NEUTRONS
FOR SOCIETY

THE INSTITUT **LAUE LANGEVIN**

THE WORLD'S LEADING FACILITY IN NEUTRON SCIENCE & TECHNOLOGY

EDITORIAL

"At a time when the world is facing a multitude of major challenges, I think we can all be proud of having succeeded in creating, at the very heart of Europe, a research institute that is truly unique in the world.

The ILL is the international leader in neutron science and technology, where researchers from far and wide come to carry out experiments that would simply be impossible anywhere else.

It is a symbol of European cooperation and scientific excellence. An institute with a rich history spanning almost 60 years, which, thanks to a series of ambitious investment programmes, has succeeded in remaining at the cutting edge of both science and technology with its suite of over 40 state-of-the-art scientific instruments.

It is a truly remarkable facility where the unique characteristics of neutrons, including their sensitivity to light atoms such as hydrogen and lithium, are proving to be invaluable assets in meeting the challenges we are currently facing in such strategic areas as health, energy, environmental sustainability and quantum materials.

Above all, ILL is an institute which, beyond its contribution to fundamental research, is constantly helping to shape the technological solutions which improve the world we live in.

The ILL has flourished over many decades by adapting to a changing world. Europe is currently reflecting on the large-scale investments needed to ensure its future competitiveness, and closing the innovation gap is a key driver. Research and innovation must be at the centre of EU strategic priorities, delivering research excellence and benefitting from investment in world-class research infrastructures. Now more than ever, the ILL is ready to contribute to European competitiveness."

Ken Andersen, ILL Director


ATTENTION
PRÉSENCE DE PEINTURE AU GADOLINIUM
NE PAS MANIPULER SANS PRÉSENCE RADIOPROTECTION
NO STEP

ABOUT US

ILL AT A GLANCE

The Institut Laue-Langevin (ILL) is a user facility which welcomes scientists from all around the world to perform cutting-edge experiments fostering progress in a variety of scientific and technological domains. Producing the most intense neutron beams in the world, it offers a unique tool for probing the heart of matter. The ILL plays a leading role in scientific research, innovation and education and has been the acknowledged world leader in its field for almost 60 years.

Resolutely in touch with the world around it and the major societal issues of today and tomorrow, the ILL helps drive significant advances in the fields of health, energy, the environment and quantum materials. The partnerships forged with academic institutions and industry help to ensure that innovations developed at the ILL benefit society as a whole.

OVER
100 M€
annual budget

OVER
40
state-of-the-art
scientific instruments

20 %
of experiments
related to industry

500
staff members
from **30** countries

1 400
scientific users per year
from **65** countries

SEVERAL
1 000
radiotherapy cancer treatment
doses delivered per week
during reactor cycles

OVER
40
PhD students

1 000
experiments
per year

500
scientific publications
per year

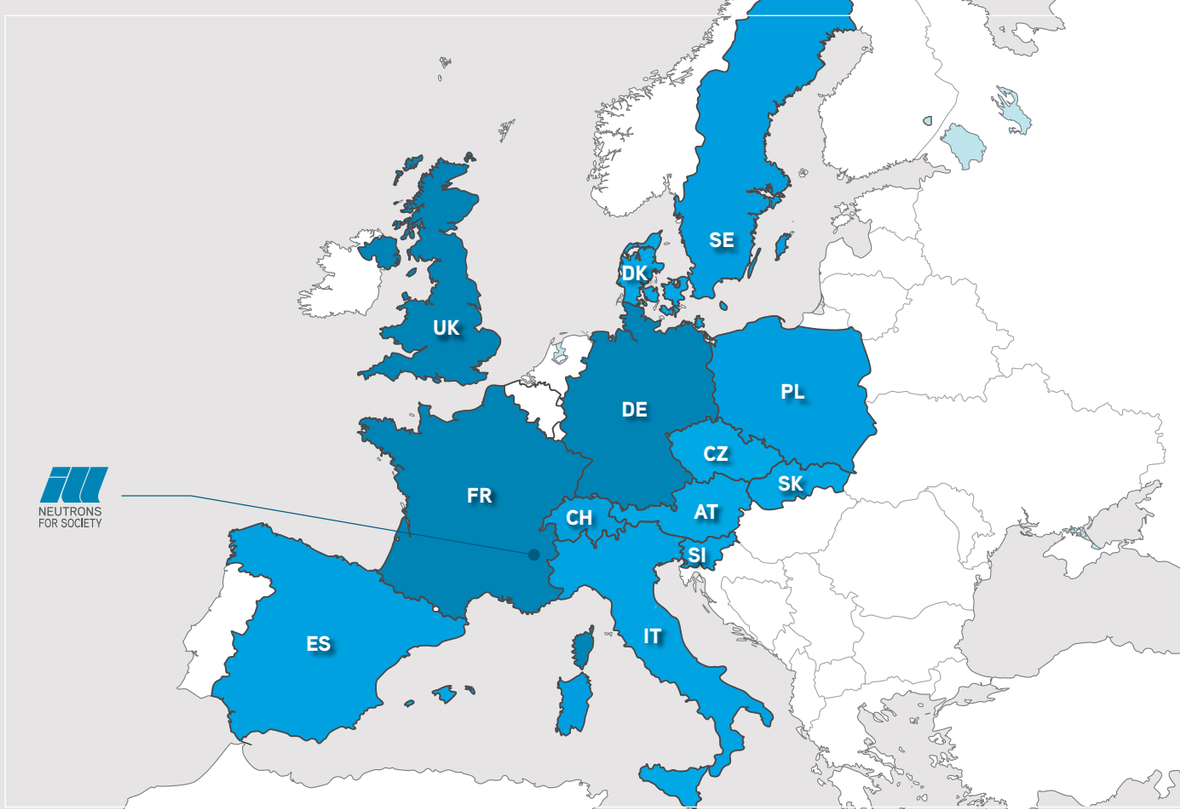
A SYMBOL OF EUROPEAN EXCELLENCE

A major European project, the ILL was founded in Grenoble in 1967 by France and Germany, joined a few years later by the UK. With the ambition of creating an international benchmark in neutron science and technology, 14 countries from Europe and beyond gradually joined the founders to contribute to this great scientific adventure.

Today, 13 countries fund the ILL for the benefit of their research communities.

Every year, more than 1400 researchers, mainly from member countries but also from 50 other countries around the world, are selected by expert committees to visit the ILL to carry out over 1000 experiments that push the boundaries of scientific knowledge.

European cooperation is further fostered through European projects and networks such as LENS - the League of advanced European Neutron Sources - and EIROforum - the European Intergovernmental Research Organisation forum.



