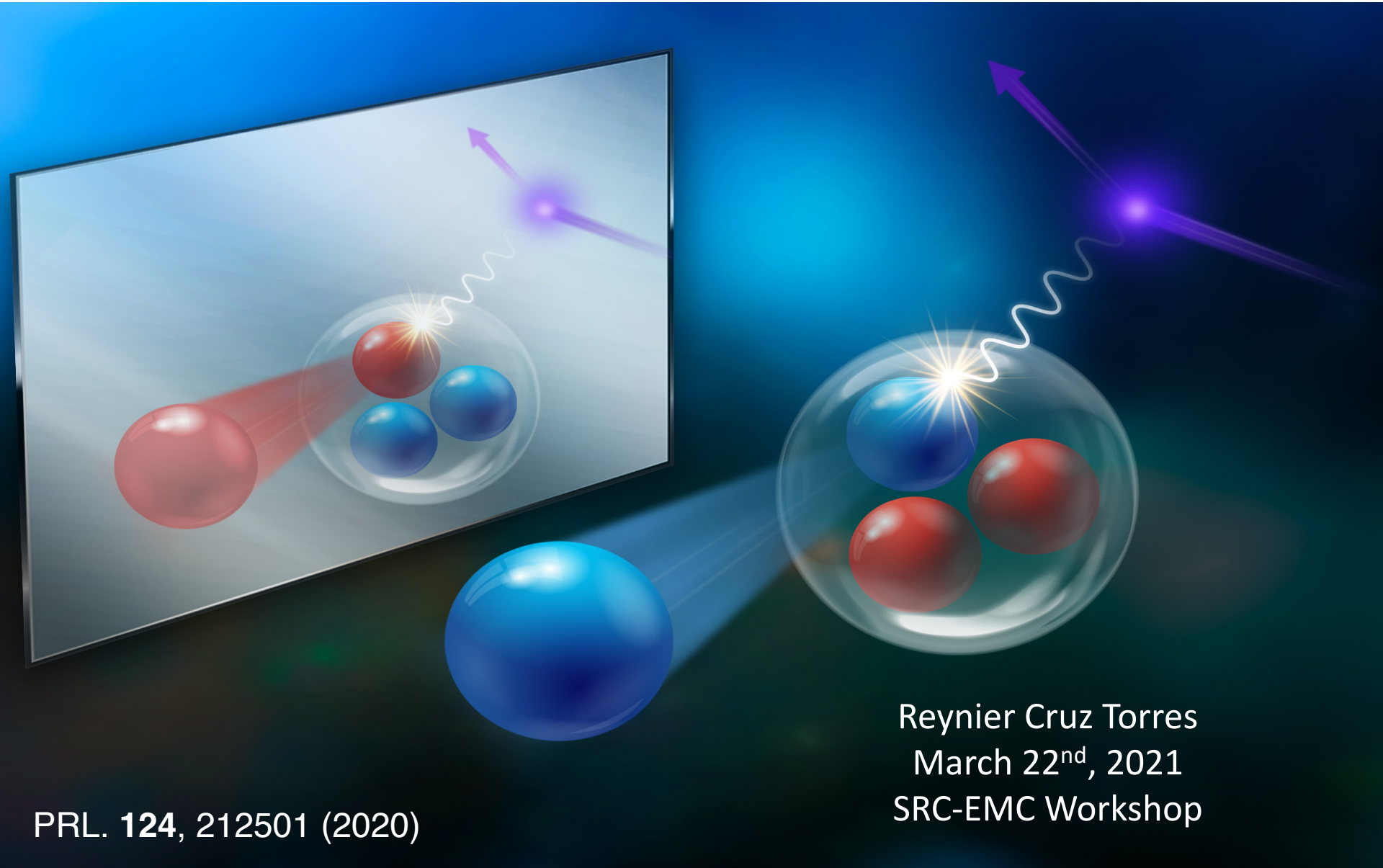
Probing few-body nuclear dynamics via ^{3}H and ^{3}He (e,e'p) cross-section measurements

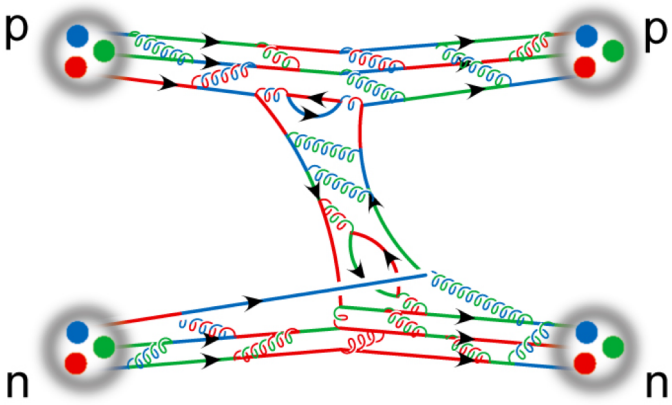


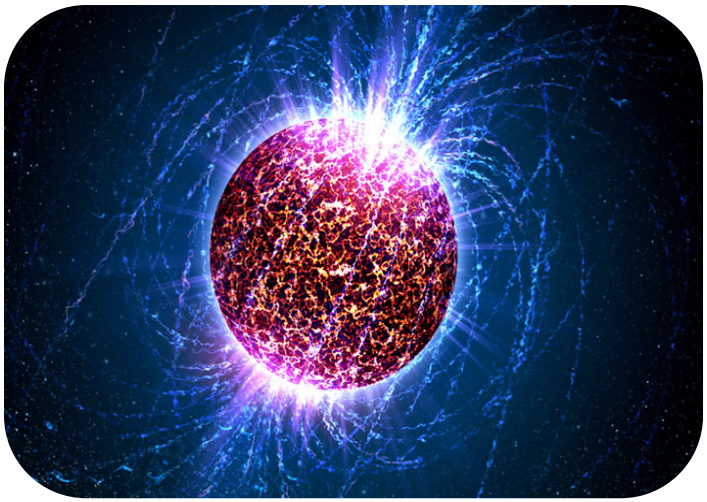
Reynier Cruz Torres
March 22nd, 2021
SRC-EMC Workshop

PRL. **124**, 212501 (2020)

Why study the NN interaction?

- Crucial input to nuclear structure calculations
- Understanding of QCD
- Connections to astrophysics





Testing Reaction-Mechanism and NN Models

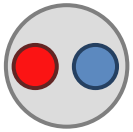
- Measure nucleon-knockout cross sections.

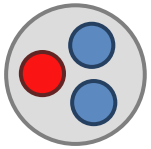
- Compare with calculations using different NN interactions and modeling of reaction.

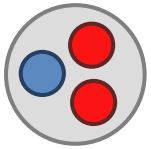
- See which one works best.

Why light nuclei?

- exactly calculable
- test and benchmark theory

Deuteron 

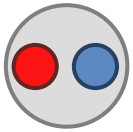
A=3 



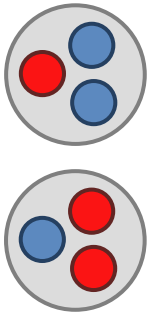
Why light nuclei?

- exactly calculable
- test and benchmark theory

Why A=3?

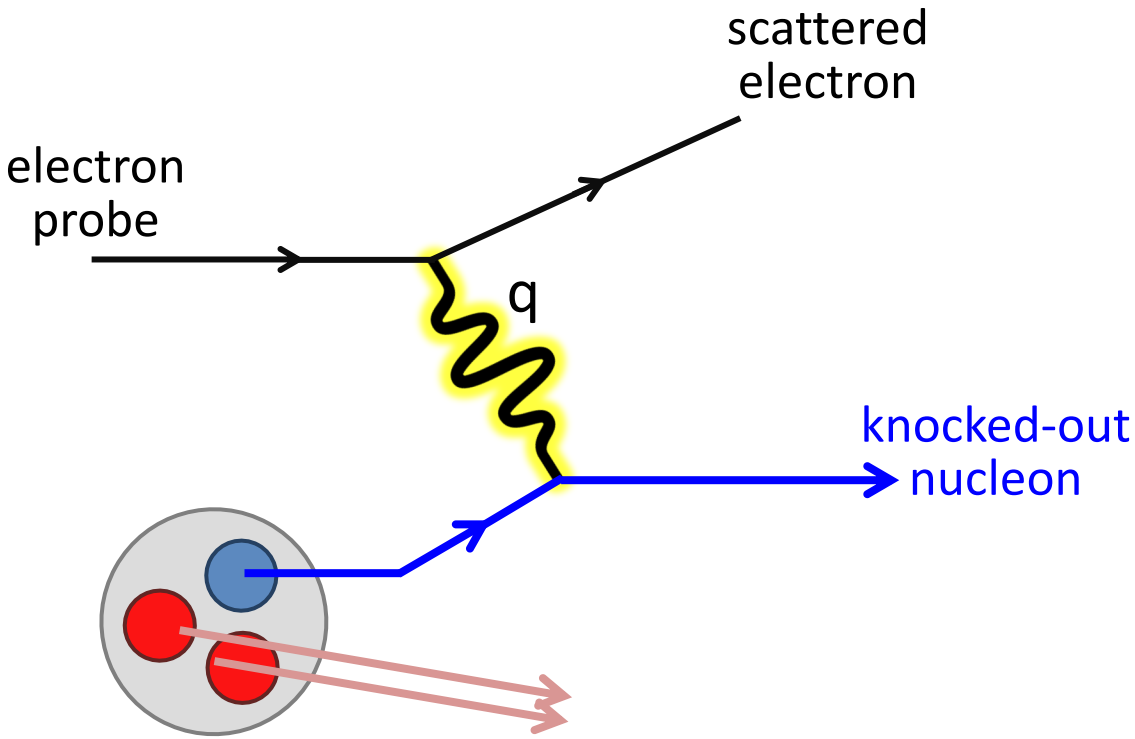
Deuteron 

- only pn interaction
- extensively measured

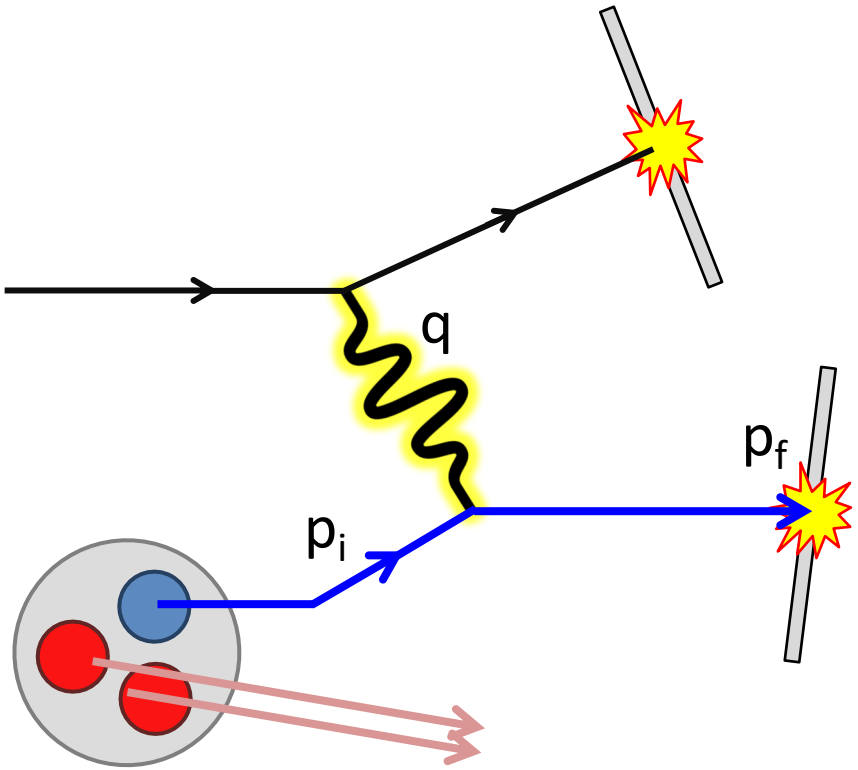
A=3 

- pp, pn, nn interactions
- ^{3}H targets are uncommon (available once a generation)

Electron-induced Proton Knockout



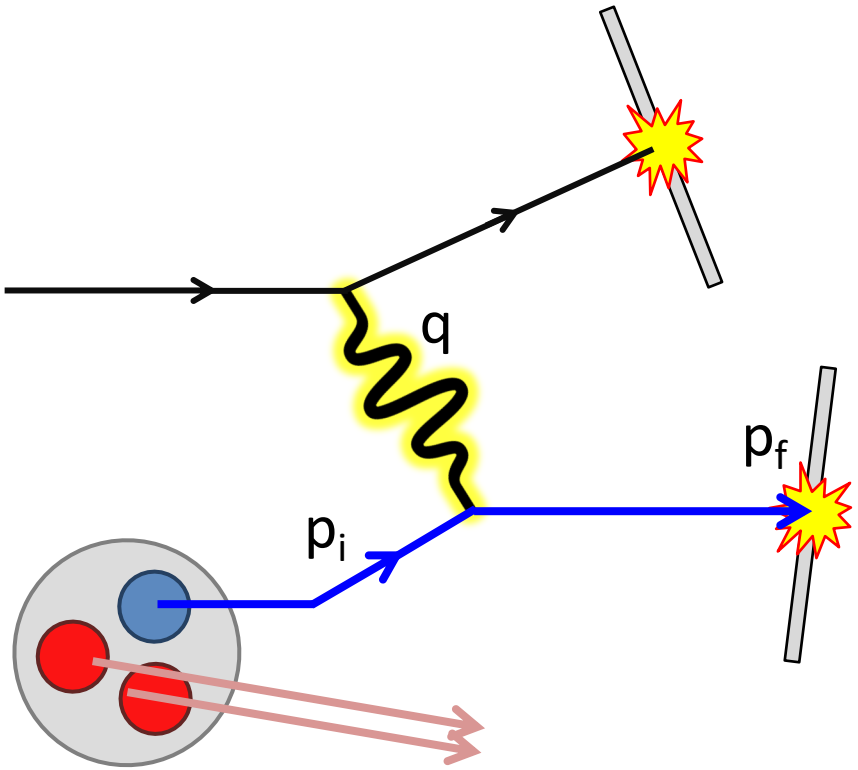
Electron-induced Proton Knockout



Missing momentum

$$\vec{p}_{miss} \equiv \vec{p}_f - \vec{q}$$

Plane-Wave Impulse Approximation (PWIA)



Missing momentum

$$\vec{p}_{miss} \equiv \vec{p}_f - \vec{q}$$

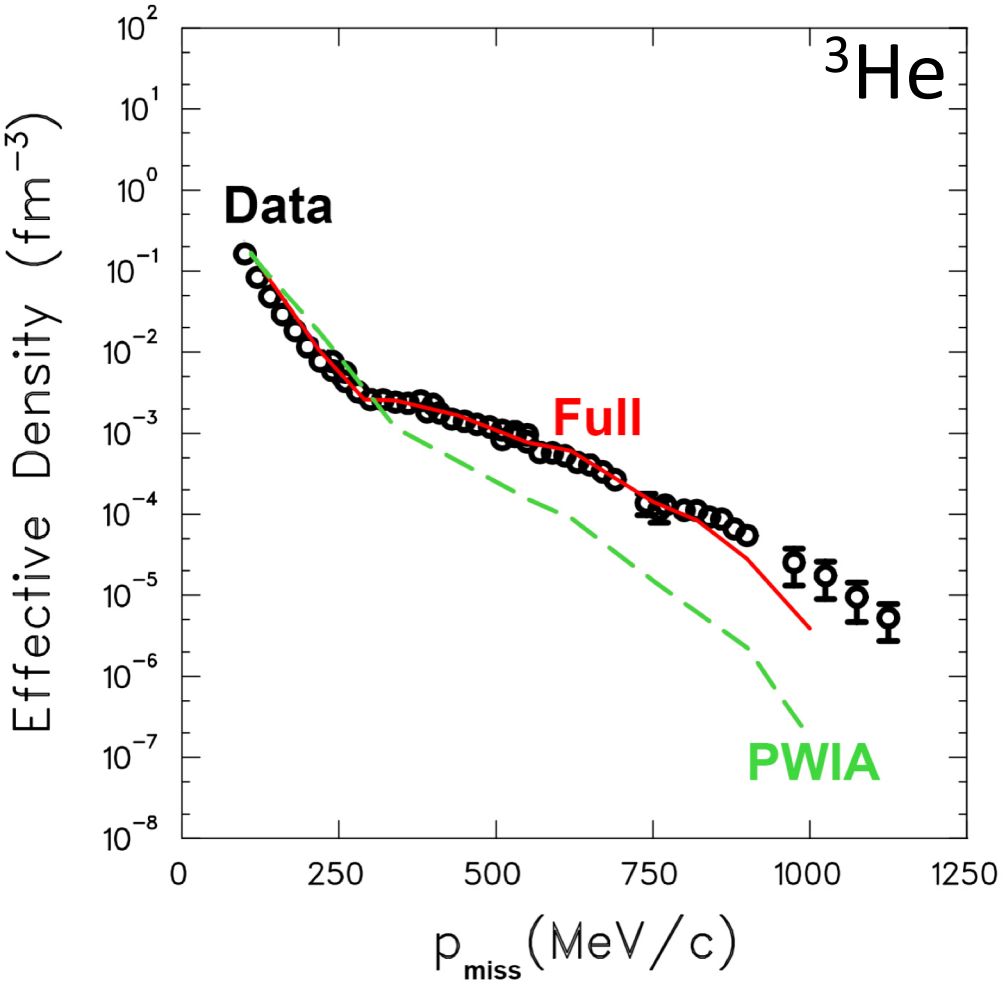
Assuming:

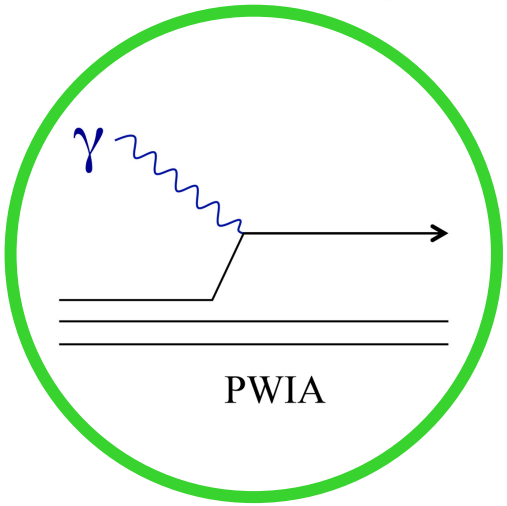
1) momentum transfer absorbed by a single nucleon.

