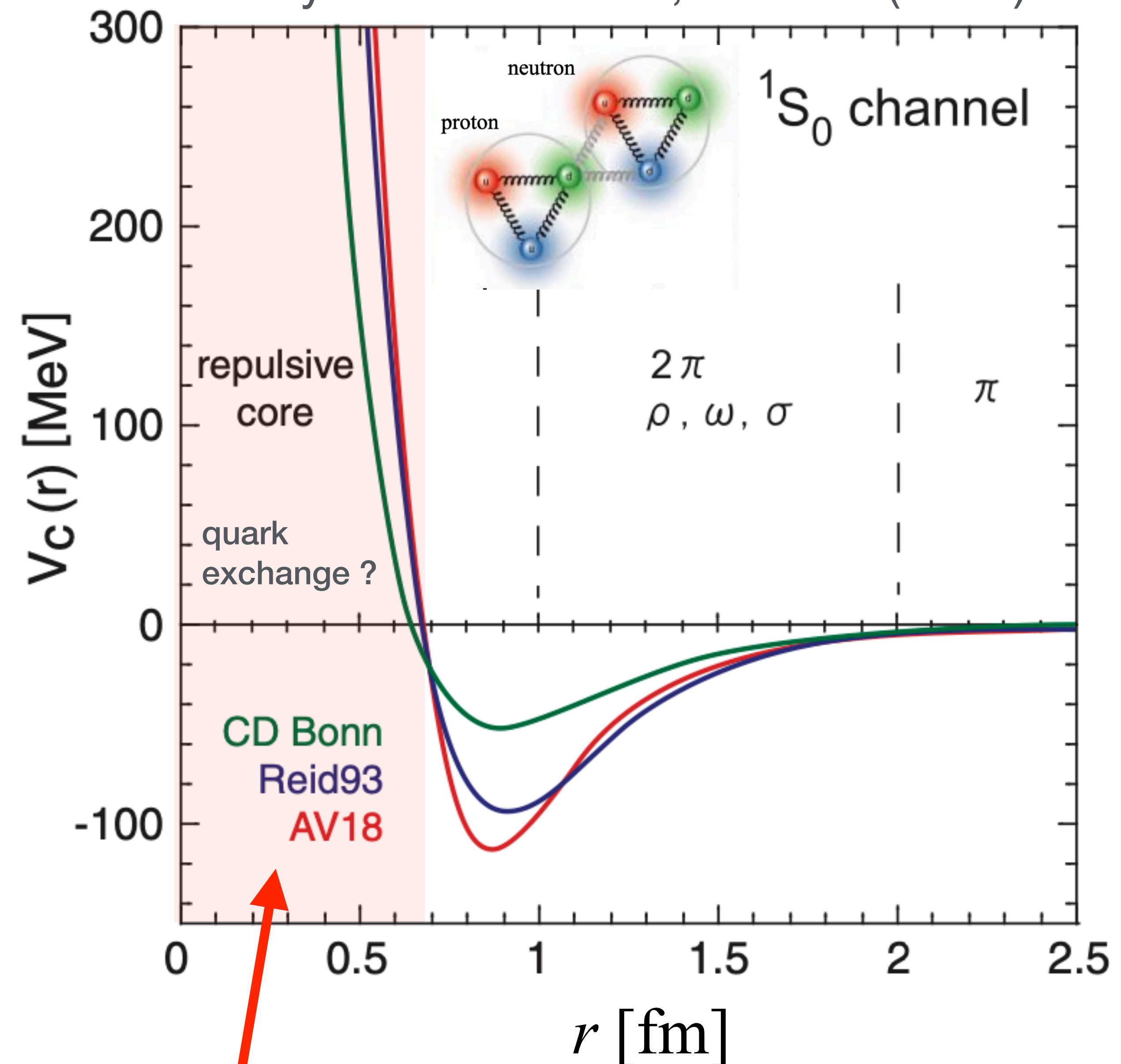
What is the dynamical origin of repulsive core ?

- <u>theoretical challenges:</u>
  - meson theory: how to describe ($r < 0.6$ fm) by meson exchange with comparable or larger radii ?
    - most phenomenological *NN* potentials today still utilize an *"ansatz"* to model the core
  - relativistic effects play a larger role at small inter-nucleon distances
  - describing heavier nuclei becomes difficult
  - QCD: repulsion expected due to Pauli Exclusion Principle on overlapping quarks but exact mechanism unclear (quark/gluon exchange ?, inelastic transitions?, etc.)

- <u>experimental challenges:</u>
  - energy limitations in the nuclear probe
  - measuring small cross sections
  - identifying observables directly related to the core (i.e., PWIA)

Phys. Rev. Lett. **99**, 022001 (2007)



Short-range repulsive part
NOT well understood

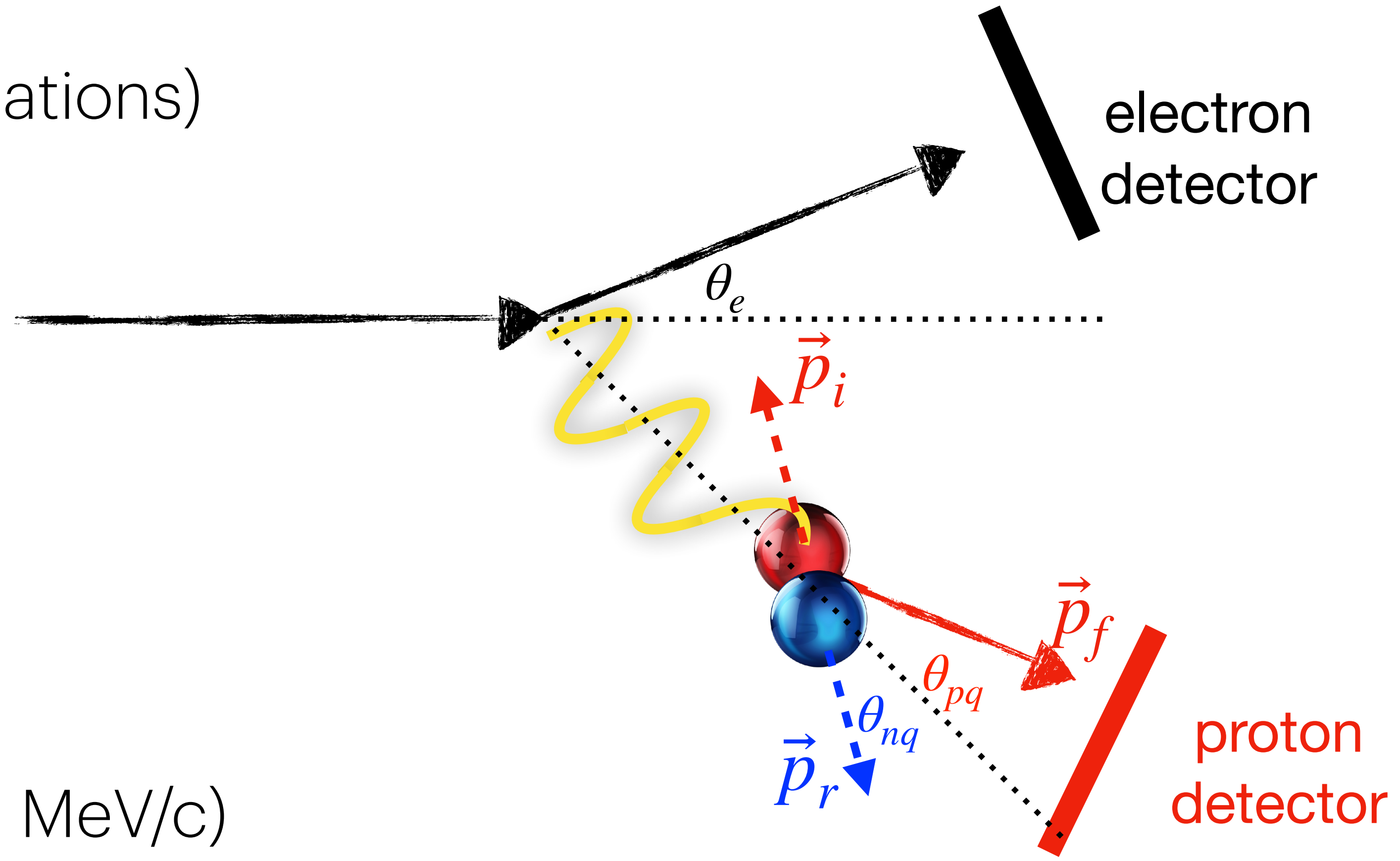
Why Study the Deuteron ?

$d(e, e'p)n$ ideal for nuclear core studies

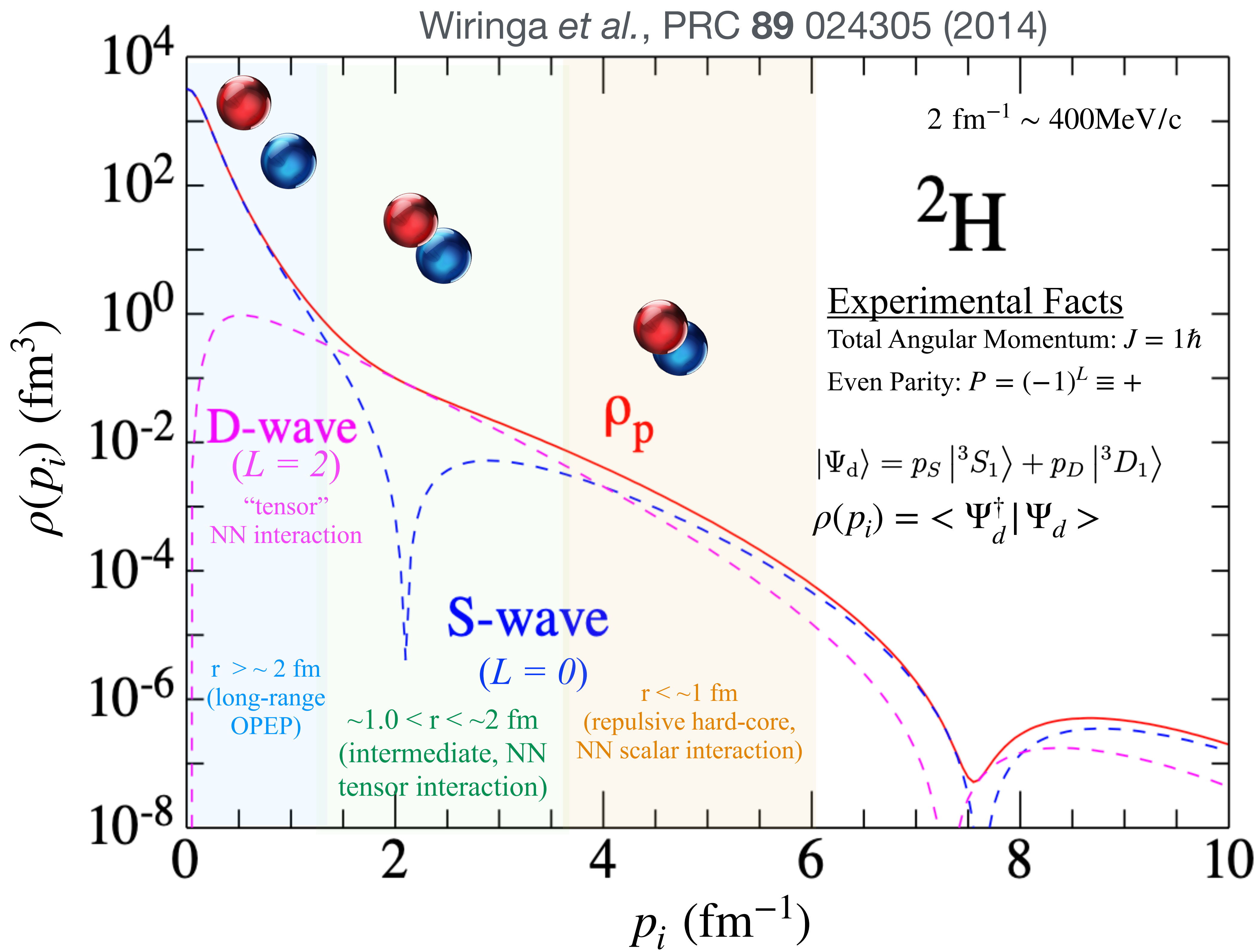
- most simple *np* bound system
  (no 3*N* forces or additional complications)

- foundation for short-range
  correlations in heavier nuclei
  (*np*-dominance, scaling in *A*>2)

- reliable FSI calculations (up to ~550 MeV/c)
  compared to heavier nuclei

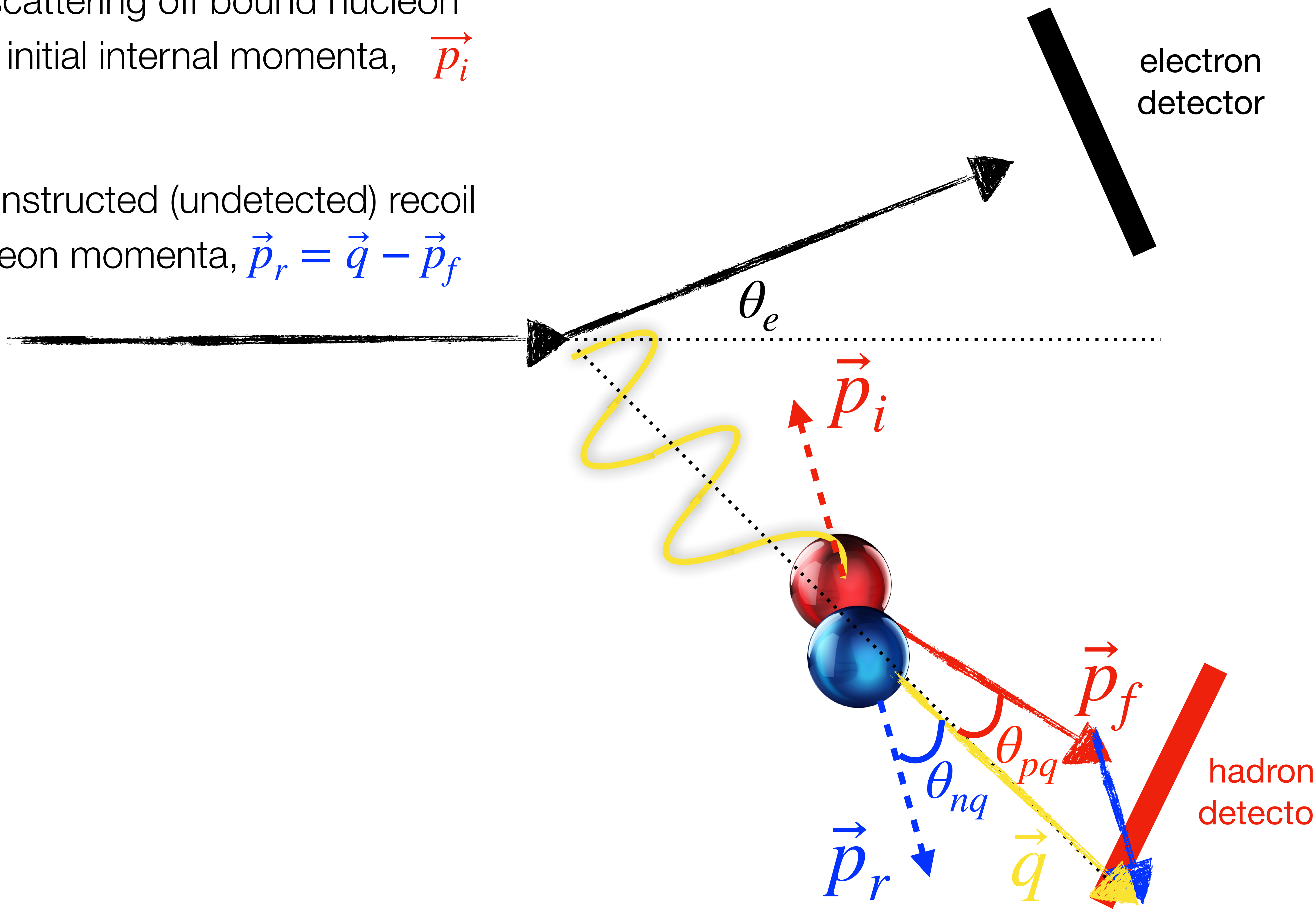


Momentum Distribution



Probing High-Momentum Structure

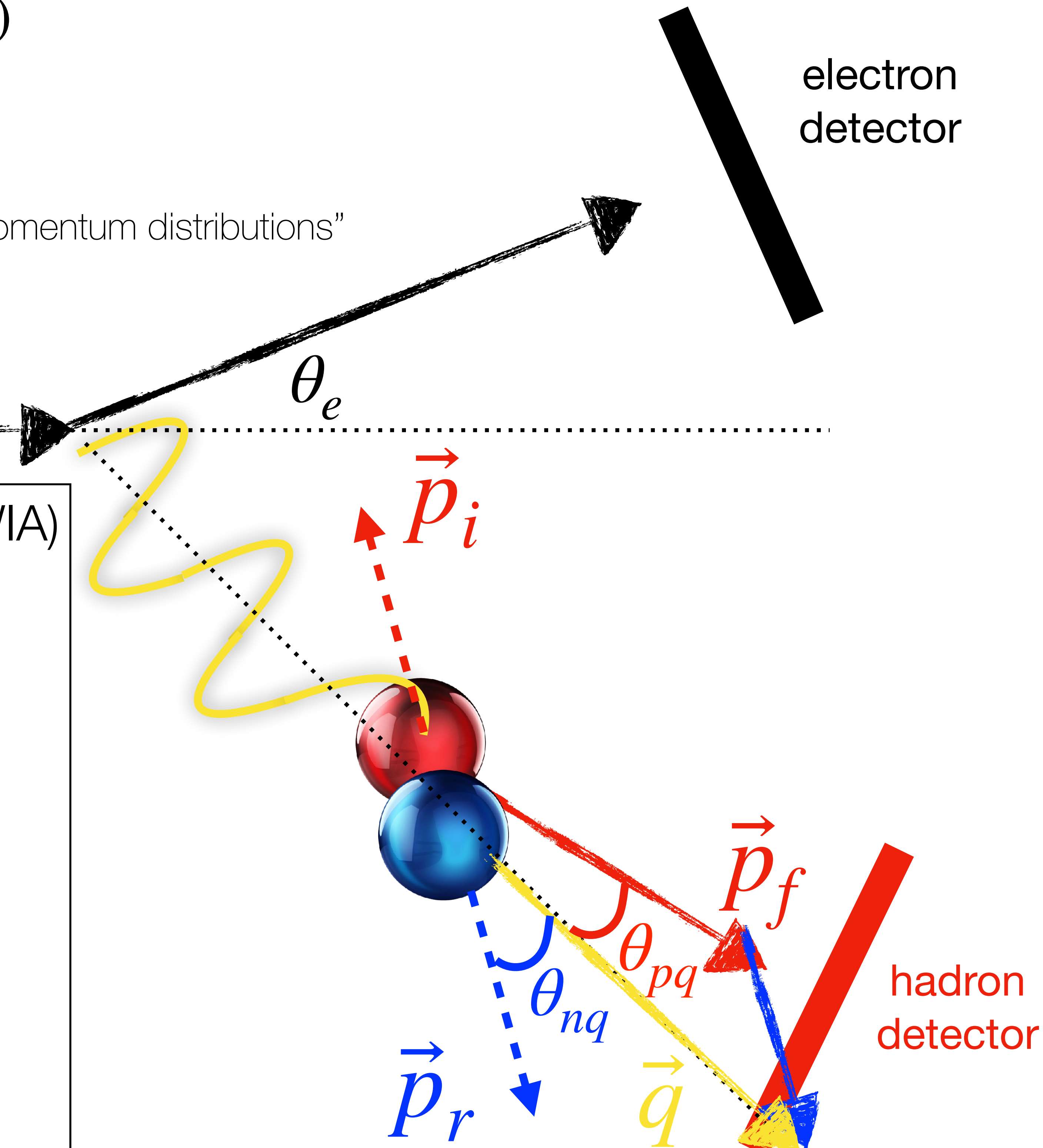
- e- scattering off bound nucleon with initial internal momenta, $\overrightarrow{p_i}$
- reconstructed (undetected) recoil nucleon momenta, $\vec{p}_r = \vec{q} - \vec{p}_f$