ASSOCIATE COUNTRIES

France, Germany and the United Kingdom contribute with roughly 75 % of the ILL's budget.

MEMBERS COUNTRIES

provide around 20 % of the ILL's budget, the remaining being assured by own income.

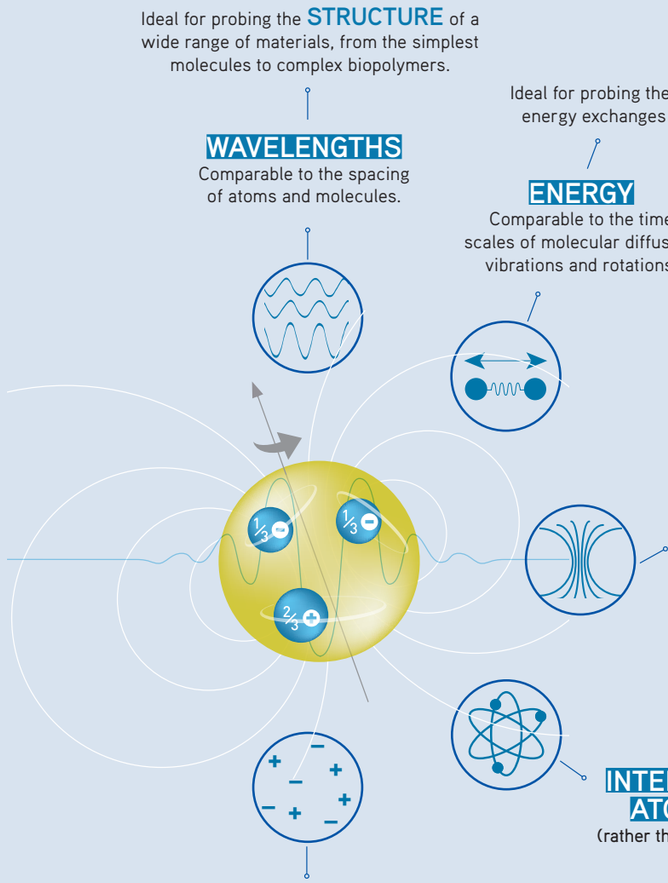
Austria, Czech Republic, Denmark, Italy, Poland, Slovakia, Slovenia, Spain, Sweden and Switzerland

NEUTRONS: GREAT EXPLORERS OF MATTER

From fundamental research to tackling the major challenges of the 21st century, neutrons play a key role in the European science and technology ecosystem.

Alongside other tools for the characterisation of matter, such as X-rays, nuclear magnetic resonance and infrared and Raman spectroscopy, neutrons make an invaluable contribution to our knowledge of materials and our understanding of the processes at work on different time and length scales.

The unique properties of neutrons make them a powerful tool for unlocking the secrets of matter.



Ideal for probing the **STRUCTURE** of a wide range of materials, from the simplest molecules to complex biopolymers.

WAVELENGTHS
Comparable to the spacing of atoms and molecules.

Ideal for probing the **DYNAMICS** of many processes; energy exchanges from1 neV to 1 eV can be detected.

ENERGY
Comparable to the time scales of molecular diffusion, vibrations and rotations.

Sensitive to the microscopic **MAGNETIC PROPERTIES** of materials, studied in great detail with polarised neutrons.

SPIN & MAGNETIC DIPOLE MOMENT
Make neutrons interact with the magnetic fields generated by unpaired electrons in materials.

INTERACTION WITH ATOMIC NUCLEI
(rather than with electron clouds).

Sensitivity to **LIGHT ELEMENTS** (e.g. hydrogen).
Ability to distinguish **ISOTOPES** of the same element.
Highly complementary to X-ray scattering.

ELECTRIC CHARGE = 0

NON-DESTRUCTIVE and with high **PENETRATION POWER**, neutrons are well suited for studying delicate or precious samples, bulky samples, as well as samples in complex sample environments (e.g. extreme temperatures and pressures).

