

Bound nucleon structure from tagged DIS with a 22 GeV CEBAF

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Science at the Luminosity Frontier:
Jefferson Lab at 22 GeV Workshop

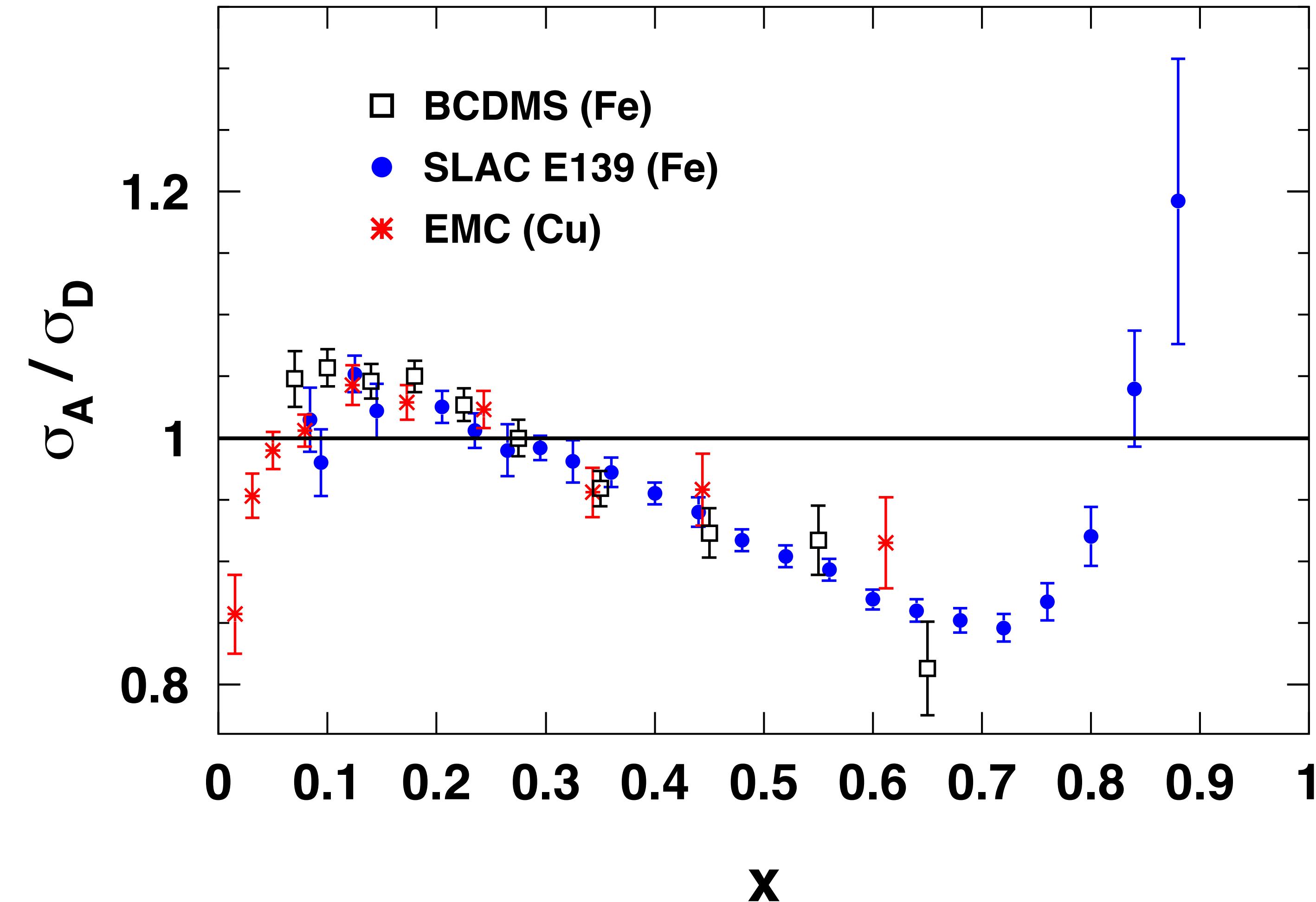
Jefferson Lab
Newport News, VA

January 25, 2023



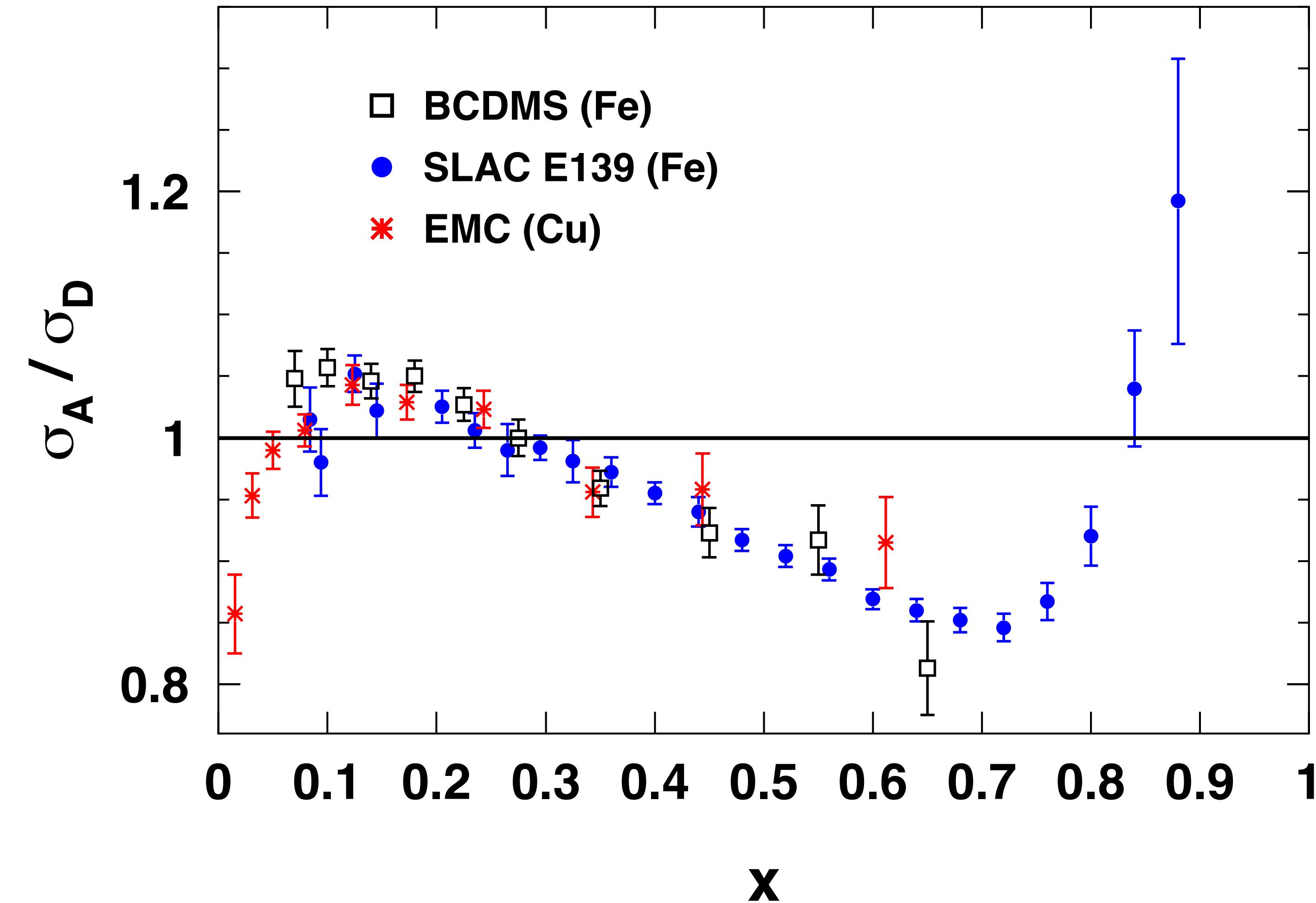
Bound nucleons are not the same as free nucleons

Guzey *et al.*, PRC (2012)



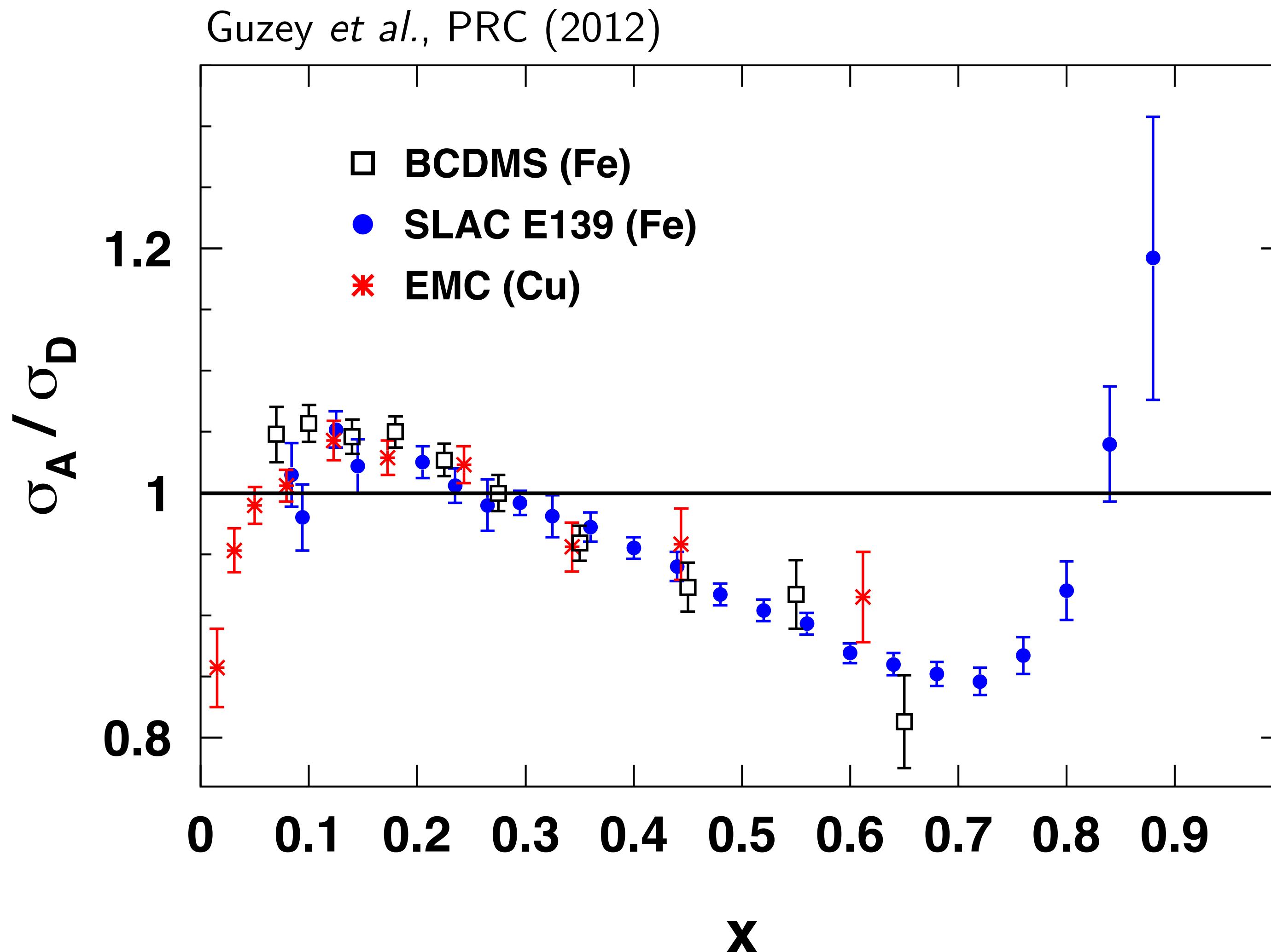
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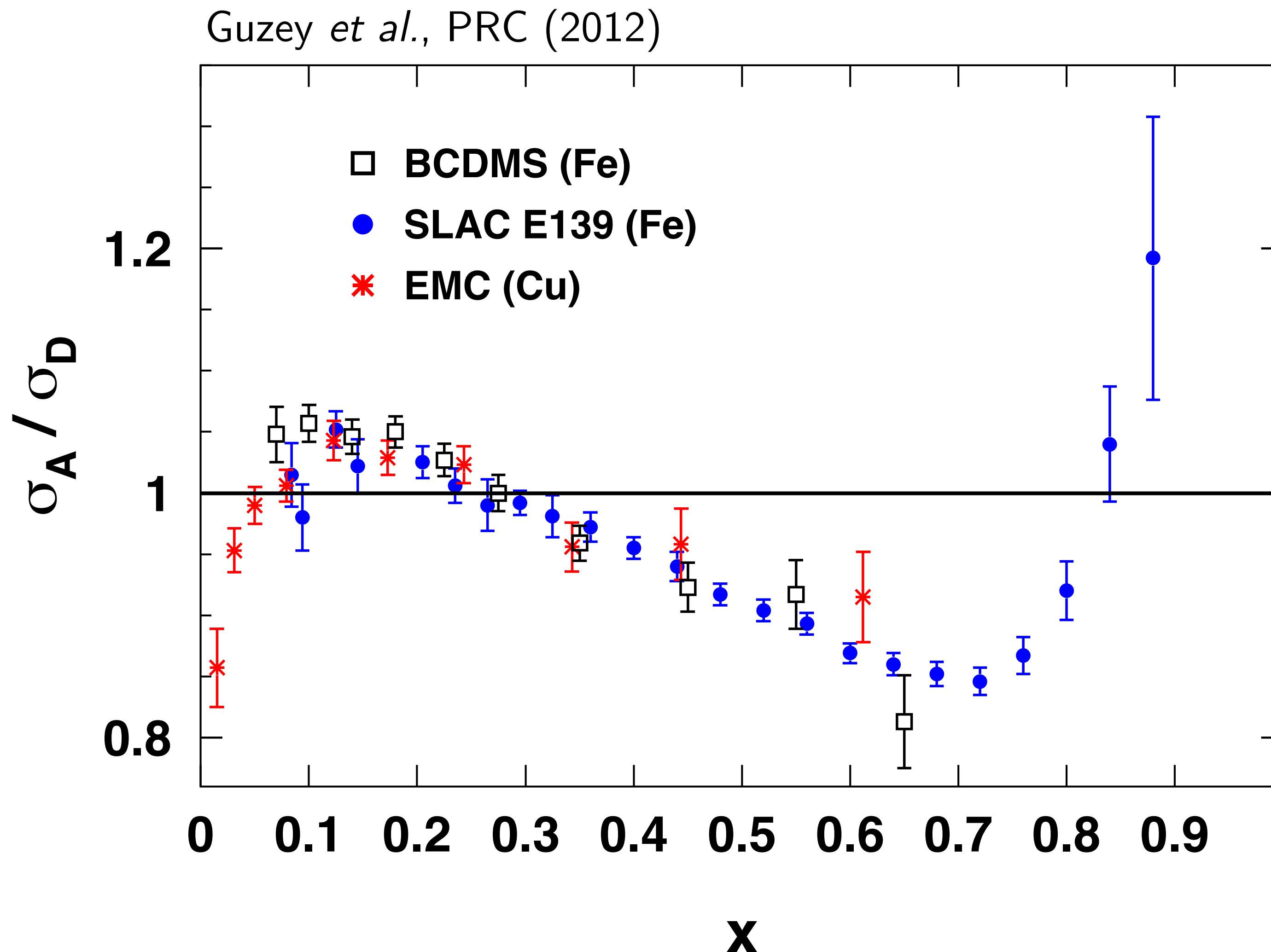
- Shadowing ($x < 0.05-0.1$):
Large A -dependent suppression

