First analysis of world polarized DIS data with small-x helicity evolution

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PANIC 2021

OCGtools: processing OCG's ...

Outline

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- This evolution requires that that an initial condition be fit to data
- We use the JAM framework to determine the parameters of the initial condition
- Resulting in the successful description of existing proton and neutron $g1$ structure functions
- as well as predictions for measurements to be made at the EIC

Proton Spin Puzzle and hPDFs

Jaffe-Manohar Spin Sum Rule:

$$\frac{1}{2} = \boldsymbol{S_q} + L_q + S_G + L_G$$

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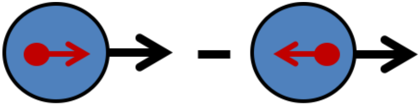
$$\boldsymbol{S_q}(Q^2) = \frac{1}{2} \int_0^1 dx \sum_q (\Delta q(x, Q^2) + \Delta \bar{q}(x, Q^2))$$

$\Delta q =$ 

- Q^2 resolution at which we probe the proton
- $x \propto \frac{1}{s}$, we need theory to find the dependence of

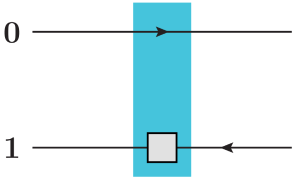
P

Calculating Helicity Distributions

Helicity distributions are computed from the polarized dipole amplitude

$$\Delta q(x, Q^2) + \Delta \bar{q}(x, Q^2) = \frac{N_c}{2\pi^3} \int\limits_0^{\ln \frac{Q^2}{x\Lambda^2}} d\eta \int\limits_{\max\left\{0, \eta - \ln \frac{1}{x}\right\}}^{\eta} ds_{10} \; G_q(s_{10}, \eta)$$

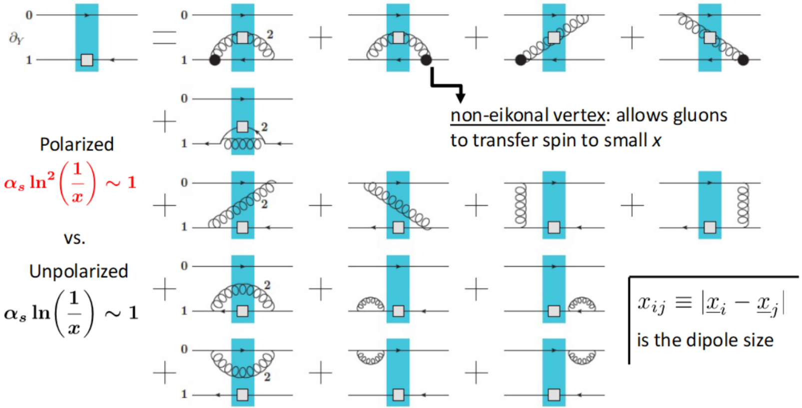
$G =$



- Rapidity, $\eta = \ln \frac{zs}{\Lambda^2}$, $z =$ momentum fraction of quark
- Log of transverse momentum, $s_{10} = \ln \frac{1}{x_{10}^2 \Lambda^2}$, x_{10} separation between quarks

Helicity Dependent Processes

Small-x helicity (KPS) evolution involves the "polarized dipole amplitude" (Kovchegov, Pitonyak, Sievert: JHEP 1601 (2016), PRL 118 (2017), PRD 95 (2017), PLB 772 (2017), JHEP 1710 (2017); Kovchegov & Sievert PRD 99 (2019);Kovchegov & Cougoulic PRD 100 (2019))



Kovchegov Pitonyak Sievert (KPS) Evolution

The polarized dipole amplitude evolves through small-x helicity (KPS[1]) evolution

In the large N_c limit, evolution closes:

$$G_q(s_{10}, \eta) = G_q^{(0)}(s_{10}, \eta) + \frac{\alpha_s N_c}{2\pi} \int_{s_{10}}^{\eta} d\eta' \int_{s_{10}}^{\eta'} ds_{21} \left[\Gamma_q(s_{10}, s_{21}, \eta') + 3G_q(s_{21}, \eta')\right.$$

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- $G_q^{(0)}(s_{10},\eta)$ is a flavour dependent initial condition that is fit to data.
- $G_q^{(0)}(s_{10},\eta) = a_q\ \eta + b_q\ s_{10} + c_q$

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Mid-talk recap

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What enters observables are linear combinations of hPDFS

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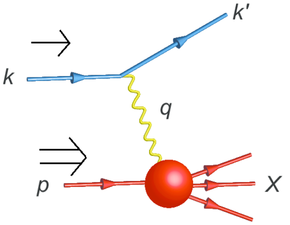
- Three relevant hPDFs in DIS: $\Delta u^+, \Delta d^+$ and Δs^+
- Three observables that contain these hPDFs in linearly independent combinations: g_1^p, g_1^n and $g_1^{\gamma Z}$.
- Only have data for g_1^p and g_1^n

