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Historical Records of Australian Science

John Oswald Newton 1924–2016

Katja Curtin[A], Mahananda Dasgupta[A,*] and David Hinde[A]

For full list of author affiliations and declarations see end of paper

***Correspondence to:**
Mahananda Dasgupta
Australian National University, Department of Nuclear Physics and Accelerator Applications, Research School of Physics, Canberra, ACT 2601, Australia
Email: Mahananda.Dasgupta@anu.edu.au

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ABSTRACT

John Newton was internationally distinguished for his work in nuclear structure and heavy-ion reactions, and played an instrumental role in enhancing Australia's nuclear science capability. Throughout his work in England, the United States, and Australia, Newton drove pivotal advancements in the study of Coulomb excitation, angular correlation methods, and the alpha decay of odd nuclei, and was a pioneer in the study of high spin states using heavy-ion reactions. Major achievements at the Australian National University under his leadership were the installation of a new tandem accelerator, the introduction of a collaborative research ethos to the Department of Nuclear Physics, and a new research initiative into nuclear fusion and fission in heavy-ion collisions. Newton's prior experience at top international laboratories inspired his vision to transform the Department into a world-recognised facility for nuclear physics research.

Keywords: Australian National University, Coulomb excitation, heavy-ion reactions, nuclear physicist, nuclear physics, nuclear science, nuclear scientist, nuclear structure.

Introduction

John Newton (Fig. 1), distinguished for his study of nuclear structure and heavy-ion reactions, and for his contributions to Australia's national scientific capability, passed away on 26 September 2016. Over his long career, Newton and his colleagues led the field of nuclear physics from sketched-out theoretical notions and rudimentary apparatus to the complex theoretical and experimental field it is today. Newton oversaw the installation of the 14UD tandem electrostatic accelerator at the Australian National University, and his vision and leadership of the host Department of Nuclear Physics played a significant role in shaping the Facility into a world-renowned research laboratory.

Background

John Oswald Newton was born on 12 February 1924 to Oswald and Rose Newton in Sutton Coldfield, just outside Birmingham in the United Kingdom (UK). Newton's parents worked at the Dunlop Rubber Company, Oswald as a clerk and Rose as a bookkeeper. From an early age Newton explored the natural world with a toy chemistry set, bought by his parents, and a Meccano set that Newton later passed on to his own children.

Newton's formal education began when he attended a local primary school at age five, where he was sorted into the highest academic stream for his grade. Under-stimulated by his lessons, Newton was put forward a year, allowing him to leave primary school at age ten and setting him up as the youngest student in nearly all his classes in future. Despite having only a rudimentary education themselves, Newton's parents strove to ensure that their son had a good education.[1]

Newton was enrolled in Bishop Vesey's Grammar School in Sutton Coldfield, where he had been awarded a County Minor Scholarship that covered the entirety of his school fees. At school, Newton was introduced to classical music by his peers, something that he

[1] Newton (2010).

later described as very important throughout his life, providing great mental relaxation and uplift.[2] Newton's enthusiasm for science in secondary school continued to be highly internally driven, with little external inspiration or opportunity at this time. In 1938 he passed the School Certificate examination and enrolled in sixth form under the science stream. Here, the courses captured his passions, and chemistry and maths became his favoured subjects over the textbook-heavy physics syllabus.[3] With his parent's encouragement, Newton spent the year following sixth form studying for the Cambridge College scholarship examinations. He won a scholarship to St Catharine's College, Cambridge, where he completed the first two years of his Bachelor of Arts (BA 1943) degree before joining the war effort in 1943. At Cambridge, Newton's interest in chemistry declined due to the high amounts of memory work required, but his enthusiasm for physics blossomed in the well-run courses and exciting laboratory experiments. The Cavendish Laboratory was located close to Newton's residential college and already boasted many great physicists of the twentieth Century, including Ernest Rutherford and James Clerk Maxwell. Electronics had been introduced for the first time at Cambridge because of the new development of radar, and Newton, who had held a long-term interest in radio, took to the course with enthusiasm. This ability in electronics led to his wartime work as a junior scientific officer at the radar facility in Malvern. During the war, Cambridge University allowed students to take only two years to complete the ordinarily three-year course, after which all science students were interviewed to be assigned to various war activities. Newton was interviewed by a board chaired by famous scientist and author Charles Percy Snow, who assigned him to the Malvern Air Ministry research establishment. Called the Telecommunications Research Establishment (TRE) to mislead the enemy, the facility employed a variety of disciplines—including scientists, engineers, Army, and Navy. Newton first attended the training school at TRE, headed by Leonard (Len) Huxley, who later became Vice-Chancellor at the Australian National University (ANU). Newton was later allocated to the Counter Measures Group, whose purpose was to counter enemy radar by 'jamming'. Newton worked on high-frequency receivers that detected enemy signals by scanning a wide range of frequencies. A notable achievement of the Counter Measures Group was the development of the technique called 'Window', in which half- wavelength-long strips of aluminium foil were dropped from aircraft.[4] These pieces of foil produced stronger reflections to the German radar than the aircraft did, and in high numbers they effectively masked the signals from planes and empowered deceptive strategy. After the war in Europe ended, Newton was transferred to a group working on missile guidance systems. The expertise in advanced electronics that Newton developed during his work on radar was of great benefit throughout his career.

