# Results from A = 3 (e,e’p) Measurements @ JLab

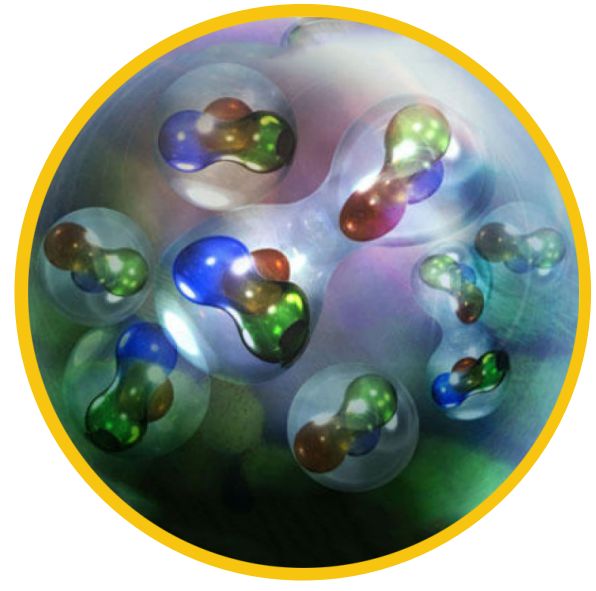
Dien Nguyen, Rey Cruz-Torres

EIC Workshop, Stony Brook

# Nucleon-nucleon interaction

<u>Crucial for</u>:

- ❑ Ab-Initio structure & reaction calculations
- ❑ Dense astrophysical objects, e.g. neutron stars



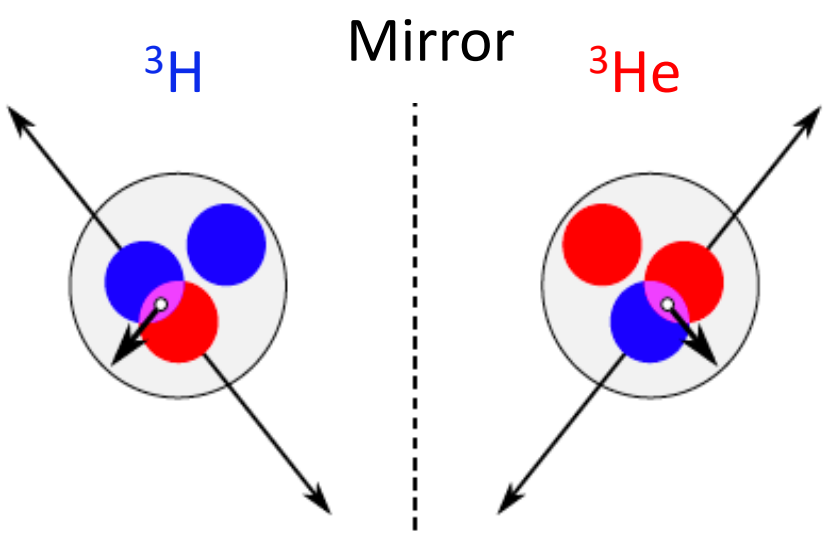
# Why light nuclei?

<u>3-Body system</u>:

- Exactly calculatable
- Test & benchmark theory

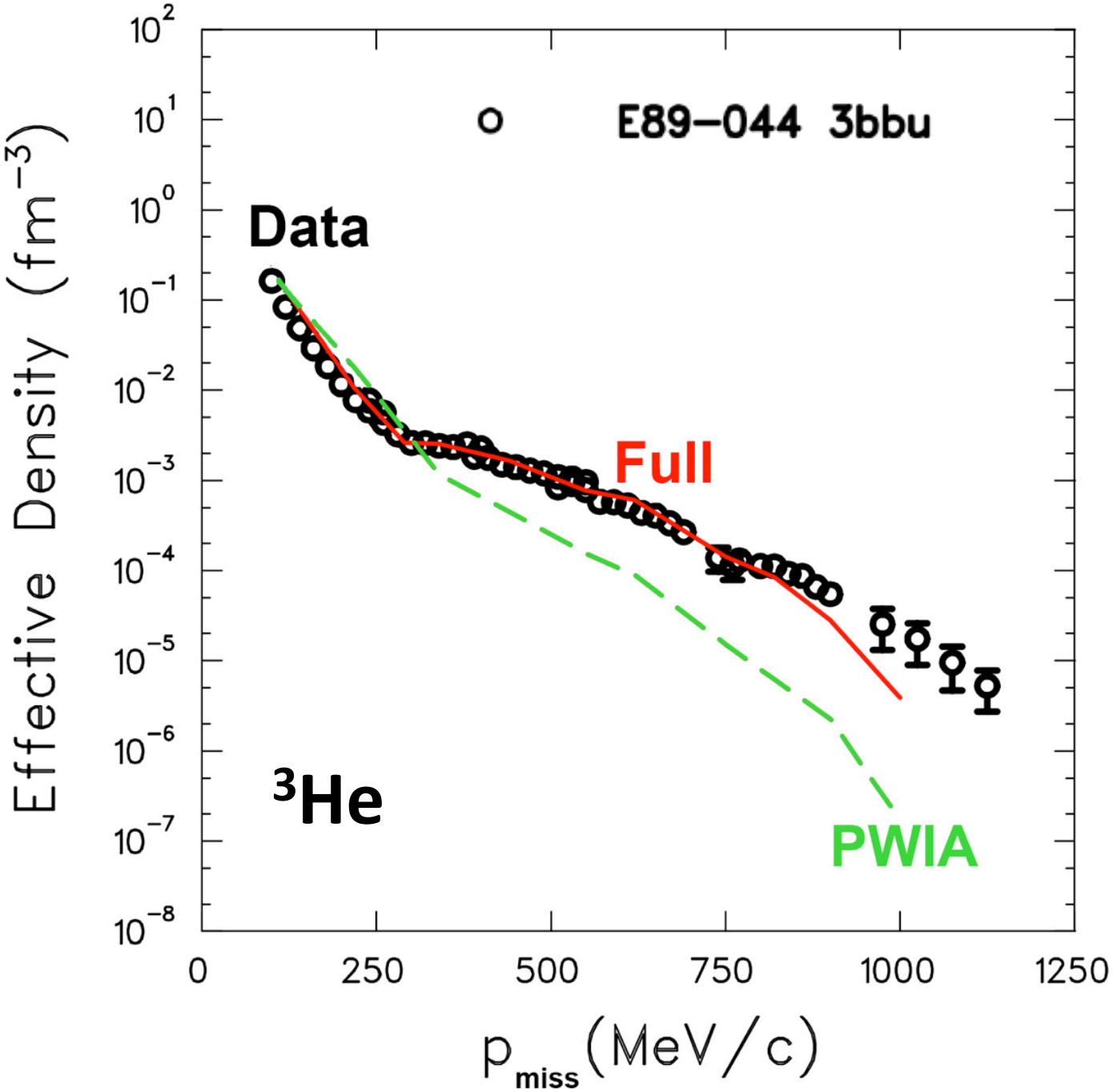
## <u>Why Tritium</u>?

- Proton in $^3$He = Neutron in $^3$H




$$\frac{^3\mathrm{He}\ (\mathbf{p})}{^3\mathrm{He}\ (\mathbf{n})} \cong \frac{^3\mathrm{He}\ (\mathbf{p})}{^3\mathrm{H}\ (\mathbf{p})}$$

# Previous studies and non-QE mechanisms

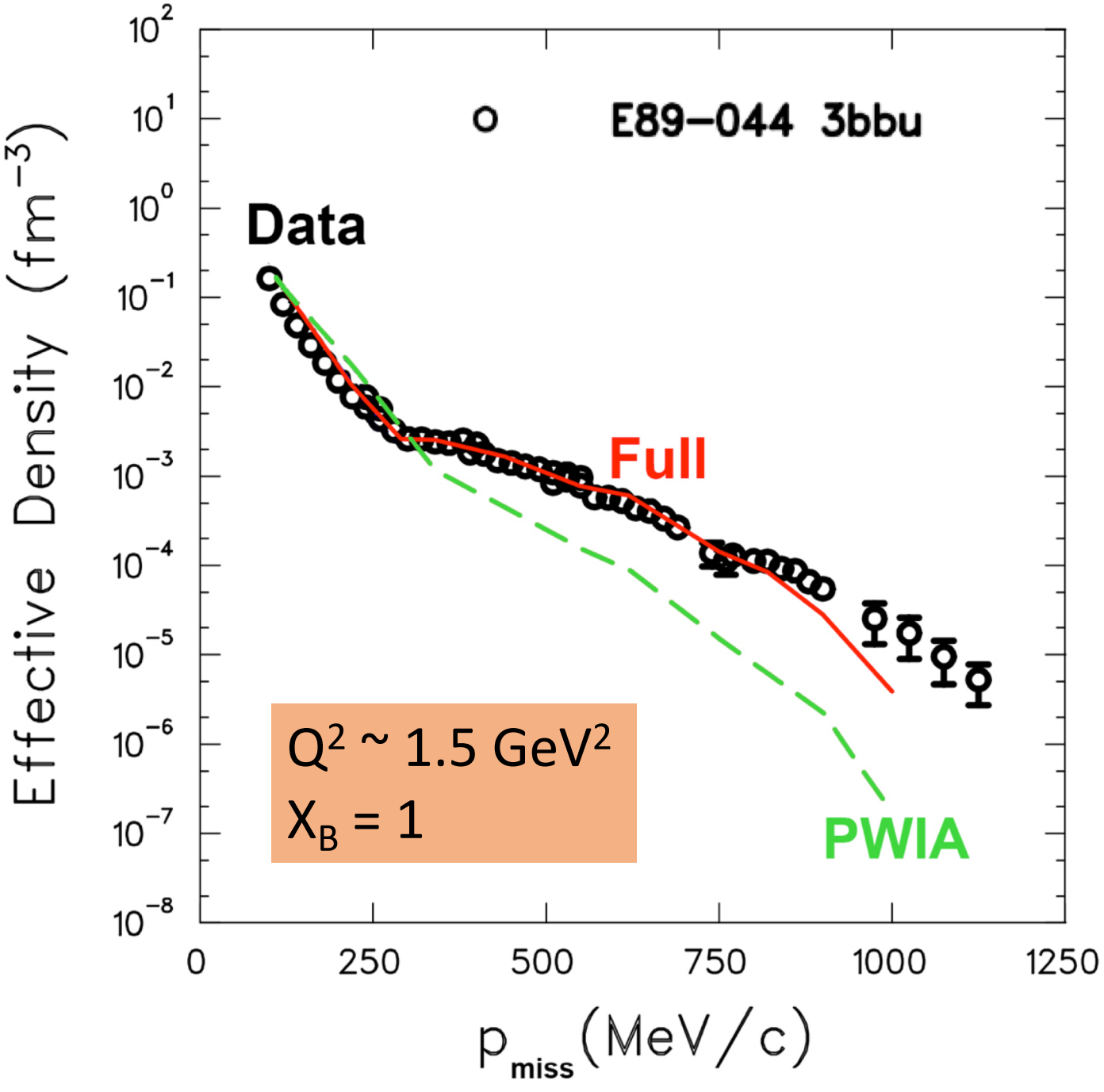



F. Benmokhtar et al., PRL 94, 082305 (2005)

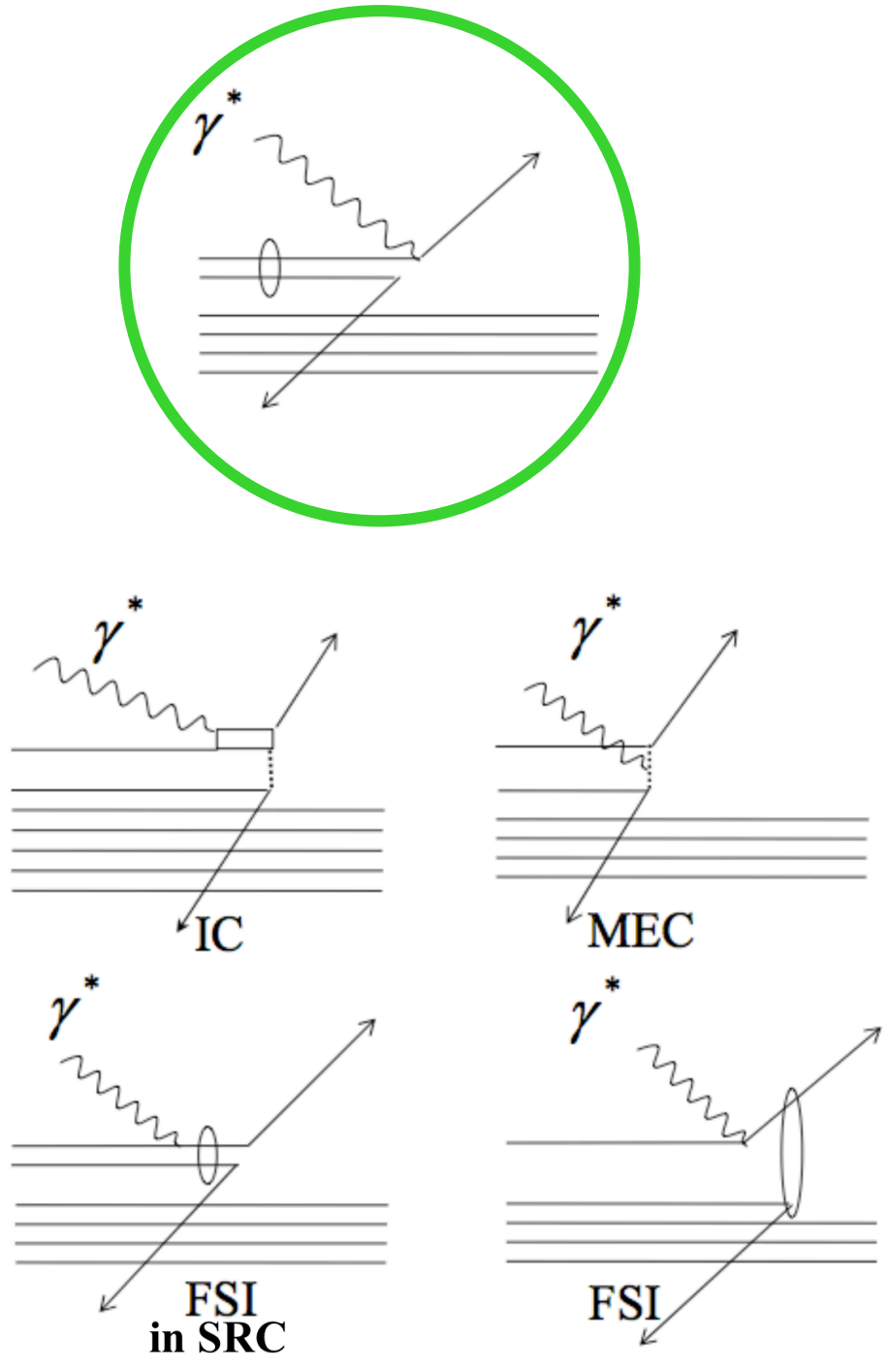
Large differences between data & PWIA

=> Data is useful to study reaction mechanism, not nucleon distributions.

