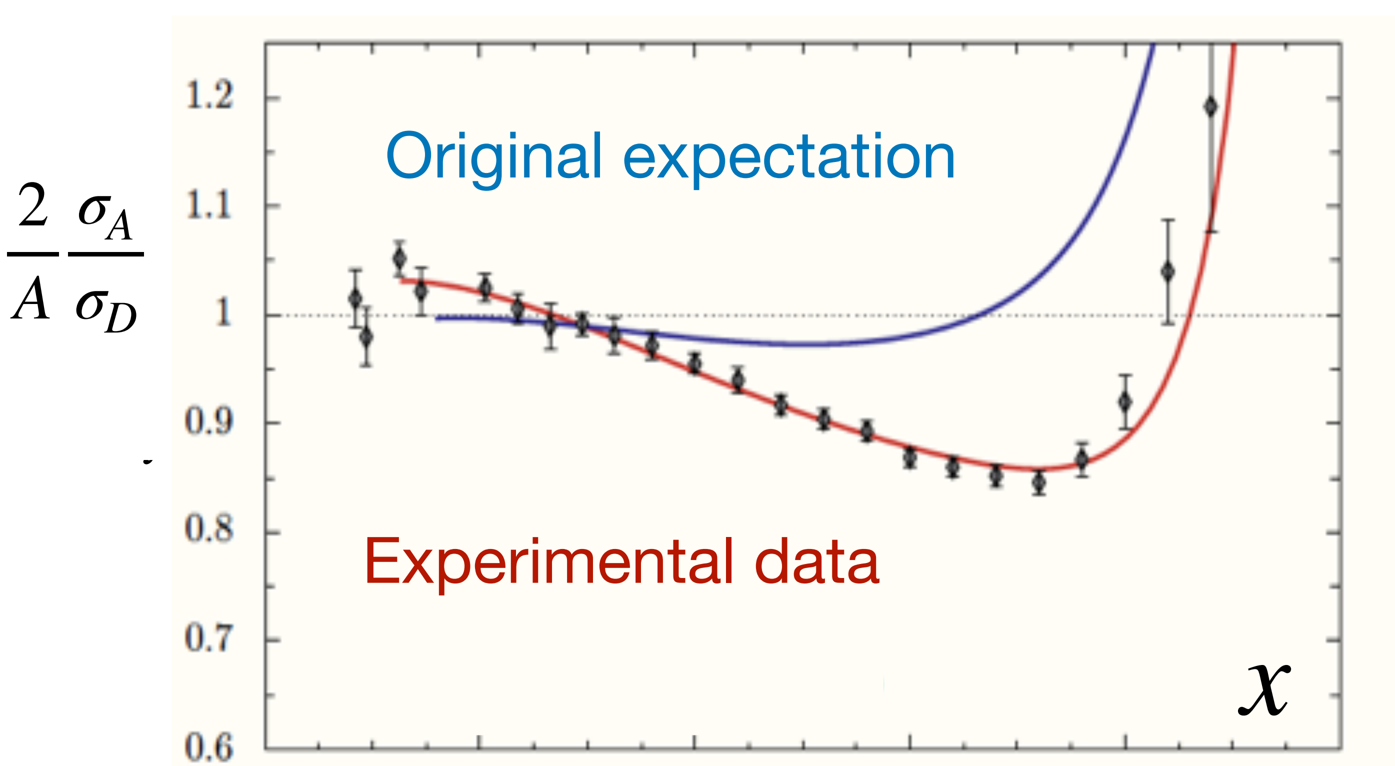
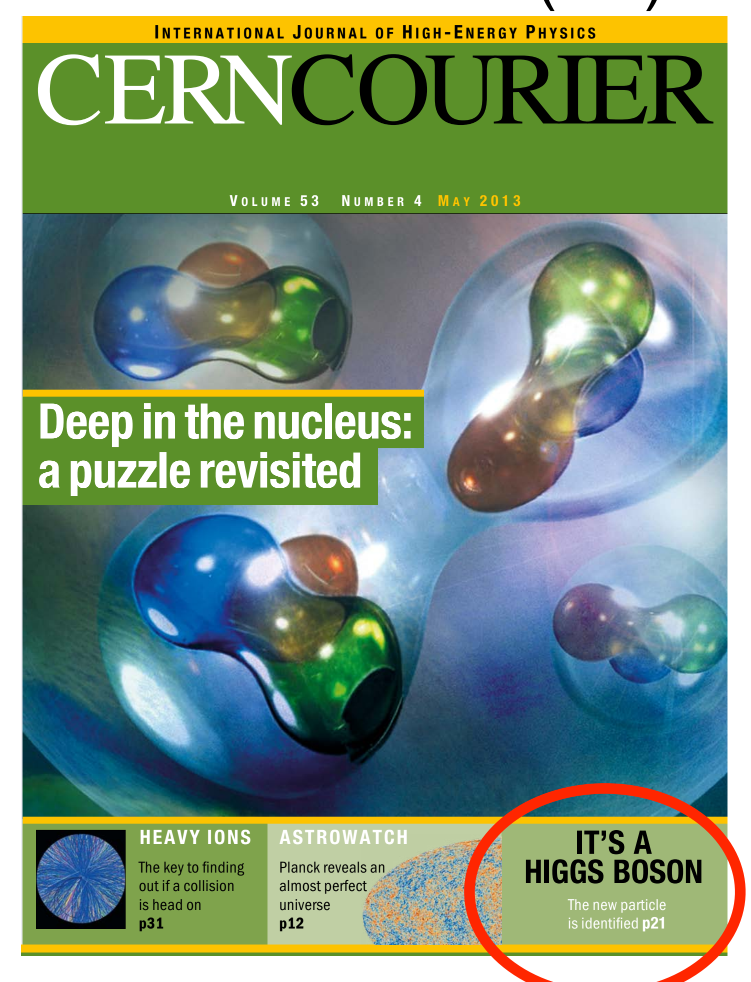
Recent thoughts on the EMC effect (1982)

