Studying the Light Sea Quark Asymmetry Using Semi-Inclusive Deep Inelastic Scattering with the SoLID using a Longitudinally Polarized ^{3}He Target at 11GeV

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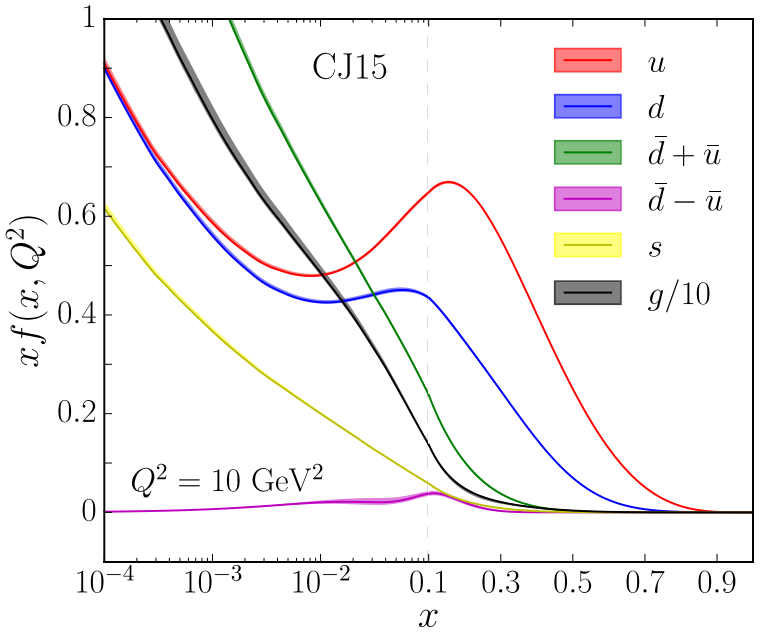
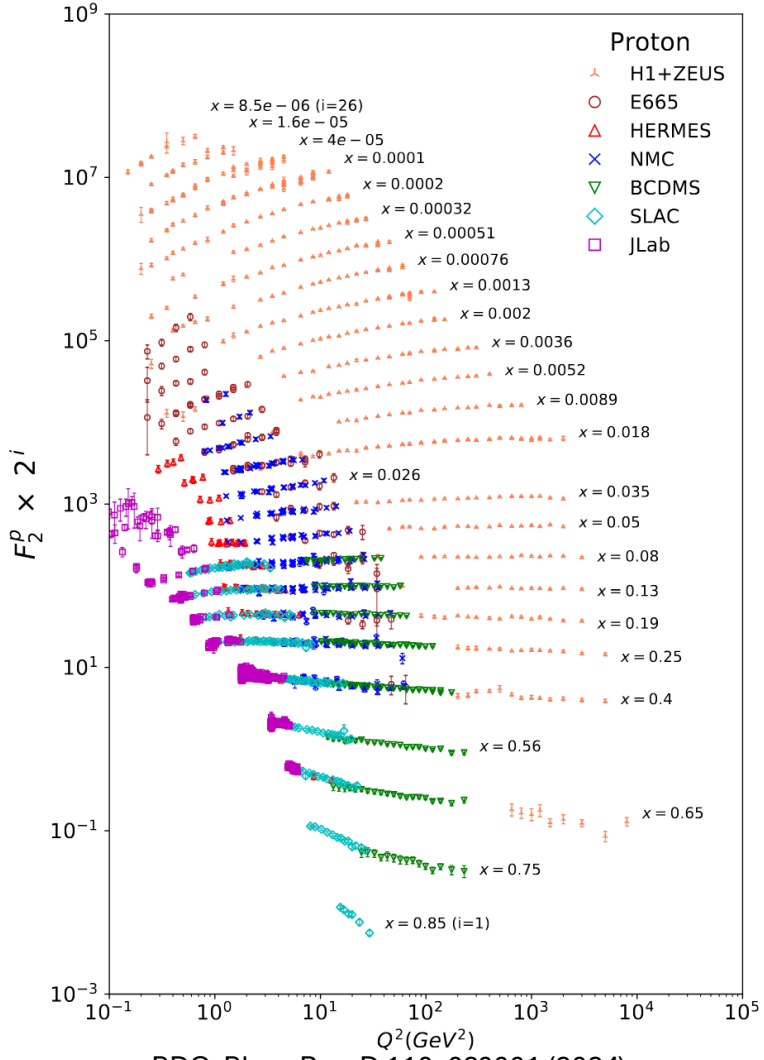
Unpolarized Structure Functions

- The unpolarized structure functions have been extensively studied by various experiments



