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

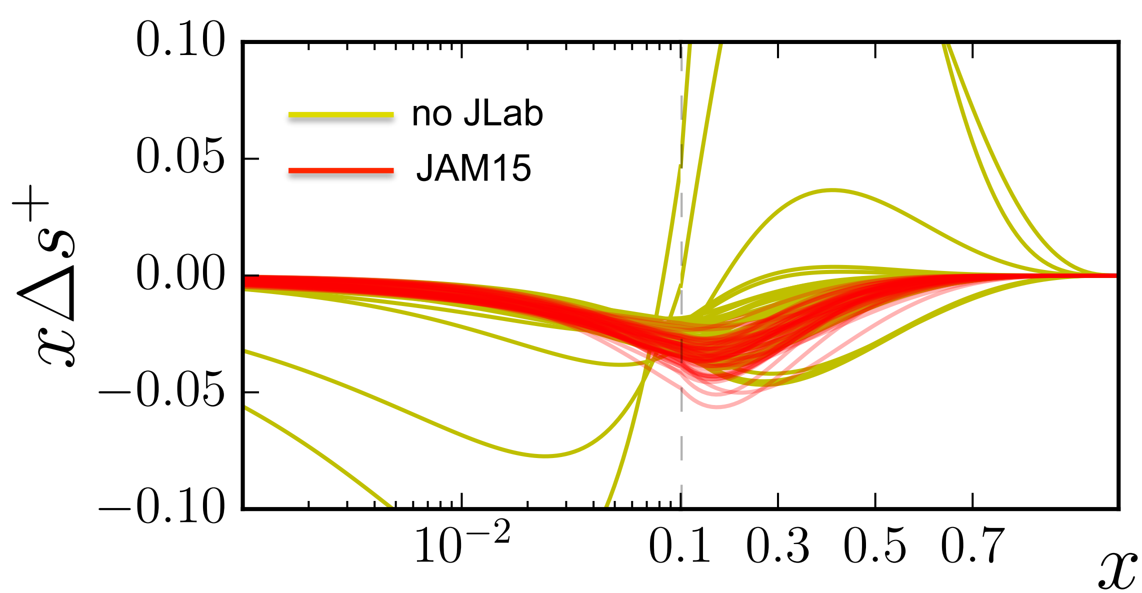
- In our JAM15 analysis,

$$\Delta \mathbf{s}^{+}(Q^2) = -0.10 \pm 0.01 \qquad \Delta \mathbf{s}^{+}(Q^2) = \int_0^1 dx \Delta s^{+}(x, Q^2)$$

- Agreement with other analysis:

