A Light for Science

Winter School of Synchrotron Radiation – 2011

31 January – 4 February 2011
Liptovsky Jan, Slovakia

A warm welcome

to all PARTICIPANTS

european photon & neutron science campus

A Light for Science

ESRF

Materials Science and Synchrotron Radiation: The ESRF

Francesco Sette – ESRF BP 220 – 38043 Grenoble – France

- WHY a Facility like the ESRF?
- WHAT is Synchrotron Radiation?
- WHERE is Synchrotron Radiation today?
- The ESRF in Numbers
- Science at the ESRF

WHY a Facility like the ESRF?

THE CHALLENGES FOR THE FUTURE OF OUR SOCIETY

Identify models for sustainable development and Improve quality of life with a "durable" approach

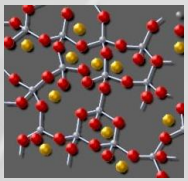
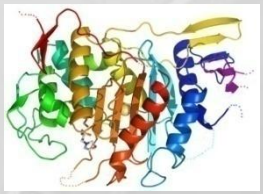
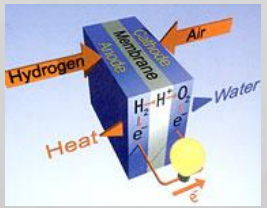
- Environment and Climate Changes Mitigation and Understanding
  - water supplies
  - global warming and tipping points
  - pollution: atmosphere, water supplies, soil
  - food supply and environmentally friendly agriculture
  - ……
- Transport
  - alternatives to oil: photo-voltaic, wind, tides, nuclear….
  - higher efficiency, limit waste
  - ……
- Health and Medicine
  - understand the mechanism of life from the molecular level
  - new drugs and treatments
  - ……

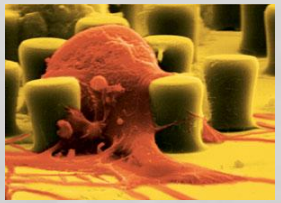
WHY a Facility like the ESRF?

THE CHALLENGES FOR THE FUTURE OF OUR SOCIETY

Identify models for sustainable development and Improve quality of life with a "durable" approach:

"Understand and Design Functioning of Materials "

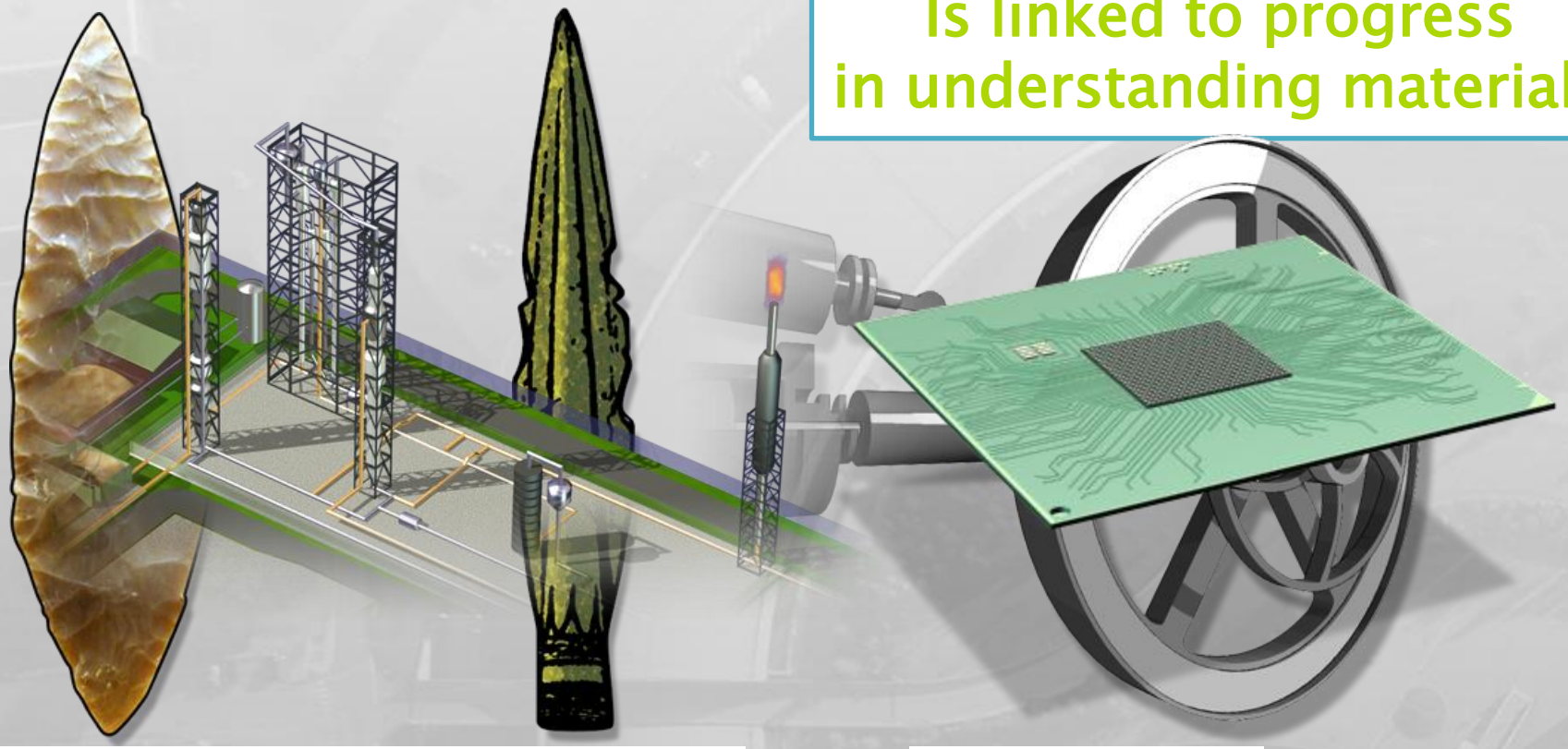






WHY a Facility like the ESRF?

Investigating materials

Technological progress
Is linked to progress
in understanding materials



Stone-age Oil-age Bronze-age

Si Silicon-age

WHY a Facility like the ESRF?

THE CHALLENGES FOR THE FUTURE OF OUR SOCIETY

Identify models for sustainable development and Improve quality of life with a "durable" approach:

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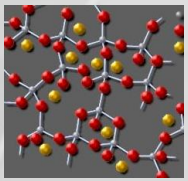
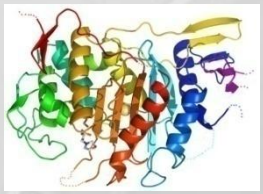
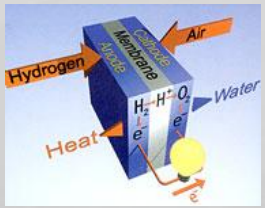
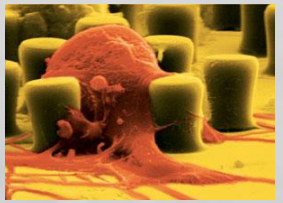
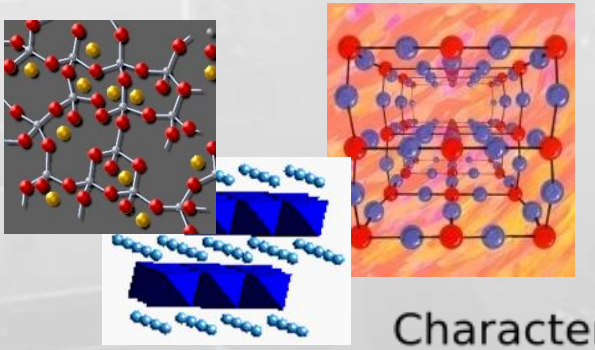




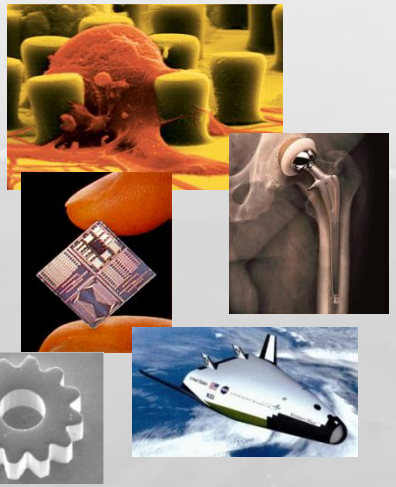


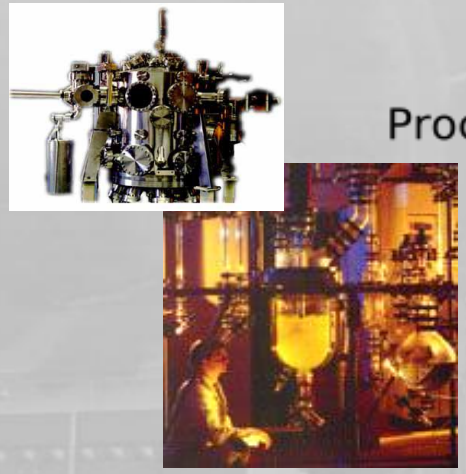
A Fantastic Challenge for Scientists:

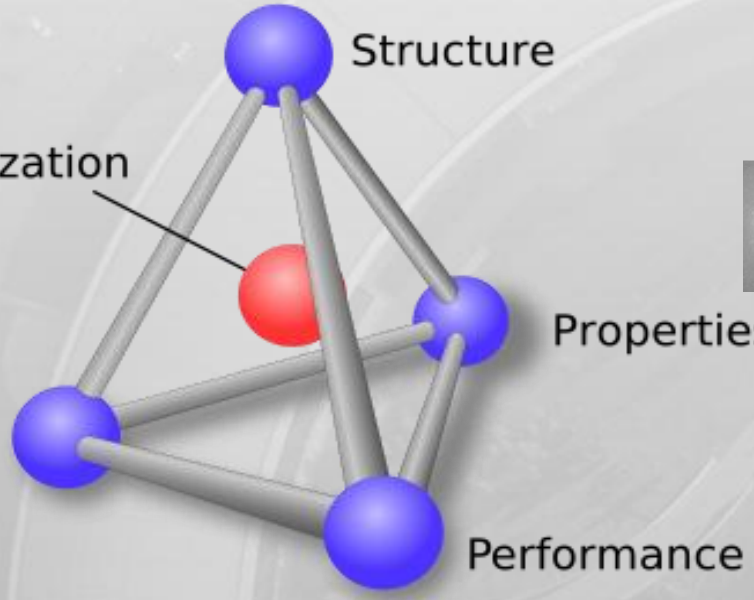
- **Fundamental Sciences:**
  - **Biology, Chemistry, Mathematics, CM Physics, …**
- **Applied Sciences and Technologies**
  - **Engineering, New Materials, Medicine, Environment, Computer Sciences, Industrial Applications……**

The Age of Knowledge Based Design of Materials









MATERIAL SCIENCE: CHARACTERIZATION TOOLS

Many Laboratory Techniques: Electron Microscopies, Optical Methods, IR, Acoustic Methods, Tribology ……

NEED FOR:

- Bulk, Surface and Interface Sensitivities
- Chemical Sensitivity
- Spatial Resolution down to the single atom (electron)
- Time resolution down to molecule bonding and electron motion times
- Magnetic sensitivity
- Non destructive ….

THERMAL NEUTRONS AT REACTORS and SPALLATION SOURCES
and
X-RAYS AT STORAGE RINGS and FREE ELECTRON LASER

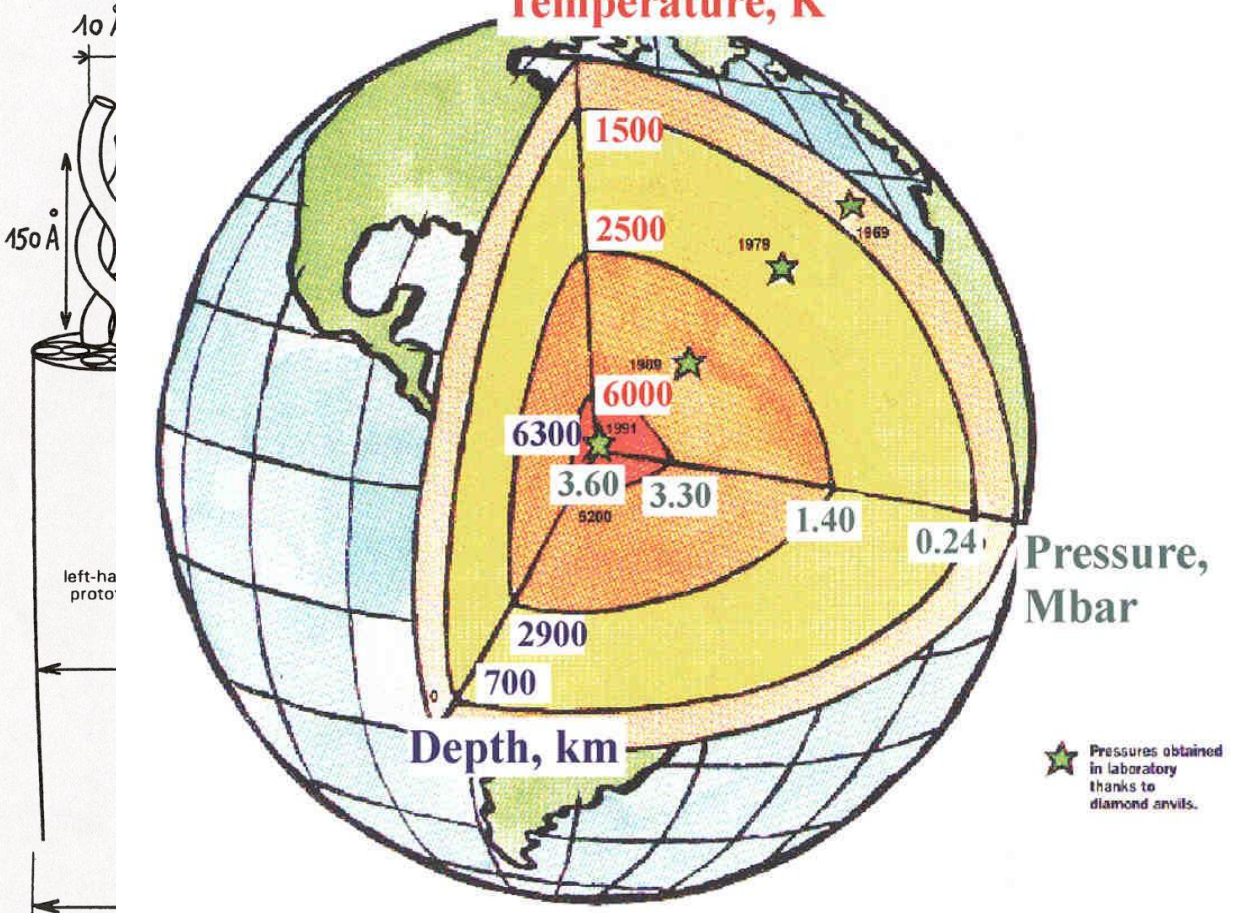
Why are Synchrotron X-rays useful for studying Materials?

