# ALBA II, new technologies and new beamlines

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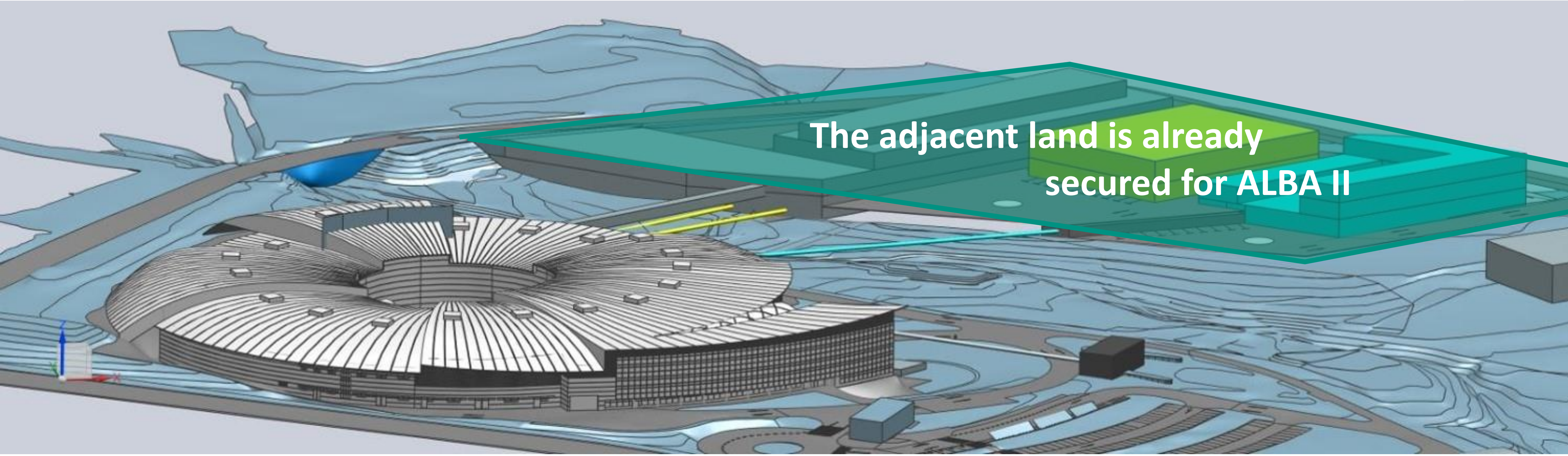
Dec 1st, 2023
Industry opportunities in light source infrastructures

