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PROTON-PROTON ELASTIC SCATTERING ANALYSIS AT 8.5 BEV

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An investigation of elastic proton-proton scattering at 8.5 BeV revealed the inconsistence of the measured center of mass differential cross section with that calculated for an optical model of a purely absorbing nucleon /1/,/2/.

The experimental results may be satisfied with an optical model of a uniform spherical absorbing and refracting nucleon with sharp boundaries, the optical parameter being as large as $R \simeq (1.5 \div 1.7) \cdot 10^{-13}$ cm, (the spins of the colliding nucleons are neglected /2/) It would be of interest to investigate the role and the magnitude of spin dependent interactions at 8.5 BeV.

This may be performed, in the simplest way assuming the phase shifts to be purely imaginary and the reaction matrix to be independent of the total angular momentum /3/.

Then the difference in the scattering amplitudes in the singlet and triplet states is due to the spin interaction of a central character, depending only on the mutual orientation of nucleon spins. In this approximation a phase shift analysis of elastic p-p scattering was made at 8.5 BeV for $\ell_{max} = 15$.

Let us try as in /3/ to approximate the experimental points by a function

$$\frac{d\sigma(\theta)}{d\Omega} = \left(b^2\cos^2\theta + c^2\right)\left[\frac{1}{a^2-\cos^2\theta} - \frac{1}{a^2}\right]^2 \qquad (1)$$

The relationship between the parameter a and the upper limits of the parameters b and c is defined by the following condition[1])

$$0 \le \eta_\ell \le 1 \qquad (2)$$

According to /3/

$$\eta_\ell = 1 - 2k_0 Q_\ell''$$

$$Q_\ell'' = 2c\left[\frac{Q_\ell(a)}{a} - \frac{\delta_{\ell 0}}{a^2}\right] \qquad \ell = 0,2,4,\dots,14 \qquad (3)$$

$$\eta_\ell = 1 - \frac{2k_0}{\sqrt{3}} Q_\ell''$$

$$Q_\ell'' = 2b\left[Q_\ell(a) - \frac{\delta_{\ell,1}}{3a^2}\right] \qquad \ell = 1,3,5,\dots,15$$

Here k_0 is the incident proton wave number in the c.m.s., $Q_\ell(a)$ -Legendre functions of the second kind for $a > 1$. As far as $Q_\ell(a)$ with the increasing ℓ decreases monotonically,

1/ For the purely imaginary phase shifts $\eta_\ell = e^{i2\delta_\ell}$; $\delta_\ell = i x_\ell$; $x_\ell \ge 0$; i.e. $0 \le \eta_\ell = e^{-2x_\ell} \le 1$

remaining at the same time positive, condition (2) is to be fulfulled first of all for $\ell = 0$ and for $\ell = 1$ ($Q_{\ell}(a)_{\ell=0 \div 15} > 0$). The parameters c and b obtained from this condition are at the same time the largest ones for the given value of a .

$$C_{max} \leq \frac{1}{4k_0\left[\frac{Q_0(a)}{a} - \frac{1}{a^2}\right]} \qquad (4)$$

$$b_{max} \leq \frac{\sqrt{3}}{4k_0\left[Q_1(a) - \frac{1}{3a^2}\right]}$$

For each set of a, b, c, η_ℓ and $\frac{d\sigma(\theta)}{d\Omega}$ were calculated. The total elastic and inelastic cross sections were calculated from the following formulae

$$\sigma_{et} = \frac{\pi}{k_0^2}\sum_{\ell=0}^{15}(2\ell+1)Q_\ell''^2$$

$$\sigma_{it} = \frac{\pi}{4k_0^2}\sum_{\ell=0}^{14}(2\ell+1)(1-\eta^2_{\ell_{even}}) + \frac{3\pi}{4k_0^2}\sum_{\ell=1}^{15}(2\ell+1)(1-\eta^2_{\ell_{odd}}) \qquad (5)$$

The calculated values of σ_{et} and σ_{it} as a function of the parameter a (and for the corresponding values of b and c) are shown in fig. 1 and 2. It follows from here that the best agreement of the calculated values of σ_{et} and σ_{it} with the experimental ones $\sigma_{et} = (8.6 \pm 0.8)$mb /2/ and $\sigma_t = 31$ mb /4/ is obtained by the following set of parameters a = 1.001, b = 1.73. 10^{-15}cm, c = 0.88 . 10^{-15} cm for which the calculated total cross sections are correspondingly $\sigma'_{et} = 8$ mb, $\sigma_{it} = 25{,}5$ mb and $\sigma_t = 33.5$ mb. However, from fig. 3 it is clear that none of the sets of a, b, c including that the cited above satisfy the experimental c.m.s. differential cross section.. When approximating the experimental points by the best fit curve of the form (1) (a = 1.01,$b^2 = 41.7\mu b$ $c^2 = 41.5\mu b$) one obtains

