E08-014: 3-nucleon correlations

Patricia Solvignon

Argonne National Laboratory

Spokepeople: John Arrington
Donal Day
Doug Higinbotham
Patricia Solvignon (contact)

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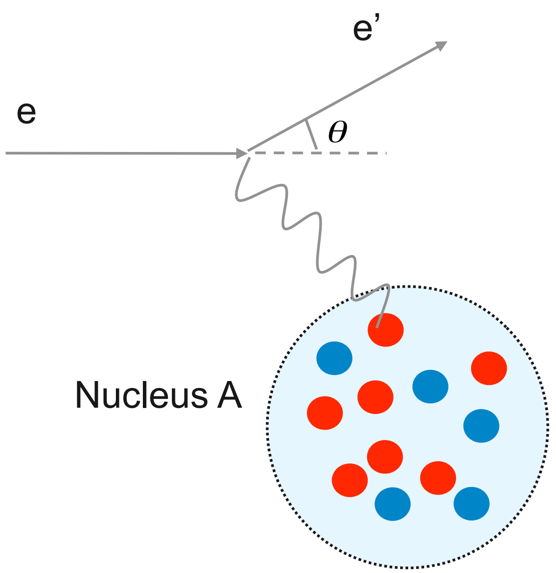
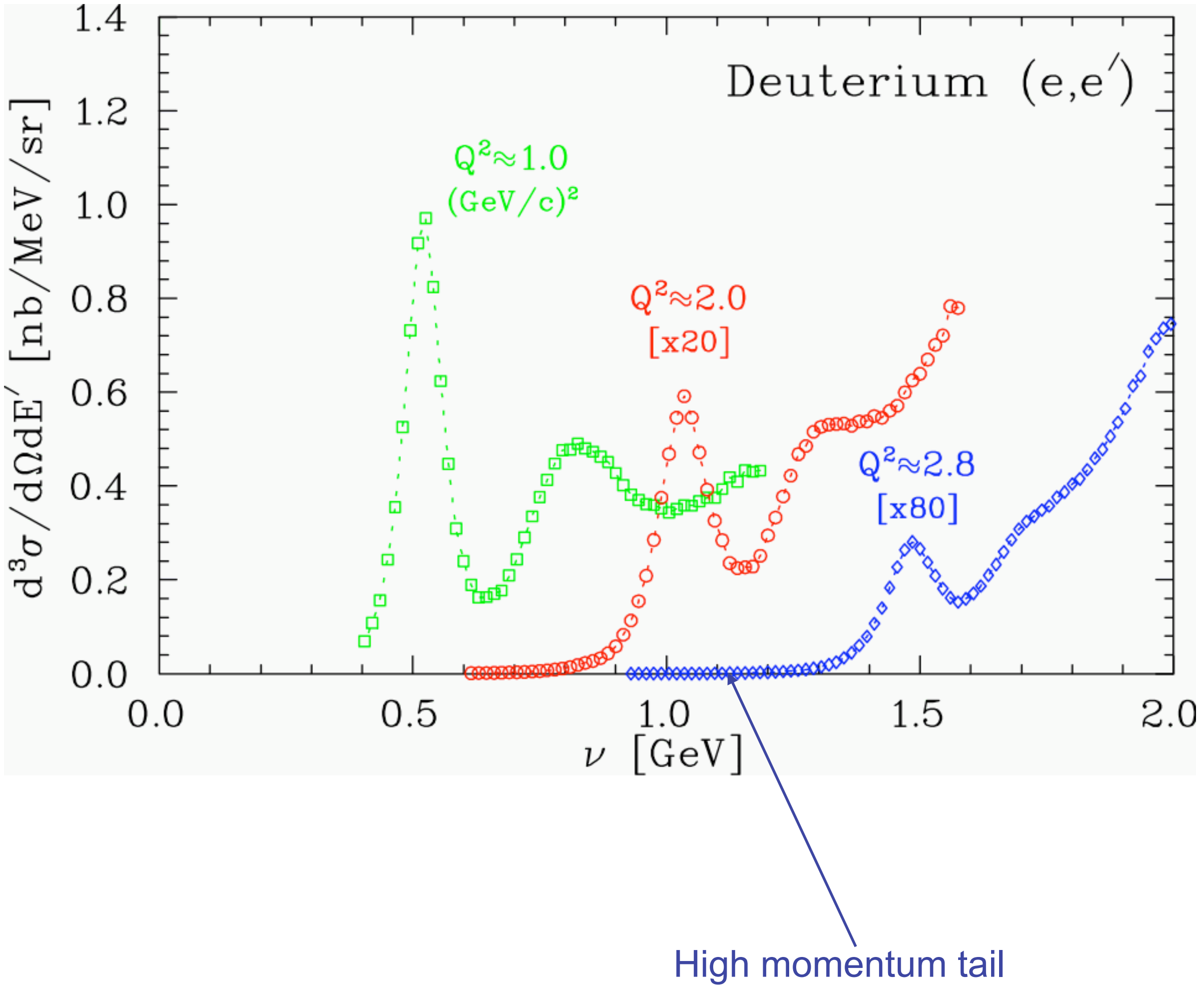
Inclusive scattering at large x



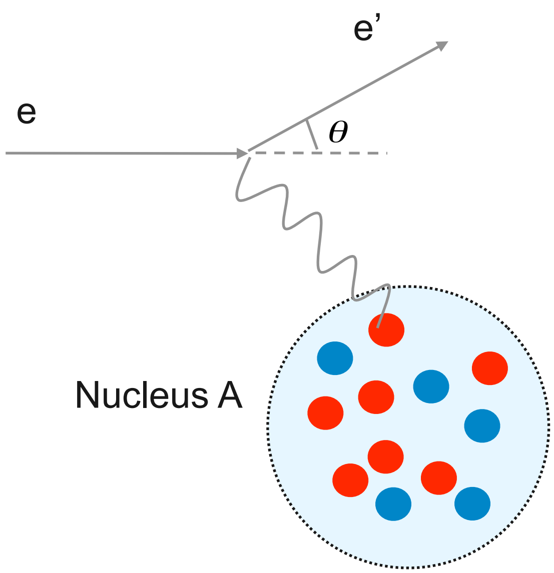


Quasi-Elastic Scattering

$x \approx 1$

Motion of nucleon in the nucleus broadens the peak

Inclusive scattering at large x

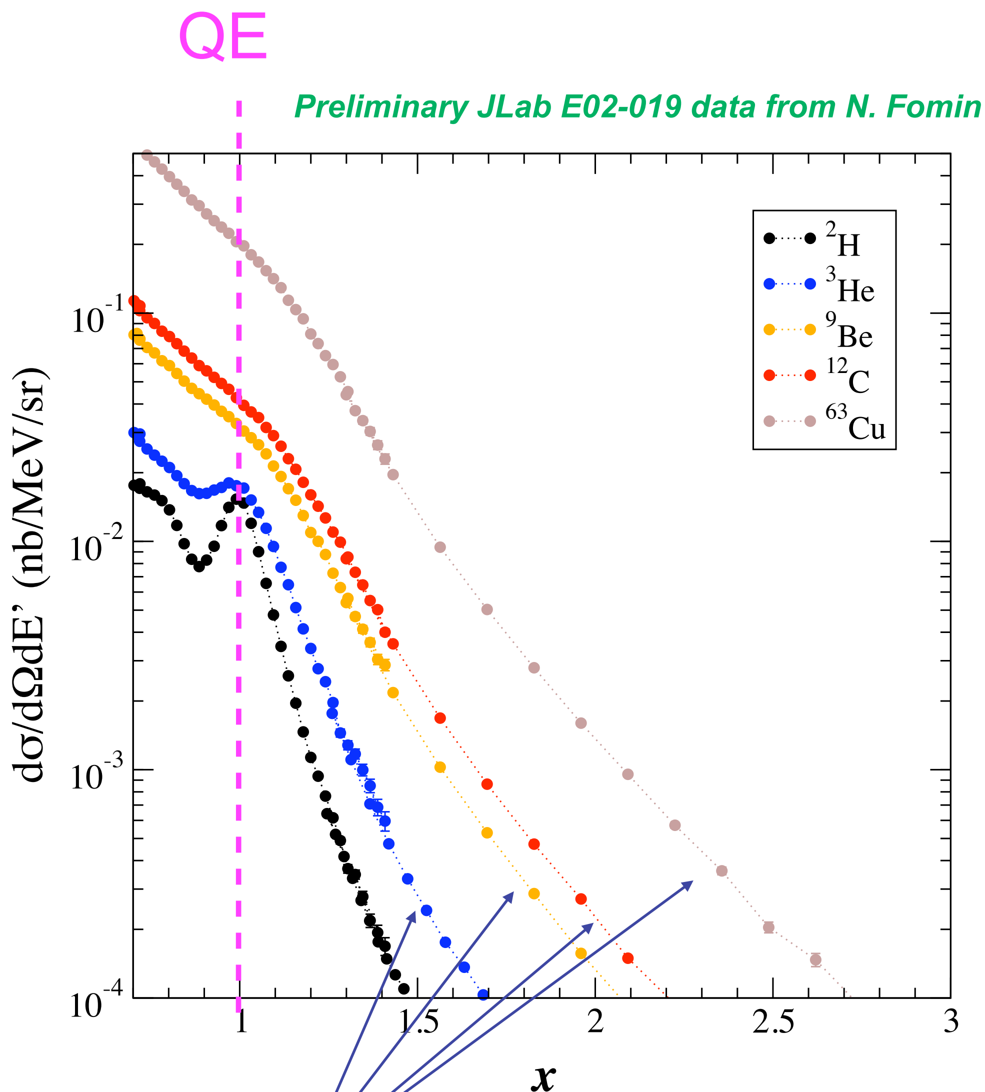


Quasi-Elastic Scattering

$x \approx 1$

Motion of nucleon in the nucleus broadens the peak

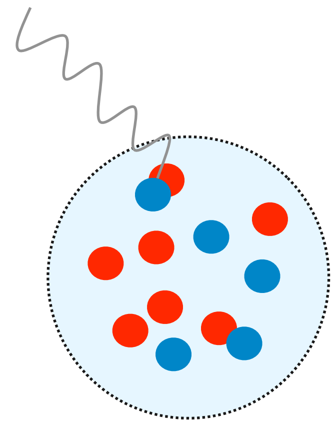
little strength from QE above $x \approx 1.3$

