



**ESRF-EBS**

**A NEW GENERATION  
OF SYNCHROTRON  
FOR EUROPE**



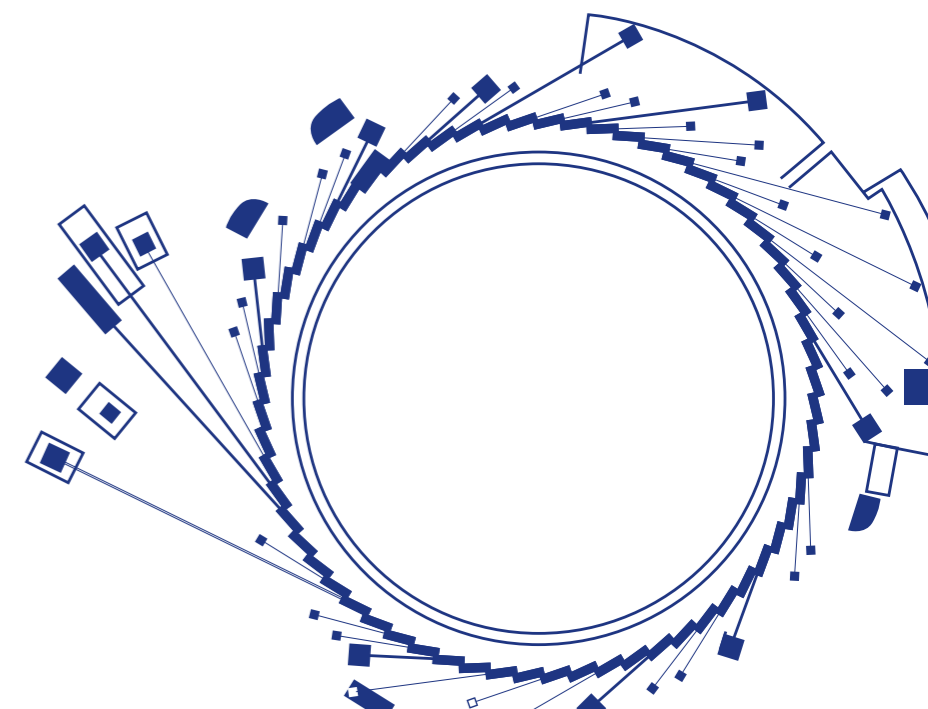
## A new generation of synchrotron for Europe

More brilliant than ever, light is back at the ESRF, the European Synchrotron in Grenoble.

On 25 August 2020, a brand-new generation of high-energy synchrotron will open its Extremely Brilliant Source (EBS) of X-rays to the international scientific community.

With X-ray performances multiplied by 100 compared to before, ESRF-EBS hails a new era for X-ray science in the 3D exploration of matter at all scales and down to the atomic scale.

ESRF-EBS will contribute to tackling global challenges in key areas such as health, environment, energy and new industrial materials, and to unveiling hidden secrets of our natural and cultural heritage through the non-destructive investigation of precious artefacts and palaeontological treasures. A shining example of international cooperation, EBS has been funded by 22 countries joining forces to construct this innovative and world-unique research infrastructure with an investment of 150 million euros over 2015-2022.



*From top to bottom, the ESRF Experimental Hall and one of the 40 ESRF beamlines.*

## A dream machine becomes a reality

"A dream machine is becoming a reality," says Pantaleo Raimondi, Director of the Accelerator & Source division at the ESRF and inventor of the ESRF-EBS concept. "In 2013, EBS was still a concept imagined on paper. Today, thanks to the expertise and enthusiasm of the ESRF teams, we are preparing to restart the scientific programme. I am excited to see the science that will result!"

