Sea Asymmetry from Polarized W-Production

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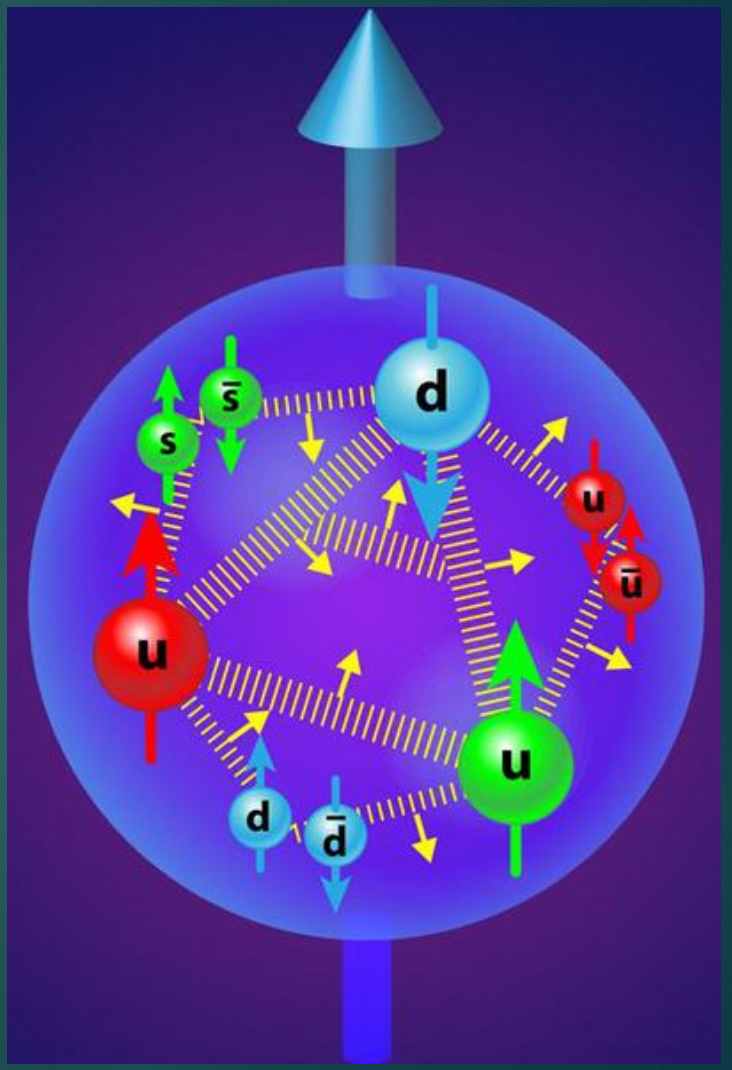
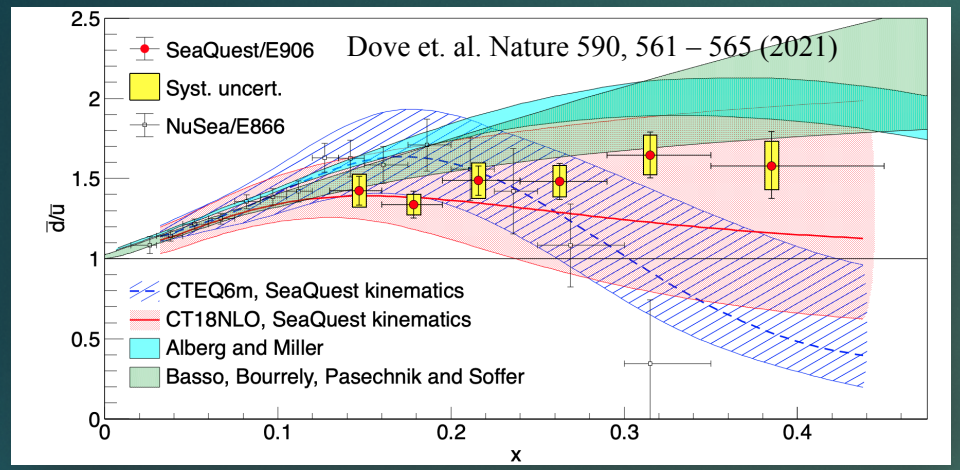
JAM Collaboration

- Understand the 3-dimensional structure of nucleons through global QCD analysis of parton distribution functions (PDFs), fragmentation functions (FFs) and transverse momentum dependent (TMD) distributions.
- Use collinear factorization in perturbative QCD to perform simultaneous determinations of PDFs, FFs, etc.
- Utilize Monte Carlo methods for Bayesian inference to achieve robust uncertainty quantification

