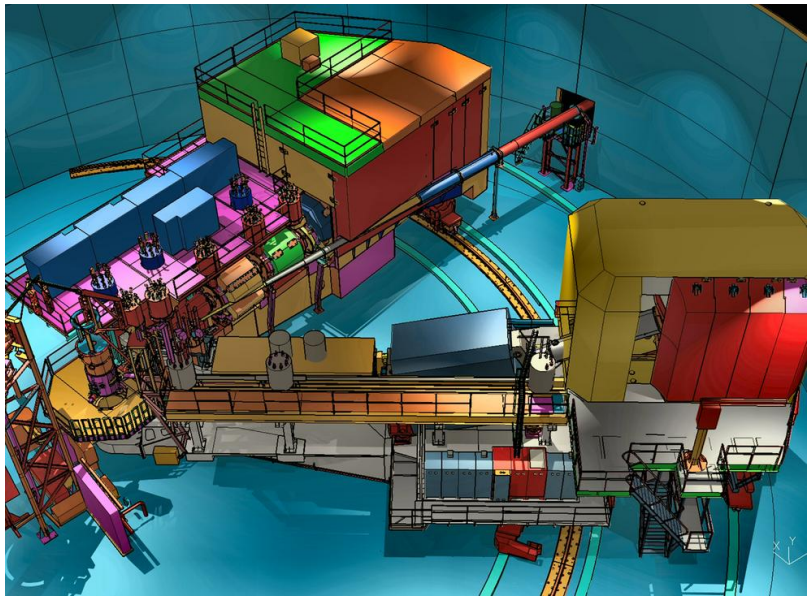
Upgrade for SRC/EMC Studies

Stephen Wood



Outline

Hall C 12 Hardware overview

- Standard Spectrometers
- Additional detectors

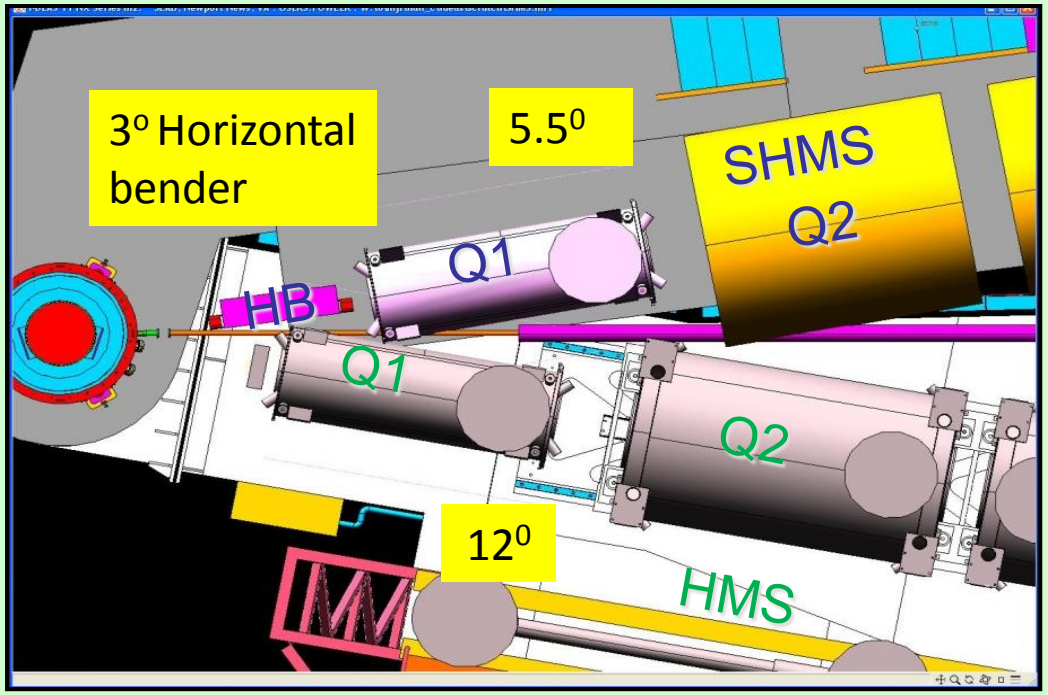
Hall C SRC/EMC/Nuclear-effects physics program

Deuteron “EMC” with LAD

Standard Hall C equipment after 12 GeV Upgrade

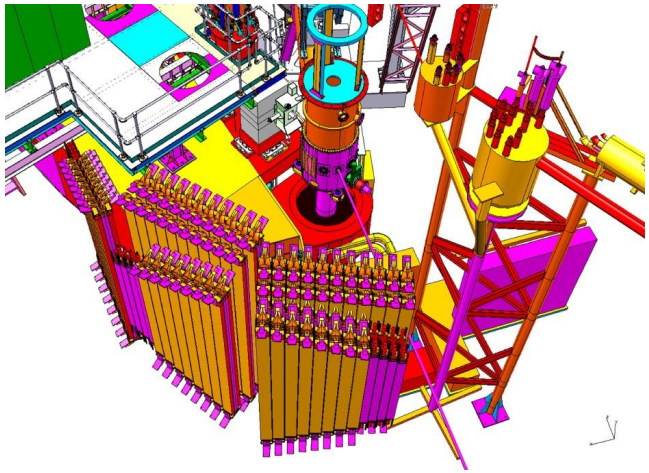
- Beam Energy: 2 – 11 GeV/c
- Super High Momentum Spectrometer (SHMS)
  - Horizontal Bender, 3 Quads, Dipole
  - P $\rightarrow$ 11 GeV/c
  - dP/P 0.5 – 1.0x10^{-3}
  - Acceptance: 4msr, 30%
  - 5.5° < θ < 40°
  - Good e^-/π^- $e^+/\pi^+/K^+/p$ PID
- High Momentum Spectrometer (HMS)
  - P $\rightarrow$ 7.5 GeV/c
  - dP/P 0.5 – 1.0x10^{-3}
  - Acceptance: 6.5msr, 18%
  - 10.5° < θ < 90°
  - Good e^-/π^- $e^+/\pi^+/K^+/p$ PID
- Minimum opening angle: 17°

- Well shielded detector huts
- 2 beamline polarimeters
- Ideal facility for:
  - Rosenbluth (L/T) separations
  - Exclusive reactions
  - Low cross sections (neutrino level)

