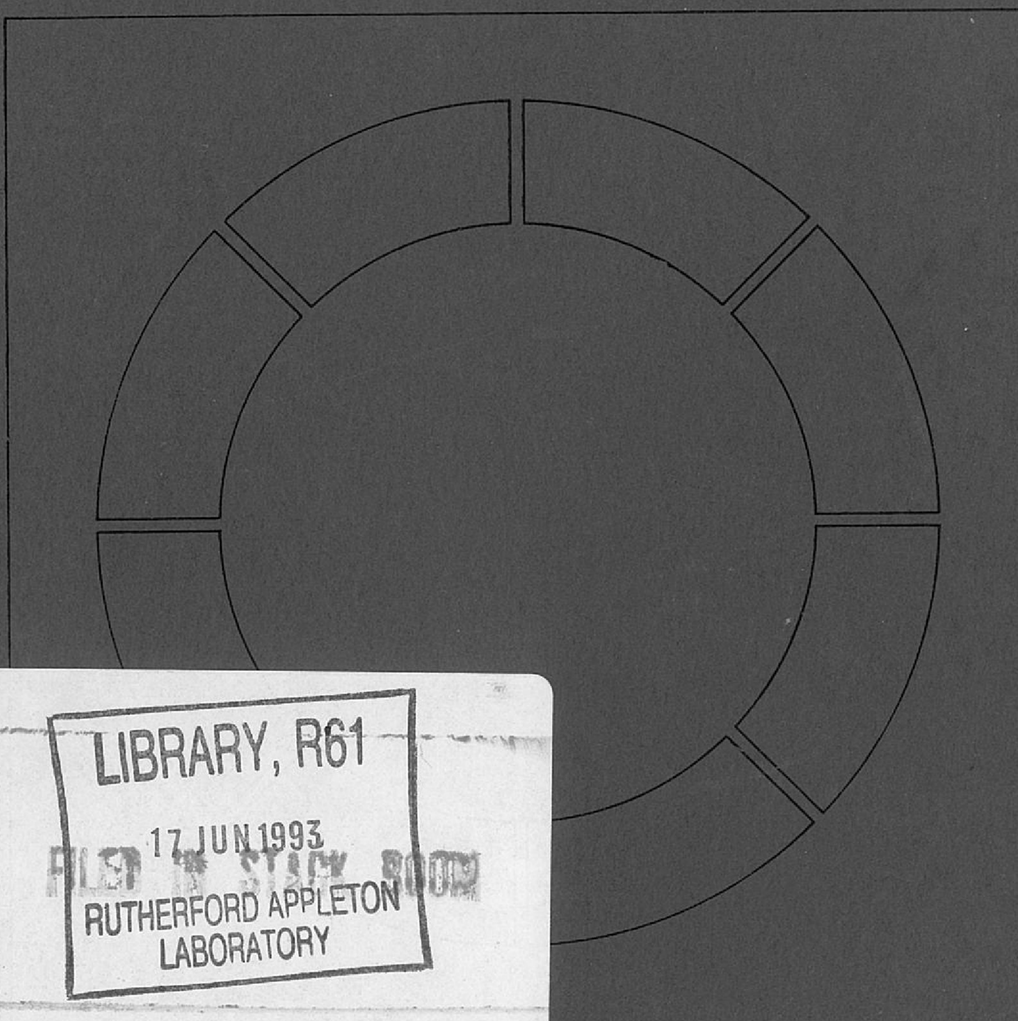
National Institute for Research in Nuclear Science

Seventh Annual Report 1963/1964



The National Institute for Research in Nuclear Science

Seventh Annual Report for the period 1 October 1963 to 30 September 1964

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 af the Institute's Royal Charter, the Seventh Annual Report of the National Institute for Research in Nuclear Science. This Report covers the period 1 October 1963 to 30 September 1964

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 SW1

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*From 15 February 1964
†Until 15 February 1964

Contents

The inauguration of Nimrod

The National Institute for Research in Nuclear Science

Seventh Annual Report
for the year ending 30 September 1964

Introduction

The National Institute for Research in Nuclear Science was set up in 1957. The main reason for its establishment was that the increasing size and cost of the apparatus needed for nuclear research made it impossible to supply the larger and major types of apparatus to individual universities. Some new and central organisation was therefore needed to furnish such facilities for British universities generally.

The first step was to establish the Rutherford High Energy Laboratory at Chilton; the chief apparatus in use here is Nimrod, the proton synchrotron, which has been in operation for over a year, and the proton linear accelerator. The formal inauguration of the Laboratory was performed by the Right Hon Quintin Hogg, QC, MP, Secretary of State for Education and Science on 24 April 1964, when the first high energy physics experiments with Nimrod were in full swing. Representatives of universities and research organisations from many countries took part, as well as representatives of the government, of local institutions, and of firms concerned with the building of Nimrod.

A second laboratory is being established at Daresbury in Cheshire, where construction of the electron synchrotron, Nina, is making very good progress. Clearance of the site started in November 1963, and the staff, previously accommodated partly at Liverpool University and partly at the Rutherford Laboratory, moved into temporary accommodation on the site in January 1964. By the end of September orders amounting to three million pounds had been placed, almost all the main components of Nina having been designed and specified, and all but one of the major plant contracts let. A great effort has also been devoted to recruitment, and by September the total strength of the Laboratory had grown to ninety-eight.

The setting up of the National Institute for Research in Nuclear Science marked the establishment of a new pattern or type of organisation in civil research. The NIRNS Laboratories are not simply government research organisations. They are establishments set up to provide University scientists with the same sort of facilities for research as they would expect to find in their own University. The Laboratories are interpenetrated with university staff. University scientists have been concerned from the outset in the design of the Institute's accelerators. Working alongside the Institute's staff, they have been concerned also in the management problems of the Laboratories, in the practical arrangements for selecting and scheduling the experiments, and in the organisation of the massive scientific and technical support required for experiments on the scale of those mounted on Nimrod. But equally, experience shows that a laboratory merely providing beams of particles and supporting services for a series of visitors' experiments, however well chosen and ably conducted, would fail to achieve the sense of purpose and the impetus which are needed for success in the highly competitive field of elementary particle physics. The laboratory management has to give cohesion and continuity to the research programme, as well as taking full responsibility for all operations. The interrelationship of the Laboratory management and the university and AEA users is thus a very subtle one, but upon it the success of the Institute's laboratories entirely depends.

The report of the Committee of Enquiry into the Organisation of Civil Science (Cmd 2171) recommended that the Institute should be merged in a wider organisation covering civil science generally. We entirely accept that it is right that research into nuclear physics should be grouped with other branches of nuclear research for the assessment of the global needs of all forms of scientific research taken together and for the allocation of resources between the various claimants. Another advantage of the new organisation is that it will make it possible to coordinate more closely the support given to nuclear physics research in international, national and University Laboratories. We trust, however, that the method of organisation which has been established in the NIRNS Laboratories and which we believe has worked very successfully, will be carried on under the new organisation.

We reached the conclusion that it would be appropriate in this, our last report, to start with an account of recent developments in elementary particle physics and to show the place of research carried out at Nimrod against this general background. This is followed by a more detailed list of the experiments in high energy physics carried out at Nimrod. Likewise an account is given in general terms of recent developments in medium energy nuclear physics as a background to the role played by the proton linear accelerator. Later passages in this report give particulars of other work carried out in the laboratories, together with membership of committees, accounts and publications of the staff and so forth.

We cannot conclude this report without recording our deep sense of gratitude to Dr Pickavance, Director of the Rutherford Laboratory, and to Professor Merrison, Director of the Daresbury Laboratory, and to all members of their staff. They have shown abilities of a very high order and great determination in facing difficulties. Moreover, it is due to them that this new form of organisation has been successfully adapted to meet the needs of research workers coming both from the universities and government service.

Recent developments in elementary particle physics and the role of Nimrod

In the following paragraphs an account is given of recent developments in some aspects of elementary particle research. No attempt is made to cover the whole field exhaustively; attention is concentrated on a few topics which are being studied intensively in several laboratories and on which experiments have been started at Nimrod.

