Flavor Dependence of the EMC Effect in ^{3}He & ^{3}H

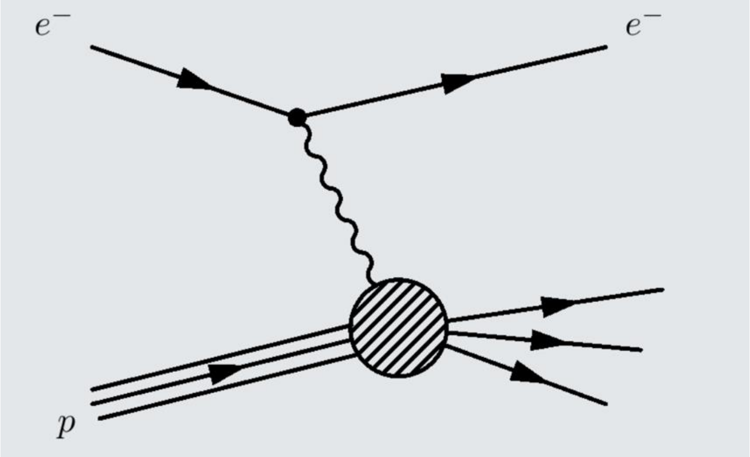
Michael Nycz

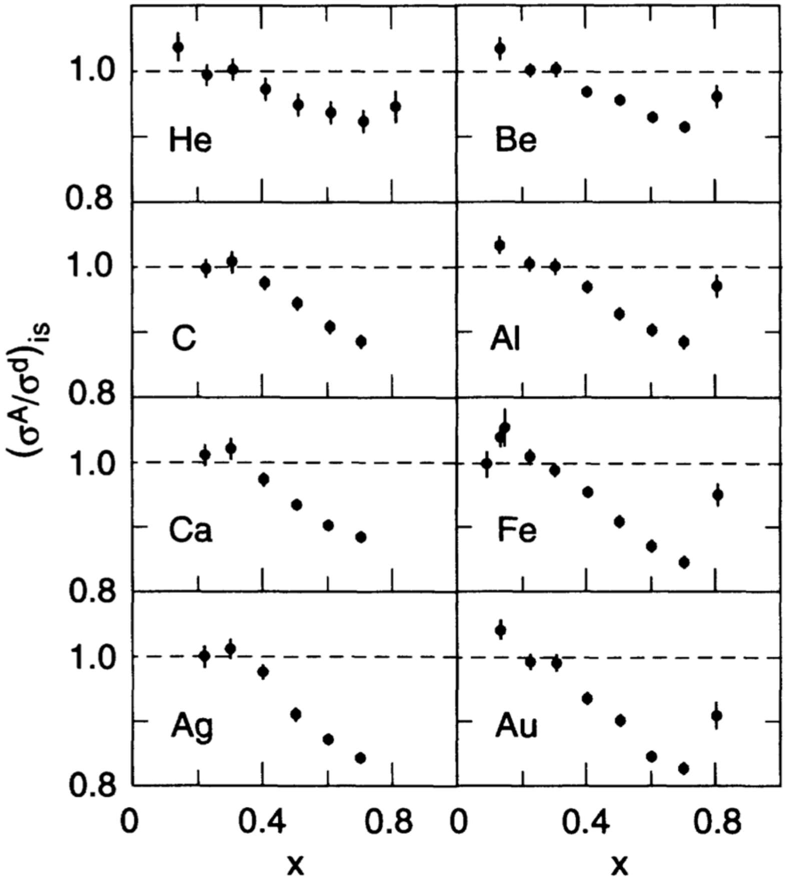
On behalf of
D. Dutta, D. Gaskell, O. Hen, D. Meekins, D. Nguyen, L. Weinstein*, J. R. West, Z. Ye,

UNIVERSITY of VIRGINIA

5th International Workshop on Quantitative Challenges in SRC & EMC-Effect Research

The EMC Effect





Gomez et al., Phys. Rev. D 49, 4348 (1994)

<u>Kinematic Quantities</u>

$\nu = E - E'$ (Energy Transfer)

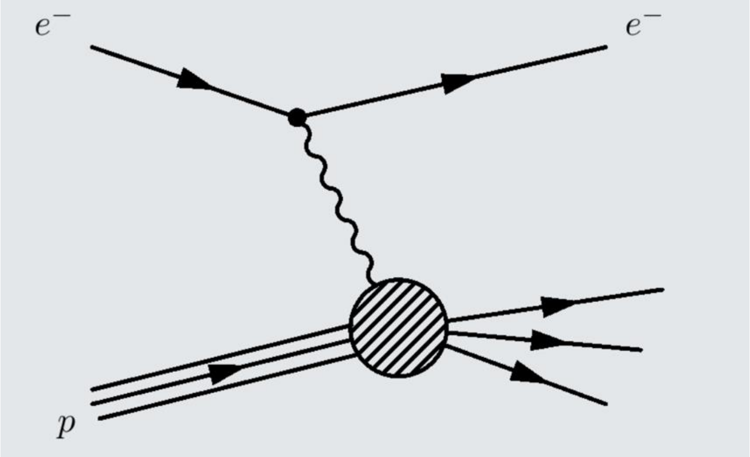
$Q^2 = 4EE'\sin^2(\theta/2)$ (Square of four-momentum transfer)

