# Parton-hadron duality in single and double diffraction dissociation

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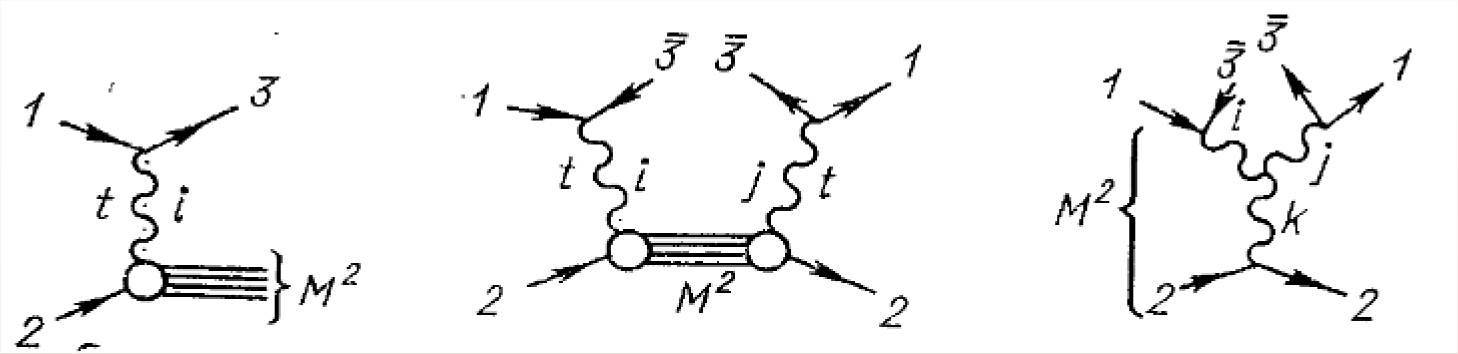
# Introduction

- The dynamics of strong interaction should be continuous across all regions of energy and momentum transfer.
- One of the priorities of LHC research program is measurements of single and double diffraction dissociation (SD and DD respectively).
- Usually SD is calculated from the triple Regge limit.

