Reflective scattering at the LHC and two–scale structure of a proton

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Overview

Abstract

- We discuss interpretation of the reflective scattering mode connecting its appearance with a resolution of a two–scale structure of a proton revealed in the DVCS process at Jefferson laboratory and in the differential cross–section of elastic *pp*–scattering at the LHC at the energy of $\sqrt{s} = 13$ TeV.

Introduction. The reflective scattering mode

- $$S(s,b) = \kappa(s,b)\exp[2i\delta(s,b)] \qquad (1)$$

- $$S_l(s) = 1 + 2if_l(s), \qquad (2)$$

- $$\mathrm{Im} f_l(s) = |f_l(s)|^2 + h_{l,inel}(s) \qquad (3)$$

- $$\kappa^2(s,b) = 1 - 4h_{inel}(s,b), \qquad (4)$$

- $$(\mathrm{Im} f - 1/2)^2 + (\mathrm{Re} f)^2 \simeq 0. \qquad (5)$$

The impact parameter b, $b = 2l/\sqrt{s}$, is a conserved quantity at high energies.

Reflective scattering mode

- $f(s,b)$: interval $0 \le f \le 1$, $f = 1/2$ – complete absorption of the initial state, i.e. $S = 0$
  $h_{el} \le 1$, $h_{inel} \le 1/4$.
  Absorptive scattering mode – $0 < f \le 1/2$, reflective scattering mode $1/2 < f \le 1$.

Picture of a proton in soft processes

- Nonperturbative sector of QCD. In this regime QCD should provide the two important phenomena: confinement (scale $\Lambda_{QCD} = 100 - 300$ MeV) and spontaneous breaking of chiral symmetry ($\Lambda_\chi \simeq 4\pi f_\pi \simeq 1$ GeV). Chiral symmetry is spontaneously broken between these two scales and this breaking generates quark masses. Since the soft hadron interactions occur at the distances where chiral symmetry is spontaneously broken one can conclude that a major role in such interactions belongs to constituent quarks which are the colored but not pointlike objects. In addition to acquiring the masses, the strong interaction dynamics provides them with finite sizes, too. Chiral models describe baryon as consisting from an inner core with baryonic charge and an outer cloud surrounding the core. Presence of the inner repulsive core is in agreement with the recent direct DVCS data and with the indirect LHC data at $\sqrt{s} = 13$ TeV.
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$$\mathcal{L}_{eff} = \mathcal{L}_\chi + \mathcal{L}_\mathcal{I} + \mathcal{L}_\mathcal{C}, \qquad (6)$$

Second diffraction cone in $d\sigma/dt$ as a result of the proton's cores interaction.

- One can consider the two exponential slopes observed in the differential cross-section at the LHC as a consequence of the two–component structure of a proton. The idea of a proton core is not new at all, e.g. it has been discussed by Orear. A core is a typical feature of various chiral models representing baryon as an inner core carrying baryonic charge and an outer cloud.
- At low and moderate energies

$$d\sigma/dt \sim \exp(-\tilde{b}_2\sqrt{-t}), \tag{7}$$

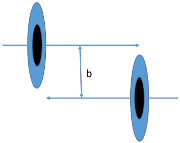
Slopes and radii

$$b_1/b_2 \simeq (r_p/r_c)^2, \quad (8)$$

where r_p is the proton radius and r_c is the radius of its core. From the experimental data at $\sqrt{s} = 13$ TeV

$$r_c \simeq 0.5 r_p$$

Proton in soft processes resembles a hard ball coated with a thick but fragile shell.



Structure and $d\sigma/dt$

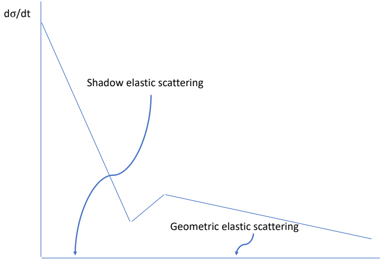


Figure: Two regions of transferred momenta $-t$ (relevant for shadow and geometric elastic scattering) in $d\sigma/dt$ at the LHC energies. The size of shadow scattering region diminishes with energy (decoupling of elastic scattering from multiparticle production) and tends to zero at $s \to \infty$.

Conclusion

- Significance of the "black ring" effect at $\sqrt{s} = 13$ TeV is greater than 5σ, the real part of the scattering amplitude gives a very small contribution as it was expected and does not change the result. Thus, the existence of the "black ring" effect should be considered now as an experimentally established fact. Dip at $b = 0$ becomes a generic property of the inelastic overlap function at high enough energies.
- Notion of core — soft interactions, we do not concern here the hard ones where the parton model of hadrons with perturbative QCD are working well. The problem of transition beetwen these two pictures is correlated with the problem of transition from $\mathcal{L}_{QCD}$ to $\mathcal{L}_{eff}$.
- Hypothesis of maximal importance of elastic scattering, is based on the saturation of unitarity due to a maximal strength of strong interactions. Chew and Frautchi —"strip approximation" .