1) knocked-out nucleon did not rescatter as it left the nucleus.

$$\vec{p}_{miss} = \vec{p}_i$$

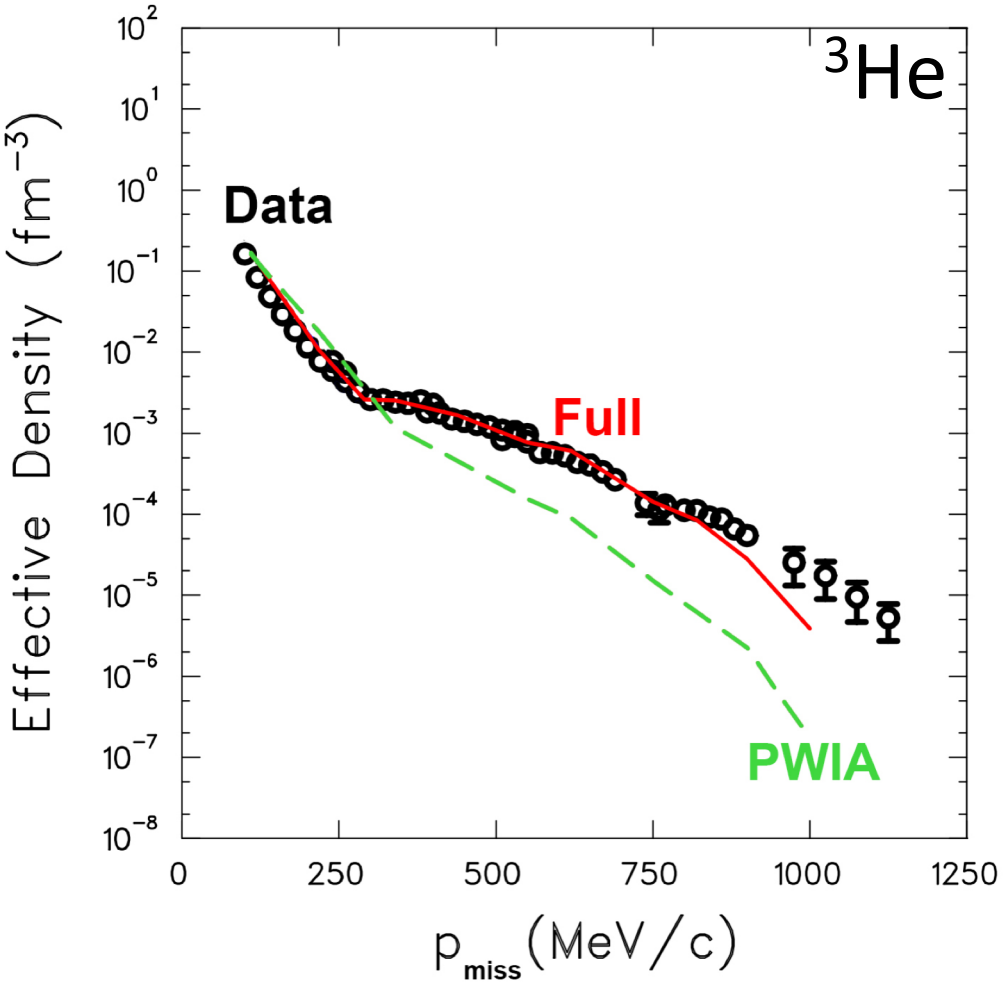
Previous studies and non-QE mechanisms

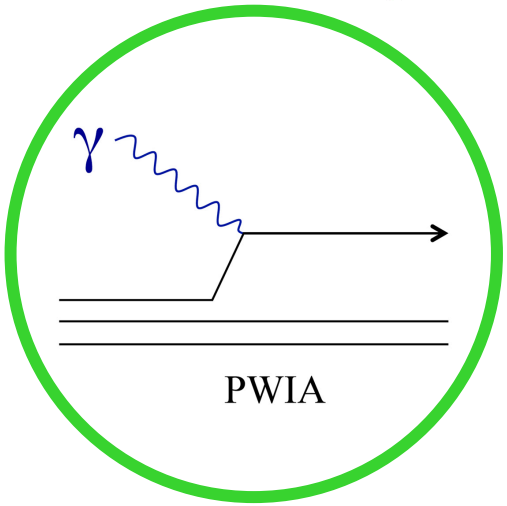


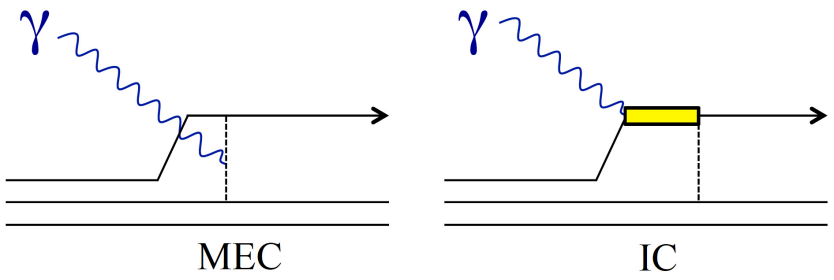


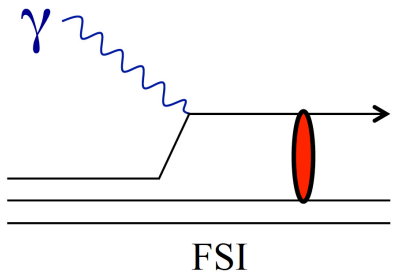
F. Benmokhtar et al., PRL 94, 082305 (2005)

Previous studies and non-QE mechanisms







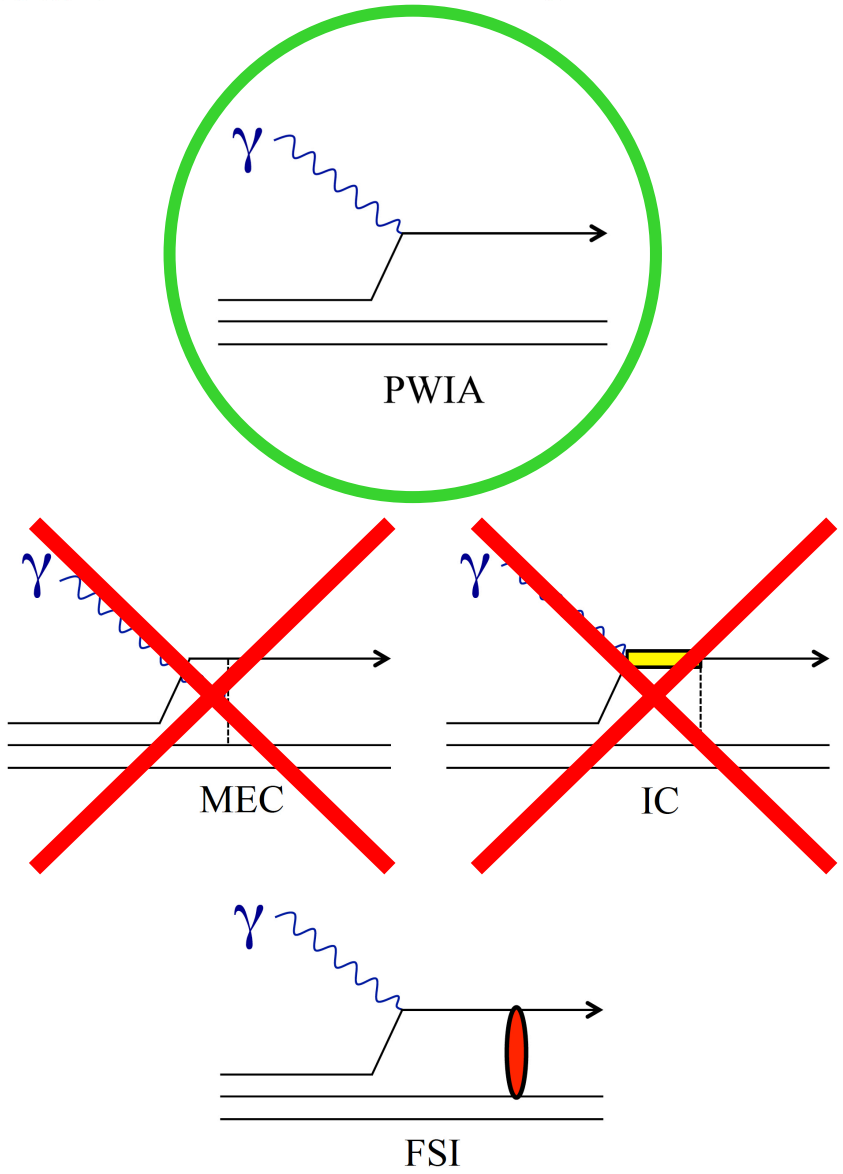


F. Benmokhtar et al., PRL 94, 082305 (2005)

Minimizing competing mechanisms

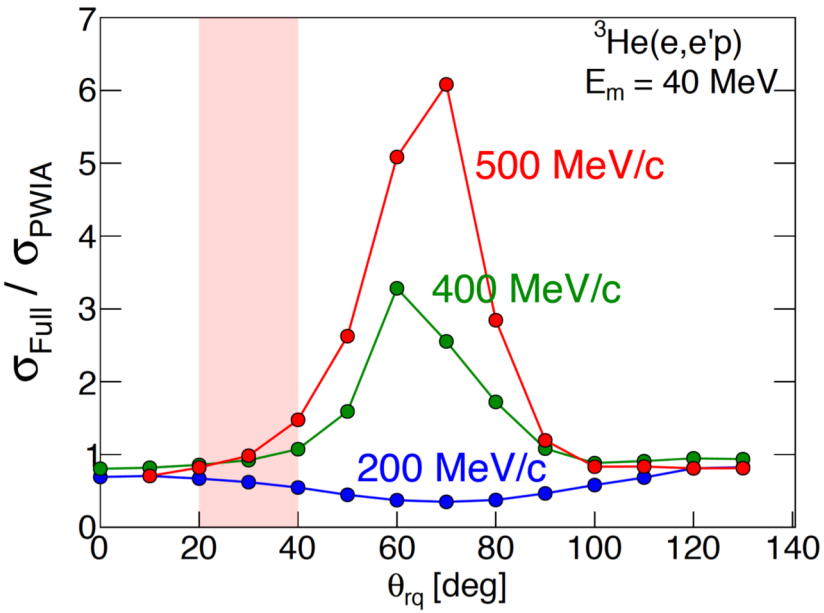
$Q^2 > 2\ GeV^2$

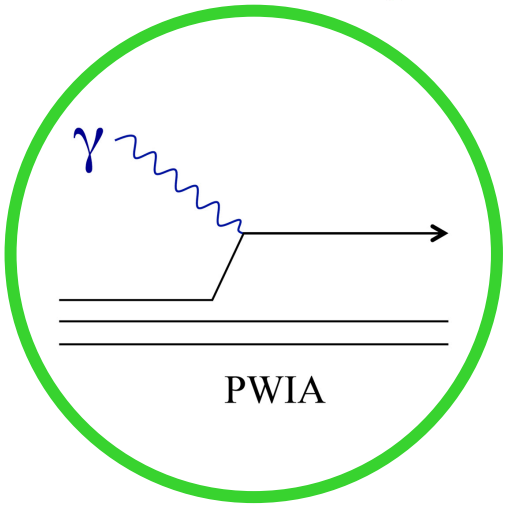
$x_B = Q^2/2m_p\omega > 1$

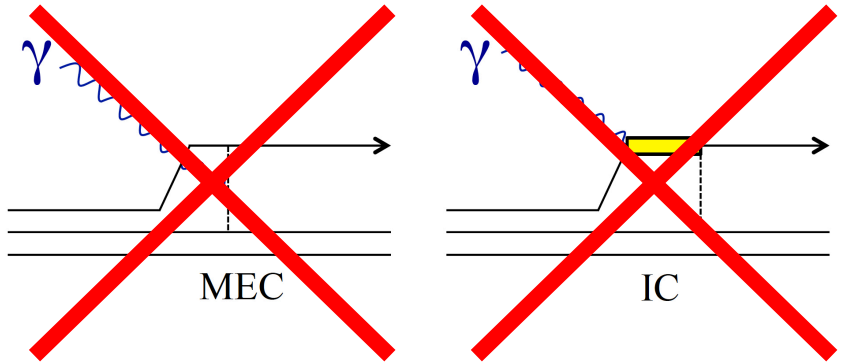


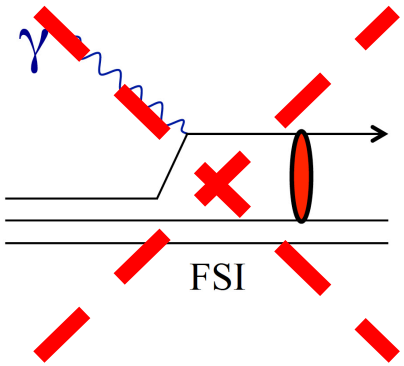
M. M. Sargsian, Int. J. Mod. Phys. E10, 405 (2001)
M. M. Sargsian et al., J. Phys. G29, R1 (2003)

