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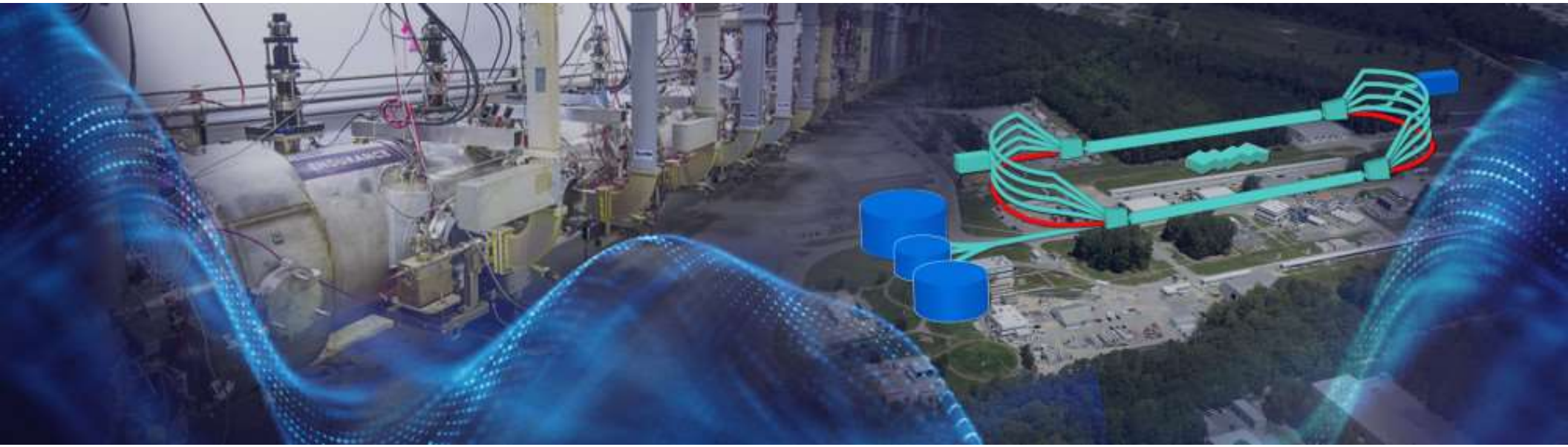
Super-fast quarks at the Luminosity Frontier

John Arrington, Lawrence Berkeley Lab

Science at the Luminosity Frontier: JLab at 22 GeV
Jefferson Lab, Jan 25 2023



Modification of nucleon structure in nuclei

- The EMC effect*
- Understanding nucleon modification is extremely interesting and important*

*See the 10 other talks in this session

Modification of nucleon structure in nuclei

- The EMC effect*
- Understanding nucleon modification is extremely interesting and important*
- Super-fast quarks! EMC effect in a completely new regime
    - Nuclear pdf modification in region where pdfs are very small

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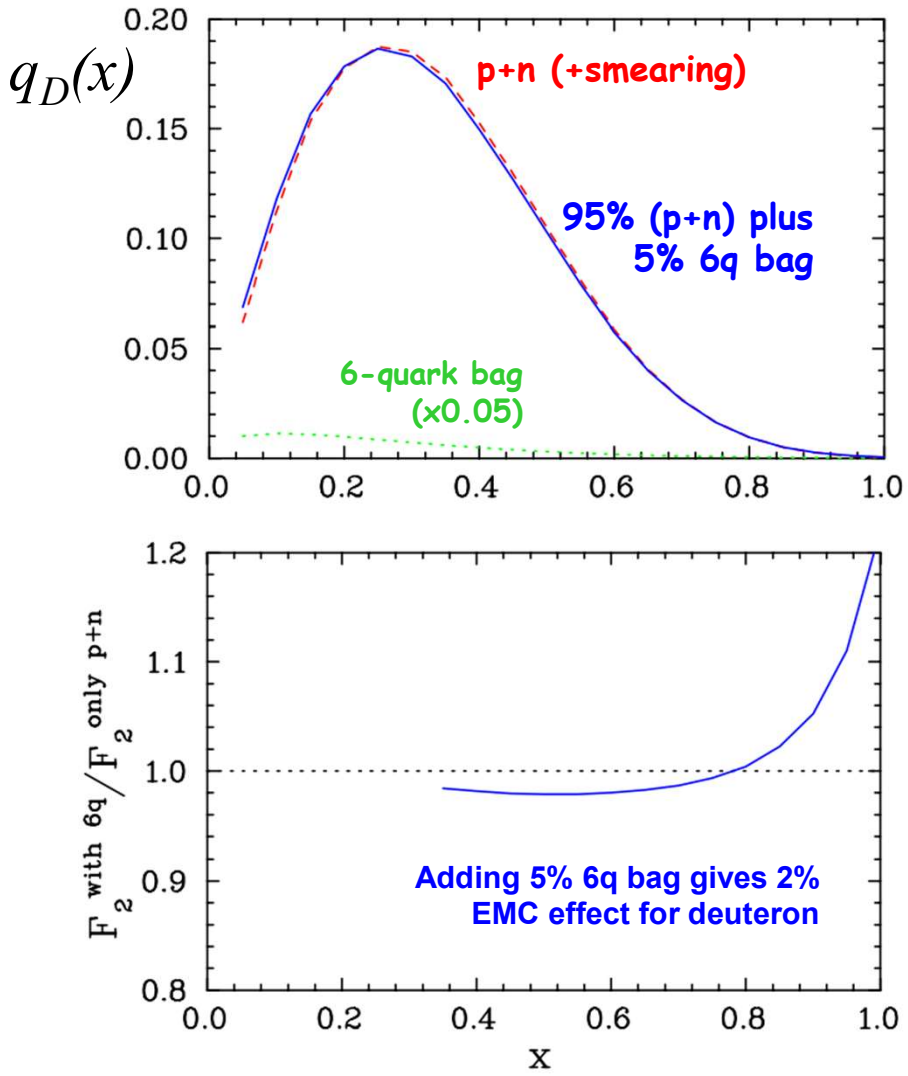
Nuclear pdfs at x>1

- Six-quark bag was potential explanation for the EMC effect
  - Two interacting 3q bags ≠ one 6q bag
  - Impact in the EMC effect region very small



