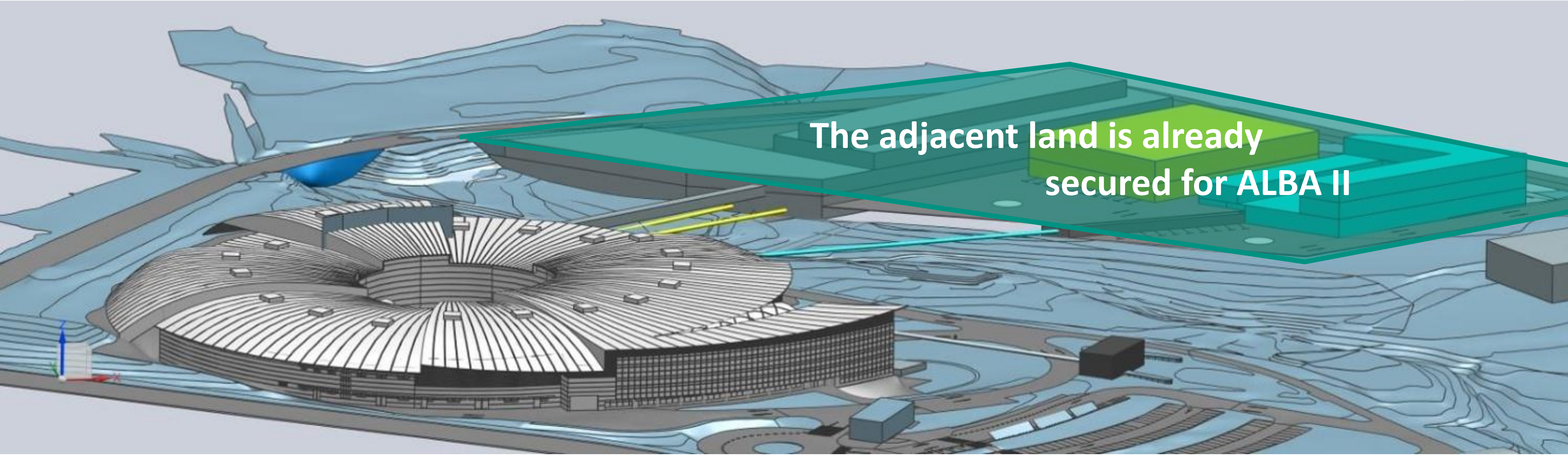
ALBA II, new technologies and new beamlines

Francis Perez / Josep Nicolas

Dec 1st, 2023
Industry opportunities in light source infrastructures

ALBA II upgrade Project



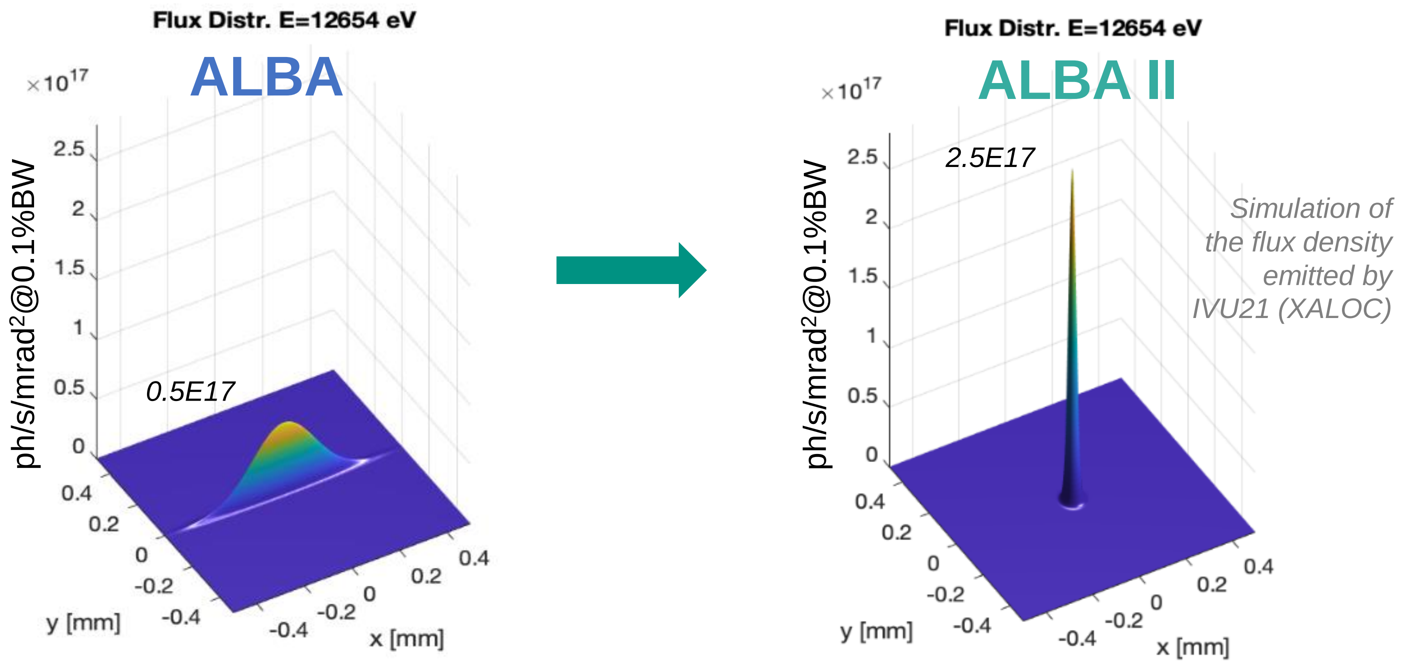
The upgrade ALBA II includes:

- **renovation** of the storage ring
- **renovation** of the existing beamlines.
- **expansion** of the infrastructure.
- **construction** of up to three new long beamlines.
- **synergy** to create a scientific and technological pole in the area.

ALBA II Accelerator Upgrade

Upgrade the 3rd Generation ALBA Storage Ring

to a 4th Generation Ultra Low Emmittance Ring: ALBA II



with the aim of doing it as efficiently as posible,

in terms of cost and time.

Optimization parameters

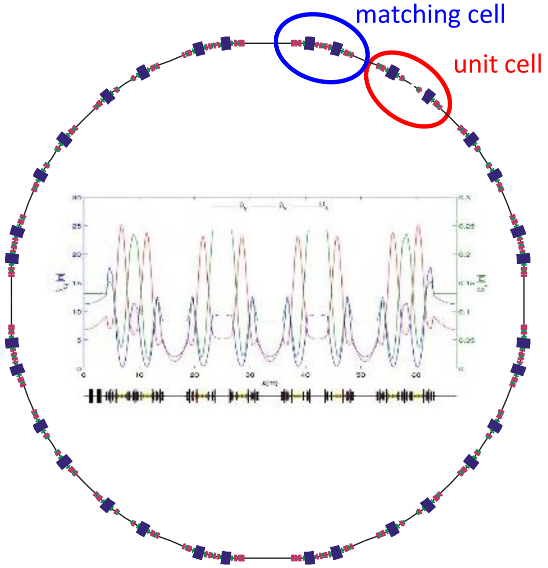
- Keep beam energy 3 GeV.
- Keep the tunnel → SR with similar compact circumference.

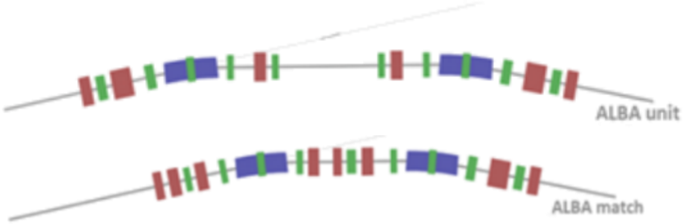
- Keep existing ID beamlines → preserve 16 cells and source points.
- Bending beamlines can be relocated.

- Keep injector (present $\varepsilon_x^{booster}$ = 10 nm·rad).
- Keep infrastructures, as much as possible.

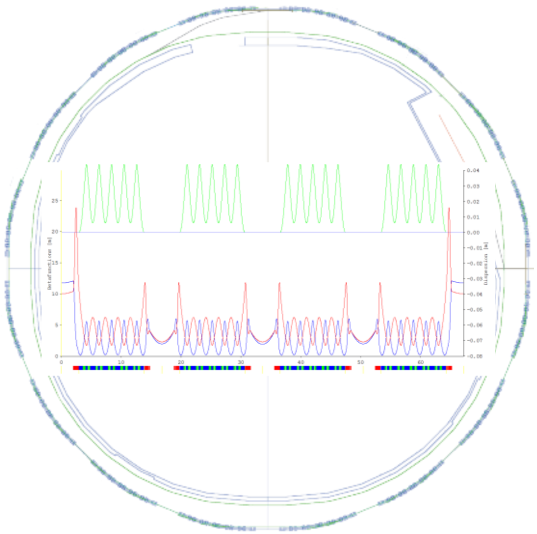
- Straight sections ~4 m, with $\beta_x \sim \beta_y \sim$ 2 m.
- Reduce emittance by more than a factor 10 (<400pmrad).
- Full coupling operation option.

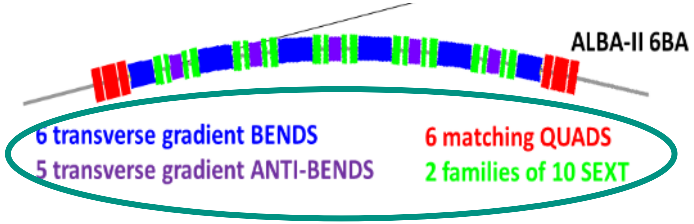
The upgrade





	ALBA	ALBA II
Energy	**3 GeV**	**3 GeV**
Circumference	268.8 m	268.8 m
Symmetry	4-fold	4-fold
Lattice	8×2 DBA cells	16×MBA cells
Emittance	**4.5 nm·rad**	**~200 pm·rad**
Nº of cells	8+8	16
# of straights	4 / 12 /8	16
Straight length	7.8 / 4.0 / 2.3m	4.0 m





Prototype program

ALBA II Enabling Technologies Project
ALBA 01 (2022 - 2025)

ALBA 01 - 7,5 M€

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Design, and prototype construction of:

WP1	Magnets
WP2	NEG Coated vacuum chambers
WP3	Pulsed magnets
WP4	Girder for arc assembly tests
WP6	Superconducting Undulator

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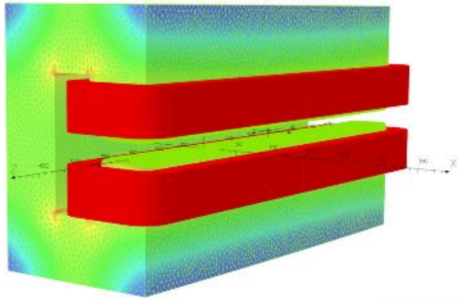
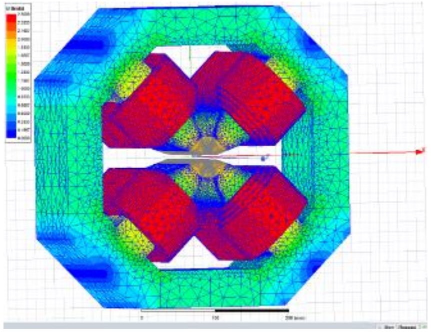
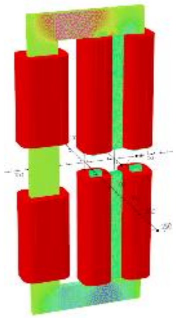
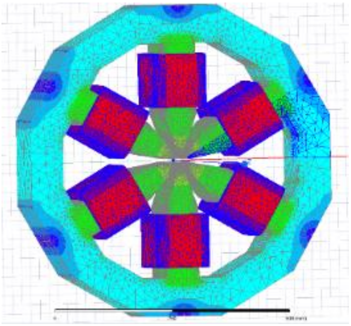
WP1 Magnets







