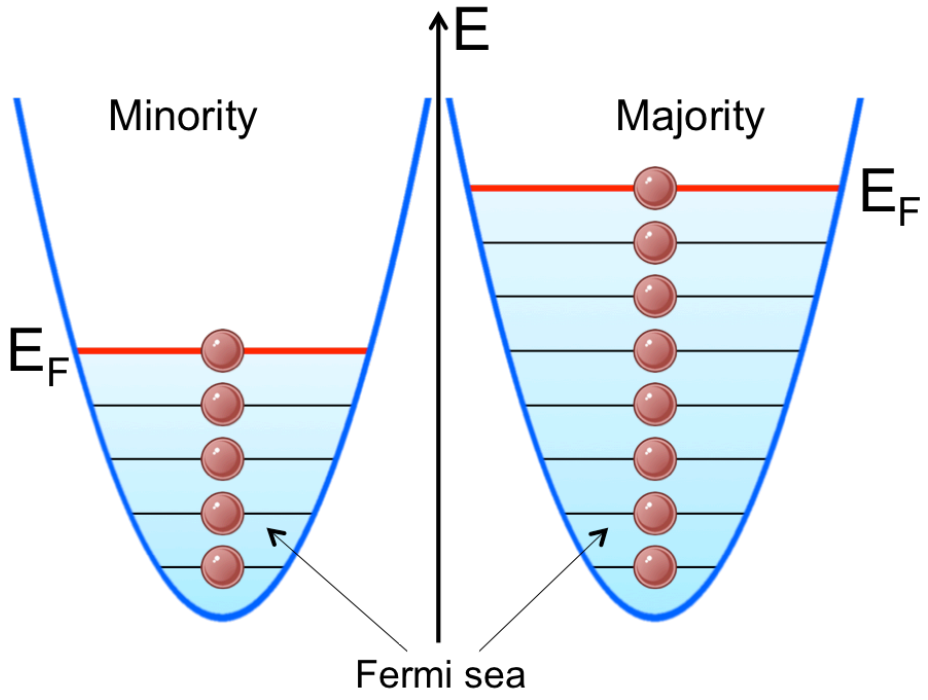
Momentum Distribution in A = 3 Asymmetric Nuclei

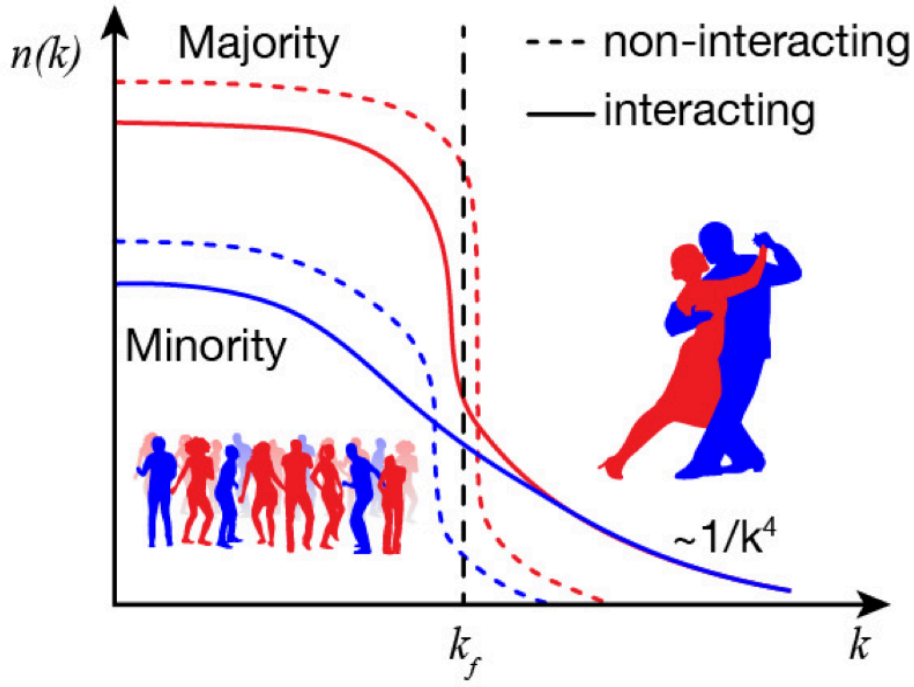
Jefferson Lab Hall-A Experiment E12-14-011

Florian Hauenstein, Old Dominion University

SRC/EMC Workshop, MIT, 03.12.16

Kinetic Energy Sharing





Pauli-Principle:

<T>(Majority) **>** <T> (Minority)

SRC np pairs

<T>(Majority) **<** <T> (Minority)

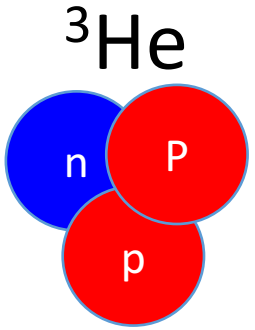
VMC Prediction for <T>

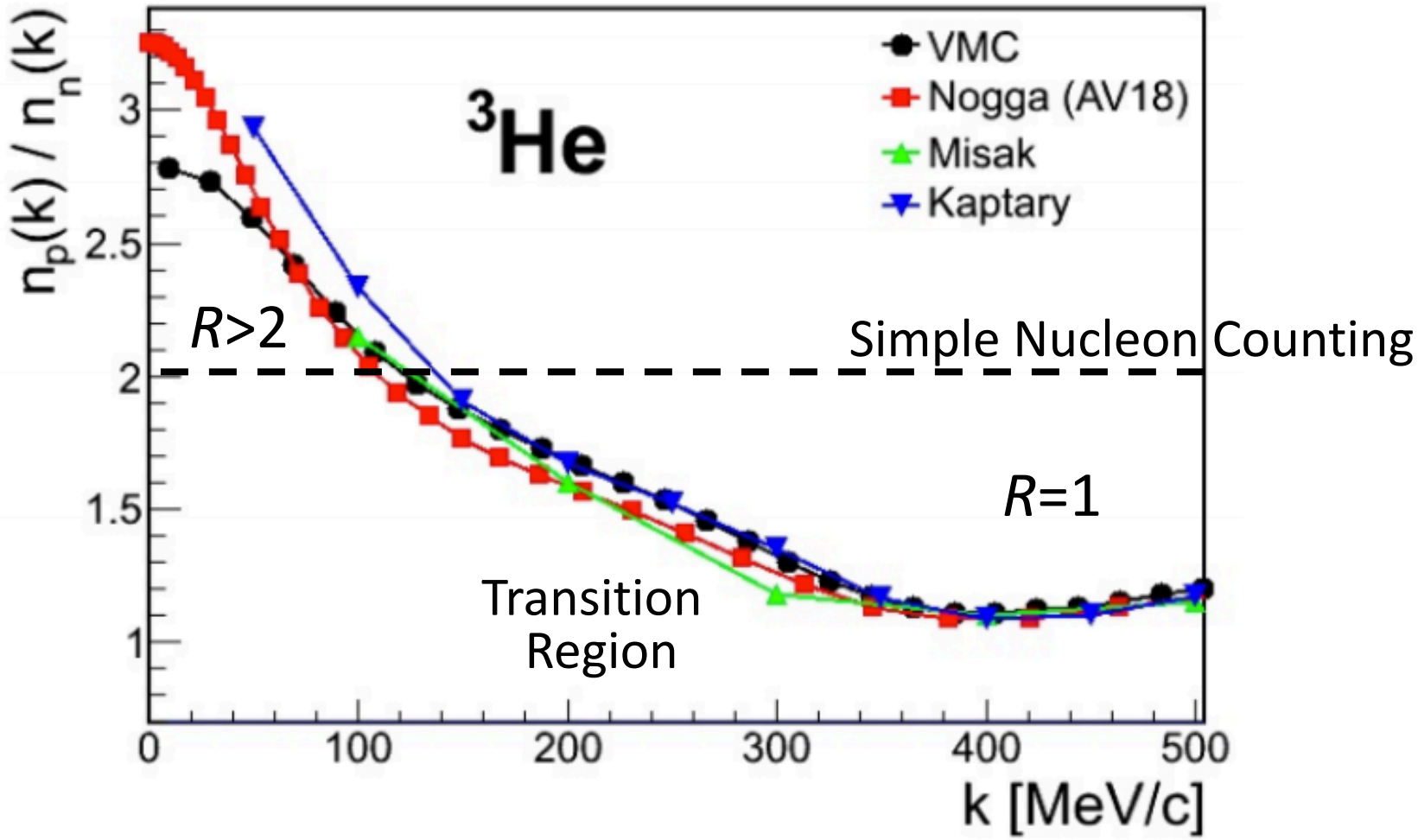
<T>(Majority) < <T> (Minority)

	$\frac{\lvert N-Z\rvert}{A}$	$\langle T_p \rangle$	$\langle T_n \rangle$	$\langle T_p \rangle - \langle T_n \rangle$
^{8}He	0.50	30.13	18.60	11.53
^{6}He	0.33	27.66	19.06	8.60
^{9}Li	0.33	31.39	24.91	6.48
^{3}He	0.33	14.71	19.35	-4.64
^{3}H	0.33	19.61	14.96	4.65
^{8}Li	0.25	28.95	23.98	4.97
^{10}Be	0.2	30.20	25.95	4.25
^{7}Li	0.14	26.88	24.54	2.34
^{9}Be	0.11	29.82	27.09	2.73
^{11}B	0.09	33.40	31.75	1.65