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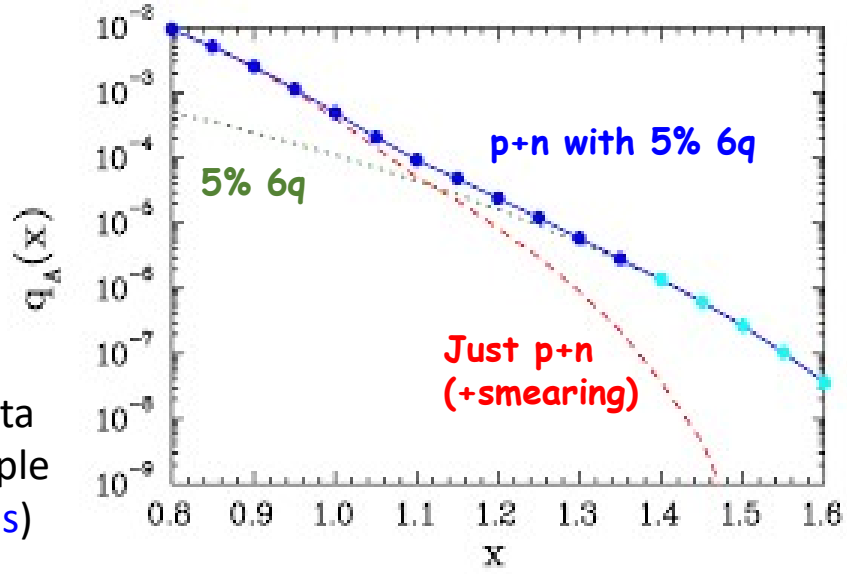
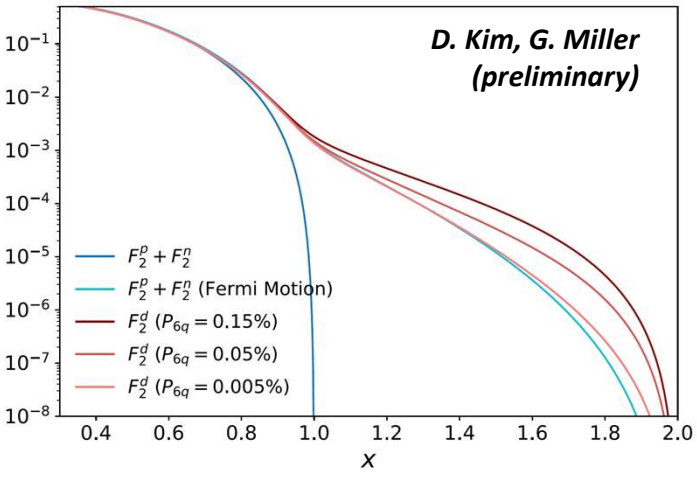
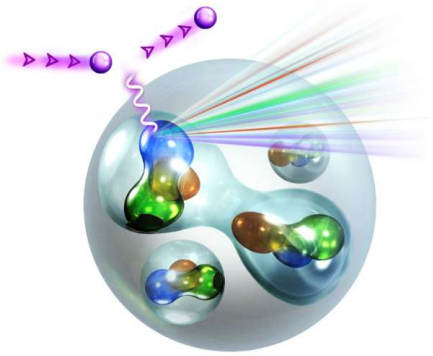
- Momentum sharing more important at largest quark momenta
  - **Dramatic enhancement** (order of magnitude) over simple convolution (high-x quarks in high-momentum nucleons)

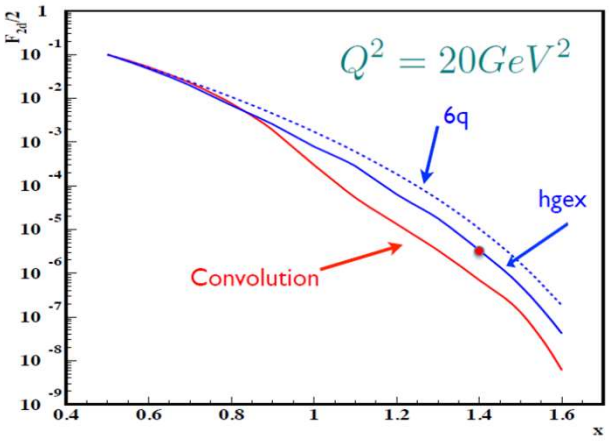
- Similar for any mechanism that allows direct momentum sharing, while off-shell effects and other models suggest suppressed pdfs







Other calculations for super-fast quarks



Convolution, hard gluon exchange, 6q bag – all yield enhancement for x>1

Misak Sargsian and Christian Weiss

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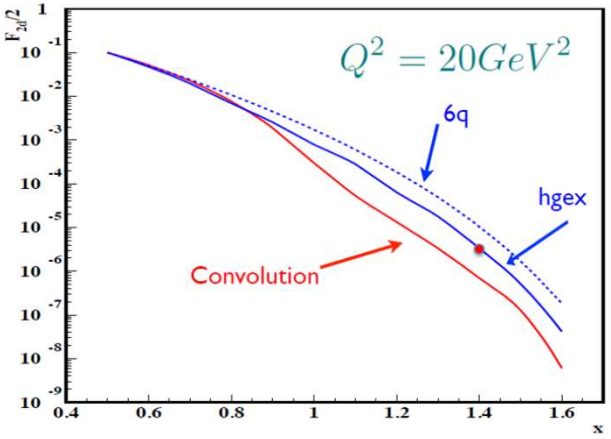