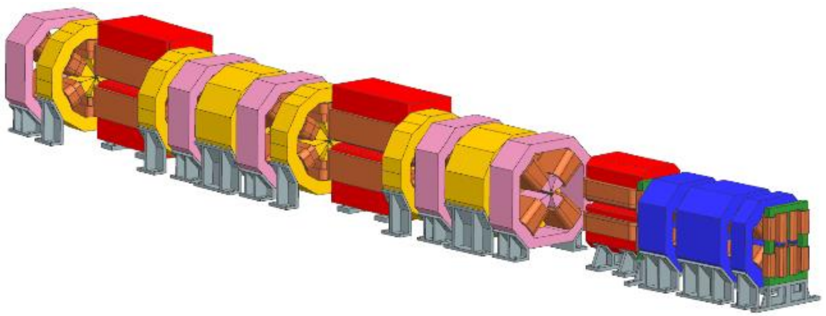


Magnet type	Prototype required?	Lots
QD	YES (1)	Lot 1
QDS	YES (2)	Lot 1
QF/QFS	YES (1)	Lot 2
Q1	NO (0)	
Q2	NO (0)	
Q3	YES (1)	Lot 2
SH	YES (1)	Lot 3
SV	YES (1)	Lot 3
CORR	YES (1)	Lot 4
Total	**8 prototypes**	**4 lots**

→ We order a conventional QDS (similar to QD), and a version with embedded coils.

→ The 2 reverse bends share the same geometry, so we order 1 single prototype.

→ We only order the triplet magnet with the highest working point.



Designs done, CfT ready.

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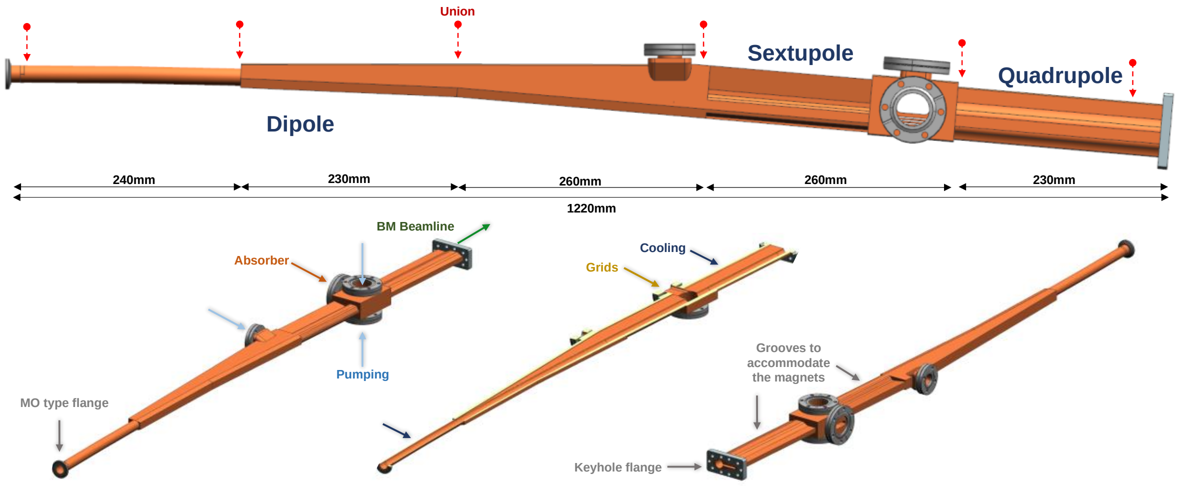
WP2 Vacuum Chambers

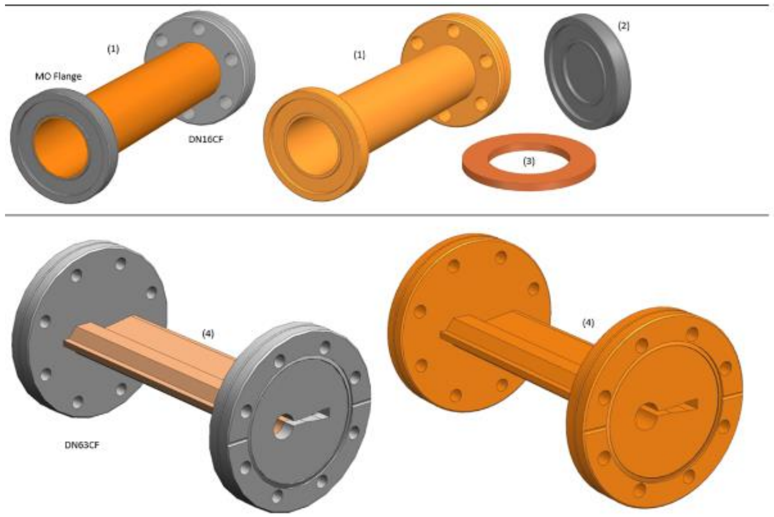
Designs on going:



Pre-prototypes being ordered:

MO flange prototype			
	Bimetallic	Bulk part	Drawing:
Nipple: MO-CF16 (1)	Chamber: Cu ETP Flanges: SS	CuCrZr	L0001 (bimetallic) L0002 (CuCrZr)
Length (between flanges)	70mm		
Blank MO flange (2)	SS	CuCrZr	L0006
Quantities:	2 sets each		
Gaskets (3)	Cu		L0005
Quantity:	20		

SV chamber prototype			
	Vacuum brazing	Bulk part	Drawing:
Nipple: both sides CF63 (4)	Cu chamber SS flanges	CuCrZr	L0003 (bimetallic) L0004 (CuCrZr)
Length (between flanges)	175mm		
NEG coating:			
e-beam	0.5 to 1.2 µm		
ph-beam	0.2 to 1.5 µm		
Quantities:	2 sets each		



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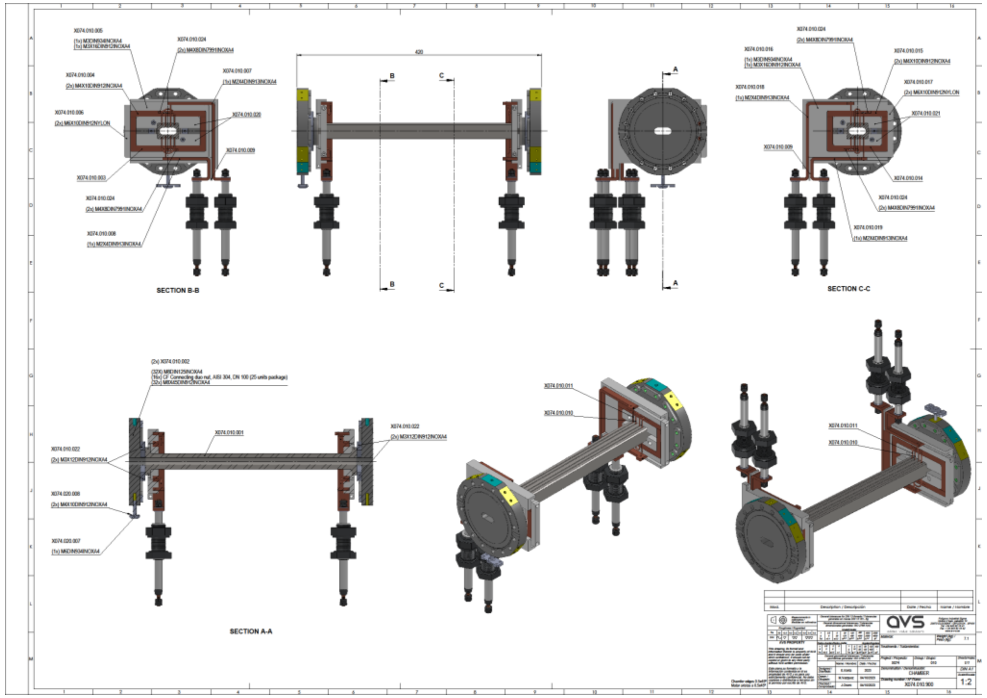
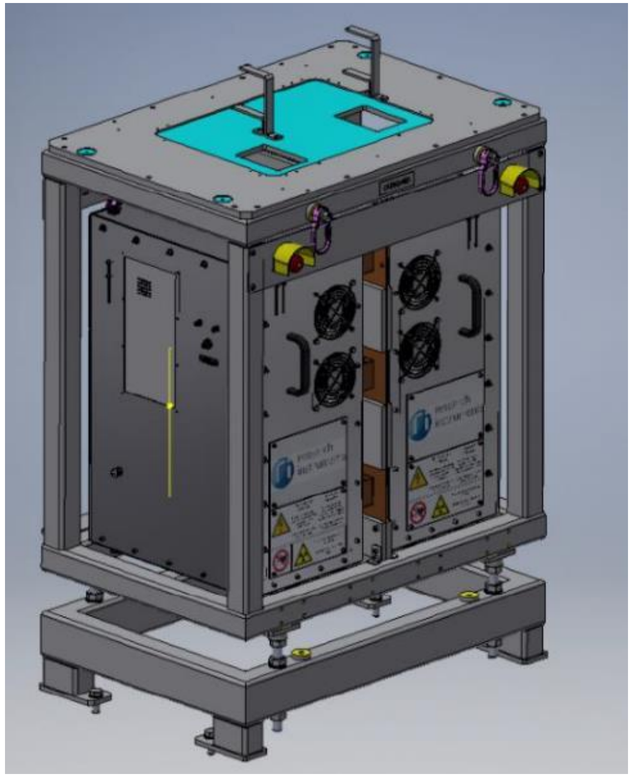
WP3 Pulsed Magnet