A. Accardi et al
Phys. Rev. D 93, 114017

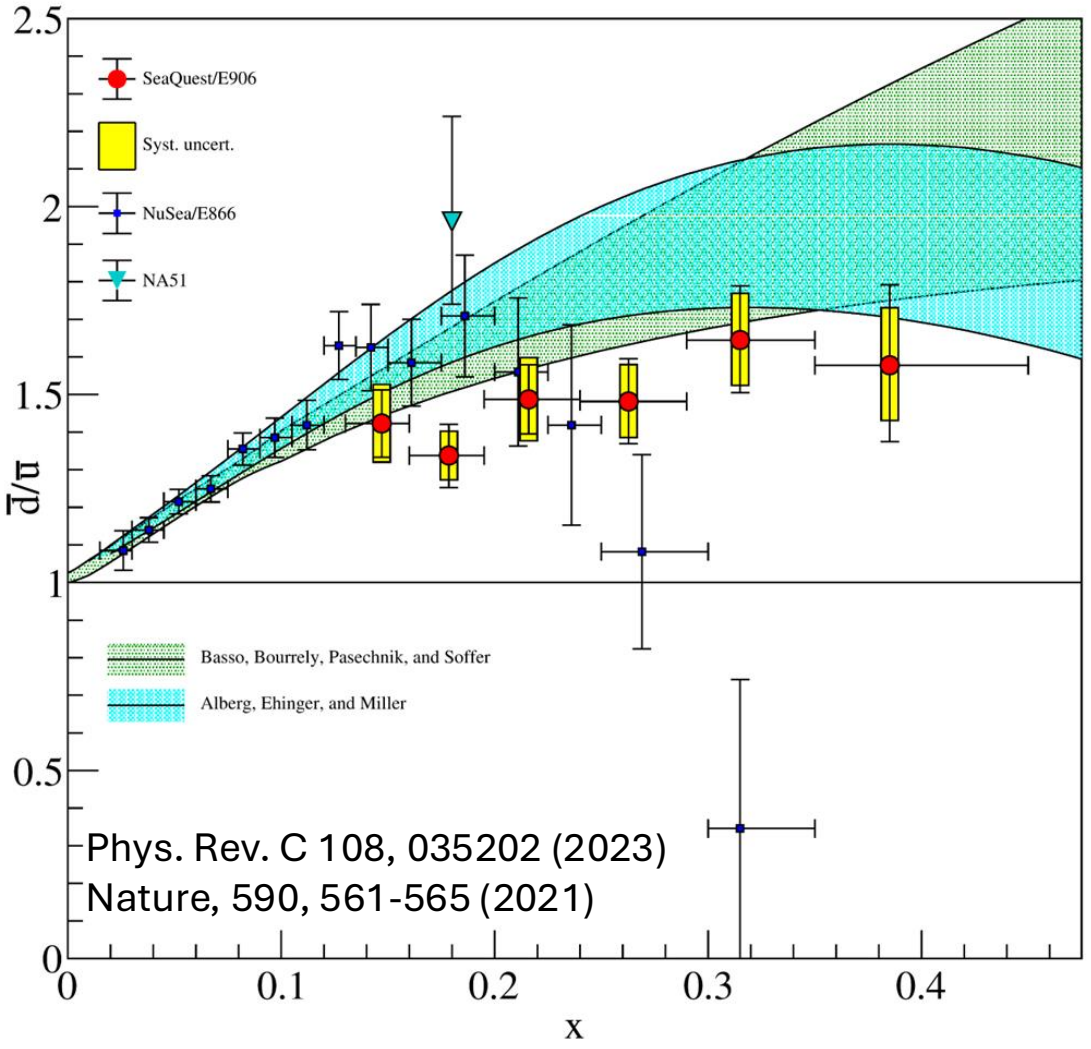


PDG, Phys. Rev. D 110, 030001 (2024)

SEAQUEST Results: Unpolarized Light Sea

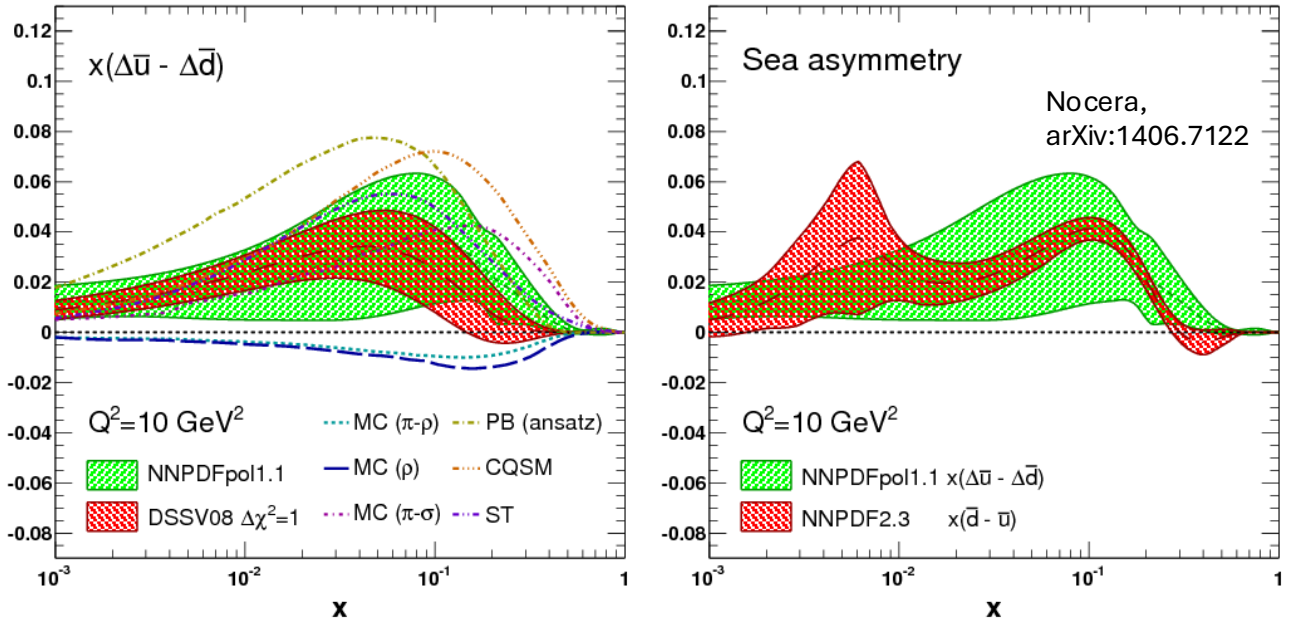
- SeaQuest results show that nature prefers $\bar{d} > \bar{u}$ in the proton
- This flavor asymmetry cannot be explained by gluon splitting, a non perturbative mechanism is needed
- The results are consistent with various models, including meson cloud and statistical model