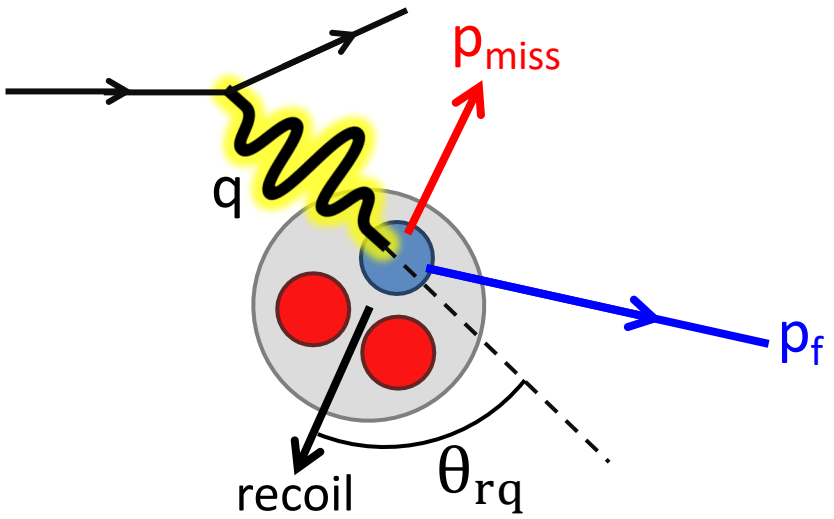
Minimizing competing mechanisms



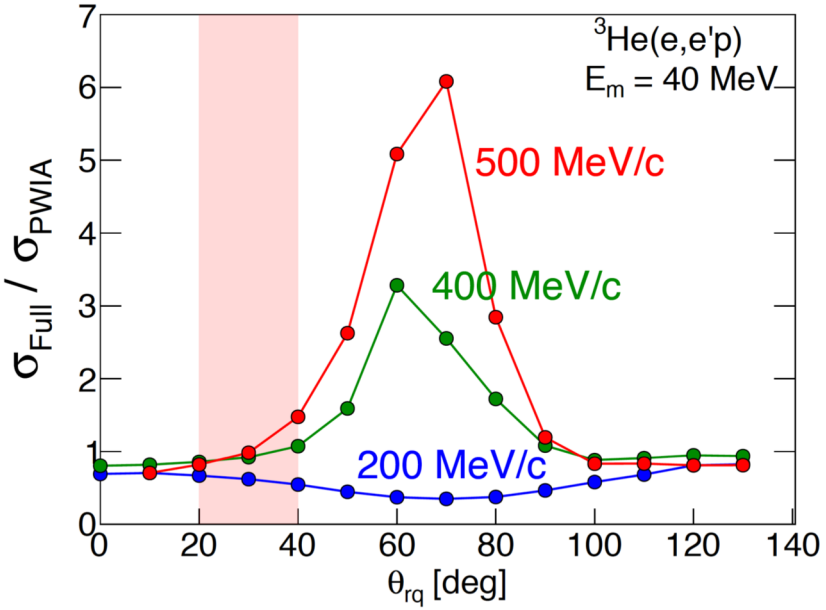


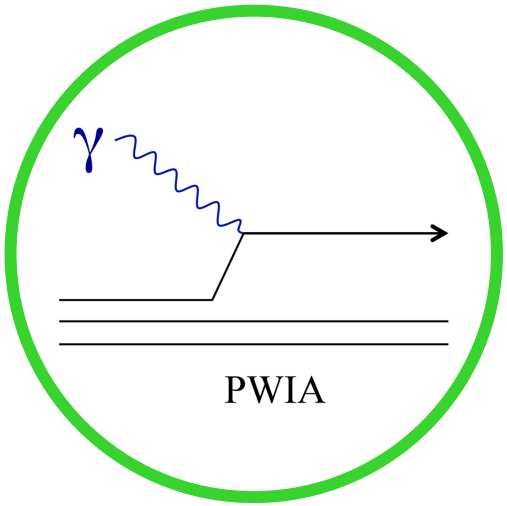


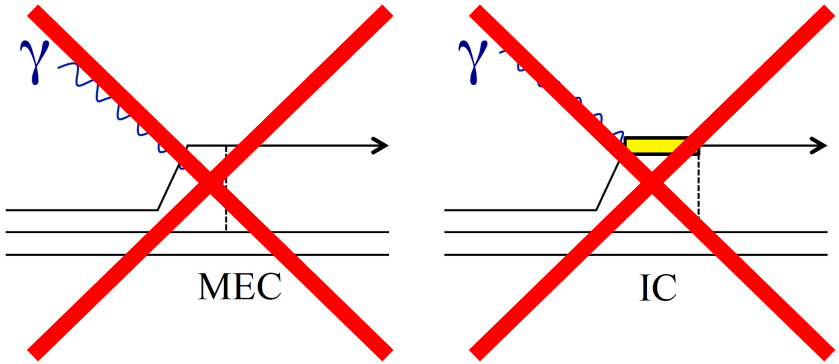


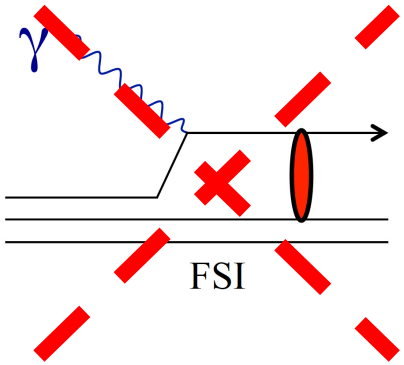


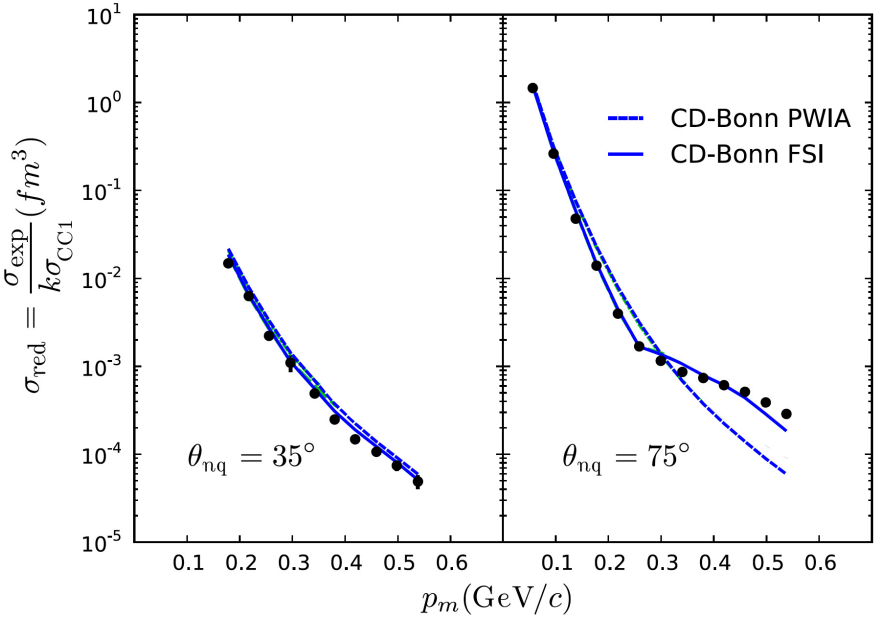
Minimizing competing mechanisms





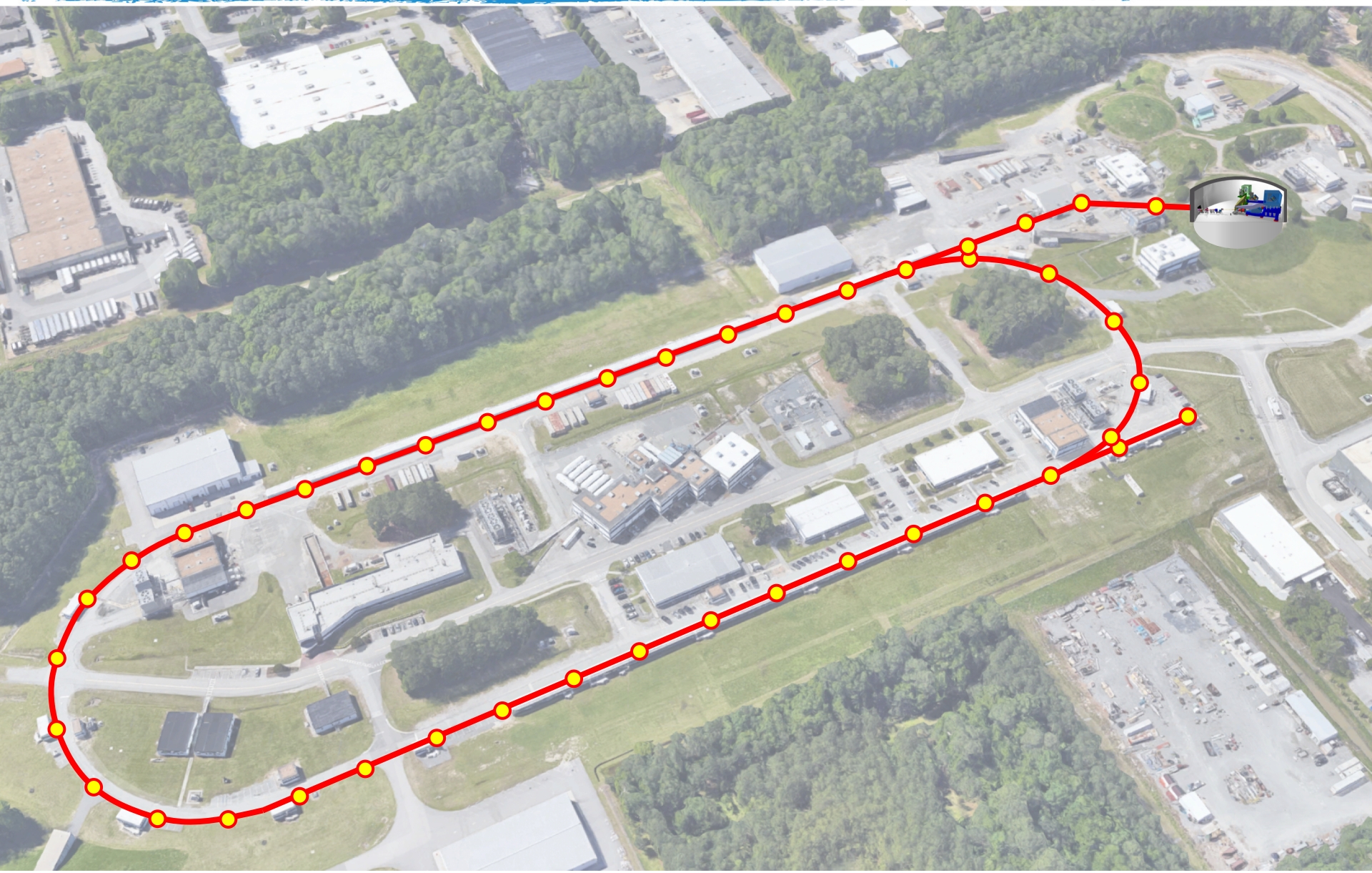




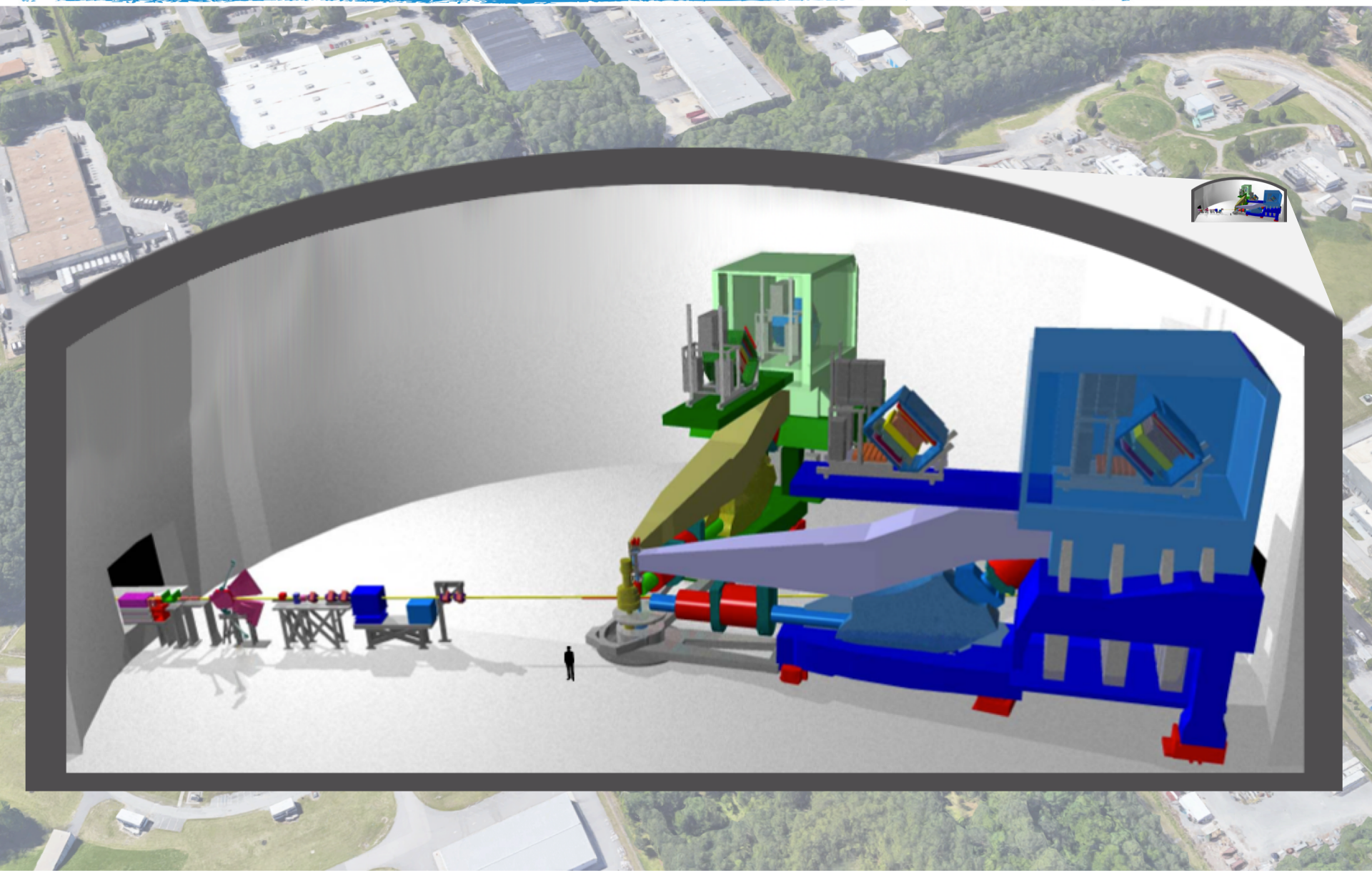


Jefferson Lab

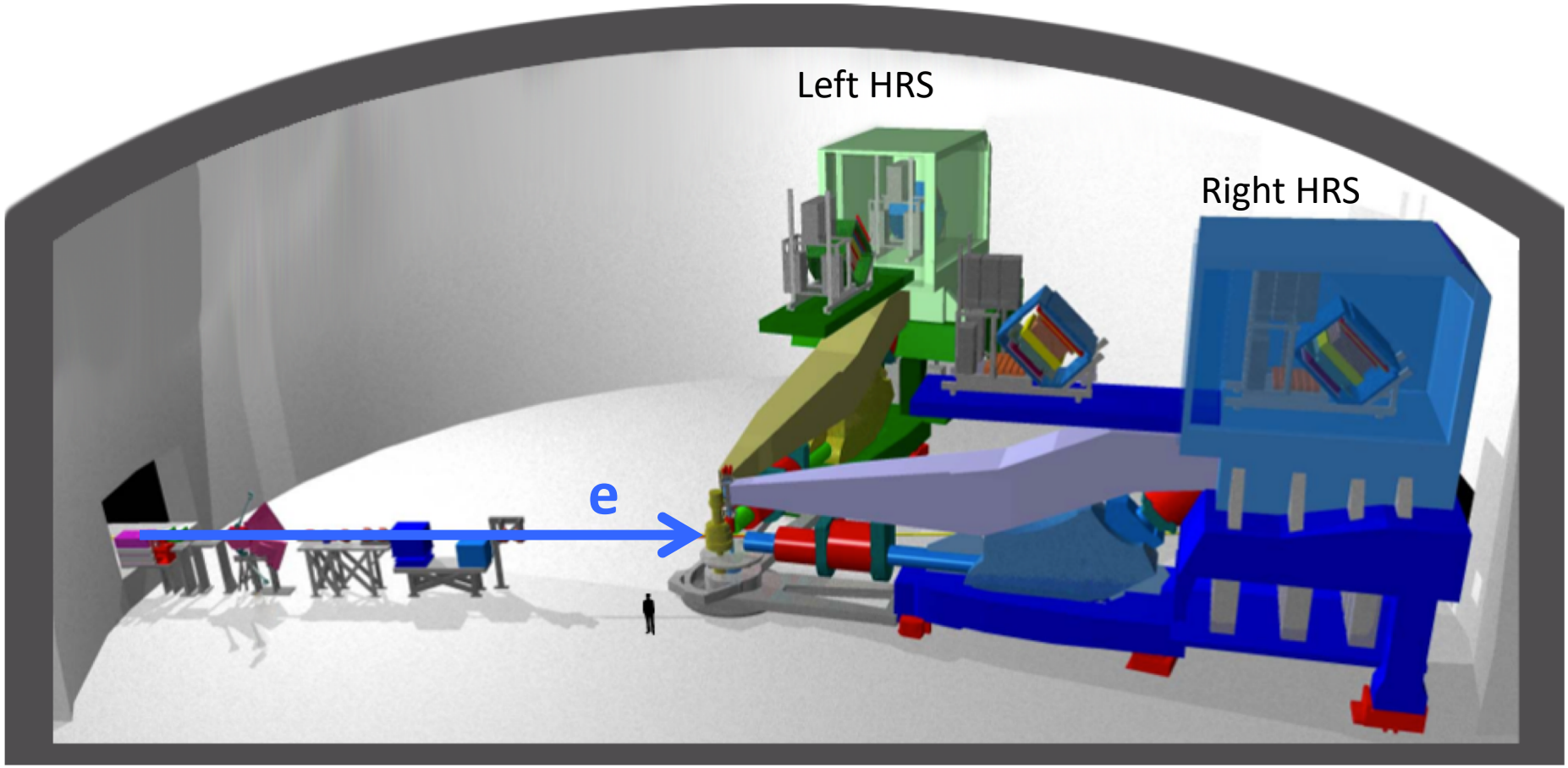
Jefferson Lab



Hall-A of Jefferson Lab



Hall-A of Jefferson Lab



