Probing Nucleon-Nucleon Correlations via the (e,e'), (e,e'p) and (e,e'pN) Reactions

presented by

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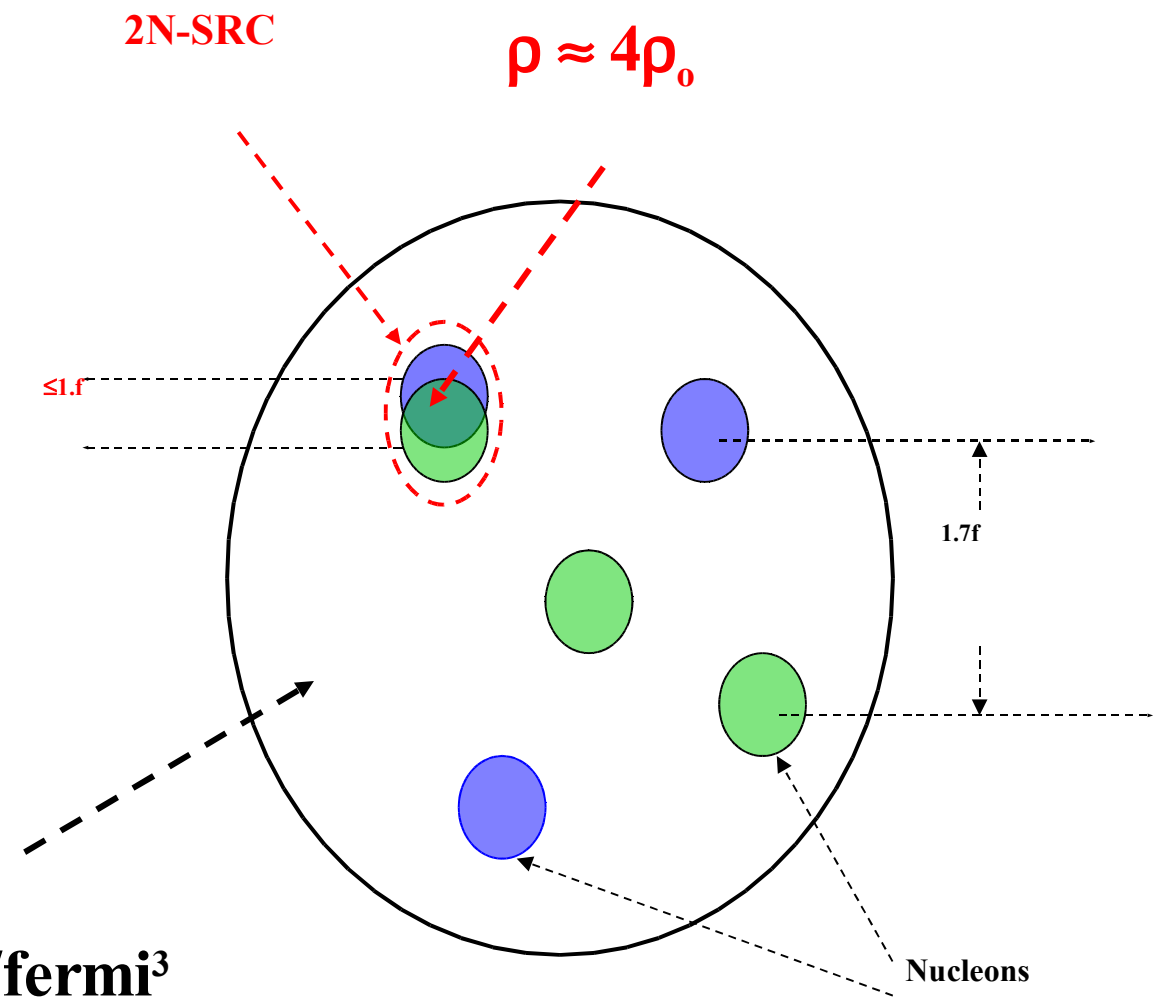
Jefferson Lab

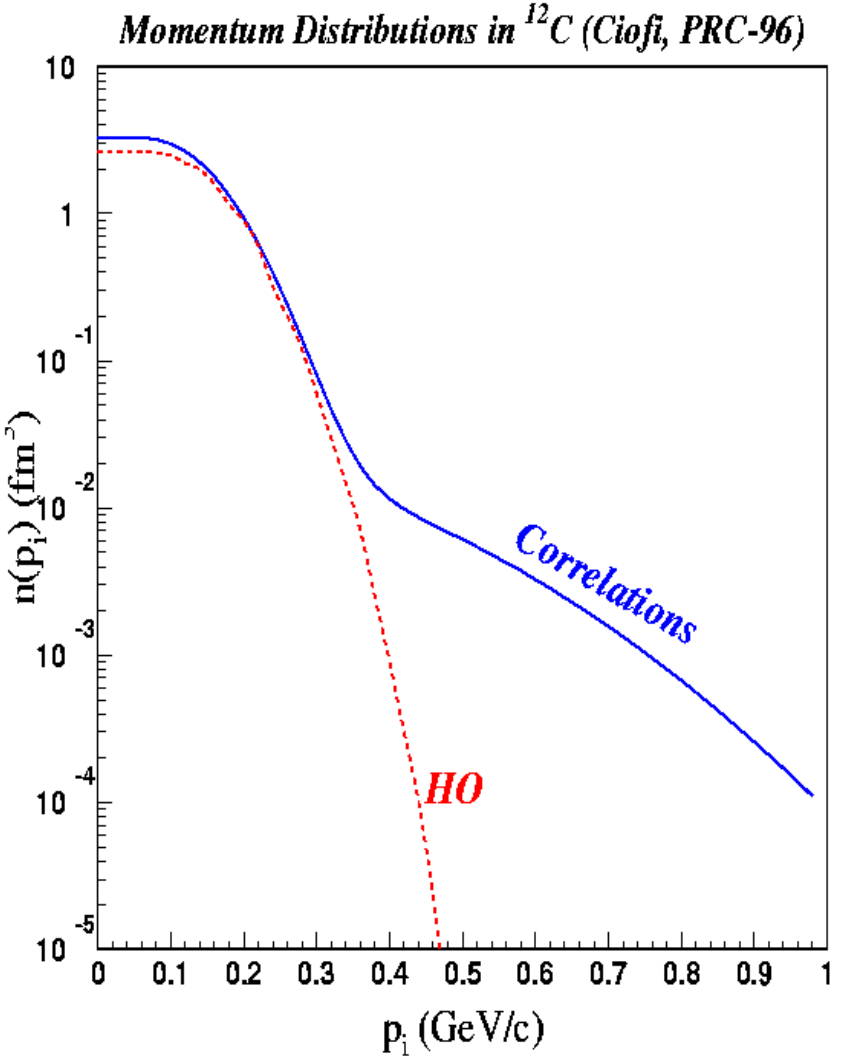
Picture of 2N-Short Range Correlations



$\rho_o = 0.17$ GeV/fermi^3

Questions

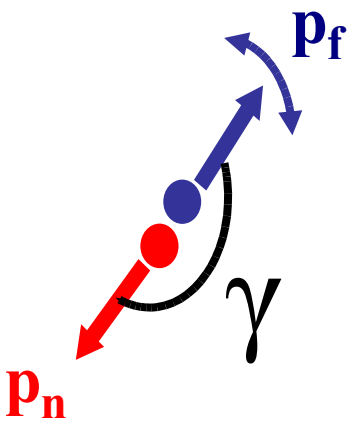
- What fraction of the momentum distribution is due to 2N-SRC?
- What is the relative momentum between the nucleons in the pair?
- What is the ratio of pp to pn pairs?
- Are these nucleons different from free nucleons (shape, mass, etc.)?