Probing High-Momentum Structure

$$\sigma_{exp} \equiv \frac{d^5\sigma}{dE'd\Omega_e d\Omega_p} \approx k \cdot \sigma_{eN} \cdot \rho(p_i)$$

$$\sigma_{red} \equiv \frac{\sigma_{exp}}{k \cdot \sigma_{eN}} \sim \rho(p_i)$$ "experimental momentum distributions"



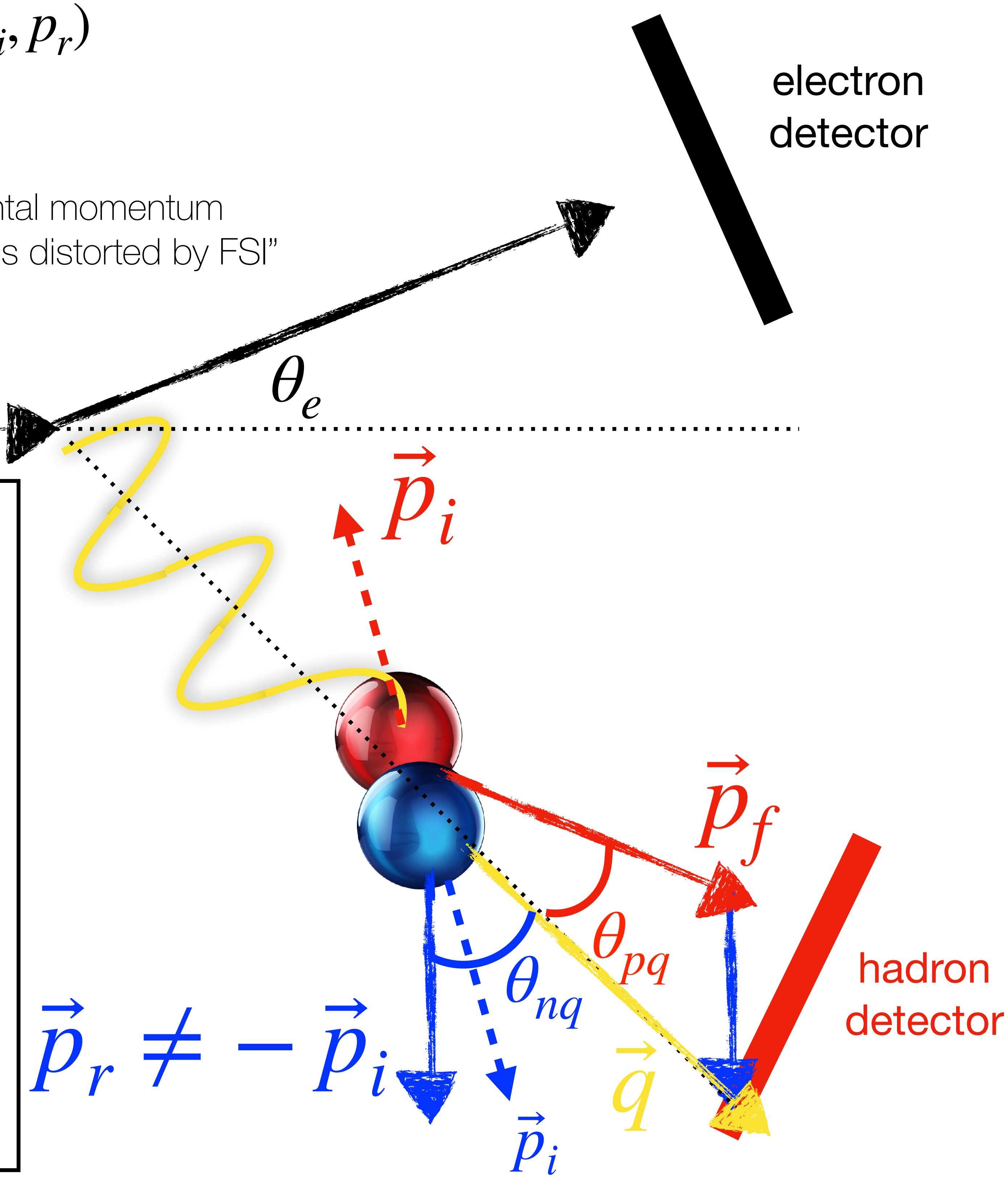
- plane-wave impulse approximation (PWIA)
  - no further re-interaction between knocked-out and recoil nucleon
  - recoil momentum unchanged, $\vec{p}_r \sim -\vec{p}_i$
  - $\vec{p}_r$ can be used to access internal nucleon momentum distributions

Probing High-Momentum Structure

$$\sigma_{exp} \equiv \frac{d^5\sigma}{dE' d\Omega_e d\Omega_p} = k \cdot \sigma_{eN} \cdot \rho_D(p_i, p_r)$$

$$\sigma_{red} \equiv \frac{\sigma_{exp}}{k \cdot \sigma_{eN}} \sim \rho_D(p_i, p_r)$$

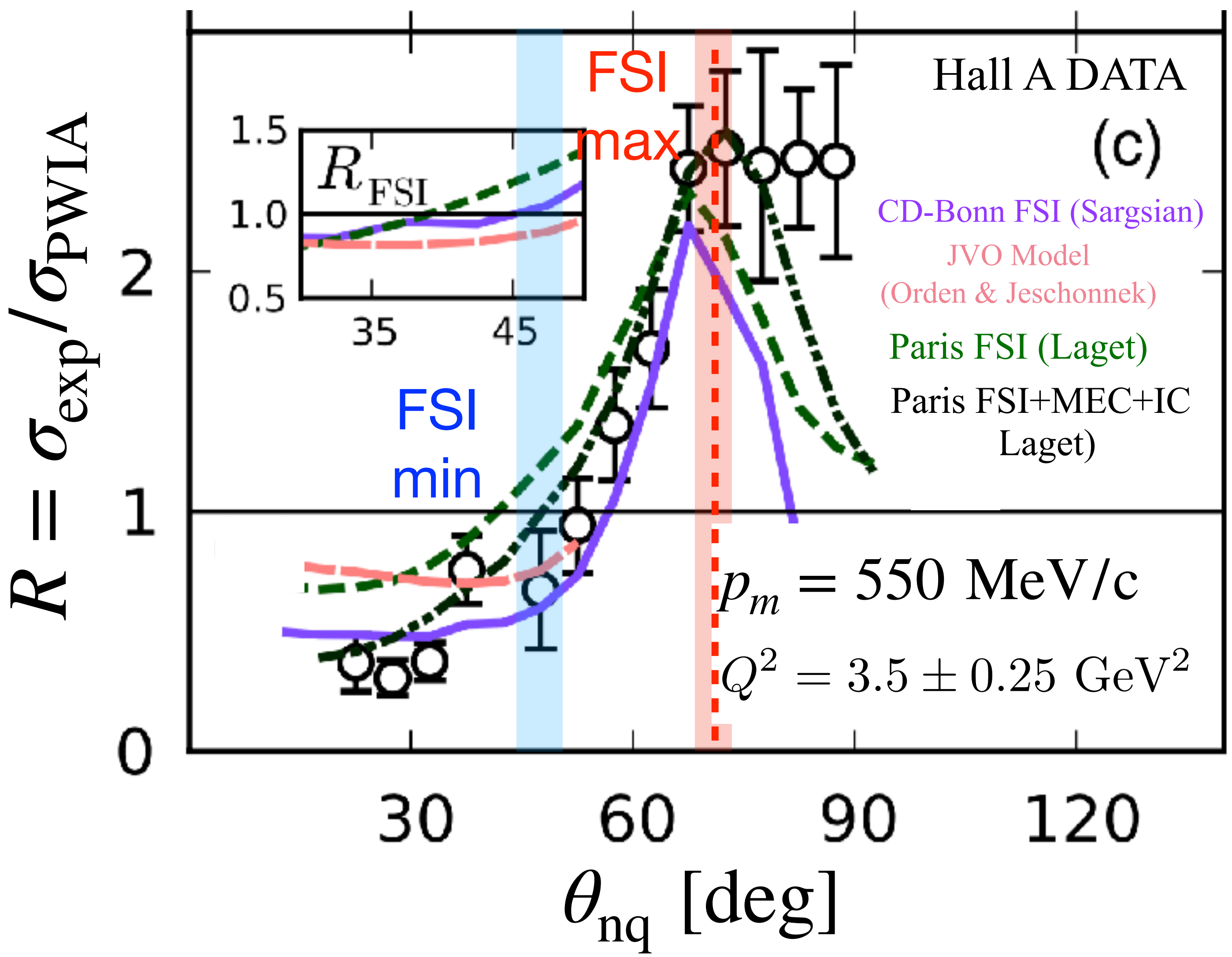
"experimental momentum distributions distorted by FSI"



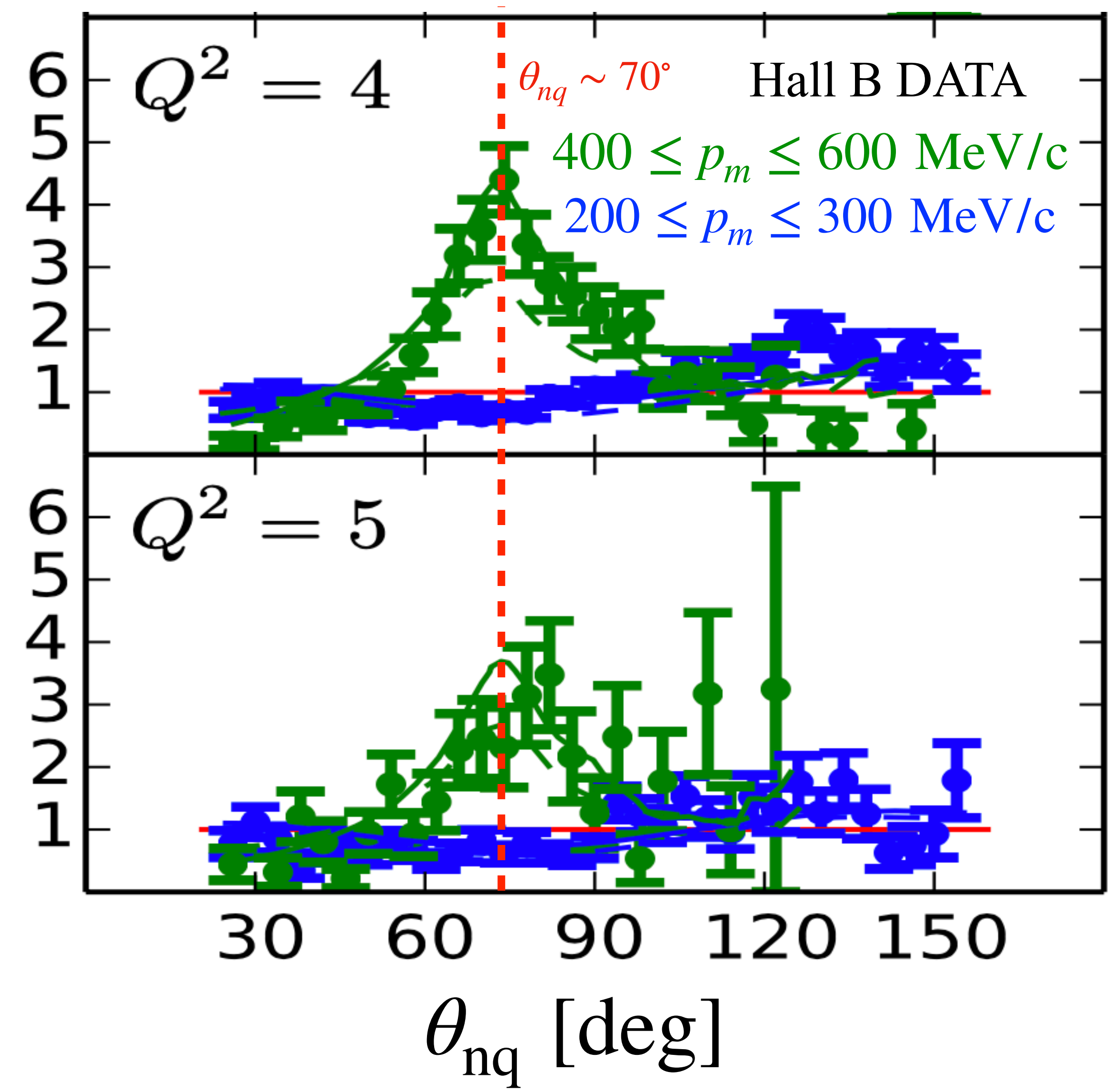
- Final-state interactions (FSI):
  - recoil nucleon re-interacts with knocked-out nucleon
  - recoil momentum modified, $\vec{p}_r \neq -\vec{p}_i$
  - $\vec{p}_r$ cannot be used to access internal nucleon momentum distributions

Controlling Final-State Interactions

Boeglin et al. (Hall A) PRL **107**, 262501 (2011)



Egiyan et al. (CLAS) PRL **98**, 262502 (2007)

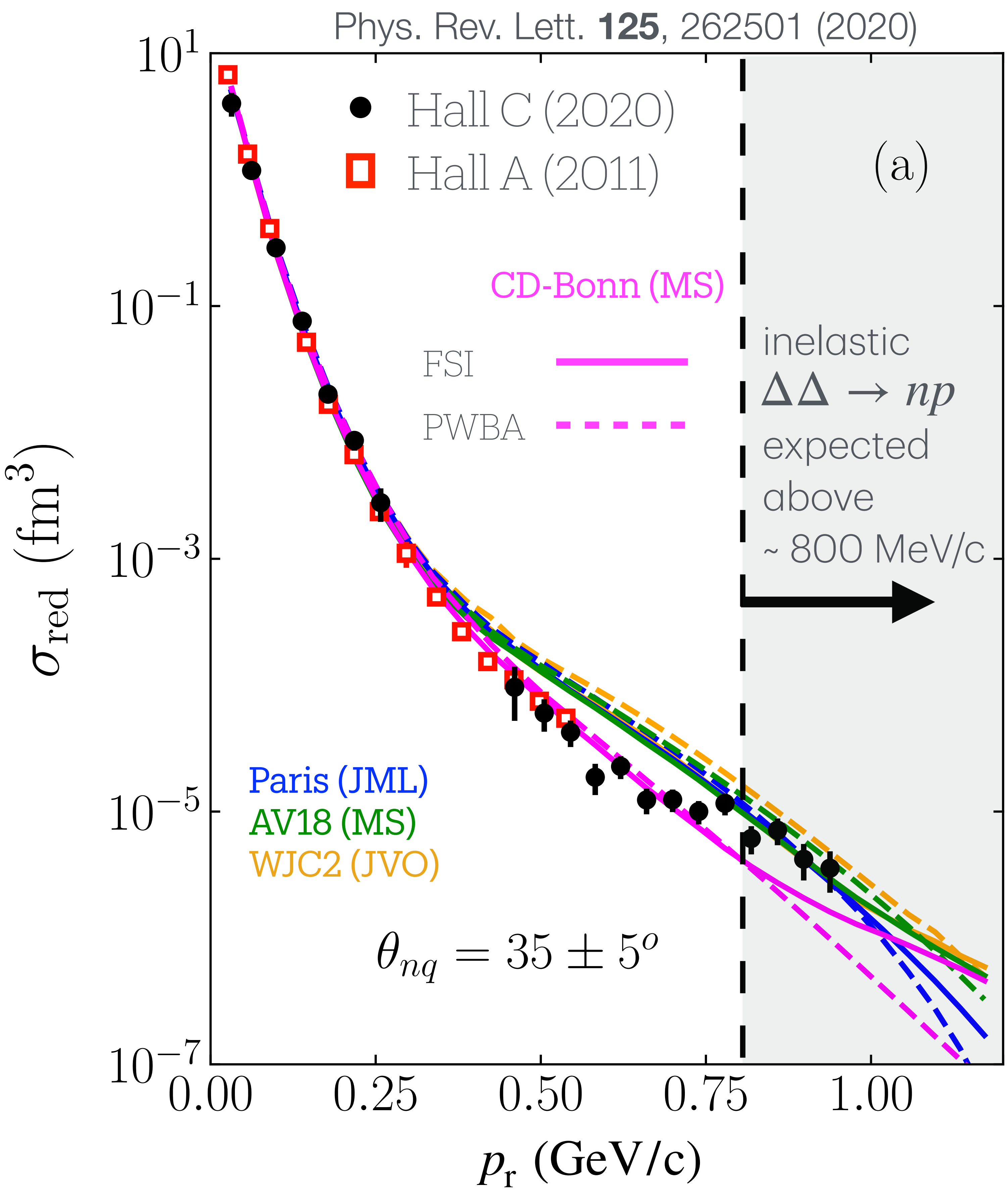


Phys. Rev. B **609**, 49 (Laget 2005)

Phys. Rev. C **78**, 014007 (Orden & Jeschonnek 2008)

Phys. Rev. C **82**, 014612 (Sargsian 2010)

Probing the NN Repulsive Core

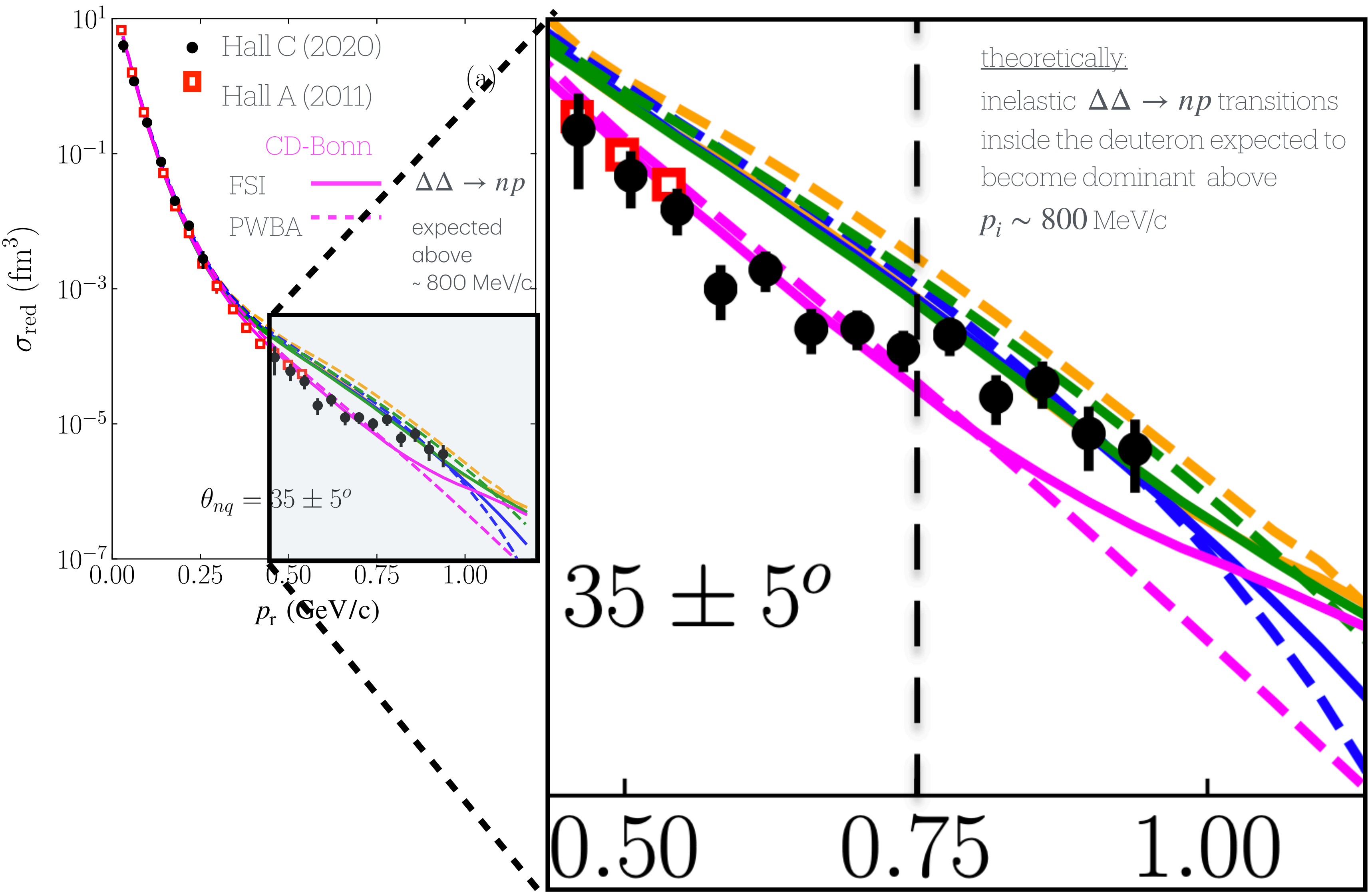


Virtual Nucleon Approximation (VNA)
Theoretical Framework (Sargsian 2010)