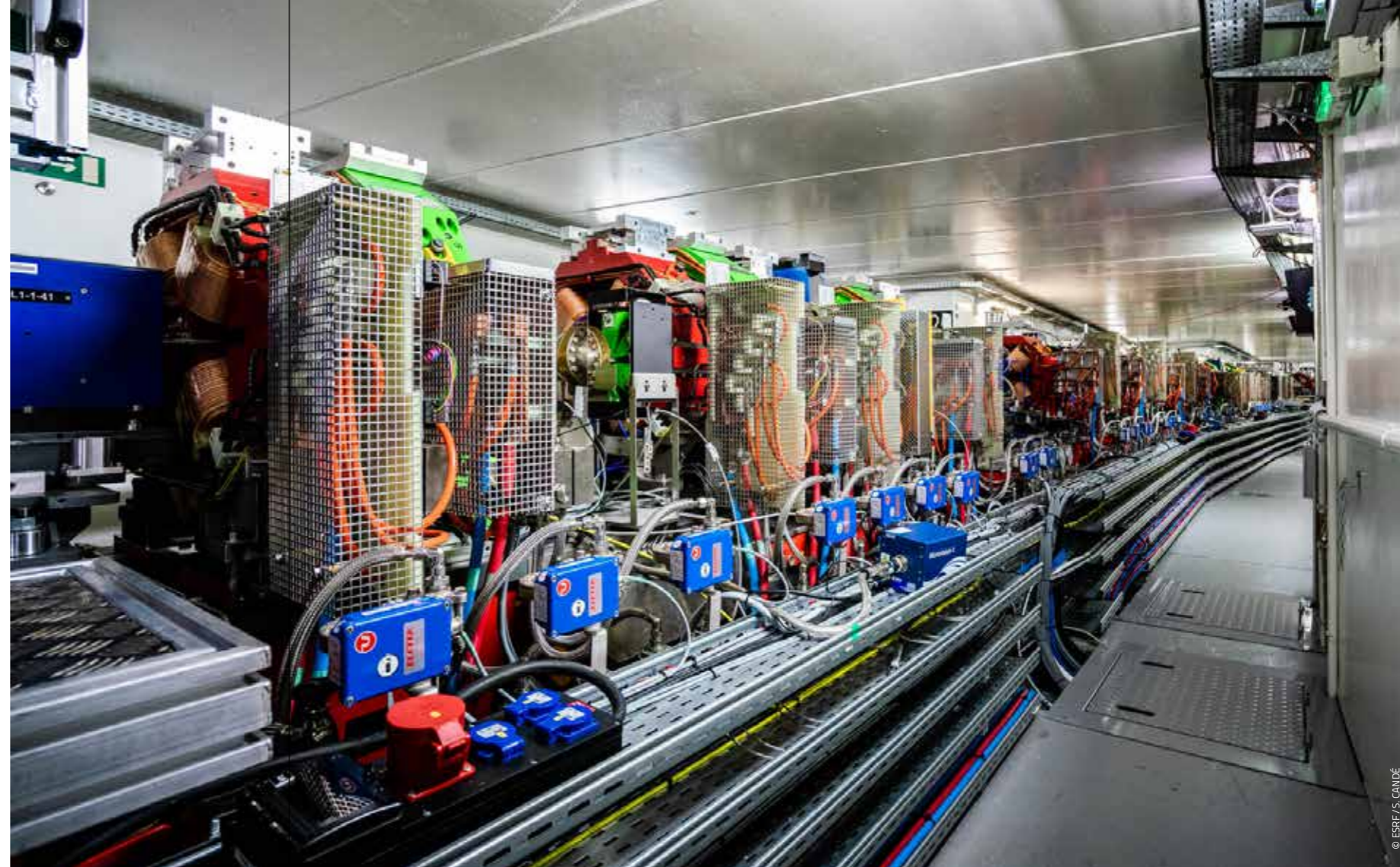
"This is a moment of pride for the whole of the synchrotron community," adds Francesco Sette, Director General of the ESRF. "With the opening of this brand-new generation of high-energy synchrotron, the ESRF continues its pioneering role to provide an unprecedented new tool for scientists from our 22 partner countries and the world to push back the frontiers of science and address vital challenges facing our society today, such as health, environment and energy."

