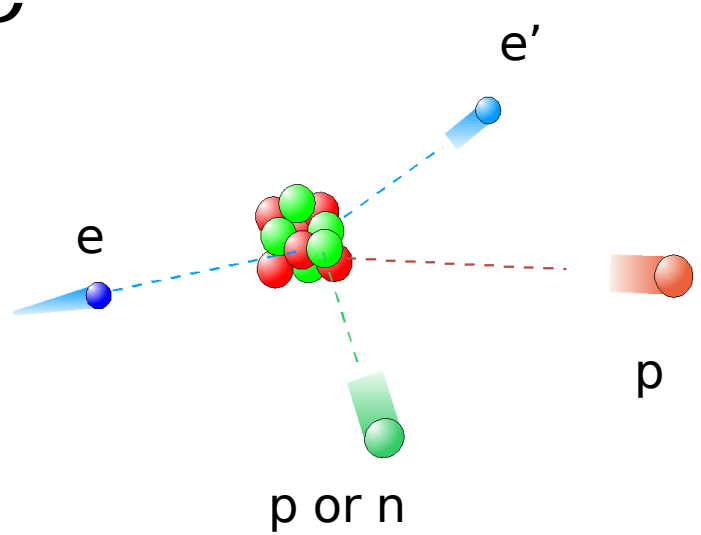
Studying Short Range Correlations in Nuclei at the Repulsive Core Limit via the Triple Coincidence *(e,e'pN)* Reaction



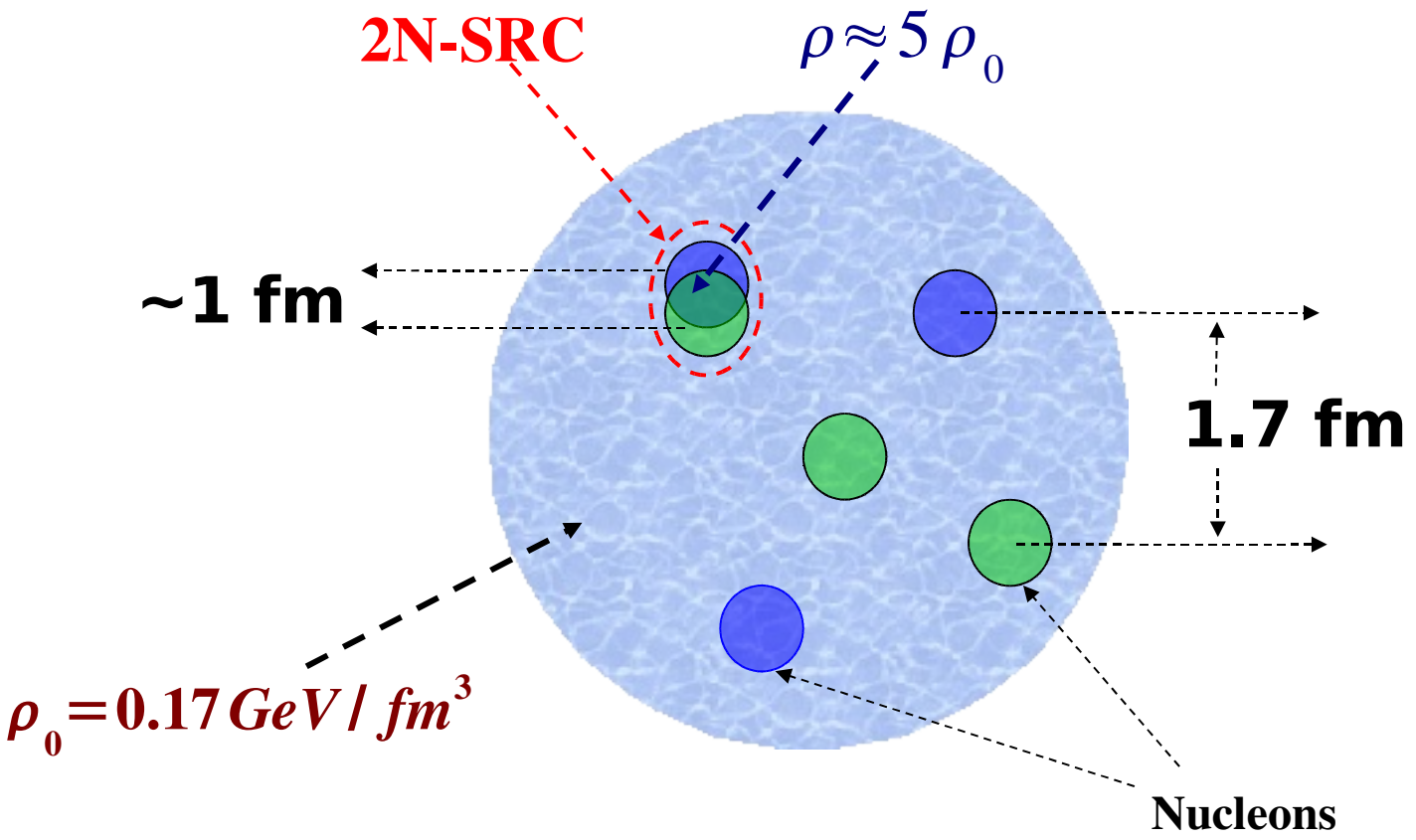
Hall A / TJNAF

Proposal 07-006
(Next Generation of E01-015)

Bryan Moffit
Hall A Collaboration Meeting

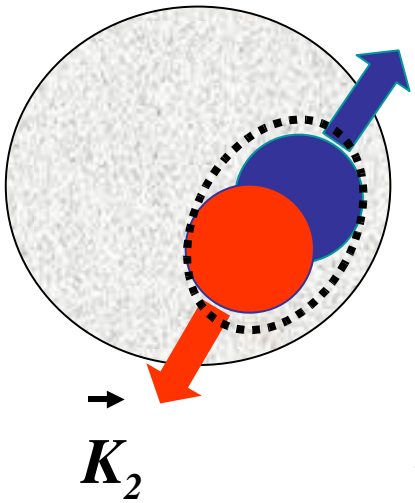
Jefferson Lab

2N-Short Range Correlations (2N-SRC)



2N-Short Range Correlations (2N-SRC)

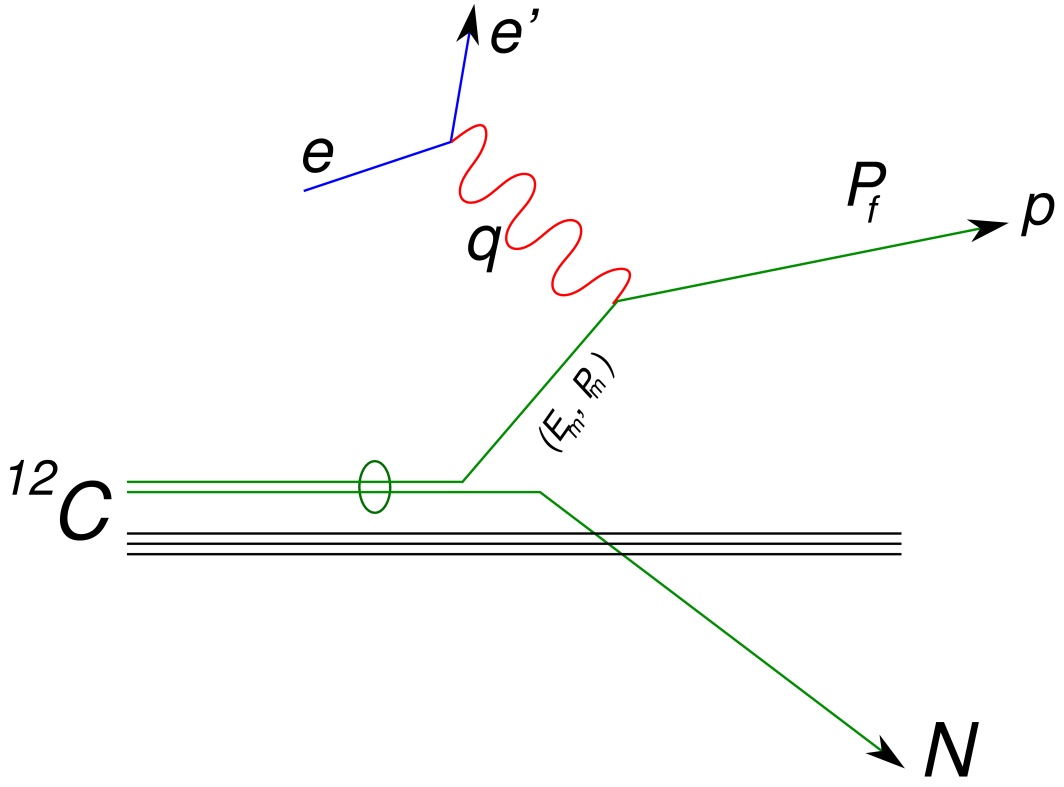
Redefine the problem in momentum space



$$\vec{K}_1 \simeq \vec{K}_2$$

$$\vec{K}_1 > K_f$$

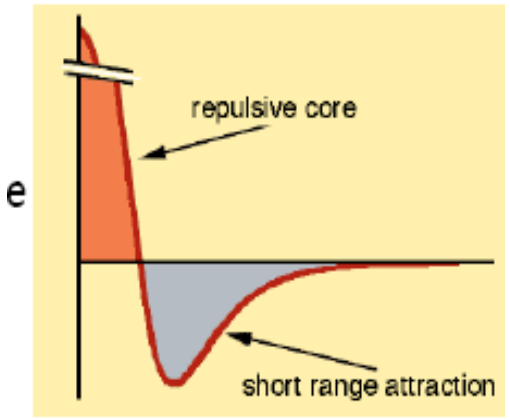
$$\vec{K}_2 > K_f$$

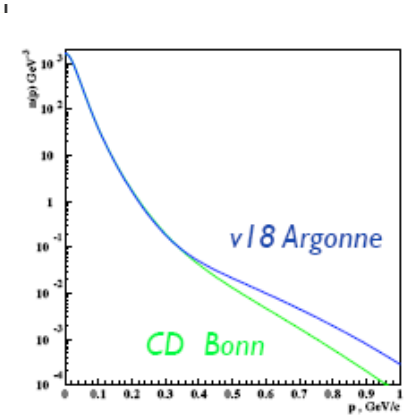


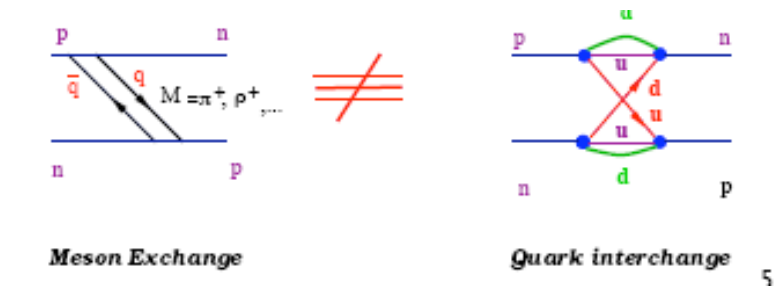
A pair with “large” relative momentum between nucleons and small CM momentum

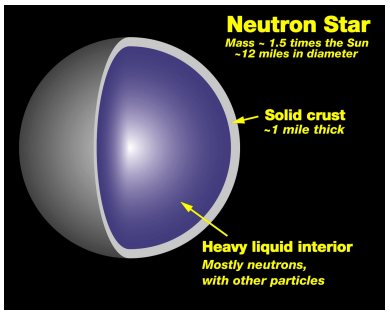
Why study 2N-SRC?