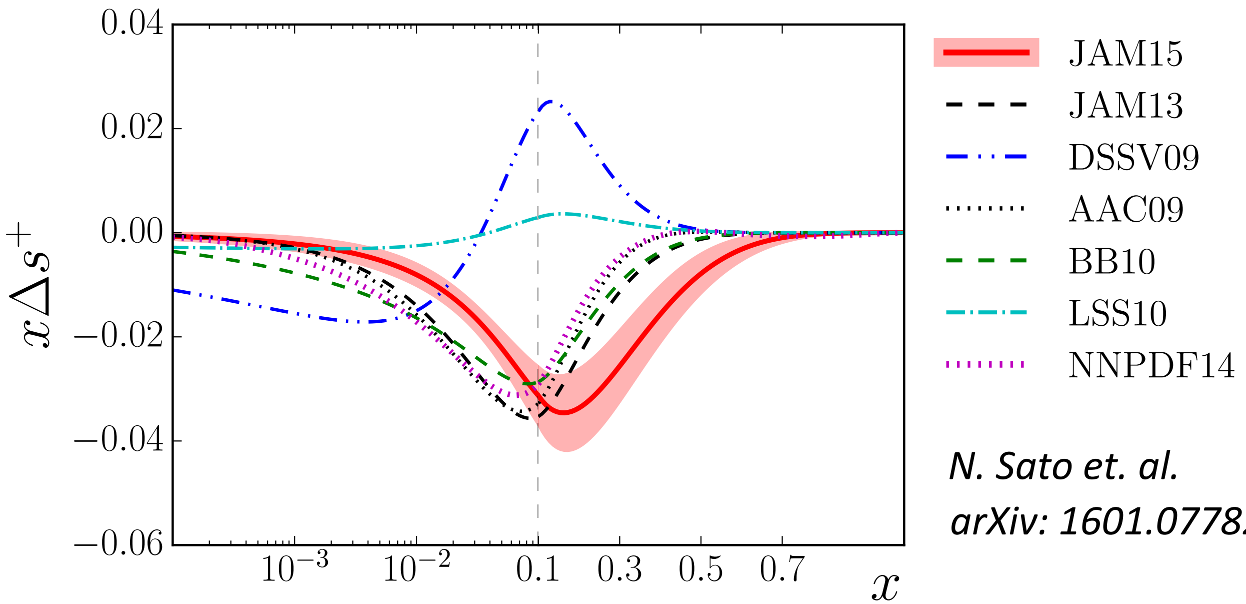
Evaluated at $Q^2 = 1\mathrm{GeV}^2$

$$\Delta \mathbf{s}^{+}(Q^2) = -0.11$$ DSSV '09



N. Sato et. al. arXiv: 1601.07782

Discrepancy in shape of strange polarization



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

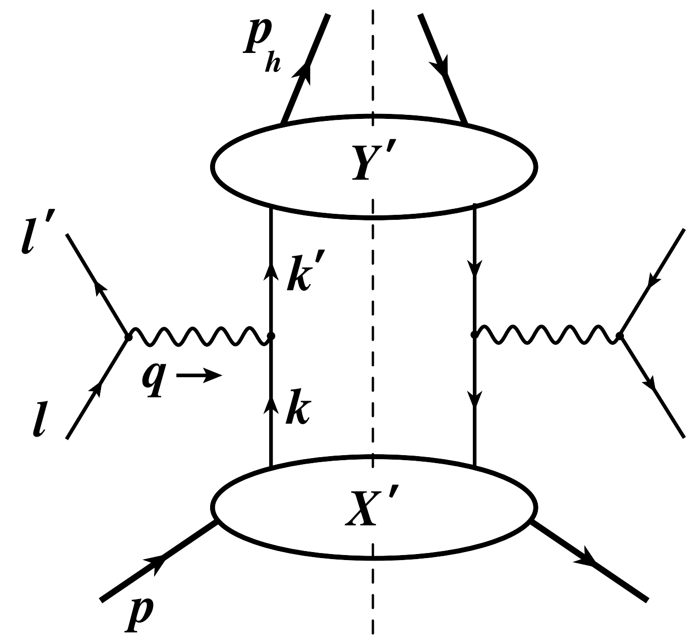
→ Analysis of SIDIS data change strange polarization shape

→ Large negative tail at low-x for Δs in DSSV is needed to keep weak baryon constraints

Semi-inclusive DIS

- Semi-inclusive DIS → 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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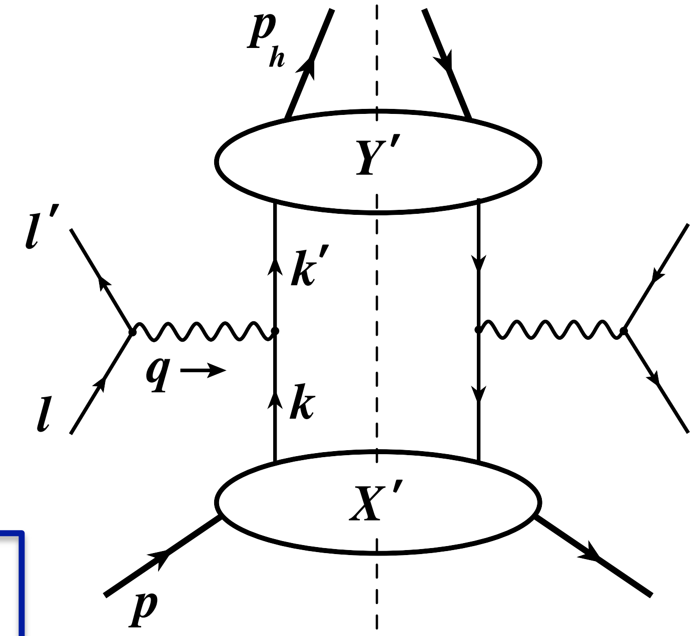
Fragmentation functions (FFs) – must also be constrained by global analyses and introduces potential new biases