Brookhaven EVA Collaboration Result

A. Tang *et al.*, Phys. Rev. Lett. **90** (2003) 042301.

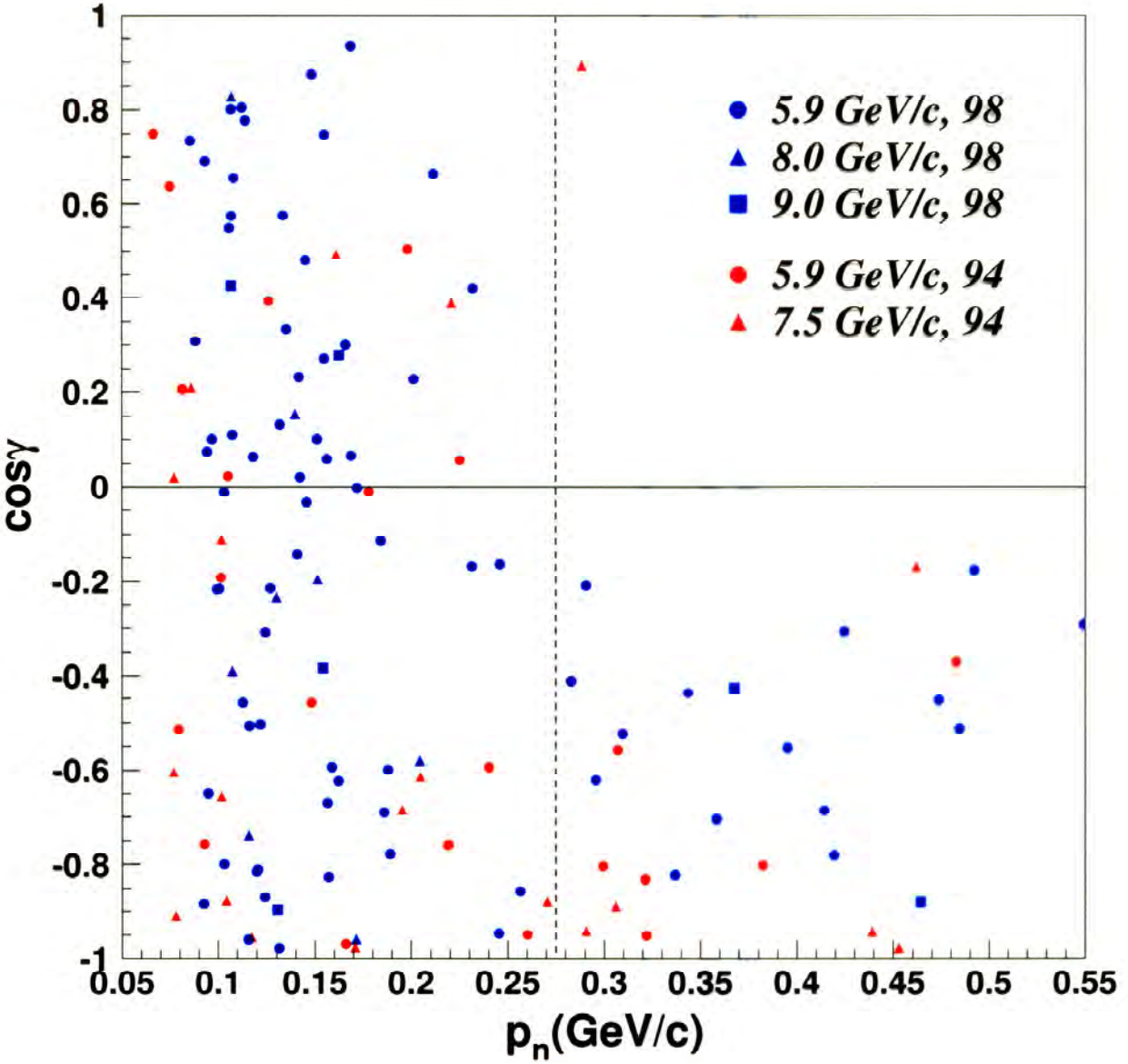
^{12}C(p,2p+n) Reaction



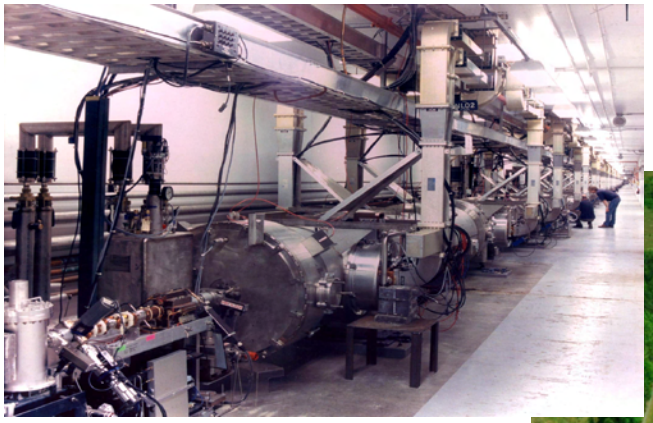
$p_f = p_1 + p_2 - p_0$

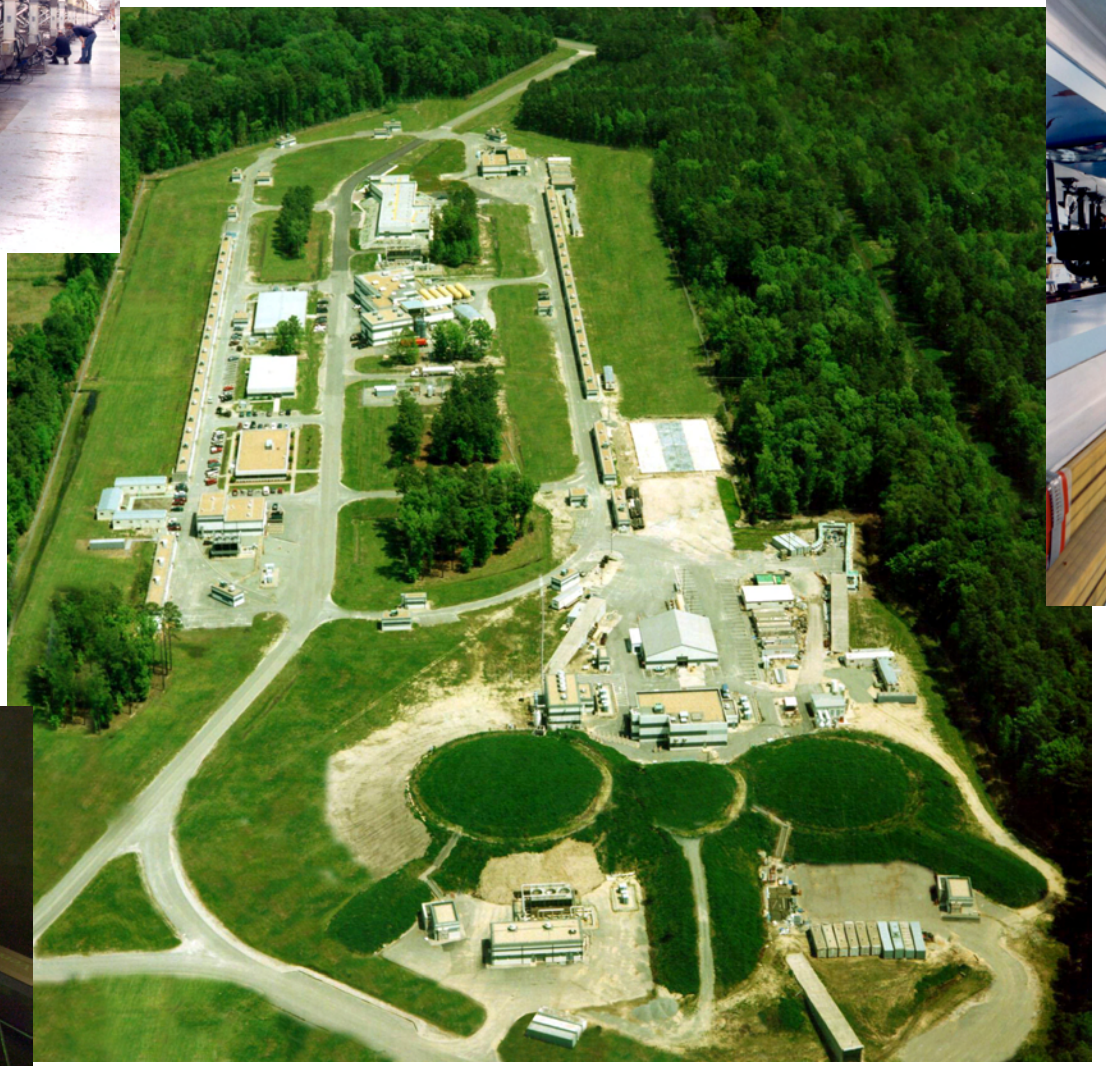
p_0 = incident proton

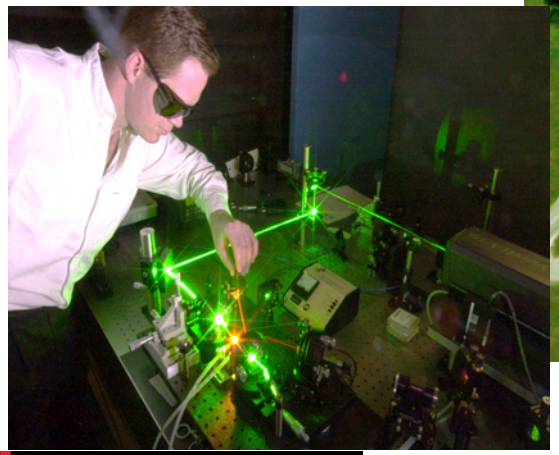
p1 and p2 are detected



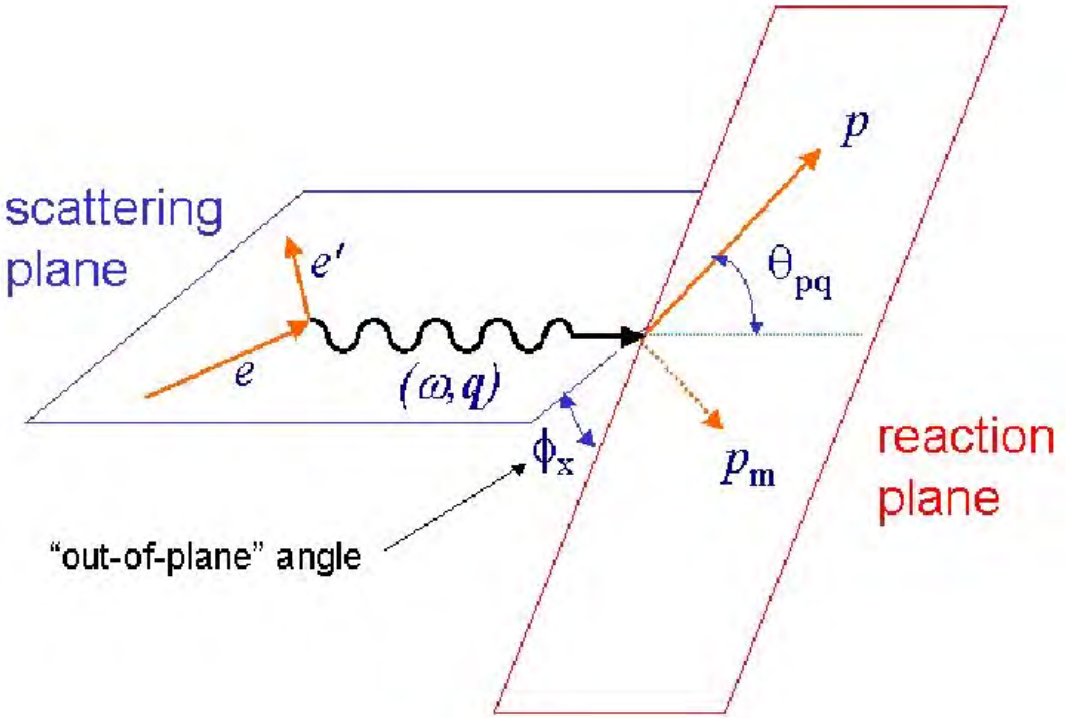
Jefferson Lab CEBAF







Review of Electro-production Kinematics



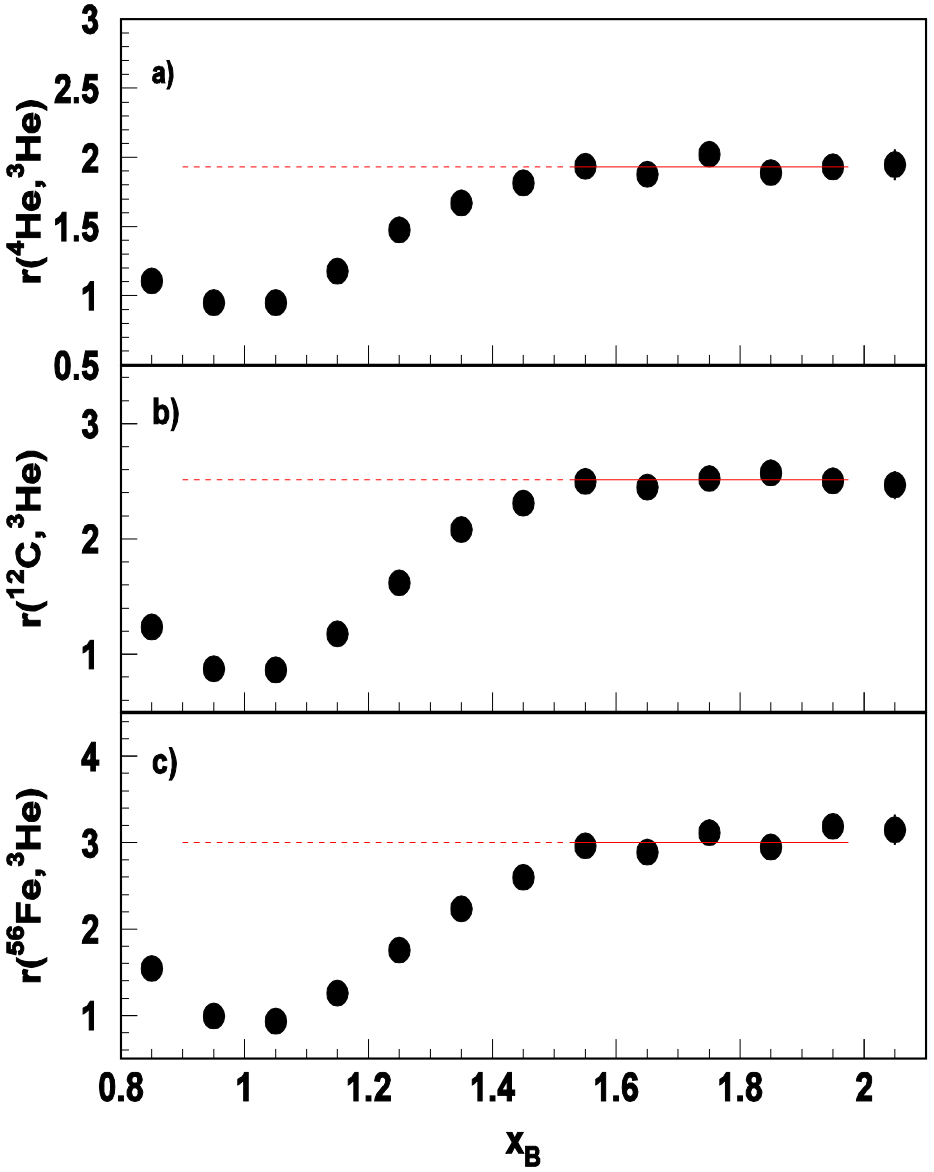
- $e - e' = \omega$
- $\omega^2 - \mathbf{q}^2 = -Q^2$
- $x_B = Q^2/2m\omega$
- $e_m = \omega - T_p - T_r$
- $\mathbf{p}_m = \mathbf{q} - \mathbf{p}$

$$\frac{d^6\sigma}{d\Omega_e d\Omega_p d\omega dp} = K\sigma_{ep}S(\vec{p}_m, \epsilon_m)$$

Let's build a picture of nucleons in Carbon from (e,e'), (e,e'p) and (e,e'pN) Reactions

