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United Kingdom Atomic Energy Authority

RESEARCH GROUP

NUCLEAR PHYSICS DIVISION PROGRESS REPORT

For period 1st July 1964 to 28th February 1965

Editor: D. L. ALLAN

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Nuclear Physics Division,
Atomic Energy Research Establishment,
Harwell, Berkshire.

1965

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Dr. B. W. Hooton	Fellow	
Dr. J. G. Jenkin	Fellow	
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NUCLEAR PHYSICS DIVISION

Division Head: Dr. E. Bretscher

Groups

Neutron Spectra and Nuclear Physics - I	Nuclear Physics - II and Nuclear Photo-effect	Pile Neutron Research
Dr. M. J. Poole	Dr. E. R. Rae	Dr. P. A. Egelstaff
Tandem Generator	5 MV Electrostatic Generator and Cockcroft Walton HT set	IBIS (3 MeV) pulsed Van de Graaff
Dr. Joan M. Freeman	Dr. G. A. Jones	Dr. A. T. G. Ferguson

Charged Particle Spectrograph

Mr. D. L. Allan

Proton Physics (50 MeV P.L.A.)	Synchrocyclotron	High Energy Physics
Dr. P. E. Cavanagh	Dr. B. Rose	Dr. W. Galbraith

Mossbauer Effect

Dr. T. E. Cranshaw

Scientific Assistants Training School

Mr. J. G. Robins

INTRODUCTION

Some readers may find it useful to have at the beginning of the Progress Report a brief guide to the work of the Division and an explanation of the headings which are used.

Broadly speaking, the work of the Division can be divided into two halves. First, we have those items of research which are associated in a direct and obvious way with the U.K. Nuclear Power Programme. This work is reported in the first part of the report. Second, and occupying the remainder of the report, are the very varied lines of research grouped under the main heading "Fundamental and Basic Research". Much of this work is carried out by visitors from the United Kingdom and from overseas who come and work with us for a year or two. The individual reports are grouped according to the accelerator on which the experiments were performed, the order being that of increasing particle energy. The kind of nuclear structure information one obtains from a nuclear reaction experiment depends to a considerable extent on the energy of the bombarding particle, so that this arrangement (with some exceptions) leads to a natural grouping of similar topics and of similar experimental techniques.

An exception to this ordering are the reports of the Pile Neutron Research Group whose contributions appear near the end of the report. This Group was originally set up to measure data in the thermal energy region and initiated a series of measurements of low energy scattering cross sections of importance to reactor calculations. They have now provided all the information the reactor physicists asked for. As the need for such work diminished, the Pile Neutron Research Group turned their attentions to the study of the solid and liquid state, using the beam from the DIDO reactor. Their efforts, in the future, will be concerned mostly with the exploration of the liquid state of matter and it was felt appropriate to transfer the Group to the Solid State Physics Division.

Let us now examine the main headings one by one.

Nuclear Data for Fast Reactors

Here we are concerned principally with the measurement of neutron inelastic scattering cross sections of the materials which make up the fuel, fertile materials and structural components of a fast reactor; for example, ^{239}Pu, $^{238, 235}U$, ^{232}Th, ^{27}Al, ^{56}Fe. The reason for these measurements is that inelastic scattering can transfer a large fraction of the energy of a neutron to exciting the internal energy states of the nuclei with which it collides. Consequently, inelastic scattering represents one of the more important ways by which a neutron loses energy in a fast reactor. The calculation of the energetics of a fast reactor therefore depends on a knowledge of the excitation energies of these states and of the probabilities (cross sections) for exciting them.

This work is performed on the IBIS pulsed accelerator which delivers extremely short bursts of neutrons; it is used in conjunction with very up-to-date electronic equipment which enables the time-of-flight of the scattered neutrons to be measured to high accuracy. From the data obtained, the energy spectra of the scattered neutrons can be deduced with a precision which, until comparatively recently, was possible only for charged particle spectra. This energy precision (resolution) is important because, for many of the nuclei of interest (e.g. ^{235}U and ^{239}Pu), the energy levels are very closely spaced.

General Nuclear Data for Reactors, I, II, III

Several groups in the Division contribute to the work of providing the detailed nuclear data required for thermal reactor calculations. Naturally, it is the various cross sections for collisions of neutrons with the nuclei of the reactor fuel and structural materials which receive the closest attention - for example, total, fission and capture cross sections - but other parameters intimately involved in the neutron economy of a reactor are measured also. For example, we present in this issue the final results of some very accurate measurements of $\bar{\nu}$ - the average number of neutrons released per fission. For some time past there has been a demand from the reactor design engineers for data of ever-increasing precision. This demand reflects the increasing reliability of the calculational methods now being employed in reactor design work.