In 1946 Newton was able to return to Cambridge to finish his Master of Arts (MA 1946) and later, his Doctor of Philosophy degrees.[5] Newton's third year of study at Cambridge, called 'Part Two of the Natural Science Tripos', was spread over two years due to the university's accommodation of those returning from war activities. The physics program exposed Newton to several notable lecturers, including Paul Dirac, Samuel Devons, Douglas Hartree, and Fred Hoyle. Cambridge experienced significant changes after the war, with financial support programs enabling those who participated in the war effort to attend university. No longer a 'rich men's club', the institution became more of a meritocracy, and Newton considered it an outstandingly positive change.[6] With this shift, many members from the Three Arts Club—a social club started by Newton and his friends back in Sutton Coldfield—attended Cambridge to complete undergraduate degrees. Newton, being a rather shy personality, found great joy in their company and the range of social and sporting activities that he commenced.[7]

Newton graduated with a first-class degree in 1948, entitling him to a grant from the Department of Scientific and Industrial Research for maintenance and a new position as a research student at Cambridge.

Life at the Cavendish Lab

When Newton began his PhD study at the Cavendish Laboratory, nuclear physics was still in its infancy. Nuclear fission had recently emerged as a potential major source of power. Nuclear fusion—the fusion of two light nuclei to create a vast amount of energy, as demonstrated by Oliphant, Harteck, and Rutherford in 1934—became the second possible source of power for the future.[8] When Newton began his postgraduate research in 1948, there was puzzling evidence regarding nuclei with certain 'magic' numbers of nucleons being particularly stable, much like noble gases for atoms. This marked the beginning of the study of the excited states of nuclei.

The Head of the Cavendish Laboratory at this time was Sir William Lawrence Bragg, who had been awarded a Nobel

[2] Newton (2010).
[3] Newton (2010).
[4] Newton (2010).
[5] Newton (2009). A full academic record is available in the Supplementary Material.
[6] Newton (2010).
[7] Newton (2010).
[8] Oliphant and others (1934).

Prize in 1915 for his work analysing crystal structure with X-rays.[9] Newton's PhD supervisor was experimental nuclear physicist Professor William (Bill) Burcham. Due to the structure of working groups at Cavendish, Newton had little interaction with his supervisor and typically met with Burcham only once each month to discuss new problems.

Burcham's research group worked with a particle accelerator that could reach up to 1 million volts on its terminal, a development of the original Cockcroft–Walton generator and the machine that Newton worked with throughout his PhD study. The accelerator hall itself was an exciting affair when the high voltage was on—brilliant flashes and loud bangs. Compared to the accelerators Newton would work with later in his life, this accelerator was very primitive. The voltage stability was very poor, as was the vacuum, and the beam energy was spread over a range of plus and minus 30 keV. The low voltage of the accelerator imposed a significant restriction: not enough energy could be generated to cause reactions in heavier elements. Consequently, Newton's PhD primarily focused on the energy states in light nuclei.

In physics research at this time there were no transistors, no computers, no electronic calculators. Most calculations were conducted with the trusty team of pen, paper, and slide rule. The electronics in the laboratory used large, power-sucking vacuum valves. Not only was most of the equipment large and cumbersome, but often unreliable.[10] Pulses were counted from detectors by placing three scalers beside each other; if two of the scalers registered the same number, this would be taken as correct. Most equipment was made for specific research purposes as required, because there was very little available to buy commercially.

