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

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Outline

- Independent particle shell model
- Nuclear potential
- Momentum distribution
- Short range correlations
- Experiment E12-11-112
- Outlook

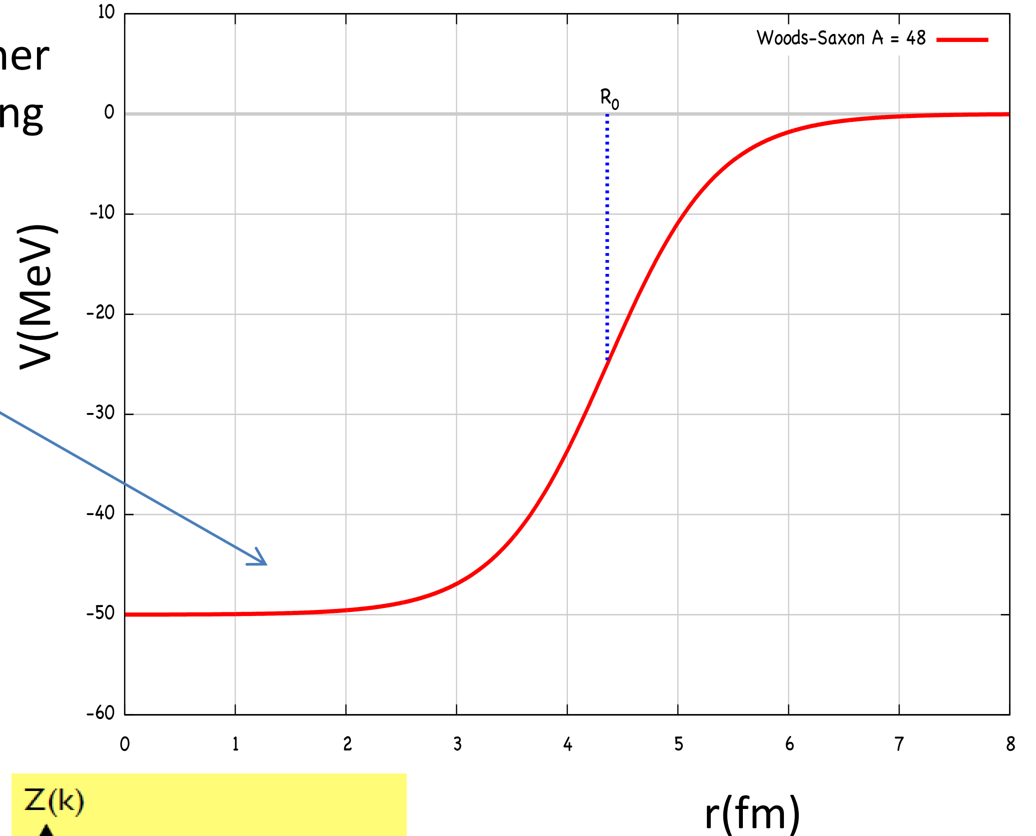
Independent particle shell model

•**<u>Single particle approximation</u>:**
nucleons move independently from each other in an average potential created by surrounding nucleons (mean field).

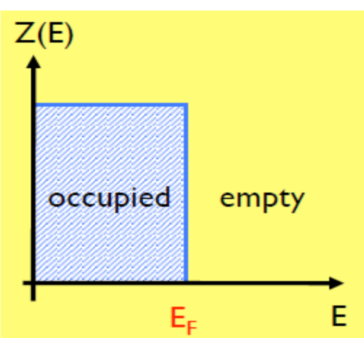
Nucleons move freely

IPSM does not include the nucleon-nucleon interaction at short distance.

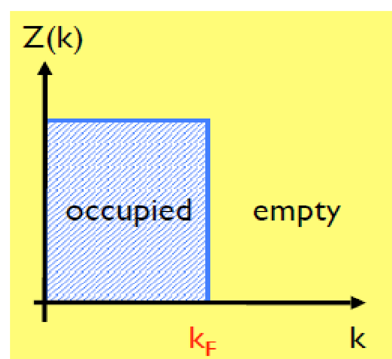
Woods-Saxon potential



•**<u>Nucleons occupy</u>** single particle state and factorized into energy and momentum



$$E \approx k^2/2m$$

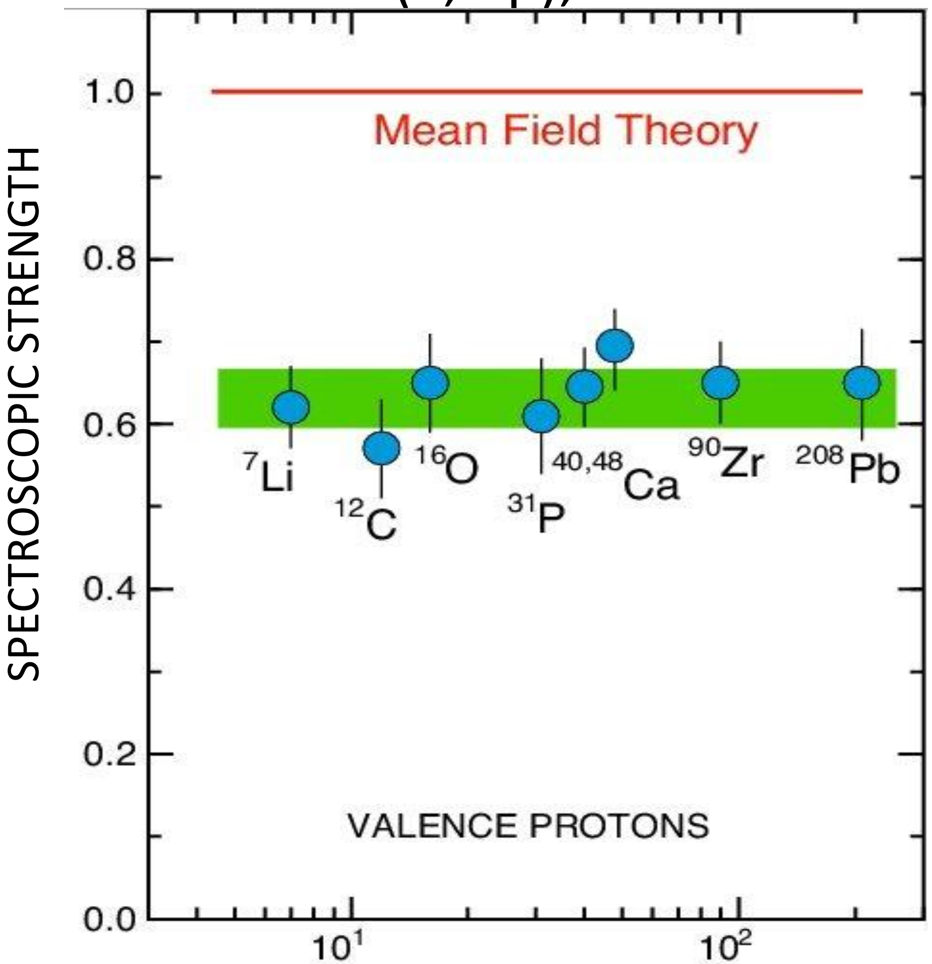


•**<u>Spectroscopic factor</u>** is the integral of the momentum distribution of a given shell = number of nucleons that can occupy that shell.

Spectroscopic factor

L. Lapikas, Nuclear Physics A 553, 297 (1993)

A(e,e'p),



Target Mass

Spectroscopic factor Z_α

$$Z_a = 4\pi \int^{k_f} dE\, dk\, k^2 S(k,E)$$

single particle state α

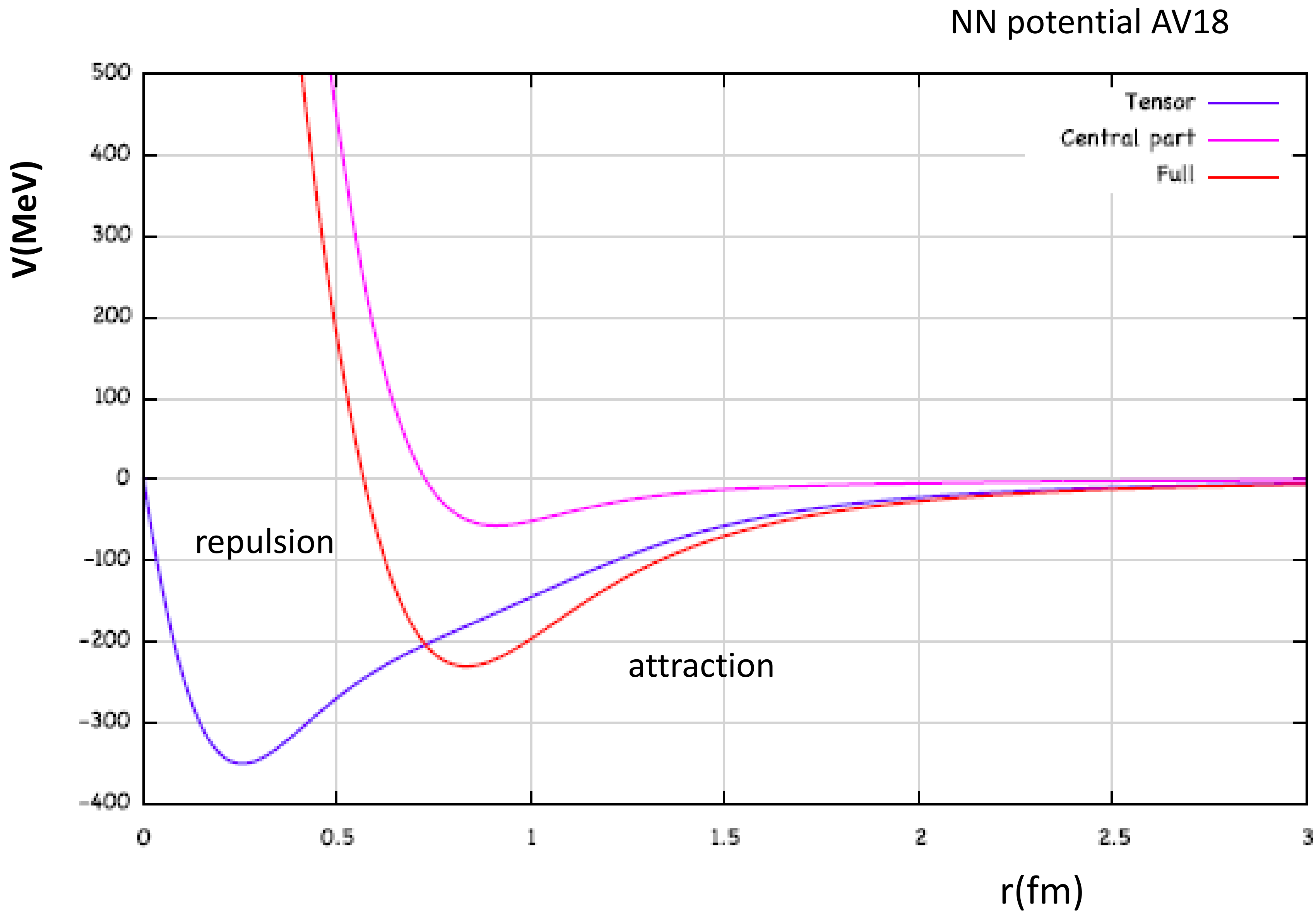
= number of nucleons in shell

30-40% missing strength

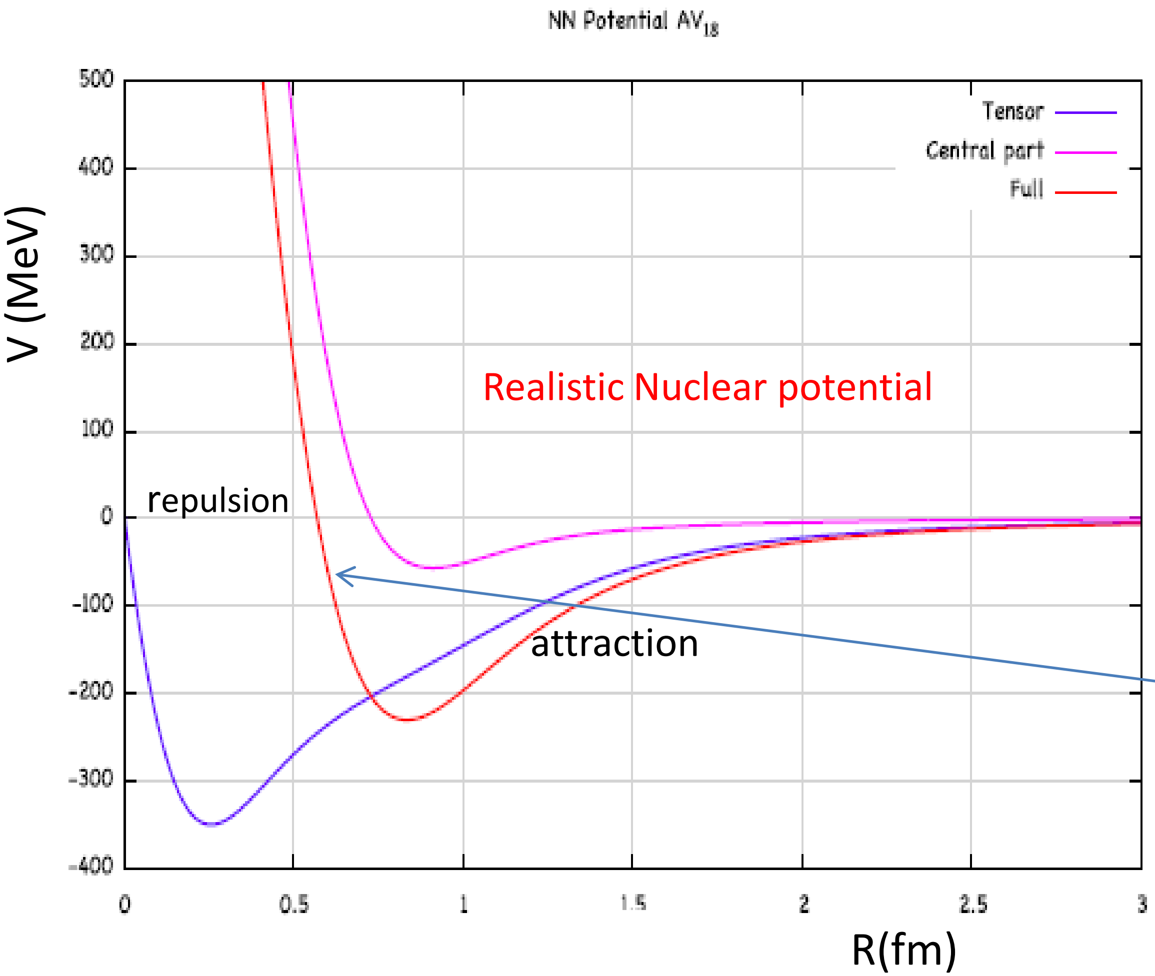
Experiment show that:
Spectroscopic ~60- 70% of the mean file prediction.

Solution: Correlations between nucleons.

