Diffraction and saturation

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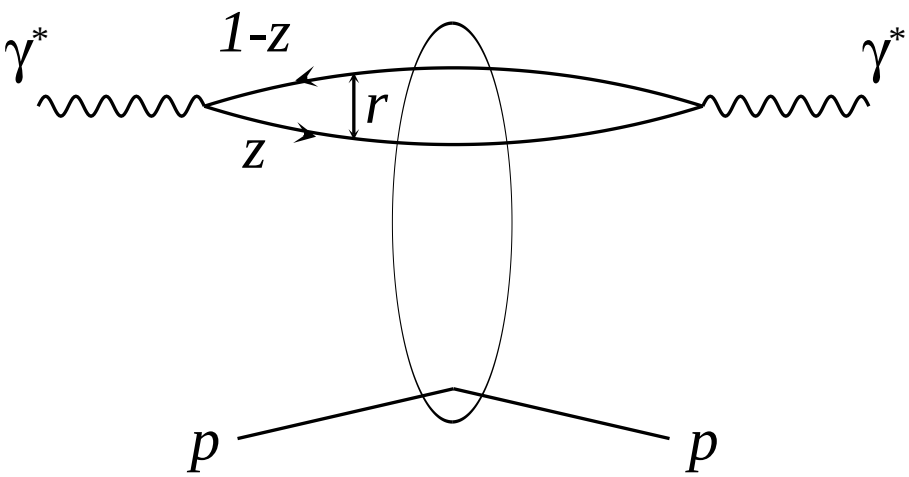
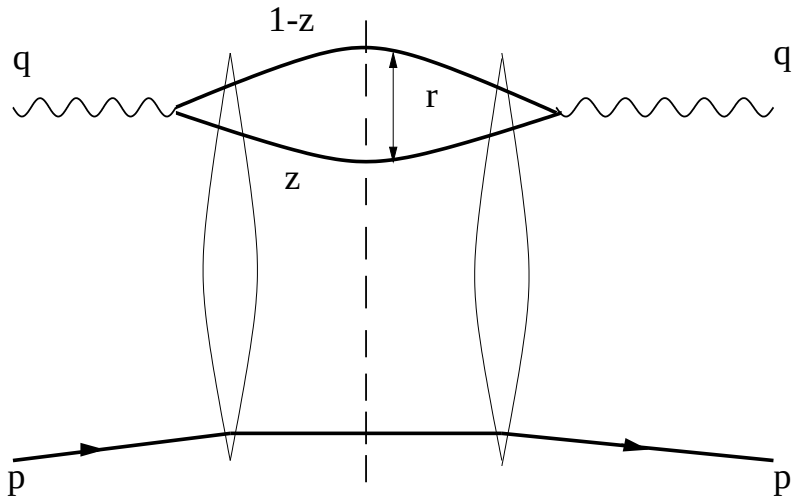
Dipole approach to DIS diffraction

Inclusive



Diffractive



$$\sigma_{tot} = \int_{r,z} |\Psi(r,z,Q)|^2 \, \hat{\sigma}_{q\bar{q}}(x,r)$$

$$\frac{d\sigma_{dif}}{dt}_{|\,t=0} = \frac{1}{16\pi} \int_{r,z} |\Psi(r,z,Q)|^2 \, \hat{\sigma}^2_{q\bar{q}}(x_{I\!P},r)$$