# ALBA II upgrade Project

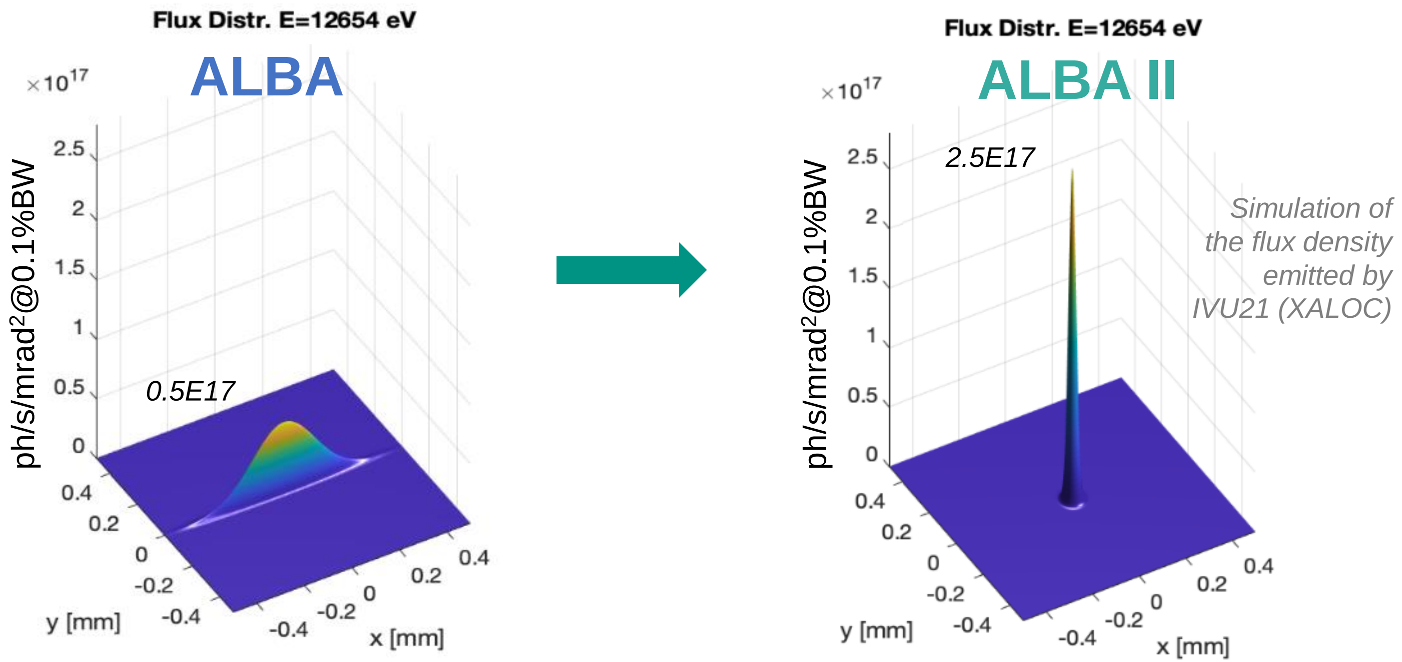



**The upgrade ALBA II includes:**

- **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

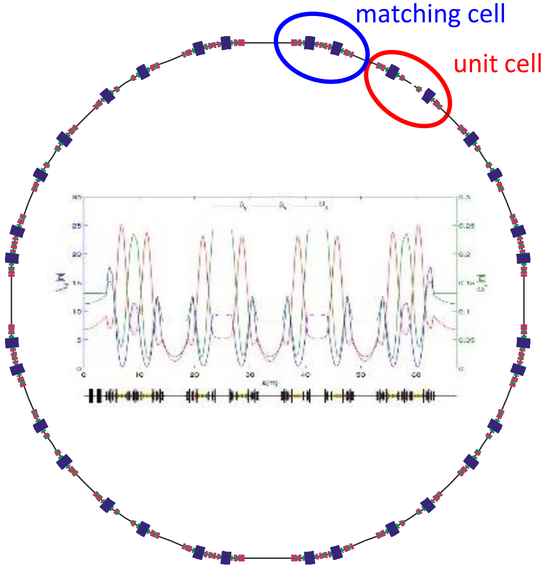
- **Keep beam energy 3 GeV.**
- **Keep the tunnel → SR with similar compact circumference.**

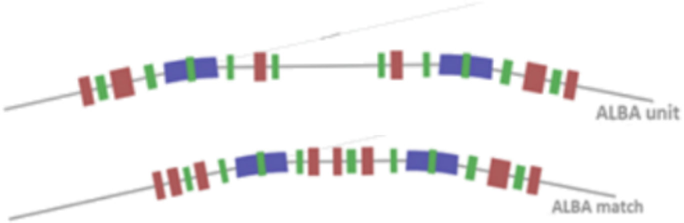
- **Keep existing ID beamlines → preserve 16 cells and source points.**
- **Bending beamlines can be relocated.**

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

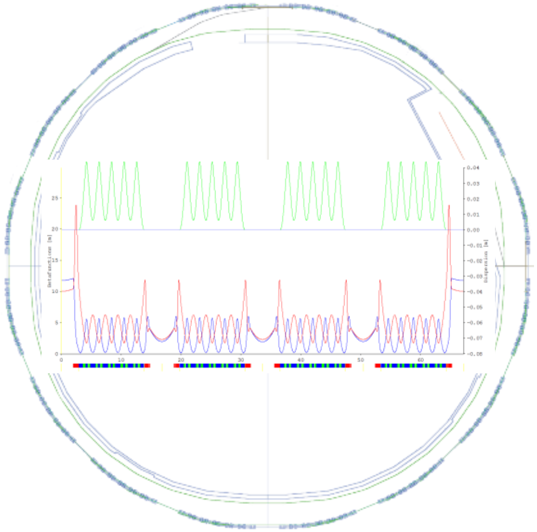
- **Straight sections ~4 m, with $\beta_x \sim \beta_y \sim$ 2 m.**
- **Reduce emittance by more than a factor 10 (<400pmrad).**
- **Full coupling operation option.**

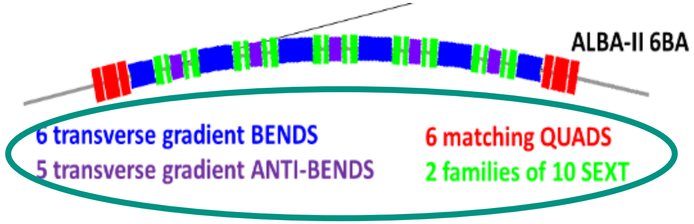
# The upgrade




| | 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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Plan de Recuperación, Transformación y Resiliencia
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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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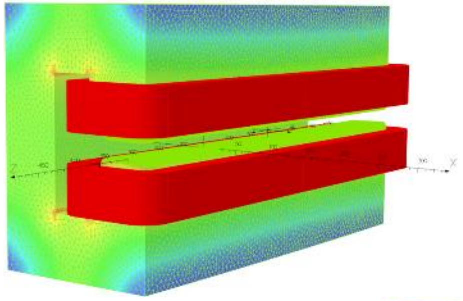
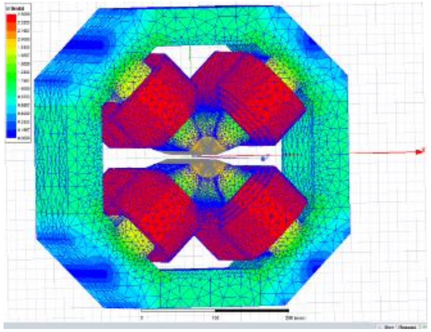
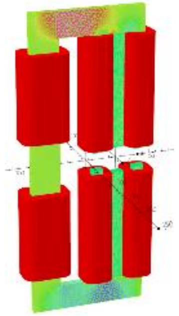
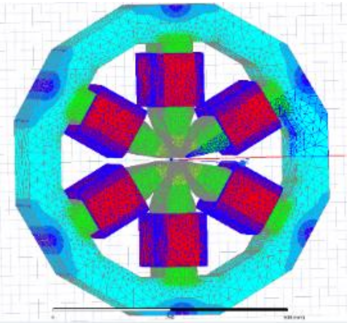
# WP1 Magnets