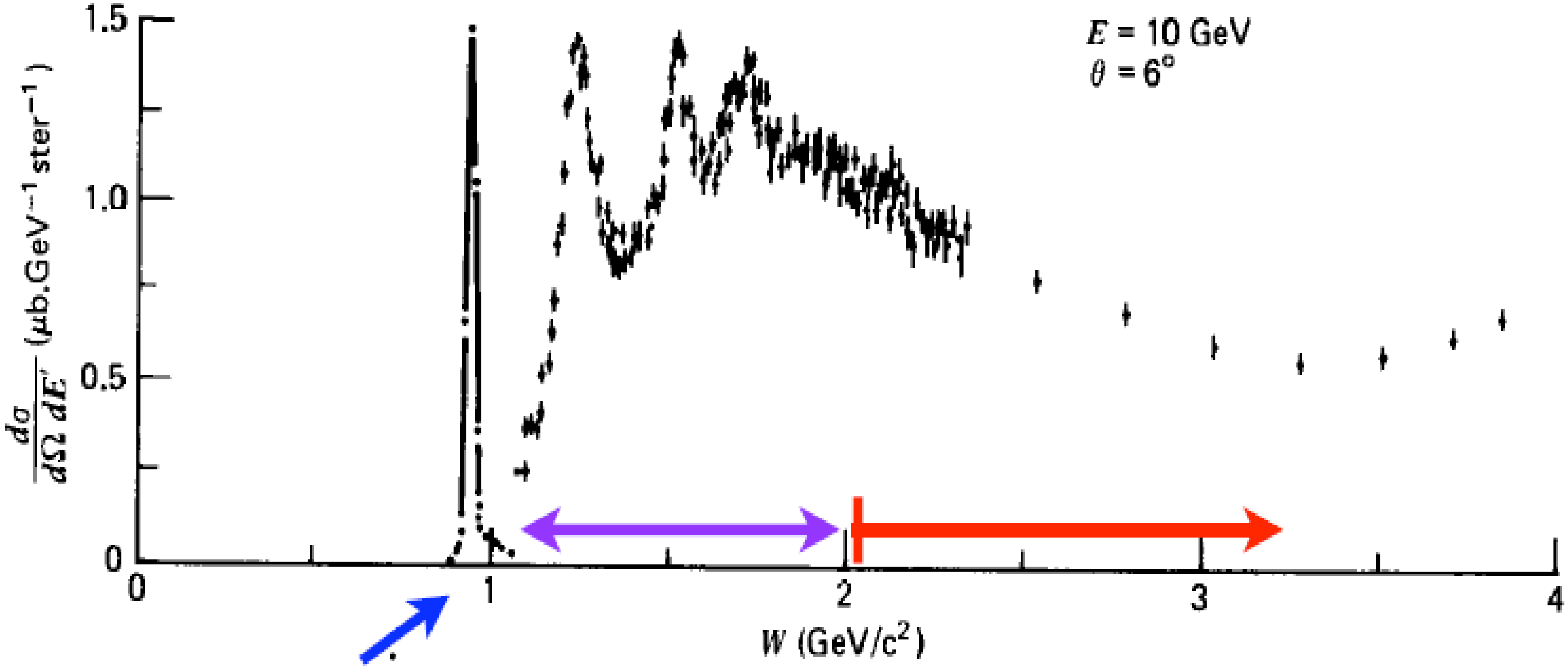


## <u>But</u> DD cannot be calculated in this approach as

- the small-$M^2$ resonance region is not considered
- the SD cross section Is more than the total one, which violates the unitarity

To overcome it we use the idea, that Reggeon-nucleon interaction is similar to deep-inelastic photon-nucleon scattering (DIS), with the replacement :

$$-Q^2 = q^2 \to t \qquad\qquad s = W^2 \to M^2$$