- only $pn \to pn$ transitions (non-nucleonic part excluded)
- dynamics of $\gamma^* N$ and FSI (GEA) are relativistic
- $d \to N\bar{N}$ (vacuum fluctuations) neglected; $\Psi_d = \Psi_d^{\rm NR} \times f_{corr}^{rel.}$ (<700 MeV/c vac. fluct. expected to be small)

PRC **82**, 014612 (Sargsian 2010)

Probing the NN Repulsive Core



NO theory calculation reproduces data trend above ~750 MeV/c

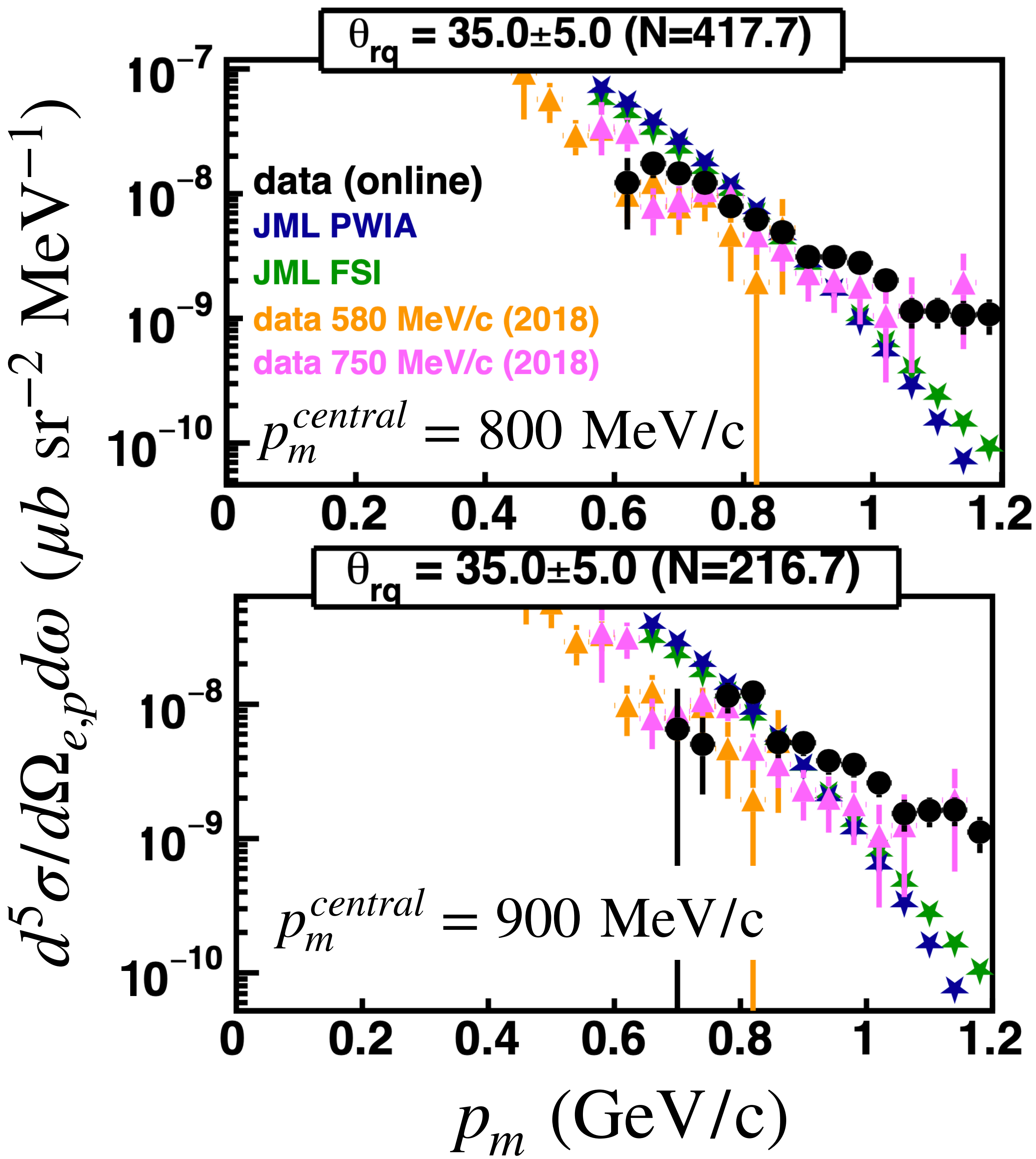
"anomaly" in data starts very close to the threshold of non-nucleonic transitions (~800 MeV/c) of the *NN* system

How to dis-entangle **FSI** + **relativistic** + **non-nucleonic** effects at high missing momenta ?

PRC **82**, 014612 (Sargsian 2010)

PRL **130**, 112502 (Sargsian 2023)

Very Preliminary Analysis of d(e, e'p)n (completed in 2023)

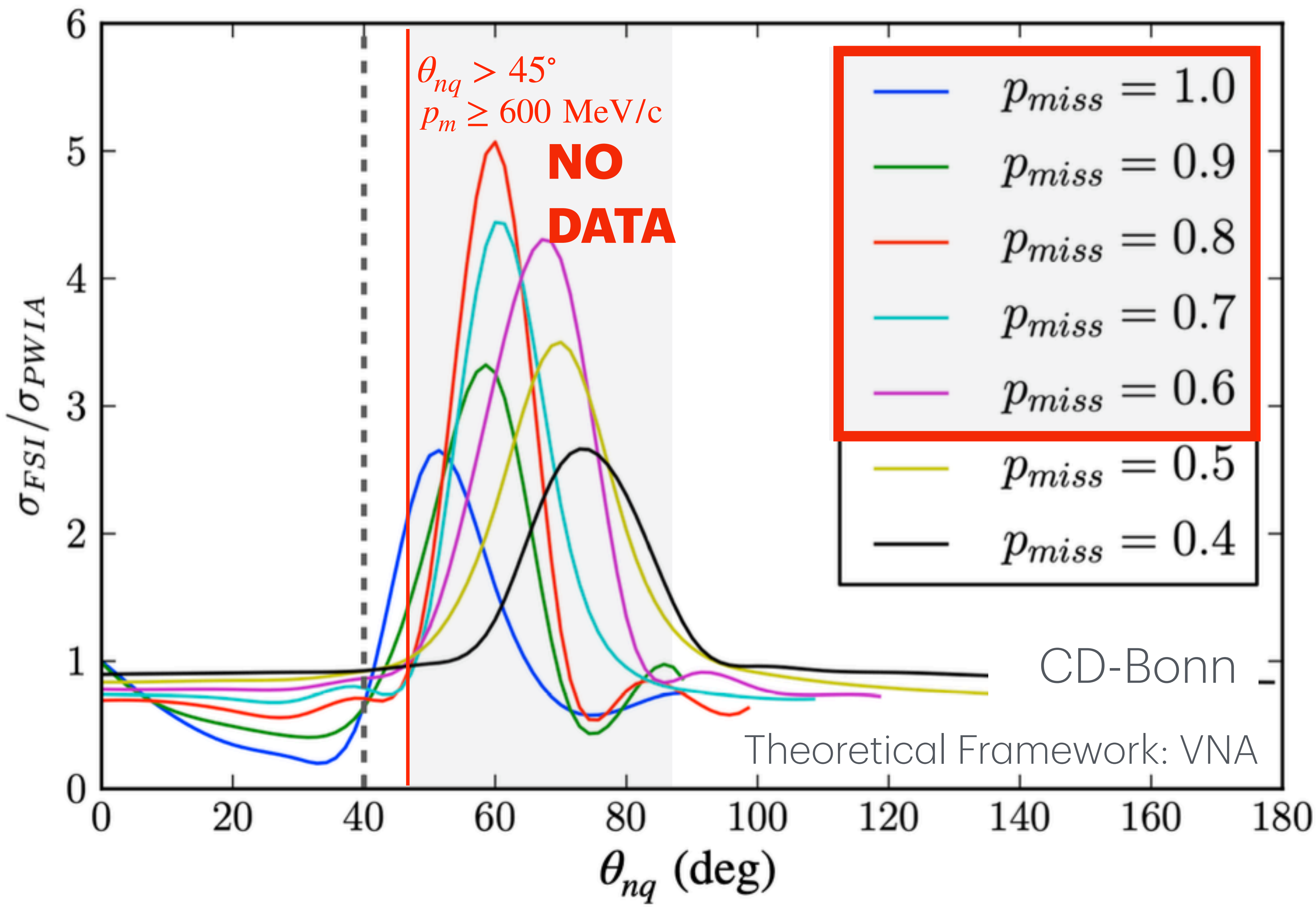


- experiment completed in 2023, extends up to missing momenta ~1.2 GeV
- datasets will be combined for overlapping kin.
- on-going analysis by graduate students:
  - Pramila Pokhrel (CUA)
  - Gema Villegas (FIU)

N: integrated coincidence counts

NN Repulsive Core Sensitivity to FSI

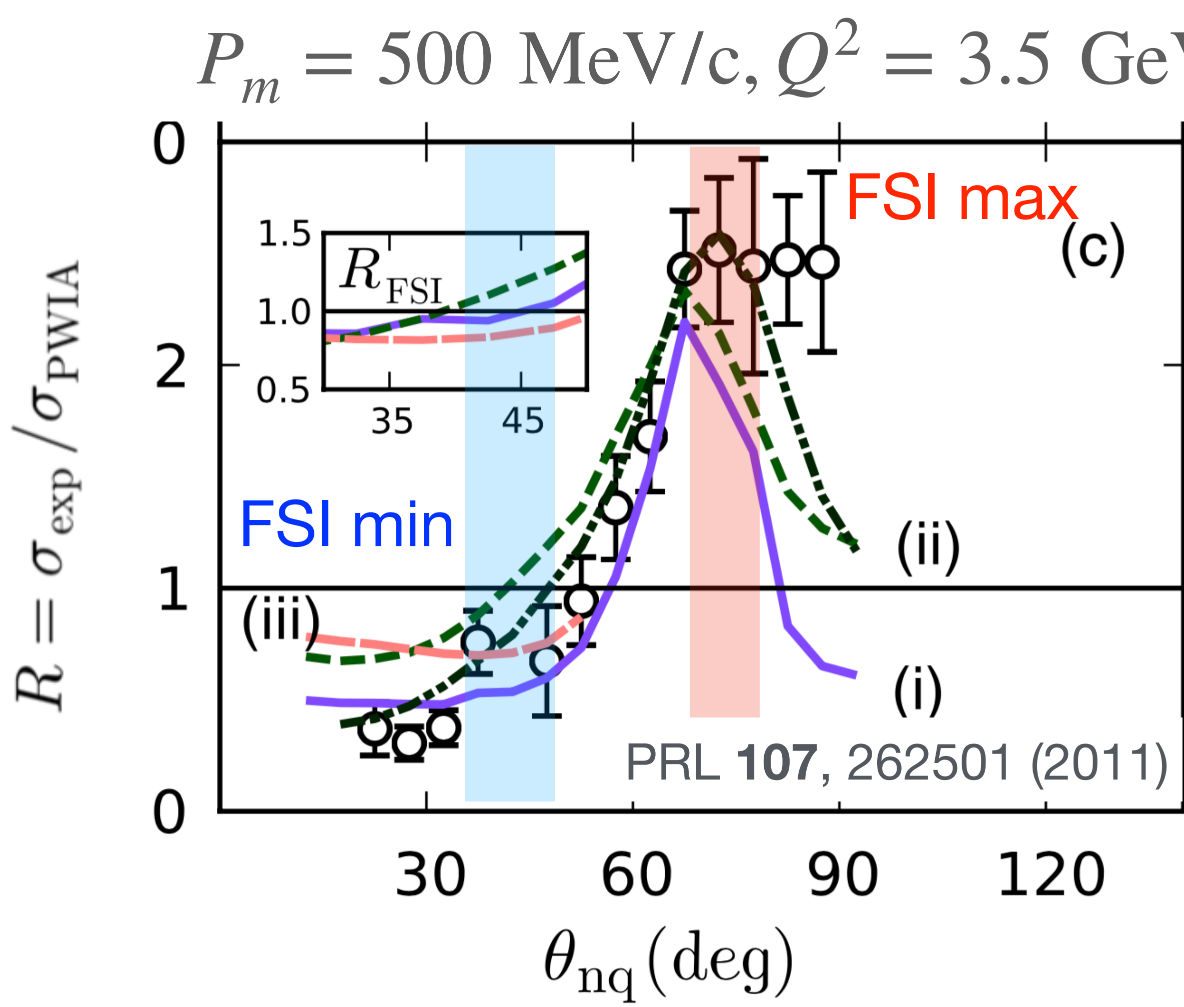
IJMP E Vol. **24**, No. 03, 1530003 (Boeglin & Sargsian, 2015)

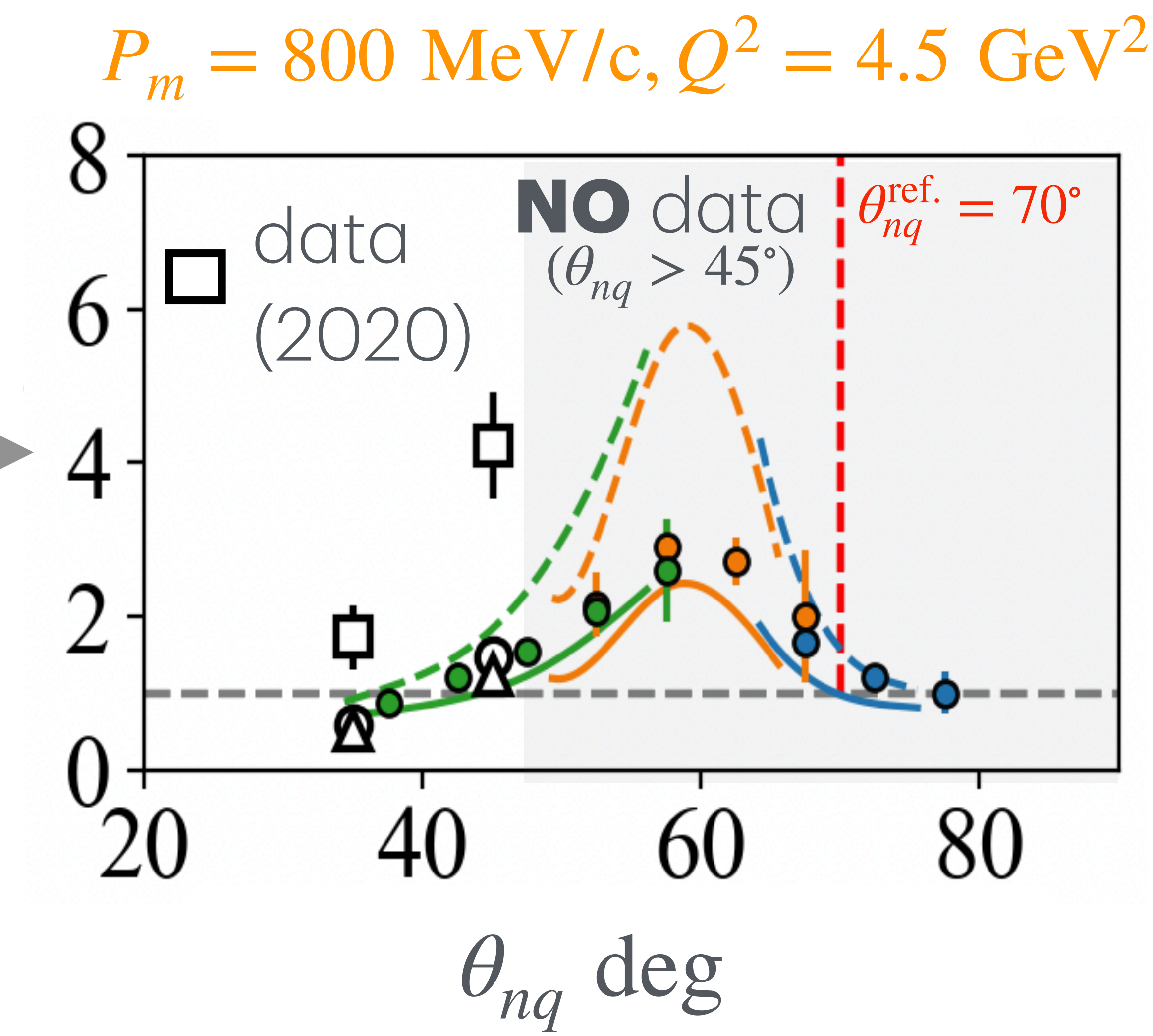


*GEA predict FSI peak shifts towards lower θ_{nq} with increasing p_m

*generalized eikonal approximation: relativistic theoretical framework for FSI calculations

NN Repulsive Core Sensitivity to FSI



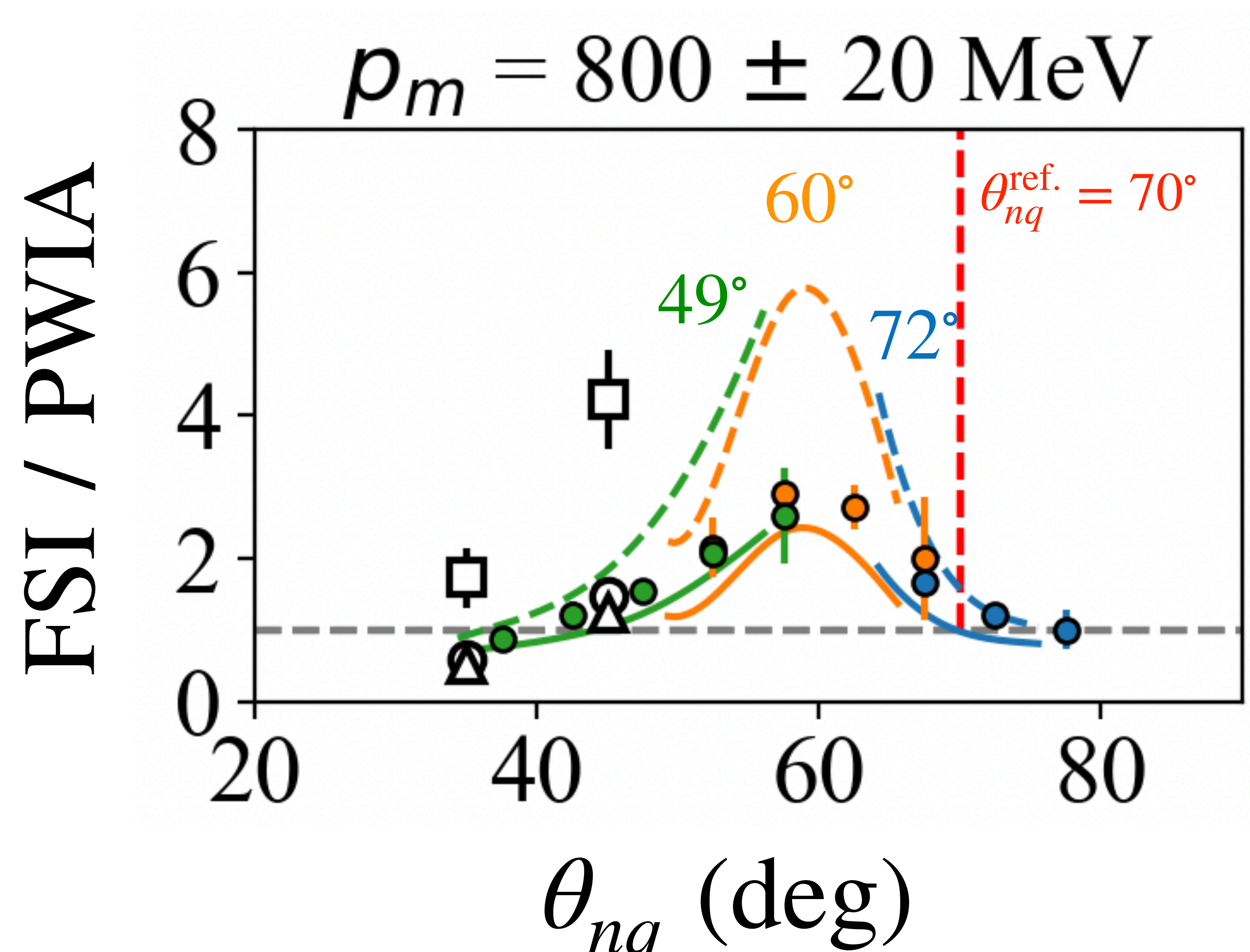


- verify reliability of FSI calculations above $p_m \sim 500$ MeV/c; (required for *NN* core studies)
- check for anomalies in the angular distribution
  - will pn component of the Ψ_d persists at such large internal momenta ?
  - will anomaly observed persist ? emergence of non-nucleonic components ?

