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In the Color Glass Condensate formalism, the amplitudes for quark anti-quark production in DIS and virtual photon (DY) production in proton (deuteron)-nucleus (pA) collisions are related via crossing symmetry. Both production cross sections involve only the dipole (two-point function of Wilson lines) function. Therefore knowledge of the dipole profile gained in DIS structure function studies can be used to predict dilepton production in pA collisions. Lam-Tung relation between the DY structure functions is shown to be sensitive to the high gluon density effects at small x.

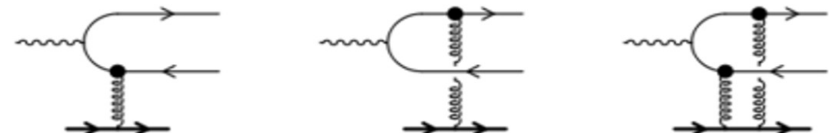
**based on work done in collaboration with F. Gelis*

MV
PRD59 (1999) 094002

DIS at small x

Gelis,Jalilian-Marian
PRD67 (2003) 074019

consider $\gamma^\star\,\mathbf{T} \to \mathbf{q}\,\bar{\mathbf{q}}\,\mathbf{X}$



$$M^\mu(k;q,p) \;=\; \frac{i}{2}\int \frac{d^2 l_t}{(2\pi)^2}\, d^2x_t d^2y_t e^{il_t\cdot x_t} e^{i(p_t+q_t-k_t-l_t)\cdot y_t}\,\bar{u}(q)\,\Gamma^\mu(k;q,p)\,v(p)$$
$$\left[V(x_t)\,V^\dagger(y_t)-1\right]$$

cross section:

averaging over
color charges ρ

$$\mathbf{2p_0\,2q_0\,\frac{d\sigma}{d^3q\,d^3p} = \frac{1}{(2\pi)^5}\,\frac{1}{k^-}\,2\pi\delta(k^-p^- - q^-)\,\langle M^\mu M^{\nu\,\star}\rangle\,\epsilon_\mu(k)\epsilon^\star_\nu(k)}$$

to get the DIS total cross section, <u>integrate over quark, anti-quark momenta</u>

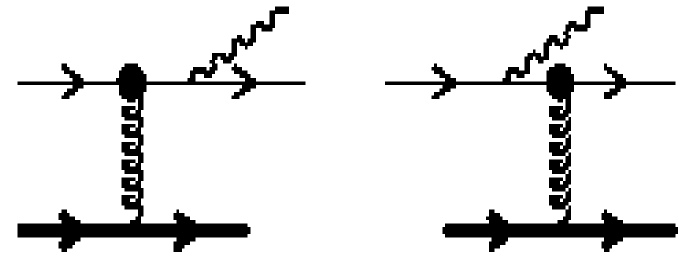
$$\sigma^{\gamma^\star\,\mathbf{T}\to\mathbf{X}} = \int_0^1 \mathbf{dz}\int \mathbf{d^2x_t d^2y_t}\,|\Psi|^2\,\underbrace{\frac{\mathbf{1}}{\mathbf{N_c}}\left\langle \mathbf{Tr}\left[\mathbf{1}-\mathbf{V}(\mathbf{x_t})\,\mathbf{V}^\dagger(\mathbf{y_t})\right]\right\rangle}_{\textit{dipole cross section}\;T(x_g,r_t,b_t)}$$

$\mathbf{T(x_g,r_t,b_t)}$

satisfies the JIMWLK/BK eqs.