Gerald A. Miller, with D N Kim U. of Washington

arXiv:2209.13753 [nucl-th]



Higinbotham, Miller, Hen, Rith
CERN Courier 53N4('13)24



Effect is small, for x between 0.3 and 0.7 linear decrease with x

Ideas: ~1000 papers 3 ideas

Drell-Yan Data

- Proper treatment of known effects: binding, Fermi motion, pionic- NO nuclear modification of internal nucleon/pion quark structure
- Quark based- high momentum suppression implies larger confinement volume
- bound nucleon is larger than free one- a

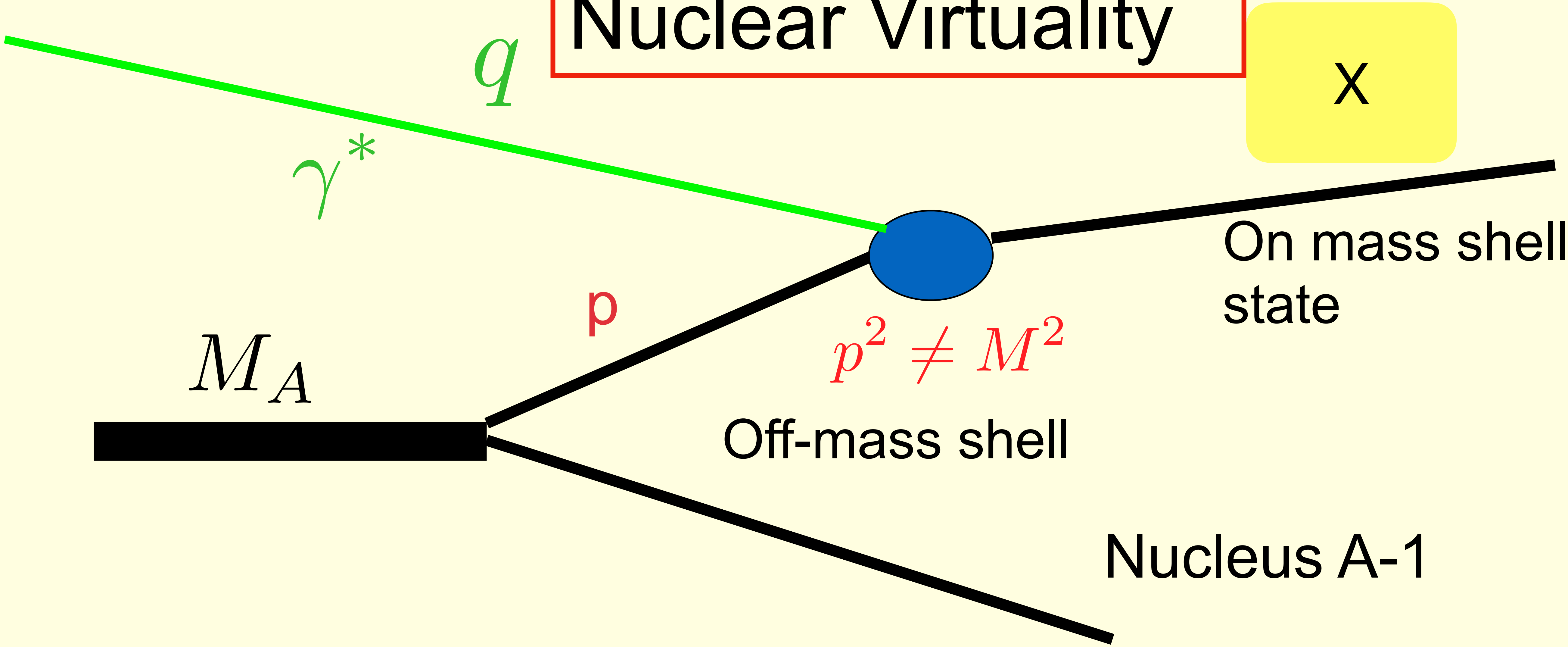
a mean field effect- $p^2 - M^2$ virtuality small

- multi-nucleon clusters - beyond the mean

b field $p^2 - M^2$ virtuality large

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

Nuclear Virtuality



a A-1 nucleus is low-lying state — is form factor of "large" proton

b A- nucleus is 1 fast nucleon +A-2 nucleus
the struck nucleon is part of correlated pair SRC

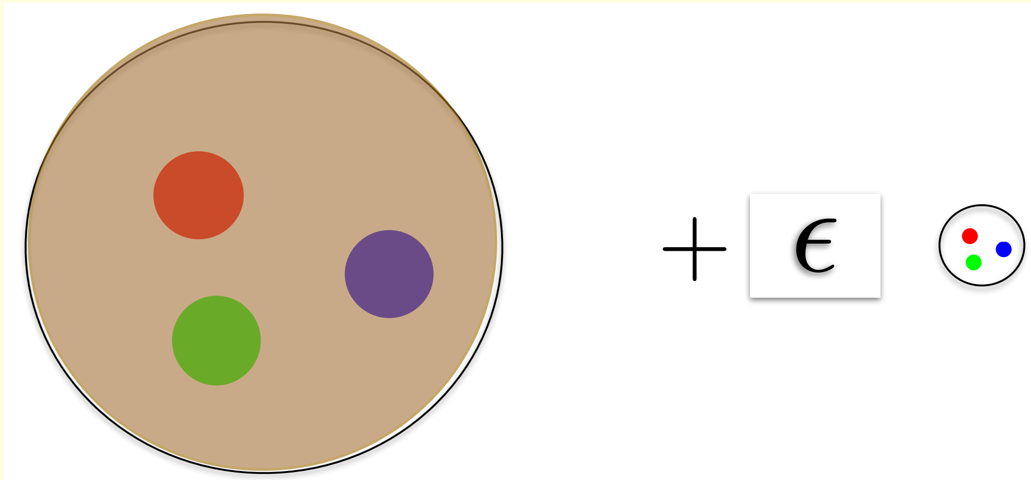
If Nucleus A-1 is highly excited, then $p^2 - M^2$ is big

Such large virtuality occurs from two nearby correlated nucleons
Highly virtually nucleon is not a nucleon- different quark config.