R. Wiringa et al. (Phys. Rev. C **89**, 024305 (2014))

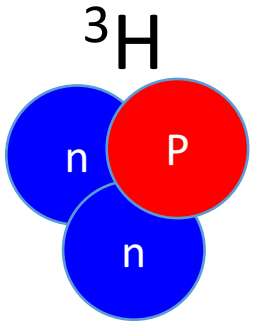
SRC and Nucleon Counting

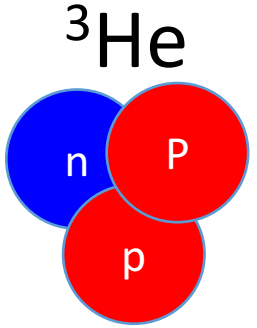




The A = 3 System

- ^{3}He and ^{3}H are mirror nuclei
  - Neutron in ^{3}He = Proton in ^{3}H
- Two-ways to study the proton-to-neutron momentum distribution ratio in ^{3}He:
  - Measure the ^{3}He(e,e'p) / ^{3}He(e,e'n) ratio
    (Low accuracy due to the neutron measurement)
  - **Measure the ^{3}He(e,e'p) / ^{3}H(e,e'p) ratio.**
    (Tritium Target necessary, available at JLab Hall-A (MARATHON))





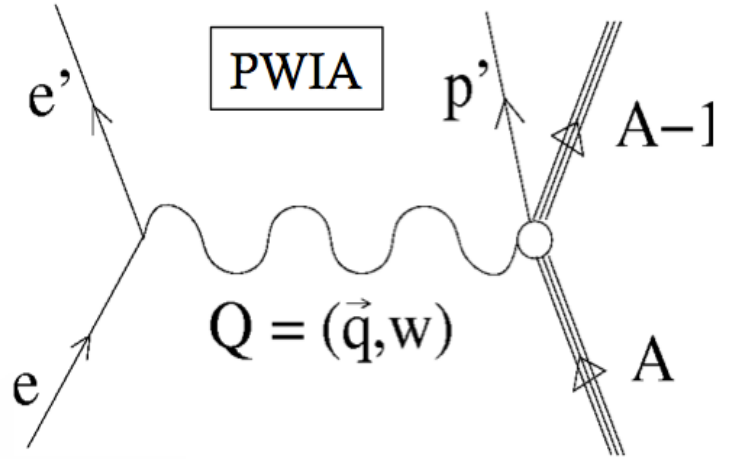
Extraction of Momentum Distribution from A(e,e‘)p

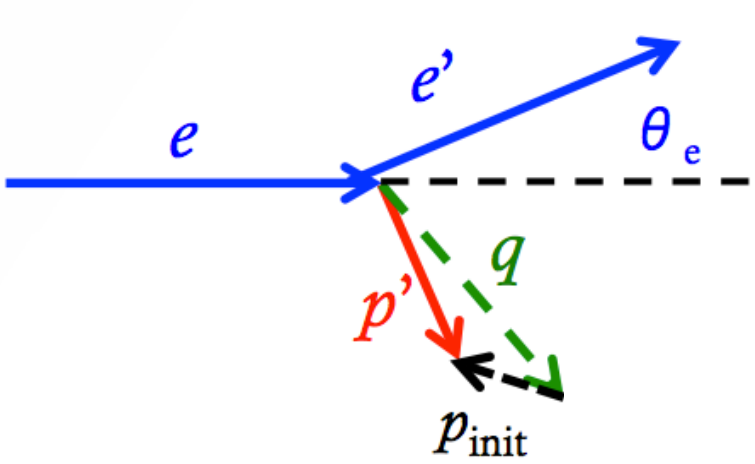
$$\sigma_{\mathrm{PWIA}} = k \cdot \sigma_{ep} \cdot S_p\left(E_{\mathrm{miss}}, p_{\mathrm{miss}}\right)$$

Spectral Function

$$E_{\mathrm{miss}} = \omega - T_p - T_{A-1}$$

$$\vec{p}_{miss} = \vec{q} - \vec{p}' = -\vec{p}_{init}$$



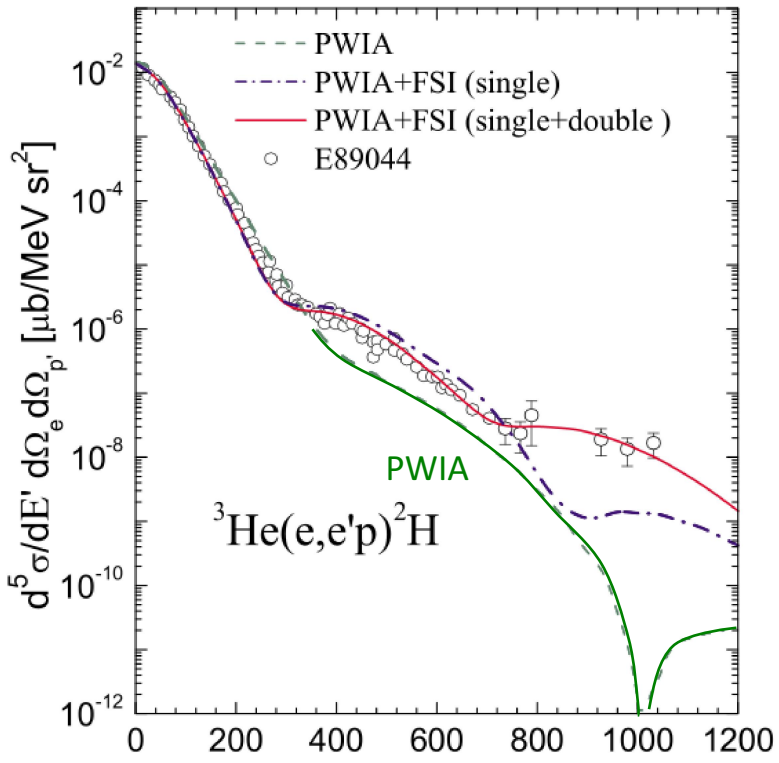


Complications:

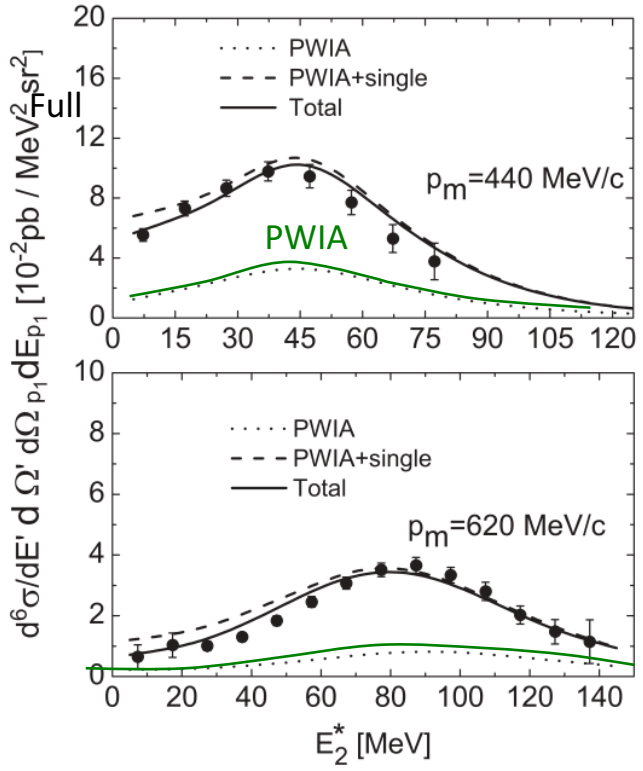
- Rescattering of the outgoing proton.
- Off-shell proton cross-section.
- Meson Exchange Currents (MEC).
- Delta production (i.e. IC).