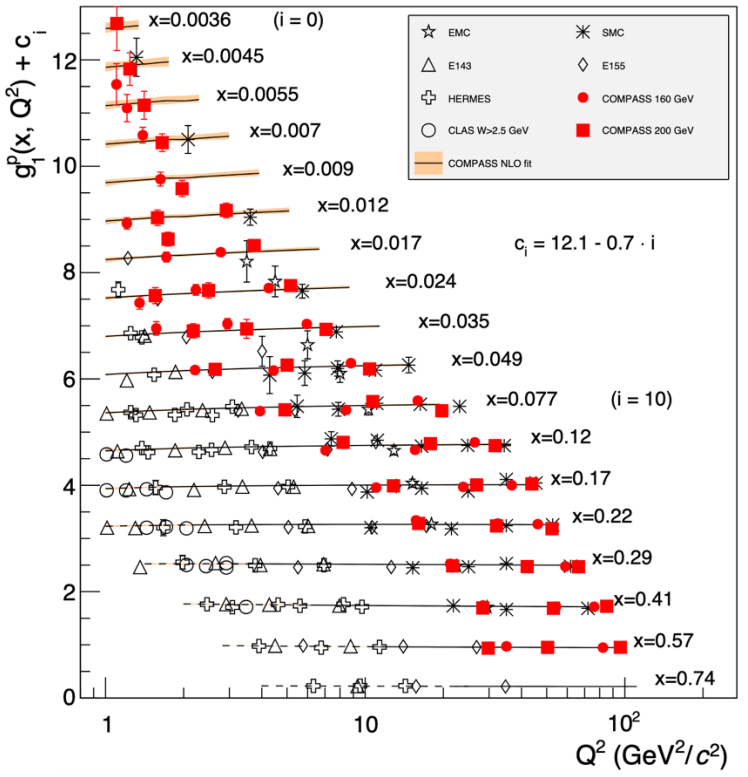
$$\left.\frac{\sigma_{pd}^{DY}}{2\sigma_{pp}^{DY}}\right|_{x_1 \gg x_2} \approx \frac{1}{2}\left(1 + \frac{\bar{d}(x_2)}{\bar{u}(x_2)}\right)$$



Polarized Structure Functions

- These models can also be used to predict polarized PDFs, with different predictions between different models





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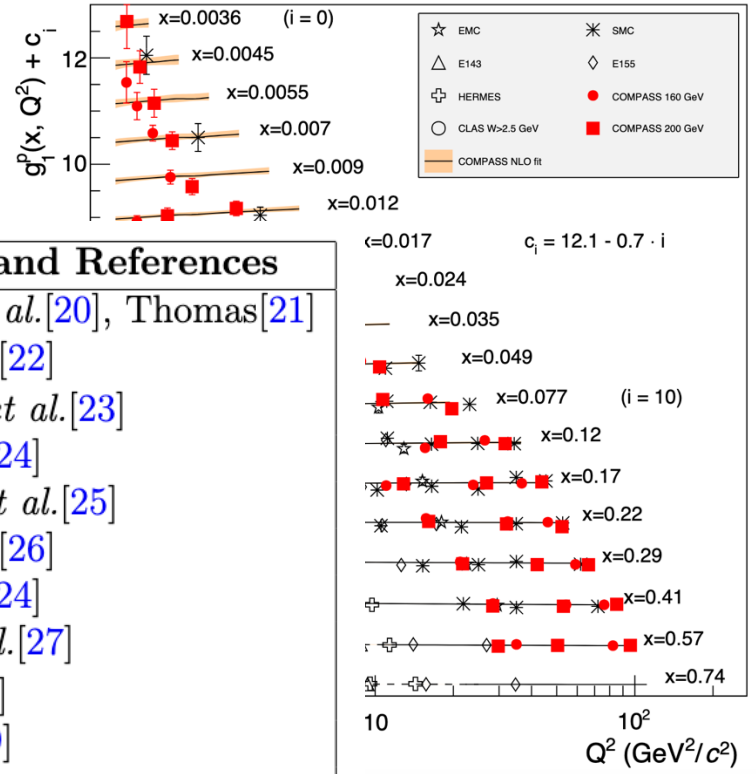
Polarized Structure Functions