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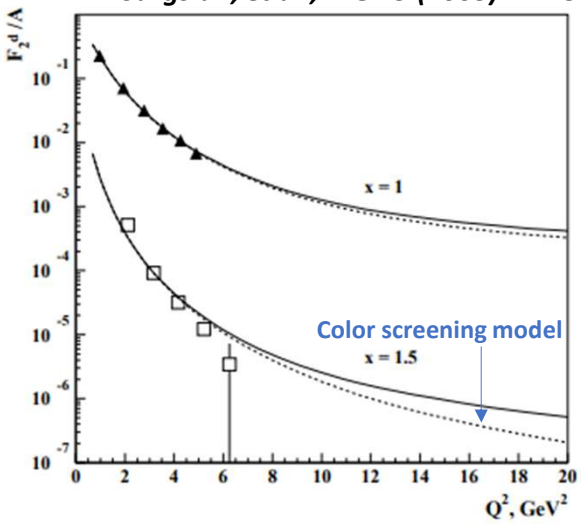
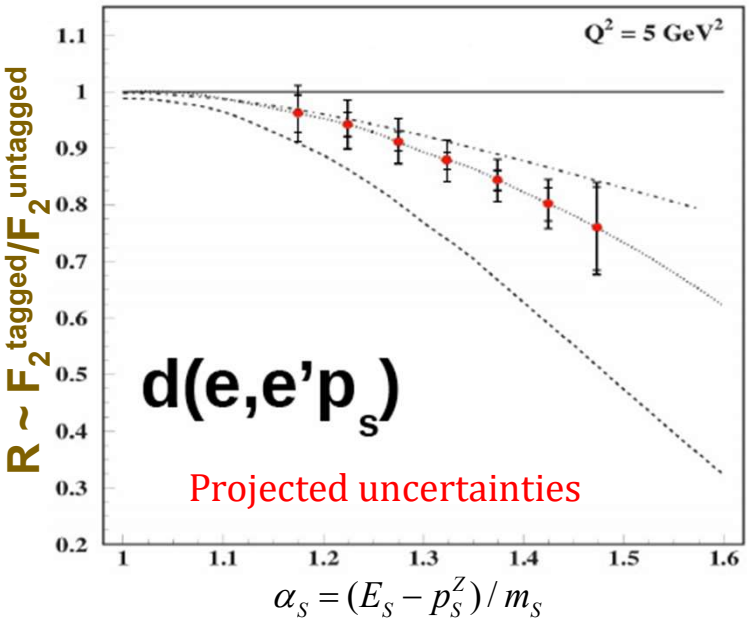
M. Sargsian, et al., JPG 29 (2003) R1-45



From E12-11-10 proposal



Various models (color screening, PLC suppression, rescaling, off-shell) yield suppression in tagged scattering for large nucleon momenta, large x → large (~factor 2) F_2 suppression for x>1

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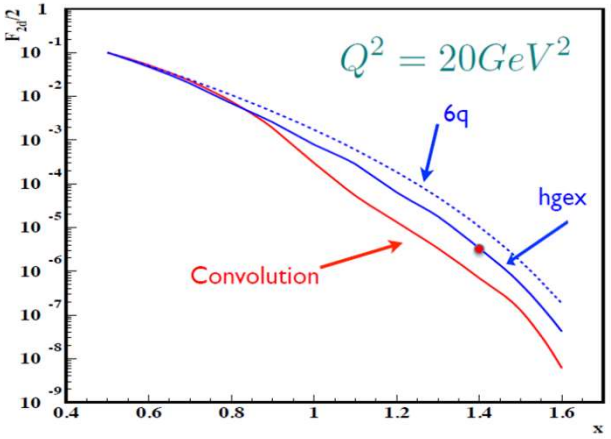

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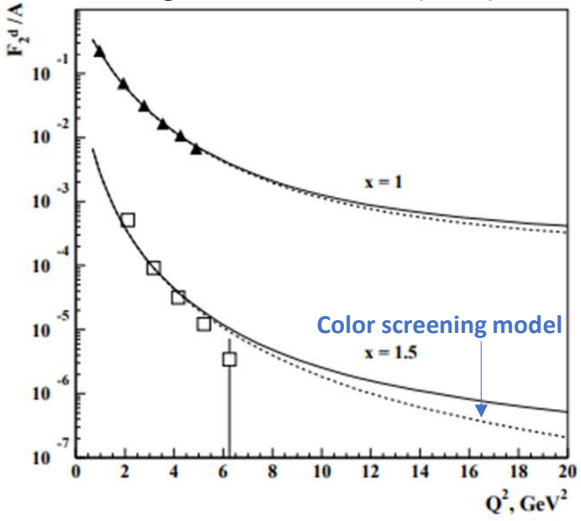

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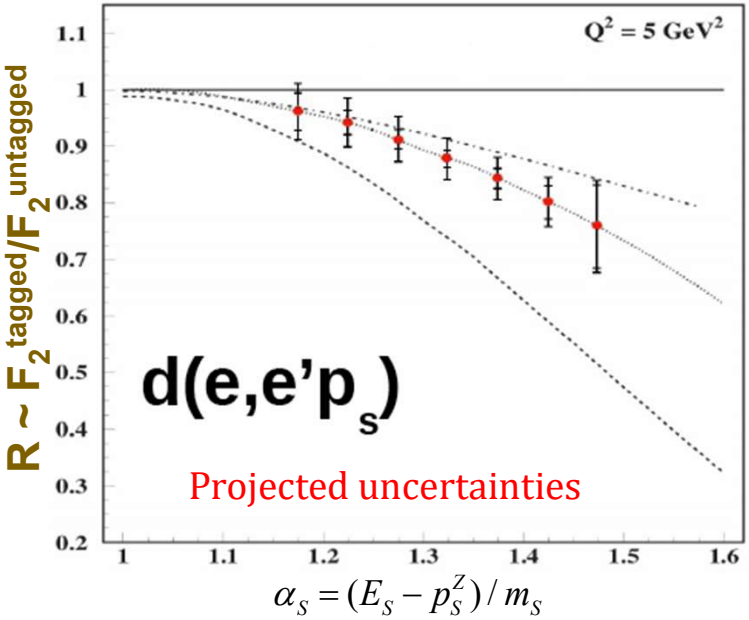

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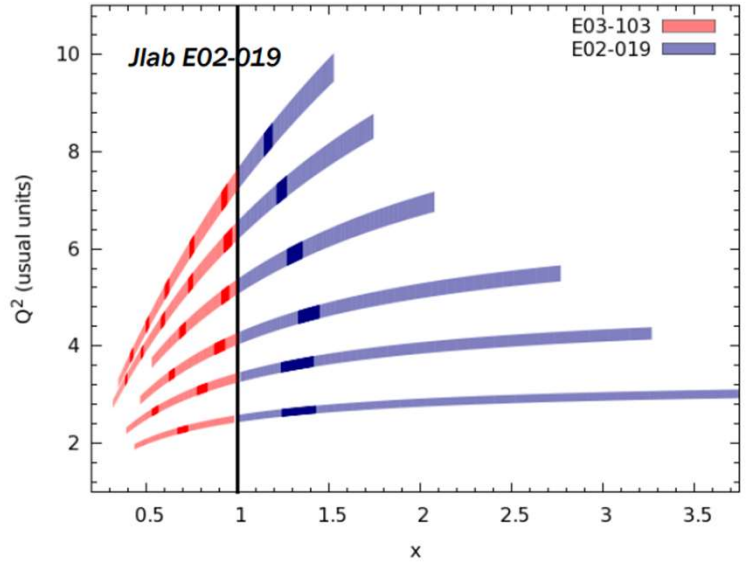
Updated predictions of $F_2(x)$ at x>1 in progress: Sargsian, Li, Kim, Miller, JA…

