# THE NATIONAL INSTITUTE FOR RESEARCH IN NUCLEAR SCIENCE

## SIXTH ANNUAL REPORT

1962—1963

RUTHERFORD HIGH ENERGY LABORATORY
CHILTON, DIDCOT, BERKSHIRE

DARESBURY NUCLEAR PHYSICS LABORATORY
DARESBURY, CHESHIRE

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*From 15th February, 1963.
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THE NATIONAL INSTITUTE
FOR RESEARCH IN NUCLEAR SCIENCE

# Sixth Annual Report

for the period 1st October, 1962
to 30th September, 1963

Presented to the United Kingdom Atomic Energy Authority
in pursuance of Article 13 of the Institute's Royal Charter

RUTHERFORD HIGH ENERGY LABORATORY
CHILTON, DIDCOT, BERKSHIRE

DARESBURY NUCLEAR PHYSICS LABORATORY
DARESBURY, CHESHIRE

Sir,

I have the honour to submit, in accordance with Article 13 of the Institute's Royal Charter, the Sixth Annual Report of the National Institute for Research in Nuclear Science. This Report covers the period from 1st October, 1962 to 30th September, 1963.

I have the honour to be, Sir,
Your obedient Servant,

Bridges

*Chairman, National Institute for Research in Nuclear Science.*

Chairman,
United Kingdom Atomic Energy Authority,
11 Charles II Street,
LONDON, S.W.1.

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Sketch map showing the university centres in the United Kingdom and the Institute's laboratories at Chilton and Daresbury.

# THE NATIONAL INSTITUTE FOR RESEARCH IN NUCLEAR SCIENCE

## SIXTH ANNUAL REPORT

### for the year ending 30th September, 1963

## INTRODUCTION

The term "nuclear science" in the Institute's title covers several fields of research, of great importance to universities, which require facilities beyond the scope of a single university. The purpose of the Institute is to provide and operate such facilities for use by all universities. The main fields of research included are high energy physics and nuclear physics, which require large particle accelerators, and experiments in a wide range of subjects using nuclear reactors as radiation sources. As the U.K. Atomic Energy Authority were engaged in the development of reactors and accelerators and in research using them, and were already making some of their own facilities available for use by university scientists, it was natural for the Institute to be set up in close association with the Authority. Indeed, in the reactor field, the Institute's main activity is still to help the universities to use the Authority's reactors. But in the accelerator field, the Institute's own staff and university physicists work together on nuclear and high energy physics research at the Rutherford Laboratory and will do so also at the Daresbury Laboratory when it has been built.

The Institute's biggest task so far has been to build the high energy proton synchrotron Nimrod, approved in 1957, and to develop the Rutherford High Energy Laboratory which contains it. The initial construction was completed during the year, and Nimrod operated successfully at full energy for the first time in August, 1963.

The Rutherford Laboratory also contains a low energy accelerator, the 50 MeV proton linear accelerator (P.L.A.). This has now been in use for three years. It has proved to be a very successful machine in research and incidentally has provided the Institute with useful experience in running a laboratory in which the research is primarily done by university visitors.

The Institute's second high energy accelerator, the electron synchrotron Nina, was planned in March, 1961 after a full study of the university requirements had shown the need for a powerful source of high-energy electrons, particularly for the universities of Glasgow, Liverpool and Manchester. The building of Nina was approved in 1962, and a suitable site has been found at Daresbury in Cheshire. The Laboratory is to be known as the Daresbury Nuclear Physics Laboratory. Daresbury is conveniently near Liverpool and Manchester Universities. Although 200 miles from Glasgow University, it is well sited for access by air, rail or road.

A further project is the very large Atlas computer now being built at the Rutherford Laboratory. At the request of the Government the Institute will operate this computer for use by universities, the Atomic Energy Authority, Government Departments and others, for research not only in nuclear science, but in any field.

## THE RUTHERFORD HIGH ENERGY LABORATORY

Physically, the Rutherford Laboratory has been built up around Nimrod and the P.L.A. Of the present staff of 900, over 300 served in the former Accelerator Division of the Atomic Energy Research Establishment and the Theoretical Physics and Engineering Groups associated with it, and transferred to Institute employment in January, 1961. At present about 100 graduate university physicists are basing a large part of their research programmes on the Rutherford Laboratory accelerators, and about 45 of them spend a substantial amount of time working in the Laboratory. These numbers are increasing rapidly as the preparation of experiments on Nimrod gathers momentum; the number of those who base their research on the Rutherford Laboratory is expected to grow to about 200 in a year's time.

The staff transferred to the Institute in 1961 brought with them the main body of experience in the U.K.A.E.A. on accelerator development. Besides building their own accelerators the Institute have also carried out two accelerator projects for the A.E.A. and universities: an electrostatic generator for Oxford University and a variable energy cyclotron for the A.E.R.E. The Rutherford Laboratory is also the centre of the Institute's activity in support of university use of nuclear reactors, and a radiochemical laboratory has been brought into use during the year for university visitors who need to carry out chemical work on the spot on materials irradiated either in the reactors of the A.E.R.E. or in the Rutherford Laboratory's accelerators.

The division of resources between the different activities of the Laboratory is shown in the following table. The figures are based upon an analysis of the estimated expenditure in the financial year 1963/64.



They show broadly how resources were deployed in September, 1963, but considerable changes must be expected during the ensuing year as Nimrod comes into full use.

| *Division of work* | *Rutherford Laboratory staff: September 1963* | *Operating expenditure 1963/64 excluding capital projects £ thousands* | *Capital payments not included in the previous column £ thousands* |
|---|---|---|---|
| *Nimrod* | | | |
| Operating groups | 255 | 1,120 | 985 (4) |
| Beam equipment groups | 51 | 230 | 500 |
| Bubble chamber operation and research (1) | 23 | 88 | 597 (5) |
| Data analysis and computing (1) | 31 | 228 | 200 (6) |
| High energy physics groups, other than bubble chamber research (1) | 66 | 620 | |
| *The P.L.A.* | | | |
| Operating groups | 89 | 430 | |
| Nuclear physics research | 17 | 155 | 70 (7) |
| *General* | | | |
| Other accelerator development | 42 | 213 | |
| Research using reactors | — | 110 | |
| Site services and central workshops | 156 | 669 | 368 (8) |
| Administration (2) | 142 (2) | 530 (2) | |
| Not included above (3) | 29 | 132 | |
| *The Atlas Computer Laboratory* | 36 | 250 | 830 |

*Notes*

1. The effort devoted to bubble chamber research, data analysis and computing is bound to increase. The effort devoted to high energy physics other than bubble chamber research is already relatively high.
2. Some services are still provided by the Atomic Energy Research Establishment. The number of A.E.R.E. staff so employed is not included, but the cost of the services is included.
3. Includes the Directorate and staff engaged on radiation protection and the cost of certain university agreements.
4. Nimrod plant and buildings £740,000; Nimrod shielding and beam extraction equipment £245,000.
5. Purchase of the National hydrogen bubble chamber, £375,000; heavy liquid and helium bubble chambers, £222,000.
6. Final payment on the Orion computer.
7. Two large analysing magnets.
8. Building work other than Nimrod buildings.

## NIMROD

Nimrod operated at full energy for the first time on 27th August, 1963, three weeks after entering the final commissioning phase, and just six years after the first contracts were placed in 1957.

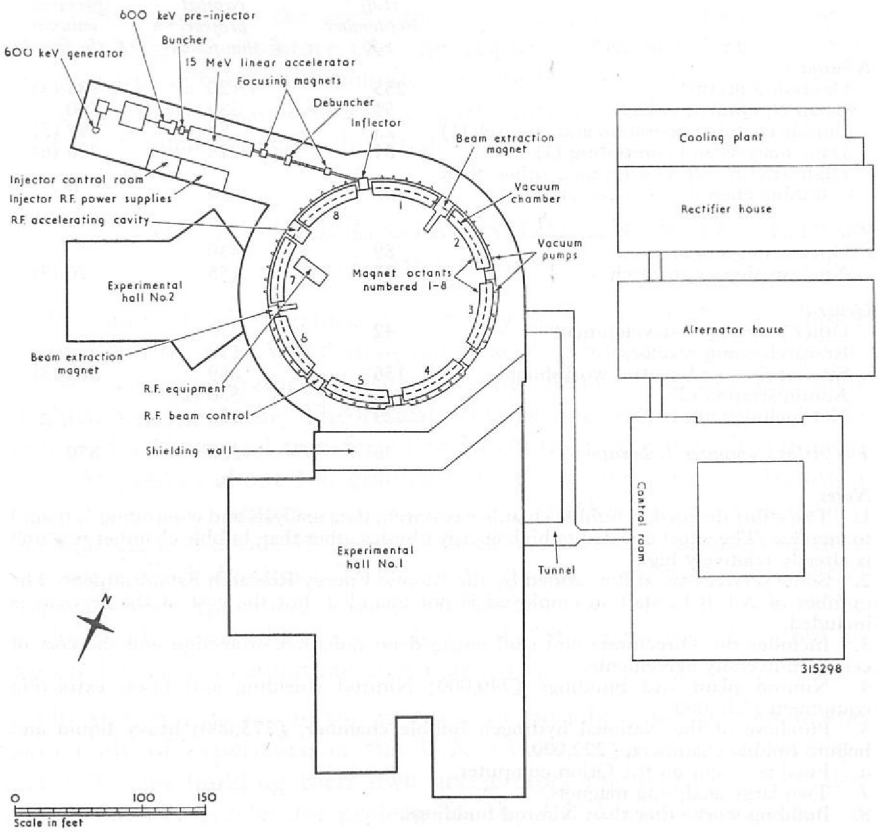



FIG. 1. Plan of Nimrod

### THE TIME AND COST OF CONSTRUCTION

The requirement for a 7 GeV proton synchrotron accelerating $10^{12}$ protons per pulse with 20 or more pulses per minute was decided upon after full discussion among British physicists. In 1957, after the formation of the Institute, the leading design features were settled, and financial approval was given. The detailed design and construction has thus taken six years, nearly two years longer than was first forecast in 1957. The total capital cost including the buildings will be just under £11 million, compared with the original estimate (including a 10% allowance for contingencies) of £7½ million. Several of the major components, and particularly the vacuum vessel, took longer to manufacture and cost more than had been estimated. Towards the end of 1961, when some of the major difficulties to be overcome in building the machine were more clearly seen, though not yet fully solved, the approved estimate was increased to £11·4 million and a new target date for the beginning of commissioning was set at 1st October, 1963. Both of these aims have been improved upon.



### CONSTRUCTION

The year under review was the final year of construction; most of the difficulties of manufacture of the component parts were over, and the available resources were concentrated upon the assembly and commissioning of the components on the accelerator. The number of physicists, engineers, technicians, craftsmen and labourers engaged in this work in the Nimrod magnet hall rose to a maximum of 250 including 200 provided temporarily by contractors.