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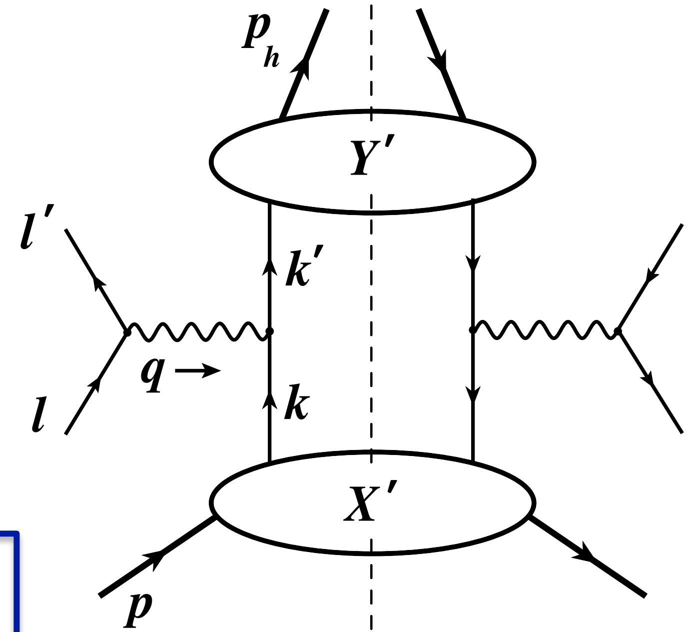

$$A_1^h(x,z,Q^2) = \frac{\sum_q e_q^2 \Delta q(x,Q^2) \boxed{D_q^h(z,Q^2)}}{\sum_q e_q^2 q(x,Q^2) \boxed{D_q^h(z,Q^2)}}$$

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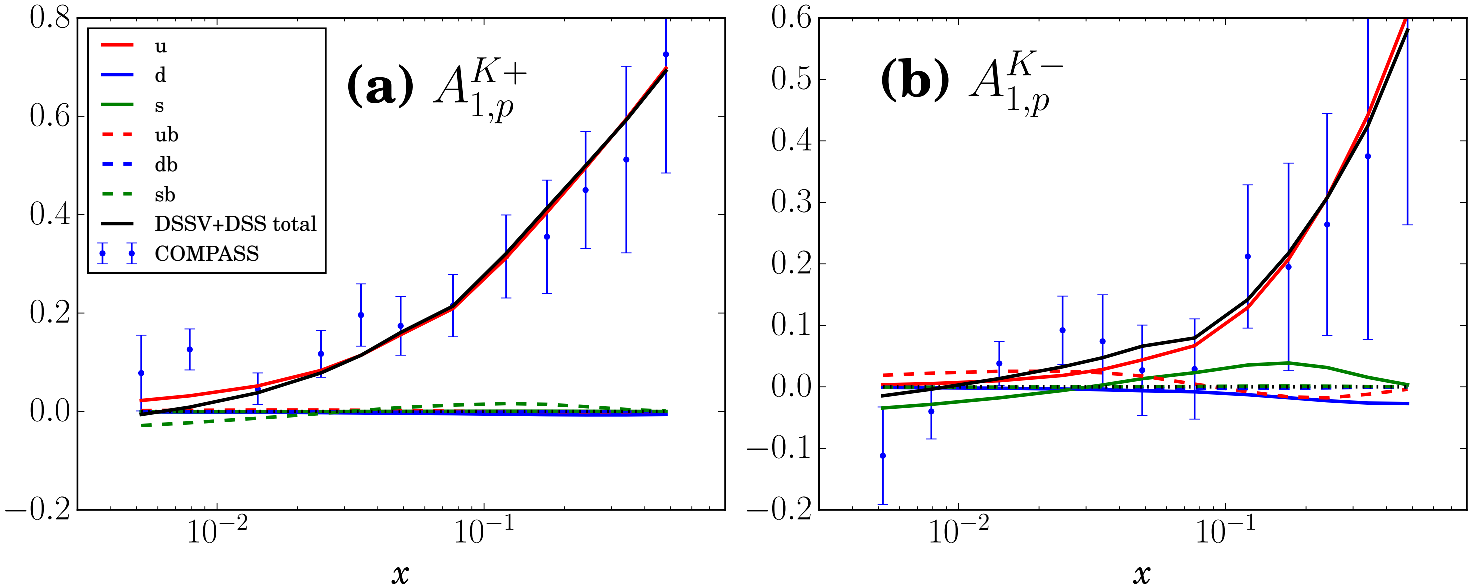
Fragmentation functions (FFs) – must also be constrained by global analyses and introduces potential new biases

