Comparing AdS/CFT inspired dipole model to HERA F_2 data

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1. Brief introduction to AdS/CFT dipole model

2. Fitting AdS/CFT inspired dipole model to HERA F_2 data

3. Predictions
    - Inclusion of charm and prediction for F_2^c
    - prediction for F_L
    - prediction for total photoproduction cross section

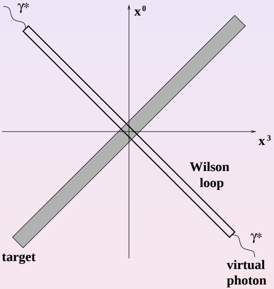
4. Summary

Reference:

Yuri Kovchegov, ZL, Amir Rezaeian, arxiv:0906.4197

- Total deeply inelastic cross-section at large s

$$\sigma_{tot}^{\gamma^\star A}(Q^2, x_{Bj}) \propto \int \frac{d^2\mathbf{r}dz}{2\pi}\Psi(r,z;Q^2)N(\mathbf{r},Y), \qquad Y = ln\left(\frac{1}{x_{Bj}}\right)$$



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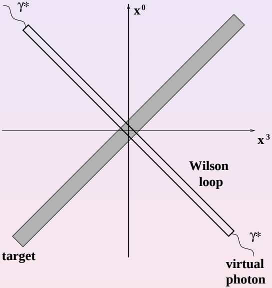

- N related to the expectation value of Wilson loop $\langle W \rangle$:

$$\begin{aligned} N(\mathbf{r},Y) &= 1 - S(\mathbf{r},Y) \\ S(\mathbf{r},\mathbf{b},Y) &= \frac{1}{N_c}\mathrm{Re}\left\langle W\left(\mathbf{b}+\frac{1}{2}\mathbf{r}, \mathbf{b}-\frac{1}{2}\mathbf{r}, Y\right)\right\rangle \end{aligned}$$

- An AdS/CFT based solution — $\mathcal{N} = 4$ Super Yang Mills $q\bar{q}$ dipole $\Longleftrightarrow$ open string in the AdS_5 space whose end points (q and $\bar{q}$) are located at the boundary of the AdS_5 space (J. Albacete et.al, arxiv: 0806.1484) :

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- ρ is the function of r,s and c_0

s-dependent dipole form:

$$N(r,s) = 1 - \exp\left[- \frac{\lambda_{YM}}{\sqrt{2}\pi s} \left(\frac{{c_0}^2 r^2}{\rho^3} + \frac{2}{\rho} - 2\sqrt{s} \right) \right]$$

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$$\Rightarrow N(r,x) = 1-\exp\left[-\frac{\lambda_{YM}\,x\,r}{{\mathcal{M}_0}^2(1-x)\pi\sqrt{2}}\left(\frac{1}{\rho_m^3}+\frac{2}{\rho_m}-2\mathcal{M}_0\sqrt{\frac{1-x}{x}}\right)\right]$$

$$\mathcal{M}_0 = b_0 c_0$$

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$$N(r,x) = 1 - \exp\left[- \frac{\lambda_{YM}\, x\, r}{\mathcal{M}_0{}^2 (1-x)\pi\sqrt{2}} \left(\frac{1}{\rho_m^3} + \frac{2}{\rho_m} - 2\mathcal{M}_0 \sqrt{\frac{1-x}{x}} \right) \right]$$

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$$\rho_m = \begin{cases} (\frac{1}{3m})^{1/4}\sqrt{2\cos(\frac{\theta}{3})} & : m \leq \frac{4}{27} \\ \sqrt{\frac{1}{3m\Delta} + \Delta} & : m > \frac{4}{27} \end{cases}$$

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$$m = \frac{\mathcal{M}_0{}^4 (1-x)^2}{x^2}$$

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$$\sigma_{L,T}^{\gamma^* p}(Q^2,x) = \sum_f \int d^2 r \int_0^1 dz \, |\Psi_{L,T}^{(f)}(r,z;Q^2)|^2 \, \sigma_{q\bar{q}}(r,x)$$

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$$\begin{aligned} |\Psi_T^{(f)}(r,z;Q^2)|^2 &= \frac{\alpha_{EM}\, N_c}{2\,\pi^2} \sum_f e_f^2 \left\{ a_f^2\, [K_1(r\, a_f)]^2\, [z^2 + (1-z)^2] \right. \\ &+ \left. m_f^2\, [K_0(r\, a_f)]^2 \right\} \\ |\Psi_L^{(f)}(r,z;Q^2)|^2 &= \frac{\alpha_{EM}\, N_c}{2\,\pi^2} \sum_f e_f^2\, \left\{ 4\, Q^2 z^2 (1-z)^2\, [K_0(r\, a_f)]^2 \right\} \end{aligned}$$