- NN interaction:
  Short range repulsive core and role played by the tensor force
- Quark vs Hadronic degrees of freedom in Nuclei
- Dynamics of Neutron Star formation and structure
- Coulomb Sum Rule Violations



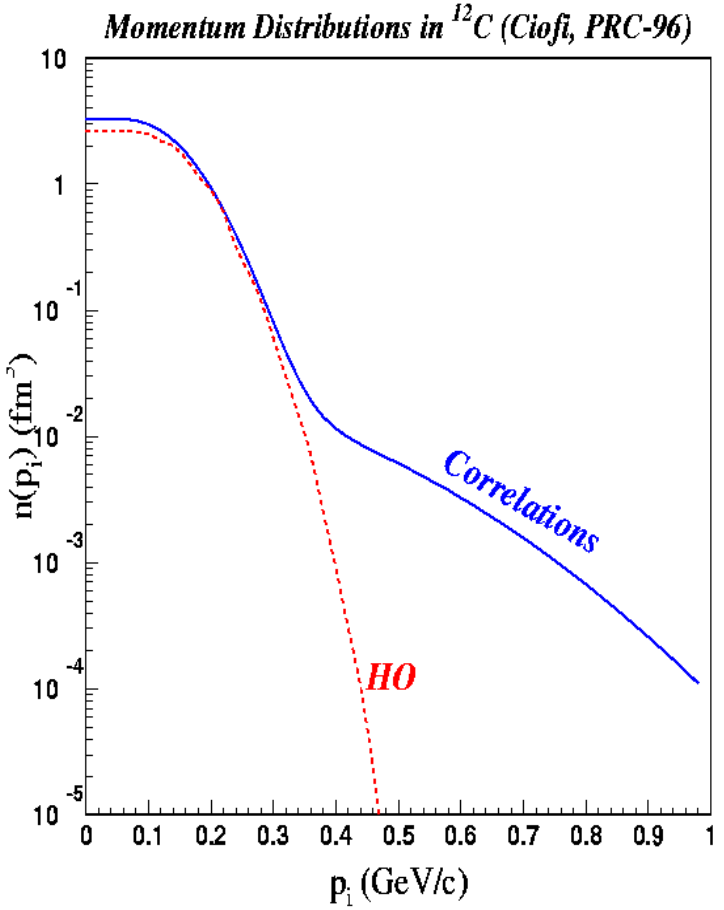






What to measure in 2N-SRC

- What fraction of the momentum distribution is due to 2N-SRC?
- What is the relative momentum between nucleons in the pair?
- What is the pair CM momentum distribution?
- What is the ratio of *pp* to *pn* pairs?
- Are these nucleons different from free nucleons?



Previous Measurements

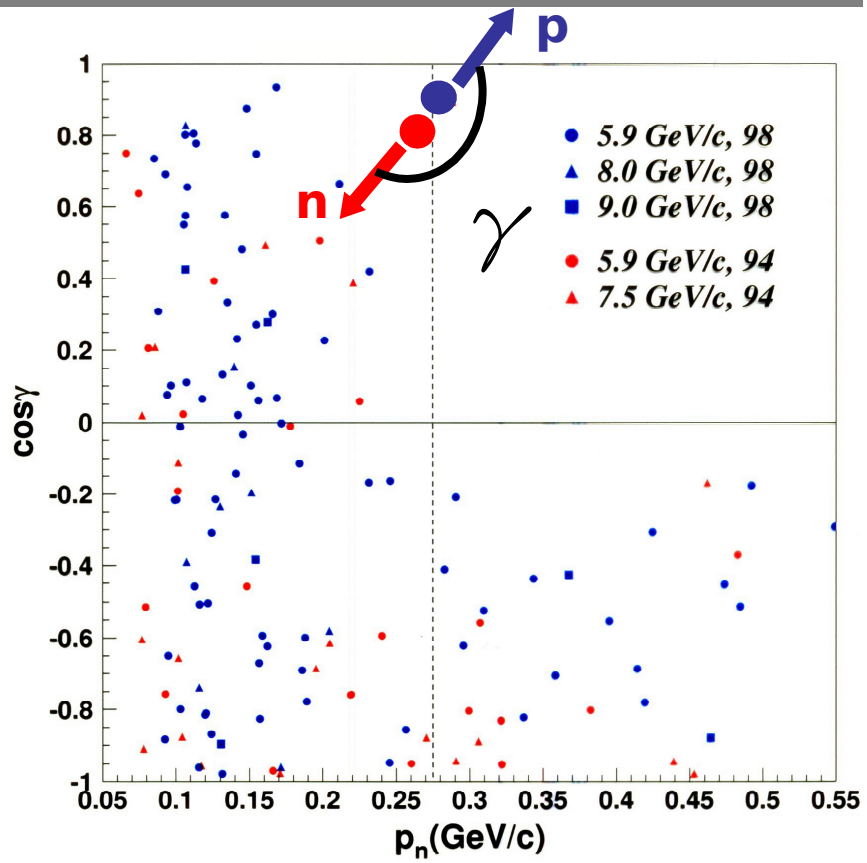
- Triple Coincidence *(p,ppn)* at EVA/BNL

• *np*-SRC pairs observed

• Ejected proton with momentum above Fermi sea level from ^{12}C is $92 \pm^{8}_{18}$ % accompanied by the emission of a neutron with momentum equal and opposite to the missing momentum

Did not observe *pp*-SRC

• Upper limit of 13% for contribution to protons with momentum above 275 MeV/c in ^{12}C.



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

Piasetzky, Sargsian, Frankfurt, Strikman, Watson **PRL 162504(2006).**

Previous Measurements

- Inclusive *(e,e')*

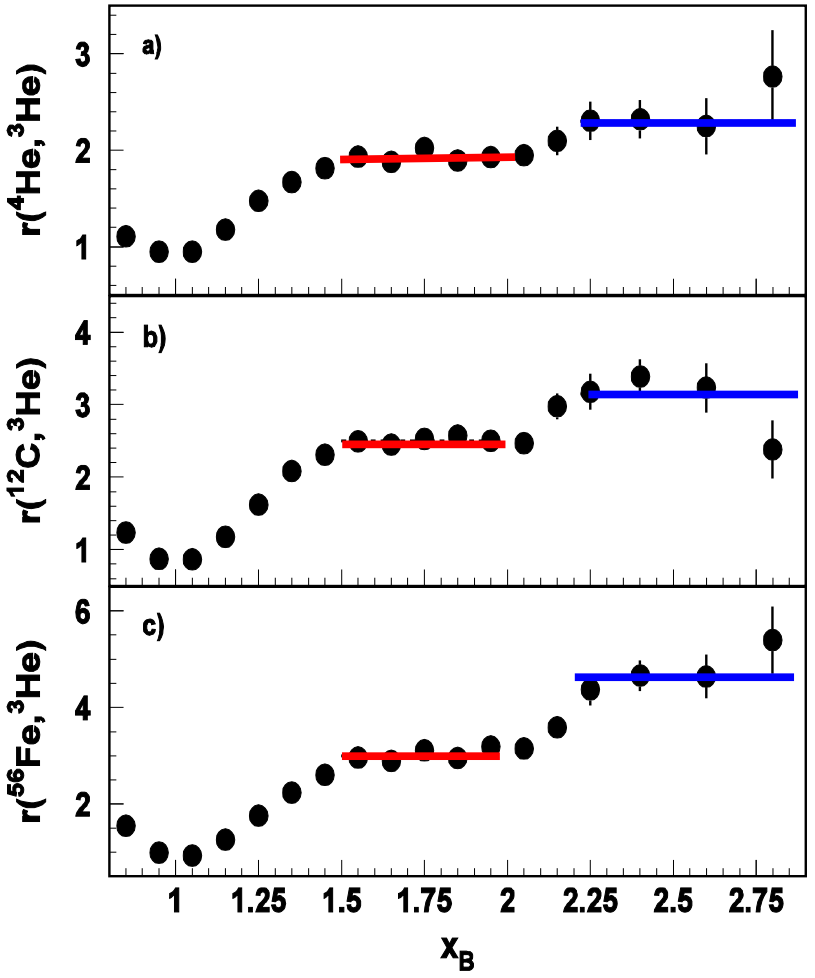
  x_B>1, large Q^2

- **2N-SRC (*pn*,*pp*,*nn*) = (20±4.5)%**
- **3N-SRC are an order of magnitude smaller**

Theory: Frankfurt, Sargsian, and Strikman

CLAS: K. Sh. Egiyan *et al.* PRC 68, 014313.
K. Sh. Egiyan *et al.* PRL 96, 082501 (2006)