On six of the magnet octants the pole-pieces had been installed temporarily for the magnetic survey before the outer vacuum vessels were available; these pole-pieces had to be removed, the outer vacuum vessels installed and the pole-pieces and pole-face windings fitted inside them. Then the inner vacuum vessels, the header vessels or closure plates and the vacuum pumping system were installed, as well as the straight sections of the vacuum chamber, between the magnet octants. Testing and commissioning of the magnet power supply system, the injector and the radiofrequency accelerating system went on throughout the year. The beam line and inflector leading the 15 MeV protons from the injector into the main accelerator were built and commissioned, and the control system which co-ordinates the operation of the different sections of the accelerator was developed to the stage required for the initial operation. All this work was completed by the end of July, 1963.

### THE FIRST OPERATION

Protons were first injected into the complete machine on 6th August, 1963. They were shown to make at least one complete circuit of the ring, and after eight days of experiment and critical adjustment a short pulse of protons was shown to circulate the ring for 110 microseconds, corresponding to about 40 turns. Acceleration was tried, and after some adjustment of the initial conditions a beam survived for 7 milliseconds, showing that acceleration, although limited, had taken place for the first time. The next advance was made after bringing into use the pole-face windings, which are provided for adjustment of the shape of the magnetic field in each octant. By 20th August, a considerable improvement had been made by applying corrections to the magnetic field gradient in this way on two particular octants (nos. 6 and 7) and in the following six days detailed measurements and adjustments of the injection and acceleration conditions were made, resulting in longer acceleration times, the maximum energy reached being 360 MeV. After further critical adjustments to the radiofrequency system on the 27th August, acceleration lasted for 650 milliseconds, i.e. right up to 6·5 GeV, corresponding to the peak magnetic field of 13·1 kilogauss which was being used. The peak field was then increased in steps to 15·9 kilogauss, with rough adjustments to the rate of rise of the field, and acceleration to 8 GeV was shown both by the survival of the beam to the full magnetic field, and by counter devices arranged to detect nuclear interactions caused by protons from the beam. Only a few pulses were carried out at the highest energy, and no attempt was made to optimise the intensity, which was about $10^9$ protons per pulse. The run continued at 7 GeV and the highest intensity achieved on that day was $10^{10}$ protons per pulse.

## BEAM EQUIPMENT

The principal items of equipment required for handling beams of charged particles are quadrupole focusing magnets, bending magnets and velocity separators using crossed electrostatic and magnetic fields. Most of the equipment required for the initial beams has been delivered, including 40 quadrupole magnets and 14 bending magnets. The beams which are being set up for the first experiments are scattered and secondary beams from internal targets in the accelerator. However, major components of the equipment for extracting the 7 GeV proton beam have been installed in the accelerator and their commissioning will run in parallel with the early experiments.

The setting up of five beams has been started:

Beam $P_2$ A scattered-out proton beam of full momentum
Beam $\pi_1$ Negative $\pi$-mesons of 0·9 to 1·15 GeV/c momentum
Beam $\pi_2$ $\pi$-mesons, positive or negative as required, of 1·6 to 3 GeV/c momentum
Beam $K_2$ Negative K mesons of 1·25 GeV/c momentum
Beam $N_1$ Uncharged particles of full momentum

The positions of these beams and the stage of installation which had been reached by the end of the year are indicated in the accompanying plan; connection of the necessary heavy power supplies, cooling water



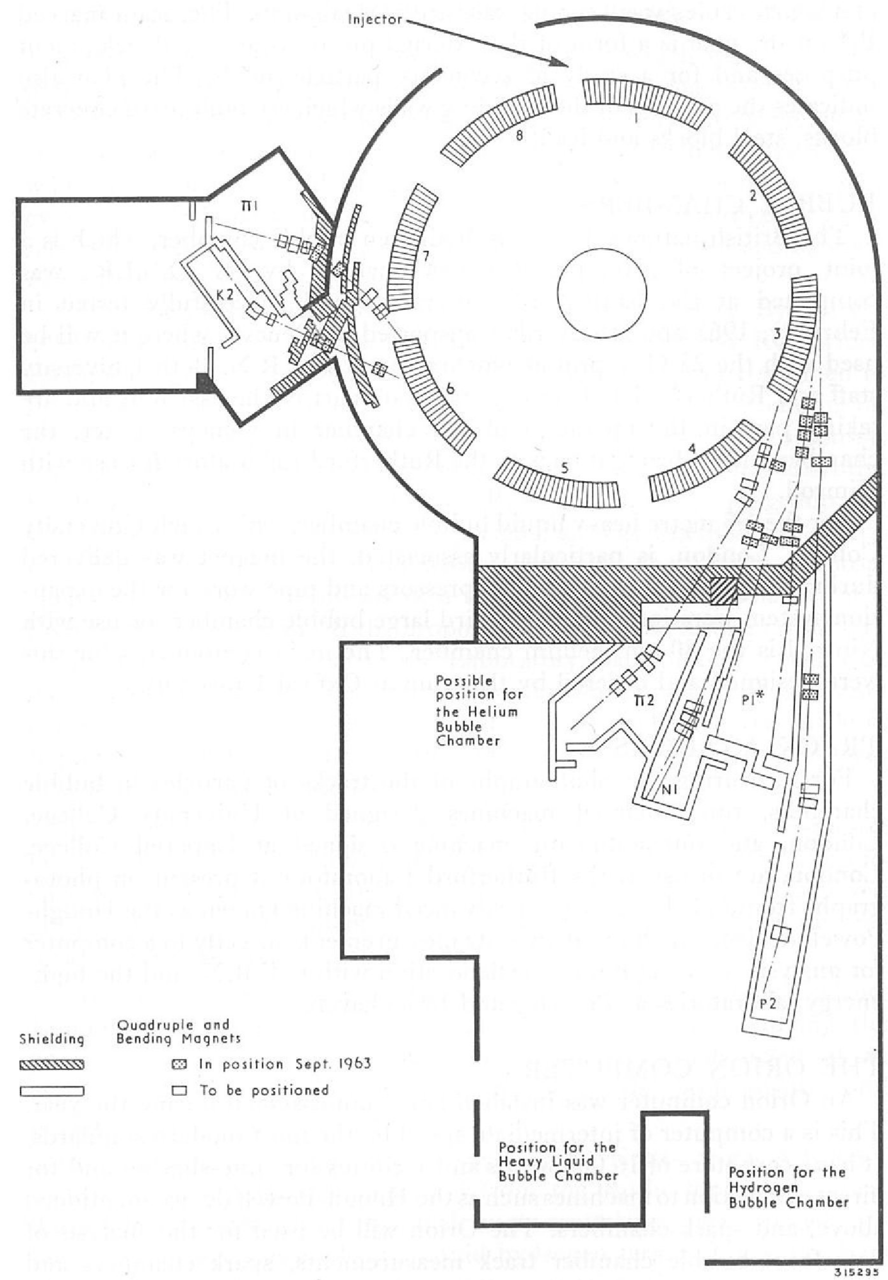



FIG. 2. Plan showing the positions of the first beams in the Nimrod experimental areas.

and signal cables was keeping pace with installation. The beam marked $P_1$* on the plan is a form of the external proton beam for development purposes and for a study of secondary particle yields. The plan also indicates the position of the shielding walls which are built up of concrete blocks, steel blocks and lead.

## BUBBLE CHAMBERS

The British national 1·5 metre hydrogen bubble chamber, which is a joint project of several universities financed by the D.S.I.R., was completed at the Rutherford Laboratory and successfully tested in February, 1963 and afterwards transported to Geneva, where it will be used with the 25 GeV proton synchrotron at C.E.R.N. Both University staff and Rutherford Laboratory staff took part in the assembly and are taking part in the operation of the chamber in Geneva. Later, the chamber will be brought back to the Rutherford Laboratory for use with Nimrod.

For the 1·5 metre heavy liquid bubble chamber, with which University College, London, is particularly associated, the magnet was delivered during the year and the main compressors and pipe work for the expansion system were installed. The third large bubble chamber for use with Nimrod is the 80 cm. helium chamber. The main components for this were designed and ordered by the team at Oxford University.

## TRACK ANALYSIS

For measuring the photographs of the tracks of particles in bubble chambers, three manual machines designed at University College, London, and one automatic machine designed at Imperial College, London, are in use at the Rutherford Laboratory at present on photographs from C.E.R.N. A more advanced machine known as the Hough-Powell device, which can deliver its measurements directly to a computer for analysis, is being built in collaboration with C.E.R.N. and the high-energy laboratories at Berkeley and Brookhaven.

## THE ORION COMPUTER

An Orion computer was installed and commissioned during the year. This is a computer of intermediate speed by the most modern standards. It has a core store of 16,000 words and facilities for time-sharing and for direct connection to machines such as the Hough-Powell device mentioned above, and spark chambers. The Orion will be used for the analysis of data from bubble chamber track measurements, spark chambers and counter experiments and for calculations concerned with accelerator development. Later on, some time on the Institute's Atlas computer will also be available for these purposes.



# THE RESEARCH PROGRAMME FOR NIMROD

Nimrod is the first accelerator in this country which will be able to produce K-mesons, anti-nucleons and hyperons. Research at Nimrod will be in the main field of elementary-particle physics; there is an enormous amount of work to be done but it is a highly competitive field in which some of the world's finest laboratories already have many years' experience. It is particularly necessary therefore for experiments to be selected carefully, and for those that are accepted to be pressed forward very vigorously with all the necessary resources.

Great interest has been shown in preparing experiments. By March, 1963, nine university groups, two A.E.R.E. groups and one Rutherford Laboratory group, representing 60–70 physicists in all had combined to form seven teams each proposing one or two experiments depending on electronics techniques of particle detection ("counter" experiments); several further counter experiments have been proposed subsequently. Seven other university groups and one Rutherford Laboratory group will participate in bubble chamber experiments. The method by which experiments are selected starts with full discussion of each proposal among all the users by means of a lecture and by the circulation of a brief written description. If the proposal survives these tests, preliminary planning of the experiment in the Laboratory takes place to check that its demands on Nimrod and other resources can be met. Final selection is then made by a small selection panel. The first selection was made in September, 1963, and time during the first six months of 1964 was allocated to four experiments:

(i) The Rutherford Laboratory group will be using a $\pi$-meson beam with an energy of about 1 GeV to determine the parity of a resonance which occurs at this energy when negative $\pi$-mesons are scattered off protons. This experiment will use a polarized target in which the free proton spins are preferentially aligned.

(ii) A second group composed of physicists from University College, London, and from Westfield College, London, will be studying the properties of two recently discovered resonances which occur at an energy of about 2 GeV. Their experiment will use both positive and negative $\pi$-mesons.

(iii) The third group is composed of physicists from A.E.R.E., Queen Mary College, London, and from the Rutherford Laboratory. They will be investigating the small angle scattering behaviour when 7 GeV protons are scattered by a liquid hydrogen target. Some members of this team have recently returned from C.E.R.N. where they were responsible with others for discovering unexpected effects in this process; the experiment is designed to throw light on these effects.