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\end{aligned}$$

$$F_2(Q^2,x) = \frac{Q^2}{4\pi^2 \alpha_{EM}} \left[\sigma_L^{\gamma^* p}(Q^2,x) + \sigma_T^{\gamma^* p}(Q^2,x) \right]$$

AdS/CFT-based fit to F_2 data

$$\sigma_{q\bar{q}}(r,x) = \sigma_0 \left(1 - \exp\left[- \frac{\lambda_{YM}\, x\, r}{\mathcal{M}_0{}^2(1-x)\pi\sqrt{2}} \left(\frac{1}{\rho_m^3} + \frac{2}{\rho_m} - 2\mathcal{M}_0 \sqrt{\frac{1-x}{x}} \right) \right] \right)$$

AdS/CFT dipole model	λ_{YM}	$\mathcal{M}_0/10^{-3}$	σ_0[mb]	χ^2/d.o.f.
$x \in [6.2\times10^{-7}, 10^{-4}]$	5	9.85	31.164	$110.70/78 = 1.42$
$x \in [6.2\times10^{-7}, 10^{-4}]$	20	6.36	22.65	$141.12/78 = 1.81$
$x \in [6.2\times10^{-7}, 6\times10^{-5}]$	5	10.114	30.97	$44.24/60 = 0.74$
$x \in [6.2\times10^{-7}, 6\times10^{-5}]$	10	8.16	26.08	$49.22/60 = 0.82$
$x \in [6.2\times10^{-7}, 6\times10^{-5}]$	20	6.54	22.47	$55.195/60 = 0.92$

Table: Parameters of the AdS/CFT dipole model determined from a fit to F_2 data reported by ZEUS in two Bjorken x bins. The value of quark mass $m_f = 140$ MeV ($f = u, d, s$) is taken for all fits. The data for the first two rows and the rest are within $Q^2/\text{GeV}^2 \in [0.045, 6.5]$ and $Q^2/\text{GeV}^2 \in [0.045, 2.5]$ respectively.

GBW dipole model fit to the same data bins

- Golec-Biernat-Wüsthoff (GBW) dipole model (Phys. Rev. D59 (1999) 014017; D60 (1999) 114023):

$$\sigma_{q\bar{q}}^{\mathrm{GBW}}(r,x) = \sigma_0 \left(1 - e^{-r^2(\frac{x_0}{x})^{\lambda}/4}\right)$$

GBW dipole model	$x_0/10^{-4}$	λ	σ_0[mb]	χ^2/d.o.f.
$x \in [6.2 \times 10^{-7}, 10^{-4}]$	2.225	0.299	22.77	$63.09/78 = 0.81$
$x \in [6.2 \times 10^{-7}, 6 \times 10^{-5}]$	2.371	0.368	21.13	$39.35/60 = 0.66$

Table: Parameters of the GBW color dipole model determined from a fit to F_2 data from ZEUS in two Bjorken x bins. The data for the first two rows and the rest are within $Q^2/\mathrm{GeV}^2 \in [0.045, 6.5]$ and $Q^2/\mathrm{GeV}^2 \in [0.045, 2.5]$

AdS/CFT-based fit to F_2 data

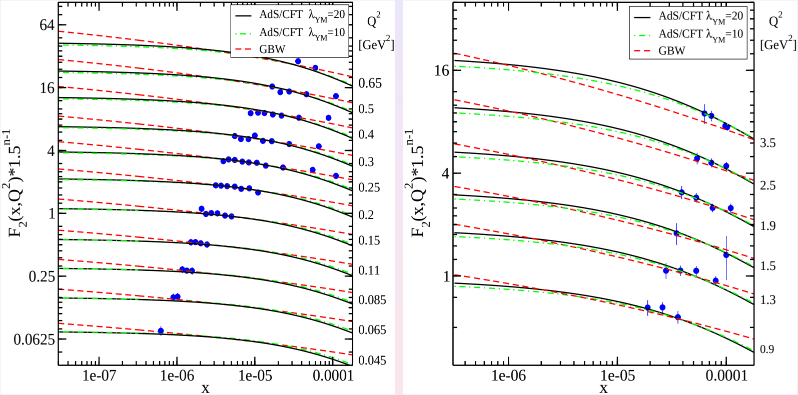
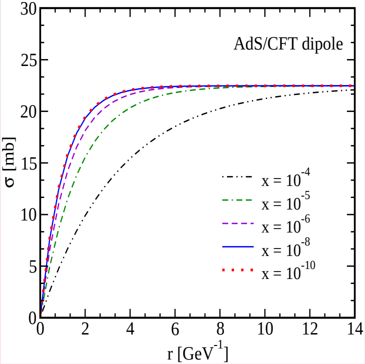


Figure: Results of our AdS/CFT-based fit to the proton structure function F_2.