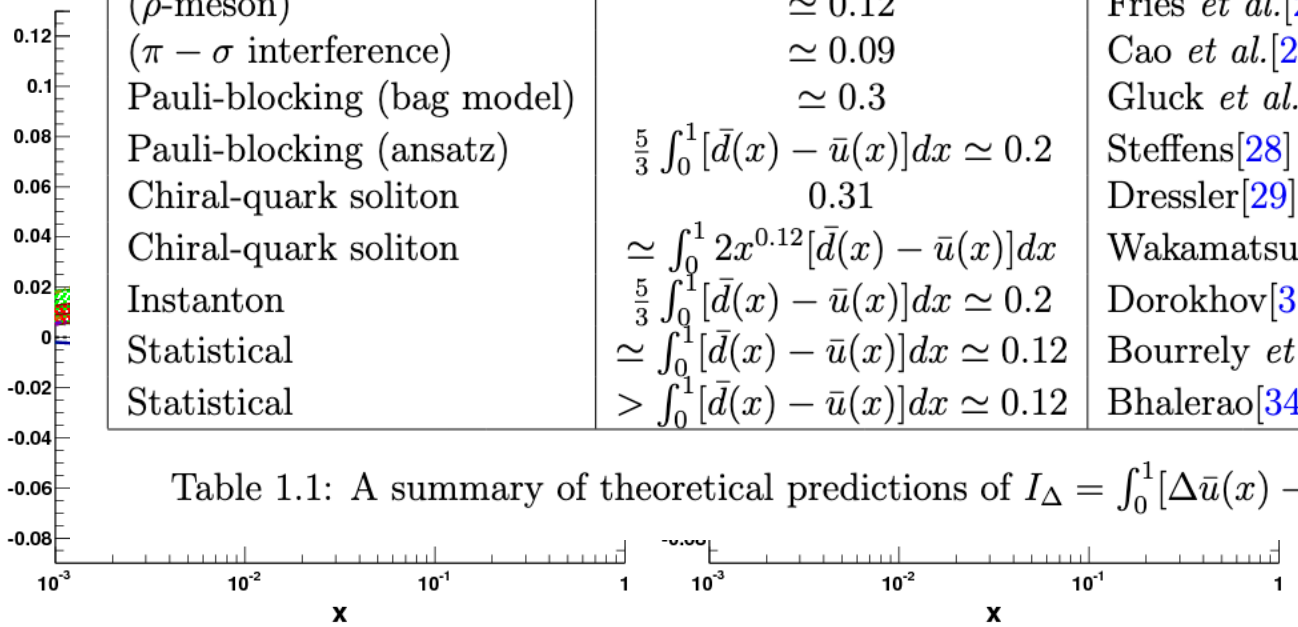
- These models can also be used to with dif betwee



10, 030001 (2024)

Model	I_Δ prediction	Authors and References
Meson cloud	0	Eichten *et al.*[20], Thomas[21]
(π-meson)	$\simeq -0.007$ to -0.027	Fries *et al.*[22]
(ρ-meson)	$= -6\int_0^1 g_1^p(x)dx \simeq -0.7$	Boreskov *et al.*[23]
($\pi - \rho$ interference)	$\simeq -0.004$ to -0.033	Cao *et al.*[24]
(ρ and $\pi - \rho$ interference)	< 0	Kumano *et al.*[25]
(ρ-meson)	$\simeq 0.12$	Fries *et al.*[26]
($\pi - \sigma$ interference)	$\simeq 0.09$	Cao *et al.*[24]
Pauli-blocking (bag model)	$\simeq 0.3$	Gluck *et al.*[27]
Pauli-blocking (ansatz)	$\frac{5}{3}\int_0^1[\bar{d}(x) - \bar{u}(x)]dx \simeq 0.2$	Steffens[28]
Chiral-quark soliton	0.31	Dressler[29]
Chiral-quark soliton	$\simeq \int_0^1 2x^{0.12}[\bar{d}(x) - \bar{u}(x)]dx$	Wakamatsu *et al.*[30]
Instanton	$\frac{5}{3}\int_0^1[\bar{d}(x) - \bar{u}(x)]dx \simeq 0.2$	Dorokhov[31]
Statistical	$\simeq \int_0^1[\bar{d}(x) - \bar{u}(x)]dx \simeq 0.12$	Bourrely *et al.*[32, 33]
Statistical	$> \int_0^1[\bar{d}(x) - \bar{u}(x)]dx \simeq 0.12$	Bhalerao[34]