This Proposal: Kinematics

target : 10 cm LD_2
E_b = 10.55 GeV
Q^2 = 4.5 $(GeV/c)^2$

p_m (MeV/c)	θ_{nq} (deg)	k_f (GeV/c)	θ_e (deg)	p_f (GeV/c)	θ_p (deg)
500	70	8.151	13.14	3.069	44.17
800	49	8.551	12.82	2.468	54.85
	60	8.151	13.14	2.891	49.27
	72	7.552	13.65	3.516	41.57



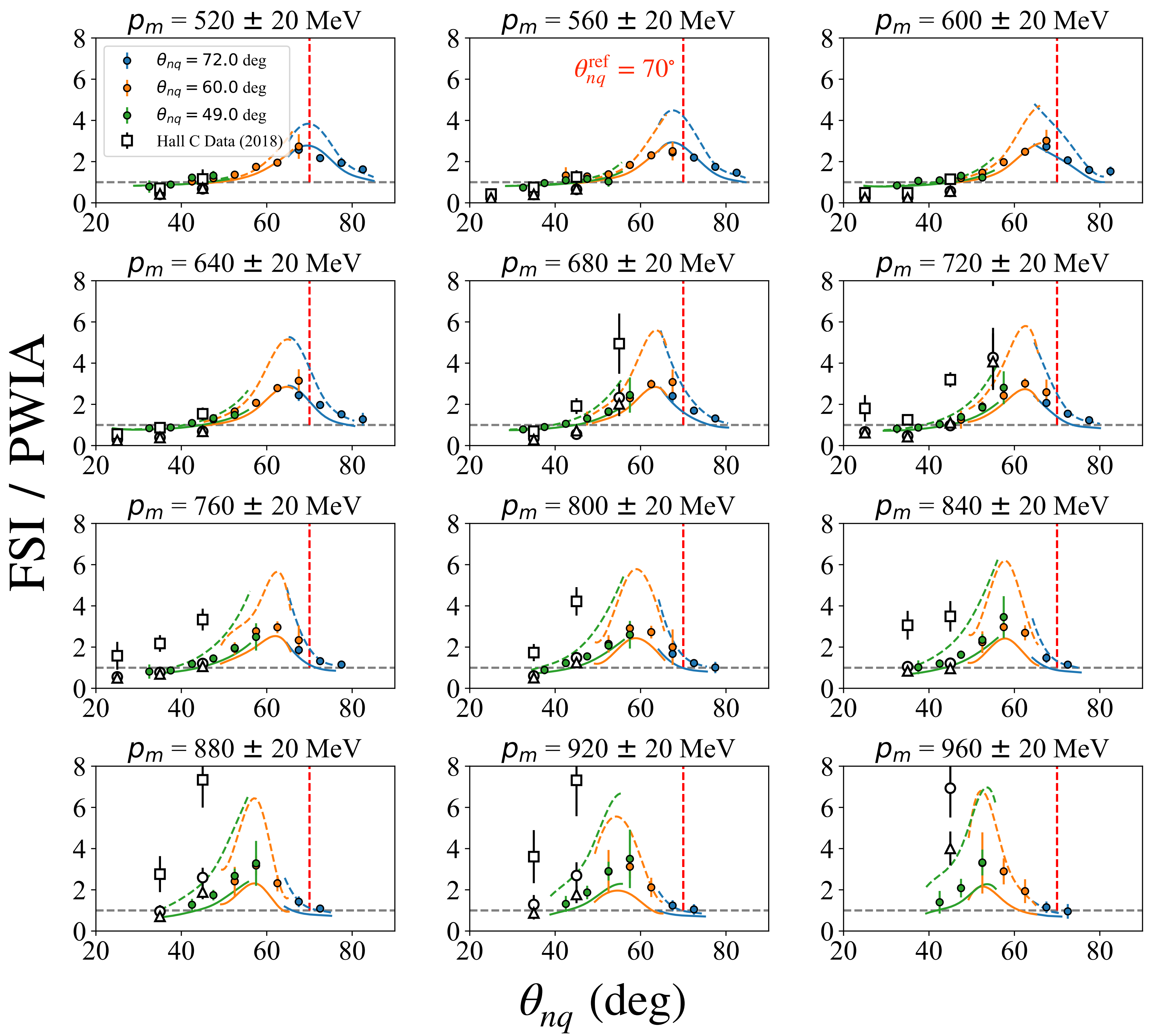
Hall C (2020)

□ $\sigma_{exp}/\sigma_{CD-Bonn}$
△ $\sigma_{exp}/\sigma_{AV18}$
○ $\sigma_{exp}/\sigma_{Paris}$

This Proposal

● JML Paris (SIMC)
— MS AV18
- - - MS CD-Bonn

This Proposal: Projected Angular Distributions



theory calculations predict FSI peak will shift toward smaller θ_{nq} with increasing p_m

(data from this proposal will be able to validate this prediction)

This Proposal: Expected Uncertainties

Statistical: $\sim 10 - 15\ \%$

Systematics:

Normalization: $\sim 3 - 4\ \%$ (BCM calibration, dead time, target boiling, proton absorption)

Kinematical: $\leq 6.5\ \%$ (beam energy, spectrometers momentum / angle)

Our previous $d(e, e'p)n$ measurements at Hall C (Yero 2020 *et al.*), covered the same range of missing momentum as presented in this proposal (~800 MeV/c), in which the **major sources of systematic uncertainties were well below 10 %.** We expect overall systematics to be similar in this proposal, given the similarities in both kinematics and small coincidence event rates (< 1 Hz)

PRL **125**, 262501 (2020)

This Proposal: Beam Time Request

target	current (μA)	p_m (MeV/c)	θ_{nq} (deg)	data-taking (hrs)	overhead (hrs)	
LD2	80	500	70	24	2	
LD2	80	800	49	200	2	
			60	144	2	
			72	160	2	
LH2	80	^{1}H$(e,e'p)$ elastic		8		
C12/LD2/LH2	10-80	target boiling		2		
no target	0-80	BCM calibration		2		
		total		540 (23 PAC days)	8	**548 hrs**

We request a total of **548 hrs (23 PAC days)**

Conclusion and Outlook

experimental objective:

map out the angular dependence of FSI at $p_m \sim 500 - 1000$ MeV/c
over the full θ_{nq} angular range (currently no data exists for $\theta_{nq} > 45^{\circ}$)

test validity of FSI models:

(i) will FSI peak shift towards smaller recoil angles (θ_{nq}) with increasing p_m as predicted by theory ?

(ii) will the inclusion of a relativistic deuteron Ψ^{LC}_{np} fix the anomaly observed above $p_m \sim 750$ MeV/c ?

Novelty of this Proposal:

The proposed experiment seeks to improve our understanding of FSI at high-p_m, a crucial step that will provide a unique opportunity to explore the possibility of discovering non-nucleonic components in the deuteron in a future *NN* repulsive core experiment.

Back-up: Theory Part

Back-up: Difficulty of Probing the NN Core

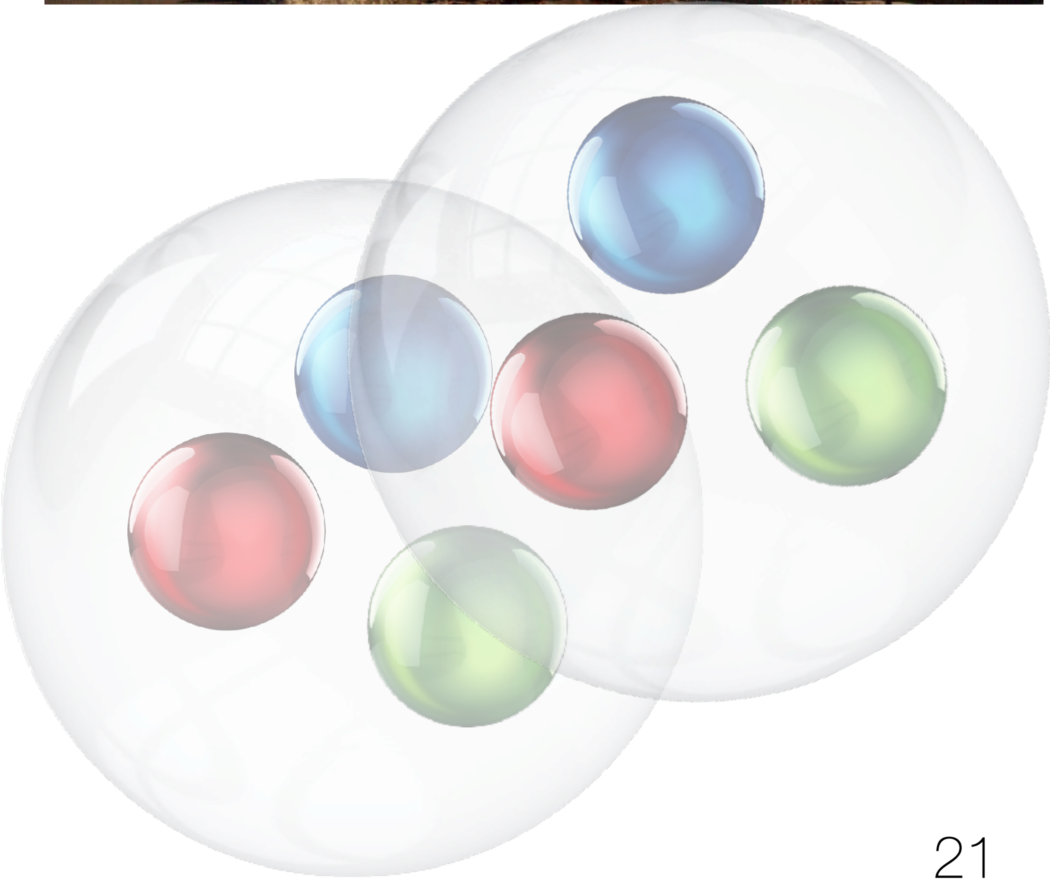
the nuclear core is responsible for the stability for atomic nuclei, without which the matter would collapse, however, since its introduction in the 1960's not much progress has been made

- the most modern *NN* phenomenological potentials based on phase-shift fits to *NN* scattering data use an ansatz for the repulsive core
- attempts to describe the core through vector-meson exchanges face conceptual difficulties, e.g. how to describe < 0.6 fm inter-nucleon distances by meson exchange with comparable or larger radii
- effective field theories faces the issue in which short-distance dynamics of the NN interaction are absorbed in the contact terms which are evaluated by comparing calculations w/ low-energy observables

Ref. "Hole in the Deuteron" (Sargsian 2024) arXiv:2410.08384

implications of probing the deuteron repulsive core in astrophysics

- observing the transition from hadronic to quark-gluons can have implications in astrophysics
  - High temperatures
    - evolution of the universe after the big bang, can be studied in heavy ion collisions
  - Low temperatures (near K~0), high density
    - understanding super-dense nuclear matter at core of neutron stars
    - can help set limits/constraints on matter density in 'Equation of State' models (EoS) before collapsing to a black hole



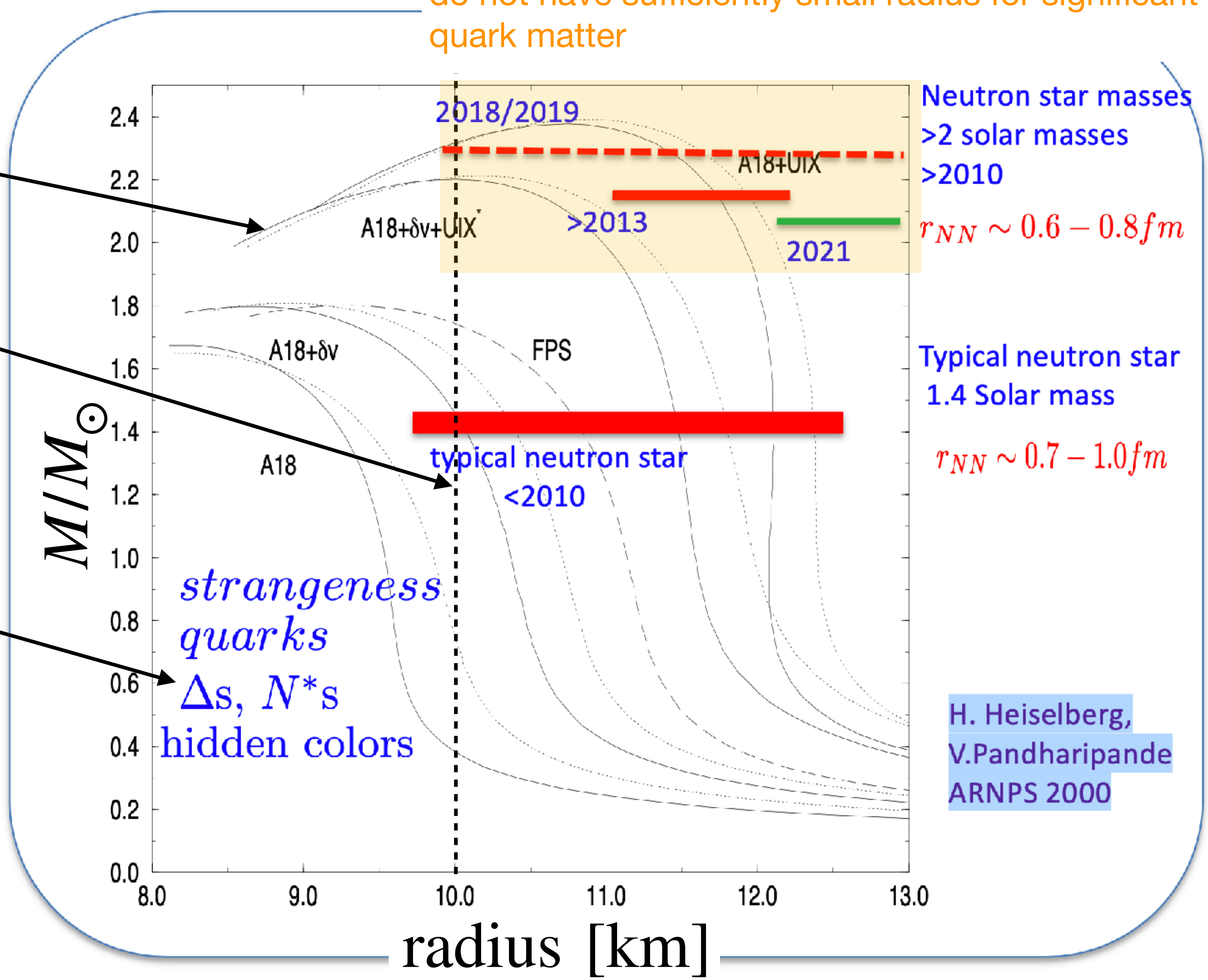
implications of probing the deuteron repulsive core in astrophysics

neutron stars equation of state (EoS) models

large quark matter content expected to occur for neutron stars radii < 10 km ?

