Semi-inclusive DIS scattering from light nuclei by tagging low energy recoil nuclei

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Hall C Summer Workshop
Jefferson Lab

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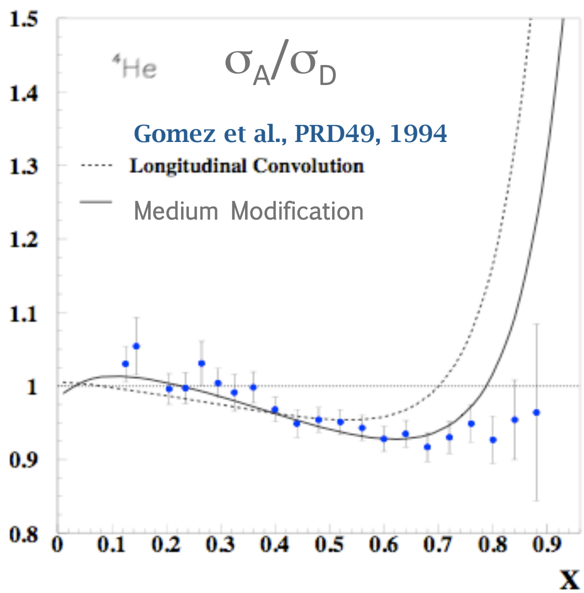
Deeply Virtual Compton Scattering off ^{4}He in CLAS

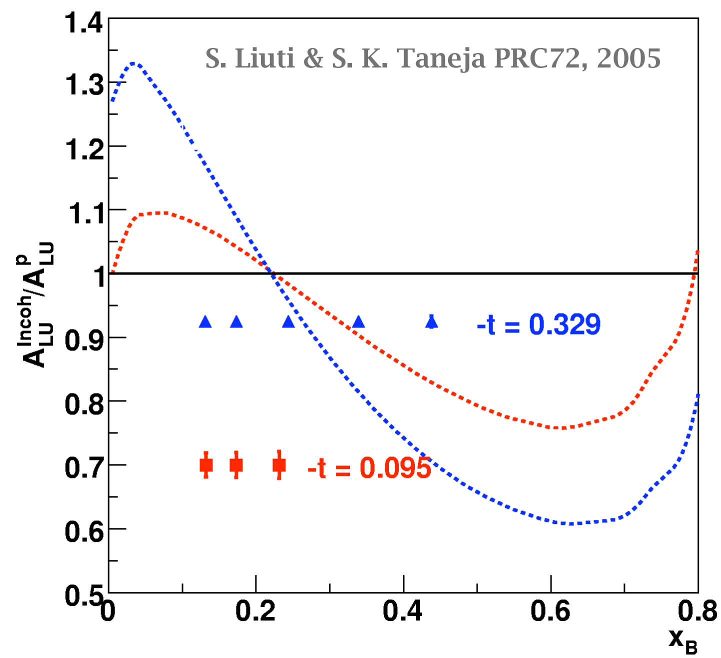
Measure Beam Spin Asymmetry for **coherent** $^4He(e,e'\gamma\ ^4He)$ and **incoherent** $^4He\ (e,e'\gamma p)$, $^4He\ (e,e'\gamma p\ ^3H)$, $^4He(e,e'\gamma n\ ^3He)$ channels

- ❑ Model independent extraction of the real and imaginary part of **the Compton Form Factor from coherent channel since ^{4}He is spin zero and therefore has only one chirally even GPD**
- ❑ Determine the **x_B and t dependences** of the **"generalized EMC ratio" $R(^4He) = A_{LU}(^4He)/A_{LU}(p)$**



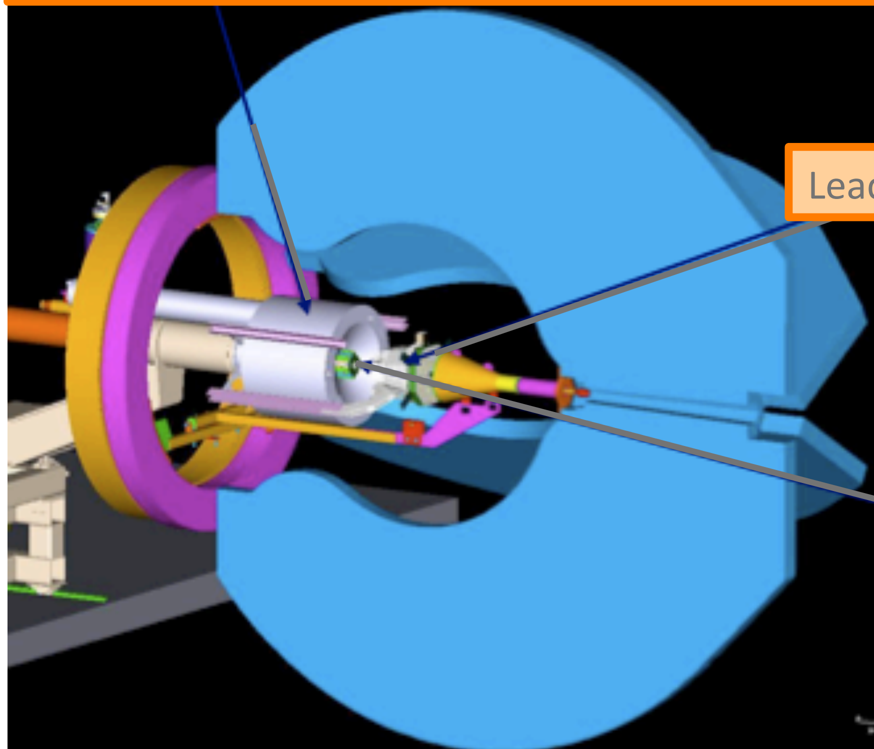
S. Liuti & S. K. Taneja PRC72, 2005

- ➢ Ran from Oct – Dec/09
- ➢ Ebeam = 6.064 GeV
- ➢ $P_b \approx 85\%$
- ➢ $I_b \approx 130$ nA
- ➢ RTPC DAQ rate ≈ 3 kHz a factor of 6 better than previously achieved with "BoNUS"
- ➢ 20 cm long ^{4}He gaseous target at 6 atm