Important to have consistent evaluation (pdfs, Q^2,…)

Challenges to interpreting SFQ distributions

- **High energies needed to isolate DIS at large x**
  - **6 GeV experiment limited to 8-9 GeV^2**
- Cross section very small (x>1, high Q^2)
- Need reliable calculations to use as 'baseline'



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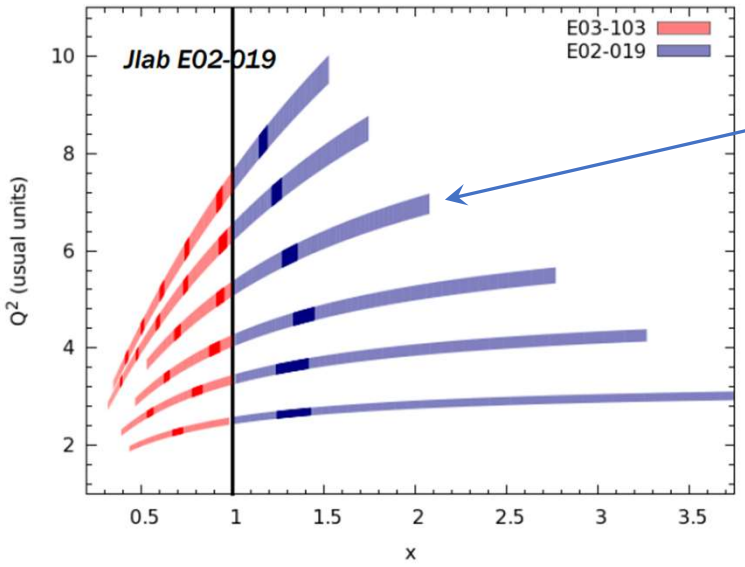

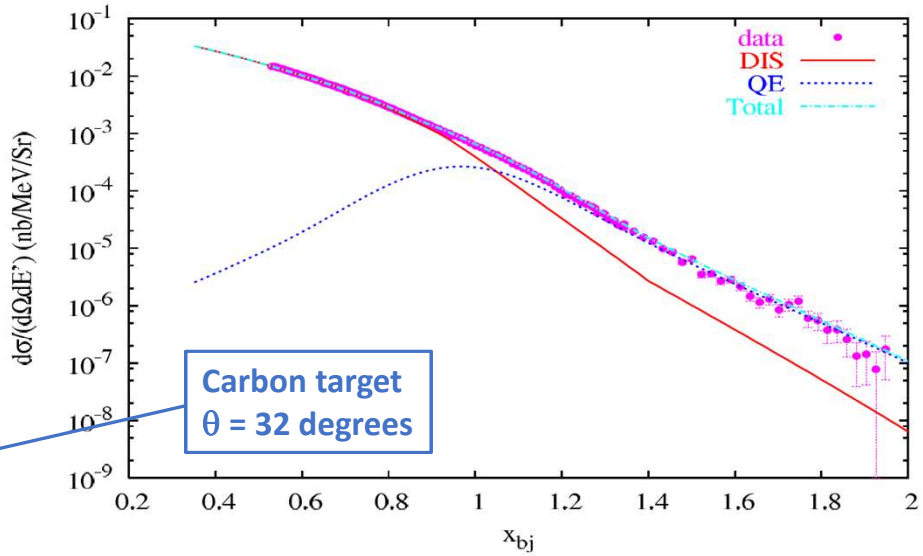

QE (blue) vs Inelastic (DIS + Resonance) (red)

QE dominated for x>1.1, and inelastic has significant resonance and DIS contributions

Not at all clear that structure function would provide access to pdfs or scale like DIS

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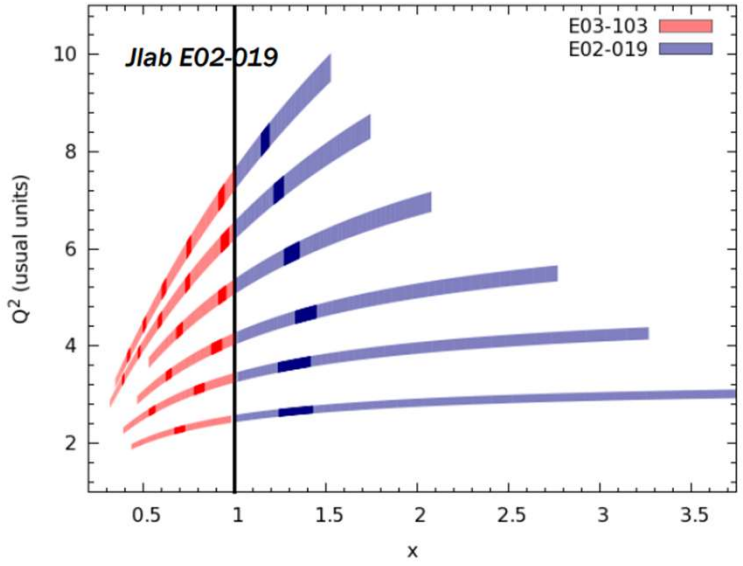
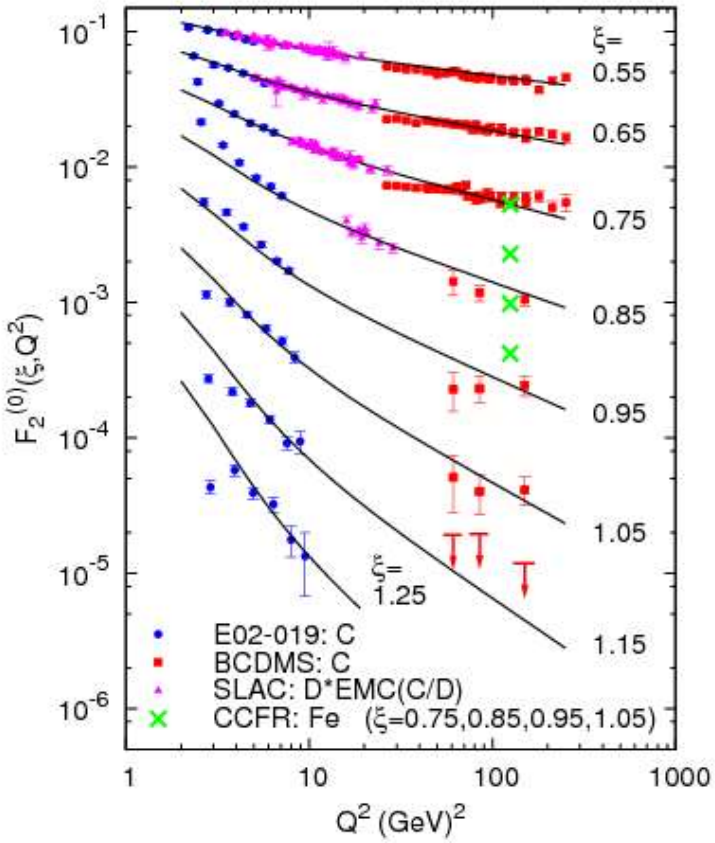


