ESRF

The European Synchrotron

LIGHTING THE WAY

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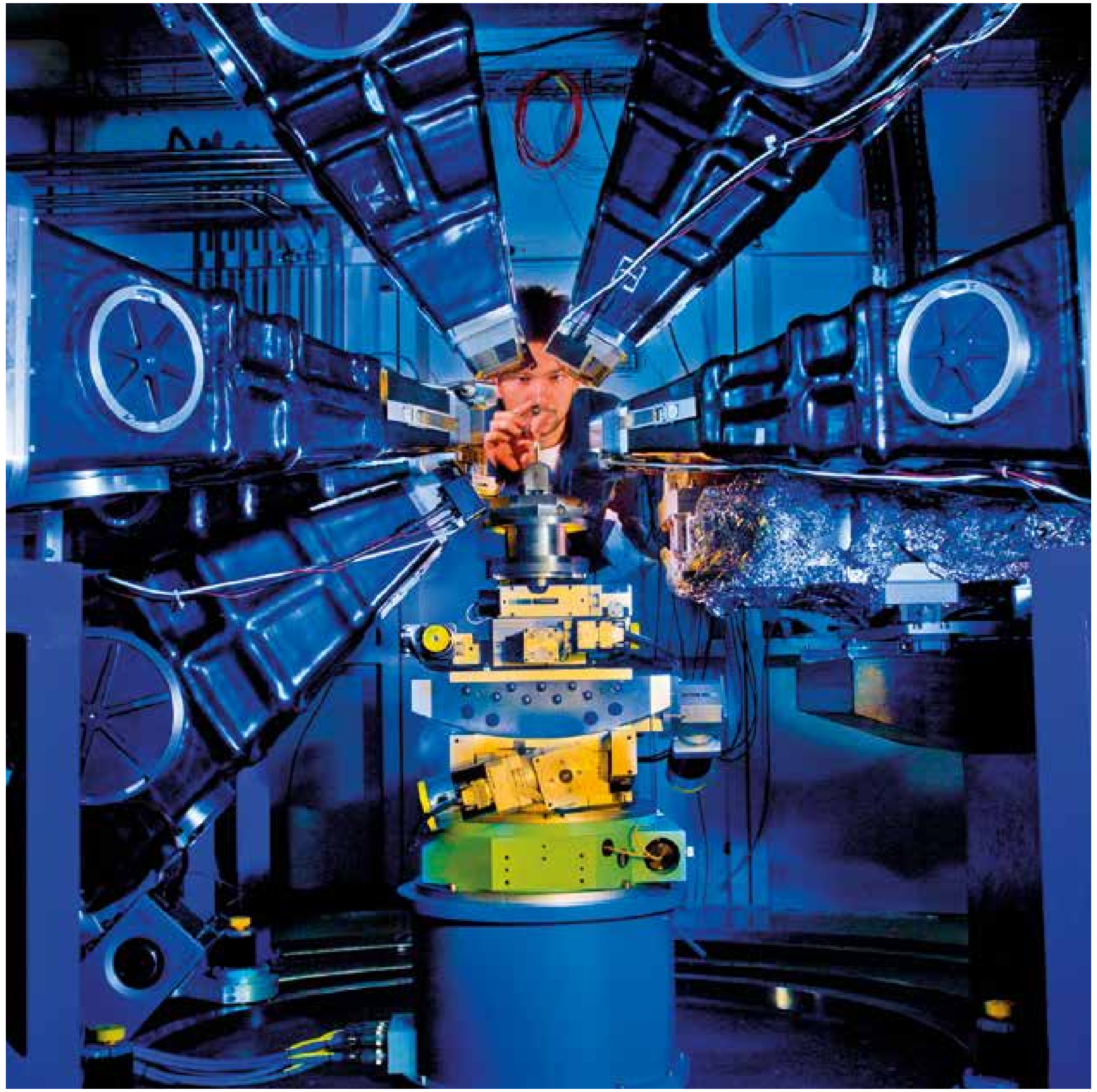

Our *raison d'être* : lighting the way to a brighter and sustainable future

The ESRF is the world's brightest synchrotron light source, providing scientists with the most brilliant X-rays to unveil the structure of materials and the mechanisms of life, down to atomic resolution.

As a landmark for fundamental and innovation-driven research, the ESRF is a prime example of international cooperation and collaboration. The ESRF unites people from all over the world in the quest to push the boundaries of knowledge and technology for the benefit of society.

In 1988, eleven countries joined forces to create the world's first 'third-generation' X-ray light source, serving the scientific community as the most intense X-ray source in the world and making a European dream a reality.

In 2020, a new dream saw the light, with the launch of a brand-new generation of high-energy synchrotron, the ESRF's Extremely Brilliant Source (EBS). With the support of the ESRF's 21 international partner countries, EBS provides scientists from all over the world with new opportunities to pioneer innovative science, human knowledge and progress for all.

Based on scientific excellence, research carried out with the EBS contributes to addressing the complex global challenges that our society faces, such as health, energy and the environment. It also contributes to the development of new technologies for industry and to preserving humanity's cultural heritage, lighting the way to a brighter, sustainable and peaceful future.

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This is the ESRF

The world's **brightest** synchrotron light source. The first high-energy, fourth-generation synchrotron. A landmark for **X-ray science** and **innovation**. A **pioneer** for synchrotron science. A powerhouse of scientific collaboration. An **international endeavour** promoting scientific **excellence**. A vibrant **hub** welcoming people from all research fields, all genders and all cultures. Pushing the frontiers of science together. **Making the invisible visible**. **Unveiling** the secrets of matter and the mechanisms of life, to advance fundamental knowledge and new applications. Serving the **international** community. Inspiring and training the next generation. Addressing **global challenges** in health and the environment. Committing to a better and sustainable **future**.

"Europe can be proud of this masterpiece of state-of-the-art technology and scientific vision."

Helmut Dosch, Chair of the ESRF Council

4
Nobel prizes

46
beamlines

21
member countries

2 000
scientific publications each year

10 000
scientific visitors each year

30 %
of research carried out with industrial partners

"The ESRF is a leader in synchrotron science and attracts the best minds worldwide. ESRF X-rays serve a vibrant international scientific community in its quest to address global challenges, lighting the way to a brighter, sustainable and peaceful future for society."

