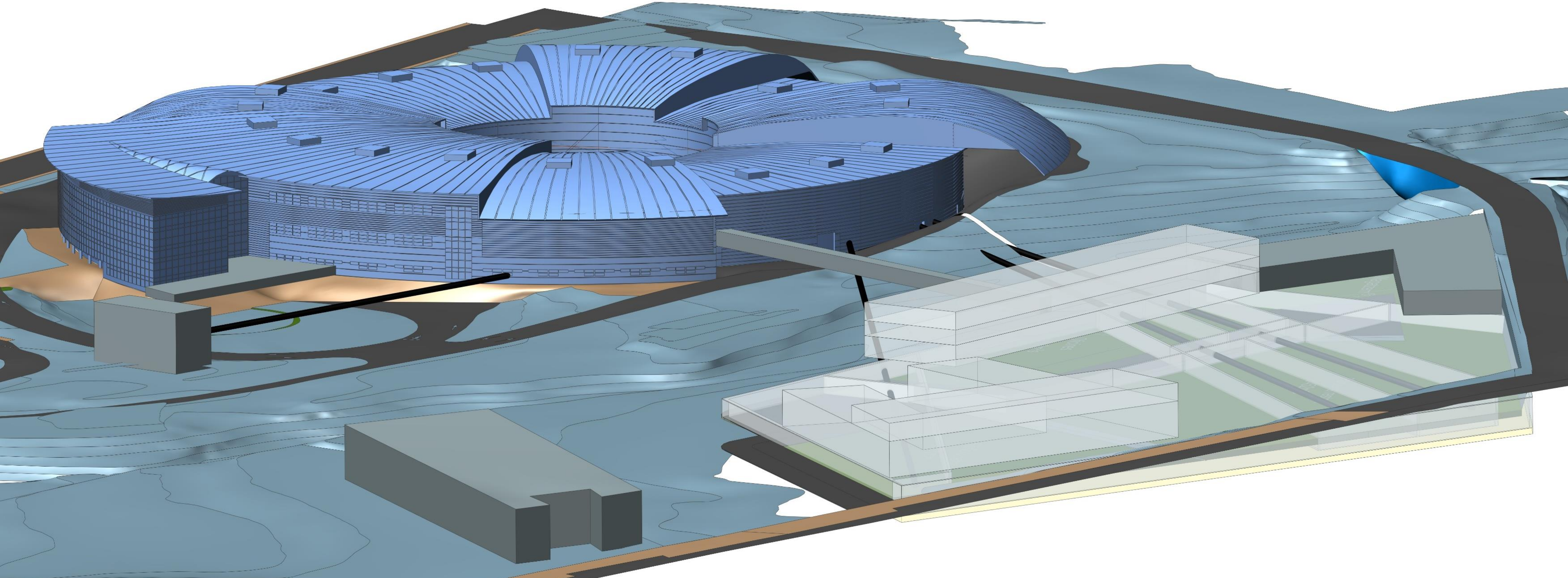
ALBA and science for sustainability

Caterina Biscari

15 December 2022



Generalitat de Catalunya
Departament de Recerca
i Universitats

Sustainable world

From a model of exploiting earth resources as if they were unlimited to the awareness of their finitude and of the need to change explotation habits

Sustainable world

What can and must scientists do?

Synchrotrons in the world, aligning their capacities to be part of the solution

https://earth.google.com/web/data=MkE
ExUlBmMDlsQl9LYnM0ehtUEFVaXZiTVFs
XWUsSFgoUMDA2NzMyODlBRjI2NDZGRE
Q

LEAPS League of European Accelerator-based Photon Sources

at a glance

LEAPS is the largest consortium of analytical facilities world-wide and further expanding its service to an interdisciplinary European user community

19 facilities - **16** institutions - **10** countries

> **300** operating End Stations

- **1.000.000** h beamtime /year

Excellence-driven access free of charge

> **5.000** publications/year

> **15** spin off companies

> **35.000** users from all EU & beyond
researchers from all research area

To be prepared for future urgent challenges ESAPS 2022

European Commission

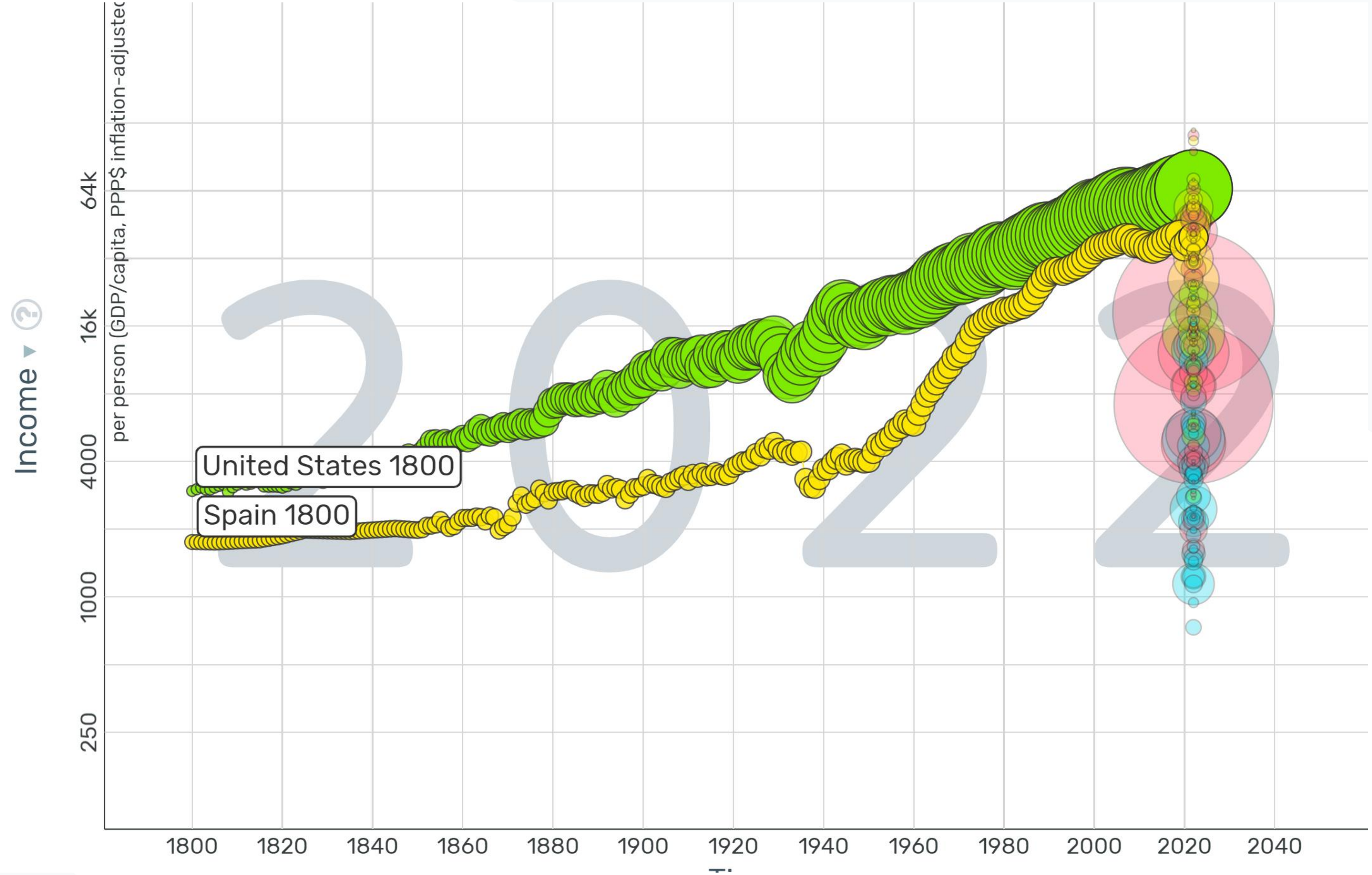
Enhancing collaboration among facilities and countries as a European assess

Aiming at European funding for targeted challenge-driven access
to support taylored operando technologies at LEAPS facilities and specific operation costs

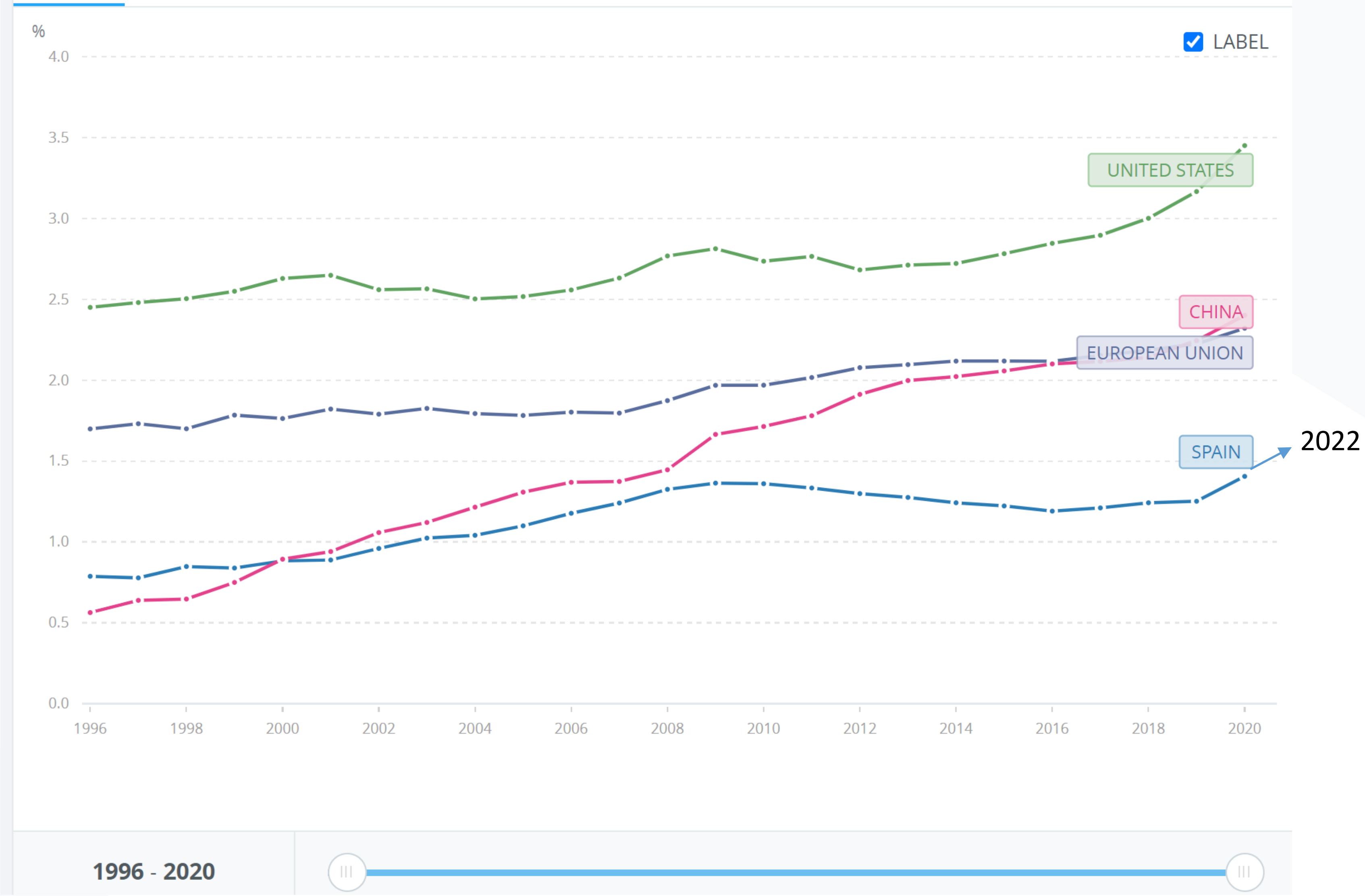
- supports **high quality research** in Europe,
- contributes to develop the skills of the **next generation of scientists and engineers** in Europe,
- subscribes to **diversity, gender balance, anti-discrimination** ("LEAPS-IDEA"),
- devises particle accelerators and associated **technologies of tomorrow** for a wide range of use in manufacturing and service industries in health, materials design, energy and security,
- supports European industry in **new product development** and market and by accelerating product design and development,
- devises **deeptech roadmaps** in close cooperation with European industries
- contributes to European **technology sovereignty**
- supports ERA Priority Actions.

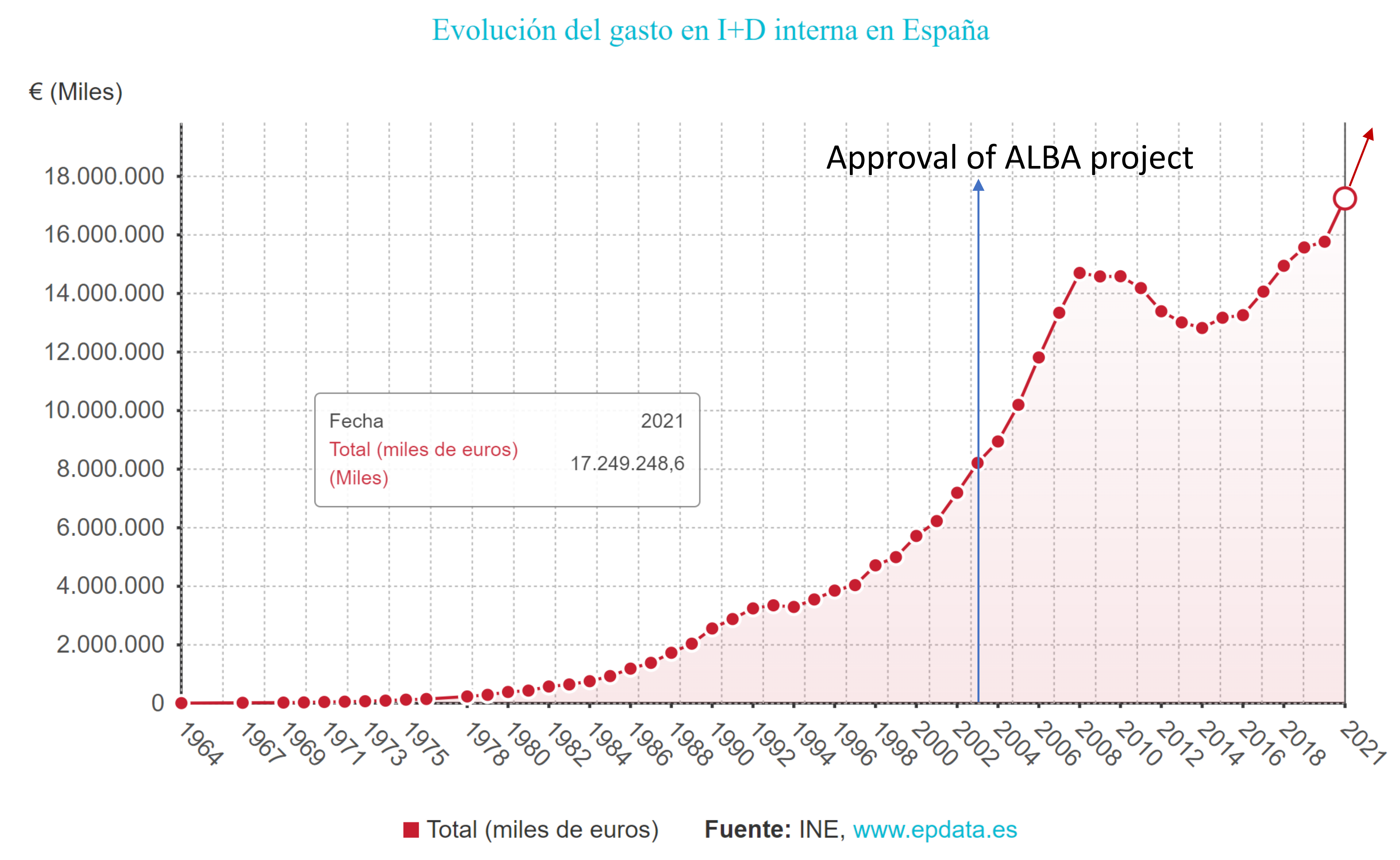
Spain
47 M inhabitants
GDP 45000$

GDP in Spain vs US (gapminder.org) – two centuries span



Research and development expenditure (% of GDP) - Spain, United States, European Union, China https://data.worldbank.org/



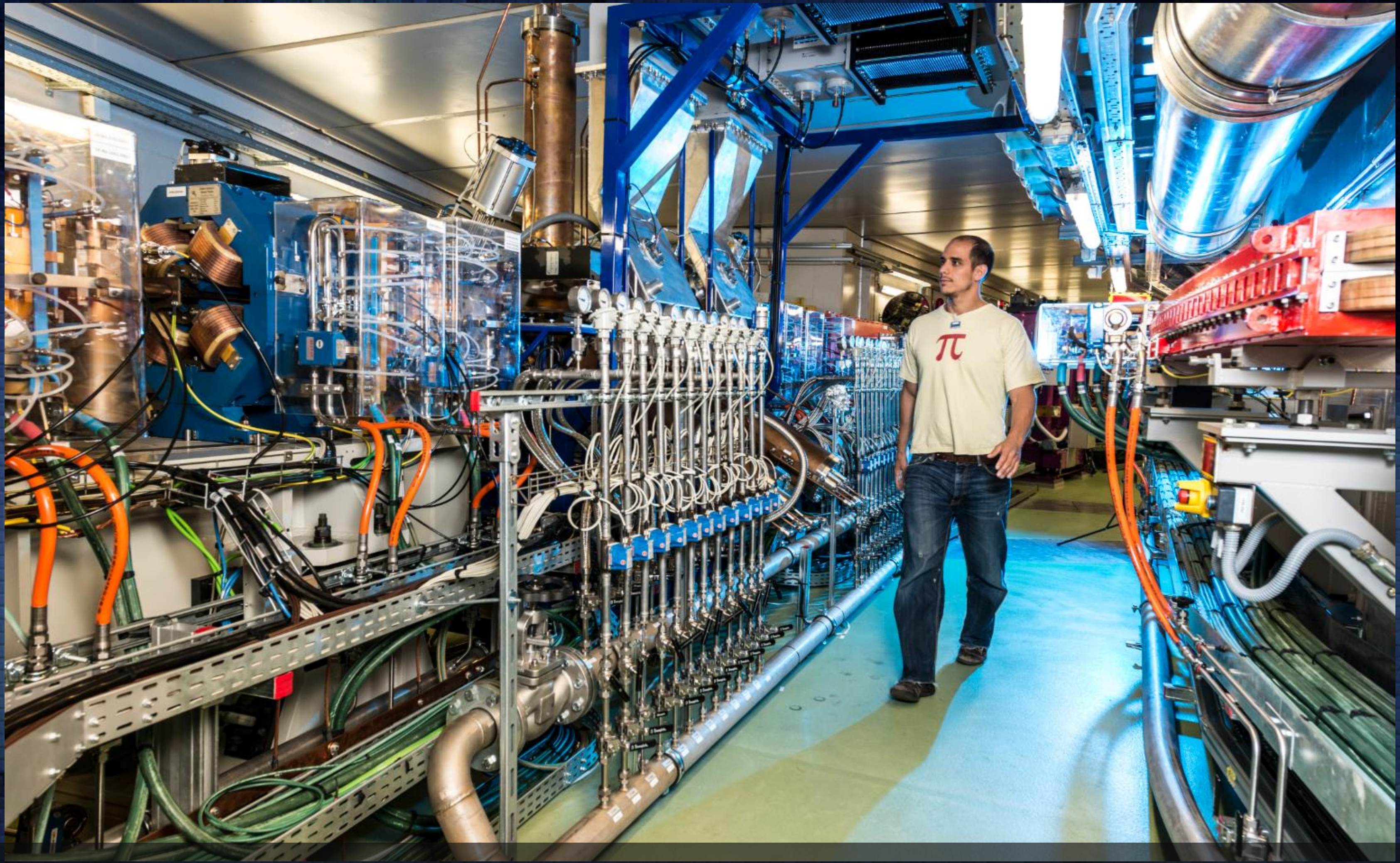


Evolución del gasto en I+D interna en España
€ (Miles)
Approval of ALBA project
18.000.000
16.000.000
14.000.000
12.000.000
10.000.000
8.000.000
6.000.000
4.000.000
2.000.000
0
Fecha 2021
Total (miles de euros) (Miles) 17.249.248,6
1964 1967 1969 1971 1973 1975 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2021
Total (miles de euros)
Fuente: INE, www.epdata.es

ALBA, the Spanish Synchrotron

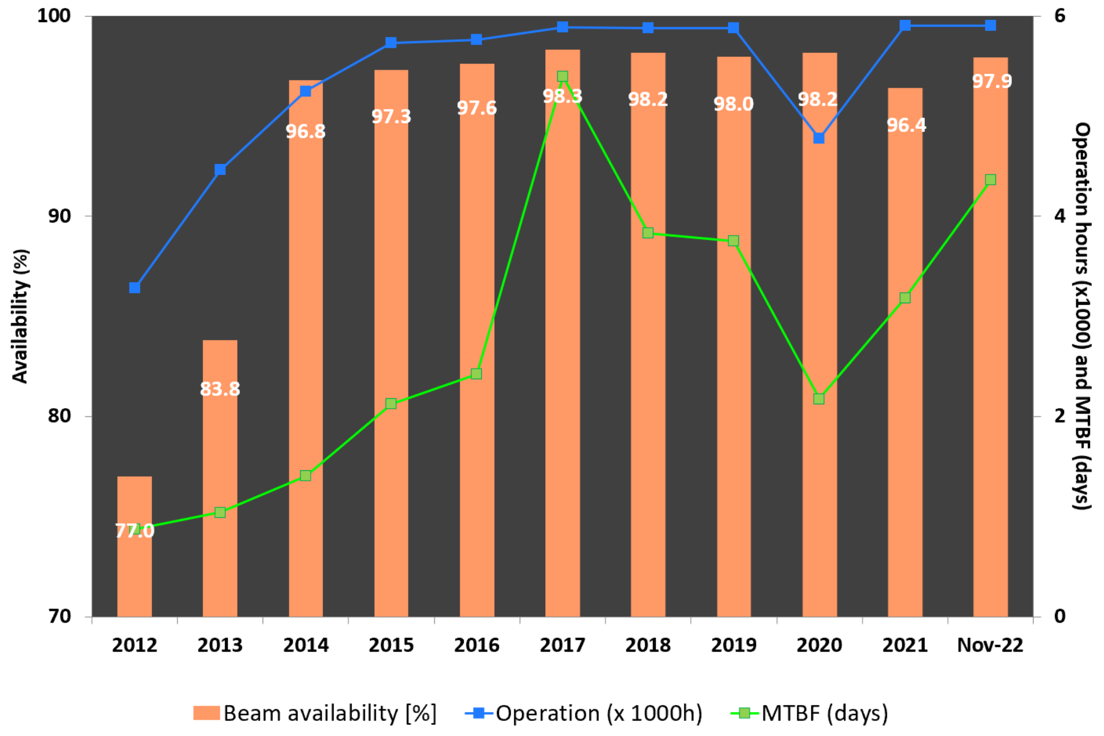
National public institution, funded
50% national Government (Ministerio de Ciencia e Innovación)
50% regional GenCat (Department de Recerca i Universitats)
User facility open to international academic and industrial communities