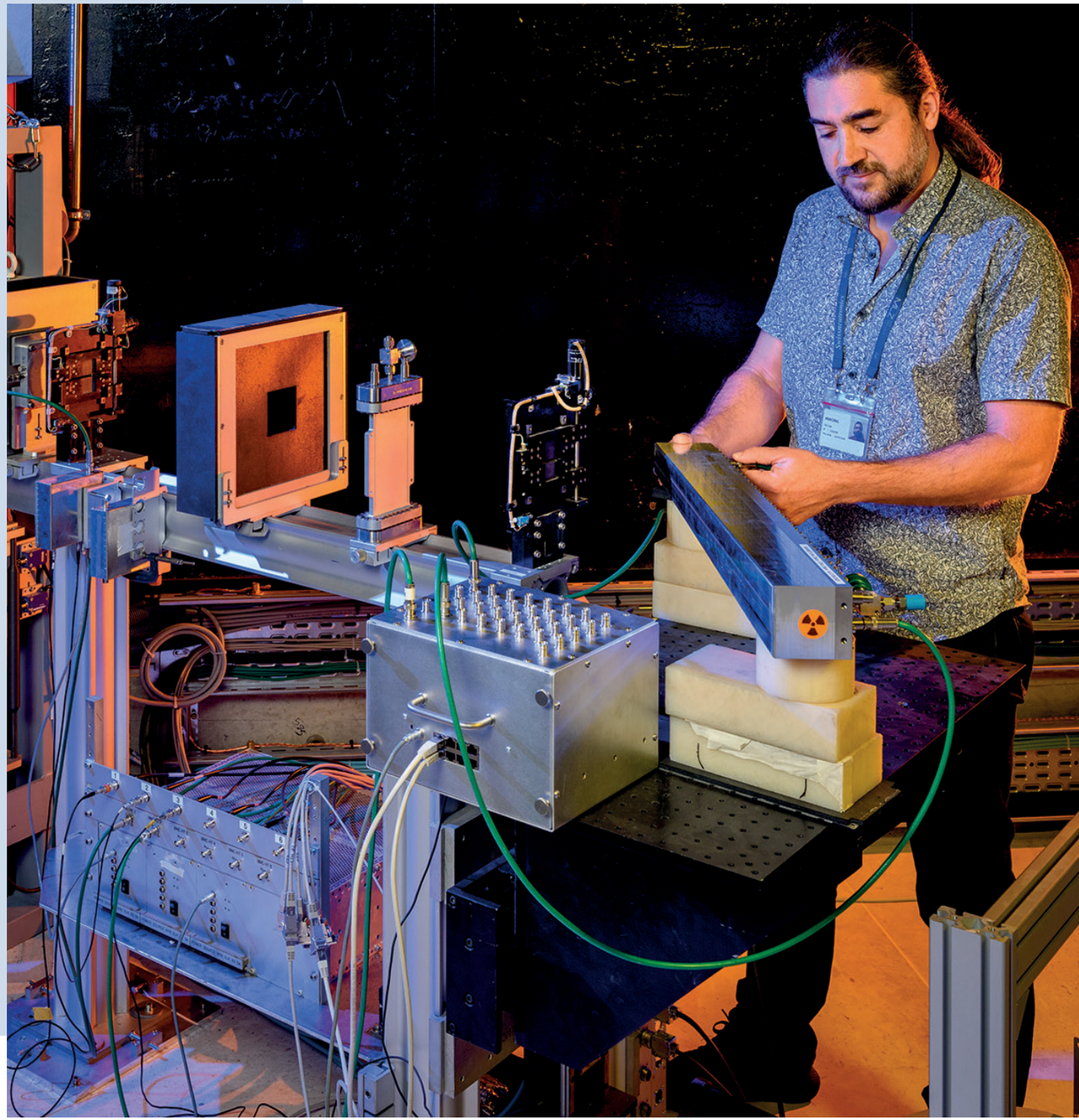
NEW TECHNOLOGY FOR NEW SCIENCE

New science and innovation require ever better research tools. The secret behind the ILL's modern and highly optimised infrastructure is the constant upgrade of its facilities and instruments.

The completion of the Endurance programme in 2024 brought to a close two decades of continuous investment in scientific infrastructures, instruments and services, bringing the ILL to its highest performance level ever.

Thanks to Endurance the ILL now has a suite of 43 state-of-the-art neutron instruments which is unparalleled in the world. The programme leveraged the ILL's technical expertise in critical areas such as neutron optics, detectors, samples and their environment, instrument control, and data analysis software. Major technical developments achieved at the ILL are made available to the wider neutron community.

The programme consolidated ILL's position as a world leader in neutron science and technology, helping to shape the European neutron landscape in a collaborative and complementary way.



TACKLING THE BIGGEST CHALLENGES OF TODAY AND TOMORROW

SCIENCE, TECHNOLOGY AND INNOVATION

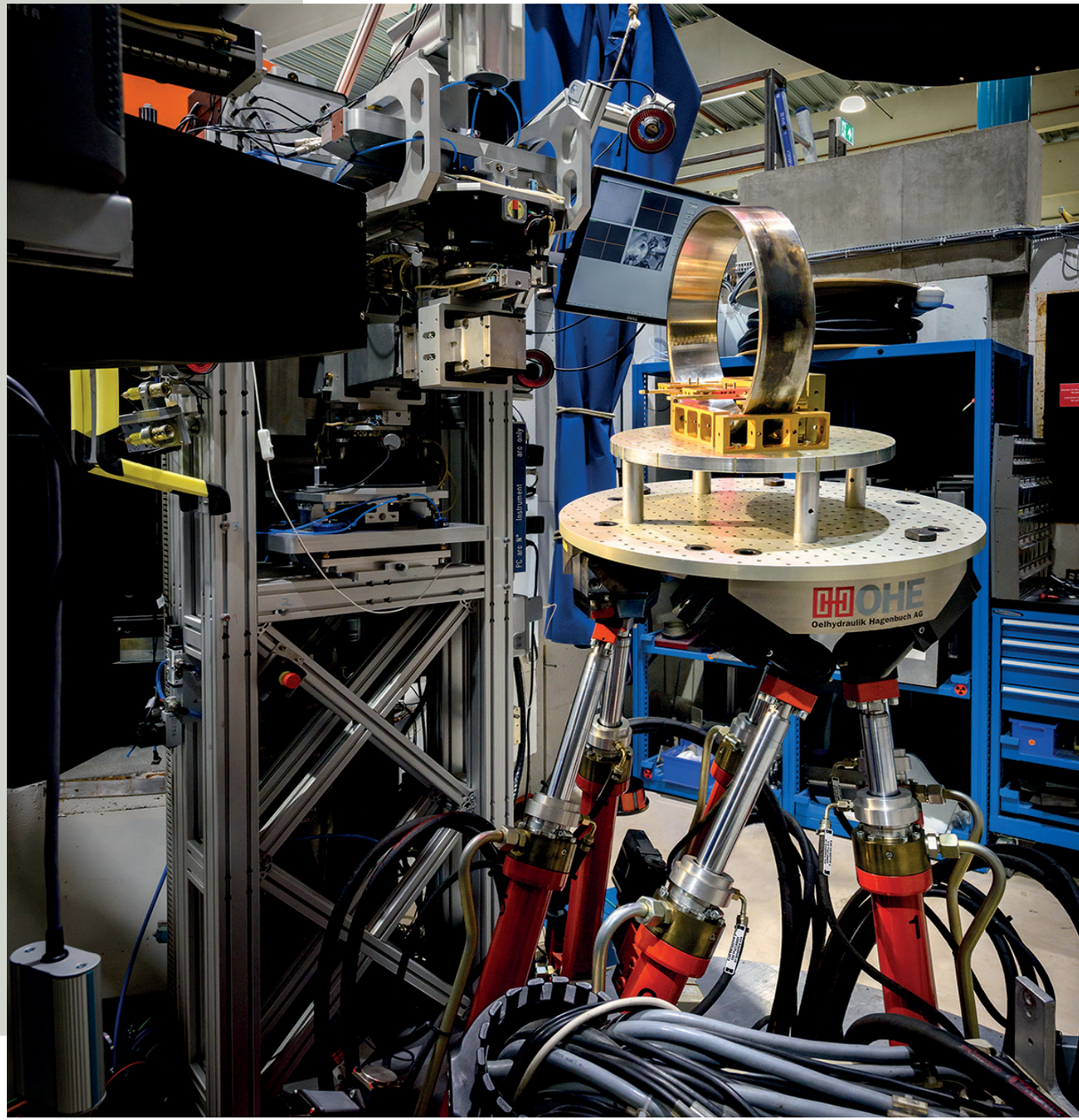
While applied research can help provide answers to the societal challenges of today, innovative discoveries and new knowledge are key to addressing the challenges of tomorrow and transforming society in the future.

An internationally renowned research institute, the ILL contributes to scientific advances in a variety of disciplines, including physics, chemistry, biology, and material science, helping to push the boundaries of knowledge.

Neutrons are not only ubiquitous across disciplines but they can also be used to address societal challenges in such wide-ranging fields as health, energy, the environment, and quantum materials.

Industry is a key partner in delivering innovative solutions for new materials, devices and processes close to market to directly address such challenges.

