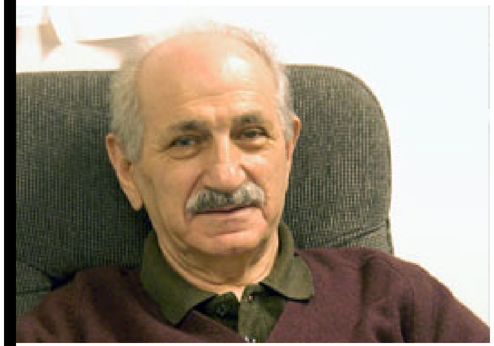
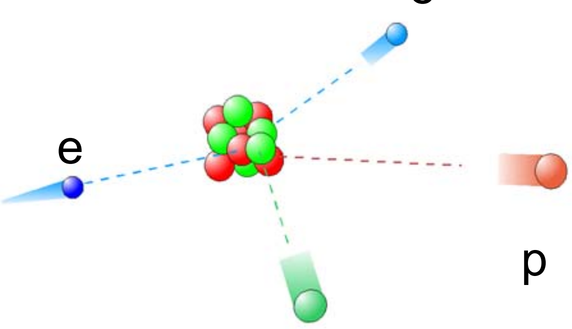

1935-2006

Investigation of Proton-Proton Short-Range Correlations via the Triple-Coincidence $^{12}C(e,e'pp)$ Measurement at Jlab / Hall A

E01-105

20 October 2006

(Jefferson National Accelerator Facility)



Eli Piasetzky

Tel Aviv University, ISRAEL

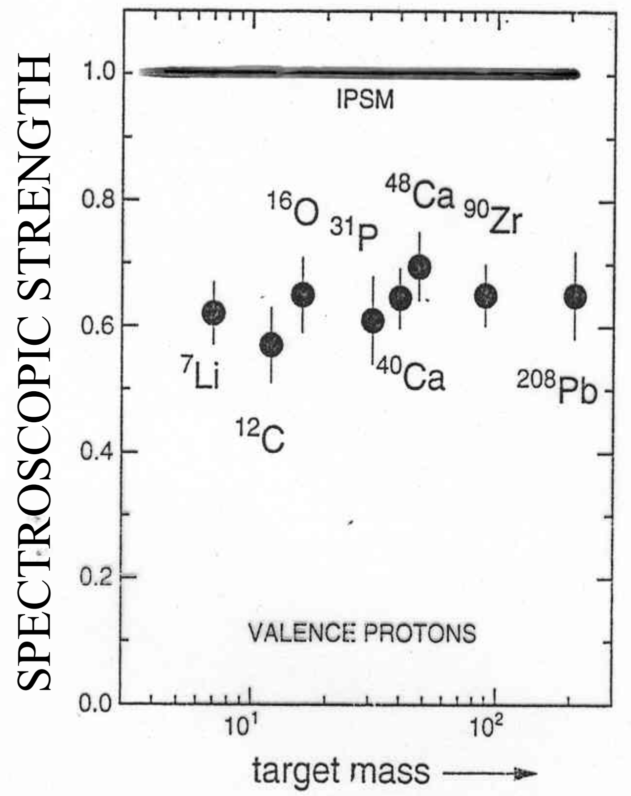
What did we know about 2N-SRC in nuclei before the Jlab triple coincidence measurement ?

Measurement: (e,e'p)

Observed phenomena: spectroscopic factors are 60-70% of the Independent Particle Shell Model (IPSM) predictions.

Deduction: Nucleons in nuclei can not be fully described as individual nucleons moving in an average potential (mean field).

Quantitative conclusion: 30-40% are due to shell model long range correlations, 2N-SRC, multi nucleon correlations…



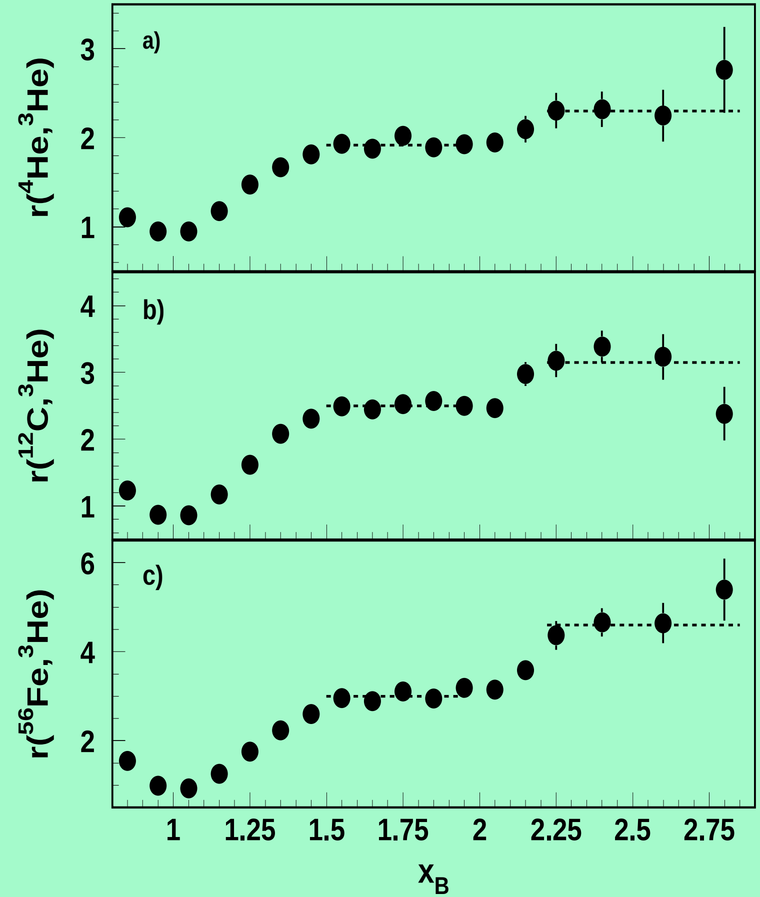
Spectroscopic strength for knocked out valence p with the reaction (e, e'p), relative to the independ model prediction.

What did we know about 2N-SRC in nuclei before the Jlab triple coincidence measurement ?

Measurement: (e,e') $X_B > 1$, large Q^2

Observed phenomena: scaling.

Deduction: The electrons probe high momentum bound nucleons from a local source (2N-SRC) with properties generally independent of the residual nucleus.



Quantitative conclusion:

* 2N-SRC (np, pp, nn) = 20±4.5%.

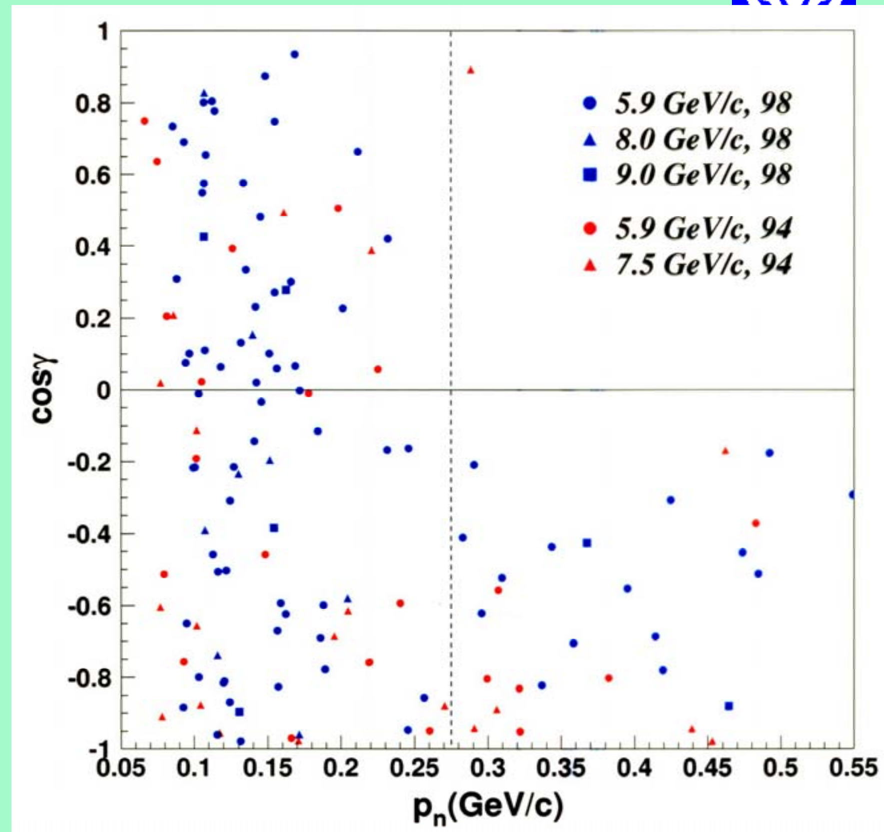
* 3N-SRC are one order of magnitude smaller than 2N-SRC.

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.

What did we know about 2N-SRC in nuclei before the Jlab triple coincidence measurement ?



Measurement: (p,ppn) EVA / BNL

Observed phenomena: Removal of a proton from ^{12}C with (p,2p) reaction and missing momentum 275-550 MeV/c is 92^{+8}_{-18}% accompanied by the emission of a neutron with momentum equal and opposite to the missing momentum.

Deduction:

np-SRC pairs have been observed.

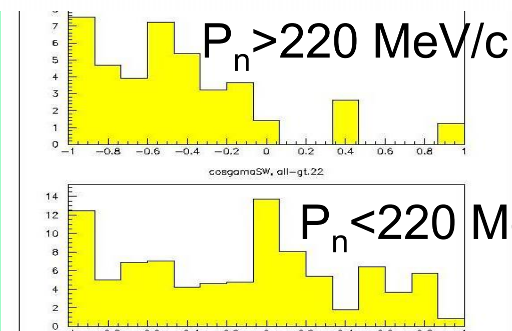
Quantitative conclusion:

In ^{12}C of all nucleons with 275-550 MeV/c :

* **2N-SRC dominance**: 74-100% are partners in 2N-SRC.

* **np-SRC dominance**:

- 92^{+8}_{-18}% are members of an np-SRC pair.
- 0-13% are pp-SRC pairs.
- \# np-SRC / # pp-SRC > 6.



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

Piasetzky, Sargsian, Frankfurt, Strikman, Watson

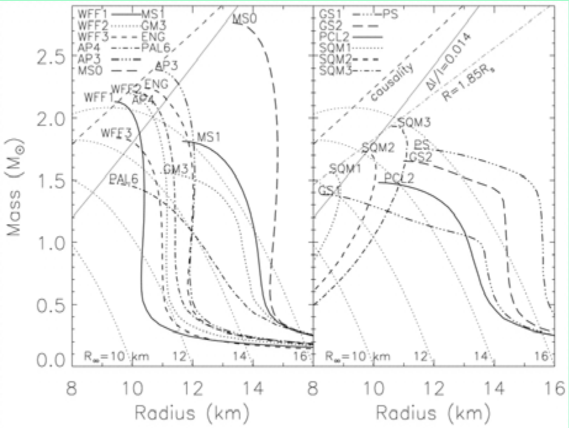
PRL 162504(2006)

★ The probability to find a pp-SRC in nuclei is small.

★ pp-SRC are important to identify and study since they can tell us about the isospin dependence of the strong interaction at short distance scale. This may have relevance to understanding the equation of state for neutron stars.

How well do we understand cold dense nuclear matter?

Stars containing nucleons (hyperons)



Stars containing exotic components

J. M. Lattimer and M. Prakash

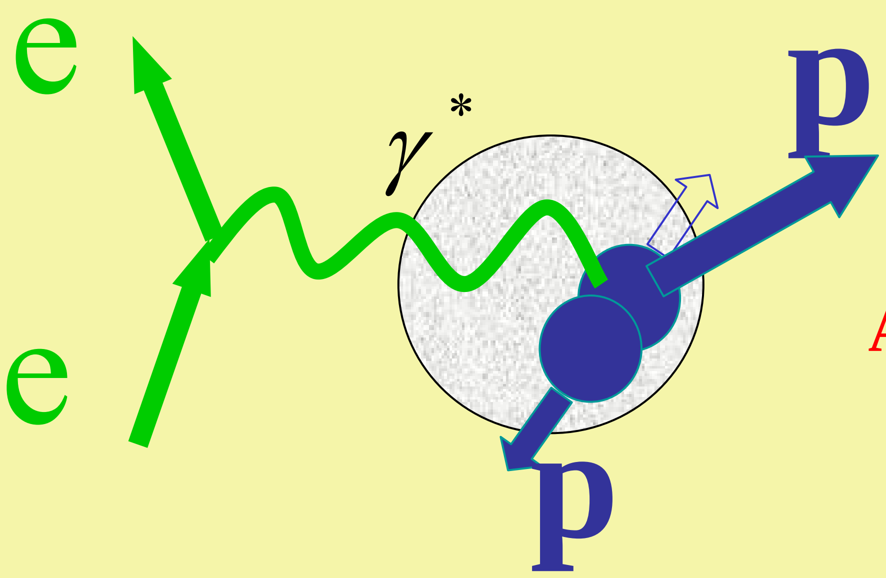
The Astrophysical Journal, 550:426-442 2001

A triple coincidence (e,e'pp) measurement is required.

Custom Experiment to study 2N-SRC

$Q^2 = 2$ GeV/c , $x_B \sim 1.2$, P_m=250-650 MeV/c, E_{2m}<140 MeV

Luminosity ~ 10^{37-38} $cm^{-2}s^{-1}$



<u>"Redefine" the problem in momentum space</u>

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

We optimized kinematics to minimize the competing processes

High energy, Large Q^2

MEC are reduced as $1/Q^2$.

Large Q^2 is required to probe high P_{miss} with $x_B>1$.

FSI can treated in Glauber approximation.

The light-cone variable α is not sensitive to FSI.

No ambiguity with respect to the identification of the struck and recoil nucleons as in low Q^2.

$x_B>1$

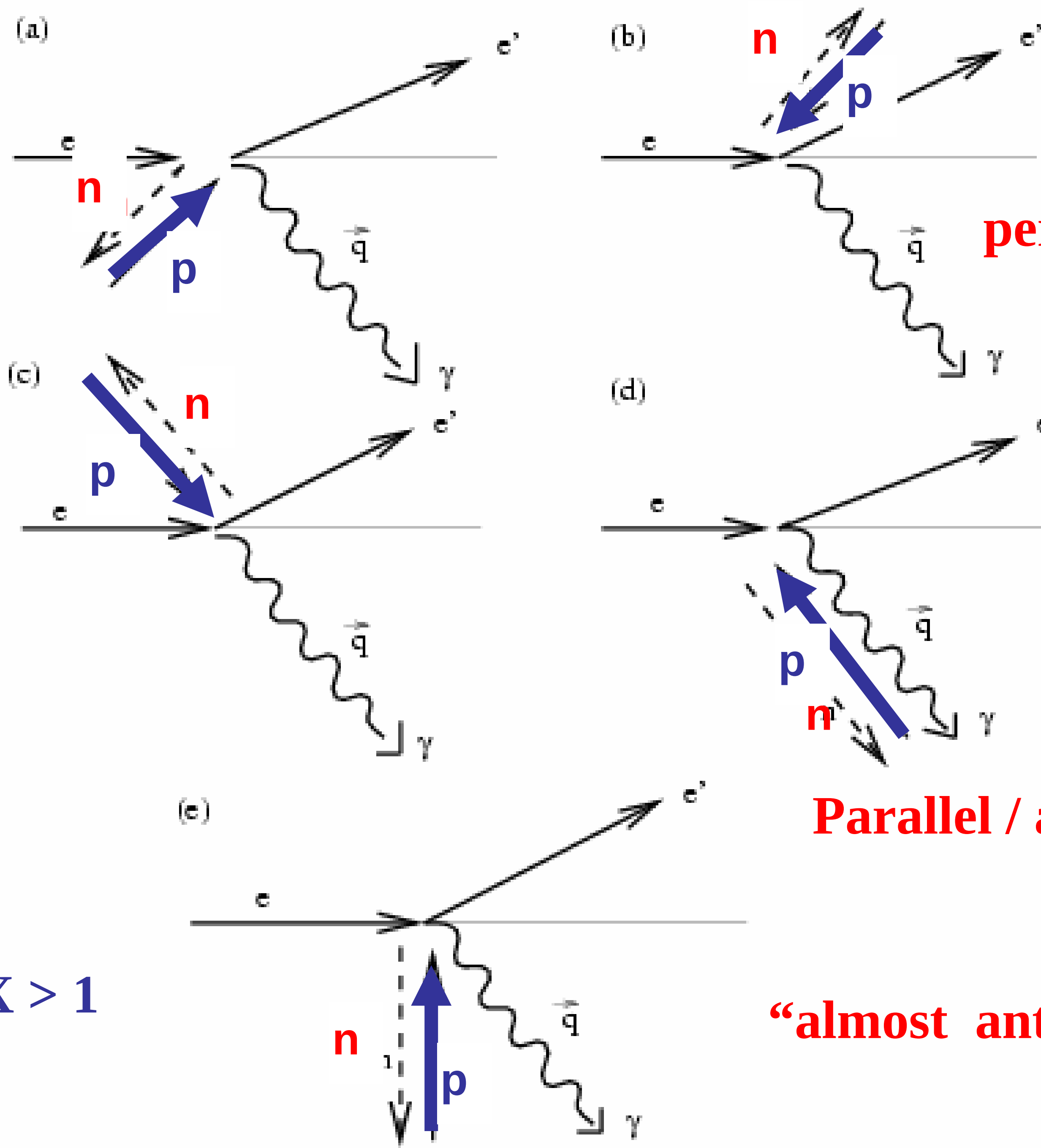
Reduce isobar currents.