CLAS A(e,e') Data

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



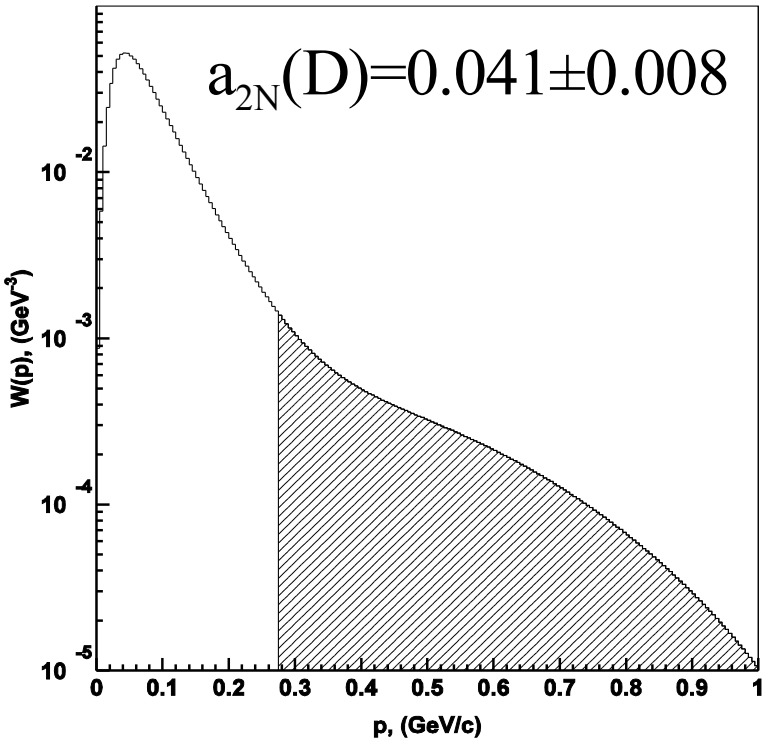
$$x_B = \frac{Q^2}{2M\nu} > 1.5,$$

$$Q^2 > 1.4\,GeV^2$$

The observed "scaling" means that the electrons probe the high-momentum nucleons in the 2N-SRC phase, and the scaling factors determine the per-nucleon probability of the 2N-SRC phase in nuclei with A>3 relative to ^{3}He.

Estimate of ^{12}C 2N-SRC

$$\frac{a_{2N}(^{12}C)}{a_{2N}(D)} = 4.93 \pm 0.27 \pm 0.28$$

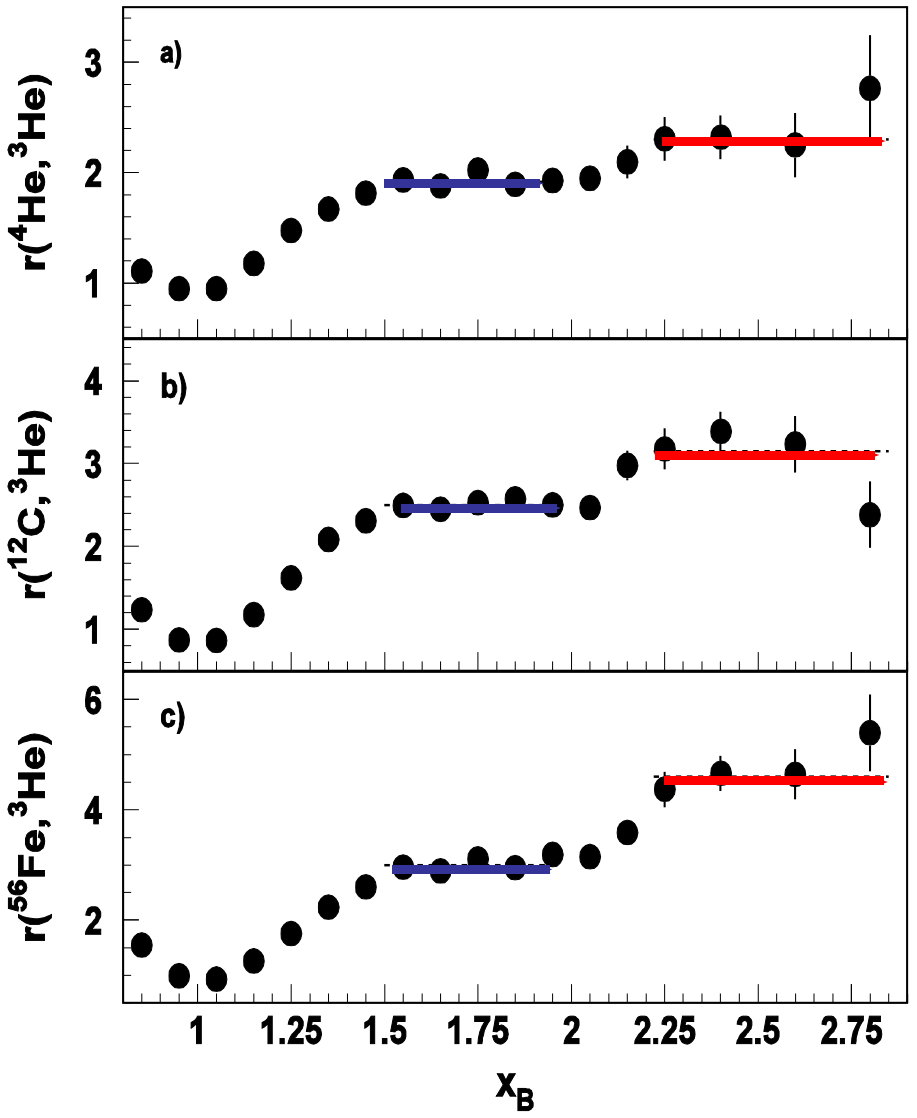


➡ **$a_{2N}(^{12}C) = 0.20 \pm 0.045$**

This includes all three isotopic compositions (pn, pp, or nn) for the 2N-SRC phase in ^{12}C.

New CLAS A(e,e') Result

K. Sh. Egiyan *et al.*, Phys. Rev. Lett., **96** (2006) 082501.



The probabilities for 3-nucleon SRC are smaller by one order of magnitude relative to the 2N SRC.