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

$$K^+ \ (u\bar{s}) \qquad K^- \ (s\bar{u})$$

Production of Kaons in SIDIS



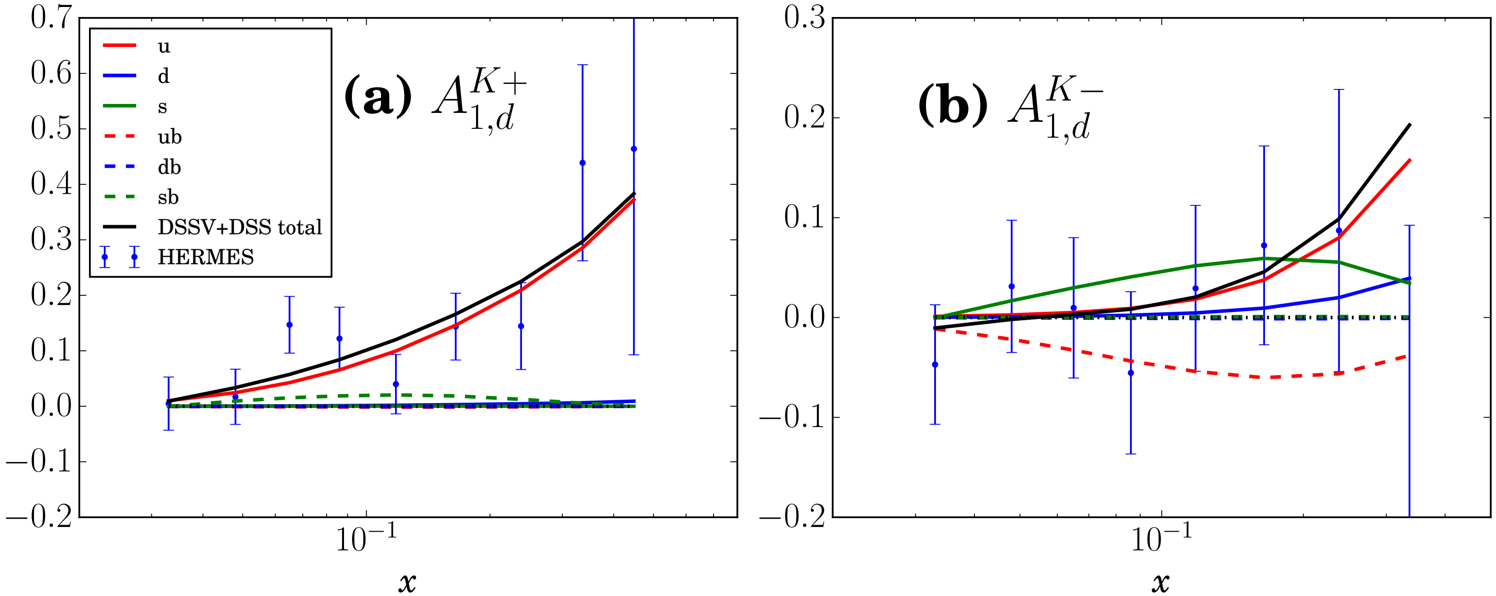
PPDFs: DSSV '09
FFs: DSS '07

- The quark contributions to the proton asymmetry are calculated as

$$A^h_{q,d}(x,Q^2) = \frac{1}{F^h_{1,d}}\left(e_q^2 \Delta q(x,Q^2) D_q^h(x,Q^2)\right)$$

