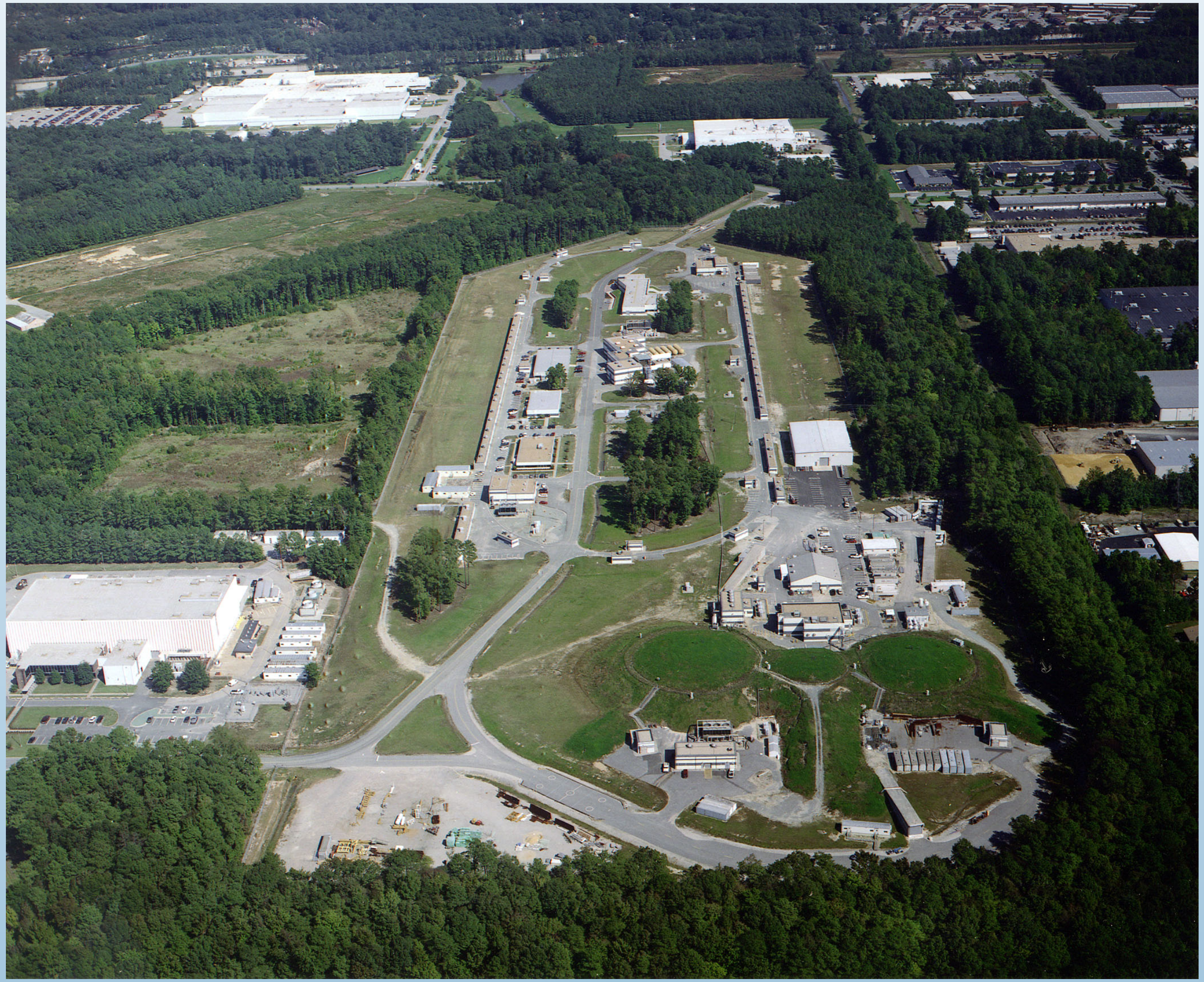
Impact Study on Polarized PDFs from SIDIS ^{3}He by JAM Collaboration

Chris Cocuzza, Nobuo Sato

www.jlab.org/theory/jam



SoLID Collaboration Meeting

July 8, 2025

Introduction

Hadron Structure

Global QCD Analysis

Hadron Structure

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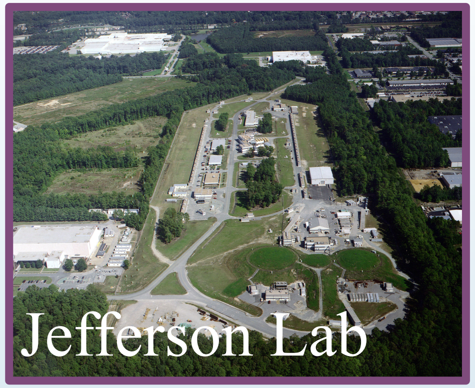
Global QCD Analysis



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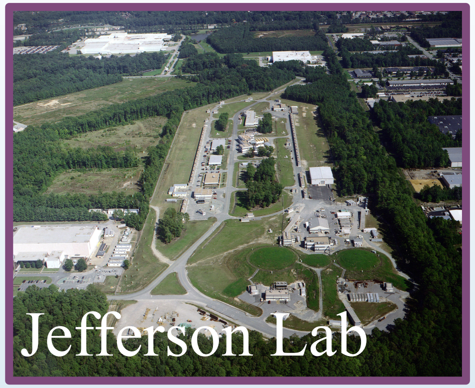

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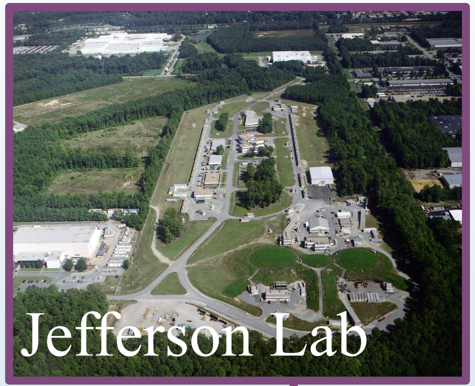
USQCD

Extended Twisted Mass Collaboration



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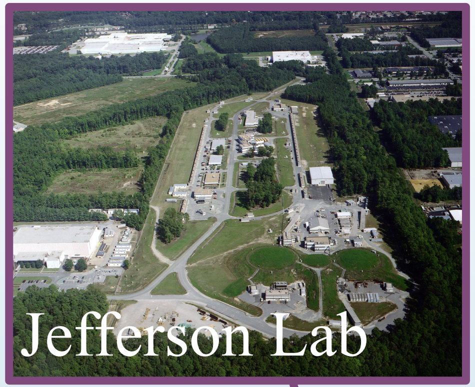

Hadron Structure

$$\frac{\mathrm{d}}{\mathrm{d}\ \ln(\mu^2)} f_i(x,\mu) = \sum_j \int_x^1 \frac{dz}{z} P_{ij}(z,\mu) f_j(\frac{x}{z},\mu)$$

Param. + Evolve + Factorization

$$\sigma = \sum_{i,j} H_{ij} \otimes f_i \otimes f_j$$

Global QCD Analysis

USQCD

Extended Twisted Mass Collaboration

$$\chi^2(\boldsymbol{a}) = \sum_{i,e}\left(\frac{d_{i,e} - \sum_k r_e^k \beta_{i,e}^k - T_{i,e}(\boldsymbol{a})/N_e}{\alpha_{i,e}}\right)^2 + \sum_k \left(r_e^k\right)^2 + \left(\frac{1-N_e}{\delta N_e}\right)^2$$

χ^2 Minimization

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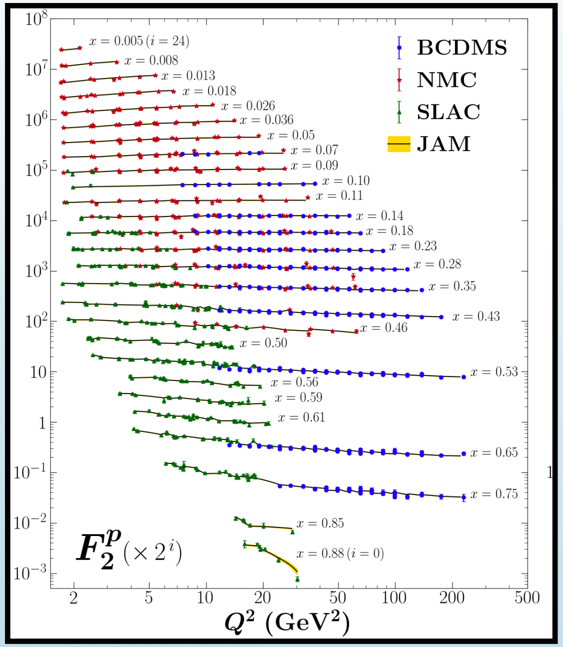
Global QCD Analysis

$$\mathcal{L}\left(\boldsymbol{a}, \mathrm{data}\right) = \exp\left(-\frac{1}{2}\chi^2\left(\boldsymbol{a}, \mathrm{data}\right)\right)$$

$$\mathcal{P}(\boldsymbol{a}|\mathrm{data}) \sim \mathcal{L}(\boldsymbol{a}, \mathrm{data})\, \pi(\boldsymbol{a})$$



