ESRF – ILL 8th Summer School
Undergraduate Students

Science at synchrotrons and at the ESRF

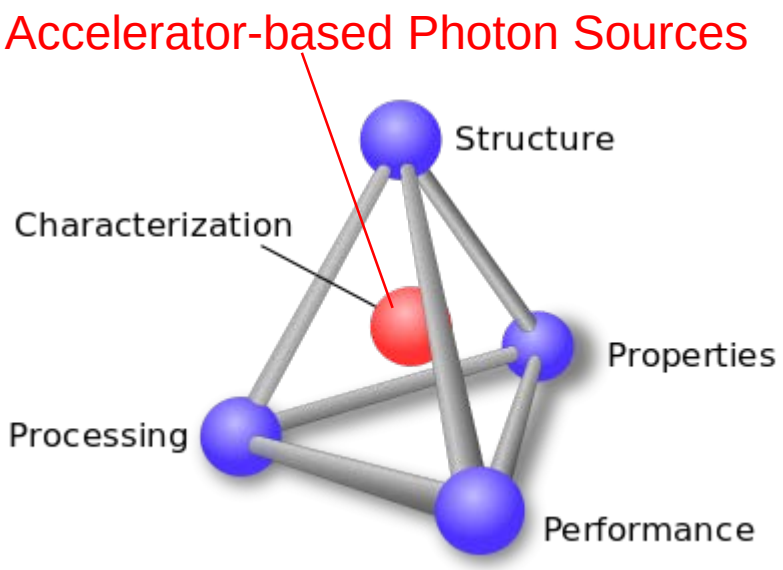
Welcome!

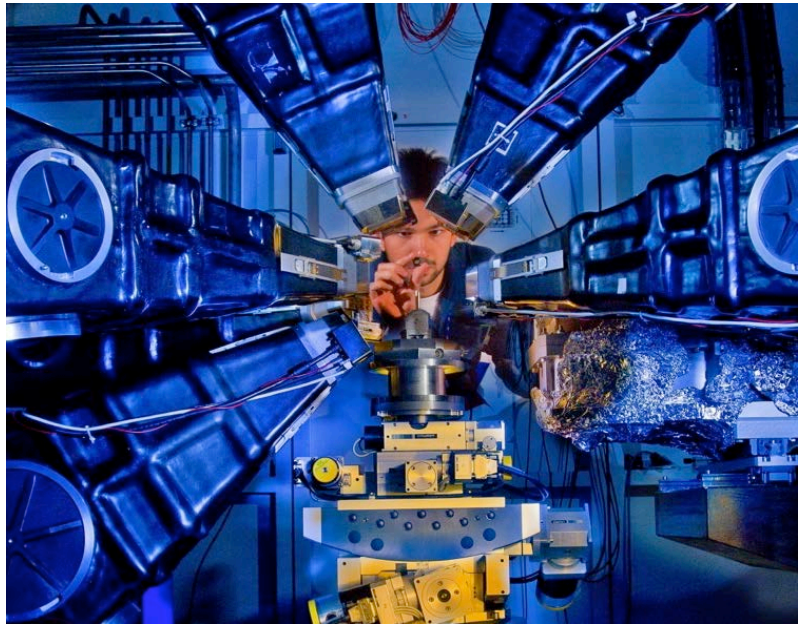
Michael Krisch and Francesco Sette

ESRF
The European Synchrotron

30 years of science

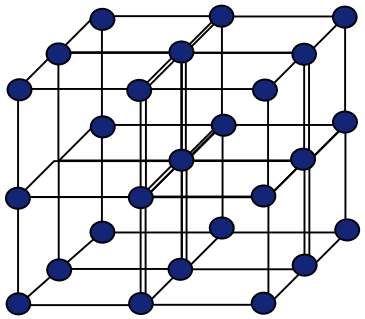
Understanding materials and living matter has always driven human progress

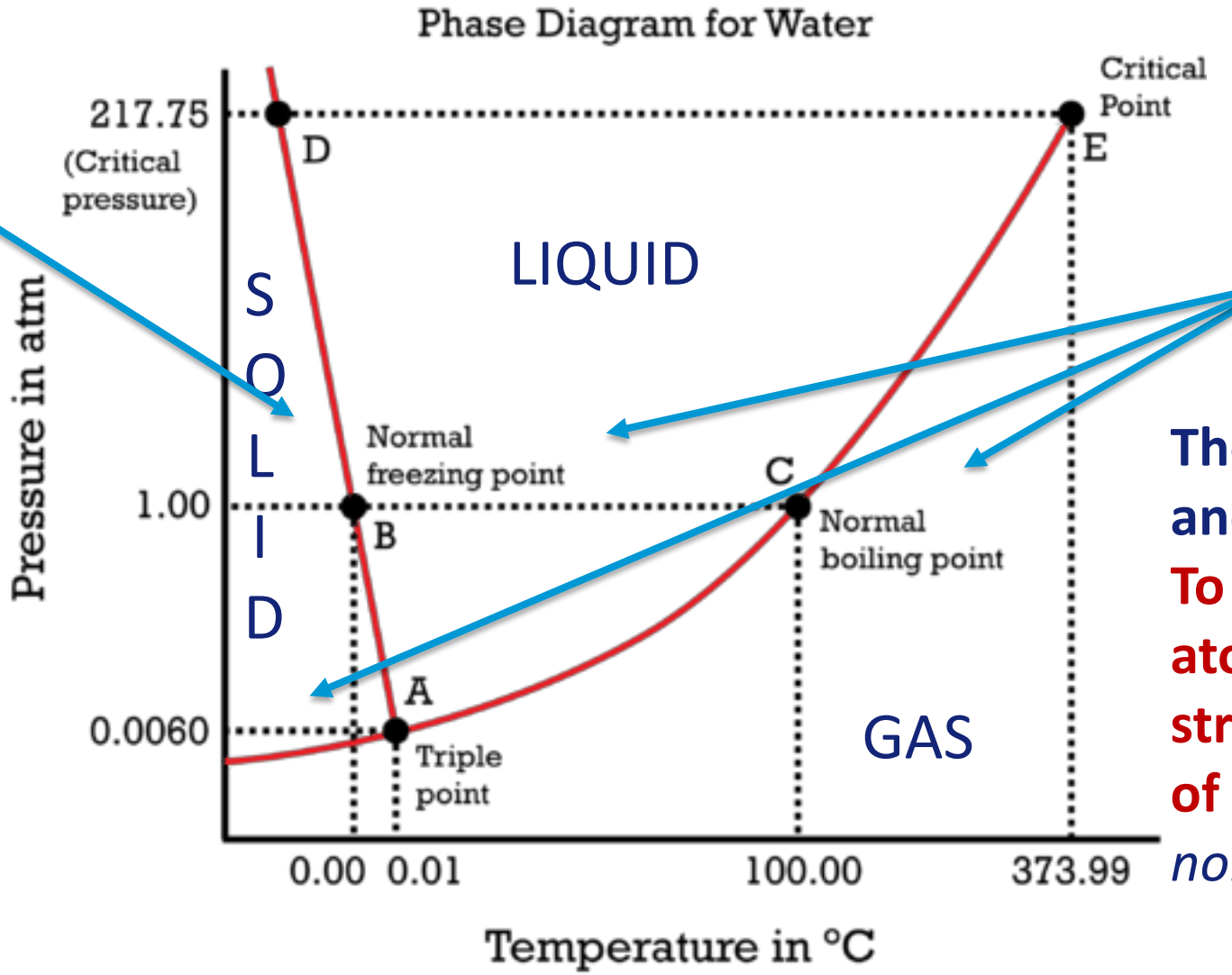


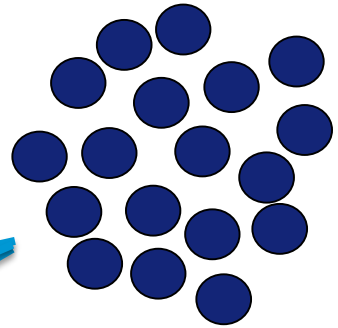


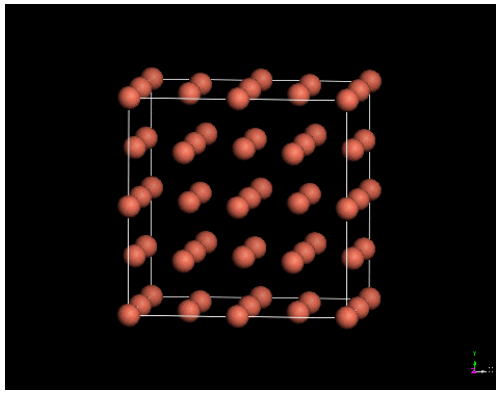
- ADDRESSING CRITICAL GLOBAL CHALLENGES IN AREAS SUCH AS HEALTH, ENVIRONMENT, ENERGY, FOOD SECURITY
- IN CONDENSED AND LIVING MATTER, SCIENTIFIC RESEARCH LINKING FUNCTIONS AND PROPERTIES TO THE STRUCTURE OF ATOMS

Atoms – Molecules – Condensed Matter



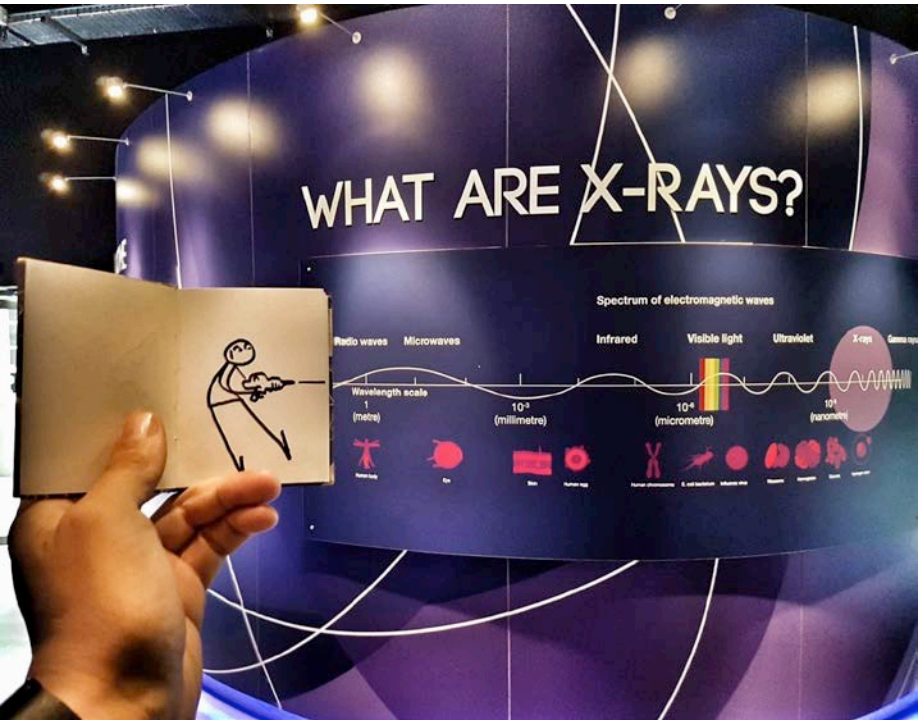


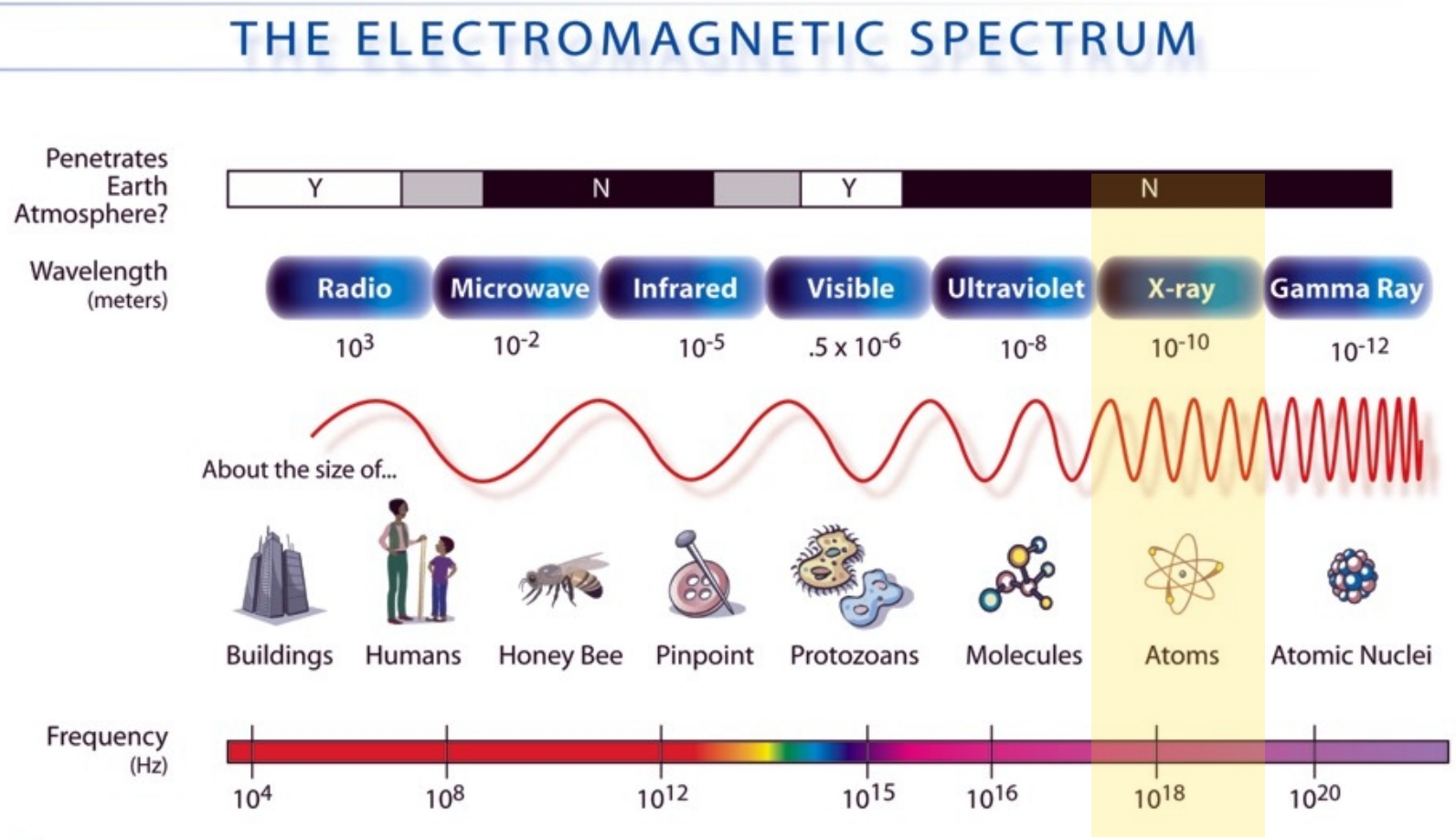




The beauty of X-rays and neutrons:
To unveil down to atomic resolution the structure and dynamics of condensed matter – *non-destructively!*

SYNCHROTRON LIGHT: THE POWER OF X-RAYS



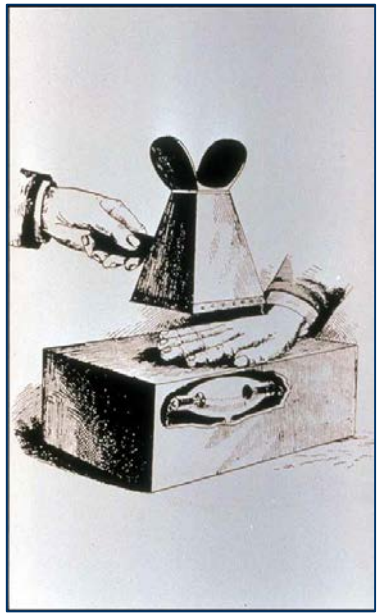


X-RAYS: DISCOVERY IN 1895 BY W.C RÖNTGEN

X-rays ... some kind of unknown particles without mass and charge

Wilhelm Conrad Röntgen (1845-1923)
First Nobel Prize for Physics, 1901

The first "röntgenogram"
8 November 1895



(1895) RÖNTGEN'S EXPERIMENT

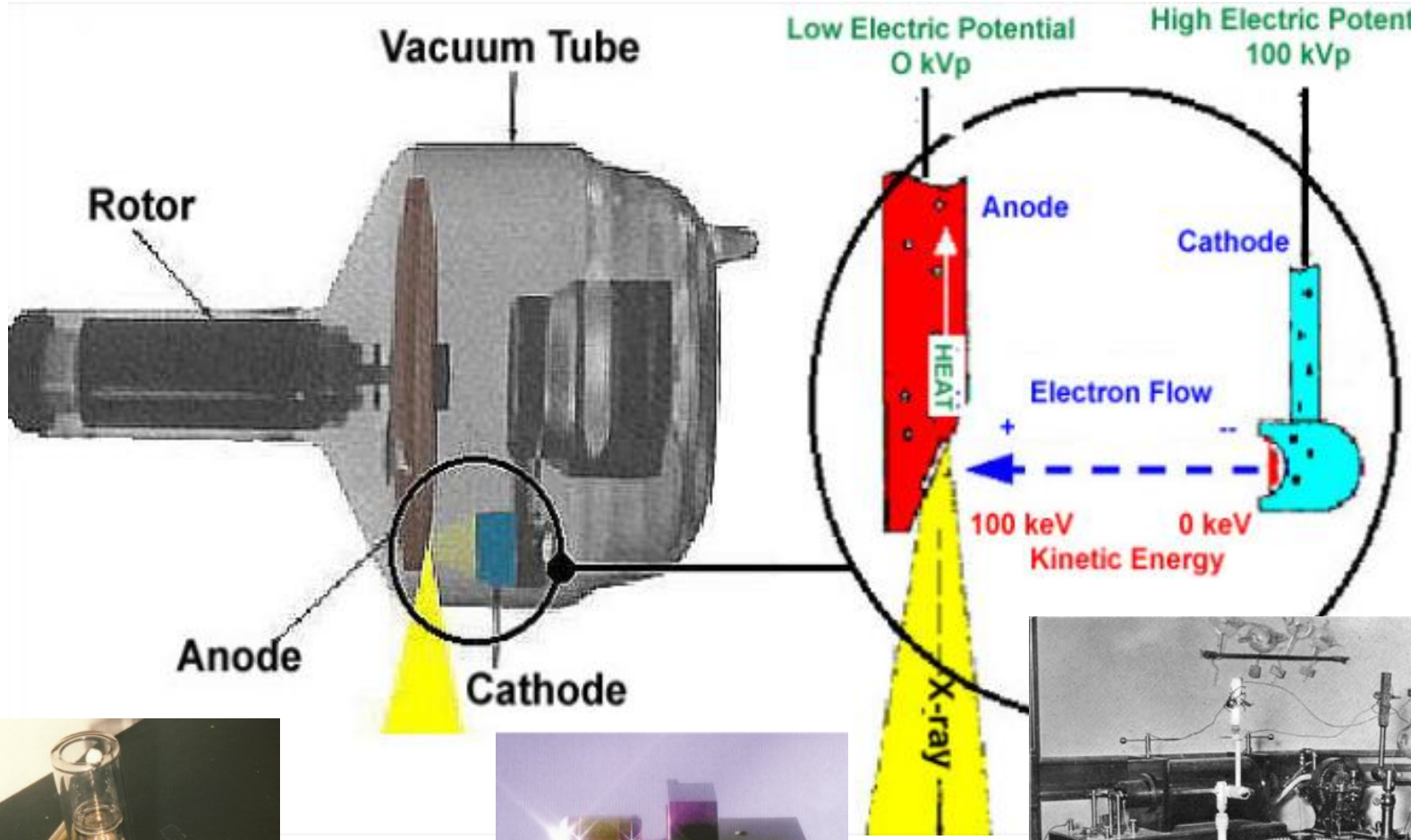
after W.C. Röntgen
Über eine neue Art von Strahlen.
Phys.-Med. Ges., Würzburg, 137, (1895)
English translation in Nature 53, 274, (1896)

