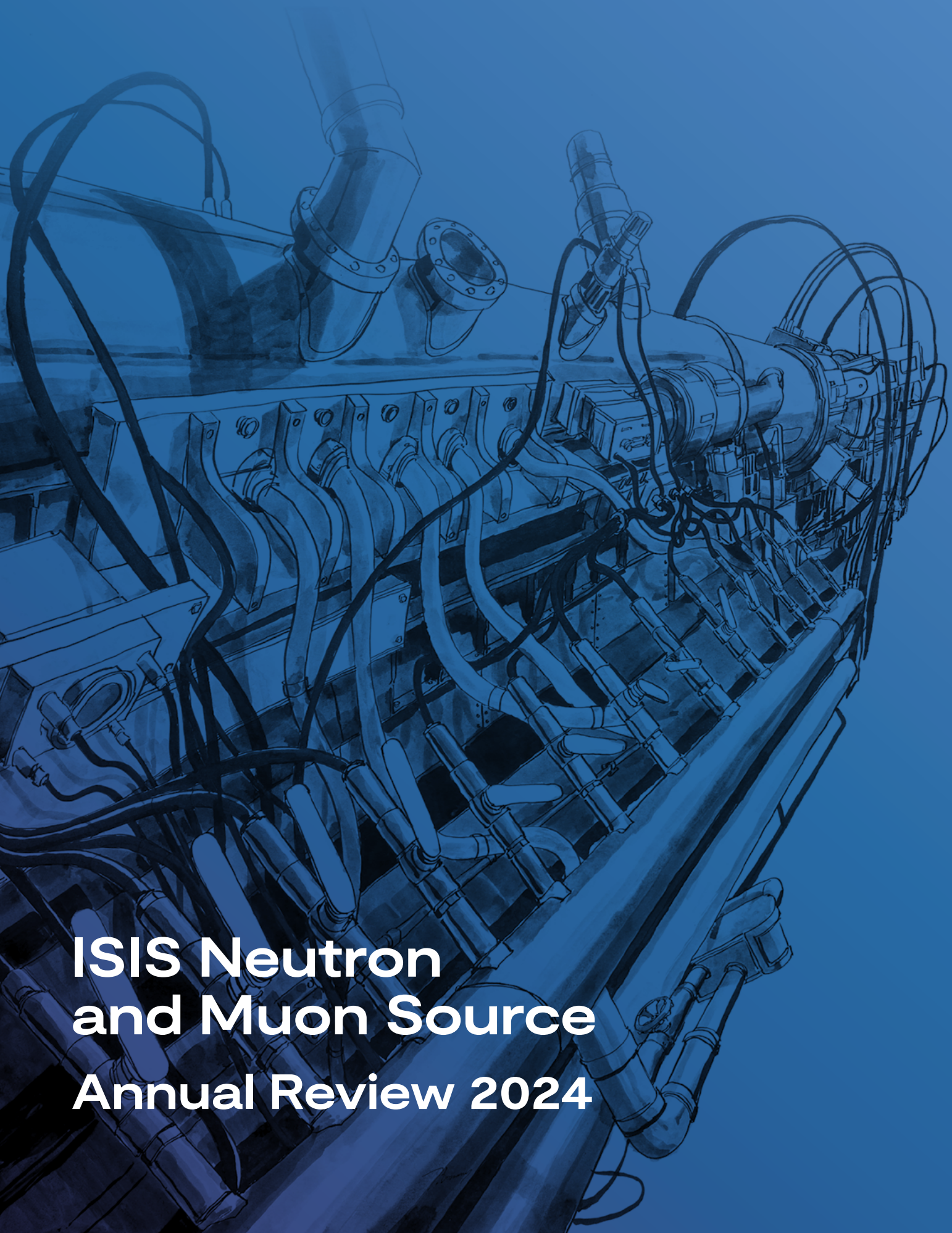
Science and Technology Facilities Council



ISIS Neutron and Muon Source

Annual Review 2024

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: drawing of the extracted proton beamline by Daniel Bossons.

Contents


ISIS-Italy Partnership:
Summa
• Ove our partnership has strengthened in sharing a common com utron and muon instrument innovation, excellent science and development of early-career researchers. All nurtured by stea friendship.
• Since emarkable milestones in various fields, including partn pment of ISIS neutron and muon instruments under the stro of bilateral Agreements CNR- ISIS.
ISIS-STFC agreement the Italian and UK teams are working program launched by STFC for the 2020s and beyond, to h capability and carry out research that advances al-world challenges in pa hip with our user
UKRI
Science and Technology Facilities Council

Foreword

2024 has been a year of celebration. Over the past four decades, ISIS has undergone a remarkable transformation, underpinned by the continuous development of our accelerator, target stations and instruments. This unwavering commitment to scientific and technical excellence, driven by the commitment and ingenuity of our staff in partnership with our user community, has enabled ISIS to grow and adapt as science needs have evolved. Together with our users, we have produced a vast body of research that addresses the increasingly complex and interdisciplinary scientific challenges of the 21st century.

During our 40th year of operation, we have reflected on these achievements. It is clear that our success has been built on the collaboration and the dedication of our staff and users. It is fitting, then, that we have marked this important milestone with those who have been instrumental in shaping ISIS into the facility it is today. Through user meetings, staff events and our UK roadshow, we have highlighted their remarkable contributions alongside the major technical and scientific advances that have established ISIS' reputation as a leading international research facility.

Anniversaries also provide the opportunity to look forward. This is an exciting time for ISIS as we embark on the Endeavour instrument development programme and progress our plans for ISIS-II. Endeavour is making excellent progress, with SuperMuSR and HRPD-X now well-advanced and subsequent projects taking shape. ISIS-II is a much longer-term programme, but it is critically important that, even at this early stage, the design is informed by our best expectation of future scientific requirements, so we will be seeking the advice of our users and other stakeholders over the next few months.

In the pages of this review, you will find summaries of all aspects of ISIS operations and development over the past year. I hope you will agree with me that the review reflects a facility that, after 40 years of operation, is still thriving and looking forward to a long and impactful future.

Roger Eccleston
Director of ISIS Neutron and Muon Source

Left: ISIS Director Roger Eccleston speaking at an event to mark forty years of collaboration with Italy.

This year at ISIS

Operations

2867
hours of beam on target

5
cycles

TS1 ran for 4 out of 5 cycles

454
mAh of beam delivered

69.4%
availability

Experiments

1243
proposals submitted

One proposal round was for TS2 only

694
unique principal investigators

of which 156 were new to ISIS

35
countries represented in proposals

501
publications

2610
authors

78.1%
international collaboration

Publications

7.1%
academic-corporate publications

Public engagement

5895
public engagement activities

1369
unique users including 568 students

3062
beam days delivered

Link to publications

bit.ly/3XuKPS5

Celebrating 40 years of neutrons at ISIS

On 16 December, ISIS will mark 40 years since first neutrons were produced. 2024 has seen ISIS' birthday marked in a variety of ways: staff events, talks and lectures, and events for the public. We have also marked 40 years of the ISIS-Italy partnership in an event that celebrated numerous joint endeavours in science and instrumentation.

Above: ISIS staff at a celebratory barbeque in July.

40 Years of ISIS Neutron and Muon Source

40 years of ISIS has seen:

35000 proposals received

80000 beam days allocated

$8x10^{23}$ protons accelerated

60000 users from 40 countries

15000 publications co-authored

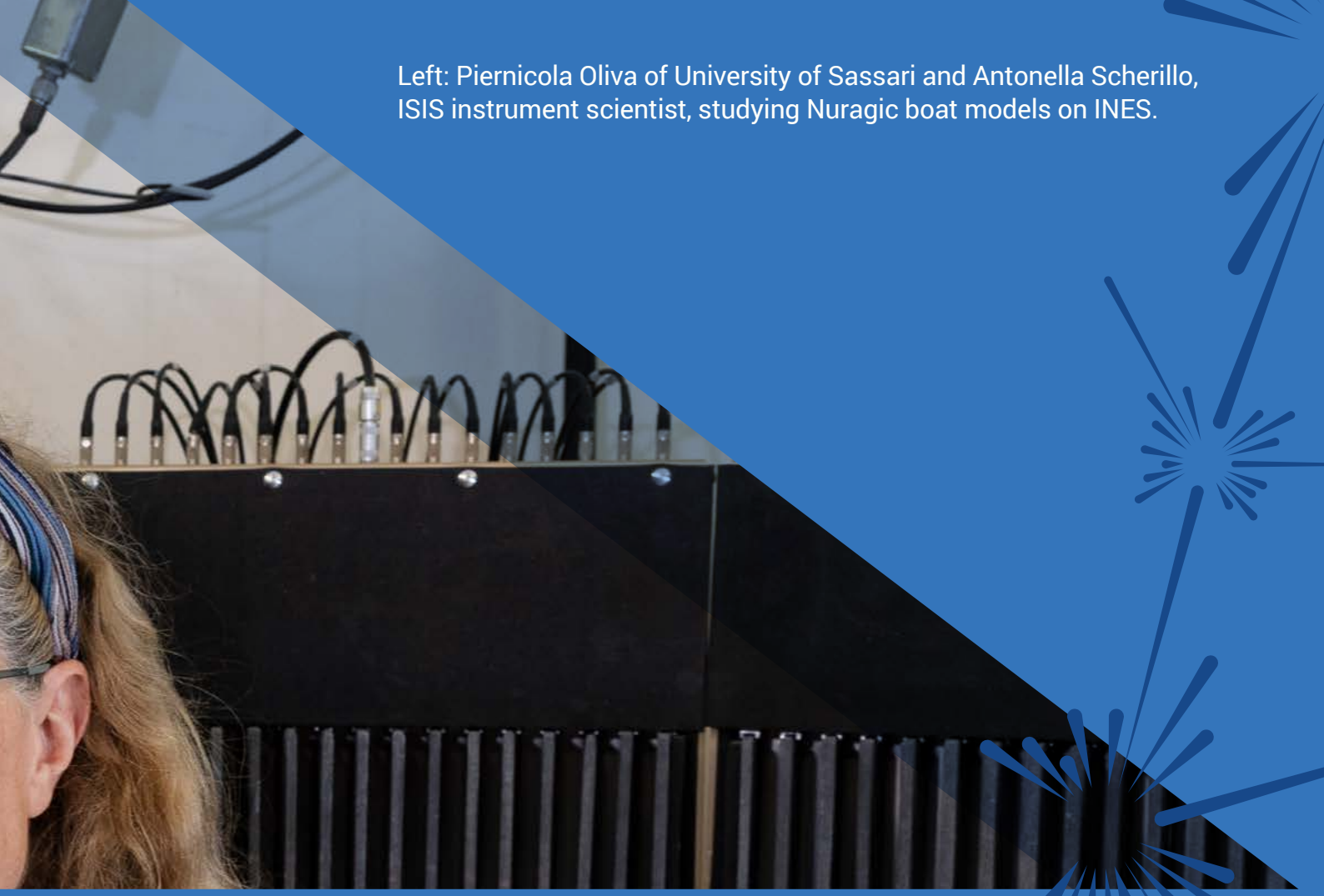
130 Tb of data collected

ISIS @ 40 roadshows

The strong engagement and collaboration between between ISIS and its user community is central to our high quality and impactful scientific output. As part of our strategic goal to grow the United Kingdom user community and to celebrate the 40th anniversary of neutron science at ISIS we have arranged a series of science meetings across the home nations. The 'ISIS Science Roadshows' have highlighted the regional strengths and diversity of the ISIS research programme and provided excellent opportunities for speakers at all career stages.

The meetings in Cardiff, Belfast, Manchester, London and Edinburgh have been vibrant and enjoyable thanks in no small part to the skill and dedication of the meeting organisers within ISIS and the UK host universities!

Attendees of the Belfast roadshow.



Left: Piernicola Oliva of University of Sassari and Antonella Scherillo, ISIS instrument scientist, studying Nuragic boat models on INES.

Delivering a world-leading science programme

The research conducted at ISIS in a year showcases the breadth, depth and quality of the research that is delivered. We have welcomed new and returning scientists and supported them to deliver outstanding research in areas including quantum materials, sustainability, manufacturing and healthcare.

Preferred sites for deuterium in an amorphous metal alloy

A UK/Japan collaboration has investigated the absorption of deuterium in the metal alloy $Ni_{67}Zr_{33}$ and how this impacts its structure.

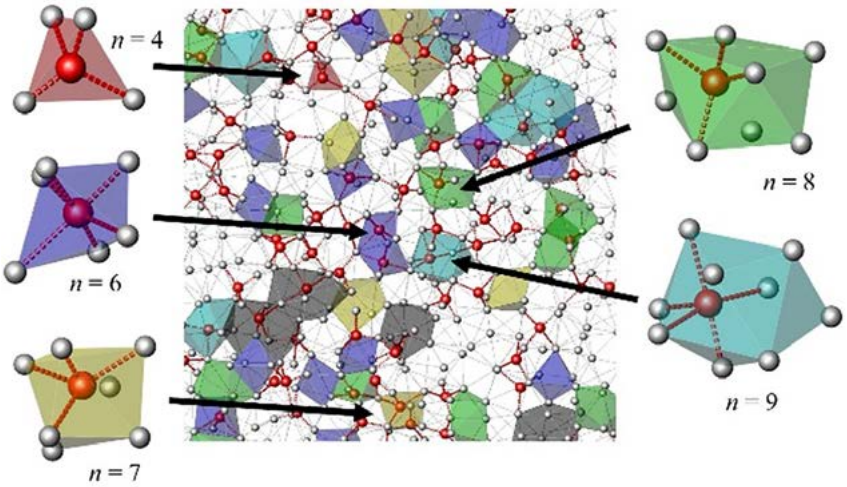
How hydrogen affects metals is a fundamental engineering challenge that has to be solved if hydrogen is to be a viable energy vector for national economies.

Neutron diffraction has the advantage that hydrogen (or deuterium) has a coherent neutron scattering length that is comparable in magnitude with those of the metals in the alloy. The group used a deuterated sample because the large neutron incoherent scattering cross-section of hydrogen results in a strong background scattering.

In this study, the scientists studied deuterium absorption into the amorphous metal alloy $Ni_{67}Zr_{33}$ using neutron diffraction experiments on Sandals alongside X-ray measurements.

They analysed their results based on a 3D-model where the metal structure contained different polyhedral holes. They found that more than half of the deuterium occupies a tetrahedral hole, with the other half occupying larger polyhedral holes and octahedral holes, despite there being more tetrahedral holes present.

The low occupancy of tetrahedral holes is likely because their occupation requires the metal atoms to move to accommodate the deuterium. Reducing this atomic displacement would be preferable in materials used for the storage and transport of hydrogen, as more displacement causes structural damage.



Examples of the coordination environments of deuterium in several polyhedral holes, where n represents the number of vertices. The red and grey spheres represent deuterium and metal atoms, respectively.

Instrument: Sandals

Related publication: Deuterium occupation of interatomic hole sites in $Ni_{67}Zr_{33}$ amorphous alloy, *J All Com*, 10.1016/j.jallcom.2023.171094

Funding: JSPS KAKENHI, Japan

Authors: K Itoh (Okayama University), J Saida (Tohoku University), ER Barney (University of Nottingham), AC Hannon (ISIS)

Studying battery cycling on the beamline

During his PhD with the University of Sheffield, ISIS facility development student Innes McClelland developed a cell for testing battery materials during their operation using muon spectroscopy.

One material that is proving increasingly vital for future batteries is $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$, known as NMC811. This cathode material has a high capacity, but often suffers an irreversible capacity loss between the first charge and discharge.

Muon spectroscopy is an excellent tool for studying these materials because it can probe the diffusion of ions such as lithium and sodium on a local scale, largely avoiding interfacial or grain boundary effects.

As part of his ISIS facility development studentship, Innes McClelland designed a cell that could study battery materials during operation. He and his colleagues were able to use this cell to study NMC811 to investigate what might be causing its lack of repeat cyclability.

By combining muon spectroscopy with electrochemical methods, they were able to see that this slow diffusion was more prevalent on the surface of the cathode, rather than in the bulk material.

This suggests that processes that focus on stabilising the surface of the material are likely to be more successful at improving its properties.

Innes on the EMU beamline with the sample cell.

> **The exciting development of operando muon spectroscopy opens up a wide range of opportunities for researchers working on energy storage materials, allowing a unique perspective of ionic diffusion from inside the materials themselves whilst in operation.**
>
> Innes McClelland

Instrument: EMU

Related publication: Direct observation of dynamic lithium diffusion behavior in nickel-rich, $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$ (NMC811) cathodes using *operando* muon spectroscopy, *Chem Mater*, DOI: 10.1021/acs.chemmater.2c03834

Funding: Faraday Institution

Authors: I McClelland, SG Booth, NN Anthonisamy, LA Middlemiss (University of Sheffield and Faraday Institution), GE Pérez, PJ Baker (ISIS and Faraday Institution), EJ Cussen, and SA Cussen (University of Sheffield and Faraday Institution).

Neutron imaging offers a view of catalysis in real time

A study of hydrogen adsorption and absorption within a packed Pd/C catalyst has demonstrated the potential of neutron imaging to capture industrially relevant catalytic hydrogenation unfolding in real time.

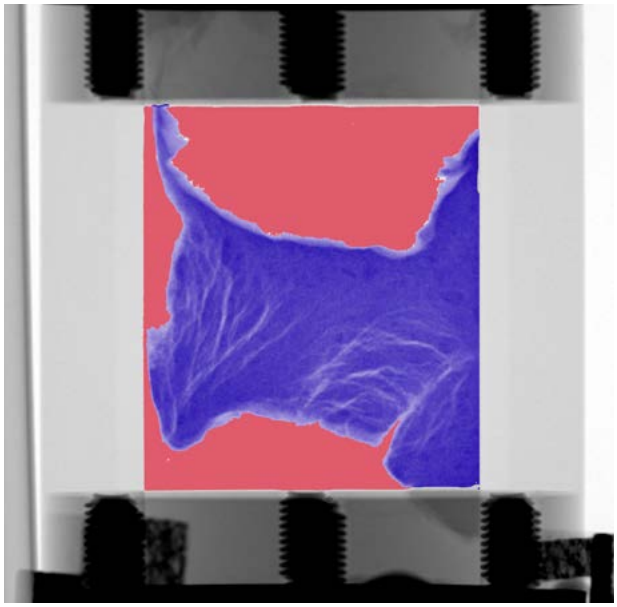
Given the widespread use of industrial catalysts, there is a drive to optimise catalyst properties to enhance their performance. To do so, it is helpful to understand how a catalyst functions at the microscopic level while under realistic reaction conditions.

Unlike X-ray imaging, neutron imaging can be used to study light atoms such as hydrogen, carbon, nitrogen and oxygen that typically make up reactants and products, in the presence of heavier elements.

With this advantage, a team including researchers from ISIS, the University of Glasgow, and industrial partners Johnson Matthey and Evonik Technology & Infrastructure GmbH used neutron imaging to follow the adsorption/absorption of hydrogen and then its replacement by deuterium on a palladium/carbon catalyst.

Neutron imaging shows that hydrogen uptake begins in the lower-left corner of the catalyst bed and advances in the form of a gas uptake front until the entire sample is saturated.

As well as highlighting the importance of catalyst packing within a reactor, the data show that it is possible to follow the progress of a reaction in real time *in situ*.



A neutron radiograph of a catalyst sample showing the silica wool packing in red and the catalyst bed in blue.