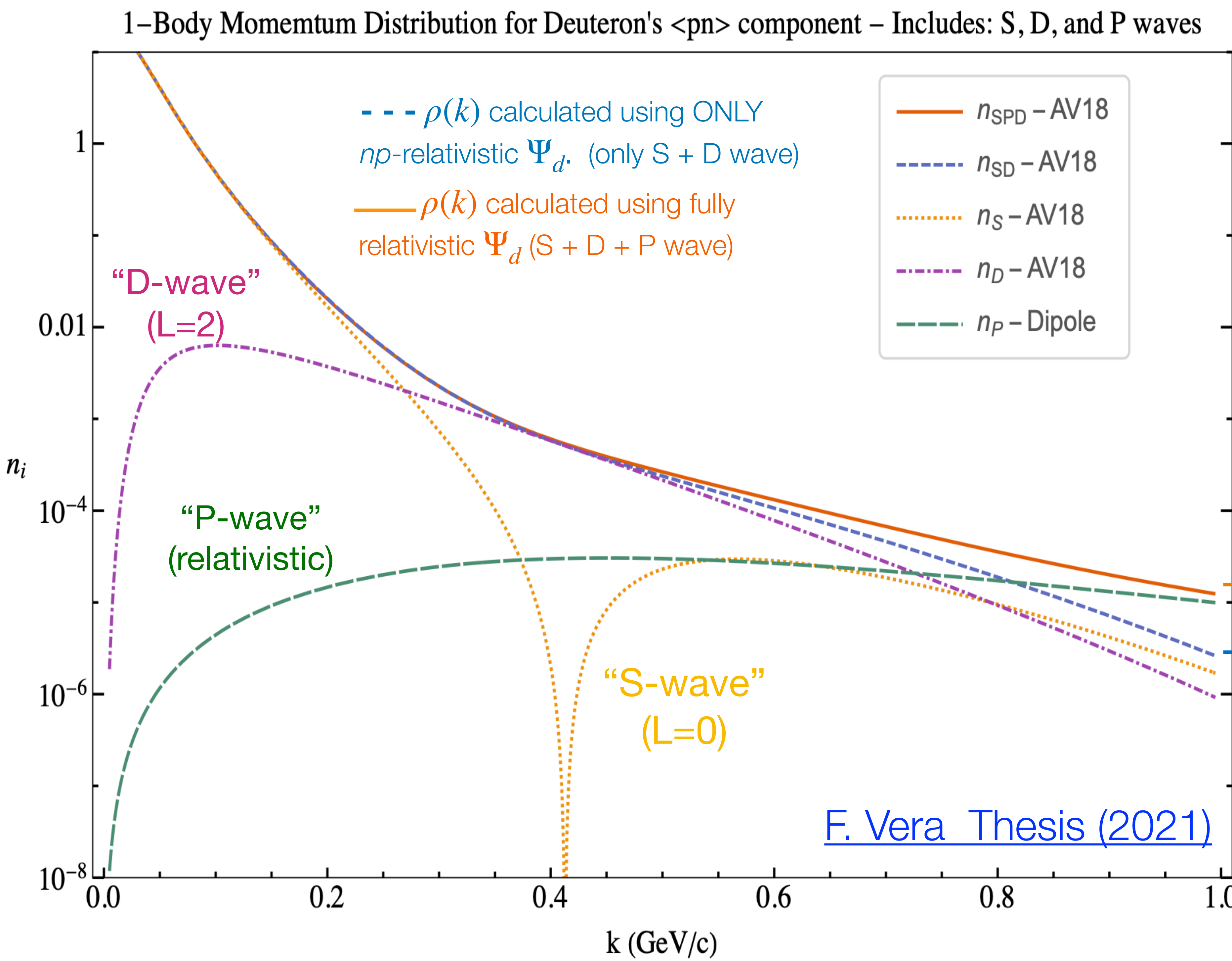
understanding transition from hadronic to quark matter may help constrain EoS for neutron stars and potentially improve accuracy of existing models

recent discoveries of neutron star masses (~$2M_{\odot}$) do not have sufficiently small radius for significant quark matter



Plot adapted from M. Sargsian
ECT* 2022 Workshop in Trento

Probing the NN Repulsive Core: Recent Theoretical Advances



- using a fully relativistic initial-pn state Ψ_d with the inclusion of non-nucleonic components, gives rise to the presence of a 'P-wave' (L=1) like structure (in violation of angular cond.)

- P-wave starts to dominate at $k \sim 800$ MeV/c, characterized by a 'flattening trend' also observed in published data [Yero et al. 2020]

fully-relativistic Ψ_d (*np* + non-nucleonic)

np-relativistic Ψ_d

NN scattering data (phase shift analysis) indicate that *NN* repulsion exist in *S* channel.

Thus deuteron is a good testing ground for the core since it has $^3S_1$ *pn* component. (tensor-pol deut LOI focuses on isolating S-node)

[M. Sargsian & F. Vera Phys. Rev. Lett. 130, 112502 (2023)]

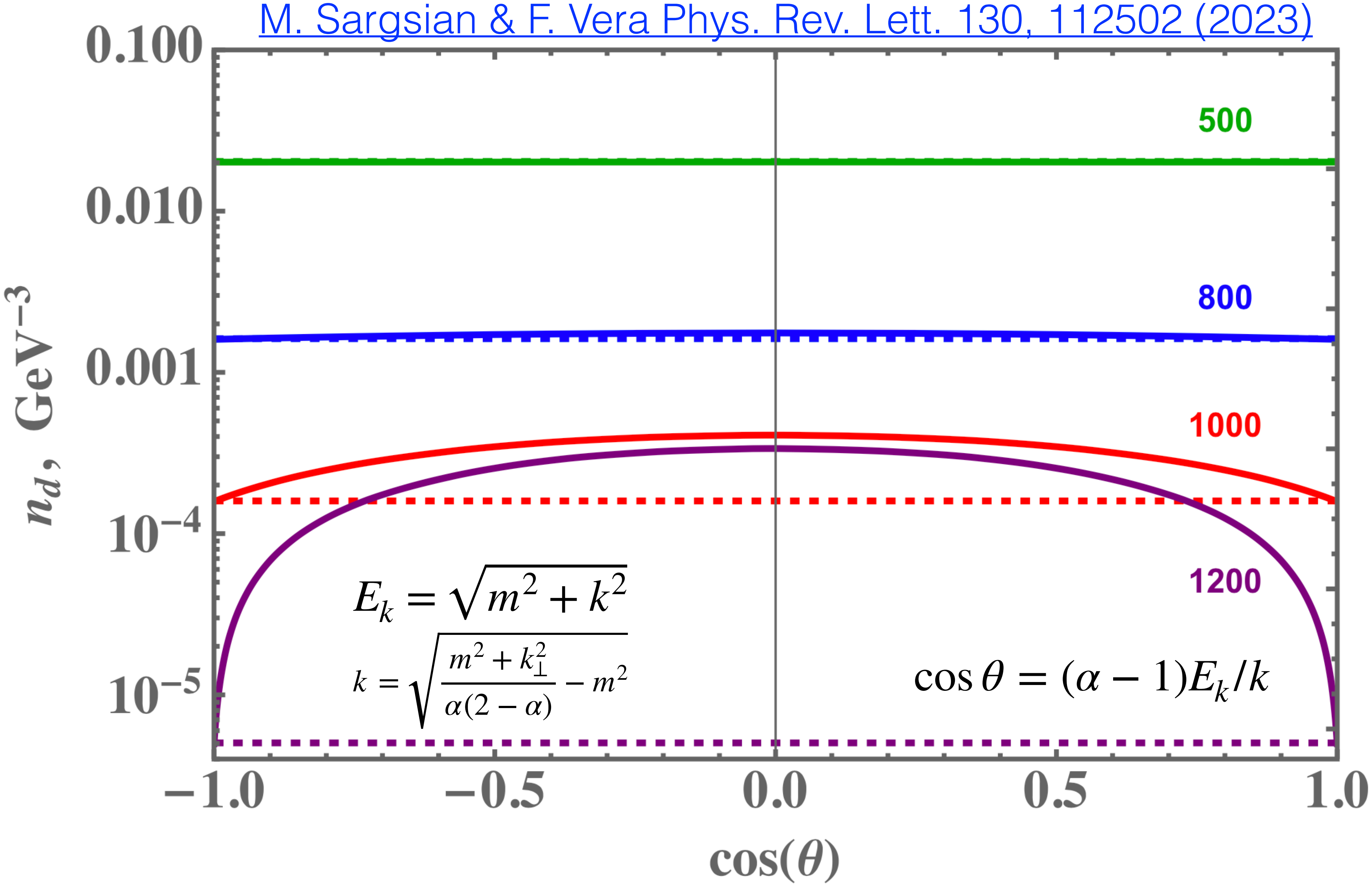
non-relativistic (or) relativistic

relativistic (non-nucleonic)

$$\Psi_d = \boxed{\Psi_{pn}} + \boxed{\Psi_{\Delta\Delta} + \Psi_{NN^*} + \Psi_{hc} + \Psi_{NN\pi} \cdots}$$

Probing the NN Repulsive Core: Recent Theoretical Advances

M. Sargsian & F. Vera Phys. Rev. Lett. 130, 112502 (2023)



Relativistic pn component

P-wave like non-nucleonic component (included)

exp. momentum distributions (light-cone)

$$\frac{d\sigma}{dEe'd\Omega_e d\Omega_s} = K\sigma_{eN}^{\rm LC}(\alpha, p_t)\rho(\alpha, p_t),$$

$$\rho(\alpha, p_t) \approx \frac{\sigma_{exp}}{K\sigma_{eN}^{LC}(\alpha, p_t)}$$

$$\alpha = 2 - \alpha_n,\ \alpha_n = \frac{E_n - p_{n,z}}{M_d/2}$$

where α is the proton light-cone momentum fraction

- In the light-front, if only Ψ_{pn}^{LC} is considered, the momentum distribution only depends on the magnitude of the internal momenta $n_d(k)$, and the angular condition (L=0 or L=2), is satisfied

- Violation of the angular condition gives rise to an additional *P-wave* like (L=1) component, which could only be explained by the emergence of non-nucleonic components in the deuteron w.f. $\Psi_{np+\Delta\Delta'}^{LC}$ giving rise to an additional dependence, $n_d(k, k_\perp)$

Updates on Theoretical Framework for this Proposal

Update from M. Sargsian

We expect Sargsian's light-front calculation of FSI effects employing different NN potentials to be available by the end of this year (2025). This will allow us to update our Monte Carlo simulations with relativistic FSI included in the light-front reference frame, where vacuum fluctuations are suppressed

Update from S. Jeschonnek

We are also communicating with S. Jeschonnek on the prospects of collaborating on her theoretical calculations of the same processes. Her code has a relativistic wave function (Wally Van Orden's model solving the spectator equation [aka Gross equation]), a fully relativistic on-shell positive energy current operator, and the FSI uses all five pieces of the NN interaction (central, single spin flip and three double spin flip contributions), see the Jeschonnek and Van Orden paper, Ref. https://journals.aps.org/prc/abstract/10.1103/PhysRevC.81.014008.

For part of the kinematics in this proposal, there won't be any experimental NN data available, and may have to use a Regge inspired model, see Ford and Van Orden, Ref. https://journals.aps.org/prc/abstract/10.1103/PhysRevC.87.014004 Sabine's code is expected to be running again within a year.

Virtual Nucleon Approximation (a detailed description)

Within the VNA (Ref. Phys.Rev.C 82 (2010) 014612), the spectator nucleon is treated as on-shell and the virtuality is introduced into the electromagnetic current of bound nucleon. This current is relativistic and has a virtuality parameter. Also the deuteron wave function has a flux factor that allows to satisfy baryonic number conservation. If one explicitly introduces the $d \rightarrow N\bar{N}$ transition, then this approximation similar to the Gross approach in the relativistic description of the deuteron. However if one neglects $d \rightarrow N\bar{N}$ (vacuum fluctuation diagram) then one can express the deuteron wave function through the non-relativistic deuteron wave function with additional factor, since normalization of the wave function is defined from the condition that the charge form-factor of the deuteron at $Q^2 = 0$ is equal to 1. In short this is a relativistic approach, in which however we neglected the contribution from vacuum fluctuations. Justification of it is that one expects that vacuum fluctuations should be small for up to 700 MeV/c.

In our published article Phys. Rev. Lett. **125**, 262501 (2020), the theoretical calculations using the AV18 & CD-Bonn NN potentials by M. Sargsian were done within the VNA framework

Phys.Rev.C **82** (2010) 014612

Calculations of Inelastic Thresholds for $\Delta\Delta$, NN_{Roper}, NN^*

particle mass (GeV)

$$M_N = 0.938272$$

$$M_\pi = 0.139$$

$$M_\Delta = 1.232$$

$$M_{\text{Roper}} = 1.440$$

$$M_{N^*} = 1.520$$

Inelastic threshold momenta (GeV/c)

$$k_\Delta = \sqrt{M_\Delta^2 - M_N^2} \sim 0.798$$

$$k_{\text{Roper}} = \sqrt{\frac{(M_{\text{Roper}} + M_N)^2}{4} - M_N^2} \sim 0.730$$

$$k_{NN*} = \sqrt{\frac{(M_{N*} + M_N)^2}{4} - M_N^2} \sim 0.793$$

($NN\pi$ not considered an inelastic threshold) $$k_{NN\pi} = \sqrt{M_N M_\pi + \frac{M_\pi^2}{4}} \sim 0.368$$

pion production threshold is suppressed, the reason being that
(a) $NN\pi$ vertex is proportional to the momentum so slow pion production is suppressed and
(b) $NN\pi$ vertex is hard and gives little contribution.

We know this also from the fact that there are very little pions observed in the nuclear medium.

Back-up: Experimental Part

Expected Systematic Uncertainties

<u>Normalization</u>

- tracking efficiencies / boiling : ~ 1%
- proton loss in HMS : ~ 0.5 %
- total live time / charge : ~ 1-2 %
- target wall contributions : < 3%
- spectrometer acceptance : ~ 1.5 %

<u>total normalization:</u> $\lesssim 4\,\%$

<u>Kinematic</u>

point-to-point uncertainty on:

- beam energy
- spectrometer angles/momentum

<u>total kinematic:</u> $\lesssim 6.5\,\%$

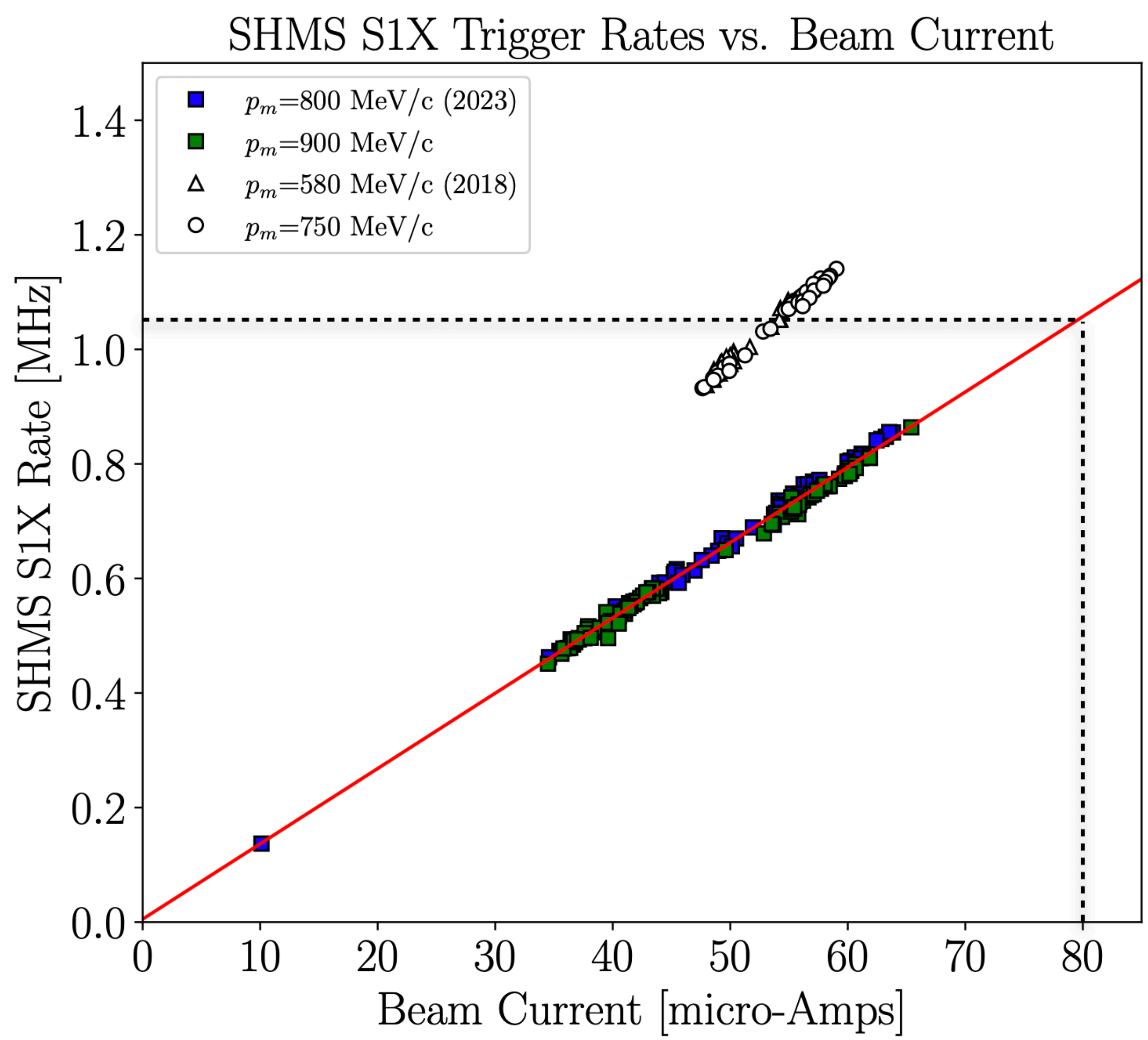
Total Systematic Uncertainty : ~ 7.6 %
(added in quadrature)

Overall Uncertainty: ~ 10-15 % (statistical) + 7.6 % (systematics) **~ 12- 16 %**
(added in quadrature)

systematics based on our published data (at very similar spectrometer settings)

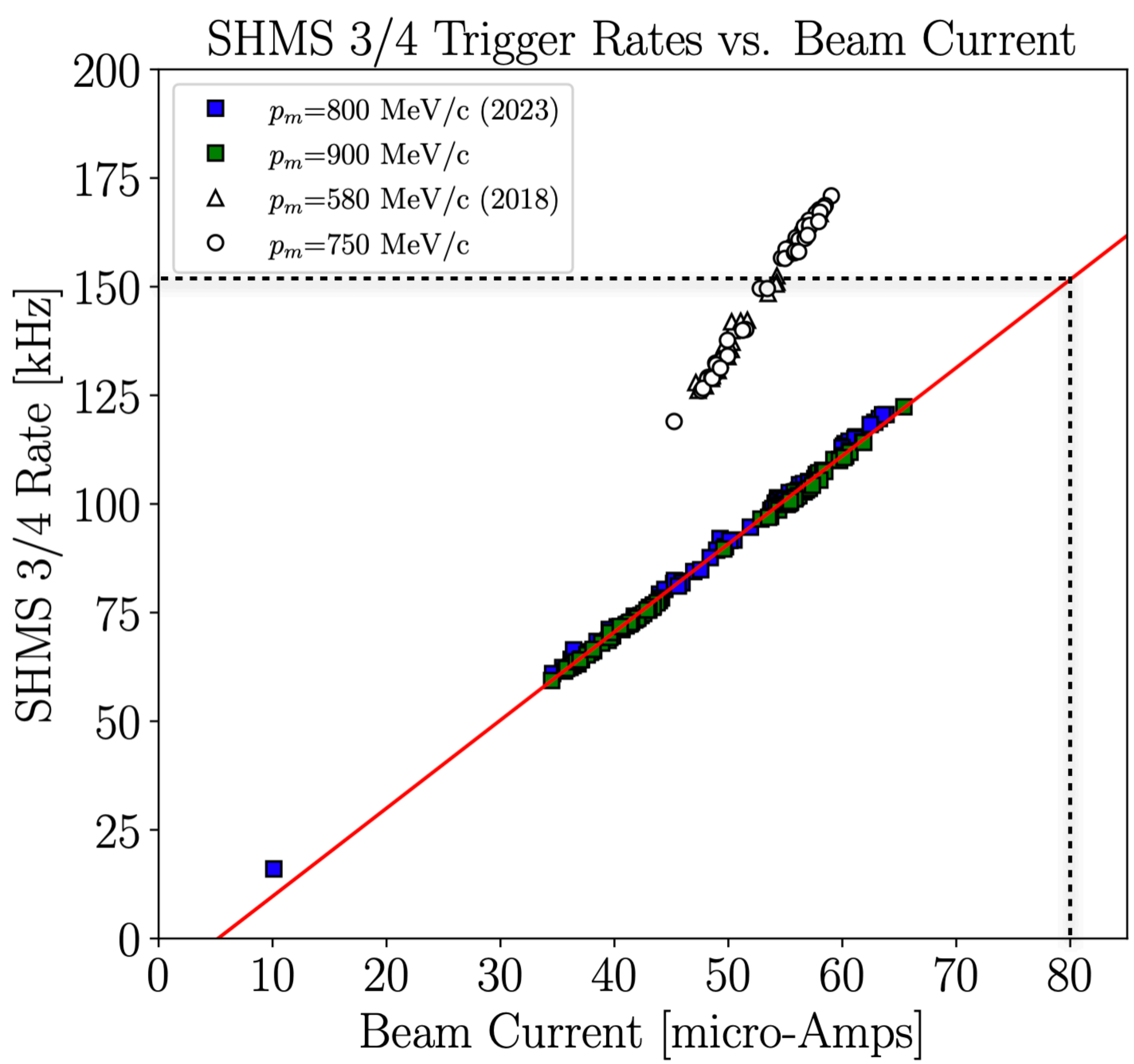
Phys. Rev. Lett. **125**, 262501 (2020)

Experimental Expectations



SHMS S1X rate vs. Beam Current for the deuteron experiment completed in 2018 [14], and the recently completed experiment in 2023 (under analysis).