Francesco Sette, ESRF Director-General

The ESRF's objectives

As an international centre of excellence for fundamental and innovation-driven research, the ESRF pursues the following objectives:

- **Bringing nations together** through science by serving the international scientific community for the advancement of knowledge and new applications.
- **Pioneering synchrotron science** by developing state-of-the-art synchrotron X-ray instruments for the benefit of its scientific user community.
- **Tackling global challenges** by encouraging innovative scientific research that addresses the important issues our societies face around the world.
- **Inspiring and training the next generation** of scientists, engineers and technical staff.
- **Committing to a sustainable future**, actively optimising the societal, environmental and economic impact of the facility.

BRINGING NATIONS TOGETHER THROUGH SCIENCE

"The strength of the ESRF is to welcome users from all over the world – with their diversity of disciplines, gender, nationality, language and culture – who all come here with the same aim: to push the frontiers of science."

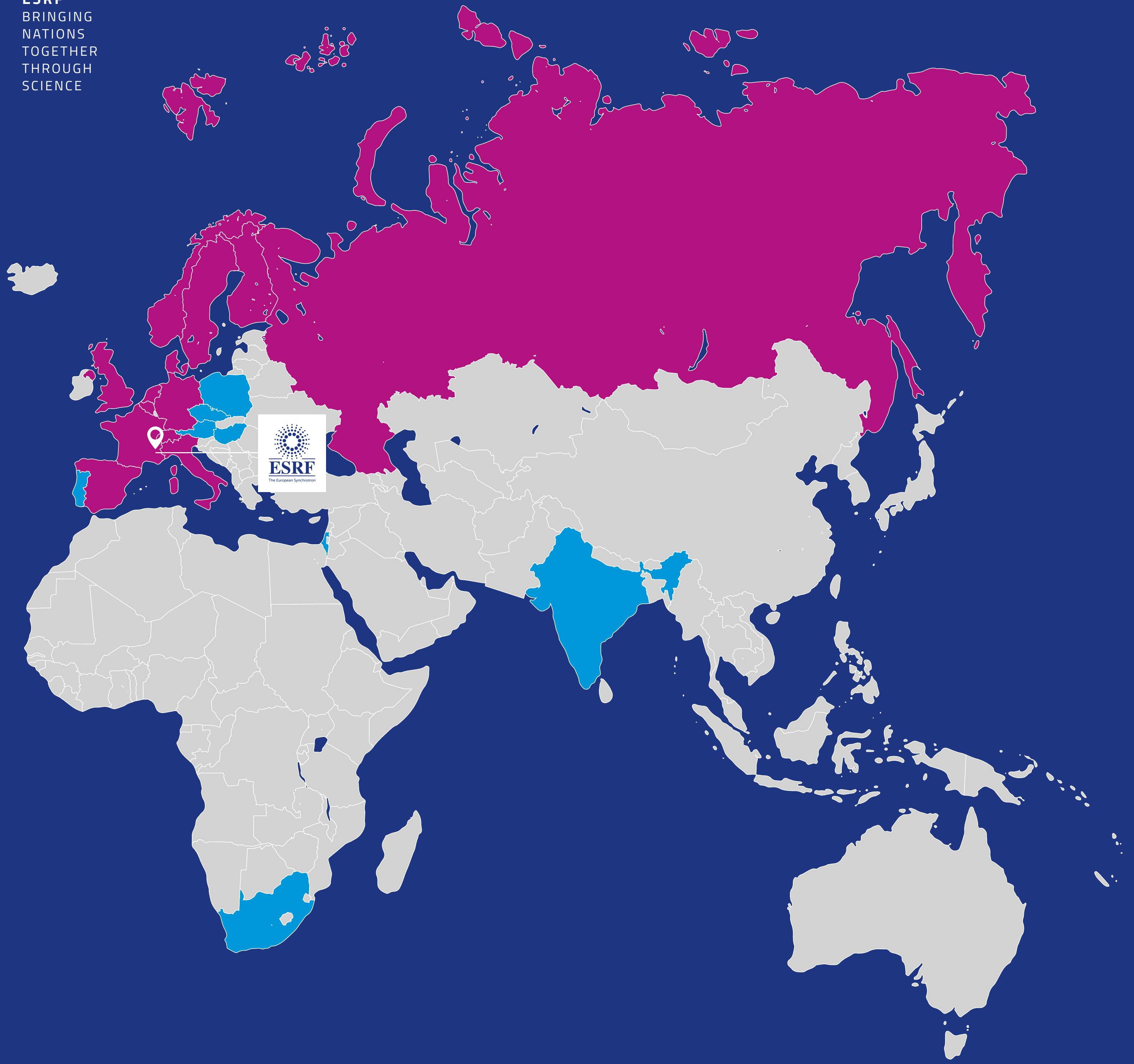
Joanne McCarthy, Head of the User Office

Bringing nations together through science

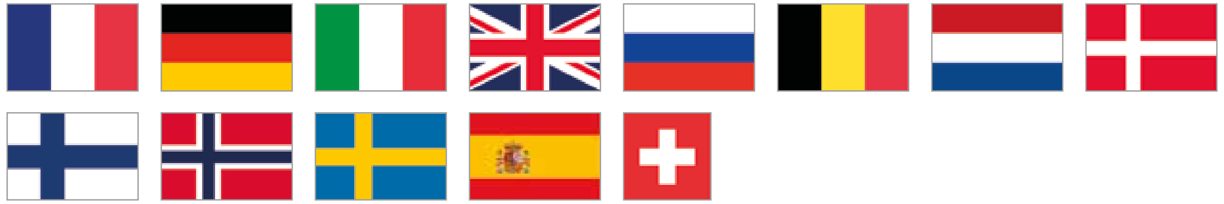
In 1988, eleven European countries joined forces to build the most powerful synchrotron in the world, a visionary project that has made an outstanding contribution to the excellence of science and a testament to what can be achieved when European nations join together.

Today, the ESRF is a world reference as a model of international cooperation, with 21 partner countries from Europe and beyond, all driven by the same quest for excellence, the same desire to find solutions to the major technological, economic, societal and environmental challenges facing the modern world.

