The APS Council and the DNP have endorsed the establishment of the

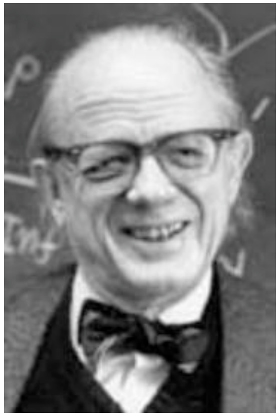
Herman Feshbach Prize in Nuclear Physics

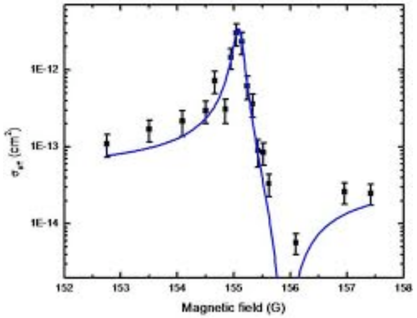
Purpose: To recognize and encourage outstanding research in theoretical nuclear physics. The prize will consist of $10,000 and a certificate citing the contributions made by the recipient. The prize will be presented biannually or annually.

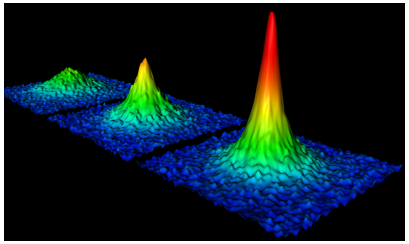
Herman Feshbach was a dominant force in Nuclear Physics for many years. The establishment of this prize depends entirely on the contributions of institutions, corporations and individuals associated with Nuclear Physics. So far, significant contributions have been made by MIT, the DNP, ORNL/U.Tenn, JSA/SURA, BSA, Elsevier Publishing, TUNL, TRIUMF, MSU, and a number of individuals. More than $150,000 has been raised, primarily through institutional contributions. **It is very important that physicists make contributions to carry the endowment over the $200,000 mark, so that the Prize will be eligible to be awarded annually.** Please help us reach that goal by making a contribution. Go online at http://www.aps.org/ Look for the support banner and click APS member (membership number needed) and look down the list of causes.

If you have any questions, please contact G. A. (Jerry) Miller UW, <miller@uw.edu>.

If annual- number of experimentalists winning Bonner prize goes up by >50%







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We are at 90%, $25, $50 matters

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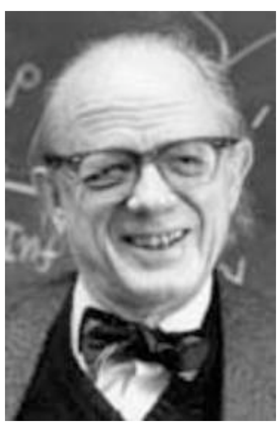
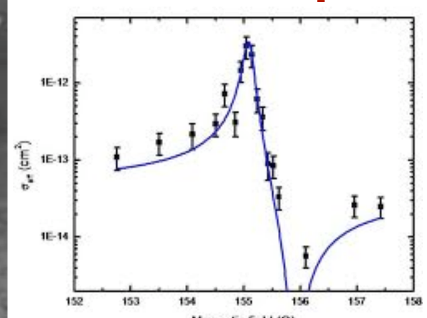
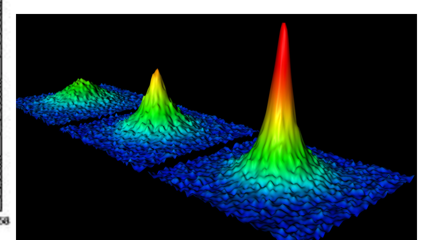






Theoretical overview of the EMC Effect

G. A. Miller, U. W. Seattle

Theoretical overview of the EMC Effect

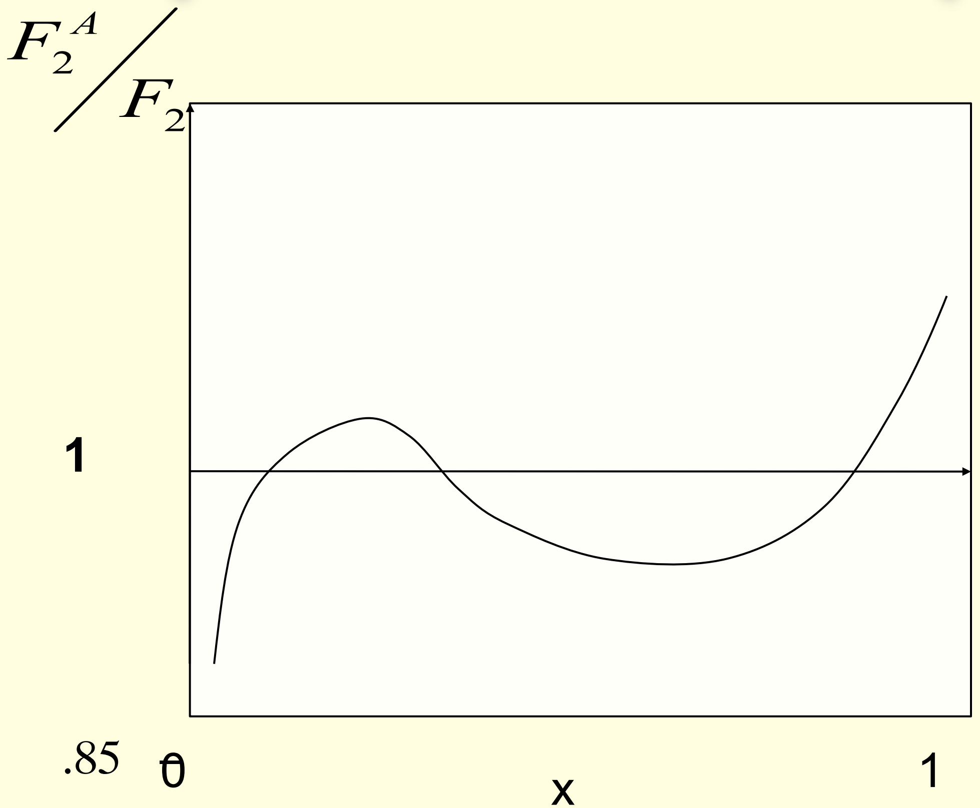
G. A. Miller, U. W. Seattle

The EMC effect was a surprise!
Q^2 =100 GeV^2
1/Q << internucleon spacing

The nucleus matters in Deep Inel Scatt

but not much, 10-15%

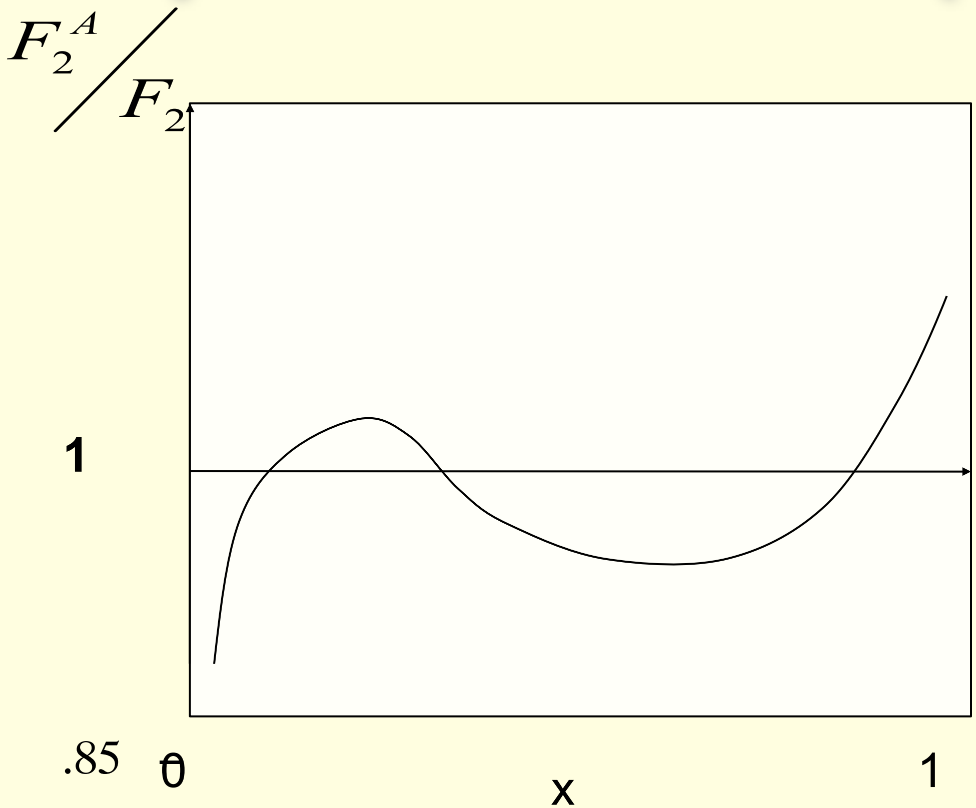
Deep Inelastic Scattering Experiments EMC('82),SLAC,NMC



Nucleon structure is modified: valence quark momentum depleted, sea or gluon enhanced. **How do quarks work in a nucleus?**

BUT EFFECTS ARE SMALL ~10%

Deep Inelastic Scattering Experiments EMC('82),SLAC,NMC



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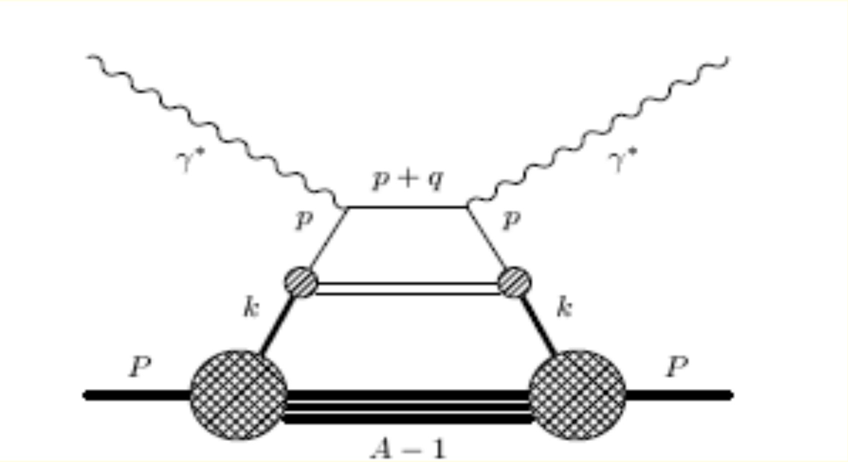
BUT EFFECTS ARE SMALL ~10%

EMC – "Everyone's Model is Cool (1985)