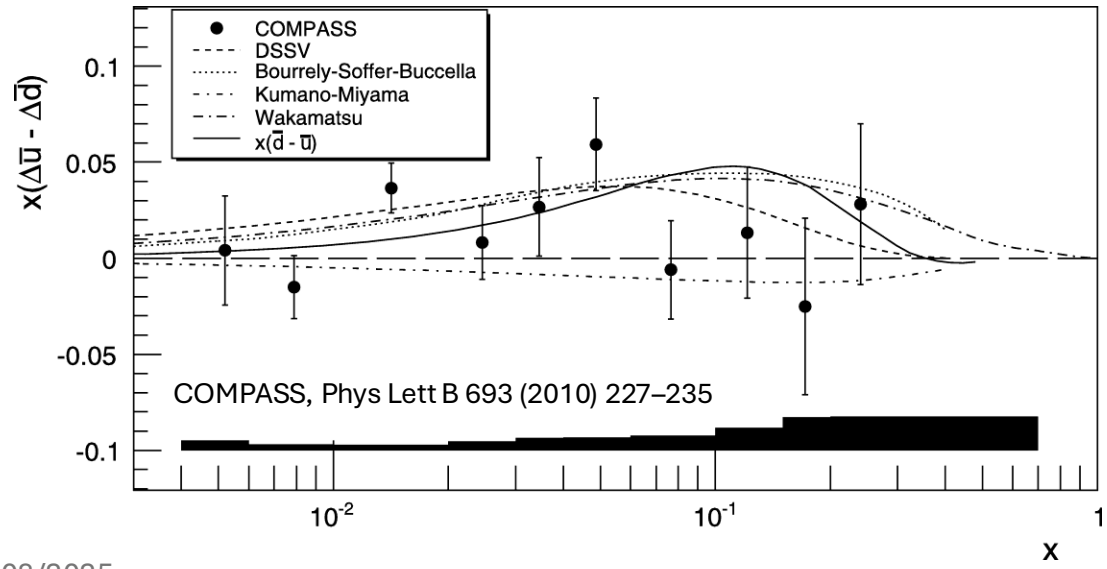
Table 1.1: A summary of theoretical predictions of $I_\Delta = \int_0^1[\Delta\bar{u}(x) - \Delta\bar{d}(x)]dx$. [35]

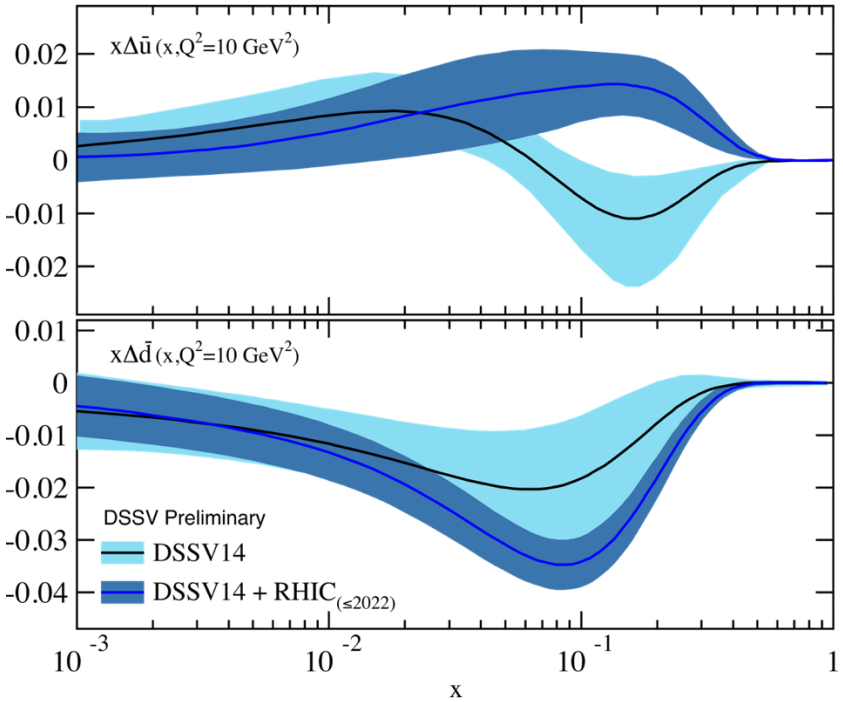


Adapted from J-C Peng, Eur.Phys.J.A18:395-399,2003

Polarized Structure Functions

- Recent global analyses that include RHIC data have found unambiguous sign for $(\Delta\bar{u} - \Delta\bar{d})$in the low-x region.
- Higher precision data is needed in the intermediate and the high-x region to map out the full kinematic dependence of $\Delta\bar{u}$ and $\Delta\bar{d}$