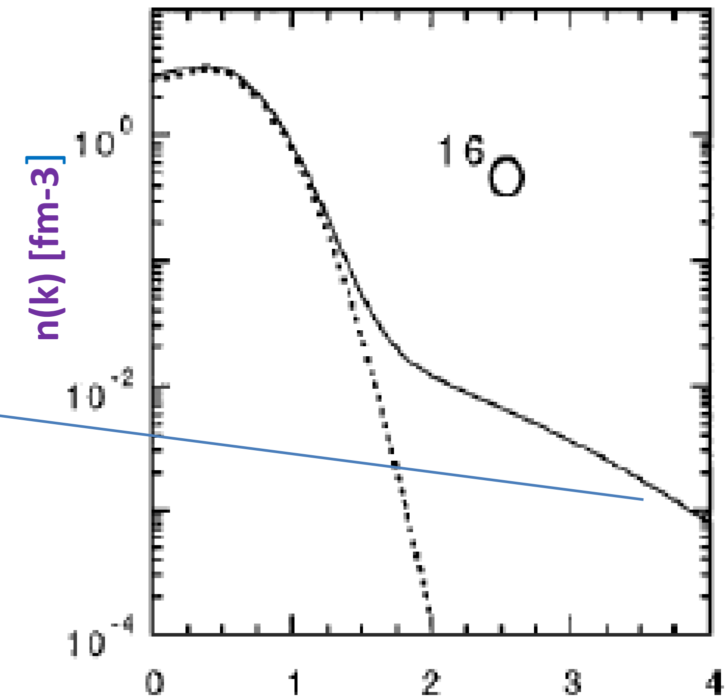
Nucleon-nucleon potential



Nuclear potential, momentum distribution



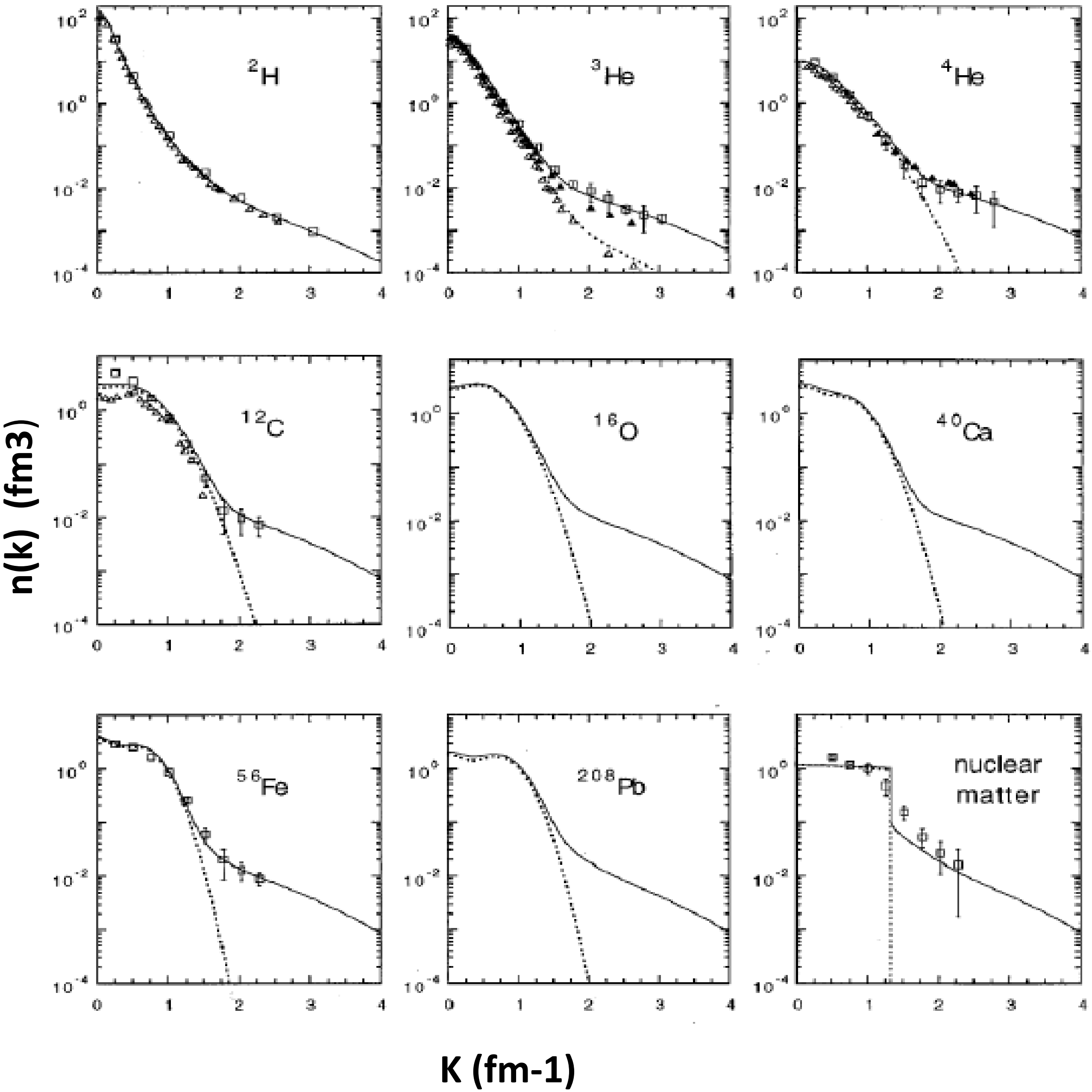
Nucleon momentum distribution in 16O



Momentum (fm^-1)

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

Nucleon Momentum distribution



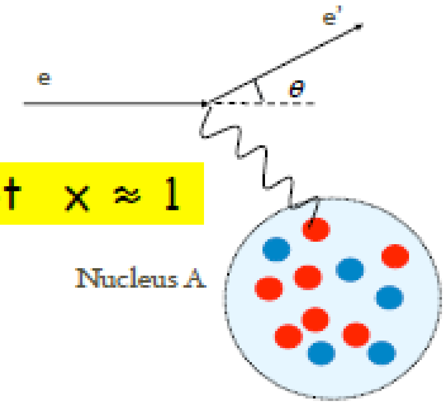
Mean field: momentum distribution rapid fall-off when k approaching kf

SLAC experiment results:
Each nucleus has a momentum tail falling off much slower at k>kf

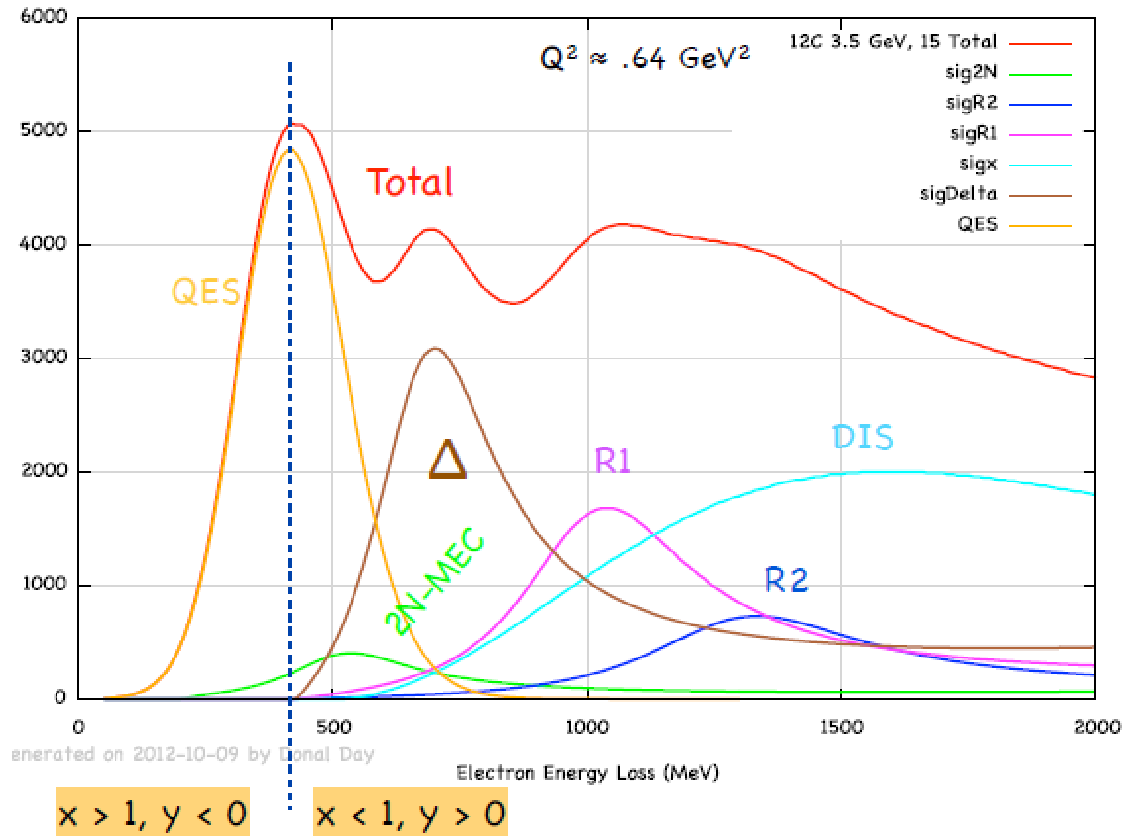
ref: C. Ciofi degli Atti and S. Simula, phys. Rev. C 53, 1689(1996)

Inclusive scattering at large x

At $x \approx 1$



Cross section



Nucleon's Fermi motion broadens QE peak

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

$$Q^2 = 4E_0 E \sin^2(\theta/2)$$

4-momentum transferred square

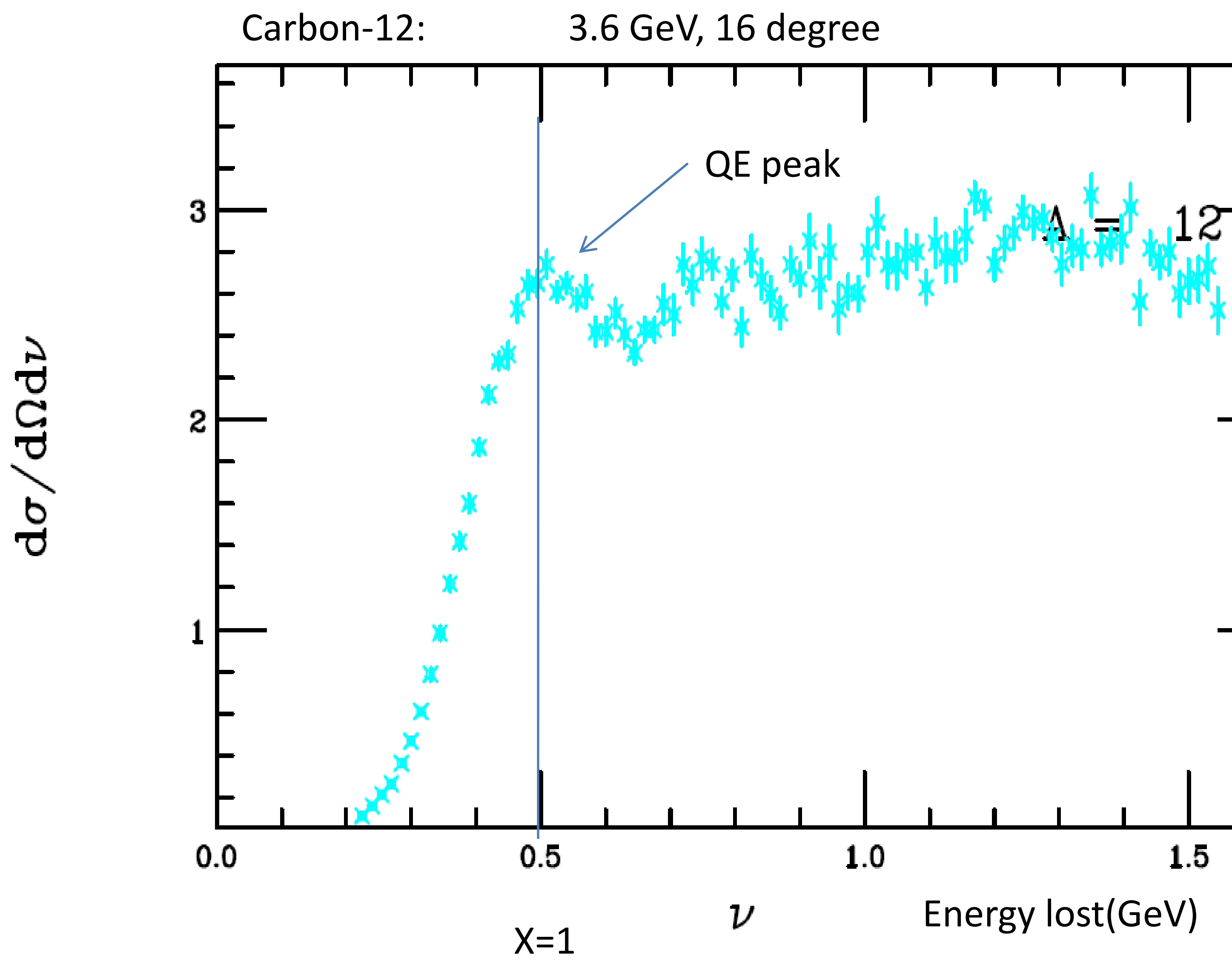
$$x_{bj} = \frac{Q^2}{2m\nu}$$

Momentum fraction of a nucleon shared by the struck quark.

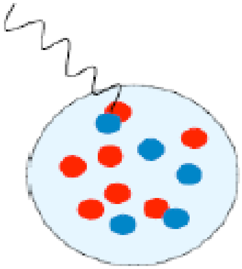
$$y \approx -q/2 + m\upsilon/q$$

Momentum of struck nucleon parallel to q vector

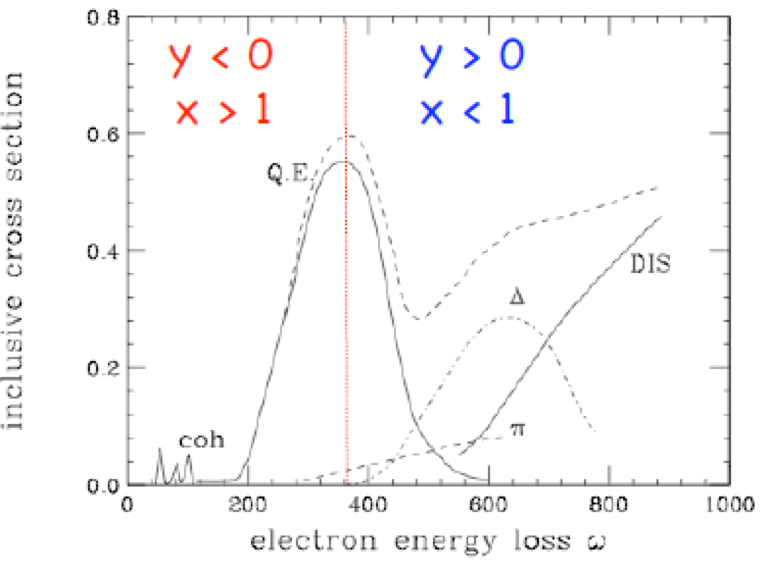
Cross section from data



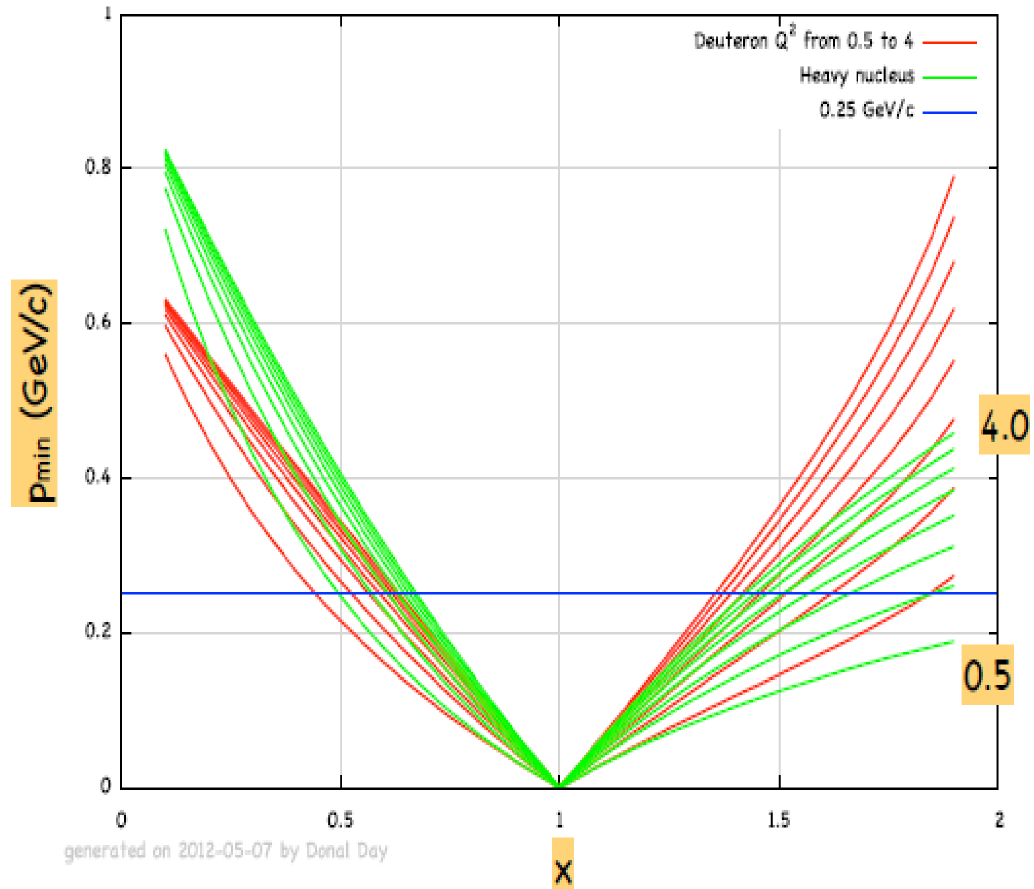
What kinematic allow us to study SRCs?