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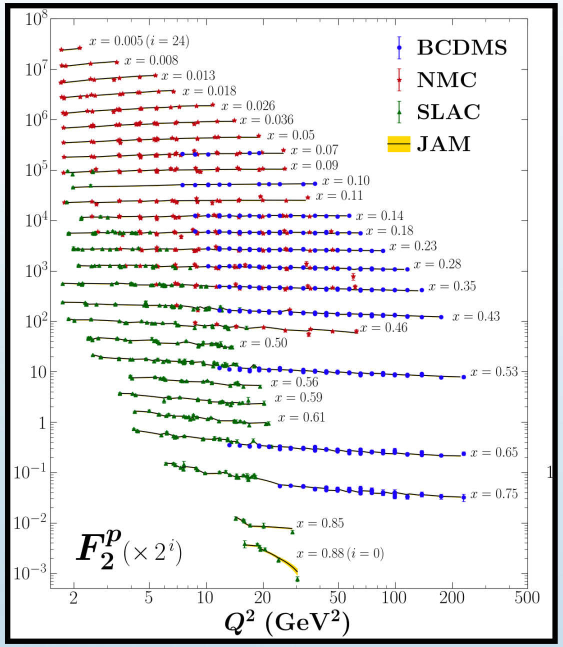

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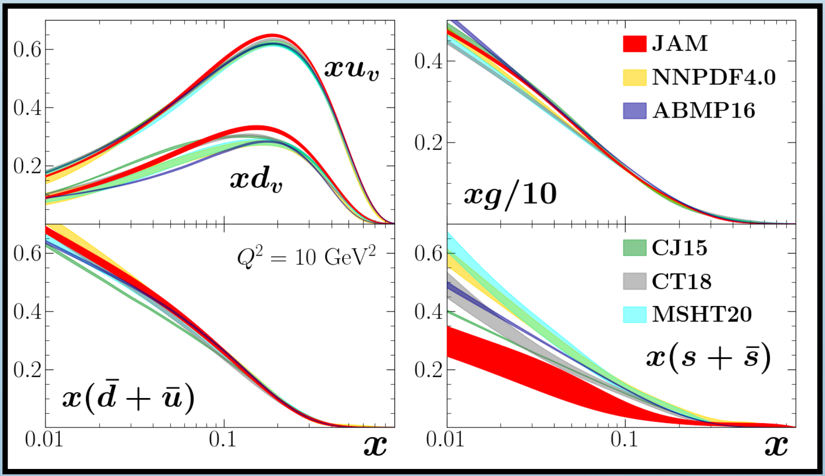

Data Resampling

$$\tilde{\sigma} = \sigma + N(0,1)\ \alpha$$

JAM Baseline

Polarized antimatter in the proton from a global QCD analysis

Jefferson Lab Angular Momentum (JAM) Collaboration • C. Cocuzza (Temple U.) Show All(4)

Feb 7, 2022

6 pages

Published in: *Phys.Rev.D* 106 (2022) 3, L031502

Published: Aug 1, 2022

e-Print: 2202.03372 [hep-ph]

DOI: 10.1103/PhysRevD.106.L031502 (publication)

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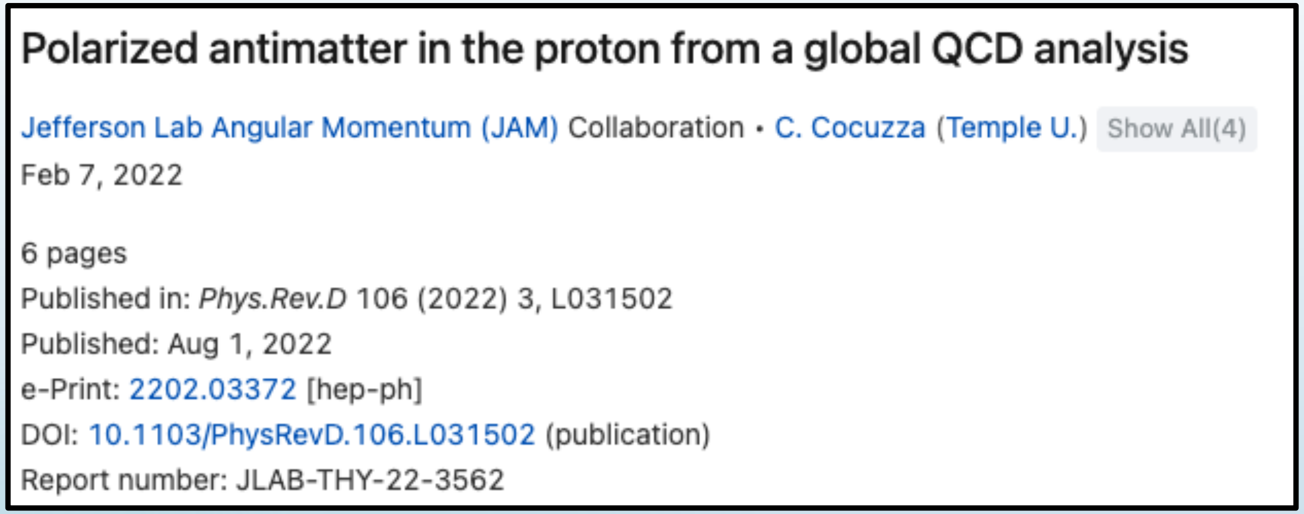
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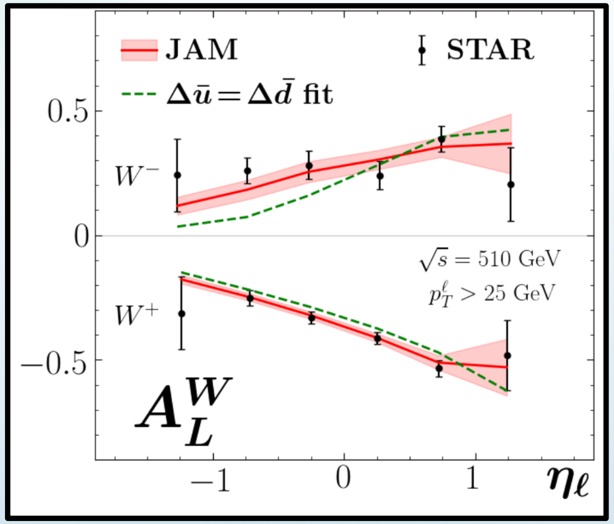

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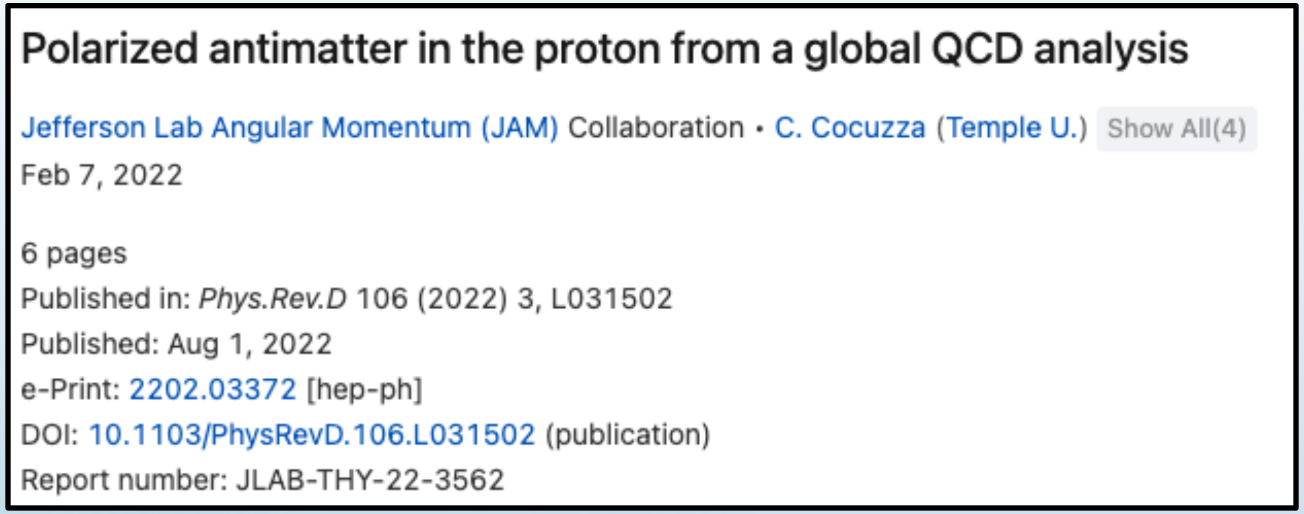
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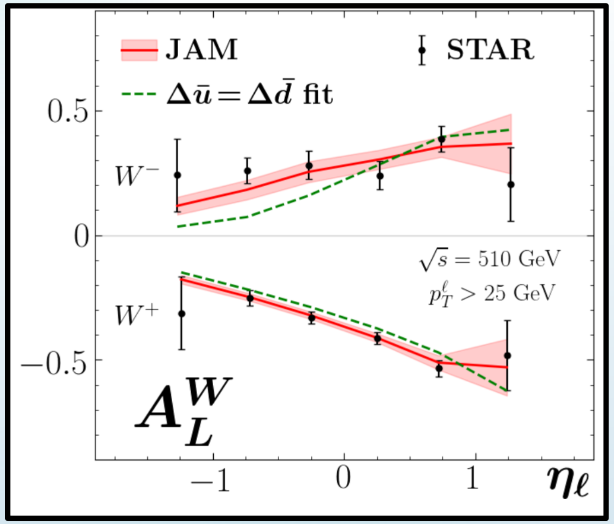