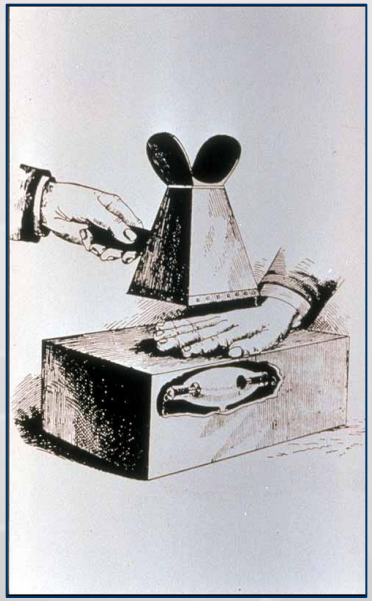
- Electromagnetic radiation produced by accelerating relativistic electrons or positrons
- Very intense and highly polarised

- Wavelength (Å) ~ inter-atomic distances
  Diffraction → structures with atomic resolution
- Energy (keV) >> phonon and electron energies
  Inelastic scattering and spectroscopy → phonon and electron dynamics
- Scattering power → varies with atomic number Z
- Absorption varies strongly with energy → element specific information
- SR is electro-magnetic radiation → magnetic information/structures

WHY a Facility like the ESRF?

MATERIALS SCIENCE





Röntgen's Experiment (1895)

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

Cathode Rays

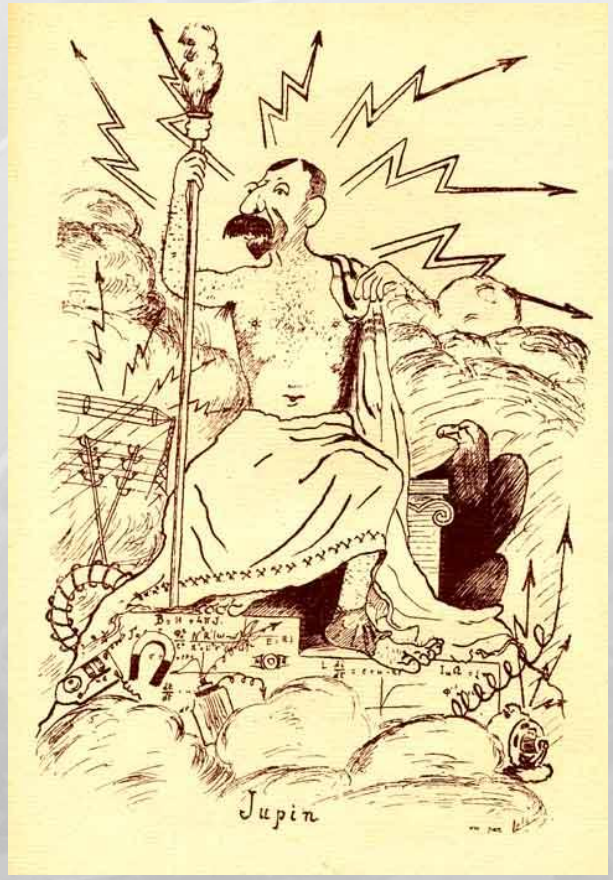
- "... Detection of interference phenomena has been tried without success, perhaps only because of their feeble intensity..."

- "... 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..."

WHAT is Synchrotron Radiation?

Alfred-Marie LIENARD (1869-1958)



Dieu Electricité

Early works on Synchrotron Radiation

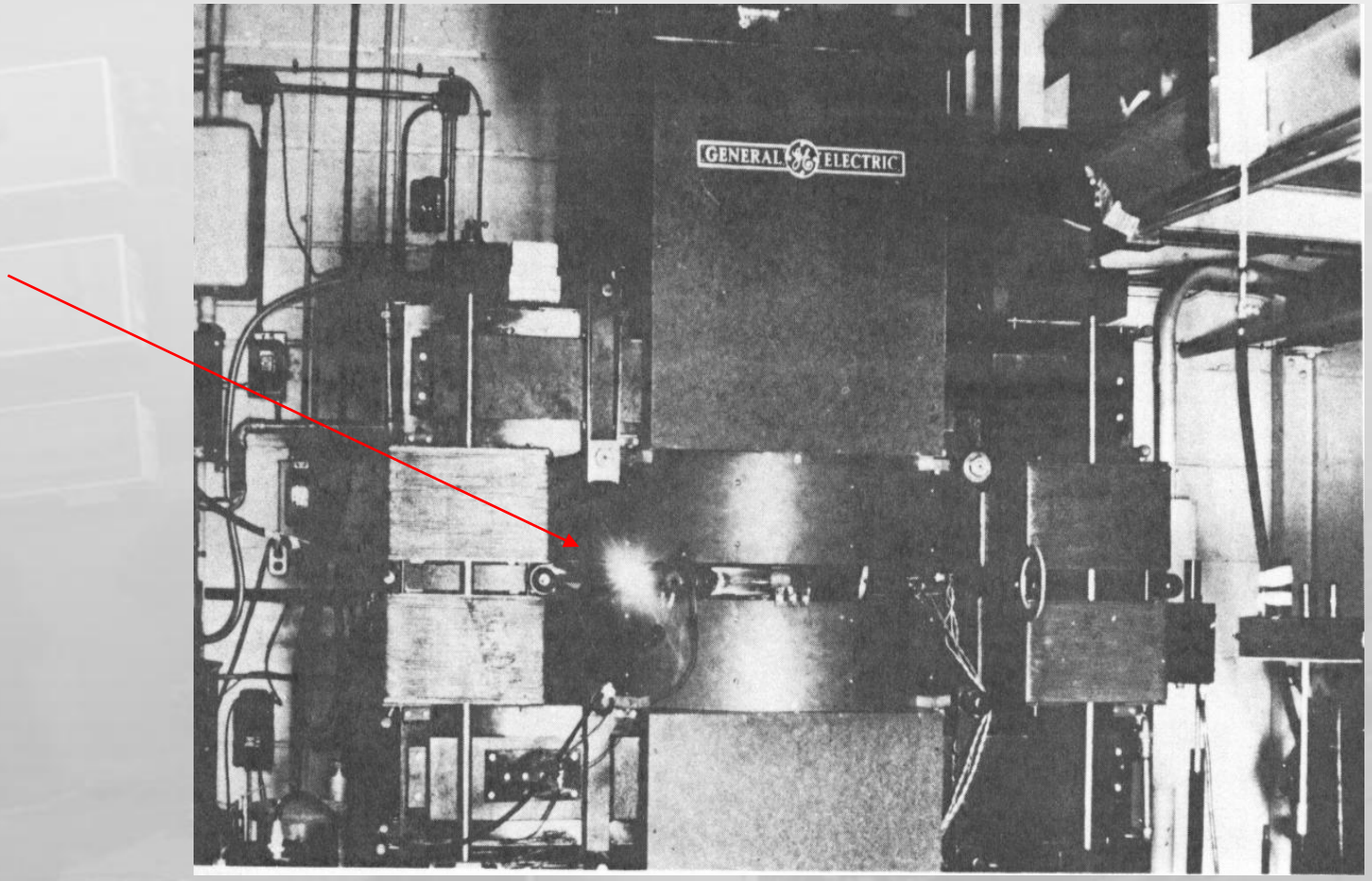
A. Liénard (Prof. à l'École des Mines de Saint-Etienne)
"Champ électrique et magnétique produit par une charge électrique concentrée en un point et animée d'un mouvement quelconque"
L'Éclairage Électrique, 16(27), pp. 5-14 (1898)

$$W = \frac{2}{3}\frac{e^2 c}{R^2}\beta^4\gamma^4$$

W is the instantaneous power emitted by an electron;
c is the speed of light;
e is the electron charge;
R is the radius of curvature of the trajectory;

$$\vec{\beta} = \frac{\vec{v}}{c} \quad \text{and} \quad \gamma = \frac{E}{mc^2}$$

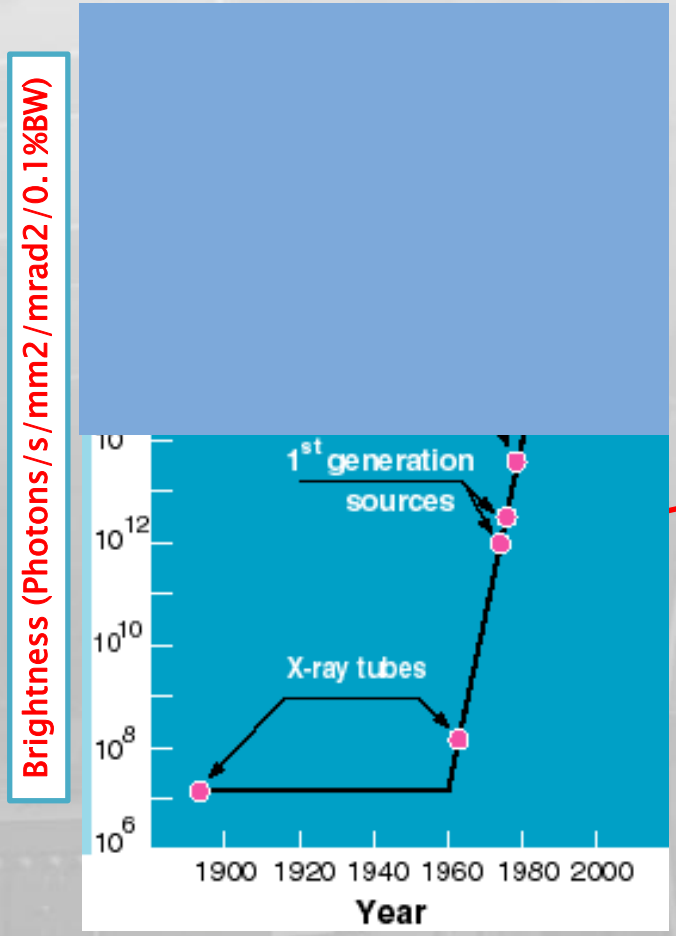
First Observation of Synchrotron Radiation



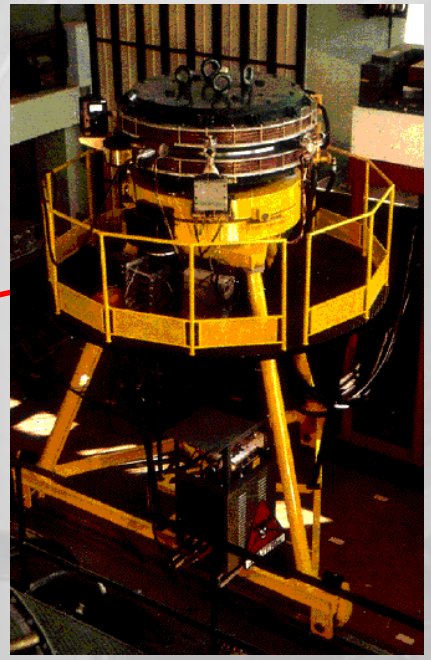
The General Electric team (Langmuir, Elder, Gurewitsch, Charlton and Pollock) looking at the vacuum chamber of the 70 MeV synchrotron (1947).

Synchrotron Radiation:

A Revolution in the use of X-rays



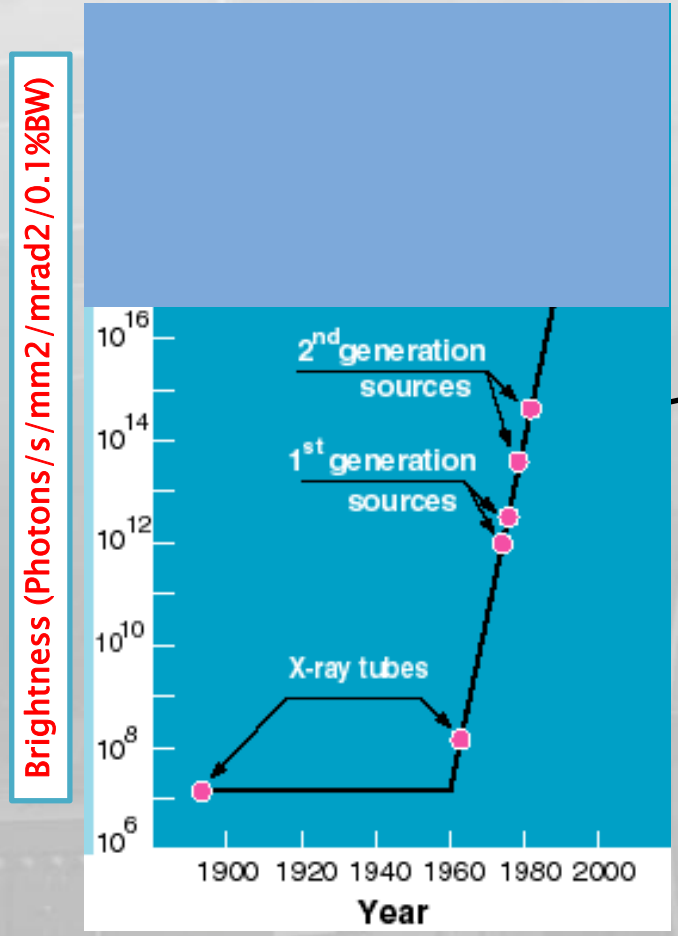
Storage Ring, 1961-1964
Key Time for SR



Construction of ADA, the first storage ring for electron and positron beam rotating in opposite Directions.
Proposed by B. Touschek (1921-1978), in 1960

Synchrotron Radiation:

A Revolution in the use of X-rays

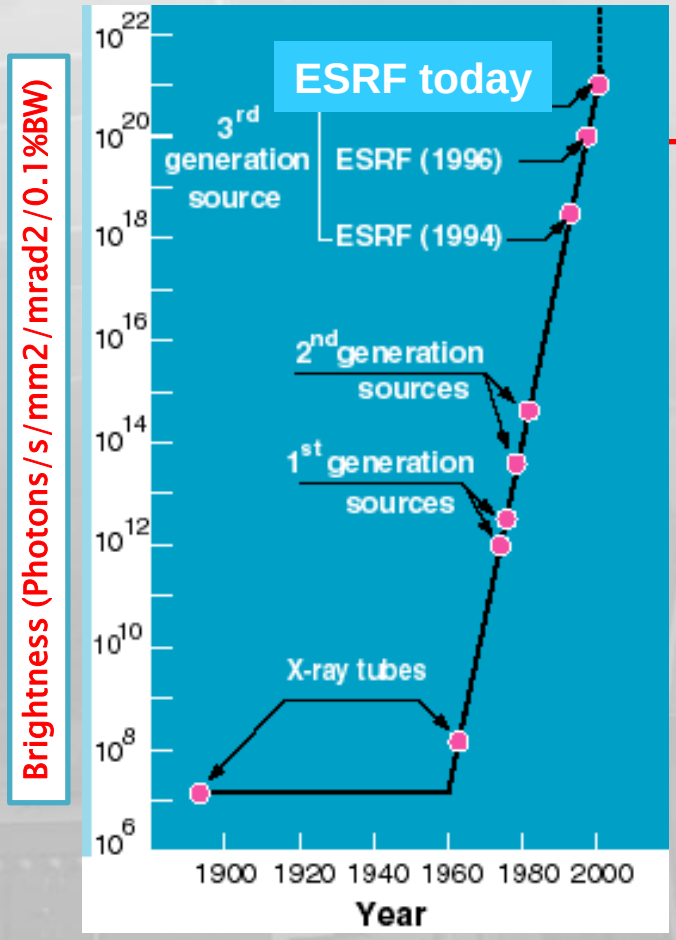


Tantalus:
The first dedicated source of Synchrotron Radiation, 1968

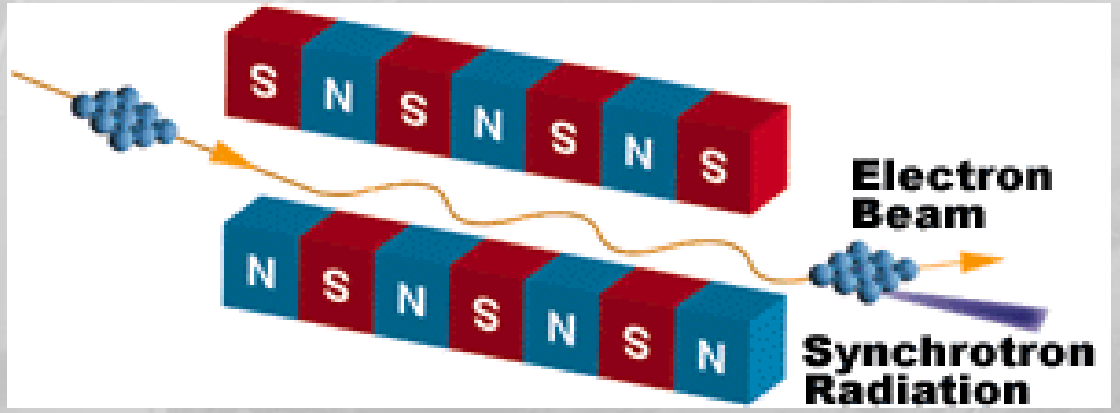
WHAT is Synchrotron Radiation?