- 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



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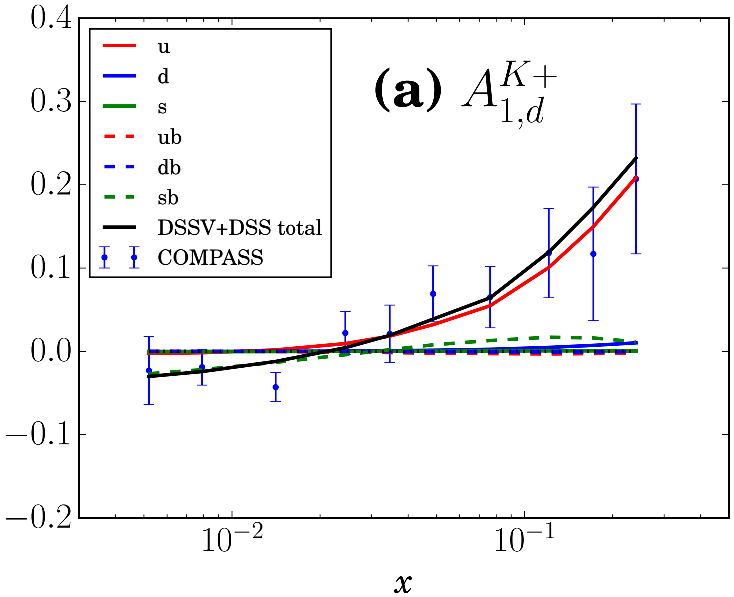
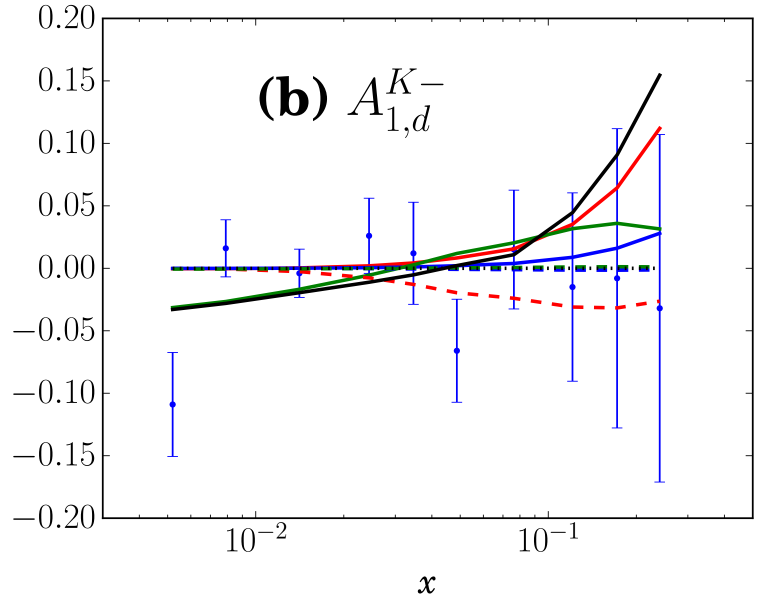
- The quark contributions to the proton asymmetry are calculated as

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

- K^+ asymmetry dominated by up quark contribution, except at low x
- Larger sensitivity to strange in K^- production → cancellation between up and down polarization