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Also includes unpolarized data to constrain unpolarized PDFs and SIA to constrain FFs

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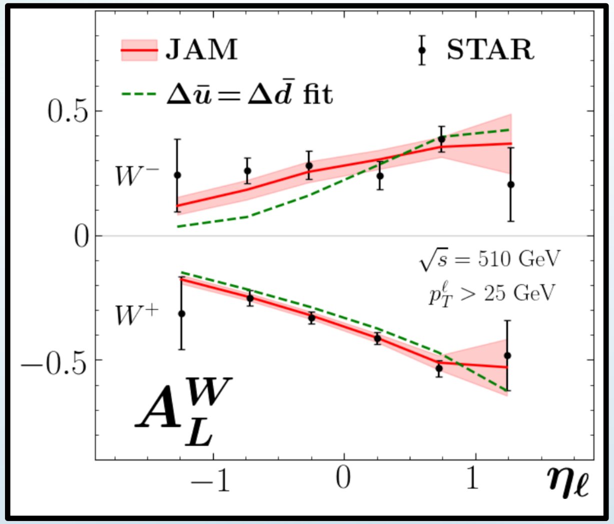

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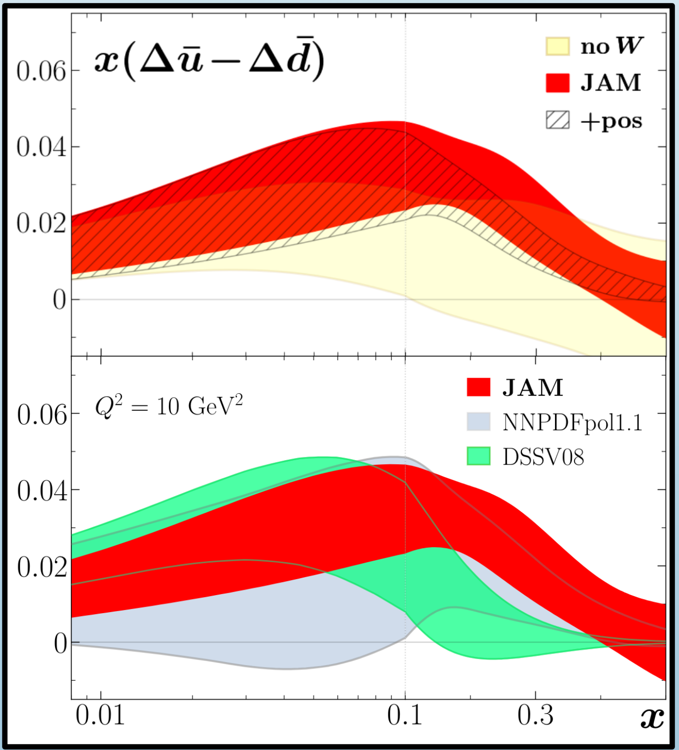

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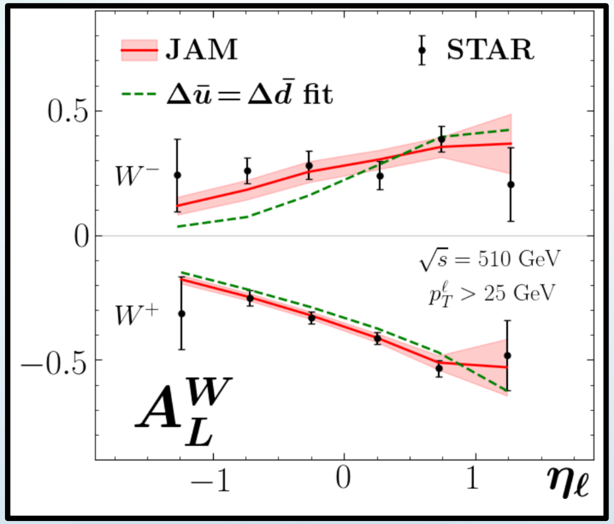

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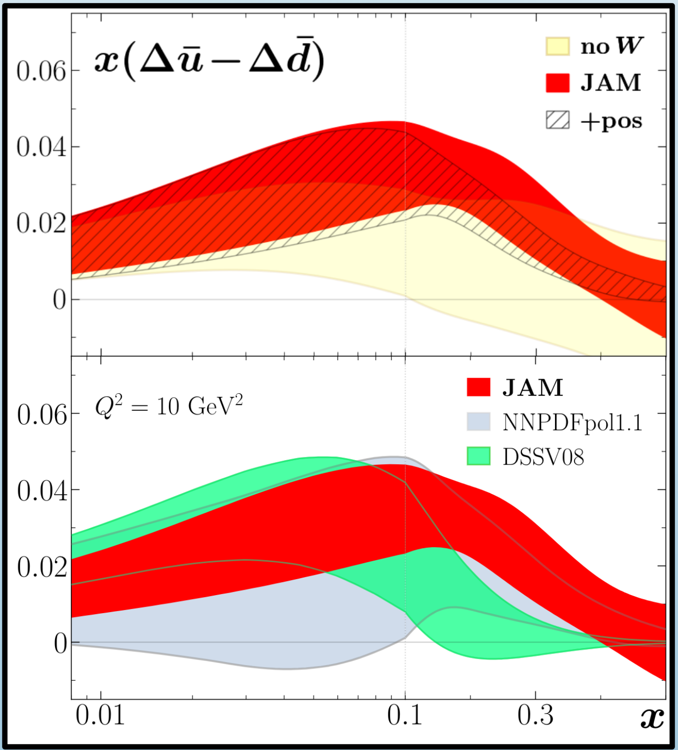
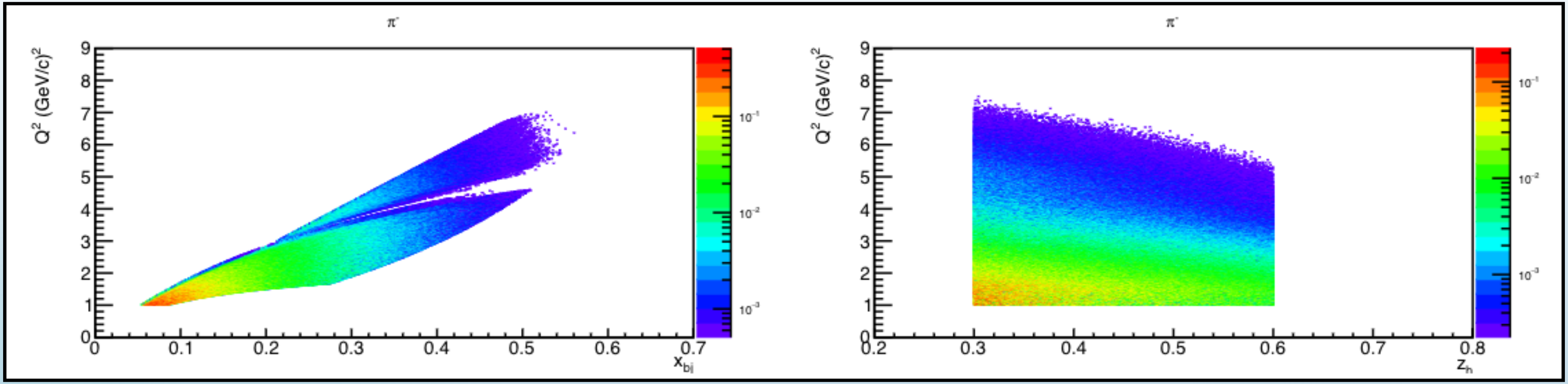
No positivity constraints on helicity PDFs