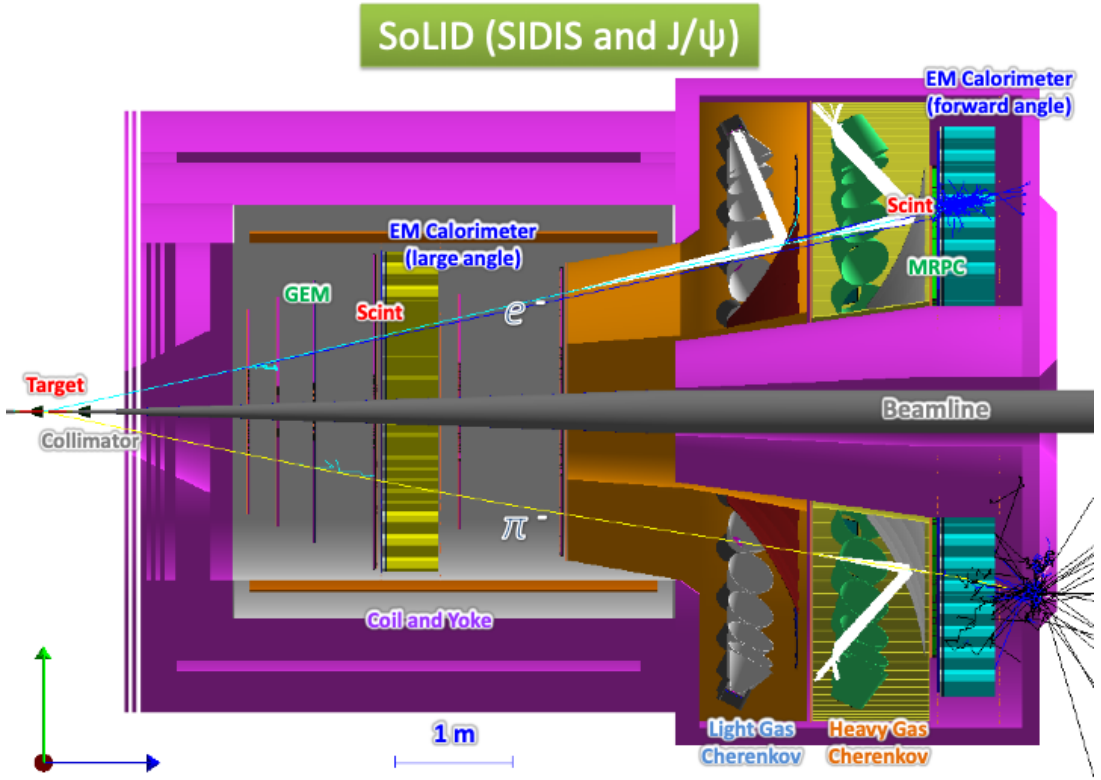




The RHIC Cold QCD Program, arXiv:2302.00605

Experimental Setup

- We propose a run group experiment, running parasitic to the approved SoLID SIDIS experiment
- E12-11-007: Single and Double Spin Asymmetries on Longitudinally Polarized 3He (neutron)
  - With 22.5 approved PAC days and 11 GeV electron



Measuring double spin asymmetry

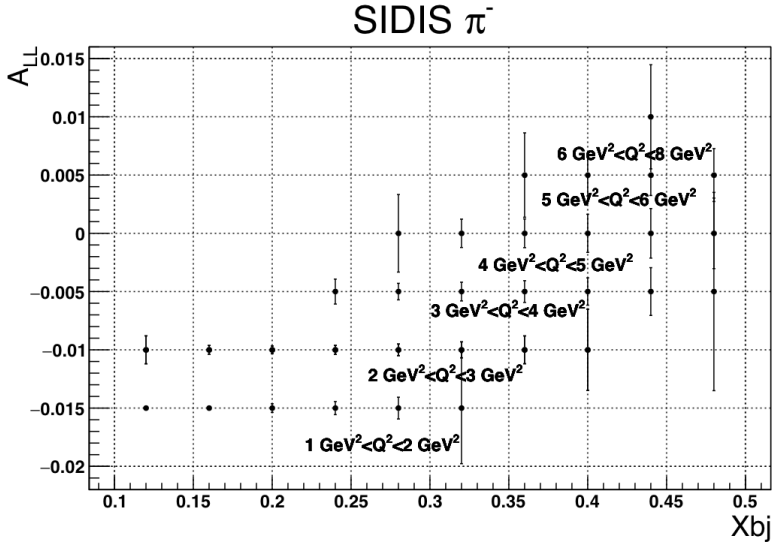
- We propose to measure the double spin asymmetry

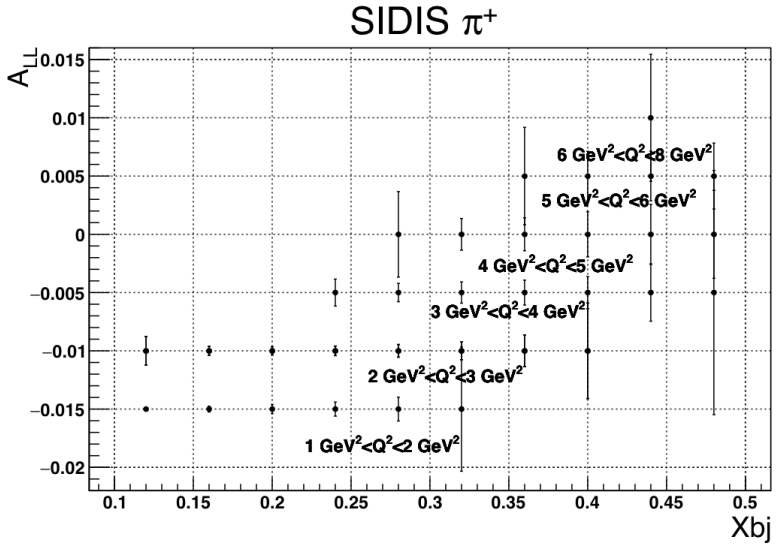
$$A_{LL}^{h}(x_{bj}, P_t, z_h, Q^2) = \frac{1}{P_b P_T} \frac{N^{\uparrow\uparrow} - N^{\uparrow\downarrow}}{N^{\uparrow\uparrow} + N^{\uparrow\downarrow}},$$

- With 22.5 PAC days, using the acceptance obtained from simulation, we expect the statistical error on the ratio to be well within 1%
- At Leading Order, assuming factorization

$$A_{LL}^{h}(x, Q^2, z) = \frac{\sum_f e_f^2 \Delta q_f(x, Q^2) D_f^h(x, Q^2)}{\sum_f e_f^2 q_f(x, Q^2) D_f^h(x, Q^2)}$$