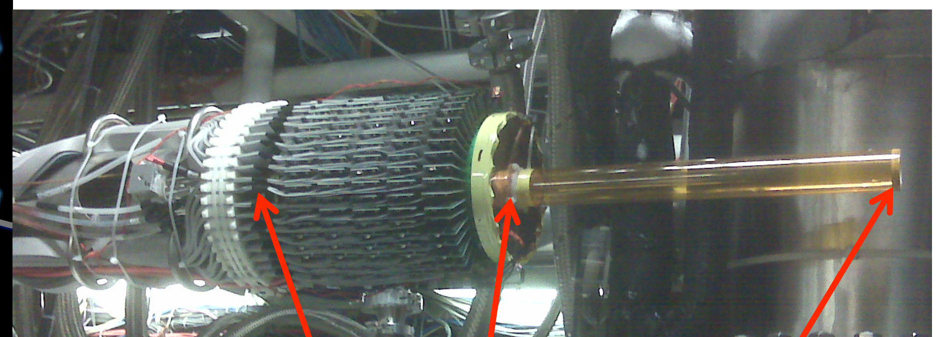
E08–024 Experimental Setup
A newly built Radial Time Projection Chamber

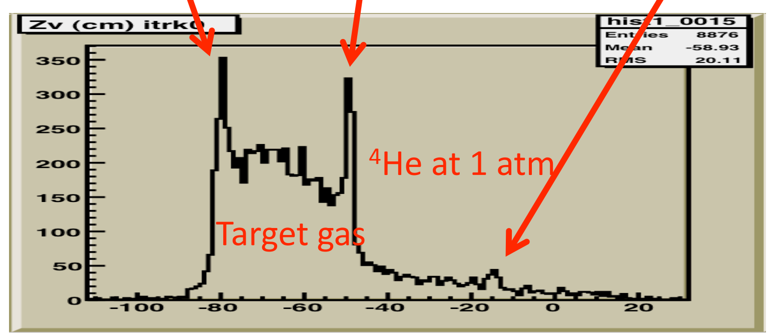
4.6 Tesla Solenoid magnet for momentum analysis and shielding of Moller electrons



$Q^2 > 1$ GeV^2 $W > 2$ GeV and $\theta_{min}(\gamma) = 4$ deg
$P_{min}(^4He) = 0.27$ GeV/c $\Rightarrow -t_{min} \sim 0.08$ GeV^2

Lead-tungstate calorimeter for small angle photon detection



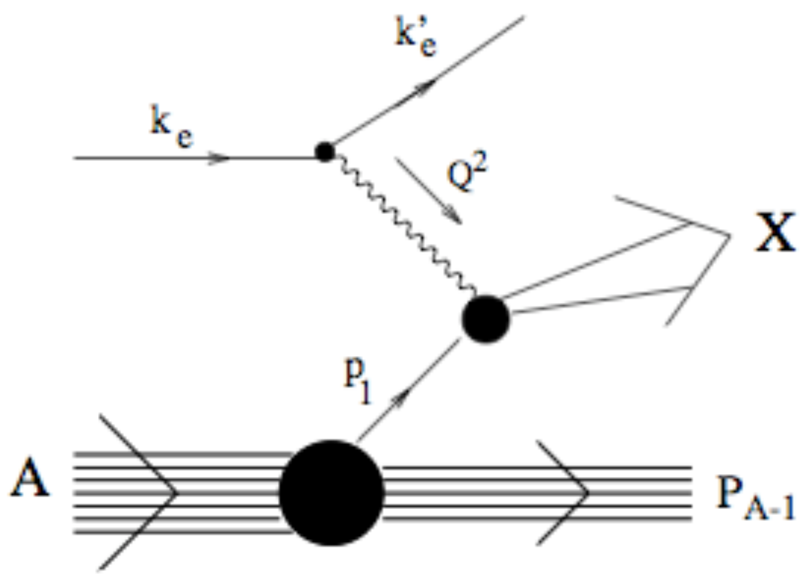


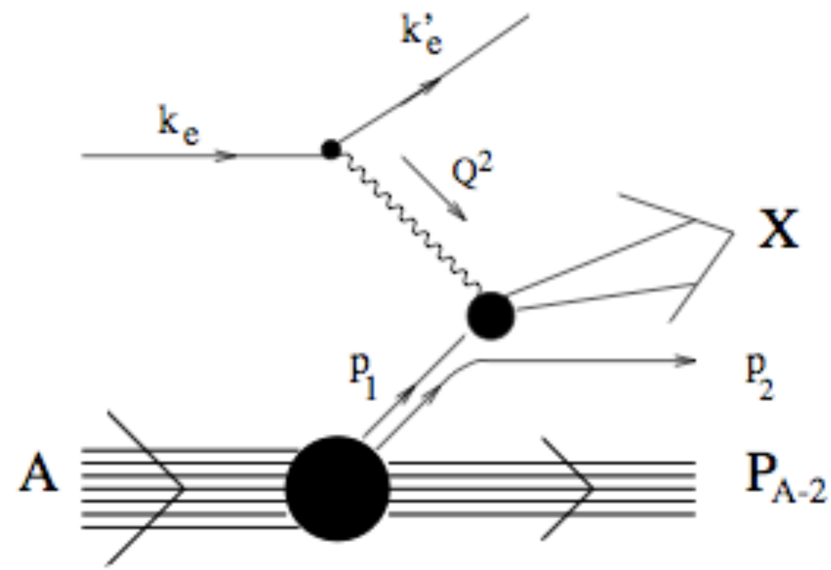
- RTPC based on cylindrical GEMs
- Open geometry detector, 3 cm drift region
- Working gas Ne-DME (80:20)
- Target 6mm diameter, 30 cm long kapton straw with 30 μm thick walls

Semi inclusive DIS off nuclei by tagging the recoil (A-1) nucleus "LOI-11–004" as well as "(A-2) + nucleon" in the final state may provide unique information on several long standing problems:

- **The nature and relevance of the final state interaction between the produced hadron and the nuclear medium e.g. hadronization length of the struck quark**
- **Test the validity of the impulse approximation (spectator mechanism) in DIS**
- **The medium induced modifications of the nucleon structure function**
- **The origin of the EMC effect and its relation to short range correlations "Local EMC": EMC effect of nucleons having different binding in the nucleus**

$A(e, e'(A\text{-}1))X$ and $A(e, e'N_2(A\text{-}2))X$ in the impulse approximation





DIS occurs on a mean-field, low momentum Nucleon and the nucleus (A-1) recoils with low Momentum and low excitation energy

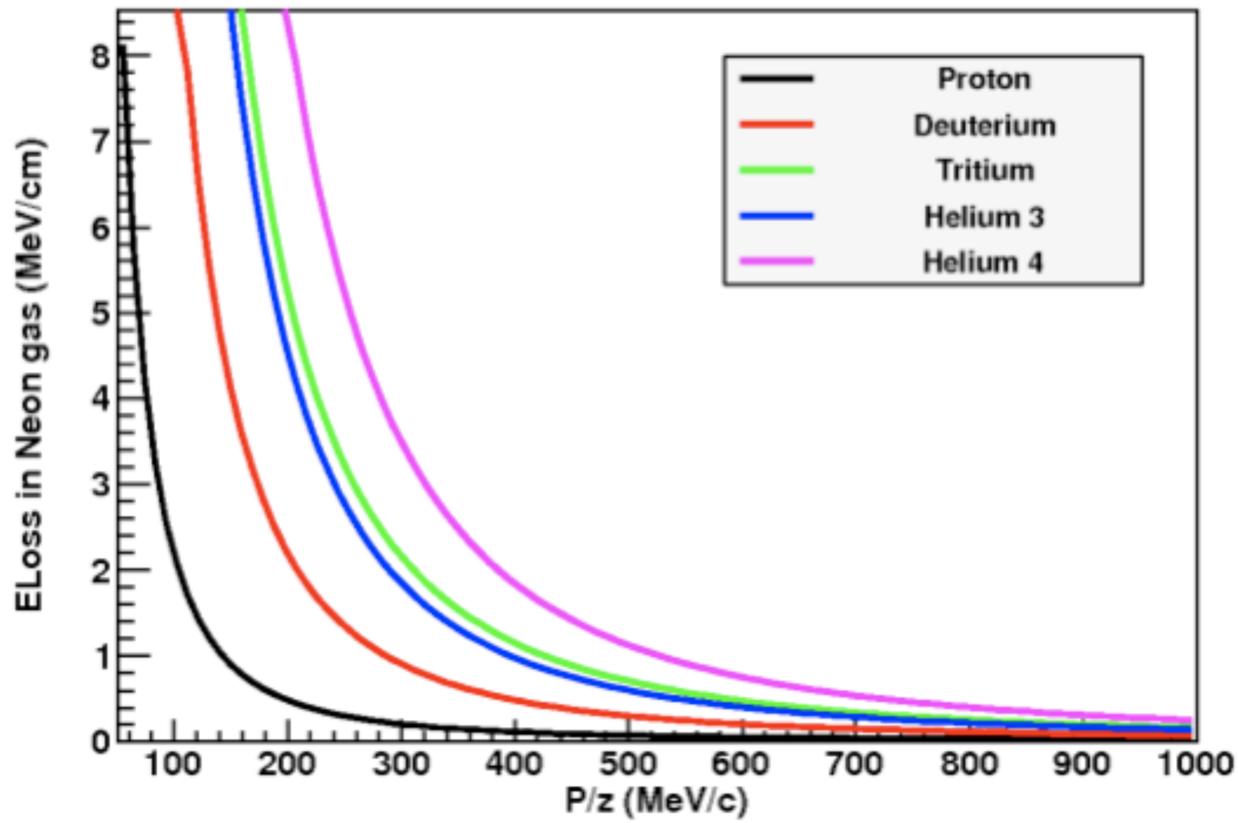
DIS occurs on a high momentum nucleon N_1 of a correlated pair, and the nucleon N_2 recoils with high momentum and the nucleus (A-2) recoils with low momentum

