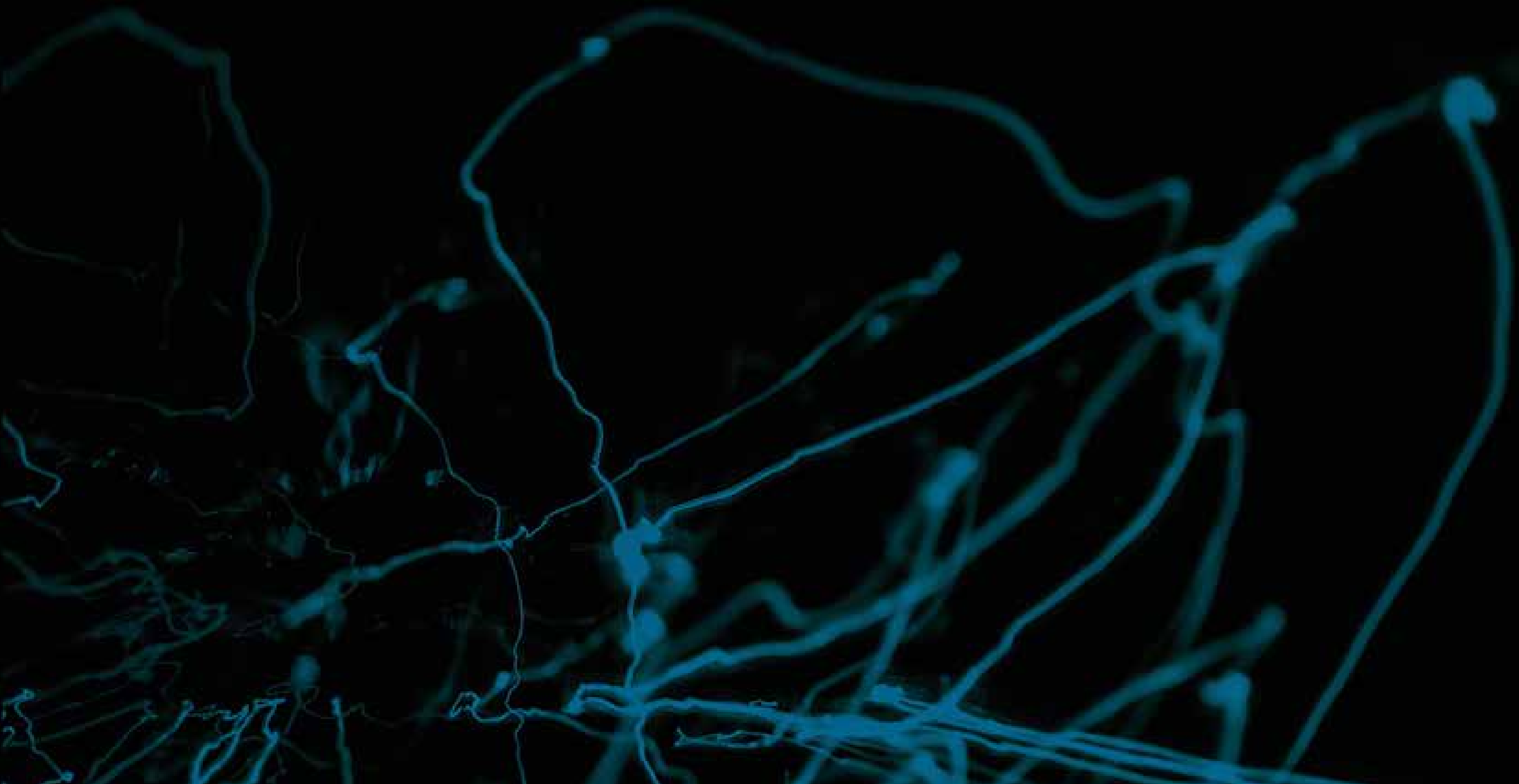
UNIVERSITY OF BIRMINGHAM | CYCLOTRON FACILITY

BIRMINGHAM
CYCLOTRON FACILITY



BIRMINGHAM CYCLOTRON FACILITY

Our facilities are unique, and the work we do – from nuclear research to isotope production for medical imaging – is wide-ranging, cutting-edge and life-changing.