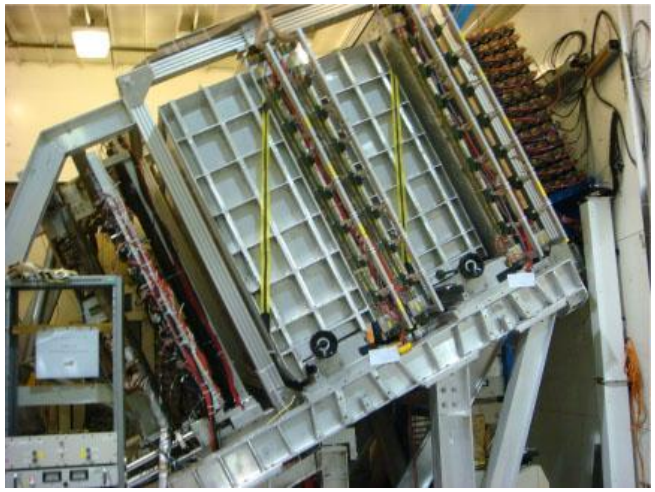


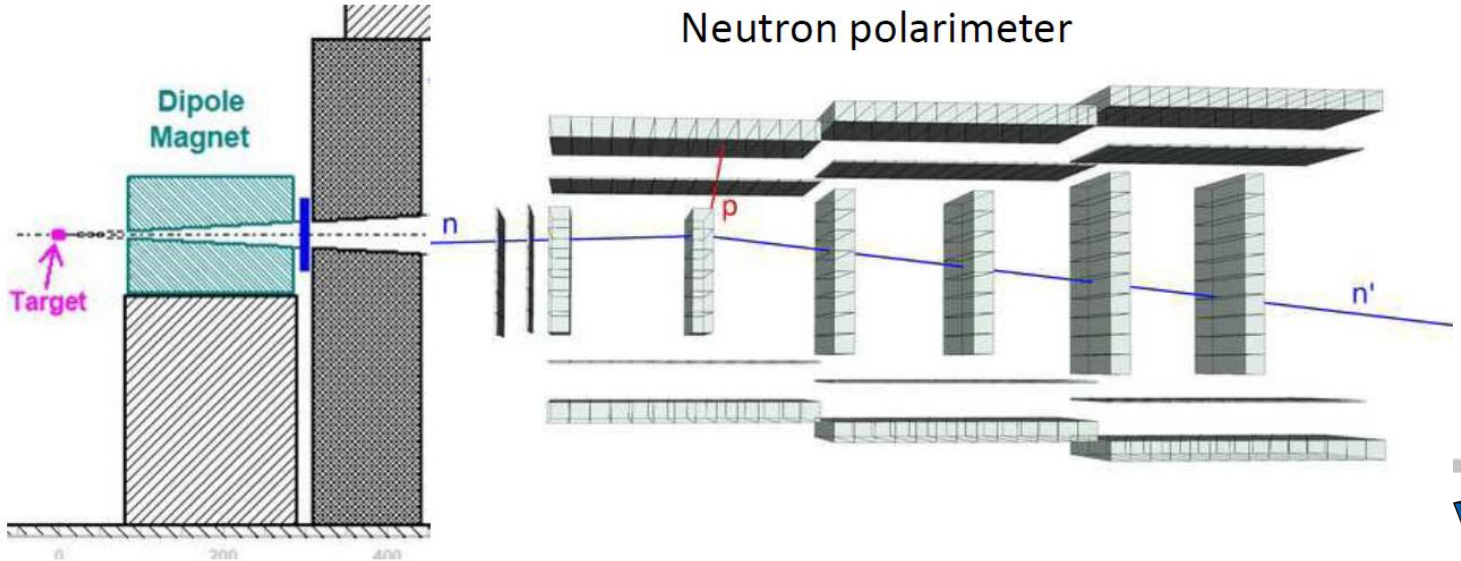
Additional Hall C detectors

Large Acceptance Detector
("Backward" protons and neutrons)



Proton Polarimeter
(SHMS or HMS)





Proposed neutrals (e.g. π^0/γ) detector facility in Hall C

- Desire to augment spectrometers with capability for precision measurements with neutral final states. (L/T separations)

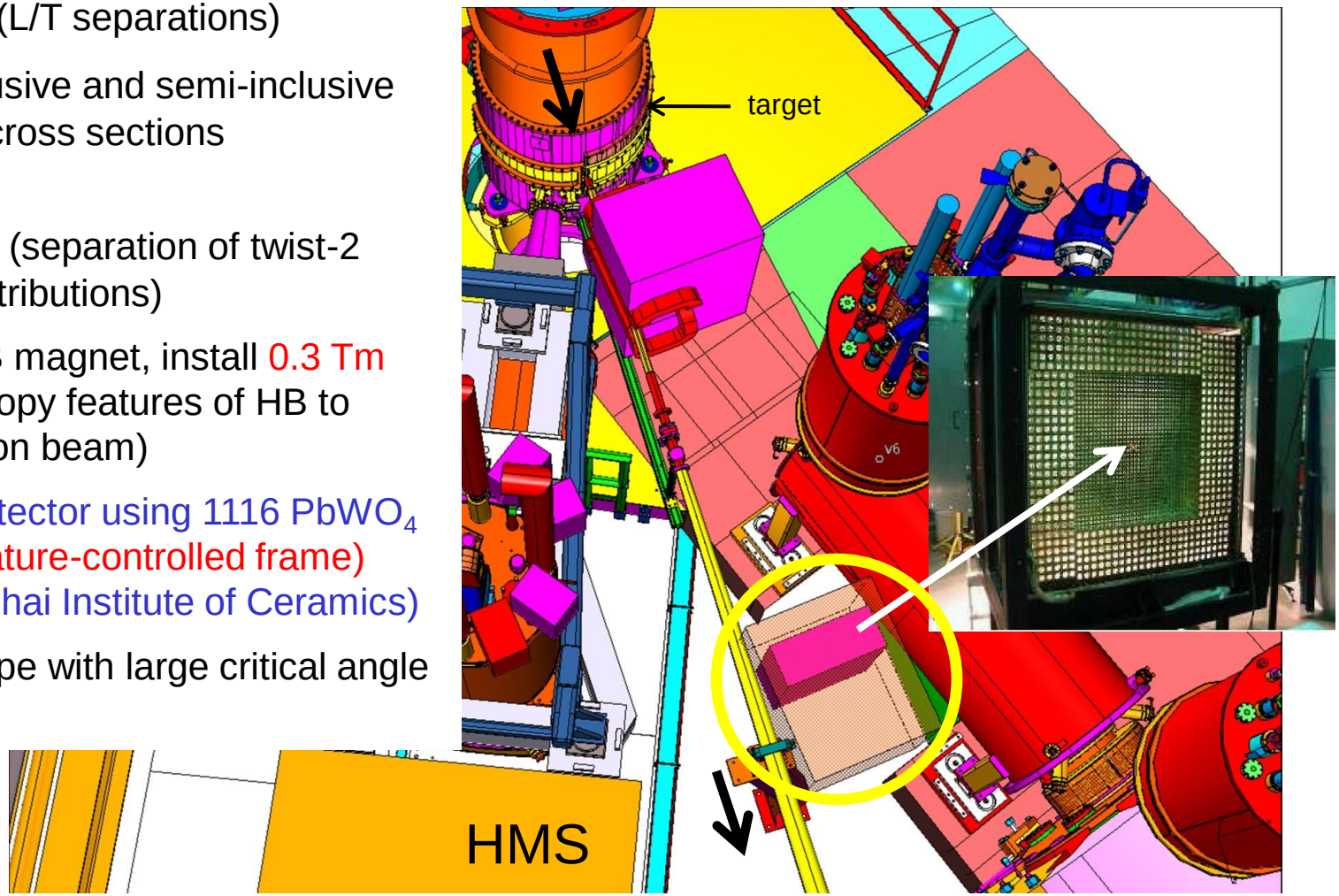
  p(e,e′π^0) exclusive and semi-inclusive L/T separated cross sections (PR12-11-111)

  p(e,e′γ) DVCS (separation of twist-2 and twist-3 contributions)