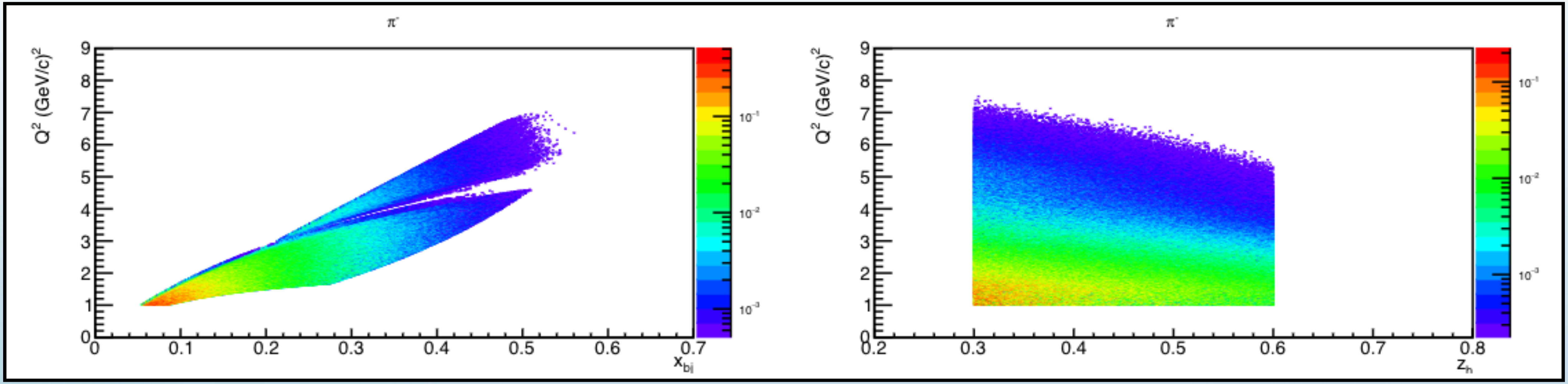


Generating Pseudo-data



Kinematics and statistical errors provided by experimentalists

Generating Pseudo-data



Kinematics and statistical errors provided by experimentalists

1% relative systematic uncertainty included, uncorrelated point-to-point

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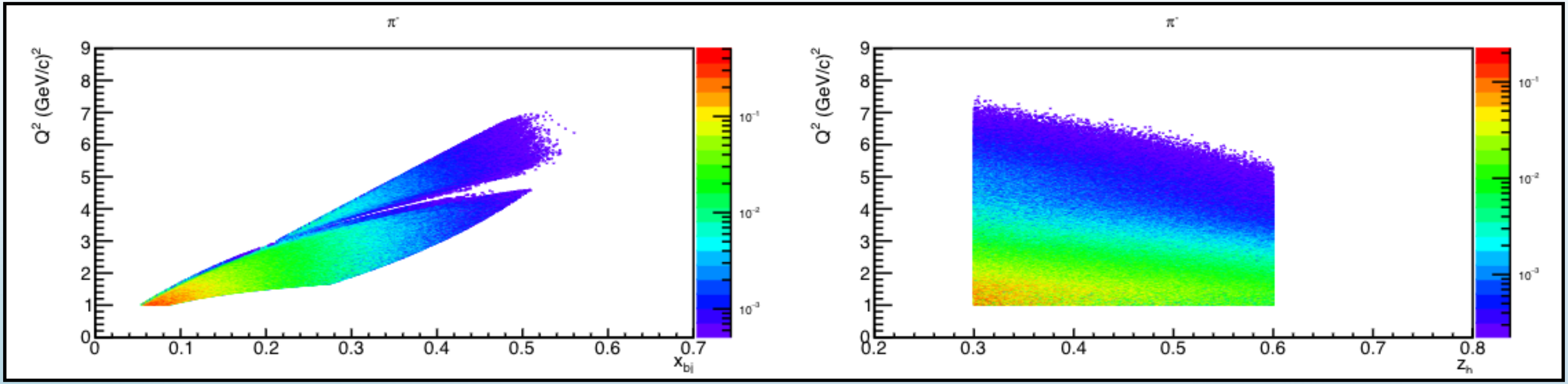

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1% relative systematic uncertainty included, uncorrelated point-to-point

Generate asymmetry values based on a single JAM FF replica, and the mean of JAM PDF replicas

Fitting pseudo-data

After generating pseudo-data, the fit is redone with the new asymmetries included

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The fit is kept identical to before in terms of theory and parameterizations

We keep the unpolarized PDFs fixed to their values from the baseline

The FFs are fixed to the single replica used to generate the pseudo-data

JAM Theory

The JAM framework uses a simple theoretical framework for polarized SIDIS, suitable for current experimental data from COMPASS, HERMES, and SMC

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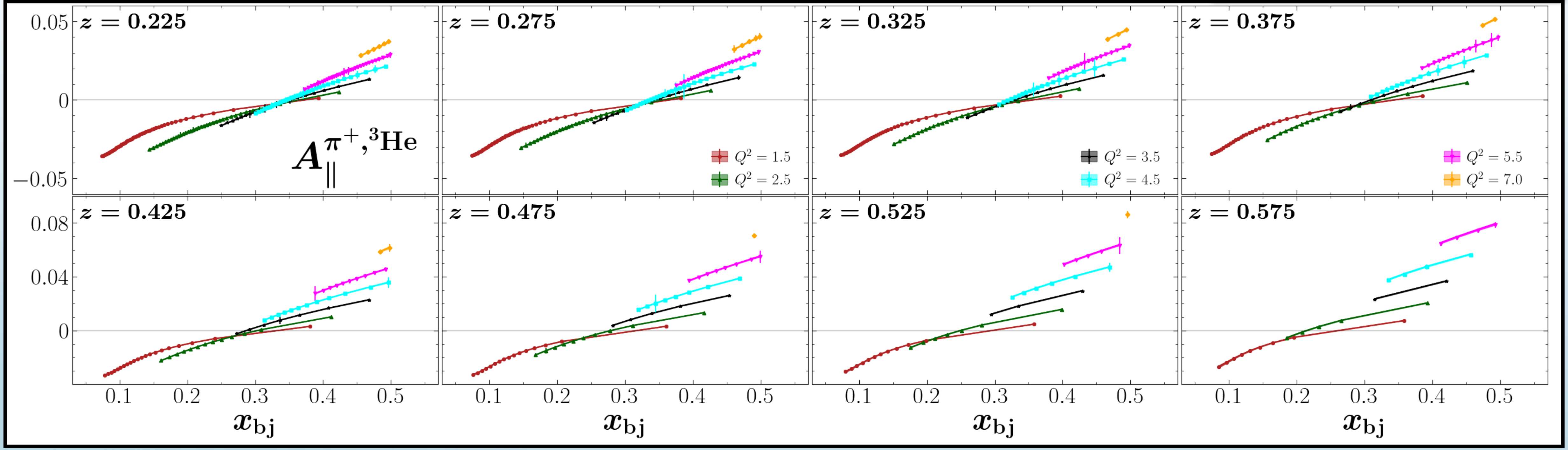
Nuclear corrections can be done using effective polarization or nuclear smearing. For A = 3 nuclei, the available wavefunctions are from SS and KPSV

A. Kievsky, E. Pace, G. Salme, M. Viviani, Phys. Rev. C **56**, 65-75 (1997)

R. W. Schulze, P. U. Sauer, Phys. Rev. C **48**, 38-63 (1992)

Results (data vs. theory)