High energy scattering

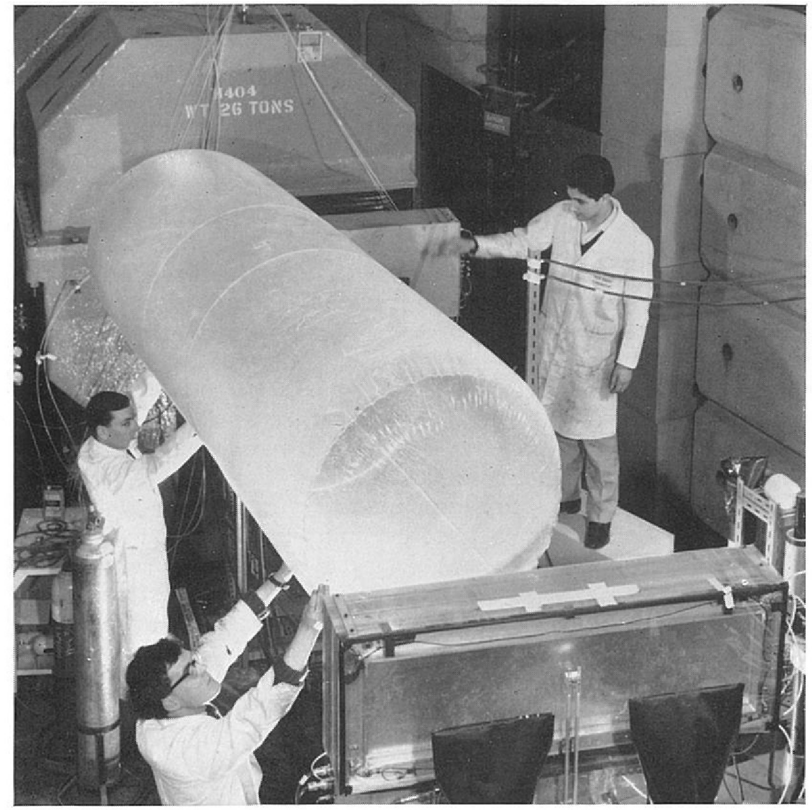
At the time of the 1962 International Conference at CERN there was great optimism that the "Regge pole" theoretical model might give a simple description of the scattering of any one type of particle by any other. In this model the force between two particles is transmitted (mediated) by the exchange of an object known as a "Regge pole"; this expression describes the purely mathematical behaviour of the exchanged object in the theory. Experimentally it can be produced as a physically observed particle; different Regge poles correspond to different particles such as the proton or the π-meson. When the object is playing its role as a mediator of forces it cannot be directly observed; it makes its presence felt only in the equations describing scattering experiments. In this role it has very curious properties, such as having a complex value for its angular momentum. The first hope was that a fairly simple theory based on a small number of Regge poles would describe all scattering experiments at sufficiently high energy; it was also hoped that the particles produced by the high energy accelerators at Brookhaven and CERN would be in this energy range (the theory could not predict its own range of applicability). Early experiments on the scattering of protons by protons gave results which followed the predictions very closely; this was the reason for great optimism. The scattering angular distribution was observed to be peaked in the forward direction; the peaking became sharper as the energy increased, as had been predicted. The same behaviour was expected for the scattering of other particles by protons. However, accurate experiments carried out at Brookhaven showed that this effect certainly does not occur for π-mesons or negative K-mesons.

A general theorem due to Pomeranchuk states that, with some simple and very fundamental assumptions, the total cross-section presented by one particle to another striking it should tend to a constant value as the energy of the projectile particle increases. When this constant value is reached the cross-sections for any particle and its anti-particle striking the same target should be equal. Very accurate measurements have been made for π-mesons, K-mesons, neutrons and anti-protons striking protons or neutrons. Up to the highest energies attainable by present-day accelerators (about 25 GeV) only the K^+-proton total cross-section is anything like constant as a function of energy, and no pairs of anti-particle cross-sections have reached equality. Another simple feature expected at very high energies is that the scattering process, which is in general described by a complex (ie. real plus imaginary) value of the scattering "amplitude", should have a purely imaginary forward scattering amplitude. Recent experiments at CERN, Dubna and the Rutherford Laboratory have shown that there is an appreciable real part in this amplitude for the scattering of protons by protons. An experiment at Nimrod(1)* has given some of the most accurate measurements of this real part of the amplitude. Another somewhat similar experiment (3) which has also been completed was a study of the high energy scattering of neutrons by protons in the rather special circumstances in which the incoming neutron picks up the electrical charge of the proton and proceeds almost undeflected in the collision. The results of this experiment have confirmed preliminary results obtained at a much lower energy at Brookhaven.

Higher symmetry

All physical theories depend on basic assumptions of invariance properties. Most of these are connected with symmetries with respect to space and time. For example, all physical laws are assumed to be unchanged if the whole system under study is rotated through any angle, or if the system is described by an observer moving past it instead of being at rest. Recently a new invariance property has been discovered called Unitary Symmetry. This is a "higher" symmetry in that it does not refer to motions in ordinary space-time but in a special space of its own. A consequence of the theory is that elementary particles should occur in groups ("multiplets",) the smallest being groups of 8, 10 or 27. The resonances, which are very short-lived combinations of two or more particles, also fall into the same pattern. In fact, there is no reason to distinguish between resonances and elementary particles; the resonances are short-lived only because they are heavy. One group of eight contains the neutron, proton, lambda hyperon, positive, negative and neutral sigma hyperons and two cascade hyperons. Another well-established group of eight contains eight mesons. Shortly after the theory was put forward by Gell-Mann and Ne'eman in 1961 it was realised that there existed nine resonances each with spin $\frac{3}{2}$ units of angular momentum and positive parity; a tenth was needed to complete a "unitary multiplet". Gell-Mann and Okubo had discovered how to calculate the mass differences of the particles in a multiplet; Okubo's formula showed that the mass of the tenth member of the multiplet should be such

**The figures in brackets refer to the list of Nimrod experiments at the end of this section of the report.*



Work in the Nimrod Experimental Hall

that it would be a relatively long-lived particle rather than a resonance. The discovery of this new particle, the Ω^-, early in 1964 at Brookhaven after vigorous searches in all the world's high energy laboratories was a dramatic success for the theory. Other successes for the theory have been the confirmation of its predictions of the mass relationships between members of the multiplets and a prediction of the magnetic moment of the lambda hyperon which, within the limits of accuracy of the experiment, is consistent with the measured value.

Two experiments that have a direct bearing on the theory of Unitary Symmetry are on the Nimrod experimental programme. One of these (10) is to search for a rare mode of decay of the neutral ω° particle into a pair of electrons, the more usual decay being into three pi-mesons. The theory predicts precisely the relative rates of decay into an electron pair of the ω° and of an associated particle which is usually given the symbol ϕ°; when both these rates have been measured the result will provide an important test of the theory. The second experiment was concerned with the possibility that a certain group of particles formed a set of 10 rather similar to that containing the Ω^- particle. If so, an as yet undiscovered particle named the Z^+ should exist. A search was made in an experiment at Nimrod (5a) very soon after the theoretical speculations about the existence of the particle had appeared in the literature.

No such particle was found, and it was thus established with considerable reliability that certain theoretical assumptions were not valid.

Almost a hundred resonances have not yet been classified into unitary multiplets. Their properties, in particular their spins and parities, must first be measured. At Nimrod, three groups are attempting to determine the properties of certain known pion-proton resonances. One group (2) is using a special hydrogenous target in which the protons are polarized, to study a momentum region between 700 and 1500 MeV/c. A second group (5b) has been studying a slightly higher momentum region where two new resonances have recently been discovered, while a third group (7) were able to study at the same time and in the same momentum region a complementary experiment, the "charge-exchange" scattering process $\pi^- + p \rightarrow \pi^\circ + n$.

The determination of the properties of known resonances and the search for new resonances at present forms a large part of the work at high energy accelerators throughout the world. A powerful tool for this work is the hydrogen bubble chamber; the large chamber of the Centre d'Etudes Nucleaires de Saclay is installed at Nimrod (18) and a specially designed separated K-meson beam for it is being constructed. Another group (11) will be using the spark chamber technique for similar studies, with a negative pion beam.

Many aspects of Unitary Symmetry could be understood if there existed three basic particles from which all others would be constructed by various combinations. These particles called "quarks" by Gell-Mann and "aces" by Zweig would have peculiar properties; for example they would have electric charges of $\frac{1}{3}$ or $\frac{2}{3}$ that of the electron—all other particles are equal to the electron in the magnitude of their charge or have ratios of 2, 3 or any larger whole number to it (or are neutral). These particles should be easily recognisable when they occur, so searches for them have been carried out at CERN and Brookhaven. They have not been found; the conclusion is that if they exist then they must be too heavy to be made by 30 GeV protons; a much higher energy machine is needed to create them.

