Neutron Tagged F_2 to probe the Origin of the EMC Effect

Bogdan Wojtsekhowski
Jefferson Lab

and

Nilanga Liyanage
University of Virginia

EMC Effect

- More than two decades after the discovery of the EMC effect, its origin still remains a mystery.
- Many models based on quite disparate physical ideas:
- Range from those in which EMC effect is attributed entirely to deformation of the nucleonic wave function to those rely effects due to meson-nucleon degrees of freedom associated with nuclear binding.

  Ex: Melnitchouk *et al.* compare three types of models

  - **Binding Model**: meson-nucleon explanation. (Miller, Kaptari, Thomas,...)
  - **Color Screening Model of Suppression of Point-Like Configurations (PLC) in Bound Nucleons** (Frankfurt and Strikman)
  - **Rescaling model, QCD Radiation - Quark Delocalization**: (Close, Jaffe,....) Gluon radiation happens more efficiently in a nucleus than in a free nucleon due to quark Delocalization.
- Currently no data to constrain these models

Neutron Tagged F_2^p off Deuteron (D(e,e′,N)X

- A precision measurement of $F_{2,p}^{eff}$ as a function of the spectator neutron momentum can reveal how the structure function start changing with increasing nuclear binding.
- The ratio of $F_{2,p}^{eff}/F_{2,p}$ vs. neutron momentum at different values of x, is sensitive to different models.
- Gives the opportunity to see the EMC effect on a proton; what has been done was for a nucleon
- Can use to understand the validity of deuteron as a neutron target.
- Choice of variables: Q^2, x, the transverse momentum of the spectator neutron, P_T^s and the light come momentum fraction of the spectator neutron α_s, where