$$x \simeq \frac{Q^2}{W^2} \ll 1$$

$$x_{I\!P} \simeq \frac{Q^2+M^2}{W^2} \ll 1$$

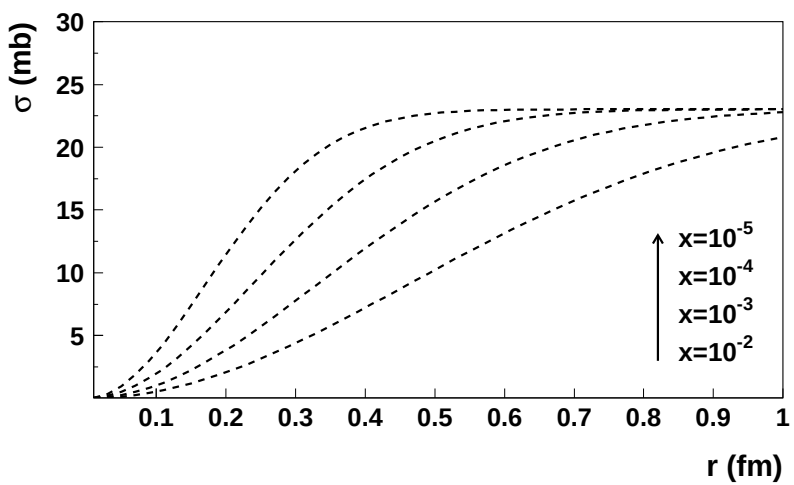
Dipole cross section: $\hat{\sigma}_{q\bar{q}}(x,r) = 2\int d^2b\,(1-S(x,r,b))$

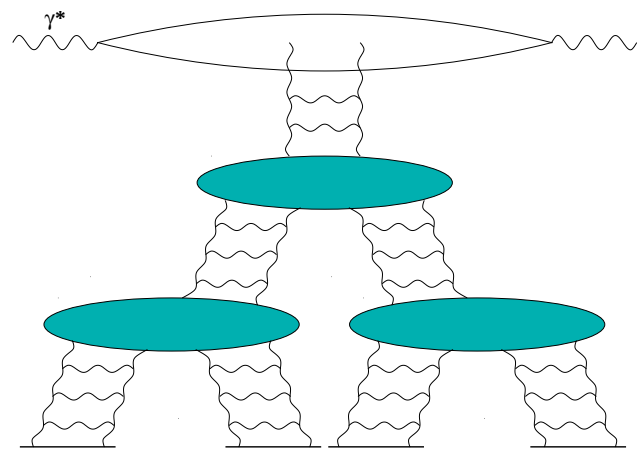
Dipole cross section

- From unitarity: $\hat{\sigma}_{q\bar{q}} \leq \sigma_0 \, \log^k(r)$ for large r
- From pQCD: $\hat{\sigma}_{q\bar{q}} \sim r^2 \, G(x, 1/r)$ for small r
- Particular model ($k = 0$): *(GBW 98-99)*

$$\hat{\sigma}_{q\bar{q}} = \sigma_0 \left\{ 1 - \exp\left(-\frac{r^2}{4R_0^2(x)} \right) \right\}$$

- Saturation scale: $Q_s(x) = 1/R_0(x)$ and scaling: $\hat{\sigma}_{q\bar{q}}(rQ_s(x))$