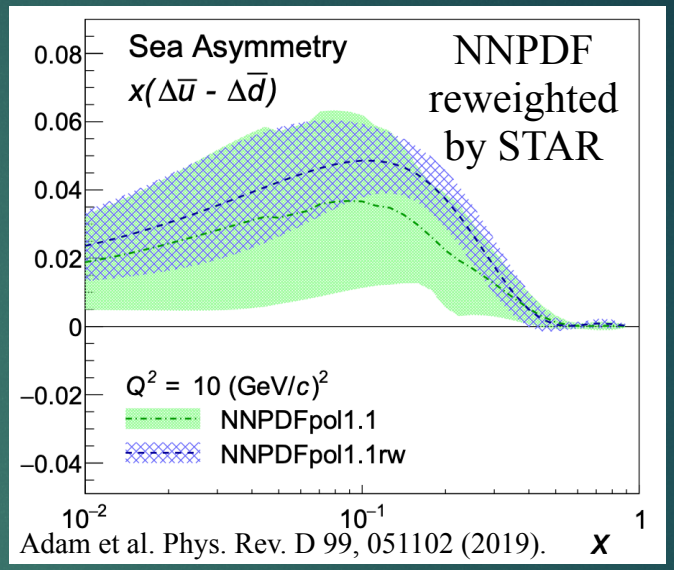


Helicity PDF Analysis

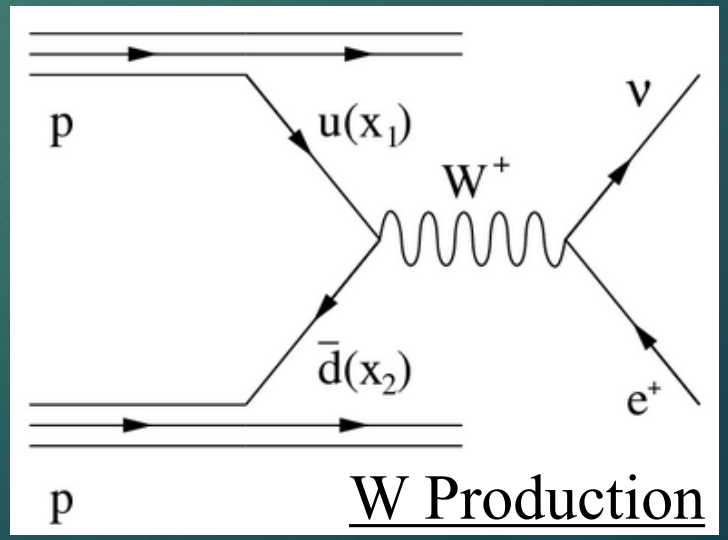
Lots of research into unpolarized sea asymmetry $\bar{d} - \bar{u}$



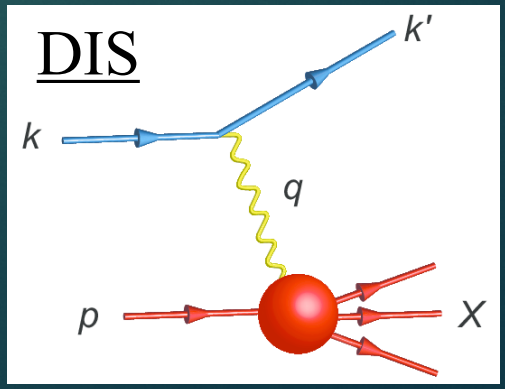
Less is known on polarized sea asymmetry $\Delta\bar{u} - \Delta\bar{d}$



First global QCD analysis of polarized W production data from STAR, with simultaneous extraction of spin-averaged and helicity PDFs