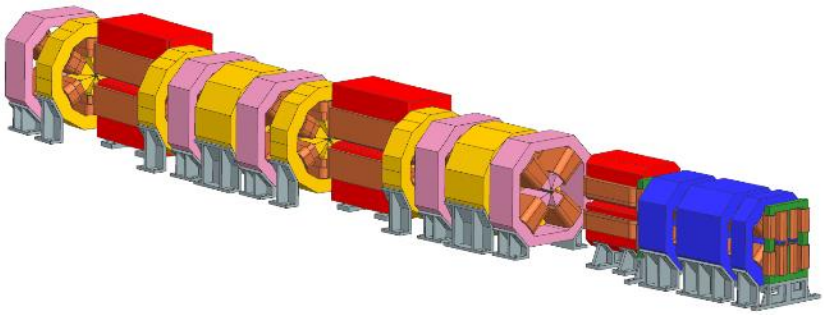


| Magnet type | Prototype required? | Lots |
|---|---|---|
| QD | YES (1) | Lot 1 |
| QDS | YES (2) | Lot 1 |
| QF/QFS | YES (1) | Lot 2 |
| Q1 | NO (0) | |
| Q2 | NO (0) | |
| Q3 | YES (1) | Lot 2 |
| SH | YES (1) | Lot 3 |
| SV | YES (1) | Lot 3 |
| CORR | YES (1) | Lot 4 |
| **Total** | **8 prototypes** | **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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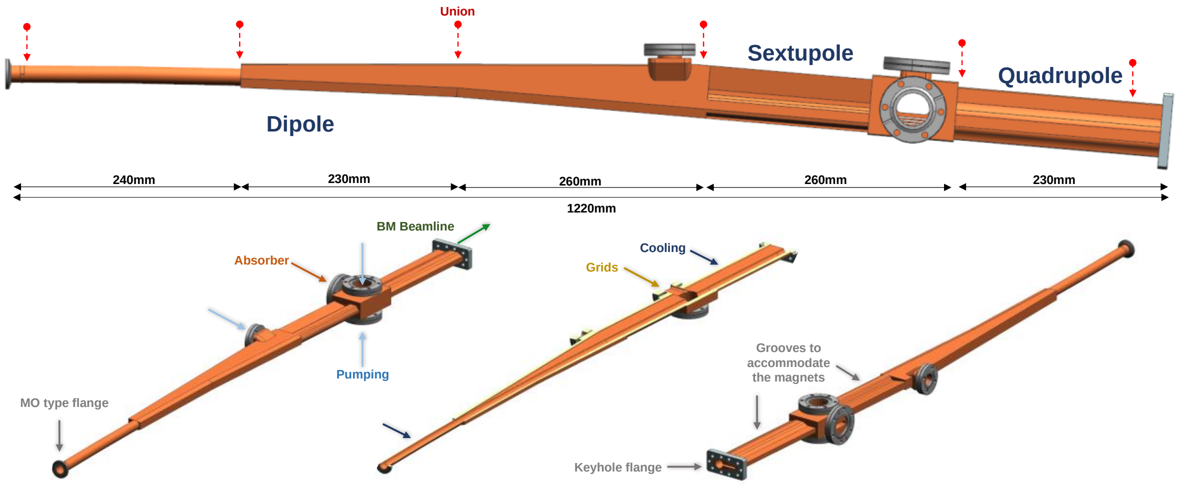
# WP2 Vacuum Chambers

## Designs on going:

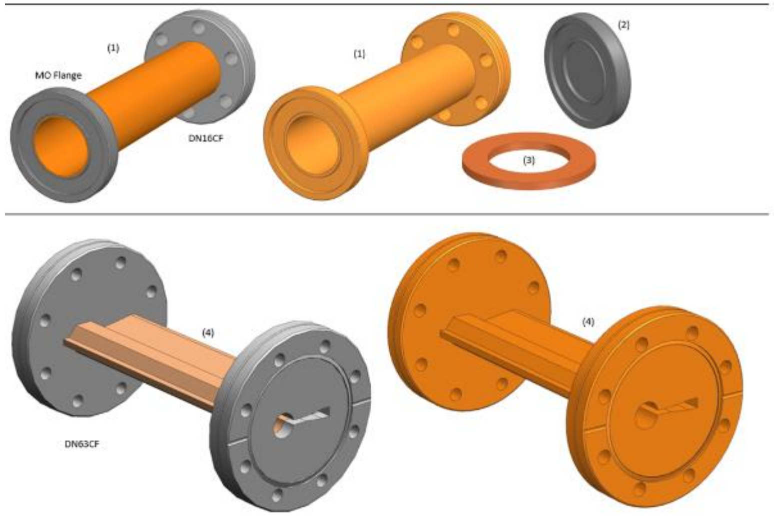



## Pre-prototypes being ordered:

| MO flange prototype | | | |
|---|---|---|---|
| | Bimetallic | Bulk part | Drawing: |
| Nipple: MO-CF16 (1) | Chamber: Cu ETP<br>Flanges: SS | CuCrZr | L0001 (bimetallic)<br>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<br>SS flanges | CuCrZr | L0003 (bimetallic)<br>L0004 (CuCrZr) |
| Length (between flanges) | 175mm | | |
| NEG coating:<br>e-beam<br>ph-beam | <br>0.5 to 1.2 µm<br>0.2 to 1.5 µm | | |
| Quantities: | 2 sets each | | |