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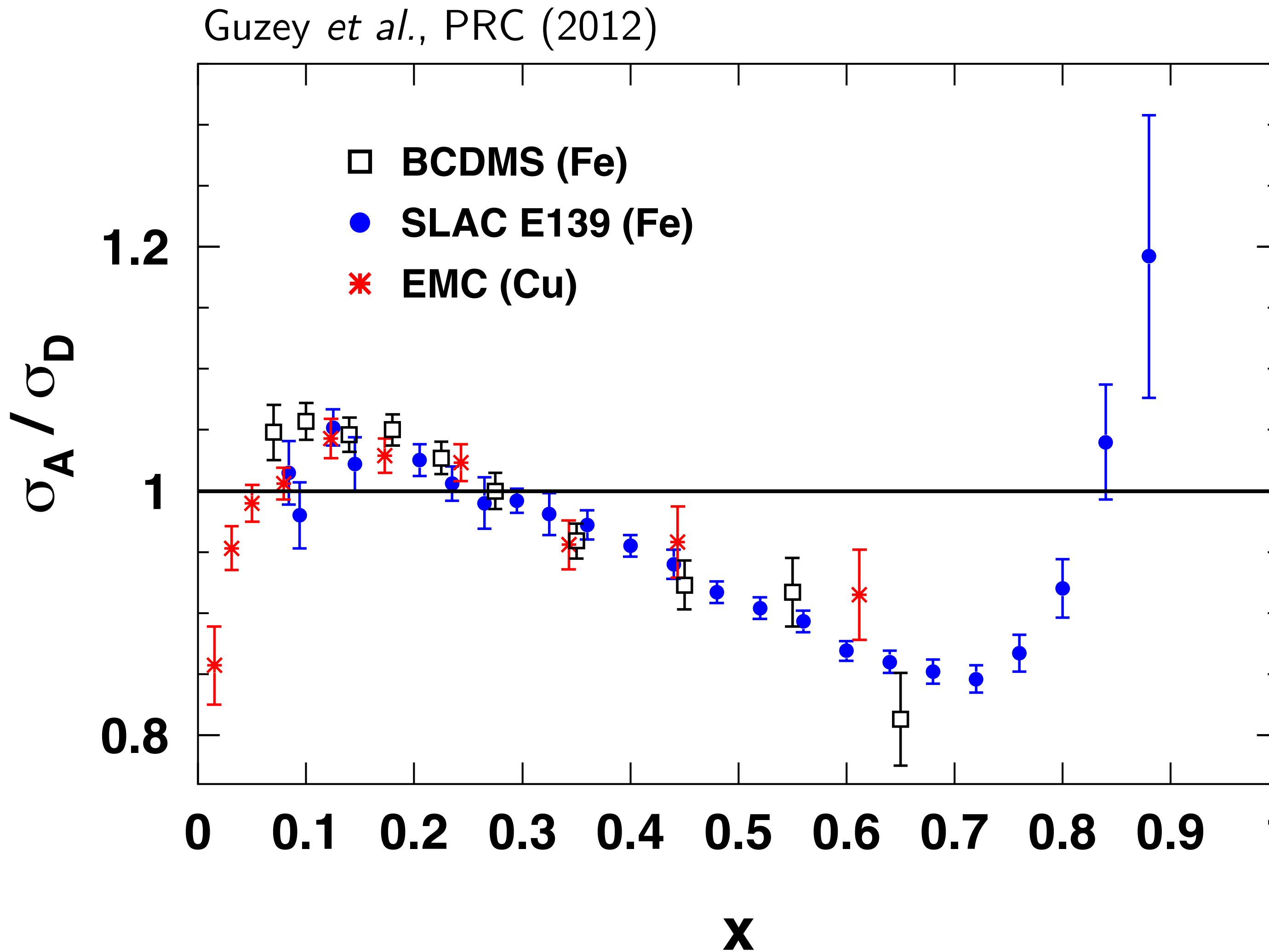
- Shadowing ($x < 0.05\text{-}0.1$): Large A -dependent suppression
- Anti-shadowing ($0.1 < x < 0.3$): Small enchantment, no conclusive A dependence

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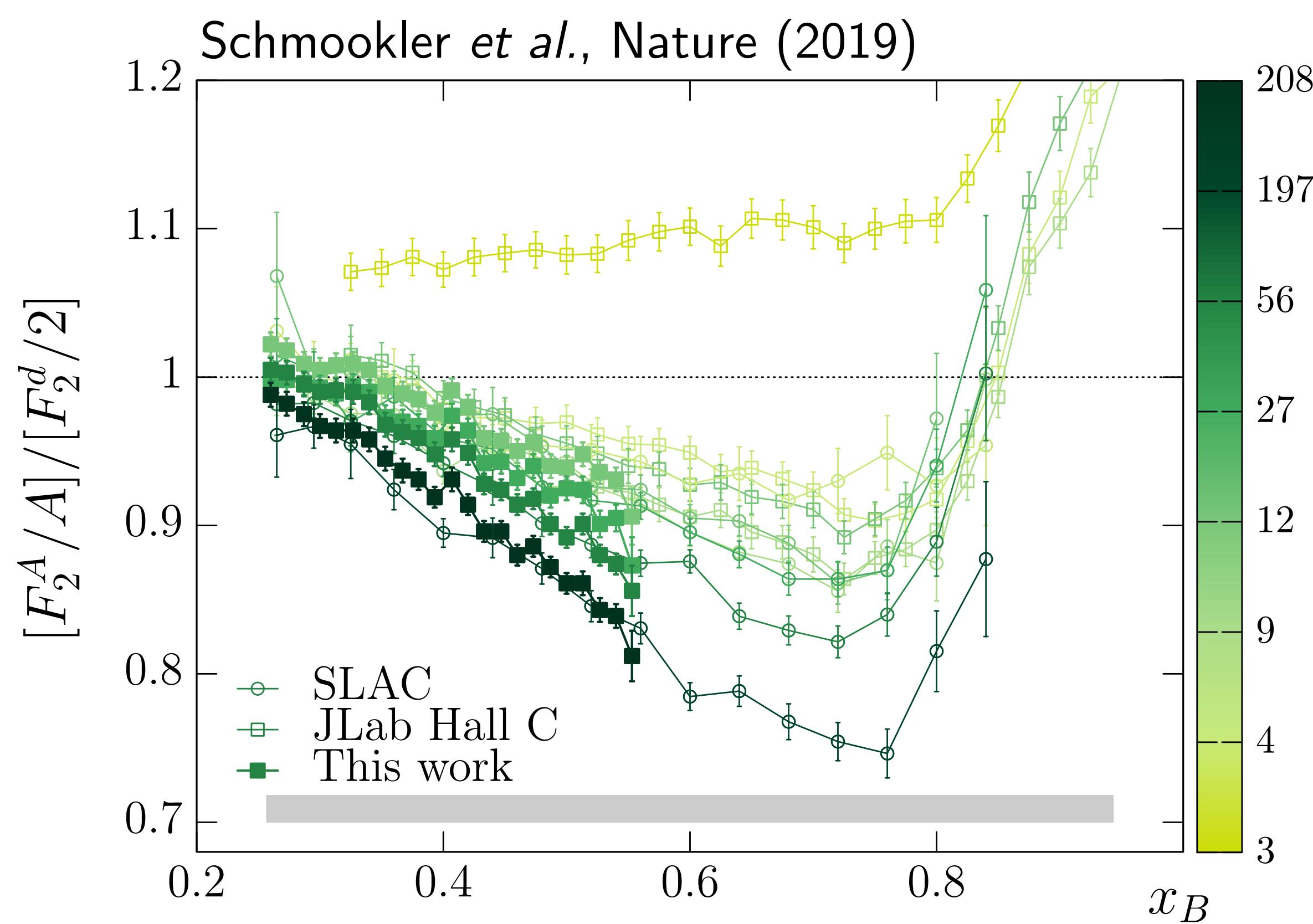
- Shadowing ($x < 0.05\text{--}0.1$): Large A -dependent suppression
- Anti-shadowing ($0.1 < x < 0.3$): Small enhancement, no conclusive A dependence
- EMC effect ($0.3 < x < 0.7$): Large A - and x -dependent suppression

Bound nucleons are not the same as free nucleons



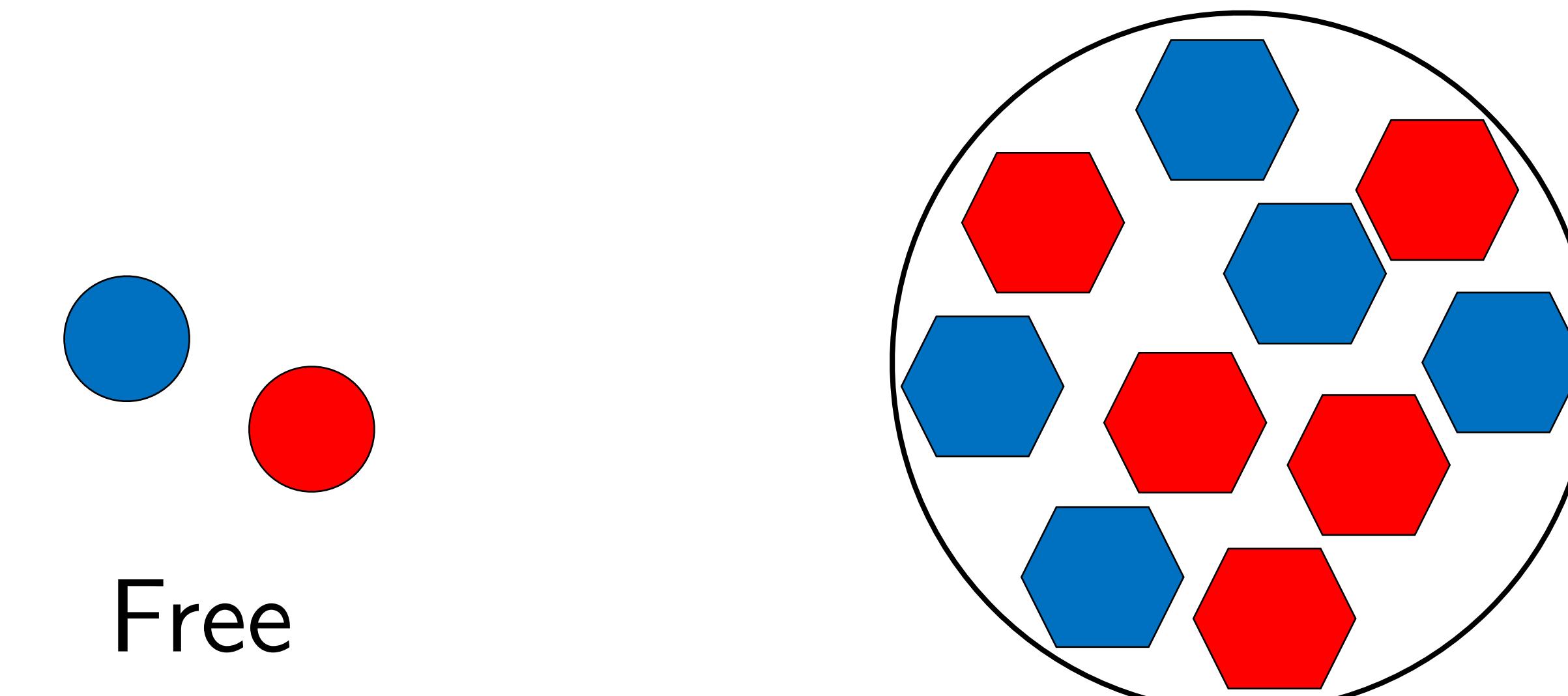
- Shadowing ($x < 0.05-0.1$): Large A -dependent suppression
- Anti-shadowing ($0.1 < x < 0.3$): Small enchantment, no conclusive A dependence
- EMC effect ($0.3 < x < 0.7$): Large A - and x -dependent suppression
- Fermi motion ($x > 0.7$)

Existing (inclusive) data has taken us far, but not far enough...