Synchrotron Radiation:

A Revolution in the use of X-rays



Third Generation Sources:
Extensive Use of Undulators



WHERE is Synchrotron Radiation?

Major X-Ray sources in the world

ESRF was the world's first 3rd generation hard X-ray source

Other hard X-ray sources: APS (USA) – SPring-8 (Japan) – Petra-III (D)

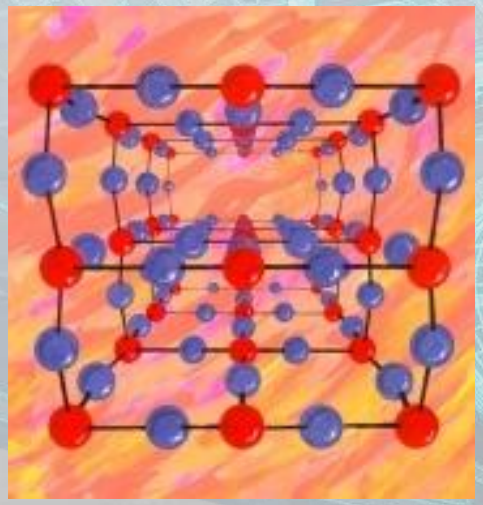
New national sources in Europe: Soleil (F) in 2006, Diamond (UK) in 2007, Petra-III (D) in 2009, ALBA (E) in 2010, Sweden, Poland, Russia.....

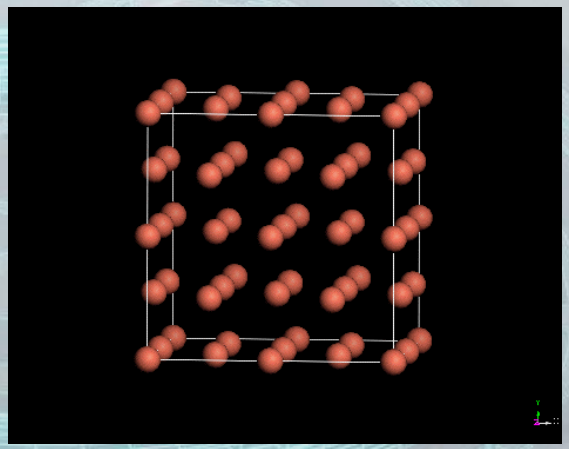
New plans also in Brasil, China, India, ...

The European Synchrotron Radiation Facility in Grenoble – France

WHY a Facility like the ESRF?

The ESRF is a User Facility supporting excellence: it provides opportunities for cutting-edge research on the structure and dynamics of matter





The ESRF science case was laid out before its construction.
Have since been updated: Annually, on a Rolling Five Years basis, and Every 10 Years

The History of the European Synchrotron Radiation Facility

• 1975	First discussions
• 1977	ESF report
• 1984	Decision to build ESRF in Grenoble
• 1988	Establishment of the ESRF Convention
• 1989	Planning and construction starts
• 1992	e-beam in the storage ring, and first X-rays (17/2)
• 1994	Inauguration (100 mA operation)
• 1995	200 mA operation
• 1995 - 99	Completion of 30 beamlines
• 1999 -	Full operation
• 2009 -	Upgrade Programme

ESRF: 19 Members and Associates Countries

Contributions to ESRF Budget

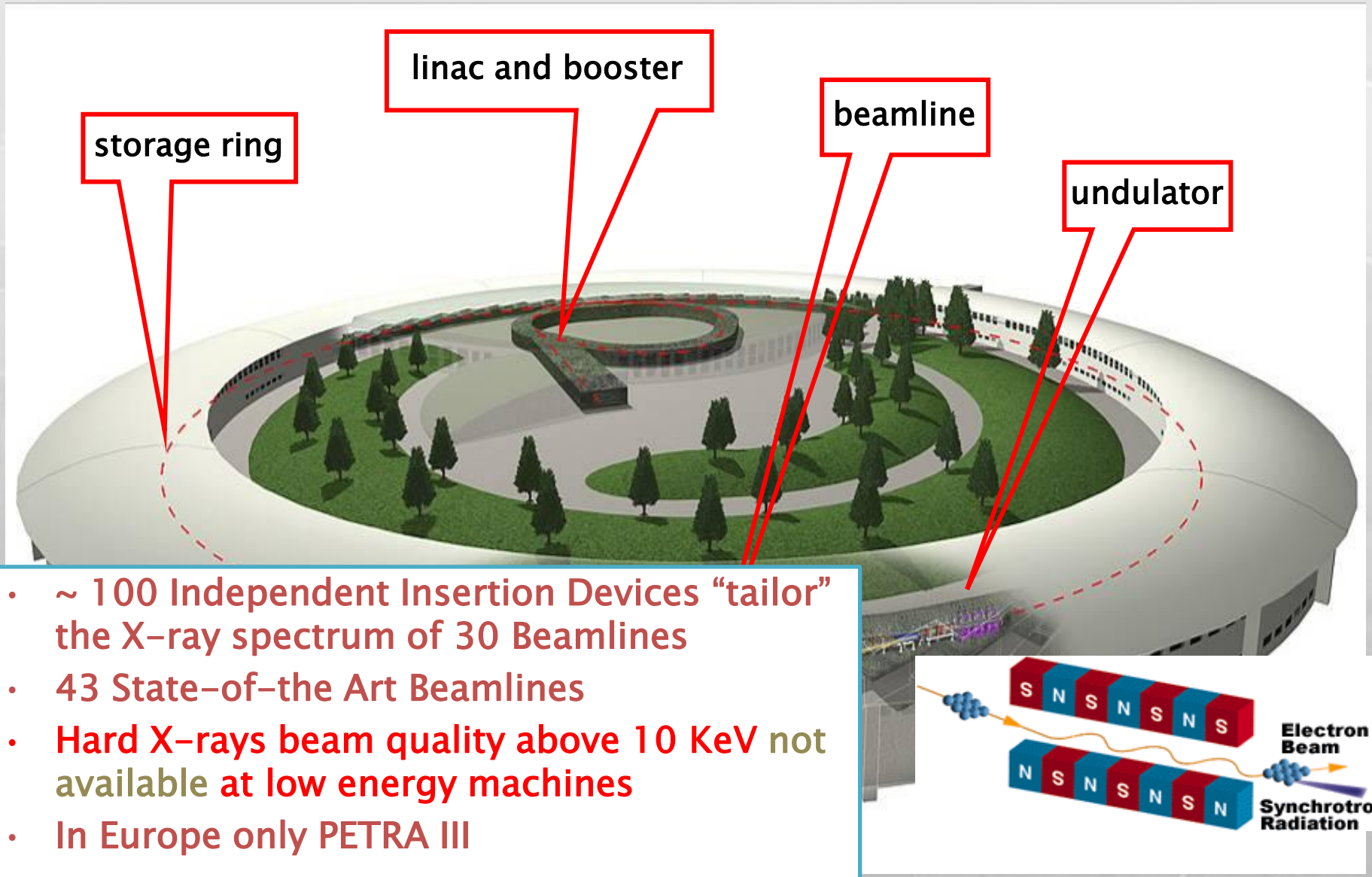
Members

France	27.5%
Germany	25.5%
Italy	15%
UK	14%
BeNeSync (Belgium, The Netherlands)	6%
NordSync (Denmark, Finland Norway, Sweden)	4%
Spain	4%
Switzerland	4%
	100%

Scientific Associates

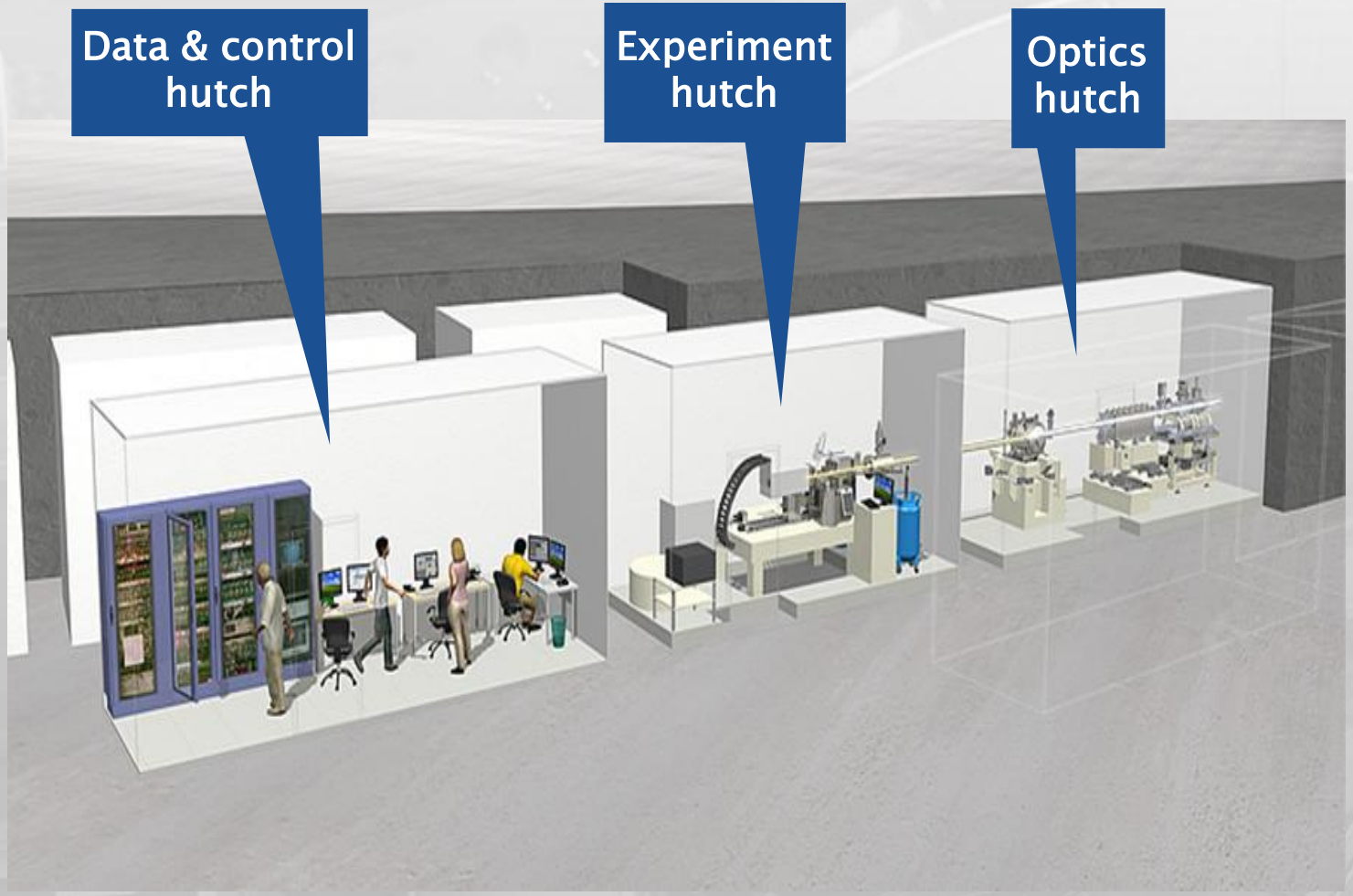
Portugal	1%
Israel	1%
Austria	1%
Poland	1%
Central-Sync (Czech Republic, Slovakia, Hungary)	1.05%

The ESRF in numbers



- ~ 100 Independent Insertion Devices "tailor" the X-ray spectrum of 30 Beamlines
- 43 State-of-the Art Beamlines
- Hard X-rays beam quality above 10 KeV not available at low energy machines
- In Europe only PETRA III

