# On the High Energy Behaviour of The Total Cross Section in the QCD Dipole Model

Emil Avsar

Institut de Physique Théorique de Saclay

France

# Outline

- Cascade evolution in high energy QCD, the scattering amplitude, and the black disc limit.
- Generalizing the evolution equations: Pomeron Loops and the dipole swing.
- Transverse profile without confinement effects
- Modeling confinement
- Transverse profile with confinement effects

# High Energy Evolution

- Consider scattering of colour singlet $q\bar{q}$ dipole on generic target
- Scattering amplitude in impact parameter space, $T_Y(\boldsymbol{b})$
- Evolution of $T$ with $Y$ determined by B-JIMWLK equations
- At each $\boldsymbol{b}$ we have $T_Y(\boldsymbol{b}) \leq 1$, cf linear evolution where $T$ can be arbitrarily large
- In large $N_c$-limit, dipolar interpretation of evolution; As $Y$ is increased a cascade of dipoles is formed

# The Black disc

- The limit where $T_Y(\boldsymbol{b}) = 1$ is called black disc limit. Here projectile completely absorbed, i.e. black target
- Usual to define black disc as:

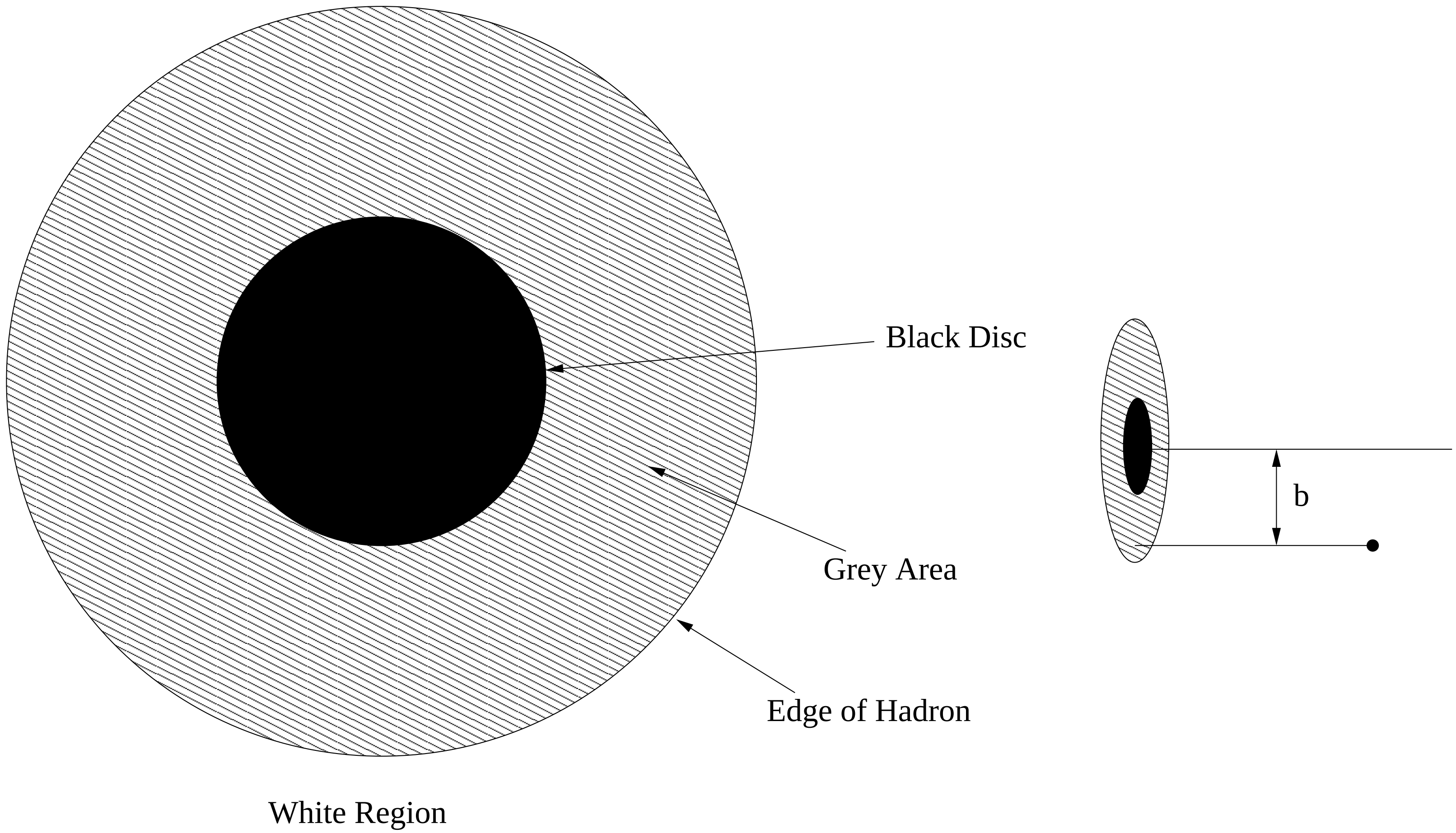
$$T_Y(\boldsymbol{b}) = a \ \text{ for } \ |\boldsymbol{b}| = R_{bd}(Y), \quad a \approx 0.5$$