Large p_{miss}, and $E_{miss} \sim p^2_{miss}/2M$

Large P_{miss_z}

"Almost anti-parallel" kinematics, with a large component of p_{miss} in the virtual photon direction, reduce FSI.

X = 1



perpendicular

X < 1

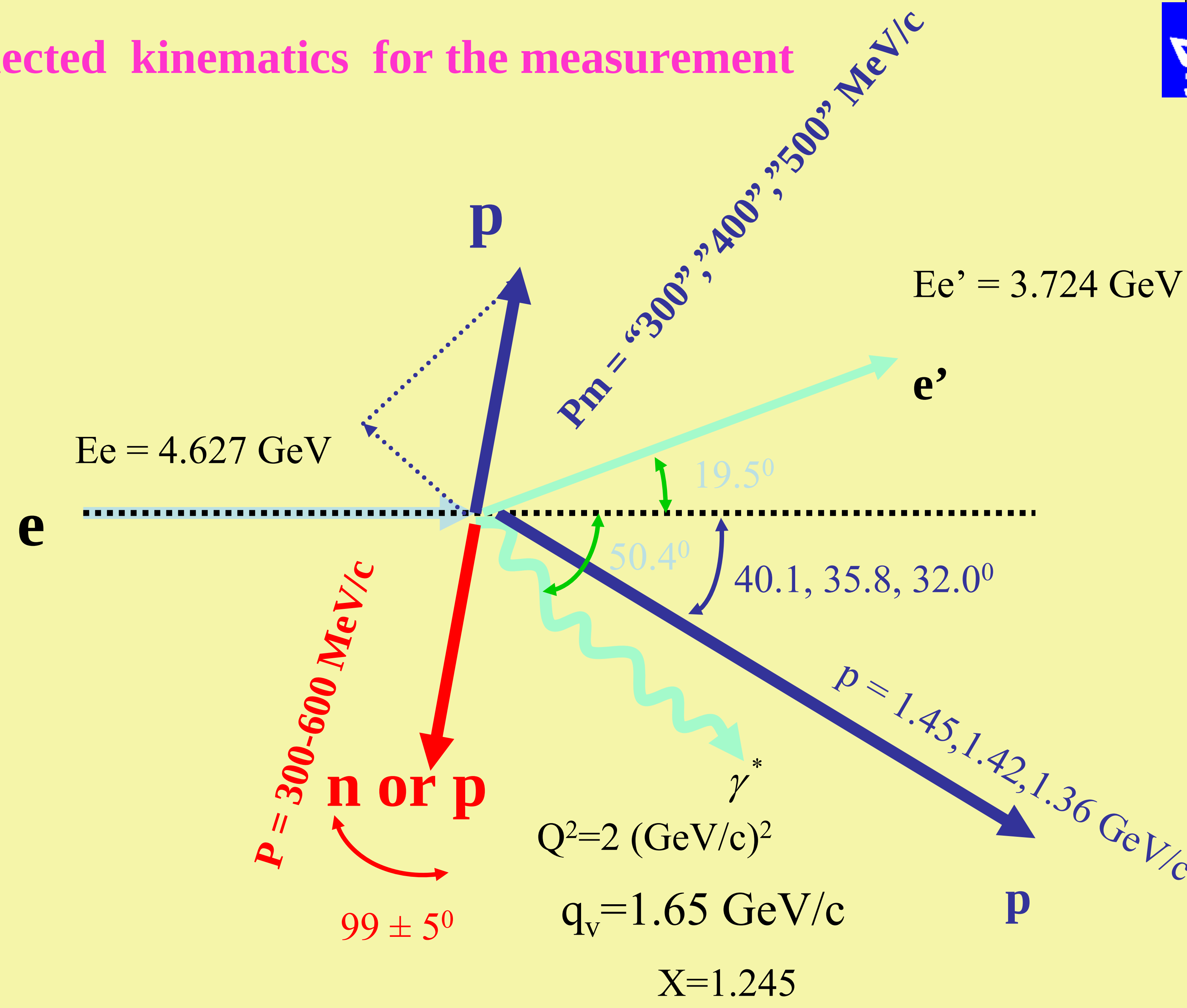
X > 1

Parallel / anti parallel

X > 1

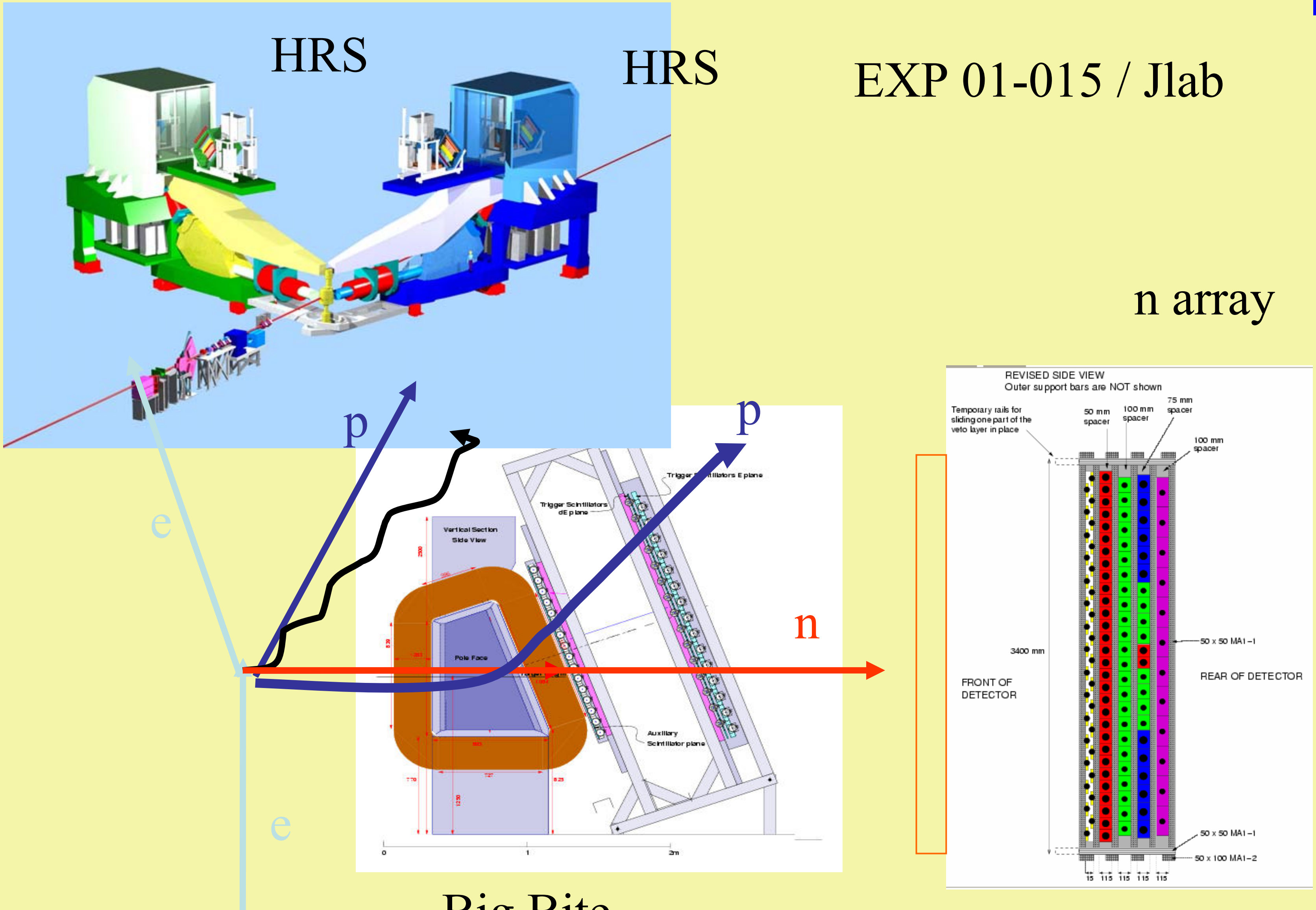
“almost anti parallel”

The selected kinematics for the measurement

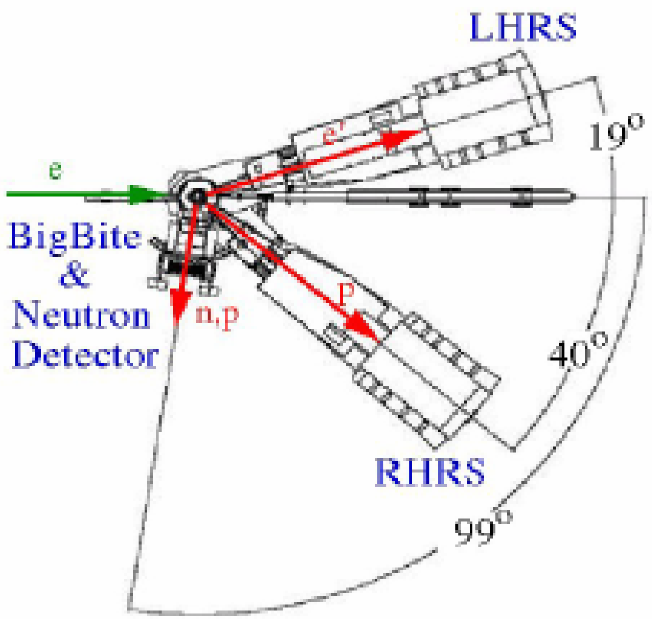


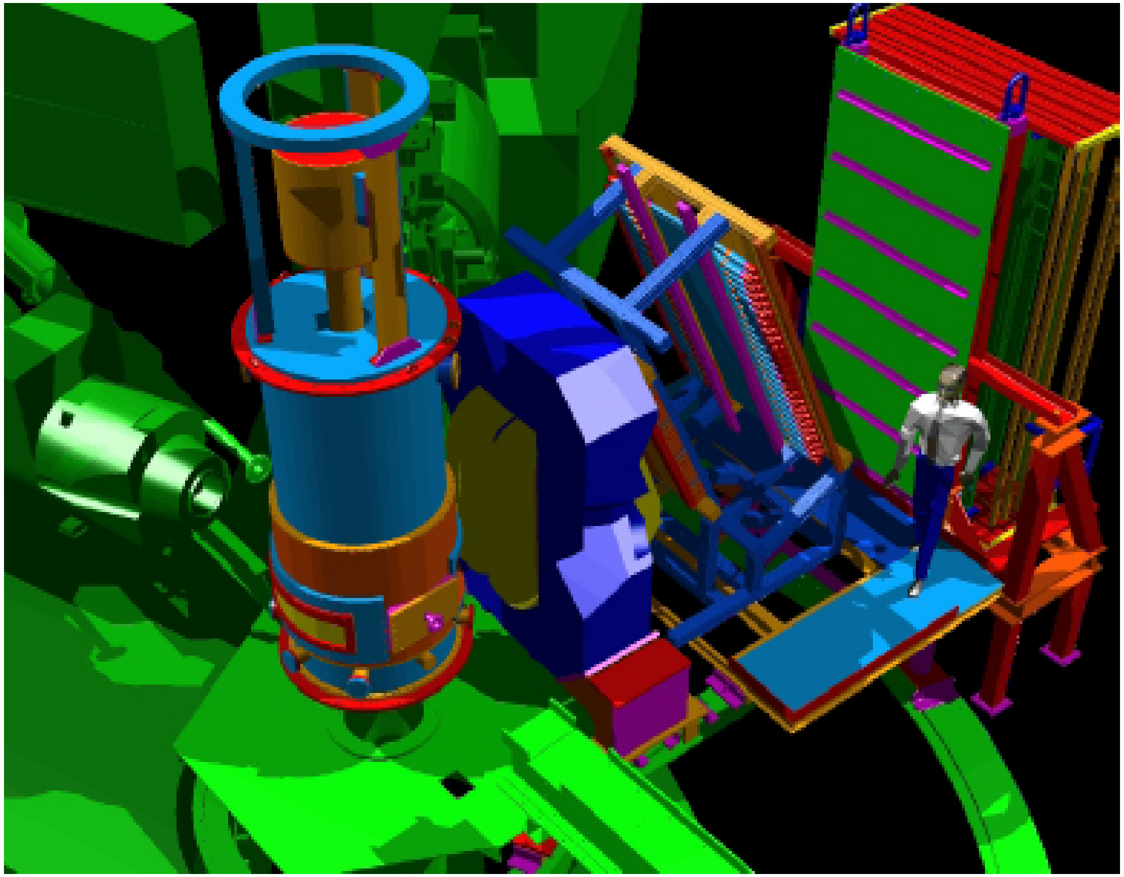
Experimental setup

EXP 01-015 / Jlab

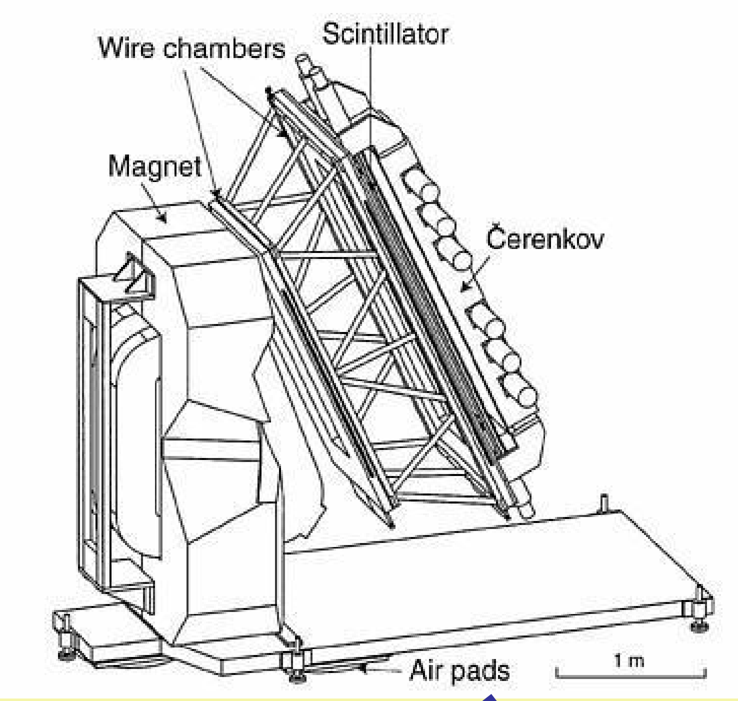


New Equipment for the Experimental Setup

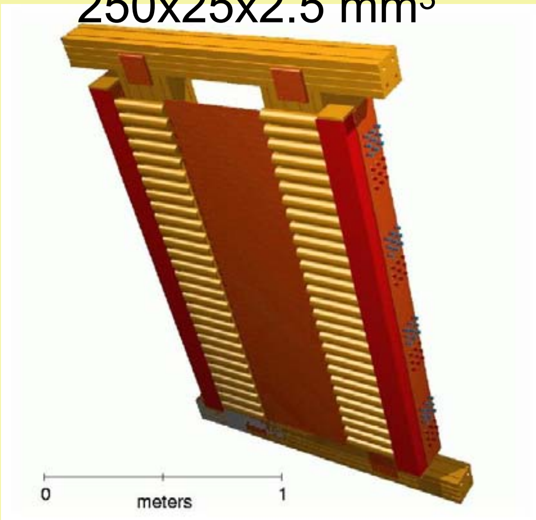




- New Scattering Chamber
- New BigBite Hadron Spectrometer (100 msr)
- New Low Energy Neutron Detector