# Previous studies and non-QE mechanisms

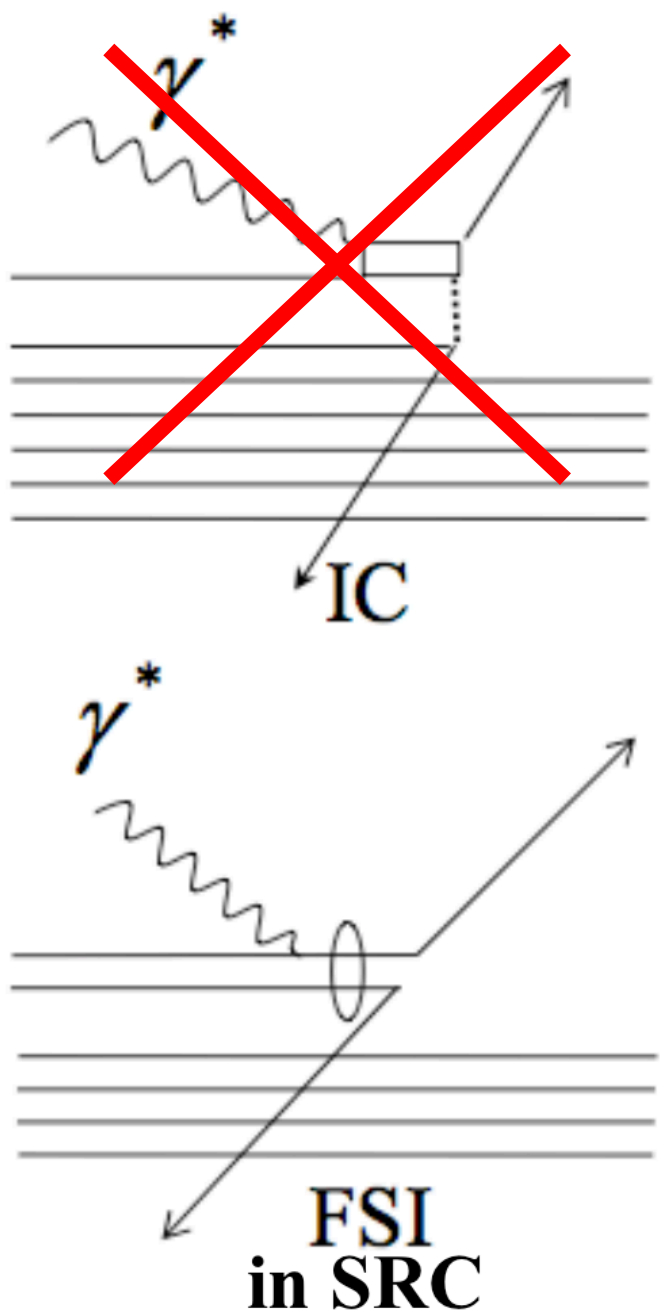



F. Benmokhtar et al., PRL 94, 082305 (2005)

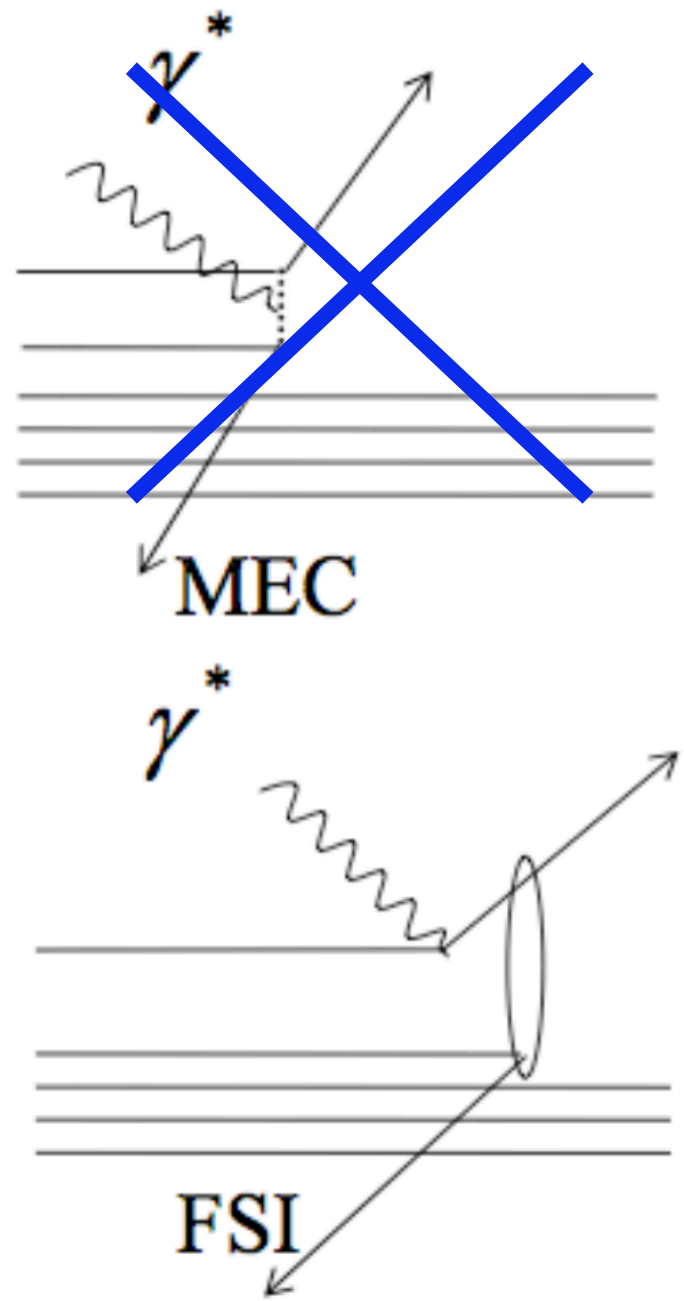


# Minimizing non-QE mechanisms

$X_B > 1$

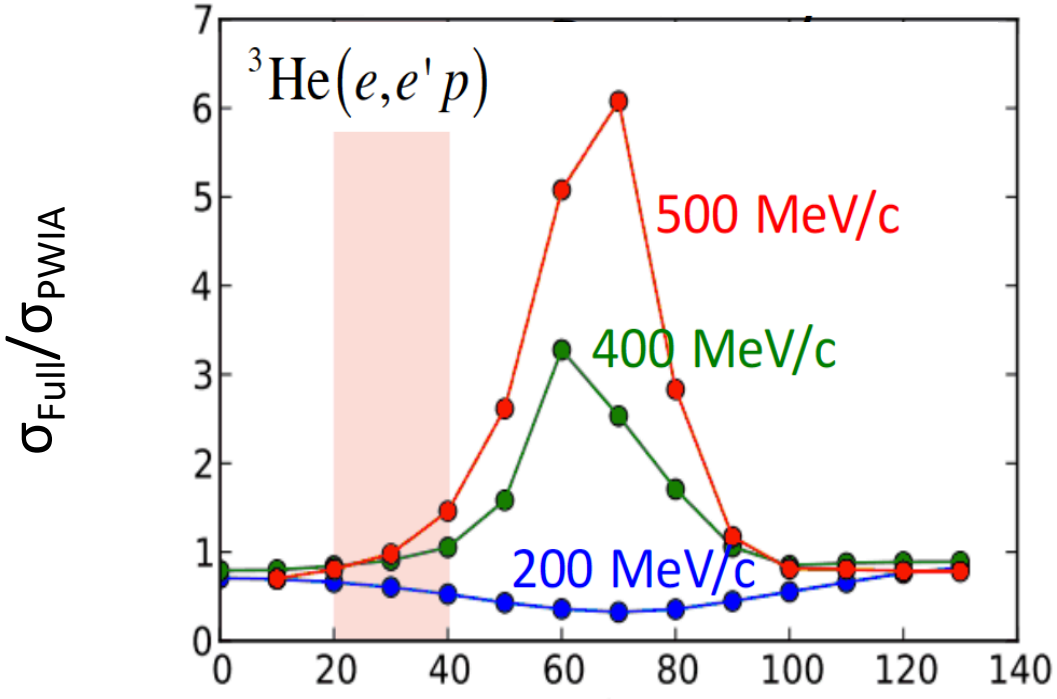


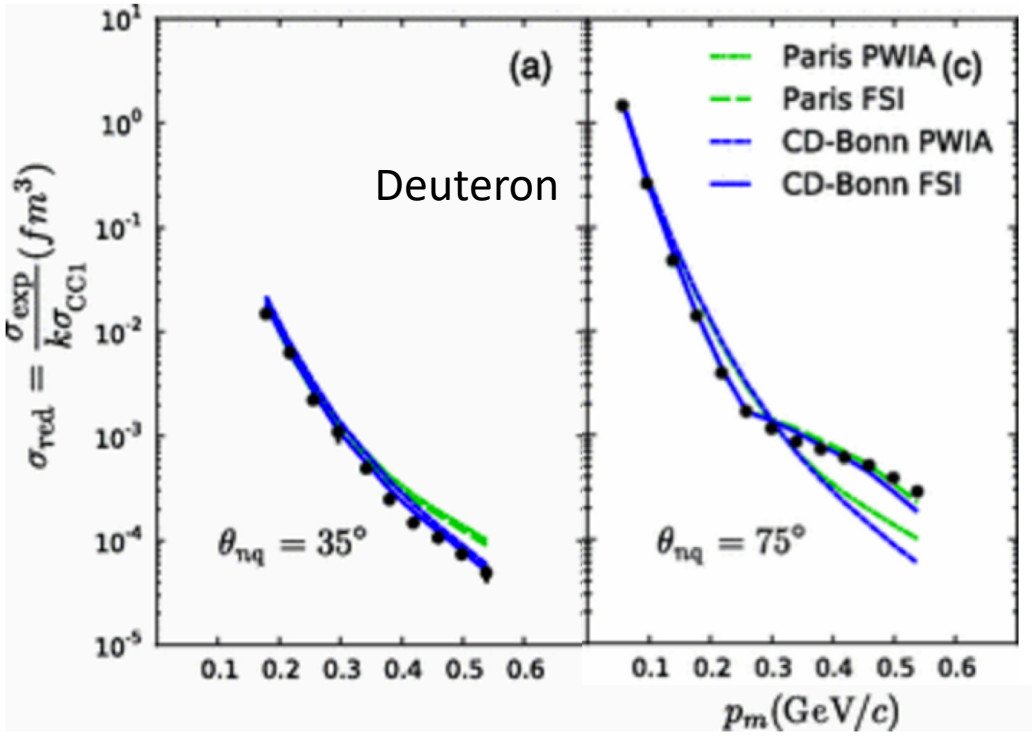

$Q^2 > 2\ GeV^2$



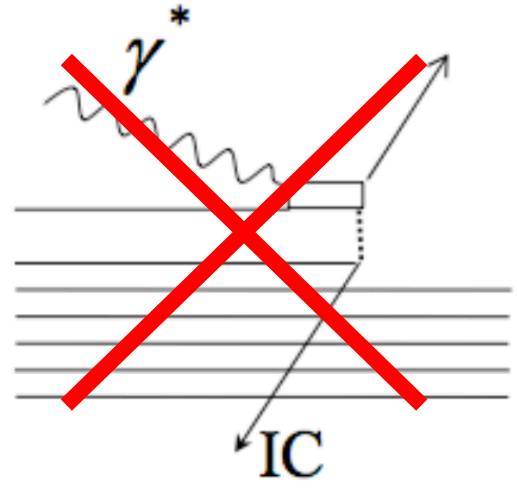

M. M. Sargsian, Int. J. Mod. Phys. E10, 405 (2001)
M. M. Sargsian et al., J. Phys. G29, R1 (2003)

# Minimizing non-QE mechanisms

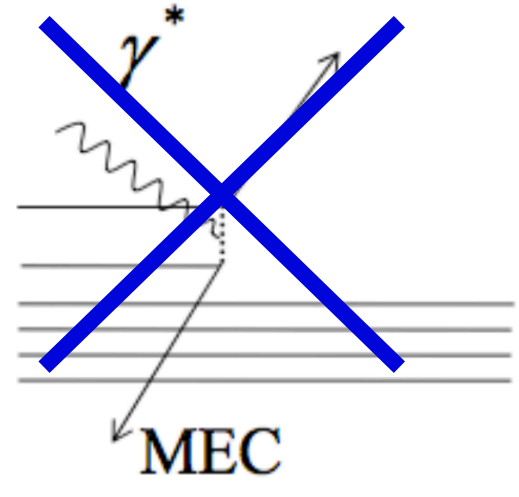


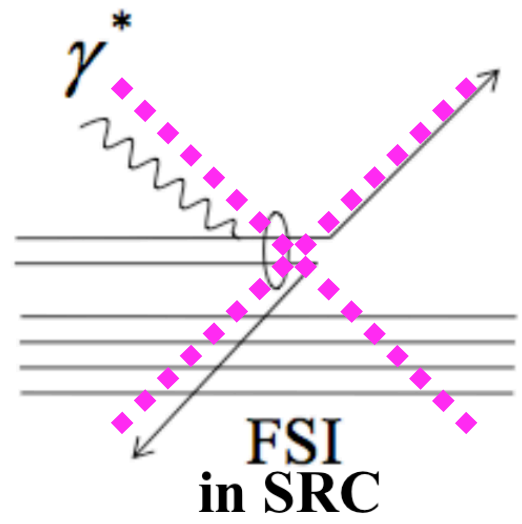