**elastic scattering**
ep → ep

**resonance region**
ep → eΔ, eN*, ...

**DIS regime: W > 2 GeV**
ep → e(X = many hadrons)

# The models that show the unified description:

- The Veneziano model

$$V\,(s,t) \sim s^{\alpha(t)} \quad \text{as} \quad s \rightarrow \infty$$

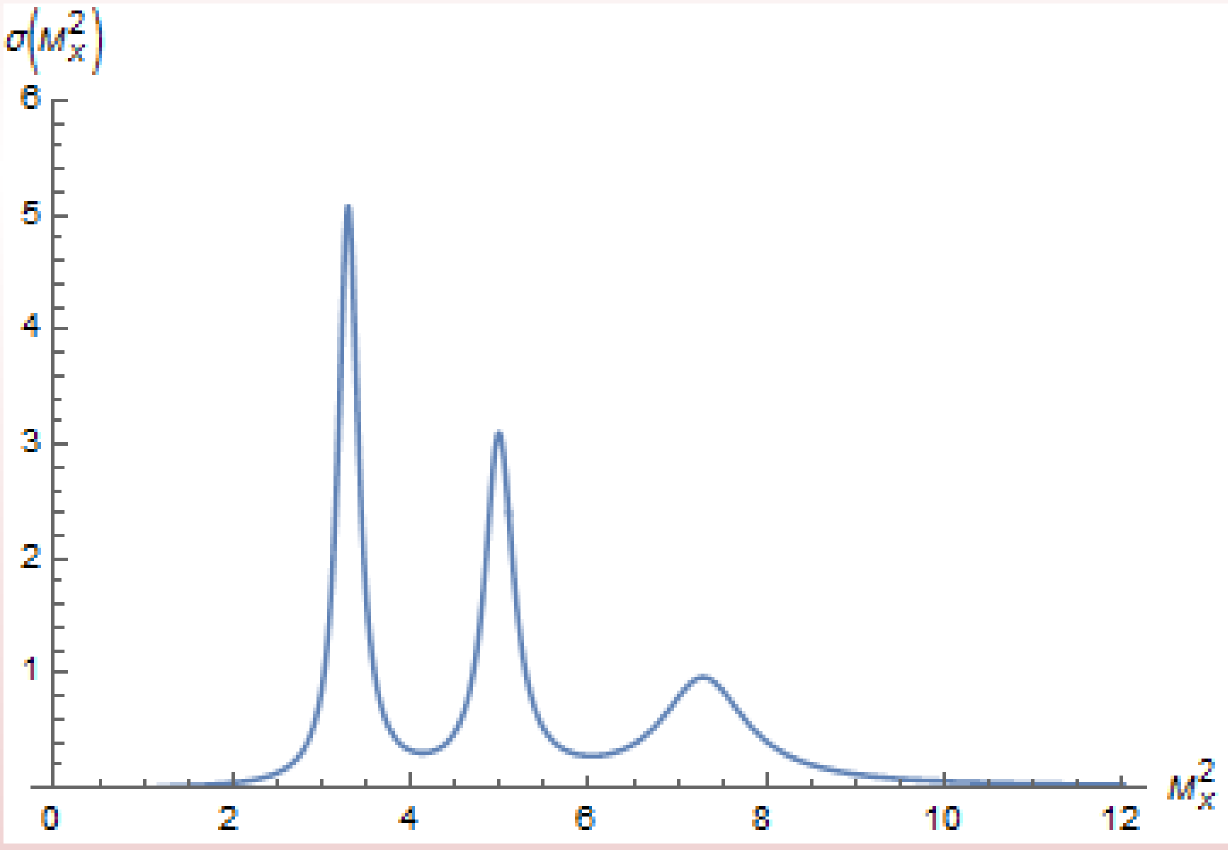
The resonances whose infinite sum gives the Regge behavior are zero width. As a consequence the unitarity is violated.

