



**HAL**  
open science

## **POLARIZATION MEASUREMENTS IN PION DEUTERON BREAKUP AND ABSORPTION**

E. Mathie, D. Yeomans, G. Huber, G. Lolos, S. Naqvi, V. Pafilis, Z.  
Papandreou, A. Feltham, R. Olszewski, G. Jones, et al.

► **To cite this version:**

E. Mathie, D. Yeomans, G. Huber, G. Lolos, S. Naqvi, et al.. POLARIZATION MEASUREMENTS  
IN PION DEUTERON BREAKUP AND ABSORPTION. Journal de Physique Colloques, 1990, 51  
(C6), pp.C1-383-C1-386. 10.1051/jphyscol:1990634 . jpa-00230901

**HAL Id: jpa-00230901**

**<https://hal.science/jpa-00230901>**

Submitted on 4 Feb 2008

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

## POLARIZATION MEASUREMENTS IN PION DEUTERON BREAKUP AND ABSORPTION

E.L. MATHIE, D.M. YEOMANS, G.M. HUBER, G.J. LOLOS, S.I.H. NAQVI,  
V. PAFILIS, Z. PAPANDREOU, A. FELTHAM\*, R. OLSZEWSKI\*, G. JONES\*,  
M. PAVAN\*, M. SEVIOR\*, R.P. TRELLE\*, P. WEBER\*, D. GILL\*\*,  
D. HEALEY\*\*, D.F. OTTEWELL\*\*, G.R. SMITH\*\*, G. WAIT\*\*, P. WALDEN\*\*  
and R. RUI\*\*\*

*University of Regina, Regina, Saskatchewan, Canada*

*\*University of British Columbia, Vancouver, B.C., Canada*

*\*\*TRIUMF, Vancouver, British Columbia, Canada*

*\*\*\*Dipartimento di Fisica, Universta' di Trieste, Italy*

## I Introduction

A broad goal of many few body physics experiments at intermediate energies is to identify shortcomings of our "conventional" descriptions based on nucleons, nucleon resonances and mesons. From these shortcomings it is often hoped to glean some evidence for the contributions of quarks and gluons. In addition one establishes specific goals for particular reaction channels, which upon realization furthers the empirical understanding of that channel, and in some small way also contributes to the above broad goal. Studies of the set of reactions involving the  $\pi$ -NN system must take into account the fact that this system is composed of a coupled set of reactions and that what is learned from one channel improves our understanding of the other coupled channels.

These reactions, which include the simplest examples of pion production and absorption and both  $\pi d$  and NN elastic scattering, are very important to nuclear physics from a bootstrapping point of view. Our specific goals thus revolve around thorough experimental tests of theoretical descriptions down to the most subtle aspects of the several reactions which form the  $\pi$ NN system, including both cross section and polarization observables.

In this work two experiments which contribute to these goals in somewhat different ways are discussed. The absorption (production) channel of the  $\pi$ NN system has extensive measurements of many independent observables, based on a wide variety of experiments utilizing the proton spin (both beam and target). In the present work rare and sensitive spin transfer observables involving the deuteron spin are reported.

In contrast the pion deuteron breakup channel has very few independent observables measured. The present work discusses a significant improvement in the uncertainty associated with the only polarization observable measured thus far in pion deuteron breakup.

## II Absorption

The extensive set of independent observables measured thus far for the pion absorption channel on the deuteron, including those measurements from the time reversed pion production reaction, encompasses differential cross sections and spin correlation data, but very few spin transfer data. Even with the variety of data available there are ambiguities in partial wave amplitude solutions which could only be resolved with spin transfer measurements. It was decided to access this information via the absorption reaction rather than the production reaction for several reasons. In particular it was clear that techniques for measuring final state proton polarizations were more convenient and better understood than those for deuterons, polarized deuteron targets are well understood after a decade of  $\pi NN$  analyzing power experiments, the system could be calibrated making use of the reaction on an unpolarized target, and finally a wider range in center of mass energies was available to the absorption reaction than to the production reaction at TRIUMF. The principle disadvantages of this approach include lower rates with incident pion beams and nuclear contaminants in the polarized target.

In this experiment pions with energies in the range 105 to 255 MeV interacted with a polarized deuteron target in the TRIUMF fast pion channel, M11. Both final state protons were detected in coincidence in arms with wire chambers in order that the strong kinematic correlation between them could be used to effectively remove background. In one of the arms the protons interacted in a second scattering with a carbon analyzer. With a target vector polarization of between 30 and 35 %, there were typically small contributions from the tensor polarization of the target which are considered in the analysis. Three orientations of target field were used to enable measurements of  $K_{LS}$ ,  $K_{SS}$ , and  $K_{NN}$ . Analysis of the  $K_{NN}$  still proceeding, however even the results available constrain the partial wave solution.

In Figure 1 a graph of  $\chi^2$  as a function of the change in phase  $\phi_2$  with respect to Bugg's fit [1] for the dominant  $^1D_2$  amplitude shows how much better determined this particular phase becomes with the addition of the single  $K_{SL}$  and  $K_{SS}$  data points at 205 MeV.

