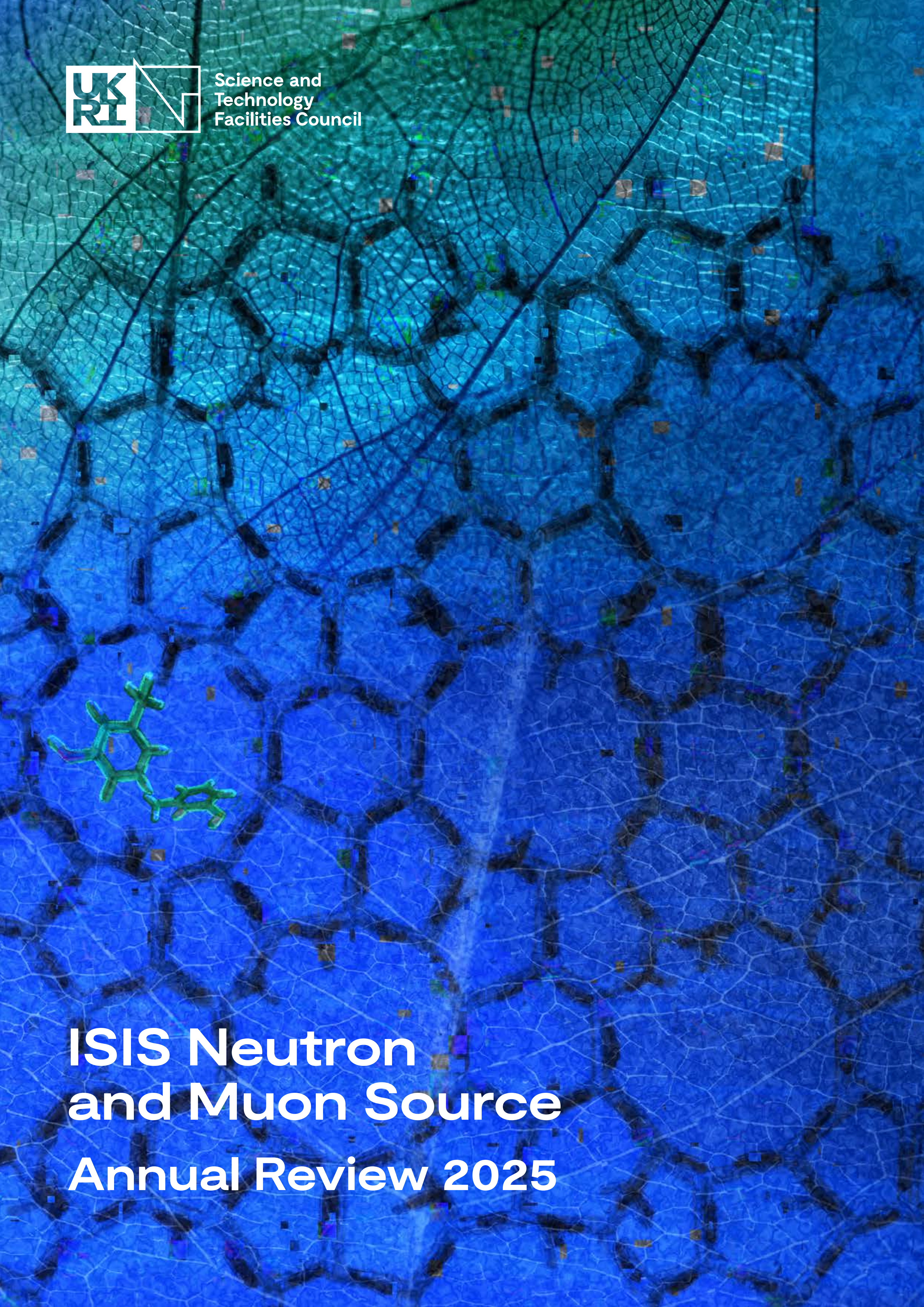


Science and Technology Facilities Council

ISIS Neutron and Muon Source

Annual Review 2025

Our mission

Our aim is to enable research that advances knowledge and improves lives. We support a large and diverse user community that uses neutrons and muons to address global challenges and answer fundamental questions across a broad range of sciences. ISIS brings together national and international academics and industrialists to advance these challenges by taking advantage of the unique insights that neutrons and muons provide. The ability of our instruments to investigate the structure and dynamics of materials with unprecedented detail helps to ensure that the UK remains at the forefront of global materials research.

Cover image: Graphical representation of the diffusion of cresol in catalysts (see page 28). Design by Vanshika Jain.

Contents

Foreword

Although I am new to the role of ISIS Director, my connection to ISIS began many years ago with my first visit to ISIS as a PhD student. From this initial visit, I was fascinated by the unique insights you can get from using neutrons (and muons!). Since joining as an instrument scientist in 2008, I have continued to be amazed by the range of science the techniques can enable.

This year's annual review contains just a snapshot of this scientific breadth. Our wide-ranging science programme has developed over the years and continues to remain cutting-edge, mapping onto the UK Government's new Modern Industrial Strategy in areas such as Clean Energy and Advanced Manufacturing, alongside fundamental materials investigations. Looking to the future, I have been leading the community consultation into the science case for ISIS-II. It is inspiring to think what science could be possible with such a facility.

This scientific excellence is only possible because of the staff who work here. As well as prize-winning graduates, PhD students and science groups, the day-to-day innovation of our engineering and technical teams allows us to make full use of our current facility while designing and building its future.

As part of this development, the Endeavour programme continues to progress. The very visible change has been the demolition of the building that housed HRPD, but much more has been happening behind the scenes and we look forward to new instruments coming online in the future.

There is no hiding from the fact that times are challenging, financially, for STFC. ISIS is not immune to these challenges – we've needed to reduce operations over the past two years and will continue to feel the impact of financial pressures. But we know that ISIS stands on a bedrock of excellent science, strong user community and far-reaching international reputation – these things, along with the unique insights that neutrons and muons bring, aren't changing and provide a firm foundation for the future.

I would like to take this opportunity to thank Steve Wakefield for his time as Interim Director and his help to me during this transition period. I look forward to working with him and our amazing staff, in collaboration with our user community, to ensure we continue to produce world-leading research here at ISIS.

Sarah Rogers
Director of ISIS Neutron and Muon Source

Sarah Rogers, the new Director of ISIS.

This year at ISIS

Public engagement

8260 people reached through our engagement programme

90 companies engaged with ISIS

Publications

559 journal publications

73.3% international collaboration

3546 authors

5.8% industry collaborators

Link to publications

http://bit.ly/3K9zhkc

Experiments

787 unique principal investigators, of which 214 were new to ISIS

3879 instrument days delivered

1673 unique users, of which 37% were students

1402 proposals submitted

Operations

5 cycles

3313 hours of beam on target

634 mAh of beam delivered

87.5% accelerator availability

Delivering a world-leading science programme

The science highlights presented in this review showcase the breadth, depth and quality of the work delivered at the facility. ISIS research plays a key role in delivering the UK Government's Modern Industrial Strategy, supporting many of the high-growth sectors it highlights. This year we have welcomed new and returning scientists and supported them to deliver outstanding research in areas such as green energy technology, quantum science, advanced materials, and healthcare.

Camilla Di Mino and Adam Clancy from UCL, on SANDALS, studying the link between sweetness and hydrogen bonding.

Energy and clean growth

Battery ageing study aims to improve cycle life at high temperature

Echion Technologies Ltd, a battery technology spinout company from the University of Cambridge, used neutron diffraction and mass spectrometry to gain insight into battery cycle life.

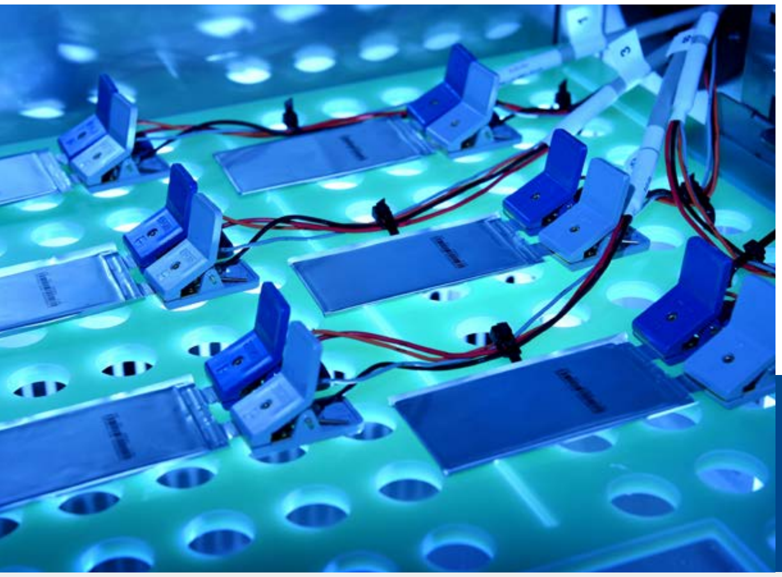
Lithium-ion batteries are ubiquitous in modern life. These batteries will go through thousands of charge-discharge cycles over their lifetime, and may start to lose capacity, especially if operating at high temperatures. Echion were interested in understanding the mechanism by which battery cell capacity faded over time by looking at changes in their patented mixed niobium oxides anode materials.

Echion collaborated with the National Physical Laboratory to use secondary-ion mass spectrometry (SIMS) to characterise the surface composition of lithium-ion battery electrodes. They also used neutron diffraction at the Polaris instrument at ISIS to study the bulk atomic structure by investigating crystallographic changes taking place within the electrode.

Neutron diffraction showed that the electrode's crystal structure remained stable. SIMS indicated elemental differences in the surface composition, suggesting that cycle life issues are related to overall cell design and surface effects.

The results allow Echion to focus their research into solving these issues and will accelerate the commercialisation of Echion's next-generation material systems.

> “Our work with ISIS Neutron and Muon Source has been an important part of the development of our niobium-based anode material, XNO®. The facilities and expertise available have given us insights and information that we wouldn't have been able to access by other means.”
>
> Fiona Coomer, R&D Programme Manager, Echion Technologies



Testing pouch cells.
Credit: Echion Technologies

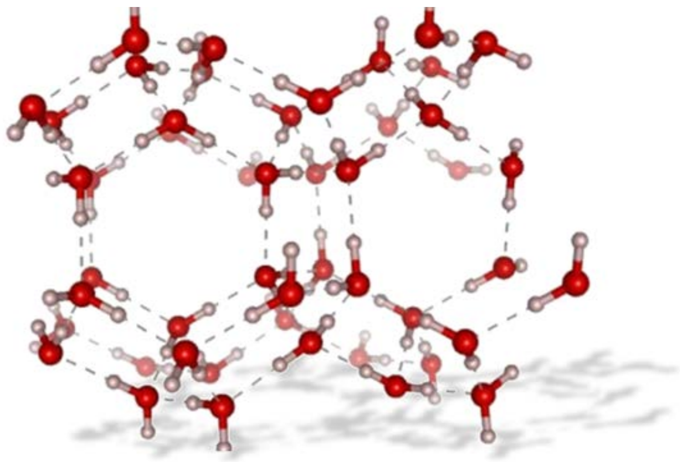
Instrument: Polaris
Funding: Innovate UK A4I
Researchers: F Coomer, P Babbar, G Jain, S Moharana, D Martin (Echion). R Smith (ISIS).

Using ice as an innovative hydrogen storage material

Researchers from the Institute of Applied Physics “Nello Carrara” of the Italian Consiglio Nazionale delle Ricerche (CNR) have used Tosca to show that gas molecules can be absorbed into the porous framework of ice XVII.

Water ice comes in many forms; ice XVII is low density and highly porous, potentially allowing it to be used as a storage material for gases such as hydrogen.

Researchers from CNR and ISIS used ice XVII made with D_2O as a porous matrix to host molecular hydrogen, nitrogen and oxygen at near ambient pressure (0.5-3 bar) and low temperature (20-90 K).



The structure of ice XVII.
Credit: Leonardo del Rosso

By combining Raman scattering, performed in the CNR-IFAC laboratory, and inelastic neutron scattering on the Tosca spectrometer at ISIS, the team were able to fully characterise the microscopic vibrational dynamics of the confined gas molecules in the channel-like environment within the ice.

The versatility of ice XVII in terms of its porosity, together with the theoretically infinite number of possible absorption/desorption cycles, suggests it could be a sustainable option for hydrogen solid-state storage, or gas sequestration and purification by molecular sieving mechanisms.

Instrument: Tosca
Related publication: Microscopic dynamics of gas molecules confined in porous channel-like ice structure. *Journal of Chemical Physics*, 160, 154707. DOI: 10.1063/5.0201961
Funding: European Union, DIITET-CNR, Fondazione CR Firenze
Authors: L del Rosso, D Colognesi, A Donati (Consiglio Nazionale delle Ricerche – Istituto di Fisica Applicata “Nello Carrara”), S Rudić (ISIS), M Celli (Consiglio Nazionale delle Ricerche – Istituto di Fisica Applicata “Nello Carrara”)

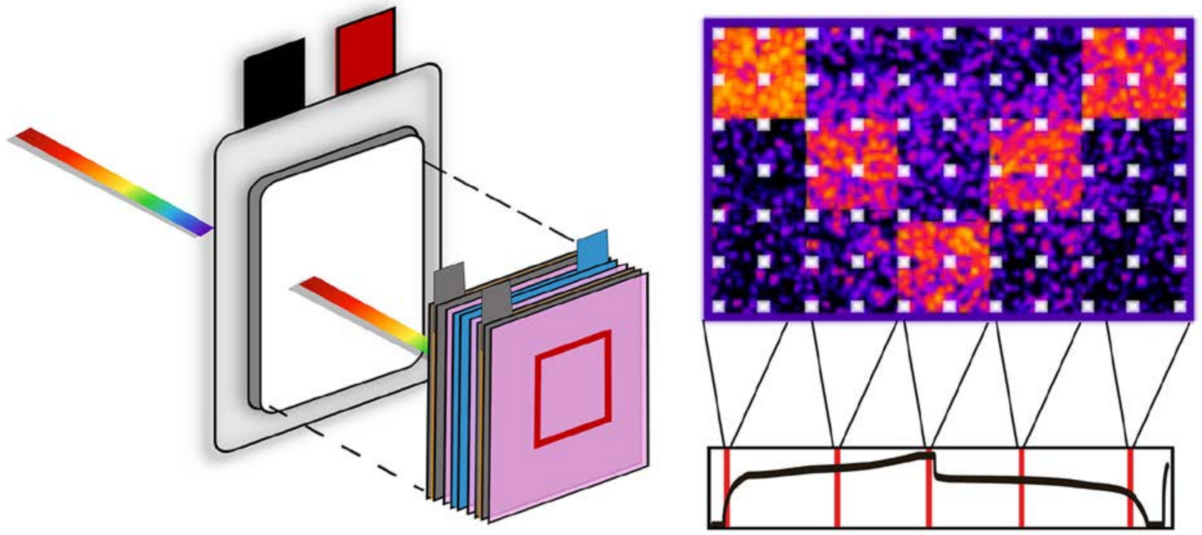
Imaging a commercial battery cell during operation

Scientists from the Paul Scherrer Institut (PSI) and ISIS have developed an experimental setup that enables quick imaging of battery materials. They used it to study the state of charge of a commercial-size pouch cell during charging and discharging.

Time-of-flight neutron imaging (ToF-NI) can map changes to the crystal structure of an electrode inside a metallic battery pack while in operation, without dismantling the cell. The researchers used ToF Bragg edge imaging on the IMAT instrument to study a commercial-size battery cell.

As a battery charges, the lithium ions intercalate into the graphite anode, changing the crystal structure and leading to shifts in the positions of the Bragg edges within the spectrum. By measuring these shifts, the team determined the stages of Li^+ intercalation as a function of the state-of-charge of the battery.

They found that intercalation, and therefore the charging, was inhomogeneous throughout the cycling process; faster intercalation occurred close to the electrode tabs. During long term use, such an effect could cause localised stress and fatigue. Different degrees of lithiation will also make the different parts of the cell age differently.



Wavelength-resolved neutron imaging maps *operando* state-of-charge in commercial batteries.

Instrument: IMAT

Related publication: Operando lateral state-of-charge inhomogeneity mapping via wavelength-resolved neutron imaging. *Materials Today Energy*, 46, 101710.
DOI: 10.1016/j.mtener.2024.101710

Funding: PSI-CROSS initiative

Authors: E R C Ruiz, F Malamud, J Lee, S Trabesinger, L Gubler, P Boillat (Paul Scherrer Institut), G Burca (ISIS, Diamond Light Source), M Strobl (Paul Scherrer Institut, University of Copenhagen).

Understanding material defects could lead to a bright future for solar panels

A new probing technique has helped scientists from the University of Coimbra in Portugal see how manufacturing defects affect the materials inside solar cells.

A team of researchers led by Rui Vilão from the University of Coimbra in Portugal used muon spectroscopy on the EMU instrument at ISIS to study the use of $Cu(In,Ga)Se_2$ (CIGS) and Cu_2ZnSnS_4 (CZTS) as possible absorber materials for thin film solar cell technology.

Such panels are typically just a few nanometres to a few micrometres thick. They use less material and elements which are more abundant in the Earth's crust, making them cheaper to manufacture and reducing their environmental impact. However, the production of these solar cells is sensitive to contamination; hydrogen can cause defects that negatively impact the cells' performance and lifespan.

Rui and the team combined positive muons with electrons to create muonium, which has very similar properties to hydrogen. Crucially, using muonium is a controllable technique for the researchers to probe how hydrogen-like atoms affect their solar cells. The researchers were able to identify the final configuration of muonium in the materials, as well as the mechanism by which the muons implant into the host lattices.

ISIS instrument scientist James Lord and Rui Vilao from University of Coimbra working on EMU.

> We're only now becoming aware in the muon community that this sensitivity to defects can be used as a 'defectometer'.
>
> Rui Vilão, University of Coimbra

Instrument: EMU

Related publication: Investigation of the solar cell materials $Cu(In,Ga)Se_2$ and Cu_2ZnSnS_4 with muon spin spectroscopy and density-functional calculations. *J. Appl. Phys*. 136, 055704.
DOI: 10.1063/5.0205837

Funding: FCT—Fundação para a Ciência e Tecnologia, I.P. through the Project Nos. UIDB/04564/2020 and UIDP/04564/2020

Authors: R C Vilão, A G Marinopoulos, D G Santos, H V Alberto, J M Gil (University of Coimbra), P W Mengyan (Northern Michigan University), M Kauk-Kuusik (Tallinn University of Technology), J S Lord (ISIS), A Weidinger (Helmholtz-Zentrum Berlin für Materialien und Energie).

Shedding light on organic solar cell optimisation

A team of researchers used small angle neutron scattering (SANS) techniques to investigate how solvent additives affect the structure and long-term stability of organic photovoltaics.

Organic photovoltaics (OPVs) are solar cells made from carbon-based semiconductors, often based on fullerene materials. They are typically thinner and more flexible than silicon solar cells and the materials for their construction are more abundant, reducing production costs and environmental impacts. However, the structure of fullerene materials is difficult to modify, limiting researchers' ability to optimise OPVs.

As a result, researchers are exploring non-fullerene acceptor materials (NFAs) which enable more control over their composition, allowing researchers to alter optical, electrical and structural properties to make more efficient devices.

One way they can do so is by using solvent additives to alter the OPV film as it dries. This process is well-understood in fullerene materials, but much less so in NFAs. Using the Larmor instrument at ISIS, a team of researchers found that the solvent additives affect fullerene materials and NFAs differently, suggesting that researchers will need to take a different approach to optimising NFA OPV films.

> "Having access to ISIS and the technique of SANS over an extended period allowed us to track the changes in nanostructure as these materials age, like they would as solar cell devices. This is one of the priorities for this field; as efficiencies are now really good, what we need to understand is how to make more stable and long lasting nanostructured solar cells."
>
> Andrew Parnell,
> Lecturer in the School of Mathematical and Physical Sciences, University of Sheffield.

Instrument: Larmor

Related publication: The nanoscale structure and stability of organic photovoltaic blends processed with solvent additives, *Small*, 20, 33. DOI: 10.1002/smll.202311109

Funding: EPSRC, Centre for Doctoral Training in New and Sustainable PV, Fundação para a Ciência e Tecnologia (FCT)/Portugal, SUPRASOL, Portuguese Foundation for Science and Technology, NSF.

Authors: R C Kilbride (University of Sheffield, now University of Warwick), E L K Spooner, S L Burg, D G Lidzey, A J Parnell (University of Sheffield), B L Oliveira, A Charas (Instituto Superior Técnico), G Bernardo (University of Porto), R Dalgliesh, S King (ISIS), R A L Jones (The University of Manchester).

