THE PROBLEM OF NONSTRANGE BARYON-BARYON RESONANCES

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Two special features are noted of the mechanism for the pp interaction in the region of 300—640 MeV. 1) On the basis of the results of a phenomenological analysis of pp scattering at 640 MeV, carried out on the assumption that strong absorption takes place in $^1D_2$ and $^3P_2$ states of the pp system, it was established that this hypothesis is consistent with all the analyzed data on pp scattering and on the total cross section at an energy of 640 MeV and does not contradict these data. 2) On the basis of an examination of the energy dependence of the partial amplitudes for pp scattering with the aid of Argand diagrams constructed on the basis of phase analysis a conclusion is drawn concerning the possible existence of a resonance in the pp system (i.e., Y = B = 2) with a mass M = 2050 ± 90 MeV and $J^P = 2^+$. Attention is drawn to the fact that the proposed hypothesis agrees with experimental data on the energy dependence of the cross section for singlet pp scattering at an angle of 90° in the c.m.s., which has a peak in the energy region of 300—550 MeV. However, for a final elucidation of the nature of this peak further experimental and theoretical investigations are needed.

N the work of Kondratyuk and Shapiro[1] estimates are given of the partial width for the decay of a hypothetical quasideuteron state[1)] with Y = B = 2, $J^P = 2^+$ and with a mass M = 2160 ± 60 MeV, with the aid of which one could explain the quasiresonance form of the excitation function for the process $pp \to \pi^+ d$ in the neighborhood of 600 MeV. Since these estimates are to a considerable extent based on the results of phase analysis of pp scattering[3] which was carried out on the assumption that the pp system has no resonance states of any kind, it is useful to carry out the phase analysis at 640 MeV anew taking into account the possible resonance effects noted in[1,4].

In the present paper we give the results of a phase analysis for elastic pp scattering at an energy of 6 640 MeV with an artificial introduction of strong absorption in the $^1D_2$ and $^3P_2$ states. The domain of allowable values for the absorption parameters has been determined which does not contradict the whole totality of data on elastic pp scattering and the total cross sections at this energy. A comparison of our results with those available at energies of 50—440 MeV enables us to postulate the existence of a resonance in the pp-system with M = 2050 ± 90 MeV and $J^P = 2^+$.

The analysis was carried out by the method described previously in[3]; meson production was taken into account in $^3P_{0,1,2}$, $^1D_2$, $^3F_{2,3,4}$ and $^1G_4$ states, $l_{max} = 5$. Fixed values from 10 to 90° were assigned to the absorption parameters under investigation $\eta_l^p = \exp(-2\mathrm{Im}\,\delta_{l,p})$, where $\mathrm{Im}\,\delta_{l,p}$ is the imaginary part of the phase shift for angular momentum l and parity $p = \pm 1$. Minimization was carried out with respect to the remaining variables with the aim of obtaining the best value for the agreement criterion. All four solutions of[5] and solutions 5 and 6 of MacGregor et al.[6] were analyzed by the method described above.

The results of the variation are given in Fig. 1. Par-

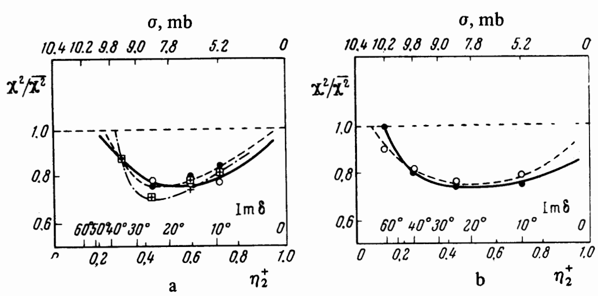

FIG. 1. Dependence of the criterion of agreement $\chi^2/\overline{\chi^2}$ on the value of the absorption parameters: a—in the state $^1D_2$, b—in the state $^3P_2$. The points are solutions from [5]; ○—I, ●—II, □—III, +—IV.

tial inelastic cross sections are also given there. The dependences obtained show quite clearly that the hypothesis of the existence of a strong ($\eta_l^\pm \approx 0$) absorption in the $^1D_2$ and $^3P_2$ states is compatible with all the analyzed data and does not contradict them. The corresponding partial inelastic cross sections for those $\eta_2^\pm$ which give $\chi^2/\overline{\chi^2} \approx 1$ turned out to be practically equal to their unitary limit.