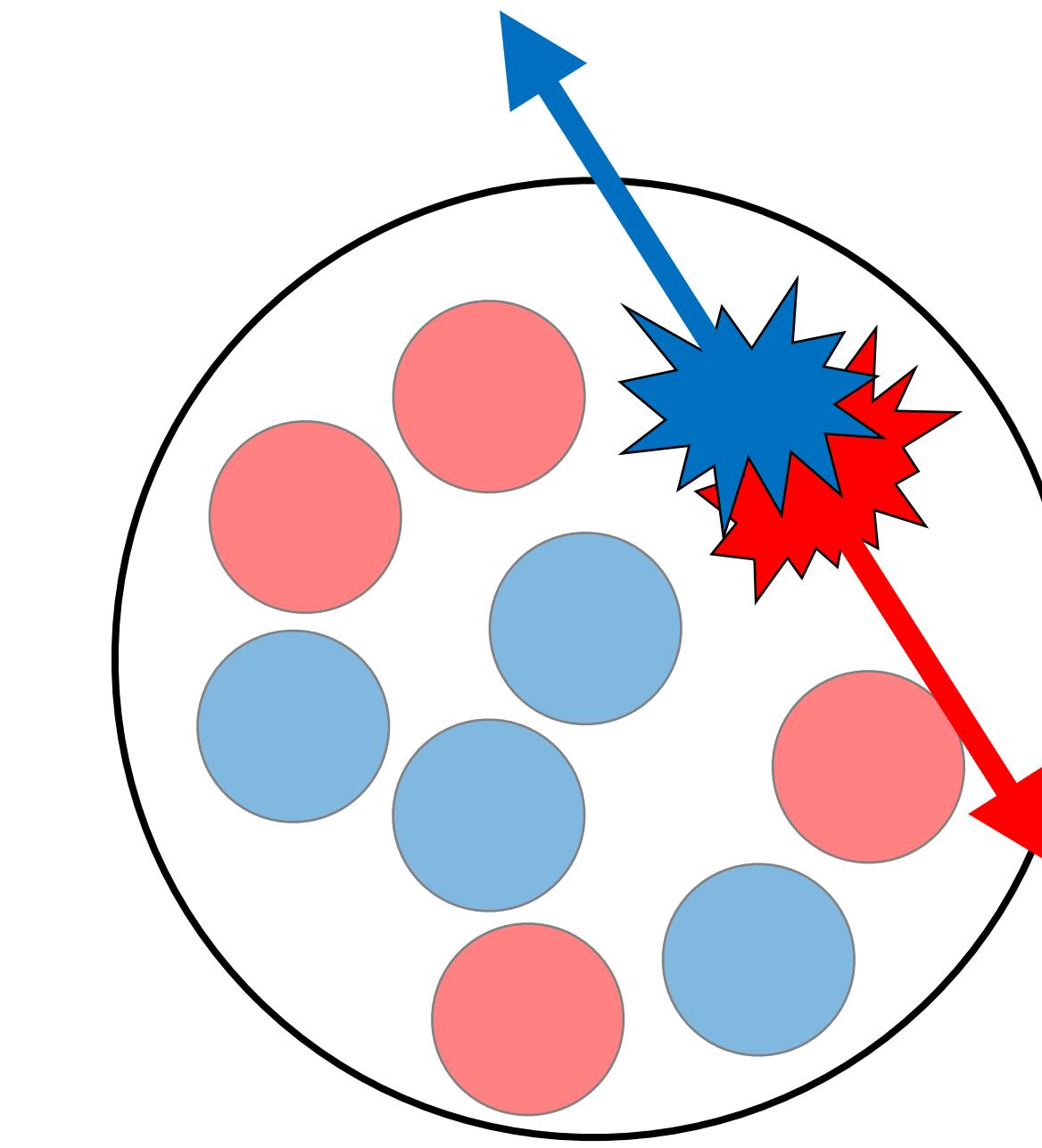
- Integrates nuclear structure over all nucleons, whole wavefunction, etc.
- Has been used to establish average EMC effect and A -dependence in wide range of nuclei
- Cannot answer...
 - ...which nucleons are modified?
 - ...is modification momentum-dependent?
 - ...are protons and neutrons modified the same?

Two example EMC effect mechanisms



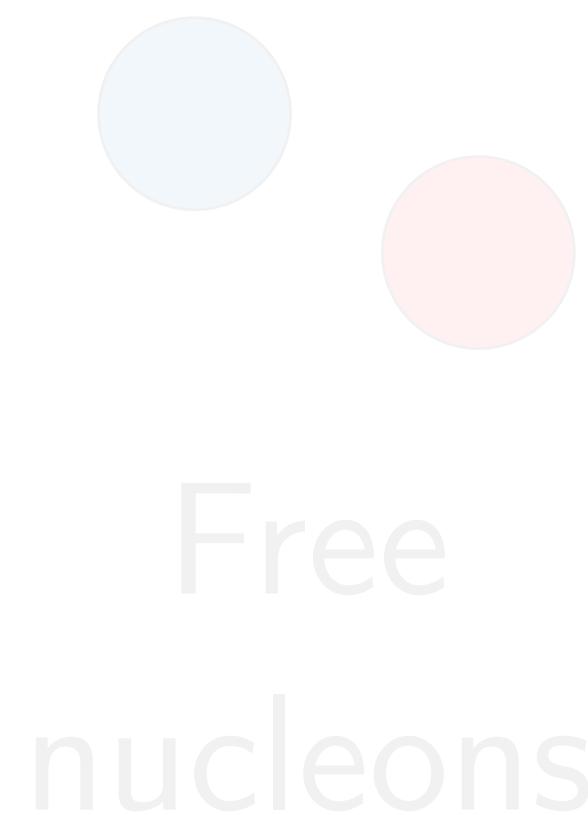
Free
nucleons

All nucleons
slightly modified?



Rare high-momentum
nucleons highly modified?

Two example EMC effect mechanisms

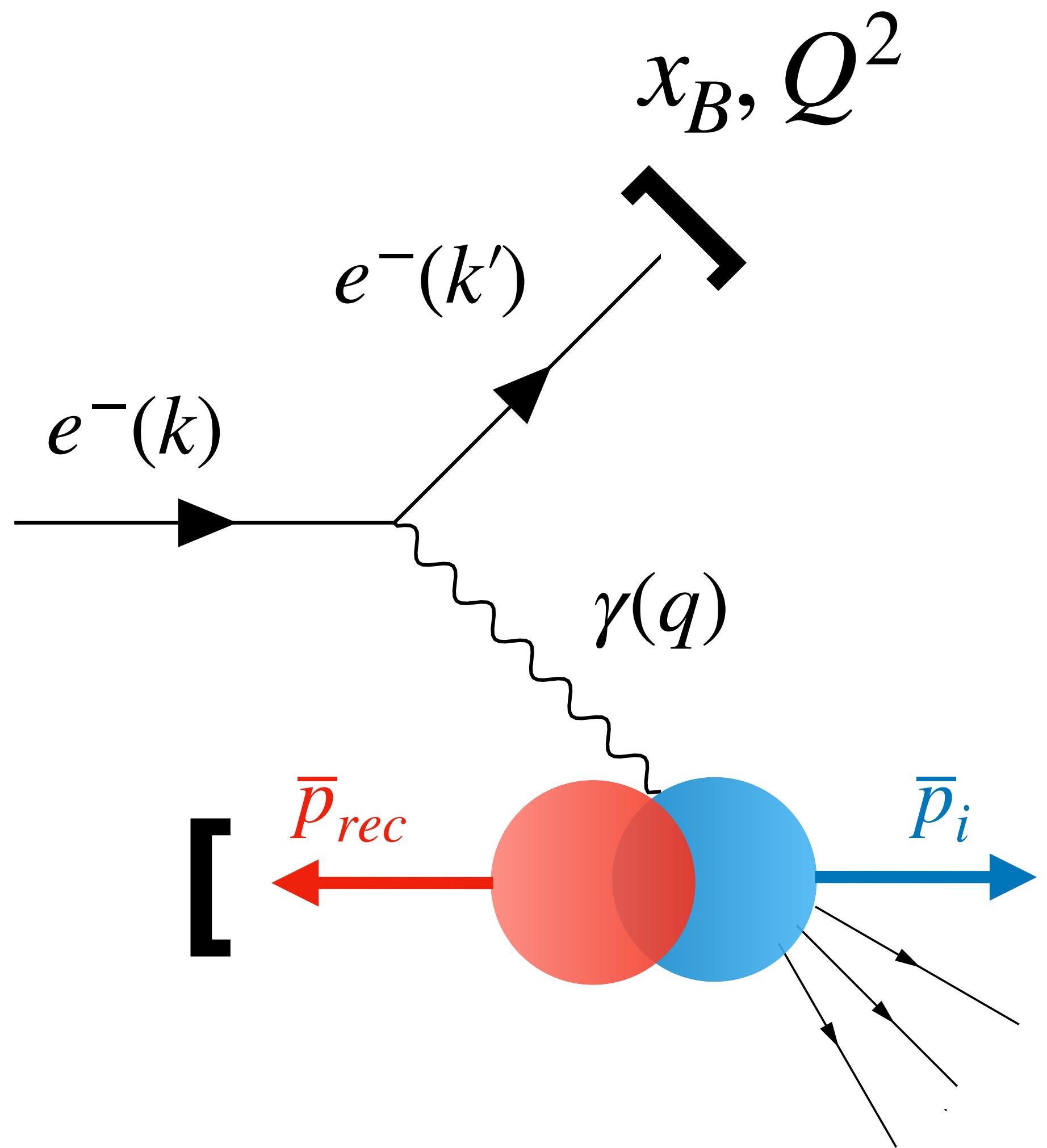


Tagged DIS can discriminate
between these two pictures!

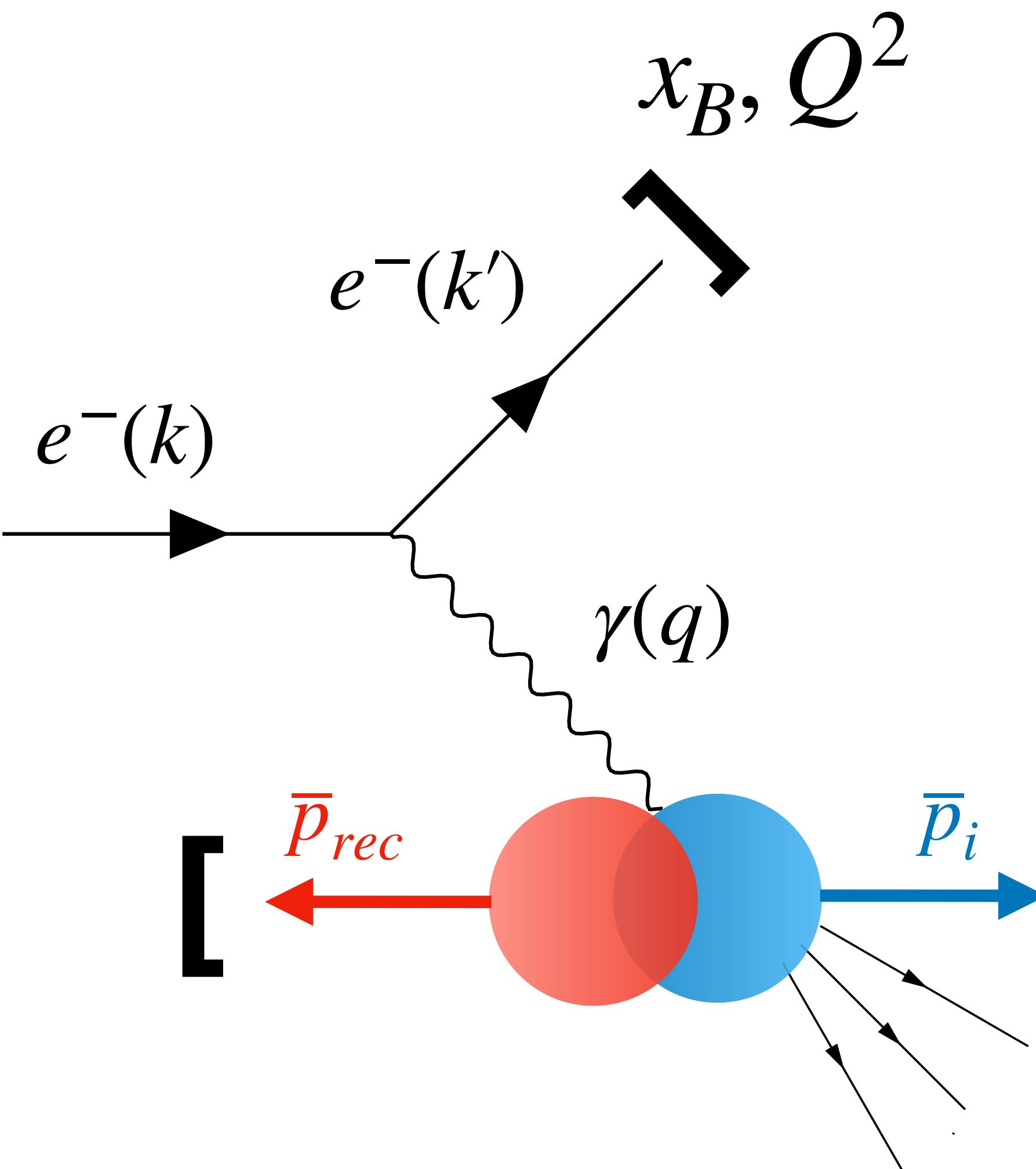
All nucleons
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Tagged DIS gives parton dynamics *and* nuclear state