- Remove SHMS HB magnet, install 0.3 Tm sweeping magnet (copy features of HB to minimize stray field on beam)

- Add 25 msr π^0/γ detector using 1116 $PbWO_4$ blocks (with temperature-controlled frame) ($PbWO_4$ from Shanghai Institute of Ceramics)

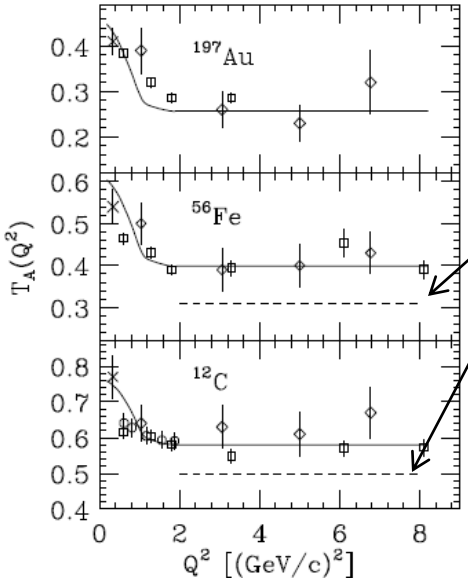
- Dedicated beam pipe with large critical angle + shielding



SRC/EMC Related Experiments

Title	Days
Inclusive Scattering from Nuclei at x > 1 in the quasielastic and deeply inelastic regimes. (E12-06-105) *Spokespersons: J. Arrington (johna@anl.gov), D. Day* X>1	32
The Search for Color Transparency at 12 GeV (E12-06-107) *Spokespersons: D. Dutta (ddutta@jlab.org) , R. Ent* A(e,e'p), A(e,e'π)	26
Deuteron Electro-Disintegration at Very High Missing Momenta (E12-10-003) *Spokespersons: W. Boeglin (boeglin@fiu.edu), M. Jones* d(e,e'p)	21
Detailed studies of the nuclear dependence of F_2 in light nuclei (E12-10-008) *Spokespersons: A. Daniel, J. Arrington, D. Gaskell (gaskelld@jlab.org)* EMC	23
Proton Recoil Polarization in the ^{4}He(e,e'p)^{3}H, ^{2}H(e,e'p)n, and ^{1}H(e,e'p) Reactions (E)12-11-102) *Spokespersons: E. Brash , R. Ransome, G. M. Huber, S. Strauch (strauch@jlab.org)*	37
In Medium Nucleon Structure Functions, SRC, and the EMC effect (PR-12-11-107) *Spokespersons:O. Hen, L.B. Weinstein (weinstei@jlab.org), S. Gilad* Deuteron EMC	40

Pion/Proton Transparency at 12 GeV

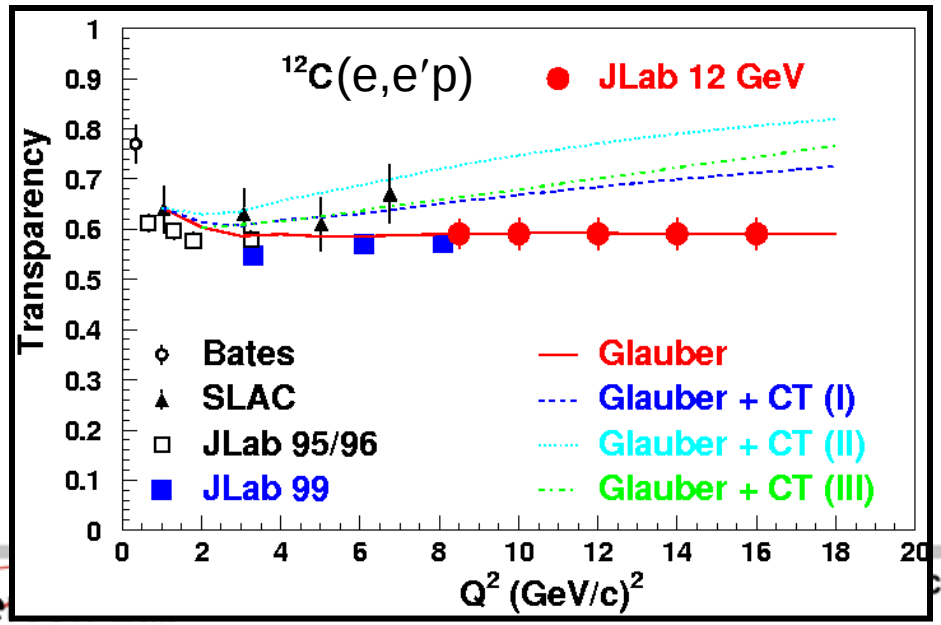


NMBT calculation with correlations ignored

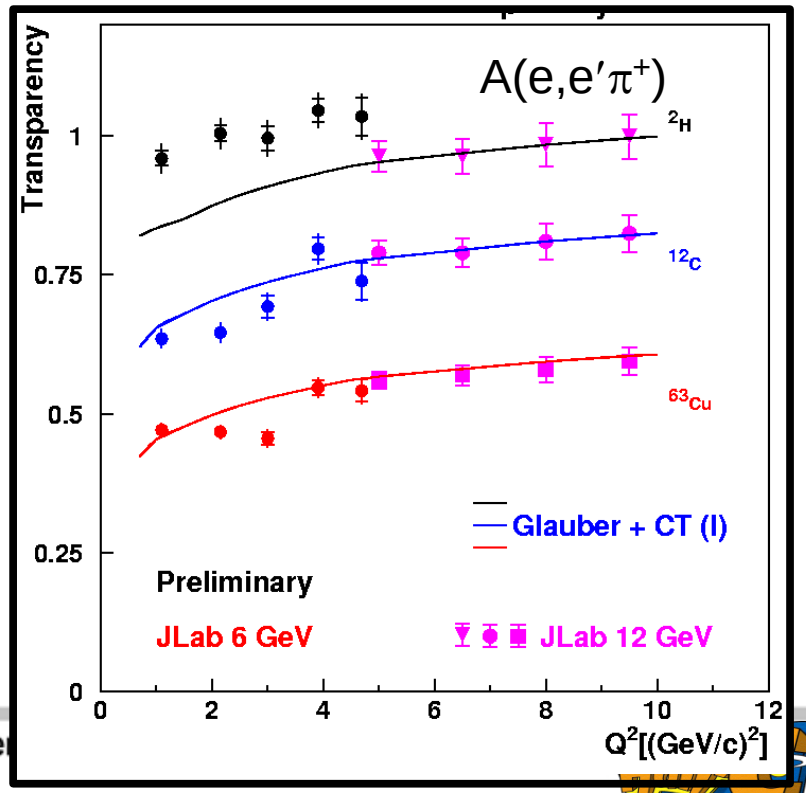
E12-06-107

D. Dutta, R. Ent

A(e,e′p) at 12 GeV (projected results)



A(e,e′π^+) at 12 GeV (projected results)