The accelerator



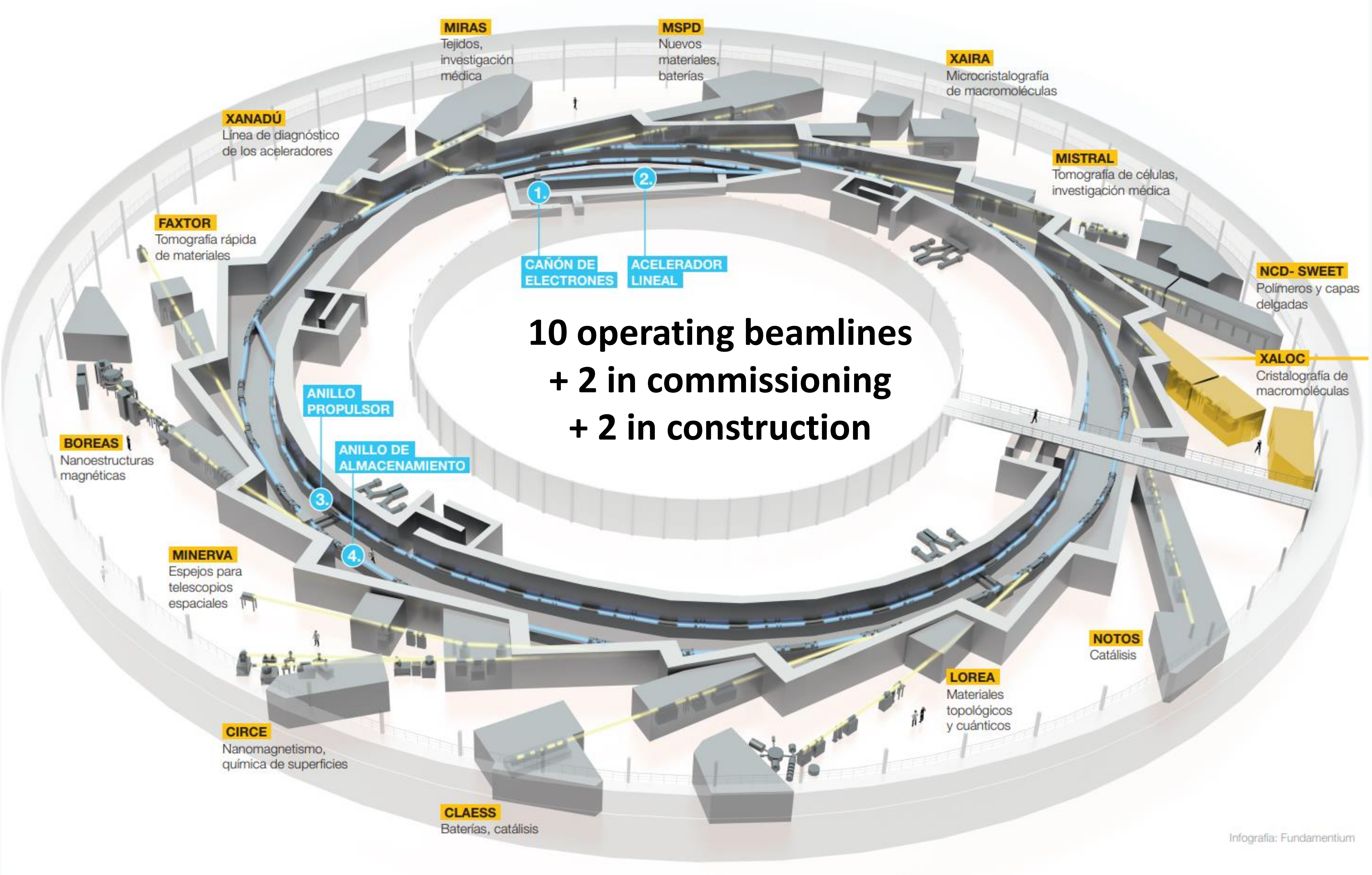
ALBA storage ring – 3rd generation light source
3 GeV electrons - 270 m circumference

Excellence in operation through one-decade



SR Parameter	Value
Energy	3 GeV
Circumference	269 m
Emittance	4.4 n mrad
Current	250 mA
Rf frequency	500 MHz
# cavities	6
Long straights	4 (8 m)
Short straights	12 (4 m)

ALBA Synchrotron



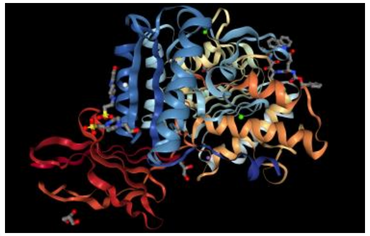
10 operating beamlines
+ 2 in commissioning
+ 2 in construction

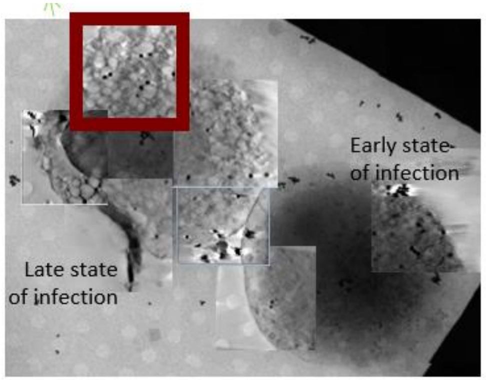
ALBA Synchrotron Research Infrastructure

Three Scientific Sections, three main research lines

Life Science

From the protein, to cell, to tissues

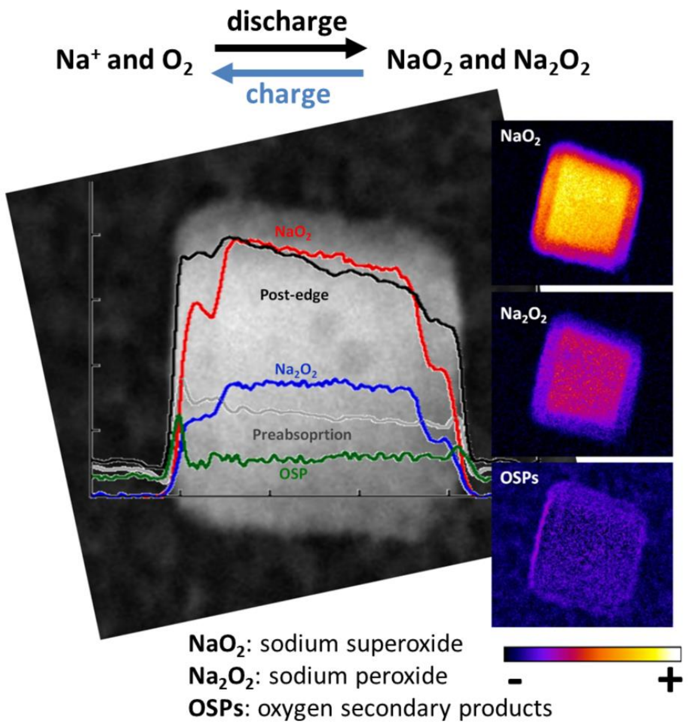




Cell infected by covid-19

Chemistry and Material Science

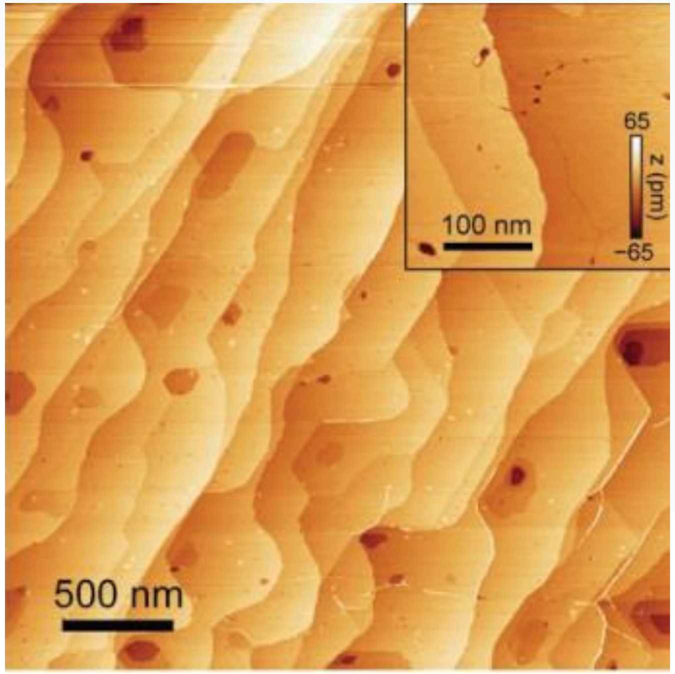
Energy material, catalysts, environment



Battery developments

Electronic and Magnetic Structure of Matter

Advanced materials



Nanomaterials for data storage

The BEAMLINES

Absorption and emission spectroscopy, soft X-ray tomography, IR microscopy, Small and Wide Angle Scattering, HR and HP Powder Diffraction, Crystalline Diffraction, Photoemission, NAPP, ARPES, Resonant absorption and scattering, *micro macromolecular crystalline diffraction, Metrology, hard X-ray tomography, Surface spectroscopy and ambient pressure photoemission*

ALBA key numbers

After 10 years of operation

230 staff

+ 2400 yearly user visits

3400 national users

+300 yearly experiments

3200 international users

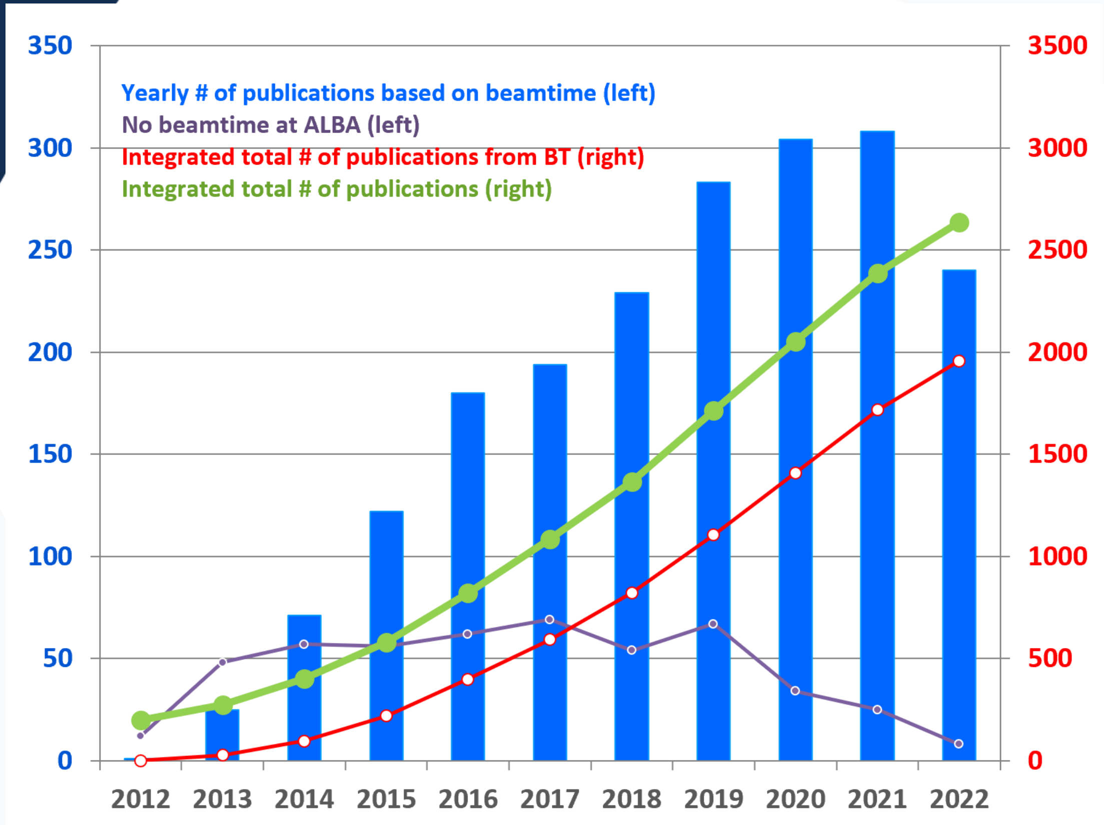
+2600 publications

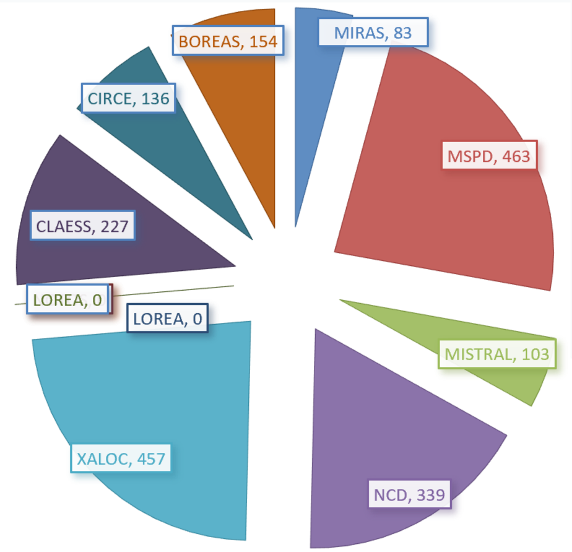
+7500 yearly public visits

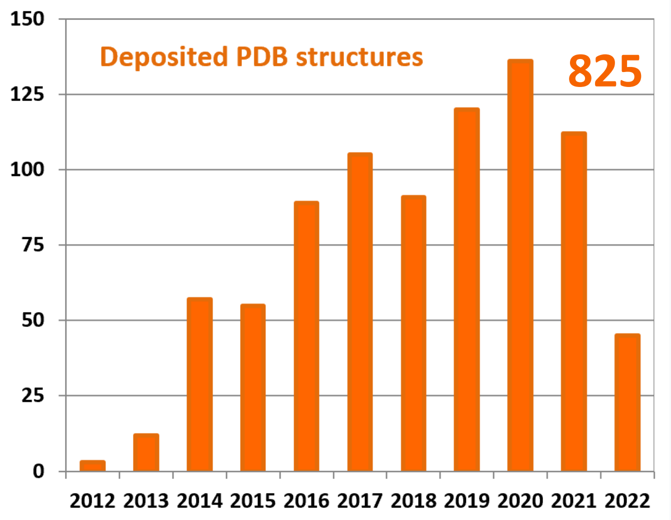
70 private user companies

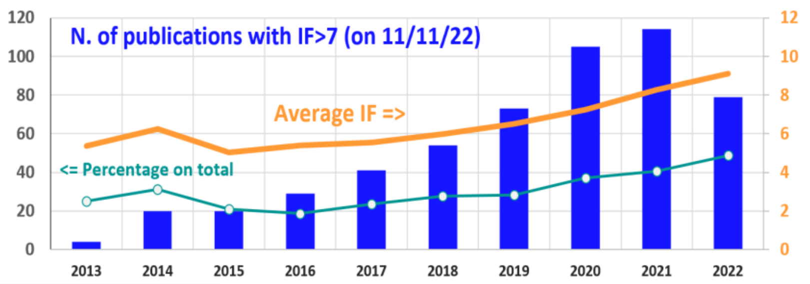
+250 trained students

Scientific productivity









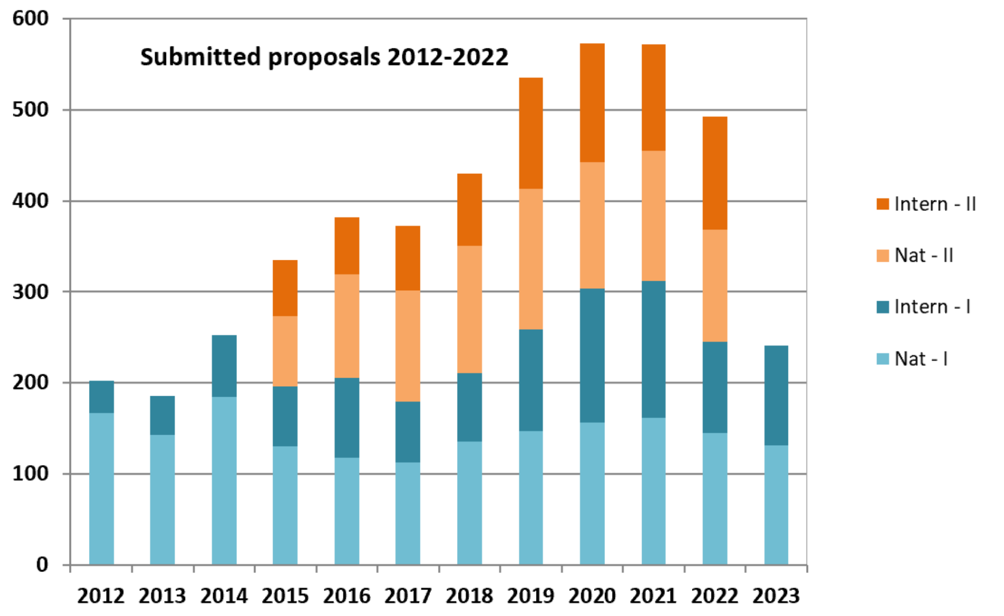
Publications per BL

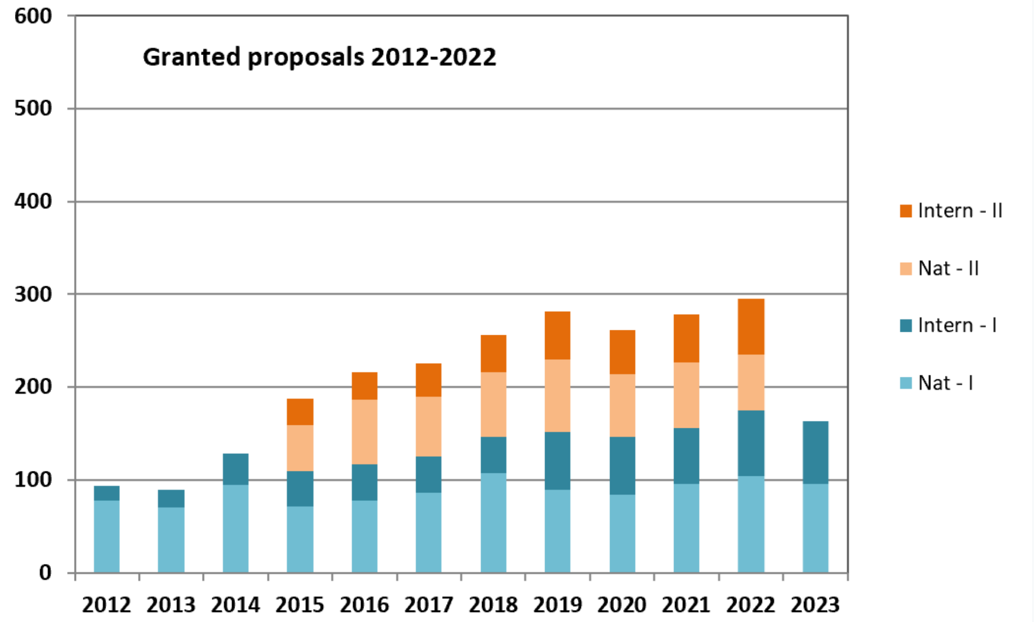
2020/2021: average # of publications per op. BL > 38

2021: <IF> = 8.3; 41% of publications with IF>7

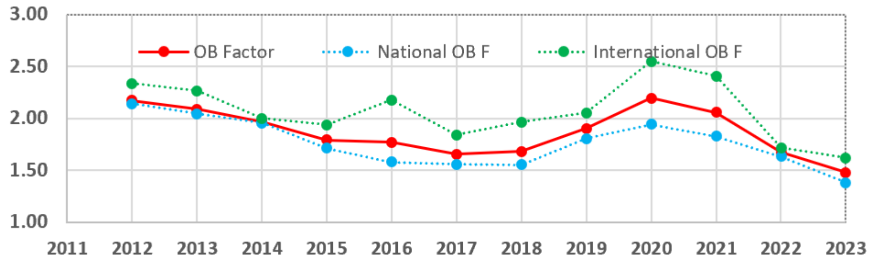
2022: <IF> = 9.1; 49% of publications with IF>7

Academic and competitive user access



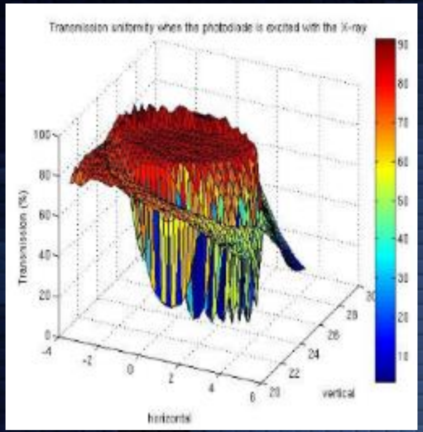


	Submitted	Granted	OF
National	2742	1582	1.7
International	1831	890	2.1
TOTAL	4573	2472	1.8



Today

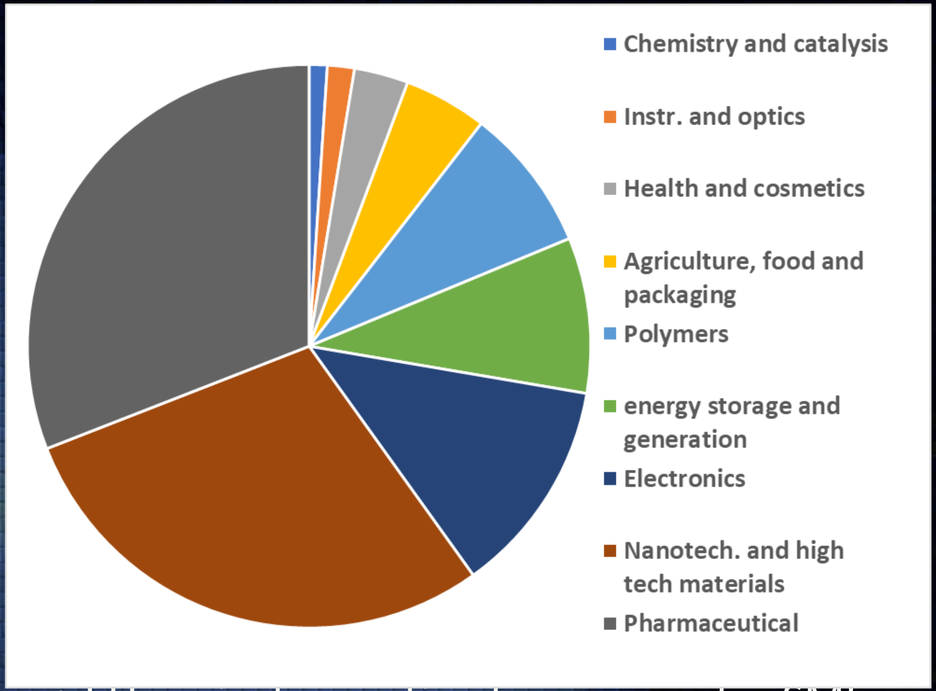
Technological transfer



Dedicated staff

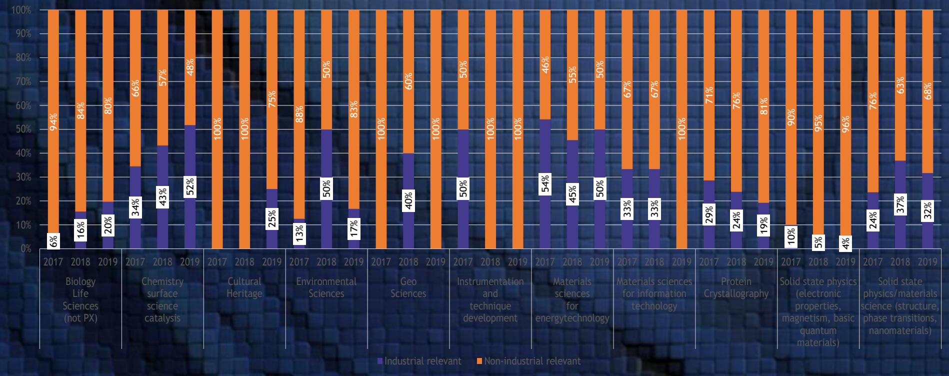
ALBA innovation

Industrial beamtime – 70 different companies

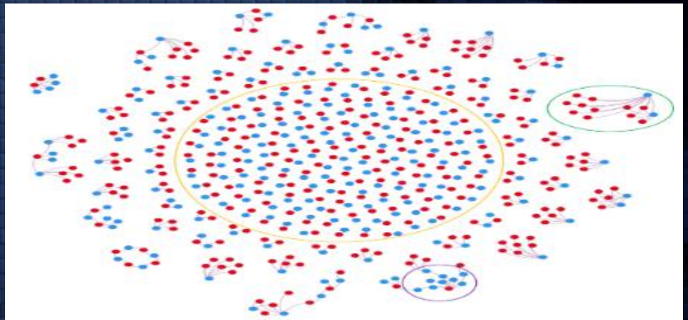


+ EU projects granting free access for SME

Industrial relevance of academic experiments



Patents citing publications

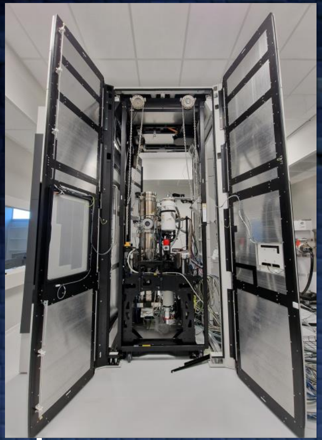


243 ALBA P1 publications (blue dots) out of a total of 9974 are directly cited by 337 patents (red dots)

H2020 pilot project (2018)