Since the year 2000, more than 170 companies, including Airbus, AstraZeneca, BP, Carlsberg, IBM, Nestlé, L'Oréal, Philips, Procter & Gamble and Rolls Royce, have performed over 700 experiments at the ILL. Together with thousands of other industry-related experiments conducted, this has resulted in over 650 scientific publications with industry.



HEALTH

An ageing population, a proliferation of chronic and neurodegenerative diseases, a growing risk of pandemics... humanity is faced with many serious public health issues. Preparing for the public health challenges of tomorrow has never been more important. As a world-class research centre, the ILL plays an active role in shaping the medicine of the future: its neutrons are at the heart of more personalised, targeted and effective treatments.

Nuclear medicine in the fight against cancer

Neutrons offer a unique technology for understanding the processes involved in the cell mutations that lead to cancer and for developing innovative treatments to combat this disease. The radioisotopes produced by the ILL's high-flux reactor are vital ingredients in the radiopharmaceuticals used to treat certain types of cancer. What's their secret? Like a "Trojan horse", they can enter cancer cells and treat them from within, without damaging the surrounding healthy tissue. Much more targeted and less invasive than external radiotherapy, radioisotopes are particularly effective in the treatment of metastatic cancer.

Recognising the contribution that radioisotopes can make to the development of new cancer therapies, a number of pharmaceutical companies are already working on a daily basis with the ILL. One such company, Curium, has signed a partnership agreement with the ILL for the production of radioisotopes for a new internal vectorised radiotherapy (IVR) drug for the treatment of metastatic prostate cancer.

Neutrons: key players in the medicine of tomorrow

Thanks to their unique properties, and in particular their ability to explore complex cellular systems right down to the atomic level, neutrons are a key ally in our quest to understand biological mechanisms and develop innovative therapeutic solutions.

The neutron science conducted at the ILL provides valuable information that contributes, among other things, to the development of messenger RNA vaccines or the early detection of neurodegenerative diseases such as Alzheimer's, Parkinson's or Huntington's disease.

"The use of neutrons offers a novel approach for the characterisation of the lipid nanoparticles used in messenger RNA delivery. The results are very exciting and open up tremendous prospects for understanding and developing new messenger RNA therapies for the future."

Marianna YANEZ-ARTETA, Associate Director, AstraZeneca Sweden

ENERGY

Among the many valuable properties of neutrons, there is one that really lights up the energy sector! Their sensitivity to light atoms such as hydrogen, lithium and oxygen places neutrons firmly at the forefront of the exploration of the complex materials used in the energy sector. From batteries and fuel cells to nuclear power and renewable energies, neutrons open up new opportunities to investigate matter and transform the world of energy.

Exploring the energy sources of the future

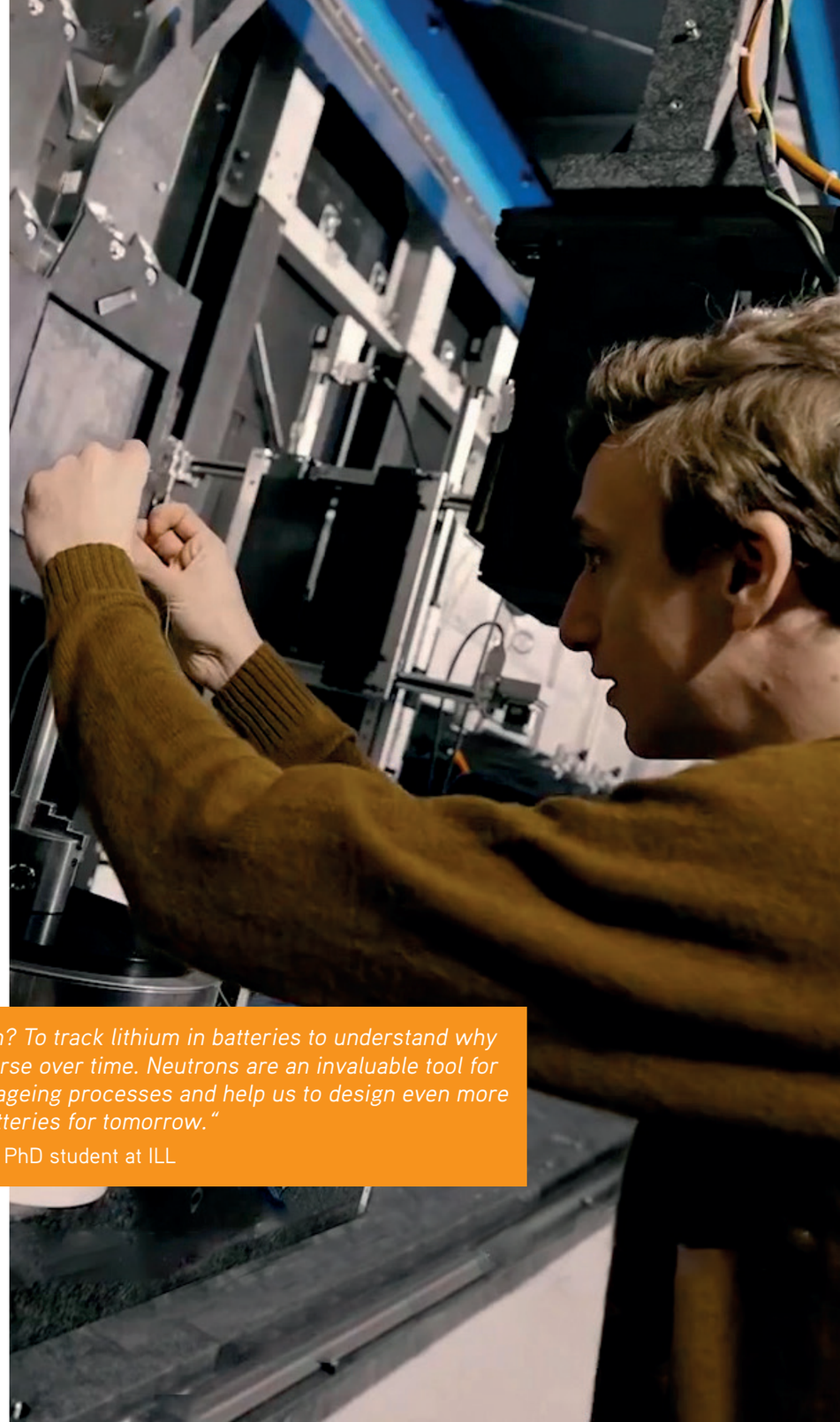
Scientists at the ILL are studying new materials and energy sources to meet tomorrow's energy challenges. Whether the aim is to improve the performance of lithium batteries, explore new alternatives such as sodium batteries or design innovative solutions for energy storage, neutrons are helping to shed new light on how to develop innovative - and virtuous - technologies.