Weak Interactions

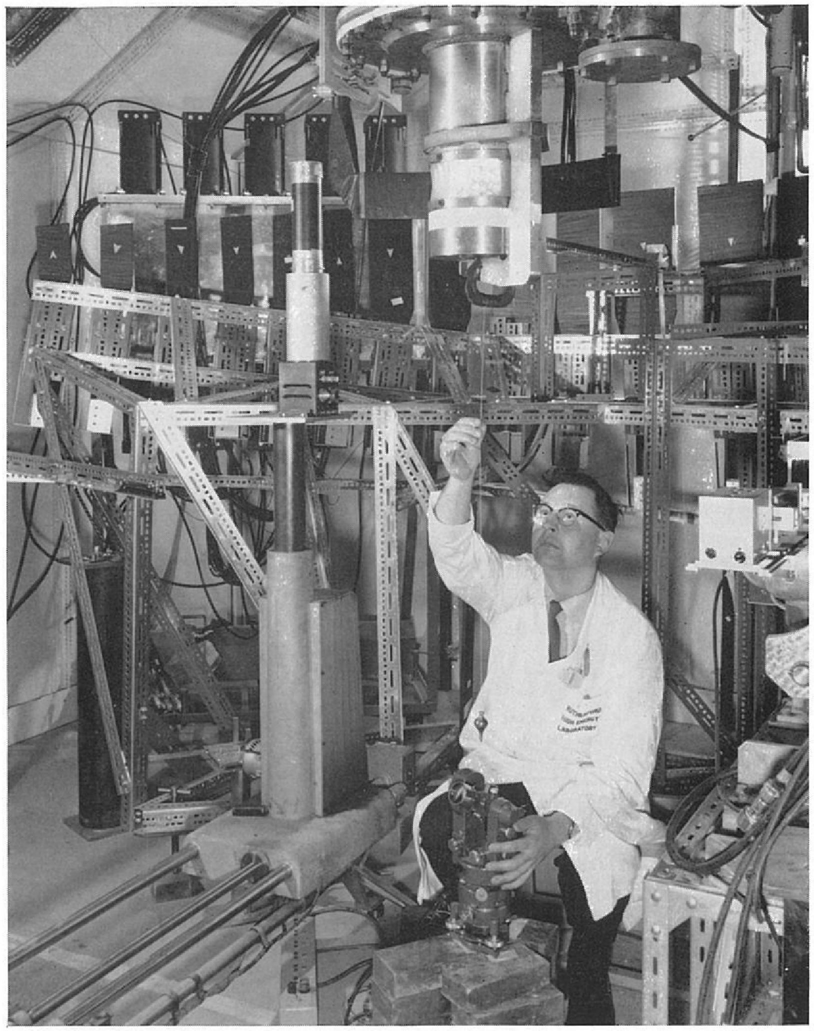
The weak interactions cause the beta-decay of radioactive isotopes, the decay of unstable particles and the interactions of neutrino beams with matter. There are always four particles involved in a weak interaction. For example, the neutron decays into a proton, an electron and a neutrino. The four particles can always be arranged in two pairs; in the case of neutron decay the neutron and the proton form one pair and the electron and neutrino form the other pair. It has been observed that the arrangement of particles in pairs in the weak interactions obeys certain rules. One rule is that in each pair one particle must be charged and the other neutral. Another rule governs the way in which the hyperons can enter. This latter rule was found to be obeyed very accurately in experiments carried out earlier this year at Berkeley, CERN and Brookhaven; physicists from the Rutherford Laboratory took part in the CERN experiment. "Selection rules" of this sort do not occur without any reason. For example, selection rules governing the spectra emitted by hot gases were discovered in the nineteenth century. The theory of quantum mechanics developed in the nineteen-twenties showed how these selection rules were consequences of invariance with respect to rotations and reflections in space. In the case of weak interactions there would be an explanation of the selection rules if there existed a family of particles called the "vector-bosons". In neutron decay the neutron could become a proton and simultaneously emit a "virtual" vector boson; the vector boson would then decay into an electron and a neutrino. (The word "virtual" means that the boson itself cannot be observed in the decay; it is so heavy that energy conservation would be violated. It plays a purely intermediary role). All the weak interactions would take place by the exchange of vector bosons between the pairs of particles. If all vector bosons were electrically charged it follows that each pair of particles must have a net charge. Other universal rules of the weak interactions would have similar straightforward explanations. If they exist, the vector bosons should be produced when high energy neutrinos are used to bombard neutrons and protons; an experiment of this sort completed recently at CERN produced no vector bosons. The conclusion is that if they exist the vector bosons must be very heavy—too heavy to be produced at the CERN accelerator; a higher energy accelerator is needed to continue the search.

It was discovered in 1956 that the phenomena of the weak interactions do not remain invariant when the laboratory is replaced by a mirror-image system; "parity conservation is violated in weak interactions". It was immediately postulated that nevertheless a mirror-image laboratory would behave the same so long as all particles were replaced by anti-particles (an operation known as "charge-conjugation"). In other words the universe was believed to be "CP-invariant" (C for charge conjugation, P for parity). Experiments to test this rule are difficult; no very accurate ones had been done until this year. Recently an experiment at Brookhaven has shown that CP-invariance is violated to the extent of two parts in a thousand in the decay of long-lived neutral K-mesons. There are two kinds of neutral K-mesons; if CP-invariance were exact then the short-lived K°_1 can decay into a pair of π-mesons while the long-lived K°_2 cannot. The Brookhaven experiment found a small number of events of K°_2 mesons decaying into two π-mesons. This unexpected result has stimulated great interest throughout the world; an experiment on K°_2 decay is being carried out at Nimrod (22).

The role of Nimrod

Hitherto, experimental work with high energy accelerators has been carried out mainly at three centres—Berkeley, CERN and Brookhaven. Much of the progress has come from these laboratories, although there have also been significant contributions from Dubna in the USSR, Saclay in France and several electron accelerators in the USA, France and Italy. In addition, a number of synchrocyclotron laboratories have made detailed studies of the properties of protons and of pi- and mu-mesons. The commissioning of Nimrod has now enabled physicists in Britain to take part in front-line research in elementary particle physics. The recent theoretical and experimental discoveries have opened up a large and exciting field of investigation. Nimrod will be able to contribute substantially. It will be possible to carry out many experiments on resonances, on particle decays and on some features of particle scattering such as those in the current programme that are referred to above. There is also the need to accumulate precise nuclear data against which theories can be tested and as a result of which new discoveries can sometimes be made. With its high intensity Nimrod is very well fitted for this role. One such study on the Nimrod programme (12) is the measurement of total proton-proton and proton-neutron cross sections, in which the object will be to attain a very high precision.

Alignment of counters around a target



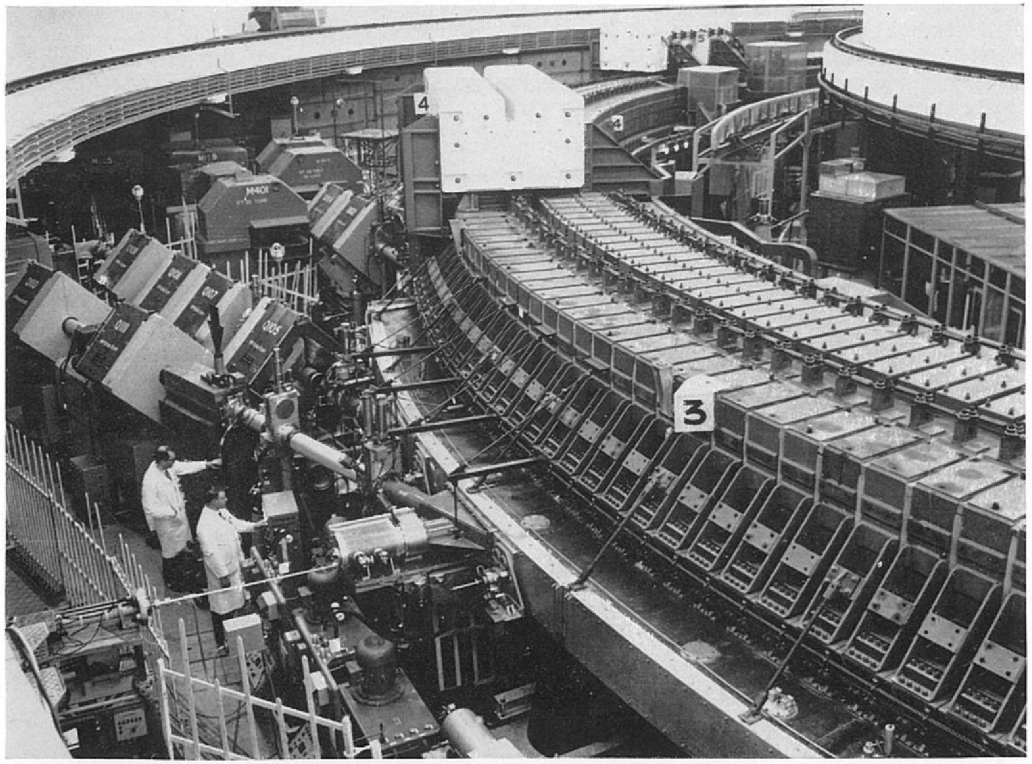
List of the experiments

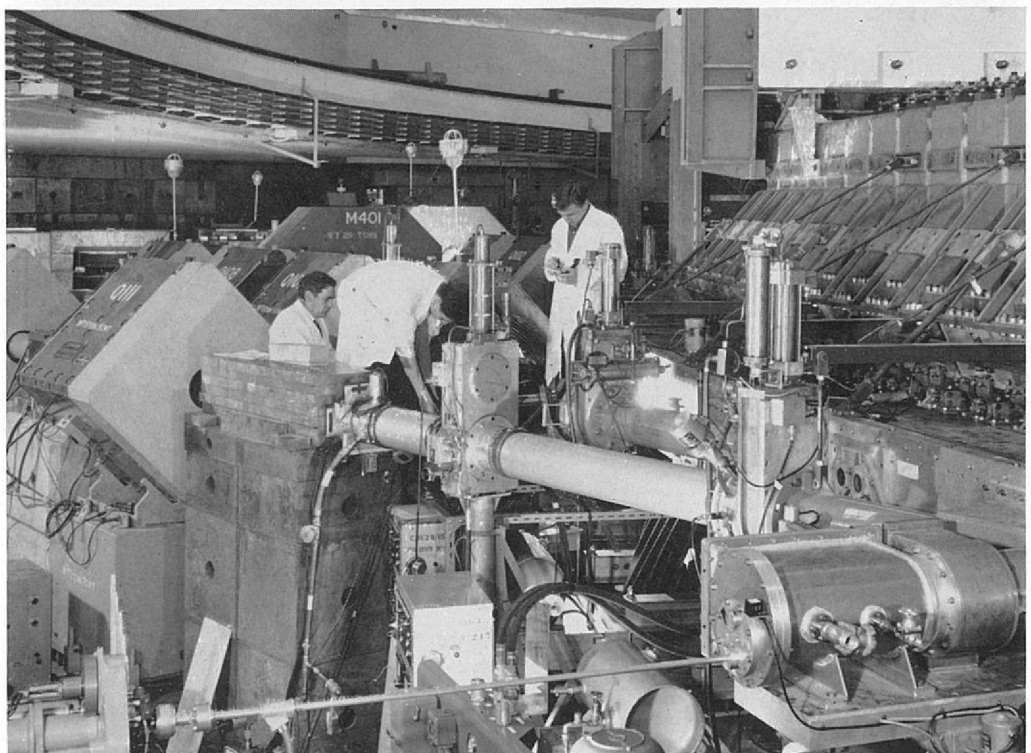
In September 1964, one hundred and forty research physicists were carrying out or preparing experiments at Nimrod. One hundred and twenty-three of them were from the universities and the Atomic Energy Research Establishment, Harwell; the remaining seventeen were Institute staff, almost all on fixed-term appointment. Experiments are chosen by a process which starts with full discussion between the experimental groups and ends with the decisions of a selection panel composed of physicists of the universities and the Laboratory. The following list shows the experiments that had been started by September 1964.