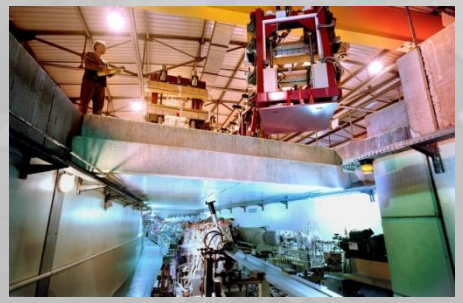
Beamline Elements



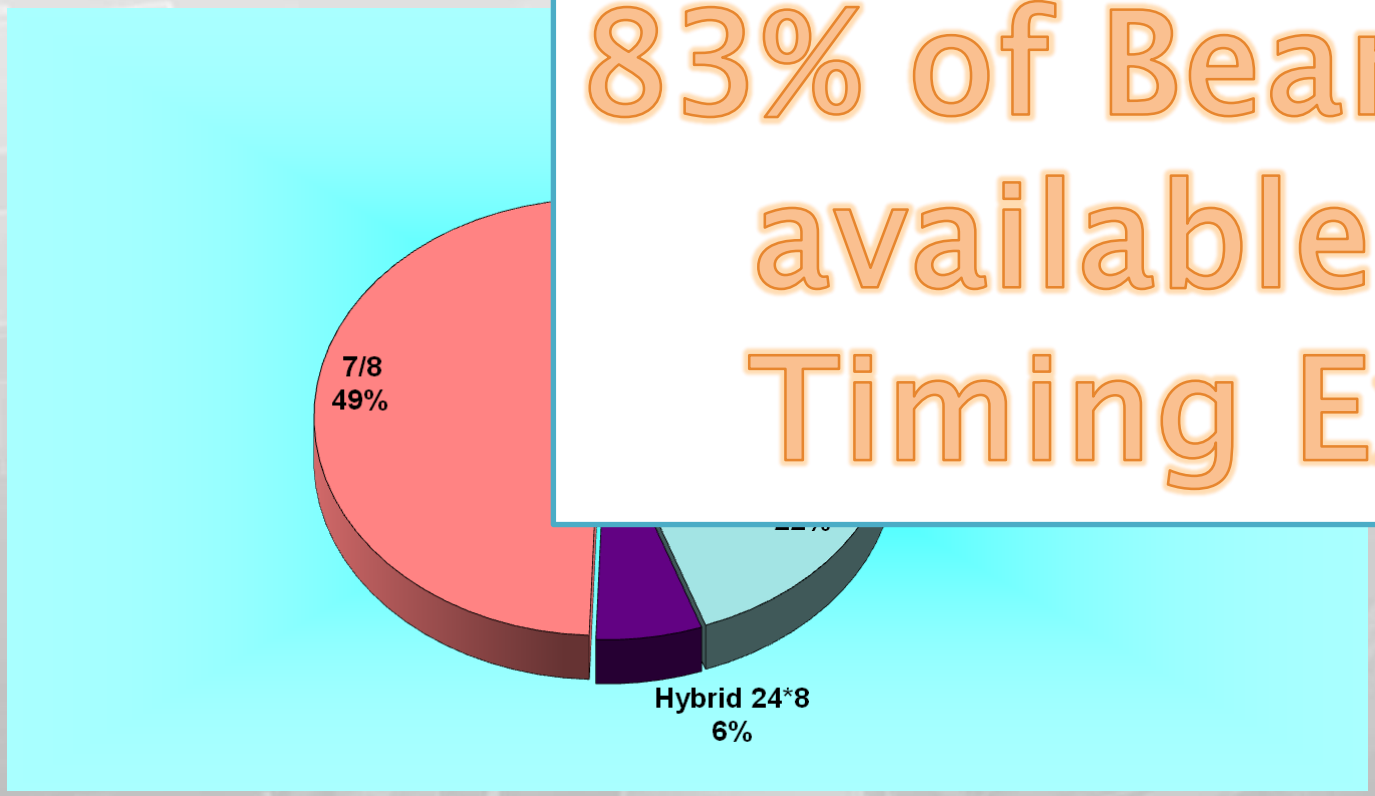
Machine Statistics for 2008-2010

	2008	2009	2010
Availability (%)	98.30	99.04	98.78
Mean time between failures (hrs)	64.50	75.80	67.50
Mean duration of a failure (hrs)	1.10	0.73	0.82

Accelerator and Source Division

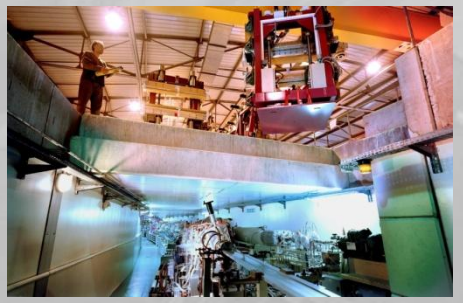


Beam Modes 2010

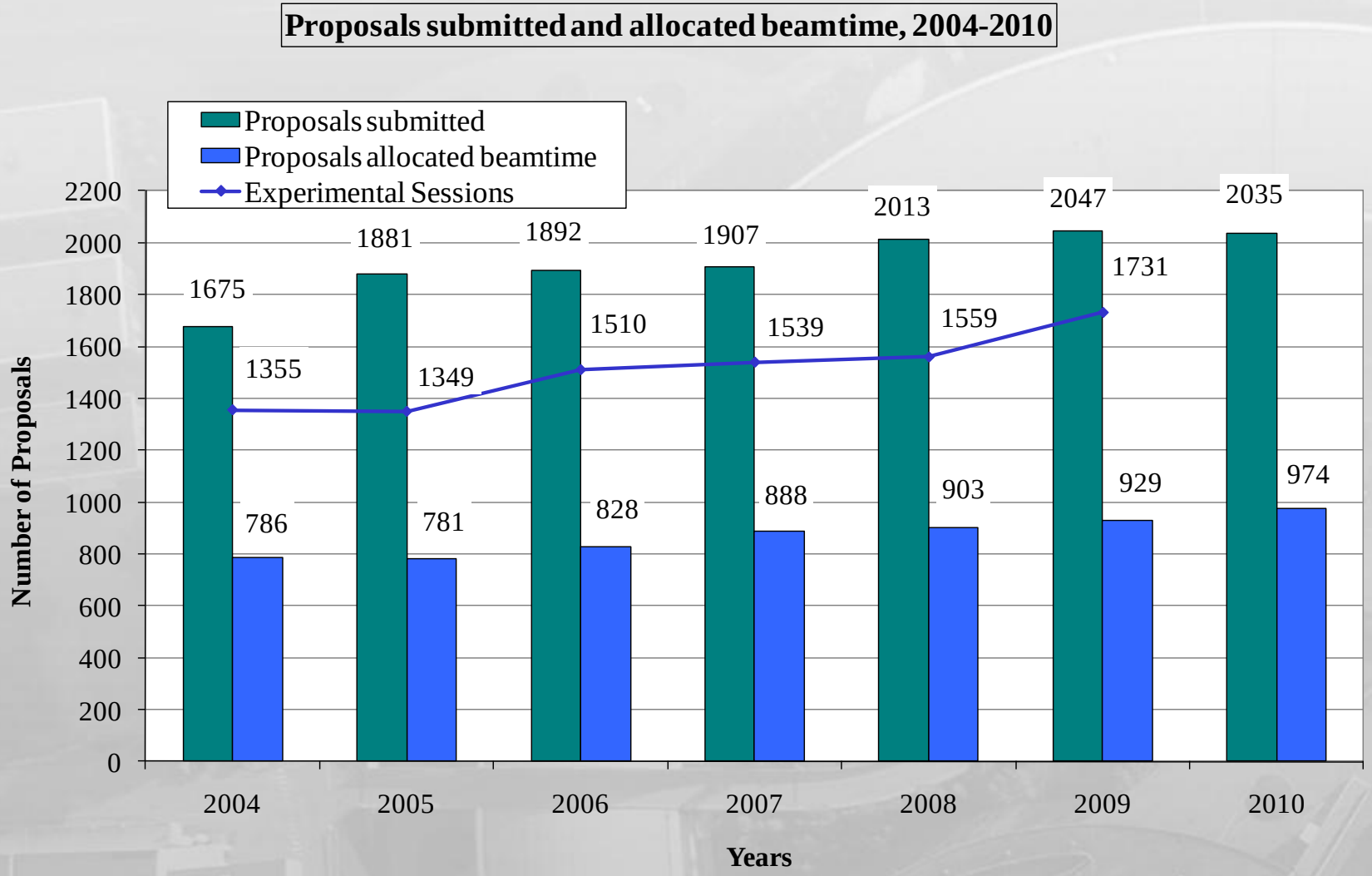


83% of Beamtime available for Timing Exps

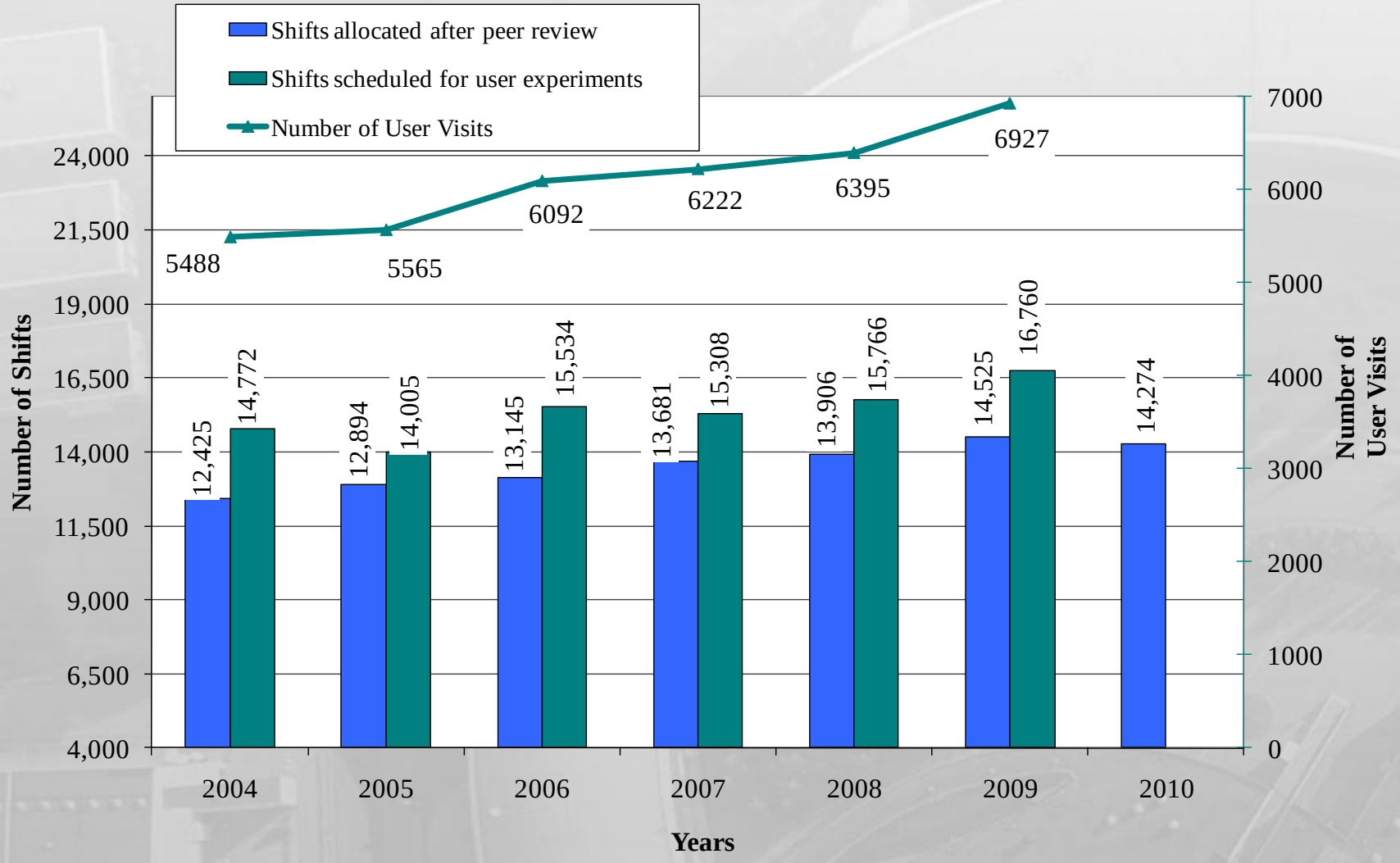
Accelerator and Source Division



The ESRF in numbers



Shifts allocated and delivered for experiments, User visits, 2004-2009



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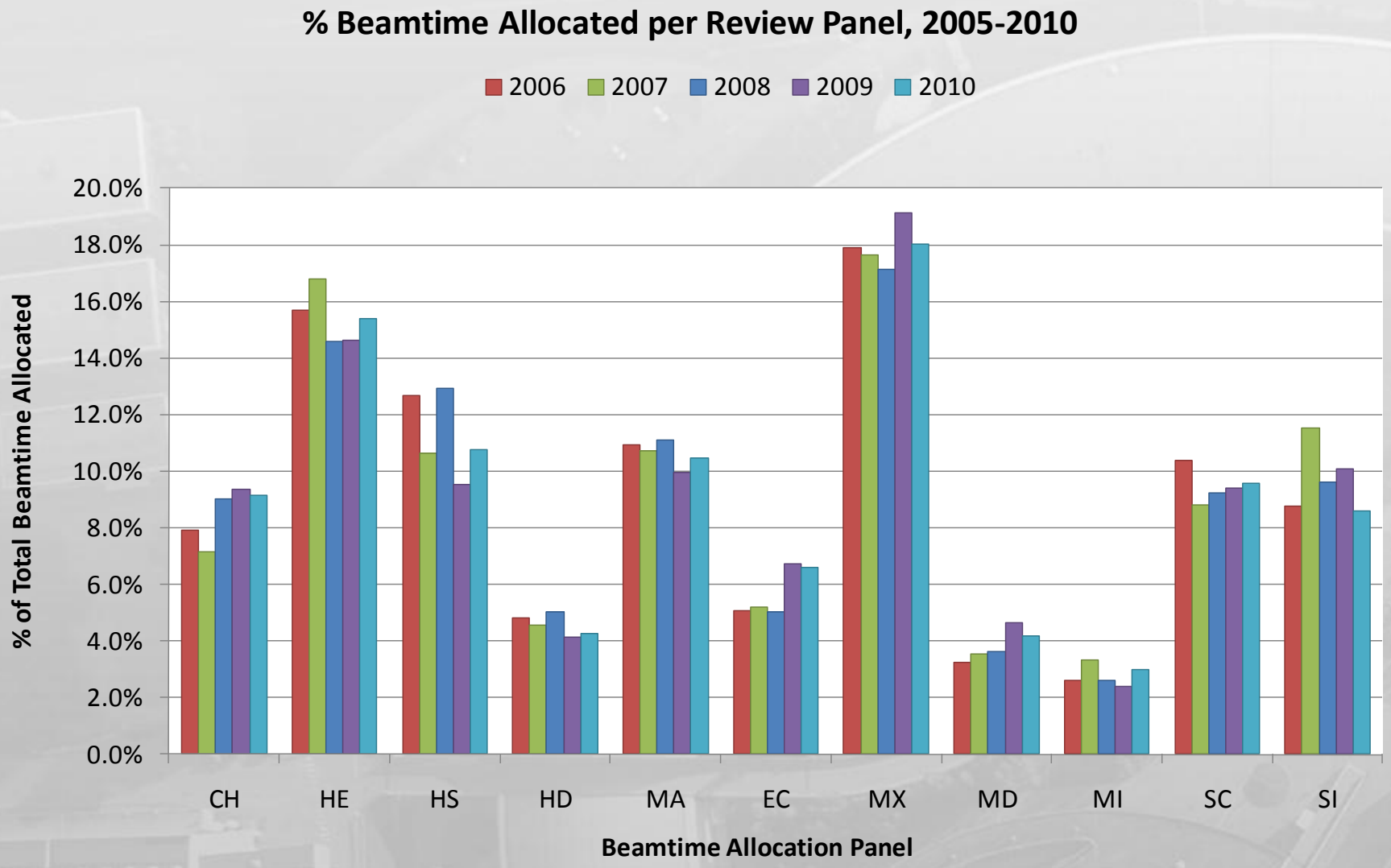
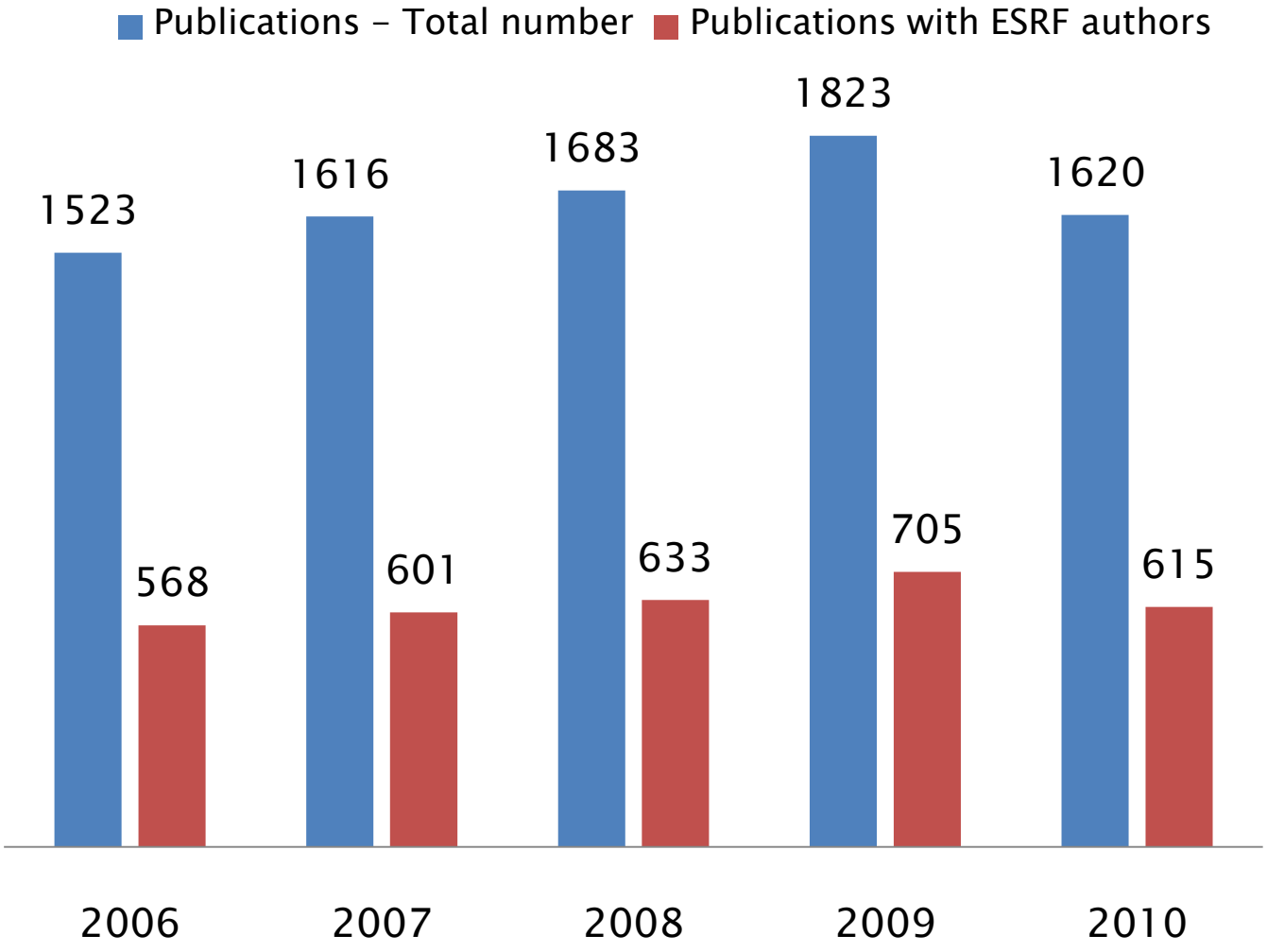


