CLAS Collaboration

Moments of nucleon structure function F_2

<u>part III - complex nuclei</u>

part II - deuteron: PRC73

part I - proton: PRD67

M. Osipenko, October 19,
JLab12 meeting,
Rome 2009

Moments

QCD $\xrightarrow{\text{OPE}}$ Structure Function Moments

observable   calculable

$$M_n(Q^2) \equiv \int_0^1 dx x^{n-2} F_2(x,Q^2) = \sum_{\tau=2k}^{\infty} E_{n\tau}(\mu^2,Q^2) O_{n\tau}(\mu^2) \left(\frac{\mu^2}{Q^2}\right)^{\frac{1}{2}(\tau-2)}$$

n – operator spin
τ - operator twist
=dimension-spin
μ - arbitrary scale

evolution

static

R. Horsley, hep-lat/0412007

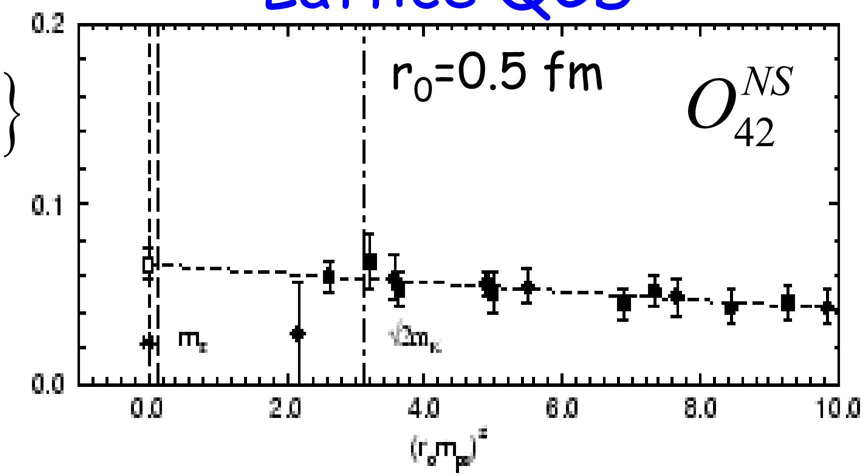
Perturbative QCD

$$E_{n\tau}(\mu,Q^2) \sim \left(\frac{\alpha_s(Q^2)}{\alpha_s(\mu^2)}\right)^{\gamma_n^\tau} \left\{1 + B_n^\tau \alpha_s(Q^2) + \ldots\right\}$$

γ_n^2 - anomalous dimension

B_n^2 - coefficient functions

Lattice QCD

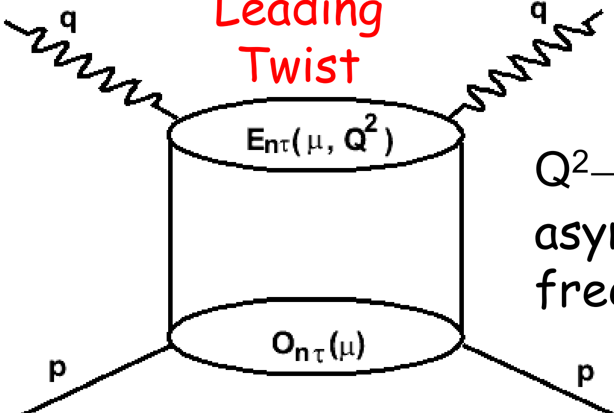


*Present technique of Lattice QCD can handle flavor Non-Singlet operators only (noisy disconnected diagrams cancel in such combination)
➔ necessary to measure moments of both the proton and neutron.

Twists

Higher Twists represent the virtual photon scattering off interacting (correlated) partons: e.g. diquarks, entire nucleon etc.

Leading Twist



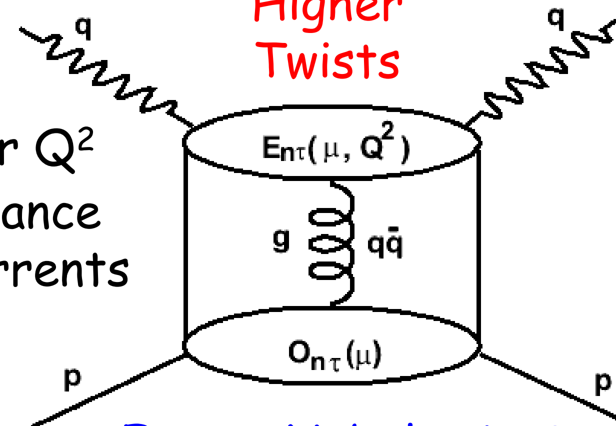
Nobel prize 2004!

$Q^2 \to \infty$
asymptotic freedom

+

lower Q^2
larger distance between currents

Higher Twists



Future Nobel prize?

- Twist separation through Q^2-evolution study of the moments in a large Q^2 interval

X. Ji and Unrau, PRD52

Leading twist

Higher twists suppressed in DIS by $1/Q^\tau$

$$M_n(Q^2) = LT_n(\alpha_S) + \sum_{\tau=2k} a_n^\tau(\mu)\left(\frac{\alpha_s(Q^2)}{\alpha_s(\mu^2)}\right)^{\gamma_n^\tau}\left(\frac{\mu^2}{Q^2}\right)^{\frac{\tau-2}{2}}$$

Operator matrix element

LO Coefficient function

* a_n^τ and γ_n^τ are known only in few cases:

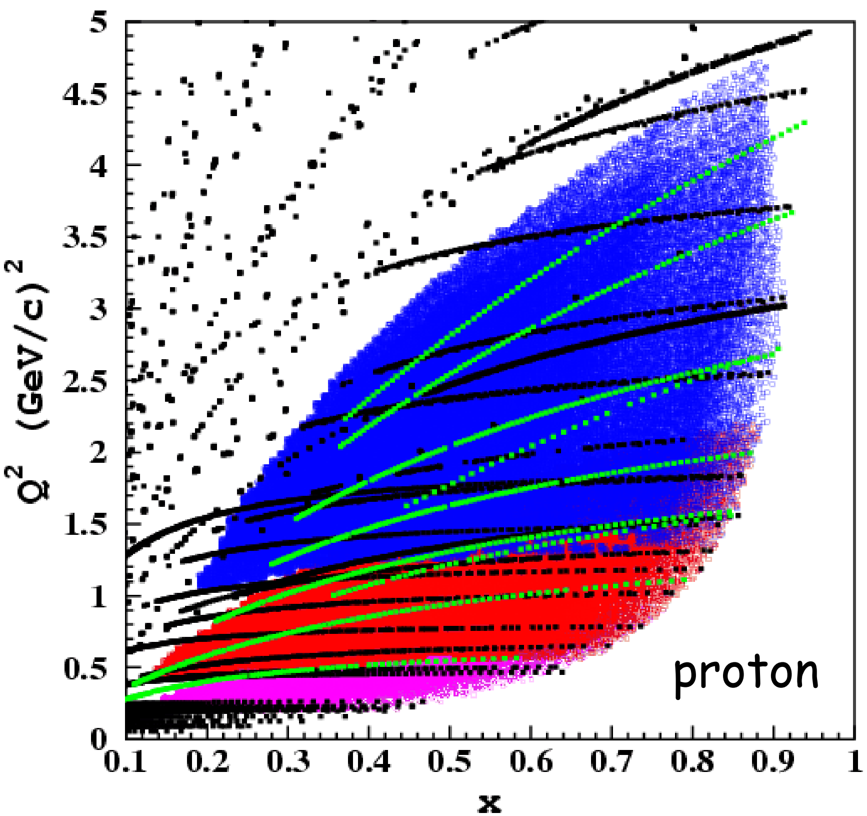
E.Shuryak and A.Vainstein, NPB201
H.Kawamura, MPLA12

M. Osipenko

CLAS F_2 Data

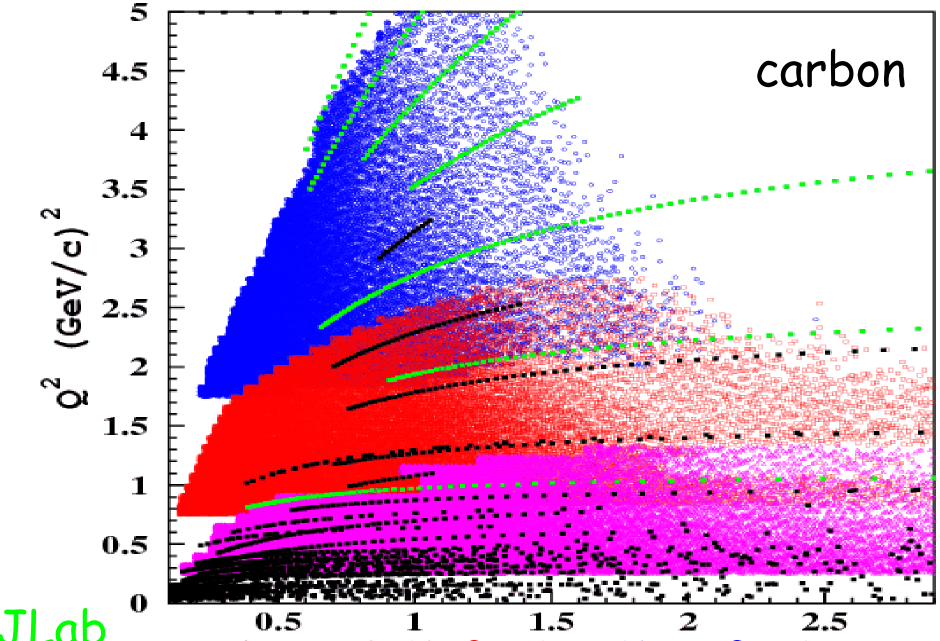
- Continuous two-dimensional kinematics
- Wide x-coverage at each fixed Q^2
- Very detailed large-x region
- $R = \sigma_L / \sigma_T$ is known from Hall-C experiment: C. Keppel E94-110

