EMC effect - constrains & and future directions of study

Can account of Fermi motion describe the EMC effect?

$$F_2A(x,Q^2) = \int F_{2N}(x/\alpha, Q^2)\rho_A^N(\alpha,p_t)\frac{d\alpha}{\alpha}d^2p_t = A$$

YES

If one violates baryon charge conservation or momentum conservation or both

Many nucleon approximation:

$$\int \rho_A^N(\alpha,p_t)\frac{d\alpha}{\alpha}d^2p_t = A$$ baryon charge sum rule

$$\frac{1}{A}\int \alpha\rho_A^N(\alpha,p_t)\frac{d\alpha}{\alpha}d^2p_t = 1 - \lambda_A$$

λ_A: fraction of nucleus momentum NOT carried by nucleons =0 in many nucl. approx.

Generic models of the EMC effect

- extra pions - $\lambda_\pi \sim 4\%$ -actually for fitting Jlab and SLAC data ~ 6%

$R_A(x,Q^2) = 1 - \frac{\lambda_A n x}{1-x}$ + enhancement from scattering off pion field with $\alpha_\pi \sim 0.15$

- 6 quark configurations in nuclei with $P_{6q} \sim$ 20-30%

- *Nucleon swelling - radius of the nucleus is 20--15% larger in nuclei. Color is significantly delocalized in nuclei*

  Larger size → fewer fast quarks - possible mechanism: gluon radiation starting at lower Q^2

  $(1/A) F_{2A}(x,Q^2) = F_{2D}(x, Q^2 \xi_A(Q^2))/2$

- Mini delocalization (color screening model) - small swelling - enhancement of deformation at large x due to suppression of small size configurations in bound nucleons + valence quark antishadowing with effect roughly $\propto k_{nucl}^2$

Drell-Yan experiments:
1989

vs Prediction

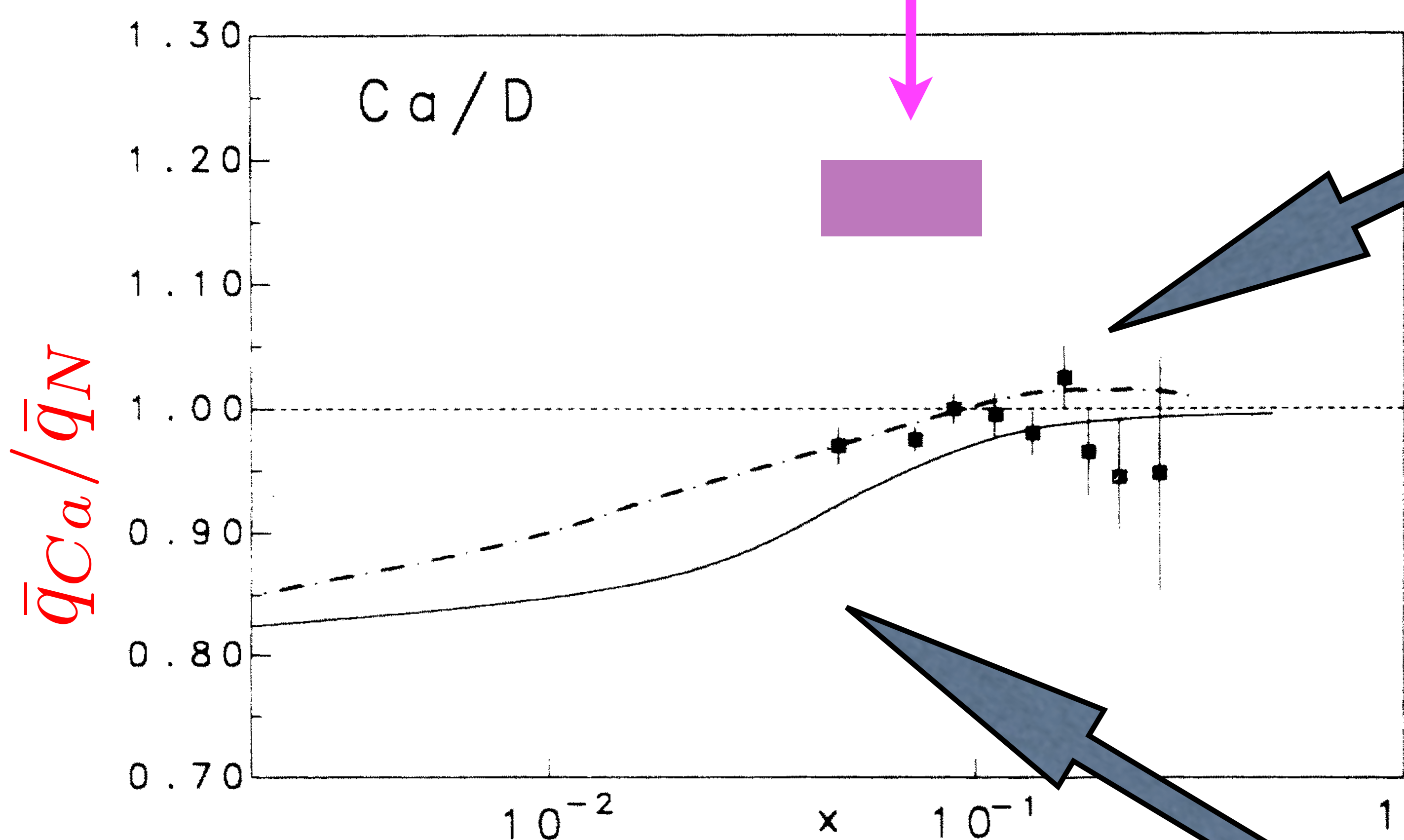
$\bar{q}_{Ca}(x)/\bar{q}_N = 1.1 \div 1.2_{|\,x=0.05\div 0.1}$