The observed "scaling" means that the electrons probe the high-momentum nucleons in the 3-nucleon phase, and the scaling factors determine the per-nucleon probability of the 3N-SRC phase in nuclei with A>3 relative to ^{3}He.

Less than 1% of total.

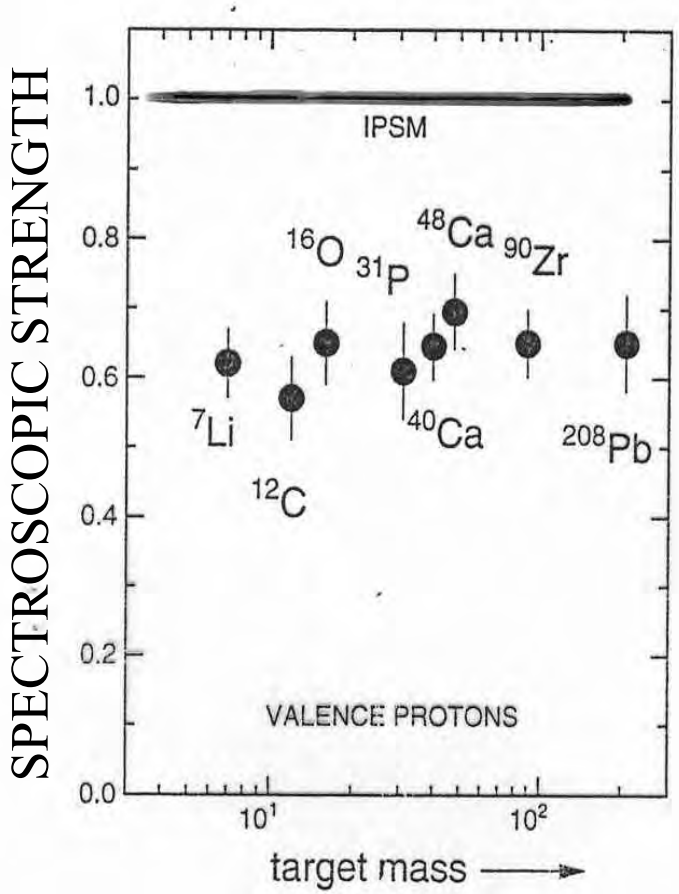
From the (e,e') Data

- 80 +/- 5% - single particles moving in an average potential
- 20 +/- 5% - two-nucleon short range correlations
- Less than 1% multi-nucleon corrections

Now Include (e,e'p) Data

Independent Particle Shell Model is based upon the assumption that each nucleon moves independently in an average potential (mean field) induced by the surrounding nucleons.

The (e,e'p) data for knockout of valance and deeply bound orbits in nuclei gives a spectroscopic factors that are 60 – 70% of the mean field result.

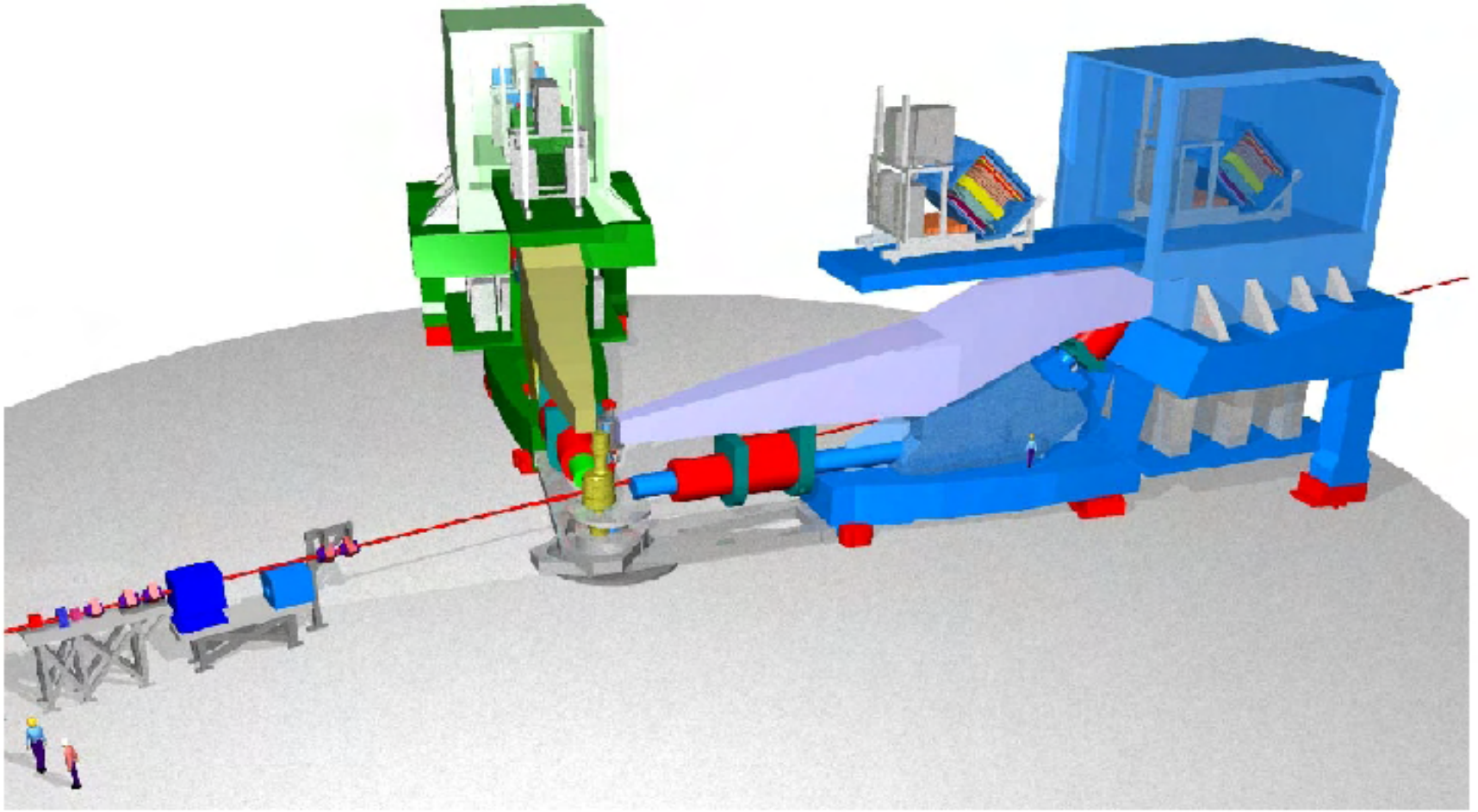


Spectroscopic strength for knocked out valence protons measured with the reaction (e, e'p), relative to the independent-particle-shell model prediction.

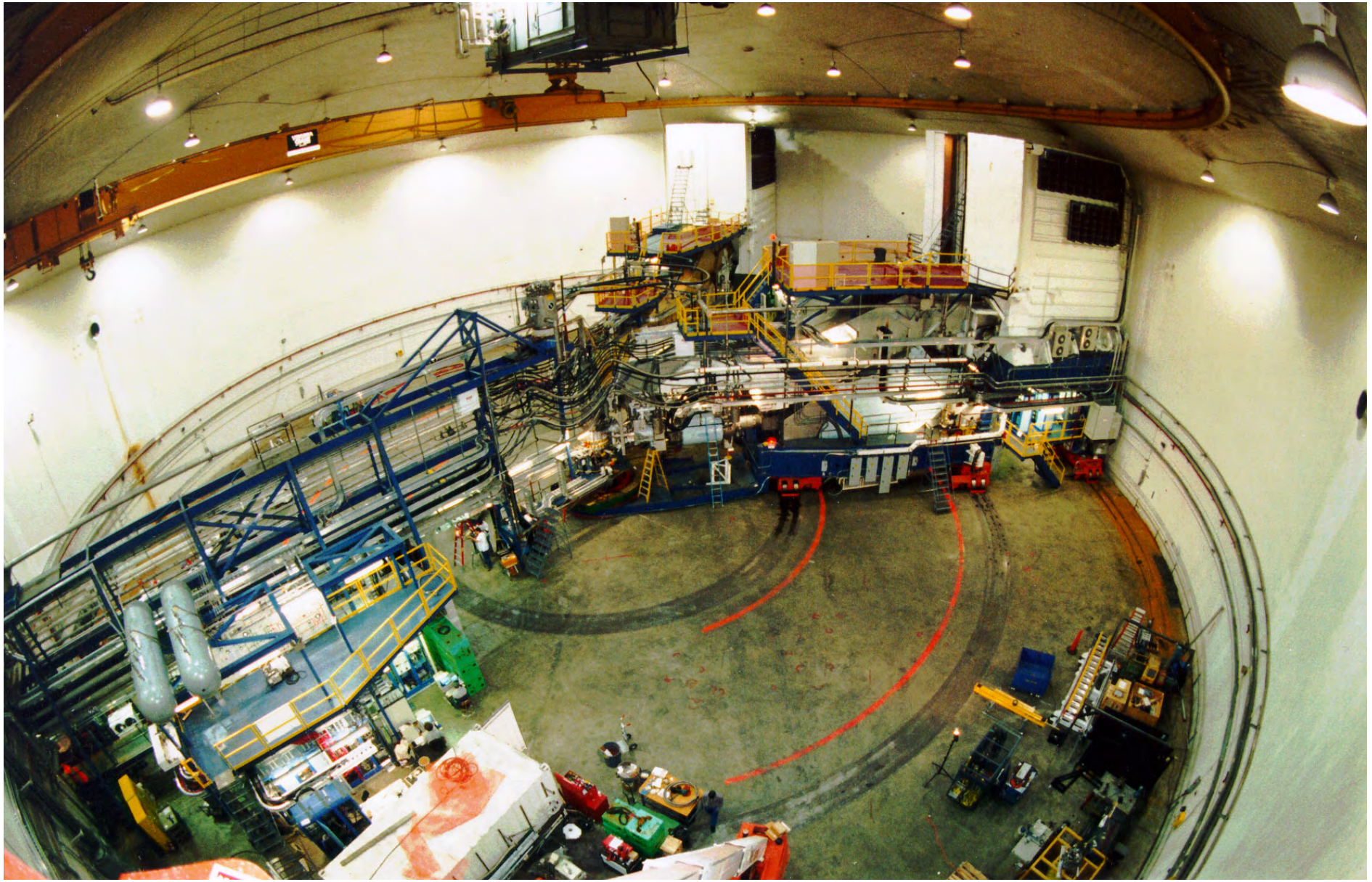
From the (e,e') and (e,e'p) Measurements

