Further Measurements of iT_{11} in π-d_{pol} Scattering as an Investigation of Dibaryon Resonance Effects

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The vector analyzing power (iT_{11}) in elastic π-d_{pol} scattering has been measured for several angles at $T_\pi = 219$, 256, 275, and 294 MeV. Strong oscillations are confirmed at 256 MeV. The data are compared with Faddeev calculations, alone and in combination with either of two resonances. At 219 MeV the Faddeev calculations are consistent with the data, while at the higher energies the general trend of the data favors the admixing of the $^1G_4$ dibaryon resonance. The forward-angle data at 294 MeV are not well described by any existing calculation.

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One of the most interesting questions in intermediate-energy physics today is the existence of dibaryon ($B = 2$) resonances. Invoking quark degrees of freedom, bag-model calculations have predicted states which are believed to be systems of six quarks consisting of colored subclusters. In view of the rather sparse evidence for color the existence of these, possibly narrow, $B = 2$ states should be investigated. There have been a number of attempts to observe $B = 2$ resonance effects in cross-section experiments, but no definite results have been obtained. Since $B = 2$ signals are most likely quite small, one has to employ more sophisticated experiments involving spin observables. Several polarization data sets involving reactions with two baryons have been published in recent years which indicate resonancelike structures. Controversy exists concerning interpretation of these structures as being due to either N-Δ dynamics or dibaryon resonances. For a thorough discussion of the present status of the subject see the reviews of Bugg,[1] Locher,[2] and Schwille.[3]

Previously published data[4] at $T_\pi = 256$ MeV were found to be in surprisingly good agreement with predictions of dibaryon resonance effects in π-d scattering.[5] From this measurement it was concluded that at least one of the three proposed $B = 2$ resonances [$^1D_2(2140)$, $^3F_3(2220)$, and $^1G_4(2430)$] could be responsible for the oscillatory pattern observed in the angular distribution. The energy dependence of the spin observables is the most important piece of information for extracting the relative importance of the individual resonances and for determining their parameters. In this Letter we report the extension of our earlier measurements of iT_{11} to 219, 275, and 294 MeV. In addition we have repeated measurements for three crucial angles at 256 MeV to reconfirm the striking oscillatory pattern.

The configuration of this experiment was identical to that described previously[4]; however, a few elements were improved. A completely new polarized target and superconducting magnet were built; however, the principle of operation, based upon a ^{3}He cryostat, was identical to that for the target used in the previous measurements. The target cell was 18×18 mm in cross section and 5 mm thick. The target material was n-butyl-$d9$ alcohol (98% atomic deuterium) and 5% deuterium oxide, doped with about 1% porphyrexide by weight. A significant improvement was made in the NMR Q-meter circuitry which measured the deuteron polarization in that the solenoidal coil surrounding the target material was replaced by a pancake coil of similar electrical characteristics immersed in the target material. This led to approximately a factor of 2 improvement in the NMR signal strength. As usual, the dynamic polarization was calibrated with respect to the thermal-equilibrium signal at approximately $T = 0.46$ K and magnetic field of 2.5 T. This calibration was repeated three times during the six weeks of experimenting and confirmed a stable polarization of 19.6% ± 1.9%. Tensor alignment components were estimated to be less than 2.9% which results in insignificant corrections to the measurement of iT_{11}.

The vector analyzing power, defined as

$$iT_{11} = \frac{\sqrt{3}}{2}\frac{1}{P}\frac{\sigma_{\uparrow} - \sigma_{\downarrow}}{\sigma_{\downarrow} + \sigma_{\uparrow}} ,$$