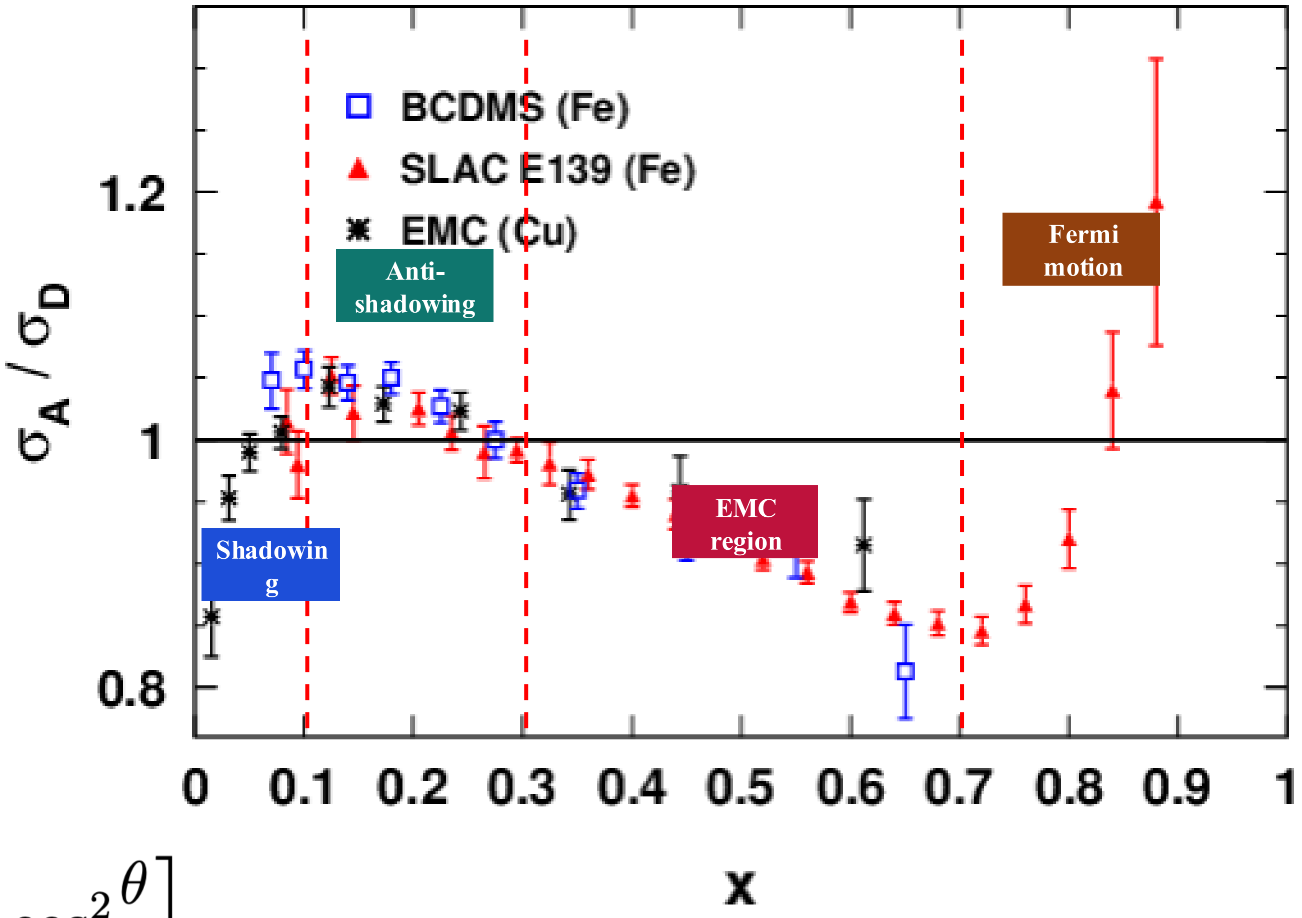
$x = Q^2 / 2M_p\nu$ (Bjorken x)

$$\frac{d^2\sigma}{d\Omega dE'} = \frac{4\alpha^2 E'^2}{Q^4}\left[\frac{2F_1(x)}{M}\sin^2\frac{\theta}{2} + \frac{F_2(x)}{\nu}\cos^2\frac{\theta}{2}\right]$$

The per-nucleon DIS cross section in a nucleus differs from that of a free nucleon

The EMC Effect





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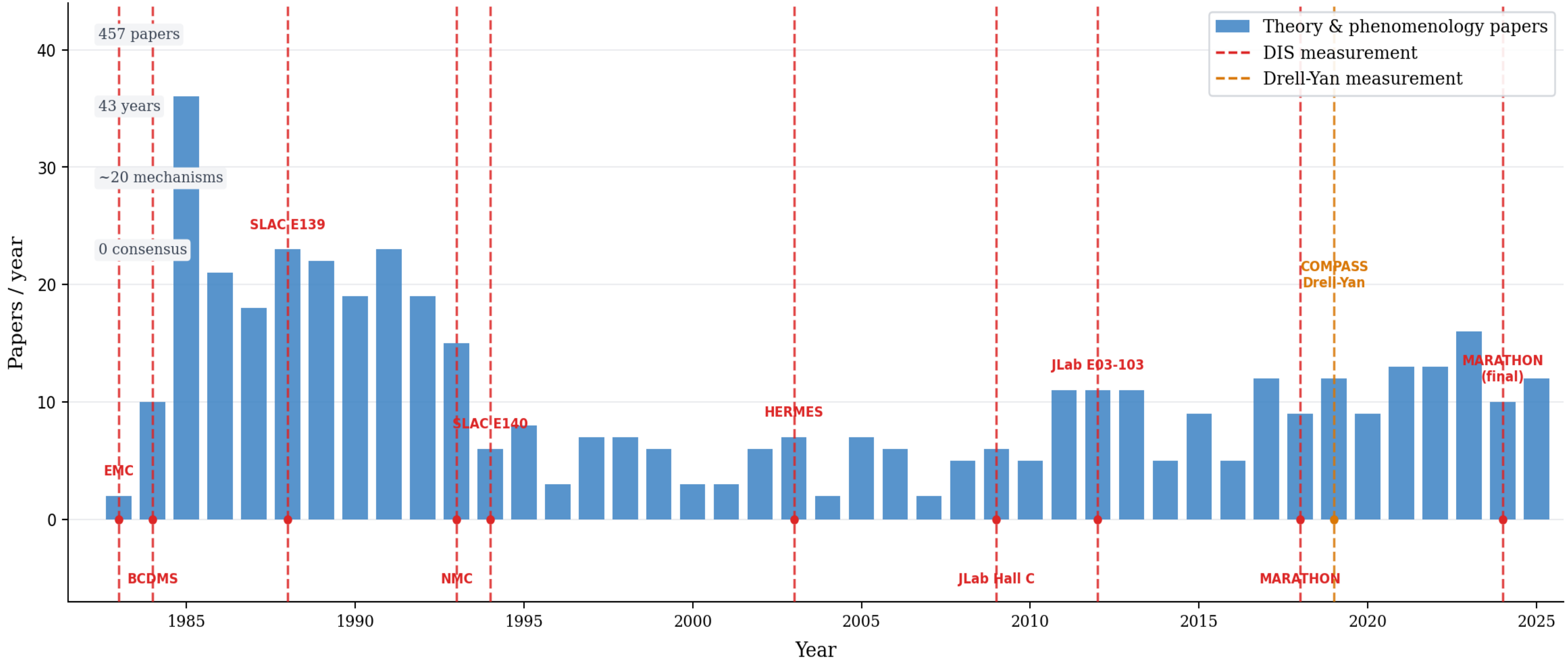
40+ Years – No Consensus