> The availability of both neutron imaging and inelastic neutron scattering at the same institution is a major advantage of carrying out these studies at ISIS.
>
> Stewart Parker,
> ISIS Catalysis Scientist

Instrument: IMAT

Related publication: *In situ* real-time neutron imaging of gaseous H_2 adsorption and D_2 exchange on carbon-supported Pd catalysts, *Chem Commun*, DOI: 10.1039/D3CC03930G

Funding: EPSRC

Authors: H Cavaye, W Kockelmann (ISIS), CE Ballas, D Lennon (University of Glasgow), P Collier, APE York (Johnson Matthey), PW Albers (Evonik Technology & Infrastructure GmbH) and SF Parker (ISIS).

Strain could have massive potential to squeeze new information out of quantum materials

A collaborative effort has resulted in a new technique to investigate quantum materials, combining strain tuning with neutron and X-ray scattering.

A key feature of quantum materials is a strong coupling between different degrees of freedom. For example, the positions of the atoms in a crystalline lattice can be coupled to the arrangement of quantum spins, such that changes in one induce changes in the other. This makes it hard to disentangle what is driving quantum effects in the material.

By applying precise strains along one direction, however, particular structural degrees of freedom can be isolated and their impact on the material properties investigated.

Researchers from UCL, ISIS and Diamond Light Source collaborated to combine strain tuning with neutron and X-ray scattering, designing custom setups to allow the structural and magnetic response of materials to be measured simultaneously.

They chose to study the material $Ca_3Ru_2O_7$, which displays a complex phase transition at low temperature where all the spins simultaneously rotate by 90°.

The team found that they could trigger the spin reorientation just by putting the material under strain. This insight was passed to their theoretician collaborators, who developed a microscopic model of the transition.

Having shed new light on the physics of $Ca_3Ru_2O_7$, the strain setups are now available for other groups to use in the future.

> The strain experiments provided a wealth of information to guide our theoretical work. It was really pleasing to see experiment and theory come together to provide new understanding of a complex problem.
>
> Adam Walker, UCL

> Strain tuning is a technique with a lot of potential for new discoveries, so we are very excited to see what new research ideas it is used for.
>
> Cameron Dashwood, UCL

Instrument: WISH

Related publication: Strain control of a bandwidth-driven spin reorientation in $Ca_3Ru_2O_7$, *Nat Commun*, DOI: 10.1038/s41467-023-41714-8

Funding: EPSRC

Authors: CD Dashwood, AH Walker (UCL), MP Kwasigroch (UCL and Cambridge), LSI Veiga (UCL and Diamond Light Source), Q Faure (UCL and ILL), JG Vale (UCL), DG Porter (Diamond Light Source), P Manuel, DD Khalyavin, F Orlandi (ISIS), F Krüger (UCL and ISIS), CV Colin, O Fabelo (ILL), RS Perry, RD Johnson, AG Green and DF McMorrow (UCL)

Exotic magnetic phase could put next generation computing on an upward spiral

Experimental evidence of rare magnetic behaviour in $LiYbO_2$ will help open the door to a new family of materials with potential applications in spintronics, quantum computing and more.

A spiral spin liquid is an enigmatic magnetic state in which spins fluctuate collectively as spirals. Although their existence has been predicted, spiral spin liquids are rare experimentally because they are very sensitive to structural distortions, which trigger transitions to more conventional magnetic states.

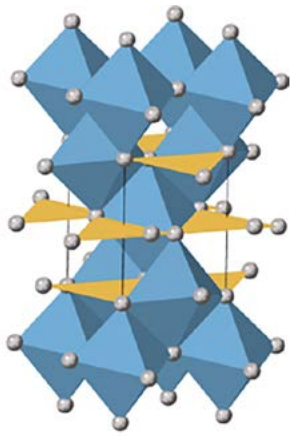
Neutrons are an ideal tool to measure exotic magnetic phases, such as spiral spin liquids.

Through a combination of high-resolution and diffuse neutron magnetic scattering studies, researchers from the University of Birmingham, ISIS and the ILL measured the spiral spin liquid ground state in $LiYbO_2$.

This is the first time that this type of spin texture has been observed in an elongated diamond lattice, having only previously been realised in perfect diamond lattices.

Their experiment on WISH showed experimentally that $LiYbO_2$ fulfils the theoretical parameters of a spiral spin liquid phase.

In proving that the elongated diamond lattice structure of $LiYbO_2$ can host a spiral spin liquid, these findings improve the fundamental understanding of magnetic phenomena and pave the way for the design of new magnetic systems with advanced technological applications.



$LiYbO_2$ adopts the tetragonal $I4_1/amd$ structure where Yb^{3+} ions (light blue polyhedra) form an elongated diamond network with tetrahedrally coordinated Li^+ ions (yellow polyhedra) lying in between.

> **Materials with partial magnetic order are becoming more prevalent in the field, and so understanding how to model systems like those with spiral spin liquid ground states are essential if quantum magnetic materials are to become functional in the future.**
>
> Jennifer Graham, lead author, University of Birmingham and ILL.

Instrument: WISH

Related publication: Experimental evidence for the spiral spin liquid in $LiYbO_2$, *Phys Rev Lett*, DOI: 10.1103/PhysRevLett.130.166703

Funding: University of Birmingham and the Institut Laue-Langevin

Authors: JN Graham (University of Birmingham and ILL), N Qureshi, C Ritter, AR Wildes (ILL), P Manuel (ISIS) and L Clark (University of Birmingham).

Floating magnetic droplets in a quantum spin liquid sea

A research team from China has used muon spectroscopy to discover an unusual magnetic ground state where both a quantum spin liquid and isolated ferrimagnetic droplets are present.

A quantum spin liquid (QSL) is an exotic magnetic state with strongly fluctuating and highly entangled spins down to zero Kelvin. Several QSL candidates have been proposed, but finding evidence of them is challenging.

Using multiple techniques, including μSR, the researchers studied $NaYbSe_2$ single crystals. The Yb^{3+} ions in this structure sit on a triangular lattice, the most common orientation for QSL candidates.

μSR enables the measurement of spin dynamics, as muons are sensitive to the local magnetic field and experiments can be done at very low temperatures. This makes it a powerful tool when determining if the ground magnetic state is static or dynamic.

They found evidence that both quasi-static and dynamic spin behaviour co-exist at low temperatures, indicating that the ground state of $NaYbSe_2$ can be regarded as a mixed state with both QSL and fluctuating short-range ferrimagnetic droplets present.

The study provides a brand new platform to study how a QSL state survives impurities and coexists with other magnetically ordered states and provides a platform to study how disorder influences the QSL state.

Magnetic droplets immersed in a sea of QSL. Each droplet has an up-up-down and Q = (1/3, 1/3) ferrimagnetic structure.

Instrument: MuSR

Related publication: Fluctuating magnetic droplets immersed in a sea of quantum spin liquid, *The Innovation*, DOI: 10.1016/j.xinn.2023.100459

Funding: National Key R&D Program of China, National Natural Science Foundation of China, Shanghai Municipal Science and Technology, Strategic Priority Research Program of Chinese Academy of Sciences and the Innovation program for Quantum Science and Technology.

Authors: Z Zhu, B Pan, L Nie, J Ni, Y Yang, C Chen, C Jiang, Y Huang, E Cheng, Y Yu (Fudan University), J Miao (University of Hong Kong), AD Hillier (ISIS), X Chen, T Wu (University of Science and Technology of China), Yi Zhou (University of Chinese Academy of Sciences), S Li and L Shu (Fudan University)

Advanced materials, manufacturing and testing

Testing transistors to improve device resilience

Global device manufacturer Broadcom Inc. used ChipIr to test the error rate of devices that are crucial to current and future technology.

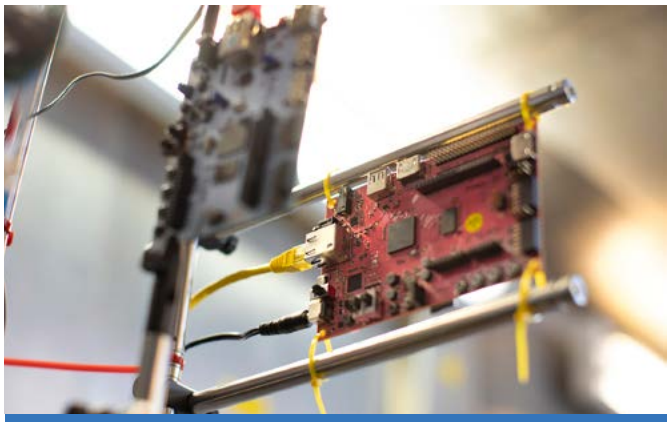
Broadcom Inc. is a company that designs, develops, and supplies semiconductors and software for applications including mobile phones and electric cars.

A team from Broadcom Inc. used the ChipIr beamline to test the error rate of FinFET devices in response to single event effects caused by cosmic rays.

FinFETs (Fin Field Effect Transistors) are three-dimensional devices that have better stability and higher current density than conventional transistors. Variations in manufacturing can lead to differences in the performance of these devices, but also their susceptibility to single event effects.

The group fabricated a range of test chips with different memories, using different processes. They studied their performance under different test conditions over a range of voltages, finding that FinFETs show a significant reduction in the per-bit error rate compared to planar systems.

Their results highlight the importance of understanding the error rates for FinFET-based circuits, as well as developing mitigation schemes based on the intended application and operating voltage range.



An electronics chip being tested in ChipIr.

Instrument: ChipIr

Related publication: Scaling trends and the effect of process variations on the soft error rate of advanced FinFET SRAMs, *2023 IEEE International Reliability Physics Symposium (IRPS)*, DOI: 10.1109/IRPS48203.2023.10118025

Funding: Broadcom Inc

Authors: B Narasimham, H Luk, C Paone, A-R Montoya, T Riehle, M Smith and L Tsau (Broadcom Inc)

Discovering the strain limits of superconducting tapes

Engin-X has been used to study mechanical stress applied to 2G HTS tape, which is used in MRI and the electrical grid.

Second generation high-temperature superconductors (2G HTS) tapes generate high magnetic fields at a wide operating temperature range. They have applications in areas such as fusion, MRI and the electrical grid.

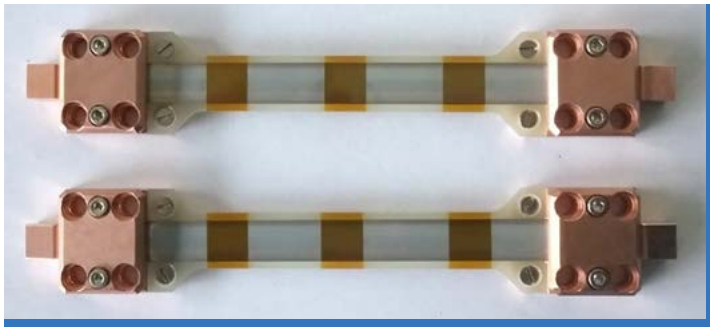
A collaboration between ISIS and Faraday Factory Japan LLC, which is the world's largest producer of 2G HTS tapes, used Engin-X to apply strain to tape samples. Strain influences the tapes' ability to carry high electrical current.

Engin-X is optimised for these types of measurements, and the ISIS sample environment team developed cryogenic testing chambers to enable neutron scattering measurements of internal strains in the materials at cryogenic temperatures.

The team established the strain limit for tapes, beyond which the superconductivity starts to deteriorate irreversibly. They concluded that this strain limit is defined by the brittleness of the HTS superconducting material.

This study, which was chosen to feature on the journal's cover, provides crucial information for the development of a new generation of HTS superconducting magnets used in MRI, NMR, fusion reactors and particle accelerators.

> "Thanks to the experiment on Engin-X, we obtained valuable information required for the design of applications for HTS tape. They include advanced magnetic-confined fusion devices, loss-less energy transmission, zero-carbon aviation and container ships, helium-free MRI systems, advanced propulsion for spaceships, and many more."
>
> Sergey Lee, Representative Director of Faraday Factory Japan.



2G HTS tape samples

Instrument: Engin-X

Related publication: Influence of mechanical stress on electron transport properties of second-generation high-temperature superconducting tapes, *Low Temp Phys*, DOI: 10.1063/10.0020169

Funding: STFC

Authors: M Gaifullin, S Lee (SuperOx Japan LLC), JF Kelleher, S Kabra (ISIS), M Myronov (The University of Warwick), BE Evans (UKAEA CCFE) and O Kirichek (ISIS).

Mummified lizard offerings brought to ISIS

Ancient Egyptian lizard coffins from the British Museum were brought to ISIS to investigate their contents with neutron imaging.

Whether securing your pet a place in the afterlife, offering gifts to the gods (like the goddess ISIS) or performing rituals to honour them, the mummification of animals was common practice in ancient Egypt. Some of these animals would have been placed inside statues of the animal or in coffins with a depiction of the animal on it.

The British Museum houses a collection that includes a set of 2500 year old animal coffins depicting lizard/eel-like figures. Researchers at the museum have been using imaging to investigate their contents without damaging them.

To see through the dense metals in a way not possible with X-rays, the team brought six boxes to ISIS to perform neutron tomography on IMAT.

The clarity of the images allowed them to identify fragments of textile wrappings used for mummification and several bones, including an almost intact skull of a lizard, similar to those of species still endemic in North Africa.

As well as characterising ancient remains, this study revealed information on the manufacturing process of these boxes, showing that lead was used, possibly to balance the weight of the boxes.

> **By utilising the capabilities of neutron imaging we were able to study the sealed animal coffins non-invasively and further our knowledge on the fascinating world of animal mummification.**
>
> Daniel O'Flynn, X-ray Imaging Scientist at the British Museum.

Animal coffin (British Museum EA36151) surmounted by a human-headed part-eel, part-cobra creature wearing a double crown, associated with the ancient Egyptian god Atum.

Instrument: IMAT

Related publication: Neutron tomography of sealed copper alloy animal coffins from ancient Egypt, *Scientific Reports*, DOI: 10.1038/s41598-023-30468-4

Funding: British Museum and STFC

Authors: D O'Flynn (The British Museum), A Fedrigo (ISIS), L Perucchetti and A Masson-Berghoff (The British Museum)

Using neutrons to understand the skin barrier

Researchers from Leiden University in the Netherlands have come to ISIS to improve understanding of the molecular differences between diseased and healthy skin.

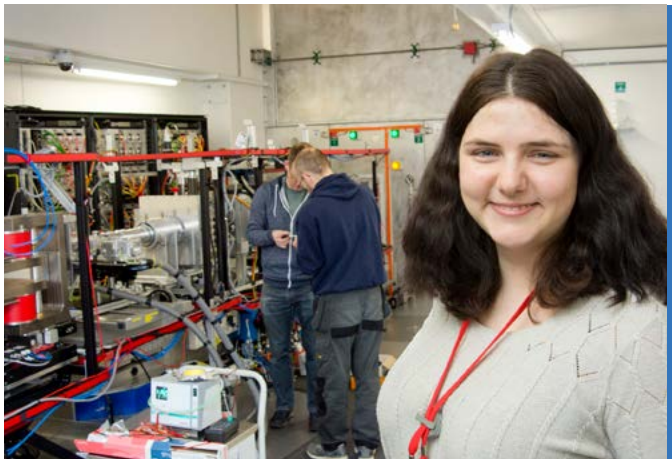
One-third of the world's population suffers with a condition affecting the skin, often caused by the skin barrier becoming impaired. Lipids play a key role in the skin barrier, in particular the ratio between different ceramides, free fatty acids and cholesterol is important.

Using the Larmor instrument, the team aimed to find out the effects of altering the ceramide head groups on lipid organisation and water loss.

Small angle neutron scattering allowed them to study the lipid arrangement in the long periodicity phase of their skin barrier model.

They found that changing the ratio of two different ceramides did not affect the long-range lipid arrangement and organisation, but it did change the water loss from the skin barrier. The ceramide ratio is therefore a contributing factor to the symptoms of inflammatory skin diseases.

This research has improved the understanding of our skin barrier structure and function and how this correlates to differences between healthy and inflamed skin. Now the team is studying whether the addition of ceramide subclasses will change the long periodicity phase.



Charlotte Beddoes, University of Leiden, Netherlands, on the Larmor instrument in 2018.

Instrument: Larmor

Related publication: Effect of sphingosine and phytosphingosine ceramide ratio on lipid arrangement and barrier function in skin lipid models, *Journal of Lipid Research*, DOI: 10.1016/j.jlr.2023.100400

Funding: National Institutes of Health

Authors: A Nădăban, J Rousel, D El Yachioui, GS Gooris, CM Beddoes (Leiden University), RM Dalgliesh (ISIS), M Malfois (ALBA Synchrotron), R Rissmann and JA Bouwstra (Leiden University)

You've got nano-mail: the role of SANS in lipid nanocarriers

Researchers from Imperial College London and Karolinska Institute, with scientists from ISIS, have exploited several techniques to gain structural understanding of lipid-based particles for clinical applications.

Lipid nanomedicines are currently undergoing a revolution and their applications have multiplied in recent years. They are already used clinically for chemotherapy treatment as well as delivery technologies for vaccines. Despite their success, it is still challenging to study these medicines on the nanoscale and at the single-particle level.

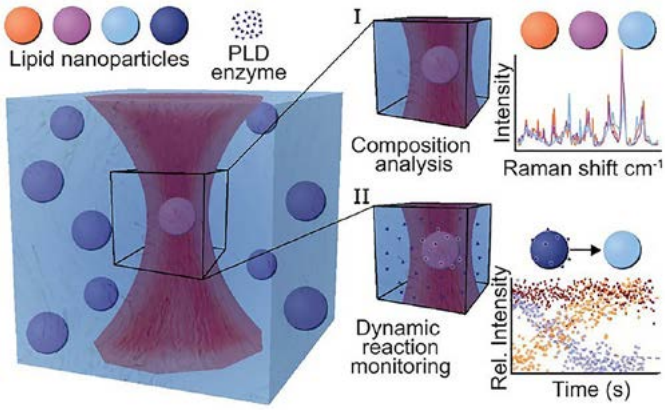
This study investigated the structure of lipid nanoparticles (LNPs) and their interaction with the Phospholipase D enzyme to understand how lipid nanoparticles could be processed by the cell.

The advantage of small angle neutron scattering is that it allows the study of particles in solution at the concentration they would be used in a clinical setting.

In this study, the researchers found that the structure of the lipid nanocarrier had a direct impact on how it interacted with the Phospholipase D enzyme and that the structure of the lipid nanoparticles was influenced by the formulation method.

The results show an interesting potential to create enzyme-responsive LNPs for pharmaceutical applications.

> We were able to demonstrate how formulation conditions impact nanoparticle structure and how different structures interact differently with enzymes. It's really fascinating to see how we can use this moving forward to design the next generation of lipid nanomedicines.
>
> Dr Hanna Barriga,
> Imperial College London



A schematic for single-particle evaluation for LNP composition analysis and dynamic processes monitoring.

Instrument: SANS2D

Related publication: Coupling lipid nanoparticle structure and automated single-particle composition analysis to design phospholipase-responsive nanocarriers, *ACS Appl. Mater. Interfaces*, DOI: 10.1002/adma.202200839

Funding: Marie Skłodowska-Curie Fellowship, H2020, EPSRC

Authors: HMG Barriga, MN Holme (Karolinska Institutet), IJ Pence (Imperial College London), JJ Doutch (ISIS), J Penders, V Nele, MR Thomas (Imperial College London), M Carroni (Karolinska Institutet), MM Stevens (Imperial College London and Karolinska Institutet)

Protecting farmers' eyes from pesticides

Researchers from University of Manchester and Syngenta used Offspec to investigate the interaction between pesticides and corneal cell membrane which causes eye irritation.

