C12-21-004

SIDIS Measurement of A=3 Nuclei with CLAS12 in Hall-B

Conditionally approved in PAC49

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On behalf of the spokespeople:

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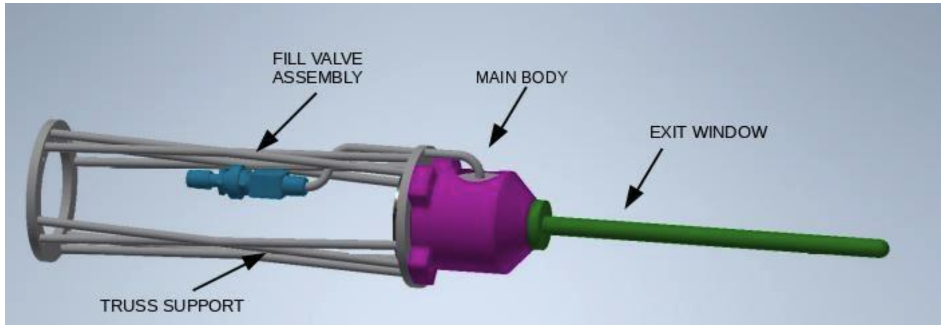
and the CLAS Collaboration

07/11/2022, PAC50 Meeting

清華大學
Tsinghua University

SIDIS with A=3 (C12-21-004)

➢ Proposed SIDIS Measurement:



- Standard CLAS12 w/ new Tritium-Target
  - ✓ Same target system for approved E12-20-005@6.6GV
  - ✓ 10.6GeV
- 50+8 days of beam time requested
- Observables: unpolarized (e,e'$\pi^{\pm}$) & (e,e'$K^{\pm}$) SIDIS cross-sections and ratios
- Main goals:
  - ✓ Flavor-dependence of the EMC effect
  - ✓ Test high-x nuclear corrections
  - ✓ Medium effect on nuclear TMDs & Fragmentation Functions
  - ✓ Medium effect in Strangeness

SIDIS with A=3 (C12-21-004)

- Conditionally approved (C2):

PAC49 Summary:
"The proposal addresses the fundamental question of the origin of the EMC effect. The physics program is very rich, but the extraction of the underlying physics observables is very challenging. Therefore the PAC strongly encourages the proponents to reinforce their links with theory groups, in order to benefit from a more complete approach within a full QCD global analysis framework."

- Very positive PAC50-TAC reports:

Theory:
"… The revised proposal has taken into account the suggestions made in PAC49, …."

Experiment:
"There are no technical issues with running the experiment in Hall-B other than safe handling of the tritium target ..."

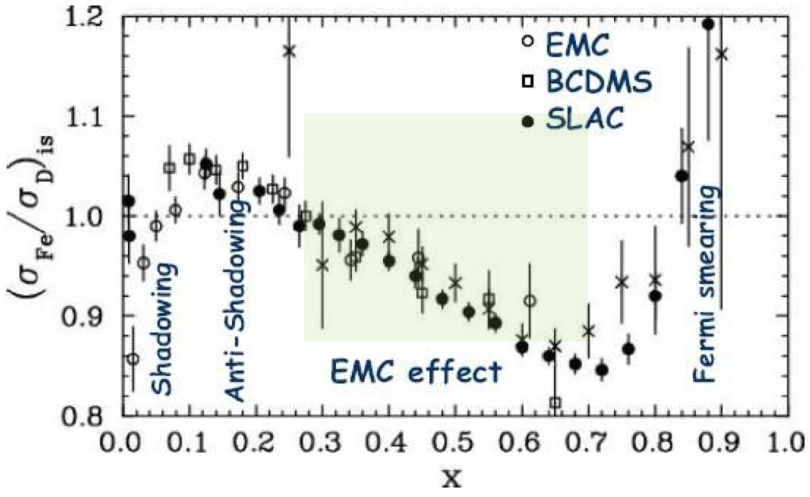
SIDIS with A=3 (C12-21-004)

- This presentation:
  - ✓ Physics motivation
  - ✓ New theoretical calculations
  - ✓ Other PAC49 comments

Motivation

➢ Flavor-Dependence of the EMC Effect:

❖ Per-nucleon DIS cross-section ratio between a nucleus-A to the deuteron decreases linearly in 0.3<x<0.7



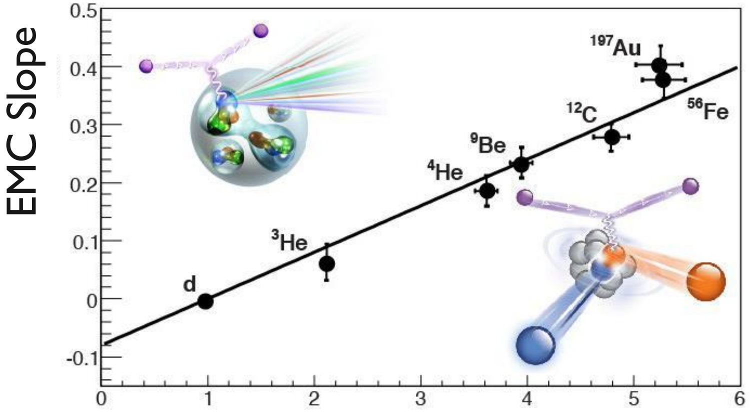
- Nucleon must be modified
- No accepted explanation

❖ EMC effect related to short range correlated (SRC) pairs:

L.Weinstein et al, PRL 106, 052301 (2011)， O. Hen et al, RMP

SRC pairs

- Predominantly pn
- High relative momentum
- Overlapping?



SRC Scale Factor

❖ Which nucleons are modified?

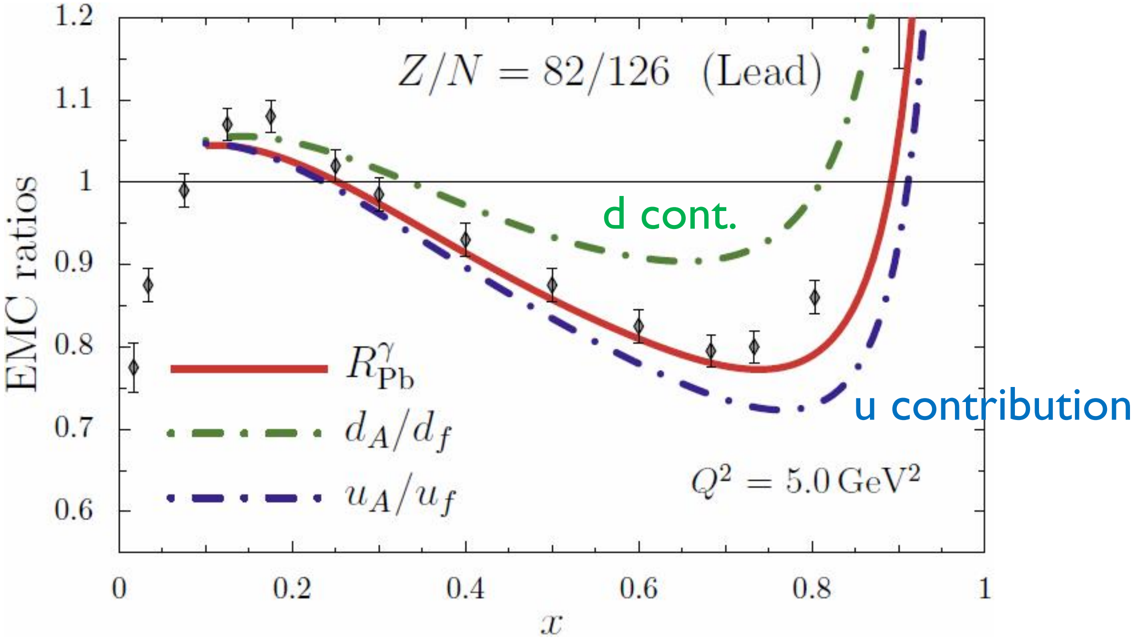
- All nucleons?
- Only SRC (pn) pairs?
- Flavor dependent?

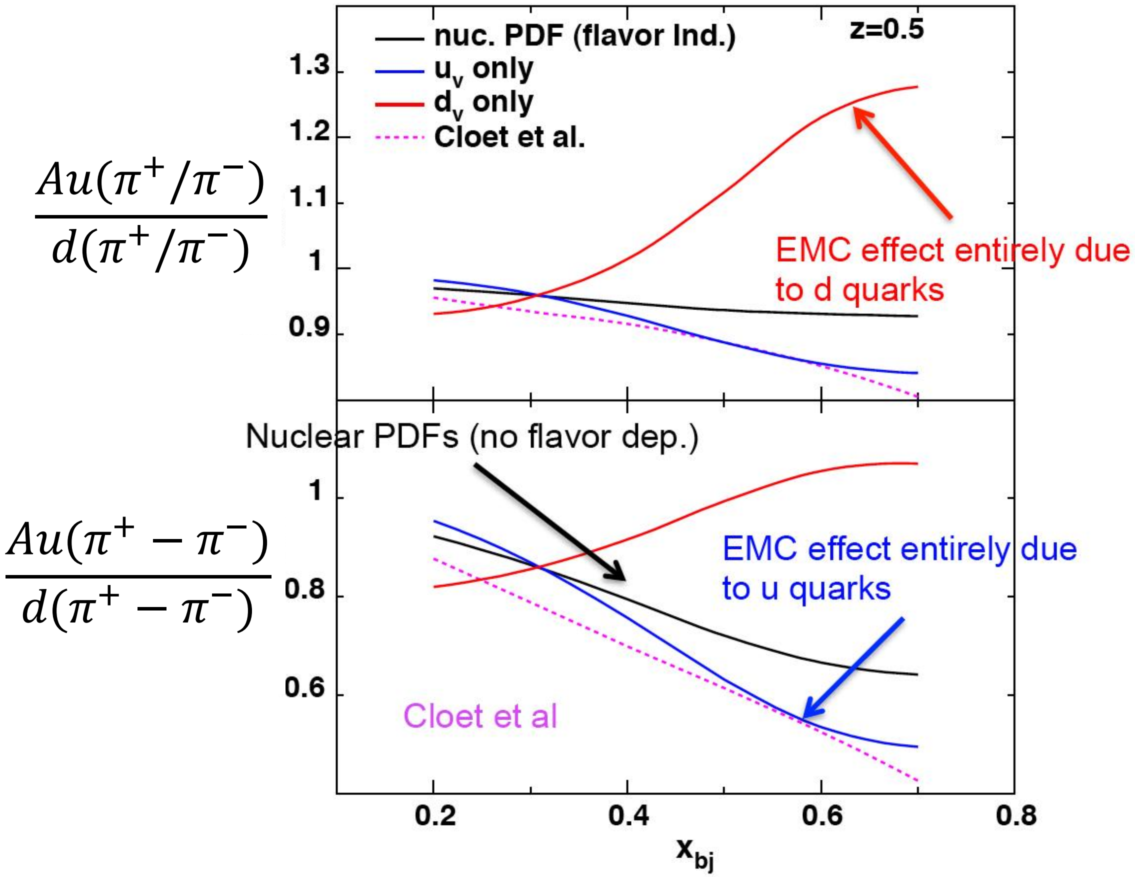
Motivation

➢ Flavor-Dependence of the EMC Effect:

❖ Gold nPDF model is flavor-dependent

- ✓ If N>Z, u-quark is more modified
- ✓ If N<Z, d-quark is more modified





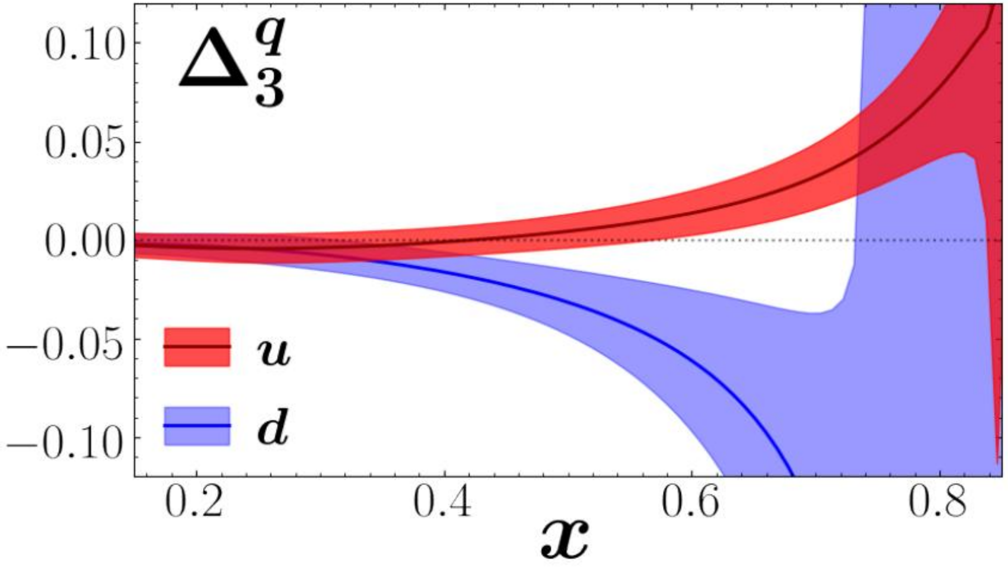
I. Cloet, et al, PRL 102, 252301 (2009); PRL 109, 182301 (2012)

Motivation

➢ Flavor-Dependence of the EMC Effect:

❖ JAM suggests strong flavor-dependent effect in A=3:

- ✓ d_p-quark more modified in ^{3}H
- ✓ Much larger difference at x>0.6



C. Cocuzza, et. al., Phys. Rev. Lett. 127, 242001

$$\Delta_3^q \equiv \frac{q_{p/^3\mathrm{H}} - q_{p/^3\mathrm{He}}}{q_{p/^3\mathrm{H}} + q_{p/^3\mathrm{He}}} \neq 0$$

⇩

$$F_2^A \stackrel{?}{=} Z F_2^{p/A} + (A-Z) F_2^{n/A}$$

✓ Need independent verification!

Motivation

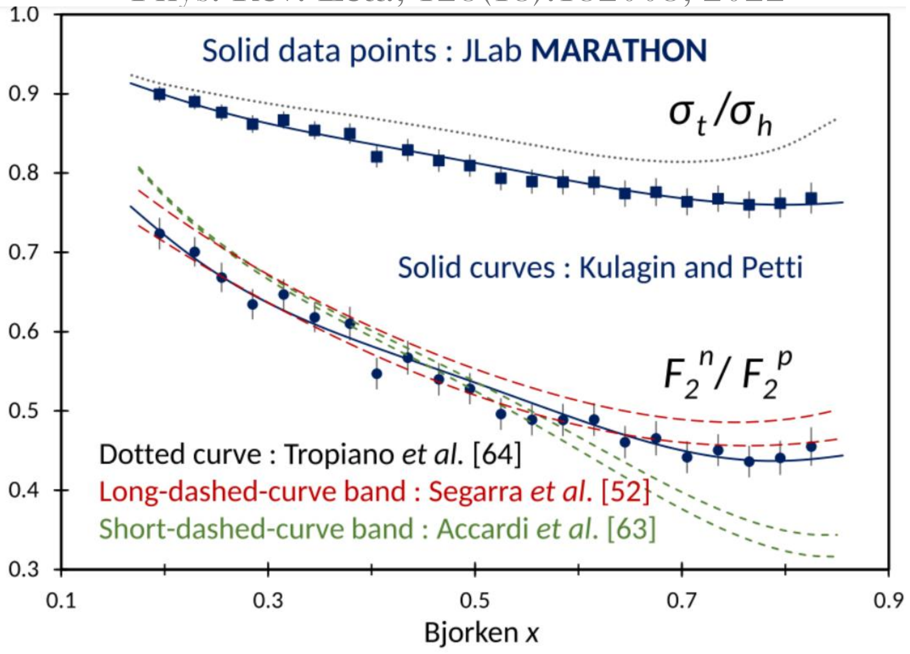
➢ Test High-x Nuclear Corrections

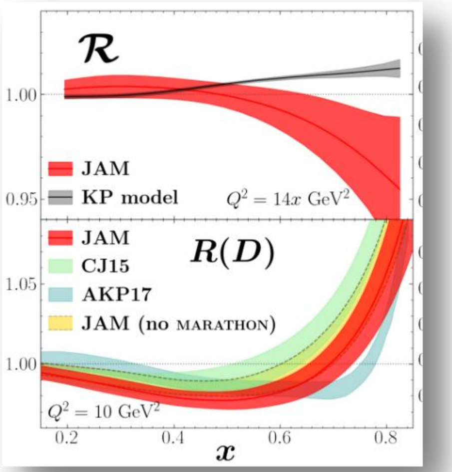
MARATHON data:

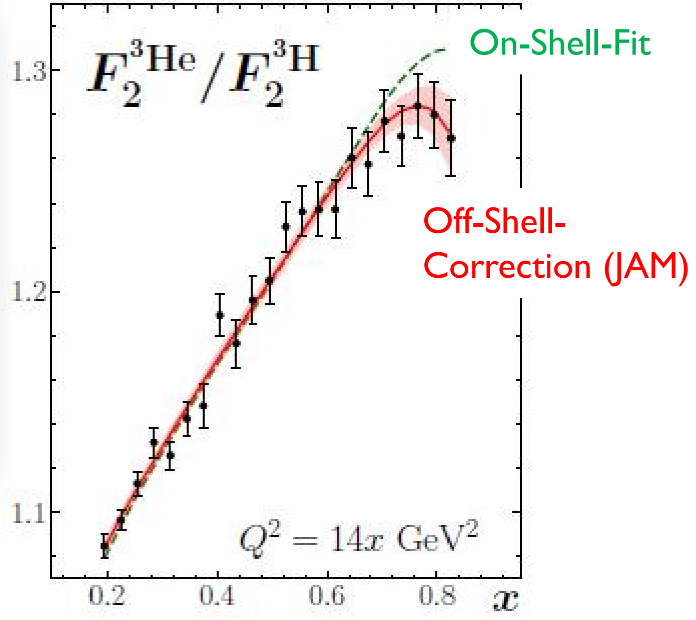
- ❖ Nucleon motion
- ❖ Offshell corrections

$$\frac{F_2^n}{F_2^p} = \frac{2\mathcal{R} - F_2^{^3\mathrm{He}} / F_2^{^3\mathrm{H}}}{2F_2^{^3\mathrm{He}} / F_2^{^3\mathrm{H}} - \mathcal{R}}$$

Phys. Rev. Lett., 128(13):132003, 2022







C. Cocuzza, et. al., Phys. Rev. Lett. 127, 242001

Motivation

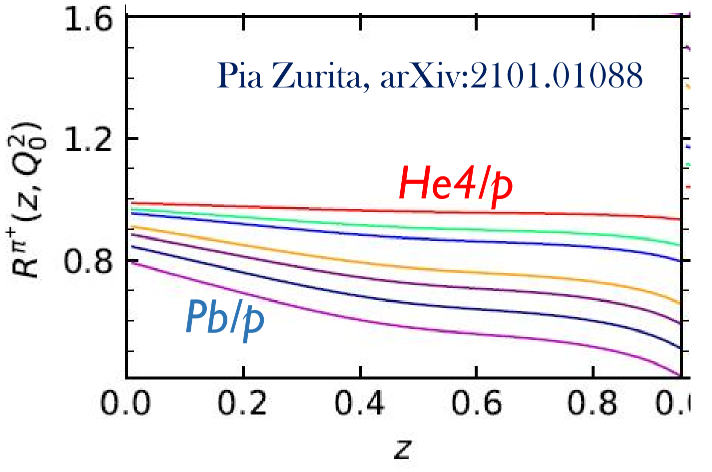
➢ Unpolarized SIDIS Cross Section with nuclei:

$$\frac{d\sigma^h}{dxdydz} = \frac{4\pi\alpha^2 s}{Q^4}(1 - y + \frac{y^2}{2}) \sum_q e_q^2 [f_1^q(x) \, D_q^h(z)]$$

Nuclear PDF (nPDF)

Nuclear Fragmentation Function (nFF)

nFF Ratios



☒ FFs are significantly modified in heavy nuclei

- **Potential:**
  - Sensitive to flavor
    - Detect π^+, π^-, K^+, K^-
  - Access 3D info via P_T distributions
- **Challenges:**
  - Common for all SIDIS:
    - Factorization Regions, FF poorly known, Theoretical Corrections
  - Nuclear-SIDIS:
    - Nuclear structure, Hadronization