Proposal Number	Particle Beam	Experiment	Team
1	P2	p-p Diffraction scattering in the coulomb interference region (completed)	AERE Queen Mary College, London Rutherford Laboratory
2	$\pi 1$	$\pi^{\pm}$-p Differential cross-sections and polarization between 800 and 1000 MeV	Rutherford Laboratory Oxford University
3	N1	Elastic charge exchange scattering of neutrons (completed)	AERE Bristol University Birmingham University Rutherford Laboratory
5	$\pi 2$	$\pi^{\pm}$-p Differential elastic cross-sections near 2 GeV	University College London Westfield College, London
—	$\pi 2$	A search for the Z^{+} particle (completed)	University College London Westfield College, London
7	$\pi 3$	Charge exchange scattering with negative pion beams near 2 GeV (completed)	Oxford University Rutherford Laboratory
10	K2	Two-body decays of the ω°	Imperial College, London Manchester University
11	P3	An investigation in $\pi^{-}+p$ processes of (a) multipion resonances (b) 2π decays of the f° (c) $K^{+} K^{-}$ decays of the f°	AERE Southampton University University College London
12	P4	p-p and p-n total cross-section measurements	Cambridge University Rutherford Laboratory
18	K1	K^{-} bubble chamber experiments over the momentum range 1·5 to 2·0 GeV/c	French and British bubble chamber groups including the Universities of Birmingham, Cambridge, Glasgow and Oxford, Imperial College and the Rutherford Laboratory
22	N2	A test of CP violation in the decay $K^{\circ}_{2} \rightarrow \pi^{+}+\pi^{-}$	AERE Bristol University Rutherford Laboratory

Nimrod magnet ring and beam lines

below P2 beam line emerging from Nimrod





The development and operation of Nimrod

After the first operation of Nimrod at full energy in August 1963, a period of intensive development continued until February 1964. During this period effort was concentrated upon operating the machine, understanding its behaviour and increasing its reliability; there were phenomena, both during injection and during acceleration, which needed to be understood in order to improve the machine's performance and both these aspects of machine development received considerable attention, the effect of which may be gauged from the progress in increasing the beam intensity.

In early December it was possible to schedule a continuous run of sixty hours during which the full energy beam was obtained for twenty-nine hours with an intensity of 10^{10} p.p.p. (protons per pulse). By early January an intensity of 1 or 2×10^{11} p.p.p. had been reached. The first high energy physics users had based their experiments on an intensity of 10^{11} p.p.p. and in February 1964, it became possible to schedule regular high energy physics runs with assurance that this intensity would be available. The final commissioning of the targets inside the machine which generate the experimental beam had also been achieved during January.

From February onwards the running time was divided between machine physics and high energy physics but with increased emphasis on the latter. Nevertheless the output of the machine continued to increase. An intensity of 6×10^{11} was obtained on 17 March and a figure of several times 10^{11} was regularly available throughout the first operational period which ended on 10 August.

During a planned shut-down from 11 August to 6 September one of the alternators was inspected and major changes were made to the shield wall in connection with a new beam for the Saclay bubble chamber. After the shutdown the machine entered the second operational period in which continuous runs of 14½ days in every 21 days were scheduled. The designed intensity of 10^{12} p.p.p. was reached for the first time on 23 September 1964.

The following table shows the number of hours of operation between February 1964, when time for high energy physics runs was first scheduled, and August 1964, when the accelerator was shut down for maintenance:—

	Total hours	High energy physics runs only (hours)
Total time scheduled	2064	
Setting up time (10 hours per run)	210	
Net possible time at full energy	1854	1266
Time at full energy realised	1277	845
Time used for machine physics	432	

Some recent developments in medium energy nuclear physics and the role of the Institute's Proton Linear Accelerator (PLA)

In the following paragraphs, some developments in medium energy nuclear physics are discussed under three headings. The part played by the PLA is only very broadly indicated here, but a list of the actual experiments on the current programme is given in an appendix to this report. Nine research teams have been working at the PLA during the year, six of them made up mostly of university physicists, one from the Atomic Energy Research Establishment, Harwell, and two almost entirely from the Rutherford Laboratory.

The nucleon–nucleon interaction

The nucleon-nucleon interaction continues to set both experimenters and theorists most interesting problems. No single laboratory can have a monopoly of studies of this interaction; not only are interesting results to be won at all energies from a fraction of an MeV to many GeV, but there is a variety of different experiments to be performed at any given energy. The PLA plays a leading part in this field; the energy is high enough for several types of experiment to be worthwhile, and there is a polarised proton beam of good energy resolution, high polarisation and high intensity. Theoretical advances in two fields call for improved experimental results. For some time it has been possible to explain the longer range part of the interaction in terms of exchange of π mesons; now the heavier mesons are being brought in to explain the interaction at shorter ranges. The second advance concerns the theories which relate the properties of nuclear matter in bulk to the forces between individual nucleons; these theories are reaching the stage where reliable values are needed of the parameters of the nucleon-nucleon interaction especially at PLA energies. For both applications there is a great need for increased precision and a greater variety of experiments concerning the neutron proton interaction, where more parameters are required than for identical particles. At the PLA measurements will soon be made of the angular distribution of protons scattered from protons to complement those which have been made already on the dependence of this distribution on the spin direction, and the way in which the spin direction of the proton is changed as a result of scattering. This will mark the completion of one phase of the work, and attention will turn to the neutron proton interaction.

Nucleon–few nucleon interactions

Advances in experimental methods have enabled more refined data to be obtained on reactions between nucleons and deuterons where two or more particles are detected in the final state and their correlations in energy and angle studied. At the PLA the most significant work has been on the asymmetry in elastic scattering of polarised protons from deuterons. A major theoretical advance is needed; the impulse approximation approach used so far gives results in disagreement with experiment and attempts to refine the theory by including multiple scattering effects have worsened the disagreement. The proton+alpha particle system has also received concentrated attention at the PLA, again with unexpected results.

The interaction of protons with complex nuclei

The simplest of the reactions between protons of 50 MeV and more complex nuclei is elastic scattering; analysis of experimental results uses the optical model which simplifies a very complex situation by substituting for the real nucleus an idealization described by a limited number of parameters—size, fuzziness of the edge, absorptive power and so on. Three experimental teams are collaborating at the PLA in this programme. There are two main interests—to discover what parameters must be included and their precise values and then to relate the variation of parameters with energy and atomic number to more fundamental approaches to nuclear structure. In both fields much remains to be done; although there are broad areas where meaningful parameters can be determined results at large scattering angles continue to show discrepancies between theory and experiment. Theorists are now including the effects of deformation of nuclei, which give nuclear states easily excited by inelastic scattering. This is a field where the facilities of the PLA are yielding very interesting results.

At medium energies it has been customary to think of two mechanisms of reaction. In the direct reactions one or a few nucleons are knocked out by the impact of the incident protons; this contrasts with the formation of a compound nucleus, where the proton shares its energy with all constituents of the nucleus, which emits predominantly low energy particles in a relatively long time. Theorists are now becoming interested in the intermediate stage, when the energy sharing process does not proceed beyond the transition of a very few nucleons to states of high excitation. Some of the earliest evidence for these doorway states comes from work at the PLA. Also under active study here is the production of isobar state neutrons, an unexpected mode of direct reaction.