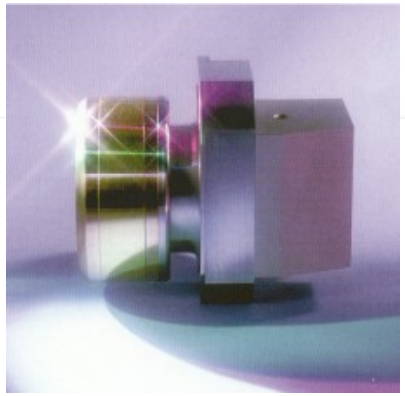
On a new kind of Rays

- "… A piece of sheet of aluminium, 15 mm thick, still allowed **the X-rays** (as I will call the rays, for sake of brevity) **to pass** …"
- "... Detection of **interference phenomena** has been tried without success, perhaps only because of their **feeble intensity**..."
- "... The **refractive index** ... cannot be more than **1.05 at most** ... X-rays cannot be concentrated by **lenses** ..."
- "... **Photographic plates and film** are *susceptible to X-rays*, providing a valuable means of **recording the effects** ..."

name, penetration, non-destructiveness, intensity, coherence, optics, detectors

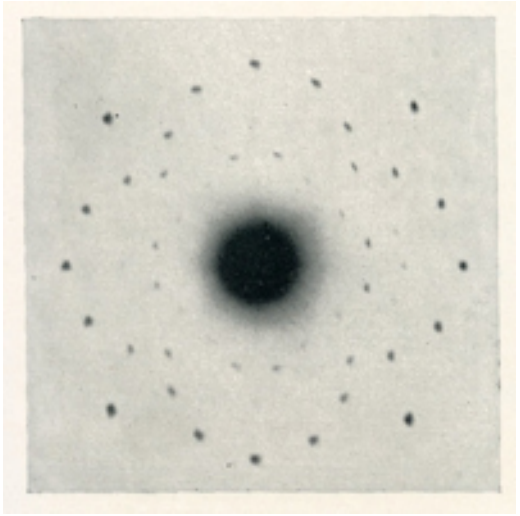
X-RAY SOURCE


Vacuum Tube
Rotor
Anode
Cathode
Low Electric Potential
O kVp
High Electric Potential
100 kVp
Anode
Cathode
HEAT
Electron Flow
+
--
100 keV
0 keV
Kinetic Energy
X-ray

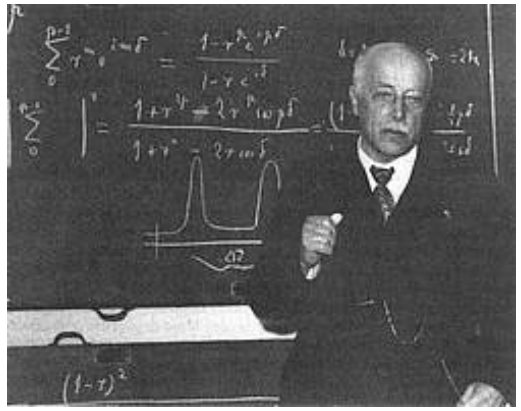


X-RAY SCIENCE: A LONG SUCCESS STORY WHICH STARTED IN 1895

Wilhelm Conrad Röntgen (1845-1923)



Max von Laue (1879-1960)



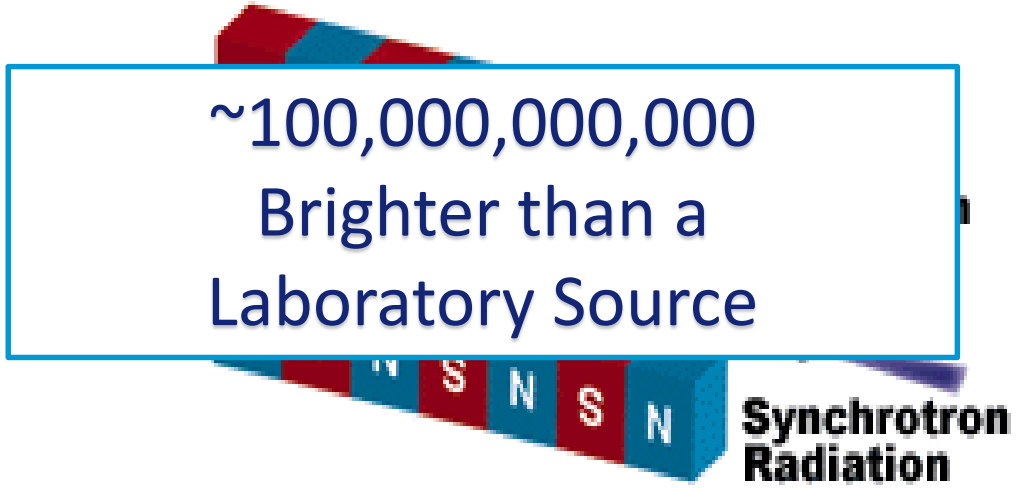
1947: First observation of synchrotron radiation at General Electric (USA).

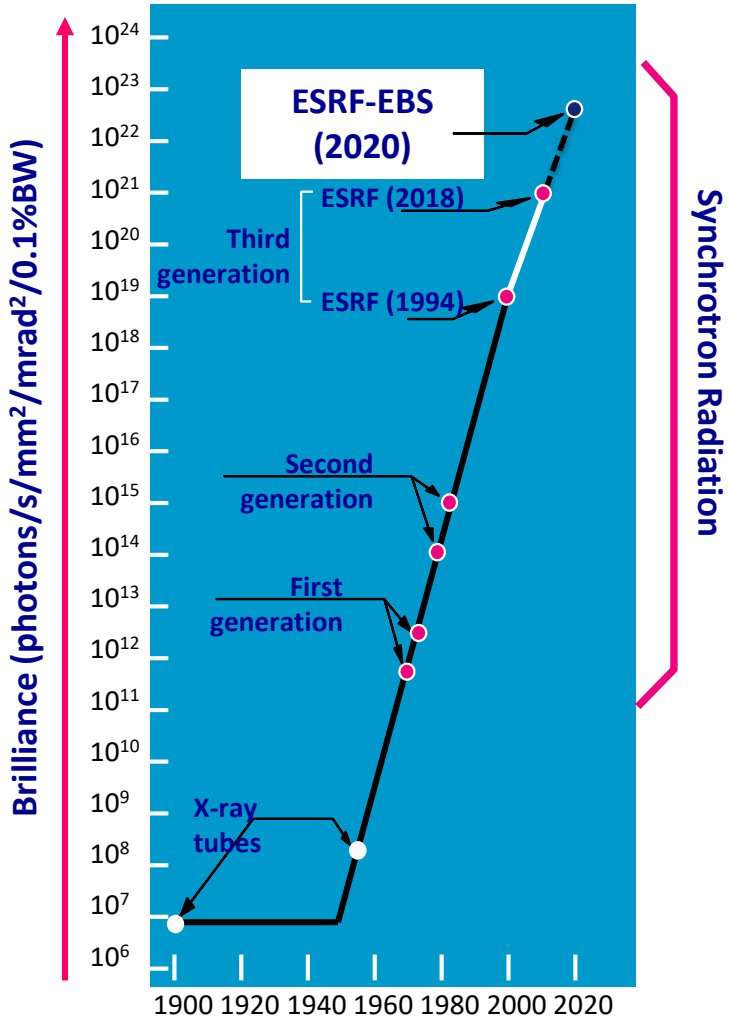
..followed by decades of parasitic use of Synchrotron radiation on high-energy machines

Conventional X-ray Sources and Synchrotron Radiation

Chasman-Green Lattice
Brookhaven, 1975
The way to very low vertical emittance storage rings, and to very high brightness
Third Generation SR Sources
ESRF 1992

~100,000,000,000
Brighter than a
Laboratory Source

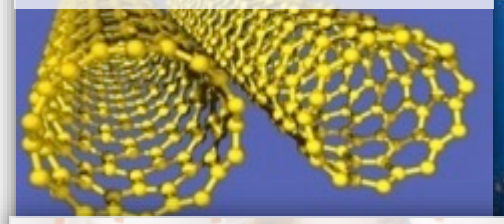




Fundamental, applied and industrial research on atoms structure and dynamics

Understanding new materials, and functioning of life-related processes

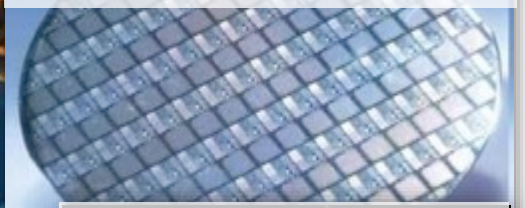
ADVANCED MATERIALS



ENERGY & ENVIRONMENT

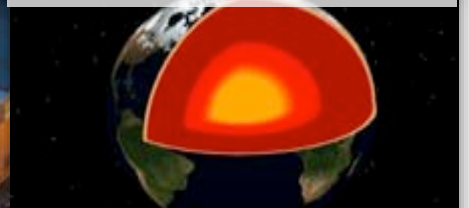
HEALTH & FOOD

MICROELECTRONICS



CONSUMER PRODUCTS

EXTREME CONDITIONS



METALLURGY

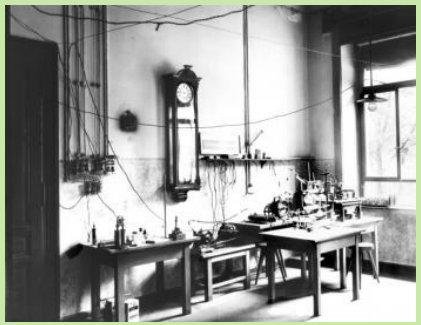
PETROCHEMICALS

CULTURAL HERITAGE

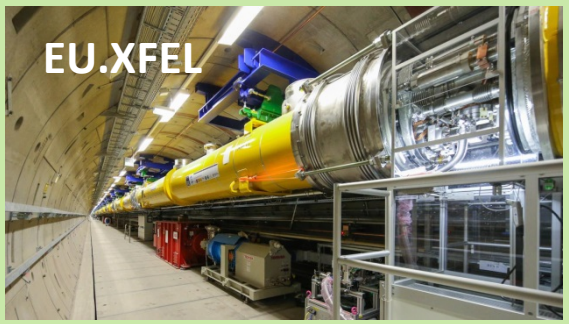
The Spectacular Success of X-ray Science

X-ray Science: Imaging, Scattering, Diffraction, Spectroscopy

1895 **2019**



W.C. Röntgen



Coherent X-ray Sources

25 Nobel prizes in Physics (14), Chemistry (12) and Medicine and Physiology (1) since the first one in 1901

Era of Crystals

1900

Structure-function-relations
Phase diagrams
Large unit cell crystals
Protein crystallography

Era of Complexity

2000

Bio- and nano-technologies
Highly correlated systems
Non-equilibrium matter

(COURTESY H. DOSCH)

MODERN THIRD GENERATION SYNCHROTRONS WORLDWIDE: CONSTRUCTED ON THE SUCCESS OF THE **ESRF**

1994 – The European Synchrotron Radiation Facility – 6 GeV

FIRST THIRD-GENERATION SYNCHROTRON

SYNCHROTRON FACILITIES SERVE NOWADAYS ~50 000 USERS WORLDWIDE: THE LARGEST SCIENTIFIC COMMUNITY IN THE WORLD

- Access based on scientific excellence
- 12 Beam time allocation panels made of international experts in charge of peer-reviewing proposals for 46 beamlines

ESRF's core missions

- Develop, construct and operate state-of-the-art *X-RAY SYNCHROTRON* instruments and *BIG-DATA IT INFRASTRUCTURE* to the benefit of the scientific communities of the Member and Associate countries
- Serve the international community *TO ADVANCE KNOWLEDGE AND TO ADDRESS GLOBAL SOCIETAL CHALLENGES*
- Support *INDUSTRIAL RESEARCH* in Member and Associate countries to strengthen Europe's competiveness
- Train the *NEXT GENERATION OF SCIENTISTS, ENGINEERS AND TECHNICAL STAFF*

ESRF
The European Synchrotron

ESRF User community since 2010: 74 000 users from more than 60 countries

TODAY

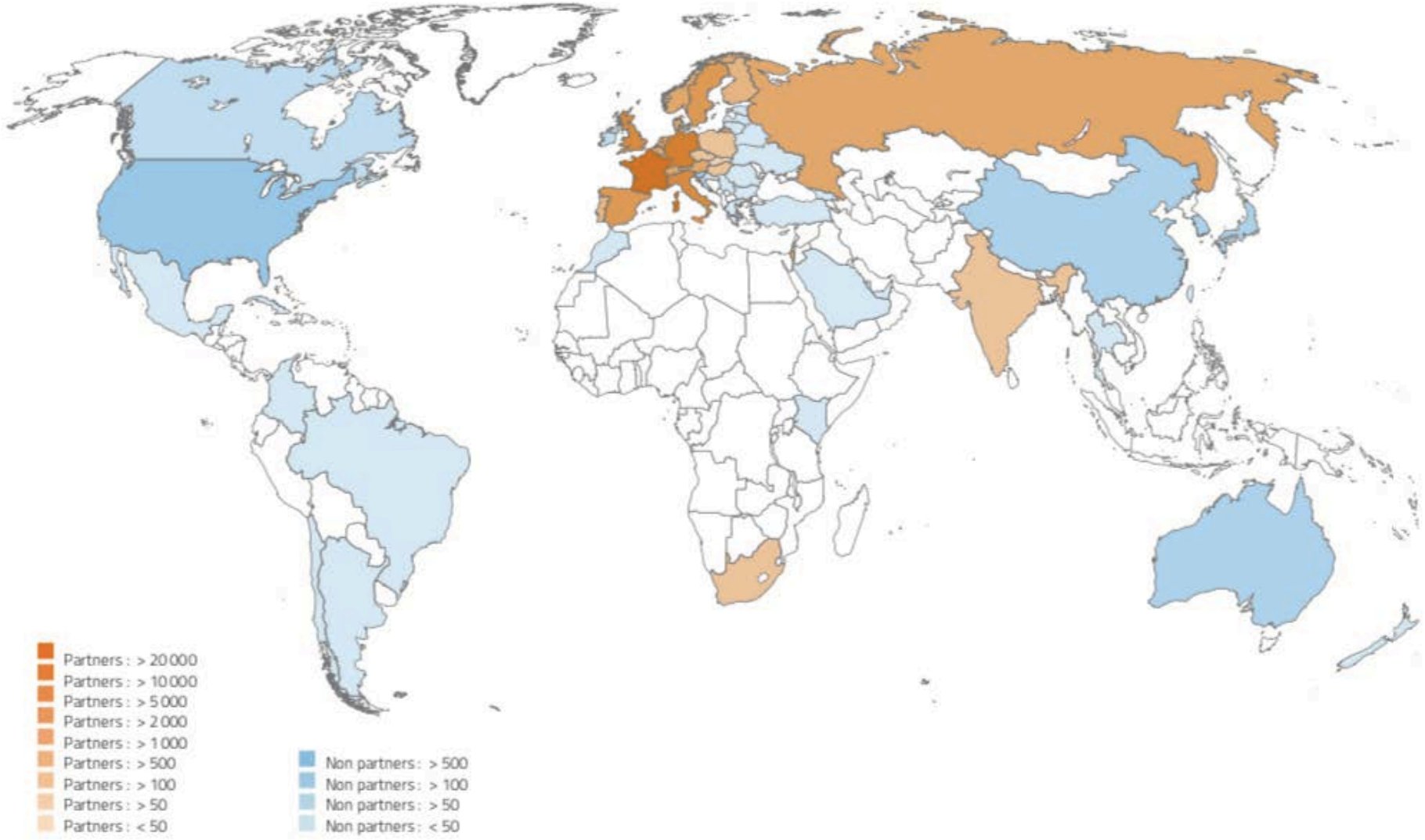
2 000 scientific publications each year

10 000 scientific visitors each year

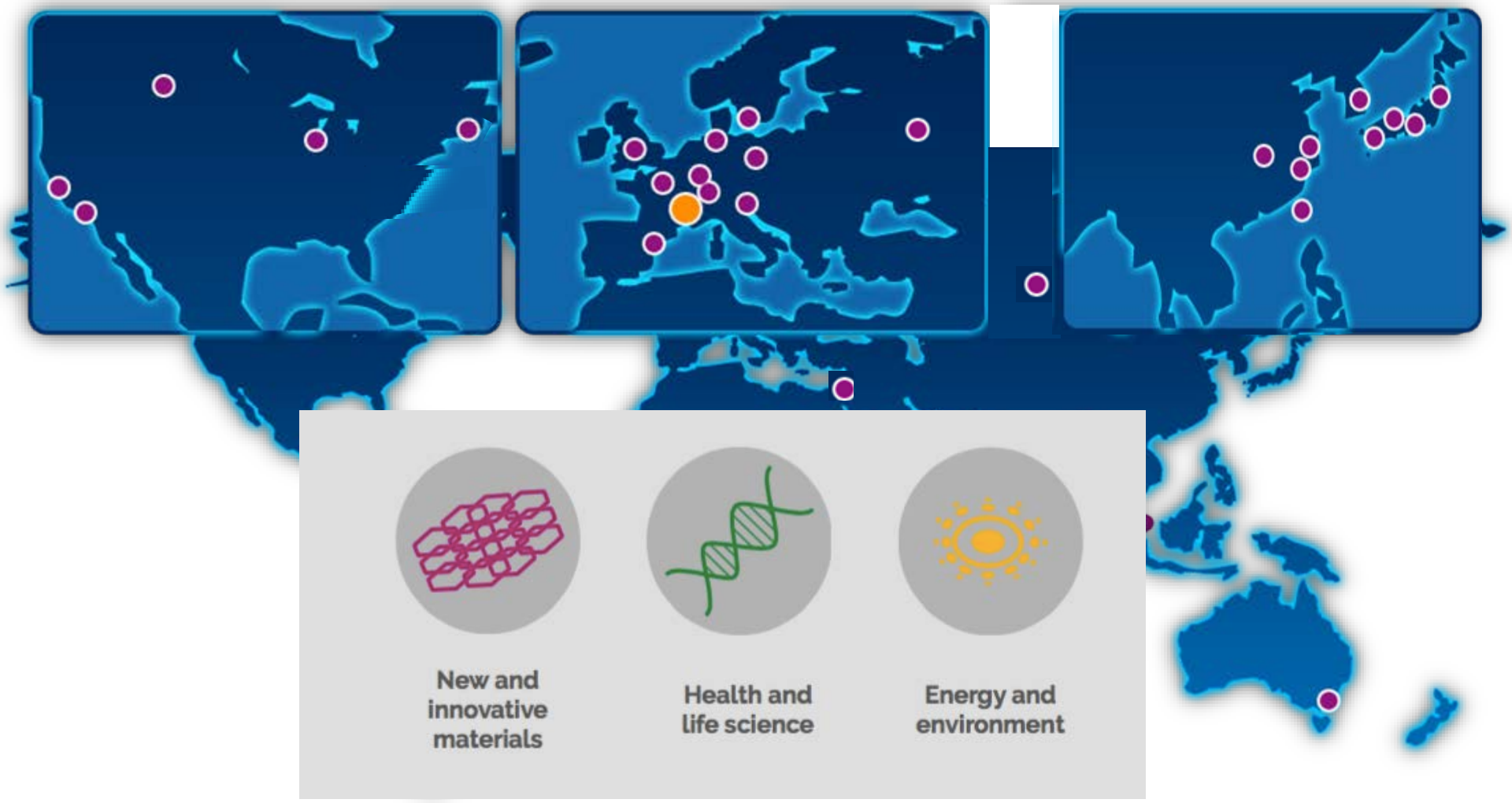
30 % of research carried out with industrial partners