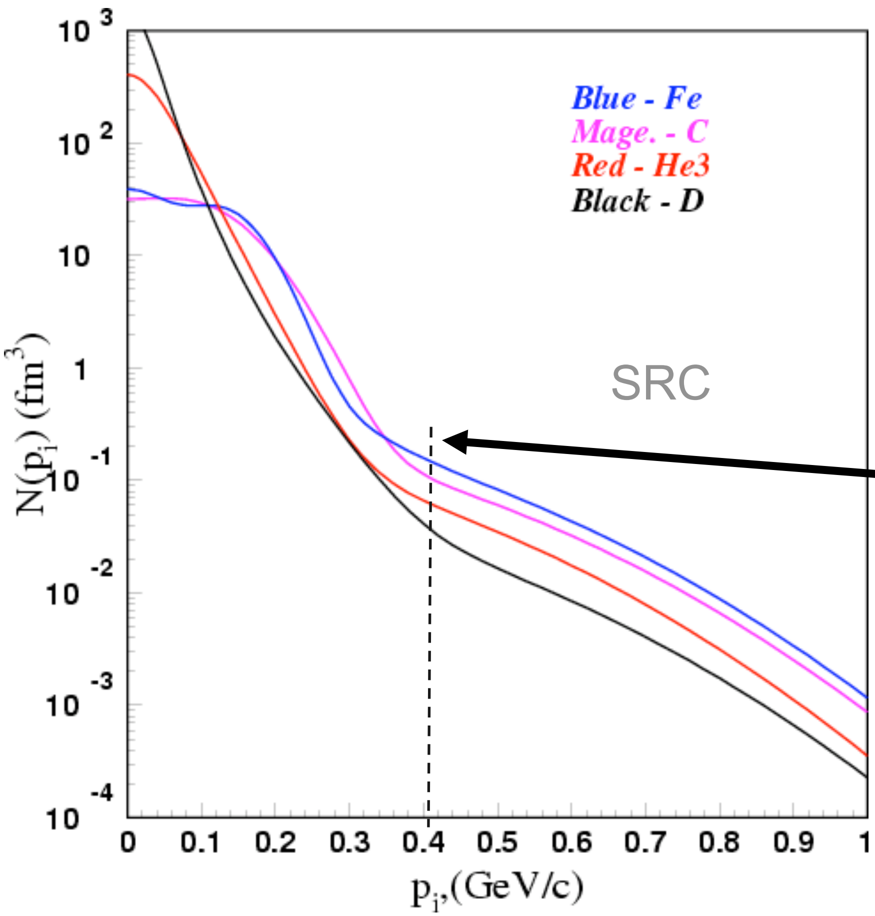


High momentum tails should yield constant ratio if seeing SRC

Short range correlations (SRC)

- High-momentum tail dominated by 2N-SRCs
- NN interaction generates high momenta ($k>k_f$)
- Similar shape for $k>k_f$





2N-SRC

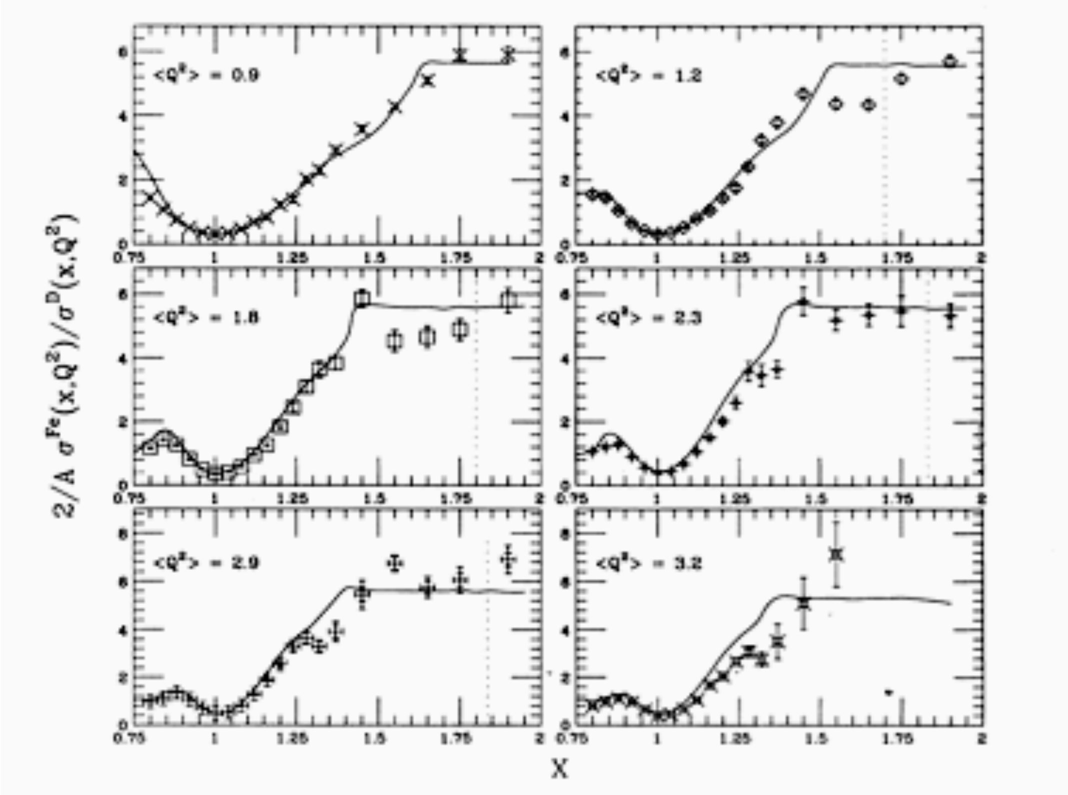
1<x<2

Above: ratio = constant

A(e',e) at x>1:
<u>the simplest way to measure relative probability of SRC</u>

Cioffi Degli Atti et Simula, PRC53, 1689 (1996)

SRC evidence at SLAC



Frankfurt, Strikman, Day, Sargsian, PRC48, 2451 (1993)

Ratio of cross section (per nucleon) shows plateau above x ≈1.4, as expected if high-momentum tails dominated by 2N-SRCs

Ratio in plateau, proportional to the number of 2N SRCs

$a_2(^3He)=1.7\pm0.3$

$a_2(^4He)=3.3\pm0.5$

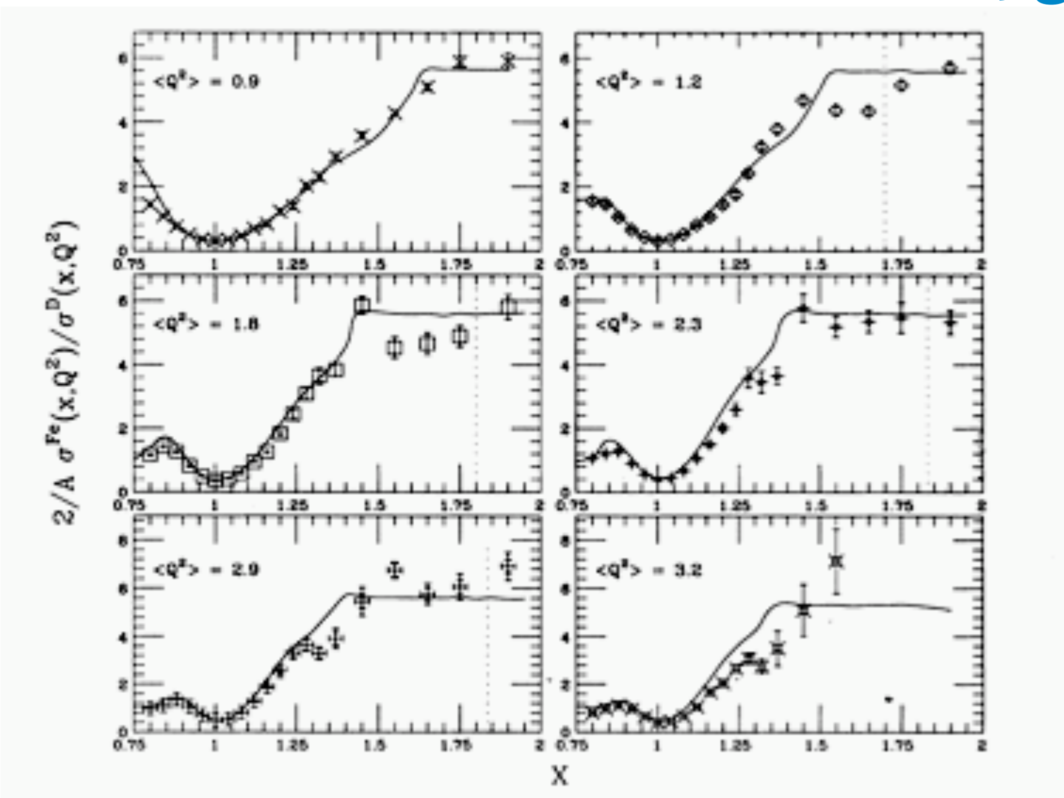
$a_2(^{12}C)=5.0\pm0.5$

$a_2(^{27}Al)=5.3\pm0.6$

$a_2(^{56}Fe)=5.2\pm0.9$

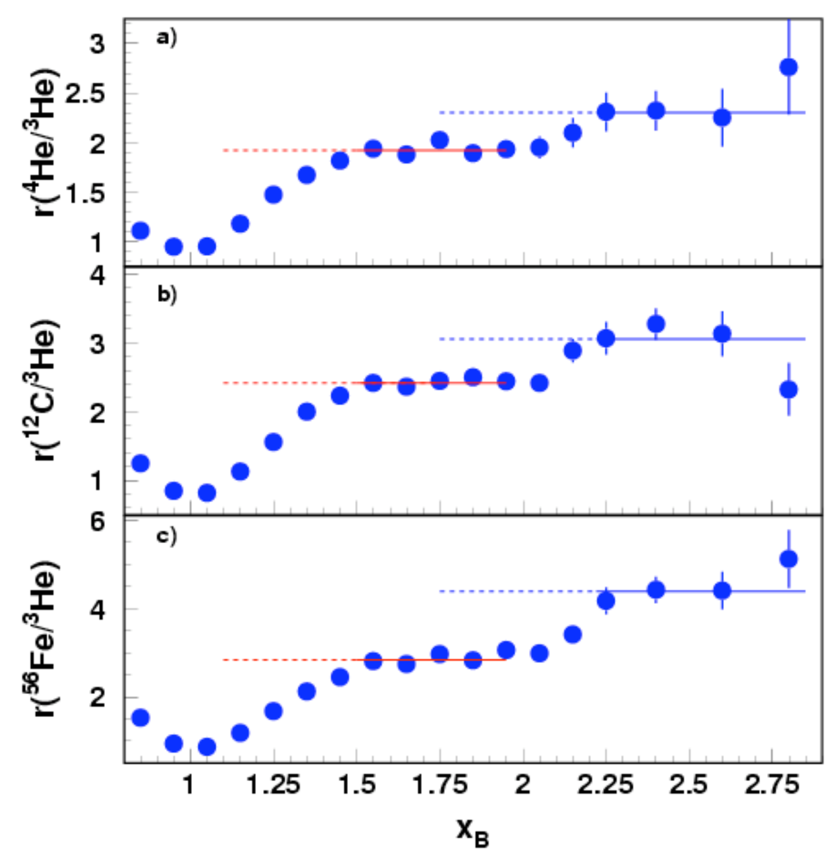
$a_2(^{197}Au)=4.8\pm0.7$

SRC evidence at SLAC, JLab Hall B



Frankfurt, Strikman, Day, Sargsian, PRC48, 2451 (1993)

K. Egiyan et al, PRL96, 082501 (2006)



Ratio of cross section (per nucleon) shows plateau above x ≈1.4, as expected if high-momentum tails dominated by 2N-SRCs