The ESRF's user community extends to several thousand scientists from all over the world and continues to grow, accomplishing feats that no one country can alone, encouraging international collaboration and partnerships, developing innovative technologies that benefit all nations, advancing knowledge and progress for all and training the next generation of scientists, engineers and technical staff.

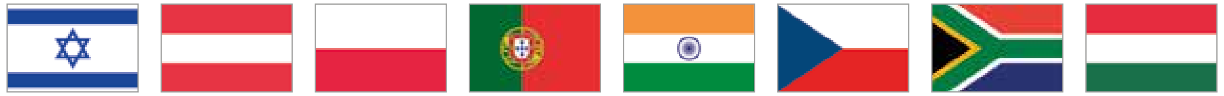


ESRF'S MEMBER AND ASSOCIATE COUNTRIES



MEMBER COUNTRIES

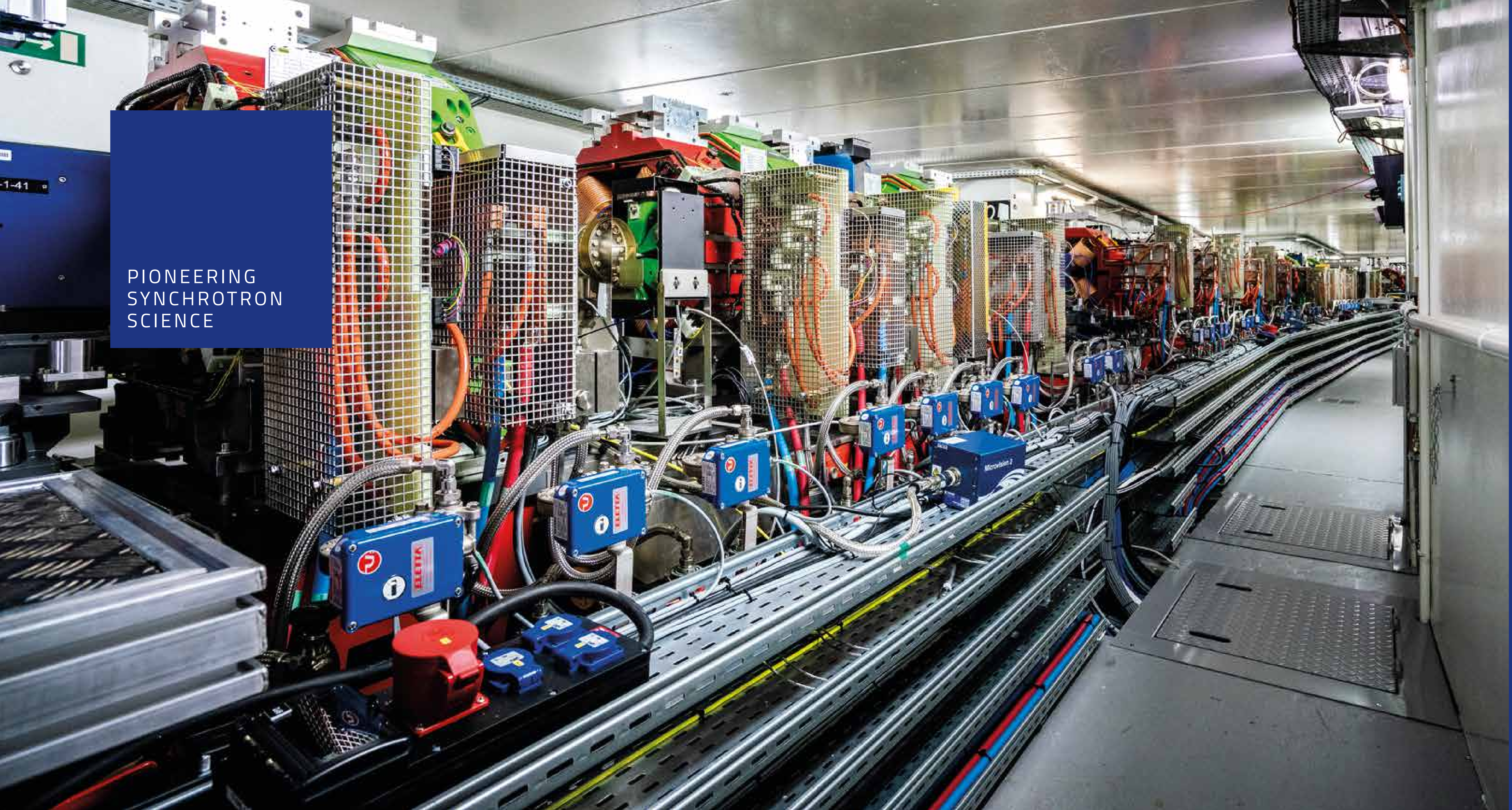
France	27.5 %	Nordsync (Denmark, Finland, Norway, Sweden)	5.0 %
Germany	24.0 %	Spain	4.0 %
Italy	13.2 %	Switzerland	4.0 %
United Kingdom	10.5 %		
Russia	6.0 %		
Benesync (Belgium, The Netherlands)	5.8 %		



ASSOCIATE COUNTRIES

Israel	1.75%	India	0.66%
Austria	1.75%	Czech Republic	0.6%
Poland	1%	South Africa	0.3%
Portugal	1%	Hungary	0.25%

PIONEERING SYNCHROTRON SCIENCE



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"One of the most exciting things about working at the ESRF is that we are always seeking to optimise and innovate, always pushing technology further to obtain higher performances."

