Study Polarized Sea with SoLID@JLab22

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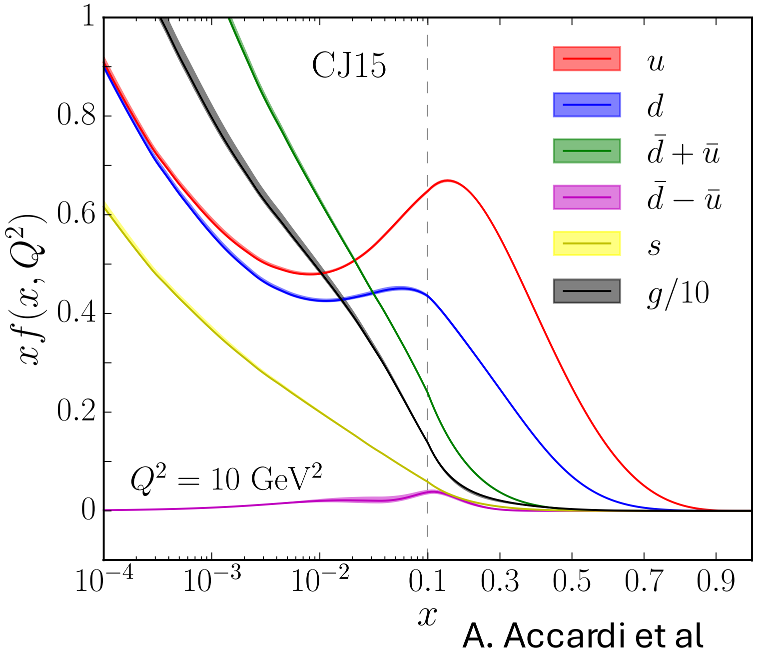
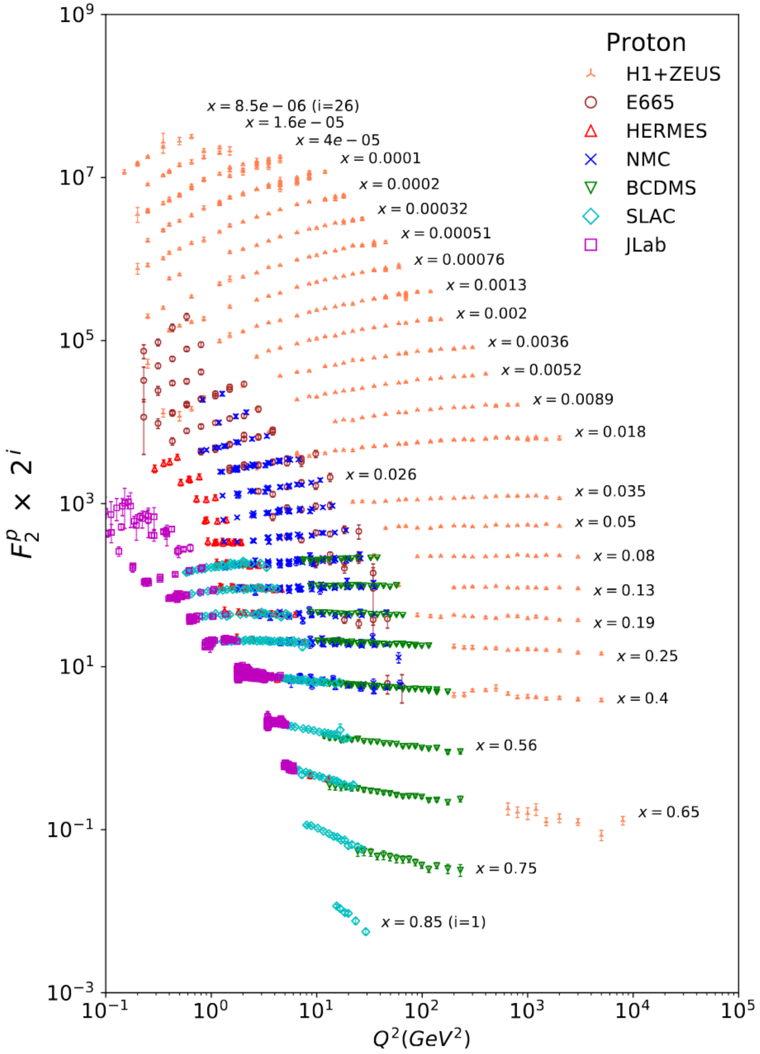
In Collaboration with Ye Tian, Jian-ping Chen, Dave Gaskell and Arun Tadepalli