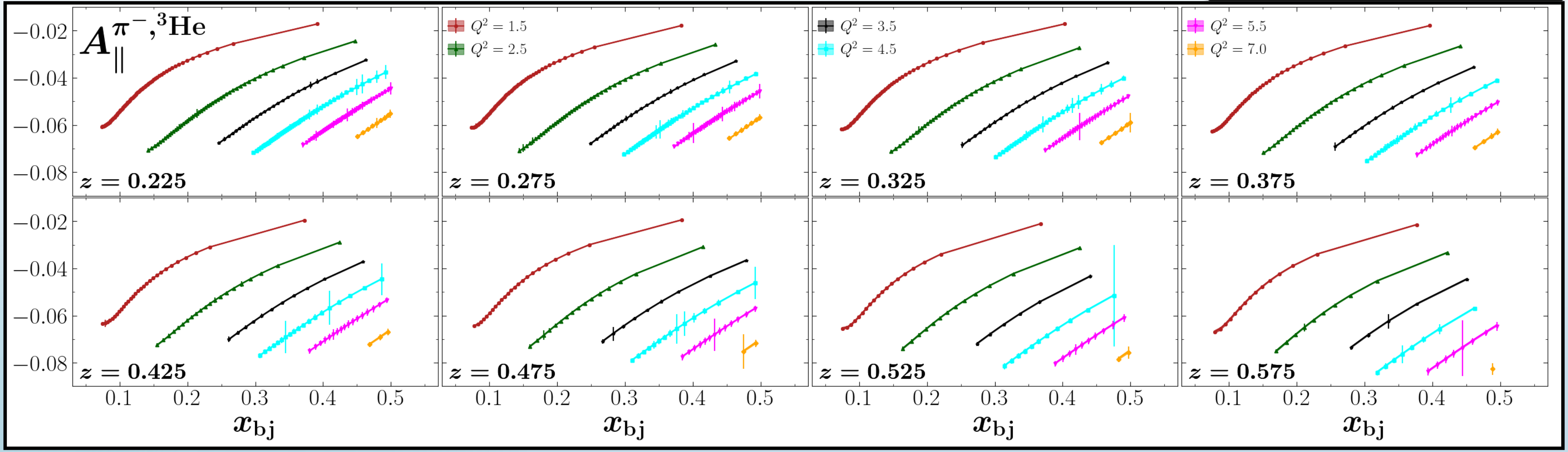
$\chi^2_{\mathrm{red}} = 0.02$



<u>NOTE:</u> Since we generate the asymmetry using our own replicas, we expect the resulting fit to be nearly perfect regardless of theory limitations

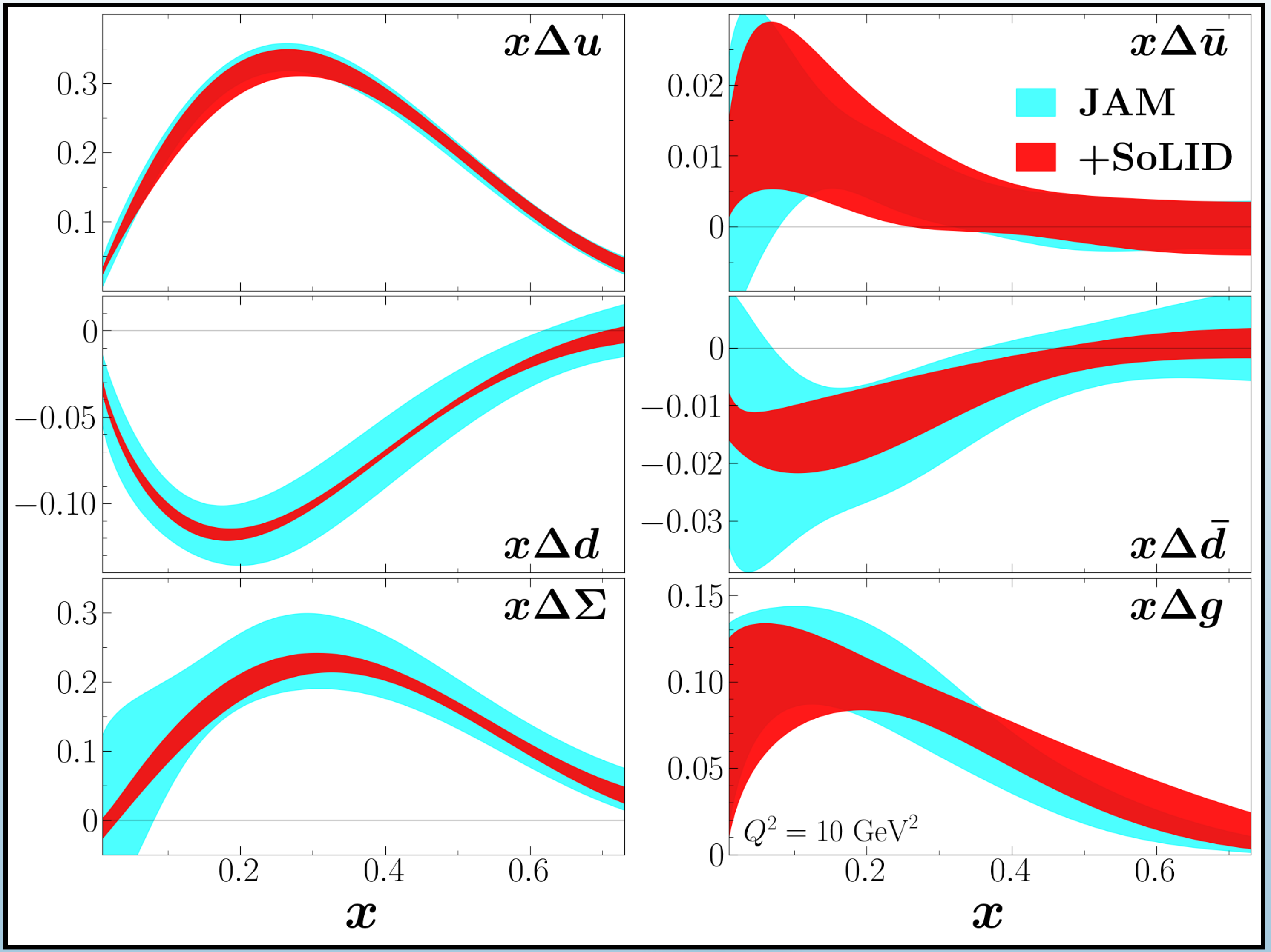
Results (data vs. theory)

$\chi^2_{\mathrm{red}} = 0.11$



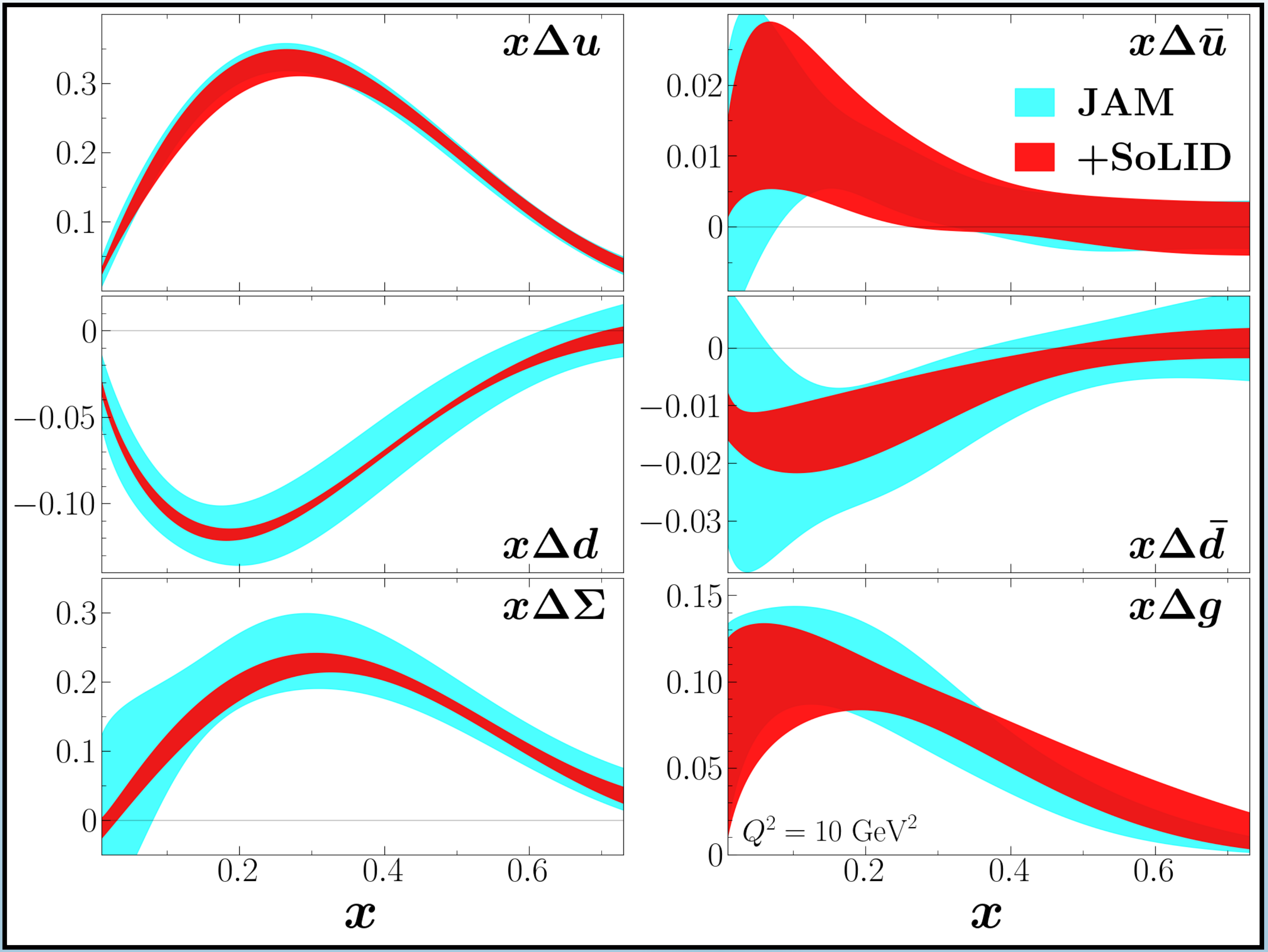
Same as previous slide, but for π^-

Results (helicity PDFs)