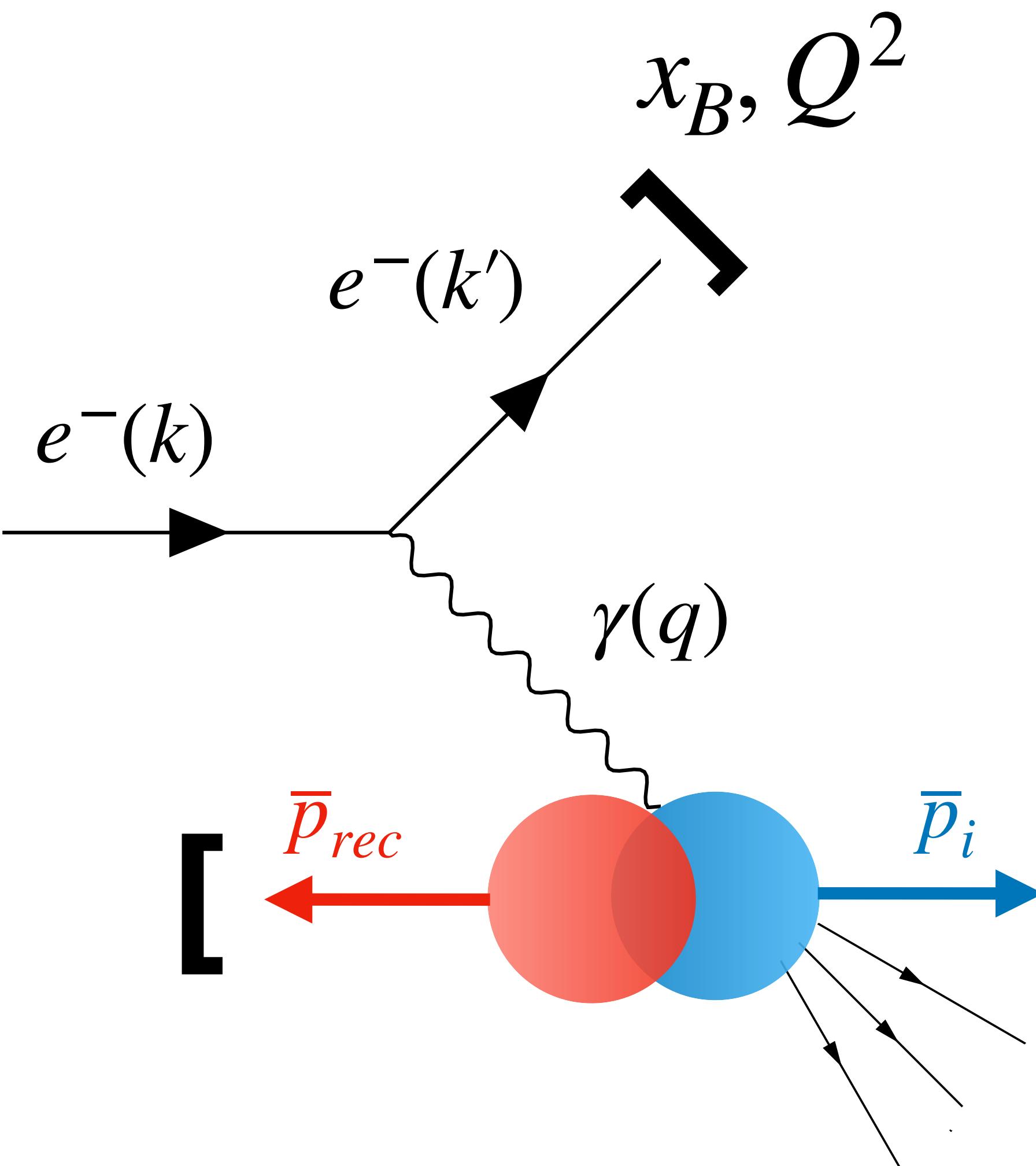


Tagged DIS gives parton dynamics *and* nuclear state



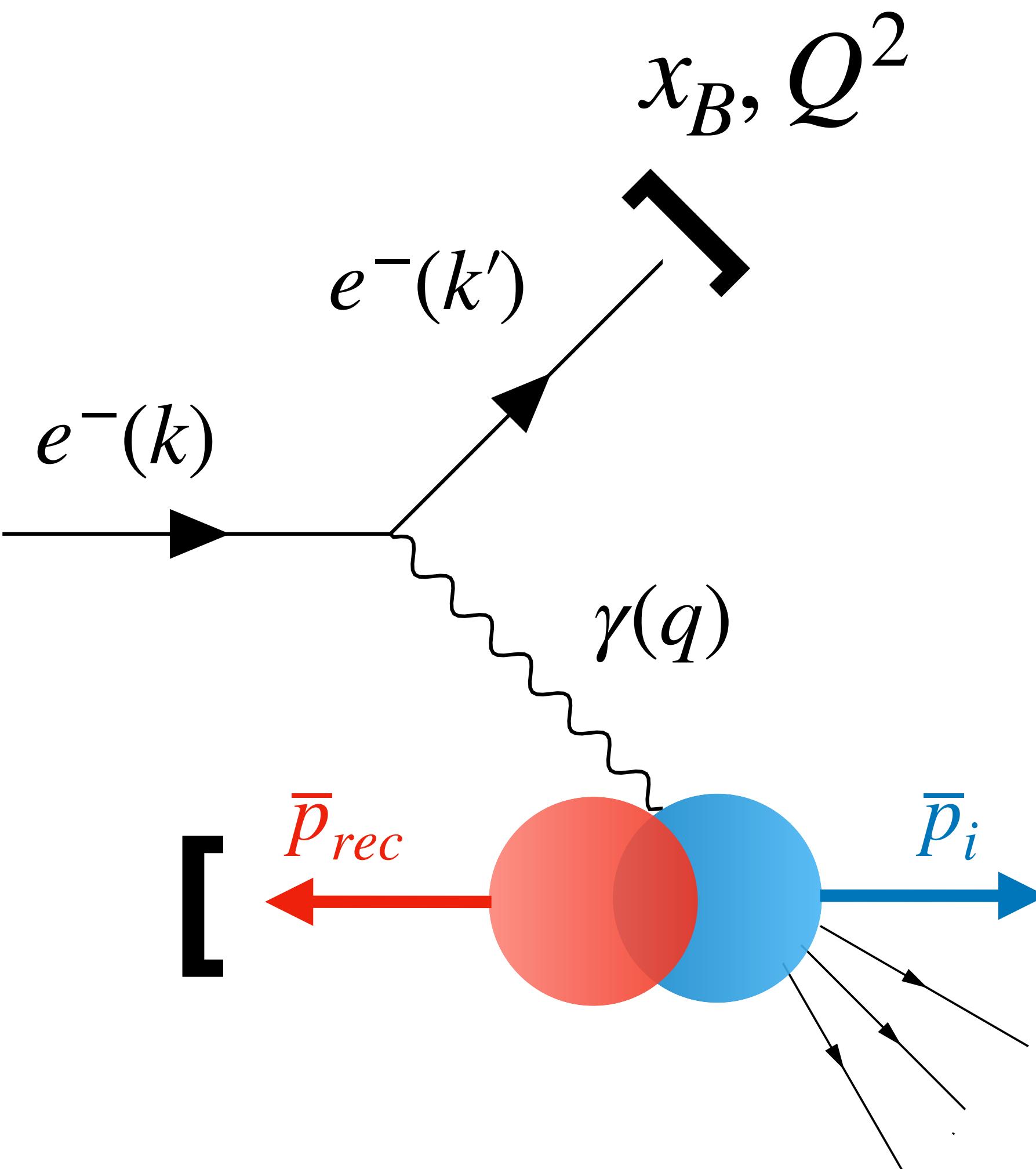
- Parton structure from electron
- Nuclear state from spectator nucleon
- Account for initial momentum of nucleon

Tagged DIS gives parton dynamics *and* nuclear state



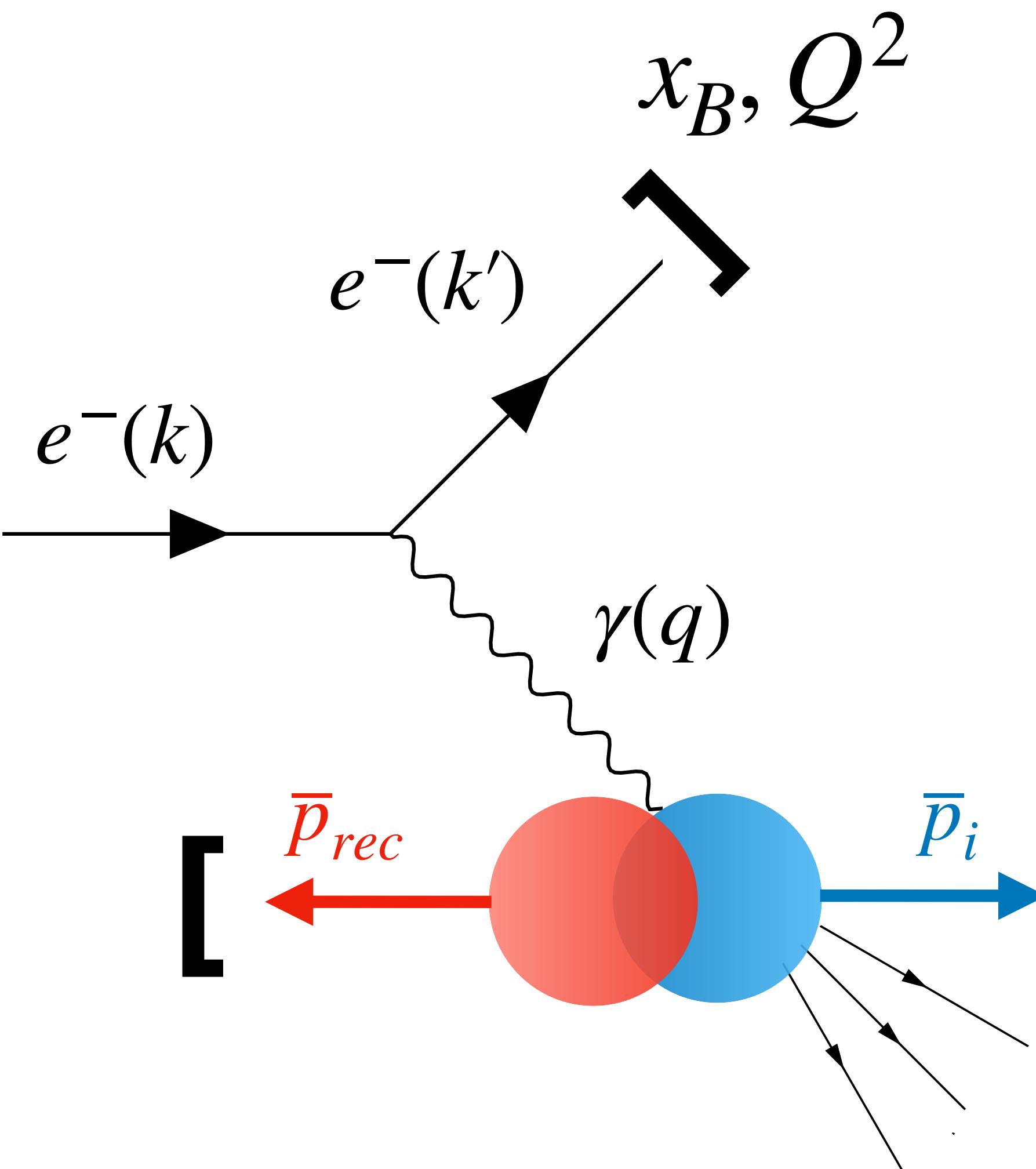
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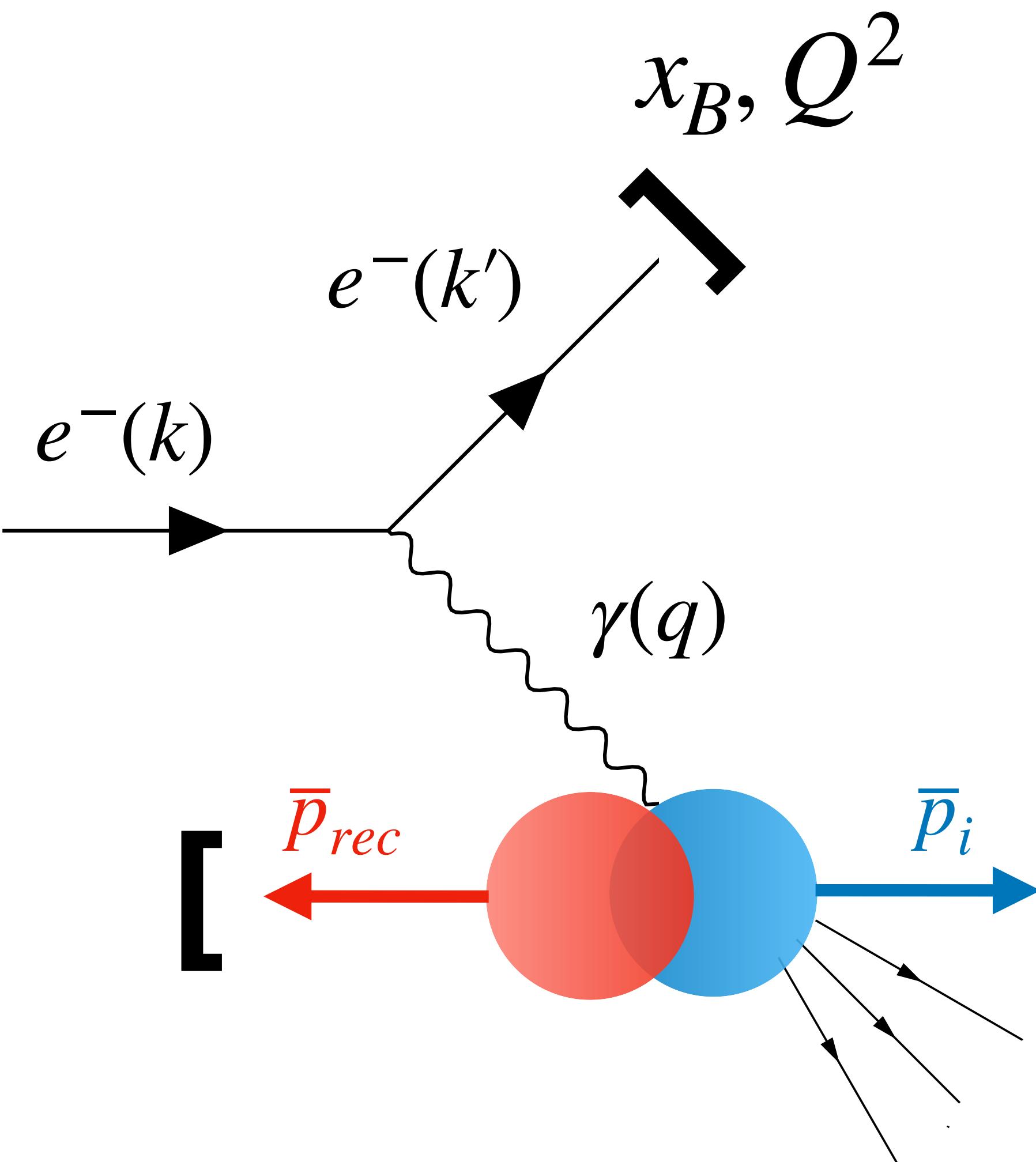
- Parton structure from electron
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- Account for initial momentum of nucleon
 - $\alpha_S \sim p_i$
 - $x_B \rightarrow x'$