2N_SRCs



Minimum initial of struck nucleon momentum

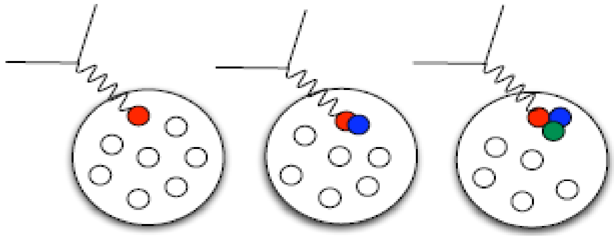


Mean field : very small
SRCs: dominant

need to go to high enough X or q2
to be above this blue line

Short-range correlations(SRCs)

In the Region where correlations should dominate , large x, k>kf.



$$\sigma_A(x,Q^2)=\sum_{j=2}^{A}\frac{A}{j}a_j(A)\sigma_j(x,Q^2)$$

$$=\frac{A}{2}a_2(A)\sigma_2+\frac{A}{3}a_3(A)\sigma_3+\ldots$$

Where:

- σ_j is cross section from j-nucleon correlation.
- $a_j(A)$ is proportional to the probability of finding a nucleon in a j-nucleon correlation.

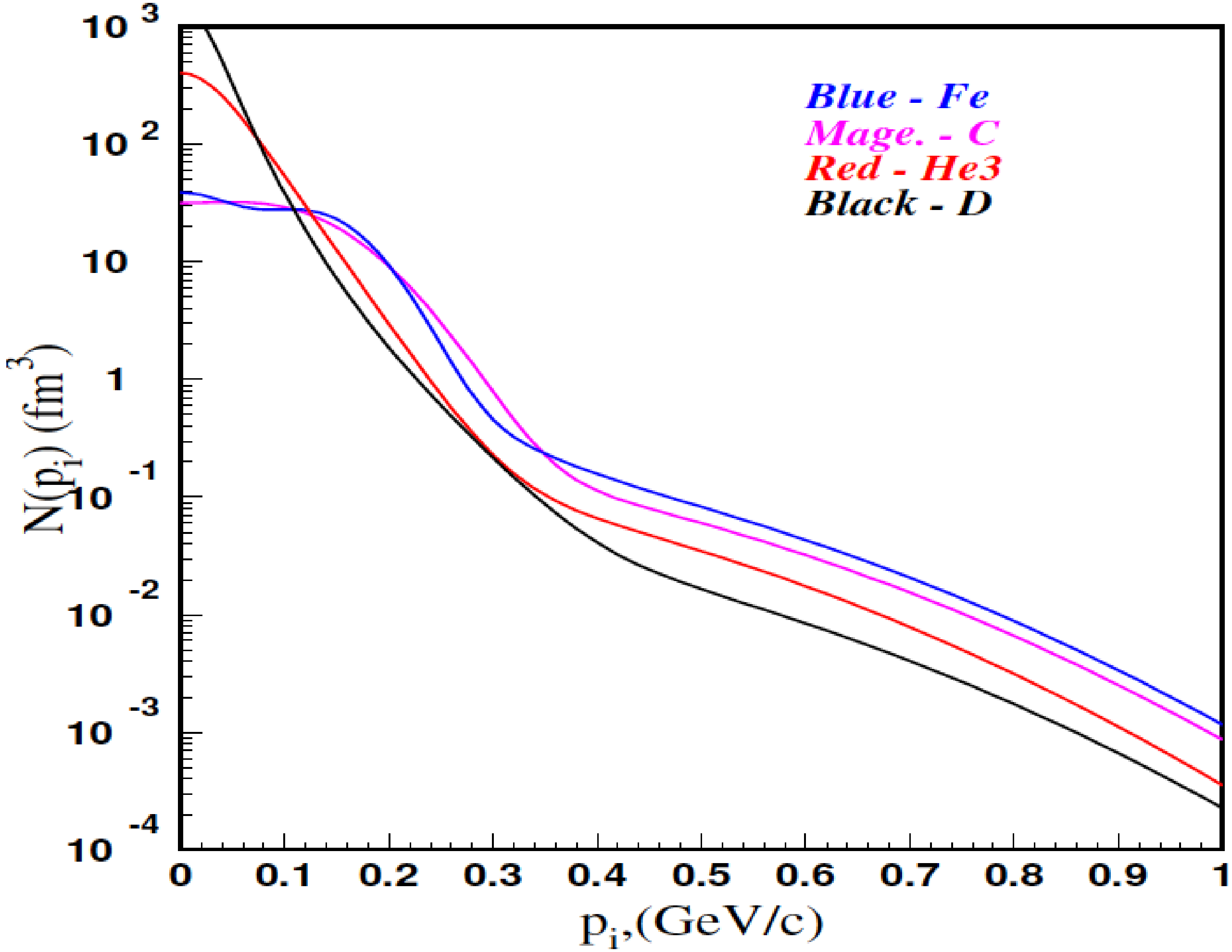
2N SRCs dominate : $\frac{\sigma_A}{A}/\frac{\sigma_D}{2}=CONSTANT$

K>KF

Cross section ratios of heavy nuclei to light nuclei are expected to scale if SRCs exist. (plateau)

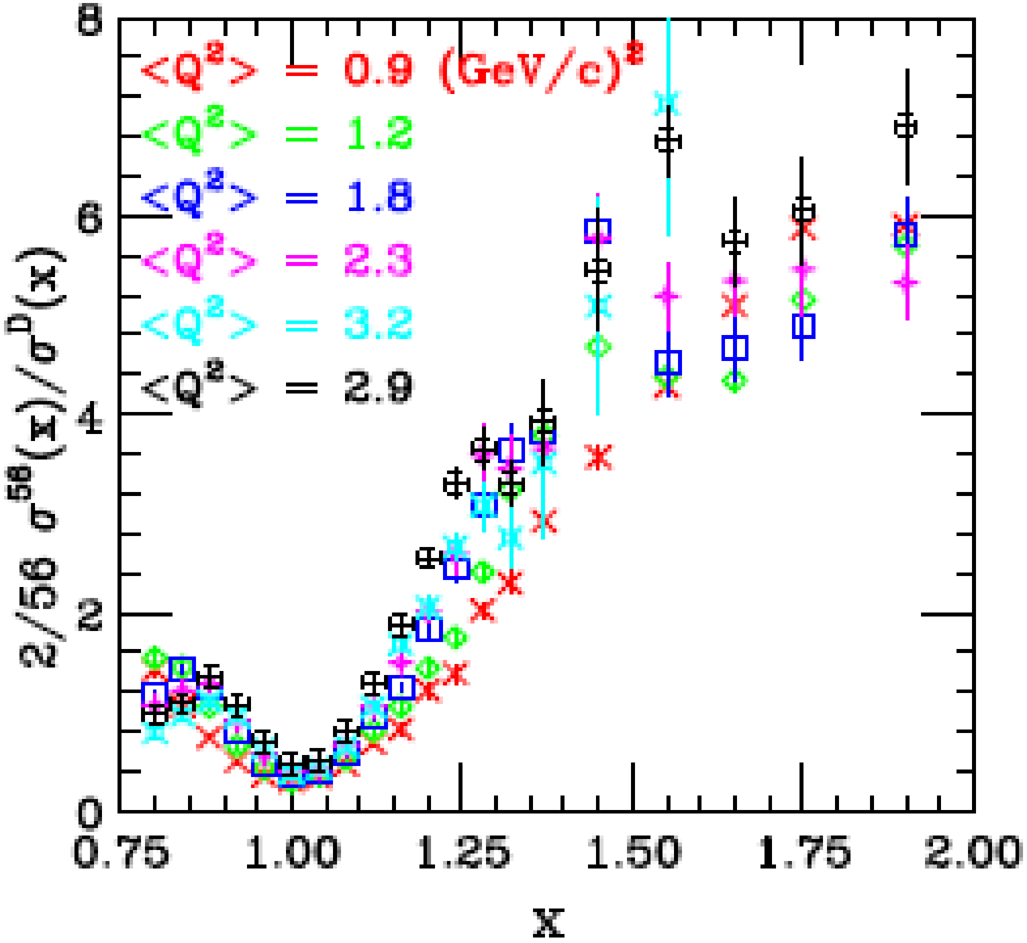
Momentum Distributions

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



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

First observation from SLAC

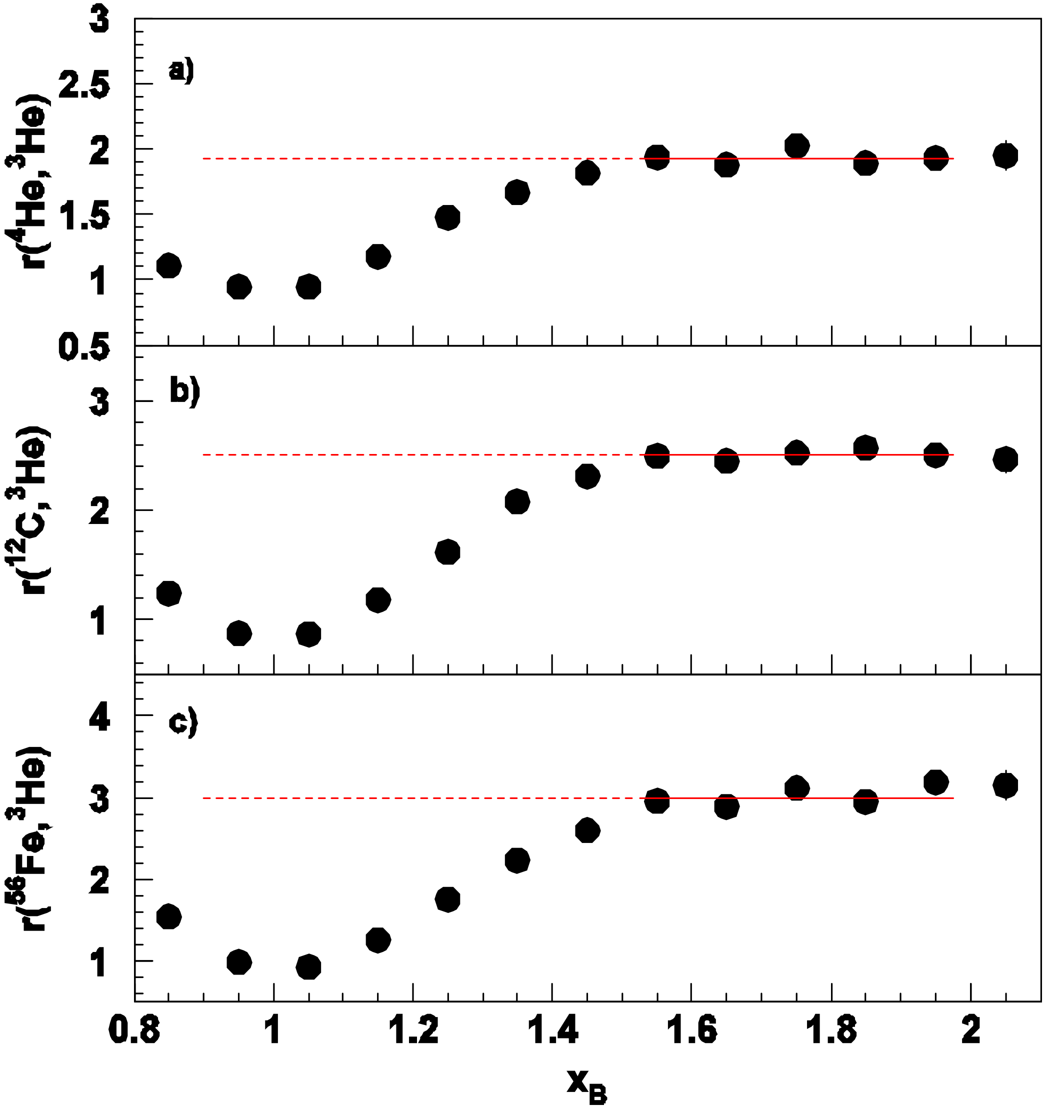


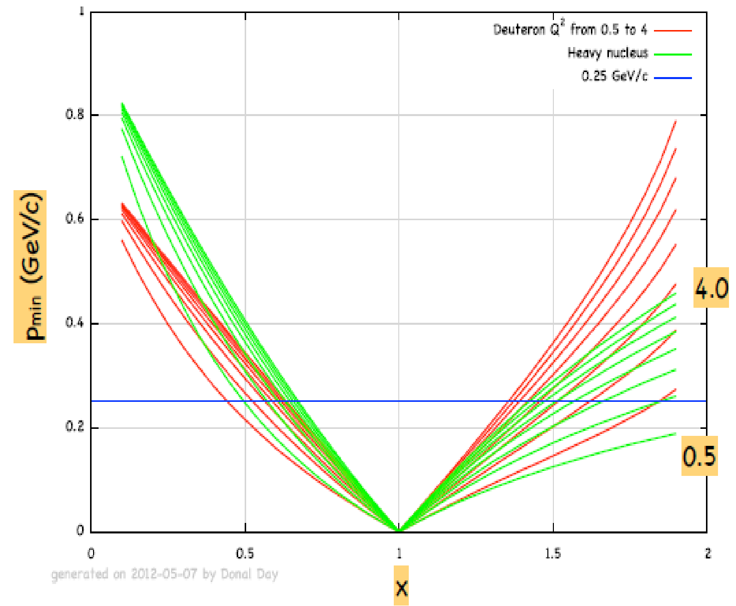
Other targets : 4He, 27Al, 64Cu were also studied and show clear evidences of 2N-SRCs plateau.

