Reflective scattering: increasing ratio of elastic to total cross–sections and interpretation

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Overview

Abstract

- We discuss energy dependence of σ_{el}/σ_{tot} ratio in proton scattering due to transition to the reflective scattering mode and possible interpretation of this mode

Introduction

- Upper bounds for inelastic cross–section are different compared to the well known Froissart–Martin bound for the total cross-sections. Hint for a different asymptotic energy dependence of the inelastic cross–section compared to the total and elastic ones? Case of the reflective scattering mode ?

- $$S_l(s) = 1 + 2if_l(s), \tag{1}$$

  Unitarity equation:

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

  Unitary upper bound for $[\mathrm{Re} f(s,b)]^2$ is only $1/4$ of the bound for $[\mathrm{Im} f(s,b)]^2$.

- $$h_{inel}(s,b) = f(s,b)(1 - f(s,b)). \tag{3}$$

Absorptive and reflective scattering modes

- $f(s,b)$: 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 $1/2 < f \le 1$.
  Relations in absorptive scattering mode $f \le 1/2$:

$$h_{el}(s,b) \le h_{inel}(s,b) \le 1/4, \tag{4}$$

$$\sigma_{inel}(s) \ge \sigma_{el}(s). \tag{5}$$

- When reflection appears at $b < r(s)$ (high enough energies):

$$\int_{r(s)}^{\infty} bdbh_{el}(s,b) < \int_{r(s)}^{\infty} bdbh_{inel}(s,b) \tag{6}$$

  and

$$\frac{r^2(s)}{2} \ge \int_0^{r(s)} bdbh_{el}(s,b) > \frac{r^2(s)}{8} > \int_0^{r(s)} bdbh_{inel}(s,b). \tag{7}$$

Lower bound for elastic cross–section

- $$\sigma_{el} > \pi r^2(s)$$
  $$r(s) \sim \ln(s)$$
- Bound for inelastic cross–section:
  $$\sigma_{inel}(s) < \sigma_{tot}(s) - \pi r^2(s).$$

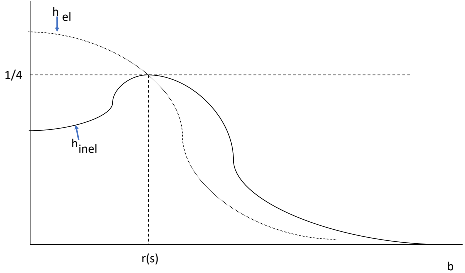

Figure: Schematic representation of the overlap functions $h_{el,inel}$ impact parameter dependencies at the energy $s > s_r$.

Redistribution of probabilities of elastic and inelastic collisions

- Redistribution of probabilities with corresponding decrease with energy of the inelastic interactions' probability at small impact parameters is a result of the reflective scattering mode appearance at the LHC energies. One could expect a speed up of the ratio $\sigma_{el}(s)/\sigma_{tot}(s)$ increase compared to the absorptive mode at lower energies due to starting decrease with energy of the inelastic interaction probability at the point of $b = 0$ and in its vicinity ($S < 0$). The region where reflective scattering mode is expected to give a noticeable contribution corresponds to the LHC energy region. Contrary, one should expect a slow down of the ratio $\sigma_{el}(s)/\sigma_{tot}(s)$ increase at the LHC energies in case of asymptotic saturation of the black disk limit at $s \to \infty$.

Saturation of unitarity

- Chew and Frautchi – Mandelstam representation and principle of maximal strength of strong interaction. Unitarity saturation corresponds to *zeroing the real part* of the partial amplitudes.
- $$f(s,b)=\frac{1}{2}[1-\sqrt{1-4h_{inel}(s,b)}], \qquad (9)$$

  $$f(s,b)=\frac{1}{2}[1+\sqrt{1-4h_{inel}(s,b)}]. \qquad (10)$$

Modes

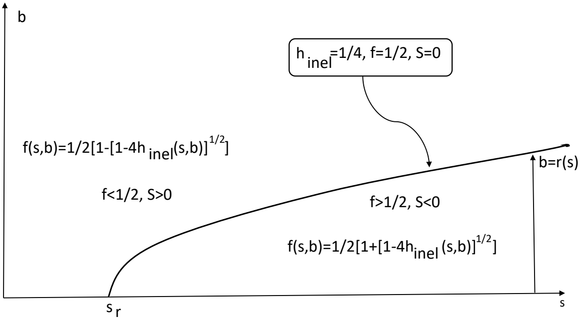

Figure: Schematic representation of the regions in s and b plane corresponding to absorptive ($S > 0$) and reflective ($S < 0$) scattering modes.

Phases

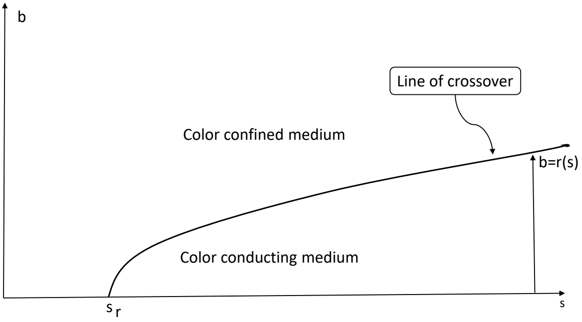

Figure: Two phases of hadronic matter associated with the two respective scattering modes.

Analogies and discussion

- Phase (1/2 of it) δ changes from 0 to $\pi/2$. Optics: phases differ by π. Reflecting medium is optically denser (i.e. it has a higher refractive index than the medium where incoming wave travels before encounter the scatterer). Thus, there is an analogy with the sign change under reflection of the electromagnetic wave by surface of a conductor.
- A reflecting disk surrounded by a black ring.
- Color conducting medium is being formed instead of color insulating one when the energy of the interacting hadrons increases beyond some threshold value.

Core in hadron

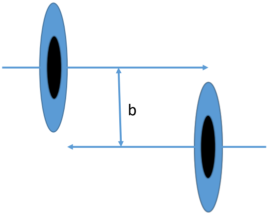

Figure: Schematic view of hadron scattering with the impact parameter b.

Couple of final comments

- There was proposed a possible connection of the reflective scattering mode with formation of color–conducting medium in the intermediate state at high energies and small impact parameter values.
- The dynamics of elastic *pp*–scattering is described by a complex function $F(s,t)$ of the two Mandelstam variables s and t which is a conjugated quantity to b. As it was noted, any quantities integrated over b (i.e. those taken at $-t=0$) are not sensitive to the details of their dependencies on b and/or t, respectively, and therefore they cannot provide required information relevant for the conclusions on the interaction dynamics at available accelerator energies. If one proceeds from the overintegrated quantities the much higher energies are needed for making definite conclusions on the new scattering mode appearance.