Detailed studies of the nuclear dependence of F_2 in light nuclei

Higher Q^2

More light and N≠Z nuclei

EMC

E12-10-008

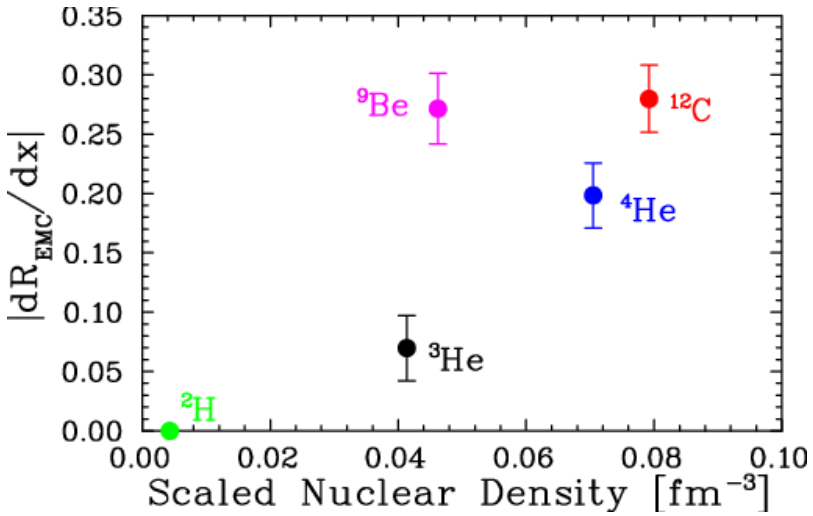
J. Arrington, D. Gaskell, A. Daniel

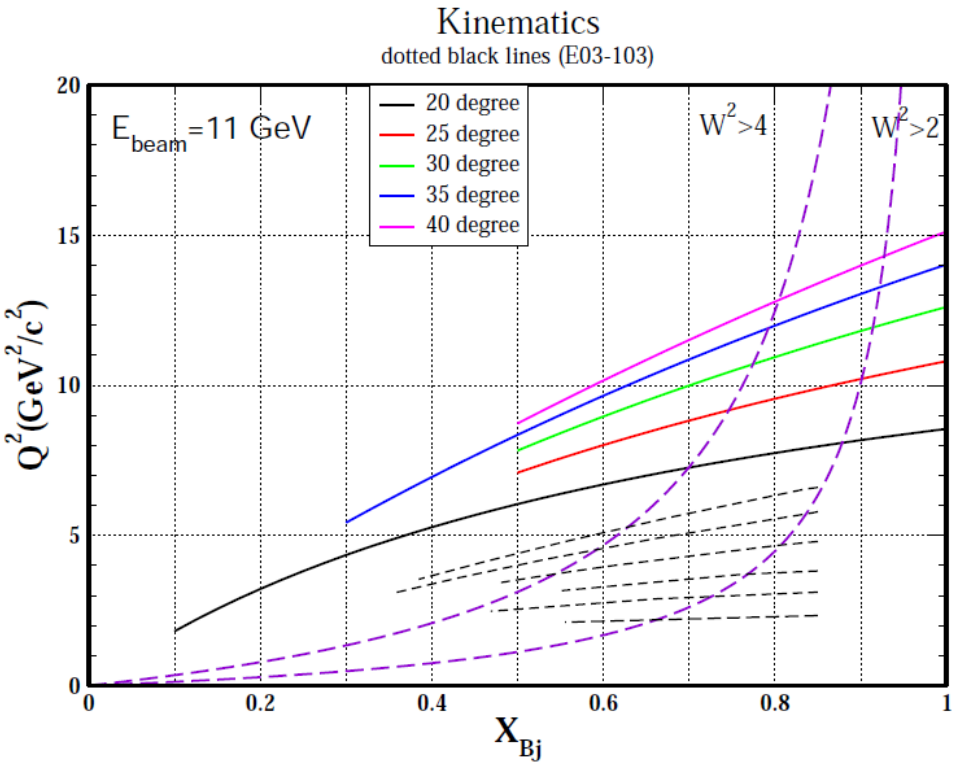
^{1}H, ^{2}H, ^{3}He, ^{4}He, ^{6}Li, ^{7}Li, ^{9}Be

^{10}B, ^{11}B, ^{12}C, ^{40}Ca, ^{48}Ca, ^{63}Cu

Large x range at 20°

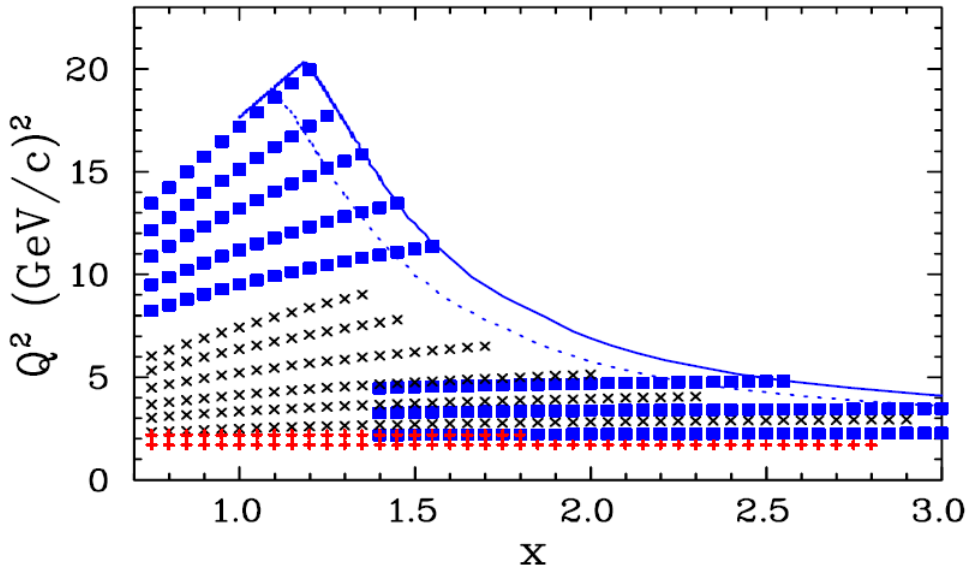
Q^2 scan for x>0.5, test scaling





Inclusive Scattering from Nuclei at x>1in the quasielastic and deeply inelastic regimes

x>1 quark distributions



E12-06-105

J. Arrington, D. B. Day

^{3}He, ^{4}He, ^{9}Be, ^{12}C, ^{63}Cu, Au

6GeV: Hall C, CLAS

2N, 3N SRC Strength

Deuteron Electro-Disintegration at Very High Missing Momenta

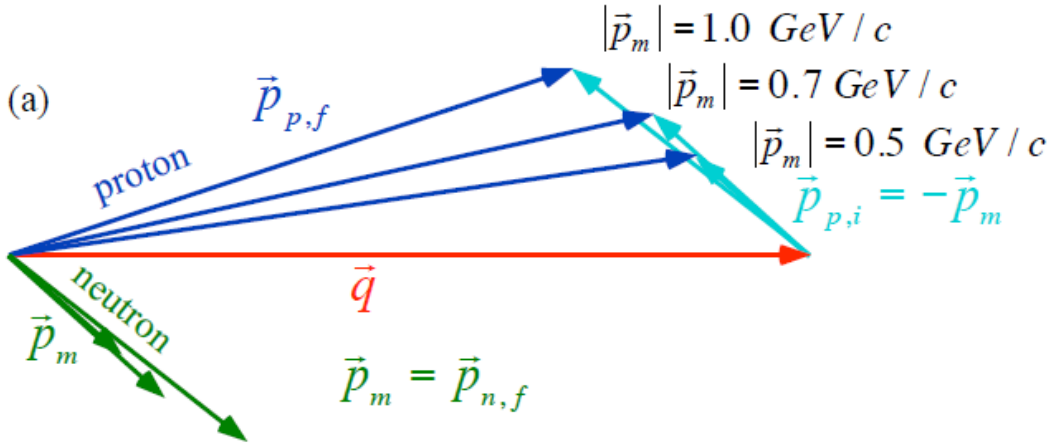
d(e,e′p)