- Deep Inelastic Scattering (DIS)

Low energies – hadronic properties.

High energies – partonic description.

- At low energies the reactions are characterized by excitation of nucleon resonances and are described in terms of hadronic excitations.
- At high energies a partonic description is more relevant and one sees a smooth curve in the scaling region.



$$\sum_n \frac{[f(Q^2)]^n \ \mathrm{Im}\alpha_s(s(x,Q^2))}{[n-\mathrm{Re}\alpha_s(s(x,Q^2))]^2+\mathrm{Im}\alpha_s(s(x,Q^2))^2}$$

$$\Uparrow_{Q^2\to 0}$$

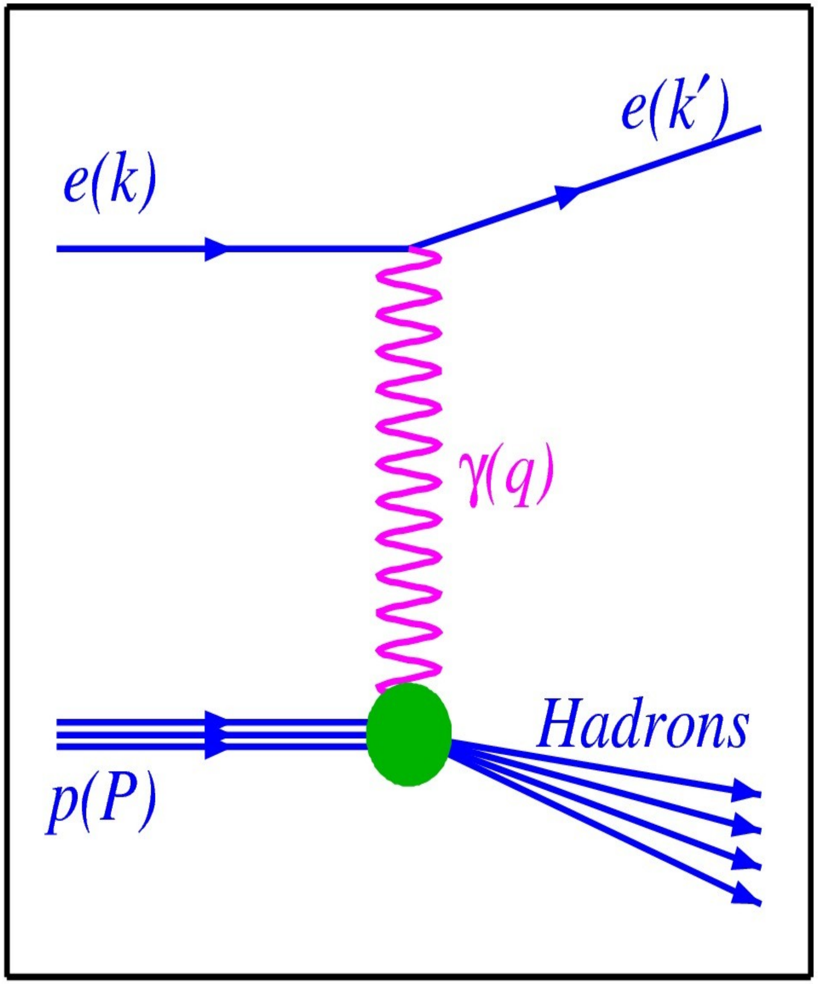
$$F_2(x,Q^2)$$

$$\Downarrow_{Q^2\to\infty}$$

$$(1-x)^{n(Q^2)}.$$

*The result can be summarized by the following formula which relates the structure function at low energy to the resonance expansion of a Veneziano type amplitude and at high energy to the parton model.*

# Kinematics of DIS




$Q^2 = -(k-k')^2$ (momentum transfer) $^2$

$-q^2$ virtuality of γ*

$x = \frac{Q^2}{2\,P\cdot q}$ fraction of the proton momentum carried by the charged part

$s = (k+P)^2$ center of mass energy of system

$W^2 = M_x{}^2 = (P+q)^2$ $(\text{mass})^2$ of γ*p system

The resulting integral representation for M-DAMA is given by

$$D(s,t,Q^2) = \int_0^1 dz \left(\frac{z}{g}\right)^{-\alpha_s(s')-\beta(Q^{2''})-1} \times \left(\frac{1-z}{g}\right)^{-\alpha_t(t'')-\beta(Q^{2'})-1}$$

$\beta\,(Q^2)$ - is a smooth dimensionless function of $Q^2$

*The structure function dependent on $Q^2$:*

$$F_2 \sim s^{\alpha_t(0)+\beta(0)} Q^2 g^{\beta(Q^2)}$$

*For a good asymptotic :* $\beta(0) = -1$

$$\begin{aligned} \beta(Q^2) &= \beta(0) - \gamma \ln\left(\frac{Q^2 + Q_0^2}{Q_0^2}\right) \\ &= -1 - \frac{\alpha_t(0)}{\ln g} \ln\left(\frac{Q^2 + Q_0^2}{Q_0^2}\right) \end{aligned}$$

To simplify, our dual amplitude is a sum of three resonances

$$D(s, t=0, Q^2) \propto \sum_{n=1}^{3} g^{n+1} \left( \frac{g Q_0^2}{Q^2 + Q_0^2} \right)^{\alpha_t(0)} \frac{1}{n - \alpha_s(s) + 1}$$