❖ Key: take advantage of the Potential while minimizing the Challenges

❖ Light nuclei are easier

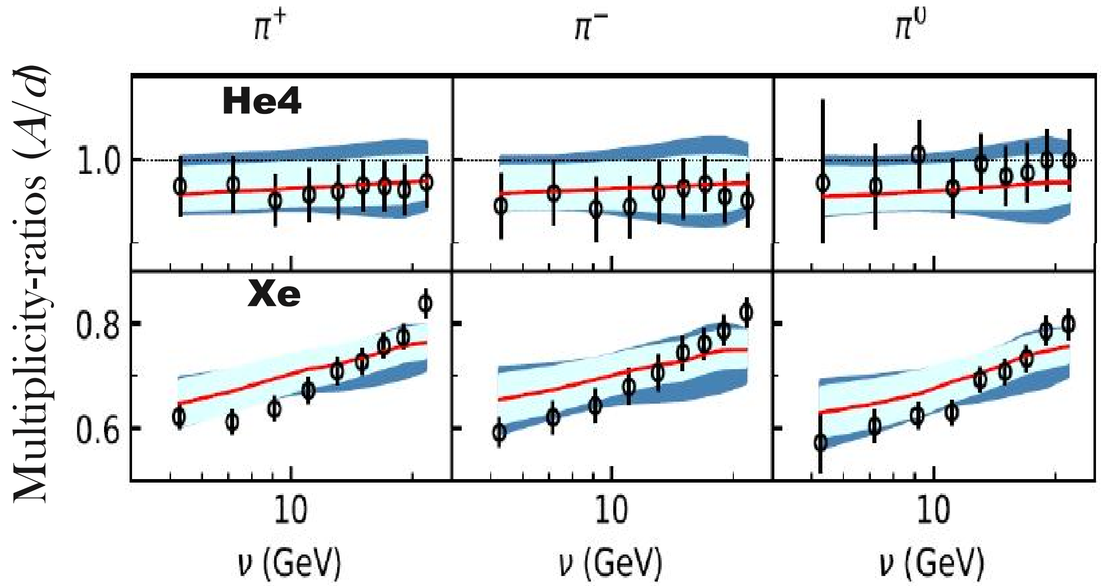
❖ Need close collaboration with theorists in global analysis

Motivation

➢ Tritium and Helium-3 → Ideal nuclei

- ❖ Minimize Challenges:
  - ✓ Precise nuclear calculations
  - ✓ Small hadronization effects
  - ✓ Fragmentation functions
    - o Nuclear effects should be small and very similar
  - ✓ Many theoretical corrections are similar

✓ He4's nFFs have small medium effects (< 5%) (Pia Zurita, arXiv:2101.01088)



- ❖ Unique advantage with mirror nuclei in SIDIS cross-section ratios
- ❖ Help disentangle SIDIS measurements using ^{3}He as "neutron"
- ❖ Complementary to other efforts, such as inclusive DIS and PVDIS with nuclear targets

Motivation

➢ SIDIS cross-section at LO

❖ Unpolarized SIDIS cross section at LO:

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

Simplify the FFs:

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

❖ Ratios:

$$R_{A_1/A_2}^{\pi;\pm}(x,z) = \frac{(\sigma_{A_1}^{\pi^+} \pm \sigma_{A_1}^{\pi^-})/A_1}{(\sigma_{A_2}^{\pi^+} \pm \sigma_{A_2}^{\pi^-})/A_2}$$
$$= \frac{4(u_{A_1} \pm \bar{u}_{A_1}) \pm (d_{A_1} \pm \bar{d}_{A_1})}{4(u_{A_2} \pm \bar{u}_{A_2}) \pm (d_{A_2} \pm \bar{d}_{A_2})} \cdot \frac{D_{A_1}^{fav} \pm D_{A_1}^{unfav}}{D_{A_2}^{fav} \pm D_{A_2}^{unfav}} = A_{A_1/A_2}^{\pi;\pm}(x) \cdot B_{A_1/A_2}^{\pi;\pm}(z),$$

⇩

^{2}D, ^{3}H & ^{3}He Similar and small nuclear effects in nFF: $B_{A_1/A_2}^{\pi,\pm} \cong 1$

❖ Most corrections are cancelled in ratios

❖ In real data, global analysis with theory frame-works to obtain u- and d-quark nPDFs and nFFs!

Motivation

➢ Proof of Principle: SIDIS cross-section at LO

✓ The ratios are uniquely sensitive to the PDFs (D=^{2}D, H = ^{3}He, T = ^{3}H):

$$R^{\pi,-}_{H/D}(x,z) \simeq \frac{4(u_H - \bar{u}_H) - (d_H - \bar{d}_H)}{4(u_D - \bar{u}_D) - (d_D - \bar{d}_D)}, \qquad R^{\pi,-}_{T/D}(x,z) \simeq \frac{4(u_T - \bar{u}_T) - (d_T - \bar{d}_T)}{4(u_D - \bar{u}_D) - (d_D - \bar{d}_D)}$$

Test these assumptions with other observables:

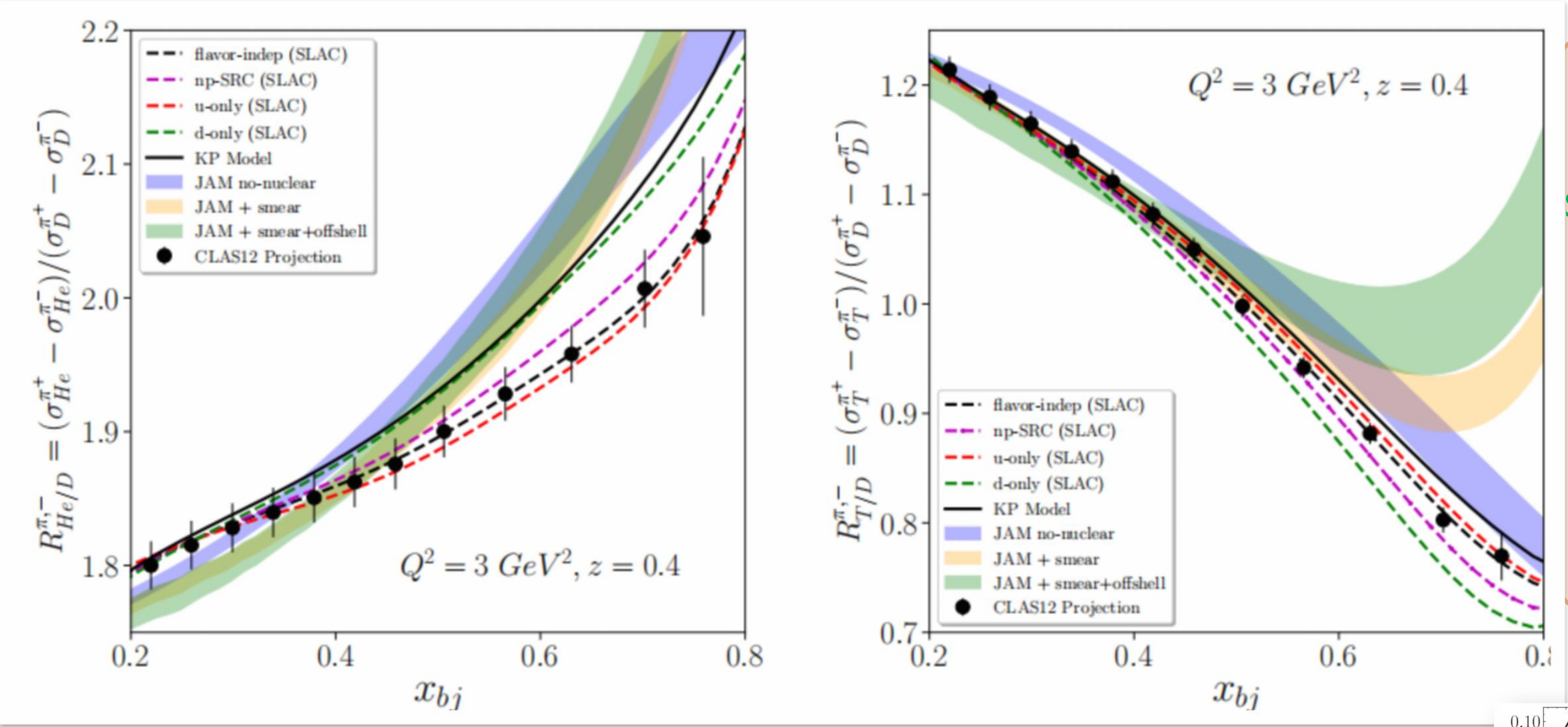
$$R^{\pi,+}_{A/D}(x,z) \overset{?}{=} R^{A}_{EMC} = \frac{2}{A}\frac{\sigma^{DIS}_A(x)}{\sigma^{DIS}_D(x)}$$

$$B^{\pi,+}_{A/D}(z) = \frac{M^{\pi+}_A + M^{\pi-}_A}{M^{\pi+}_D + M^{\pi-}_D}$$

SIDIS multiplicity ratios:

$$M^h(z) = \frac{\sigma_{SIDIS}}{\sigma_{DIS}}$$

Updated Projections

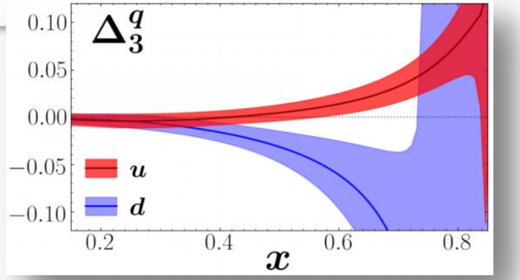


New JAM Calculations

Smear+Offshell

Smear

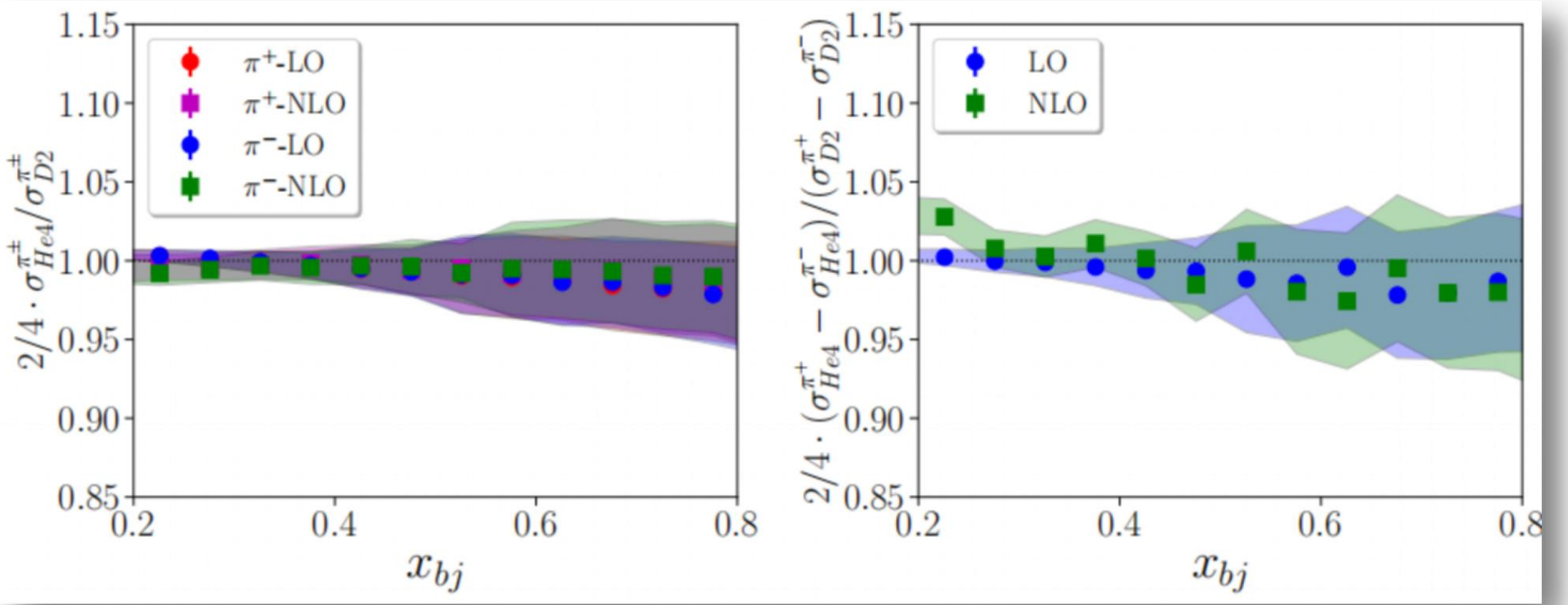
Free



<u>Data-Points:</u> MC events with CLAS12 acceptance, standard SIDIS cuts, one z-bin (0.35 < z < 0.45).
Statistical errors + 1% point-to-point systematic errors