## The challenge: building a new generation of high-energy synchrotron

On 10 December 2018, after having paved the way for modern, third-generation synchrotron sources worldwide, and after 26 years of loyal service, one of the highest-performing X-ray sources in the world was shut down for 20 months. The aim: to replace it with a new source of light based on a revolutionary new concept and even more brilliant than before: ESRF-EBS.

Teams took three months to dismantle the ESRF's historic storage ring (disconnecting 200 km of cables and removing 1720 tonnes of equipment) and nine months to install the new machine in the 844-m-circumference tunnel, before carrying out the precise alignment of 10,000 innovative technological components to a relative accuracy of less than 50 microns – around half the width of a human hair – over kilometre distances.

On 28 November 2019, electrons were injected into the new EBS storage ring for the first time. Commissioning followed and, by 14 March, just before the site closed due to the COVID-19 pandemic, the machine operation parameters necessary to open EBS were reached, five months ahead of schedule. Thanks to this intensive work, EBS is opening to the scientific community, as planned, on 25 August 2020.



The new EBS storage ring.

### KEY FIGURES

**A 150M€ project funded by 22 partner countries** over 2015-2022

**The construction of a new storage ring**, inside the existing infrastructure, with **X-ray performances increased by a factor of 100**

**90% of the existing infrastructure re-used**

**20% decrease in energy consumption**

**4 new state-of-the-art beamlines** to be constructed, through refurbishments of existing beamlines

**An ambitious instrumentation programme and data management strategy**

### KEY DATES

**2022-2023**  
Completion of all new and refurbished beamlines

**2020**  
EBS commissioning and restart, open to scientific users on 25 August

**2019**  
Pause in ESRF scientific programme as previous storage ring dismantled and EBS installed

**2017-2018**  
In-house assembly of new state-of-the-art storage ring

**2016**  
Manufacture and delivery of over 10,000 innovative components

**2015**  
EBS project launched



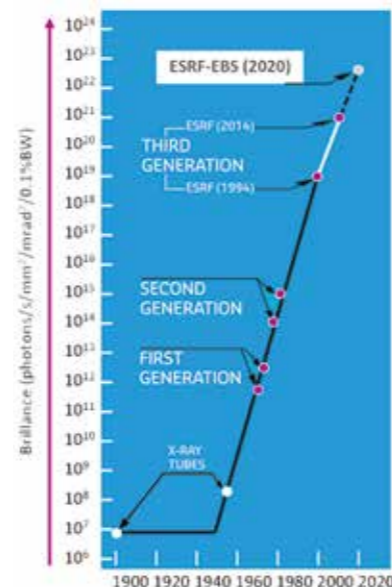
## The quest for brilliance: physics' Holy Grail

Since the 1970s, thanks to an acceleration in technological progress, several new generations of synchrotron have been developed, each one improving the brilliance and coherence of the X-rays produced compared to its predecessor, each one pushing the frontiers of what is possible in the exploration of matter.

The graph shows the evolution of synchrotrons as the brilliance of the X-rays produced increases over time.

When it opened in 1994, the ESRF was the world's first third-generation synchrotron light source, with X-ray performances 100 to 1000 times higher than the synchrotrons of the day. Today, the ESRF continues its pioneering role by opening the first fourth-generation high-energy synchrotron, improving X-ray performances of brilliance and coherence once again by a factor of 100.

This new concept, based on innovative technology, paves the way for a new generation of synchrotrons around the world. Indeed, several upgrade projects based on EBS are already in development worldwide.