Refereed Publications from work at the ESRF



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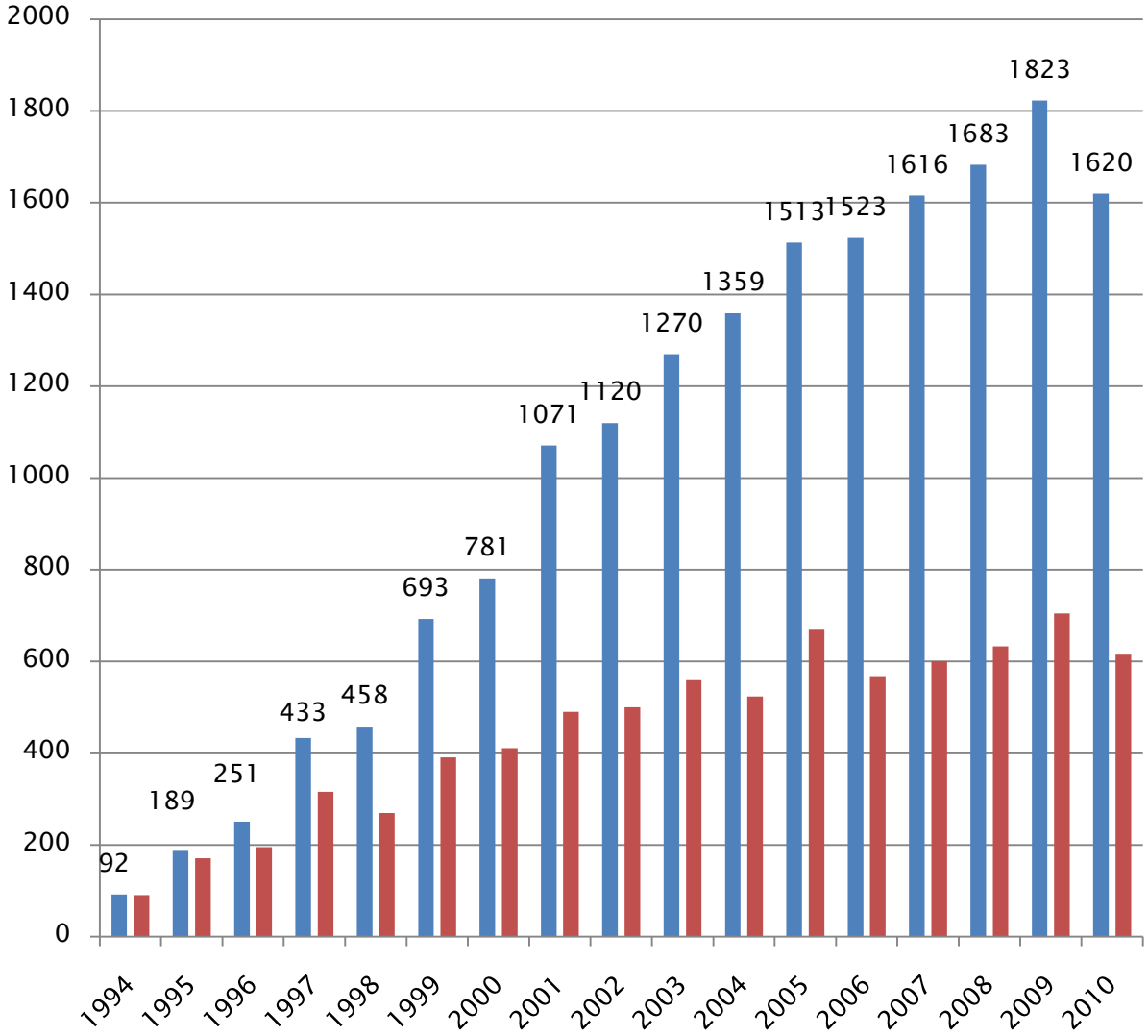
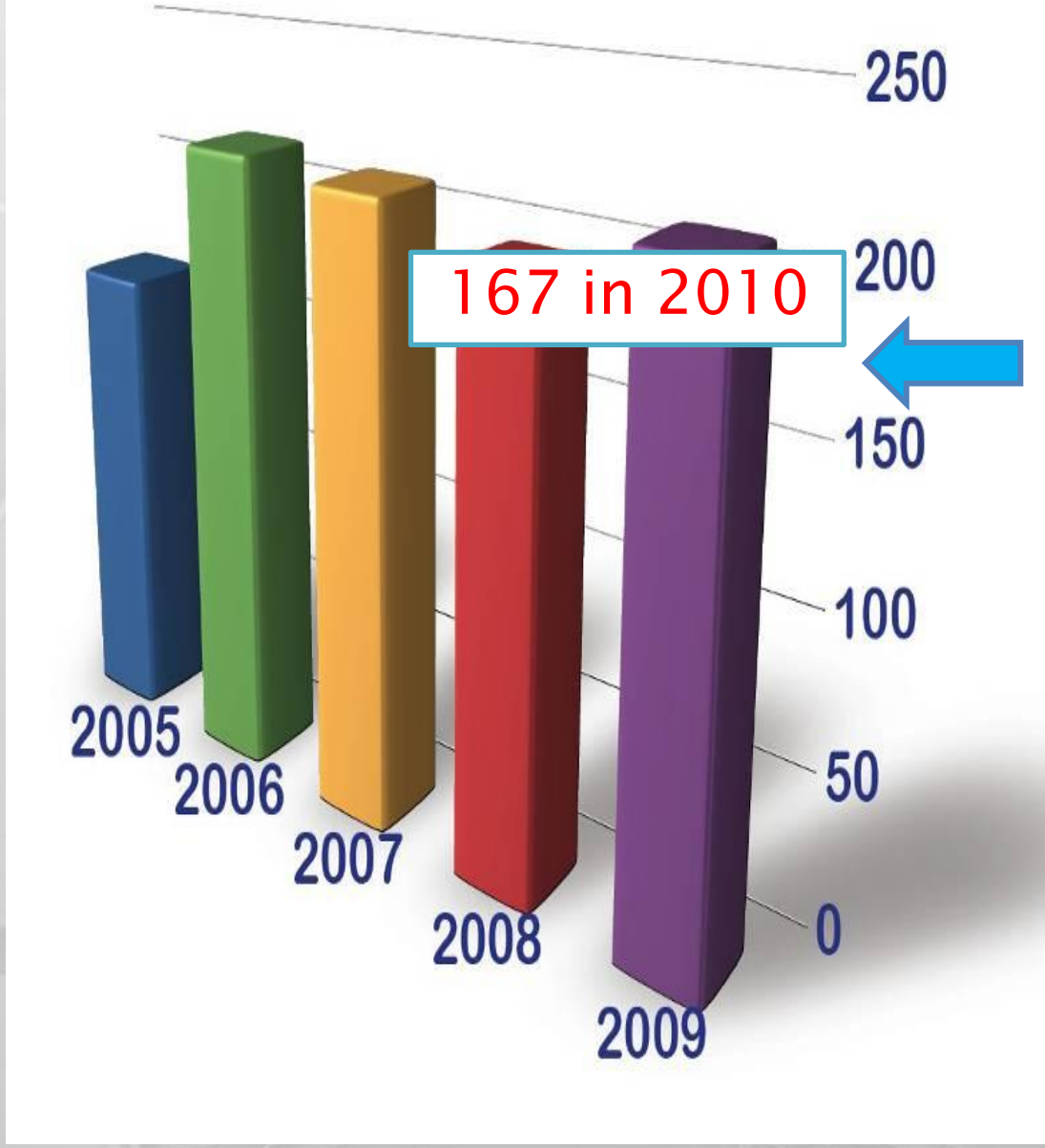