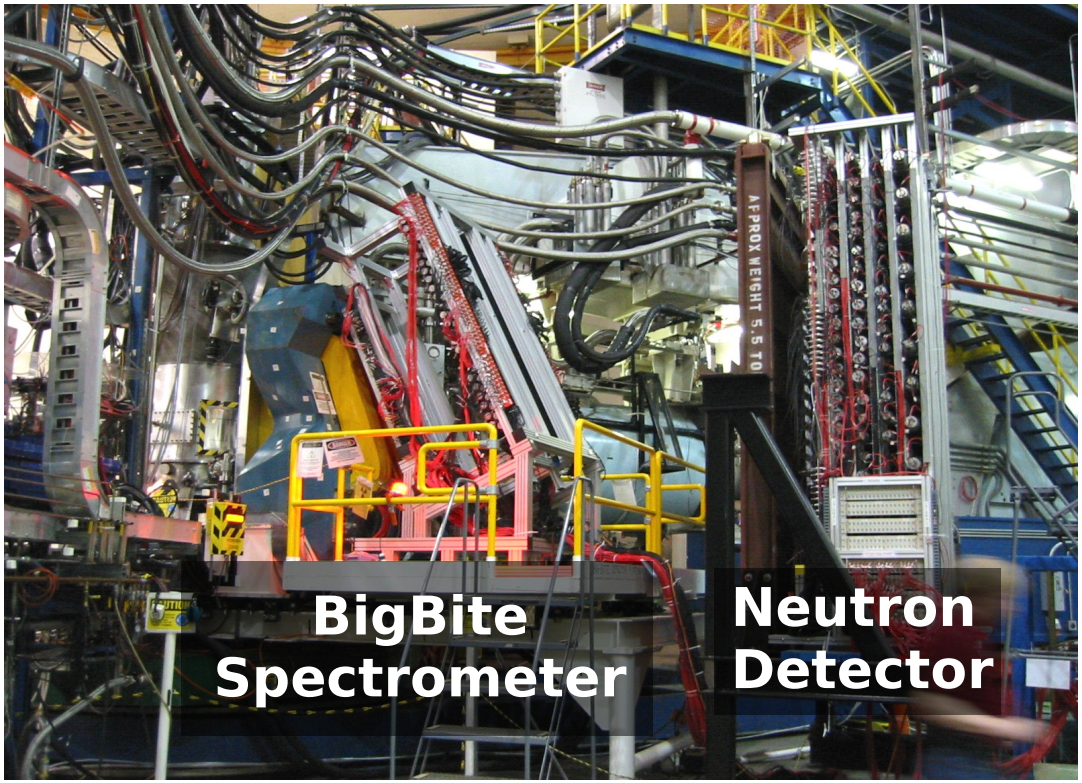
SLAC: D. Day *et al.*



Previous Measurements

Hall A E01-015

- Simultaneous measurements of *(e,e'p)*, *(e,e'pp)*, *(e,e'pn)*
  p_{miss} = 250-650 MeV/c
- *pp*-SRC/*pn*-SRC ratio important to determine isospin dependence of strong interaction at short distance scale.



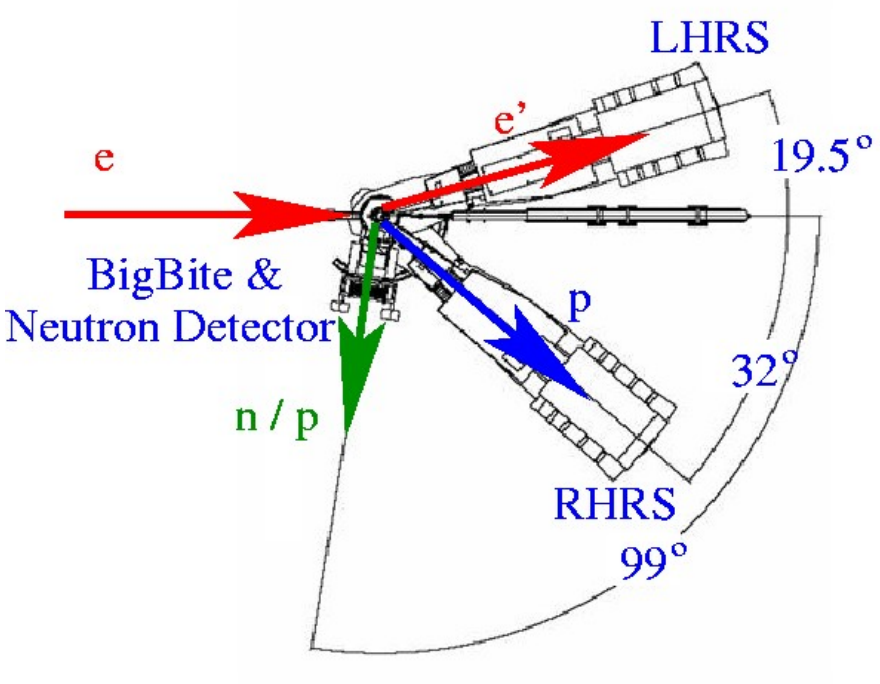
E01-105 Kinematics

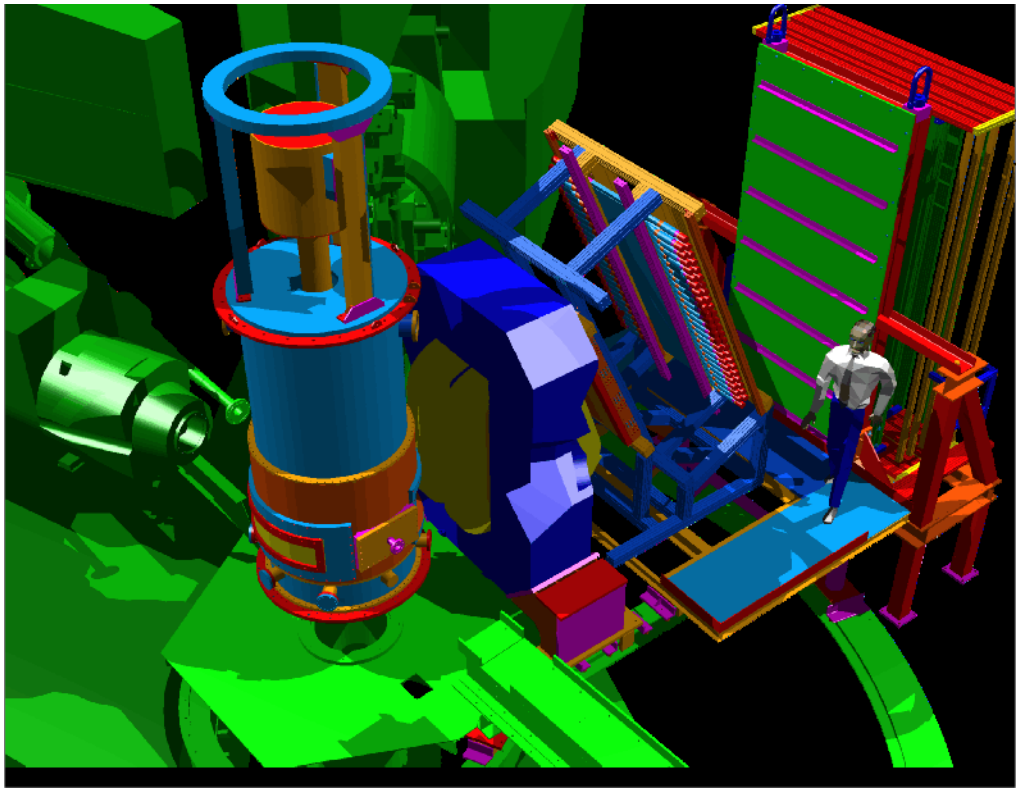
$Q^2 \approx 2$ (GeV/c)^2, $x_B = 1.2$, $p_{miss} = 300$-500 MeV/c

Kinematics optimized to minimize competing processes

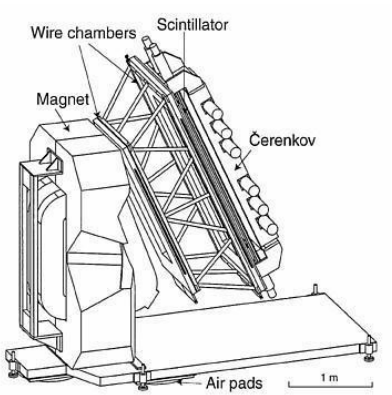
- **High Energy, Large Q^2**
  - *MEC* are reduced as $1/Q^2$
  - *FSI* may be treated in the Glauber approximation
- **$x_B > 1$**
  - Reduced contribution from Isobar Currents
- **Large p_{miss_z}**
  - Reduced *FSI* with a large component of p_{miss} in the virtual photon direction