Eg6 RTPC & BoNuS12

PID based on energy loss & momentum measurements

ID of heavy fragments is more difficult to achieve

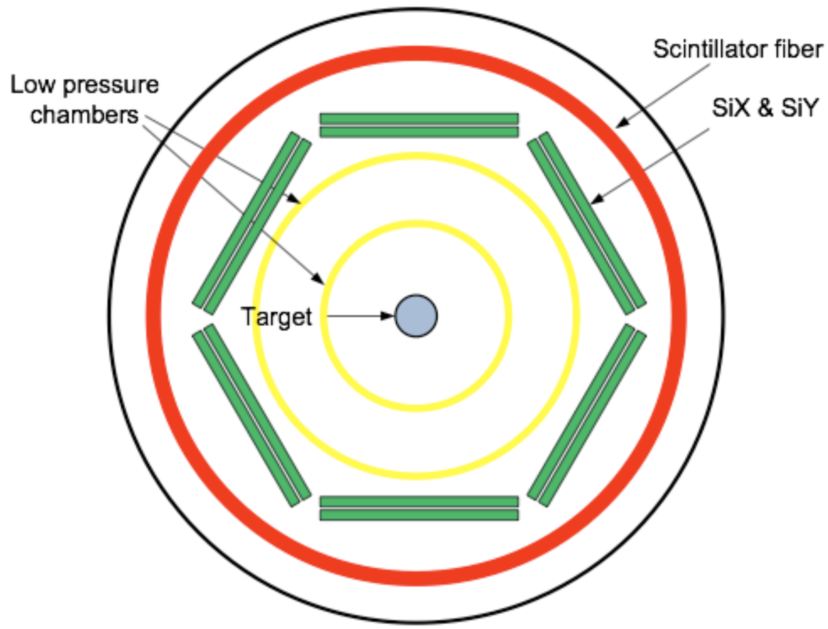
The radius of curvature depends on P/z

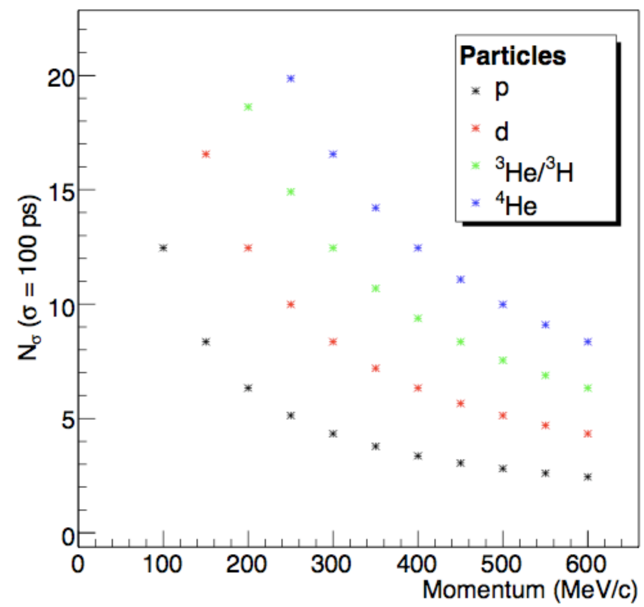


- Eloss depends on the readout pad gains. It is believed that the space variations between GEM layers (curved geometry) causes large gain variations
- BoNuS12 will be longer and the target length will be doubled: double luminosity & increased acceptance
- Maximum radial drift length will be increased from 3 to 6 cm: improved momentum resolution, extended momentum coverage & curvature of GEM surface will be smaller (improve gain uniformity)

New low energy recoil detector for CLAS12 based on the AmPS (NIKHEF) recoil detector – preliminary design: good timing and energy loss measurements

View from the beam direction





4cm path

Momentum range for different particles
In the recoil detector

p	40 - 240 MeV/c
d	60 - 410 MeV/c
^{3}H	80 - 550 MeV/c
^{3}He	130 - 600 MeV/c

- Two low pressure chambers to provide additional Trajectory information
- Scintillator fibers similar to Central TOF Important to reduce particle eloss through the Material
- 5 planes of wire chambers with a total thickness of ~ 1.2 cm

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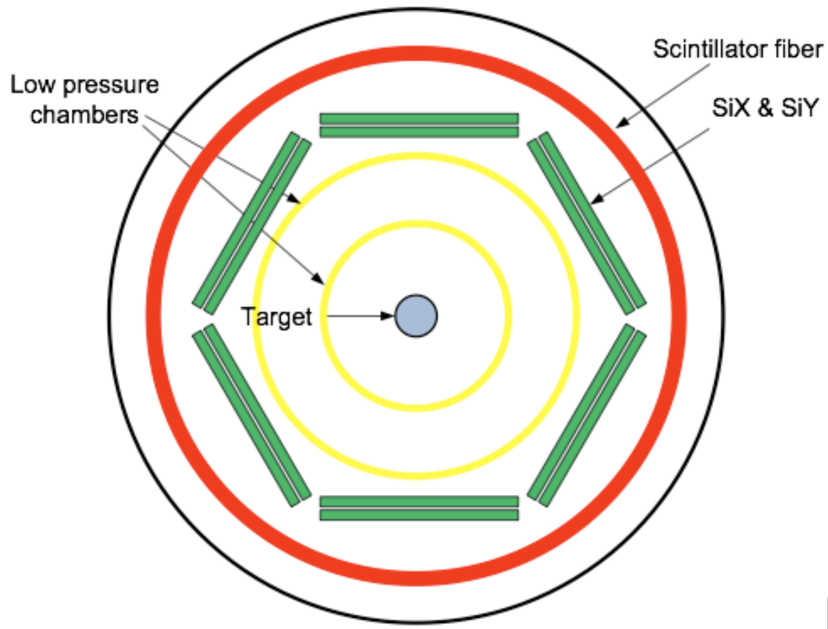

