Fit of polarized DIS data within the small-x helicity evolution framework

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In collaboration with

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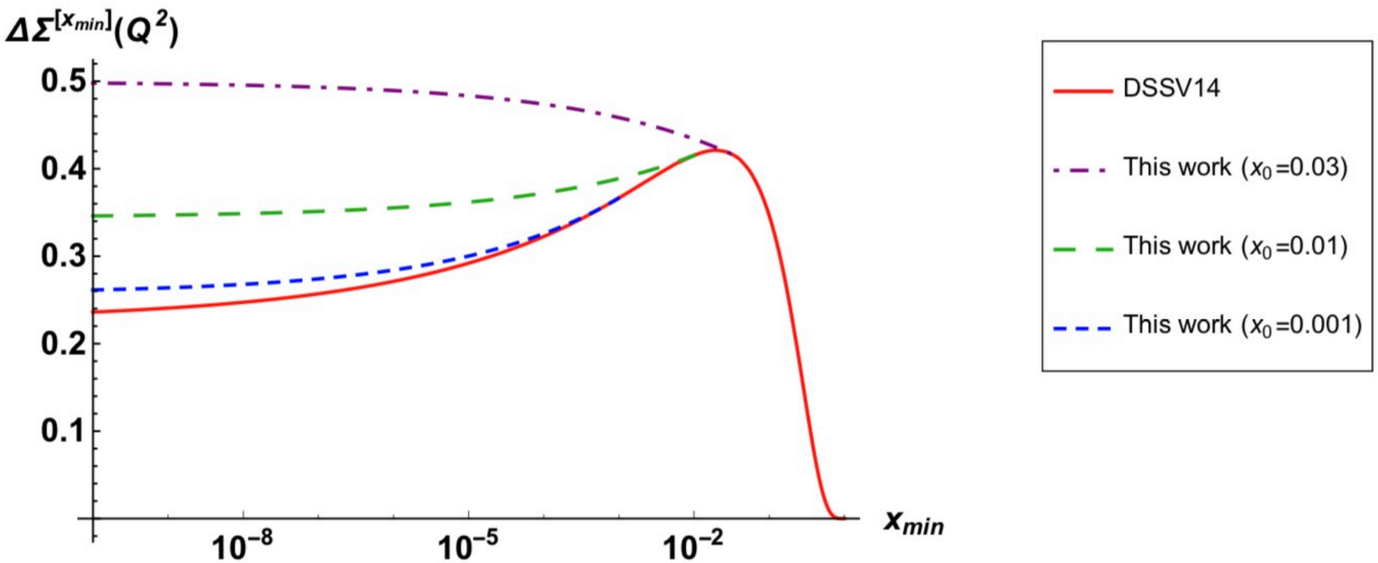
Motivation: The EIC will probe helicity PDFs down to very low *x* values, where small-*x* effects will become important and a different evolution will take over from DGLAP. In our "JAM-small*x*" fit, we are trying to properly implement small-*x* helicity (KPS) evolution into phenomenology in order to correctly extract the proton spin.