$\eta_{\ell=0,2,4,6} < 0$ $|\eta_{\ell=0,2,4}| > 1$ and $\eta_{\ell=1,3} < 0$ in contradiction with condition (2). In order to investigate the influence of the form of the approximating curve the phase shift analysis was performed for the approximating curve of the form

$$\frac{d\sigma(\theta)}{d\Omega} = \left[A^2 + B^2\cos^2\theta + C^2\cos^4\theta + D^2\cos^6\theta\right]\left[\frac{1}{a^2-\cos^2\theta} - \frac{1}{a^2}\right]^2 \qquad (5)$$

$$C^2 = 23D$$

Then conditions (4) take the following form

$$1-\eta_{\ell_{even}} = 4k_0\left[\frac{Q_\ell(a)}{a} - \frac{\delta_{\ell,0}}{a^2}\right] A_{max} \leq 1$$

$$1-\eta_{\ell_{odd}} = \frac{4k_0}{\sqrt{3}}\left(B_{max} + a^2 D_{max}\right)\left[Q_{\ell_{odd}}(a) - \frac{2\delta_{\ell,1}}{3a^2}\right] - \frac{2k_0 D_{max}}{a^2\sqrt{3}}\int_{-1}^{+1} x^3 P_\ell(x)\,dx \leq 1 \qquad (6)$$

$$x = \cos\theta$$

The second term in the last inequality with the increasing ℓ decreases more rapidly than the first one, so that $1-\eta > 0$ for all $\ell = 1 \div 15$. The coefficients $A = 3.38 \cdot 10^{-15}$cm, $B = 2 \cdot 10^{-15}$cm, $D = 6 \cdot 10^{-15}$cm found from the experiment do not satisfy (6) in contradiction with condition (2).

A similar situation takes place for an approximating curve of the form

$$\frac{d\sigma(\theta)}{d\Omega} = \alpha^2\left(\frac{1}{a^2-\cos^2\theta} - \frac{1}{a^2}\right)^2$$

$$\alpha = 8{,}68 \cdot 10^{-15}\ \text{cm}$$

In conclusion one may state that it is impossible to describe the results of the experiment / 1 /, / 2 / by a model of a purely absorbing nucleon with account of the spin-spin interaction in the approximation of / 3 /.

