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SUMMARY OF FACILITIES

ATOMIC ENERGY RESEARCH ESTABLISHMENT, HARWELL

NUCLEAR PHYSICS DIVISION

Head of Division: Dr. E. Bretscher

High Voltage Laboratories: Dr. J. Freeman, Dr. G.A. Jones, Dr. A.T.G. Ferguson.

Synchrocyclotron (160 MeV): Mr. B. Rose

Proton Linear Accelerator, A.E.R.E. Group: Dr. P.E. Cavanagh.

Neutron Project: 28 MeV electron linear accelerator: Dr. M.J. Poole, Dr. E.R. Rae.

Neutron Chopper Experiments: Dr. P.A. Egelstaff.

THEORETICAL PHYSICS DIVISION

Head of Division: Dr. W. Marshall.

Nuclear Theory: Dr. A.M. Lane.

ATOMIC ENERGY RESEARCH ESTABLISHMENT, HARWELL

NUCLEAR PHYSICS DIVISION

Electron Linear Accelerator

Electron energy: 27 MeV at 40 mA peak current
35 MeV at low current.

Electron current: 400 mA for pulse lengths up to 1 μsec.
200 mA for 2 μsec pulse length.

(Improvements are in hand to increase the current to 750 mA for all pulse lengths).

Pulse lengths: $7 \cdot 10^{-9}$ sec., $\frac{1}{4}$ μsec., $\frac{1}{2}$ μsec., 1 μsec., 2 μsec.

Number of flight paths: 12, one of 60 metres length.

Number of target cells: 3.

Ancillary equipment: fast time-of-flight equipment for timing to the order of 10^{-9} sec.

Multi-channel digital magnetic tape recording system for time-of-flight data.

A new type of capture gamma-ray detector (described at the Time-of-Flight Symposium, Saclay, 1961).

Staff: Dr. E.R. Rae, Dr. M.J. Poole, N.J. Pattenden, A.G.G.H. Robinson, Dr. C.A. Uttley, Dr. M.S. Coates, Dr. D.B. Gayther, Dr. G.D. James, Dr. R.N. Sinclair, F.D. Brooks, F.W.K. Firk, J.E. Lynn, D.H. Day.

Programme of Research

Neutron physics in the energy range from thermal to 100 keV.
Total cross-section and fission cross-section measurements.
Studies of capture cross-sections in the resonance region, and associated gamma-ray spectra.
Photodisintegration studies.
Mass distribution in fission.

ATOMIC ENERGY RESEARCH ESTABLISHMENT, HARWELL

NUCLEAR PHYSICS DIVISION

Neutron Chopper Techniques used on Dido Reactor at A.E.R.E.

Staff: Dr. P.A. Egelstaff, Dr. F.J. Webb, S.J. Cocking, D.H. Saunderson.

Over the past five years neutron choppers of advanced design and also techniques for running them have been developed at Harwell. The main problems tackled and solved have been as follows:-

(1) Relative phase control of two rotors running at high speed (up to 600 cycles per second).

(2) The spinning of rotors with elliptical plan form on flexible supports.

(3) The use of new materials and methods of construction.

Full details of the work carried out under item (1) have been published in the Journal of Institution of Electrical Engineers and a reprint of this article is available.

The spinning of elliptical plan form rotors is desirable because this plan form has much greater resistance to transverse stresses, especially in rotors containing large area slots. The dynamical theory and the results of experiments on the spinning of these rotors has been published in the Proceedings of the I.A.E.A. Conference on Pile Neutron Research. Reprints of this article are not yet available from the I.A.E.A.

The novel materials which we have employed are magnesium/cadmium alloy and fibre glass. Both of these materials have very favourable stress/weight ratio, are easy to obtain and not too difficult to machine. In our use of them over the past few years we have demonstrated both their long-term reliability and neutron-absorbing properties and their mechanical strength. Details of the design and construction of the rotors using these materials are given in report No. AERE X/PR 2357 (Final) by Pickles and Hazlewood, a copy of which was sent to Dr. V.I. Mostovoi of Moscow two years ago.

Finally, a review of the techniques which we and others have employed has been published in Neutron Time-of-Flight Methods edited by J. Spaepen and published by Euratom. A reprint of this article is also available.

ATOMIC ENERGY RESEARCH ESTABLISHMENT, HARWELL

NUCLEAR PHYSICS DIVISION

HIGH VOLTAGE LABORATORIES - Accelerators and ancillary equipment available.

(a) 500 kV Cockcroft-Walton Generator

Accelerates protons or deuterons.
Beam current ~ 100 μA, (limited by radiation hazard).
Produces 3 MeV neutrons by $D(d,n)He^3$, 14 MeV neutrons by $T(d,n)He^4$, 6 MeV gammas by $F^{19}(p,\alpha\gamma)$, 14.8 and 17.6 MeV gammas by $Li^7(p,\gamma)$ and 20 MeV gamma-rays by $T(p,\gamma)$.