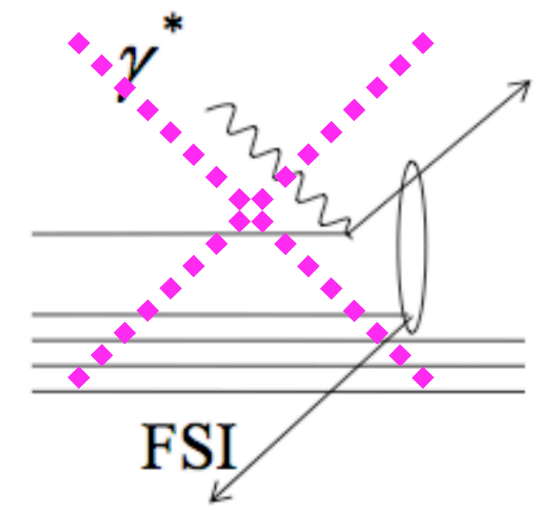

$X_B > 1$




$Q^2 > 2$ GeV$^2$



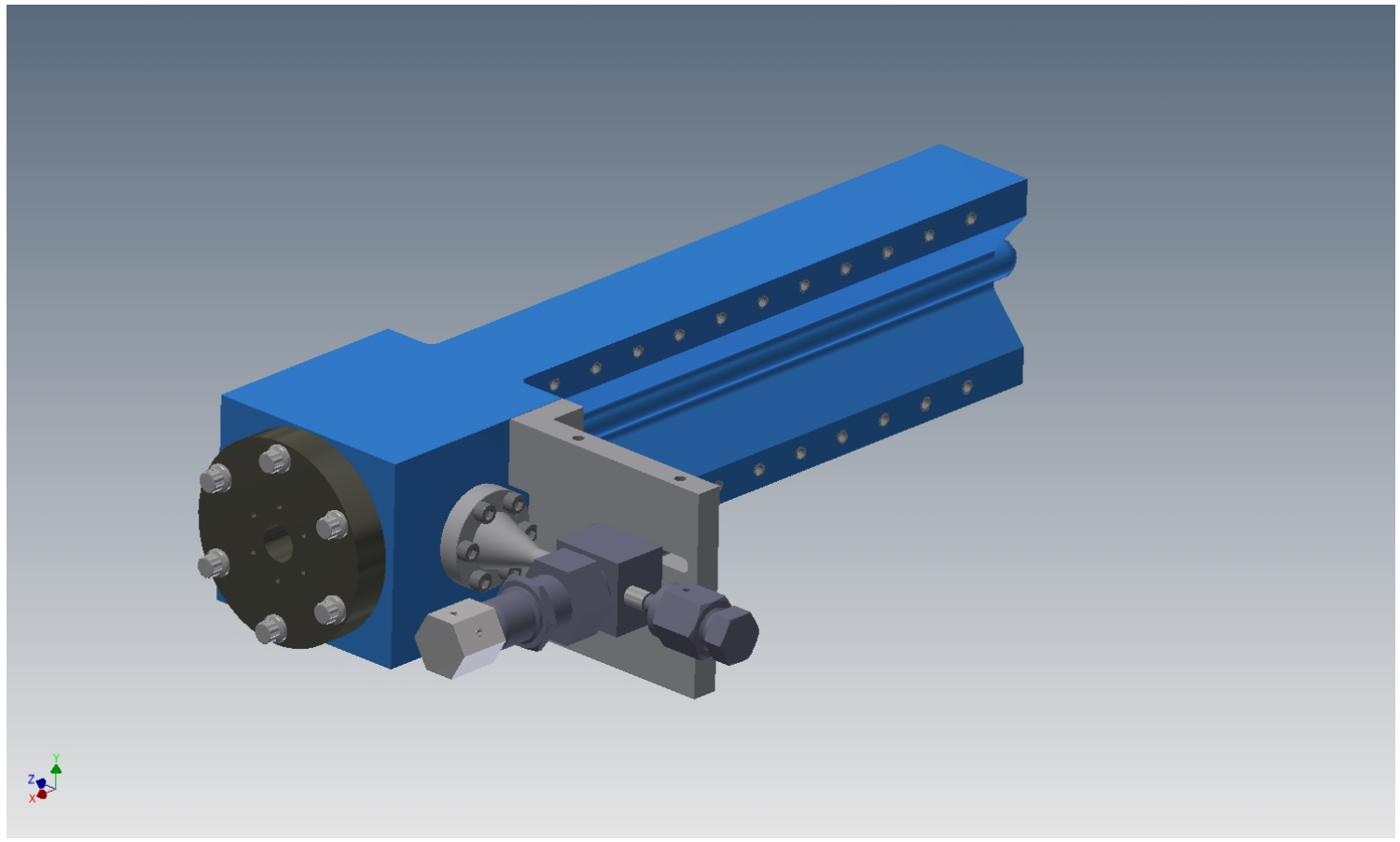



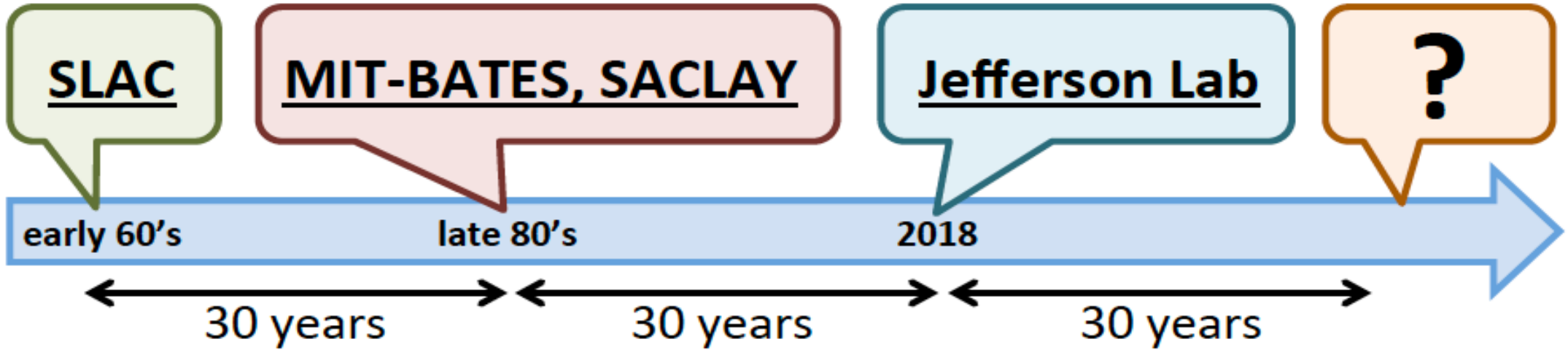

$\theta_{qr} < 35°$

Boeglin et al., PRL 107 (2011) 262501

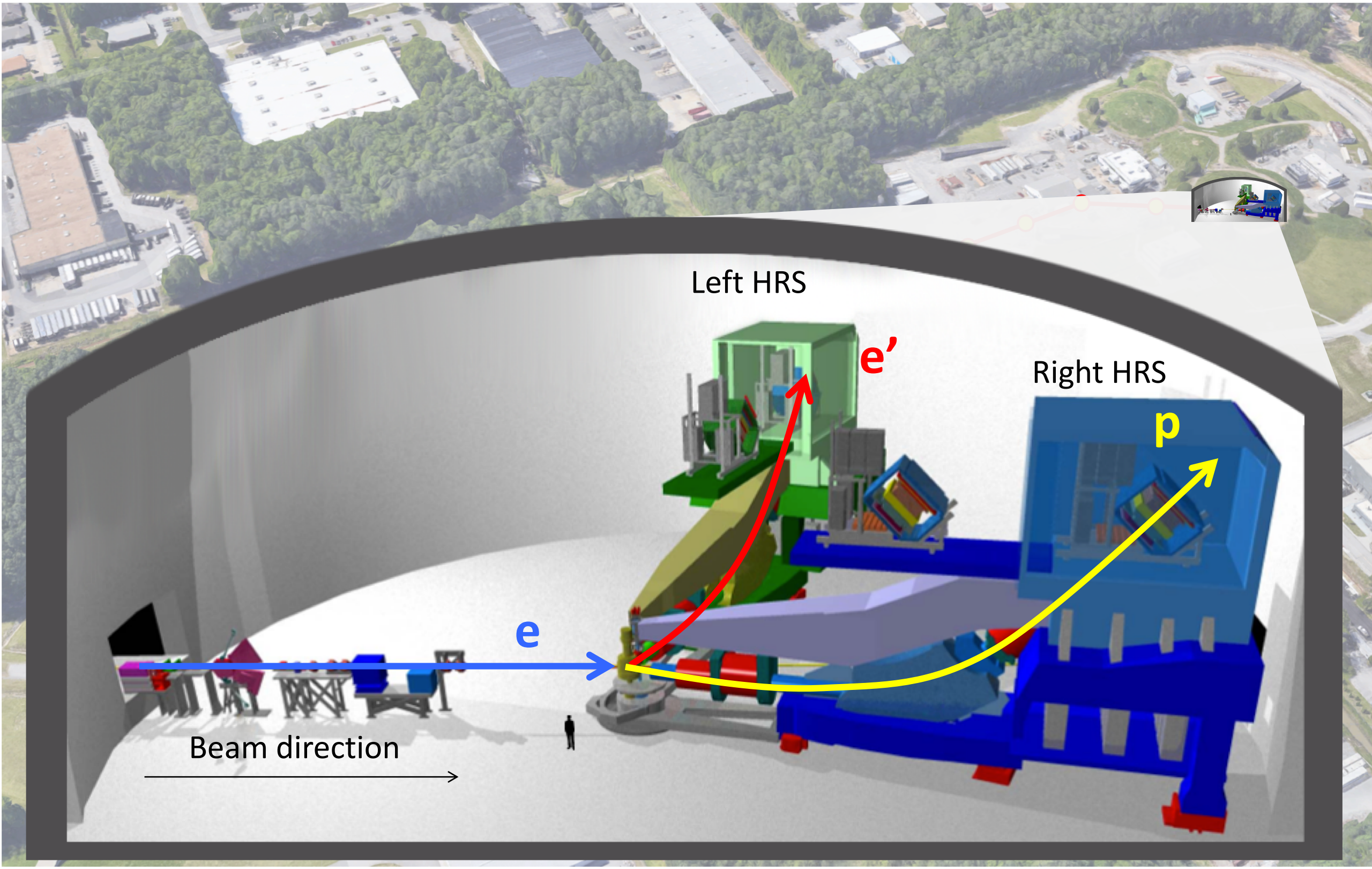
# Tritium Experiment @ JLab



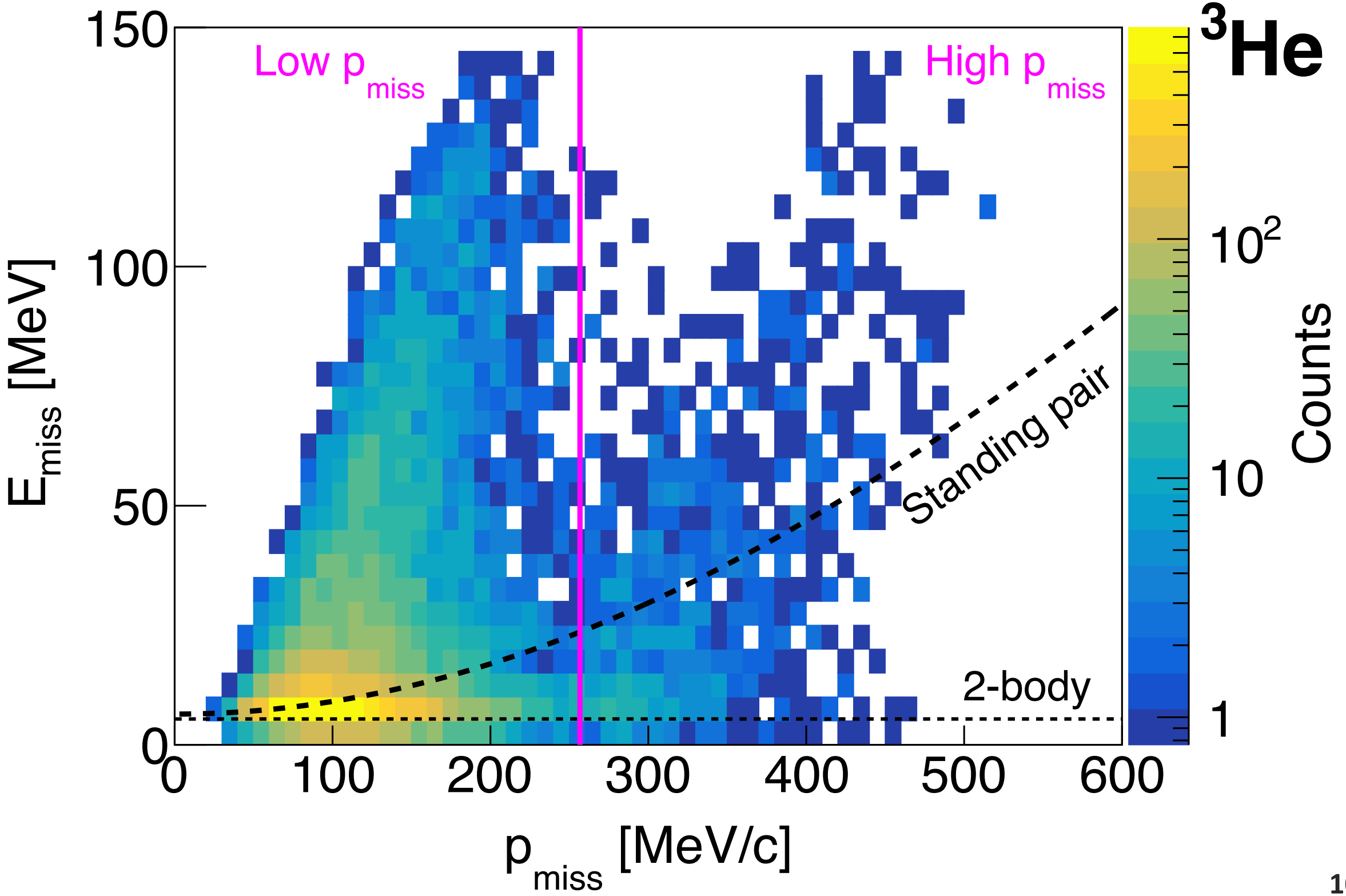


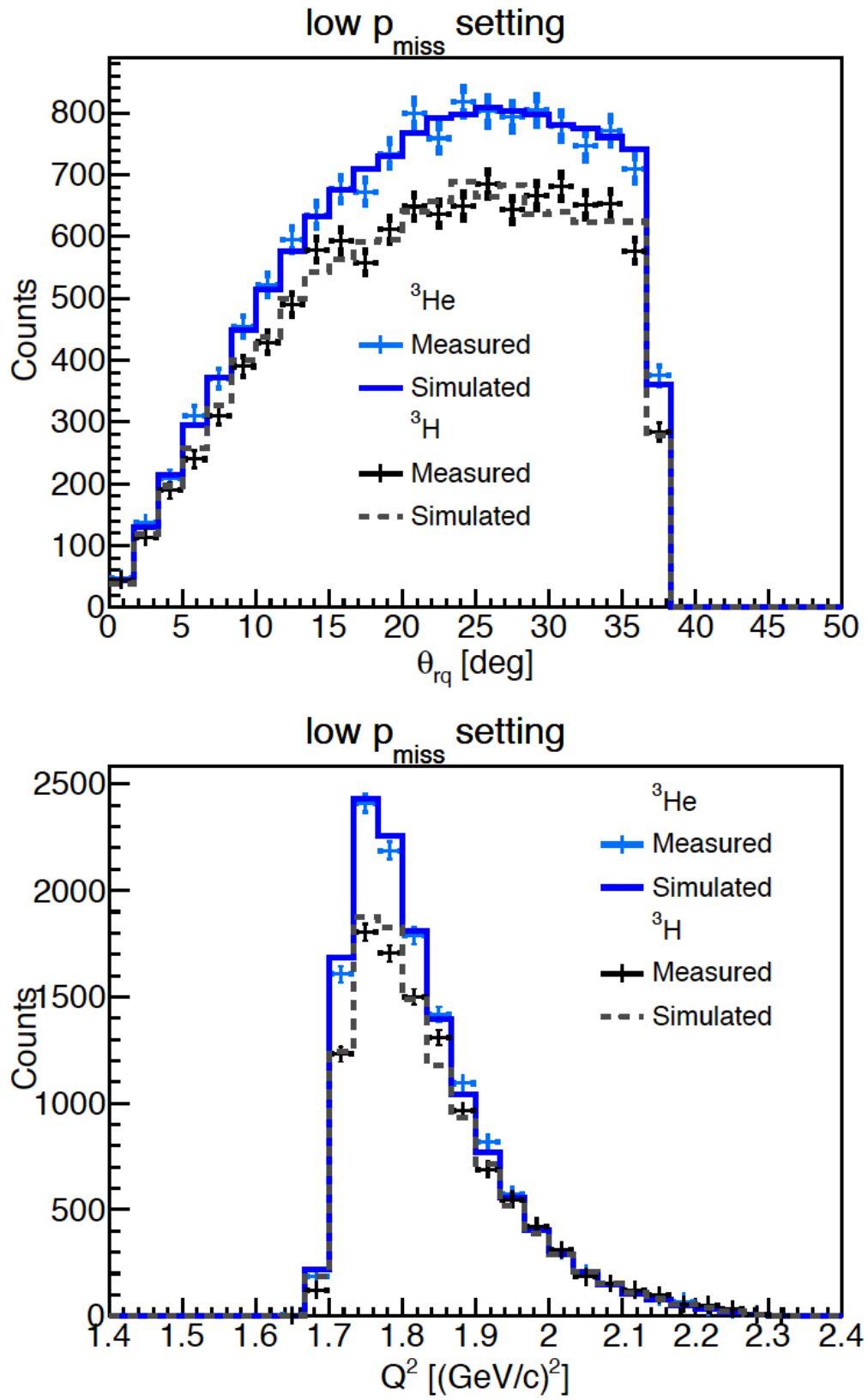
# Hall-A of Jefferson Lab

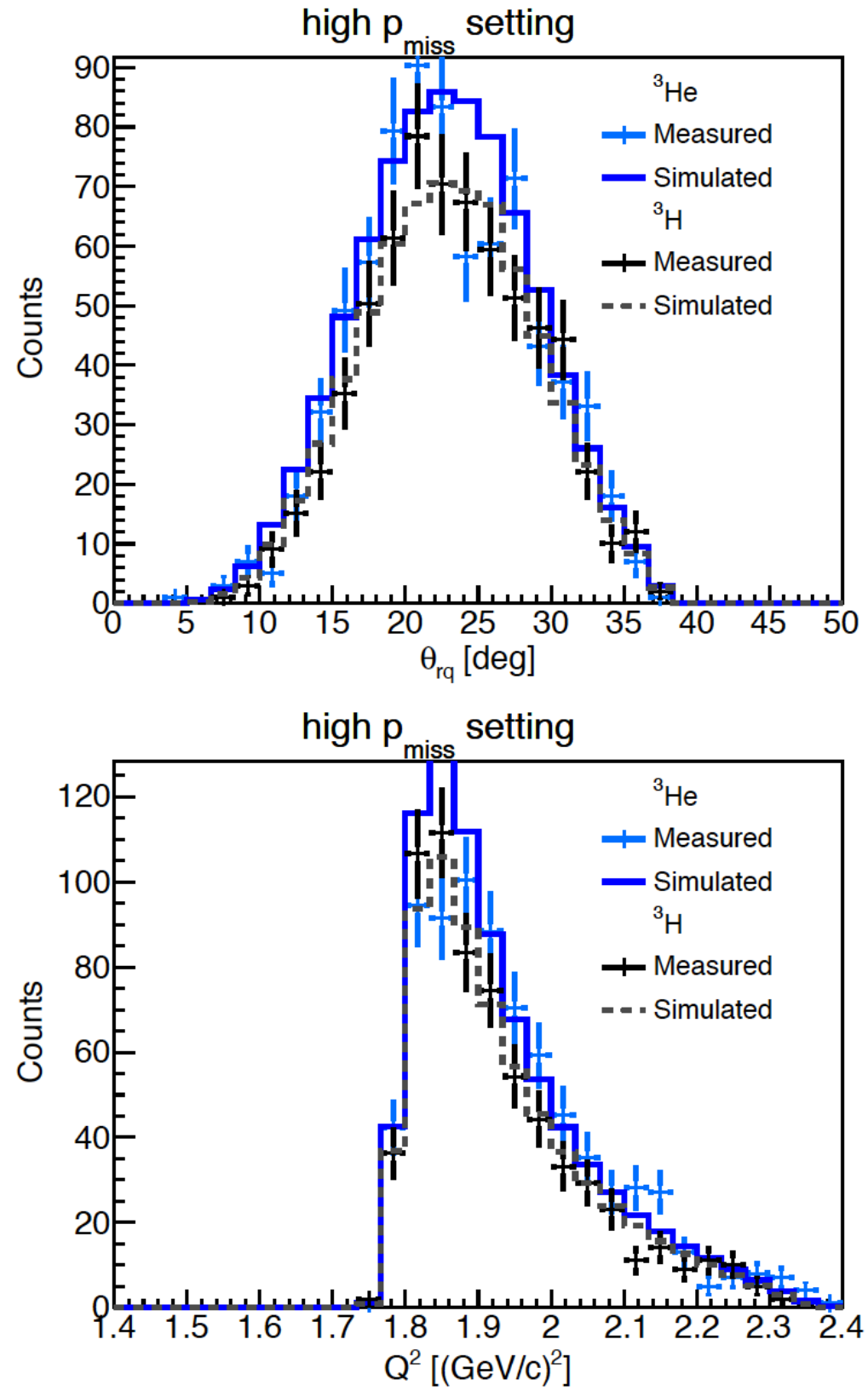


# Kinematic distribution

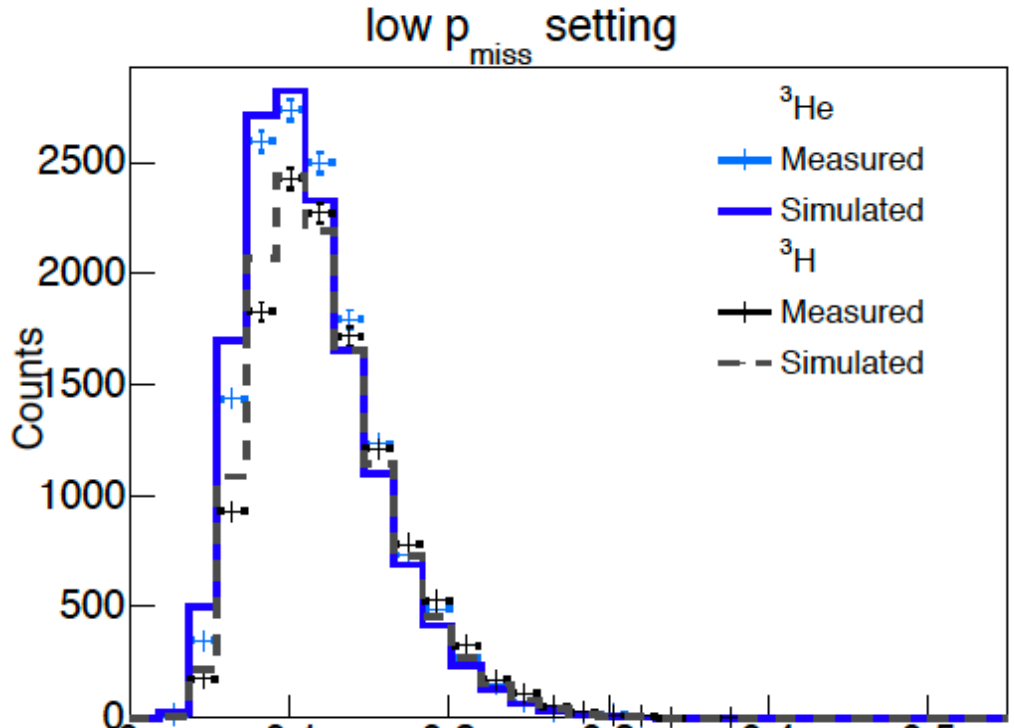


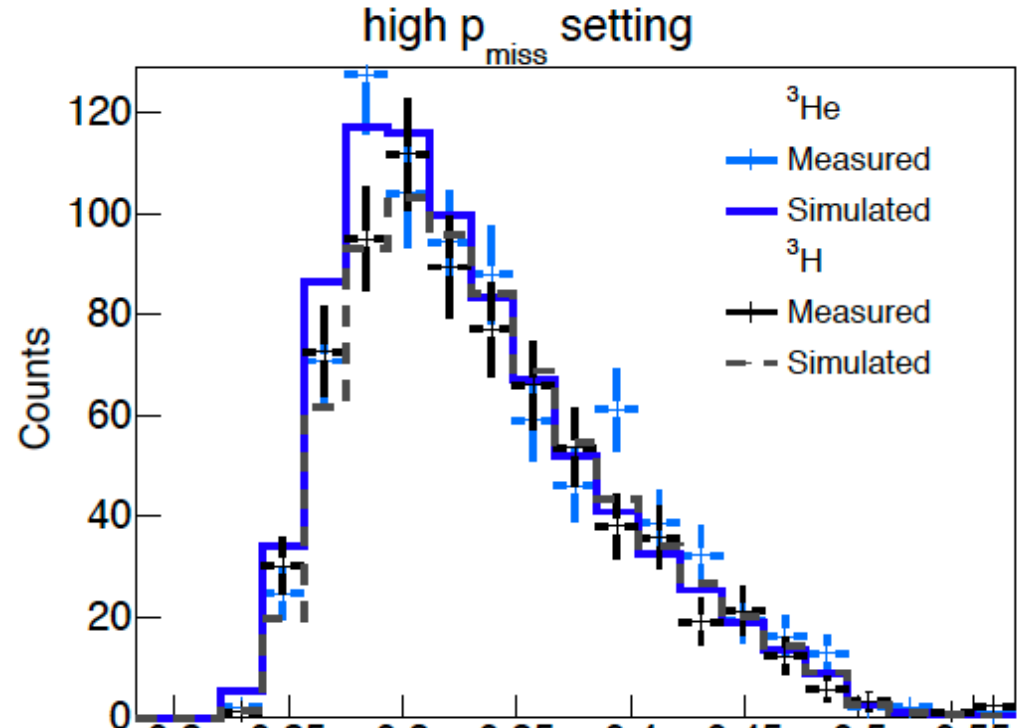
# Kinematic distribution Data & Simulation