Production of Kaons in SIDIS





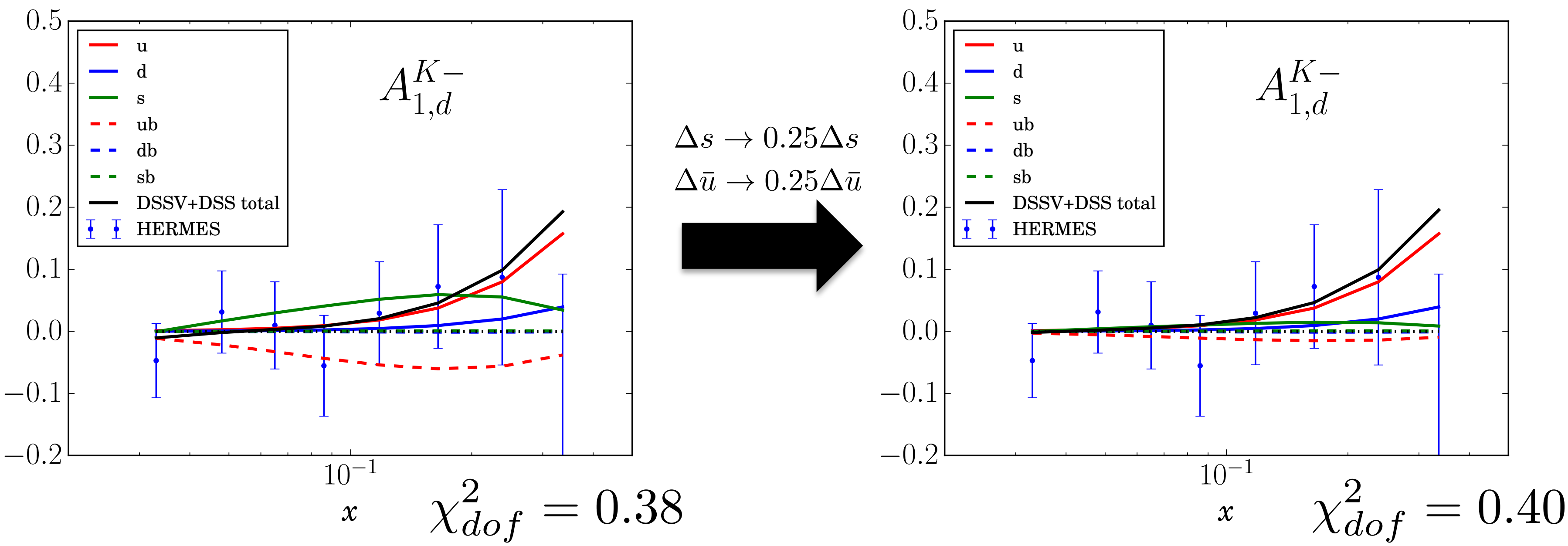
PPDFs: DSSV '09
FFs: DSS '07

- 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 Δs curves appear anti-correlated