The development and operation of the PLA

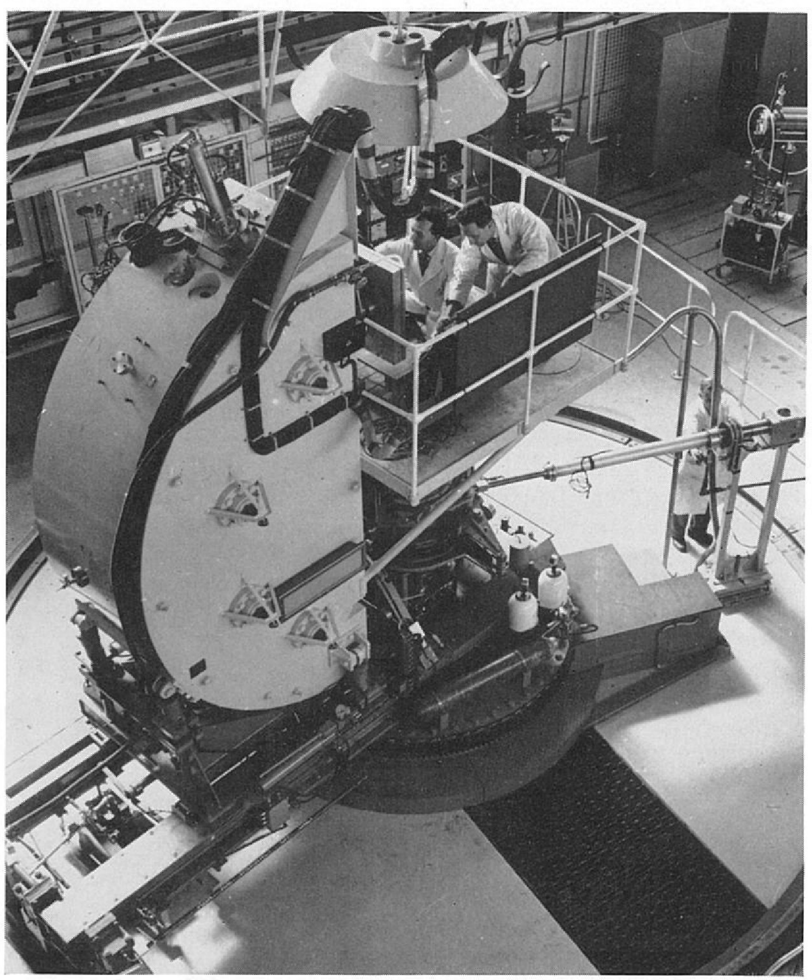
Further improvements have been achieved in the reliability and performance of the PLA. The following table shows the number of hours of operation during the year:—

	Total hours	Nuclear physics runs only (hours)
Total time scheduled	6,208	5,651
Time of satisfactory operation	5,392	4,984

The beam current available with the polarised proton source in operation was improved during the year to 2×10^8 protons per second, with 40% polarisation, and the polarised beam can now be made available at any target with any desired direction of spin. The energy of the accelerated beam has been made more precise by a system which stabilizes the radiofrequency accelerating fields in the resonators, and the mechanical design of a new resonator for the first vacuum tank has nearly been completed.

Two particular improvements to the experimental facilities were made during the year. The "clearing magnet" which removes protons from the beam in neutron time-of-flight measurements was re-sited so as to permit the measurement of the energies of neutrons emitted at any angle between 0 and 90 degrees from the incident proton beam, whereas previously measurements could only be made in line with the incident beam. Secondly, a large double focussing magnetic spectrometer was installed. It can be rotated by remote control for analysis of reaction products emitted at any angle between $\pm$ 157°. It incorporates a novel scattering chamber designed in the Laboratory.

Double focussing magnetic spectrometer



Other work at the Rutherford Laboratory

Bubble chambers

The British national 1·5 metre hydrogen bubble chamber has been at the CERN laboratory in Geneva since early in 1963. In January 1964, responsibility for the chamber was transferred from the DSIR to the Institute. An Institute team are operating the chamber at CERN. After a trial run in March, the chamber was dismantled to effect improvements; it was then reassembled and started to produce experimental photographs early in July 1964.

At the Rutherford Laboratory assembly of the heavy liquid bubble chamber continued and most of the main components arrived during the year; preliminary tests on the magnet at full current were satisfactorily completed. Design work on the 80 cm helium bubble chamber was nearly completed and components started to arrive in June.

The first bubble chamber to be used with Nimrod will now be the chamber of the Centre d'Etudes Nucleaires of Saclay, France, which was transferred to the Rutherford Laboratory at the end of June 1964. It was desirable to have a hydrogen bubble chamber at Nimrod without curtailing the programme of the British chamber at CERN, and discussions with French physicists at Saclay led to the transfer of the French chamber after it had completed an experimental programme on the 3 GeV synchrotron "Saturne". It has an active length of 82 cm and is to be used for π-meson and K-meson experiments. The assembly of a complex beam line to be used with this chamber was commenced during the year. This beam line, Kl, which is designed to give a very pure beam of K-mesons, has over thirty beam components including separators of total length fifty feet.

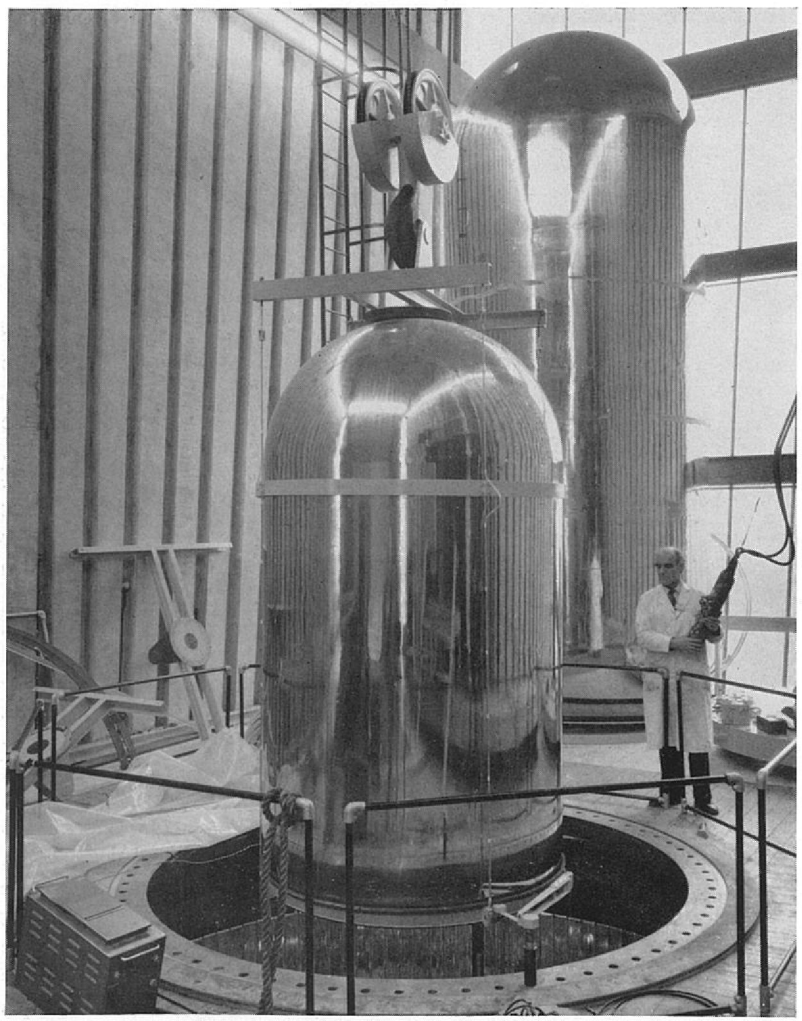
Bubble chamber film analysis equipment

The track analysis equipment known as the "Hough Powell" device is being developed in the laboratory. In this equipment a flying spot of light scans a bubble chamber photograph from side to side while it is simultaneously moved forward, and thus the spot traverses the whole photograph. When the light crosses a track on the photograph the electrical output from a photo-multiplier behind it is suddenly reduced, the reduction is detected and used to give a numerical record of the position at which the track was crossed. A complete numerical interpretation of the tracks on the photograph is obtained in this way and may be directly analysed by computer.

The Orion computer

The Orion computer came into full operation during the year. During the early part of 1964 a considerable amount of effort and computing time was used in preparing master programmes which determine the way in which the machine handles computational programmes. With this work completed more time became available for computation, particularly for the analysis of data from bubble chamber film, but the load grew so rapidly during 1963 and 1964 that it became necessary to buy time on other computers, leaving Orion available for shorter calculations and data processing from counter experiments running on Nimrod. The time-sharing feature of Orion has made it possible to complete short jobs without delay.

Oxford electrostatic generator components



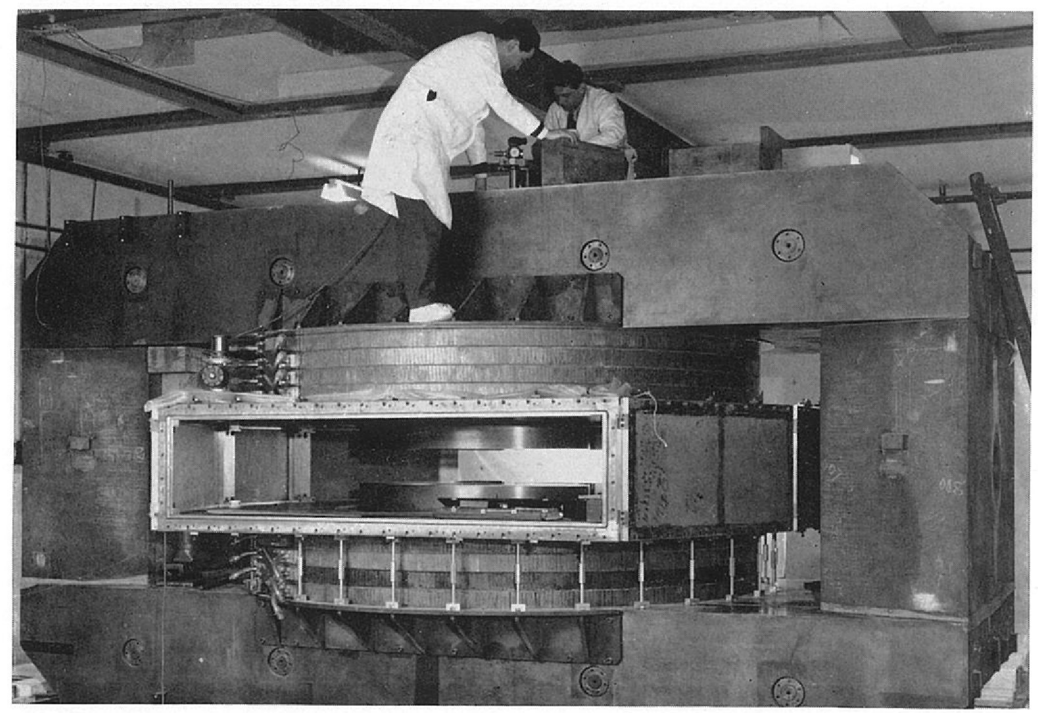
The electrostatic generator for Oxford University