## EBS innovation

- EBS is based on a revolutionary new HMBA lattice, or magnetic configuration in the storage ring
- Increasing the number of bending and focusing magnets reduces the horizontal emittance, or spread of the electron beam by a factor of 30
- This increases the brilliance and coherence of the X-rays produced by a factor of 100



*Francesco Sette, ESRF Director General with Pantaleo Raimondi, Director of the Accelerator and Source Division and EBS inventor, who was awarded the prestigious Gersh Budker prize in 2017 for his outstanding contribution to the accelerator field.*

### What is the HMBA lattice?

The hybrid multi-bend achromat lattice is an award-winning (Gersh Budker prize, 2017) new design for the arrangement of magnets in the ESRF storage ring that will guide and focus the electrons in order to produce an X-ray beam 100 times more brilliant and coherent than before.

- Multi-bend: there will be seven bending magnets per cell – five more than previously. More bends mean lower emittance, which results in brighter X-rays.
- Achromat: electrons are bent and focused similarly, independent of their energy, resulting in very small and stable beams.
- Hybrid: refers to the inclusion in the multi-bend achromat cells of specialised features (e.g., a very efficient scheme to create the achromat thanks to proper placing of the sextupoles in the lattice).

## Tackling global challenges



*« We will be able to study the structure of the biological molecules in natural conditions and see the protein machines at work, and thus better understand the machinery of life. »*

DANIELE DE SANCTIS, ESRF SCIENTIST

EBS will provide new tools for the investigation of the structure of living matter and materials at the atomic scale, with applications in numerous fields including health, energy, environment, new sustainable materials, and also cultural heritage and palaeontology.

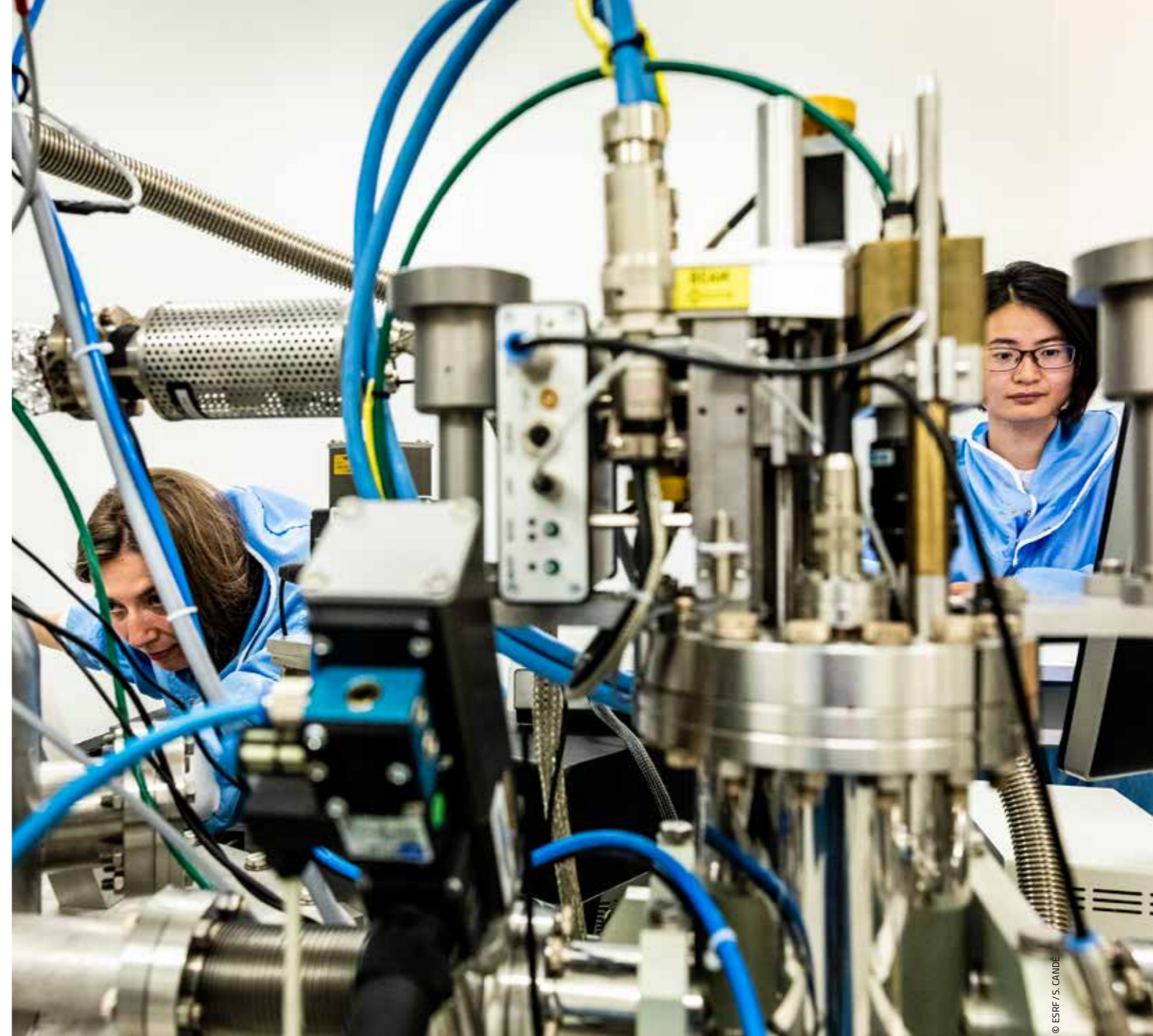
Imagine being able to scan a human organ at extremely high resolution to better understand the process of infection, such as in diseases like COVID-19. Or the ability to map the human brain at the synapse level, with important implications for neurodegenerative disease and emerging artificial neural network architecture-based technologies. How about being able to track the presence in soil of nanoparticles from our everyday products at doses that were, until now undetectable, to better evaluate their potential toxicity for the environment? Or being able to carry out a virtual autopsy of a complete mummy down to the cellular level, thus enriching our knowledge of ancient civilisations? And being able to better identify the chemical reactions at the origin of the degradation of artistic masterpieces to help preserve humanity's natural and cultural heritage. Such capabilities will enable scientists to better understand life and the world around us, and to make the invisible visible.