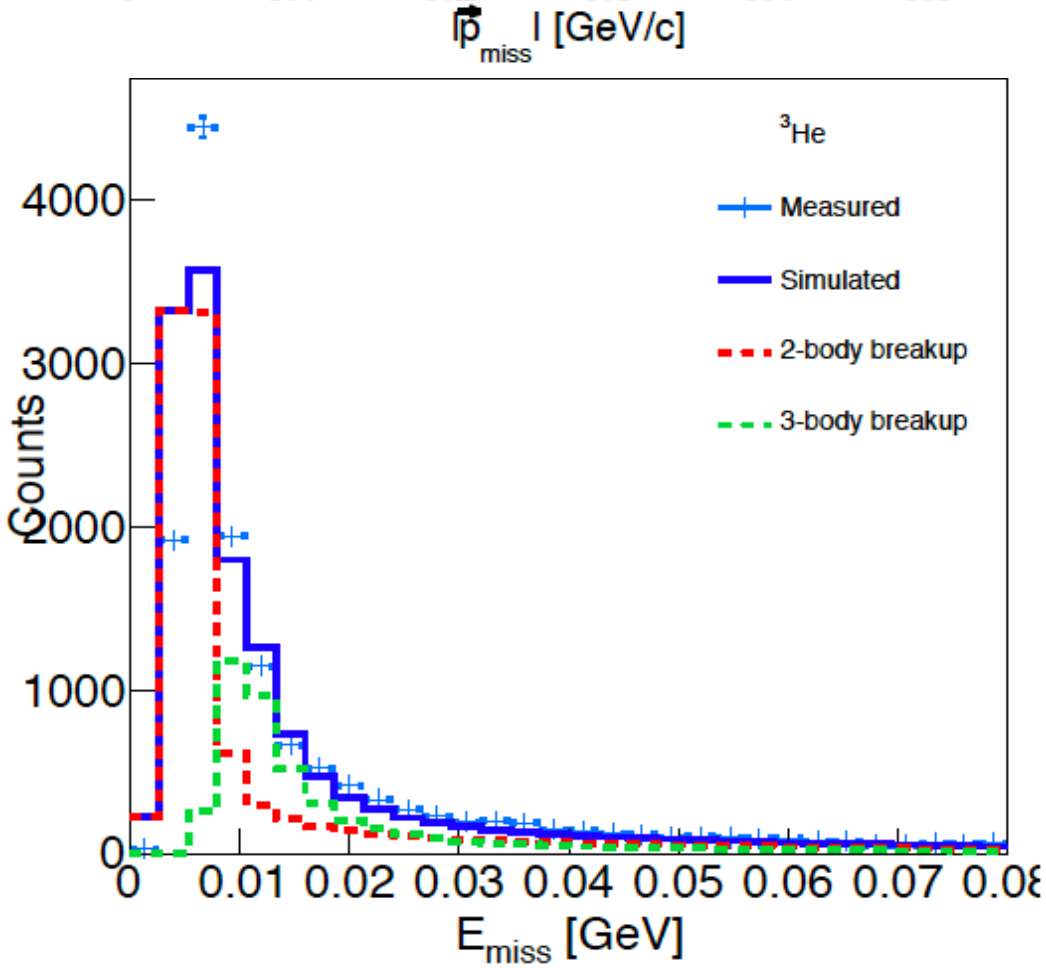


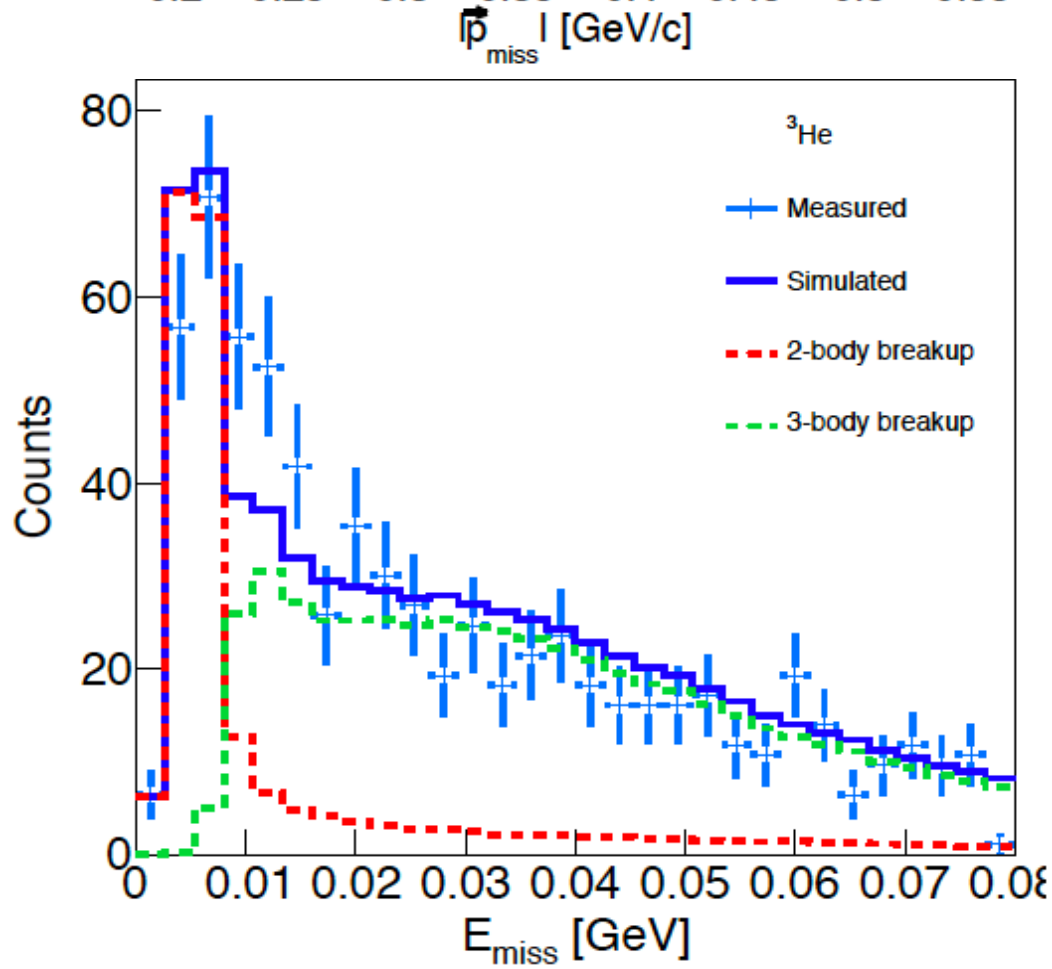



# Kinematic distribution Data &Simulation



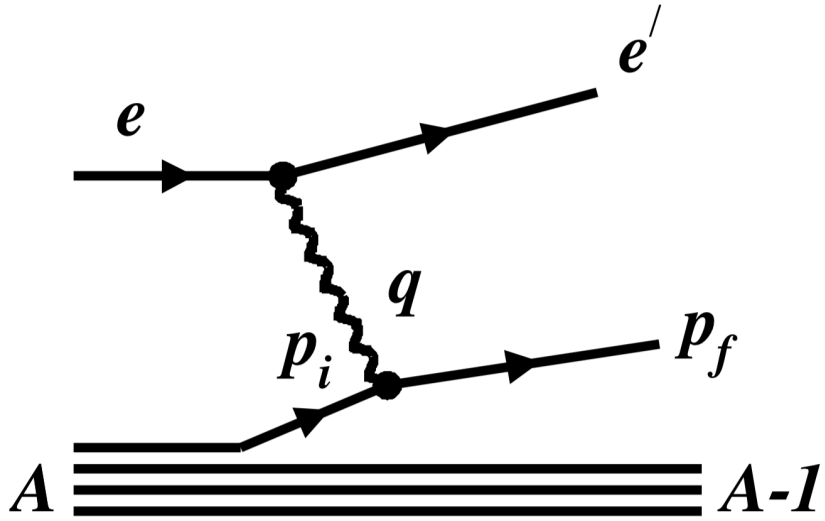



# High $Q^2$: PWIA factorized approximation

$$\frac{d^6\sigma}{d\omega dE_p d\Omega_e d\Omega_p} = K\,\sigma_{ep}\,S(\left|\overrightarrow{P_i}\right|, E_i)$$

PWIA approximation:

$\mathbf{p}_i \sim \mathbf{P}_{miss} = \mathbf{p}_f - \mathbf{q}$

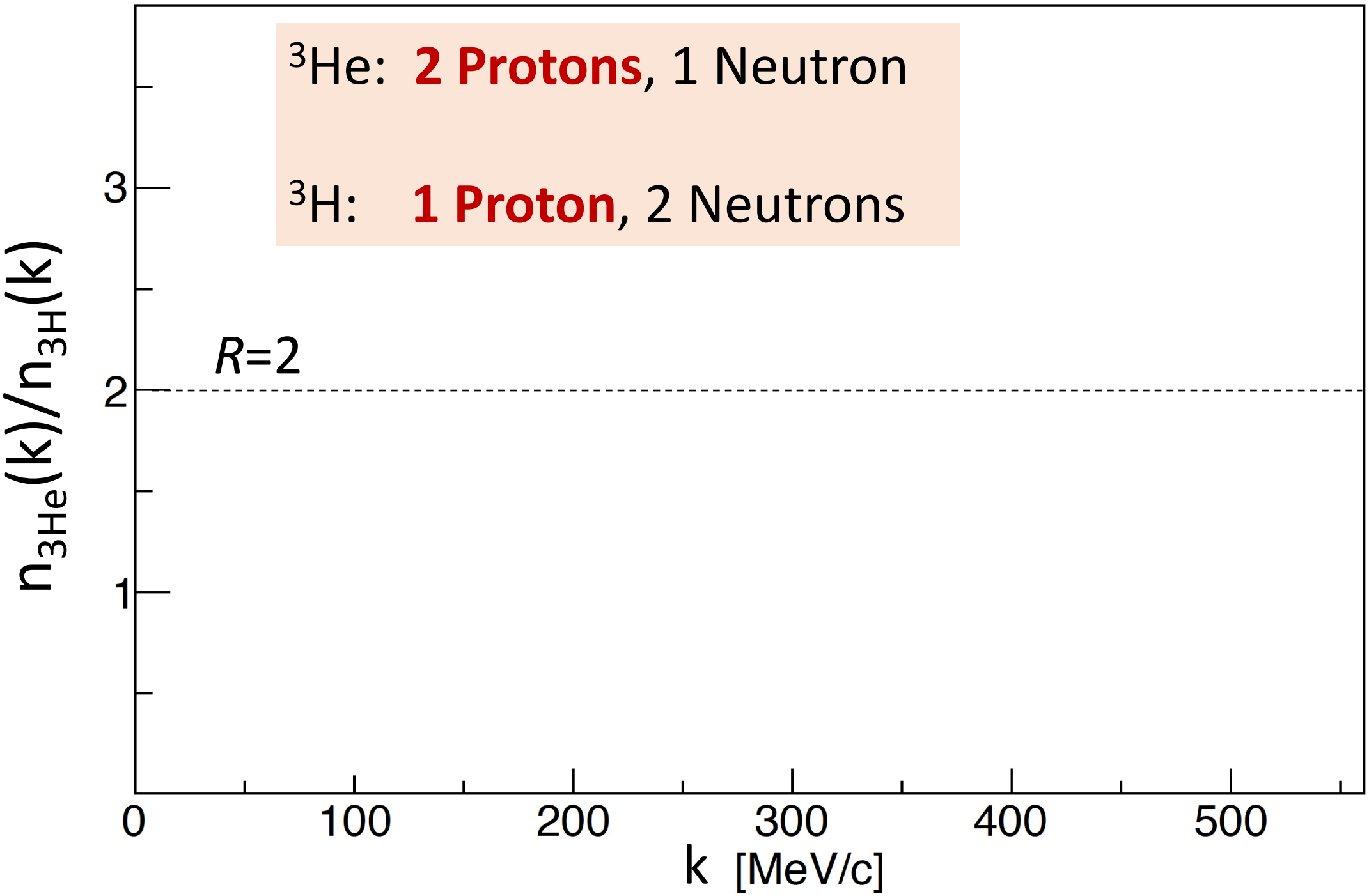



$$\frac{\sigma^3He(e,e'p)}{\sigma^3H(e,e'p)} \approx \frac{S^3He(\left|\overrightarrow{P_i}\right|,E_i)}{S^3H(\left|\overrightarrow{P_i}\right|,E_i)}$$