Suppression of Point Like Configurations

Frankfurt Strikman

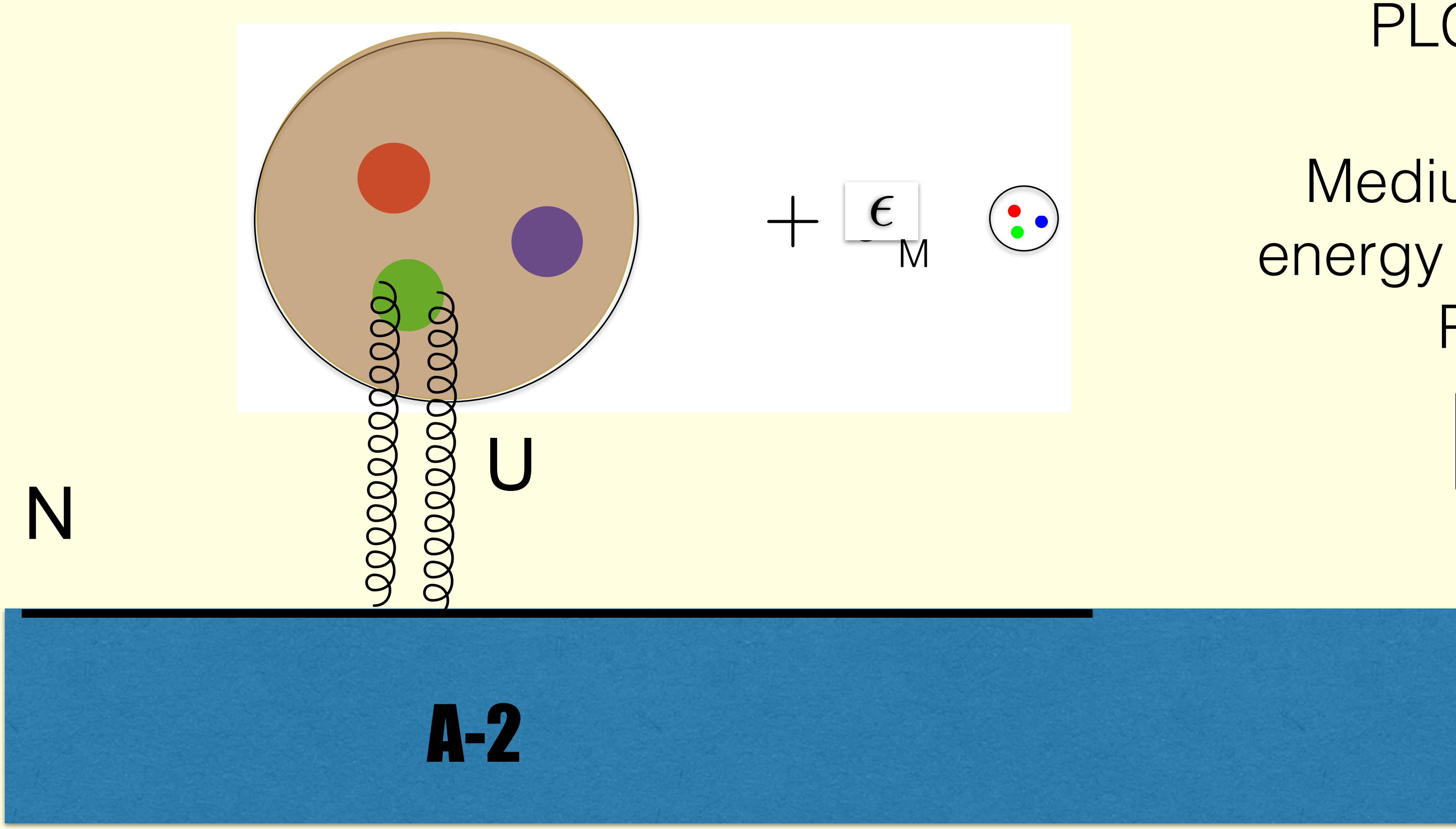
Free nucleon



Schematic
two-component
nucleon model

Blob-like config:BLC
Point-like config: PLC

Bound nucleon



PLC smaller, fewer quarks
high x

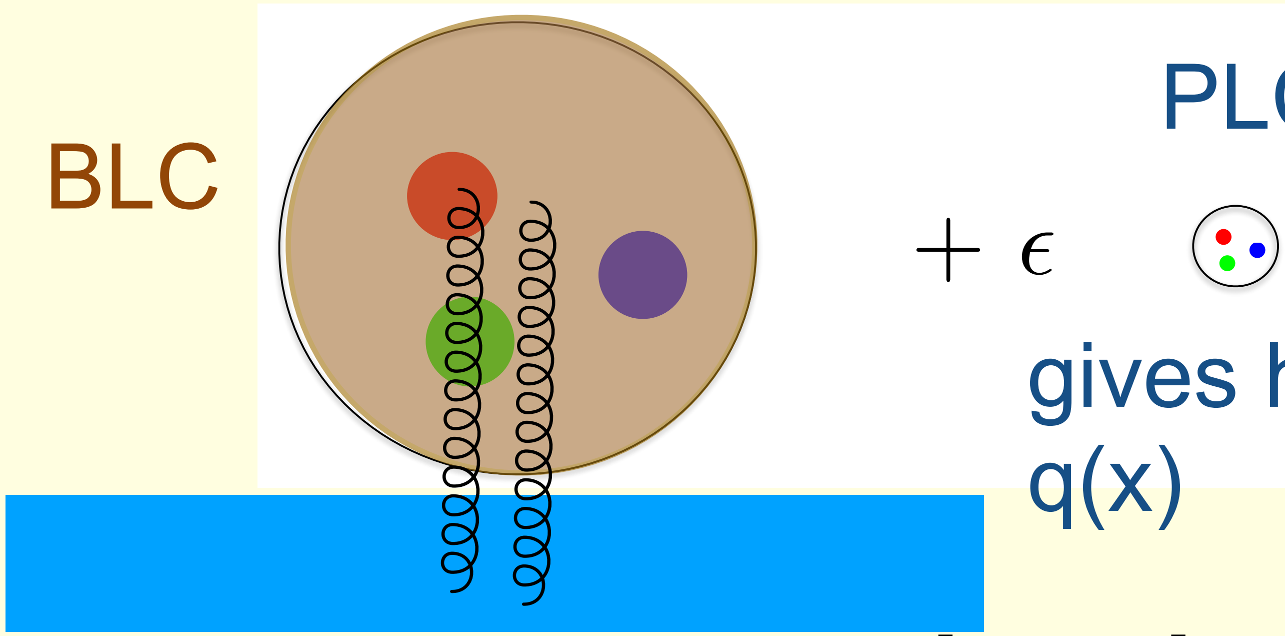
Medium interacts with BLC
energy denominator increases
PLC Suppressed

$$|\epsilon_M| < |\epsilon|$$

Quark structure of nucleon

Frankfurt-Strikman

BLC



PLC

gives high x q(x)

Schematic two-component nucleon model:
Blob-like config:BLC
Point-like config: PLC

PLC doesn't interact with nucleus

Free space $H_0 = \begin{bmatrix} E_B & V \\ V & E_P \end{bmatrix}, |N\rangle = \frac{1}{\sqrt{1+\epsilon^2}}(|B\rangle + \epsilon|P\rangle)$

Medium (M) $H = \begin{bmatrix} E_B - |U| & V \\ V & E_P \end{bmatrix}, |N\rangle_M = \frac{1}{\sqrt{1+\epsilon_M^2}}(|B\rangle + \epsilon_M|P\rangle)$

$$\epsilon_M = \epsilon\left(1 - |U|/(2\sqrt{(E_P - E_B)^2 + 4V^2})\right)$$

$$q_M = q + 1/2(\epsilon_M - \epsilon)q_B(q_P/q_B - 1) = q + 1/2 q_B(\epsilon_M - \epsilon)(f(x) - 1)$$

$$\epsilon_M < \epsilon, \frac{df}{dx} > 0, \frac{q_M}{q} = 1 + \text{function that decreases with x}$$