One thing I learned since ‘85

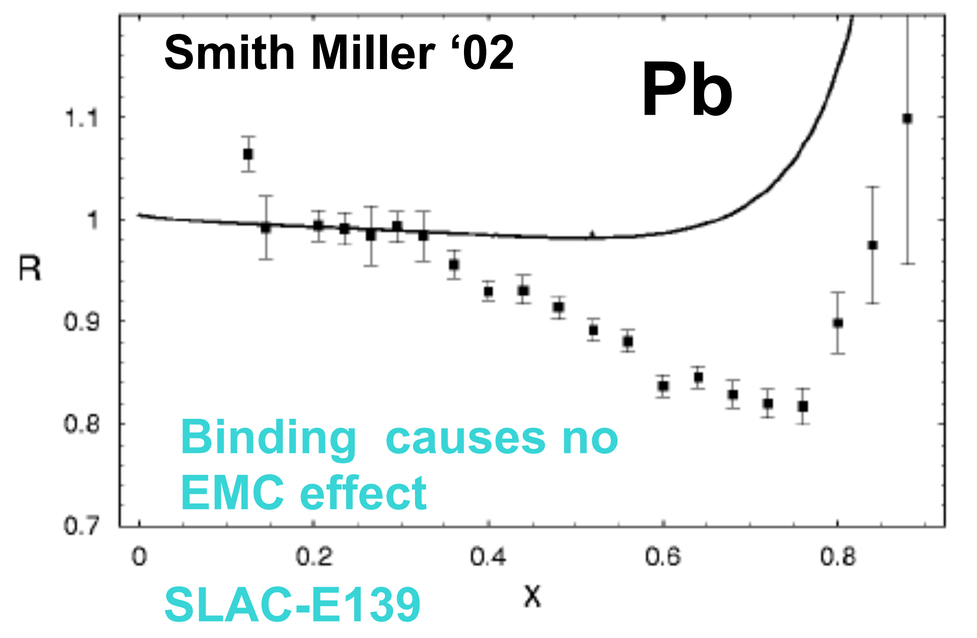
- One model is not cool

Deep Inelastic scattering from nuclei-nucleons only free structure function



$$\frac{F_{2A}(x_A)}{A} = \int_{x_A}^{A} dy f_N(y) F_{2N}(x_A/y)$$

$y = A\, k^+/P^+$



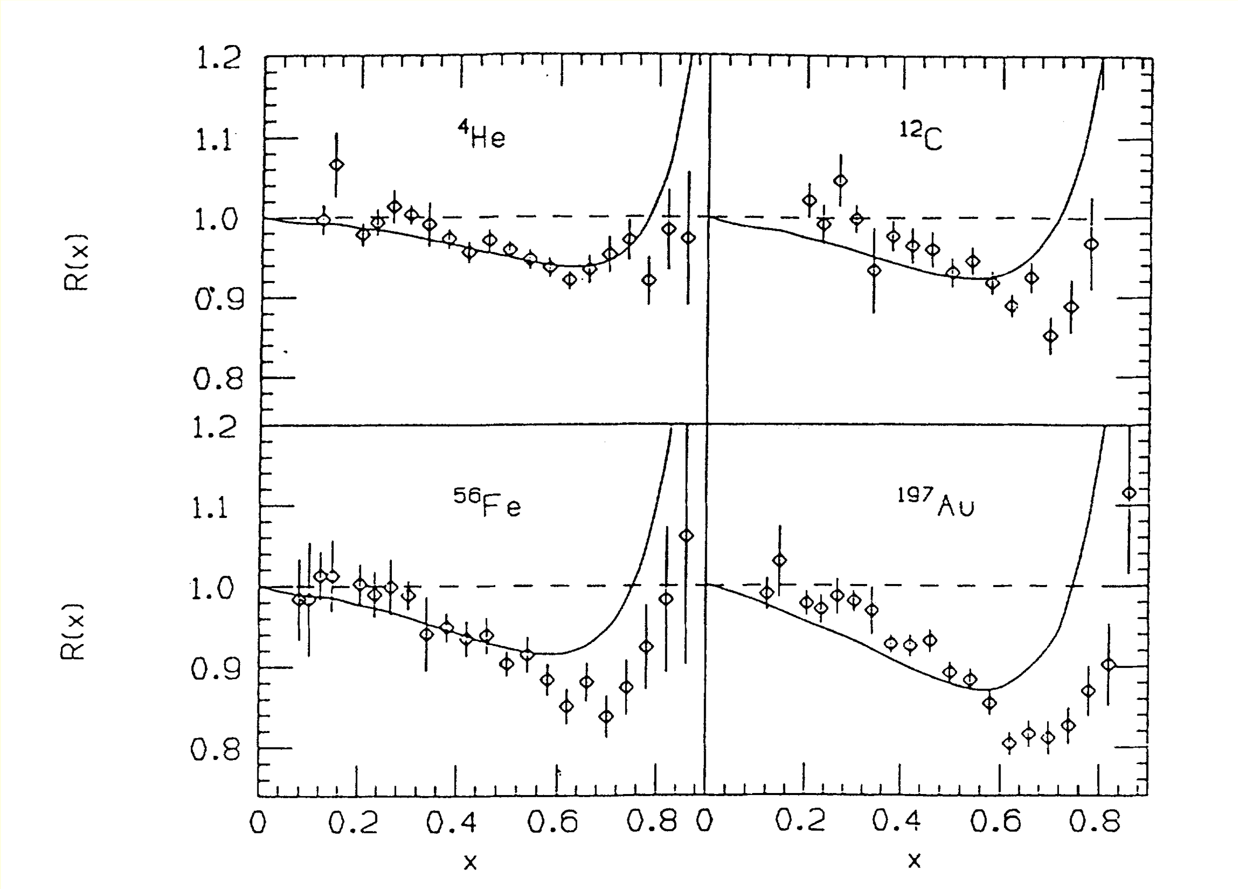
Mean field models

- Hugenholz van Hove theorem nuclear stability implies (in rest frame) $P^+ = P^- = M_A$
- $P^+ = A(M_N - 8\text{ MeV})$
- average nucleon p^+

$p^+ = M_N - 8$ MeV, y → 1

$F_{2A}/A \sim F_{2N}$ no EMC effect

Correlations matter!



No medium modifications

Claudio, Simonetta PR 44, R1269

Dieperink and Miller, Phys.Rev. C44 (1991) 866

Mark Lonya arXiv:1203.5278

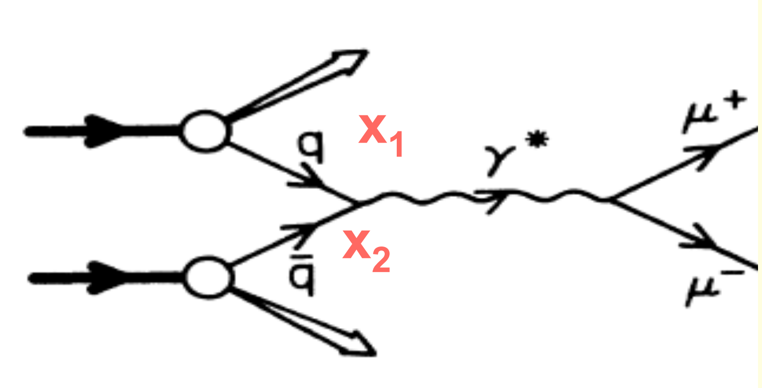
Nucleons and pions

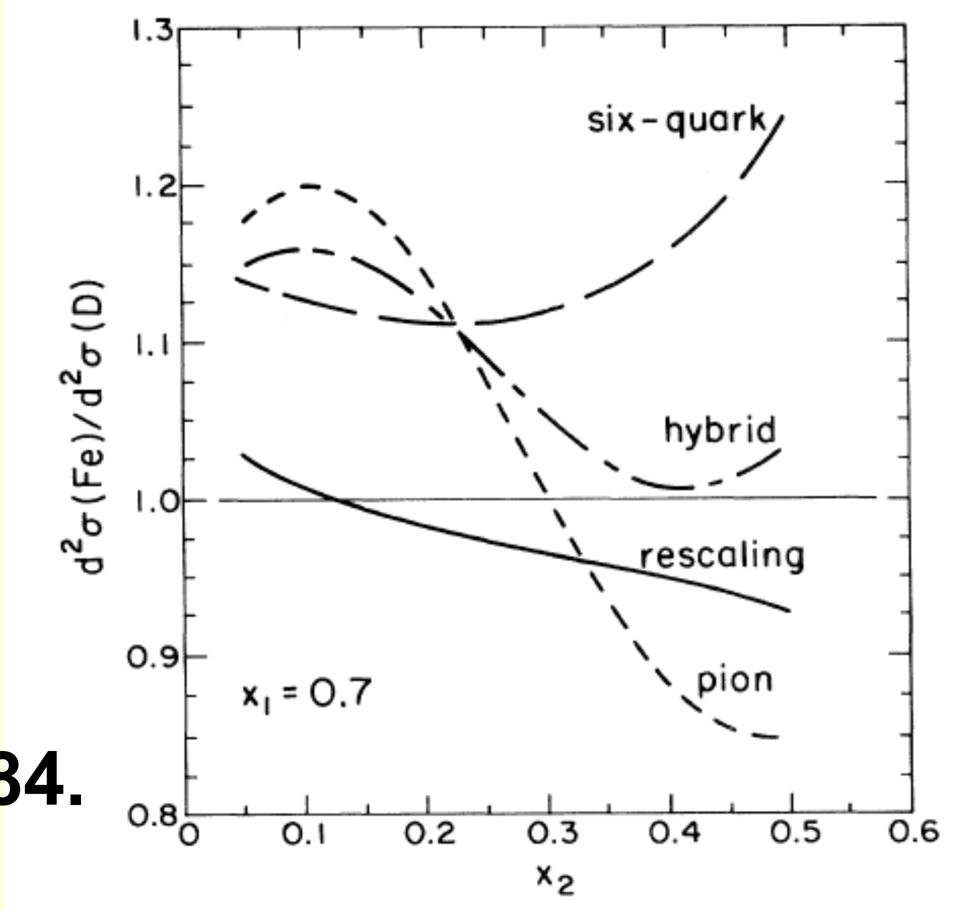
$P_A^+ = P_N^+ + P_\pi^+ = M_A$

$P_\pi^+ / M_A = .04$, explain EMC

try Drell-Yan, **Bickerstaff, Birse, Miller 84**

proton(x_1) nucleus(x_2)





Phys.Rev.D33:3228,1986

Phys.Rev.Lett.53:2532,1984.

Nucleons and pions

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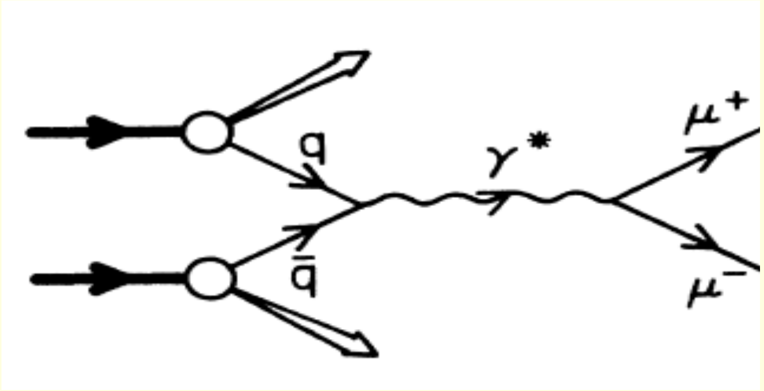
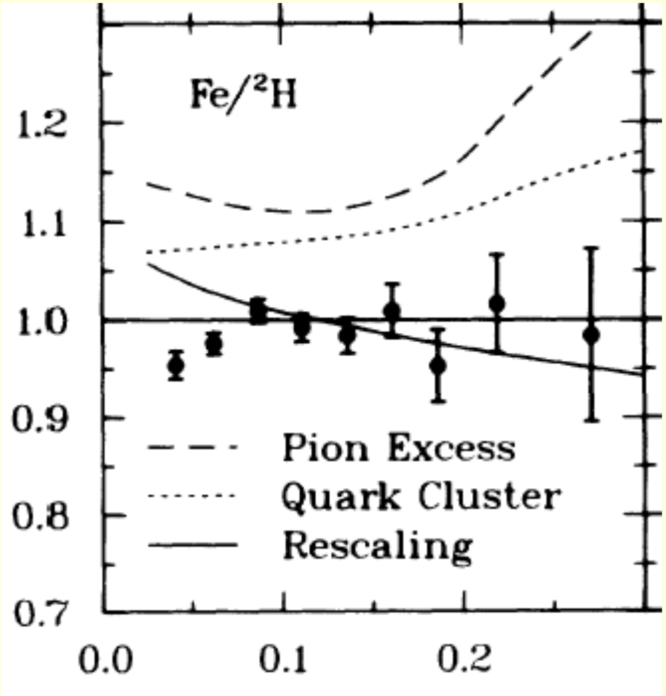
Drell-Yan, E772