Unpolarized Structure Functions

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



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

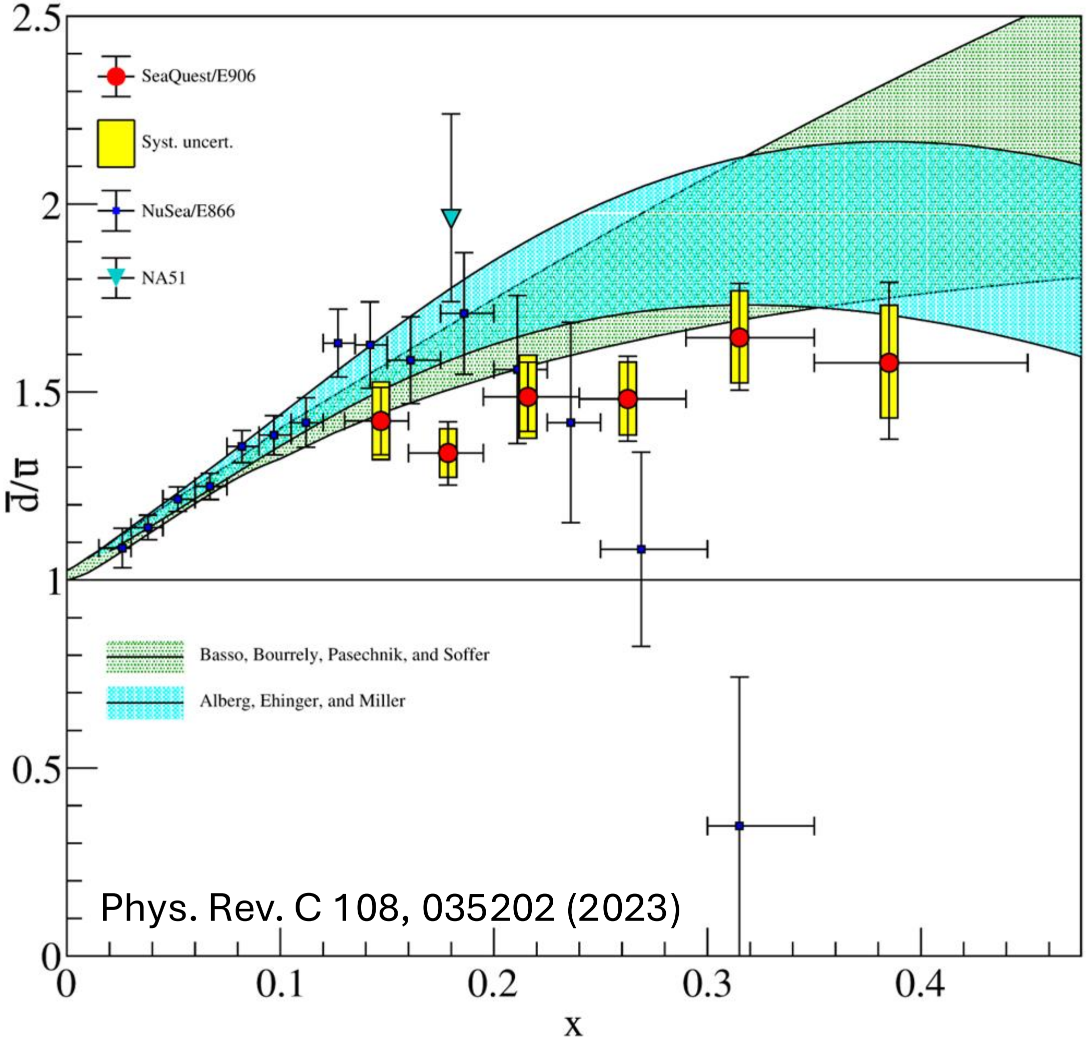


PDG, Phys. Rev. D 110, 030001 (2024)

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

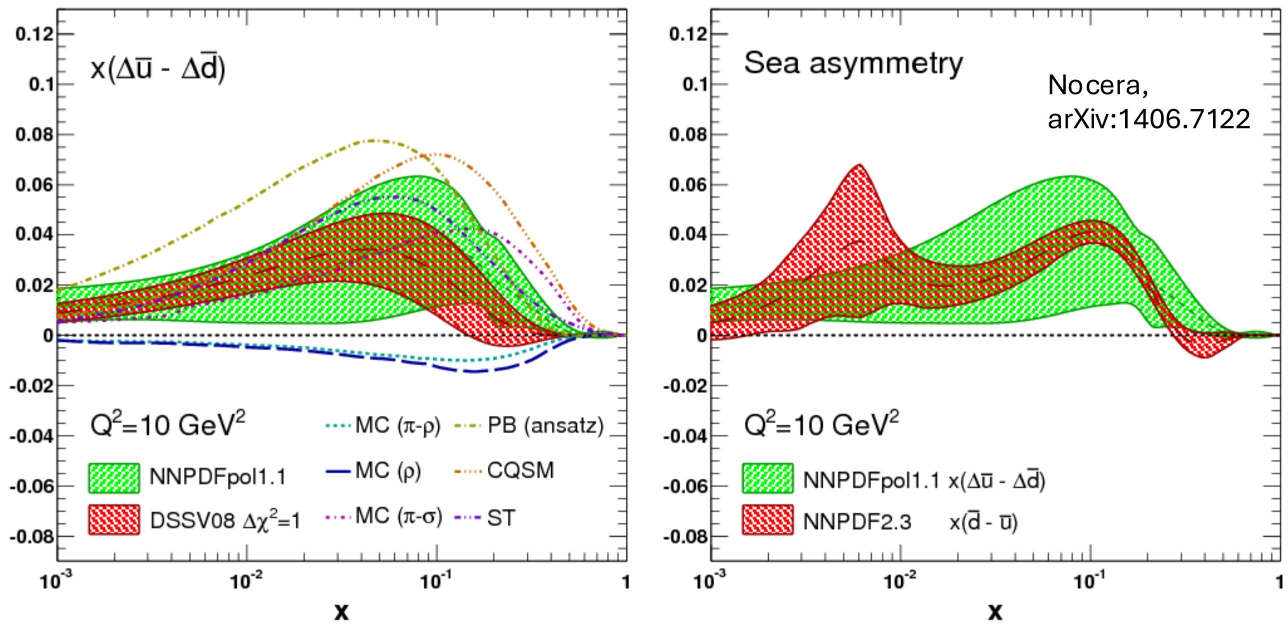
$$\left.\frac{\sigma_{pd}^{DY}}{2\sigma_{pp}^{DY}}\right|_{x_1 \gg x_2} \approx \frac{1}{2}\left(1 + \frac{\bar{d}(x_2)}{\bar{u}(x_2)}\right)$$

