Study of Short Range Correlations (SRCs) at JLab

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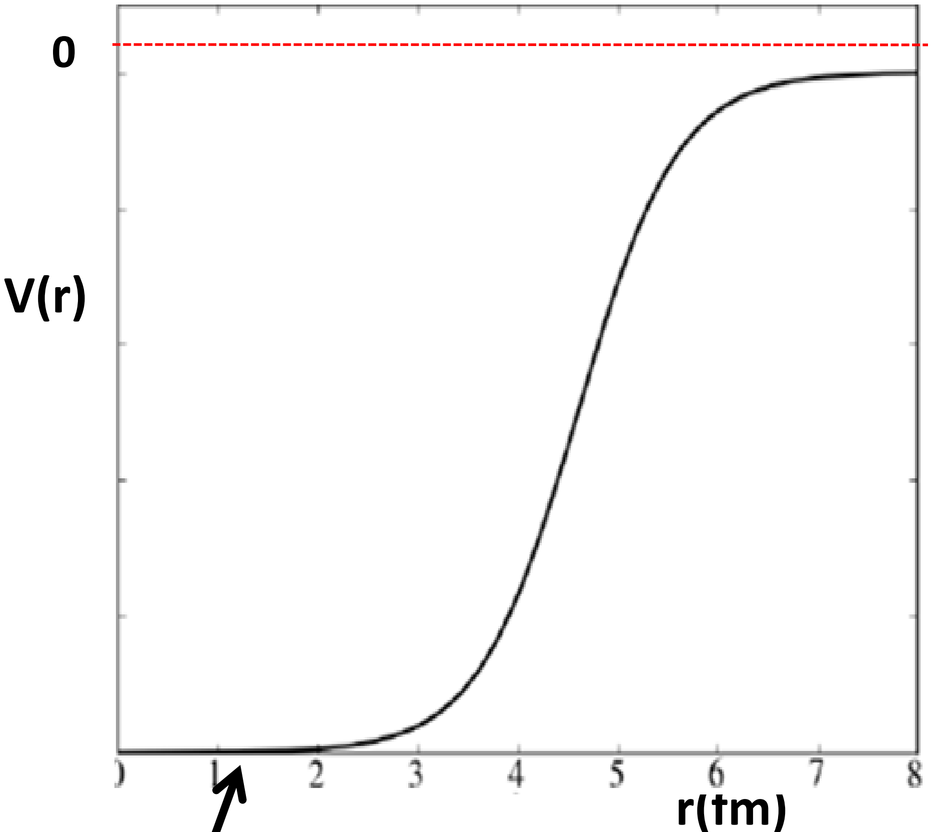
HUGS summer school 2015

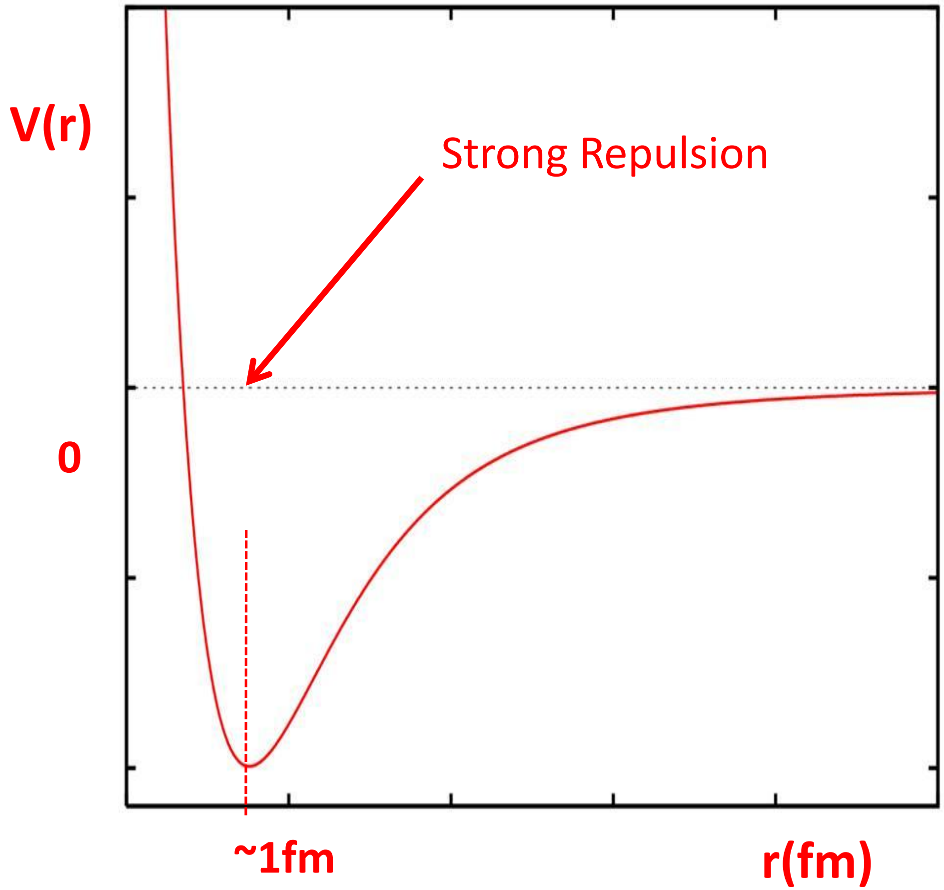
How Nucleons behave at short distance?

Woods-Saxon nuclear potential



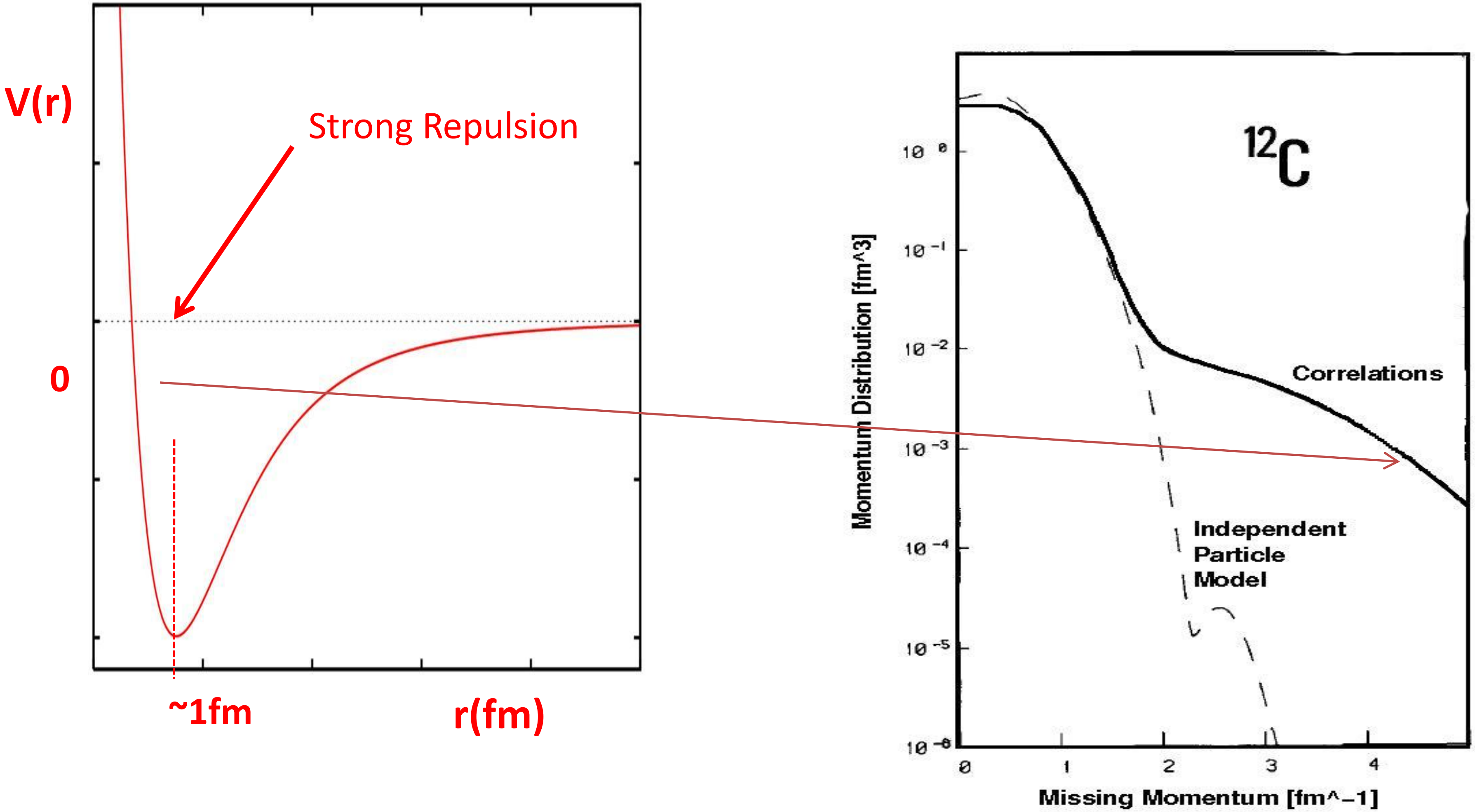
Nucleons don't interact with each other at short distance (Free)

