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Measurements of iT_{11} in πd Elastic Scattering at 49 MeV

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Abstract

Measurements of the vector analyzing power iT_{11} in πd elastic scattering at 49 MeV have been performed using a dynamically polarized target and a magnetic spectrometer. Data at seven π^+ laboratory scattering angles between 50° and 130° were taken together with a complementary measurement at 60° for $\pi^- d$ elastic scattering. In general, we find agreement with models that include the πN P_{11} amplitude and disagreement with models that exclude or suppress it.

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The method of satisfactorily handling the P_{11} πN intermediate potential in πd elastic scattering has been a central issue for many of the theoretical models. Most resolve this by splitting the P_{11} into its pole (pion absorption) and non-pole (rescattering) components [1,2] with the overall value for the phase of P_{11} being constrained to experiment. However, the pole term is Pauli blocked [3,4] in some waves and when this factor is included most models fail to reproduce the measured observables as well as when it is ignored or when P_{11} is omitted altogether.

To attempt to understand the missing physics that exists between theory and experiment some have added additional higher-order terms to theoretical models. For example, the long-standing discrepancies in the back-angle cross-sections and forward-angle vector analyzing power iT_{11} can be resolved by including short-range $\Delta - N$ interactions [5] and the discrepancies in the tensor analyzing power T_{20} can be largely removed if second order diagrams involving $NN\pi\pi$ intermediate states are introduced [6].

In the low energy regime (below 100 MeV) the P_{33} has a diminished influence and one would expect to be more sensitive to the treatment of the P_{11} interaction. Near 50 MeV the analyzing powers are particularly sensitive to the P_{11} input due to a combination of the above mentioned effect coupled with the observation that the real part of the forward amplitude goes through zero near this energy [7]. For these reasons the vector analyzing power, iT_{11}, was measured for $\pi^+ d$ elastic scattering at 49 MeV over the angular range of 50–130° (lab) [8,9].

In addition to these measurements of iT_{11} with positively charged pions we also undertook to take complimentary data of the $\pi^- d$ elastic system. The interest in measuring this observable with both species of charged pions stemmed from the effect of the Coulomb interactions which cause significant differences at this energy, particularly at forward angles. Indeed, it has been shown that iT_{11} is the most sensitive observable to the Coulomb interactions [10,11]. Other effects, including Charge Symmetry Breaking (CSB), also contribute to the differences between $\pi^+ d$ and $\pi^- d$ elastic scattering.

The measurements were performed at TRIUMF in the M13 channel using a polarized deuterium target [12–14] and the QQD spectrometer [15]. The layout of the experiment is shown in fig. 1. Details of the experimental technique and some of the earlier measurements were reported before [8,9].

Briefly, the target consisted of deuterated butanol immersed in liquid helium coolant and dynamically polarized by microwave radiation. A strong magnetic field (2.6 T), necessary to produce and hold the deuteron polarization states, caused distortion of the pion trajectories and this had to be carefully accounted for when positioning the detection equipment. Vector polarizations ~25% were routinely achieved and verified by two independent methods [12,14,16] to within a relative normalization uncertainty of 6%.

The spectrometer consisted of four wire chambers (W2–5), a quadrupole focussing magnet (Q2), a resolving dipole magnet (BT), and two trigger scintillators (E1 and E2). The incoming beam was defined by scintillators B1 and B2. Further beam diagnostic information was provided by a wire chamber (PCOS) and various scintillators (μ_{1-4} and A–D).

For the purpose of data collection, an event was defined as a coincidence of a beam event (using B1 and B2) and a spectrometer trigger (using the W2–5 "fast"

signals in coincidence with E1 and E2). At each scattering angle, data were collected using the deuterated target polarized "up" and "down" and also unpolarized. Background spectra were obtained using an identical "normal" butanol target. The beam rate (typically $3 \times 10^6 \pi^+ s^{-1}$; $4 \times 10^5 \pi^- s^{-1}$) and target polarization were monitored throughout each run and did not vary significantly.

After subtraction of background spectra [8,9] the vector analyzing power is calculated via:

$$iT_{11} = (\sigma^+ - \sigma^-)/(2\sqrt{3}p_Z\sigma^0) + \delta \qquad (1)$$

where σ^+, σ^-, and σ^0 represent the normalized yields for πd elastic scattering for the various polarization states of the target; p_Z is the target polarization; and δ is a correction to account for the small differences between corresponding "up" and "down" polarization values (negligible except for the θ_π^{lab} =101° datum). For the π^- datum no unpolarized data was accumulated and σ_0 was computed from the mean of the two polarized states. Since the magnitude of the tensor polarization of the target was small ($\sim$ 6%) it was not practical to extract any tensor analyzing values from these measurements.

Unfortunately, we were unable to complete our measurements of $\pi^- d$ analyzing powers. A comparison of the analyzing power measurements in both $\pi^+ d$ and $\pi^- d$ at 60° does seem to confirm that Coulomb effects are very significant at these forward angles but without additional $\pi^- d$ data it is not appropriate to make any further assertions at this time.