- 80 +/- 5% - single particles moving in an average potential
  - 60 – 70% independent single particle
  - 10 – 20% long range correlations
- 20 +/- 5% - two-nucleon short range correlations
- Less than 1% multi-nucleon corrections

Jefferson Lab's Hall A

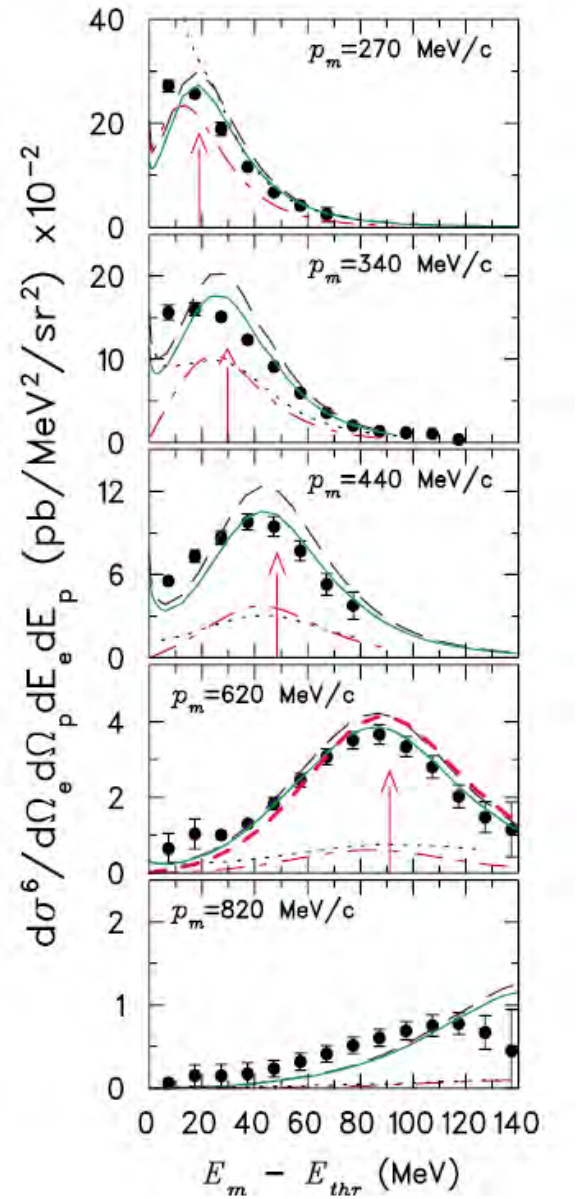


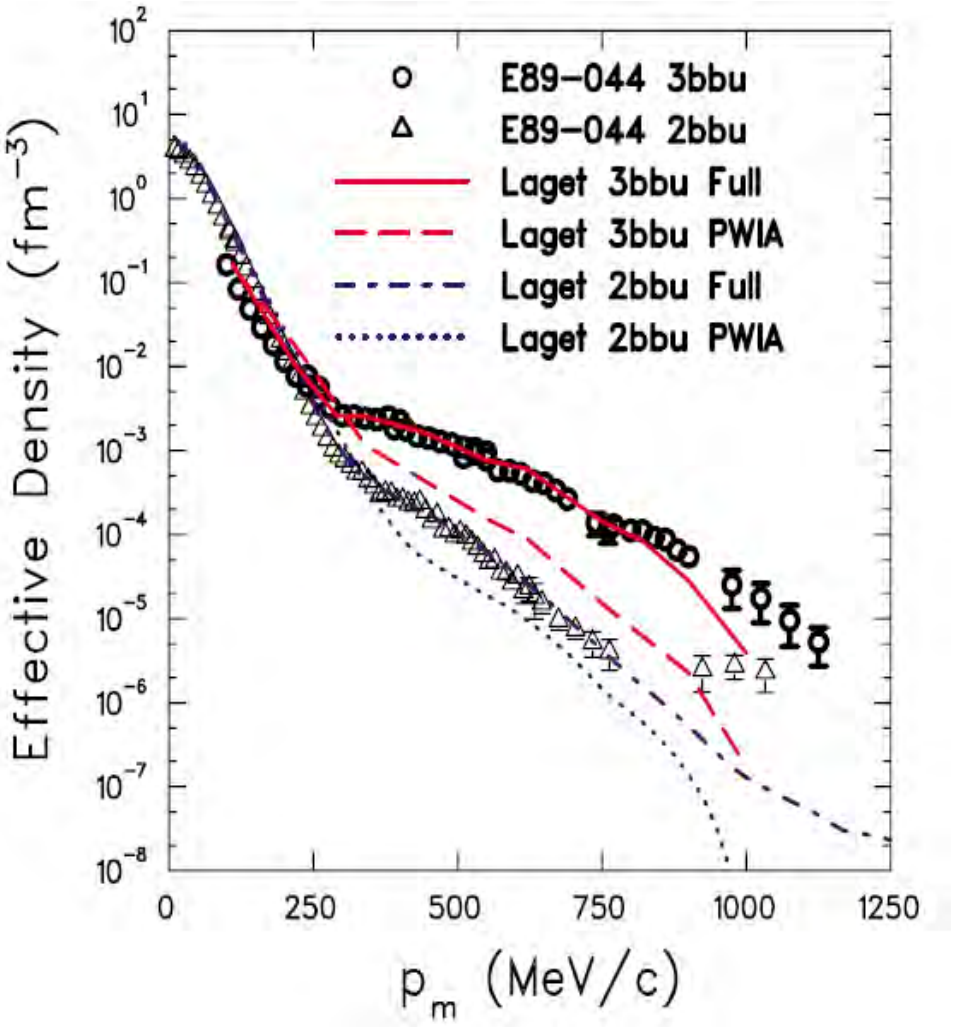
Jefferson Lab's Hall A



E89-044 ^{3}He(e,e'p)pn Results

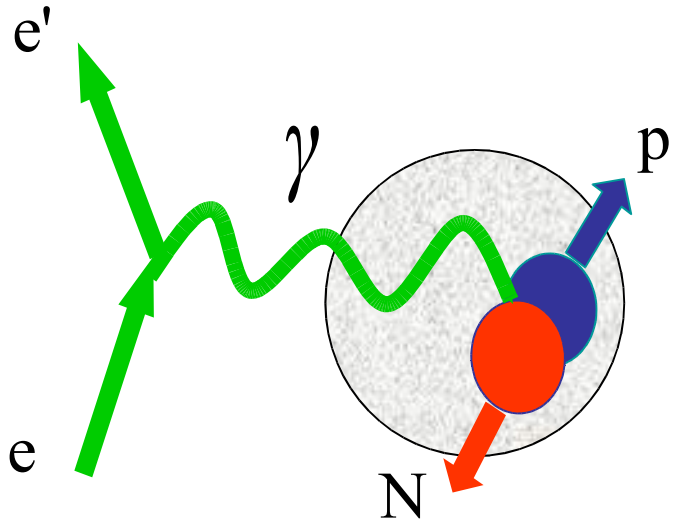
F. Benmokhtar *et al.*, Phys. Rev. Lett. **94** (2005) 082305.





Further Studying Nucleon Pairs

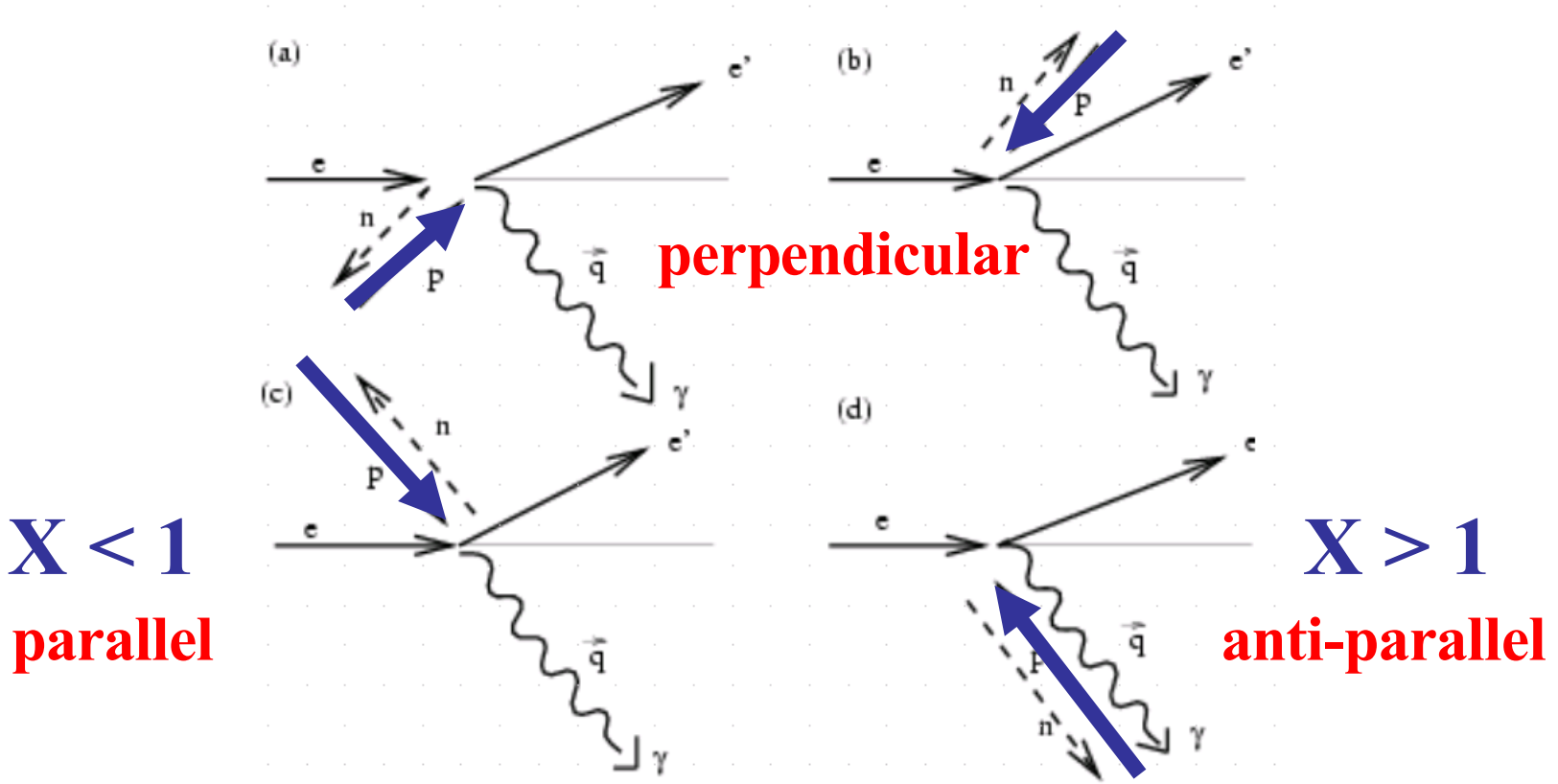
To study nucleon pairs at close proximity and their contribution to the large momentum tail of nucleons in nuclei.