Double Dipole Kicker

Design done, prototype under construction

Magnet **and** **Pulsed Power Supply**





WP4 Girders

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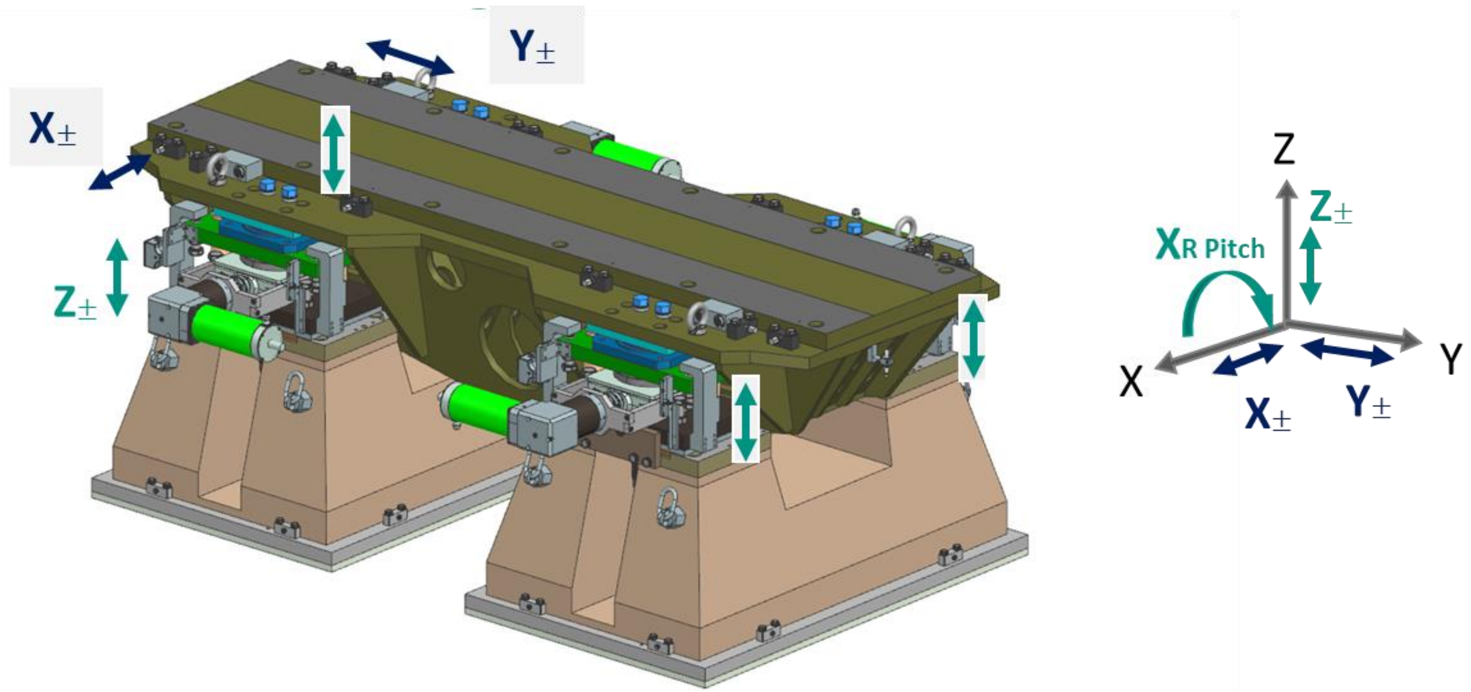
Design ready – PDR with external panel on Oct’23

Working details on the movement system



1st eigenfrequency 77Hz – Max. deformation 30um

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WP6 SCU

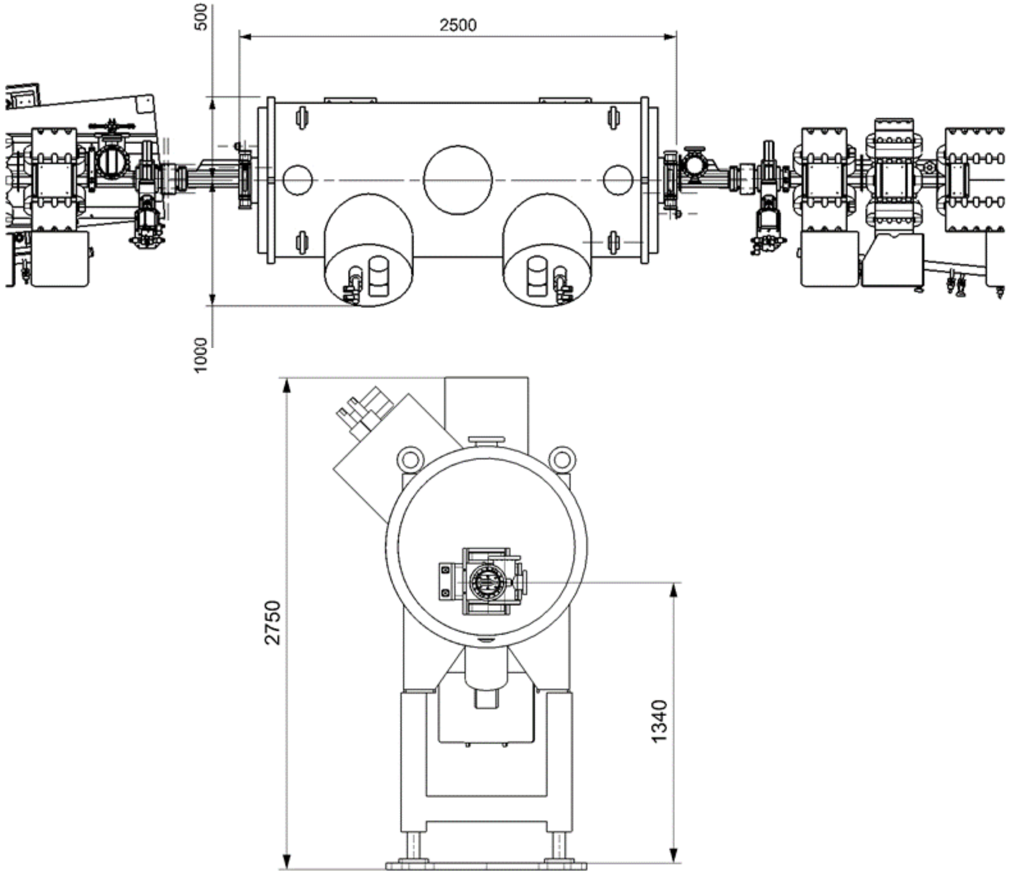
Order on the basis of functional specifications

Detailed design is required in the tender

Table 6.2 outlines the main magnetic parameters of the SCU as required by CELLS.

Table 6.2: Magnetic parameters of the SCU.

Total SCU Length (flange to flange)	2.5 m
Expected Magnet Length	≲ 2.0 m
Target Period	≲ 16.0mm
Maximum K	≲ 1.7mm
Minimum vertical vacuum stay clear gap	5.5 mm
Minimum horizontal vacuum stay clear gap	60 mm
General Energy Range	8 – 40 keV
Transverse field roll-off at ±10 mm @ maximum K	< 0.1 %
Field stability ΔBy / By over 72 hours at maximum K	$< 10^{-4}$
The Hysteresis effects and repeatability shall be:	
within 58% to 100% of maximum K	< 0.1 %
within 20% to 58% of maximum K	< 1.0 %
Maximum phase angle error on x=0, z=0	< 5 degrees RMS



RF System
3rd Harmonic Active Cavity

The **prototype tests** were co-funded by ALBA, HZB and DESY through the collaboration agreement RCN-CIN202100124 (2020-2023).

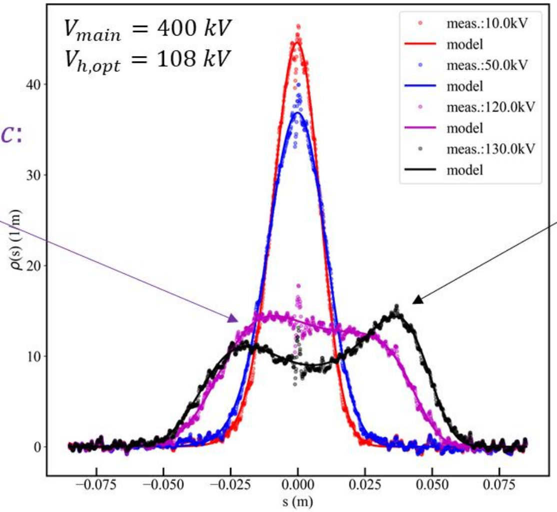
Cavity

SSPA

DLLRF

*Bunch lengthening **beam tests at BESSY II** with the **3rd Harmonic EU Active Cavity Prototype***

Near quartic: $\xi > 1$



Overstretched bunch: $\xi > 1$

Single bunch profile for different harmonic voltages

Successfully tested with beam

Call for tenders

Several CfT are under way:

- Digital LLRF upgrade	Production
- Doble Dipole Kicker prototype	Production
- 3rd Harmonic RF Cavity	Tendering
- Super-Conductor Undulator (SCU)	Ready to tender
- Electro-magnets prototypes	Ready to tender

Foresee for 1st half 2024:

- 3rd Harmonic 1.5GHz SSPA	Technical specs under revision
- Girders prototypes	Design ready, tech specs by Q1/24
- Vacuum chambers prototypes	Design ongoing, tech specs by Q2/24
- Permanent magnets prototypes (QDS & SB)	Design started, tech specs by Q2/24

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Future needs

Accelerator's components 2026-2029

- New magnets
  - ~ 600 magnets
  - ~ 1000 power supplies
  - Some, permanent magnets?

- New vacuum chambers
  - ~ 270 m vacuum chambers
  - SS, Cu, NEG coated

- New Girders
  - High vibration modes
  - High precision remote movement

- Many others:
  - Upgrade RF system with SSA and 3rd Harmonic Cavity
  - New Diagnostics equipment
  - New Insertion Devices
  - Upgrade electronics
  - …