17 495 PAPERS SINCE 1994

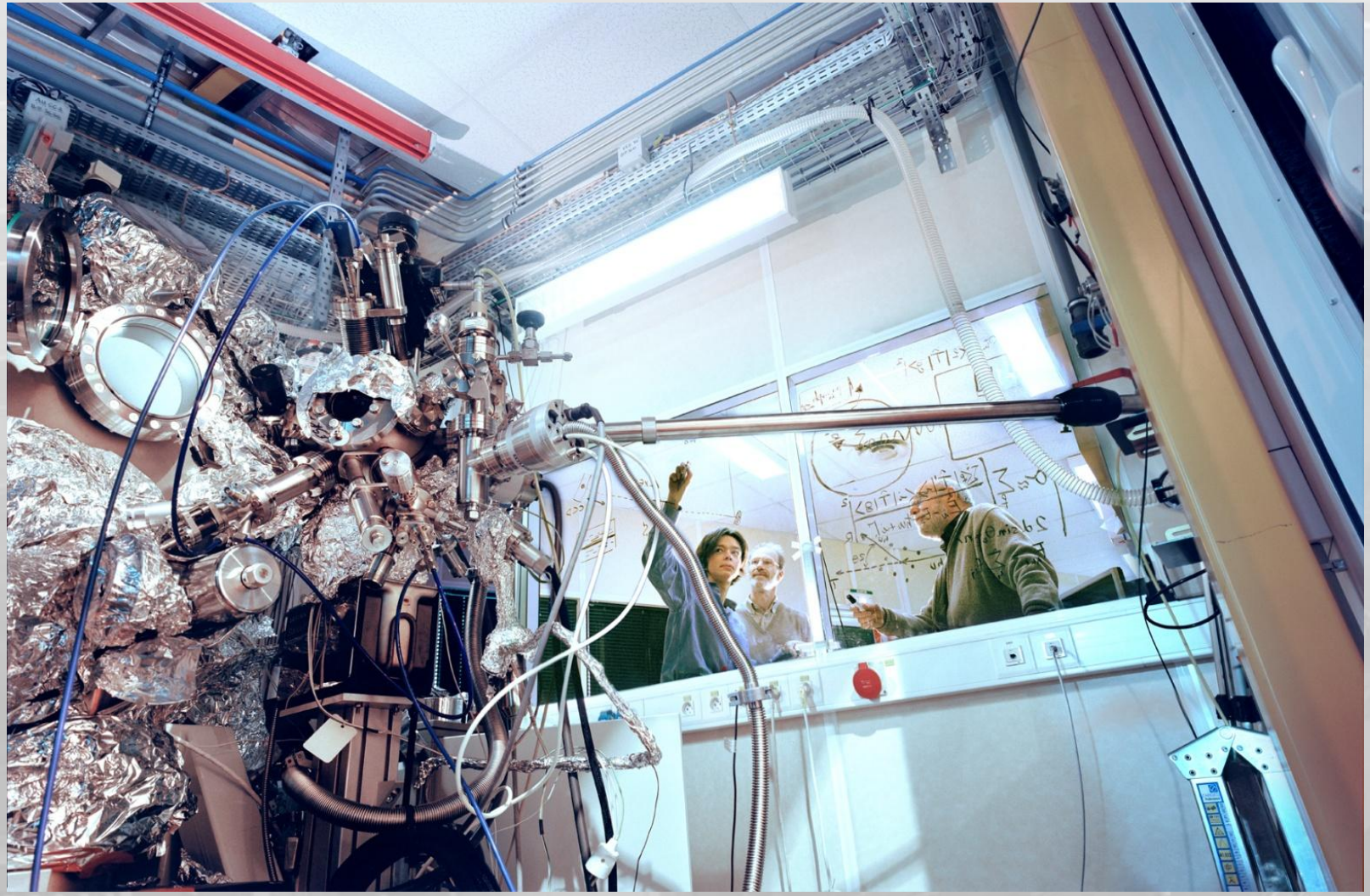
Publications: Total number

Publications with ESRF authors

The ESRF in numbers

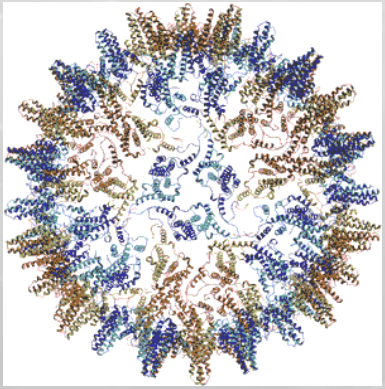


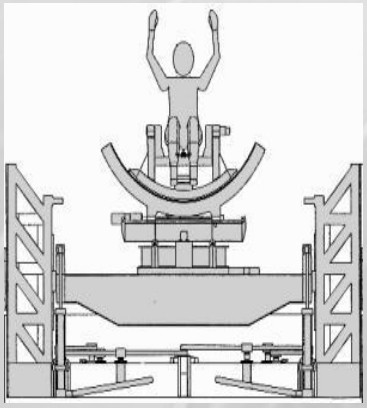
Science at the ESRF

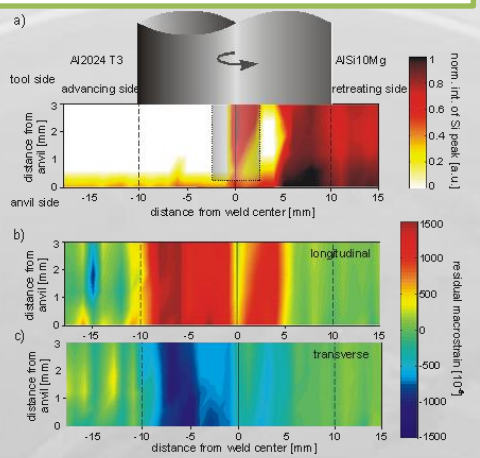


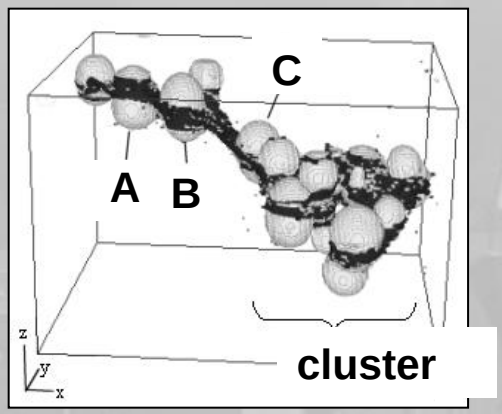
Synchrotron Light Science at the ESRF

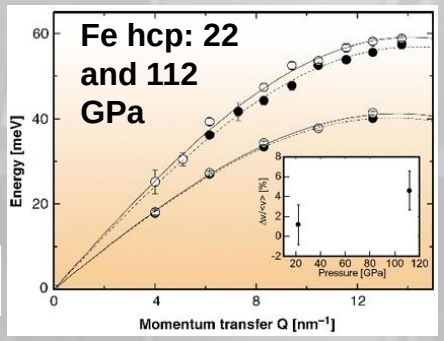
Biology/life sciences ⇨ medicine ⇨ engineering ⇨ materials ⇨ earth sciences ⇨ chemistry ⇨ physics ⇨…
Growth in environment, palaeontology, cultural heritage …

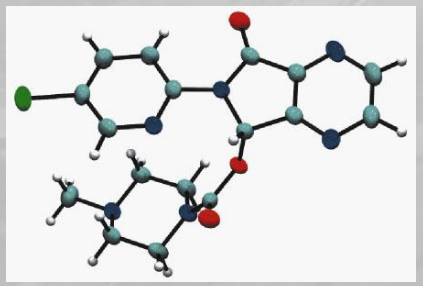


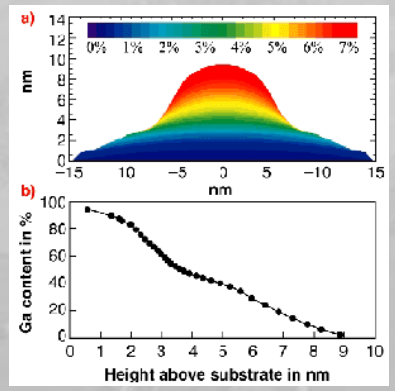












Congratulations to two ESRF Users
Ada Yonath and Venki Ramakrishnan
2009 Nobel Prize in Chemistry

Nobelprize.org

NOBEL PRIZES | ALFRED NOBEL | PRIZE AWARDERS | NOMINATION | PRIZE ANNOUNCEMENTS

By Year | Nobel Prize in Physics | **Nobel Prize in Chemistry** | Nobel Prize in Medicine | Nobel Pr

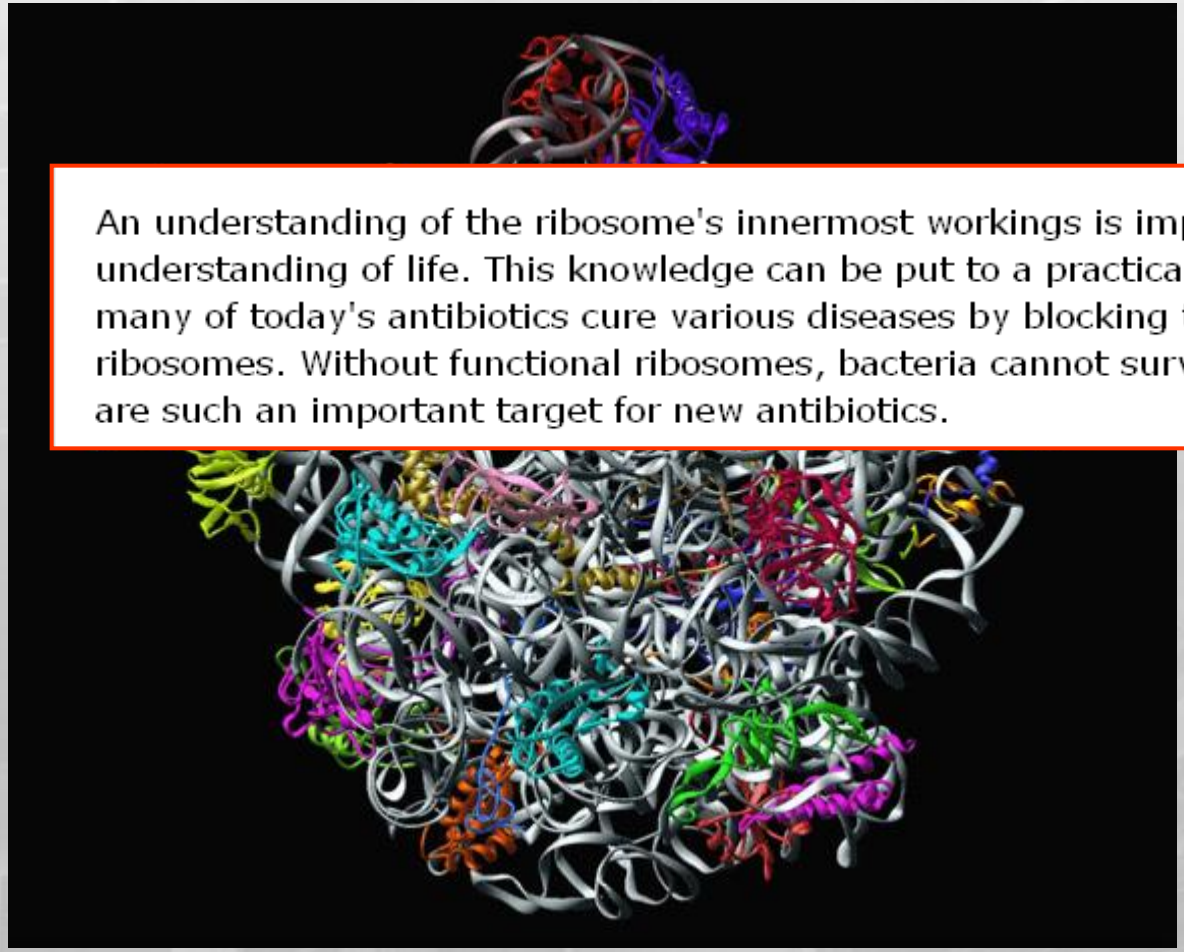
The Nobel Prize in Chemistry 2009

This year's Nobel Prize in Chemistry awards Venkatraman Ramakrishnan, Thomas A. Steitz and Ada E. Yonath for having showed what the ribosome looks like and how it functions at the atomic level. All three have used a method called X-ray crystallography to map the position for each and every one of the hundreds of thousands of atoms that make up the ribosome.

Press Release

7 October 2009

First “synchrotron” Nobel Prize may lead to new and more efficient antibiotics

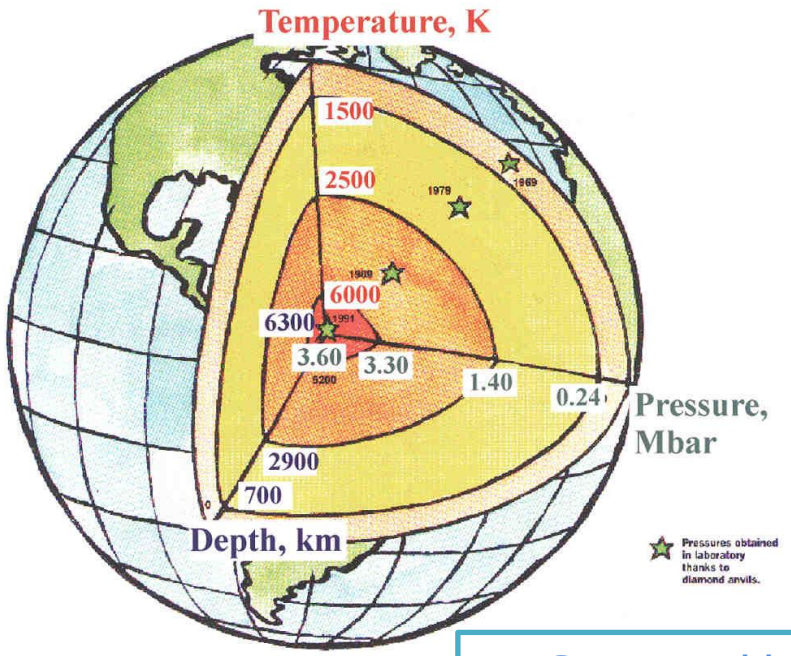


An understanding of the ribosome's innermost workings is important for a scientific understanding of life. This knowledge can be put to a practical and immediate use; many of today's antibiotics cure various diseases by blocking the function of bacterial ribosomes. Without functional ribosomes, bacteria cannot survive. This is why ribosomes are such an important target for new antibiotics.

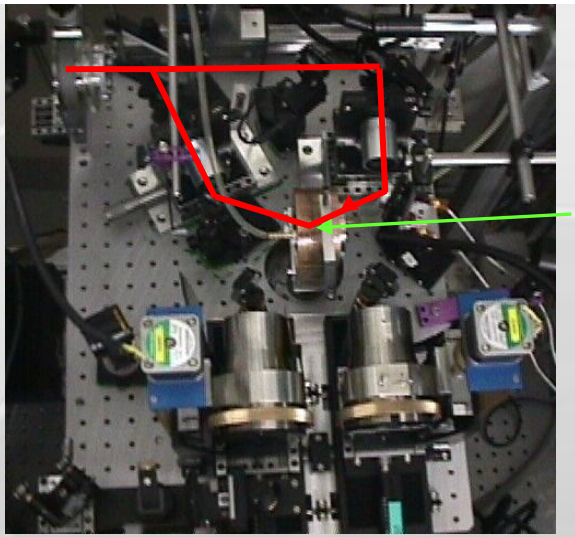
Large ribosomal subunit from Deinococcus radiodurans (courtesy A.Yonath,Weizmann Institute)

High Pressure Beamline ID27

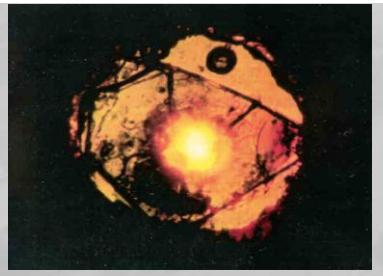
A unique tool to explore the Earth's interior



Double sided laser heated diamond anvil cell setup on ID27

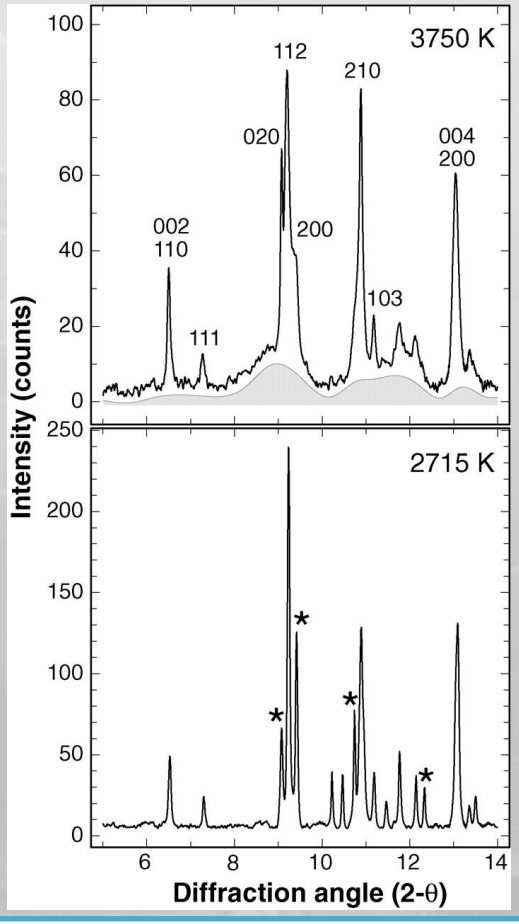


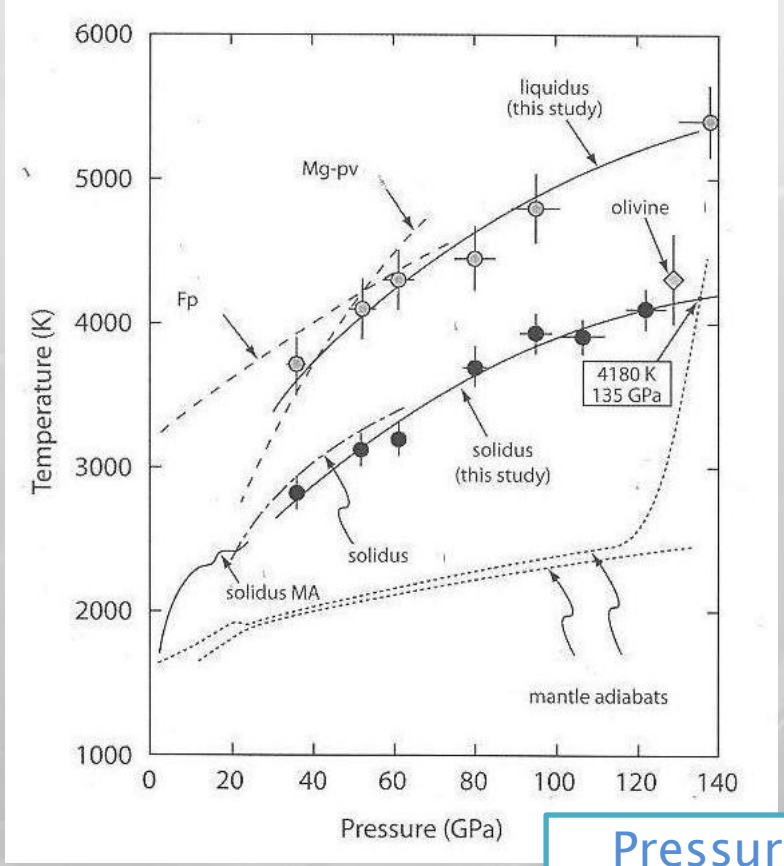
Laser heating of minerals at HP and HT



Structural investigation of planets cores at real conditions (P>2Mbar and T>4000 K)

First direct evidence that the D'' layer located at the bottom of the Earth's mantle (2900 km depth) contains partially molten minerals





- This result supports the existence of a deep magmatic ocean.
- It will contribute to our understanding of the complex geodynamics of our planet.