$$\epsilon_M - \epsilon \propto U \propto \frac{p^2 - M^2}{2M} \text{ virtuality}$$

what is $f(x)$

Previous model not complete:
Needs specific x-dependence for BLC & PLC

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Light-front holographic QCD and emerging confinement

CrossMark

Stanley J. Brodsky[a,*], Guy F. de Téramond[b], Hans Günter Dosch[c], Joshua Erlich[d]

LFQCD -good description of much data

Universality of Generalized Parton Distributions in Light-Front Holographic QCD

Guy F. de Téramond,[1] Tianbo Liu,[2,3] Raza Sabbir Sufian,[2] Hans Günter Dosch,[4] Stanley J. Brodsky,[5] and Alexandre Deur[2] PHYSICAL REVIEW LETTERS **120,** 182001 (2018)

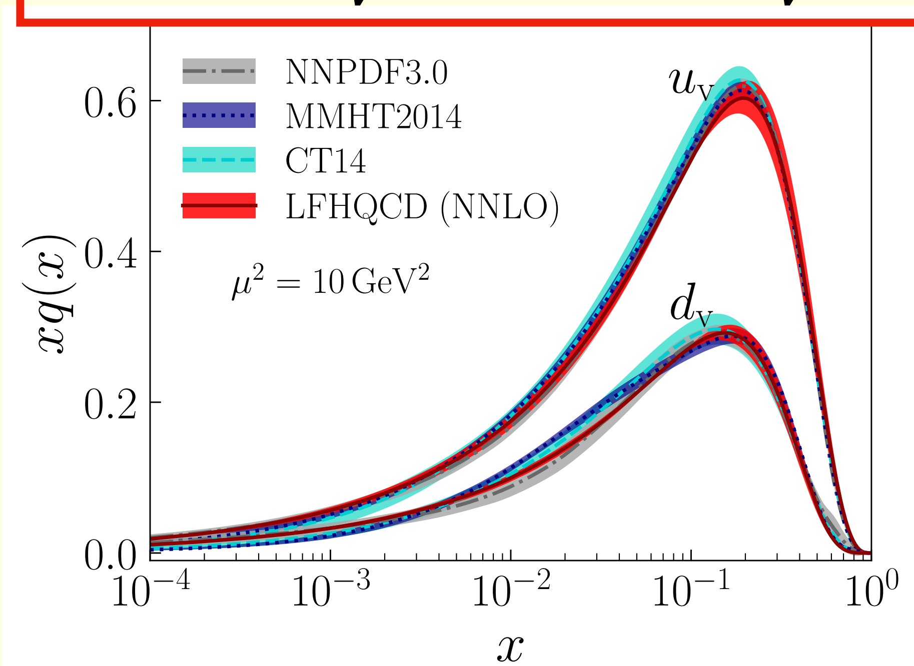
- 4 dimensional QFT equivalent to 5 dim. gravitational theory- space time is bent (Maldecena conjecture), holographic dual
- Bottom up procedure: construct four dimensional light front wave equation that has holographic dual
- Use holographic dual to compute electromagnetic form factors for systems of arbitrary spins, arbitrary number of particles
- Form factor is a Beta function, reparametrization invariance gives