Part of Newton's thesis project involved the measurement of gamma-rays in time-coincidence with particles from deuteron-induced reactions, with the purpose of better understanding the energy levels from which the gamma-rays came. The available electronics of the radar period allowed for a resolving time of approximately one microsecond; this was completely inadequate for Newton's task, which required one hundred times better resolution, but he successfully developed a system that allowed this, an outstanding achievement. This was a feat that did not stand alone, as throughout his PhD study, Newton developed a variety of specialised instruments and equipment, ranging from amplifiers and double-pulse generators to scintillation detectors for both particles and gamma rays.

As a result of his efforts, Newton broke new ground in isotope polarisation measurements during his study from 1950 to 1952. First, after bombarding lithium-6 with deuterons, Newton established that the first excited state in lithium-7 had a spin of one half.[11] With another proton-induced reaction, Newton measured the polarisation of the 6.1 MeV gamma-rays from the first excited state of oxygen-16 and demonstrated that it had negative parity.[12] This was the highest energy gamma ray whose polarisation had been measured at this time, and Newton's record stood for many years following. Even today, very few measurements have been taken at such high energies. Accompanying this work, Newton proposed one of the most powerful general methods for studying nuclear states, the angular correlation method.

Due to the structure of research at the Cavendish Laboratory, Newton conducted most of his PhD research alone, but there were many students from across the world also working there. Amongst them were three Australians: John Carver and Peter Treacy, from the Australian National University, and Joan Freeman. Freeman remained in England and later became the Head of the tandem accelerator group in Harwell. It was during his time at Cambridge that Newton also met his first wife, Cordula Kuntze.

The move to Harwell

Newton completed his experimental work at Cavendish but he was unable to complete writing his thesis there as the grant from the Department of Scientific and Industrial Research was strictly for three years, so he took the opportunity to join the Atomic Energy Research Establishment (AERE) in Harwell, UK, as a fellow in 1951. He had been attracted to Harwell due to the generous Harwell Fellowships, which enabled researchers to complete any work they desired with the facilities available.[13] He was interviewed by Sir John Cockcroft, then the Director of the AERE who had famously performed the first artificial disintegration of an atomic nucleus with Ernest Walton at Cavendish in 1932. Harwell also boasted an excellent theoretical physics group which, unlike many institutions of the time, interacted strongly with the experimentalists. Newton started his research with experimentalist Basil Rose, and together they investigated gamma rays from radioactive nuclei. It was far easier to access irradiated sources at Harwell compared to Newton's experience at Cambridge, with production based at local nuclear reactors and, in some cases, from atom bomb testing sites.[14] The instrumentation at Harwell was also elevated in comparison to Newton's previous work, with several high energy resolution proportional counters, filled with

[9] The Nobel Prize (2024).
[10] Newton (2010).
[11] Newton (1951). A full list of publications by Newton is available in the Supplementary Material.
[12] French and Newton (1952).
[13] Newton (2010).
[14] Newton (2010).

xenon or krypton. Such equipment was crucial for the identification of gamma rays close to one another in energy.

By the early 1950s there had been significant theoretical developments in the field of nuclear physics. The old shell model had been refined and challenged by a new model from Bohr and Mottelson.[15] The new model indicated that nuclei were not all spherical, as previously assumed, but could have deformed 'rugby-ball' shapes that could exhibit collective motions, such as rotation and vibration. Experimentalists of the time had set out to test whether this theory was correct, and in the process, enhanced the field's understanding of heavy nuclei. In 1952, Austrian-born British physicist Otto Robert Frisch came to Harwell and asked Newton to write a review article for *Progress in Nuclear Physics* on the topic of 'the nuclear properties of the very heavy elements'.[16] During the writing process, Newton noticed two aspects on the subject of heavy nuclei that had not yet been explained: first, the favoured and unfavoured transitions observed in the alpha decay of odd nuclei; and second, the inhibition of decay by spontaneous fission for odd and doubly-odd nuclei. Newton was able to provide simple, yet essentially correct, explanations for both these phenomena which were published in his review article. He later regretted not publishing them as separate journal articles.[17] Newton completed his PhD with Cavendish in 1953, and in 1954 was promoted from a Fellow at Harwell to a Principal Scientific Officer.

The year 1953 also marked the birth of John and Cordula's first child, Oliver Newton. The family grew in 1956 with the birth of son Rupert, and in 1959 with daughter Susanna, the children being three years apart in age. The family lived in Abingdon, next to Oxford, for much of this time. Oliver grew up to be a computer programmer working in the finance industry, Rupert an engineer in the IT world, and Susanna a professional oboe player.