15 patents + 337 citing ALBA

Today



Partnerships:
- Joint Electron Microscope Center at ALBA (JEMCA)
- InCAEM – Planes Complementarios on Advanced Materials
- Battery and catalysis programs with CSIC

League of European Accelerator-based Photon Sources

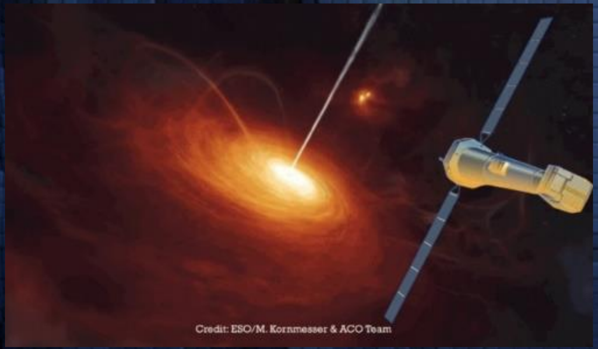
19 facilities - 16 institutions - 10 countries

ALBA Chairing LEAPS on 2020 and 2021, vice chair now

ALBA collaborations

ARIE spokesperson for start-up the collaboration

Minerva: BL in collaboration with ESA



Participation in European Commission programs

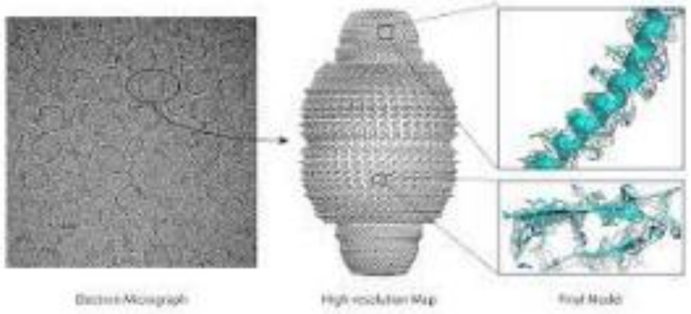
Joint Electron Microscope Center at ALBA (JEMCA)

50% Funded through Catalan ERDF and 50% co-funded by different partners

Life science

Cryo-EM receiving users from partners

- 200 kV Glacios cryo-TEM
- X-FEG optics
- Autoloader
- Equipped with the last generation of direct electron detector (Falcon 4)
- Falcon 4 server with 60 TB
- ALBA storage with 100 TB
- GPU allowing for on-the-fly processing

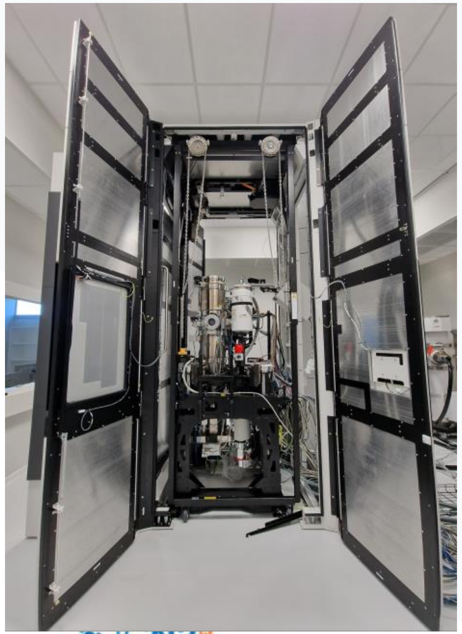


Material Science

TEM finishing commissioning

First call for external users in Spring 2023

- 60-300 keV Spectra (S)TEM
- Double aberration correction
- Monochromatic beam
- Atomic scale spectroscopy by EELS and EDX
- ALBA storage with 100 TB
- Spatial resolution < 1 Å even at 60 kV (<50 pm at 300 kV)
- Energy resolution < 30 meV

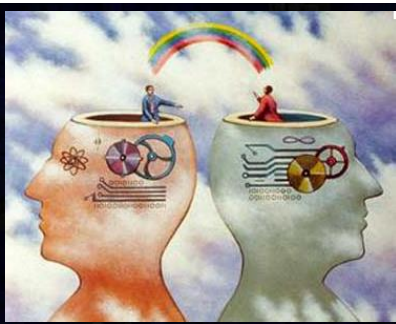


Generalitat de Catalunya Departament de Recerca i Universitats

Unió Europea Fons Europeu de Desenvolupament Regional

African School of Fundamental Physics and Applications

High-qualified job offers



+200 students trained

ALBA & society

Involvement in educational programs from schools to universities in Spain and abroad

+7500 outreach visits per year

230 staff

Outreach projects for children

Organization of scientific and industrial workshops for pharma, chemistry,…

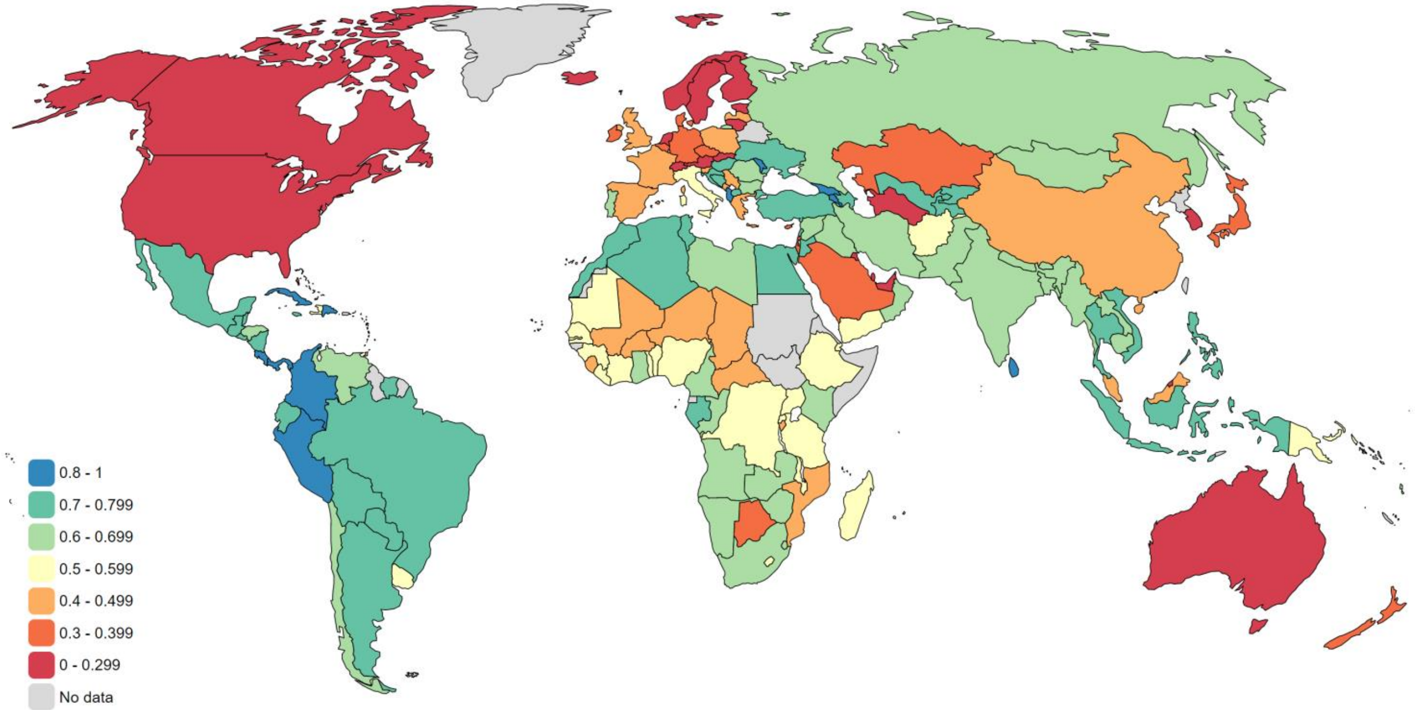
Academic and Industrial PhDs

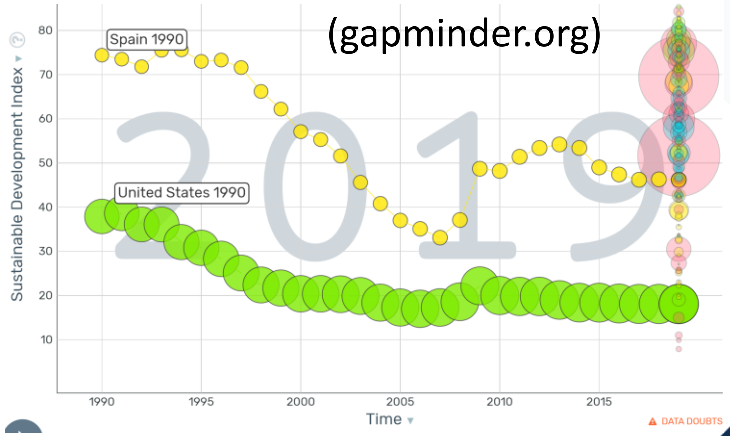
Contributing to health, clean energy, advanced technologies, climate change, environment, food, agriculture, transport & mobility, security, cultural heritage,…

Sustainable Development Index

https://www.sustainabledevelopmentindex.org/

The Sustainable Development Index (SDI) **measures the ecological efficiency of human development, recognizing that development must be achieved within planetary boundaries**. It was created to update the Human Development Index (HDI) for the ecological realities of the Anthropocene.





SDI gets higher if

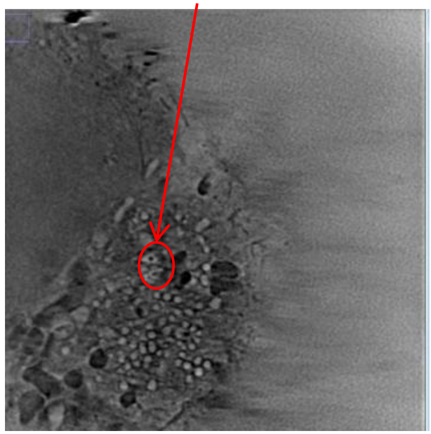
Increase: life expectancy, education and income

Decrease: consumption-based CO_2 emissions and material footprint

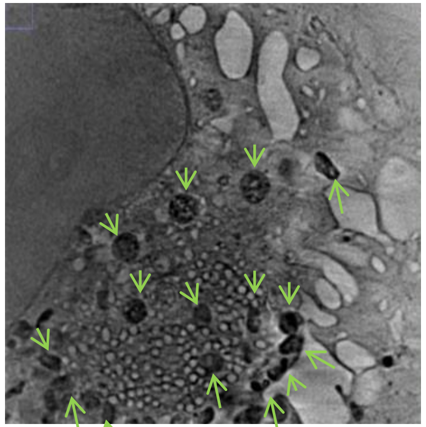
Pandemic affecting the whole world population

COVID research at BL09-MISTRAL

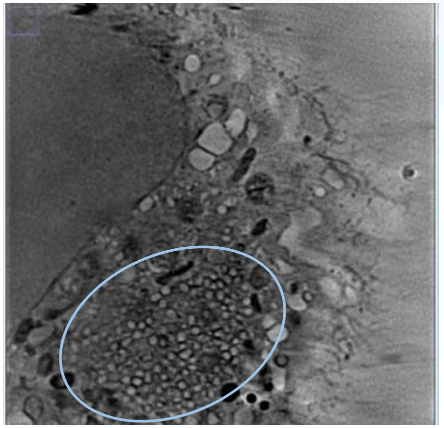
SARS-CoV-2 Intracellular viral particles



Morphological dysfunction with abnormal mitochondria

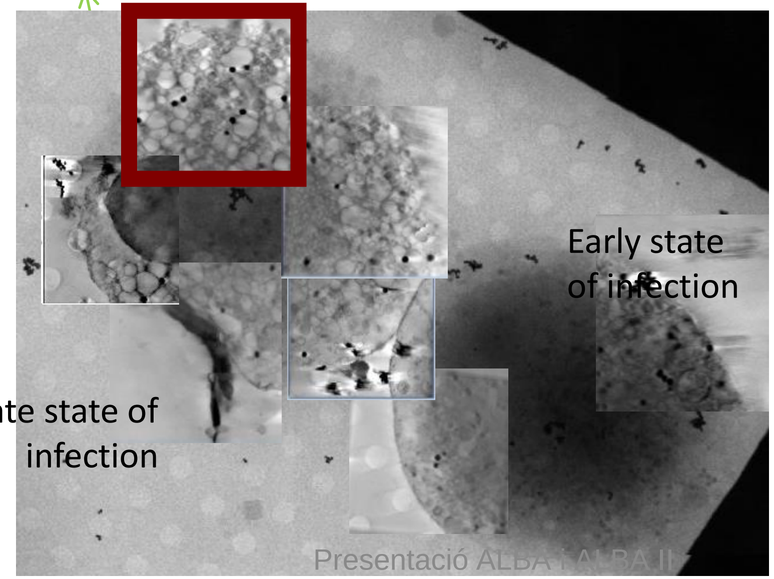


SARS-CoV-2 viral factory



Morphology of adenocarcinomic human alveolar basal epithelial cell (A549) infected with SARS-CoV-2

Evolution of cells can be studied

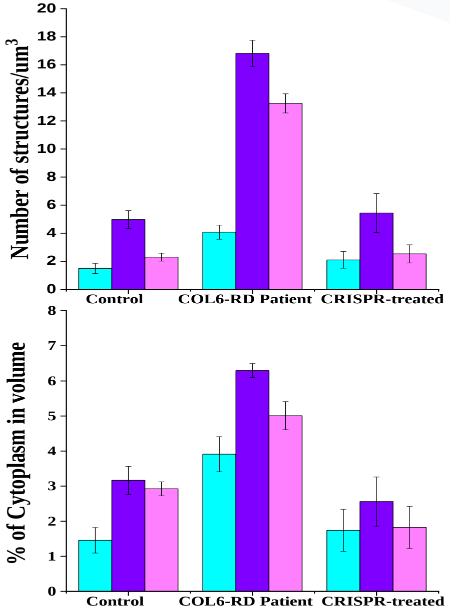


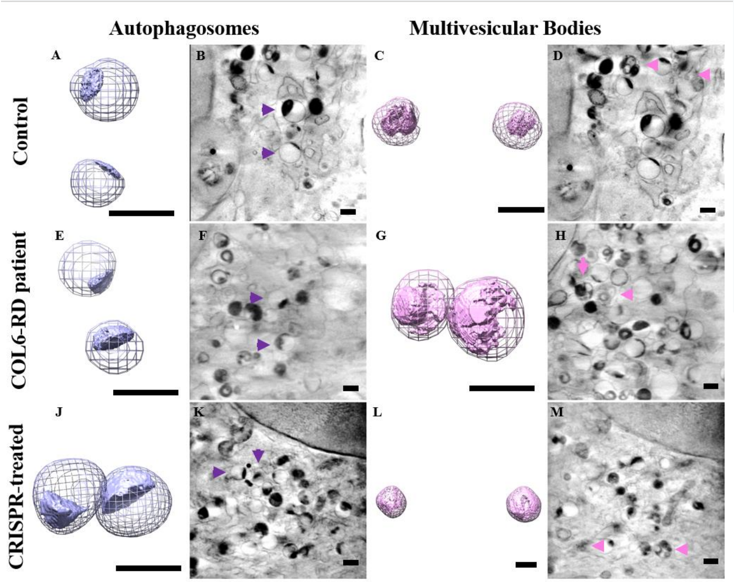
Late state of infection

3D reconstruction:
Transparent volumes: vesicles where the replicating complexes are formed.
Blue volumes: the SARS-CoV2 virus

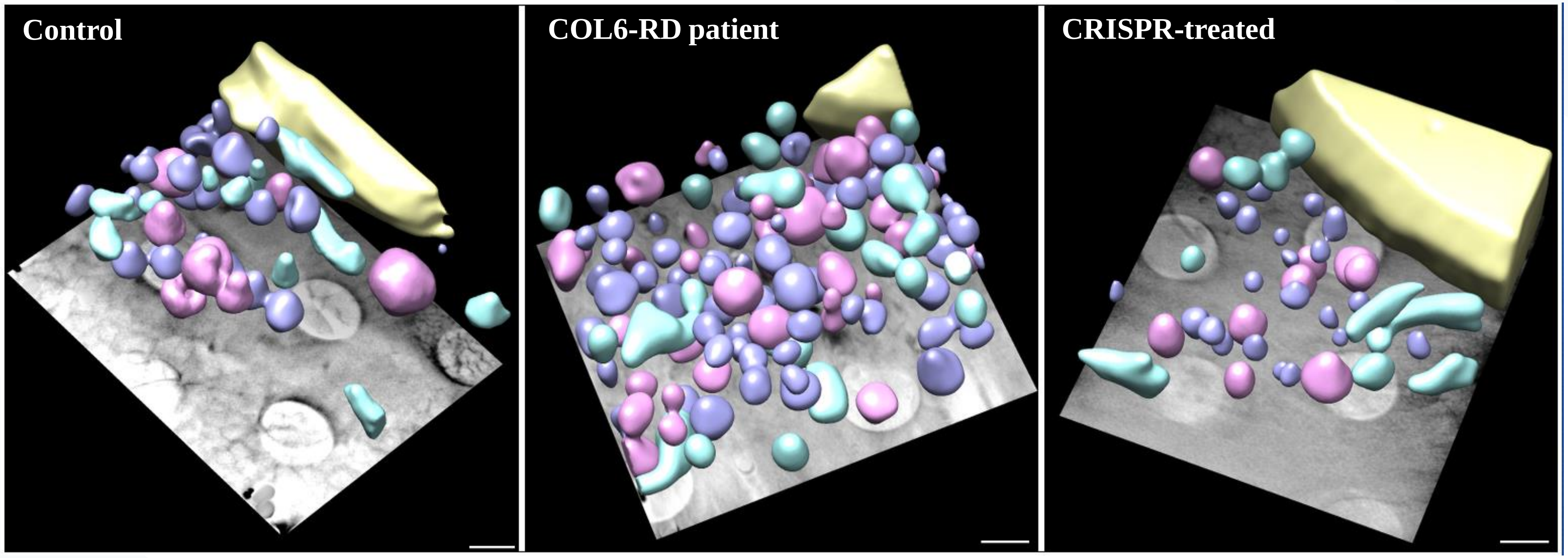
AJ Pérez-Berná, P. Gastaminza group (CNB-CSIC)

A New Tool to Proof Effectiveness of CRISPR/Cas9 Therapies: X-ray Tomography





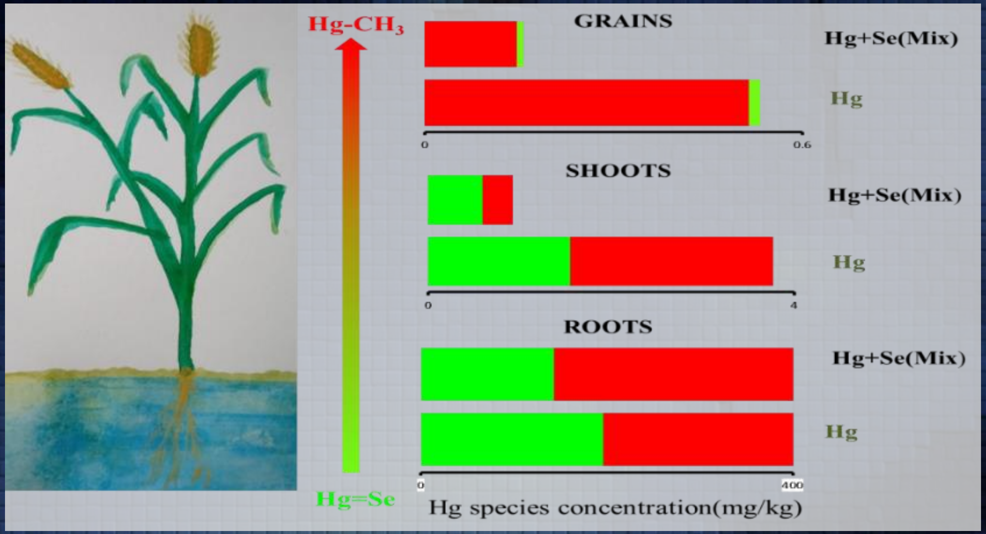
Contribution of the X-Ray tomography in the cellular pathologies field: possibility to develop the proof of concept of ***the success of gene therapy application*** *in the disease reversion of the cellular and biochemical phenotype of cells harbouring the cellular mutation triggering the disease by application of CRISPR/Cas9.*



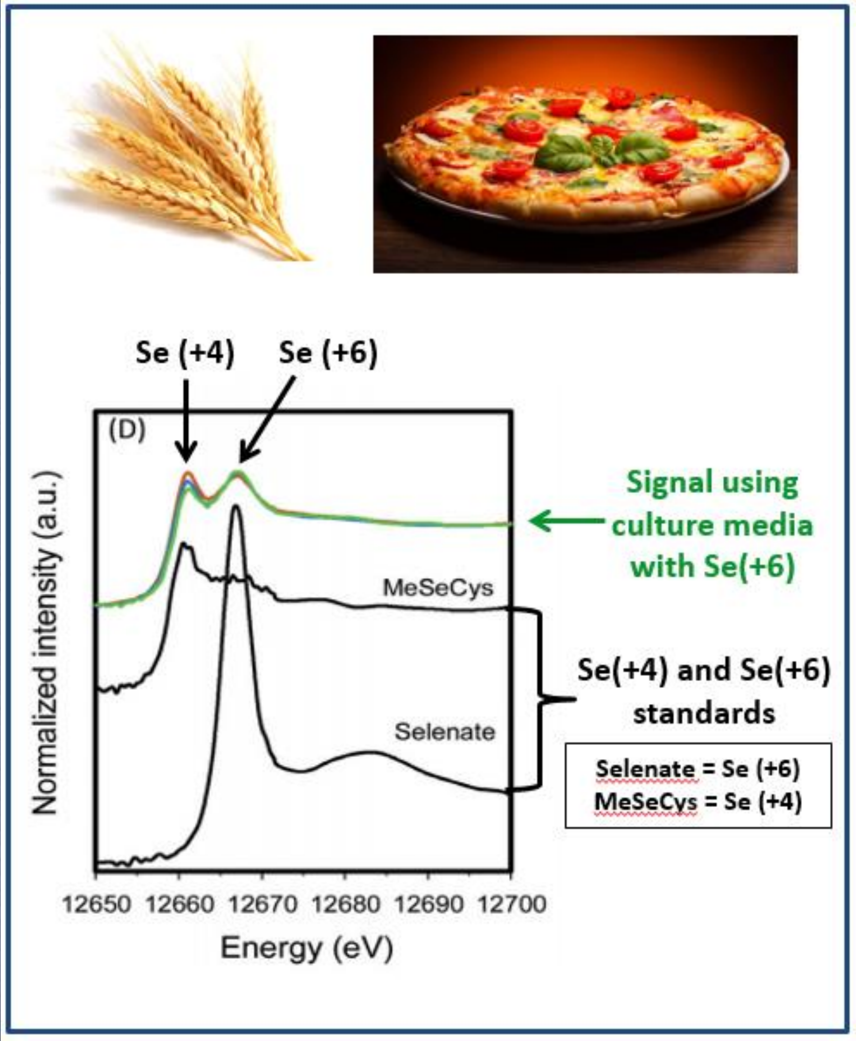
We care for food, its production and conservation

Monitoring contamination, developing environment-friendly packaging

NUTRITION



Characterization of wheat plants with Se: Se(+4), Se(+6), Se(organic). Selenium benefits: helps to prevent common forms of cancer, to fight off viruses, defend against heart disease, and to slow down symptoms correlated with other serious conditions like asthma.