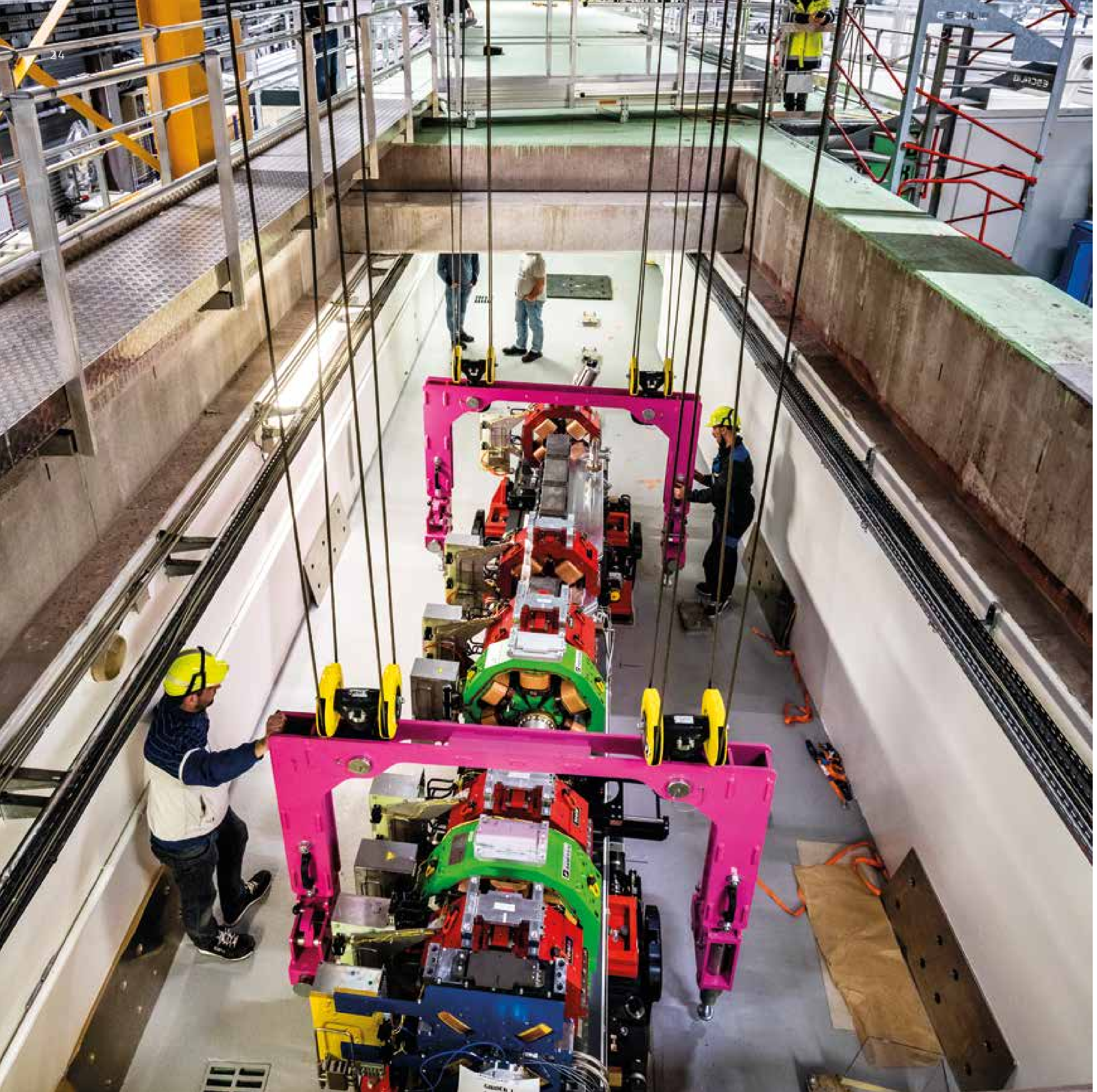
Simon White, Head of Beam Dynamics

Pioneering synchrotron science

From making history in 1998 as the world's first third-generation synchrotron, to launching the first of a new generation of high-energy light sources in 2020, the force of the ESRF is its capacity to innovate, pushing technology to its limits and seeking ever-higher performances in order to provide scientists with state-of-the-art instruments.

With the Extremely Brilliant Source (EBS), the ESRF has once again raised the bar, opening new vistas for X-ray science. EBS enables scientists to bring X-ray science into research domains and applications that could not have been imagined a few years ago, with existing third-generation sources. Looking to the future, the ESRF continues to pioneer cutting-edge technology, investing in innovative R&D programmes to optimise the performances of EBS.

EBS has become the new standard for synchrotron light sources, inspiring future constructions and upgrades around the world.