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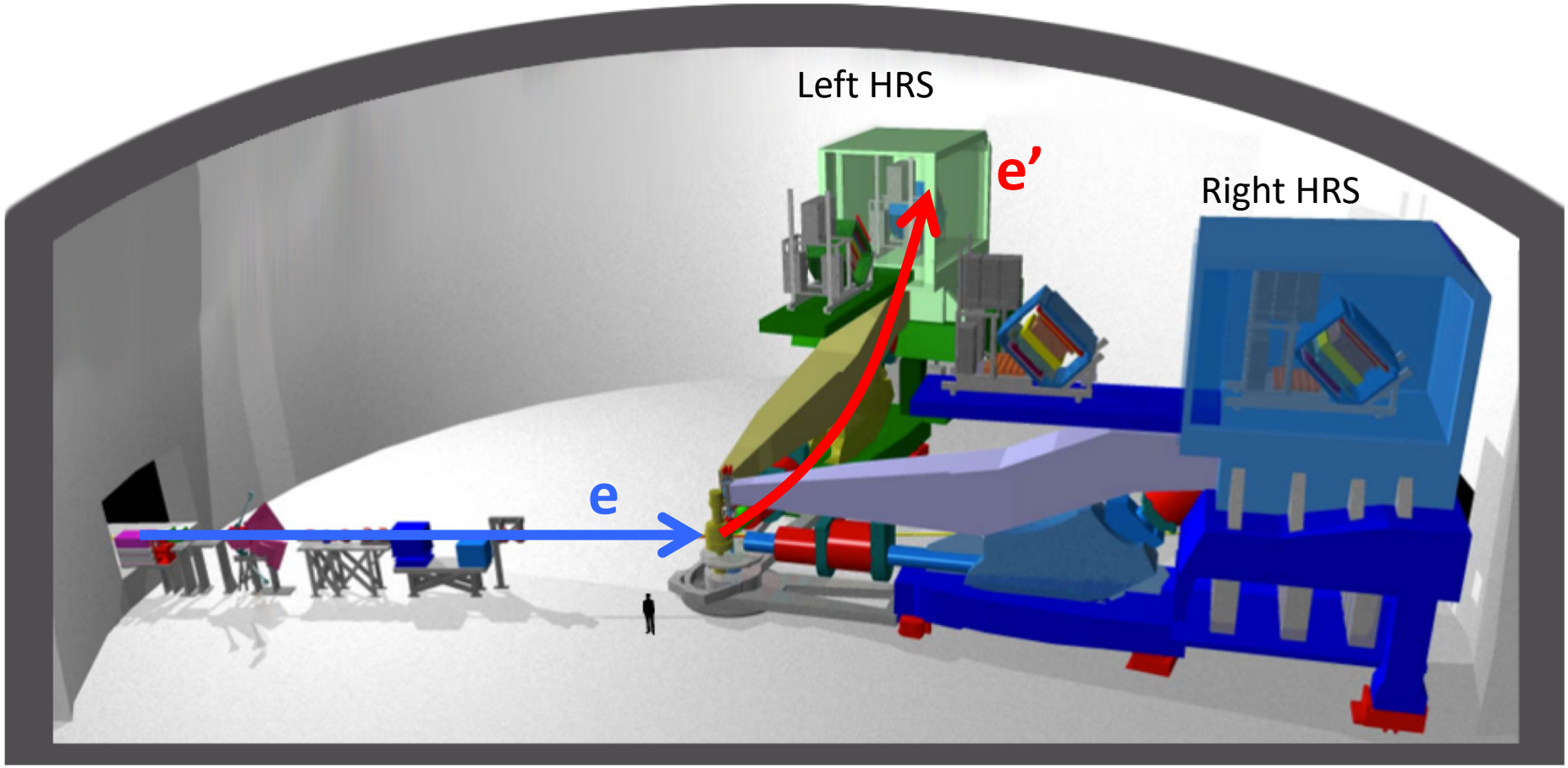
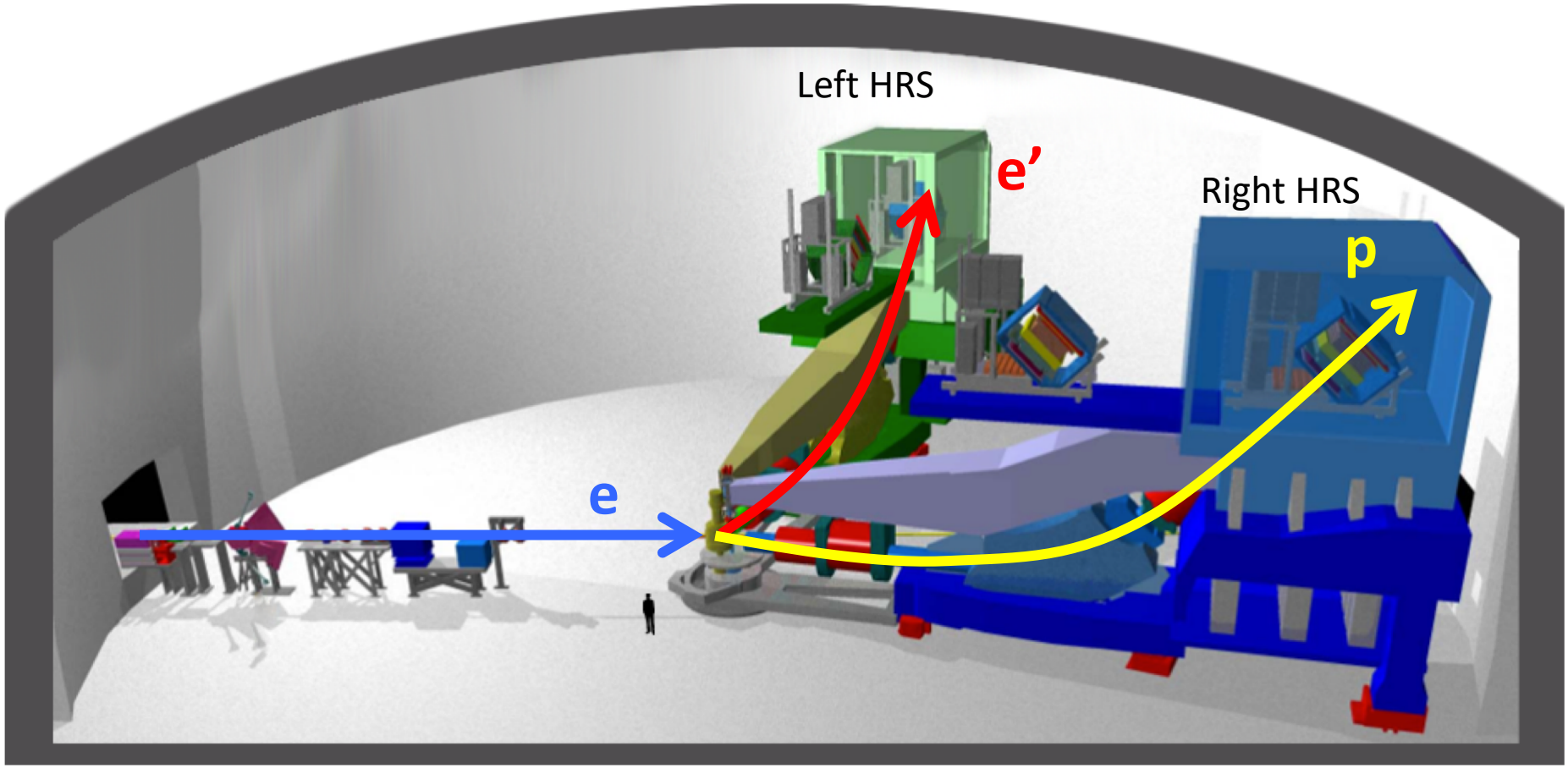
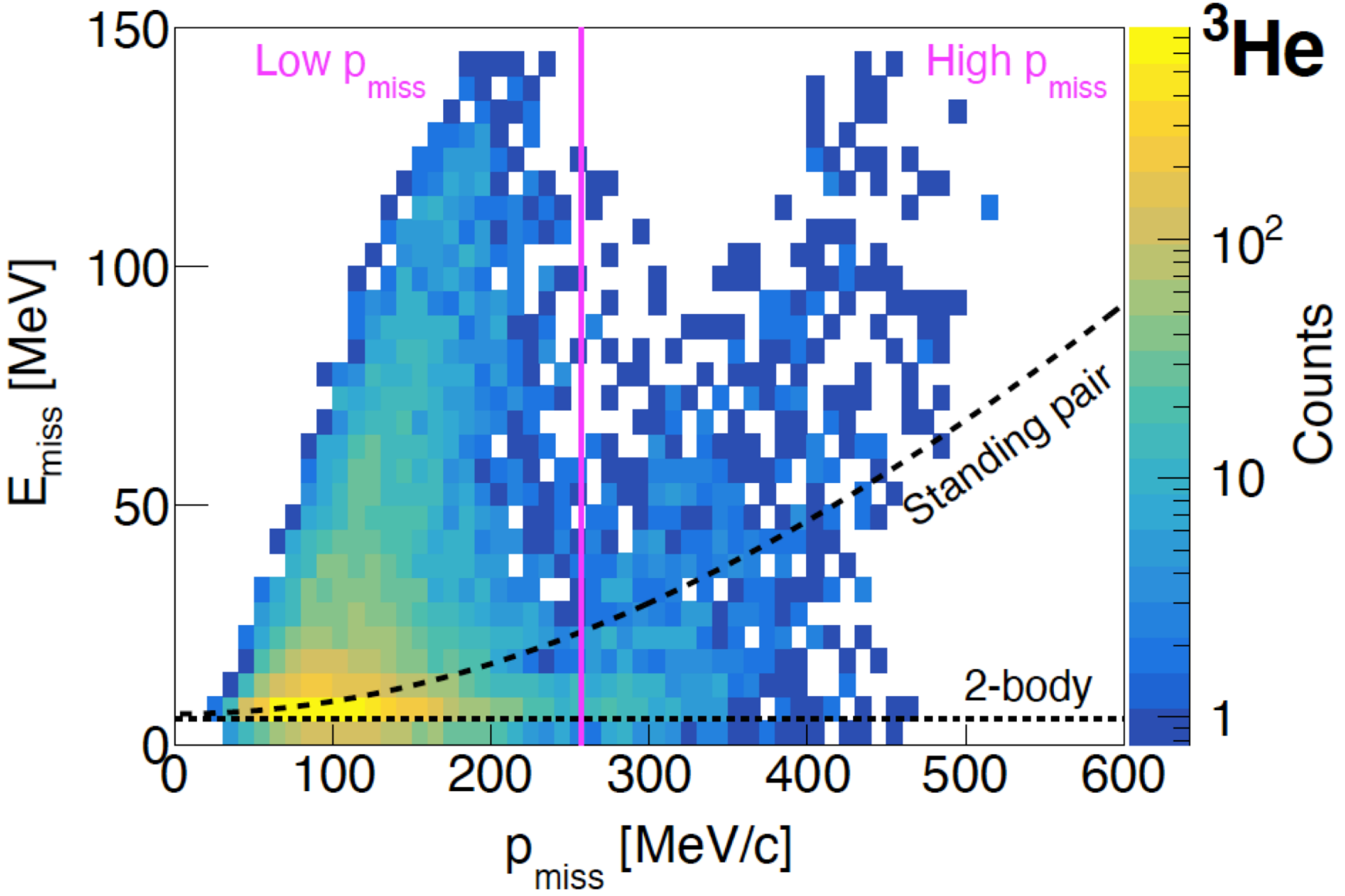


Hall-A of Jefferson Lab



Experiment kinematics



From Counts to Cross Section

$$\frac{d^6\sigma}{dE_e\,d\Omega_e\,dE_p\,d\Omega_p} = \frac{\text{Counts}}{Q \cdot \left(\frac{\rho}{A}\right) \cdot t_{live} \cdot \varepsilon \cdot V_B} \times C$$

Luminosity

Live time

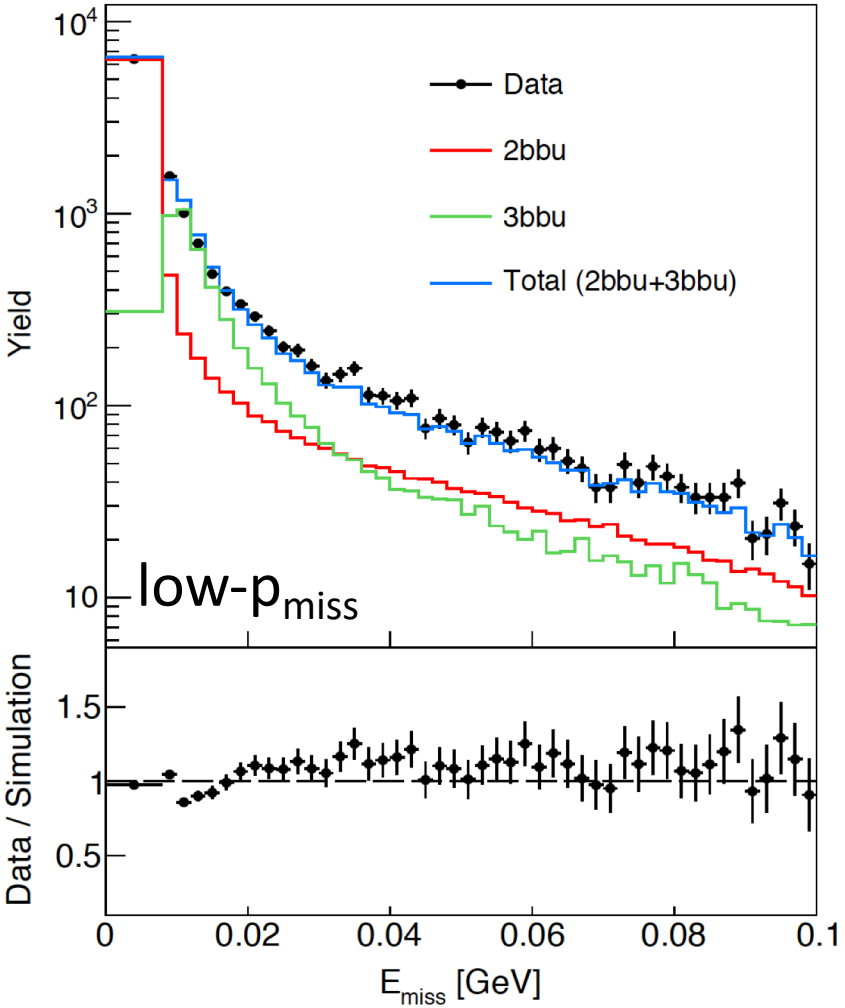
Detector Efficiency
- PID
- tracking
- trigger