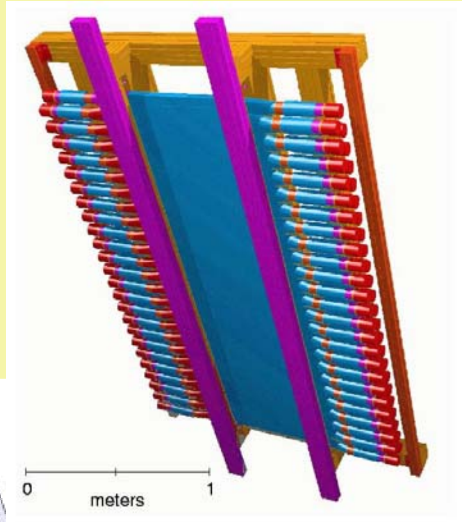


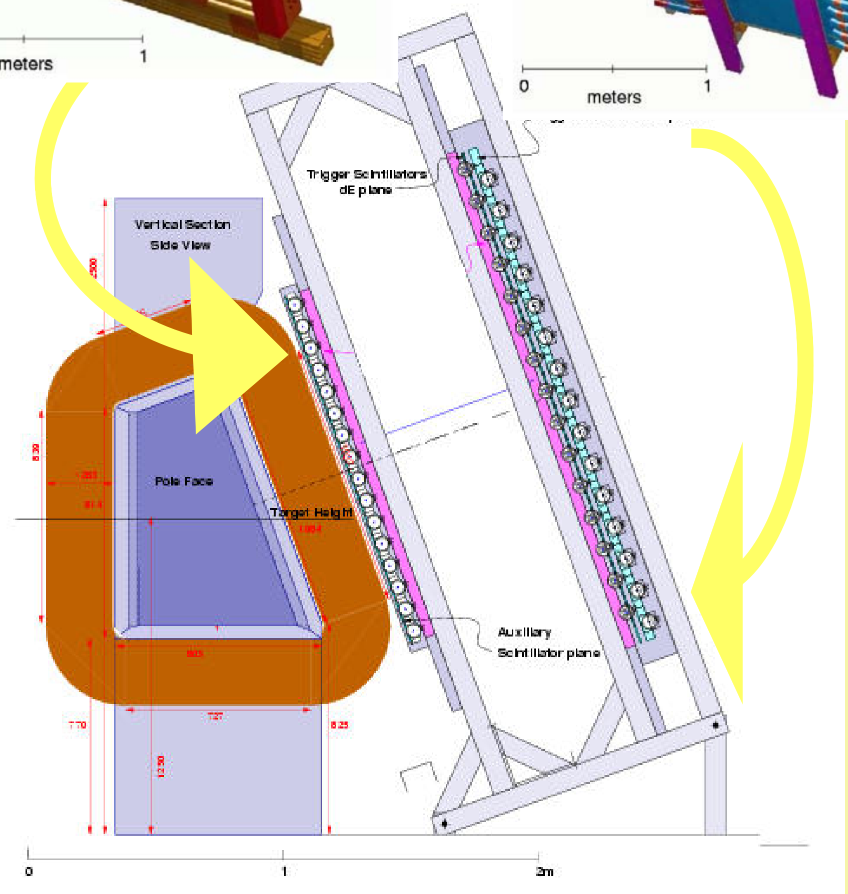
56 Scintillators: 250x25x2.5 mm^3



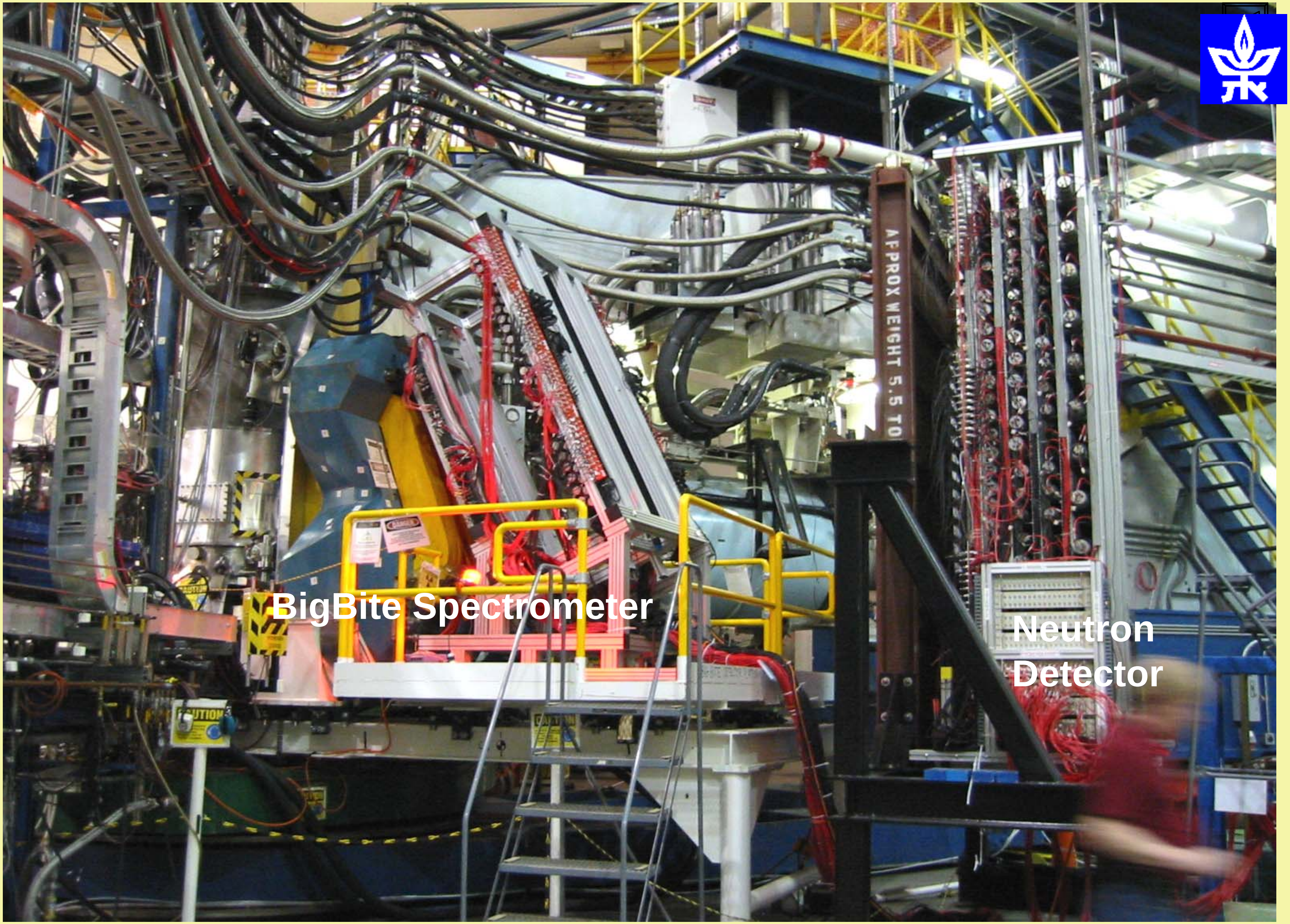
24 3 mm ΔE counters

24 30 mm E counters





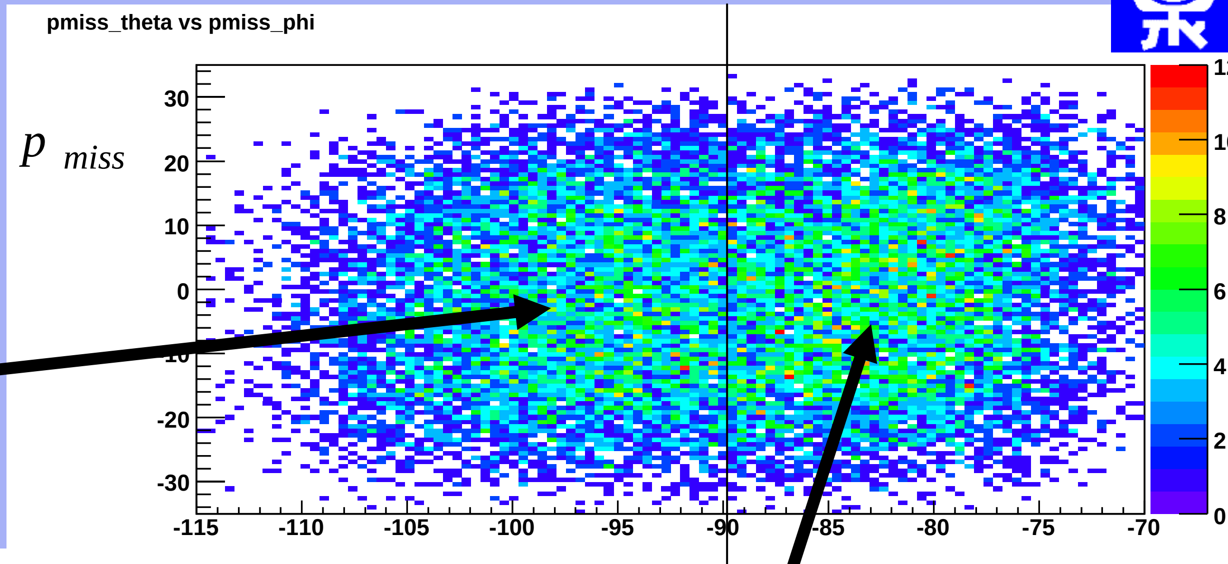
Commission experiment for BigBite at Jlab.



EXP 01-015 **Jlab / Hall A** Dec. 2004 – Apr. 2005

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

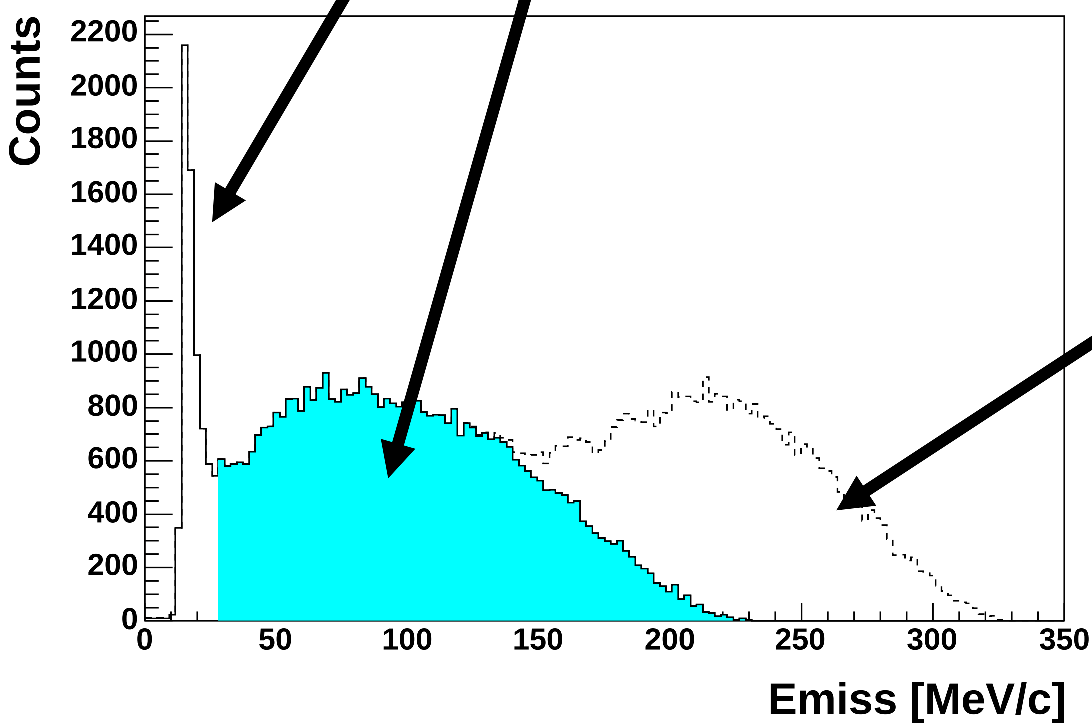
$x_B>1$



(e,e'p)

P-shell removal

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



(e,e'Δ)

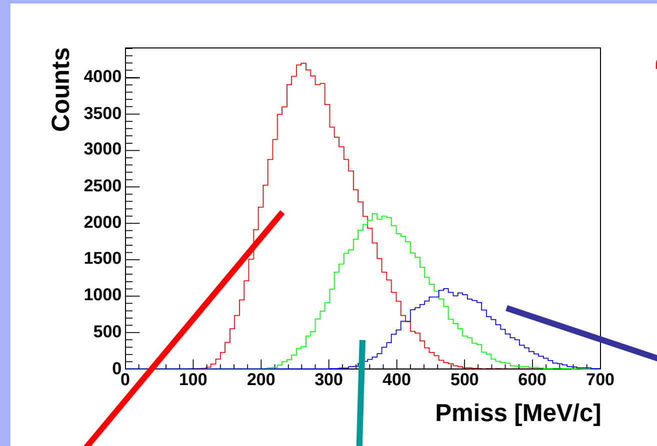
$^{12}C(e,e'p)$

$x_B>1$

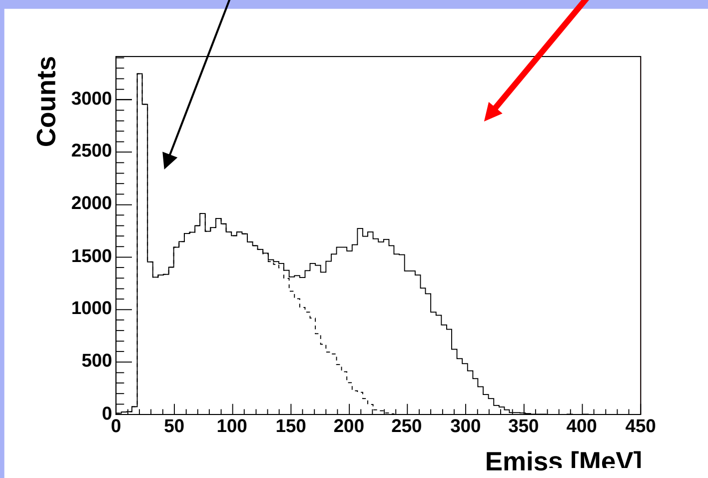
"300 MeV/c"

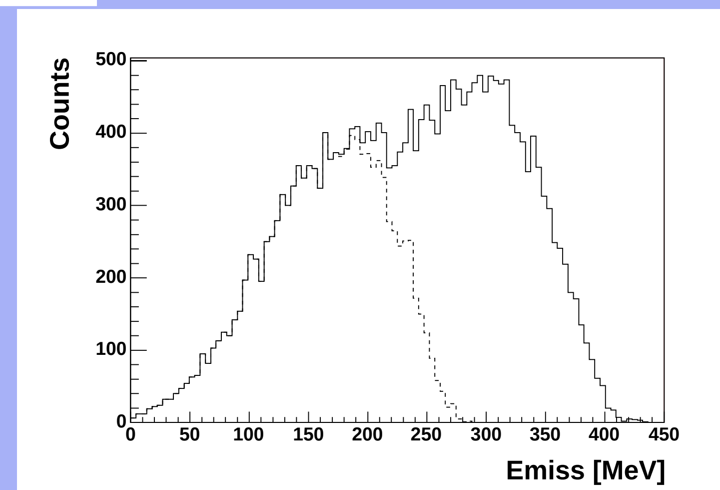
"400 MeV/c"

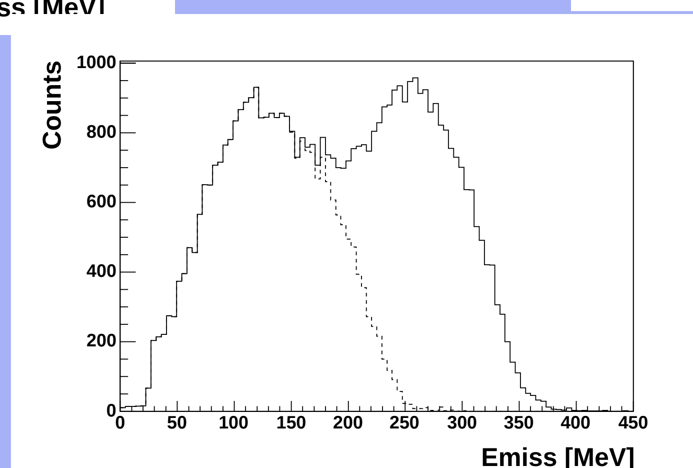
"500 MeV/c"