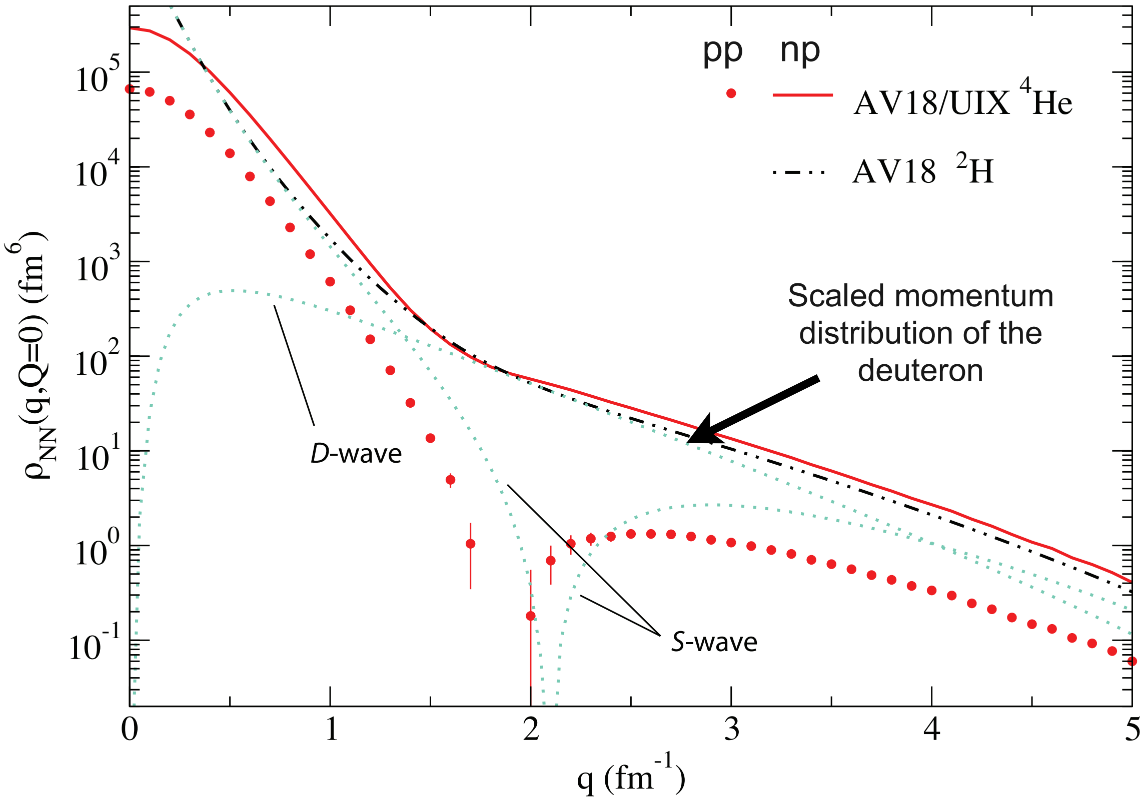
Experimental observations:

- Evidence of 2N-SRC at x>1.5
- Indication of 3N-SRC plateau
- Isospin dependence ?

Dominance of the tensor force

Simple SRC model assumes isospin independence

R. Schiavilla, R. Wiringa, S. Pieper and J. Carlson, PRL98, 132501 (2007)



Dominance of the tensor force

R. Subedi et al, Science 320, 1476(2008)

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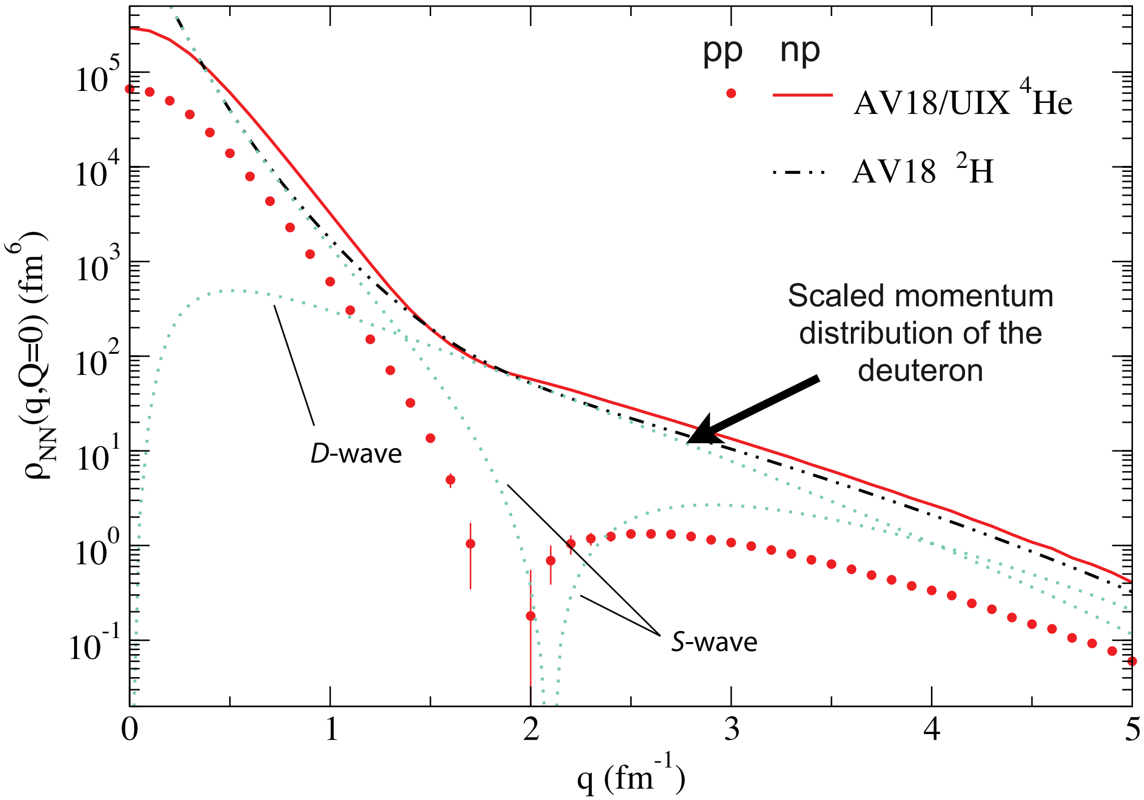
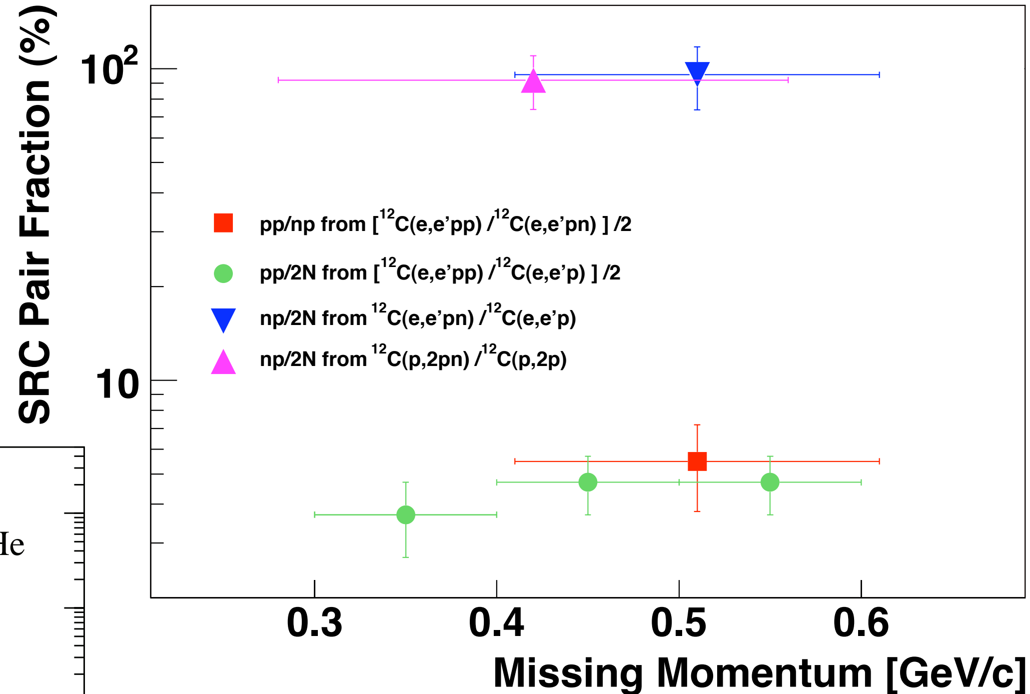
R. Schiavilla, R. Wiringa, S. Pieper and J. Carlson, PRL98, 132501 (2007)





From A(p,ppn) and ^{12}C(e,e'pN): 90% are pn 2-body tensor force leads to dominance of T=0 pairs

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SRC isospin study from inclusive scattering

- Inclusive ratio is 'isospin-blind' (sum of n and p)

- ***Target*** can be isospin sensitive

  - ✓ *Compare ^{40}Ca to ^{48}Ca – approved JLab experiment*
  - ✓ *Compare ^{3}H to ^{3}He – proposed JLab experiment, 12 GeV upgrade*

- n-p pair dominance ➞ equal number of high momentum p, n

- Isospin-independent correlations ➞ Z protons, N neutrons at high p

Isospin study of SRC

Simple mean field estimates for 2N-SRC

Isospin independent:

$$\frac{\sigma_{48}/48}{\sigma_{40}/40} = \frac{(20\sigma_p + 28\sigma_n)/48}{(20\sigma_p + 20\sigma_n)/40} \xrightarrow{\sigma_p \approx 3\sigma_n} 0.92$$

n-p (T=0) dominance:

$$\frac{\sigma_{48}/48}{\sigma_{40}/40} = \frac{(20*28)/48}{(20*20)/40} = 1.17$$

25% difference isospin indep. vs.pn-only (compare to 40% for $^3He/^3H$)

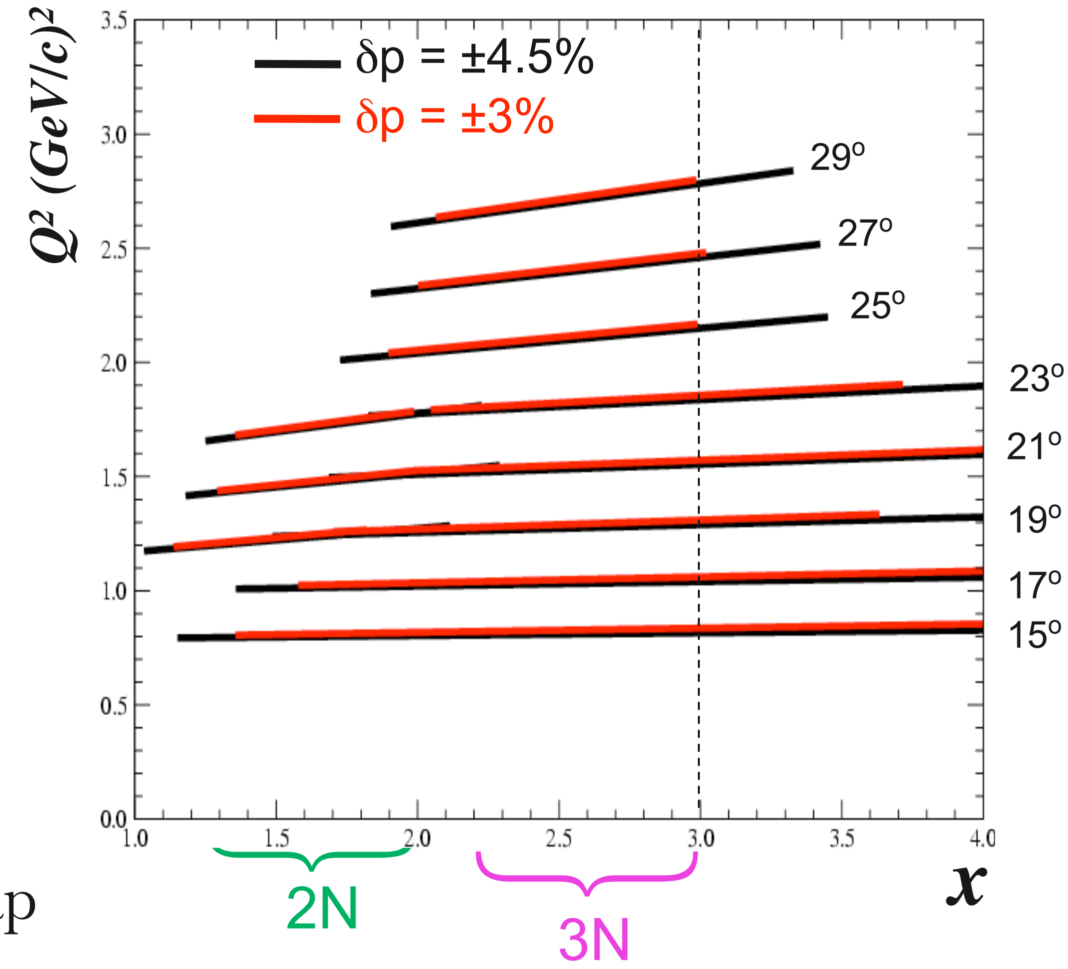
For no extra T=0 pairs with f7/2 neutron:

$$\frac{\sigma_{48}/48}{\sigma_{40}/40} = \frac{\sigma_{40}/48}{\sigma_{40}/40} = 0.83$$