Realistic two nucleon potential



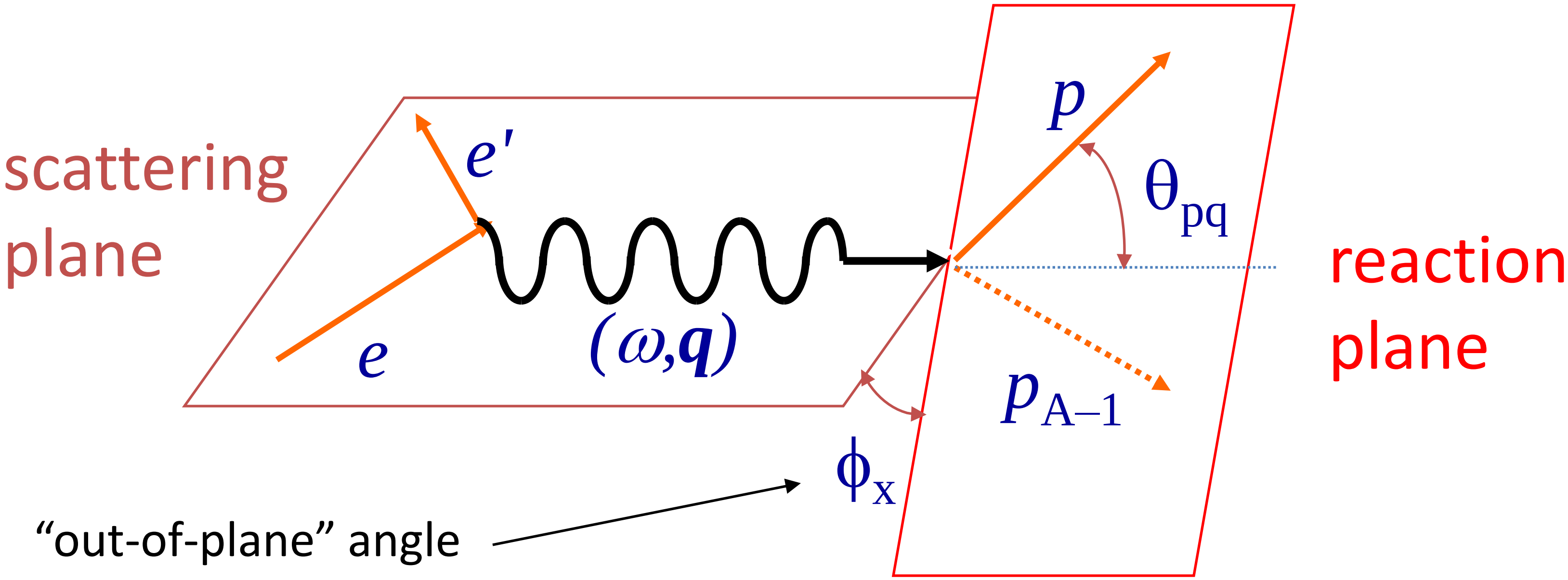
Need to understand about nuclear structure at short distance

Realistic potential & momentum distribution



Short range N-N interaction is responsible for high momentum tail of the momentum distribution in nuclei (significant contribution with k>kf)

Electron Scattering Kinematics



Energy transfer: $\omega = e - e'$

Four-momentum transfer: $Q^2 \equiv -q_\mu q^\mu = \mathbf{q}^2 - \omega^2$

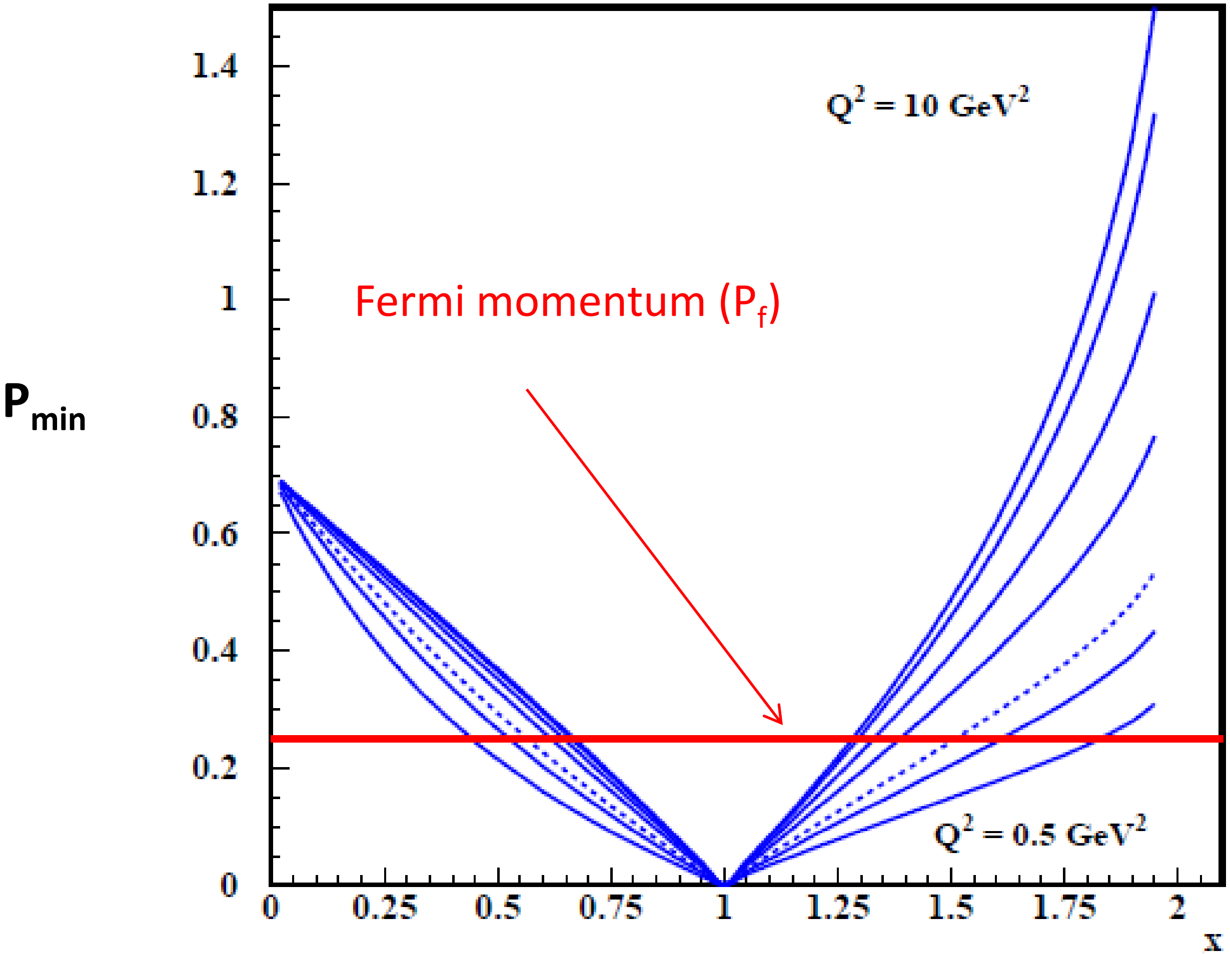
Missing momentum: $\mathbf{p}_m = \mathbf{q} - \mathbf{p} = \mathbf{p}_{A-1}$