At 6 GeV, high Q^2 data consistent with DIS data up to x ≈ 0.8 and consistent with QCD scaling behavior for x>1

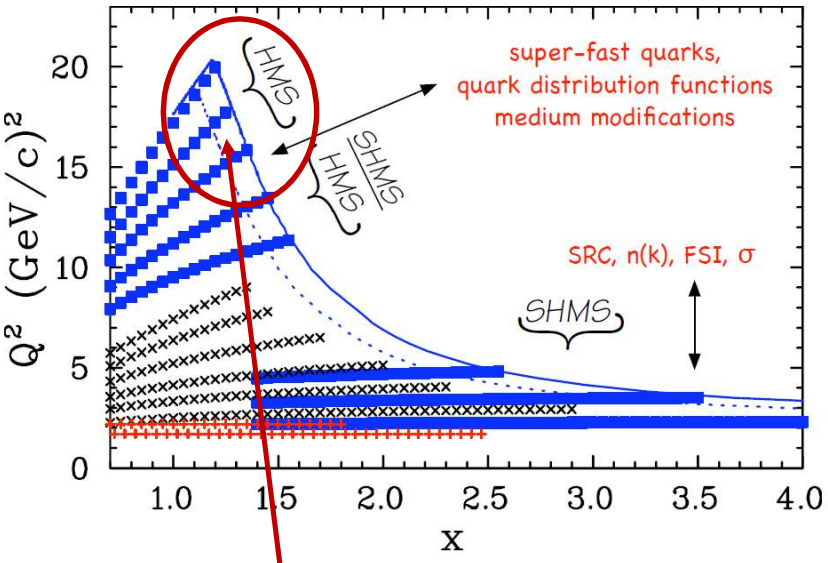
Consequence of *quark-hadron duality*

N. Fomin et al, PRL 105 (2010) 212502



JA, et al, PRC 73 (2006) 035205

SFQs at 11 GeV



SRCs at x>1 at 12 GeV
[E06-105: JA, D. Day, N. Fomin, P. Solvignon]

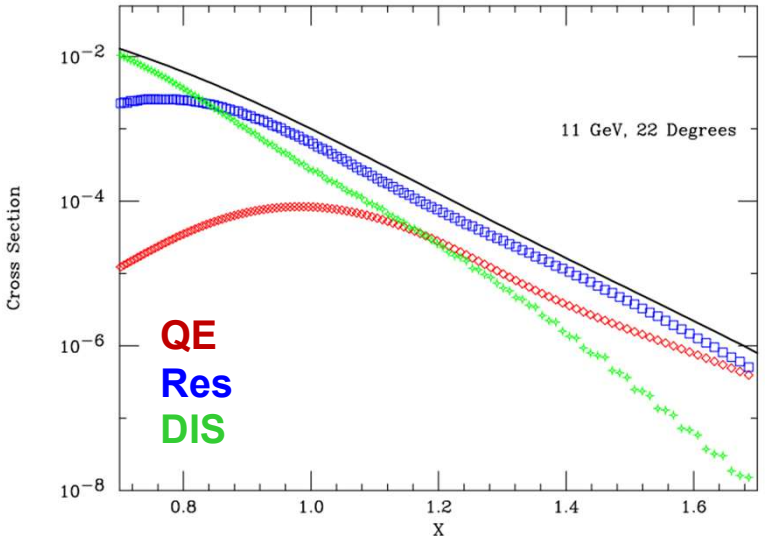
Currently running in Hall C with EMC effect experiment E12-10-008

Inclusive scattering at x>1; push to largest Q^2 to study super-fast quark distributions

Q^2 was scaled back from proposed kinematics (above)

22 degrees: F_2 dominated by resonance region

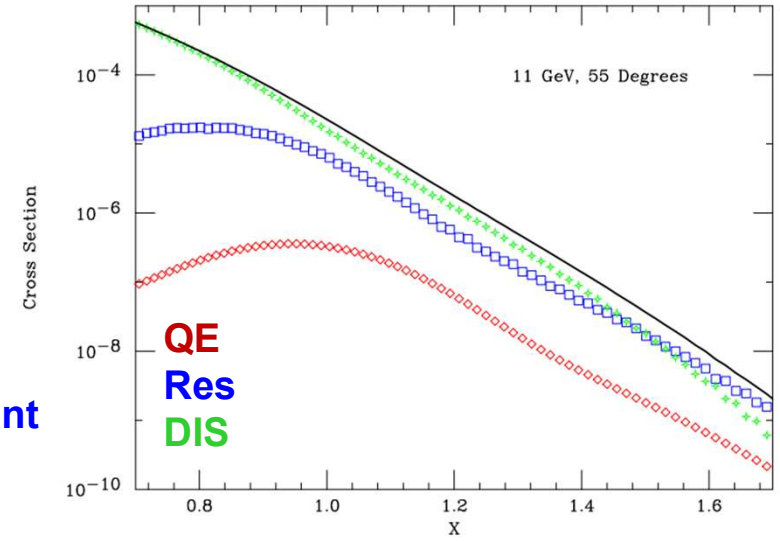
(QE & DIS small)