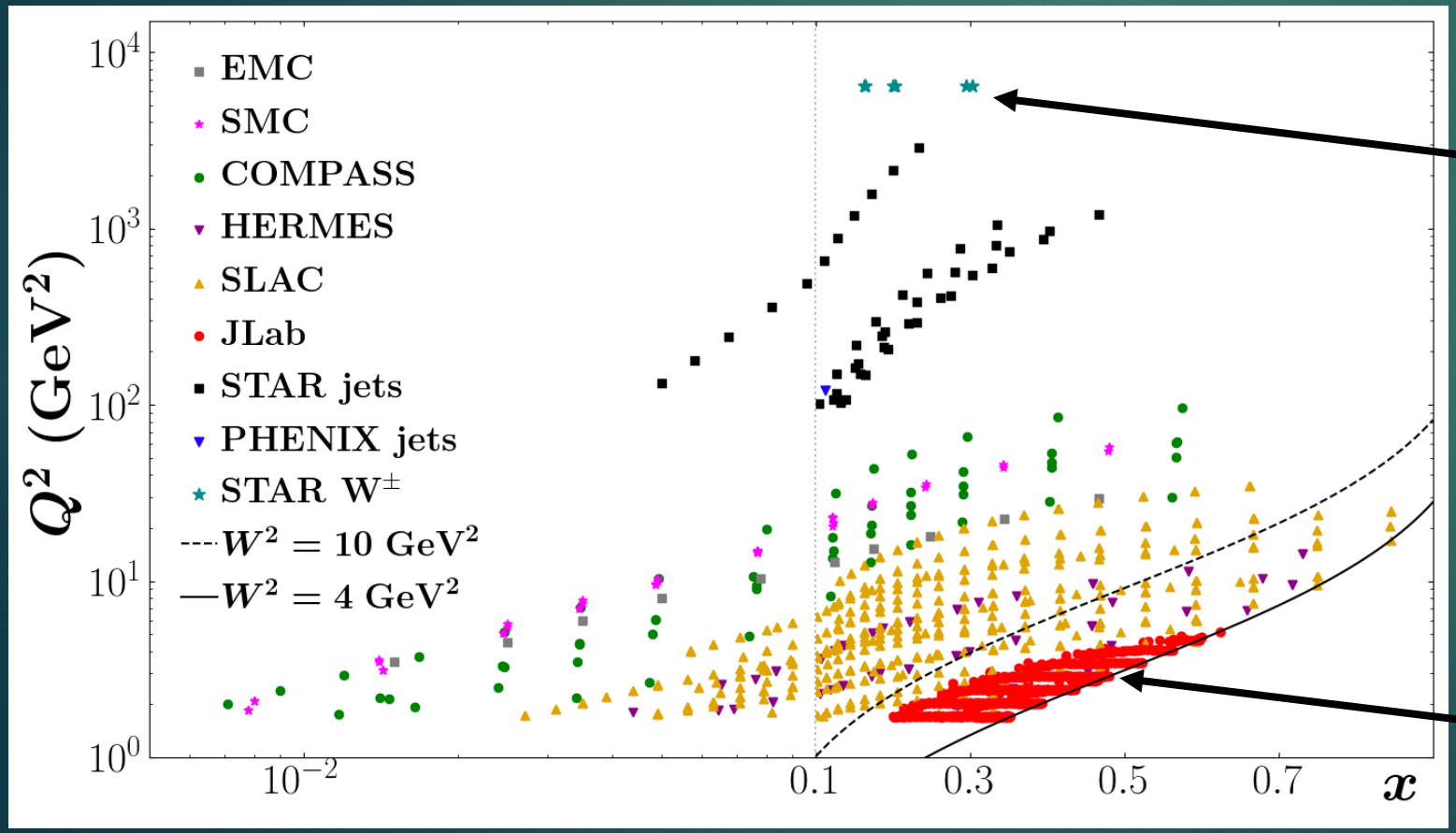


+ Jets



Data

- **Deep Inelastic Scattering**: EMC, SMC, COMPASS, HERMES, SLAC, Jefferson Lab (1,675 points)
- **Jets**: RHIC STAR/PHENIX (45 points)
- **W Production**: RHIC STAR (12 points)



New STAR Data

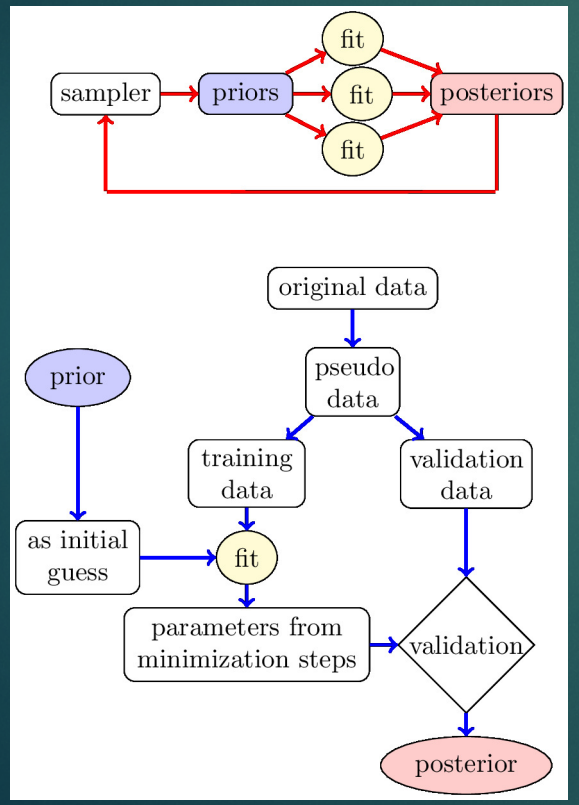
Low W^2 cut allows inclusion of high-x Jefferson Lab data

High-x Data (Proton/Deuteron/Helium)

JAM Methodology

- Parameterize PDFs at input scale $Q_0^2 = m_c^2$: $f(x) = Nx^{\alpha}(1-x)^{\beta}(1+\gamma\sqrt{x}+\eta x)$
- Evolve PDFs using DGLAP and compute observables
- Determine parameters through Bayesian posterior sampling with likelihood function $e^{-\frac{\chi^2}{2}}$
- Repeat process hundreds of times to get different sets of parameters (replicas)

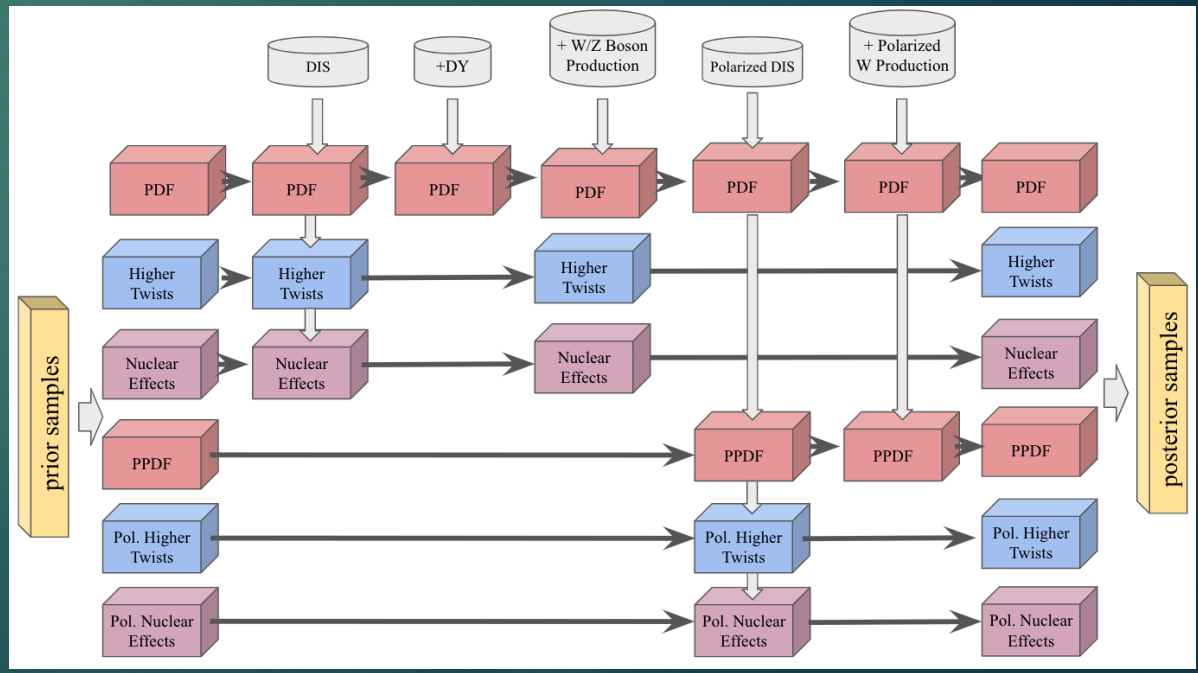
Data Resampling:



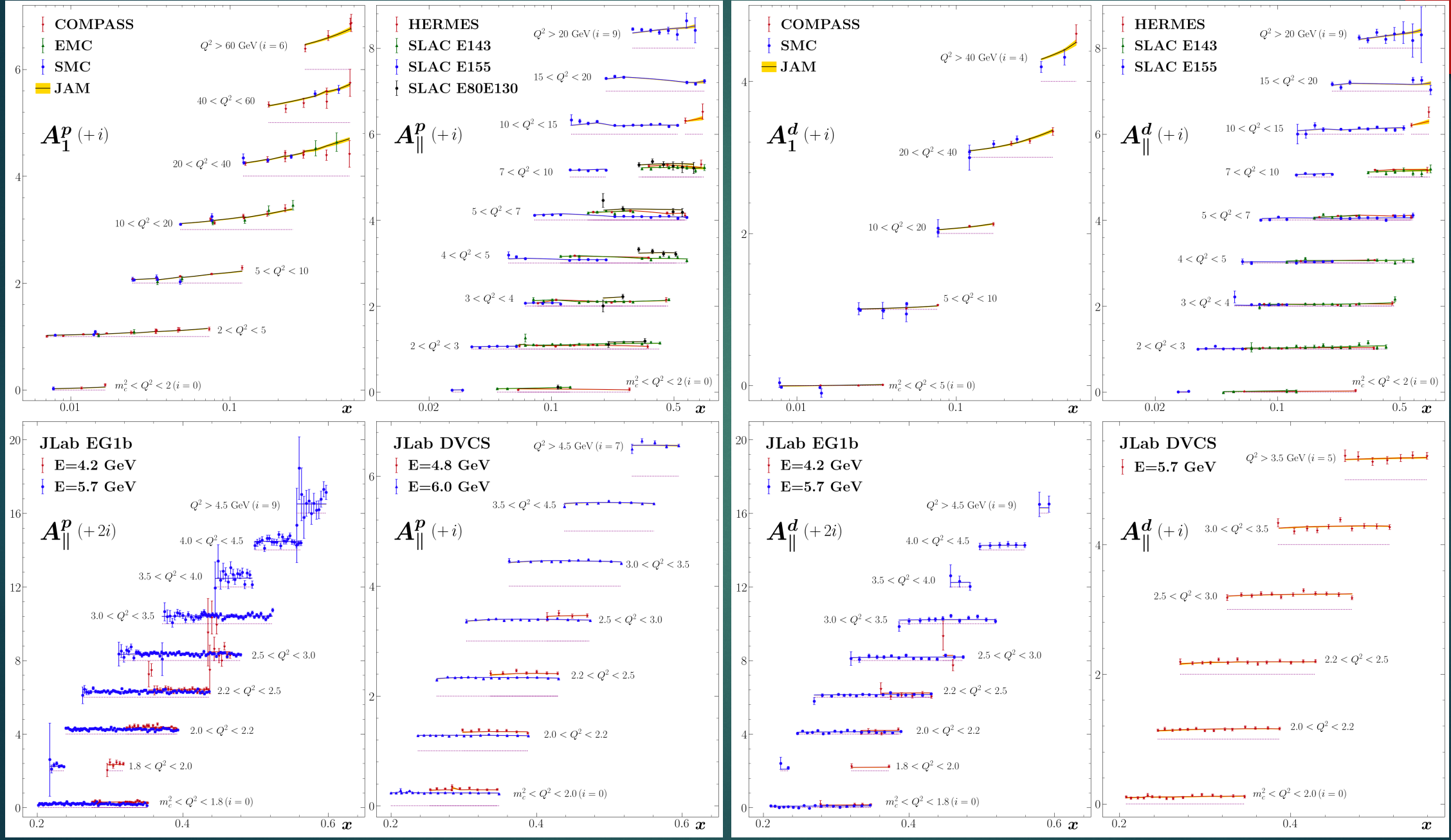
$$\tilde{\sigma} = \sigma + R\alpha$$

$\tilde{\sigma}$: Pseudo-Data
σ: Original Data
R: Random Gaussian number $N(0,1)$
α: Quadrature sum of uncertainties