Previous Hall-A ^{3}He (e,e'p)X measurements

^{3}He(*e,e'p*)*d*



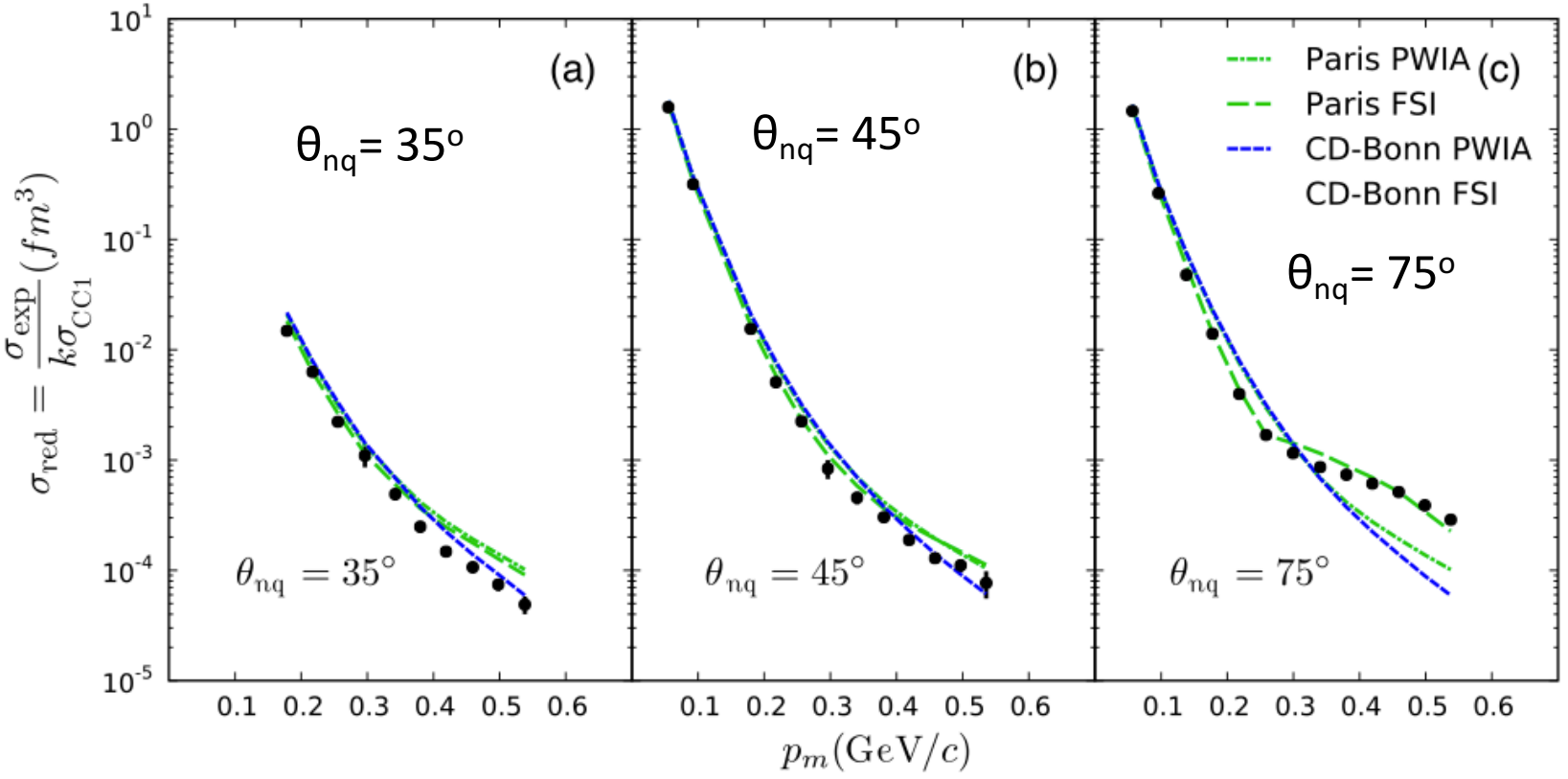
^{3}He(*e,e'p*)*np*



- Dominated by FSI at large momentum
- Well described by theory

Data: Rvachev *et al.*, PRL94 192302 (2005); Benmokhtar *et al.*, PRL94 082305 (2005)
Theory: Ciofi degli Atti and Kaptari, PRL95 052502 (2005) ; Alvioli *et al.*, PRC81 021001 (2010)

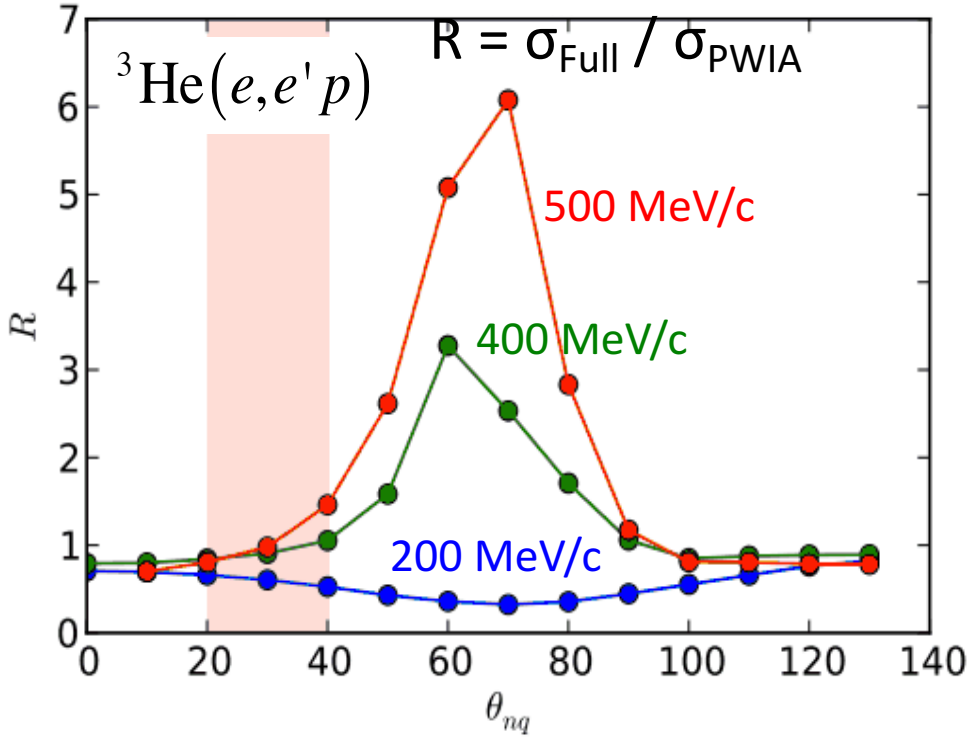
Minimizing FSI Effects in d(e,e‘)p



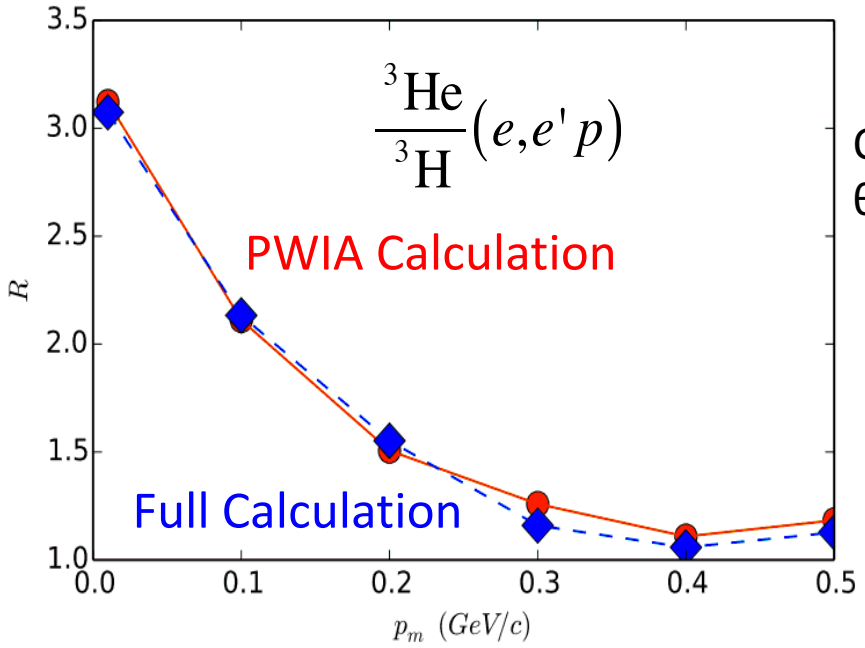
- FSI effects decrease for smaller values of θ_{nq}
- Assume similar suppression for A = 3 nuclei

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

Access Momentum Distribution w/o FSI



- Rescattering minimized at small angles (verified for deuterium).
- Small angles => x_B>1 => suppress MEC and IC effects.



Q^2 = 2 GeV²
θ_{nq} = 30º

Rescattering effects cancel in the ^{3}He/^{3}H ratio

JLab-Hall A Measurement E12-14-011

$\langle p_m \rangle$ (MeV/c)	x	E_e (GeV)	θ_e	p_p	θ_p	Time ^{3}H+^{3}He (days)
100	1.15	3.47	20.9º	1.61	48.7º	1
300	1.41	3.64	20.4º	1.35	58.6º	10

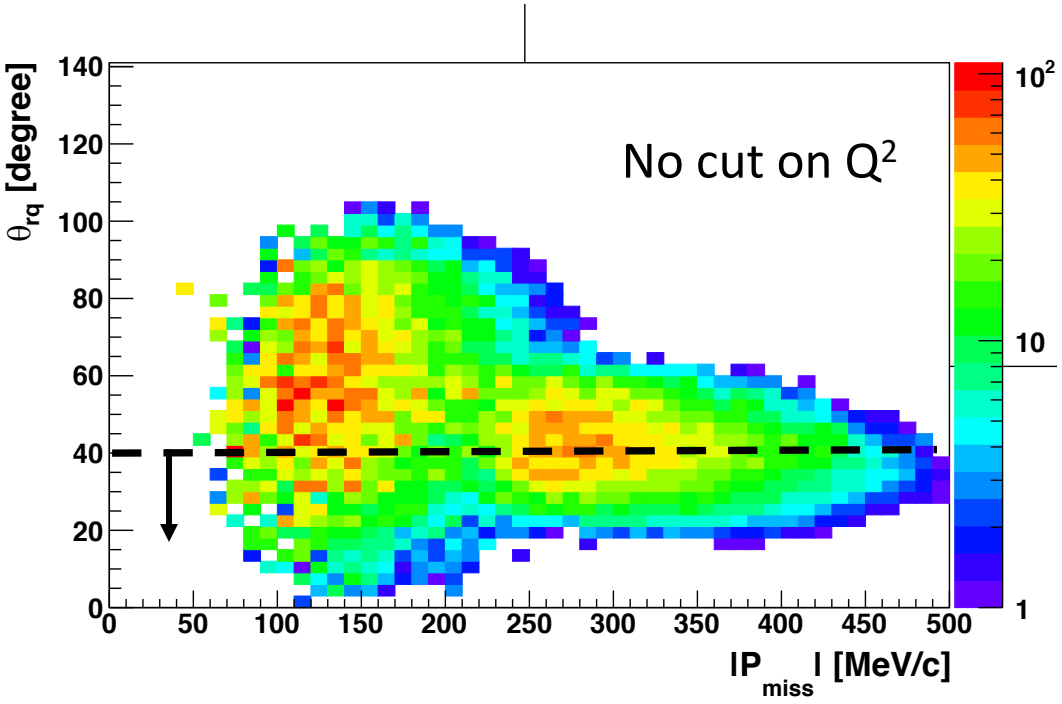
Kinematics:

- E_b = 4.4 GeV
- I_{beam} = 20 μA
- Q^2 = 2 GeV^2
- x = $Q^2/2m\omega$> 1 (quasi-elastic)
- θ_{nq} < 40º