CLAS 1.5 GeV + 2.5 GeV + 4 GeV

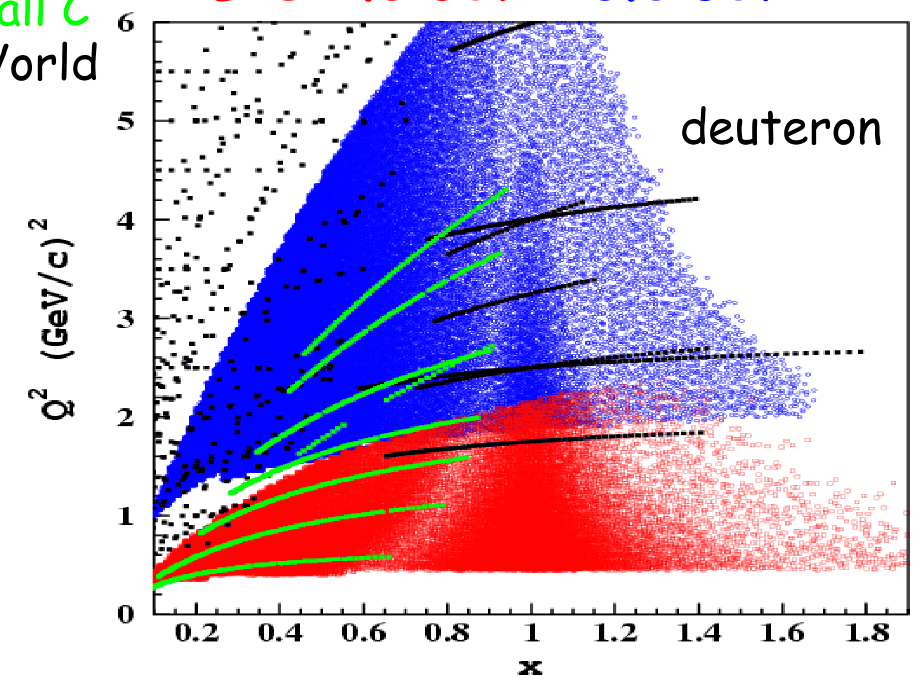


JLab Hall C
World

CLAS 1 GeV + 2 GeV + 4.4 GeV

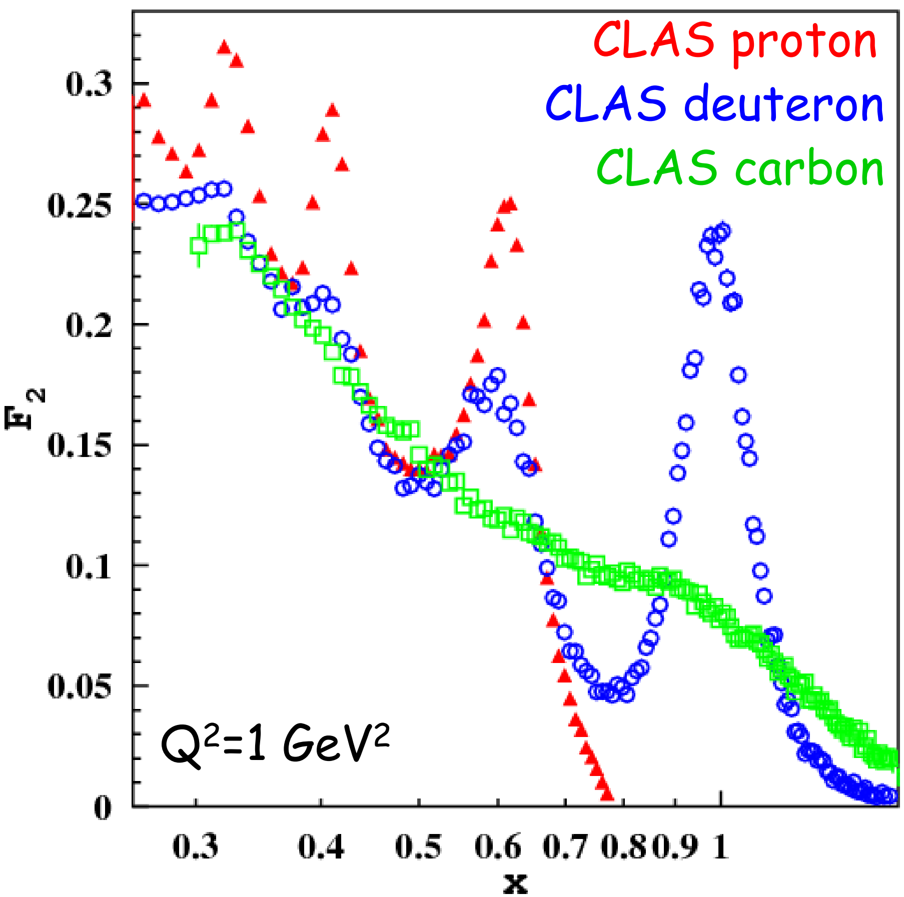


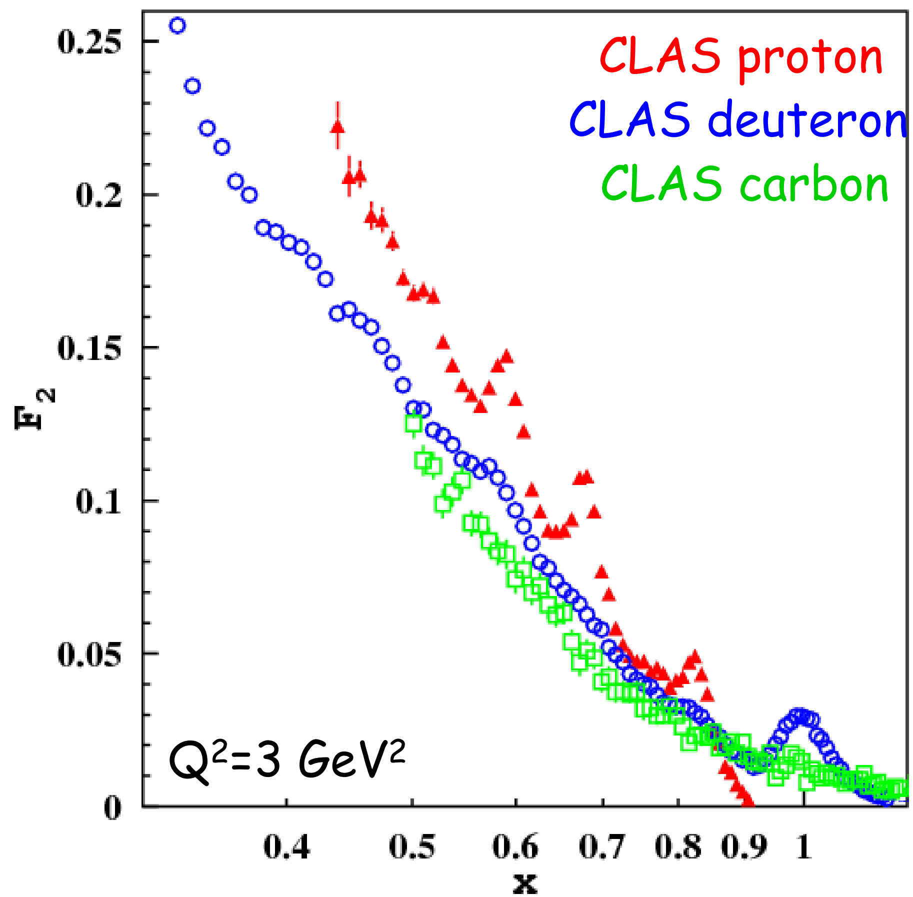
CLAS 2.5 GeV + 5.8 GeV



F_2 Nuclei vs. Proton

- The measurements of the nuclear structure functions were performed in the same bins as for proton F_2.
- Resonance peaks seem to be smaller in the deuteron and completely disappeared in carbon even at low Q^2. But, mostly it is the effect of the Fermi motion.