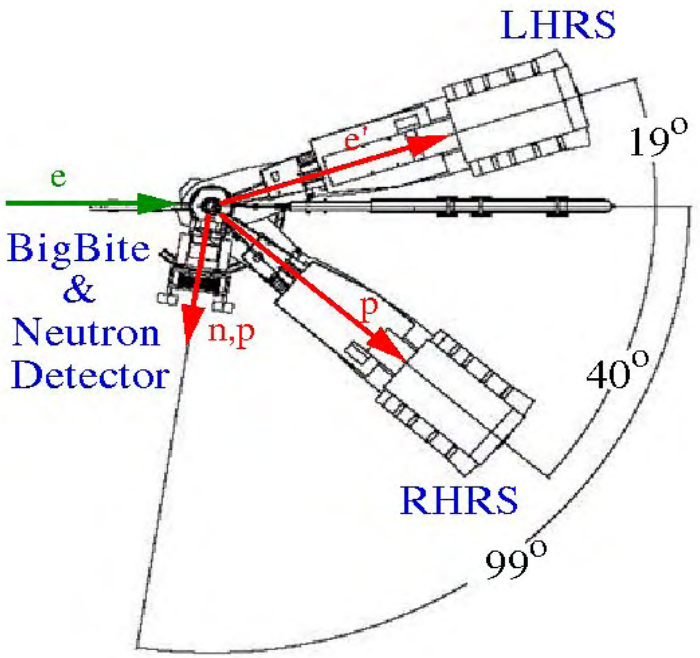
A pair with "large" relative momentum between the nucleons and small CM momentum

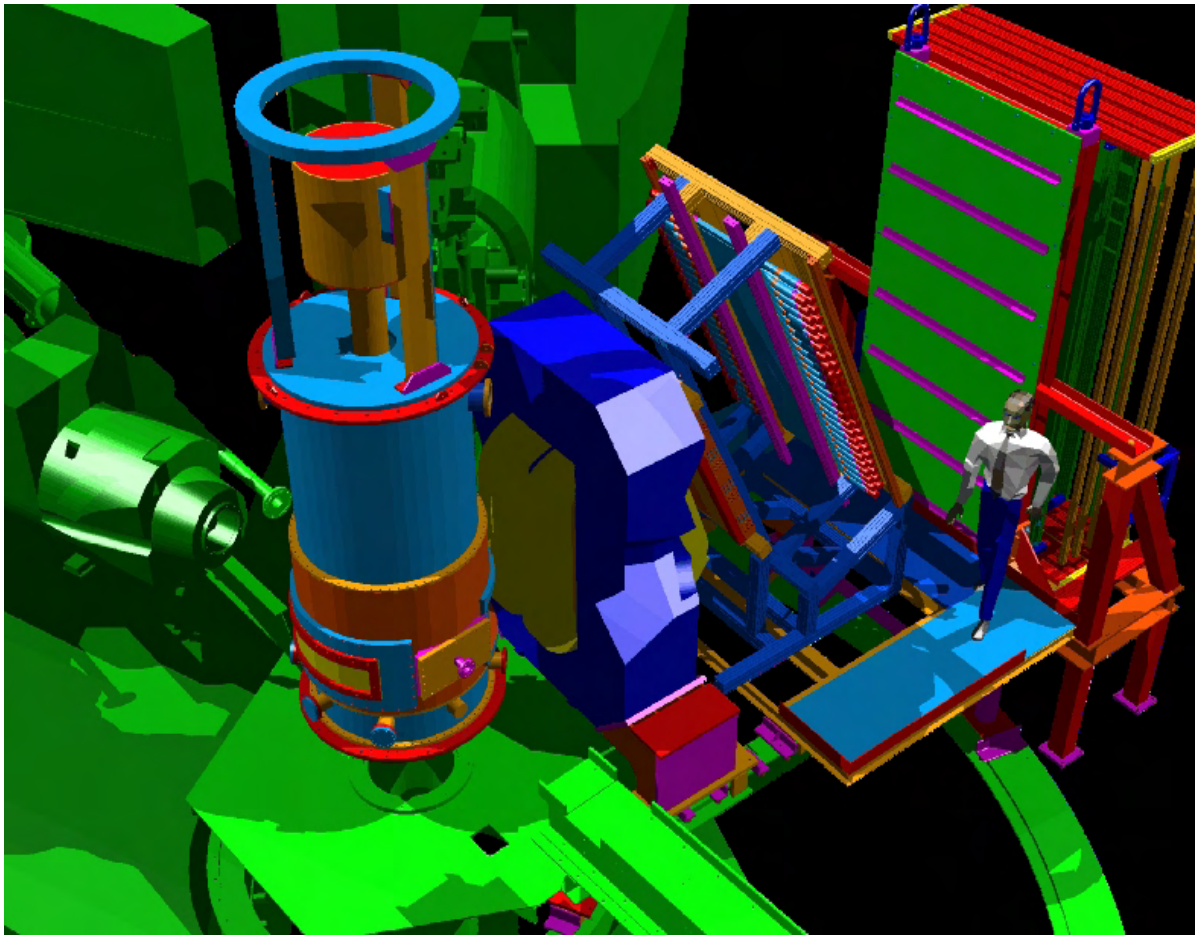
Customized (e,e'pN) Measurement

- high Q^2 minimizes MEC which are reduced as $1/Q^2$
- $x_B > 1$ to suppress isobar contributions
- anti-parallel kinematics to suppress FSI