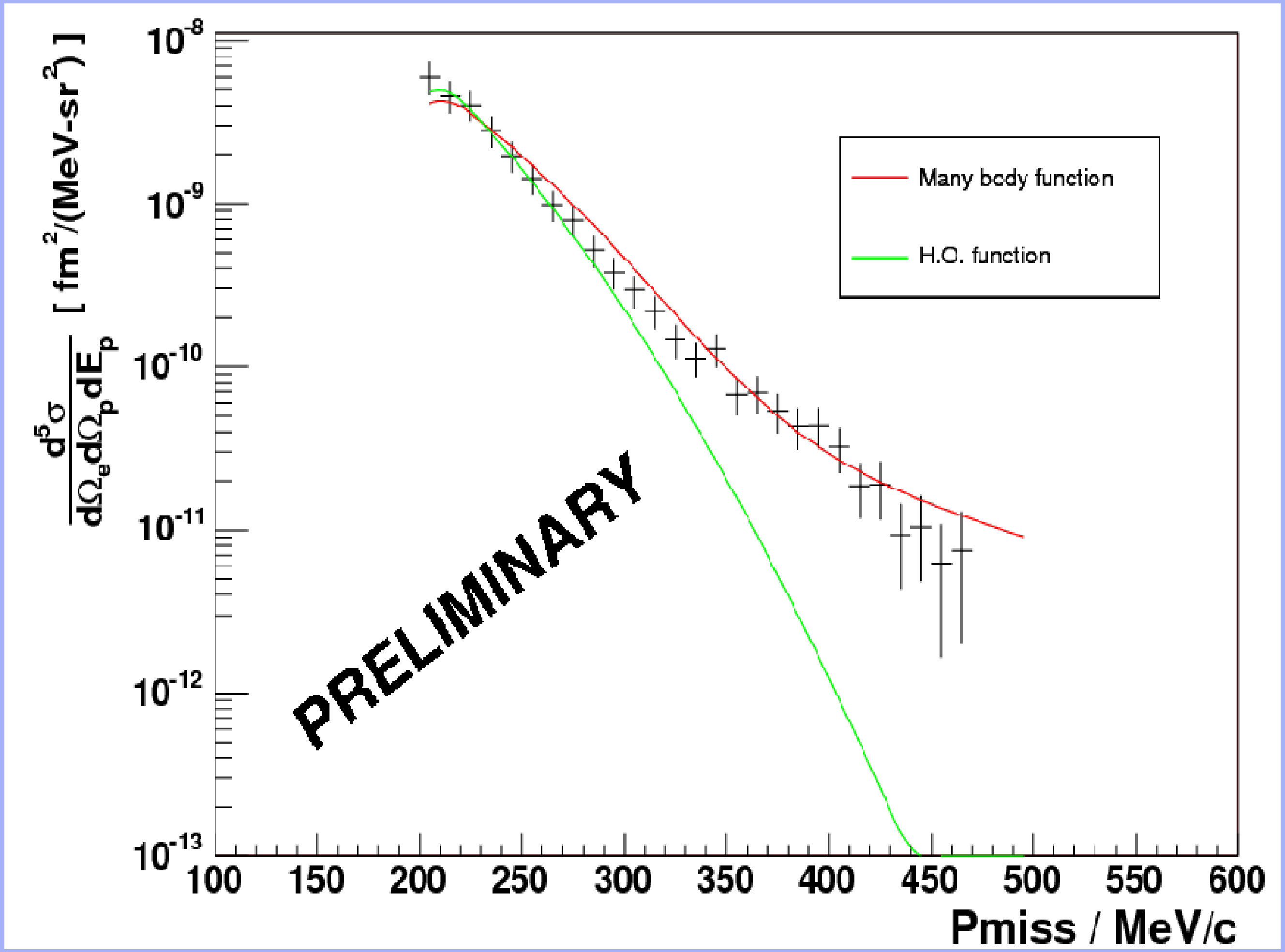
$^{12}C(e,e'p)^{11}B$





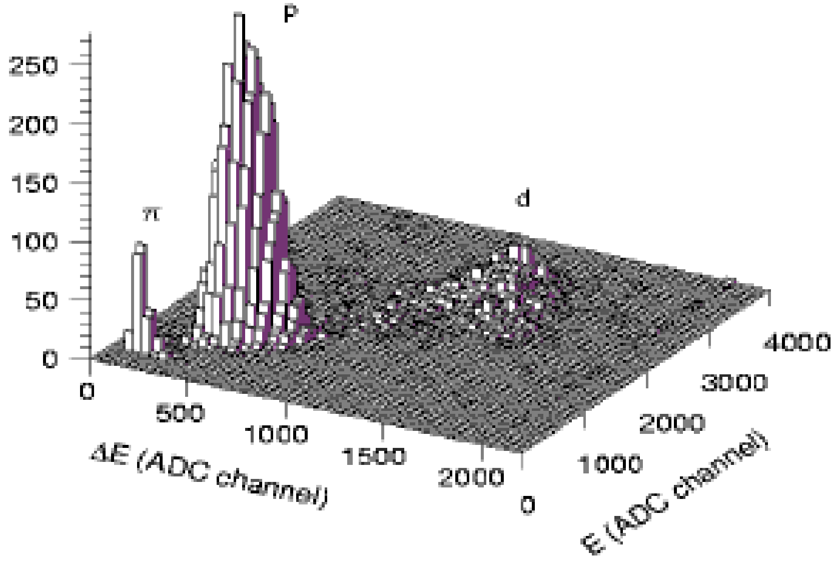


$^{12}C(e,e'p)^{11}B$ Thesis of *Peter Monaghan (MIT)*

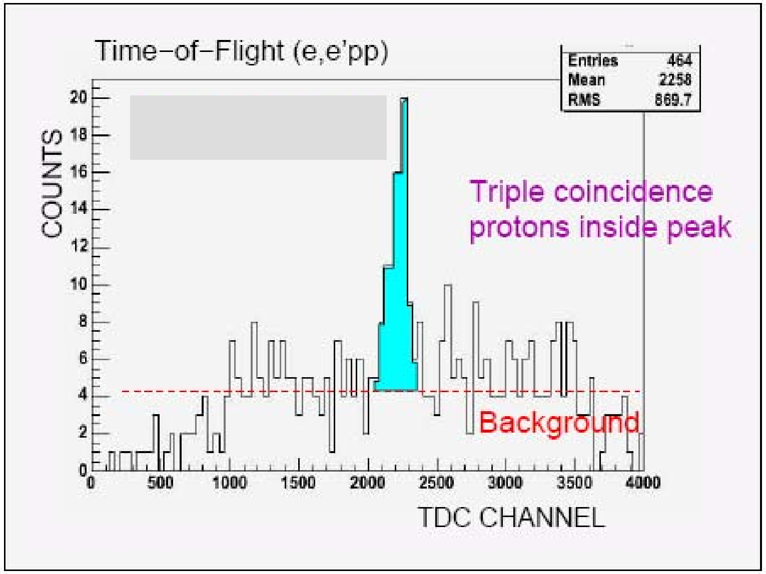


Analysis of the 12C(e,e'p) continuum cross sections underway.

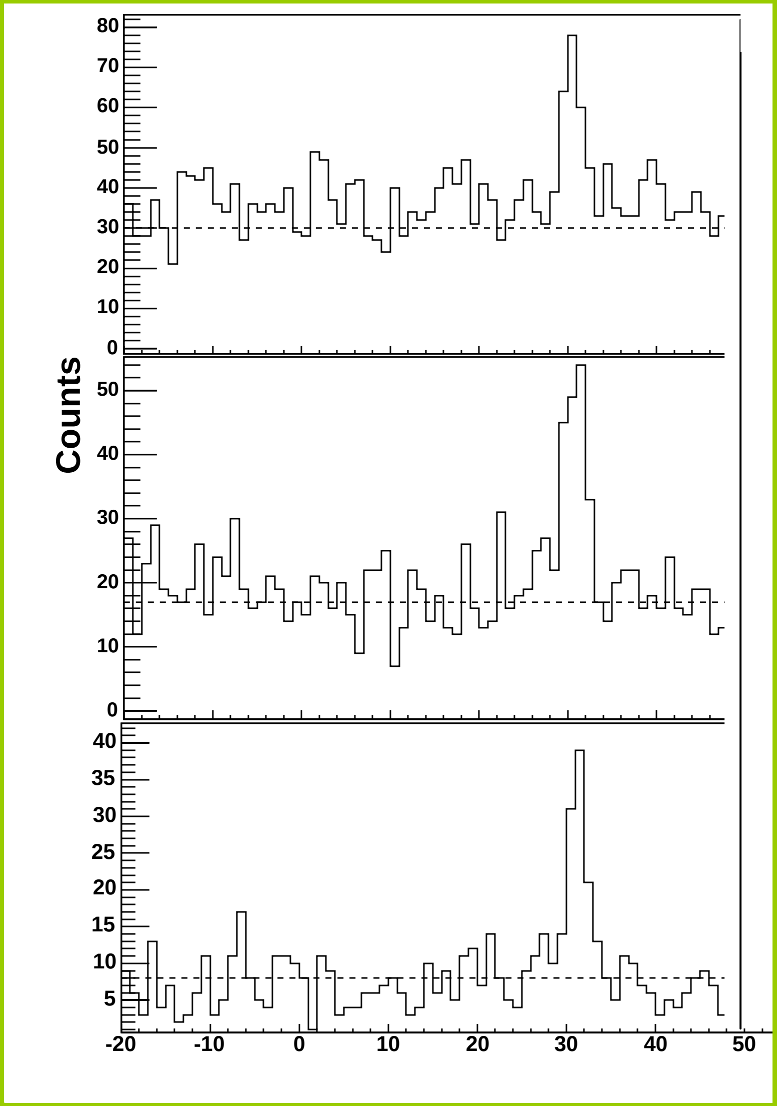
Performance of the BigBite Spectrometer



Triple Coincidence Events



- Operated at a luminosity of up to 10^{38} cm^{-2} s^{-1}
- ΔE/E Particle Identification
- Timing Resolution of 0.4 ns
- Momentum Resolution dp/p of 2% from time of flight



TOF [ns]

P_{mis}="300" MeV/c

(Signal : BG= 1.5:1)

P_{mis}="400" MeV/c

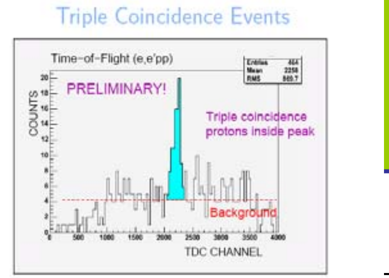
(Signal : BG= 2.3:1)

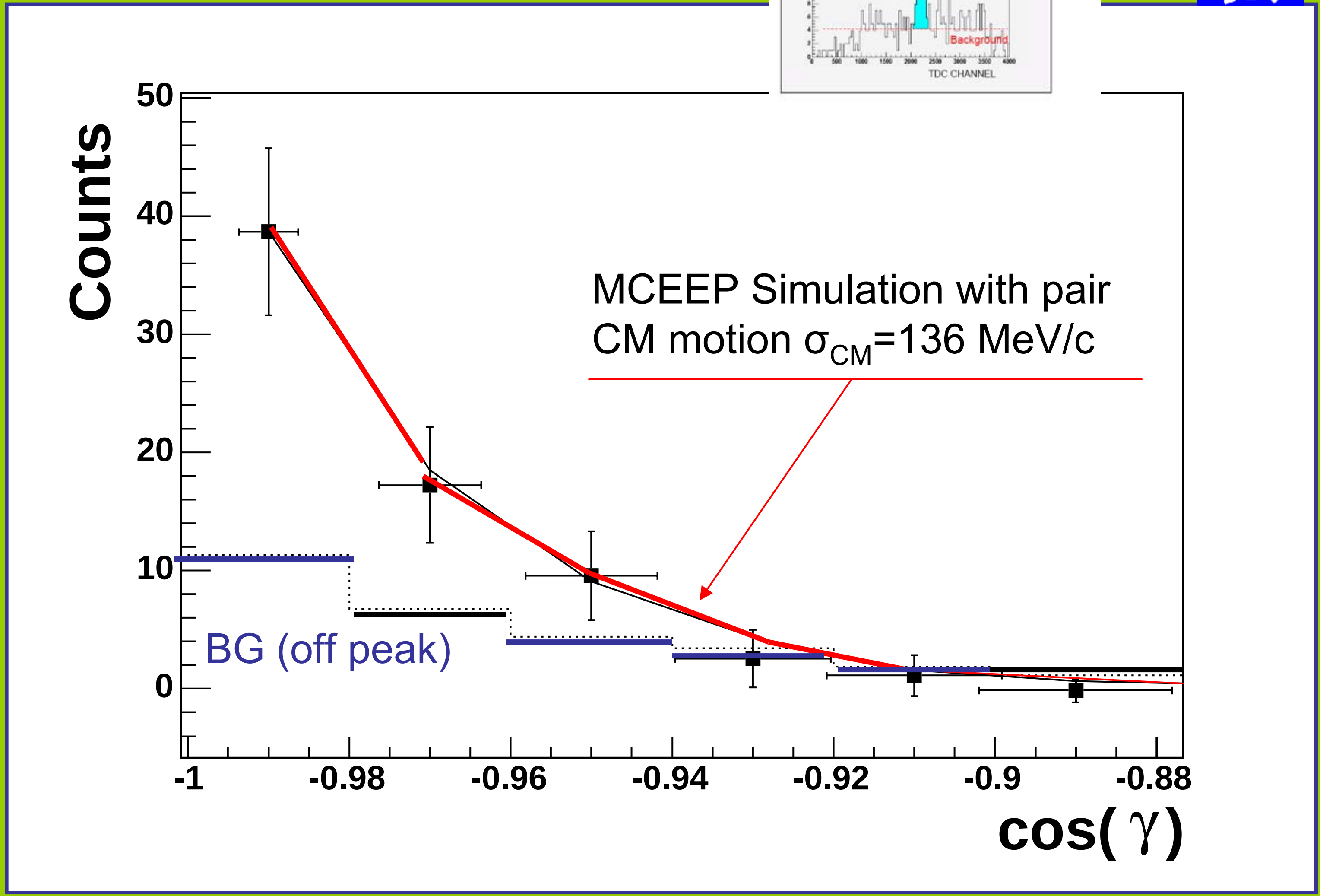
P_{mis}="500" MeV/c

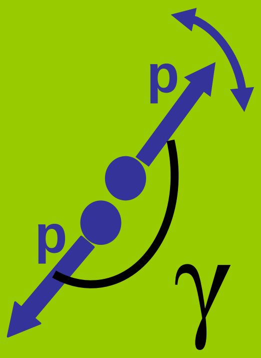
(Signal : BG= 4:1)

Directional correlation

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

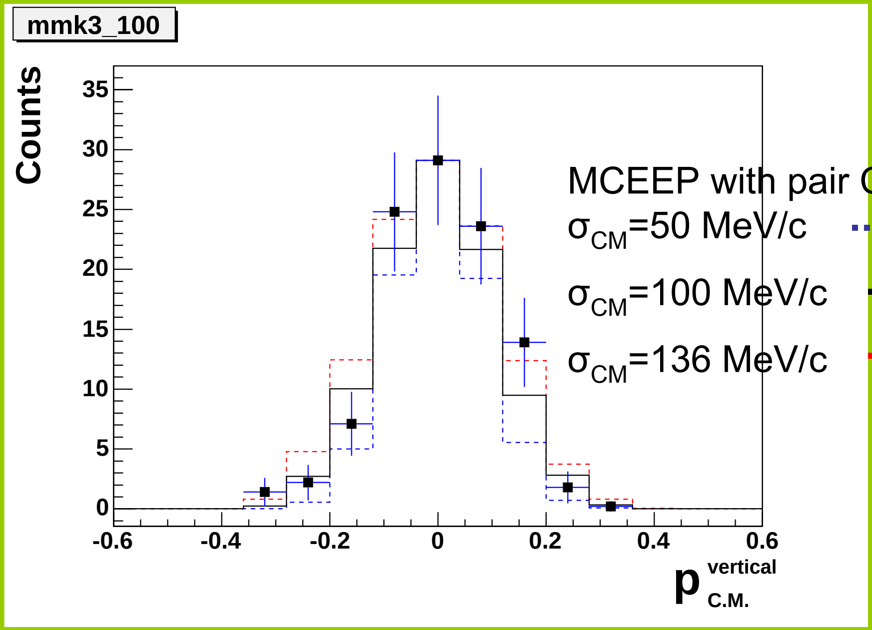




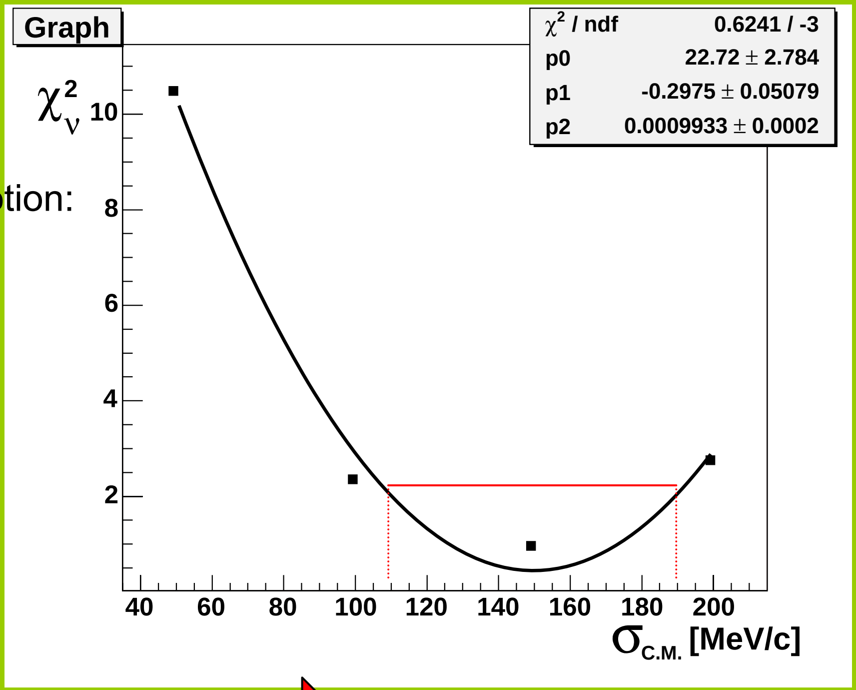


CM motion of the pair:

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



MCEEP with pair CM motion:
σ_{CM}=50 MeV/c
σ_{CM}=100 MeV/c
σ_{CM}=136 MeV/c

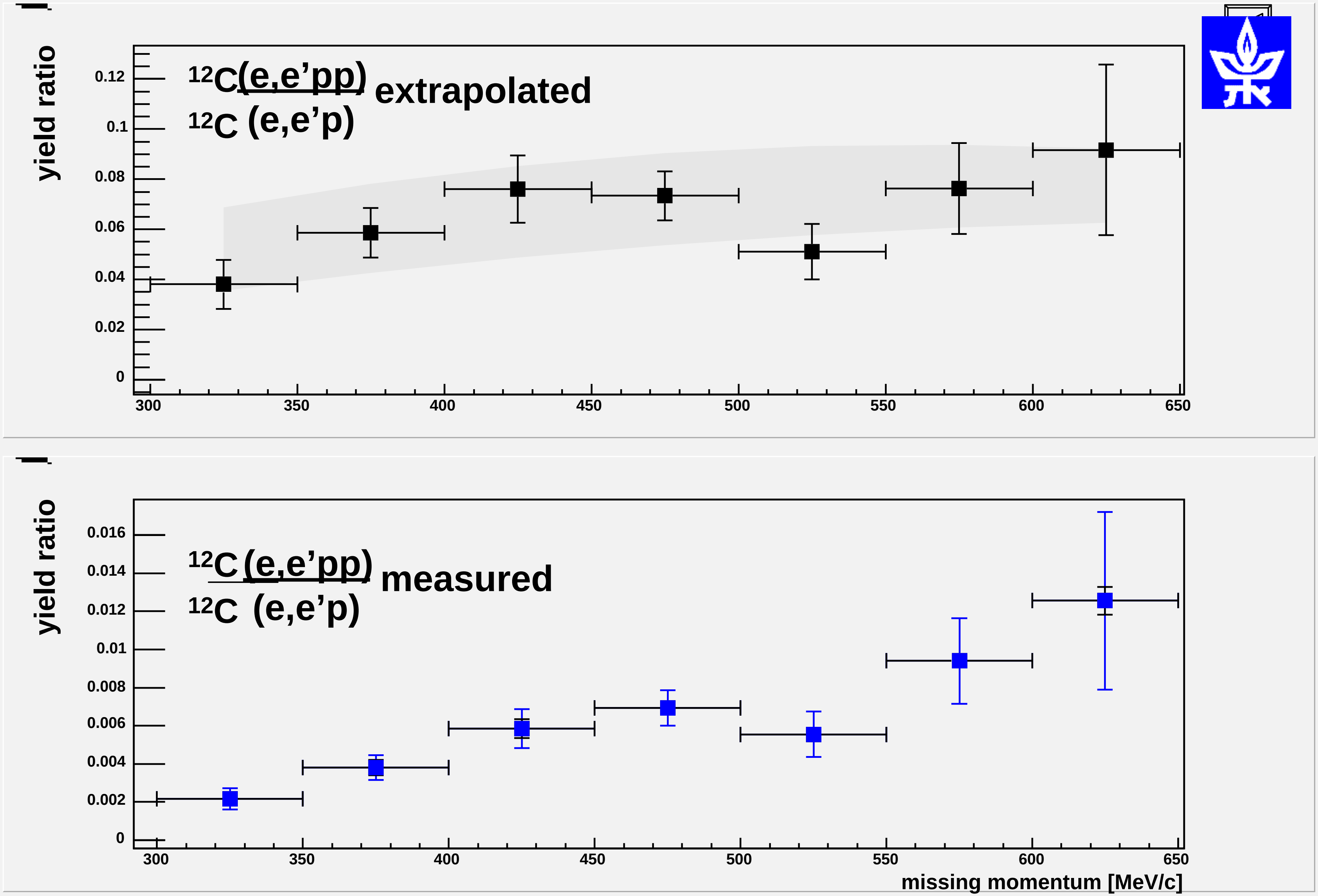


3 components of $\vec{p}_{c.m}$ and 3 kinematical setups

This experiment : σ_{CM}=0.136±0.008 GeV/c

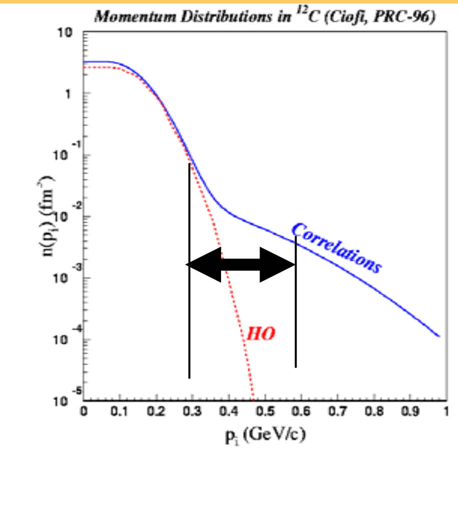
(p,2pn) experiment at BNL : σ_{CM}=0.143±0.017 GeV/c