$F_\tau(t) = \int H_\tau(x,t)\, dx$ in a flexible form amenable to fitting data, τ is parton number

Nucleon pdfs

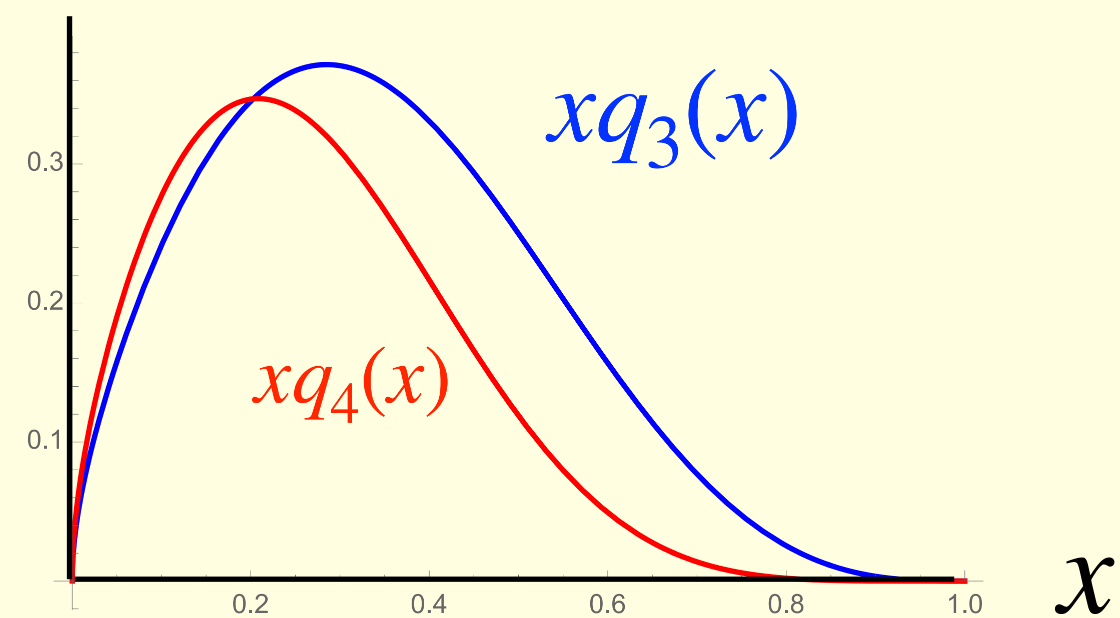
$$u_v(x) = 3/2\,q_3(x) + 1/2\,q_4(x),\ d_v(x) = q_4(x)$$

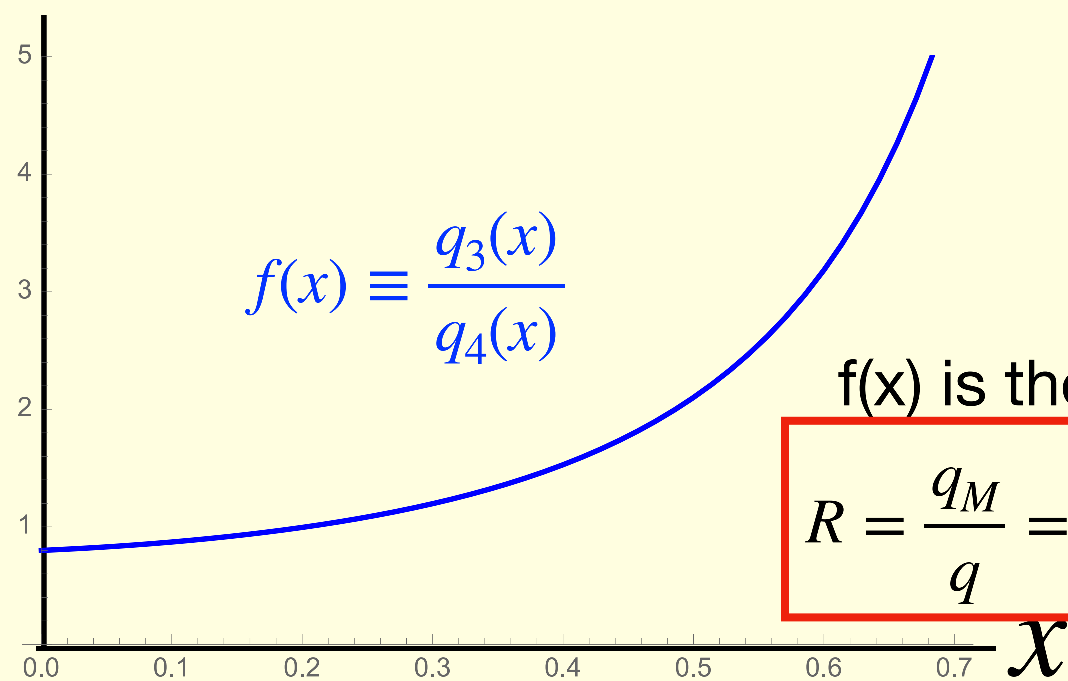
$$u_V(x) + d_V(x) = 3/2\,q_3(x) + 3/2\,q_4(x)$$



