EMC Effect Overview

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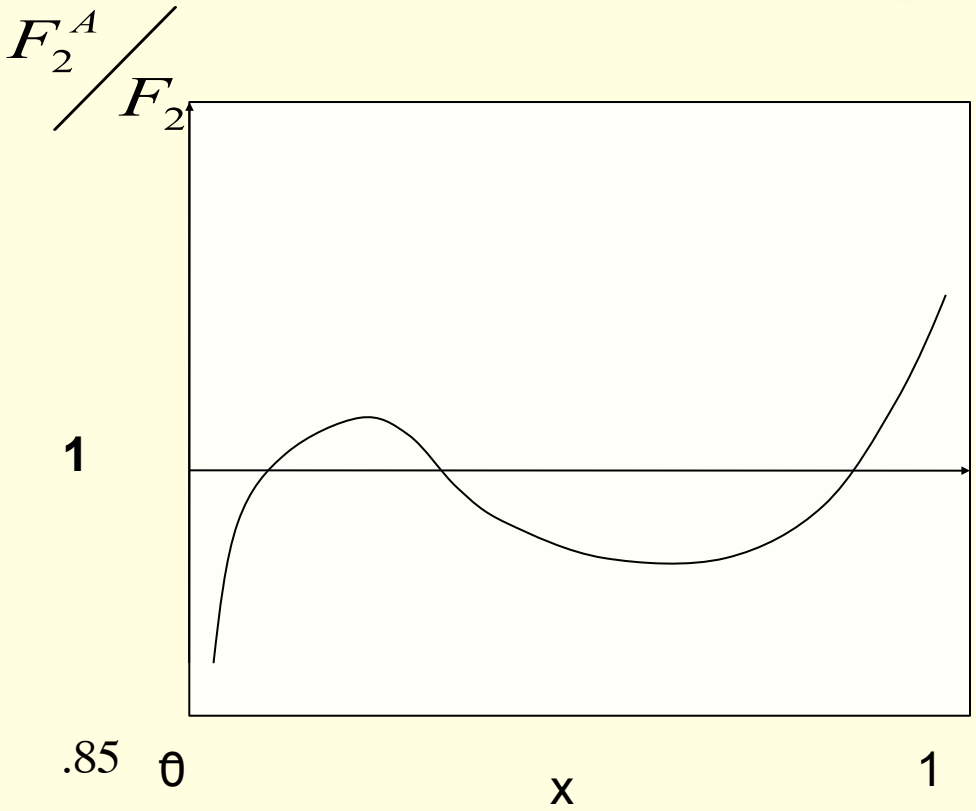
Outline

EMC effect & Drell Yan DY
Hadron dynamics fails EMC/DY
Nucleon is modified
Models and consequences

New experimental opportunities: but lots of data we don't understand now, implications of effect

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



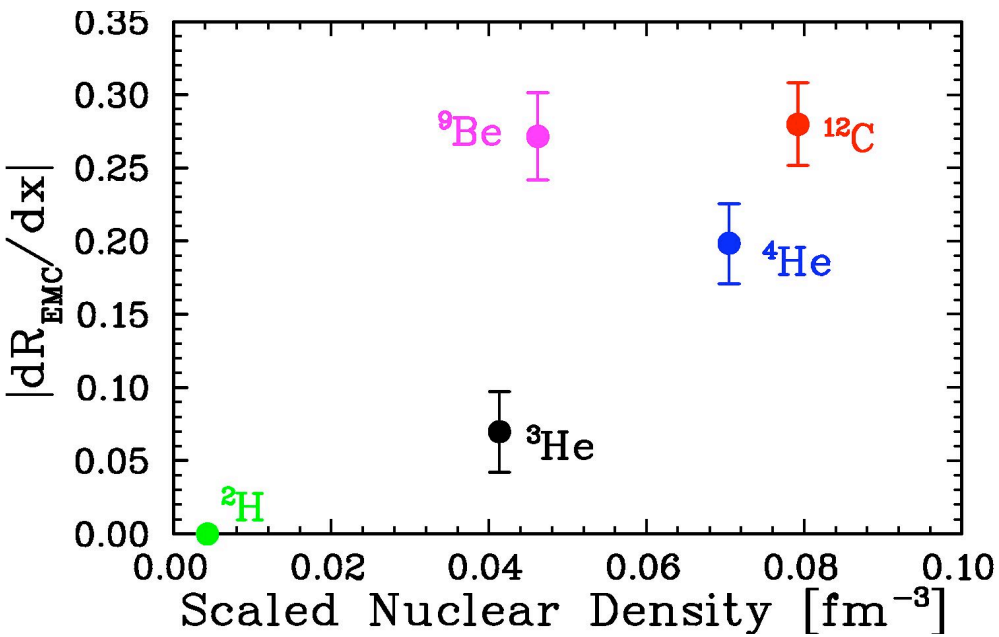
Nucleon structure is modified: valence quark momentum depleted, sea or gluon enhanced. How do quarks work in a nucleus?