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



yield ratio
12C(e,e'pp) extrapolated
12C (e,e'p)
0.12
0.1
0.08
0.06
0.04
0.02
0
300
350
400
450
500
550
600
650
yield ratio
12C (e,e'pp) measured
12C (e,e'p)
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
missing momentum [MeV/c]

For ^{12}C(e,e'p) p_{miss} = 275-600 MeV/c

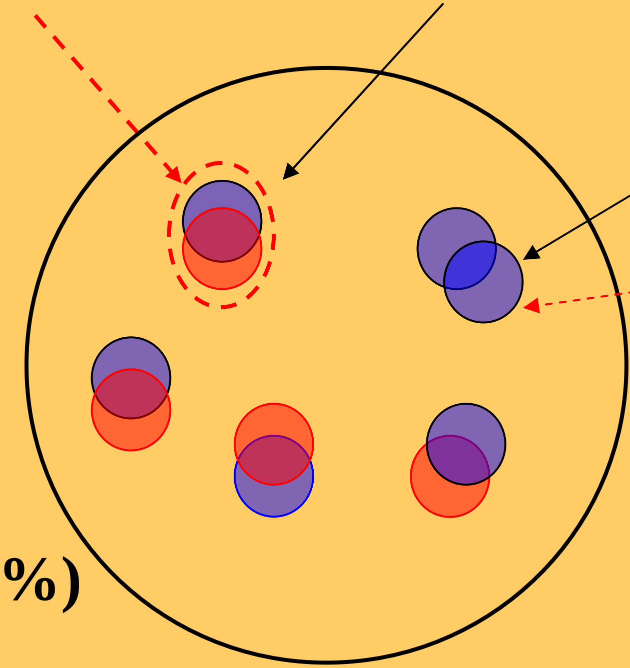


pn - SRC

74 – 100 % *
74 – 95 % *

7 ± 2 %

pp - SRC



np-SRC dominance:

$$(0.92^{+0.06}_{-0.18}\%)$$

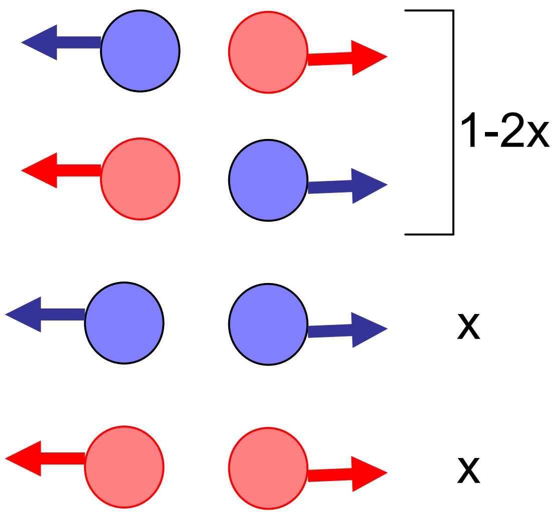
2N-SRC dominance: 84-100%

* Deduced from ^{12}C(p,2pn)

Notice: 100% is the sum of all the protons in this momentum range

$$\frac{(e,e'pp)}{(e,e'p)} = 2x \quad \Rightarrow \quad \frac{\text{pp-SRC}}{2N-SRC} = x$$

Assuming in ^{12}C nn-SRC = pp-SRC and 2N-SRC=100%

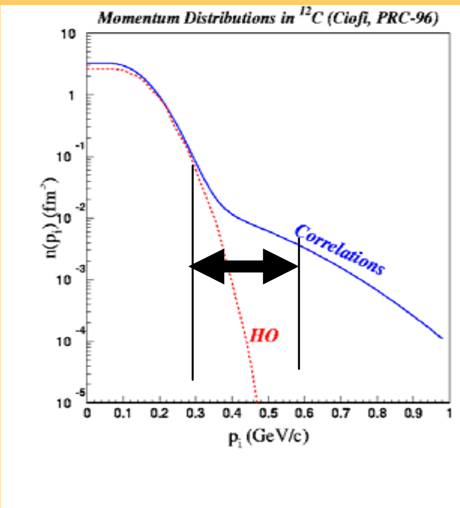


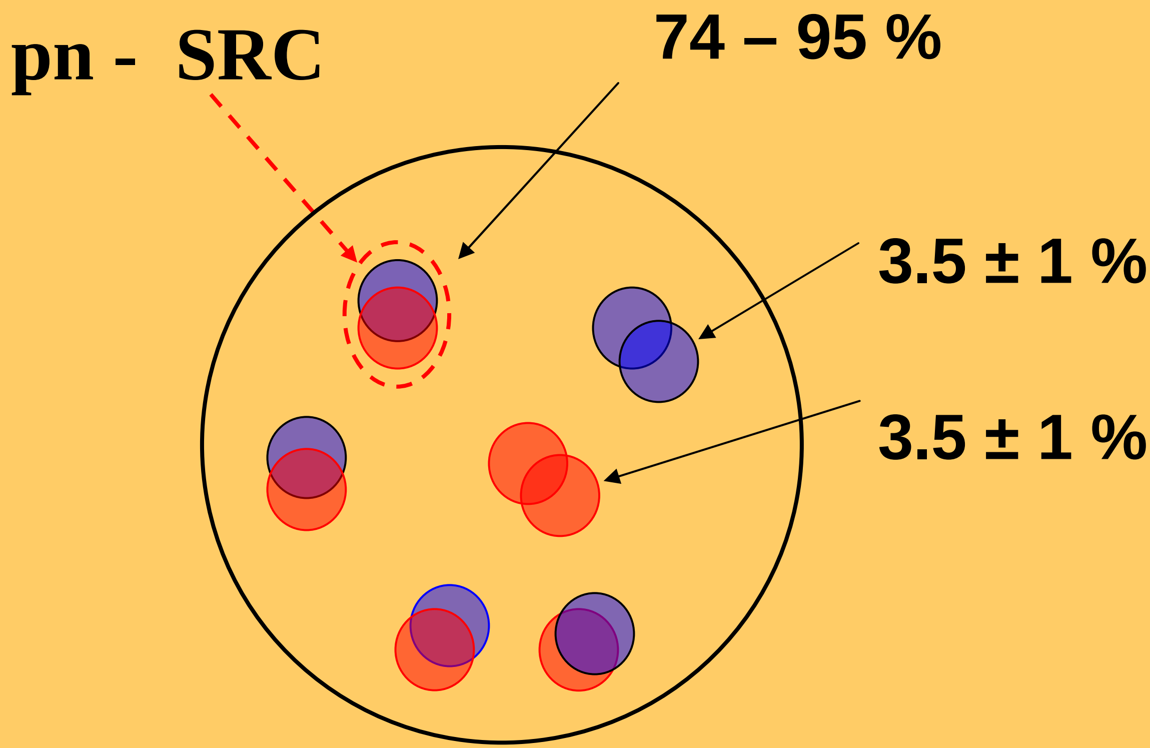
A virtual photon with x_B >1 “sees” all the pp pairs but only 50% of the np pairs.

$$\frac{(e,e'pp)}{(e,e'p)} = \frac{x}{x+(1-2x)/2} = 2x$$

For 275-600 MeV/c protons in ^{12}C:

Assuming for ^{12}C nn-SRC = pp-SRC





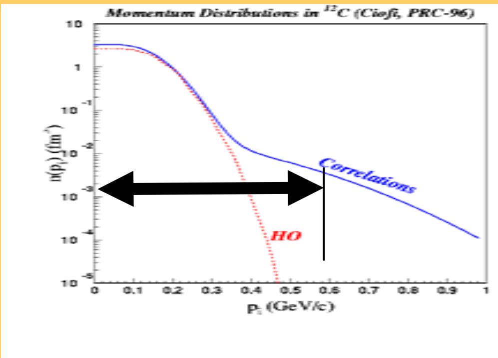
2N –SRC dominance

np-SRC dominance

Notice: 100% is the sum of all the nucleons in this momentum range

For all protons in ^{12}C:

Assuming for ^{12}C nn-SRC = pp-SRC



np-SRC
18.4±4.5 %

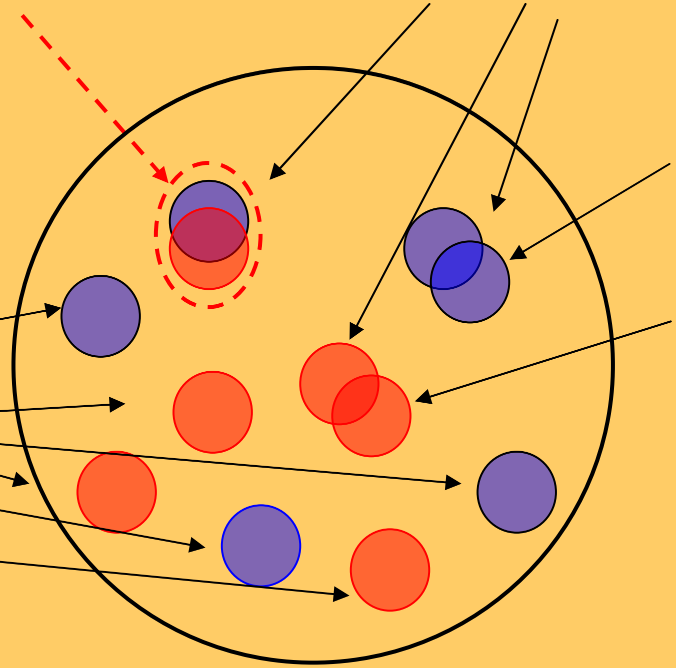
2N-SRC
20±4.5 %

pp-SRC
0.7 ± 0.2 %

A single “particle” in an average potential

80±4.5%

nn-SRC
0.7 ± 0.2 %



2N –SRC dominance
np-SRC dominance

Notice: 100% is the sum of all the nucleons in this momentum range

pp-SRC versus pn-SRC pairs

$$P_{pn}(^{12}C)/P_{pp}(^{12}C) = 74-95\% \big/ 3.5\pm1\% > 16$$

Is this large or small? What to expect?

Just counting pairs in ^{12}C:

#np=6*6=36

#pp=6*5/2=15

$$P_{pn}(^{12}C)/P_{pp}(^{12}C) = 36/15 = 2.4$$

A statistical distribution obtained by assuming that the SRC are L=0 pairs with equal occupation of each possible quantum state:

np (spin=0,1) : 4 states
pp (spin=0) : 1 state
nn (spin= 0): 1state

$$P_{pn}(^{12}C)/P_{pp}(^{12}C) = 4$$

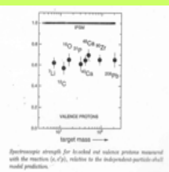
I. Yaron et al., PRC C66, 024601 (2002).

Does it mean that a nucleus of only protons or only neutrons (like what a n-star might be) behaves more like an ideal Fermi gas or more like nuclei?

Thus, the deduced ^{12}C structure is:

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

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

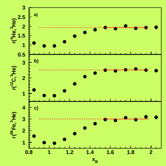


(e,e'p)

10-20 % - shell model

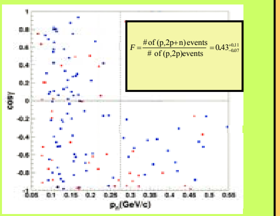
long range correlations

(e,e')



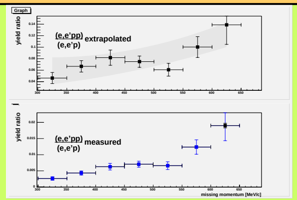
20 ± 4.5 % - 2N SRC .

18.4 ± 4.5 % - SRC np pairs .



(p,2pn)

0.7±0.2% - SRC pp pairs

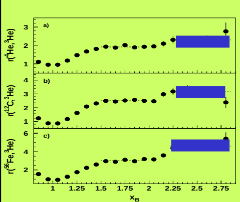


(e,e'pp)

0.7±0.2 % - SRC nn pairs.

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

? ~1% -non nucleonic degrees of freedom

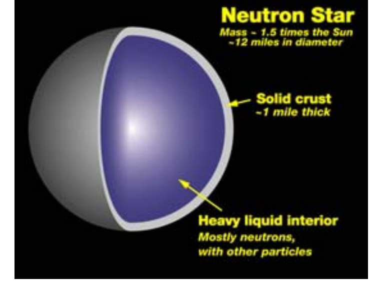


(e,e')

Analysis of more data, available from the triple coincidence measurement of the (e, e'pn) and (e, e'pp) reactions at Jlab / Hall A (E01-015) will allow to check, confirm, and to reduce the uncertainties

(e,e'pn)/(e,e'p) → pn-SRC to compare with the (p,2pn) result.

(e,e'pp)/(e,e'pn) →A direct comparison between pn and pp SRC pairs.

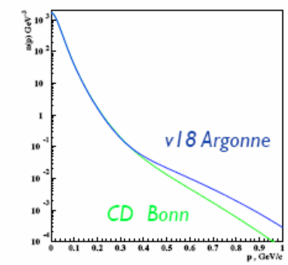


Study of cold dense nuclear matter complementary to study of hot dense nuclear matter

Dynamics of neutron star formation and structure

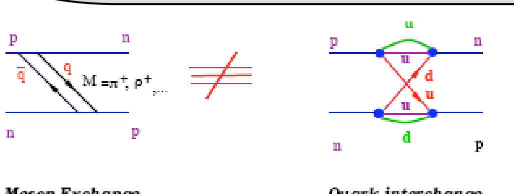
SRC

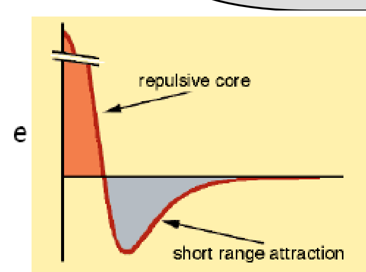
in nuclei

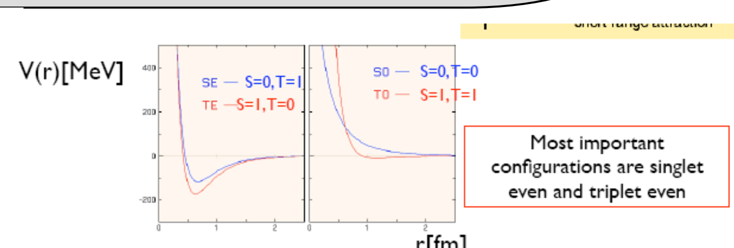


NN interaction:
short range repulsive core and
the role played by the tensor force

Quark vs. hadronic degrees of freedom in nuclei







Acknowledgment

Exp 01 – 015 collaboration **Hall A / TJNAF**

S. Gilad , S. Wood, J. Watson, W. Bertozzi,

D. Higinbotham, R. Shneor, P. Monaghan, R. Subedi

Kim Egiyan: For many years of collaboration and friendship.

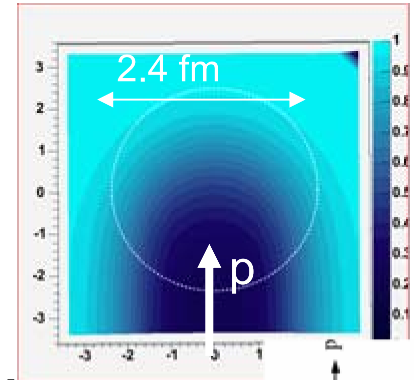
M. Sargsian, L. Frankfurt, M. Strikman:
For their theoretical support and guidance.

Why FSI are predicted to be small in the chosen kinematics?

The FSI between the two nucleons in the SRC pair

The large mass of the pair (~2.15 GeV), which corresponds to relative momentum of about 0.5 GeV/c reduce the FSI.

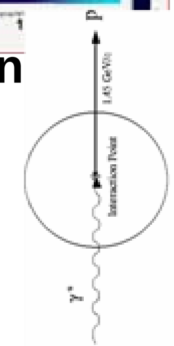
Frankfurt, Sargsian, Strikman PR C56, 1124 (1997).