# Phenomenological expectations

$^3$He: **2 Protons**, 1 Neutron

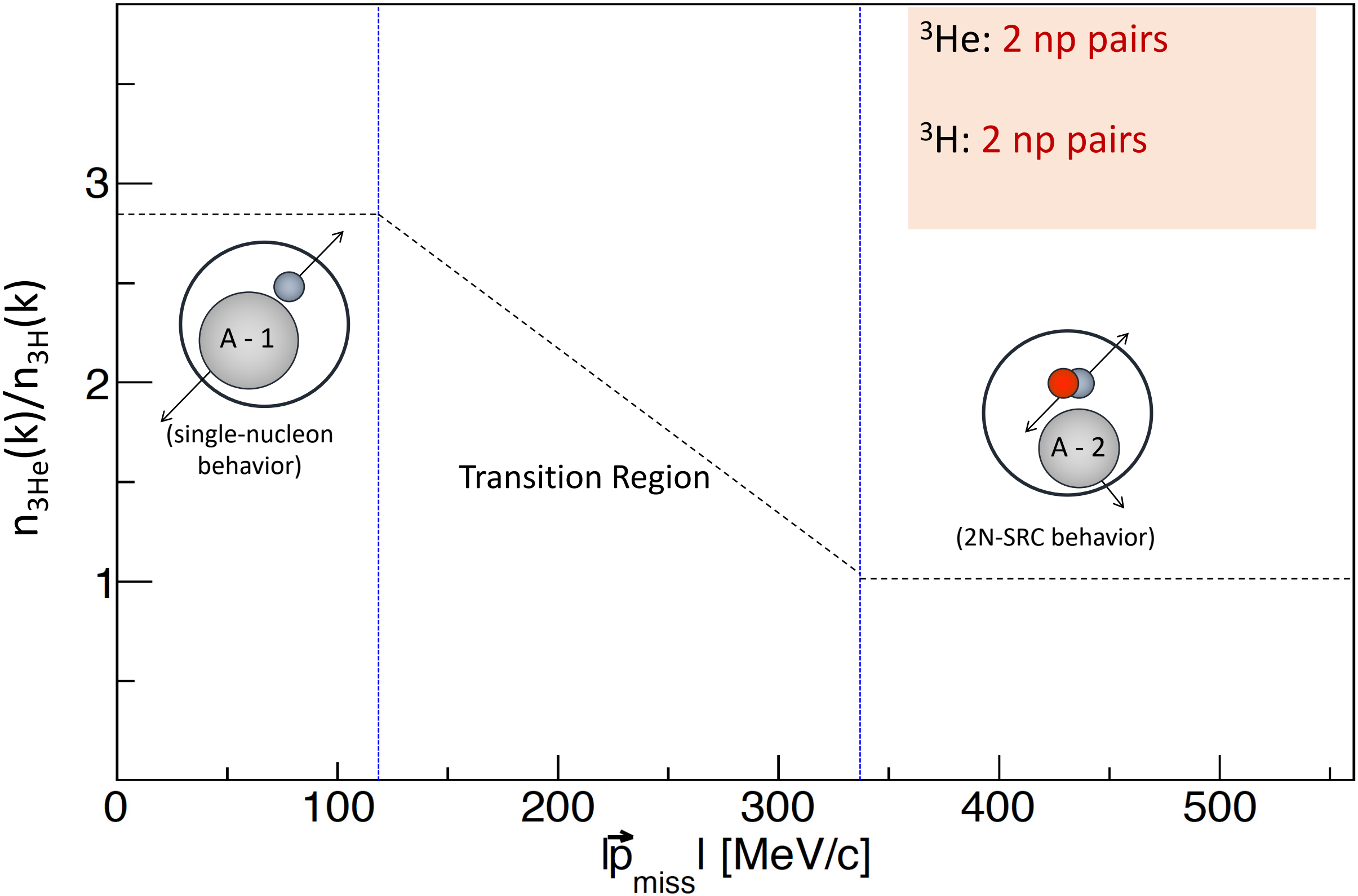
$^3$H: **1 Proton**, 2 Neutrons



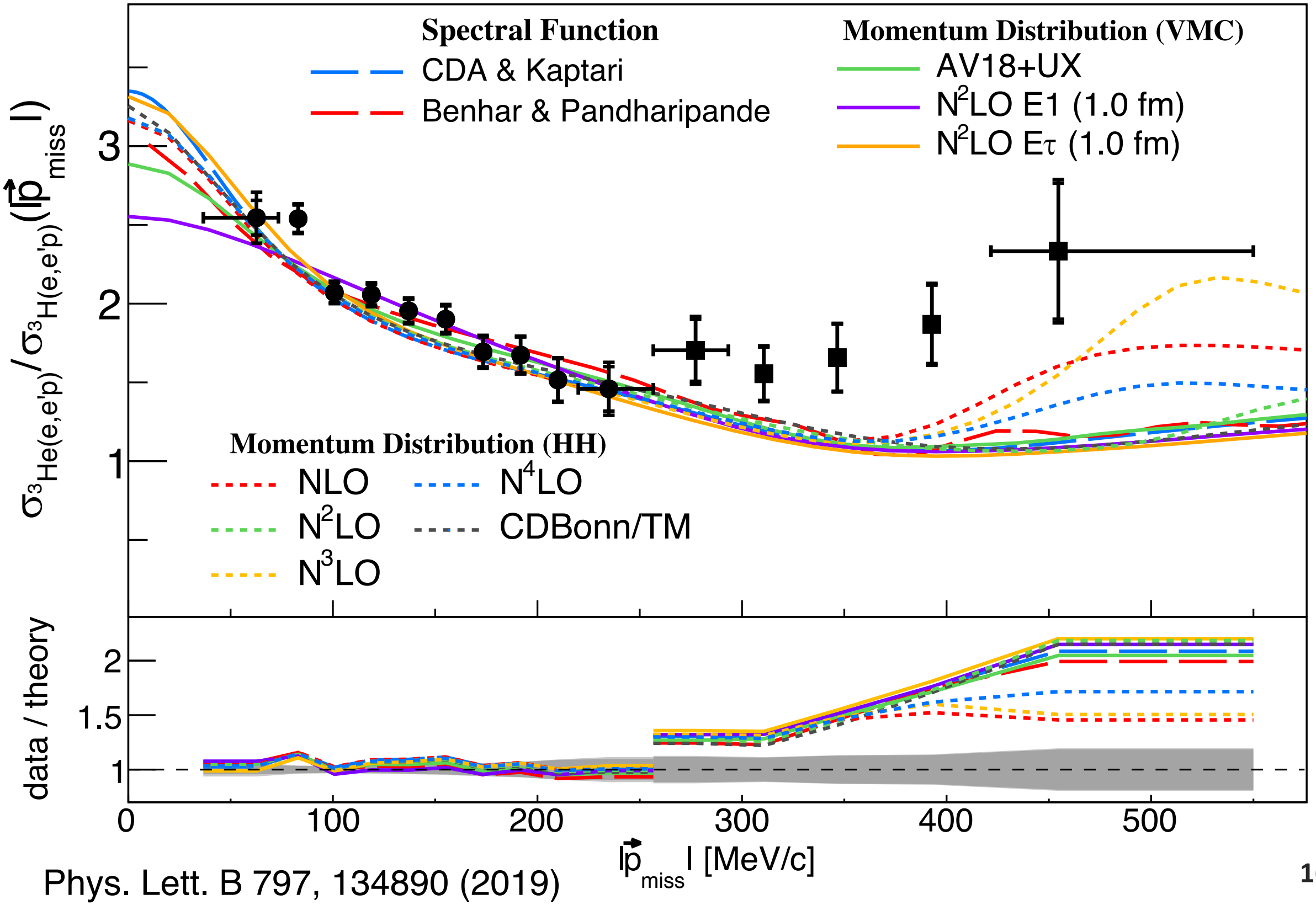
# Phenomenological expectations

$^3$He: 2 np pairs

$^3$H: 2 np pairs

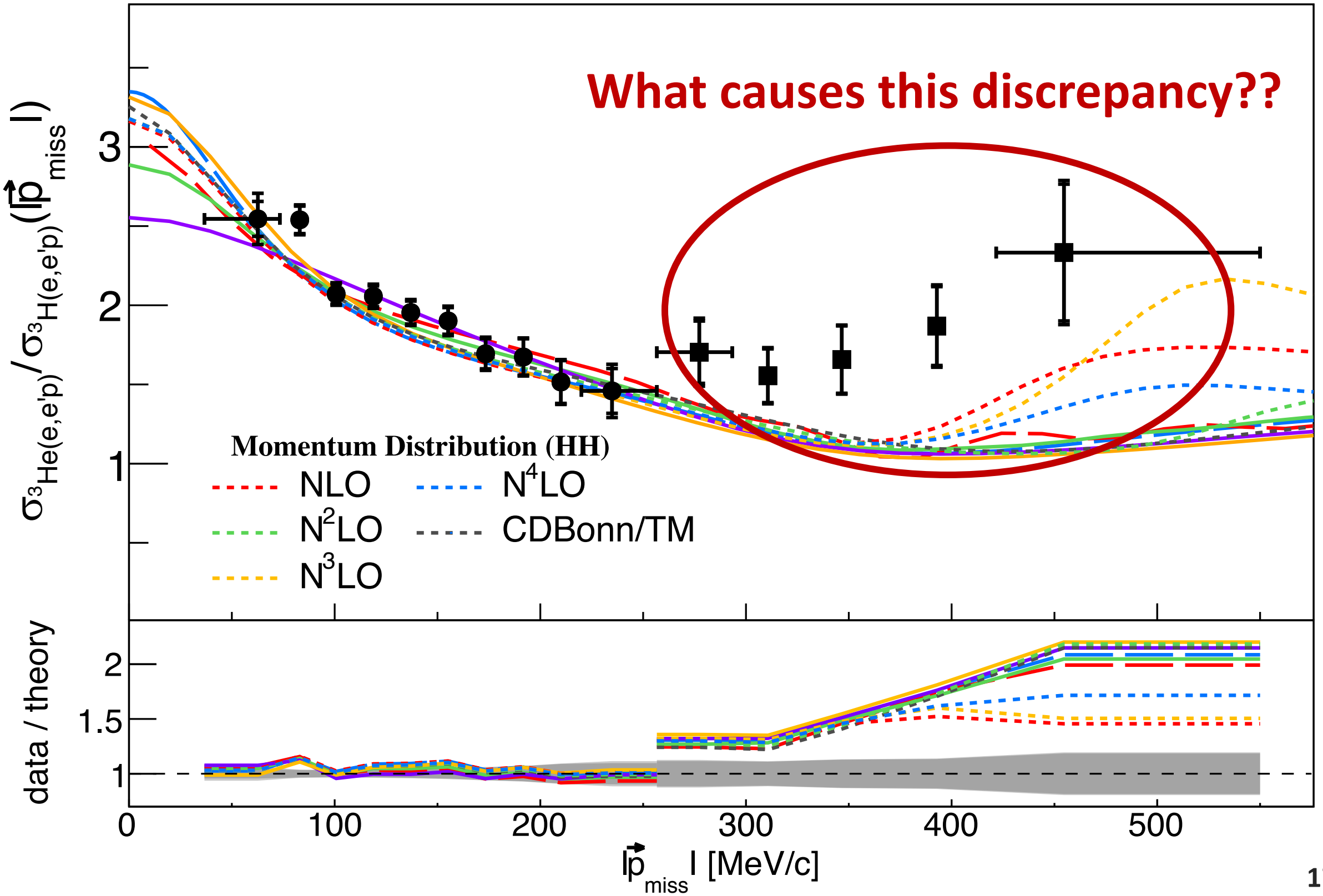


# $^3$He/$^3$H Cross-section ratio result:




Phys. Lett. B 797, 134890 (2019)

# $^3$He/$^3$H Cross-section ratio result:



# Extracting the absolute cross section

$$\frac{d^6\sigma(p_{miss}, E_{miss})}{dE_e dE_p d\Omega_e d\Omega_p} = \frac{Yield(p_{miss}, E_{miss})}{Q * \rho_A * \boldsymbol{\varepsilon} * \boldsymbol{VB} * \boldsymbol{C_{corr}}}$$

Integrated Luminosity

Detected phase space corrected for acceptance

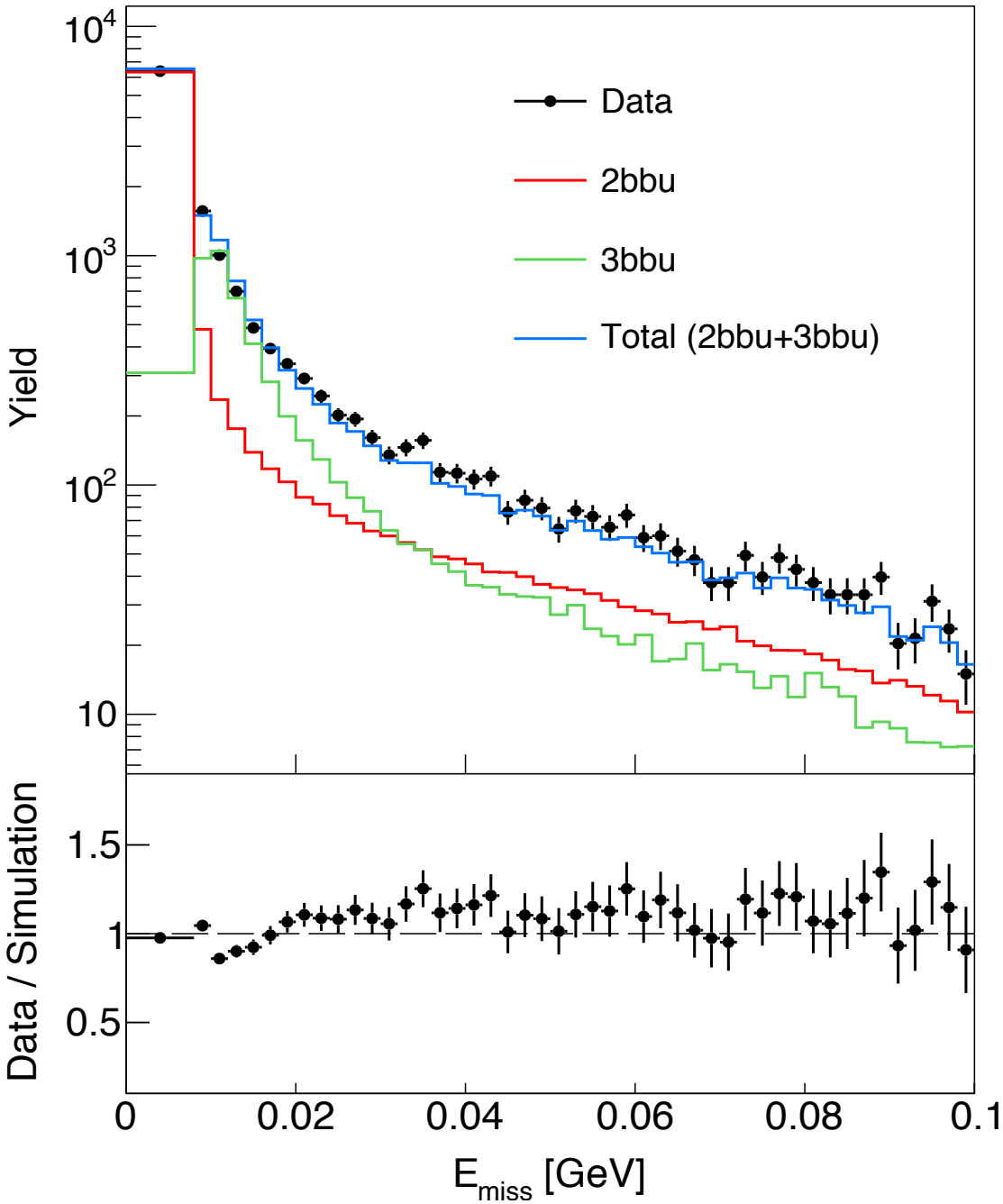
**Efficiencies**

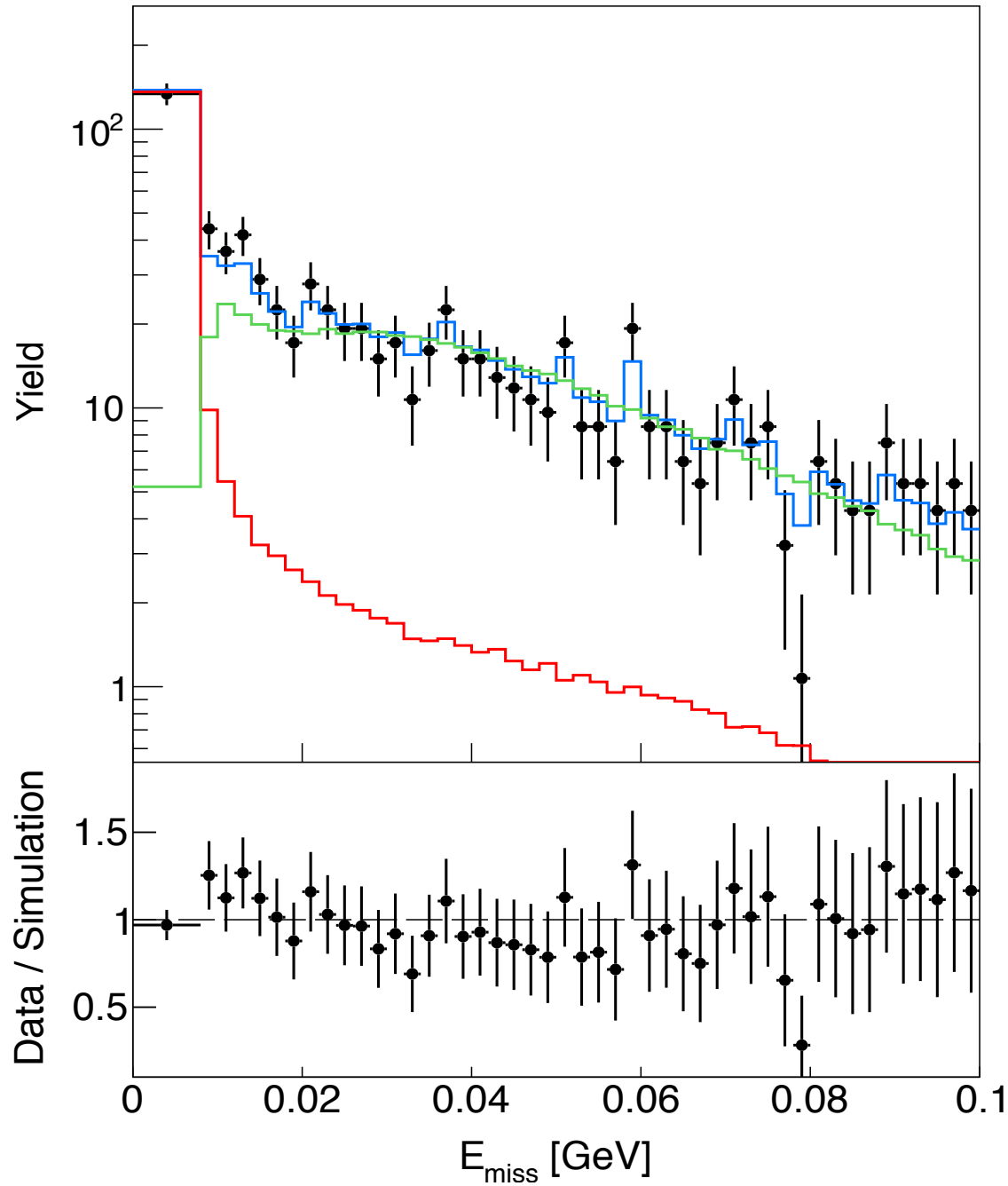
- Detectors
- Trigger
- Live time
- Boiling