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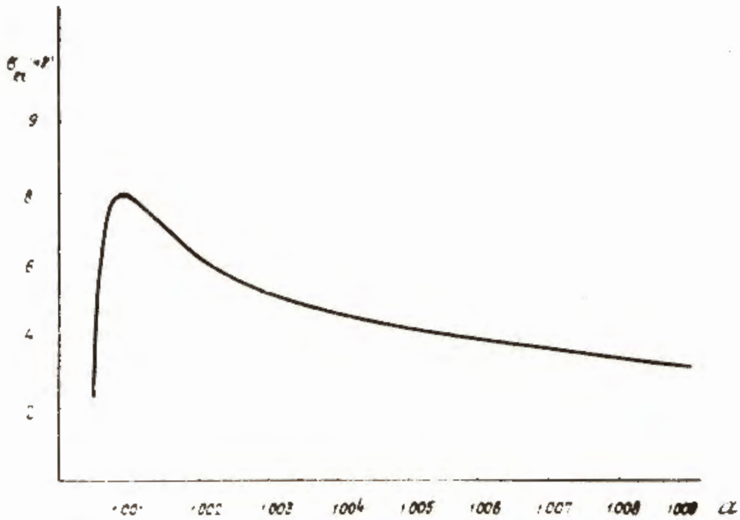
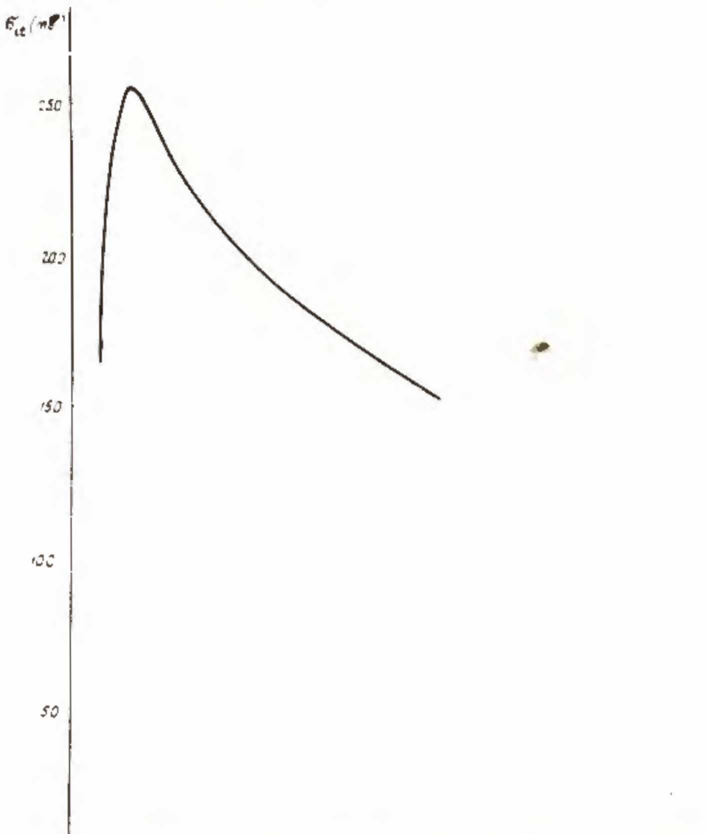
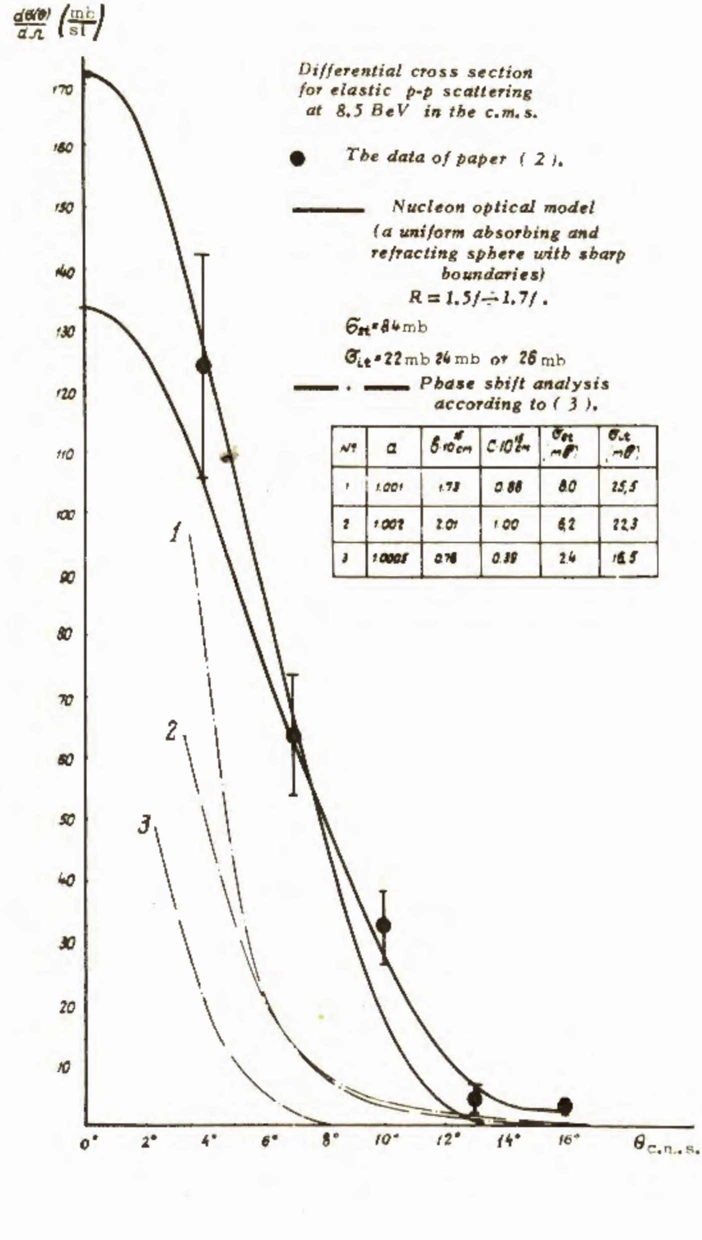


F i g. 1. The calculated values of the total cross section for the elastic proton–proton interaction at 8.5 BeV as a function of the values for the parameter a.



F i g. 2. The calculated values of the total cross section for the inelastic proton–proton interaction at 8.5 BeV as a function of the values for the parameter a.



№	a	$b\cdot10^{-14}$ cm	$C\cdot10^{-14}$ cm	σ_{el} mb	σ_{it} mb
1	1.001	1.73	0.88	8.0	25,5
2	1.002	2.01	1.00	6,2	22,3
3	1.0005	0.76	0.39	2.4	16.5

Fig. 3. The experimental and calculated differential cross sections for elastic proton–proton scattering at 8.5 BeV in the c.m.s.

REFERENCES

1. V.B. Luibimov, P.K. Markov, E.N. Tzyganov, Chen Pu-in, M.G. Shafranova. 'Elastic p-p scattering at 8.5 BeV'. Preprint of JINR.

2. P.K. Markov, E.N. Tzyganov, M.G. Shafranova, B.A. Shahbazyan Report made by V.I.Veksler at the IX Conference on High Energy Physics 'Nucleon-nucleon and Pion-Nucleon Interaction'.

3. D. Ito, S. Minami and H. Tanaka. Nuovo Cimento 8, 135, 1958.

4. N.P. Bogachev, S.A. Bunjatov, I.M. Gramenitsky et al. 'Proton Interaction with Free and Quasifree Nucleons in the photoemulsion'. Preprint. (Report by V.I.Veksler at the IX Conference on High Energy Physics').