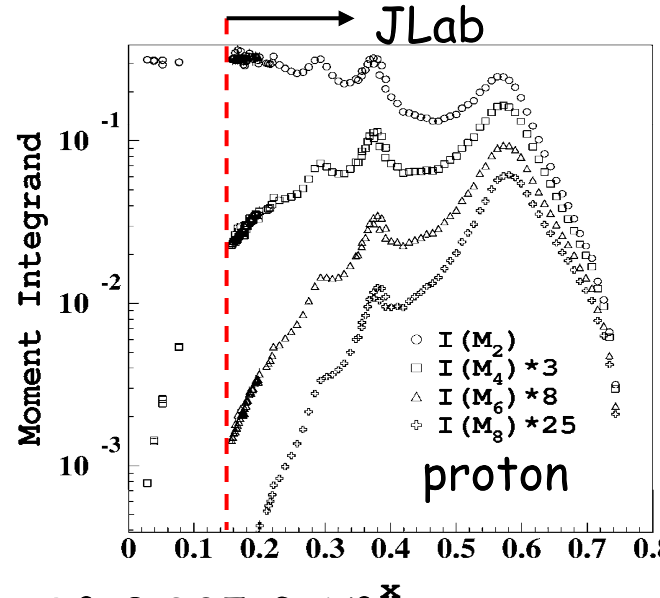




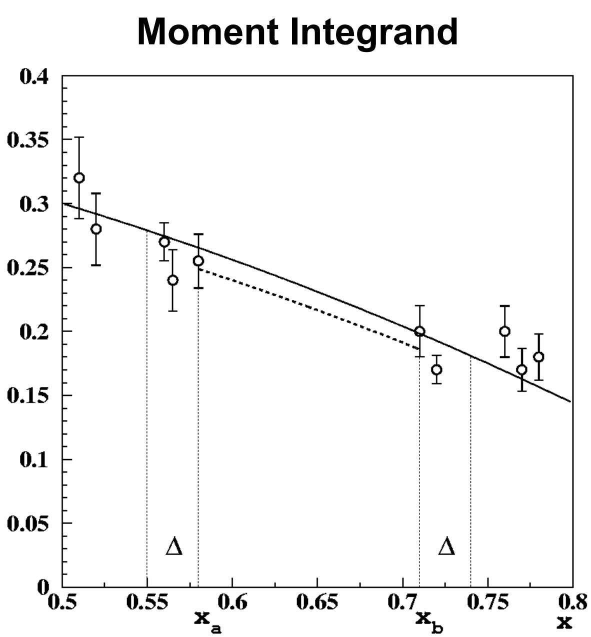
Extraction of moments

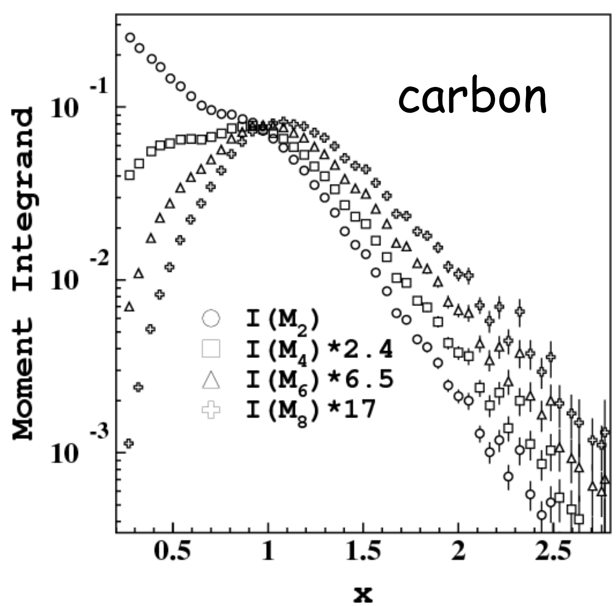
- CLAS data cover most significant region for higher moments (n>2)
- For nuclei we also measured the quasi-elastic peak at each Q^2 value
- Extraction method is essentially independent of x-behavior of the structure function

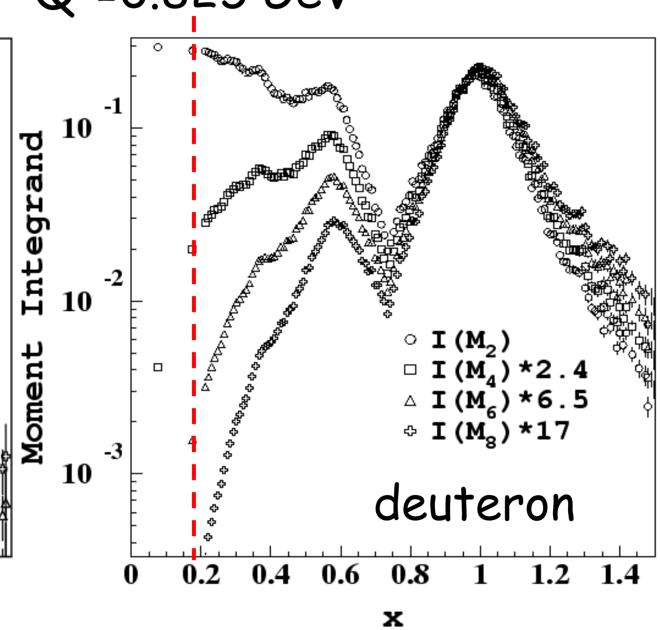
➔ Reliable evaluation of the Q^2-evolution of structure function moments.