Utilizing more exact values for the inelastic cross sections we have repeated the estimates for the widths of the decay of the resonance with M = 2160 MeV discussed in[1]. Calculations have shown that the new values of the widths for the decay differ somewhat from those obtained in[1], but, as before, there remains a great difference between the calculated and the experimental values. The last circumstance confirms the conclusion made in[1] concerning the impossibility of explaining the energy dependence of the cross section for the process $\pi^+ d \to pp$ in the neighborhood of ~200 MeV by the decay of the resonance with M = 2160 ± 60 MeV and $J^P = 2^+$.

It is characteristic that beginning with $\eta_2^- = 25°$ and $\eta_2^\pm = 25$—$40°$ all the solutions investigated turned into one which is close in terms of its phase shifts to the solution III of[5].

[1)]Sometimes such a state is referred to in the literature as an isonucleus [2] or a resonance in the proton-(3, 3)-isobar system.

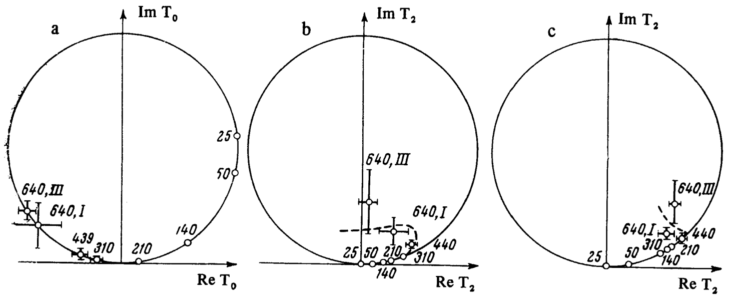

FIG. 2. Argand diagrams for pp-scattering in the region of 25-640 MeV; a—the state $^1S_0$, b-T_2^+, the state $^1D_2$, c-T_2^-, the state $^3P_2$. The numbers adjacent to the points denote the energy in MeV. A, C are the corresponding solutions from [5].

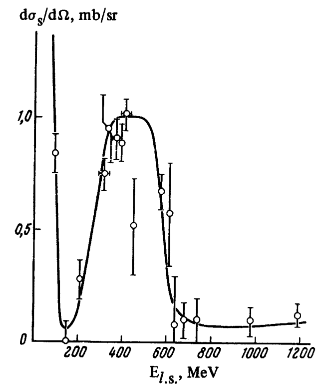

FIG. 3. The energy dependence (in the LS) of the differential cross section for the scattering in the singlet state at an angle of 90° in the c.m.s. in the range 100-1140 MeV. The values of C_{nn} at energies of 575, 680, 735 MeV are averaged over the range of angles 87-95° in the c.m.s. The horizontal bar on some of the points denotes averaging over an interval of energies. The curve has been constructed visually.

An investigation of the energy dependence of the partial amplitudes T_l with the aid of Argand diagrams constructed on the basis of the phase analysis of pp scattering[7] (cf., Fig. 2) shows that in the range of 310—640 MeV the variation in the partial amplitude for the $^1D_2$ state exhibits a nonmonotonic, looplike character with a counterclockwise direction of motion in the complex plane. In accordance with the well-known properties of an Argand diagram[8] and the results of Kondratyuk and Shapiro[1] the circumstance noted by us can testify to the presence of a resonance in the pp-system with a mass 2000 MeV $\leq$ M $\leq$ 2200 MeV and $J^P = 2^+$. The possibility mentioned by us is also supported by the experimental data on the energy dependence of the singlet pp scattering at an angle of 90° in the c.m.s.[2)], which (cf., Fig. 3) has a peak in the energy range 300—550 MeV. According to these data the mass of the supposed resonance is close to 2050 MeV with a half-width of ~90 MeV. In connection with this we note that the total cross sections for meson production in pp collisions at energies of 381, 437, 440, and 485 MeV in accordance with the results of[11] also vary nonmonotonically and are respectively equal to 0.65 ± 0.06, 4.75 ± 0.24, 4.0 ± 1.0 and 3.35 ± 0.33 mb. A similar prominence in the energy dependence of the differential cross section for pp scattering at an angle of 5° in the c.m.s. is observed in the region of 400—560 MeV also according to the data of[12].