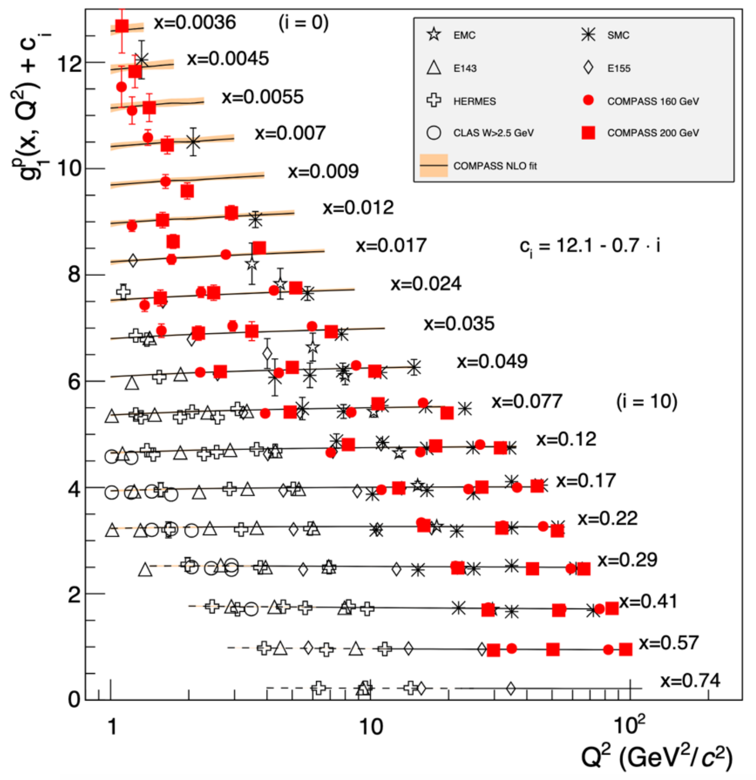


Phys. Rev. C 108, 035202 (2023)

Polarized Structure functions

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





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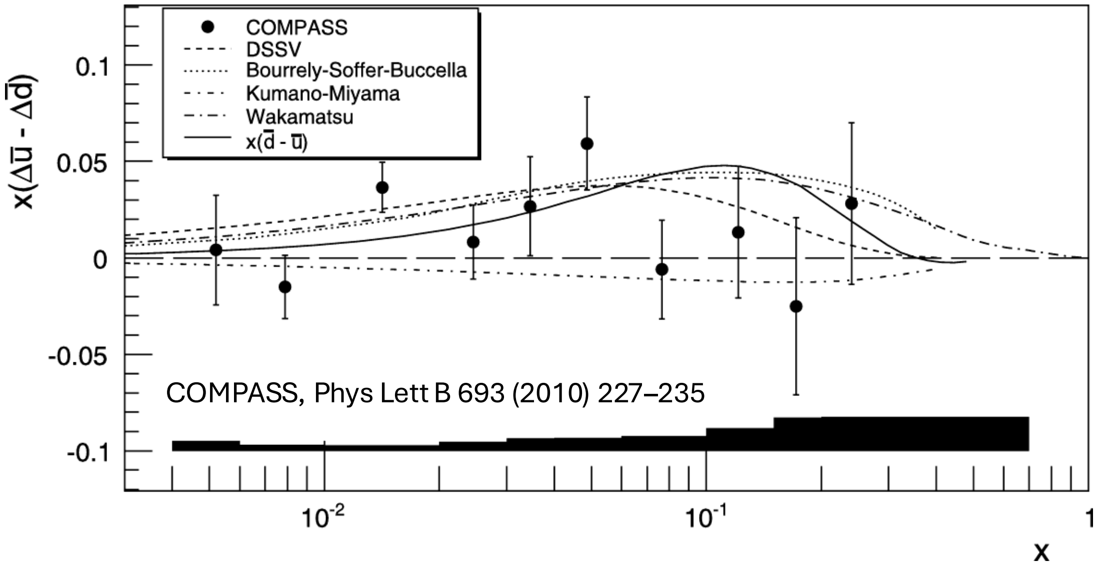
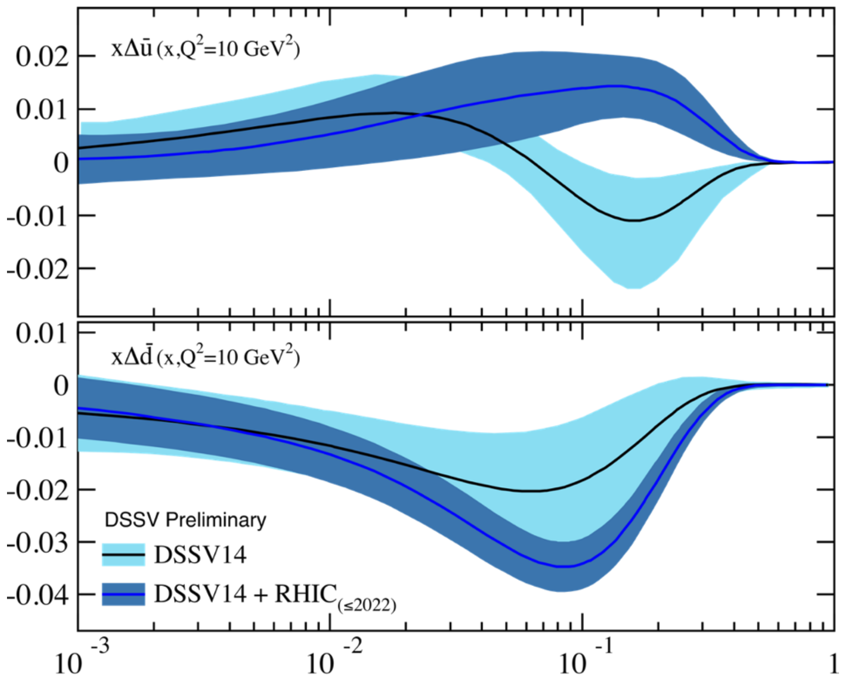