Q^2=0.825 GeV^2





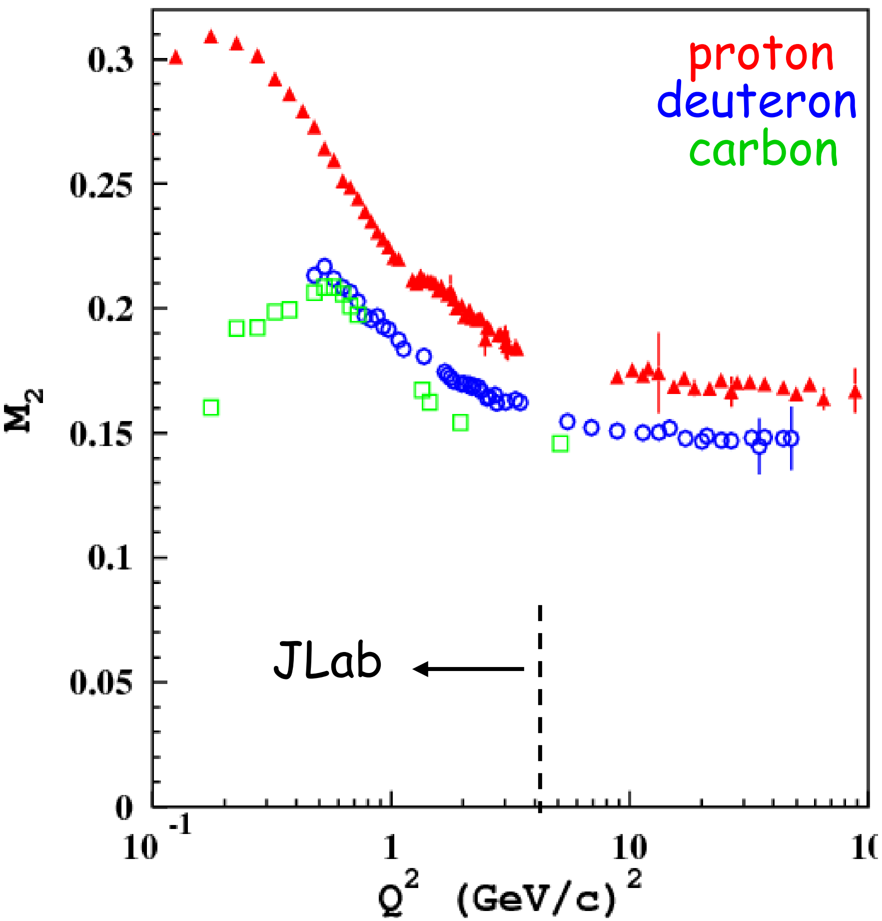


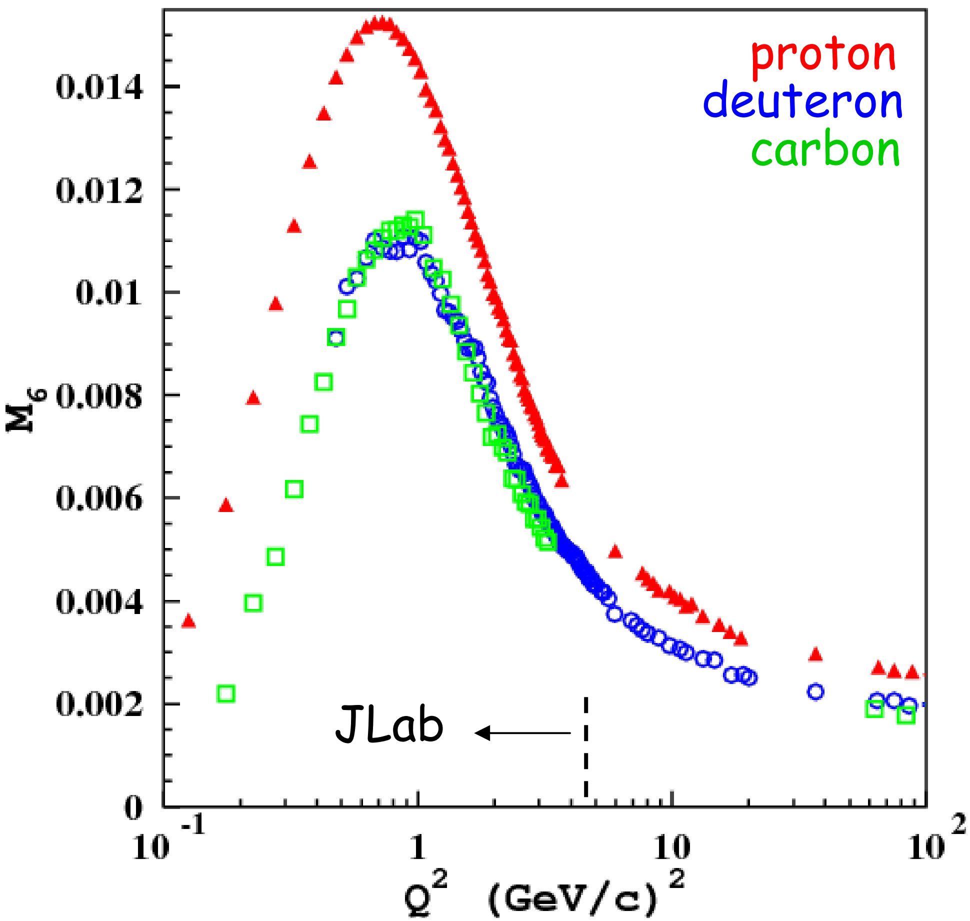
Moments

- Leading Twist Q^2-evolution is the same for the proton, deuteron and carbon.
- Higher Twist contribution in nuclei contains additional nuclear HT terms

➔Proton and nuclear moments have similar Q^2-behavior suggesting a small contribution of nuclear Higher Twists.