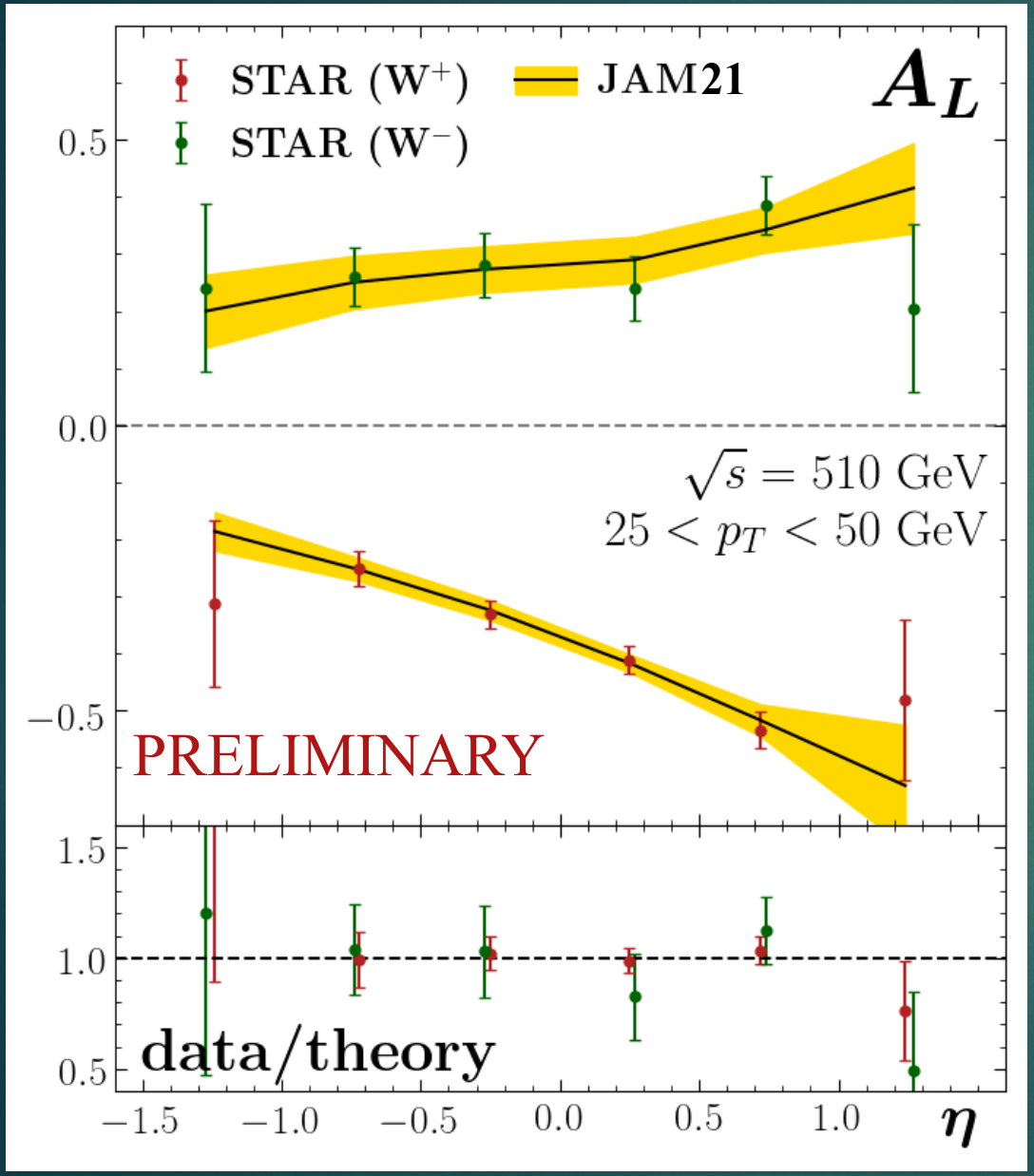
Multi-Step Strategy:



Polarized DIS



Single-Spin Asymmetry from STAR



$$A_L^{W^+}(y_W) \propto \frac{\Delta\bar{d}(x_1)u(x_2) - \Delta u(x_1)\bar{d}(x_2)}{\bar{d}(x_1)u(x_2) + u(x_1)\bar{d}(x_2)}$$

$$A_L^{W^-}(y_W) \propto \frac{\Delta\bar{u}(x_1)d(x_2) - \Delta d(x_1)\bar{u}(x_2)}{\bar{u}(x_1)d(x_2) + d(x_1)\bar{u}(x_2)}$$

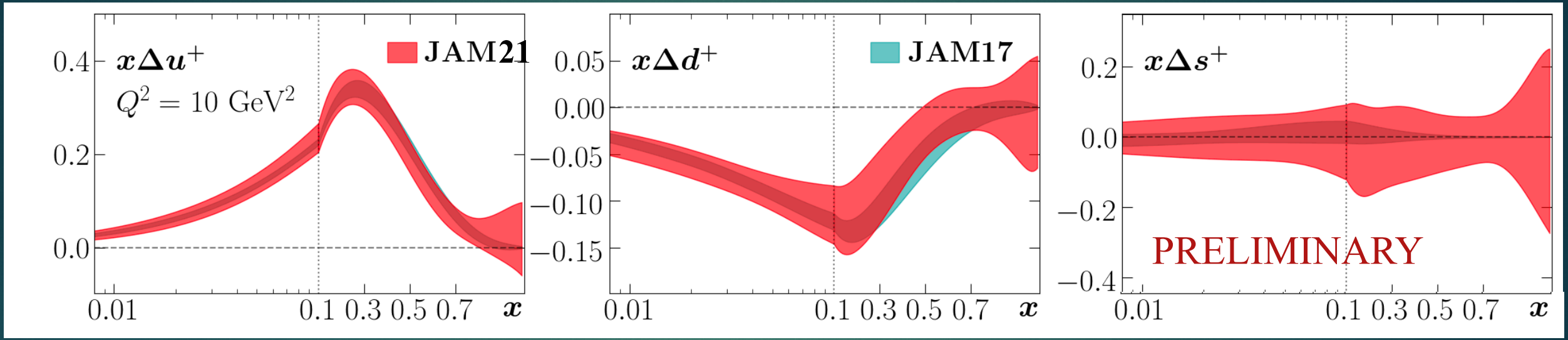
Simultaneous analysis of spin-averaged and helicity PDFs important for this observable!