DY at small x

$$\mathbf{q\,T \rightarrow q\,\gamma^{\star}\,X}$$



$$\mathbf{M^{\mu}(p;k,q) = i \int d^2x_t e^{i(q_t+k_t-p_t)\cdot x_t}\, \bar{u}(q)\,\bar{\Gamma}^{\mu}(k;q,p)\,u(p)\;[V(x_t)-1]}$$

$$= \frac{i}{2}\int \frac{d^2 l_t}{(2\pi)^2}\, d^2x_t d^2y_t e^{il_t\cdot x_t} e^{i(q_t+k_t-p_t-l_t)\cdot y_t}\,\bar{u}(q)\,\Gamma^{\mu}(-k;q,-p)\,u(p)$$

$$\left[V(x_t)\,V^{\dagger}(y_t)-1\right]\;\underbrace{V(y_t)}_{\text{extra: unitary matrix}}$$

same as DIS

cross section

$$\frac{d\sigma}{dz\,d^2k_t\,d\log M^2\,d^2b_t} = \frac{2\alpha_{em}^2}{3\pi}\int\frac{d^2l_t}{(2\pi)^4}\,d^2r_t e^{il_t\cdot r_t}\,T(x_g,b_t,r_t)\Bigg\{$$

$$\left[\frac{1+(1-z)^2}{z}\right]\frac{z^2\,l_t^2}{[k_t^2+(1-z)M^2][(k_t-zl_t)^2+(1-z)M^2]}$$

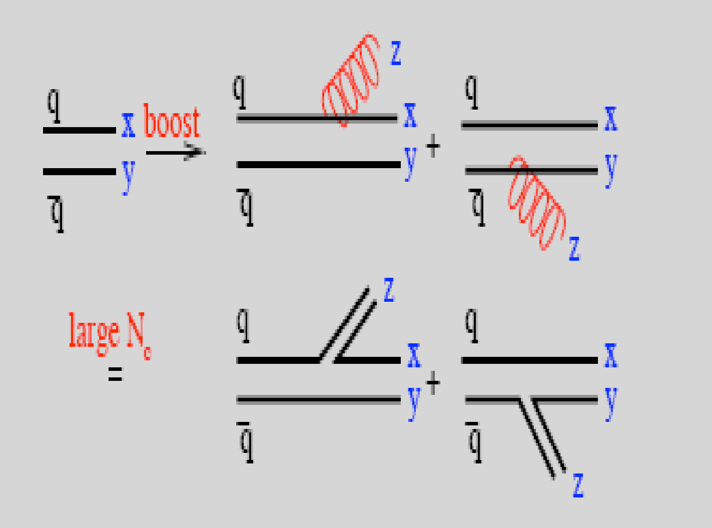
$$-\quad z(1-z)M^2\left[\frac{1}{[k_t^2+(1-z)M^2]}-\frac{1}{[(k_t-zl_t)^2+(1-z)M^2]}\right]^2\Bigg\}$$

Gelis,Jalilian-Marian
PRD66 (2002) 094014

Evolution of a dipole (2-point function): BK

$$\frac{d}{dy} < \mathrm{Tr} V_x^\dagger V_y >= -\frac{\bar{\alpha}_s}{2\pi} \int d^2 z \frac{(x-y)^2}{(x-z)^2 (y-z)^2} \times$$

$$\left[< \mathrm{Tr} V_x^\dagger V_y > - \frac{1}{N_c} < \mathrm{Tr} V_x^\dagger V_z \, \mathrm{Tr} V_z^\dagger V_y > \right]$$



$$\frac{d}{dy} S_4(r, \bar{r} : s) \simeq \frac{d}{dy} [S_2(s - \bar{r}) \, S_2(r - s)] + O(\frac{1}{N_c^2})$$

DIS F2,FL
DY in pA are sensitive
to dipoles only

Dijet production probes quadrupoles

A quadrupole *is not* the same as dipole X dipole
AD-JJM, 2011

NLO BK:
B-KW-G-BC (2007-2008)