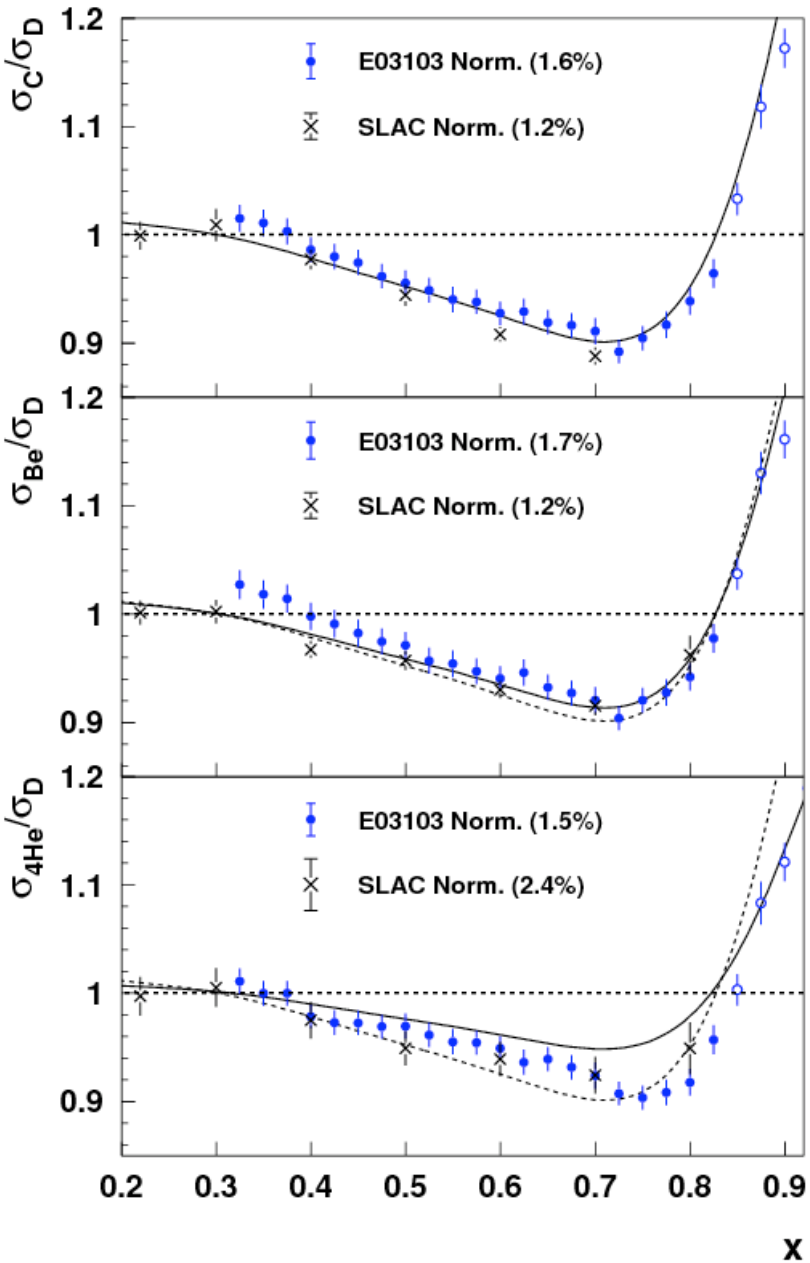
BUT EFFECTS ARE SMALL ~10%

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

E03-103: A≤12

- New data for A=3,4,9,12
- Norm. uncertainty for ^{3}He large relative to size of EMC effect
  - Use difference between low, high x
- Both A- and ρ-dependent fits fail to describe these light nuclei