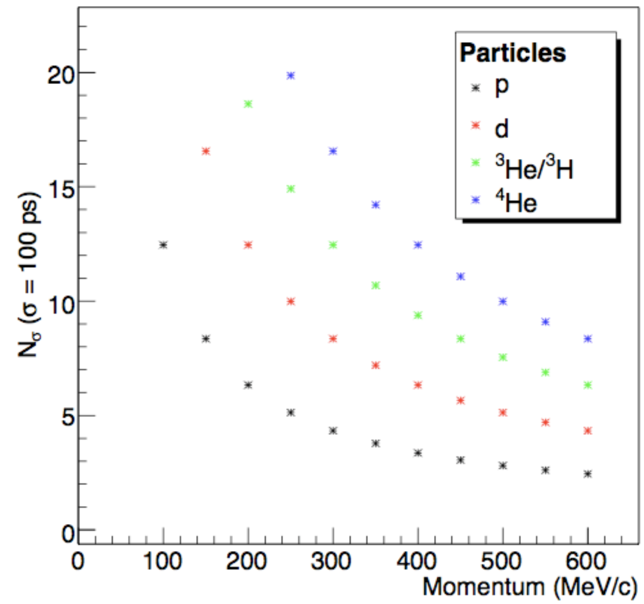

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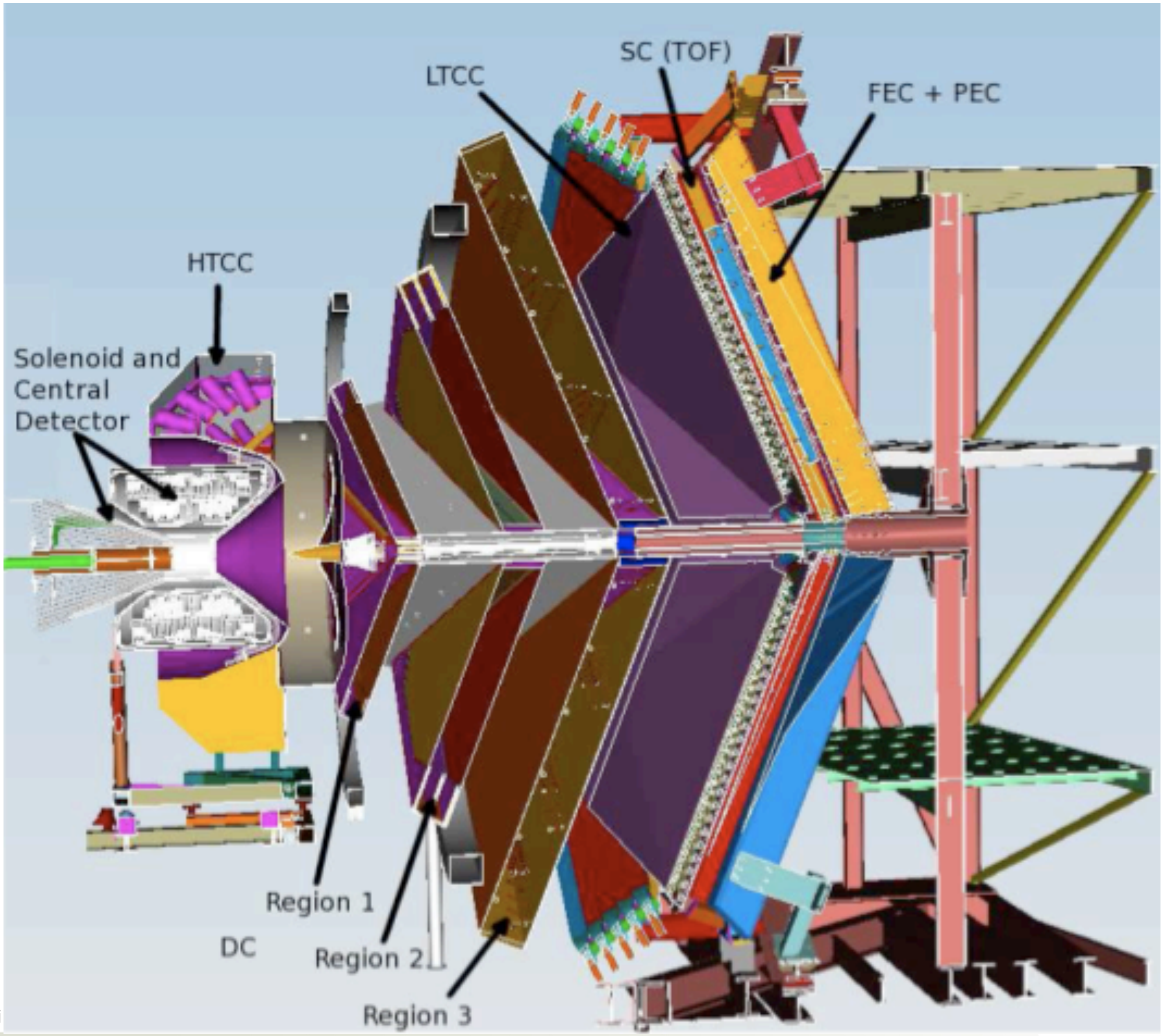
TABLE I: Main characteristics of the new recoil detector.

Target	$r = 5$mm, 3 atm D/^{3}He/^{4}He, ~ 40 cm long
Target wall	15 μm Kapton
Avalanche chamber 1,2	$r_1 = 4$ cm, $r_2 = 8$cm, $\sigma_t \sim 100$ ps, $\sigma_s \sim 200$ ps
Chamber gas	2-10 Torr isobutane
Chamber window	$40 - 50\mu g/cm^2$ Polypropylene
Silicon strip detectors	$r = 10$ cm, 100, 475μm thick, $\sigma_s \sim$ mm
Scintillator	$r = 15$ cm, 1 cm thick scintillator fiber