The $\pi^+ d$ results, shown in Table 1 and Fig. 2, are seen to be in good agreement with the model of Blankleider and Afnan especially when the additional Coulomb terms of Jennings and Rinat are added[6]. In contrast, there is disagreement when the model omits the πN P_{11} potential or with a model that has suppressed its components [2]. This observation is interesting since it runs contrary to the findings at higher energies. It has been concluded that higher order terms omitted from all model calculations are necessary to adequately describe the πd system at higher energies and efforts to patch up this inadequacy by incorporating additional diagrams etc. have had a measure of success as they tend to bring the complete model calculations more in line with the data [5,6,17]. In contrast, our lower energy data, in the region where the additional higher order terms are probably insignificant, indicate that the P_{11} potential is being handled correctly by standard methods (e.g. Blankleider model) and one should not remove or suppress it.

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Table 1 iT_{11} measurements for πd elastic scattering at 49 MeV.

	θ_π^{lab} (deg.)	$\theta_\pi^{c.m.}$ (deg.)	iT_{11}	$\Delta(iT_{11})$
π^+d	50.0	54.3	0.33	0.05
	60.0	64.9	0.31	0.04
	70.0	75.3	0.30	0.03
	80.0	85.5	0.20	0.05
	90.0	95.6	0.14	0.03
	101.0	106.4	0.07	0.04
	130.0	134.2	0.07	0.03
π^-d	60.0	64.9	0.06	0.07

Figure Captions

1. Layout of the experiment in the M13 pion channel at TRIUMF. Scintillators B1,B2, A–D, and μ_{1-4} monitor the beam flux and position (up–down, left–right) along with the in–beam wire chamber PCOS. The spectrometer wire chambers W2–5 and scintillators E1 and E2 detect scattered pions. PDT is the polarized deuterium target. Q2 and BT are the quadrupole and dipole of the spectrometer respectively.

2. iT_{11} measurements in πd elastic scattering at 49 MeV compared with theoretical calculations. The solid curve is the full $NN - \pi NN$ prediction of the Flinders group [1]; the dashed curve is this model without any P_{11} contribution; the dash-dotted curve is the full calculation with the addition of the Jennings-Rinat terms [6]; and the dotted curve is the model calculation of Garcilazo [2]. Coulomb corrections [11] have been applied to the model calculations.

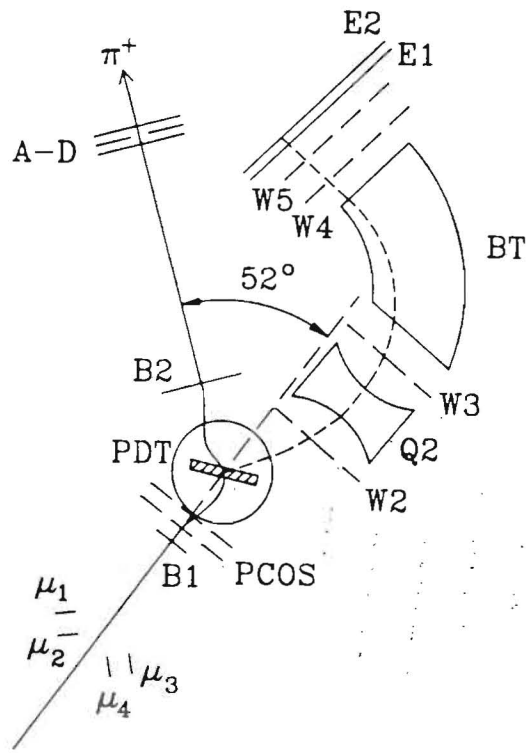

Fig. 1

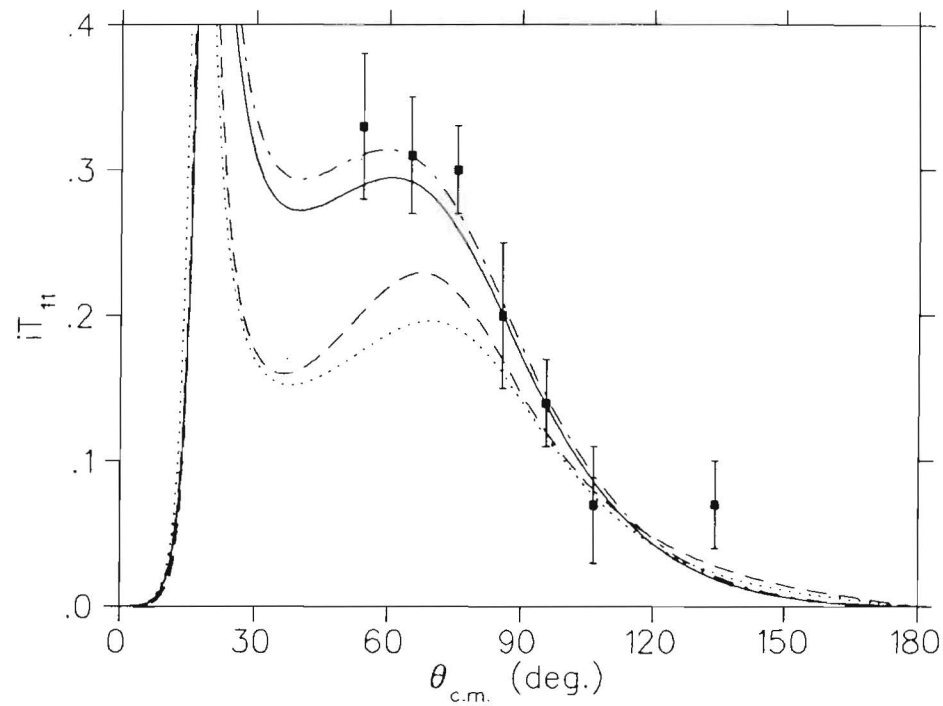

Fig. 2