Experiment E08-014

- Study onset of scaling, ratios as a function of α_{2n} for 1<x<2

- Verify and define scaling regime for 3N-SRC:
  - 3N-SRC over a range of density: ^{40}Ca, ^{12}C, ^{4}He ratios
  - Test α_{3n} for x> 2



- Absolute cross sections: test FSI, map out IMF distribution $\rho_A(\alpha)$

needed for $q_A(x)$ convolution
(EMC, hard processes in A-A collisions, …)

- Isospin effects on SRCs: ^{48}Ca vs. ^{40}Ca

12 days of beam time in Hall A in standard configuration

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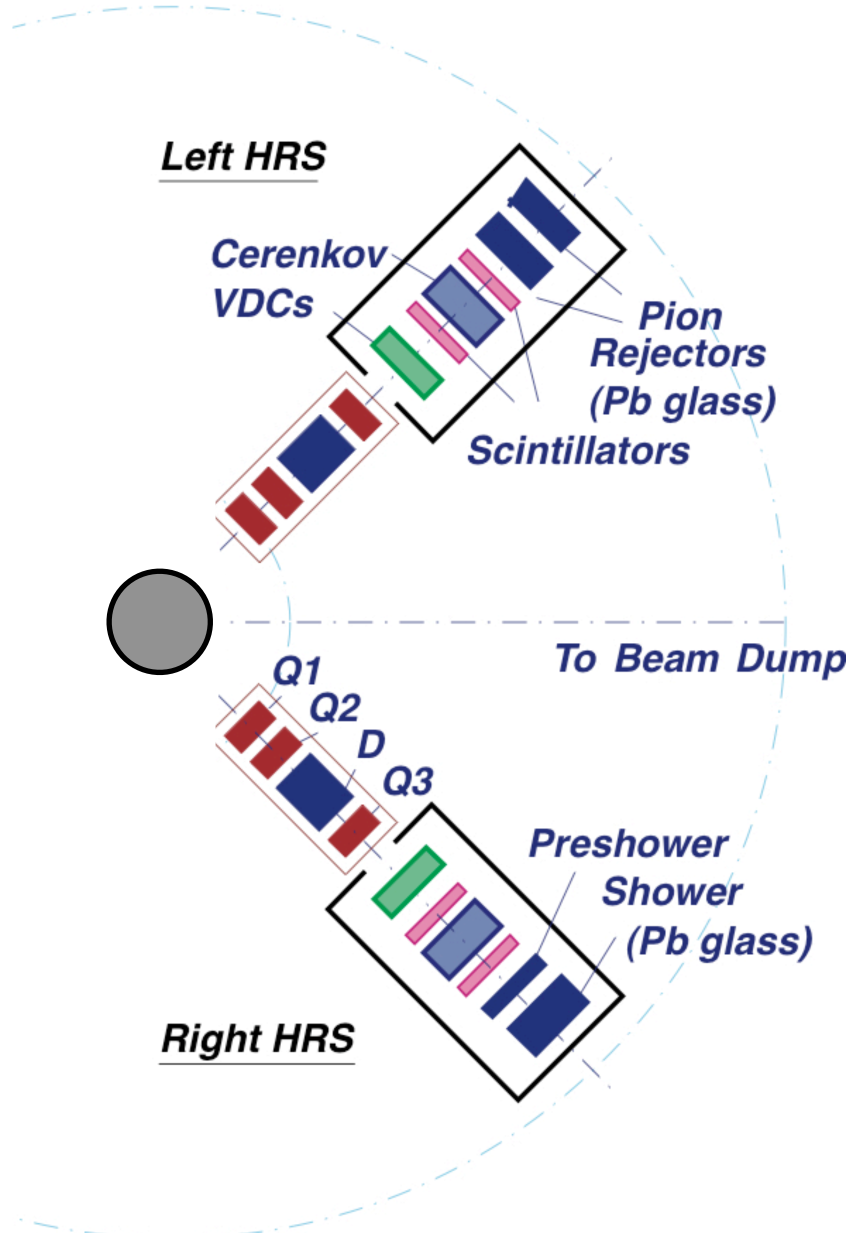
Experimental setup

- Standard Hall A configuration
- ^{2}H, ^{3}He, ^{4}He cryo-target
- ^{12}C, ^{40}Ca, ^{48}Ca
- Empty Al cell for cryo-window subtraction
- Carbon foils for optics
- Gas Cerenkov + Calorimeter for PID
- Beam energy: 3.6 GeV
- Eight scattering angles: 15° to 29°



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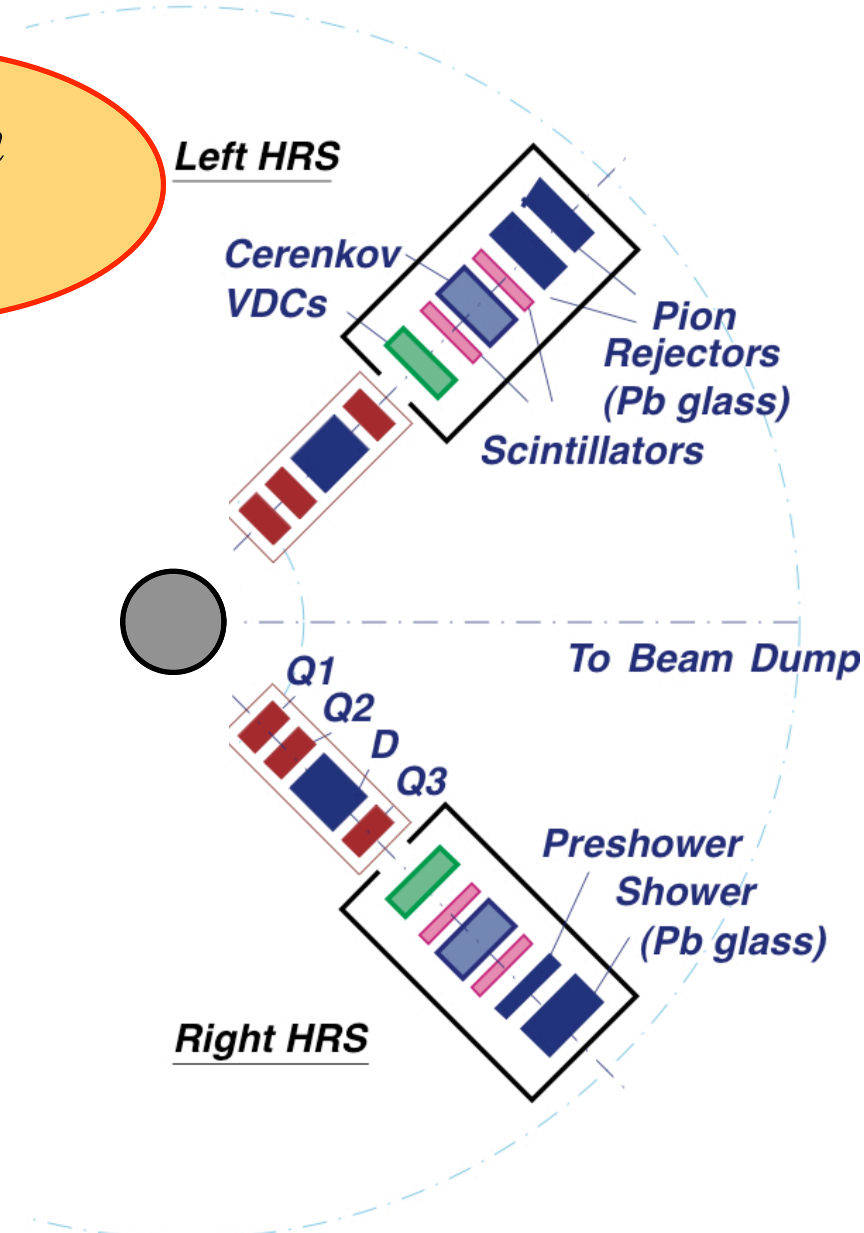