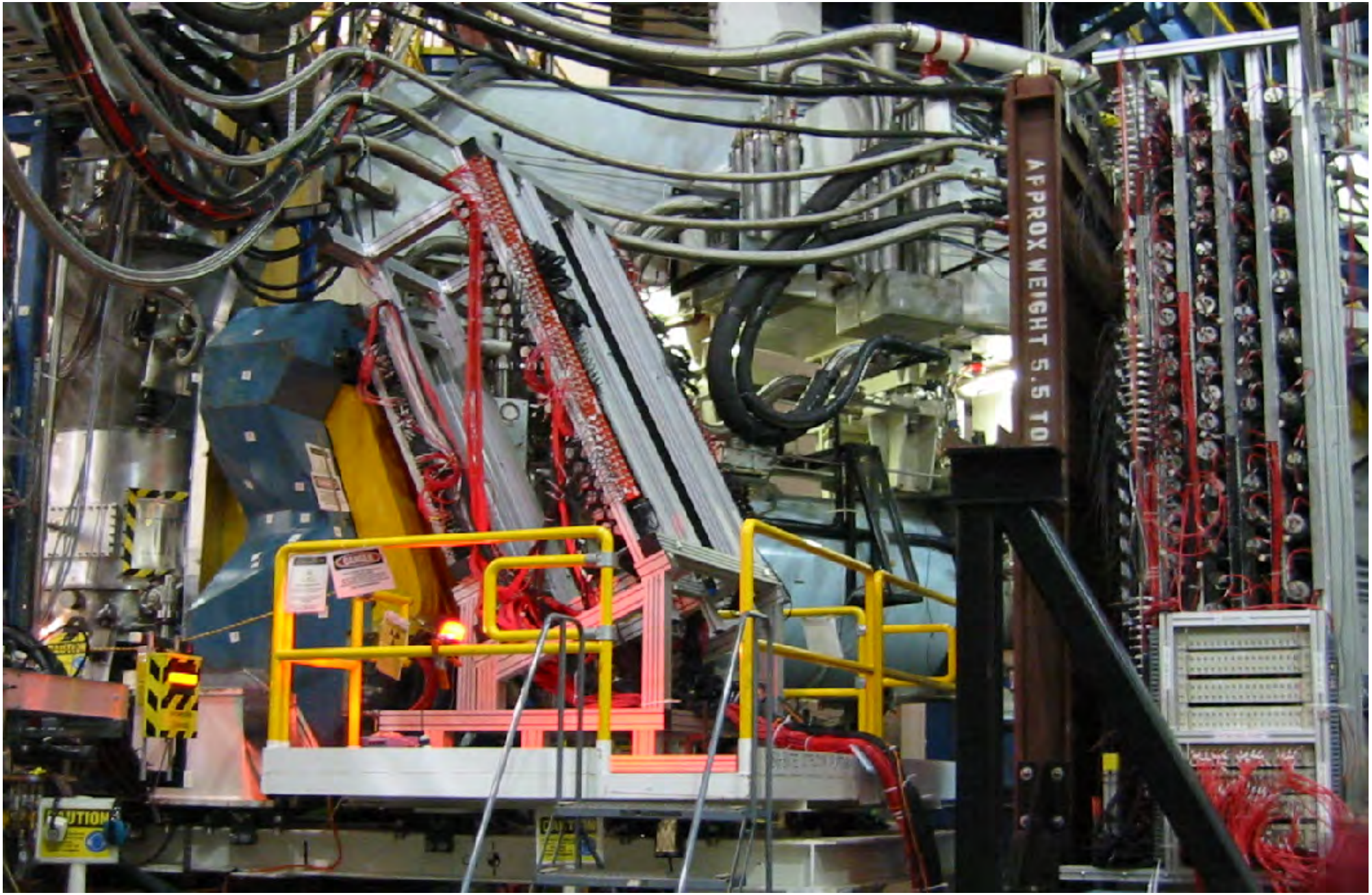
Hall A SRC Experimental Setup





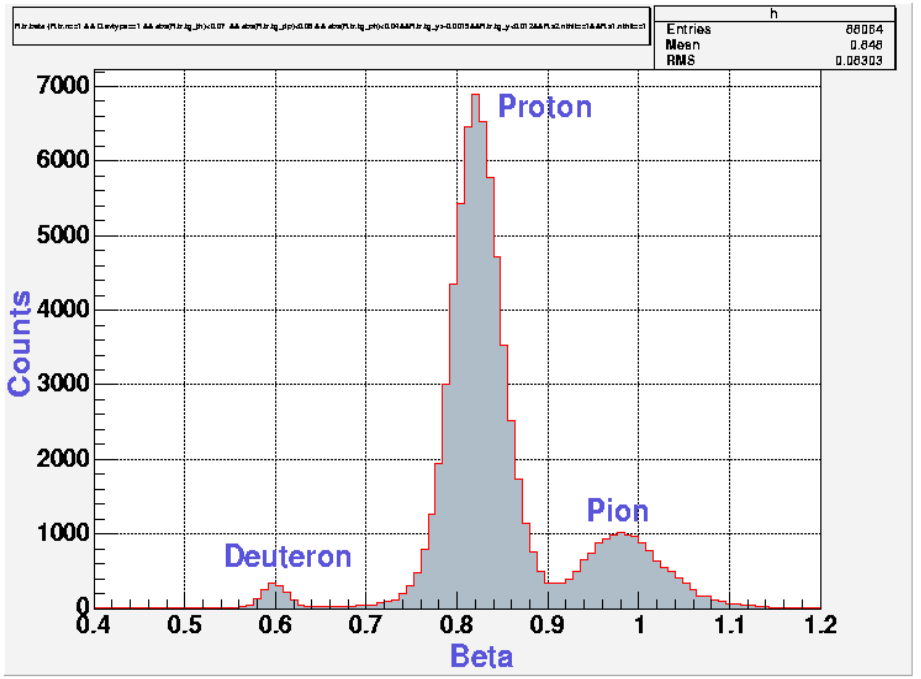
New BigBite Hadron Spectrometer (100 msr)
New Low Energy Neutron Detector
New Scattering Chamber

BigBite Spectrometer During SRC Experiment

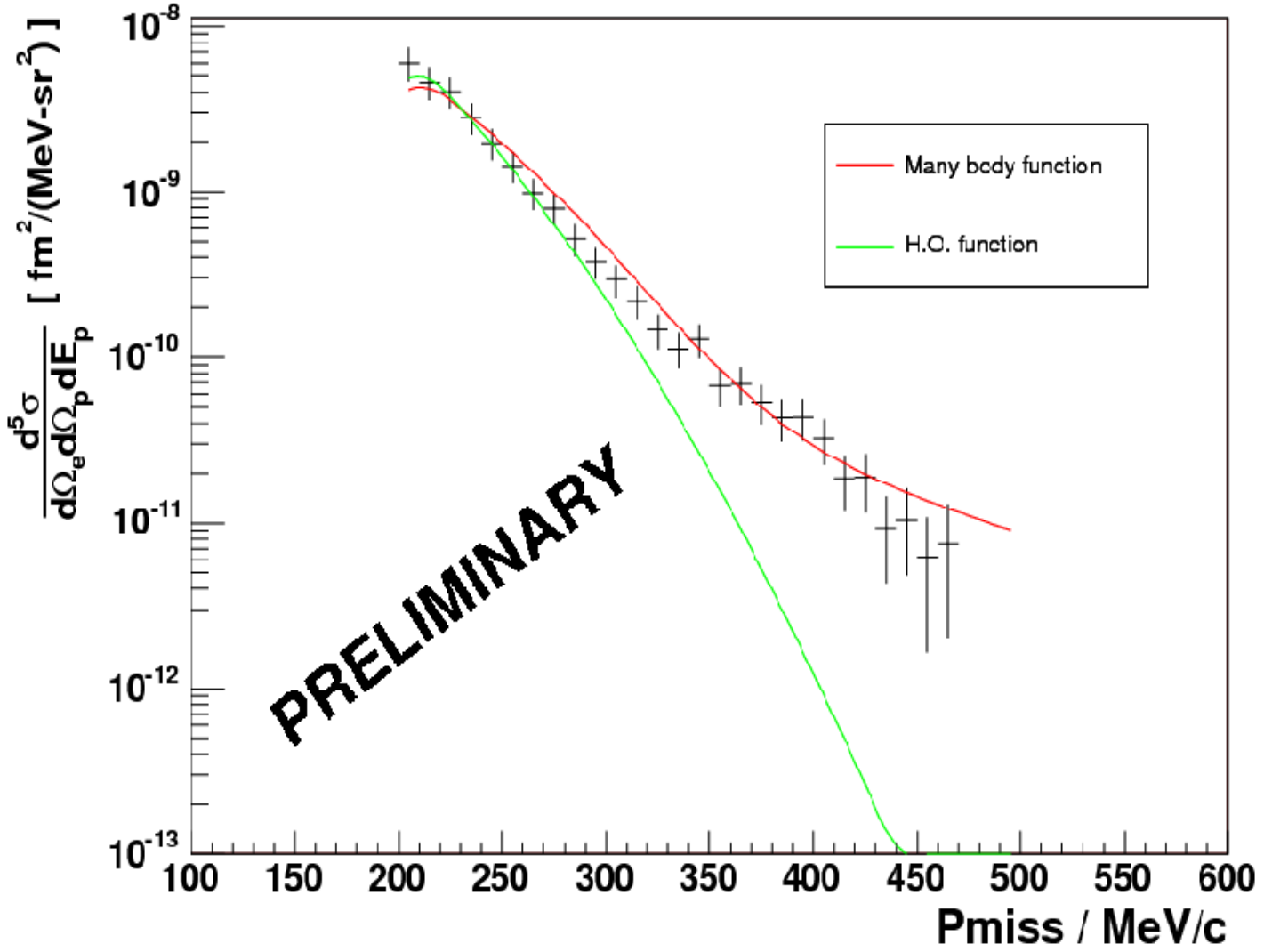


Expected Results

- Determination of the fraction of the (e,e'p) events which are associated with two-nucleon short range correlations as a function of the missing momentum from 200 to 650 MeV/c.
- Direct comparision of the ratios of pp and pn SRC pairs.
- Determination of the pair kinematic quantities.
- Presently investigating $^{12}C(e,e'dN)$ Neil Thompson, Glasgow.