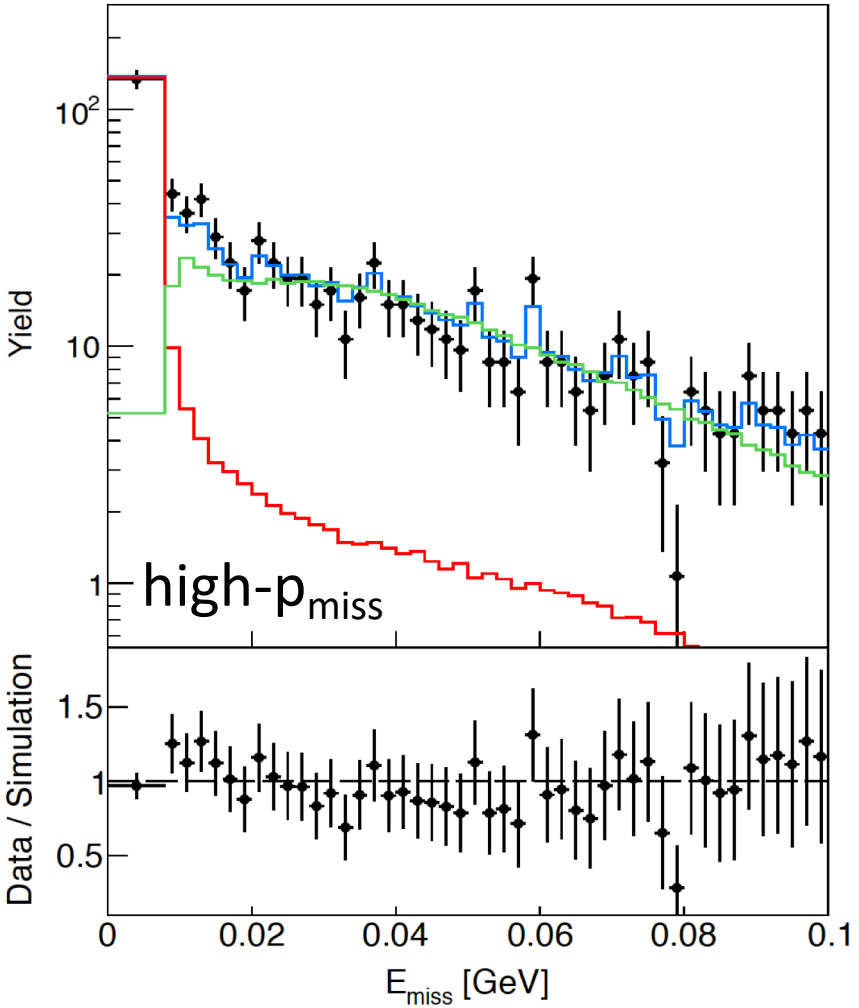
Phase-space volume
and acceptance correction

Corrections
- bin migration
- bin centering
- radiation

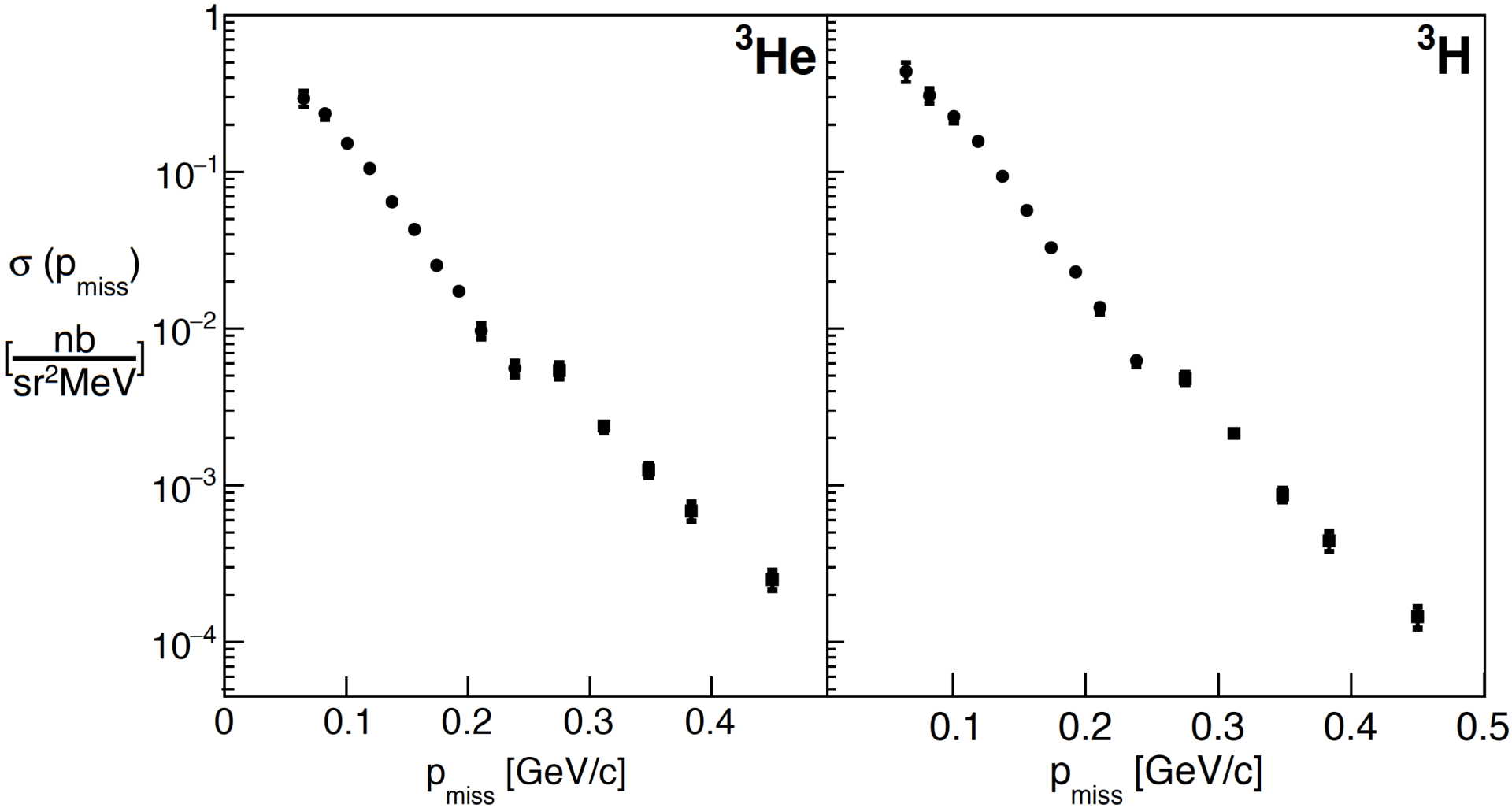
Isolating the ^{3}He 3bbu channel

- ^{3}He(e,e'p) final state can be 2bbu (pd) or 3bbu (ppn)
  - ^{3}H(e,e'p) does not have a 2bbu channel

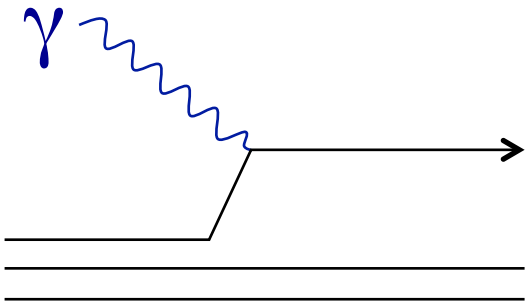




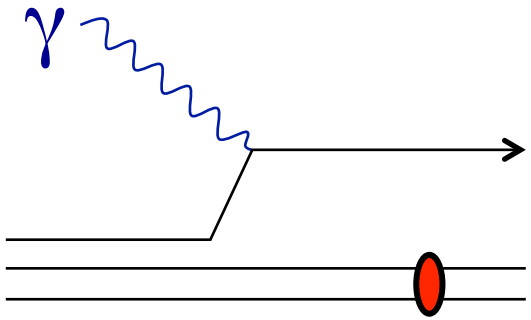
Extracted Absolute Cross Sections



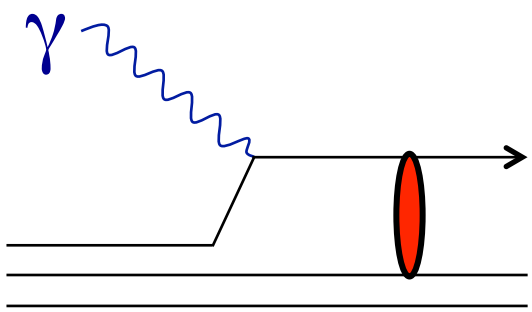
Cross Section Models



a) PWIA



b) FSI_{23}



c) FSI

Cracow:

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

CK + *CC1*:

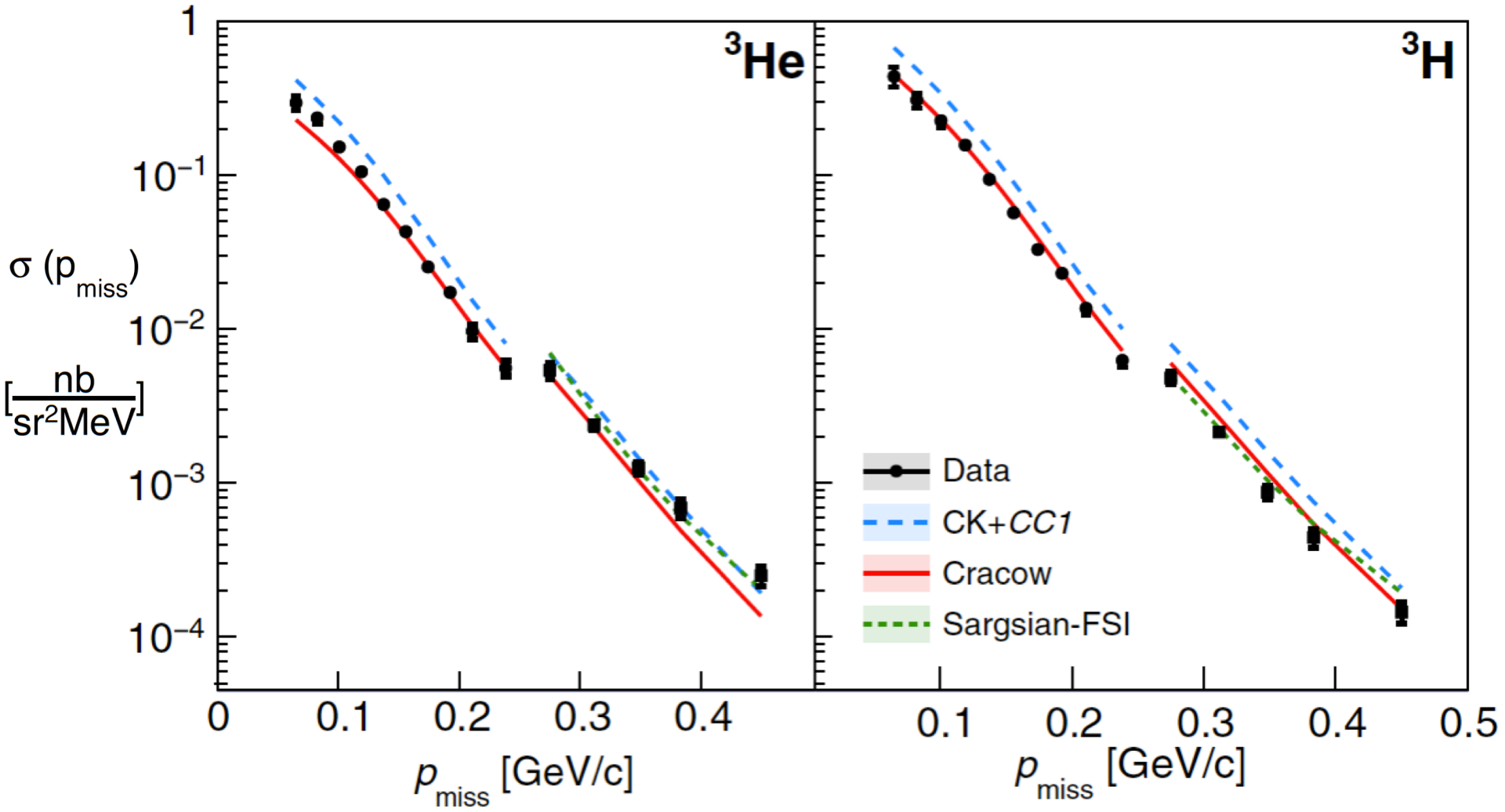
- ^{3}He spectral function of CDA and L.P. Kaptari and electron off-shell nucleon cross-section
- Continuum interaction between two spectator nucleons (FSI_{23})

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

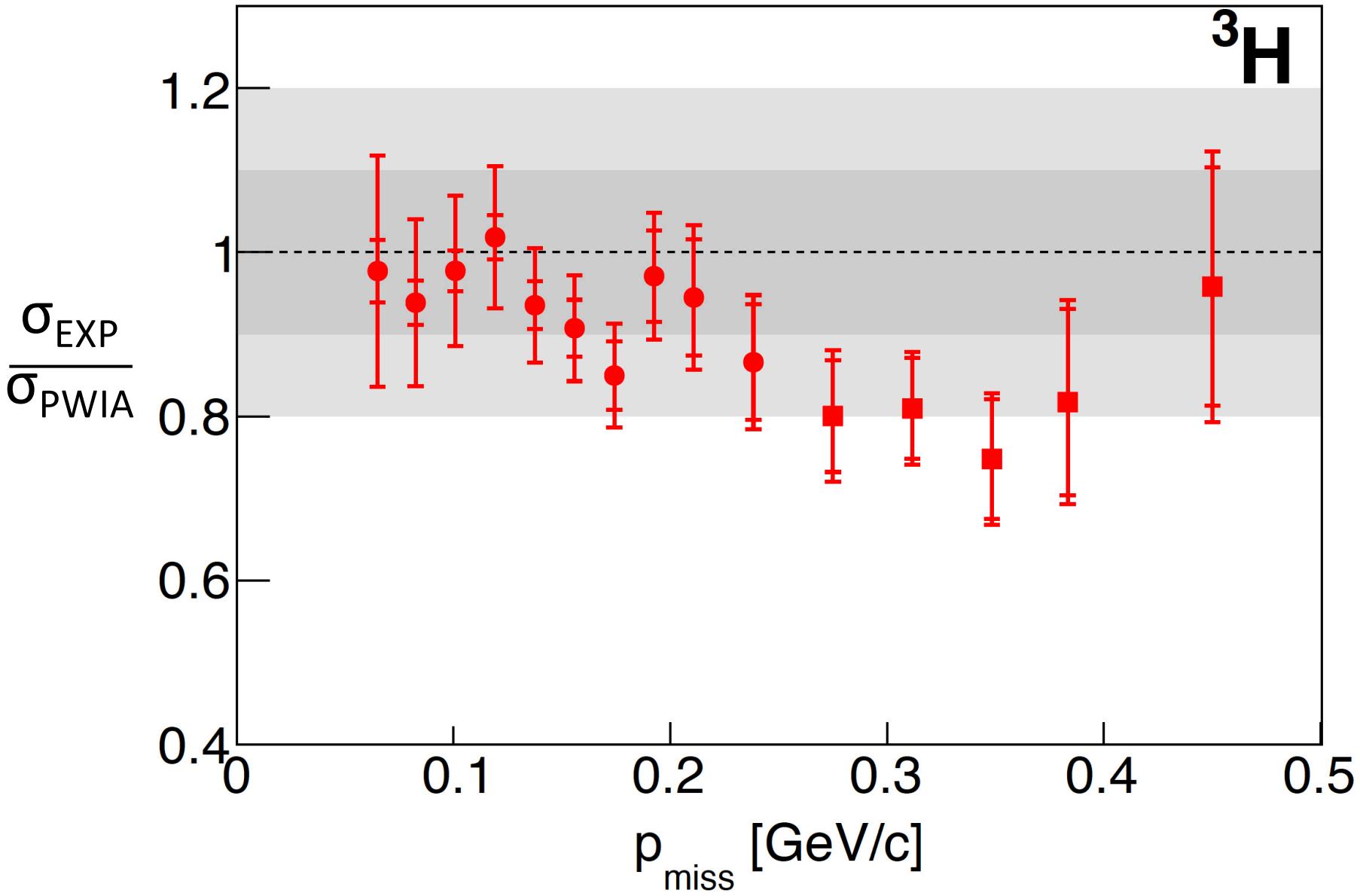
M. Sargsian (FSI):