4 Nobel prizes

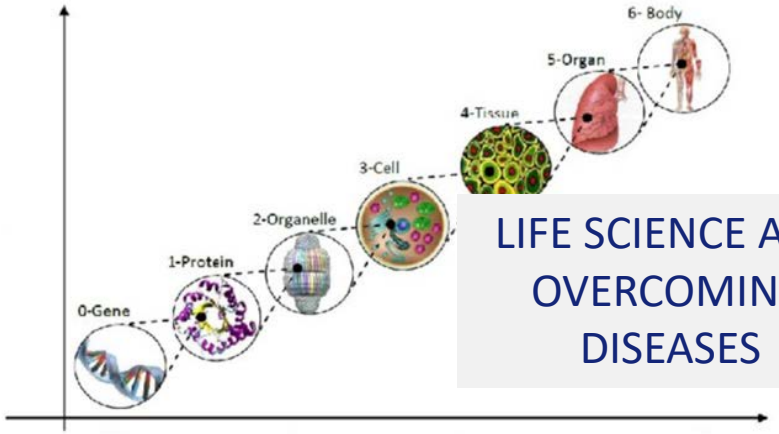
21 partner countries



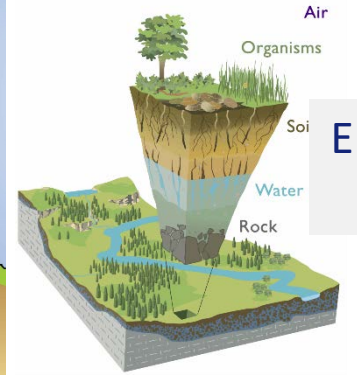
Synchrotron X-ray Science in the world and its growing User community



FUNDAMENTAL AND APPLIED SCIENCE WITH X-RAYS: UNDERSTANDING COMPLEXITY IN CONDENSED AND LIVING MATTER

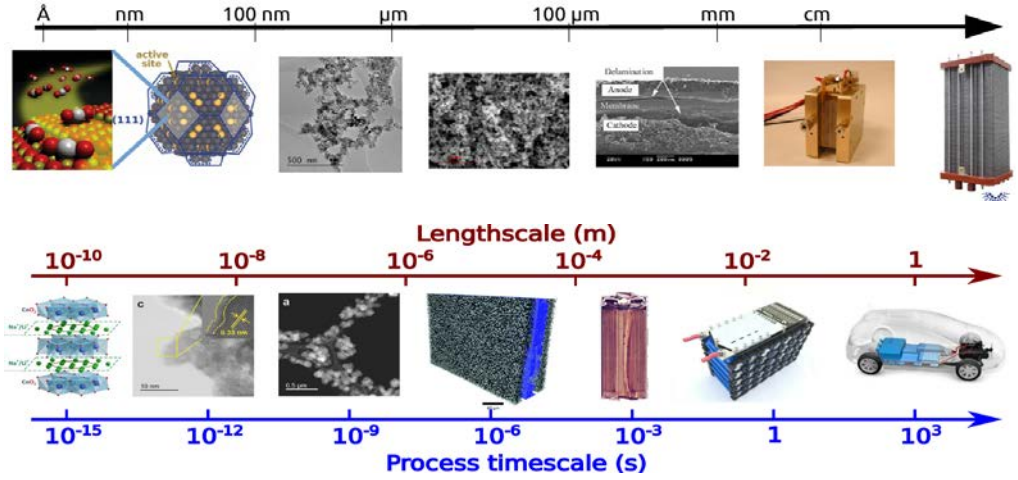


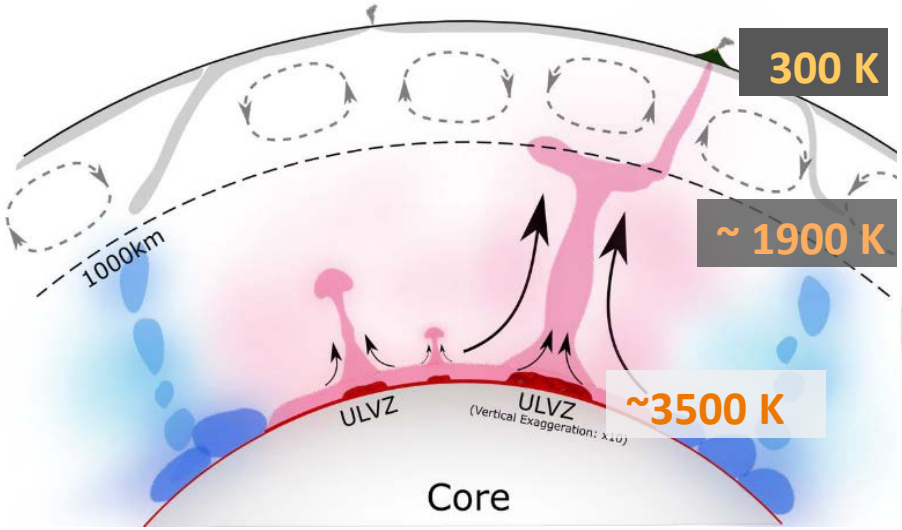
LIFE SCIENCE AND OVERCOMING DISEASES



ENVIRONMENT AND SUSTAINABILITY

MATERIALS AND PROCESSING

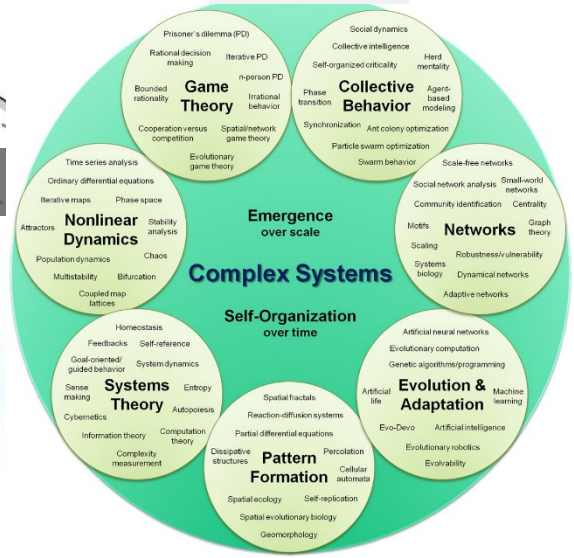




~6000 K

GEOSCIENCE

PHYSICS



ESRF-EXTREMELY BRILLIANT SOURCE: A NEW STANDARD FOR SYNCHROTRON LIGHT SOURCES

NEW PERSPECTIVES FOR SCIENCE FIRST PROMISING RESULTS

ESRF UPGRADE PROGRAMME 2009-2022

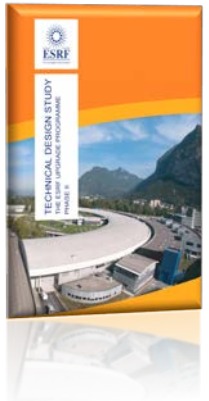
A « landmark » in the ESFRI roadmap

- Investments: 330 M€
- Staff cost: 220 M€
- **TOTAL : 550 M€**

ESRF UPGRADE: ON THE ESFRI ROADMAP SINCE ITS INCEPTION

ESRF UPGRADE PROGRAMME PHASE I (2009-2015) & PHASE II (2015-2023) – EBS

Purple Book
January 2008



Orange Book
January 2015

ESRF UPGRADE PHASE I (2009-2015) - 180 M€ :

- 19 upgraded or deeply refurbished beamlines
- Upgrade and renewal of facilities and support labs
- Study for a new storage ring

ESFRI

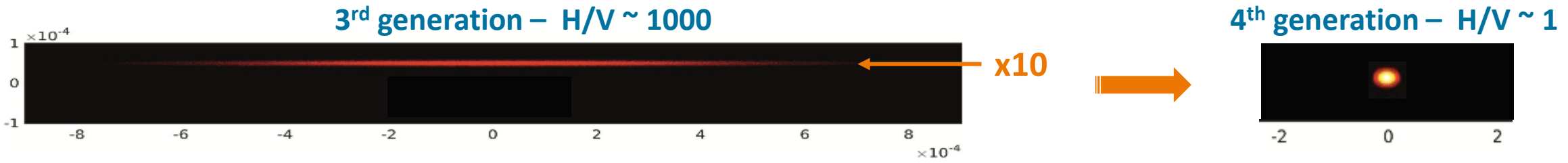
European Commission

ESRF-EBS
Extremely Brilliant Source (2015-2023) - 150 M€

- A new generation of synchrotron storage ring
- Four new EBS beamlines
- Detector and instrumentation
- Data Analysis as a Service

2009 — 2015 — 2023

ESRF UPGRADE PROGRAMME –THE QUEST FOR INCREASED BRILLIANCE AND COHERENCE



Synchrotron X-ray brilliance and coherence to the benefit of science

The objectives of the ESRF-EBS project:

- **Decrease the storage ring horizontal emittance – HMBA CONCEPT (a factor ~40 better than 3rd SR generation)**
- Increase the source brilliance (a factor ~ 100)
- Increase the coherence of the beam (a factor ~40)
- Re-use the existing infrastructure (90%)
- Minimise the impact on the ESRF activity (dark-brown time)
- Reduce environmental impact – reduce electrical power consumption by ~20%

ESRF-EBS LATTICE VS. PREVIOUS ESRF-DBA LATTICE: DBA → H7BA

➢ **Previous ESRF lattice (cell)**

Double Bend Achromat = 17 M (2 dipoles + 15 quad. sext.) per cell

ID length = 5 m (standard) / 6m / 7m

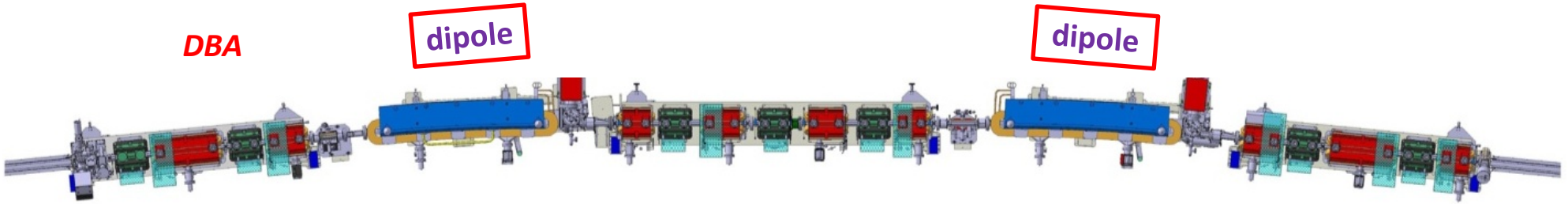
$$\varepsilon \propto \frac{E_e^2}{\left(N_{sect} \cdot N_{dipole}\right)^3}$$

➢ **EBS lattice (cell)**

Hybrid 7 Bend Achromat = 31 M (4 dipoles-lg + 3 dipole-quad + 16 quad., 6 sext., 2 oct.)

ID length = 5 m

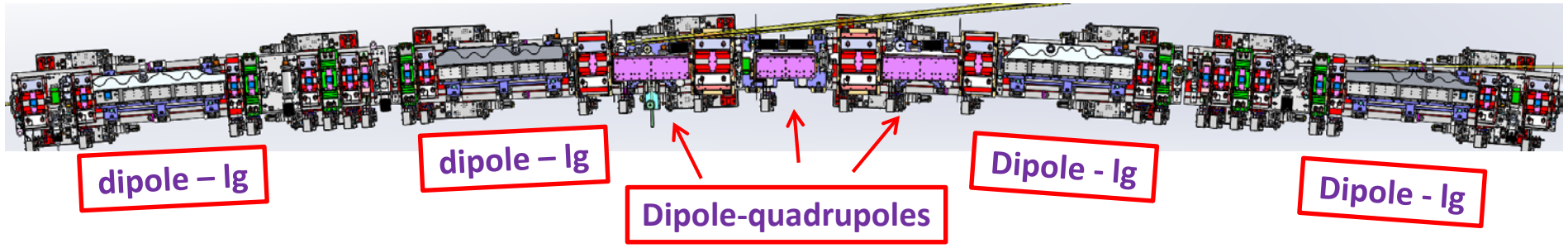
DBA



31 magnets per cell instead of 17

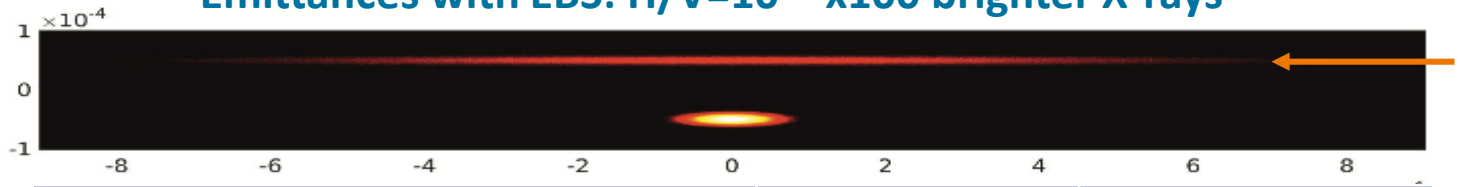
32 cells (arcs) with 4 girders each

EBS-H7BA



ESRF-EBS LATTICE VS. PREVIOUS ESRF-DBA LATTICE: DBA → H7BA

Emittances with EBS: H/V=10 – x100 brighter X-rays



x10

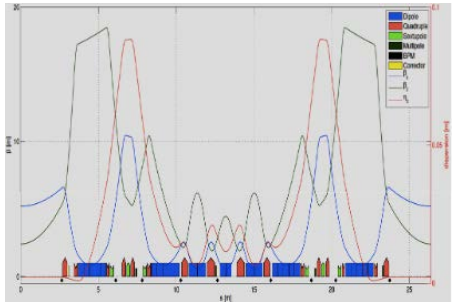
	ESRF-EBS	ESRF-3rd G
Energy [GeV]	6.04	6.04
Tunes	75.21, 26.34	36.44, 13.39
Emittance x [pmrad]	134	4000
Emittance y (target) [pmrad]	2	3
Energy loss per turn [MeV]	2.6	4.9
RF voltage (acceptance) [MV]	6 (5.6%)	9 (4%)
Chromaticity	6, 4	4, 7
Circumference [m]	843.98	844.39
Energy spread [%]	0.095	0.106
Beam current [mA]	200	200
Lattice type	HMBA	DBA
Touschek lifetime [h]	~20	~80

UPGRADE OF EXISTING STORAGE RINGS TO A NEW LOW HORIZONTAL EMITTANCE LATTICE AND AT THE SAME ENERGY IS NO LONGER A DREAM:

MANY NEW AND EXISTING FACILITIES WORLWIDE CONSIDERING AN *HMBA* BASED LATTICE

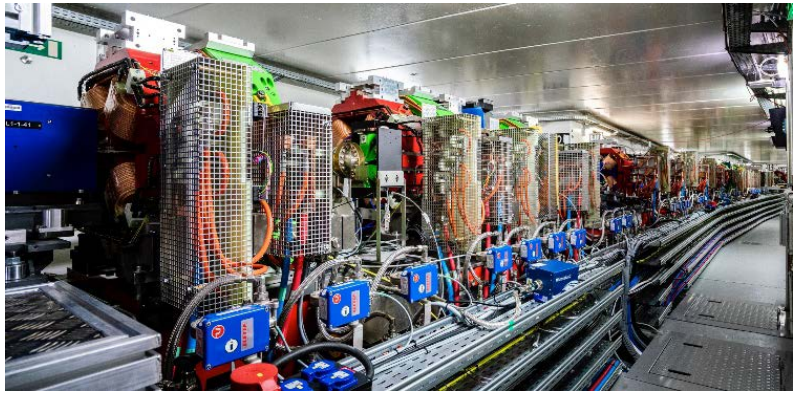
ESRF-EBS: A MACHINE DREAM BECOMES A REALITY IN 5 YEARS SINCE ITS CONCEPTION

From the idea – 2011/13

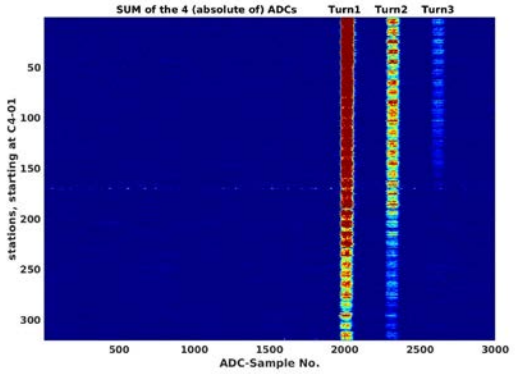


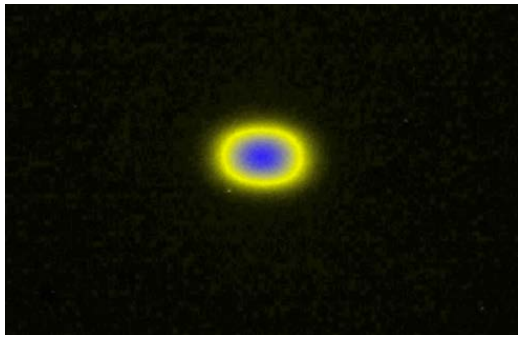
To the design – 2014/16

To the installation – 2016/19



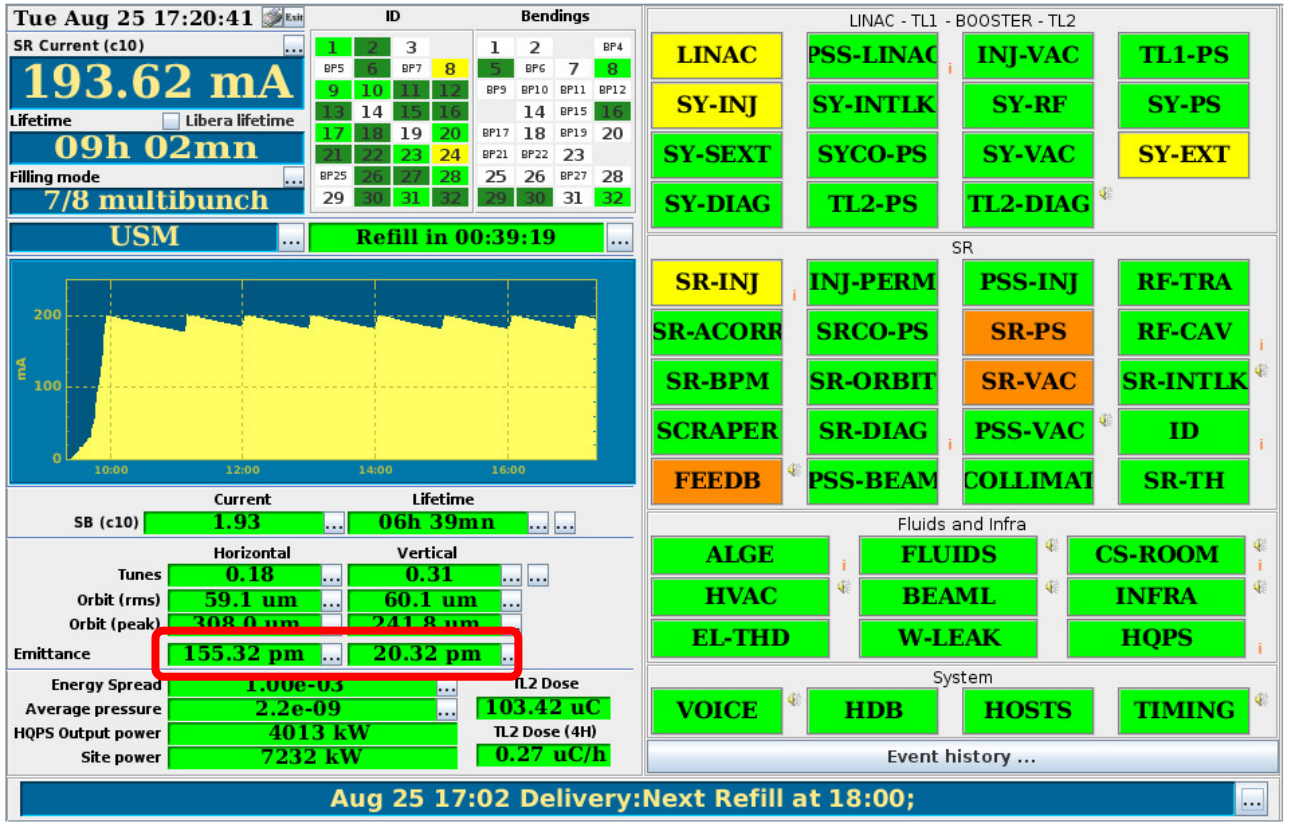
To the 1st electrons – 28-11-2019





25TH AUGUST 2020 : A TIME TO REMEMBER !