Quantum science

Steering skyrmion strings using a thermal gradient

Researchers from ShanghaiTech, Diamond Light Source, ISIS and the University of Oxford have demonstrated that skyrmion strings, three-dimensional topological magnetic structures, can be bent and steered using a temperature gradient.

Using SANS on Larmor, the team observed this behaviour in the chiral magnet MnSi. By applying a thermal gradient perpendicular to the axis of the skyrmion string, they found that spatial changes in temperature along the string induce a variation in the skyrmion Hall angle. This variation arises from magnon friction, a temperature-dependent dissipative force, which in combination with the skyrmion Hall effect, causes the string to bend.

Magnetic skyrmions are nanoscale whirlpools of magnetisation with topological protection, making them promising candidates for next-generation data storage and processing. While most research in this area had focused on manipulating skyrmions within a two-dimensional plane, this novel manipulation technique provides a way to control these structures in another dimension.

The findings reveal a new degree of freedom for skyrmion manipulation and provide the first experimental evidence of magnon friction, an effect recently proposed to modify the standard description of skyrmion dynamics. The ability to bend skyrmion strings in 3D could have important implications for future device architectures and for understanding how temperature inhomogeneities affect topological spin textures.

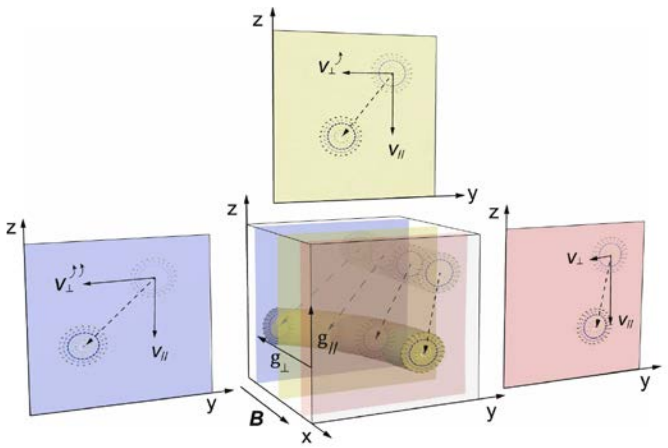


Illustration of the skyrmion string bending mechanism in a 2D thermal gradient.

Instrument: Larmor

Related publication: Bending skyrmion strings under two-dimensional thermal gradients. *Nat Commun* 15, 4860 (2024). DOI: 10.1038/s41467-024-49288-9

Funding: National Key R&D Program of China. The Science and Technology Commission of the Shanghai Municipality. The National Natural Science Foundation of China. ShanghaiTech University. EPSRC.

Authors: S Zhang, K Ran, W Tan, X Sun (ShanghaiTech University), Y Liu (RIKEN), R M Dalgliesh, S Langridge (ISIS), N-J Steinke (ILL), G van der Laan (Diamond Light source) and T Hesjedal (University of Oxford)

A new route to quantum spin liquid materials

Scientists from the University of Birmingham and the Felix Bloch Institute for Solid-State Physics, Germany, have produced a route to materials with complex disordered magnetic properties at the quantum level.

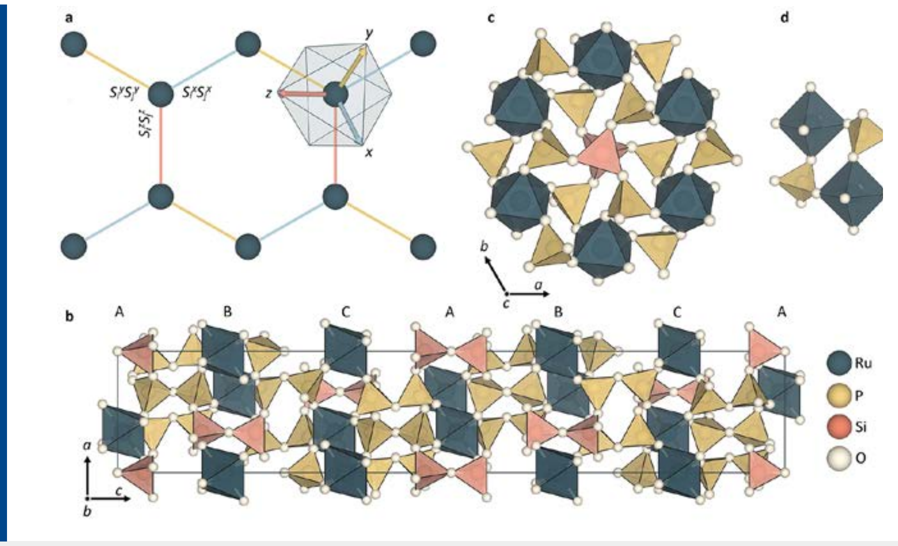
The material, RuP_3SiO_{11} (RPSO), is based on a framework of ruthenium. It fulfils the requirements of the 'Kitaev quantum spin liquid state' – an elusive phenomenon that scientists have been trying to understand for decades. Although quantum spin liquids have been modelled by scientists, researchers have not been able to create them experimentally or to find them in nature.

Such materials provide a route to magnetic properties which behave differently from conventional ferromagnets.

The researchers used synchrotron X-ray diffraction alongside neutron diffraction on the WISH instrument at ISIS to determine the crystal structure of RPSO. The neutron diffraction data also helped determine the nature of the magnetic ground state of the material, finding that it had reduced magnetic order, The team then used inelastic neutron scattering on LET to confirm its magnetic structure.

The researchers found that a new material with an open framework structure can tune the interactions between the ruthenium metal ions, providing a new route to a Kitaev quantum spin liquid state.

The first author, Aly Abdeldaim, completed the work during his PhD, part-funded by ISIS through the Facility Development and Utilisation Scheme.



Mapping the crystal structure of RuP_3SiO_{11} (RPSO) to the Kitaev model on a honeycomb network.

Instruments: WISH, LET

Related publication: Kitaev interactions through extended superexchange pathways in the j_{eff}=1/2 Ru^{3+} honeycomb magnet RuP_3SiO_{11}. *Nat. Comms*, 15, 9778.
DOI: 10.1038/s41467-024-53900-3

Funding: STFC, EPSRC, Deutsche Forschungsgemeinschaft.

Authors: A H Abdeldaim (University of Birmingham, ISIS, Diamond Light Source), H Gretarsson (Deutsches Elektronen-Synchrotron DESY), S J Day (Diamond Light Source), M D Le, G B G Stenning, P Manuel, R S Perry (ISIS), A A Tsirlin (University of Leipzig), G J Nilsen (ISIS, University of Stavanger), L Clark (University of Birmingham).

Science highlights – quantum science

New insights into gravity-defying fluids

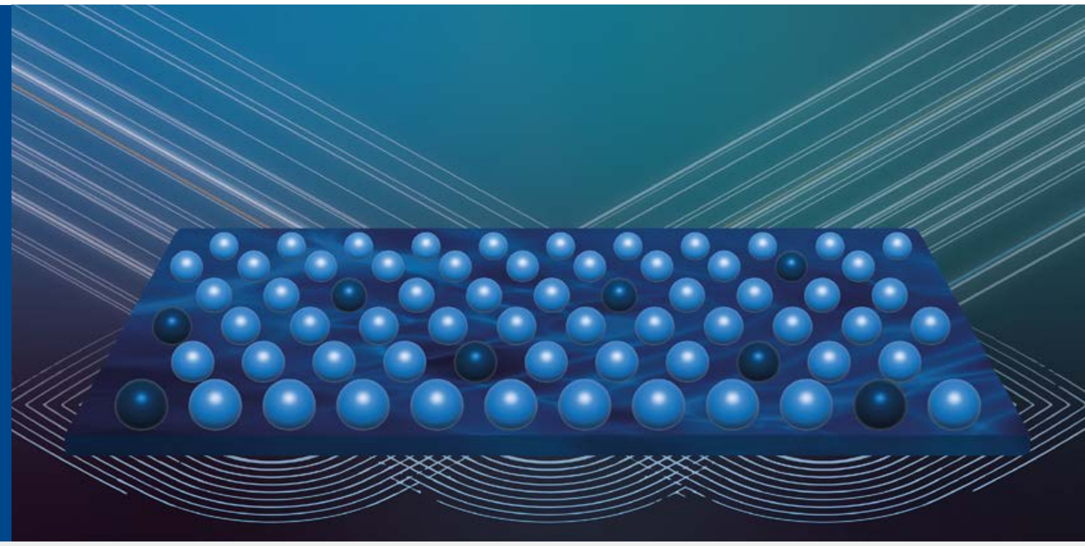
Researchers from ISIS, the University of Lancaster, and Oak Ridge National Laboratory used neutrons to explore what happens to superfluid ^{4}He when they add a drop of ^{3}He, at close to absolute zero. The research also serves as an example of how neutron techniques can be used to study quantum systems.

Liquid ^{4}He is a superfluid, which means it has zero viscosity and can flow without losing kinetic energy, including flowing uphill or escaping from open containers. Superfluidity has been discovered in quantum liquids formed by ^{4}He and ^{3}He at extremely low temperatures. It is also theorised to describe matter in neutron stars.

The team used the PolRef instrument at ISIS with a dilution refrigerator to reach very low temperatures, and a specially designed experimental cell. Neutrons are particularly suited to studying systems at cold temperatures as they interact weakly with matter, so impart very little energy to the system, unlike X-rays. Neutrons also allow the researchers to distinguish between ^{3}He and ^{4}He due to their different absorption cross sections.

The researchers found a phase-separated mixture film at a temperature of 170 millikelvin, and the experiment hinted at possible as-yet unstudied phase transitions at 300 millikelvin. The behaviour at 300 millikelvin also appeared to destroy the superfluid state entirely.

Graphical representation of the nano-film of ^{3}He and ^{4}He.



Instrument: PolRef

Related publication: Density profile of ^{3}He in a nanoscale ^{3}He-^{4}He superfluid film determined by neutron scattering. *Commun Phys*. 7, 181. DOI: 10.1038/s42005-024-01683-w

Funding: STFC

Authors: O Kirichek, C R Lawson, C J Kinane, A J Caruana, S Langridge (ISIS), T R Charlton (Oak Ridge National Laboratory), P V E McClintock (Lancaster University).

Advanced materials, manufacturing and testing

An unconventional superconductor with the potential to revolutionise quantum electronics

Muon spectroscopy at ISIS has revealed an unusual combination of properties in the material HfRhGe that mean it could have exciting applications as a superconducting diode.

The team from Indian Institute of Science Education and Research Bhopal, Indian Institute of Technology Kanpur, Université de Sherbrooke, Technion-Israel Institute of Technology and ISIS used magnetisation and thermodynamic measurements alongside muon spectroscopy on MuSR. They found that the Weyl semimetal HfRhGe is a noncentrosymmetric superconductor with strong spin orbit coupling that spontaneously breaks TRS in the superconducting state.

A superconducting material has no electrical resistance, so a current can pass through it without losing any energy. A classic property of superconductors is that they expel magnetic fields. One class of superconductors, however, can form spontaneous magnetic fields in the superconducting state. This leads to breaking of time-reversal symmetry, which occurs when a physical system in a symmetric state ends up in an asymmetric state.

These 'unconventional superconductors' are of particular interest due to their potential application in quantum computing and spintronics. One subset of these is noncentrosymmetric superconductors, which lack inversion symmetry. These superconductors are a promising platform for realising the intrinsic superconducting diode effect.

Two of the paper authors, Ravi Prakash Singh and Roshan Kumar Kushwaha on MuSR.

Instrument: MuSR

Related publication: Time-reversal symmetry breaking superconductivity in HfRhGe: a noncentrosymmetric weyl semimetal. *Advanced Materials*, 37, 7. DOI: 10.1002/adma.202415721

Funding: Science and Engineering Research Board (SERB), Government of India. IIT Kanpur. UGC, Government of India.

Authors: K P Sajesh, R K Kushwaha, P K Meena, S Srivastava, D Singh, R P Singh (Indian Institute of Science Education and Research Bhopal), D Samanta, S K Ghosh (Indian Institute of Technology), T Tula (Institut quantique and Département de physique, Université de Sherbrooke), P K Biswas, A D Hillier (ISIS), A Kanigel (Technion-Israel Institute of Technology).

Synthesising Ruddlesden-Popper-type nitrides

An international team of researchers have created and characterised three nitrides with Ruddlesden-Popper-type structures. The team used high pressure synthesis to create the compounds, followed by neutron diffraction using the WISH instrument at ISIS and the D20 beamline at ILL to characterise them.

The three nitrides are layered perovskites with Ruddlesden-Popper-type structures. Similar halides and oxides are used in photovoltaics, superconductors, diodes, and more. However, it is difficult to create the equivalent nitrides, as the nitrogen triple bond is particularly stable and nitrogen shows low electron affinity.

To overcome that challenge, the researchers adopted techniques used to create other nitrogen-containing metal compounds. By using high pressures and temperatures – 8 GPa and 1,000°C – combined with either sodium azide or ammonium azide they produced three nitrides: Pr_2ReN_4, Nd_2ReN_4 and Ce_2TaN_4.

They found that these three compounds showed a range of interesting properties. For instance, thin layers of Pr_2ReN_4 and Nd_2ReN_4 show conductivity and could form the basis of superconductors. Nd_2ReN_4 is also a hard ferromagnet. Unusually for a Ruddlesden-Popper material, Ce_2TaN_4 contains both Ce^{3+} and Ce^{4+} cations.

The results show that it is possible to create such materials and recover them under ambient conditions, potentially enabling more Ruddlesden-Popper nitrides to be developed for a range of applications.

Instrument: WISH

Related publication: High-pressure synthesis of Ruddlesden–Popper nitrides. *Nat. Chem*. 16, 1723–1731. DOI: 10.1038/s41557-024-01558-1

Funding: Deutsche Forschungsgemeinschaft

Authors: M Weidemann, D Werhahn, C Mayer, S Kläger and S D Kloß (Ludwig-Maximilians-Universität München), C Ritter (Institut Laue-Langevin, Grenoble, France), P Manuel (ISIS), J P Attfield (University of Edinburgh).

First neutron scattering study of common ionic liquids

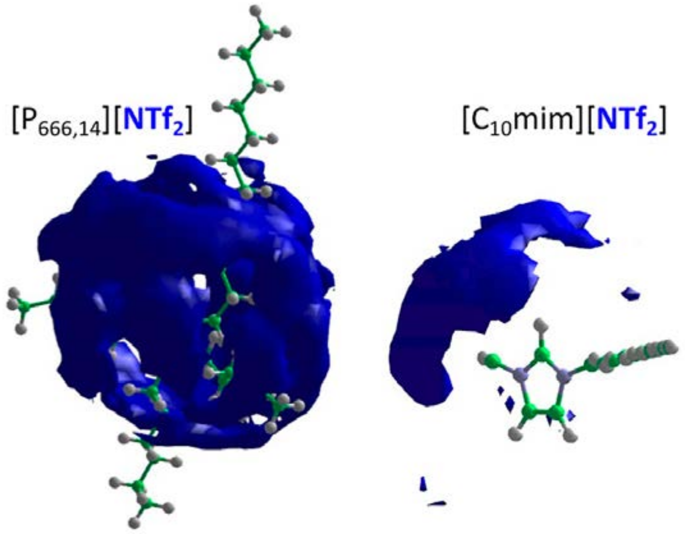
Researchers from Queen's University Belfast and ISIS have used neutron scattering to investigate the structure of three common ionic liquids (ILs). The new data analysis package, Dissolve, enabled for the first time the analysis of larger cations with long alkyl chains. It was the first use of Dissolve to model ionic liquids, and the first demonstration of its capabilities in modelling neutron scattering data for lipophilic liquids.

ILs are low-melting salts, often liquid at ambient temperatures. ILs with the bis(trifluoromethanesulfonyl)imide anion, $[NTf_2]^-$ are used as electrolytes in energy storage devices and in electrocatalysis. In this study, the researchers looked at $[NTf_2]^-$ ILs based on three cations: $[C_2mim][NTf_2]$, $[C_{10}mim][NTf_2]$, and $[P_{666,14}][NTf_2]$.

The team used the Nimrod and SANDALS instruments at ISIS to gather neutron scattering data. Using Dissolve, they could model the structure of the two cations with long alkyl chains, $[C_{10}mim][NTf_2]$, and $[P_{666,14}][NTf_2]$, for the first time.

These two cations showed increased nanosegregation, whereby the longer alkyl chains formed distinct non-polar domains. The results also provided information on the strength, directionality, and angle of hydrogen bonds between the cations and the $[NTf_2]^-$ anion. For instance, the longer alkyl chain cations formed more linear hydrogen bonds with the anion.

The team also reported a detailed method for producing fully deuterated $[P_{666,14}][NTf_2]$, providing the foundation for further neutron scattering studies of these ILs.



The structure of $[C_{10}mim][NTf_2]$, and $[P_{666,14}][NTf_2]$.

Instrument: Nimrod, SANDALS

Related publication: Liquid Structure of Ionic Liquids with $[NTf_2]^-$ Anions, Derived from Neutron Scattering. *The Journal of Physical Chemistry* B. 128, 13. DOI: 10.1021/acs.jpcb.3c08069

Funding: EPSRC, Royal Academy of Engineering.

Authors: A McGrogan, J Lafferty, L O'Neill, L Brown, J M Young, P Goodrich, M J Muldoon, L Moura, J D Holbrey, M Swadźba-Kwaśny (Queen's University Belfast). S Youngs, T-L Hughes, S Gärtner, T G A Youngs (ISIS).

A magnetic skin effect in a multiferroic crystal

Researchers from the University of Glasgow, Cardiff University, ISIS, the PSI and the NIST Center for Neutron Research have identified a magnetic skin effect in a crystal of the multiferroic material $Pb(Fe_{1/2}Nb_{1/2})O_3$ (PFN). The change in properties is analogous to the structural skin effect seen in non-magnetic relaxor compounds.

The team used muon spectroscopy to investigate a large, 1 cm^3, single crystal of PFN. PFN is a multiferroic as it displays both ferroelectric order, showing relaxor-like dielectric properties, and antiferromagnetism. Multiferroic materials could transform how we control magnetism using electrical fields.

To understand the changes in magnetic properties within the crystal, the researchers used positive muon spin relaxation on the Chronus instrument at ISIS. By increasing the momentum of the muons, researchers can increase the depth to which they penetrate a sample, providing information about magnetic properties at different depths. They found that the magnetic properties changed over a scale of around 100μm, similar to that seen in non-magnetic relaxors.

Their second experiment used negative muons on the MuX instrument to explore Fe^{3+} distribution in the PFN crystal. They found a small change in concentration which was unlikely to account for the changes in magnetic properties. As a result, the researchers concluded that the skin effect is likely due to the structure of the crystal itself.

Instrument: Chronus, MuX

Related publication: Magnetic skin effect in $Pb(FeNb)O_3$. *J. Phys.: Condens. Matter*, 36, 435802. DOI 10.1088/1361-648X/ad6523

Funding: EPSRC, STFC

Authors: N Giles-Donovan (University of Glasgow, now University of California), S Cochran (University of Glasgow), A D Hillier, K Ishida, B V Hampshire (ISIS), S R Giblin (Cardiff University), B Roessli (PSI), P M Gehring, G Xu (NIST Center for Neutron Research, National Institute of Standards and Technology), X Li, H Luo (Chinese Academy of Sciences, Shanghai Institute of Ceramics), C Stock (University of Edinburgh).

New insights into the structure of a hydrous borate

Researchers from the Università degli Studi di Milano, Italy, and ISIS have described the chemical composition and structure of the boron-containing mineral inderite.

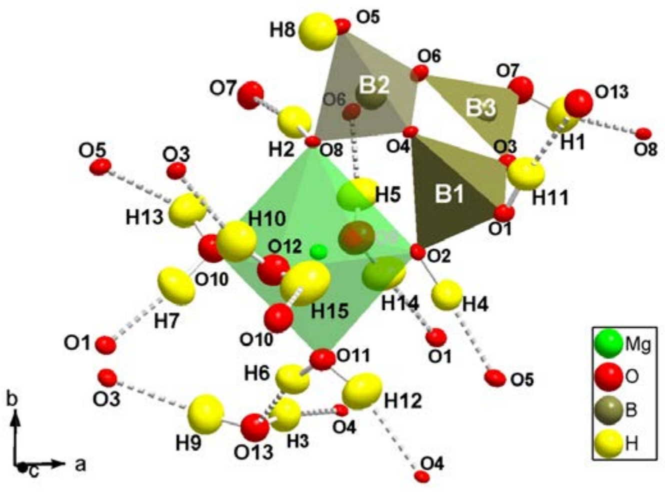
The team used single crystal neutron diffraction on the SXD instrument at ISIS, alongside other techniques, to examine millimetre-sized crystals of inderite, a hydrous borate from the Kramer Borate Deposit, in California, USA.