AdS/CFT-based dipole cross-section

$$\sigma_{q\bar{q}}(r,x) = \sigma_0 \left(1 - \exp\left[-\frac{\lambda_{YM}\, x\, r}{\mathcal{M}_0{}^2(1-x)\pi\sqrt{2}}\left(\frac{1}{\rho_m^3} + \frac{2}{\rho_m} - 2\mathcal{M}_0\sqrt{\frac{1-x}{x}}\right)\right]\right)$$



The AdS/CFT dipole cross-section obtained from the fit for $\lambda_{YM} = 20$ and $m_q = 140$ MeV at various fixed Bjorken-x as a function of r

Saturation scale

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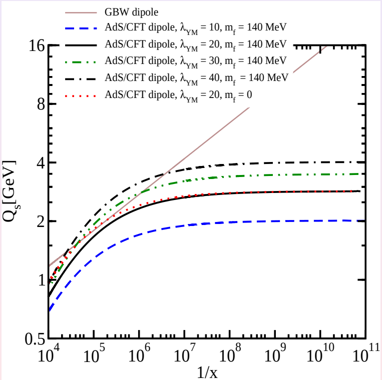

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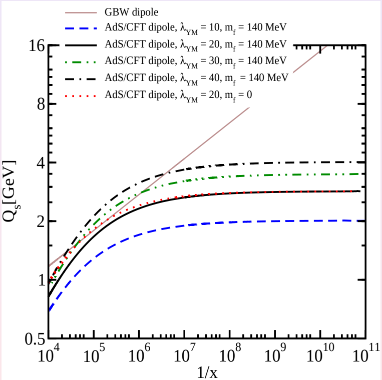

x-independence of $Q_s^{\mathrm{AdS}}(x)$ at small x: saturation of saturation

Conjectured in arxiv:0707.0811, D. Kharzeev et.al.

s-dependent dipole fit

$$\sigma_{q\bar{q}}(r,s) \quad = \quad \sigma_0 \left(1 - \exp\left[-\frac{\lambda_{YM}}{s\pi\sqrt{2}}\left(\frac{{c_0}^2 r^2}{\rho^3} + \frac{2}{\rho} - 2\sqrt{s}\right)\right]\right)$$

λ_{YM}	c_0	σ_0[mb]	χ^2/d.o.f.
5	0.00583	40.55	$62.61/60 = 1.04$
10	0.00440	36.30	$77.17/60 = 1.29$
20	0.00324	33.58	$92.11/60 = 1.53$

Table: Parameters of the s-dependent AdS/CFT dipole model determined from a fit to F_2 data from ZEUS. The data are within $x \in [6.2 \times 10^{-7}, 6 \times 10^{-5}]$ and $Q^2/\text{GeV}^2 \in [0.045, 2.5]$.

- In $\mathcal{N} = 4$ SYM: $c_0 = \frac{\Gamma^2(\frac{1}{4})}{(2\pi)^{3/2}} = 0.834$.
- our fitting result is two orders of magnitude smaller: difference between QCD and $\mathcal{N} = 4$ SYM.

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   - prediction for total photoproduction cross section
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Inclusion of charm and prediction for F_2^c

$$F_2 = F_2^u + F_2^d + F_2^s + F_2^c$$

m_c[GeV]	λ_{YM}	$\mathcal{M}_0/10^{-3}$	σ_0[mb]	χ^2/d.o.f.
-	10	8.16	26.08	$49.22/60 = 0.82$
-	20	6.54	22.47	$55.195/60 = 0.92$
1.4	10	7.66	24.72	$61.66/60 = 1.03$
1.4	20	6.16	21.31	$70.99/60 = 1.18$