- Carbon moments are very similar to the deuteron ones.



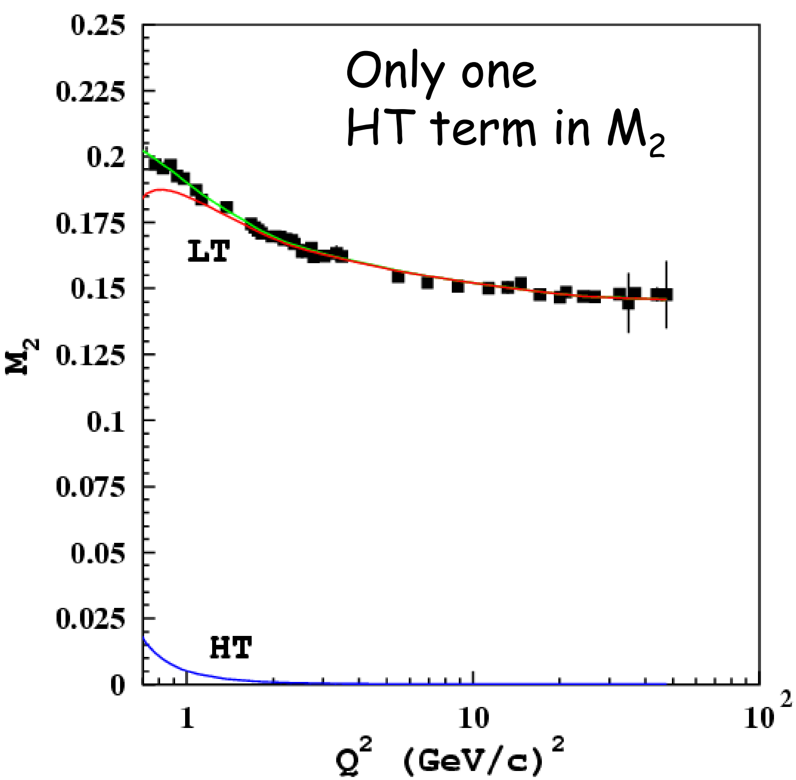


Twist Expansion

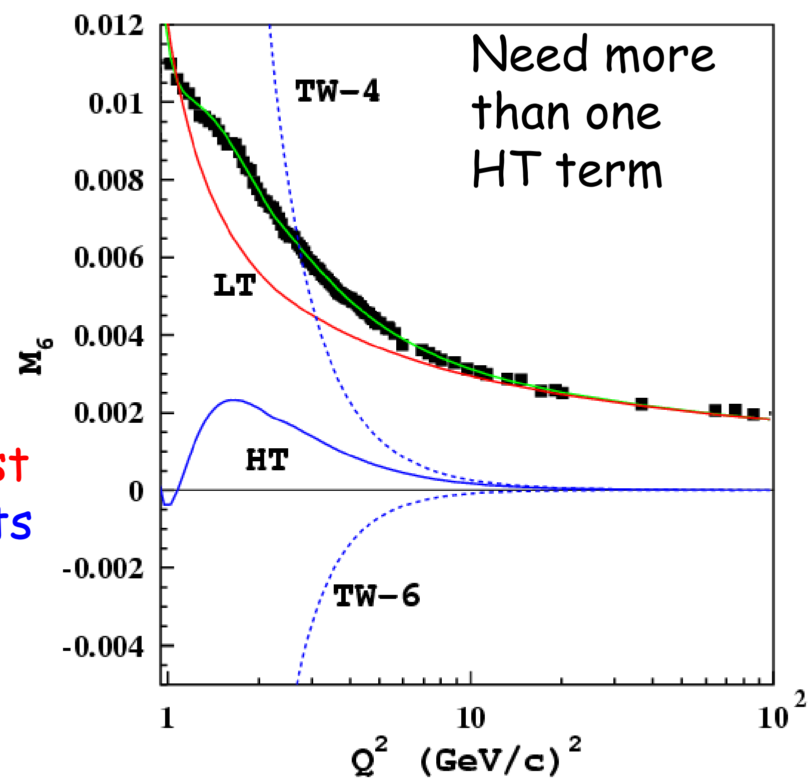
Leading and Higher Twists were separated by fitting the data with the following expression:

$$M_n(Q^2) = LT_n(\alpha_S) + \sum_{\tau=4,6} a_n^\tau \left(\frac{\alpha_s(Q^2)}{\alpha_s(\mu^2)} \right)^{\gamma_n^\tau} \left(\frac{\mu^2}{Q^2} \right)^{\frac{\tau-2}{2}}$$

- Leading Twist is determined by one free parameter $LT_n(\mu^2)$
- Higher Twist contribution is described by four free parameters $a_n^4, \gamma_n^4, a_n^6, \gamma_n^6$