(iv) The fourth group consists of physicists from A.E.R.E., Birmingham University, Bristol University and the Rutherford Laboratory. They will be using 7 GeV neutrons produced as a secondary beam from an internal target for a neutron-proton scattering experiment. In this collision the charge of the stationary proton can be transferred to the incident neutron. It is hoped that this experiment will help to explain some results obtained at different energies which appear to be inconsistent.

Additional experiments in the first six months of 1964 will be considered at later selection panel meetings.

# THE 50 MeV PROTON LINEAR ACCELERATOR

The P.L.A. gives, in its energy range, a beam of very good intensity and well defined energy and it has an exceptionally good polarized proton source. The accelerator operates reliably, and it is being used for successful experiments.

## OPERATION

The P.L.A. is in use for 24 hours a day. Operators work in 12-hour shifts, and a team of two is on duty at all times except for two days at Christmas. As time is usually allocated to different experiments in blocks of several days, the experimental teams also divide themselves into shifts, usually of 12 hours. The 12-hour shift system has been in force for nearly two years, and so far it is very successful. It is liked by the operating staff, the health record is very good, and it is found to be a help in the reliable full-time operation of the machine.

As in previous years, the machine was shut down in the summer for eight weeks for repairs and modifications; for the rest of the year a cycle of 10 days for experiments and then 4 days for maintenance and the installation of experimental equipment was followed. The operating record for the 360 days from the start of the 1962 shut-down to the start of the 1963 shut-down was:

| | | |
|---|---|---|
| Scheduled running time | | 5,575 hours |
| Maintenance, including testing and running-up | | 2,153 ,, |
| Planned shut-down (38 days) | | 912 ,, |
| Total 360 days | = | 8,640 ,, |



A satisfactory beam was available on the target for 4,475 hours; 80% of the scheduled running time and 52% of the total number of hours in the period. These are very high figures for a machine of this type.

A mean current of $12{\cdot}5\times10^{12}$ protons per second (2 $\mu$A) was available. With the polarized proton source, a mean current of $6{\cdot}0\times10^{7}$ protons per second was available with 35% polarization, the direction of polarization being reversible by means of a switch.

## DEVELOPMENT AND RESEARCH

Modifications to improve the reliability and efficiency of the P.L.A. continued and in particular, the variation in energy among the protons in the beam was reduced to 1% of the average energy. The design was completed for a future major improvement of the P.L.A. by replacing the first of the three tanks to give an approximately ten-fold increase in beam current. In the present Tank I the beam is focused by means of grids which intercept some of the beam, whereas the new design would have quadrupole focusing magnets.

In research on alternative accelerating structures for linear accelerators at intermediate particle velocities, including the "clover-leaf" and "crossed bar" structures, it has been shown that the "crossed bar" structure should be the best for a proton accelerator at 200 MeV. A design study has been undertaken in collaboration with C.E.R.N. for a 200 MeV injector for the possible 300 GeV proton synchrotron which C.E.R.N. are investigating. Long-range research on the future use of superconducting cavities in linear accelerators has also been continued on a limited scale.

# NUCLEAR RESEARCH WITH THE PROTON LINEAR ACCELERATOR

Most of the nuclear physicists using the P.L.A. come from the universities: the numbers at present are 17 university staff and 20 graduate research students, 8 nuclear physicists from the Atomic Energy Authority and 8 from the Rutherford Laboratory itself. Members of the supporting staff from the Laboratory are allocated to research teams wherever their help is most needed. Altogether there are about 12 research teams, varying in size from three to six people, and nearly half of them made up from more than one university, or from a university and the Rutherford Laboratory. Between them they have about 20 experiments on the P.L.A. programme. The current list is given in Appendix IV. Many of the experiments take two years or more to complete, including the construction of apparatus and the calculation of results, but the stage has now been reached when experiments are being completed at a steady rate. During the year five Ph.D degrees were given (four by the University of London and one by the University of Belfast) for nuclear research at the P.L.A. and associated theoretical studies.

The two main fields of experiment are proton scattering and proton induced reactions.

## PROTON SCATTERING

Proton scattering experiments are one of the main sources of information about the forces between two protons, between protons and neutrons and between protons and other nuclei, and in its particular energy range, the P.L.A. is exceptionally well fitted for these experiments. A beam of protons is directed at a target and the number of protons scattered in one or more particular directions in a given time is measured. In many experiments the target consists of liquid hydrogen (in a very thin-walled vessel), and because the nucleus of an ordinary hydrogen atom is just a proton, the scattering of protons by protons can then be studied directly. Similarly, the scattering of protons by other nuclei can be studied by using targets of the appropriate elements.

Most of the experiments are concerned with polarization of the protons, that is, the net alignment of the proton spins along a particular direction. Scattering produces polarization, varying in a complicated way with energy and scattering angle. Conversely, a polarized proton beam is scattered asymmetrically—the numbers scattered to the left and to the right (or up and down) are not the same. In these experiments, where a polarized proton beam is not available from the accelerator it has to be produced by scattering from a preliminary target; such a beam is usually of low intensity and accompanied by large numbers of scattered neutrons which may cause a high "background" in the counters. The P.L.A., with its polarized proton source gives a polarized proton beam of reasonable intensity directly from the accelerator with a low background, and moreover the direction of polarization can be reversed immediately by a switch, a feature which can be used most effectively to eliminate certain sources of experimental error.

## PROTON-INDUCED REACTIONS

The study of proton-induced nuclear reactions yields quantitative information about the structure of nuclei. In such a reaction, the proton is not simply deflected by the nucleus but reacts with it. In the customary notation, $^{12}C(p, n)^{12}N$, for example, represents a reaction in which a proton (p) reacts with a nucleus of the carbon isotope of mass 12 and a neutron (n) is emitted, leaving a nucleus of the nitrogen isotope of mass 12. Such reactions have been studied for many years. Most of the experiments are concerned with the energies of the incident proton (or other particle) at which the reaction occurs, and the energies of the emitted particles. The results give information about the energy with which particles are held in the nucleus, and hence about the nuclear structure.



The P.L.A. finds a special place in this work, because it gives a proton beam of good intensity and precisely determined energy above the energy range of electrostatic generators. At 50 MeV, most of the reactions that are observed take place between the incident proton and nucleons (protons or neutrons), near the surface of the target nucleus. The experiments therefore give information about the energy with which nucleons are held near the nuclear surface, a subject in which highly interesting developments are taking place.

## THEORETICAL STUDIES

Work by university groups at the Rutherford Laboratory includes theoretical studies connected with the fields of research of the P.L.A. There are constant opportunities for interchange of ideas between members of different experimental teams, and many theoreticians work in close association with the Laboratory, and with the experimental workers.

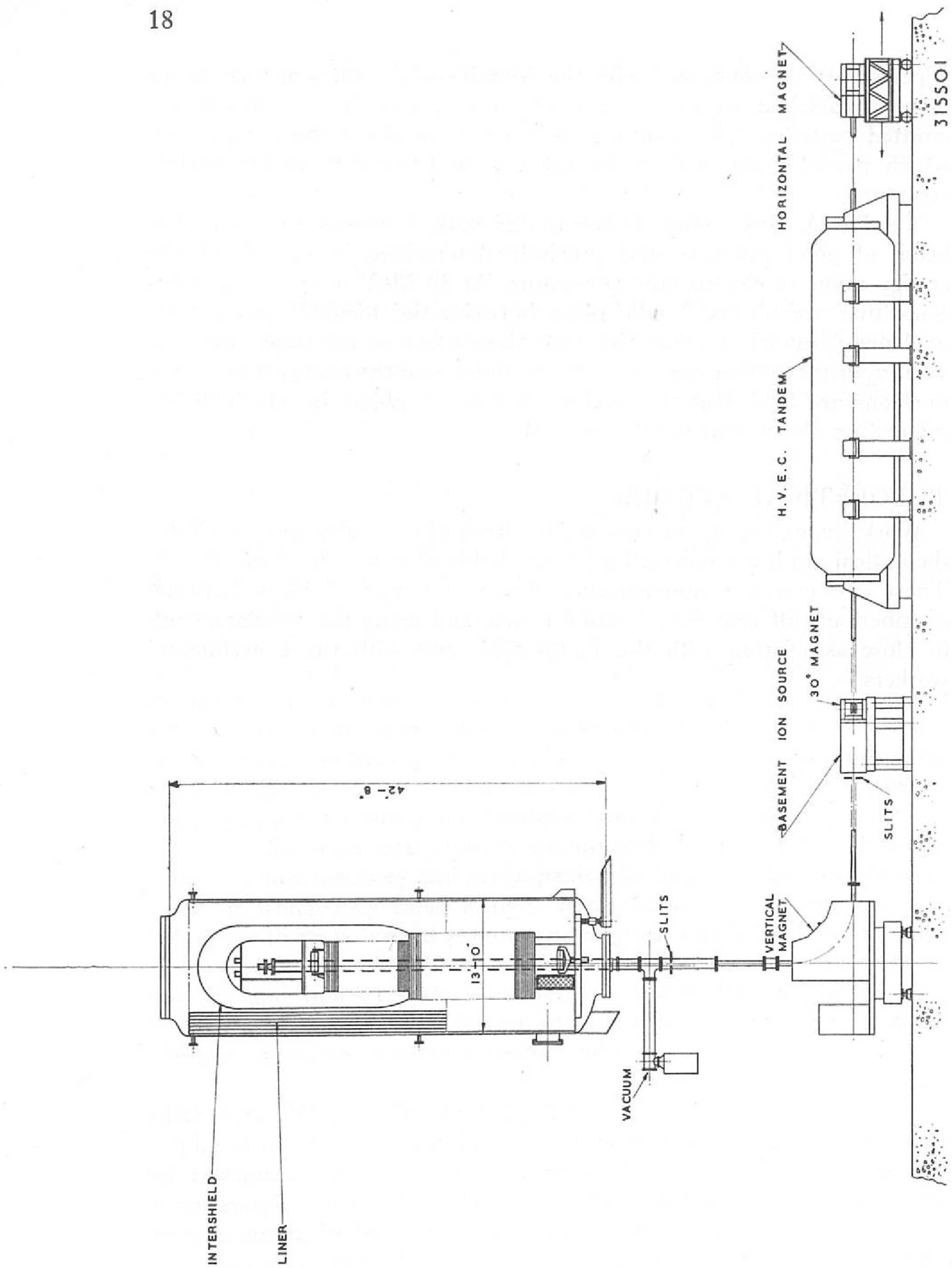



FIG. 3. Diagram of the electrostatic generator for Oxford University, showing the vertical generator in section.