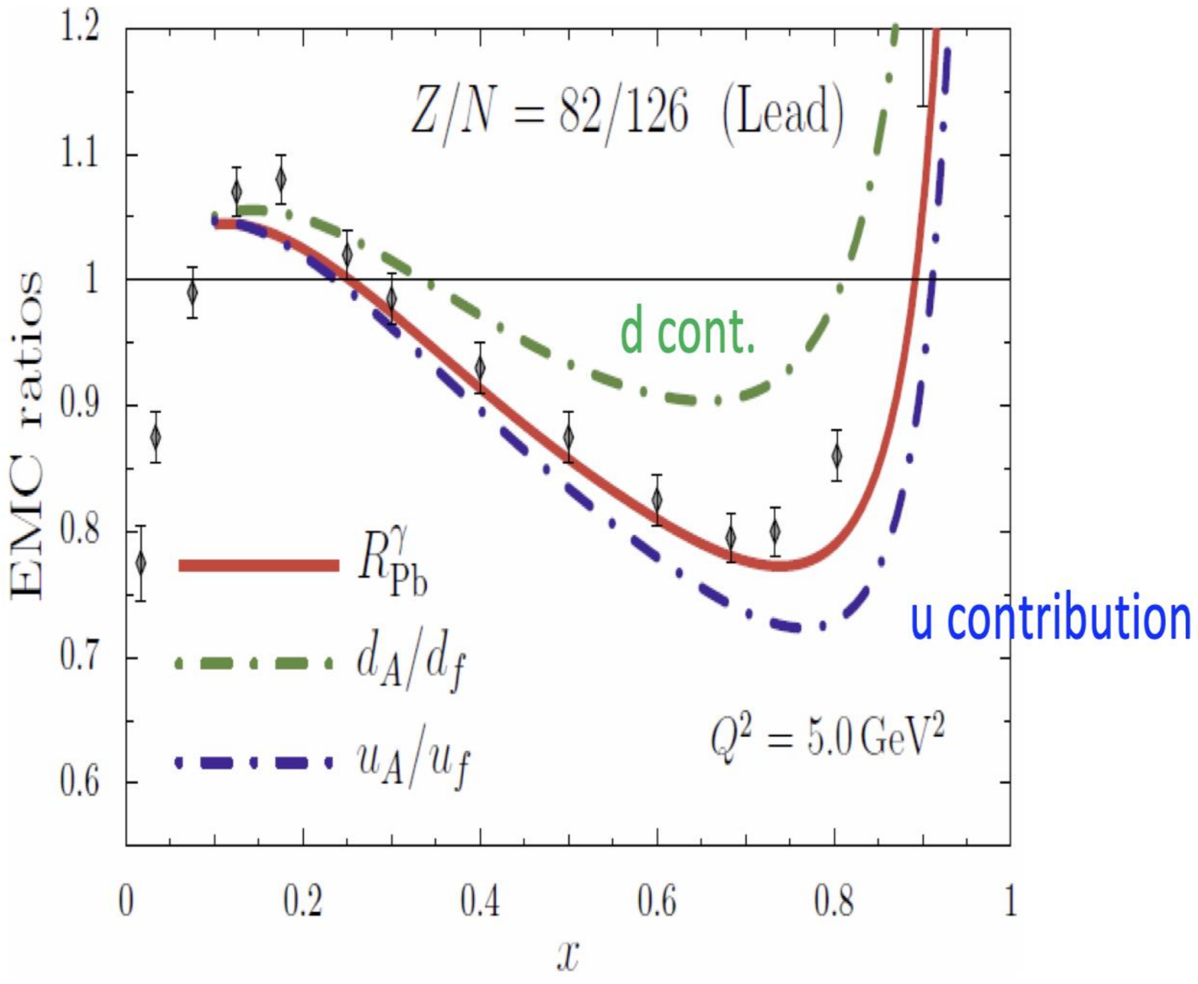


Flavor Dependence

Are there differences in the EMC effect in the up and down quark distributions?

Flavor Dependence of the EMC Effect

- Quark-meson coupling model for "gold"
  - Nuclear matter using same N/Z as gold
  - up quark distribution is more modified than the down quark distribution (N>Z)
  - down quark distribution is more modified than the up quark distribution (N<Z)