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- Parton structure from electron
- Nuclear state from spectator nucleon
- Account for initial momentum of nucleon
 - $\alpha_S \sim p_i$
 - $x_B \rightarrow x'$
 - $W \rightarrow W'$

Tagged DIS gives parton dynamics *and* nuclear state



- Parton structure from electron
- Nuclear state from spectator nucleon
- Account for initial momentum of nucleon
 - $\alpha_S \sim p_i$
 - $x_B \rightarrow x'$
 - $W \rightarrow W'$
- Minimize FSI by detecting backward spectators and forming ratios

Tagged DIS efforts at Jefferson Lab

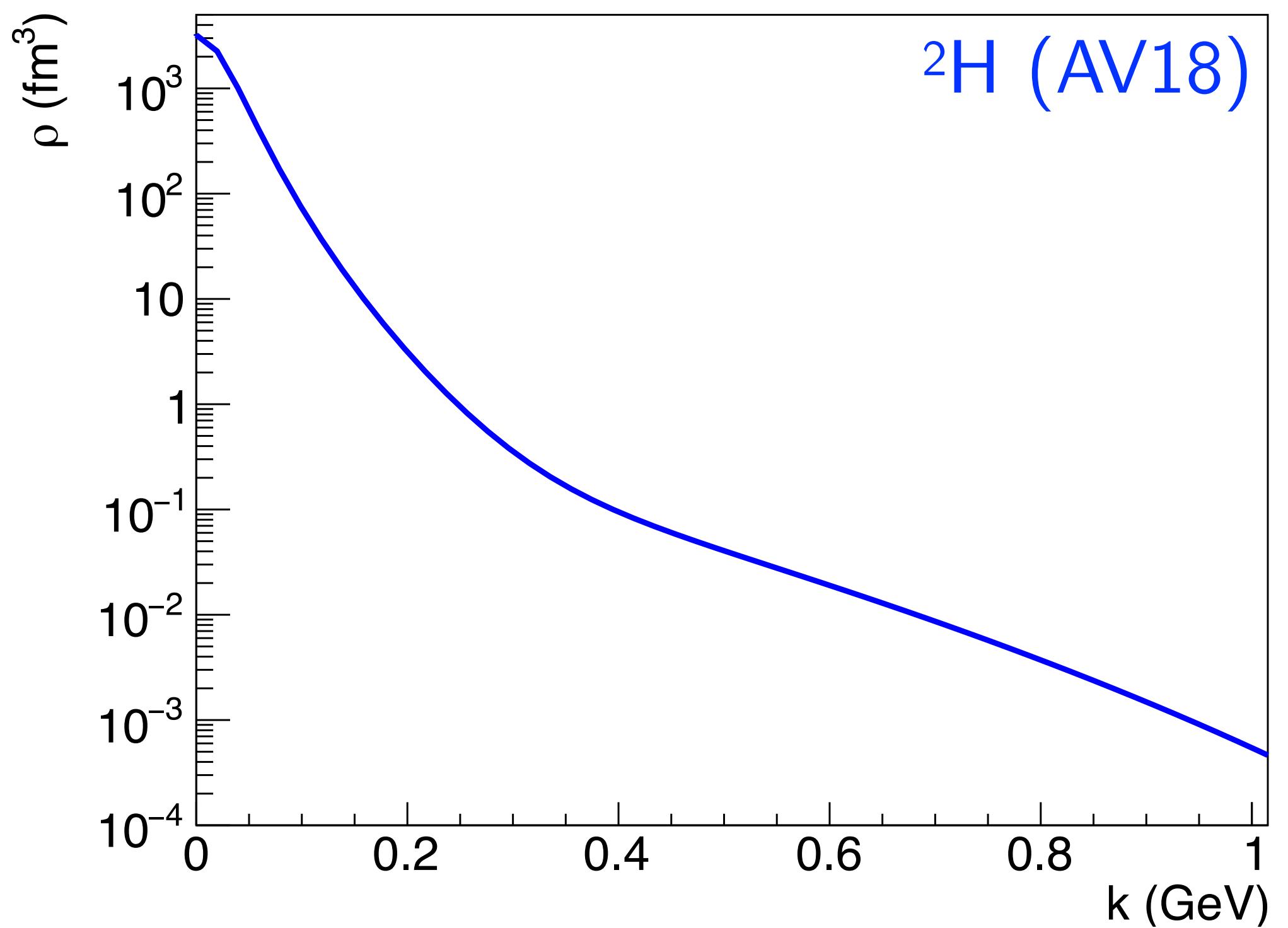
Past/current

- BoNuS (Proton-tagged DIS from deuterium)
- BAND (Neutron-tagged DIS from deuterium)

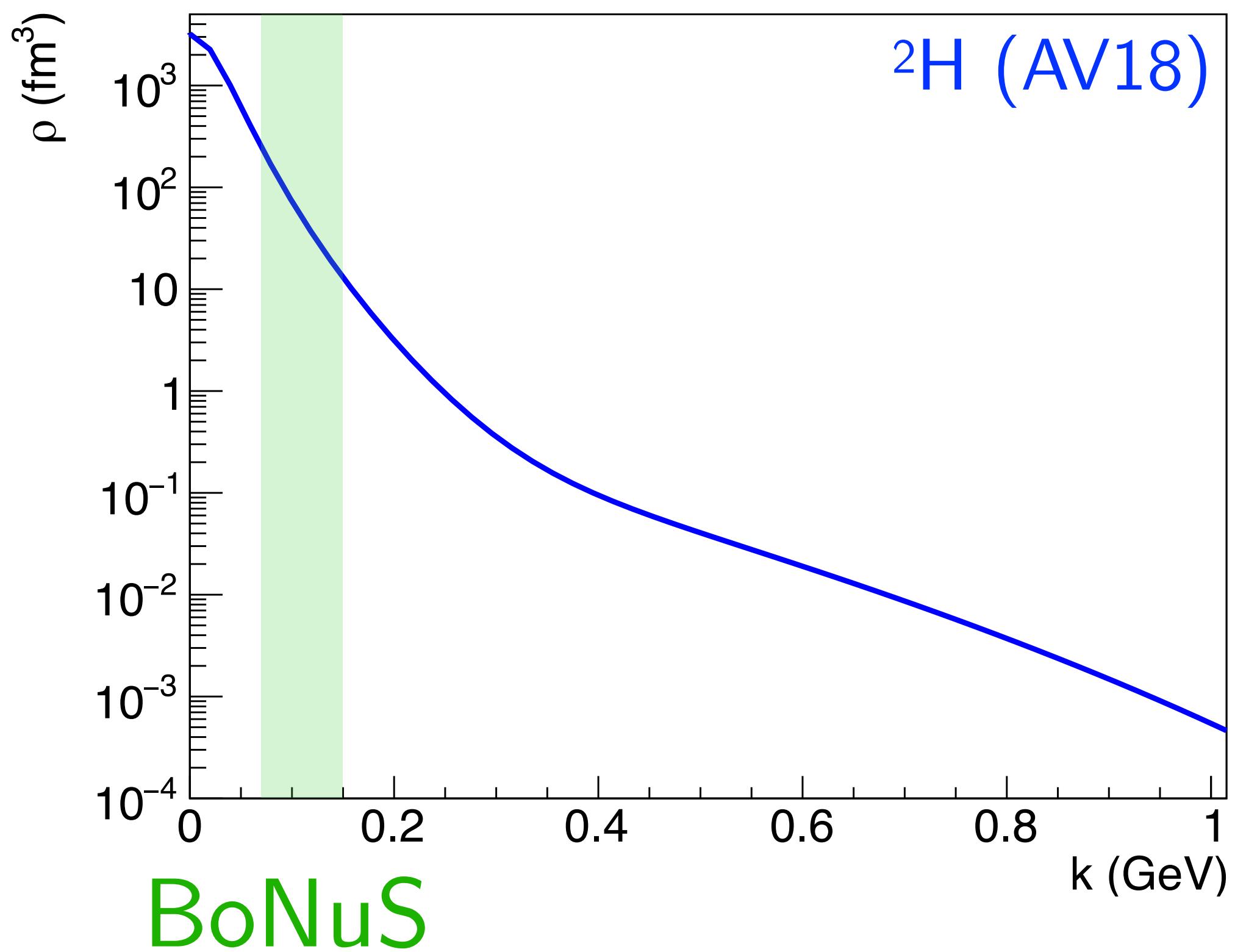
Future:

- ALERT (${}^3\text{H}/{}^3\text{He}$ tagged DIS from ${}^4\text{He}$)
- LAD (Proton-tagged DIS from deuterium)