PRL 120,182001 gets good fit

3 is PLC, 4 is BLC





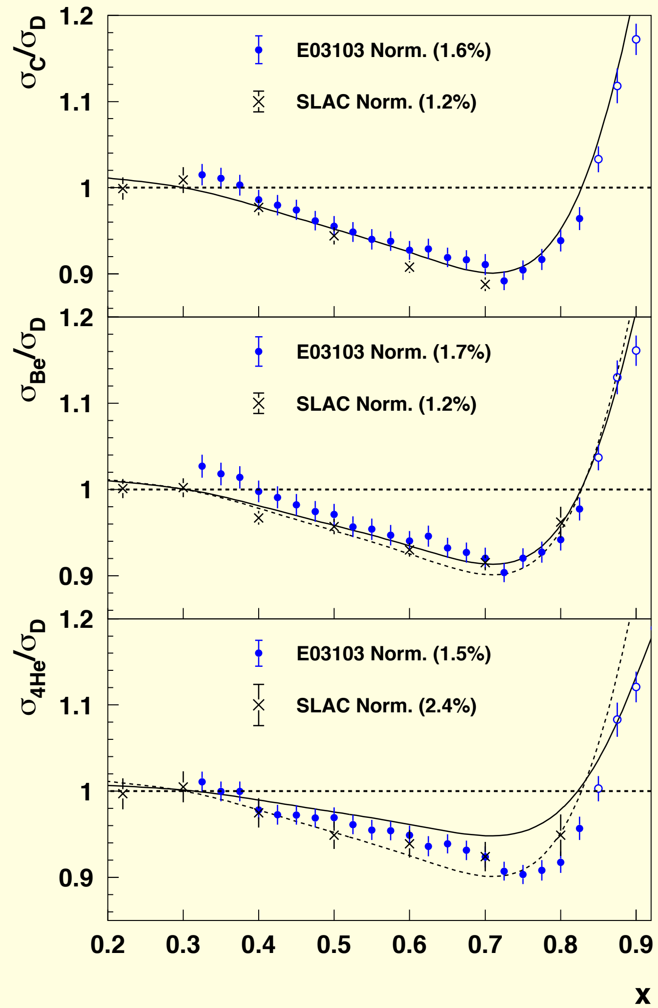
f(x) is the ratio we needed to understand the EMC effect

$$R = \frac{q_M}{q} = 1 + \delta\frac{1-f}{1+f},\quad \delta = \frac{|U|}{E_P - E_B + \sqrt{(E_P - E_B)^2 + 4V^2}}$$

N=Z nuclei

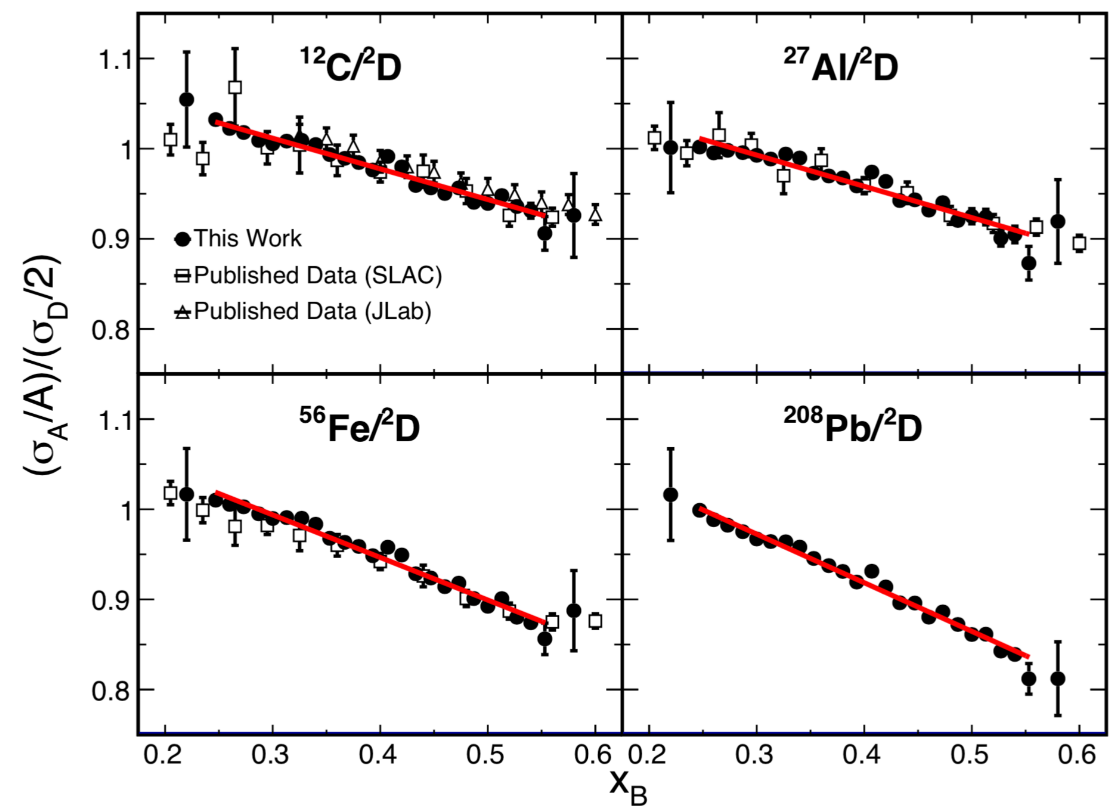
Simplified: N=Z

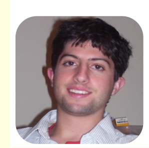
$$R = \frac{q_M}{q} = 1 + \delta\frac{1-f}{1+f}, \delta = \frac{|U|}{E_P - E_B + \sqrt{(E_P - E_B)^2 + 4V^2}}$$