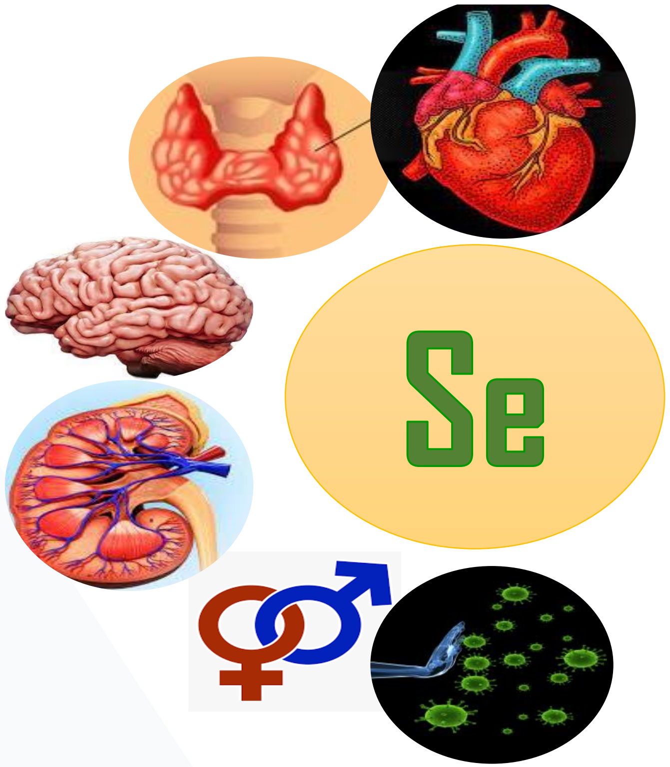


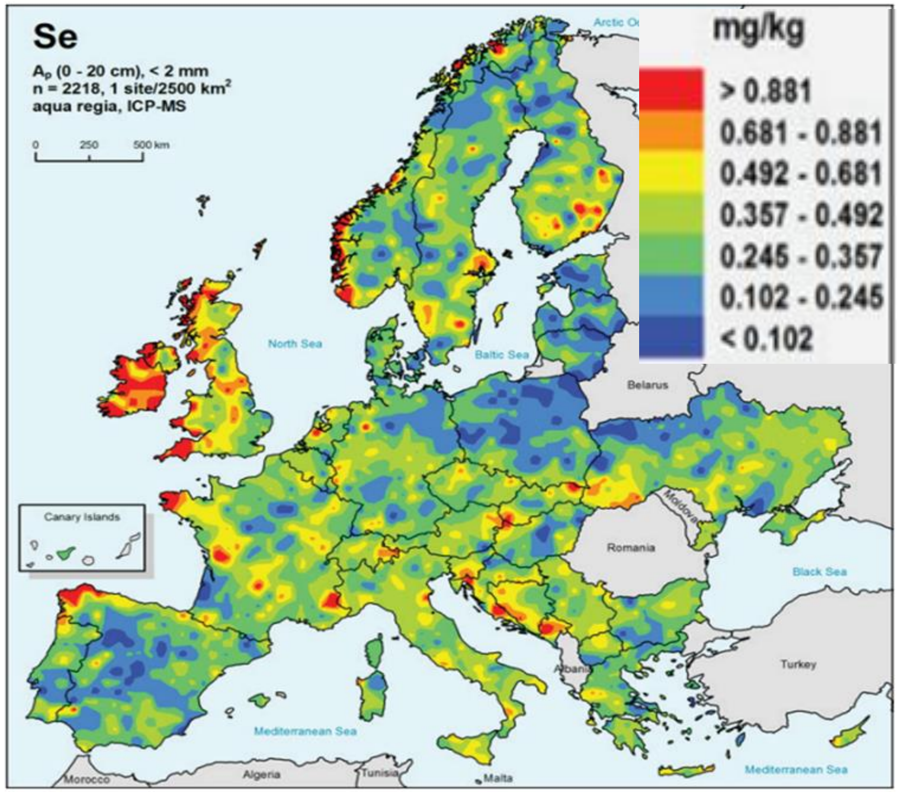
B. Guerrero, Tesis UAB, 2013; Wang et al. doi:10.1093/jxb/erv254

Food science for a proper alimentation in all world regions

Se recommended: 50-70 µg/day

Se tolerable upper limit: 400 µg/day





2018-2021 ALBA PhD thesis – DOCFAM project *"Study of Se-biofortified functional food: Interactions and competing mechanisms among different elements using synchrotron analytical techniques"*

2020-2024 Se4All MSCA RISE EU project *"Se-bioFORtified ALfaLfa for Se-enriched Dairy products"*

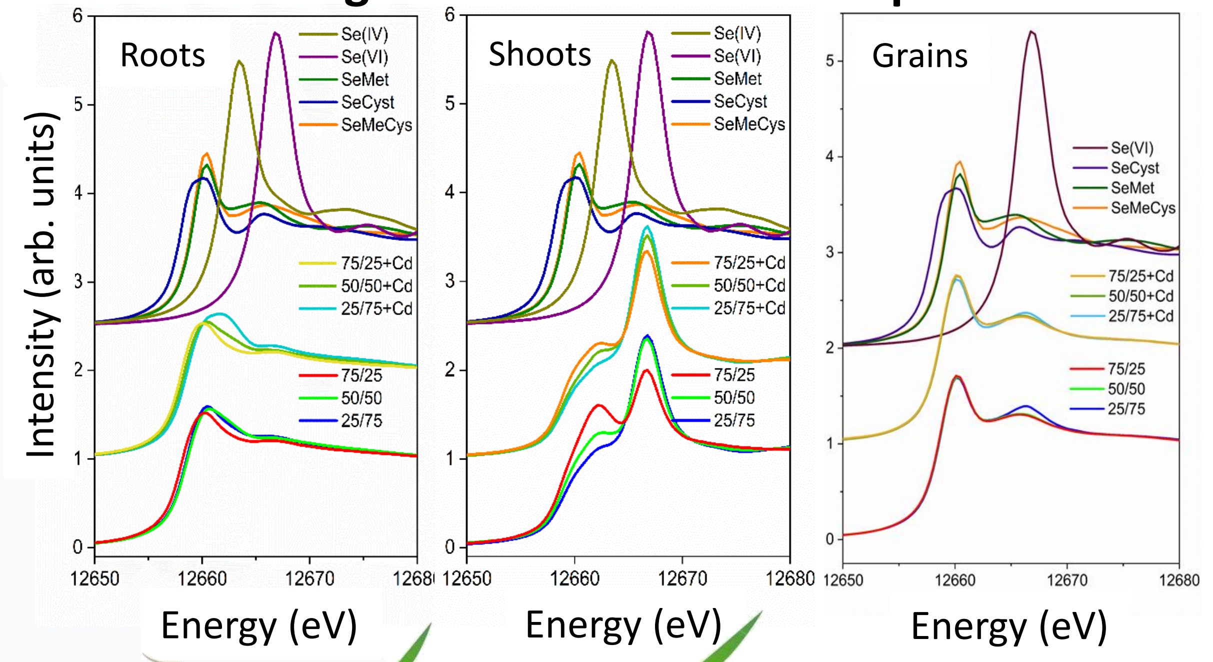
Selenium biofortification in plants

Inorganic Se — *Organic Se*

toxic — bioavailable

Wheat
(*Triticum aestivum*)

Se K-edge XAS to access the Se speciation



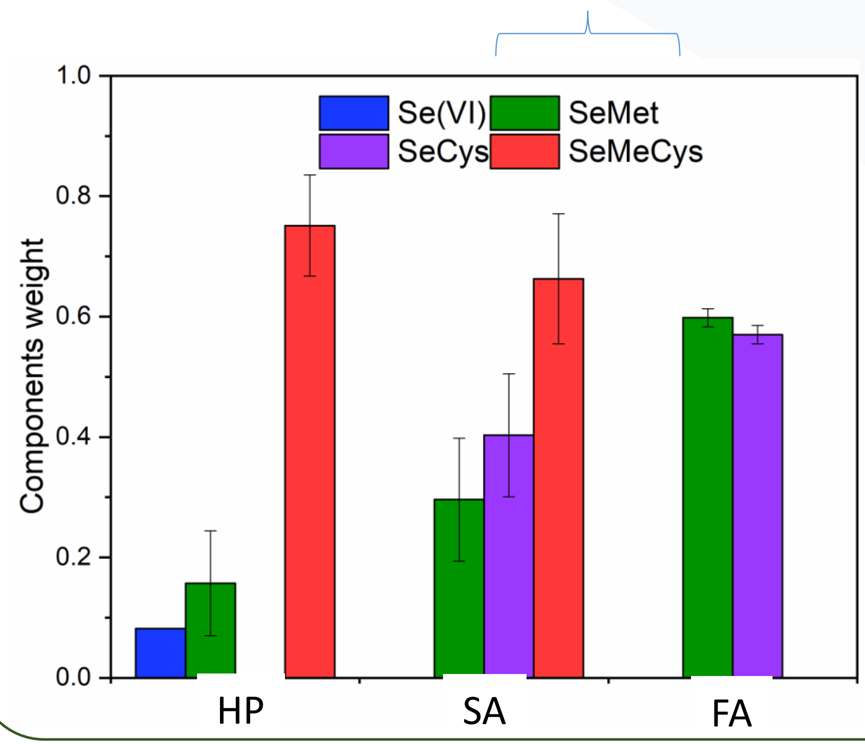
@ CLAESS Beamline

Application methods

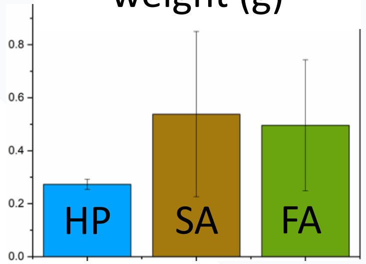
Hydroponics (HP) | Soil (SA) | Foliar (FA)

Hydroponics (HP)	Soil (SA)	Foliar (FA)
Controlled parameters ☺	Soil interaction ☹ Large scale application ☺	Applicable in both hydroponic and soil culture ☺ No soil interaction ☺ Large scale application ☺

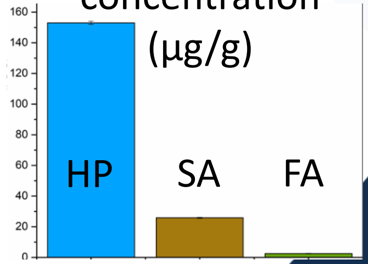
Bioavailable to humans



Average grain weight (g)

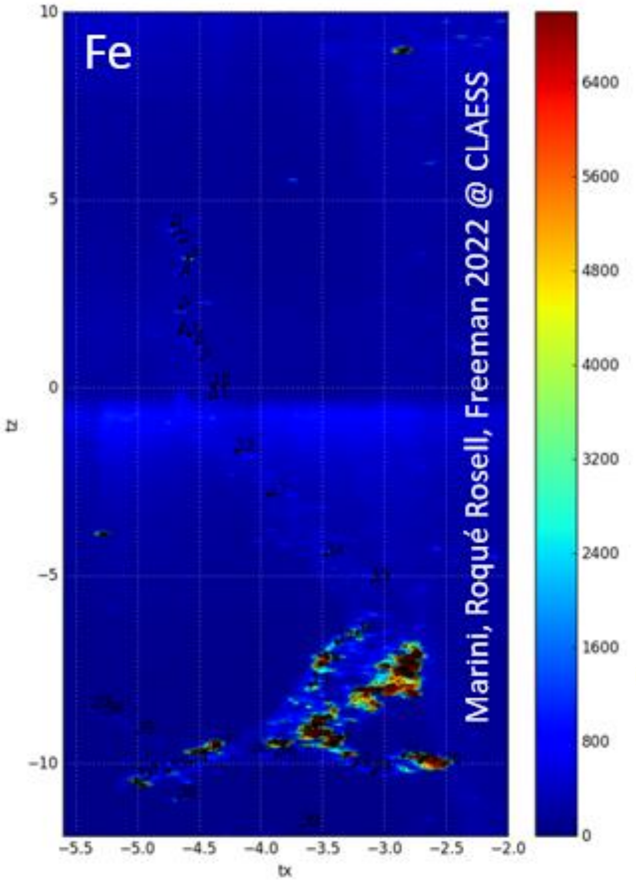


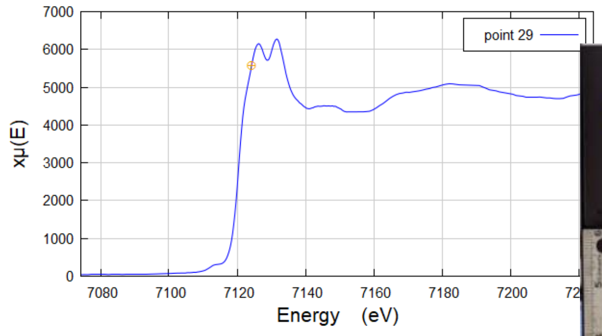
Grains Se concentration (µg/g)

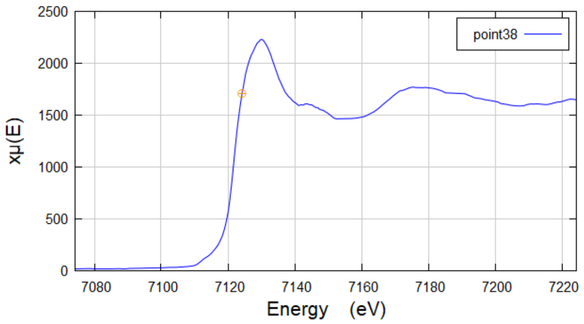


Food science looking at the future plans of humankind

NASA: Which kind of plants are able to grow in the moon soil, to guarantee a continuous air depuration system in the space bases?







UNIVERSITAT DE BARCELONA

Sustainable Development Index

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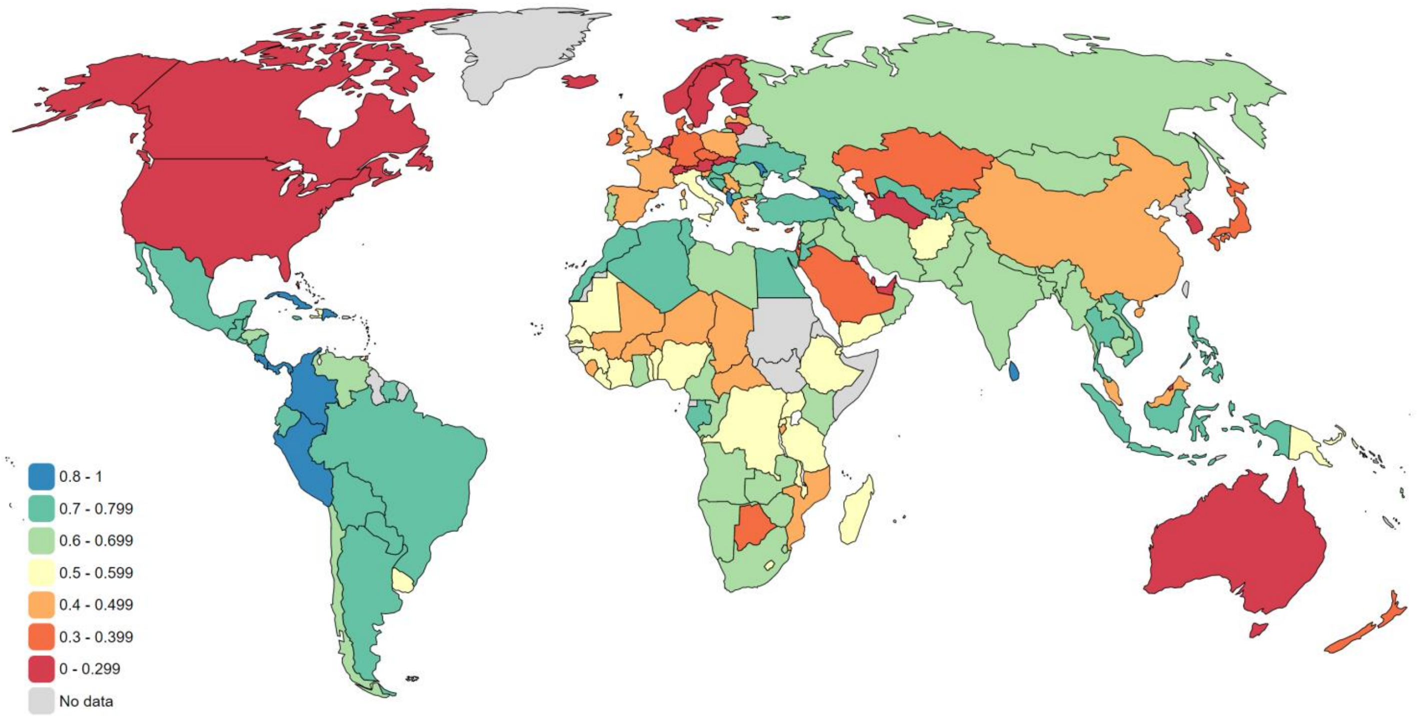
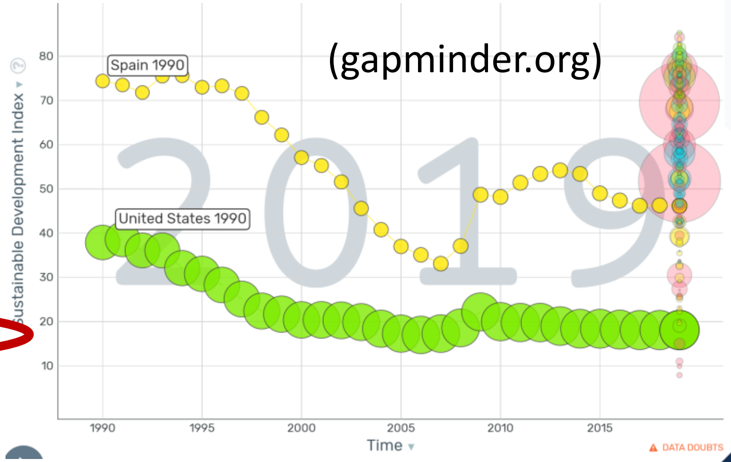




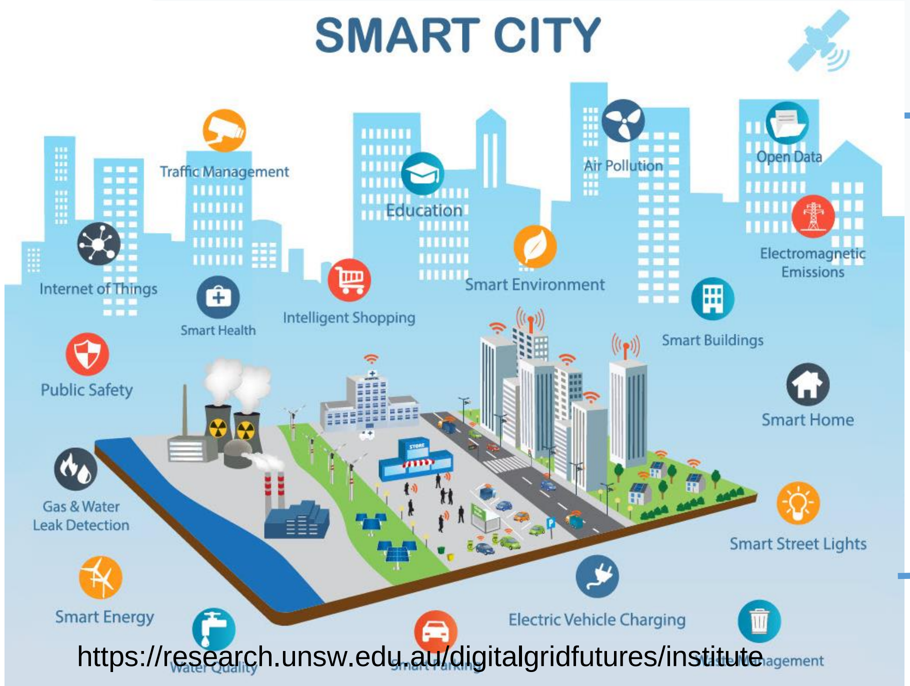
SDI gets higher if

Increase: life expectancy, education and income

Decrease: consumption-based CO_2 emissions and material footprint

The Big Picture: alignment with EU Missions
Climate neutral and smart cities

Flexible, self-optimized, interconnected processes for higher efficiency and adaptability



https://research.unsw.edu.au/digitalgridfutures/institute

Novel devices:
Sensors
Transmitters
Memories

Create
Exchange
Process
Store
Protect

} information

Novel approaches:
Quantum
Neuromorphic
Reservoir
Stochastic
AI

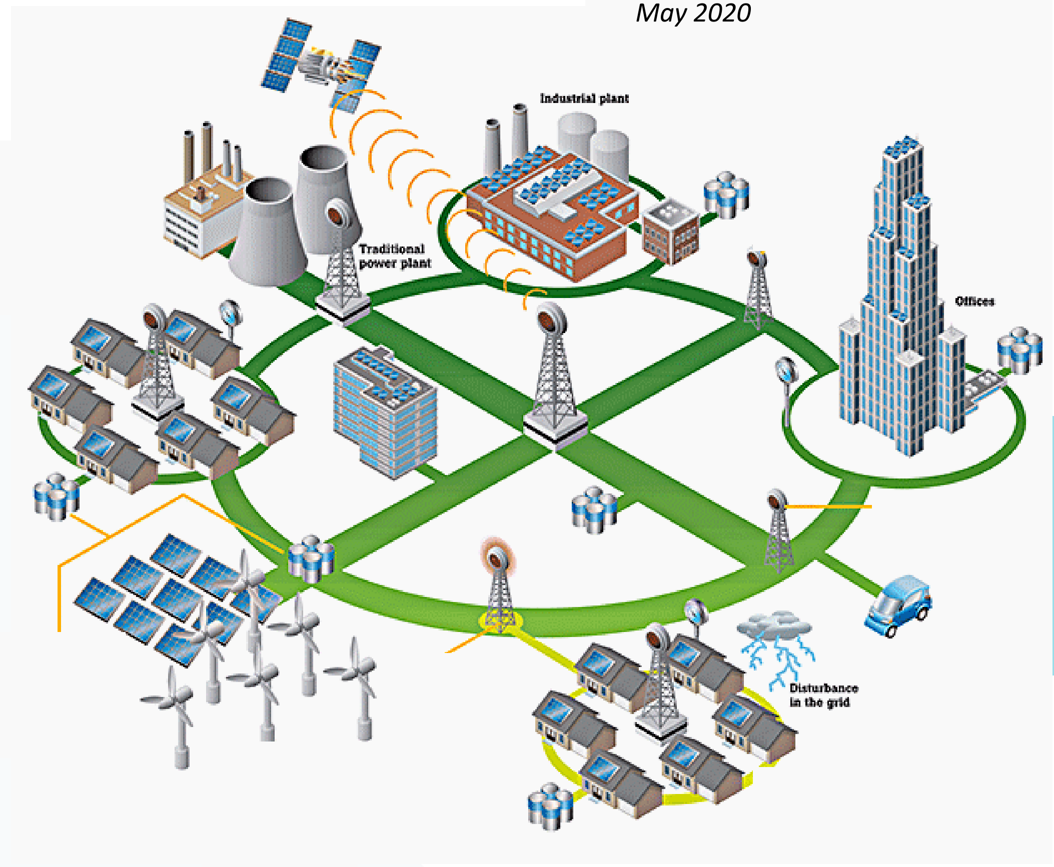
} computing

Some challenges for future devices:

- Fast
- Portable
- Sustainable
  - *Low/self-powered*
  - *Long lifetime*
  - *Based on abundant materials*
- Multifunctional

Scientific focus: global picture

SMART GRID – dynamic network to tune at real time the electrical demand

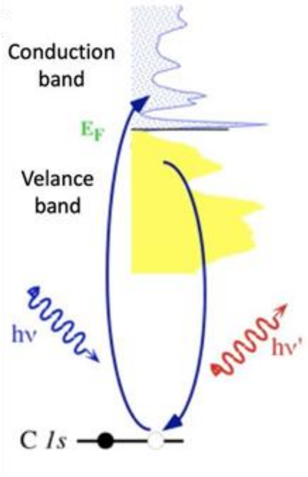


https://www.ennomotive.com/what-are-and-why-of-smart-grids

Solar cell (Charge Transfer)

Fundamental understanding of the processes involving CT state is essential for an optimization of the performances.
XAS,XES,RIXS as important characterization tools

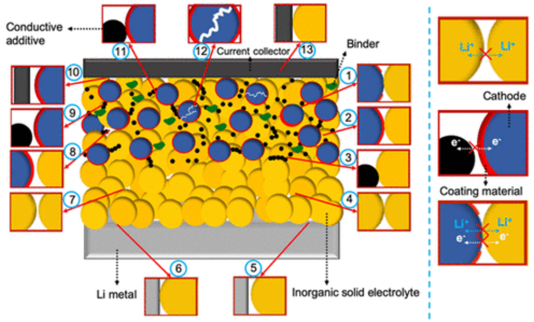
Solar Energy Materials and Solar CellsVolume 208, May 2020



Battery (multiple scales approach)

Battery 2030+: Special attention must be paid to the complex reactions taking place at the many material interfaces within batteries.

