“EMC” in D(e,e’n_s) / H(e,e’)

N. Liyanage and B. Wojtsekhowski

"EMC" in D(e,e'n_s) / H(e,e')

B. Wojtsekhowski

Outline of the talk

- High interest in EMC origin, esp. connection to SRC
- DIS cross section at x = 0.2-0.7
- LAD and ALERT plans for SRC proton tag $p_s > 200$ MeV/c
- EIC paper/proposal – Ch. Weiss
- 2004 proposal PR05-014: D(e,e'n_s)
- Layout of the D(e,e'n_s) experiment
- Focus on a slow neutron with $p_s < 200$ MeV/c
- Accidental background is due to neutron rate from LD2 target
- Non-accidental is due to neutron produced in DIS from proton
- Resulting Signal/Background ratio at 3×10^{36} luminosity
- Projected results in 10-day run with SBS for electrons

EIC plan for D(e,e'n_s/p_s)

PHYSICAL REVIEW C **104**, 065205 (2021)

estion

Deep-inelastic electron-deuteron scattering with spectator nucleon tagging at the future Electron Ion Collider: Extracting free nucleon structure

Alexander Jentsch,[1,*] Zhoudunming Tu,[1,2,†] and Christian Weiss[3,‡]

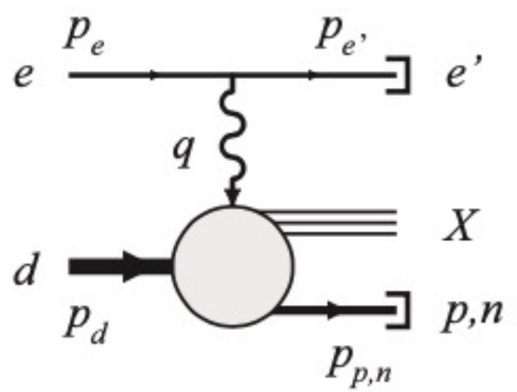


FIG. 1. DIS on the deuteron with detection of a proton (or neutron) in the nuclear fragmentation region, $e + d \rightarrow e' + X + p(n)$ ("tagged DIS").

Proposal 05-014 for D(e,e’n_s)

(A New Proposal to Jefferson Lab PAC27)
Neutron Tagged bound proton structure to probe the Origin of the EMC Effect

G.D. Cates, D. Day, N. Liyanage (Spokesperson and contact person),
R. Lindgren, V. Nelyubin, B. Norum, O. Rondon, K. SLifer, A. Tobias, K. Wang,
S. Tajima, B. Craver, R. Chang
University of Virginia, Charlottesville, VA 22904

J.P. Chen, P. Degtiarenko, E. Chudakov, J. Gomez, O. Hansen, D. Higinbotham, B. Reitz,
B. Wojtsekhowski (Spokesperson)
Jefferson Lab, Newport News, VA 23606

PAC27 report

Proposal: PR-05-014

Scientific Rating: N/A

Title: Neutron Tagged Bound Proton Structure to Probe the Origin of the EMC Effect

Spokespersons: Nilanga Liyanage, Bogdan Wojtsekhowski

Motivation: The determination of the ratio F_2^n/F_2^p and the *d/u* quark momentum distributions at large *x* in the proton suffer from uncertainties due to our lack of understanding of the EMC effect in the deuteron. Different classes of models lead to very different results at large *x* making the extraction of the neutron structure function from the deuteron ambiguous. The proposed experiment aims to probe the EMC effect from a barely bound to a strongly bound proton by means of deep inelastic scattering off the proton in the deuteron and by tagging the spectator neutron. This would allow discrimination between different models of the EMC effect.