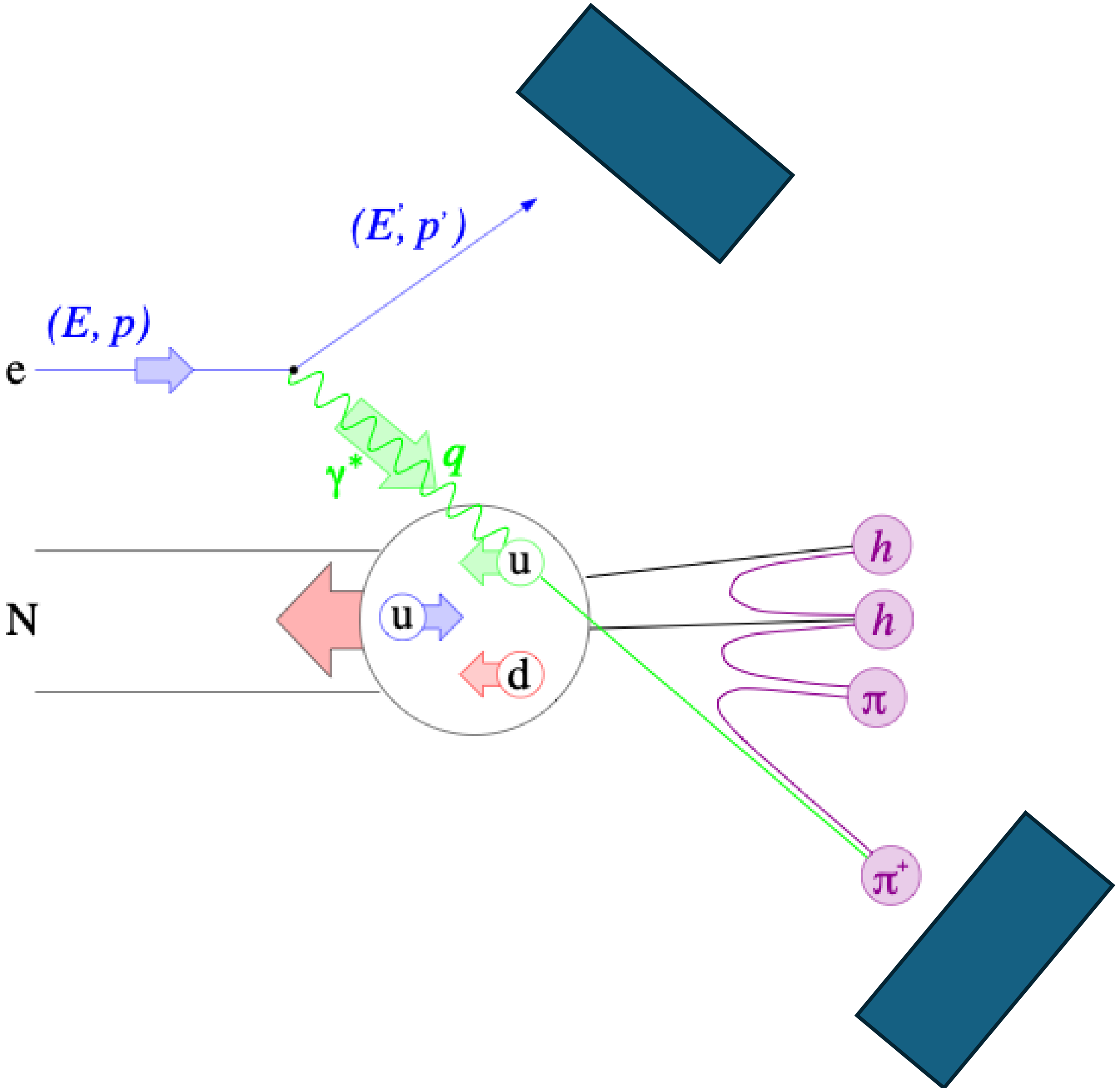


Cloet et al. (PRL 102, 252301; PRL 109, 182301)

Flavor Dependence of the EMC Effect

How to access the flavor dependence?

Semi-Inclusive Deep Inelastic Scattering



SIDIS Cross Section Ratio

$$\frac{d\sigma_A^h}{dx\,dQ^2\,dz} = \frac{4\pi\alpha^2 s}{Q^4}\left(1 - y + \frac{y^2}{2}\right)\sum_{\mathrm{q}} e_q^2 f_1^{A,q}(x)\cdot D_{A,q}^h(z)$$

$$D_u^{\pi^+} = D_{\bar{d}}^{\pi^+} = D_d^{\pi^-} = D_{\bar{u}}^{\pi^-} = D^{fav}$$
$$D_d^{\pi^+} = D_{\bar{u}}^{\pi^+} = D_u^{\pi^-} = D_{\bar{d}}^{\pi^-} = D^{unfav}$$

<u>Ratio of cross sections</u>

$$R_{A_1,A_2}^{\pi,\pm}(x,z) = \frac{(\sigma_{A_1}^{\pi^+} \pm \sigma_{A_1}^{\pi^-})/A_1}{(\sigma_{A_2}^{\pi^+} \pm \sigma_{A_2}^{\pi^-})/A_2}$$

$$= \frac{4(u_{A_1} \pm \bar{u}_{A_1}) \pm (d_{A_1} \pm \bar{d}_{A_1})}{4(u_{A_2} \pm \bar{u}_{A_2}) \pm (d_{A_2} \pm \bar{d}_{A_2})}\cdot\frac{D_{A_1}^{fav} \pm D_{A_1}^{unfav}}{D_2^{fav} \pm D_{A_2}^{unfav}}$$

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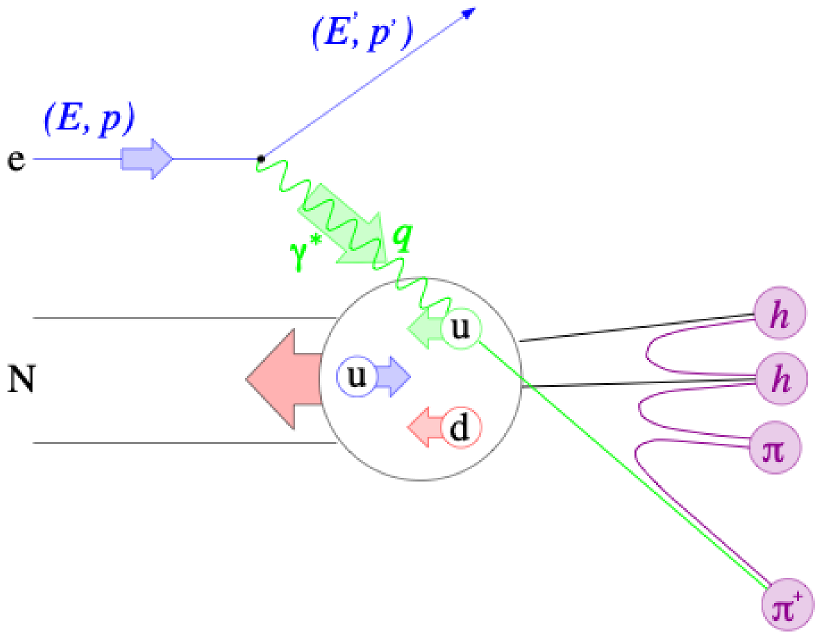

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Choosing Nuclei to Study

- Ratio of light nuclei
  - reduced uncertainties due to hadron attenuation & hadronization

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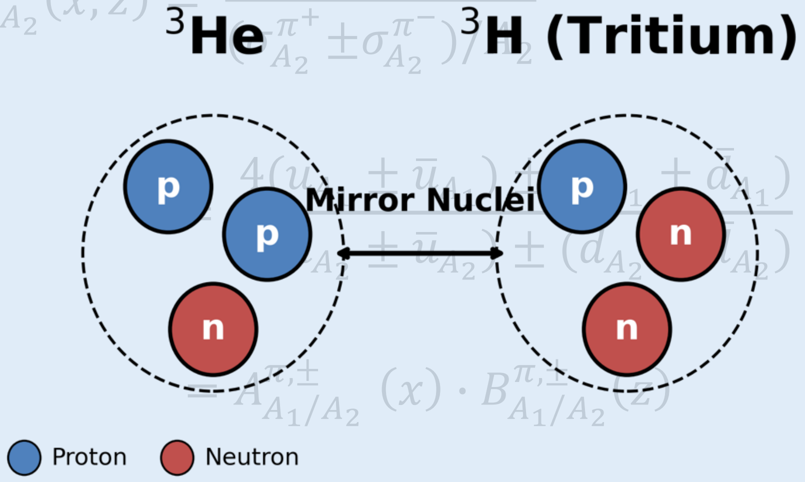
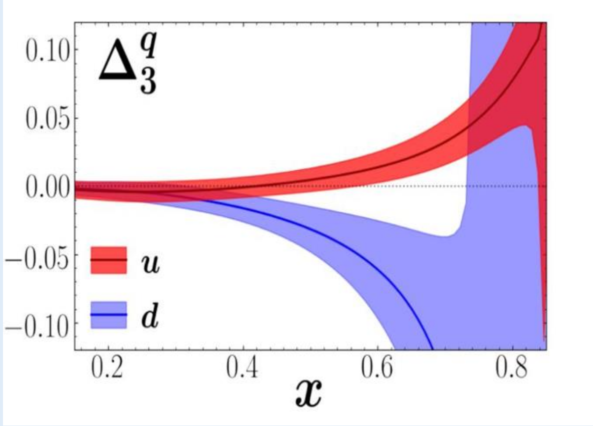