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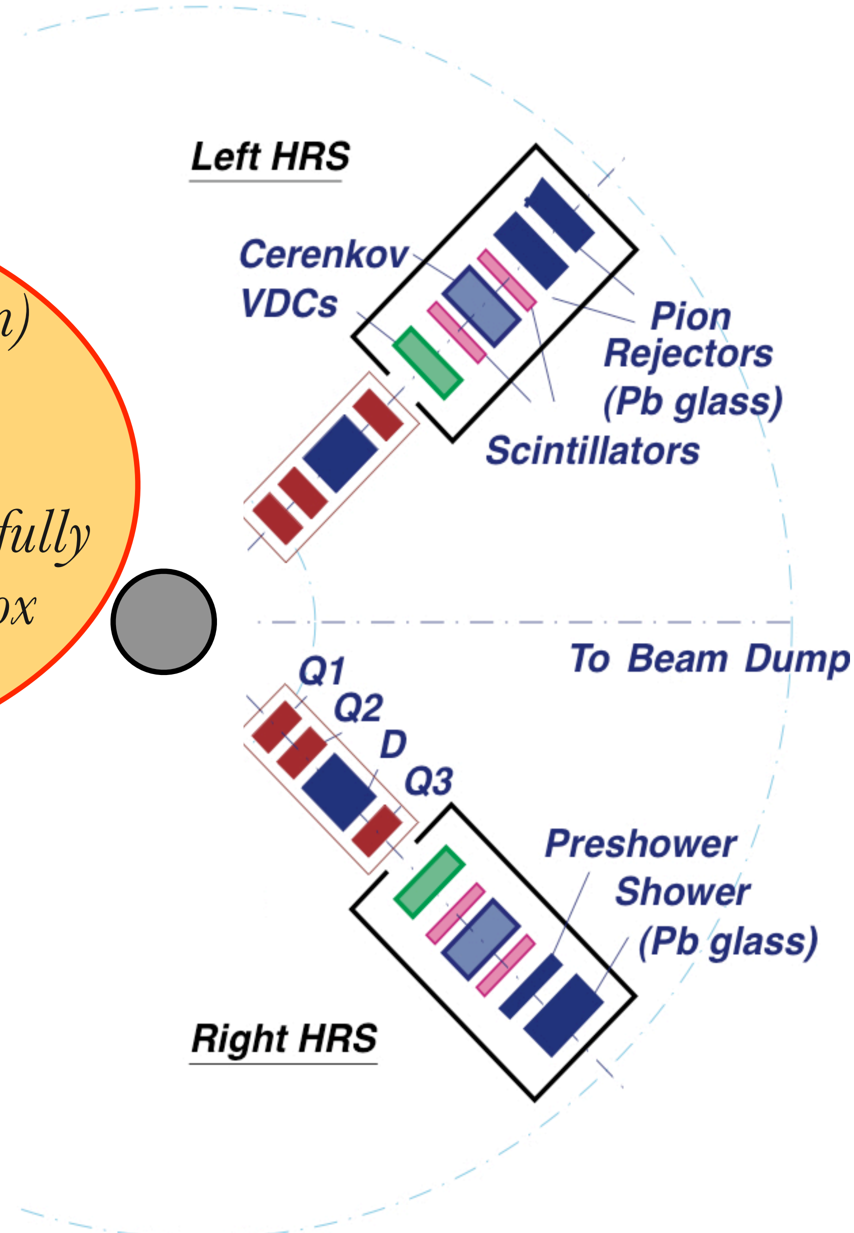
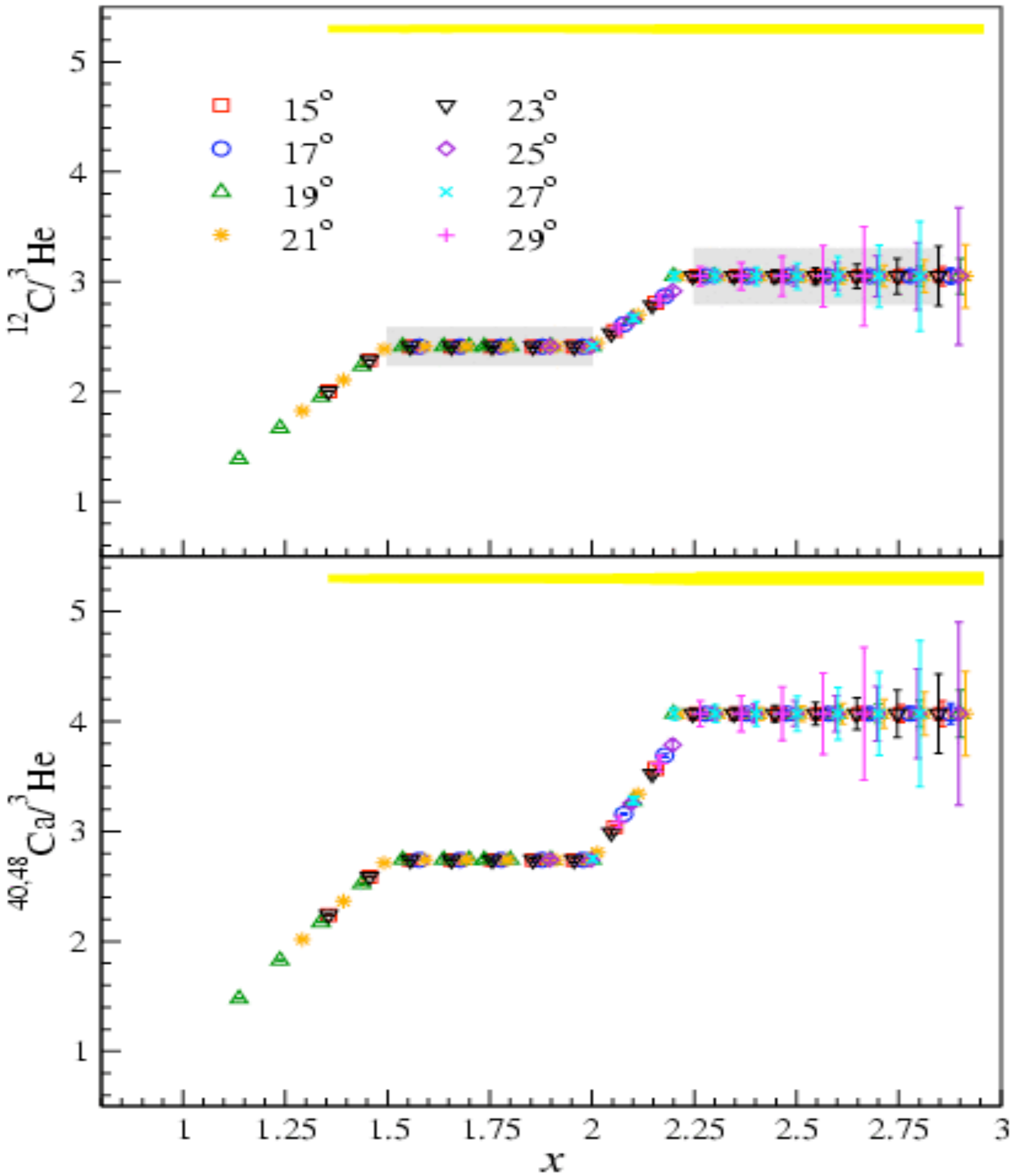
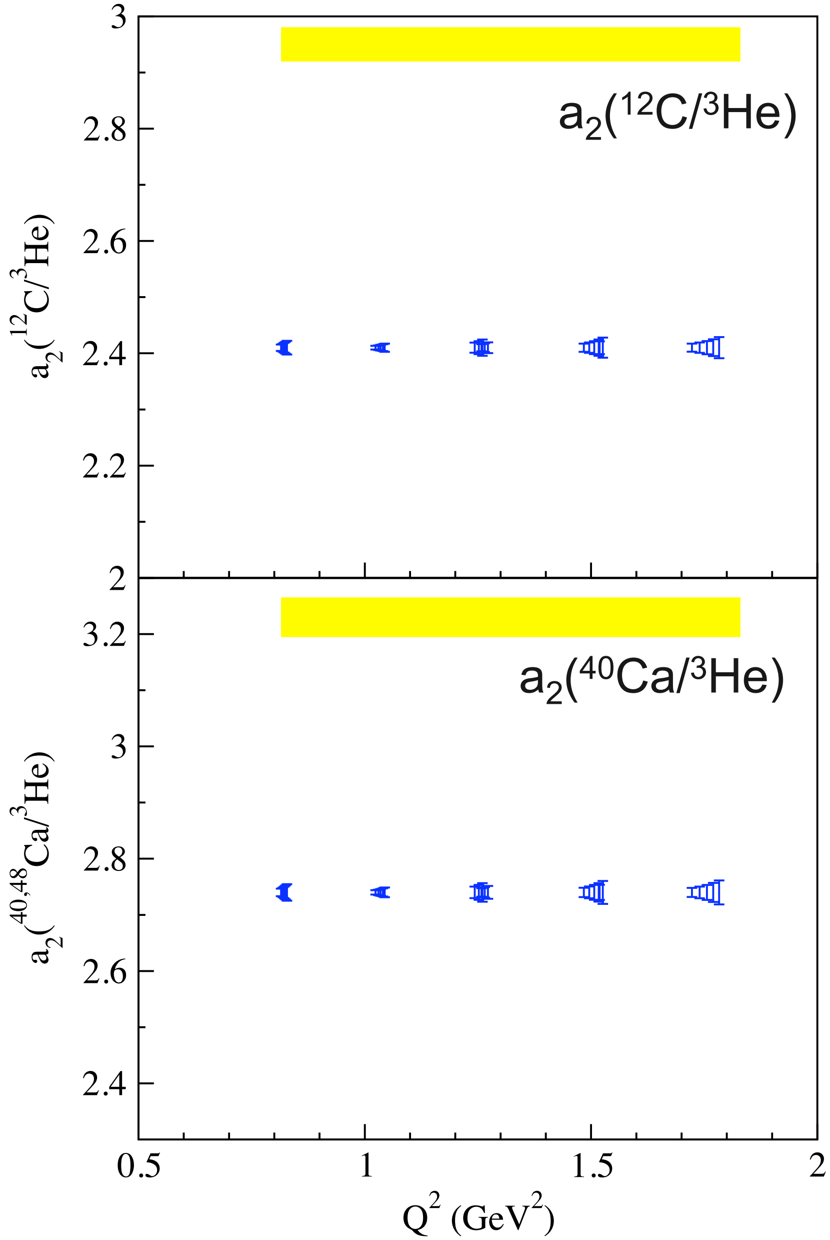
- Beam energy: 3.6 GeV
- Eight scattering angles: 15^{o} to 29^{o}

very costly
(~150K-250K per gram)
--> need 1g
plan is to borrow it
but need to handle very carefully
--> very efficient glove-box
will be purchased