Chem. Rev. 2020, 120, 14, 6878–6933



Energy production

Energy transportation

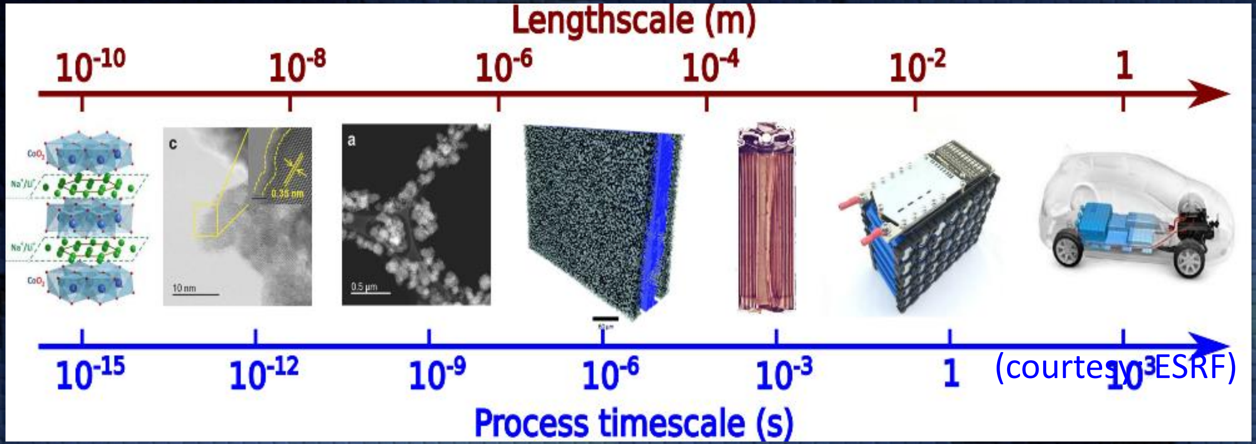
Energy exploitation

Challenges:

- **Safety**
- **Efficiency**
- **Performances**
- **Environmental impact:**
    - **Sustainability**
    - **Impact of production**
    - **Pollution and recycling**

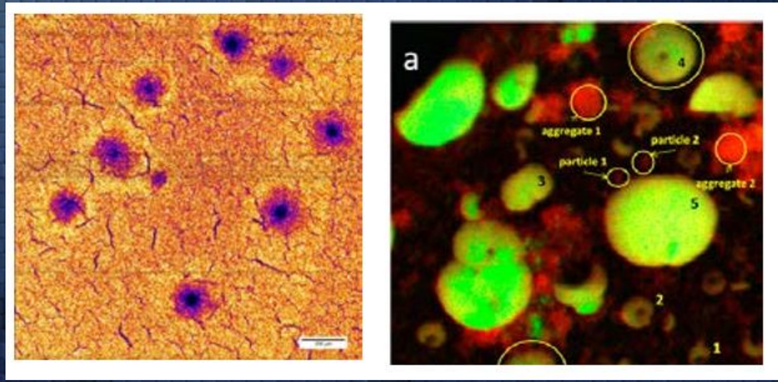
ENERGY Materials

We develop new materials for efficient generation-, storage-, conversion-, and ultimately transport of energy

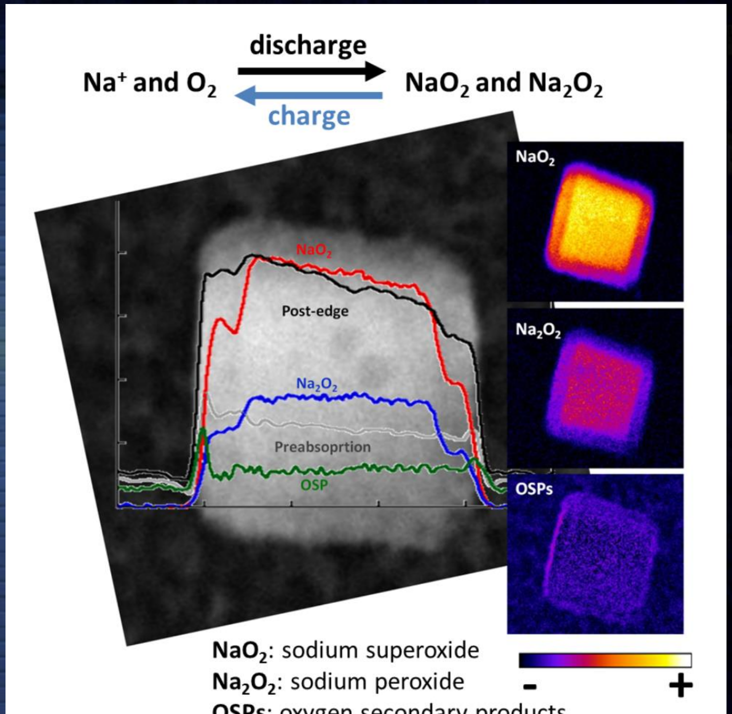


(courtesy: ESRF)

Length scale challenge in battery research
Bridging spatial, temporal and chemical information



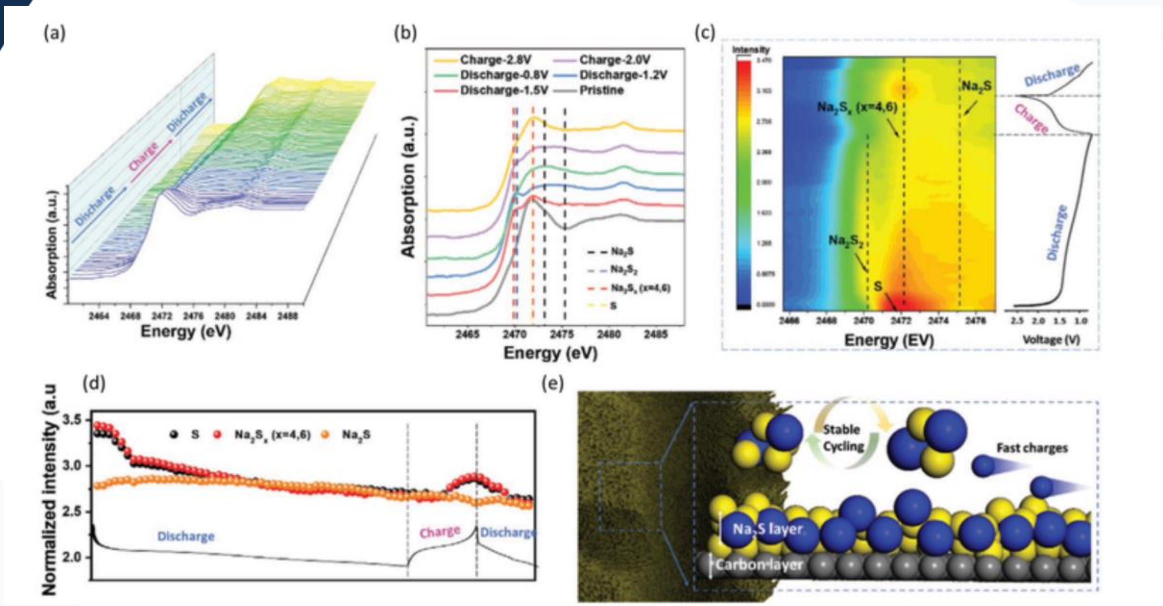
Synchrotron X-ray studies of Li battery materials (courtesy: ALBA)



https://doi.org/10.1016/j.nanoen.2017.05.021

Li is expensive and scarce. Research on batteries based on alternative electrodes are investigated in LEAPS facilities
Example: Na based batteries (Na, V, P, O and F) at ALBA

CARBON NANOSPHERES FOR IMPROVED SODIUM-SULFUR BATTERIES



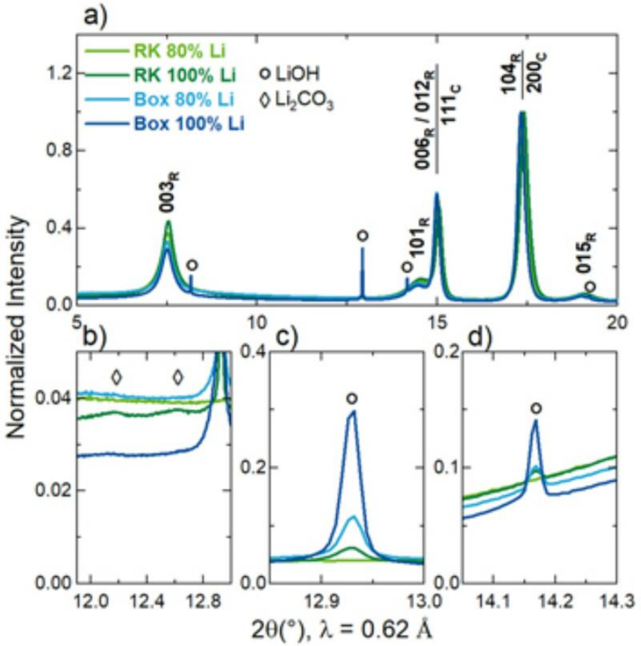
(a) A series of XAS near-edge spectra for the S K-edge recorded from an MMPCS-800@S electrode during the first sodiation-desodiation cycle and the second sodiation cycle. (b) X-ray absorption spectra of S in various states during the first charge/discharge. (c) 2D XAS image of different initial S species, intermediates, and final products. (d) The intensity changes of S, Na_2S_x (x = 4,6), and Na_2S from in situ XAS measurements corresponding to the charge/discharging curves. (e) Schematic illustration of the irreversible Na_2S layer formed after the discharge process.

Sodium-sulfur batteries are promising electrical energy storage technologies that can serve as a key solution to intermittency problems and can be integrated with renewable forms of energy generation. An international research team has reported the synthesis of micro-mesoporous carbon nanospheres with continuous pore distribution as an efficient sulfur host for sodium-sulfur batteries. The work sheds new light on the progress of the sulfur cathode in sodium-sulfur batteries and provides a promising strategy for the viable design of other metal–sulfur batteries. Experiment at CLAESS allowed determining the sulfur species during charge/discharge processes.

BASF COLLABORATES WITH THE ALBA SYNCHROTRON IN IMPROVING THE PRODUCTION OF BATTERIES FOR ELECTRIC VEHICLES

A research lead by the company BASF has characterized a new methodology to produce nickel-rich cathode materials used in lithium-ion batteries that optimizes the conventional production process. The proposed model leads to an increase in throughput by a factor of three, representing a considerable increase in the efficiency of future cathode active materials production for battery electric vehicles. The contributions of the MSPD beamline at ALBA have been key in these findings.

Philipp Kurzhals, Felix Riewald, Matteo Bianchini, Shamail Ahmed, Andreas Michael Kern, Felix Walther, Heino Sommer, Kerstin Volz, and Jürgen Janek. **Deeper Understanding of the Lithiation Reaction during the Synthesis of $LiNiO_2$ Towards an Increased Production Throughput**. *J. Electrochem. Soc* (2022). DOI: [10.1149/1945-7111/ac6c0b](https://doi.org/10.1149/1945-7111/ac6c0b)



Synchrotron powder X-ray diffraction (PXRD) patterns of the samples after a partial-lithiation step at 500 °C and a dwell time of one hour using either the rotary kiln setup (RK) or the box furnace (Box)

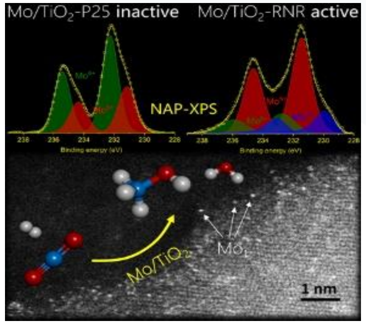
The Challenge of Catalyst Development

- higher selectivity,
- better energy efficiency
- smaller raw material consumption
- Reduction of required H2 pressure

At ALBA

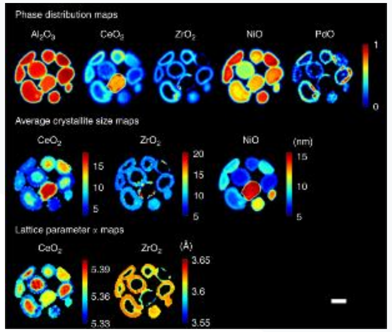
- Rational design of novel catalyst classes
- Optimizing existing catalyst classes using combinatorial approaches
- Understanding degradation effects
- Search for replacement of critical materials (especially for the H2 production)

Soft X-ray spectroscopy



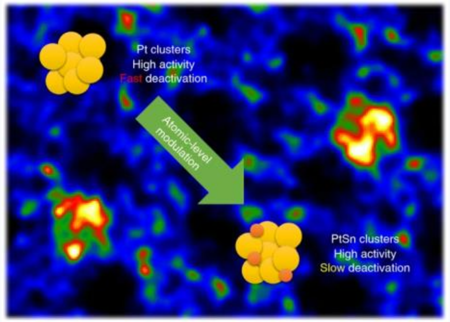
DOI: 10.1039/d1gc01761f

X-ray microscopy



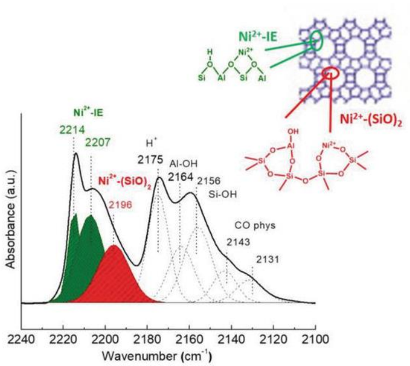
doi.org/10.1038/s41467-018-07046-8

Hard X-ray spectroscopy



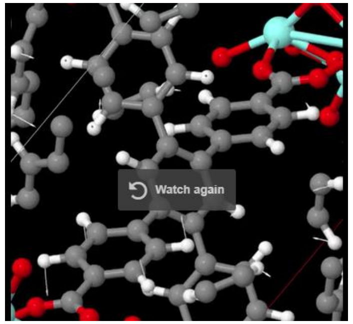
DOI: 10.1038/s41929-020-0472-7

Far IR spectroscopy



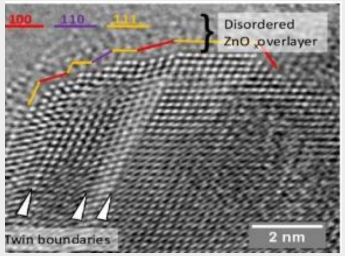
DOI: 10.5772/intechopen.80524

Powder diffraction (operando and high resolution)



https://dx.doi.org/10.1021/jacs.0c01459

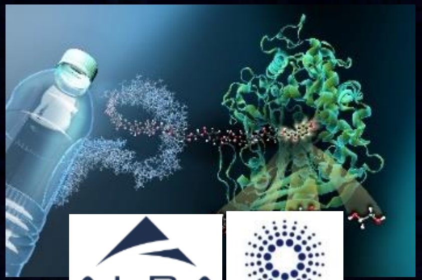
And high resolution TEM



DOI 10.1515/recat-2015-0009

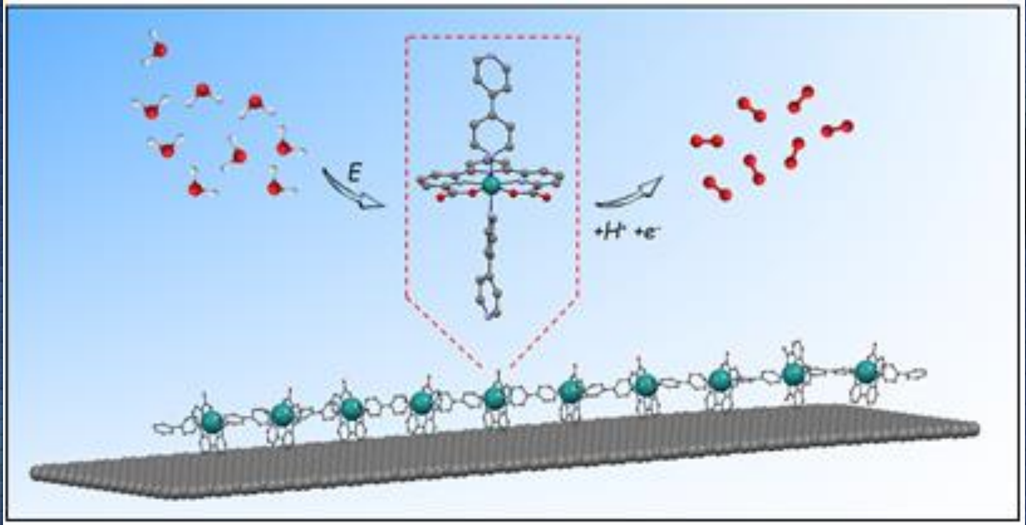
We care for environment

developing new catalysts for green fuels, cybor plants … or PET digesting bacteria



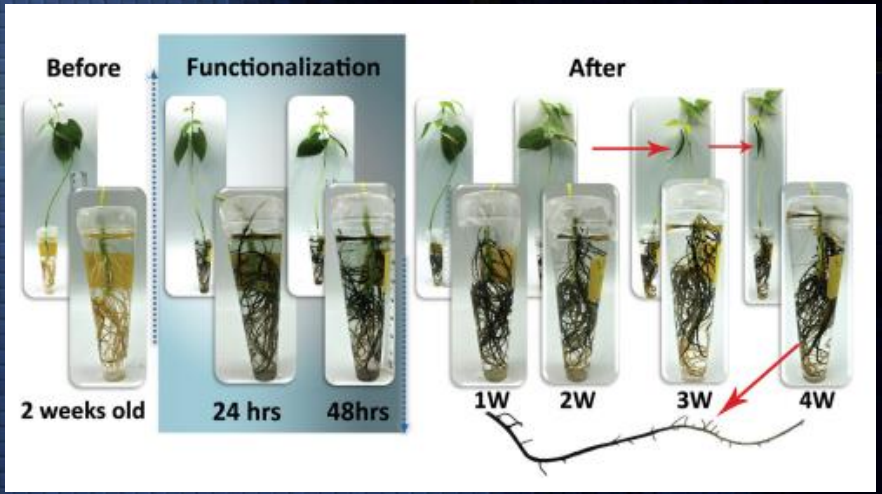
ENVIRONMENT

Photocatalytic water splitting is being investigated to produce **hydrogen**, a clean-burning fuel. Photocatalytic water splitting has the simplicity of using a catalyst and sunlight to produce hydrogen out of water.

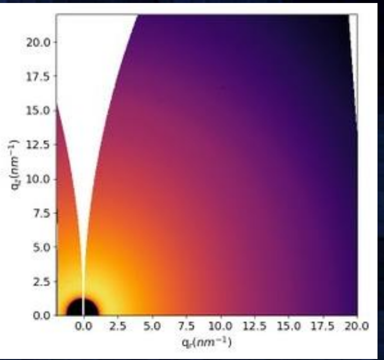


NCD-SWEET: putting the basis for designing robust and efficient hybrid molecular electro-anode materials for the **oxidation of water-based on Ru complexes**, that can be extended to other transition metals and other catalytic reactions. The team is already working on implementing the hybrid material on photoelectrochemical cells to test its applications in a water-splitting device

Water oxidation electrocatalysis using ruthenium coordination oligomers adsorbed on multiwalled carbon nanotubes Hoque, A et al A. *Nat. Chem*. **2020** (DOI: 10.1038/s41557-020-0548-7).



CYBORG PLANTS: ROOTS CAN STORAGE ENERGY



Materials Horizons (2021). DOI: 10.1039/d1mh01423d

A CATALYST TO REMOVE EMISSIONS OF METHANE, A POWERFUL GREENHOUSE GAS

Researchers from the UPC, the University of Udine (Italy) and the ALBA Synchrotron have discovered a palladium and platinum catalyst, the first to eliminate methane emissions from transport and other human activities to reduce global warming.

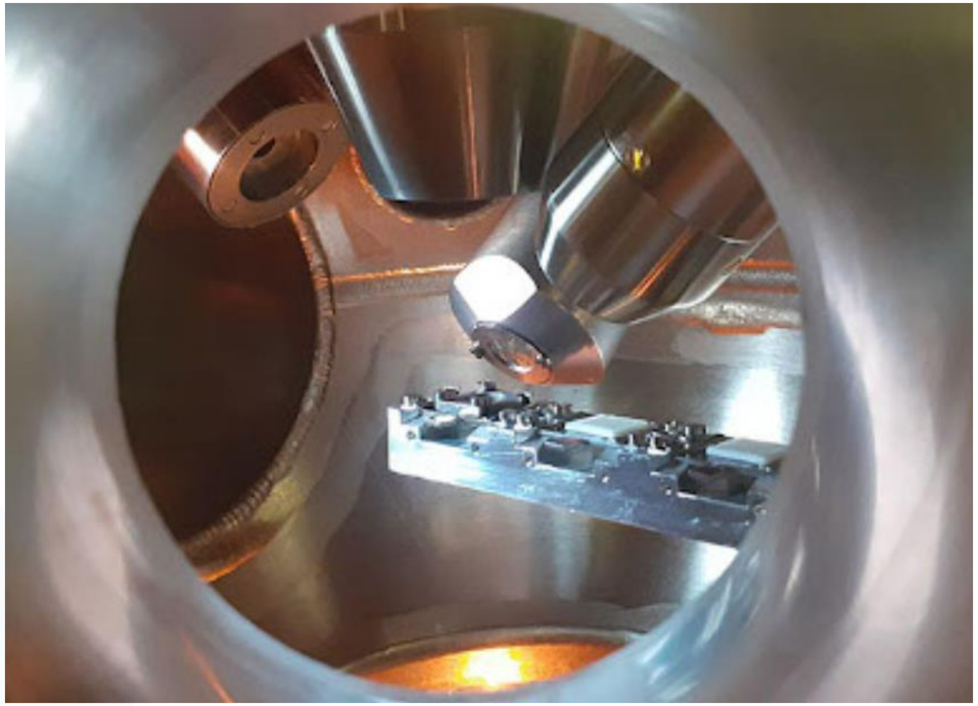
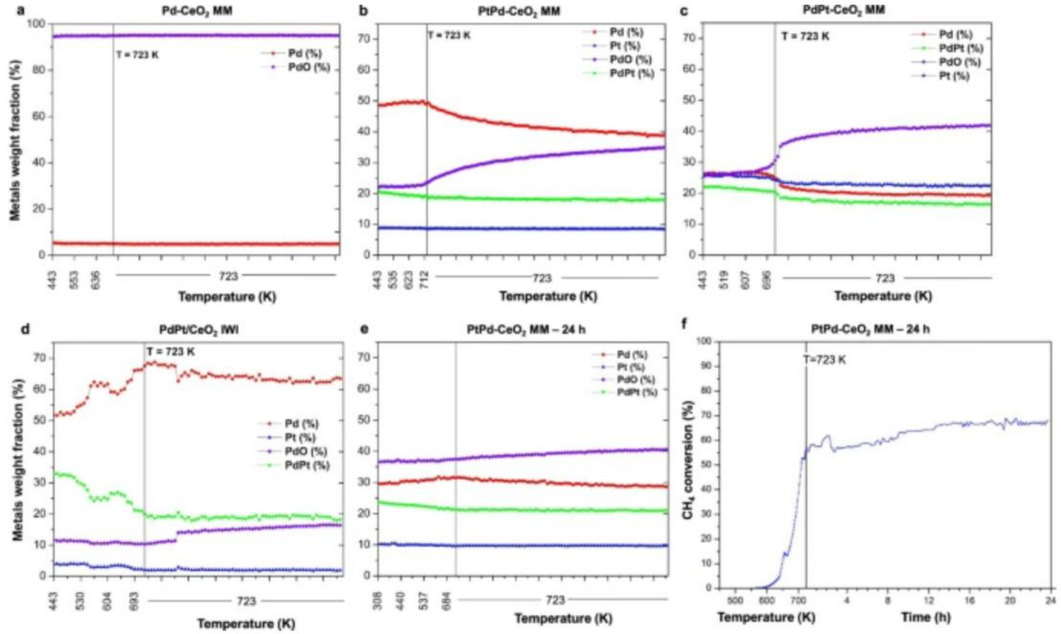


Fig. 2: Evolution of the normalized weight fraction of the phases obtained from the Rietveld refinement under wet lean methane oxidation conditions at different temperatures.



a–**e** For the indicated catalysts. **f** Methane conversion of PtPd-CeO$_2$ MM under time-on-stream at 723 K for 24 h under wet lean methane conditions (0.5% CH_4, 2% O_2, 10% H_2O, balance He). MM mechanical milling, IWI incipient wetness impregnation.