# OTHER ACCELERATOR PROJECTS

## THE ELECTROSTATIC GENERATOR FOR OXFORD UNIVERSITY

The horizontal tandem generator for this project has been tested and delivered by the contractor and is ready for installation. The main components for the 8–10 MeV vertical generator including the pressure vessel, the accelerating tube and the vertical magnet were completed or very nearly completed during the year, and the horizontal magnet for the tandem generator was also completed. The chief problem has been delay over the building. The ion source for the tandem generator was undergoing final test at the end of the year; the development of the ion source for the vertical generator had not been completed, but was proceeding satisfactorily. This source is required to provide an unusually large range of ions—positively charged hydrogen and helium, and negatively charged hydrogen, oxygen and sulphur.

Development work was carried out with a test machine of about half the linear dimensions of the vertical generator. In particular, satisfactory stabilisation by the use of a liner was demonstrated in negative running of the machine with an electron beam. The use of an accelerating tube with tilted electrodes, a device to limit the unwanted acceleration of electrons produced within the tube, was explored in the test machine and also in the electrostatic generator at Manchester University, and it showed considerable promise.

## THE VARIABLE ENERGY CYCLOTRON FOR THE ATOMIC ENERGY RESEARCH ESTABLISHMENT

The Cyclotron Group is responsible for the design of a 70 inch variable energy cyclotron for the Atomic Energy Research Establishment, Harwell, and for supervising its construction, installation and commissioning. The versatility required for this cyclotron leads to many difficult design problems. There is to be provision for the acceleration of many different ions, and for the extraction of beams at various energies. The proton energy will be 50 MeV and an extracted beam of 100 $\mu$A is required. To meet these requirements complicated and accurately adjustable movable ion sources and beam extraction equipment have to be incorporated within the accelerator, and in addition to the main magnet power supply more than 20 separately controlled coil windings are required to provide fine adjustment of the magnetic field distribution.

Assembly of the magnet in its building has begun, and the largest of the other components, namely the high frequency amplifier, the dee system and the radiofrequency line have been designed and ordered. The main components which have not yet been completely designed are the probes for adjusting components inside the accelerator and for measuring characteristics of the beam, the deflector system for beam extraction and the external beam handling equipment.

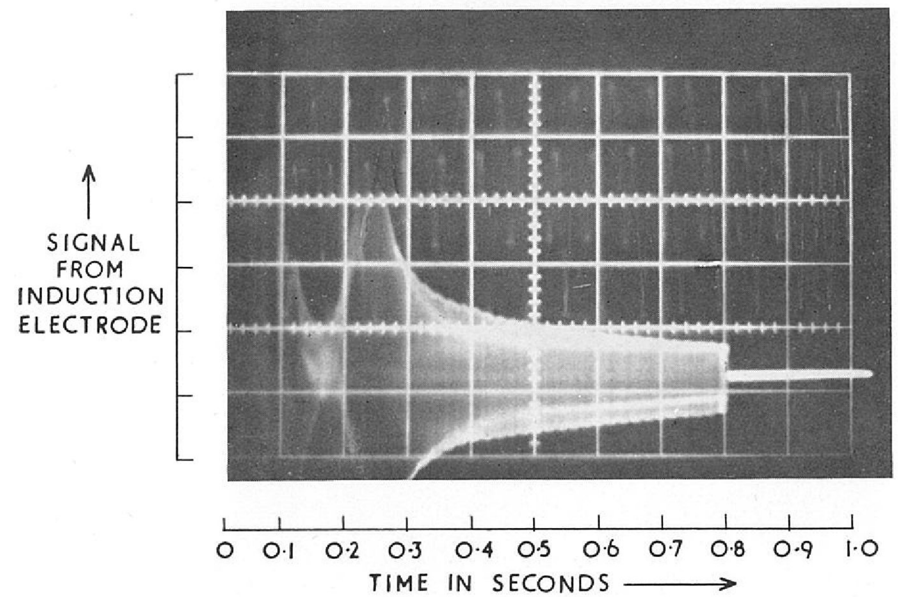
## RESEARCH REACTORS

The main interest in the use of research reactors by universities is for solid state physics. Experiments on crystals using beams of neutrons include the determination of atomic positions, studies of magnetisation distribution and studies of structural defects, while techniques which have been developed more recently enable the dynamical properties of solids such as spin waves and lattice vibrations to be investigated. The Institute have continued to help the universities to get materials irradiated, and experiments installed in research reactors of the U.K. Atomic Energy Authority, and to pay the charges for these services. During the year, the research reactor "Herald" at the Atomic Weapons Research Establishment, Aldermaston, has been made accessible to university workers without security restrictions, and at present, university teams from Birmingham, Cambridge and Reading have experiments in progress there. The Institute are providing two new facilities in the Herald reactor which are needed for the university work; a liquid-nitrogen cooled irradiation hole and a liquid-hydrogen cold neutron source. In the former, specimens under irradiation are kept very cold, so that the irradiation damage which is being studied is "frozen in" and not repaired by thermal agitation. The cold neutron source is for a quite different purpose. In it neutrons will be slowed down to very low energies in a volume of liquid hydrogen within the reactor, and beams of these low-energy neutrons will flow out of the reactor through suitable channels, for experiments particularly in the study of lattice defects in crystals and relaxations around solute atoms.

## THE RADIOCHEMICAL LABORATORY

In the last report, it was stated that a radiochemical laboratory was being built at the Rutherford Laboratory, for university scientists who need to carry out chemical operations on the spot on materials irradiated in the Rutherford Laboratory accelerators or in the reactors or accelerators of the Atomic Energy Research Establishment, Harwell. Three laboratory suites each accommodating three or four chemists, were brought into use in February, 1963, and a fourth is to be completed

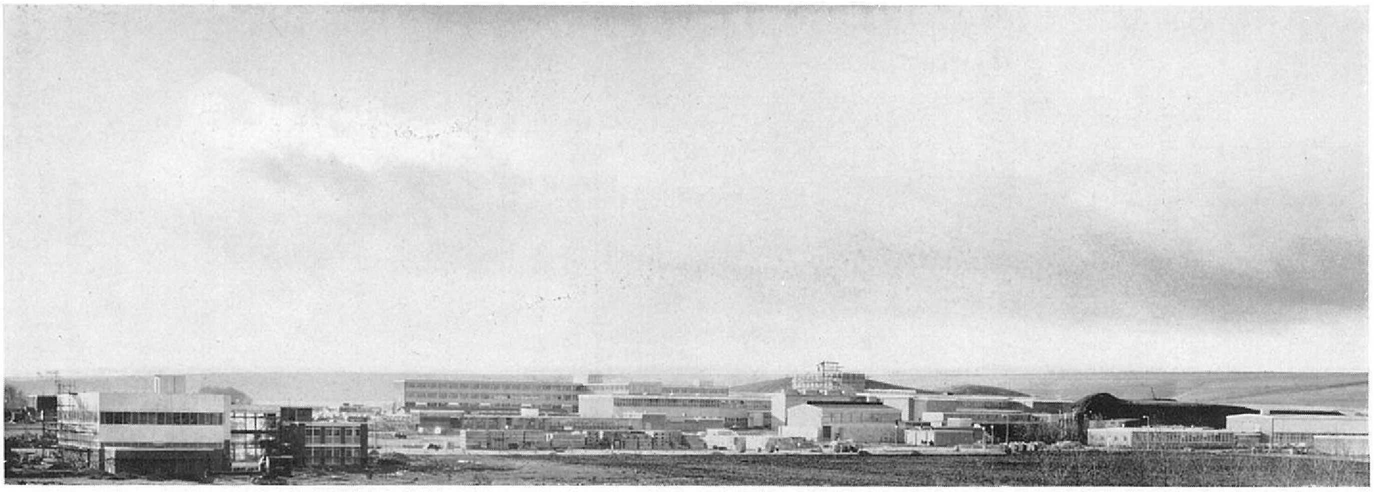
PHOTOGRAPH OF AN OSCILLOSCOPE TRACE MADE ON 27th AUGUST, 1963, SHOWING ACCELERATION OF PROTONS TO 8 GeV IN NIMROD.

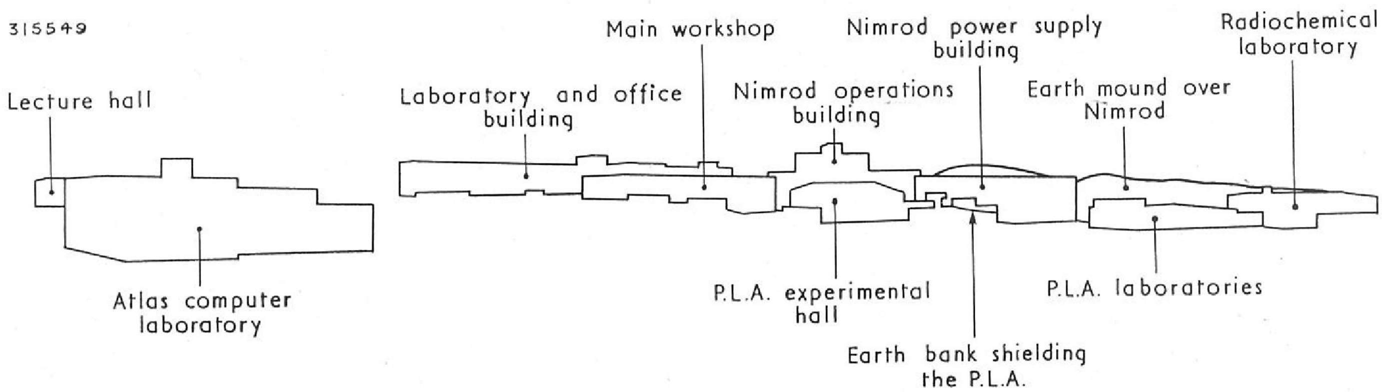



The trace shows the signal from an induction electrode: a hollow metal box through which the proton beam passes on each circuit of the accelerator. Each circulating proton on passing through the electrode induces a charge on it, so a circulating bunch of protons is detected by an oscilloscope connected to the electrode, as a voltage pulse whose area is proportional to the circulating charge.