L. L Frankfurt, M. I Strikman , D. B. Day, and M. Sargsyan, Phys. Rev. C 48, 2451 (1993)

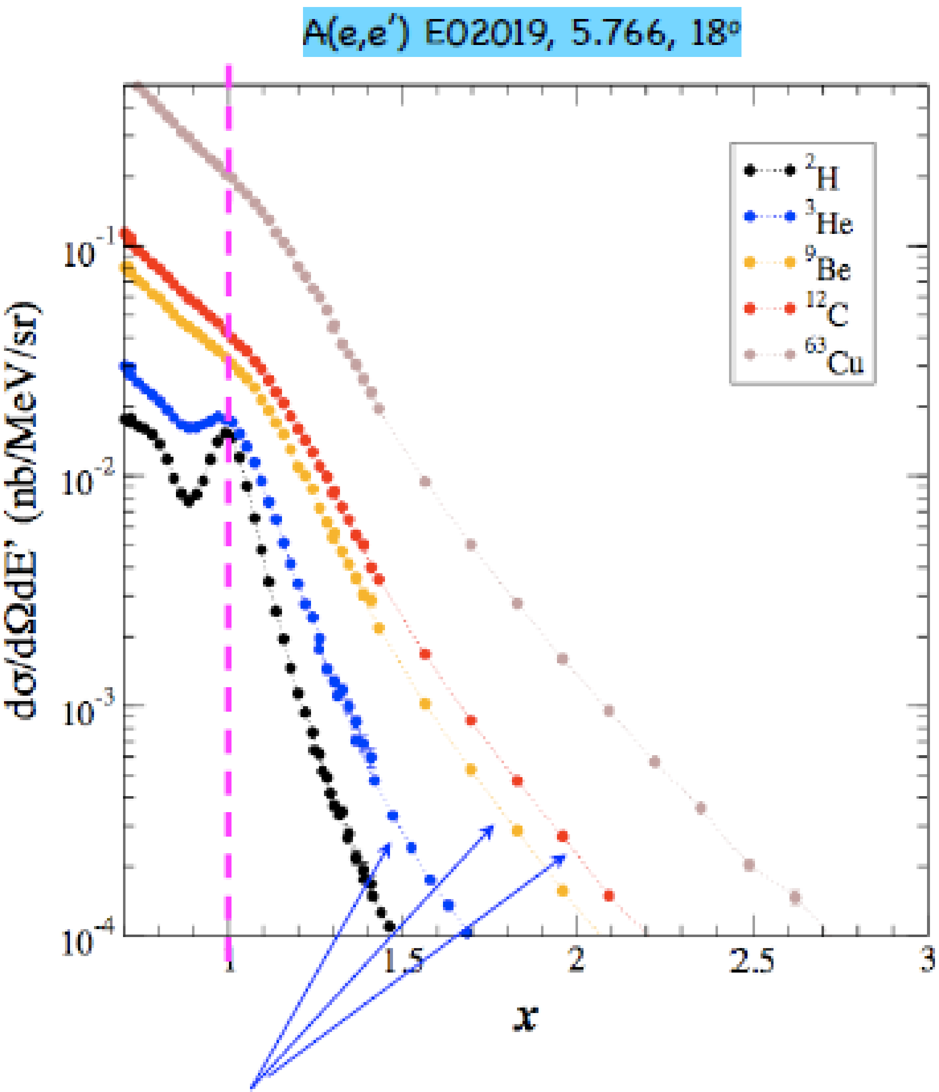
Observation from CLAS: HallB Jlab

K. Sh. Egiyan *et al.,* Phys. Rev. C **68** (2003) 014313.



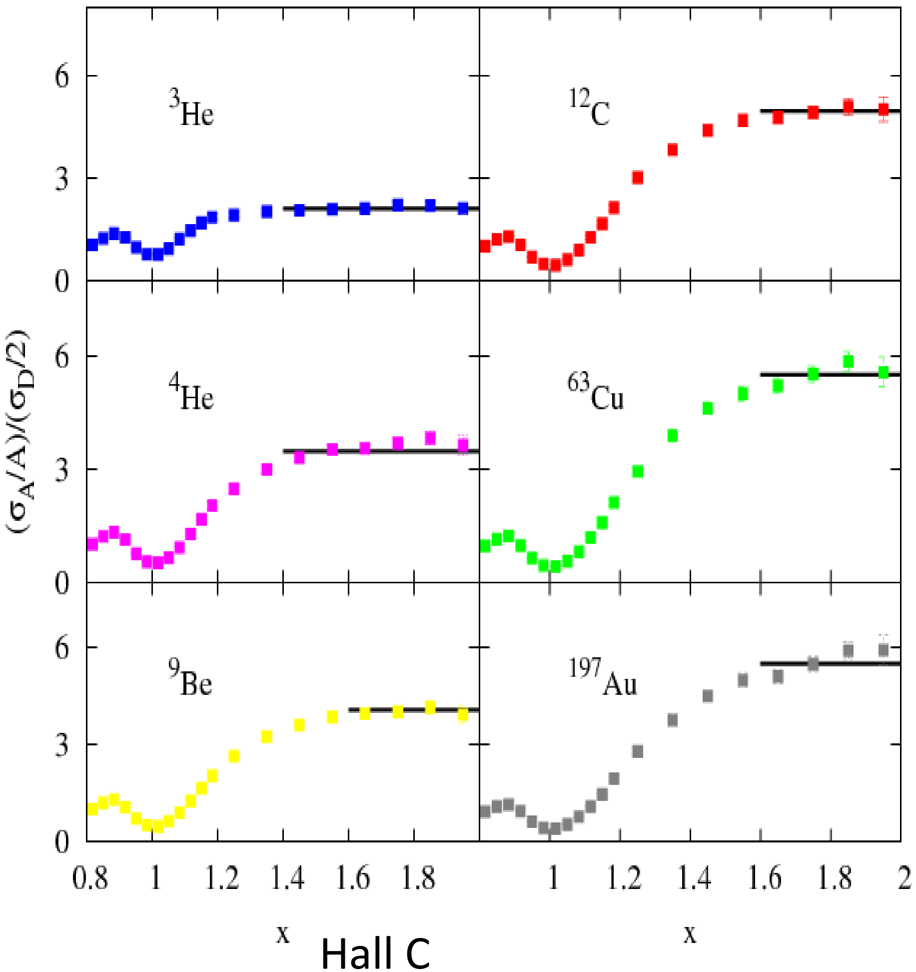


More 2N-SRCs Evidence: Jlab HallC



High momentum tails yield constant ratio if SRC exist

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

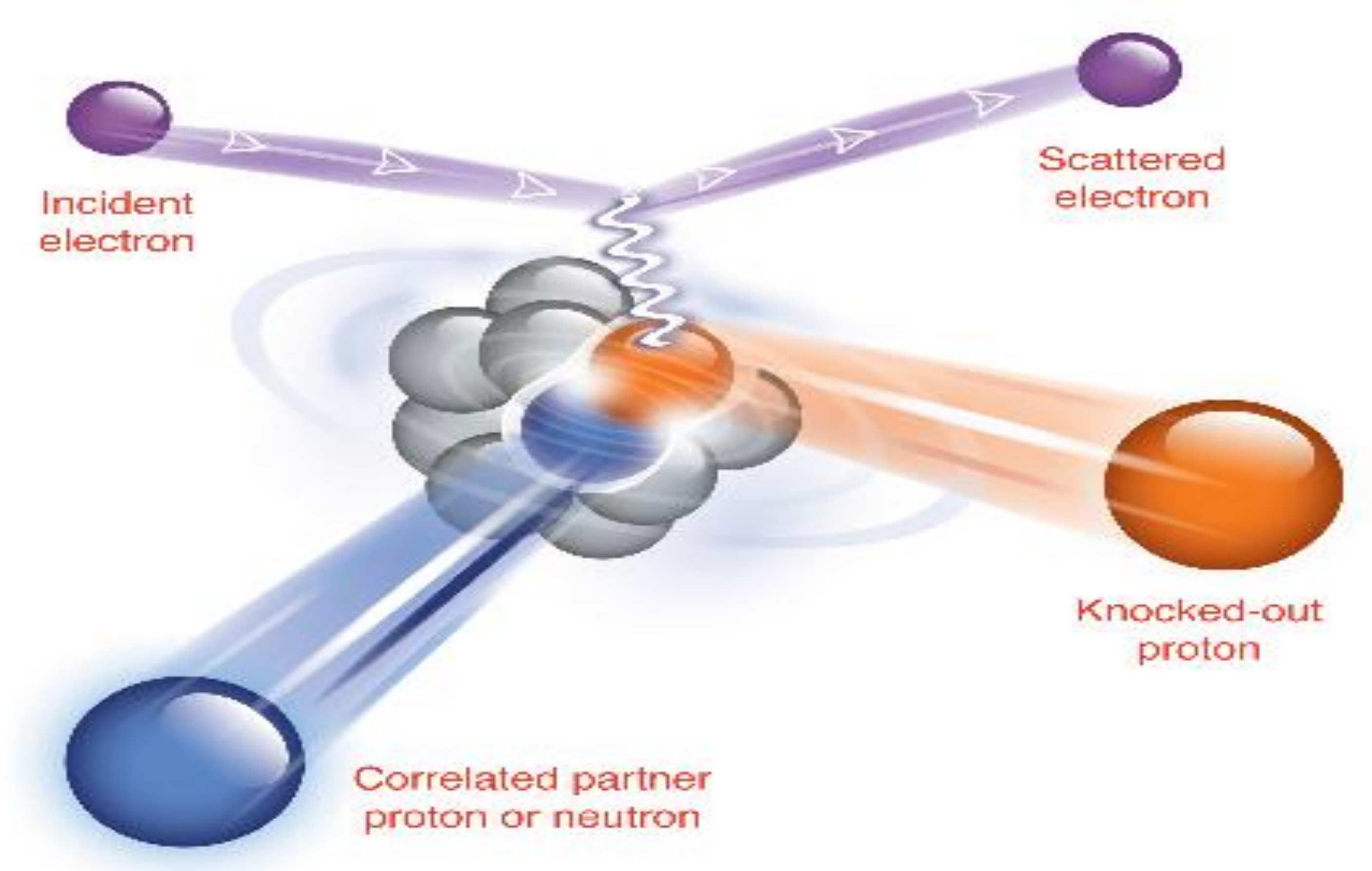


Evidence of 2N-SRCs at x>1.5

Isospin dependence 2N-SRCs

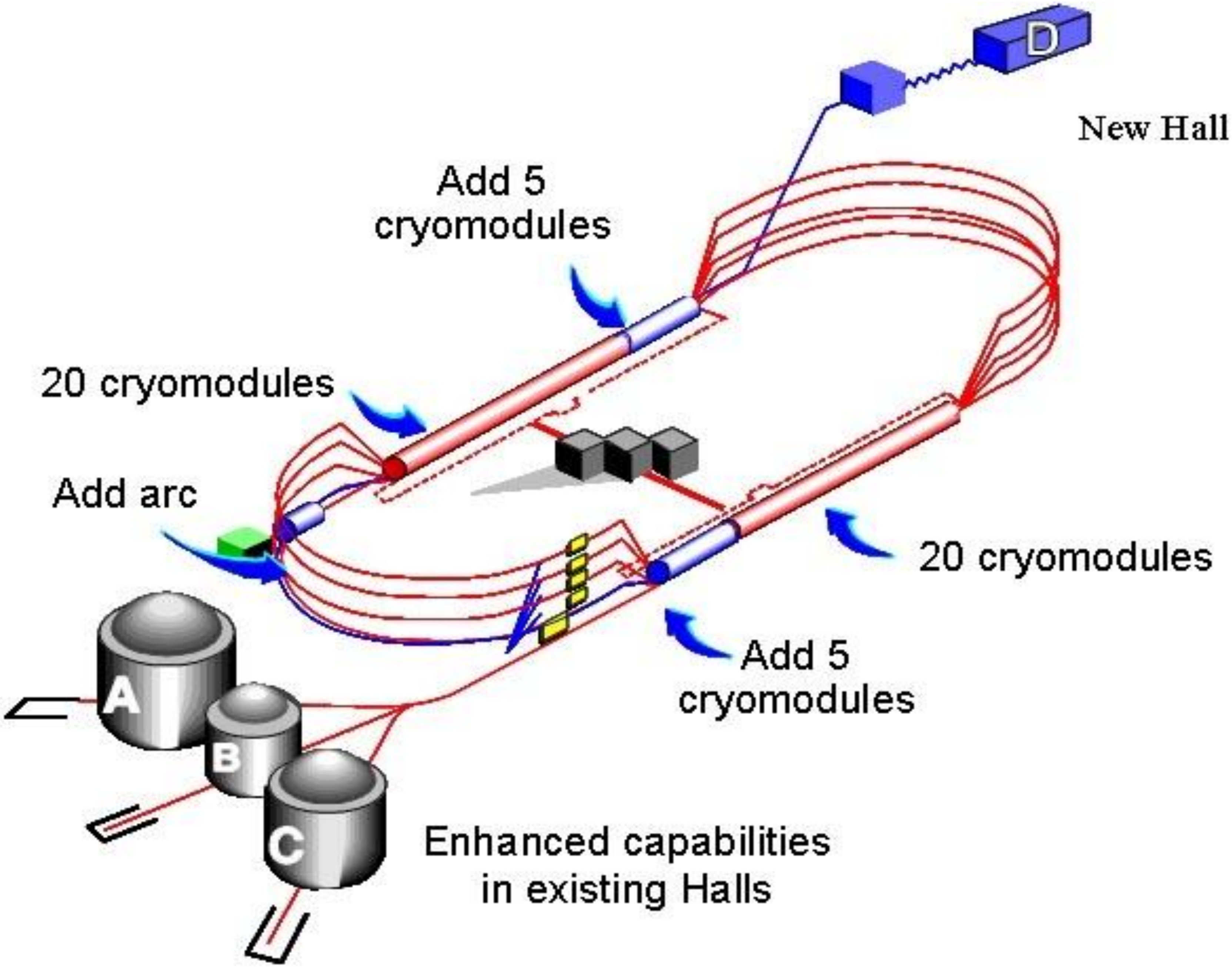
•**SRCs model**: the nucleon correlation are assumed to be isospin independence