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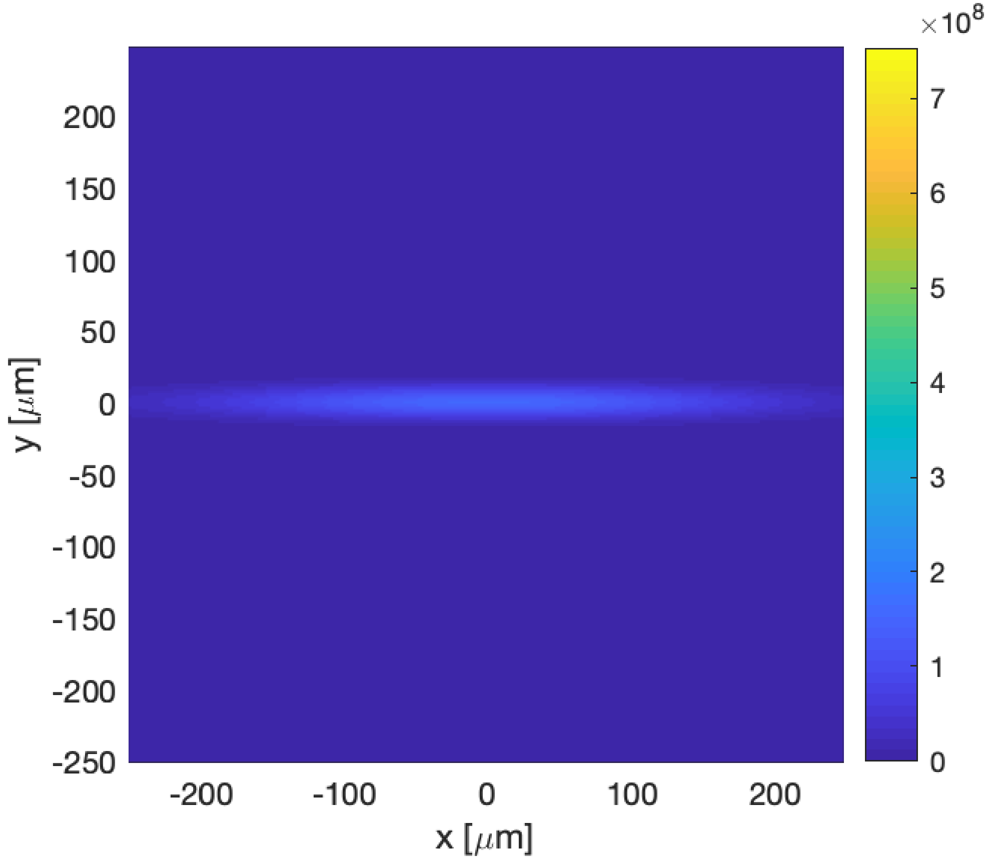
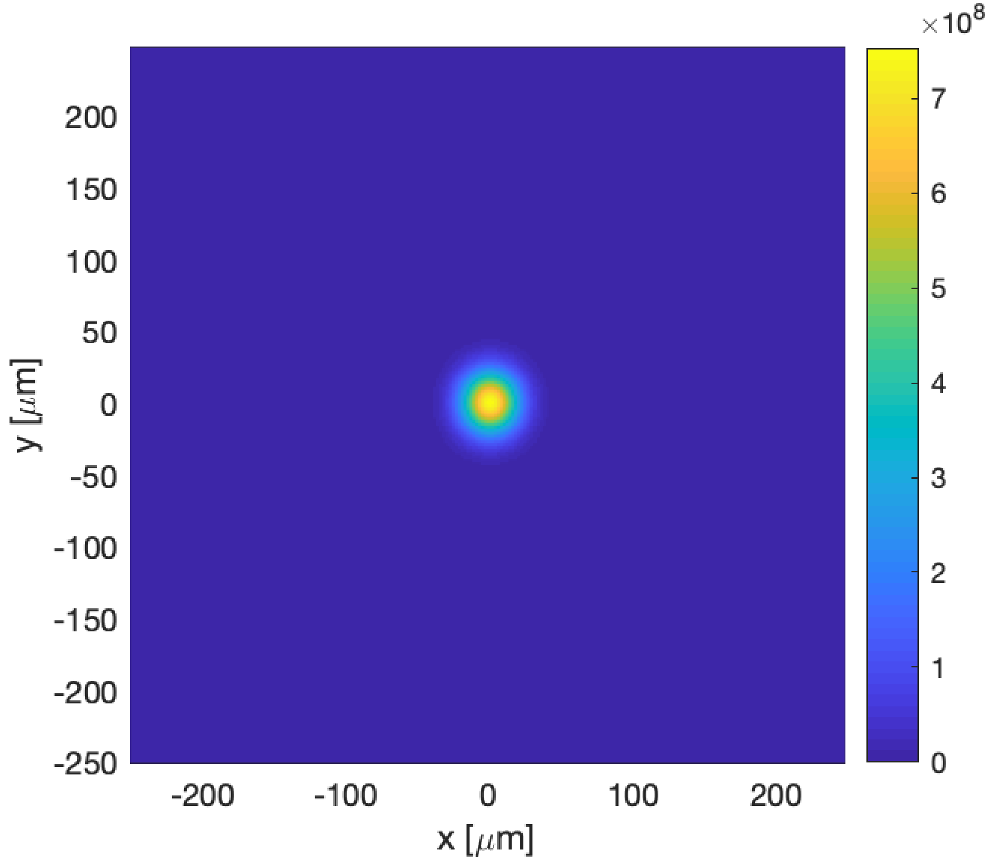
Beamlines for a new source

The beamline program aims at translating the features of the new source into an improved tool for the scientific research in many fields relevant for society.



ALBA



ALBA-2

Beamline upgrades

Reasons

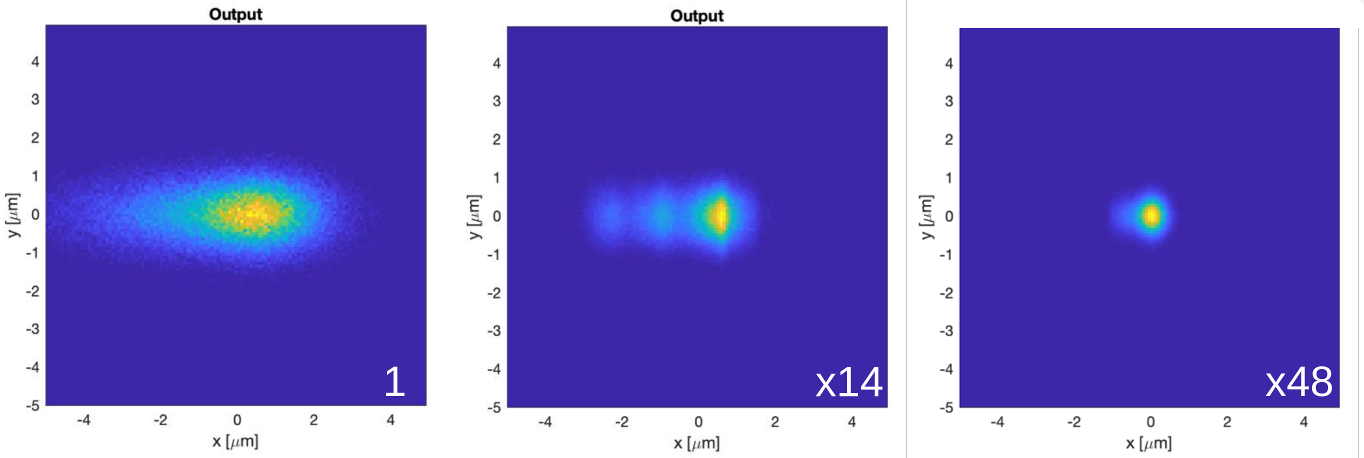
- *Adapt to higher brilliance*

- *New opportunities*

- *Aging of instrumentation*

- *Compatibility with new machine*

Spot on sample at the Xaira beamline



At ALBA | *Current beamline at ALBA-II* | *Upgraded beamline at ALBA-II*

Scope:

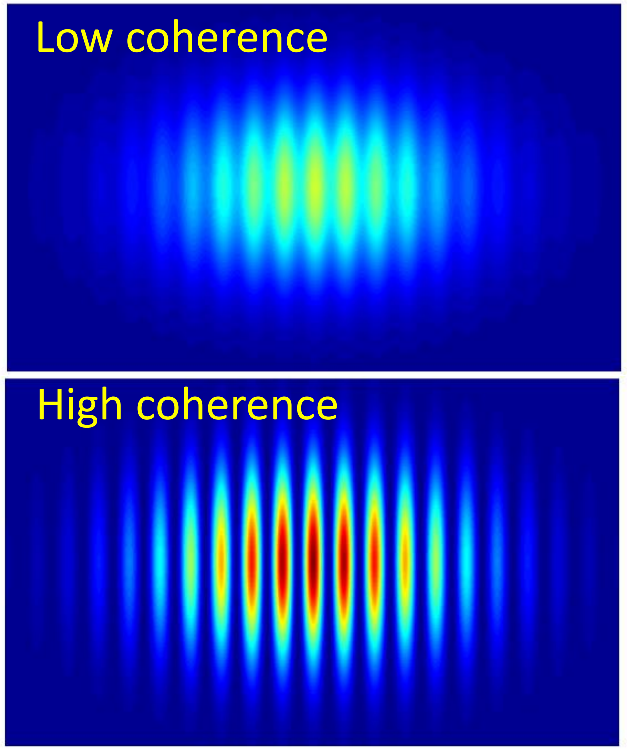
***-** Detectors, Optics, endstation and endstation instrumentation, infrastructure.*

The definition and prioritization of the upgrade of the existing beamlines will be available early in 2024

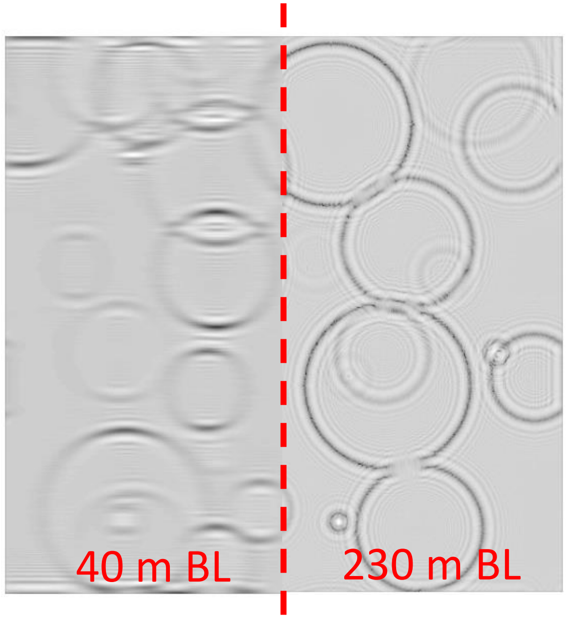
Beamline program for ALBA-II

Brightness / coherence

- More flux on diffraction beamlines.
- Wave optics for x-rays.
- Approach ultimate resolution limit.
- **Diffraction and imaging**



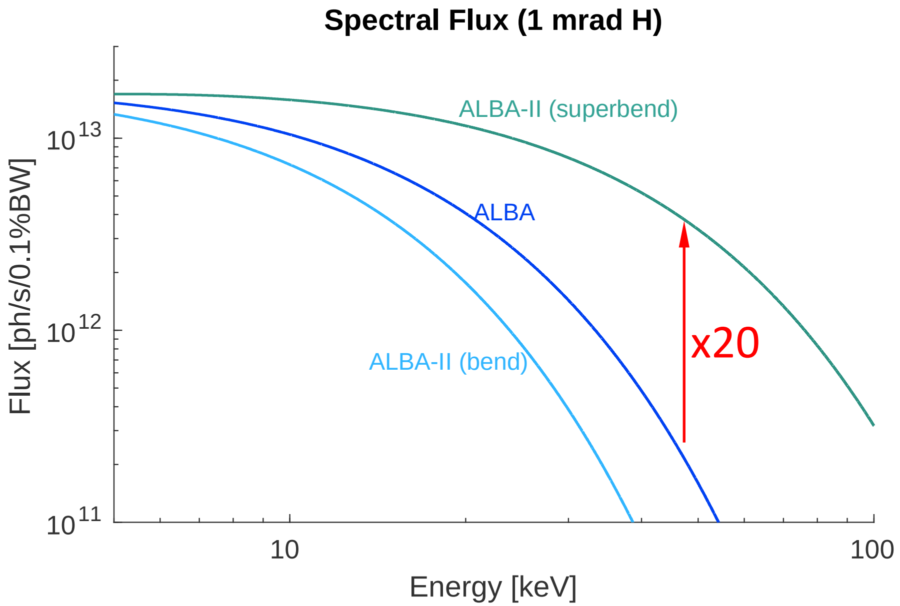
Long beamlines



- Better spatial resolution at large working distance.
- **Coherence** at high photon energy.
- **Nanoprobes and imaging**

Superbends

- Enable the use of BM beamlines for **higher photon energies.**
- **Spectroscopy and diffraction**