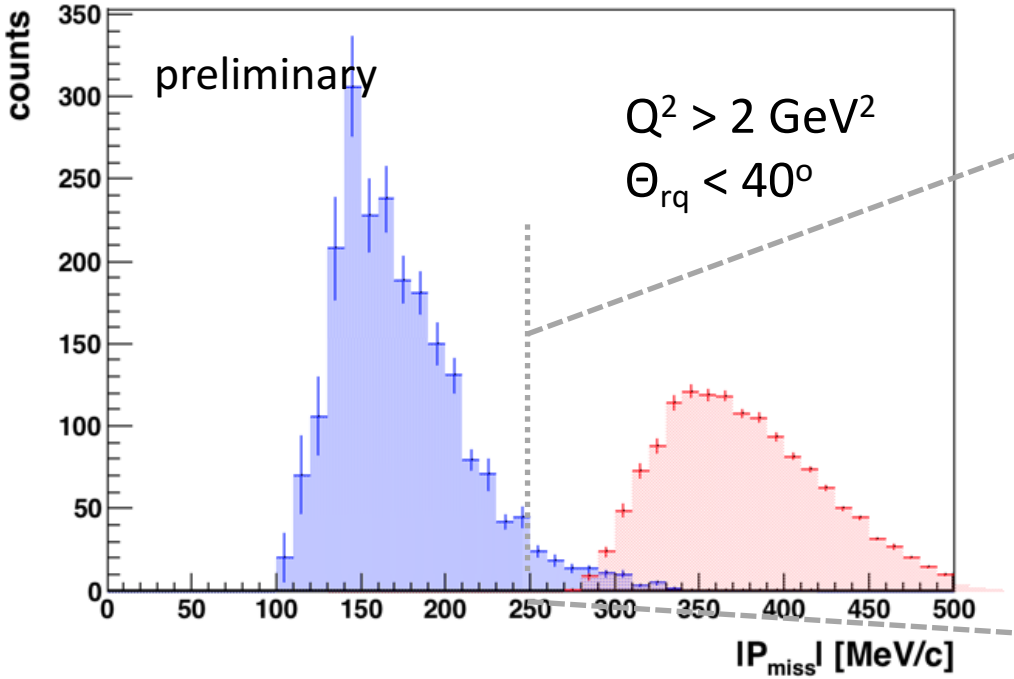
Setup:

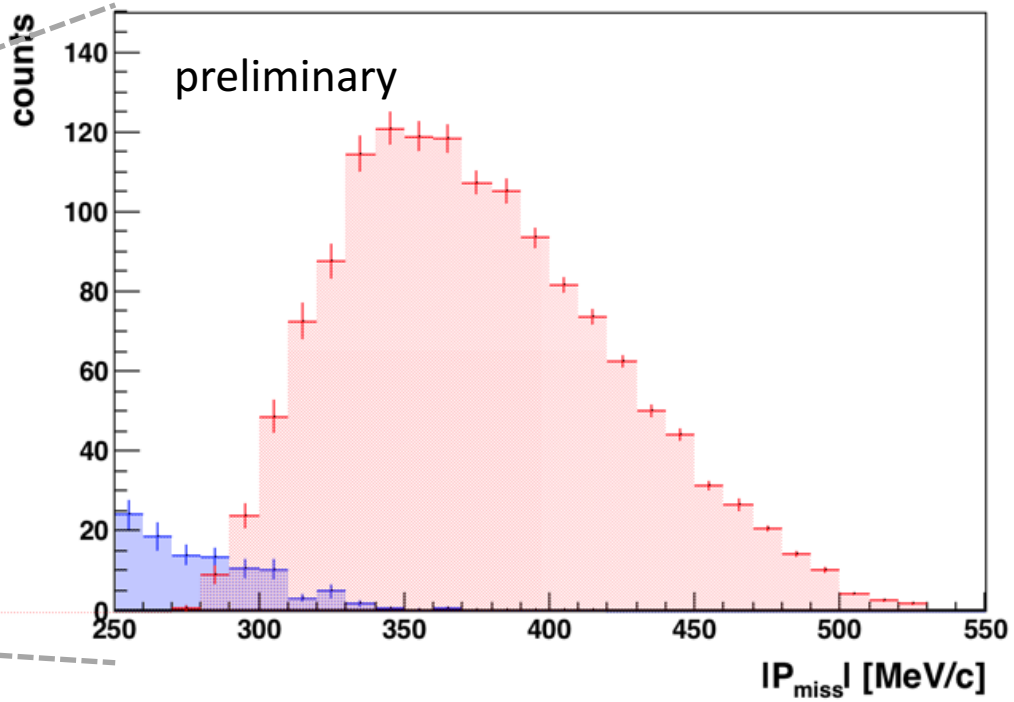
- MARATHON Target
- HRS spectrometer in Hall-A at Jefferson Lab
- Low luminosity $\mathcal{L}$ (^{3}H) = 8×10^{36} nucleons cm^{-2} s^{-1}

Simulation Results for ^{3}H

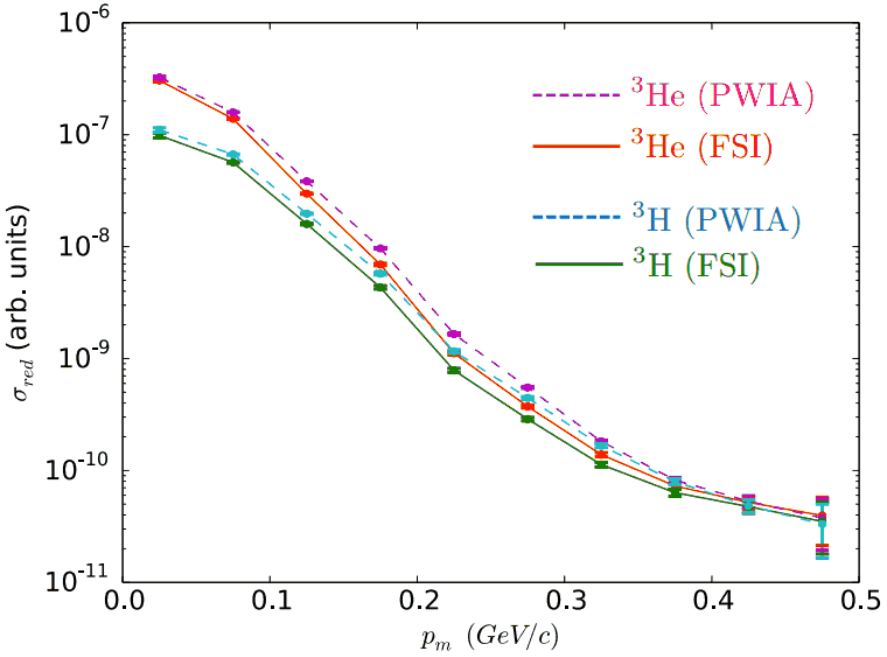


similar for ^{3}He,
no full acceptance cuts!

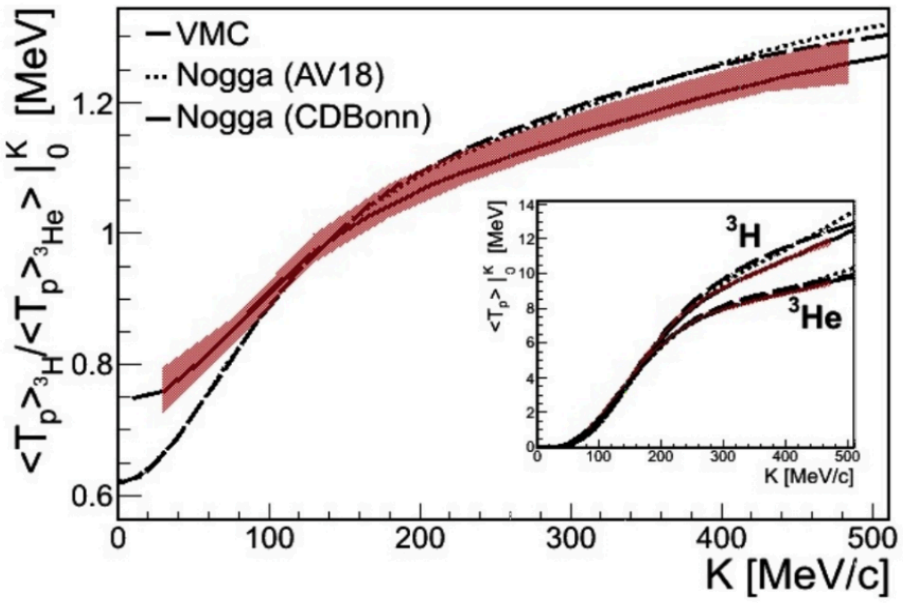




Expected Results

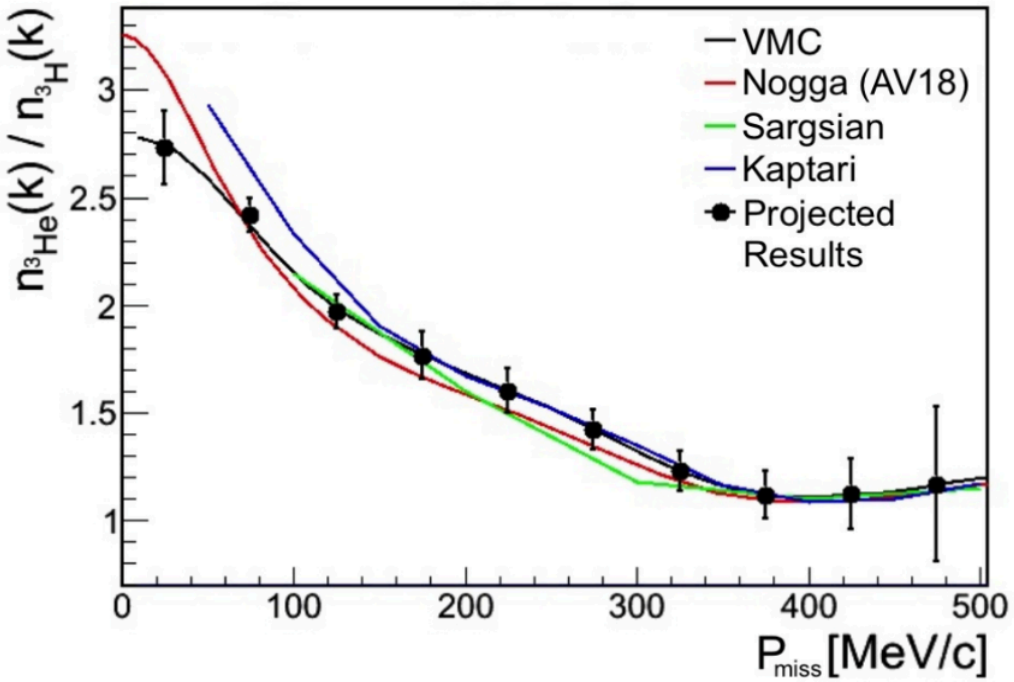


^{3}He and ^{3}H reduced cross-sections; Compared to calculations.