Experimental Setup

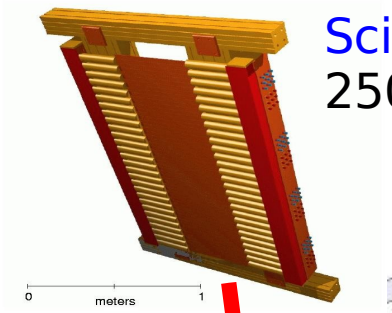


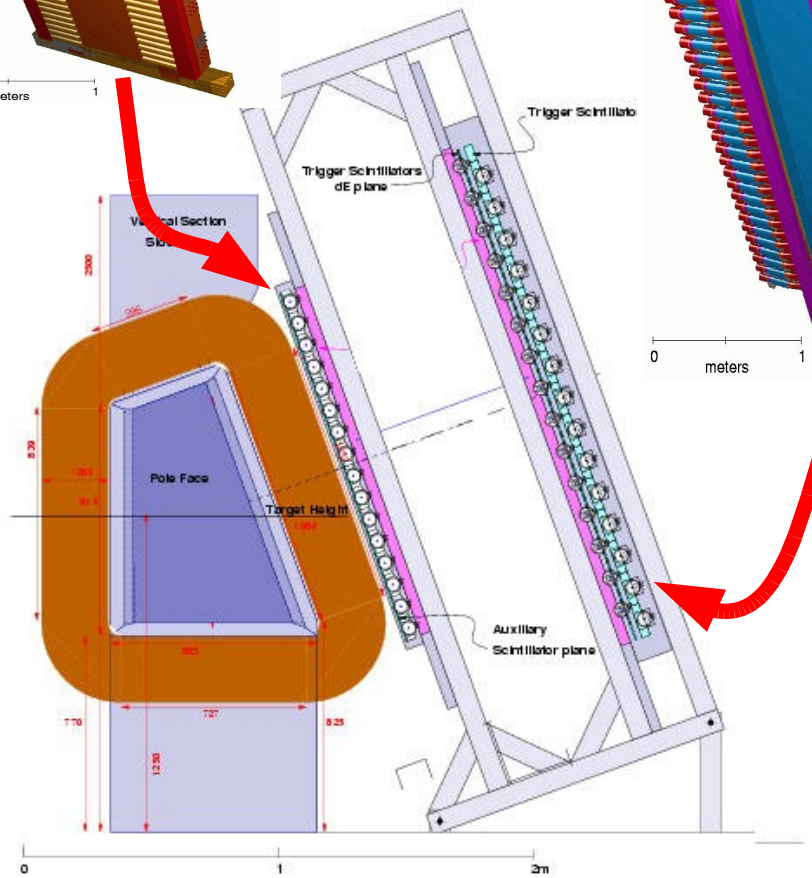


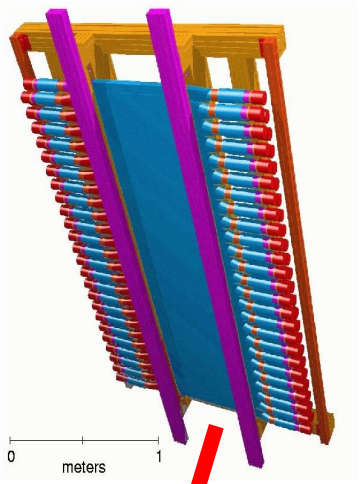
BigBite Detector



Auxiliary Plane
Scintillators:
250x25x2.5 mm³







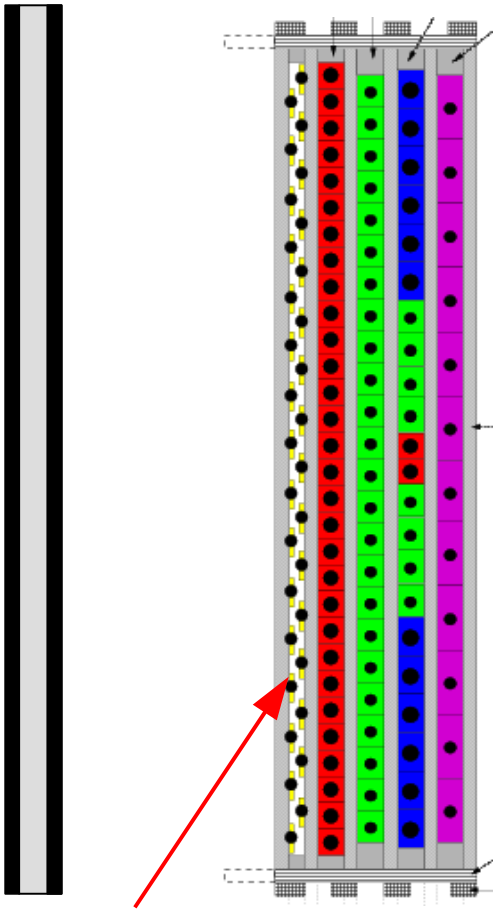
3 mm ΔE counters
30 mm E counters

Neutron Detector

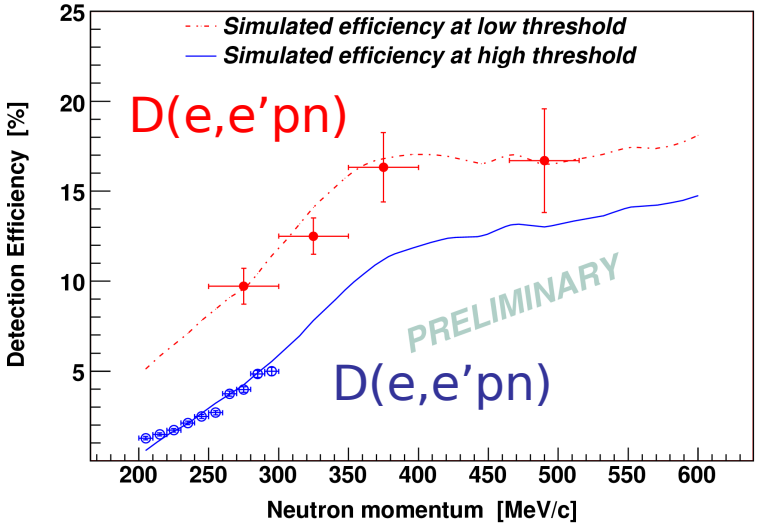
Shield Wall

2” Lead
1” Iron

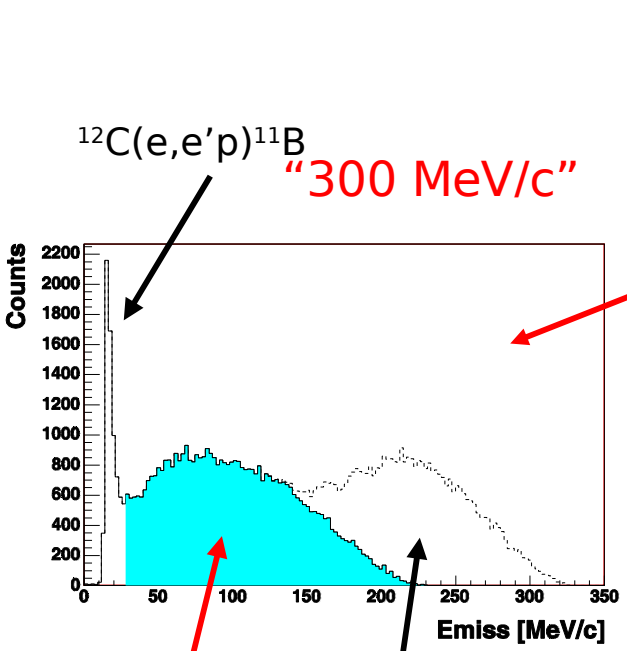
4 Layers of
Scintillator Detectors



Veto Counters

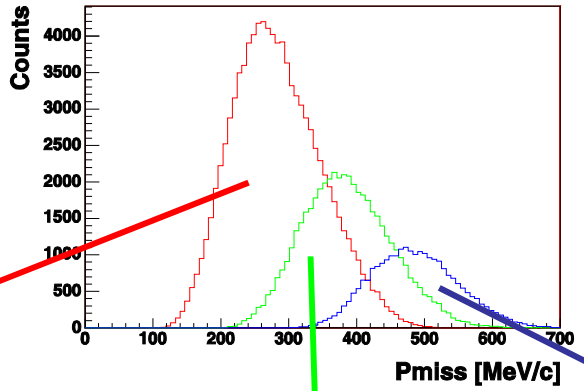


$^{12}C(e,e'p)$, $x_B>1$

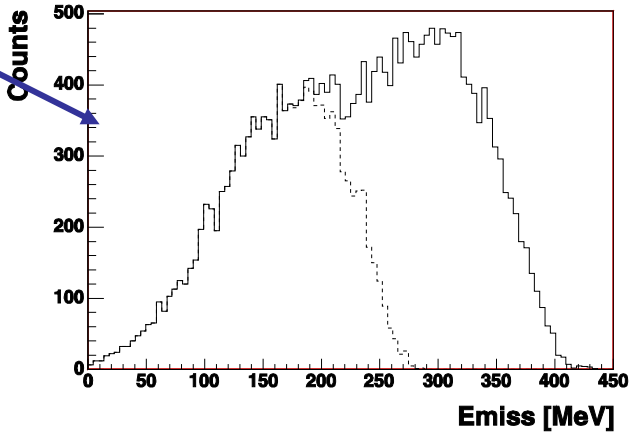


$^{12}C(e,e'p)^{11}B$

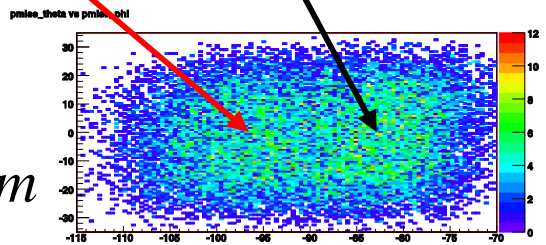
"300 MeV/c"



"500 MeV/c"



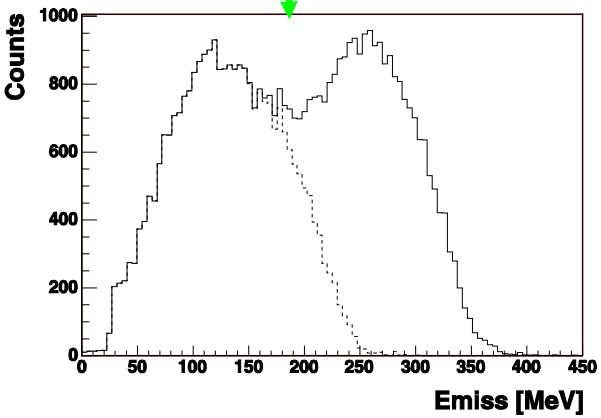
(e,e'p) (e,e'Δ)



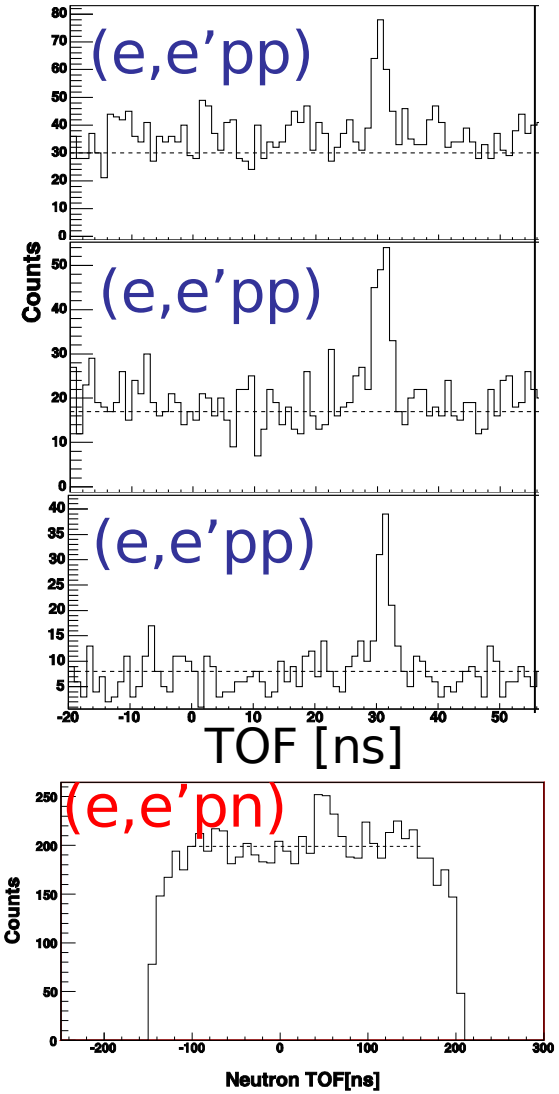
θ_{Pm}

ϕ_{Pm}

"400 MeV/c"