COMPASS, Phys Lett B 693 (2010) 227–235



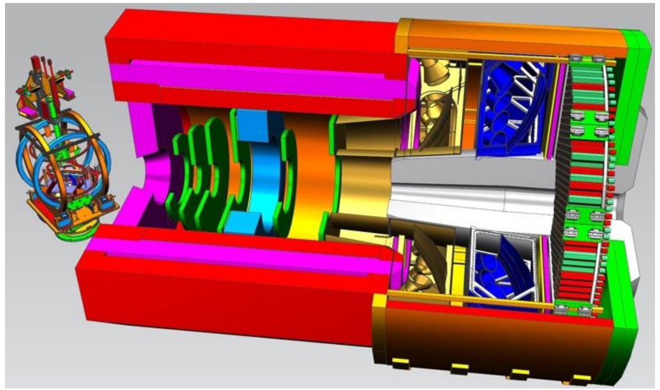
The RHIC Cold QCD Program, arXiv:2302.00605

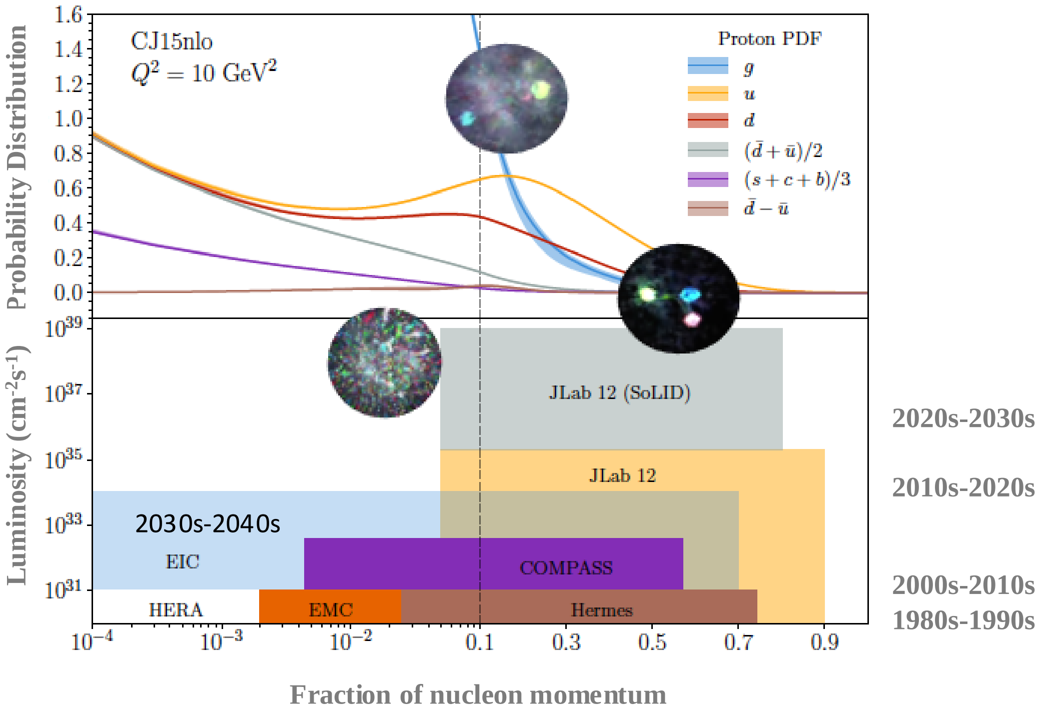
SoLID@JLab: QCD Intensity Frontier

- Nucleon spin, proton mass, beyond standard model experiments require precision measurements of small cross sections and asymmetries, combined with multiple particle detection

➢ critical need for high luminosity (10^{37}-10^{39} $cm^{-2}s^{-1}$) and large acceptance

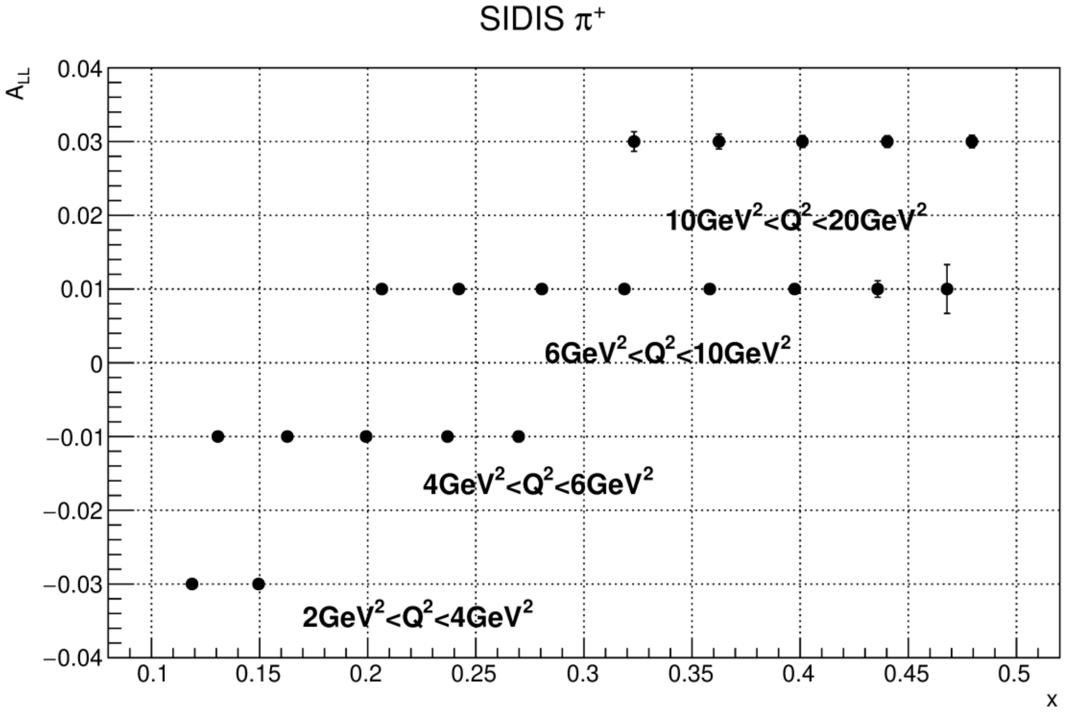
- Science reach:
  - Precision 3D imaging of the nucleon in the valence quark region
  - Beyond Standard Model searches
  - Exploring the origin of the proton mass and gluonic force in the non-perturbative regime.