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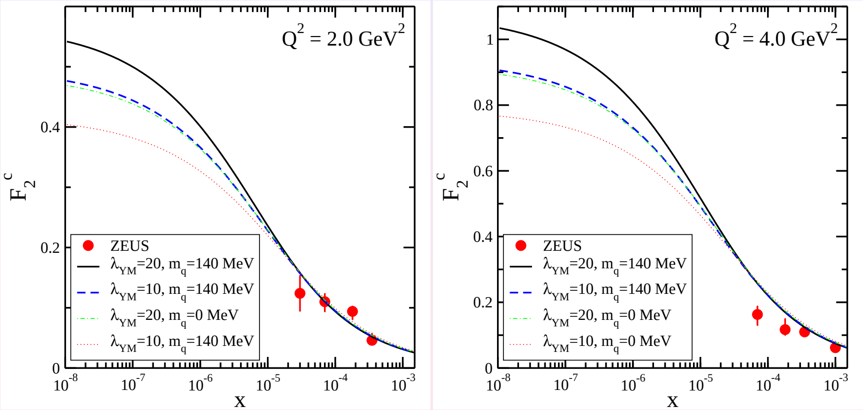
Inclusion of charm and prediction for F_2^c



prediction for F_L

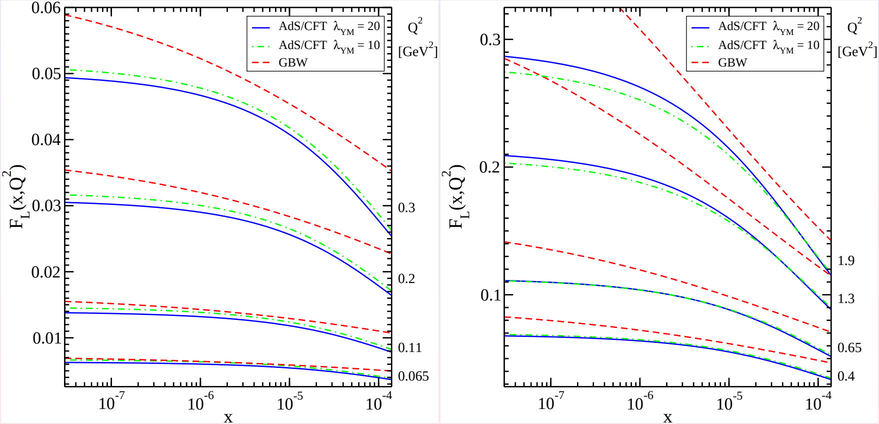


Figure: F_L predicted from our fit

photoproduction

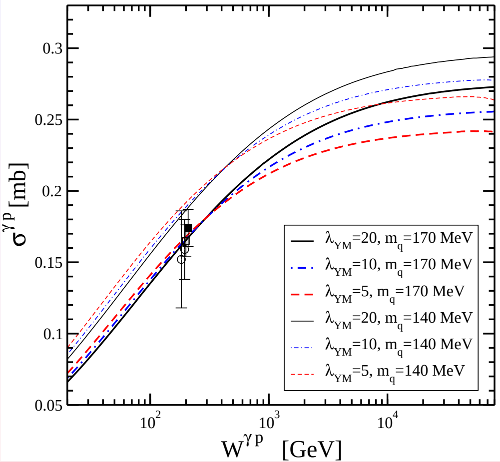


Figure: Photoproduction cross section at large $\sqrt{s}$ predicted from our fit compared with ZEUS (square) and H1 (circle) data.

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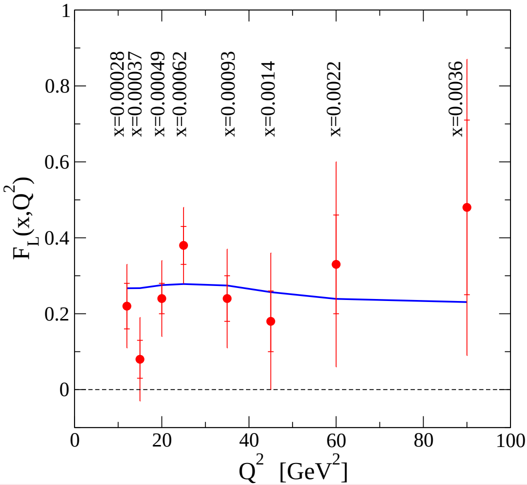
- Predictions for F_2, F_2^c, F_L and photoproduction in the kinematical regions of future experiments.
- AdS/CFT-based model of non-perturbative physics at large coupling could be viewed as complimentary to the perturbative description of data based on saturation/Color Glass Condensate physics.

Backup slides


x=0.00028
x=0.00037
x=0.00049
x=0.00062
x=0.00093
x=0.0014
x=0.0022
x=0.0036
$F_L(x,Q^2)$
Q^2 [GeV^2]
0
0.2
0.4
0.6
0.8
1
0
20
40
60
80
100