Triple Coincidence Signals



P_{miss}="300" MeV/c
(Signal:BG = 1.5:1)

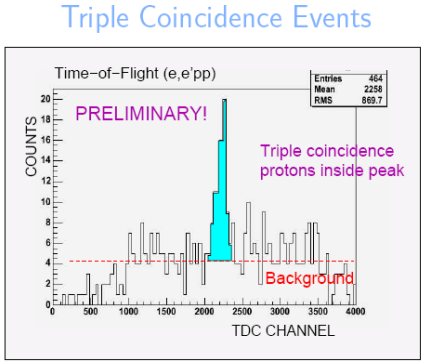
P_{miss}="400" MeV/c
(Signal:BG = 2.3:1)

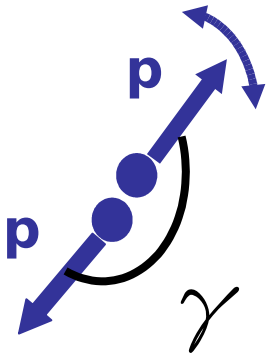
P_{miss}="500" MeV/c
(Signal : BG= 4:1)

P_{miss}="500" MeV/c
(Signal : BG= 1:7)

Directional Correlation

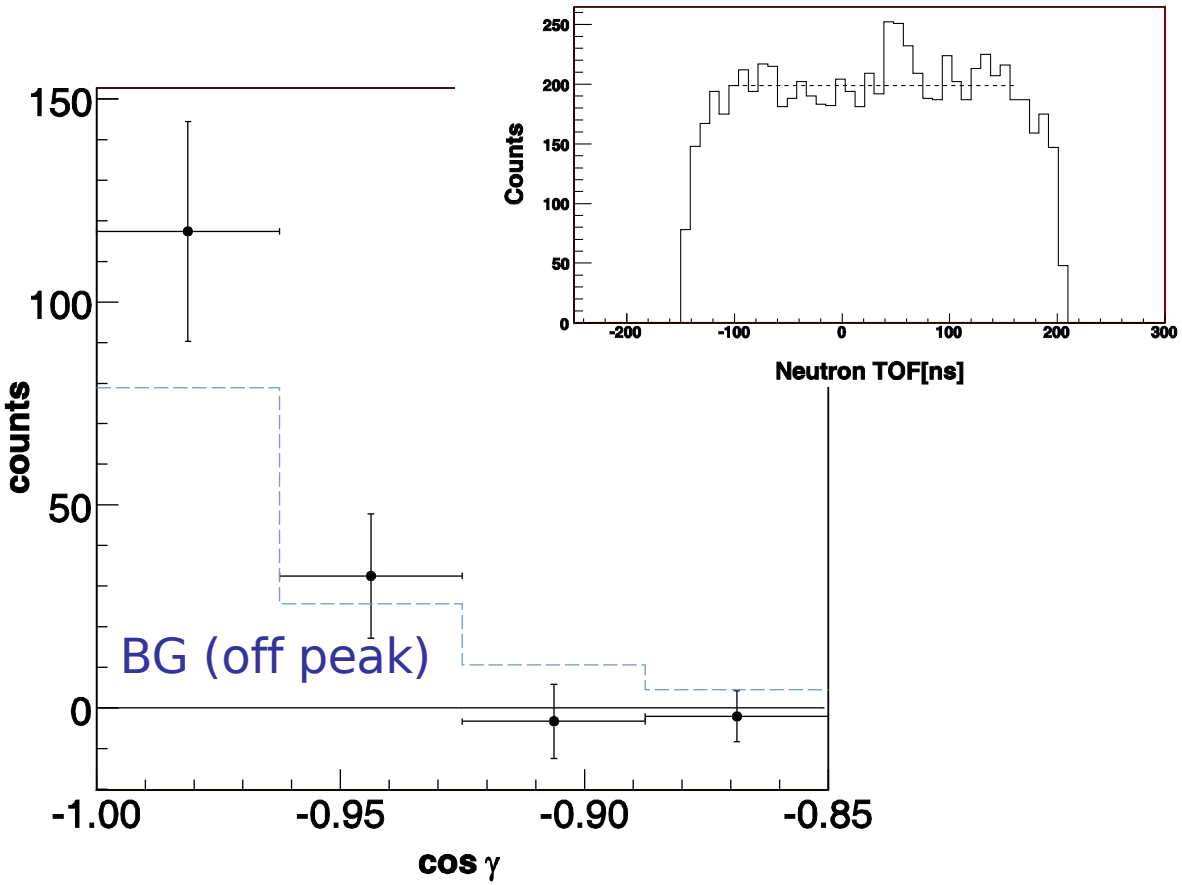
$^{12}C(e,e'pp)$

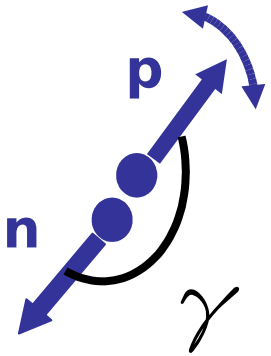




Directional Correlation

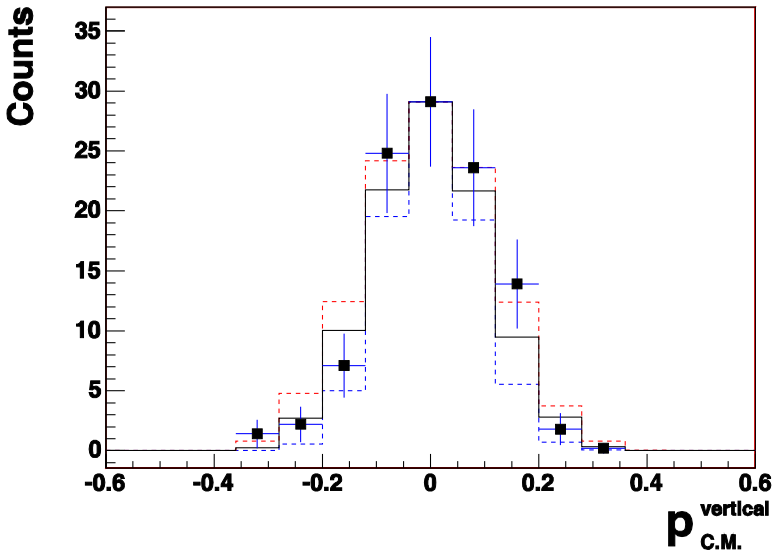
$^{12}C(e,e'pn)$





CM motion of the pair

$P_{c.m}^{vertical}$, "500 MeV/c " setup



MCEEP with pair CM motion:

σ_{CM}=50 MeV/c

σ_{CM}=100 MeV/c

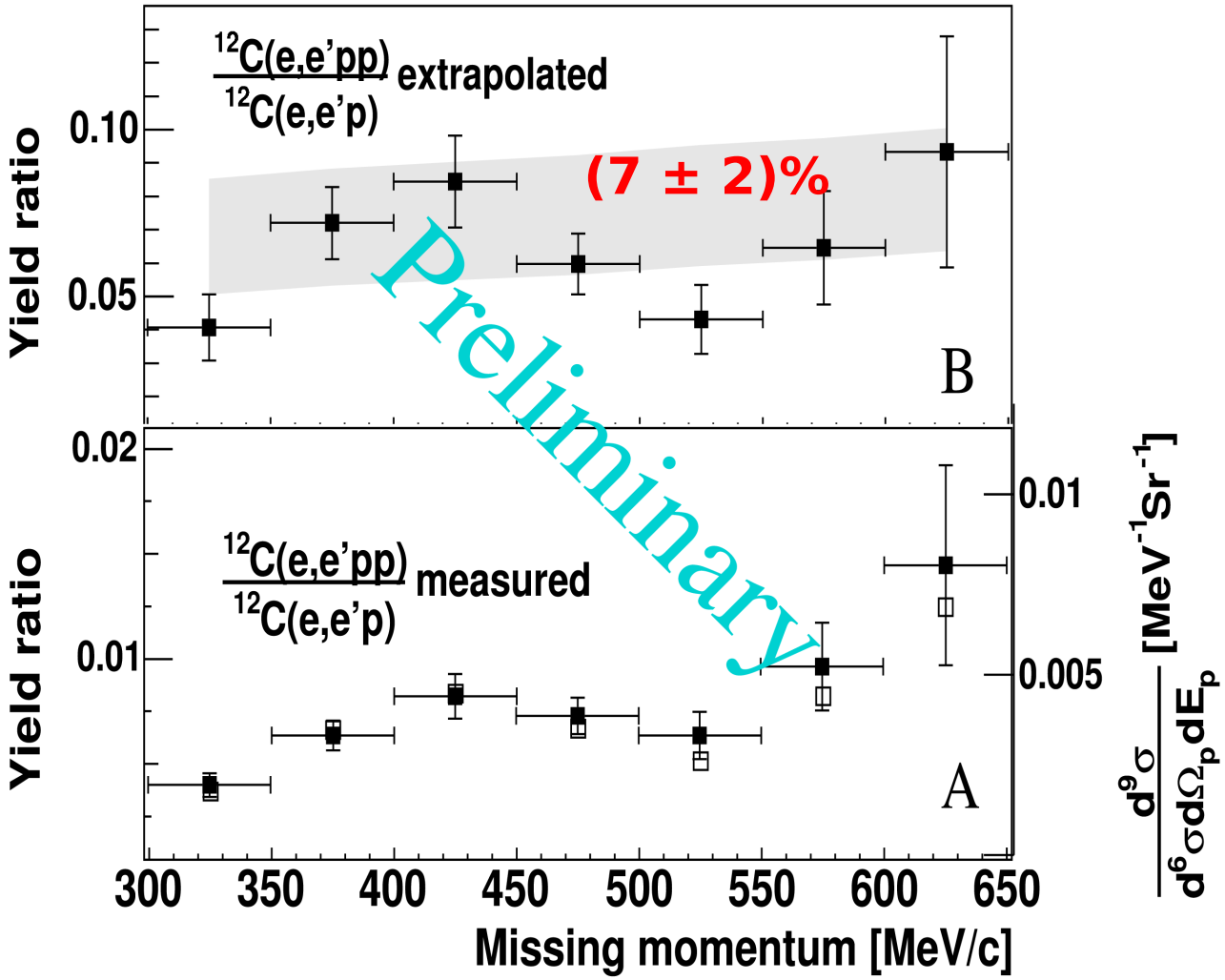
σ_{CM}=136 MeV/c

3 components of p_{CM} and 3 kinematical setups

This experiment : σ_{CM}=0.136±0.020 GeV/c

(p,2pn) experiment at BNL : σ_{CM}=0.143±0.017 GeV/c

Theoretical prediction (Ciofi and Simula) : σ_{CM}=0.139 GeV/c



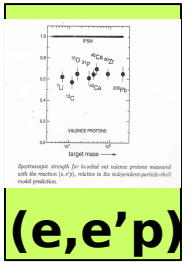
R. Shneor *et al.*, To be submitted

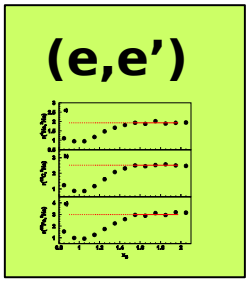
Deduced ^{12}C Structure

80 ± 4.5 % - single particle moving in an average potential.

