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The stationary points and structure of high-energy scattering amplitude

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Abstract

The ISR and the 7 TeV LHC data indicate that the differential cross-section of elastic proton–proton scattering remains almost energy-independent at the transferred momentum $t \approx -0.21\,\text{GeV}^2$ at the level of $\approx 7.5\ \text{mb}/\text{GeV}^2$. This property of $d\sigma/dt$ (the "first" stationary point) appears due to the correlated growth of the total cross-section and the local slope parameter and can be expressed as a relation between the latter quantities. We anticipate that this property will be true up to 13 TeV. This enables us to normalize the preliminary TOTEM data for $d\sigma/dt$ at 13 TeV and $0.05 < |t| < 3.4\,\text{GeV}^2$ and predict the values of $d\sigma/dt$ at this energy. These data give an evidence of the second stationary point at $t \approx -2.3\,\text{GeV}^2$ at the level of $\approx 33\ \text{nb}/\text{GeV}^2$. The energy evolution of $d\sigma/dt$ looks as if the high energy elastic scattering amplitude is a sum of two similar terms. We argue that the existence of the two stationary points and the two-component structure of the high energy elastic scattering amplitude are general properties for all elastic processes.

Keywords: Elastic pp scattering; Differential cross-section; Stationary points; Local slope

1. Introduction

The simplest, at first sight, hadron–hadron elastic scattering process at low transferred momentum is in reality one of the most complicated problems of high energy physics. The properties of the elastic scattering amplitude in this diffraction region are dominated by unknown, essentially nonperturbative properties of the fundamental strong interactions. This is why we do

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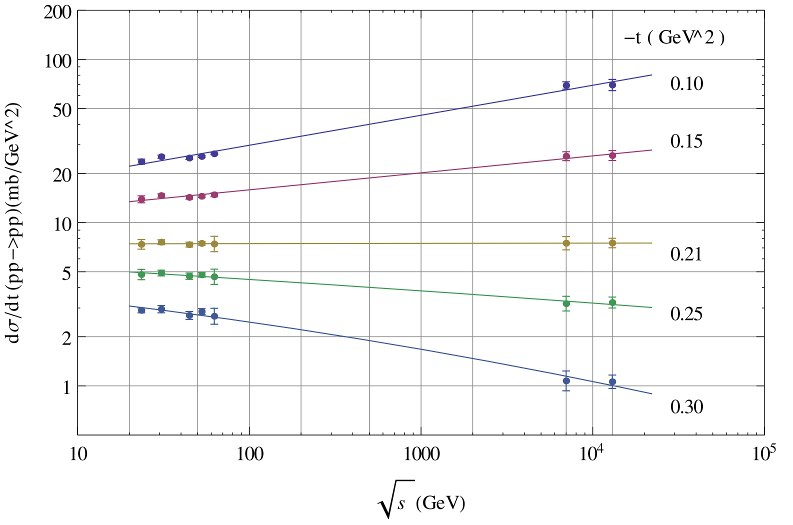

Fig. 1. Energy evolution of the differential cross-section for pp elastic scattering at fixed values of transferred momenta in the vicinity of t_*. The ISR and 7 TeV TOTEM experimental data are from Refs. [1], [2]. The points at $\sqrt{s} = 13$ TeV are the TOTEM preliminary data [11] in our normalization (11), see Table 2.

not have so far an adequate model for the soft hadronic phenomena and why at every generation of accelerators one reveals some new *unexpected* properties of the hadron–hadron elastic scattering.

In the present paper we discuss one of such new unexpected properties of the elastic differential cross-section. In Section 2 it is shown that the ISR and the 7 TeV LHC data give an evidence of the stationary point of $d\sigma/dt$ in the forward peak region. We analyse the nature of this new scaling property which leads to a specific relation between the total cross-section and the mean value of the local slope. In Section 3 we estimate the value of energy at which this new scaling will be broken. Suggesting that the stationarity persists up to 13 TeV we normalize the preliminary 13 TeV TOTEM data and predict the values of $d\sigma/dt$ at this energy. Comparing in Section 4 the behaviour of $d\sigma/dt$ in the region beyond the second maximum at the ISR and LHC energies we have got an evidence of the second stationary point. The existence of two shrinking with energy diffraction cones motivates the two-component structure of the high energy pp elastic scattering amplitude. We argue that the latter are general properties of elastic scattering. A brief summary and discussion are given in Section 5.

2. The first stationary point

Comparing the differential cross-section for pp elastic scattering $d\sigma(s,t)/dt$ at the ISR energies [1] with the 7 TeV LHC data [2] in the forward peak region one can observe that the shrinkage of the diffraction cone in this energy range goes in some specific way. At any fixed value of the transferred momentum $(-t) \in [0, 0.21)$ GeV^2 the differential cross-section grows with energy, while for $(-t) \in (0.21, 0.53)$ GeV^2 it decreases. At $t \approx -0.21$ GeV^2 the differential cross-section remains almost energy-independent at energies from the ISR up to 7 TeV (see Fig. 1). Thus, there is an evidence of *a stationary point* [3] of the differential cross-sections (t_*, σ_*):