direct input from theory

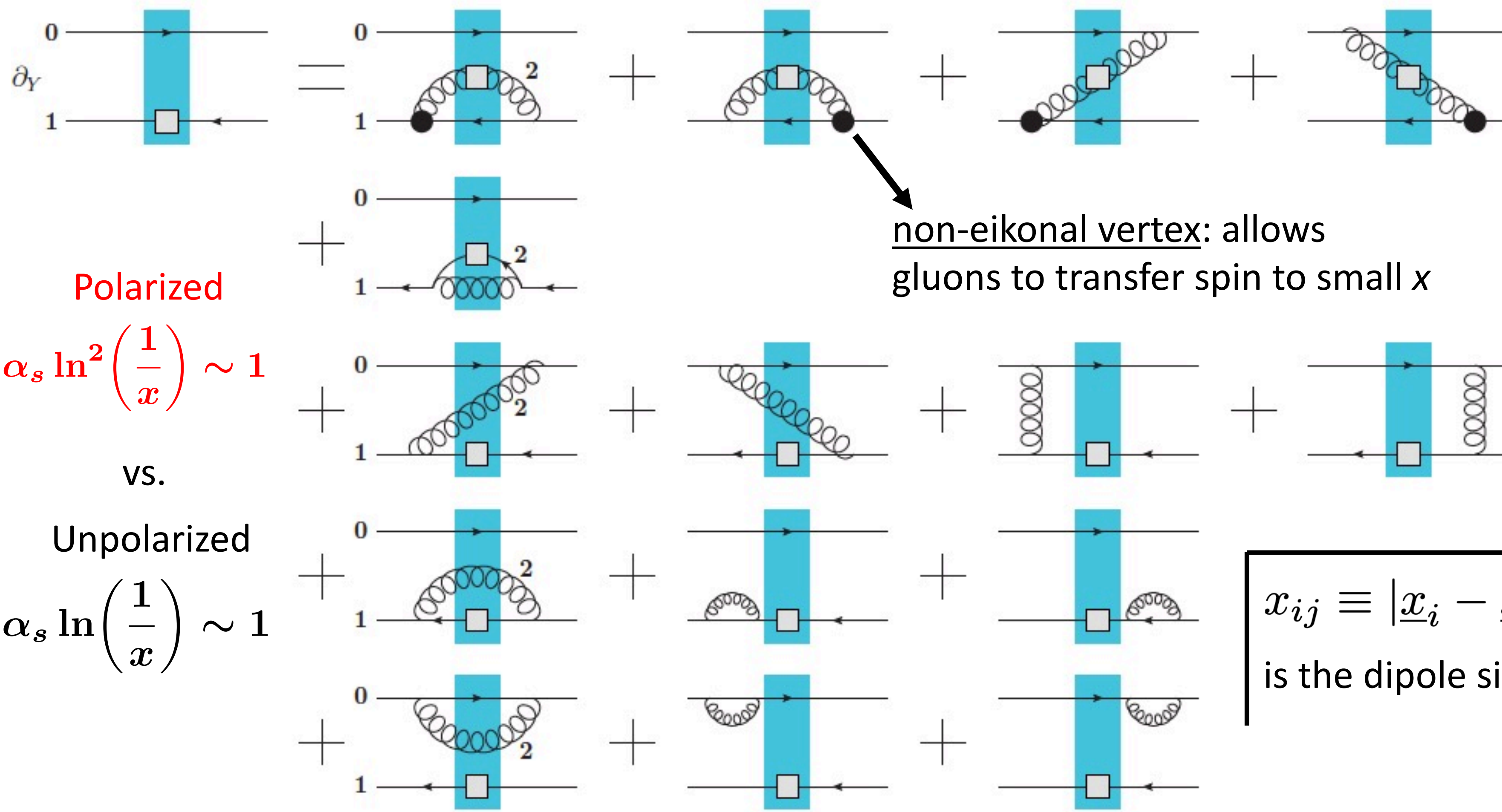
$$\Delta q(x) \sim \left(\frac{1}{x}\right)^{\alpha_h^q} \quad \text{with} \quad \alpha_h^q = \frac{4}{\sqrt{3}}\sqrt{\frac{\alpha_s N_c}{2\pi}} \approx 2.31\sqrt{\frac{\alpha_s N_c}{2\pi}} \overset{\alpha_s=0.3}{\approx} 0.874$$

$$\Longrightarrow \Delta\Sigma(x) \sim \left(\frac{1}{x}\right)^{\alpha_h^q}$$

Kovchegov, DP, Sievert, PRL **118** (2017)



Small-x helicity (KPS) evolution involves the "polarized dipole amplitude"
(Kovchegov, DP, Sievert: JHEP **1601** (2016), PRL **118** (2017), PRD **95** (2017), PLB **772** (2017), JHEP **1710** (2017); Kovchegov & Sievert PRD **99** (2019))



non-eikonal vertex: allows gluons to transfer spin to small x

Polarized

$$\alpha_s \ln^2\left(\frac{1}{x}\right) \sim 1$$

vs.