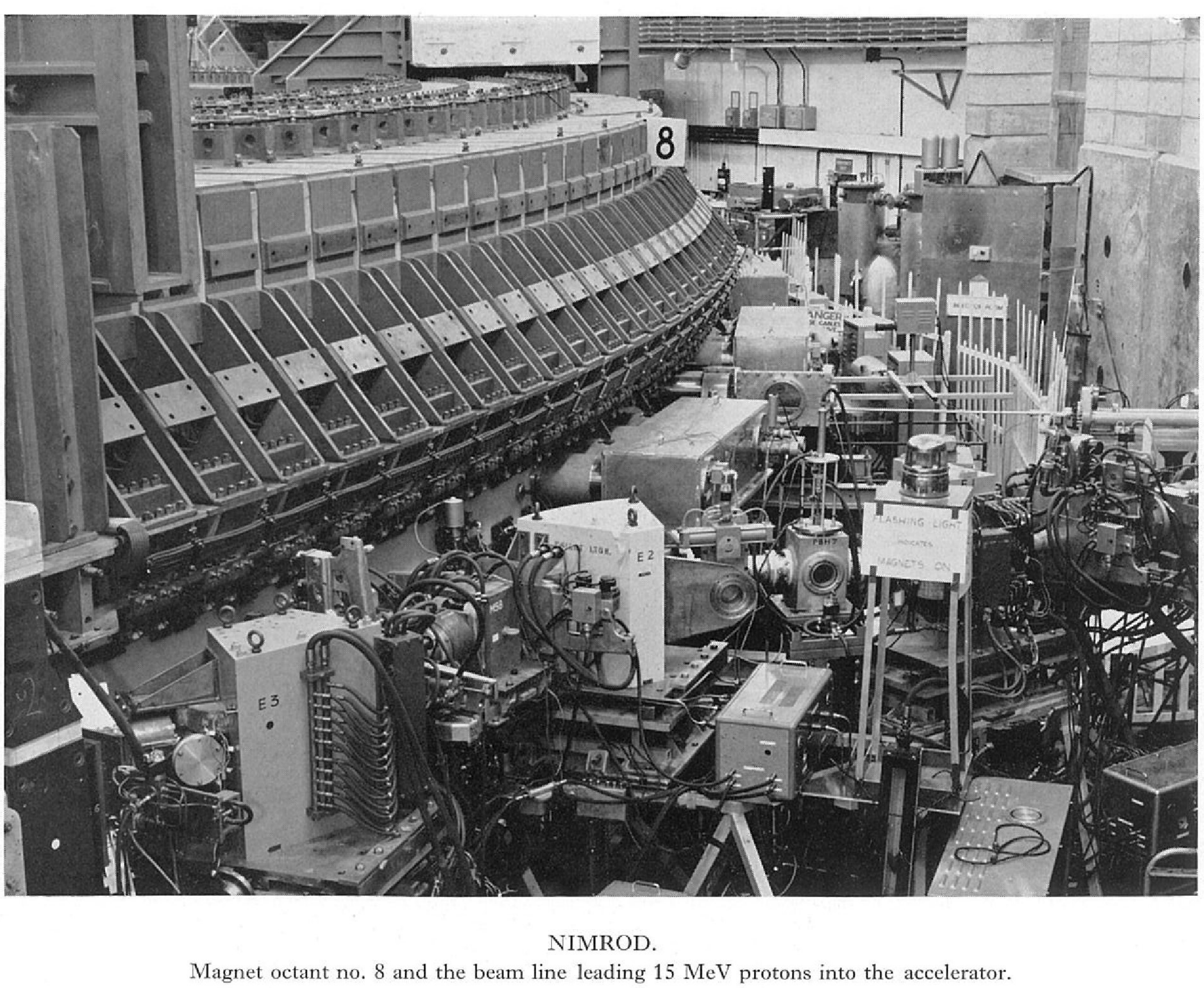
The photograph shows the train of very short pulses, each due to one passage of a bunch of protons through the electrode and lasting for less than one ten-millionth of a second. The individual pulses are thus much too short to be seen separately but their amplitude is clearly shown except during the first 0·3 seconds when the signal was disturbed. The train extends to 0·8 seconds, at which time the magnetic field has reached 15,900 gauss. The corresponding proton energy in Nimrod is 8 GeV.

Examination of the pulse shape using a trace with a greatly extended time scale makes it possible to determine the circulating charge from the amplitude of the pulses. The intensity indicated in this case is about $10^9$ protons per pulse.

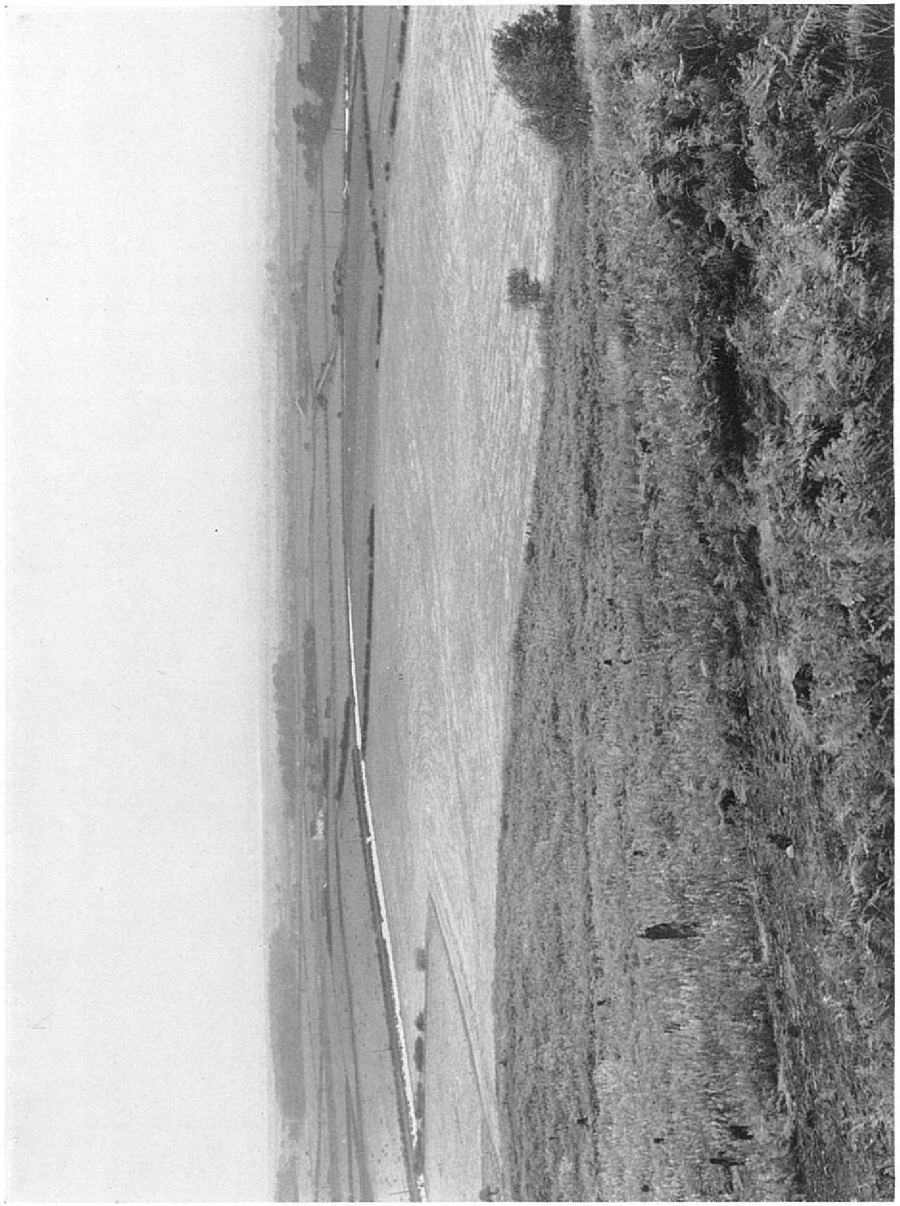





THE RUTHERFORD HIGH ENERGY LABORATORY, SEPTEMBER, 1963.



NIMROD.
Magnet octant no. 8 and the beam line leading 15 MeV protons into the accelerator.



THE SITE OF THE DARESBURY LABORATORY, SEPTEMBER, 1963.
The centre of Nina is to be about where the two small figures may be seen standing near the middle of the picture, in the large light-coloured field.



later. The laboratory can handle materials up to several curies in activity and it is being equipped with counting equipment (for measuring and analysing the radioactivity of specimens), which has been specially designed by the Chemistry and Electronics Divisions of the A.E.R.E. Altogether the laboratory, while small, is well equipped to take advantage of the exceptional range of irradiation facilities in the immediate vicinity, a range perhaps unequalled anywhere else in the world.

The laboratory is operated in close co-operation with the A.E.R.E., who provide the resident team of chemists to organise the work and manage the laboratory. This team was the first to start experimental work in the laboratory; one university scientist (from Cambridge) quickly joined them and others followed, but the laboratory is not yet in full use. Two of the types of work in progress are described below.

## RADIOACTIVATION ANALYSIS

Radioactivation analysis is an extremely sensitive method of determining the quantities of certain trace elements in specimens of any kind; it is often applied for example to biological and geological specimens. The sample is irradiated in a nuclear reactor and the presence and quantities of trace elements are determined by analysis of the induced radioactivity. In many cases a chemical separation of the irradiated material is necessary before the radioactivity is measured, and in that event known amounts of isotopic carriers are added to facilitate chemical manipulations and the activities are corrected for chemical yield. In some cases a laboratory very close to the place of irradiation is necessary because the activity produced in short-lived. At present two university departments and one hospital are using the laboratory for work of this kind in the fields of geology, crystallography and biology.

## NUCLEAR CHEMISTRY

The study of the structure and properties of atomic nuclei by chemical techniques is often called nuclear chemistry. One field of experiment is concerned with the fission of heavy nuclei, under neutron, proton or photon irradiation. A chemical study of the products of fission under different conditions can give information about the mechanism of fission, and hence about the nature of the nucleus. This work usually requires elaborately designed experiments both as regards the irradiation and the chemical operations. The work of the resident team, and of two visiting groups already accepted for the coming year, is in this field.

# THE ATLAS COMPUTER LABORATORY

Organisational and technical details about the Atlas Computer Laboratory were given in the last report. The computer will be a very powerful one, able to undertake calculations on the largest scale. It is to be used for research in any field, not only nuclear science. During the year good progress has been made with construction and with the recruitment of staff.

## CONSTRUCTION

Construction of the buildings started in October, 1962, and has kept to the programme which calls for completion at the end of December, 1963. The buildings can be seen in the foreground of the photograph of the Rutherford Laboratory in this report. An interesting factor in the design is that with such a large and fast computer the time taken by electrical impulses to travel along signal cables from one part of the machine to another is quite significant, and a compact layout on two floors was therefore specified in some detail by the manufacturers.

All the units which make up the computer were completed by the end of September, 1963, as planned. The next stages are assembly and testing at the maker's works, expected to take six months, followed by installation at the Laboratory and commissioning, which are expected to take about a further six months. The contract date for the handing over of the complete installation is 1st April, 1965.

## STAFF

The staff of the Laboratory rose to 37, largely through the transfer of the computer operations section from the A.E.R.E., Harwell, to the Institute on 1st April, 1963, to form the nucleus of the Atlas Laboratory Operations Section; this section continues to operate the computing-machine services for the A.E.R.E.

The head of the Programming Group and several members of the Mathematical Research Group were appointed during the year. The purpose of the latter small group is partly to help in maintaining a high mathematical standard, and partly to see that the computer is used in novel and imaginative ways. Most members of the group will be appointed for a few years only, often in association with a university post, and four joint appointments by the Institute and a university are under discussion, two with Cambridge and two with Oxford colleges.