The proper analysis of cross section data is just as important as the precision of the measurements themselves. Recent calculations have shown that interference effects in neutron interactions with heavy nuclei can lead to quite erroneous resonance parameters when experimental cross section curves are analysed in terms of the single level formalism. Neglect of this effects may yield incorrect statistical distributions of the resonance parameters and lead to difficulties in interpreting neutron induced fission cross sections in terms of the channel theory of fission (see contribution: 'quasi-resonances').

Integral Data Measurements

The advance in calculational methods referred to above has been achieved by a process of invention and experimental test. The Division contributes to the experimental testing of new theoretical approaches to reactor problems by building a variety of assemblies which simulate some aspect of a reactor problem. The assemblies must be simple from the point of view of physics and geometry so that the number of correcting factors and unknown parameters is minimized. In a typical experiment, a pulse of neutrons from the 45 MeV electron linac is injected into the assembly and various neutron measurements are made by time-of-flight techniques. The experimental data are then compared with the theoretical predictions to test the validity of a theoretical model or the applicability of the calculations. An example of an 'integral' experiment of this kind is the Two Blocks experiment, where the parameters characterizing the diffusion of neutrons in the vicinity of a temperature discontinuity established in two large blocks of graphite are measured and compared with the results of computer calculations.

Integral measurements are also being made in connexion with fast reactor systems. For example, the spectra of fast neutrons emerging from spheres of uranium and sodium have been measured. The primary neutrons for these experiments were obtained by bombarding a small target of natural uranium with the electron beam from the 45 MeV linac.

Fundamental and Basic Research

Most of the experiments whose titles are listed under this heading are concerned with Nuclear Structure studies. A large part of what we know about the internal structure of atomic nuclei has been derived from nuclear reaction experiments in which fast particles from an accelerator bombard a target containing the nuclei of interest and the energy and angular distributions of the particles (or γ-quanta) emitted as a result of various reactions are measured. From such energy and angular distributions, it is often possible to deduce the spins and parities of the excited states of the nuclei. This information, together with the cross sections and excitation energies obtained directly from these distributions, provide the raw material from which theoretical models of nuclear structure are constructed. Another important source of information comes from measurements of the lifetimes of excited states, which may last for only 10^{-13} sec or less.

Individual nuclear reactions are studied for two reasons: 1) to provide a direct test of a particular prediction of a theoretical nuclear model; 2) to gain a better understanding of the reaction mechanism itself, with a view to using this knowledge to learn more of the properties of individual nuclei. In either case the ultimate aim is the same; namely, to make available more searching means of testing the theoretical predictions. Examples of both kinds of experiment can be found in this report.

The experiments relating to pure Fermi decays and theories of weak interactions are, perhaps, rather out of place under the heading Nuclear Structure and Dynamics. Here we have some low energy nuclear physics experiments (they are performed on the Tandem accelerator) which yield important information in a field which is normally associated with High Energy Physics and the very largest accelerators. It is therefore interesting that from the results of some very accurate measurements of the energies of the particles (neutrons and protons) involved in certain low energy neutron reactions, coupled with the results of some accurated half-life measurements, deductions have been made about the role of elementary particles, including the so-called 'strange' particles, in weak interaction processes.

The experiments performed on the Synchrocyclotron are concerned in the main with providing the theorists with the data they need for formulating and testing theories of nuclear forces. Many of these experiments involve a painstaking study of how neutrons and protons scatter off each other and off simple nuclei, particularly with regard to scattering angles and the orientation of the neutron and proton spin directions. Recent measurements (reported in this issue) have revealed that the absolute value of the proton-carbon polarization in the energy range 100-140 MeV is 15% lower than was formerly believed. This finding is important as the old values have been used in the interpretation of many experiments carried out at Harwell, Harvard and Orsay on the p-p interaction - and the correct evaluation of the latter is vital to the building up of a quantitative fundamental theory of nuclear forces.

Moving on now to much higher particle energies, several physicits in the Division are collaborating with physicists from Universities in performing High Energy Physics Experiments on the 7 GeV proton synchrotron NIMROD at the Rutherford Laboratory, Chilton. A particularly exciting experiment carried out recently was concerned with the slow decay of K_2^0 meson into two charged π-mesons. This mode of decay is strictly forbidden if the C P operation (charge conjugation-parity) is conserved in the process. This important decay mode has now been confirmed in vacuo; furthermore, it was shown that the quadratic energy dependence of the decay rate predicted by the theorists does not occur.

Periods covered by future Nuclear Physics Division Progress Reports

It has been decided to alter the periods covered by the PR/NP series of reports as follows:

PR/NP 10 and later issues	May 1st - October 31st November 1st - April 30th

To smooth over the transition to the new periods, reports PR/NP8 and PR/NP9 will cover the following periods:

PR/NP8	July 1st 1964 - February 28th 1965
PR/NP9	March 1st 1965 - October 31st 1965