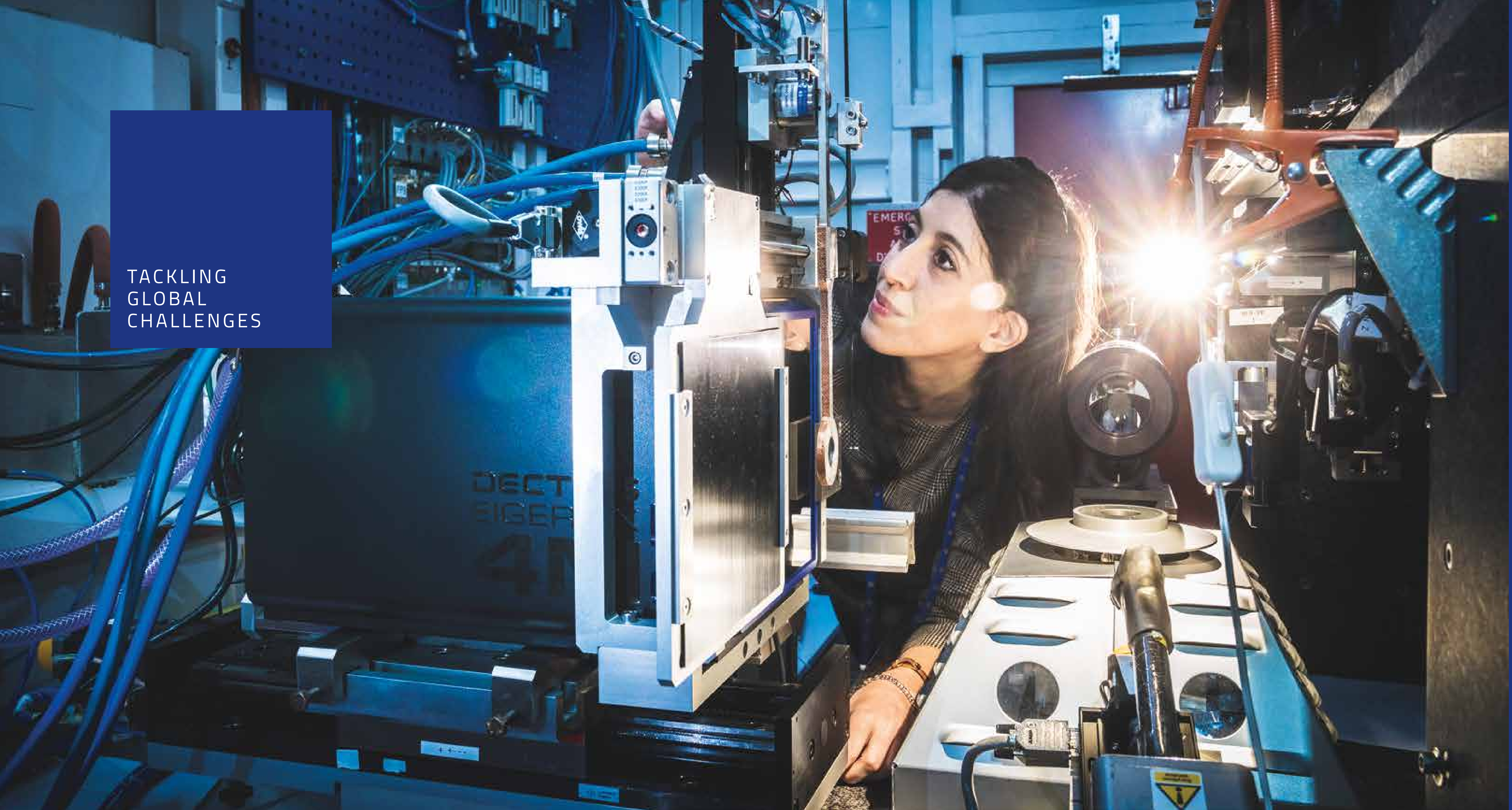
The ESRF's Extremely Brilliant Source

The Extremely Brilliant Source (EBS) is an accelerator physics dream come true. This revolutionary new machine increases the brilliance and coherence of the X-rays produced by a factor of 100 compared to the previous source.

Based on an award-winning lattice design, the HMBA lattice, with innovative magnet technology, this new generation of high-energy synchrotron paves the way for many new synchrotron projects worldwide.

The enhanced performance of the X-rays, combined with new EBS beamlines and platforms, state-of-the-art instruments and an ambitious data strategy, makes it possible to study the structure of condensed and living matter at the atomic level in higher resolution, with greater image quality and much faster data collection, helping scientists to carry out the science of the future.

The EBS machine is also much more energy-efficient compared to previous and existing synchrotron storage rings, with a 30% reduction in electricity consumption.



TACKLING GLOBAL CHALLENGES

"The ESRF is the facility where we collected our best data. This is where we did our real science."

Ada Yonath,
winner of the 2009
Nobel Prize in Chemistry

"The ESRF was an essential ingredient of our work on the ribosome. A large international facility can do things on a scale that is not possible by one country. By bringing top scientists together, the ESRF has led to a lot of pioneering ideas."

Venki Ramakrishnan,
winner of the 2009
Nobel Prize in Chemistry

Science for society

Observing matter and decoding its secrets are at the heart of humanity's quest to improve the understanding of the world around us and to inspire and drive progress.

Fundamental questions and global challenges such as developing better drugs against disease and tackling environmental pollution and climate change can be addressed through understanding the structure of matter.

Thanks to the brilliance and quality of its X-rays, the ESRF functions like a 'super microscope', providing invaluable insight into the microscopic and atomic structure of matter in all its complexity.

The ESRF has defined seven EBS Science goals, in line with UNESCO's objectives for sustainable development and with the global challenges identified by the EU's Horizon Europe research and innovation programme:

1 • **Health innovation, overcoming diseases and pandemics**

2 • **Materials for tomorrow's innovative and sustainable industry**

3 • **Clean energy transition, sustainable energy storage and clean hydrogen technologies**

4 • **Planetary research and geoscience**

5 • **Environmental and climatic challenges**

6 • **Bio-based economy and food security**

7 • **Humanity and world cultural heritage**

HEALTH INNOVATION

Revolutionising bio-imaging

High-quality medical imagery greatly aids the understanding, diagnosis and treatment of diseases. The ESRF, in collaboration with scientists from University College London, UK, has developed a new imaging technique that will enable scientists to scan complete human organs with a resolution of 25 microns – thinner than a human hair – and 20 times the resolution of a CT scanner.

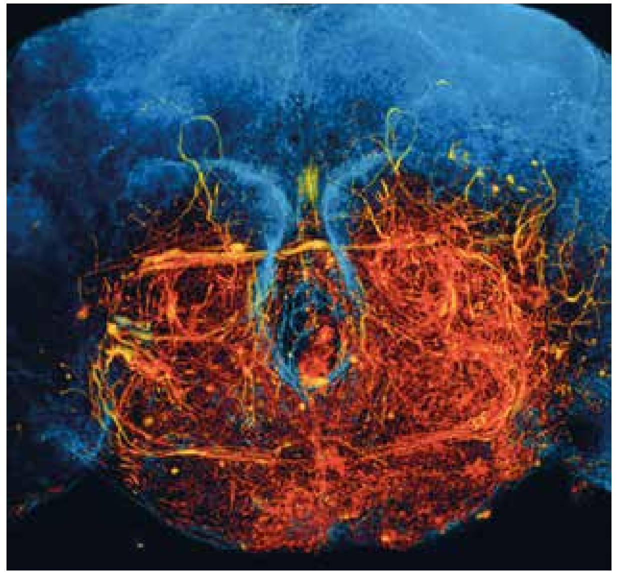
Hierarchical phase-contrast tomography allows scientists to zoom continuously from a macroscopic organ down to imaging individual cellular processes, in 3D and non-destructively, in a minimally invasive manner. Studies of human lungs from COVID-19 victims have shown that the technique can resolve major airways down to individual red blood cells, revealing the damage caused by the disease to the vascular system.

This new technique will help provide a more in-depth and detailed understanding of complex living organisms, revolutionising our anatomical understanding of health and disease down to the cellular level on the scale of whole organs and – with the BM18 beamline – whole bodies.

