Small-x Helicity Phenomenology

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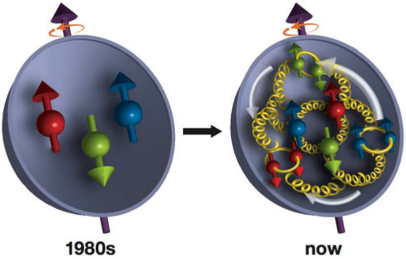
Proton Spin Problem



Spin Sum Rule

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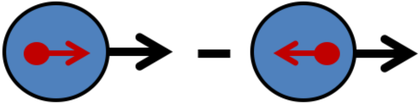
Must account for orbital angular momentum, L_q, and angular momentum of gluons, S_G and L_G.
Quark spin obtained from quark helicity distribution:

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

Helicity Parton Distribution Functions

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

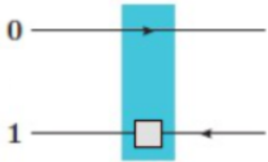
$\Delta q =$ 

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

Calculating Helicity Distributions

Helicity distributions are computed from the polarized dipole amplitude

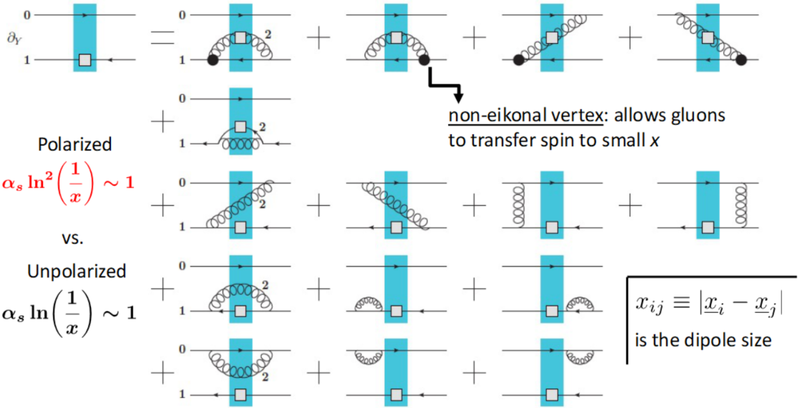
$$\Delta q(x, Q^2) + \Delta \bar{q}(x, Q^2) = \frac{N_c}{2\pi^3} \int\limits_0^{\ln \frac{Q^2}{x\Lambda^2}} d\eta \int\limits_{\max\left\{0,\ \ln \frac{1}{x}\right\}}^{\eta} ds_{10}\ G_q(s_{10}, \eta)$$

$G =$ 

- η is rapidity
- s_{10} is a log of transverse momentum

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))



KPS Evolution

Evolution of polarized dipole amplitude closes in the large N_c limit:

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

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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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- $\Gamma_q(s_{10}, s_{21}, \eta')$ is an auxiliary function which obeys a separate integral equation that mixes with G.

Phenomenology

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The g_1 structure function can be measured in deep inelastic scattering

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

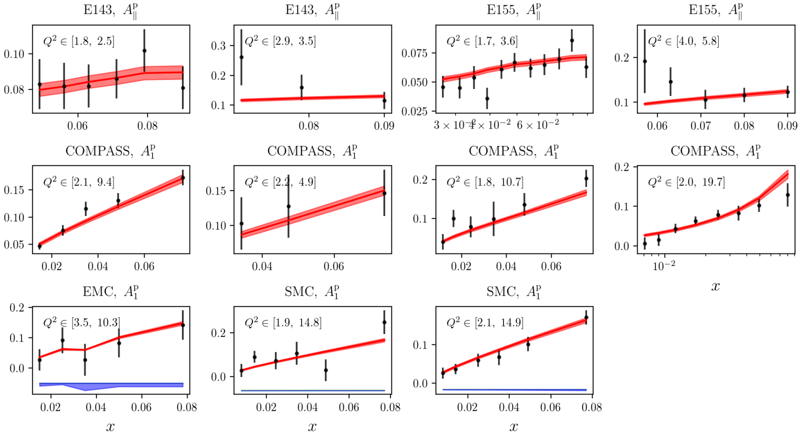
Fitting to data

Observables predicted by our formalism: Spin asymmetries

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

$\uparrow$ ($\downarrow$) is Positive (negative) helicity electron
$\Uparrow$ ($\Downarrow$) is Positive (negative) helicity proton

Fitting to data



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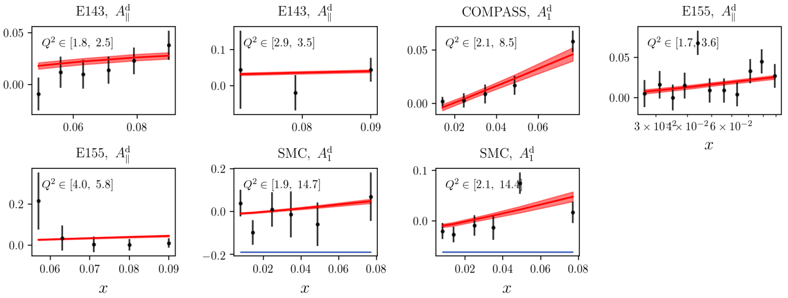
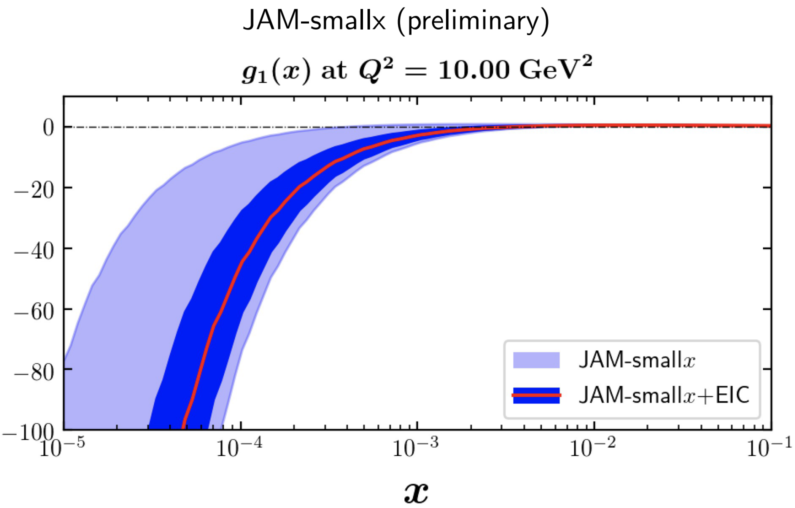


$$\chi^2/d.o.f. \approx 1$$

Predictions for Electron Ion Collider



- Significant improvement in error from EIC

To do

- Fit to other measurements (Semi-inclusive DIS) to further constrain the helicity PDFs
- Large N_c & N_f (include quarks into quark evolution)(Kovchegov, Tawabutr, JHEP 08 (2020))
- Include higher-order correction to evolution and running coupling
- Calculate gluon helicity PDFs
- Investigate L_q and L_G

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