## THE DARESBURY NUCLEAR PHYSICS LABORATORY

The programme of the Daresbury Laboratory is to construct a 4 GeV electron synchrotron and the laboratory to house it. During the year a site has been found, the detailed design of the buildings has been completed and the basic physical design of the machine has been settled. Contracts for some of the major components of the machine have already been let.

One of the major problems facing the new Laboratory was to get the synchrotron and its buildings designed as quickly as possible, at a time when no well-defined design team existed. This has been achieved by the most generous help from the Universities of Glasgow and Liverpool, and with assistance from the Atomic Energy Authority and from the Rutherford Laboratory. It has been a fine example of co-operation between public bodies and the universities.

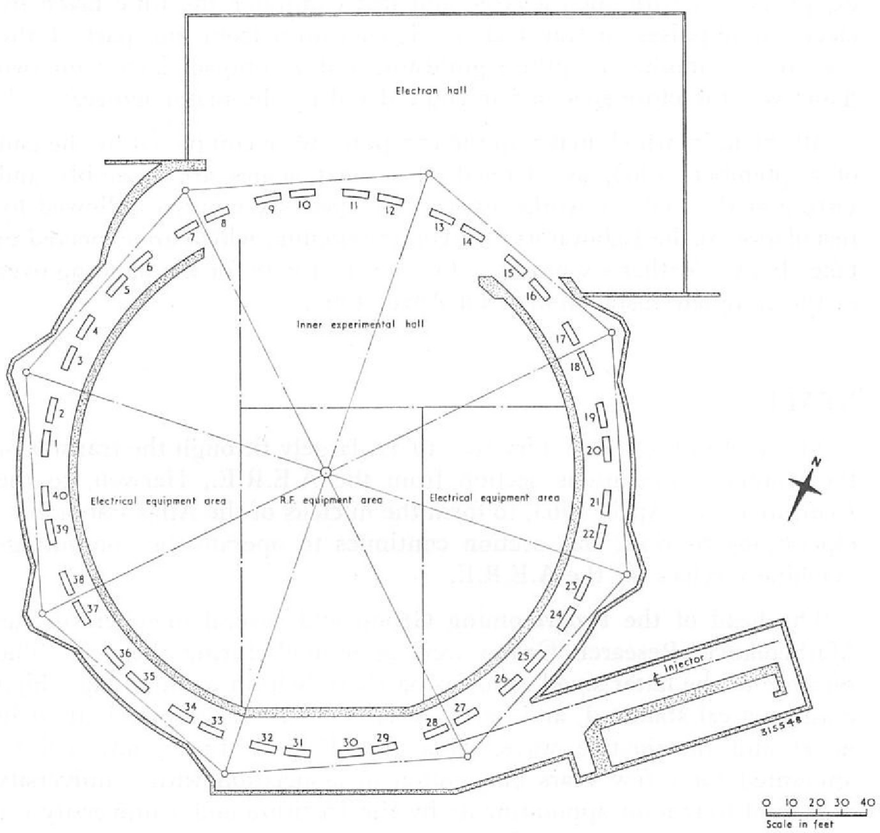



FIG. 4. NINA. Plans showing the general arrangement



### THE ELECTRON SYNCHROTRON, NINA

The electron synchrotron, which has been named Nina, will be of the strong-focusing kind in which the electron beam circulating in the machine is confined to a small region by very strong magnetic focusing forces. The virtues of such an accelerator have been demonstrated in a very striking way by the successful operation of the joint Harvard-M.I.T. electron synchrotron designed on these principles. Besides Nina, two other similar machines are under construction at Hamburg in Western Germany and at Erevan in Soviet Armenia.

The electrons in Nina will be steered in a circle of 70·2 metres diameter by 40 magnet units, each unit of length 3·3 metres; (see the diagram on the opposite page). The gaps between these magnets will be alternately 1 and 3·5 metres long. These very large field-free straight sections are a feature of the machine which should make it particularly accessible for experiments. Although the design energy of the machine is 4 GeV, it should be capable of operating at reduced intensity up to 5·3 GeV.

The acceleration of the electrons will take place at 5 radio frequency stations around the machine; this number has been made small so that as many straight sections as possible will be available for experiments. The vacuum pipe in which the electrons will travel will be elliptical in section with a major axis of 15 cms.

The electrons will be injected into Nina from a 40 MeV linear accelerator and it is hoped that currents in excess of 1 $\mu$A and perhaps as large as 10 $\mu$A will be accelerated.

The following table summarises the major physical parameters of the accelerator:

| | |
|---|---|
| Mean orbit radius | 35·09 metres |
| Magnetic field at 4 GeV | 6·43 kilogauss |
| Number of magnet units | 40 |
| Length of magnet unit | 3·26 metres |
| Lengths of straight sections | 1 metre and 3·5 metres alternately |
| Magnet gap in focusing magnet unit | 6·10 centimetres |
| Magnet gap in defocusing magnet unit | 7·62 centimetres |
| Weight of magnet unit | 10 tons |
| Magnet excitation frequency | 50 cycles/second |
| Injection energy | 40 MeV |

### THE SITE AND BUILDINGS

The siting of the Laboratory presented a problem which was not easy to solve. The synchrotron magnets must be positioned with great accuracy, in fact, to about two parts in one million on the diameter of

200 ft. This in turn means that the foundations of the accelerator must rest on a very stable rock base. Eventually, after considerable help from the Cheshire County Planning Officer, a suitable site was found near the North Cheshire village of Daresbury, already well-known as the birthplace of Lewis Carroll. The site is a very good one for the new Laboratory with easy access to the closest Universities, Liverpool and Manchester, and near the M.6 motorway and Ringway and Speke Airports. Many universities in the North and Midlands will find it easy to use the facilities of the Daresbury Laboratory. The necessary planning permission was obtained for the site in June and it was purchased in August. The main civil engineering and construction contract has been given to Sir Alfred McAlpine and Son.

In the past year the major part of the design of the buildings has been completed by the Atomic Energy Authority's Engineering Group, working very closely with N.I.R.N.S. and Liverpool University staff. The main problems here were to design a circular building with sufficiently stable foundations to house the magnet of the accelerator and to group around this building the experimental halls and the various facilities required for doing experiments on the accelerator. In addition to this a laboratory and office block has been designed to meet the needs of the Daresbury Laboratory when a total of 250 people are working there.

## ADMINISTRATIVE AND OTHER MATTERS

### FINANCE

The funds provided by Parliament for the Institute under Subhead J of the Atomic Energy Vote amounted to £6,790,000 for the financial year 1962/63, which sum was increased to £7,205,000 in a supplementary estimate. For the financial year 1963/64 the Parliamentary Grant was £8,445,000, which also was increased by supplementary estimate to £8,998,000.

Expenditure in the financial year 1962/63 was £92,000 in excess of the revised Grant, the additional funds being found by transfer within the Atomic Energy Vote. Early in the financial year 1963/64 it became clear that expenditure would again substantially exceed the Grant, and steps were at once taken to reduce the level of experimental effort at the Rutherford Laboratory, although it was still necessary to seek additional funds of £553,000 in the financial year 1963/64.

This situation arose through an under assessment of the level of effort and cost required to start and sustain an experimental programme which would fully utilise Nimrod. The amount of funds which can be made available to the Institute in future is under consideration with the Government; meanwhile, experimental programmes continue, but not to the extent of using Nimrod to full capacity.



### STAFF

The total strength of the Rutherford Laboratory at the end of September, 1963, was 954 including 37 at the Atlas Laboratory. The Daresbury Laboratory strength was 31 of whom 21 were working at Liverpool University and 10 at the Rutherford Laboratory.

### SERVICES PROVIDED BY THE U.K. ATOMIC ENERGY AUTHORITY

The Institute retain very close links with the Authority, who provide many services both general and local. Funds are obtained from the Authority, under a Subhead of the Atomic Energy Vote, and the Authority exercise supervision over the Institute's finances and accounts. The Institute's staff structure, salary scales and conditions of service are modelled on those of the Authority, and changes do not usually have to be negotiated in detail separately by the Institute. The Authority's principal superannuation scheme was specially extended to include Institute staff.

The Institute use the Authority's contracts branch as their sole agent for making contractual commitments, and other specialised branches including the legal and lands branch and the patents branch for advisory and agency services. Most of the Institute's building work has been supervised by the Engineering Group of the Authority.

At the Rutherford Laboratory, which is built on land transferred from the Authority and formerly part of the Atomic Energy Research Establishment, the A.E.R.E. provide many services, including water, gas, steam, effluent treatment, bus transport, medical services, fire services and some specialised technical services including photography. There is also of course a very close two-way scientific collaboration; for example the A.E.R.E. provide substantial electronics development services, and they are among the users of the Rutherford Laboratory accelerators.

### RUTHERFORD LABORATORY BUILDINGS

A large new laboratory for the development and testing of nuclear equipment for Nimrod, and for general accelerator research, together with an associated office building were brought into use early in 1963, and the Rutherford Laboratory staff restaurant was opened in July.

### EUROPEAN 300 GeV ACCELERATOR PROPOSAL

The Institute, in co-operation with the D.S.I.R., and with the help of their Joint Consultative Panel for Nuclear Research, have studied proposals developed at C.E.R.N. for a very high energy European accelerator. A detailed report was submitted in April, 1963, to the Advisory Council on Scientific Policy.