Unpolarized

$$\alpha_s \ln\left(\frac{1}{x}\right) \sim 1$$

$x_{ij} \equiv |\underline{x}_i - \underline{x}_j|$ is the dipole size

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The evolution equations take on a closed form in the large-N_c limit:

$$G_q(s_{10},\eta) = G_q^{(0)}(s_{10},\eta) + \underbrace{\int_{s_{10}}^{\eta} d\eta' \int_{s_{10}}^{\eta'} ds_{21} \left[\Gamma_q(s_{10},s_{21},\eta') + 3G_q(s_{21},\eta')\right]}_{\text{flavor } independent \text{ evolution}}$$

$G_q(s_{10},\eta)$ → polarized dipole amplitude

$G_q^{(0)}$ → flavor dependent initial condition → fit to the data: $a_q\eta + b_q s_{10} + c_q$

$$\eta \equiv \sqrt{\frac{\alpha_s N_c}{2\pi}} \ln \frac{zs}{\Lambda^2}$$

$$s_{ij} \equiv \sqrt{\frac{\alpha_s N_c}{2\pi}} \ln \frac{1}{x_{ij}^2 \Lambda^2}$$

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"neighbor dipole"

$$\Gamma_q(s_{10},s_{21},\eta') = G_q^{(0)}(s_{10},\eta') + \int_{s_{10}}^{\eta'} d\eta'' \int_{\max[s_{10}\,,\,s_{21}-\eta'+\eta'']}^{\eta''} ds_{32} \left[\Gamma_q(s_{10},s_{32},\eta'') + 3G_q(s_{32},\eta'')\right]$$

$$\eta \equiv \sqrt{\frac{\alpha_s N_c}{2\pi}} \ln \frac{zs}{\Lambda^2}$$

$$s_{ij} \equiv \sqrt{\frac{\alpha_s N_c}{2\pi}} \ln \frac{1}{x_{ij}^2 \Lambda^2}$$

Using the polarized dipole amplitude, we can calculate

$$\Delta q^+(x,Q^2) \equiv \Delta q(x,Q^2) + \Delta\bar{q}(x,Q^2)$$

$$= \frac{1}{\alpha_s\,\pi^2} \int\limits_0^{\ln\frac{Q^2}{x\,\Lambda^2}} d\eta \int\limits_{\max\left\{\eta - \ln\frac{1}{x},0\right\}}^{\eta} ds_{10}\; G_q\left(s_{10},\eta\right)$$