When it comes to clean energy, hydrogen holds great promise for a number of sectors. Because neutrons are extremely sensitive to hydrogen, they are contributing to the development of clean hydrogen production, the emergence of new materials for energy storage, and the use of solar energy in countries with extreme climate conditions.

Ensuring the safety of nuclear facilities

As one of the lowest-carbon energy sources, nuclear power is set to become a key component of the energy mix in the decades ahead. Nevertheless, there are still major challenges to be met in terms of the service life of nuclear facilities, their safety, and waste management.

In all these areas, research reactors, such as the one operated by the ILL, are invaluable tools not only for evaluating the reliability and robustness of nuclear reactor components, but also for studying safe processes for waste processing and storage.



"My mission? To track lithium in batteries to understand why they get worse over time. Neutrons are an invaluable tool for identifying ageing processes and help us to design even more efficient batteries for tomorrow."

Erik LÜBKE, PhD student at ILL

ENVIRONMENT

Climate change is one of the most pressing challenges facing humanity today. There can be no denying the impact of human activities on the environment: the devastating effects are being felt everywhere on the planet. The world's leading research centres are working hard to combat global warming and protect the environment. At the ILL, neutron techniques are helping to make significant progress in reducing greenhouse gas (GHG) emissions and developing cleaner, more environmentally friendly technologies.

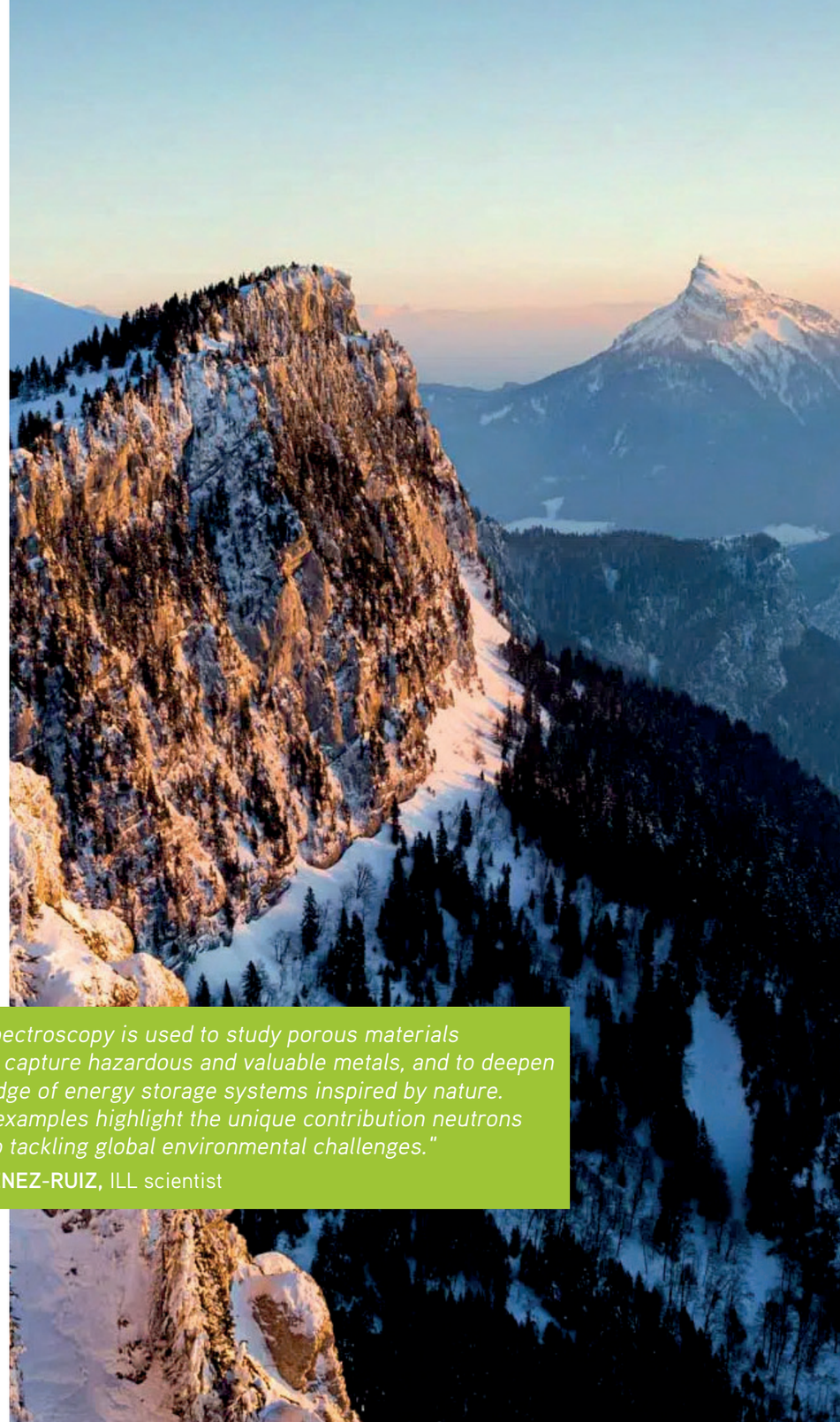
Reducing greenhouse gas emissions

The fight against greenhouse gas emissions is crucial, particularly in sectors with a high environmental impact, such as the building industry. Concrete is one of the most widely used materials in the world, but the production of cement, one of the main components of concrete, is extremely energy-intensive. New techniques developed in ILL's laboratories in partnership with the cement company Lafarge have made it possible to gain a better understanding of concrete ageing and extend its lifespan.

Neutrons are also behind the development of more environmentally friendly materials with porous systems that help to capture and store molecules of gases such as CO_2, methane and SF_6.

ILL, a pioneer in clean technology

Whatever the challenge - whether it's optimising the performance of catalysts to reduce the electricity consumption of industrial processes, developing clean technologies to reduce environmental pollution, or understanding how plants absorb water in order to develop crops that are more resistant to drought – the ILL is at the cutting edge of neutron technology, helping to unlock the secrets of matter and tackle the major environmental issues of today and tomorrow.



"Neutron spectroscopy is used to study porous materials designed to capture hazardous and valuable metals, and to deepen our knowledge of energy storage systems inspired by nature. These two examples highlight the unique contribution neutrons can make to tackling global environmental challenges."