$$\alpha_s = \frac{E_z - p_z^s}{M}$$

Sensitivity of $F_{2,p}^{eff}$

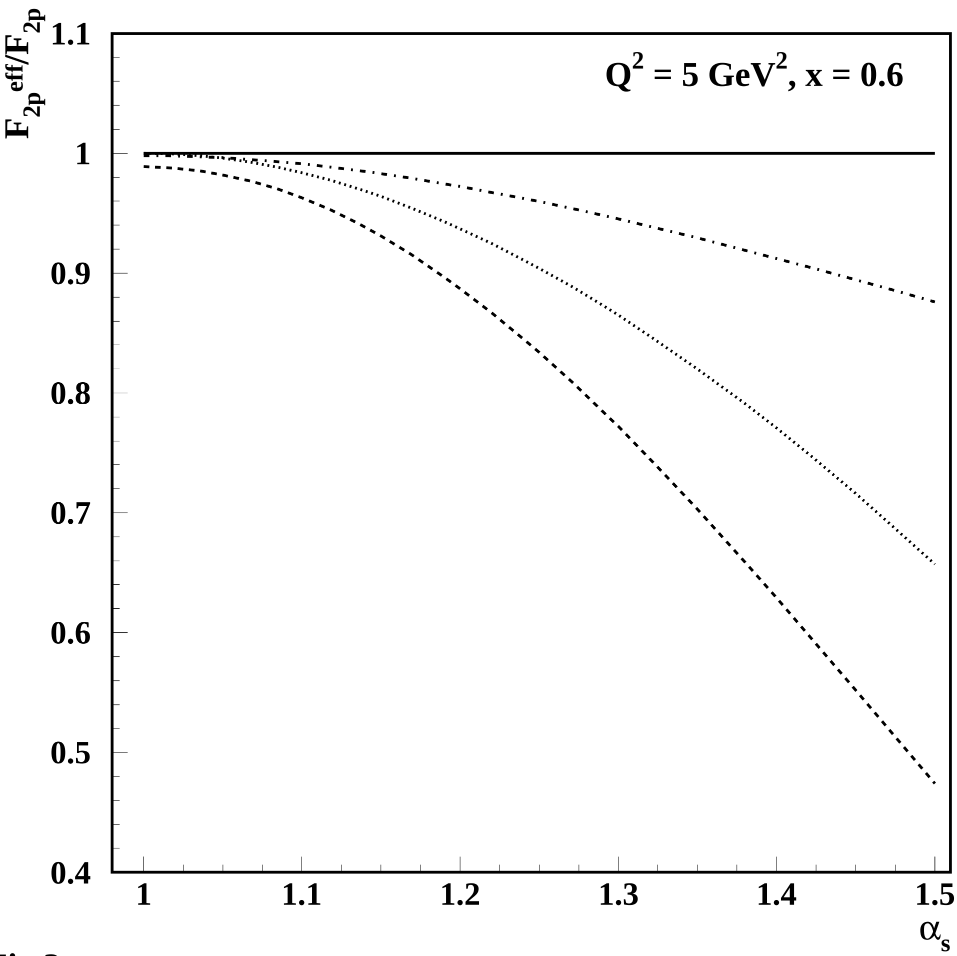


Fig.3

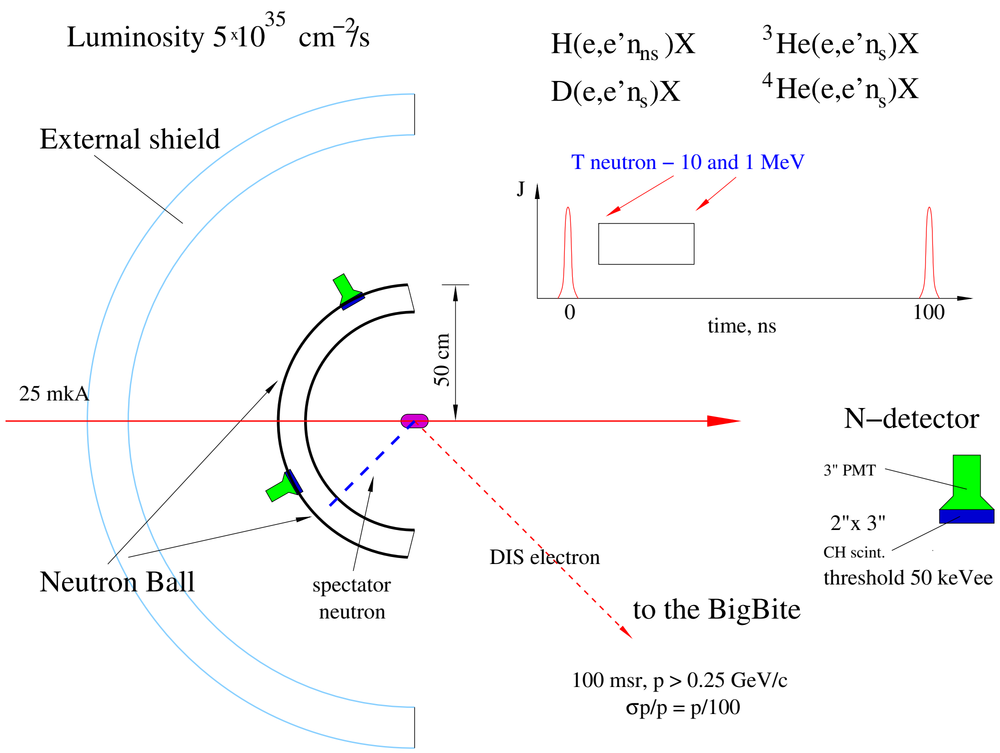
Dashed: PLC suppression model; Dotted: Rescaling model, Dot-dashed: nuclear binding model

- Need to control FSI and dependence on the deuteron wave function.
- FSI are minimized for small P_T^s

  ◇ need to detect slow recoil neutrons at extreme backward angles.
- Deuteron is the best nucleus: re-scattering effects at large x small compared to heavier nuclei.
- Variation in FSI and dependence on the deuteron wave function are expected to be minimal with changing x
- Thus, data on a grid of α_s and x would help eliminate these systematics
- For example the ratio $F_{2,p}^{eff}(x)/F_{2,p}^{eff}(x = 0.2)$ would cancel dependence on deuteron wave function.