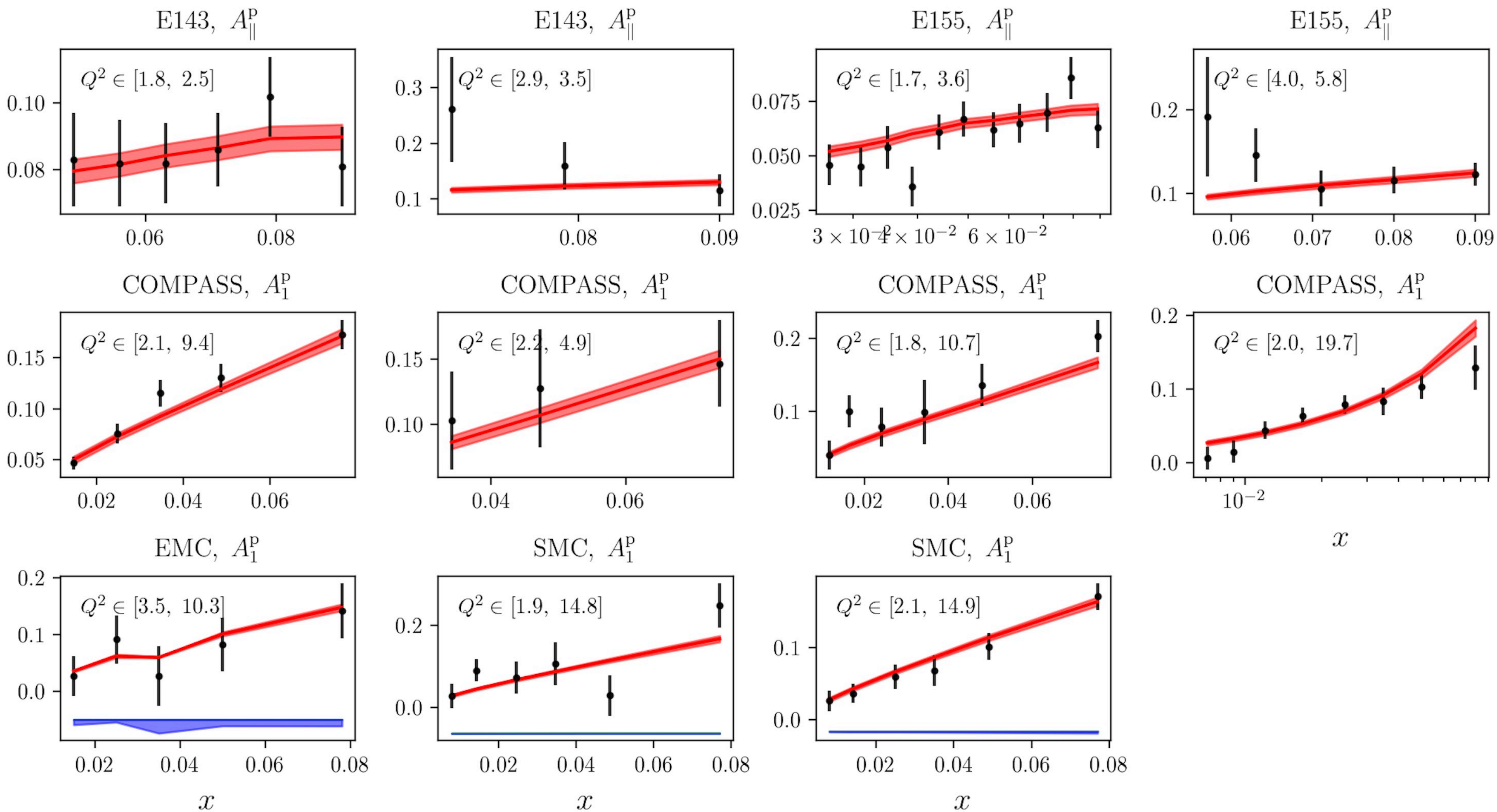
and at LO

$$g_1(x,Q^2) = \frac{1}{2}\sum_q e_q^2\,\Delta q^+(x,Q^2)$$

This allows us to carry out a fit of polarized DIS data. In the following plots, we have placed a cut of $x < 0.1$ on the data (116 points) and used the above formulas to calculate g_1. We find $\chi^2/\text{npts} = 1.0$.