Monica JIMENEZ-RUIZ, ILL scientist

QUANTUM MATERIALS

Quantum technology is set to revolutionise the world of information technology. New electronic states of matter involving the nanoscale magnets of electron spins will be at the heart of new solutions for data storage, data transmission and quantum computers. Quantum materials are also smart materials for new devices which combine electronic and magnetic properties and include superconductors, as the quest for high-temperature superconductivity continues. The neutron, with its spin and magnetic moment, is an exquisite probe of quantum materials, an area which represents about 30% of the research conducted at the ILL.

Probing magnetism in materials

Neutrons are nanomagnets able to explore matter in the extreme conditions in which new quantum states emerge: high pressures, very low temperatures and high magnetic fields.

Spintronic materials allow information to be transported without the movement of electrons and the associated energy cost. They can be explored with neutron spectroscopy.

Skyrmions are magnetic spin vortices with huge potential for nanoscale data storage. They are studied with neutrons as a function of applied magnetic field and temperature.

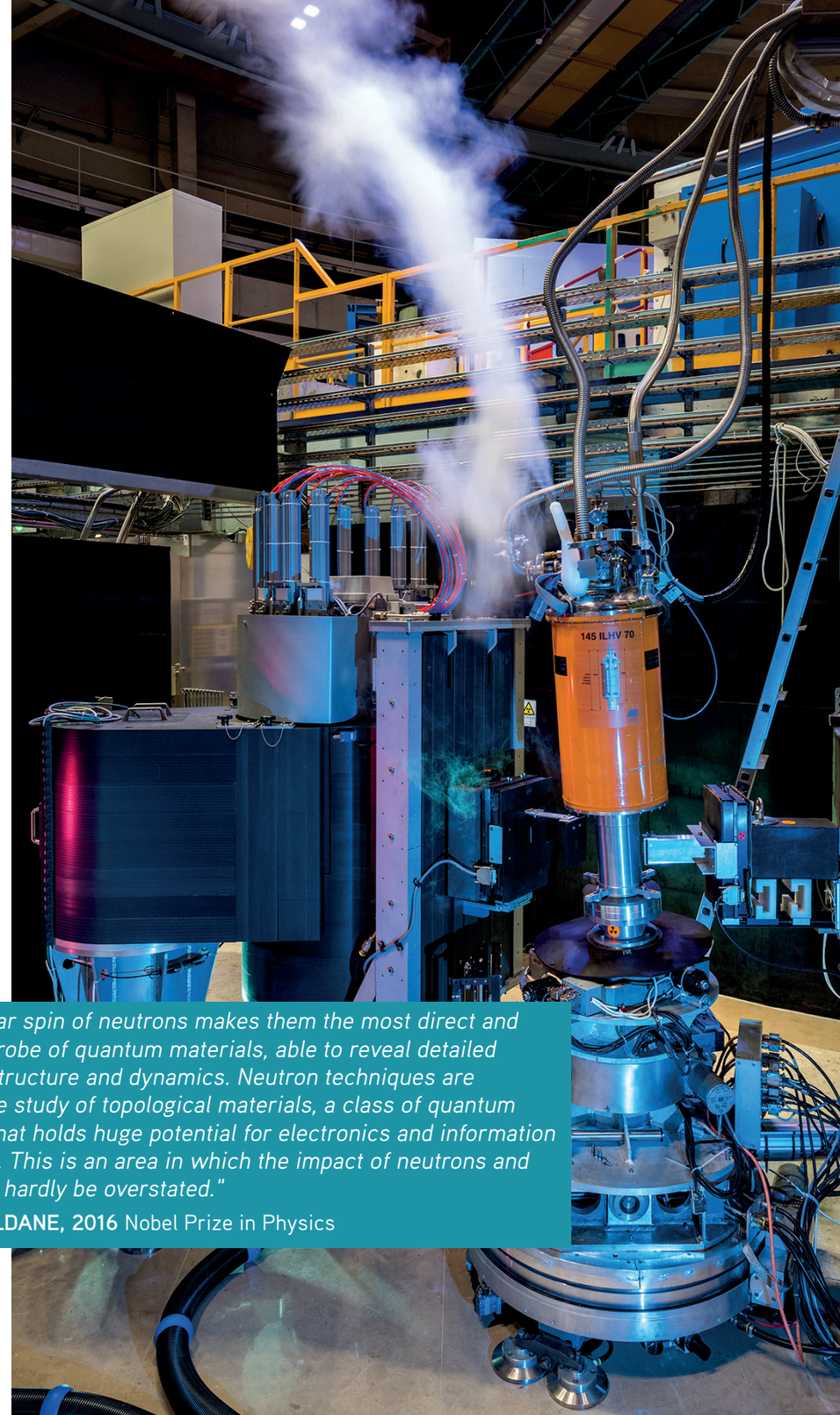
Quantum spin liquids were observed experimentally for the first time with neutrons at the ILL some 50 years after they were predicted by theory. Entangled quantum states of nanomagnets, they offer huge potential for information processing and storage.

While room-temperature superconductivity is still the holy grail, a major breakthrough - the interaction of electron and spin waves in these materials – has recently been resolved using neutron spectroscopy.

Inside electronic devices

When new materials and components make their way into the electronic devices that are increasingly used in critical applications such as self-driving cars, they must be tested for radiation resistance, including neutron irradiation.

At the ILL a dedicated beamline is used to induce logic errors with low energy neutrons, while high energy neutrons are used to cause physical damage in devices. Aircrafts are exposed to high levels of radiation and an ILL neutron detector has been used by Airbus to measure the neutron flux in flight.



"The nuclear spin of neutrons makes them the most direct and powerful probe of quantum materials, able to reveal detailed magnetic structure and dynamics. Neutron techniques are ideal for the study of topological materials, a class of quantum materials that holds huge potential for electronics and information technology. This is an area in which the impact of neutrons and the ILL can hardly be overstated."

Duncan HALDANE, 2016 Nobel Prize in Physics

MYSTERIES OF THE UNIVERSE

At the ILL, we push the boundaries of knowledge in many different ways, and in particular by studying the properties of the neutron and observing its decay. Progress in particle physics is constantly improving our knowledge of the origins and evolution of the Universe.

Delving into the heart of matter

While the Standard Model of Particle Physics, which dates back to the 1970s, is still the best theory scientists have to describe the most basic building blocks of matter, many pieces of the puzzle are missing and we have a lot more to discover.