### COVID-19 RESEARCH

The EBS's extremely brilliant light has already been made available for priority research on COVID-19 in two fields: structural biology to understand the functions and interactions of the virus with the host cell, with the aim to contribute to the development of vaccines or effective antivirals, and the use of 3D imagery for lung scanning in order to understand the effects of coronavirus on organs, especially during the infection phase.

*« We will be able to scan non-destructively a T. rex skull, a human mummy in its wooden sarcophagus, or even a complete human body. »*

PAUL TAFFOREAU, ESRF SCIENTIST



In addition to the ESRF's existing state-of-the-art beamlines, four brand-new flagship beamlines will be constructed over 2020-2023:

- EBSL1: Coherent X-rays for dynamics and imaging at the nanoscale
- EBSL2: Microscopy by hard X-ray diffraction on material complexity
- EBSL3: Large-field phase-contrast tomography on metre-sized objects with nanoscale 3D spatial resolution
- EBSL8: Serial crystallography on macromolecular nanocrystals

These beamlines, each one specialised in different imaging techniques, will allow scientists to study the structure of matter at the atomic level in greater detail, with higher quality and much faster.

*« We will be able to study nanoparticles such as titanium oxide, often used in cosmetics, at lower concentration levels, which will allow us to better understand issues such as nanopollution in soil and plants. »*

HIRAM CASTILLO-MICHEL, ESRF SCIENTIST

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## A bright example of international cooperation