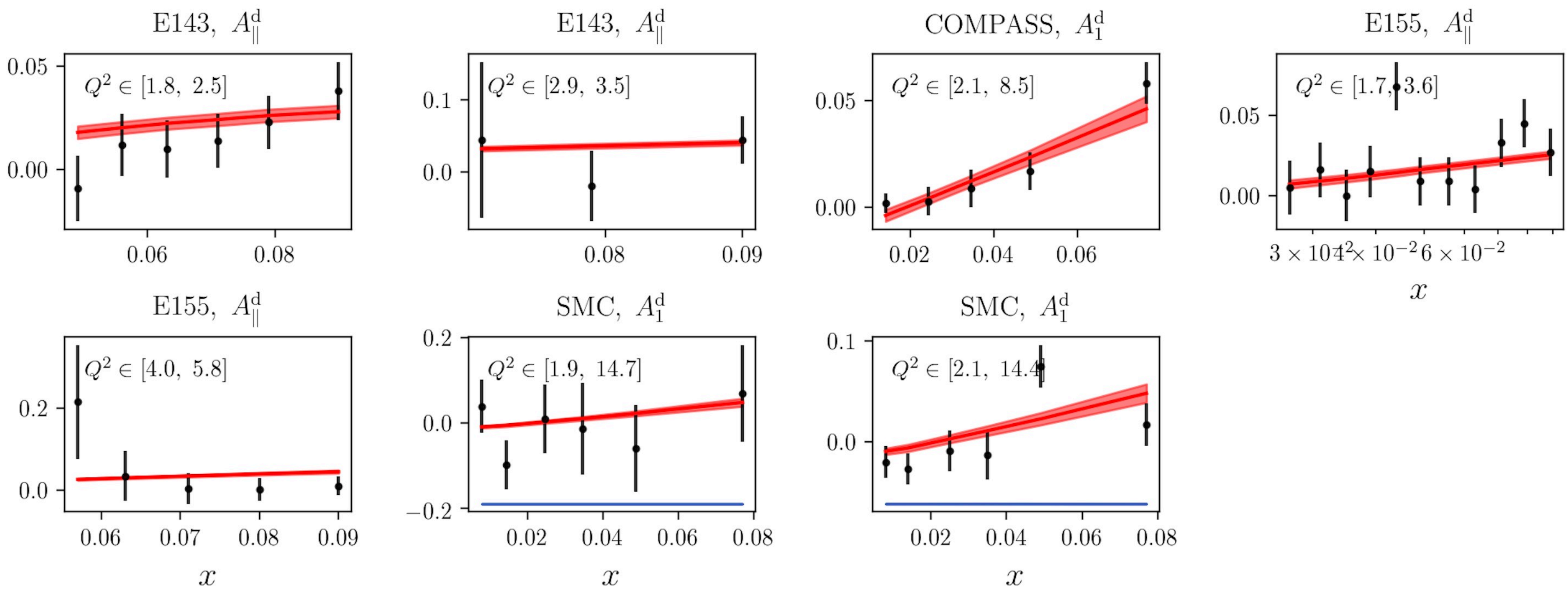
Proton target

JAM-smallx (preliminary)