Results (helicity PDFs)

Since ^{3}He $\approx n$, biggest impact is seen on Δd and $\Delta \bar{d}$



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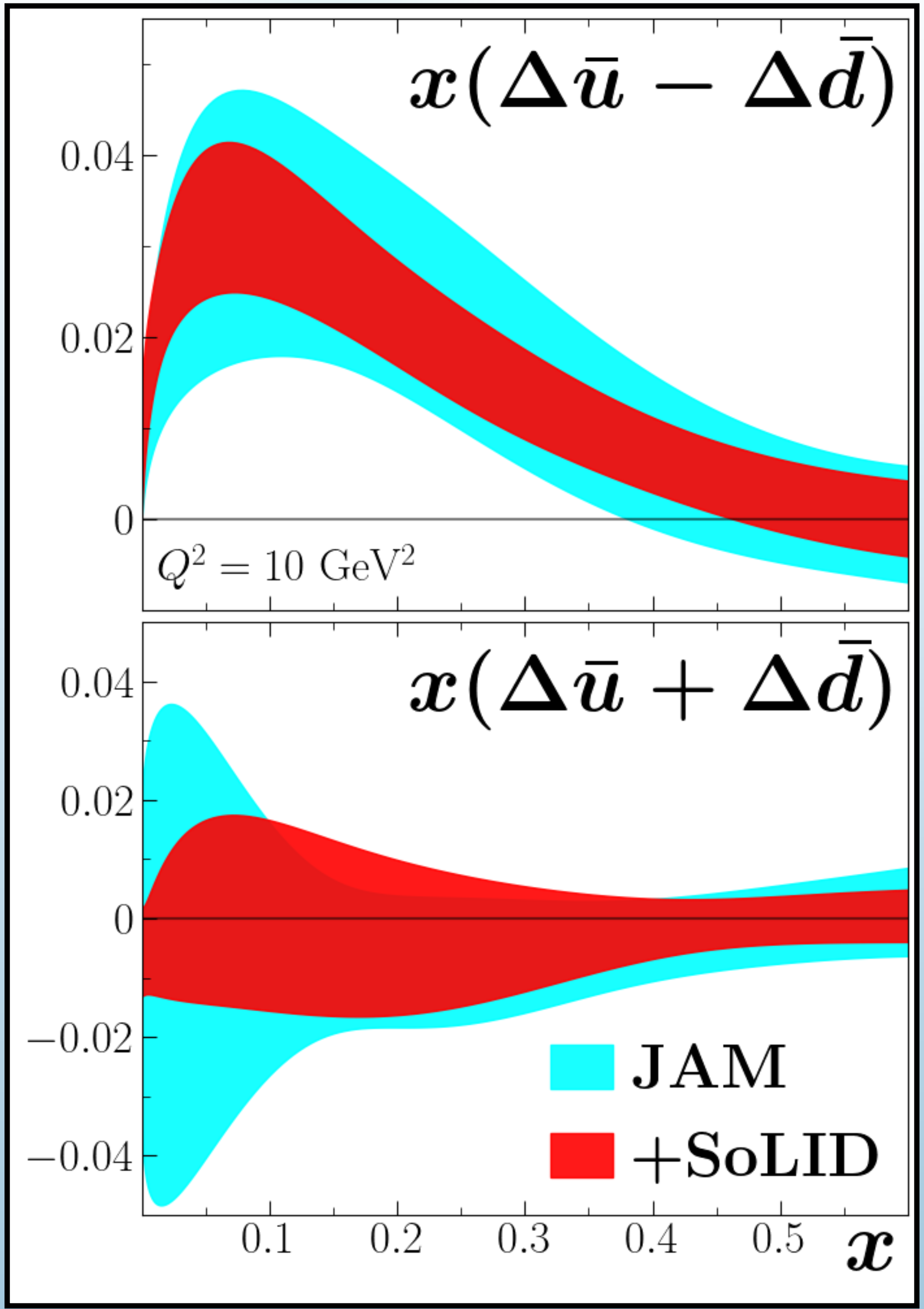
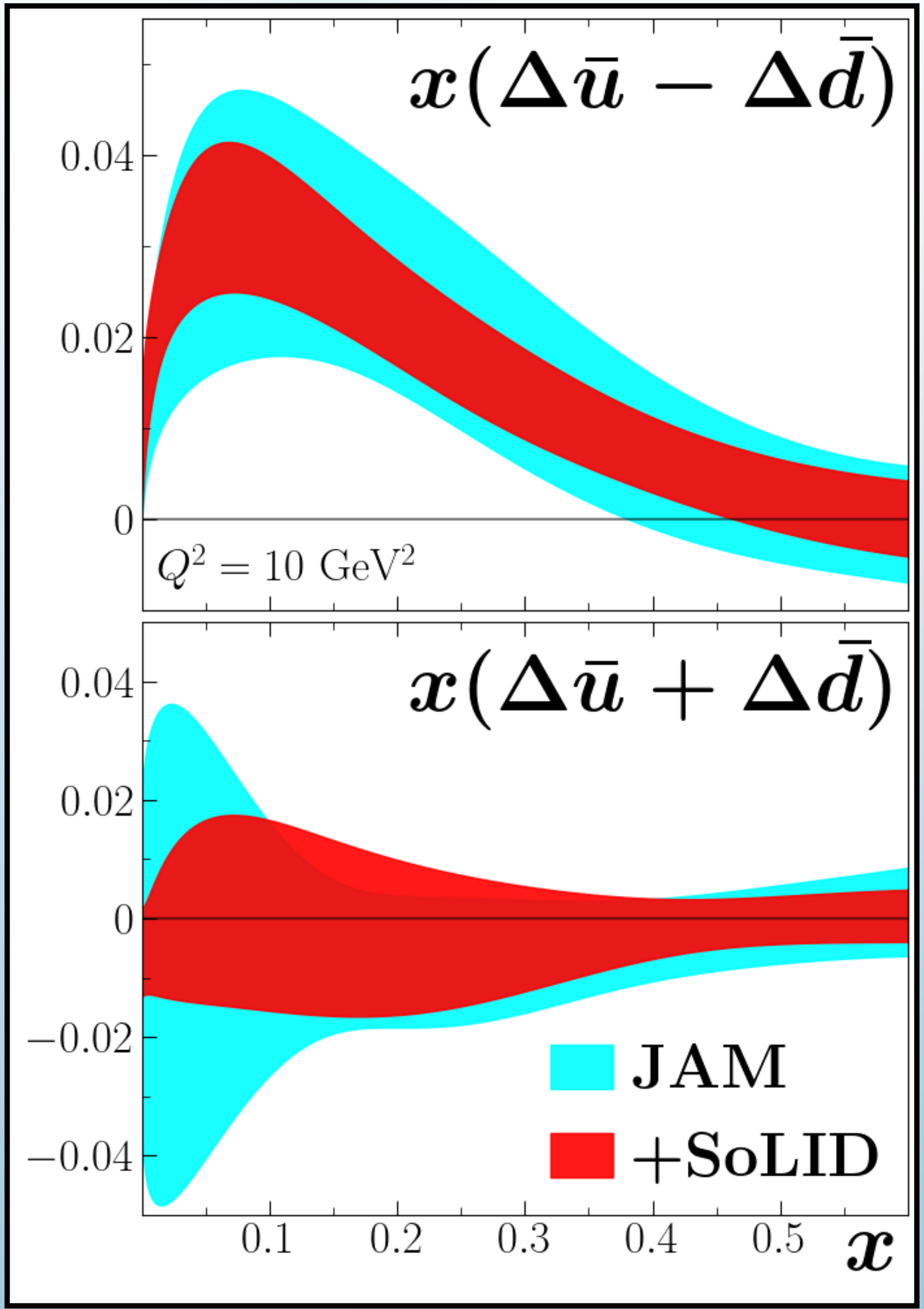


Results (helicity PDFs)