- Total cross section then given by:

$$\sigma_{tot}(Y) = 2 \int d^2\boldsymbol{b}\, T_Y(\boldsymbol{b}) \sim 2\pi R_{bd}^2(Y),$$

- The FM bound: $\sigma_{tot} \leq C \cdot \ln^2(s/s_0) \Longrightarrow R_{bd}(Y)$ can at most grow linearly with $Y = \ln(s/s_0)$

# Picture of a Hadron



# Growth of Black Disc

- Even though pQCD provides $T \leq 1$ at each $\boldsymbol{b}$, it is obvious that FM bound will be violated by B-JIMWLK eqs

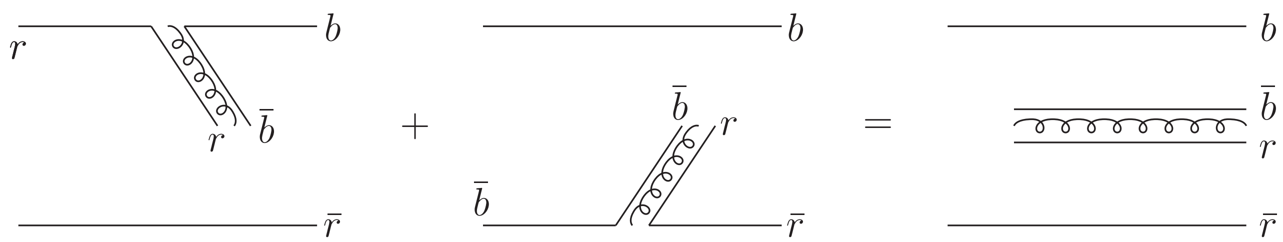
- A simple way to determine behaviour of $R_{bd}(Y)$ is to use BFKL evolution. This gives

$$T_Y(r, b) \sim \frac{r_0 r}{b^2} \, e^{\omega Y}$$

- Use definition of $R_{bd}(Y) \Longrightarrow$ exponential growth. This is due to the long Coulomb tails of the gluon fields.

# Consistency of dipole evolution

- In dipole model unitarization at each $\boldsymbol{b}$ due to multiple scatterings
- However, evolution of cascade linear, completely driven by the $1 \to 2$ splitting vertex




- Multiple Interactions: Boost to different frame $\Longrightarrow$ interactions among dipoles in same cascade, i.e. saturation effects

# Generalizing the Evolution

- Linear evolution related to the leading $N_c$ approximation, $\propto \alpha_s N_c \equiv \bar{\alpha}$, nonlinear contributions formally $N_c$ suppressed, $\alpha_s^2 = \bar{\alpha}^2/N_c^2$
- Subleading $N_c$ corrections can generate nondipolar contributions. However, the “leading” piece of the nonleading contribution admits a dipolar interpretation
- The $2 \rightarrow 2$ process generated is called a dipole swing:

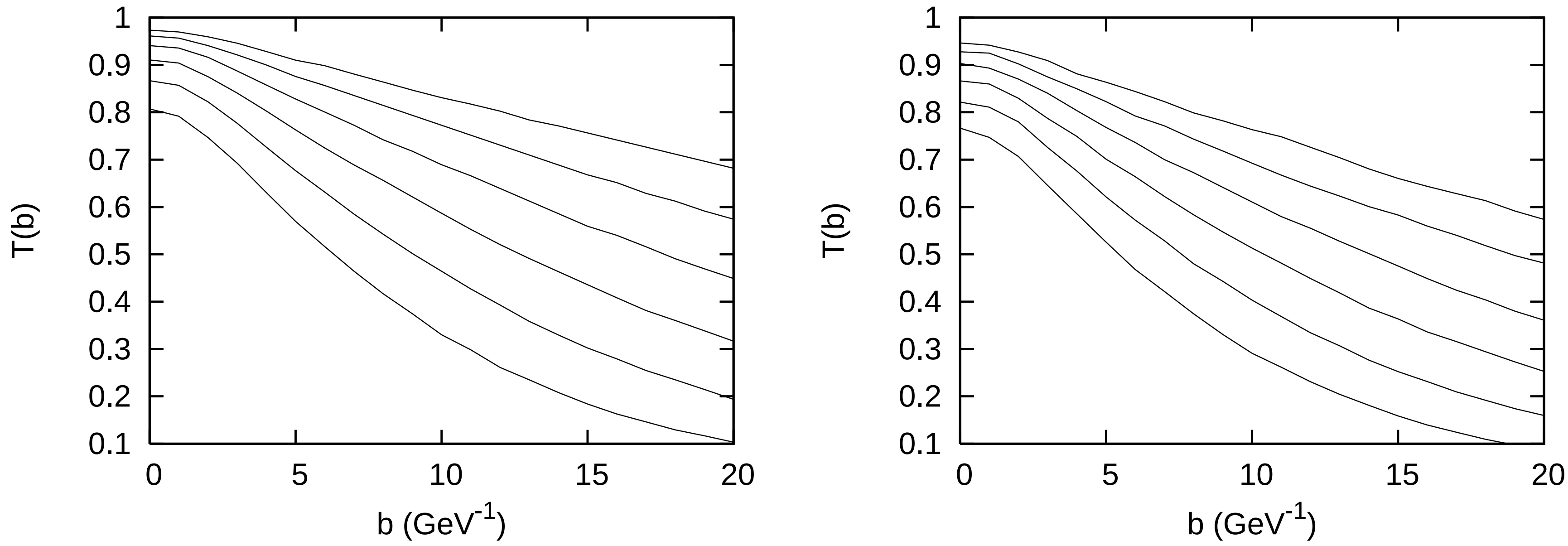
# New Evolution

- Evolution can then be formulated using $k \to k+1$ vertices
- Such vertices also appear in explicitely boost invariant toy models
- In full model, however, no proof exists. We therefore implement an approximation in a numerical Monte Carlo code
- Our implementation gives similarities with the saturation mechanism in the CGC approach. In particular