Shortly after the completion of his PhD, Newton made several more discoveries that had a profound impact on his career. In Copenhagen, physicists had just discovered Coulomb excitation,[18] and it occurred to Newton that he could use the newly developed high-pressure proportional counters, that had a greater efficiency of detection, to study the Coulomb excitation of heavy nuclei. This was an extremely difficult task because gamma rays from the radioactive targets and background radiation both work to obscure the gamma-rays of interest. In 1956, Newton was successful in making the first observations of the gamma rays from these nuclei.[19] From the theory of Bohr and Mottelson, Newton further deduced, for the first time, the deformation of the 'rugby-ball' shapes.[20]

The first visit to Berkeley

Stanley G. Thompson, a gifted chemist from the Lawrence Berkeley Laboratory (LBL), visited Harwell briefly for two days, where he met Newton. Impressed by Newton's work, Thompson deemed Newton the perfect fit to start up a new field of Coulomb excitation at the Berkeley laboratory, where they were building a new Heavy-Ion Linear Accelerator (HILAC). After Thomspon returned to Berkeley, Harwell's Egon Bretscher received a letter from Glenn Seaborg, the Head of the Nuclear Chemistry Division at LBL (and Nobel Prize winner for the discovery of plutonium), proposing the establishment of an exchange scheme between Harwell and Berkeley.[21] Seaborg requested that Newton be the first person to be exchanged, and Bretscher kindly agreed.

Newton first visited the United States in 1956 and was struck by the stark contrast with his previous life in post-war England. The bountiful products in supermarkets, generous serving sizes, and lack of strict class distinctions in academia—which Newton felt were appalling and humiliating in Britain—left a distinctly positive impression.[22] Newton sailed to San Francisco on the *Orcades*, travelling through the Panama Canal. At the LBL, he shared an office with Sven Gosta Nilsson, the Swedish theorist famous for developing the independent-particle model for deformed nuclei. As a result of their proximity, Newton became close friends with Nilsson and his wife, Anna. Newton and his family would also become long time family friends with the Lipworths through Newton's work with Professor Edgar Lipworth, a pioneer in early laser research. It was at Berkeley that Newton learnt transcendental meditation, something he routinely practiced for the rest of his life as a way to relax and find focus (R. Newton and M. Dasgupta, pers. comm., 2024).

In the first year before the HILAC was completed, Newton spent time investigating the energy levels of rhenium nuclei, which are produced in the decay of radioactive osmium. The osmium itself was produced by bombarding tungsten in a cyclotron; Newton was provided with this piece of intensely radioactive tungsten, from which he separated the osmium and plated it on to a thin platinum wire, marking his first venture into radiation chemistry.[23] The experiment was

[15] Bohr and Mottelson (1952).
[16] Frisch (1952).
[17] Newton (2010).
[18] Alder and Winther (1953).
[19] Newton (1956).
[20] Newton (1957).
[21] Newton (2010).
[22] Newton (2010).
[23] Newton (2010).

successful, with Newton demonstrating that these rhenium nuclei were indeed deformed.[24] His research with rhenium and osmium in this period also further enhanced understanding about Auger transitions.[25]

After the HILAC was completed in 1957, Newton took the opportunity to study multiple Coulomb excitation but the accelerator was not especially suited to the experiments he hoped to perform. It produced only two beam energies, 10 MeV per nucleon and 1 MeV per nucleon, and the beam itself was discontinuous, consisted of two millisecond pulses every one hundred milliseconds. This meant Newton could not perform coincidence experiments and, more crucially, the required energies for Coulomb excitation were less than 5 MeV per nucleon, but not as low as 1 MeV. Frank Stephens, who had newly completed his PhD at the Berkeley laboratory, was chosen to work with Newton on this project.