CLAS12 Central detector

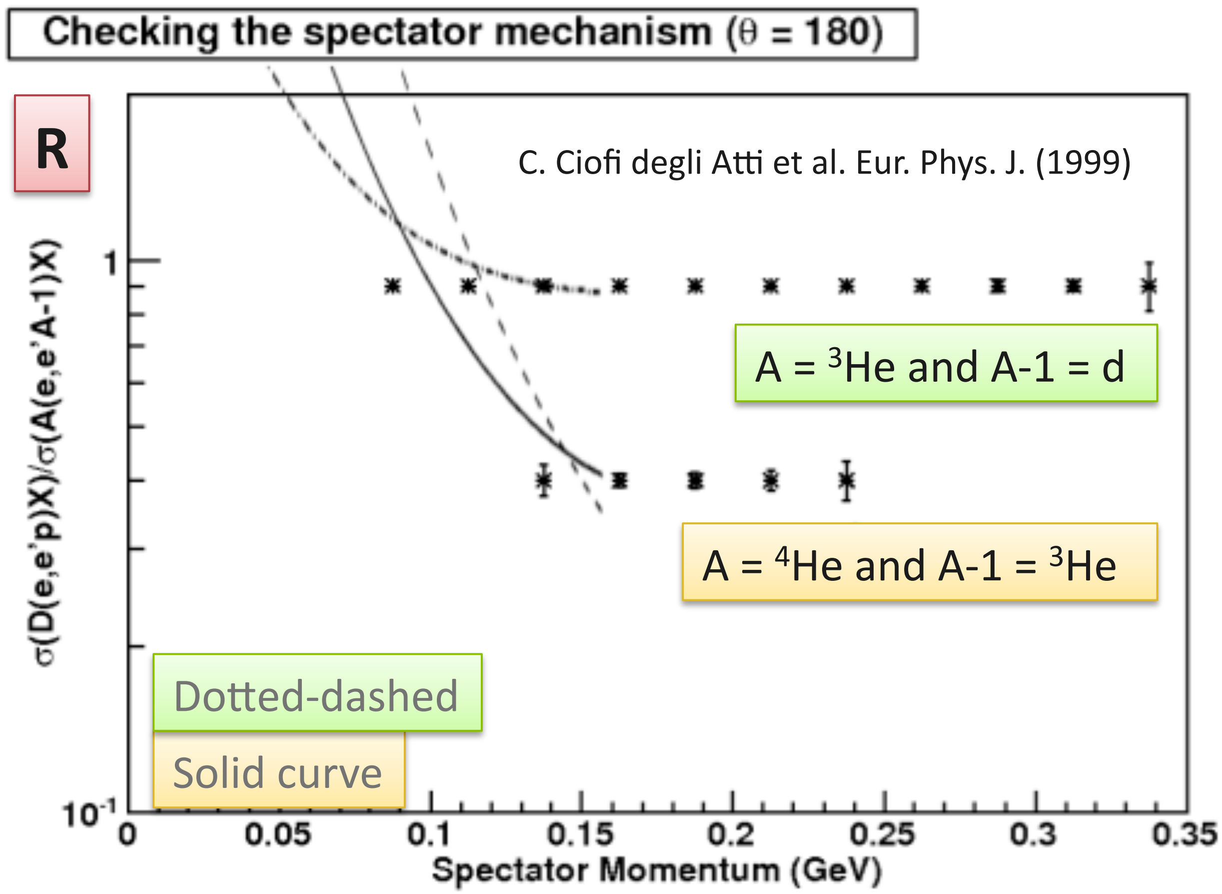


Proposed Measurements – complementary to Hall C measurements

- Measure SIDIS scattering off d, ^{3}He and 4He by tagging a low momentum recoiling spectator (A-1) with $P_{(A-1)} < 400$ MeV/c
  - d(e, e'p)X – bound neutron
  - ^{3}He(e, e'd)X – bound proton
  - ^{4}He(e, e'^{3}H)X – bound proton
  - ^{4}He(e, e'^{3}He)X – bound neutron
- SIDIS cross section will be measured for each target and $P_{(A-1)}$ and x dependences will be studied
- Ratios of cross sections will be used to test the spectator mechanism and the medium induced modification of the nucleon structure function
- A dependence of the n/p ratio of bound structure function will be studied
- d/u of a bound nucleon will be extracted from ^{4}He(e,e'^{3}H) and ^{4}He(e,e'^{3}He)

Test the spectator mechanism assuming that the DIS took place on a neutron (θ = 180 ± 15deg)

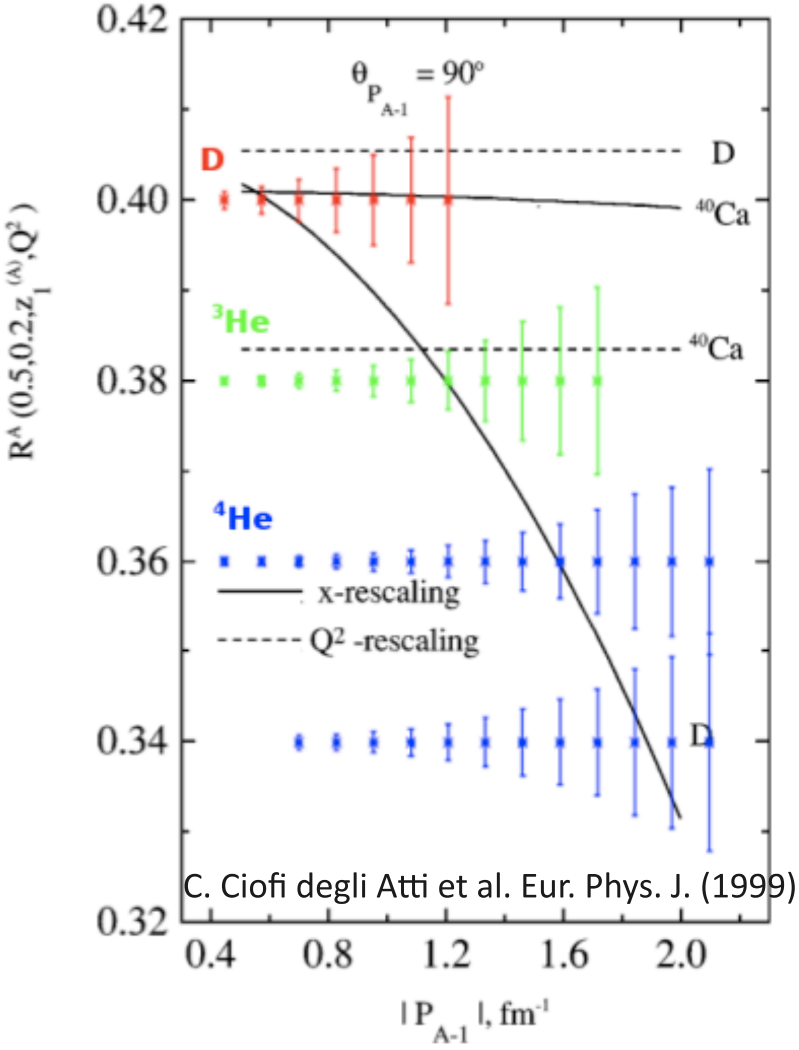
Projections using 10^{35}/cm^{2}s luminosity and 5 days per target