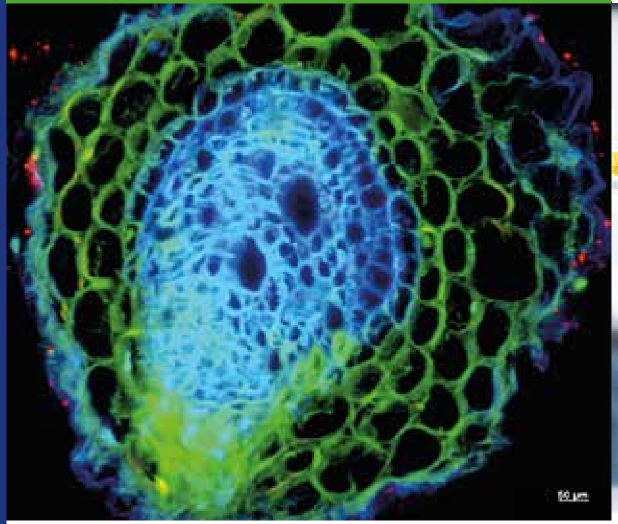
Mapping the brain

From the quest to overcome cancer and infectious diseases to the better understanding of neurodegenerative diseases, the ESRF has always been at the forefront of innovation in health-related research. In the field of neuroscience, a new technique developed at the ESRF, X-ray holographic nanotomography, is enabling scientists to produce super-fast 3D imaging of the brain's neural circuits at nanoscale-synapsis resolution levels for the first time.

Knowledge of brain circuitry is essential to understand how collections of neurons in the human brain give rise to thoughts, cognition and behaviour, and how their malfunction leads to neurodegenerative diseases such as Alzheimer's, Parkinson's and multiple sclerosis – knowledge that will be vital for the understanding and the development of potential treatments.



ENVIRONMENT AND ENERGY



Tracking nanoparticles in the environment

Preserving our planet and resources for the next generations is one of the greatest tasks humanity faces today. A growing share of the research carried out at the ESRF is devoted to addressing complex processes that have important environmental impacts. Synchrotron X-ray techniques such as X-ray fluorescence and spectroscopy help scientists to study soil pollution from nanoparticles that end up in the environment from the washing of consumer products or the use of agrochemicals.

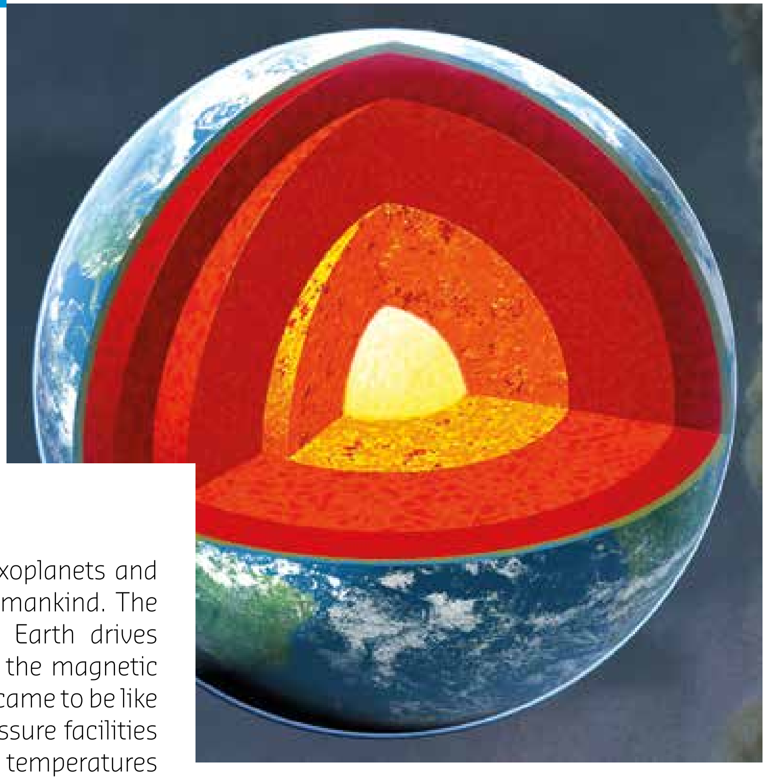
From mapping multiple elements down to resolutions of tens of nanometres to distinguishing chemical species from one another at hitherto undetectable doses, the ESRF's beamlines enable researchers to identify synthetic nanoparticles in plants, investigate their risks to human health and the environment, and to contribute to finding biological solutions to soil contamination.

Towards better batteries

The urgent need for renewable energy production and storage technology that helps the world shift towards a smaller carbon footprint has led to intensive research on batteries, hydrogen-storage technologies and perovskite-based solar cells at the ESRF. Lithium-ion batteries are used in numerous applications from consumer electronics to medical devices and electric vehicles but need to be safer, charge faster and last longer.

A wide variety of complementary X-ray scattering and imaging techniques, such as hard X-ray phase-contrast nanotomography, enable scientists to image the insides of batteries under real working conditions, at high speed and in multiple dimensions, revealing the internal functioning and failure mechanisms at ultrahigh spatial and temporal resolution. Such studies will help manufacturers design the next generation of smaller, safer, cheaper and higher-performing batteries.

PHYSICS AT THE LIMITS



Matter at extremes

The scientific enigmas of our planet, exoplanets and outer space have always fascinated humankind. The intense heat and pressure inside the Earth drives volcanic eruptions, plate tectonics and the magnetic field, yet understanding how our planet came to be like this is a challenge. The ESRF's high-pressure facilities enable geophysicists to recreate the temperatures and pressures found deep inside the Earth while using X-ray diffraction or spectroscopy techniques to probe the structure of mineral samples at such extreme conditions.

Scientists using the ESRF have provided the first evidence of tiny microfractures in rock that could lead to faults, information that could be key in earthquake forecasting and risk mitigation. EBS will also open new horizons for studying materials subjected to the extreme conditions that prevail in the cores of giant gas planets such as Neptune or Super-Earth planet-type exoplanets, contributing to reconstructing the histories of planetary formation.

Towards the bottom of the periodic table

Since Mendeleev proposed the first periodic table of elements in 1869, new elements have been added until as recently as 2016. Pushing the frontiers of fundamental knowledge of the elements at the bottom of the table, scientists at the ESRF are using high-quality X-ray spectroscopy data to study the properties of two groups of metallic elements: actinides (including plutonium, uranium and other radioactive elements) and lanthanides (a family of rare earth metals).