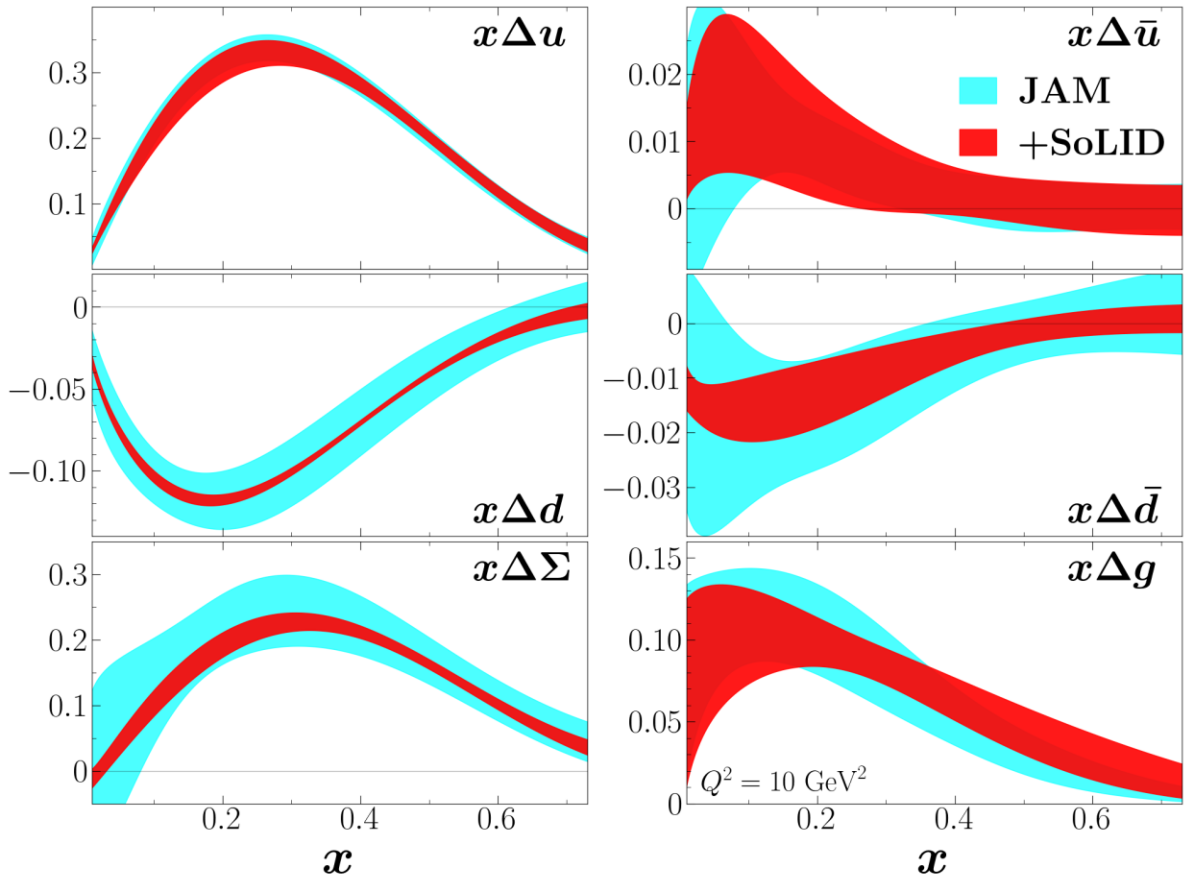
- By measuring both the π^+ and π^-, we can also provide information on the flavor dependence