Tagged DIS can probe selected regions of the nuclear wave function

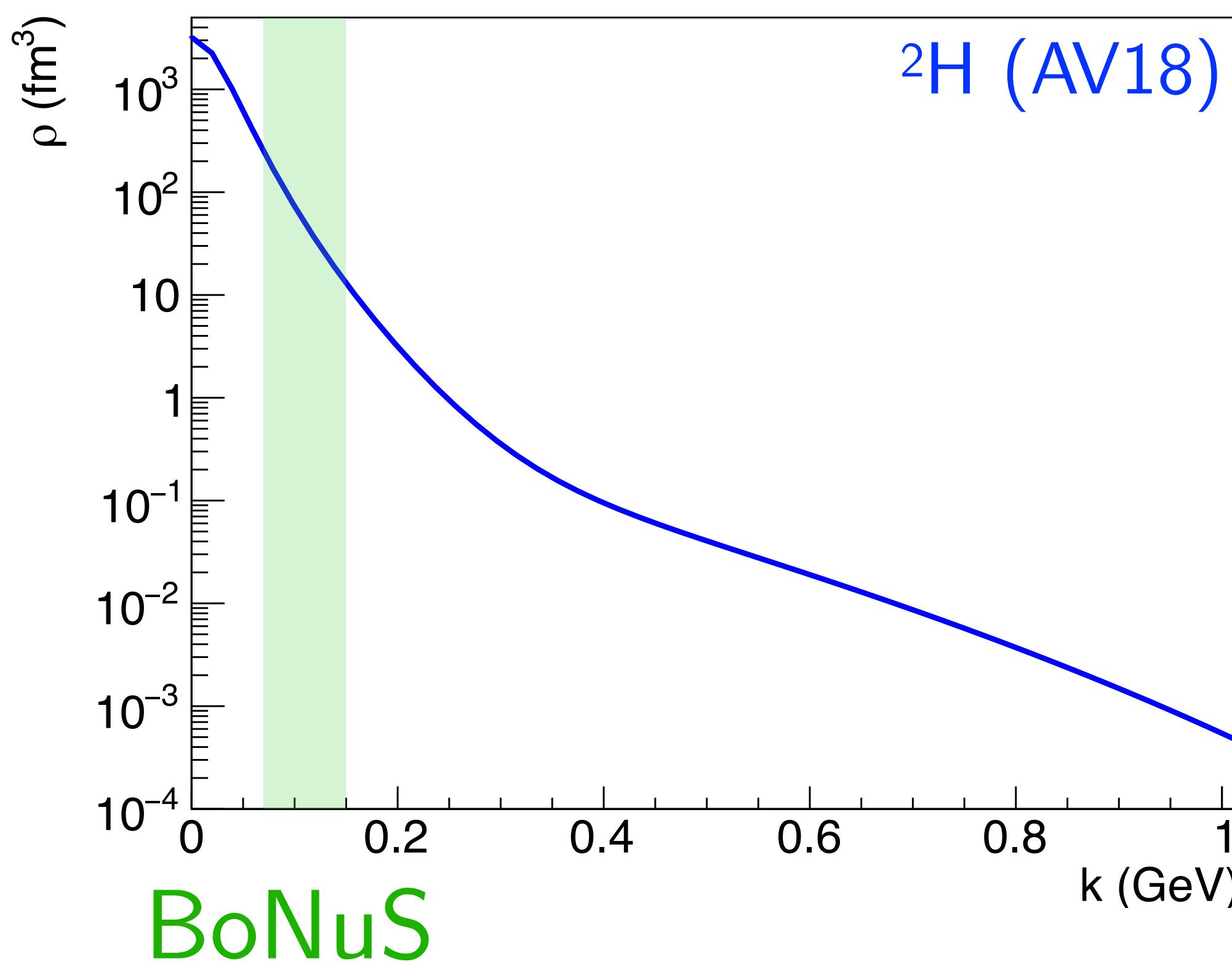


Tagged DIS can probe selected regions of the nuclear wave function

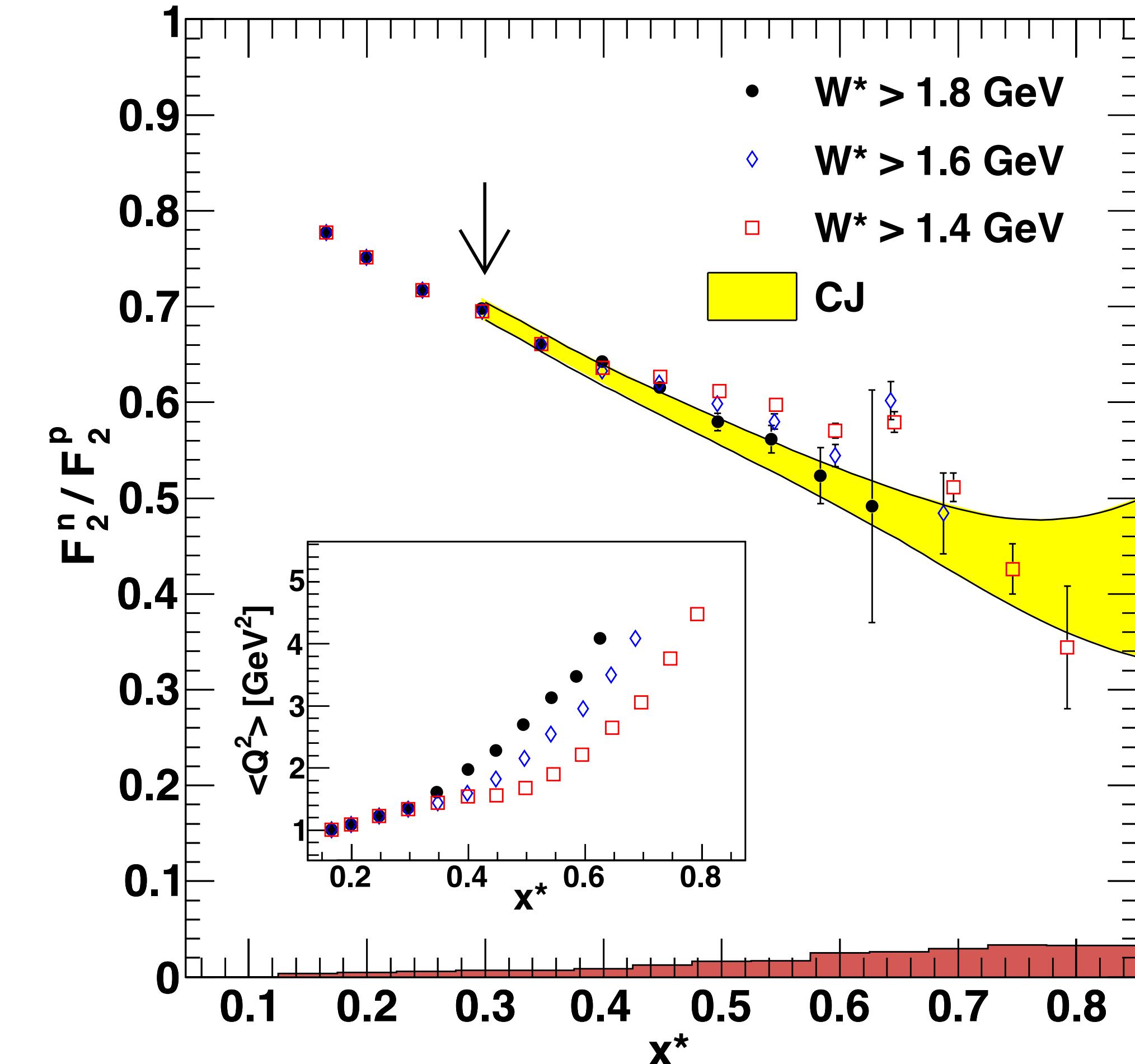


What is the free neutron structure?

Tagged DIS can probe selected regions of the nuclear wave function

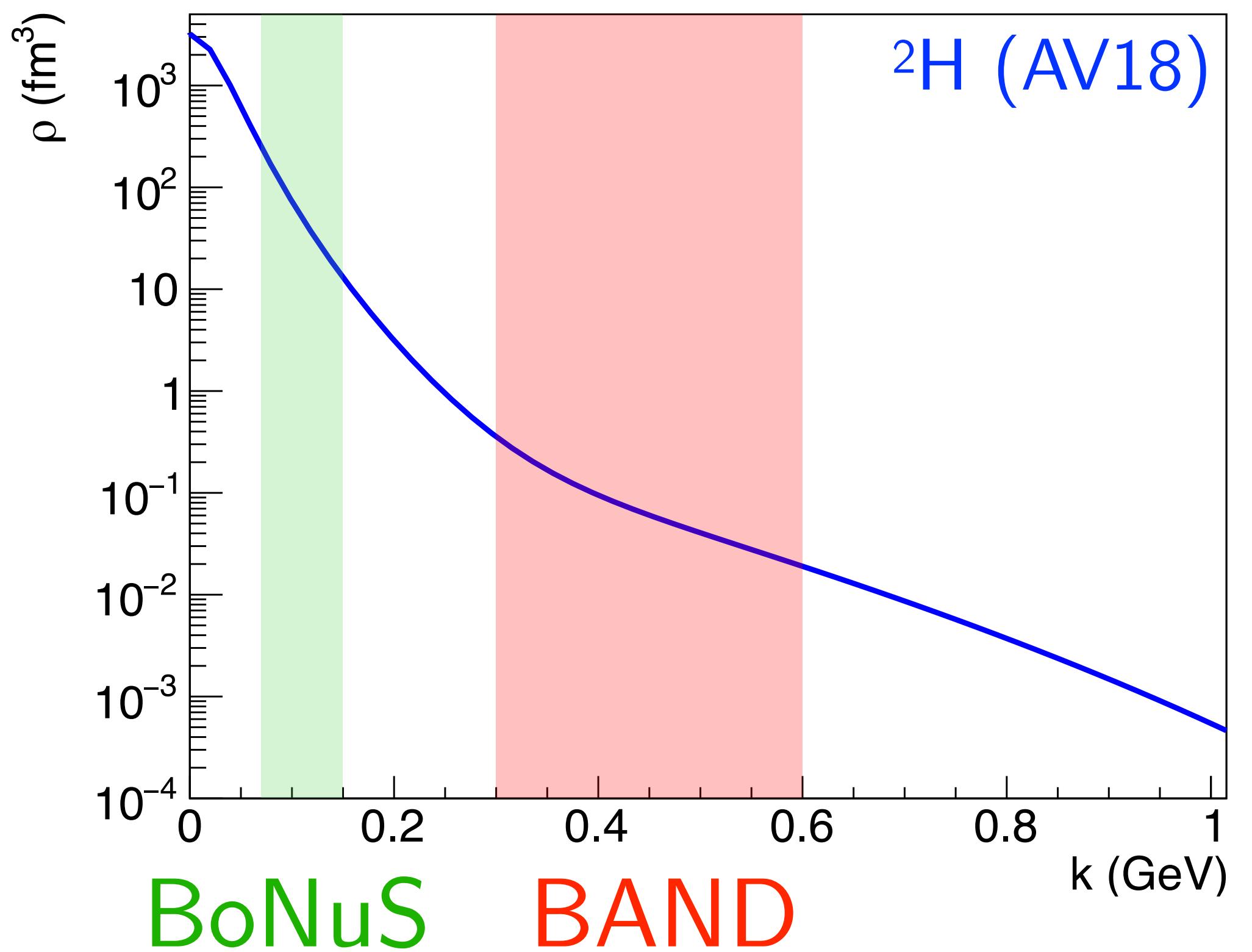


PRL 108, 142001



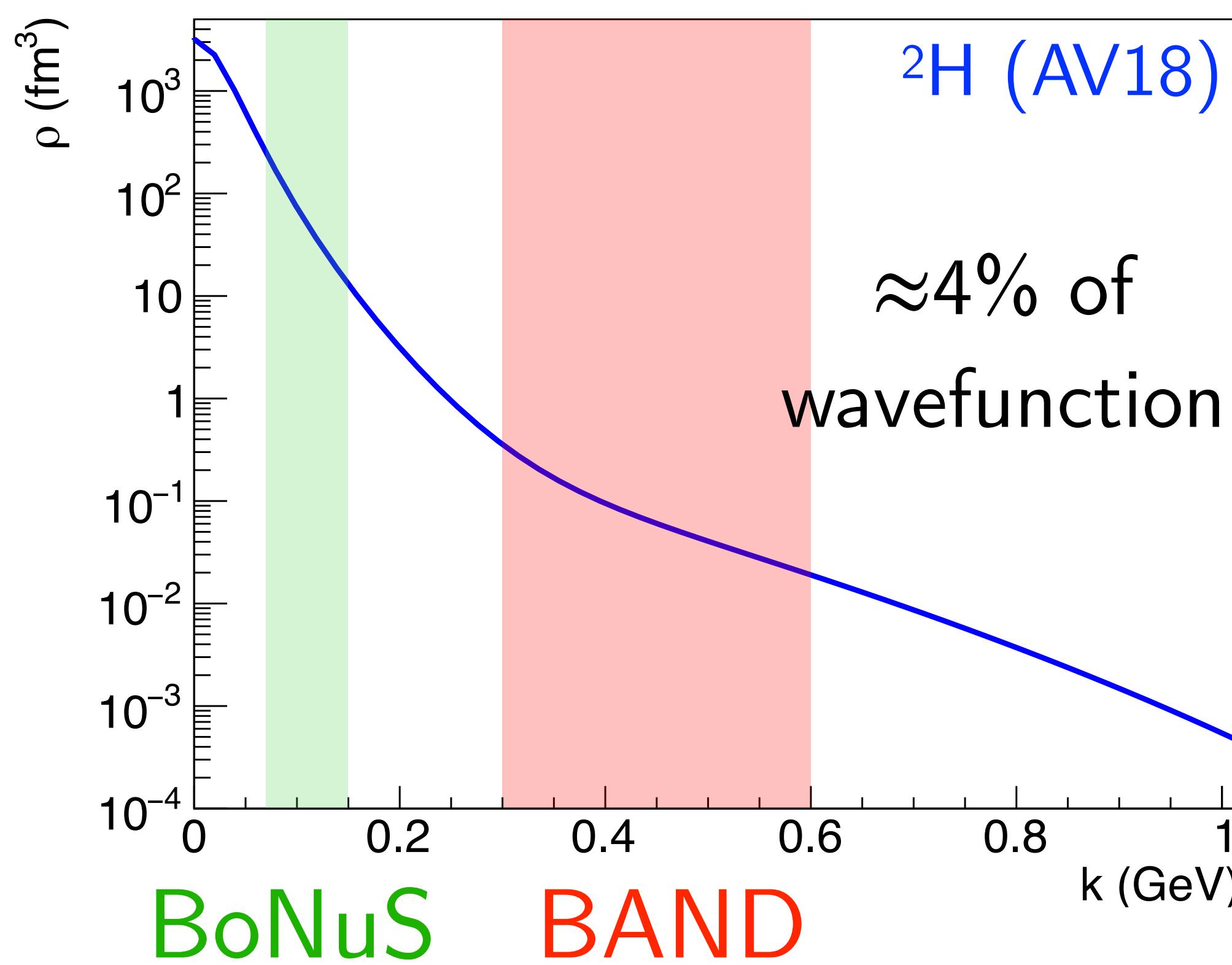
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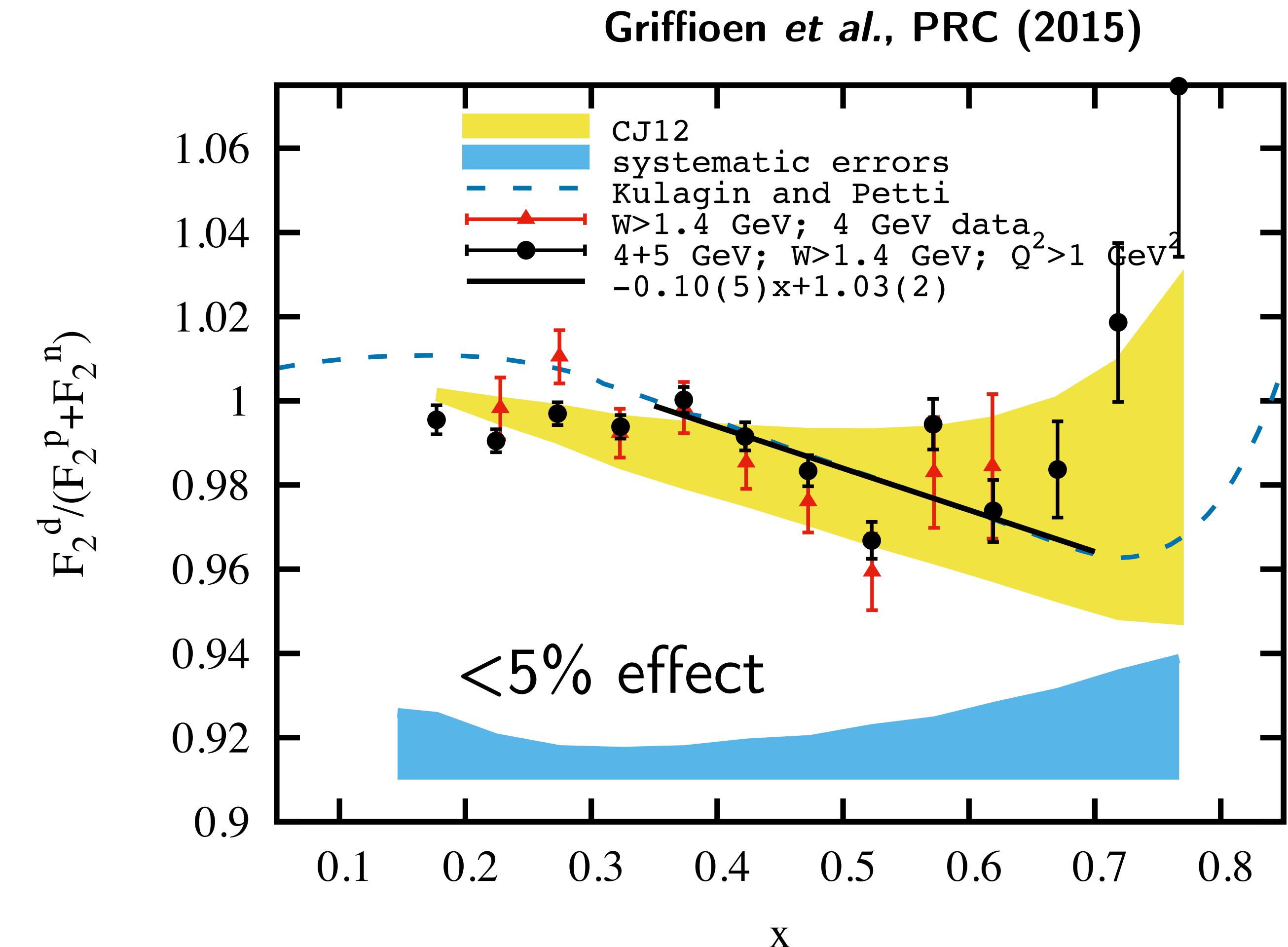