**Correction factors**

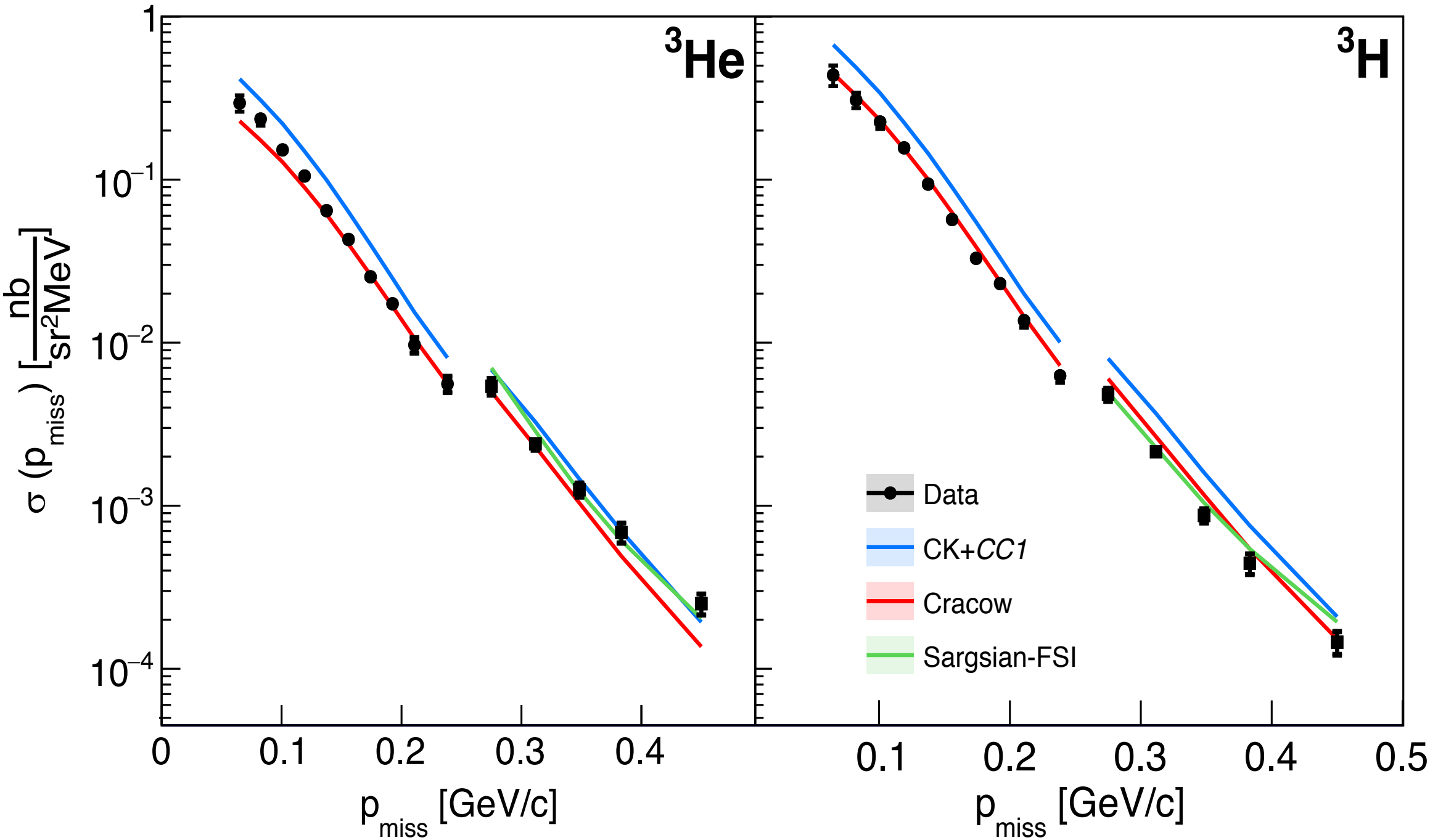
- Radiative correction
- Bin migration
- Bin centering
- Tritium Decay

# Separating two-body-breakup



# Extracted Absolute cross-section



# Compare to different theory calculation

## PWIA with exactly continuum $FSI_{23}$

**Cracow:**

- Faddeev-formulation-based calculations
- Continuum interaction between two spectator nucleons ($FSI_{23}$)

**CK + *CC1*:**

- $^3$He spectral function of C. Cio degli Atti and L. P. Kaptari and electron off-shell nucleon cross-section
- Including $FSI_{23}$

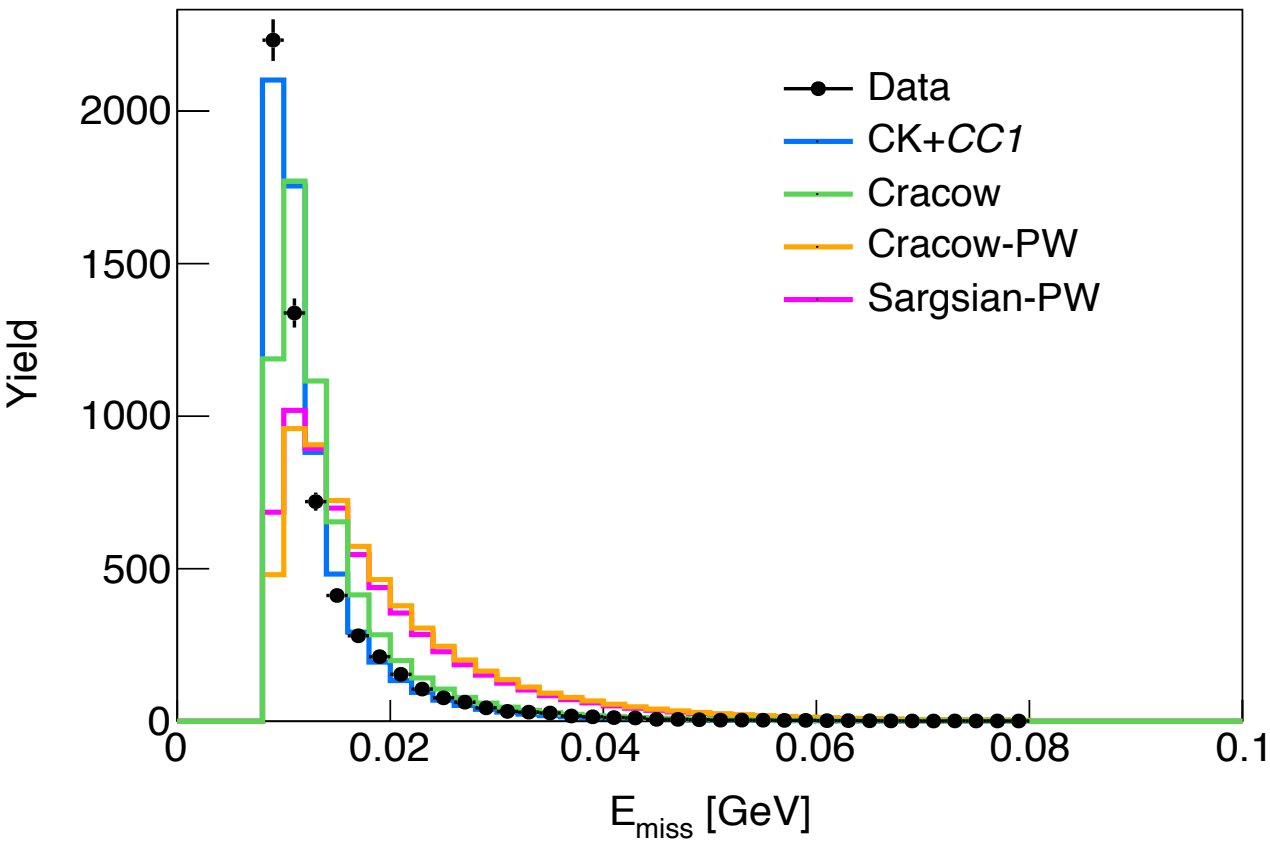
## FSI of struck nucleon, NO $FSI_{23}$

**M. Sargian (FSI):**

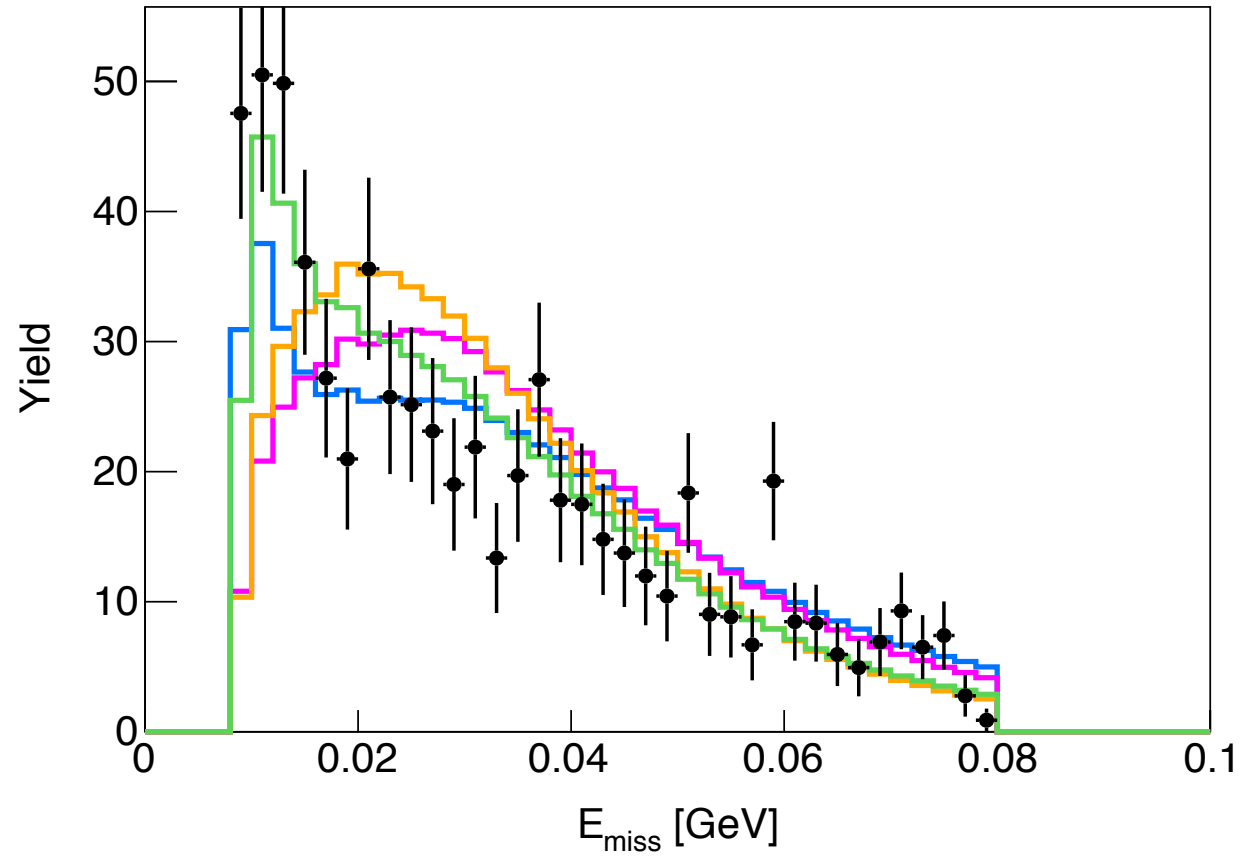
- generalized Eikonal approximation

# Model comparison in $E_{miss}$

Low $p_{miss}$




High $p_{miss}$



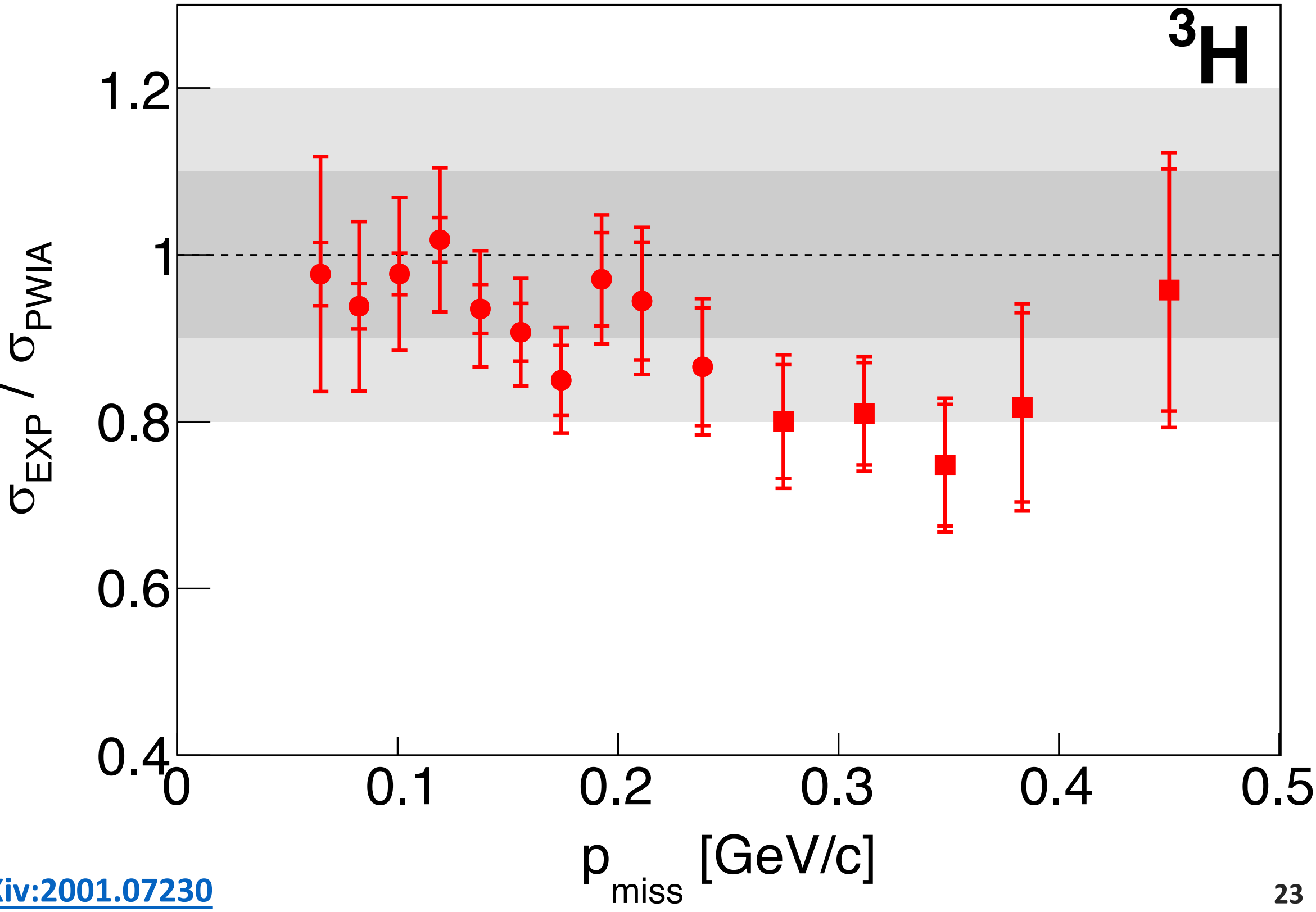

PWIA+FSI$_{23}$:

- Cracow
- CK + *CC1*

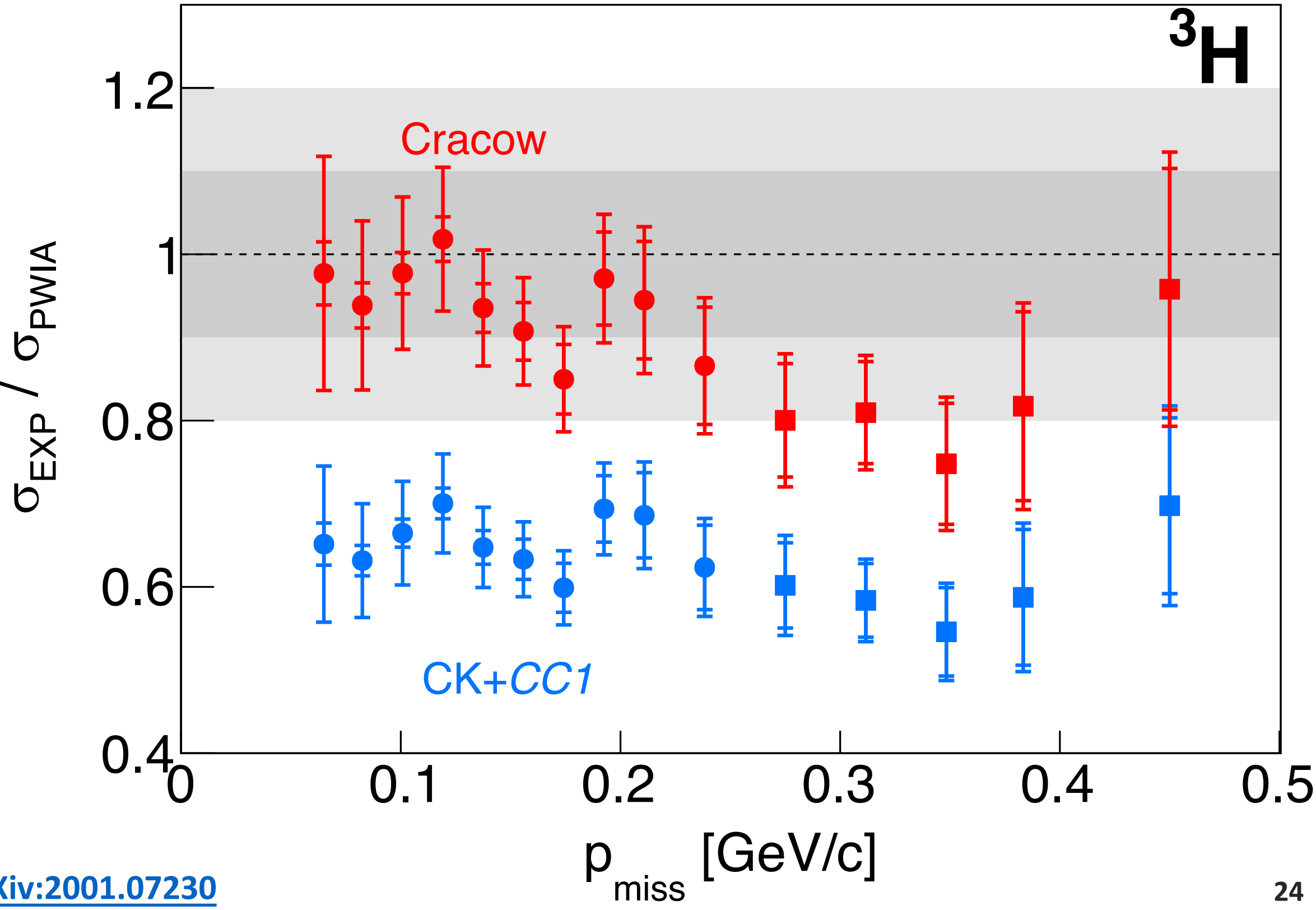
PWIA NO FSI$_{23}$:

- Cracow-PW
- Sargsian-PW

# Data & cracow calculation agree within 20% for H

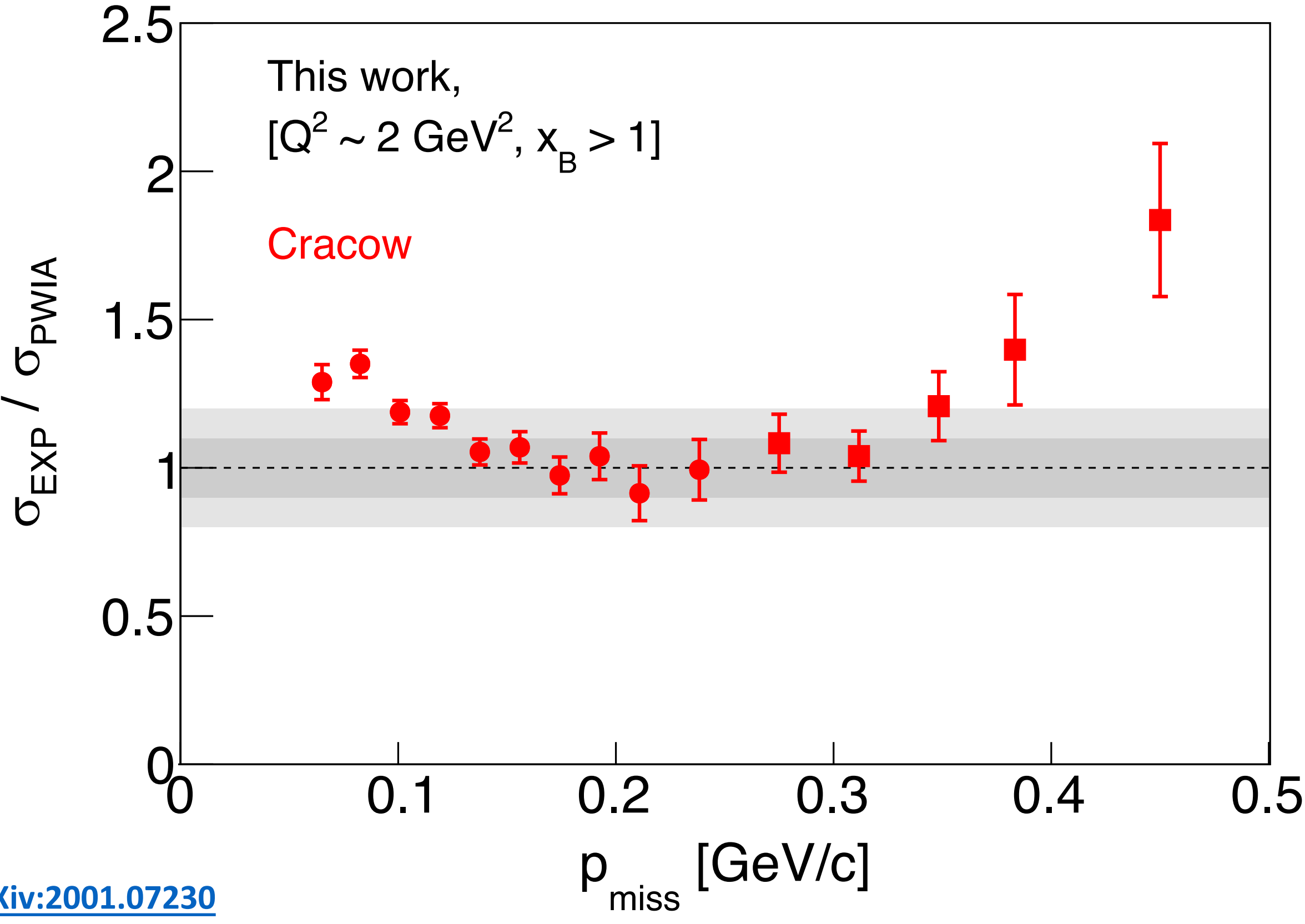



arXiv:2001.07230



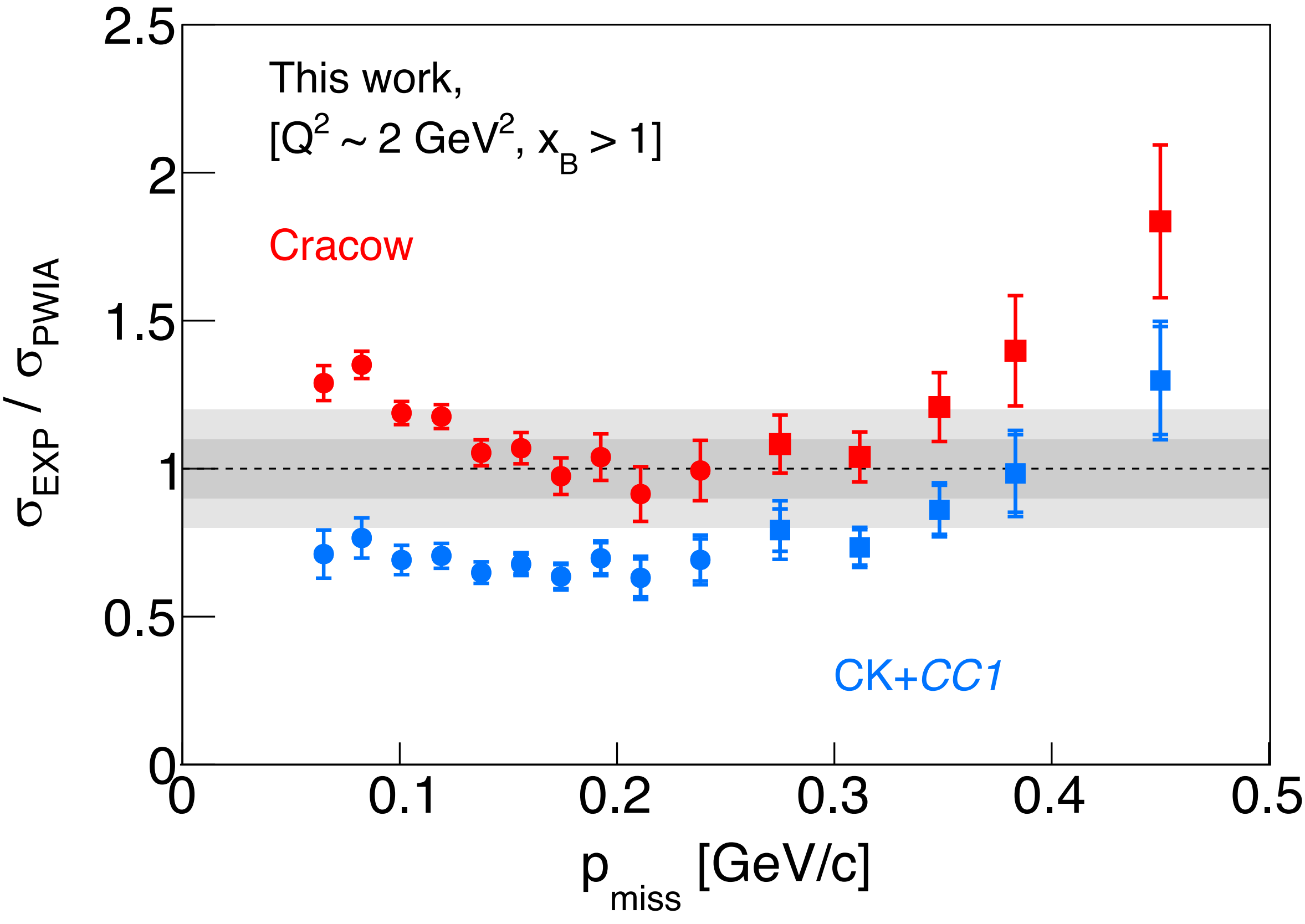

arXiv:2001.07230

# Exp/PWIA: Cracow For $^3$He

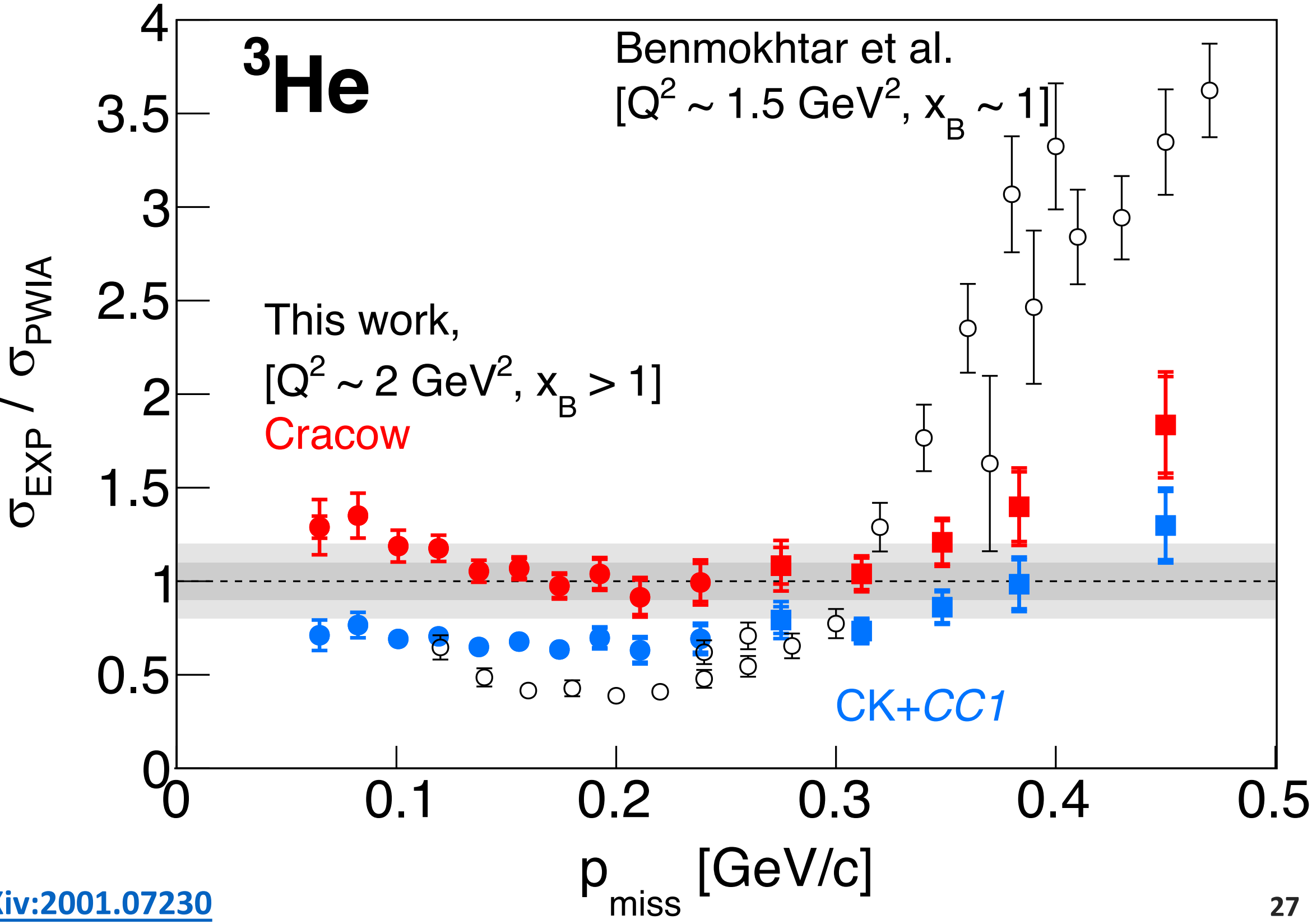



arXiv:2001.07230

# Exp/PWIA: Cracow and CK+CC1 For $^3$He

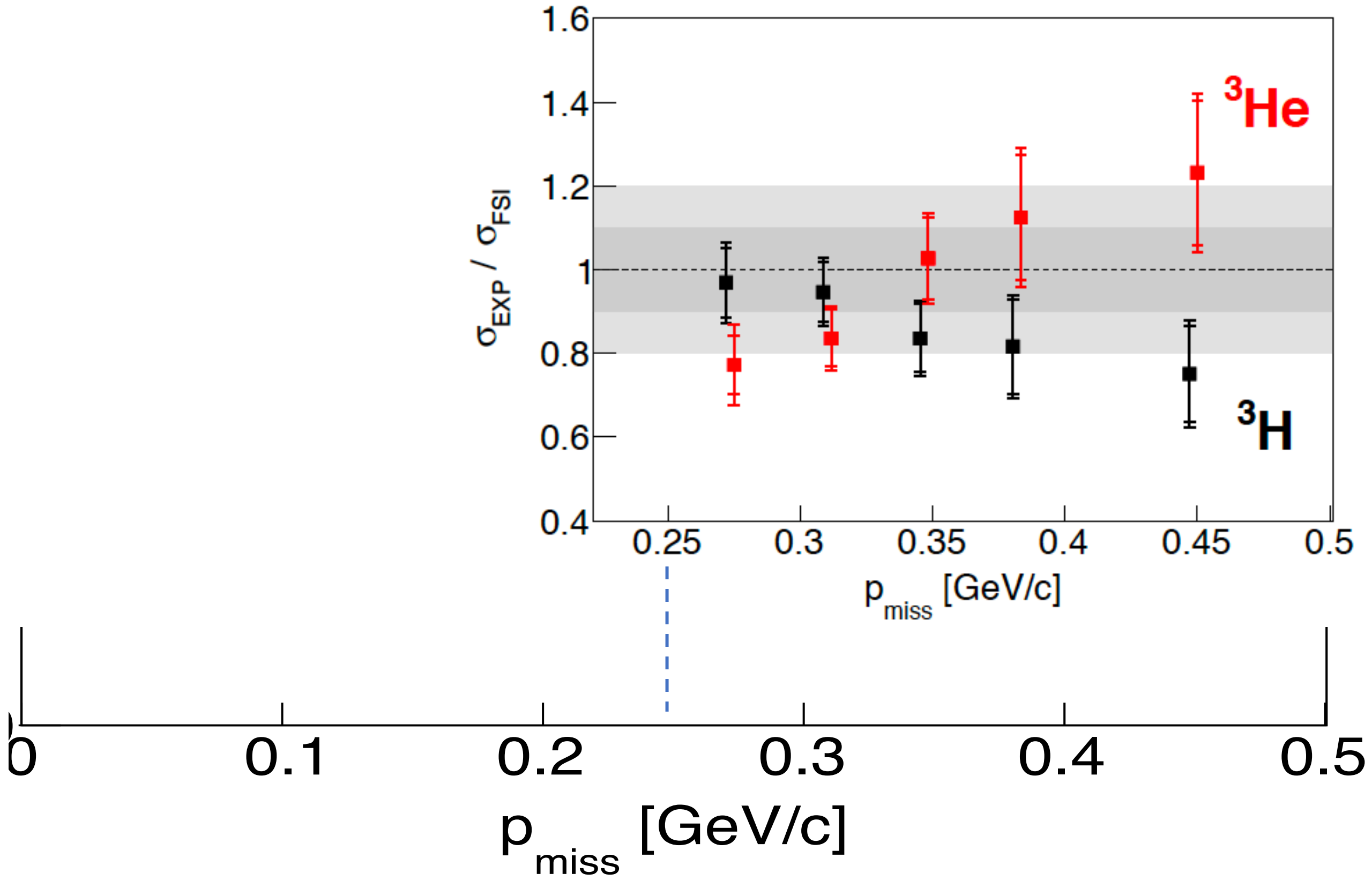


# Much better agreement than previous data!

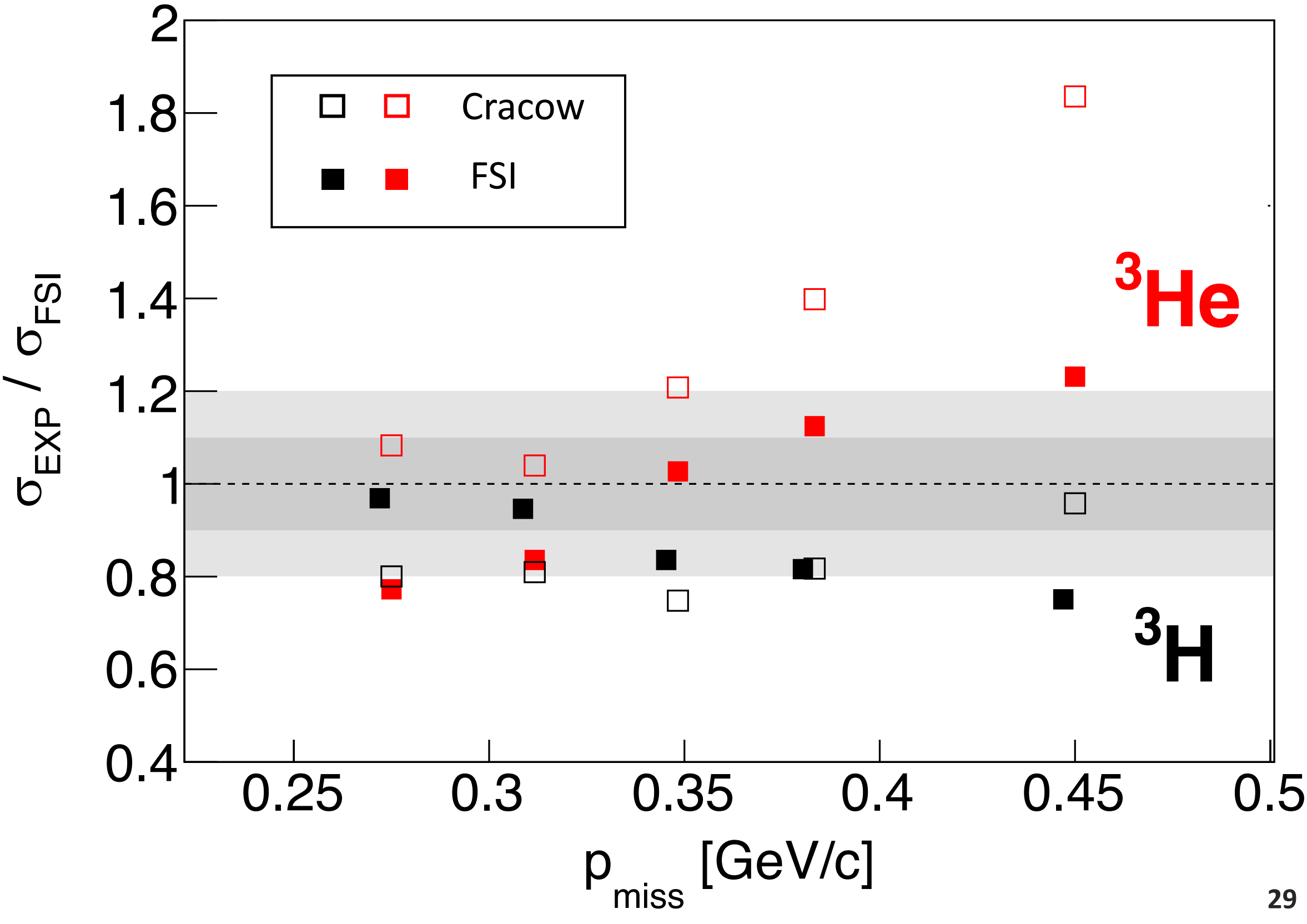



arXiv:2001.07230

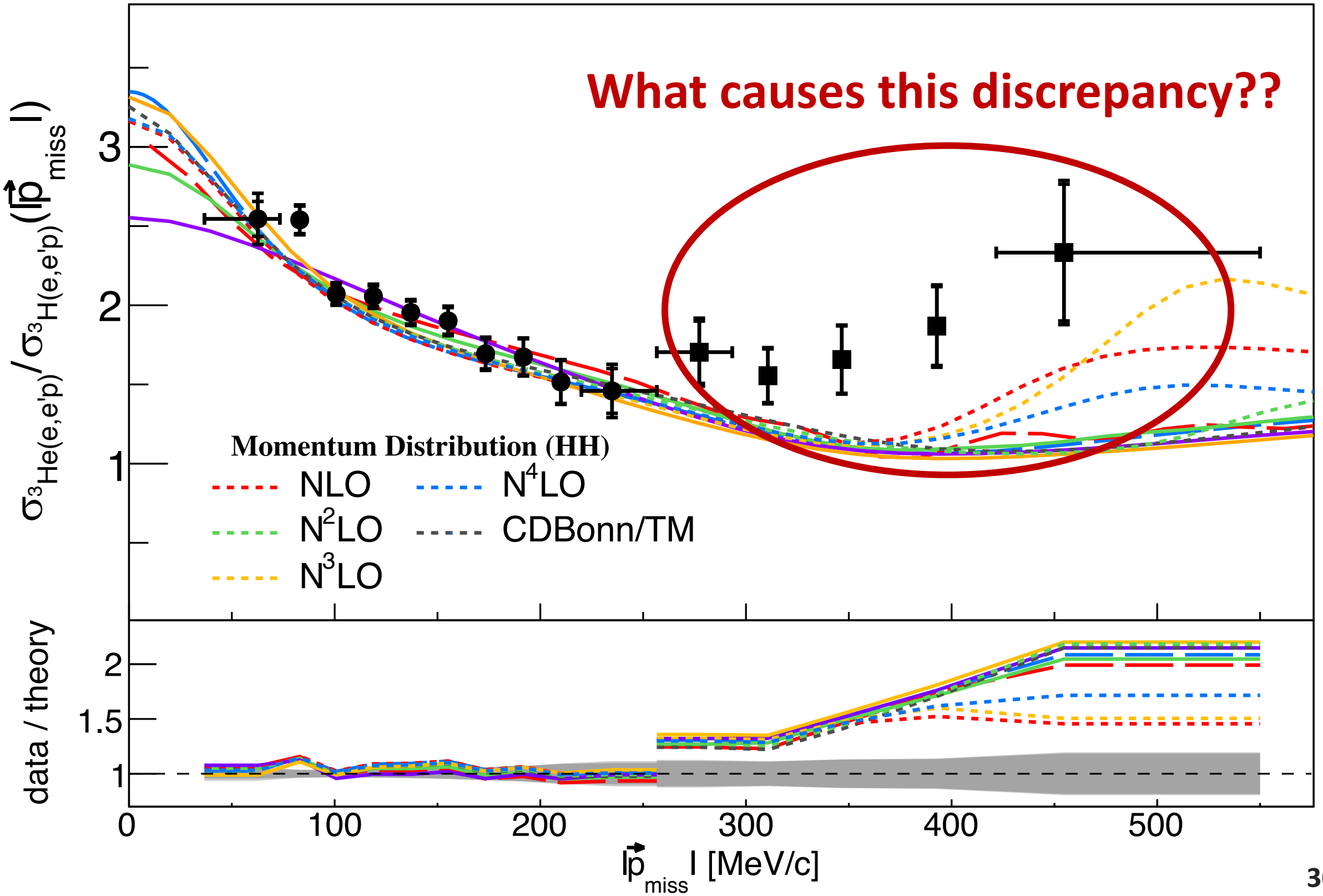
# Leading Nucleon FSI: Small but improve things!



# Leading Nucleon FSI: Small but improve things!

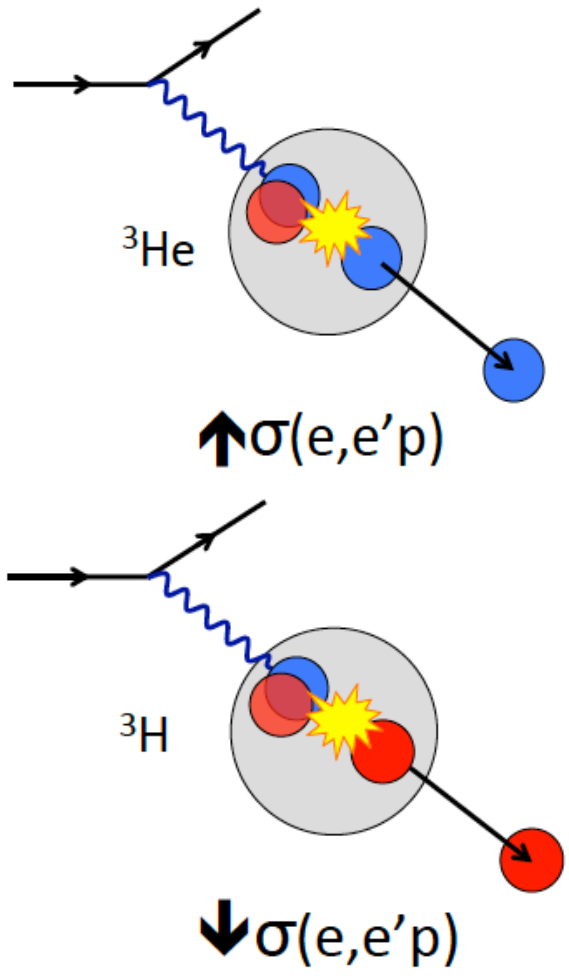


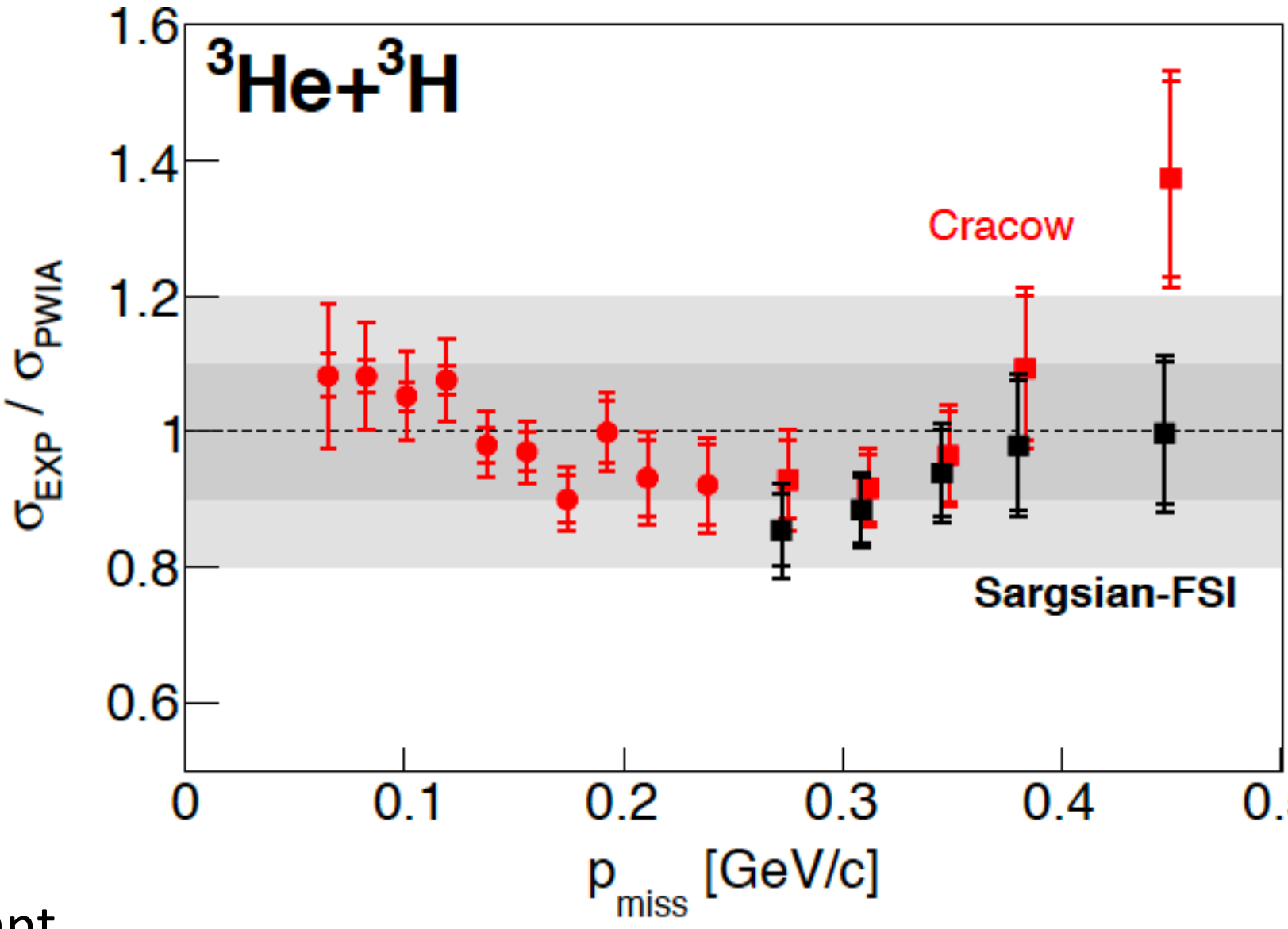
# $^3$He/$^3$H Cross-section ratio result:



# Still missing single charge exchange!

Single Charge exchange:



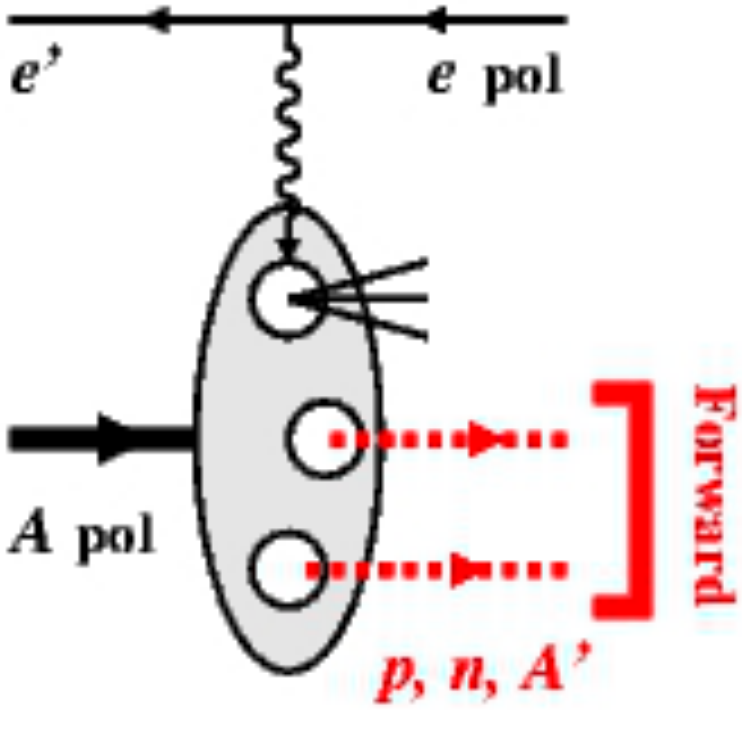

High-pmiss and np-doninant

# Results from A = 3 (e, e'p) at Jlab show:

- ❑Smaller Non-QE contribution compared to the previous measurements