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

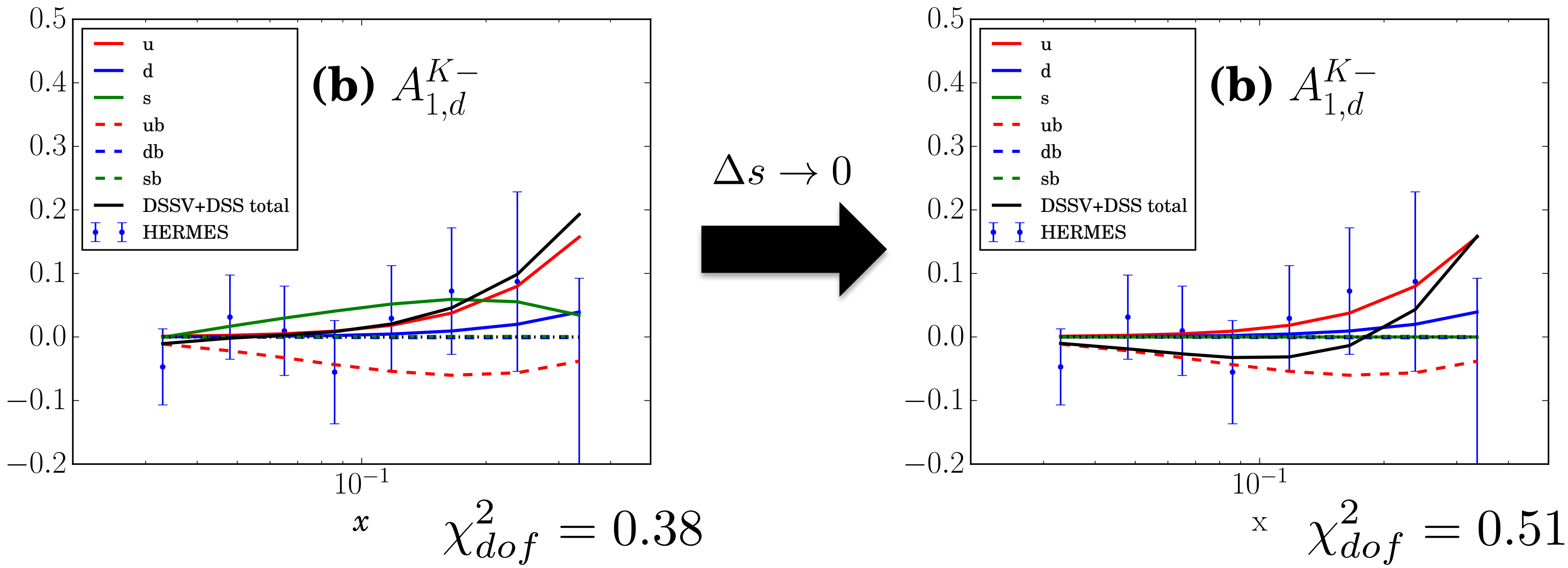


→ Suggests strong correlation between $\Delta\bar{u}$ and Δs PDFs in DSSV fit

→ 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?

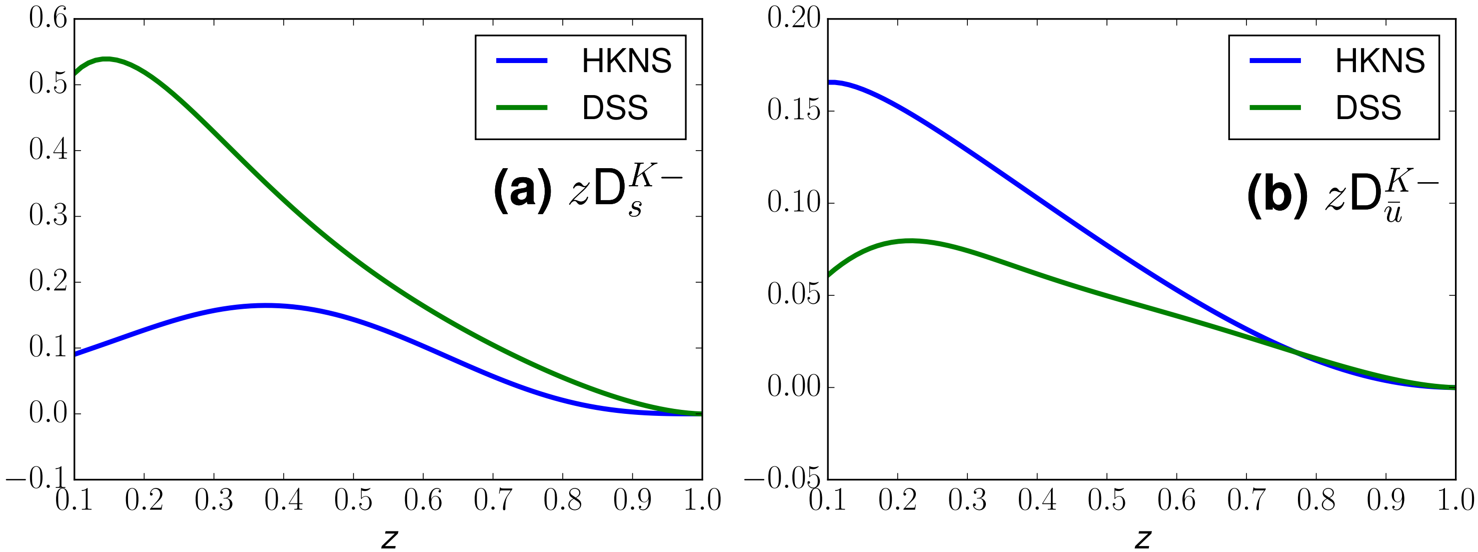


- Large errors in HERMES data (only kaon data set used in DSSV fit) may also have contributed to change in sign
- Difficult to constrain strange from HERMES data alone