Address PAC49 Comments

- **How good is Leading-Order?:**
  - SIDIS cross-sections in LO: $$\frac{d\sigma^h}{dxdydz} = \frac{4\pi\alpha^2 s}{Q^4}(1 - y + \frac{y^2}{2}) \sum_q e_q^2 [f_1^q(x) \cdot D_q^h(z)]$$
  - Super-ratios of charge-sum &-difference: $$R^{\pi,\pm}_{A_1/A_2}(x,z) = \frac{(\sigma^{\pi^+}_{A_1} \pm \sigma^{\pi^-}_{A_1})/A_1}{(\sigma^{\pi^+}_{A_2} \pm \sigma^{\pi^-}_{A_2})/A_2}$$



LO is a good approximation for ratios →Use sophisticated theory in final analysis

Additional PAC49 Comments

➢ PAC49 Comment#1:

Issues: Currently the impact studies for the sensitivity of the measured observables to the physics quantities, i.e. PDFs, FFs, TMDs, need in all cases significant theoretical input to extract information. Unfortunately, the theoretical models used in the proposal are of very simplistic nature and do not include treatment of nuclear effects, higher order corrections, target mass effects and so on. Consequently, the interpretation of the data might be strongly model dependent. The proposal does currently also not address any of the challenges highlighted in the PAC 48 theory TAC report for SIDIS measurements at JLab, which might be enhanced in nuclear targets.

Response:

- These issues are common to the entire Jlab SIDIS program.
- We directly measure nuclear and higher order effects.
- Strong support from theorists → ongoing efforts
  - ✓ JAM (calculation included)
  - ✓ Pia Zurita (LO vs. NLO, nFF)
  - ✓ T.B Liu, B.Q. Ma, M.C. Cai, QED/QCD radiative corrections, flavor-dependent EMC effects
  - ✓ Jennifer Rittenhouse West, et. al, based on diquark-models
  - ✓ Ian Cloet, et. al. , flavor-dependence, nuclear effect on transverse directions

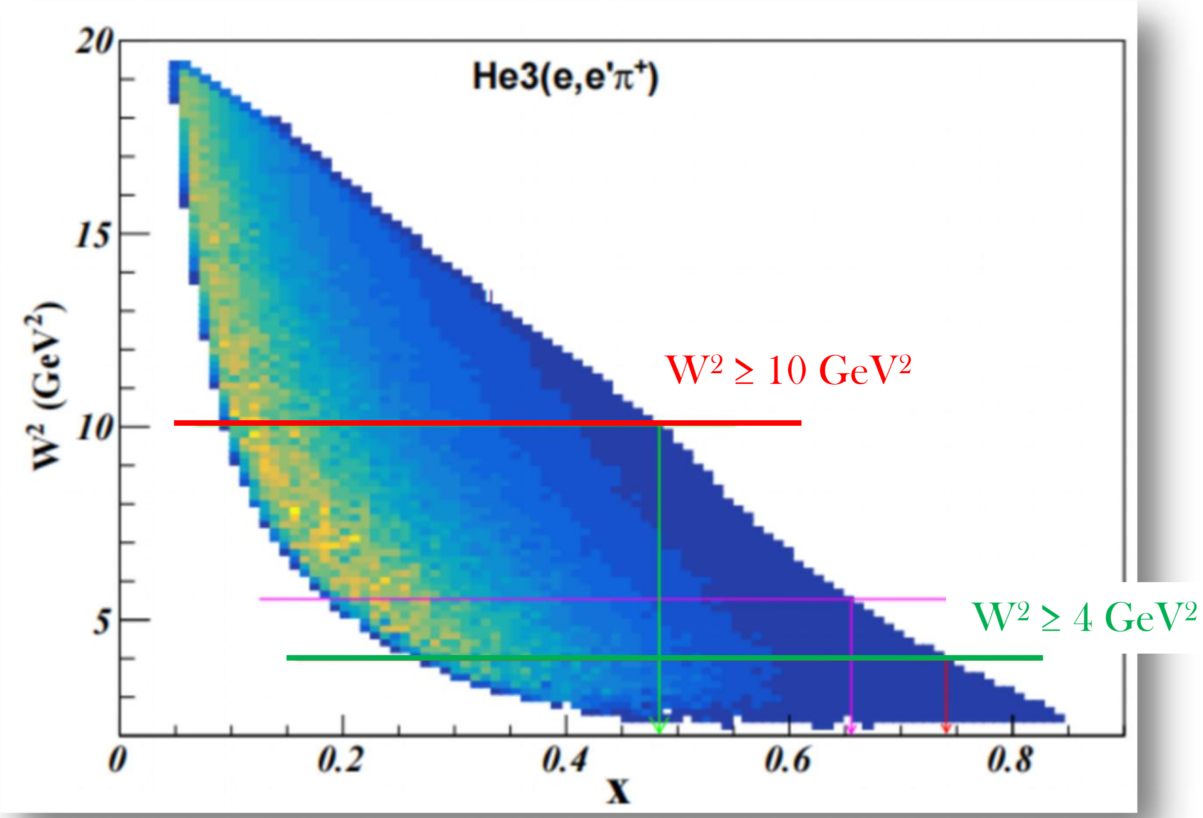
Additional PAC49 Comments

➢ PAC49 Comment#2:

Issue#1: The committee would like to see which kinematic coverage remains when applying stricter cuts like $W^2 > 10$ GeV^2 which may be more appropriate for A=3 targets.

Response:

- $W^2 \geq 10$ GeV^2 cut reject most of the DIS events at large x
- $W^2 > 4$ GeV^2 cut: balance between kinematical coverage and theoretical corrections
- $W^2 > 4$ GeV^2 cut is commonly used by all Jlab SIDIS programs w/ proton, ^{2}D & ^{3}He targets



Additional PAC49 Comments

➢ PAC49 Comment#3:

Issue#2-1: The study of the flavor dependence of the EMC effect and of the 3D structure of A=3 nuclei would benefit from a synergy with complementary measurements at JLab. The proponents should detail clearly where the proposal is complementary to other experiments scheduled or proposed.

Response:

- No other complementary measurements
  - Provide far more info than inclusive EMC ratios
  - New PAC50 proposal (PR12-21-002) to use PVDIS@SoLID with Ca40 and Ca48

Issue#2-2: They should also provide a clear assessment how one can extrapolate from what one learns from A=3 nuclei for the EMC in heavier nuclei.

Response:

- SIDIS w/ heavy nuclei: difficult to decouple nPDF/nTMD and nFF, bigger corrections
- SIDIS w/ A=3 provides the first step toward heavy nuclei
  - ✓ Large isospin asymmetries → enhance flavor-dependent EMC effects
  - ✓ Nuclear structures are precisely calculable
  - ✓ Smaller & similar nuclear effects → nuclear corrections partially cancel in ratios
- Possible extrapolation to heavy nuclei via SRC

Additional PAC49 Comments

➢ PAC49 Comment#4:

Issue#3: Various observables may exhibit different sensitivity to the ingredients of theoretical calculations. The PAC therefore suggests to study how strongly extracted physics quantities depend on theoretical assumptions, regarding for instance QCD and QED radiative corrections and target mass effects

Response:

- Two new theoretical methods: *Phys. Rev. D, 104(9):094033, 2021, JHEP, 11:157, 2021*
- Radiative effects should largely cancel in ratios of SIDIS cross-sections among ^{2}H, ^{3}H, and ^{3}He
- New data can be used to test and improve radiative correction techniques.

Additional PAC49 Comments

➢ PAC49 Comment#5:

Summary#2: The proposal mentions further physics opportunities with exclusive measurements using the same setup and beamtime, and the PAC regards this as an attractive prospect. Once the issues spelled out above have been addressed, the PAC recommends a resubmission as part of a Run-Group Proposal, which will detail all the measurements (e.g. SIDIS, DVCS, exclusive meson production) to be done as part of the A = 3 Nuclei target program with CLAS12.

Response:

- SIDIS by itself contains many rich physics topics that can not be studied elsewhere.
- DVCS and exclusive meson production are still under development
  - ✓ Another big efforts
  - ✓ New collaborators identified

Summary

- New Hall-B Tritium Target
  - Maximize its usefulness
- SIDIS w/ A=3 is conditionally approved:
  - ✓ Flavor-dependence of the EMC effect
  - ✓ Test nuclear-correction at high-x
  - ✓ Measure medium effect on TMDs and FFs
  - ✓ Medium effect in strangeness
- Ongoing theoretical support → New JAM calculations added
- All PAC49 comments are addressed!
  - ✓ Very positive theory TAC report
  - ✓ Other parallel physics topics to follow
- Request full approval!