Coincidence (e,e'pN) Measurement

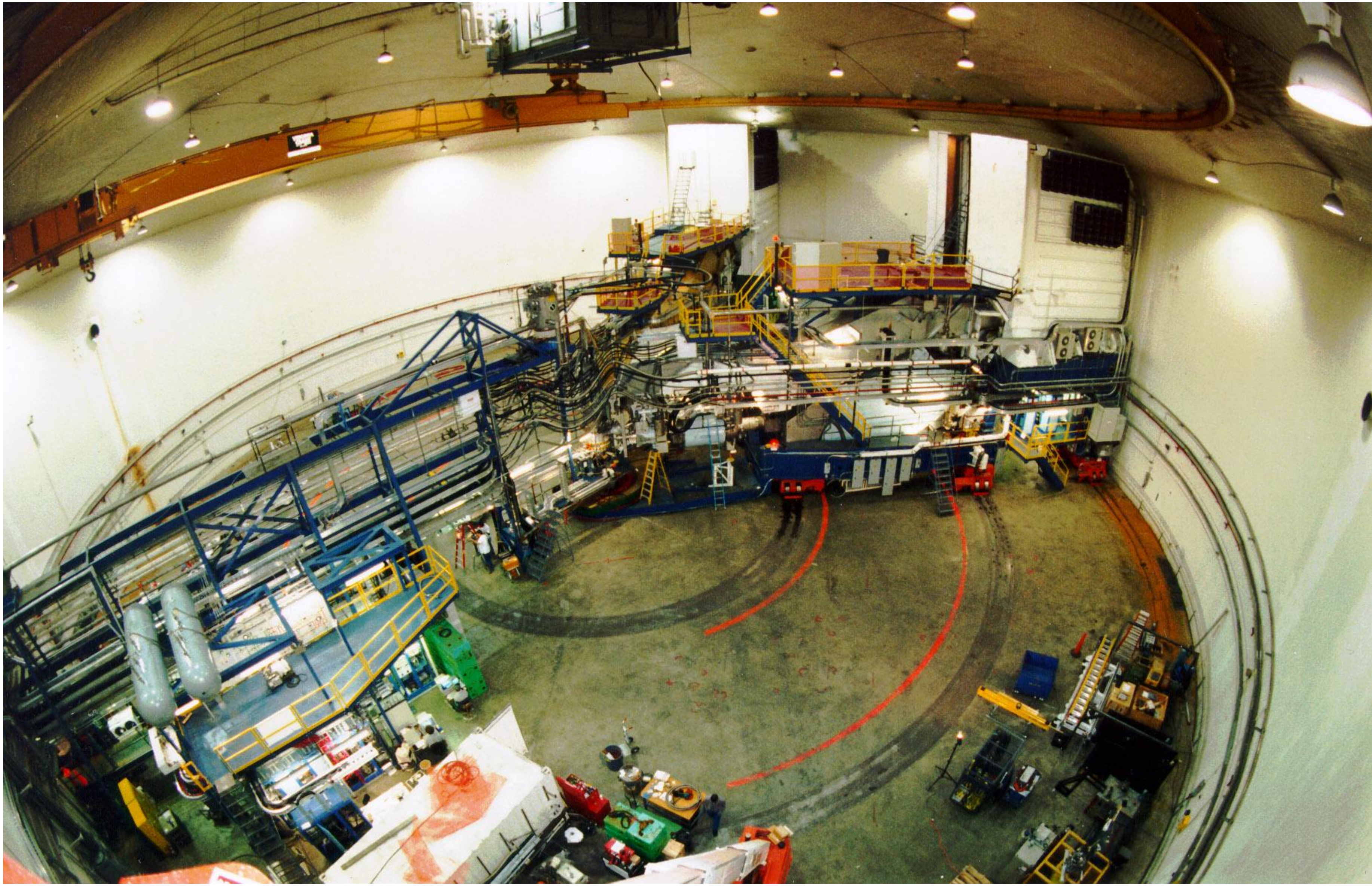


x> 1 , Q^2 = 1.5 $[GeV/c]^2$ and missing momentum of 500 MeV/c

Jefferson Lab's accelerator view

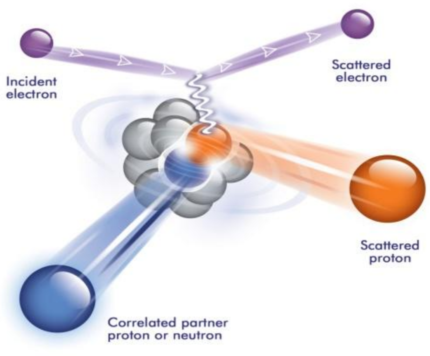


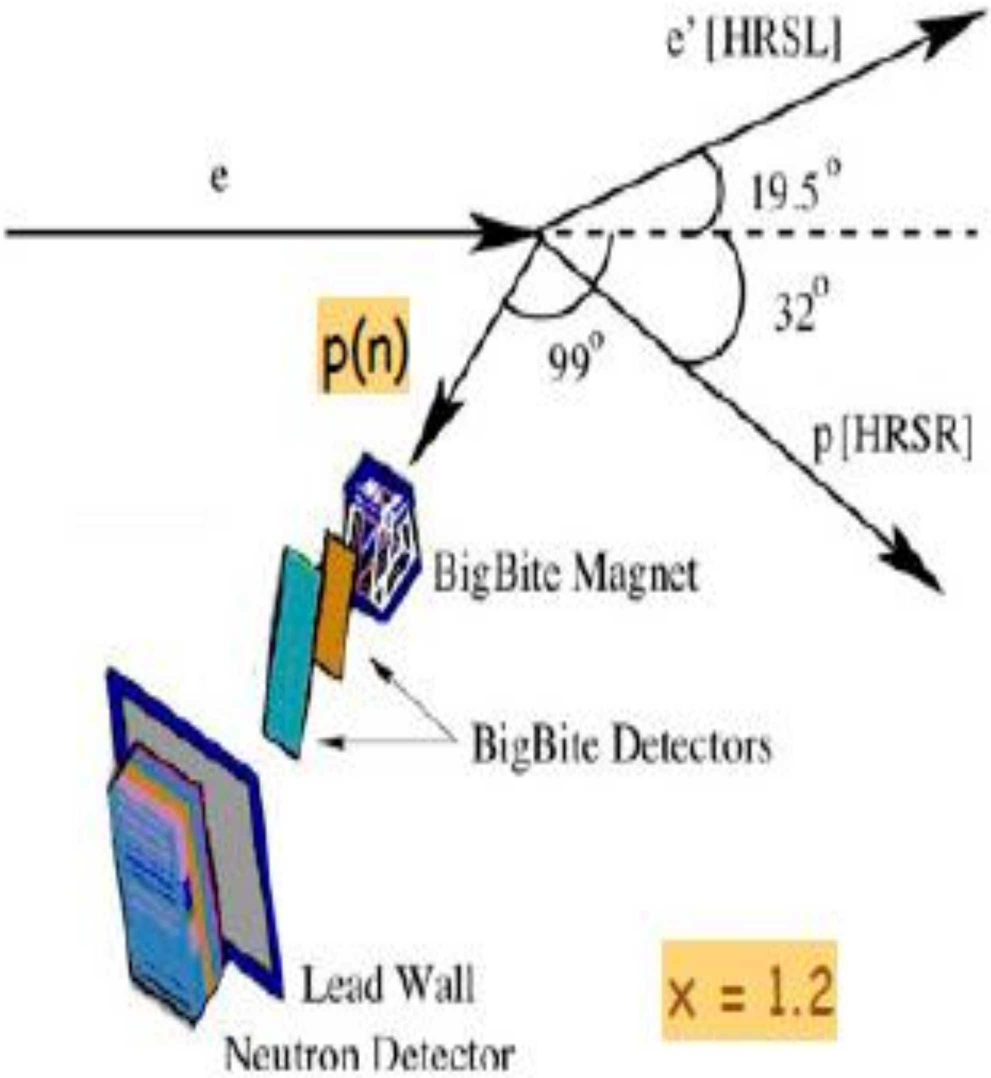
Jefferson Lab's Hall A



Isospin dependence SRCs

- **Experiment E01-015: A(e,e'2N)**



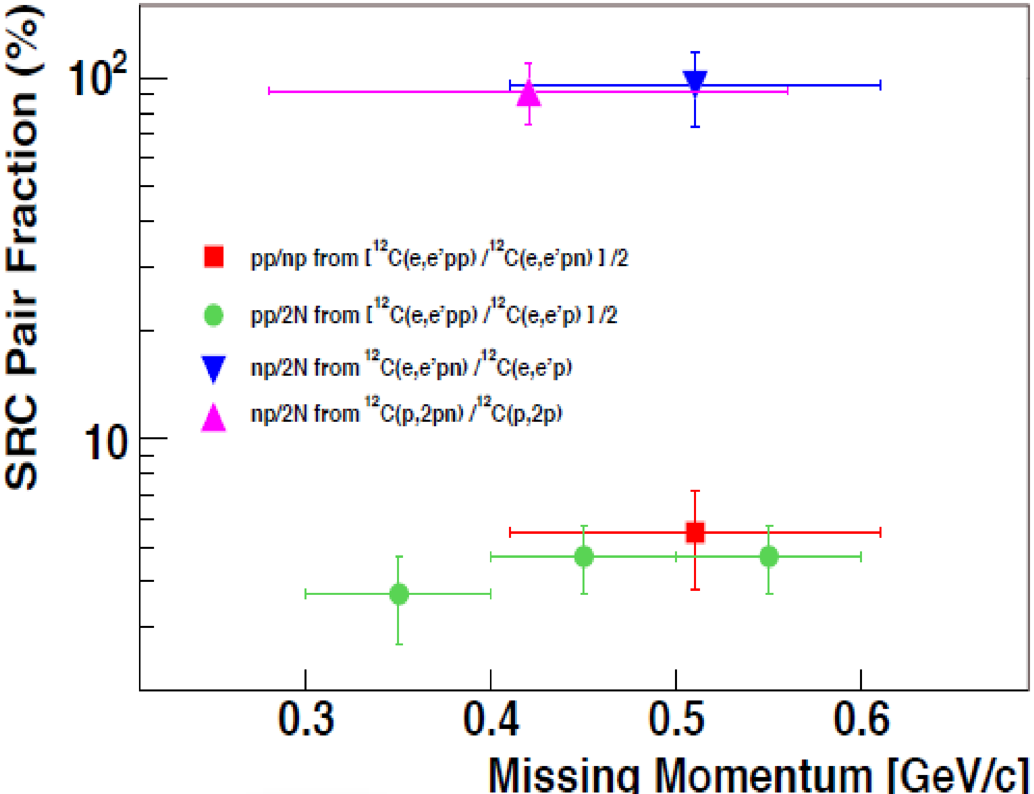


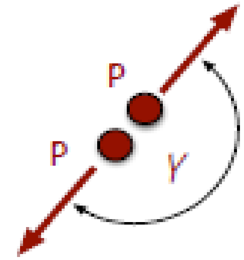
Simultaneous measurements of (e,e'p), (e,e'pp) and (e,e'pn)

And the ratio of (e,e'pn)/(e,e'pp)

Results from Experiment E01-015:

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



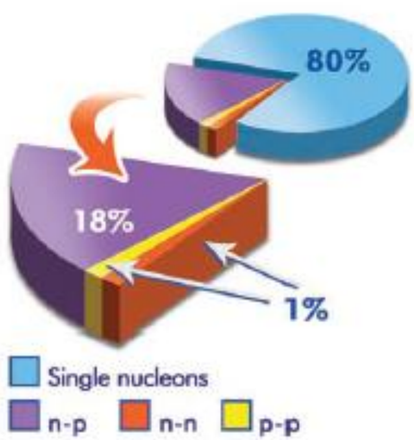


Almost all proton with p>kF in C(e,e'p) have a paired proton or neutron with similar momentum in opposite direction.

$$^{12}C(e,e'pp)/^{12}C(e,e'p) = 9.5 \pm 2\%$$

$$^{12}C(e,e'pn)/^{12}C(e,e'p) = 96 \pm 22\%$$

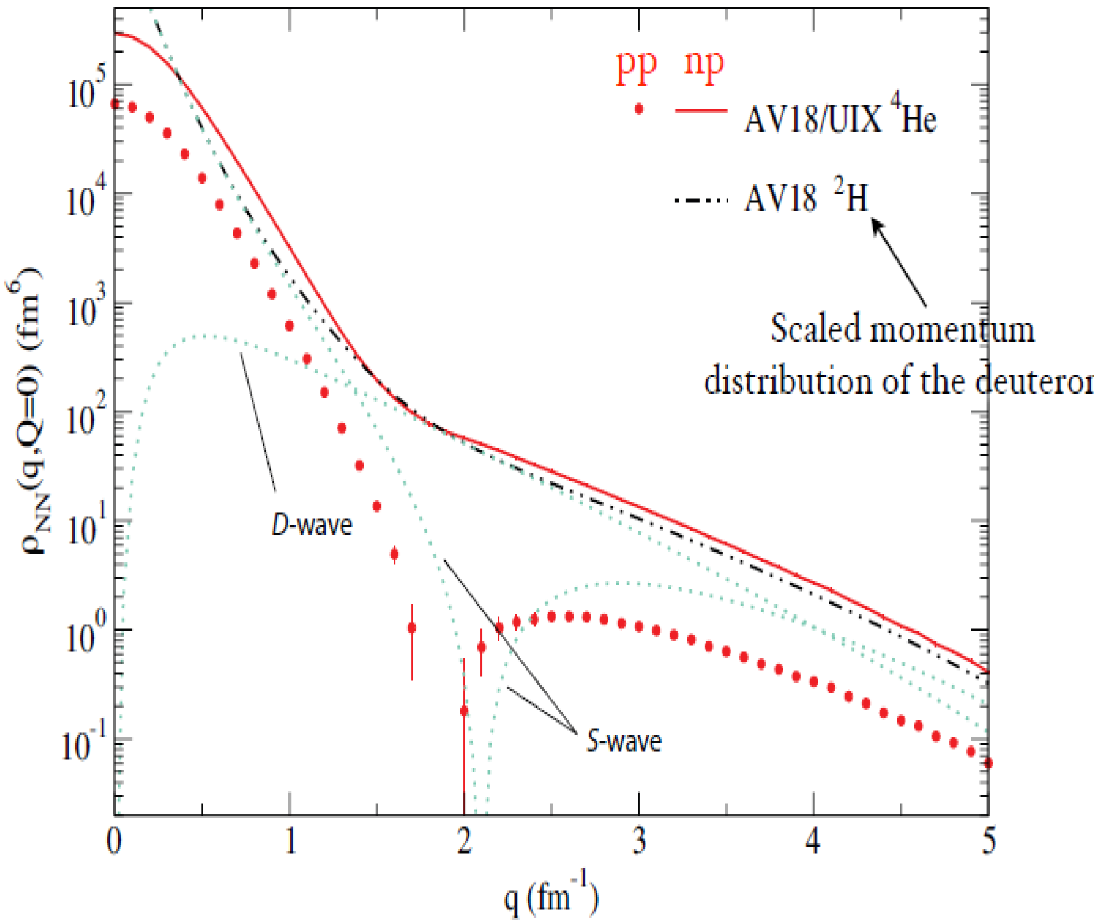
$$^{12}C(e,e'pn)/^{12}C(e,e'pp) = 9 \pm 2.5\%$$



Data show large asymmetry between pp and pn pair.

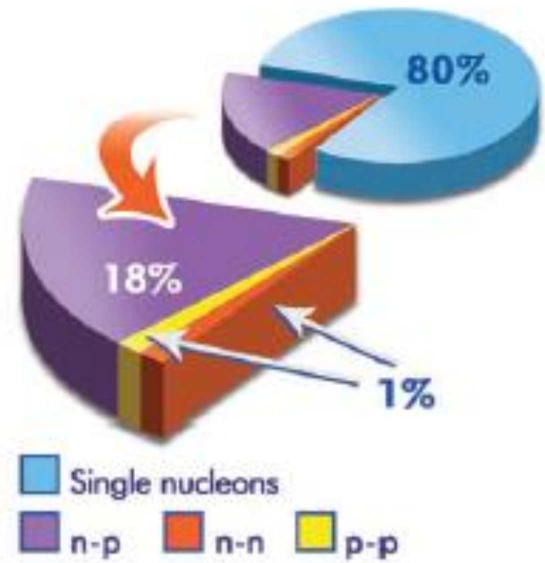
Experimental Evidence Isospin dependence of SRC

Tensor force responsible for dominant part of SRC and correlation are largely on pn pair



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

Good agreement from theoritical calculation and experiment

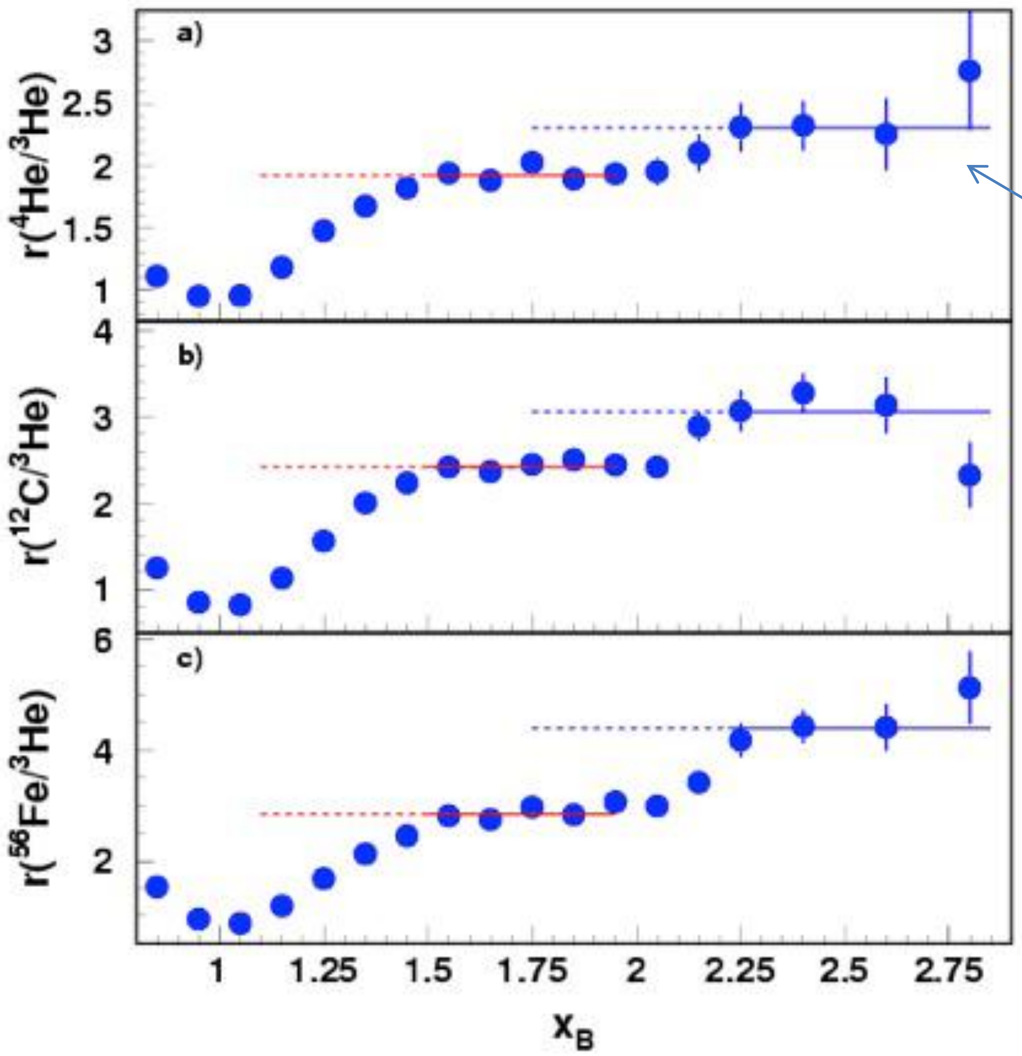


SRCs measurement: approximately 20% contribute. Where 90+-10% from p-n SRC pairs, 5+-1.5% from p-p n-n pairs.

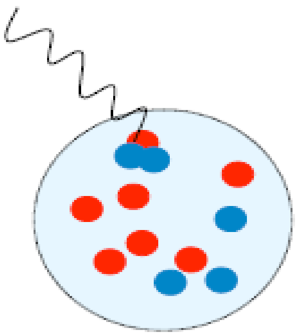
Solid evidence of Isospin dependence of SRCs

How about 3N- SRCs?