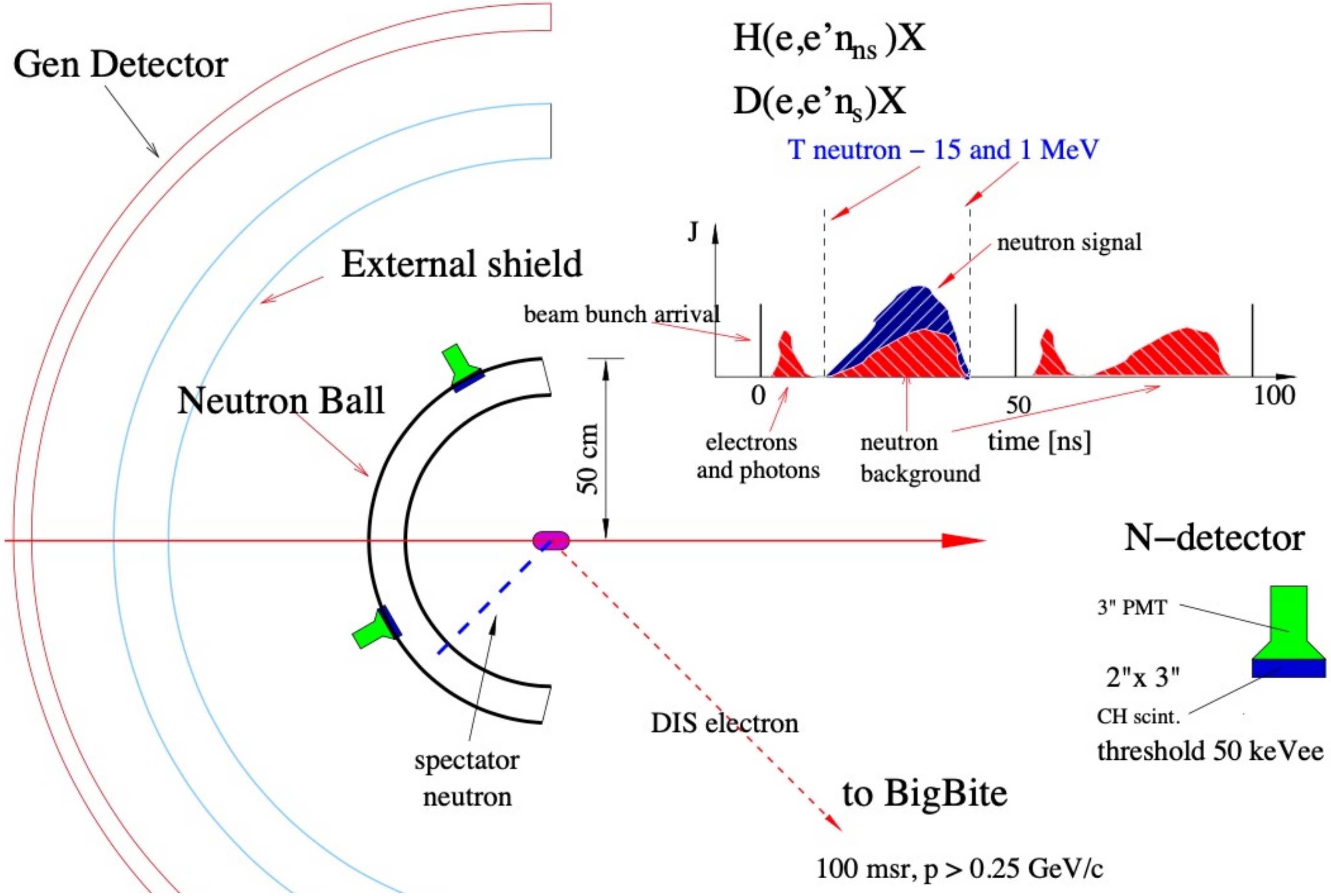
PAC27 report

Measurement and Feasibility: In the proposed experiment the ratio $\sigma[D(e,e'N)X]_{(x',\alpha^{sp},p_t,Q^2)}/\sigma[p(e,e')X]_{(x',Q^2)}$ is measured at values of *x'* from 0.11 up to 0.6 and spectator momentum fraction $1.04 \leq \alpha^{sp} \leq .4$ where $\sigma[D(e,e'N)X]_{(x',\alpha^{sp},p_t,Q^2)}$ is normalized to the inclusive *D(e,e')* cross section. An absolute measurement of this ratio is performed at each of the proposed α^{sp} by using the reaction *D(e,e'pn)* to calibrate the neutron detector efficiency to about 3%. Furthermore, to improve on the relative uncertainty in the determination of this ratio as a function of α^{sp}, it is normalized at each value of *x'* by its measured value at *x'*=0.2 leading to the determination of the ratio $G=\sigma[D(e,e'N)X]_{(x'_1,\alpha^{sp},p_t,Q_1^2)}/\sigma[D(e,e'N)X]_{(x'_2=0.2,\alpha^{sp},p_t,Q_2^2)}$. The experiment makes use of the BigBite spectrometer to detect electrons. The spectator neutrons are detected by using the neutron detector of the G_E^n experiment (E02-013) for the largest momenta and a new specially designed low energy neutron detector. The method takes advantage of the beam time structure as used in the G0 experiment in order to reduce the electromagnetic background and determine the shape of the neutron background with precision.