No one's model is cool



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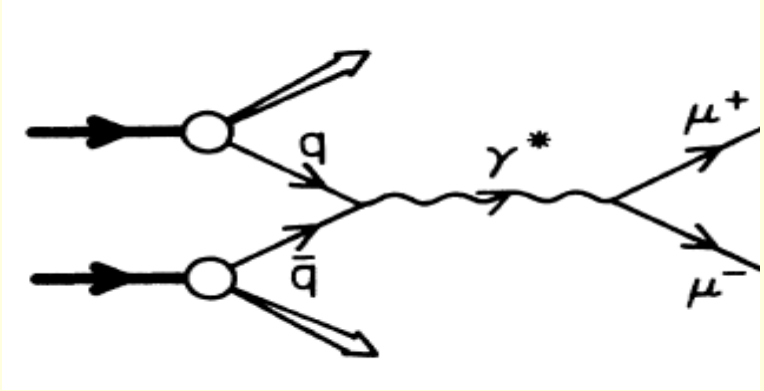

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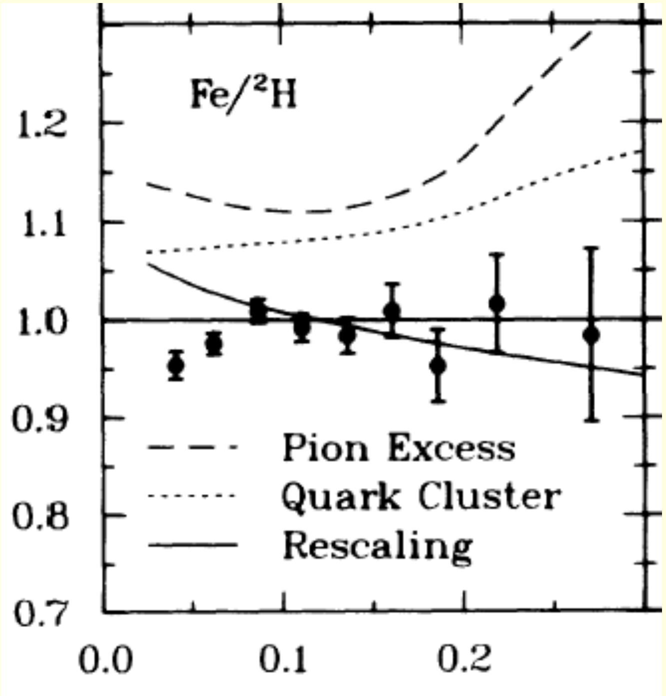

π fails

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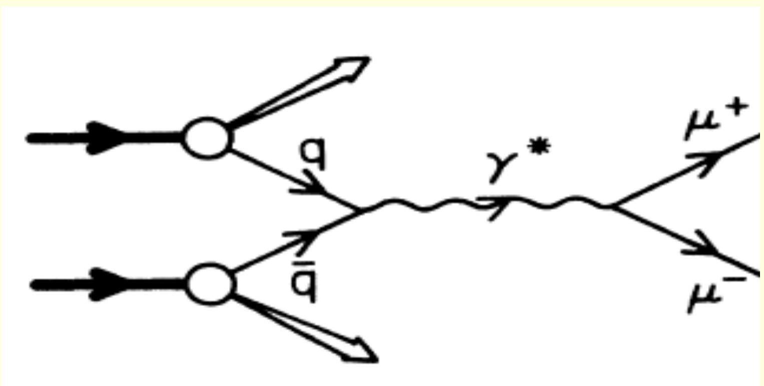

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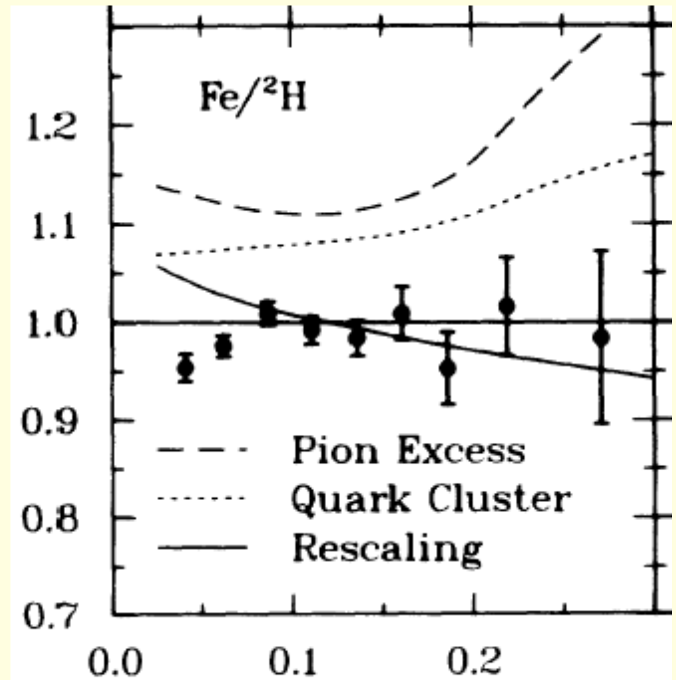


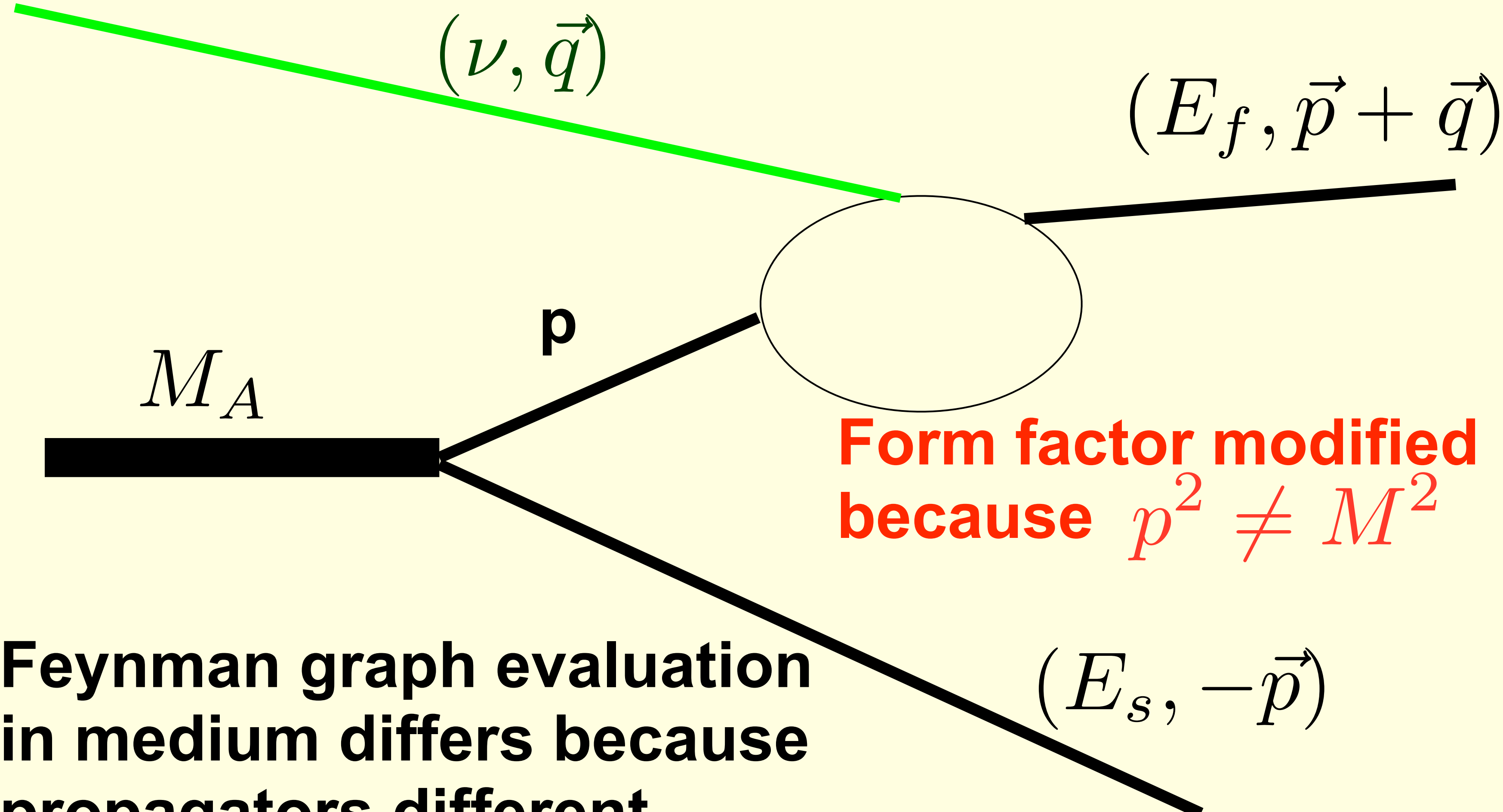
π fails

Bertsch, Frankfurt, Strikman "crisis in nuclear theory" conventional physics does not work

Single nucleon modification by nuclei

- Does it make sense? It is inevitable.
- Neutron in nucleus is modified, lifetime changed from 15 minutes to forever
- Binding changes energy denominator, suppresses $|pe\nu\rangle$ component
- Change energy denominator change wave fun
- Also Strong fields polarize nucleons- analog of Stark effect

Inevitability of medium modifications-(e,e'p)



Form factor modified because $p^2 \neq M^2$

Feynman graph evaluation in medium differs because propagators different.