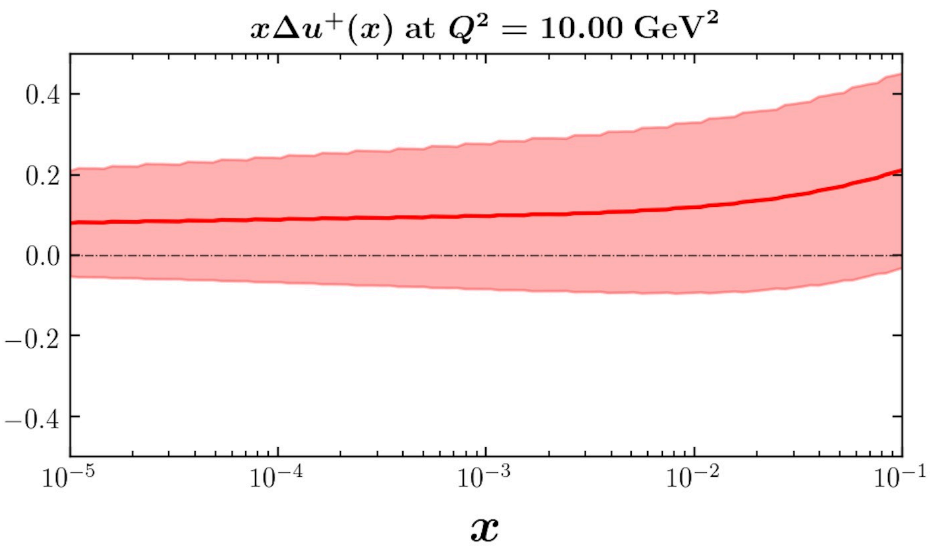


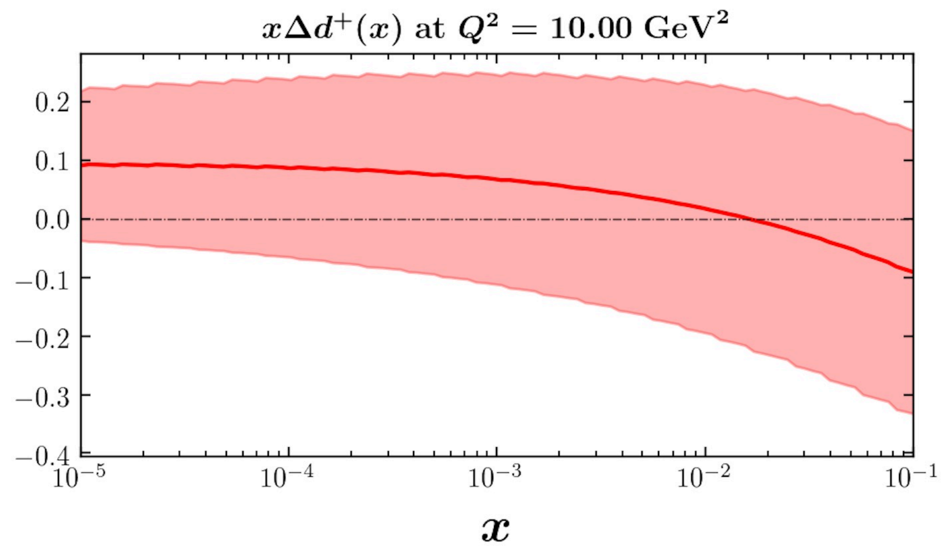
Deuteron target

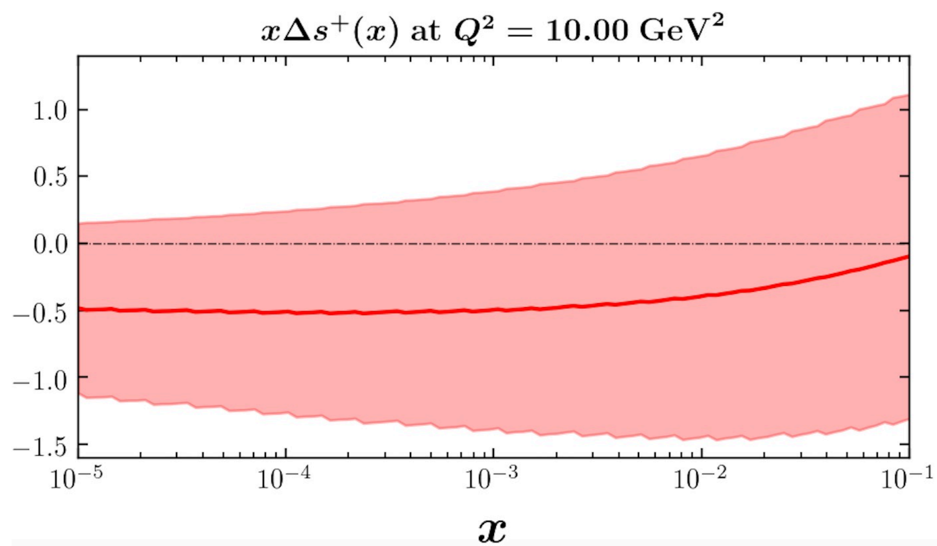
JAM-small*x* (preliminary)