Pesticides are widespread in the agriculture industry to minimise the effects of weeds, pests and diseases on crops. Debates about costs to wildlife and their environmental impact are common, but the health impact on the farmers using the pesticides is rarely considered.

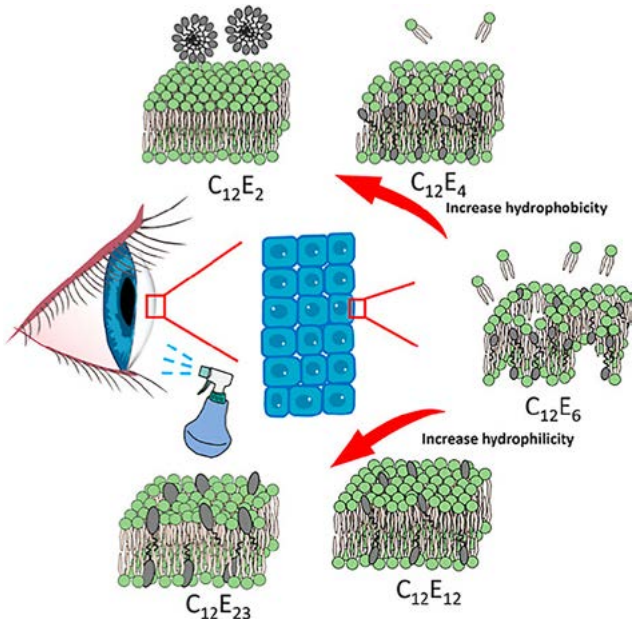
This study observed how the pesticide surfactants interact with the eye and cause irritation.

By doing neutron reflectometry of the samples in water and deuterated water, the team could selectively study the structure of a deuterated model eye membrane, and how this responded to surfactant binding.

> Neutron reflection together with deuterium labelling is really powerful in telling us about the amount and location of a particular surfactant bound to cell membrane. Such structural details could directly impact cytotoxicity!
>
> Jian Lu, University of Manchester

The surfactants varied in hydrophobicity and had differing interactions with the membrane. Surfactants that were highly hydrophilic or hydrophobic elicited fewer structural changes. In these cases, cell death was not immediately caused by cytoplasm leakage, but occurs over a longer period due to membrane leakage.

The researchers hope that these findings, and information on the physiochemical properties such as membrane leakage and permeability, will provide a basis to reduce the potential eye irritation of industrial pesticide formulations.



Cartoon schematic showing the different surfactant-lipid bilayer interactions observed.

Instrument: OffSpec

Related publication: Unraveling how membrane nanostructure changes impact the eye irritation of nonionic alkyl ethoxylate surfactants, *ACS Appl. Mater. Interfaces*, DOI: 10.1021/acsami.3c14794

Funding: University of Manchester, Innovate UK and Syngenta

Authors: X Hu, M Liao, K Shen, K Ding (University of Manchester), M Campana (ISIS), S van der Kamp, EF McInnes, F Padia (Syngenta) and JR Lu (University of Manchester)

Your parcel has been delivered: RNA lipid nanoparticles as a drug delivery system

Researchers from Lund University and the Chalmers University of Technology came to ISIS to investigate the interaction between different components in lipid nanoparticles.

Messenger RNA (mRNA) is created during transcription of DNA in the nucleus. It has been used in pharmacology to create drugs that are specific and relatively quick and easy to manufacture. mRNA-based drugs can be made to target a particular area within the body, reducing unintended side effects.

> "Despite the wealth of research conducted on lipid nanoparticles for mRNA delivery in recent years, there are still a lot of remaining questions. By studying the LNP components in a simpler system, we can start to understand the fundamental interactions that drive the stability and structure of these formulations. This work was only made possible by close collaboration with our excellent colleagues at ISIS and their extensive experience."
>
> Jennifer Gilbert, Lund University

The next step in mRNA-based drug research is improving the functionality of the drug packaging, often a lipid nanoparticle (LNP), to ensure it can successfully reach its target.

Neutron reflectometry at ISIS enabled these researchers to study the model lipid layers containing the main component of mRNA lipid nanoparticles and discover how composition and pH impacts how different mRNAs interact with it.

They found that either a lower pH or higher percentage of the cationic ionisable lipid MC3 resulted in greater adsorption of mRNA to the lipid layer. They also saw that the way the mRNA adsorbed to the lipid layer was related to the structure of the mRNA.

This research improves understanding of how different components in LNPs interact and how this affects their structure, which in turn affects how efficiently they can deliver mRNA to a cell.

Instrument: PolRef

Related publication: On the interactions between RNA and titrateable lipid layers: implications for RNA delivery with lipid nanoparticles, *Nanoscale*, DOI: 10.1039/d3nr03308b

Funding: Swedish Research Council

Authors: J Gilbert (Lund University), I Ermilova (Chalmers University of Technology), M Fornasier, M Skoda (ISIS), G Fragneto (ILL, ESS), J Swenson (Chalmers University of Technology) and T Nylander (Lund University, Lund Institute of Advanced Neutron and X-Ray Science)

Hydrogen bonding under pressure

Using synchrotron and neutron diffraction, researchers from the University of Strathclyde have studied the effects of pressure on hydrogen bonding in pharmaceutical cocrystals.

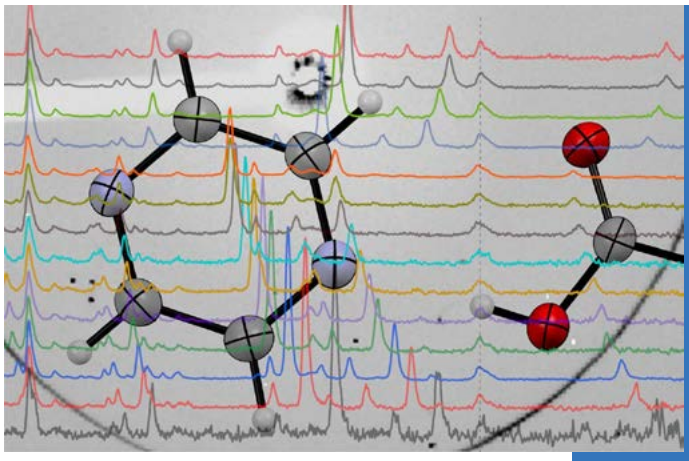
High pressure is of increasing interest to the pharmaceutical industry due to the impact it has during the manufacturing process. During processes such as compaction to form tablets, materials can undergo phase transitions, potentially impacting their physicochemical properties and hence their ability to deliver the active ingredient.

The high-pressure experimental setup on ISIS' Pearl instrument, and its equivalents at Diamond Light Source, enabled the researchers to study pharmaceutical cocrystals under conditions relevant to these industrial processes.

In a systematic study of a common hydrogen bonding motif, they studied five pyrazine dicarboxylic acid systems and observed that hydrogen bonding compresses at a similar rate in all the systems, despite the change in the molecular structures and the starting interaction distances.

The changes in structure when compressed suggest that the layers move along the major slip planes in the structure which has been alluded to in many studies of macroscopic properties. Here, the authors show this at the molecular level detail.

This work is one of the first systematic studies of cocrystalline structures under high pressure, which will aid the understanding of compaction of active pharmaceutical materials.



The cocrystal structure, shown on top of a series of diffraction patterns.

Instrument: Pearl

Related publication: Exploring the effects of high pressure on hydrogen bonding in pharmaceutical cocrystals: A systematic study of pyridine dicarboxylic acid systems using synchrotron and neutron diffraction, *Int J Pharmaceutics*, DOI: 10.1016/j.ijpharm.2023.123514

Funding: EPSRC, STFC

Authors: MR Ward (University of Strathclyde), CL Bull, NP Funnell (ISIS), MR Warren (Diamond Light Source), IDH Oswald (University of Strathclyde)

Studying the building blocks of biomaterials at the nanoscale

A collaborative effort led by the University of Leeds has used neutron scattering to provide detailed analysis of nanoscale building blocks, which could offer significant impact in the study of biomaterials.

Understanding the structure and assembly of nanoscale building blocks is vital for the development of biomaterials and is a well-known challenge in areas such as pharmaceuticals, construction and engineering.

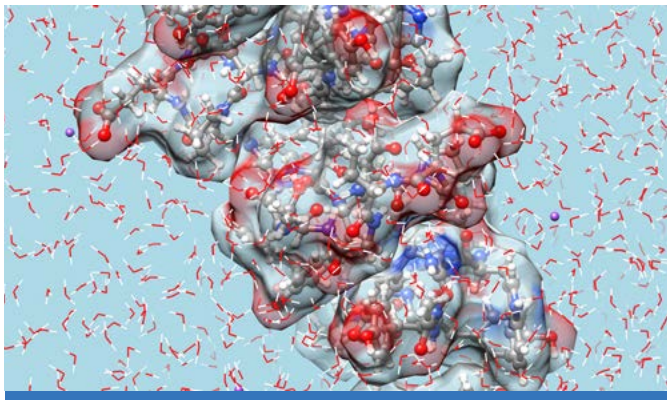
One of the best and most powerful techniques for integrative nanoscale modelling is neutron scattering, as neutrons are deeply penetrating, cause no radiation damage and exhibit much greater sensitivity to hydrogen than X-rays.

In this study, the team used an integrative small- and wide-angle neutron scattering (SANS/WANS) approach, coupled with computational modelling, to reveal the multiscale structure of the nanoscale β-hairpin, also known as the 'mini-protein,' CLN025.

Their method provided a detailed map of the hydrophobic and hydrophilic character of this model self-assembled biomolecular surface. The study demonstrates the power of a self-consistent approach that models both large scale self-assembly and small-scale atomic interactions of a β-hairpin as a simple model protein system.

This integrated approach could offer significant impact in the study of biomaterials, such as protein and peptide hydrogels.

> "This paper is a textbook demonstration of how neutron scattering methods can now give atomistic-resolution insight in biomolecular self-assembly."
>
> Daniel Bowron, ISIS Group Leader.



Snapshot of the structure refinement simulation containing an atomistic view of CLN025 hairpins (ball and stick representation) with transparent solvent excluded surfaces.

Instrument: Nimrod and Zoom

Related publication: Visualization of self-assembly and hydration of a β-hairpin through integrated small and wide-angle neutron scattering, *Biomacromolecules*, DOI: 10.1021/acs.biomac.3c00583

Funding: EPSRC and a European Research Council Consolidator Fellowship/ UKRI Frontier Research Fellowship for the MESONET project

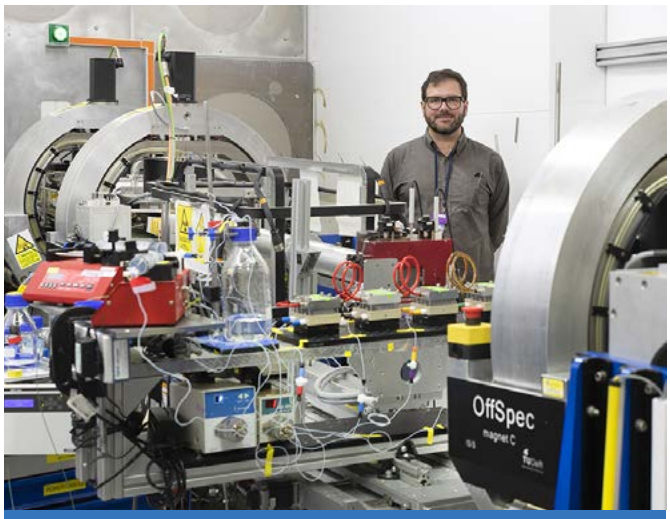
Authors: H Laurent, MDG Hughes, M Walko, DJ Brockwell (University of Leeds), N Mahmoudi, TGA Youngs, TF Headen (ISIS) and Lorna Dougan (University of Leeds).

Understanding programmed cell death – crucial to the body's prevention of cancer

Through both static and time-resolved neutron reflectometry, a Swedish/UK research collaboration has revealed the molecular mechanism of the first stage of cell death.

Programmed cell death, called apoptosis, is essential to human life but its disruption can lead to cancer. The 'Bax' protein is responsible for triggering cell death, but the molecular-level mechanism by which Bax operates has been unclear.

Neutron reflectometry is a key technique to understand the operation of the Bax protein. In particular, the ability to isolate key elements of Bax and the cell membrane it interacts with via deuterium isotope substitution enables neutron scattering to give unique information.



Luke Clifton by the OffSpec beamline.

The experiment team from ISIS, University of Umea and the European Spallation Source used Surf and OffSpec to study in real-time the way that Bax interacts with cell membranes using time-resolved reflectometry together with surface infrared spectroscopy in the ISIS biolab.

The interaction of Bax with the cell membranes was found to occur in two stages: an initial fast adsorption of Bax followed by perforation of the membrane on the timescale of hours.

The complex findings of this study give unique and direct evidence of the involvement of mitochondrial lipids in the structure formed during the membrane perforation by Bax.

> "This work has relevance to understanding fundamental mammalian cell processes and understanding cancer biology. It really shows the capabilities of neutron reflectometry in structural studies on membrane biochemistry."
>
> Luke Clifton,
> ISIS scientist and lead author.

Instrument: Surf and OffSpec

Related publication: Creation of distinctive Bax-lipid complexes at mitochondrial membrane surfaces drive pore formation to initiate apostosis, *Science Advances*, 9 (2023). DOI: 10.1126/sciadv.adg7940

Funding: Swedish Research Council, Kempe Foundation, Umeå Insamlingsstiftelsen

Authors: LA Clifton (ISIS), HP Wacklin-Knecht (European Spallation Source, Lund University), J Åden, A Ul Mushtaq, T Sparman and G Gröbner (University of Umeå)

Thriving under pressure: achieving the challenge of creating a compressible liquid

Using a metal organic framework, a research team led by Stuart James at Queen's University Belfast have been able to achieve the challenging task of compressing a liquid.

Liquids typically can't be compressed much because there isn't any space between the molecules. If liquid compressibility could be controlled, then it could lead to new applications in hydraulics and shock absorption.

By adding tiny particles of the metal organic framework ZIF-8 to water, the researchers created a liquid that looks like milk, but 7% of it is empty space. This means that, when pressure is applied, the liquid can be compressed.

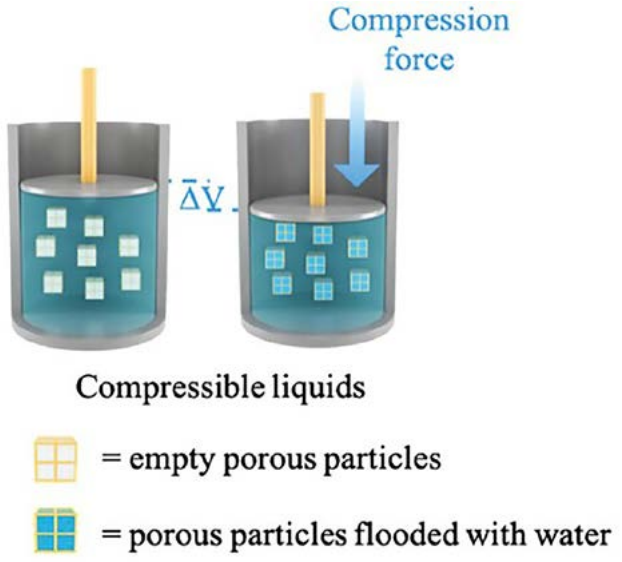


Diagram showing the porous particles (yellow) in a liquid and how the liquid is forced into the pores of the dispersed particles when pressure is applied, causing a decrease in the total volume.

Neutron scattering enabled the team to see what structural changes happened to the ZIF-8-water mixture during compression.

In their study, highlighted both as an Editor's Choice article and in *Nature*, they show reversible compressibility of the liquid up to 20 times greater than a standard liquid.

They also found that the degree of compression could be controlled by varying the concentration of porous particles, and that introducing methanol or salt to the mixture changed the pressure at which compression occurred.

This simple and economical approach could potentially be scaled up to give large amounts of highly compressible liquids.

Instrument: Nimrod

Related publication: Liquids with high compressibility, *Advanced Materials*, 10.1002/adma.202306521

Funding: EPSRC

Authors: B Lai, S Liu, J Cahir (Queen's University Belfast), Y Sun, H Yin (University of Birmingham), T Youngs (ISIS), J-C Tan (University of Oxford), SF Fonrouge, MG Del Pópolo (Universidad Nacional de Cuyo), JL Borioni (Universidad Nacional de Córdoba), DE Crawford, FM Alexander, C Li, SEJ Bell, B Murrer and SL James (Queen's University Belfast)

Aromatics could be the key to more stable microemulsions

By using SANS and SAXS, a group from the Indian Institute of Technology Madras have found that a microemulsion is more stable over a wider temperature range when the oil used is an aromatic compound.

Reverse microemulsions of water-in-oil have been exploited in various applications, such as lubricants, and could even be used as unique environments for multiphase chemical reactions. Although much is known about the structure, properties and interactions of water-in-alkane microemulsions, there is very little information on microemulsions where the oil is an aromatic compound.

The researchers used small-angle X-ray and neutron scattering to study water-in-xylene microemulsions enabling them to probe length scales across several orders of magnitude. They used D_2O instead of the aqueous phase in their neutron experiments to enhance scattering contrast, which highlighted the aqueous core.

They found that the water-in-xylene reverse microemulsions were insensitive to moderate temperature change, in stark contrast to systems in which the oil is either a linear or a branched alkane.

Their fundamental study on this model system is key to understanding the behaviour of these multiple component systems, and for informing future formulations used at higher temperatures, where the structure of most reverse microemulsions breaks down.

> **This research utilising neutrons offered an opportunity to uncover the role of aromatic compounds in the formation and stability of water-in-fuel microemulsions**
>
> Basavaraja Madivala Gurappa, Indian Institute of Technology Madras

Instrument: Zoom

Related publication: Investigation of nanostructure and interactions in water-in-xylene microemulsions using small-angle x-ray and neutron scattering, *Langmuir*, 10.1021/acs.langmuir.3c00010

Funding: Government of India

Authors: P Rastogi (IIT Madras), D Honecker, D Alba Venero, N Mahmoudi (ISIS), NS Kaisare and MG Basavaraj (IIT Madras)

Combining techniques enables a challenging magnetic characterisation

Using neutron and muon beamlines at multiple facilities, as well as computational techniques, a European collaboration have studied the low-temperature magnetic phases of a quantum material.

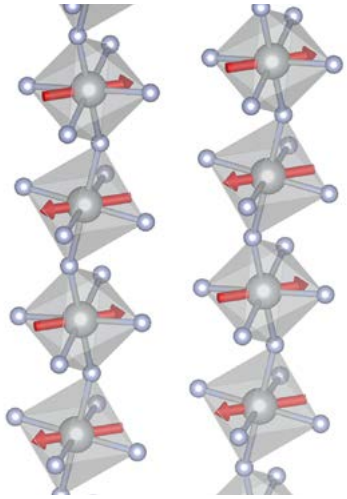
The position of the silver atoms in $KAgF_3$ creates a one-dimensional quantum antiferromagnet, which hosts a series of intriguing structural and magnetic transitions. Researchers from the universities of Oxford, Köln, Warsaw, Italy's CNR and the Jožef Stefan Institute have used instruments at the ILL, PSI and ISIS to investigate its magnetic behaviour.