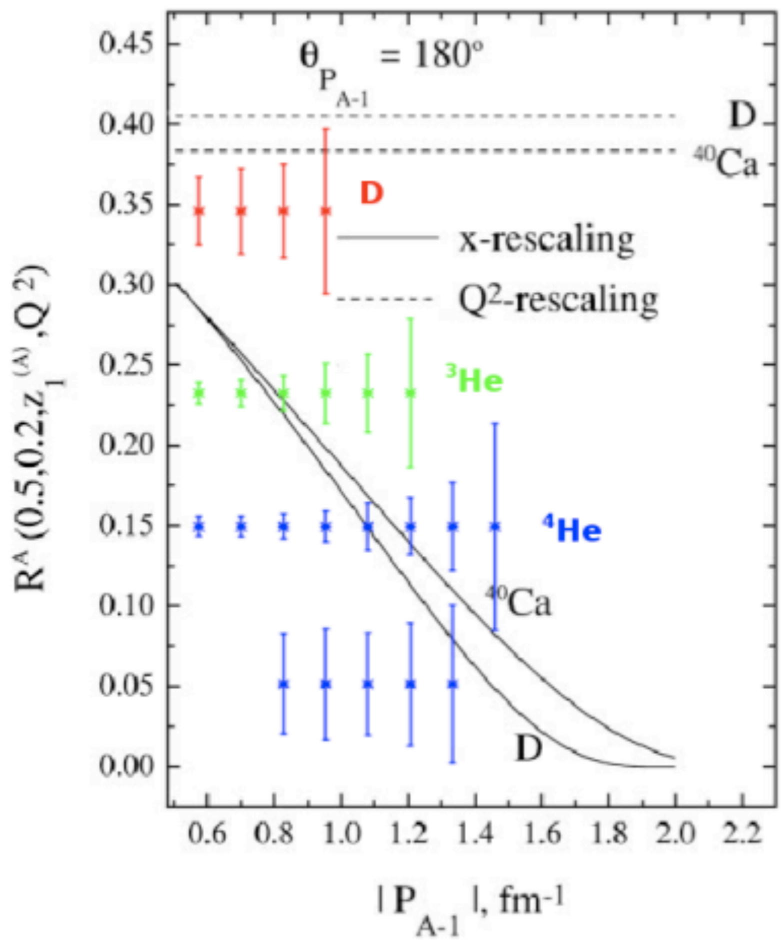
- Two different nuclei with the same values of x, Q^2 and $P_{(A-1)}$
- In the Bjorken limit, the A dependence of R becomes entirely dependent of the nucleon momentum distribution (shown by the plotted Curves)
- If the measurements are in agreement with the curves then the spectator mechanism is valid and FSI effects should be very small

Testing different assumptions of the EMC effect – sensitivity to the bound nucleon structure function (θ=180±15deg and 90±40deg)

Ratio of the same nucleus at different x values mostly sensitive to the in-medium structure function