Simonetta's talk

Medium Modification Models

- **chiral restoration:** $m_q \to m_q - g\sigma$
- Implement via bag model, Chiral instanton model, or NJL Thomas, Cloet, Miller Smith
- **Modified energy denominator –PLC suppression of Frankfurt Strikman**
- **Enhancement of blob-like configurations, QCD Stark color neutrality nucleon-nucleon interaction depends on** $\sum_q (r_q - R_N)^2$
-

PLC suppression of FS

Energy denominator (virtuality) two-component

$$|\phi\rangle = |\phi_1\rangle + \frac{1}{E_2 - E_1} V_{21} |\phi_2\rangle$$

FS PLC

nucleon bound by potential U

$$|\psi\rangle = |\phi_1\rangle + \frac{1}{E_2 - E_1 - U} V_{21} |\phi_2\rangle,$$ U suppresses (2)

$$|\psi\rangle = |\phi\rangle + U/(E_2 - E_1) V_{21} |\phi_2\rangle$$

Denominator effect

U acts on $|\phi_1\rangle$ **so another way to formulate is enhancement of BLC**

Enhancement of BLC-Frank, Jennings, Miller '95

Free nucleon $|\phi\rangle = |\phi_1\rangle + \frac{1}{E_2 - E_1} V_{21}|\phi_2\rangle, \; |\phi_2\rangle$ is PLC

In medium $|\phi\rangle \rightarrow |\Psi\rangle$

U acts on $|\phi_1\rangle$

in nucleus $H = H_N + \frac{P^2}{2M_N} + U$

$|\Psi\rangle = |\phi\rangle + \frac{1}{E-H} \Lambda_1 U |\phi_1\rangle$

$\Lambda_1 U |\phi_1\rangle$ is a Blob Like Configuration

Wave function must be normalized

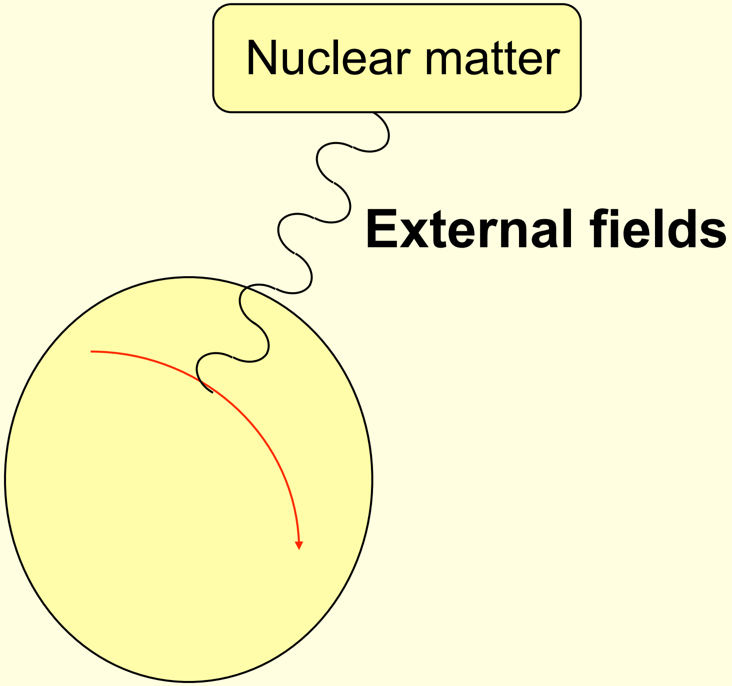
enhancement of BLC suppresses PLC

same result for high x DIS, other predictions differ

General to particular, Requirements -Goals

- **Model the free distributions**
- **Good support**
- **Consistency with nuclear properties**
- **Describe deep inelastic and di-muon production data- valence plus sea**
- **Predict new phenomena**
- **New challenge- describe detailed A dependence**

Nucleon in medium- 5 models



1. QMC- quarks in nucleons (MIT bag) exchange mesons with nuclear medium, quark mass
2. Use NJL instead of bag Cloét
3. CQSM- quarks in nucleons (soliton) exchange infinite pairs of pions, vector mesons with nuclear medium, m_q
4. Suppression of point-like-configurations,
5. Enhancement of blob-like configurations polarization

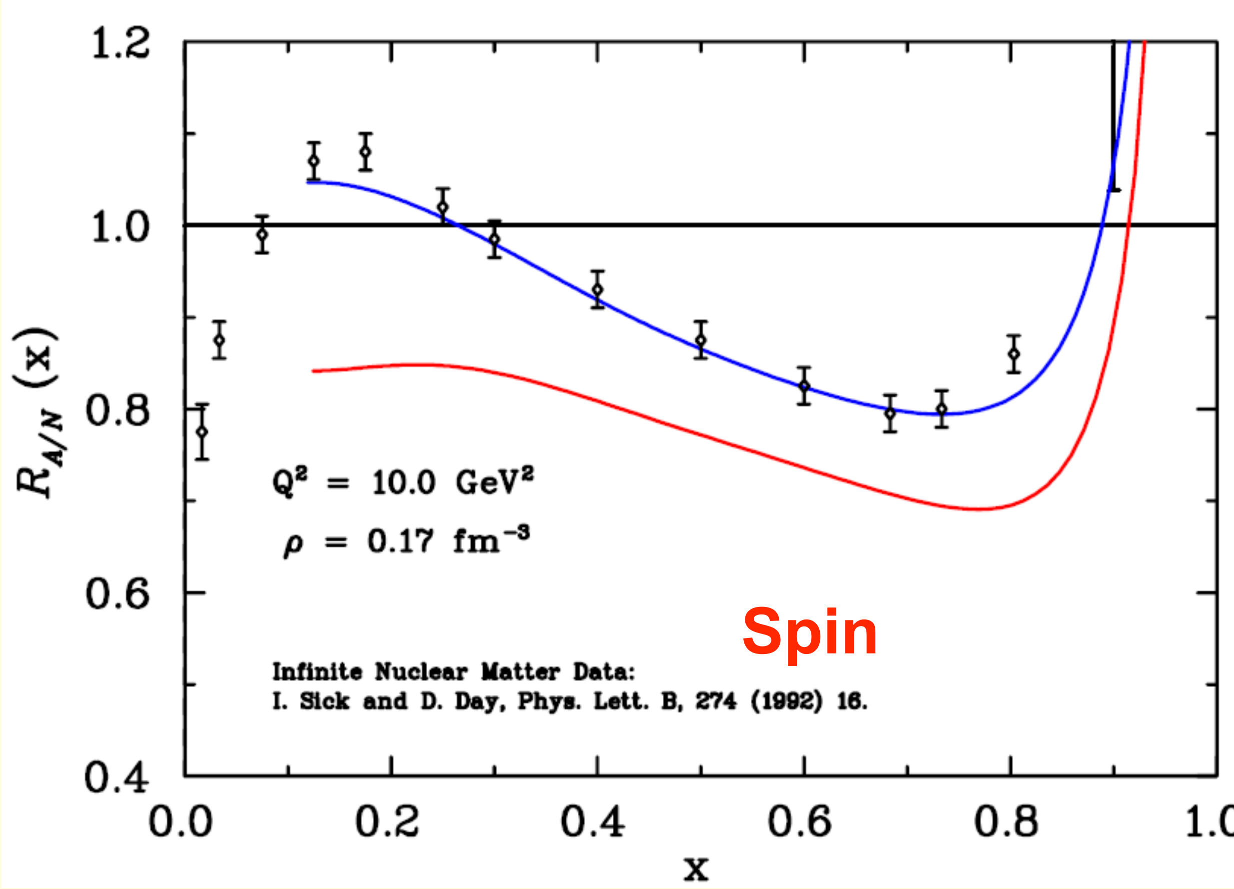
Spin experiments-NJL in medium

- g_{1n} , g_{1p} in nuclei

- other way to enhance EMC?

  ratio of g_1 medium to free

Bentz, Cloet, Thomas



Chiral Quark Soliton Model –

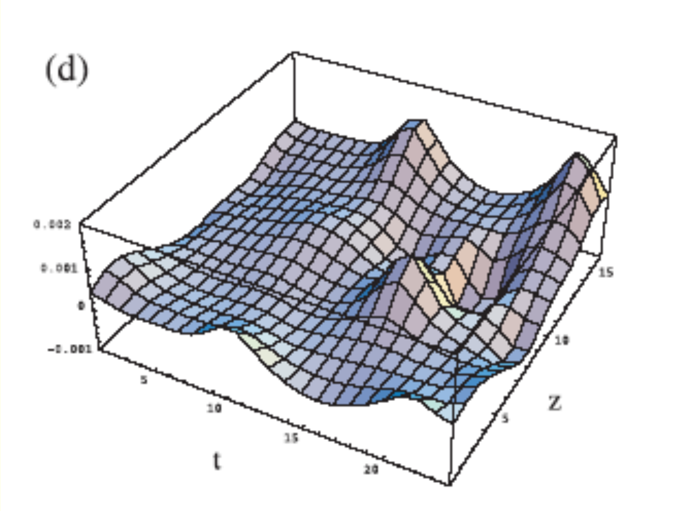
Diakonov, Petrov, Polykov, quarks couple to vacuum instantons

- Vacuum dominated by instantons
- quarks with spontaneously generated masses interact with pions

$$\mathcal{L}_{\text{eff}} = \bar{q}\ \left[i\partial\!\!\!/ - M \exp(i\,\gamma_5\,\pi^A\lambda^A/F_\pi)\right]\ q,$$

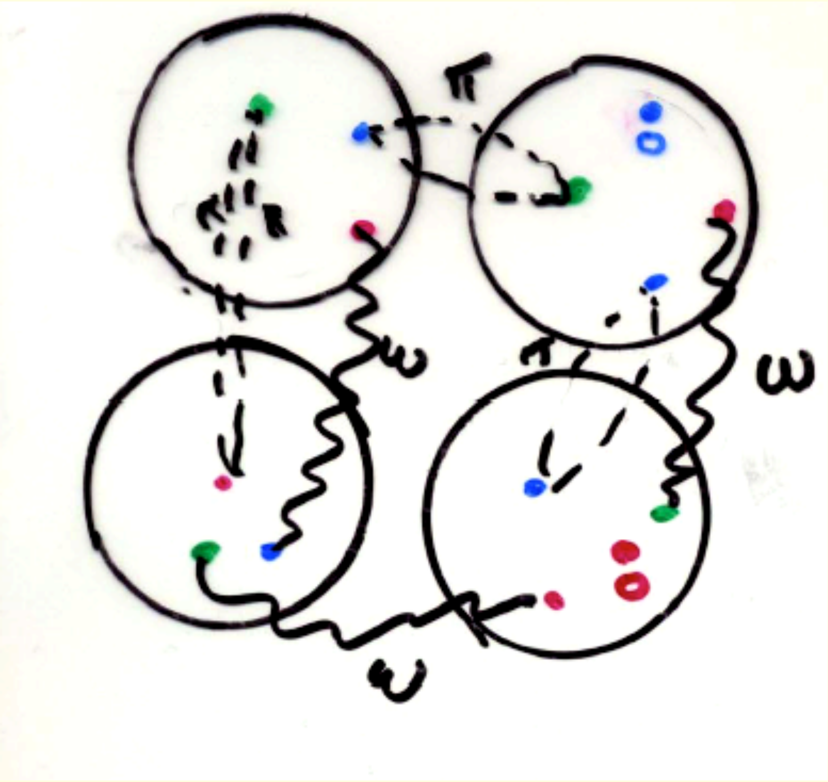
- Nucleon is soliton in pion field
- M=420 MeV
- good nucleon properties, DIS and magnetic moments