Divins, N.J., Braga, A., Vendrell, X. *et al.* Investigation of the evolution of Pd-Pt supported on ceria for dry and wet methane oxidation. *Nat Commun* **13**, 5080 (2022). https://doi.org/10.1038/s41467-022-32765-4

1905: article by A. Einstein on photoelectric effect

41 years

Courtesy S. Ferrer

1946: Russell Ohl patented the modern junction semiconductor solar cell

Today: solar cells, LED, photocatalysis, photemission techniques,…

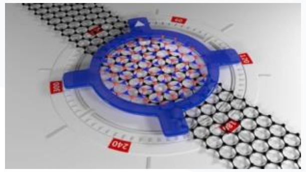
Basic research leads to applications after several decades

Our goal at a glance: **2D-VdW materials**

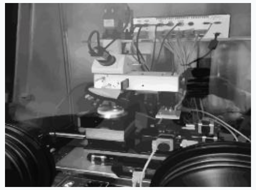
MBE, 2D Materials and VdW Foundry at MS Lab, offline bl equipment, as a complement & bridge to user facilities

Challenges addressed and advantages:

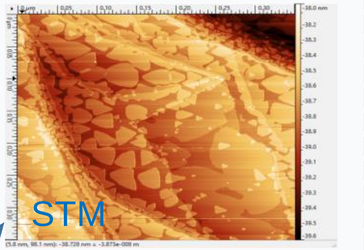
- air sensitive / short duration
- repeatibility / efficiency / on-the-go experiment adjustments
- Deeper partnership (projects, shared PhDs, short and mid term stays related to experiments and projects)



twistronics



VdW transfer setup

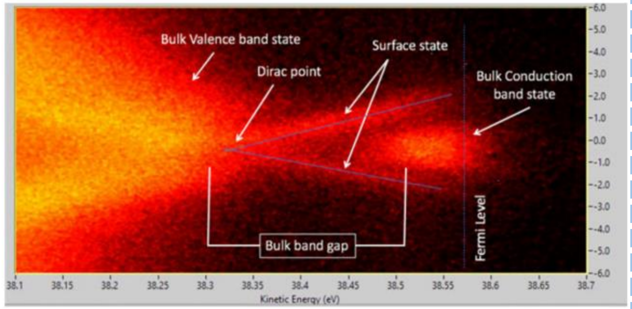


STM

Microscale* averaged electronic & magnetic properties

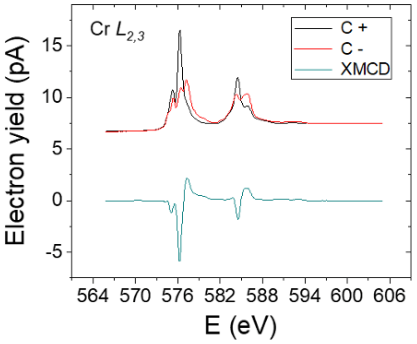
ALBA provide the X-ray & electron- tools, enhanced sample preparation capabilities enabling pre-experiment preparation, mid-term visitor /missions and stronger collaborations and partnerships

LOREA: ARPES



first ARPES image of LOREA, one can see the angular band dispersion of Bi_2Te_3 in the angular range (-6˚,+6˚)

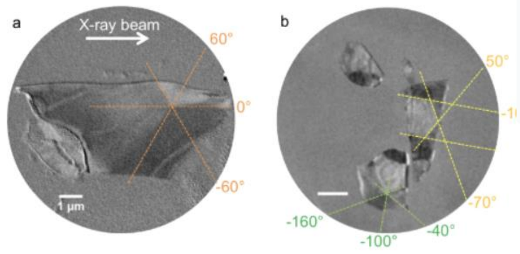
BOREAS - XMCD



Cr XMCD in CrCl3 sl, ArXiv 2020

Micro to nanoscale imaging

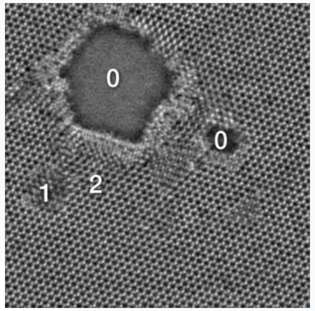
CIRCE, MISTRAL & BOREAS



PEEM, Multilayer flakes of CrTe2 VdW, *ACS AMI 2020*

Atomic imaging

HR-(S)TEM



Defects in a MoS2 imaged with high-resolution STEM *Spectra, ThermoFischer*

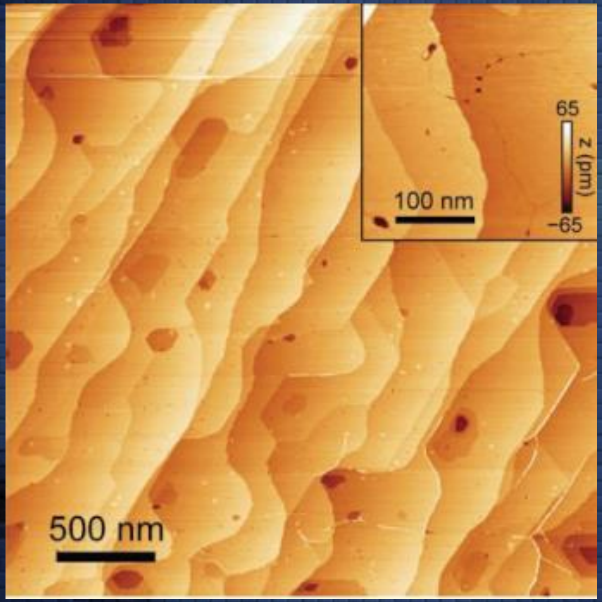
-Aiming at a multi-modal approach from meso to nanoscale, from surface to bulk-like

	Resolution	complementary x-ray + SPM, TEM imaging capabilities
XTM MISTRAL	20-30 nm	fast ; 2D imaging ; **3D tomo** ; bulk (only C+ BM)
PEEM CIRCE	20-30 nm (<10nm possible)	fast; 2D; part 3D (shadow tech.) ; surface, mod. Field & LN temp
Coh. Imag. BOREAS	25 nm (3-5 nm possible)	slow (reconst. or scanning) 2D ; 3D possible; LHe ; Hig field

We advance in complex materials and technologies developments

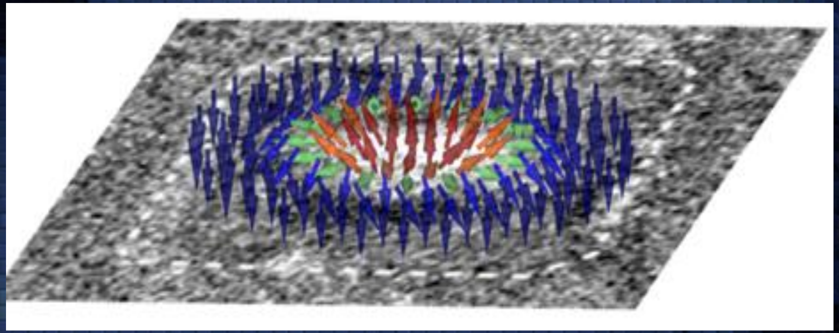
Tools for the ERA of Complexity

Optimizing complex materials needs experimental tools including extreme conditions (T, P, magnetic fields) and real-time control (in-situ and operando) of relevant parameters and their functionality: quantum materials, superconductors, nanomagnetism are bricks of complex technologies



DISCOVERY OF NOVEL CLASS OF 2D MAGNETS: 2D-XY FERROMAGNETISM IN MONOLAYER $CrCl_3$ **Science (2021).** DOI: 10.1126/science.abd5146

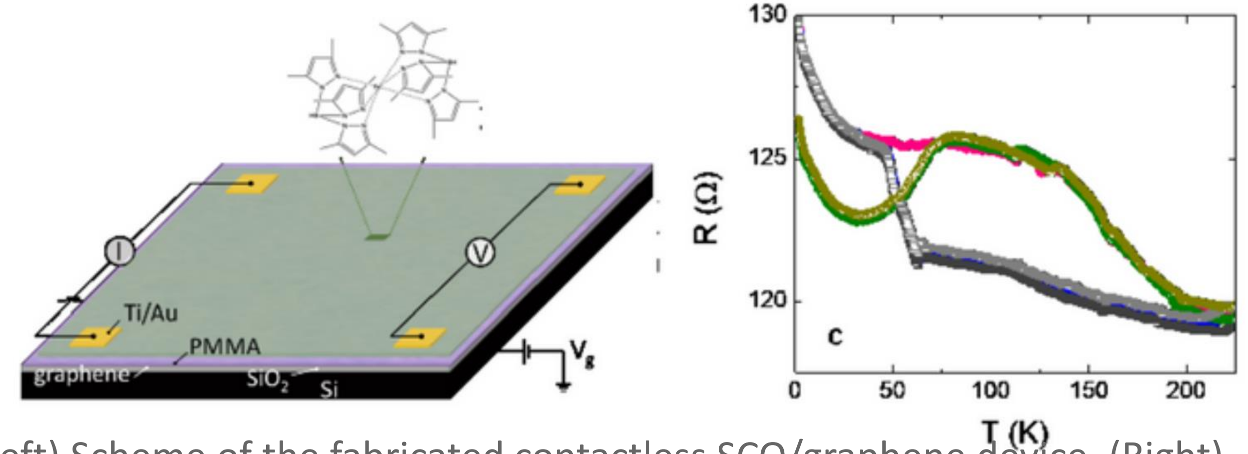
Skyrmion schematic



Nature Nanotechnology (2016) O. Bulle ….L. Aballe, M. Foester, …G. Gaudin , ALBA

DESIGN OF A LIGHT-INDUCED SPIN SWITCHING DEVICE WITH PROMISING APPLICATIONS IN SPINTRONICS

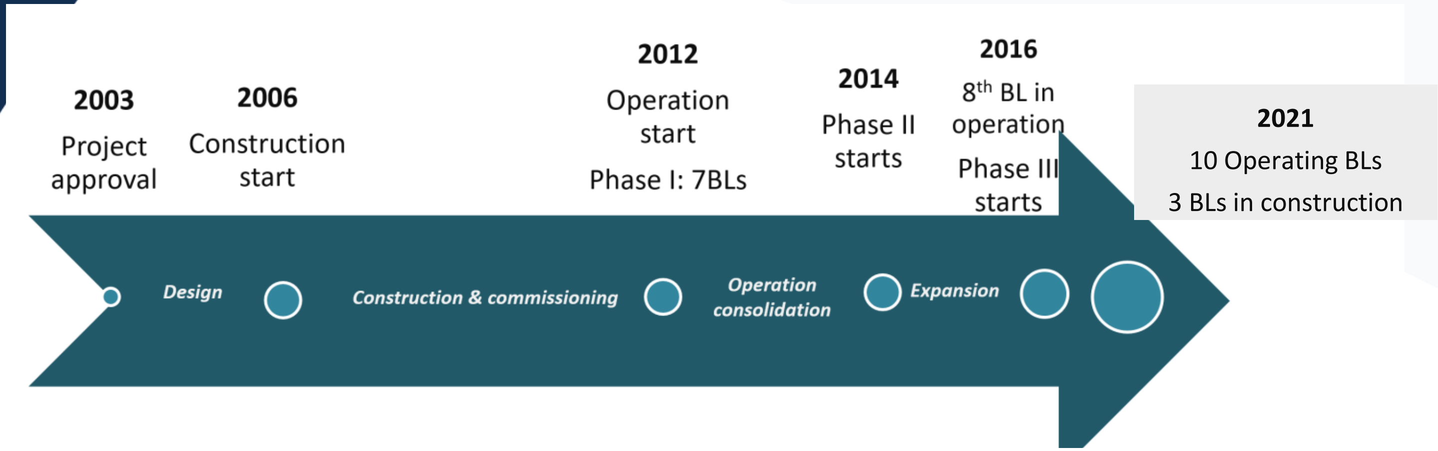
A research work led by the University of Valencia (Spain) has reported the fabrication of a novel device that allows the robust electrical detection of a fast and effective light-induced and thermally induced spin transition with an outstanding performance. It represents a tool with promising potential for generating new systems with applications in spintronics and straintronics. Experiments carried out at the BOREAS beamline have been crucial in this study



(Left) Scheme of the fabricated contactless SCO/graphene device. (Right) Temperature-dependent electrical measurements showing cycles without light irradiation (black, grey and blue lines: cooling process and pink line: heating process) and after light irradiation (two green lines: heating process by irradiating at 2 K with a laser for 5 minutes). Cooling cycles reveal an abrupt thermally induced spin transition at 60 K. Heating cycles without irradiation are indicative of a more progressive reversibility in the transition finishing at 180 K.

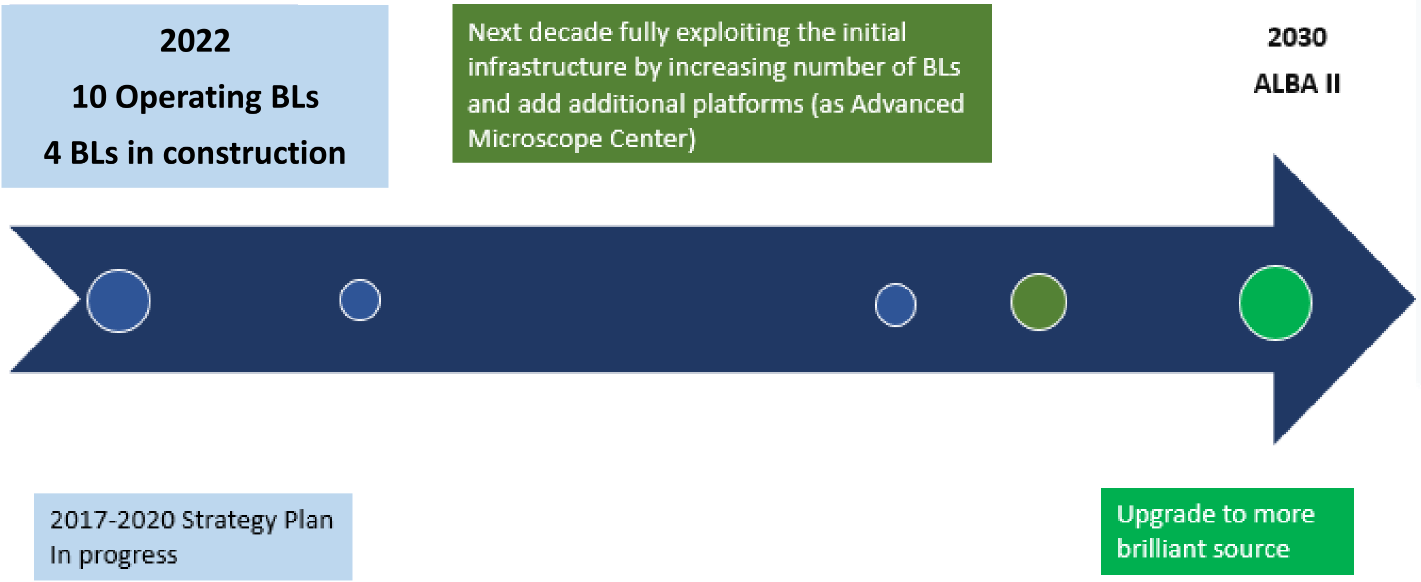
Electrical Sensing of the Thermal and Light-Induced Spin Transition in Robust Contactless Spin-Crossover/Graphene Hybrid Devices. *Advanced Materials* (2022). DOI: https://doi.org/10.1002/adma.202202551

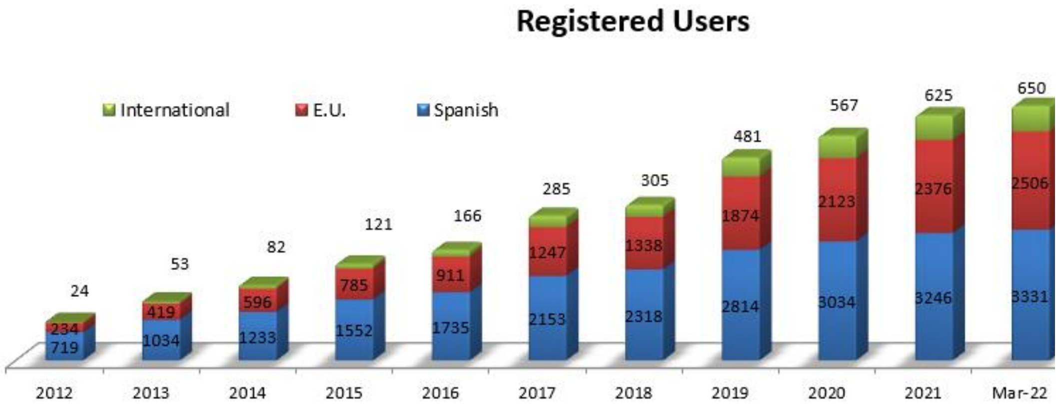
ALBA History and Future



First proposal for building a synchrotron in Spain: in the '90s

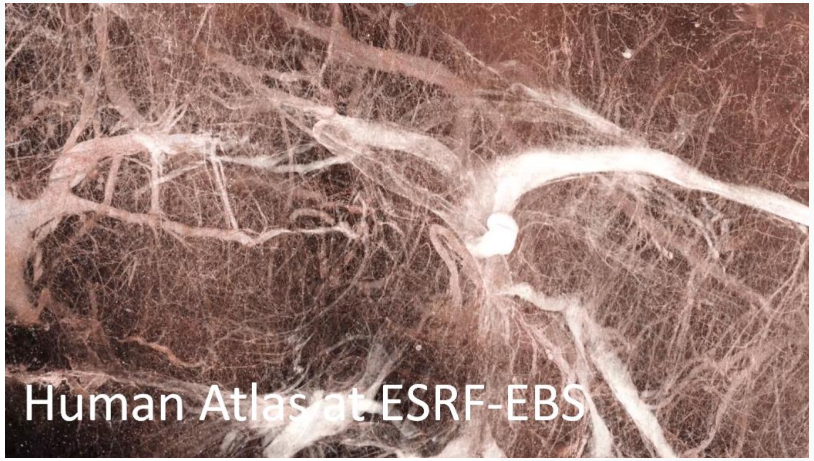
10 Years for the approval - 10 Years for the operation

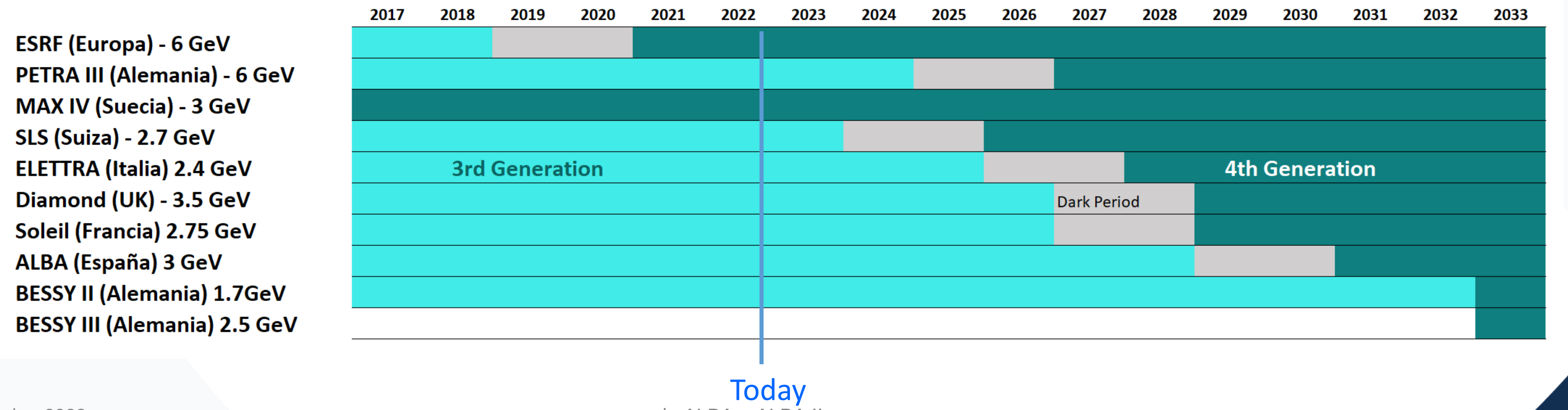




Evolution from 3rd to 4th generation in Europe

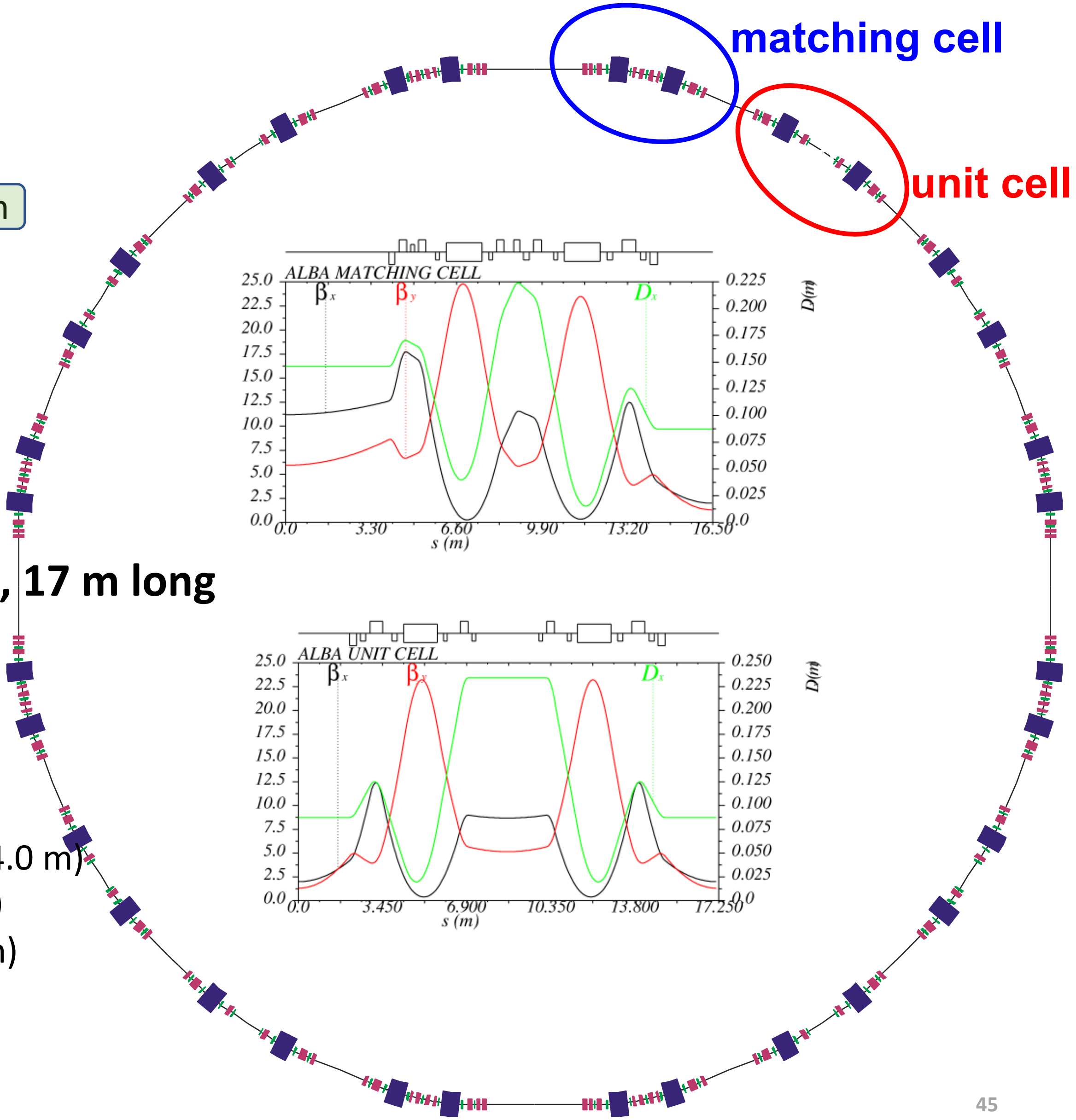
All synchrotrons in Europe (and in America and Asia) are evolving towards the 4th generation