The FSI of the recoil proton with the rest of the nucleus

Suppressed due to Pauli blocking and the geometry of the (e,e'p) reaction

Pandharipande and Pierper PR C45, 791 (1992).



The FSI of the fast proton with the rest of the nucleus

The large anti-parallel component of p_{miss} ($>k_F$) reduce the FSI.

Frankfurt, Sargsian, Strikman PR C56, 1124 (1997).

The absorptive (imaginary) part of the FSI amplitude does not modify the (e,e'pp)/(e,e'p) ratio.

The small reduction in the (e,e'pp)/(e,e'p) ratio due to the transparency of the low energy proton is partially compensated by a small increase in the ratio by single charge exchange that can turn pn-SRC pairs into (e,e'pp) events.

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 C 761 (1992)

The data itself indicate that FSI are small. The extracted pair c.m distribution is a combination of c.m motion and FSI. The fact that we get :

- a narrow width (σ_{cm}=136 MeV/c),
- similar in the transverse and longitudinal directions,
- Same as in previous measurements of the (p,2pn) reaction,
- Same as theoretical predications,

indicates that FSI contribution are not dominant.

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 C 761 (1992)

The transparency of the low momentum protons is about 0.8.
i.e the measured (e,e'pp)/(e,e'p) ratio should be increased by 20%

The same ratio should be decreased by 8-16% due to SCX.

These two, within the errors, compensate each other.

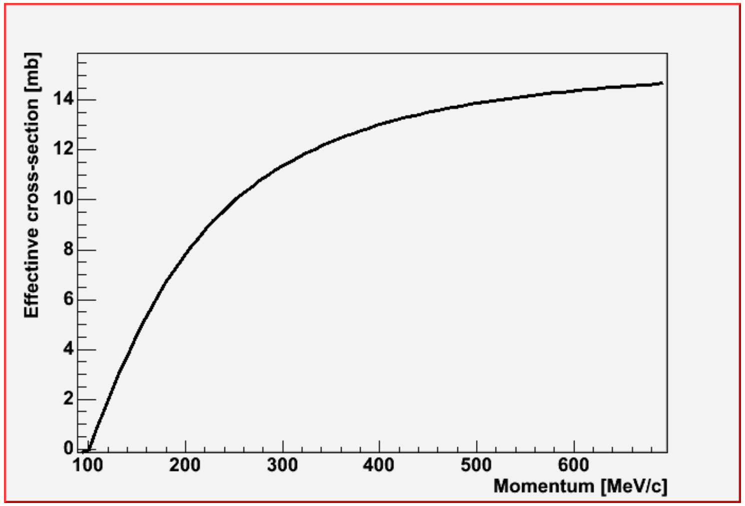
$$T = \frac{1}{A}\int \rho \, \mathbf{exp}\left(-\sigma_{eff} \int \rho \hat{z} dl\right) dv$$

we adjust the effective cross section to obtain the measured Transparency:

$$\sigma_{eff}(1.5GeV/c) = 26mb$$

$$\sigma_{eff}(180MeV/c) = 14mb$$

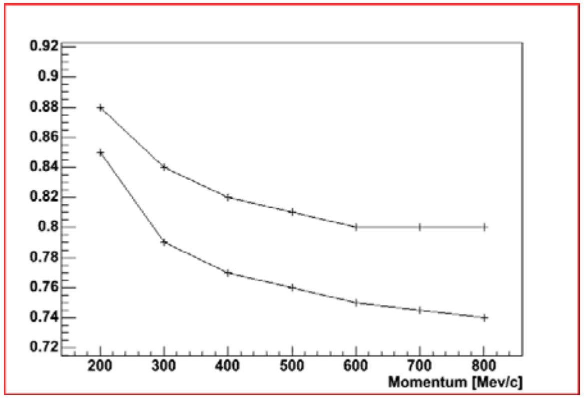
We used the measured effective cross section at 180 MeV/c and the energy dependent of the mean free path as calculated by Pandharipande and Pieper (Phys. Rev C45(1992)791.).

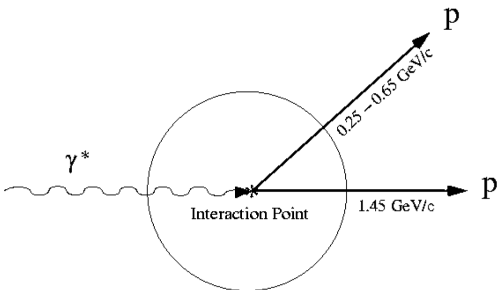


The transparency of the recoil particle in the triple coincidence experiment is higher than that calculated for (e,e'p) since the (e,e'p) already selected an interaction point in the nucleus where the transparency of the (e,e'p) proton is high and therefore the transparency of the recoil proton is also high.

We calculated the conditioned transparency as:

$$T = \frac{1}{A}\int \rho \, \mathbf{exp}[-\sigma_{eff}(1.5GeV/c)\int \rho \hat{z} dl \,]\mathbf{exp}[-\sigma_{eff}(p_{recoil})\int \rho \hat{n} dl \,] dv$$





Single Charge Exchange (SCX)

$$\sigma_{eff}^{SCX} = \sigma_{eff}(1.5GeV/c)\frac{\sigma_{SCX}}{\sigma_{TOTAL}}$$

$$\frac{\sigma_{SCX}}{\sigma_{TOTAL}} = \frac{1.1mb}{40mb}$$

Assuming the (e,e'pn) is 5-10 times the magnitude of the (e,e'pp), the contamination of (e,e'pp) events with contribution from the np correlated pairs is 8-16%.
Since the SCX is very forward peaked at these energies we assumed that each proton produced in a SCX process will be considered a correlated partner.

PRL 97, 162504 (2006) PHYSICAL REVIEW LETTERS week ending 20 OCTOBER 2006

Evidence for Strong Dominance of Proton-Neutron Correlations in Nuclei

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[2]*Department of Physics, Florida International University, Miami, Florida 33199, USA*
[3]*Department of Physics, The Pennsylvania State University, University Park, Pennsylvania, USA*
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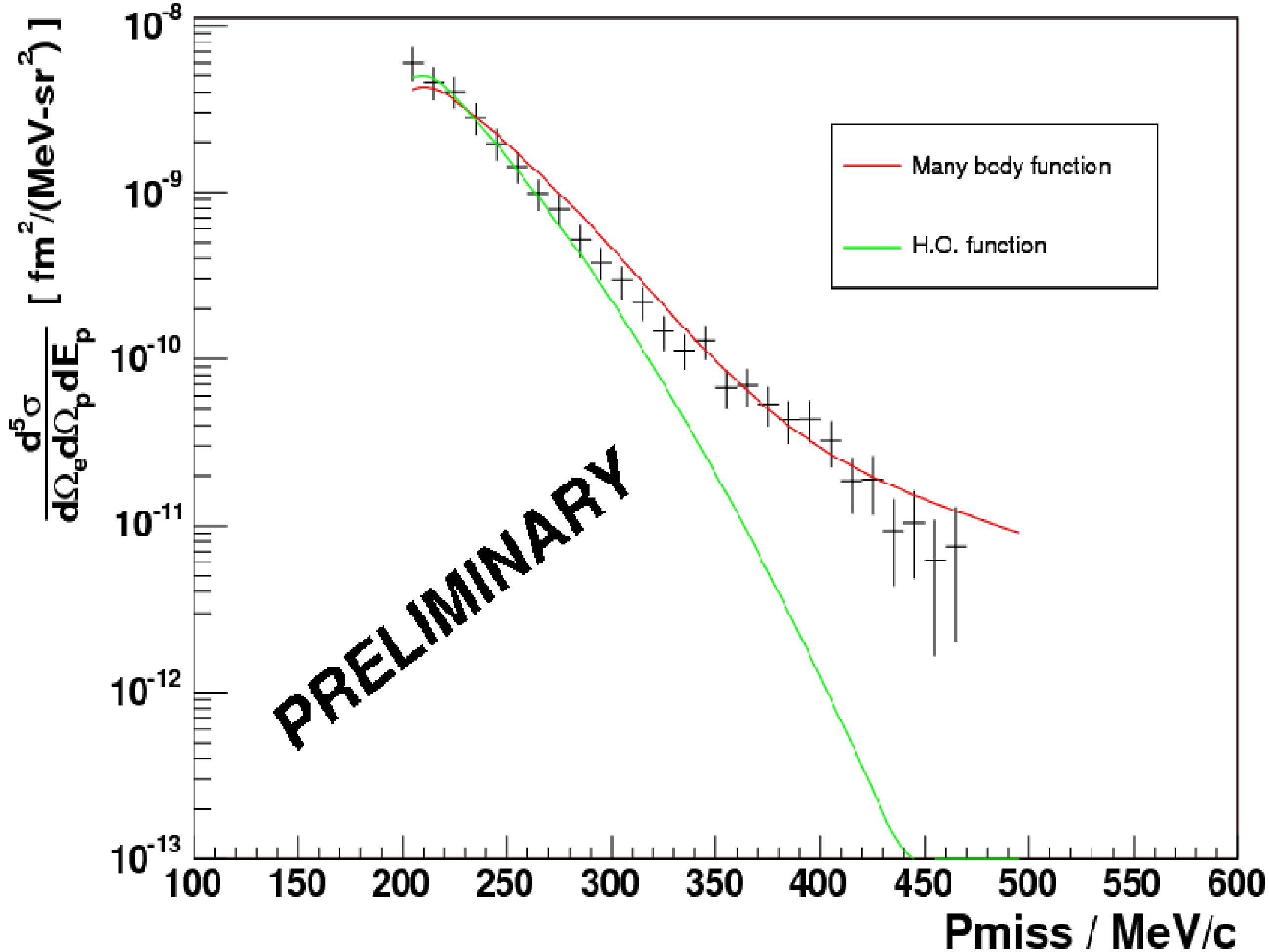
(Received 11 April 2006; published 18 October 2006)

We analyze recent data from high-momentum-transfer (p, pp) and (p, ppn) reactions on carbon. For this analysis, the two-nucleon short-range correlation (NN-SRC) model for backward nucleon emission is extended to include the motion of the NN pair in the mean field. The model is found to describe major characteristics of the data. Our analysis demonstrates that the removal of a proton from the nucleus with initial momentum 275–550 MeV$/c$ is $92^{+8}_{-18}\%$ of the time accompanied by the emission of a correlated neutron that carries momentum roughly equal and opposite to the initial proton momentum. This indicates that the probabilities of pp or nn SRCs in the nucleus are at least a factor of 6 smaller than that of pn SRCs. Our result is the first estimate of the isospin structure of NN-SRCs in nuclei, and may have important implication for modeling the equation of state of asymmetric nuclear matter.

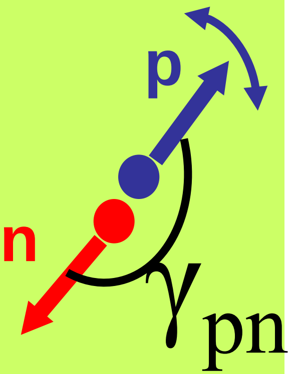
$^{12}C(e,e'p)^{11}B$ *Peter Monaghan (MIT)*

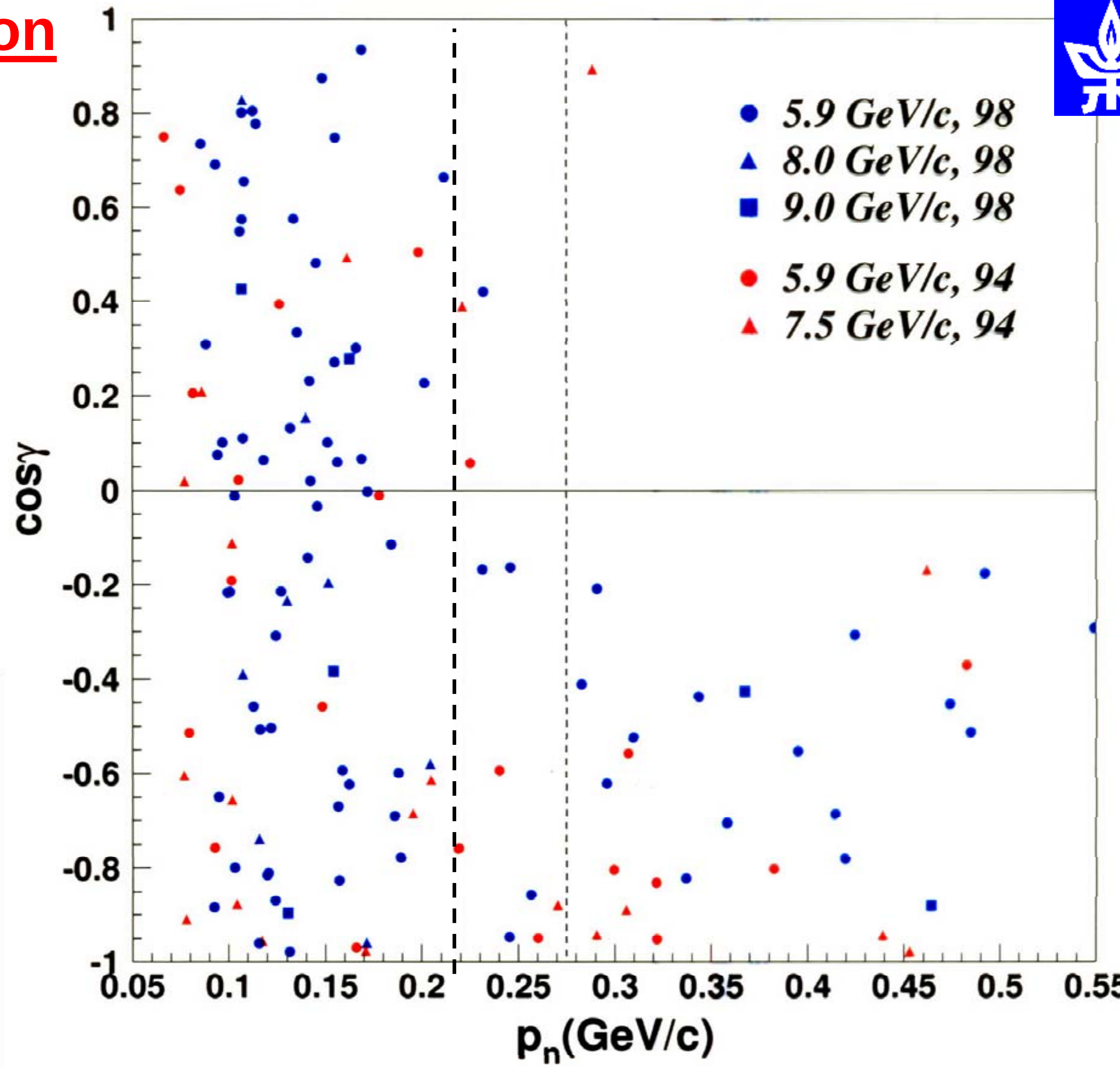


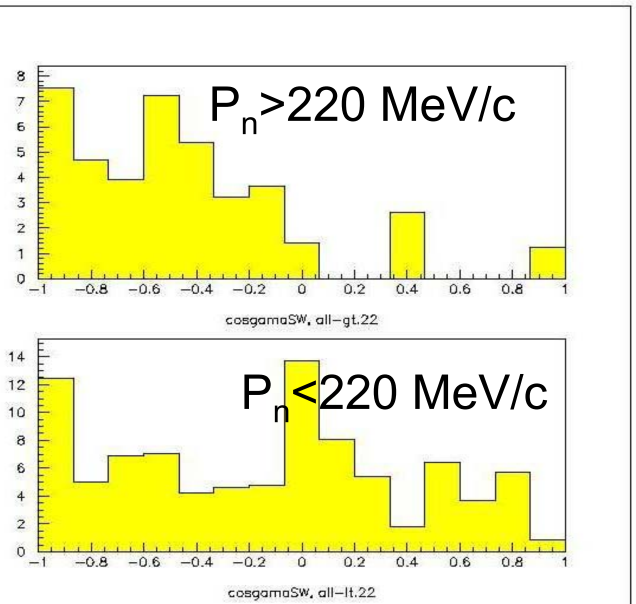
Analysis of the 12C(e,e'p) continuum cross sections underway.