Negele et al hep-lat/9810053
spont. chir. symm breaking



Chiral Quark Soliton Model of Nucleus-

Smith, Miller



2 π exchange – attraction

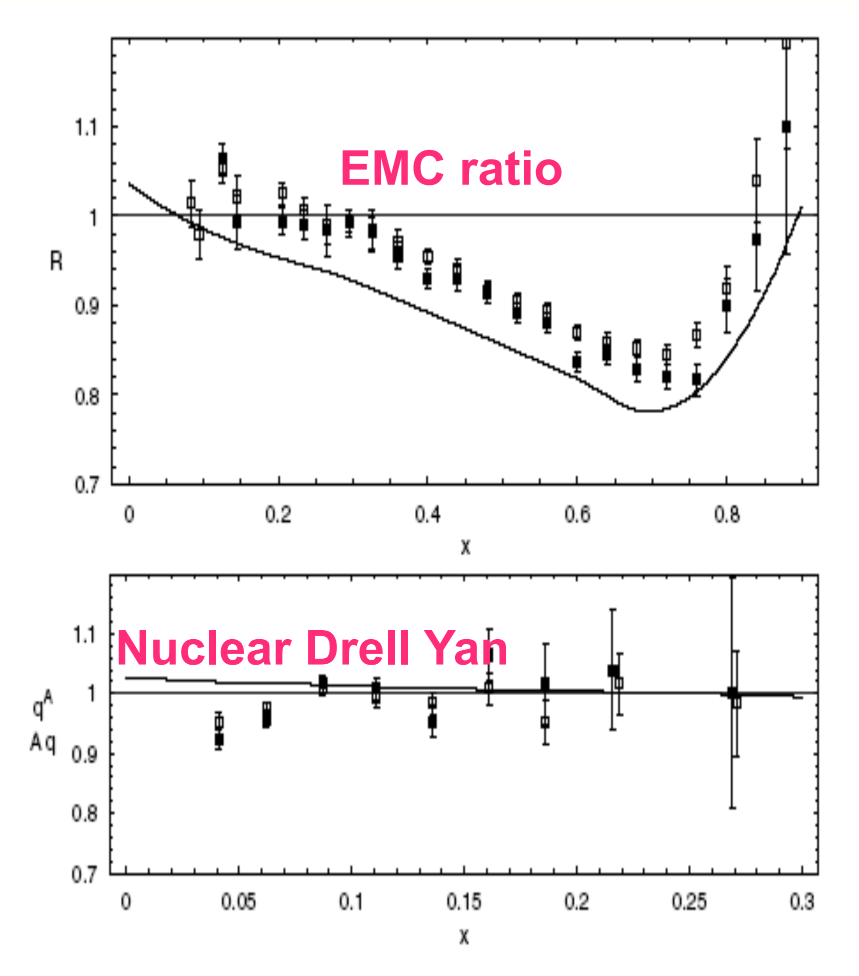
ω (vector meson) exchange - repulsion

Double self consistency

profile function and k_f

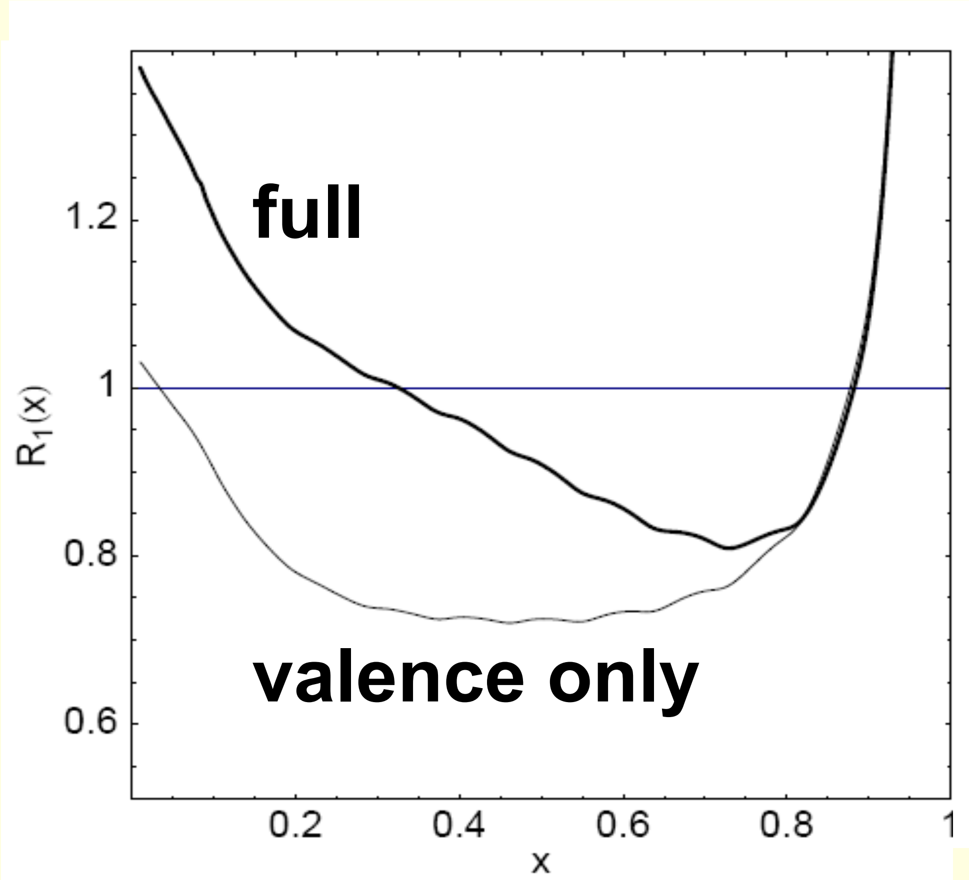
Mean field like

Results Smith & Miller '03,04,05



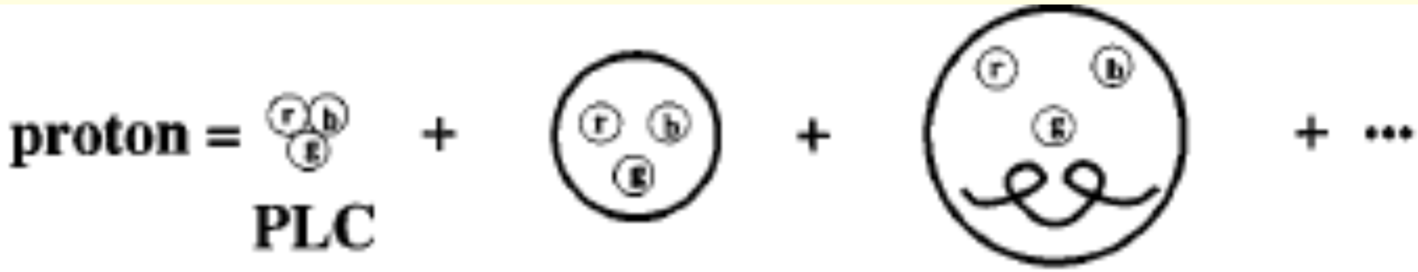
sea is not much modified

g_1 ratio



About same as DIS, not larger

Enhancement of Blob-like Configurations- Frank, Jennings, Miller Phys.Rev. C54 (1996) 920

free 

place in medium:

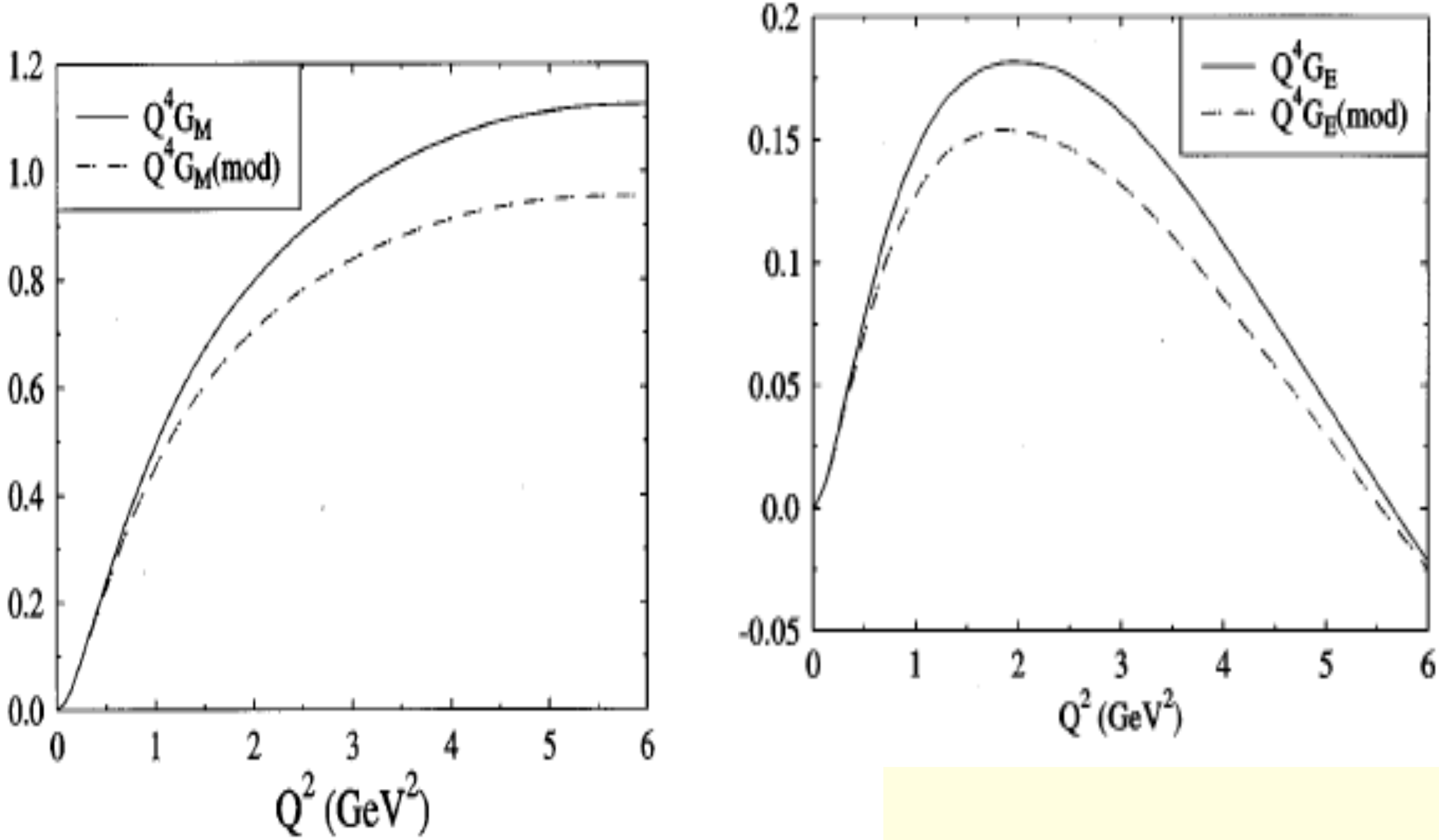
normal size components attracted energy goes down