ALBA-II upgrade

ALBA main building
- Accelerators
- Experimental hall
- Laboratories

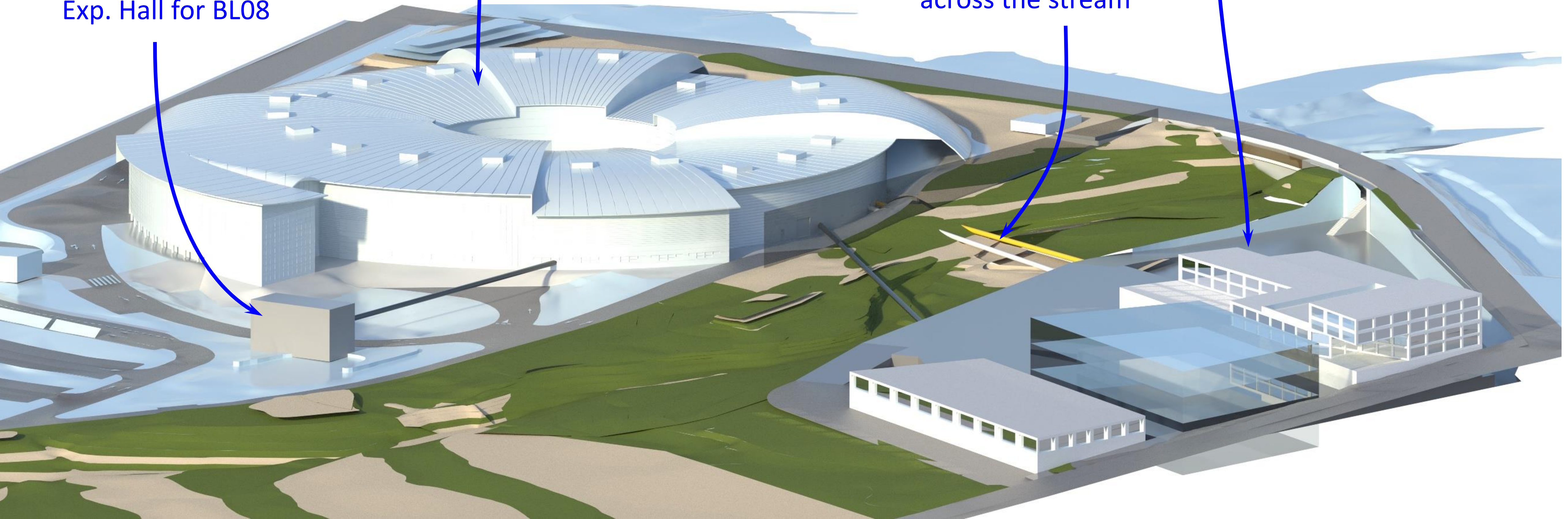
…

ALBA-II extension
- Experimental halls for BLs 2,3 and 4
- Laboratories
- Collaboration institutes

…

Exp. Hall for BL08

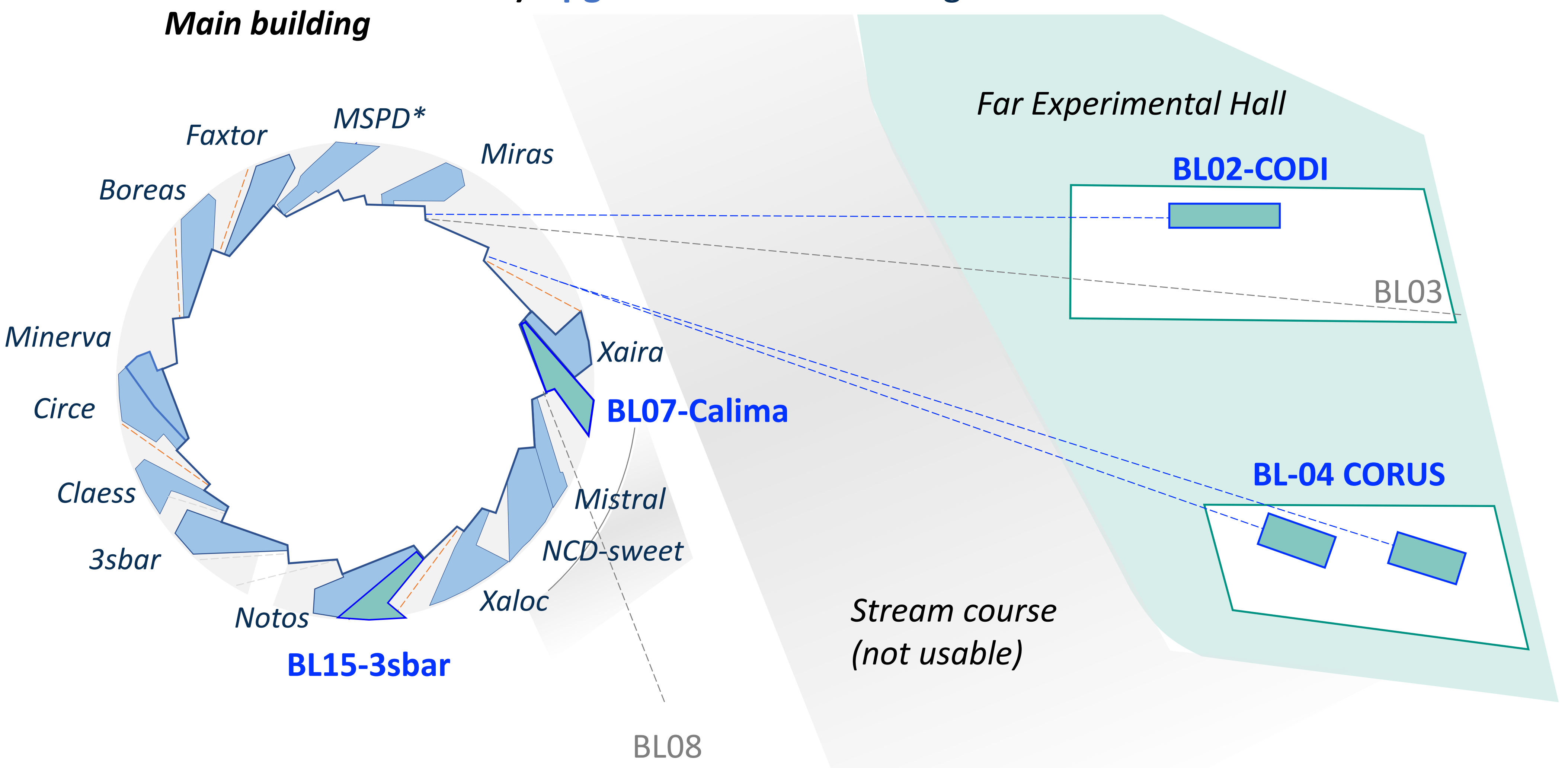
Beam transport
across the stream



ALBA-II Beamline program

A) Construction of **4 new beamlines**

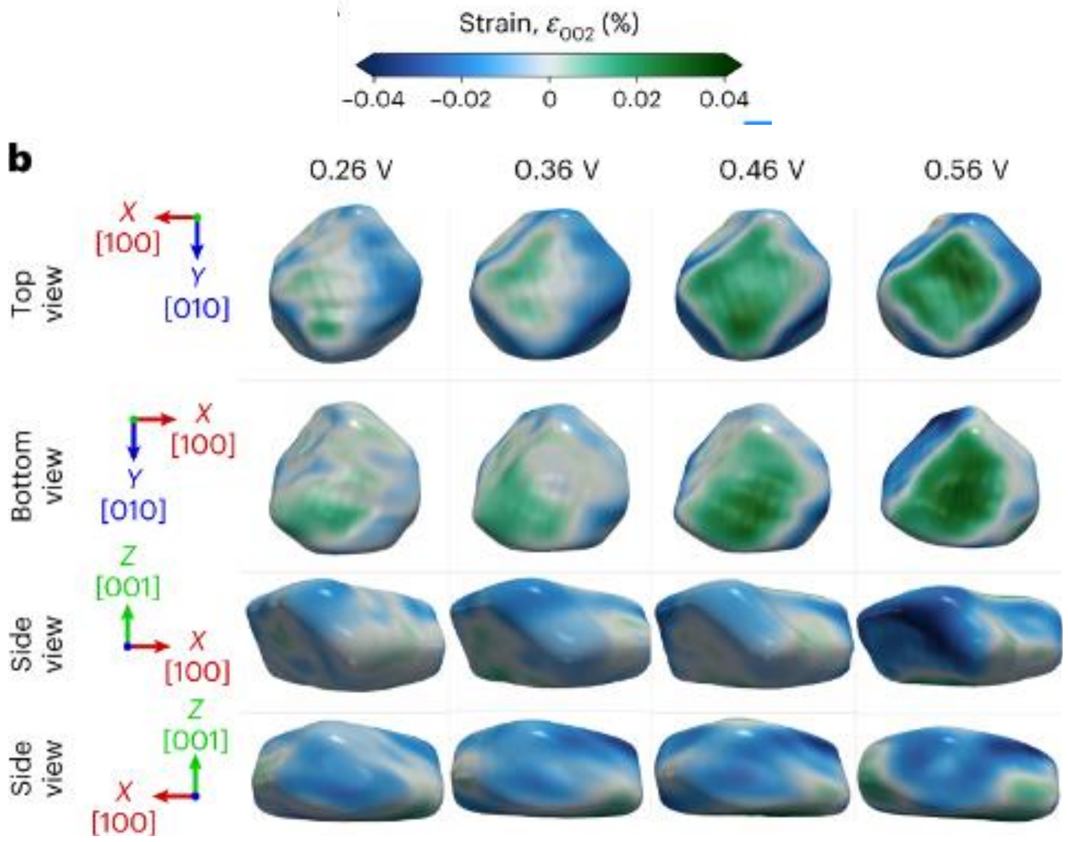
B) **Upgrade** of the 13 existing beamlines of ALBA



BL02-CoDI

Hard X-ray nanoprobe beamline devoted to **Coherent Diffraction** Imaging techniques, for in-operando studies in material science.