BACKUP

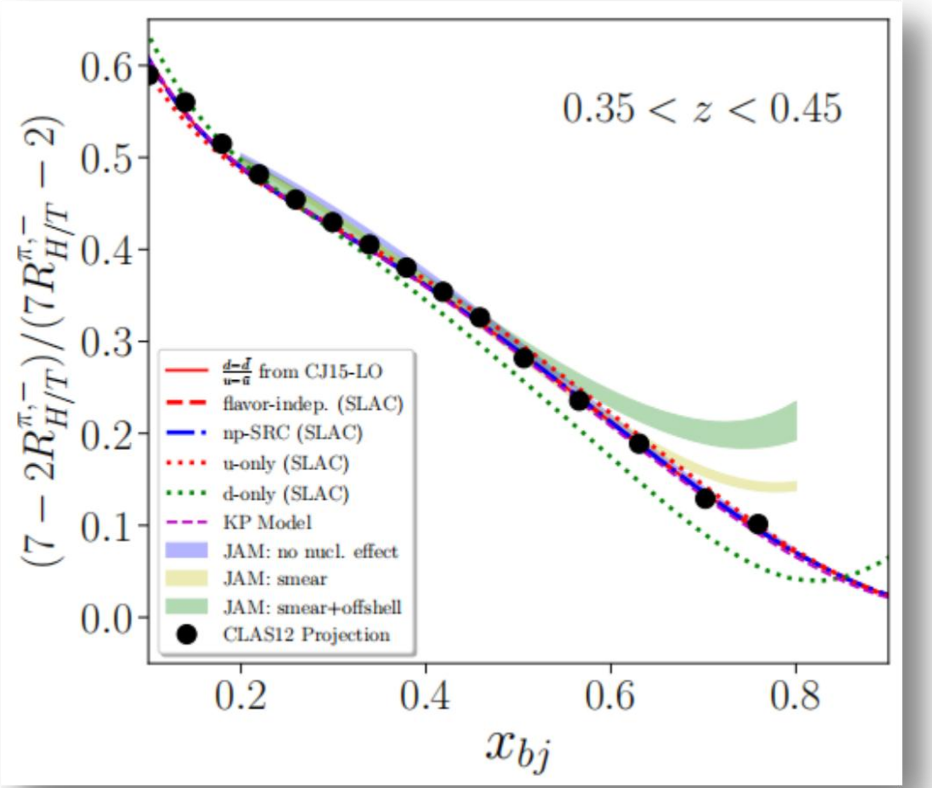
Updated Projections

➢ Nuclear-Correction at high-x → Verify "d/u" with A=3

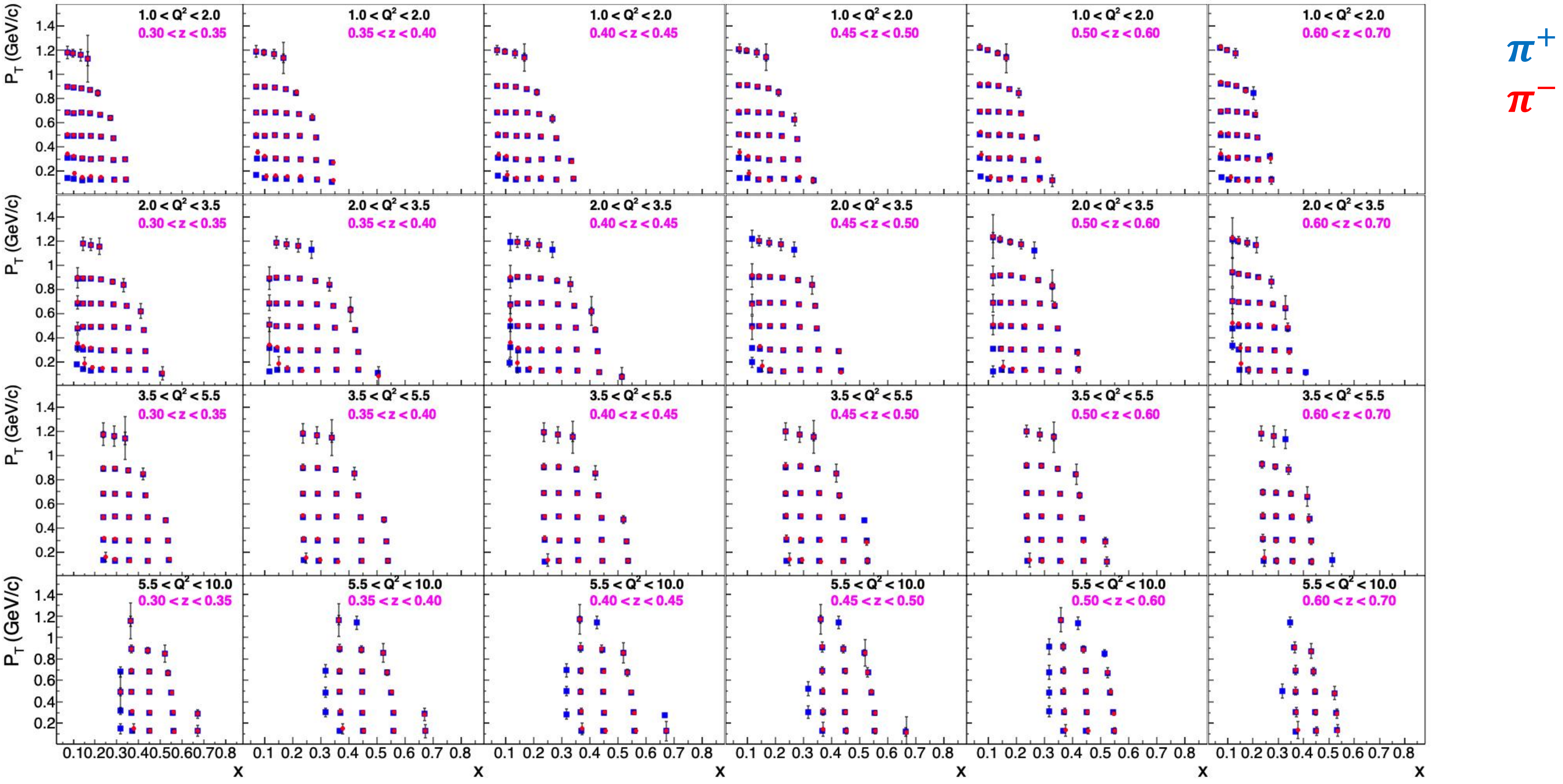
- Model-independently measure nuclear-effects of d/u w/ A=3 at high-x

$$R^{\pi,-}_{H/T} = \frac{(\sigma^{\pi^+}_H - \sigma^{\pi^-}_H)}{(\sigma^{\pi^+}_T - \sigma^{\pi^-}_T)} \simeq \frac{4u_H - d_H}{4u_T - d_T} \quad \Rightarrow \quad \frac{\tilde{d}}{\tilde{u}} \simeq \frac{7 - 2R^{\pi,-}_{H/T}}{7R^{\pi,-}_{H/T} - 2}$$

- New theory curves

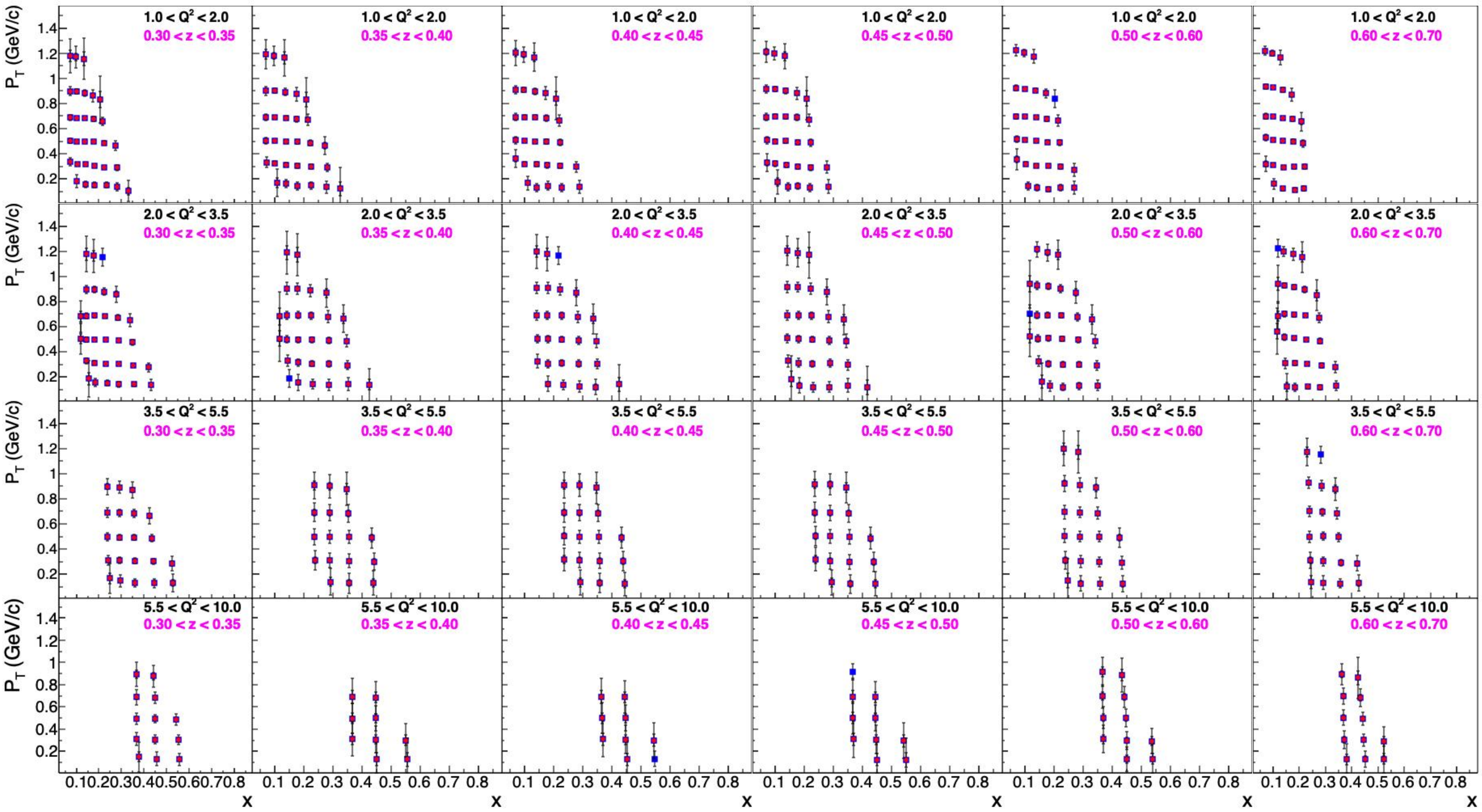


Expected Pion-SIDIS Statistics



C12-21-004

➢ Projected Results of A=3 in SIDIS: Kaon Data 4D Binning



K+

K-

Assumes 6 RICH sectors

Motivation

➢ Proof of Principle: SIDIS cross-section at LO

✓ The Super-Ratios are uniquely sensitive to the PDFs (D=^{2}D, H = ^{3}He, T = ^{3}H):

$$R^{\pi,-}_{H/D}(x) \simeq \frac{4(u_H - \bar{u}_H) - (d_H - \bar{d}_H)}{3(u - \bar{u}) + 3(d - \bar{d})} \qquad R^{\pi,-}_{T/D}(x) \simeq \frac{4(u_T - \bar{u}_T) - (d_T - \bar{d}_T)}{3(u - \bar{u}) + 3(d - \bar{d})}$$

- Case#1: EMC effect flavor-independent:

$$u_T = R_T \frac{u + 2d}{3}, d_T = R_T \frac{d + 2u}{3},$$
$$u_H = R_H \frac{2u + d}{3}, d_H = R_H \frac{2d + u}{3},$$