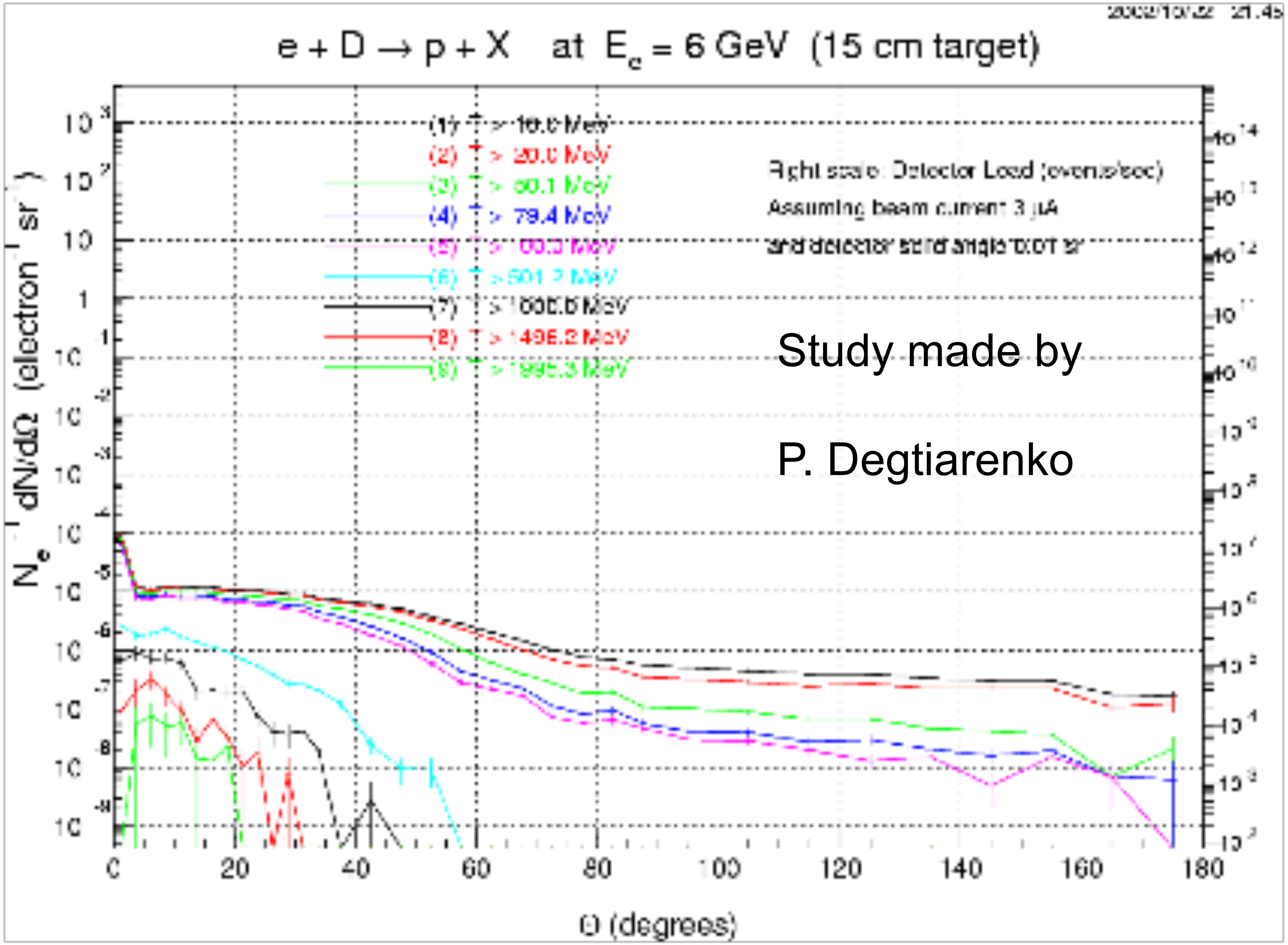
Issues: While the PAC is in principle very positive about this method, some issues remain to be addressed. The sensitivity of this experiment is at the 4σ level, which is marginal. The rate of accidental coincidences in the neutron detectors needs to be investigated by a test measurement, as already considered by the proponents, in order to optimize the luminosity of the experiment. A more complete estimate of the resulting systematic errors must be performed and must include the effect of $R=\sigma_L/\sigma_T$, as well as the possible uncertainty resulting from the normalization of the deuteron coincidence cross section to the inclusive one when the spectator is far off-shell.