Their study, highlighted by the journal's editors, aimed to characterise the low-temperature magnetic phases of $KAgF_3$ using μSR spectroscopy, powder neutron diffraction, and density functional theory calculations.

They used the continuous muon source at PSI for detailed measurements of the magnetic ordering, and the pulsed muon source at ISIS for measuring details of the entanglement between the muon and the fluorine nuclei to obtain details of the muon site. They then used the ILL for their neutron diffraction experiments.

They were able to comprehensively characterise the antiferromagnetic ground state of the material below 29 K and saw evidence for an intermediate phase at slightly higher temperatures.

However, they were unable to determine the magnetic structure of this phase, as they had reached the detection limits of the techniques, leaving the nature of this phase an open problem.



The one-dimensional magnetic structure of $KAgF_3$

> Silver (II) fluorides are a potential precursor to new superconducting materials, but due to the small electronic moments they can be really difficult to characterise. Nevertheless, by combining both neutrons and muons we can use the best features of both techniques to work out exactly what's going on.
>
> Johnny Wilkinson,
> ISIS scientist and lead author

Instrument: MuSR

Related publication: Low-temperature magnetism of $KAgF_3$, *Phys Rev B*, DOI: 10.1103/PhysRevB.107.144422

Funding: Narodowe Centrum Nauki, UKRI, Italian MIUR, Slovenian Research Agency, German Research Foundation

Authors: JM Wilkinson (ISIS and University of Oxford), SJ Blundell (University of Oxford), S Biesenkamp, M Braden (Universität zu Köln), TC Hansen (ILL), K Koteras, W Grochala (University of Warsaw), P Barone (Cnr SPIN), J Lorenzana (Università di Roma "La Sapienza"), Z Mazej and G Tavčar (Jožef Stefan Institute)

Understanding imperfections in ionic liquids

Scientists from Universität Rostock and ISIS have made full use of selective deuteration to study hydrogen bond defects in ionic liquids.

The real world is far from perfect, and defects in materials bring opportunity for performance enhancement, such as in semiconductors. In this study, the group studied hydrogen bonding in ionic liquids, as these can act as defects in amorphous systems.

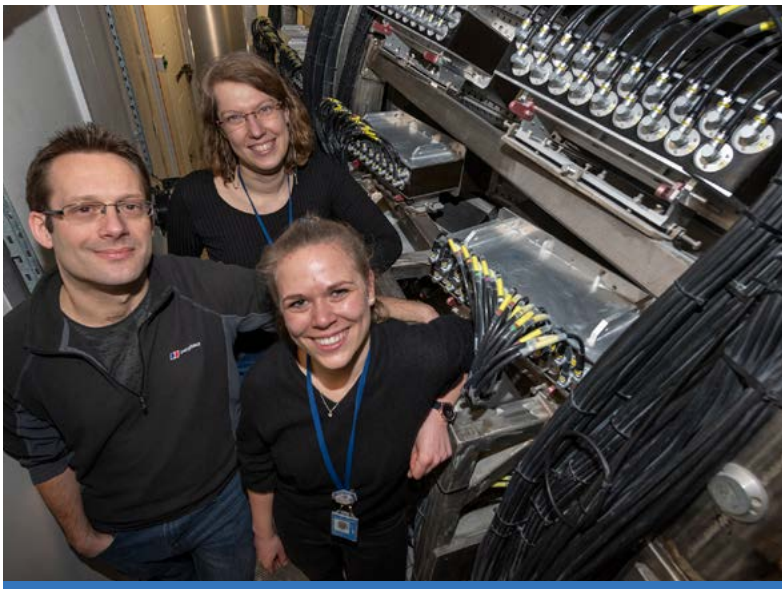
Neutron scattering with multiple isotopic substitutions gave the team a unique way to explicitly highlight different interactions in the system. Using both Sandals and Nimrod, they could carry out a simultaneous investigation of the molecular and nano-scaled phenomena.

They supported their experimental results by doing molecular dynamics simulations, which enabled them to characterise the occurrence, geometries, and strength of hydrogen bond defects in ionic liquid mixtures.

The researchers observed two types of hydrogen bond defects: those formed by ions of opposite charge and of like charge.

Being able to study the hydrogen bonding in this way is not only relevant to the study of ionic liquids but could be useful for other materials with similar defects.

The next step is to relate the number and stability of defects to macroscopic properties such as diffusion, viscosity, and conductivity, which are of utmost importance for the performance of electrolytes in batteries and other electrical devices.



Joanna Busch, Sabrina Gärtner and Tristan Youngs on Nimrod.

Instrument: Sandals and Nimrod

Related publication: Role of hydrogen bond defects for cluster formation and distribution in ionic liquids by means of neutron diffraction and molecular dynamics simulations, *ChemPhysChem*, DOI: 10.1002/cphc.202300031

Funding: Deutsche Forschungsgemeinschaft

Authors: J Busch, T Niemann, J Neumann, P Stange (Universität Rostock), S Gärtner, T Youngs, S Youngs (ISIS), D Paschek and R Ludwig (Universität Rostock)

The 2024 ISIS Impact Awards

2024 Science Impact Award winner:

Yujie Ma from The University of Manchester

Awarded for his work applying neutron scattering techniques to the development of defective Metal-Organic Frameworks for clean air and sustainable energy.

Porous materials such as Metal-Organic Frameworks (MOFs) have the potential to be used across a range of applications and industries for their ability to selectively adsorb/store gas molecules and catalyse reactions. The presence of active sites in porous materials can control and significantly affect their performance in adsorption and catalysis. However, fine tuning of the active sites and revealing the interactions between substrate and active sites in porous materials with atomic precision remains a challenging task.

Yuije's work focusses on designing new MOFs by creating structural defects and introducing single-atom metal sites. Introducing these defects changes the properties of a MOF material, increasing its specificity in capturing particular gases or catalysing reactions of interest. His work encompasses a range of environmental and energy applications including ammonia and nitrogen dioxide capture, and the catalysis of methane and carbon dioxide conversion.

2024 Society Impact Award winner:

Stephen J Perkins and Jayesh S. Bhatt from University College London

Awarded for their work determining the molecular structures of therapeutic antibodies in solution.

In humans, immunoglobulin (IgG) is the most common type of antibody found in blood circulation. There are four subclasses of human IgG molecules, which are created by plasma B cells and used by the immune system to identify and neutralise pathogens. Starting from neutron scattering data obtained from SANS2D, they developed a new method of atomistic scattering modelling to determine the structure of all four IgG subclasses: IgG1, IgG2, IgG3 and IgG4 and modified forms of these antibodies.

By using neutrons, they were able to gain insights that were not available using other techniques such as protein crystallography. Their state-of-the-art molecular dynamics calculations have enabled them to produce full atomistic simulations of the antibody structures in solution. Using Monte Carlo simulations to generate tens of thousands of physically realistic structures, they were then able to determine the best-fit solution structures by comparison of these trial structures with the experimental neutron and X-ray scattering curves. They have also made their findings available in public databases for use by the community.

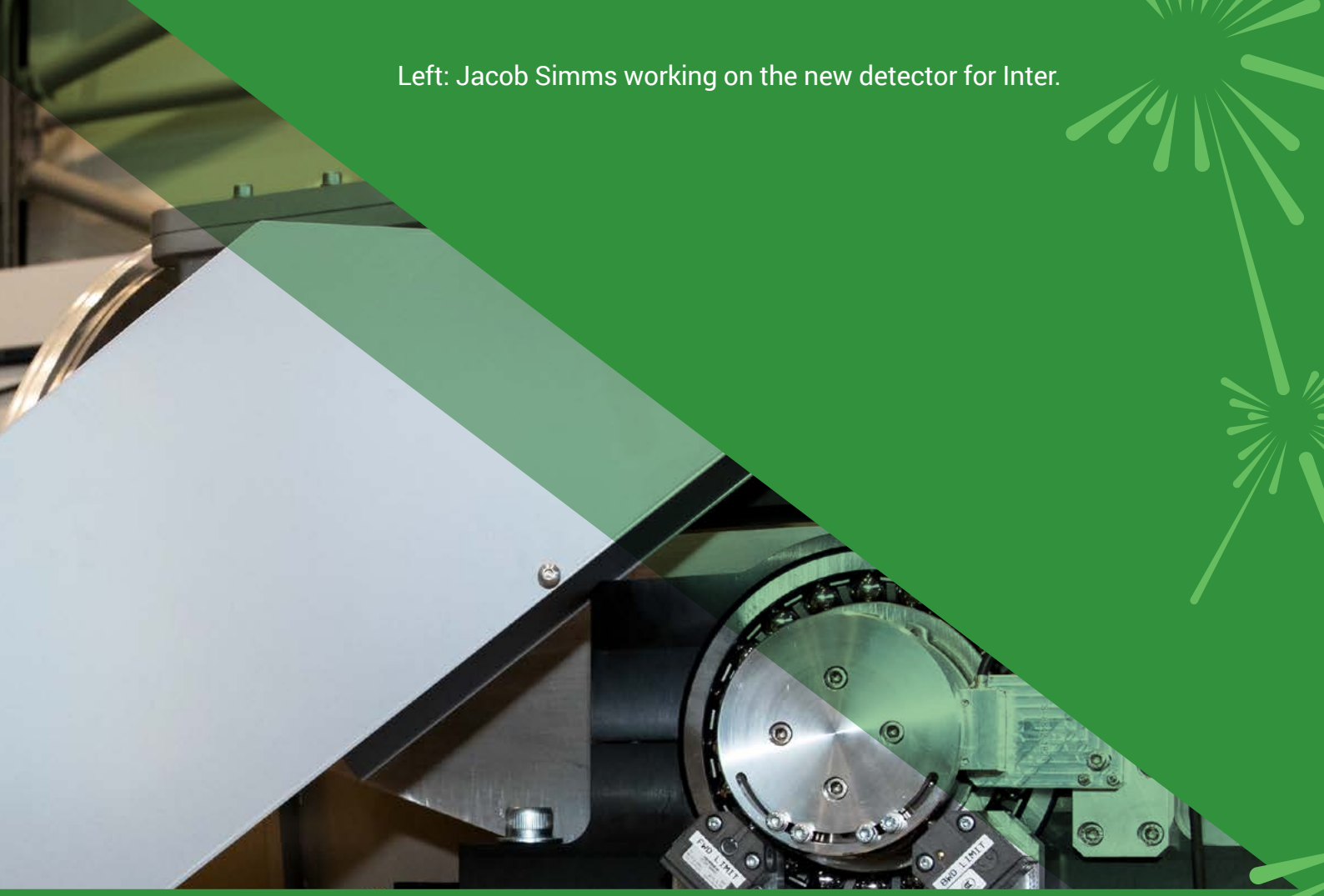
Yujia Ma, Stephen Perkins and Tan Sui (left to right) after receiving their impact awards.

2024 Economic Impact Award:
Tan Sui from the University of Surrey

Awarded for her research mapping residual stress distribution in materials for nuclear fusion applications.

Fusion offers an opportunity for abundant clean energy. Tan Sui's research focusses on the joints that hold parts of a fusion reactor together. Understanding the distribution of residual stress in reactor joints is crucial for enhancing their structural integrity, and therefore for planning maintenance and enduring safe operations. To study the residual stress within these dense components, she used neutron diffraction and imaging, complementing her team's plasma focused ion beam and nanoindentation approaches to enhance structural integrity, maintenance strategies, and safety.

Her work not only impacts the nuclear fusion industry through the development of a model that can be used for lifetime prediction of joints, but also benefits the wider ISIS user community. By using neutron Bragg edge imaging combined with 3D tomography, she has broadened the scope of strain measurement, establishing new benchmarks in this area of research.



Left: Jacob Simms working on the new detector for Inter.

World-class technology and infrastructure

In the 40 years since the first neutrons were produced at ISIS, we have continued to develop 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.

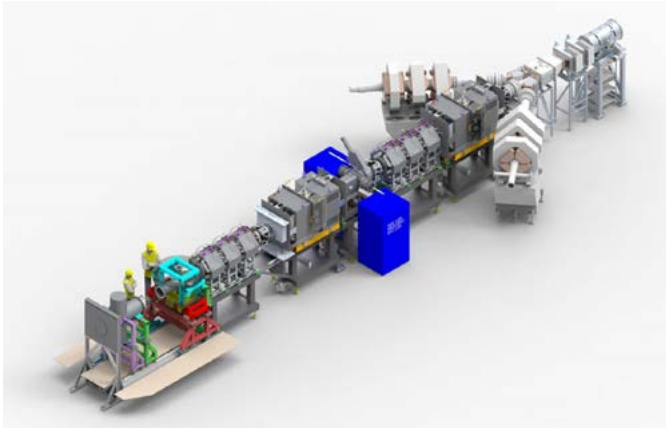
Looking ahead, implementation of the Endeavour programme has begun, and plans for ISIS-II are progressing well, with sustainability at the forefront.

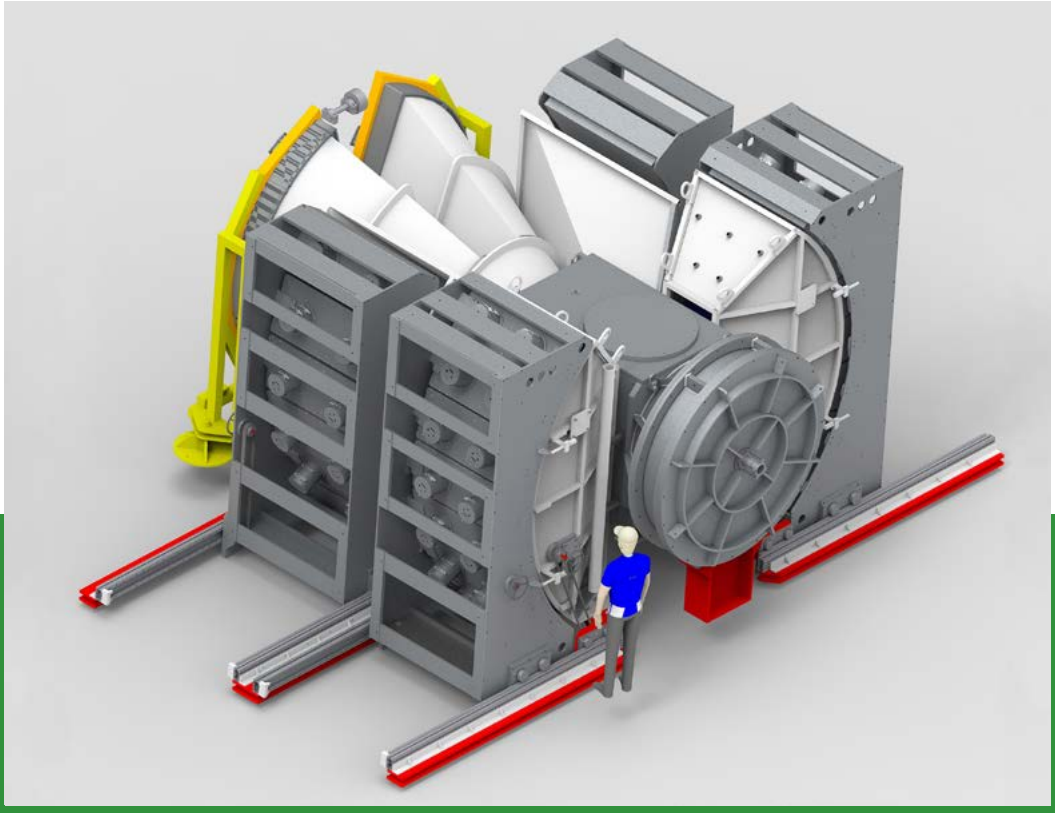
Major projects

Endeavour

Endeavour is the programme of large instrument developments at ISIS. It consists of nine projects: four entirely new instruments and five major instrument upgrades. The ten-year Programme – a £93m investment in the ISIS instrument suite – received formal UK government approval in Spring 2023, and then the work of implementing the projects began.

Two of the nine projects are now fully in implementation, with detailed plans and designs in place, and components being bought. SuperMuSR is a new concept of muon instrument, designed to give greater time resolution as well as flux – it is well progressed in procurement of key items. HRPD-X is a significant upgrade of the high-resolution powder diffractometer which includes a rebuild of the instrument building. Detailed work to plan and cost the building and instrument equipment has been underway this year with the aim of starting in late 2024. SuperMuSR and HRPD-X are currently planned to be ready for the user programme in the first half of 2028 following installation and commissioning. Over the next year, two other projects will be moved into implementation, with remaining projects following in a phased way.





CAD drawings of the SuperMuSR beamline (top) and HRPD-X instrument layout (left).

UK-ESS

As the beam on target milestone at the European Spallation Source (ESS) approaches, the ISIS-delivered instruments, LoKI and FREIA, are making good progress.

This year has seen considerable progress on LoKI, with STFC deliveries to the ESS almost complete and installation nearing its final stages. This has included the electronics and cabling for most of the instrument components, installation of the sample area door and roof mechanisms, detector modules and support frames, and in-bunker components, such as the heavy shutter and chopper, as well as neutron guide installation and alignment. The LoKI team also celebrated passing its final design review milestone, which marks a major documentation milestone before the final instrument review.

FREIA has also made good progress with installation beginning with the optics that go into the bunker wall. Most major components are now in the pre-build phase at ISIS and some have even been delivered to ESS, including the sample positioning hexapod. Manufacture of the neutron guide is also complete and testing of the technically challenging large carbon-fibre chopper disks is underway with good progress being made.

LoKI detector module installation.