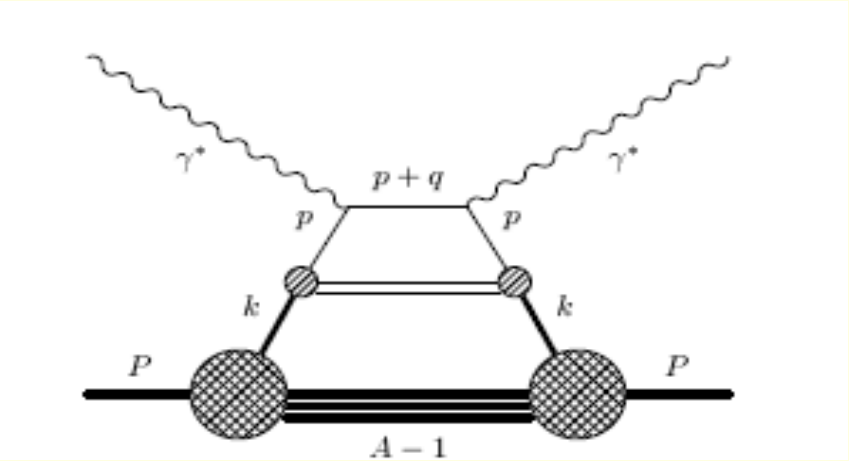




One thing I learned since ‘85

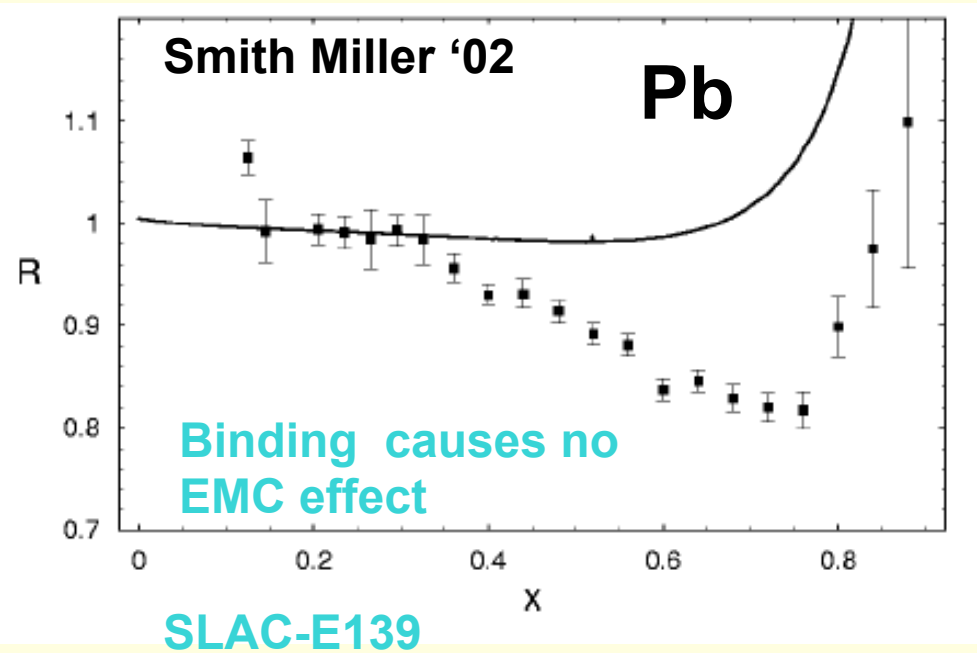
- One model is not cool

Deep Inelastic scattering from nuclei-nucleons only free structure function



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

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



- 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

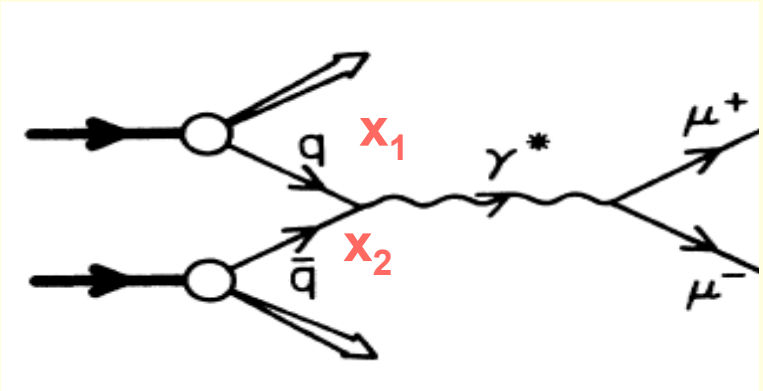
Nucleons and pions

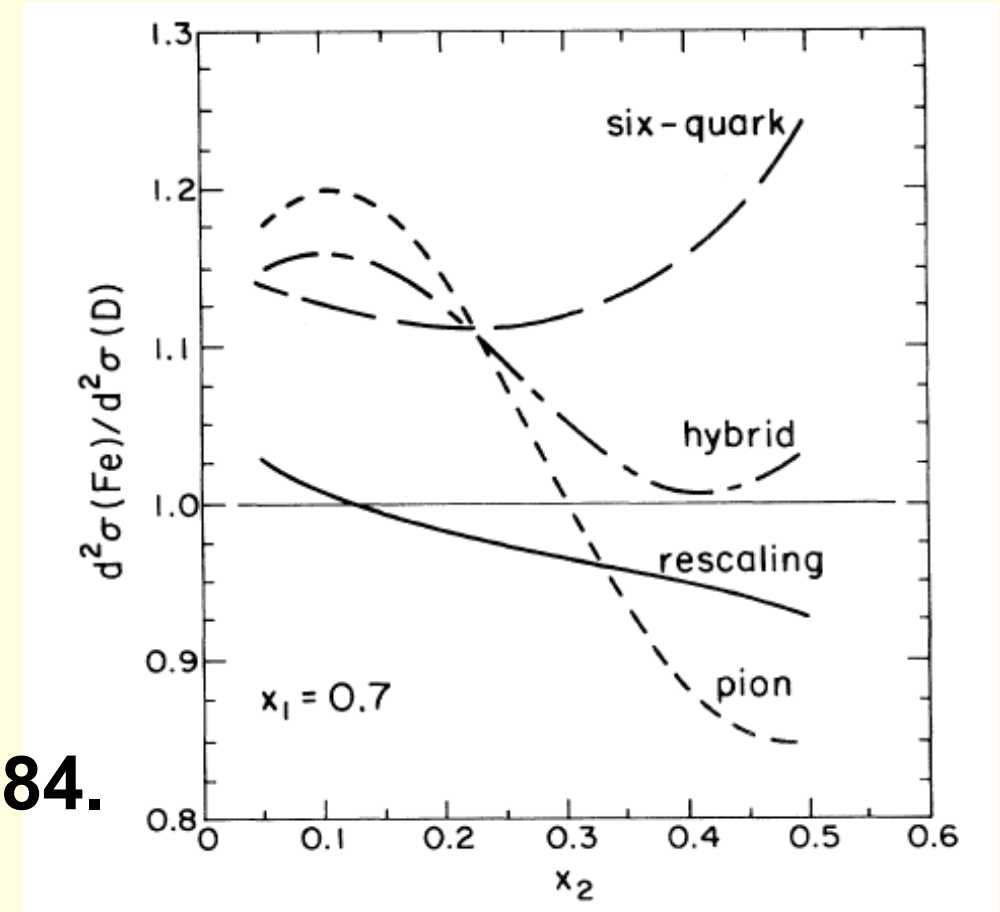
$P_A^+ = P_N^+ + P_\pi^+ = M_A$

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

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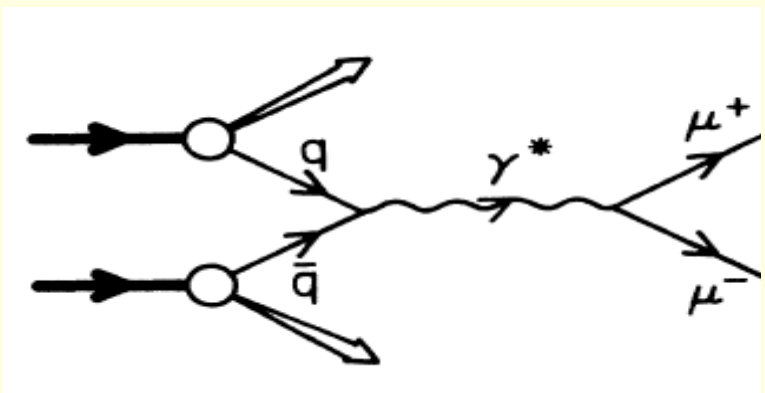
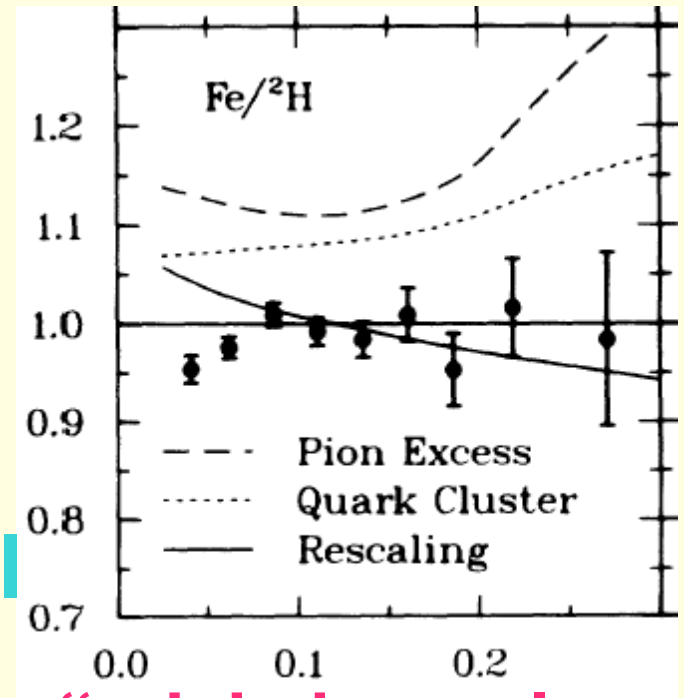
Drell-Yan, E772