PLC does not interact- color screening-FS

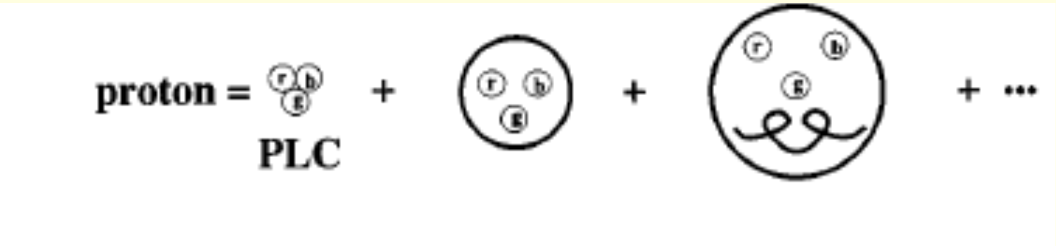
BLC is enhanced

quarks lose momentum in medium

1995 Frank, Jennings, Miller



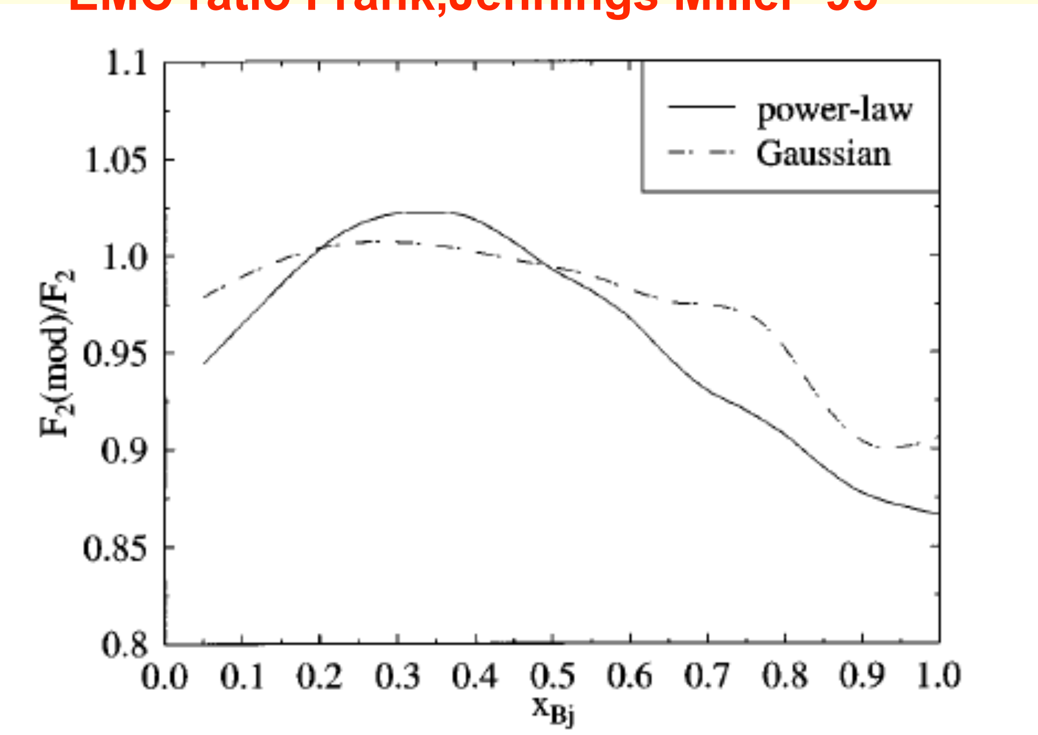
Enhancement of Blob-Like Configurations



FS-PLC has NO int. with medium

energy denominator increased

EMC ratio Frank,Jennings Miller '95



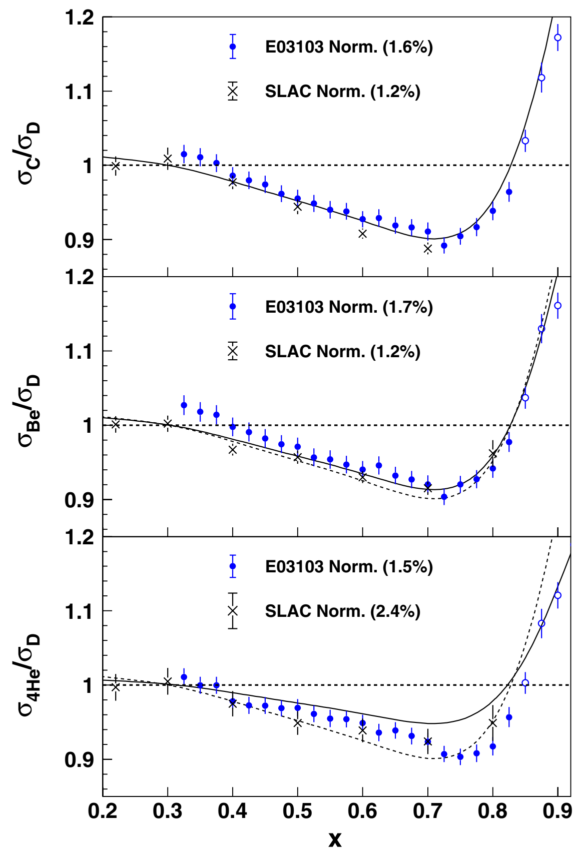
evaluated as QCD Stark, not modified energy denominator

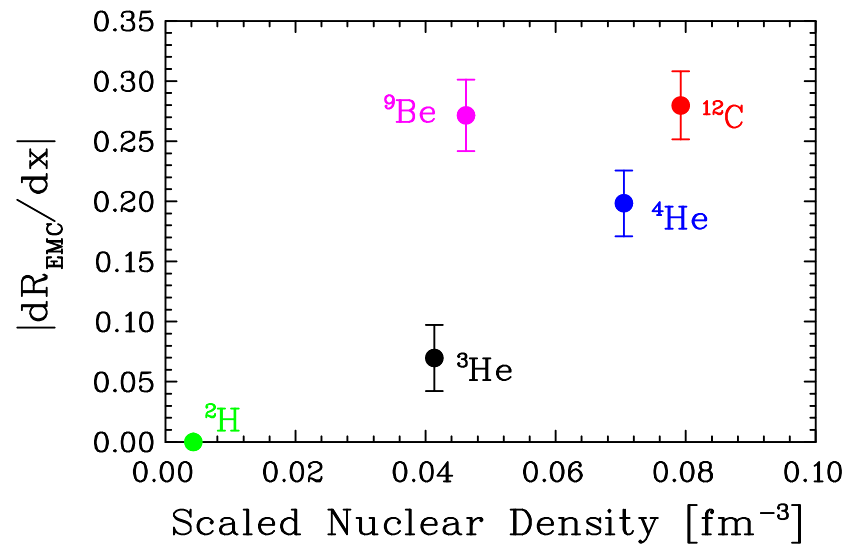
Correlations in the EMC effect

Hen, Higenbotham, Miller, Piasetsky, Weinstein to appear soon

Goal: Test hypothesis that medium modifications of nucleons in a correlated pair are responsible for the EMC effect, also test alternate hypothesis that modification of nucleons caused by mean field give EMC effect

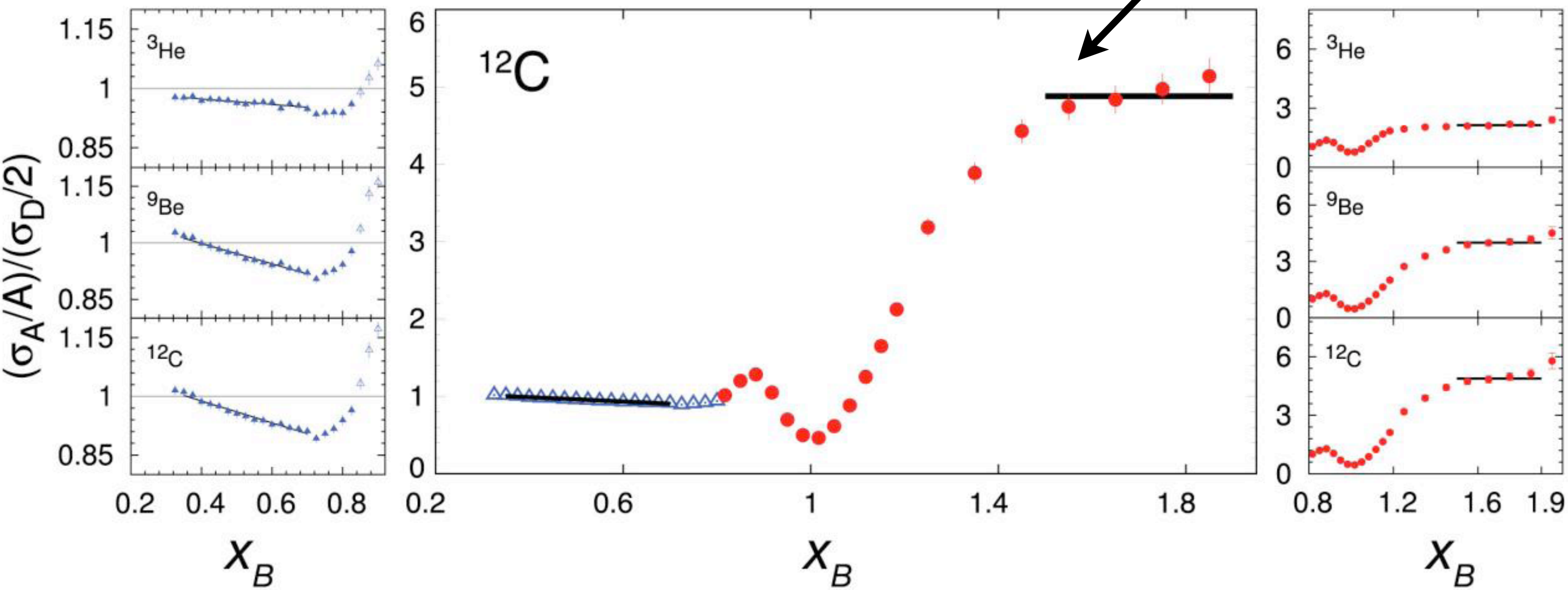
Nuclear dependence of quark distribution depends on local environment, Seely et al PRL 103,202301





e,e' plateau and DIS

Plateau associated with NN correlations a_2

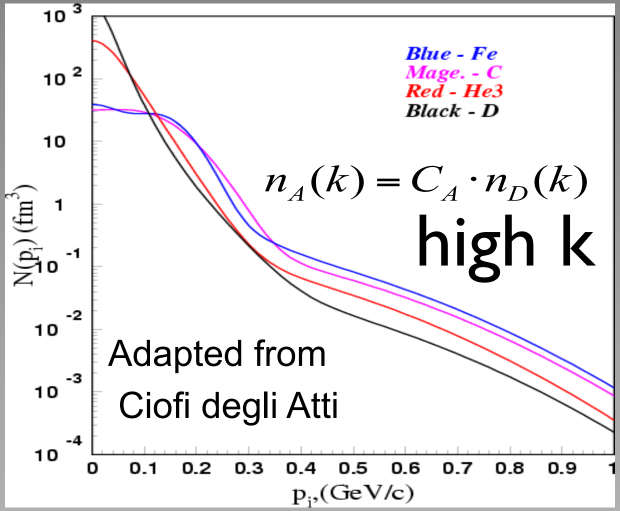


Physics Opportunities with the 12 GeV Upgrade at Jefferson Lab

Jozef Dudek, Rolf Ent, Rouven Essig, Krishna Kumar, Curtis Meyer, Robert McKeown, Zein Eddine Meziani, Gerald A. Miller, Michael Pennington, David Richards *et al.*. Aug 2012. 64 pp.