Choosing Nuclei to Study

- Ratio of light nuclei
    - reduced uncertainties due to hadron attenuation & hadronization
- JAM analysis suggests strong flavor-dependent effects for A=3 mirror nuclei



JAM calculation (Cocuzza et al., PRL 127, 242001

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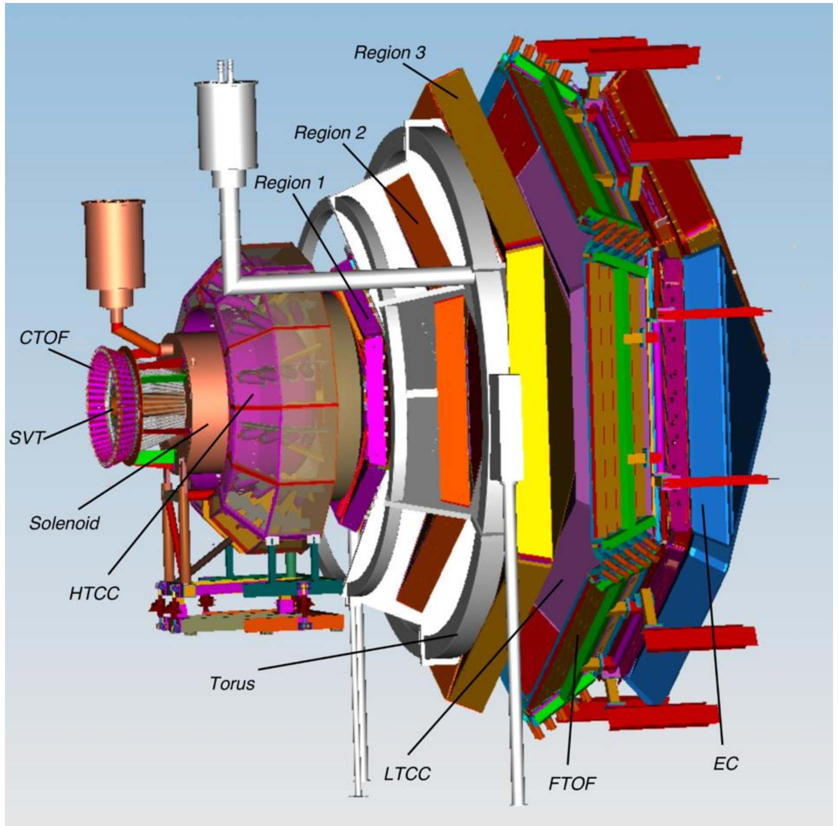
1. **Ratio of charged pion electroproduction in SIDIS deuterium, ^{3}He and ^{3}H**
2. **Global analysis with theory to obtain u- and d-quark nPDFs and nFFs!**

C12-21-004

Semi-Inclusive Deep Inelastic Scattering Measurements of A = 3 Nuclei with CLAS12 in Hall B

- Beam Energy
  - 10.6 GeV/c
- Standard CLAS12
- Targets - Deuterium, Helium-3, Tritium
  - Utilize approved Tritium target system: E12-20-05
- Observables
  - Unpolarized (e,e',$\pi^{\pm}$) and (e,e',$K^{\pm}$)
  - (There is more physics than can be discussed in 10 minutes)



C12-21-004

- Beam Energy
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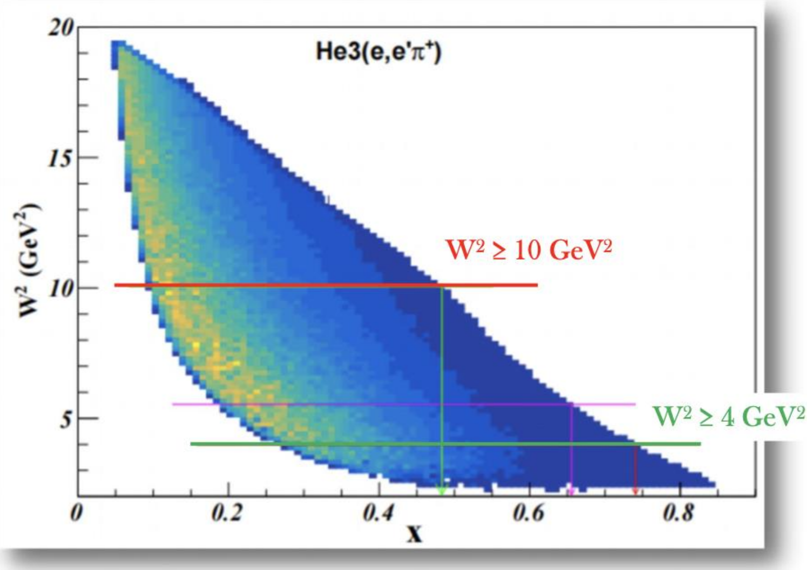
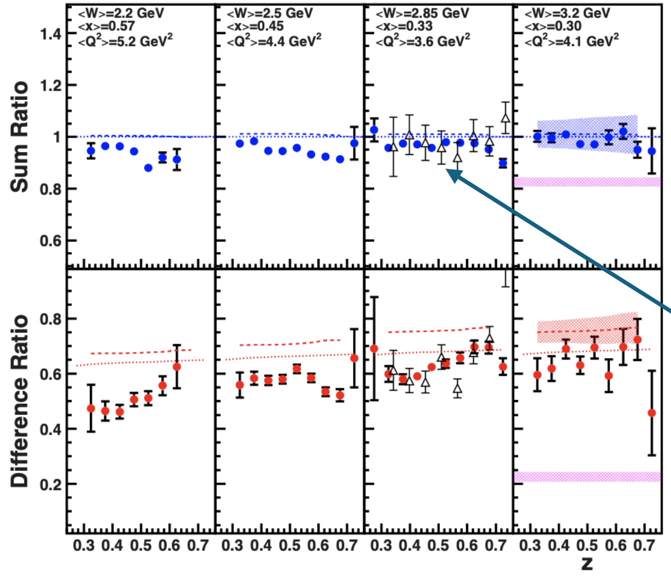