Researchers have discovered a new, unexpectedly stable compound of plutonium with a dramatic change in chemical properties such as solubility, providing a significant step towards a better understanding of plutonium chemistry. This finding could also be important in the context of global efforts to improve the safety of nuclear waste storage and the long-term storage challenge of plutonium compounds.

PALAEONTOLOGY AND CULTURAL HERITAGE

Palaeontology

Fossils are a most valuable link to our past and the history of life on our planet. The ESRF leads the way in the development of non-destructive X-ray microtomography techniques that provide microscopic insights into fossil bones and virtual 3D reconstructions at extremely high quality and resolution.

Scientists using the ESRF's beamlines revealed a new species of bird-like dinosaur, *Halszkaraptor escuilliei*, which lived 75 million years ago. The two-million-year-old skull of *Australopithecus sediba*, one of the world's best-preserved hominid fossils, was also examined at the ESRF, in order to study the evolution and development of our early ancestors.

New EBS beamline BM18 pushes these capabilities even further, allowing scientists to study even larger specimens, from a complete T-rex skull to an entire human mummy in its wooden sarcophagus.

Cultural heritage

Preserving the cultural heritage of humankind for future generations requires detailed insights into the composition and conservation state of rare objects. The ESRF has pioneered research in archeology and cultural heritage, developing the use of non-destructive X-ray microscopy techniques at several beamlines to study tiny fragments sampled from famous cultural masterpieces, including paintings by Van Gogh, Rembrandt and Leonardo Da Vinci.

X-ray micro-analyses can be used to investigate the chemical processes that take place in the degradation over time of paint pigments in masterpieces – findings that are vital for improving conservation and allowing restoration. They can also reveal secrets and lost knowledge about the practices of ancient artists and craftspeople, such as the composition of ink in early writing or the invention of colour photography.

INDUSTRY

Developing effective drugs and medicines

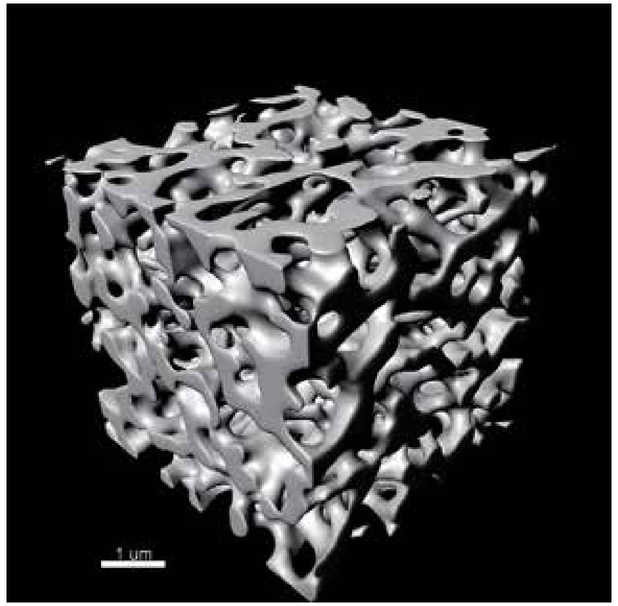
Health crises such as COVID-19 or malaria show the urgent global need for effective drugs, medicines and vaccines. X-ray techniques provide scientists with an accurate picture of biological processes essential for drug discovery, drug development and drug delivery systems, as well as aid in developing healthcare technologies such as prostheses and radiotherapy.

Many pharmaceutical and biotechnology firms make use of the ESRF's state-of-the-art structural biology beamlines, which include fully automated macromolecular crystallography facilities and a cryo-electron microscope. Hundreds of samples can be screened every day, allowing researchers to resolve the crystal structures of drug formulations, check the stability of pharmaceutical compounds inside pills and characterise the interactions of active ingredients under different conditions.

New materials

Understanding how engineering materials behave under different conditions helps manufacturers to assess their capabilities and limitations as well as to improve their lifetime – knowledge that is vital for the creation of new, sustainable products and innovative and responsible industry.

The ESRF's high-energy X-rays allow researchers to probe for defects inside huge industrial objects such as turbine blades, or in materials used in space. Techniques such as X-ray diffraction and spectroscopy allow scientists to characterise composite materials and alloys, to conduct stress tests on materials, to analyse the performance of corrosion-resistant coatings, to characterise fuel cells or to follow catalysis processes in real time and real working conditions.