*APPENDIX I*

## Membership of Committees of the National Institute for Research in Nuclear Science September, 1963

### General Purposes Committee

*Chairman :* THE RT. HON. THE LORD BRIDGES, G.C.B., G.C.V.O., M.C., F.R.S.

| | |
|---|---|
| SIR ROBERT AITKEN, M.D. | *University of Birmingham* |
| PROFESSOR J. M. CASSELS, F.R.S. | *University of Liverpool* |
| MR. A. E. DRAKE, O.B.E. | *Atomic Energy Authority* |
| DR. F. A. VICK, O.B.E. | *Atomic Energy Authority* |
| SIR HARRIE MASSEY, F.R.S. | *University College, London* |

*Secretary :* DR. J. A. V. WILLIS

### Personnel Committee

*Chairman :* THE RT. HON. THE LORD BRIDGES, G.C.B., G.C.V.O., M.C., F.R.S.

| | |
|---|---|
| SIR HARRIE MASSEY, F.R.S. | *University College, London* |
| PROFESSOR A. W. MERRISON | *Daresbury Nuclear Physics Laboratory* |
| MR. D. S. MITCHELL | *Atomic Energy Authority* |
| DR. T. G. PICKAVANCE | *Rutherford High Energy Laboratory* |
| DR. F. A. VICK, O.B.E. | *Atomic Energy Authority* |
| SIR JOHN WOLFENDEN, C.B.E. | *University of Reading* |

*Secretary :* DR. J. A. V. WILLIS

### Atlas Computer Committee

| | |
|---|---|
| *Chairman :* SIR WILLIAM PENNEY, K.B.E., F.R.S. | *Atomic Energy Authority* |
| DR. J. B. ADAMS, C.M.G., F.R.S. | *Atomic Energy Authority* |
| DR. R. A. BUCKINGHAM | *University of London* |
| SIR JOHN COCKCROFT, O.M., K.C.B., C.B.E., F.R.S. | *University of Cambridge* |
| MR. C. JOLLIFFE | *Department of Scientific and Industrial Research* |
| DR. J. C. KENDREW, F.R.S. | *University of Cambridge* |
| PROFESSOR T. KILBURN | *University of Manchester* |
| DR. M. J. LIGHTHILL, F.R.S. | *Royal Aircraft Establishment, Farnborough* |
| SIR HARRIE MASSEY, F.R.S. | *University College, London* |
| PROFESSOR R. E. PEIERLS, C.B.E., F.R.S. | *University of Oxford* |
| DR. T. G. PICKAVANCE | *Rutherford High Energy Laboratory* |
| SIR GRAHAM SUTTON, C.B.E., F.R.S. | *Meteorological Office* |
| DR. F. A. VICK, O.B.E. | *Atomic Energy Authority* |
| DR. M. V. WILKES, F.R.S. | *University of Cambridge* |

*Secretary :* DR. J. A. V. WILLIS

## Physics Committee

| | |
|---|---|
| *Chairman :* Sir John Cockcroft, O.M., K.C.B., C.B.E., F.R.S. | *University of Cambridge* |
| Dr. J. B. Adams, C.M.G., F.R.S. | *Atomic Energy Authority* |
| Professor C. C. Butler, F.R.S. | *Imperial College of Science and Technology* |
| Professor J. M. Cassels, F.R.S. | *University of Liverpool* |
| Professor P. I. Dee, C.B.E., F.R.S. | *University of Glasgow* |
| Professor B. H. Flowers, F.R.S. | *University of Manchester* |
| Sir Harrie Massey, F.R.S. | *University College, London* |
| Professor A. W. Merrison | *Daresbury Nuclear Physics Laboratory* |
| Professor R. E. Peierls, C.B.E., F.R.S. | *University of Oxford* |
| Sir William Penney, K.B.E., F.R.S. | *Atomic Energy Authority* |
| Dr. T. G. Pickavance | *Rutherford High Energy Laboratory* |
| Professor C. F. Powell, F.R.S. | *University of Bristol* |
| Professor D. H. Wilkinson, F.R.S. | *University of Oxford* |

*Secretary :* Dr. J. A. V. Willis

## Research Reactor Committee

| | |
|---|---|
| *Chairman :* Sir John Cockcroft, O.M., K.C.B., C.B.E., F.R.S. | *University of Cambridge* |
| Dr. I. G. Campbell | *University of Manchester* |
| Dr. V. S. Crocker | *Atomic Energy Authority* |
| Dr. S. C. Curran, F.R.S. | *Royal College of Science and Technology, Glasgow* |
| Professor J. Diamond | *University of Manchester* |
| Dr. P. A. Egelstaff | *Atomic Energy Authority* |
| Mr. C. Jolliffe | *Department of Scientific and Industrial Research* |
| Mr. J. J. McEnhill | *Atomic Energy Authority* |
| Professor E. W. J. Mitchell | *University of Reading* |
| Dr. T. G. Pickavance | *Rutherford High Energy Laboratory* |

*Secretary :* Dr. J. M. Valentine

## Rutherford Laboratory Visiting Committee

| | |
|---|---|
| *Chairman :* Sir Harrie Massey, F.R.S. | *University College, London* |
| Dr. A. Ashmore | *Queen Mary College, London* |
| Professor E. H. Bellamy | *Westfield College, London* |
| Dr. E. Bretscher | *Atomic Energy Authority* |
| Professor W. E. Burcham, F.R.S. | *University of Birmingham* |
| Professor C. C. Butler, F.R.S. | *Imperial College of Science and Technology* |
| Professor J. M. Cassels, F.R.S. | *University of Liverpool* |
| Professor P. I. Dee, C.B.E., F.R.S. | *University of Glasgow* |
| Professor B. H. Flowers, F.R.S. | *University of Manchester* |
| Professor O. R. Frisch, O.B.E., F.R.S. | *University of Cambridge* |
| Dr. F. F. Heymann | *University College, London* |
| Professor G. Hutchinson | *University of Southampton* |
| Professor A. W. Merrison | *Daresbury Nuclear Physics Laboratory* |
| Professor P. B. Moon, F.R.S. | *University of Birmingham* |
| Professor E. B. Paul | *University of Manchester* |
| Professor R. E. Peierls, C.B.E., F.R.S. | *University of Oxford* |
| Professor C. F. Powell, F.R.S. | *University of Bristol* |
| Professor G. D. Rochester, F.R.S. | *University of Durham* |
| Professor A. Salam, F.R.S. | *Imperial College of Science and Technology* |
| Professor D. H. Wilkinson, F.R.S. | *University of Oxford* |



*Secretary :* Dr. J. M. Valentine

## Daresbury Laboratory Advisory Committee

| | |
|---|---|
| *Chairman :* Sir James Chadwick, F.R.S. | |
| Professor J. M. Cassels, F.R.S. | *University of Liverpool* |
| Professor P. I. Dee, C.B.E., F.R.S. | *University of Glasgow* |
| Professor B. H. Flowers, F.R.S. | *University of Manchester* |
| Dr. T. G. Pickavance | *Rutherford High Energy Laboratory* |

*Secretary :* Mr. D. J. Kinnersley

## Daresbury Laboratory Experimental Facilities Committee

| | |
|---|---|
| *Chairman :* Professor J. M. Cassels, F.R.S. | *University of Liverpool* |
| Dr. R. J. Ellison | *University of Manchester* |
| Dr. S. G. F. Frank | *University of Liverpool* |
| Professor J. C. Gunn | *University of Glasgow* |
| Dr. P. G. Murphy | *Rutherford High Energy Laboratory* |
| Professor E. B. Paul | *University of Manchester* |
| Dr. J. C. Rutherglen | *University of Glasgow* |
| Dr. G. H. Stafford | *Rutherford High Energy Laboratory* |

*Secretary :* Dr. N. R. S. Tait

# APPENDIX II

## NATIONAL INSTITUTE FOR RESEARCH IN NUCLEAR SCIENCE

### Revenue Account for the year ended 31st March, 1963

| *1961–62* £ | | £ |
|---|---|---|
| *749,251* | Salaries and Wages | 988,284 |
| *52,812* | Employers' Superannuation Contributions | 66,459 |
| *16,098* | Employers' National Insurance Contributions | 20,397 |
| *40,174* | Travel and Subsistence Expenses | 60,041 |
| *610,817* | Materials and Services | 1,160,224 |
| *54,777* | Research and Development by Universities and Industry | 107,730 |
| *8,475* | Expenses on Hostel and Houses | 13,950 |
| *42,425* | Miscellaneous Expenses | 75,254 |
| *1,113,176* | Supplies and Services by the United Kingdom Atomic Energy Authority | 1,226,673 |
| *£2,688,005* | | £3,719,012 |

| *1961/62* £ | | £ |
|---|---|---|
| | Grant from United Kingdom Atomic Energy Authority to meet Recurrent Expenditure | |
| *2,622,746* | Research, Administration, etc. | 3,613,473 |
| *8,938* | Capital Expenditure | 2,533 |
| *6,680* | Receipts from Hostel and Houses | 12,998 |
| *49,641* | Miscellaneous Income | 90,008 |
| *£2,688,005* | | £3,719,012 |

### Capital Account as at 31st March, 1963

| *31st March 1962* £ | | £ |
|---|---|---|
| | *Capital Grant Account* | |
| *8,867,623* | Balance as at 1st April, 1962 | 11,806,102 |
| *2,929,963* | Add Grant from United Kingdom Atomic Energy Authority to meet capital expenditure for the year ended 31st March, 1963 | 3,577,972 |
| *8,938* | Expenditure from Revenue Account | 2,533 |
| *11,806,524* | | 15,386,607 |
| *422* | *Deduct*—Amounts written off for Assets no longer in service | 3,349 |
| *£11,806,102* | | £15,383,258 |

| *31st March 1962* £ | | £ |
|---|---|---|
| | *Assets at Cost* | |
| *4,209,598* | Land and Buildings | 4,575,421 |
| *2,729,646* | Plant and Machinery, Ancillary Installations and Motor Vehicles | 3,126,666 |
| *175,153* | Loose Apparatus, Tools, Furniture, Fittings and Office Machinery | 328,732 |
| *7,114,397* | | 8,030,819 |
| *4,691,705* | Assets in course of construction | 7,352,439 |
| *£11,806,102* | | £15,383,258 |

*NOTE.*—Capital expenditure authorised but not provided for in these accounts amounted to £10,926,633 of which £5,771,938 has been committed contractually.

BRIDGES, *Chairman.*
J. A. V. WILLIS, *Secretary.*

I have examined the above Accounts. I have obtained all the information and explanations that I have required, and I certify, as the result of my audit, that in my opinion the above Accounts are correct.

EXCHEQUER AND AUDIT DEPARTMENT,
*17th December, 1963.*

E. G. COMPTON,
*Comptroller and Auditor General.*

*APPENDIX III*

## Notes on the Accounts

Although expenditure during the year ended 31st March, 1963 was predominantly on Rutherford High Energy Laboratory activities, there was some expenditure for the first time on the Atlas Computer Laboratory and on the Daresbury Nuclear Physics Laboratory.

An analysis of revenue expenditure under the main objects is given below:

**Revenue expenditure for the year ended 31st March, 1963:**

| | £000 |
|---|---|
| Nimrod .. .. .. .. .. | 2,368 |
| The P.L.A. .. .. .. .. | 855 |
| Other accelerator development .. | 300 |
| Research using reactors .. .. | 51 |
| | 3,574 |
| Atlas Computer Laboratory .. .. | 12 |
| Rutherford Laboratory, including Atlas | 3,586 |
| Daresbury Laboratory .. .. .. | 27 |
| | 3,613 |

A summary of the Institute's assets at the 31st March, 1963 is as follows:

**Assets at costs**
**(including expenditure to date on assets in course of construction)**

| | £000 |
|---|---|
| Nimrod .. .. .. .. .. .. .. | 10,871 |
| The P.L.A. .. .. .. .. .. .. | 1,391 |
| Other Rutherford Laboratory buildings and land | 1,708 |
| Other Rutherford Laboratory plant and equipment | 564 |
| Atlas Computer Laboratory, including buildings .. | 819 |
| Daresbury Laboratory .. .. .. .. .. | 30 |
| | £15,383 |

*APPENDIX IV*

## List of Nuclear Physics Experiments on the P.L.A. Programme and Associated Theoretical Studies

1. The following experiments were completed during the year:

(i) Measurements of the polarization in 30 and 50 MeV proton-proton scattering at 45° (c.m.)* (Rutherford Laboratory and Queen's University, Belfast). Published in *Nuclear Physics*, **45**, No. 3, pp. 481–491 (1963).