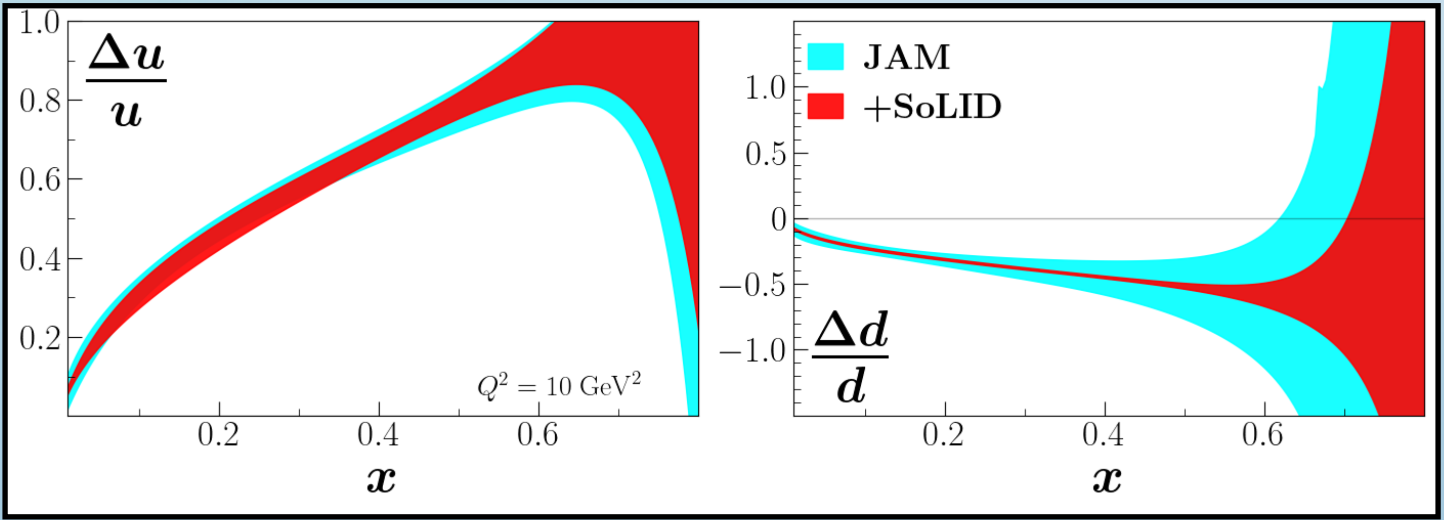
Big impact on asymmetry due to impact on $\bar{d}$

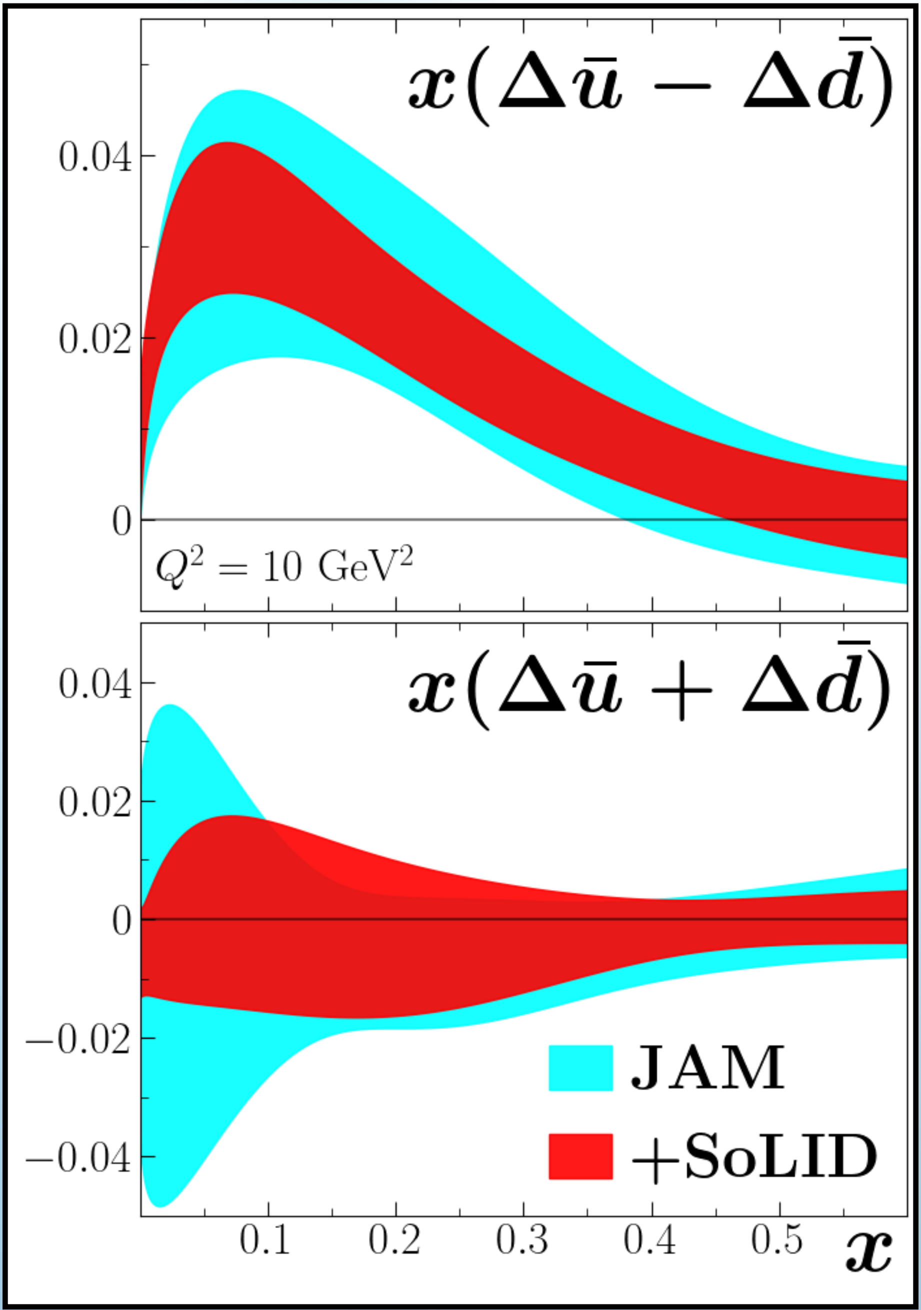


Results (helicity PDFs)

Big impact on asymmetry due to impact on $\bar{d}$

Big impact on $\Delta d/d$ as well





Nuclear Corrections

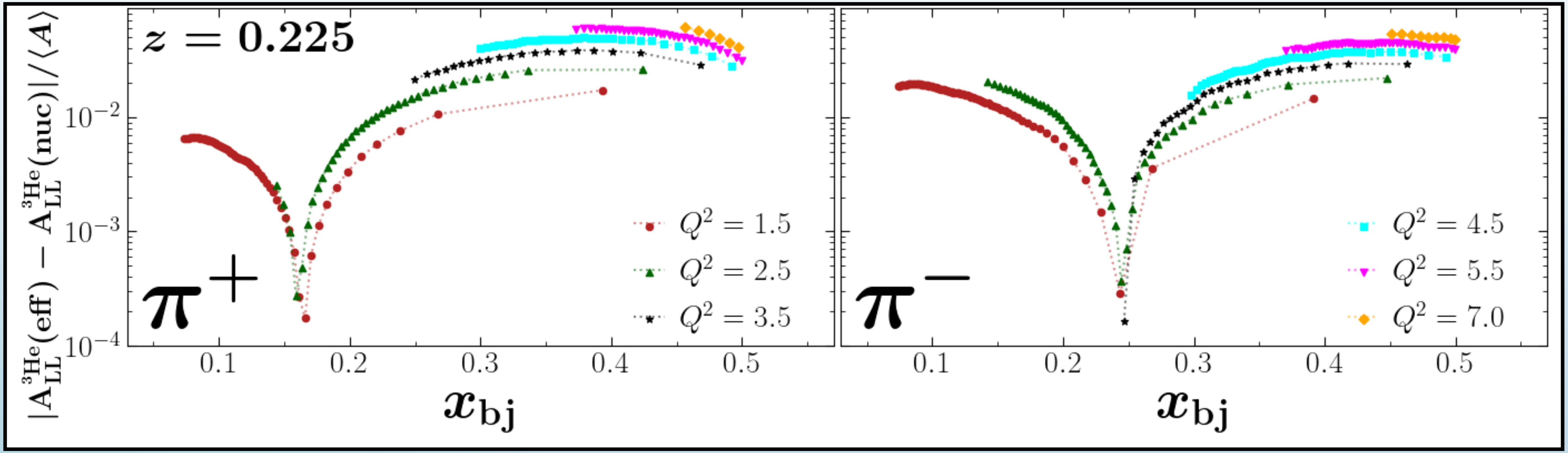


Figure 3.5: The difference between the fit performed using effective polarizations and a prediction using nuclear smearing, both using the KPSV wavefunction [8]. The difference is normalized to an approximate average value of the asymmetry $\langle A \rangle = 0.03$. The ratio is shown as a function of x_{bj} at the lowest z bin $z = 0.225$, with the different colors showing different bins of Q^2. The results for the other z bins look similar. The left panel shows the result for π^+ while the right panel shows the result for π^-.