Recommendation: Defer

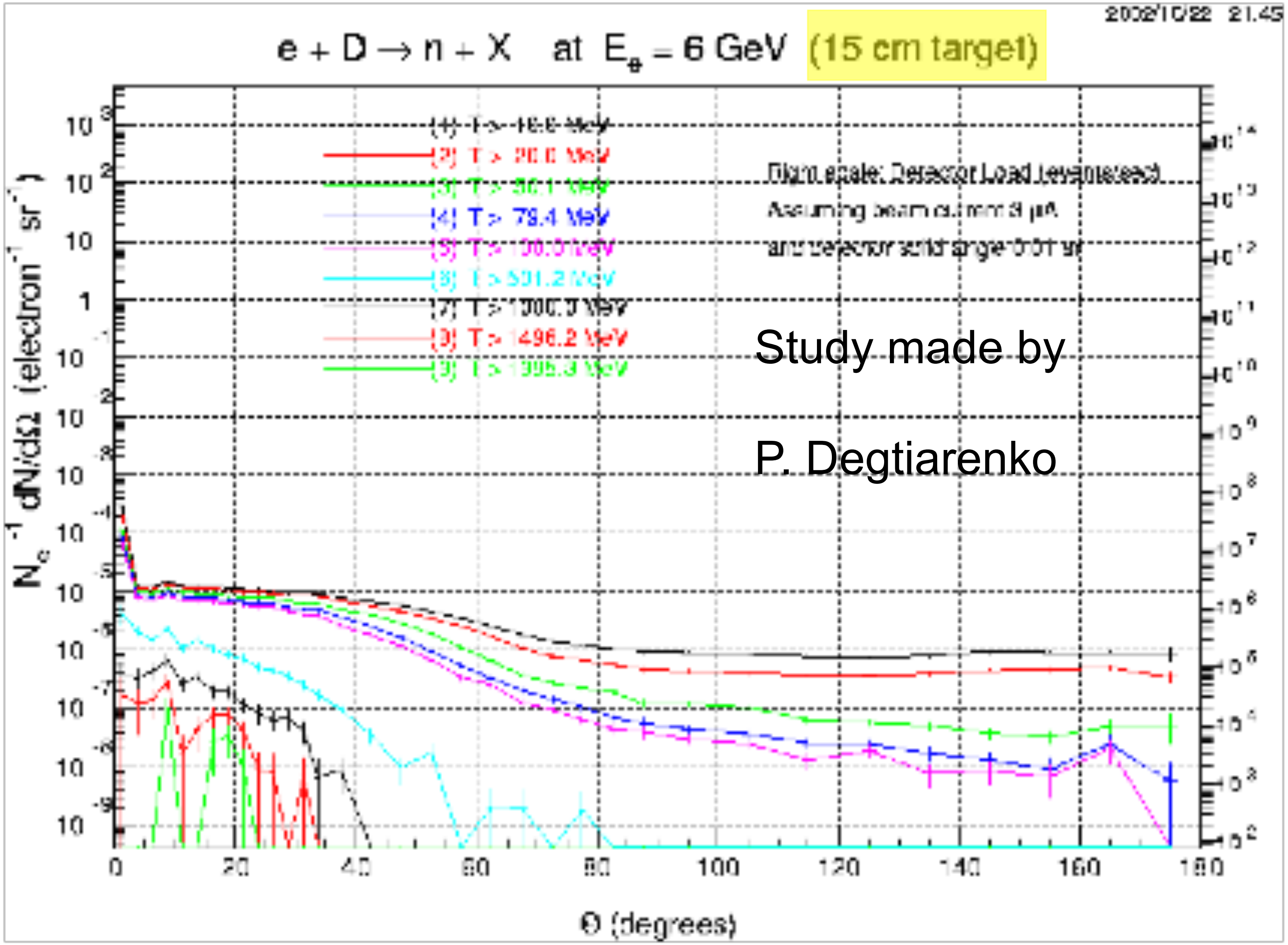
2004 proposal for $D(e,e'n_s)$



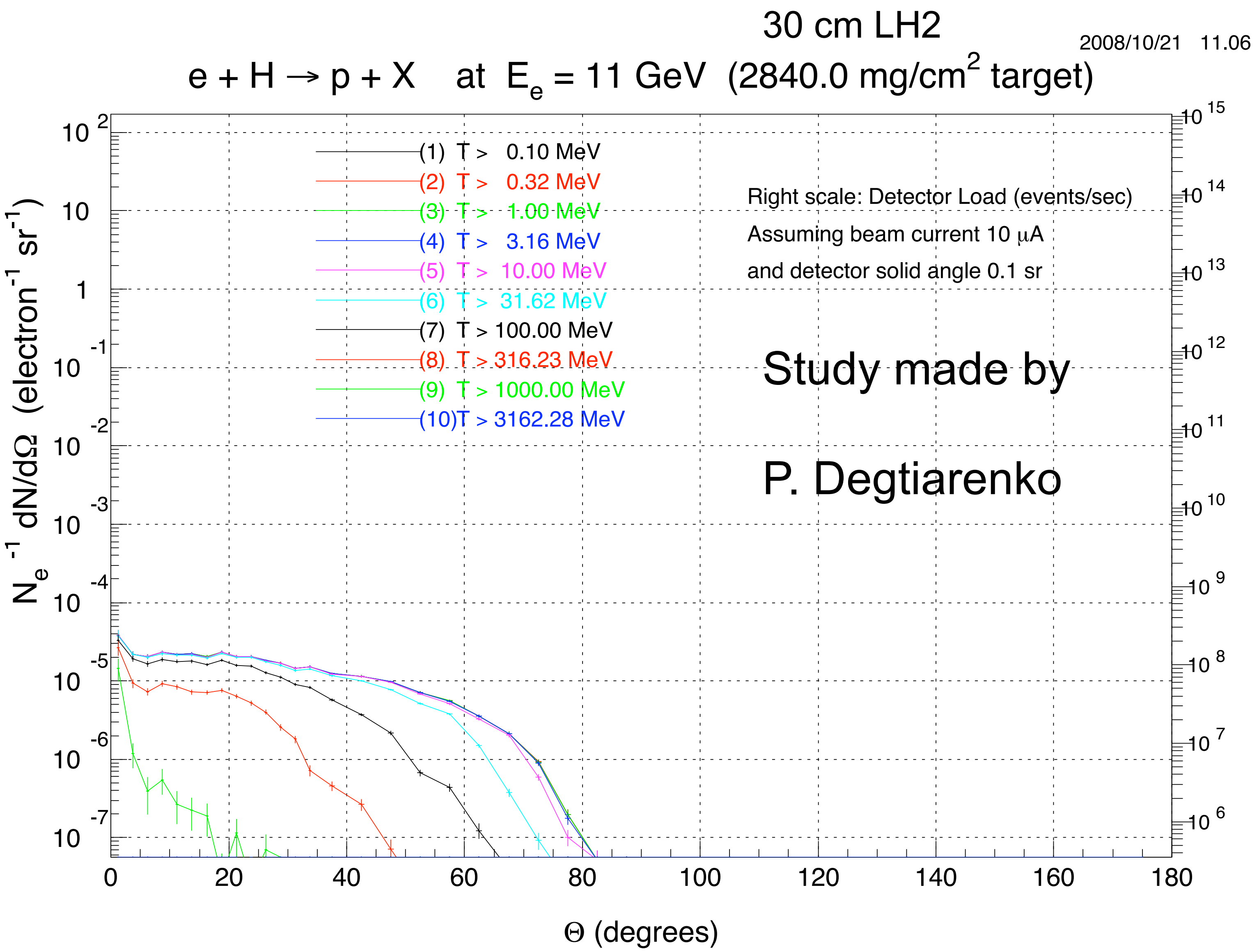
Detector rate vs angle



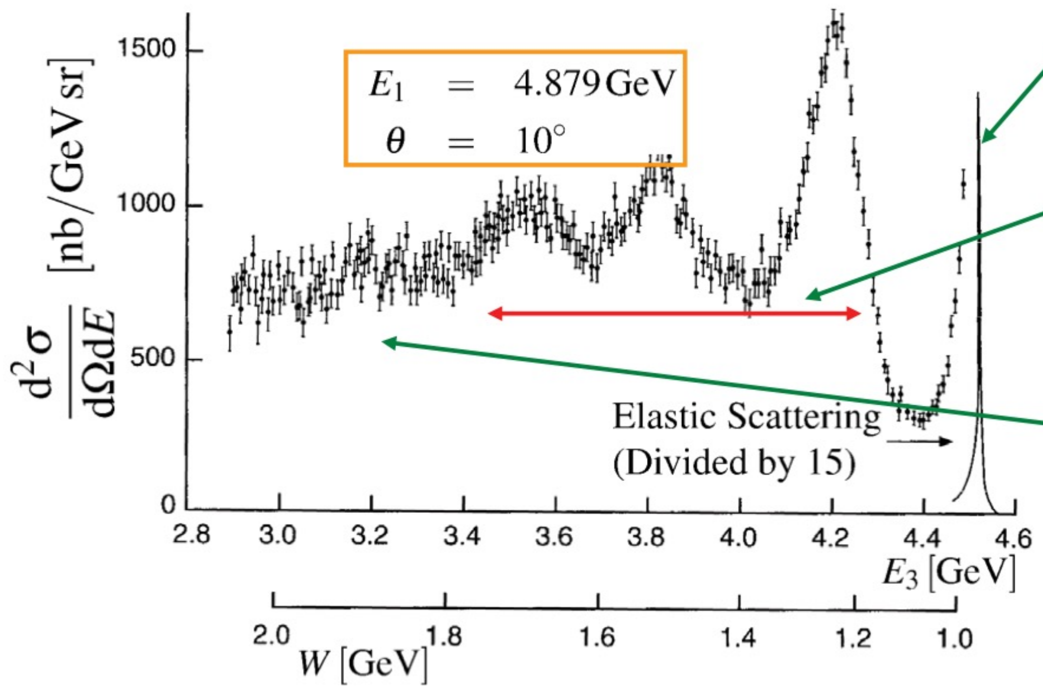
Detector rate vs angle



Detector rate vs angle



DIS event rate



- **Elastic Scattering**
  proton remains intact
  $W = M$
- **Inelastic Scattering**
  produce "excited states" of proton e.g. $\Delta^+(1232)$
  $W = M_\Delta$
- **Deep Inelastic Scattering**
  proton breaks up resulting in a many particle final state