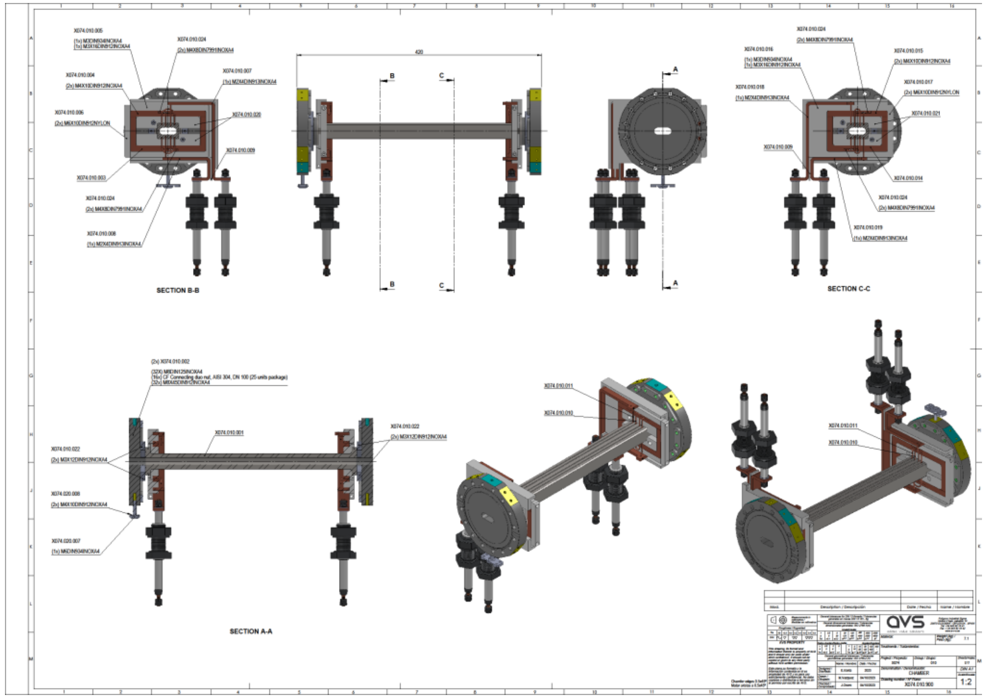


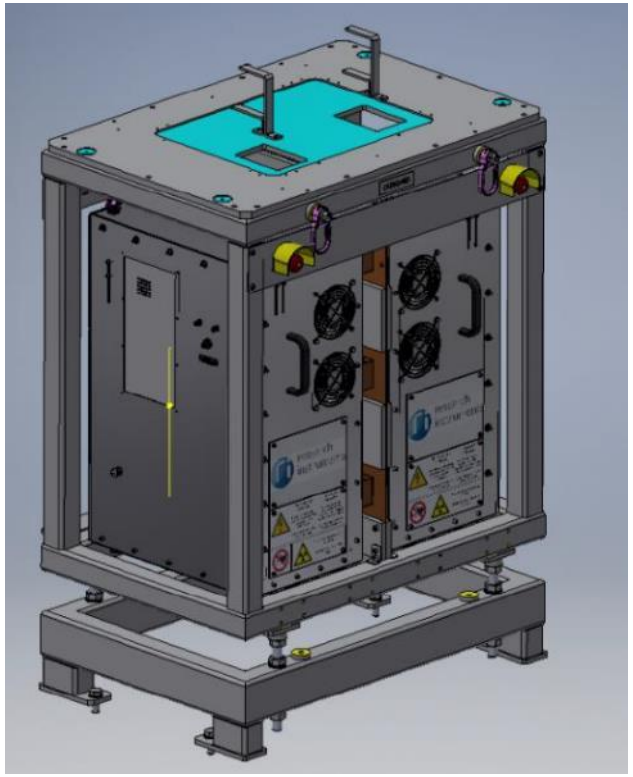
# WP3 Pulsed Magnet

## Double Dipole Kicker

Design done, prototype under construction

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





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ALBA

# WP4 Girders

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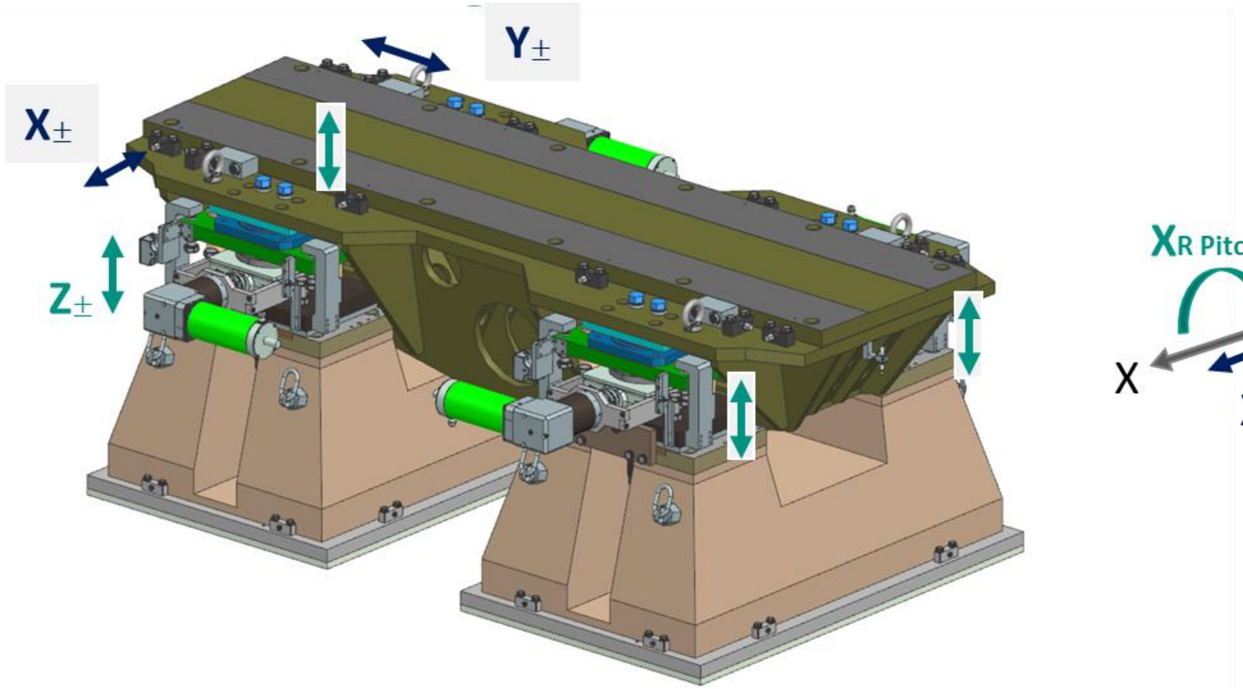
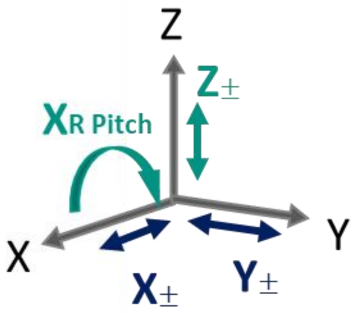
## Design ready – PDR with external panel on Oct’23