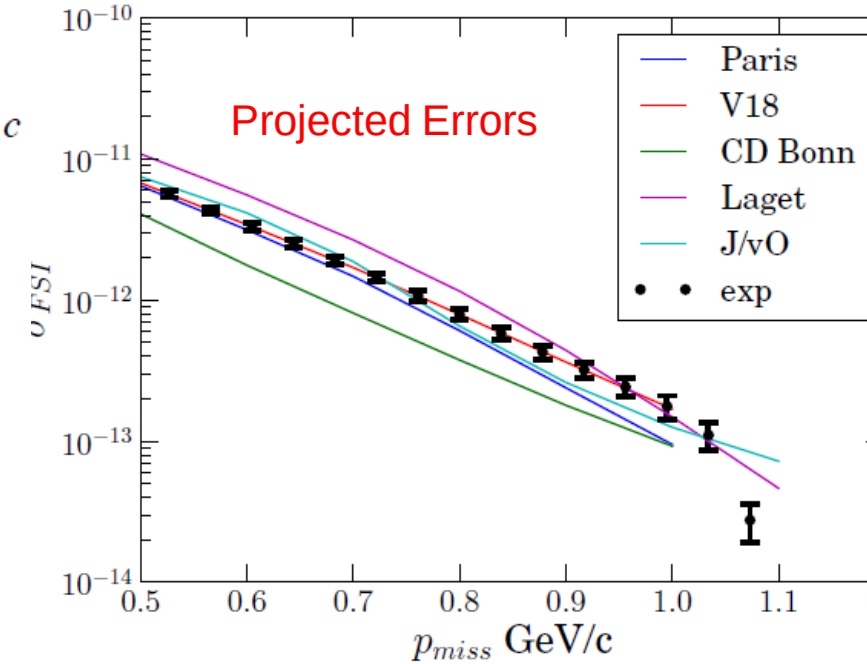
Q^2 = 4.25 $(GeV/c)^2$, x=1.35

$P_{miss} \rightarrow$ 1 GeV/c

E12-10-003

W. U. Boeglin, M. K. Jones





Recoil Polarization in the ^{4}He(e,e′p)^{3}H, ^{2}H(e,e′ p)n, and ^{1}H(e,e ′p) Reactions

Key features	Impact
Wide coverage of proton virtualities at Q^2=1.0 GeV^2	Study the momentum (virtuality) dependence of nucleon medium effects
^{4}He, ^{2}H, ^{1}H targets	Study the density dependence of nucleon medium effects
High-precision data point of the proton recoil polarization in ^{4}He(e,e'p)^{3}H at Q^2=1.8 GeV^2	Compare free and bound proton recoil polarizations where models predict largest sensitivity to effect of in-medium form factors

$$R = \left(\frac{P_x'}{P_z'}\right)_A \Big/ \left(\frac{P_x'}{P_z'}\right)_H$$

E12-11-002 E.J. Brash, G.M. Huber, R. Ransome, S. Strauch

Early running plans - 2015

SHMS/Hall C Commissioning

E12-06-107 partial Search for color transparency

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

E12-10-002 $F_2^{p,d}$ structure functions at large x

Momentum scans help understand acceptance

E12-10-108 partial EMC Effect

Integrate ^{12}C Q^2 scan with F_2 run.

E12-10-003 partial d(e,e'p)

Time permitting

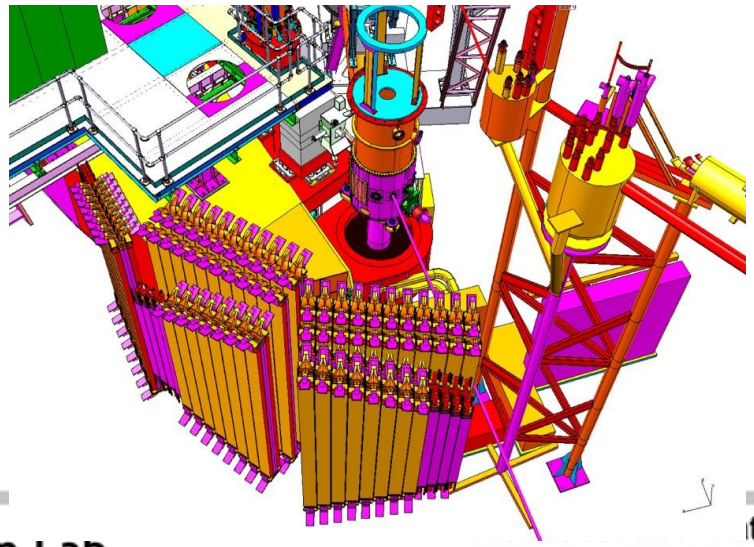
In Medium Nucleon Structure Function, SRC, and the EMC Effect

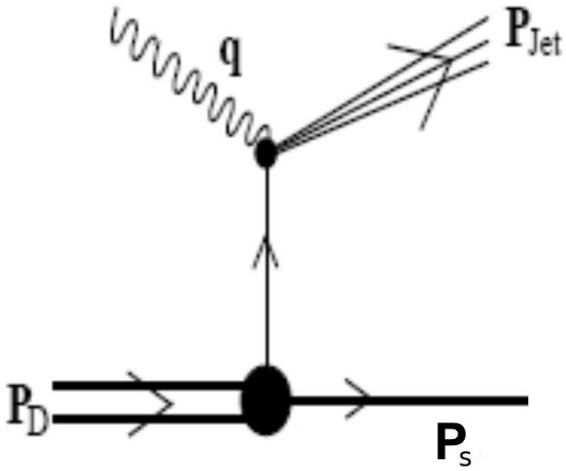
E12-11-107 O. Hen (TAU), L. Weinstein (ODU), S. A. Wood (JLab), S. Gilad (MIT)

Collaboration:

Experimental groups from : ANL, CNU, FIU, HU, JLab, KSU, MIT, NRCN, ODU, TAU, U. of Glasgow, U. of Ljubljana, UTFSM, UVa