π fails

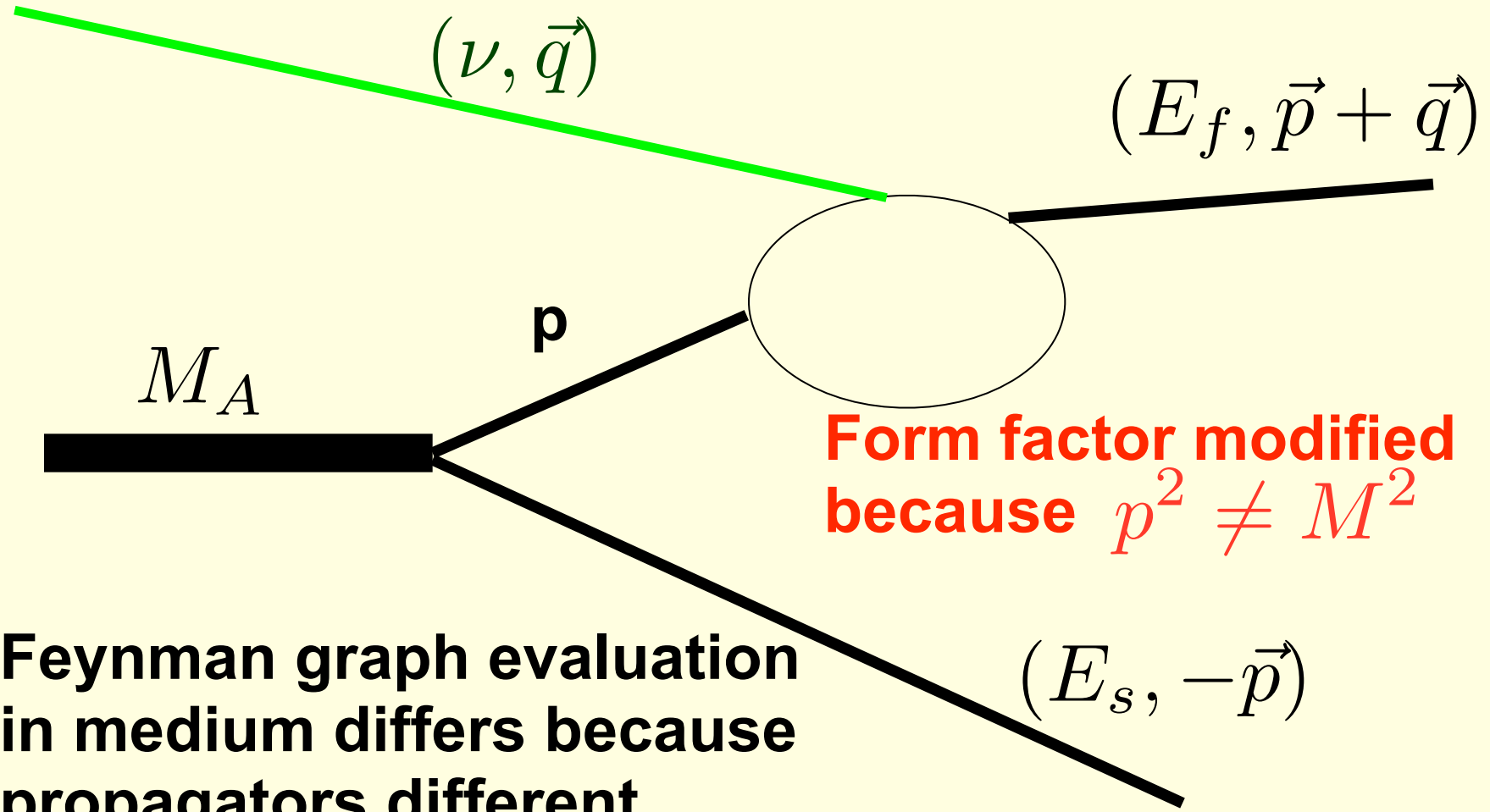
No one's model is cool

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)



Feynman graph evaluation in medium differs because propagators different.

- FS '84 $p^2 - M^2 \approx -2MS - \vec{p}^{\,2} = 2MV = U$
- degli Atti, Kaptari, FS 0706.2937

Medium Modification Models

- **chiral restoration:** $m_q \rightarrow m_q - g\sigma$
- Implement via bag model, Chiral instanton model, or NJL
- **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

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

$|\phi_2\rangle$ is PLC in FS

nucleon bound by potential U **attractive <0**

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

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

$$|\psi\rangle \approx |\phi\rangle + (p^2 - m^2) |\cdots\rangle, \text{ general result}$$

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

Enhancement of BLC-Frank, Jennings, Miller '95

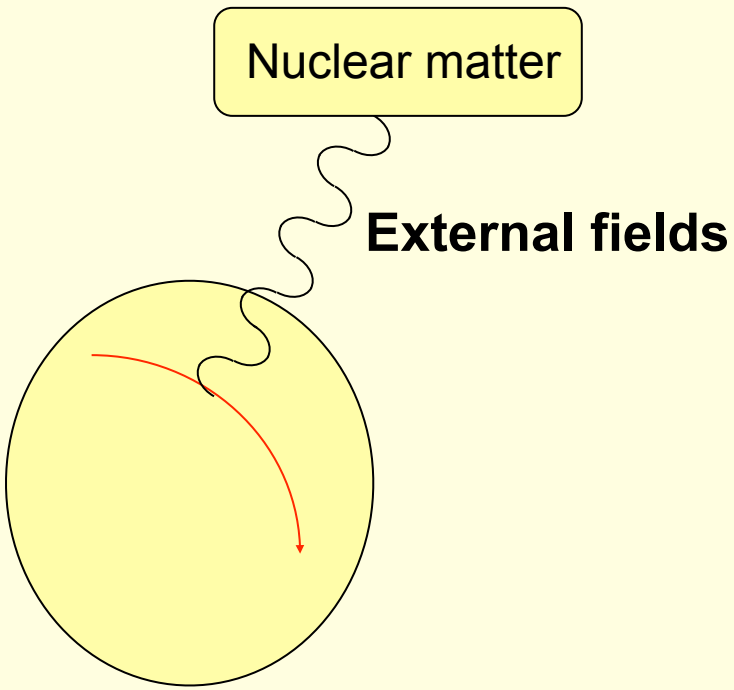
Free nucleon $|\phi\rangle = |\phi_1\rangle + \frac{1}{E_2 - E_1} V_{21} |\phi_2\rangle$, $|\phi_2\rangle$ is PLC
In medium $|\phi\rangle \rightarrow |\Psi\rangle$