60-70 % - independent particle in a shell model potential.

10-20 % - shell model long range correlations



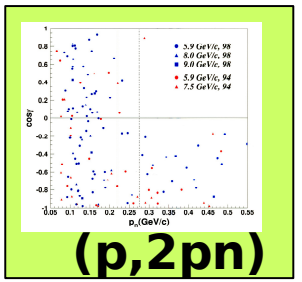


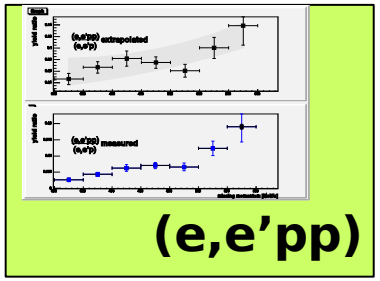
20 ± 4.5 % - 2N SRC

18.4 ± 4.5 % - SRC np pairs

0.7±0.2% - SRC pp pairs.

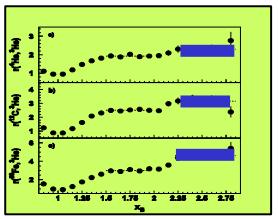
0.7±0.2 % - SRC nn pairs.





Small ~1% - SRC of "more than 2 nucleons".

? **~1%** -non nucleonic degrees of freedom



^{12}C Ratio of *pp*-SRC to *pn*-SRC

From the EVA / BNL ^{12}C(p,ppn) data :

$$\rightarrow \quad \frac{P_{pp}(^{12}C)}{P_{pn}(^{12}C)} < 13\%$$

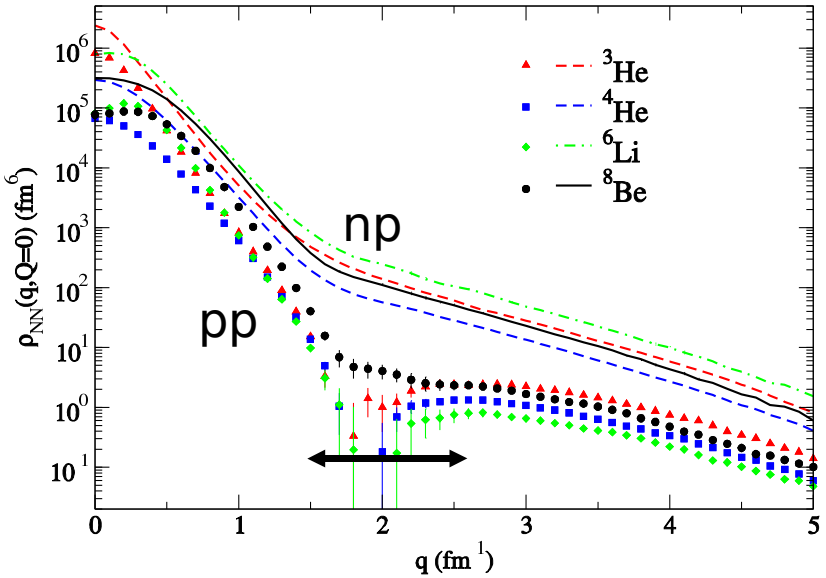
Combined EVA /BNL ^{12}C(p,ppn) and the E01-015 ^{12}C(e,e'pp) data:

$$\rightarrow \quad \frac{P_{pp}(^{12}C)}{P_{pn}(^{12}C)} = \frac{(3.5 \pm 1)\%}{(74-95)\%} = (2.5-6.0)\%$$

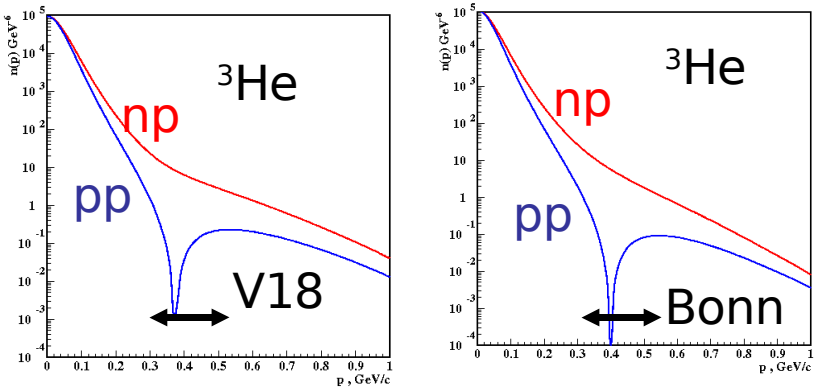
Why is this ratio so small?

p_{miss} = 300-500 MeV/c

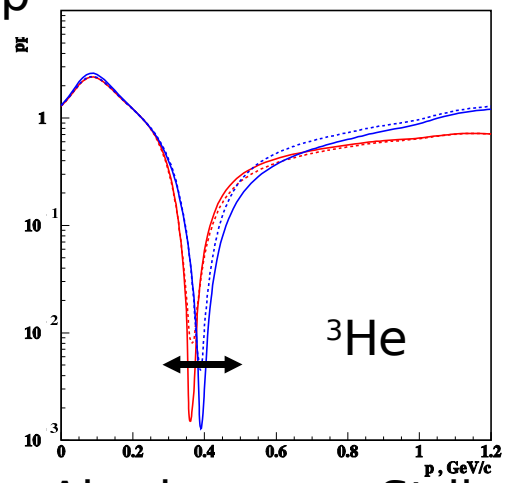
Excess strength in the *np* momentum distribution. Strong correlations induced by underlying Tensor NN potential.



Schiavilla, Wiringa, Pieper, Carlson nucl-th /0611037 (2006).



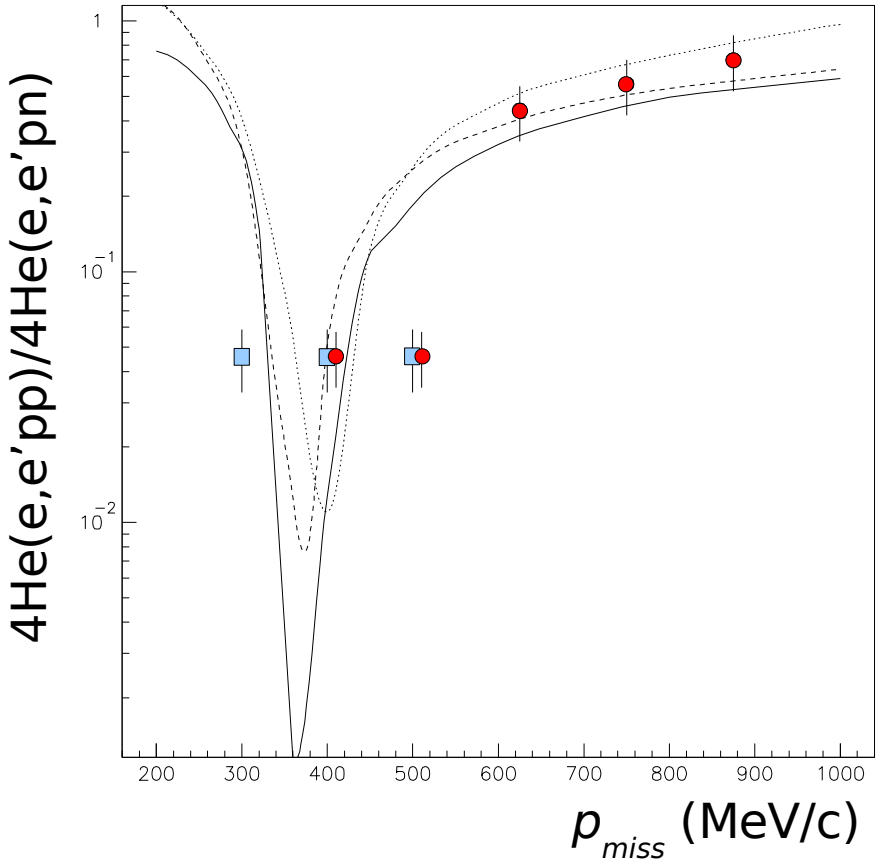
pp/np



Sargsian, Abrahamyan, Strikman, Frankfurt Phys. Rev. C71 044615 (2005).

Proposal 07-006

Measurement of the ^{4}He(e,e'pp)/^{4}He(e,e'pn) reactions over the ^{4}He(e,e'p) missing momentum range from 400 to 875 MeV/c.