Data is impossible to fit with $\Delta\bar{u} = \Delta\bar{d}$
Breaking this assumption, we find:

STAR: χ^2/# points = 0.50

Overall: χ^2/# points = 1.11

Helicity PDFs

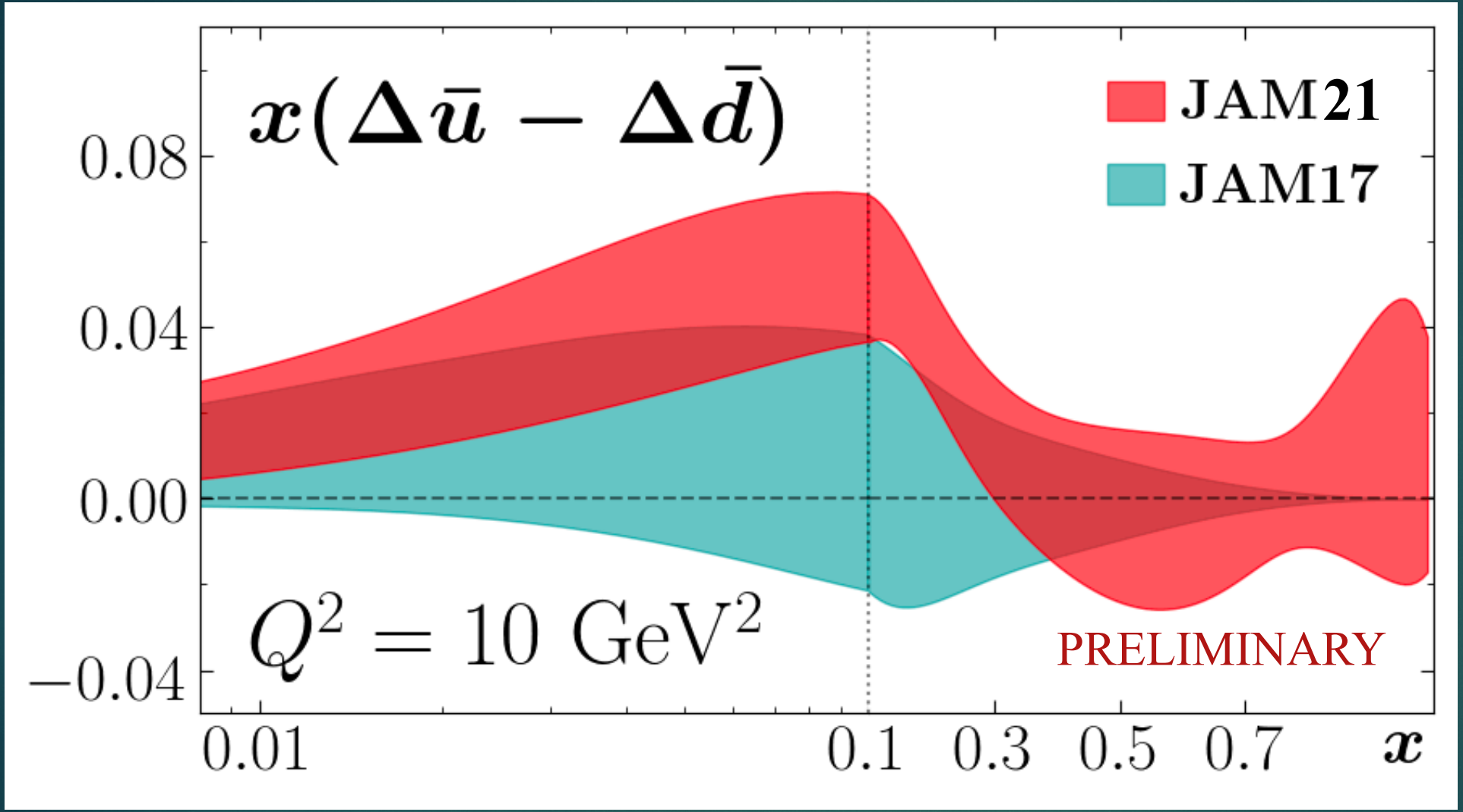


JAM17: Simultaneous analysis of helicity PDFs, pion FFs, and kaon FFs using SIDIS

Values for $g_A = 1.24(4)$ and $a_8 = 0.46(21)$ taken from JAM17 and used to impose SU(2) and SU(3) in this analysis

No positivity constraints in this analysis.