(b) 5 MV Van de Graaff Accelerator

Accelerates protons, deuterons He^3, He^4, Li^6, Li^7 all singly ionized. Machine orientation: vertical. Proton beam current: 100 μA at 600 keV, reducing to 10-20 μA at the upper limit of machine energy. Energy definition: about 0.1%.

A rotatable 90° resolving magnet directs the beam into any one of 12 outlets, some of which carry permanent experimental arrangements, e.g.:-

(i) 180° double-focussing rotatable magnet spectrometer for measurements between 0° and 150°, fitted with semiconductor detectors at the focal plane.

(ii) Pulsed-beam equipment for fast time-of-flight work.

(iii) Scattering chamber with rotatable semiconductor detectors, to be equipped for dE/dx and E measurements.

(c) 3 MV Pulsed Van de Graaff Accelerator

Accelerates protons or deuterons.
Pulse duration of 10^{-9} sec. Pulse repetition rate 10^6 per second.
Current during pulse: 10 milliamperes.
Machine orientation: horizontal.

(d) 12 MV Tandem Van de Graaff Accelerator

Accelerates protons or deuterons up to 12 MeV and oxygen ions up to 42 MeV.

Beam current: 1-2 μA of protons
0.5 μA of oxygen ions, O^{6+}.
Energy definition: 0.1%.
Machine orientation: vertical.

Ion stripping at centre terminal by thin carbon foils.

Rotatable 90° magnet analyser can defect the beam into any one of ten outlets.

Permanent experimental equipment includes:

(i) Broad-range magnetic spectrograph (Buechner type) for high precision charged particle work.

(ii) Gas target assembly as high energy neutron source.

(iii) Gamma-ray angular distribution turntable, equipped with two 5" diameter NaI scintillation detectors.

(iv) Scattering chamber with two rotatable semiconductor counters for charged particle reaction and scattering studies. The detector assembly is interchangeable with that on the 5 MV accelerator so that measurements can be made continuously from 0.6 to 12 MeV.

High Voltage Laboratory

Staff: Dr. J.M. Freeman, Dr. G.A. Jones, Dr. A.T.G. Ferguson, Dr. J.H. Montague, D. West, Dr. G. Dearnaley, Dr. G.C. Morrison, D.L. Allan, B.H. Armitage, J.E. Evans.

Programme of Research

(a) 500 kV Cockcroft-Walton Generator:

Chiefly as a source of neutrons or gamma-rays for testing or calibrating neutron detectors and determining the response curve for gamma-ray detectors.

(b) 5 MV Van de Graaff Accelerator:

Studies in nuclear structure and dynamics, and measurement of nuclear data required for fast reactors. Angular distribution and polarization in (d,p) reactions. Elastic scattering of charged particles. Studies of reactions induced by accelerated lithium ions. Studies of neutron cross-sections by fast time-of-flight methods. Inelastic neutron scattering. Proton capture γ-ray measurements.

(c) 3 MV Pulsed Van de Graaff Accelerator

Used almost exclusively for neutron time-of-flight work. Also to be used from time to time for research into

(i) the mechanism of the stripping reaction

(ii) accurate determination of nuclear masses up to A = 80 by precise measurement of (p,n) thresholds

(iii) lifetimes of isomeric states of nuclei.

(d) 12 MV Tandem Van de Graaff Accelerator

(i) Studies of nuclear structure and the mechanism of nuclear reactions by observations of charged particle reactions and elastic scattering.

(ii) Proton capture in the giant resonance region and gamma-ray total absorption measurements.

(iii) Precise determination of ft values in positron decay by accurate determination of the available energy from (p,n) reactions, and measurements of the half-life of the decay.

(iv) Total neutron cross-sections particularly in the energy range 6 to 14 MeV.

ATOMIC ENERGY RESEARCH ESTABLISHMENT, HARWELL

PROTON LINEAR ACCELERATOR (At National Institute for Research in Nuclear Science)

A.E.R.E. Staff using these facilities: Dr. P.E. Cavanagh, Dr. C.F. Coleman, J.F. Turner, Dr. B.W. Ridley, A.C. Hardacre.

Programme of Research

(i) Measurement of total reaction cross-sections for 30 and 50 MeV incident protons for a number of nuclei, as part of a coordinated programme for the determination of optical model parameters. Other measurements are being made of the elastic scattering differential cross-section and its polarization dependence.

(ii) Study of direct reactions produced by 30 and 50 MeV incident protons using fast time-of-flight techniques together with others for mass and charge identification of the produce particles. Energy spectra and angular distributions for the reactions (p,p'), (p,d), (p,t), (p,He^3), and (p,α) have been measured for a number of nuclei at 30 MeV.