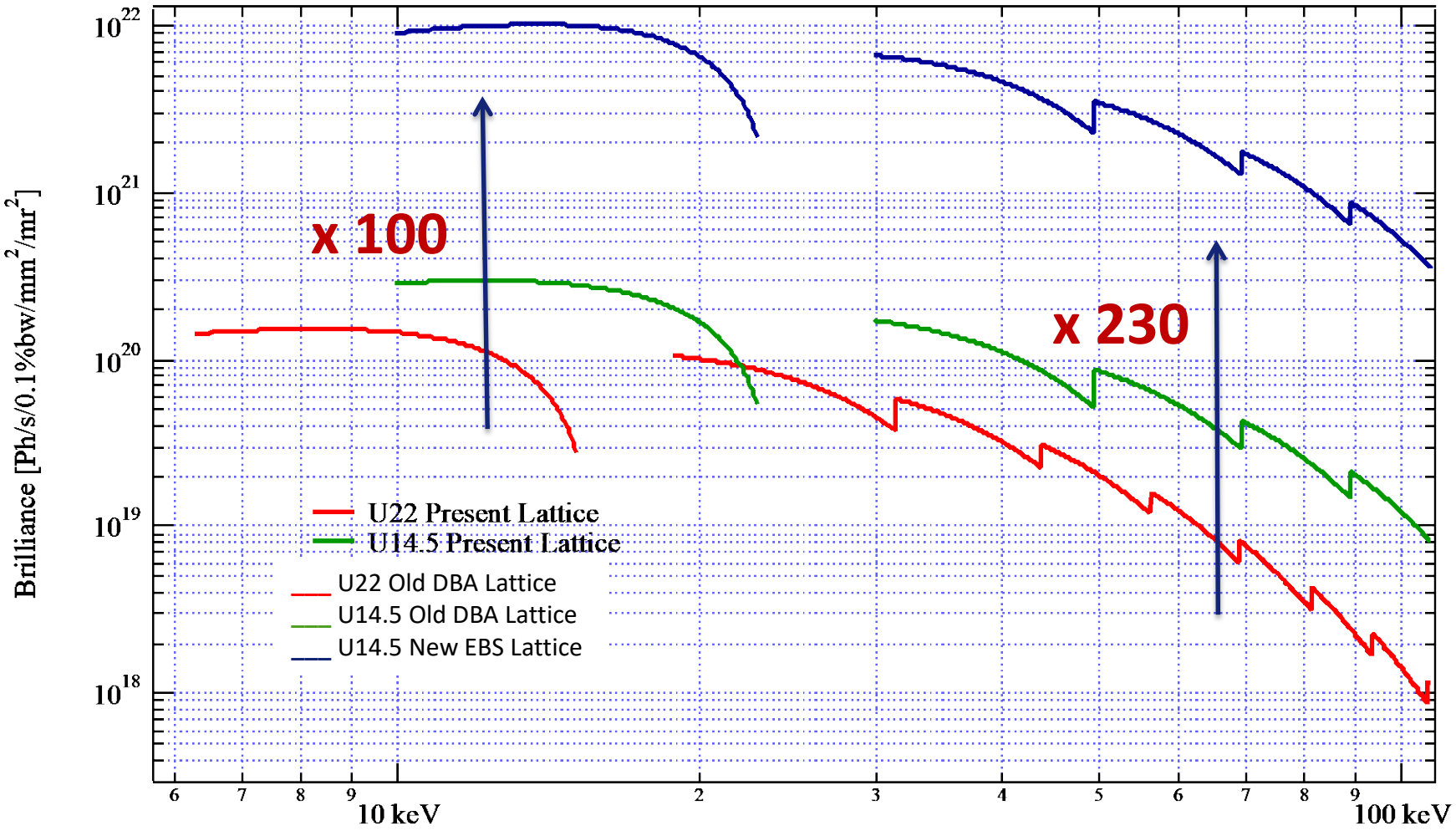
The 25th August 2020, first official USM shift starts



- 28 beamlines take beam
- 200 mA
- $\varepsilon_x = 150\ pm \cdot \mathrm{rad}$
- $\varepsilon_z = \ \ 20\ pm \cdot \mathrm{rad}$

ON TIME – WITHIN BUDGET

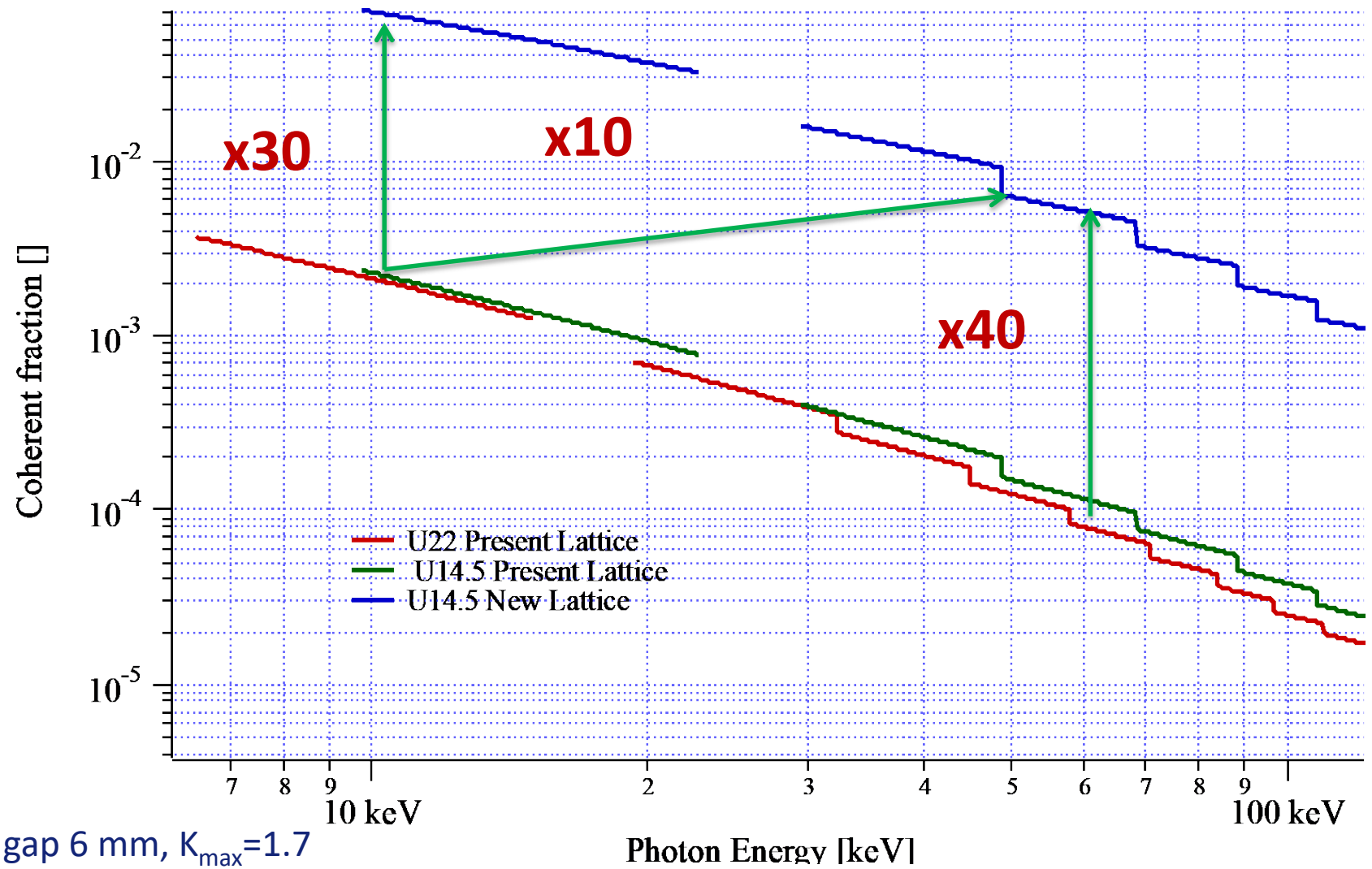
CPMUS AT SMALLER GAP: INCREASED BRILLIANCE



IVUN22 min. gap 6 mm, K_{max}=1.7

CPMU14.5 min. gap 4 mm, K_{max}=1.7

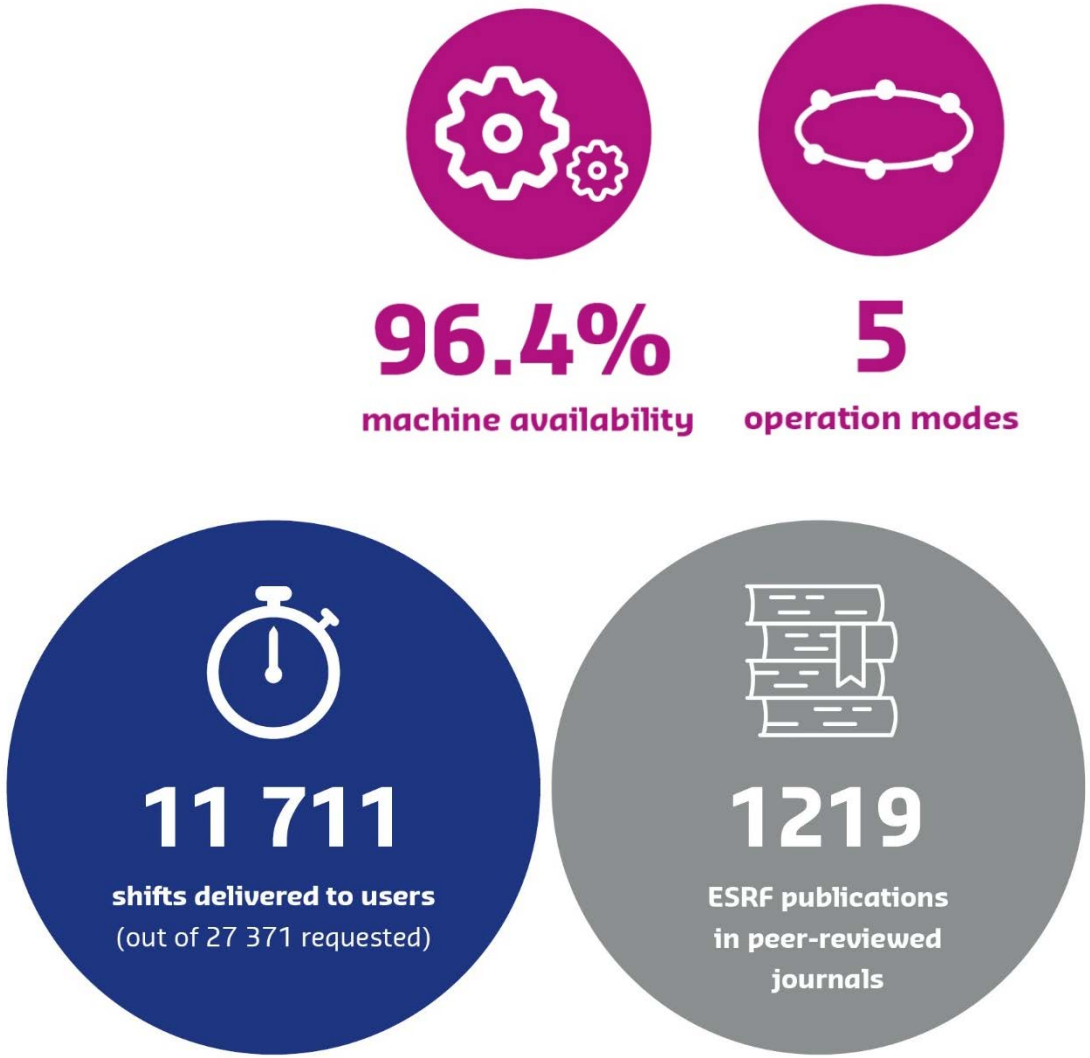
ESRF-EBS: MAIN LATTICE PARAMETERS



IVUN22 min. gap 6 mm, K_{max}=1.7

CPMU14.5 min. gap 4 mm, K_{max}=1.7

ESRF: 2021 OPERATION FIGURES



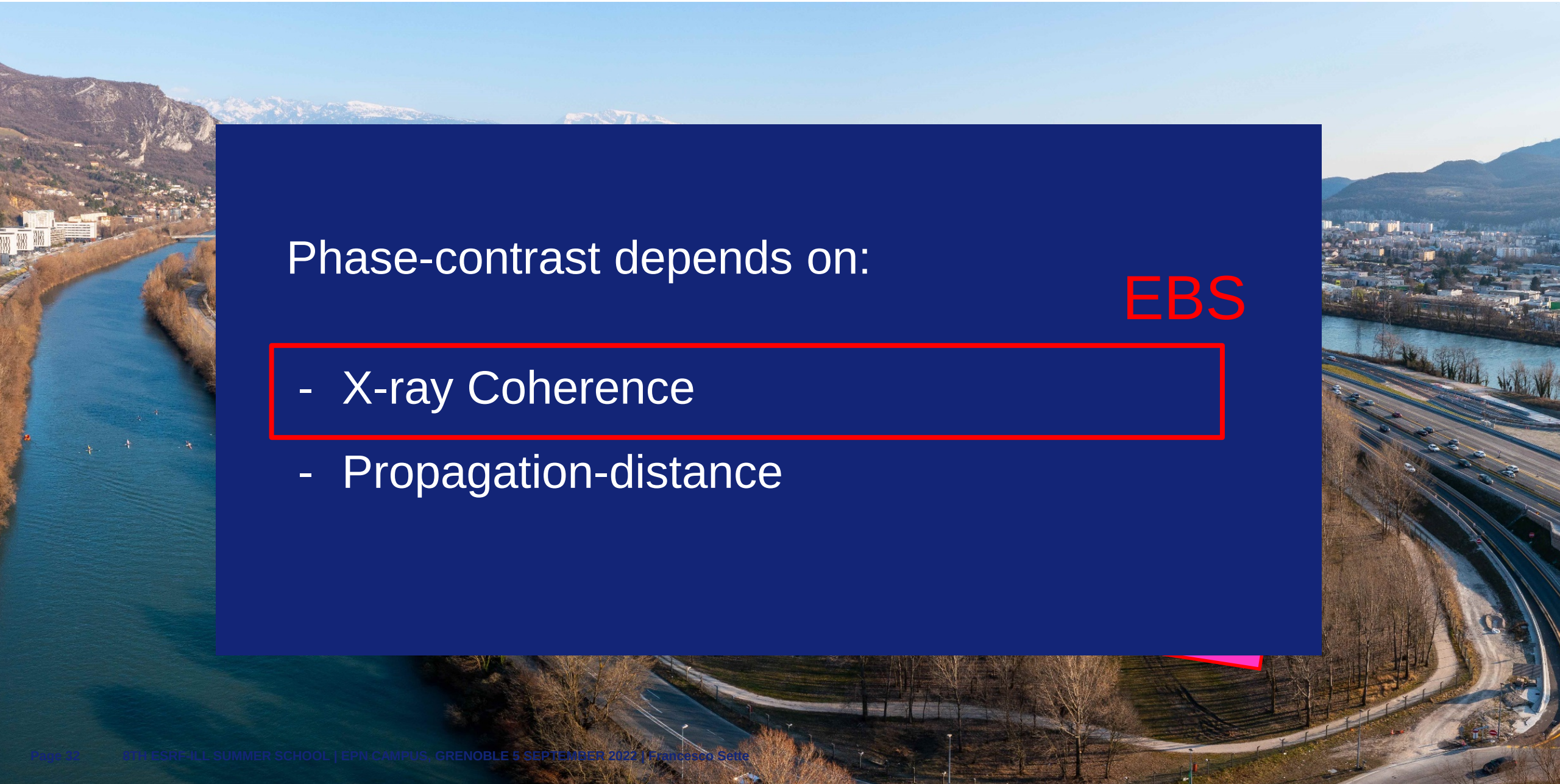
EBS SCIENCE

ESRF-EBS, AN EXTREMELY BRILLIANT SOURCE TO TACKLE GLOBAL CHALLENGES

1. **Health, Health Innovation**, overcoming diseases and pandemics
2. **Material for tomorrow,** and innovative and sustainable industry
3. **Clean Energy transition**, sustainable energy storage and clean hydrogen technologies
4. **Planetary research** (terrestrial and extra-terrestrial)
5. **Environmental and climatic challenges**,
6. **Bio-based economy and food security**
7. **Humanity and world cultural heritage**

CHANGING SCALE, FROM BM05 TO BM18

CHANGING SCALE, FROM BM05 TO BM18

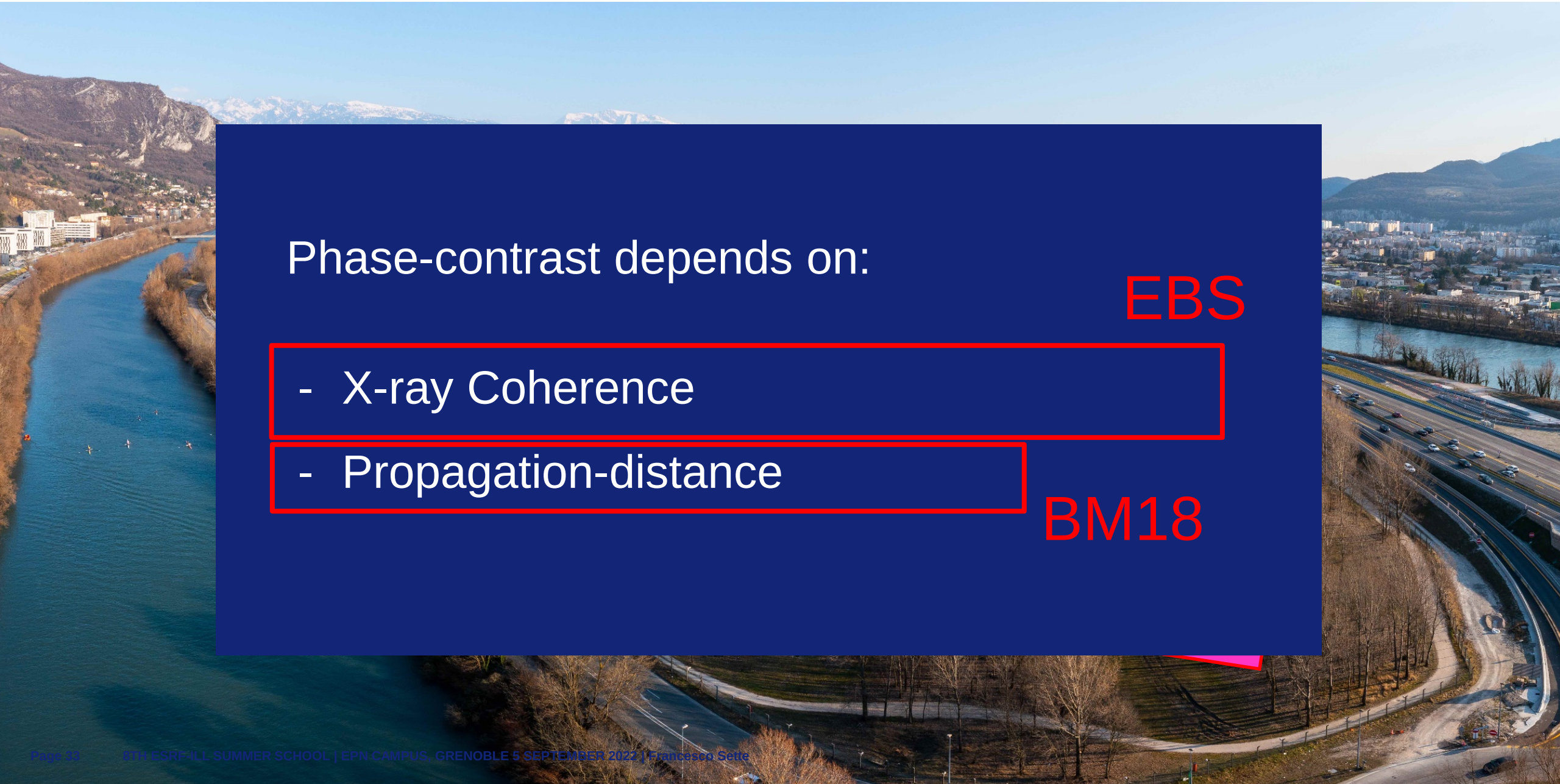


Phase-contrast depends on:

EBS

- X-ray Coherence
- Propagation-distance

CHANGING SCALE, FROM BM05 TO BM18



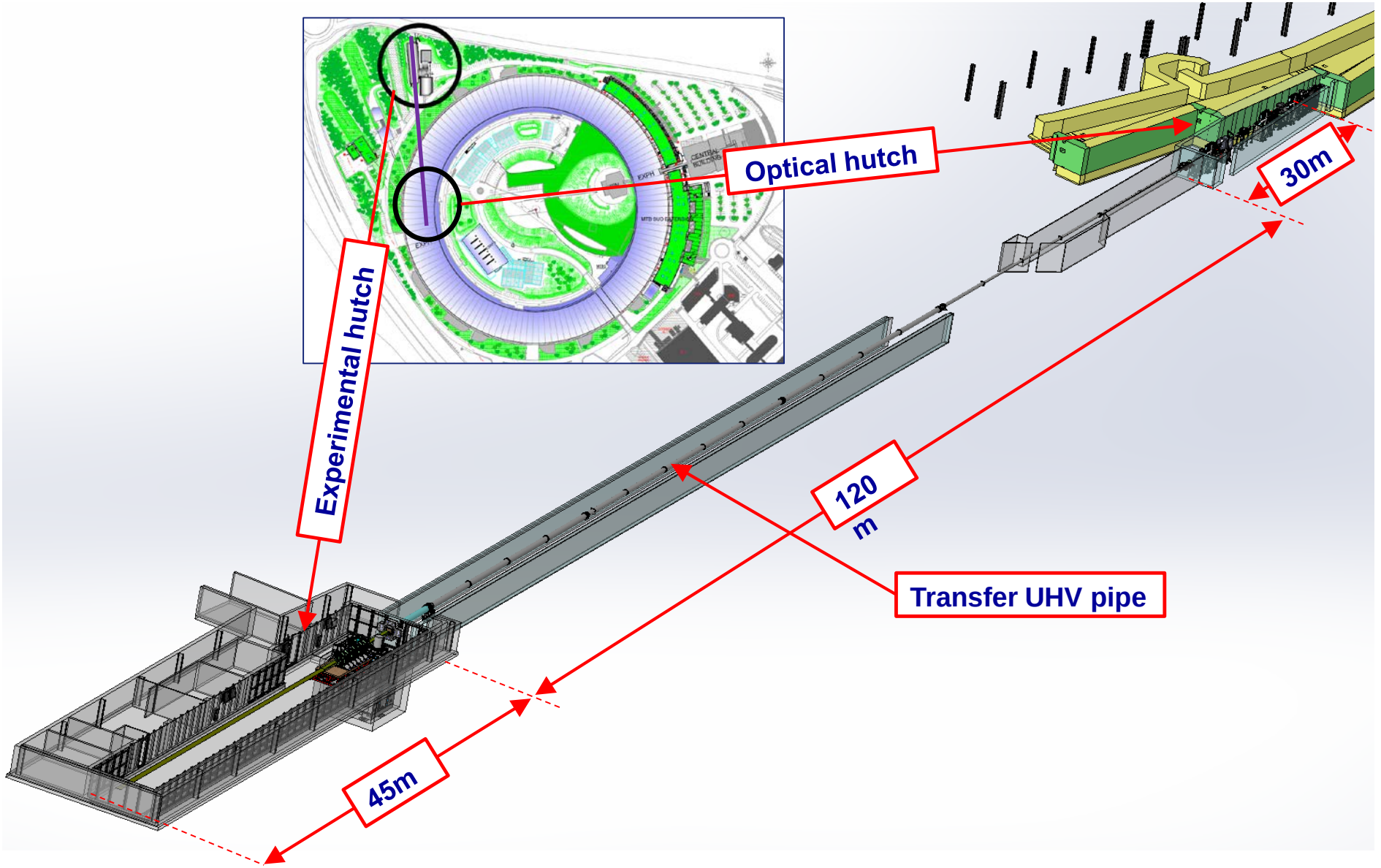
Phase-contrast depends on:

EBS

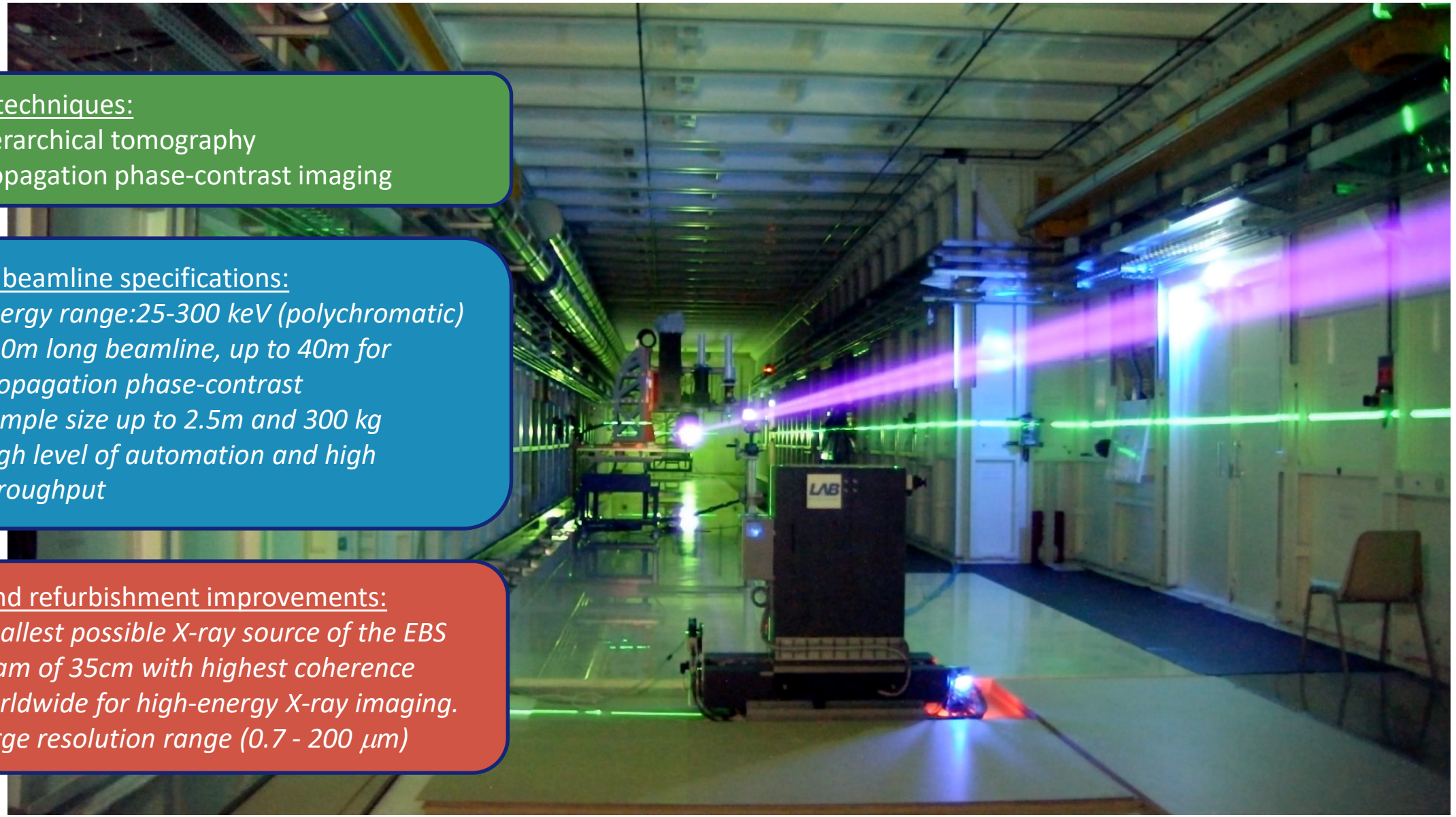
- X-ray Coherence
- Propagation-distance

BM18

EBSL3 - BM18, LARGEST HIGH-ENERGY X-RAY IMAGING BEAMLINE IN THE WORLD



EBSL3 - BM18, LARGEST HIGH-ENERGY X-RAY IMAGING BEAMLINE IN THE WORLD



Main techniques:

- Hierarchical tomography
- Propagation phase-contrast imaging

Main beamline specifications:

- *Energy range:25-300 keV (polychromatic)*
- *220m long beamline, up to 40m for propagation phase-contrast*
- *Sample size up to 2.5m and 300 kg*
- *High level of automation and high throughput*

EBS and refurbishment improvements:

- *Smallest possible X-ray source of the EBS*
- *beam of 35cm with highest coherence worldwide for high-energy X-ray imaging.*
- *Large resolution range (0.7 - 200 μm)*

BM18: HIERARCHICAL PHASE-CONTRAST TOMOGRAPHY

Biomedical imaging

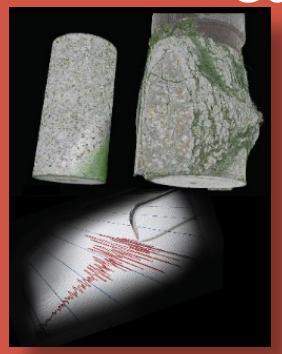
- A new scale in human body knowledge
- Understanding effects of diseases

Natural and cultural heritage

- understanding the evolution of life on earth
- Non-invasive structural study of archaeological specimens and art pieces

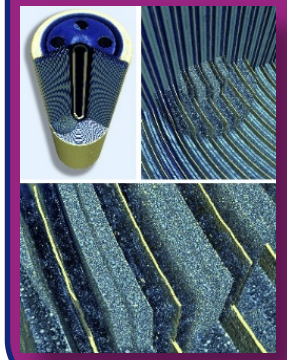
High sensitivity phase-contrast tomography in large and complex samples

Geology



- origin of earthquakes
- Mechanisms of volcanoes
- Climate change

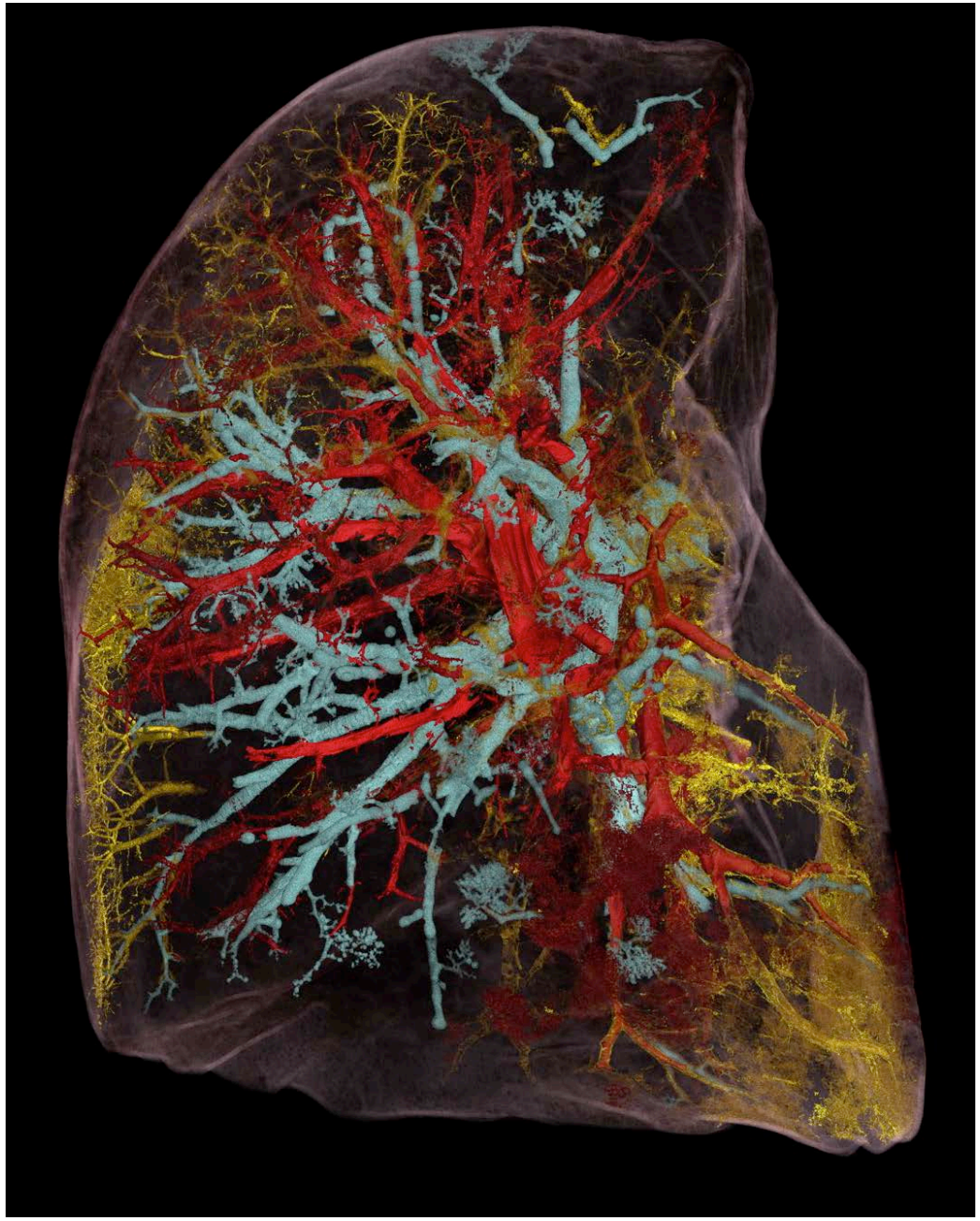
Material sciences



- Non-destructive control of large devices (batteries, complex mechanical parts)
- Additive manufacturing (in-situ and ex-situ)

Industrial applications

- Testing high-value objects
- Analysis of 3D structures of industrial products
- Industrial processes



Hierarchical imaging of complete human organs, how the EBS changed the game

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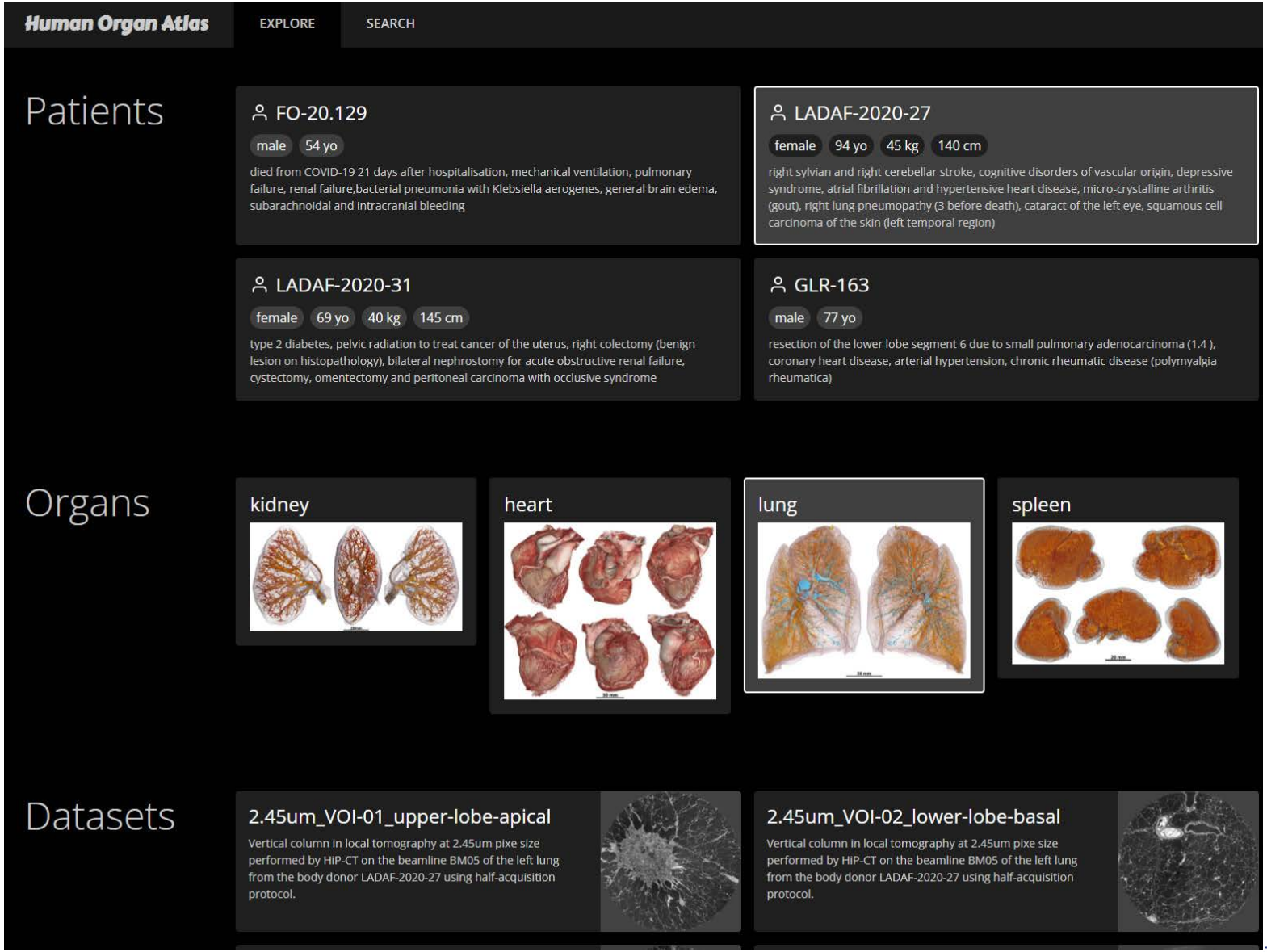
P. Tafforeau, M. Ackermann, D. Jonigk, C. Walsh, W. Wagner, C. Berruyer, E. Boller, A. Bellier, J. Brunet, M. Kuehnel, C. Werlein, J. Jacob, R. Shipley, S. Verleden *and* P. D. Lee

The Human Organ Atlas

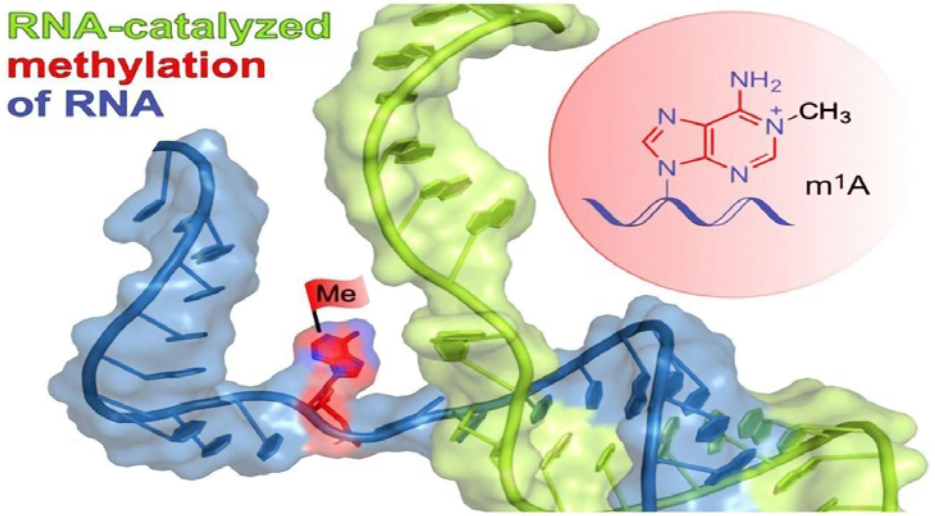
An open access database, developed as part of the EU PaNOSC project.