Bjorkenx: $x_B = Q^2/2m\omega$ ***(just kinematics!)***

Quasi_elastic: expect peak at $X_B = 1$ and Broadened by Fermi motion of nucleon

Study 2N SRCs regime

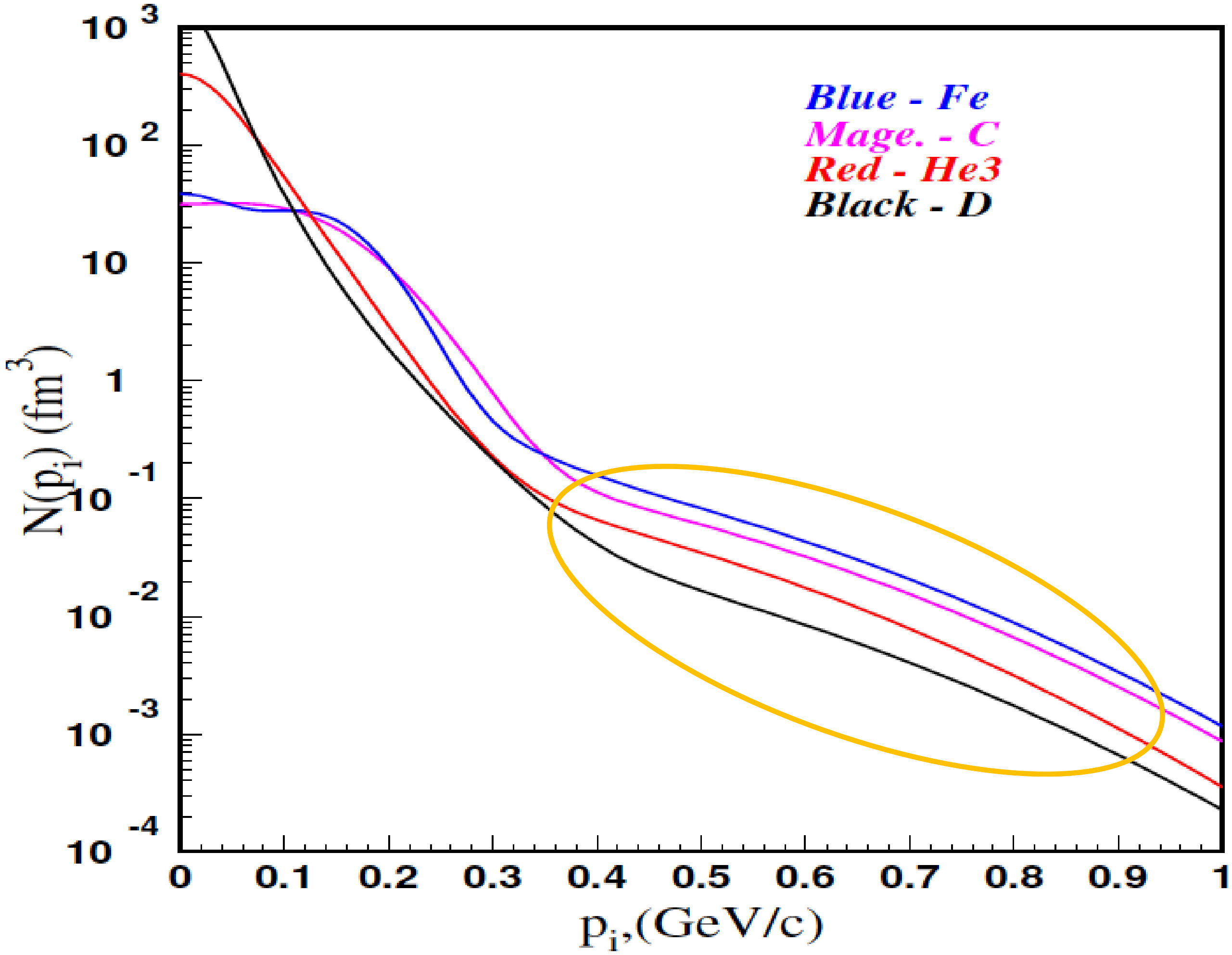
Minimum initial struck nucleon momentum



We need to go to high x and Q^2 where $P_{min} > P_f$ where SRCs are dominant. In addition, inelastic processes are repressed insuring clean quasi-elastic scattering from a nucleon in a pair.

Momentum Distributions

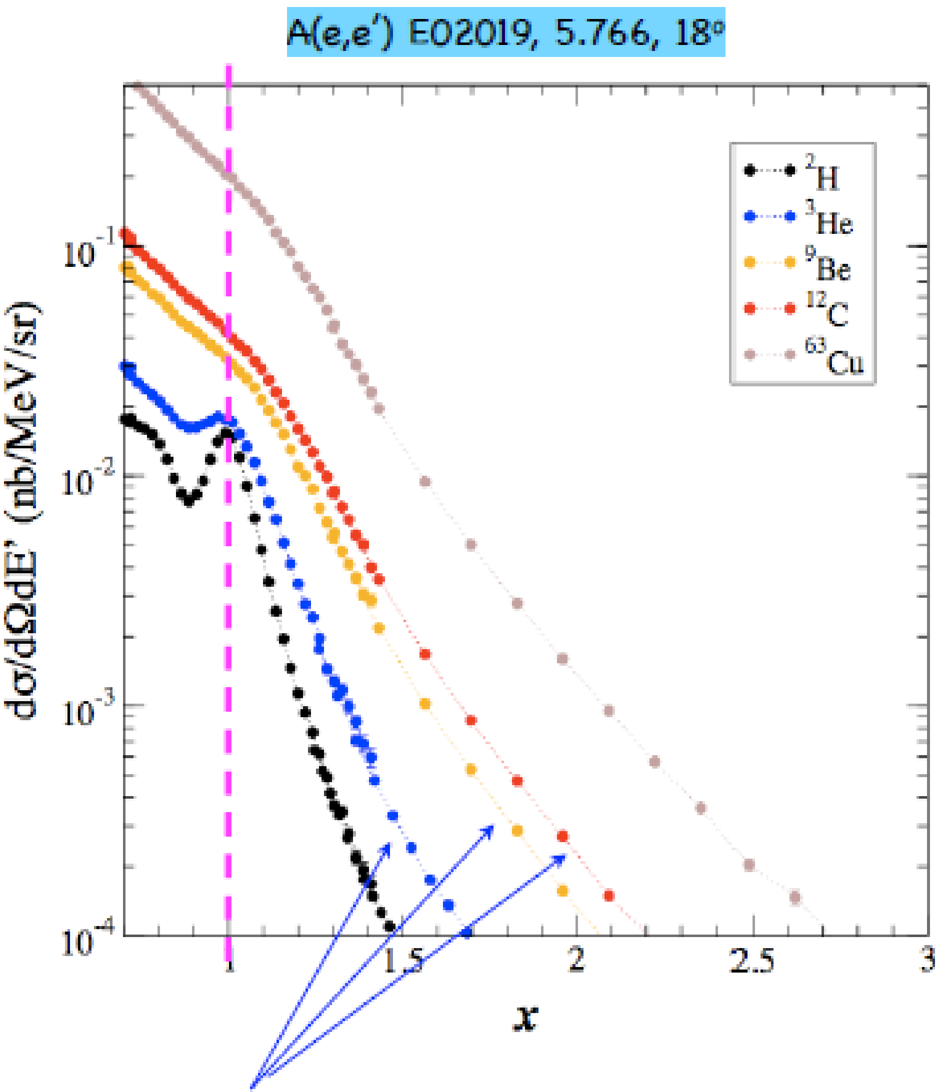
C. Ciofi degli Atti and S. Simula, Phys. Rev. C **53** (1996) 1689.

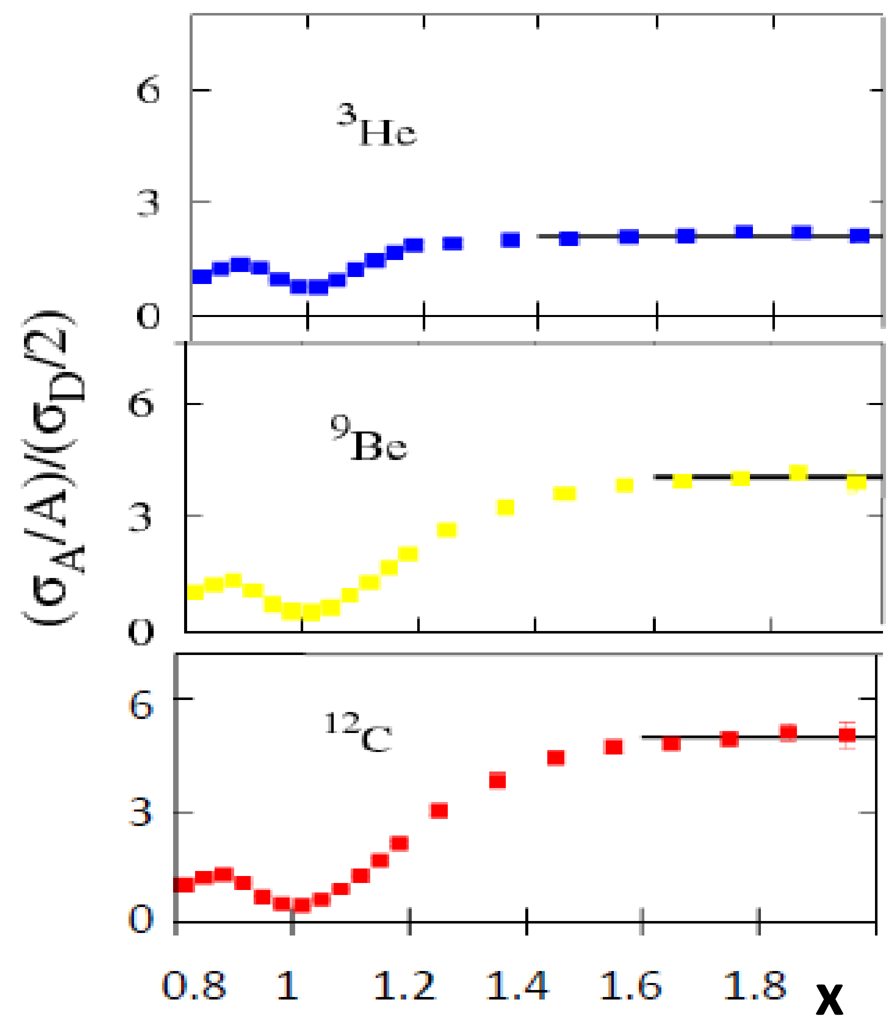


At high *initial* momentums $\mathbf{n_A(p) = N(A) * n_D(p)}$

2N SRCs Evidence: Cross section ratios

N.Fomin, Phys.Rev. Lett. 108 (2012)