- Generalized Eikonal Approximation based
- NO continuum interaction between two spectator nucleons (FSI_{23}). Only use for high-p_{miss} comparison

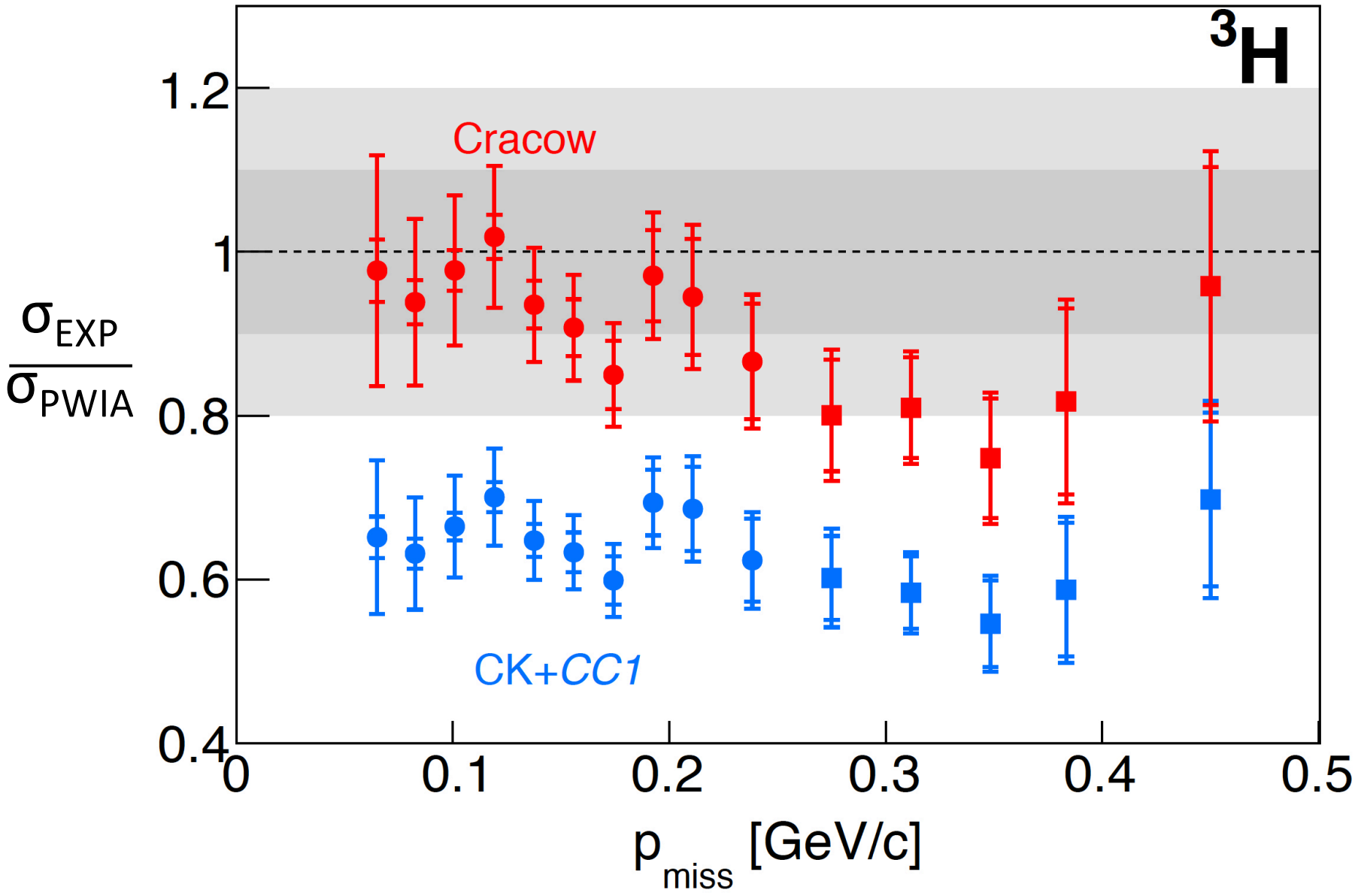
Comparison to theory



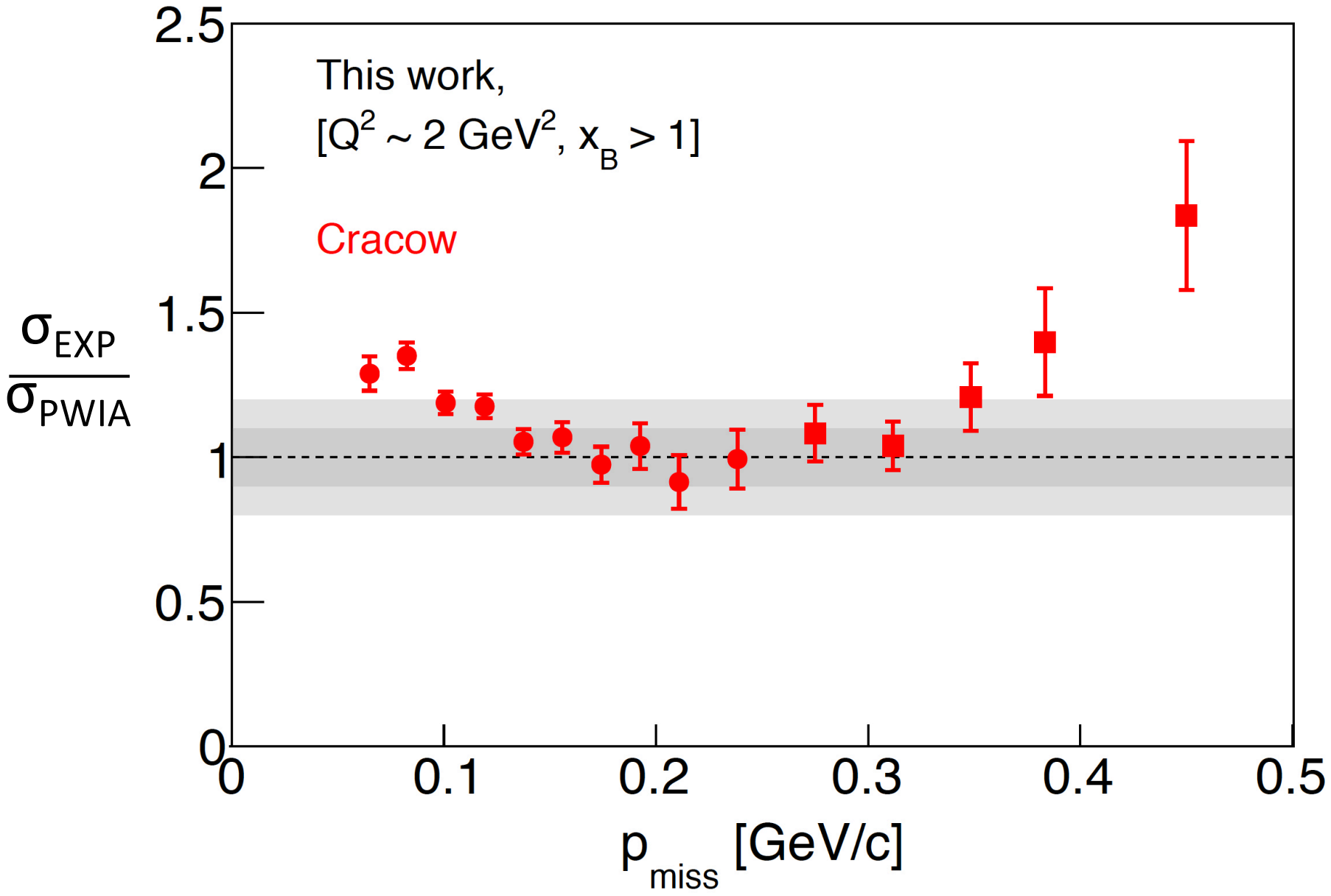
^{3}H Data, Cracow agree within 10-20%!!!