- ❑Better agreement with Cracow than with CK+CC1
- ❑Better agreement of PWIA calculations with 3H than with 3He
- ❑Inclusion of leading nucleon FSI enhances the agreement
- ❑High-pmiss disagreement could be explained by SCX in an np-SRC dominated regime.

These Data are a crucial benchmark for few-body nuclear theory and are essential test of theoretical calculation

# Exploring QCD with light nuclei at EIC



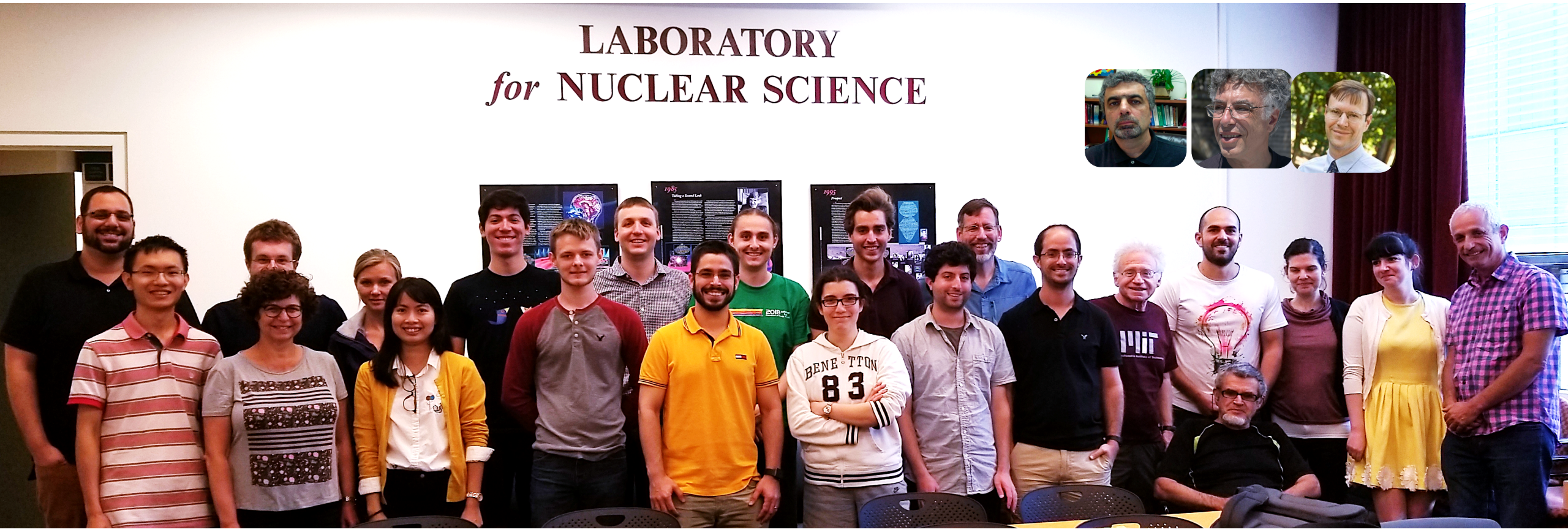

## EIC Capabilities:

- CM energy: ~ 20 – 100 (140) GeV
- Luminosity: ~ $10^{34}$ $cm^{-2}$ $s^{-1}$
- Polarized proton and light nuclei

## Physics and Objectives:

- Free neutron structure, neutron-spin structure, ect
- Partonic structure of light nuclei
- Short-range correlation studies with light nuclei

# Thank you !



# Compare to different theory calculation

## Unfactorized Calculation

$$\sigma = \sigma_{\mathrm{Mott}} \hat{l}^{\mu\nu} W^{A}_{\mu\nu}$$

Cracow, M. Sargsian

## Factorized Approximation

$$\sigma = \sigma_{ep} \cdot S(p_i, E_i)$$

CK + *CC1*