Bhatt, et al, PLB 865 (2025) 139485

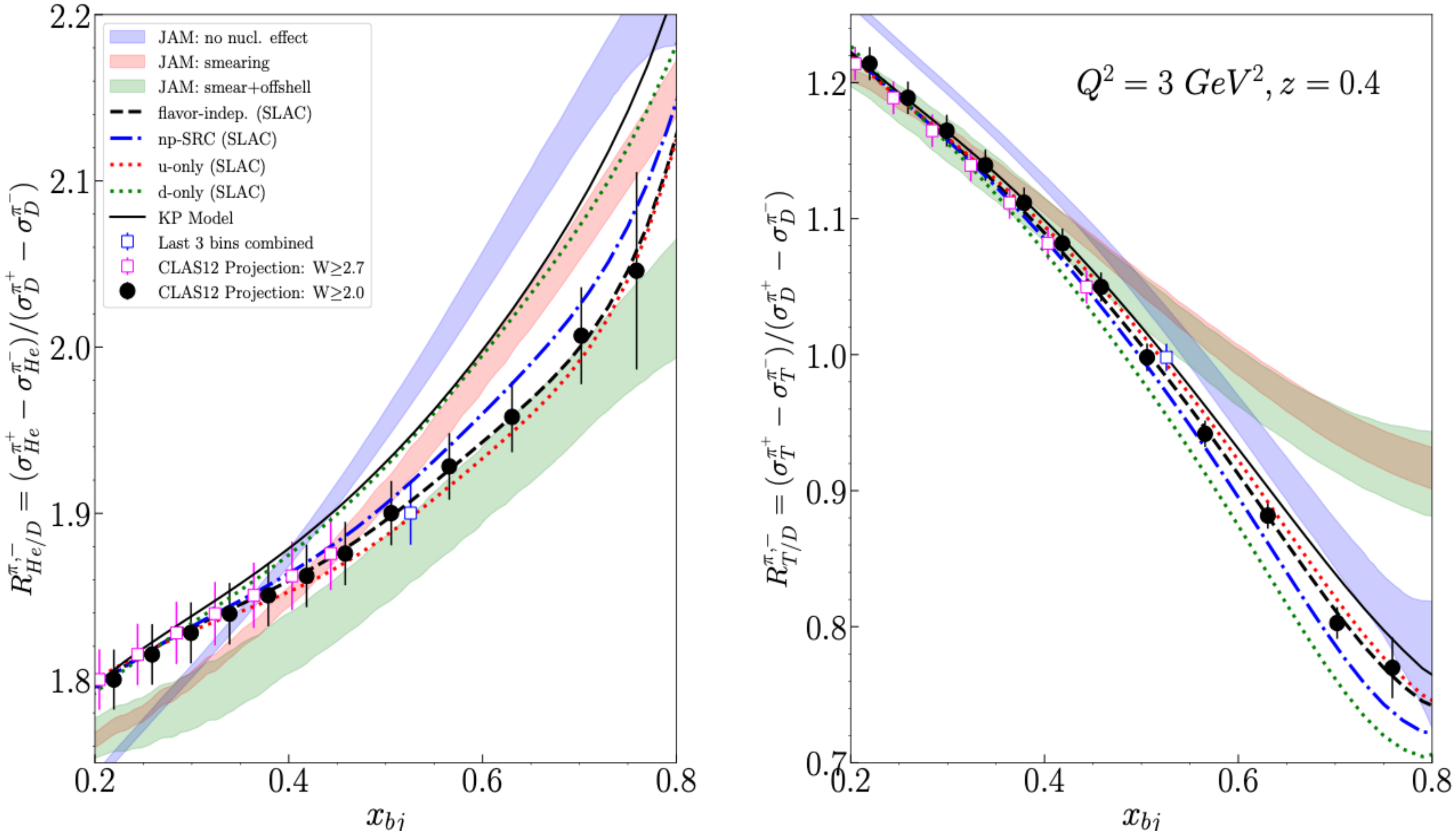
Have studied using the standard cuts

- $Q^2>1$ (Gev/c^2)
- $0.1 < y < 0.85$
- $0.3 < z < 0.8$
- W>2

Have also investigated more restrictive W cuts (factorization)

- W>2.7

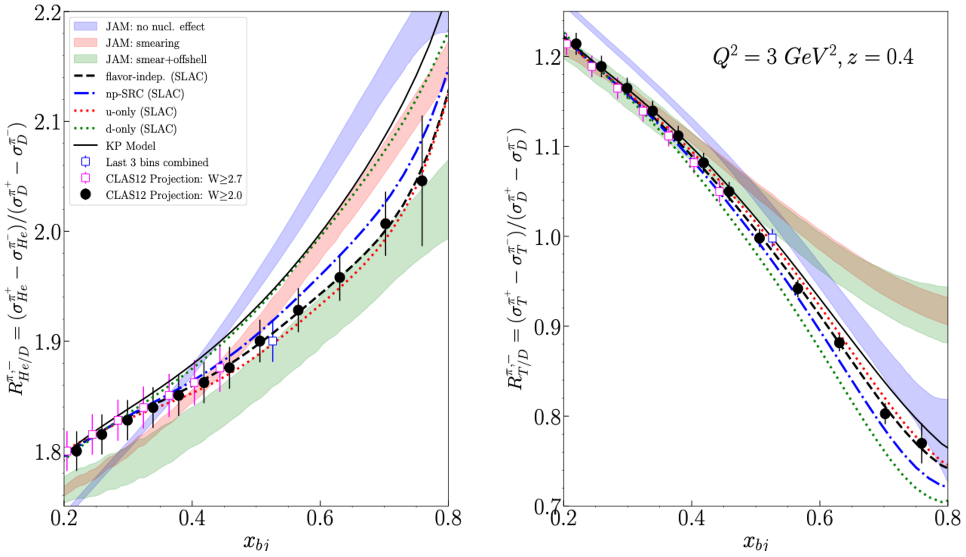
Projection Results



Projected π± SIDIS super-ratios (^3H, ^3He vs ^2H) with 1% point-to-point systematics. Theory curves span flavor-independent to u- or d-only scenarios; JAM smear+offshell shown in green.