Published online on 4/11/2021
https://human-organ-atlas.esrf.eu/

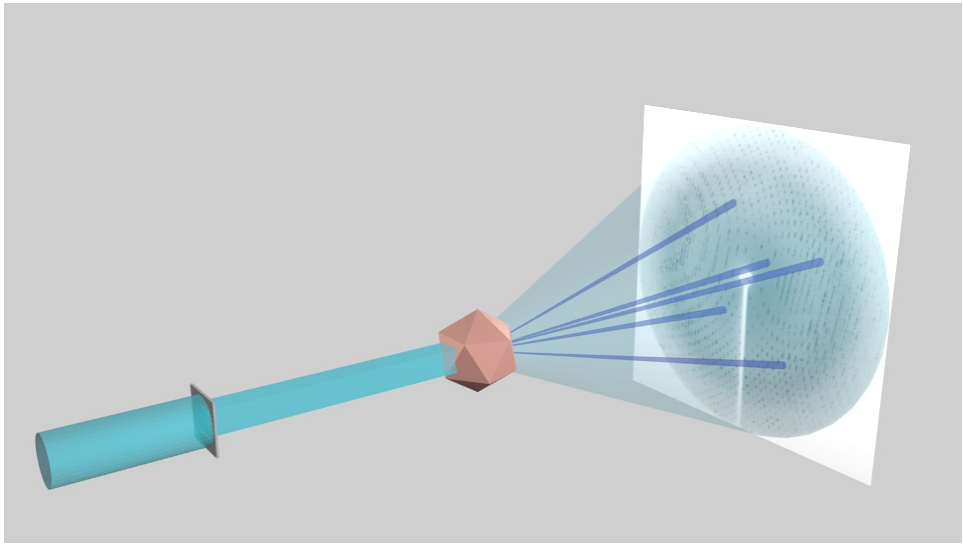
The Human Organ Atlas uses Hierarchical Phase-Contrast Tomography to span a previously poorly explored scale in the understanding of human anatomy, the micron to whole intact organ scale.



Structure and mechanism of the methyltransferase ribozyme MTR1 (methyltransferase reaction)



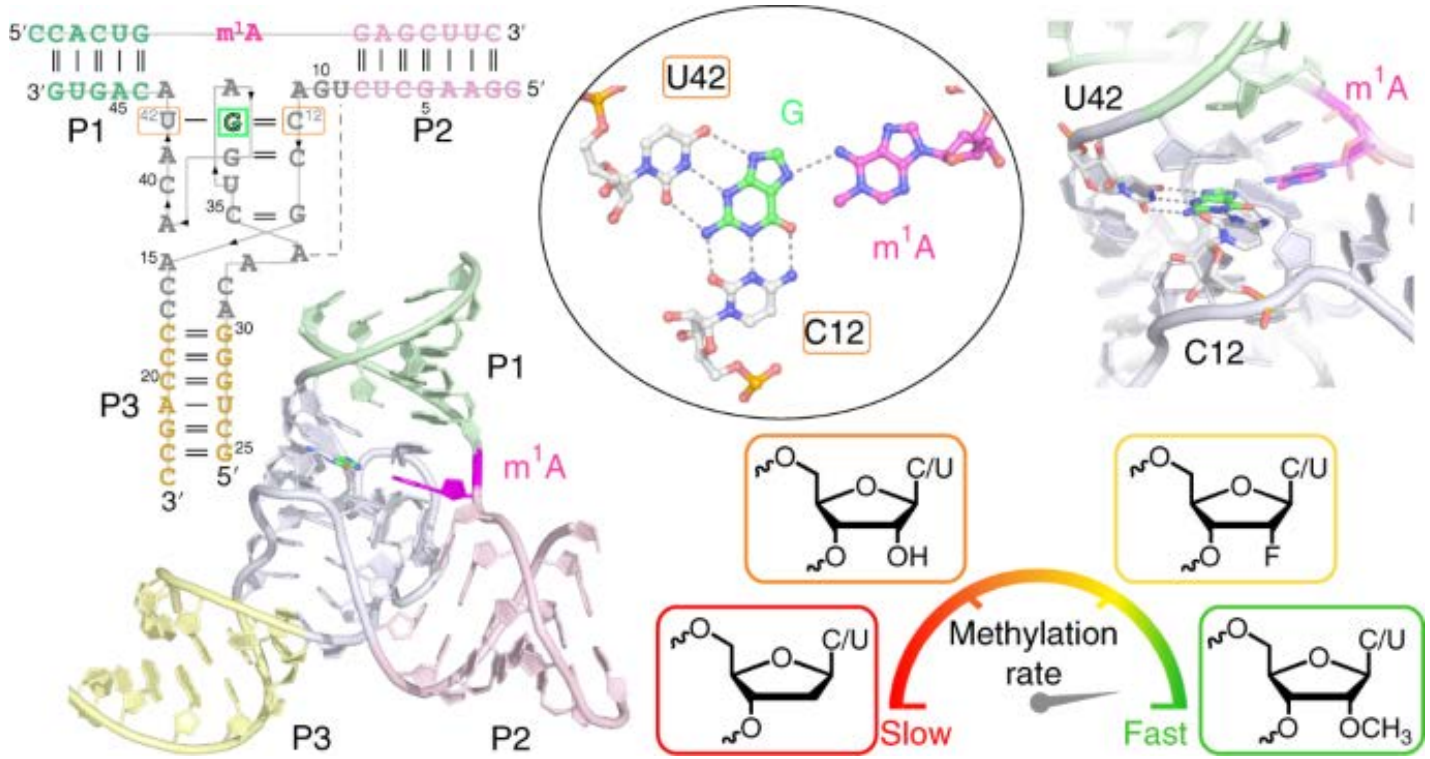
C. P. M. Scheit et al
Nature Chemical Biology 18, 547 (2022)



Open question:

How ribozymes, the RNA catalysts, can catalyze a site-specific methyl transfer in RNA?

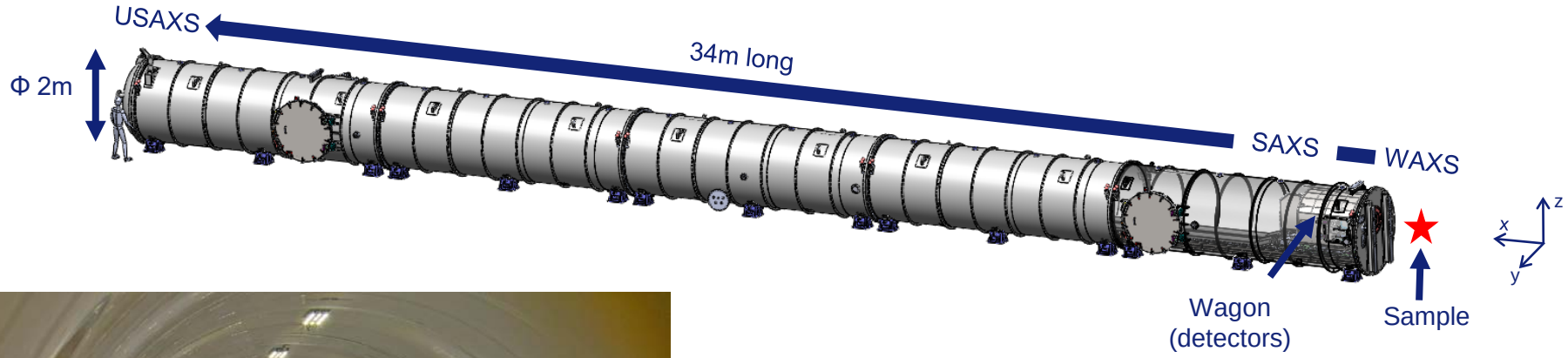
Structure and mechanism of the methyltransferase ribozyme MTR1 (methyltransferase reaction)

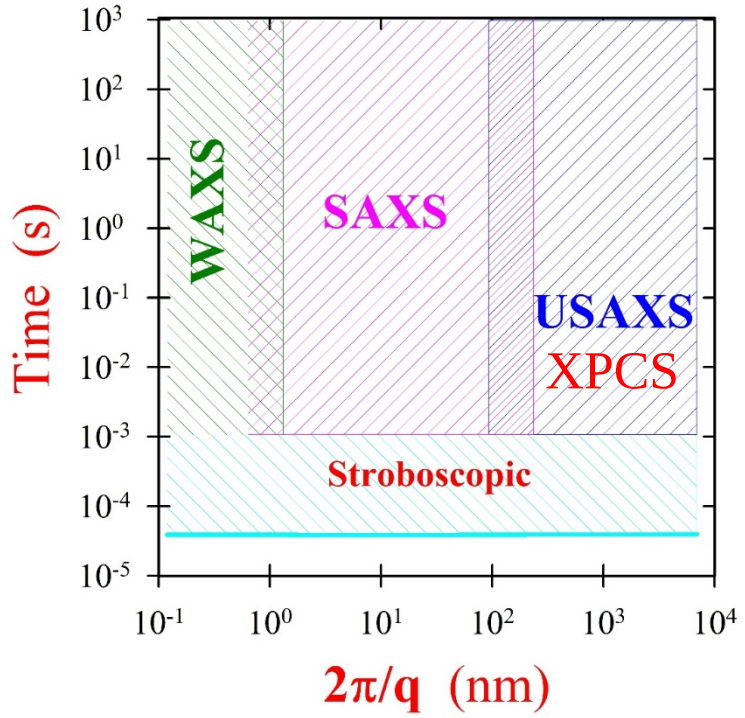


C. P. M. Scheit et al
Nature Chemical Biology
18, 547 (2022)

ID23-1 structural data at atomic resolution show that MTR1 folds in a specific way and proposes a sophisticated mechanism for the methyl transfer reaction. These studies provide further insights into the RNA world hypothesis, suggesting that life on Earth began with RNA molecules

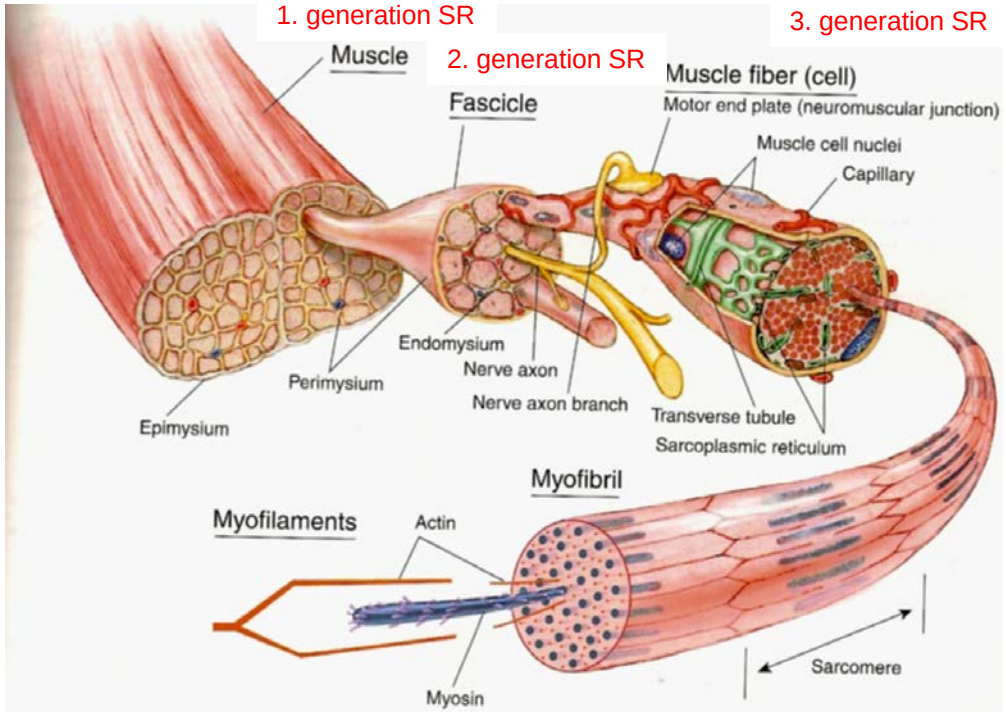
ID02:TIME-RESOLVED ULTRA SAXS BEAMLINE

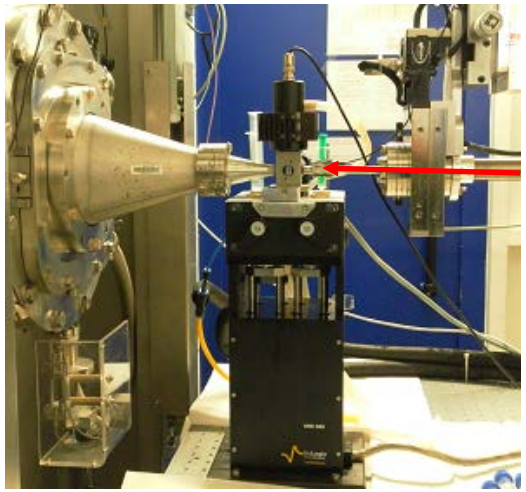


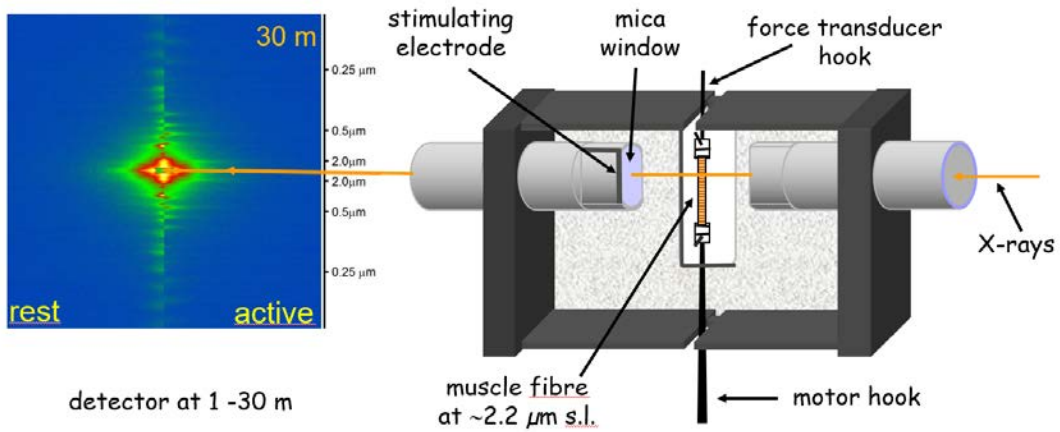


High flux: 10^{14} photons/sec
Time resolution: ~ 100 ms
q – range: 10^{-3} – 50 nm^{-1}
Δq: $2x10^{-4}$ nm^{-1} (FWHM)

HIERARCHICAL STRUCTURE OF MUSCLE





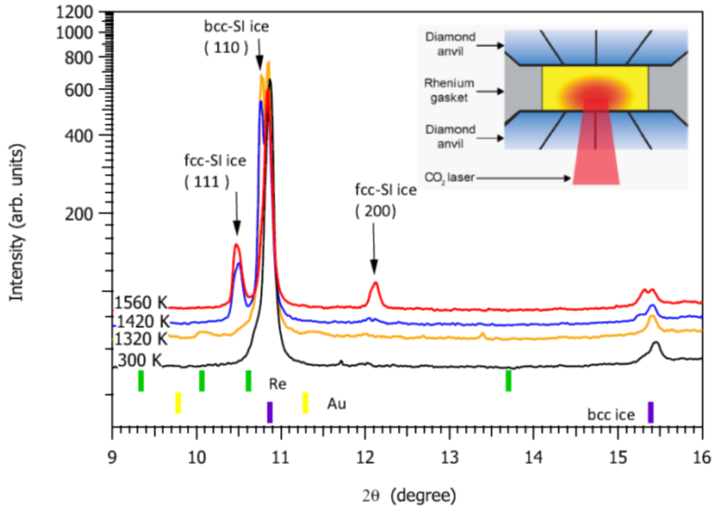


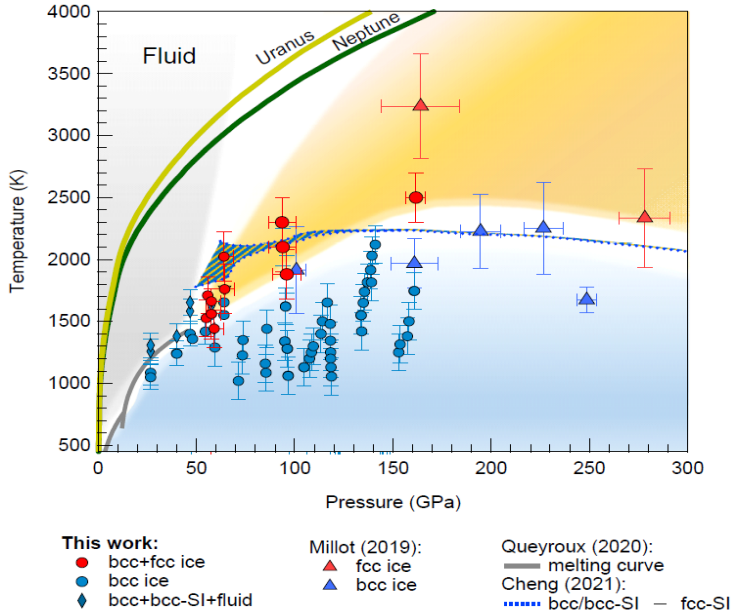
Much smaller specimen, applying physiological protocols, addressing clinically relevant questions, etc.

Close the current knowledge gap in cardiac muscle regulation
Gain deeper insights into the molecular basis of cardiomyopathies

Observing of hot dense superionic water

Could influence the magnetic field of Neptune-like planets





Open question:

What are the phases of warm dense ice present
in the planetary interiors of Uranus, Neptune and other giant icy exoplanets ?

Predictions: superionic (SI) state - hydrogen atoms migrate through the oxygen crystal as in a fluid

HP, HT XRD → reveal superionic ice could occupy a large part of the interior of the planets Uranus and Neptune

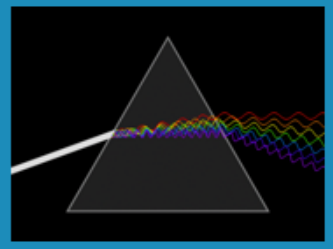
Weck et al. Phys. Rev. Lett. 128, 165701 (2022)

EBSL1 – ID18: COHERENT X-RAYS DYNAMICS AND IMAGING

Dynamics of glassy state

- How do glasses age ?
- How do glasses rearrange ?

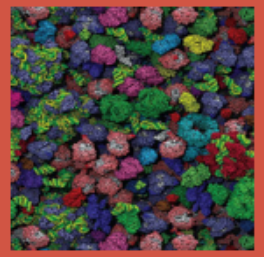
Physics of light



- Investigating fundamental quantum & non-linear optics processes (SHG, DFG)

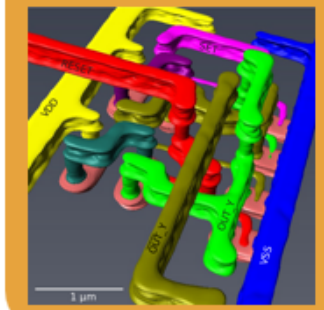
Mesoscale Structure and Dynamics

Dynamics in crowded systems



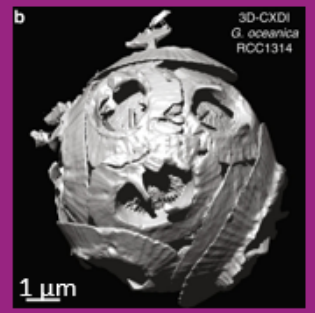
- How proteins move in crowded environment (e.g. cells) ?

High resolution 3D imaging



- How systems are organized in the mesoscale ?
- How manufacturing at sub micron can be optimized ?

Bioimaging

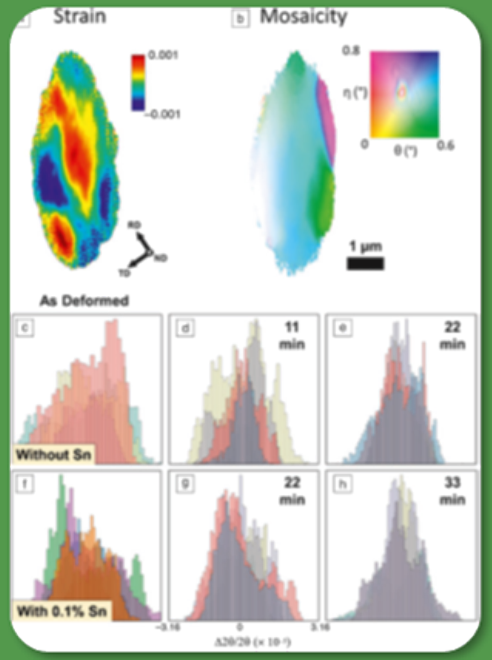


- Growth of mesoscale structures
- How are building blocks of life connected ?