Working details on the movement system




*1st eigenfrequency 77Hz – Max. deformation 30um*

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# WP6 SCU

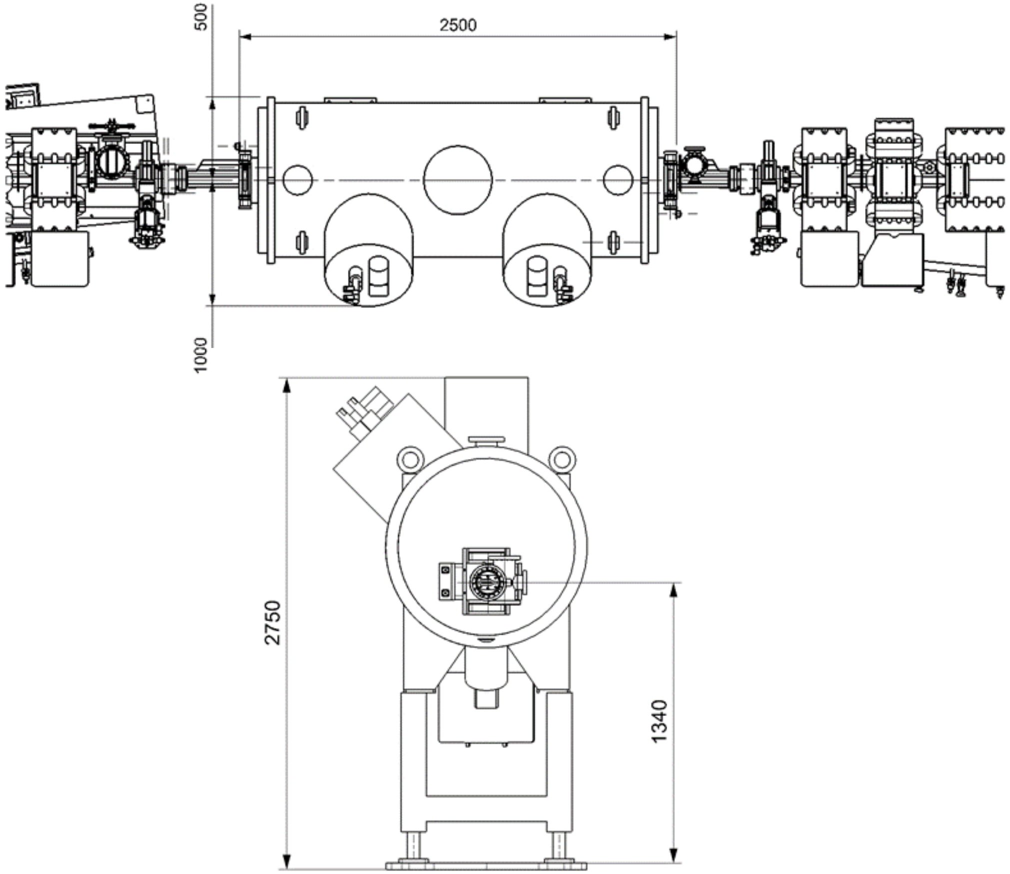
## Order on the basis of functional specifications

## 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

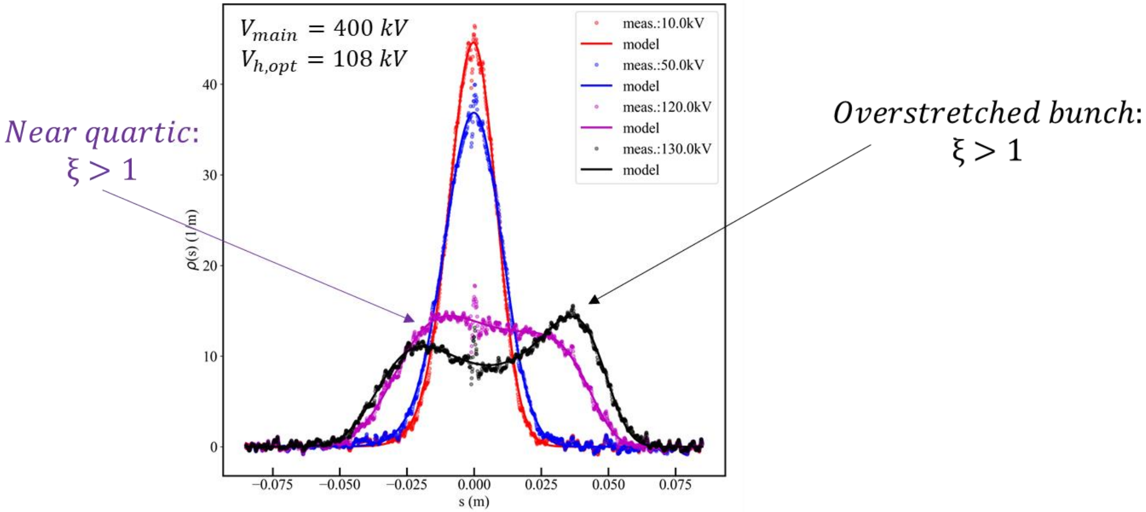
The **prototype tests** were co-funded by ALBA, HZB and DESY through the collaboration agreement RCN-CIN202100124 (2020-2023).