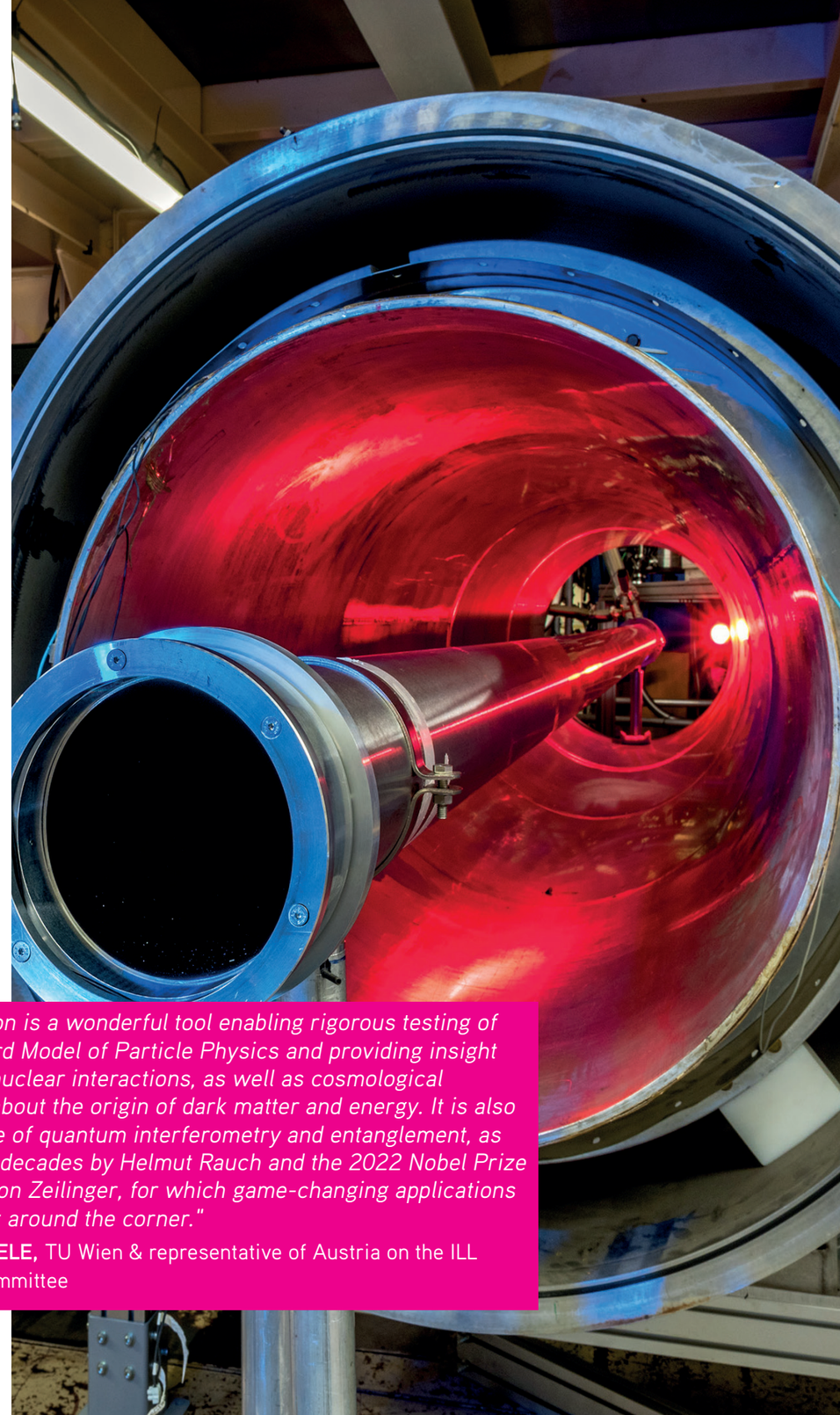
New interactions that could account for dark matter and energy are searched for. Neutrinos, the tiny subatomic particles produced in neutron decay, are key to shedding light on some of science's greatest enigmas, such as the mysteries of matter-antimatter asymmetry.

Possible deviations from the known gravitational pull are investigated with exquisite experiments using neutrons to probe gravity – a modern day Newton's apple. Neutron interference experiments also search for new interactions with ever more sensitive experiments.

What happened to all the antimatter?

The same amounts of matter and antimatter must have been generated during the Big Bang. However, observations of the cosmos today indicate that mainly matter has survived. The laws of physics appear to act differently for matter and antimatter in ways that are not fully covered by the Standard Model.

Scientists at the ILL are seeking the origins of matter-antimatter asymmetries by studying in detail the properties of neutrons, including searching for an electric dipole moment.



"The neutron is a wonderful tool enabling rigorous testing of the Standard Model of Particle Physics and providing insight into weak nuclear interactions, as well as cosmological questions about the origin of dark matter and energy. It is also a fine probe of quantum interferometry and entanglement, as studied for decades by Helmut Rauch and the 2022 Nobel Prize winner Anton Zeilinger, for which game-changing applications may be just around the corner."