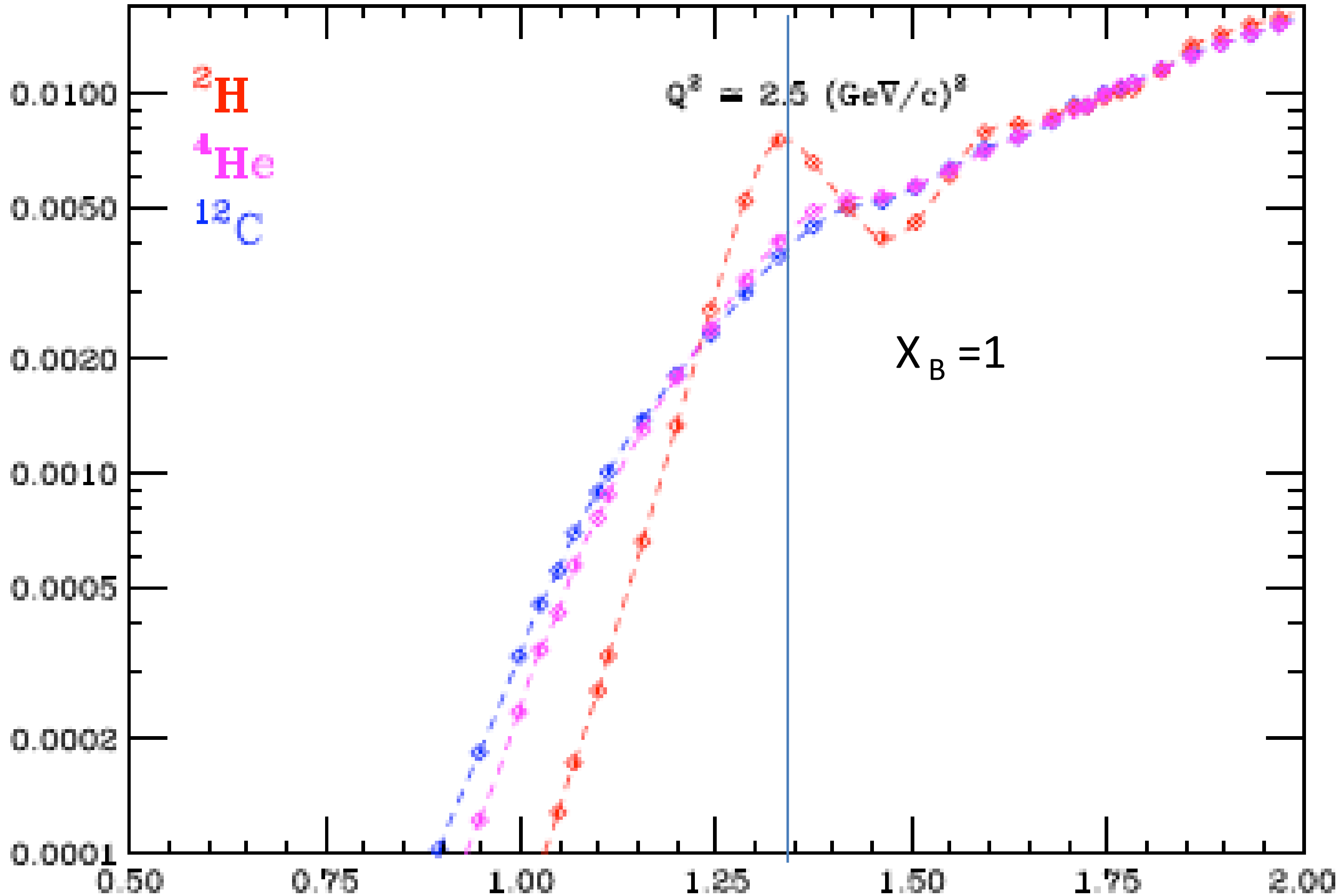


High momentum tails yield constant ratio if SRC exist

Evidence of 2N-SRCs at x>1.5

Cross section per Nucleon

Cross section
Per Nucleon



$\omega = Q^2/2X_B$

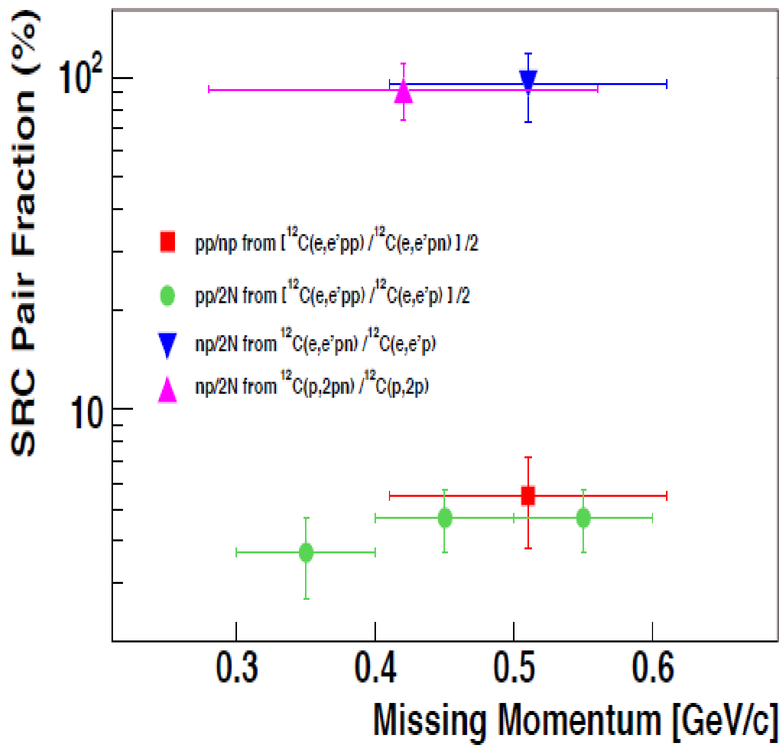
X B

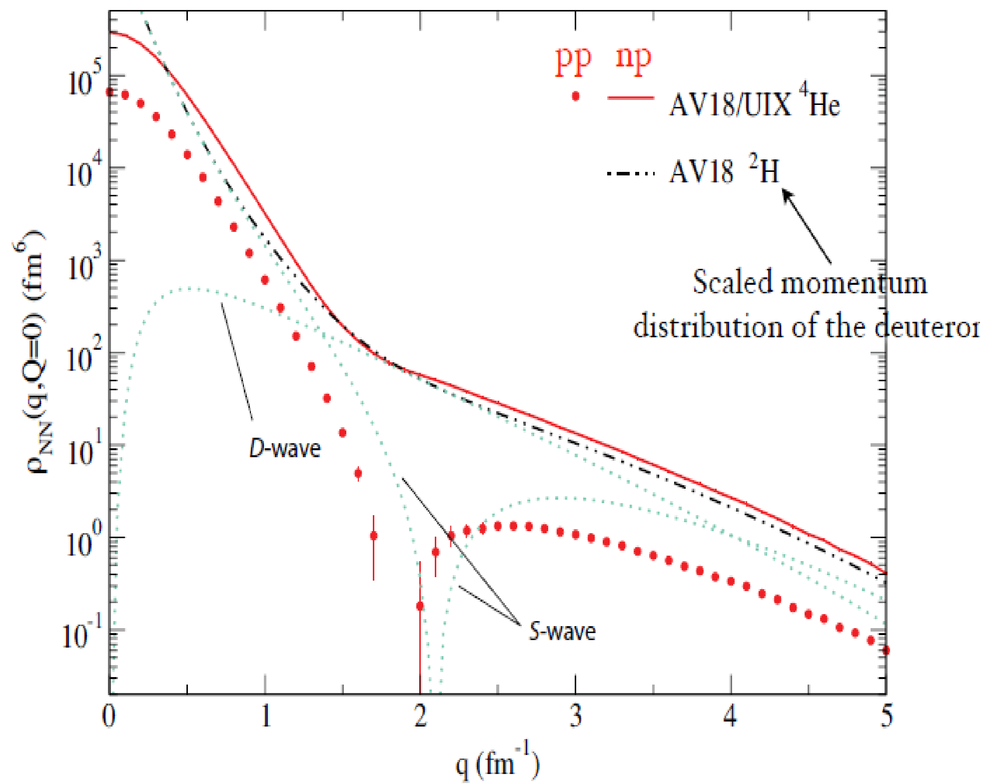
Isospin dependence SRCs

Simple SRCs model assumes isospin independence

Experiment E01-015 (e.e'Np)
R. Subedi et al, Sc 320, 1476(2008)

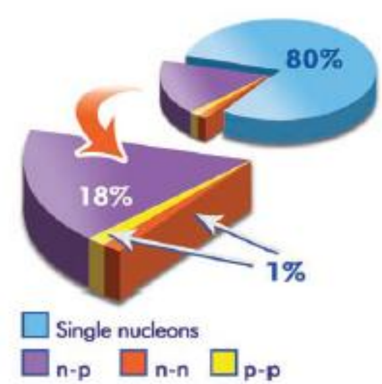
Phy. Rev Letters. PRL 98,13501 (2007)





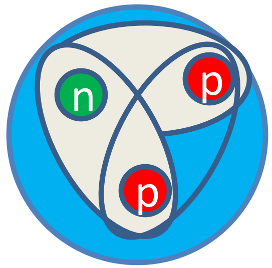
SRCs measurement: approximately 20% contribute.
Where 90+-10% from p-n SRC pairs, 5+-1.5% from p-p n-n pairs.

Solid evidence of Isospin dependence of SRCs



SRCs Isospin study from ^{3}He/^{3}H

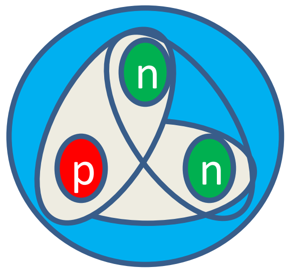
^3He



Mirror

$P > P_f$

^3H



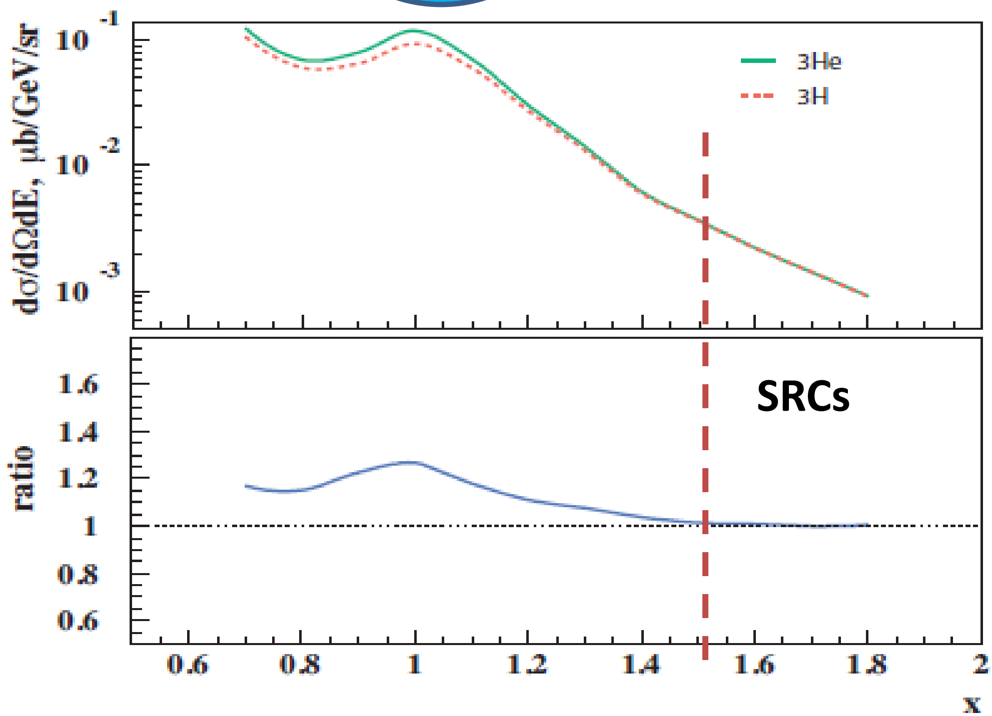
•n-p (T=0) dominance

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

•Isospin-independent

$$\frac{\sigma_{^3He}}{\sigma_{^3H}} = \frac{(2\sigma_p + 1\sigma_n)}{(1\sigma_p + 2\sigma_n)} \xrightarrow{\sigma_p = 3\sigma_n} 1.4$$