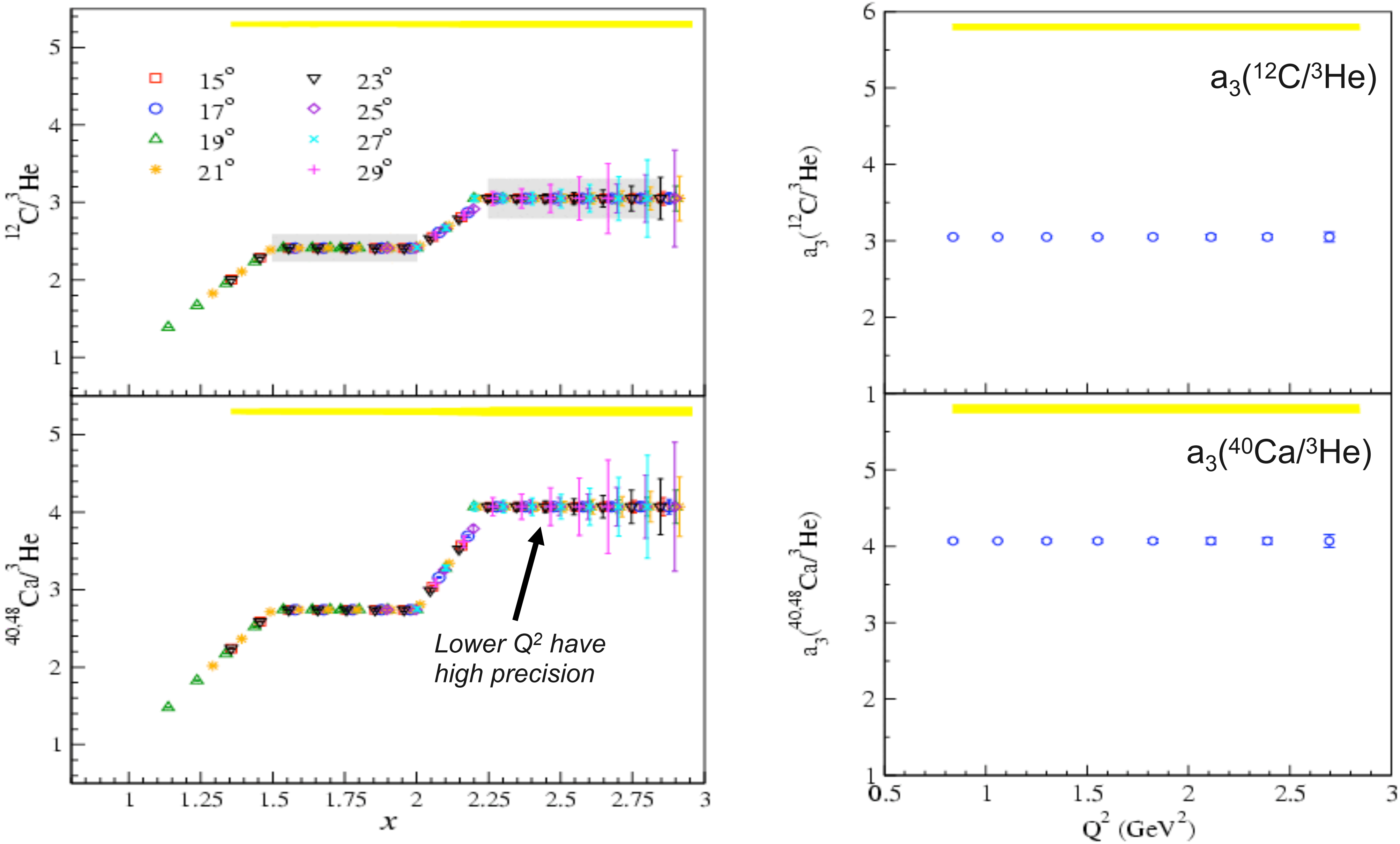


A/^{3}He ratios: map out 2N scaling region



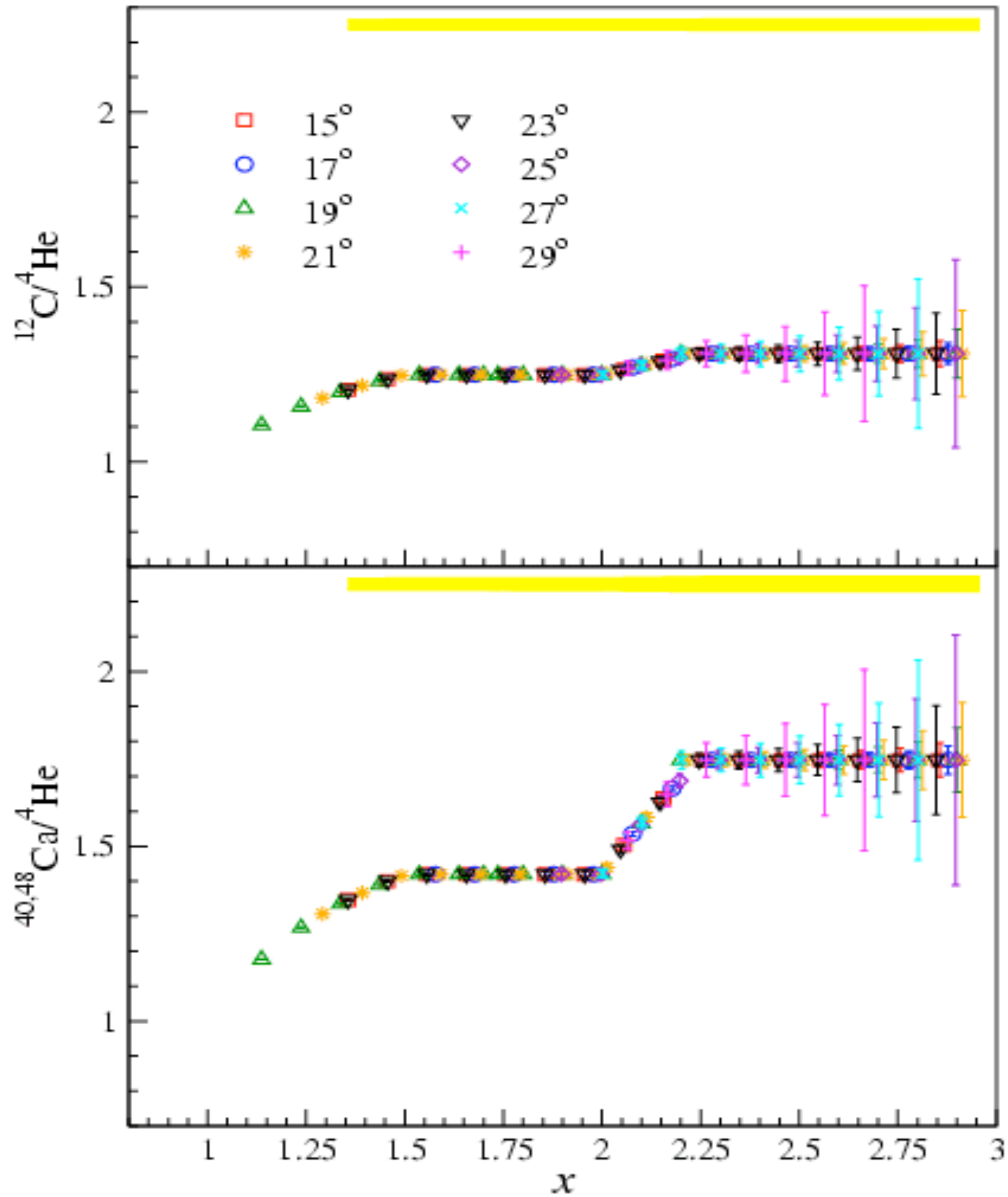


$A/^3He$ ratios: map out 3N scaling region

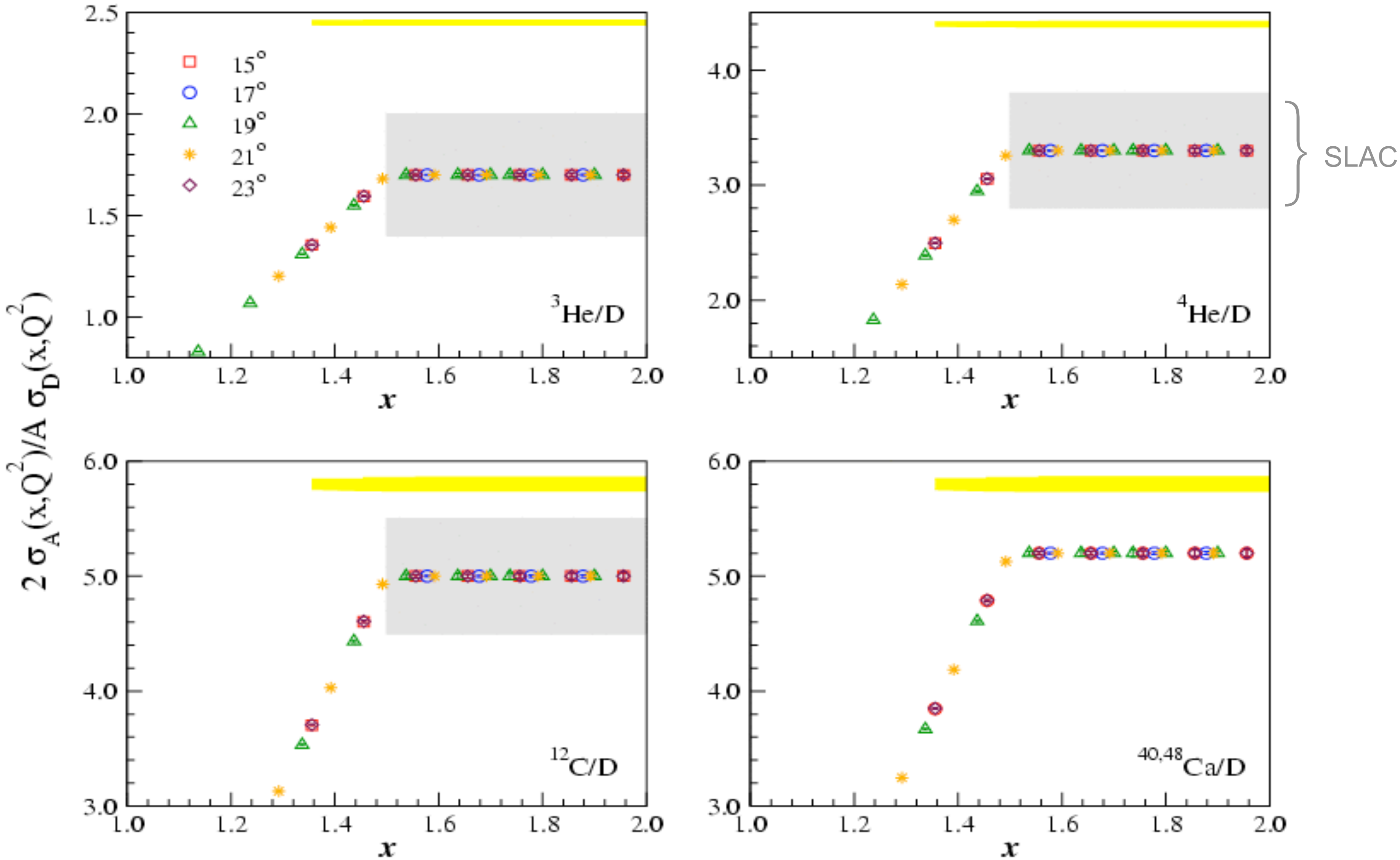


A/^{4}He ratios: map out 3N scaling region

Suppression of the c.m. motion of 3N-SRC



A/D ratios: map out scaling onset vs. x, Q^2

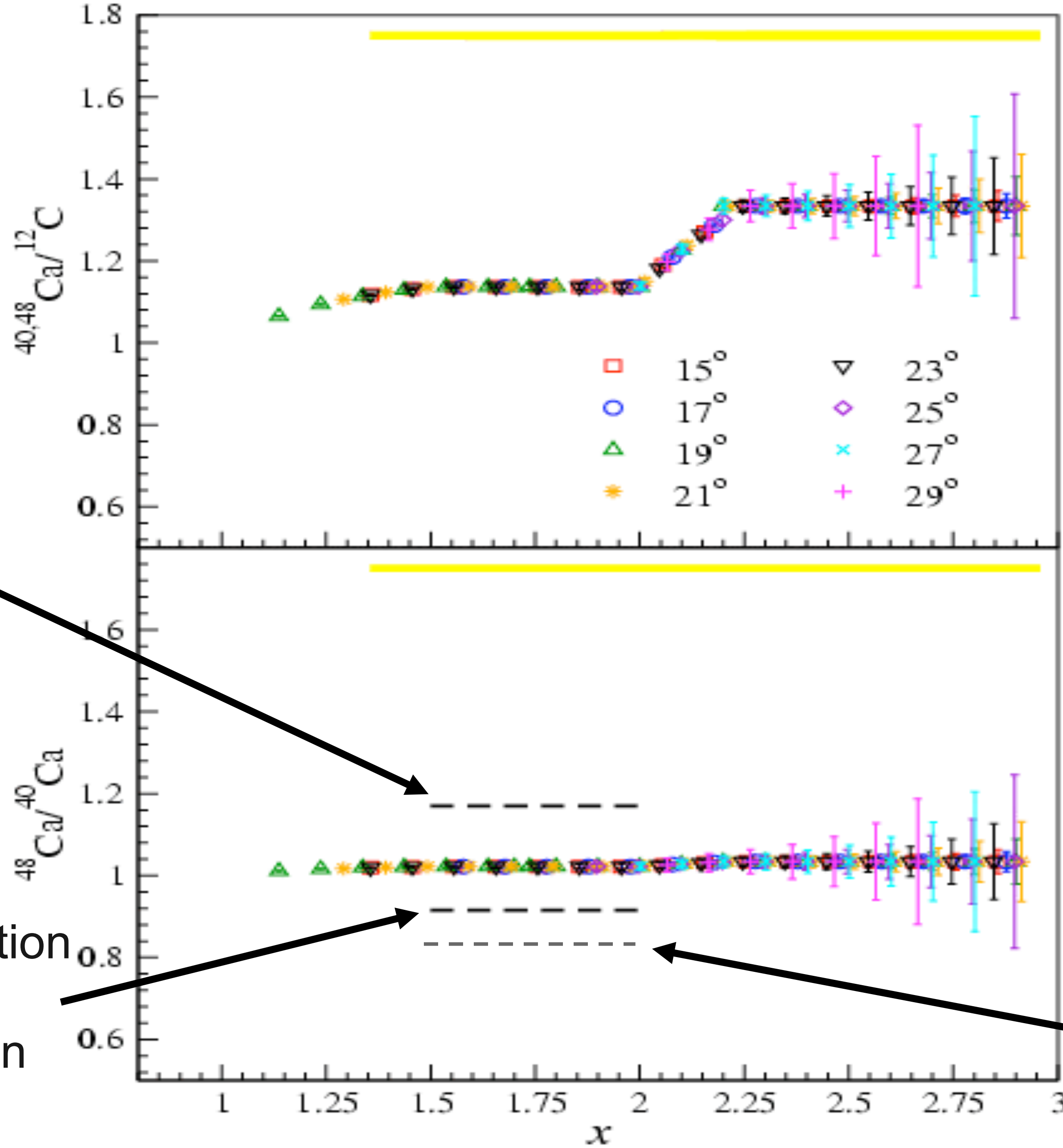


1.2-2.8% scale uncertainty not shown

→ Improved test of scaling and a_2 extraction

→ Add heavy isoscalar study

Isospin study from $^{48}Ca/^{40}Ca$ ratio



Mean field prediction for pn-dominance in 2N-SRC

Mean field prediction for isospin independence in 2N-SRC

No extra n-p pair

Isospin study from $^3He/^3H$ ratio

^{3}He/^{3}H is simple/straightforward case:

Simple mean field estimates for 2N-SRC

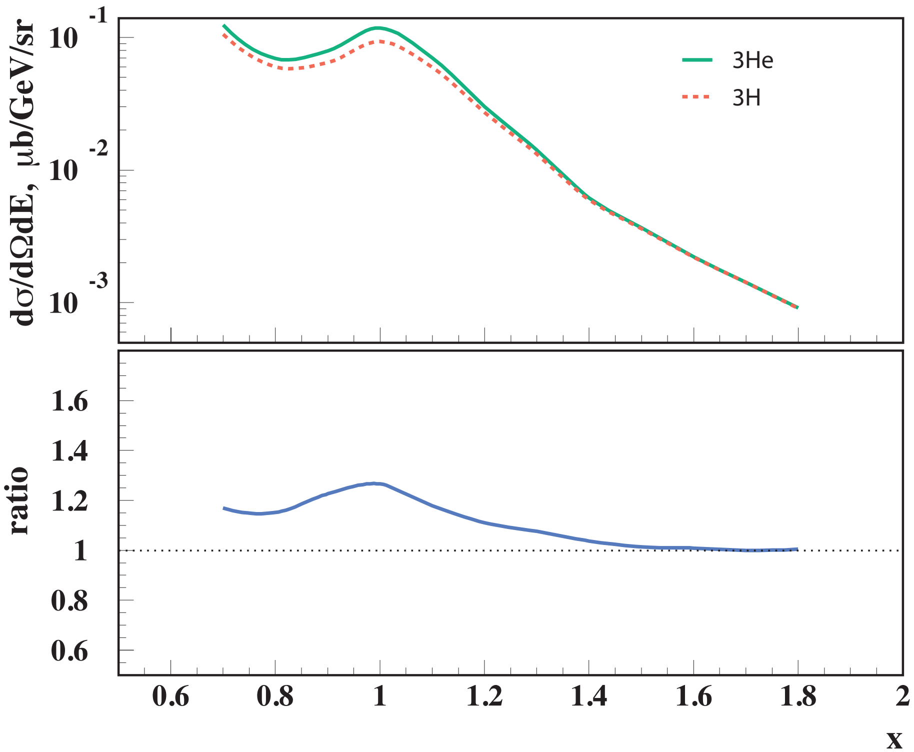
Isospin independent:

$$\frac{\sigma_{^3He}/3}{\sigma_{^3H}/3} = \frac{(2\sigma_p + 1\sigma_n)/3}{(1\sigma_p + 2\sigma_n)/3} \xrightarrow{\sigma_p \approx 3\sigma_n} 1.40$$

n-p (T=0) dominance:

$$\frac{\sigma_{^3H}/3}{\sigma_{^3He}/3} = \frac{(2pn + \cancel{1nn})/3}{(2pn + \cancel{1pp})/3} = 1.0$$

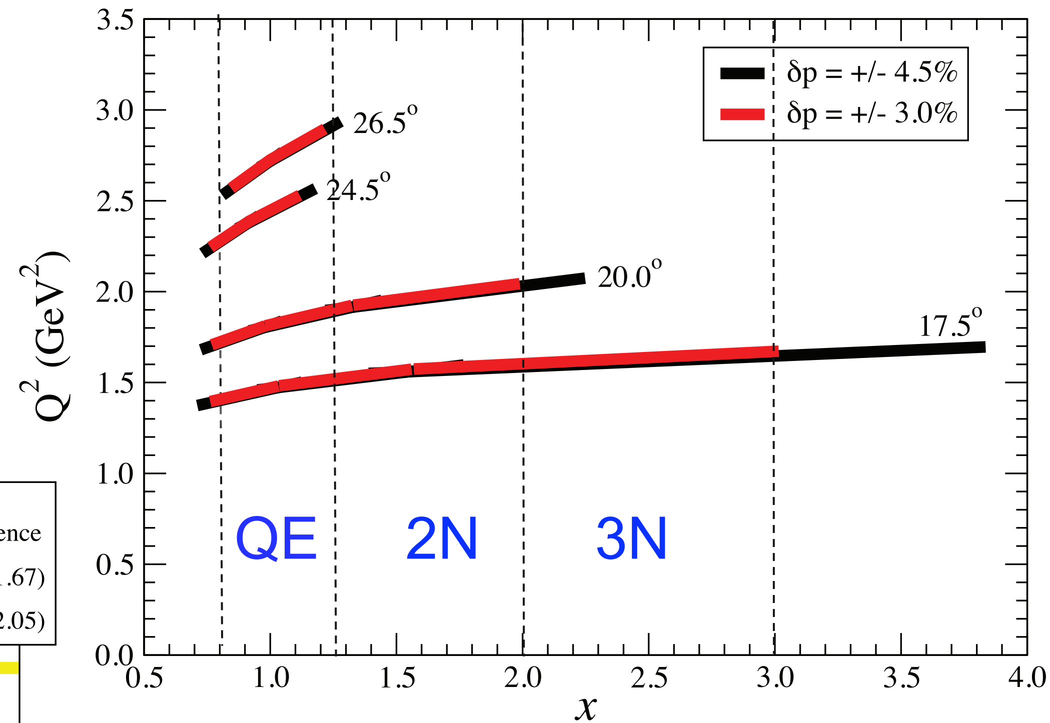
Inclusive cross section calculation from M. Sargsian using AV18/UIX

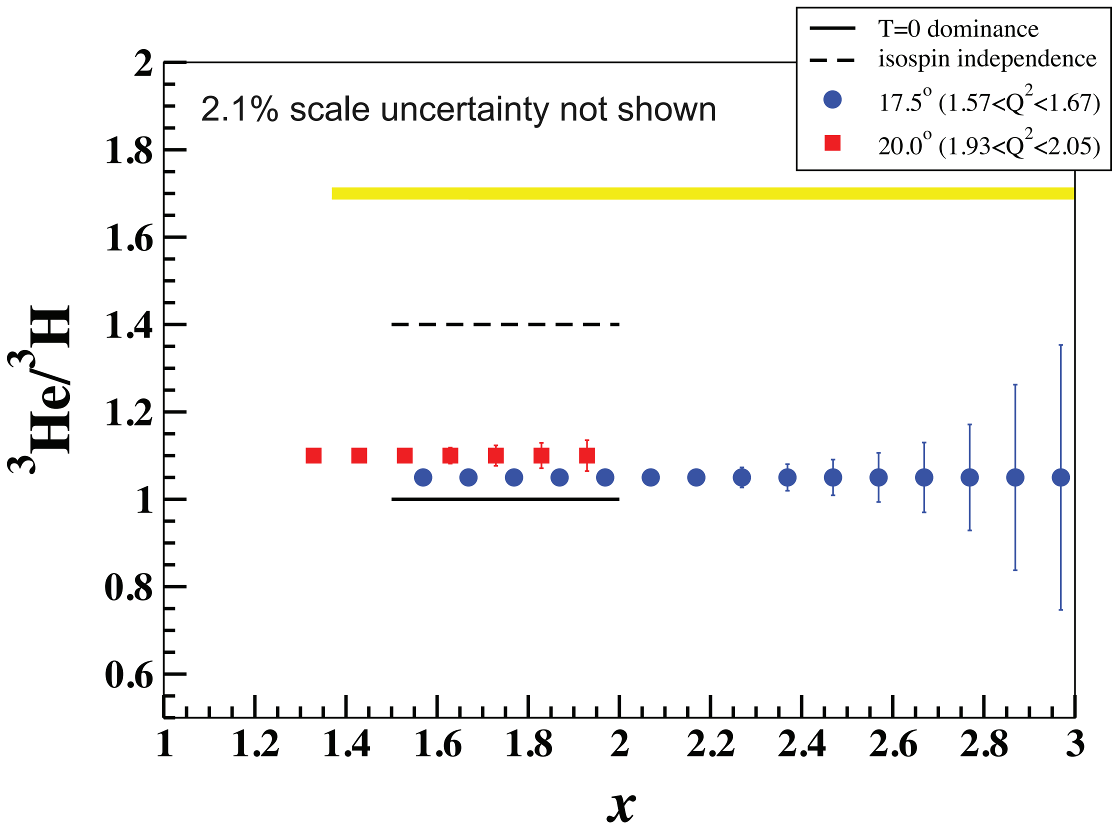


M. Sargsian, private com.

PR09-010

- ❖ Beam energy: 4.4 GeV (unpolarized)
- ❖ Max. beam current: 30 μA with raster interlock
- ❖ 4 scattering angles





- ❖ Standard Hall A configuration
- ❖ ^{3}H, ^{3}He at room temperature, then H and ^{2}H cryo-targets
- ❖ Empty stainless steel cell for window subtraction
- ❖ Carbon foils for optics
- ❖ Gas Cerenkov + Calorimeter for PID

Summary

Inclusive scattering measurements from E08-014 (and PR09-010) will produce a detailed study of:

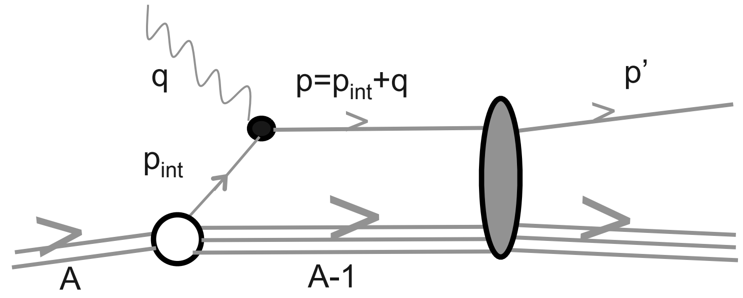
- Q^2 dependence of 2N, 3N-SRC from A/^{2}H, A/^{3}He and A/^{4}He ratios
- Study of isospin dependence of 2N-SRC
- Look at isospin dependence in 3N-SRC region

➥Nice complement to the results of 2N knock-out experiments

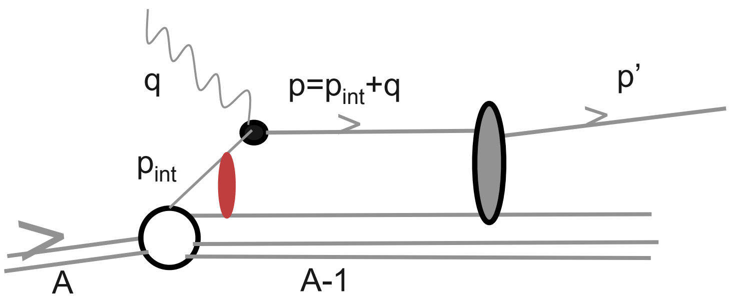
E08-014 is scheduled to run in Spring 2011