Since the presence or absence of resonances in NN systems is fundamentally significant from the point of view of understanding the physics of NN interactions, it is desirable to check our arguments (which are to a certain extent speculative) experimentally. With this aim in mind pp scattering in the energy region 310—550 MeV should be investigated more thoroughly than this has been done to date. In particular, it is useful to remeasure the energy dependences of the singlet and triplet cross sections for elastic NN scattering, of the total cross section and of the differential cross section for pp scattering in the domain of small angles ($\theta \approx 0°—5°$) and to measure the spectrum of effective masses of the pp system in the reaction pp → π^0pp.

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2)The cross section for singlet scattering σ_s was obtained by us in accordance with the formula $2\sigma_s(90°) = \sigma_0(1-C_{nn}(90°))$ where σ_0 is the unpolarized cross section for pp scattering, C_{nn} is the spin correlation coefficient the values of which have been taken from [9,10].

[1] L. A. Kondratyuk and I. S. Shapiro, Proceedings of the School on High Energy Physics, part II, LFTI (Leningrad Physico-technical Institute) 1969; Yad. Fiz. (in press).

[2] G. A. Leksin, Proceedings of the School on High Energy Physics, part I, LFTI (Leningrad Physico-technical Institute) 1968, p. 548.

[3] R. Ya. Zul'karneev, V. S. Kiselev, V. S. Nadezhdin and V. I. Satarov, JINR Preprint, R1-4155, 1968.

[4] F. J. Dyson and Nguen-Huu Xuong, Phys. Rev. Letters 13, 815 (1964); 14, 339 (1965). W. Gale and T. Duck, Nucl. Phys. B8, 109 (1968).

[5] V. G. Vovchenko, R. Ya. Zul'karneev and V. S. Kiselev, Zh. Eksp. Teor. Fiz. 58, 825 (1970) [Sov. Phys.-Phys.-JETP 31,442 (1970)];JINR Preprint R1-4712,1969.

[6] M. MacGregor, P. Arndt and P. Wright, Phys. Rev. 169, 1149 (1968).

[7] R. Wilson, Nucleon-Nucleon Interactions (Russ. Transl., "Mir" 1965, Table 26). L. S. Azhgireĭ, Yad. Fiz. 1, 867 (1965) [Sov. J. Nucl. Phys. 1, 620 (1965)].

[8] R. Tripp, Intern. School of Phys. "Enrico Fermi" 23, 70 (1966).

[9] A. Beretvas, N. E. Booth, C. Dolnik et al., Rev. Mod. Phys. 39, 536 (1967).

[10] R. Wilson, Nucleon-Nucleon Interactions (Russ. Transl., Mir, 1965, Table 18).

[11] H. de Carvalho, H. Heiberg, J. Marshall and L. Marshall, Phys. Rev. 94, 1796 (1954). S. Passman, N. Block and W. Havens, Phys. Rev. 88, 1247 (1952). A. Rosenfeld, Phys. Rev. 96, 130 (1954). B. S. Neganov and O. V. Savchenko, Zh. Eksp. Teor. Fiz. 32, 1265 (1957) [Sov. Phys.-JETP 5, 1033 (1957)]. H. Stadler, Phys. Rev. 96, 496 (1954).

[12] J. Holt, J. Kluyver and J. Moore, Proc. Phys. Soc. 71, 781 (1958), N. P. Boagchev, Dokl. Akad. Nauk SSSR 108, 806 (1956) [Sov. Phys.-Doklady 1, 361 (1957)].

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165