	CoDI
Source	In vacuum undulator (IVU19)
Energy Range	10 - 30 keV (DCM + MLM)
Spot Size	30-50 nm
Technique	nanoDiffraction, nanoFluorescence, CDI, Ptychography, Holography, Bragg-ptychography, Tele-ptychography
Features	20 m flight tube Laser Heating, High Pressure, Gas dosing, Cryostream, Cryostat… (space around sample for versatile sample environment)
Sample	Micro reactors / Electro chemistry cells for in-situ and operando
Detector	One large area detector (6M type) One small detector mounted on robot arm Multielement SDD



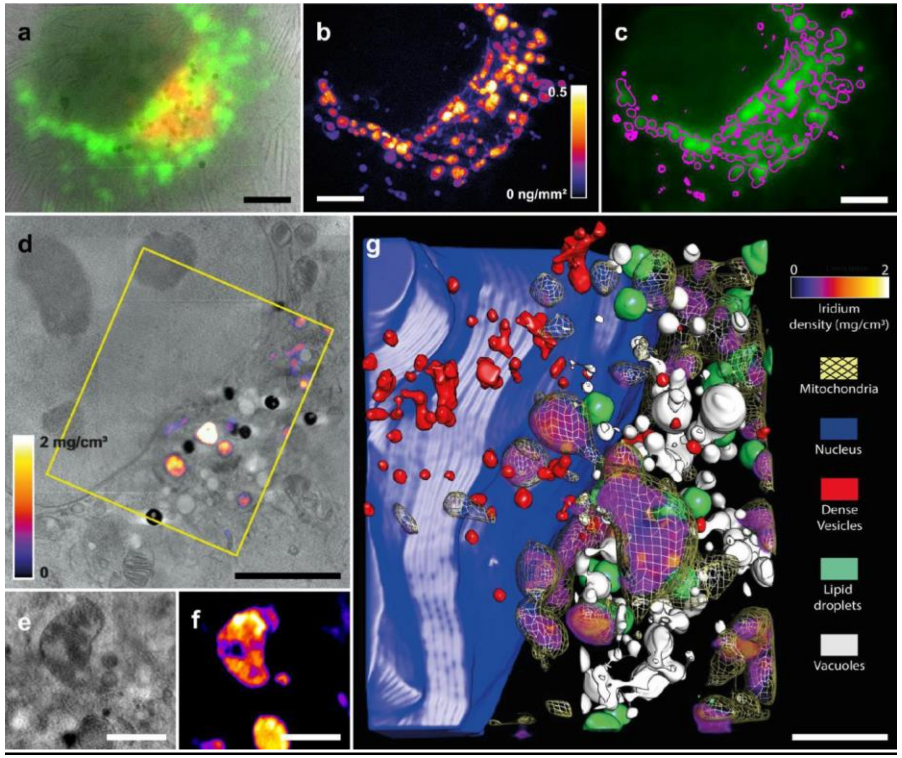
3D reconstruction and Evolution of strain in a Pt nanoparticle as varying electrode potential. Useful for the design of strain-engineered nano-catalysts

From C. Atlan, et al. Nat. Mater. 23, (2023), https://doi.org/10.1038/s41563-023-01528-x

BL04-Corus

Hard X-ray nanoprobe beamline devoted to spectral Imaging and tomography for life sciences.

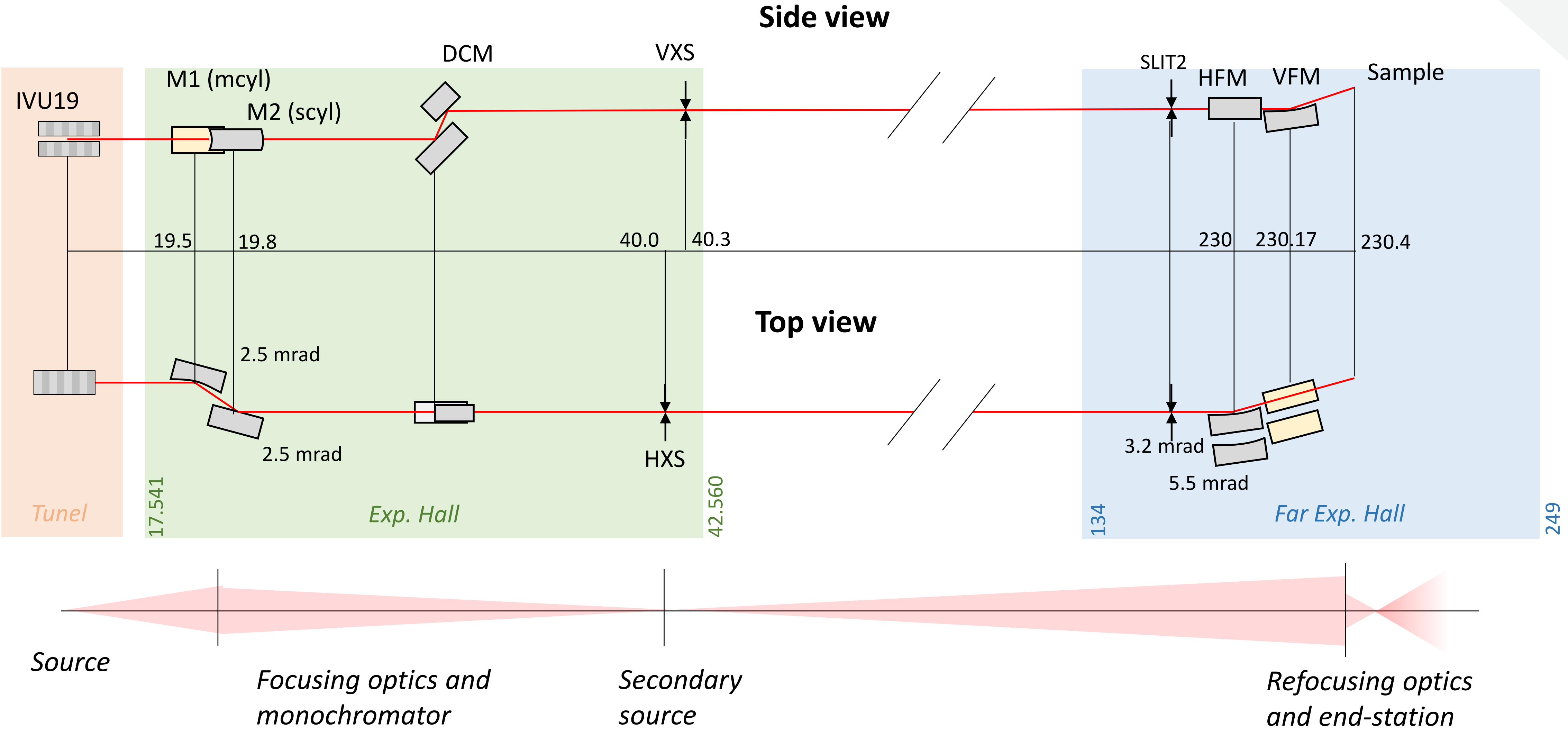
	Corus
Source	In vacuum undulator (IVU19)
Energy Range	10 - 27 keV (DCM + MLM)
Spot Size	20-50 nm
Technique	3D-nanoXRF, XANES (STXM) Holo-tomography (Full Field)
Features	LN2 cryogenics, 180º Rotation, XY mapping UHV, Visible microscope
Sample	Multi-sample shuttle system
Detector	Nanospec:: Two Multielement SDD, Diode NanoImag: Two Multielement SDD, sCMOS Area detector.



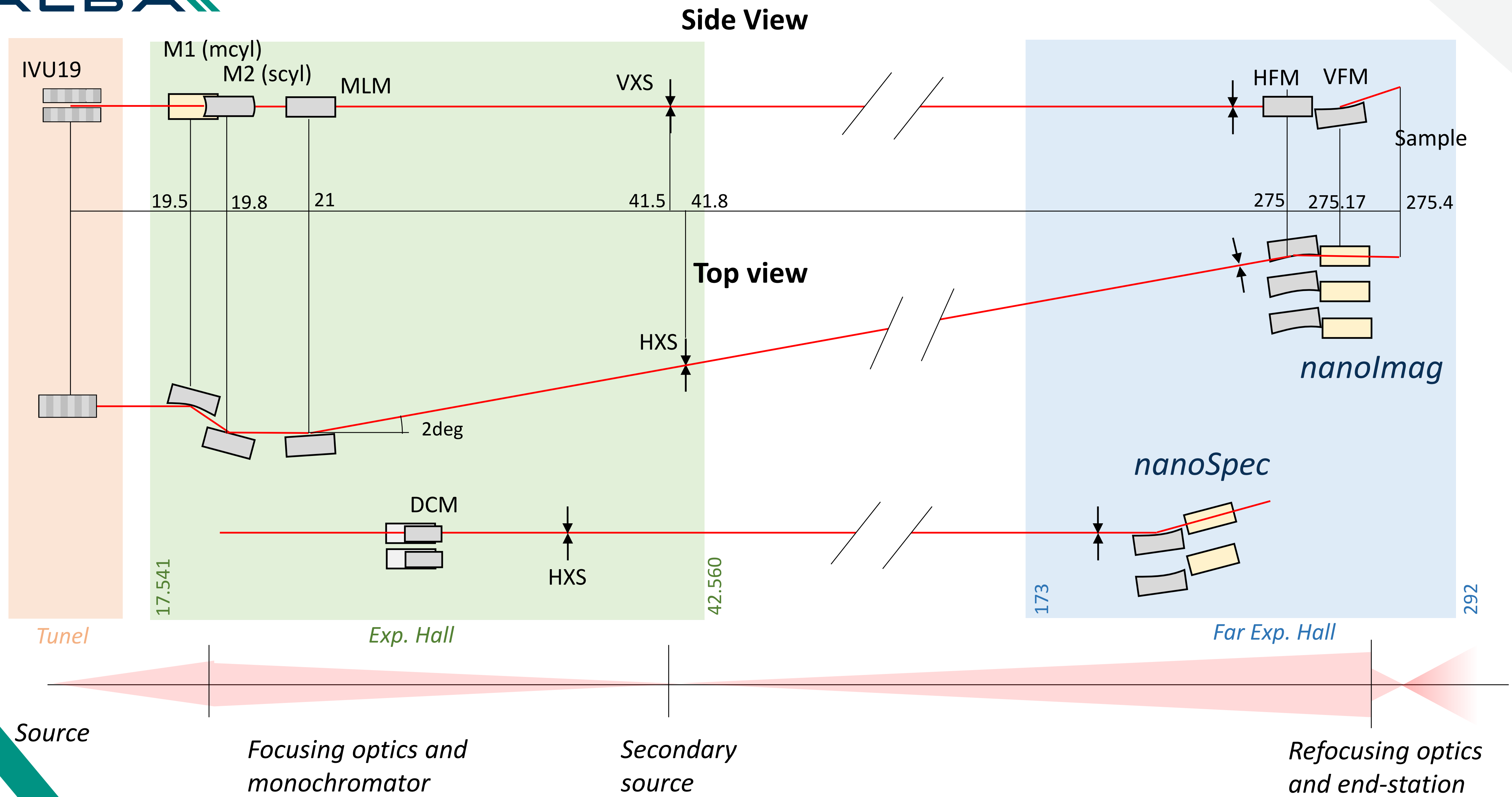
Determination of intra-cellular location of Ir in breast cancer cells. Imaging at nm-resolution with chemical sensitivity.

From Conesa et al. Angew Chem Int Ed Engl 2020, 59 (3), 1270-1278. DOI:10.1002/anie.201911510.

