Dibaryon resonances in the π-deuteron channel

K. Kanai
Tokyo Metropolitan University, Tokyo, Japan

A. Minaka and G. Sutieti
Kyushu University, Fukuoka, Japan

A. Nakamura
Waseda University, Tokyo, Japan

(Submitted 10 May 1979)
Pis'ma Zh. Eksp. Teor. Fiz. **30**, No. 2, 133–136 (20 July 1979)

Experimental differential cross section data are analyzed on the basis of the Glauber model for elastic pion-deuteron scattering with dibaryon resonances taken into consideration. The structure observed at 438 and 441 MeV/sec with a minimum in the vicinity of 100° can be interpreted as the result of interference of the amplitude scattering by intranuclear nucleons and the amplitude of the resonance scattering corresponding to the $^3F_3$ dibaryon state.

PACS numbers: 13.75.Gx, 14.20.Gk

Recent experiments with a polarized proton beam and a proton target[1] have yielded evidence favoring the existence of dibaryon resonances. A phase analysis of *pp*-scattering data[2] indicates the existence of a dibaryon resonance in the $^3F_3$ state. In this paper we show that a dibaryon resonance also appears in the elastic scattering of π-deuteron. An analysis of this process of dibaryon resonance formation in the π-deuteron channel can give us abundant information about the properties of dibaryon resonances.

Different methods exist for calculating the amplitude of elastic π-deuteron scattering, in particular—different kinds of multiple scattering theories and the use of Fadeev-type equations. It is well known that the Glauber model,[3,4] among these theories, gives an unexpectedly successful description of the experimental data on pion scattering by deuterons: all the known results at momentums of (0.895–15.2 GeV/sec), 0.245 GeV/sec and 0.29 GeV/sec are reproduced extremely satisfactory.[5–7] However, recent measurements at momentums in the vicinity of 500 MeV/sec [8,9] have revealed some new structure, namely, a deep minimum near 100° (in the center of momentum system), which cannot be explained by using existing theories. We will show that this structure can be satisfactorily explained by the interference of the amplitude of pion scattering by intranuclear nucleons and the dibaryon resonance amplitude in the $^3F_3$ state.

As mentioned above, the Glauber model describes amazingly well the elastic scattering of π-deuteron everywhere, with the exception of the momentum interval near 500 MeV/sec. The reason for this unexpectedly good agreement has been discussed many times. Here we will only touch on this question and we will simply assume that the Glauber model gives the correct background amplitude for the dibaryon resonance scattering of π-deuteron. We will start from the fact that the spiral $f_{\mu\nu}$ of the elastic scattering of π-deuterons is the sum of two terms

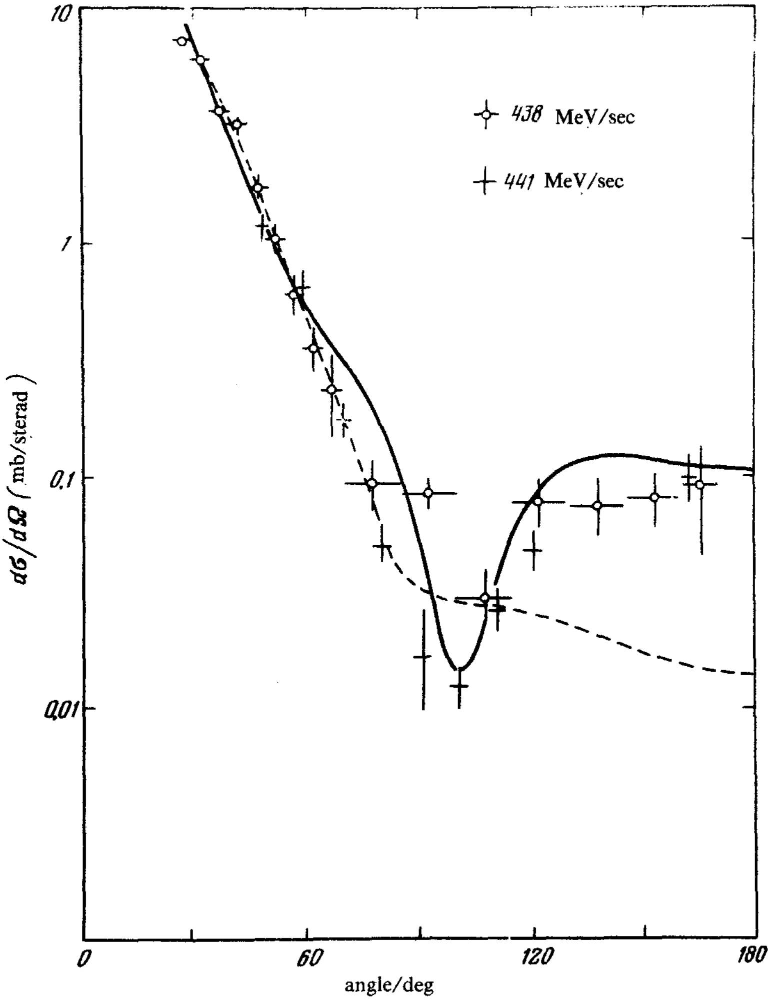

FIG. 1. Differential effective cross section in the center of momentum system for $P_L = 438$ and 441 MeV/sec. Solid and dashed curves are calculations from Glauber model with and without consideration of the $^3F_3$ dibaryon resonance $P_L = 441$ MeV/sec, respectively. The theoretical curves for $P_L = 434$ and 441 MeV/sec practically coincide. The experimental data are from Refs. 8 and 9.

$$f_{\mu\nu} = f^D_{\mu\nu} + f^C_{\mu\nu} . \tag{1}$$

The amplitude $f^D_{\mu\nu}$, corresponding to dibaryon resonance, has the form

$$\begin{aligned} f^D_{\mu\nu} = \frac{1}{2k^*} \sum_J \sum_{L,L'} [(2L+1)(2L'+1)]^{1/2} C^{L'1J}_{0\mu\mu} C^{L1J}_{0\nu\nu} \\ \times \langle JL' | T^J | JL \rangle \exp[i(\nu-\mu)\phi] d^J_{\nu\mu}(\theta), \end{aligned} \tag{2}$$

TABLE I. Dibaryon resonance parameters.