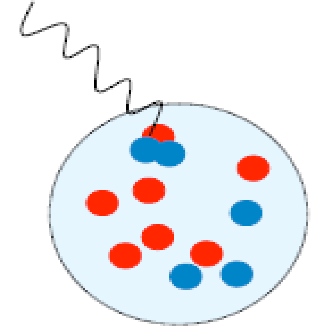
40% different



References:

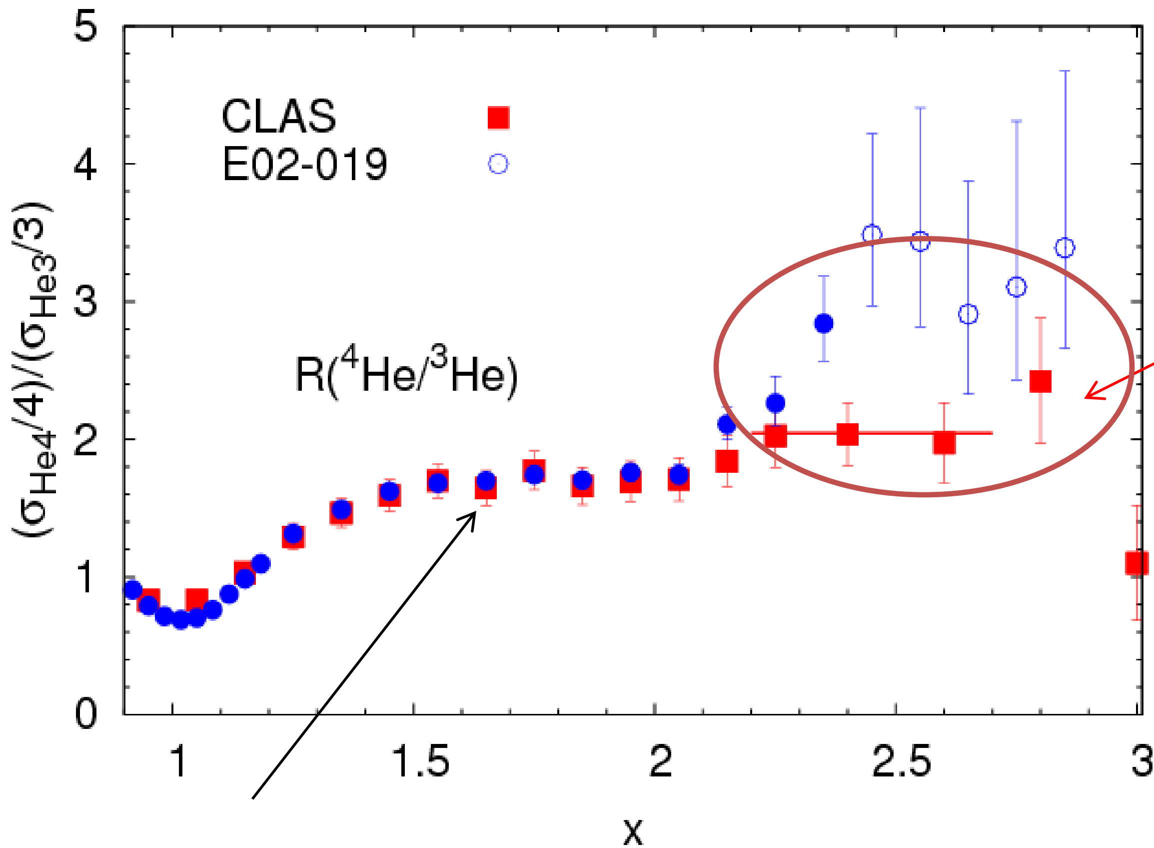
-Exclusive electrodisintegration of ^{3}He at high Q^2. Decay function formalism. Phys. Rev. C 71, 044615.
(M.M Sargsian, T. V. Abrahamyan, M. I Strikman and L. L. Frankfurt)

How about 3N- SRCs ?



3N SRCs: 2<x<3

CLAS: Q2~1.6 GeV2, E02-019: Q2 ~ 2.9GeV2



Disagreement in 3N-SRC region

New data (x>2) from Jlab experiment E08014 is coming

Good agreement in 2N SRC region

CLAS: Hall B, Jefferson lab, K. S Egiyan et al. (CLAS), Phys. Rev. Lett. 96, 082501 (2006).
E02-019: Hall C, Jefferson lab, PRL 108, 092502 (2012)

Conclusion:

- We got several important results about short range correlation also isospin dependence.
- Need more precise experiment to study about isospin dependence.

-Need to study more about 3N short range correlations to understand how nucleons behave in this region.

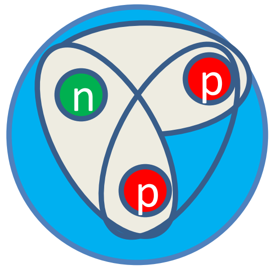
We are getting ready
for tritium experiment in Spring 2017.

Thank you very much for your attention

Back up

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

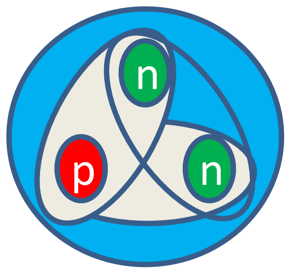
^3He



Mirror

P> P_f

^3H



- **n-p (T=0) dominance**

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

- **Isospin-independent**

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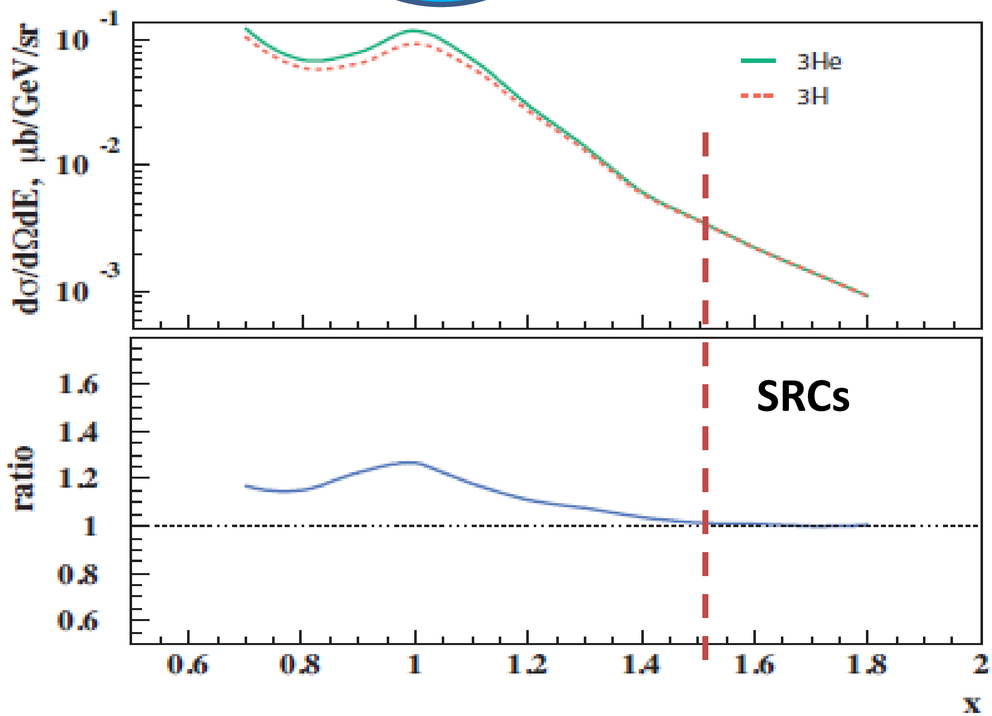
40% different



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E12-11-112: kinematics

Beam current : 20 muA, unpolarized.