- Case#2: EMC effect only on np-SRC pairs

$$u_H = \frac{(\tilde{u}_p + \tilde{u}_n)_{SRC} + u_p}{3}, d_H = \frac{(\tilde{d}_p + \tilde{d}_n)_{SRC} + d_p}{3},$$
$$u_T = \frac{(\tilde{u}_p + \tilde{u}_n)_{SRC} + u_n}{3}, d_T = \frac{(\tilde{d}_p + \tilde{d}_n)_{SRC} + d_n}{3}.$$

- Case#3: EMC effect only on u-quark (or d-quark):

$$u_H = \frac{2\tilde{u} + d}{3}, \quad d_H = \frac{2d + 2\tilde{u}}{3},$$
$$u_T = \frac{u + 2\tilde{d}}{3}, \quad d_T = \frac{\tilde{d} + 2u}{3}.$$

Modification is normalized to inclusive EMC ratio:

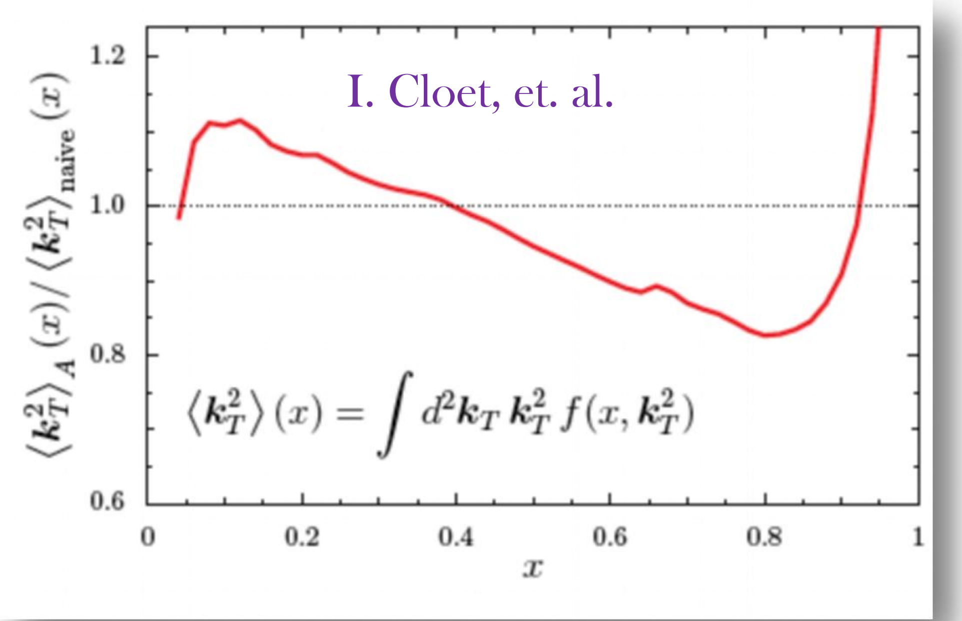
$$R^A_{EMC} = \frac{2}{A} \frac{\sigma^{DIS}_A(x)}{\sigma^{DIS}_D(x)} \simeq \frac{4(u_A + \bar{u}_A) + (d_A + \bar{d}_A)}{4(u_D + \bar{u}_D) + (d_D + \bar{d}_D)}$$

Motivation

➢ Other Goals:

❖ 3D TMD & FF in A=3

- P_T distributions are measured:
- (Q2, x, z, pT) SIDIS data
  - ✓ Unpolarized TMDs and FFs (flavor-separation)
  - ✓ Study of Factorization and Hadronization
  - ✓ Medium-modification effects in the transverse directions

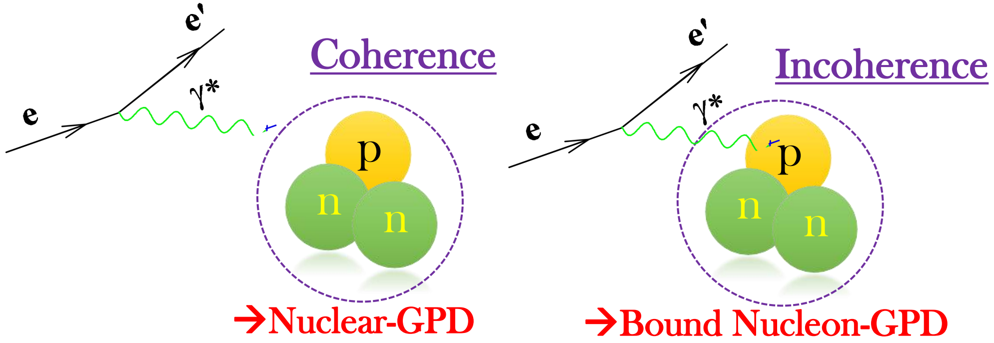


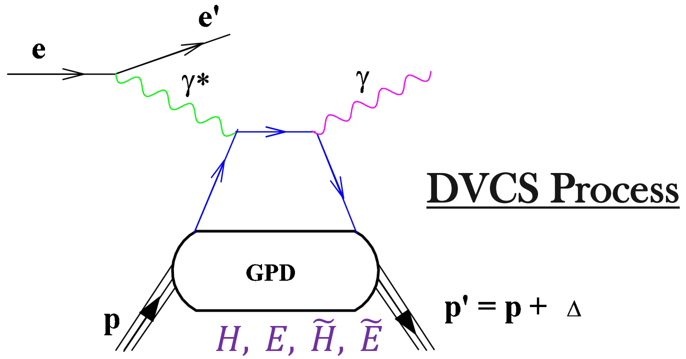
❖ Strangeness in A=3 with Kaon-SIDIS w/ RICH

- Measure possible nuclear modification effect in s
- Extract 3D strangeness TMD and FFs
- Great inputs for Jlab 24GeV & future EIC

The Proposed Measurement

- Parasitic Run: DVCS measurement on H3 and He3:
  - ❖ DVCS off He3 and H3 (4 GPD for spin ½ targets):



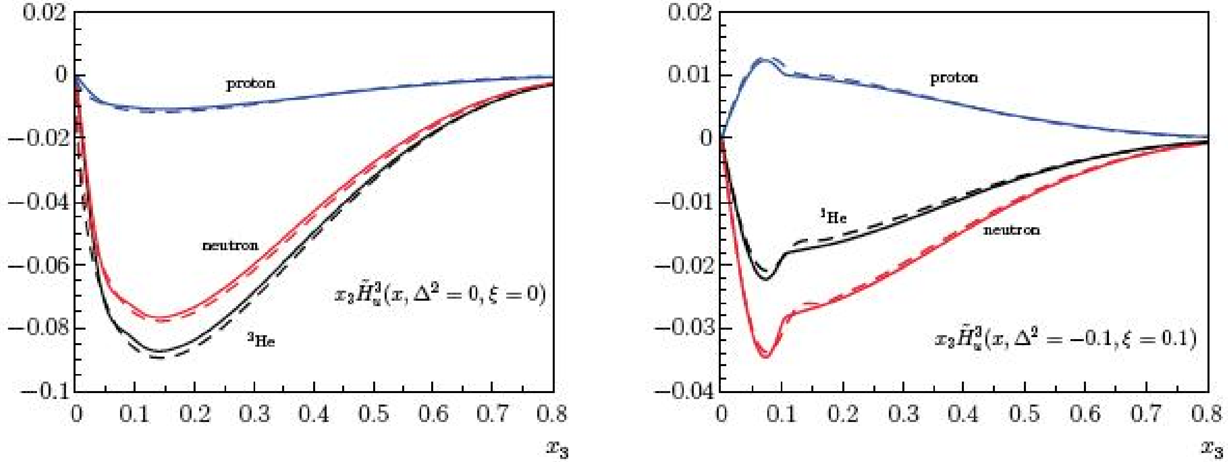


$$H_q^A(x,\xi,\Delta^2) \simeq \sum_N \int \frac{d\bar{z}}{\bar{z}} h_N^A(\bar{z},\xi,\Delta^2) H_q^N\left(\frac{x}{\bar{z}},\frac{\xi}{\bar{z}},\Delta^2\right)$$

  - ❖ Advantage of using DVCS off He3 & H3:
    - ✓ Neutron-contribution dominates in He3-GPDs
    - ✓ Sensitive to GPD-E (orbital angular momentum)
    - ✓ Use H3 to isolate pure neutron/proton contributions
    - ✓ Get access to the flavor-dependence GPDs

$$H_u^{He3} = H_d^{H3}$$

    - ✓ Medium Modification Effect in GPDs



Scopetta, PRC70 (2004) 015205; PRC79 (2009) 025207;
Rinadli and Scopetta, PRC87 (2013) 035208; arXiv:1401.1350 (2014)

- ❖ In collaboration with Silvia Nicolai, Alex Camsonne to explore this run-group proposal
- ❖ Welcome new collaborators
- ❖ Strong theory support needed!

Address TAC49 Concerns

- **TAC-EXP:**

1. This proposal intends to utilize the tritium target system to be developed for E12-20-005 experiment. This will be a multi-year project requiring significant installation and safety considerations related to handling and operating the tritium target sample, with a cost expected to exceed \$1M. Modifications to the Hall B infrastructure,

We believe this concern has been addressed during the E12-20-005 approval process

2. Will the extra 3He contamination in the T2 target sample be problematic? Replacing or replenishing the sample may not be possible.

- Tritium has a life-time of 12 year. He3 contamination was almost negligible in Hall-A Tritium experiments (measured, evaluated and corrected)
- A whole year of running E12-20-005 and this proposal requires a refill in the summer shutdown

3. The experiment requires several changes in torus polarity and target changes that may reduce the effective data taking. Have the authors correctly accounted for the configuration-change?