J_r	Mass	Total width	Probability of decay along πd channel	
			D- wave	G- wave
3^-	2.26 GeV	150 MeV	0.0	0.1

where k^* is the momentum (in the center of momentum system) of the dibaryon, $C^{jj'J}_{mm'M}$ are the Klebsh–Gordon coefficients, and the matrix element $\langle JL'|T^J|JL\rangle$ has the Breit–Wigner form. The spiral Glauber amplitude $f^G_{\mu\nu}$ can be obtained from the amplitude $\langle M|T|M'\rangle$, constructed by Michael and Wilkin[3] with the aid of the following transformation

$$f^G_{\mu\nu} = \sum_{M,M'} <\mu|\tilde{R}|M'><M'|T|M><M|R|\nu> \left[\frac{\partial\Omega_{Lab}}{\partial\Omega_{CM}}\right]^{1/2}, \tag{3}$$

$$<\mu|\tilde{R}|M'> = \sum_{\lambda} \exp[-i\phi\mu]\, d^l_{\mu\lambda}(\zeta)\, D^l_{\lambda M'}\left(\frac{\pi}{2}, -\pi, 0\right), \tag{4}$$

$$<M|R|\nu> = D^l_{M\nu}\left(-\frac{\pi}{2}, \zeta, -\phi\right) \tag{5}$$

here ζ is the angle between the bombarding pion and the deuteron recoil momentum in the laboratory system. A detailed derivation of these formulas is contained in Ref. 10. We then use the results of AYED 74 phase analysis of πN-scattering, performed at Saklei, and the Reid potential with a rigid repulsive core for the deuteron wave function. Since the Glauber amplitude contains no free parameters, our spiral amplitude depends only on the parameters of the dibaryon resonance.

The angular distribution for momentums of $P_L = 438, 441$ MeV/sec is shown in Fig. 1, in which curves, calculated for two assumptions—absence and presence of the dibaryon resonance—are compared. The Glauber model (dashed curve) cannot explain the minimum near 100°. This structure, however, can be obtained if dibaryon resonance in the $^3F_3$ state is taken into consideration (solid curve). The resonance parameters, used in our calculations, are listed in Table 1. They are not the optimum. The coupling parameters (amplitudes of D- and G-waves) were assumed to be the actual ones. Let us note that if the contributions of the D- and G- waves in the channel were equal, the πd-minimum in the differential cross section would be shallower.

The scattering of pions by intranuclear nucleons at large angles is heavily suppressed by the nucleon form factor. Therefore, dibaryon resonance can introduce a considerable contribution to the scattering at large angles even in the case when its relative decay probability along the π-deuteron channel is small.

The theoretical calculation with this isolated resonance taken into consideration explains better than expected the experimental data throughout the entire angular interval for bombarding pion momentums of 343, 441 and 537 MeV/sec.[10] The presence of the resonance has very little effect on the angular distribution at 290 MeV /sec[12] which is well described by the Glauber model. These facts can serve as a strong additional argument in favor of the existence of the $^3F_3$ dibaryons. Dibaryon resonance should also appear in experiments with a polarized deuteron target. In this case the calculations of the cross sections, with and without dibaryon resonance taken into account, lead to very different results.

We have also investigated the effect of the hypothetical $^1D_2$ dibaryon resonance (2.16 GeV). We arrived at the conclusion that if it exists, then in any case its relative probability of decay along the π-deuteron channel does not exceed several percent. The angular distribution at a higher energy $P_L = 637$ MeV/sec and the energy dependence of the scattering cross section at 180°[13] indicate the possible presence of another dibaryon resonance with a mass of about 2.5 GeV.

We wish to thank I. I. Strakovskiĭ, who directed our attention to the paper by A. V. Kravtsov and co-authors.

[1] I. P. Auer *et al.*, Phys. Lett. B **70**, 475 (1977); Phys. Rev. Lett. **41**, 354 (1978); K. Hidaka *et al.*, Phys. Lett. B **70**, 479 (1977).
[2] N. Hoshizaki, Prog. Theor. Phys. **58**, 716 (1977).
[3] C. Michael and C. Wilkin, Nucl. Phys. B **11**, 99 (1969).
[4] G. Alberi and L. Bertocchi, Nuovo Cimento A **63**, 285 (1969).
[5] D. V. Bugg, In Proceedings of the Quebec Conference on Few-Body Problems in Nuclear and Particle Physics, 1974, Quebec, Canada, Laval University Press, 1975.
[6] M. M. Hoenig and A. S. Rinat, Phys. Rev. C **10**, 2102 (1974).
[7] L. Bertocchi, In: Methods in Subnuclear Physics, V, edited by M. Nikolic, Gordon and Breach, New York, p. 53.
[8] R. H. Cole *et al.*, Phys. Rev. C **17**, 681 (1978).
[9] A. V. Kravtsov *et al.*, Preprint Leningrad, 426 (1978).
[10] K. Kanai, A. Minaka, A. Nakamura and H. Sumiyoshi, To be Published.
[11] R. V. Reid, Ann. Phys. (N.Y.) **50**, 411 (1968).
[12] J. H. Norem, Nucl. Phys. B **33**, 512 (1971).
[13] L. S. Schroeder *et al.*, Phys. Rev. Lett. **27**, 1813 (1971).