By the end of the year under review the horizontal tandem machine supplied by the High Voltage Engineering Corporation, Inc., was being commissioned as an accelerator and the installation of the 8 MeV vertical generator had begun. Building delays continued throughout 1963, and it was not until mid-December that the pressure vessel of the vertical generator was installed. In January 1964 the installation of the horizontal tandem was commenced. From then onwards the building proceeded more closely to programme. The commissioning of the horizontal machine as a generator was complete by mid-May, when the guaranteed voltage of 6 million volts on the centre terminal was achieved. The ion source and magnet installation (the responsibility of the NIRNS Oxford teams) proceeded smoothly at the same time, and in early June a beam was first accelerated through the machine. Target room flight lines were being installed in September 1964. In the vertical generator, commissioning of the annular lift was in progress in preparation for the assembly of the central accelerating structure.

The Variable Energy Cyclotron

The Variable Energy Cyclotron has been designed at the Rutherford Laboratory for the Atomic Energy Research Establishment, Harwell, where it will be used mainly for radio-chemistry, radiation chemistry

Variable Energy Cyclotron magnet with vacuum box



and studies of radiation effects on the physical properties of materials.

Installation of cyclotron components is well advanced. The magnet was delivered and installed in the winter of 1963/64, and the first field survey (without correcting coils) was made in the spring. The high frequency power supply, the vacuum system and various power supplies were installed but serious delay was caused by unexpected difficulties in fabricating the correcting coil assembly. The main radio-frequency components were assembled at the manufacturer's works, and work was started on the manufacture of probes, deflector and beam handling equipment.

There are still a number of detailed design points to be settled; the main problems arise from the need to make the machine versatile. Studies of heavy ion sources, beam optics at the machine centre and in the external system are continuing with the aid of auxiliary experimental equipment such as the 22″ cyclotron, and computations on the Orion computer.

High magnetic fields

A limited amount of experimental work is being carried out on super-conducting materials, both to investigate the problems of magnet construction and low temperature operation, and to clarify the performance and reliability of the materials themselves. In addition theoretical study is in progress of the economic and practical aspects of high magnetic fields in high energy physics, covering all applications from simple focussing devices to large storage ring magnets.

Experimental and theoretical work continued on the design of pulsed coils for producing fields of over 250 kilogauss, energised by discharging capacitors.

Research using nuclear reactors

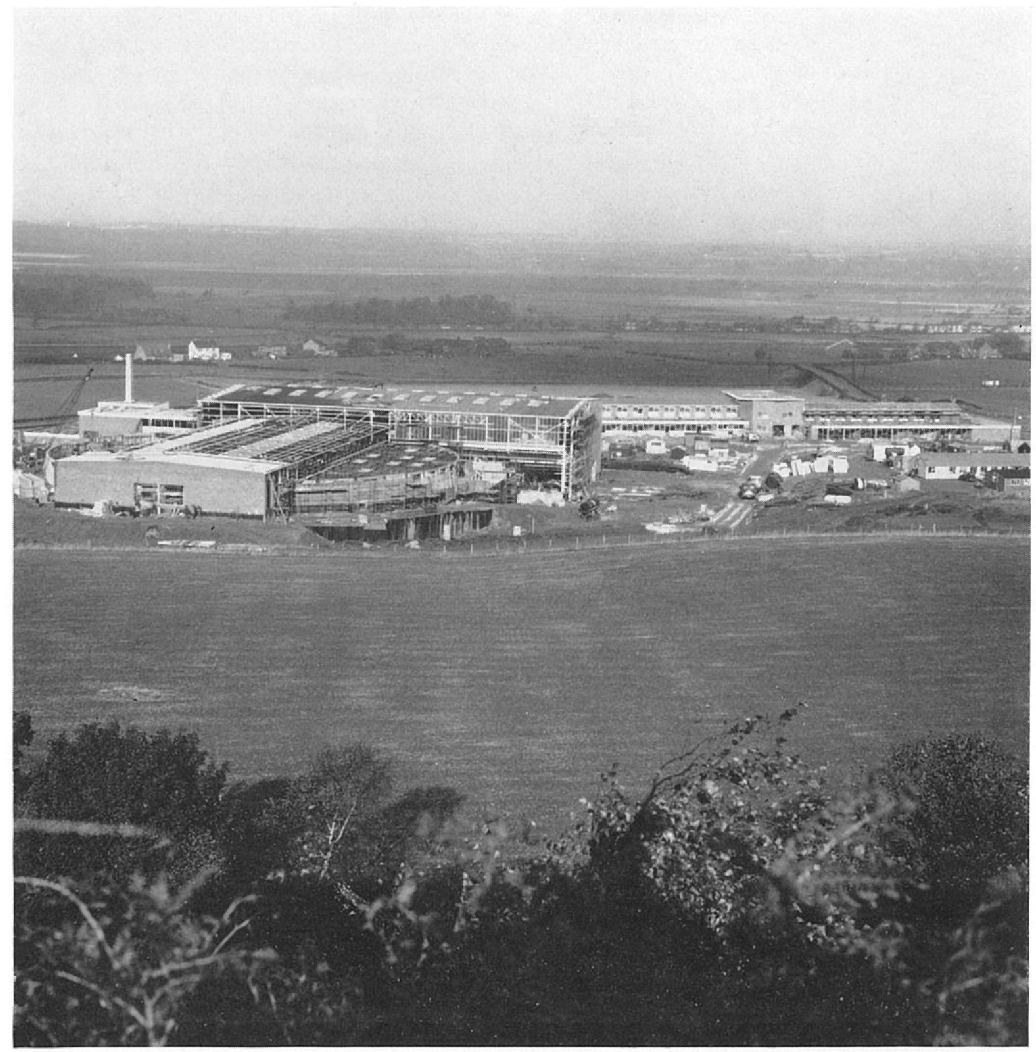
The Institute have continued to help to arrange for university experiments in research reactors of the UK Atomic Energy Authority, and to pay the charges for these. Two special research facilities are being provided for this work in the "Herald" reactor at the Atomic Weapons Research Establishment, Aldermaston; a liquid nitrogen cooled irradiation apparatus and a liquid hydrogen cold neutron source. The former was completed and brought into use during the year.

Requirements for large reactors for university research have been kept under review, in conjunction with other bodies concerned. In this connection, a representative meeting of potential users of a high-flux thermal neutron source took place at the Rutherford Laboratory in July 1964.

The radiochemical laboratory

The radiochemical laboratory was built to provide for chemical work on materials irradiated in the Rutherford Laboratory accelerators and in nearby reactors. During the year it has been used principally by teams from the Atomic Energy Research Establishment, Oxford University and Chelsea College of Advanced Technology, and by two scientists attached to the Rutherford Laboratory on leave from Los Alamos Laboratory and the University of Washington, USA.

The Daresbury Nuclear Physics Laboratory



Nina magnet foundations

Building construction

The total area of the Daresbury Laboratory site is 50 acres, but the present construction work is confined to an area of 15 acres. The principal buildings themselves, which cover about 2¾ acres, are the magnet ring and injector building, the main experimental area known as the Electron Hall, the Inner Hall within the magnet ring, the distribution services building, the research services building, the equipment assembly building and the main laboratory and office building.

The magnet foundations are an interesting feature of the magnet ring building. They consist of 60 concrete piers set into the underlying sandstone rock at a depth 24 feet below the basement level. The tops of the piers are connected by a continuous cap ring 2 by 3 ft in cross-section, and on top of the cap ring there are concrete columns on which the 40 magnet units will be supported. These foundations are completely independent of the rest of the building, and the stability of the positioning of the synchrotron magnet should not be affected by movements elsewhere. To achieve the required stability of the magnet it will also be necessary to control the temperature in the building within 1°C. The Electron Hall is 200 ft long by 110 ft wide and has a 25 ton overhead crane. The synchrotron ring passes through part of it, and in this area is shielded by about 8,000 tons of concrete shielding blocks. The Inner Hall, 200 ft long by 95 ft wide has a 15 ton overhead crane. The main Laboratory and Office block will be a long building on two floors, designed with a 12 ft module. Most of the offices will be 12 ft by 12 ft and there will be several large laboratories, 24 ft by 36 ft, as well as a drawing office, library and common room.