Dilepton production: k_t integrated

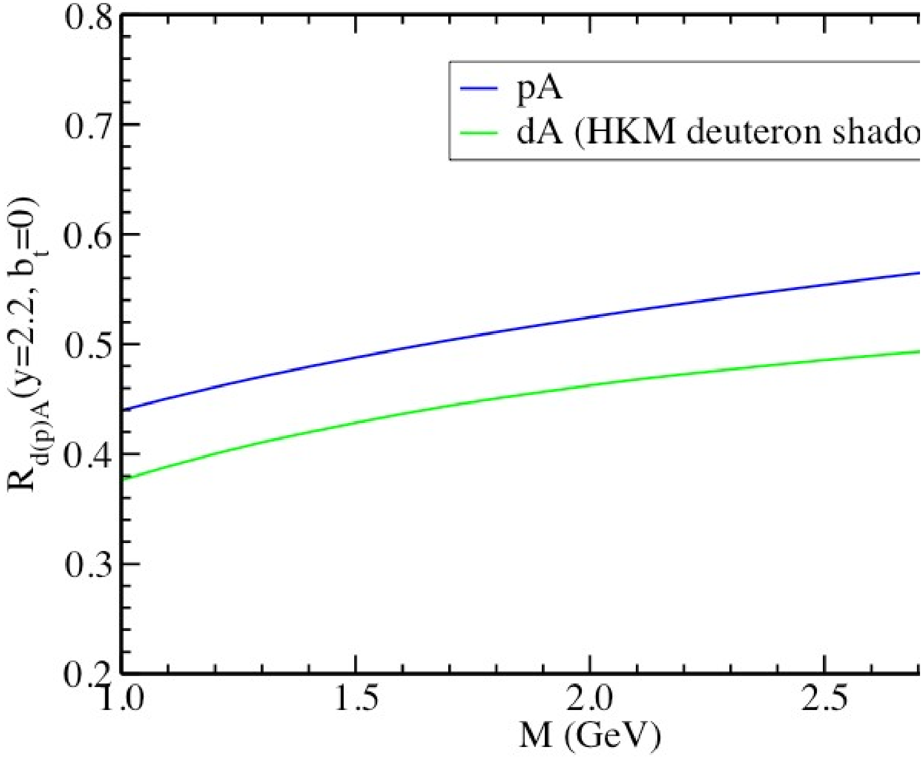
$$\frac{d\sigma^{d(p)\,A\to l^+ l^-\,X}}{d^2b_t\,dM^2\,dx_F} = \frac{\alpha_{em}^2}{6\pi^2}\frac{1}{x_q+x_g}\int_{x_q}^1 dz \int dr_t^2\,\frac{1-z}{z^2}$$

F. Gelis & JJM 02, JJM 04

$$F_2^{d(p)}(x_q/z)\,\gamma(x_g,b_t,r_t)$$

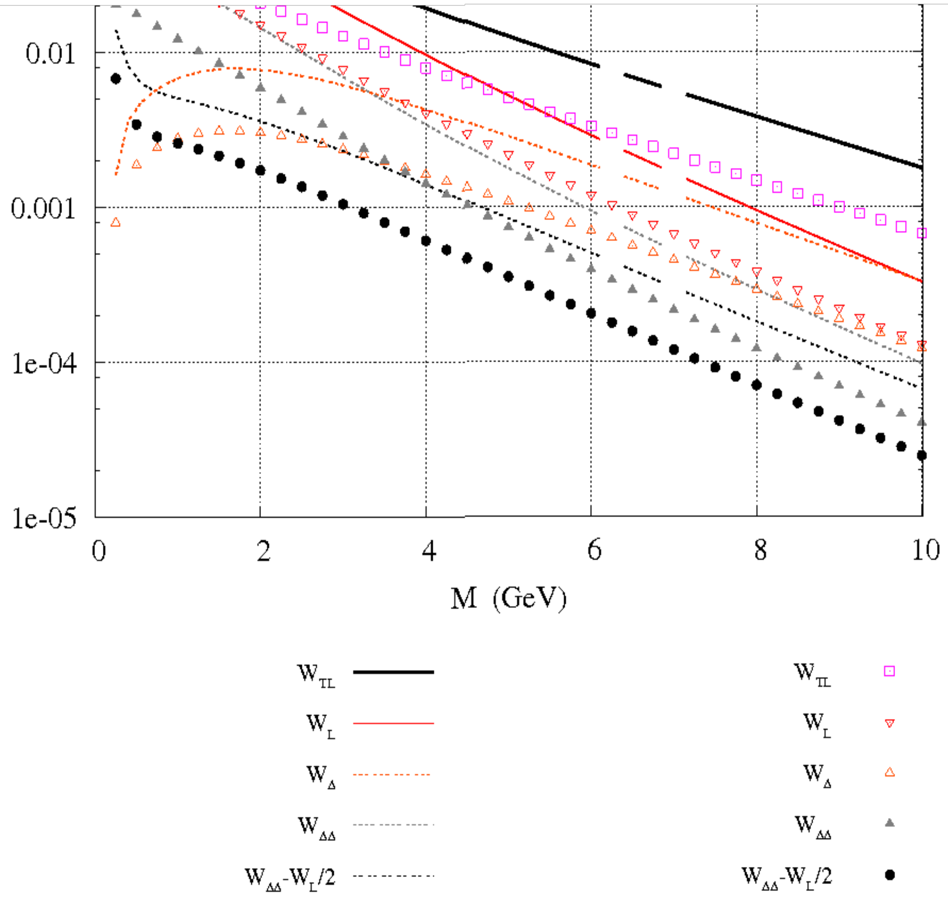
$$\Big[[1+(1-z)^2]\,K_1^2[\frac{\sqrt{1-z}}{z}Mr_t]$$