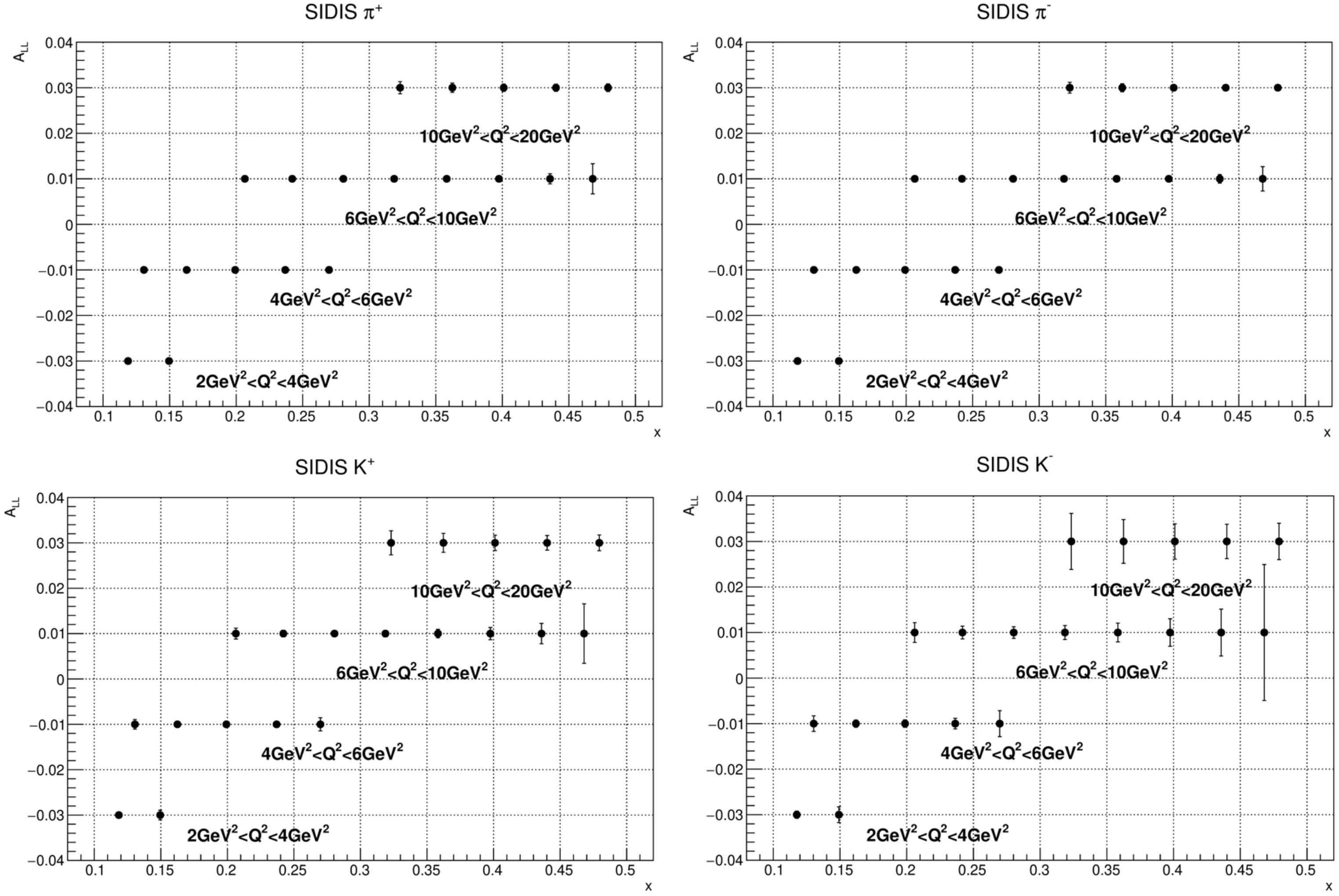


SoLID @ JLab22 SIDIS Polarized Asymmetries π+ on n

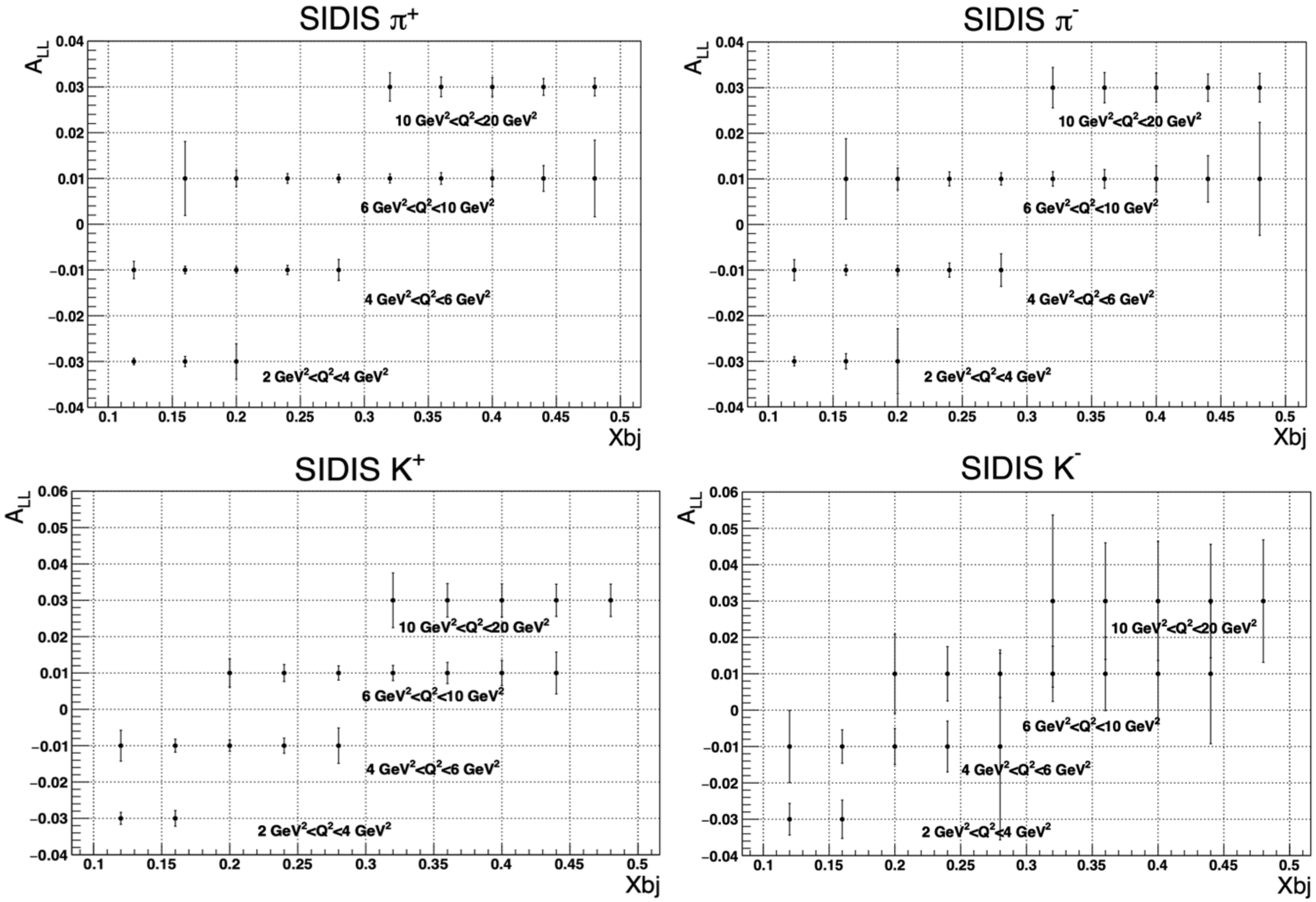
- Statistical uncertainty only (systematics to be studied in the next a few months)
- 100 PAC days; Luminosity = $10^{36}cm^2s^{-1}$, acceptance form EvneSoLID simulation
- Event generator (LO),   PDF: CJ15lo; FF: DSSFFlo
- $\delta A_{LL} = \frac{1}{fn \cdot 0.6 \cdot 0.86}\sqrt{\frac{1}{N_{acc}}}$
- P_b=85% beam polarization; P_t=60% pol ^{3}He target polarization (P_t =70% for pol proton target)