Summary

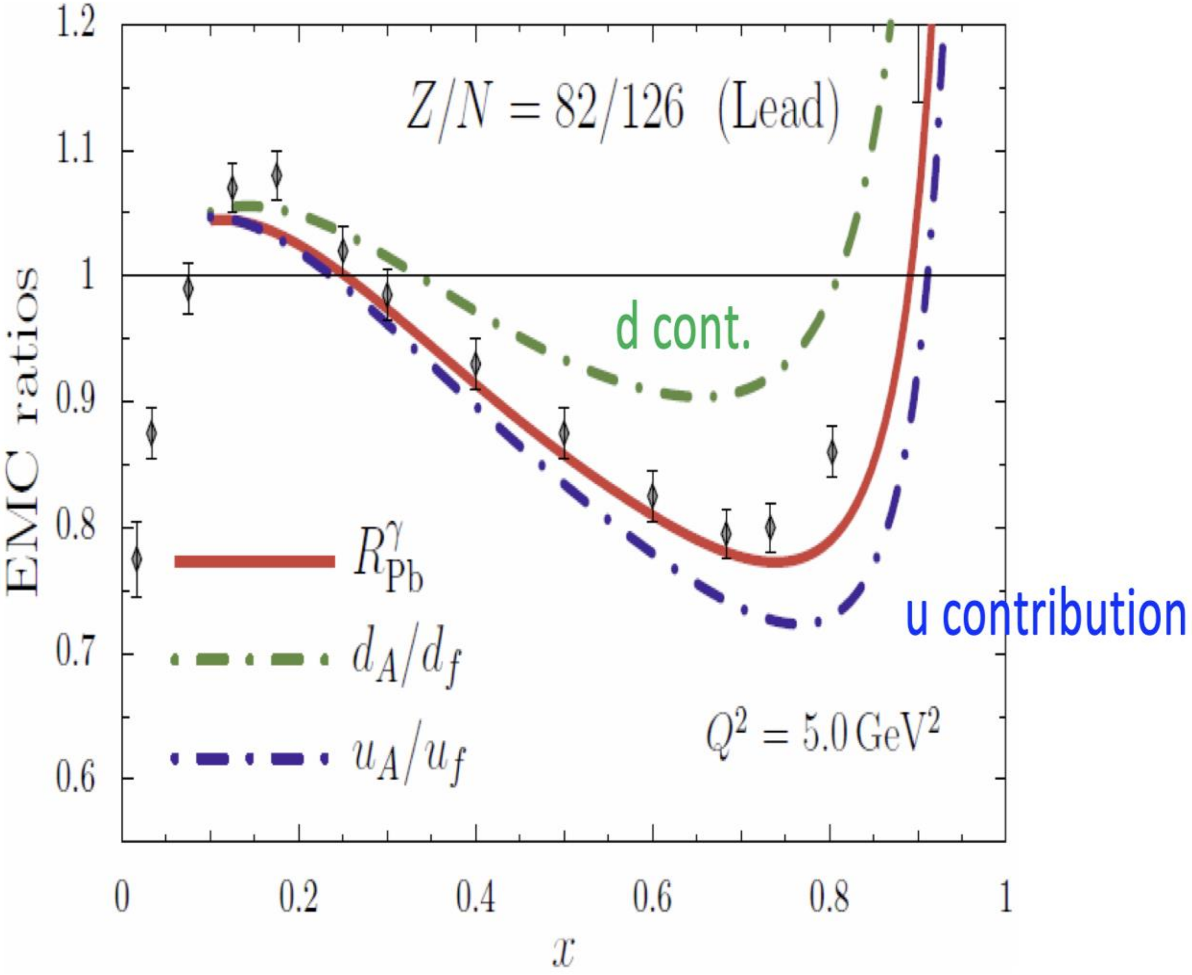
- Over 40 years……
  - A complete understanding and description of EMC effect remains illusive
- SIDIS with A=3 nuclei
  - Provide critical insight into the flavor dependence of the EMC effect in nuclei
- Ongoing theoretical support
  - New JAM calculations
  - Preliminary impact study highlighting impact
  - Continuing to work with theorist