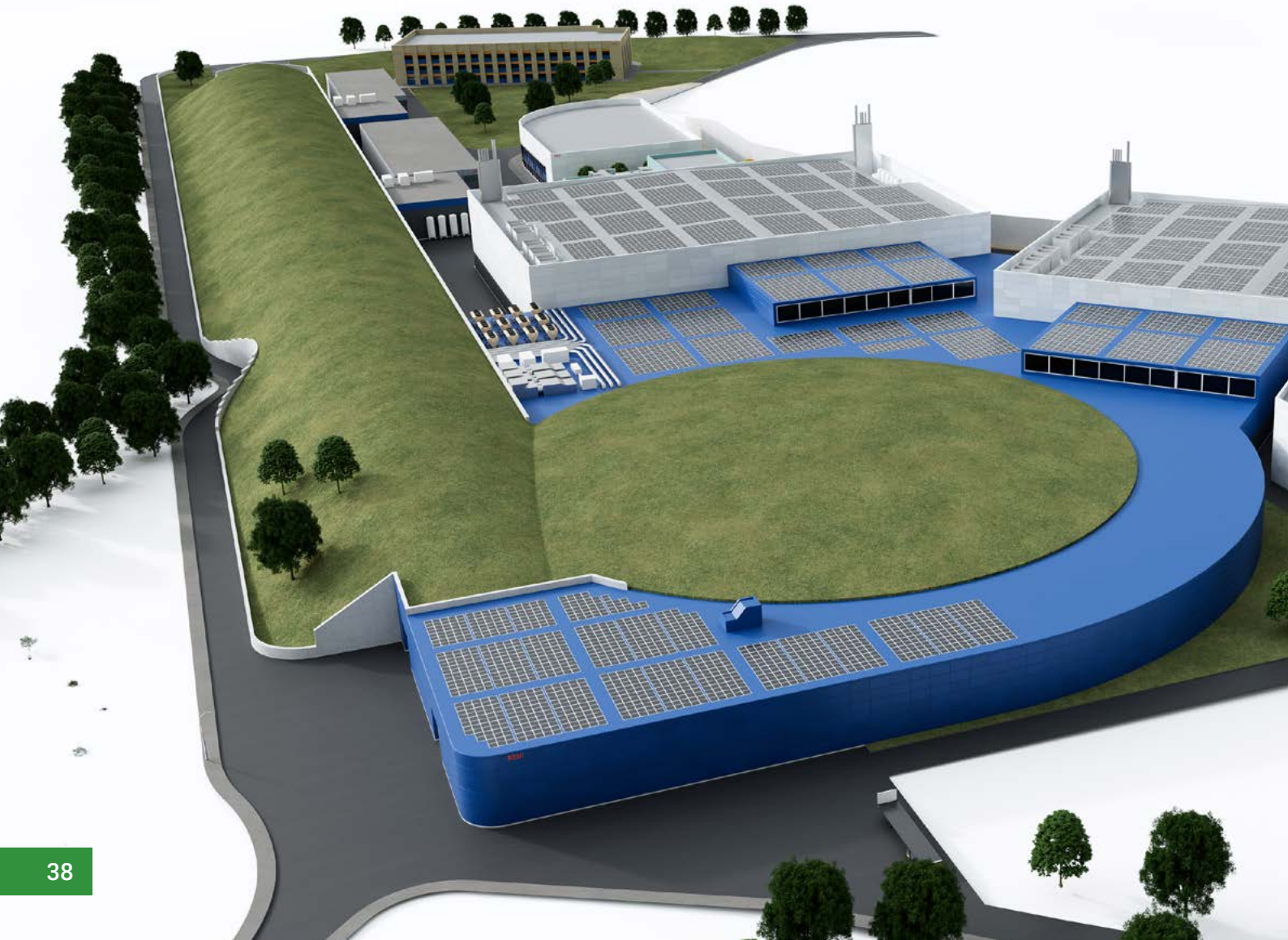
The LoKI beamline at the ESS.

ISIS-II: Designing the UK's next-generation neutron and muon source

Although ISIS will continue to develop, and operate, for many years to come, plans for a new facility will be developed over the next decade to be ready for construction sometime after 2030. This will maintain and enhance the UK's neutron and muon provision, in a way complementary to the ESS and in support of the UK research community.

A project has been established to consider the requirements for an ISIS-replacement facility, and to explore the technologies that might underpin this. This includes considering the science drivers for neutrons and muons over coming decades and how these will influence the design of new neutron and muon instrumentation. In turn, these affect the nature of the source and hence the accelerator characteristics. Feasibility work on accelerator possibilities is ongoing, with the aim of ramping this up over coming years.

We will be developing the science case in consultation with the ISIS user community. A webinar on 13 March 2024 provided an update on the project to date for over 300 of our staff, users and other stakeholders. A wider, 'town' meeting is being planned for 2025. Input from the community will be a vital part of defining the capabilities of the new facility and informing science and business cases.



Within the feasibility studies for ISIS-II, efforts have been made to understand the facility's potential lifetime environmental impact. A sustainable design methodology is being developed, learning from facilities around the world, and working with them in the quest for more sustainable accelerator-based facilities. In addition, the global sustainable development company, Arup, will use the ISIS-II project to investigate solutions for overcoming decarbonisation barriers at STFC. The environmental impact of different accelerator options is also being considered.

There has been significant engagement with the STFC Estates team to look at the footprint of the facility and ensure buildability, and a comprehensive landscape and visual appraisal has informed views on location, tree planting and promotion of biodiversity.

The latest representative layout of a new stand-alone ISIS-II facility.

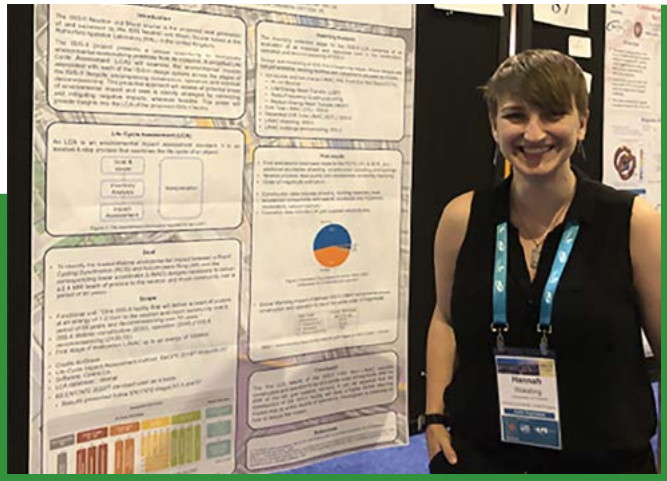
Hannah Wakeling - evaluating the environmental impact of ISIS-II

Hannah is a post-doctorate research assistant in particle accelerator sustainability at the John Adams Institute for Accelerator Science at the University of Oxford.

After her PhD, she chose to pursue an interest in making research more environmentally sustainable. She learned to evaluate the environmental impact of research and tried to carry out such an evaluation of her own PhD project. Despite finding this challenging, it inspired her to do more of this type of work, which led to her current role.

Hannah's role at ISIS is to evaluate the environmental impact of the whole life cycle of ISIS-II, from construction through its working life to decommission. This has included exploring areas such as implementing remote facilities to reduce user travel, comparing various designs of components and looking at improvements to the construction process.

"Improving the environmental impact of ISIS-II will be a cumulative effect of small- and large-scale changes. What's really exciting is the potential for this to lead to new research. For example, concrete and steel used for radiation shielding has a huge environmental impact, so perhaps new materials for shielding, or ways to use less material, can be explored."



Hannah Wakeling presenting a poster on her ISIS-II work.

Sustainability

Cooler installation

A project has been underway to replace the cooling towers which provide cooling for the instrument systems associated with Target Station 2 with newer ones that use less electricity and less water. The five closed-circuit cooling towers have been replaced with eight modern, energy efficient, adiabatic coolers, which will significantly reduce the water and electricity consumed. The new cooling system will reduce ISIS' water consumption by 6,500m^3 per year, approximately 15% of the total annual ISIS consumption. The system will also save 2,000m^3 entering the RAL site wastewater system.

Aerial photo of ISIS R80 showing the old cooling towers in action.

Sustainable Accelerators Conference

In collaboration with the Institute of Engineering Technology Particle Accelerator Engineering Network (IET PAEN), STFC hosted the Sustainable Accelerators Conference at the ESA Harwell conference centre. 99 people from the scientific, university, medical and industrial sectors attended, listening to talks on the themes of future facilities, efficiency, skills and knowledge as well as invited talks from sustainable high energy physics and the ESA climate change initiative.

Attendees of the Sustainable Accelerators Conference.

RIKEN solenoid

ISIS are working to replace the 30-year-old liquid-helium cooled superconducting solenoid on the RIKEN muon beamline with a dry, cryogen-free solenoid. Removing the need for non-renewable liquid helium cryogens and their necessary high-power compressors will reduce energy usage to a sixth of the existing system. The current solenoid is responsible for 1% of STFC's total CO_2 emissions and so this upgrade will significantly reduce CO_2 production.

Computing sustainability

There is active work to embed sustainability into ISIS computing activities. Work has focused on producing guidance for software developers' use of STFC cloud and automated testing systems, and adding sustainability into the planning of new software projects.

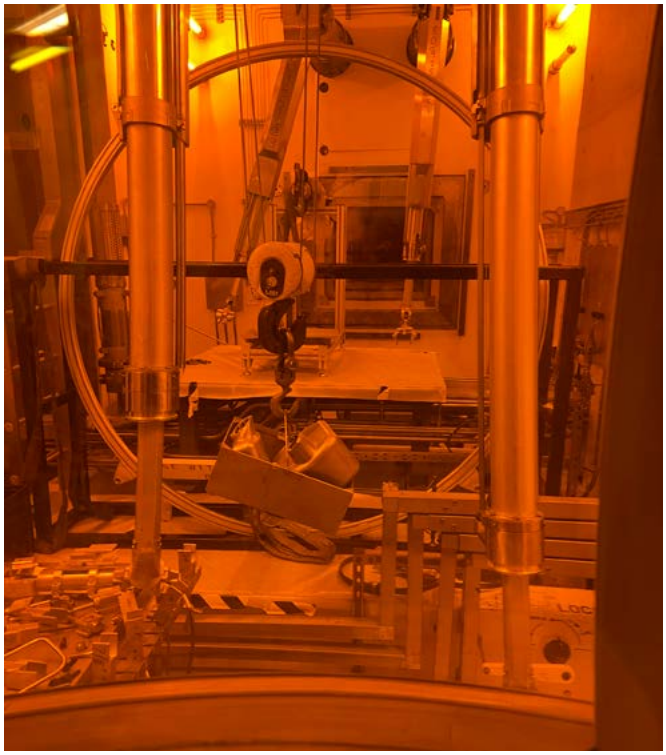
Linac tanks 2 and 3

As ISIS celebrates its 40th year, it is interesting to note that two of the current Linac tanks were manufactured by Metropolitan & Vickers in 1953 and saw use in two major facilities prior to ISIS.

After several Tank 3 radio frequency window failures late last year, the tank was opened to allow cleaning and polishing of the drift tubes, a process taking several days to complete. Although the tanks are over 70 years old, they are still performing well, which is a testament to the engineering that went into their manufacture and to the teams that have operated and maintained them over the years.

Chris Robinson and Nick Terzino cleaning Tank 3.

All change for the ISIS moderators



During the January 2024 shutdown, the target station crew changed all four cryogenic moderators in both TS1 and TS2. Significant preparatory work was required prior to shutdown to develop the tooling and procedures needed to carry out the work in the scheduled time. This was particularly challenging as it was the first time replacing the new hydrogen and methane moderators in TS1, and changing the TS2 coupled hydrogen moderator after 10 years of service.

Changing the TS2 moderators.

Construction of a new muon target

Muons are produced from a thin carbon target in the proton beam upstream of the TS1 neutron target. For the muon target to be replaced, a completely new build must be assembled and tested. The utmost care must be taken as, once the target is inserted into the extracted proton beamline, the unit will become too contaminated to rectify most faults. In 2023, a cleanroom was set up for the intermediate target pre-build. Since then, the cooling system has been pressure-tested, and intricate wiring for the profile monitor installed. The mechanical build has progressed well, and motion system commissioning will shortly be underway.

Improving target replacement

During the 2024 Easter shutdown, the TS2 target was replaced, using a previously untested method which did not involve the removal of the decoupled moderator. This reduced time, cost and active waste, allowing the team to also drain, filter and replace the target cooling water.

There is also a new Hot Isostatic Press facility within Target Operations group, which is used to manufacture ISIS targets. It is capable of processing materials, components and assemblies up to 1400°C and 2000 bar.

Instrument developments

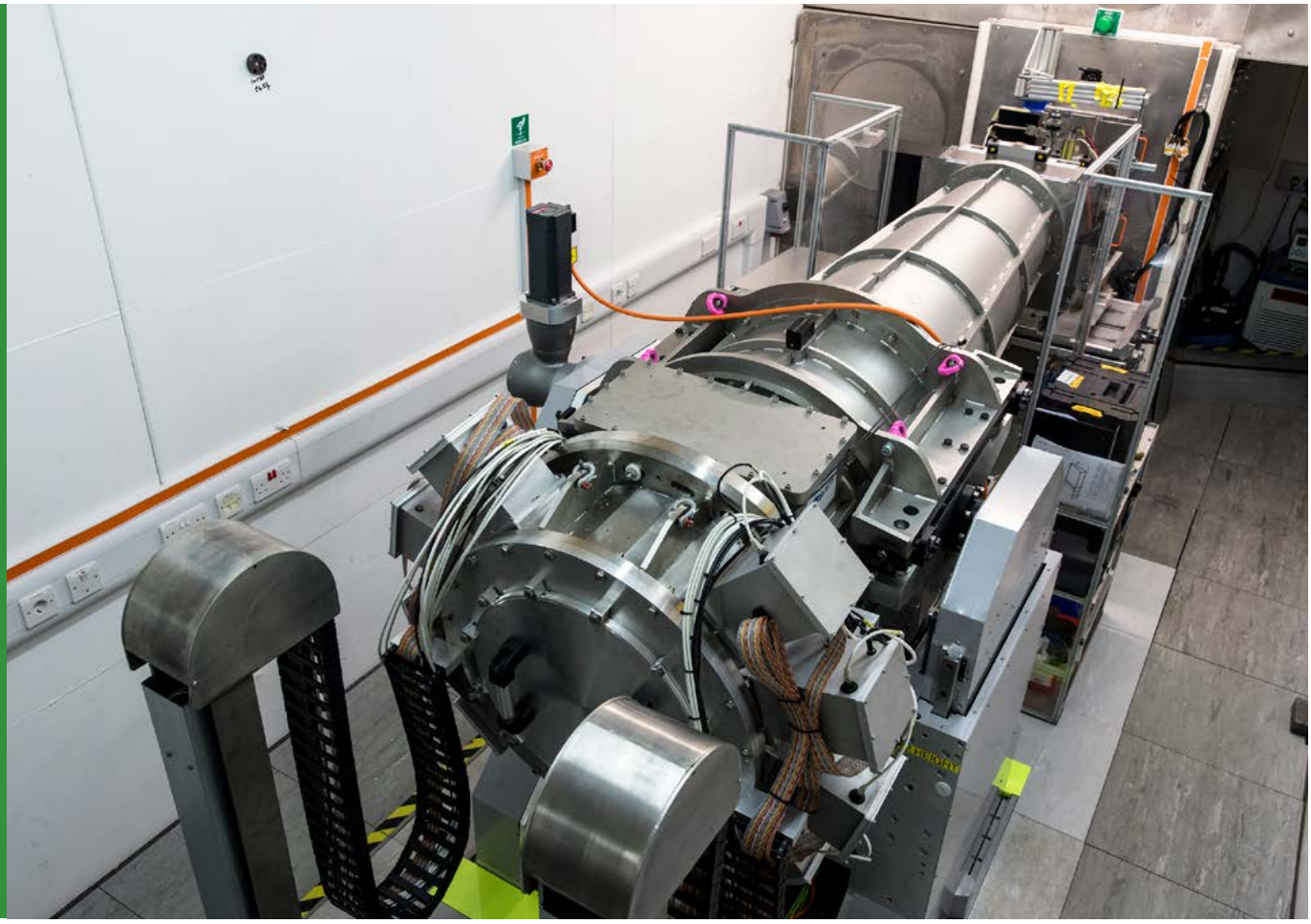
Sandals front-end upgrade

In 2023, Sandals benefited from a front-end upgrade, which successfully delivered a wavelength-dependent increase in neutron flux of a factor of two on average. This was achieved by increasing the methane moderator view from an 8 cm diameter circle to a 10 cm square, optimising the collimation geometry, and the insertion of three beam-defining jaw sets. This has significantly decreased counting times which, for a typical Sandals isotopic series sample, is now approximately four hours. The altered energy spectrum and profile produced from the TS1 neutron source refurbishment was addressed via the installation of a 50Hz frame overlap chopper.

Reflectometer developments

Surf is now back in operation following a major upgrade and is now undergoing commissioning. The upgrade comprised a new upstream vacuum chamber, two supermirrors, a focusing guide section and upgraded services.

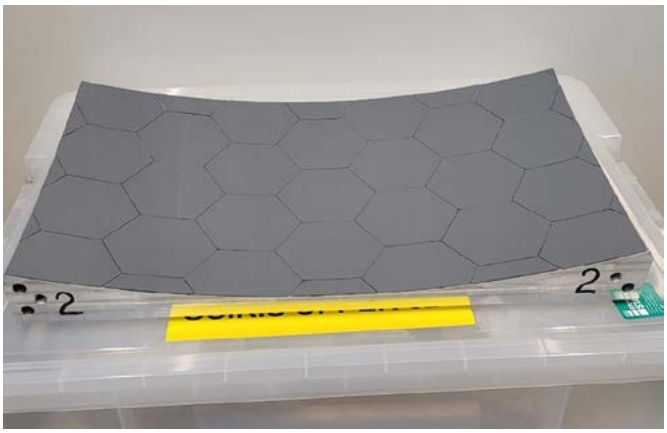
Inter is now back in user operation following a major upgrade. The usable flux has increased by a factor of four due to a horizontally focusing guide, new detector and evacuated flight path.



The new setup in the Inter beamline.

Osiris secondary upgrade

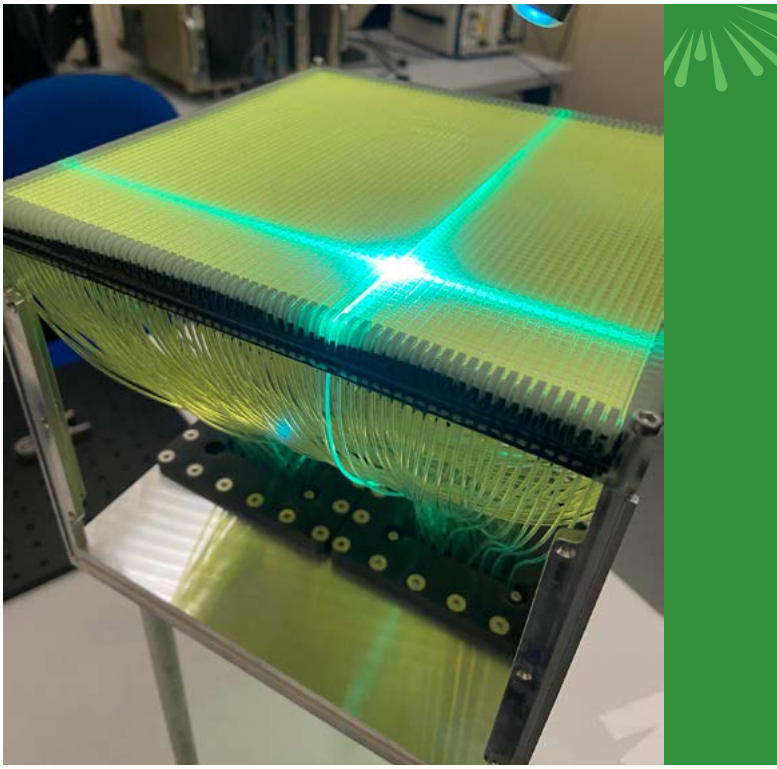
Osiris is being upgraded with the addition of a silicon analyser which will measure small energy transfers with high precision and provide new information about the mobility of ions, atoms and molecules. The pre-installation work has now finished, with a new tank lid and sample bin installed. As part of this, the whole vacuum control system was upgraded and the newly installed vacuum bin, with its new shielding, provides a higher count rate at the detectors of a factor of 1.5. With the hydrogen moderator upgrade, this amounts to an intensity increase of a factor of three for Osiris. Bonding of the silicon wafers on the aluminium frames has progressed well so that about half of the analyser surface is now ready for installation.



One of the finished analyser frames.

SXD capabilities expand thanks to new detectors

In the last few years, a very successful collaboration between the Detector and the Crystallography groups at ISIS has led to the development, building and testing of a new type of neutron detector, especially suited for the use on single-crystal diffraction instruments. During the 2023/24 winter shutdown, all eleven detectors that were in use on SXD since 2001 were replaced. The new detectors have higher efficiency, meaning that in the same exposure time they count up to four times more neutrons. This improvement gives SXD the ability to measure crystals of smaller sizes, or to decrease the exposure times on average-size samples, allowing users to collect more data in the same length of time. This also opens the possibility for SXD to expand the range of science that can be done, moving towards more challenging science topics.