$$\frac{dN}{d^2\boldsymbol{b}d^2\boldsymbol{r}} \lesssim \frac{1}{\alpha_s^2}$$

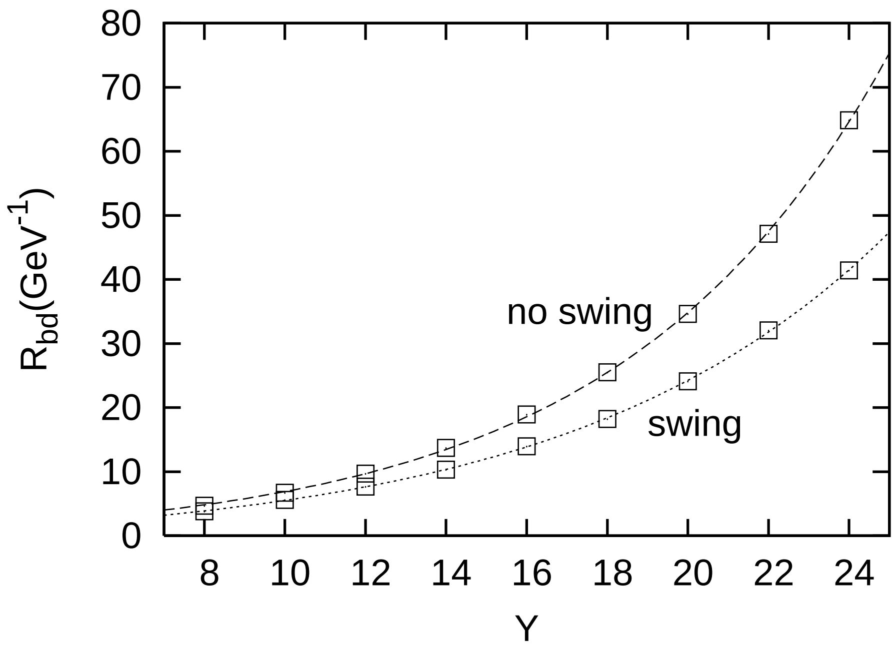
# Results

- We present results for $pp$ collisions where the "proton" initially consists of 3 dipoles in a specific topology.