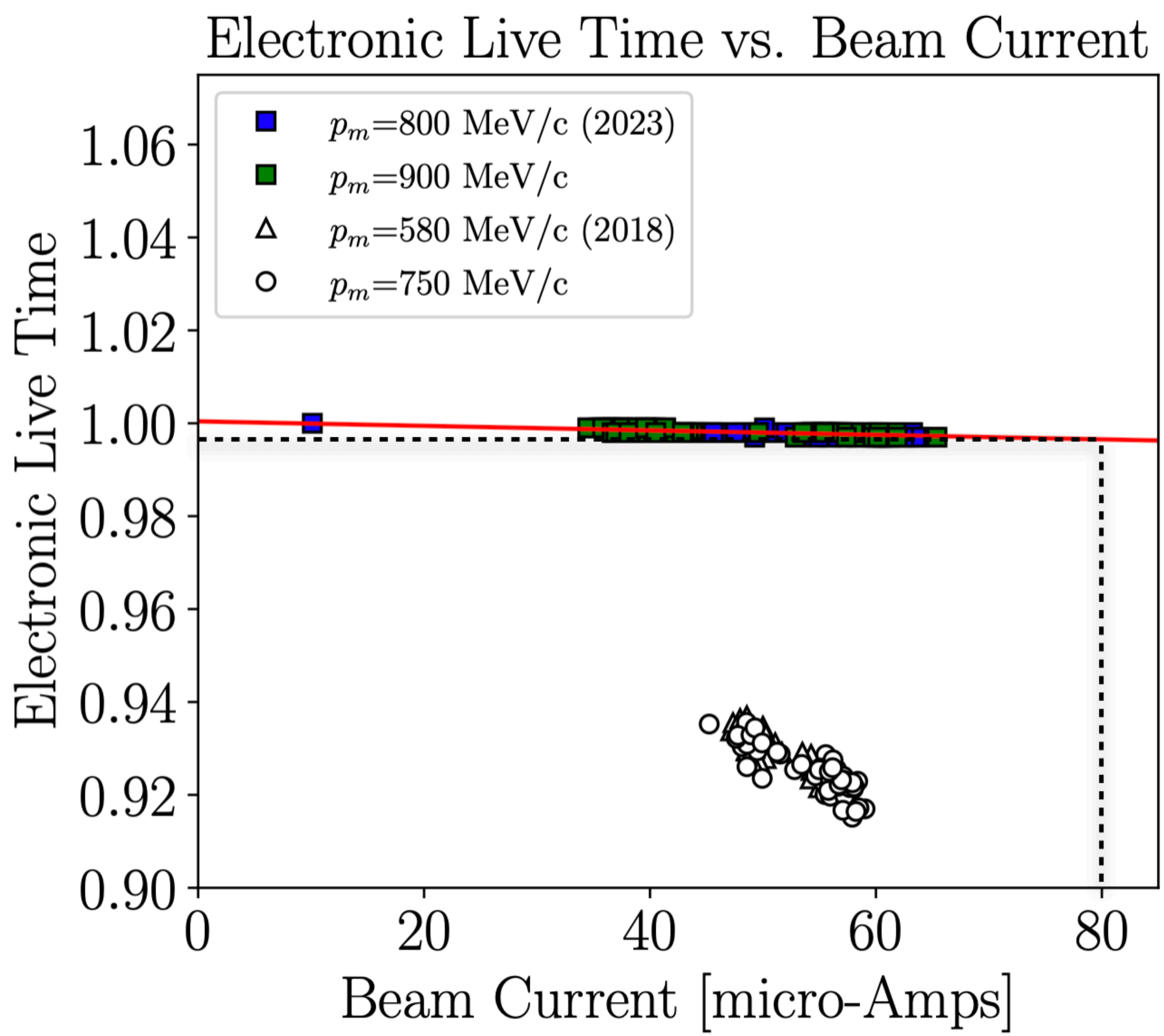
Experimental Expectations



SHMS 3/4 rate vs. Beam Current for the deuteron experiment completed in 2018 [14], and the recently completed experiment in 2023 (under analysis).

SHMS 3/4 is the Hall C standard event-selection criteria requiring at least any 3 of the 4 hodoscopes plane to produce a signal trigger.

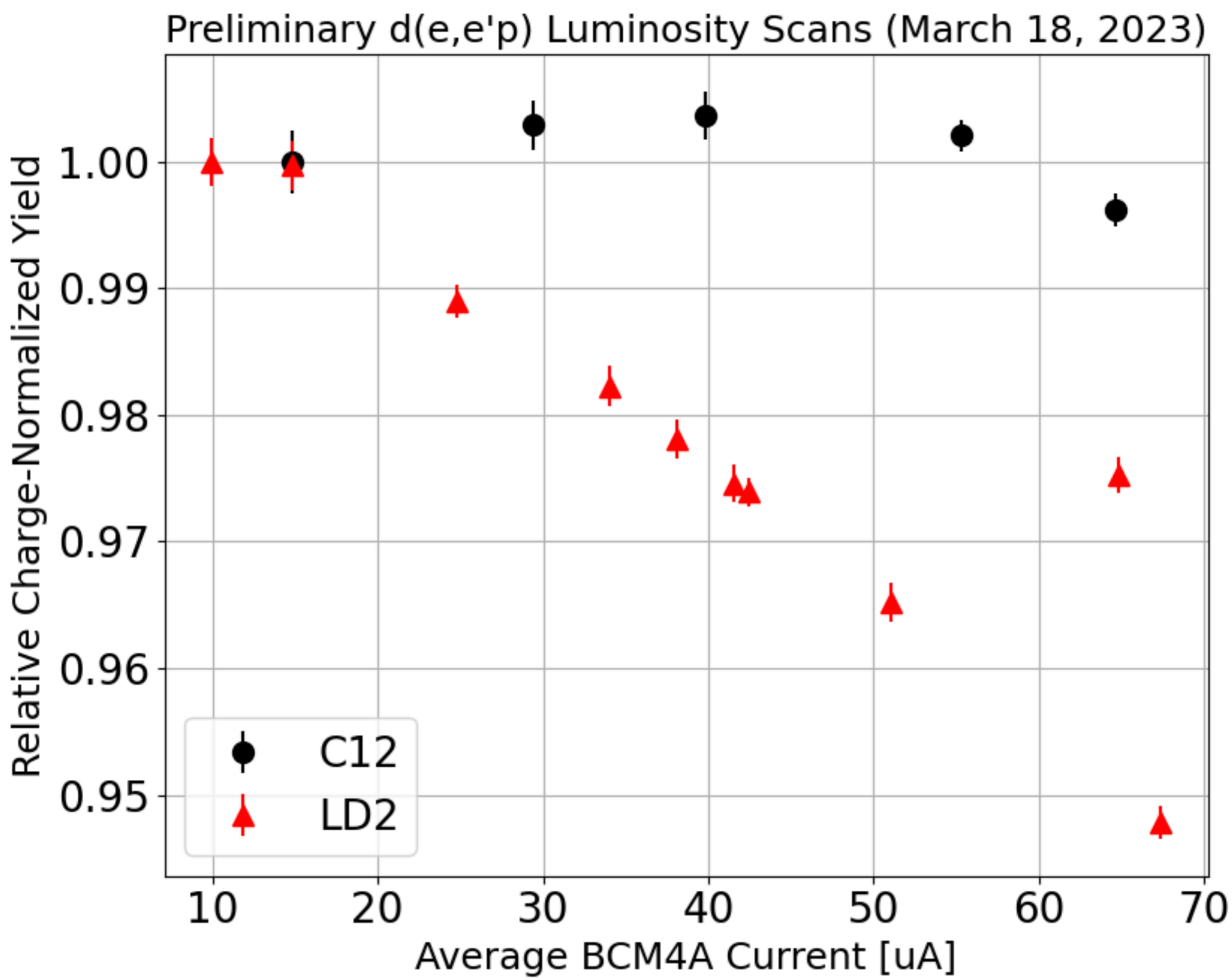
Experimental Expectations



$\tau_{\text{total.LT}} = \tau_{cpu} \text{ x } \tau_{\text{electronic}} \sim \tau_{\text{electronic}}$

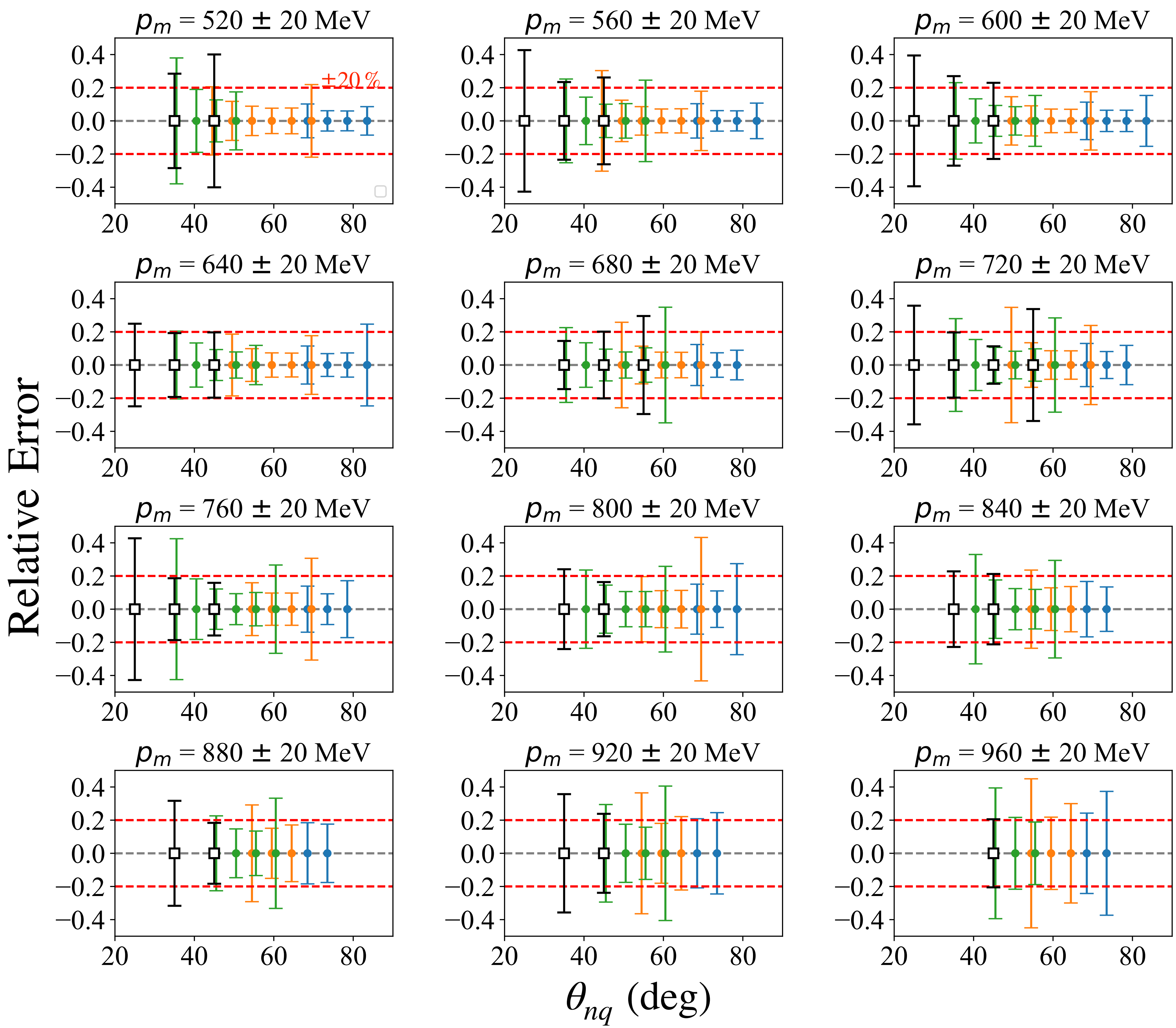
$\tau_{cpu} = 1$ (coincidence trigger rates < 1 Hz)

Experimental Expectations

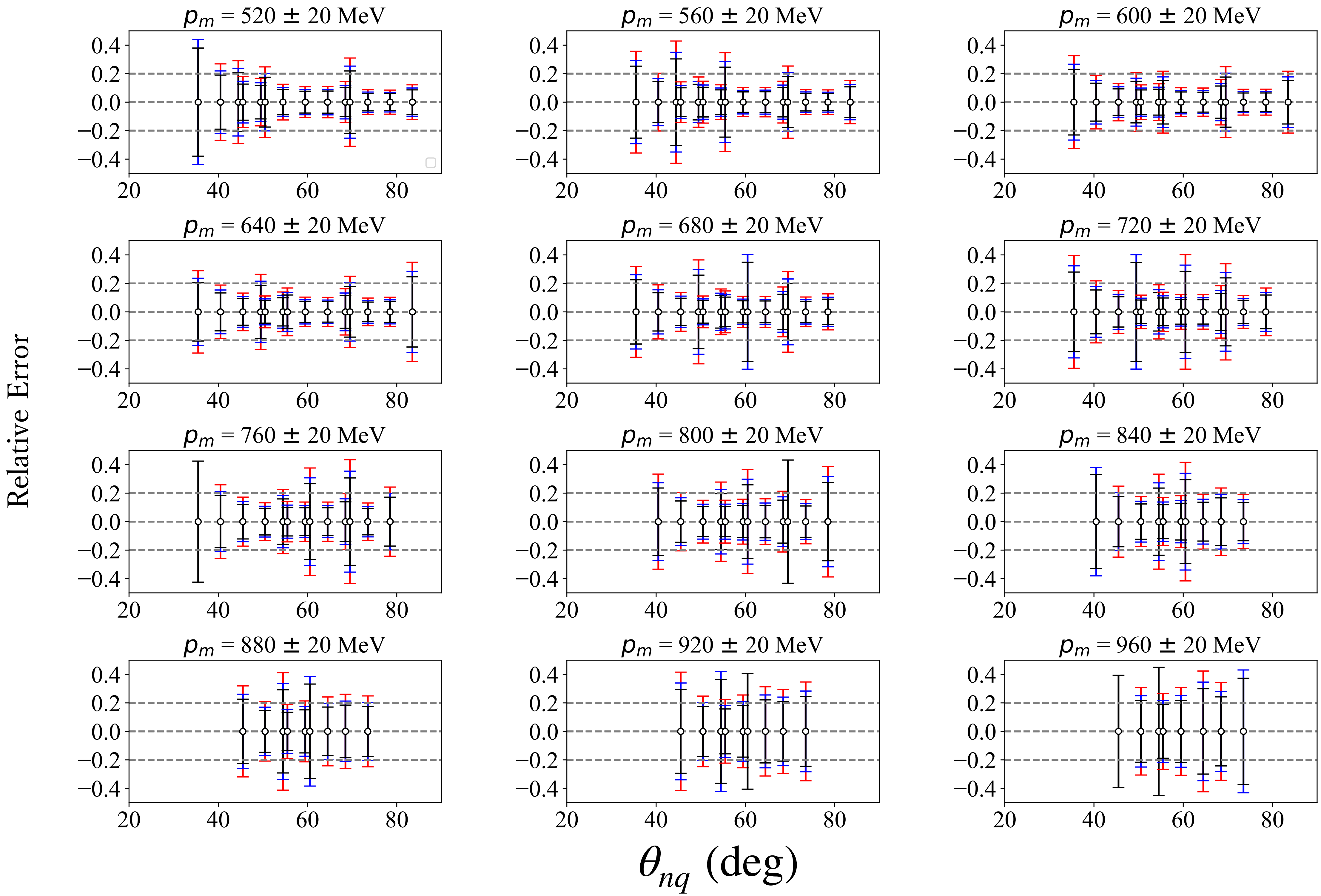


very preliminary target boiling studies for our completed d(e,e'p)n experiment in 2023.

This Proposal: Projected Uncertainties (Statistical)



This Proposal: Beam Current Study on Statistics



Relative statistical errors of the simulation presented in Fig (1) of this response.
The errors were scaled based on: 80 (black), 60 (blue) and 40 (red) micro-Amps.
The dashed outer horizontal lines represent , as a reference.

Expected Radiative Corrections

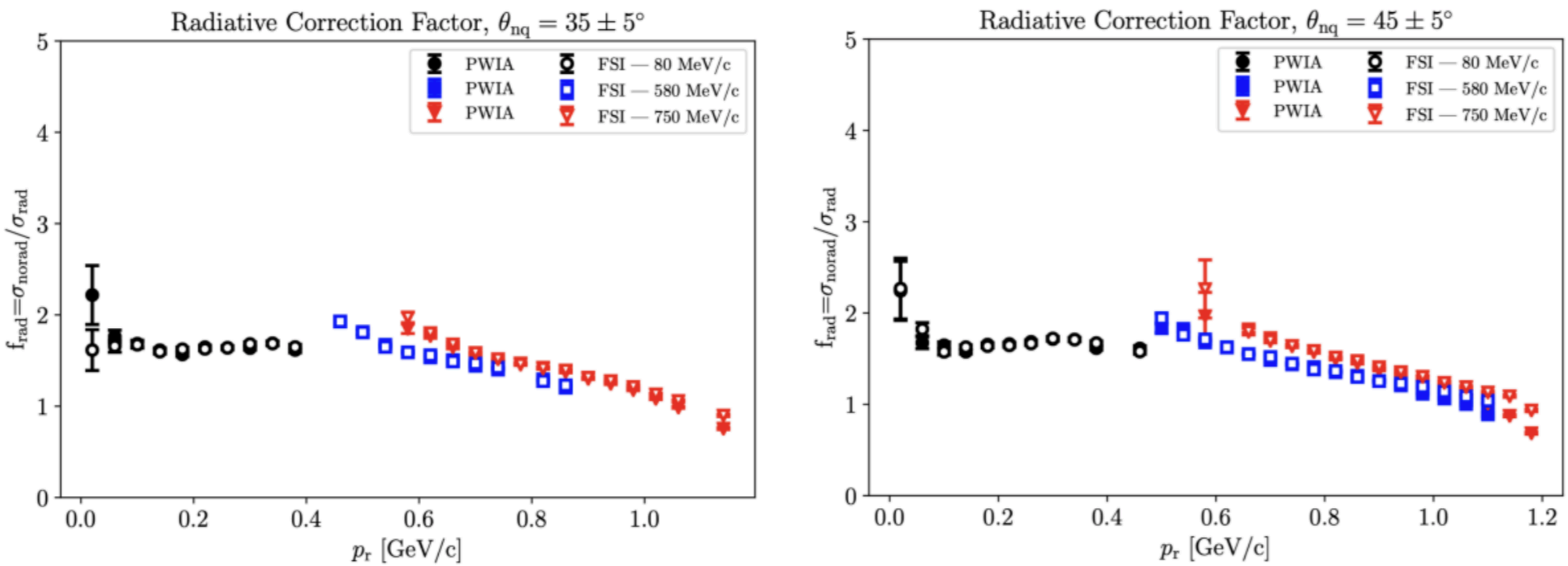


FIG. 10. Radiative correction factor versus neutron recoil momenta, p_r, for $\theta_{nq} = 35°$ (left) and $45°$ (right).