$\bar{q}_{Ca}/\bar{q}_N \approx 0.97$

meson model expectation

$\bar{q}_{Ca}(x)/\bar{q}_N = 1.1 \div 1.2_{|\,x=0.05\div 0.1}$

Q^2 = 15 GeV^2



A-dependence of antiquark distribution, data are from FNAL nuclear Drell-Yan experiment, curves - pQCD analysis of Frankfurt, Liuti, MS 90. Similar conclusions by Eskola et al 93-07 data analyses

Q^2 = 2 GeV^2

Combined analysis of (e,e') and knockout data

Structure of 2N correlations - probability ~ 20% for A>12
→ dominant but not the only term in kinetic energy

90% pn + 10% pp < 10% exotics ⇒ probability of exotics < 2%

Analysis of (e,e') SLAC data at x=1 -- tests Q^2 dependence of the nucleon form factor for nucleon momenta k_N < 150 MeV/c and Q^2 > 1 GeV^2 :

$$r_N^{bound}/r_N^{free} < 1.036$$

Similar conclusions from combined analysis of (e,e'p) and (e,e') JLab data

$$|r_N^{\mathrm{bound}}/r_N^{\mathrm{free}} - 1| \lesssim 0.04$$

Analysis of elastic pA scattering

Problem for the nucleon swelling models of the EMC effect with 20% swelling

First five commandments

Remember baryon conservation law

Honour momentum conservation law

Thou shalt not introduce dynamic pions into nuclei

Thou shalt not introduce large deformations of low momentum nucleons

However large admixture of nonnucleonic degrees of freedom (20-- 30 %) strange but was not initially ruled out.

Qualitative change due to direct observation of short-range NN correlations at JLab and BNL