Boron is used in glass manufacture, agriculture, cosmetics, and radiation shielding concretes, and global consumption is increasing. Currently, boron is recognised as a "Critical Raw Material" by the European Commission. Researchers therefore need to understand the nature of boron sources and their suitability for various applications.

The team from Italy found that inderite crystals contained very few substituents (at part per million level), meaning the samples closely resembled the ideal formula: $MgB_3O_3(OH)_5.5H_2O$ (or $Mg[B_3O_3(OH)_5](H_2O)_4{\cdot}H_2O$). Inderite contains *ca*. 37.3 wt% of B_2O_3.

This neutron diffraction study on the mineral showed that the structure closely matched earlier single-crystal X-ray diffraction studies and density functional theory (DFT) calculations. It additionally provided accurate data on all the proton positions in the crystal structure, including those missing from earlier works, and complete information on the complex and pervasive hydrogen-bonding scheme sustaining the crystalline edifice.

The high boron and hydrogen content of this mineral would usually be considered an impediment for any neutron diffraction measurement, due to the extraordinary ability of boron to absorb neutrons and the high background scattering produced by the hydrogen atoms. The SXD experiment shows that single crystal neutron diffraction on small samples is a powerful technique that can be used to investigate materials that, at first sight, would not be considered compatible with neutrons.



The complex and pervasive H-bonding network in inderite structure.

Instrument: SXD

Related publication: On the crystal-chemistry of inderite, $Mg[B_3O_3(OH)_5](H_2O)_4{\cdot}H_2O$. *Phys Chem Minerals*, 51, 21. DOI: 10.1007/s00269-024-01281-w

Funding: Italian Ministry of Education (MIUR). Open access funding provided by Università degli Studi di Milano within the CRUI-CARE Agreement.

Authors: G D Gatta, D Comboni, E Cannaò (Università Degli Studi Di Milano), S C Capelli (ISIS).

Science highlights – advanced materials, manufacturing and testing

Strength vs flexibility – this steel has it all, even at low temperatures

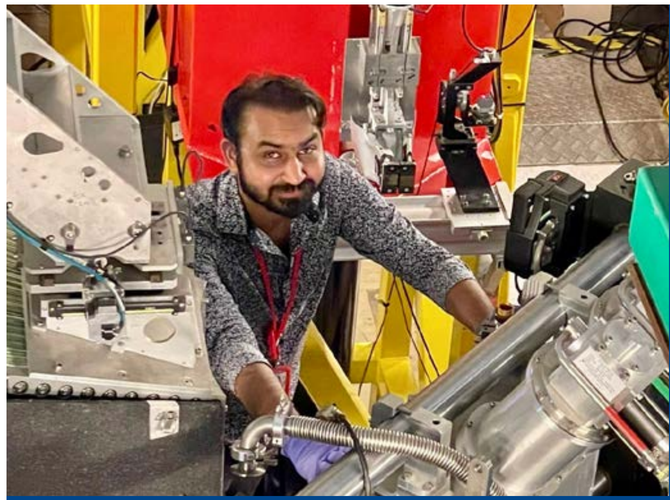
A type of steel has been identified as having exceptional strength and ductility at temperatures as low as 77 K, making it a good candidate for applications in space or superconductivity.

Conventional materials typically become brittle at very low temperatures. A research team led by Muhammad Naeem and Dr Liliana Romero with colleagues from the universities of Birmingham, Bournemouth and Kings College London, in collaboration with ISIS scientists, discovered that the heterostructured and antimicrobial stainless steel (HS&AMSS) 316L+3Cu achieved a yield strength of 1400 MPa and 36% ductility at 77 K.

They came to ISIS to use the Engin-X beamline to find out what was happening to the structure of the steel that gives it these excellent properties.

The researchers found that the improved combination of strength and ductility in HS&AMSS is driven by the synergy between dislocation-blocking capabilities of defects, which enhance strengthening, and the formation of new phases or domain regions that provide sites for dislocation accumulation, thus enhancing ductility.

The results offer new pathways to engineer materials with superior mechanical properties, potentially influencing the design of future alloys and composites.



Muhammad Naeem, team leader and corresponding author, at the Engin-X beamline.

> "The unique insight gained by using neutrons in this study comes from their ability to provide real-time, in-situ analysis of the phase transformations and microstructural evolution under tensile deformation. Thanks to the custom-designed stress rig cryostat developed by the ISIS Sample Environment Group, this could even be measured at cryogenic temperatures."
>
> ISIS scientist and paper co-author Tung Lik Lee

Instrument: Engin-X

Related publication: Exceptional strength–ductility combination of heterostructured stainless steel for cryogenic applications. *Scripta Materialia*, 258. DOI: 10.1016/j.scriptamat.2024.116527

Funding: Horizon Europe under the Marie Sklodowska-Curie Actions and financed by UKRI and Programa de Apoyo a Proyectos de Investigación e Innovación Tecnológica.

Authors: L Romero-Resendiz (University of Birmingham, Bournemouth University, Universidad Nacional Autónoma de México), A J Knowles, M Naeem (University of Birmingham), Y Huang (Bournemouth University), J Kelleher, T L Lee (ISIS), T Mousavi (King's College London).

Cementing neutrons as an ideal method for studying water dynamics

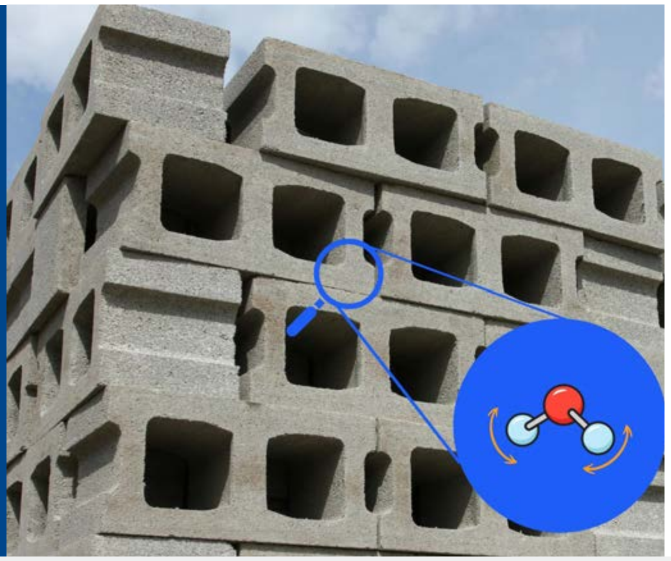
An international research team has used neutron experiments alongside other techniques to investigate the hydrated phases inside cement that are key to its strength.

Cement is the single most used material in the world. Understanding water organisation in calcium silicate hydrate (C-S-H), the key compound controlling the final properties of cement, is important for understanding how cement sets.

However, C-S-H is difficult to characterise. Moreover, the presence of aluminate phases both in common Portland cement and in new low-CO_2 emissions cement results in the formation of C-(A)-S-H, an aluminate-containing C-S-H.

The researchers used inelastic incoherent neutron scattering (IINS) on the Tosca beamline at ISIS and Lagrange at the ILL to investigate the dynamics of water in synthetic C-(A)-S-H. They combined these studies with molecular dynamics simulations and laboratory-based methods.

The team found evidence of multilayer interfacial water, which turned into ice-like features upon capillary condensation at higher relative humidity. They also observed confined water at lower energies for drier C-(A)-S-H samples. Water in C-(A)-S-H samples at higher Ca/Si ratios was found to be more structured and less bulk-water like, due to an increased number of hydrophilic sites created by calcium ions.



Graphical representation of the water dynamics in concrete.

Instrument: Tosca

Related publication: Water dynamics in calcium silicate hydrates probed by inelastic neutron scattering and molecular dynamics simulations. *Cement and Concrete Research*, 184, 107616. DOI: 10.1016/j.cemconres.2024.107616

Funding: ANR-JCJC, US Department of Energy, IDEX mobility scholarship program of the University of Grenoble-Alpes.

Authors: Z Zhakiyeva (Institut Laue-Langevin, University of Grenoble Alpes, Nazarbayev University), V Magnin, A Poulain, S Campillo, R Besselink (University of Grenoble Alpes), M P Asta (University of Grenada), S Gaboreau, F Claret, S Grangeon (BRGM), S Rudic (ISIS), I C Bourg (Princeton University), A E S Van Driessche (University of Grenoble Alpes, CSIC – University of Granada), G J Cuello, S Rols, M Jiménez-Ruiz (Institut Laue-Langevin), A Fernández-Martínez (University of Grenoble Alpes).

Life science and healthcare

A route to more efficient chocolate tempering

An international team of researchers found that certain phospholipids can help improve the tempering process in chocolate, potentially simplifying the chocolate production process without compromising quality.

To make the perfect glossy chocolate with the creamy texture that consumers expect, the cocoa butter used in its manufacture must crystallise in a specific way, known as a form V polymorph. Its formation can be influenced by external factors such as temperature, shear, pressure and time.

The chocolate we buy undergoes a long multi-step process to ensure the cocoa butter crystalises properly. Researchers want to know if it is possible to simplify the process by adding a phospholipid called 1,2-dimyristoyl-sn-glycero-3-phosphatidylcholine (DMPC).

Using small angle neutron scattering on SANS2D and at the ILL, and specific temperature measurements, the team confirmed that DMPC can be used to temper chocolate. However, they also observed some unwanted side effects, including cracking in chocolate at the sub-mm range when tempered solely with DMPC. The team concluded that the DMPC phase separates from the cocoa butter phase, creating large crystalline imperfections, or large microstrains, which then grow into a macroscopic crack.

Chocolate undergoes a long process to achieve the glossy texture consumers want. *(Image: Pixabay)*

> Unfortunately, the observed cracks means that DMPC does not perfectly simplify the chocolate tempering process. Although it is a promising compound for tempering chocolate, more recent work suggests that a similar phospholipid molecule to DMPC can actually temper chocolate without leading to crack formation, as it incorporates better within the cocoa butter crystalline lattice. Another visit to ISIS is warranted!
>
> Alejandro Marangoni, from the University of Guelph.

Instrument: SANS2D

Related publication: Phospholipid Self-Assembly in Cocoa Butter Provides a Crystallizing Surface for Seeding the Form V Polymorph in Chocolate. *Crystal Growth & Design*, 24, 7. DOI: 10.1021/acs.cgd.3c01130

Funding: National Research Council of Canada

Authors: J A Stobbs, E Pensini, S M Ghazani (University of Guelph), A F G Leontowich, A Quirk, K Tu (Canadian Light Source Inc), S Prévost (Institut Laue-Langevin), N Mahmoudi (ISIS), A-L Fameau (Université of Lille), A G Marangoni (University of Guelph).

Challenging assumptions about coherent scattering

ISIS researchers led by Mona Sarter have used neutron polarisation analysis to discover that coherent scattering in Quasielastic Neutron Scattering (QENS) protein studies cannot be fully attributed to the buffer solution, as previously thought.

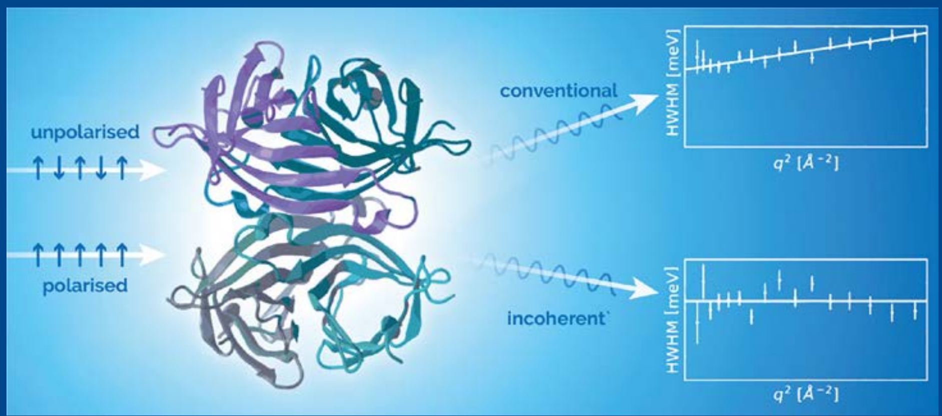
QENS is used for studying proteins and other biological systems as it gives information about the molecular dynamics. Researchers often assume the buffer solution contributes the entirety of the coherent scattering to the sample signal. This leaves the molecule of interest solely responsible for the incoherent contribution. However, this assumption has never been checked.

Recent instrumentation improvements allowed the researchers to carry out polarised QENS measurements on the LET instrument and separate the signals from the buffer solution and the molecule of interest.

Using neutron polarisation analysis (NPA), Mona and team found that the assumption was incorrect; the coherent contribution could not be fully attributed to the buffer, probably due to a hydration layer surrounding the protein contributing to the coherent scattering.

Ideally, researchers would use NPA alongside QENS measurements. However, access to NPA spectrometers is limited, so the group included in their paper an experimental solution for other researchers.

> "My first thought was that I needed to double check the results! Despite being unaware that the assumption was incorrect, I am lucky in that my previous results are unaffected."
>
> Mona Sarter, ISIS Instrument Scientist



Graphical abstract showing how the protein contributes to the sample signal.

Instrument: LET

Related publication: Data analysis of dynamics in protein solutions using quasi-elastic neutron scattering – important insights from polarized neutrons. *JACS*, 146, 41. DOI: jacs.4c06273

Funding: STFC

Authors: M Sarter, J R Stewart, G J Nilsen, M Devonport, K Nemkovski (ISIS)

Mona Sarter
Instrument Scientist

Curious from a young age, Mona first pursued theoretical particle physics but found her true passion at the intersection of physics and biology. During her studies at RWTH Aachen and Forschungszentrum Juelich, Germany, she discovered neutron scattering and the fun of combining life science experiments with data analysis. Her PhD explored the streptavidin-biotin interaction, which is the second strongest non-covalent binding in biology.

Mona joined ISIS in 2020, becoming a member of the Molecular Spectroscopy group, supporting users from beginners to seasoned neutron scientists. Her research spans interactions between chemotherapy drugs and proteins, enzyme ligand binding and testing assumptions about polarised neutron beams. For her, the surprising findings are often the most rewarding. "A bad result isn't one that just disproves your theory, only one that's inconclusive" she says.

She has also continued and completed a project begun at ISIS by her colleagues before she joined. This was the testing and designing of sample cans for a sample stick that can perform in-situ DSC (differential scanning calorimetry) and QENS at the same time. As a convener of the life science focus area at ISIS, she has contributed to the implementation of the ISIS science strategy.

Mona Sarter speaking during the ISIS 40th Anniversary celebrations.

Helping biomass 'leaf' crude oil behind by decoding the diffusion of cresol in catalysts

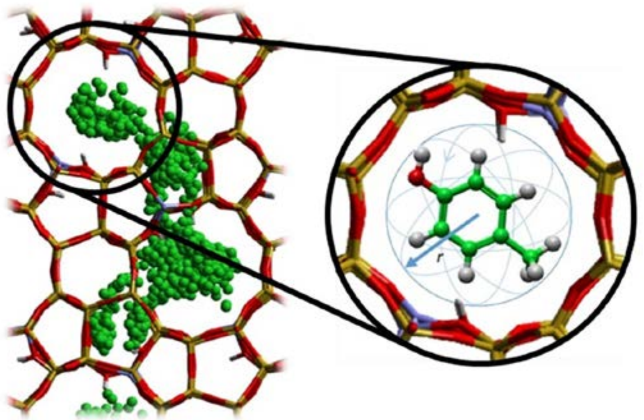
Researchers from the University of Bath used the Osiris instrument at ISIS to probe the behaviour of biomass derivatives within commercial porous zeolite catalysts.

Key to reducing reliance on crude oil is biomass, a renewable carbon-based feedstock. Lignin, a significant component of biomass, has historically been difficult to convert into useful products. Optimising acidic zeolites for lignin conversion can leverage existing infrastructure but, before optimisation, researchers must understand zeolite-lignin interactions, focusing on rate-limiting processes such as diffusion and adsorption.

The research team studied cresol isomers, model lignin derivatives, within the commercial zeolite catalysts H-Y and H-Beta. Their Quasielastic Neutron Scattering (QENS) experiments revealed rotational motions, with the proportion of rotating molecules depending on the size and shape of both the zeolite pores and the molecules.

Using Molecular Dynamics (MD) simulations, the team were able to validate their QENS results, reproducing molecular rotations and providing further insights into the motions occurring over different timescales.

> "Osiris can uniquely probe the behaviour of lignin derivatives within porous zeolite catalysts. By combining these results with molecular dynamics simulations, we can unravel the diffusive and adsorptive mechanisms to later optimise catalysts for the sustainable production of fuels and other important chemicals."
>
> Lead author and ISIS facility development student Katie Morton.



This image shows the diffusive motions (left) compared to rotational motions (right) within zeolites.

Instrument: Osiris

Related publication: The effect of molecular shape and pore structure on local and nanoscale cresol behaviour in commercial zeolite catalysts. *Catal. Sci. Technol.*, 2024,14, 3756-3770. DOI: 10.1039/D4CY00321G

Funding: EPSRC, ISIS Facilities Development studentship, Whorrod Fellowship, IChemE

Authors: K S C Morton (University of Bath, UK Catalysis Hub, ISIS), A J Porter (University of Bath), J Armstrong (ISIS), A J O'Malley (University of Bath, UK Catalysis Hub).

Understanding the structure of lipid nanoparticles

An international team led by scientists from Lund University, Sweden, have used the SANS2D instrument at ISIS alongside other techniques to investigate the structure of lipid nanoparticles containing different nucleic acids.

Lipid nanoparticles are increasingly being used to carry therapeutics, such as mRNA vaccines like the Moderna and Pfizer-BioNtech mRNA vaccines for COVID-19. In these, the lipid matrix protects the fragile RNA molecules and aids their delivery into cells.

The researchers were interested in how the structure of these lipid nanoparticles evolve during the formulation process, and the effect that different nucleic acid cargoes have on their structure. They used in situ small angle X-ray scattering (SAXS) and microfluidics to investigate changes during the formulation process and SANS at ISIS to investigate the final formulation, alongside other techniques such as cryoTEM and dynamic light scattering.

The SANS data revealed the composition and the location of the different components in the LNPs containing nucleic acids, i.e. DNA and -RNA mimics. Cholesterol was found to be mainly located in the shell of the particle and the nucleic acids in the core. LNPs containing single stranded nucleic acids aggregated more readily during the dialysis step of formulation. They also found that the concentration of the cargo nucleic acids was not evenly distributed in the population of LNPs, but that some were found to be empty and others loaded with nucleic acids.

Instrument: SANS2D

Related publication: Evolution of the structure of lipid nanoparticles for nucleic acid delivery: From in situ studies of formulation to colloidal stability. *Journal of Colloid and Interface Science*, 660, 66-76. DOI: 10.1016/j.jcis.2023.12.165

Funding: Swedish Research Council, NanoLund

Authors: J Gilbert (Lund University, NanoLund), F Sebastiani (Lund University, University of Copenhagen), M Y Arteta (AstraZeneca), A Terry, A Fornell (Lund University), R Russell (Australian Nuclear Science and Technology Organisation), N Mahmoudi (ISIS), T Nylander (Lund University, NanoLund, LINXS Institute of Advanced Neutron and X-Ray Science, Sungkyunkwan University).

Neutron reflectometry uncovers how proteins stabilise interactions between cell membranes

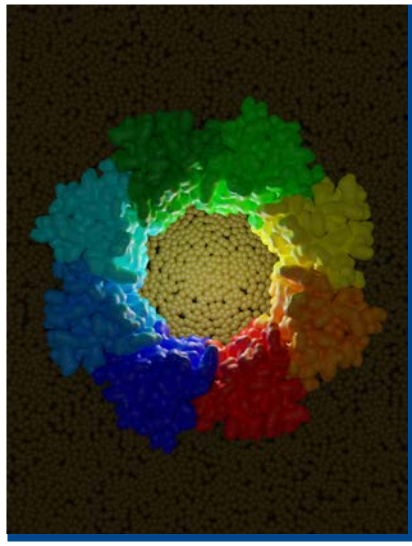
A collaborative project involving the Universities of Birmingham and Oxford, and ISIS, has revealed that the PqiC lipoprotein helps to stabilise interactions between cell membranes in Gram-negative bacteria.

Cell membranes consisting of a lipid bilayer studded with proteins provide an effective barrier against environmental stresses. Unlike other organisms, Gram-negative bacteria such as E. coli have two cell membranes, although researchers are still unsure how the transport system that enables the creation of these membranes works.