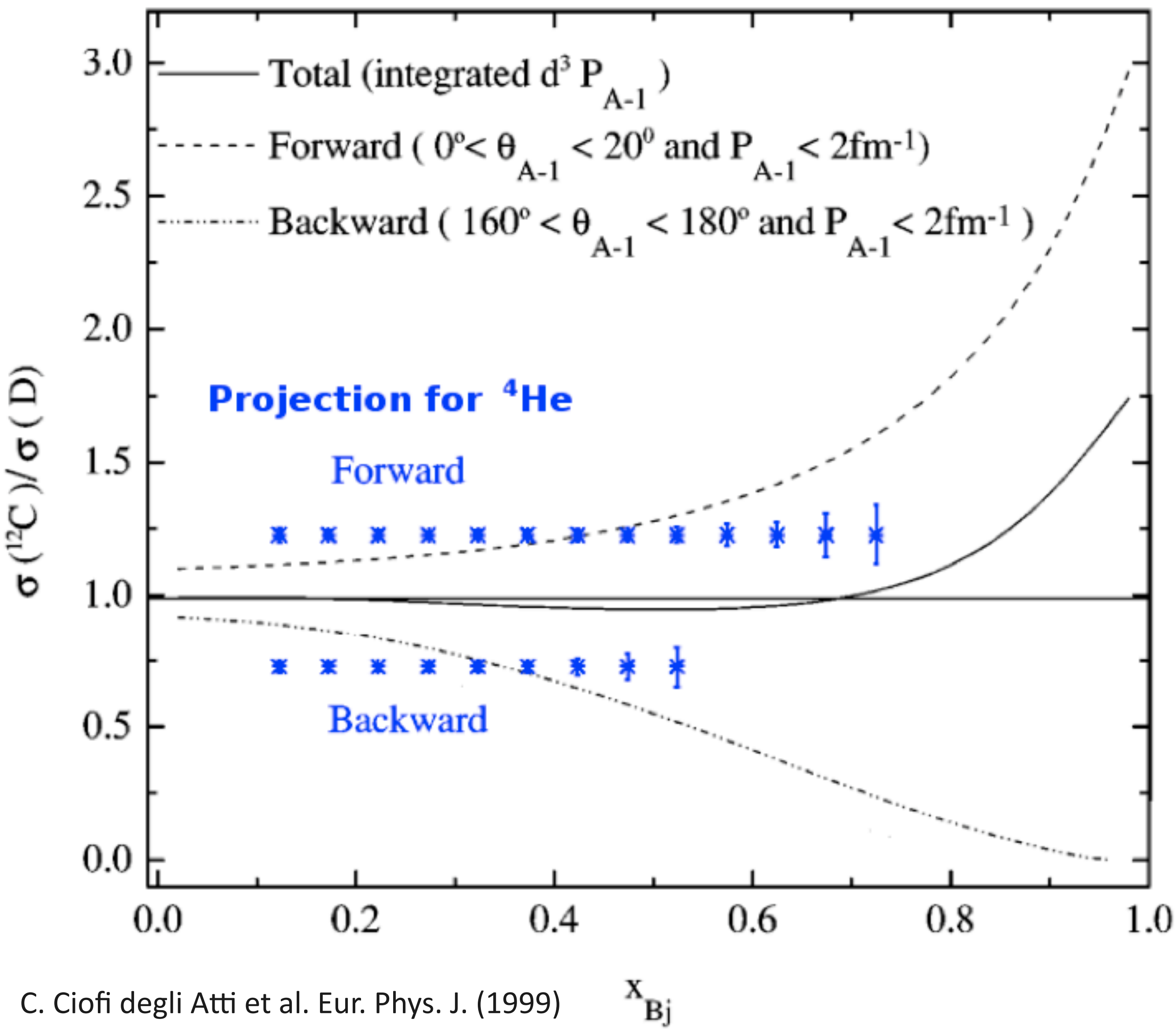


C. Ciofi degli Atti et al. Eur. Phys. J. (1999)



For ^{4}He: upper point are for tagged ^{3}He and lower points are for ^{3}H

The semi inclusive EMC ratio

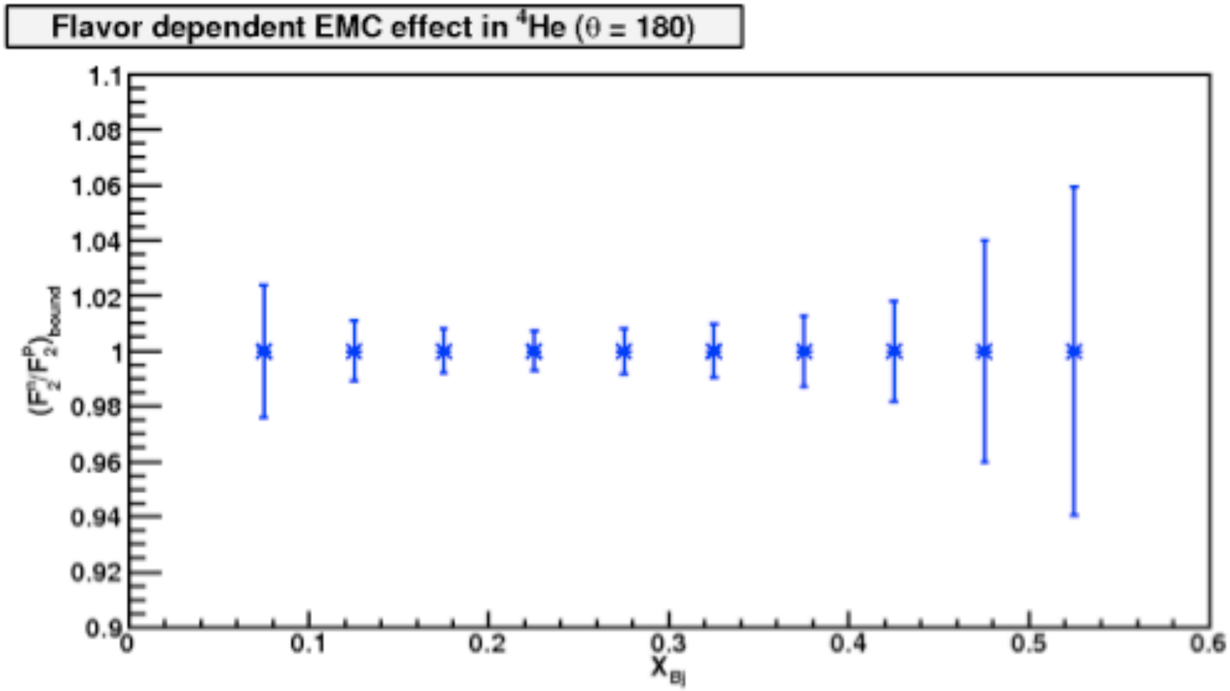


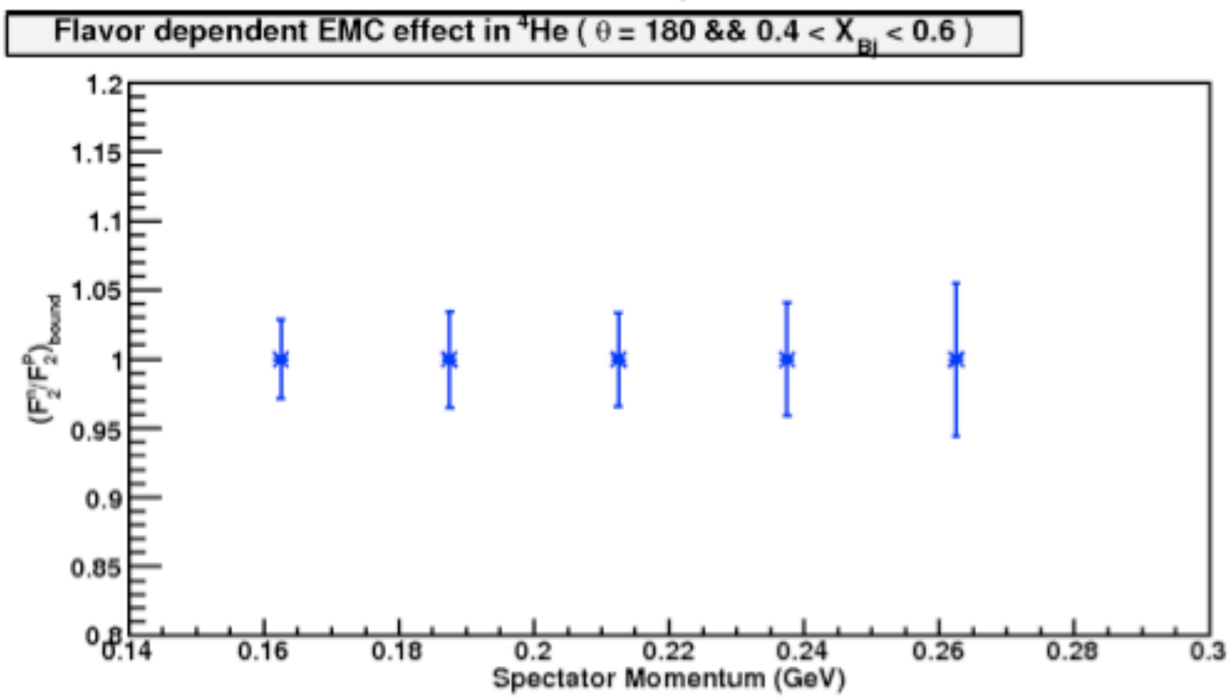
In forward scattering, the FSI effects are Expected to be large

In that case, hadrons produced from quark hadronization represent an important contamination

C. Ciofi degli Atti et al. Eur. Phys. J. (1999)

Flavor dependent EMC effect F2(n)/F2(p) bound





Projections using $10^{35}/cm^2s$ luminosity and 5 days per target – Still room for Statistical improvement

Summary and outlook

- **After the JLab 12 GeV upgrade we will certainly witness a golden era for EMC studies using tagged measurements, pion production and DVCS**
- **Both Free and bound nucleon structure functions will be measured with unprecedented precision and with different methods**
- **Studies of complicated nuclear effects such as final state interaction look promising**
- **Hall B and C experiments are usual complementary and absolutely necessary to get the full picture**
- **More work is needed to develop the LOI to a full proposal especially finalizing the design and studying the A(e,e'N(A-2)) channel**