Honour existence of large predominantly nucleonic short-range correlations

Thou shalt not introduce large exotic component in nuclei

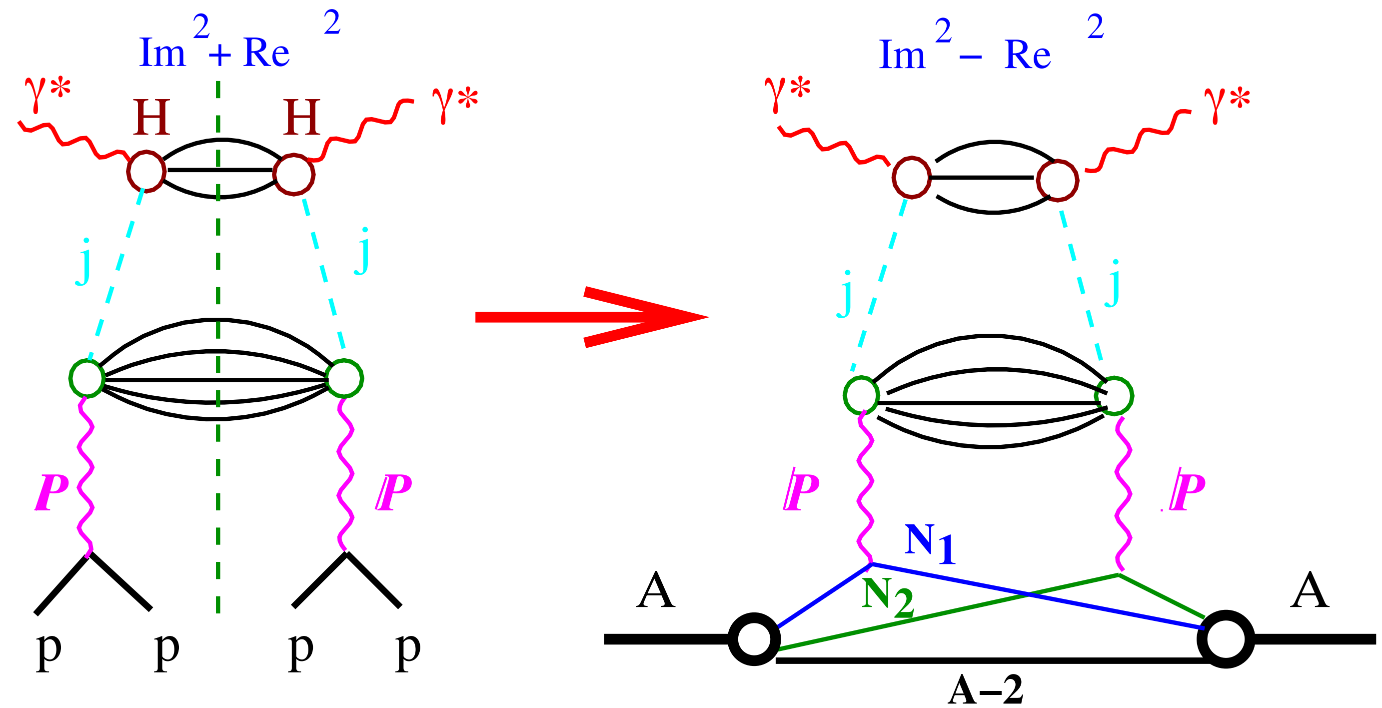
- 20 % 6q, Δ's

Thou shalt take into account leading twist shadowing andrelated leading twist antishadowing

Leading twist nuclear shadowing phenomena in hard processes with nuclei

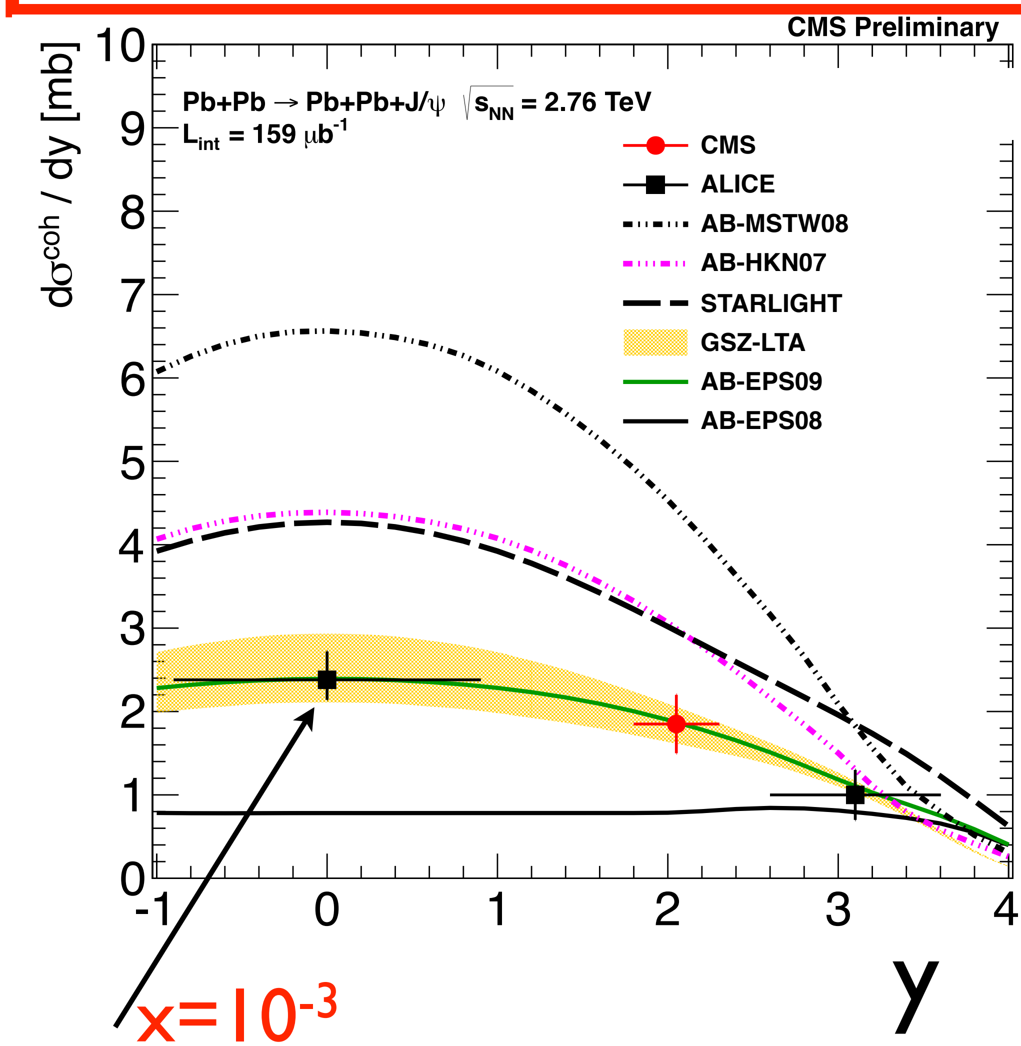
Physics Reports 512 (2012) 255–393 L. Frankfurt[a], V. Guzey[b,*], M. Strikman[c]