Beam Energy : 2.2 GeV and 4.4 GeV

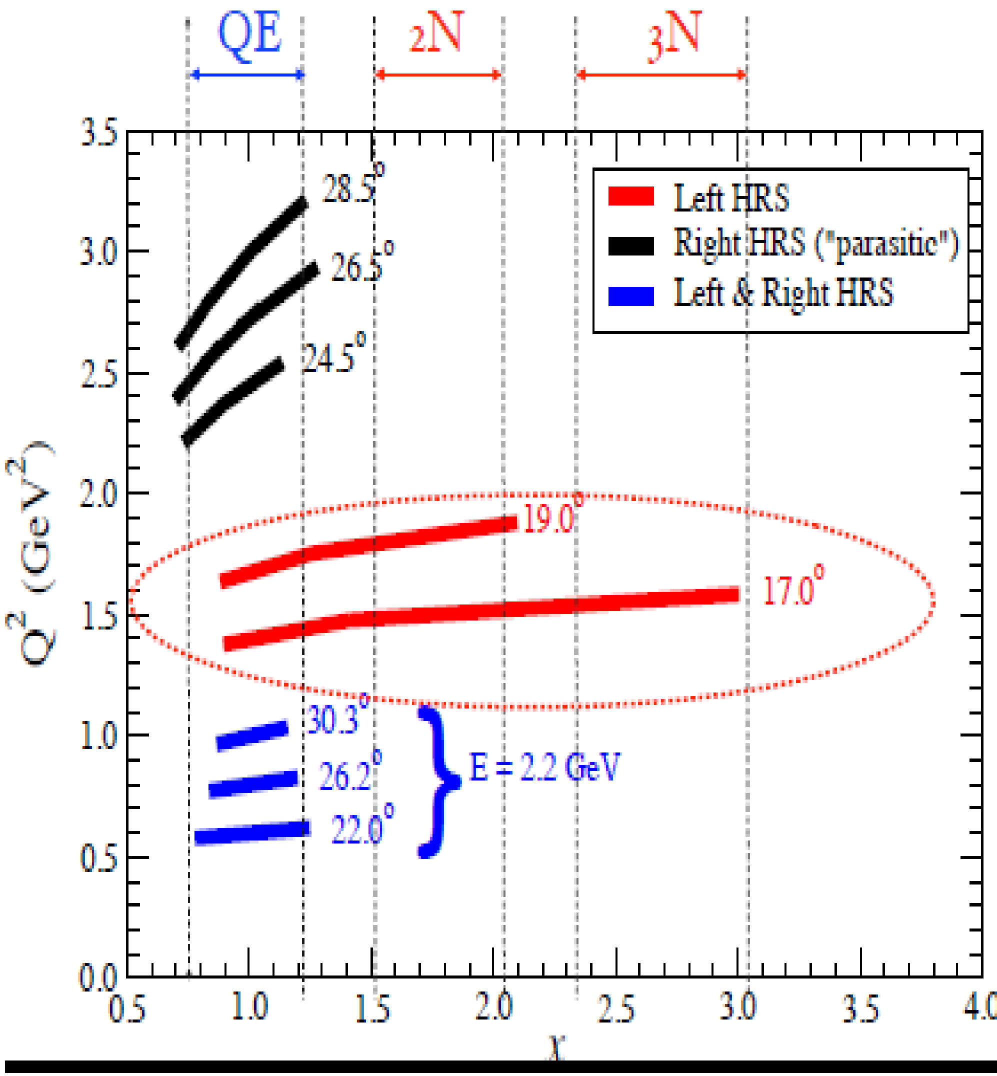
Scattering angle: 17 and 19 degree

Beam time :
17.5 days 4.4 GeV (main production)
1.5 days 2.2 GeV (checkout + QE)

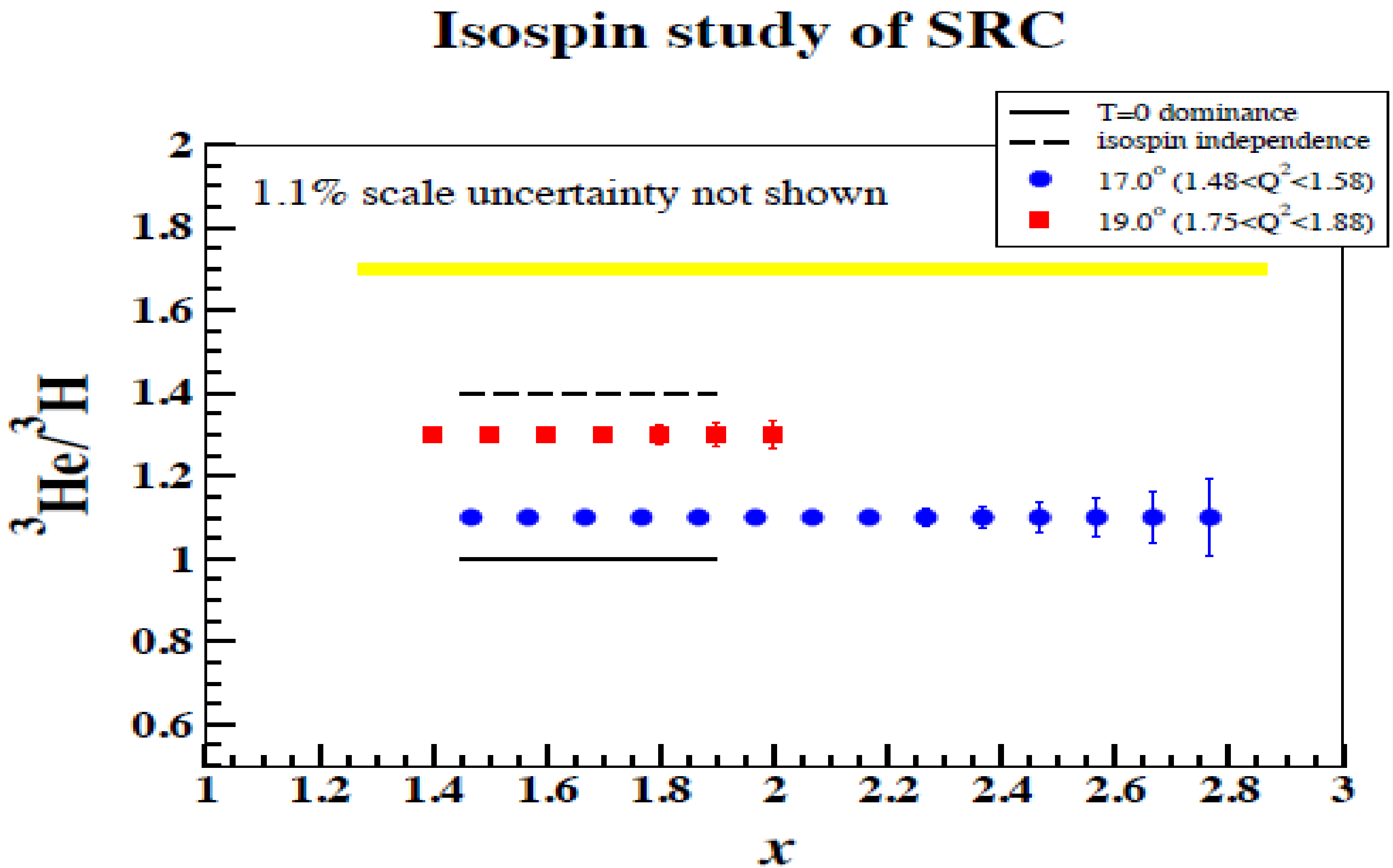
Right HRS running ("parasitic")

Left HRS running (380 hours)

Left+Right HRS running (about 1 day)



E12-11-112: Projected results



At x>2 3He/3H # 1.4 implies isospin dependence AND non-symmetric momentum sharing

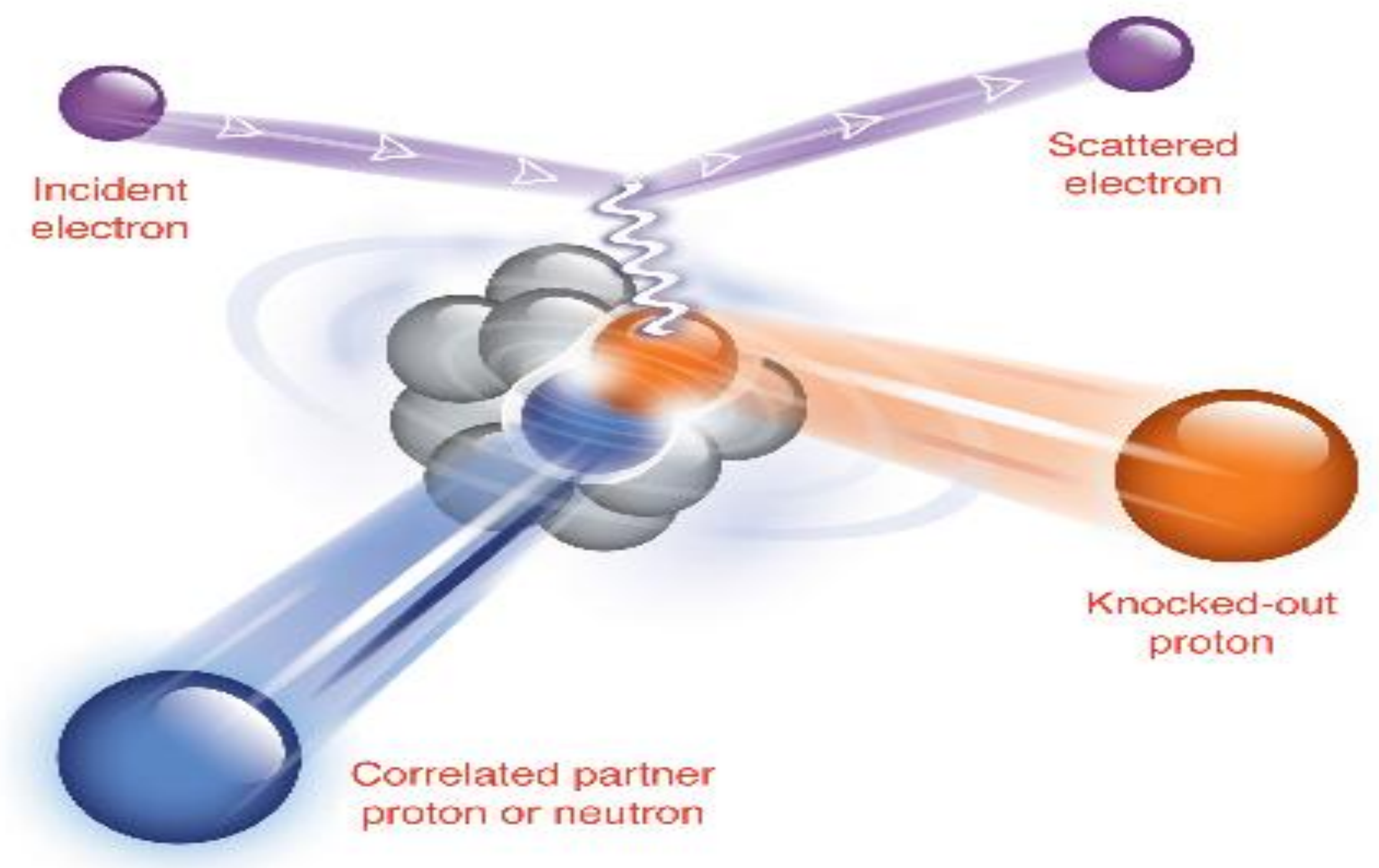
Expected uncertainty in 2N-SRCs region approximately 2%