Directional correlation

(p,2pn)







The EVA/BNL collaboration

Theory:

Frankfurt, Sargsian, and Strikman

New CLAS A(e,e') Result:

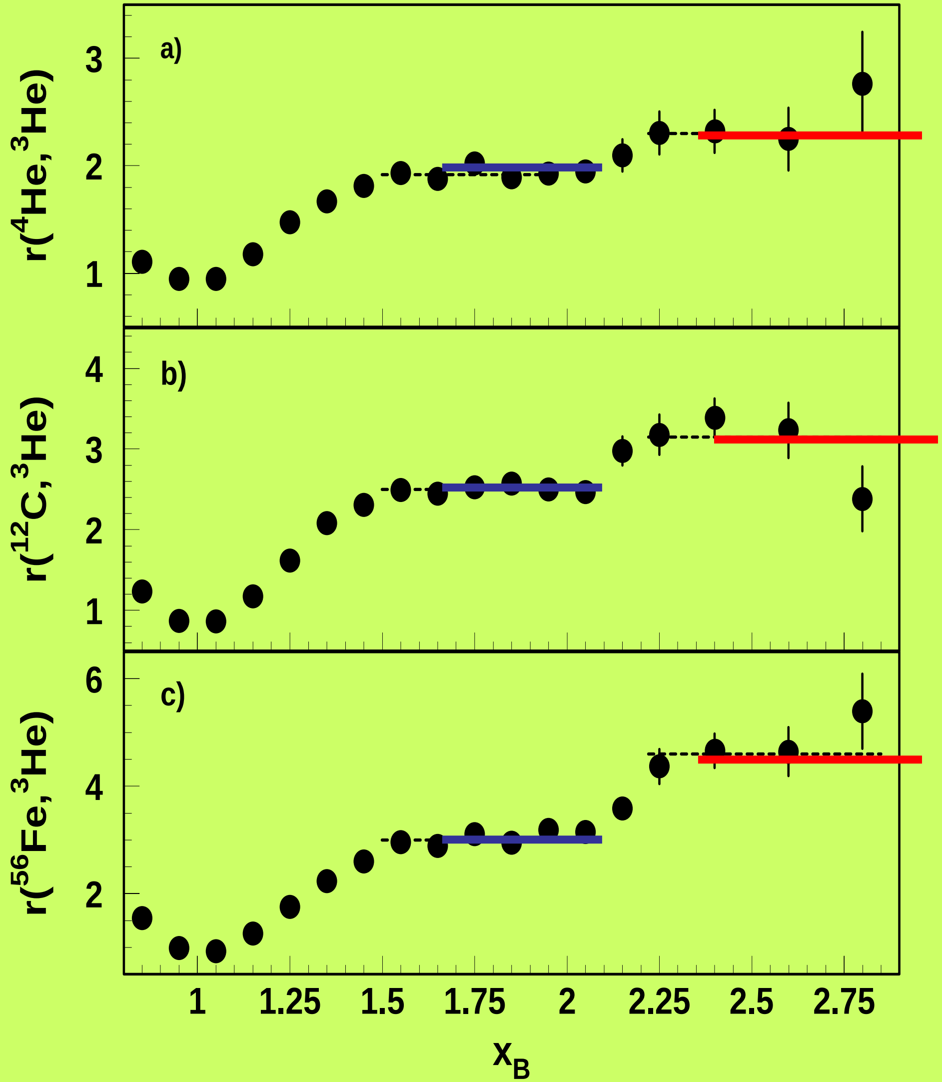
K. Sh. Egiyan et al. PRC 68, 014313.

K. Sh. Egiyan et al. PRL. 96, 082501 (2006)

$$x_B = \frac{Q^2}{2M\nu} > 1.5, \quad P_{in} \geq 275 MeV/c$$

$$2 < x_B = \frac{Q^2}{2M\nu} < 3,$$

$$Q^2 > 1.4 GeV^2$$



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

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

For ^{12} C:

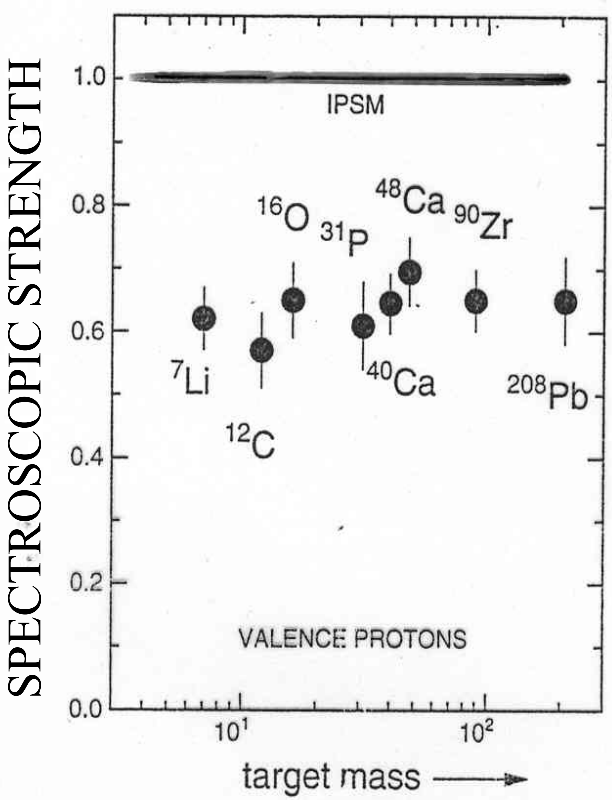
2N-SRC(np,pp,nn) = 0.20 ± 0.045%

3N-SRC Less than 1% of total

Now Include (e,e'p) Data

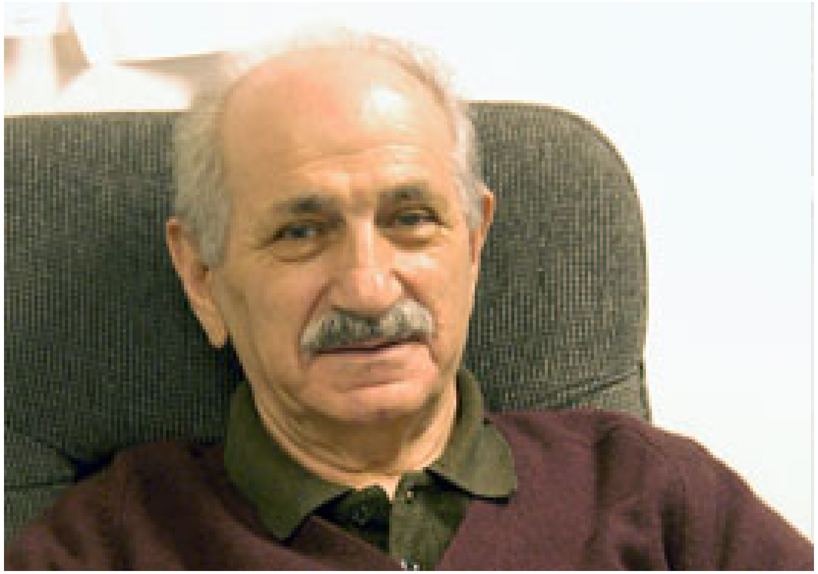
The Independent Particle Shell Model is based upon the assumption that each nucleons moves independently in an average potential (mean field) induced by the surrounding nucleons.

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



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

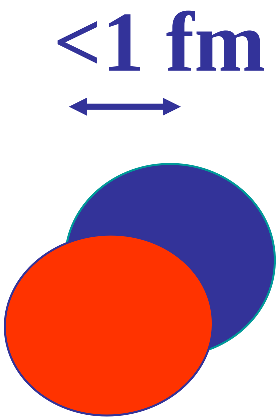
1935-2006





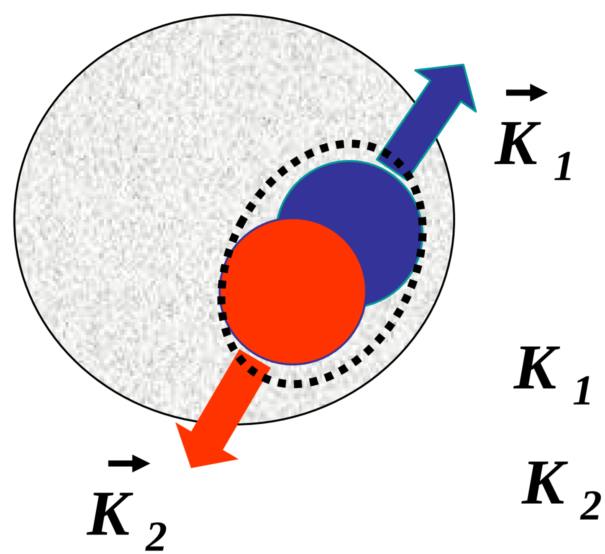
Triple – coincidence measurements
of large momentum transfer high energy reactions:

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



NN SRC

"Redefine" the problem in momentum space



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

$$K_1 > K_F\,,$$

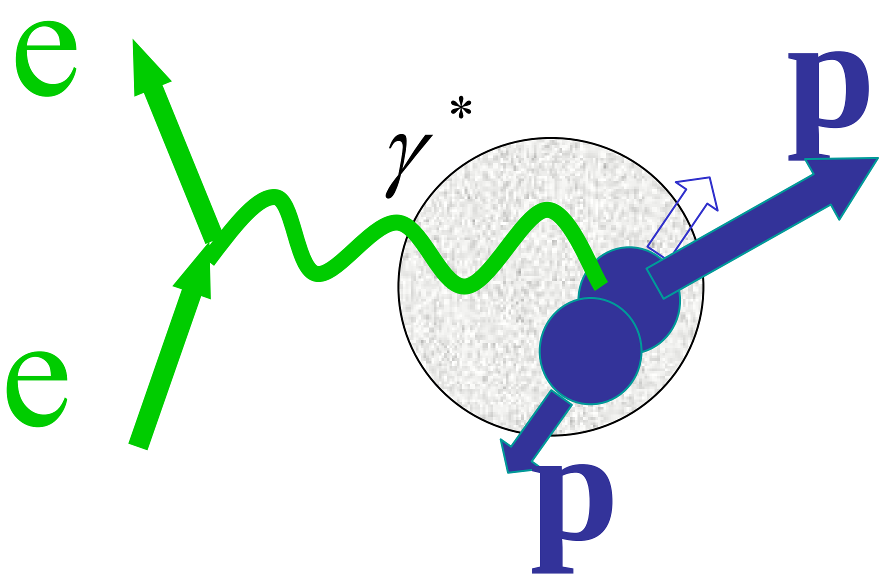
$$K_2 > K_F$$

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

Custom Experiment to study 2N-SRC

$Q^2 = 2$ GeV/c , $x_B \sim 1.2$, P_m=250-650 MeV/c, E_{2m}<140 MeV

Luminosity ~ 10^{37} $cm^{-2}s^{-1}$



"Redefine" the problem in momentum space

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

- high Q^2 minimizes MEC (reduced as $1/Q^2$),
- x_B>1 suppress isobar contributions.
- almost anti-parallel kinematics to suppress FSI.

Acknowledgment

EVA collaboration **/ BNL**

A. Carroll, S. Heppelman, J. Alster,
J. Aclander, A. Malki, A. Tang

Exp 01 – 015 collaboration **Hall A / TJNAF**

S. Gilad , S. Wood, J. Watson, W. Bertozzi,

D. Higinbotham, R. Shneor, P. Monaghan, R. Subedi

Hall B collaboration / TJNAF

K. Egiyan

"Evidence for the strong dominanace of pn-correlations in nuclei"
arXiv:nucl-th/0604012 April 06
E. Piasetzky M. Sargsian, L. Frankfurt, M. Strikman, J. W. Watson

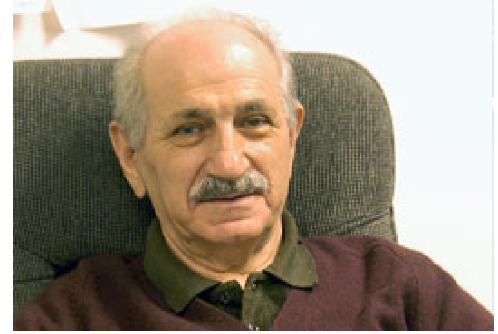
What do we know about pp-SRC ?

A triple coincidence measurement of the (e, e'pn) and (e, e'pp) reactions

Jlab / Hall A

The measurement was done Dec. 2004 – Apr. 2005.

Data are being analyzed by 4 students from TAU, MIT, KSU, and Glasgow.

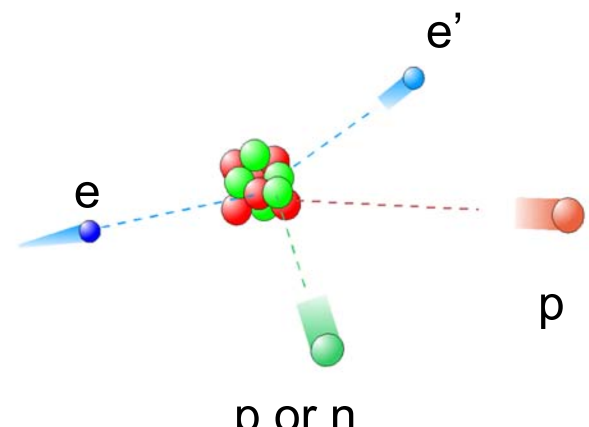


1935-2006

Investigation of 2N Short-Range Correlations via the Triple-Coincidence $^{12}C(e,e'pp)$ and $^{12}C(e,e'pn)$ measurements at Jlab / Hall A

20 October 2006

(Jefferson National Accelerator Facility)



Eli Piasetzky

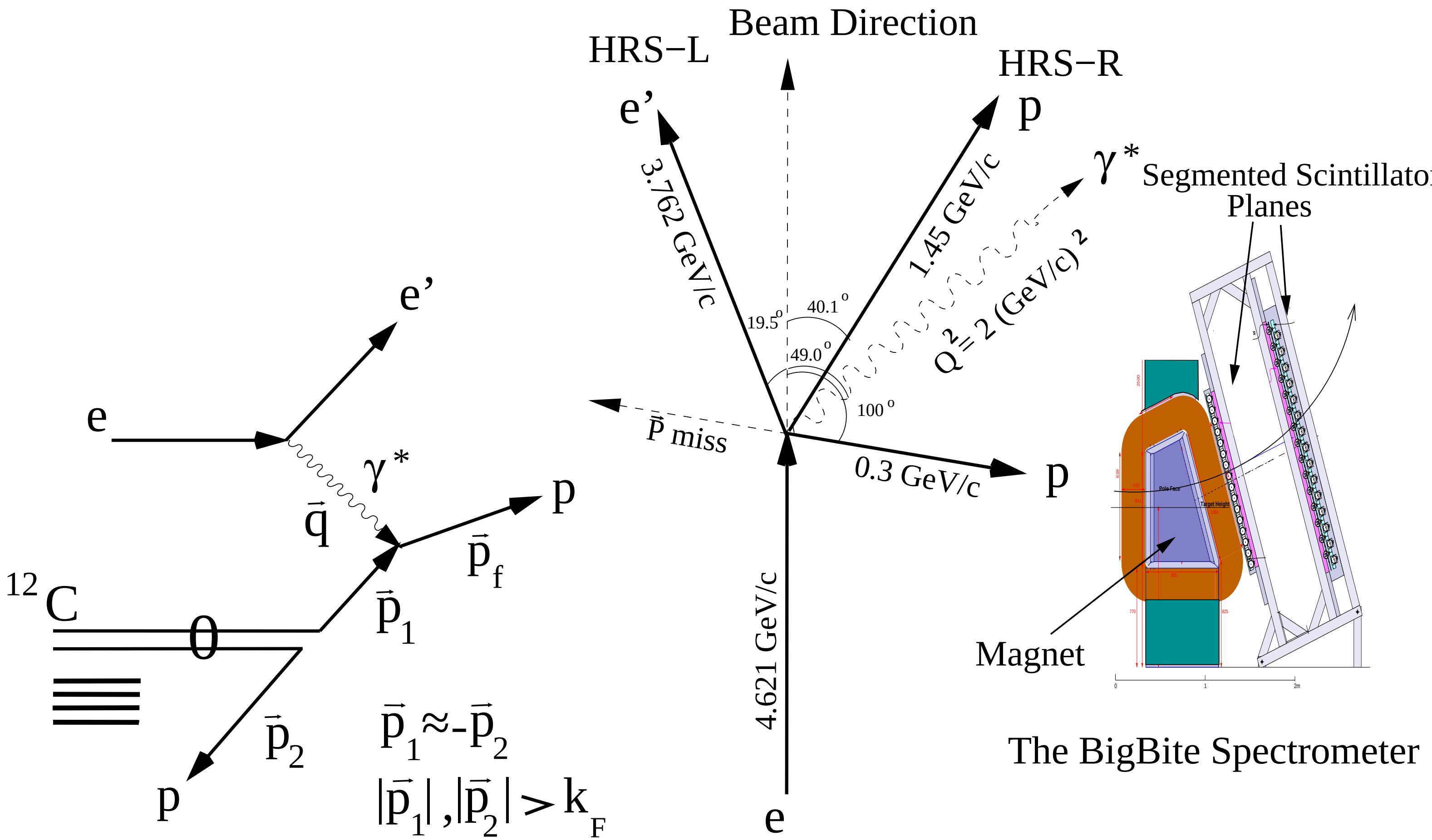
Tel Aviv University, ISRAEL

- The probability to find a pp-SRC in nuclei is small.