The facility did not frequently perform online experiments with the HILAC, yet Newton and Stephens persuaded them to install concrete shielding and a gamma-ray cave. With the upgraded system, Newton decided it would be interesting to study double Coulomb excitation, which had never been observed before. To achieve the energies required for this experiment, the 10 MeV per nucleon beam was passed through a tube of hydrogen gas. By changing the pressure of the gas, the energy could be reduced but this also spread the beam and hence, lacking focussing arrangements, the beam was quite large. Newton and Stephens were ultimately successful, being the first to demonstrate the phenomenon of multiple Coulomb excitation in 1958. The results appeared in the first issue of *Physical Review Letters*.[27]

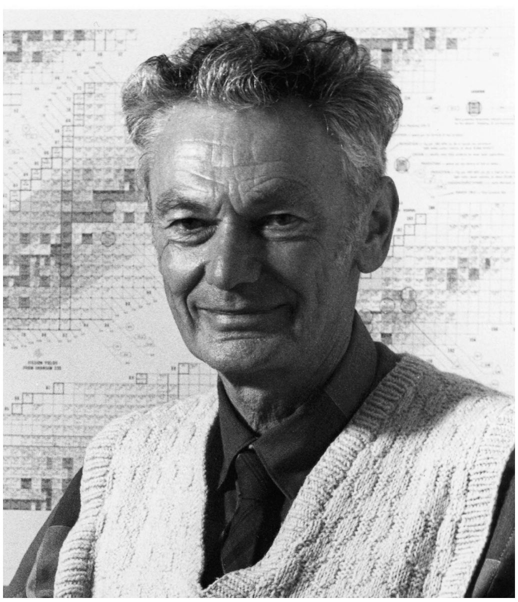

Fig. 1. John Newton (1995).[26]

Following this success, Newton conducted preliminary experiments at Berkeley to examine projectile Coulomb-excitation. The same year, Newton was the first to observe projectile excitation in aluminium-27 and neon-20. This was achieved only days before Newton had to return to Harwell—his exchange period having already been extended by six months—so he was not able to complete detailed measurements of this phenomenon. Multiple and projectile Coulomb excitation later became a powerful and crucial tool in spectroscopy, and was a key part of later work by physicists in both Manchester and Canberra.

Back to England: Manchester

In 1959, Samuel Devons had visited Berkeley and asked Newton to apply for a senior lectureship at the University of Manchester, where Devons himself was Langworthy Professor of Physics and Director of Physical Laboratories. The university already housed a six-million-volt accelerator and had the funding to build a new heavy-ion linear accelerator, similar to the HILAC at Berkeley. Newton accepted the appointment and served as a Senior Lecturer in Physics (1959–67), and then later as a Reader in Physics (1967–70). His family relocated with him to live in Cheadle, just outside of Manchester. Unlike Newton's previous appointments at Harwell and Berkeley, the post was not solely research focussed. Teaching was taken very seriously at Manchester, and hence Newton gave lectures, tutorials, practical classes, attended Steering Committees, and so on, which he later noted 'took a lot of time away from the research'.[28] An International Nuclear Physics Conference was held at Manchester in 1961 to celebrate the fiftieth anniversary of Rutherford's discovery of the nucleus. Newton was on the organising committee, and facilitated a special session attended by many of the pioneers of nuclear physics, including Niels Bohr, Lise Meitner, and Walter Greiner.

At Manchester, Newton's first project was to use the six-megavolt accelerator to experimentally verify his theoretical idea on angular correlations from his PhD thesis, which he had hoped to do for many years.[29] Following this, he spent a significant portion of time working with the new Manchester HILAC. As with the machine at Berkeley, there were significant problems with vast amounts of background gamma and radiofrequency radiation throughout the

[24]Gallagher and others (1959).
[25]Newton (1960).
[26]Ophel (1998).
[27]Newton and Stephens (1958).
[28]Newton (2010).
[29]Newton (2010).

laboratory. Newton was instrumental in solving these problems, in addition to setting up the new beamlines, and generally equipping the new HILAC with the systems necessary for a functioning experimental division. A new method of studying nuclear structure had been discovered by Morinaga and Gugelot in 1963.[30] This heavy-ion fusion-evaporation reaction offers the most powerful method for studying excited states, including at high angular momentum, through the measurement of the discrete gamma-rays, which captured Newton's attention. There are two types of detectors that are suitable to study these reactions: the germanium detector, and a magnetic spectrometer. The University of Manchester did not have any germanium detectors at this time, and so Newton encouraged David Ward, a bright and enthusiastic student, to create a single-gap wedge spectrometer. This was a key tool used in several experiments with the HILAC.