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**

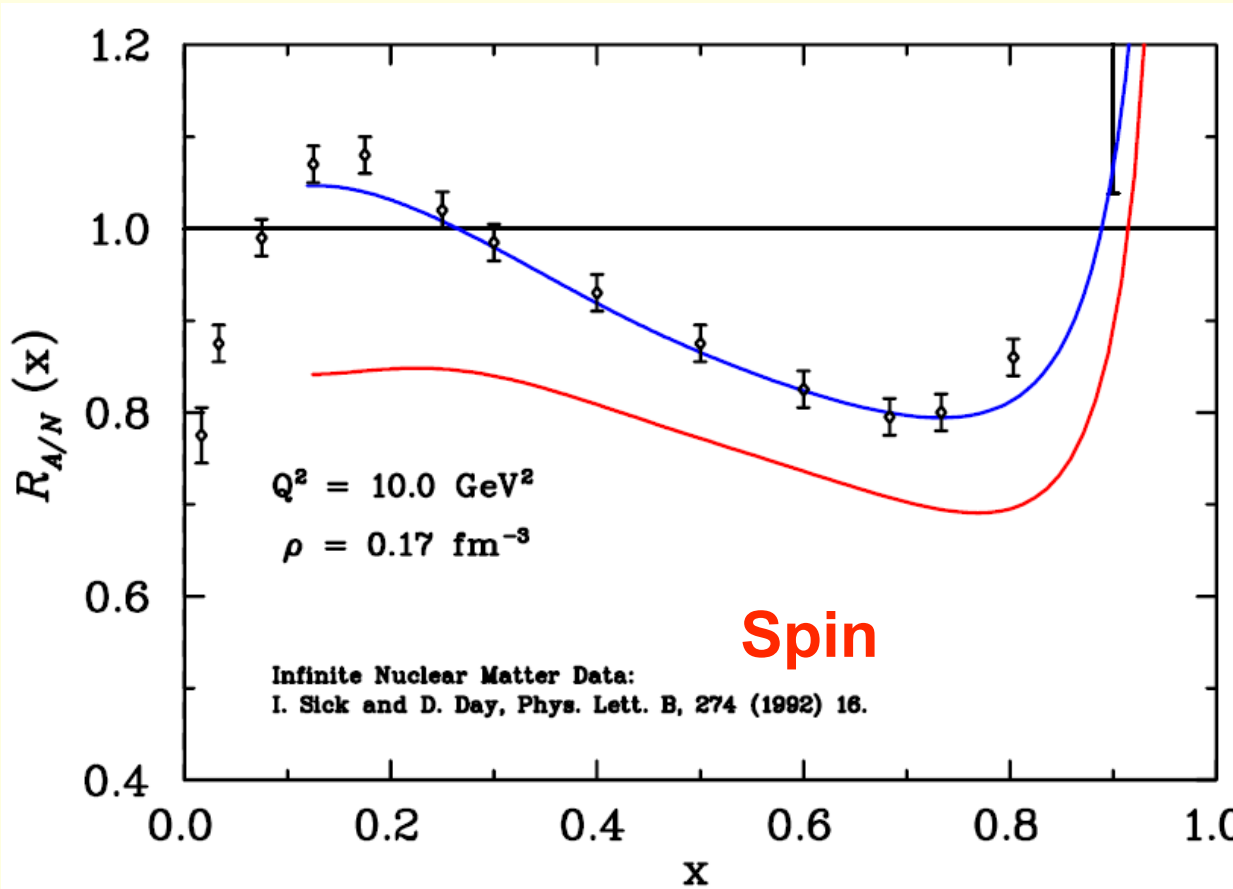
Spin experiments-NJL in medium

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

Bentz, Cloet, Thomas

- other way to enhance EMC?