***Cavity***

***SSPA***

***DLLRF***

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




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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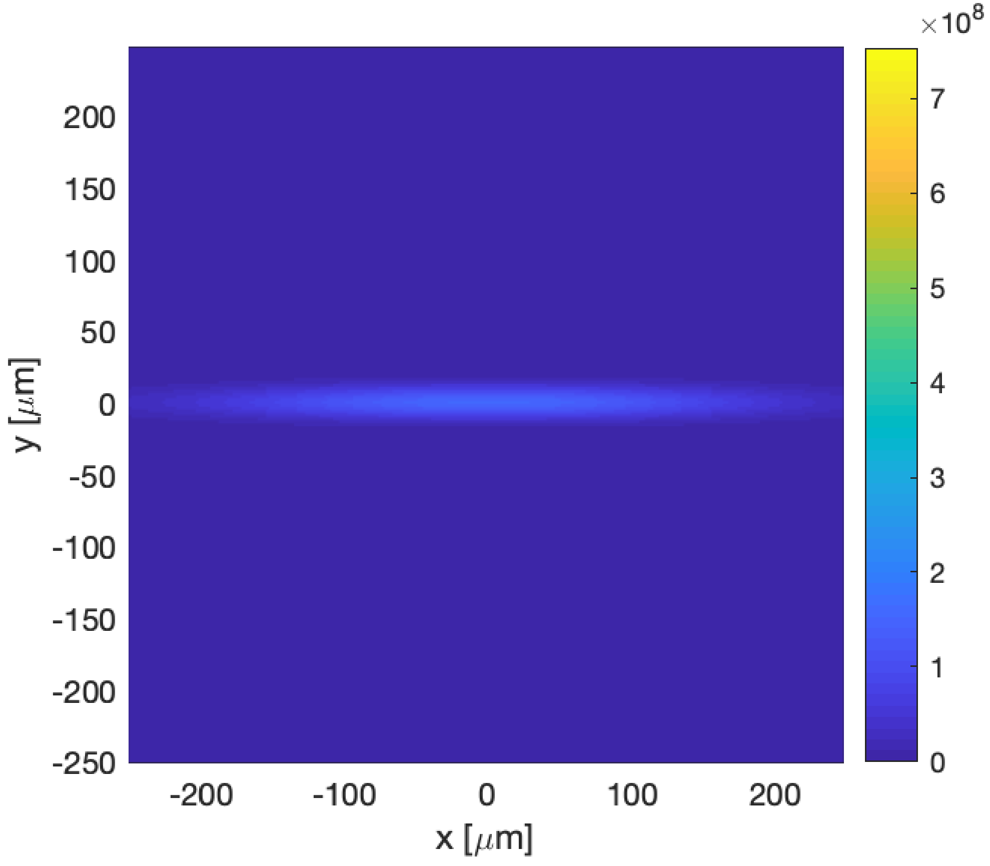
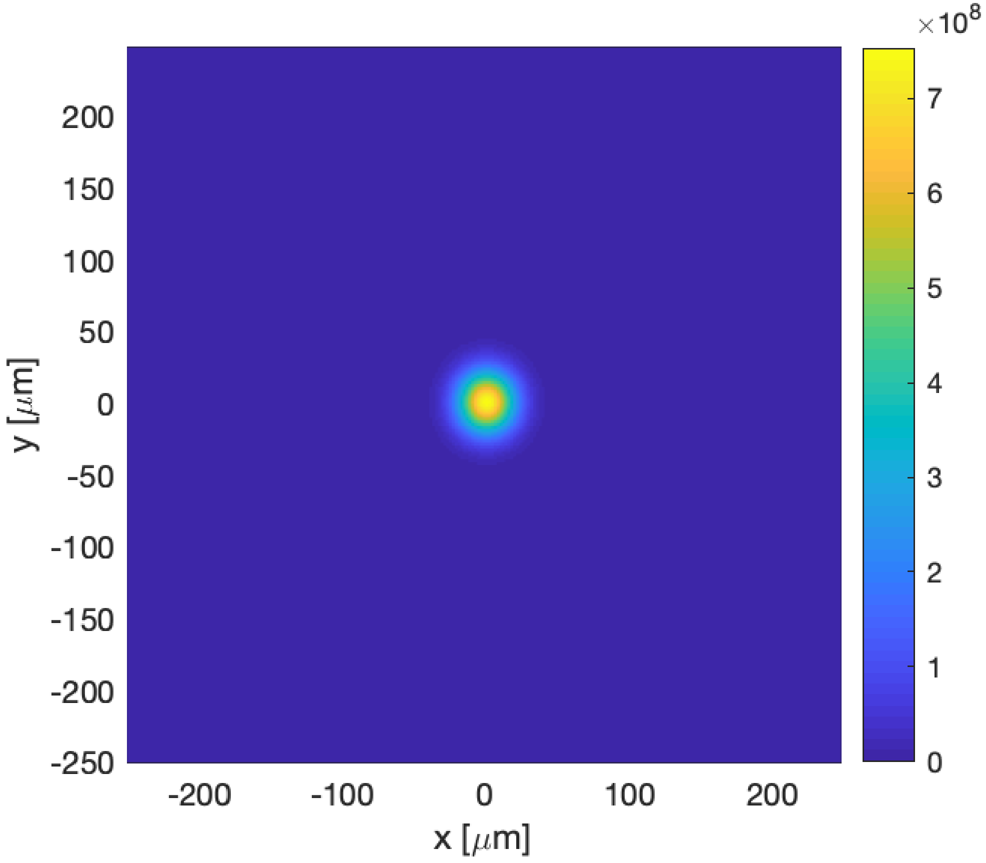
# Beamlines for a new source