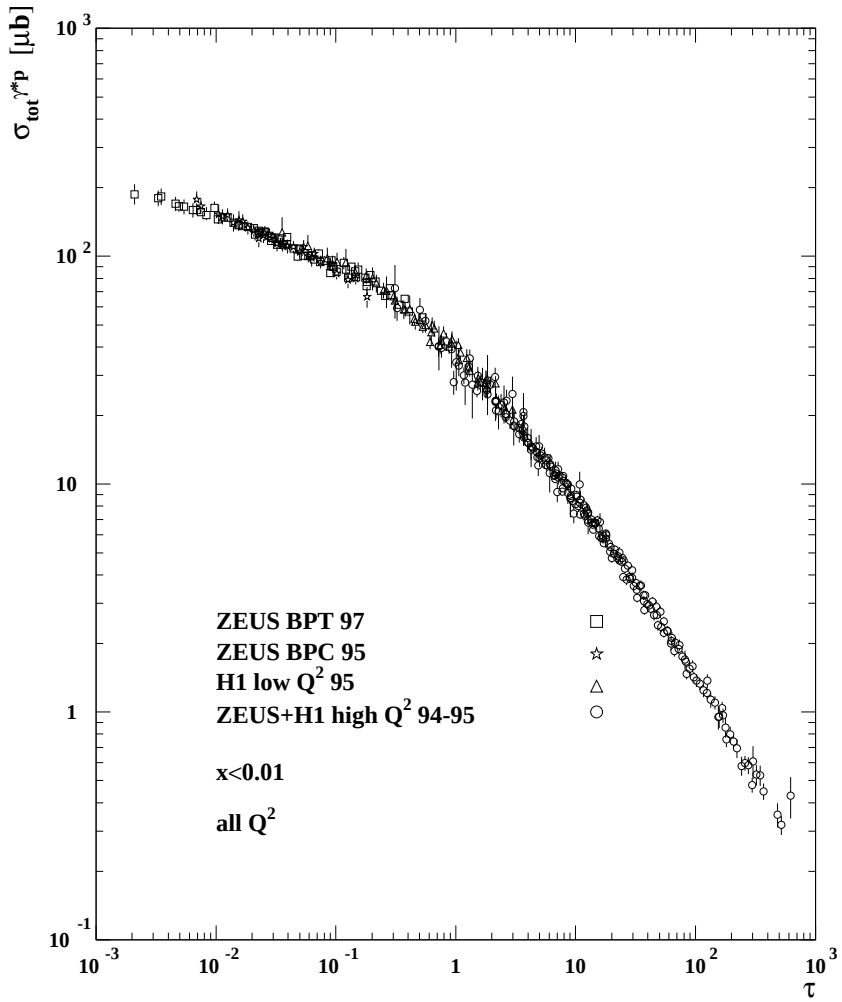




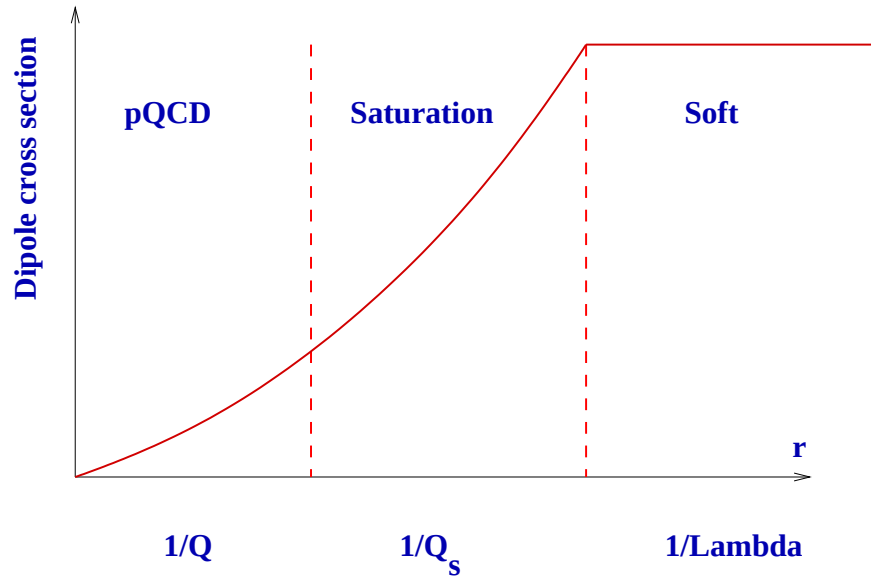
Geometric scaling in DIS

- From scaling of dipole cs $\hat{\sigma}_{q\bar{q}}(rQ_s)$: *(Staśto,GB, Kwieciński 2000)*

$$\sigma_{tot} \sim \int_0^1 dz \ldots \int_0^\infty d(\underline{rQ})^2 \, K_1^2(\ldots \underline{rQ}) \, \hat{\sigma}_{q\bar{q}}\left(\underline{rQ}\,\frac{Q_s}{Q}\right) \quad \rightarrow \quad \sigma_{tot}\underbrace{\left(\frac{Q^2}{Q_s^2(x)}\right)}_{\tau}$$