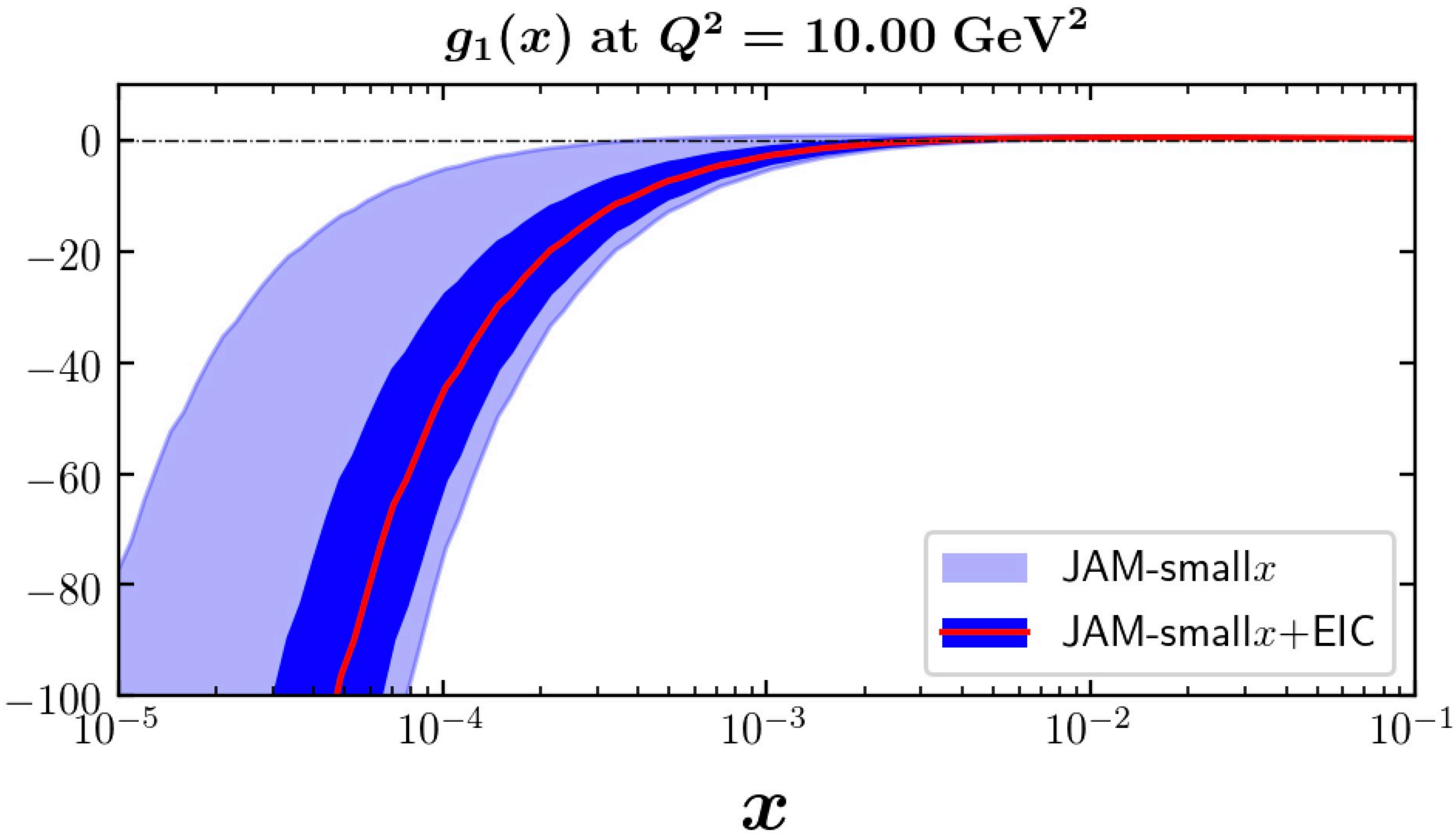
JAM-small*x* (preliminary)







JAM-small*x* (preliminary)



Conclusions and To-Do List:

Small-x helicity approach seems to be working and can describe current "low-x" DIS data ($x < 0.1$).

Need to confirm results of fit and impact of EIC.

Need to work on the matching of JAM-small$x$ helicity PDFs with JAM (large-x, DGLAP-evolved) helicity PDFs to create a "smooth" single function that is valid at all x.