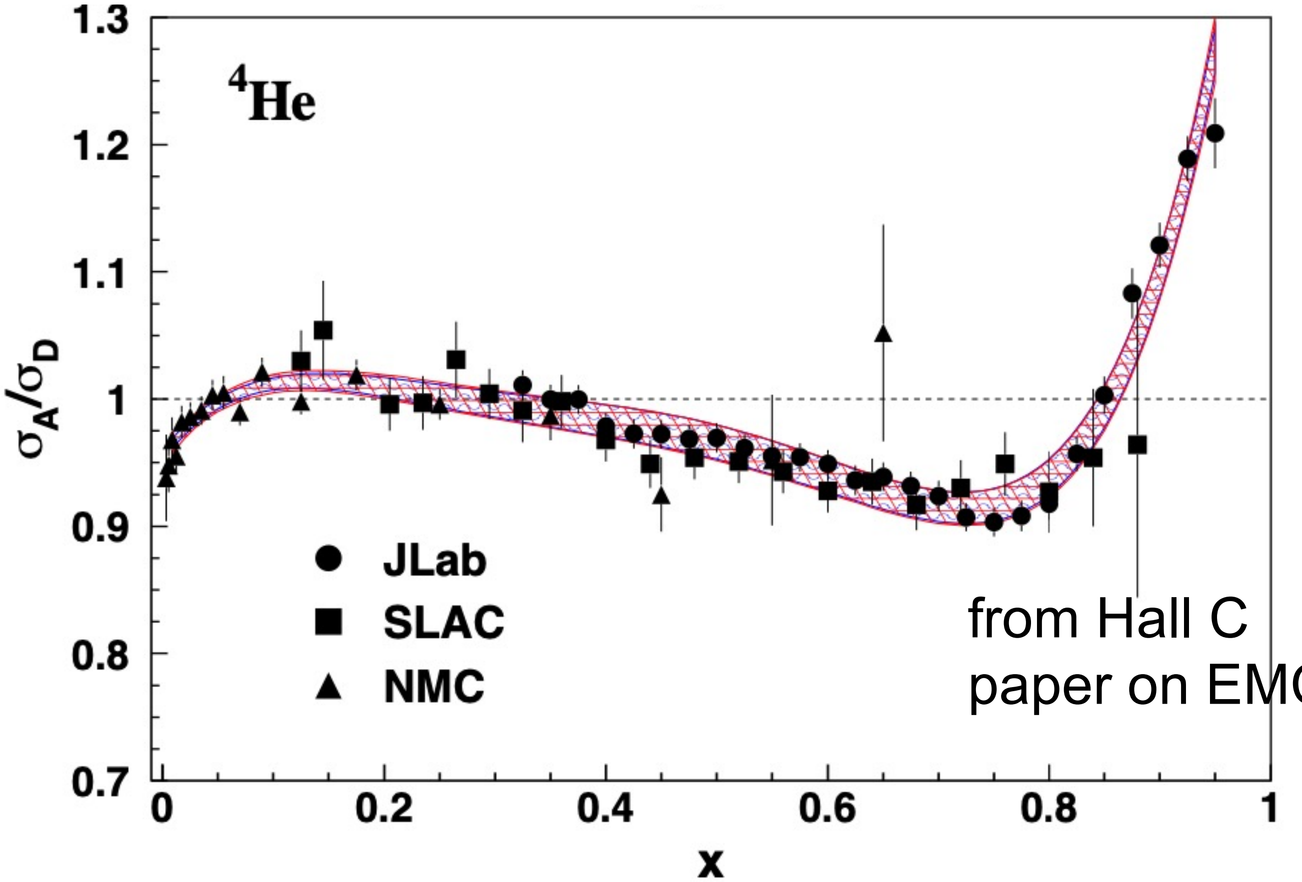
DIS = large W

$$\frac{d^2\sigma}{dE_3 d\Omega} = \frac{\alpha^2}{4E_1^2 \sin^4\theta/2}\left[\frac{1}{\nu}F_2(x,Q^2)\cos^2\frac{\theta}{2} + \frac{2}{M}F_1(x,Q^2)\sin^2\frac{\theta}{2}\right]$$

~ 0.3

$F_2(x) = 2xF_1(x)$

EMC effect



from Hall C
paper on EMC

Detector rates at L = 3 x 10^{37}
(10 μA x 5 cm LD2)

- Neutron energy of 5 MeV (p = 100 MeV/c) and angle > 100 deg
- Rate of n ~ 0.3 x10^{-6} per electron/sr = 20x10^{6} Hz/sr for 10 μA x 5 cm LD2
- Those soft neutrons are from the many-particle final state processes
- DIS rate: E = 11 GeV beam at 15 deg on the proton target (see also a plot).
- The DIS rate with SBS = > 0.05 sr x 1x10^{-32} cm^{2}/sr x 3x10^{37} cm^{-2}/s = 1.5 x 10^{4} Hz

Detector rates at L = 3 x 10^{37}

(10 μA x 5 cm LD2)