where the subscript ↑ indicates the direction of $\vec{k}\times\vec{k}'$ ($\vec{k}$ is the incident-pion momentum and $\vec{k}'$ is the scattered-pion momentum), was determined by measuring the differential cross sections $\sigma_{\uparrow}$ and $\sigma_{\downarrow}$ of elastic π-$d_{\rm pol}$ scattering for the two spin states of a vector-polarized deuteron target of polarization P. The experiment was performed at the high-resolution pion beam and spectrometer facility at the Swiss Institute for Nuclear Research [Schweizerisches Institut für Nuclearforschung (SIN)]. The beam purity, spot definition, and alignment were monitored as in the previous experiment with two in-beam scintillation counters and an out-of-reaction-plane monitor telescope. For all but the most forward angles, the recoil deuteron was detected in coincidence with the scattered pion. A new four-element scintillator telescope was employed which yielded information on the time of flight, energy loss, and total energy of the coincident recoil particles. This gave much better particle identification between protons and deuterons. The solid angle was limited by the pion spectrometer which had an angular acceptance of approximately ± 5 deg. For each angle measured, the analysis was performed upon a variety of subsets of the data in which deuteron recoil requirements were turned off and on and the resolution of the pion channel was varied by requirements on a sixteen-element scintillator hodoscope located at the momentum dispersed, intermediate focus of the pion beam line. Consistent results for each of the data subsets were obtained within the experimental uncertainties. Agreement was required among a variety of fitting methods for extracting the number of counts in the elastic π-d peaks.

The reproducibility of the data at 256 MeV with respect to the previous experiment is good. The new iT_{11} values for $\theta_{\rm c.m.} = 55$, 70, and 100 deg are (21 ± 5)%, (− 5 ± 7)%, and (53 ± 11)% compared with the previous experimental values of (13 ± 6)%, (− 7 ± 10)%, and (42 ± 7)%.

In Fig. 1 we compare all existing data of iT_{11} with the predictions of Grein and Locher.[6] The angular distributions at $T_{\pi} = 142$ and 256 MeV from our previous measurements are included with the present data. In Fig. 1(a) the curves are the iT_{11} calculated by Grein and Locher using the Faddeev partial wave amplitudes of Abishai *et al.*[7] including the effect of pion absorption. At 275 MeV no Faddeev amplitudes were available and so the curve shown is a linear interpolation of the predictions at 256 and 294 MeV. Other Faddeev calculations[8,9] give similar results. Clearly the calculations agree with the data only at 142 and to some extent at 219 MeV. In Fig. 1(b) a comparison is shown with only a $^3F_3(2220)$ dibaryon resonance added to the Faddeev amplitudes. The resonance parameters were the "standard set" of Ref. 5, except for an increase in the channel coupling $\Gamma_{\pi d} = 20$ MeV. The choice of angular momentum mixing used for the calculation was $L_{\pi} = J + 1$ since this leads to stronger oscillations. The value of the mixing parameter, however, was not adjusted to fit the data. Except for the lowest energy there is general disagreement with the data. Similarly, in Fig. 1(c) the data are compared with calculations in which only the $^1G_4$ dibaryon resonance has been taken into account, again with $L_{\pi} = J + 1$. As one can see the general trend of the energy dependence of the data is reproduced semiqualitatively. However, some words of caution seem to be in order. In predicting effects of dibaryon resonances in π-d scattering it has been emphasized that data at forward angles are particularly significant, since