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

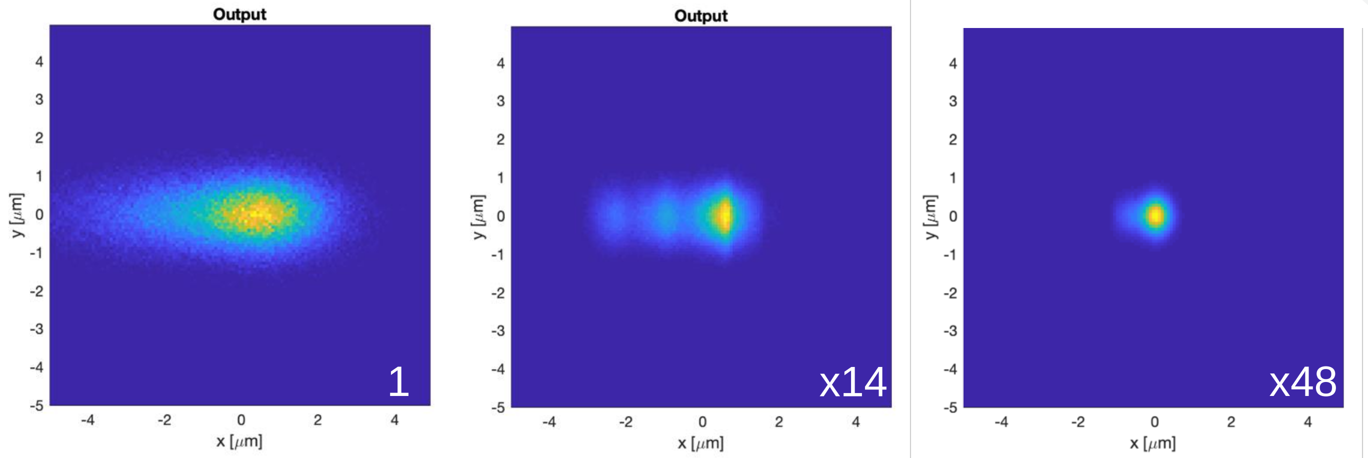
**Reasons**

- *Adapt to higher brilliance*
- *New opportunities*
- *Aging of instrumentation*
- *Compatibility with new machine*