It is unique experiment and have very strong advantage to see isospin dependence. (40% difference)

Isospin dependence 2N-SRCs

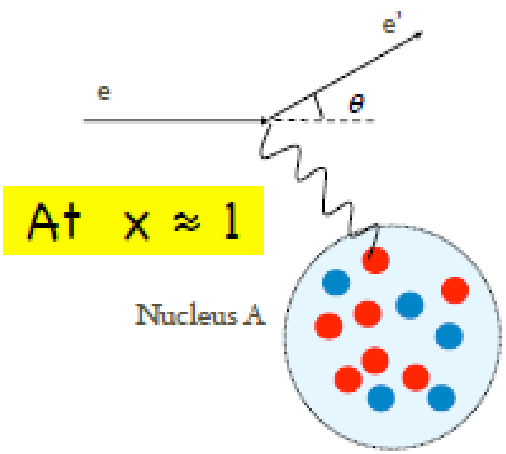
•**SRCs model**: the nucleon correlation are assumed to be isospin independence

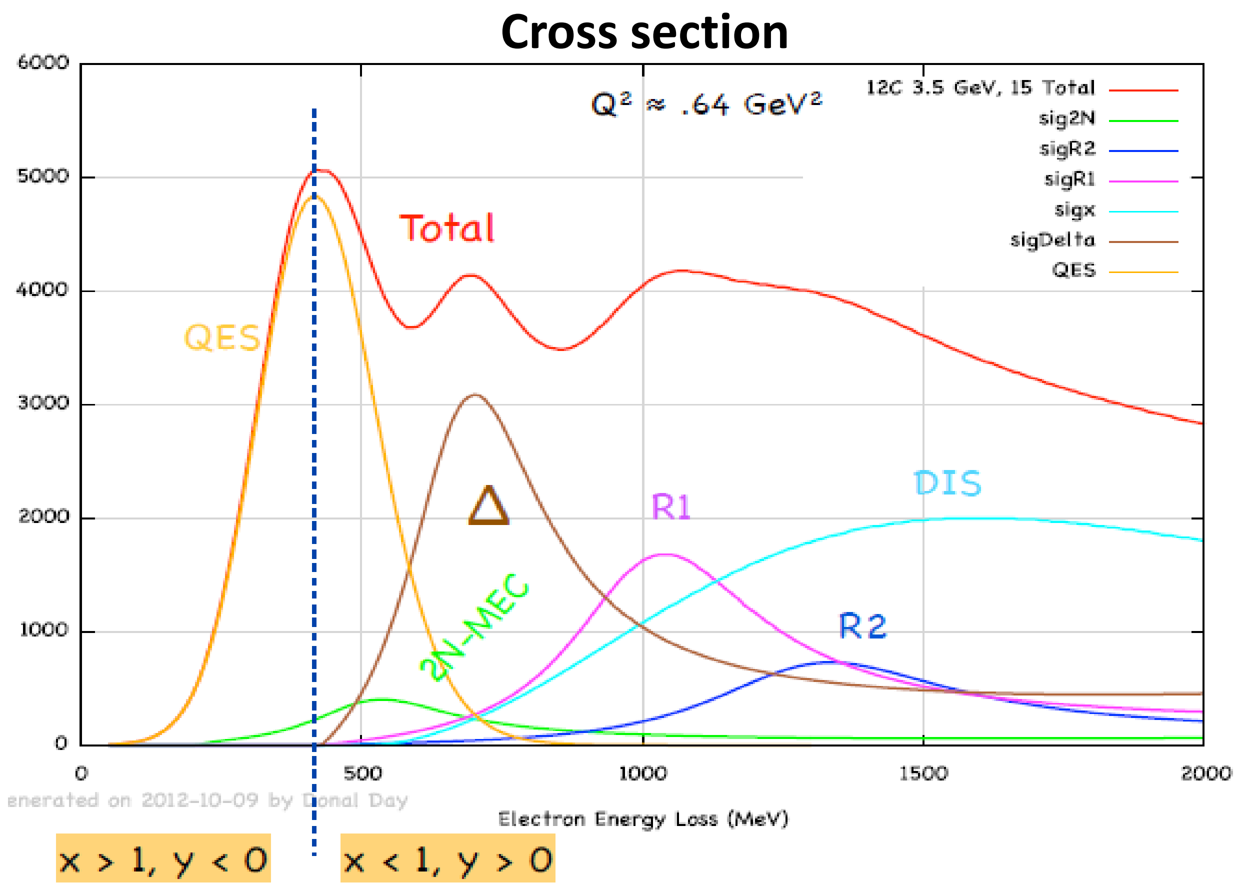
Coincidence (e,e'pN) Measurement



x> 1 , Q^2 = 1.5 $[GeV/c]^2$ and missing momentum of 500 MeV/c

Inclusive scattering at large x





Nucleon's Fermi motion broadens QE peak

The strength of the single particle reaction extends to x~1.3

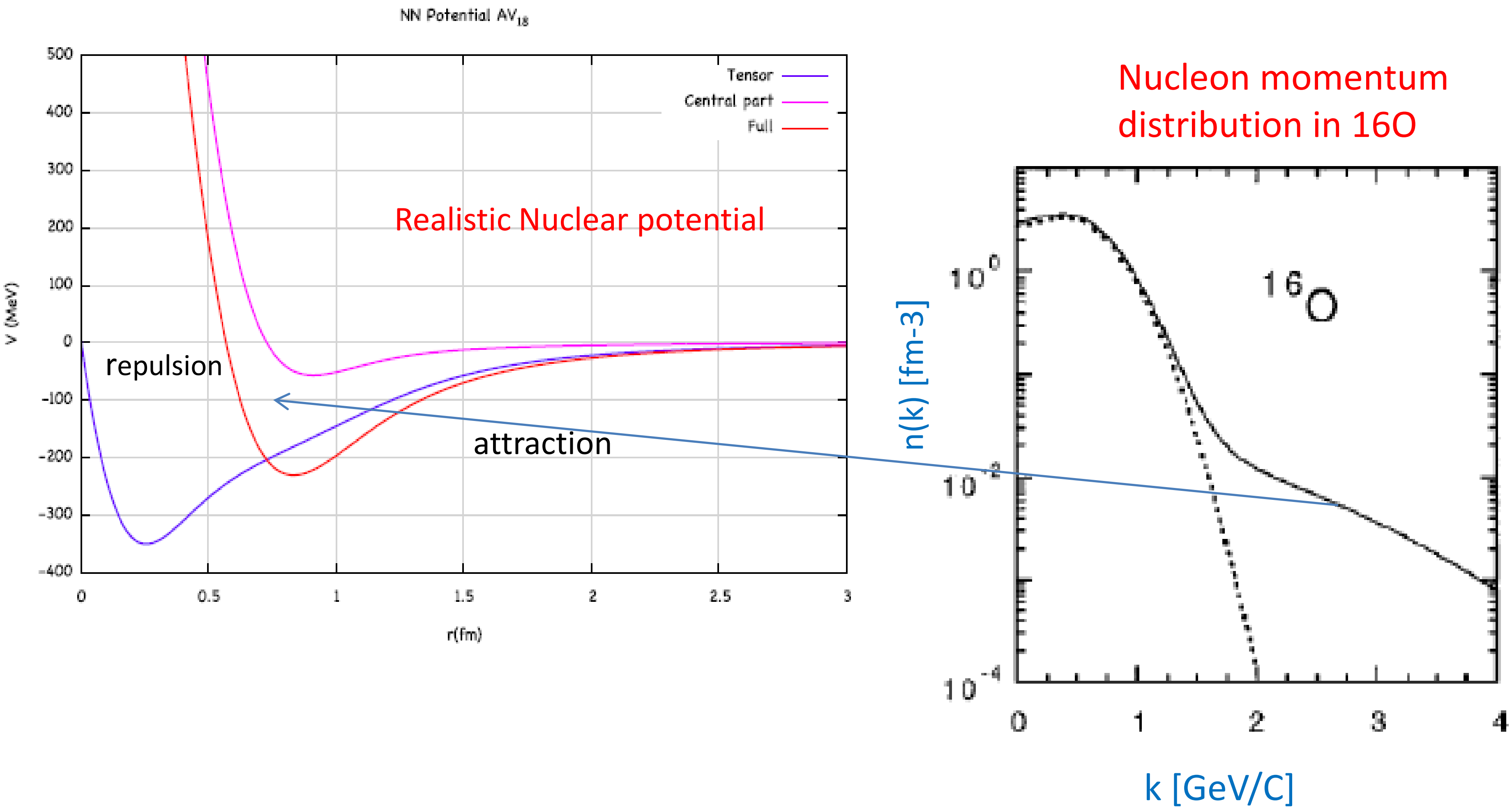
E12-11-112

Precision measurement of Isospin dependence in the 2N and 3N short range correlation region