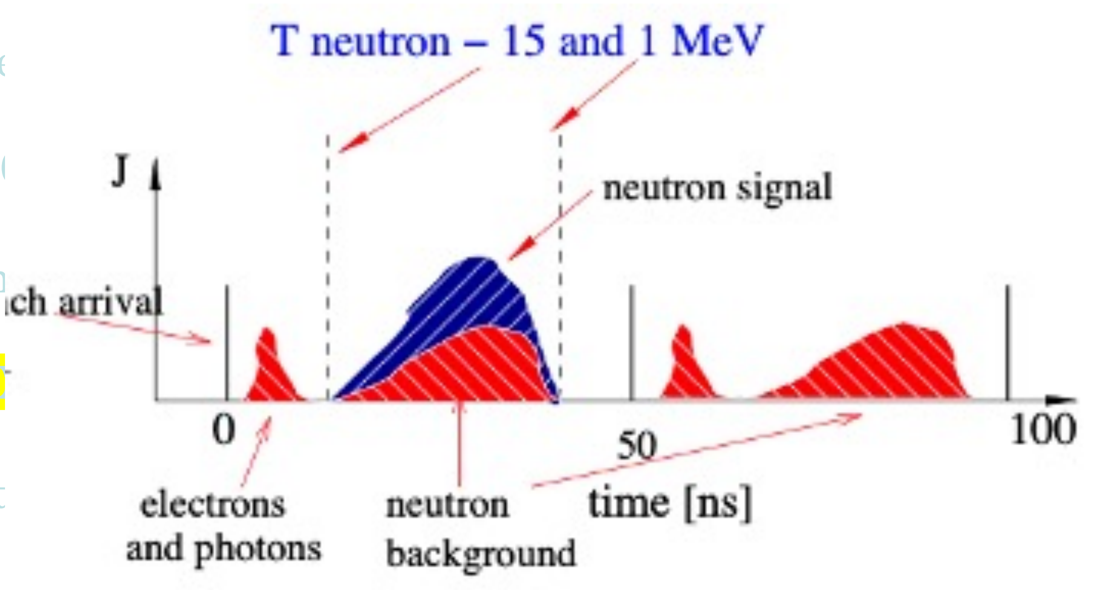
- Neutron energy of 5 MeV (p = 100 MeV/c) and angle > 100 deg
- Rate of n ~ 0.3 x10^{-6} per electron/sr = 20x10^{6} Hz/sr for 10 μA x 5 cm LD2
- Those soft neutrons are from the many-particle final state processes
- DIS rate: E = 11 GeV beam at 15 deg on the proton target (see also a plot).
- The DIS rate with SBS = > 0.05 sr x 1x10^{-32} cm^{2}/sr x 3x10^{37} cm^{-2}/s = 1.5 x 10^{4} Hz
- For each e,e' event there is 1/12 probability of a correct hit in the neutron detector
- For 1 sr neutron detector Signal (e,e'n_s) rate is $N_{DIS}/4\pi$ ~1/12 => 1.2x10^{3} Hz
- In each e,e' event will be some extra hits in the neutron detector:
- For 32 ns beam RF the probability is 20 MHz x 0.032 μs = 0.64 => 15 kHz x 0.64 background events with a potential neutron in one RF bucket.