The researchers were interested in the PqiABC system in E. coli, comprised of PqiA, an integral inner membrane protein, PqiB, which spans between the two membranes and an outer membrane lipoprotein, PqiC. Together, this trio of proteins is thought to provide a transport system between the two membranes.

They used X-ray crystallography to solve the structure of PqiC, before using neutron reflectometry on the Offspec instrument at ISIS to investigate the nature of the membrane interaction between PqiB and PqiC.

They found that the PqiC octomeric ring embeds partially into the outer membrane, suggesting PqiC acts as an anchor for the C-terminal element of PqiB, limiting its flexibility, whilst potentially allowing its movement within PqiC.



PqiC lipoprotein with lipid headgroups in the background. *Image © Benjamin Cooper, University of Oxford; EMBO Reports 25:1*

> **Central to this research is the ISIS Neutron and Muon Source, its incredible capabilities provide unique tools for studying the complexities of membrane biogenesis in ways never conceived before, we will continue to work closely with them to push what is possible with neutron science.**
>
> Tim Knowles, Reader in Structural Biology and Director of the Midlands Integrative Biosciences Training Partnership at the University of Birmingham.

Instrument: Offspec

Related publication: An octameric PqiC toroid stabilises the outer-membrane interaction of the PqiABC transport system. *EMBO Rep* (2024) 25. DOI: 10.1038/s44319-023-00014-4

Funding: BBSRC and the University of Birmingham

Authors: B F Cooper, G Ratkevičiūtė (University of Oxford), L A Clifton, S C L Hall (ISIS), H Johnston, R Holyfield, D J Hardy, S G Caulton, W Chatterton, P Sridhar, P Wotherspoon, G W Hughes, A L Lovering, T J Knowles (University of Birmingham).

Science highlights – life science and healthcare

Under water and under pressure: protecting proteins from denaturation

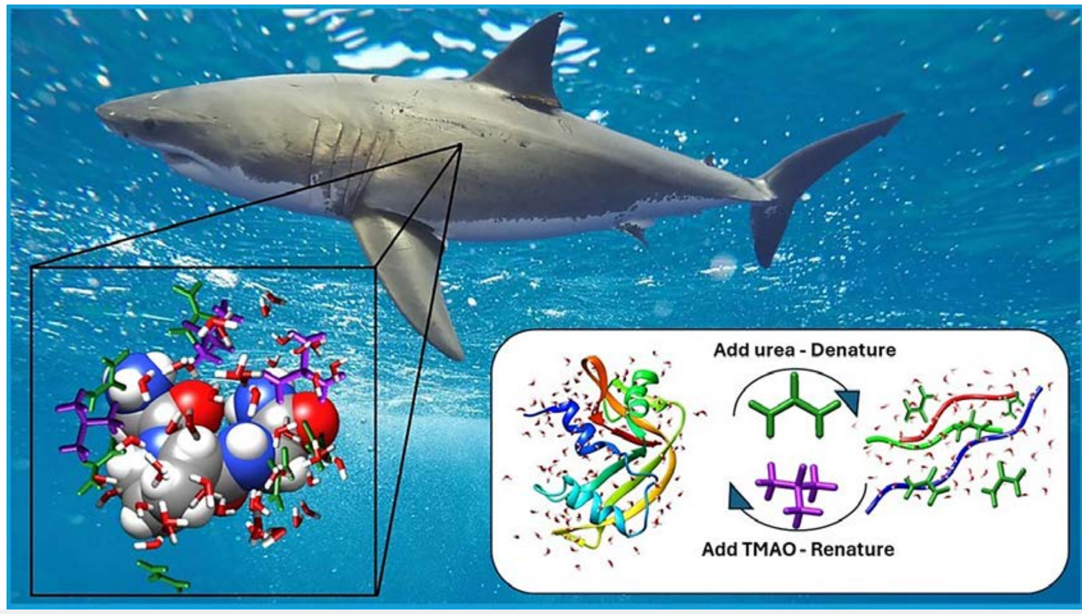
Researchers from the University of Leeds have returned to ISIS to further investigate the properties of Trimethylamine-N-oxide (TMAO), a common metabolite found in marine animals.

A class of marine animals, including sharks, has evolved to use the metabolites urea and TMAO to regulate cellular volume in their saline environment. These osmolytes are of interest because of their opposing effects on the energetic stability of globular proteins.

Urea denatures proteins by directly interacting with the protein molecule. In contrast, TMAO protects proteins from denaturation, but researchers don't fully understand the mechanisms behind its protective effects.

The team from the University of Leeds used neutron diffraction on Nimrod to study the atomic interactions between TMAO, urea and the tripeptide glycine–proline–glycinamide (GPG), a peptide that has a propensity to take on a structural form similar to the β-turn, a structural motif associated with the nucleation of protein folding.

Their results showed that adding TMAO depletes urea from the surface of the protein molecule and that the underlying mechanism might relate to the formation of a TMAO-urea-water hydrogen bond network in the bulk solution that prevents urea from partitioning towards the peptide surface.



The changes in protein structure caused by urea and TMAO.

Instrument: Nimrod

Related publication: Trimethylamine-N-oxide depletes urea in a peptide solvation shell. *Biophysics and Computational Biology*, 121 (14) e2317825121. DOI: 10.1073/pnas.2317825121

Funding: EPSRC, ERC, UKRI

Authors: M Nasralla, H Laurent, L Dougan (University of Leeds), O L G Alderman, T F Headen (ISIS).

Using pH to control antibody orientation for improved drug delivery

Scientists from the University of Manchester and Imperial College London, in collaboration with ISIS and the pharmaceutical company AstraZeneca, have investigated how pH influences the binding of a monoclonal antibody to a solid interface.

Monoclonal antibodies (mAbs) are laboratory-made proteins that bind to specific targets. They can be used to treat and diagnose diseases and as biosensors to detect pathogenic bacteria in the body.

However, mAbs can stick to the surfaces inside medical equipment, making it difficult to know the exact dose a patient receives. This interfacial adsorption of mAbs can also cause problems during manufacturing.

The scientists were interested in how changes to pH affected the attachment of a bioengineered mAb based on the human antibody IgG1k onto a SiO_2/water interface. They used neutron reflectivity on the Inter and PolRef instruments at ISIS alongside molecular dynamics simulations to gain a comprehensive understanding of the orientation, structural stability, and conformation of the adsorbed mAbs.

They found that pH changes caused a reversible change in the orientation of the mAb, moving between 'flat-on' and 'tilted' positions. The findings highlight the potential to fine-tune antibody conformation and orientation, which could allow researchers to develop innovative strategies for optimising mAb adsorption onto surfaces, for instance in the creation of biosensors.

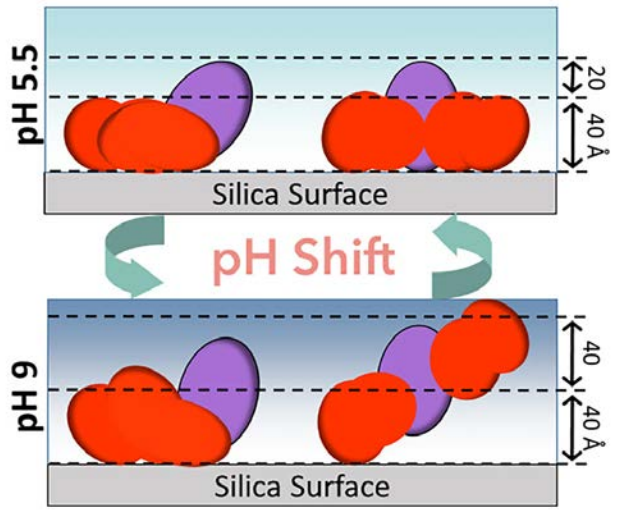


Diagram showing the change in orientation of the antibodies.

Instrument: PolRef and Inter

Related publication: pH-dependent conformational plasticity of monoclonal antibodies at the SiO_2/water interface: insights from neutron reflectivity and molecular dynamics. *ACS Applied Materials & Interfaces*, 16, 51. DOI: 10.1021/acsami.4c14407

Funding: AstraZeneca, BBSRC

Authors: Z Li, P Hollowell, T A Waigh, J R Lu (The University of Manchester), S Saurabh, J M Seddon, F Bresme (Imperial College London), C K Kalonia (AstraZeneca), P Li, J R P Webster (ISIS).

Discovery science

Neutrons reveal modern modification of ancient Iranian swords

Researchers from Cranfield University, ISIS and the British Museum, led by ISIS facility development student Alex Rodzinka, have used neutron tomography to see the internal structures of Iron Age Iranian swords for the first time.

They found the swords, which were seized by the UK Border Force during a trafficking operation, were modern pastiches made combining fragments of different ancient swords.

The bronze and iron swords are around 3000 years old and come from northwestern Iran; a hub of ancient metalworking and metallurgical innovation. Modern tampering makes the swords more appealing to potential buyers but also obscures the manner of their original construction.

Visual inspection of the collection of swords revealed some irregularities: unusually-shaped blades, inconsistent corrosion patterns and presence of iron in otherwise bronze swords. Neutron tomography on the IMAT beamline at ISIS helped the researchers reveal the extent of modification, uncovering that some swords were originally bimetallic. They found that modern glue was used to attach ancient bronze blades to bimetallic swords, replacing authentic but heavily corroded iron blades. A modern drill bit was still embedded in one of the swords, and hilts were drilled into to better accommodate ill-fitting blades.

Iranian authorities gave permission for the research, and the swords will be repatriated to Iran once the research is complete.

Alex Rodzinka examining one of the swords on INES.

Instrument: IMAT

Related publication: Neutron tomography reveals extensive modern modification in Iron Age Iranian swords. *Journal of Archaeological Science*, 171, 106018. DOI: 10.1016/j.jas.2024.106018

Funding: STFC, Cranfield University

Authors: A E Rodzinka (Cranfield University, ISIS), A Fedrigo (Institut Laue-Langevin, ISIS), A Scherillo (ISIS), A J Shortland, N L Erb-Satullo. (Cranfield University), St J Simpson (The British Museum).

Using DNA for data storage

Microsoft researchers based in Redmond, USA, have used neutron irradiation to investigate the resilience of DNA as a medium for digital data storage.

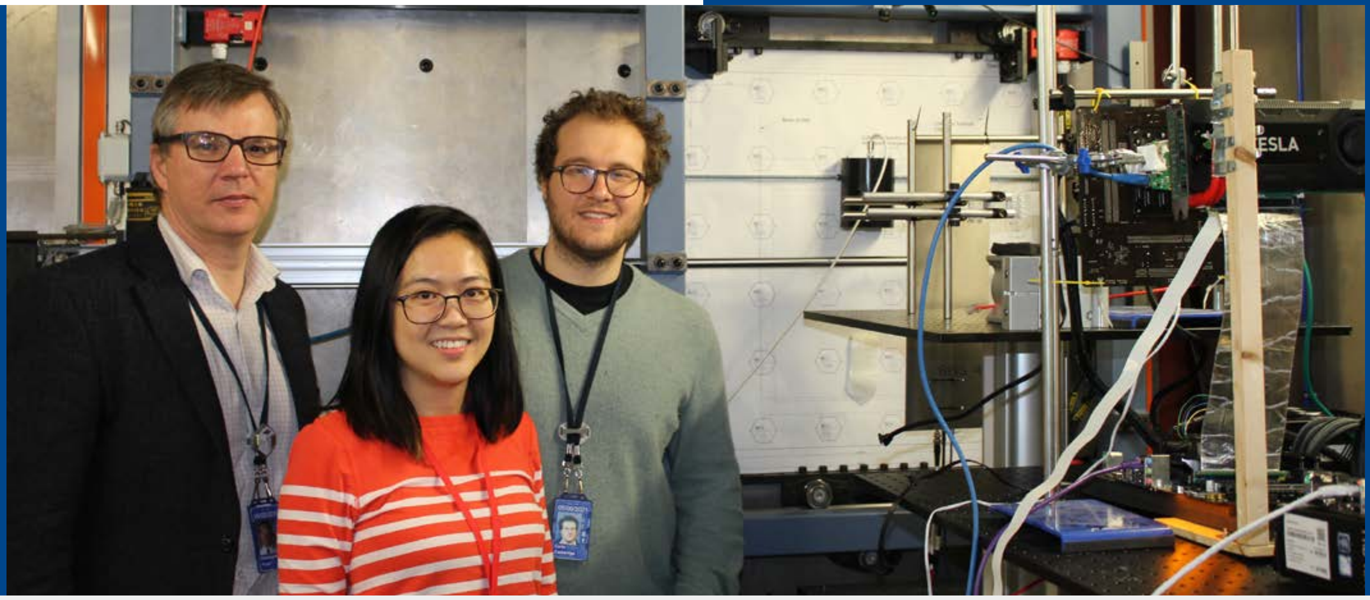
Technology is progressing so fast that data storage methods quickly become outdated and difficult to access. Researchers know DNA can survive for hundreds of thousands of years, and the need to read DNA sequences will remain. DNA could therefore be an ideal long-term data storage medium.

The researchers visited the ChipIr instrument at ISIS to better understand the effects of cosmic rays, which cause showers of subatomic particles to rain down onto Earth, on digital data encoded in DNA. The team irradiated their samples with neutron particle radiation, with the longest exposed samples experiencing the equivalent to 4.4 million years of exposure at sea level in New York City.

After some issues with the control samples measured at ISIS, the team carried out a replicate experiment at the Los Alamos Neutron Science Center (LANSE).

They then sequenced the DNA and decoded the original data to see if any errors had been introduced. The DNA turned out to be inherently resistant to damage from particle radiation, unlike traditional magnetic storage.

ChipIr beamline scientists Chris Frost and Carlo Cazzaniga with Microsoft researcher Bichlien Nguyen.



Instrument: ChipIr

Related publication: Evaluating the risk of data loss due to particle radiation damage in a DNA data storage system. *Nat Comms*, 15, 8067. DOI: 10.1038/s41467-024-51768-x

Funding: Microsoft

Authors: C N Takahashi, D P Ward, (University of Washington), C Cazzaniga, C Frost (ISIS). P Rech (University of Trent), K Ganguly, S Blanchard, S Wender (Los Alamos National Laboratory), B H Nguyen, J A Smith (University of Washington, Microsoft Research)

Science highlights – discovery science

Neutrons reveal new insights about the alloys and metallurgy of The Vittoria Alata

Using the INES and IMAT Instruments at ISIS, a group of Italian researchers unearthed the manufacturing techniques behind Brescia's beloved symbol.

The "Vittoria Alata" (Winged Victory) is a 1.9 m tall bronze statue dating from around the 1st Century BCE. It was discovered beneath the Capitolium of Brescia in 1826 and has since become a symbol of the city. While the statue was undergoing restoration work an Italian team of researchers took the opportunity to study the metal alloy composition and manufacturing methods used in its creation.

The team used scanning electron microscopy analysis at the OPD Lab in Florence, and time-of-flight neutron diffraction and neutron imaging at ISIS on millimetre sized samples from the statue. Two larger samples, a feather fragment from the right wing, and a frame, were also analysed.

The researchers found that the ancient forgers used more compression resistant alloys for the base of the statue, and softer alloys for the most delicate parts, such as the torso. Their analysis also uncovered clues about the order in which different components of the statue were cast and joined together.

The "Vittoria Alata" (Winged Victory).

Instruments: Ines and IMAT

Related publication: The Vittoria Alata from Brescia: a combined neutron techniques and SEM-EDS approach to the study of the alloy of a bronze Roman statue. *Journal of Archaeological Science: Reports*, 51, 104112. DOI: 10.1016/j.jasrep.2023.104112

Authors: F Cantini (Università degli Studi di Firenze, CNR-IFAC, INFN -Labec, Ministero della Cultura, Opificio delle Pietre Dure di Firenze), A Scherillo, A Fedrigo (ISIS), M Galeotti, A Cagnini, S Porcinai, A Patera (Ministero della Cultura, Opificio delle Pietre Dure di Firenze), F Morandini (Comune di Brescia – Fondazione Brescia Musei), F Grazzi (CNR-IFAC, INFN -Labec).

The 2025 ISIS Impact Awards

Science Award

The winner of the 2025 Science Award is Fabrizia Foglia from University College London for her innovative use of neutron techniques to understand and improve the performance of membrane nanotechnologies for sustainable applications.

Ion-conducting polymer membranes are essential in many separation processes and electrochemical devices, including flow batteries, fuel cells and electrolysers. All of these applications are relevant for achieving Net Zero carbon emissions.

Fabrizia Foglia has made significant contributions to understanding how morphology and local dynamics influence transport in the nanostructures of these membranes for fuel cell and filtration applications. She has been instrumental in expanding the use of neutron techniques in membrane science, including reflectometry, quasielastic neutron scattering and small angle neutron scattering.

Economic Award

The winner of the 2025 Economic Award is Pete Dowding from Infineum for his work using neutron reflectometry to study organic friction modifiers for improving the efficiency of combustion engines.

Twenty percent of worldwide CO_2 emissions comes from road and marine transport. Inside the engines of these vehicles, friction can cause both energy loss and damage over time. Organic Friction Modifiers (OFMs) are surface-active molecules (surfactants) that are included in engine oil formulations to reduce friction by approximately 3%.

Improving this friction reduction could lead to improvements in fuel economy with a resulting decrease in global CO_2 emissions of up to 50 MT each year, almost as much as the total emissions from global aviation. To reach this target, businesses need to understand how lubricant additives work at the molecular level, enabling better molecules to be designed and synthesised on short time scales. Pete Dowding and his collaborators built and commissioned a unique beamline tribometer to carry out neutron reflectometry of a sample under conditions that replicate those inside an engine.

Society Award

The winner of the 2025 Society Award is Christian Pfrang from the University of Birmingham for his work using neutron reflectometry to investigate the effect of cooking emissions on indoor air quality.

Cooking produces fatty acids, which can accumulate on water droplets in the atmosphere, or on surfaces in the home. From research using neutron reflectometry, Christian Pfrang and his collaborators found that these fatty acids are not easily broken down, and therefore very stable. In the atmosphere, their continued presence can impact the climate. In the home, they can build up and trap toxic pollutants, affecting indoor air quality and therefore health.

With ISIS beamline scientist Max Skoda, he co-supervised the ISIS co-funded PhD student Ben Woden to create a new sample environment on the Inter beamline for measuring these atmospheric systems.

Pete Dowding, Christian Pfrang and Fabrizia Foglia (left to right) after receiving their impact awards.

World-class technology and infrastructure

At ISIS we are always developing the accelerator, target stations and instrument suite. We also continue to make progress in detector technologies, sample environments and computing, keeping the facility at the forefront of accelerator-based neutron and muon sources. Implementation of the Endeavour programme is underway and, looking ahead, plans for ISIS-II are progressing well, with sustainability at the forefront.

Upgrading the Linac modulator 1 control system. Luke Afford, James Cox and Enock Okornoe

Major projects

Endeavour

Endeavour is the programme of large instrument developments at ISIS, providing a £93m investment in the ISIS instrument suite. It received formal UK government approval in Spring 2023.

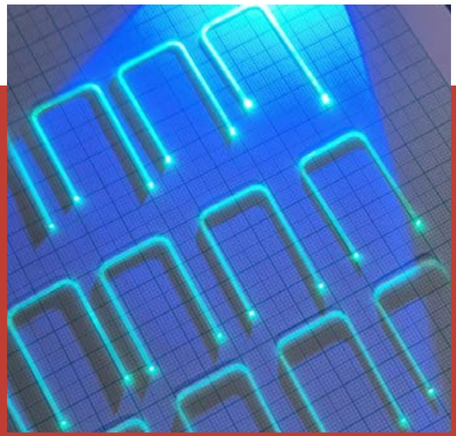
Two of the nine projects being developed as part of the Endeavour programme are in implementation with component procurement well underway.

- Super MuSR is a new concept of muon instrument, designed to give greater time resolution as well as flux. Key components including the pulse slicer and spin rotator electrodes have been manufactured and the pre-build has begun. Production of detectors for Super MuSR began in summer 2025. The first 200 optical fibres have been bent into a tight U-shape, critical to building a gapless detector for muon spectrometers.
- HRPD-X is a significant upgrade of the high-resolution powder diffractometer, which includes a rebuild of the instrument building. The original instrument has been dismantled and the building demolished ready to make way for its replacement.