SYNCHROCYCLOTRON WORK AT A.E.R.E.

The A.E.R.E. synchrocyclotron accelerates 1-2 μs of protons to an energy of ~ 166 MeV and is used to study proton and neutron induced processes in external beams up to an energy of ~ 150 MeV. The pulsed neutron facility[1], whereby the internal beam is deflected on to an internal target during a single R.F. cycle, giving a neutron burst of length 18 ns and enabling time-of-flight techniques to be applied to fast neutron studies in the energy range 20-120 MeV, is unique.

The AERE staff working with the synchrocyclotron consists of seven physicists and seven technicians for the experimental work, and an engineering staff of nine for operation and maintenance. The machine normally operates on a twenty four hour schedule.

The experimental work is almost entirely devoted to nuclear physics, though a small fraction of the time (2%) is given over to chemical studies and isotope production - in particular of the isotopes Be^7 and Mg^{28}. Extensive use is made of synchrocyclotron beams by various Universities in England, and ~ 30% of the running time during the past three years has been used by teams from Oxford University, Imperial and University Colleges (London) and Birmingham University. Sixteen students have been awarded Ph.D.'s during the past three years as a result of work carried out on the cyclotron.

The principle effort of the AERE teams is devoted to nucleon-nucleon scattering, though there is a wide range of other work covered by AERE teams, by visiting teams from the Universities and by mixed teams. The following measurements have been made in the past five years, or are nearing completion.

Proton-proton interaction

Wolfenstein Triple Scattering Parameters R at 140 MeV.	Edwards, Rose, Taylor[2]
R at 140 MeV.	Griffiths, Lush, Methringham (University College, London).
D at 140 MeV.	Taylor and Christmas[3]
A at 140 MeV.	Jarvis, Rose, Scanlon.
Polarization at several energies in range 30-90 MeV.	Christmas.

Neutron-proton interaction

Differential cross section at all energies in range 20-120 MeV.	Scanlon, Stafford, Thresher, Langsford.
Polarization at all energies 20-120 MeV.	Huxtable, Langsford, Scanlon, Thresher.[4]
Radiative capture cross section at ~ 50 MeV.	Barford, Palmer[5]. (Imperial College, London).

Proton-deuteron interaction

Elastic differential cross section and polarization at 140 MeV.	Taylor (AERE) and van Zyl (Birmingham University).
Differential cross sections and asymmetries in d(p,2p)n at 140 MeV.	Taylor (AERE) and van Zyl (Birmingham University).
p-d interactions at 140 MeV, in "event-controlled" cloud chamber.	Griffiths, Lush and Metheringham (University College, London).
p-d interactions at 80 MeV, in liquid deuterium bubble chamber.	Hopkins and Lyons. (Clarendon Laboratory, Oxford).

Deuteron-deuteron interaction

d-d interaction at 70 MeV in liquid deuterium bubble chamber (60,000 pictures being analyzed).	Hopkins and Lyons (Clarendon Laboratory, Oxford).

Interactions with heavier nuclei

(p,α) interaction with polarized protons at ~ 53 MeV, using event-controlled cloud chamber.	Griffiths, Lush, Metheringham[6] (University College, London).
(p,2p) studies of elements from Li to Ca.	Gooding, Pugh and Riley[7].
(n,n'γ)(p,p'γ) studies of light nuclei.	Clegg, Salmon, Fisher, Foley[8]. (Clarendon Laboratory, Oxford).
C(p,2p) interaction in propane bubble chamber (20,000 pictures being analyzed).	Bowman and Bowden. (Clarendon Laboratory, Oxford).
Wolfenstein parameters R in p-nucleus scattering.	Edwards, Rose, Taylor[9].
A in p-nucleus scattering.	Jarvis, Rose, Scanlon.
Neutron spectra from (p,n) processes at 0° and 45°.	Huxtable, Langsford, Scanlon, Thresher[10].
Neutron total cross sections from 20-120 MeV.	Scanlon, Stafford, Thresher[11].

Miscellaneous

Gyromagnetic ratio of free protons at ~ 150 MeV. Manning and Rose[12].

Experiments under preparation

Wolfenstein parameter R in p-p scattering at 100 MeV.
Wolfenstein parameter R' in p-p scattering at 140 MeV.
Studies of (p,pα) reactions.
n-"n" total cross sections at all energies from 20-120 MeV.

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7. Nuc. Phys. 18, p.46 and 65, 1960.
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9. Journal de Physique et le Radium 21, p.329, 1960.
10. Nuclear Physics, 22, p.640, 1961.
11. Nuclear Physics, 22, p.640, 1961.
12. Proc. 10th High Energy Physics Conf. (Rochester) 1960, p.787.