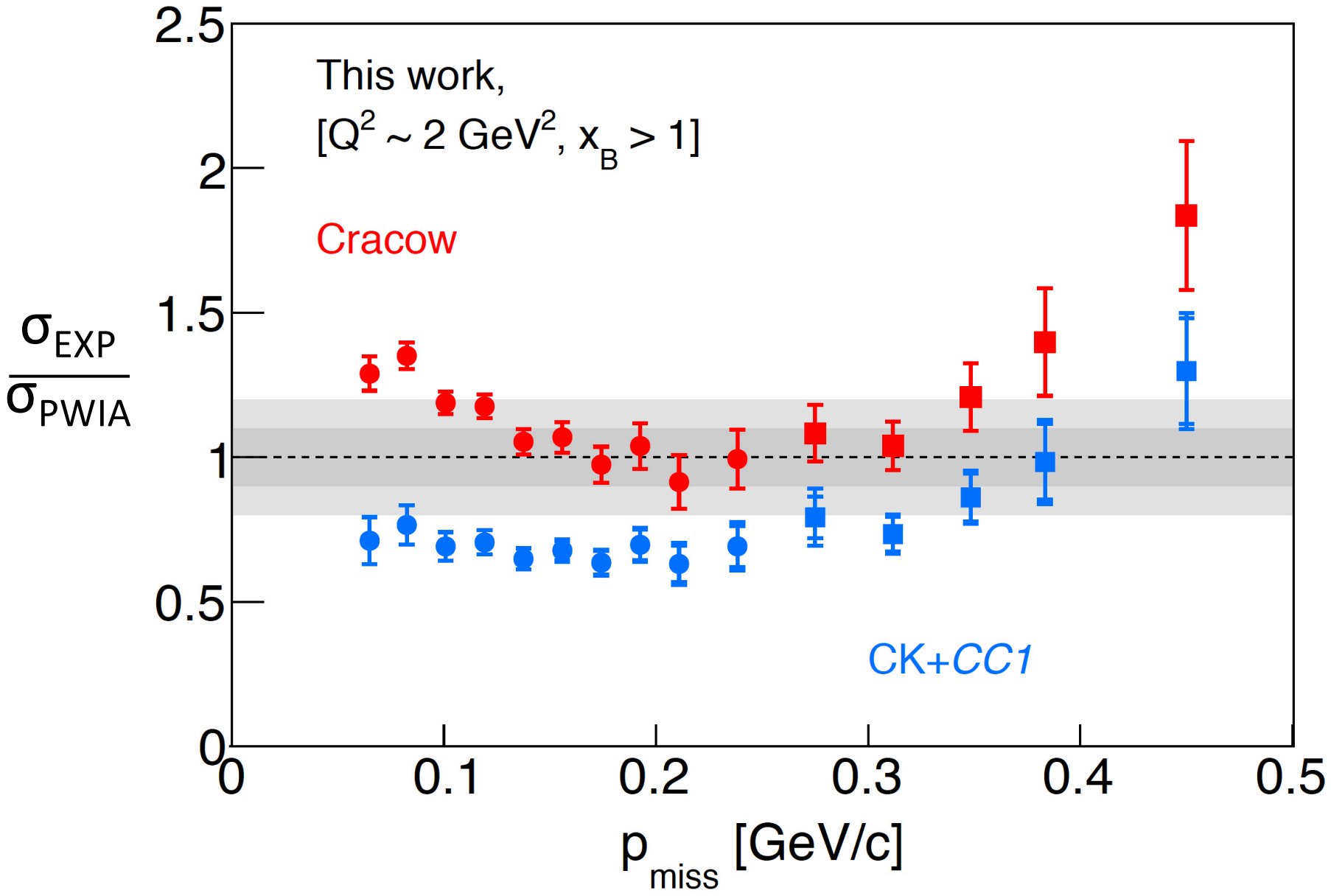
^{3}H Data, PWIA-calculation comparison



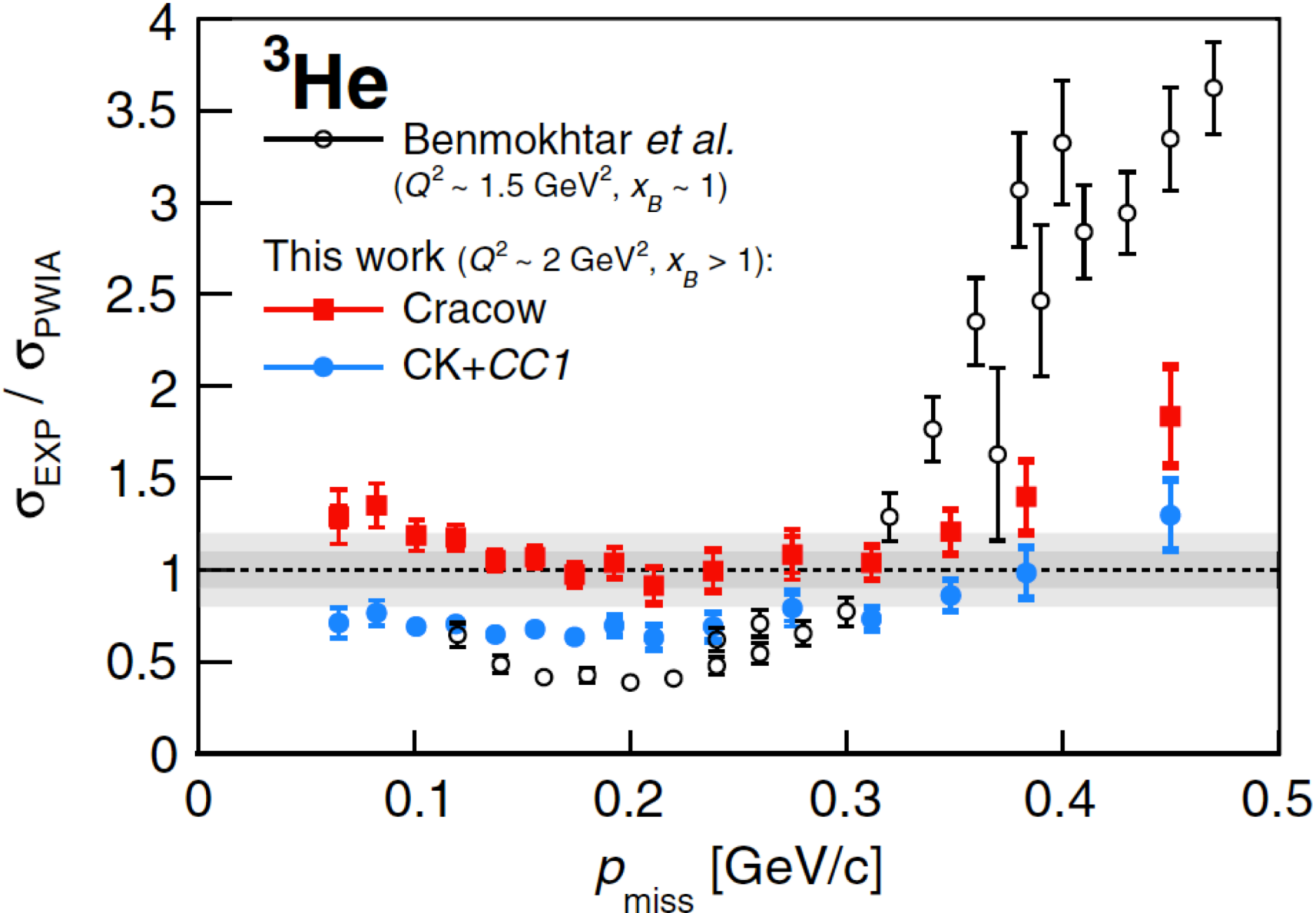
^{3}He agreement is limited



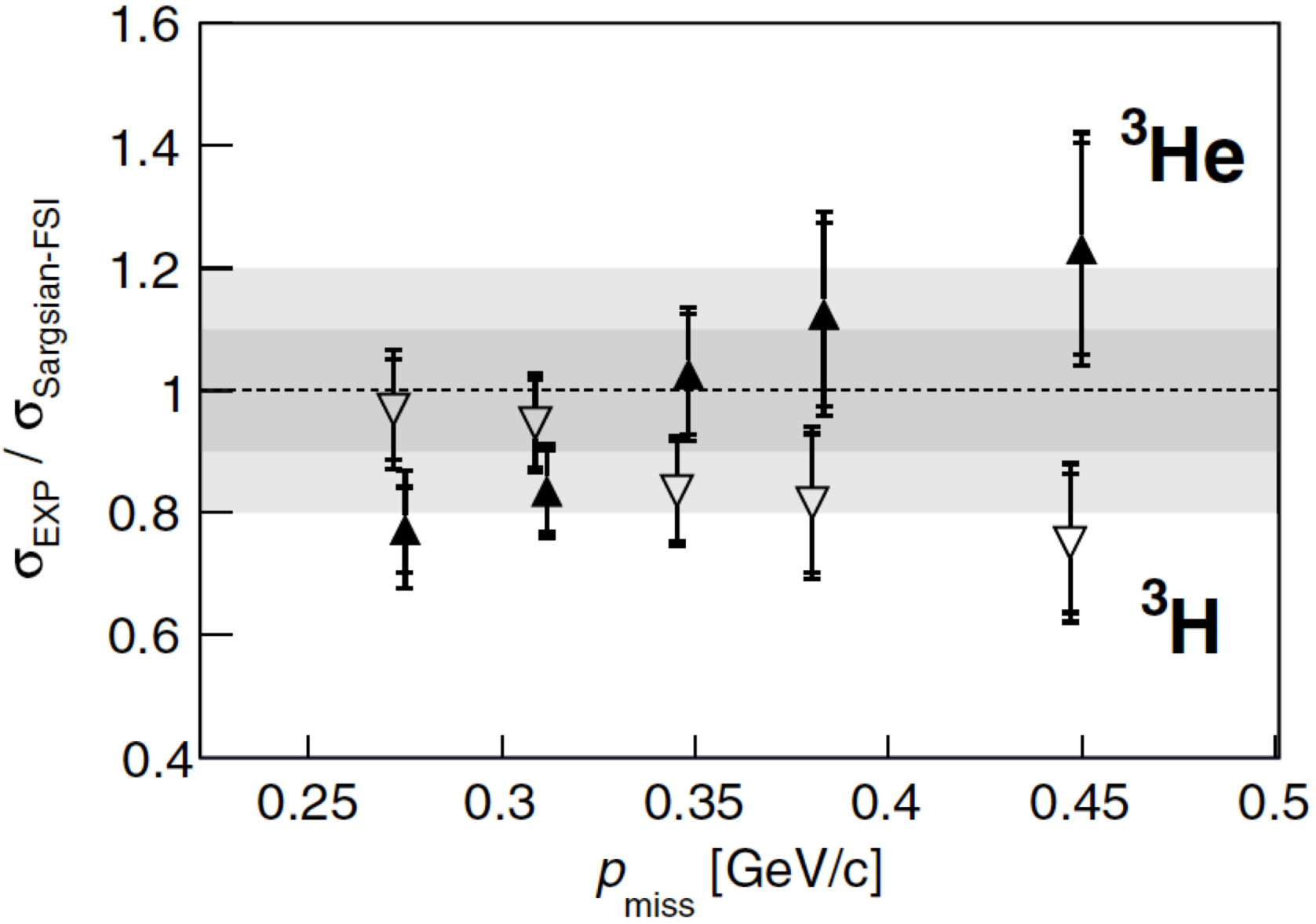
^{3}He agreement is limited



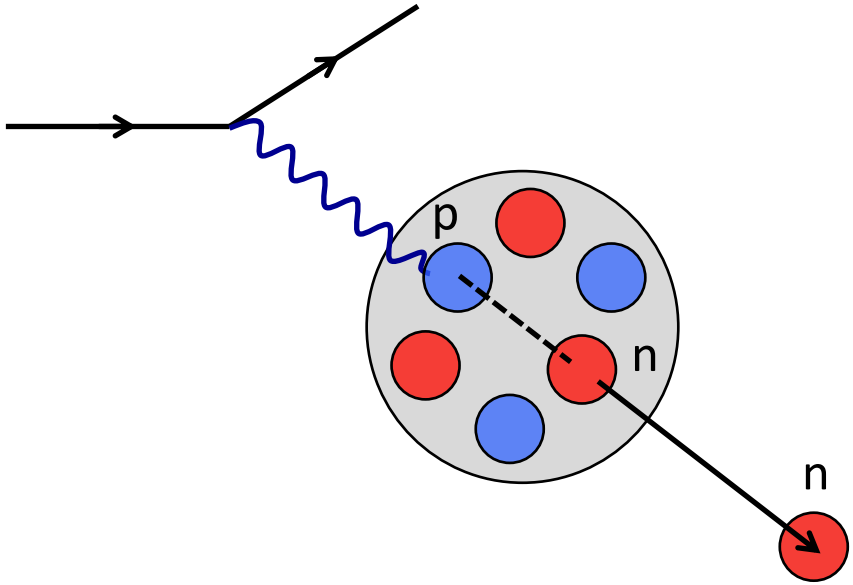
Still better agreement than previous data



Struck-nucleon FSI at high-p_{miss}



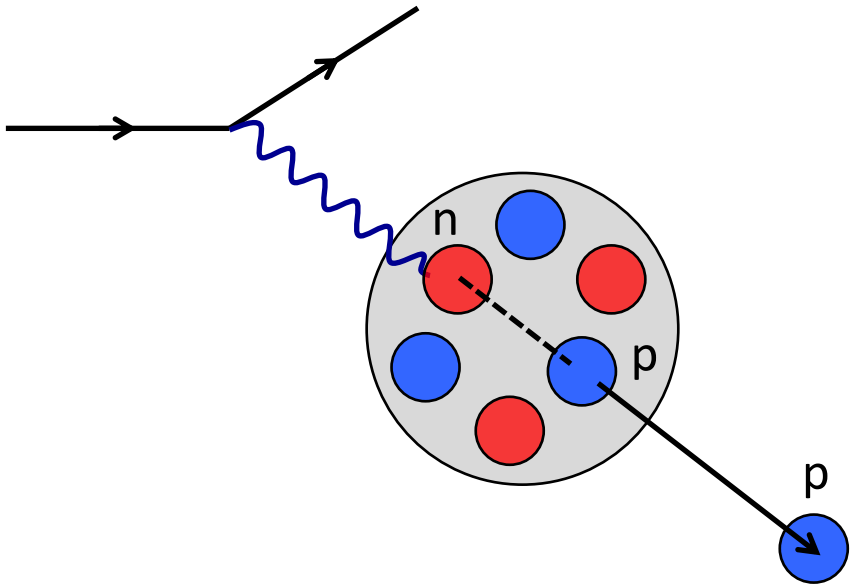
Single-Charge Exchange (SCX)



pn-SCX

(e,e'p) -> (e,e'n)

decreases σ(e,e'p)

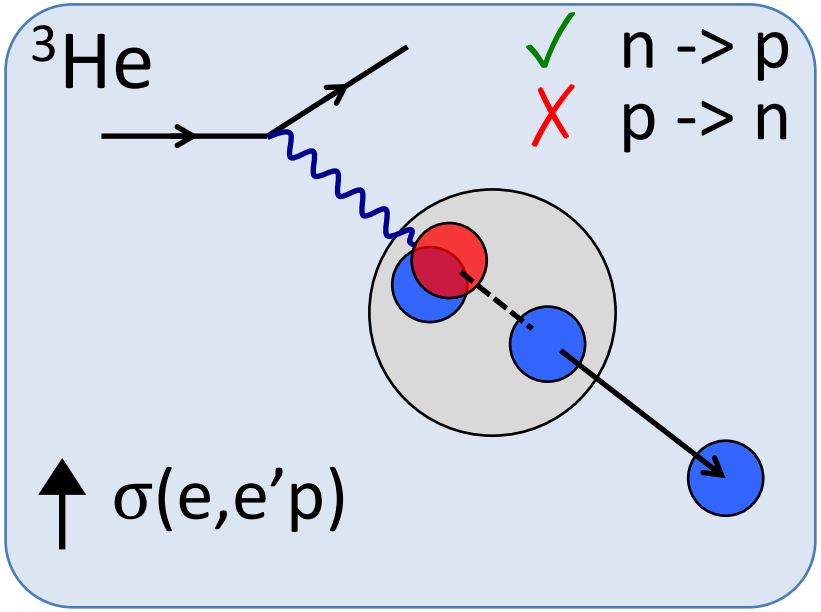


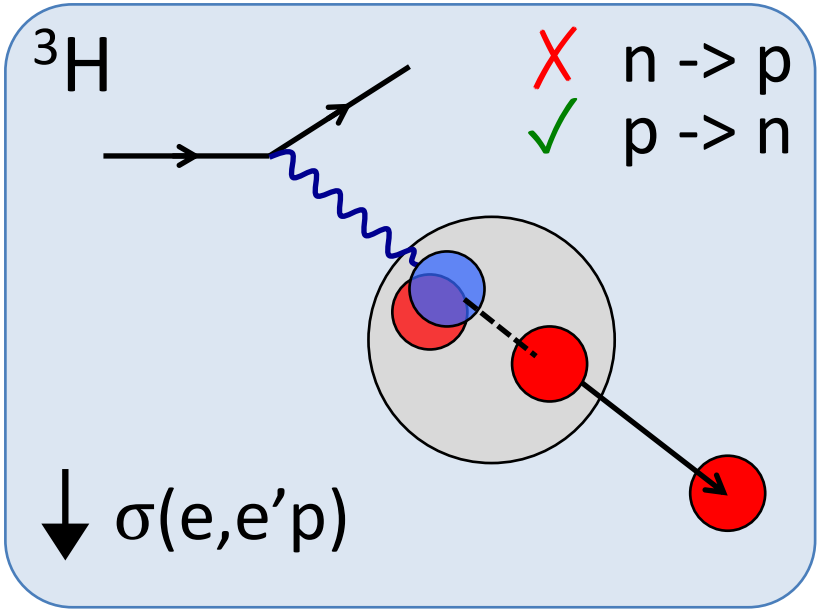
np-SCX

(e,e'n) -> (e,e'p)

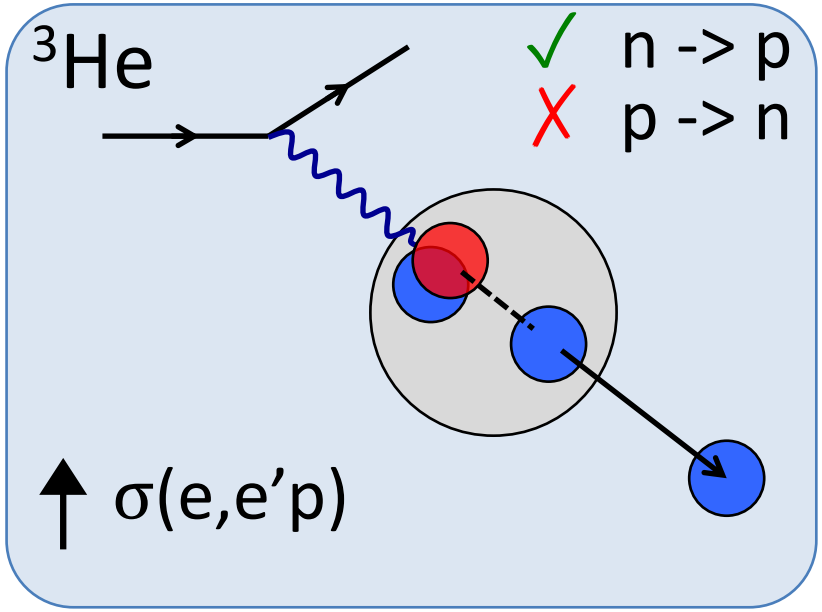
increases σ(e,e'p)