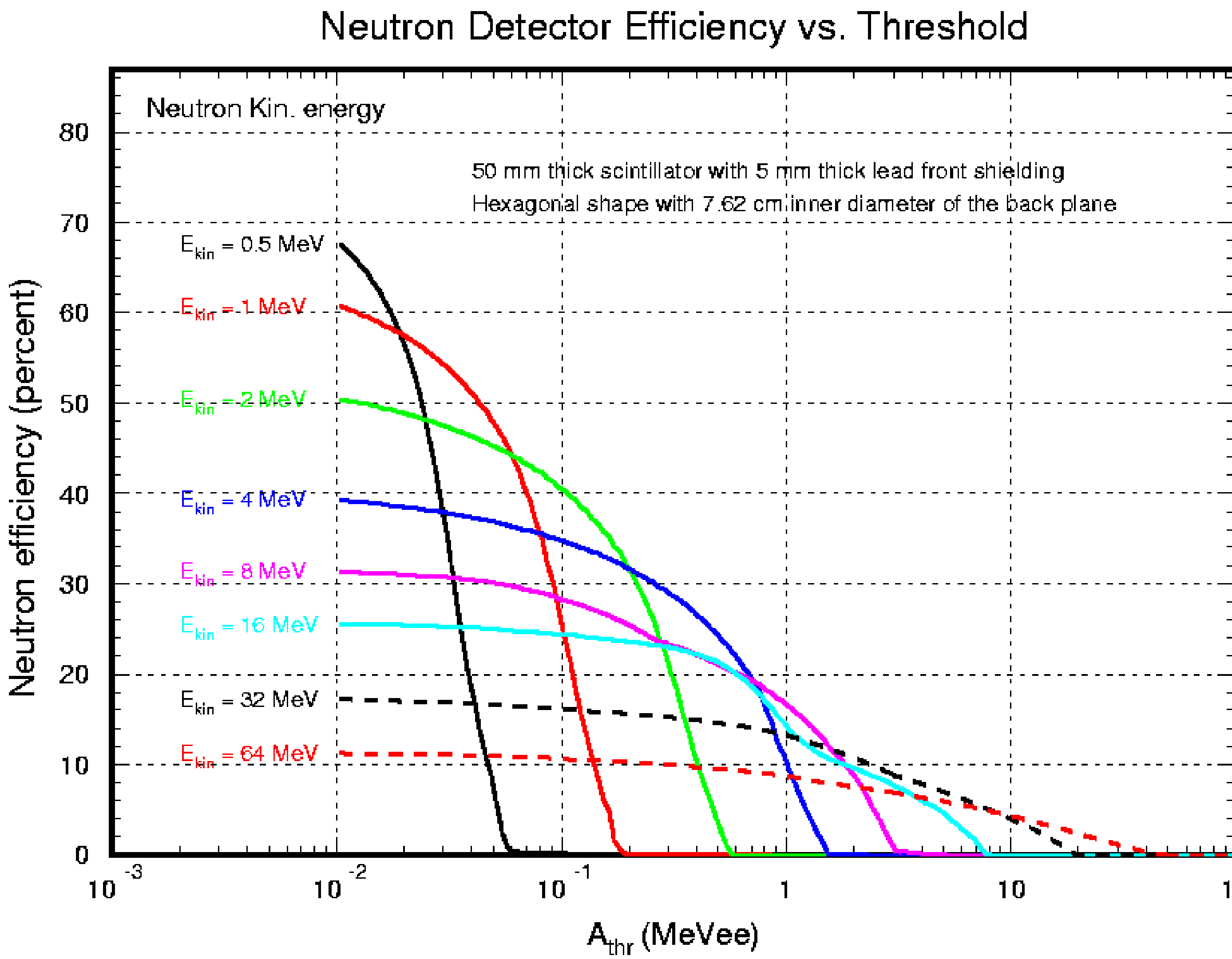
Proposed Experiment

- Measure $\sigma(D(e,e',N)X)/\sigma(p(e,e')X)$ in the DIS region over a grid of x and α_s.
- Use BigBite for the electron
- Use a combination of low energy neutron detector and the Gen neutron detector for the recoil neutron.
- Forming the ratio: $F_{2,p}^{eff}(x)/F_{2,p}^{eff}(x=0.2)$: divides out neutron detection efficiency.