E01-015 - ^{12}C

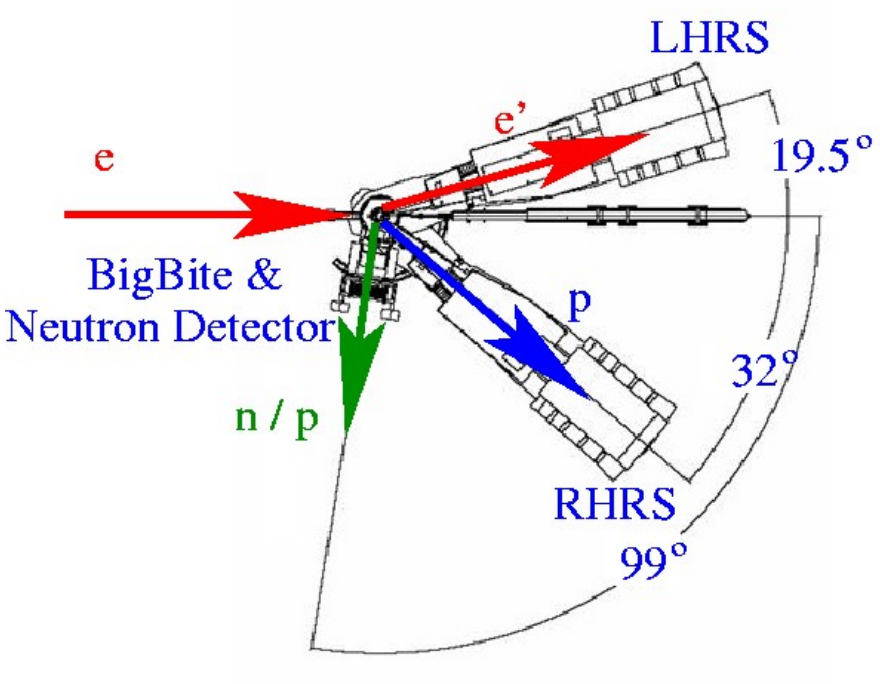
This Proposal - ^{4}He

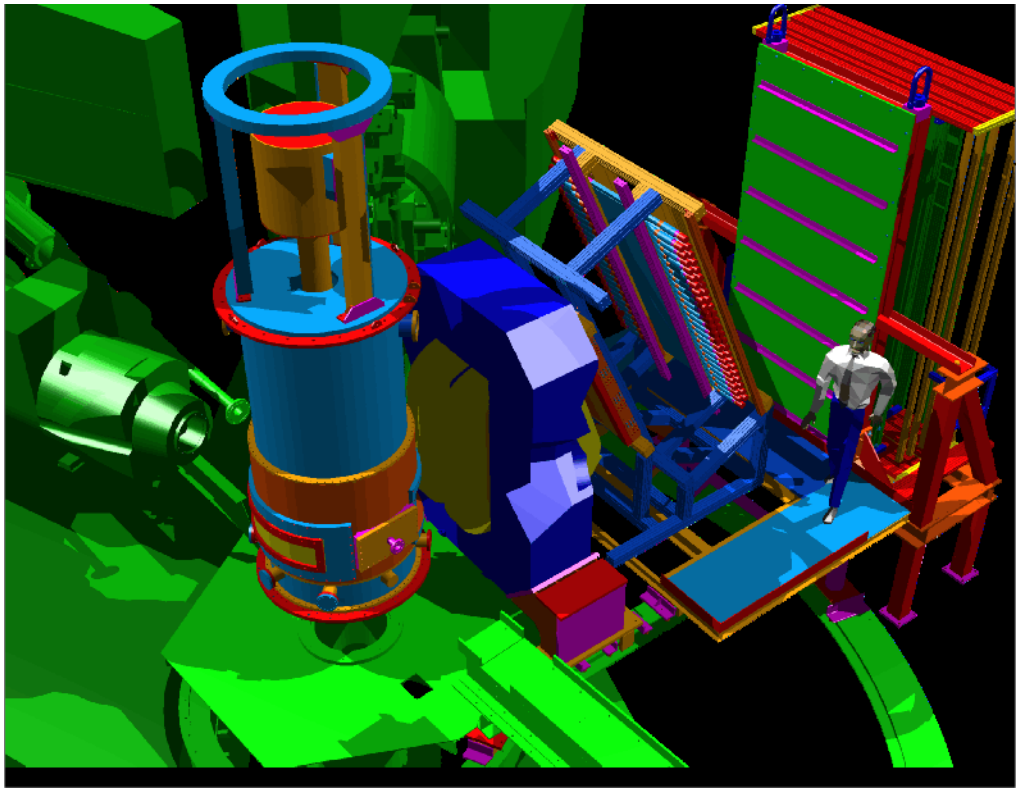
E_{beam} = 4.5–5.1 GeV

$Q^2 \approx 2$ (GeV/c)^2

$x_B = 1.25$

PR07-006: Experimental Setup



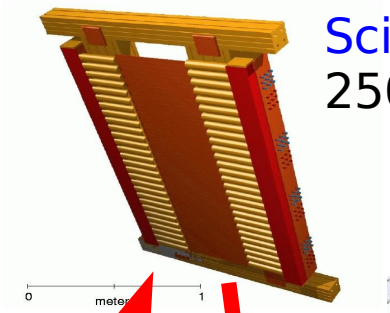


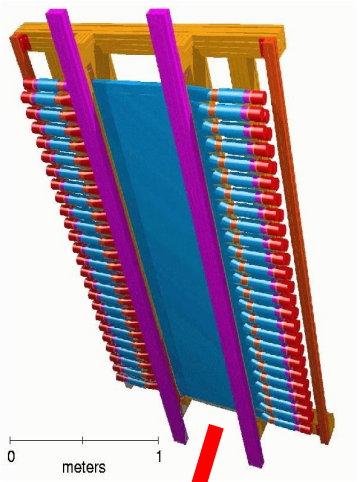
New for PR07-006:

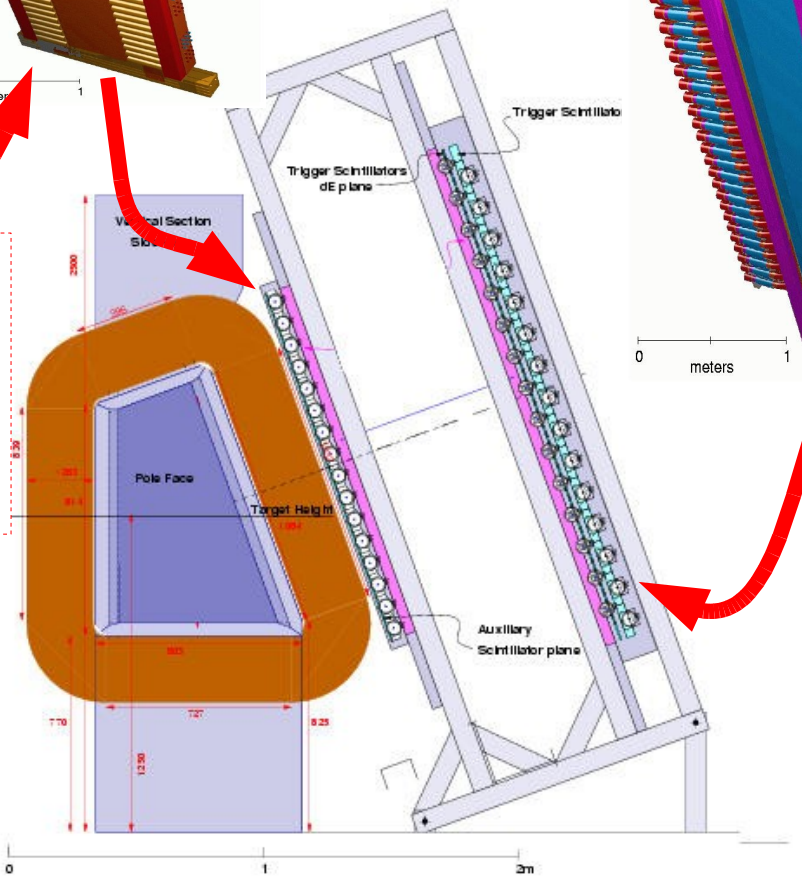
- Target: ^{12}C Slanted Foil ⇒ ^{4}He Cryotarget
- Upgrade to BigBite detector
- Upgrade to Lead Wall and Neutron Detector

BigBite Detector

Auxiliary Plane Scintillators:
250x25x2.5 mm³







New for PR07-006:
- Replace Aux. Plane with Scintillating Fiber

⇒ Better position & momentum resolution

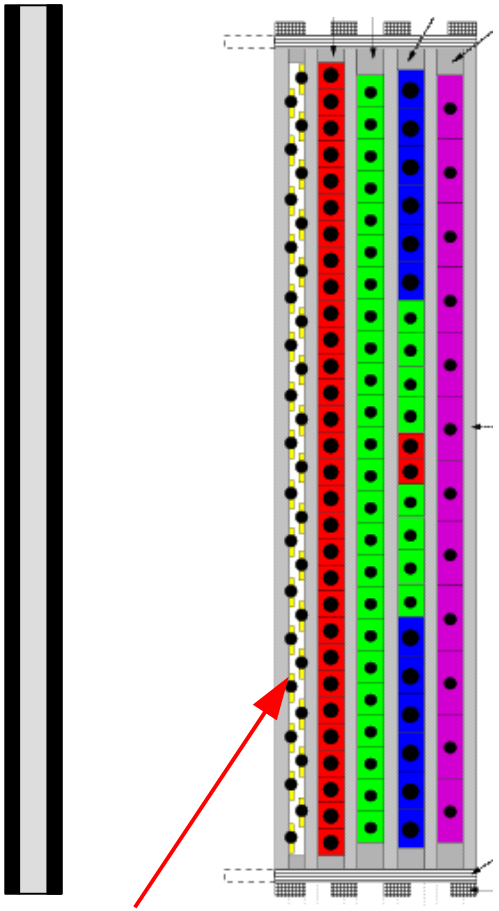
3 mm ΔE counters
30 mm E counters

Neutron Detector

Shield Wall

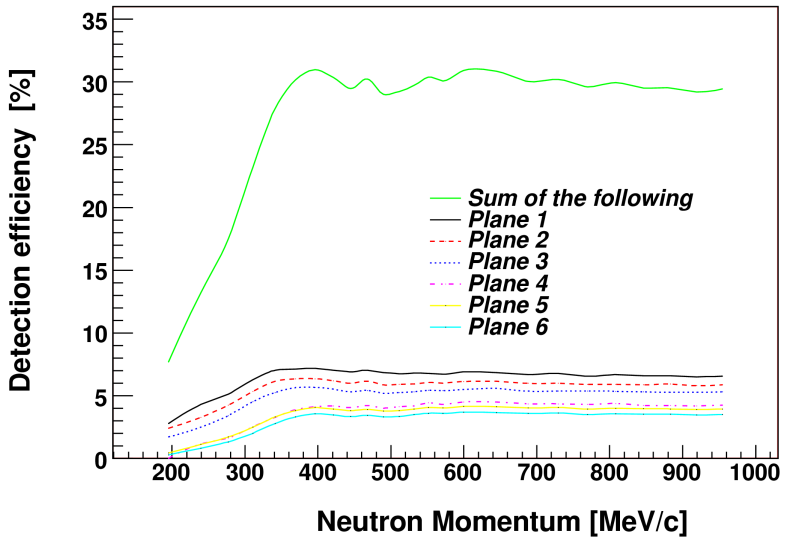
2” Lead
1” Iron

4 Layers of
Scintillator Detectors



Veto Counters

New for PR07-006:
- Less Shielding
- 2 More Detector Planes



The Proposed Measurement

P_{miss} (MeV/c)	days	(e,e'pp) events	(e,e'pn) events
400	5	110	200
500	5	110	200
625	5	235	160
750	5	280	150
875	5	320	140

Setup, calibrations, checks: 4 days

Total number of triple coincidence events ~ 2000

(E01-015: Total number of triple coincidence events ~ 600)

Total requested beam time = 29 days

Summary

E01-015:

Simultaneous measurement of
(e,e'pp), *(e,e'pn)*, and *(e,e'p)* reactions on ^{12}C
over the *(e,e'p)* missing momentum range 300-500 MeV/c.