Birmingham is the only university in the UK with an MC40 cyclotron (particle accelerator). Originally designed for industrial use, we have adapted it to enable us to also carry out fundamental research and push the frontiers of nuclear science.

The MC40 cyclotron is the latest in a series of particle accelerators operated at Birmingham since the 1930s. Brought over from America 15 years ago, it delivers a flexible range of ions and energies. It is capable of accelerating hydrogen (protons and deuterons) and helium (helium-3 and helium-4) with high intensities to energies at which it's possible to perform nuclear reactions.

The flexibility and reliability of the cyclotron – and the expertise of our nuclear physics, particle physics and medical physics groups in manipulating its capabilities – have led to us carrying out a wide range of commercial and research work for, among others, hospitals, Formula 1 and CERN's Large Hadron Collider.

Our activities have expanded significantly in the past few years. With the cyclotron only half-way through its expected lifespan, our aim is to broaden still further our research, as well as continuing our long-established applications and commercial work, thus bringing benefits to more users from across the UK nuclear community.

“Birmingham is the only university in the UK with an MC40 cyclotron particle accelerator.”

THE MC40 CYCLOTRON FACILITY

We bought the Scanditronix MC40 cyclotron in 2002 from a hospital in Minneapolis, in the US. We dismantled it, shipped it and reassembled it in Birmingham.

The first beam was obtained in February 2004. Soon afterwards, a 12-way switching magnet was bought second-hand from Strasbourg. In 2006, a beam line was extended out of the cyclotron vault into the adjoining target room. Since then, the cyclotron has performed two main functions:

- Making radioactive isotopes, for research and commercial use
- Testing materials for the effects of radiation

In 2012, the target room was subdivided by a new central shielding wall, and a second beam line was run into the newly created shielded area. This second beam line is used for high-current radiation damage runs.

‘The MC40 cyclotron has shown itself to be a versatile machine for both research and applications. At the facility, nuclear structure investigations coexist happily with applications such as detector testing, radiation hardness irradiations and routine production of both PEPT and medical isotopes.’

PROFESSOR DAVID PARKER,
PROFESSOR OF PHYSICS

COMMERCIAL USE

MEDICAL IMAGING

The creation of radioactive isotopes is used in a variety of applications. In particular, the cyclotron produces radioisotopes used nationally for lung imaging. We produce the isotope rubidium-81 every evening, five days a week, for a local NHS Trust that supplies hospitals across the country. Production of rubidium-81 started in March 2006 and has continued ever since, with a success rate of more than 96 per cent.

PEPT

As Positron Emission Tomography (PET) was being developed elsewhere as a medical imaging technique, we had the idea of using PET to study flows in engineering. Mapping the tracer concentration in PET requires acquisition of a large volume of data, and since engineering flows are often much faster compared to metabolic processes in biology, we adopted the alternative approach of tracking a small positron-emitting particle. This Positron Emission Particle Tracking (PEPT) technique proved extremely powerful for characterising granular and fluid flow in a wide range of engineering systems. The MC40 cyclotron makes it possible to accelerate helium-3 to generate fluorine-18 from natural oxygen to make the necessary radioisotopes for PEPT. Because the shelf-life of fluorine-18 is less than two hours, we make it every morning.

TRIBOLOGY – WEAR TESTING

We irradiate pieces of engineering equipment to activate them in order to quantify how quickly surface material wears off. Among other things, we have worked on parts of F1 car engines.

APPLIED RESEARCH

At a time when university accelerator labs are closing, with most such research being conducted at large, dedicated sites, we have shown that it's possible to adapt existing equipment – in this case, the MC40 cyclotron – to achieve experimental scientific 'firsts'. Our world-leading applied research includes:

AIDA–2020

The cyclotron has been used to develop a programme of irradiation of nuclear electronics with beams of protons. This allows the study of damage mechanisms that is done by the neutrons inside a nuclear reactor. The advantage of using protons as opposed to neutrons is that the same damage that is produced inside a reactor by neutrons over many years can be achieved in several weeks. This allows the study of damage mechanisms on an accelerated timescale. In as little as two minutes, we can reproduce the doses expected after ten years next to the collision point at the High Luminosity Large Hadron Collider (HL-LHC) accelerator at CERN. Our facility is now part of the European Transnational access programme AIDA-2020 and is being used to irradiate components for the HL-LHC upgrade programme. Taking samples from around the world, we irradiate them to the required doses operating at the chosen radiation rate and operating temperature.