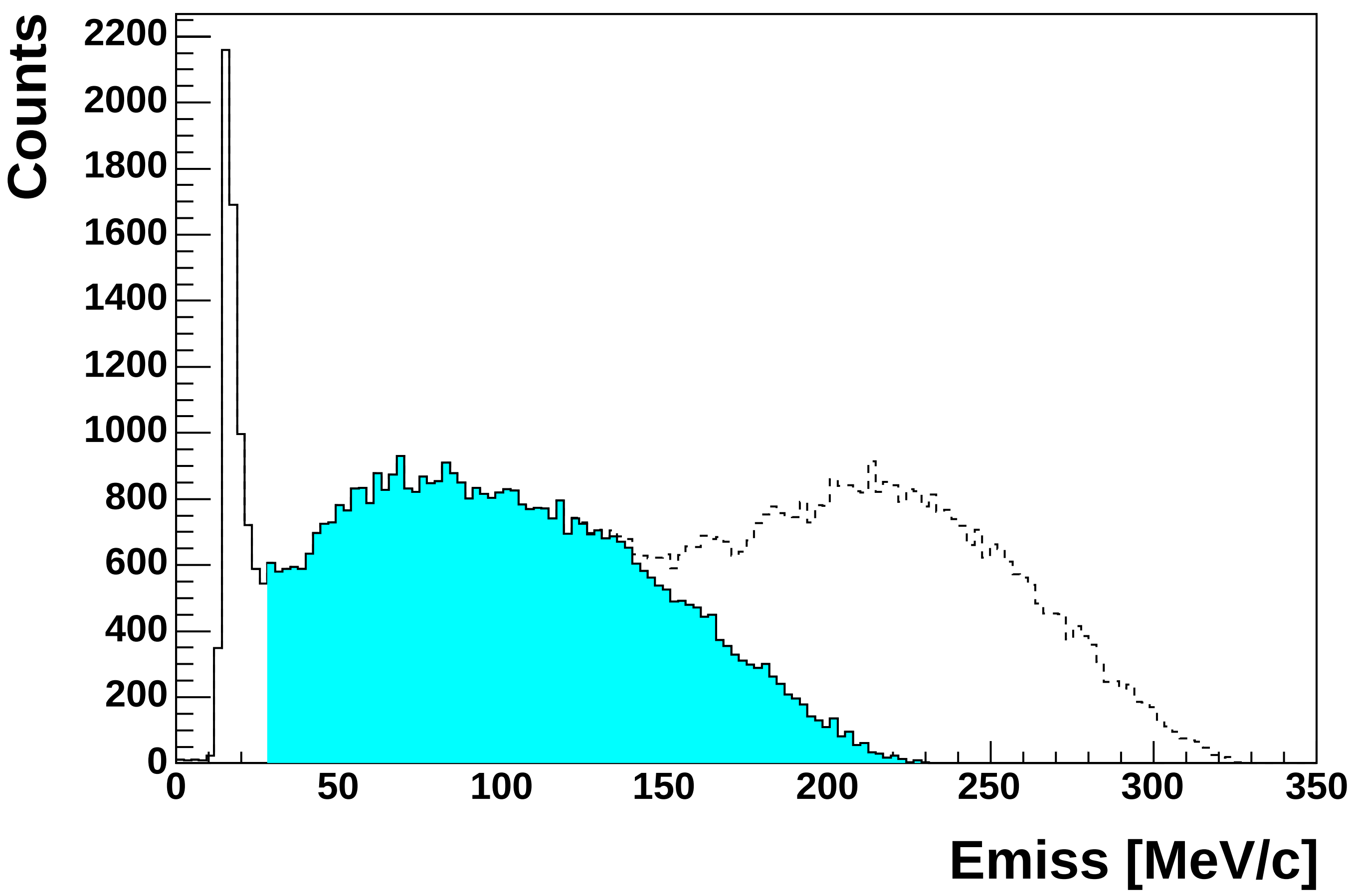
- pp-SRC are important to identify and study since they can tell us about the isospin dependence of the strong interaction at short distance scale. This may have relevance to understanding equation of state for neutron stars.

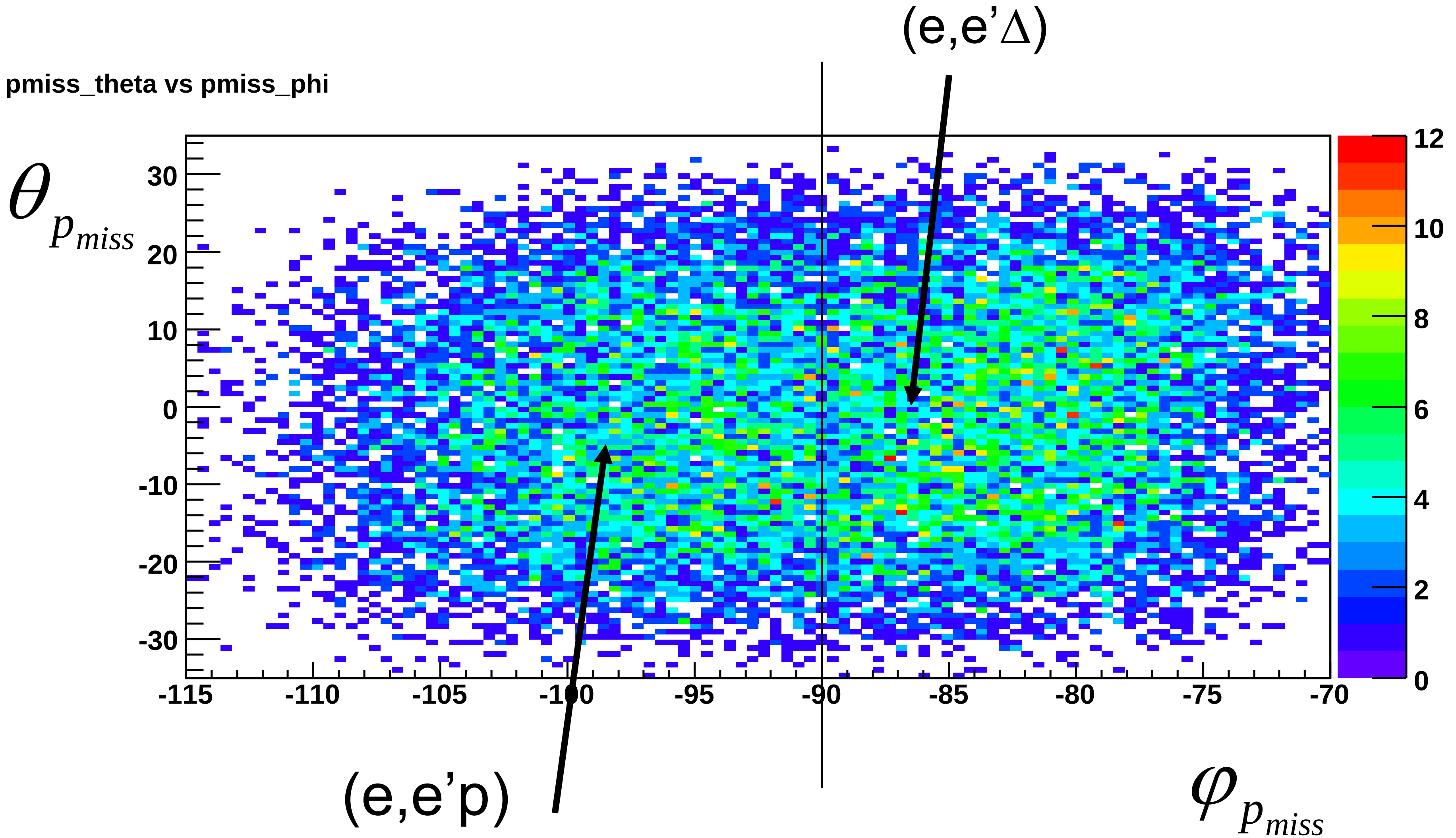
⇒

A triple coincidence (e.e'pp) measurement is required.

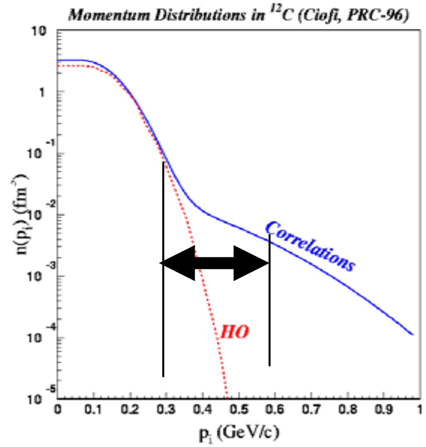


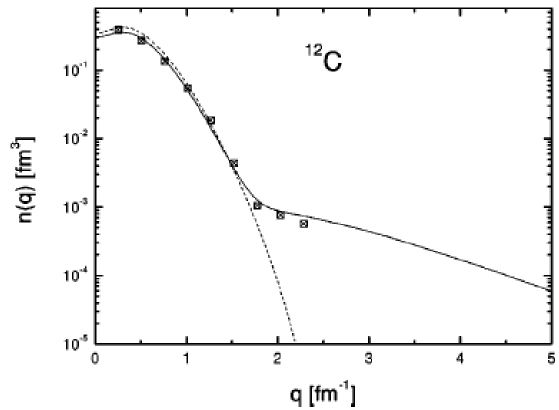
e
e'
γ*
q
p
^{12}C
θ
p
p_1
p_f
p_2
$\vec{p}_1 \approx -\vec{p}_2$
$|\vec{p}_1|, |\vec{p}_2| > k_F$
Beam Direction
HRS−L
HRS−R
e'
p
γ*
3.762 GeV/c
1.45 GeV/c
$Q^2 = 2$ (GeV/c)^2
19.5°
40.1°
49.0°
100°
P miss
0.3 GeV/c
p
4.621 GeV/c
e
Segmented Scintillator Planes
Magnet
The BigBite Spectrometer


Counts
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
50
100
150
200
250
300
350
Emiss [MeV/c]



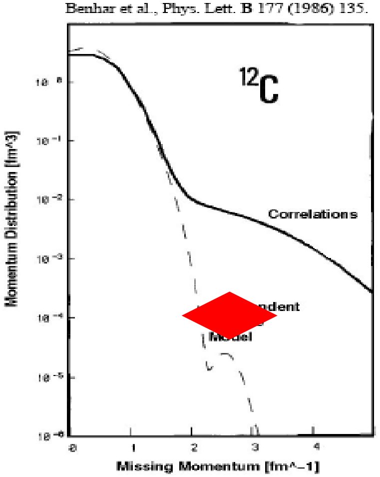
(e,e'Δ)
pmiss_theta vs pmiss_phi
$\theta_{p_{miss}}$
30
20
10
0
-10
-20
-30
-115
-110
-105
-100
-95
-90
-85
-80
-75
-70
12
10
8
6
4
2
0
(e,e'p)
$\varphi_{p_{miss}}$

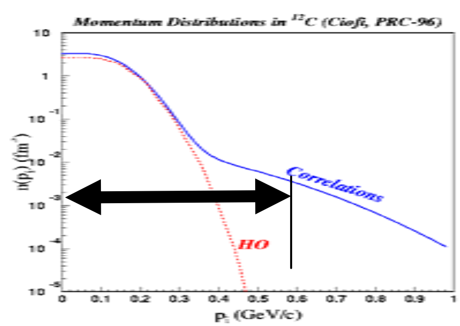


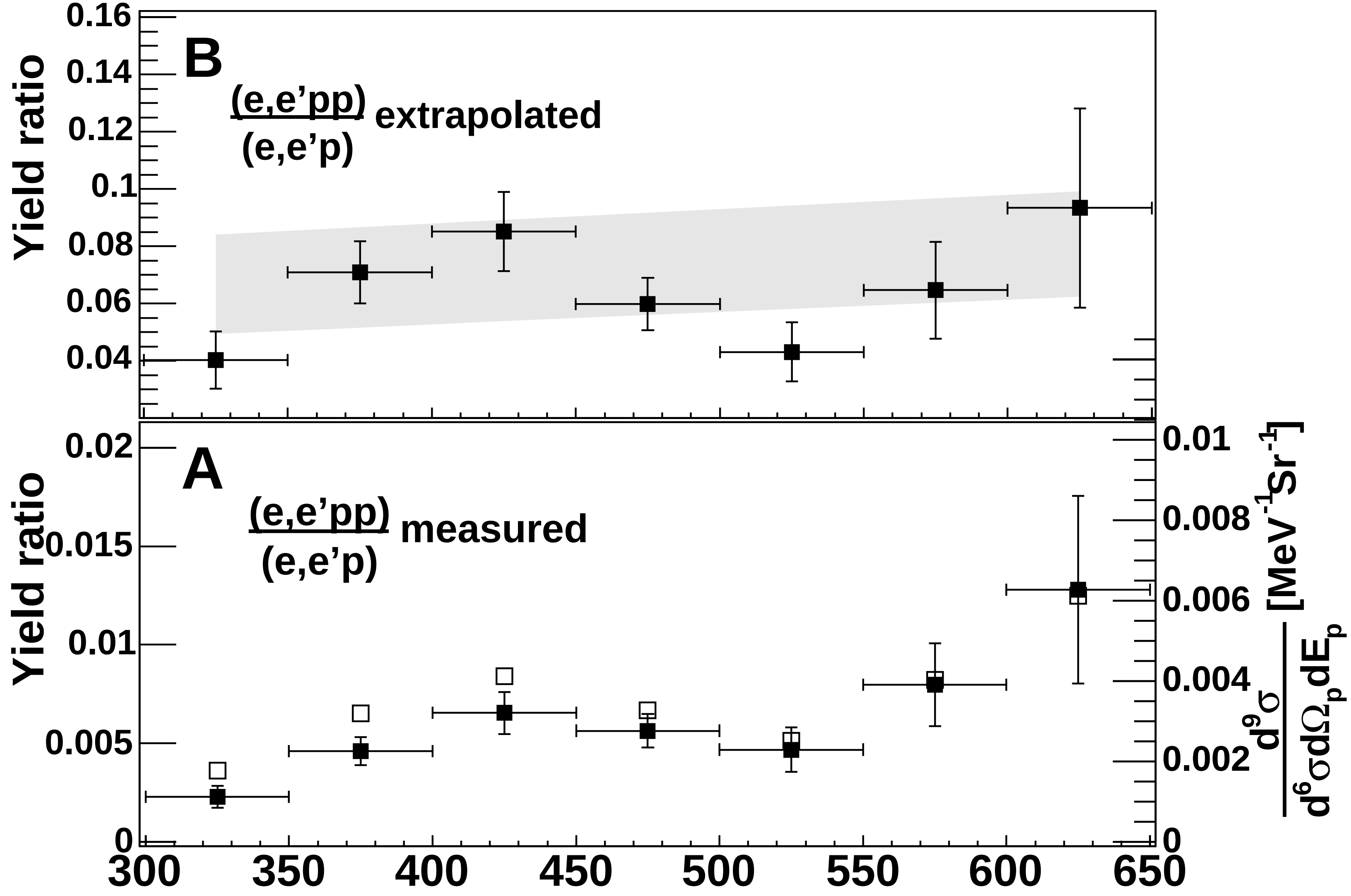


PRC 65 (2002) 024306.

Benhar et al., Phys. Lett. B 177 (1986) 135.






B
(e,e'pp) / (e,e'p) extrapolated
A
(e,e'pp) / (e,e'p) measured
Yield ratio
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0.015
0.01
0.005
0
300
350
400
450
500
550
600
650
0.01
0.008
0.006
0.004
0.002
0
$\frac{d^9\sigma}{d^6\sigma d\Omega_p dE_p}$ [MeV^{-1}Sr^{-1}]

FSI

We optimized kinematics to minimize the competing processes

HIGH ENERGY, LARGE Q^2

MEC are reduced as $1/Q^2$.

LARGE X

IC are reduced by performing the experiment in "anti-parallel" kinematics ($x_B > 1$), possible for large Q^2 only.

LARGE E_m, P_m, P_{mz}

FSI can be treated in Glauber approximation. Also, the relevant parameter in the light-cone formalism is not sensitive to FSI.

Significant reduction of the ambiguity in low Q^2 measurements with respect to the identification of the struck and recoil nucleons.

XXXL

We optimized kinematics to minimize the competing processes

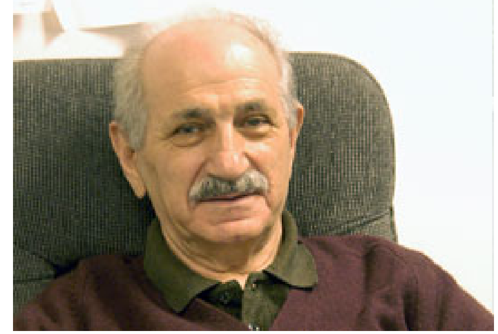
HIGH ENERGY

LARGE Q^2

LARGE X

LARGE E_m, P_m, P_{mz}

$Q^2 = 2$ GeV/c , $x_B \sim 1.2$, P_m=250-650 MeV/c, E_{2m}<140 MeV



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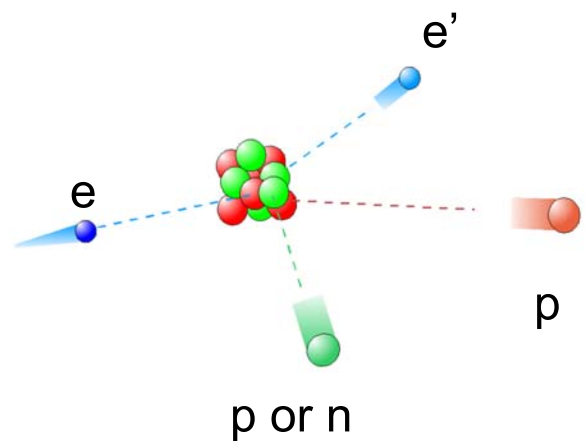
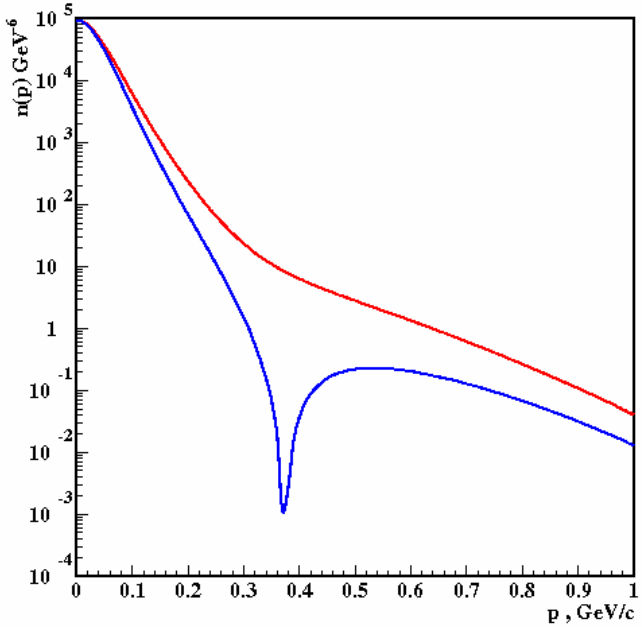
Investigation of Proton-Proton Short-Range Correlations via the Triple-Coincidence $^{12}C(e,e'pp)$ Measurement at Jlab / Hall A

E01-105



Eli Piasetzky

Tel Aviv University, ISRAEL



Argon V18

Bonn