K. Sh. Egiyan *et al.,* Phys. Rev. C **68** (2003) 014313.



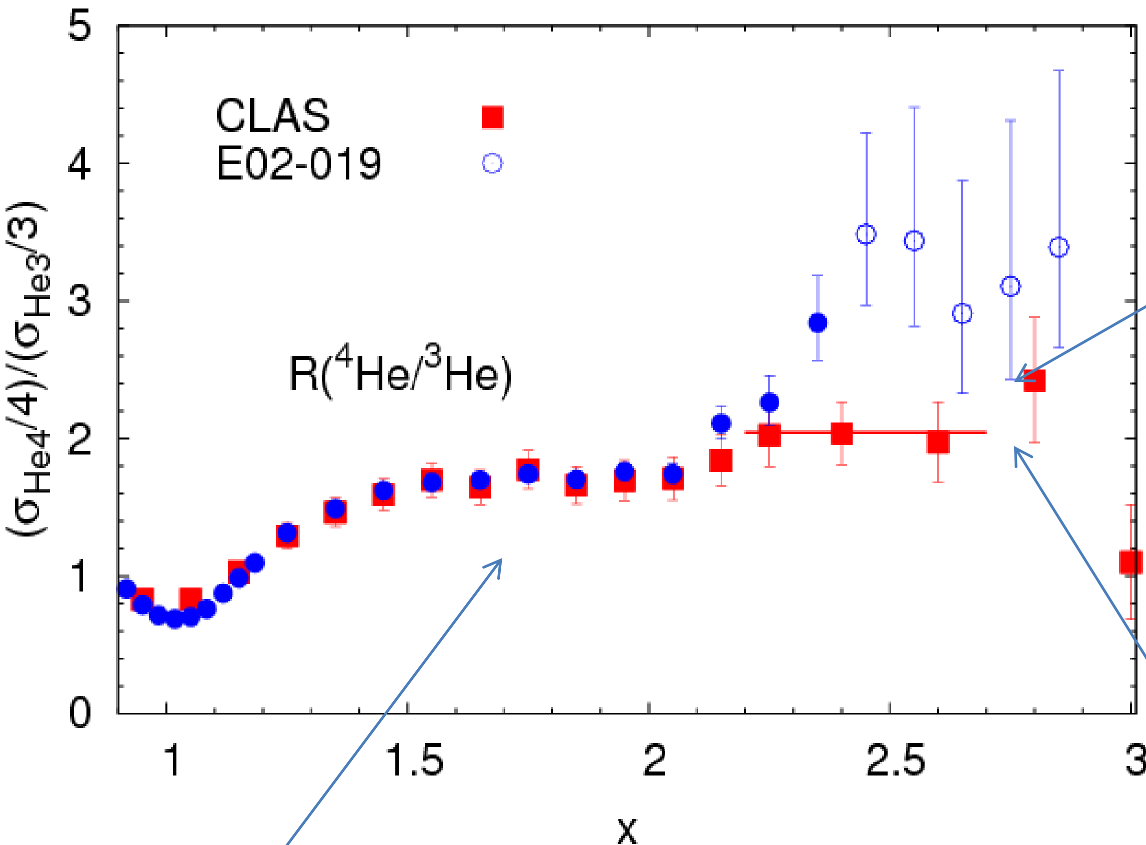
Jlab hall B data:



3N SRCs: 2<x<3

3N-SRCs?

How about 3N- SRCs ?



Disagreement in 3N-SRC region

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

Douglas and O. Hen paper

Good agreement in 2N-SRC region

New data (x>2) from Jlab experiment E08014 is coming (zhihong Yez phd thesis)

E12-11-112

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

Main physics goals

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

E12-11-112: kinematics

<u>Beam current</u> : 20 muA, unpolarized.

<u>Beam Energy</u> : 2.2 GeV and 4.4 GeV

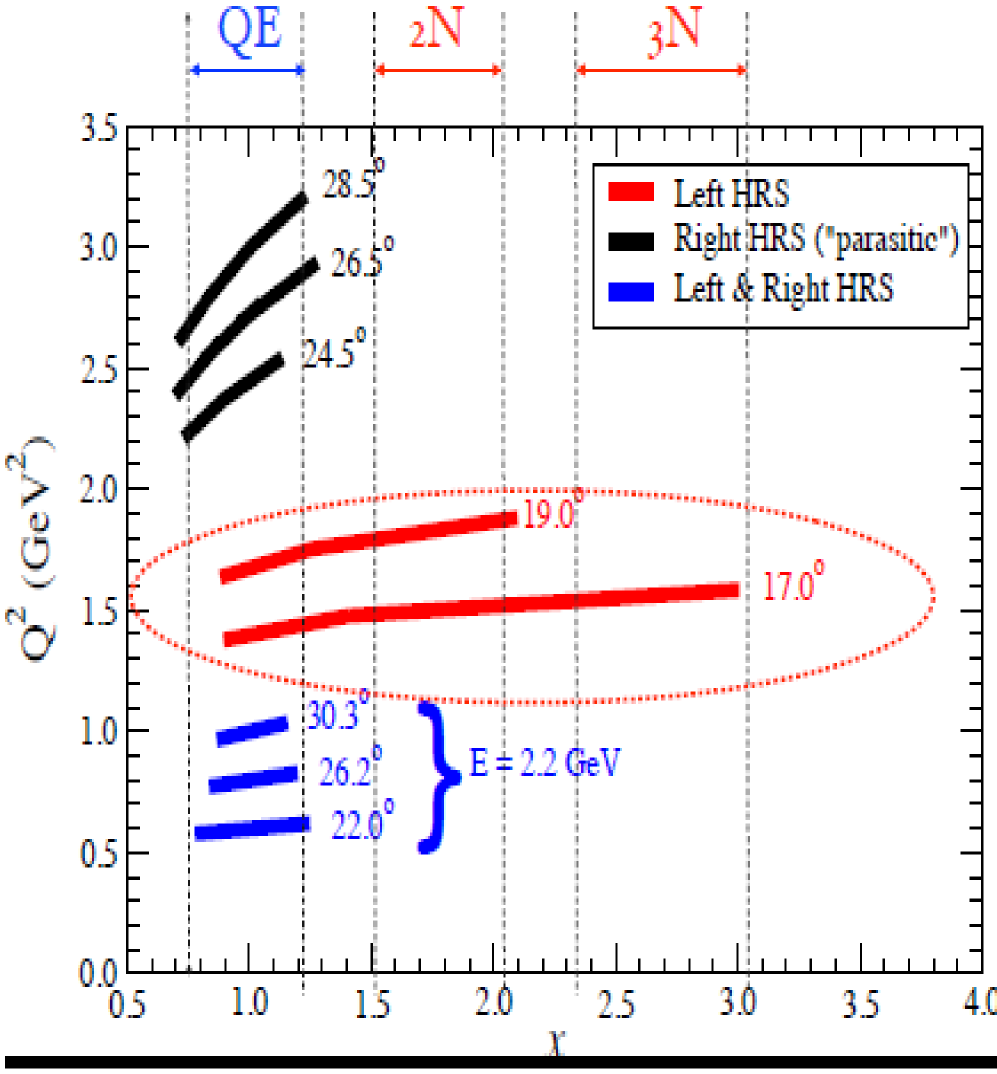
<u>Scattering angle</u>: 17 and 19 degree

<u>Beam time</u> :
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)



SRCs Isospin study from 3He/3H

- Isospin-independent

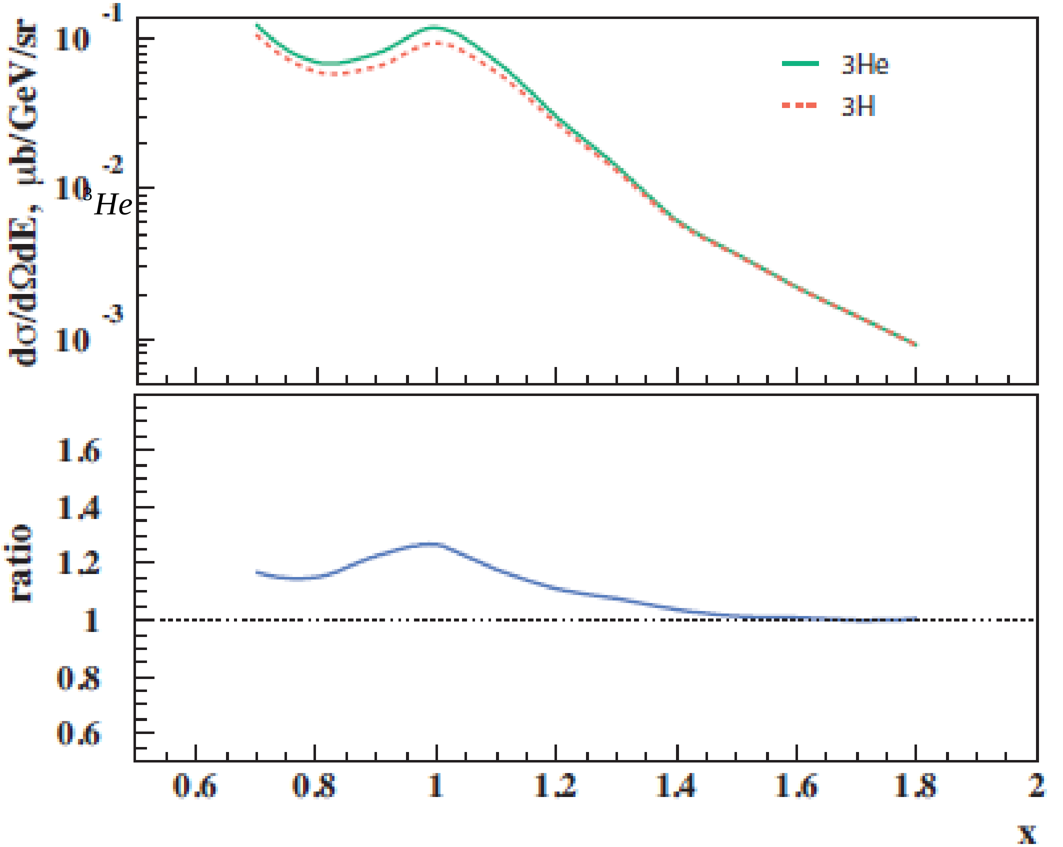
$$\frac{\sigma_{^3He}/3}{\sigma_{^3H}/3} = \frac{(2\sigma_p + 1\sigma_n)/3}{(1\sigma_p + 2\sigma_n)/3} \xrightarrow{\sigma_p = 3\sigma_n} 1.4$$

- n-p (T=0) dominance

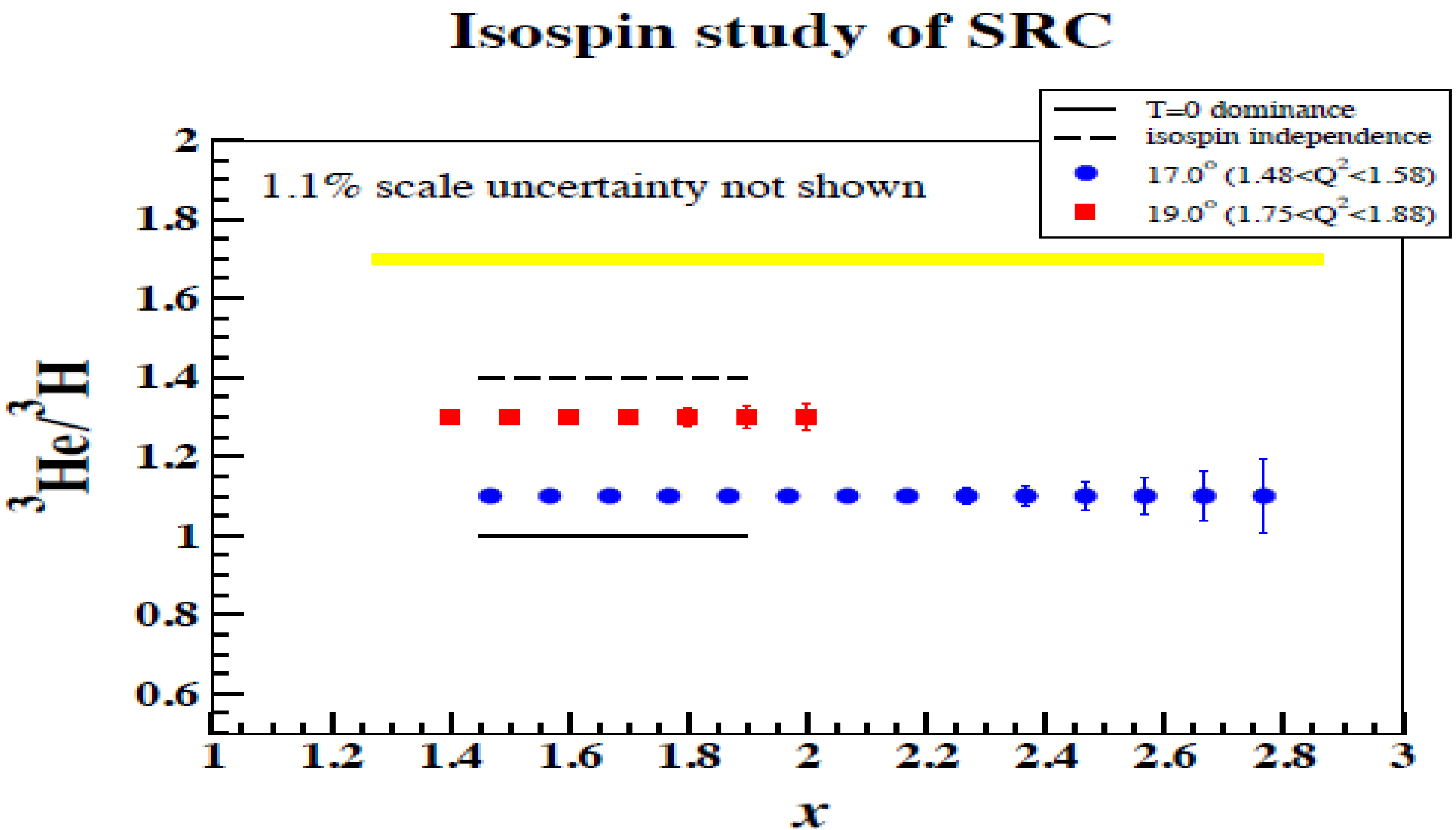
$$\frac{\sigma_{^3H}/3}{\sigma_{^3He}/3} \approx \frac{(2pn)/3}{(2pn)/3} = 1.0$$

Reference:

-Exclusive electrodisintegration of He3 at high Q2.
-Decay function formalism. Phys. Rev. C 71, 044615.
(M.M Sargsian, T. V. Abrahamyan, M. I Strikman and L. L. Frankfurt)



E12-11-112: projected results

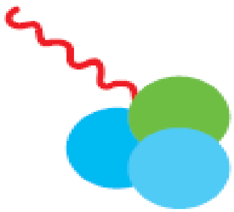


At x>2 3He/3H # 1.4 implies isospin dependence AND non-symmetric momentum sharing

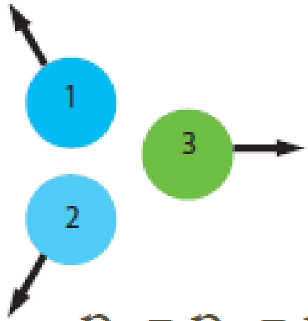
Expected uncertainty in 2N-SRCs region approximately 2%

It is unique experiment and have very strong advantage to see isospin depence. 40%

what is structure of 3N-SRCs?