Theory of the leading twist shadowing based on the Gribov unitarity relations and QCD factorization theorem for hard diffraction. Predictions for LHC, EIC,...



Hard diffraction off parton "j"

Leading twist contribution to the nuclear shadowing for structure function $f_j(x,Q^2)$



Cross section of coherent J/ψ production in γ+A →J/ψ +A ultraperipheral collisions.

Yellow band is our prediction - large (~ 0.6) gluon shadowing is observed

Two minor effects to be included in a precision analysis of the EMC ratio requires

a) correction for the definition of $x = AQ^2/2q_0mA$

b) 1% of heavy nucleus LC momentum carried by Weizsäcker-William photons

Very few models of the EMC effect survive when constraints due to the observations of the SRC are included & lack of enhancement of antiquarks and Q^2 dependence of the quasielastic (e,e') at $x=1$

It appears that essentially one generic scenario survives - strong deformation of rare configurations in bound nucleons increasing with nucleon momentum and with most of the effect due to the SRCs .

Dynamical model - color screening model of the EMC effect

(FS 83-85)

Combination of two ideas:

(a) Quarks in nucleon with x>0.5 --0.6 belong to small size configurations with strongly suppressed pion field.

prediction for pA with trigger - confirmed by pA LHC and BNL DAu studies of large x jet produciton.

(b) Nucleon in a quark-gluon configurations of a size << average size (PLC) should interact weaker than in average configuration. Already application of the variational principle indicates that probability of such configurations in bound nucleons is suppressed by factor

$$\delta(p, E_{exc}) = \left(1 - \frac{p_{int}^2 - m^2}{2\Delta E}\right)^{-2}$$

$\Delta E \sim 0.5$ GeV

effect ∝ virtuality

In color screening model modification of average properties is < 2- 3 %.

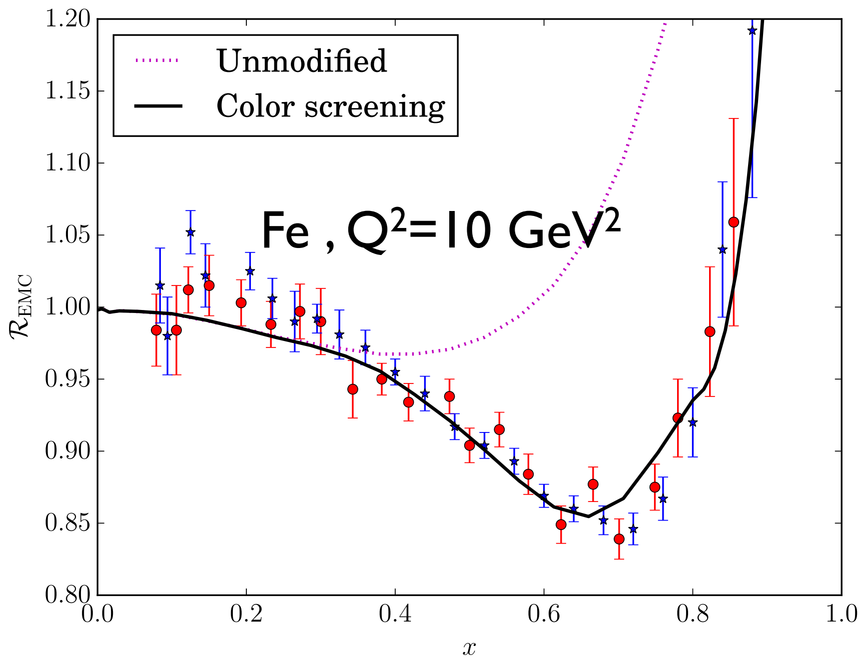
Dependence of suppression we find for small virtualities: $1-c(p^2_{int}-m^2)$

