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Understanding two slopes in the $pp(p\bar{p})$ differential cross sections

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Recent experiments have discovered two exponents in the pp elastic differential cross sections with two different slope parameters, of the order $(16{-}20)\,\mathrm{GeV}^{-2}$ and $(4{-}4.8)\,\mathrm{GeV}^{-2}$ in the regions $-t \lesssim 0.5\,\mathrm{GeV}^2$ and $-t \gtrsim 1\,\mathrm{GeV}^2$, respectively. We suggest a simple model of the pp elastic scattering with two types of particle exchanges : 1) when the exchanged particle transfers the momentum $\mathbf{Q}$ from a quark of the proton p_1 to one quark in another proton p_2, producing the slope B_1; 2) when the transfer occurs from two quarks in the p_1 to two quarks in the p_2, giving the exponent with the slope B_2. The resulting amplitude is proportional to the product of the form factors of two protons, depending on $\mathbf{Q}$, but with different coefficients in the cases 1) and 2). Using the only parameter – the proton charge radius $r_{ch}^2 = 0.93\,\mathrm{fm}^2$, one obtains $B_1 = 16\,\mathrm{GeV}^{-2}$, $B_2 = 4\,\mathrm{GeV}^{-2}$ with the strict value of the ratio, $\frac{B_1}{B_2} = 4.0$, independent of r_{ch}. These predictions are surprisingly close to the data both in the pp and in the $\bar{p}p$ differential cross sections. Comparison to experimental data reveals that the situation drastically changes from GeV to TeV regions. Indeed, in the TOTEM experiments at $E = 2.76{-}13\,\mathrm{TeV}$ the first slope is changing from 16.8 to $21.4\,\mathrm{GeV}^{-2}$ while the second slope is around $4{-}4.5\,\mathrm{GeV}^{-2}$. A similar situation occurs in the $p - \bar{p}$ scattering in the CDF and E710 collaborations, thus supporting the suggested model in both systems. However at the GeV energies the situation is completely different, which may imply multiple hadron exchanges with less definite structures. The present model also provides an understanding of the value of the first dip separating two slopes. From the glueball (pomeron) exchange diagram between two protons one can derive the position of the dip around $0.5\,\mathrm{GeV}^2$ which is close to the experimental value $(0.46$–$0.6)\,\mathrm{GeV}^2$. The suggested mechanism opens a possibility of explanation and of new questions in the basic theory of high energy hadron-hadron interaction. In particular, the question of the ratio of the inelastic to the elastic cross sections which is decreasing at high energy is remaining unanswered, but the suggested two-slope mechanism is connected to the overlap integral of the initial and final (highly excited) proton wave functions, which may decrease with higher energy and more distorted excited (inelastic) wave functions. A discussion of the resulting picture in connection with the proposed theoretical models is given.

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