S C A T T E R I N G   O F   P O L A R I Z E D

N E U T R O N S

F R O M   L I G H T   N U C L E I

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requirements for the degree of
Doctor of Philosophy.

R. Garrett
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TO MY WIFE

P R E F A C E

My first start in nuclear physics was made during 1962. My supervisor, Professor Brown, had suggested the use of 14 MeV neutrons from the $T(d,n)He^4$ reaction for studying nuclear structure by observing the angular distribution of outgoing protons and deuterons from (n,p) and (n,d) reactions. At this time this was the only feasible method of studying nuclear structure in this laboratory as the highest accelerated beam energy then available was 400 KeV.

During the next two and a half years of part time work some familiarity with neutron sources, associated particle systems and counter telescopes was acquired. However this is a very difficult way of studying nuclear structure and by this time a much higher energy van der Graaff accelerator and a polarized ion source were looming large on the horizon. As a consequence I shifted my attention to problems that could be solved with polarized neutrons generated still by means of the $T(d,n)He^4$ reaction at low energies but using a polarized incident deuteron beam.

The outgoing neutron polarization is determined by the ingoing deuteron vector polarization and the dynamics of the $T(d,n)He^4$ reaction. It was therefore initially proposed that the neutron polarization should be measured using a helium analyzer. If one assumes that the $T(d,n)He^4$ reaction proceeds via a $3/2^+$ level in the compound state and that the incoming channel contains s waves only then the outgoing polarization and angular distribution is dependent only on the conservation laws. As the extent to which this assumption is correct is not yet known precisely the work began to be oriented towards a study of the $T(d,n)He^4$ reaction itself. However there is a slightly easier way of doing the same thing and that is by use of the mirror reaction $He^3(d,p)He^4$. An experiment to measure the outgoing proton polarization vector is currently being set up by J. Clare of this laboratory.

For this reason and because the polarized ion source was not yet available for routine work it was decided to change the emphasis. This meant that a gas scintillation counter which was developed during 1966 was not immediately needed. However as this device is needed for the proposed absolute polarization measurements suggested in § 2.2.6 a chapter of this thesis has been devoted to it.

With the successful completion of the AURA II accelerator (Naylor (1968)) late in 1966 it became possible to generate polarized neutrons from the $T(d,n)He^4$ reaction using an unpolarized 6 MeV deuteron beam. The emphasis was therefore changed to the problem of measuring the polarization in neutron proton scattering at 16.4 MeV. The techniques and apparatus needed did not differ greatly from those already developed so that the first polarization measurement was made within a year of commencing work in the AURA II laboratory.

The first chapter of this thesis is concerned mainly with the present state of the phenomenological understanding of the nucleon - nucleon interaction. Very brief discussions of n - d and n - α polarization are included because it is intended to use the same apparatus for this work in the future. Since the only polarization measurement reported in this thesis is for n - p scattering, the need for such measurements has been the main concern of chapter 1.

Chapter 2 contains a general discussion of neutron scattering methods concluding with details of the associated particle techniques used here which have not previously been used for neutron polarization studies at neutron energies above 3 or 4 MeV.

Chapter 3 describes the electronic system as originally set up by the author and which was used for the work with unpolarized neutrons described in chapter 5 and early work with polarized neutrons using the $T(d,n)He^4$ reaction at E_d = 6 MeV. This electronic system was not really designed - it was built as much as possible from available equipment in such a way as to conserve time and money and yet provide a workable system. Since the AEC standards+ for nuclear instrumentation were set up the electronic system has been gradually converted to comply with this standard. I am indebted to my colleague Mr. A. Chisholm for carrying out the bulk of this program. The performance of the new system does not differ from the old and the logic is the same but the convenience of interchangeable modules and standard pulse shapes has greatly accelerated the speed and efficiency of the experimental work.

Chapter 4 is devoted to the work carried out on developing a gas scintillator for reasons already explained while chapter 6 is concerned with the problems of making a practical associated particle system for 6 MeV deuteron energy and the measurement of the neutron - proton polarization at 16.4 MeV.

The research for this thesis was carried out entirely while I was a full time member of the University of Auckland teaching staff. As a consequence the demands on my "leisure" time were very great and I am greatly indebted to my wife and children for putting up with a physicist in the house for a seemingly interminable period instead of a husband and father.

+ NBS - AEC Standard for Nuclear Instrumentation TID - 20893 (Revised)

I would also like to thank the many people who contributed by taking part in discussions. Amongst these are my supervisor, Professor D. Brown, and colleagues R.E. White, H. Naylor and especially A. Chisholm whose active interest has contributed an immeasurable amount. Thanks are due also to Mr. F. Blair and his machine shop staff for his ready response to - "this job is really urgent" - and also to Mr. R. Noble whose electronics workshop staff have built a number of electronic "boxes" for use in this work.

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C O N T E N T S