Hartmut ABELE, TU Wien & representative of Austria on the ILL Steering Committee

A GREAT PLACE TO WORK AND IMPACT SOCIETY

A UNIQUE WORKPLACE TO MAKE A DIFFERENCE

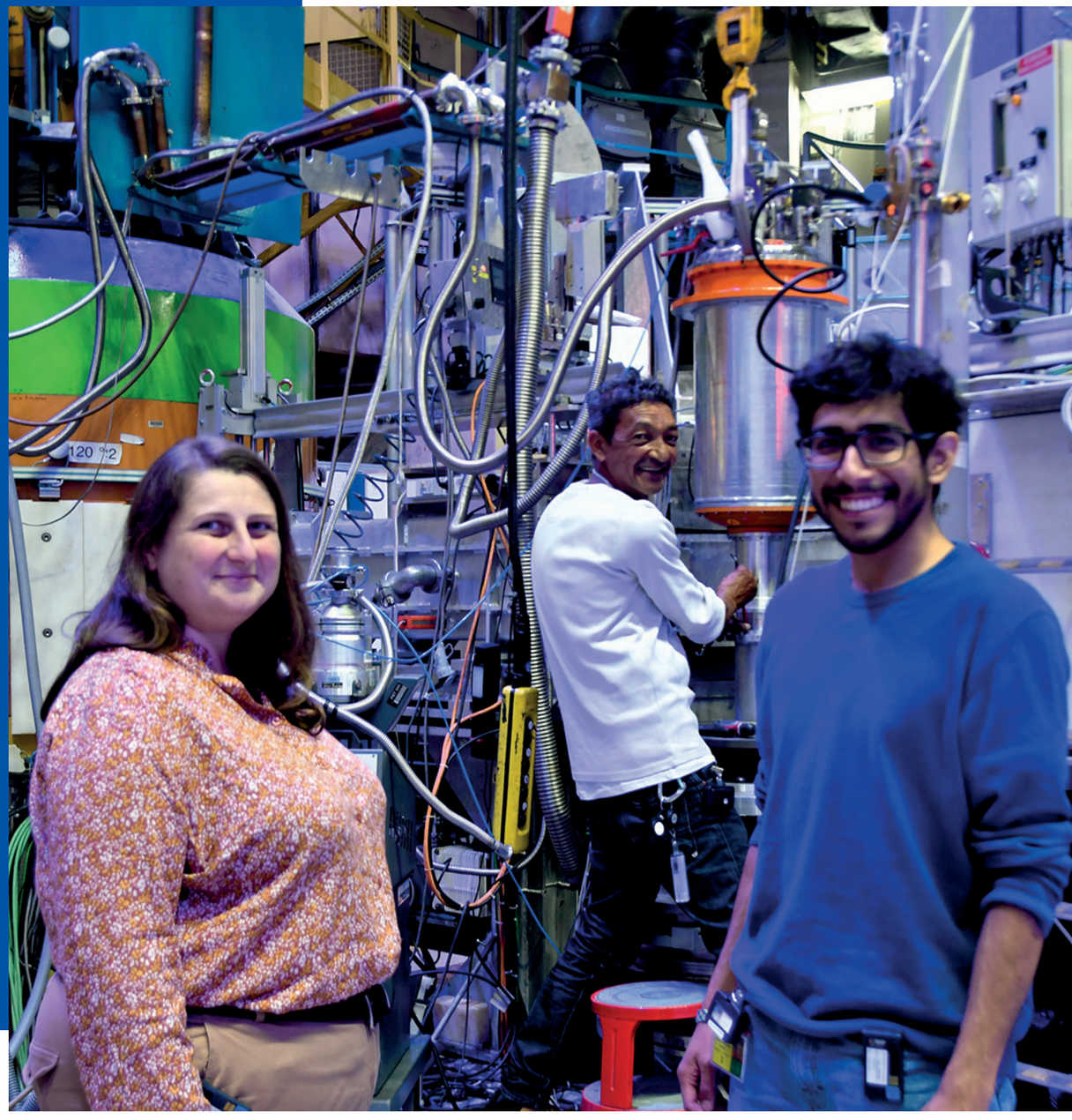
The ILL is a research centre of international renown with a staff of over 500 people from 30 different countries. Whether they have a scientific or technical background - physics, neutron science, IT, electronics, mechanical engineering - or work in support roles, they all contribute to the success of scientific research that is fully in tune with the needs of society.

What does it mean to work at the ILL?

It means the opportunity to work with cutting-edge scientific instruments, to work with colleagues with many different career backgrounds, to work in a multicultural environment. It also means living in one of the most dynamic and innovative cities in the world. Situated in the heart of the French Alps, Grenoble offers an exceptional quality of life! A flagship for neutron research, the ILL nonetheless remains a human-sized institute, with a strong commitment to offering excellent working conditions that also foster a good work-life balance.

Diversity

The ILL firmly believes in the benefits of embracing diversity and inclusion. It therefore devotes special attention to the recruitment of employees with disabilities. And when it comes to attracting talent from abroad, the ILL offers newcomers tailored support to help them and their families settle into their new lives.



#NewGeneration

Preparing for tomorrow starts today. Working with leading universities in France, Germany, the UK and elsewhere, the ILL recruits a large number of interns, apprentices and PhD students every year. The ILL also has a clear focus on helping young scientists step into a career in research as post-doctoral researchers.

To raise its profile among the younger generation - and in particular with young women interested in careers in science and technology – the ILL regularly takes part in forums and conferences aimed at highlighting the variety and wealth of careers on offer at the institute.

"My PhD at the ILL has been a fantastic opportunity to combine fundamental research at a world-class research facility with applied research in a pharmaceutical laboratory. I really love science and I'd like to pursue a career in science so that I too can help to inspire a new generation of scientists!"

Ilaria MOSCA, PhD student at ILL

SAFETY, SECURITY AND SUSTAINABILITY

ILL's high-flux reactor is devoted exclusively to research activities. Nevertheless, the nuclear core at the heart of the reactor makes the ILL a sensitive site, requiring special surveillance.

Keeping our facilities safe and secure

ILL's facilities are continuously maintained, refurbished and upgraded to ensure compliance with the increasingly stringent requirements of the French safety and security authorities. These requirements take into account extreme external hazards such as earthquakes and flooding, as well as the risk of fire. The risks associated with unwanted intrusion are fully integrated into ILL's security approach.

Environmental protection

The ILL performs both continuous and sampling-based monitoring of the levels of radioactivity in the air and water, as well as in bioindicators such as milk and certain agricultural produce. Monitoring is carried out in a fully transparent manner. ILL's environmental monitoring laboratory is approved by the French nuclear safety authority and is part of the French national network of environmental radioactivity monitoring. The aim is to ensure that the facility has no radiological impact on people or the environment.

Sustainability

As a reactor-based neutron source, ILL's energy comsumption is relatively low. Combined with largely carbon-free electricity in France, the carbon footprint of ILL operation is about 10 times lower than that of any other neutron facility. Nevertheless, the ILL carefully reviews all aspects of its infrastructure and operations, including travel (staff and users) and its supply chains, in terms of environmental impact as part of a process of continuous improvement.

WHAT DOES THE FUTURE HOLD?

WHAT DOES THE FUTURE HOLD?

ILL's position as the world leader in neutron science has been a major asset for Europe for almost 60 years. Our scientific and technological expertise has been instrumental in ensuring that Europe remains competitive and influential on the world stage, and is a key element in maintaining Europe's sovereignty in a highly strategic field. Thanks to outstanding collaboration, there can be no doubt that it is in Europe that the very best in neutron research and applications are to be found.

Today, new prospects are opening up. Recognising the power of neutrons to help us understand the Universe and provide answers for the challenges of tomorrow, Europe is equipping itself with the latest developments in cutting-edge infrastructures. A new scientific research centre, the European Spallation Source (ESS), in Lund, Sweden, will one day become the new world leader in neutron science.

We firmly believe that the ILL has a vital strategic role to play in this rapidly changing European science landscape. Working alongside the ESS, delivering complementary capabilities, and in cooperation with all the neutron sources operating in Europe, the ILL will remain at the forefront of progress in neutron science. Now more than ever, the ILL's scientific excellence and unique infrastructure make it an invaluable player in driving advances in science that are truly at the service of society.

In this way, ILL will be an integral part of Europe's approach to global competitiveness, which aims to close the innovation gap, based on research excellence, education at every level and world-leading scientific infrastructures.

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