BL02-CoDI: Optical layout

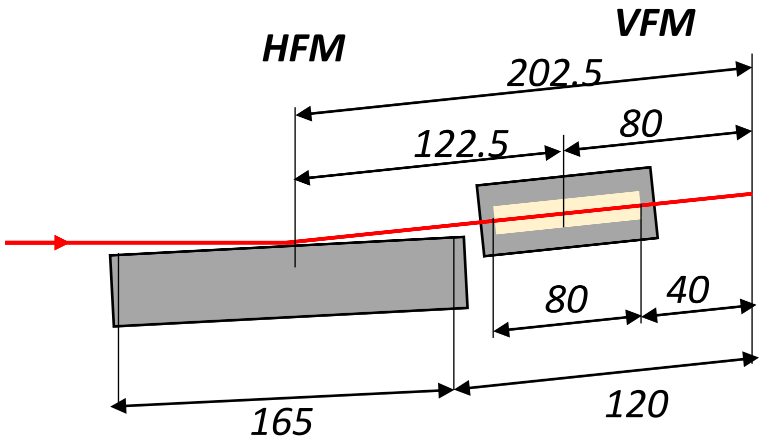


BL04-CORUS: Optical layout

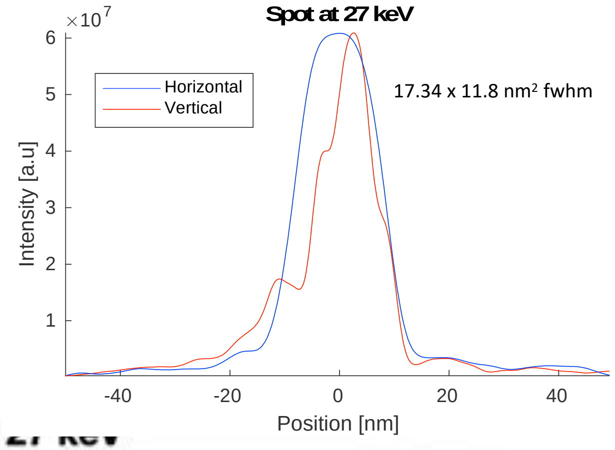


A challenge: Nanofocusing KB optics

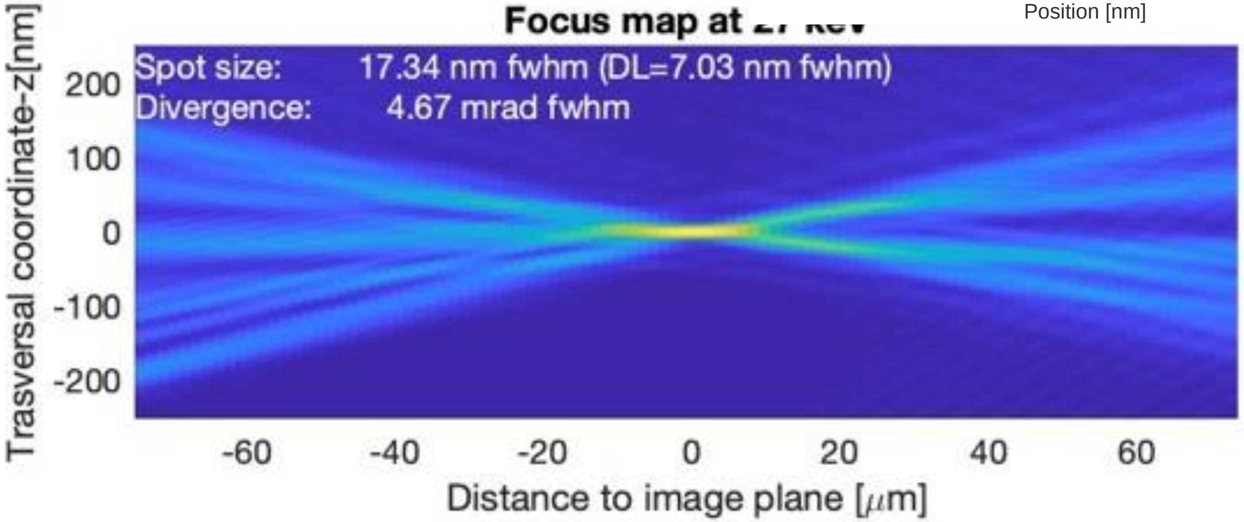
The intended nanoprobes represent a challenge, first in optics



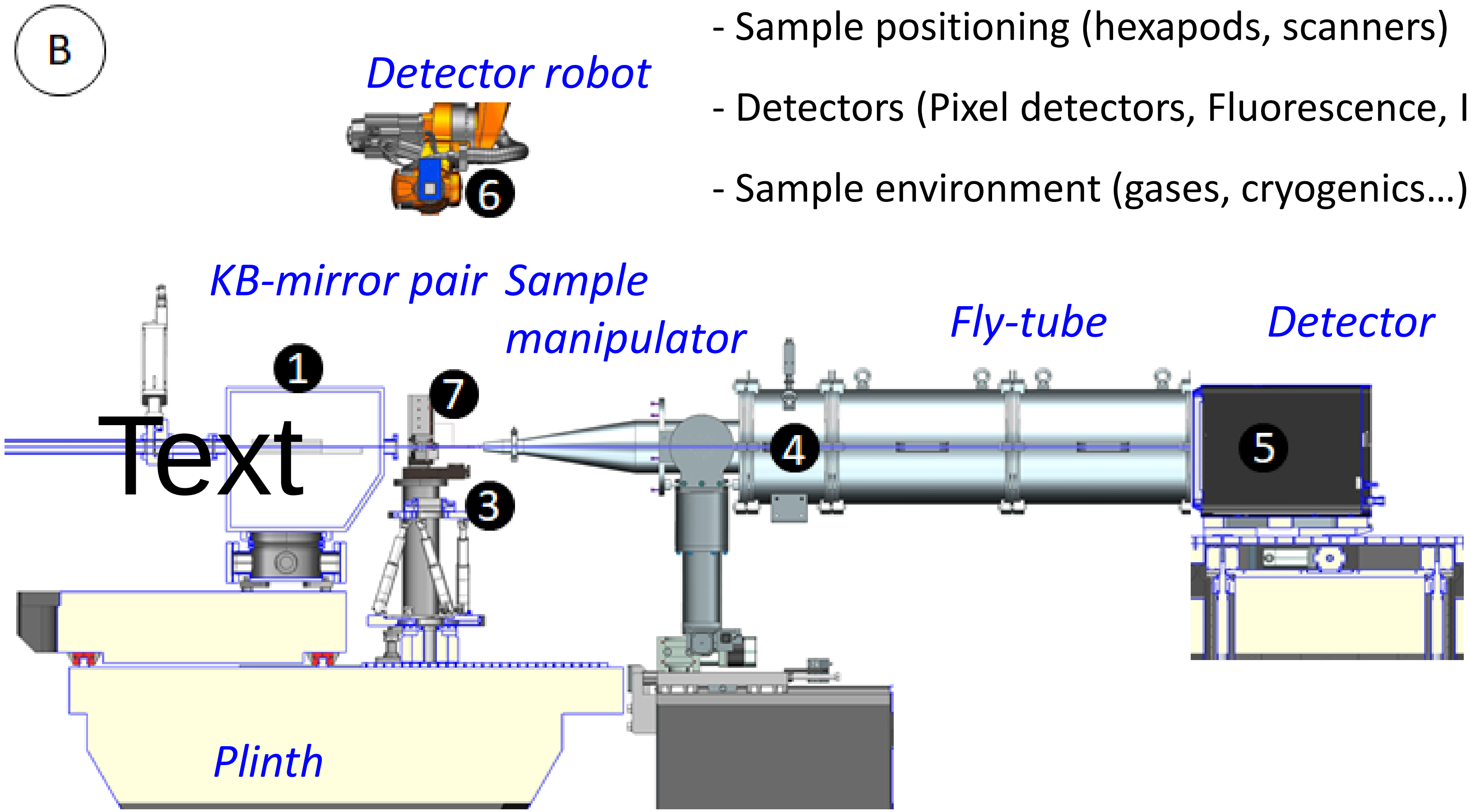
- *Spot size **<25 nm** fwhm*
- *Depth of focus < 10 µm*
- ***Distance to sample <40 mm***



- *Plano-elliptic mirrors*
- *Graded multilayer coating*
- *R_{min} ~ 10 m*
- *Length >80 mm*
- *Figure Errors **< 1 nm, < 50 nrad***
- *Transversal acceptance **< 1 mm²***



Endstation (CoDI)

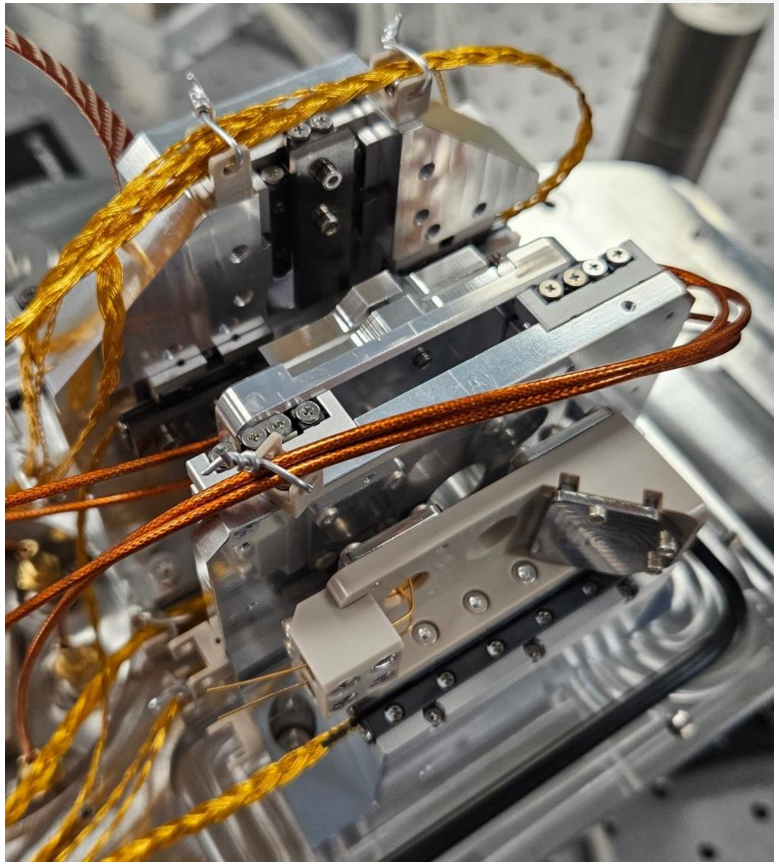


Endstations for CoDI (and Corus) include

- Sample positioning (hexapods, scanners)

- Detectors (Pixel detectors, Fluorescence, Izero)

- Sample environment (gases, cryogenics…)



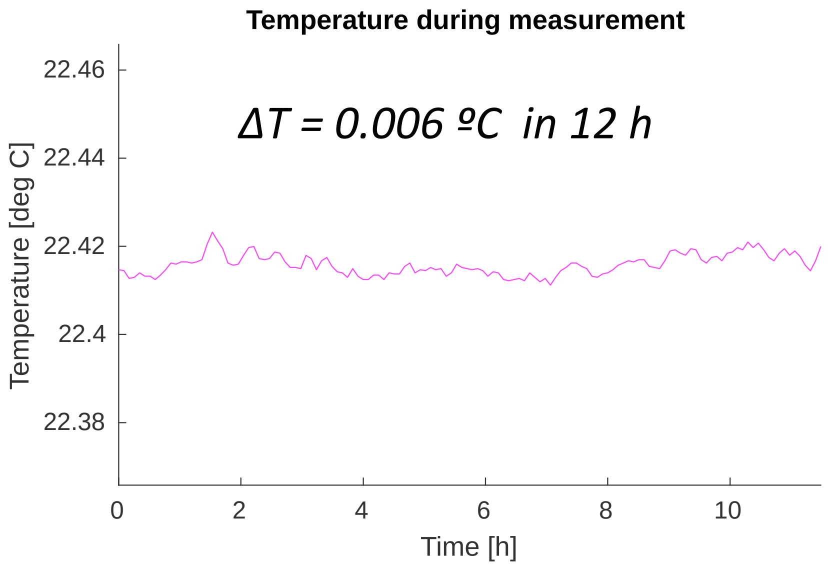
Lightweight, speed and compactness are required.