(ii) Measurement of the p–p scattering cross section at 90° (c.m.) between 20 and 50 MeV. (Rutherford Laboratory and Queen's University, Belfast).

(iii) Measurement of the depolarization parameter for 50 MeV proton–proton scattering at 70° (c.m.) (University College, London). Published in *Phys. Rev. Letters*, **10**, No. 10, pp. 444–446 (1963).

*c.m. = centre of mass.



(iv) Polarization in proton–$^4$He elastic scattering between 22 and 50 MeV. (Rutherford Laboratory and King's College, London). Published in *Physics Letters*, **5**, p. 335 (1963).

(v) Measurement of differential cross sections for elastic p–$\alpha$ scattering. (Rutherford Laboratory and King's College, London).

(vi) Polarization angular distributions in the elastic scattering of 30 MeV protons from complex nuclei. (Birmingham University and Rutherford Laboratory).

(vii) Investigation of the deuteron by correlation techniques. (Westfield College, London and Queen's University, Belfast).

(viii) Studies of proton radiative capture by activation methods. (Oxford University).

(ix) A study of gamma-ray yields from the $^{15}$N (p, $\gamma$)$^{16}$O reaction. (Oxford University).

(x) States of $^{16}$F excited in the reaction $^{16}$O (p,n)$^{16}$F. (Rutherford Laboratory and King's College, London).

(xi) Differential proton scattering cross-sections at 30 MeV. (A.E.R.E.).

(xii) The spectrum of neutrons from the reaction D(p,n)2p at 30 and 50 MeV. (At 0°). (Rutherford Laboratory and Queen's University, Belfast).

(xiii) Excitation of isobaric states in (p,n) reactions at 30 and 50 MeV. (At 0°). (Rutherford Laboratory and Queen's University, Belfast).

(xiv) (p,$\alpha$) and (p,$^3$He) reactions in $^{58}$Ni and $^{59}$Co at 50 MeV. (A.E.R.E.).

2. The following experiments are in progress:

(i) Measurement of the A. parameter in p–p scattering at 50 MeV. (Queen Mary College, London).

(ii) Measurement of the $^{12}$C (p,n)$^{12}$N excitation function. (Oxford University).

(iii) Polarization effects in proton–deuteron elastic scattering at 50 MeV. (Westfield College, London and Queen's University, Belfast).

(iv) Differential proton scattering cross-sections at 30 MeV. By different techniques from experiment 1 (xi). (A.E.R.E.).

(v) p–2p reaction cross sections for carbon and calcium at 50 MeV. (Westfield College, London and Queen's University, Belfast).

(vi) Inelastic proton scattering and the excitation of states with large $\alpha$ decay widths—the reactions $^{12}$O (p,p′$\alpha$) and $^{16}$O (p,p′$\alpha$). (Oxford University).

(vii) The spectrum of neutrons from the reaction D(p,n)2p at 30 and 50 MeV. At different angles from experiment 1 (xii). (Rutherford Laboratory and Queen's University, Belfast).

(viii) Polarization of neutrons produced in the bombardment of deuterons with polarized protons of energy 30 MeV. (Rutherford Laboratory and King's College, London).

(ix) Excitation of isobaric states in (p,n) reactions at 30 and 50 MeV. At different angles from experiment 1 (xiii). (Rutherford Laboratory and Queen's University, Belfast).

(x) (p,$\alpha$) and (p,$^3$He) reactions in $^{58}$Ni and $^{59}$Co at 50 MeV. (A.E.R.E.).

(xi) Measurement of the R parameter in p–p scattering at 50 MeV. (Queen Mary College, London).

(xii) Measurement of the rotation parameter in p–$\alpha$ scattering at 50 MeV. (University College, London).

3. The following theoretical studies relating to the work at the P.L.A. were in progress and in most cases completed, during the year:

(i) Phase shift analysis of p–p scattering at 25 and 50 MeV. (Rutherford Laboratory).

(ii) Optical model analysis of 30 MeV proton elastic scattering by $^{120}$Sn and $^{208}$Pb. (Oxford University).

(iii) The density of p-nucleons in T=0 and T=1 states of $^{6}$Li. (Battersea College of Technology, London).

(iv) The validity of the W.K.B. approximation for distorted waves (Battersea College of Technology, London).

(v) The (p,pd) reaction for $^{6}$Li and $^{7}$Li. (Battersea College of Technology, London).

(vi) Configuration mixing in the $^{6}$Li wavefunction. (Battersea College of Technology, London).

(vii) Form factors from elastic electron scattering. (Battersea College of Technology, London).

## *APPENDIX V*

### List of Publications by Staff of the Institute: October, 1962 to September, 1963


ARNISON, G. T. J. A porous enclosure for electroplating anodes of unusual shape. *J. Sci. Instrum.*, Vol. **40**, No. 9, p. 464, September, 1963.

BATTY, C. J., STAFFORD, G. H. and GILMORE, R. S. Excitation of isobaric states in (p, n) reactions at 30 and 50 MeV. *Physics Letters*, **Vol. 6**, No. 3, pp. 292–293, September, 1963.

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BOWLES, P., HADLEY, H., MARCHBANKS, M. J. and (the late) WILKINS, J. J. Magnet power supply for the 7 GeV proton synchrotron Nimrod. Part 1. General.
*Proc. Instn. Elect. Engrs.*, Vol. **110**, No. 3, pp. 561–572, March, 1963.

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JONES, F. L. and NICHOLAS, D. J. The theory and design of an analyser for investigating the electron emission characteristics of surfaces in gases. *Brit. J. Appl. Phys.*, Vol. **13**, No. 10, pp. 514–520, October, 1962.

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## N.I.R.N.S. Reports

(on sale through H.M.S.O. in cases where a price is shown)

NIRL/R/4 (7*s.* 0*d.*) Measuring apparatus and methods used during the design and commissioning of the Nimrod magnet. By D. A. Gray, M. R. Harold, P. F. Jones, R. H. C. Morgan, Miss J. E. Partington and I. C. Pyle, January, 1963.

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NIRL/R/21 A new type of accelerating tube for electrostatic generators. By W. D. Allen. October, 1962.

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NIRL/R/23 Electrostatic generator group progress report, 1962. December, 1962.

NIRL/R/24 P.L.A. Progress Report, 1962. Eds. R. C. Hanna and J. M. Dickson. 1963.

NIRL/R/26 Computer program used to produce a corrected (isochronized) magnetic field for a variable energy cyclotron. By D. A. Harragan and A. R. Mayhook. February, 1963.

NIRL/R/28 Design study for the trim-coil system to be used on the variable energy cyclotron at Harwell. By A. R. Mayhook. March, 1963.

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NIRL/R/36 A description of some corrected (isochronous) fields used for design studies on the Harwell variable energy cyclotron. By D. A. Harragan and A. R. Mayhook. March, 1963.

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NIRL/R/39 A mechanical safety device for the Nimrod vacuum system. By R. J. B. Hadden and G. J. Homer. September, 1963.

NIRL/R/40 Report of the shielding conference held at the Rutherford Laboratory on September 26–27, 1962. Ed. R. H. Thomas. June, 1963.

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NIRL/R/50 (2*s.* 6*d.*) A geometry program for heavy liquid bubble chambers. By J. Sparrow. August, 1963.

NIRL/R/27 Computer program for finding closed orbits and studying motion in a variable energy cyclotron. D. A. Harragan. February, 1963.

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*APPENDIX VI*

## List of the Senior Staff
## September, 1963

### Rutherford High Energy Laboratory

| | |
|---|---|
| *Director* | DR. T. G. PICKAVANCE |
| *Assistant Director (Accelerator and Applied Physics)* | MR. L. B. MULLETT |
| *Chief Engineer* | MR. P. BOWLES |
| *Proton Linear Accelerator and High Energy Physics Research* | DR. G. H. STAFFORD |
| *Secretary, Rutherford Laboratory* | DR. J. M. VALENTINE |
| *Secretary, N.I.R.N.S.* | DR. J. A. V. WILLIS |
| *Head of the Electrostatic Generator Group* | DR. W. D. ALLEN |
| *Head of the Theoretical Studies Group* | MR. W. WALKINSHAW |
| *In charge of the commissioning of Nimrod* | DR. L. C. W. HOBBIS |
| *Head of the Cyclotron Group* | MR. J. D. LAWSON |
| *Head of the Nimrod Engineering Group* | MR. J. C. LOUTH |
| *Head of the P.L.A. Engineering Group* | MR. J. B. MARSH |
| *Head of the Central Engineering Group* | MR. G. E. SIMMONDS |
| *Head of the Bubble Chamber and Radiation Protection Groups* | MR. M. SNOWDEN |
| *Head of the High Energy Physics Engineering Group* | MR. G. N. VENN |

**Atlas Computer Laboratory**

| | |
|---|---|
| *Director* | DR. J. HOWLETT |
| *Head of the Programming Group* | DR. R. F. CHURCHHOUSE |

### Daresbury Nuclear Physics Laboratory

| | |
|---|---|
| *Director* | PROF. A. W. MERRISON |
| *Head of the Magnet Design Group* | DR. J. R. HOLT |
| *Secretary* | MR. D. J. KINNERSLEY |
| *Head of Site Services* | MR. M. MOORE |

## Objects of the National Institute for Research in Nuclear Science

The objects for which the Institute are established and incorporated are set out in the Royal Charter as follows:

(a) To carry out research of any nature in connection with nuclear science or any matter related thereto.

(b) To provide, equip and operate facilities of any description which may, in the opinion of the Institute, be required for the purposes of any such research as aforesaid.

(c) Without prejudice to the generality of the foregoing, to provide, equip and operate, for common use by Universities and by other institutions and persons engaged in research in nuclear and related matters, facilities which by reason of their size or cost or otherwise howsoever are beyond the scope of individual Universities, institutions or persons as aforesaid.

(d) To permit and encourage scientists of Universities, Colleges and the United Kingdom Atomic Energy Authority and other institutions, as well as scientists of industrial laboratories, to make such use of facilities provided as aforesaid as the Institute may determine to be appropriate.

(e) To co-operate with the United Kingdom Atomic Energy Authority in the solution of specific problems in the field of nuclear or related research.

(f) To train scientists and engineers in matters relating to nuclear science.

(g) To disseminate scientific and technical knowledge in the field of nuclear or related research.

(h) To acquire from the United Kingdom Atomic Energy Authority or from any other body or person whatsoever any property, equipment or other assets of any kind which in the opinion of the Institute are requisite for or conducive to the carrying out of research in connection with nuclear science or any matter related thereto and to enter into any contracts or agreements in furtherance of any such research.

(i) Generally to do all things necessary or expedient for the proper and effective carrying out of any of the objects aforesaid.