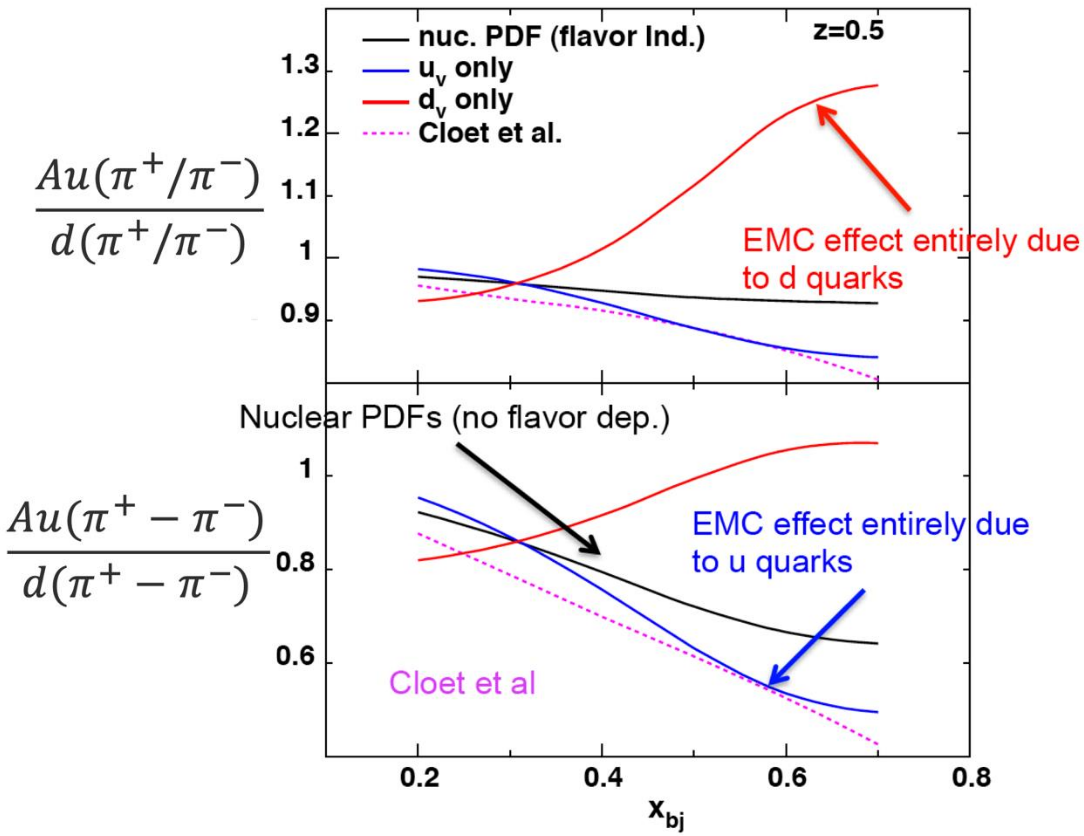


- Tritium is back - E12-20-05
  - Opportunity to maximize the physics using this novel target!
- And many other physics topics…..
  - *d/u* ratio at high-x
  - Measure medium effects on TMDs and FFs

Thank You!

Accessing the Flavor Dependence of the EMC Effect

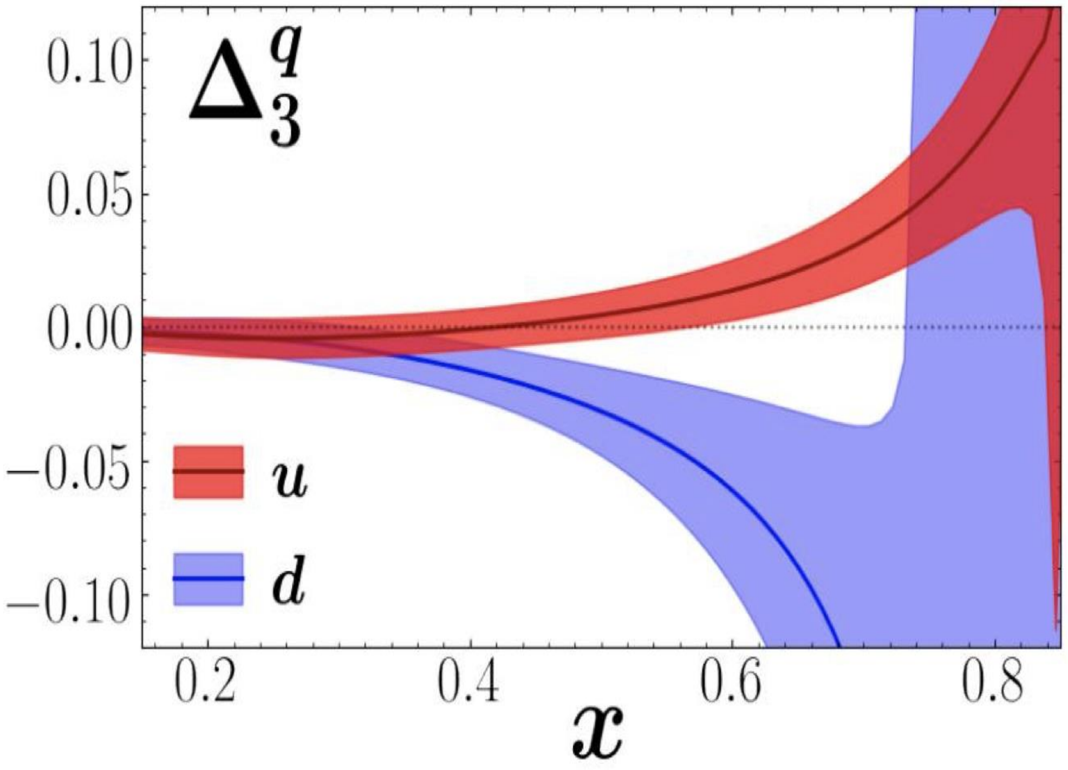




Cloet et al. (PRL 102, 252301; PRL 109, 182301)

PRL 109, 182301 (2012)

JAM Global Analysis: Flavor-Separated nPDFs for ^3He and ^3H



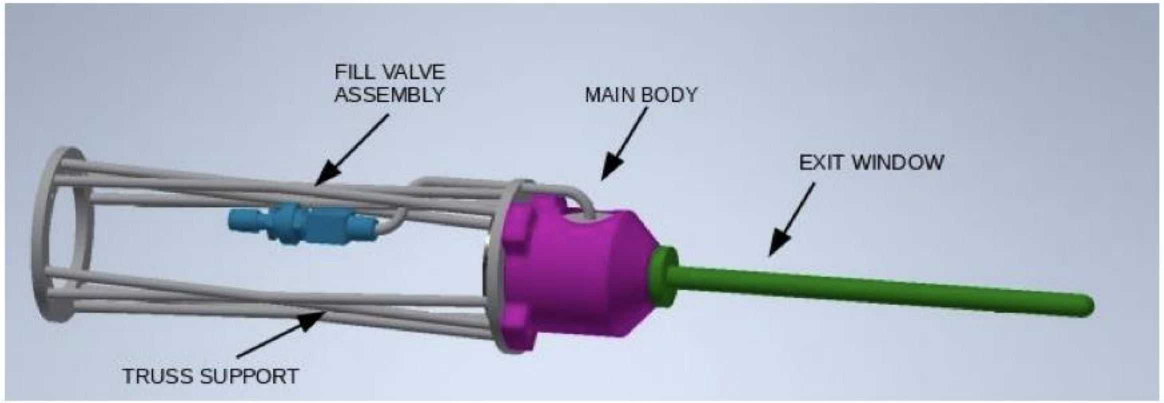
$\Delta 3q = nPDF(^3He) - nPDF(^3H)$

- **u-quark:** more modified in ^3He at large x
- **d-quark:** more modified in ^3H — opposite sign, large uncertainty
- Large uncertainty band: **experiment is needed**

Cocuzza et al., PRL 127, 242001 (2021)

JAM calculation (Cocuzza et al., PRL 127, 242001) shows d-quark is more strongly modified in ^3H, with significantly larger flavor difference at x>0.6. Independent verification needed. (C. Cocuzza et al., 2021)

Tritium Target System: Enabling the A=3 SIDIS Program



Shared target system with approved E12-20-005 (Tritium-SRC experiment). 50+8 days of beam time requested. Same ^2H, ^3He, ^3H targets at 10.6 GeV.