Is the EMC effect driven by
high-momentum nucleons?

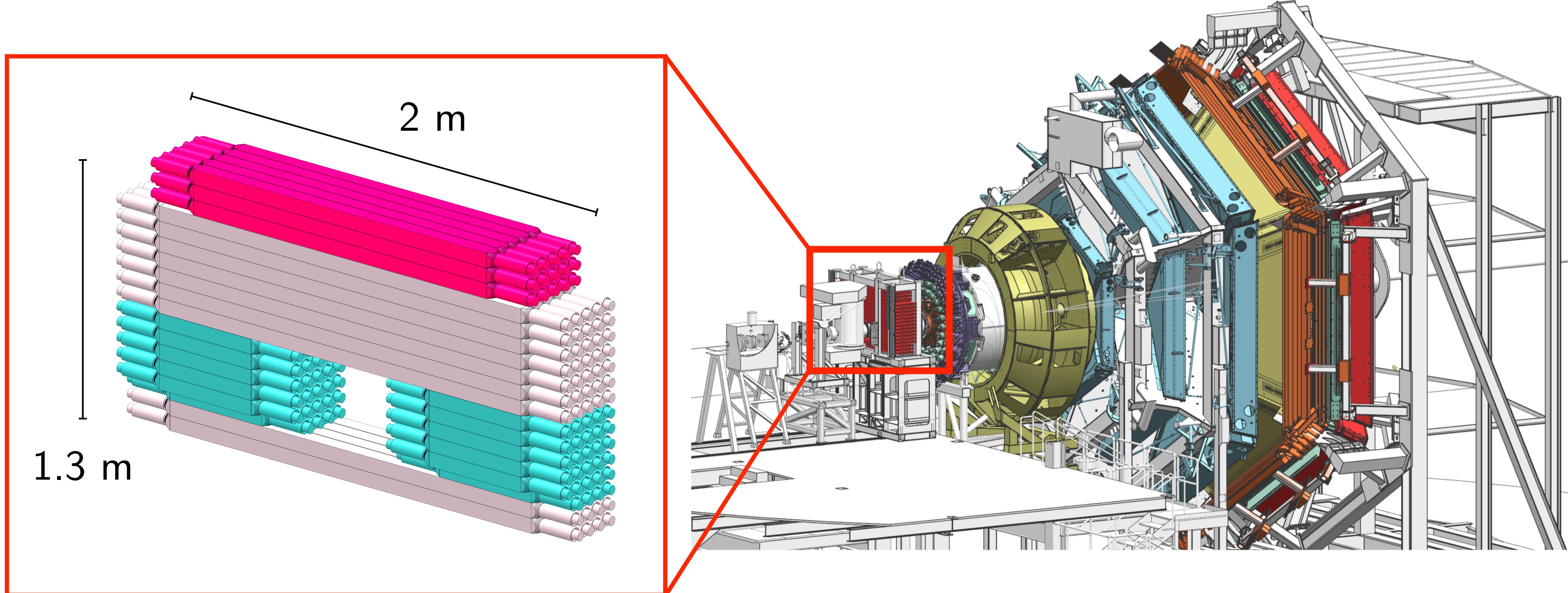
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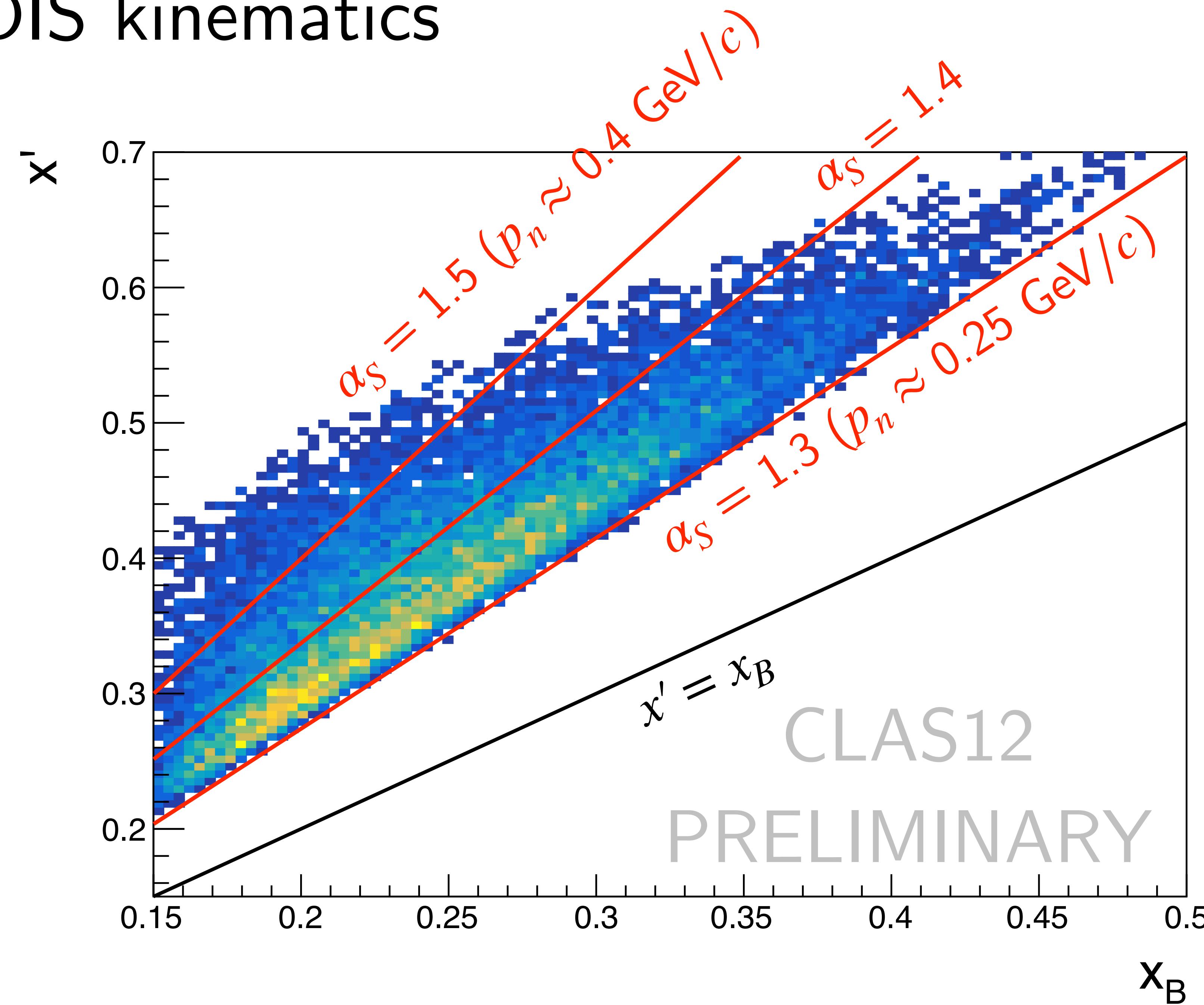
BAND (Backward Angle Neutron Detector) and CLAS12



- e^- to CLAS12, spectator n to BAND
- Addition to Run Group B

Segarra et al., NIMA 978, 164356 (2020)
Denniston et al., NIMA 973 164177 (2020)