Main physics goals

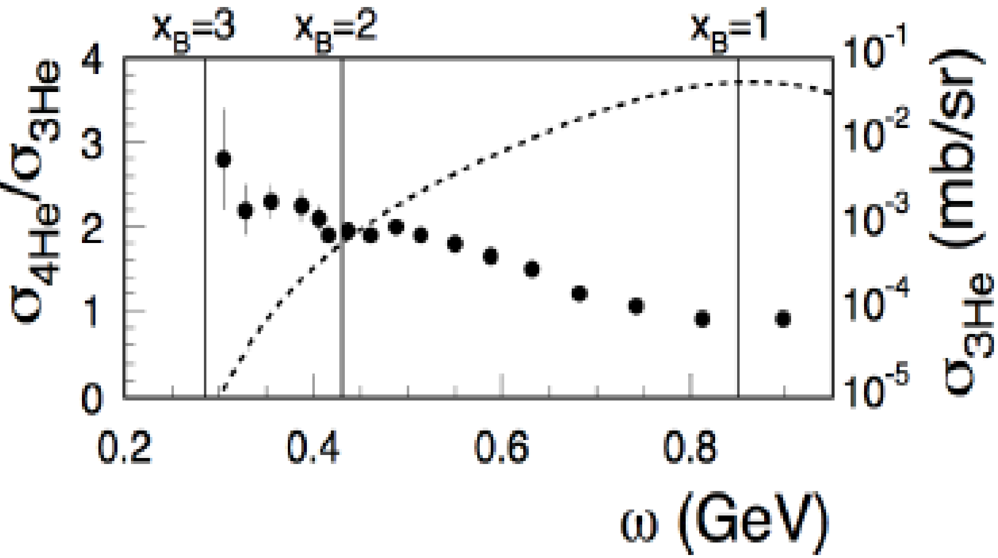
- Isospin-dependence of 2N_SRCs.
- 3N –structure (Momentum-sharing and Isospin).
- Cross section and ratio for the test of few-body calculation and final-state interactions.

Nuclear potential, n(k)



Short range N-N interaction is responsible for high momentum tail of the momentum distribution in nuclei (significant contribution with k>kf)

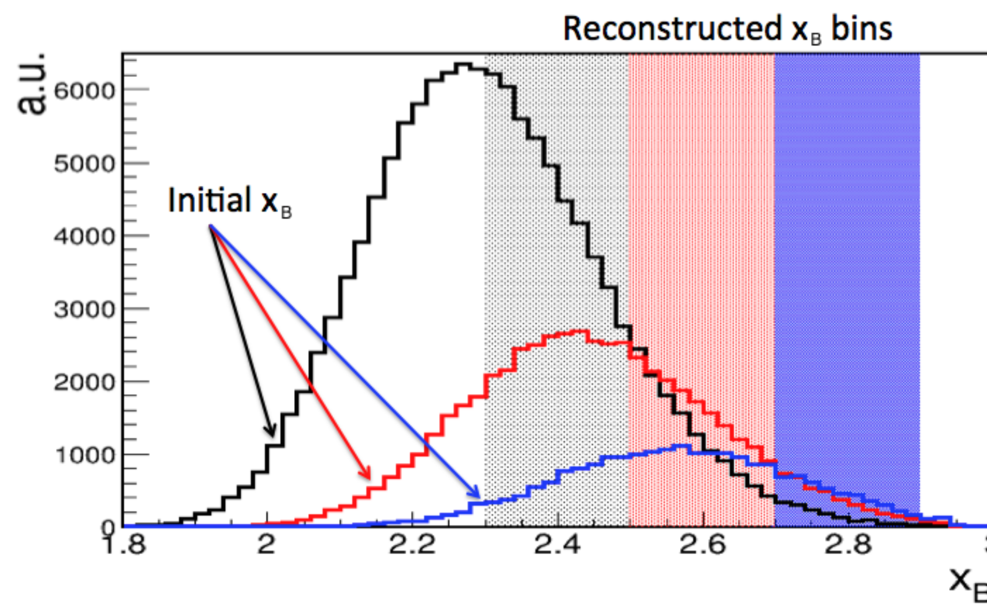
Binning correction in hall B Data



Clas : q ~1.6 GeV2
E02-019: Q2~2.9GeV2

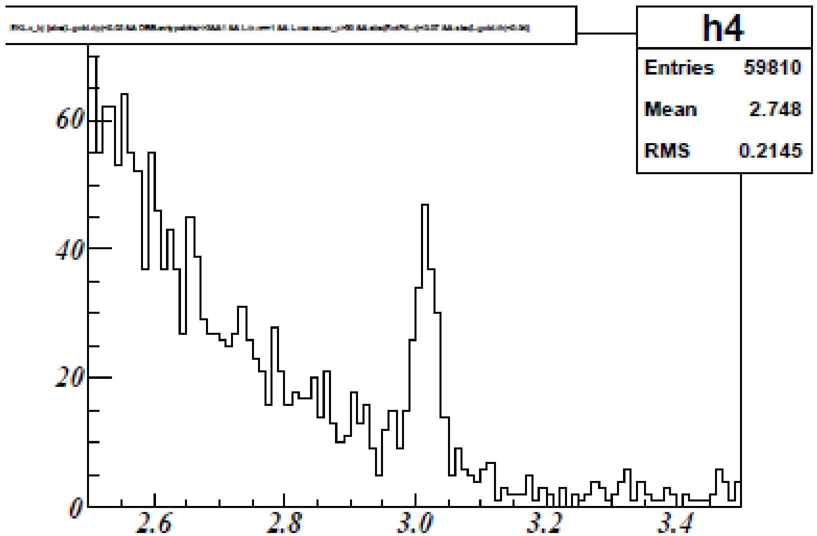
Reference : ArXiv: 1409.3069v1
10 Sep 2014

(Douglas's paper)



Calculation the absolute thickness of Target for Triton experiment

Question: How can we check the target thickness g/cm2?



Maybe the answer is elastic scattering?

E0=3.356 GeV and Theta= 21, ~1 hour run time

$$yield = \frac{d\sigma}{d\Omega} * L * \Delta\Omega$$

E0= 2.2 GeV, Theta= 12.5 degree

Run time ~ 1 Hour 3He Yield ~ 1e7 events Statistic ~

3H Yield ~ 1e5 events Statistic ~ 0.3%

How about 15 degree ?

1 hour 3He yield ~5e5 events Statistic ~ 0.14%

3H yield ~5e4 events Statistic ~ 0.45%

Yield from theoretical calculation

Beam enery : 3.356 GeV, theta=21 degree
Runtime= 0.786 hour
Target He3: ideal density 0.029g/cm3, length=20cm
Total charge: 0.283 C.

$$N_e = 1.766e18(electrons)$$

$$N_n = 1.2e23(nucleons)$$

$$L = N_e * N_n$$

$$XS = 1.36e-6\mu b$$

$$\theta_{tg} = \pm 30mrad$$

$$\varphi_{tg} = \pm 20mrad$$

$$\Delta\Omega = 2.4msr$$

$$yield = \frac{d\sigma}{d\Omega} * L * \Delta\Omega$$

Yield = 692 events

About 3 times different from real data with the same condition.

Simulation: MCEEP

Setup simulation like theoretical calculation: with target is thin foil with the same thickness (g/cm2)

$$yield_{mc} = 694 events$$

? Question for experiment will be how can we check the target thickness g/cm2

Target 3He, current= 25 muA
Rho=0.029g/cm3, length=30 cm
=>thickness ~0.9g/cm2
Lu= 22.5 muA.g/cm2

Target 3H, current=25muA
Rho=2.5mg/cm3, length=30cm
=>thickness~0.075g/cm2
Lu=0.075*25=1.875 muA.g/cm2

E0=2.2 GeV, theta=12.5, Rate=0.8699e4
E0=2.2GeV, theta=21, Rate=5.409

E0=2.2 GeV, theta=12.5, Rate=0.5338e3
E0=2.2 Gev, theta=21, Rate =0.4508

Assume runtime = 1hour

3He theta=12.5 Yield(ideal)=3.131e7 events => experimental Yield ~1e7 events
3He theta=21 Yield(ideal)=1.94e4 events => experimental Yield~ 6500 events
3H theta=12.5 Yield(ideal)= 1.9e6 events => experimental Yield ~ 6e5 events
3H theta=21 Yield(ideal)=1623 events => experimental Yield ~ 541 events

Uncertainty for Tritium experiment

Systematic	$\delta\sigma/\sigma$	$\delta R/R$ (normalization)	$\delta R/R$ (pt-to-pt)
Acceptance correction	2.0%*	0.5%	1.0%
Radiative correction	3.0%*	0.4%	0.3%
Tracking efficiency	1.0%*	-	0.2%
Trigger efficiency	0.5%*	-	0.1%
PID efficiency	1.5%*	-	0.2%
Target thickness	2.0%	2.0%	-
Charge measurement	0.5%	-	0.5%
Energy measurement	0.05%	-	-
COMBINED UNCERTAINTY	4.6%	2.1%	1.2%