- With running $\alpha_s$. Very "flat" transverse profile

# Results

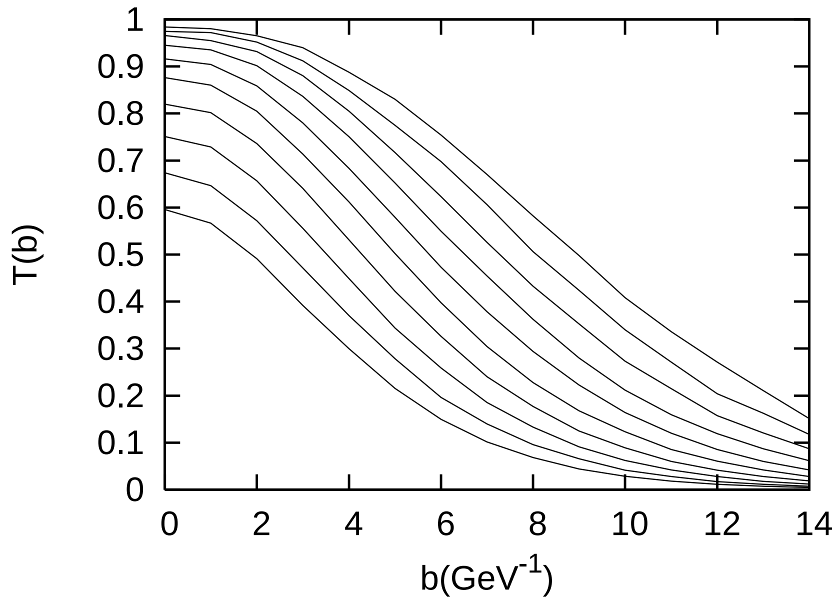


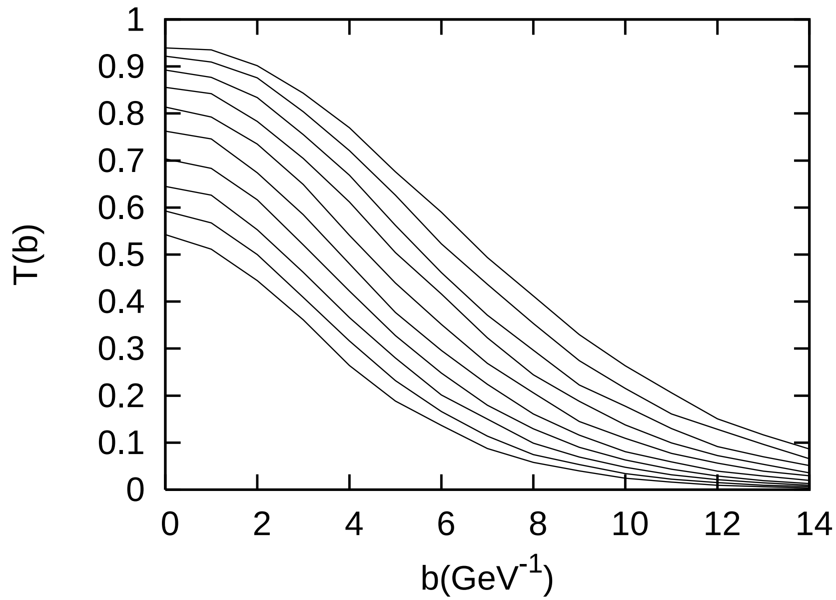

- Exponential growth in both cases, $\sigma_{tot} \propto \exp(0.26Y)$ with swing
- Use of pQCD questionable, especially with running $\alpha_s$

# Modeling Confinement

- At large distances confinement must be taken into account.
- We try most simple approach: replace everywhere $1/\boldsymbol{k}^2 \to 1/(\boldsymbol{k}^2 + M^2)$
- In coordinate space $1/(\boldsymbol{k}^2 + M^2)$ gives $K_0(rM)$
- In our model, $M$ was fitted to give correct normalization for $pp$ cross section, $M \approx 0.28\mathrm{GeV}$

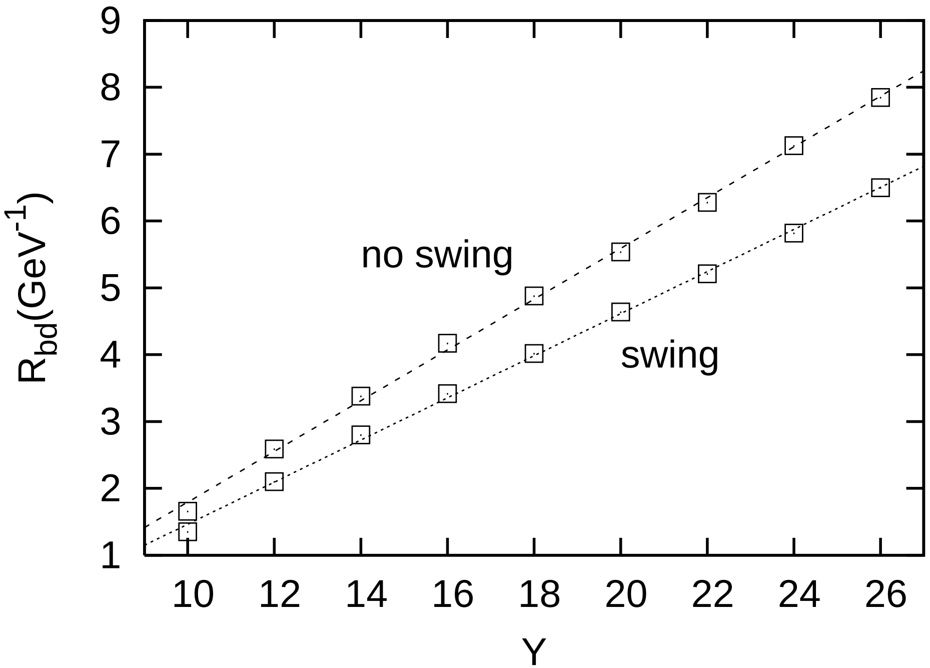
# Results




- Linear growth of $R_{bd}(Y)$ in both cases, i.e. FM bound saturated

# Results




- $\sigma$ grows like $0.24 \ln^2 s$ mb, including the swing. Actually close to fit by Block $\&$ Halzen