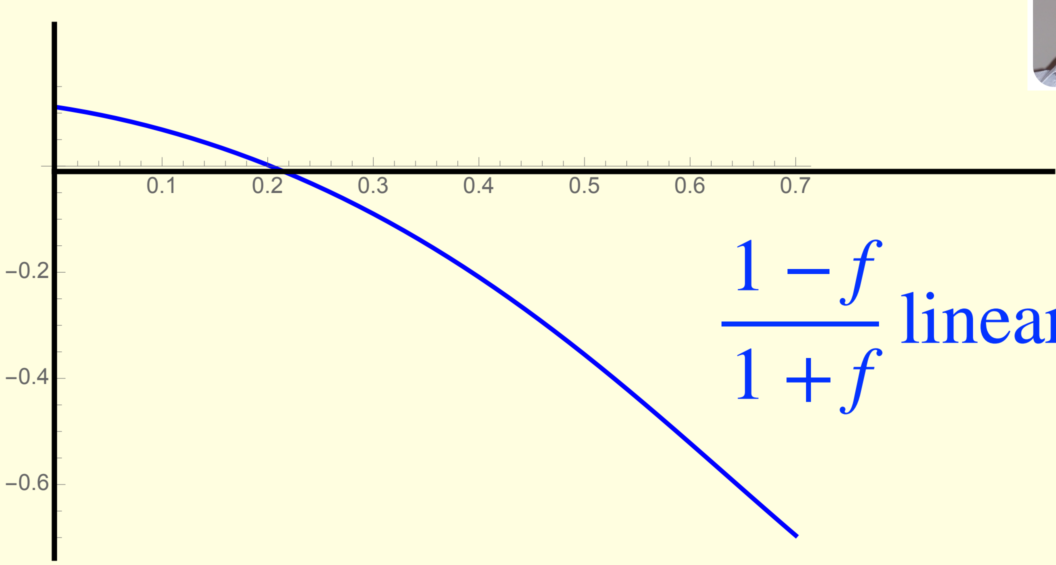
Previous fit

Previous fit





Schmookler et al., Nature (2019)



$\frac{1-f}{1+f}$ linear for $0.3 \leq x \leq 0.7$

Our results

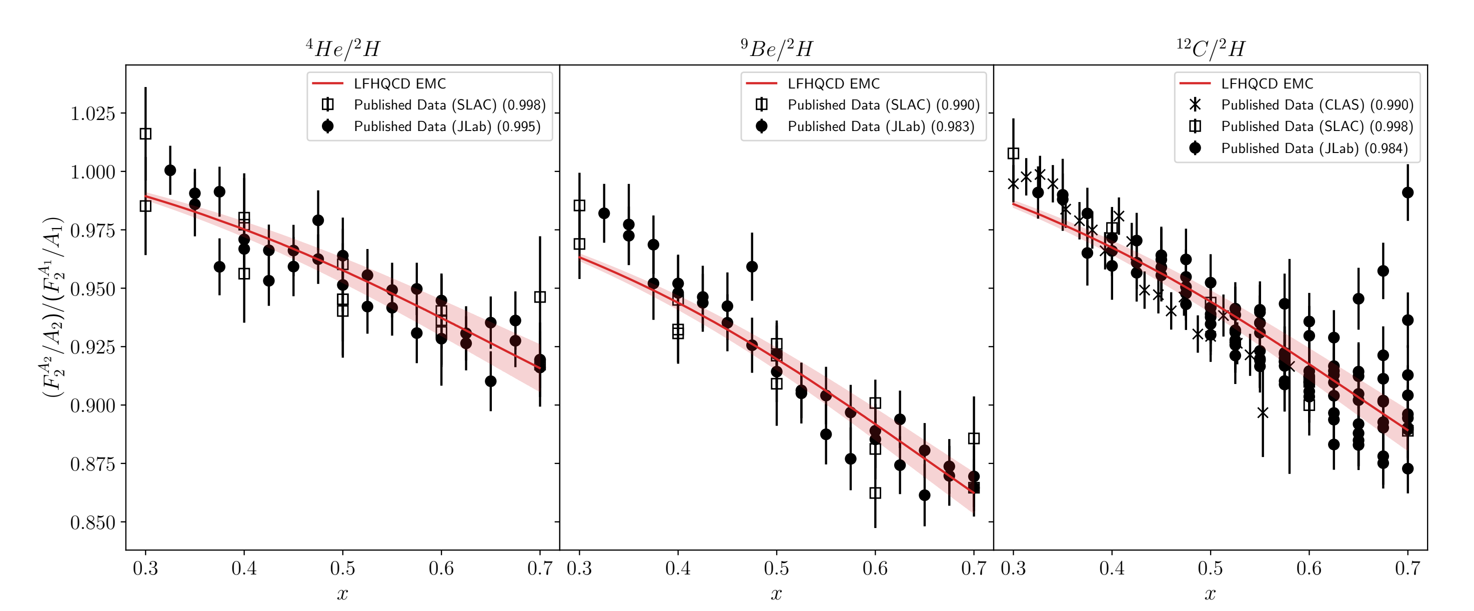


FIG. 4: EMC ratio comparisons between the LFHQCD model (red line) and experimental data (removed isoscalar corrections) obtained from SLAC (open boxes), JLab (solid points), and CLAS (crosses). The red bands display 1σ uncertainties for the LFHQCD EMC model. The number in parenthesis next to the experiment name in the legend is the normalization factor that multiplies all the data points, η_{exp} in Eq. (61).