Recoil neutron detection

Preliminary MC results for neutron efficiency by P. Degterenko.



Recoil neutron detection

- Use 100-150 ns beam structure.
- At projected luminosity maximum pulse beam current will not exceed standard CEBAF operation parameters even with a target as thin as 0.1 g/cm^2.
- Such thin target could be useful for reduction of the soft photons production in the target.
- Flight path ~ 50 cm: The soft neutron will be detected about 10-15 ns after the photons and high energy particles pass through the counters.
- These will occupy less then 10% of counters. The rest will be ready to detect soft neutron in the time window where only slow particles could come.
- Soft protons will stop in 5 mm lead shield in front of the neutron counters.

σ to F_2

$$F_2(x,Q^2) = \left[\frac{d^2\sigma/d\Omega dE'}{(d\sigma/d\Omega)_{Mott}}\right]\left[\frac{\nu\epsilon(1+R(x,Q^2))}{1+\epsilon R(x,Q^2)}\right]$$

- $R(x,Q^2)$ from Whitlow parametrization: available with good precision in the kinematic region we need.
- Whitlow *et al.* showed that $R_D = R_p$ with high precision:
- What we are interested is the point-to-point change in F_2 with x and α_s
- Will form ratios: $F_{2,p}^{eff}(x=0.2)/F_{2,p}(x=0.2)$: and $F_{2,p}^{eff}(x)/F_{2,p}^{eff}(x=0.2)$: this divides out most systematic issues:
  - neutron detection efficiency
  - deuteron wave function dependence
  - overall uncertainty due to $R(x,Q^2)$
- If needed we can check dependence of $R(x,Q^2)$ on α_s with an L/T separation up to $x < 0.45$ in another 100 hours

Kinematics

- 6 GeV beam
- Final electron detected on Bigbite at 35°:
  $0.5 < E' < 2.1$ GeV.
- Bigbite solid angle 0.1 sr.
- Kinematic cuts used to keep only $Q^2 > 1$ GeV^2 and $W > 2$ GeV. Resonance region is also available at no extra cost.
- Luminosity 5×10^{35}
- Neutron detector solid angle 4 sr.
- Neutron detection efficiency 30%
- Neutron momentum range: 70 MeV/c - 500 MeV/c.