During this time, Newton was involved in a sad divorce (1961) from his first wife, Cordula. Cordula and her new husband moved to the United States with Oliver, Rupert, and Susanna, placing significant physical distance between Newton and his children in their early childhood. Newton would visit Boston to see his children and attend academic conferences at the Massachusetts Institute of Technology (MIT) as often as possible. At Christmas and on birthdays, Newton posted the latest Beatles and Rolling Stones records before they were released in the United States, which his son Rupert would recall made him the coolest kid among his friends (R. Newton and M. Dasgupta, pers. comm. 2024). Whilst at Manchester in 1964, Newton remarried to Silva Cirilov, a nuclear physicist with a PhD from Belgrade, who became a significant supporting person in his life and work.

Return to Berkeley

Shortly after this marriage, Newton returned to Berkeley in 1965 for an extended visit. Between work, Newton took the opportunity to spend time travelling with his children and wife Silva, enjoying day trips around San Francisco and Berkeley. There had been several significant changes to the Berkeley laboratory since Newton's last visit. There was now an 88-inch diameter heavy-ion cyclotron in addition to the HILAC, which had itself been upgraded to have a duty-cycle of 20–50 percent (up from two percent). The HILAC consumed nearly as much power as the entire city of Berkeley due to the upgrades and required water to be poured over the machine to keep it cool. With new facilities far superior to what he had been working with in Manchester, Newton saw the opportunity to embark on truly remarkable research.

The team at Berkeley had also shifted, with Isadore Perlman succeeding Seaborg (who had left to head the Atomic Energy Commission) as the Head of the Nuclear Chemistry Division. Frank Stephens and Richard Diamond had established a fantastic group in nuclear physics, which received some of Newton's old Manchester students during his visit—David Ward and Jack Leigh. Newton became involved in a systematic study of gamma-ray angular distributions in heavy-ion fusion-evaporation reactions. Newton and his colleagues conducted the first experiments with heavy argon-40 projectiles and compared the population of discrete gamma rays emitted to those from lighter projectiles, contributing to a greater understanding of these reactions.[31] Such was his success, that from 1966 Newton was hailed as a pioneer in the study of high spin states using heavy-ion reactions. During this visit, Newton was offered the chance to remain in Berkeley, which he declined and returned to Manchester. He later expressed regret at this decision, on the basis that Berkeley's facilities were especially unique at this time, and his forté lay in research rather than undergraduate teaching.[32] Newton was awarded a Doctor of Science (DSc) degree at Manchester in 1967.

Across the world to Canberra

In 1970, Newton left England to become professor of nuclear physics and Head of the Department of Nuclear Physics at the Australian National University (ANU) in Canberra. (Sir) Ernest Titterton (then Director of the ANU Research School of Physics) had visited Manchester soon after Newton's return from Berkeley, and asked him to apply for the position, with the sweetener that Titterton had already secured A$2.2 million to buy a new tandem electrostatic accelerator. This was a highly appealing offer for Newton, as the accelerators in the UK were quite outdated, and there was little prospect of new equipment in the near future.

Newton arrived in Canberra in February 1970, travelling on the aptly named liner *Canberra*. At the ANU, Titterton had set up a thriving laboratory with a well-functioning six megavolt tandem accelerator and a talented team. Newton was involved in the final choice on the type of tandem accelerator purchased: a vertical 14 megavolt tandem accelerator (14UD), built by the National Electrostatic Corporation (NEC). This was a far better accelerator than the Department had initially anticipated they would be able to purchase, with an entirely new and original design. This was a risk taken, yet it turned out to be extremely successful. Fifty years on from its initial construction, the 14UD accelerator at the Heavy Ion Accelerator Facility (HIAF) continues to be a world-class

[30] Morinaga and Gugelot (1963).
[31] Ward and others (1967).
[32] Newton (2010).

machine that has capabilities unique in Australia and rare in the world.

The NEC was to build the internal accelerator in the United States. The pressure-vessel to contain the accelerator, the associated support system, the beam lines, vacuum systems, and other mechanisms would be built in Australia. The 14UD accelerator was far from an off-the-shelf product, but rather a highly specialised machine tailored to the department's vision. Excess money from the accelerator budget was put into the purchase of a cyclotron that could inject negative ions into the existing six megavolt tandem accelerator, making it a more powerful machine with much higher energy. The 14UD accelerator was completed in 1973, with the first proton beams delivered for experiments on 15 August that year.[33]

From 1970 to 1980, the Nuclear Physics Department underwent many significant changes in both the style and program of research under Newton's leadership. His primary objective was to initiate research in heavy-ion reactions, which had not been previously performed at the ANU. Further to this, Newton aimed to encourage researchers to work in larger groups, which he believed facilitated mutual interactions beneficial for stimulation and the generation of new ideas.[34] The tradition in Canberra, along with many other institutions, was to have one employed researcher with a small group of research students working on one project, with other staff working on separate projects and little interaction between groups. However, the rapid advance of technology by 1970 meant that experiments and equipment were now far more complex, producing immense amounts of data that made group work increasingly essential to undertake modern research. Newton held the ambition to make the laboratory more democratic than under Titterton, hoping to improve the atmosphere in the department.[35] This restructuring was ultimately a success.