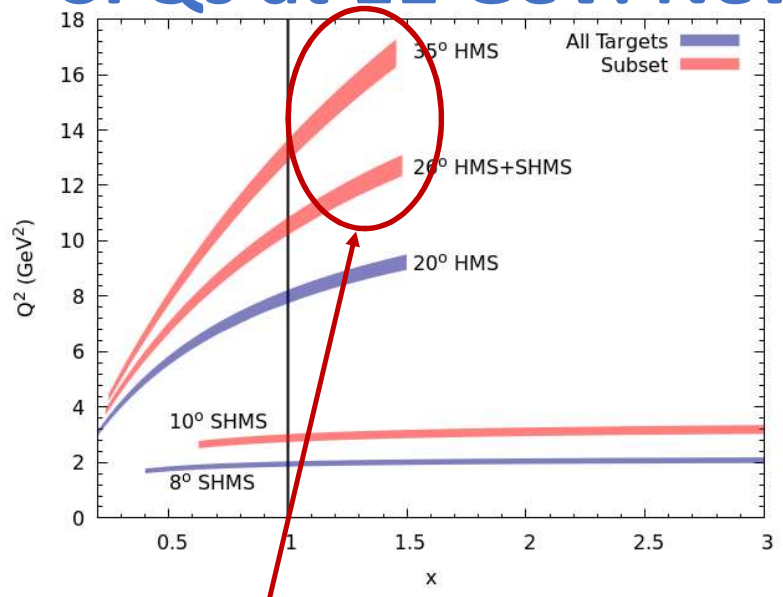
55 degrees: DIS dominated x<1.4

resonance important

(QE negligible)



SFQs at 11 GeV: New kinematics



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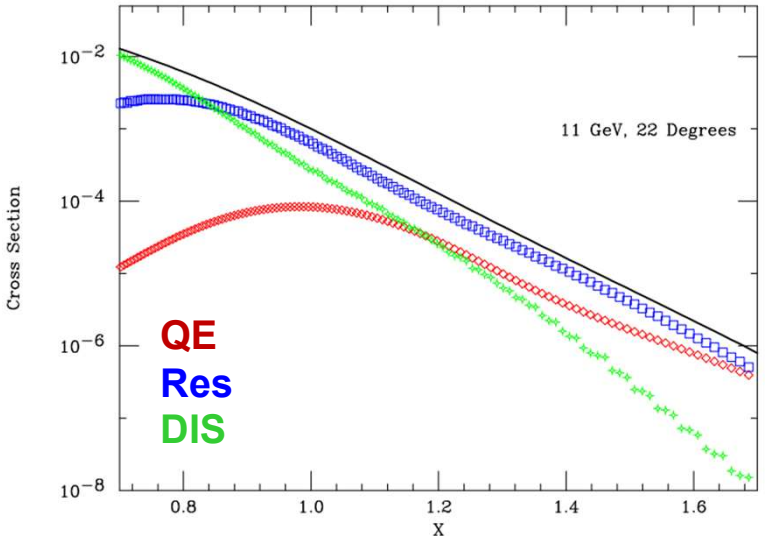

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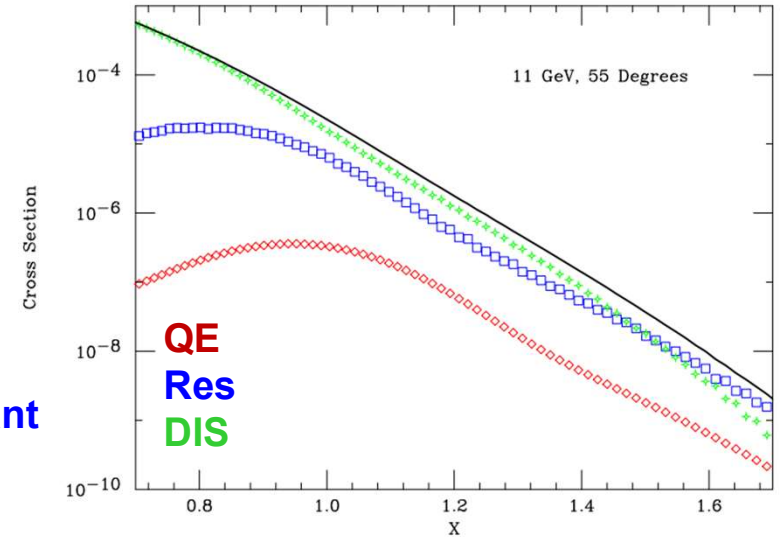
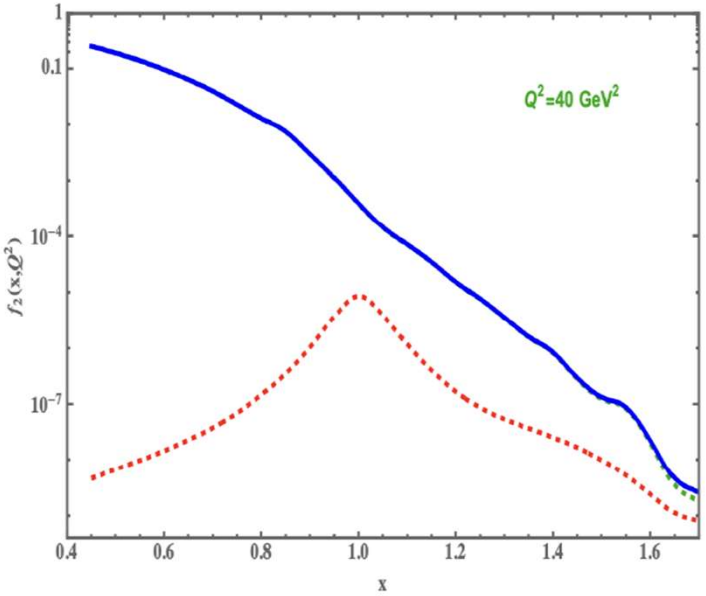