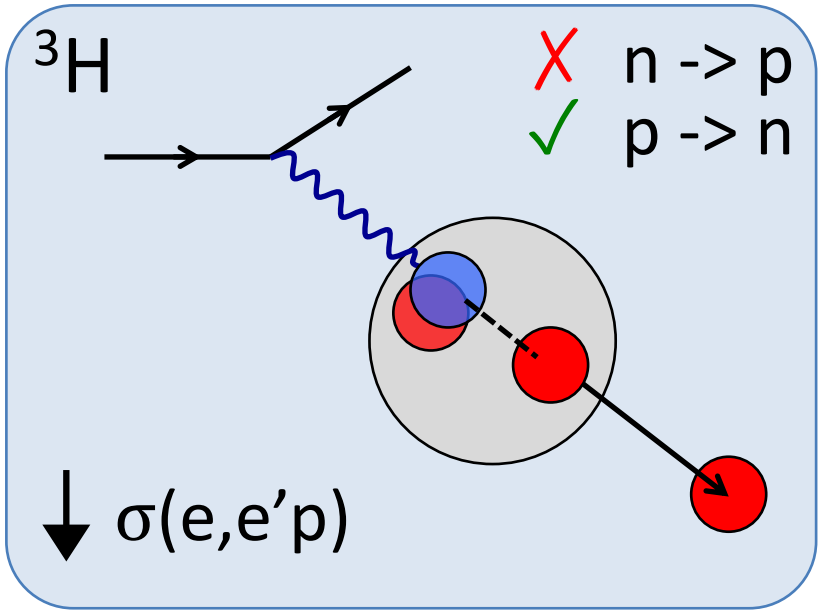
SCX in A=3 at high-p_{miss}

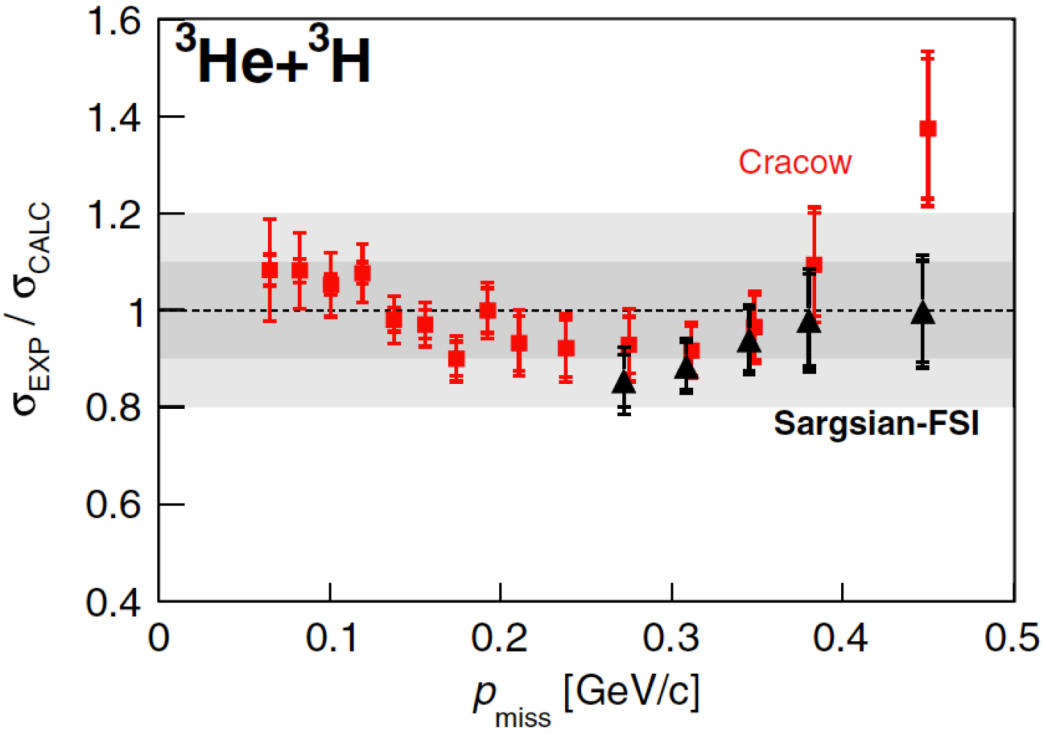




SCX in A=3 at high-p_{miss}

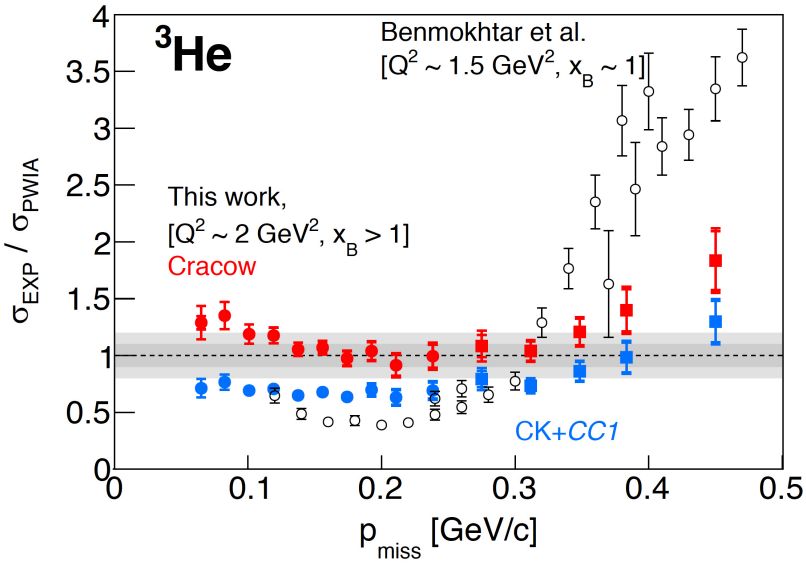






Summary

- Much Smaller Non-QE contribution compared to previous measurements



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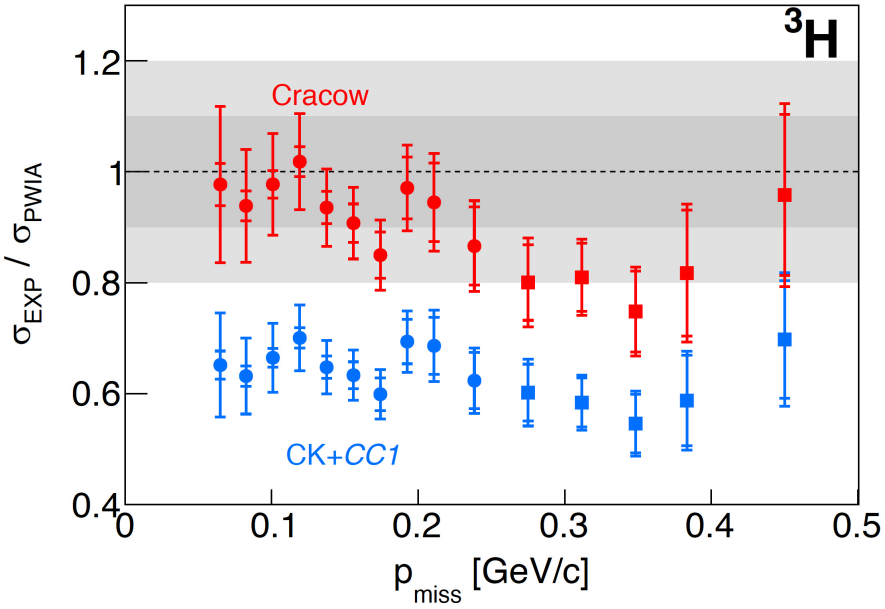

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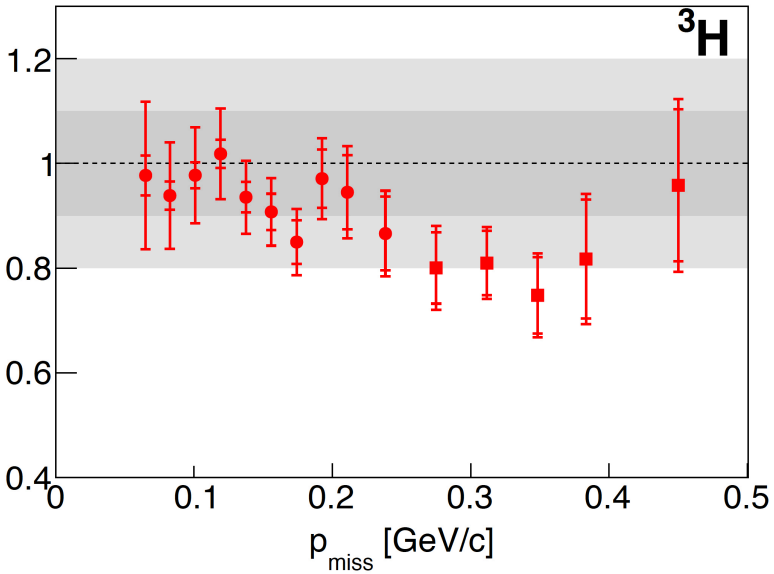

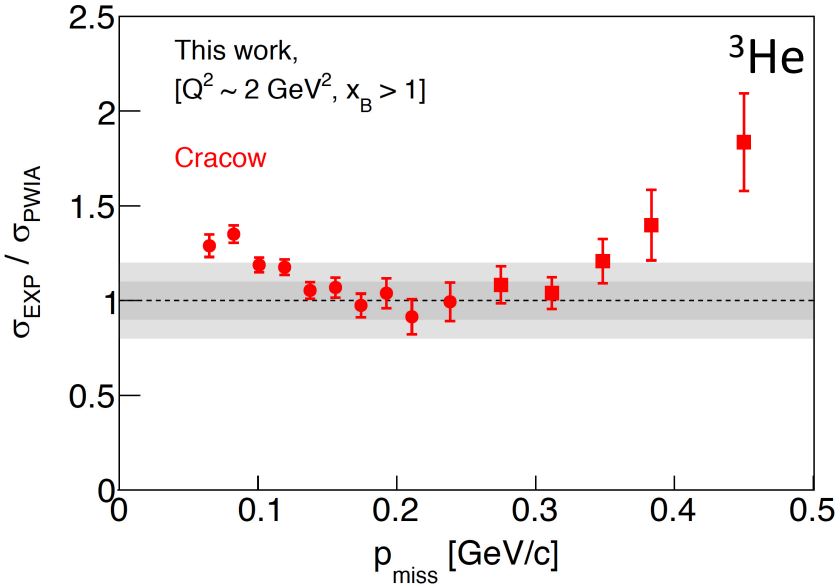

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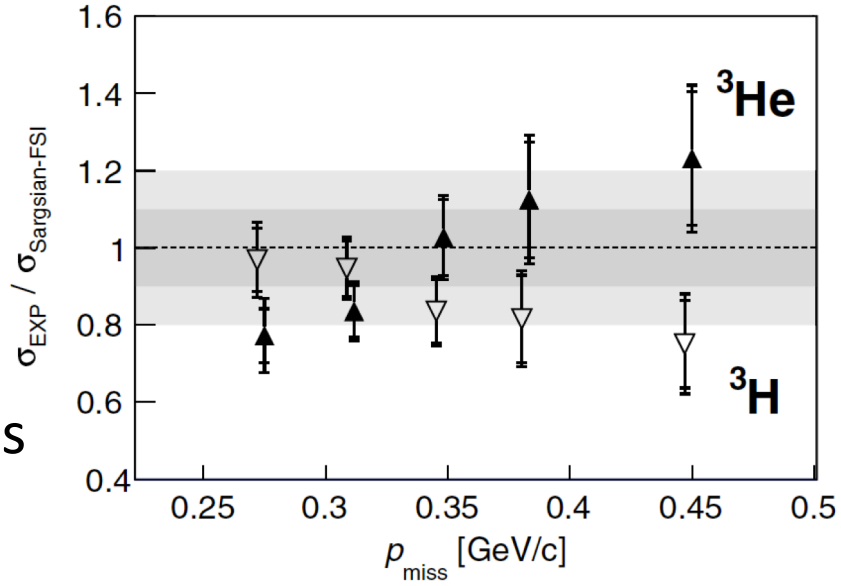

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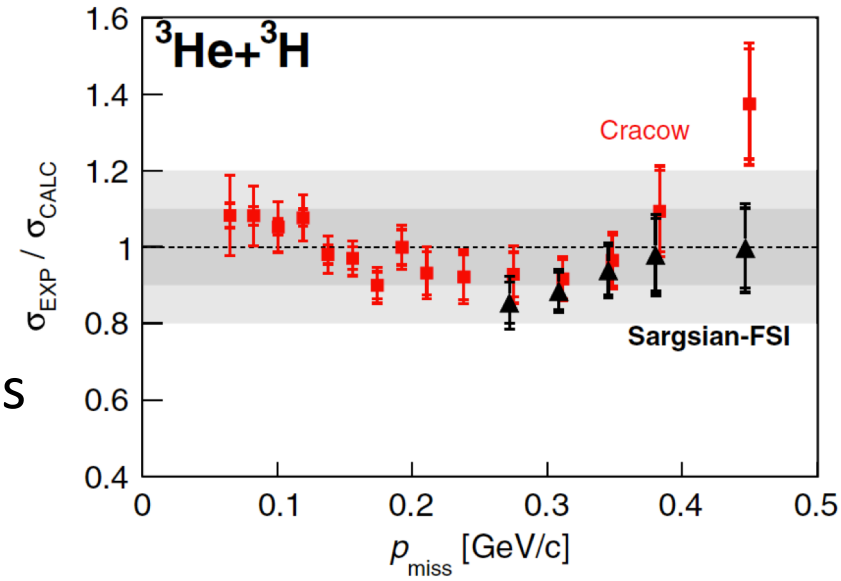

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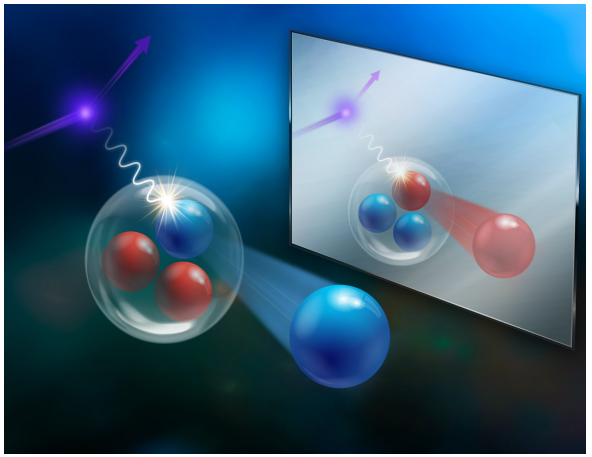


PRL. **124**, 212501 (2020)

These data are a crucial benchmark for few-body nuclear theory

More coming… stay tuned!

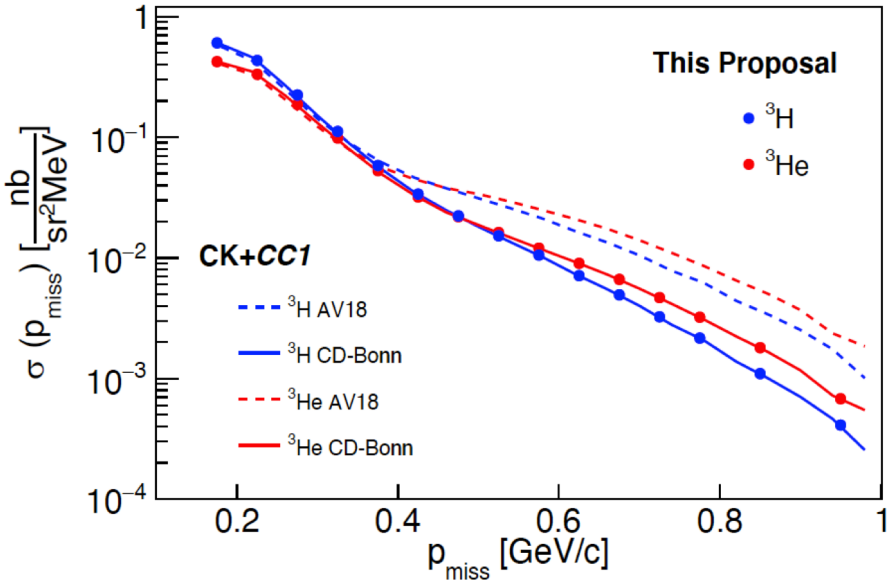
^{3}He, ^{3}H, ^{2}H (e,e'p) in Hall-B

- Hall A showed importance of using Helium & Triton BUT \w limited statistics
- CLAS12:

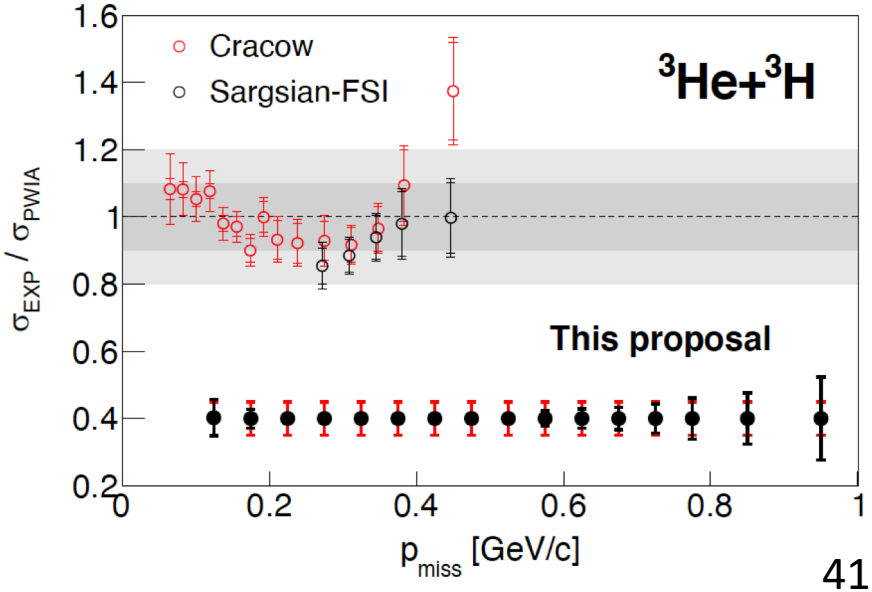
  x0.1 luminosity

  x100 acceptance

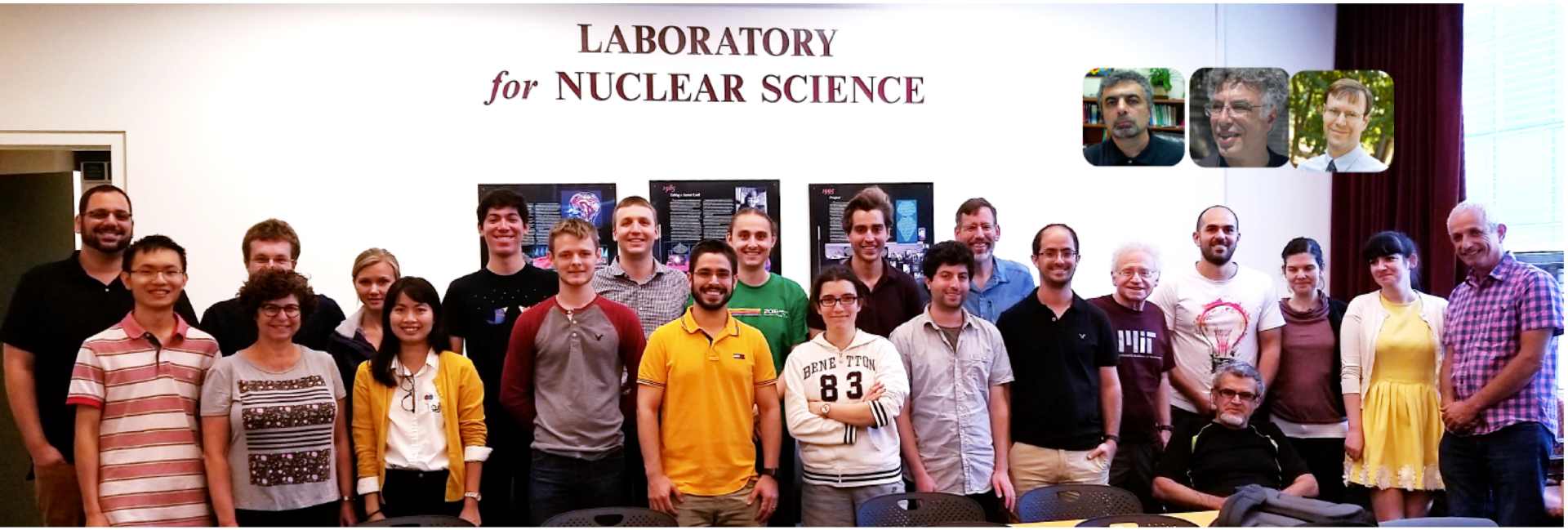
  => x10 statistics + larger kinematical coverage!



R. Cruz, D. Nguyen et al. PRL (2020)



Thank you!



JL

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