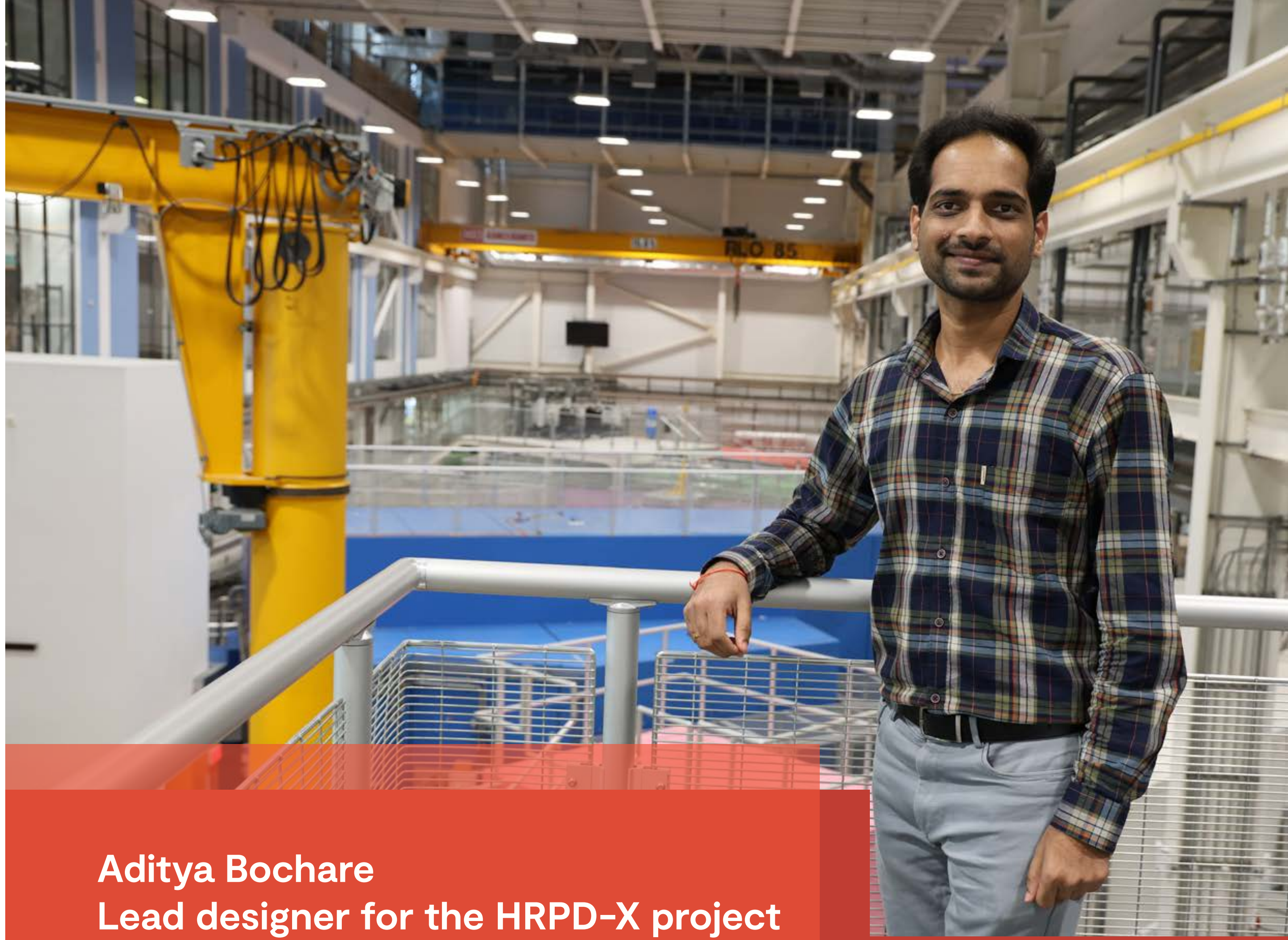
Super MuSR and HRPD-X are currently planned to be ready for the user programme in the first half of 2028. Wish-II, Mushroom and Sandals-2 are now in the detailed design phase, with Osiris+ and Tosca+ likely to follow during 2026/27.

The selection process to determine the instruments that will be built in the final phase of the programme will be completed by early 2026.

Demolition of the building that housed HRPD.



Bent wavelength shifting fibres for Super MuSR.



Aditya Bochare
Lead designer for the HRPD-X project

Aditya was drawn to the UK by his love of motorsport. He's now one of the lead designers for the HRPD-X project and is enjoying the challenge of designing a new ISIS beamline.

After his degree, Aditya worked for three years in the automotive industry in India. His passion for motorsport brought him to the UK to pursue a masters in motorsports engineering. On graduating, he saw the role of design engineer at ISIS and joined the ISIS Design Division in 2022. "I thought - it's something different. I'll give it a shot," he says.

He has worked on the new analyser for the Osiris beamline and the flight tube for FREIA, which will be built at the European Spallation Source. He is now lead designer for the HRPD-X instrument upgrade project, part of the Endeavour programme. This will be the first project he's worked on at ISIS that he'll see through from the start all the way to completion.

"I loved the challenge of motorsports – having to fit that much complex design into such strict parameters," he explains. Although the new HRPD beamline will be built from scratch in a new building, there are still a lot of constraints to consider, and it's this that Aditya finds interesting. When he started on the project, he thought; "Yes! This is what I wanted to do – it's just the type of challenge I was looking for. I just love it, as we're making truly bespoke products."

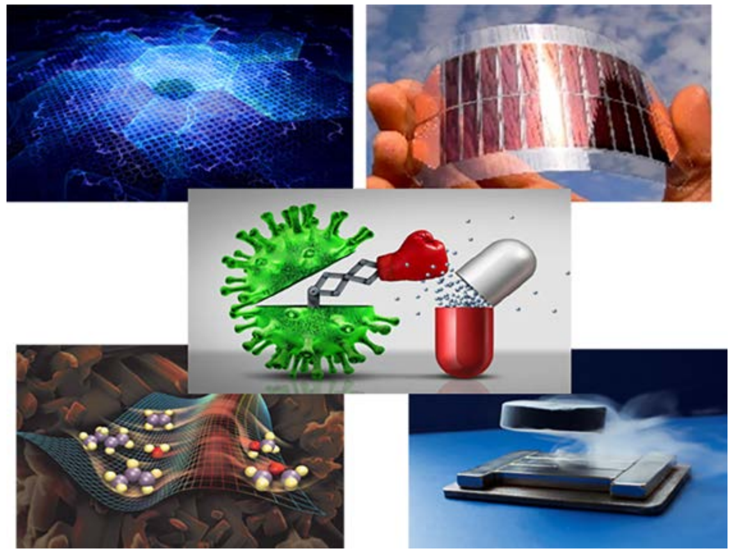
Major projects

ISIS-II

Developing the science case for the UK's next-generation neutron and muon source

The ISIS-II project team has identified the scientific parameters and likely performance of the ISIS-II source. After a detailed options analysis, they agreed that ISIS-II will be a short-pulse spallation source, based optimally on a 2.4 MW accelerator option with two target stations. The combination of the increased source power, advances in computation and in instrumentation such as neutron guides and detectors, as well as engagement with our vibrant and growing user community, will allow neutron and muon science to answer the fundamental scientific and societal challenges of tomorrow.

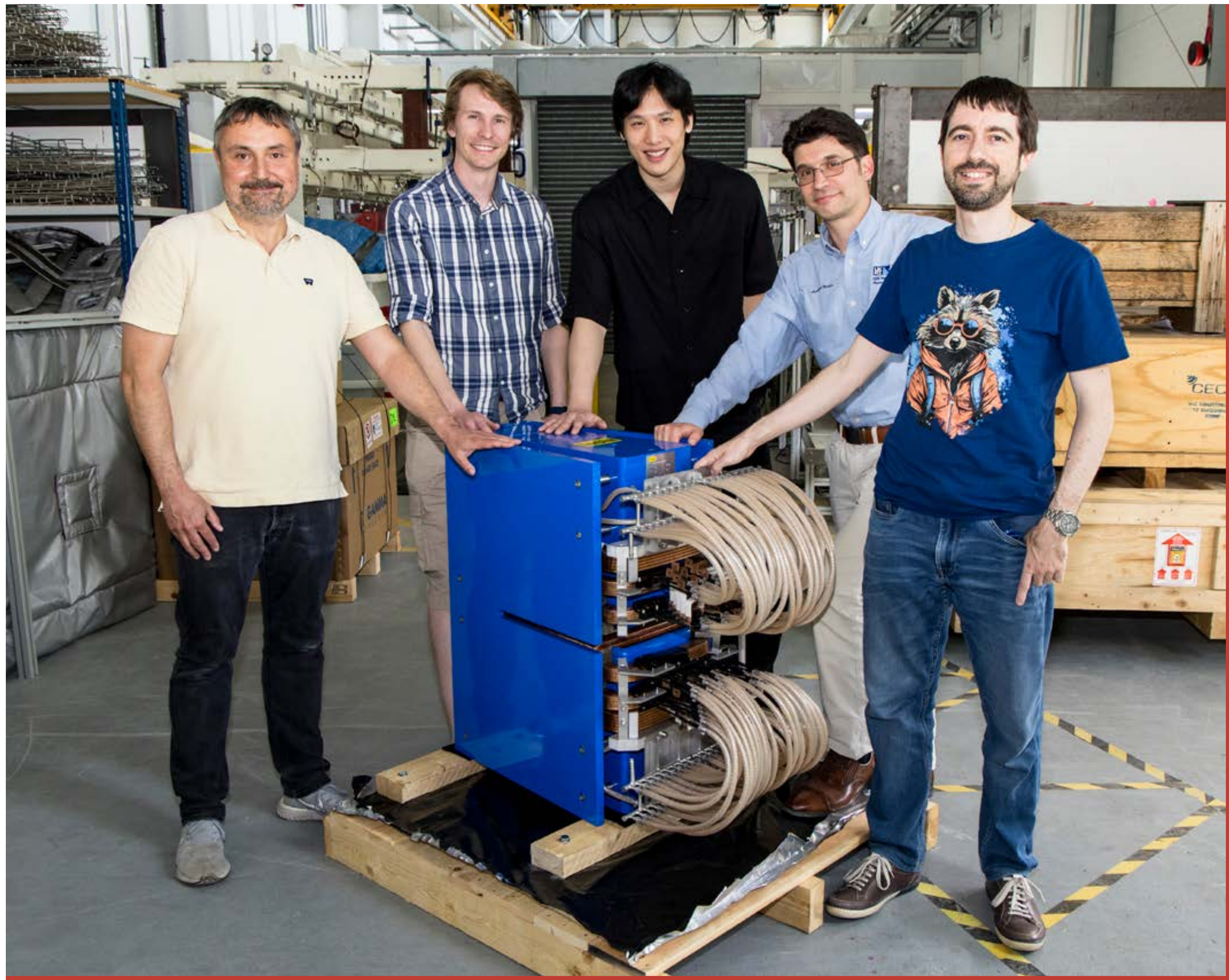
The ISIS-II science case is now being developed in consultation with the ISIS user community. Dedicated science meetings were held at ISIS on 23-25 October 2024, the outputs of which formed the basis for discussion at an ISIS-II session at the 2025 UK Neutron & Muon Science and User Meeting (NMSUM) in March 2025.



A representation of some of the potential ISIS-II science areas.

Outputs from NMSUM and further consultations with stakeholders during 2025 will be incorporated into the science case, with a first full draft anticipated by the end of the calendar year.

The dedicated ISIS-II session at NMSUM.



Left to right, Jaroslaw Pasternak, Jon Speed, Ta-Jen Kuo, Jean-Baptiste Lagrange, and Iker Rodriguez with the prototype magnet for ISIS-II feasibility studies.

FFA prototype magnet

In May 2025, after four years of design work, the intense beams group at ISIS took delivery of a prototype magnet as part of the feasibility study for using a fixed field alternating gradient accelerator (FFA) to power ISIS-II.

One accelerator option being considered for ISIS-II is a low energy linear accelerator combined with an FFA, which could accelerate protons up to 1.2 GeV. An FFA uses DC magnets that hold a constant field rather than AC magnets like those used in a synchrotron, with the protons travelling in a spiral as in a cyclotron. One advantage is that it will cost less to operate. However, no high power FFAs have been built before.

UK-ESS

Installation progress for ISIS contributions to the European Spallation Source

As part of the UK's contribution to the European Spallation Source (ESS), ISIS staff are delivering the LoKi and FREIA instruments.

The Detector Systems Group (DSG) at ISIS recently completed assembly and testing of detectors for the small angle scattering instrument LoKI. They have now been installed at the ESS and cold commissioning of the instrument is underway. All modules in the second phase are also ready for shipment to the ESS. LoKI should be one of the first instruments ready to receive neutrons and start hot commissioning.

ISIS teams are also finalising the manufacture and testing of components for neutron reflectometer FREIA, including large 1.6 m carbon-fibre choppers.

LoKI detectors in the instrument tank at ESS.

Sample environment and experimental support

Soft Matter

To support an *in-situ* neutron experiment on sodium-ion battery pouches, the Soft Matter Sample Environment team collaborated with Zhenyu Guo from Imperial College London, to design, prototype, and test a bespoke clamp and mounting assembly. The project relied on collaboration between the sample environment technicians, STFC Technology department's additive manufacturing team for the rapid printing, and the ISIS workshop, who machined the aluminium clamp plates.

Pressure and Furnace

The Pressure and Furnace team have developed new equipment allowing a fine level of humidity control for a flowing gas at high temperatures. The system was run on HRPD for an *in-situ* hydration experiment to study zirconate ceramic, which is known to be a proton conductor with potential applications in fuel cells, particularly at higher temperatures.

Cryogenics

The Cryogenics team have taken receipt of a new suite of controllers for the group's superconducting magnets, featuring modern electronics and enabling intelligent independent control from the touchscreen front panels.

Case study: Safe handling of notorious poison gas phosgene

The Sample Safety and Sample Environment teams constantly seek to enable complex and high-hazard experiments. One recent example of this was a series of experiments with phosgene, a notorious WWI poison gas that accounted for around 70000 deaths, which had been rejected by other institutions due to the difficulty of handling this material.

The experiments were successfully delivered after a year of careful planning between the ISIS teams and Frank Tambornino's group at the University of Marburg, Germany. The researchers used HRPD to confirm the known solid-state structure of phosgene and structurally characterise a second metastable phase for the first time. Tosca enabled the researchers to observe and assign the solid-state vibrational spectrum for the first time.

The project team – Stewart Parker, Sven Ringelband, Chris Howard, Frank Tambornino, Dominic Fortes, Chris Goodway, Maxim Schastny, James Taylor, Jason Chandler, Ian Hickman, Kimberly Greenough.

Accelerator and Targets

Replacement of the TS2 proton beam window

In January 2025, the Target Operations Group successfully replaced the proton beam window on TS2. This is only the second time this has been carried out in the life of TS2.

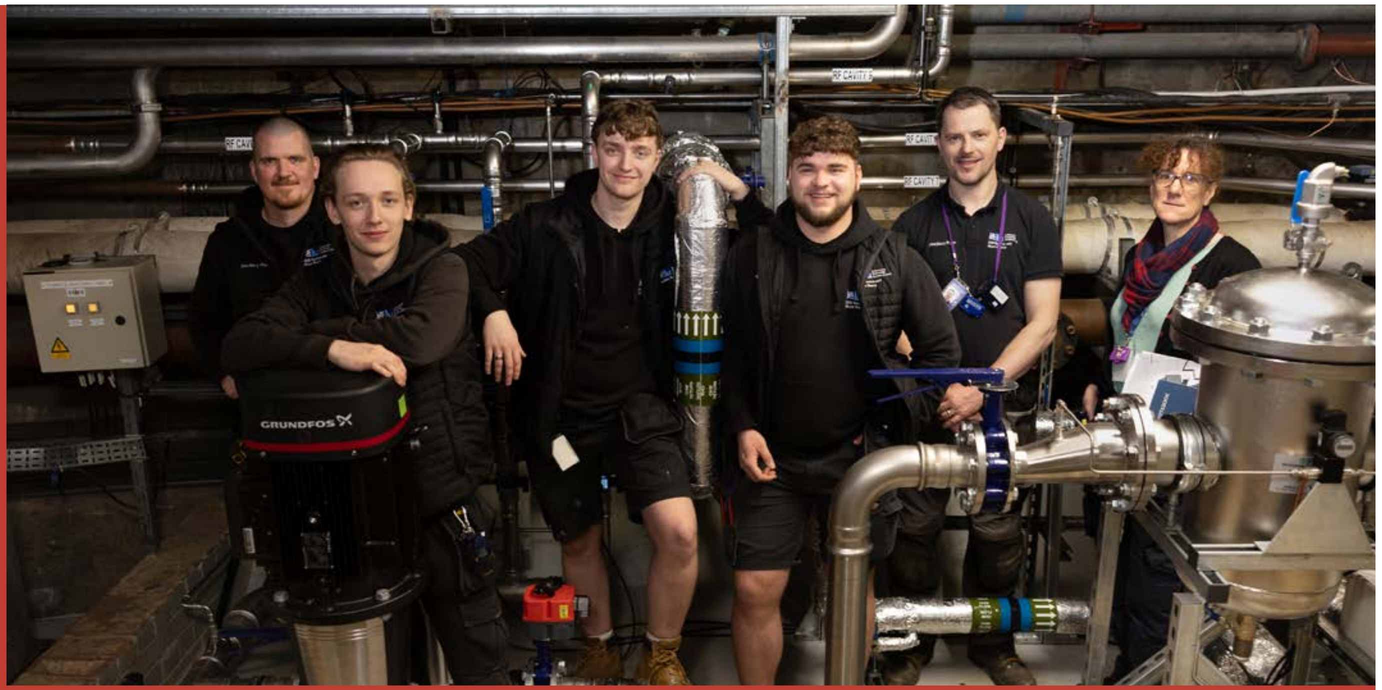
Catacomb water circuit upgrade

The catacomb water circuit upgrade completed in January 2025 improves resilience of the circuit and adds telemetry to allow remote monitoring and control without interrupting beam delivery. The catacomb water circuits provide cooling water to the RF cavities in the synchrotron. To achieve our high availability targets, the water circuits have been renewed with modern pumps and controllers. The new system will operate more efficiently, saving 147 MWh per year.

RF screen replacements

This year several RF screen failures were discovered inside key magnets in the synchrotron. Replacing the RF screens in these components is a complex task, involving careful coordination of mechanical engineering team, health physics team, survey team and vacuum team.

Harry Woolliams working on the ISIS synchrotron



Catacombs water circuit upgrade – Nick Sherwood, Ben Nuttall, Ben Naisby, Luke Stevens, Steve Keable, Judith Cave.

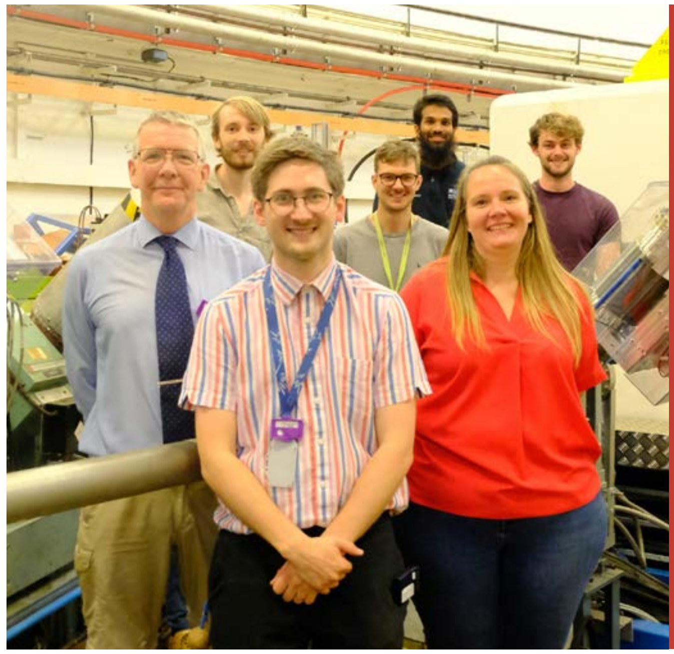
Electrical work

Behind the scenes, ISIS electrical engineers and technicians are continually improving systems to be more reliable, more maintainable and more user-friendly. Over the year, significant upgrades have been made to the linac modular control system, the extract septum, and the synchrotron air handling control system.

Replacing the extract septum 1 power supply – Nathan Stone, Stanley Musarurwa, Jack Bowden, Steve Reeves, Gavin Jones, Ethan Hawkins, Toby Soper.

Injector wire scanner profile monitor

Throughout the year, the ISIS diagnostics team have installed and commissioned the first pair of a new generation of wire scanners; crucial diagnostics for achieving a high-efficiency transfer through the High Energy Drift Space (HEDS) that connects the linac to the synchrotron. This new design will eventually replace all fifteen of the existing wire scanners, which were originally installed when ISIS was built.