Fit
Leading Twist
Higher Twists

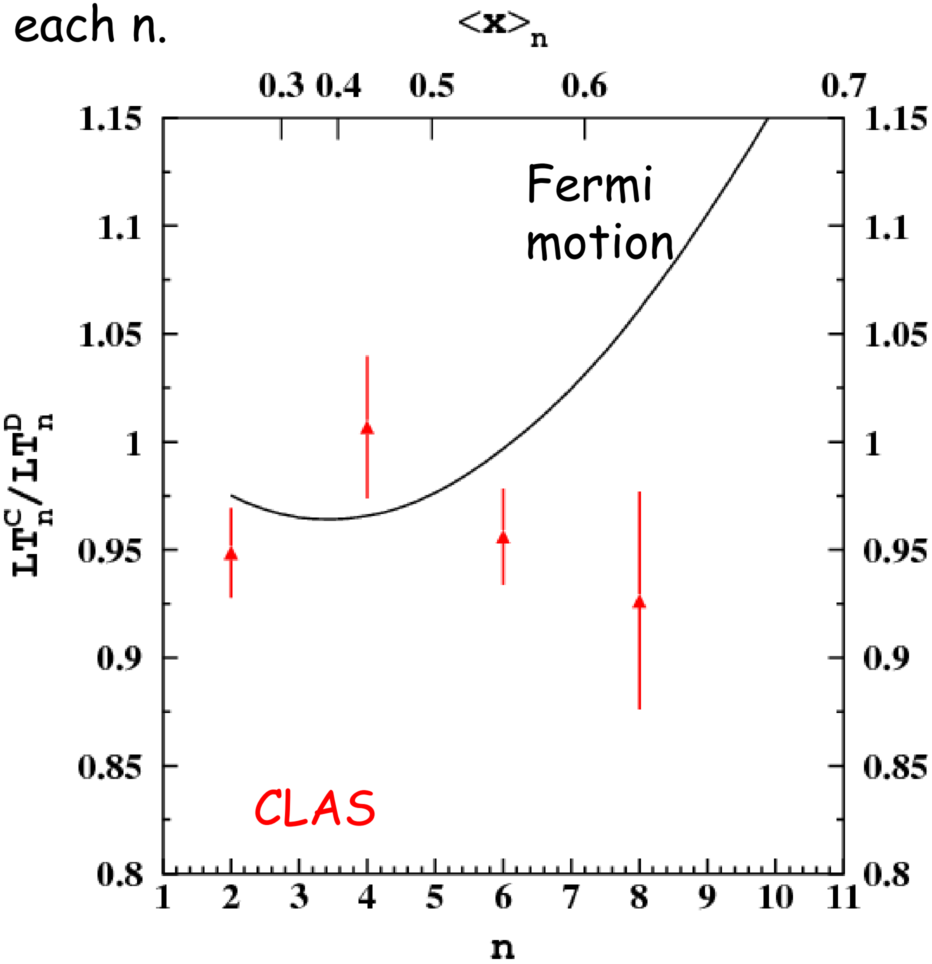


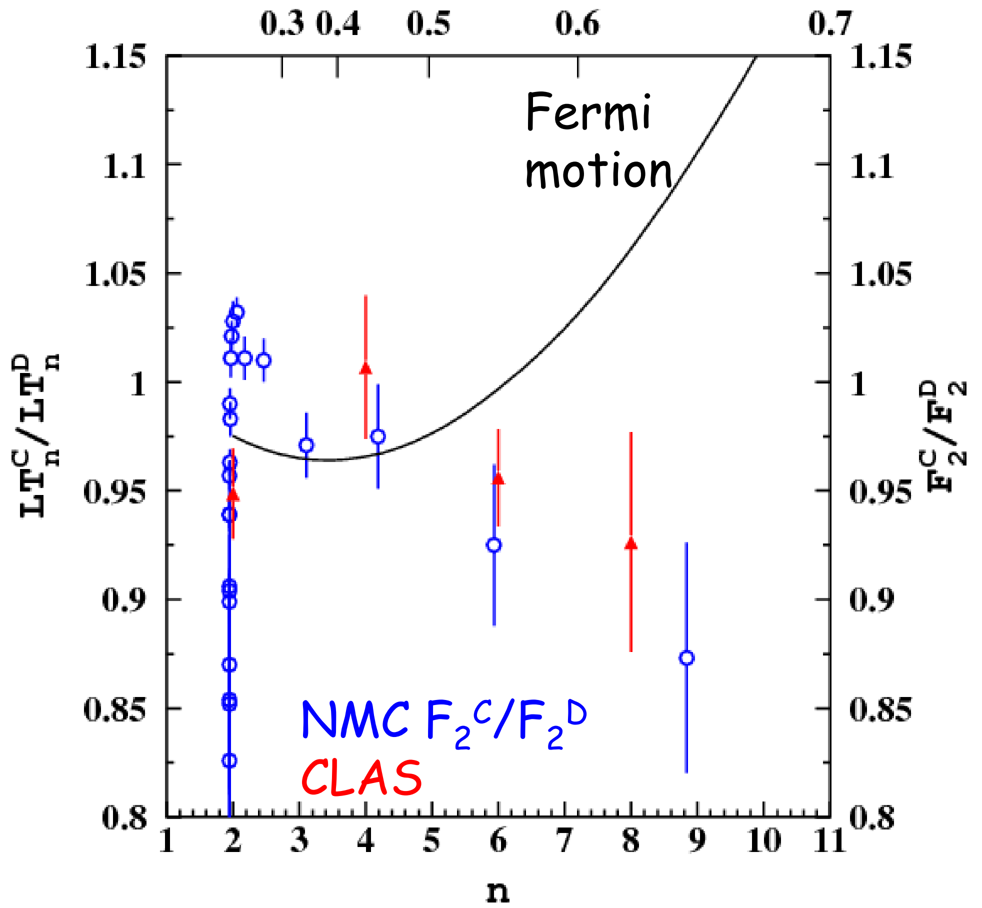
M. Osipenko

EMC effect: Leading Twist

- Ratio of C/D moments exhibits deviation from IA Fermi motion prediction, demonstrating EMC effect discovered in x-space.
- The ratio of moments is in good agreement with the ratio of the structure functions taken at average value of x for each n.