EBSL2 – ID03: BEAMLINE FOR HARD X-RAY MICROSCOPY

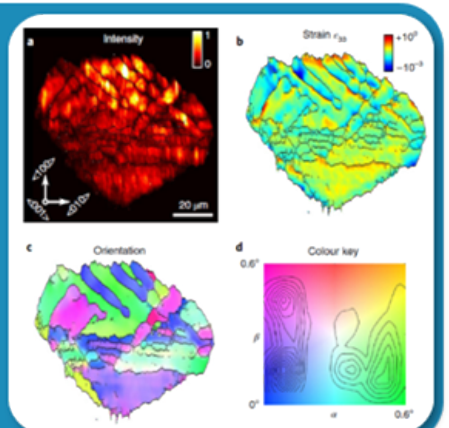
Metallurgy

- Pattern formation
- Materials fatigue
- Recovery and recrystallization



Functional materials

- Strain at grain boundaries
- Formation of domain patterns
- Dynamics of domain switching



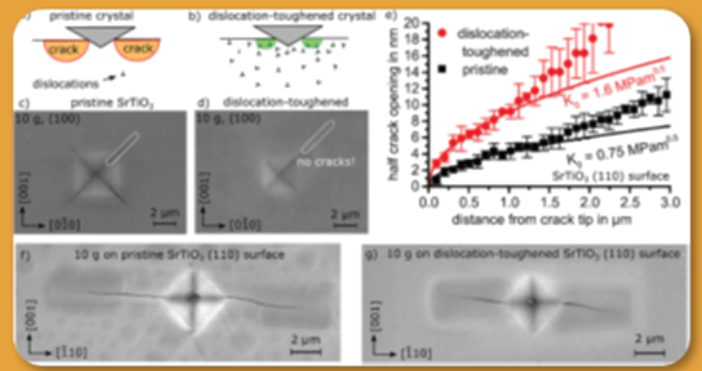
3D strain maps with 100 nm spatial resolution

Biominerals

- Microstructure

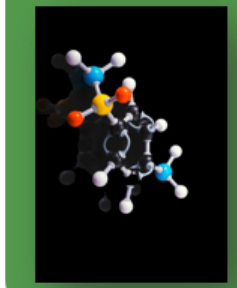
Ceramics

- Dislocation-toughening
- Nano-twinning



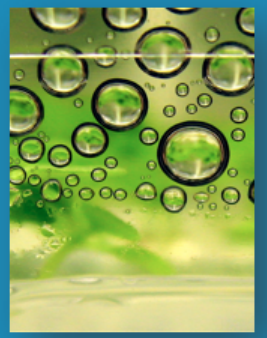
EBSL8 – ID29: SERIAL MACROMOLECULAR CRYSTALLOGRAPHY

Drug design



- Exploit room temperature fragment screening
- Identify time dependent structure: ligand complexes

Biofuel



- Characterize and optimize biochemical processes for production new carburants
- Exploit novel sources for bioenergies

Serial and Time resolved Crystallography

Enzymology

- Study enzymatic reaction in crystals
- Enzyme design and repurposing by synthetic biology

Photobiology

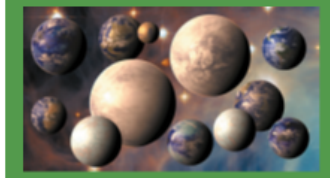
- Study light activatable biological processes
- Investigate light dependent biochemical reaction

Bioremediation

- Study and engineering of macromolecular complexes involved in bioremediation
- Develop enzymatic processes for plastic waste treatment

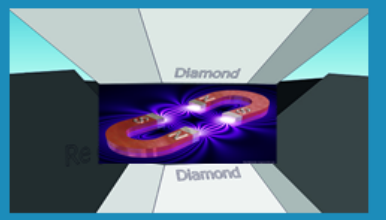
ID14 (ID18): NUCLEAR RESONANCE SCATTERING

Geoscience and Exoplanets



- Identification of chemical phases
- Electronic and magnetic transitions
- Sound velocities, elastic moduli, thermodynamics and heat conductivity

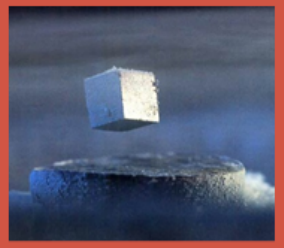
Magnetism at Megabars



- Magnetic states
- Magnetic transitions
- Transition from ferromagnetism to superconductivity

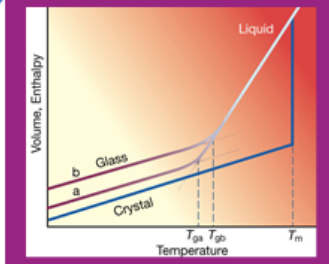
Electronic properties, magnetism and atomic dynamics at extreme conditions

Superconductivity



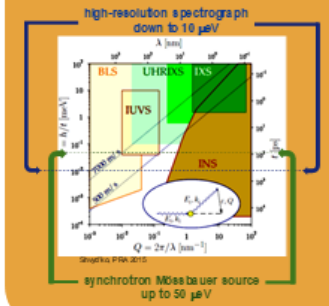
- Superconductivity at high pressure
- Visualization of the vortex structure

Glass transition



- Dynamical heterogeneities
- Time and length scale

No-man's land



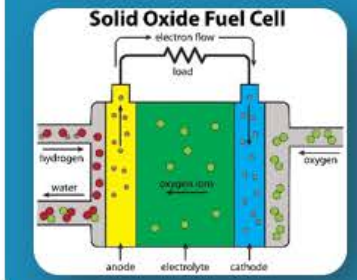
- Entering "No-man's land" between meV and neV energy transfer
- Anharmonicity, phonon life-time

ID21: X-RAY MICROSCOPY BEAMLINE

Cultural Heritage

- What are the masters' secrets?
- Why and how do artworks degrade?

Manufactured materials



- Efficiency and stability of manufactured materials
- Chemical reactions at boundaries in electrodes, catalysts and micro-electronics

Identification and location of chemical markers in complex materials

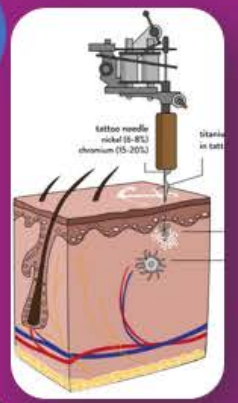
Environmental science

- Positive and negative impacts of materials in the environment
- Metal accumulation in plants

Earth and planetary sciences

- Chemical signature (element composition, trace elements, speciation) of geological processes
- Paleoclimate

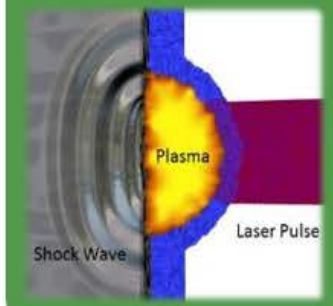
Health



- Interactions of manufactured materials (drugs, implants, tattoos, etc.) with living systems
- Chemical modifications induced by neuro-degenerative diseases

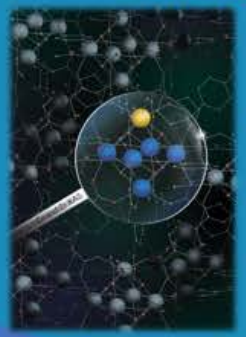
ID24 – ED: HIGH POWER LASER FACILITY

Laser shock science



- Warm Dense Matter
- Planets and Inertial Confinement Fusion
- Dynamic behavior of matter

Structure of novel materials



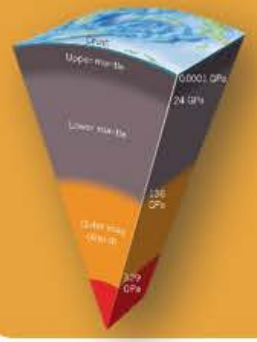
- Batteries and fuel cells
- Nanoparticles
- Gas sensors and separators
- Drugs

Physics and chemistry of complex materials under relevant conditions

Environmental science

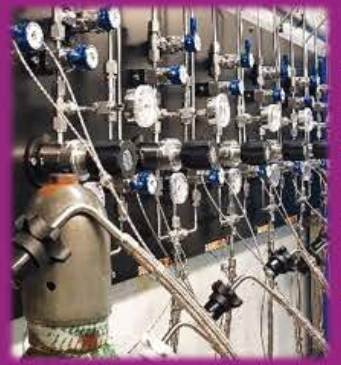
- Geo-resources
- Biogeochemical processes
- Impact of human activity on our environment

Matter at extremes



- Planetary interiors
- Condensed matter physics
- Material sciences
- Materials under high pulsed magnetic field

In-situ and *operando* chemistry



- Catalysis
- Synthesis
- Electrochemistry
- Photochemistry

ID27: HIGH FLUX NANO-XRD BEAMLINE FOR SCIENCE UNDER EXTREME CONDITIONS

High Density Physics

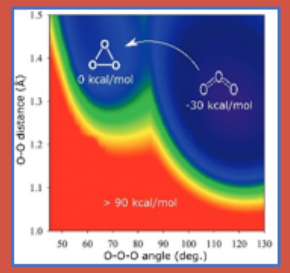
- Search for room temperature superconductivity
- Structure of metallic hydrogen

Materials under Extreme P&T

- Synthesis of superhard materials
- Materials under high stress

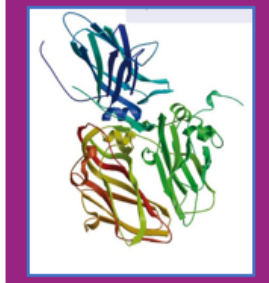
In situ studies of materials subjected to extreme P,T conditions

High Pressure Chemistry



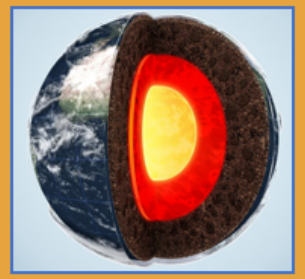
- Emergence of structural complexity
- New high pressure compounds

Soft and biological matter under pressure



- Polymerization
- Protein conformation

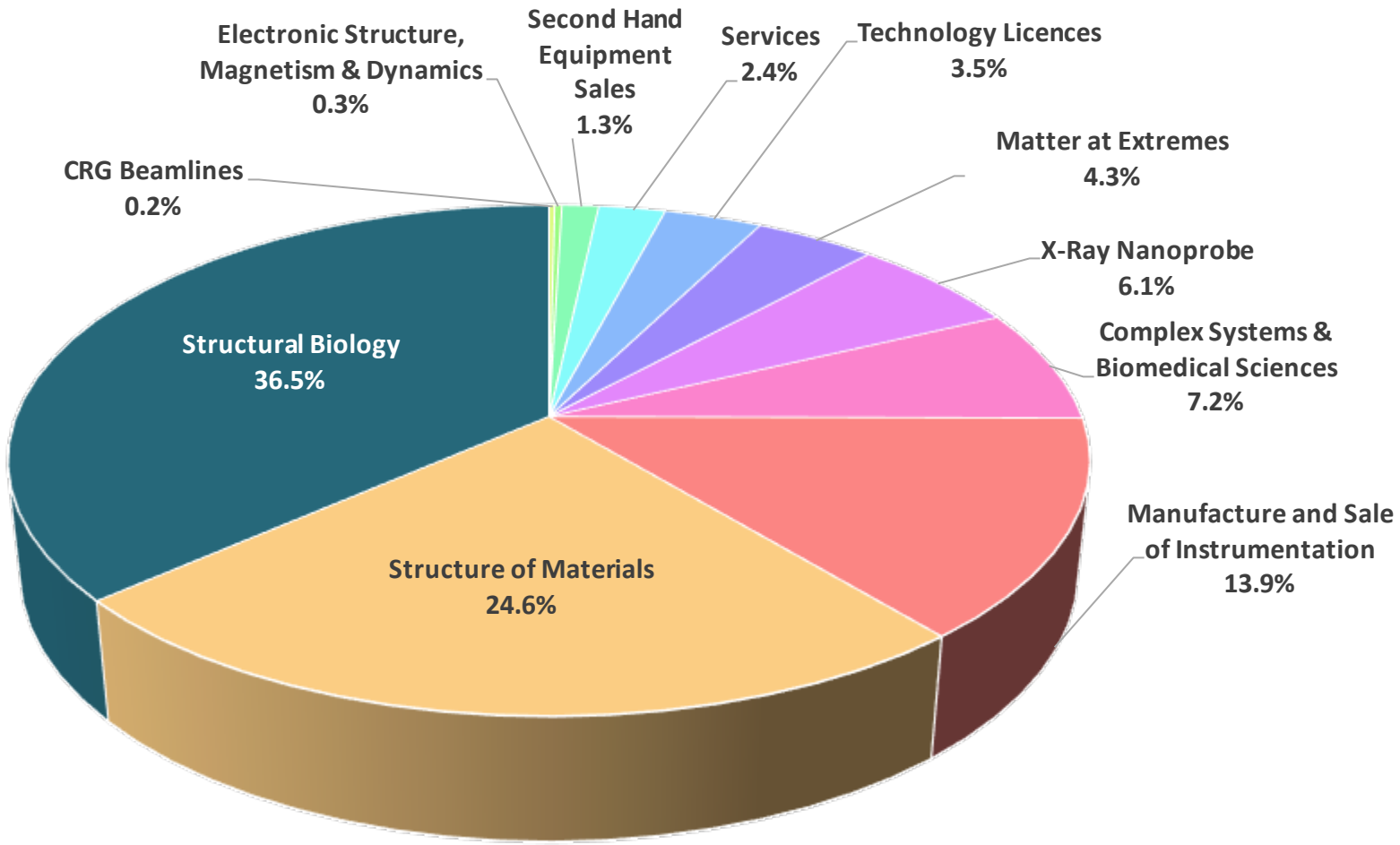
Earth and planetary sciences



- Structure and dynamics of deep Earth materials
- Understanding large scale geological phenomena (volcanism, plate tectonics)

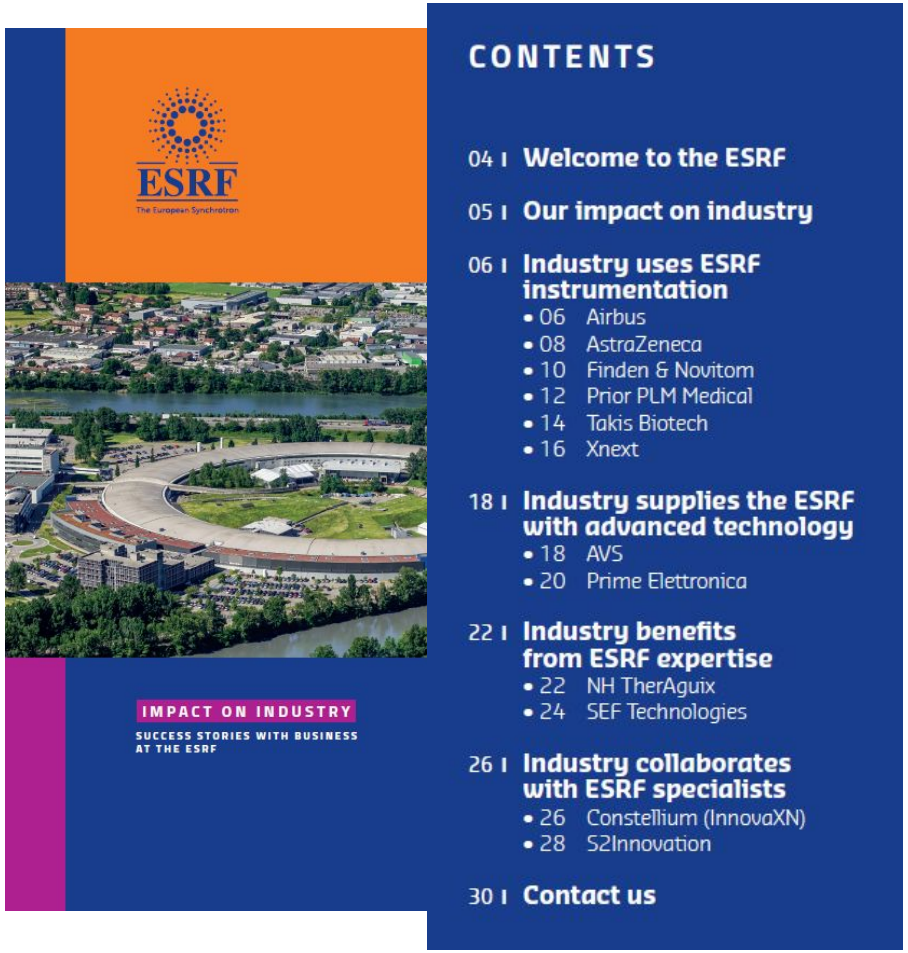
2022 Commercial AND INDUSTRIAL ACTIVITIES (2022)

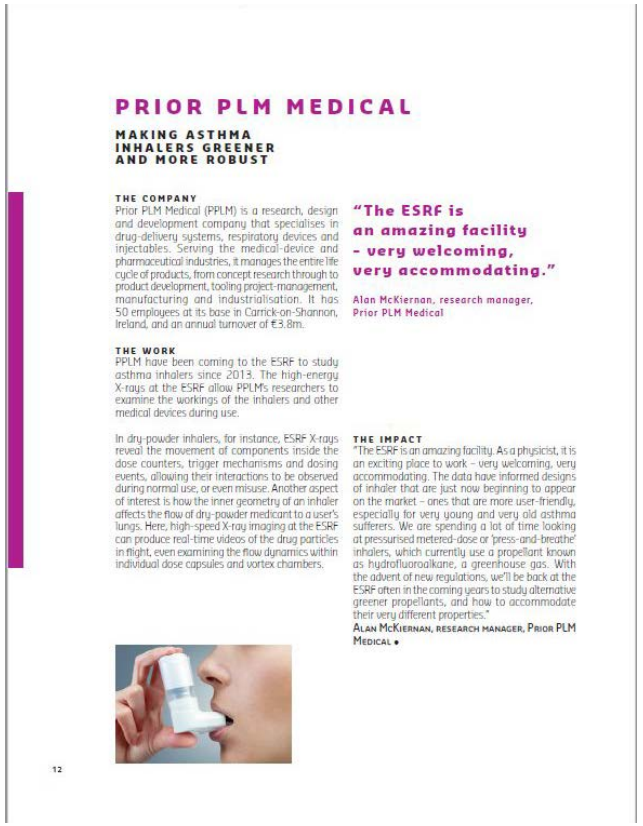
**Committed = orders received for work till year end*



EBS OPERATION: INDUSTRY IMPACT BROCHURE – 12 STORIES WITH INDUSTRY

- Stories with industry as a facility user, technology user/provider and collaborator
- PDF available on Zenodo: https://doi.org/10.5281/zenodo.5770307
- Print copies available





PRIOR PLM MEDICAL

MAKING ASTHMA INHALERS GREENER AND MORE ROBUST

THE COMPANY

Prior PLM Medical (PPLM) is a research, design and development company that specialises in drug-delivery systems, respiratory devices and injectables. Serving the medical-device and pharmaceutical industries, it manages the entire life cycle of products, from concept research through to product development, tooling project-management, manufacturing and industrialisation. It has 50 employees at its base in Carrick-on-Shannon, Ireland, and an annual turnover of €3.8m.

"The ESRF is an amazing facility – very welcoming, very accommodating."

Alan McKiernan, research manager, Prior PLM Medical

THE WORK

PPLM have been coming to the ESRF to study asthma inhalers since 2013. The high-energy X-rays at the ESRF allow PPLM's researchers to examine the workings of the inhalers and other medical devices during use.

In dry-powder inhalers, for instance, ESRF X-rays reveal the movement of components inside the dose counters, trigger mechanisms and dosing events, allowing their interactions to be observed during normal use, or even misuse. Another aspect of interest is how the inner geometry of an inhaler affects the flow of dry-powder medicant to a user's lungs. Here, high-speed X-ray imaging at the ESRF can produce real-time videos of the drug particles in flight, even examining the flow dynamics within individual dose capsules and vortex chambers.

THE IMPACT

"The ESRF is an amazing facility. As a physicist, it is an exciting place to work – very welcoming, very accommodating. The data have informed designs of inhaler that are just now beginning to appear on the market – ones that are more user-friendly, especially for very young and very old asthma sufferers. We are spending a lot of time looking at pressurised metered-dose or 'press-and-breathe' inhalers, which currently use a propellant known as hydrofluoroalkane, a greenhouse gas. With the advent of new regulations, we'll be back at the ESRF often in the coming years to study alternative greener propellants, and how to accommodate their very different properties."