Watchmaker mechanics.

More challenges

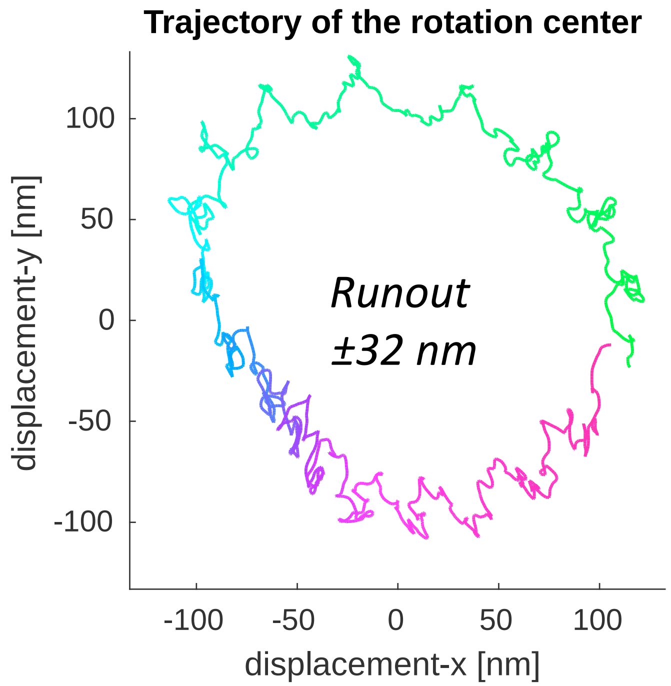
Nanometer stability

- *Vibration isolation*
- *Drift compensation*
- *Temperature, humidity stability*



Nanometer positioning accuracy

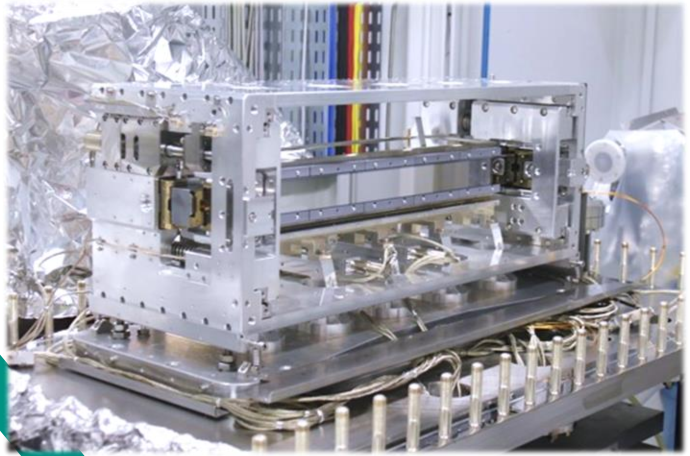
- *Feedback positioning systems*
- *Nanometer resolution*
- *Nanometer guidance errors*
- *Fast actuators*



Future needs

Optomechanics

- In vacuum undulators
- Front End
- Mirrors systems (incl. cooling, and bending)
- Double crystal monochromators
- Multilayer monochromators
- Slit systems
- Diagnostic sets
- Wavefront sensors

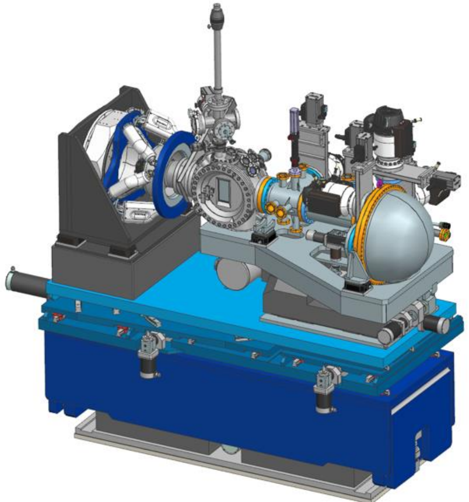


Infrastructure

- Rad. Shielding hutches
- Cabling
- Media supply
- Vacuum system
- Gas handling
- **Beam transport**
- **HVAC**
- **Building isolation**
- **BioSafety BSL2**

Data

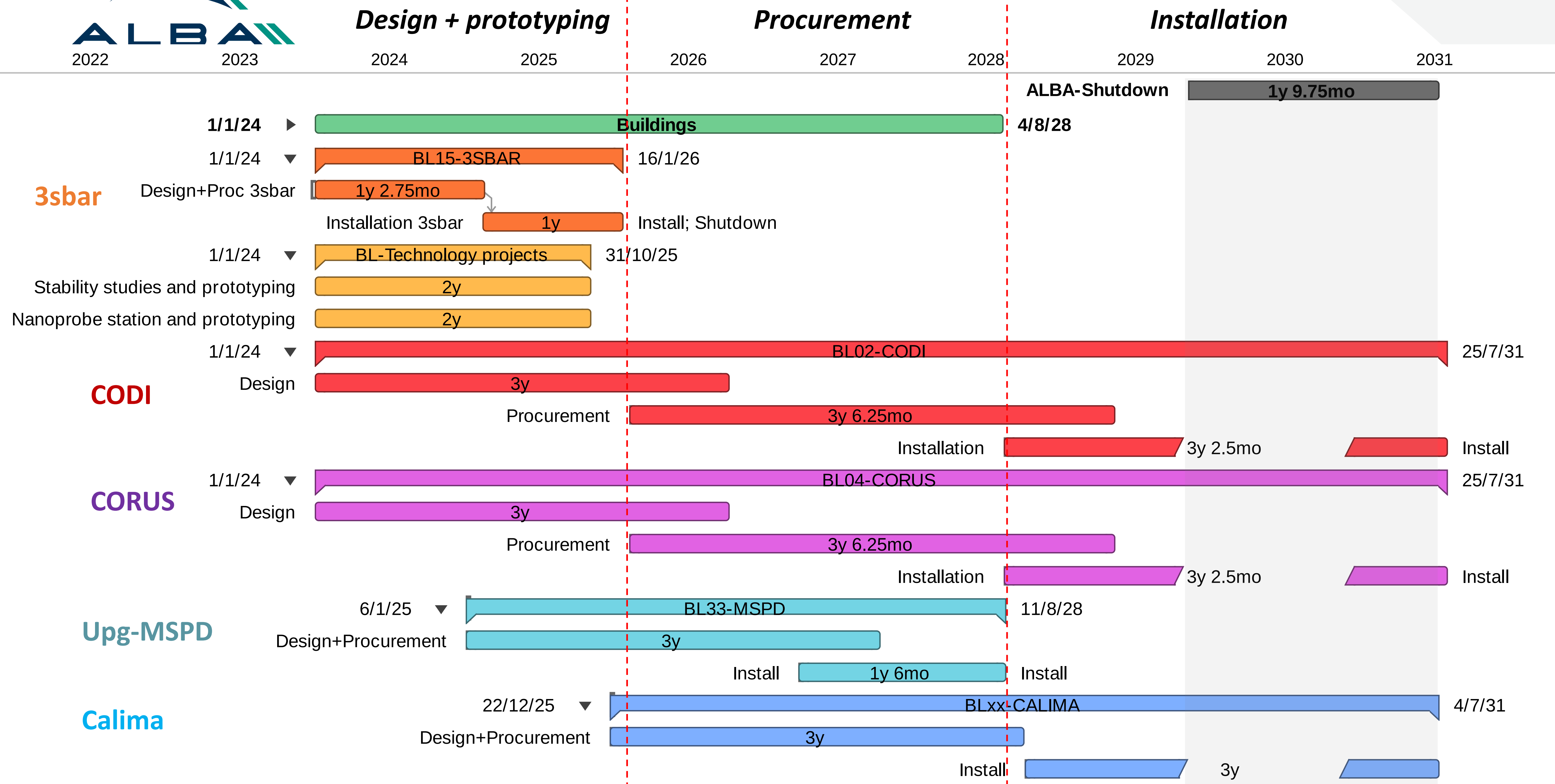
- **High data volume**
    - **Networking**
    - **Storage**
- **Complexity**
    - **Real Time processing**
    - **Data Analysis**



Endstation

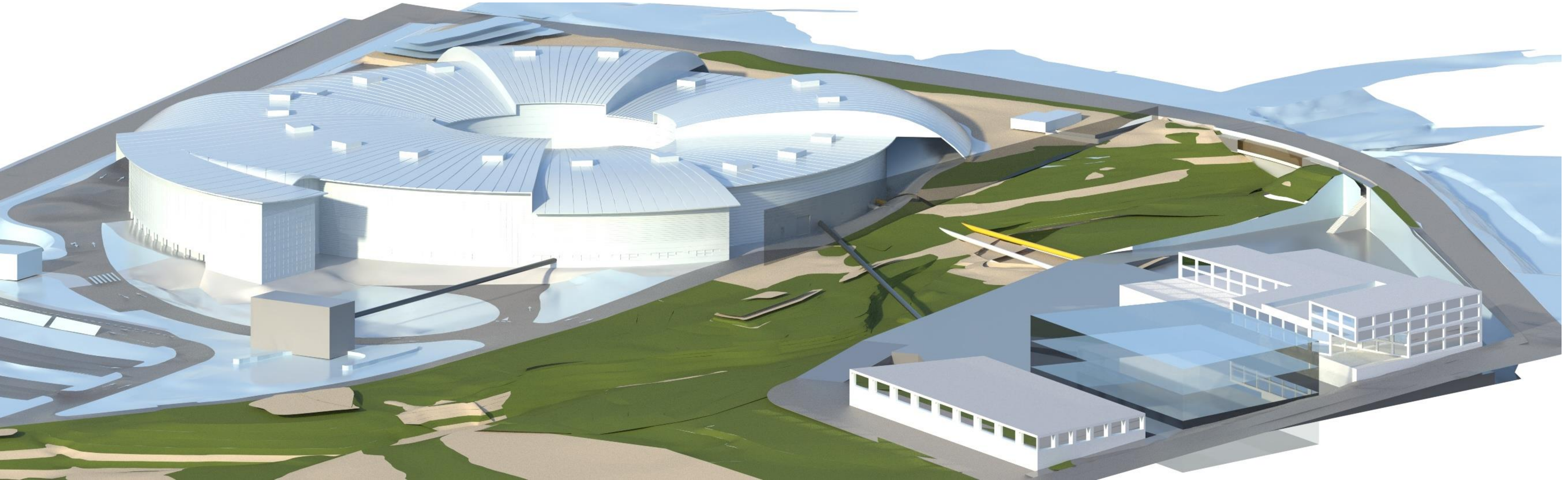
- **Sample manipulator**
    - Hexapodes
    - Goniometers
    - Scanning stages
- **Detectors**
    - Pixel detectors
    - Si drift detectors
    - Izero monitors
- **Sample environment**
    - Gas dosing
    - Cryogenics
    - Heating
    - Sample Exchange robots
    - …

Timeline (work in progress)



Summary

- One brand new **4th generation storage ring**.
- Construction of **4 new beamlines**
- **Upgrade** of the 13 existing beamlines of ALBA



Thanks!