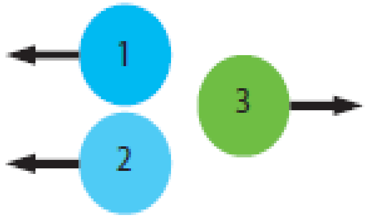


Symmetric



$p_1 = p_2 = p_3$

Non-Symmetric:



$p_3 = p_1 + p_2$

Symmetric:

$$\frac{^3He}{^3H} = \frac{2\sigma_p + \sigma_n}{\sigma_p + 2\sigma_n} \approx 1.4$$

Non-symmetric:

- **Case1:** nucleon 3 is singly-occurring nucleon

$$\frac{^3He}{^3H} = \frac{\sigma_n}{\sigma_p} \approx 0.3$$

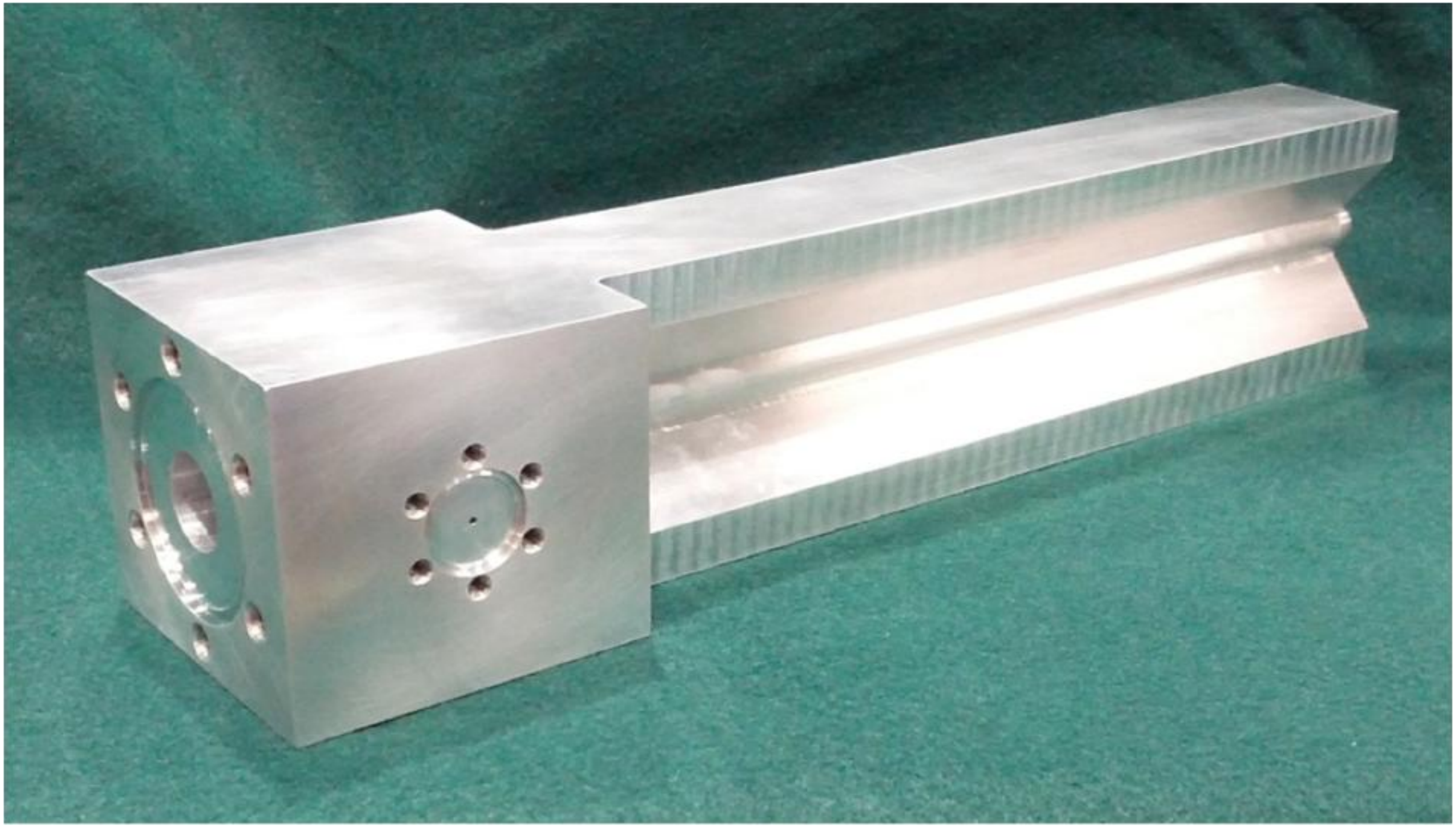
- **Case2**: nucleon 3 is doubly-occurring nucleon

$$\frac{^3He}{^3H} = \frac{\sigma_p}{\sigma_n} \approx 3$$

E12-11-112 : Targets

This experiment using mirror targets Tritium H3 and He3

Tritium Target



Tritium target

Lab	Year	Quantity (kCi)	Thickness (g/cm2)	Current (muA)	Current* Thickness (muA-g/cm2)	Safe FOM (muA-g/cm2/kCi)
Stanford HEPL	1963	25	0.8	0.5	0.4	0.016
MIT-Bates	1982	180	0.3	20	6.0	0.033
SAL	1985	3	0.02	30	0.6	0.2
Saclay	1985	10	1.1	10	11	1.1
JLab	201?	1	0.084	25	2.1	2.1

Main goal: the conceptual design and safety devices can minimize the amount and density of tritium necessary for experiment and keep the system and procedures as simple and reliable as possible.

Safe figure of merit (FOM): the JLab target has a superior safe figure of merit ~ 2.1

Calculation the absolute thickness of Target for Triton experiment

Question: How can we check the target DENSITY g/cm3?

Tritium Target will be filled at Savannah River site(SRS) located in South Carolina.

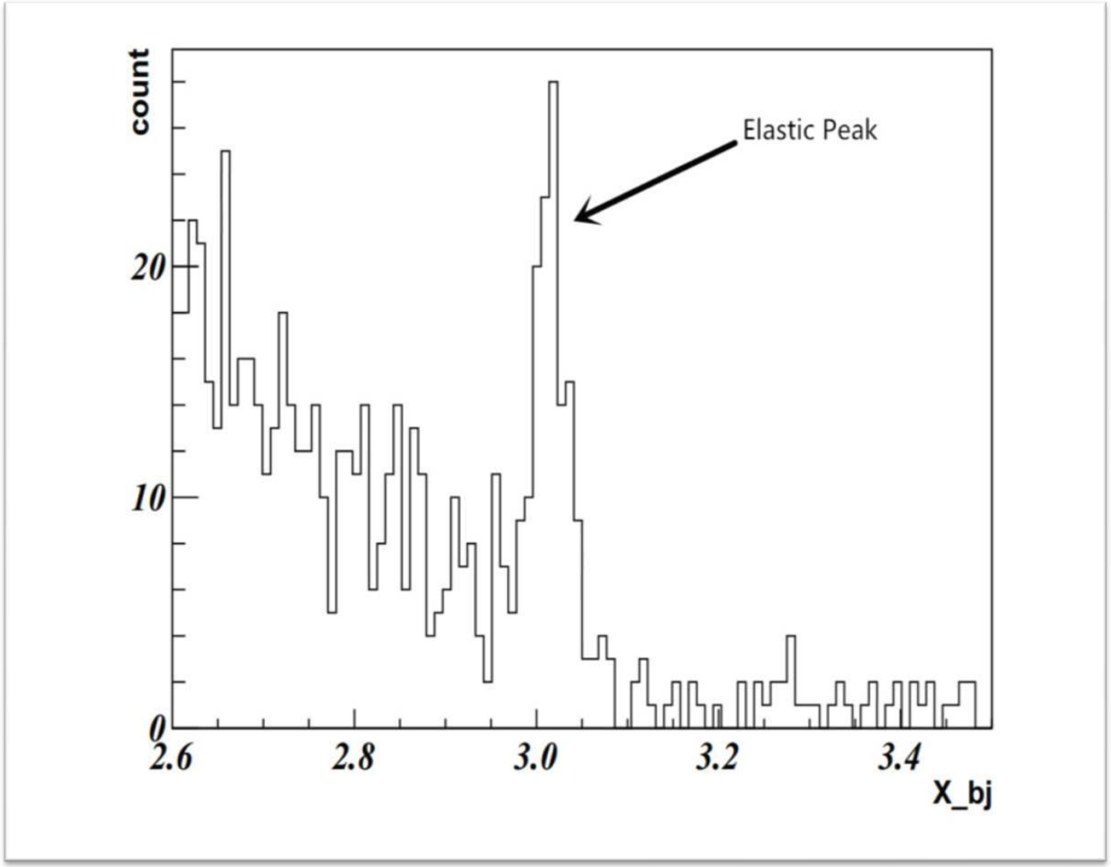
Give us the target thickness information

How can we cross check this information?

<u>Answer:</u> we can use the elastic scattering

Calculation the absolute thickness of Target for Triton experiment

Experiment E08014



E0=3.356 GeV

Theta= 21,

~1 hour run time

Q2=1.35 GeV2

We can check the density of this target up to level of 3%

The cuts: on trigger type, PID , endcap , solid angle, tracking

Getting Yield from experiment we can find Luminosity ~ thickness of the target

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

First checking result:

~1 hour beam time, energy beam = 2.2 GeV and current 25muA

Target	Angle1	Angle2	Yield1	Yield2	Uncertainty1 (%)	Uncertainty2 (%)
He3	12	15	3e6	1.7e	0.05	0.16
H3	12	15	4e5	1.9e4	0.24	0.72

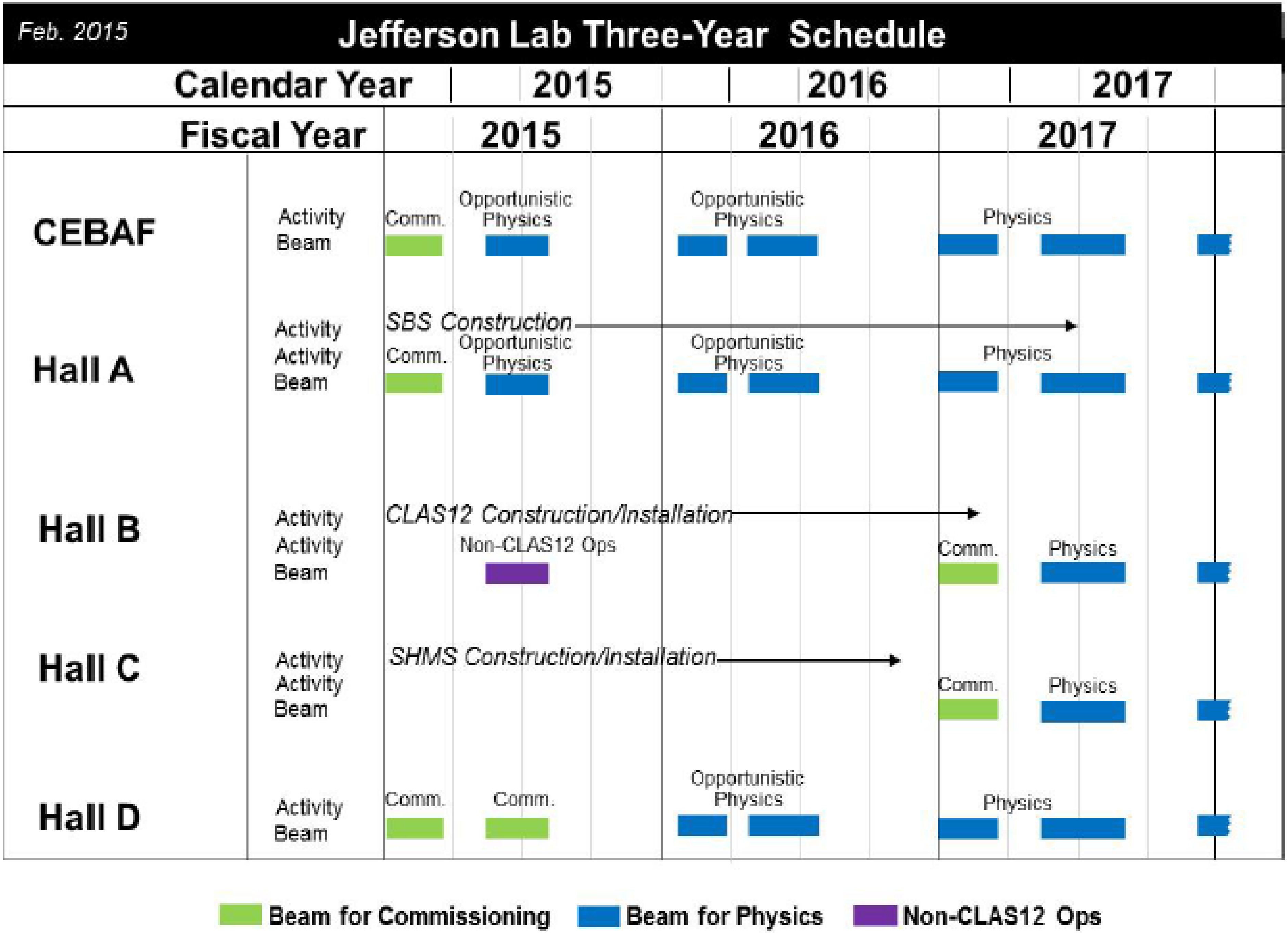
We should be able to check the target thickness of tritium target to the 1-2 percent level.

Reference:

J. S McCarthy, I. Sick, R.R Whitney, "electromagnetic structure of helium isotopes" Phys. Rev. C15, number 4, 1396-1414 (1976).

I. Sick, "Model independent nuclear charge densities from elastic electron scattering", Nucl A218, 509-541(1974)

Amroun, Sick et al.,


Feb. 2015
Jefferson Lab Three-Year Schedule
Calendar Year
2015
2016
2017
Fiscal Year
2015
2016
2017
CEBAF
Activity
Beam
Comm.
Opportunistic Physics
Opportunistic Physics
Physics
Hall A
Activity
Activity
Beam
SBS Construction
Comm.
Opportunistic Physics
Opportunistic Physics
Physics
Hall B
Activity
Activity
Beam
CLAS12 Construction/Installation
Non-CLAS12 Ops
Comm.
Physics
Hall C
Activity
Activity
Beam
SHMS Construction/Installation
Comm.
Physics
Hall D
Activity
Beam
Comm.
Comm.
Opportunistic Physics
Physics
Beam for Commissioning
Beam for Physics
Non-CLAS12 Ops

Conclusion:

-Precision measurement of Isospindependence in 2N-SRCs

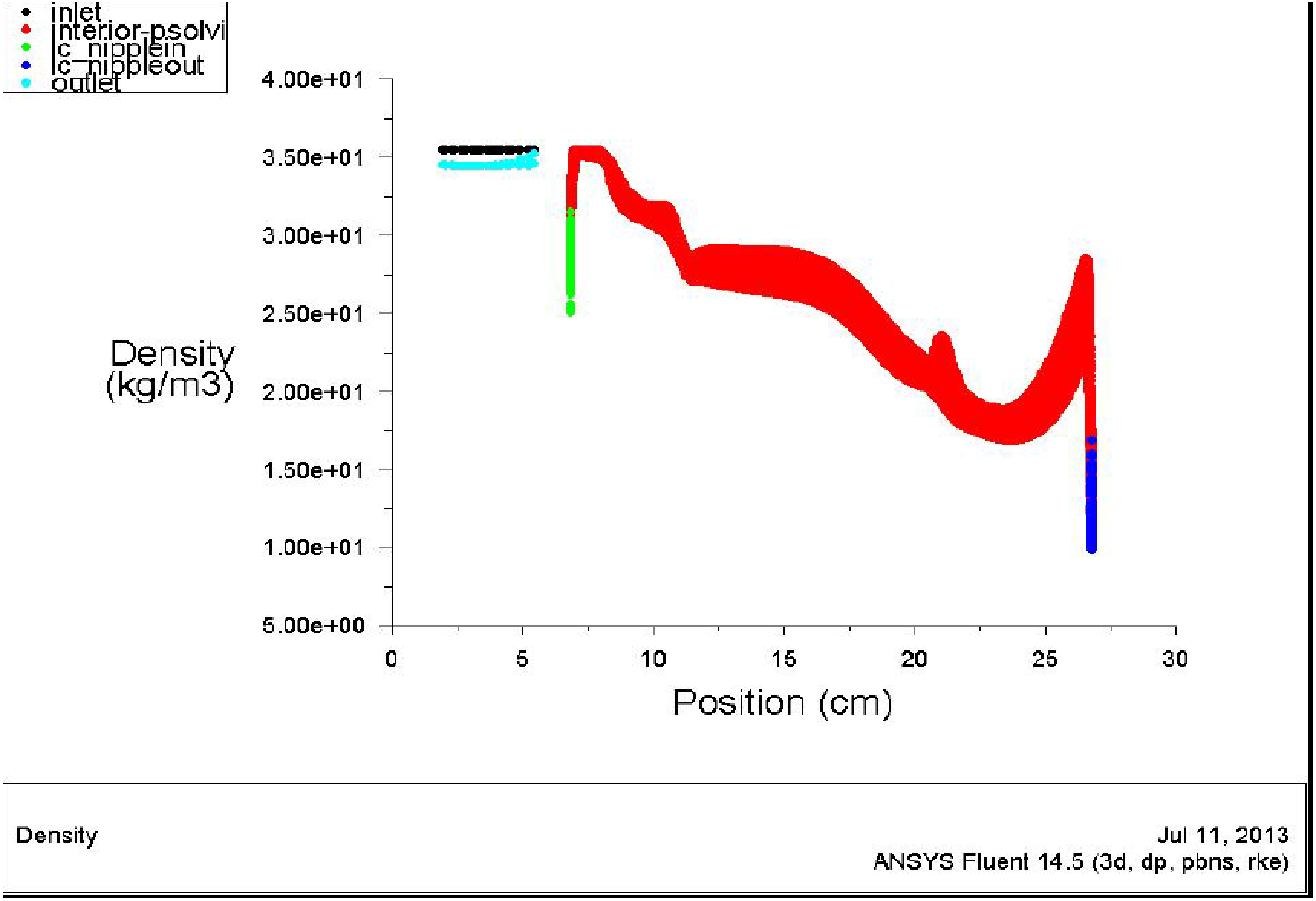
-Will get absolute cross section to study about 3N-SRCs structure. Compare to theoritical

-Will get the absolute value for thickness of target 3He and Tritium 3H.