From ALBA to ALBA II – the accelerator
Present lattice

- Energy = 3 GeV
- Circumference = 268 m
- Symmetry = 4 fold
- Emittance = 4.5 nmrad



- **8+8 DBA-like cells, 17 m long**

Straight sections:

- 12 medium straights (4.0 m)
- 4 long straights (7.8 m)
- 8 short straights (2.3 m)

45

ALBA II lattice

From 2x8 double-bend lattice
*to 16 multi-bend lattice (**6BA**)*

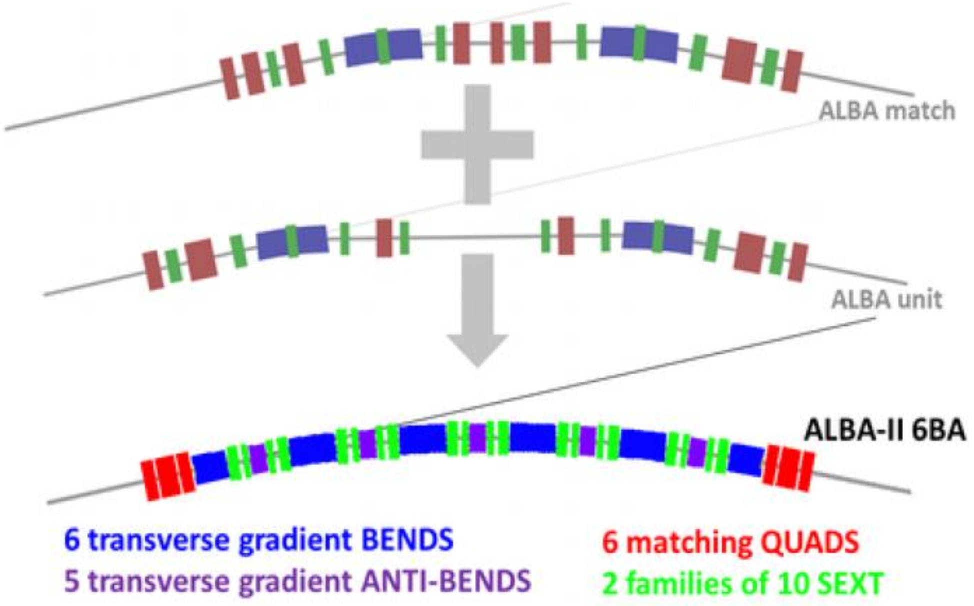
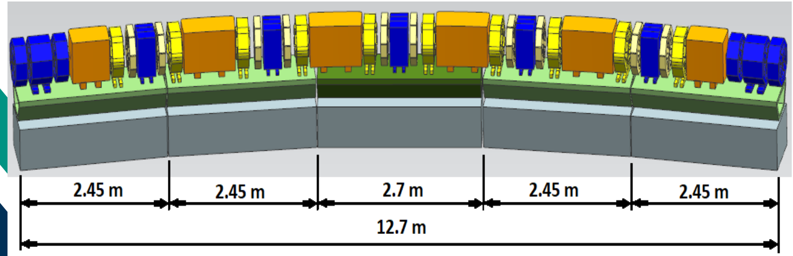
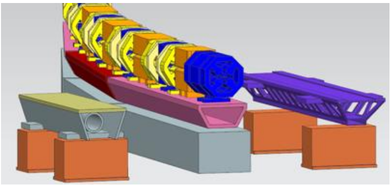


Figure 1: In ALBA-II, the two types of DBA cell (8 matching cells plus 8 unit cells) of the current lattice are replaced by 16 identical 6BA+anti-bend cells.



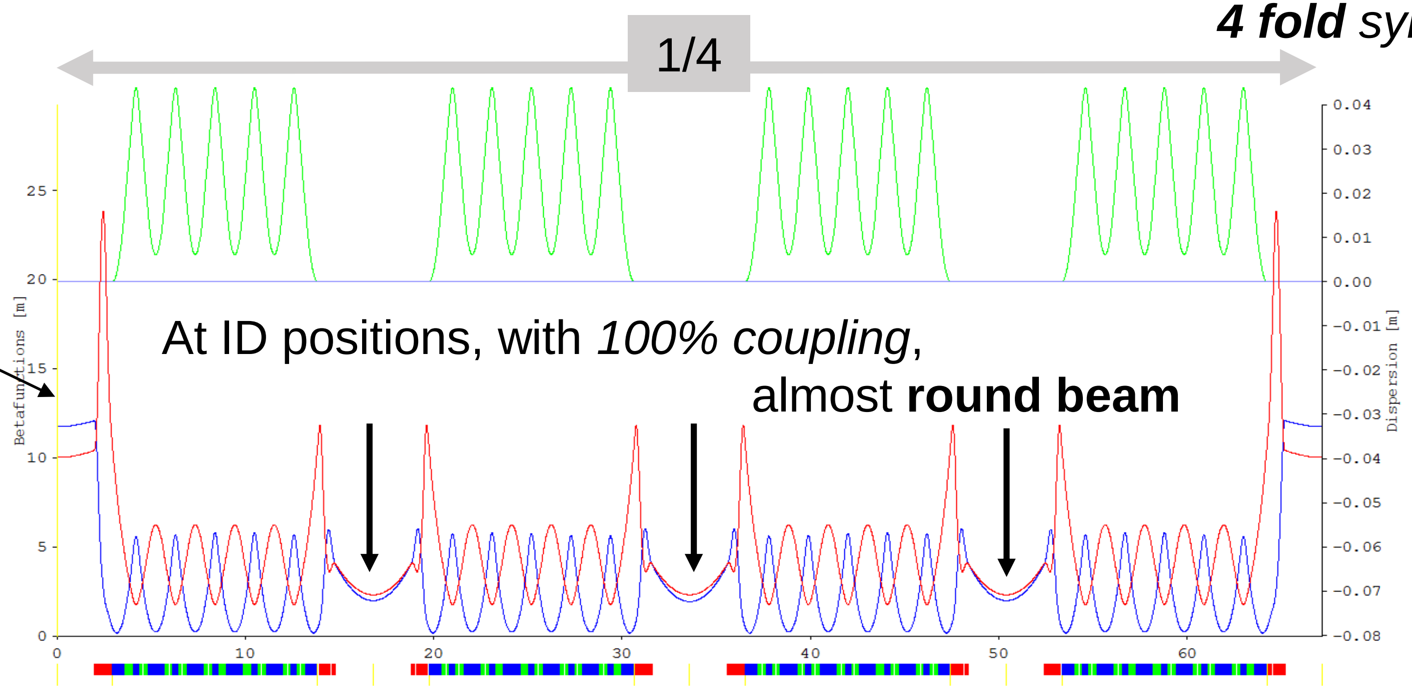


	Current DBA	6BA
Emittance	4.5 nm·rad	140 pm·rad
Energy	3 GeV	3 GeV
Circumference	268.8 m	268.8 m
N.of cells	8+8	16
N. of straights	4 / 12 / 8	16
Straight length	7.8 / 4 / 2.3 m	4.0 m
Straight ratio	36%	24%
Working point	18.15, 8.36	43.68, 11.67
Chromaticity	-39, -29	-94, -51
Mom.comp.fact.	$8.9 \cdot 10^{-4}$	$0.8 \cdot 10^{-4}$
Energy spread	$1.0 \cdot 10^{-3}$	$1.1 \cdot 10^{-3}$
Energy loss/turn	1023 keV	843 keV
Damping times	4 / 5 / 3 ms	3 / 6 / 6 ms

46

The 6BA lattice

***4 fold** symmetry*



High beta required for Injection

At ID positions, with *100% coupling*, almost **round beam**

Transversal beam size comparison:

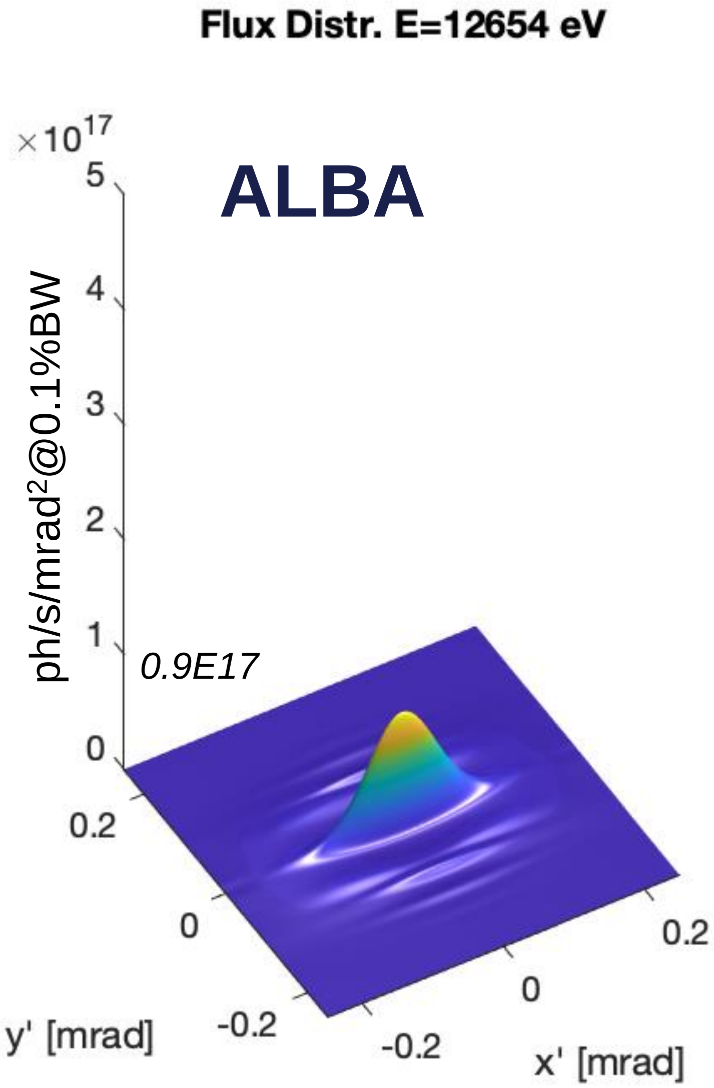
At ID position, today:

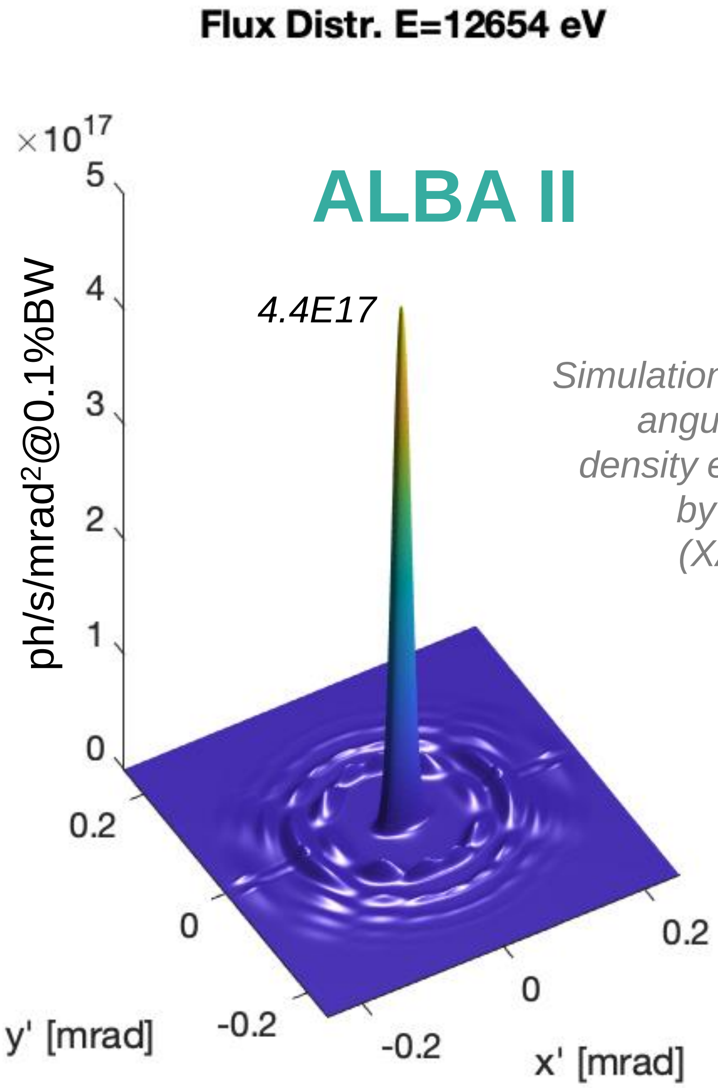
$\sigma_x = 127$ *um* ; $\sigma'_x = 47$ *urad*
$\sigma_y = 5.2$ *um* ; $\sigma'_y = 4{,}4$ *urad*

At ALBA II ID position,
with *100% coupling*, almost **round beam**:

$\sigma_x = 14.0$ um $\quad \sigma'_x = 7.1$ urad
$\sigma_y = 15.1$ um $\quad \sigma'_y = 6{,}6$ urad

Angular flux density (hard x-ray undulator)



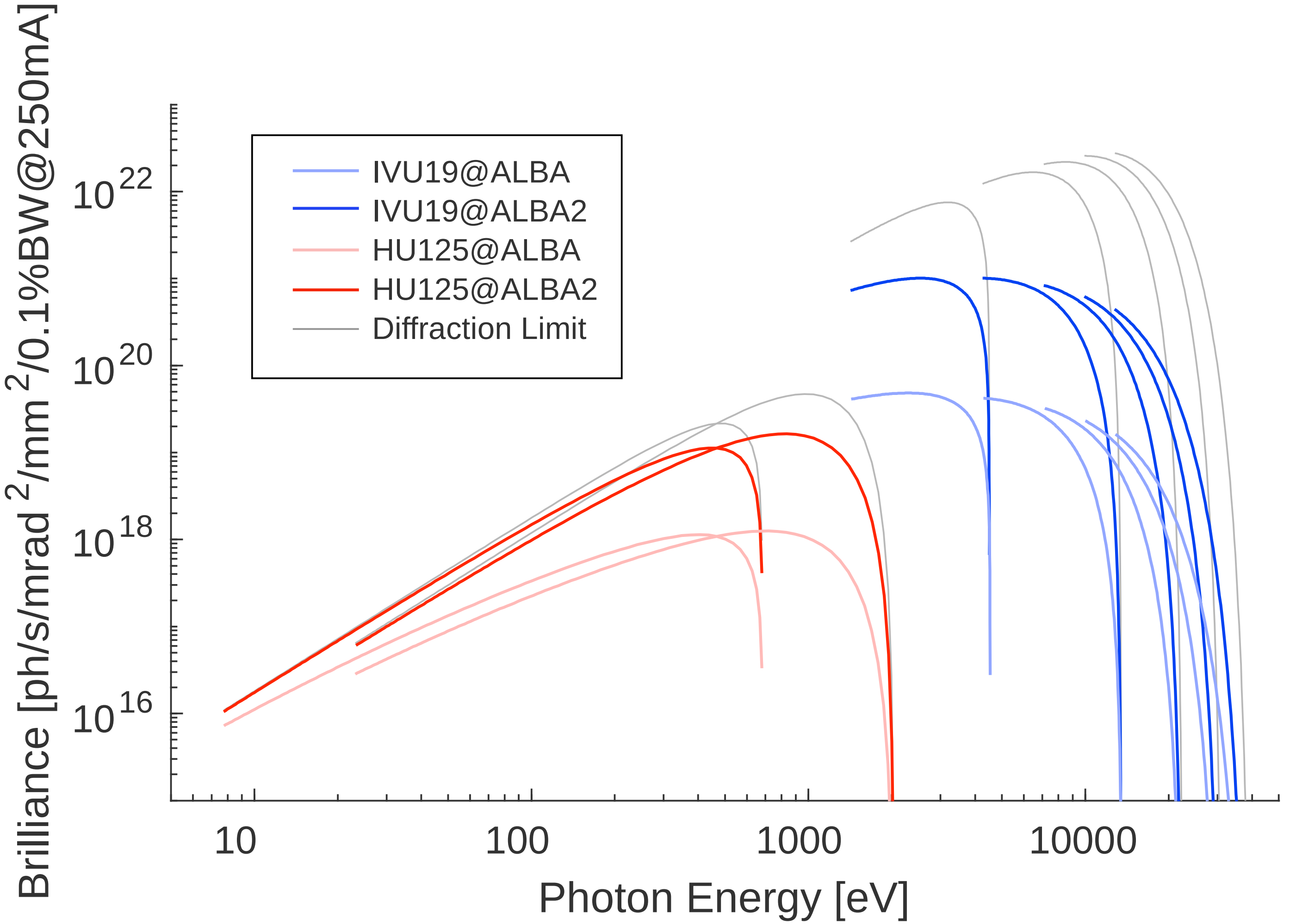


Simulation of the angular flux density emitted by IVU21 (XALOC)

For hard x-Ray BLs the emission cone is dominated by the electron beam size, Although the integrated flux does not change, it is concentrated in a narrower cone.

Brilliance and coherence

Comparison of the brilliance emitted at ALBA, ALBA-II and the diffraction limit for a SXR and a HXR undulator



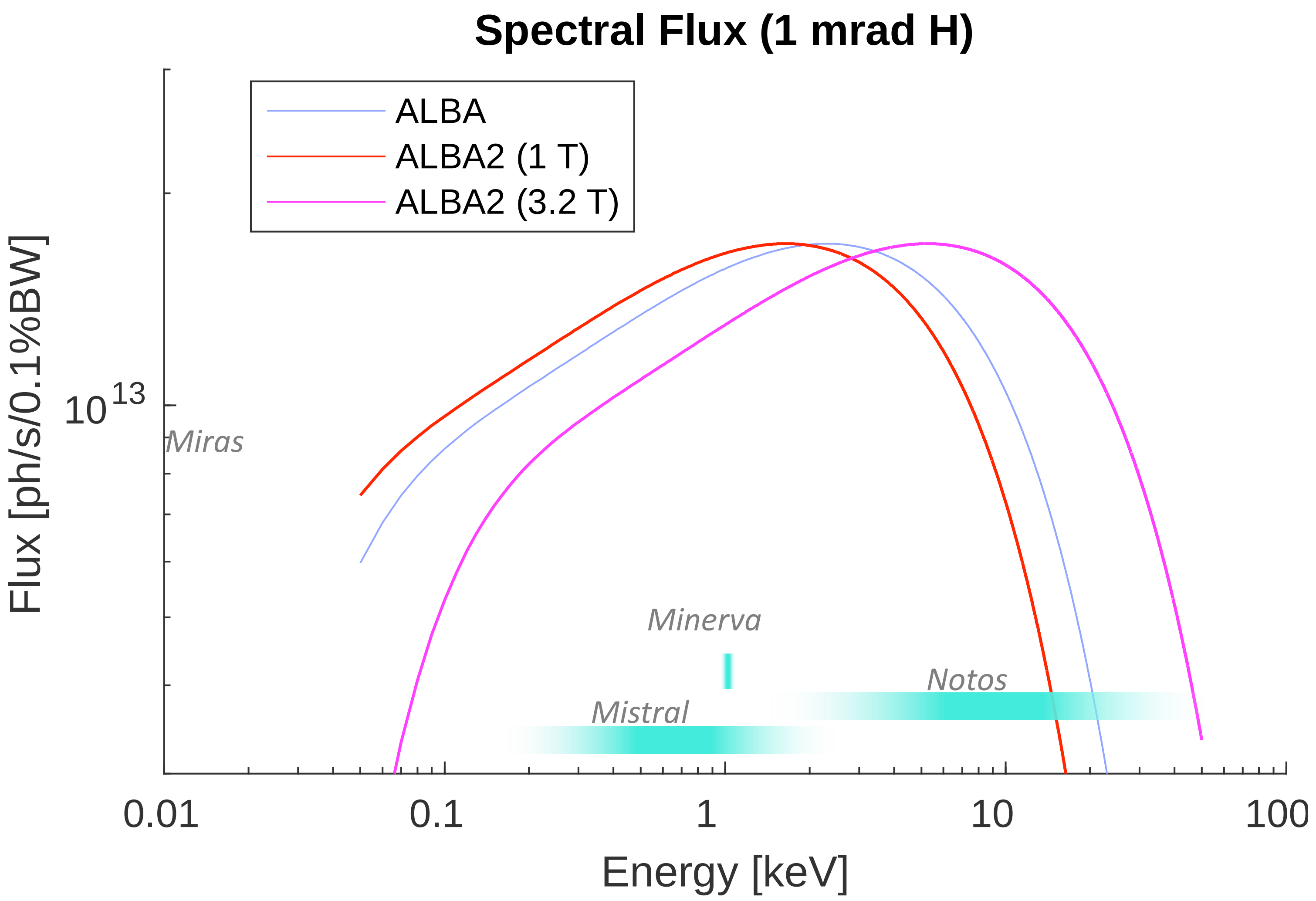
For soft x-rays brilliance does not improve very much, because it is already very ***close to the diffraction limit.***
The coherent fraction is large.

For hard x-rays ***brilliance improves a lot****, but it is still far from the diffraction limit.*
The coherent fraction is smaller.

Long beamlines still allow for higher degree of coherence, but at the expense of flux.

