Constraining the strange polarization from SIDIS data

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Next Generation Nuclear Physics with JLab12 and EIC
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Outline

• Motivation

• Spin contribution from strange
  • JAM15 results

• Discrepancy in shape of strange polarization

• Difficulties of extracting strange polarization from SIDIS data

• JAM – IMC work in progress
Proton Spin Puzzle

- In the naïve parton model
  \[ \Delta q^+ = \Delta q + \Delta \bar{q} \]
  \[ \Delta \Sigma(Q^2) = \int_0^1 dx \left( \Delta u^+(x, Q^2) + \Delta d^+(x, Q^2) + \Delta s^+(x, Q^2) \right) \]
  represents fraction of the proton spin carried by the quarks/anti-quarks

- DIS experiments measure asymmetries to extract information on the polarized structure function
  \[ g_1^p(x, Q^2) = \frac{2}{9} \Delta u^+ + \frac{1}{18} \Delta d^+ + \frac{1}{18} \Delta s^+ + \mathcal{O}(\alpha_s) \]

- From additional information of neutron and hyperon β decays:
  \[ \int_0^1 dx \left( \Delta u^+ - \Delta d^+ \right) = g_A = 1.269(3) \]
  \[ \int_0^1 dx \left( \Delta u^+ + \Delta d^+ - 2\Delta s^+ \right) = a_8 = 0.586(31) \]

\[ \Delta \Sigma \] can be determined, as well as contributions from individual flavors
Strange Contribution to Proton Spin

- In our JAM15 analysis,
  \[ \Delta s^+(Q^2) = -0.10 \pm 0.01 \]
  \[ \Delta s^+(Q^2) = \int_0^1 dx \Delta s^+(x, Q^2) \]

- Agreement with other analysis:
  \[ \Delta s^+(Q^2) = -0.11 \quad \text{DSSV '09} \]

Evaluation at \( Q^2 = 1\text{GeV}^2 \)

\[ N. Sato et. al. arXiv: 1601.07782 \]
Discrepancy in shape of strange polarization

- JAM15 strange shifted to slightly larger-$x$
- All parameterizations except BB10 allow for node-type distribution
- DSSV09 and LSS10 show $\Delta S$ that is positive around $x=0.1$

→ Analysis of SIDIS data change strange polarization shape
→ Large negative tail at low-$x$ for $\Delta S$ in DSSV is needed to keep weak baryon constraints

N. Sato et. al.  
arXiv: 1601.07782
**Semi-inclusive DIS**

- Semi-inclusive DIS $\rightarrow$ detect hadron in final state
  - Separates quark/antiquark flavors through fragmentation
- SIDIS asymmetry at leading order is defined

$$A_1^h(x, z, Q^2) = \frac{\sum_q e_q^2 \Delta q(x, Q^2) D_q^h(z, Q^2)}{\sum_q e_q^2 q(x, Q^2) D_q^h(z, Q^2)}$$

$$x = \frac{p \cdot k}{p \cdot q} \quad z = \frac{p \cdot p_h}{p \cdot q}$$
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\]

Fragmentation functions (FFs) – must also be constrained by global analyses and introduces potential new biases

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**Fragmentation functions (FFs)** – must also be constrained by global analyses and introduces potential new biases

- What SIDIS observable(s) best constrain the strange polarization?

$$K^+ \ (u \bar{s}) \quad K^- \ (s \bar{u})$$
Production of Kaons in SIDIS

- The quark contributions to the proton asymmetry are calculated as

\[ A_{q,d}^h(x, Q^2) = \frac{1}{F_{1,q}^h} \left( e_q^2 \Delta q(x, Q^2) D_q^h(x, Q^2) \right) \]

- \(K^+\) asymmetry dominated by up quark contribution, except at low \(x\)
- Increase in sensitivity to strange in \(K^-\) production, especially at low \(x\)
**Production of Kaons in SIDIS**

- The quark contributions to the proton asymmetry are calculated as

  \[
  A_{1,d}^{h} (x, Q^2) = \frac{1}{F_{1,d}^h} \left( e_q^2 \left[ \Delta q_p(x, Q^2) + \Delta q_n(x, Q^2) \right] D_q^h(x, Q^2) \right)
  \]

- \(K^+\) asymmetry dominated by up quark contribution, except at low \(x\)

- Larger sensitivity to strange in \(K^-\) production \(\rightarrow\) cancellation between up and down polarization
Production of Kaons in SIDIS

- Again, $K^+$ asymmetry dominated by up quark contribution, except at low $x$ → Strong sensitivity to anti-strange polarization in this region
- Conclusion: asymmetry measurements from deuteron target provide potentially valuable information on the strange polarization → Important to understand how DSSV have obtained a positive strange
Production of Kaons in SIDIS

- Also notice that $\Delta \bar{u}$ and $\Delta s$ curves appear anti-correlated

→ Can change normalization of polarized PDFs by ~75% with negligible change in asymmetry

→ Suggests strong correlation between $\Delta \bar{u}$ and $\Delta s$ PDFs in DSSV fit

→ IMC method will help separate any correlation between PDFs
Production of Kaons in SIDIS

- What happens when we remove the strange PDF in the theory calculation?

![Graph showing $A_{1,d}^{K-}$](image)

- Large errors in HERMES data (only kaon data set used in DSSV fit) may also have contributed to change in sign

- Difficult to constrain strange from HERMES data alone
Fragmentation Functions

- Large uncertainty between HKNS and DSS fragmentation function parameterizations

→ Another factor that influences the sign of the strange polarization as determined by LSS group

→ Constrained through global fits of semi-inclusive annihilation (SIA), unpolarized/polarized SIDIS data, single inclusive pp collision data
Summary and Resolutions

• Most reliable constraint we have on the strange polarization is from DIS.

1. Need better determination of fragmentation functions
   → IMC analysis of SIA kaon data in progress with JAM
   → Eventually will include unpolarized SIDIS

2. Need to de-correlate the anti-quark distributions
   → IMC simultaneous fit of both fragmentation functions and PDFs with DIS, SIA, and polarized SIDIS data
   → Eventually will include W+/− production data to further constrain sea distributions

3. Need higher precision SIDIS kaon data from deuteron (or ³He) targets from JLab12/EIC
   → For now, JAM will work with all existing SIDIS data to get the most reliable determination of sea quark polarization and their uncertainties
Thank You
Asymmetry at NLO

(a) $A_{1,d}^{K^+}$

(b) $A_{1,d}^{K^-}$