The ISIS diagnostics team – David Posthuma de Boer, Tony Kershaw, Sarah Fisher, Ross Titmarsh, James FitzGibbon, Khalid Fazlee, Oliver Coster.

Pre-injector upgrade

The pre-injector upgrade will improve the reliability and efficiency of the front end of the ISIS linac through the installation of a new Caesiated RF ion source and the addition of a Medium Energy Beam Transport (MEBT) section prior to tank 1. The new MEBT also includes an electrostatic chopper, allowing for more efficient injection into the synchrotron and will enable higher intensity beams in the future.

This year there has been significant progress on reconditioning the ISIS RFQ, delivery of quarter wave resonators, installation of controls infrastructure, and testing the new ion source.

The team carrying out the pre-injector upgrade.

Using machine learning to tune the ISIS beam

We have made the first attempts to automatically tune the Low Energy Beam Transport (LEBT) at ISIS using Bayesian Optimisation (BO) during start up. Manual tuning times vary between 15 minutes to hours, while results from the automatic tuning show that it can reproduce the performance achieved with manual tuning within approximately 20 minutes. This provides greater consistency and reliability in time. Ongoing work is now focusing on developing a GUI to allow accelerator physicists and crew to make use of the tool during start up.

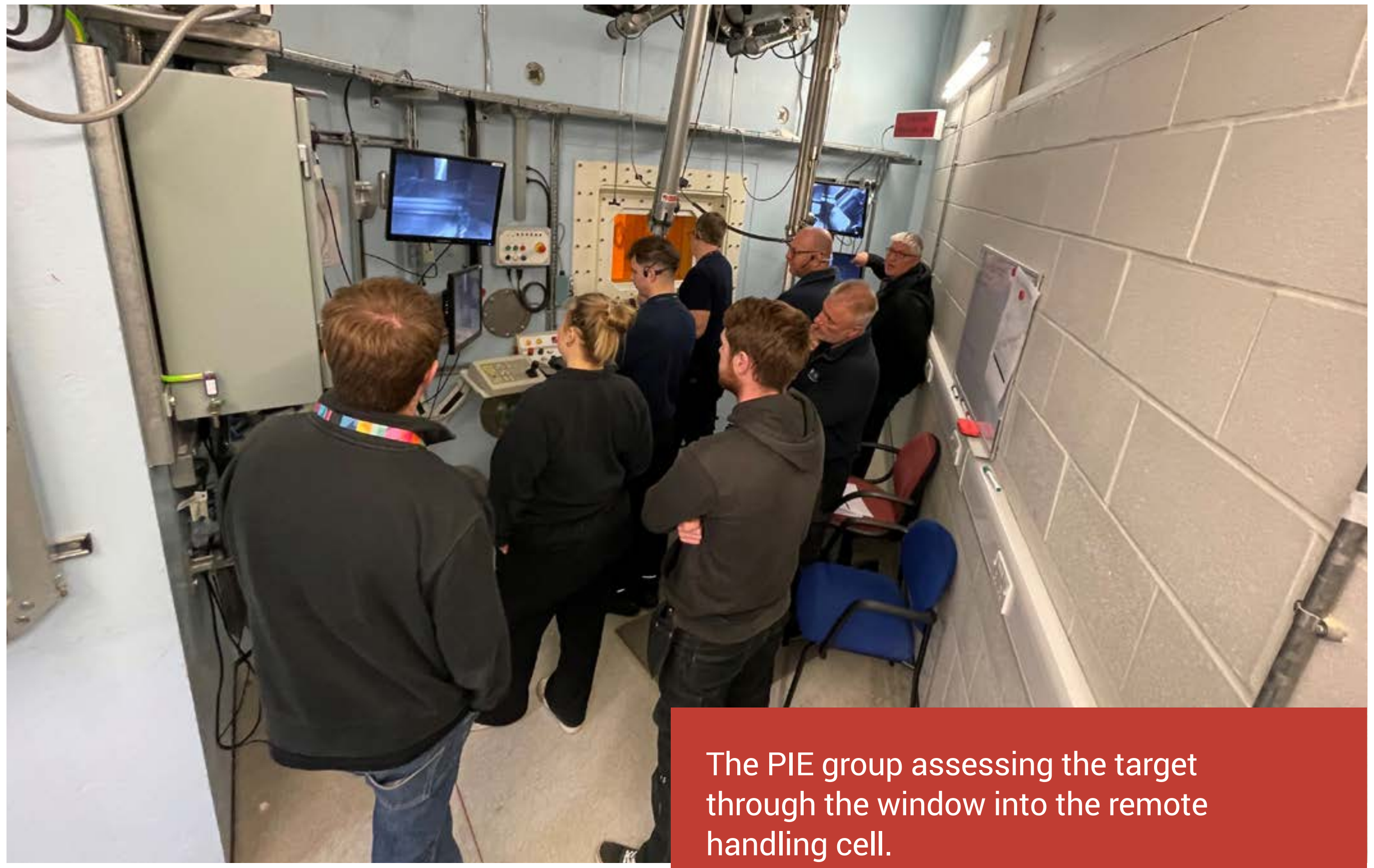
The machine learning application for particle accelerators conference, attended by ISIS staff members Kathryn Baker, Mihnea Romanovschi and Mateusz Leputa.

Accelerator and Targets

The first slice of PIE

During the October 2024 ISIS shutdown, the Target Operations Group completed a complex post irradiation examination (PIE) to slice open an old target to investigate the effects of its time in operation.

Supported by engineers from the Target Design group and Health Physics, they were able to cut off the end of an old target and take detailed photographs of the inside. The teams will now look for evidence of cracking, corrosion or oxidation. In future they hope to carry out a similar procedure on a more recent target, with a different design, to see if this influences the failure mechanisms.



The PIE group assessing the target through the window into the remote handling cell.

TS2 decoupled methane moderator

The start of June saw the culmination of several years of planning, design work and offline testing with beam commissioning of the new TS2 decoupled solid methane moderator. The new design iteration includes features to support future Endeavour and post-Endeavour instruments and provides the current WISH instrument with improved resolution. This is part of ongoing efforts from the neutronics, operations, controls and design teams to continue to develop the scientific performance of the facility.

Instrument developments

New diffraction detectors for IMAT

New diffraction detectors have been installed on IMAT. Built in-house at ISIS, these detectors will render IMAT a one-of-a-kind instrument where neutron imaging can be combined with neutron diffraction to yield additional information regarding the morphology and the crystalline composition of samples in a non-destructive way. The project was partially funded by a grant from VR, the Swedish Research Council. A second tranche of installation is expected at the beginning of 2026.

Some of the ISIS staff involved in the project.

New decay positron degrader for EMU

A new decay positron degrader has been designed and installed on EMU. Positron degraders filter out low-momentum positrons and allow high-momentum positrons to be primarily detected. This filtering can improve an instrument's efficiency in data acquisition, resulting in a more efficient use of muon beam. The new degrader is now an essential part of the instrument, with a figure-of-merit improvement in data quality of 50%.

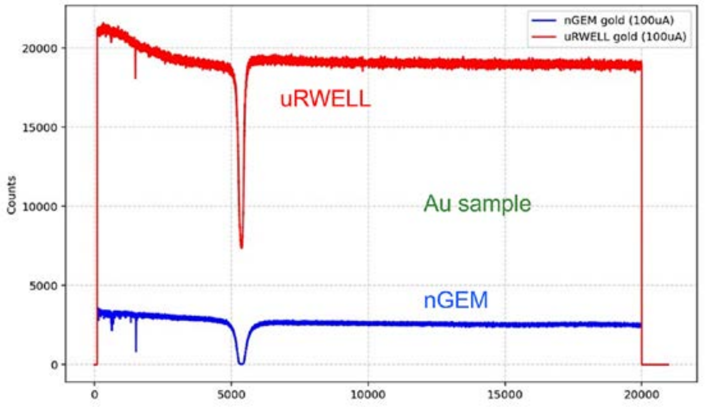
The new degrader for EMU.

ChipIr collimation

As part of the servicing and replacement of the ChipIr collimation jaws, the instrument team collaborated closely with ISIS engineers to improve the collimation performance—particularly for the smallest beam sizes, which are increasingly requested by users. This work built on earlier measurements using the new ChipIr SRAM area monitors, and a test collimation setup constructed at the front of ChipIr by the operations staff, which demonstrated the expected improvements.

New detector technology

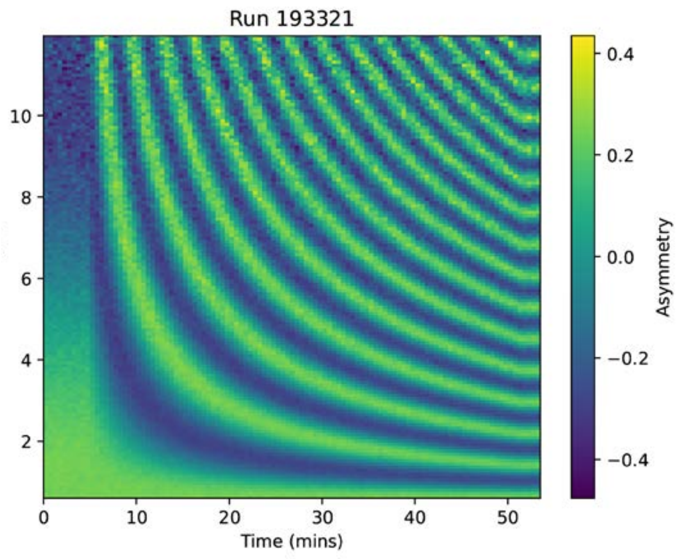
The Detector Systems Group (DSG) is developing a new type of detector technology called the µRWELL, which is around six times more efficient than the current Ines detector while being able to operate at high count rates. Thanks to industrial placement student Henry Bichard we have demonstrated how such a detector would speed up measurements on Ines, opening up new capabilities that are currently too demanding in terms of beamtime. The ISIS DSG and the ESS detector group have signed a partnership for the next three years to accelerate the development of µRWELL-based detectors for applications at both facilities.



Efficiency comparison between the nGEM detector currently used on Ines for NRTI measurements and the µRWELL detector.

Digital muons

In the past year the data acquisition electronics and software being developed for Super MuSR have been prototyped on HiFi and MuSR. This has bought event-mode data streaming to muon instruments for the first time! Scientists have been putting this to good use; slicing up the data dynamically.



Muon spin oscillations plotted in 20 s slices, while sweeping the applied magnetic field.

Osiris secondary upgrade

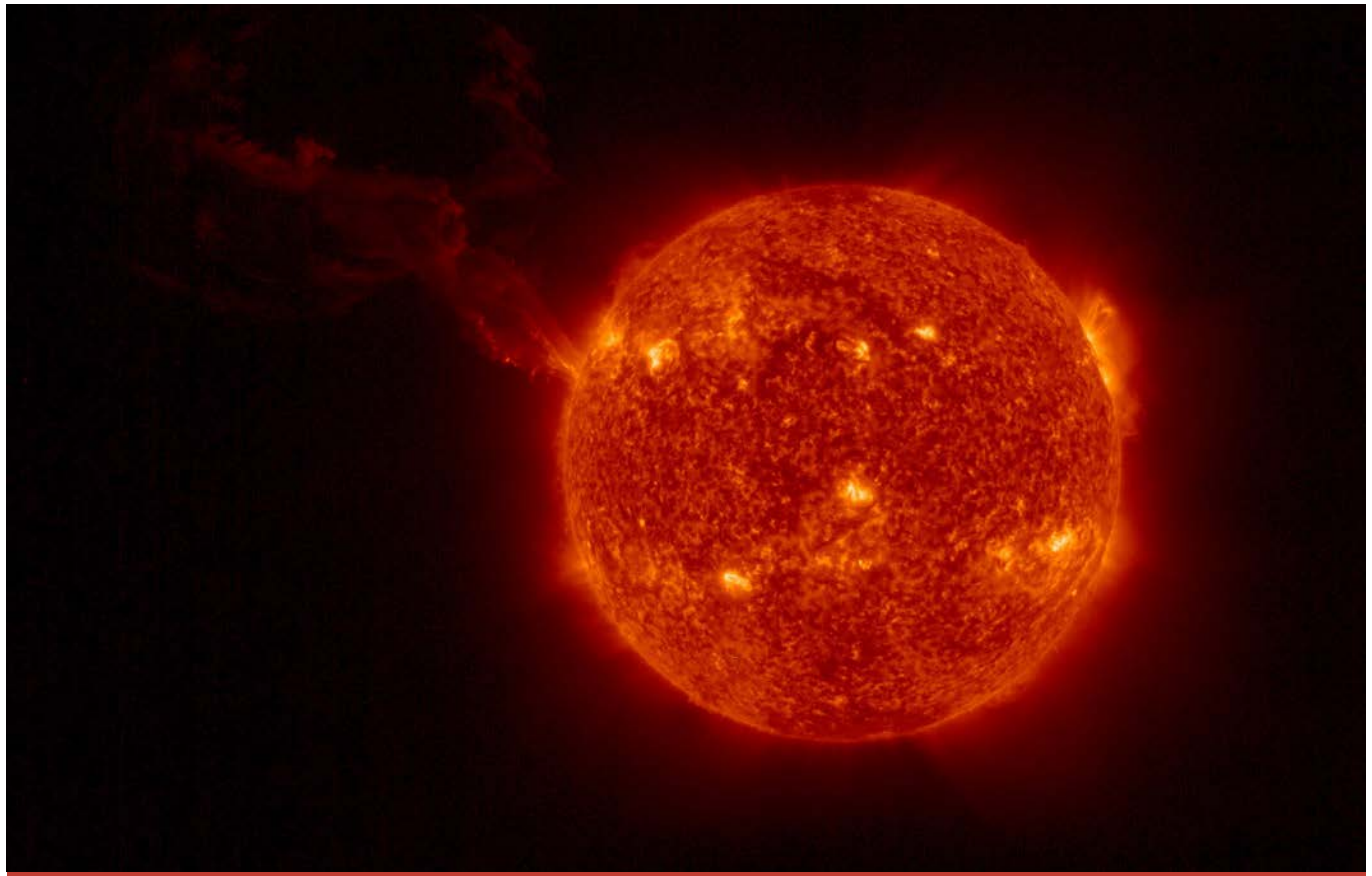
Osiris is being upgraded with the addition of a silicon analyser which will measure small energy transfers with high precision and provide new information about the mobility of ions, atoms and molecules on a longer timescale. Bonding of the silicon analyser crystals to the analyser "towers" is almost complete and all the other components are either already at ISIS or will arrive shortly. Full installation is scheduled to begin at the start of 2026 with commissioning expected in May/June 2026.

Case study: Ground-based space weather monitor

As part of ISIS's microelectronics irradiation programme, the ChipIr team have been working with RAL Space on the SWIMMR project (Space Weather Instrumentation, Measurement, Modelling and Risk). SWIMMR is a four-year programme that will improve the UK's capabilities for space weather monitoring and prediction. As part of this, ISIS scientists have helped to develop a new space weather ground-based monitor, which has since been deployed in the UK and also been adopted by researchers in Italy. The new monitor will help researchers study cosmic rays and solar energetic particles at the Earth's surface by detecting the secondary neutrons produced when they hit the atmosphere. The monitor is the first new design of neutron monitor since 1964 and is both more compact and lower cost. It also avoids the use of highly toxic BF_3.

The new monitor was designed and tested by researchers led by Michael Aspinall at Lancaster University and collaborators at the UK Atomic Energy Authority and Mirion Technologies. The latter stages of the design were tested at ISIS before being deployed by the UK Met Office at Camboure, Cornwall.

Space weather, such as solar flares and coronal mass ejections, can potentially disrupt power supplies, aviation, GPS and telecommunications satellites, and damage ground-based electronic components. The disruption this could cause means that space weather is included on the UK Government's National Risk Register.



The European Space Agency (ESA)-led Solar Orbiter captures a giant solar eruption. Similar events cause space weather on Earth. *Image: Solar Orbiter/EUI Team/ESA & NASA*

Sustainability

The ISIS Sustainability Strategy has been in place since 2022. Its focus is to enable ISIS to support the STFC Environmental Sustainability Action Plan to reach net zero by 2040. This includes developing the environmental sustainability skills, knowledge and processes that will allow us to minimise our emissions whilst maximising our science output.

Continued efficiency drives for the synchrotron radio frequency systems

In the last year the ISIS synchrotron radio frequency team have completed an upgrade on the second harmonic radio frequency (RF) cavities, following a similar process to replace the tetrode valves on the fundamental RF systems in 2021. The latest upgrade yielded an additional annual carbon emission saving of about 100 tonnes of CO_2 equivalent.

The team have also implemented a smarter control system that automates the switching of the RF so that if ISIS has to run just to TS2 the power consumption is automatically reduced. This equates to a 500 kW power saving whenever ISIS runs in this mode. The control system can also respond rapidly to beam losses in the synchrotron at the individual pulse level, saving an extra 51 tonnes of CO_2 equivalent if accelerator availability is at a typical level of 90%.

Electric forklifts

The Lifting team have brought in a fleet of electric forklift trucks and are now running the diesel fleet of vehicles on biodiesel.

New air blast cooler

ISIS now has a new air blast cooler that will be used during colder periods to air cool the synchrotron main magnet power supply water cooling circuit, instead of using the existing chiller system. The system was commissioned during the summer of 2024 and has potential energy savings of 56 MWhrs per year, which equates to 12.7 tonnes of CO_2 equivalent.

The new air blast cooler.

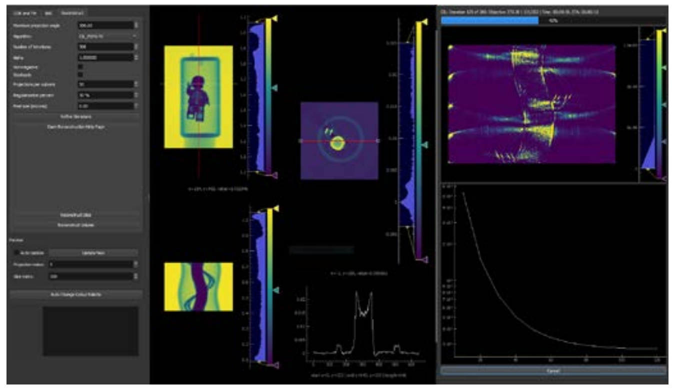
Computing

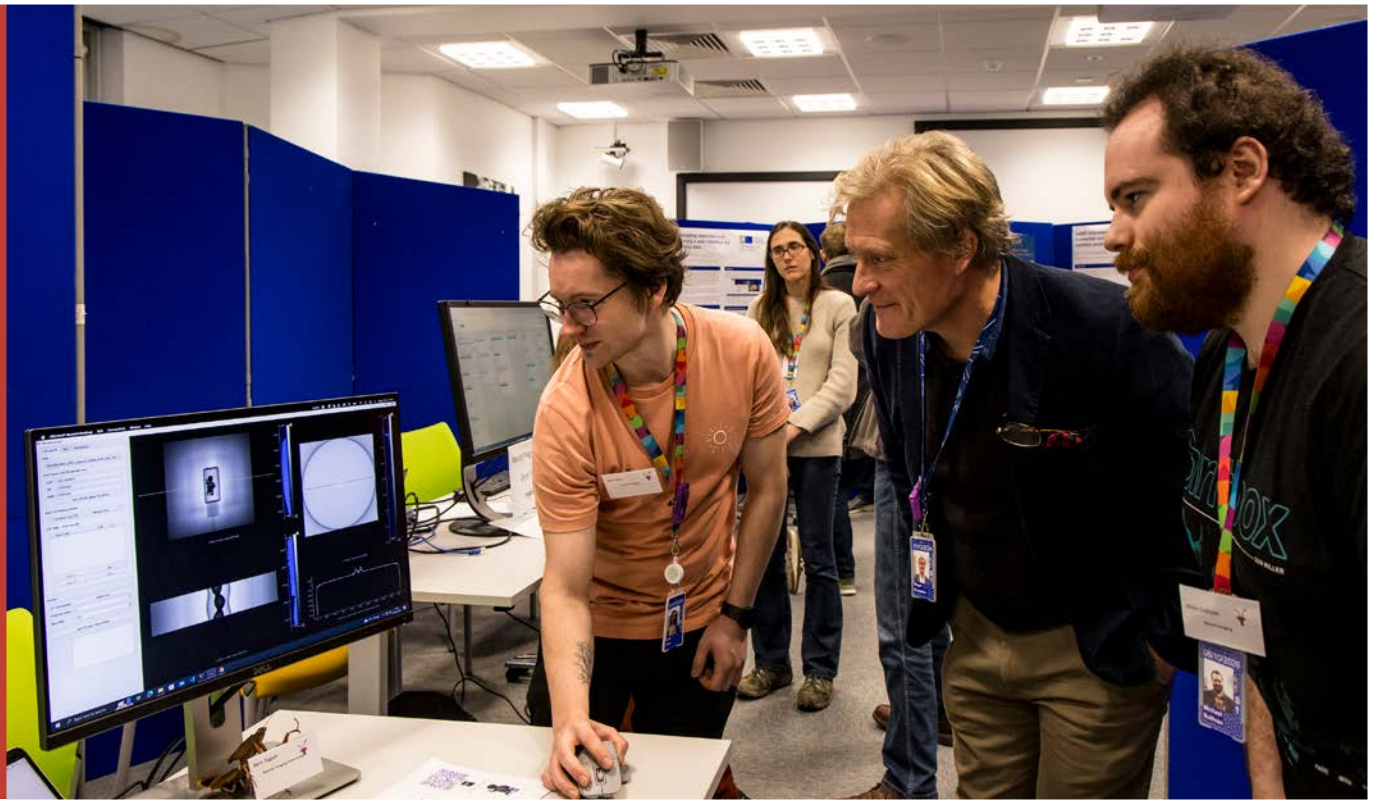
Data treatment

Mantid is ISIS's data reduction and analysis framework used across the instrument suite. This year we introduced new algorithms for polarised SANS, single crystal diffraction, reflectometry, and inelastic data analysis. An algorithm to create Monte Carlo workspaces and streamlined workflows were also added, while ongoing software policy enhancements ensured improved maintenance and user experience. Mantid imaging added time-of-flight imaging support for IMAT, enhanced tomography workflows and a user-friendly interface.