ratio of g_1 medium to free

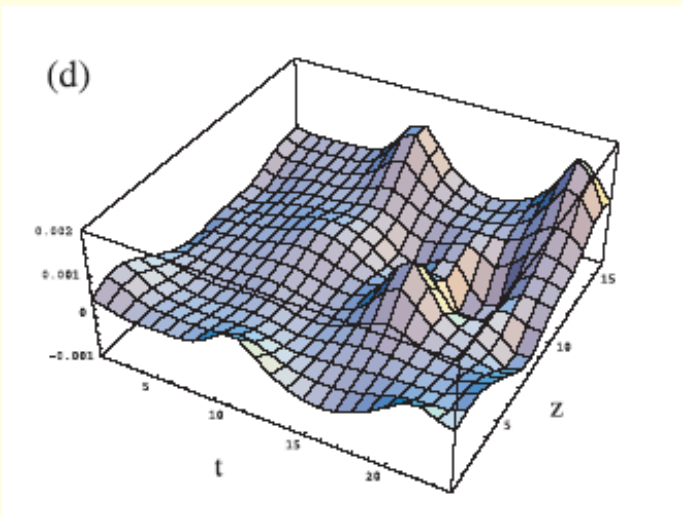


Chiral Quark Soliton Model –

Diakonov, Petrov, Polykov, quarks couple to vacuum instantons

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

Negele et al hep-lat/9810053
topological charge density

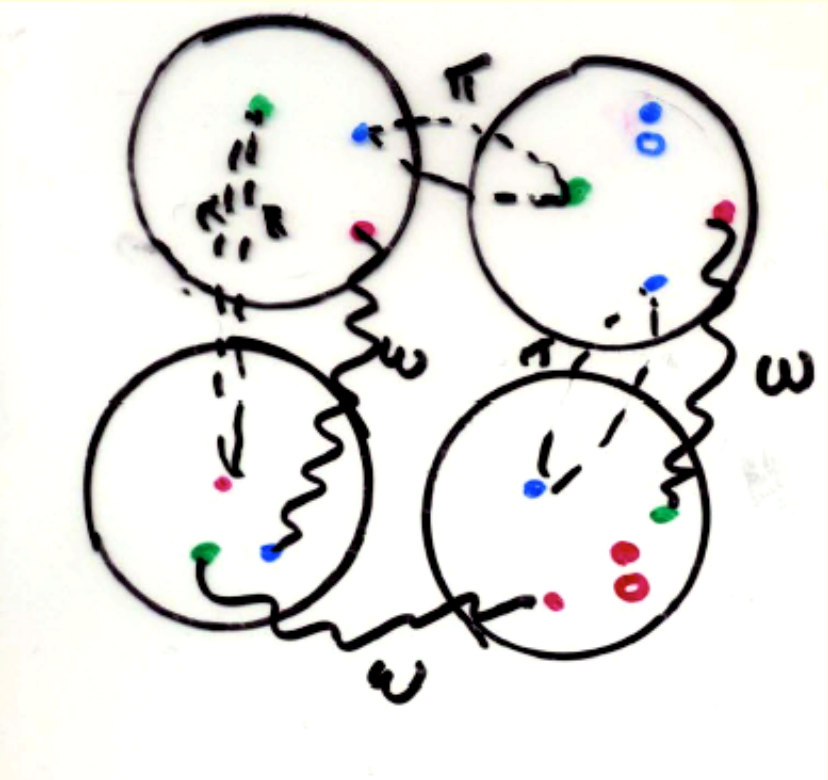


$$\mathcal{L}_{\rm eff} = \bar{q}\ \left[i\partial\!\!\!/ - M \exp(i\,\gamma_5\,\pi^A \lambda^A / F_\pi)\right]\ q,$$