Part of the new SXD detector system.

Robotic arm speeds up commercial testing of electric vehicle components

As part of a long-running collaboration with the ChipIr team, electronics company Infineon has adapted a robot arm specifically to help with their neutron irradiation experiments. Infineon Technologies is a global semiconductor leader in power systems and the Internet of Things.

Currently, Infineon visit ISIS several times a year, testing products on ChipIr to ensure their products are resilient to atmospheric neutron damage. This time, they brought with them a robot arm to change their samples instead of doing it manually, reducing their sample change time from six minutes down to just over ten seconds. The fact that Infineon have adapted a robot purely for this purpose shows the value that the company gets out of their neutron experiments, and their commitment to the longstanding collaboration with the ChipIr beamline.

Philipp Bender and Matthias Benda from Infineon with the robot arm in the ChipIr blockhouse.

Tracking carbon capture and utilisation in real time

A group from Queen Mary University of London (QMUL), together with the companies Cambridge Carbon Capture (CCC), Modern Age Plastics (MAPI) and researchers/ collaborators at Sapienza University of Rome, McMaster University and the University of British Columbia worked with ISIS science and engineering staff to develop a new piece of equipment for testing a process that not only permanently captures carbon dioxide but turns it into a greener ingredient for making concrete.

This allowed the team to replicate industrial conditions of the mineral-carbonation reactions and to watch and study the material during the mineralisation process in real time. “We were insistent on retaining relevance, including real-world impure starting materials and conditions that are like the ones in real-world settings and not at all well-behaved!”, said Dr Gregory Chass from QMUL.

First neutrons for the Migdal experiment

The Neutron Irradiation Laboratory for Electronics (NILE) at ISIS is a new facility with two desktop neutron sources. Whilst one is being used for testing electronics to evaluate their resilience to cosmic ray damage, the other is helping a group of physicists, led by the STFC Particle Physics Department (PPD) and Imperial College London, in their hunt for the elusive Migdal effect in which a neutral particle scattering from a nucleus can produce atomic ionisation alongside the nuclear recoil.

Chris Frost, ISIS Irradiation Group Leader, says: "We did not expect to be helping Pawel Majewski from PPD and his team in their hunt for dark matter, but a coffee conversation leading to a major collaboration between scientists from different areas is what makes working at RAL so rewarding."

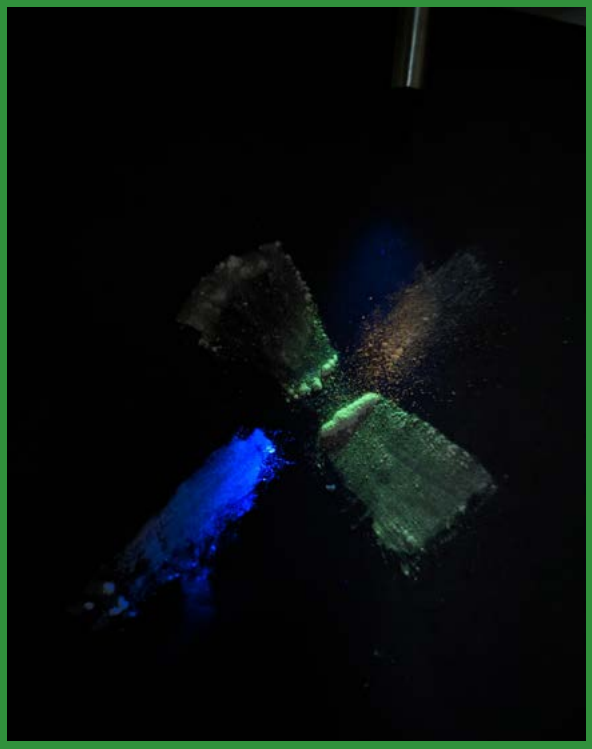
Pawel Majewski, Dave Newbold, Sergey Balashov, Timothy Marley, Chris Frost, Maria Kastriotou and Carlo Cazzaniga next to the Migdal experiment on the NILE instrument.

Detector developments

Attendees of PSND 2024.

The ISIS Detector Systems Group (DSG) hosted the Position Sensitive Neutron Detectors (PSND) conference at the University of Oxford in April this year. PSND 2024 brought together the world's foremost experts on neutron detector technology to exchange new ideas, solutions and continue building international collaborations addressing the neutron community's strategic objectives.

This year, new neutron sensitive nanoparticle scintillators that emit light in a few nanoseconds and can distinguish between neutrons and gammas were developed by the DSG research team. These were used to create a detector that could count neutrons at rates exceeding 1 million neutrons per second per readout channel – a gain of 50 over the current scintillators.



The new neutron sensitive nanoparticle scintillators.

Sample environment and experimental support

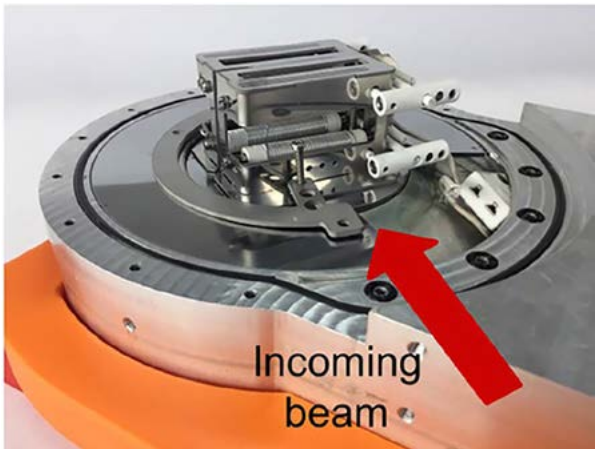
The Sample Environment Team continues to improve the resilience and capability of its offering to ISIS users. Their programme of obsolescence work, supported by the efforts of two sample environment working groups, has seen the gradual upgrade of control electronics for superconducting magnets, the inclusion of a greater number of dilution refrigerator inserts available for experiments, and an investigation into the use of automatic intensifiers for high pressure work.

Their links with sample environment teams around the globe is of strategic importance, and they continue to engage with colleagues worldwide to understand the latest developments in sample environment technologies and explore new possibilities. The group will present their progress, and seek out new links and ideas, at the International Workshop on Sample Environment at Scattering Facilities this year.

New sample holder developed for Delft furnace

The ISIS Soft Matter group have been key in delivering an experiment on the Larmor beamline which required the use of the Delft furnace, a loaned piece of equipment from Delft University in The Netherlands. It allows a magnetic field to be applied to a sample whilst heating it or rapidly cooling it.

However, a suitable sample holder needed to be produced which would both fit in the challenging geometry of the furnace and allow precision measurement of the temperature. This was successfully delivered via a collaboration between the Soft Matter team and the ISIS workshop. The experiment investigated oxide-dispersed-strengthened steels and welds, and their precipitate evolution and optimum tempering temperature.



The new furnace in place on the beamline.

New Deuteration Facility Laboratory now open!

The Deuteration Facility officially opened its doors to the newly-refurbished synthesis laboratory on 14 February 2024. The laboratory was destroyed by a fire in May 2021 and since then the team have been hard at work in a temporary home. This came with a lot of challenges due to limited equipment and space, and therefore it was difficult to keep up with the influx of requests from the ISIS users and other collaborators. After the fire, the opportunity was taken to design a new laboratory with safety and sustainability in mind.

This has included changing the layout of the rooms and introducing automatic fume hoods and automatic chemical cupboards. The laboratory has built-in remote features that allow elements such as vacuum and air handling to be controlled remotely.

Opening of new deuteration lab.

Yao Chen and James Keer working in the new deuteration lab.

Luke Broughan – making deuterated bacteria

Luke has been doing an industrial placement in the ISIS BioLabs as the final year of his Biomedical Sciences degree at the University of Warwick. His project is in Biomolecular Deuteration Method Development, working on a method to grow bacteria on a medium that is 90% deuterated.

The overall goal is to purify deuterated lipopolysaccharide (LPS), a fatty molecule that is the primary component of the outer layer of gram-negative bacteria. The team hope to use Luke's method to produce deuterated LPS for beamline studies to learn more about how the surface of bacteria interacts with drugs and human cells.

"Most higher organisms can't tolerate above 30-50% deuteration due to the severe toxicity that comes from D replacing H in bacterial molecules and D_2O replacing H_2O in the environment. But bacteria can adapt to overcome the detrimental biological effects" Luke explains. "This project is a fact-finding mission to inform the development of future experiments. Our work is brand new and it's exciting to make such an important contribution to future science."

Luke is also using his time here to influence his decisions on his next steps. He has enjoyed the exposure to different fields of research through working with users, something that he has not encountered before. Luke also joined the Equality, Diversity and Inclusion working group and has been involved in public engagement activities.

> "I've had such a positive experience here, being treated like a valued member of staff, not just a student, and exploring interdisciplinary science. Where else combines analytical chemistry, cell biology and high-energy physics?"
>
> Luke Broughan

Luke working in the laboratory.

Dale Keeping – recycling helium from beamlines and balloons

Dale Keeping is the Helium Recovery Manager at ISIS, responsible for the helium recovery facility. Recently, he has expanded the facility's work to the local community.

Dale's career began in mechanics, working as an apprentice vehicle technician at Volkswagen. After his apprenticeship, Dale turned his hand to some plumbing and gas work before applying to a role in the cryogenics team at ISIS, where he is now Helium Recovery Manager.

Set up in 2015, the ISIS Helium Recovery Facility is a recycling initiative to recover the helium used by ISIS and store it to be reused for future experiments. Currently, ISIS' helium recovery runs at over 95% efficiency, recycling around 53,000 litres of liquid helium each year.

After an encounter with a stranger buying helium balloons and discussions around its importance to science and technology, Dale started thinking about how the facilities at ISIS could be applied to the recycling of helium on a community scale. He reached out to his local primary school and kickstarted the 'helium recovery at schools' project.

As part of this scheme, collection points for helium balloons are established in local schools and businesses, which are then brought to ISIS for storage and reuse. This was made possible due to the support from staff across STFC and their passion for the project.

"This project aims to give the children a sense of pride and be empowered to recycle, help the planet, and have a direct impact on the science undertaken at ISIS through their good will. Hopefully, some of the children will also be interested in a STEM related career and perhaps work in our Cryogenics team one day!"

Dale Keeping in the helium recovery facility.

Computing

The User Programme Software group look after the software used to administer the User Programme at ISIS and the Central Laser Facility (CLF). Our proposal submission software has been developed in collaboration with the ESS (European Spallation Source) and in the past year has been extended to support more proposal calls, including those for High-Powered Lasers within CLF. The Facility Access Panels for ISIS have been brought online with new software to allow FAP members to review experiment proposals before FAP meetings take place.

Our scheduling system has been in place for a number of years and has this year been extensively upgraded to ensure it remains supported and compliant with current security processes. The Experiment Risk Analysis is in the early stages of being modernised and improved to include new support for Xpress experiments. Similarly, the team have been modernising the interface between our software for managing user visits for experiments and other services. They are also developing a replacement for the user interface that will enhance the user experience and improve the maintainability of the system.

Cybersecurity

This year, ISIS has made significant strides in enhancing our cybersecurity. We conducted our first departmental exercise to simulate potential cyber threats to help refine our response strategies. Additionally, we developed the ISIS Cybersecurity SharePoint site, facilitating easier information sharing and collaboration across teams. We are also in the process of developing a robust ISIS Incident Response Plan to ensure prompt and effective action in the event of a cybersecurity incident.

Treating neutron data

ISIS supports Mantid and Mantid Imaging for the treating / reduction of neutron data. Both packages have seen significant updates in 2024 including new algorithms for SANS2D, working with single-crystal Bragg peaks and improved file loading plus, for Mantid Imaging, improved performance of iterative tomography, tools for energy resolved imaging and a live data viewer.

Discussions taking place during an ISIS all-computing-staff meeting.

Behzad Fuladpanjeh Hojaghan and Pantea Ghahremani from the University of Calgary preparing solid state battery electrolyte samples in the Chemistry laboratory.

Partnerships and collaborations

Our external partnerships continue to grow: from industrial partnerships to increasing access for researchers in Canada, Brazil, Indonesia and Malaysia. 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.

Industry

ISIS has reached record numbers of beamdays for industry, commercial income and grant-funded industrial access. One example is sustainable bio-material developer Tensei Ltd, who used SANS to study sustainable papers and adhesives, using the Industry Impact Fund (I2F).

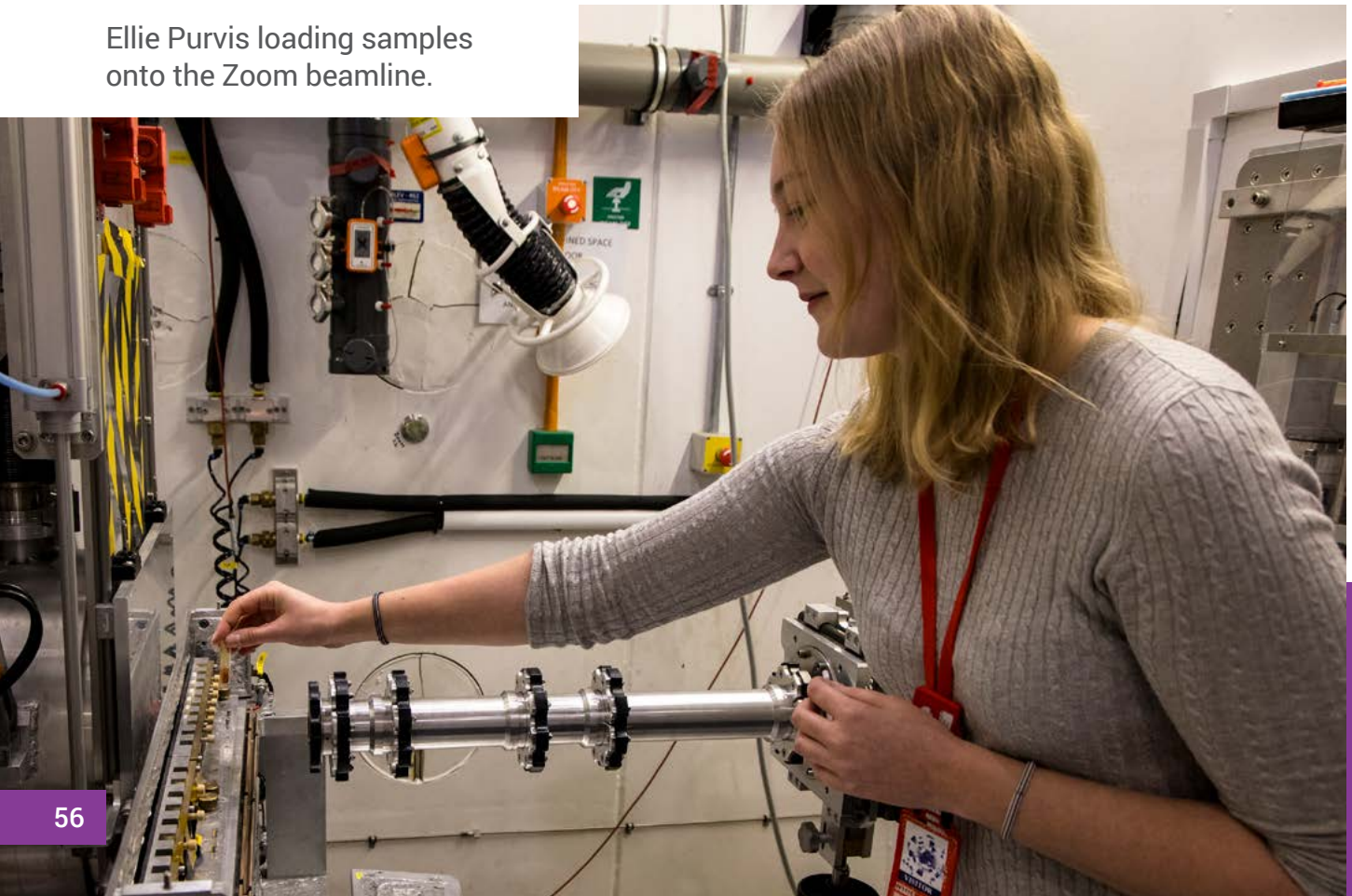
After meeting ISIS staff at a sustainable materials event, Tensei's CEO Annabel Cox realised that neutrons could benefit the company's work in developing sustainable papers and adhesives from agri-residues.

Working with SANS scientists James Doutch and Yi Zhang, Tensei applied for an I2F grant, which provides UK companies with access to STFC capabilities.

Tensei were allocated four days of beamtime on Zoom. "It was more hands-on than I expected," explains Ellie. "It was great to learn how to do it rather than just observing. The flexibility of being able to get some analysis in real-time and adapt the experiment, using the labs to reprocess our materials to create new samples, was very helpful."

"Neutrons allow us to look at our materials on the molecular level and, in particular, their interaction with water. There is no way to do this with other techniques and without the I2F funding, we wouldn't have been able to access the facility at all."

> Our collaboration with ISIS has given us a unique insight into our materials further development. A combination of comprehensive training on the equipment and the support of an experienced and helpful team led to some great results from our initial visit.
>
> Ellie Purvis
> Research Scientist, Tensei Ltd



Ellie Purvis loading samples onto the Zoom beamline.

Ruiyao Zhang – Industrial Liaison scientist

Ruiyao Zhang joined ISIS in 2024 as an industrial liaison scientist with a focus on the use of the engineering and imaging beamlines Engin-X and IMAT.

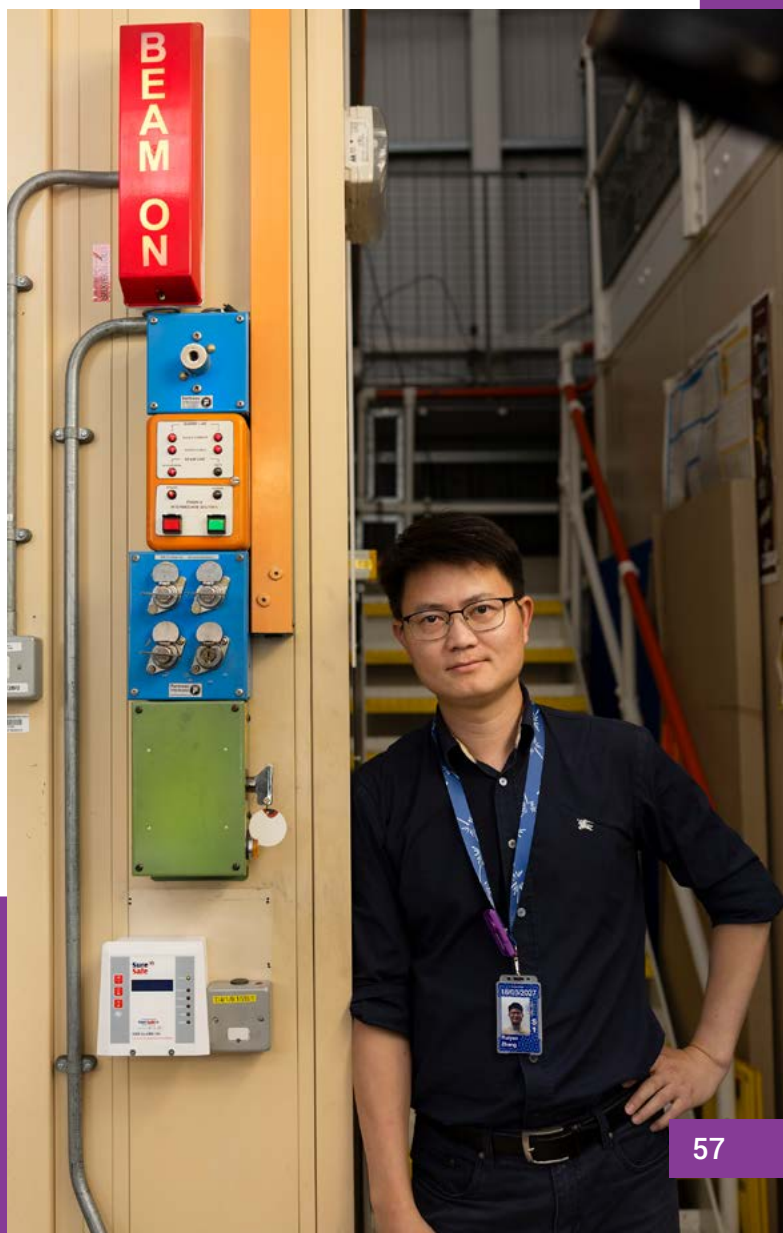
After an undergraduate Physics degree, Ruiyao moved into industry, working on product safety and performance testing. Looking for more of a challenge, he moved to the UK for a PhD at the University of Leicester. His project was studying nickel-based superalloys for use in jet engines, in partnership with an industrial collaborator.