Phys. Rev. Lett. **125**, 262501 (2020)

Expected Bin-Centering Corrections

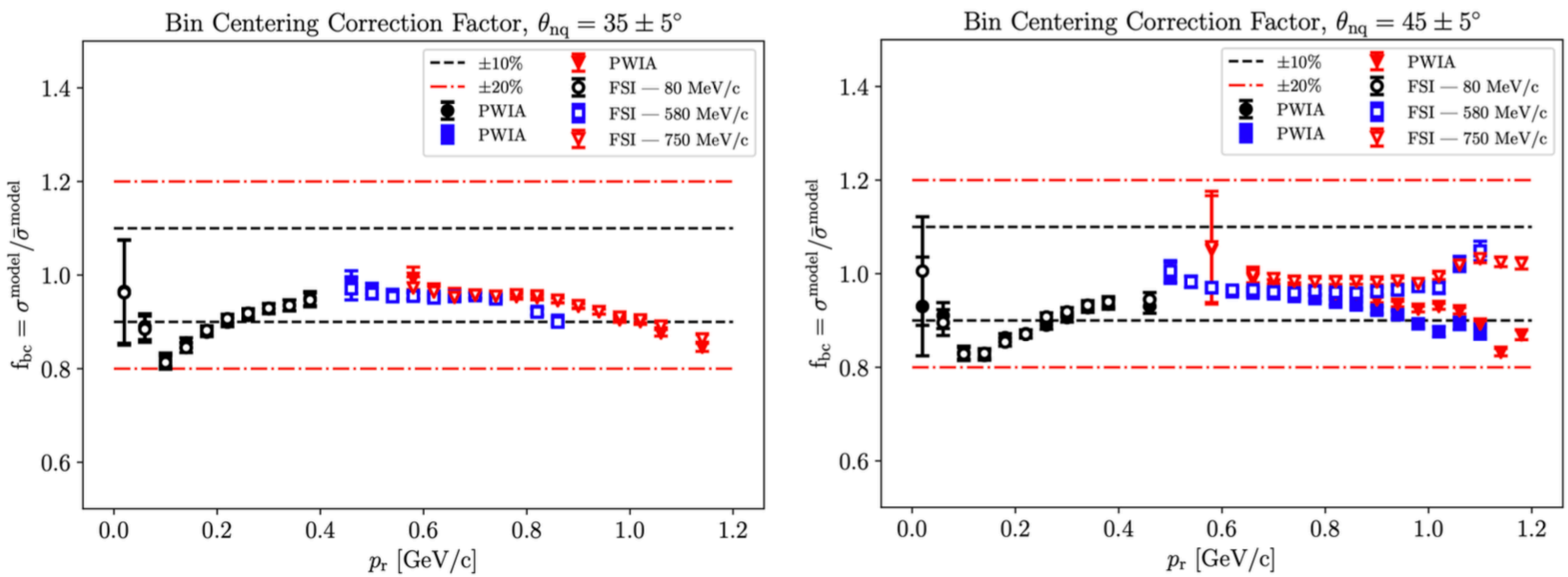


FIG. 11. Bin centering correction factor versus neutron recoil momenta, p_r, for $\theta_{nq} = 35°$ (left) and $45°$ (right). The inner (black dashed) and outer (red dash-dotted) lines represent a percent deviation from unity of ±10% and ±20%, respectively.

Phys. Rev. Lett. **125**, 262501 (2020)

This Proposal: Kinematics

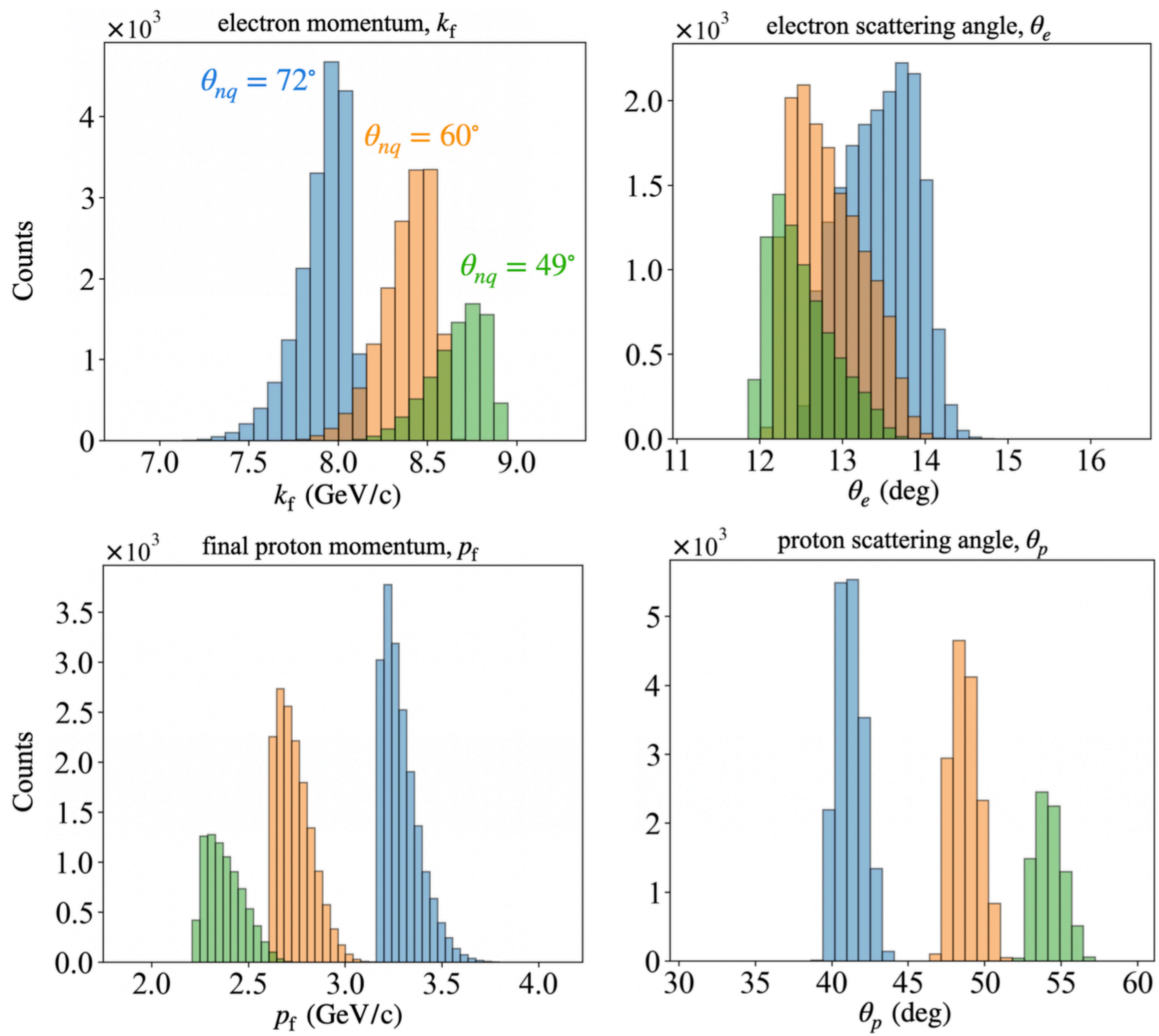


Figure 9: Simulated spectrometer kinematic distributions for SHMS (electrons) and HMS (protons) at 80 μA.

This Proposal: Kinematics

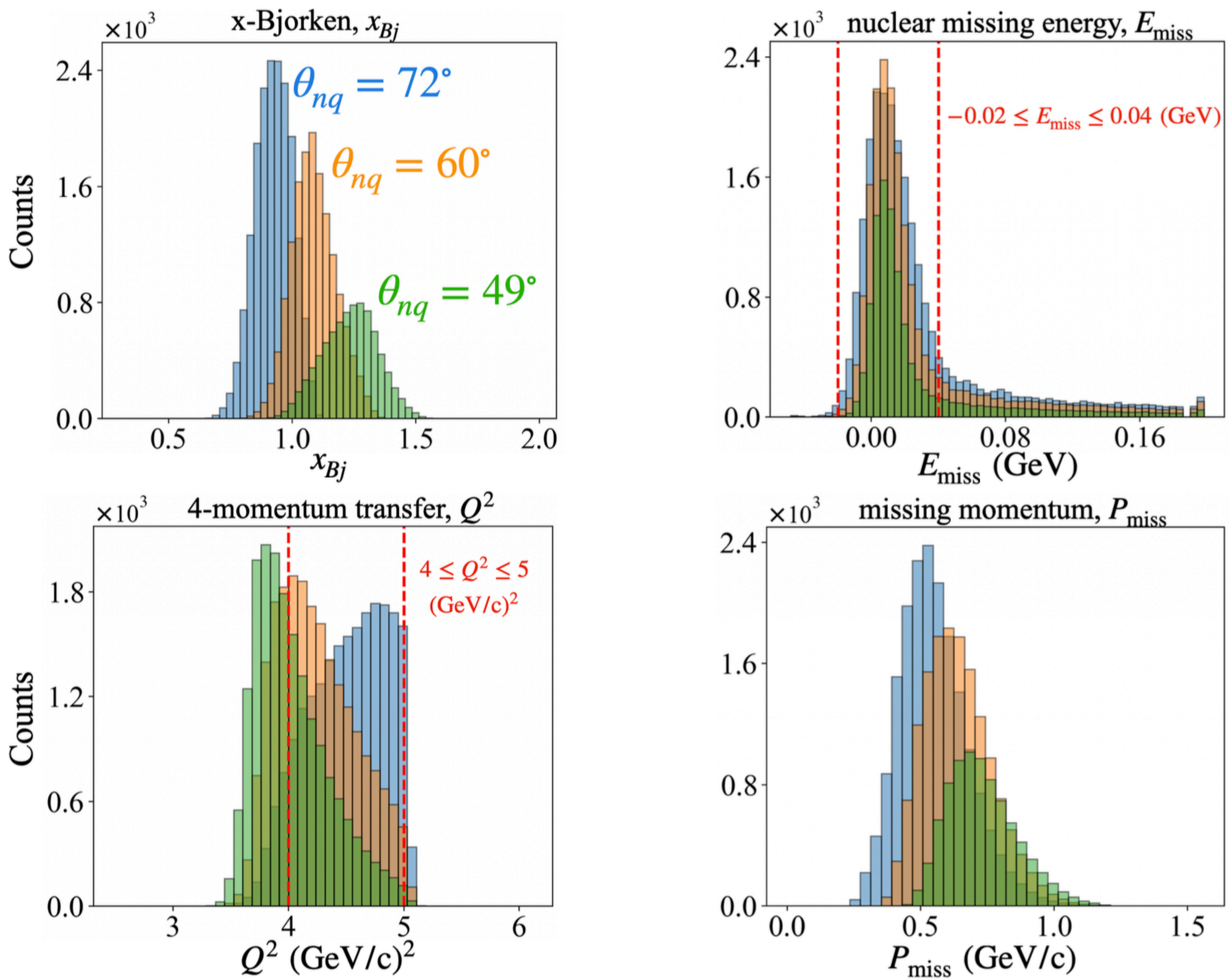


Figure 10: Additional kinematic distributions for x_{Bj} and Q^2

This Proposal: Kinematics

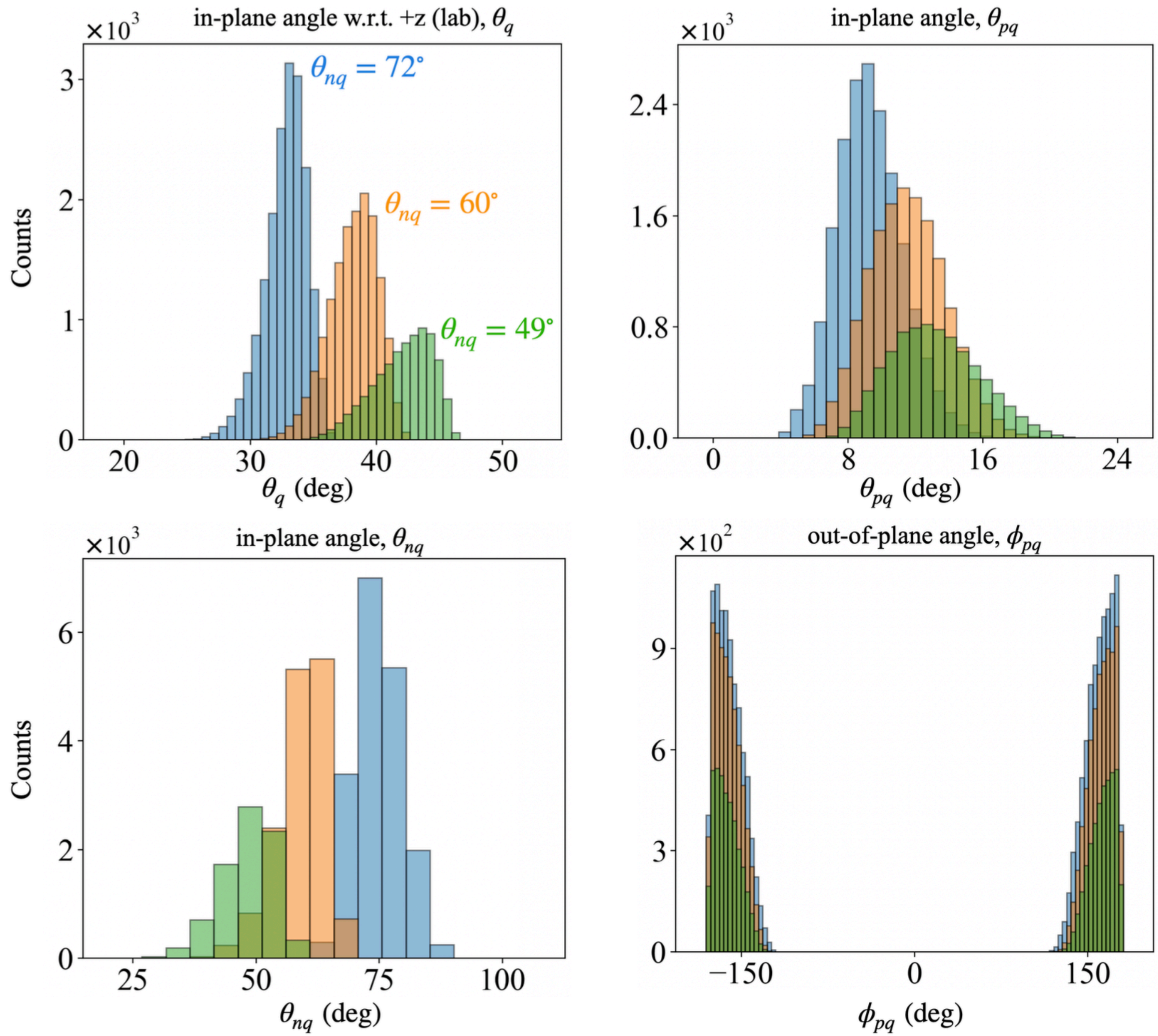


Figure 11: Angular kinematics showing the angles of $\vec{q}$ and the angles of the proton and neutron relative to $\vec{q}$ at 80 μA.

This Proposal: Acceptance

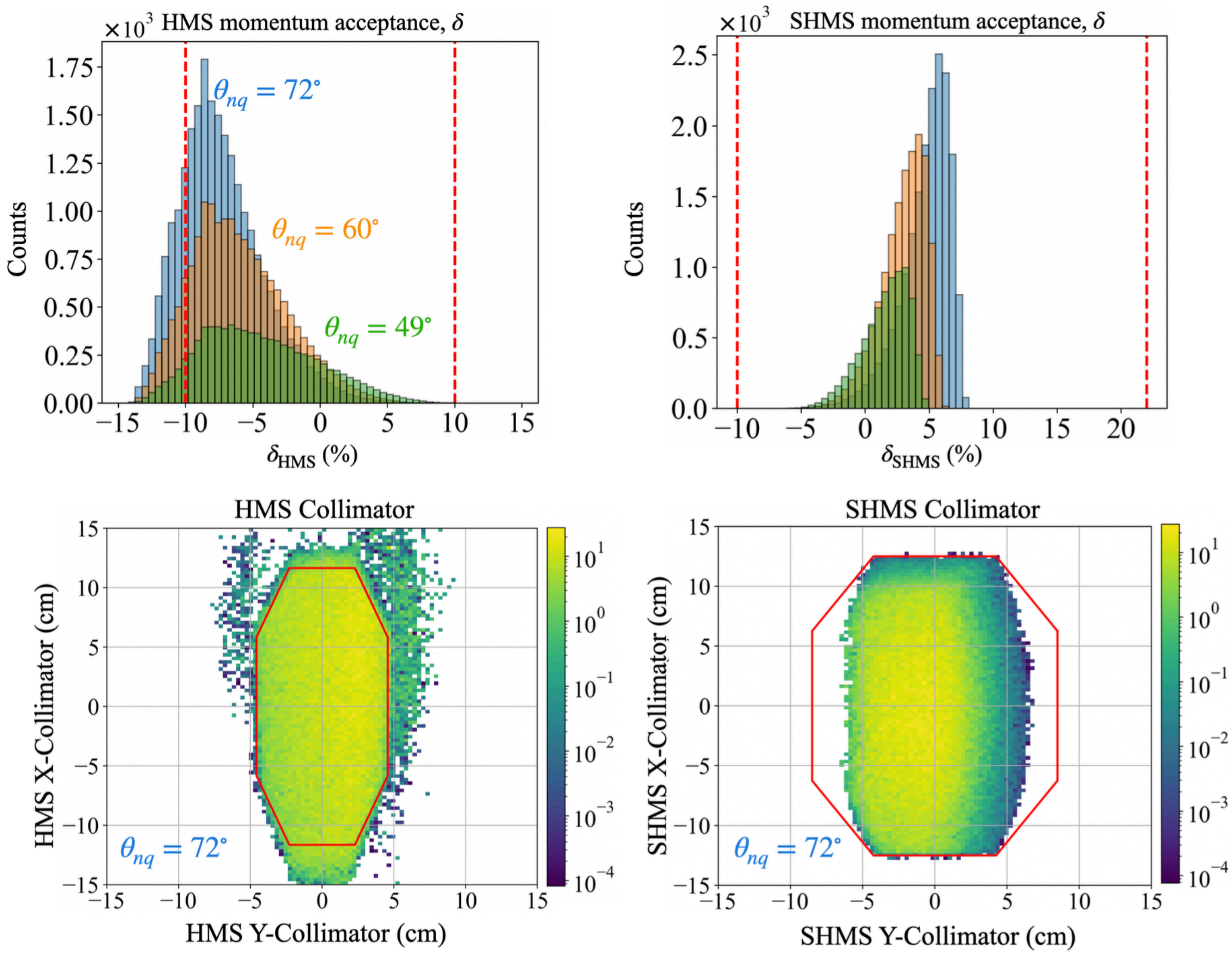


Figure 12: Momentum (top) and angular (bottom) acceptance distributions. The bottom panels show a contour line indicating the collimator geometry boundary; the HMS collimator determine the acceptance of the SHMS, as evidenced by most events in SHMS acceptance falling within the collimator geometry.

PAC 52 LOI Response # 1

6.1.1 Question 1:

So, why invoking "exotic" effects (".. possible indication of the onset of non-nucleonic degrees of freedom...") before having all relativistic corrections under control?