=> Signal/Background (accidental) = 1.2 kHz / 9.6 kHz = 1/8

Detector rates at L = 3 x 10^{37}

(10 μA x 5 cm LD2)

- Neutron ene
- Rate of n ~ (… m LD2
- Those soft n … ses
- DIS rate: E … so a plot).
- The DIS rat … = 1.5 x 10^4 Hz
- For each e,e … neutron detector



- For 1 sr neutron detector Signal (e,e'n_s) rate is $N_{DIS}/4\pi$ ~1/12 => 1.2x10^3 Hz
- In each e,e' event will be some extra hits in the neutron detector:
- For 32 ns beam RF the probability is 20 MHz x 0.032 μs = 0.64 => 15 kHz x 0.64 background events with a potential neutron in one RF bucket.
  Signal/Background = 1/8
- 20-day run is needed due to 10% neutron detection efficiency => 120 Hz of Signal

EMC signal size

The window 10 ns wide for 32 ns RF structure allows to remove high speed particles

For 1 m from the target => 33 ns (for 5 MeV) => +/-50% energy window (3 to 8 MeV)

The Signal (DIS + neutron) statistics in 20 days ~ 2.1×10^8 +/- 1.4×10^4

Need to measure accidental Background with high accuracy

and in 100 RF buckets = windows will collect the accidental Background
mostly originated from the reaction D($\gamma_{q\text{-real}}$, n)X

Hit rate in the neutron detector (in such wide window and detector 10% efficiency) is
100 x 0.64 = 6.4 per e,e' event. It will have a total statistics of 1.7×10^{11} with +/- 4×10^5

Only 1/100 of these events will be in the correct RF bucket, so background will be
1.7×10^9 +/- 4×10^3 inside the bucket with the Signal

EMC signal size

The window 10 ns wide for 32 ns RF structure allows to remove high speed particles

For 1 m from the target => 33 ns (for 5 MeV) => +/-50% energy window (3 to 8 MeV)

The Signal (DIS + neutron) statistics in 20 days ~ 2.1×10^{8} +/- 1.4×10^{4}

Need to measure accidental Background with high accuracy

and in 100 RF buckets = windows will collect the accidental Background mostly originated from the reaction $D(\gamma_{q\text{-real}}, n)X$

Hit rate in the neutron detector (in such wide window and detector 10% efficiency) is 100 x 0.64 = 6.4 per e,e' event. It will have a total statistics of 1.7×10^{11} with +/- 4×10^{5}

Only 1/100 of these events will be in the correct RF bucket, so background will be 1.7×10^{9} +/- 4×10^{3} inside the bucket with the Signal

The Signal statistics is 2×10^{8} +/- 1.5×10^{4}.

The 1% size EMC effect (it corresponds to 2×10^{6} events) will be well visible

$2 \times 10^{6} / 1.5 \times 10^{4}$ ~ 130 / 1

Summary

- We propose to investigate EMC effect in a deuteron:
  a ratio of the DIS on a free proton and DIS on
  a barely bound slow proton in the deuteron

- This is a natural part of the SBS program at Hall C

- The understanding of EMC will be advanced