"My PhD gave me the opportunity to come to ISIS many times as a user," says Ruiyao. "Primarily, we accessed Engin-X to study residual stress, deformation and phase transformations in our materials, but I also used IMAT, HRPD and muon instruments for other experiments."

After his PhD, Ruiyao joined the Open University StressMap team, which provides residual stress analysis for commercial clients. "In this role, I gained knowledge of several techniques for doing residual stress measurements, beyond using neutrons. I had the opportunity to work with commercial projects, finding that their requirements and demands are often very different to academic partners."

Ruiyao's current role is to provide technical support to industry users with their proposals, experiments and data analysis. He is also promoting awareness of ISIS in the commercial sector, identifying the needs of industry and bringing new industrial users to the facility.

"The most exciting part of coming to work at ISIS is returning to the UK neutron science community," says Ruiyao. "I have known some of the ISIS staff for many years, and have kept in touch with many UK neutron users in the community. I look forward to continuing to work with colleagues from the wider neutron research community."



Ruiyao Zhang on the Engin-X beamline.

International partnerships

ISIS is used by researchers from around the world, and has significant, long-standing international partnerships with several countries. These partnerships provide support for ISIS instrument developments for all users whilst allowing particular access for researchers from the partner country.

ISIS and Italy celebrate 40 years of partnership

On 15 February 2024, a celebration was held at RAL to mark four decades of collaboration and friendship between Italy and ISIS. The event was attended by Inigo Lambertini, Italy's Ambassador to the UK, and the President of the Italian research council (CNR), Maria Chiara Carrozza.

The first collaboration agreement between ISIS and Italy was signed in 1984. Since then, the partnership has seen some 4000 Italian researchers use ISIS leading to over 900 research publications. In addition, twelve neutron or muon instruments have been constructed at the facility through ISIS-Italy collaboration.

"This long-standing partnership between ISIS and Italy is impressive in its breadth and depth," Maria Chiara Carrozza, CNR President, noted. "It is a fantastic achievement that we are celebrating today – one that the CNR and ISIS can be rightly proud of."

Left to right: Inigo Lambertini, Maria Chiara Carrozza, Mark Thomson and Roger Eccleston at the ISIS-Italy 40 year partnership event.

Philip King being presented with the Commendation by the Japanese Ambassador to the UK, Hajime Hayashi.

Japanese government honours RIKEN-ISIS partnership

The longstanding collaboration between RIKEN (Japan) and ISIS was recognised by the award of the Japanese Foreign Minister's Commendation to Philip King, Associate Director for Partnerships and Programmes at ISIS and former Director of the RIKEN Office at the Rutherford Appleton Laboratory.

This award acknowledges Philip's significant contributions to the partnership between ISIS and Japan's largest research institution, RIKEN. It also recognises the impact of the RIKEN-ISIS partnership in advancing scientific collaboration and strengthening relations between the UK and Japan.

ISIS-Canada partnership

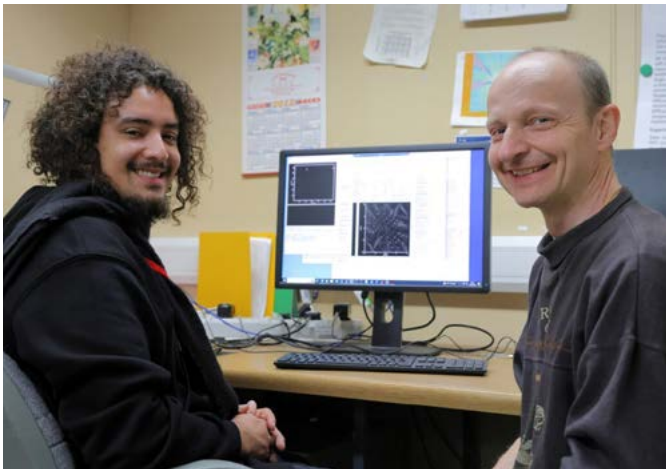
ISIS is working with Neutrons Canada, a collaboration of 15 Canadian universities, to foster and develop the Canadian long-range plan for neutrons. The two organisations signed a partnership agreement in 2023. Since then, two calls for proposals for Canadian use of ISIS have been held, with experiments supported by funds from the UK International Science Partnerships Fund (ISPF). The Canadian neutron long-range plan should see a long-term relationship established between ISIS and Canadian researchers.

Drew Marquardt, Natalie Robison and Stuart Castillo, University of Windsor, Canada, using SANS2D to explore the effects of a cancer drug candidate on mitochondrial membranes.

Access to ISIS for Brazilian scientists

ISIS has an award from the UK International Science Partnerships Fund (ISPF) to partner with Brazilian researchers to foster use of neutron and muon techniques for Brazilian science priority areas.

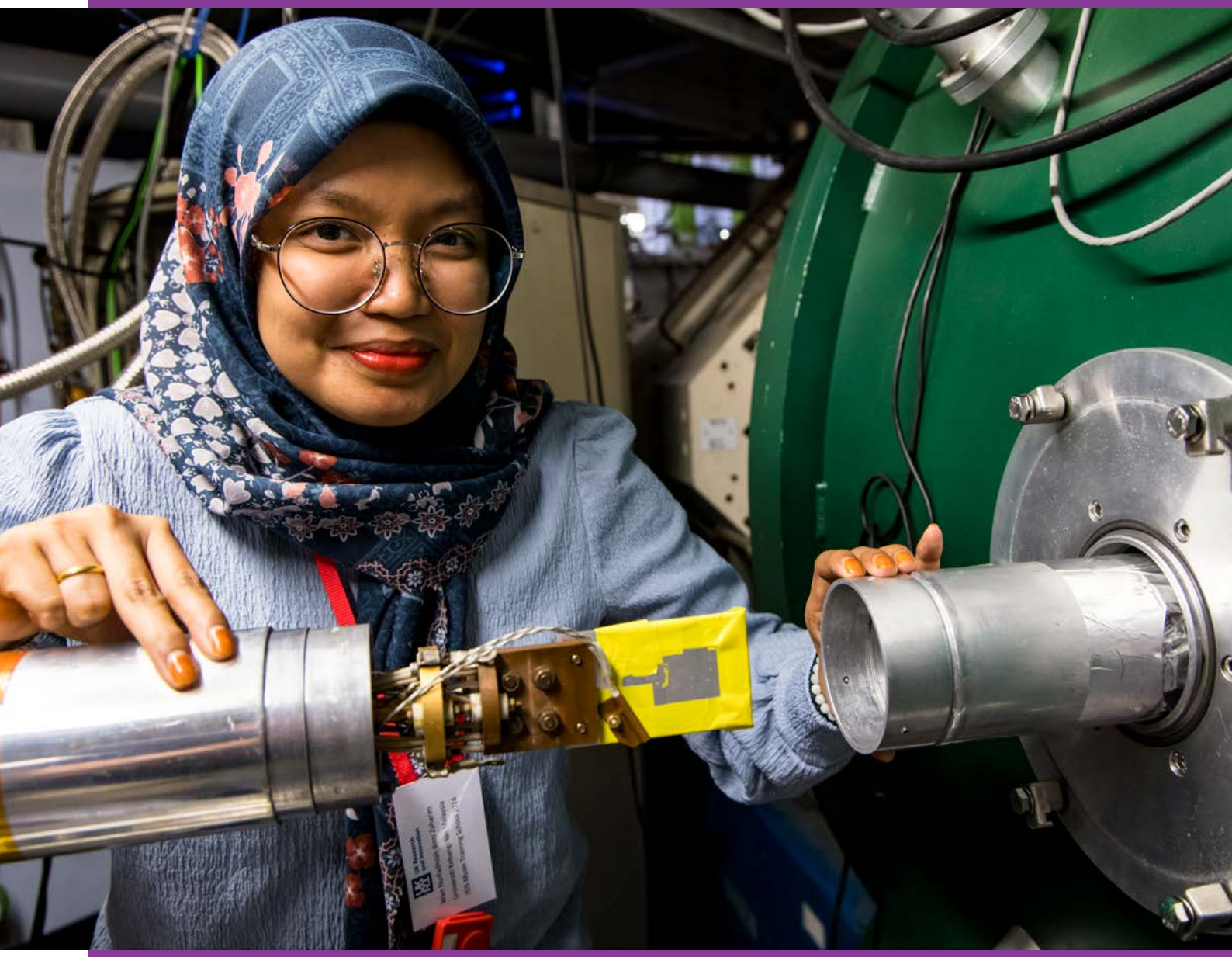
The past year has seen a series of webinars held to introduce Brazilian researchers to ISIS and its science, followed by a meeting with Brazilian researchers and funders in Sao Paolo and a lecture tour by ISIS staff. Over 25 proposals have subsequently been received from Brazilian researchers, on topics including catalytic biofuel synthesis, mercury encapsulation and bacterial uptake to help remove pollution, and multiferroics for energy applications.



Alexandre Henriques da Silva, Universidade de São Paulo, Brazil, with Matthias Guttman, ISIS, using SXD to study phonon behaviour in $BaBiO_3$.

Working with the Malaysian Ministry of Higher Education

ISIS has partnered with the Malaysian Ministry of Higher Education (MOHE) on a joint call to enable Malaysian researchers to use neutron or muon techniques. The collaboration, funded through both MOHE and the UK ISPF, attracted 30 proposals to use the facility for topics from Li-ion battery material development, investigation of rice bran proteins, neutron tomography for soil composition studies and nanoparticles for seed priming.



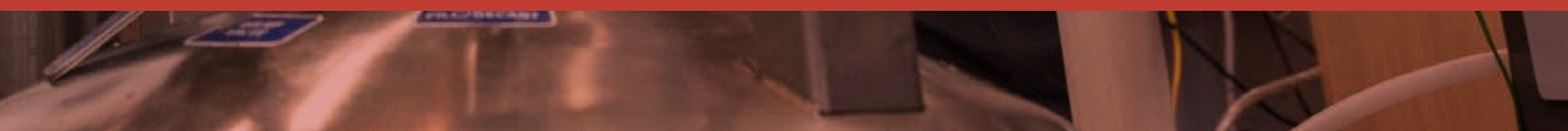
Wan Nurfadhilah Binti Zaharim, Universiti Kebangsaan Malaysia, on the HiFi instrument during the ISIS Muon Training School.


HELIUM

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.

Alex Jones and Lucy Bain of the ISIS Cryogenics team setting up an experiment in TS1.



Visits and events

The UK ITSS Technical Council visit ISIS

On 23 April 2024, sixteen members of the Technical Council of the UK Institute of Technical Skills and Strategy (ITSS) visited the Rutherford Appleton Laboratory (RAL) to attend their third annual Council meeting. The ITSS is a new venture originating from the Technician Commitment initiative with the main mission to “ensure the long-term sustainability of UK technical skills and careers.”

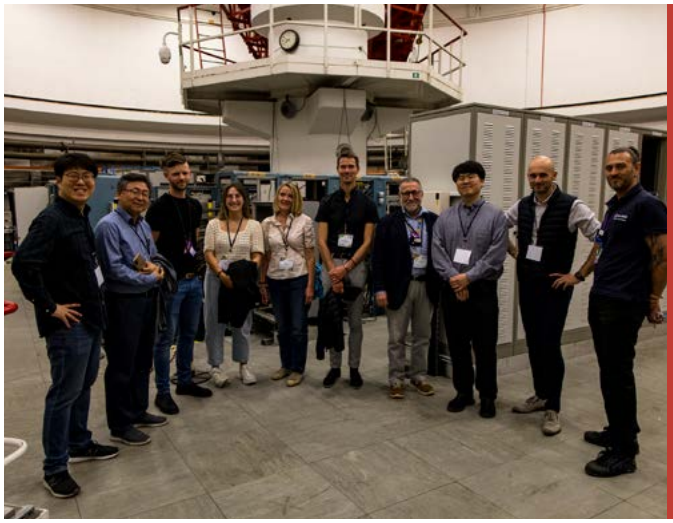
The day included meetings with STFC senior managers, a tour of ISIS and discussions with the STFC Technician Commitment Steering and Working groups. It was a highly successful and informative event for the council, as well as a good opportunity to make introductions and network.

ITSS Technical Council group at ISIS.

Attendees of RaPHEA at RAL

ISIS Health Physics team host international workshop

The first Radiation Protection in High Energy Accelerators (RaPHEA) international workshop took place from 17 - 19 June. It was attended by 40 delegates from seven high-energy accelerator facilities around the world. There were talks covering area monitoring, environmental dose assessment, personal dosimetry, activated material, radioactive waste, training, and learning from incidents. All the talks were followed with great interest, and lengthy discussions took place. At the end of the workshop, everybody agreed that it was a very successful event and that the second RaPHEA should be held soon.



Attendees of RaPHEA in the ISIS inner synchrotron.

UK Neutron & Muon Science and User Meeting (NMSUM)

Over 300 members of the UK community gathered at Warwick over three days in April 2024 to hear science with neutrons and muons and talk about facility developments at the main UK neutron and muon user meeting.
A day for PhD students to present their work, with over 100 present, was followed by a day of parallel science sessions and a final morning of facility updates and community discussion. In addition, the BT Willis Prize for neutron science was awarded to Andrew McCluskey, ISIS Impact Award winners were announced, over 80 posters were presented and 40 years of ISIS were celebrated with a dinner quiz. Next year's meeting will will also be held at Warwick from 17-19 March 2025.

Attendees at the 2024 UK Neutron and Muon Science and User Meeting.

Student engagement

ISIS placement student is the first Gulf Cooperation Council national to be employed by UKRI

Aziza al Mugheiry, a Physics and Astronomy undergraduate at Cardiff University, is currently completing an industrial placement in the development of online scientific training. At 19 years old, she is the first Gulf Cooperation Council national to be employed by UKRI and her role here is a milestone for gulf Arab representation in science.

During her placement, she was invited to give a lecture at the British Omani Society about the heritage research conducted at ISIS and became their youngest ever speaker since its inception in 1976.

Aziza presenting at the British Omani Society.

> **I've only ever done 15-minute presentations at university so an hour's lecture at a society representing my birth country and the country I am having these amazing opportunities in felt very daunting! But it was a unique opportunity and a fantastic challenge.**
>
> Aziza al Mugheiry

Facility Development Student Conference

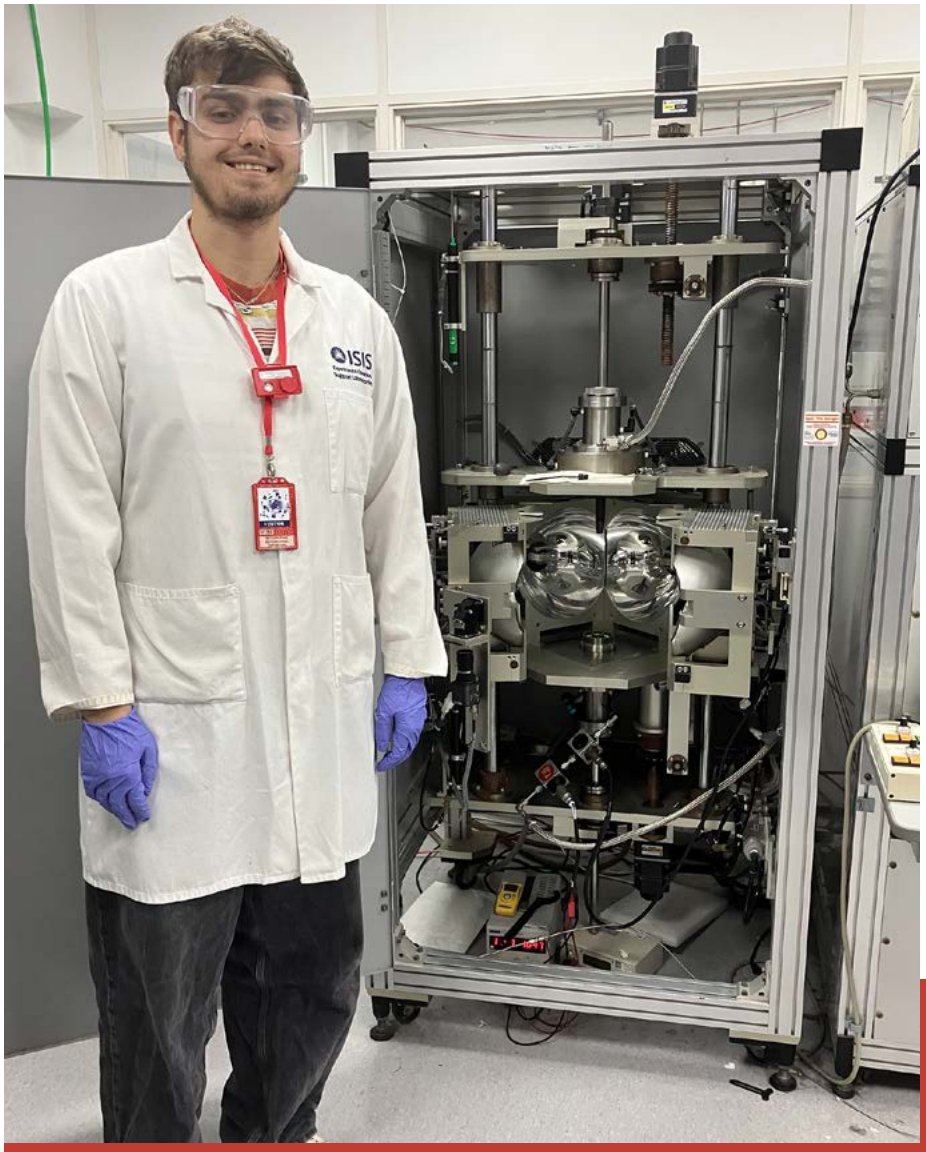
On 5 - 6 June, we held a conference for students funded through ISIS' facility development studentship scheme. The event brought together students from across five cohorts to share their research through talks and poster presentations. The sheer quality of the talks is to be commended and there was also an engaging careers session, where speakers who had done ISIS-funded PhDs and then gone on to work in roles across ISIS and academia gave crucial advice on life post-PhD, as well as discussion sessions to talk about student life on campus, and an opportunity for PhD students from other RAL facilities to meet one another.