22 GeV

- 6 GeV data, $Q^2<8$ GeV^2: QE dominated, looks ("by eye") consistent with scaling
- 11 GeV, $Q^2<16$ GeV^2 : DIS comparable to resonance region; QE small
  - Not a precise measurement of pdfs; expect modest scaling violations (which can be measured)
  - Could be very compelling if very large deviations observed
- 22 GeV, $Q^2 \approx 36$ GeV^2
  - Much smaller resonance contributions
  - Better check of scaling (Q^2 dependence)
  - Push to higher x at 'lower' Q^2 – larger predicted effects

Plot (Sargsian) illustrates small QE contribution
Need to update Resonance vs DIS estimate



Kinematic projection (not quite right yet)

- 24 GeV: made kinematic/cross section projections 1992 CEBAF@HE workshop
  - Don't have electronic versions of full results
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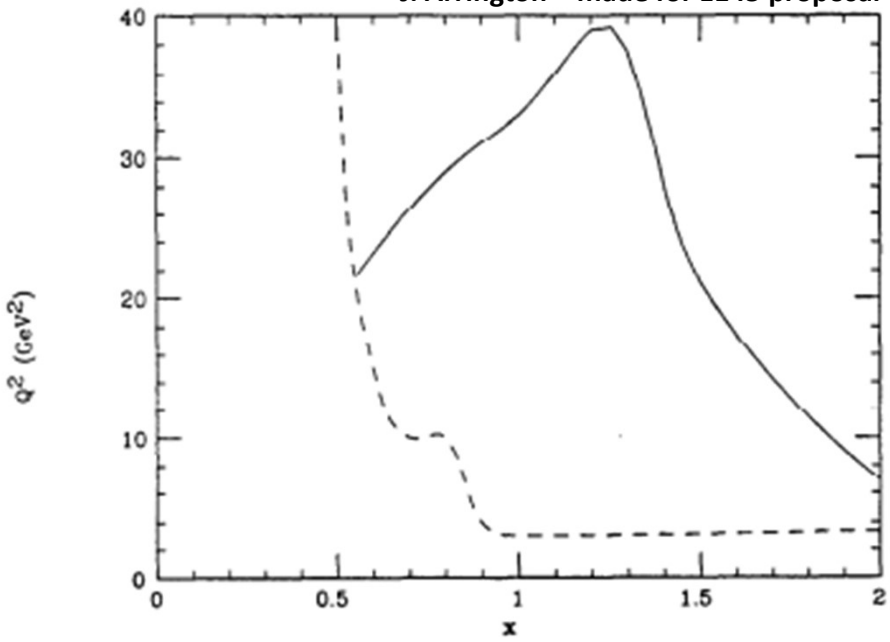
- 23 GeV projections: SLAC E145 proposal (1992)
  - 2uA, 3.4 msr solid angle
  - 15cm LD2 target, 6-12% R.L. targets
  - $\theta_{max} < 35$ degrees at highest Q^2

J. Arrington – made for E145 proposal



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- 22 GeV projections
  - Straightforward; still need to be done

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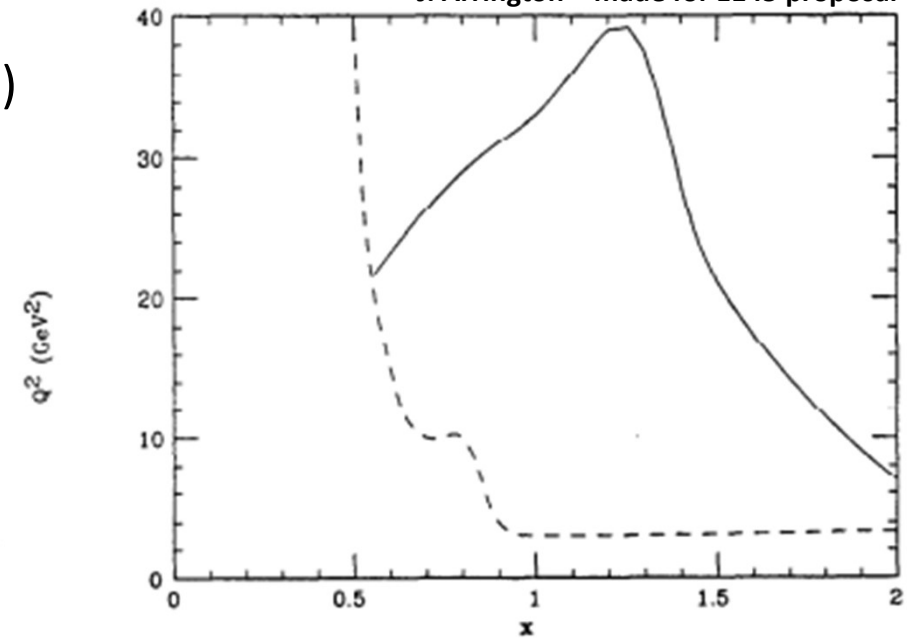


Where do we go from here?

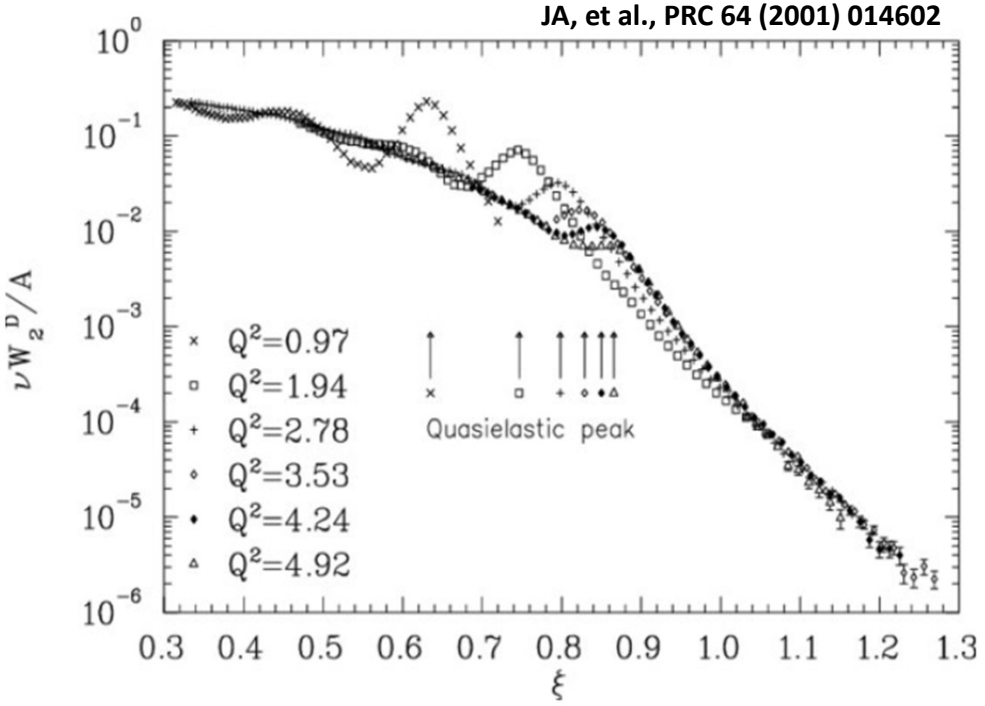
- Short-term:
  - Compare baseline convolution calculations, including pdf, TMC, HT effects
  - Extract the inclusive x>1 structure function from various models vs x, Q^2
  - Map out kinematic coverage, experimental needs for 22 GeV experiment