Kinetic Energy Sharing; Mapping of Inversion

Proton/neutron momentum ratio



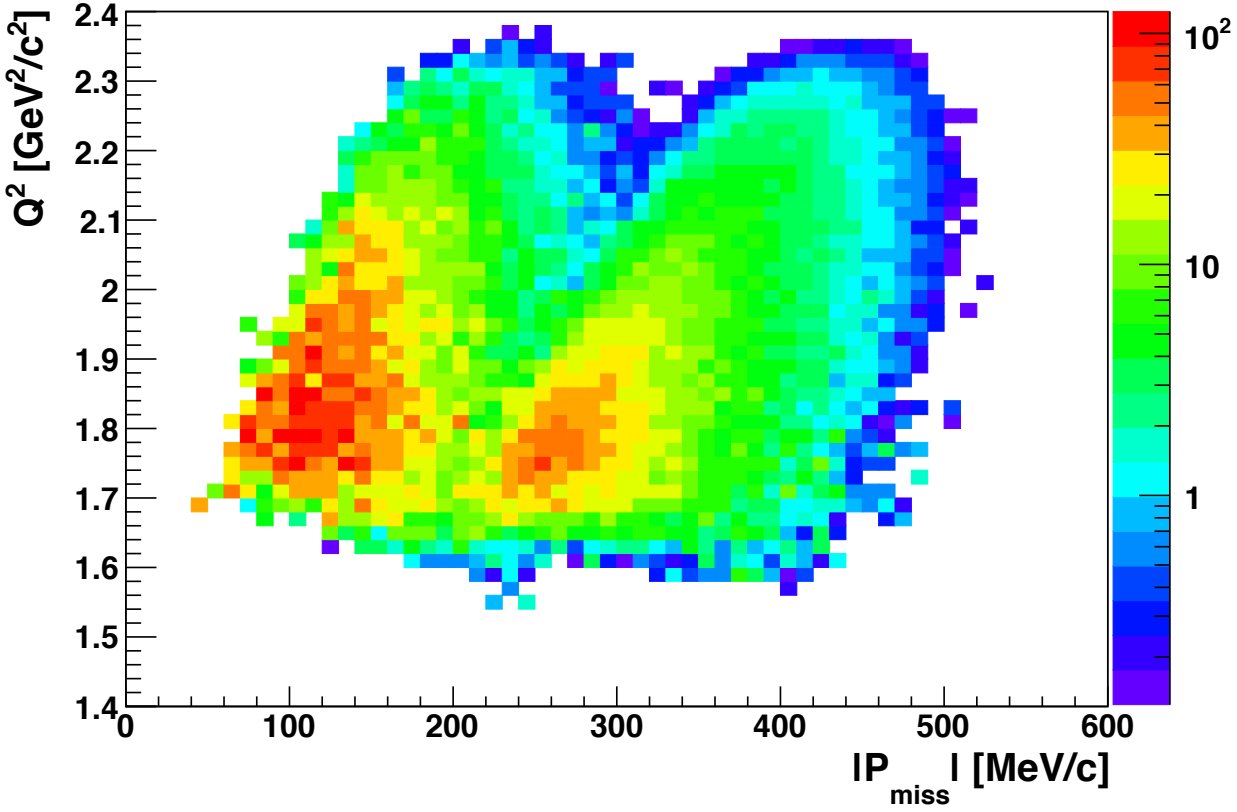
Summary and Outlook

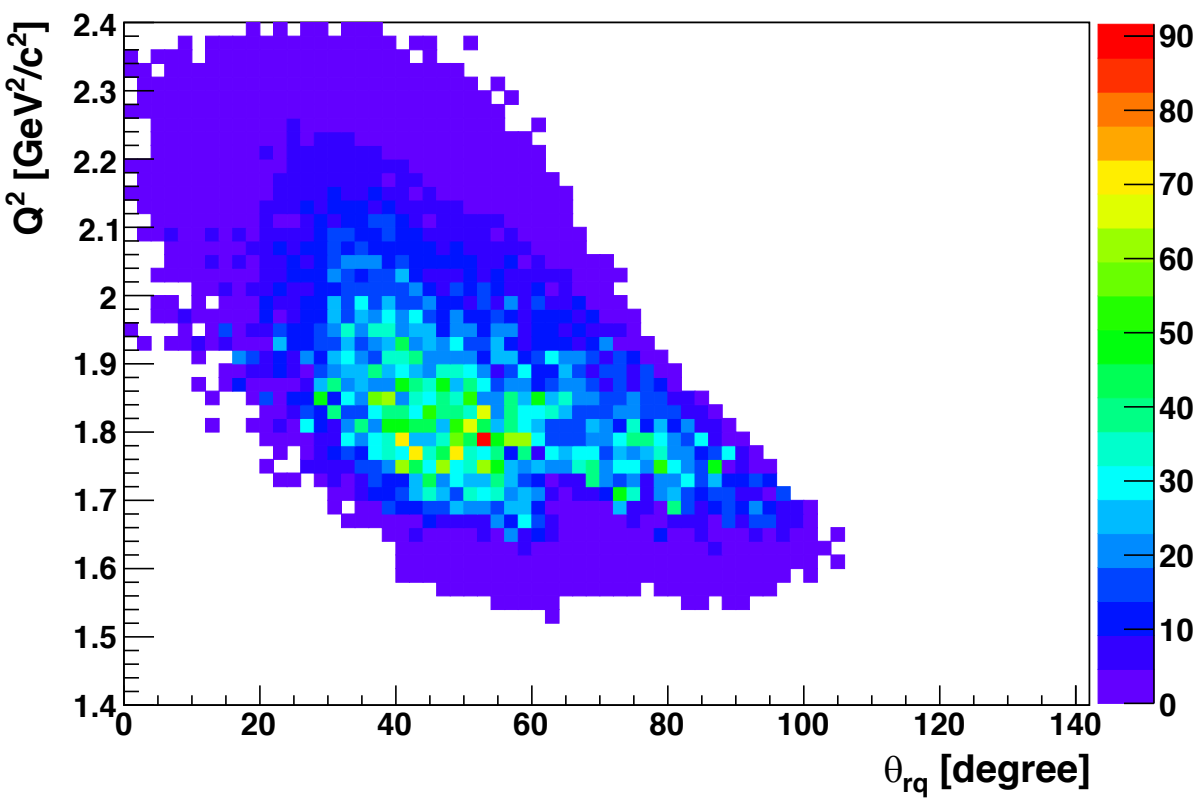
- Measurement of momentum distribution in A = 3 mirror nuclei
- Approved experiment scheduled for december 2017 at JLab Hall-A
- Improved kinematic setting to reduce FSI, MEC and IC effects

- Since E_b = 4.2 GeV next year kinematic setting will change slightly
- Other theoretical calculation i.e χPT?

Backup Slides

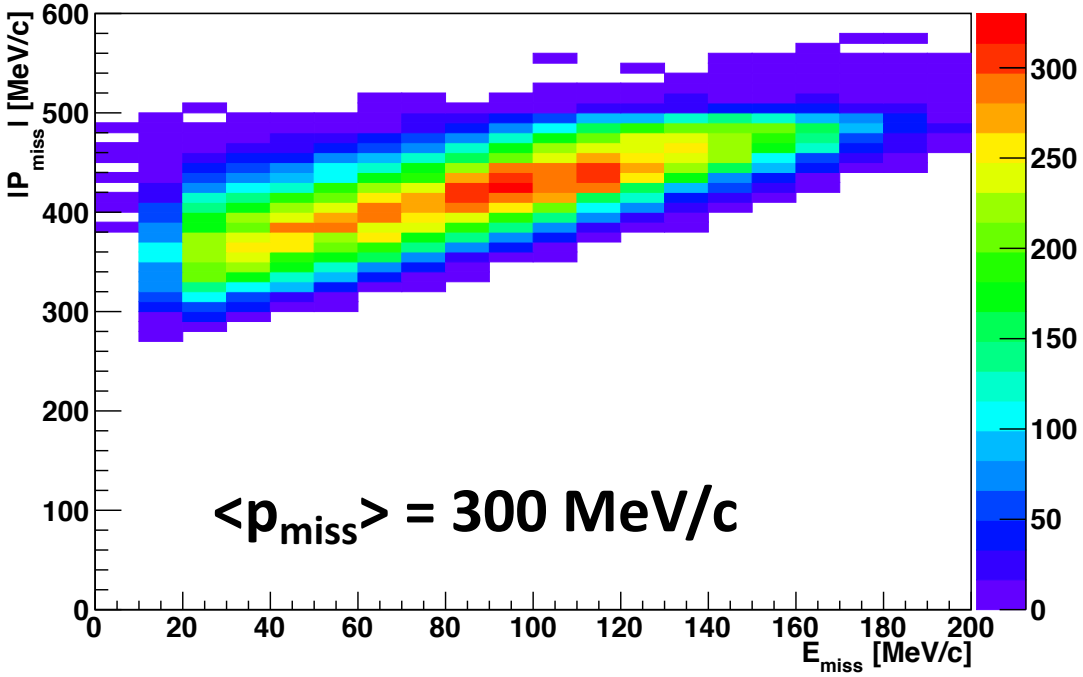
Simulation ^{3}H Results (2)