- $P_n = 86\%$ neutron polarization in ^{3}He; neglecting the proton part
- f_n is the dilution factor-fraction of neutron cross section relative to the nuclear cross section
- Summing over P_T and z ranges: $0 < P_T < 1\text{GeV}$, 0.2 < z < 0.6



SoLID @ JLab22 SIDIS Polarized Asymmetries: π/K on n



SoLID @ JLab22 SIDIS Polarized Asymmetries: π/K on p



- 100 PAC days; Luminosity = $10^{35}cm^2s^{-1}$
- P_t =70% for pol NH_3 target

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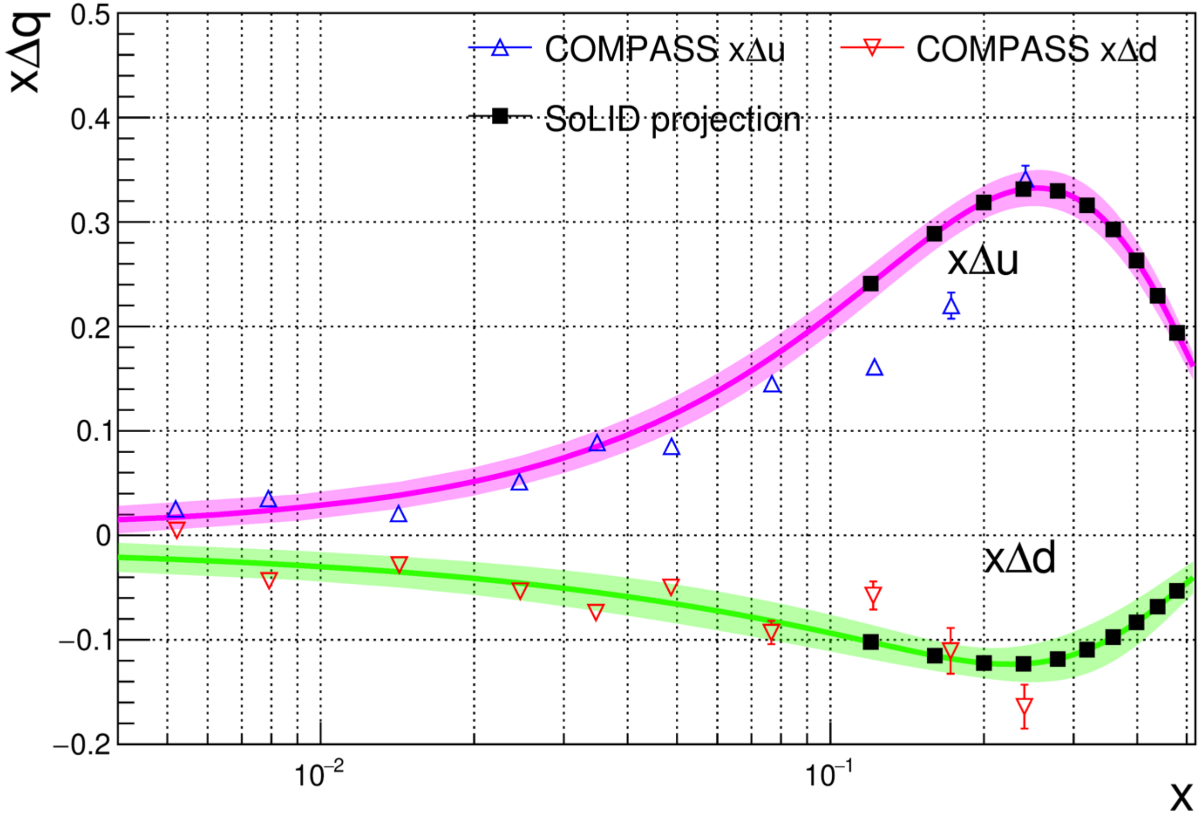
SoLID @ JLab22 SIDIS Polarized u and d PDFs