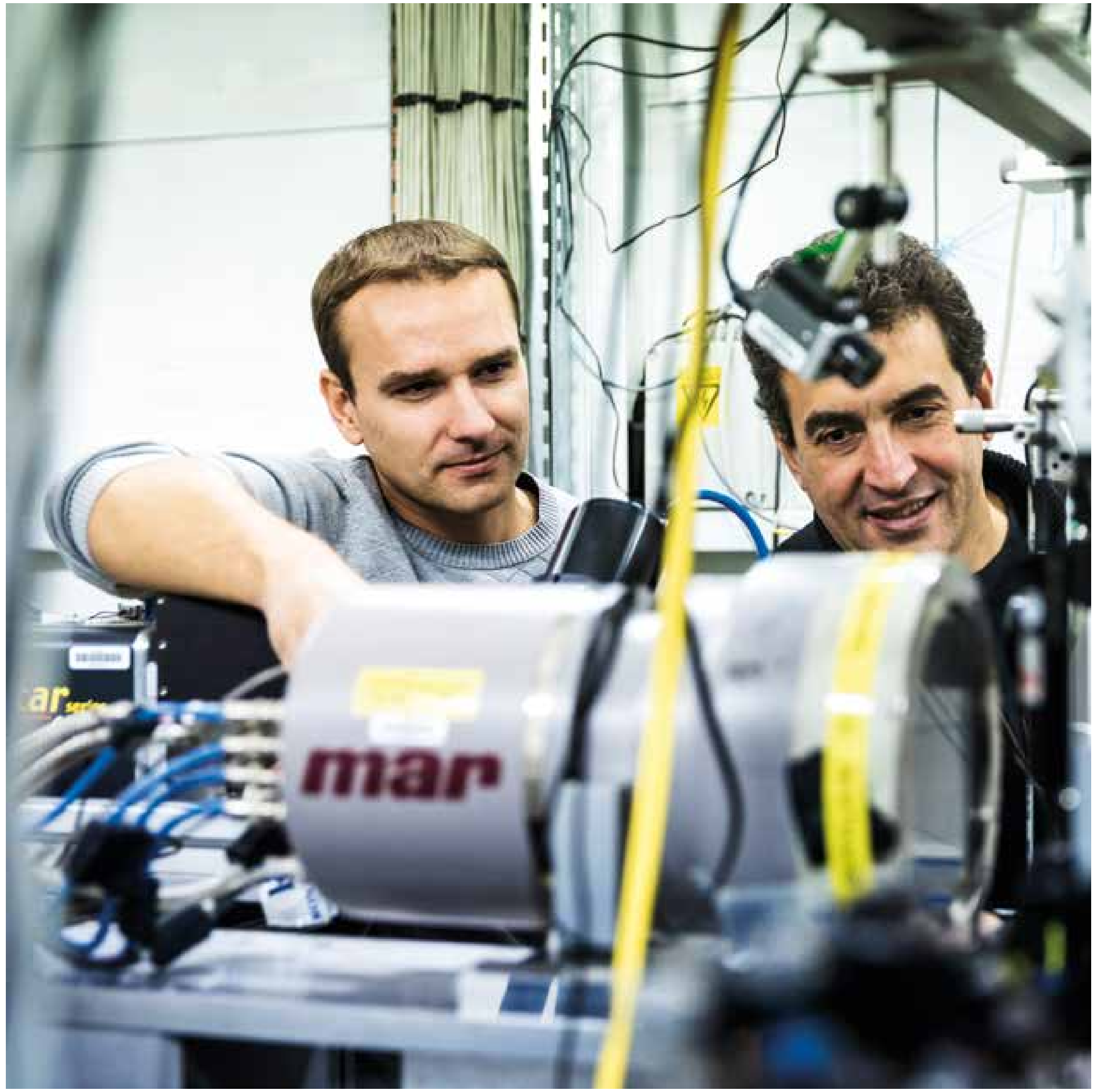


INSPIRING THE NEXT GENERATION

Inspiring the next generation

The ESRF supports many initiatives and public events aimed at sharing knowledge of science and engaging with a diverse range of audiences, including school students and young children.

At the heart of this mission, the ESRF offers different educational programmes for students of all levels. Synchrotron@School, a hands-on day of science and discovery for secondary school students, showcases the diversity of science careers and research carried out in an international research facility. The HERCULES European school, the Joint Universities Accelerator School (JUAS), and the joint ESRF/ILL International Summer Student programme offer introductory lectures and specialised courses, practical sessions, tutorials and visits of European research facilities for university students, postdoctoral fellows and senior scientists.



“Growing up in a country being rebuilt after years of war and destruction, I learned how important restoration and conservation is. Now, I am living my dream at the ESRF, studying with world-renowned experts, feeling more motivated than ever and completely integrated in the Grenoble environment.”

Ida Fazlić, PhD student in cultural heritage studies

Training tomorrow’s scientists

The international PhD programme represents the ESRF’s commitment to first-class training and education. Each year, the ESRF welcomes new PhD students from among the top science graduates in their countries, from fields as diverse as physics, chemistry, materials science, health and life sciences, earth and environmental sciences, information science and nanotechnology, engineering, cultural heritage and palaeontology.

Accompanied by the ESRF’s office for Higher Education and our Doctoral programme, these students pursue ambitious research projects in an exciting, international environment, becoming part of a vibrant scientific community at a world-class facility and benefitting from local and international networks and partnerships to advance young careers.

The ESRF is located in Grenoble, at the heart of the French Alps. It is an actor of the European Photon and Neutron (EPN) Science Campus, a unique science hub that hosts four major international research institutes (ESRF, ILL, EMBL, IBS), devoted to the exploration of living matter and materials.

The ESRF is also an active partner of the GIANT (Grenoble Innovation for Advanced New Technologies) innovation campus, the lifeblood of Grenoble’s economic and scientific development, and of the Université Grenoble Alpes (UGA), one of the the top 100 universities in the world.*

*Source: Shanghai Ranking (www.shanghairanking.com/ARWU2020.html)

COMMITTING TO A SUSTAINABLE FUTURE

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Committing to a sustainable future

As a landmark for science rooted in a unique setting in Grenoble, France, the ESRF is committed to demonstrating its engagement and integration with society, and to optimising its societal, economic and environmental impact.

Fostering an interest in science and technology and recruiting and training the next generation of scientists is a vital part of the ESRF's mission. From driving knowledge transfer for a sustainable economy to improving science education through partnerships with schools and public outreach programmes, the ESRF strives to produce positive social and economic benefits on both a local and international scale.

Since its creation in 1988, the ESRF has returned contracts to commerce and industry totalling more than €2bn. Socio-economic impact studies also demonstrate that each euro invested in the ESRF has a return to society of two to three euros. The engineering challenges of ESRF-EBS are a great example of the ESRF's impact in boosting industrial capacity in innovative technologies in its partner countries and beyond.

The ESRF is committed to minimising its environmental impact and improving the quality of life on campus with initiatives such as tree-planting, minimising power consumption and waste production, eco-friendly construction and maintenance programmes, waste recycling, and supporting sustainable mobility for staff and visitors. Environmental considerations inform all ESRF projects, as illustrated by the new EBS storage ring technology, which reduces electricity consumption by 30%. Identifying and implementing best practices and procedures to reduce the ESRF's carbon footprint, and thus to help mitigate climate change, are strong factors in decisions being made at the ESRF in the short, medium and long term.

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PHOTOS : ESRF/S. CANDÉ EXCEPT FOR COVER AND PAGES 11, 46-47 (ESRF/J. CHAVY), PAGE 6 (ESRF/A. MCBRIDE), PAGE 9 (DESY), PAGE 28 (V. RAMAKRISHNAN), PAGE 31 (A. PACUREANU *ET AL.*), PAGE 32 (A.E PRADAS DEL REAL *ET AL.*), PAGE 34 (DR), PAGE 35 (ESRF/ D. MOREL), PAGE 36 (P. TAFFOREAU), PAGE 37 (MUNCH MUSEUM), PAGE 39 (DR). **DESIGN** : SONIA ROUSSIN