The Nina magnet

The Nina magnet will consist of 40 units arranged on the circumference of a circle of diameter 70·2 metres. Twenty of these units will be horizontally focussing ("F" type) and twenty will be horizontally defocussing ("D" type). The exciting coils are wound with stranded conductor of rectangular cross-section with tubes for water cooling. The insulation is glass tape and mica, vacuum impregnated with epoxy resin.

Three full-sized blocks of both "F" and "D" type were manufactured by Messrs. Joseph Sankey and Sons from Armco hot-rolled silicon steel, and were used for the assembly of short lengths of magnet at Liverpool University for accurate survey of the magnetic field. By similar trials the design of the end blocks (which can be determined only approximately by calculation) were adjusted to make the magnetic end perpendicular to the orbit direction and to minimise eddy currents; these are only two examples illustrating the experimental work involved in the magnet design.

The steel for the magnet blocks was ordered in December 1963, from the Armco Steel Corporation in the United States. It is hot-rolled box-annealed silicon steel in sheets of thickness 0.0185 ins. Delivery was completed in May 1964. The contract for the manufacture of the magnet blocks was placed with Siemens-Schuckert-werke in Germany. Punching of the laminations with the necessary high precision was well advanced in September 1964, and the first ten blocks had been fabricated. The contract for the magnet coils was placed with the Oerlikon Engineering Company in April 1964, and that for the pole-face windings was placed with the Allgemeine Elektrisitäts-Gesellschaft in August 1964.

To excite the magnet to the necessary field cycle requires a combination of an alternating current at 50 cycles/sec. with a direct bias current approximately equal to the peak value of the alternating current. Because of the relatively high inductance of the magnet, direct excitation would be very wasteful and so the magnet system is made to resonate at 50 cycles/sec. by the addition of a number of capacitors and an "energy storage choke" having a number of primary windings through which about 900 kW of power is supplied to make up for the losses. The design of this system was developed with the aid of a one-tenth scale model constructed at the Rutherford High Energy Laboratory. The contract for the main components of the magnet power supply was placed with the English Electric Co, Ltd.

Injection

The choice of the energy at which the electrons are injected into a synchrotron is a matter of compromise. The lower energy limit is determined mainly by the minimum magnetic field at which the required accuracy of magnetic field gradient can be achieved. A higher energy than this is desirable to ease the problems associated with synchrotron phase acceptance, but the cost of the injector rises nearly in direct proportion to the energy. The injection energy chosen for Nina is 40 MeV, and to achieve the desired mean circulating current of 10 micro-amps, the injected current pulse needs to be nearly 500 milli-amps for about three quarters of a micro-second. This will be obtained from an electron linear accelerator of the type that uses the fields, set up by a radio frequency wave travelling down a corrugated waveguide, to accelerate the electrons. A contract for the linear accelerator was placed with MEL Equipment, Ltd (part of the Mullard/Philips Group) in March 1964.

Radio-frequency acceleration

Acceleration in Nina will take place at five cavities uniformly distributed around the orbit in long straight sections. The cavities will be strongly coupled together by a wave-guide ring into which the radio-frequency power will be fed from the amplifier at a tee-junction. At the beginning of the year, it had been decided to aim at producing a mean accelerated current of 10 micro-amps, that is, $1{\cdot}2 \times 10^{12}$ electrons per pulse at 4 GeV. This high beam current involves a large beam loading effect on the accelerating cavities, and 150 kW of radio-frequency power is required. The contract for the amplifier was placed with the Radio Corporation of America in August 1963, and it was delivered in June 1964.

Atlas Laboratory, forecourt and entrance

The Atlas Computer Laboratory

The Atlas Computer Laboratory is staffed and equipped to enable university and government research workers in any subject to use its computer, which is more powerful than any other to which the general body of university research workers has access at present. It is the intention to steer small problems on to small local machines, and use the Atlas mainly for large-scale work. At present there are two particularly large potential demands, from the Atomic Energy Authority and from bubble chamber film analysis groups respectively. Agreements have been reached in each case to limit the allocation of Atlas time, so as to leave adequate capacity for the general university and government work.

Within the complement of the laboratory, a small number of fixed-term research posts have been provided with the intention that their holders will contribute special skills and high standards to the laboratory, and stimulate in this country the use of a large computer in novel ways. Of the five present holders of these posts three have been elected to Fellowships of Oxford colleges—Pembroke, St Catherine's and Trinity—and one has been seconded from the University of Edinburgh.

Progress during the year

The laboratory building has been completed, and the staff moved into it in January 1964. The computer, after assembly and test in Messrs ICT's works, was installed in the laboratory in May. It was not handed over during the year, but by the end of September a small amount of computing work for university users had begun.

Atlas Computer Committee

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Dr J B Adams, CMG, FRS, *Atomic Energy Authority*
Dr R A Buckingham, *University of London*
Sir John Cockcroft, OM, KCB, CBE, FRS, *University of Cambridge*
Mr C Joliffe, *Department of Scientific and Industrial Research*
Dr J C Kendrew, FRS, *University of Cambridge*
Professor T Kilburn, *University of Manchester*
Dr W C Marshall, *Atomic Energy Authority*
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Mr H J Millen, *Atomic Energy Authority*
Professor R E Peierls, CBE, FRS, *University of Oxford*
Dr T G Pickavance, *Rutherford High Energy Laboratory*
Sir Graham Sutton, CBE, FRS, *Meteorological Office*
Dr M V Wilkes, FRS, *University of Cambridge*
Secretary, Dr J A V Willis

Physics Committee

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Professor C F Powell, FRS, *University of Bristol*
Dr F A Vick, OBE, *Atomic Energy Authority*
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Research Reactor Committee

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Professor J Diamond, *University of Manchester*
Dr P A Egelstaff, *Atomic Energy Authority*
Mr C Joliffe, *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

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Professor E H Bellamy, *Westfield College, London*
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Dr P G Murphy, *Rutherford High Energy Laboratory*
Dr J C Rutherglen, *University of Glasgow*
Dr G H Stafford, *Rutherford High Energy Laboratory*
Professor J C Wilmott, *University of Manchester*
Secretary, Dr N R S Tait

National Institute for Research in Nuclear Science

Revenue account for the year ended 31 March 1964

1962–63	1963–64	
988,284	1,236,374	Salaries and Wages
66,459	84,910	Employers' Superannuation Contributions
20,397	26,951	Employers' National Insurance Contributions
60,041	70,314	Travel and Subsistence Expenses
1,160,224	1,584,387	Materials and Services
107,730	132,115	Research and Development by Universities and Industry
13,950	33,371	Expenses on Hostel, Houses and Restaurant
75,254	90,245	Miscellaneous Expenses
1,226,673	1,187,579	Supplies and Services by the United Kingdom Atomic Energy Authority
£3,719,012	£4,446,246	

1962–63	1963–64	
		Grant from United Kingdom Atomic Energy Authority to meet Recurrent Expenditure
3,613,473	4,290,039	Research, Administration, etc.
2,533	2,926	Capital Expenditure
12,998	25,360	Receipts from Hostel, Houses and Restaurant
90,008	127,921	Miscellaneous Income
3,719,012	4,446,246	

Capital account as at 31 March 1964

1963	1964	*Capital Grant Account*
11,806,102	15,383,258	Balance as at 1 April 1963
3,577,972	4,392,503	Add Grant from United Kingdom Atomic Energy Authority to meet Capital Expenditure for the year ended 31 March 1964
2,533	2,926	Expenditure from Revenue Account
15,386,607	19,778,687	
3,349	5,189	*Deduct* Amounts written off for Assets no longer in service
£15,383,258	£19,773,498	

1963	1964	*Assets at cost*
4,575,421	5,698,084	Land and Buildings
3,126,666	10,629,759	Plant and Machinery, Ancillary Installations and Motor Vehicles
328,732	513,600	Loose Apparatus, Tools, Furniture, Fittings and Office Machinery
8,030,819	16,841,443	
7,352,439	2,932,055	Assets in course of construction
£15,383,258	£19,773,498	

NOTE: Capital Expenditure authorised but not provided for in these Accounts amounted to £7,609,368, of which £5,357,671 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.