Alan McKiernan, research manager, Prior PLM Medical •

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SEF TECHNOLOGIES

ELECTROMAGNETS, FROM MANUFACTURE TO TESTING

THE COMPANY

For 40 years, SEF Technologies has been manufacturing electromagnets for particle accelerators such as CERN, SOLEIL and the ESRF. Electromagnets are fundamental components of these big-science facilities, used to steer and focus particle beams. Based in Toulouse, France, the company has 15 employees and an annual turnover of €1.1m.

"Our purchase of the ESRF's SWM bench was a strategic decision. Our investment has already paid off!"

Eric Fanio, CEO, SEF Technologies

THE WORK

Historically, SEF has been a supplier to the ESRF: it provided electromagnets for the synchrotron's original storage ring, as well as for the synchrotron's new storage ring, the Extremely Brilliant Source (EBS). As is common in these cases, the ESRF performed its own testing of the magnets to make sure they conformed to design specifications and to make adjustments as necessary. For the EBS upgrade, the ESRF developed its own magnet testing benches, based on the latest "stretched-wire measurement" (SWM) technology.

On completion of the EBS upgrade, SEF switched from being a supplier to an ESRF customer by arranging to buy one of these testing benches. At about 10% of its annual turnover, the purchase has been a significant investment for the small company. However, it has already enabled SEF to offer magnet testing as an additional service to its clients.

THE IMPACT

"Our purchase of the ESRF's SWM bench was a strategic decision. Several of our larger competitors already offer magnetic measurement as a service. The new bench is helping us transition from being a pure manufacturing company to a more integrated-technology company that can model, design and measure magnets, as well as build them. Meanwhile, it is good for our clients because they will be getting pre-characterised magnets and will no longer have the expense of doing this kind of testing in-house. Recently, we won a call for tender on the basis that we could test as well as supply the electromagnets. As a result, the investment has already paid off!"

Eric Fanio, CEO, SEF Technologies •

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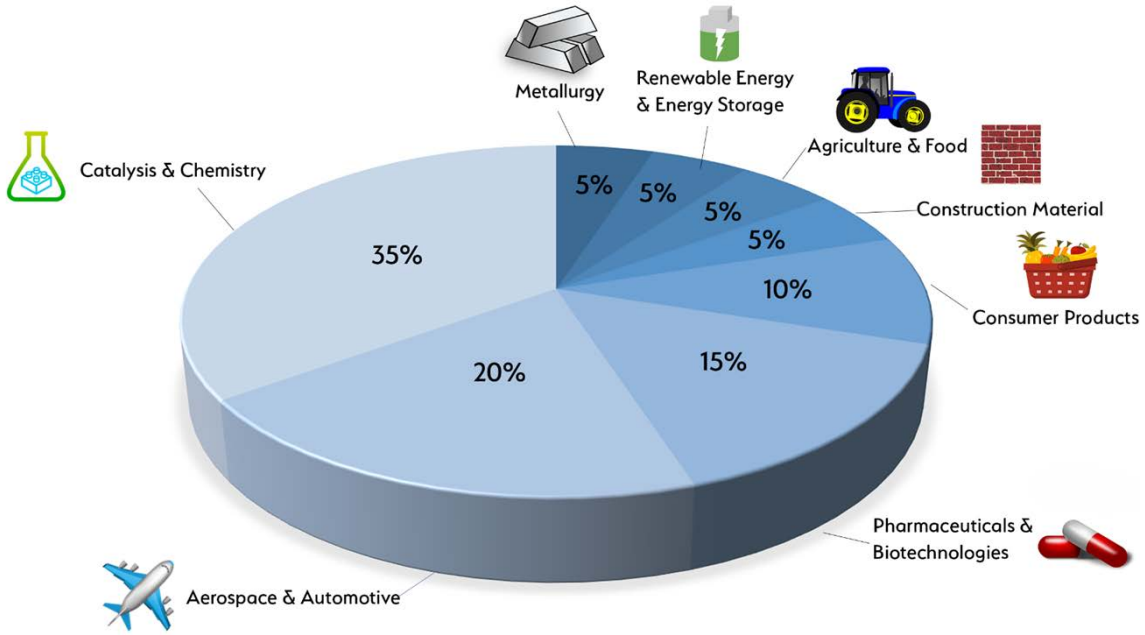
This work was funded from the EU's H2020 Research and Innovation programme under Grant Agreement No 730872 "CALIPSOplus".

ANALYTICAL RESEARCH INFRASTRUCTURES BRING NATIONS TOGETHER THROUGH SCIENCE

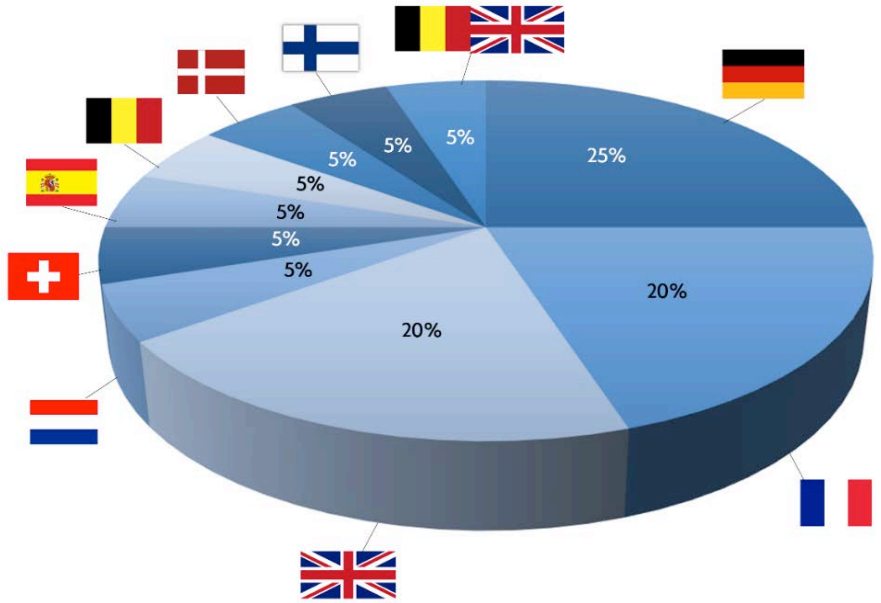
InnovaXN Marie Skłodowska Curie COFUND Programme

APPLYING FOR NEW CALL IN 2023

Co-funding of 40 PhD student programmes on research driven by precompetitive industrial R&D topics



Industrial sectors of Round 1 (Sept.2020)



Industrial partner countries in Round 1

This project has received funding from the EU Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 847439.

INNOVAXN PHD PROGRAMME: AN MSCA COFUND PROJECT

- **ESRF and ILL welcomed 20 more PhD students** in early October 2020 to start projects using X-ray and neutron techniques in partnership with companies driving the R&D projects
- **On 6 December 2021, a half-day symposium** brought together 36 InnovaXN PhD students, with 5’ Interventions to pitch their projects.

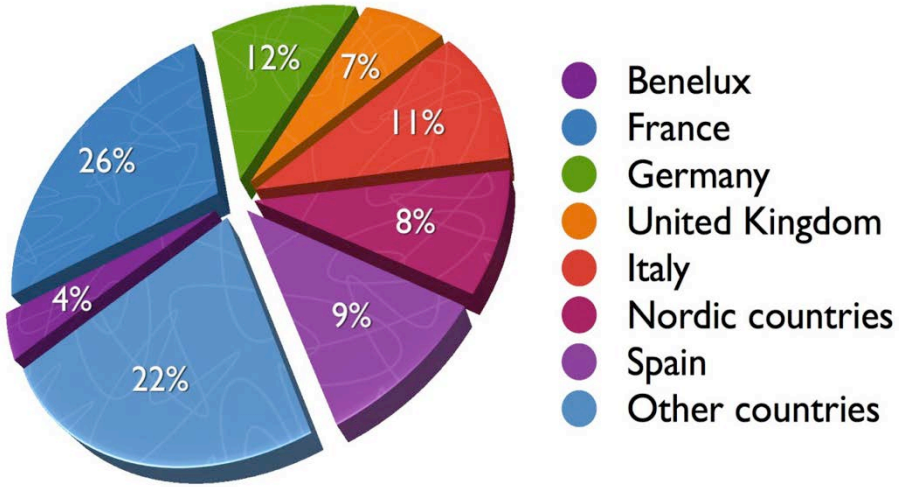
HERCULES

European School

HERCULES UNIQUENESS relies on a careful balance between **lectures** from internationally well known experts **and practical work at cutting edge experimental setups**, in neutron and synchrotron radiation large facilities

UNIVERSITÉ Grenoble Alpes

- **> 2400 participants since 1991**

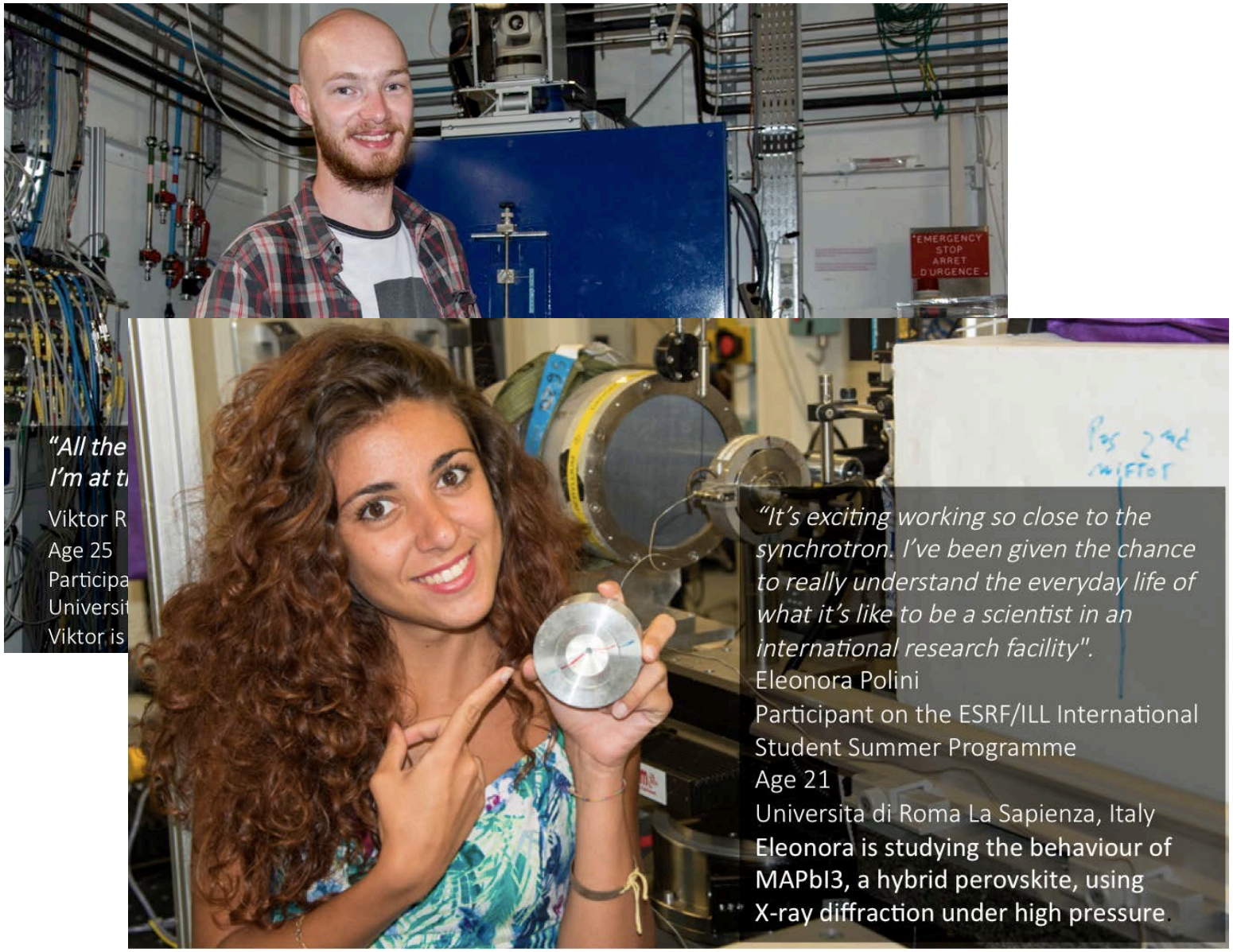


➪29 Hercules Annual Sessions (1991-2022)

➪~75 participants/session

ESRF | Institut Laue-Langevin | DESY | Elettra Sincrotrone Trieste | European XFEL | Institut de Physique du Globe de Paris | PAUL SCHERRER INSTITUT PSI | SOLEIL SYNCHROTRON

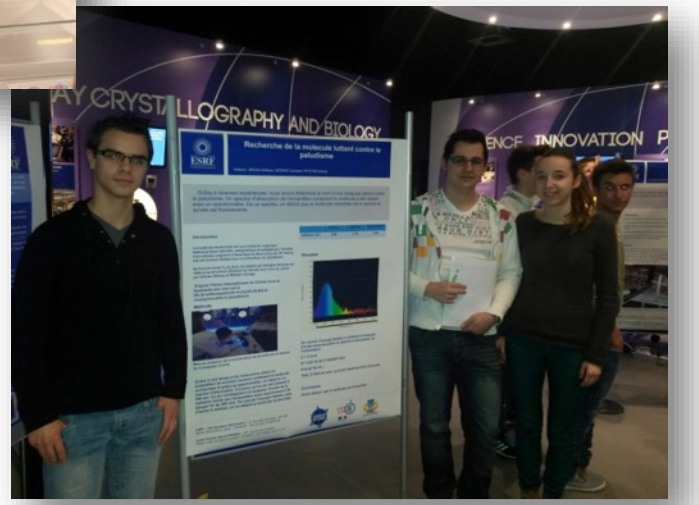
ESRF FOR THE NEXT GENERATIONS: UNDERGRADUATE STUDENT SUMMER PROGRAMME



ESRF-ILL International Undergraduate Student Summer Programme

- **Increase visibility and attractiveness of ESRF and ILL among undergraduate students**
- ~170 applications
- 20 students from 10-15 countries

Science made by and for the youngsters



SYNCHROTRON @ SCHOOL

- A partnership of ESRF and Académie de Grenoble
- ~1 500 high school students every year
  - High schools with scientific and technical specializations
- A day of full scientific immersion, with scientific experiments carried out
- Schools fr*om all over*

académie Grenoble

MINISTÈRE DE L'ÉDUCATION NATIONALE

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR ET DE LA RECHERCHE

SCIENCE AND R&D AND CHALLENGES FOR 2021 -2025

Delivery of new state-of-the-art beamlines (health, innovation, biology, new materials, etc.)

- EBSL3-BM18 2021
- ID21 – uXAS 2021
- EBSL8-ID29 2022
- ID27 – HP 2022
- ID24 – XAS 2022
- ID14 – NRS 2024
- EBSL2-ID03 2023
- EBSL1-ID18 2024

A far looking accelerators programme

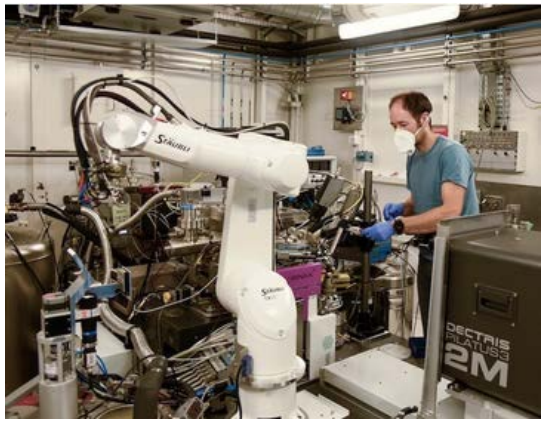
INCREASED BRIGHTNESS COHERENCE, RELIABILITY AND STABILITY

NEW GENERATION UNDULATORS, 4TH HARMONIC CAVITY, IMPROVED INJECTION CHAIN, PREVENTIVE MAINTENANCE

An IT-DATA PROGRAMMNE to fully exploit the information contained in the EBS DATA

IT DIGITAL STRATEGY
and a new DATA-CENTER

CONCLUSIONS



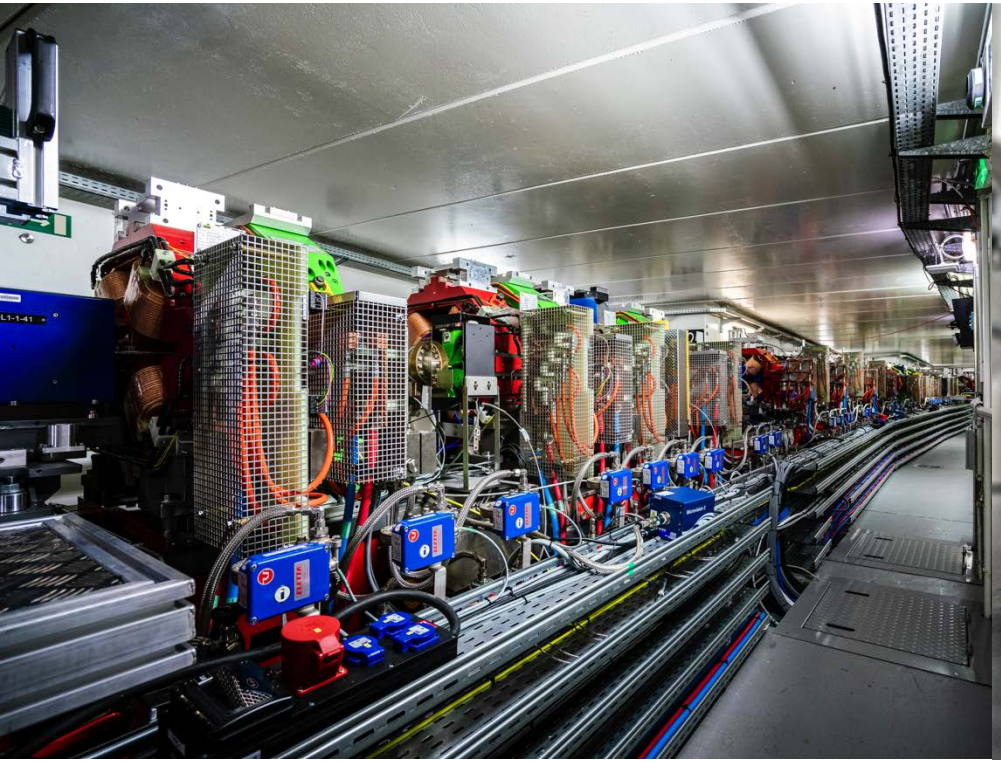
EXCITING TIME FOR X-RAY SCIENCE!

→ NEW SCIENTIFIC OPPORTUNITIES

→ TECHNOLOGICAL, INSTRUMENTATION AND IT CHALLENGES

WELCOME AT THE ESRF!

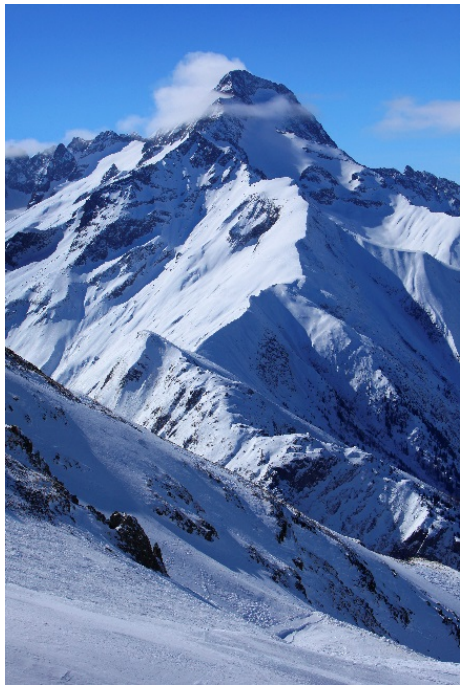
THANK YOU FOR YOUR ATTENTION



Looking forward to welcoming you at the ESRF!

- Twitter @esrfsynchrotron – Instagram @esrf_synchrotron

GRENOBLE AND ITS SURROUNDINGS: A BEAUTIFUL REGION



THE COUNTRYSIDE .....
















.... AND A STIMULATING CULTURAL ENVIRONMENT