The Regge trajectory is assumed to be linear

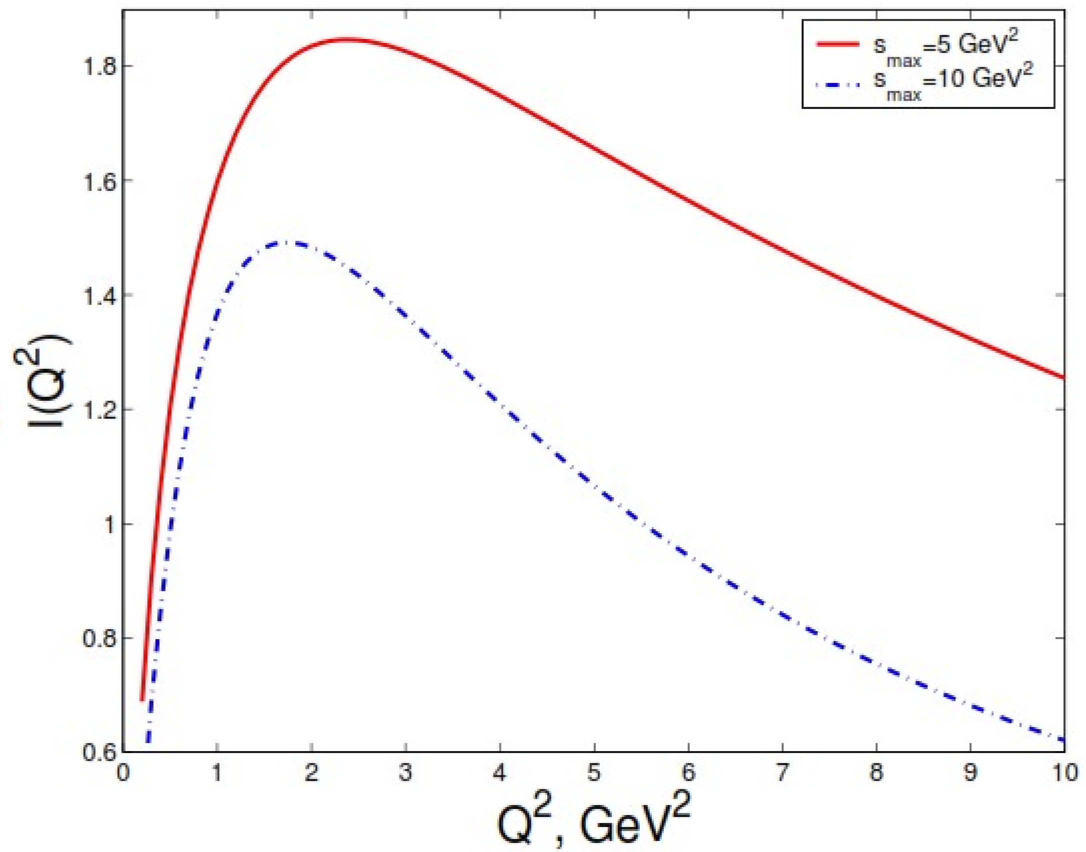
$$\alpha(s) = \alpha_0 + \alpha_1 s + \alpha_2 (\sqrt{s_0} - \sqrt{s_0 - s})$$