Newton struck gold in his own research efforts in 1974, using the new accelerator for the characterisation of continuum gamma-rays in heavy-ion fusion reactions. It was the first observation of this kind of continuum gamma rays, and it started an entirely new field of research.[36] The work caused a lot of consternation and distress at the Berkeley laboratory, where they had been hoping to perform a similar study. The day Berkeley received Newton's publication henceforth became known at Berkeley as 'Black Friday'.[37] In 1975, Newton was elected a Fellow of the Australian Academy of Science.

Confident that the new research programs at the ANU were going well, Newton embarked on another sabbatical visit to Berkeley (1980–1). It was a favourite place: he very much enjoyed working with Frank Stephens and Richard Diamond, and had a great appreciation for the impressive facilities and environment.[38] During this visit, Newton worked on continuum gamma rays with Stephens, Diamond, and Bent Herskind, a visitor from Copenhagen. Their research was concerned with the possible effect that the giant dipole-resonance might have on continuum gamma-rays, which they experimentally tested.[39] Newton's previous research at the ANU positioned him to provide much of the theoretical input for the interpretation of the results, which is credited for starting the new area of research into continuum gamma rays. This observation of giant dipole resonances built on states of high energy and spin is Newton's second-most cited first-authored work.

In 1979 Newton had made an inspired decision to redirect his and his research group's activities into a completely new field, studying fission following heavy-ion fusion. While Newton was in Berkeley, Jack Leigh (Newton's PhD student at Manchester and now Research Officer in the department) and PhD student David Hinde developed new detector systems, and made the group's first measurements of heavy-ion induced fission according to Newton's suggestions. This soon resulted in a *Physical Review Letters* publication, later contributing to Leigh's promotion to Fellow in 1985.[40]

Another of Newton's Manchester students, David Ward, spent a sabbatical year starting in 1981, from his position at Chalk River Laboratories in Canada. He arrived as a new capability was being developed. David Hinde's calculations had shown measurement of neutrons emitted during fission would be valuable. Newton decided to invest the effort to develop that capability, and Jack Leigh designed the ingenious experimental setup. David Ward volunteered to develop the analysis software and analysed the experimental results. This was a great example of teamwork, with Newton and (ex)-students all contributing in different ways.

After completing his PhD, David Hinde exploited this capability, leading a systematic program of measurements of neutron multiplicities. These gave information not only on multi-chance fission as planned, but also showed that the fission process is slower than had been expected, providing information on nuclear viscosity.[41] Newton recognised the

33 Ophel (1998).
34 Newton (2010).
35 Newton (2010).
36 Newton (1974).
37 Newton (2010).
38 Newton (2010).
39 Newton and others (1981).
40 Leigh and others (1982).
41 Hinde and others (1986).

importance of this result, and contributed to interpretation and promoting these results internationally.[42]

After the neutron multiplicity work came to an end at ANU, an even more significant discovery was made, concerning the heavy-ion fusion process itself. It had generally been understood that there was a single Coulomb barrier to fusion, but Rowley, Satchler, and Stelson proposed that there should be a distribution of barriers, and furthermore, this may be measurable experimentally.[43] Jack Leigh heard Rowley's presentation at an overseas conference, and came back full of enthusiasm. They invited Rowley to visit the ANU, and an experimental program was established, led by Jack Leigh using his unique new detector. It was discovered that the barrier distribution was real, and even revealed fine details of the shapes of deformed nuclei! Key to the success of this project was the remarkable flexibility, stability, and reproducibility provided by the 14UD accelerator itself. Newton gave much credit to David Weisser and Trevor Ophel for the continual improvements since the 14UD's first use in 1973. The precision of the experiments was also crucial, achieving ten times better than previously. This work attracted Mahananda Dasgupta to apply for a position in the group, which later grew from strength to strength. Newton felt great satisfaction that the research group involved in this work, initially led by Jack Leigh until his retirement in 1997, then by David Hinde, and currently by Dasgupta, is an undisputed international leader. Laboratories around the world have tried to emulate their work, with less success.