- At LO, assuming $x - z$ factorization
- $A_{LL}(x, Q^2, z) = \frac{\sum_f e_f^2 \Delta q_f(x,Q^2) \cdot D_f^h(z,Q^2)}{\sum_f e_f^2 q_f(x,Q^2) \cdot D_f^h(z,Q^2)}$
- Using LO Fragmentation Function DSSFFLO
- The band represent the 67% uncertainty band in NNPDFpol1.1
- The SoLID measurement can reach higher x than previous measurements



SoLID @ JLab22 SIDIS Polarized $\bar{u}$ and $\bar{d}$ PDFs

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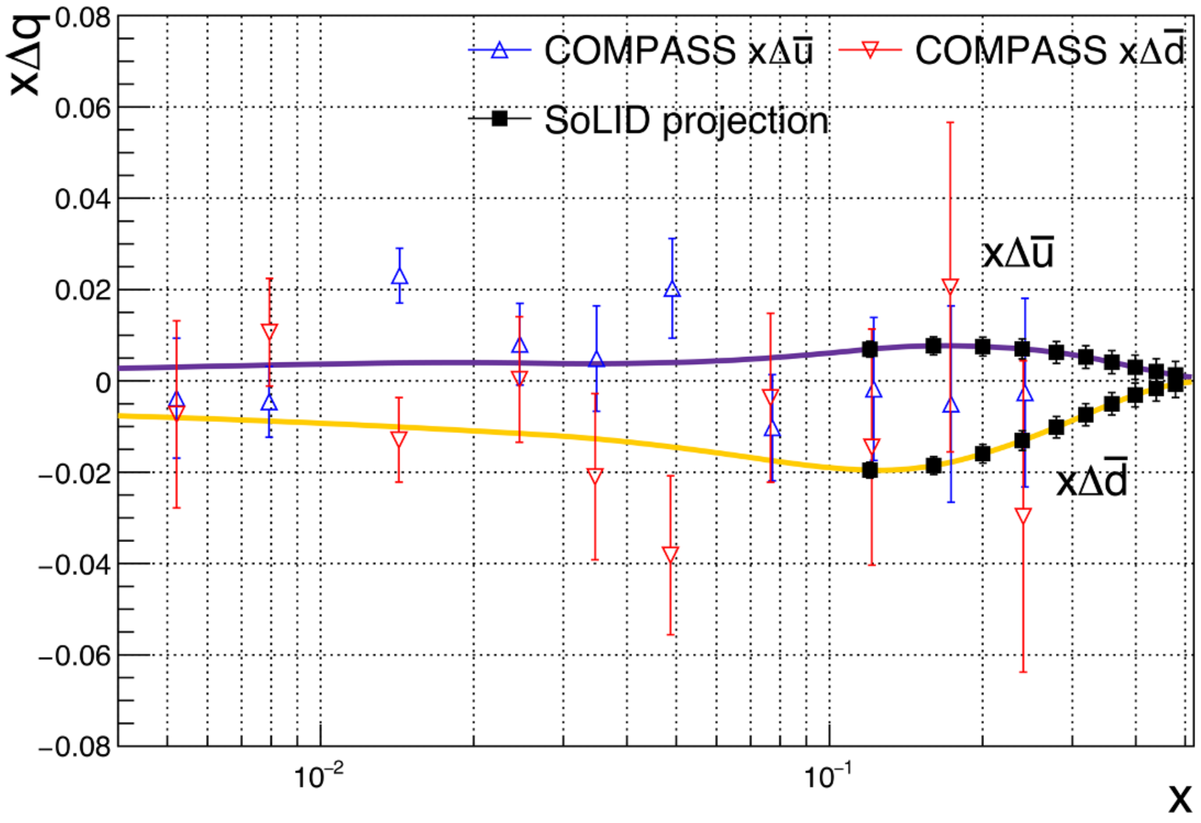