Response:
We agree that one should expect significant relativistic effects for momenta above ~ 800 MeV/c, without attributing it to exotic non-nucleon component in the deuteron. However, as it was predicted in Ref. [15] the existence of non-nucleon components above the *pn* threshold will result in a violation of so-called "angular condition", in which case the extracted light-cone momentum distribution of the deuteron will depend on light cone momentum k and its transverse component $k_\perp$ independently. Or in other words the non-polarized momentum distribution will depend on the direction of the internal momentum of the deuteron on the light-front. Even for the most relativistic case, if deuteron consists of proton and neutron only, the angular condition is satisfied and light-cone momentum distribution depends on the magnitude of k only. However, the existence of non-nucleonic component in the deuteron will result in an angular anisotropy [15]. Thus to obtain the signature of non-nucleon component the experiment needs to isolate the light-cone momentum distribution of the deuteron without effects of final-state interaction at different angles of recoil neutron. As a result, exploring the possible onset of non-nucleonic degrees of freedom in the deuteron requires a solid understanding of final-state interactions at bound nucleon momenta above ~ 800 MeV/c.

As such this proposal does **not** focus on searching for non-nucleonic components, but rather focuses on investigating the angular dependence of final-state interactions with θ_{nq} at momenta where non-nucleonic effects are expected to emerge in the ground state of deuteron wave function, i.e., ~ 800 MeV/c, (above the inelastic threshold of *pn* system) as there is currently **no** data that explores FSI in this region.

[15] PRL **130**, 112502 (2023)

PAC 52 LOI Response #2

6.1.2 Question 2:

In all previous experiments, and in the simulation discussed in Fig.12(Fig.14 in PAC 53 proposal), there seems to be a specific angle, theta_nq $\sim$ 40 deg, at which FSI "switch off", irrespective of the kinematics explored (small or large pmiss, it does not matter). Since the indication instead is for a peak of FSI over PWIA shifting with pmiss, I'm wondering if there is any special reason for this 40 deg. angle. If there were one, it could solve the main problem raised in the LOI (= switch off FSI) without any additional measurement...

Response:

Experimentally, there is **no** angle at which FSI are "turned off". The mention of a specific angle $\theta_{nq} \sim 40°$ just refers the central value of a broader angular region at which FSI are suppressed. There are only certain angular regions in which FSI are the dominant contribution to the $d(e, e'p)n$ cross-section, and there are other regions in which FSI are suppressed, mainly at forward ($\theta_{nq} \lesssim 40°$) and backward ($\theta_{nq} \gtrsim 120°$) angles. At backward angles, the kinematics are inelastic ($x_{Bj} < 1$) and intermediate nucleonic excitations like Isobar contributions contribute significantly to the cross-section, whereas at forward angles, $x_{Bj} > 1$, the PWIA becomes the dominant contribution to the $d(e, e'p)n$ cross-section.

The suppression of FSI at $\theta_{nq} \sim 40^0$ is due to cancellation of PWIA-FSI interference term with the $|FSI|^2$ term. This is a feature of eikonal (high energy) regime of FSI in which case pn rescattering amplitude is mainly imaginary and as a result Real part of the $iA_{FSI}A_{PWIA}$ interference term is negative, cancelling the $|A_{FSI}|^2$ term. As a result of this cancellation the cross section in this case is dominated by $|A_{PWIA}|^2$ term. This cancellation is in a fairly broad range of θ_{nq} and p_m. It was investigated in Ref. [1] within generalized eikonal approximation (GEA) and has been found that its position is defined by the average characteristics of the deuteron, pn re-scattering amplitude and kinetic energy of recoil particle. In the most simplified version (assuming single exponential form of the deuteron wave function) the cancellation happens at the transverse momentum of recoil nucleon:

[1] IJMP E Vol. **24**, No. 03, 1530003 (Boeglin & Sargsian, 2015)

PAC 52 LOI Response #2 (cont.)

$$p_{r\perp} \sim \sqrt{\frac{1}{\alpha_d}\ln\frac{32\pi\alpha_d}{\sigma_{pn}} + \frac{B_{pn}M_N^2}{2}\Delta^2},$$

where σ_{pn} is the total cross section of pn scattering, $\alpha_d = \frac{r_{rms}}{2p_{rms}}$, where r_{rms} and p_{rms} are RMS values of deuteron radius and internal momentum, B_{pn} is the exponent of the pn scattering amplitude presented in the diffractive form, M_N - is the mass of the nucleon, and $\Delta = \frac{q_0}{q}T_r$ where T_r, q_0 and q are the kinetic energy of the recoil nucleon, energy and momentum of the virtual photon respectively. Note that the Δ term accounts for the non-zero momentum of the of the scatterer in the deuteron which is not accounted in the standard Glauber approximation [34].

It is important to note that the angular dependence of the cross-sections on FSI has only been measured for recoil neutron momenta up to $\sim$ 500 MeV/c [12], and predictions made about the suppression of FSI above $\sim$500 MeV/c can be checked in the proposed experiment.

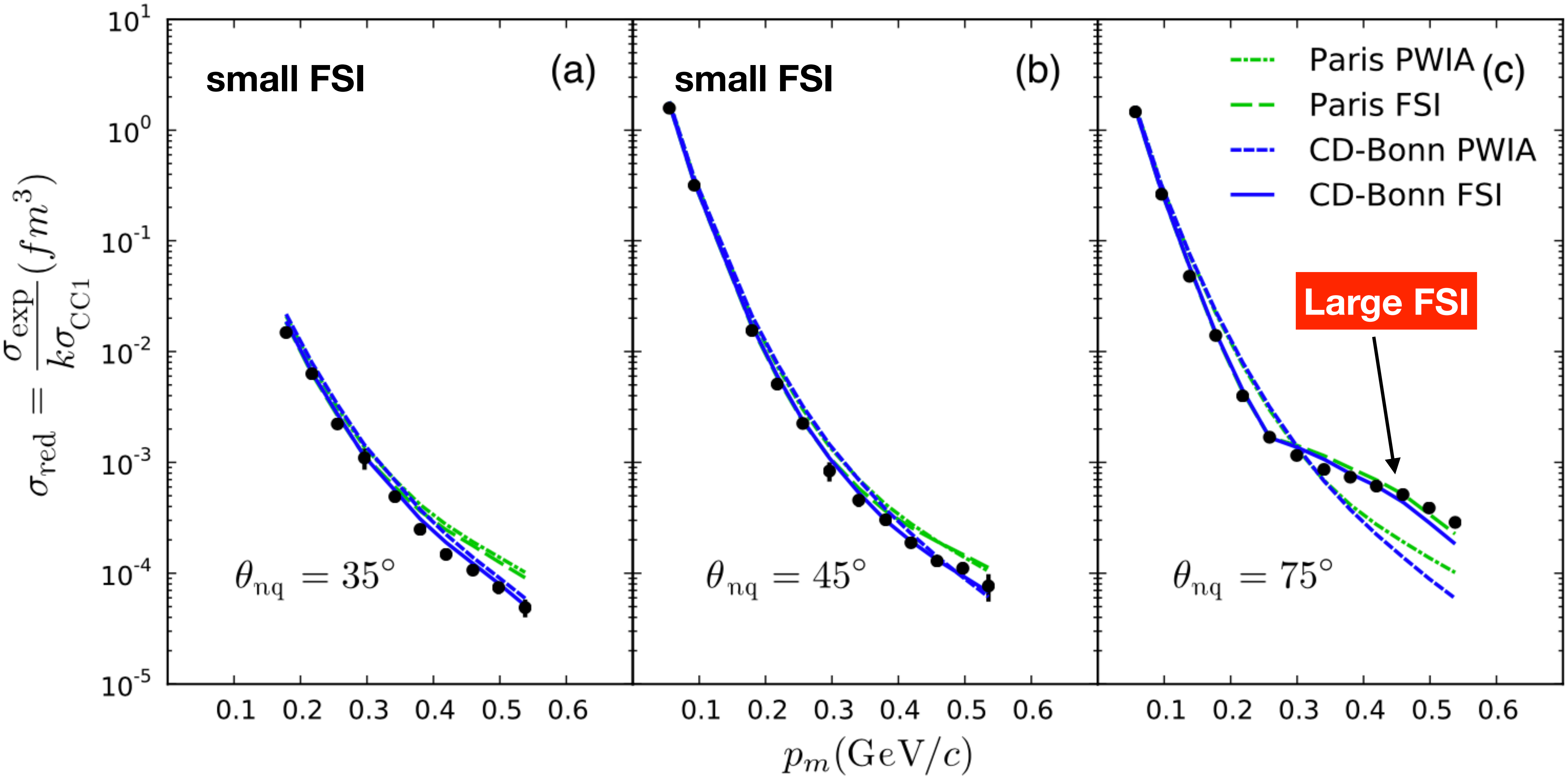
[12] Phys. Rev. Lett. **107**, 262501

[34] Phys. Rev. C **56**, 1124

Back-Up Slides: Previous Exp. Results

Controlling Final-State Interactions

Boeglin *et al.* (Hall A) Phys.Rev.Lett. **107**, 262501 (2011)

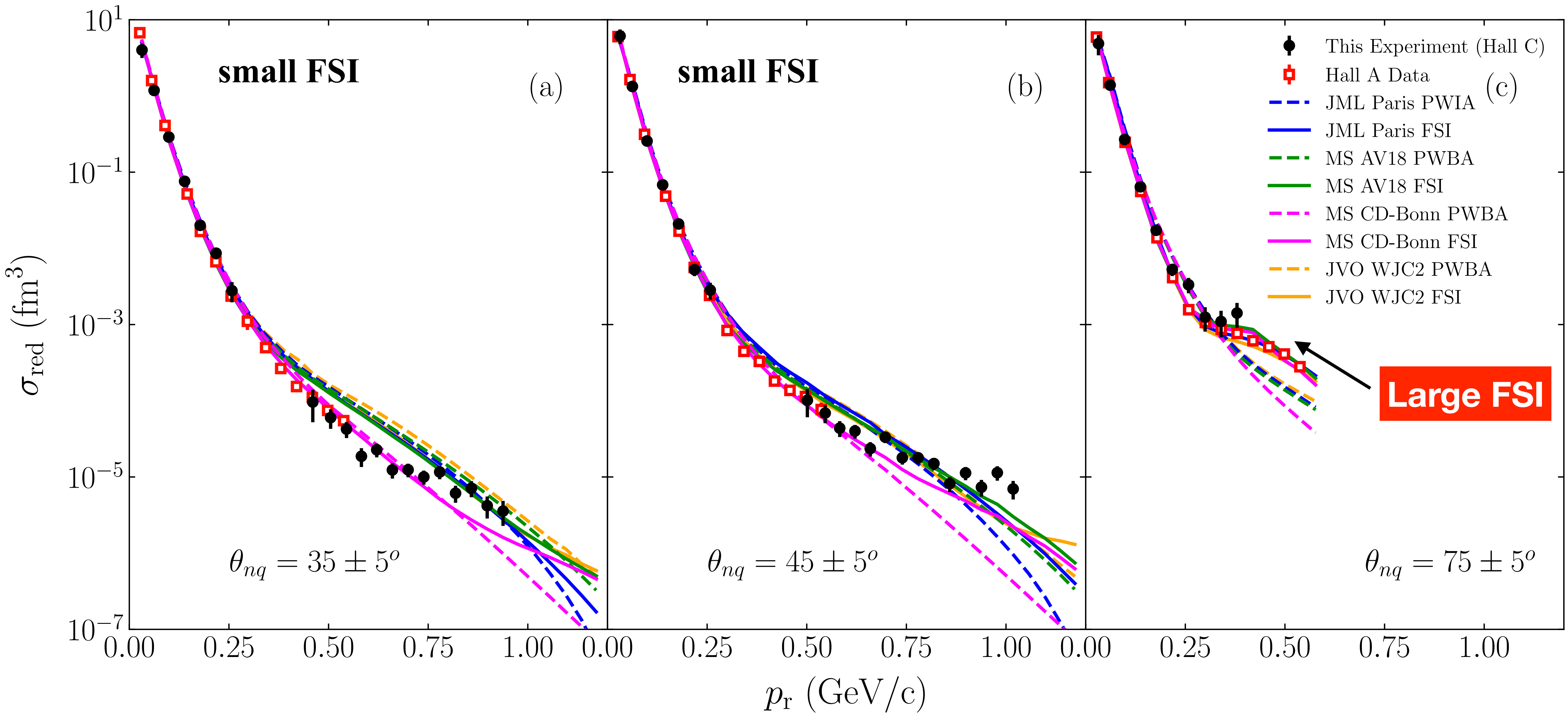


CD-Bonn (Calculations: Misak Sargsian) Misak M. Sargsian Phys.Rev.C82014612 (2010)

Paris (Calculations: J.M. Laget) J. Laget Phys.Lett.B60949 (2005)

Probing the NN Repulsive Core

Yero *et al.* (Hall C) Phys. Rev. Lett. **125**, 262501 (2020)



< 400 MeV/c, all models reproduce data (OPEA Yukawa-type potential)

> 400 MeV/c, **ONLY** CD-Bonn reproduces data up to ~700 MeV/c

Probing the NN Repulsive Core

PAC 36 (2010)

■ **E12-10-003 (p_m □ 300 MeV)**: "Deuteron Electro-Disintegration at Very High Missing Momentum"

Rating: B+

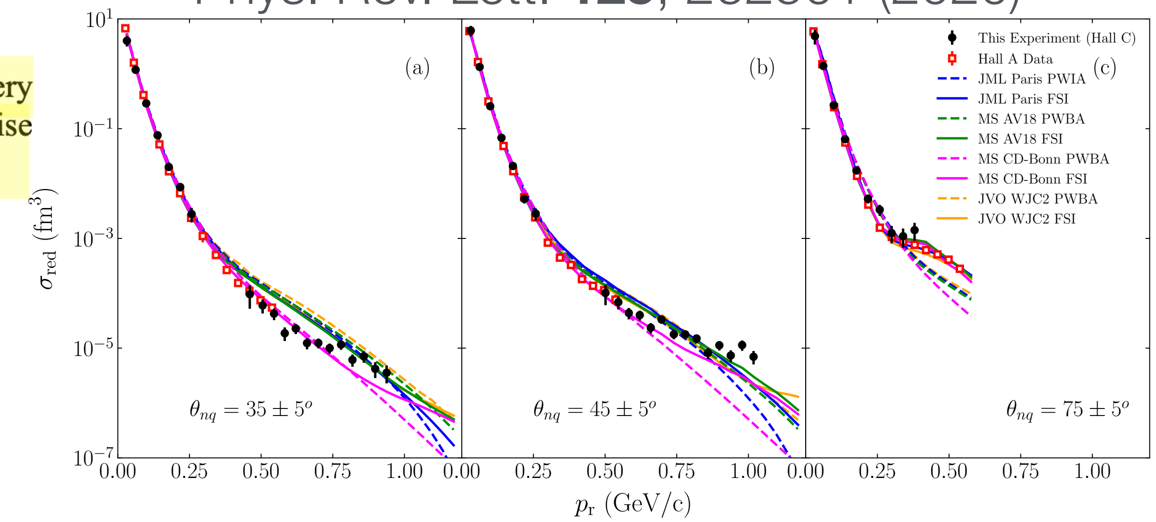
data are essential to constrain further theory developments. Overall the experiment was viewed very highly; the lower rating simply reflects the likelihood that the data will not reveal any particular surprise and that their impact may thus be limited to experts in the field.

PAC 49 (2021)

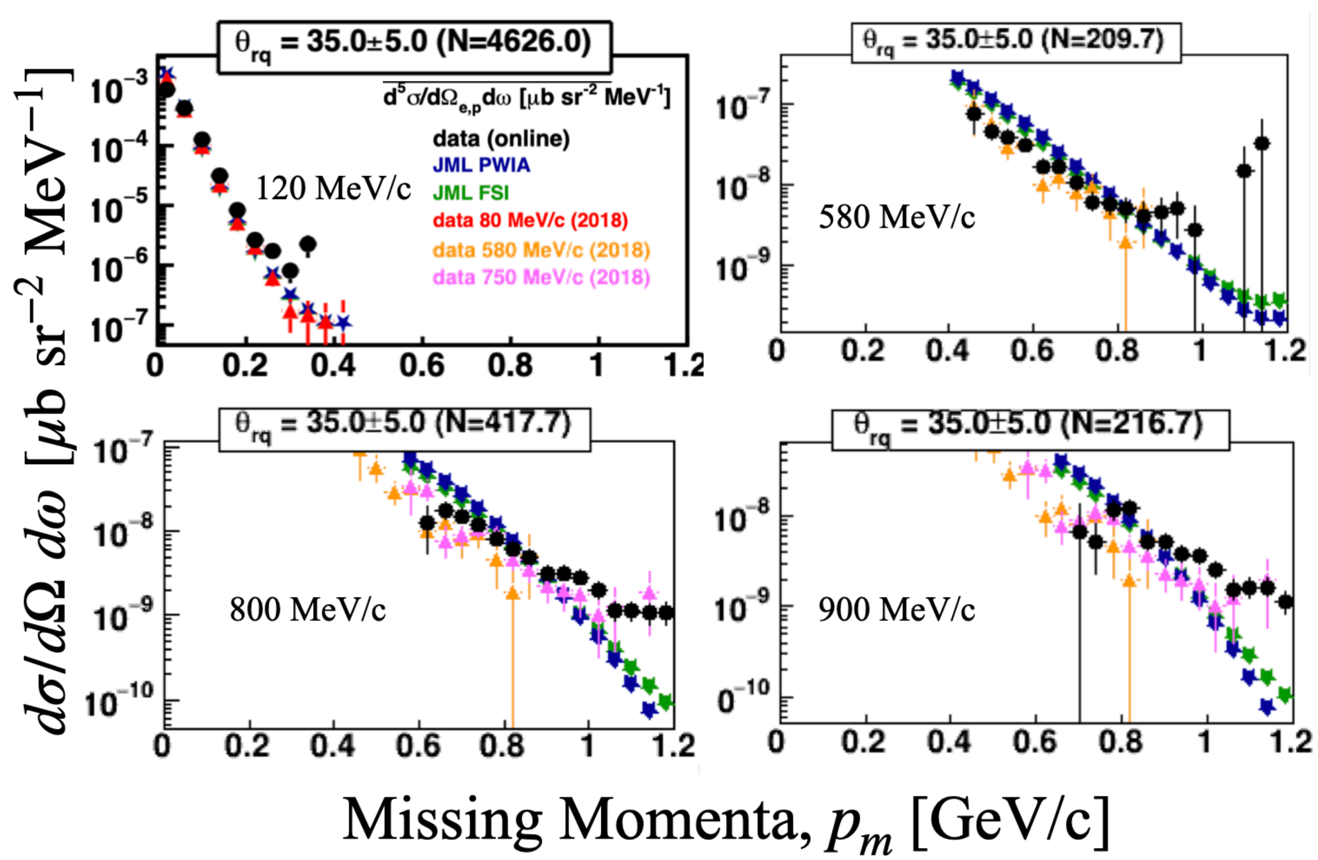
PAC 49 SUMMARY OF JEOPARDY RECOMMENDATIONS								
E12-10-003	W. Boeglin	Deuteron Electro-Disintegration at Very High Missing Momentum	C	21	3	18	Upgrade Rating to A-

PAC 36 graded the proposal with B+ because, even though the physics motivation was viewed highly, the foreseen impact of the result was judged to be limited. The results of the three days commissioning in April 2018, published in Physical Review Letters 125, 262501 (2020), exhibit an unexpected behavior when compared with theoretical calculations. Therefore, the expected impact of future data has increased.

Phys. Rev. Lett. **125**, 262501 (2020)



Very Preliminary Analysis of d(e,e'p)
(experiment completed in 2023)



On-going analysis by graduate students:

- Pramila Pokhrel (CUA)
- Gema Villegas (FIU)