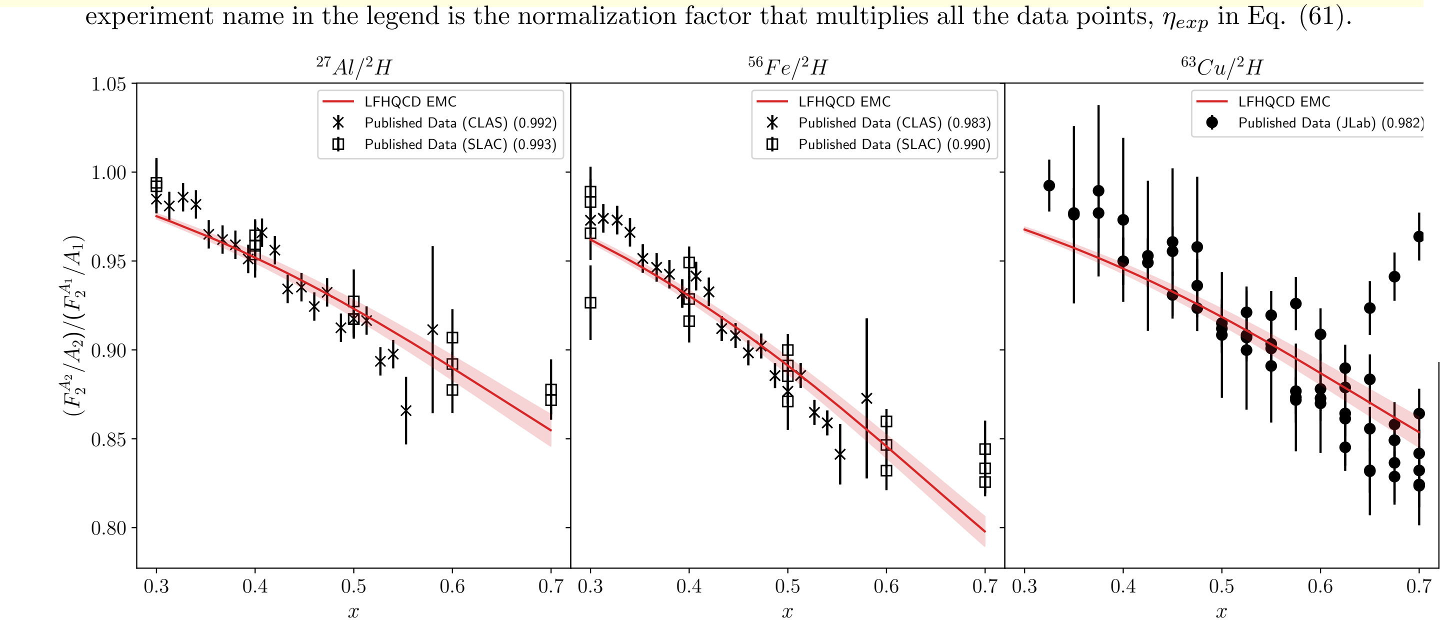
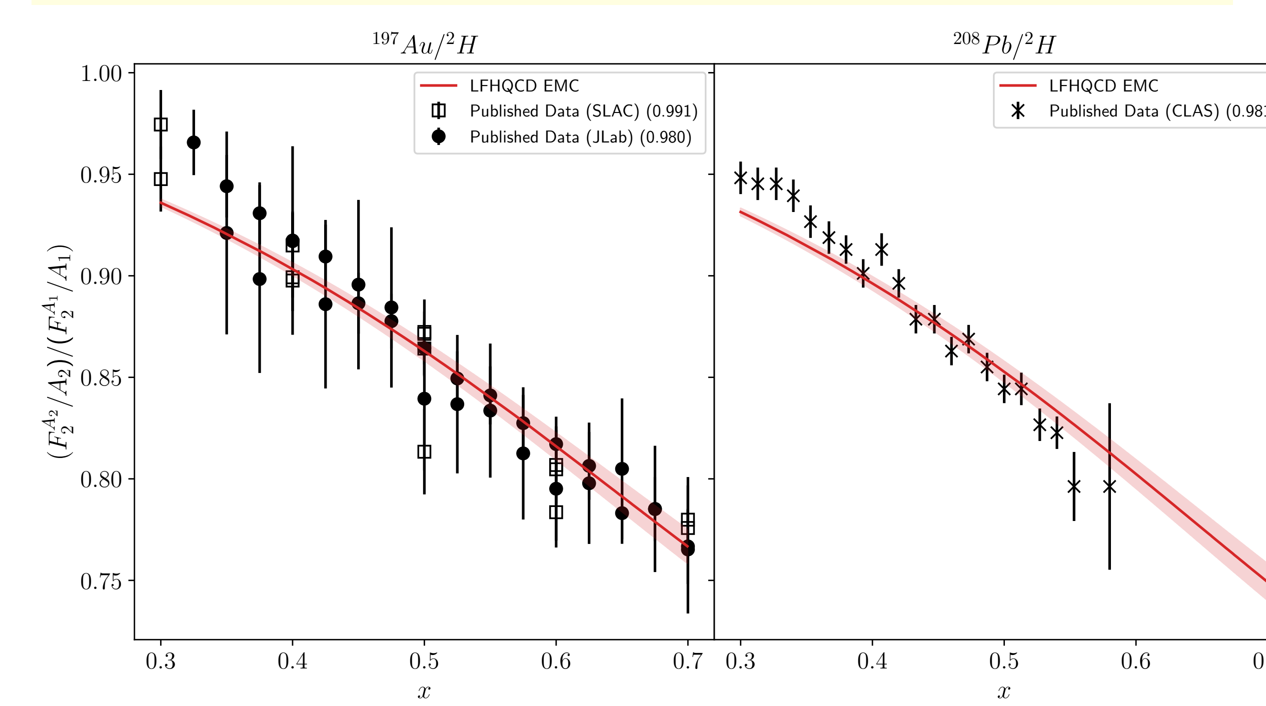


FIG. 5: EMC ratio comparisons between the LFHQCD model (red line) and experimental data (removed isoscalar corrections) obtained from SLAC (open boxes), JLab (solid points), and CLAS (crosses). The red bands display 1σ uncertainties for the LFHQCD EMC model. The number in parenthesis next to the experiment name in the legend is the normalization factor that multiplies all the data points, η_{exp} in Eq. (61).



δ & U large, consistent with SRC

These numbers are consistent with small medium modifications of proton radius

Summary

- Basic model is suppression of point like configurations, PLC
- Light front holographic QCD, based duality with a gravitational theory in 5 dimensions provides distribution functions (x) for PLC and BLC components
- x dependence accounts for EMC effect
- Values of parameter δ need to describe data indicate large virtuality is needed, so SRC explanation seems favored over mean field

Dmitriy (Dima) Kim