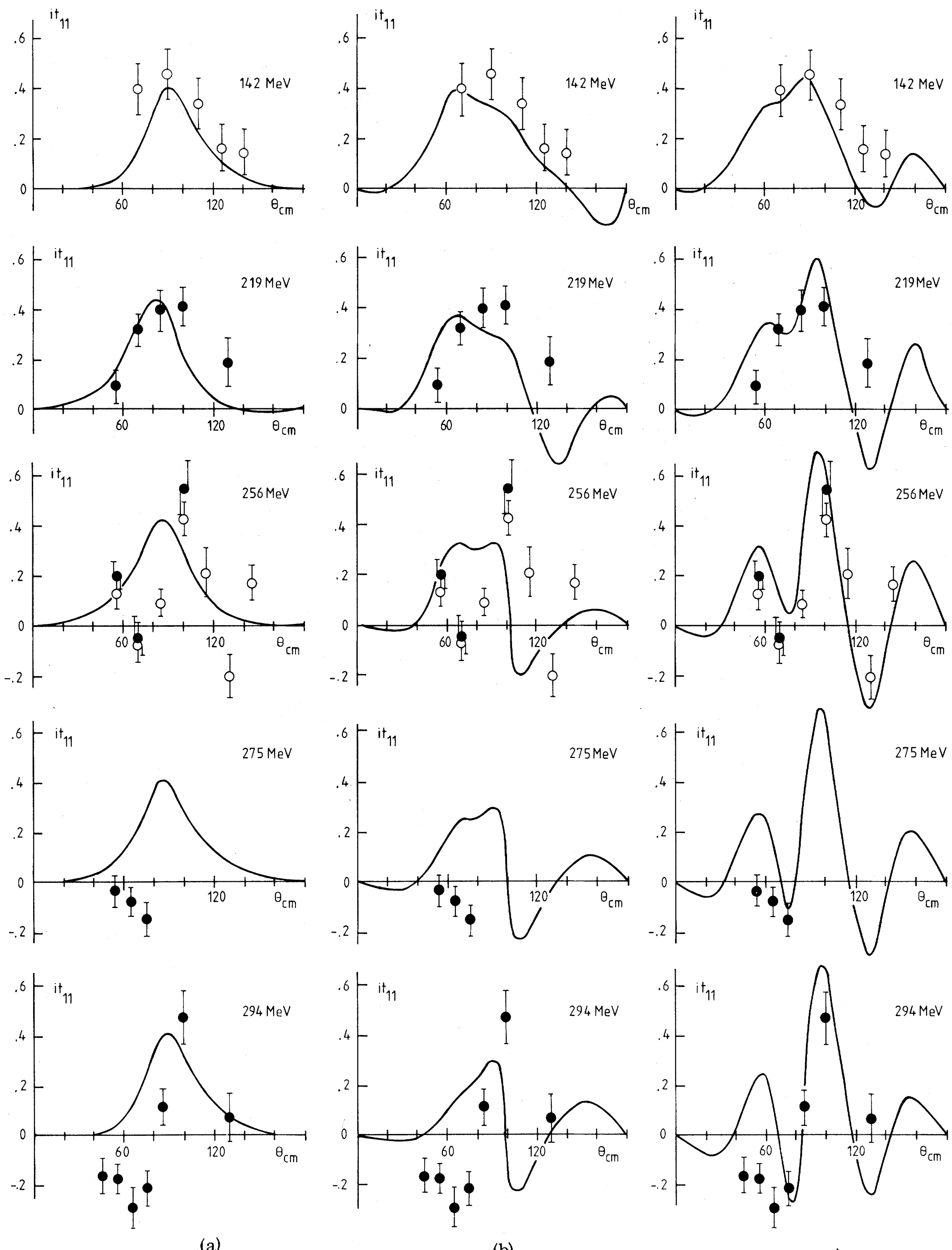

FIG. 1. (a) Energy dependence of iT_{11} where the data of this experiment are plotted as solid dots and the data of Ref. 4 are plotted as open circles. The smooth curves are the results of Faddeev calculations, with pion absorption, obtained from Ref. 7. (b) Comparison of the data to calculations in which the ${}^3F_3(2220)$ dibaryon resonance amplitude with $L_\pi = J+1$ is added to the Faddeev amplitudes which were used to produce the curves of (a). (c) Identical to (b) except the effects of the ${}^1G_4(2430)$ dibaryon resonance with $L_\pi = J+1$ are exhibited instead of the ${}^3F_3(2220)$.

the calculations of "background amplitudes" (Faddeev, impulse, or Glauber approximations) are most reliable in the forward hemisphere. Therefore the discrepancies for the smallest angles at 275 and 294 MeV are serious and still must be explained. On the other hand, when comparing the data with a given set of predictions one should remember that the data were taken with an angular acceptance of almost 10 deg which tends to average out any rapid angular changes. Furthermore the theoretical results also contain uncertainties. There is, for example, the effect of pion absorption which has been demonstrated in Fig. 2 of Ref. 6. Reducing the pion absorption in the Faddeev calculation would lower the second minimum of the oscillation in Fig. 1(c). Variation of the resonance parameters would change details of the oscillatory pattern as well.

In summary, when considering the general trend of the energy dependence of iT_{11} above 219 MeV the closest agreement is obtained in Fig. 1(c), indicating the importance of the $^1G_4$ dibaryon resonance in this energy region. As we have previously stated[4] so far no conventional calculation has been able to reproduce this rapid variation of iT_{11} as a function of angle and energy.

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