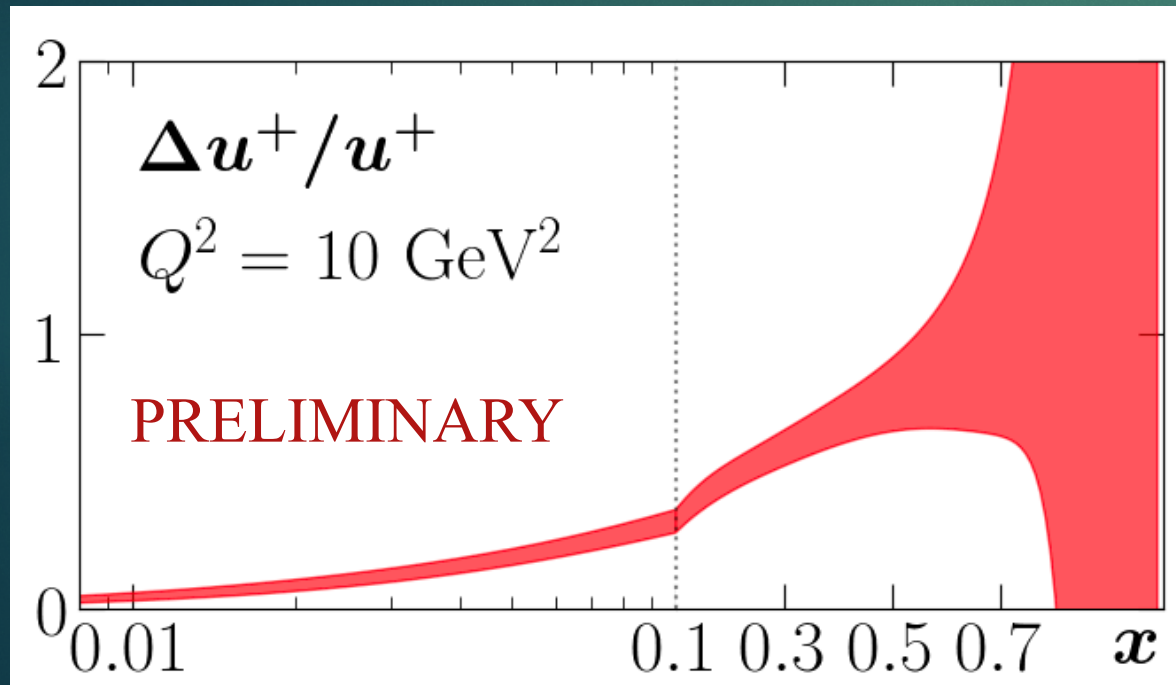
Sea Asymmetry

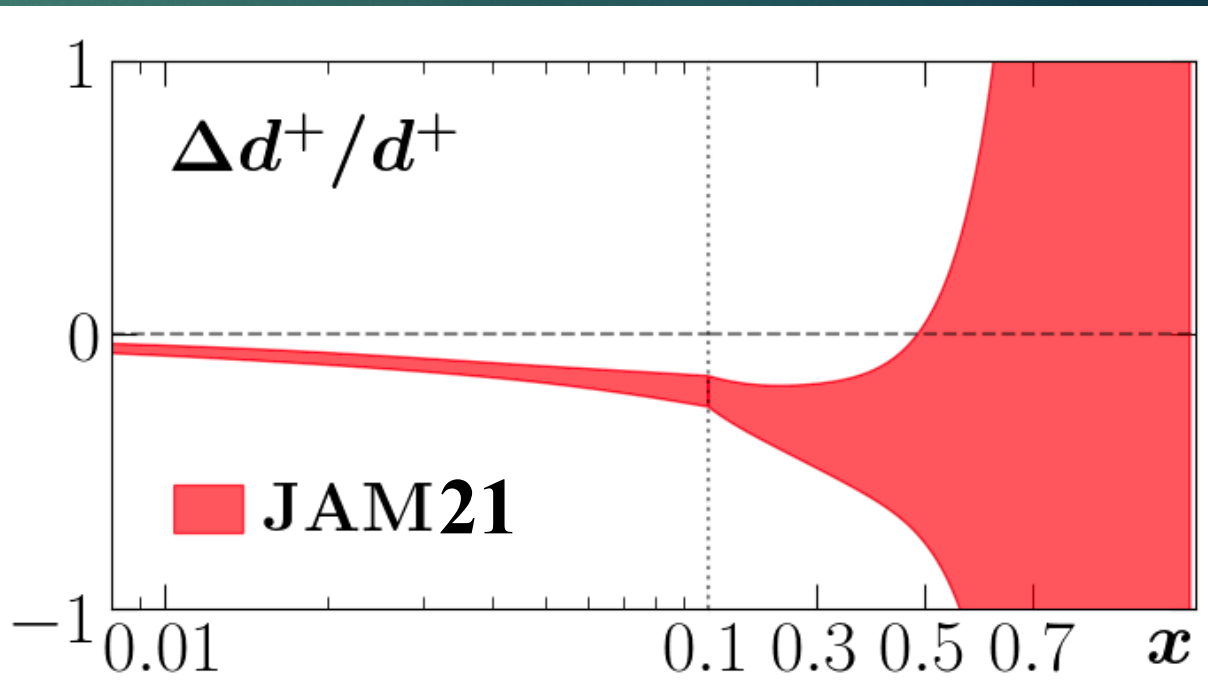


Asymmetry is positive below $x = 0.3$! Opposite of unpolarized PDFs.

Quark Polarizations

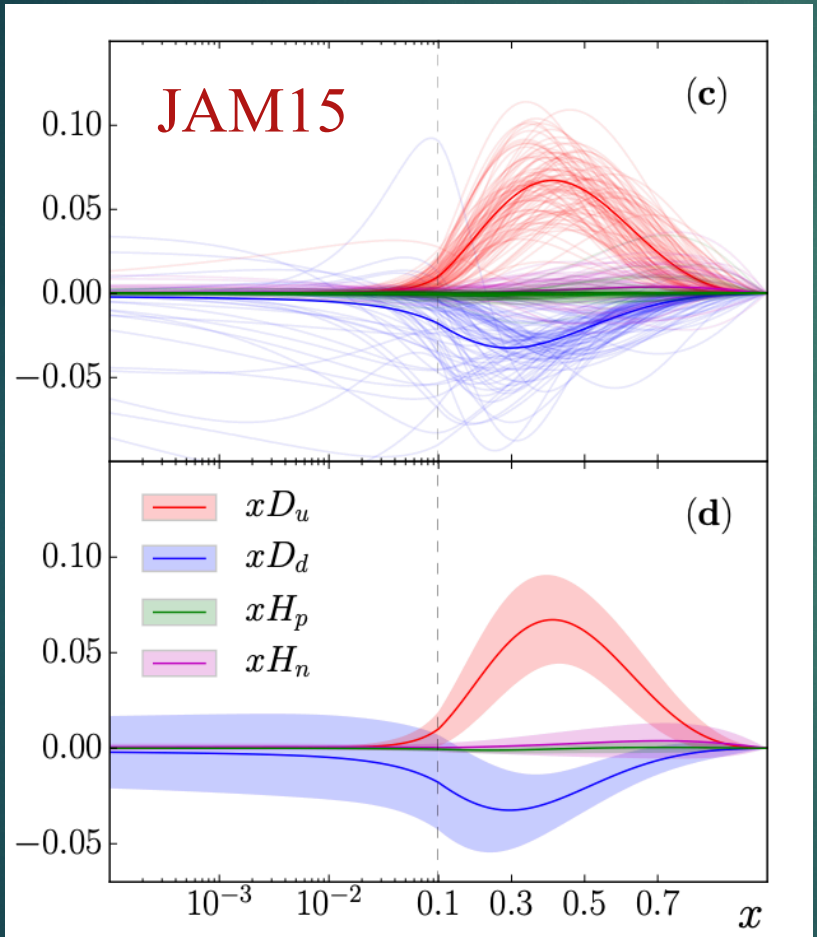
Simultaneous extraction of spin-averaged and helicity PDFs allows for completely consistent extraction of quark polarizations!