This year, we enhanced automation of data reduction workflows with the Flexible Interactive Automation service, significantly reducing the time instrument scientists and ISIS users need to process raw data. Nearly 20000 jobs have been processed, with capacity for further scaling.

Right: The Mantid Imaging Reconstruction window reconstructing a neutron tomography of a Lego man.





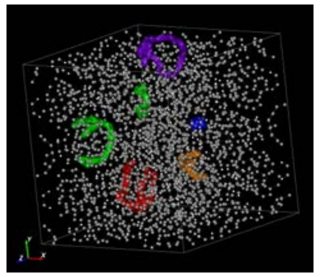
Jack Allen (left) and Mike Sullivan (right) from the Mantid Imaging team demonstrate the functionality of their application to Roger Eccleston (centre) at the Scientific Software Day event.

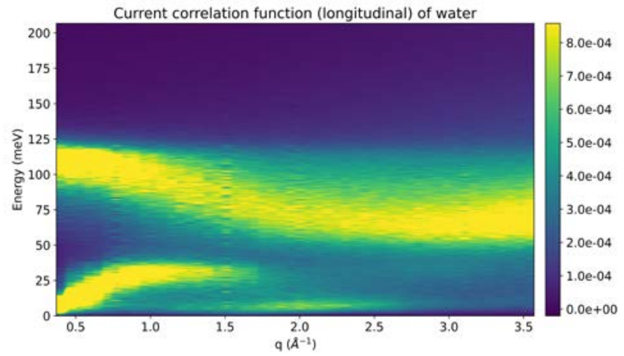
Data Analysis

This year saw a major release of MDANSE, a software package designed for the visualisation and analysis of molecular dynamics trajectories, and a new MDANSE GUI package, which were presented at ICNS and PAQMAN. In addition to general analyses of dynamics and structure, MDANSE allows for the calculation of neutron scattering experiment results, with an emphasis on quasielastic and inelastic neutron scattering.

SasView releases this year added the MuMag tool, developed with the University of Luxemburg, for magnetic SANS analysis, pore size analysis for geology and engineering uses, the didactic Shape2SAS tool for modelling particle geometry and scattering patterns, and faster algorithms.

An example plot of a 3D view of a trajectory, together with the atom trace of several selected atoms indicated in colour (left) and a result of the current correlation function (CCF) calculation for a water trajectory (below).





User programme software

Recent improvements to the proposal system have resulted in one of the most seamless beamtime submission processes to date, greatly enhancing the experience for scientists.

Infrastructure & platforms

Network security has been enhanced ensuring only approved devices can connect. Staff device management was improved with tools that require approval and monitoring for administrative actions. Participation in a simulated cyber-attack helped validate these existing security projects.

Software engineers in the Reviews & Allocations team – Josh Dawes, Bhaswati Dey, Tom Cottee Meldrum, Rasmia Kulan, and Alex Lay.

Software engineers in the Users and Authentication team heavily focused on replacing old, insecure, legacy systems with modern solutions; increasing reliability and security - James Argent, Vladimir Garanin, and Jonathan Fijalkowski.

The ISIS Electrical and Electronic User Support Group.

Team case study: The ISIS Electrical and Electronic User Support Group

The Electrical and Electronic User Support Group (EEUSG) at ISIS is made up almost entirely of ex-apprentices. Their work underpins three main areas: the running of experiments during a user cycle, the engineering work during the shutdowns and the ongoing delivery of small and major projects.

Jamie Nutter was appointed as group leader in 2024. “I am immensely proud of this achievement and of leading the group that I have been working in since my apprenticeship,” he says. “This role brings new challenges and opportunities as I lead a great team of skilled technical professionals to develop and support increasingly complex experiments and equipment.”

Tara Allinson (image, above right) joined the team recently, after finishing her apprenticeship and winning STFC's Apprentice of the Year award in the process. “I decided to take the apprenticeship route as I was drawn to the vocational rather than purely academic route,” Tara explains.

For Maksim Schastny, an electronics technician, completing an apprenticeship turned out to be the best decision he ever made. "I'd say the diversity and the ability to help people makes my job so fulfilling. We make scientific experiments possible and that helps to create a better future for the planet," says Maksim.

Max Williams (pictured, centre, right) the Instrument & User Support Section Leader agrees; “The best thing about my job is the incredible variety of work I get to engage in. Each day brings new challenges and opportunities, ensuring that no two days are ever the same.”

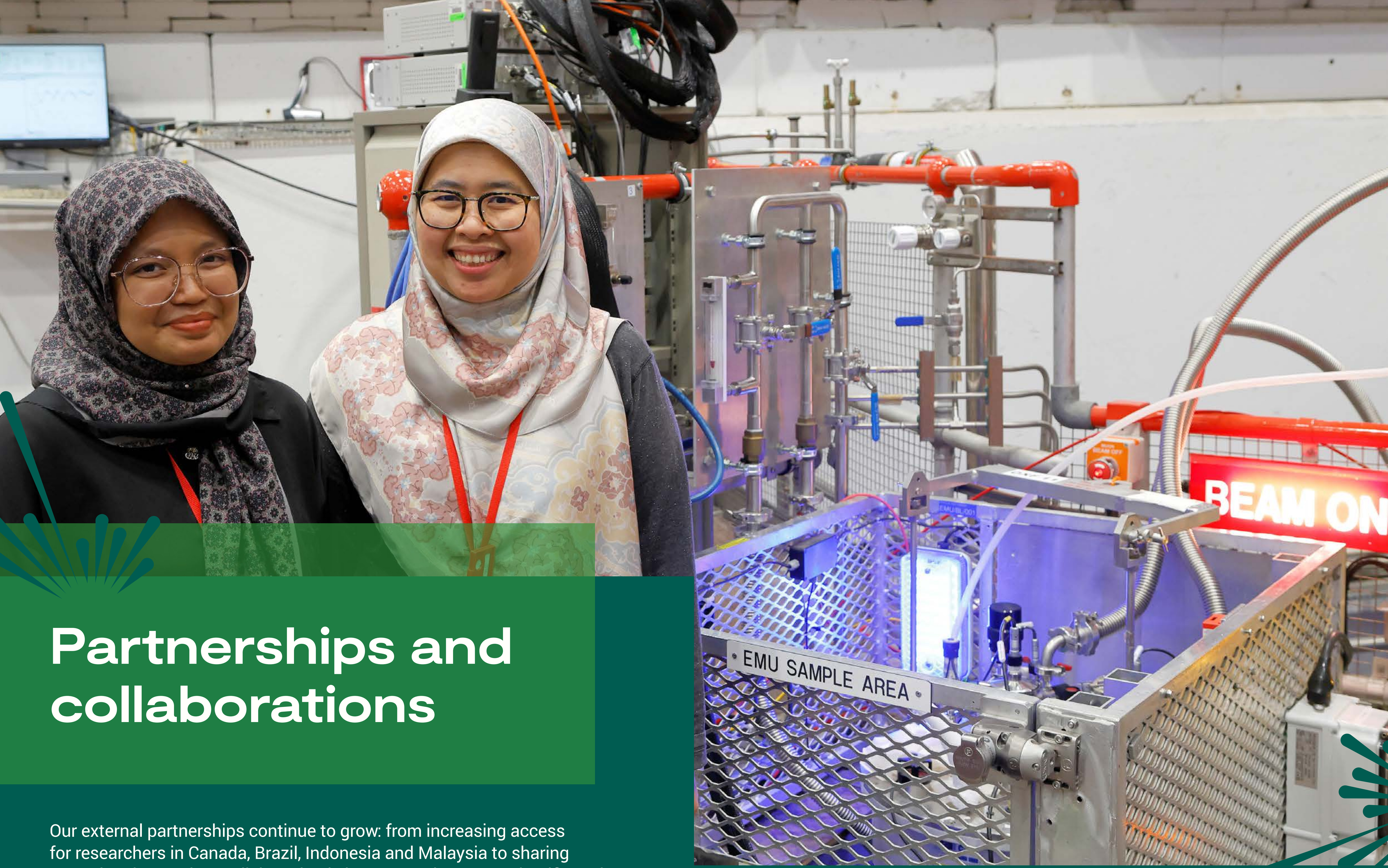
Matt North is Instrumentation Division Head. He says, "I actually studied Art and Business during my AS levels so you can probably tell I didn't think I was going to become an engineer at that point!"

> “For those considering doing a job like mine in the future, I'd recommend that you think about how you prefer to learn and take into account that apprenticeships and degrees are both valid routes to a successful career.”
>
> Matt North

Tristan Canfer (image, bottom right) joined the ISIS beam diagnostics team as a technician after his apprenticeship and has since moved into the EEUSG as an electronics engineer.

“Science at ISIS has impact from the products in your home to cutting-edge tech and exploration of the universe. My job is to help build the equipment that makes the science possible.” Tristan explains.

From top: Tara Allinson, Max Williams and Tristan Canfer.



Partnerships and collaborations

Our external partnerships continue to grow: from increasing access for researchers in Canada, Brazil, Indonesia and Malaysia to sharing operational expertise. Collaboration is key as we share our scientific and technical knowledge, pushing the boundaries of neutron and muon science to enable new discoveries that benefit society.

Wan Nurfadhilah Binti Zaharim and Nurul Izzaty Hassan, from Universiti Kebangsaan Malaysia, on the EMU instrument.

International collaborations

Italy

ISIS marked 40 years of Italian partnership in 2024. Part of the celebrations included an event at University of Rome Tor Vergata, where Mark Thomson, STFC Executive Chair, was invited to give a seminar followed by cake cutting.

Philip King (ISIS), Silvia Licoccia (University of Rome Tor Vergata), Mark Thomson (STFC), Carla Andreani (University of Rome Tor Vergata).

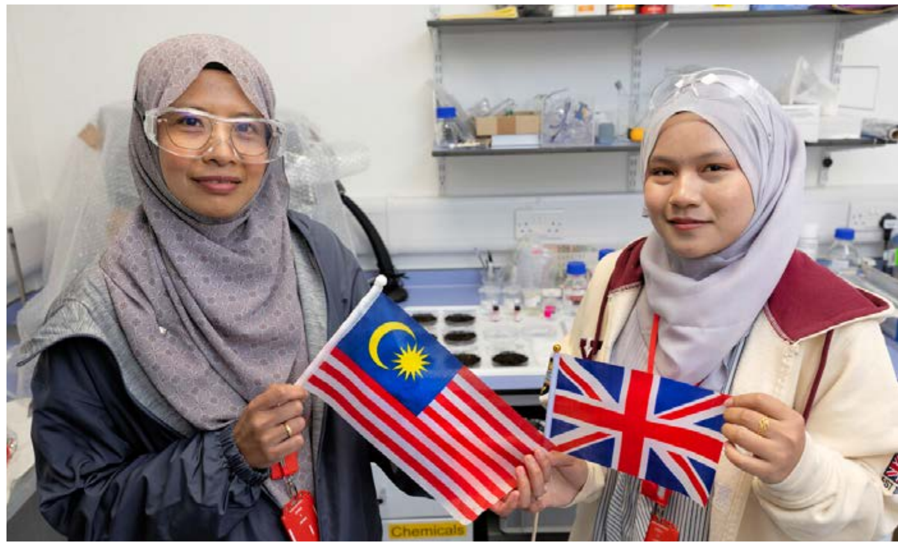
STFC and Italian Research Council CNR signed a new partnership agreement to develop the Tosca+ instrument as part of Endeavour in February.

Roger Eccleston, STFC Executive Director for National Laboratories and Giuseppe Colpani, CNR Director General, at the signing ceremony in Rome.

Indonesia and Malaysia

ISIS currently has an award from the International Science Partnerships Fund (ISPF) to support Indonesian and Malaysian use of the facility.

Ratno Nuryadi, Chairman of Research Organisation for Nanotechnology and Materials, BRIN, Indonesia, visited ISIS in November 2024 following the signing of an ISIS-BRIN Memorandum of Understanding. BRIN is Indonesia's National Research and Innovation Agency.



Nurfarwizah Azwan and Noor Fitrah binti Abu Bakar (Universiti Teknologi MARA, Malaysia) using IMAT to study seed germination under abiotic stress conditions.

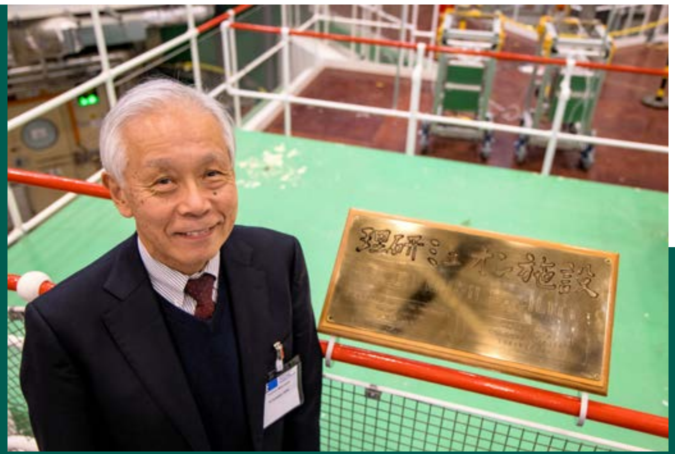
Sweden

The long-term partnership agreement between ISIS and Swedish Research Council Vetenskapsrådet was renewed in early 2025.

Ayan Samanta and Tim Günter (Uppsala University, Sweden) investigating cross-linking and thermo-gelling of a novel collagen-based hydrogel with medical applications using small angle scattering at ISIS.

Japan

The long-term RIKEN-ISIS partnership was marked by a celebration event at RIKEN in November 2024.



Above: RIKEN President, Makoto Gonokami, Philip King (ISIS), Emil Levendoğlu (Minister and Deputy Head of Mission, British Embassy in Tokyo) and other senior RIKEN and British Embassy staff marking the occasion.

Left: Yoichiro Matsumoto, Science Advisory to Japanese Ministry of Foreign Affairs, visited ISIS in Oct 2024.

Canada

ISIS has seen a strong increase in Canadian usage following an ISPF award to enable partnership working with Canadian researchers.

Drew Marquardt and students Stuart Castillo and Maks Dziura (University of Windsor, Canada) are using small angle scattering at ISIS to study mechanisms of cell death.

Switzerland

ISIS, Diamond and the PSI in Switzerland are collaborating on 16 projects to develop the science and technologies of neutron and X-ray scattering, and muon spectroscopy, supported by an ISPF award. The photo shows the first collaboration meeting, held at RAL and attended by over 50 ISIS, Diamond and PSI staff.

Brazil

ISIS is working with Brazilian colleagues to further develop Brazilian use of neutrons and the ISIS facility, also supported through an ISPF award.

Manuela Sabino (Universidade de São Paulo, Brazil) and Fernando Rei (Univ. of ABC, Brazil) are seen here on SANS2D during a visit to ISIS in November 2024.

Case study: Barium bismuth surprises scientists with anomalous thermal conductivity characteristics

An international team of researchers used the SXD instrument to help explore the unusual thermal conductivity of barium bismuth crystal (BaBiO3). The research was led by Professor Valentina Martelli from the Institute of Physics at the University of São Paulo, Brazil.

This publication is the first to come out of the Brazilian use of ISIS funded through the International Science Partnerships Fund (ISPF) programme.

Alexandre Henriques and Matthias Gutmann at ISIS.

Sharing operational expertise

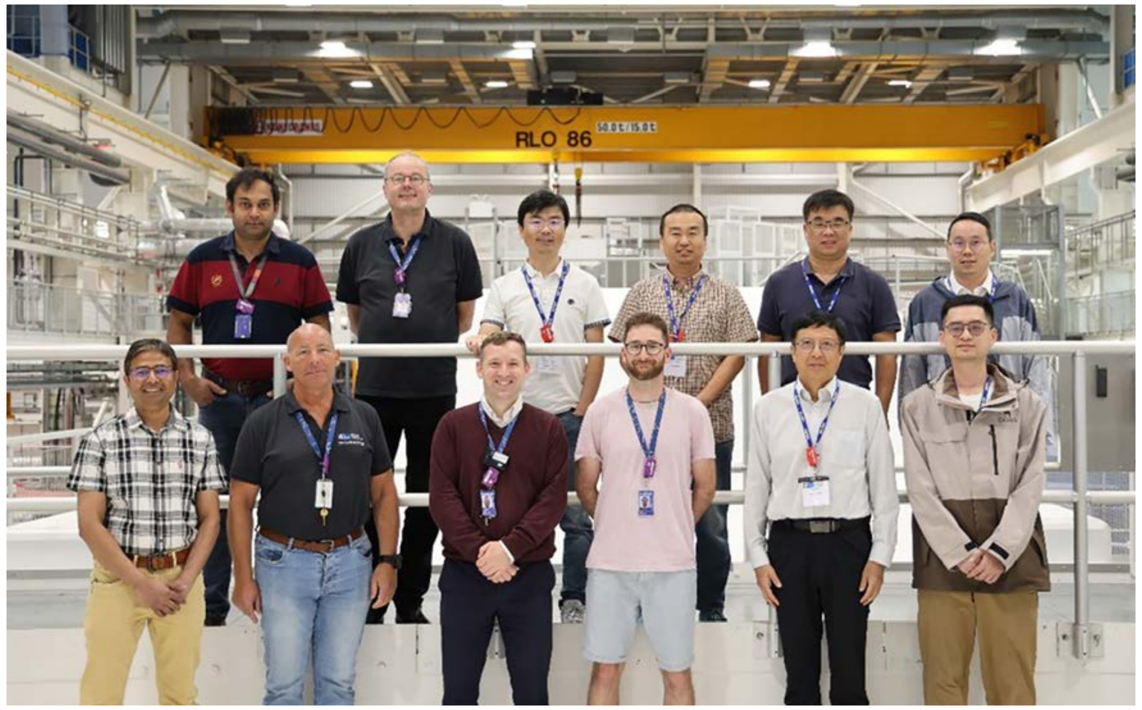
Building relationships

The Operations Group have been pro-actively building relationships with other facilities and working with UK institutions such as National Physical Labs for non-destructive testing, and The Welding Institute for hot isostatic press and electron beam welding technology. Visits to PSI and the ESS have been used to discuss safety issues and operational discussions around targets and cryogenics. Ongoing meetings with the Spallation Neutron Source (SNS) in the US are focussed around sharing best practice and discussing collaborations around manufacturing and operational experience.

Collaborations with other facilities and institutions

Developing collaborative relationships with other facilities and institutions is fairly common for the scientific and engineering groups, but less so for sharing of operational experience directly between technical teams. This has been improved by Jeremy Moor, Head of the Targets Operations Group. 2024 has seen many mutually productive meetings and visits with SNS, ESS and PSI, and ISIS is already seeing the benefits.

In addition, the target design group within ISIS' design division have signed an addendum to an existing MoU with CERN looking to strengthen collaboration specifically around the design and production of high-power tungsten-based targets. Visits and (remote) workshops have also been held with CSNS (China) and SNS (US), where current progress and plans have been shared and discussed.



The CSNS and ISIS teams at ISIS.

People and teams

The research conducted at ISIS is supported by approximately 600 staff – from beamline scientists that run our instruments to engineers that keep the accelerator operational and the User Office that supports our visiting researchers – everyone at ISIS plays a key role in keeping the facility running.