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

Fitting to data

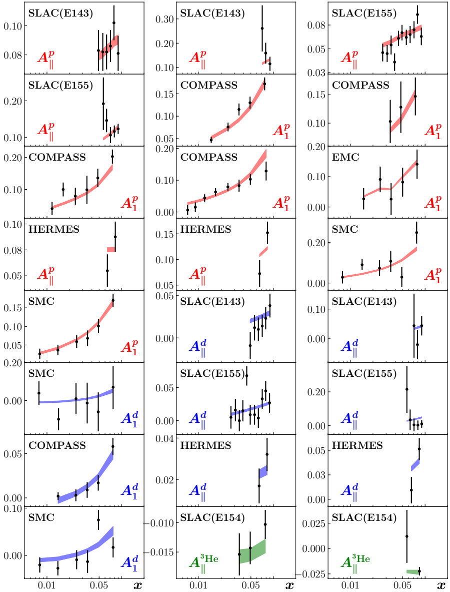
Observables predicted by our formalism: Double spin asymmetries in DIS

$$A_{||} = \frac{\sigma^{\uparrow\Downarrow} - \sigma^{\uparrow\Uparrow}}{\sigma^{\uparrow\Downarrow} + \sigma^{\uparrow\Uparrow}} \propto A_1 \propto g_1$$



$\uparrow$ ($\downarrow$) is Positive (negative) helicity electron
$\Uparrow$ ($\Downarrow$) is Positive (negative) helicity proton
A_1 is a virtual photoproduction asymmetry

Fitting to data



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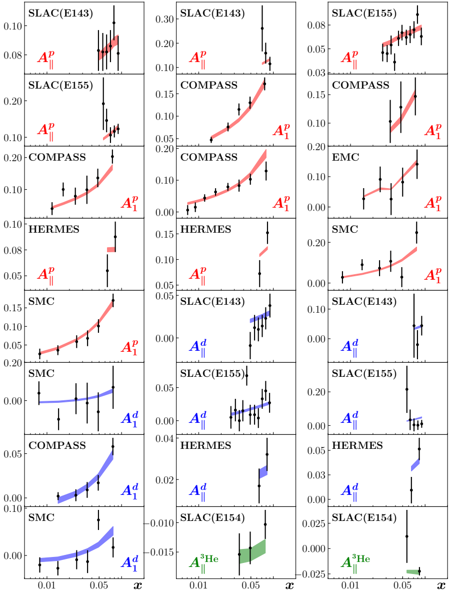

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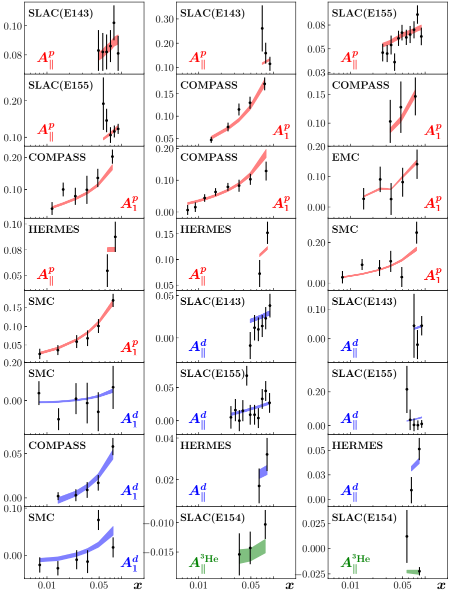

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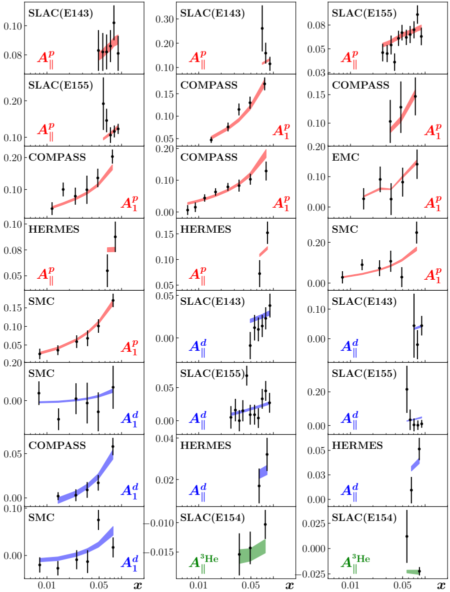

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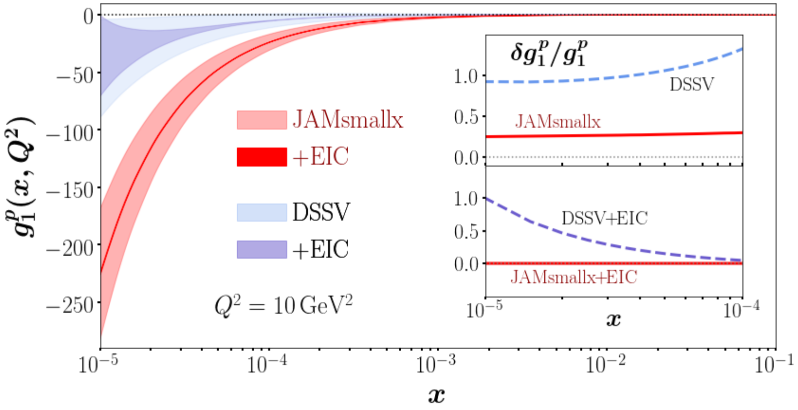
- $\chi^2/npts = 1.01$

Predictions for Electron Ion Collider



- Predict large negative g_1
- Significant improvement in error from EIC

Conclusions

- We have a theory that describes the hPDFs in terms of the polarized dipole amplitude
- Performed the first small-x fit of world polarized DIS data
- Predicted g_1 down to $x = 10^{-5}$
- While maintaining control over the uncertainty
- In the future, look at other observables (SIDIS) to nail down hPDFs separately and compute total spin contribution

Thank you!

Helicity PDFs

Preliminary extraction of hPDFs and $\Delta\Sigma = \sum_q \Delta q^+(x, Q^2)$

(EIC pseudo data generated assuming $\Delta s^+ = 0$, then fitted with $\Delta s^+ \neq 0$)