Projected uncertainties for 300 h of beam

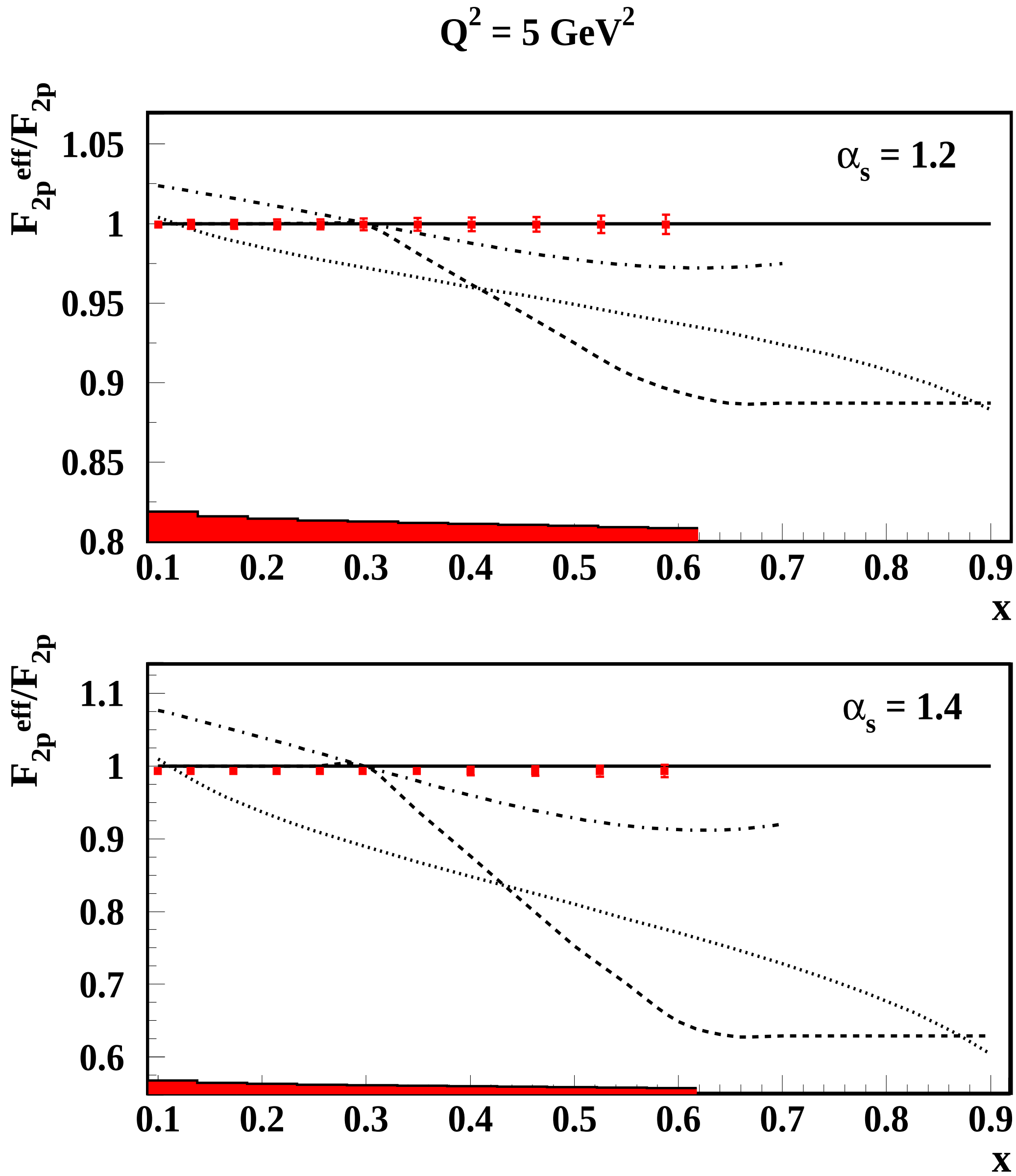
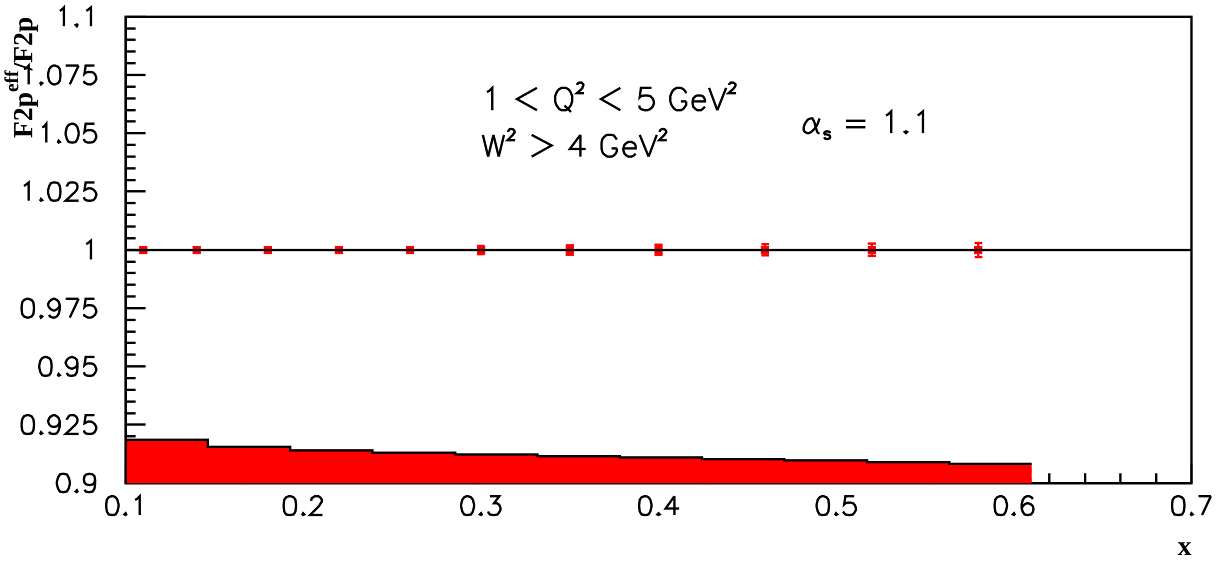