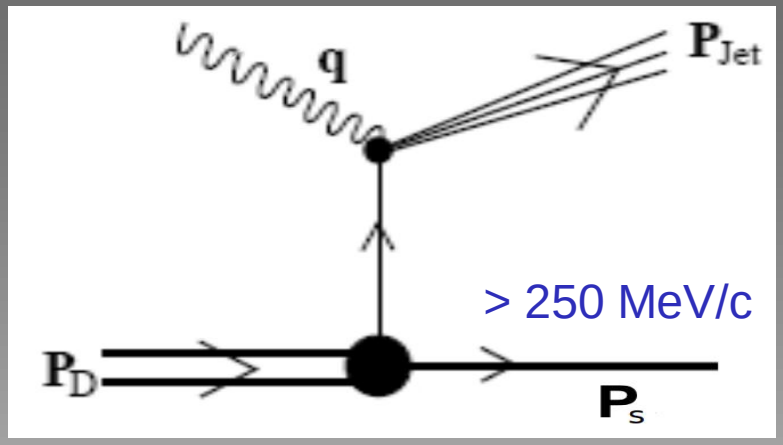
Theoretical support: Accardi, Ciofi Degli Atti, Cosyn, Frankfurt, Kaptari, Melnitchouk, Mezzetti, Miller, Ryckebusch, Sargsian, Strikman





Measurement concept

1. Spectator Tagging:



➔ **Selects DIS off high momentum (high virtuality) nucleons**

$$x' = \frac{Q^2}{2 p_m q^m} = \frac{Q^2}{2[(M_d - E_S)w + \vec{p}_S \times \vec{q}]}$$

x in rest frame of struck nucleon

2. Cross sections ratio

➔ **Minimize experimental and theoretical uncertainties**

$$\frac{\sigma_{DIS}(x'_{high}, Q_1^2, \vec{p}_s)}{\sigma_{DIS}(x'_{low}, Q_2^2, \vec{p}_s)} \cdot \frac{\sigma_{DIS}^{free}(x'_{low}, Q_2^2)}{\sigma_{DIS}^{free}(x'_{high}, Q_1^2)} \cdot R_{FSI} = \frac{F_2^{bound}(x'_{high}, Q_1^2, \vec{p}_s)}{F_2^{free}(x'_{high}, Q_1^2)}$$

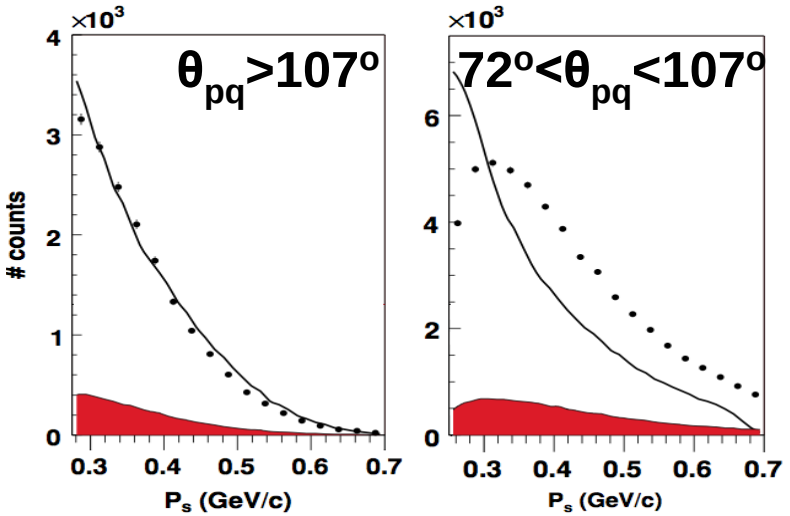
$x'_{high} \geq 0.45$

$0.25 \geq x'_{low} \geq 0.35$

(No EMC effect region)

R_{FSI} is the FSI correction factor

Obstacle – Final State Interactions



What do we know about FSI:

Decrease with Q^2

Increase with W'

Not sensitive to x'

Decrease with recoil spectator angle

CLAS d(e,e'p_s) vs. PWIA

How are we going to minimize (correct for) FSI:

* Collect data at very large recoil angles (small FSI) and at ~90^0 (large FSI)

* look at ratios of two different x'

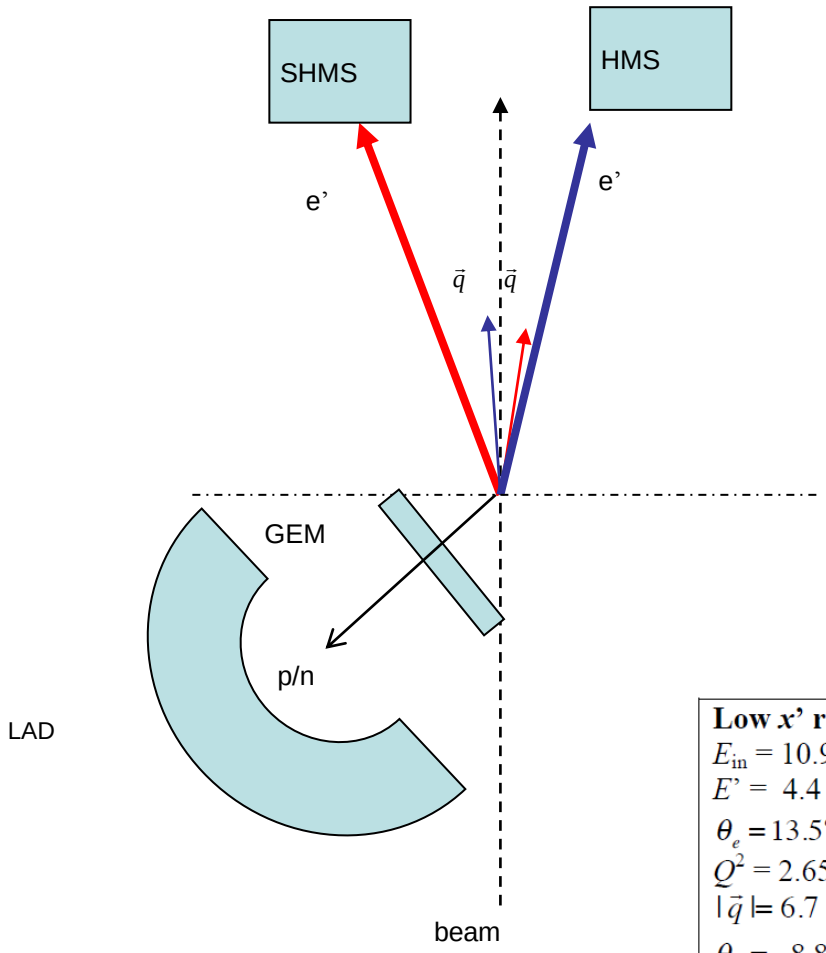
* Use the low x' large phase space to check / adjust the FSI calculations (Study the dependence of FSI on Q^2, W' and θ_{pq})

* Get a large involvement of theoretical colleges at all stages of proposal, measurement, analysis

Physics Questions

1) Is there an ‘EMC effect’ in Deuterium?
2) Is there a large ‘EMC effect’ in tagged DIS off Deuterium
3) Is the EMC effect in nuclei predominantly associated with high momentum nucleons?
4) How does the EMC effect depend on nucleon virtuality?
5) Are nucleon structure functions in nuclei the same as free structure functions?

Experimental Layout



E_{beam} = 11 GeV

HMS and SHMS simultaneously trigger on d(e,e') with different kinematics. (Q^2 2.65 & 4.19 GeV/c)

(SHMS and HMS not in coincidence)

Look for p and n at backward angle in coincidence with SHMS or HMS.