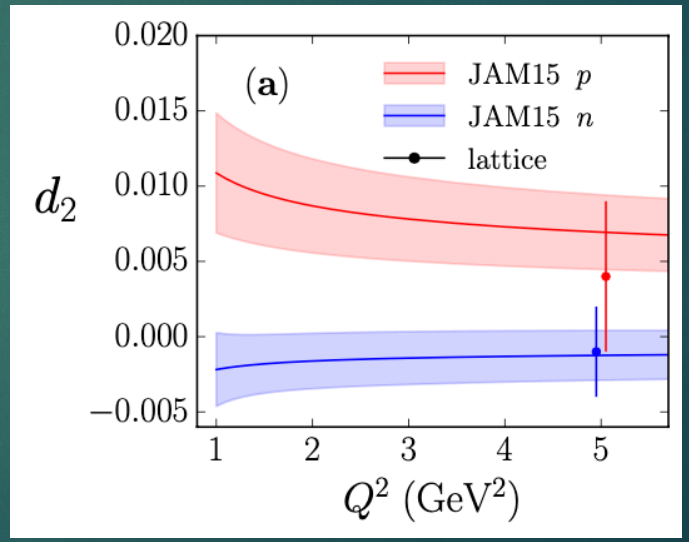
Future: Nuclear Effects

Redo and improve upon JAM15 analysis using latest JAM technology, data, and theory.



Higher twist corrections from JAM15

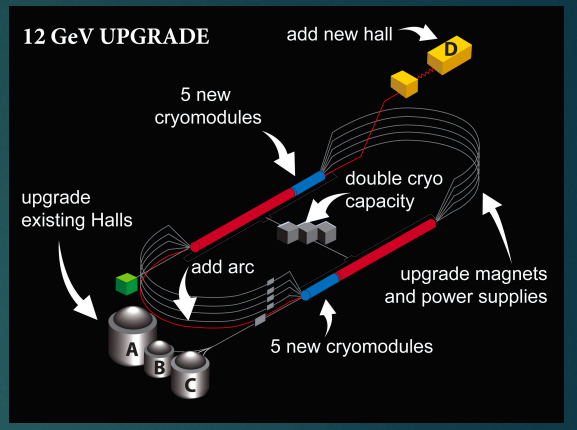
$$d_2(Q^2) = 2\mathbf{g_1}(3,Q^2) + 3\mathbf{g_2}(3,Q^2) = \sum_q e_q^2 \mathbf{D}_q(3,Q^2)$$

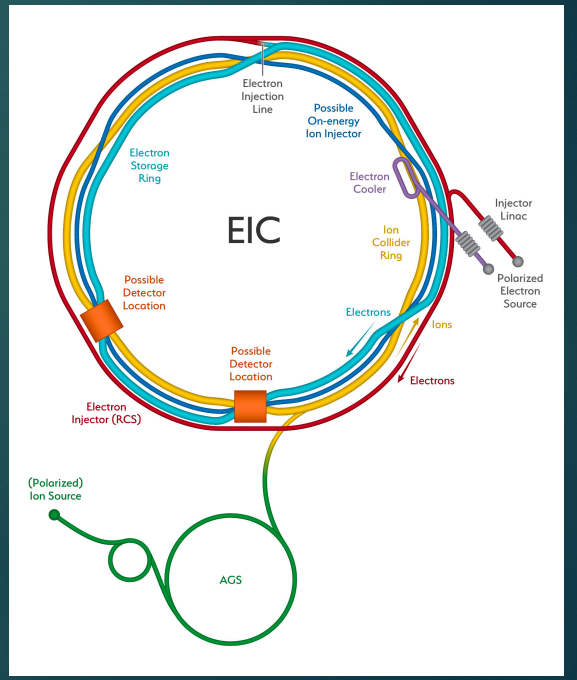


New data from JLab Hall A will provide information on d_2^n

Conclusions and Outlook

- First global QCD analysis of polarized W and polarized jet from RHIC within simultaneous analysis of spin-averaged and helicity PDFs.
- First confirmation of positive sea asymmetry from global QCD analysis
- Future analysis: Simultaneous extraction with pion and kaon fragmentation functions (improve upon JAM17)
- JLab 12 GeV program and EIC extremely important for giving constraints on helicity PDFs, with the EIC being the first polarized electron-hadron collider.





Collaboration

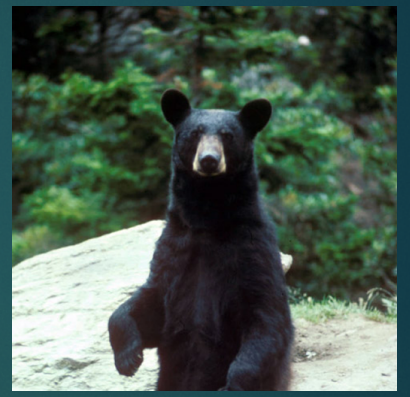
This project was done in collaboration with:

Andreas Metz

Wally Melnitchouk

Nobuo Sato

Jacob Ethier



Jefferson Lab Angular Momentum Collaboration

Thank you to Yiyu Zhou and Patrick Barry for helpful discussions.