Inclusion of the spin transfer measurements promises to remove ambiguities in the partial wave analyses and expedite the comparison of experiment and theory at the level of partial waves rather than at the level of observables.

## III Breakup

The importance of observations of the breakup reaction  $\pi d \rightarrow \pi pn$  in experimental tests of the theoretical description of the coupled  $\pi NN$  reactions is often overlooked. Several modern theoretical efforts focus on the reactions leading to final states with only two bodies for a variety of practical reasons. These new experimental results complement earlier efforts by the Karlsruhe group working at PSI (SIN) [2,3,4], the Rice group working at LAMPF [5], and the Regina group at TRIUMF [6]. An

advantage of the three body final state is that with suitable choices of kinematics one might separately focus on regions where for example the quasifree scattering process dominates, where the final state NN reaction is important, or where the formation of a  $\Delta^{++}$  might be considered most important. Failings in the general description which might only be reflected in certain kinematical extremes may be indicative of a need to broaden the range of processes explicitly considered.

Since there are simply insufficient data for a partial wave analysis for the breakup channel, all groups have directly compared their results with varying degrees of success with calculations of Garcilazo obtained using the relativistic Faddeev equations within the three-body helicity formalism [7,6]. Most surprising in these comparisons is the failure to adequately describe the cross section data in some of the quasifree scattering regions studied, particularly at larger pion angles.

This experiment was performed at TRIUMF on the fast pion channel M11, making use of a 12 arm time of flight array of plastic scintillation counters, which enabled the coincident detection of a pion at any one of six angles with a proton at any one of six angles on the other side of the beamline. All detectors were carefully synchronized in time in order that a common absolute time conversion could be used for pions detected in the pion counters and protons detected in the proton counters. The absolute time of flight calibration was based on known free  $\pi p$  scattering timings measured with a  $\text{CH}_2$  target. The breakup vector analyzing power data were obtained with the TRIUMF polarized deuterium target.

The theoretical results shown in comparison with the figures were obtained using the relativistic Faddeev equations within the three-body helicity formalism [7,3]. The results shown below are preliminary in the sense that the absolute time of flight calibrations need to be further checked and that details of the background subtraction need to be evaluated. The time calibration is not expected to shift substantially, however changes in the background could increase the magnitude of the vector analyzing powers by up to 20 %. In places where there are data from both the Karlsruhe and Regina experiments there is good agreement between the experiments with much improved statistical precision in this work, particularly in the regions away from the quasifree peak.

In Figure 2, final state proton momentum distributions of the vector analyzing power are shown corresponding to cases where the proton angles are smaller than those for free  $\pi p$  elastic scattering by 5-10 degrees. In general the two experiments (this work at TRIUMF and Gyles et al at SIN) are in agreement, with the magnitude of the Regina preliminary results somewhat lower (as expected, see above), and with the statistical uncertainty much improved in this kinematical region. The magnitude of  $iT_{11}$  in the calculation by Garcilazo [3] typically overestimates the observations, and falls below the data at the high momentum end of the distribution..

The failure of the theory to describe the cross section data at larger pion angles, which is also true for a variety of observables in some of the coupled two body reaction channels, may well be an indication of the need to consider intermediate states with pion delta and perhaps even delta-delta interactions explicitly included. Calculations of differential cross sections and vector analyzing powers for the pion deuteron breakup reaction are urgently required from independent theory groups who may have already addressed some of the two body reactions in the same system.

## References

- [1] D.V.Bugg, Nucl.Phys.A**477**,546(1988)
- [2] E.L.Mathie, *et al.*, Phys.Lett.B**154**, 28(1985).
- [3] W.Gyles, *et al.*, Phys.Rev.C**33**, 583(1986).
- [4] W.List *et al.*, Phys.Rev.C**37**, 1594(1988).
- [5] P.V. Pancella *et al.*, Phys.Rev.C**38**, 2716(1988).
- [6] E.L.Mathie *et al.*, Phys.Rev.C**41**, 193(1990).
- [7] H. Garcilazo, J.Math.Phys.**27**, 2576(1986).

Fig. 1.

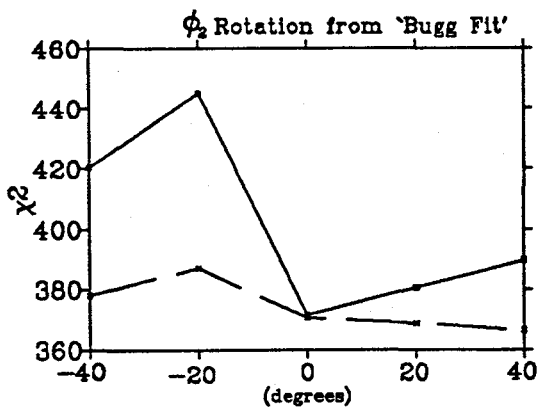


Fig. 2.