ISIS placement student Joanna Panchadcharam in the Catalysis Lab.

Student engagement

Facility Development Scheme

To mark ten years of the ISIS Facility Development Studentship scheme, we carried out a formal review, which included collecting feedback from previous and current students and supervisors. The results were overwhelmingly positive, with almost a quarter of the respondents specifically requesting the scheme be expanded.

Other benefits commonly cited were the increased collaboration between ISIS and the host universities, for both supervisors and the students. The scheme was also recognised as offering a unique training opportunity for students. Over 80% of the survey respondents said that being part of the scheme, as a student or supervisor, positively impacted their career journeys.

40% of those who have completed their PhD through the scheme have gone on to work in industry, 28% to academia, 11% join a neutron or X-ray facility (or in a position joint with both), and others now work for UK and USA government departments, or in the third sector.

10 years

435 applications

118 studentships

35 partner institutions

59 staff members

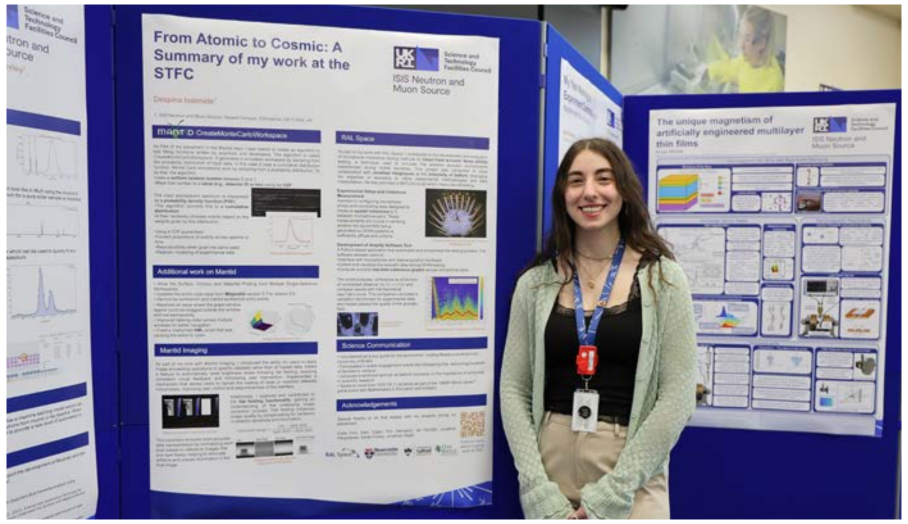
100 external supervisors

So far:

52 PhDs awarded

92% completion rate

Industrial Placement student poster event



Despina Ioannide at the ISIS student poster event.

ISIS hosted 25 year-in-industry students in the 24/25 year. At the end of their year at the facility, the students had the opportunity to present their work as a poster to the rest of the facility. The event showcased the quality and breadth of the work carried out by the students over the past year.

Ella Beck: radiation monitoring, pixel counting and a unique experience

How do you measure gamma radiation levels inside the gigantic concrete and steel monolith at the heart of the ISIS target stations?

Industrial placement student Ella Beck had just twelve months to answer that question when she joined the Neutronics team at ISIS. The Target Operations Group had video footage from within the monolith, from which Ella hoped to estimate relative levels of gamma radiation by counting the brighter damaged pixels that appeared.

It had been done elsewhere with footage that had a plain black background. The challenge facing Ella was that her footage was moving, with a shifting, coloured background, and full of reflections and other details.

“It was quite satisfying to overcome those challenges and find a solution,” says Ella.

The code Ella developed compares each pixel to its neighbours, and to itself in adjacent frames of the video. It can filter out reflections and adapt to changes in brightness as well as movement in the footage.

For Ella, the project provided a unique insight into the workings of a large research facility and allowed her to follow her interests.

“I’ve always been interested in radiation monitoring,” Ella explains. “But I had no idea what I would be doing on my placement. For placements at ISIS you can tailor it to your personal interests. Because I like dosimetry, that’s where I took it!”

“Working at ISIS definitely made a career in research feel more accessible,” she adds.

> **This project was something I could never do at university. We wouldn’t have the footage, access to the computing cluster, or see the monolith first hand.**
> Ella Beck

Ella Beck in front of the TS1 monolith.

Technicians

ISIS continues to play a leading role in the delivery of the STFC Technician Commitment, which aims to improve the visibility, recognition, career development, and sustainability of technical careers across the organisation. Members of staff from ISIS chair both the Technician Commitment Steering Group and the associated Working Group, helping to shape and drive technician-focused activity across STFC.

STFC's work in this area was recognised nationally with a Technician Commitment Impact Award, highlighting the organisation's progress in embedding the values of the Technician Commitment.

STFC Technician Commitment Conference 2024

The STFC Technician Commitment Conference 2024 brought together technical staff to share knowledge, celebrate success, and build stronger cross-site connections. ISIS staff made a strong contribution to the conference, through both organisation and presentations.

The programme included talks by technicians, a communications workshop, a session on professional registration, and an inspiring keynote from an Ulster University embroidery technician. The event concluded with the presentation of the STFC Technician Awards, recognising excellence in four categories: Early Career Excellence, Sustained Achievement, Visibility and Engagement, and Champion of Technical Expertise.

Attendees at the Technicians Commitment Conference 2024.

Rachel Pearce: from lifeguard to senior lab technician.

Rachel joined ISIS in 2018. Previously, she had worked as a lifeguard but, in 2002, she wanted a career change and started work as a Lab Technician at a food science lab in Banbury, before moving to Warwick University and the Research Complex at Harwell.

Rachel currently works in the fourteen sample prep labs at ISIS, where she ensures the labs are prepared for users, manages samples and equipment, orders consumables, and maintains an overall clean environment for users to work in.

One key material that Rachel stocks in each sample preparation lab is D_2O, which is used a lot at ISIS. ISIS is looking to be more sustainable with its use of D_2O, and Rachel is part of a new team who are exploring D_2O recovery and recycling. The project is only six months into development, but Rachel is excited to be part of it.

Rachel Pearce

Public engagement

Inspiring the next generation

2024-25 has been a record-breaking year for public engagement at ISIS, as we reached 8260 school pupils, students in further education, teachers and members of the public through our engagement programme. Over the year, the ISIS public engagement team have delivered close to 50 public and school events, with activities spanning a wide range of themes to reflect the variety of work and expertise at the facility.

Through in-person tours and activities, ISIS is able to showcase science and engineering on a scale beyond that experienced at school, and our virtual activities inspire audiences that are unable to visit the facility in person.

Engaging diverse and under-represented audiences is an important part of our programme. This year, we have continued to increase our engagement with under-represented audiences, including those from areas of high deprivation, providing crucial support to enable participation in our engagement activities. We continue to deliver events highlighting diversity in STEM, including linking into national campaigns such as International Women's Day, and have created new resources for schools to support careers education and help strengthen science identity amongst young people.

> Particularly enjoyed visiting ISIS. I know about the technology but visiting such a large-scale facility and seeing it for myself is something completely different.
> Visitor to ISIS

A-level students building solar cars during ISIS workshop at Engineering Your Future event.

> ISIS was epic. I never ever saw a synchrotron before. I explored the experiments with tesla coils, the robohand and all experiments with muon beams there.
> Visitor to ISIS

Work experience placements

Work experience placements at ISIS continue to be extremely popular. This summer the facility hosted 32 work experience students for week-long placements, offering unique insights into the facility alongside diverse roles and career pathways. ISIS also hosted virtual and in-person events as part of training days for over 30 UK educators and delivered training in public engagement for 96 undergraduate and postgraduate students at UK universities.

ISIS team at Stargazing public event.

ISIS team at Oxford Brookes Science Bazaar.

> ISIS was fantastic. The staff were brilliant. I learned so much about how it is used and for what purpose. Really impressed.
> Visitor to ISIS

Awards and prizes

ISIS Springboard Award Winners

The ISIS Neutron and Muon Source has presented three early-career researchers with its first ISIS Springboard Awards. The awards were won by Shurui Miao from the University of Oxford, Jennifer Johnstone-Hack from the University of Sheffield and William Sharratt from the University of Liverpool.

ISIS created the Springboard Awards in 2024 to support and encourage early-career researchers to use neutrons and muons in their research. Awards last three years and will provide recipients with funding to present ISIS research at conferences, a case study highlighting their research and the chance to spend an extended period at ISIS, amongst other benefits.

Shurui Miao works with ionic liquids, a novel class of solvent which may enable more sustainable chemical processes. "The Springboard Award provides an excellent opportunity to collaborate with scientists at ISIS, to make new connections and to learn new neutron techniques," Shurui explains.

Jennifer Johnstone-Hack investigates electrochemical devices using complementary neutron and X-ray methods. "Collaboration is the best way to do high-quality science, and I feel that the award is an ideal platform to encourage neutron users to work together to solve challenges relating to electrochemical devices, as well as to improve communication and collaboration between researchers," says Jennifer.

William Sharratt uses neutrons to study how polymers and surfactants (soaps) assemble in liquids in order to develop new materials. "This award will support me in establishing an independent research programme using neutron scattering to investigate hydrogels," William explains.

ISIS Springboard Award winners Shurui Miao (Oxford), Jennifer Johnstone-Hack (Sheffield), and William Sharratt (Liverpool).

Samantha Fedorenko and Nayan Kumar receiving their award from Mark Thomson, former STFC Executive Chair.

Brian Strugnel and Niall Smith receiving their award from Mark Thomson, former STFC Executive Chair.

ISIS graduates recognised at STFC awards

Samantha Fedorenko and Nayan Kumar from the ISIS design division were highly commended for the Outreach award, and Brian Strugnell and Niall Smith from the Magnet Power Supplies Group both won Rising Star awards.

All four have been involved with the Engineering Experience Programme (EEP), which links school students with STFC science and engineering, where students work on real engineering projects over several months.

ISIS PhD student Katie Morton wins Founder's Award

University of Bath PhD student Katie Morton has won the British Zeolite Association's 2024 Founder's Award for her PhD research.

Katie performed a wide range of experiments spanning different neutron spectroscopy techniques, taking her across the globe to facilities in Japan, France and Switzerland. Her project focused on how lignin, a component of biomass that is difficult to convert to useful products, behaves in a range of commercially available porous zeolite catalysts. The research could help scientists optimise catalysts to convert lignin into biofuels and other valuable compounds used by the chemicals industry.

The Founder's Award recognises the most promising PhD student each year working in the field of micro- or mesoporous research.

Jeff Armstrong, Katie Morton and Alex O'Malley.

Awards

2025 RSC Horizon Prize win for David Keen

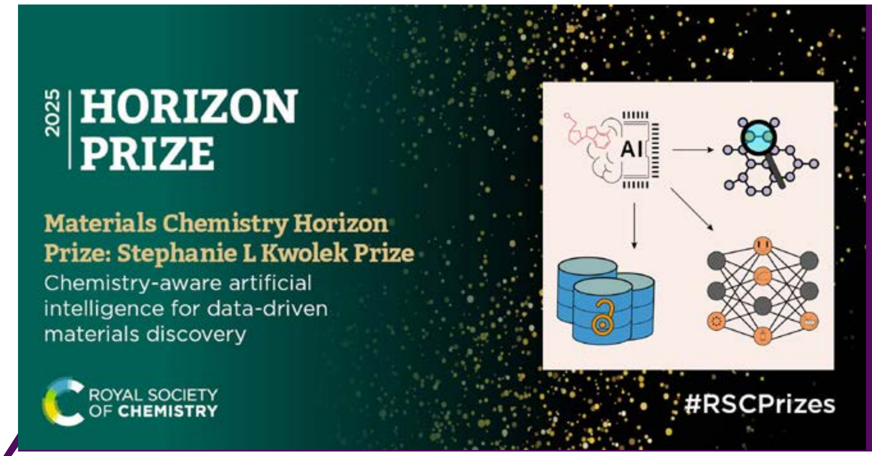
ISIS scientist David Keen is part of an international team awarded this year's Dalton Horizon Prize from the Royal Society of Chemistry. The prize-winning team includes 18 researchers from ten countries, led by Professor Tom Bennett from the University of Canterbury and The MacDiarmid Institute for Advanced Materials and Nanotechnology in New Zealand. The Prize recognises their discovery and development of hybrid glasses, a new family of glasses separate to the known inorganic, organic and metallic families.

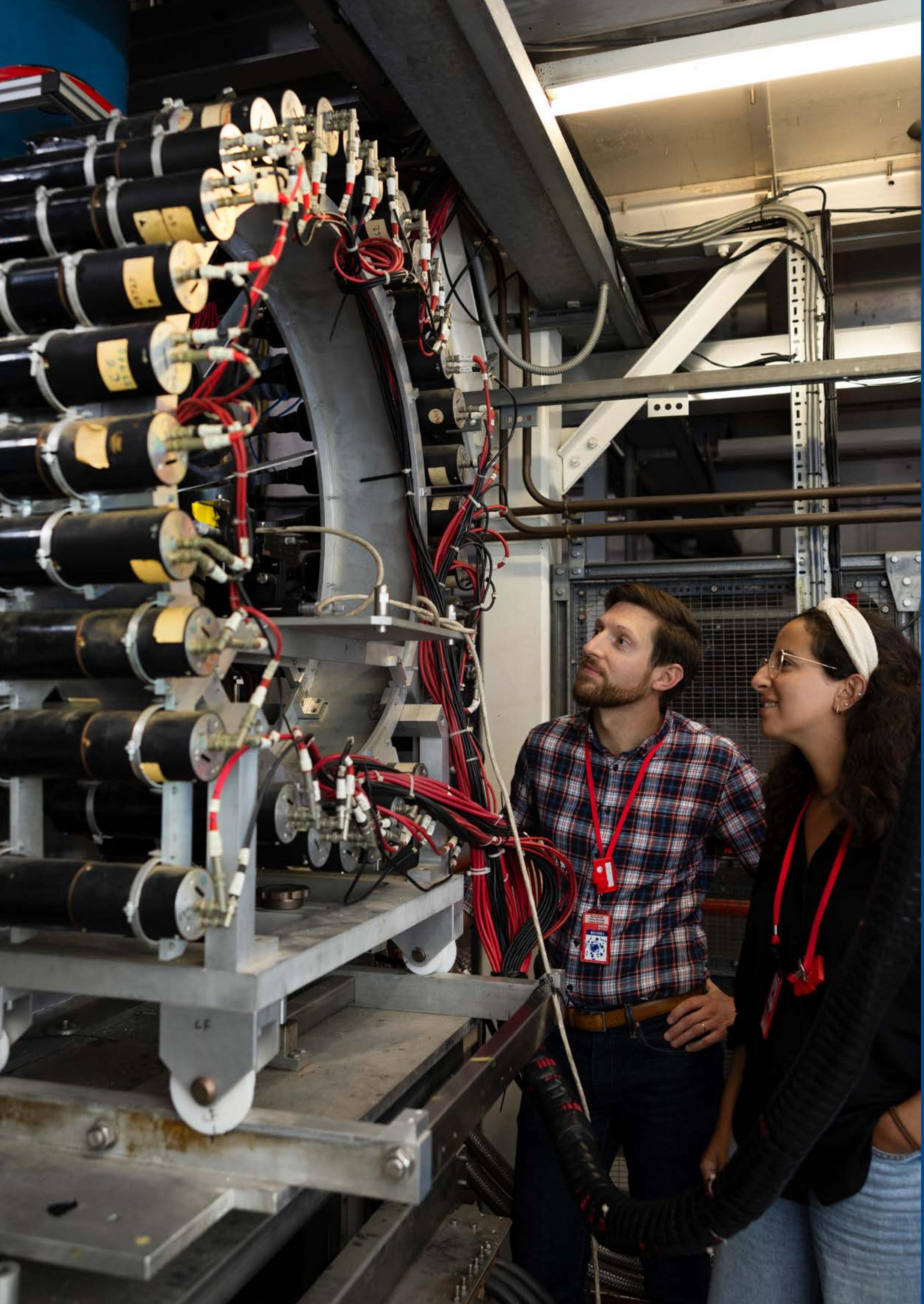
ISIS scientists were part of a collaboration that won the RSC 2025 Materials Chemistry Horizon Prize

The team, led by Jacqui Cole, won the prize for their development of chemistry-aware artificial intelligence (AI) software. They have applied this software to data-driven materials discovery, and provided these open-source materials databases and language models to the global scientific community.

Jacqui Cole is Head of Molecular Engineering at Cambridge, BASF / Royal Academy of Engineering Research Chair in Data-driven Molecular Engineering of Functional Materials and held a joint appointment at ISIS during the period where some of this work was conducted.

Alongside Jacqui, the prize-winning team includes current and former ISIS staff members Jos Cooper, James Doutch, Stephen Hall, Ritchie Haynes, Nina Juliana-Steinke, Saurabh Kabra, Daniel Nye, Mostafa Saad Ali Ebied, Gavin Stenning, Adam Washington and John Webster.





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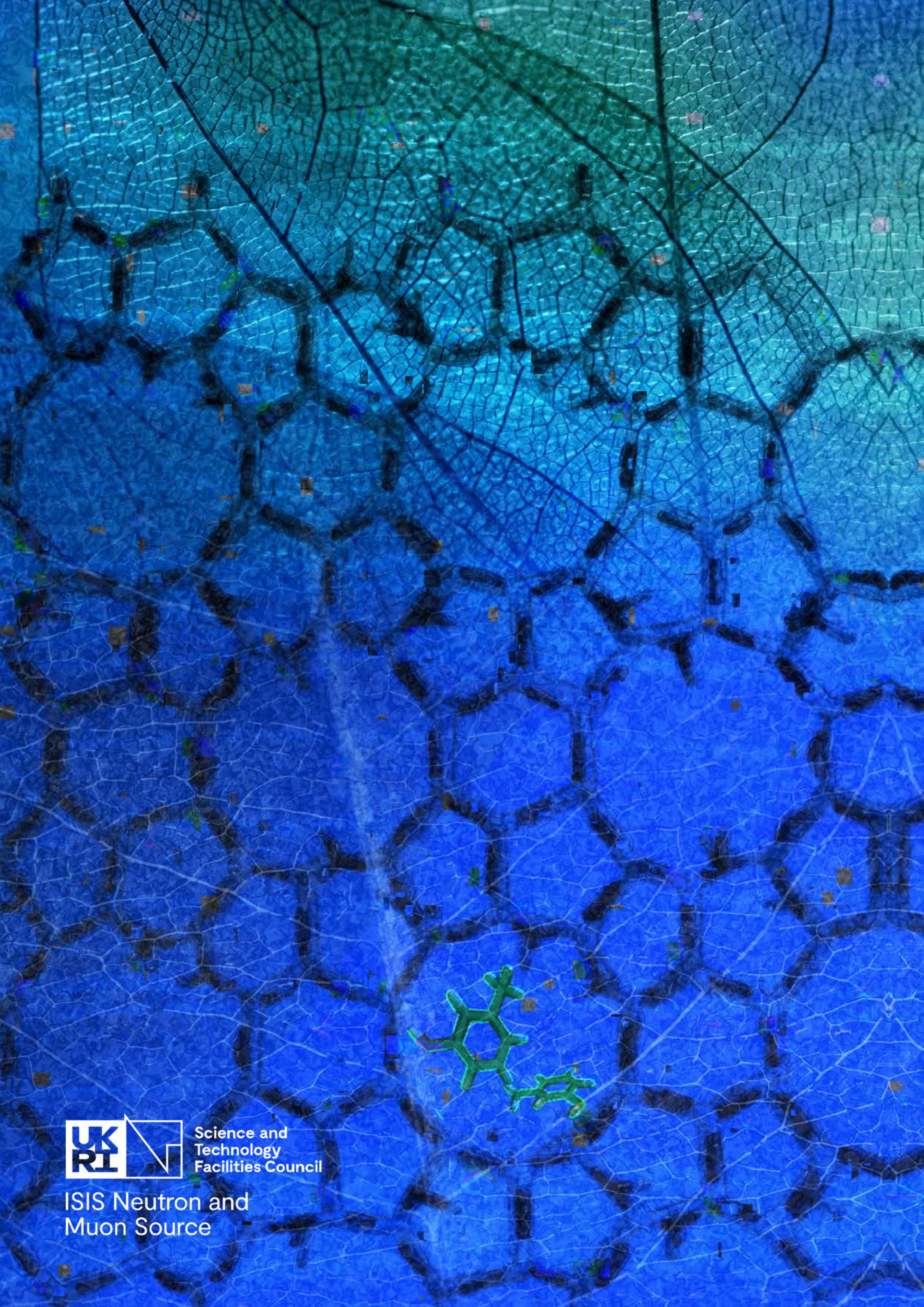

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