PRaVDA

Proton radiotherapy promises clinical advantages over conventional X-ray radiotherapy for certain cancers, particularly those in paediatrics and head and neck. Proton therapy (PT) enables a lower integrated radiation dose to a patient receiving radiotherapy – compared to X-rays – due to the finite range of protons, so allowing more accurate targeting of the dose. We are part of the PRaVDA Consortium, funded by the Wellcome Trust, to develop new concepts and instrumentation to provide accurate information about the proton beam's dose, energy and profile before and during treatment.

PURE RESEARCH

As well as applied research, the Birmingham Cyclotron Facility conducts equally groundbreaking pure research. This includes:

IT'S IN THE STARS

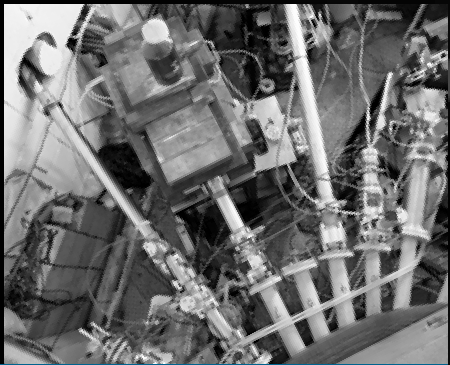
We have painted the most precise picture yet of the somewhat perplexing 'Hoyle state' – an excited state of carbon-12 – which affects the nucleosynthesis of carbon in stars and, therefore, life itself. By developing two scattering chamber set-ups on beamline 4 at the cyclotron, we were able to carry out nearly 100,000 observations to watch the Hoyle State fall apart, producing an experimental result that is the most specific to date – and significantly smaller than previous ones – of the rate of its break-up, or decay, into three alpha particles.

IONS AND ENERGIES

RADIATION HARDNESS IRRADIATIONS

To ensure the reliability of materials under extreme conditions, such as those used in the nuclear industry, scientists need to deepen their understanding of the basic physics behind radiation damage processes. This includes testing new materials, such as novel types of steel. Using protons from the cyclotron, we are able to compare damage models with real experiments in order to test the robustness of new materials. This process is used to simulate the damage that is done by the neutrons inside a nuclear reactor. By using protons as opposed to neutrons the same damage that is produced inside a reactor by neutrons over many years can be achieved in several weeks.

The MC40's RF systems can be tuned over the range 27.4 to 14.2 MHz (the original design could go lower, but the resonators were shortened to fit in the low vault at Minneapolis). This gives the nominal operating ranges summarised in Table 1. The N=1 and 2 modes refer to the fundamental frequency and first harmonic respectively of the radio frequency accelerating voltage.



In practice, the maximum achievable proton energy is around 38 MeV. Helium-3 is run using the recirculating gas system acquired from the decommissioned Hammersmith cyclotron; the MC40 vacuum is maintained using a single diffusion pump whose exhaust is passed through a cold zeolite filter and then returned to the ion source. Additionally, small beams of 46 MeV $^{14}N4^{+}$ and 71 MeV $^{14}N5^{+}$ have also been extracted and used for nuclear physics studies.

BEAM ION	ENERGY (N=1)	ENERGY (N=2)
Protons (^{1}H)	10.8-40 MeV	2.7-10 MeV
Deuterons (^{2}H)	---	5.4-20
Helium-3 (^{3}He)	33-50 MeV	8-28 MeV
Helium-4 (^{4}He)	---	10.8-40 MeV

Table 1: Commonly produced ions and energies available at the MC40 cyclotron

> 'The cyclotron facility has given us the opportunity to push the frontiers of nuclearscience. It has the capacity to serve not just our own needs, but also those of external researchers who are welcome to use this unique UK centre.'
>
> DR CARL WHELDON, SENIOR LECTURER IN NUCLEAR PHYSICS

UNIVERSITY OF BIRMINGHAM

Edgbaston, Birmingham,
B15 2TT, United Kingdom
www.birmingham.ac.uk

Designed and printed by

UNIVERSITY OF BIRMINGHAM | creativemedia

18684