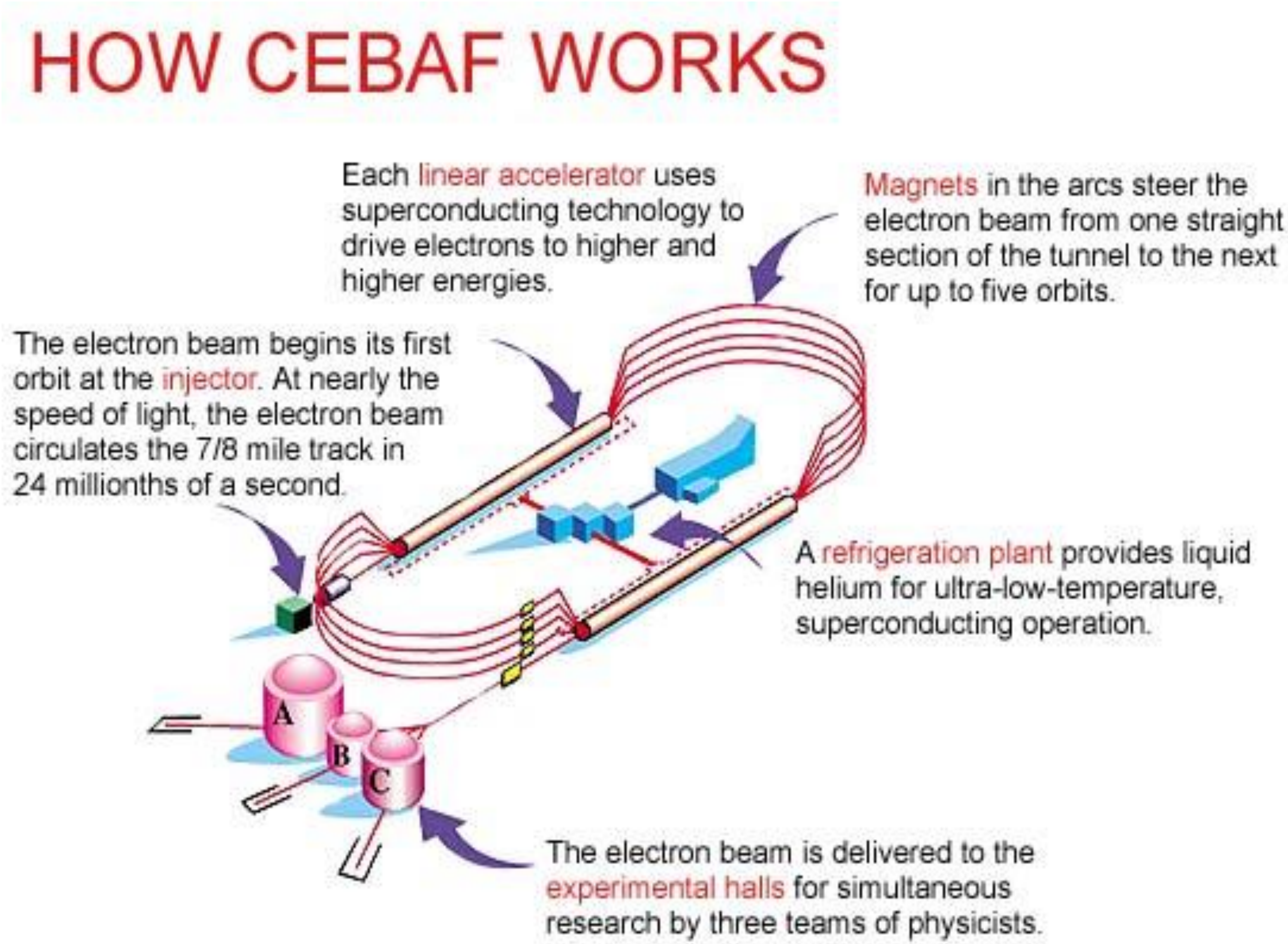
We are getting ready for exciting tritium experiment in 2016.

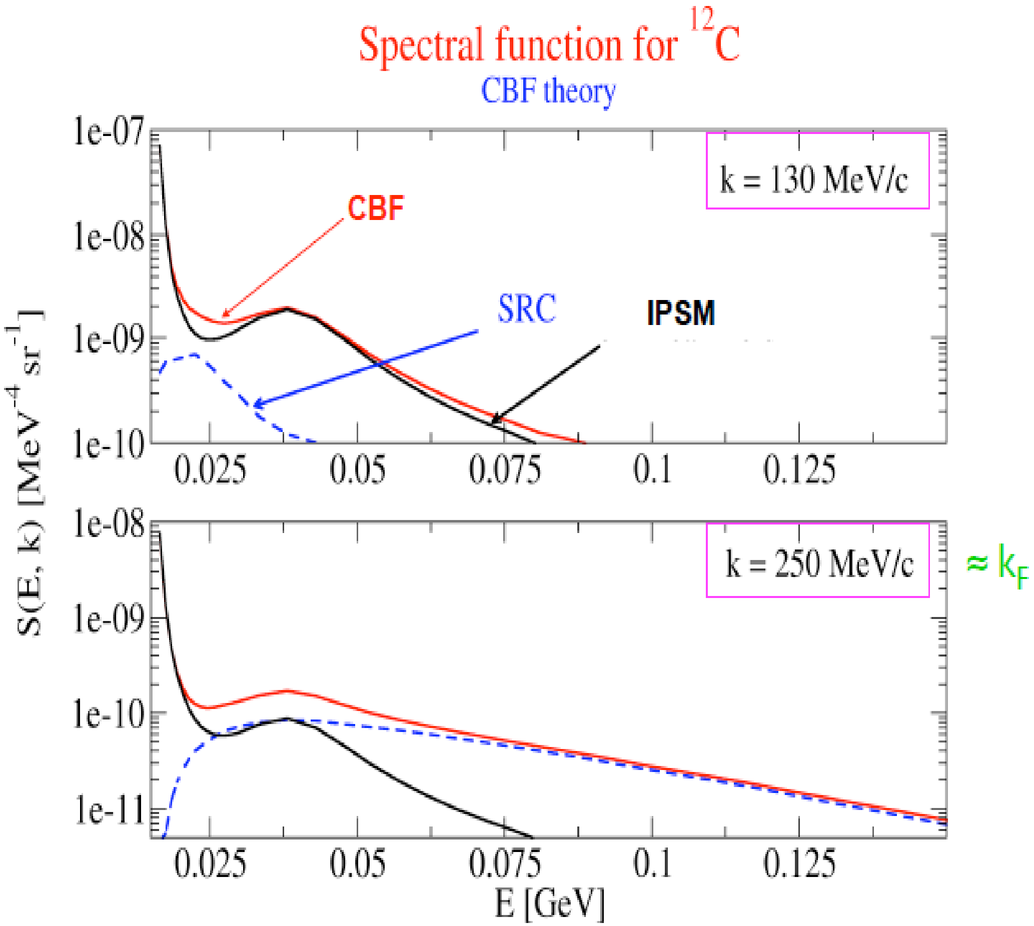
Thank you very much for your attention

Density profile

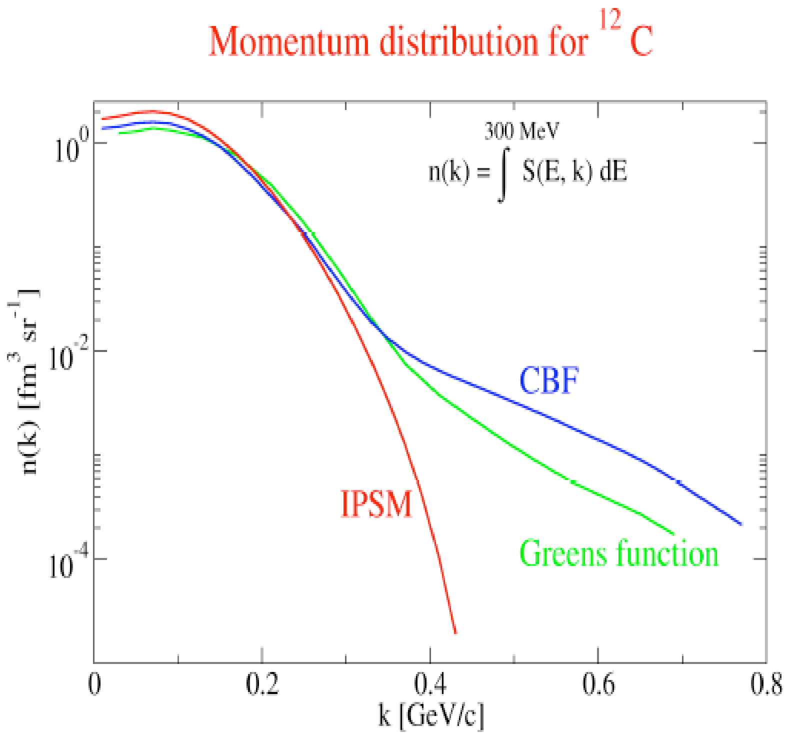


CEBAF in Jefferson Lab





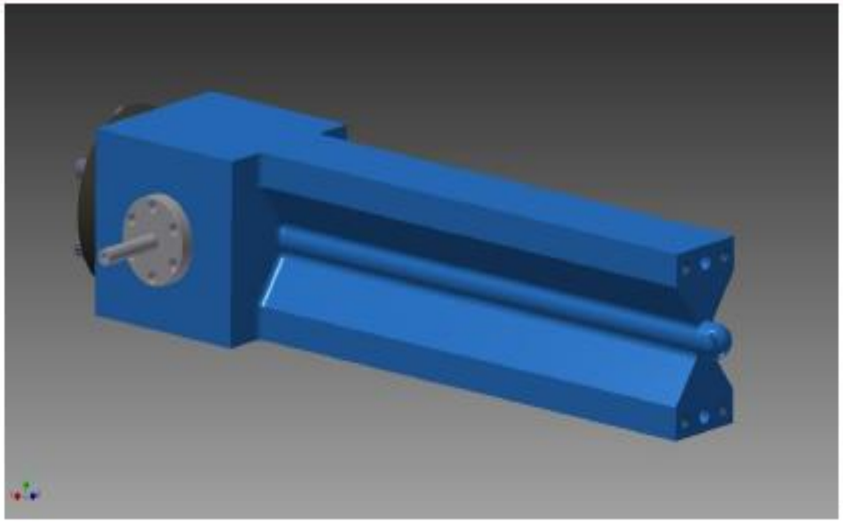
CBF: Correlated Basis Function theory
(Nucl. Phys.A505, 267 (1989))
Green Function approach (2^{nd} order)
(Phys. Rev. C52, 2955 (1995))

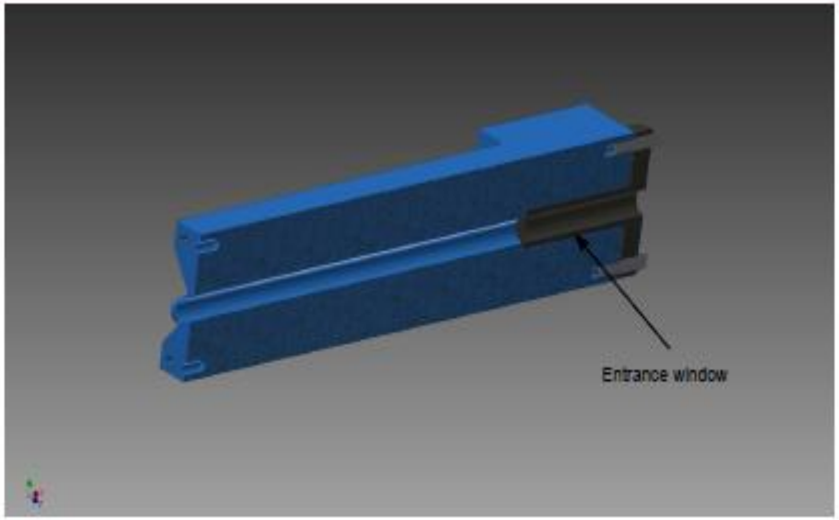


k<kF : single-particle contribute dominates
k~kF : SRC already dominated for E>50 MeV
K>kF: single-particle ignorable

Signature of SRCs at high momentum of momentum distribution

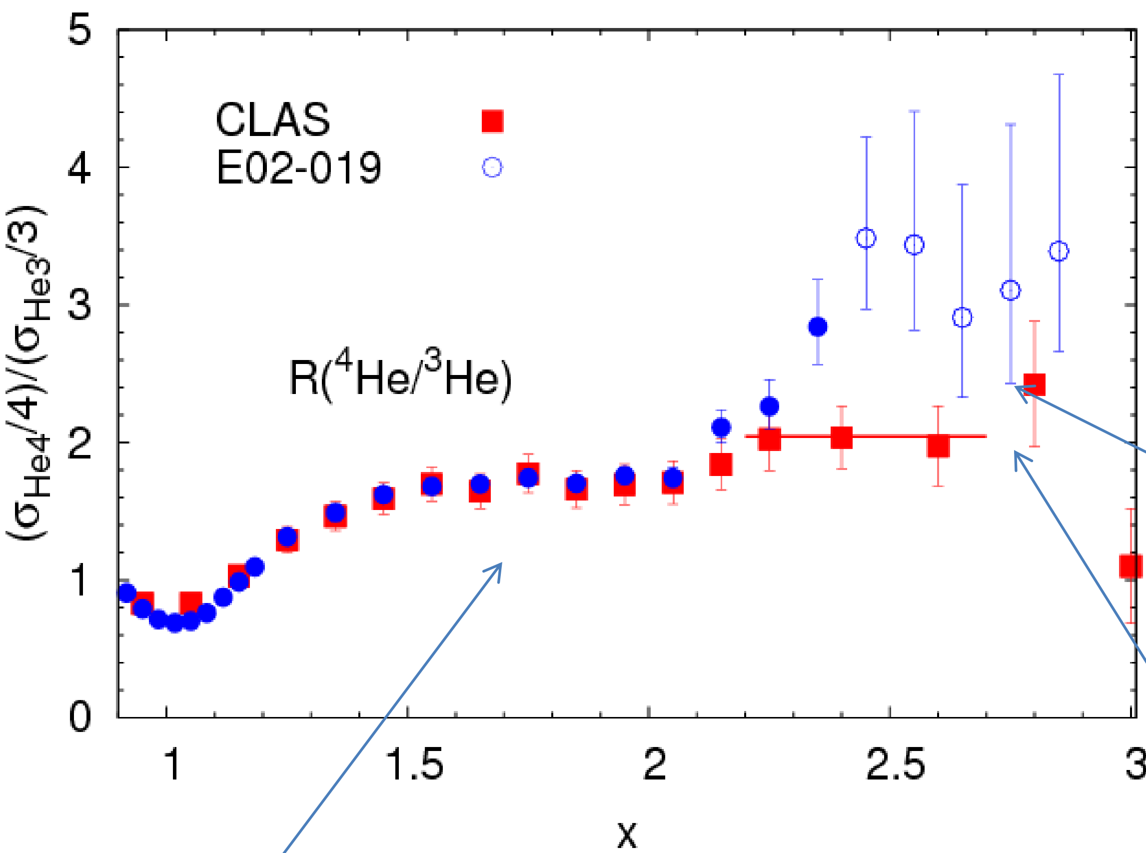
Target design and pressure testing

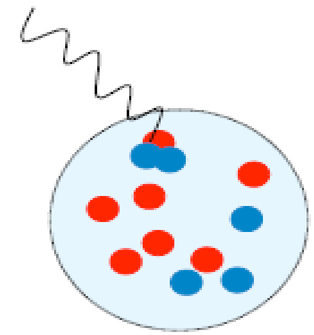




- Prototype cell made at Rutgers U. machine shop
- Made from Al 7075-T651
- Entrance windows attached with CF flange
- Design pressure: T2 = 200 psi, 3He = 375 psi
- Contains 1 kCi of T2
- Window thicknesses: entrance: 0.010 inch, exit: 0.010-0.018 inch, wall: 0.018 inch

How about 3N- SRCs ?





3N SRCs: 2<x<3

Disagreement in 3N-SRC region

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

Douglas and O. Hen paper

Good agreement in 2N-SRC region

New data (x>2) from Jlab experiment E08014 is coming (zhihong Yez phd thesis)