Published in **Eur.Phys.J. A48 (2012) 187**

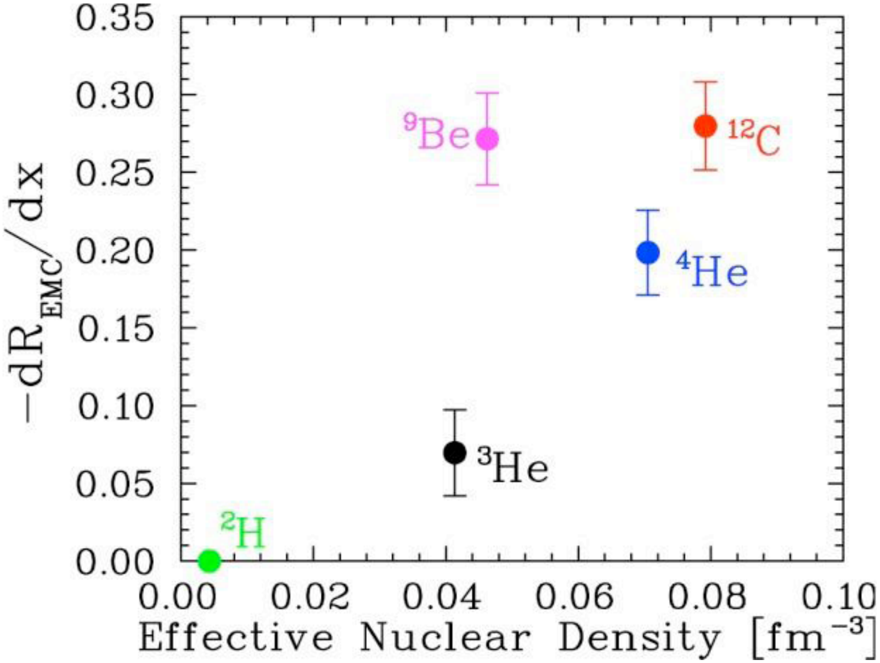
Inclusive A(e,e') measurements

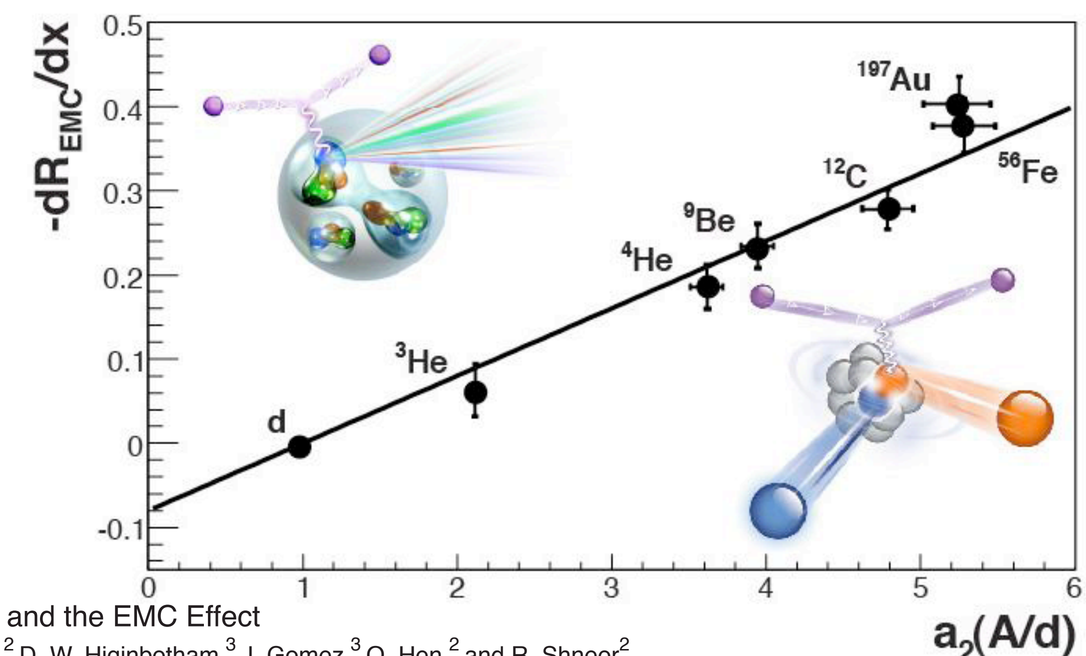


- At high nucleon momentum, distributions are similar in shape for light and heavy nuclei: **SCALING**.

- Short distance two-nucleon relative wave function same in all nuclei .

- **One can get the probability of 2N-SRC in any nucleus, from the scaling factor.**

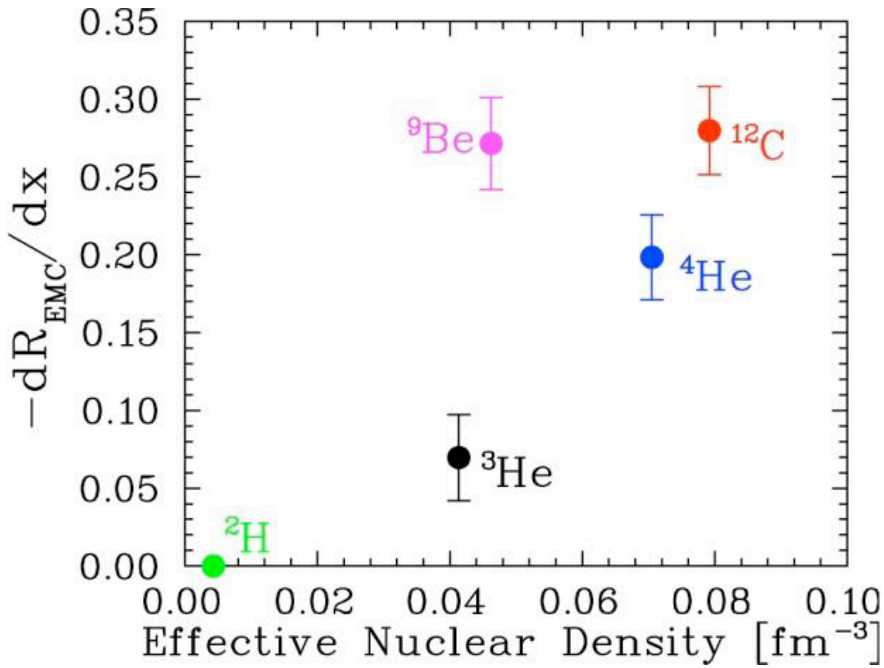




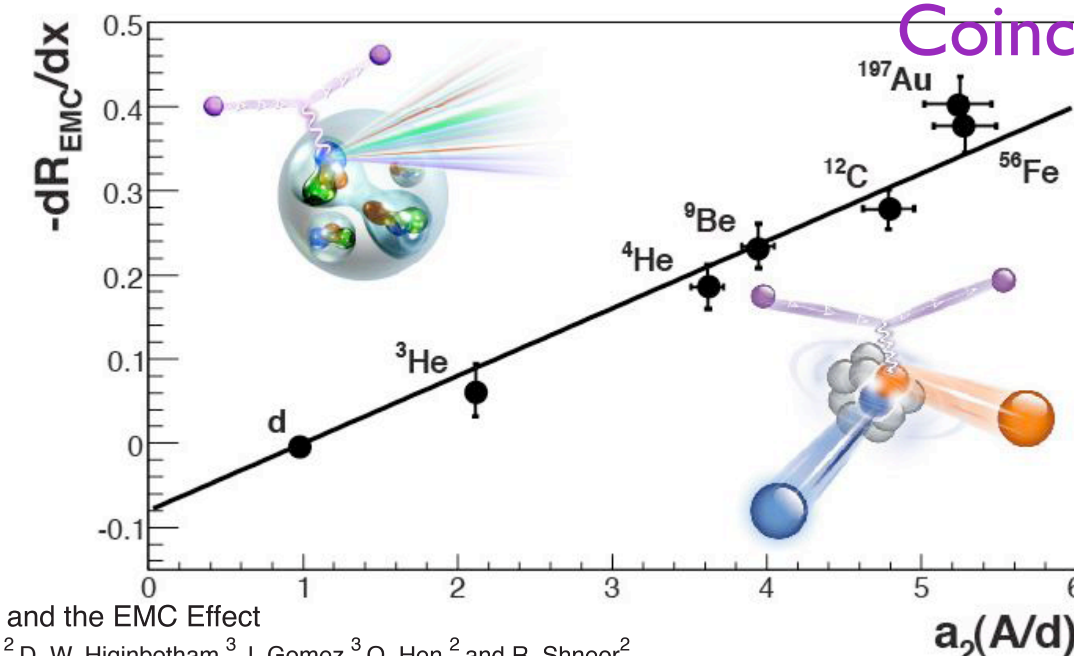
Short Range Correlations and the EMC Effect

L. B. Weinstein,[1,*] E. Piasetzky,[2] D. W. Higinbotham,[3] J. Gomez,[3] O. Hen,[2] and R. Shneor[2]

PRL106,052301



Coincidence or not?



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PRL106,052301

Are nucleons in the SRC modified?

- Need to start with a nuclear model of SRC and compute resulting EMC effect caused by modified structure function
- Will try to do that here
- Strikman & Frankurt: EMC effect depends on two computable integrals, PLB 183, 254 (87)
- Ciofi degli Atti & Simula, PRC53,1689 (96)-nuclear model
- Medium modification due the mean field (previously discussed models) alternate hypothesis

Review Frankfurt Strikman

$$\frac{1}{A}F_{2A}(x,Q^2) = \int_0^A \alpha\rho_A(\alpha)F_{2N}(x/\alpha,Q^2)d\alpha, \alpha \equiv \frac{Ak\cdot q}{p_A\cdot q} \approx \frac{k^0+k^3}{m-\epsilon_A}$$

ϵ_A : binding energy per nucleon, m : nucleon mass

$$\rho_A(\alpha) = \int d^4k P_A(k, E = M_A - k_0)\delta(\alpha - \frac{k^0+k^3}{m_N}),\ P_A(k,E) \equiv \langle A|a_k^\dagger \delta\left(E-H\right)a_k|A\rangle$$

$$n_A(k) = \int dE P_A(k,E)$$

$\rho_A(\alpha)$ narrow about $\alpha = 1$, expand $F_{2N}(x/\alpha)$

$$\frac{1}{A}F_{2A}(x,Q^2) \approx F_{2N}(x,Q^2)I_1 + xF'_{2N}I_2 + [xF'_{2N} + \frac{1}{2}x^2F''_{2N}(x,Q^2)]I_3$$

$$I_1 \equiv \int \rho_A(\alpha)\alpha d\alpha = 1,\ I_2 \equiv \int \rho_A(\alpha)\alpha(1-\alpha)d\alpha,\ I_3 \equiv \int \rho_A(\alpha)\alpha(1-\alpha)^2 d\alpha$$

$$n_A(k) \equiv \langle A|a_k^\dagger a_k|A\rangle,\ I_2 = \int d^3k n_A(k)(\frac{2\epsilon_A}{m} + \frac{A-4}{A-1}\frac{k^2}{6m^2}),\ I_3 == \int d^3k n_A(k)\frac{k^2}{3m^2})$$

Last step uses Koltun sum rule Claudio, Simonetta

Ciofi degli Atti & Simula: spectral function arises from intermediate states below and above the continuum threshold:

$$n_A(k) = n_A^{(0)}(k) + n_A^{(1)}(k)$$

(0): low energy mean field, (1): high energy SRC

$$I_{1,2,3} = I_{1,2,3}^{(0)} + I_{1,2,3}^{(1)}$$

Fe:

$$I_1^{(0)} = 0.80,\ I_1^{(1)} = 0.20,\ I_2^{(0)} = 0.011,\ I_2^{(1)} = 0.009,\ I_3^{(0)} = 0.008,\ I_3^{(1)} = 0.014.$$

Assumption: nucleons in high energy excited state are modified - have different structure function

$$\widetilde{F}_{2N}(x) \neq F_{2N(x)}$$

$$F_{2N} \to I_1^{(0)}(A)F_{2N} + I_1^{(1)}\widetilde{F}_{2N},\ etc.$$

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Assumption: nucleons in high energy excited state are modified - have different structure function