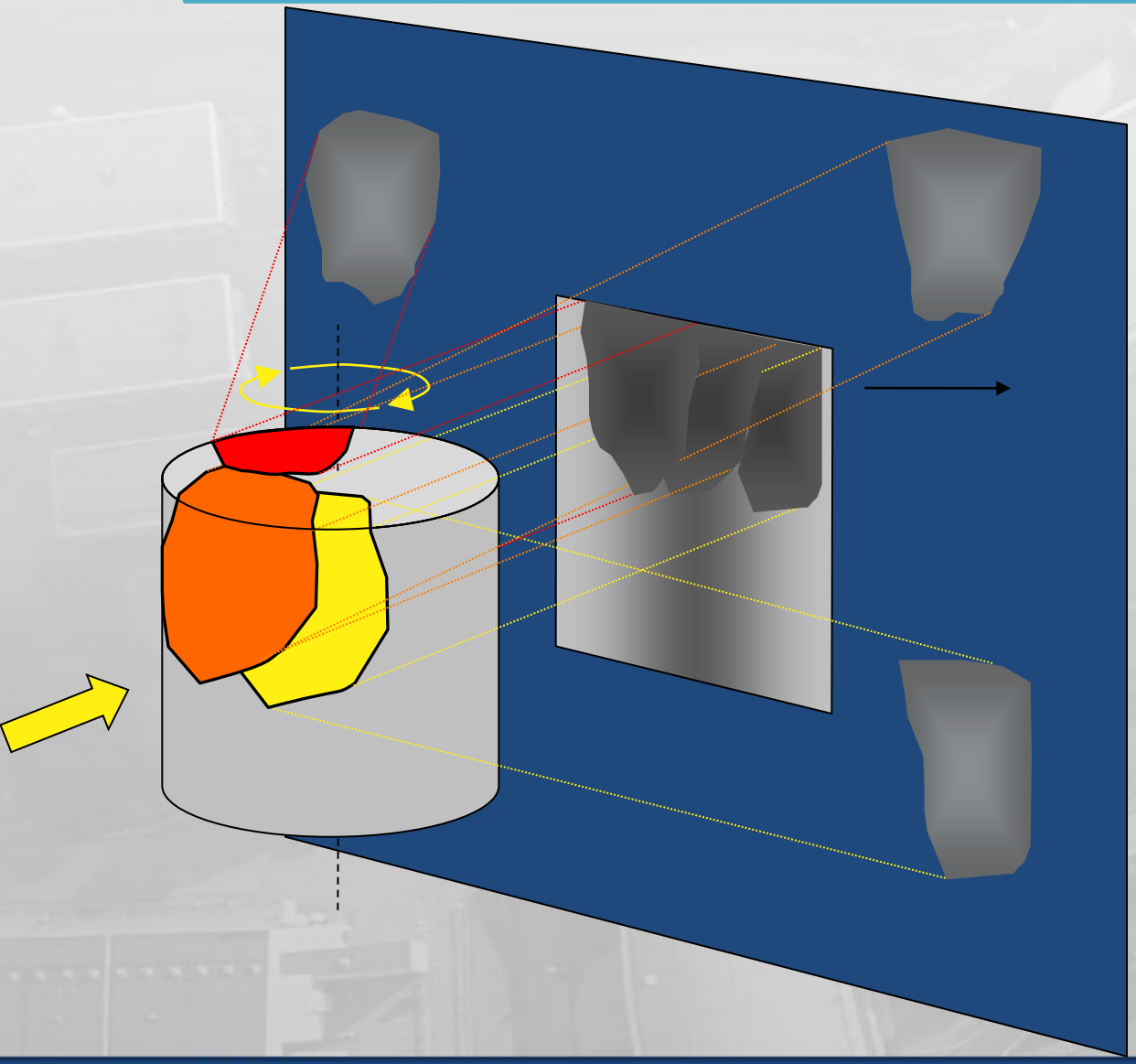
Pressures: 36 – 140 Gpa
Temperatures:2500–5000 K

Melting of Peridotite

(Olivine and iron–magnesium silicates)

Reference: G. Fiquet et al., Science, 329,1516 (2010)

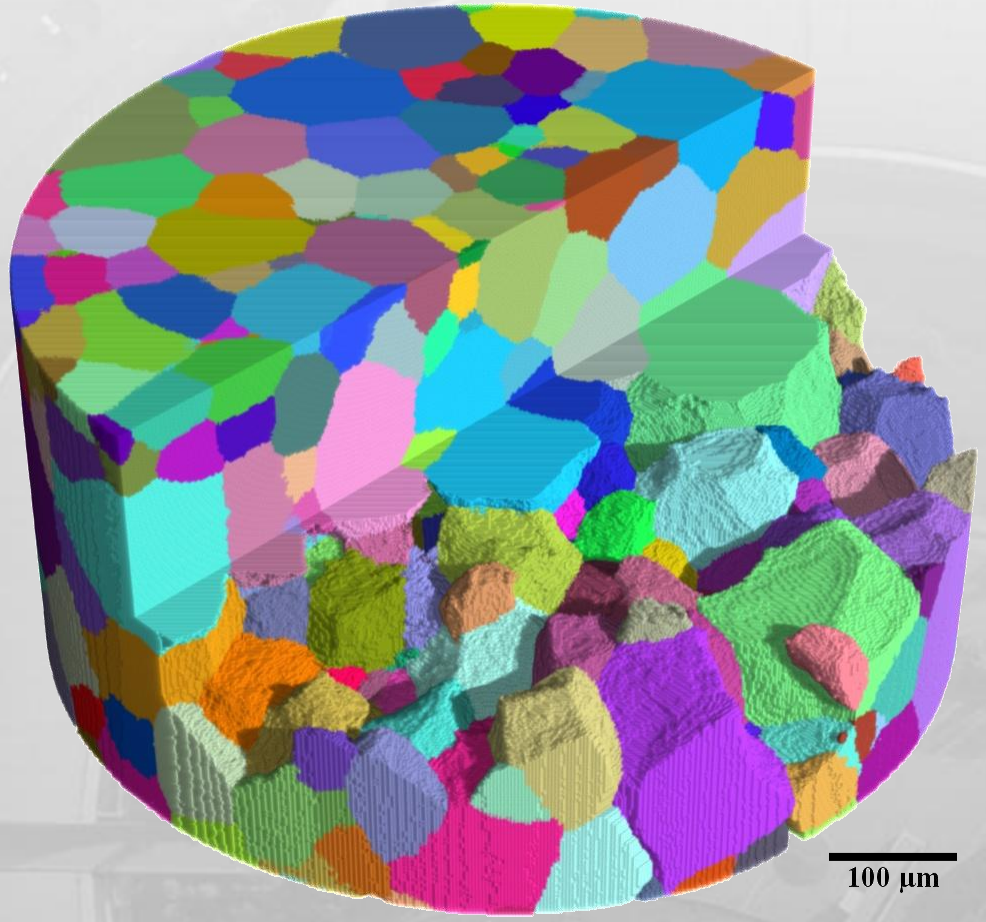
Diffraction Contrast Tomography



Acquisition of both diffraction and extinction data provides grain distributions, orientations and strain state in materials without density contrast

Diffraction Contrast Tomography

Algebraic reconstruction methods allow the calculation of 3 dimensional grain maps with micron-level precision



W. Ludwig et al., *Rev. Sci. Instrum.* (2009)

Combining Grain Mapping and Tomography

Grain map from diffraction contrast tomograph to identify grain shapes and orientations

A. King, et al., *Science (2008)*
G. Johnson, et al., J. Appl. Cryst. (2008)

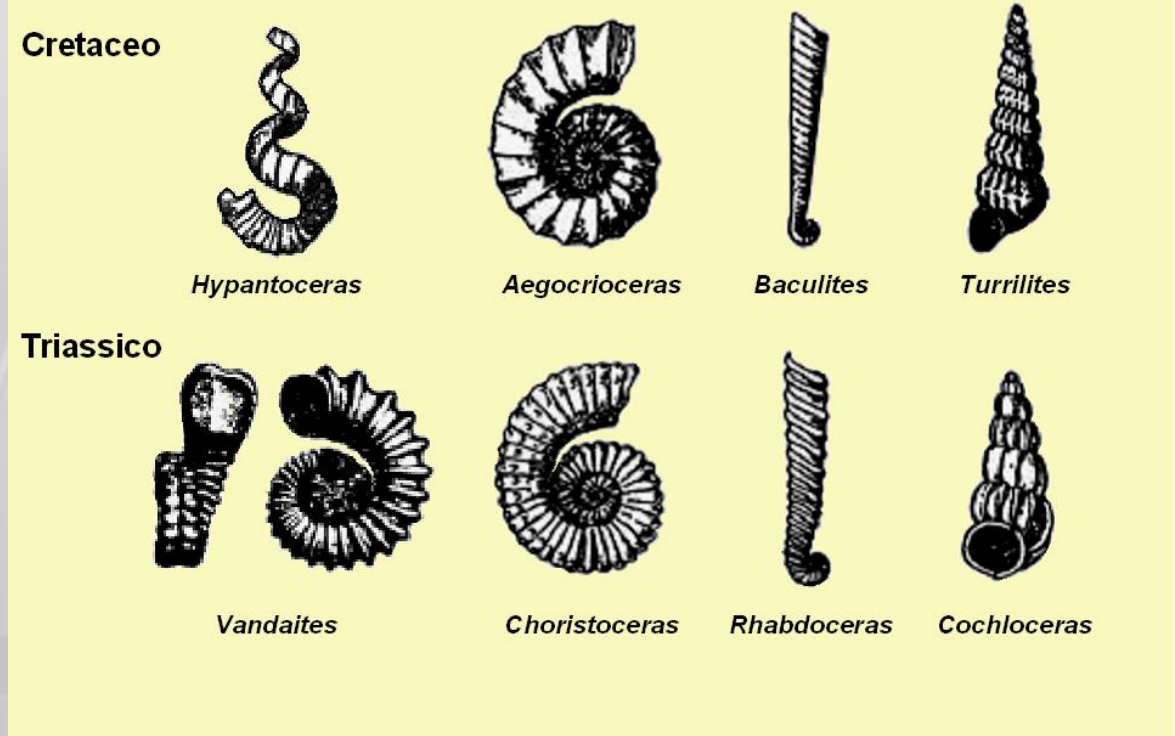
To relate crystal orientations to crack propagation

X-ray imaging: the first steps

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

The first "röntgenogram"
8 November 1895

Ammonites where almost everywhere ~100 Million years ago!



Ammonites last meal: ESRF sheds a new light on past marine food chains

Kruta I., Landman N., Rouget I., Cecca F. and Tafforeau P.

The Role of Ammonites in the Mesozoic Marine Food Web Revealed by Jaw Preservation

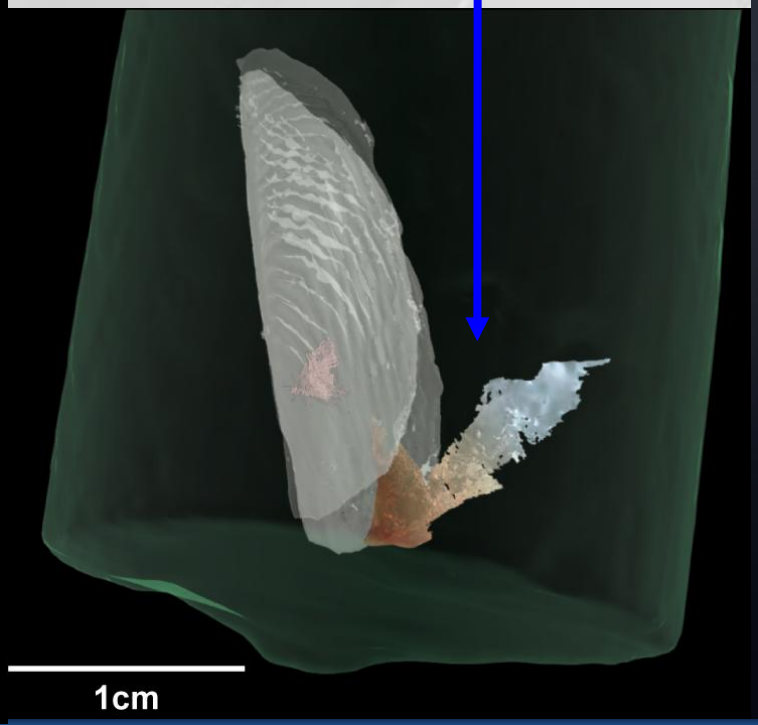
Science. 331(6013): 70-72.

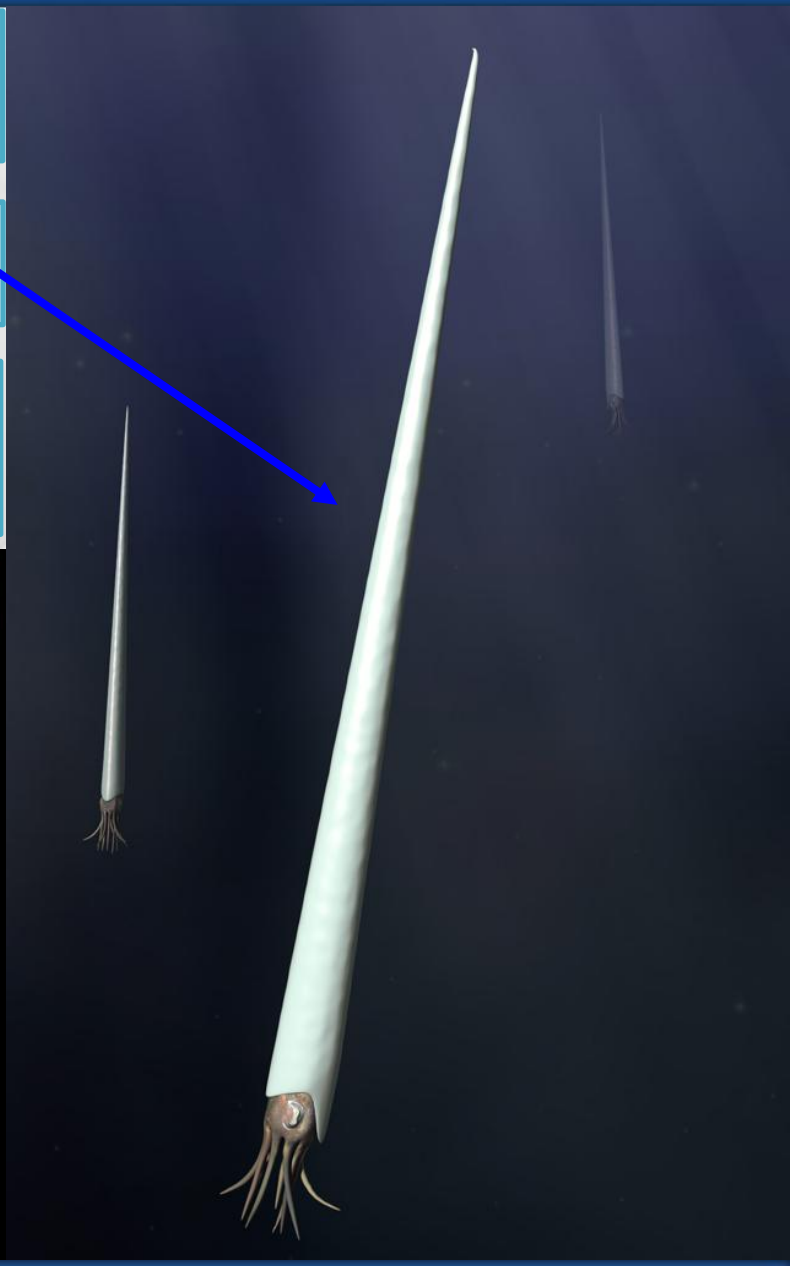
One of the fossil *Baculites* sp.