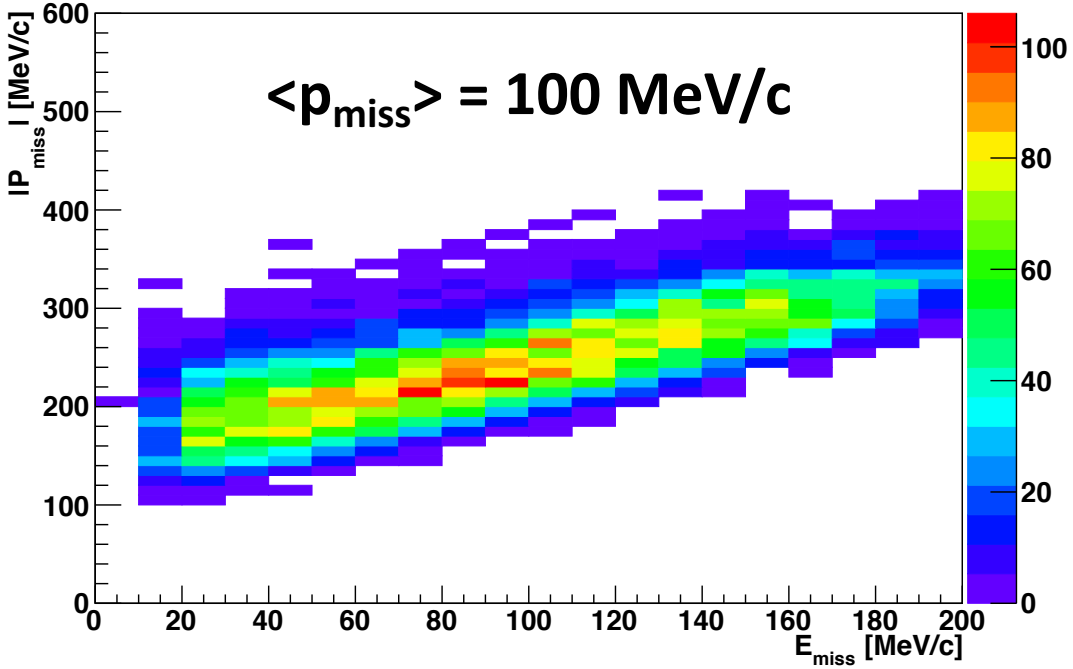




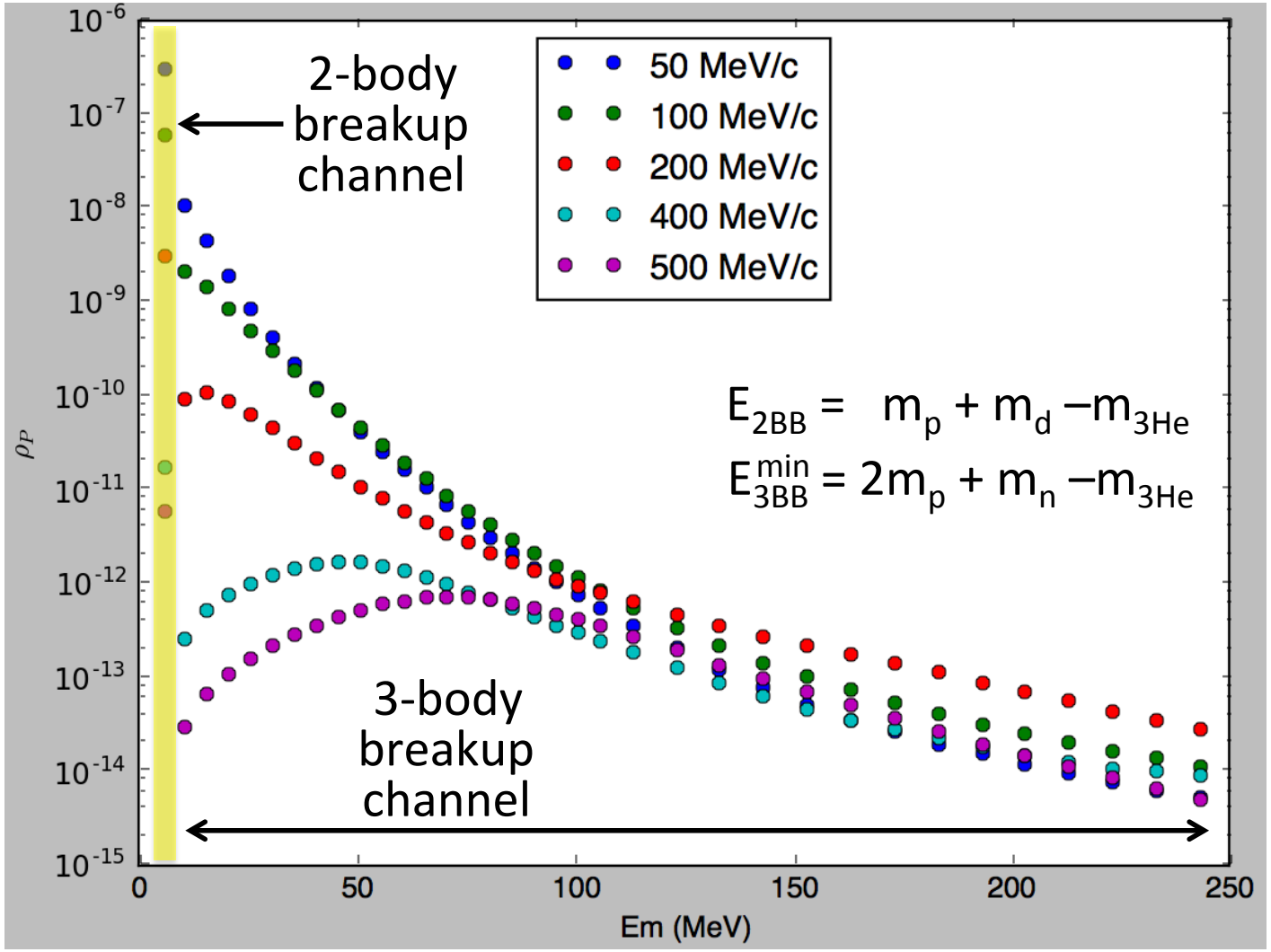
Simulation ^{3}H Results: P_{miss} & E_{miss}

Cut $Q^2 > 2$ GeV^2 and $\theta_{nq} < 40º$, no cross section scaling





^{3}He Spectral Function



from Rey

Previous ^{3}H(e,e'p) measurements

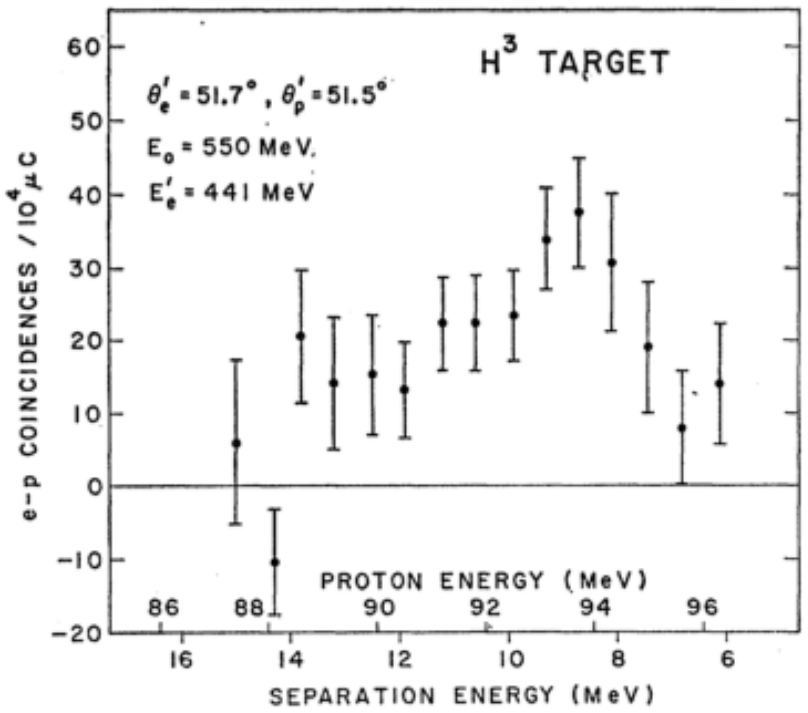


FIG. 2. The energy spectrum of protons at 51.5° in coincidence with 441-MeV electrons at 51.7° from H^3 $(e,e'p)$.