Yes. Changing Torus polarity is very fast. Changing targets adopt the same estimation as E12-20-005

Address TAC49 Concerns

- **TAC-THY:**

1) It is important to note that such simplification should not be viewed as final results as additional ingredients such as higher order corrections, treatments of nuclear effects need to be systematically taken into account preferably within a full QCD global analysis. It is then advisable to consult with global analysis groups to provide theoretical estimates on the actual measurements instead of relying on simple LO expressions. The

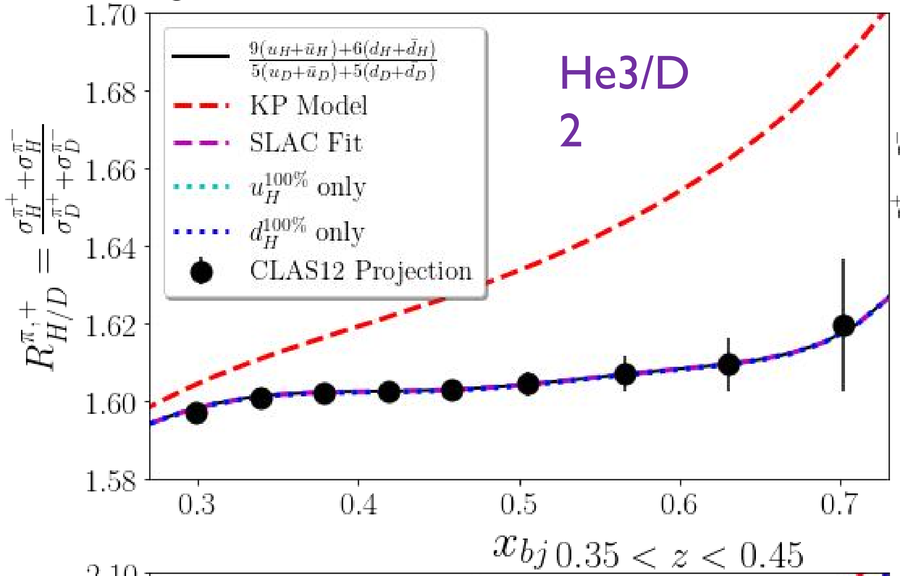
- We agree. LO approach here only serves as proof of experimental sensitivity.
- We measure cross-sections and will perform sophisticated global analysis with helps from theocratists.
- We have been working with two groups of theorists for the NLO estimations (one result is given in this talk)

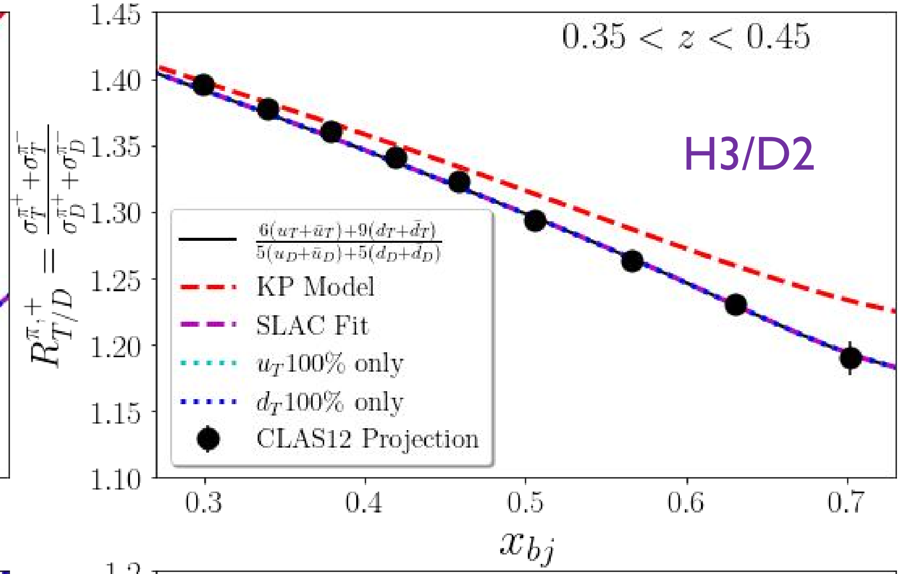
2) proposal does not provide a clear plan for how the data will be presented. Effects such as QED radiative corrections or the exclusive production which are commonly discussed in SIDIS measurements are not discussed at all. It is then advisable that the authors provide details for how the data would be processed with effects where theoretical assumptions are involved. Our general statement of last year regarding SIDIS measurements applies, so we

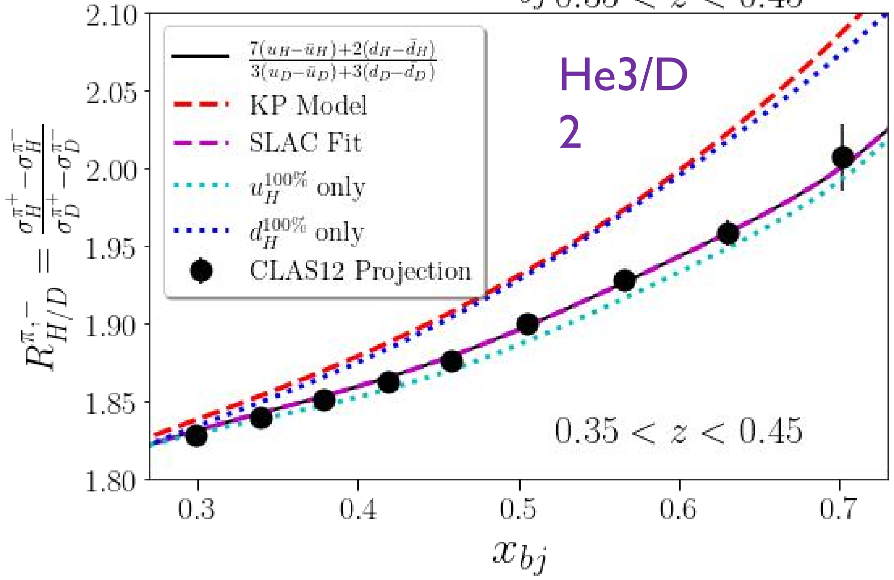
- We will present cross-section values after all experimental and theoretical corrections applied with uncertainties estimated
- We will adopt the conventional SIDIS QED radiative corrections (e.g., tools developed by Igor Akushevich et. al.) like all other Jlab SIDIS experiments. We will also explore the new radiative correction techniques in the factorized approach discussed in arXiv:2008.02895.
- Contributions from exclusive production are small and will be carefully eliminated with kinematic cuts and theoretical corrections

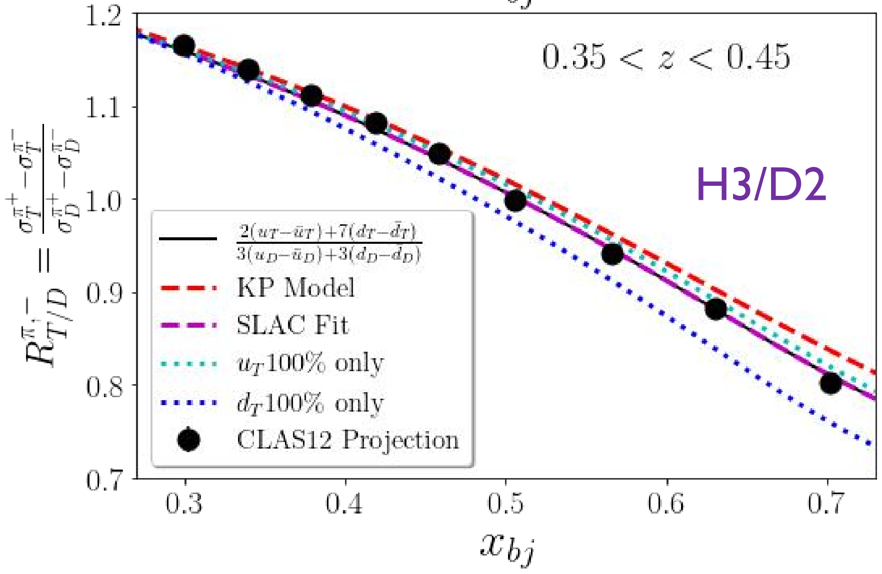
Original Proposal

➢ Projected Results of A=3 in SIDIS









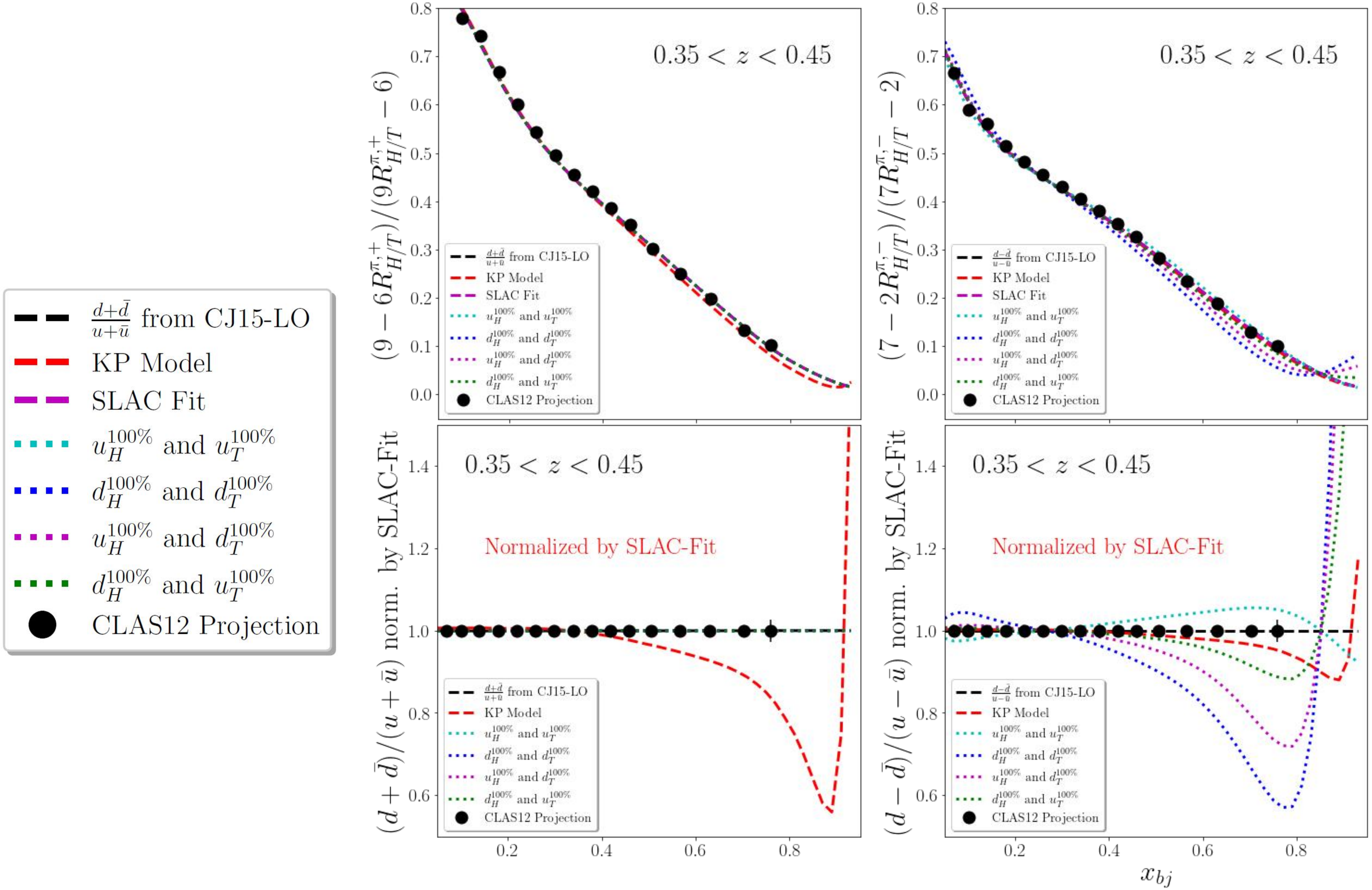
- ❖ Integrating P_T and fix z-bins
- ❖ D2, H3 ("T") and He3 ("H")
- ❖ Statistical errors only