seems to be very general for the modification of the nucleon properties. Indeed, consider analytic continuation of the scattering amplitude to $p^2_{int}-m^2=0$. In this point modification should vanish. Our quantum mechanical treatment of 85 automatically took this into account.

Our dynamical model for dependence of bound nucleon pdf on virtuality - explains why effect is large for large x and practically absent for x~ 0.2 (average configurations V(conf) ~ <V>).

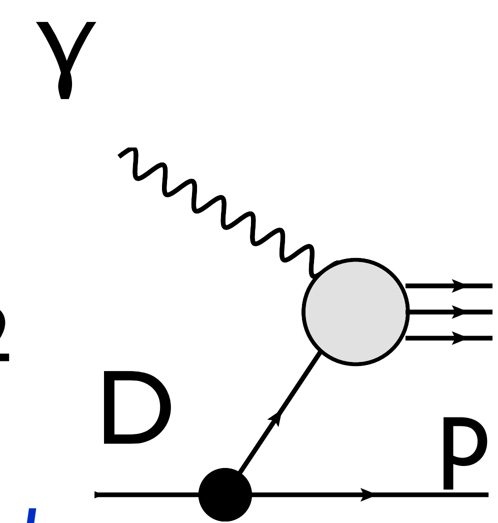
This generalization of initial formula allows a more accurate study of the A-dependence of the EMC effect.

Simple parametrization of suppression: no suppression $x \leq 0.45$, by factor $\delta_A(k)$ for $x \geq 0.65$, and linear interpolation in between



Freese, Sargsian, MS 14

"Gold plated test" (FS85) (Silver?)



Tagging of proton and neutron in e+D→e+ backward N +X (lab frame). Collider kinematics -- nucleons with $p_N > p_D/2$

➡ *interesting to measure tagged structure functions where modification is expected to increase quadratically with tagged nucleon momentum. It is applicable for searches of the form factor modification in (e,e'N). If an effect is observed at say 100 MeV/c - go to 200 MeV/c and see whether the effect would increase by a factor of ~3-4.*

$$1 - F_{2N}^{bound}(x/\alpha, Q^2)/F_{2N}(x/\alpha, Q^2) = f(x/\alpha, Q^2)(m^2 - p_{int}^2)$$

Here α is the light cone fraction of interacting nucleon

$$\alpha_{spect} = (2 - \alpha) = (E_N - p_{3N})/(m_D/2)$$

A>2 -- two step contributions, motion of the pair. mask effect.
In neutrino scattering BEBC tried to remove two step processes to see better 2N SRC "Doppler" shift

Experimental challenges

- Jlab Q range - separate LT and HT (50 :50) contribution to the EMC effect at Jlab. Precision relative normalization to study scaling of

$F_{2A}(x) / F_D(x) - 1 = f(A)\, \varphi(x)$ and precision of $f(A) \sim a_2 - 1$

COMPASS DIS --- improve old DIS data which have errors ~50% for x=0.6

- *Superfast (x> 1) quarks* Jlab: Study of Q^2 dependence, trying to reach LT regime for x~ 1 at $Q^2 \sim 15\ GeV^2$

$$F_{2A}(x=1)/F_{2D}(x=1) > a_2(A)$$

x~1 LHC dijet production in pPb

feasible: Freese, Sargsian, MS

- EIC --- x~0.1: u-, d- quarks, gluons

- Direct searches for exotics - isobars,...

Large angle processes like γ+A --> N π + (A-1)

In color transparency regime - breaking of factorization due to suppression of small size configurations in bound nucleons. -- by factor

$$\delta(p, E_{exc}) = \left(1 - \frac{p_{int}^2 - m^2}{2\Delta E}\right)^{-2}$$