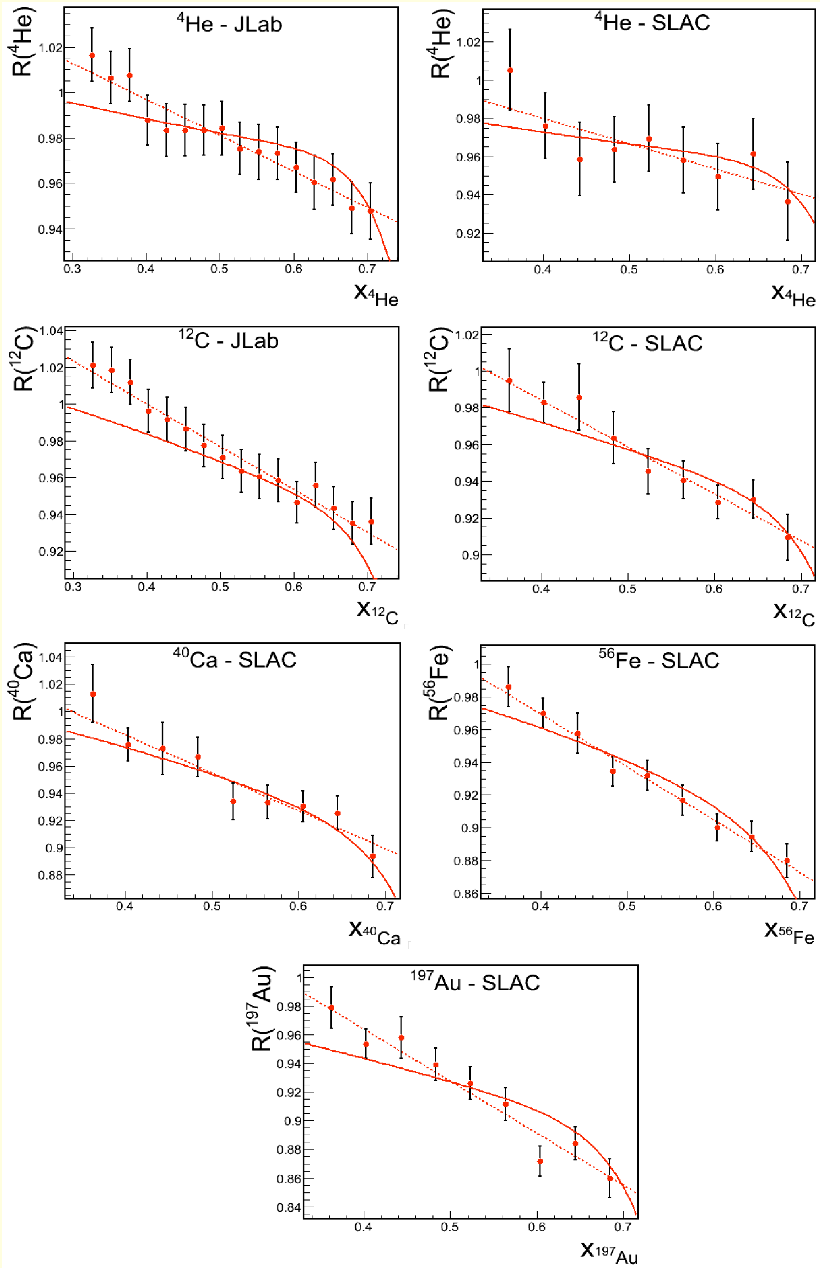
$$\widetilde{F}_{2N}(x) \neq F_{2N(x)}$$

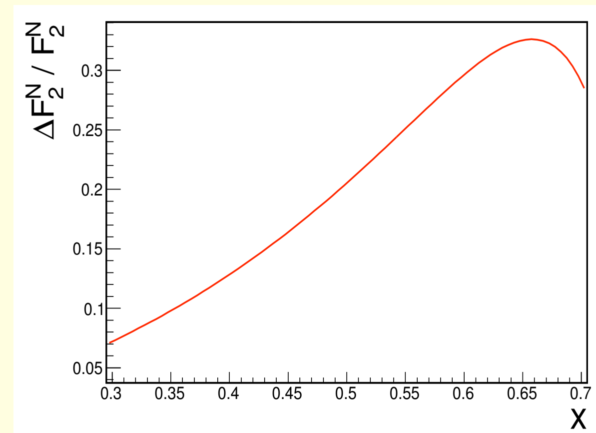
$$F_{2N} \rightarrow I_1^{(0)}(A) F_{2N} + I_1^{(1)} \widetilde{F}_{2N},\ etc.$$

OR $F_{2N} \rightarrow I_1^{(0)}(A)\widetilde{F}_{2N} + I_1^{(1)} F_{2N}$ Mean Field

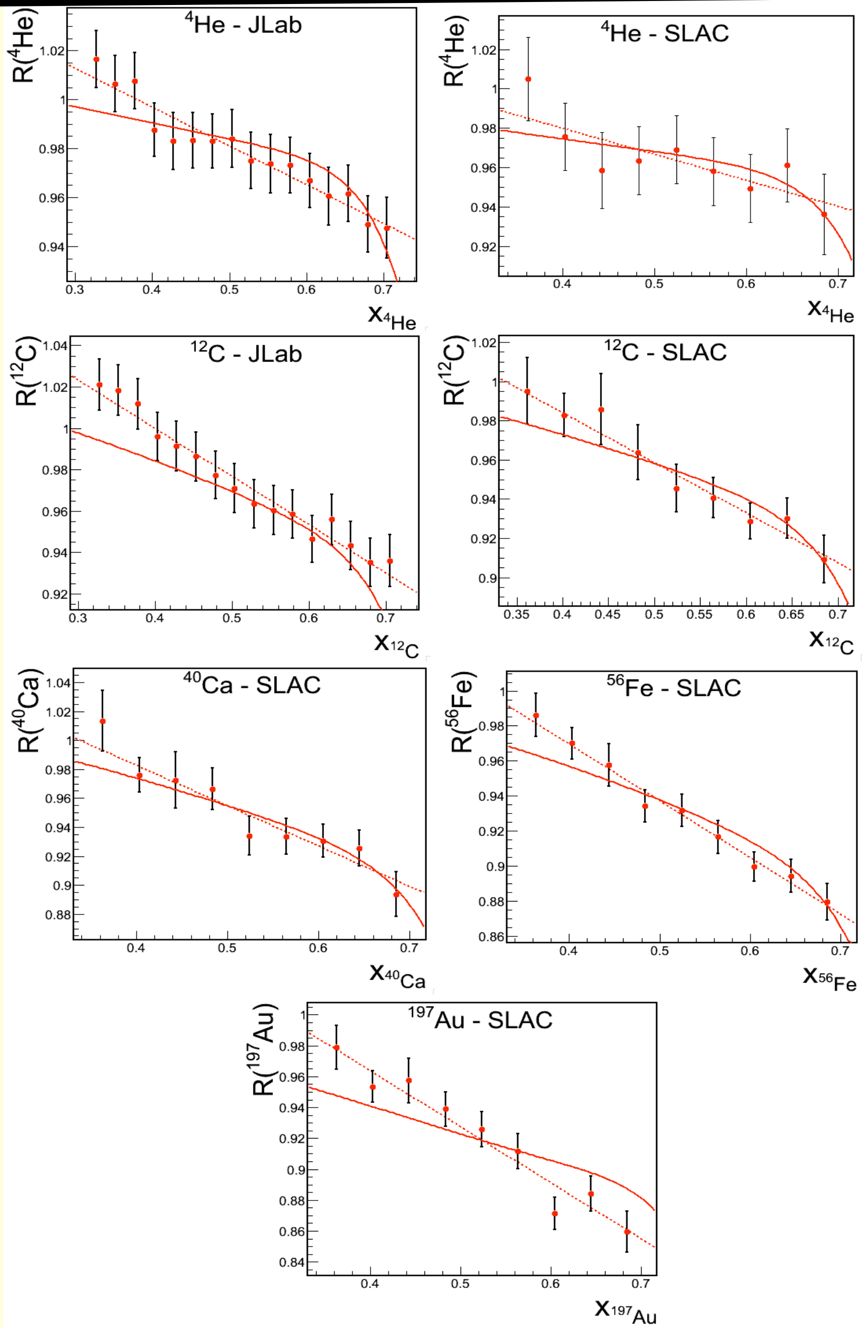
20 O. Hen et al.

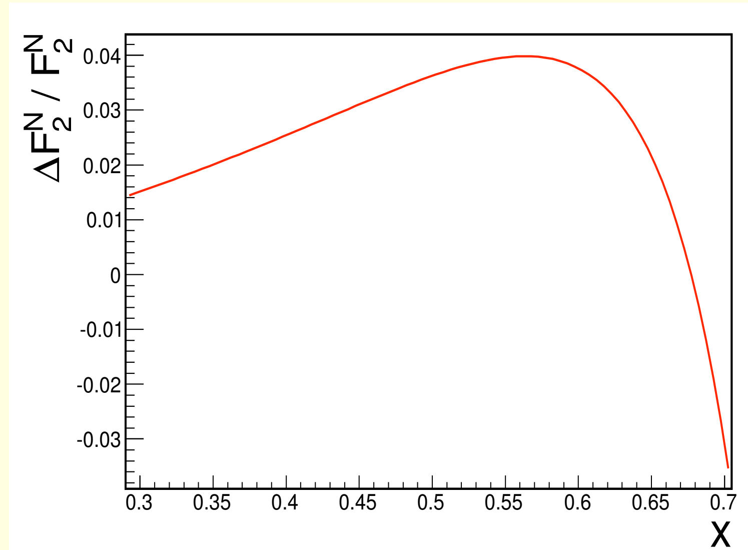
Medium modification in SRC





Medium modification in Mean Field

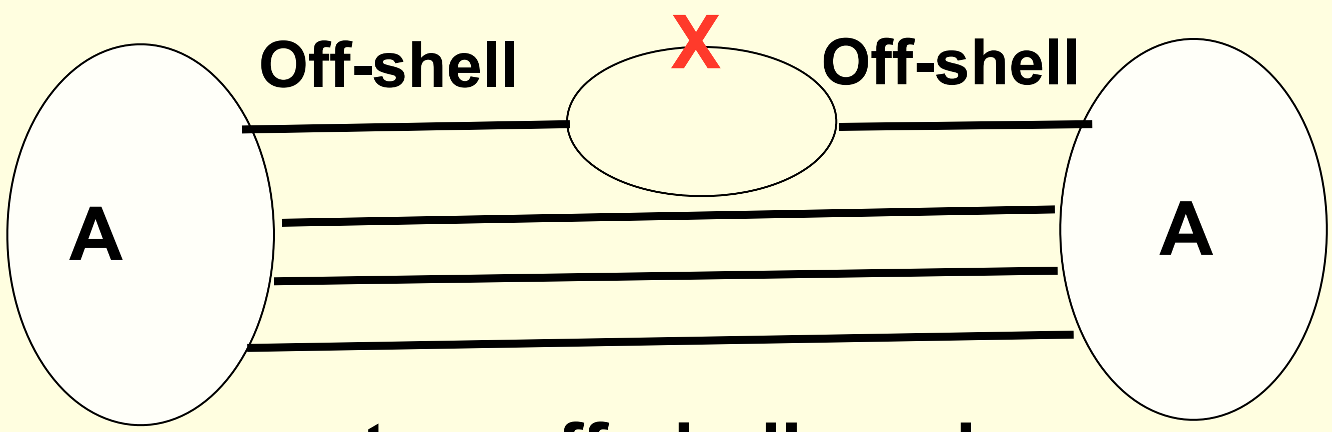




Much smaller

ΔF_2

Other Ways to search for medium modification

- Quasi-elastic scattering
- Quasi-elastic, recoil polarization- G_E/G_M
- DIS on deuteron, detect spectator
- problem- modified nucleon is different for quasi-elastic and deep inelastic
- 

two off-shell nucleons

Summary

- nucleon structure is modified by nucleus
- can't tell if associated with mean field or src
- if mean field -consistency ? how can mean field work if nucleons overlap in space
- better models are needed

- minimum model requirements- EMC, DY, nuclear saturation, A-dependence

$eA \to e' X N$

- also predict new phenomena
- new experiments Jlab and others to find out how quarks work in a nucleus