✓ EMC effect has a strong cancellation XS-Sum ratio(except KP-model)

✓ Flavor-dependence sensitive to XS-Difference ratio

Original Proposal

➢ Use H3 and He3 to extract nucleon-PDFs



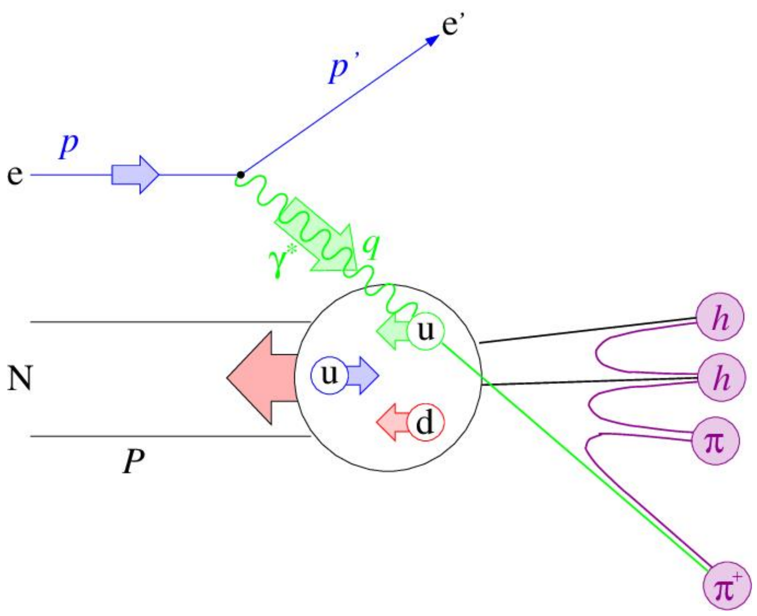
- ❖ Integrating P_T and fix z-bins
- ❖ D2, H3 ("T") and He3 ("H")
- ❖ Statistical errors only

✓ EMC effect has a strong cancellation XS-Sum ratio(except KP-model)

✓ Models w/ flavor-dependent EMC effect can be distinguished in the XS-Difference ratio

SIDIS with A=3

- **SIDIS w/ Nucleons:**



$$x_B = \frac{Q^2}{2M\nu} = \frac{q \cdot P}{M} \qquad z = \frac{E_h}{\nu} = \frac{P \cdot P_h}{P \cdot q}$$

$$y = \frac{\nu}{E_l} = \frac{q \cdot P}{l \cdot P} \qquad P_T = \frac{p \cdot P_h}{|q^2|} = p_{h\perp}$$

❖ Unpolarized SIDIS Cross Section (Factorization, LO, P_T integrated):

$$\frac{d\sigma^h}{dxdydz} = \frac{4\pi\alpha^2 s}{Q^4}\left(1 - y + \frac{y^2}{2}\right) \sum_q e_q^2 [f_1^q(x) \cdot D_q^h(z)]$$

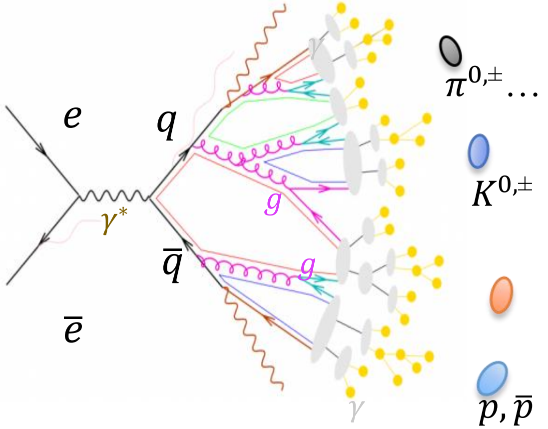
PDF (from DIS) — Fragmentation Function

❖ Fragmentation Functions (FF):

- How quarks become hadrons
- Normally obtained from $e + e^- \longrightarrow h^\pm + X$
- Also from SIDIS multiplicity:

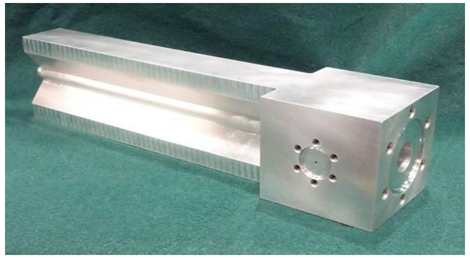
$$M^h(Q^2, z) = \frac{\sigma_{SIDIS}}{\sigma_{DIS}} = \frac{\sum_q e_q^2 f_1^q(Q^2, x) \cdot D_q^h(Q^2, z)}{\sum_q e_q^2 f_1^q(Q^2, x)}$$

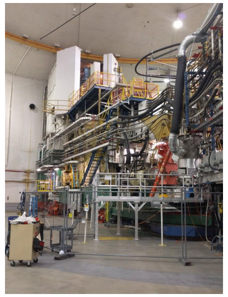
- Relatively poorly known.

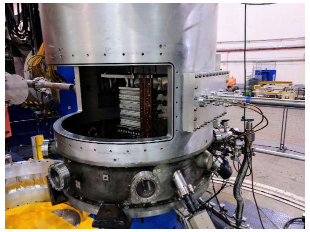


First Tritium Run-Group

- ➢ Successfully ran in 2017-2018 @ Hall-A:
  - ✓ 10+ years of preparation (Many Tritium Target Safety reviews)
  - ✓ 1-year of smooth running → Completed four different experiments;
  - ✓ Great results published; More to come!







PHYSICAL REVIEW LETTERS **124**, 212501 (2020)

Editors' Suggestion

Probing Few-Body Nuclear Dynamics via ^{3}H and ^{3}He $(e,e'p)$pn Cross-Section Measurements

R. Cruz-Torres,[1,*] D. Nguyen,[1,2,*] F. Hauenstein,[3] A. Schmidt,[1] S. Li,[4] D. Abrams,[5] H. Albataineh,[6] S. Alsalmi,[7]

PHYSICAL REVIEW C **105**, L051001 (2022)

Letter

Spectroscopic study of a possible Λnn resonance and a pair of ΣNN states using the $(e, e'K^+)$ reaction with a tritium target

B. Pandey,[1] L. Tang,[1,2,*] T. Gogami,[3,4] K. N. Suzuki,[4] K. Itabashi,[3] S. Nagao,[3] K. Okuyama,[3] S. N. Nakamura,[3] D. Abrams,[5]

PHYSICAL REVIEW LETTERS **128**, 132003 (2022)

Measurement of the Nucleon F_2^n/F_2^p Structure Function Ratio by the Jefferson Lab MARATHON Tritium/Helium-3 Deep Inelastic Scattering Experiment

D. Abrams,[1] H. Albataineh,[2] B. S. Aljawrneh,[3] S. Alsalmi,[4,5] D. Androic,[6] K. Aniol,[7] W. Armstrong,[8] J. Arrington,[8,9]

Article To be appeared on Nature

Revealing the short-range structure of the "mirror nuclei" ^{3}H and ^{3}He

S. Li[1,2], R. Cruz-Torres[3,2], N. Santiesteban[1,3], Z. H. Ye[4,5] D. Abrams[6], S. Alsalmi[7,41],

Nuclear Inst. and Methods in Physics Research, A 940 (2019) 351–358

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

ELSEVIER

Density changes in low pressure gas targets for electron scattering experiments

S.N. Santiesteban[a], S. Alsalmi[b], D. Meekins[c], C. Ayerbe Gayoso[e], J. Bane[d], S. Barcus[e], J. Campbell[f], J. Castellanos[g], R. Cruz-Torres[h], H. Dai[i], T. Hague[b], F. Hauenstein[j],

Physics Letters B 831 (2022) 137165

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

ELSEVIER

Search for a bound di-neutron by comparing ^{3}He(e,e'p)d and ^{3}H(e,e'p)X measurements

D. Nguyen[a,b,1], C. Neuburger[c,1], R. Cruz-Torres[d,b], A. Schmidt[e,b], D.W. Higinbotham[a,*], J. Kahlbow[b,c], P. Monaghan[f], E. Piasetzky[c], O. Hen[b]

Physics Letters B 797 (2019) 134890

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

ELSEVIER

Comparing proton momentum distributions in $A = 2$ and 3 nuclei via ^{2}H ^{3}H and ^{3}He $(e, e'p)$ measurements

Jefferson Lab Hall A Tritium Collaboration

R. Cruz-Torres[a], S. Li[b], F. Hauenstein[c], A. Schmidt[a], D. Nguyen[d], D. Abrams[d],

Motivation

➢ Natural Fit for Jlab 12GeV:

❖ Major goal: 3D structure of nucleons and nuclei

12 GeV Experiments by PAC Days (status at May 1st)

Topic	Hall A	Hall B	Hall C	Hall D	Total
Hadron spectra as probes of QCD	0	219	11	540	770
Transverse structure of the hadrons	150.5	85	146	25	406.5
Longitudinal structure of the hadrons	19	230	211	0	460
3D structure of the hadrons	359	872	196	0	1427
Hadrons and cold nuclear matter	220	275	205	15	715
Low-energy tests of the Standard Model and Fundamental Symmetries	547	180	0	79	806
Total Days	1295.5	1861.0	769.0	659	4584.5
Total Days - (includes MOLLER)	821.5	1861	769	659	4110.5
Total Approved Run Group Days (includes SoLID)	1295.5	1026	726	459	3506.5
Total Approved Run Group Days (includes MOLLER)	821.5	1026	726	459	3032.5
Total Days Completed	240.5	283	159.0	184	866.5
Total Days Remaining	581	743	567	235	2166

+167 (PAC) days completed in FY20 to date

A DECADE OF EXCELLENT SCIENCE!

3

Jefferson La

Bob Mckeown, 48 PAC Report, Aug 10th, 2020

❑ 3D structure of the hadrons ("free" nucleons)
- PDF, d/u at high-x
- TMD, GPD
- ^{2}H as protons, ^{2}D & ^{3}He as effective neutrons

❑ Hadrons and cold nuclear matter ("bound" nucleon)
- Nuclear structure, NN interaction
- EMC effect
- Hadronization

❑ Missing pieces?
- Flavor-Dependent EMC effect
- Nuclear-TMD, FF, GPD
- Nuclear corrections in ^{2}D & ^{3}He

❖ SIDIS with A=3: a natural bridge between free-nucleons and heavy nuclei!