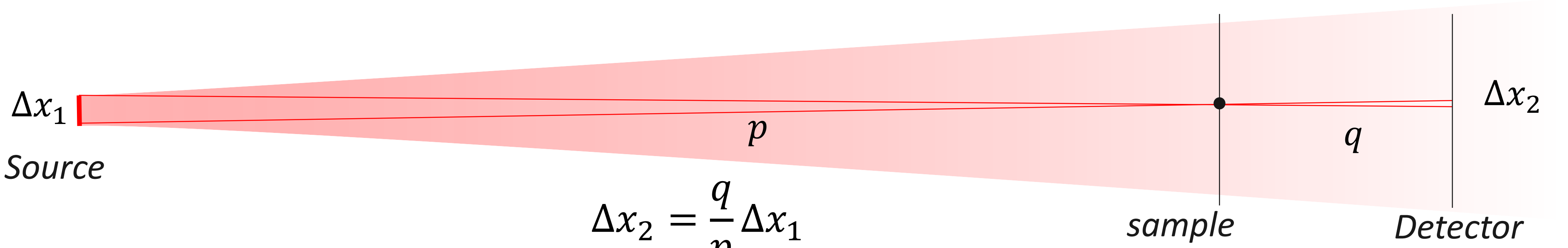
Bend v superbend

ALBA2 offers the option of having 3.2T superbends (in addition to 1T Dipoles)



Source	Critical Energy
ALBA BM	8.4 keV
ALBA2 1.0T BM	6.0 keV
ALBA2 3.2T BM	19 keV

1) HXR tomography



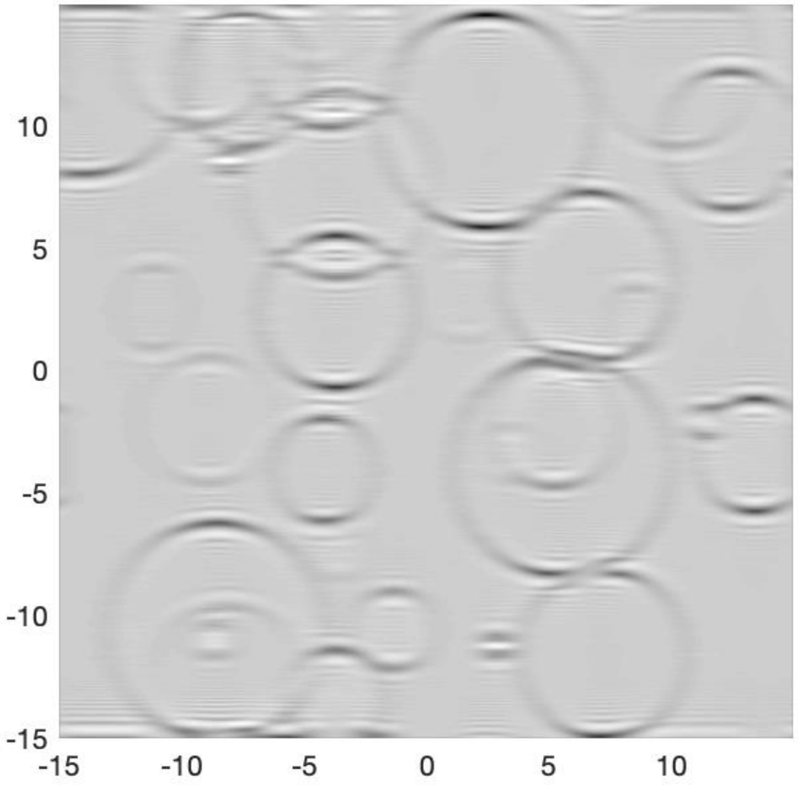
$$\Delta x_2 = \frac{q}{p}\Delta x_1$$

- *Resolution proportional to object distance.*

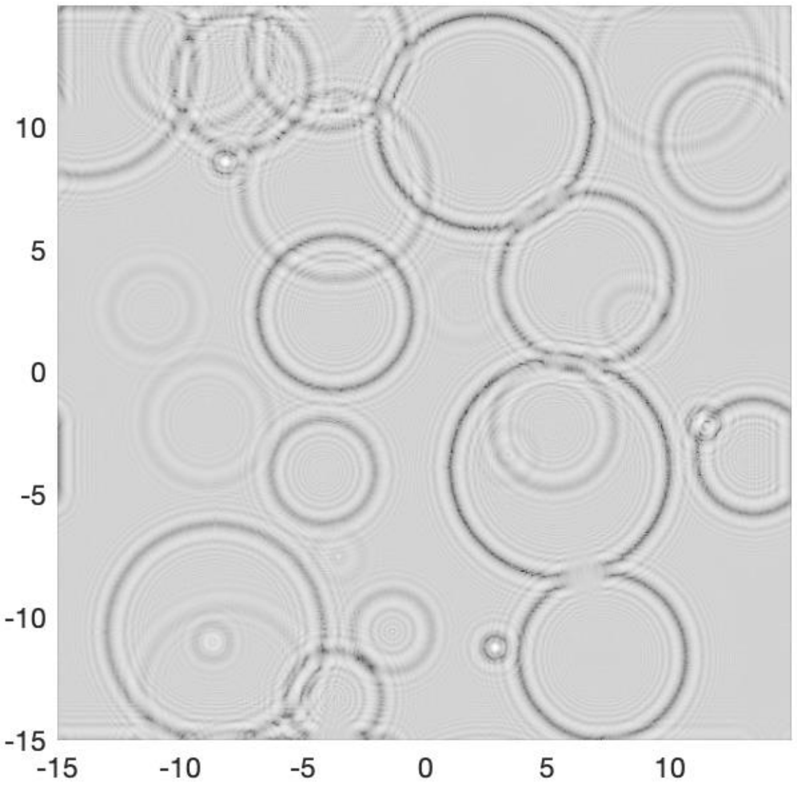
- *FOV proportional to distance to source.*

- *Coherence (phase contrast) depend on distance to source*

Large source, short BL



Small source, long BL

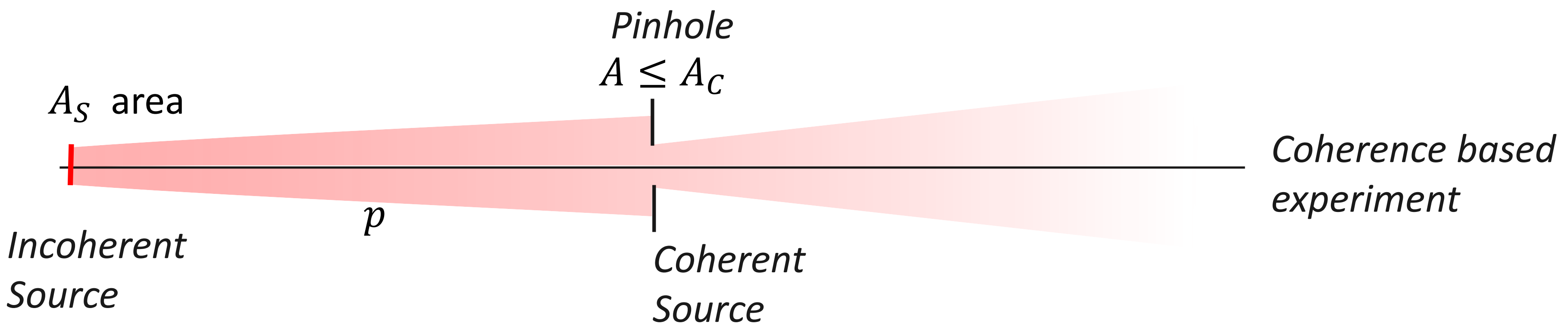


2) Enhanced coherence

Correlation length increases with distance

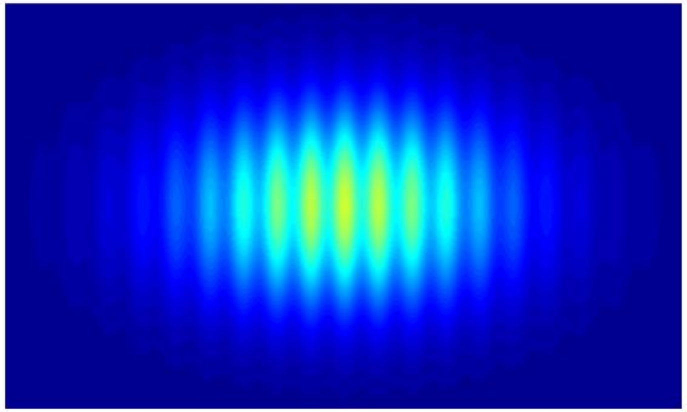
$$A_C(p) = \frac{(\lambda p)^2}{A_S}$$

J. Goodman "statistical optics" Ch. 5

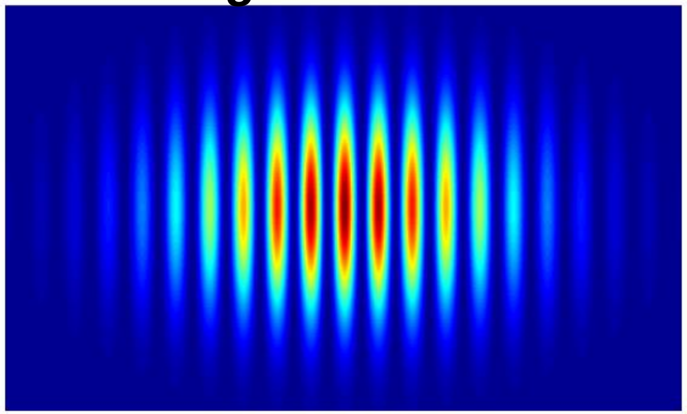


Most basic example: Young's Double slit interference

Low coherence

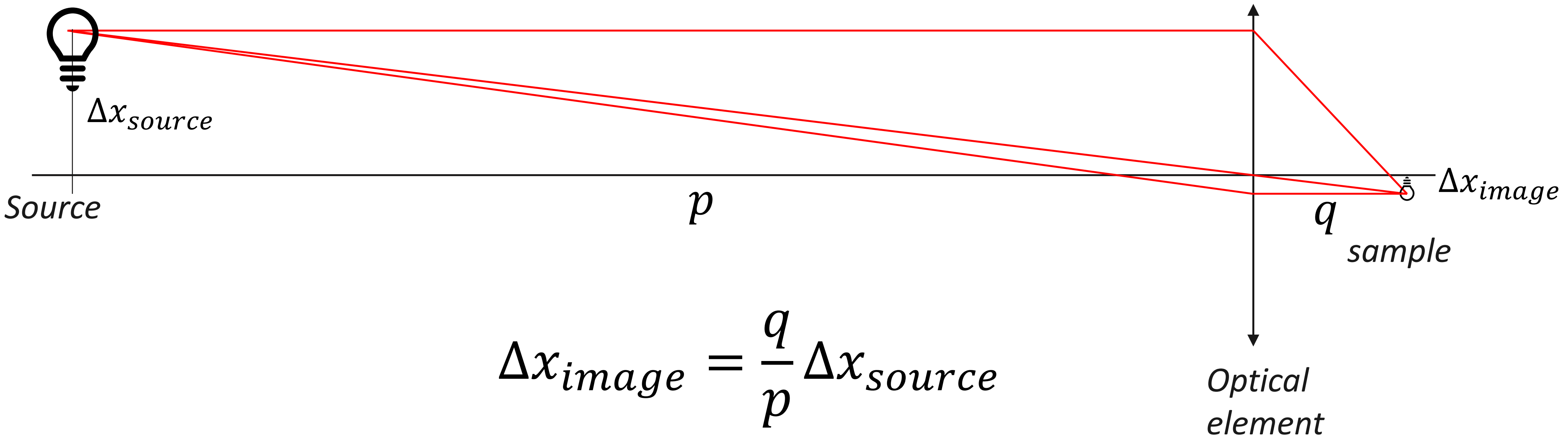


High coherence



3) Nano-probes

Geometric optics resolution proportional to object distance (p)



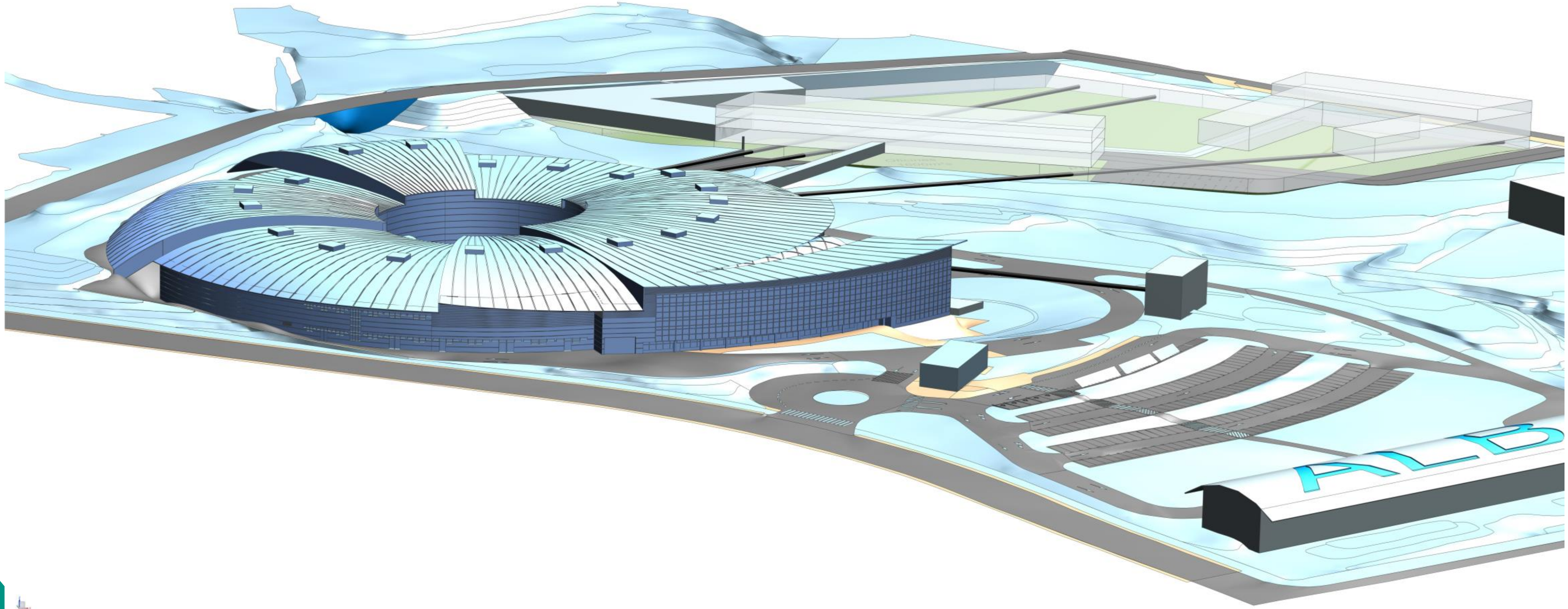
$$\Delta x_{image} = \frac{q}{p} \Delta x_{source}$$

Optical elements could be:

KB mirrors, capillaries (mirrors), Fresnel zone plates, CRLs, Kinoforms,

Long Beamlines increase resolution and coherence

New plots have been assigned to ALBA for building long BLs



Preparing the future instruments: Call for proposals for ALBAII long BLs

https://indico.cells.es/event/1230/

Deadline: 16th December 2022

Successful workshop mid November with presentation of five preproposals by scientists from Spanish community

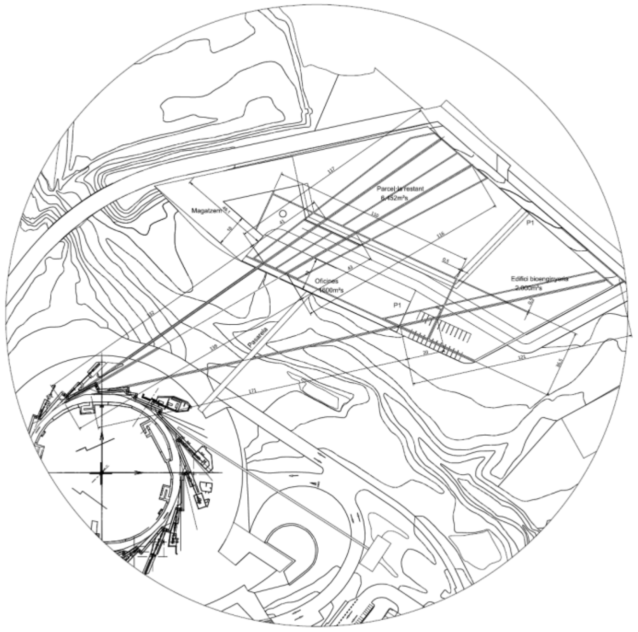
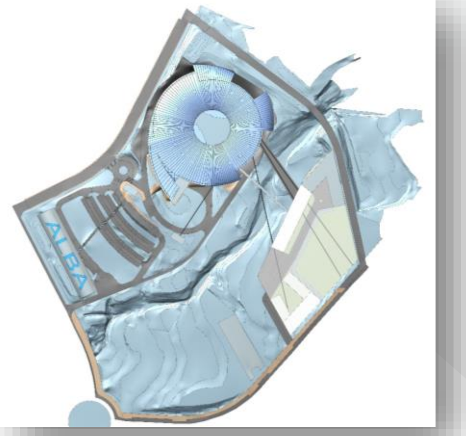


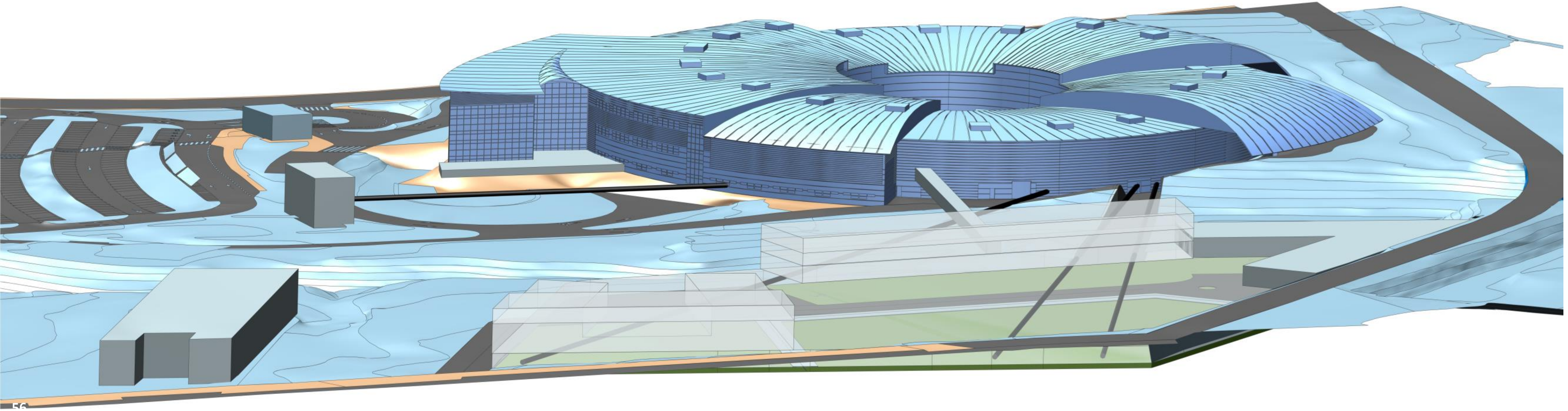
Figure 1-1 – Layout of the four long BLs

Port	*Unit*	*Value*				*Note*
Electron energy	*GeV*	3				1)
Current	*mA*	300				1)
Bunch length	*ps rms*	6 to 15				1)
time between bunches	*ns*	2				1)
Pulse current	*nC*	0.7 to 0.9				1)
Port		**BL02**	**BL03**	**BL04**	**BL08**	
Source type		Undulator	Superbend	Undulator	Undulator	
Length available for ID	*m*	2	N.A.	2	2	1) 2)
Source Size X	*um rms*	14	7.7	14	34	1) 3)
Source Size Y	*um rms*	15.1	24.8	15.1	31.4	1) 3)
Source Divergence X	*urad*	7.1	< 2000 [7)]	7.1	2.9	1) 3)
Source Divergence Y	*urad*	6.5	< 310[8)]	6.5	3.1	1) 3)
BL length within EH	*m*	25-42	28-41	25-42	22-42	1) 4)
BL length at the Far Exp. Hall	*m*	134-249	141-255	173-292	85-125	1) 5)
Position stability	*%*	10	10	10	10	1) 6)

Preparing the Infrastructures



- *Preliminary design started (number of buildings, position of each building, new limits for the parcels, size of the buildings, number of floors, roads, parkings, etc..), to be completed for an external team to produce the Executive Project (during 2023)*
- *<u>Topography of the river</u> A high accuracy topography of the river has been obtained (previous one was from air) to prepare a suitability report for the public administration (Agència Catalana de l'Aigua). The approval from this agency is mandatory to proceed with the construction licensing. The report will be prepared externally. As per today, no modification of the river would be needed.*
- *By March 2023 construction works related to the public zone (the river and the surroundings of the new plot of land), will start, carried out by "Consorci Parc de l'ALBA"*
- *Preparing CFT for the first building to be published by end 2023/beginning 2024*



What ALBA II will provide

ALBA II is the next step of currents ALBA user program to provide beyond user experiments a full infrastructure to tackle the grant challenges of our time to the Catalan, Spanish, European users

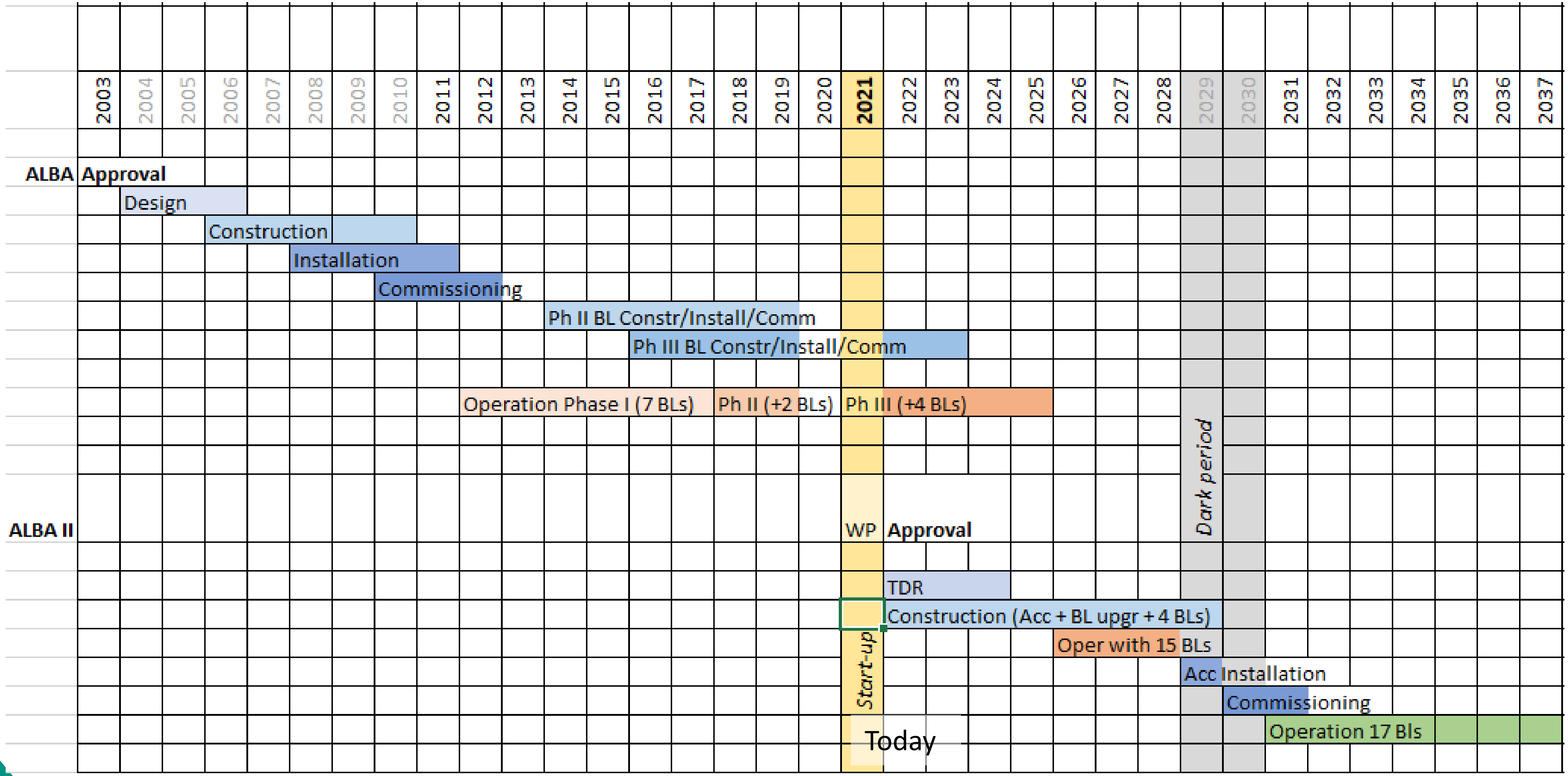
ALBA II will provide:

- Enhanced microscopy capabilities,
- Multimodal methodologies to address complex development tasks.
- High throughput capabilities and big-data connectivity for fast innovation,
- And optimized operando environments to optimize functional materials and devices.

ALBA II combines the excellence and availability of the user program of ALBA with the development of full characterization suites for characterizing multi-lengthscale problems:

- Provides full characterization suites for selected areas like advanced materials for Energy with fully integrated data pipelines and connectivity to the big data world.
- This includes multi-lengthscale correlative imaging (including TEM) and multimodal operando capabilities.
- Acts as a hub for additional characterization, sample preparation and explotation facilities.

Tentative ALBA II timeline



Thank you for your attention