- *pp*-SRC and *pn*-SRC identified and abundances determined.
- Data show sensitivity to the short range NN Tensor Force

PR-07-006:

Simultaneous measurement of these reactions on ^{4}He
over the *(e,e'p)* missing momentum range 400-875 MeV/c.

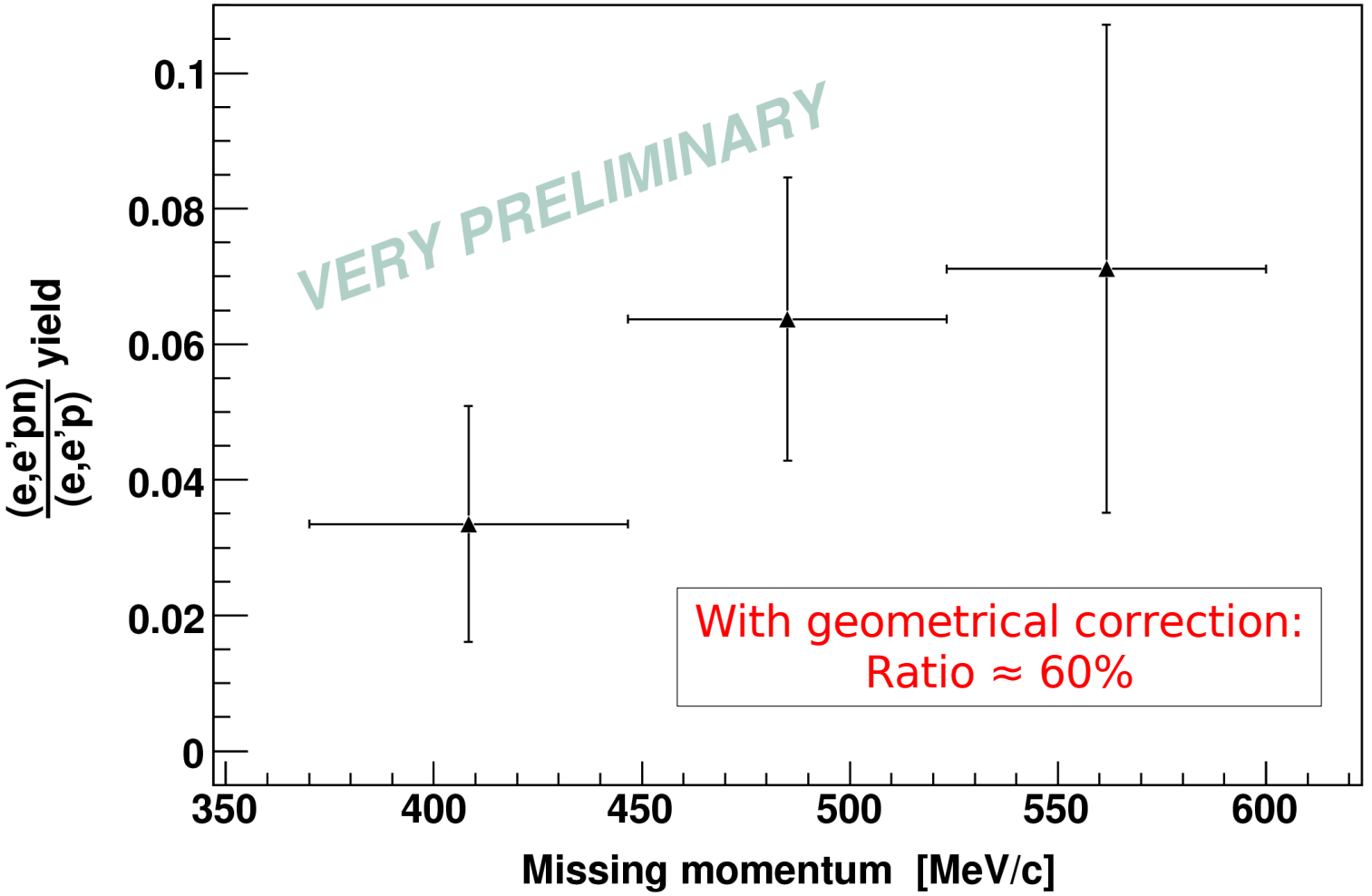
- Data expected to be sensitive to the NN Tensor Force & NN Short Range Repulsive Force.

The proposed experiment uses the Hall A cryotarget, the two HRSs, BigBite, and an array of neutron counters.

Total Beam Time Request: 29 days

Backup Slides

Very Preliminary Neutron Results



FSI Effects

Simple estimates of the FSI effects, based on a Glauber approximation show that these are small compared to the large errors of the data.

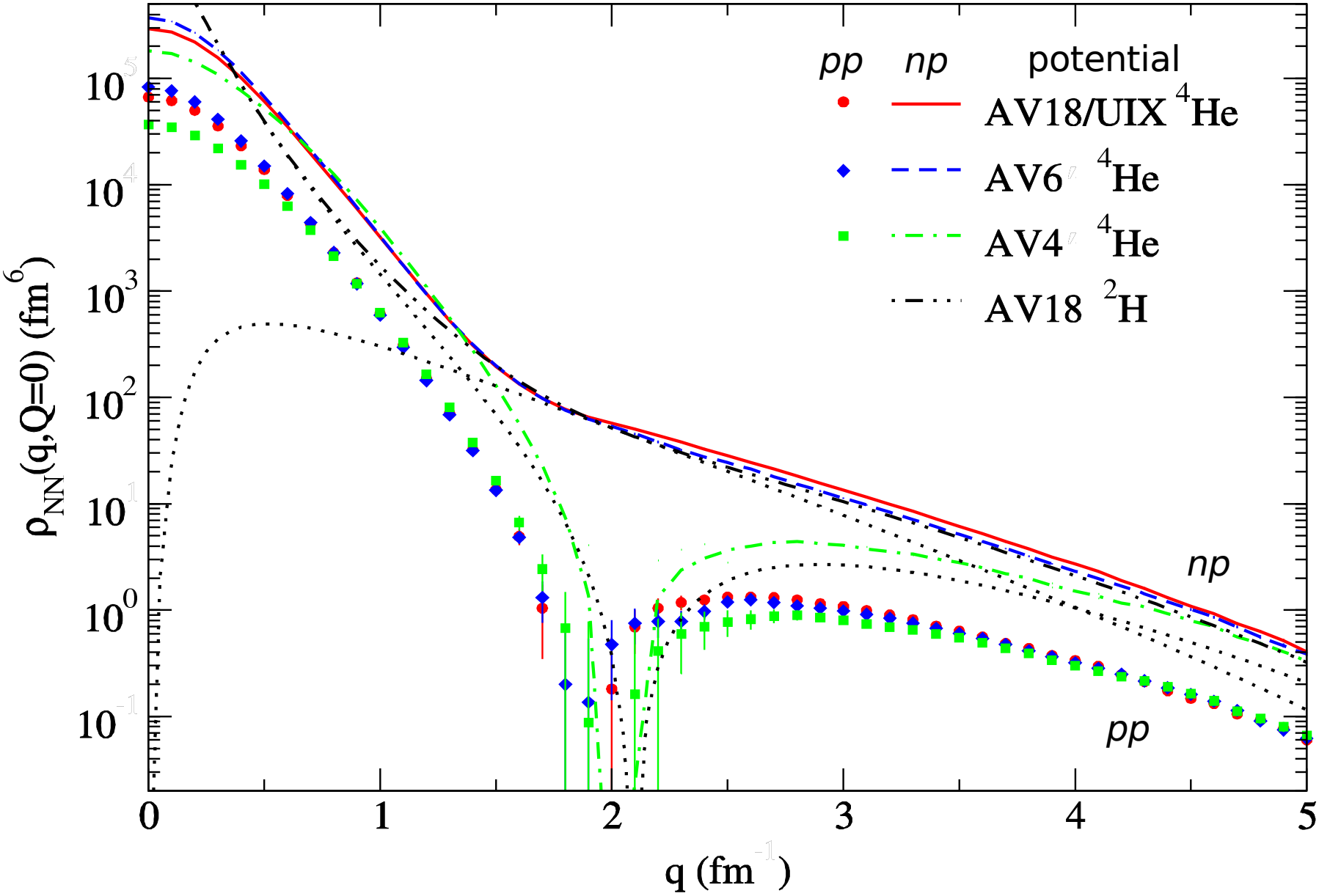
Mardor, Mardor, Piasetzky, Alster, and Sargsian PR C761 (1992)

The data itself indicate that FSI are small.

The extracted pair CM distribution is a combination of CM motion and FSI. The fact that we get :

- a narrow width ($_{cm}$=136 MeV/c),
- similar in the transverse and longitudinal directions,
- Same as in previous measurements of the (p,ppn) reaction,
- Same as theoretical predications,

indicates that FSI contribution are not dominant.


pp
np
potential
AV18/UIX ^{4}He
AV6′ ^{4}He
AV4′ ^{4}He
AV18 ^{2}H
np
pp
$\rho_{NN}(q,Q=0)$ (fm^6)
q (fm^{-1})
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
0
1
2
3
4
5