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### ESRF IS FUNDED

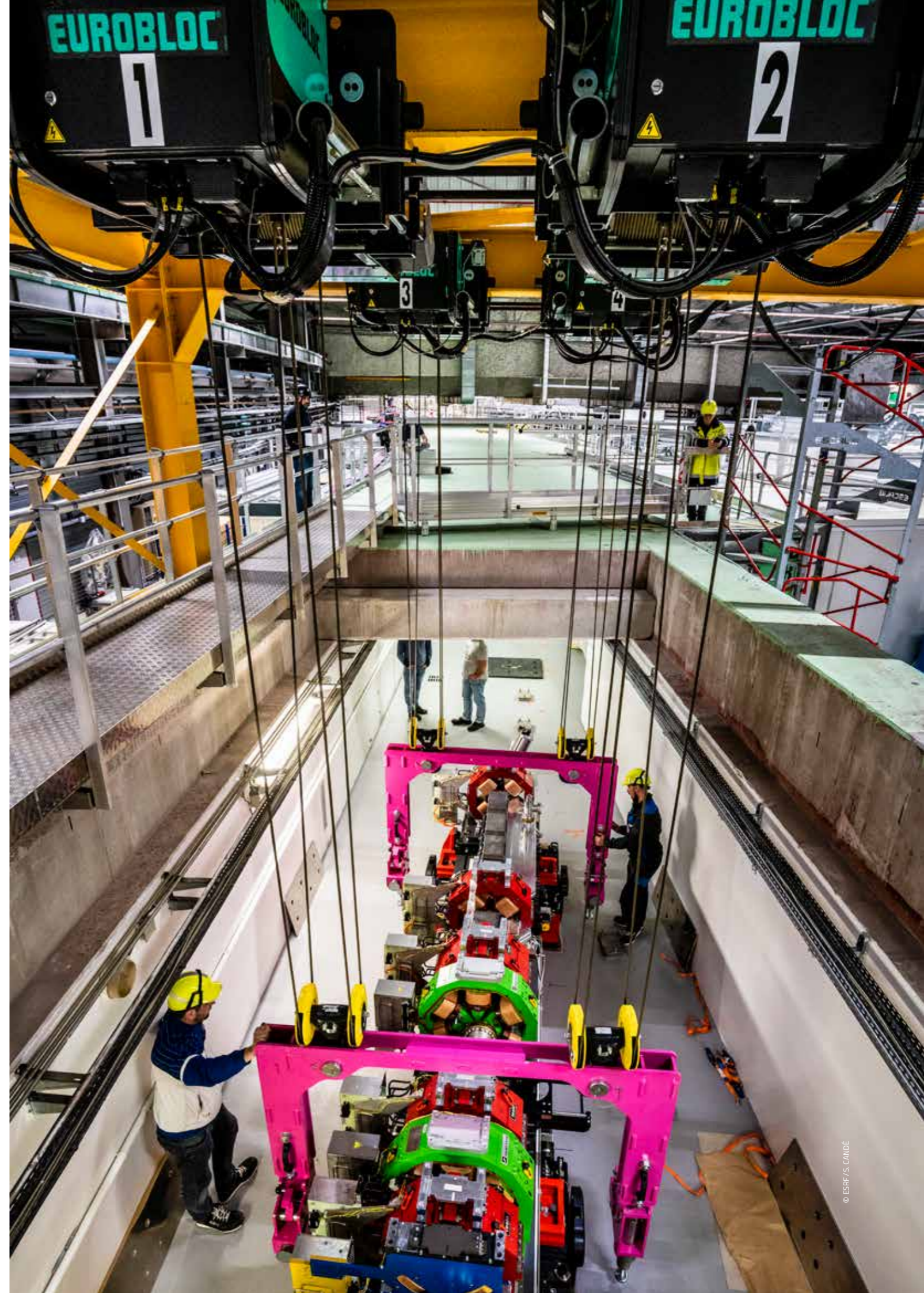
#### BY 22 PARTNER COUNTRIES

##### 13 MEMBER STATES

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

##### 9 ASSOCIATE COUNTRIES

Austria	1.75 %
Israel	1.75 %
Centralsync	1.05 %
(Czech Republic, Hungary, Slovakia)	
Poland	1.00 %
Portugal	1.00 %
India	0.66 %
South Africa	0.30 %



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