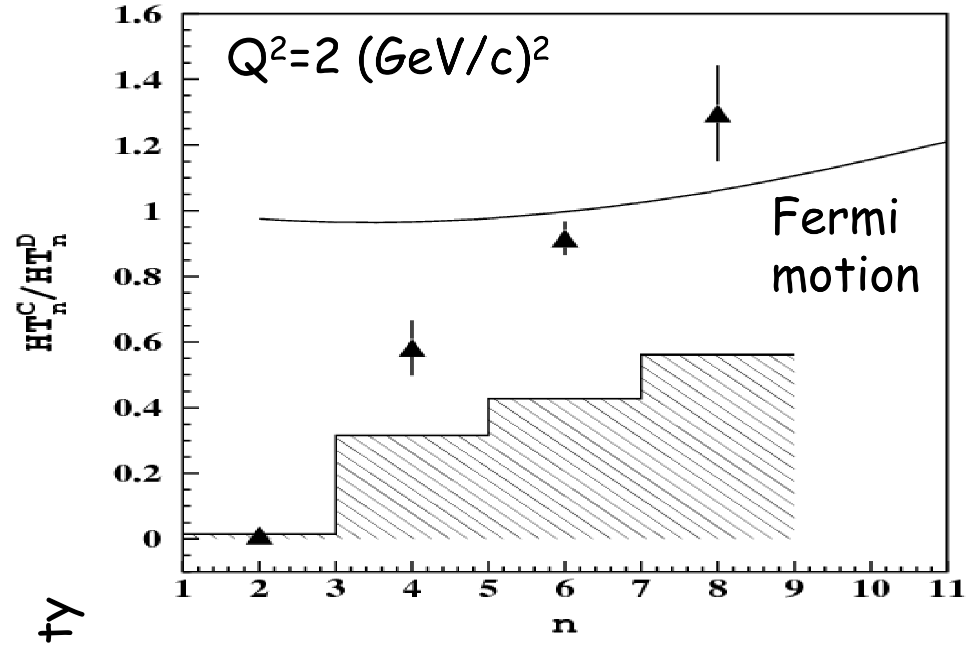
$$\frac{LT_n^C}{LT_n^D} = \frac{\int_0^{12} dz f^C(z) z^{n-1}}{\int_0^{2} dz f^D(z) z^{n-1}}$$

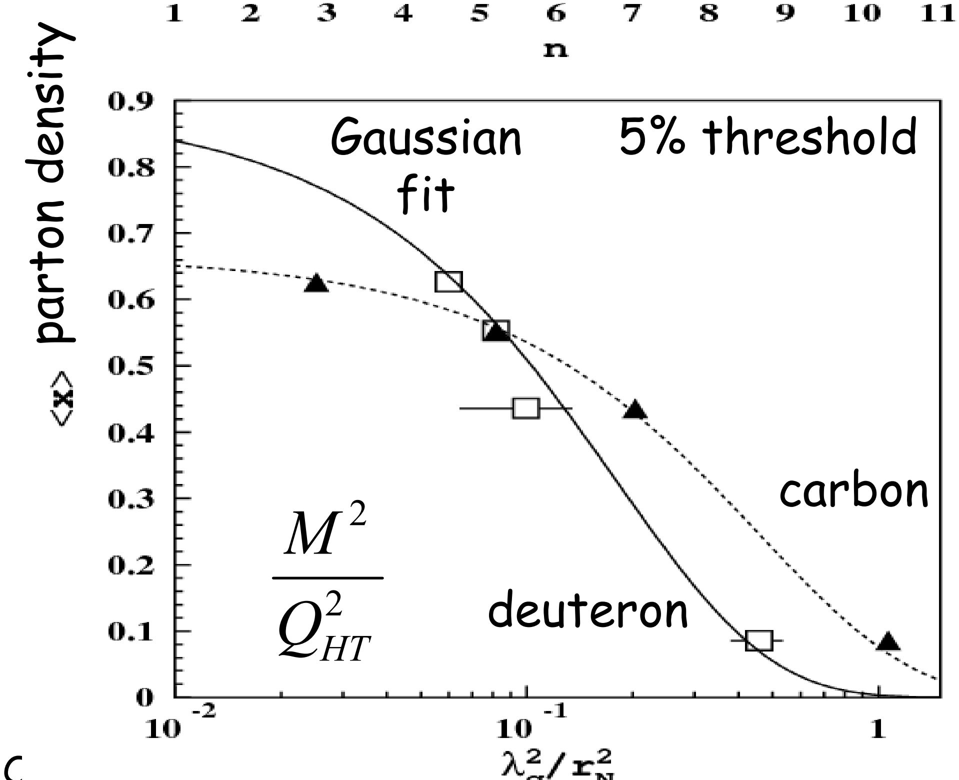




HTs in Nuclei

- Ratio of Higher Twists in carbon and deuteron, taken at fixed Q^2, demonstrates linear rise with n;
- At small n<8 the Higher Twist contribution in carbon is smaller than in the deuteron;
- For n=2 the Higher Twist contribution in carbon is compatible with zero;
- The suppression of Higher Twists in complex nuclei can be related to a partial quark deconfinement;
- For higher moments n>=8 the contribution of Short Range Correlations, found in the region x>1, becomes important. This contribution, not related to internal nucleon structure, may be responsible for the rise of nuclear Higher Twists with n.





Summary

•Carbon structure functions F_2 were measured in continuous two-dimensional kinematical range of x and Q^2;

•These data combined with all previous measurements were used to obtain experimental moments of the structure function F_2;

•Extracted moments were analyzed in terms of Operator Product Expansion;

•The ratio of Leading Twists of carbon to deuteron reveals EMC effect compatible with that in the x-space.

•The ratio of Higher Twist contributions in carbon and deuteron is found to be suppressed for low n and increasing rapidly with n.

•The draft of the paper is in AdHoc review of CLAS Collaboration.
WG review (Nuclear): Michael Dugger (chair), Tony Forest, Rakhsha Nasseripour
Started – September 27, 2007,
Approved – February 12, 2009, →1 year and 4 months
AdHoc review: Tony Forest (chair), Stepan Stepanian, Chaden Djalali
Started – April 10, 2009
Today – October 19, 2009 → 7 months