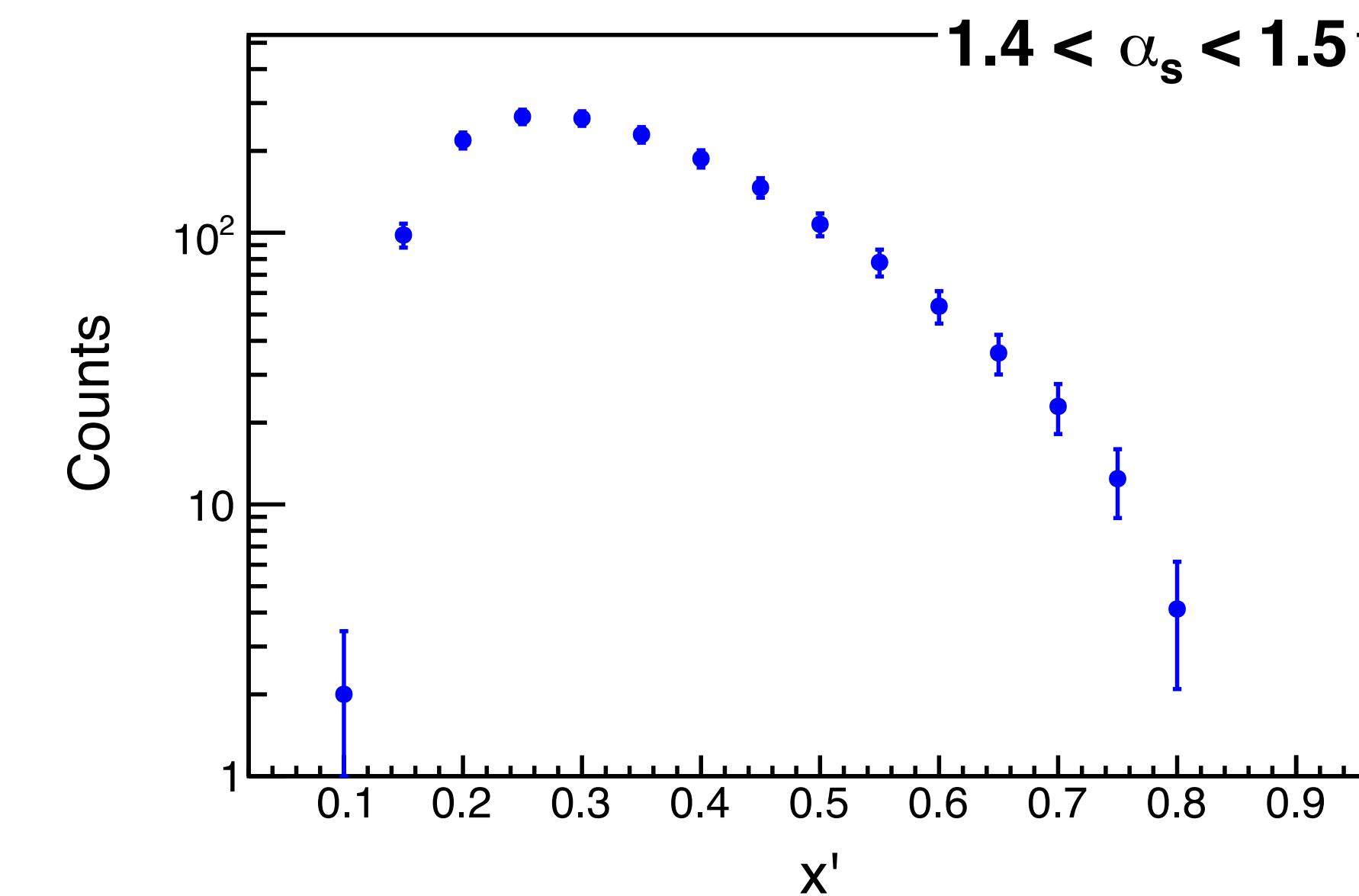
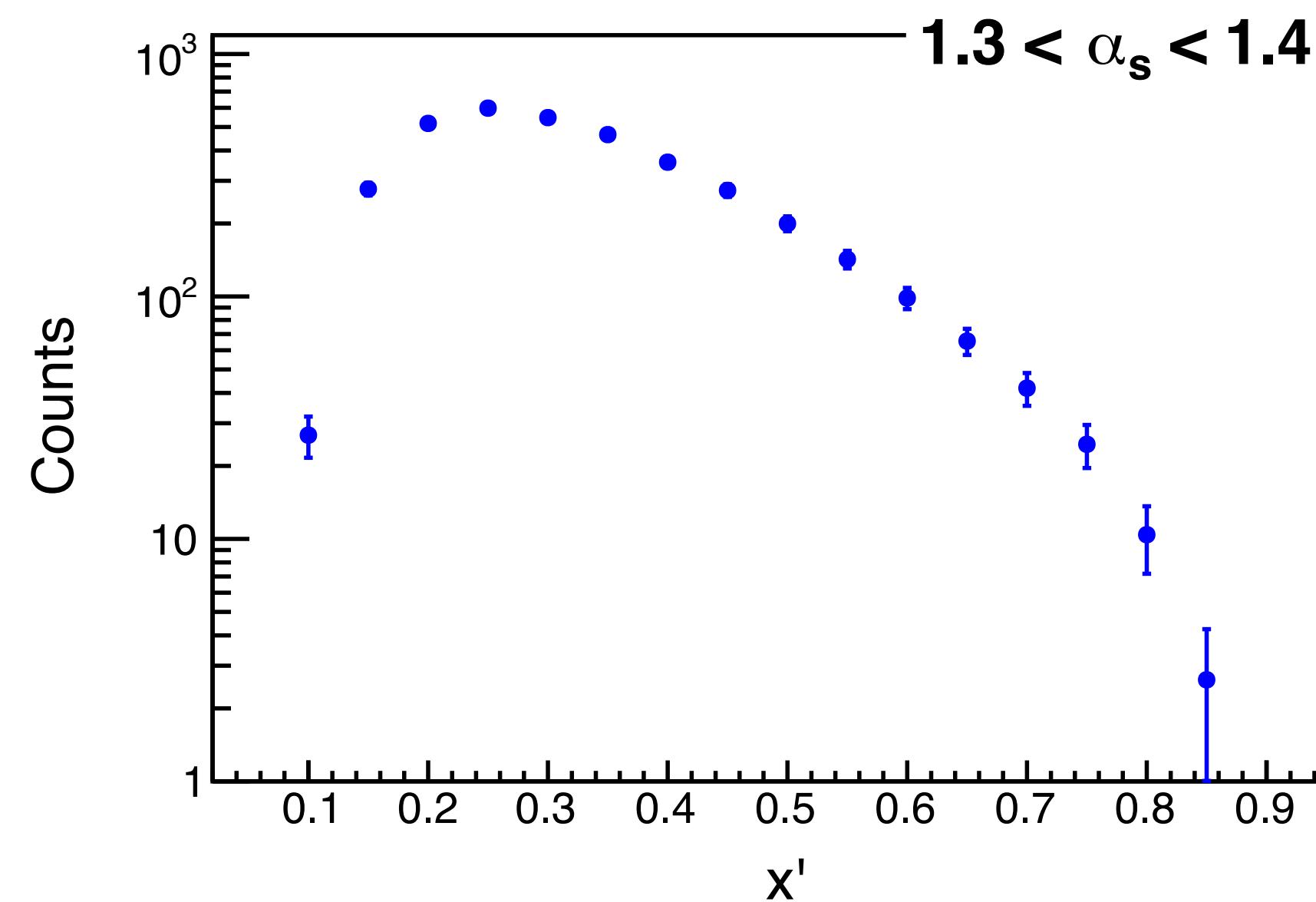
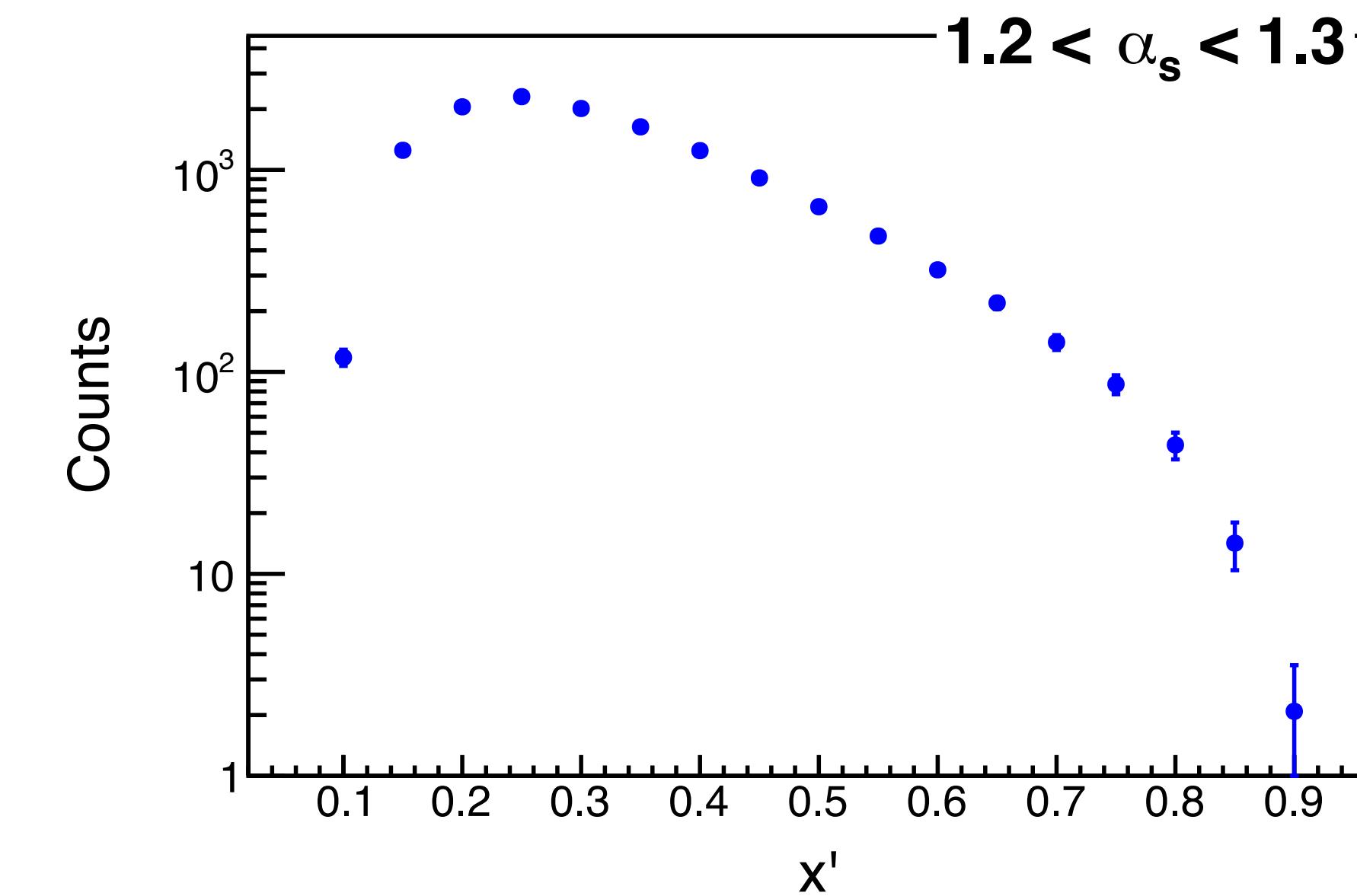
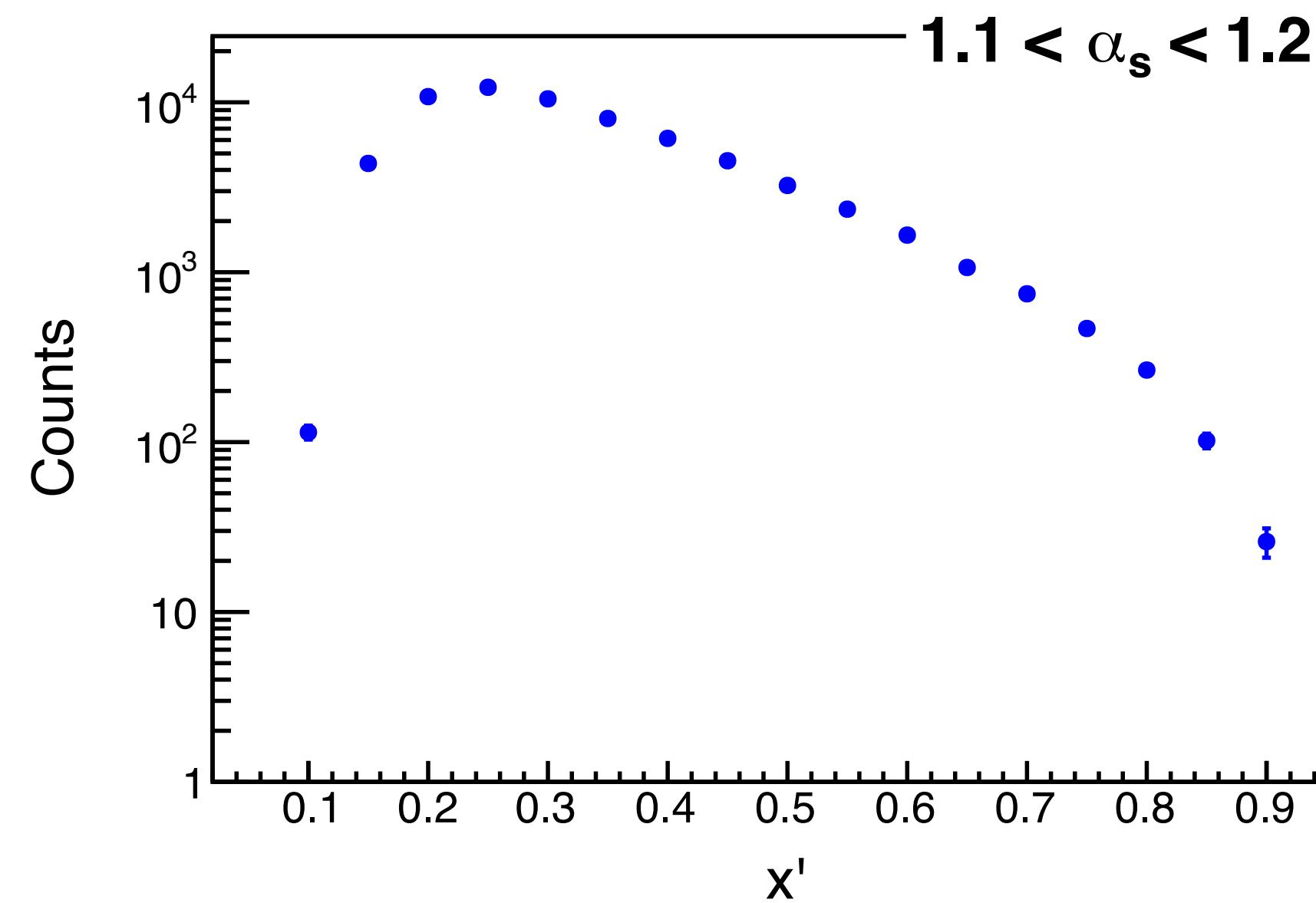
Tagged DIS kinematics



What could be done with a 22 GeV electron beam?

- Approach:
 - Assume detectors the same, only beam energy changes
 - Use same luminosity (180 fb^{-1}) as RGB data used for present analysis
 - Estimate rates with fast Monte Carlo
(CLAS12 electron acceptance, BAND neutron acceptance/efficiency)

Projected statistical reach in data ratio at 22 GeV



Summary

- Tagged DIS allows measurements of parton structure sensitive to nuclear configuration
- BoNuS used proton-tagged DIS from deuterium to extract free neutron structure
 - Existing BoNuS data from 6 GeV; BoNuS12 collected data in 2020
- BAND/CLAS12 carried out first measurement of neutron-tagged DIS from deuterium
- Upgraded 22 GeV electron beam would extend possible tagged-DIS measurements further into anti-shadowing and EMC effect region