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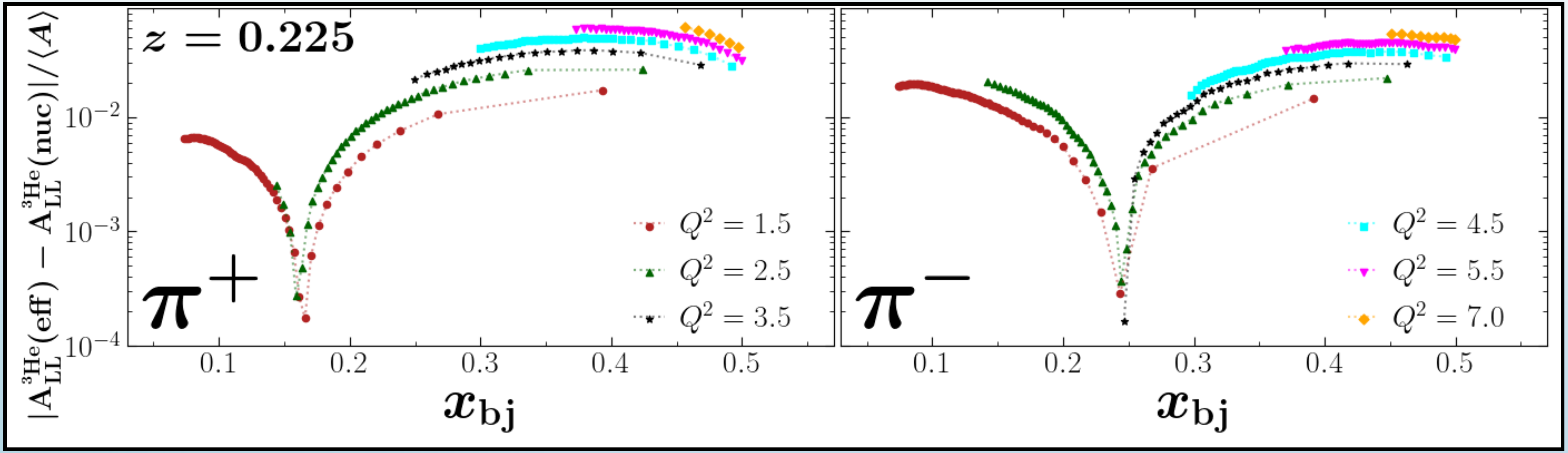

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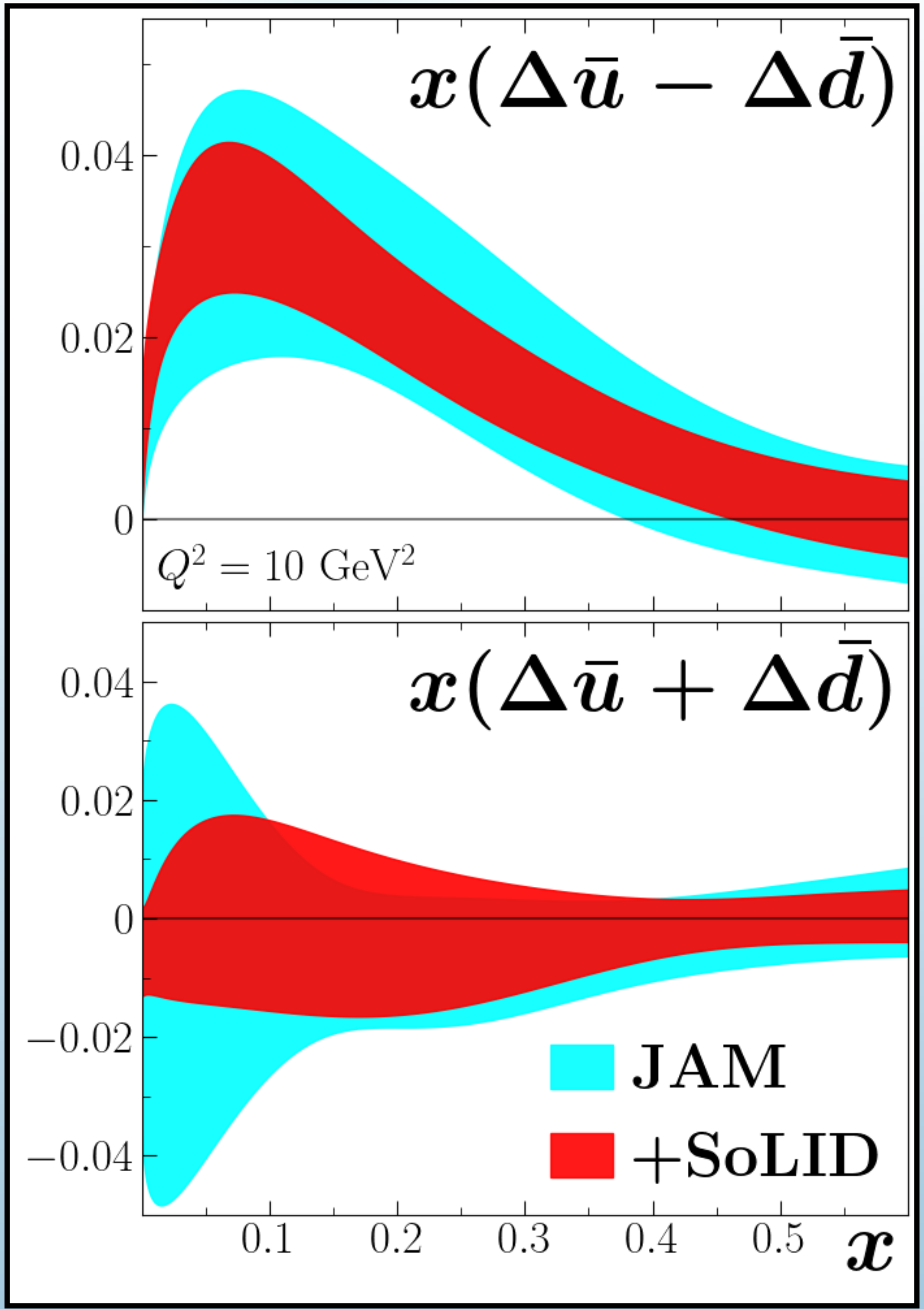
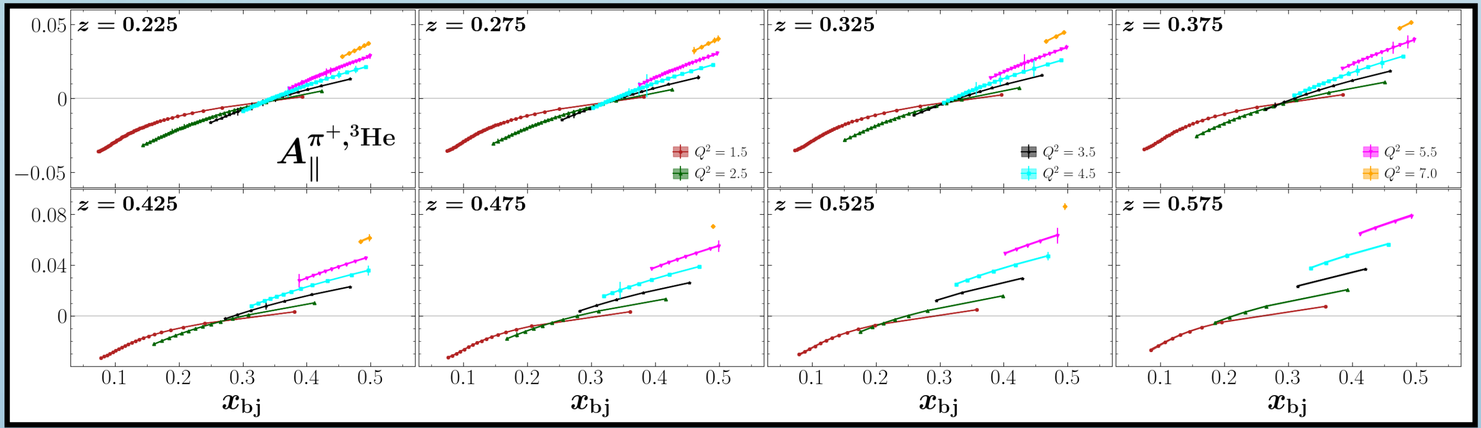
Errors do not exceed 8%

Conclusions

SoLID data would provide substantial constraints on Δd and $\Delta\bar{d}$





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On theory side, need to look into higher twists, target mass corrections, off-shell corrections