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

Chiral Quark Soliton Model of Nucleus-

Smith, Miller



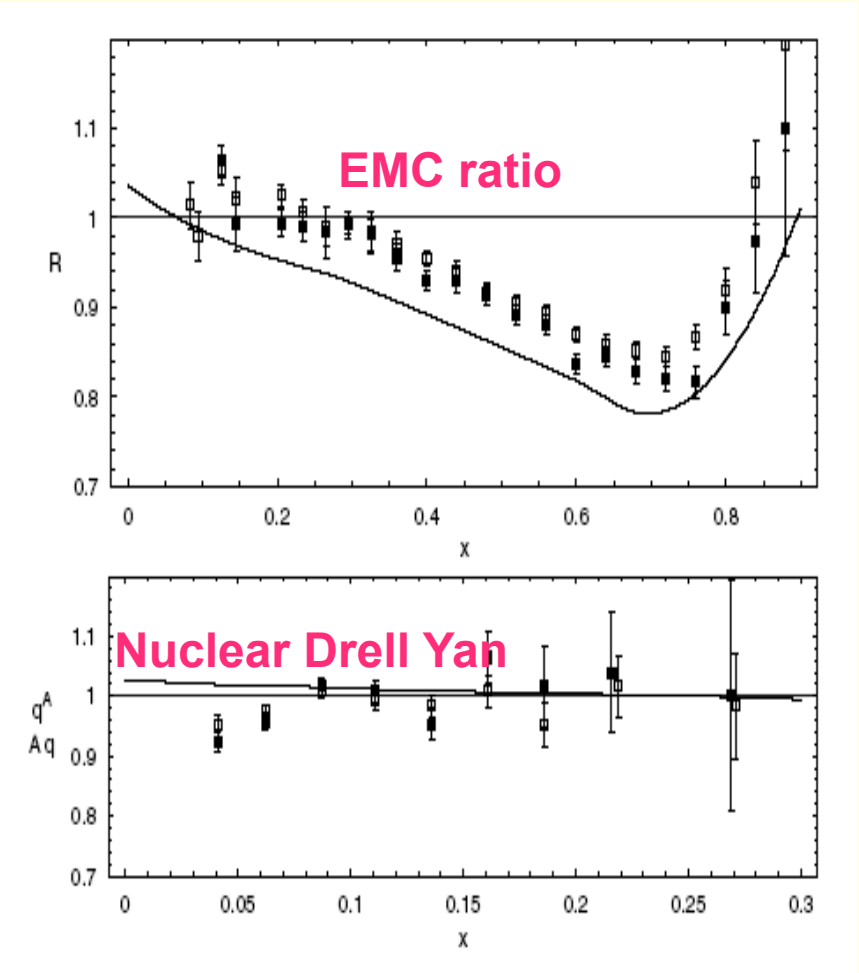
2 π exchange – attraction

ω (vector meson) exchange - repulsion

Double self consistency

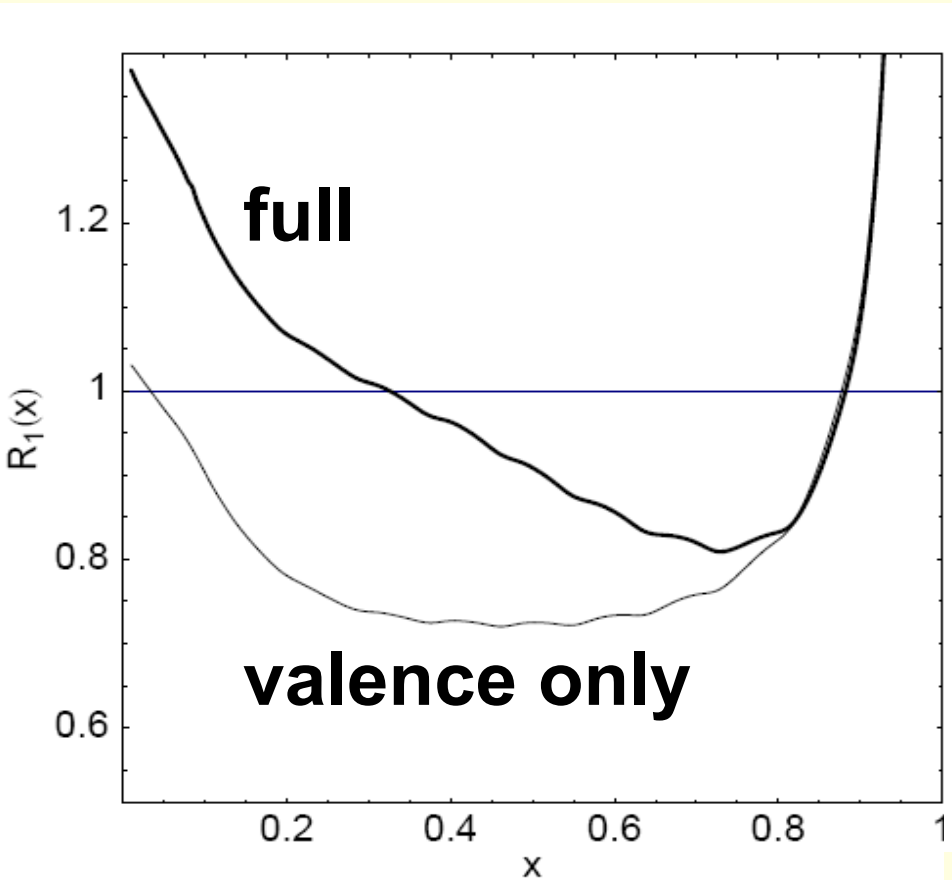
profile function and k_f

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- FJM

place in medium:

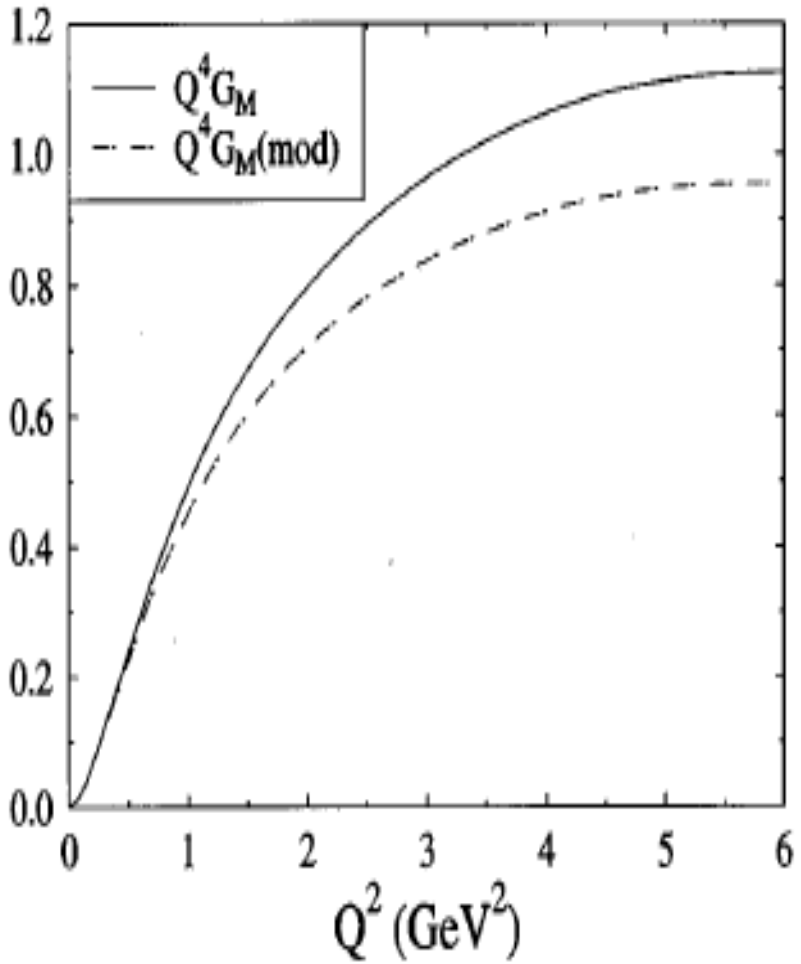
normal size components attracted energy goes down

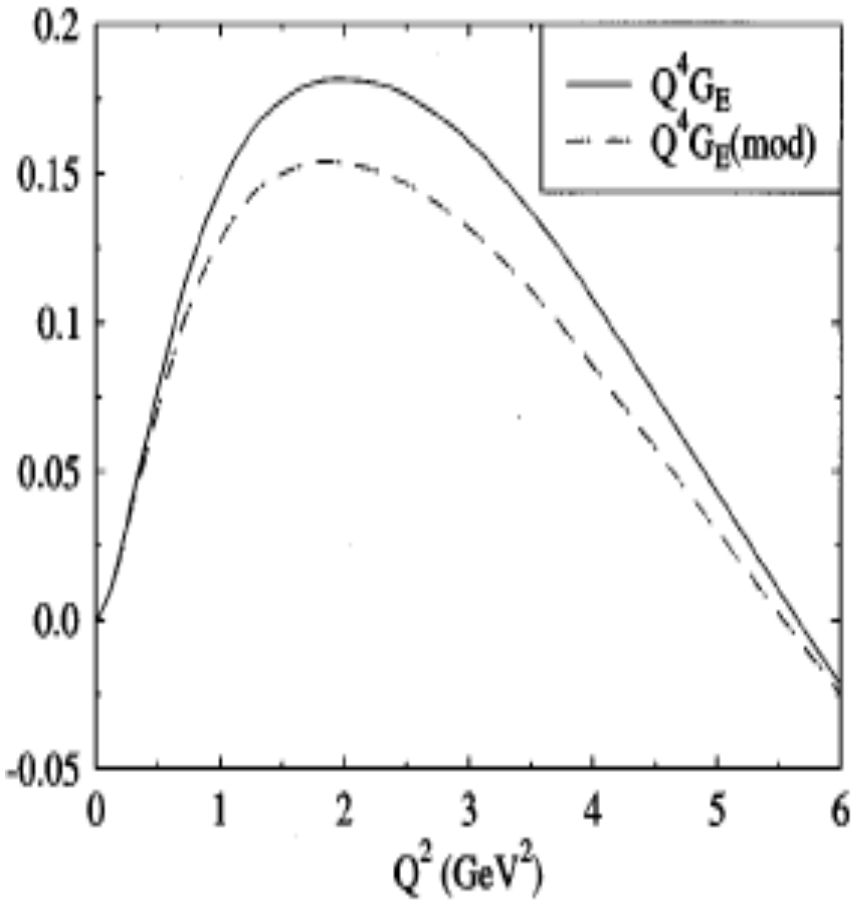
PLC does not interact- color screening-FS