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

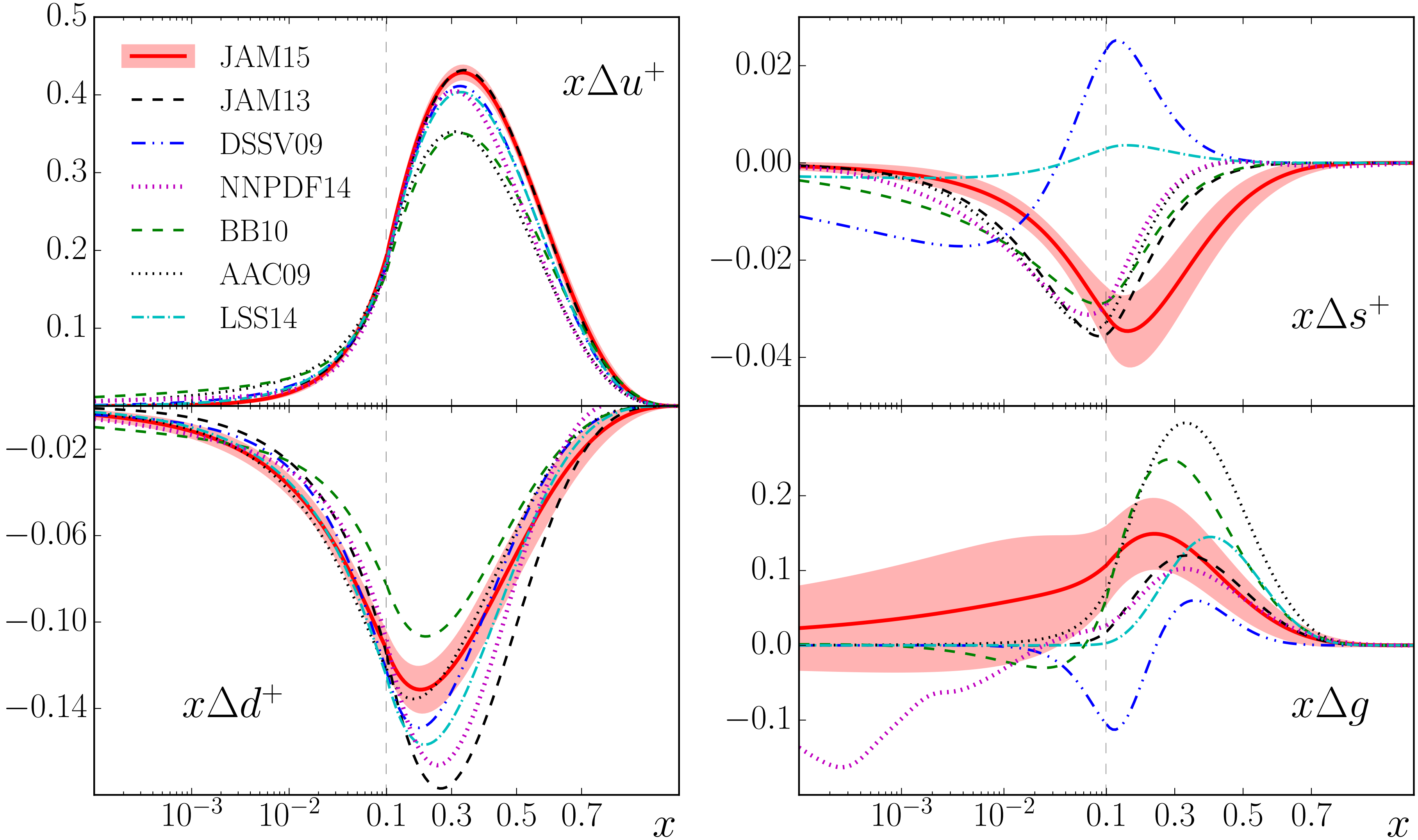
   → IMC simultaneous fit of both fragmentation functions and PDFs with DIS, SIA, and polarized SIDIS data

   → Eventually will include W+/- production data to further constrain sea distributions

3. Need higher precision SIDIS kaon data from deuteron (or ^{3}He) 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


JAM15
JAM13
DSSV09
NNPDF14
BB10
AAC09
LSS14
$x\Delta u^+$
$x\Delta s^+$
$x\Delta d^+$
$x\Delta g$
0.5
0.4
0.3
0.2
0.1
0.02
0.00
−0.02
−0.04
−0.02
−0.06
−0.10
−0.14
0.2
0.1
0.0
−0.1
10^{-3}
10^{-2}
0.1
0.3
0.5
0.7
x

Asymmetry at NLO