After eighteen years as the Head of the Department of Nuclear Physics at ANU (1970–88), Newton eventually stepped down for health reasons in 1988. But his health did not deteriorate as feared, and he became emeritus professor at the ANU in 1990 and continued as a visiting fellow in the Department of Nuclear Physics until 2008. In total, Newton continued to carry out research within his research group for another twenty years after retirement. Among his first-authored papers, Newton's last paper (on fusion)—submitted to the journal on his eightieth birthday—has received the highest number of citations.[44] The study presented the need for a new dynamical approach to fusion, identifying the systematic failure of the Woods-Saxon Nuclear Potential to describe both fusion and elastic scattering.

Newton's remarkable vision and intelligent decision to initiate the new research program in the field of nuclear fusion and fission in heavy-ion collisions deserved much credit for contributing to the international success of Canberra's Heavy Ion Accelerator Facility. As a result of his wide international experience, Newton recognised the opportunities presented by the 14UD tandem accelerator, and the gap in the field of nuclear physics that it was ideally positioned to fill. This decision surely led to far more recognition across the field, and a stronger legacy than if Newton had remained in the United States. In 2001, Newton was awarded the centenary medal by the Australian Government in recognition of the impact of his achievements and research on Australian physics.

Throughout his career, Newton was careful about the research he undertook, and consequently his work has stood the test of time. Newton always took the science seriously and had a measured way of presenting to other researchers and observers. He was described by coworkers as fundamentally shy, but fair, and helpful in supporting his students to advance their own careers. Newton remained engaged with the broader scientific community throughout his life, feeling passionate about the global challenges posed by climate change, resource depletion, and environmental destruction.[45] Later in his career, Newton produced a number of talks and written articles objectively addressing these issues.[46]

At the ANU, Newton's wife Silva was a part of his team in every sense. When Newton was appointed professor and Head of Department in February 1970, Silva also had a formal position as a visiting fellow, beginning in July the same year. Whilst Silva did not remain an employed physics researcher, she continued to have a strong relationship with the department, looking after Newton's interests and engaging strongly with his students as a hostess and carer. She provided proactive care for her husband's health in his final years, as he did with hers.

John Newton passed away on Monday 26 September 2016. Silva Newton died very soon after, within a week of her husband's passing. At this time, Newton had three grandchildren, Colin, James and Jefferey, and two great-grandchildren, Corin and Oliver.

Newton is well-remembered in the department he led for so long at the ANU. The HIAF (perpetual) Endowment Fund was created in 2012 by Professor David Hinde, then Head of the Department of Nuclear Physics; Emeritus Professor Keith Fifield, then Director of the HIAF; and Professor Mahananda (Nanda) Dasgupta, ARC Laureate Fellow. The Fund's mission is to offer career advancement opportunities that would not otherwise be available to those working with this national infrastructure, and to train a new generation of researchers to enable innovation in sectors of national importance.[47] Nanda discussed the Fund with John several times. In 2018,

[42] Newton and others (1988).
[43] Rowley and others (1991).
[44] Newton and others (2004).
[45] Newton (2010).
[46] Newton (2010).
[47] HIAF Endowment Fund Brochure (2023).

the Endowment Fund received a massive boost through a very generous bequest from the estate of the late Professor John Newton and Dr Silva Newton. This allowed the establishment of The John and Silva Newton Award for the support of graduate students from the Department of Nuclear Physics. Both John and Silva Newton had lived through challenging times in their youth, and both being physicists, they recognised the importance of providing opportunities to students.

The key decisions made by Newton regarding the direction of nuclear research at the ANU have contributed to an outstanding legacy of world-leading physics research that continues in Canberra, and finally to a perpetual source of financial support for students into the future.

Supplementary material

Supplementary material is available online.

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Data availability. Data sharing is not applicable as no new data were generated or analysed during this study.

Conflicts of interest. The authors Mahananda Dasgupta and David Hinde were professional colleagues of John Newton and have collaborated and published scientific papers with him, some of which are referenced here. The authors declare no other conflicts of interest.

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Author affiliation

[A]Australian National University, Department of Nuclear Physics and Accelerator Applications, Research School of Physics, Canberra, ACT 2601, Australia.