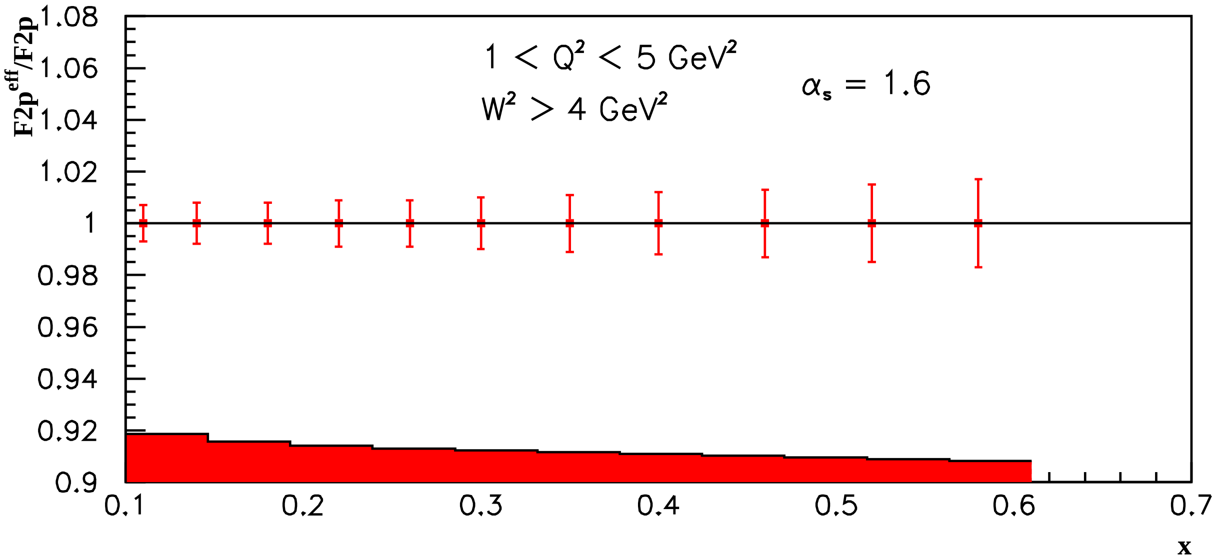
Fig.5

Theory curves from: Melnitchouk *et al.*, evaluated at $Q^2 = 5$ GeV^2 : Dashed: PLC suppression model; Dotted: Rescaling model, Dot-dashed: nuclear binding model.

Data estimated for 300 hours of beam, $1 < Q^2 < 5$ GeV^2. The error bands show the systematic uncertainty in F_2 due to uncertainty in $R(x, Q^2)$ from Whitlow parametrization.

Projected uncertainties for 300 h of beam





Conclusion

- A precision measurement of neutron Tagged F_2^p off Deuteron (D(e,e′,N)X) as a function of recoil neutron momentum can be used to study the origin of EMC effect.
- This measurement can be done in Hall A in about 300 hours.

We would like to thank Wally Melnitchouk and Pavel Degtiarenko for their help in pareparing this proposal.