Possible use of GEM near target for vertex locating.

Low *x'* range (central values):	**High *x'* range (central values):**
E_{in} = 10.9 GeV	E_{in} = 10.9 GeV
E' = 4.4 GeV	E' = 4.4 GeV
$\theta_e = 13.5^o$	$\theta_e = -17^0$
$Q^2 = 2.65$ GeV^2	$Q^2 = 4.19$ GeV^2
$\lvert\vec{q}\rvert = 6.7$ GeV/c	$\lvert\vec{q}\rvert = 6.8$ GeV/c
$\theta_q = -8.8^0$	$\theta_q = 10.8^0$
$x = 0.217$	$x = 0.34$

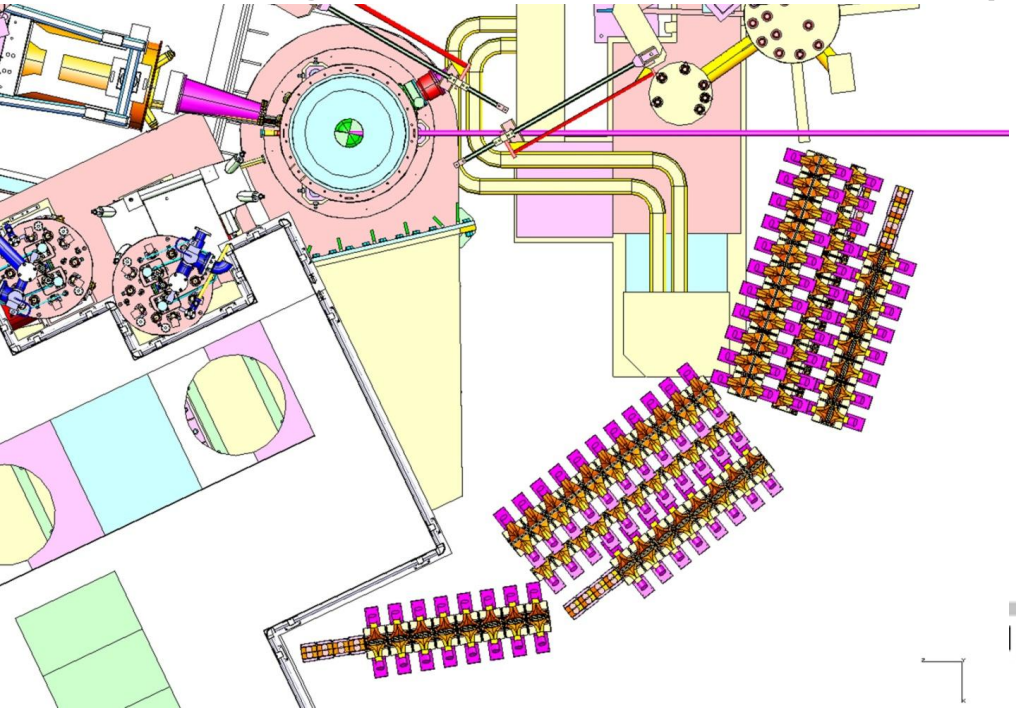
LAD – Large Acceptance Detector

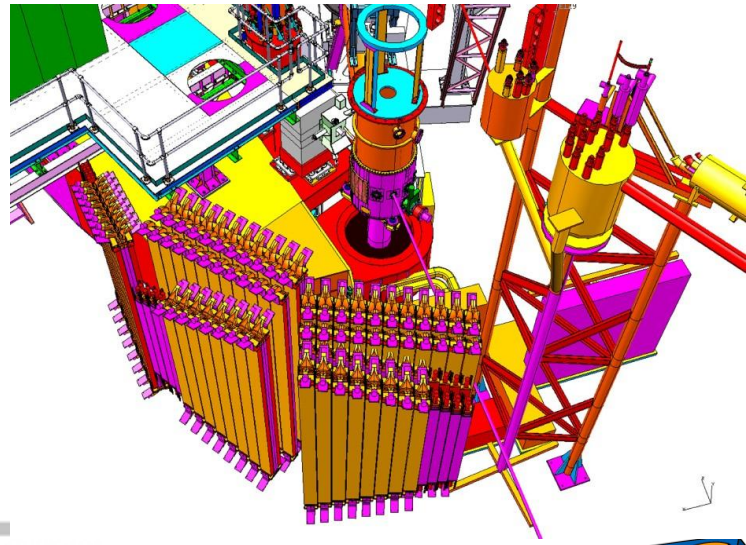
Capability:

- Very large solid angle for $L = 10^{36}$ cm^{-2} s^{-1} and $\theta > 90^{o}$
- Optimized for medium momentum nucleons

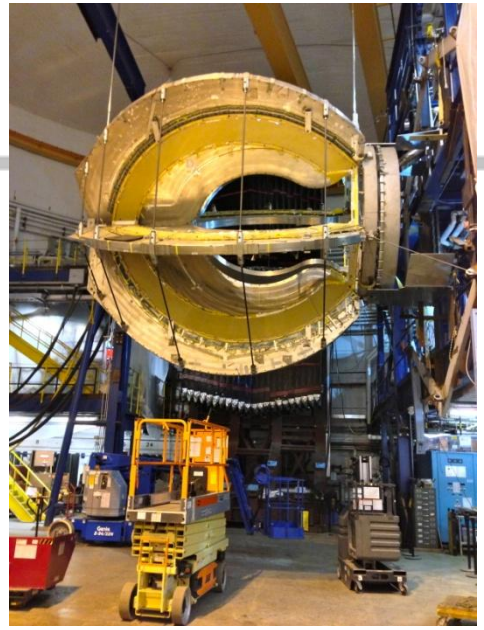
$$0.3 \pounds p_N \pounds 0.7 \text{ GeV}/c$$

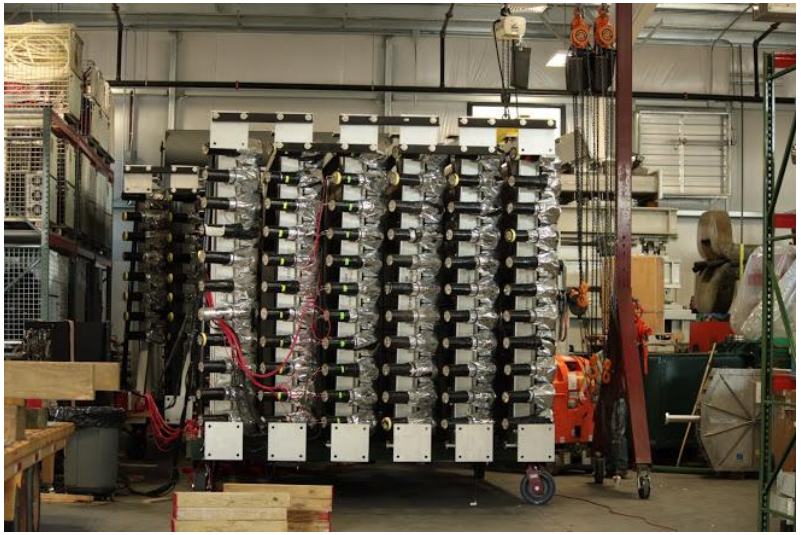
- Modular (frame based): can maximize either proton solid angle or neutron detection probability (thickness)