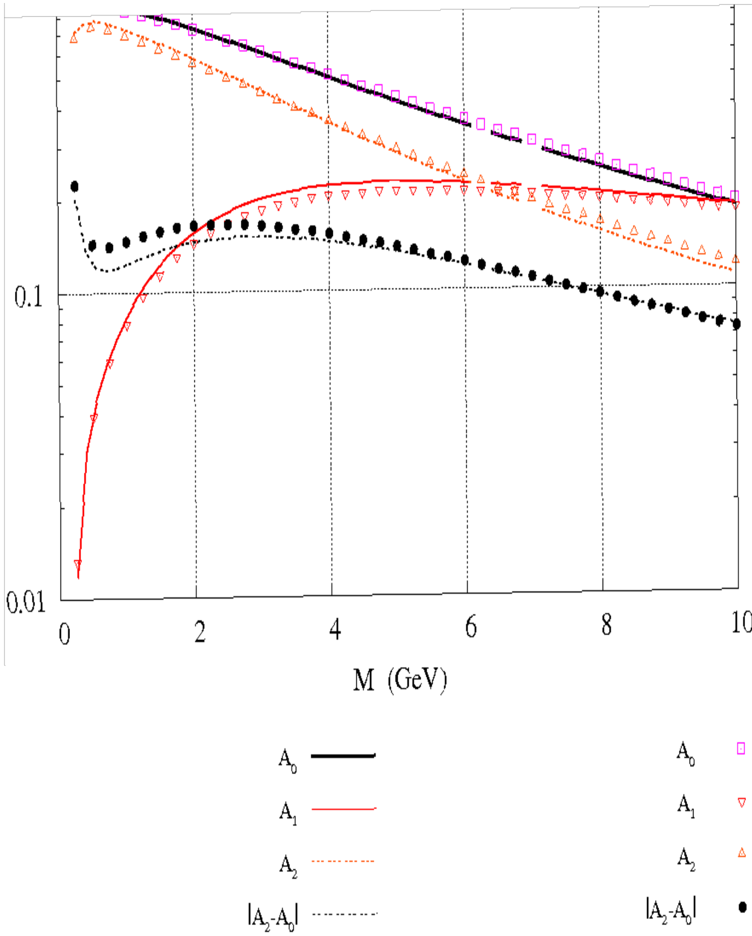
$$+2(1-z)\,K_0^2[\frac{\sqrt{1-z}}{z}Mr_t] \Big]$$



$$x_F \equiv \frac{M}{\sqrt{s}}[e^y - e^{-y}]$$

RHIC: k_t = 3 GeV, y = 2





Lines: (fixed coupling) BK
Points: DHJ