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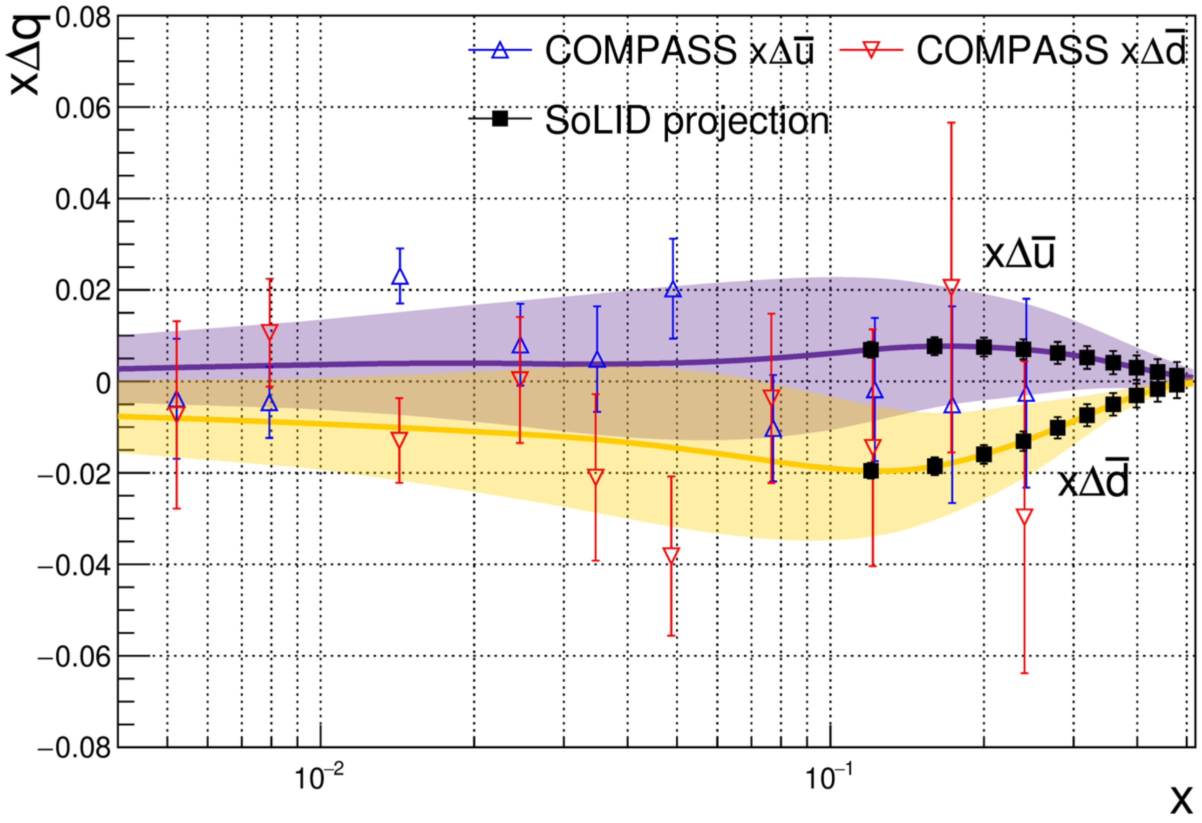
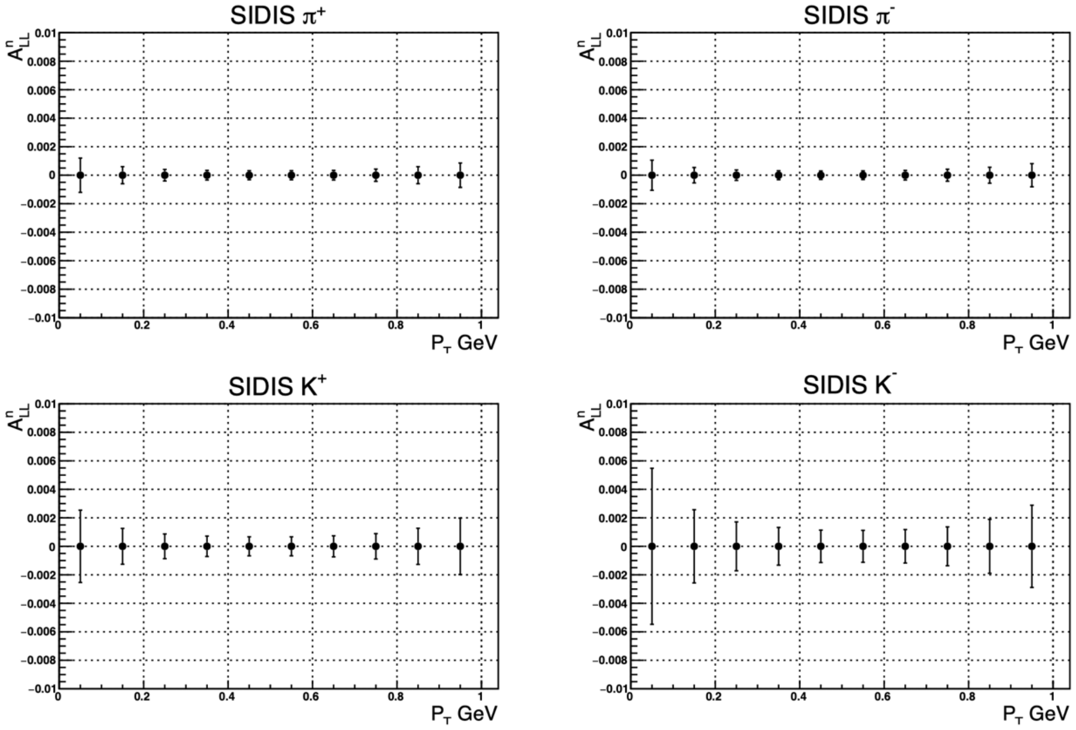


P_T Dependence of Longitudinal Asymmetries from n



- The helicity TMDs can also be extracted by studying the P_T dependence
- 100 PAC days, statistic uncertainty only
- Integrate over
  - $0.2 < z < 0.6$
  - $1\ \mathrm{Gev}^2 < Q^2 < 20\mathrm{Gev}^2$
  - $0 < x_{bj} < 1$

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Systematic Uncertainties

- Next steps:
  1. evaluation of experimental systematic uncertainties
  2. evaluation of theoretical uncertainties: need help from theory and global fit groups.
- Experimental Systematics:

  similar to SIDIS-TMD study done for 11 GeV program?
- Theoretical Systematics:
  1. NLO extraction
  2. contamination from non-current fragmentation and higher-twist effects
  3. contamination from vector mesons
  4. effect from missing high high-Pt region
  5. assumptions of charge symmetry and isospin symmetry in FF
  6. nuclear effect for neutron extraction
  7. ……?

Summary

- Light sea ($\bar{u}$ and $\bar{d}$) at intermediate x (0.1-0.5) is of great interest and in need of high precision data
- High luminosity at 22GeV would be ideal for studying light sea at intermediate x
- SoLID @ JLab22 projections show potential to make an impact on polarized light sea; need careful systematic/theoretical studies.
  - Projections on P_t dependence of longitudinal asymmetries also suggest SoLID can provide strong constraints on helicity TMDs
- Next steps: systematic uncertainty studies
  - And perhaps extracting Δs from kaon production