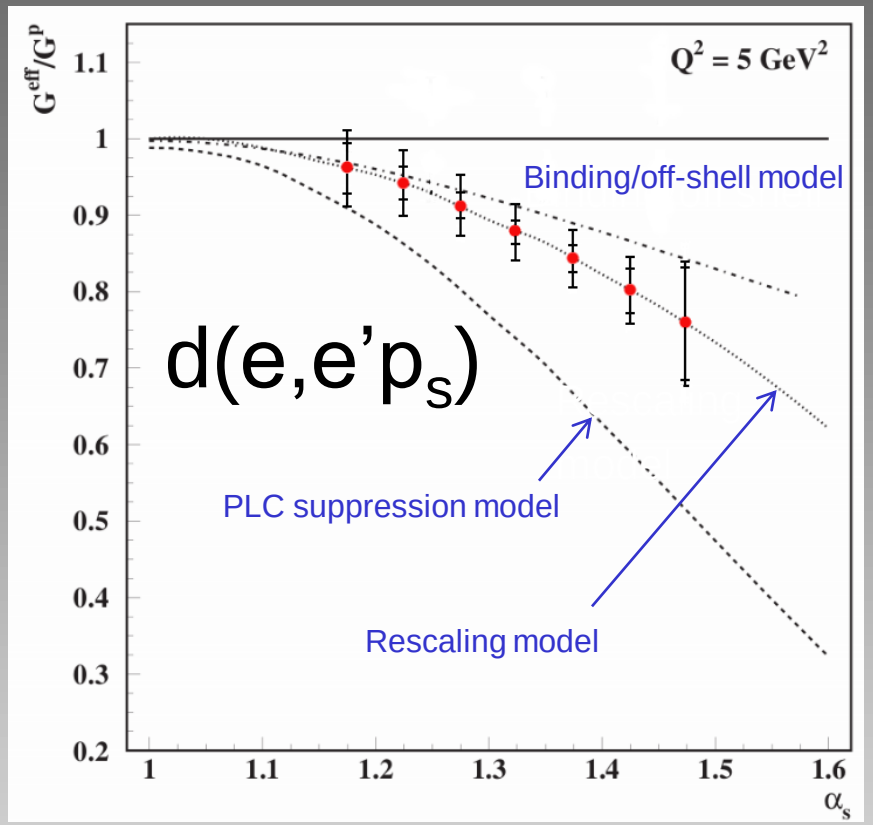
CLAS Scintillator Transfer

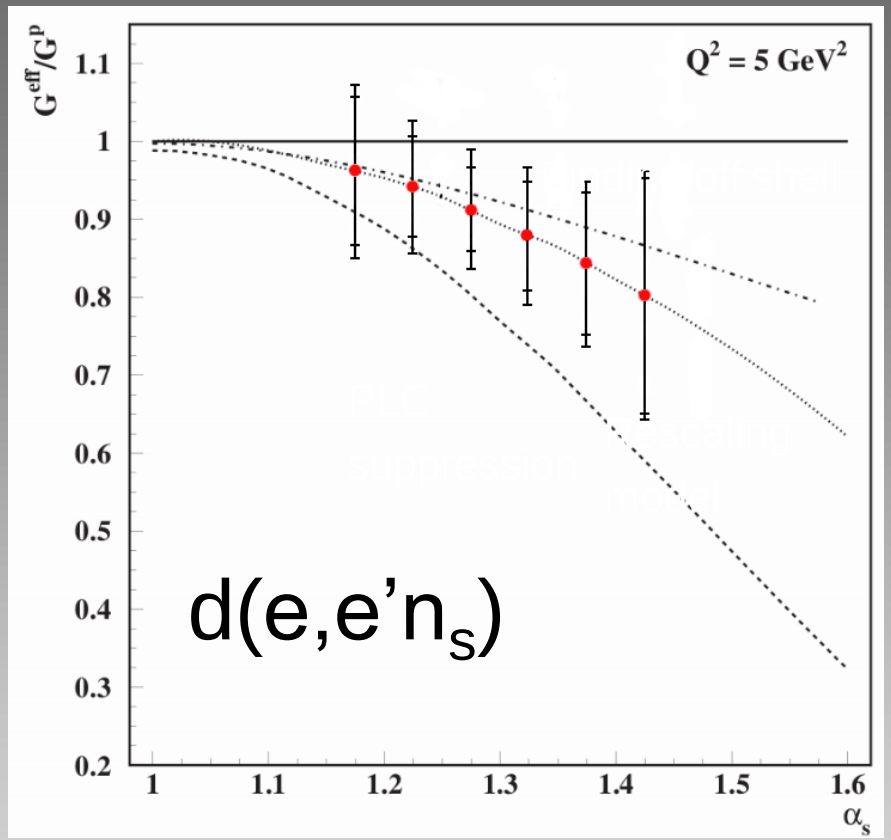




NSF MRI being submitted to refurbish detectors (ODU, Kent SU, Tel Aviv U, MIT)

Expected Results





$$a_s = (E_s - p_s^z)/m_s$$

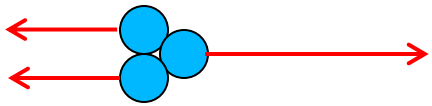
Melnitchouk, Sargsian, Strikman Z. Phys. A359 (97) 99.

LAD: Other potential uses

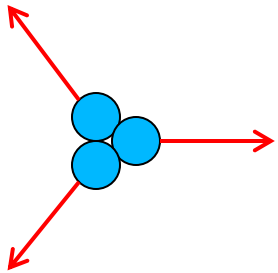
Use LAD as a tag of spectator nucleons

LOI-09-002: 3 nucleon correlations

- Detect A(e,e'p) with 2 spectrometers
- Detect 2 backward nucleons with LAD
- Measure ratios



$$\frac{\sigma\,(e,e'p\;p_s\;p_s)}{\sigma\,(e,e'p)} \qquad \frac{\sigma\,(e,e'p\;p_s\;n_s)}{\sigma\,(e,e'p)}$$



Practical considerations:

- Difficult to fully cover backward hemisphere

- Need x<1 to have sufficient energy to liberate detectable backward nucleons

LAD: Other potential uses

LOI-11-104: Singly and doubly tagged EMC ratios

Use spectrometers to detect (e,e') simultaneously at two different x on deuterium and ^{4}He

Detect "spectator" nucleons at backward angles with LAD

Select SRC-like "spectator" nucleons with $p_s > 275$ MeV/c $\theta_s > 110^o$

Integrate over spectator kinematics

Single-tagged and double-tagged ratios

$$\frac{^4\mathrm{He}(e,e'\,N_s)}{d(e,e'\,N_s)} \qquad \frac{^4\mathrm{He}(e,e'\,N_s)}{d(e,e')}$$

Summary

Hall C in 12 GeV Era

- 2 high momentum spectrometers
- Proton and neutron polarimeters
- Pi0/gamma detector
- Large Acceptance Detector

Hall C SRC/EMC/Nuclear-effects physics program

Deuteron “EMC” with LAD