- 11 GeV: First test in compare of deuteron data to calculations
  - Try to quantify how well F_2 connects to pdfs at these kinematics
  - Look for potentially large increase (suppression) over baseline convolution
  - If observe large effect (relative to uncertainties associated with limit Q^2), look at A-dependence: 2H, 4He, 12C, 40Ca to see if it scales as predicted

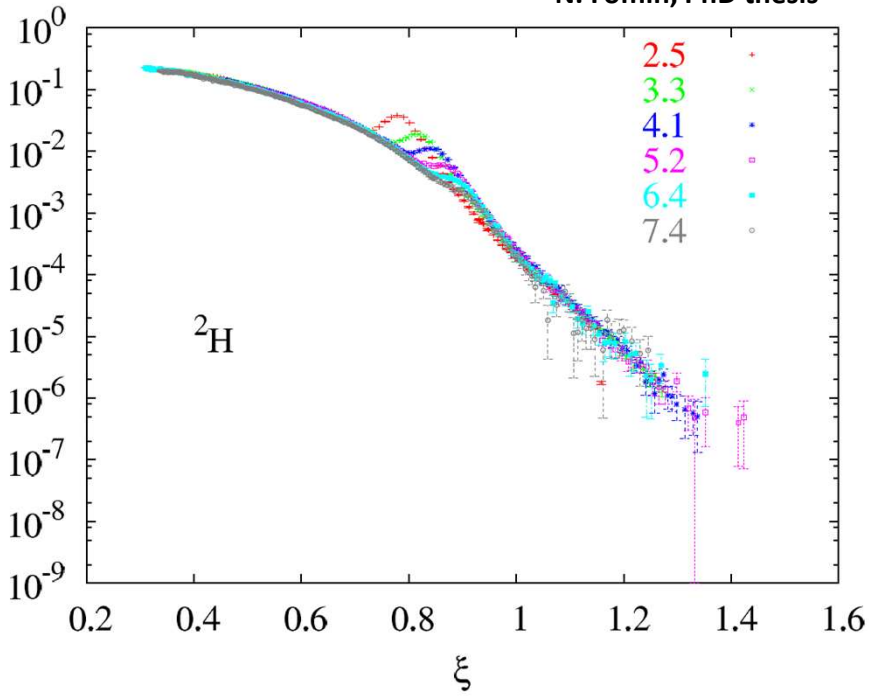
- 22 GeV:
  - Cleaner measurement at much higher Q^2
  - Extend x range, where several models show rapid variation
  - Examine Q^2 dependence – test/constrain HT contributions

Quark hadron duality in nuclei

JA, et al., PRC 64 (2001) 014602



N. Fomin, PhD thesis



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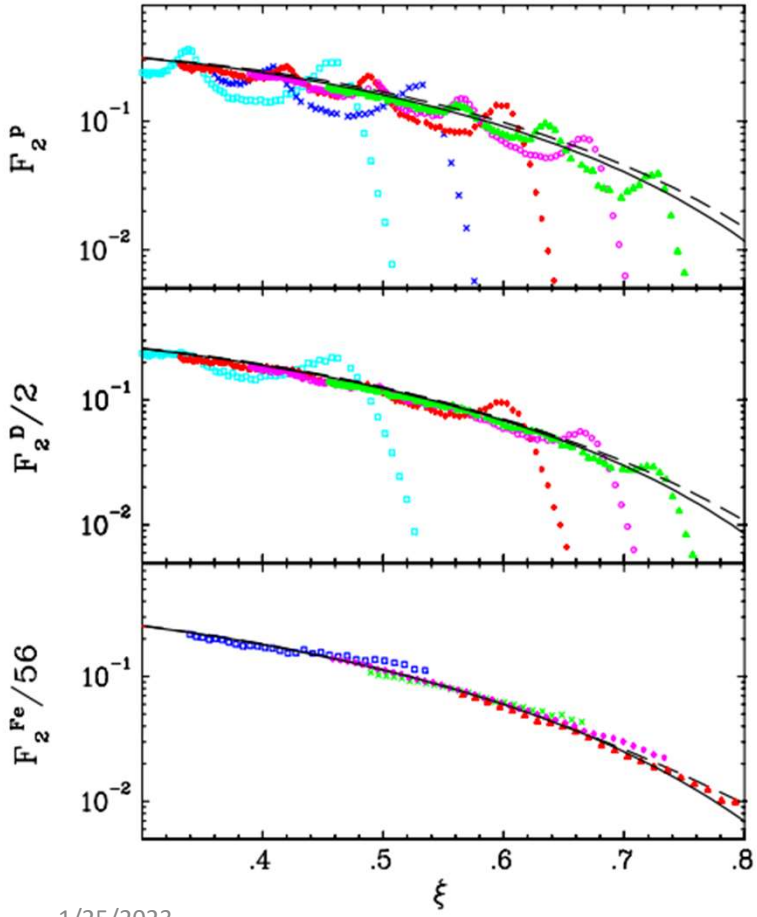

JA, et al., PRC 73 (2006) 035205