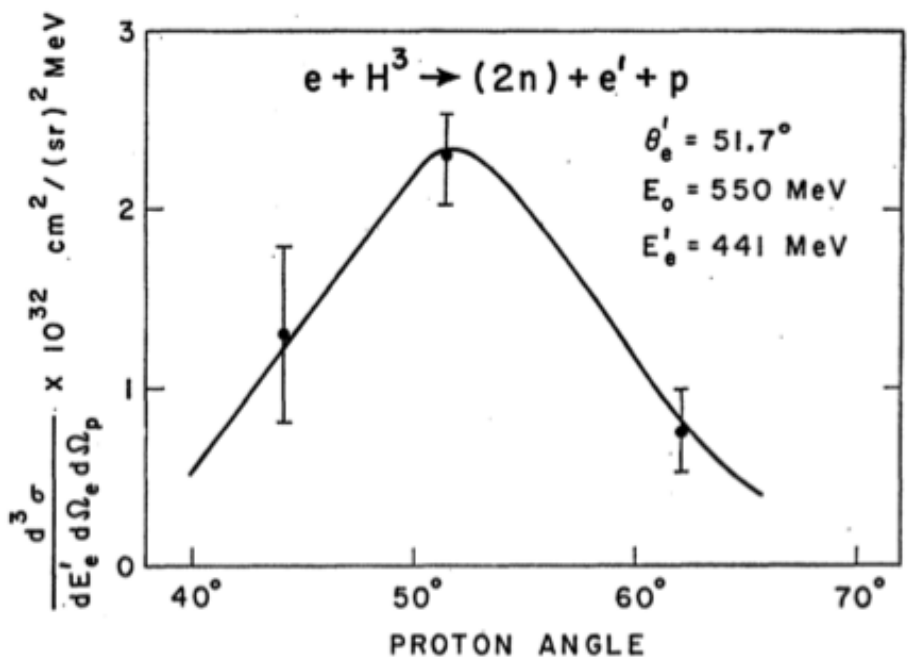
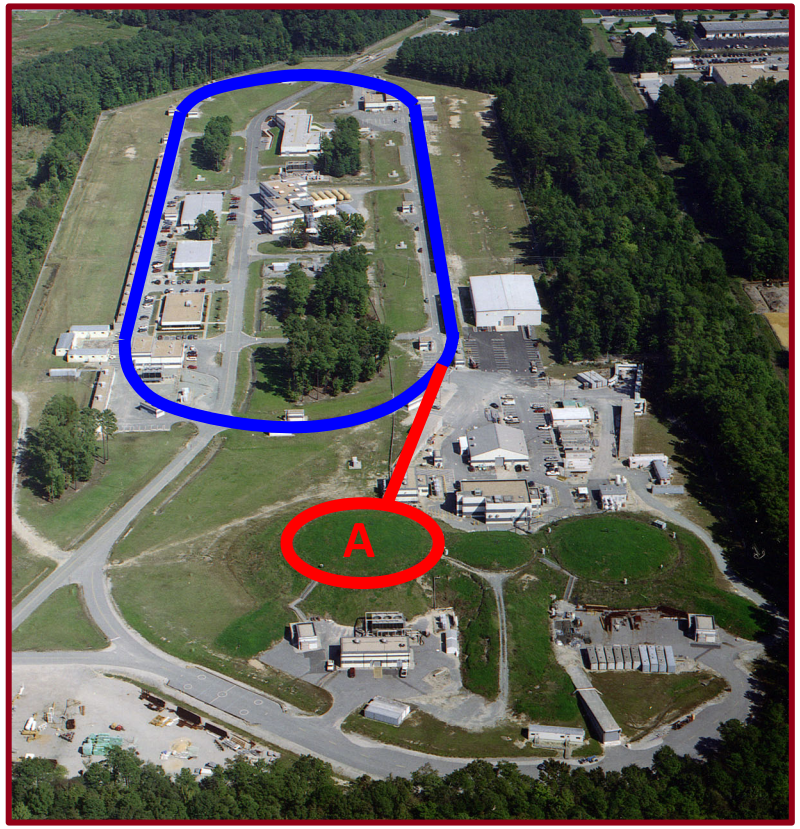
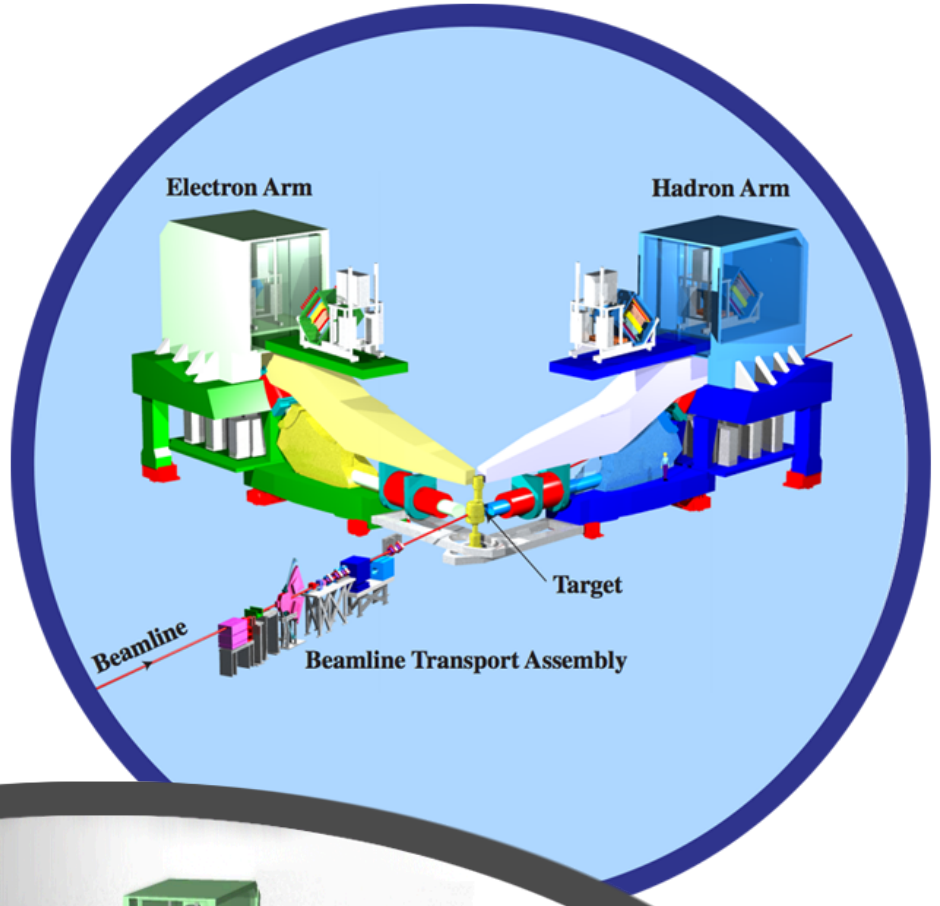


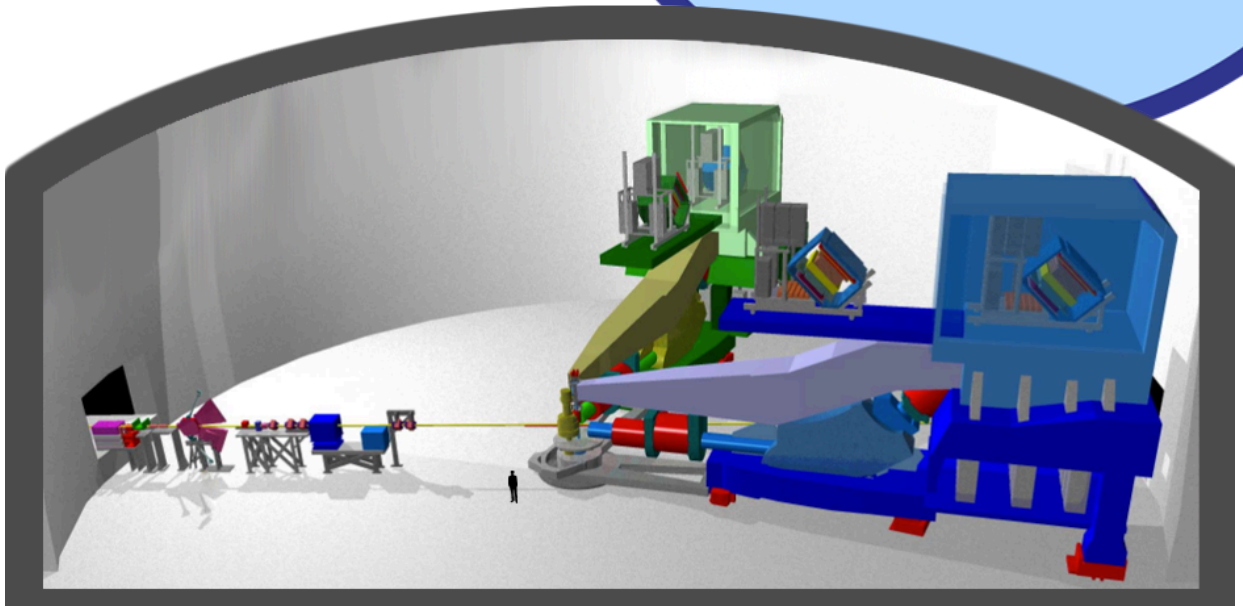
FIG. 4. The coincidence cross section of reaction (C) as a function of proton angle. The curve is explained in Sec. VI of the text.

