Measurement of the slope parameter of the diffraction cone of elastic *pp* scattering in the energy region 650–1000 MeV

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The absolute differential cross sections of elastic *pp* scattering in the momentum-transfer range $0.006 \lesssim |t| \lesssim 0.04$ (GeV/*c*)^2 in the energy region 650–1000 MeV were measured. The energy dependence of the slope parameter of the diffraction cone was determined and the contribution of the spin amplitudes to the elastic forward *pp* scattering was estimated.

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The existence of dibaryon resonances has been discussed for some time past. This problem has arisen in connection with the experiments conducted in Argonne National Laboratory.[1] The energy dependence of the difference in the total cross sections of *pp* scattering in the states with a different polarization of the beam and target was measured in these experiments. An analysis[2,3] of the data obtained at ANL favors the existence of dibaryon resonances. The authors of other articles,[4] however, account for these data without the assumption of the existence of resonances. Additional experiments must be conducted in order to clarify this situation.

The available experimental data for the slope parameter of the diffraction cone in elastic $\Pi^{\pm}p$ and K^-p scattering show[5] that it increases at energies corresponding to the locations of known resonances; moreover, the slope increases with increasing spin and elasticity of the resonance. Lasinski *et al.*[5] proposed a model, according to which the resonance variation of the slope parameter is related to the resonance parameters by the approximate formula

$$\Delta b\,(E_0) \approx \frac{2\pi(2J+1)}{k^2\sigma_{tot}}\,0.4\left(\frac{l(l+1)}{2k^2} - b_b\right)x, \qquad (\mathrm{GeV}/c)^{-2}, \tag{1}$$

where Δb is the increase of the slope parameter relative to the diffraction background in the resonance region, J and l are the spin and orbital angular momentum of the resonance, b_b is the slope parameter of the diffraction background, σ_{tot} is the total interaction cross section (mb), k is the center-of-mass momentum (GeV/*c*), $x = \Gamma_{el}/\Gamma$ is the resonance elasticity, and E_0 is the resonance energy. This model describes satisfactorily the experimental data for K^-p scattering. The existence of the $^3F_3$ (2260) resonance at an energy of about 800 MeV with an elasticity $x \approx 0.2$ can be predicted from the data of the ANL group. An estimate obtained by using Eq. (1) in this case gives $\Delta b \approx 2$ (GeV/*c*)^2. The behavior of the slope parameter of elastic *pp* scattering in the energy region of the predicted resonance is worth investigating. The slope

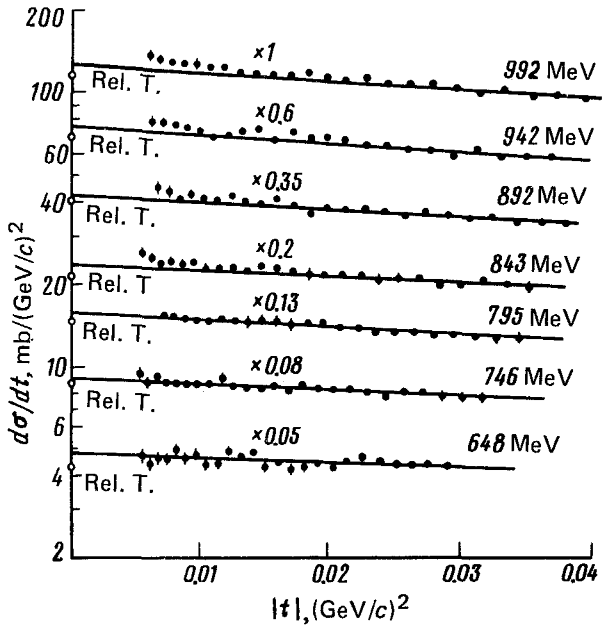

FIG. 1. Measured differential cross sections. The straight lines represent a contribution to differential cross sections of nuclear interaction [the first term in Eq. (2)].

parameter for small $|t|$ heretofore has not been measured systematically in this energy region.

Using the method of simultaneous recording of a scattered particle and a recoil proton, we have measured the absolute differential cross sections of elastic pp scattering in the region $0.006 \leqslant |t| \leqslant 0.04$ (GeV/c)^2 at incident-proton energies 648, 746, 795, 843, 892, 942, and 992 MeV. The accuracy of absolute normalization was 2%. The experimental setup and measurement methods were described in Ref. 6. Figure 1 shows the measured differential cross sections. The experimental data were fitted

TABLE I. Fitting parameters.

T_0	σ_{pp}	ρ	β	$\Delta\beta$	b	Δb	$\langle t \rangle$
MeV	mb	–	–	–	(GeV/c)$^{-2}$	(GeV/c)$^{-2}$	(GeV/c)^2
992	47,5	–0,178	0,025	±0,022	6.24	±0,37	0,0227
942	47,5	–0,148	0,040	±0,030	6.49	±0,60	0,0216
892	47,5	–0,108	0,017	±0,025	5.53	±0,46	0,0223
843	47,4	–0,06	0,026	±0,022	4.88	±0,45	0,0204
795	47,1	0,0	0,063	±0,022	5.83	±0,39	0,0208
746	46,3	0,065	0,026	±0,023	4.42	±0,51	0,0185
648	41,1	0,202	0,096	±0,030	3.56	±1,09	0,0174