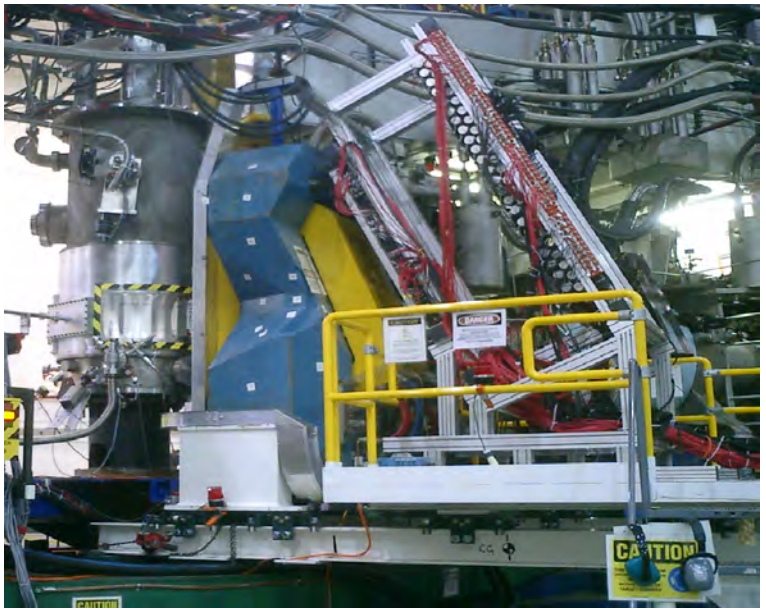


$^{12}C(e,e'p)^{11}B$ *Peter Monaghan (MIT)*

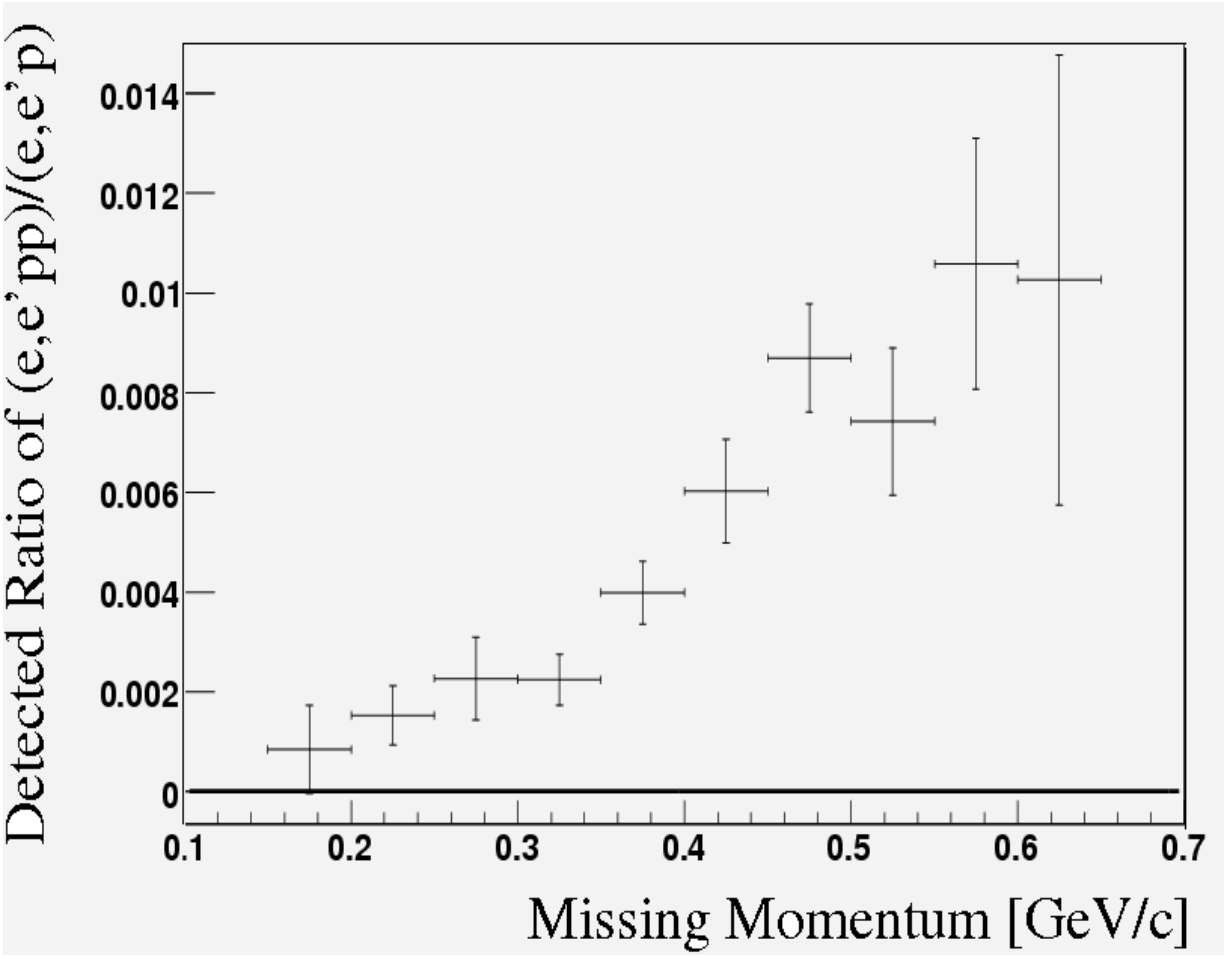


Analysis of the $^{12}C(e,e'p)$ continuum cross sections underway.

^{12}C(e,e'pp) *Ran Shneor (Tel Aviv University)*

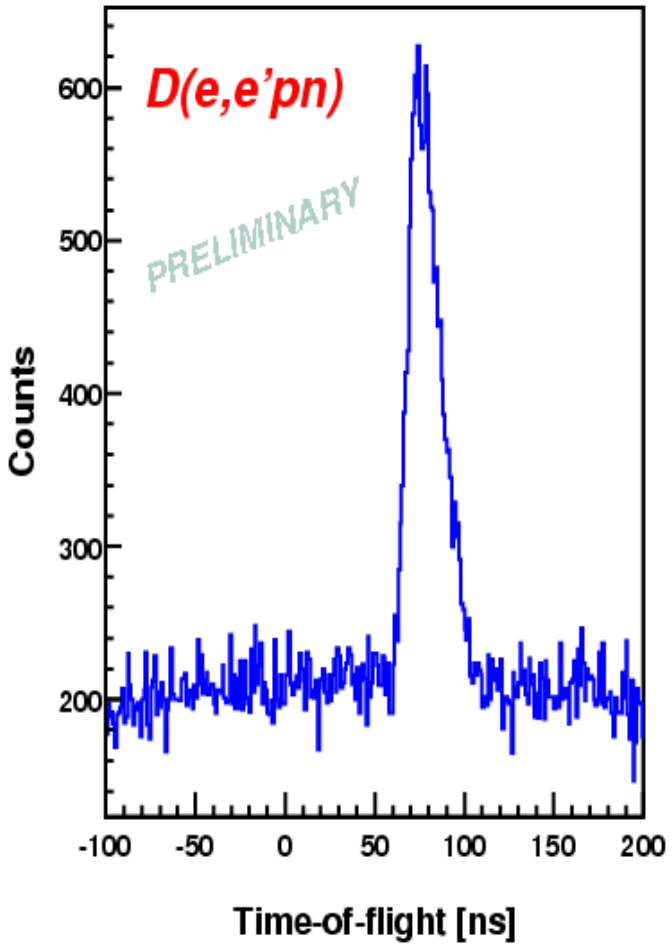


Raw ratio of detected recoiling protons.

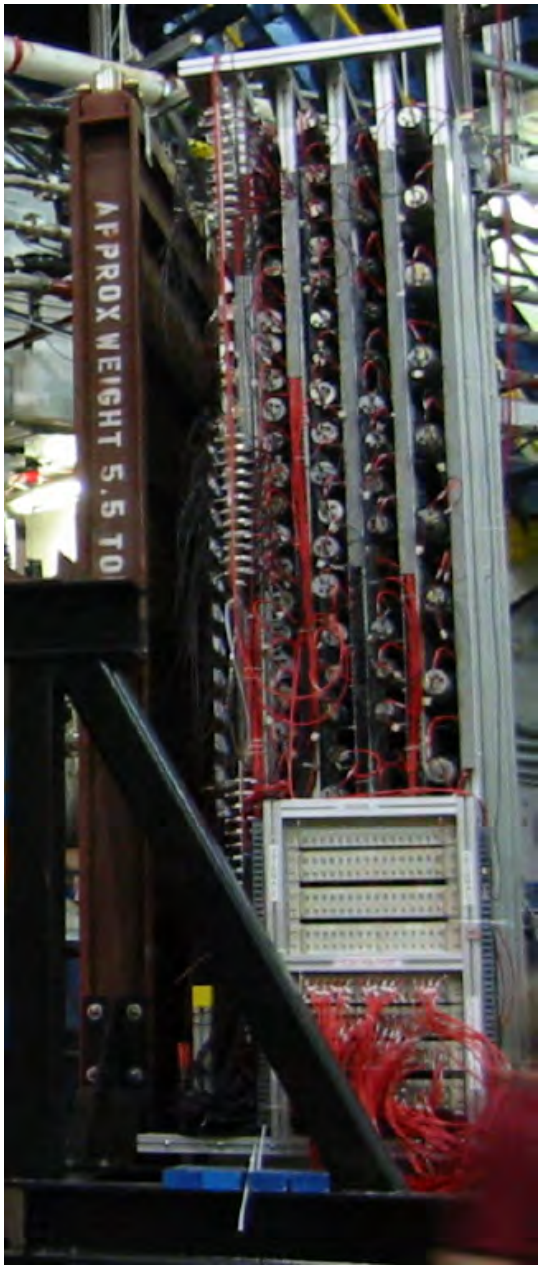


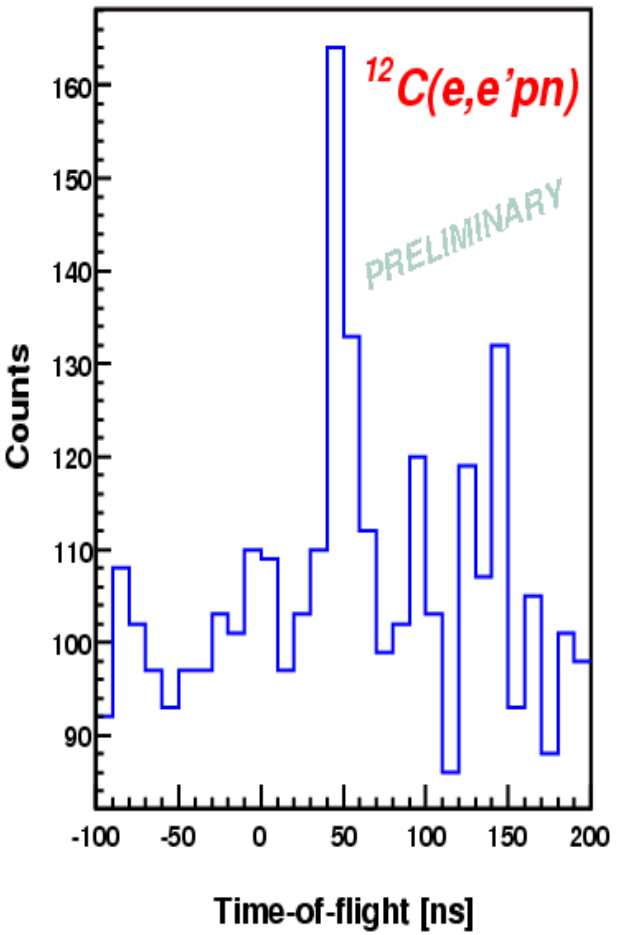
Correcting for the finite acceptance of BigBite yields nearly 10% for the ratio of (e,e'pp)/(e,e'p).

^{12}C(e,e'pn) *Ramesh Subedi (Kent State University)*



Deuterium used to determine absolute neutron detection efficiency.





Correcting for detection efficiency, there are more recoiling neutrons then protons.

Summary

By combining (e,e'), (e,e'p) and (e,e'pN) measurements a coherent picture of the nucleons within the ^{12}C nucleus is emerging.

- 80% single particles moving in an average potential
  - 60 – 70% independent single particle
  - 10 – 20% long range correlations
- 20% two-nucleon short range correlations
  - from (e,e'pp) 1-2% pp SRC
  - exact ratio for (e,e'pn) / (e,e'pp) soon, but clearly pn dominance
  - combining results we can deduce 1-2% nn SRC
- less than 1% multi-nucleon correlations

E89-044 ^{3}He(e,e'p)d Results

M. Rvachev *et al.*, Phys. Rev. Lett. **94** (2005) 192302.

- x_B= 1
- fixed (**q**,w) kinematics
- Q^2 =1.5 [GeV/c]^2
- low p_m PWIA works
- medium p_m FSI
- high p_m multiple effects
  - R. Schiavilla *et al.*,nucl-th/0508048