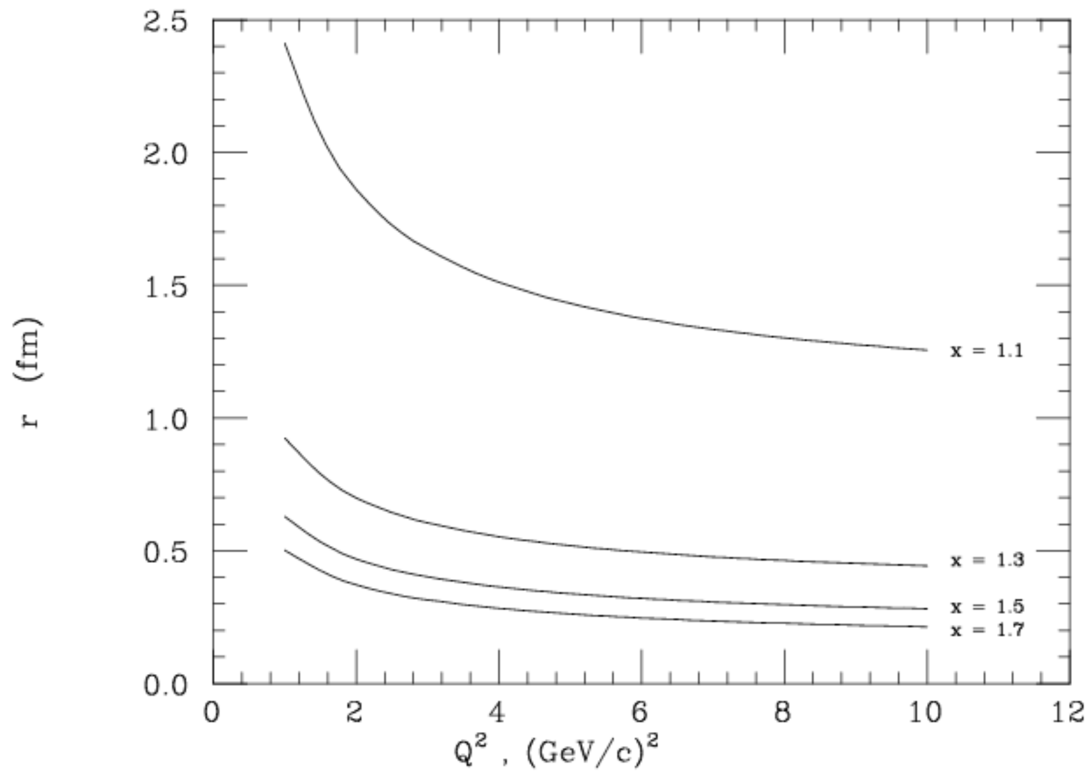
Back-ups

Final state interactions



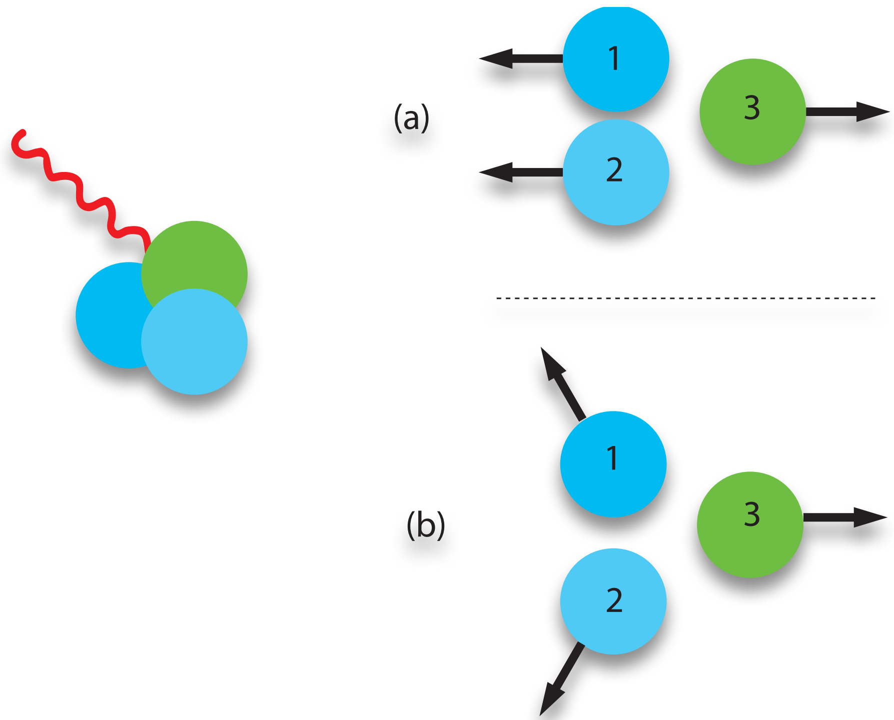
- GEA very successful in A(e,e'p)
- GEA predicts FSI:
  1. small
  2. A-independent
  3. conserve α





Inclusive data in deuterium support FSI small

3N-SRC configurations



$p_3 = p_1 + p_2$

extremely large momentum

"Star-configuration"

$p_1 = p_2 = p_3$

Inclusive measurement should be able to differentiate between these momentum ranges

E08-014 systematics

	$\delta\sigma/\sigma$	$\delta R/R$ (normalization)	$\delta R/R$ (pt-to-pt)
Acceptance correction	2.0%*	0.5-2.0%	0.0-1.0%
Radiative correction	2.0%*	-	0.3%
Tracking efficiency	1.0%*	-	0.2%
Trigger efficiency	0.5%*	-	0.1%
PID efficiency	1.5%*	-	0.2%
Target thickness	0.5-2.0%	1.1-2.0%	-
Charge measurement	0.5%	-	0.5%
Energy measurement	0.05%	-	-
COMBINED UNCERTAINTY	4.1-4.6%	1.2-2.8%	0.7-1.2%
Uncertainty on a_2, a_3		1.5-3.0%	
CLAS		6.3-8.1%	
SLAC		10-18%	

Most kinematics are systematics dominated

World data limitations

- SLAC A/D ratios: Frankfurt, Strikman, Day, Sargsian, PRC48, 2451 (1993)
  - interpolations of ^{2}H data to kinematics of other targets.
  - Limited x coverage at high Q^2

- JLab E89-008:
  - No ^{3}He, ^{4}He
  - Limited x coverage at high Q^2

- JLab CLAS A/^{3}He ratios: K. Egiyan et al, PRC68, 014313 (2003) and PRL96, 082501 (2006)
  - No deuterium data: rely on SLAC ^{3}He/^{2}H ratios
  - Limited Q^2 range
  - Limited statistics to study x and Q^2 dependence at x>2

- JLab E02-009 (preliminary): limited statistics for x>2.3 (mainly limited by ^{3}He)

Experiment flexibility

- No special detector configuration needed

- Beam energy: range between ~3.4 to 4.6 GeV
  - E < 3.6 GeV → larger angles, slight loss of rates → slight increase in time
  - E > 4.0 GeV → better rates but lose right arm running possiblity → slight increase in time

- May 08 running:
  - Run at high end of beam energy range

Why at 6 GeV

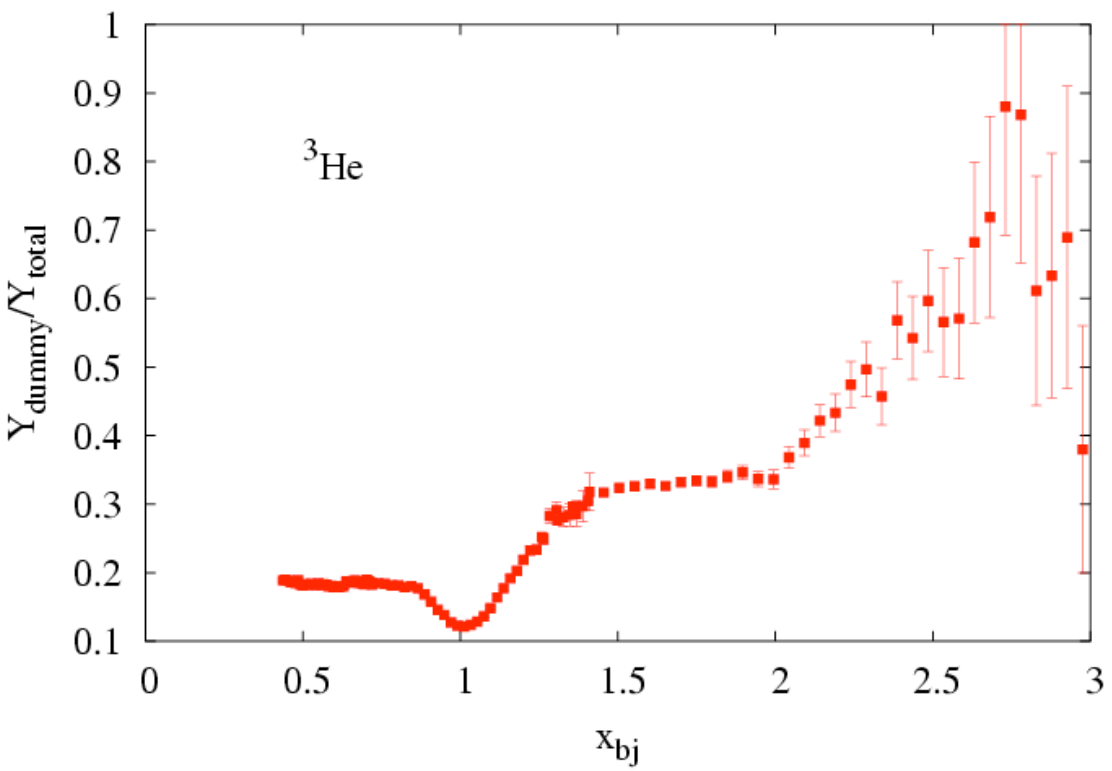
- Higher energy not needed for this physics

- Higher energy would require running in Hall C
  - Lower $\Delta\Omega$
  - Larger momentum acceptance: large background

- Desirable to have timely measurement to establish scaling region
  - Determine if CLAS ratios can be interpreted as 3N-SRC
  - Optimize 12 GeV studies
    - *Systematic target dependence studies*
    - *$^3He/^3H$ ratios: feasible with proposed targets*

Cryo-window contamination

- E01-019: study of 3N-SRC region limited due to the Al cryo-target window contamination



Advantage of PR08-104:

- Will use 20cm target
- HRS resolution: cut away most of the window contribution
- Empty can running: subtract the remaining contamination

Kinematics

	^{4}He	^{2}H	^{4}He	^{12}C	^{40}Ca	^{48}Ca	Total (per kin)
15°	2.0	2.8	1.2	0.8	0.7	0.7	8.2
17°	2.4	1.9	1.4	1.5	1.6	1.6	10.4
19° (2N)	2.4	3.8	1.3	0.9	1.2	1.2	10.8
19° (3N)	3.0	2.4	0.9	0.9	2.0	2.0	11.2
21° (2N)	3.0	2.4	1.1	1.2	2.9	3.1	13.7
21° (3N)	6.0	-	1.8	1.8	3.9	4.1	17.6
23° (2N)	6.0	4.8	2.1	2.3	5.8	6.2	27.2
23° (3N)	12.0	-	3.5	3.7	7.9	8.2	35.3
25°	24.0	-	7.1	7.3	15.7	16.4	70.5
27°	42.0	-	12.4	12.8	27.6	28.6	123.4
29° *	21.0*	-	6.2*	6.4*	13.8*	14.3*	61.7
Total (per tgt)	72.8	10.9	23.4	23.3	46.8	48.5	225.7 (226.0)

9.4 days (data taking) + 2.6 days (calibration + overhead) = 12 days of beam time