E G Compton, *Comptroller and Auditor General*
Exchequer and Audit Department, 25 November 1964

Appendix III

List of nuclear physics experiments on the PLA programme

Proton scattering

1 Measurement of the A and R Parameters in p-p Scattering at 47·8 and 27·6 MeV. *Queen Mary College and King's College, London and Rutherford Laboratory.*

2 Measurement of the Spin Rotation Angle β in p-He^4 Elastic Scattering at 48·0 MeV. *University College London*

3 Elastic and Inelastic Proton Differential Cross Section Measurements. *Atomic Energy Research Establishment*

4 Elastic and Inelastic Scattering of 50 MeV Protons by Zn^{64} and Cd^{114}. *King's College, London and Rutherford Laboratory (with a scientist on leave from the Institute for Nuclear Research, Warsaw)*

5 Angular and Energy Dependence of Polarization in Proton Scattering by Nuclei. *Birmingham University*

6 A proposed Experiment to Measure the Proton-Proton Differential Cross Section at 50 MeV. *University College London and Rutherford Laboratory*

7 Proton-Deuteron Elastic Scattering. *Westfield College, London, Queen's University, Belfast and Rutherford Laboratory*

Proton induced reactions

8 Inelastic Scattering of Protons from C^{12}. *Oxford University*

9 Pick-up Reactions on a C^{12} Target. *Oxford University*

10 Measurements of the C^{12} (p,n)N^{12} Excitation Function. *Oxford University*

11 Measurement of Neutron Spectra by Time of Flight Methods. *Rutherford Laboratory and Queen Mary College, London*

12 The Study of (pα) Reactions. *Westfield College, London, Queen's University, Belfast and Rutherford Laboratory*

13 Proton-induced Fission. *Rutherford Laboratory (attached scientist on leave from the University of Washington, Seattle, USA)*

14 Polarization of Neutrons Produced in the Reaction D(p,n)2p using Polarized Protons. *Rutherford Laboratory*

15 A Study of (p,2p) Direct Reactions. *Westfield College, London, Queen's University, Belfast and Rutherford Laboratory*

16 A Search for C^9 as a Product of the Reaction B^{10}(p,2n)C^9. *Oxford University*

Appendix IV

List of publications by Staff of the Institute October 1963 to September 1964

Allen, W D, and others
Studies of alloy carbides at Westinghouse Astronuclear Laboratory. TID–7676, pp 75–98

Astbury, A, and others
Search for neutrino induced reactions. Phys. Rev. Lett., 11, 5, pp 234–237, 1 September 1963. Also UCRL 10826

Atkinson, H H
A new type of high vacuum gauge. Transactions of the 10th National Vacuum Symposium. Boston, 16–18 October 1963. pp 213–217

Auld, E G, and others
An experiment on the elastic scattering of electrons on carbon. CERN 64–30, pp 147–153, June 1964

Auld, E G, and others
A sonic spark chamber system with on-line computation for studying the reaction $\pi^- + P \rightarrow f^\circ + n$ at 3 GeV/c. CERN 64–30, pp 251–260, June 1964

Batty, C J, Stafford, G H, and Gilmore, R S
Measurement of the cross-section for proton-proton scattering at 90° (cm) between 20 and 50 MeV. Nucl. Phys., 51, 2, pp 225–233, February 1964

Brooks, H C, and others
Ultrasonic inspection of the Nimrod power plant alternator rotors. 4th International Conference on Non-destructive Testing. London, 9–13 September 1963. pp 131–137

Bugg, D V, and others
Interactions of positive pions with protons near threshold for single pion production. CERN 63–27, July 1963

Bugg, D V
Neutron-proton scattering at 970 MeV. Phys. Rev., 133, 4B, pp 1017–1031, 24 February 1964

Burren, J W, and Mitchell, M J
A method of filtering HPD data using "track following". CERN 64–34, pp 29–40, October 1963

Burren, J W, Pickup, E, Sparrow, J, and Wilson, A G
A preliminary report on a study of the interactions of 3·5 GeV/c K^--mesons in hydrogen. Proceedings of the Sienna International Conference on Elementary Particles. 30 September–5 October 1963. Vol 1 pp 146–154

Carroll, A S, and others
Measurement of neutron-proton polarization at 126 MeV. Phys. Rev., 134, 3B, pp 595–600, 11 May 1964

Davis, D G, Ghani, A, Hanna, R C, and others
The polarization of protons recoiling from $\pi^+ + p$ collisions at 265 MeV. Nuovo Cim., 29, 2, pp 507–514, 16 July 1963

Dawton, R H V M
A negative ion source using a mercury pool cathode. Nucl. Instrum. Meth., 24, 3, pp 285–289, September 1963

Duke, P D, Kemp, M A R, and others
Evidence for giant resonance excitation induced by the capture of muons in 0^{16}. Phys. Lett., 9, 1, pp 84–88, 15 March 1964

Dunn, P D, and Wright, J K
Unconventional methods of electricity generation. Proc. Instn. Elect. Engrs., 110, 10, pp 1837–1954, October 1963

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The branching ratio and proton spectrum of the leptonic decay $\Lambda^\circ \rightarrow p + e^- + \bar{\nu}$. Proceedings of the Sienna International Conference on Elementary Particles. 30 September–5 October 1963. Vol 1 pp 8–11

Elliott, R T, Rangan, L K, and others
Proton spectra in Λ° beta decay. Phys. Lett., 6, 2, pp 186–189, 1 September 1963

Fisher, C M, Scarr, J M, and others
Preliminary results on $\Xi^- + K_1^0 + n\pi$ final states produced by 3·5 GeV K. Phys. Lett., 6, 4, pp 316–318, 1 October 1963. Also Proceedings of the Sienna International Conference on Elementary Particles. 30 September–5 October 1963. Vol 1 pp 173–178

Fisher, C M, Scarr, J M, Thomas, R H, and others
Ξ^- properties. Phys. Lett. 5, 4, pp 261–266, 15 July 1963. Also Proceedings of the Sienna International Conference on Elementary Particles. 30 September–5 October 1963. Vol 1 pp 4–8

Galbraith, W, Manning, G, Parham, A G, Taylor, A E, Walker, T G, and others
Particle production in proton-proton collisions at 19 and 24 GeV/c. Nuovo Cim, 31, 5, pp 961–973, 1 March 1964

Gilmore, R S, and others
Digitized sonic spark chamber for operation with counter hodoscope, data handling system and on-line computer. CERN 64–30, pp 237–244, June 1964

Griffiths, R J, and Knight, K M
The d(p,2p)n reaction at 50 MeV. Nucl. Phys., 54, 1, pp 56–64, May 1964

Griffiths, R J, Knight, K M, and others
Shell structure in direct interactions at the nuclear surface. Proceedings of the Conference on Direct Interactions and Nuclear Reaction Mechanisms. Institute of Physics of the University of Padua. 3–8 September 1962. pp 58–61

Hanna, R C, and others
The polarization of protons recoiling for $\pi^+ + p$ collisions at 265 MeV. Nuovo Cim., 29, 2, pp 507–514, 16 July 1963

Howlett, J
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Production cross sections of pions, kaons and protons in proton-proton collisions. Proceedings of the Sienna International Conference on Elementary Particles. 30 September–5 October 1963. Vol 1 pp 641–643

King, N M
Theoretical techniques of high-energy beam design. Progr. Nucl. Phys. 9, pp 71–116, 1964.

Lawson, J D
Differential bremsstrahlung cross sections for low-energy electrons. ORNL-TM-790, February 1964

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A cryogenic liquid level detector employing thermistors. J. Sci. Instrum., 40, 11, pp 539–540, November 1963

Lewin, J D, and Smith, P F
Production of very high magnetic fields by flux compression. Rev. Sci. Instrum., 35, 5, pp 541–548, May, 1964

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Measurement of the μ^- capture rate in He^3. Phys. Rev. Lett., 11, 1 pp 23–26, 1 July 1963. Also UCRL 10836

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Pion-pion scattering at low and high energies. Proceedings of the Sienna International Conference on Elementary Particles. 30 September–5 October 1963. Vol 1 pp 356–362

Moorhouse, R G, Morgan, D, and others
Pion-pion scattering in the strip approximation- I. Nuovo Cim. 30, 1, pp 207–229, 1 October 1963

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Marginally singular forces and their role in producing pseudovector resonances. CERN 9358/TH.463, (September 1964)

Murphy, P G
The isotopic spin of the f_0 resonance. Phys. Lett., 6, 2, p 208, 1 September 1963

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Covariant description of the photo-disintegration of the deuteron. Nucl. Phys., 49, pp 475–480, December 1963

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Aberrations in electrostatic quadrupoles. Nucl. Instrum. Meth., 24, 4, pp 377–380, October 1963
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Resonances and Regge poles in e^- -H scattering. Proceedings of the III International Conference on the Physics of Electronics and Atomic Collisions. London, 22–26 July 1963. pp 89–97
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Appendix V

List of the senior staff. September 1964

Rutherford High Energy Laboratory
Director, Dr T G Pickavance
Assistant Director, Mr L B Mullett

Nimrod Division
Division Head, Dr L C W Hobbis
Head of the High Energy Physics Engineering Group, Mr G N Venn
Head of the Nimrod Engineering Group, Mr J C Louth

High Energy Physics Division
Division Head, Dr G H Stafford
Joint Head of Counter Group (Resident), Dr P G Murphy

Applied Physics Division
Division Head, Mr W Walkinshaw
Head of the Bubble Chamber and Radiation Protection Group, Mr M Snowden
Head of the Cyclotron Group, Mr J D Lawson

Proton Linear Accelerator Division
Division Head, Dr R C Hanna
Head of the PLA Engineering Group, Mr J B Marsh

Engineering Division
Division Head and Chief Engineer, Mr P Bowles
Head of the Central Engineering Group, Mr G E Simmonds

Administrative Division
Division Head, Secretary, Rutherford Laboratory, Dr J M Valentine
Head of the Electrostatic Generator Group, Dr W D Allen

Atlas Computer Laboratory
Director, Dr J Howlett
Head of the Programming Group, Dr R F Churchhouse

Daresbury Nuclear Physics Laboratory
Director, Professor A W Merrison
Head of the Injector Group, Mr M C Crowley-Milling
Head of the Magnet Design Group, Dr J R Holt, FRS
Head of Site Services, Mr M J Moore
Secretary, Mr H Rothwell
Head of the Apparatus Group, Dr R G P Voss
Secretary, NIRNS, Dr J A V Willis