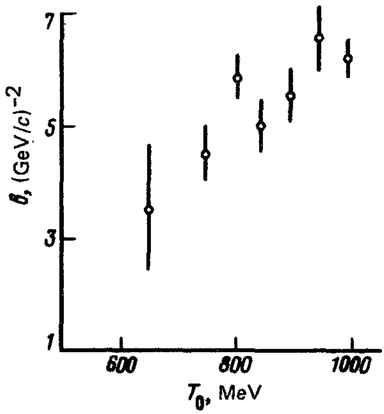

FIG. 2. Energy dependence of the slope parameter of the diffraction cone.

by using an interference formula

$$\frac{d\sigma}{dt} = N\left[\frac{\sigma_{pp}^2}{16\pi\hbar^2}(1+\rho^2+\beta)\,e^{bt} + \frac{4\pi\alpha^2\hbar^2}{\beta_p^2 t^2}G_p^4(t) - \frac{\sigma_{pp}\alpha}{\beta_p|t|}G_p^2(t)(\rho\cos\delta + \sin\delta)\,e^{bt/2}\right] \mathrm{mb}/(\mathrm{GeV}/c)^2, \qquad (2)$$

where σ_{pp} is the total pp scattering cross section, $\alpha = 1/137$, β_p is the proton velocity in the laboratory system, $G_p(t) = (1+|t|/0.71)^{-2}$ is the proton form factor, b is the slope parameter of the diffraction cone,

$$\delta = -\frac{\alpha}{\beta_p}\left[\ln((b/2 + r_p^2/3)|t|) + 0.577\right]$$ – Bethe's phase (Ref. 7),

and $r_p = 0.8$ F is the rms electric radius of a proton. The parameters $\rho = \mathrm{Re}A(0)/\mathrm{Im}A(0)$ and $\beta = [2|B(0)|^2 + |E(0)|^2]/[\mathrm{Im}A(0)]^2$ were determined in accordance with the parametrization of the strong-interaction amplitude in the form

$$f(t) = A(t) + B(t)\sigma_{1n}\sigma_{2n} + C(t)(\sigma_{1n} + \sigma_{2n}) + D(t)\sigma_{1m}\sigma_{2m} + E(t)\sigma_{1l}\sigma_{2l}.$$

The parameters b and β were found by using the method of least squares. The σ_{pp} cross sections were determined by interpolating the available experimental data. We used the value of ρ, calculated in Ref. 2 on the basis of the dispersion relations. The sensitivity to ρ and σ_{pp} of the specified b and β parameters was tested. A 0.01 variation of ρ increases b by 0.1 $(\mathrm{GeV}/c)^{-2}$ and β by 0.008, while a 1% variation of σ_{pp} changes b by -0.016 $(\mathrm{GeV}/c)^{-2}$ and β by -0.022. The normalization coefficient N was assumed to be an experimental point with a specified error $N = 1.00 \pm 0.02$. The values of b and β parameters and their statistical errors are given in Table I.

The energy dependence of the slope parameter of the diffraction cone (Fig. 2) shows no evidence of a pronounced resonance structure. A certain irregularity in the 800-MeV region can hardly be an indication of the manifestation of a diproton resonance $^3F_3$ (2260).

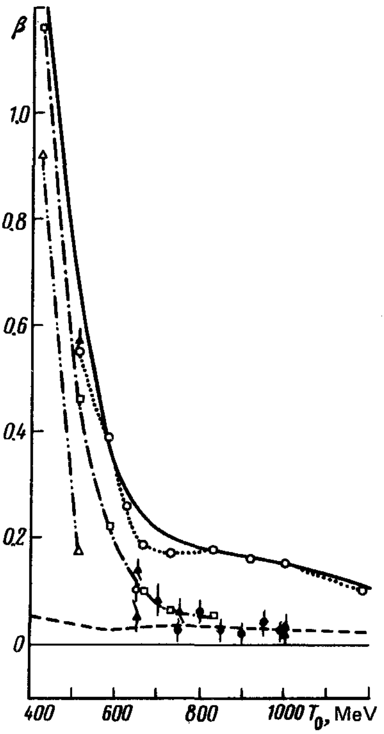

FIG. 3. The values of β parameter which takes into account the relative contribution of spin-spin interaction to the cross section of elastic forward *pp* scattering. ●, our experiment; ▲, results of Ref. 8. The solid curve represents the result of a calculation of the dispersion relations using the β method.[2] The dashed line denotes the value of $\beta_{\min}$, which is governed by the imaginary parts of the spin-spin amplitudes taken from Ref. 1,

$$\beta_{min} = \frac{2\,|\,\mathrm{Im}\,B\,(0)\,|^2 + |\,\mathrm{Im}\,E\,(0)\,|^2}{(\mathrm{Im}\,A\,(0)\,)^2}\,.$$

□, △, and ○ are the values of β, which were calculated from the phase analyses of Arndt *et al.*,[9] respectively. For a comparison, curves have been drawn through the points of the phase analyses.

The obtained values of β confirm the conclusion reached by Velichko *et al.*[8] that the spin-spin interaction contributes little to the elastic forward *pp* scattering at higher incident-proton energies than 650 MeV. Figure 3 shows the values of β obtained by us together with the data of Ref. 8. It also shows the values of β calculated by using the *NN* amplitudes,[9] which were reconstructed from the results of different phase analyses. The solid curve represents the result of a calculation of β by using the method of dispersion relations[2] and the dashed curve denotes the lower limit of β, which is governed by the imaginary parts of the spin-spin amplitudes obtained in the ANL experiments.[1] We can see that the measured values of β parameter disagree systematically with those calculated by using the dispersion relations. This discrepancy is apparently attributable to the fact that the available experimental data are insufficient to calculate the spin-spin amplitudes correctly.

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