A. Johansson, PR136, 1030B (1964)

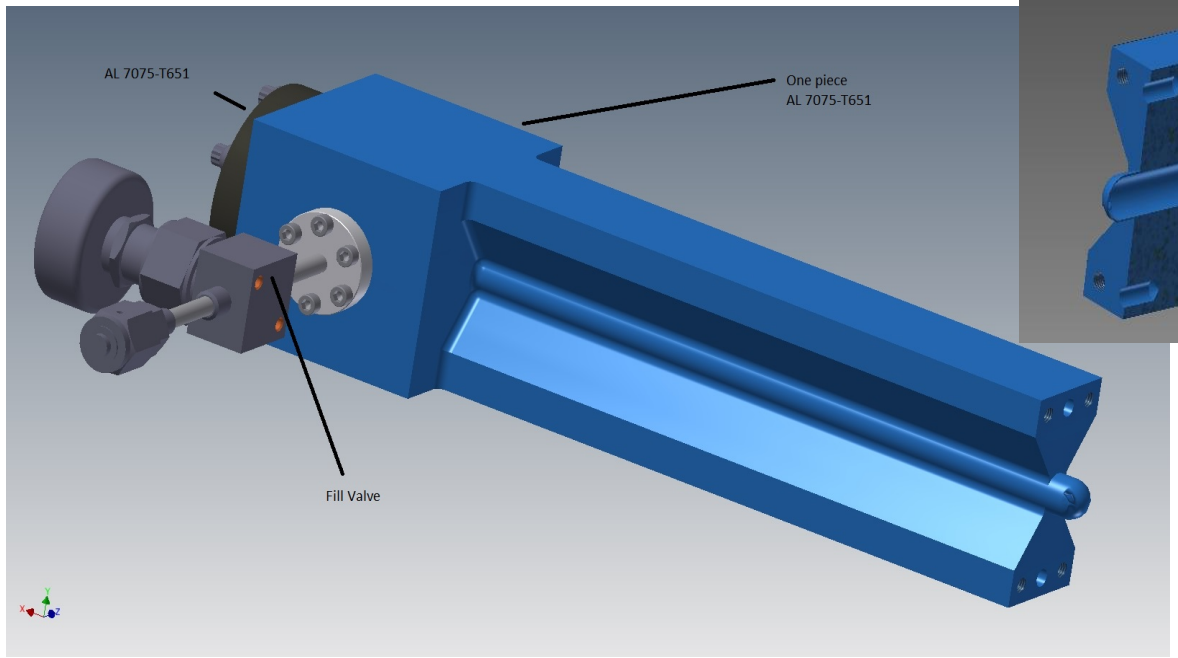
Experimental Setup – Hall A

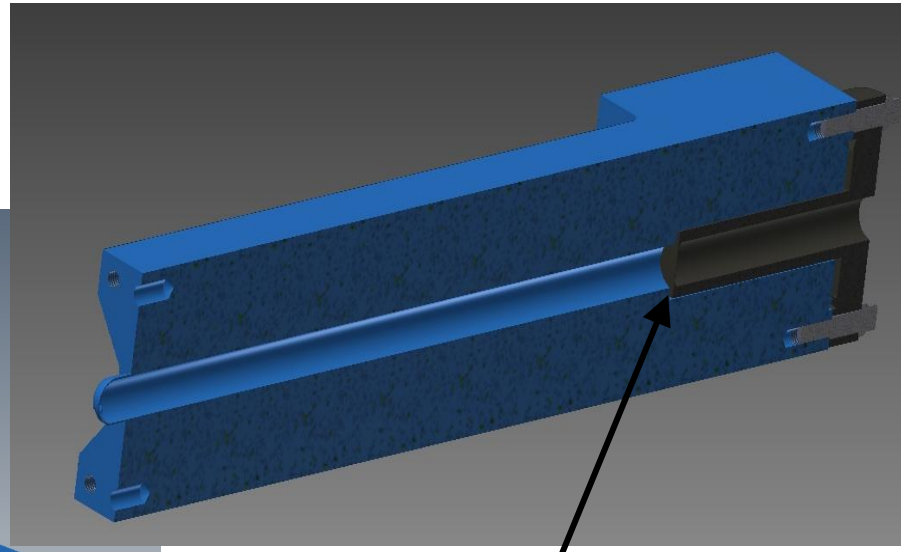






Marathon Target





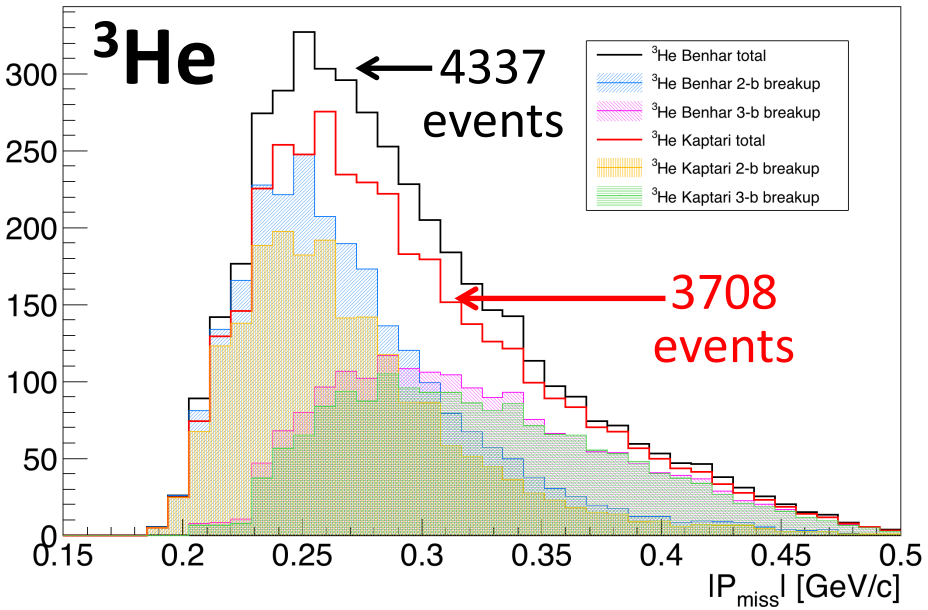
- Open cell design allows a wide range of scattering angles
- Wall thickness 0.018” Al (120 mg/cm^2)
- Entrance and exit windows: 0.010” Al (65 mg/cm^2)
- The proton HRS will not see the cell windows

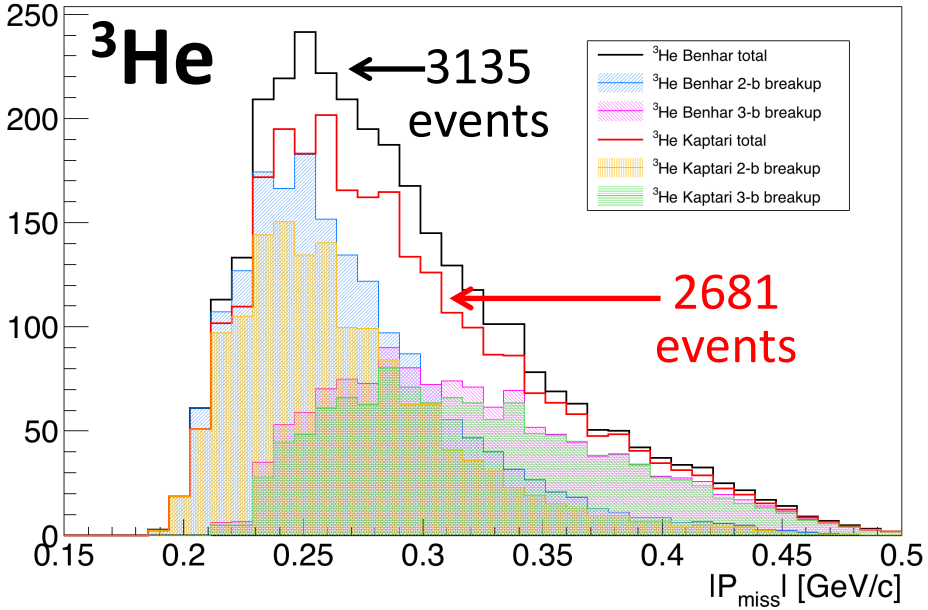
Adopted From David Meekins

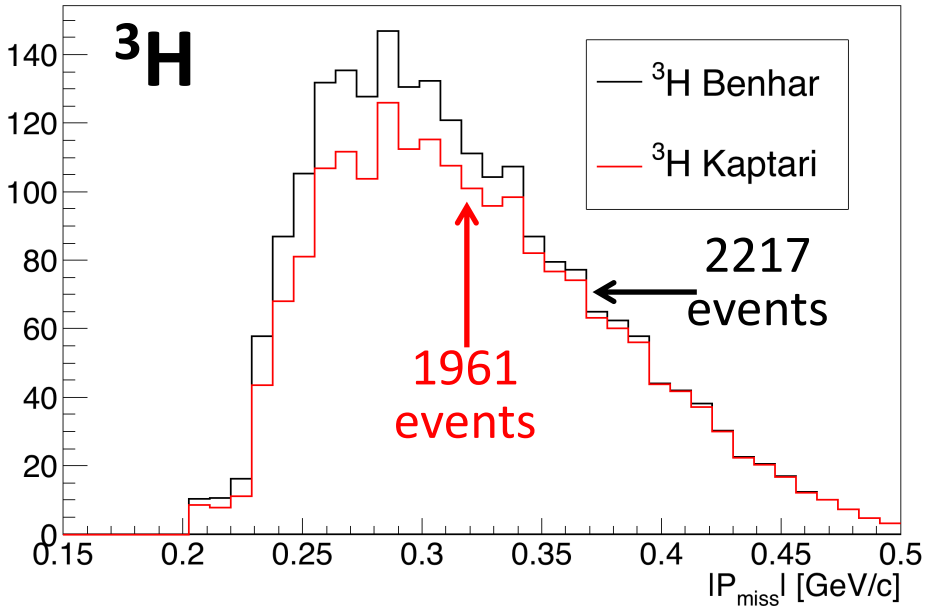
P_{miss} distributions (slow kinematics configuration, scaled to 4 days)

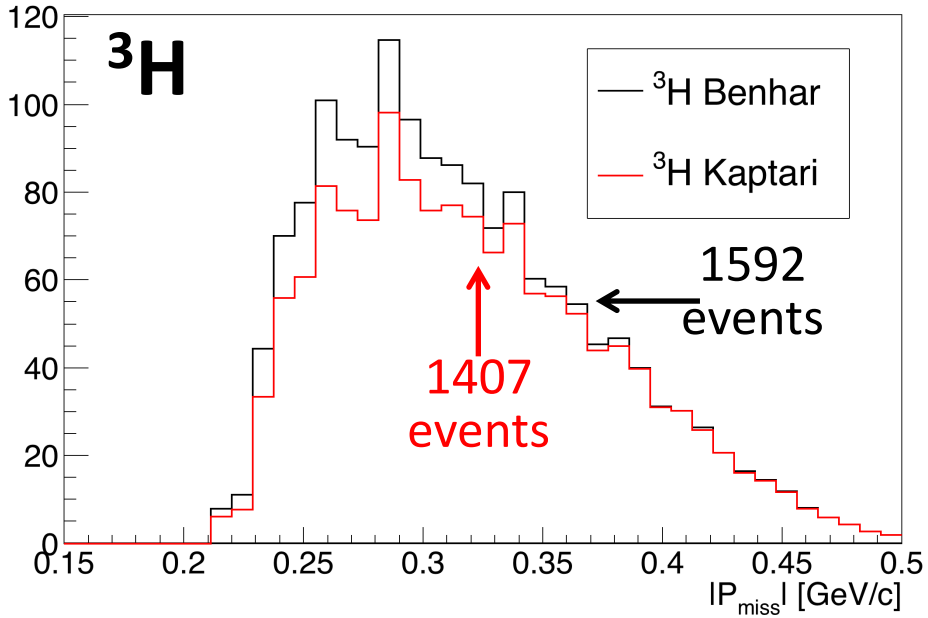
← before R-cut

after R-cut →









from Rey