with a square root branch point at the pion – proton threshold

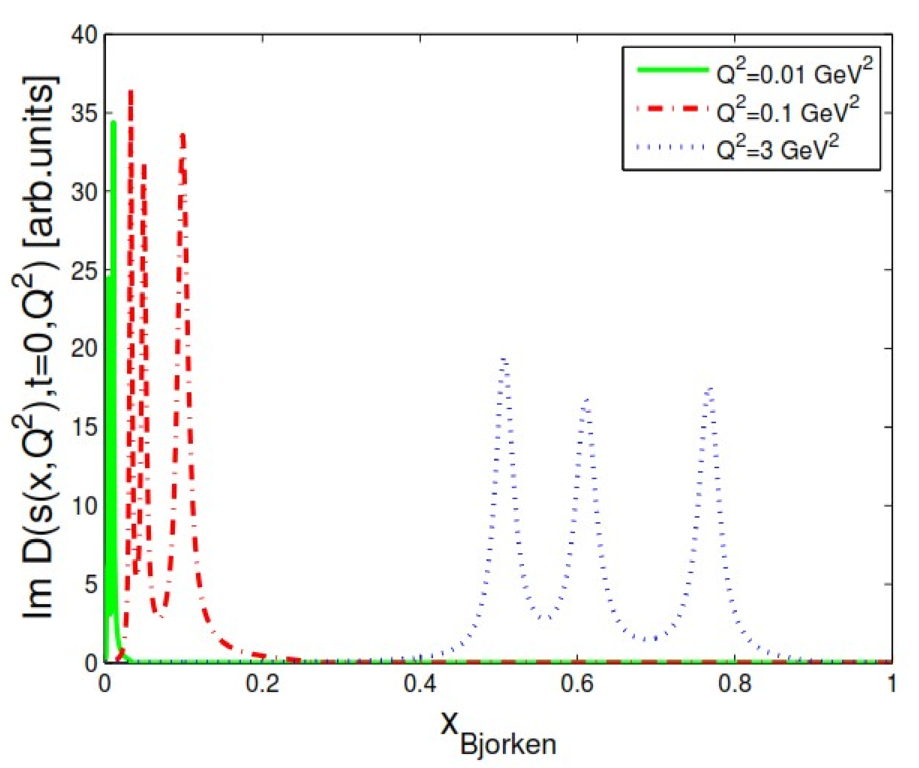
$$s_0 = (m_\pi + m_p)^2$$

$$I(Q^2) = \frac{I_{Res}}{I_{Scaling}}$$

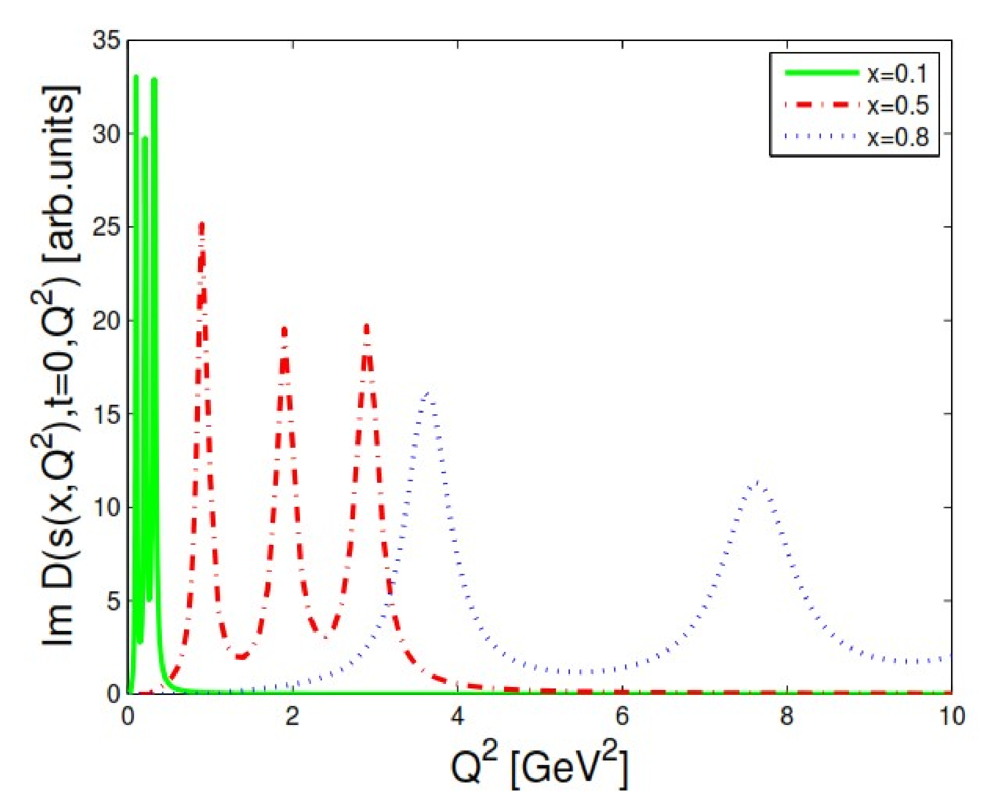
$$I_{scaling}(Q^2) = \int_{s_{min}}^{s_{max}} ds\ F_2^{scaling}$$
$$I_{Res}(Q^2) = \int_{s_{min}}^{s_{max}} ds\ F_2^{Res} ,$$




Global parton-hadron duality for different values of $s_{max}$



Q$^2$=0.01 GeV$^2$
Q$^2$=0.1 GeV$^2$
Q$^2$=3 GeV$^2$
Im D(s(x,Q$^2$),t=0,Q$^2$) [arb.units]
x$_{Bjorken}$

x=0.1
x=0.5
x=0.8
Im D(s(x,Q$^2$),t=0,Q$^2$) [arb.units]
Q$^2$ [GeV$^2$]

# Literature

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3. E.D. Bloom and E.J. Gilman, Phys. Rev. Lett. 25, 1149 (1970); Phys. Rev. D 4, 2901 (1971).;
4. Barone V., Predazzi E. High-Energy particle diffraction (Springer 2002)(ISBN
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