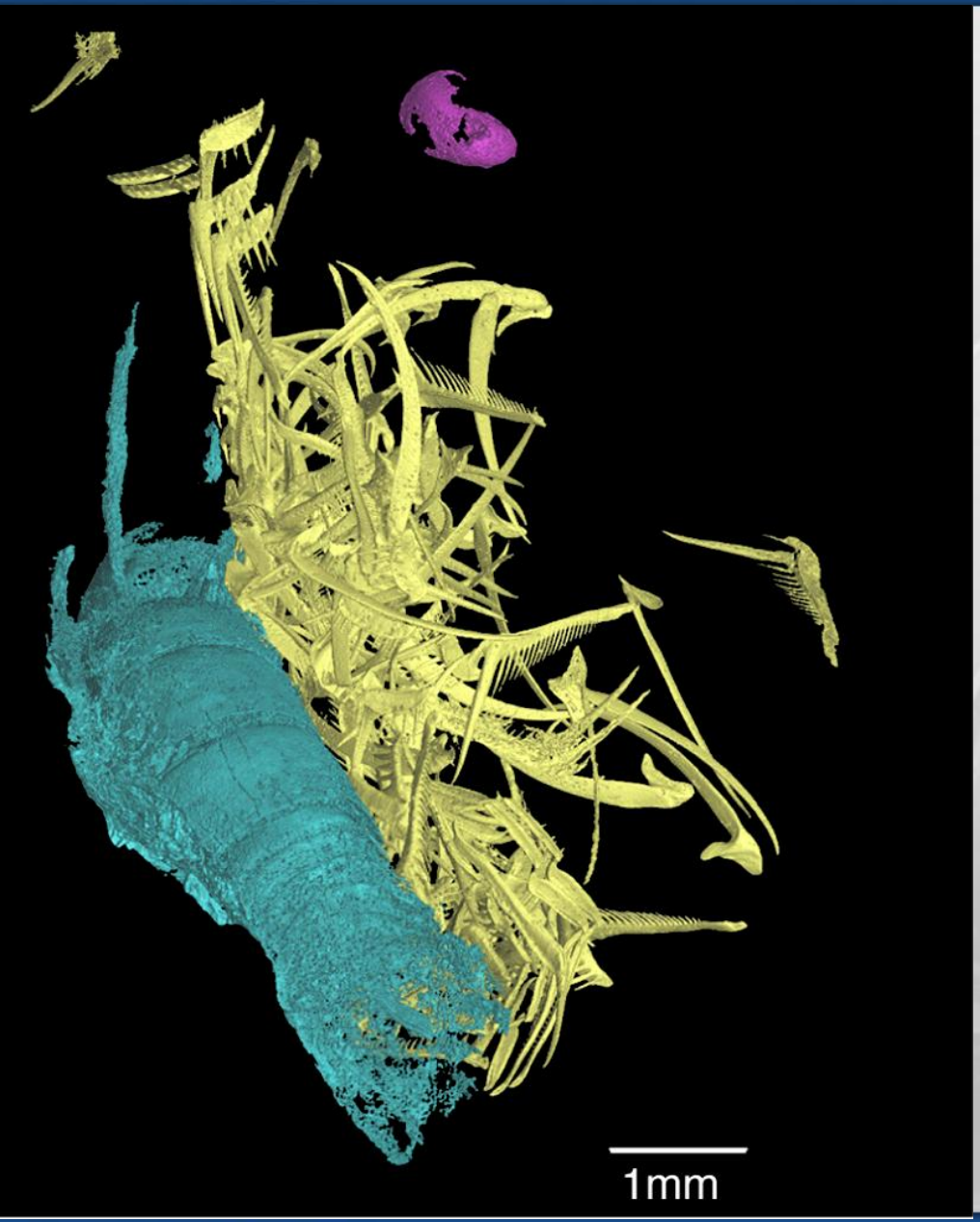
Cretaceous uncoiled ammonite

Hypothetical reconstitution of *Baculites* sp. in its life position

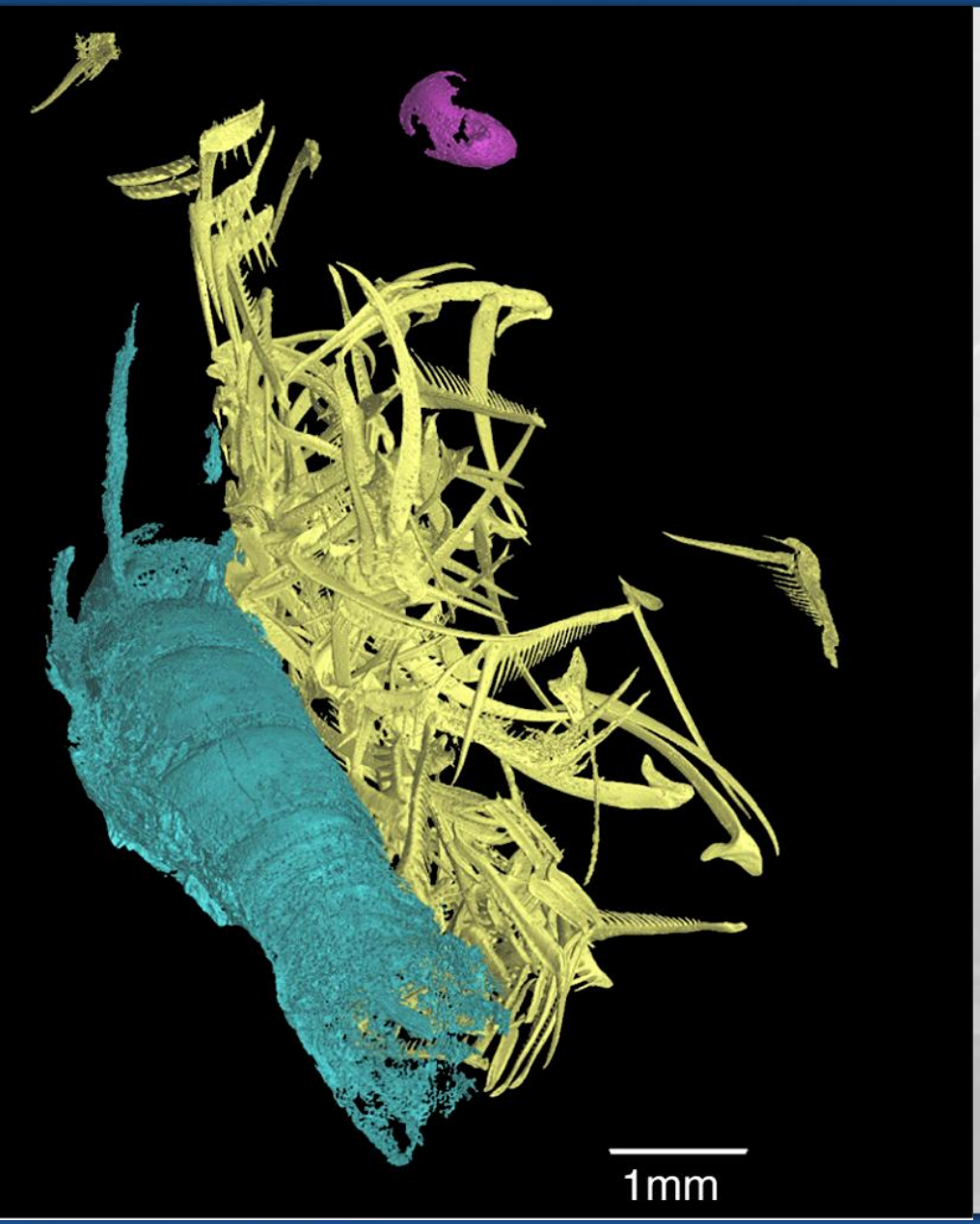
Discovery of the internal structures of the mouth (jaws and radula)






1mm

Virtual 3D extraction of the radula of *Baculites* sp. using propagation phase contrast microtomography on the ID19 beamline (pink beam, voxel size 5μm)



- Extraction of the radula and the last meal of *Baculites.*
- *Baculites* and most of upper Cretaceous period ammonites were feeding on plankton.
- At the end of the Cretaceous period, when dinosaurs went extinct, plankton was also strongly decimated.
- Reduction of plankton led to breakage of some marine food chains, and may then have played a major role in the extinction of the ammonites.

The ESRF Upgrade Programme

ESRF Upgrade Programme

New, better science

ESRF Upgrade Programme

Vision for 2009 to 2018 mapped out in Purple Book

07: to ap

- Science
- Enabl
- Bud

300 M€ New Investment for 2009-18
166 M€ Approved (PHASE-I) for 2009-15
86 M€ NEW Investment for 2009-15

ESRF Upgrade Programme

Instruments and more powerful and stable source for users

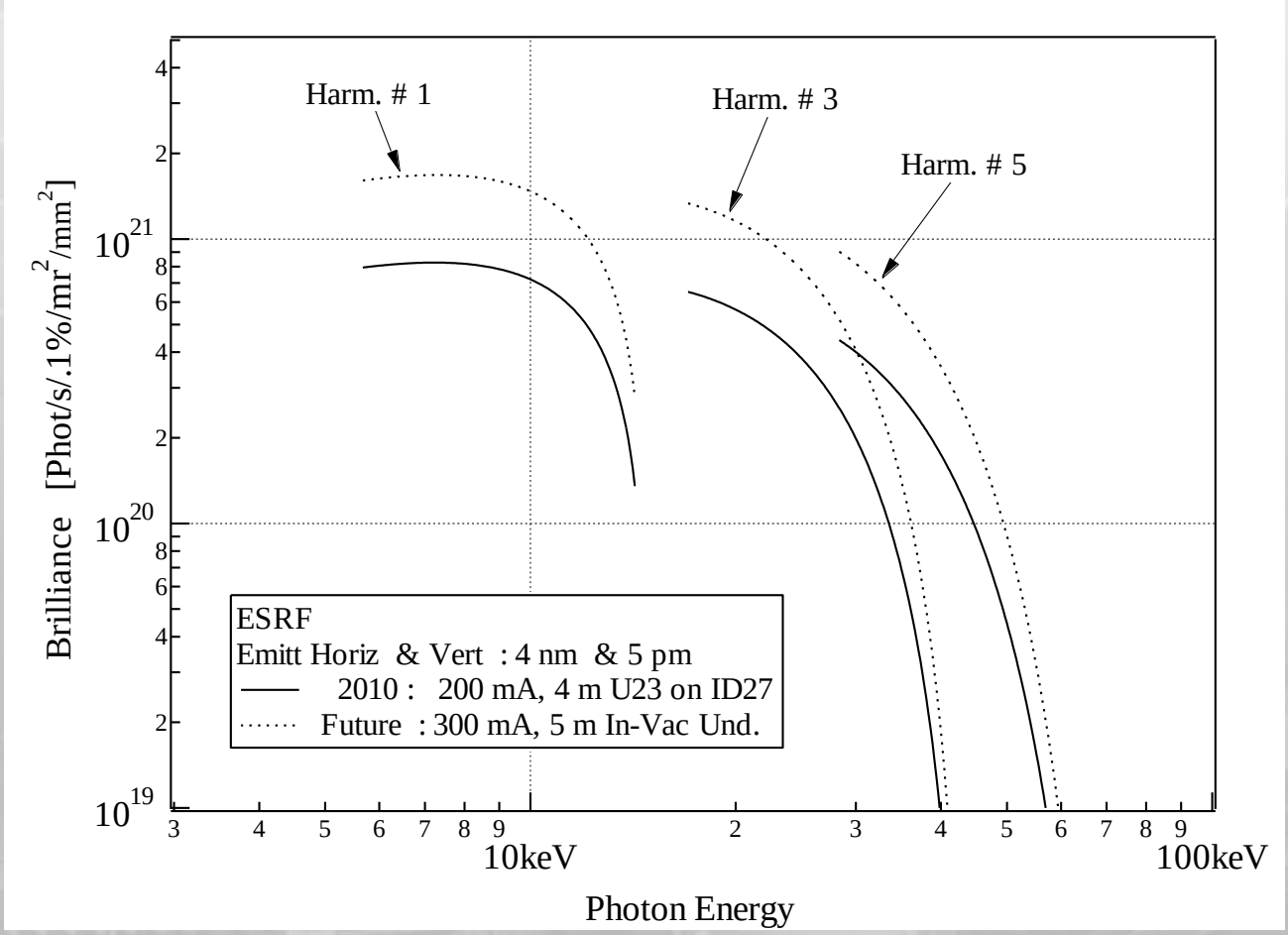
Objective: new, better science in five key areas linked to societal challenges.

ESRF Upgrade Programme

A busy time at the ESRF …..

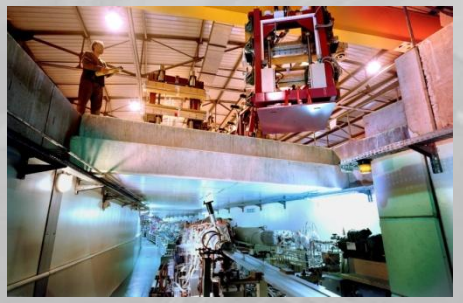
- Preparing the Future: Five Pillars
  - 8 New *state-of-the-art* Beamlines
  - New Instruments
  - Accelerator and Source Upgrades
  - Extension of the Experimental Hall
  - Partnerships and Collaborations

Accelerator and Source Upgrades



ID27 benefits from World Record Brilliance!

Accelerator and Source Division



Partnerships and Collaborations

- Partnership for Strucural Biology:
  ESRF + ILL + EMBL + IBS + UJF
- Institut de Biologie Structurale (CEA-CNRS-UJF)
- Partnership for Soft condensed Matter:
  ESRF + ILL + ….

- Partnership for Extreme Conditions:
  ESRF + ILL + ….
- Initiative in Paleontology: ESRF+….
- High Magnetic Field Project:
  ESRF + ILL + EMFL + CNRS ….
- Technology Building for Industry:
  ESRF + ILL + CEA + ….

Grenoble: a stimulating environment

GIANT GRENOBLE INSTITUTE OF NANO TECHNOLOGIES

ESRF

EMBL

ILL

CNRS

CEA

Minatec

Grenoble: a rich and stimulating environment for EMBL, ESRF and ILL

70,000 University Students
20,000 Professionals in Science and Technology

STMicroelectronics

Schneider

Mérieux

Universities INP and UJF

Siemens

Thank you!

A Light for Science

ESRF