Diffraction and saturation



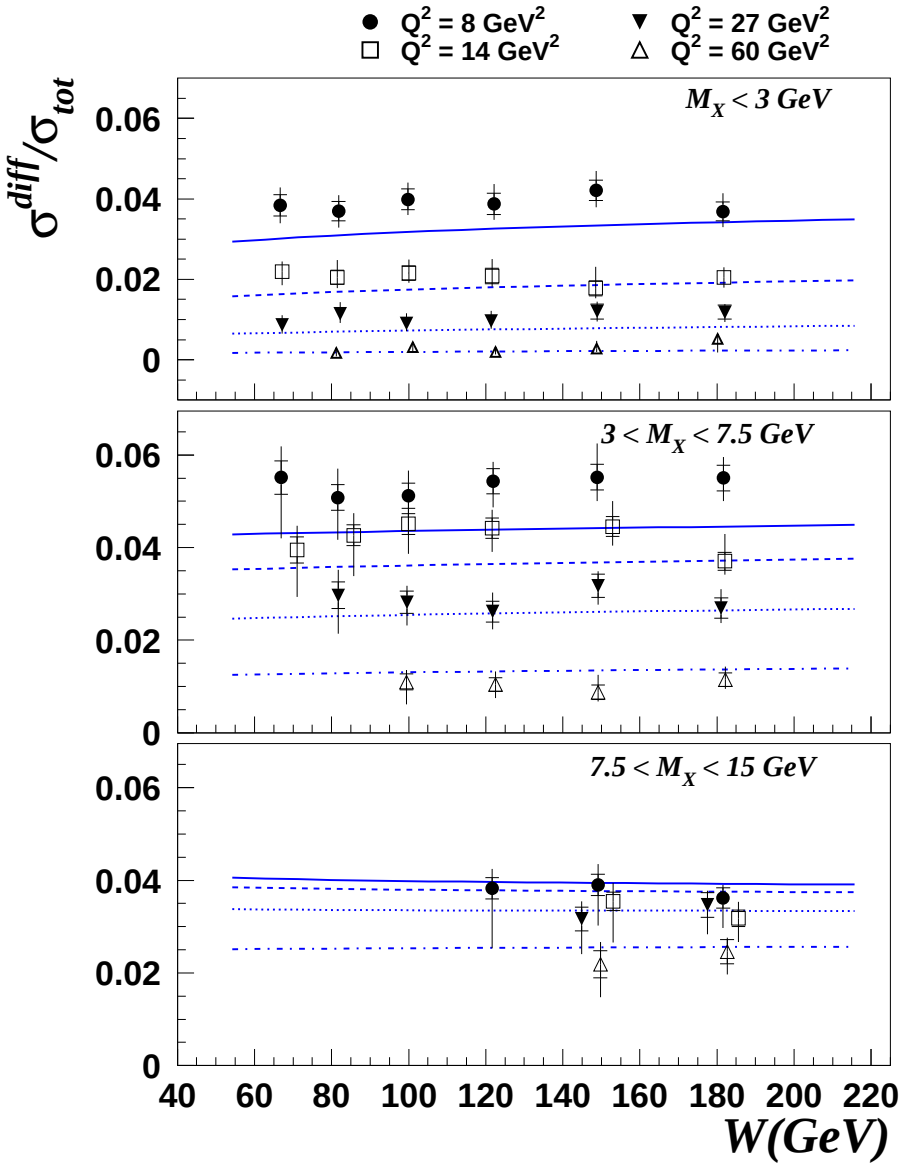
$$Q^2\sigma_{tot} \sim 1 + \log\left(Q^2/Q_s^2\right) + 1$$

$$Q^2\sigma_{dif} \sim \frac{1}{Q^2} + 1 + 1$$

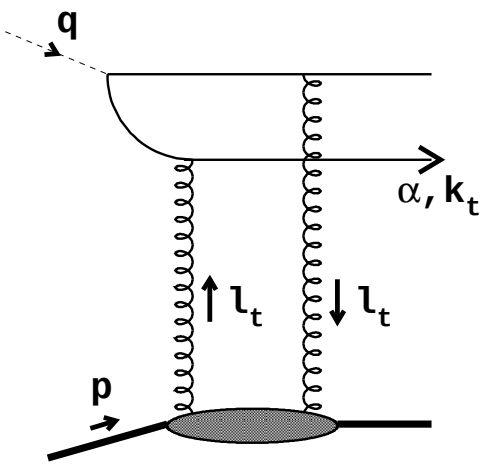
- DIS diffraction is directly sensitive to saturation region.
- Constant ratio:

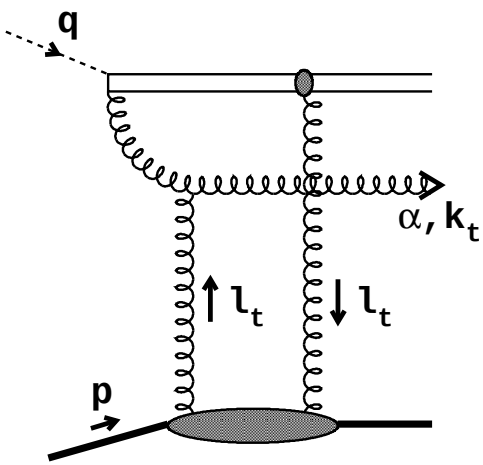
$$\frac{\sigma_{dif}}{\sigma_{tot}} \sim \frac{1}{\log(Q^2/Q_s^2(x))}$$

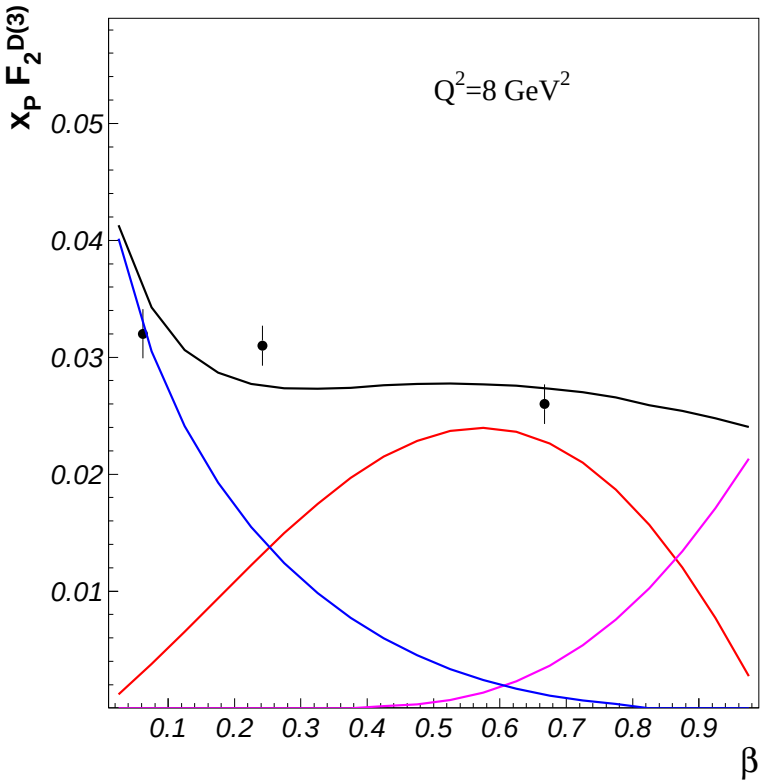
Constant ratio



Diffractive final states







- $\beta = Q^2/(Q^2 + M^2)$
- $F_2^D(\beta, x_{I\!P}, Q^2) = F^L_{q\bar{q}} + F^T_{q\bar{q}} + F^T_{q\bar{q}g}$
- $F^L_{q\bar{q}} \sim 1/Q^2$ is higher twist

Geometric scaling in diffraction

- F_2^D contains all powers $1/Q^2$. Extracting leading twist-2:

$$x_{I\!P} F_2^D \simeq Q_s^2(x_{I\!P}) \sum_f e_f^2 \, \beta q_f(\beta)$$

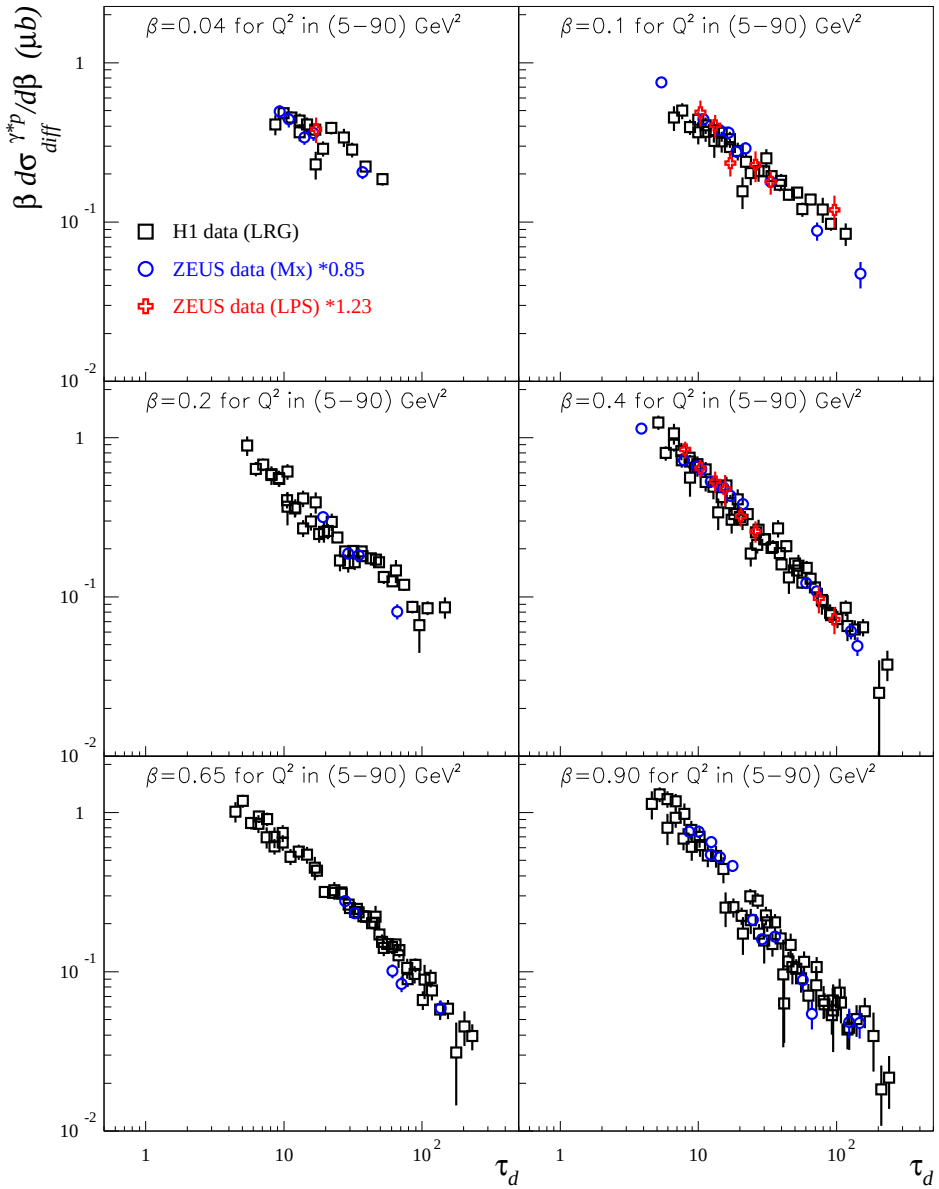
- Scaling for fixed β:

$$\beta \frac{d\sigma_{dif}}{d\beta} = \frac{x_{I\!P} F_2^D}{Q^2} \sim \frac{Q_s^2(x_{I\!P})}{Q^2}$$

- For $\beta \to 1$ longitudinal sf dominates:

$$\beta \frac{d\sigma_{dif}}{d\beta} = \frac{x_{I\!P} F_L^D}{Q^2} \sim \left(\frac{Q_s^2(x_{I\!P})}{Q^2} \right)^2$$

From Marquet and Shoeffel (hep-ph/060679)



Summary

- Unified description of inclusive and diffractive DIS at small x.
- With saturation constant ratio $\sigma_{dif}/\sigma_{tot}$ found.
- Correct energy behaviour:

$$F_2^D \sim x_{I\!P}{}^{1-2\alpha_{I\!P}} \quad => \quad \alpha_{I\!P} \simeq 1.15$$

- Geometric scaling in inclusive and diffractive processes.