BLC is enhanced

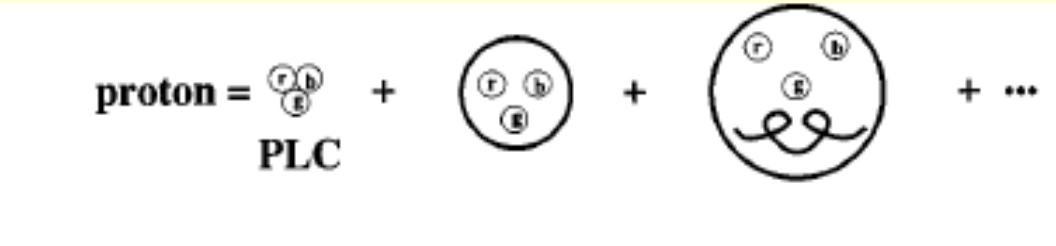
quarks lose momentum in medium

1995 Frank, Jennings, Miller



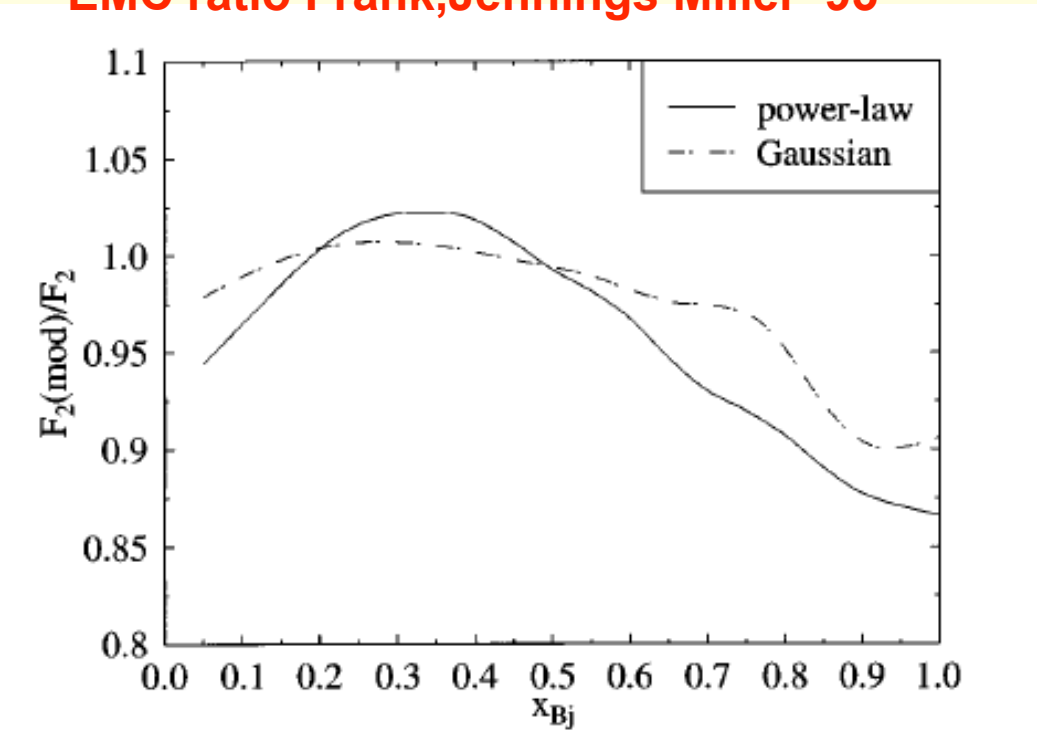


Enhancement of Blob-Like Configurations



energy denominator increased

EMC ratio Frank,Jennings Miller '95

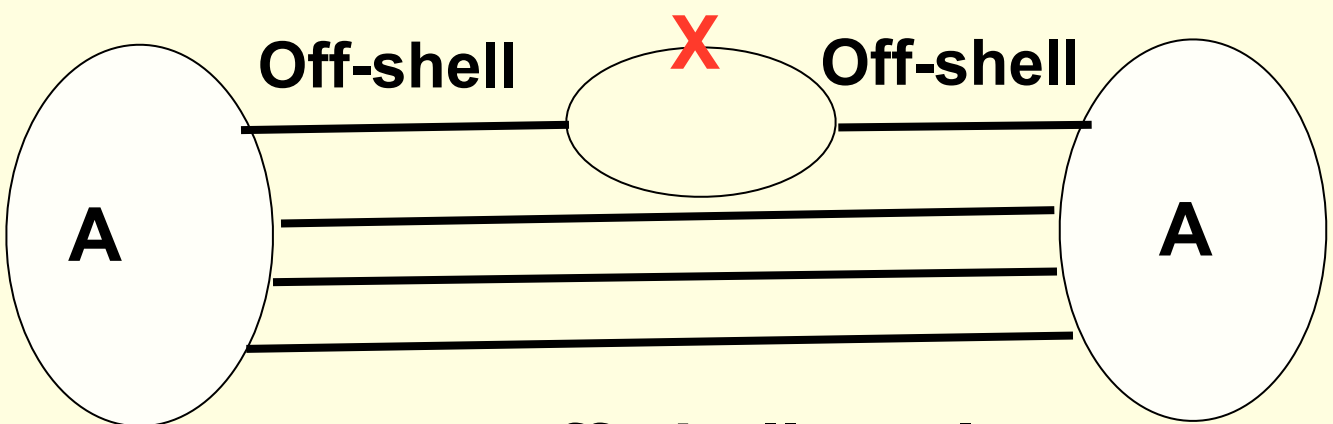


FS-PLC has NO int. with medium

evaluated as QCD Stark, not modified energy denominator

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
- minimum model requirements- EMC, DY, nuclear saturation, A-dependence
- predict new phenomena
- needed –better evaluations of models
- experimental tests –form factors
  in medium, ($eA \rightarrow e'XN$) spectator tag, nuclear gluon distribution, σ_L
- new experiments Jlab and others to find out how quarks work in a nucleus