Benji Moore – placement year to PhD, with a publication along the way!

During his industrial placement at ISIS, Benji Moore worked on a project that saw him publish a paper as its first author. The paper detailed how a new synthesis technique, which uses a modified optical floating zone set-up, can be used to grow a ternary sulphide crystal from an open melt. This method, developed by Robin Perry, opens opportunities for the study of other ternary transition metal sulphides, which are attractive candidates for semiconducting and thermoelectric materials.

Since completing his degree, he has started a PhD at the University of Manchester and returned to ISIS as a user. The scholarship that Benji is on is one of only two awarded that year and is therefore very competitive.
"I don't think I would have been considered if I did not have the experience from my year in industry," he adds.

It wasn't only his research skills that he developed during his placement, as speaking at group meetings developed his presentation skills. He is also still in contact with other placement students, one of whom is also using neutrons for their research, but in another area of science. Who knows? There may be a future collaboration waiting to happen...!



Benji Moore by the set-up he worked on during his placement.

Training schools

Both the neutron and muon training schools returned to ISIS in 2024.

The 2024 ISIS Muon Training School, which was held at RAL on 18 – 22 March, welcomed 32 participants from eight different countries, including the UK and several ISIS partner nations. The participants engaged in lectures, data analysis workshops and practical beamtime experiments led by ISIS Muon group scientists, with plenty of opportunities for scientific discussion between the participants and instructors throughout the school. The week culminated in a series of student presentations, which gave the participants the opportunity to demonstrate and share what they had learned with others. The organisers have since received overwhelmingly positive feedback from the students, and we look forward to welcoming them back to ISIS as muon facility users in the future.

Attendees of the muon training school.

Attendees of the neutron training course.

The 2024 running of the ISIS Neutron Training Course took place in May, with 32 participating students from UK, Italy, Sweden and from our newest partner countries, Brazil and Indonesia. The course is aimed at new neutron scatterers wishing to gain practical experience of and training in neutron scattering experiments and data analysis on the ISIS beam lines.

Public engagement

Inspiring the next generation

2023-24 has been another exciting and active year for public engagement at ISIS. The ISIS team delivered 60 public and school engagement events – virtual, in-person, onsite and offsite – reaching 5895 school students, teachers and members of the public through our hybrid programme of activities.

From particle physics and space science, to cryogenics and remote handling, our activities span a wide range of themes to reflect the variety of work and expertise at ISIS. Engaging diverse and under-represented audiences is also an important part of the ISIS Public Engagement programme and we continue to work to increase our engagement with more diverse audiences and those from areas of high deprivation. Through our programme of activities and events, we continue to highlight diversity in STEM, creating new materials and linking into campaigns including Black History Month and International Women's Day.

A highlight in the ISIS Public Engagement calendar this year includes the expansion of the Engineering Experience Programme (EEP), led by an ISIS Graduate and supported by the ISIS and RAL Public Engagement teams.

After the successful initial expansion of the programme beyond ISIS and across RAL, this year EEP saw further expansion across RAL Apprentices, Industrial Placement Students and Graduates, who mentored A-level students from ten local schools over 6 months.

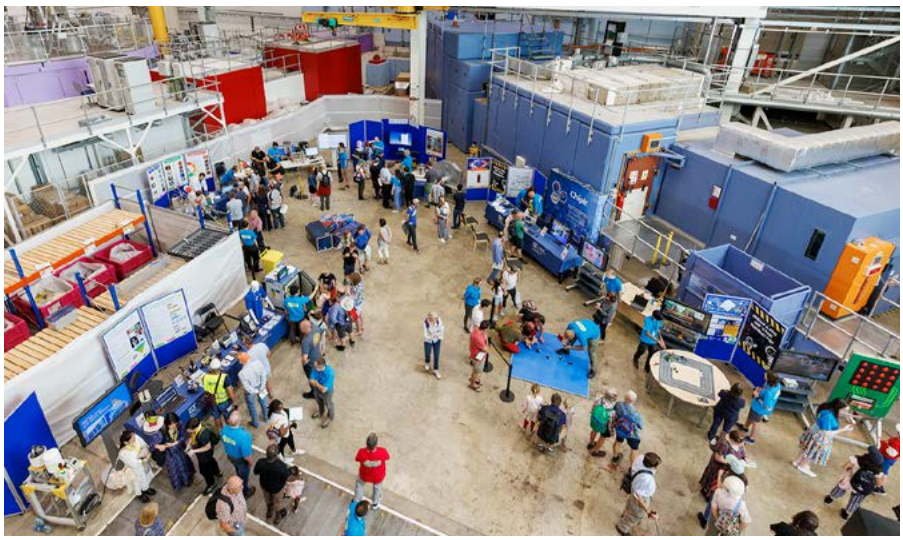
> **I would totally work here in the future if I could. This has been an amazing experience and the technology and previous discoveries here is astounding.**
> Student participating in EEP

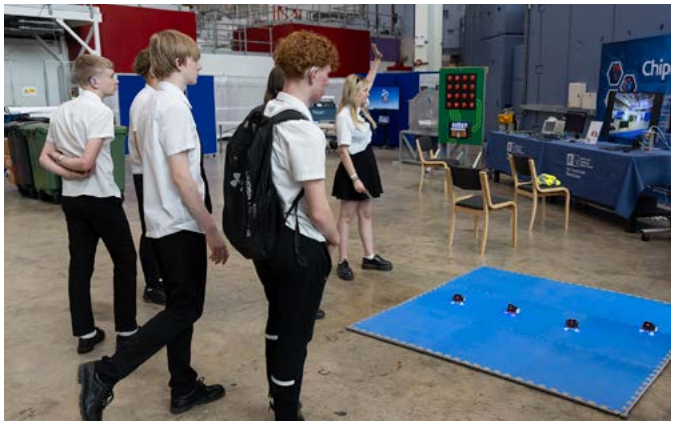
The facility also hosted 56 work experience students for week-long placements in summer 2023 as part of the RAL work experience programme, offering students the opportunity to work alongside ISIS staff across a range of disciplines and areas of work. ISIS also hosted training events for 23 UK educators, offering unique insights into the facility and our science and engineering.

Attendees of the Engineering Experience Programme listening to an introduction.

Harwell Open Week

In the summer of 2023, ISIS staff ran a series of engagement activities as part of Daresbury Open Week, allowing the facility to engage with the Daresbury local community and schools, as well as other STFC staff. Daresbury Open Week was then followed by Harwell Open Week in 2024, with ISIS opening its doors and welcoming over 500 students and close to 2900 members of the public over the week. Visitors were able to explore the facility on a self-guided tour, discovering our cutting-edge science and engineering through hands-on activities, meeting our staff and hearing their stories.



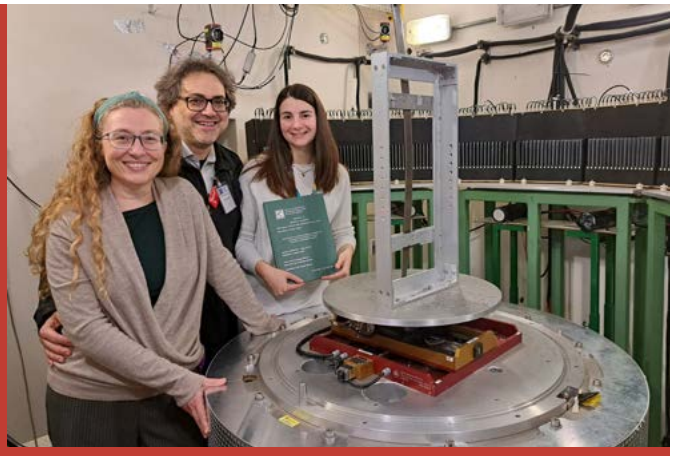


Visitors to ISIS during the Harwell open week.

Awards

ISIS post-doctoral researcher Giulia Marcucci wins INFN national award for Best PhD thesis

Giulia Marcucci, a post-doctoral researcher at ISIS and the University of Milano-Bicocca, Italy has won the National Institute of Nuclear Physics' award for Best PhD Thesis in Accelerator Physics and New Technologies. Giulia's main research focuses on the development of quantitative 2D Neutron Resonance Spectroscopy techniques on the instrument INES at ISIS, which is combined with neutron diffraction, imaging, and elemental analysis methods to investigate complex materials.



Left to right: INES instrument scientist and supervisor Antonella Scherillo, INFN and University of Milano-Bicocca supervisor Professor Massimiliano Clemenza and Giulia Marcucci.

Shinji Machida wins the Institute of Physics Prize for Outstanding Professional Contributions in Accelerator Science and Technology

This annual prize recognises someone who has contributed to accelerator science and technology in the UK or Ireland and raised its public profile. The IoP Award Committee citation said: 'Dr Shinji Machida has been the pre-eminent theoretical accelerator physicist working in the field of high intensity proton and ion accelerators in the UK for the last ten years. He must rank in the top two or three theoretical accelerator physicists working on high intensity proton machines world-wide at the present time and is a world authority on fixed-field alternating gradient accelerators (FFAs)'

Chris McKay wins Jack Martin Prize

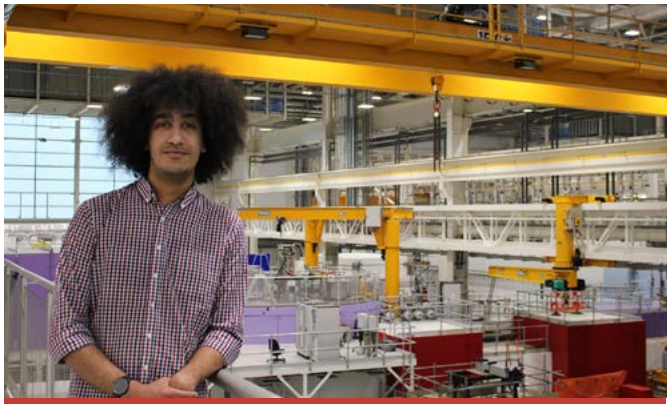
Chris McKay, ISIS Radioactive Waste Manager and Chair of the ISIS Sustainability Network, has been awarded the prestigious Jack Martin Prize for best presentation at the Society for Radiological Protection's Annual Conference in May.

Chris's presentation, titled 'Accelerating sustainable radioactive waste: lessons learned in the management of radioactive waste at a spallation neutron source,' highlighted practices related to the generation and management of radioactive waste at ISIS. Chris shared insights gained from navigating challenges and achieving successes in radioactive waste management at ISIS and addressed future efforts toward more sustainable approaches.

Mohamed Aouane wins SFN Thesis Prize

MARI instrument scientist Mohamed Aouane has been awarded the SFN (the French Neutron Society) thesis prize. Mo's thesis used Inelastic Neutron Scattering to probe endofullerenes, which consist of atoms or small molecules entrapped inside C_{60} cages. These systems represent a real-life manifestation of the particle in a box system where the encapsulated atom or molecule is confined within the nearly spherical cavity.

"Mo's work has re-defined what is possible with inelastic neutron scattering. It is amazing that he is able to extract so much detailed information from only a few tens of milligrams of sample." ISIS Molecular Spectroscopy Group Leader, Stewart Parker.



Mo in ISIS Target Station Two.

ISIS Electronics Engineer Tara Allinson wins STFC Apprentice of the Year 2023

Tara Allinson has not only won STFC Apprentice of the Year but was also awarded 'Highly Commended' for both the Impact and Peer Support Awards and the 'Regional Highly Commended' at the National Apprentice Awards.

"Becoming an apprentice at ISIS is a really good opportunity to be introduced into the workplace, whilst simultaneously gaining an education and also receiving a salary. A levels isn't necessarily the preferable route. I started at ISIS when I was 17 and I can't tell you how much it's helped me with my personal confidence."

Tara Allinson accepting her award for Apprentice of the Year.

RSC 2024 Dalton Horizon Prize

Dr Ivan da Silva, Dr Pascal Manuel, and Dr Svemir Rudić were all part of a collaboration who received the Royal Society of Chemistry's prestigious Dalton Horizon Prize. The Functional Framework Materials: Design and Characterisation Team is a collaboration between the University of Manchester, Oak Ridge National Laboratory, Diamond Light Source, ISIS Neutron and Muon Source STFC, Berkeley Advanced Light Source, Peking University, Xiamen University and the University of Chicago.

They received the prize for their seminal contributions to in situ and operando characterisation of porous materials and catalysts for the binding, capture and separation of fuels, hydrocarbons, and pollutants.

Governance

The ISIS Leadership Team (ILT) is the senior leadership board within ISIS, responsible for the development and delivery of the strategy and the oversight of all projects and operations. It consists of the ISIS Director, Deputy and Associate Directors and Division Heads, and meets formally once per month and more informally weekly.

ISIS is supported by various oversight and advisory boards.

The **ISIS Facility Board** provides advice and oversight to all aspects of ISIS operations. It reports to the STFC Director of Large Scale Facilities. It consists of senior members of the community and other facilities and meets twice per year. The current membership is:

Meeting Chair: Phil Withers (University of Manchester)

Catrin Davies (Imperial College London)

Lorna Dougan (University of Leeds)

Katia Pappas (TU Delft)

Fulvia Pilat (Oak Ridge National Laboratory)

Neal Skipper (University College London)

Giovanna Fragneto (European Spallation Source)

Jacques Jestin (Institut Laue–Langevin)

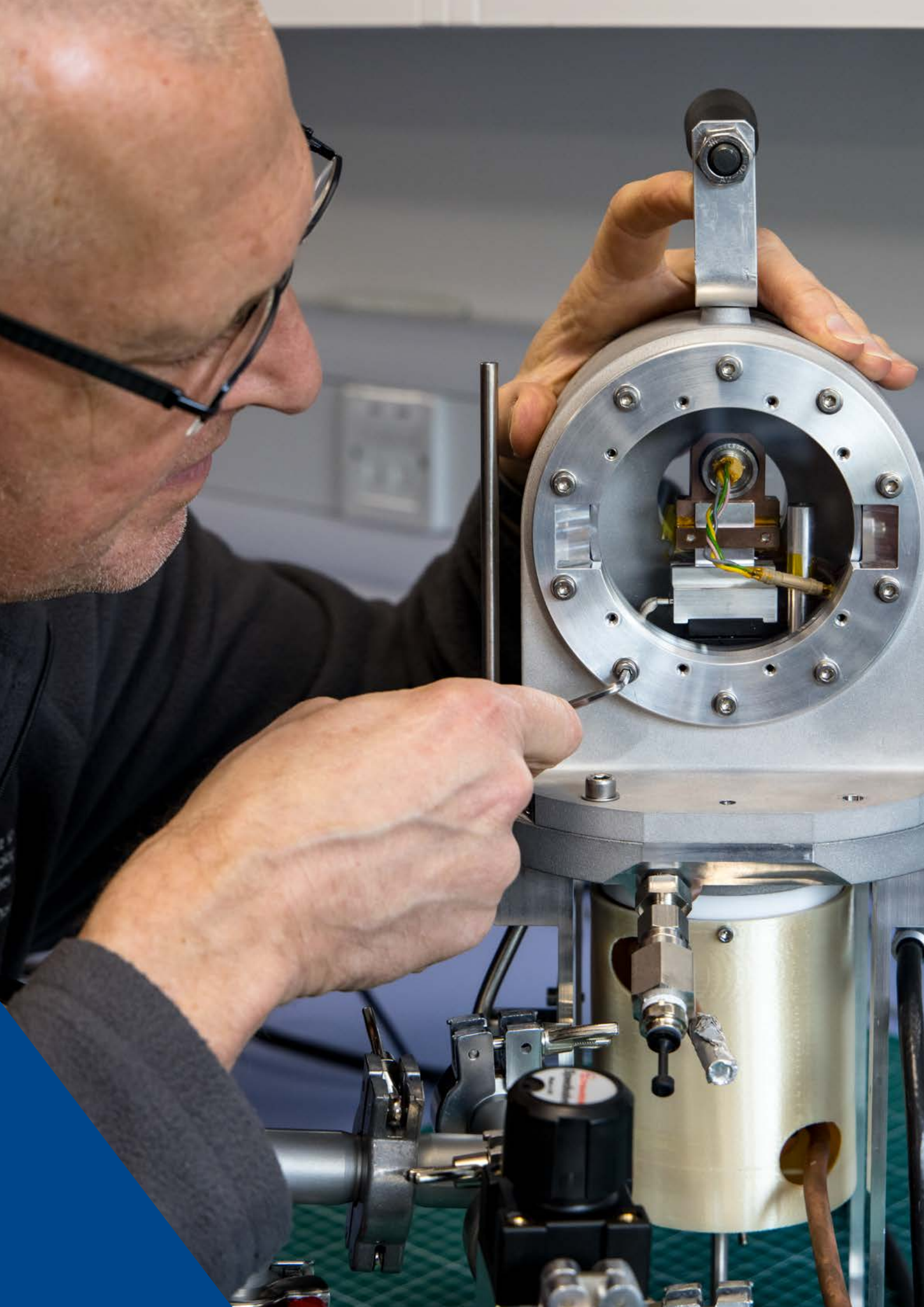
The ISIS Facility Board in December 2023. L to R: Neal Skipper, Jacques Jestin, Fulvia Pilat, Catrin Davies, Philip Withers, Katia Pappas; online: Giovanna Fragneto and Lorna Dougan.

The **ISIS Science Advisory Committee (SAC)** provides advice to the ISIS Director on all aspects of facility science and instrumentation. It meets twice per year and consists of senior members of the UK and international community. As of March 2024, the membership was:

Meeting Chair: Richard Catlow (University College London, Cardiff University)
Bill Stirling (Institut Laue–Langevin, European Synchrotron Radiation Facility)
Alan Tennant (Oak Ridge National Laboratory)
Pascale Deen (European Spallation Source)
Michael Preuss (Manchester & Monash Universities)
Leila Moura (Queen's University Belfast)
Adam Clancy (University College London)
Chris Ridley (ISIS)
Heloisa Nunes Bordallo (University of Copenhagen)
Andrew Goodwin (University of Oxford)
Ivana Evans (Durham University)
Michael Toney (University of Colorado Boulder)
Tom Lancaster (Durham University)
Stuart Clarke (University of Cambridge)
Markus Strobl (Paul Scherrer Institute)
Tim Hyde (formerly Johnson Matthey)

The **ISIS User Committee** represents the user community and provides advice to ISIS on all aspects of the user programme. It meets twice per year, and has membership drawn from across the ISIS science areas.

The **ISIS Facility Access Panels (FAPs)** meet twice per year to review all proposals that come into the facility for beamtime. There are ten panels, each consisting of experts in relevant areas from the science community. The FAPs provide a recommendation to the ISIS Director of the experiments that should be run at the facility over the next six to nine months.



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ISIS Director, Roger Eccleston
01235 445599
User Office; 01235 445592
Web www.isis.stfc.ac.uk

ISIS production team: Rosie de Laune, Stephanie Richardson
Design and layout: Sarah Haines

Left: Andy Church, ISIS, working on the new humidity cell thaas designed and 3D printed by the sample environment team.

Science and
Technology
Facilities Council

ISIS Neutron and
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