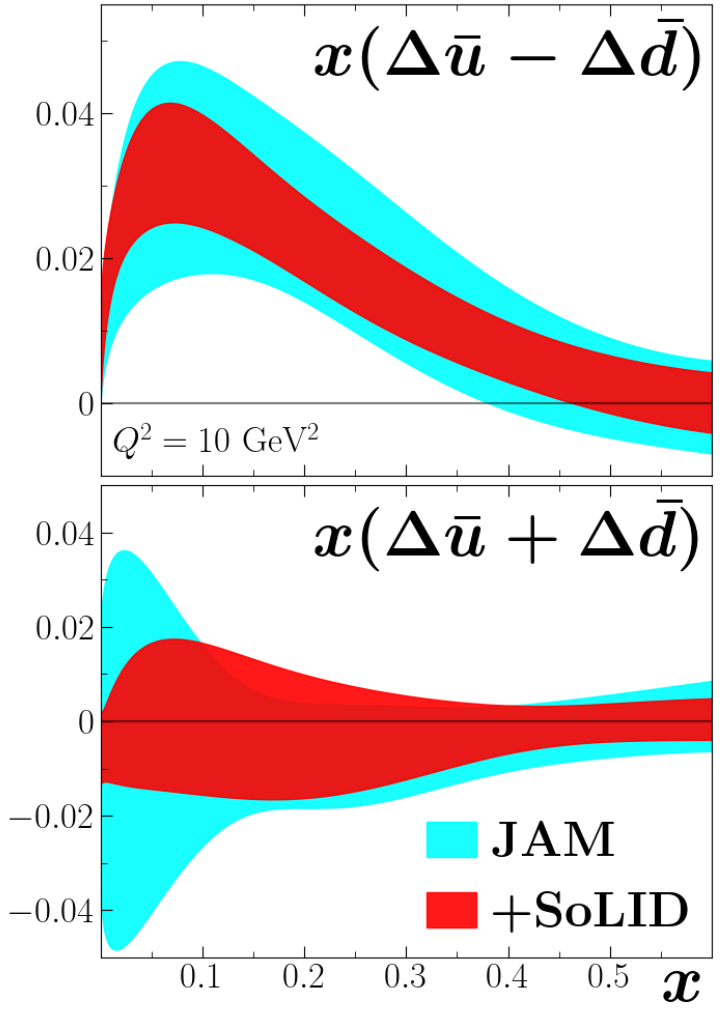
Impact on Global Analysis

- The impact of this measurement on helicity PDFs is evaluated using the JAM framework
- This extraction has a large impact on the on the $\Delta\bar{d}$ and Δd, due to the quark content in ^{3}He
- The net quark spin content $\Delta\Sigma$ is also expect to improve significantly
- A polarized SIDIS measurement at SoLID can significantly improve our knowledge of the down-quark sector in the nucleon



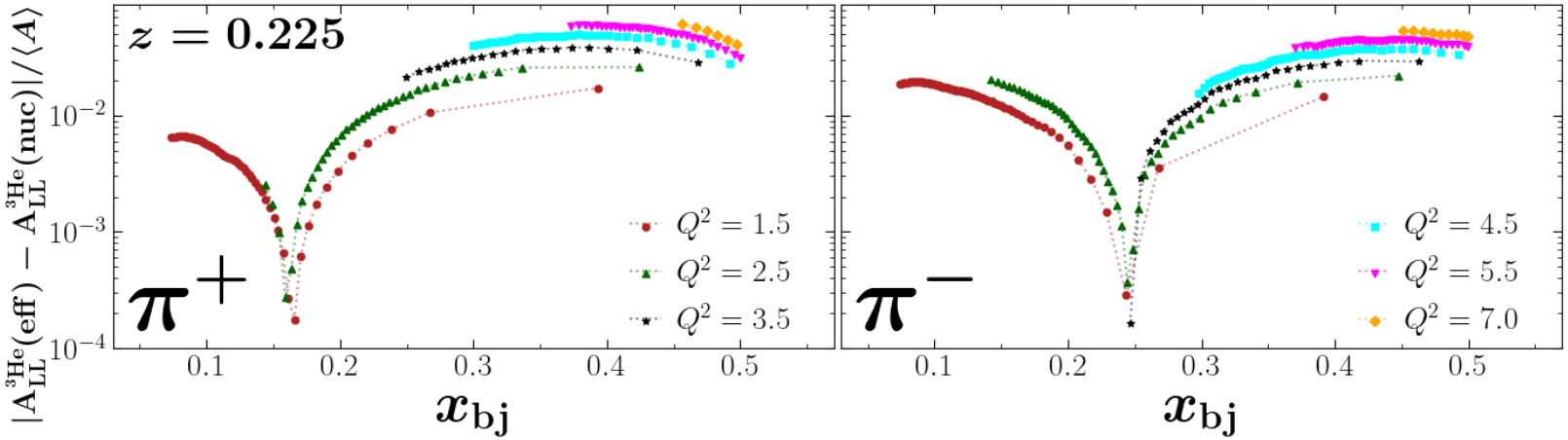
Impact on Global Analysis

- A significant reduction of the uncertainties on the $\Delta\bar{u} - \Delta\bar{d}$ asymmetry
- The 1% uncorrelated systematic uncertainty was also included during the impact study



Theoretical Uncertainties

- With help from the JLab theory group, we have also looked into some of the theoretical uncertainties
- The treatment of nuclear effects on ^{3}He will have roughtly 1- 8% effect on the extracted helicity PDFs.



- Other systematic effects include NLO corrections, hadron mass and higher-twist effects, the impact of missing high-P_t regions, and contamination from exclusive vector meson production

Systematic Uncertainties (Experimental)

- Due to the rapid helicity reversal of the beam at 30 Hz, we expect the systematic uncertainty on the raw asymmetry due to normalization errors, and detector efficiency to largely cancel out in the ratio.
- The main source of uncorrelated experimental systematic uncertainty is expected to be from the random coincidence, which simulations suggest to be around 1%.
- We also assumed the relative uncertainties on polarimetry are 3% for the target, and 2% for the beam polarization.

Sources	Uncertainty
Raw asymmetry (abs.)	negligible
Random coincidence (Rel.)	1%
Polarimetry (Rel.)	$< 4\%$
Nuclear effects (Rel.)	1–8%
Diffractive vector meson (Rel.)	3%
Radiative corrections (Rel.)	3%
Total (Abs.)/Total (Rel.)	Negligible/$< 9.9\%$

Table 3.1: Systematic uncertainty budget of A_{LL}

Summary and Outlook

- We propose a run group experiment to be carried out parasitically with the approved E12-11-007 experiment.
- With the goal of measuring the double spin asymmetry A_{LL}
- The polarized light sea quarks ($\bar{u}$ and $\bar{d}$) at intermediate x (0.1-0.5) is of great interest and in need of high precision data to guide non-perturbative mechanisms that connect polarized and unpolarized sectors
- This measurement will significantly improve constraints on flavor-separated helicity PDFs in the intermediate- and high-x region, especially for the down-quark sector