***Scope:***

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

**Spot on sample at the Xaira beamline**




*At ALBA*

*Current beamline at ALBA-II*

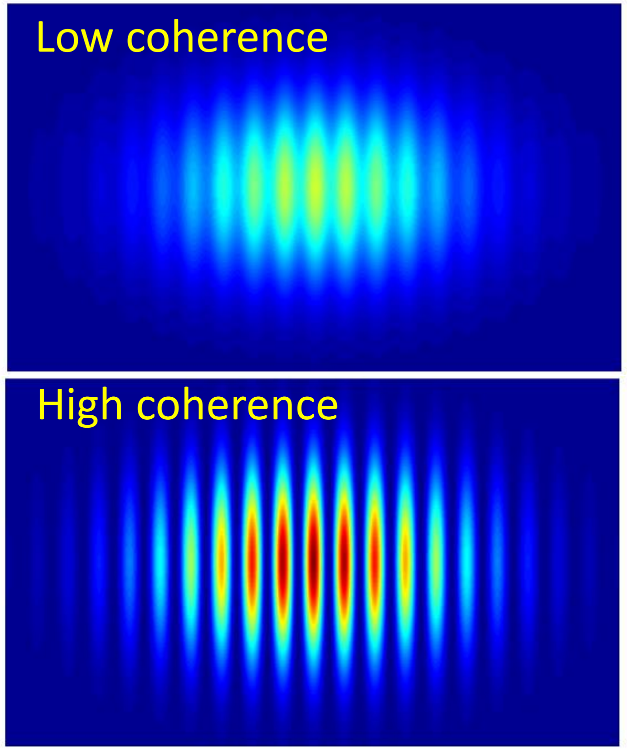
*Upgraded beamline at ALBA-II*

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

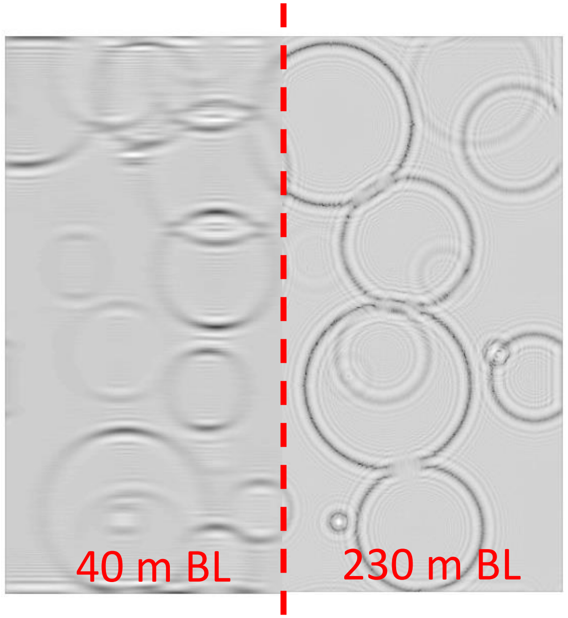
# Beamline program for ALBA-II

## Brightness / coherence

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



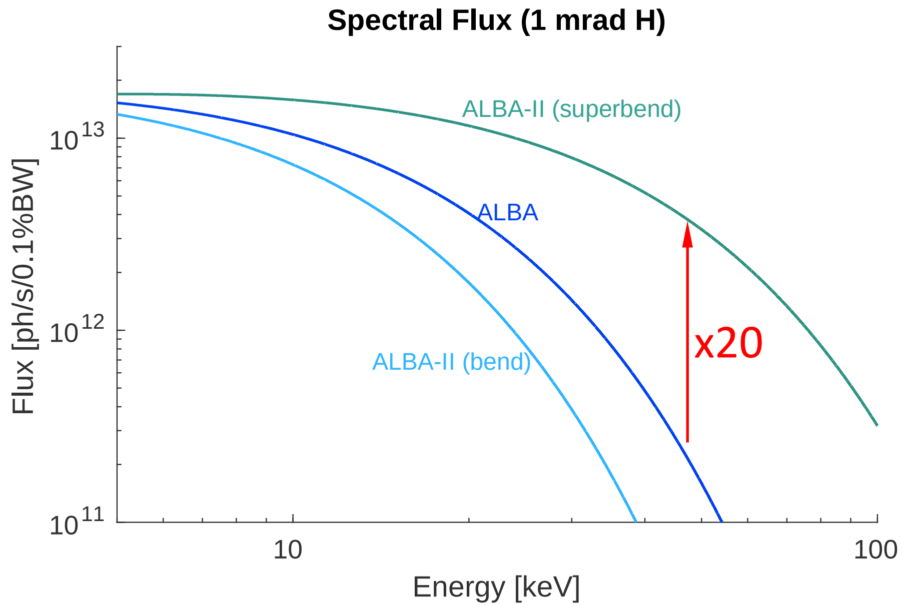

## Long beamlines




- 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**



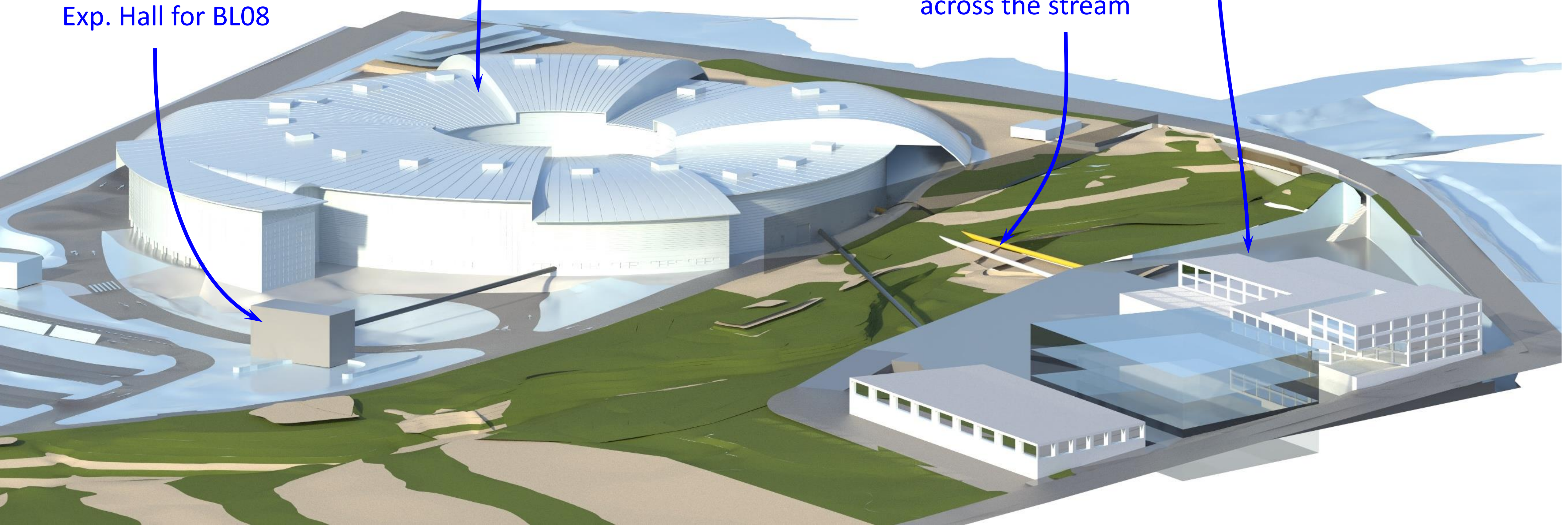
# ALBA-II upgrade

**ALBA main building**
- Accelerators
- Experimental hall
- Laboratories

…

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

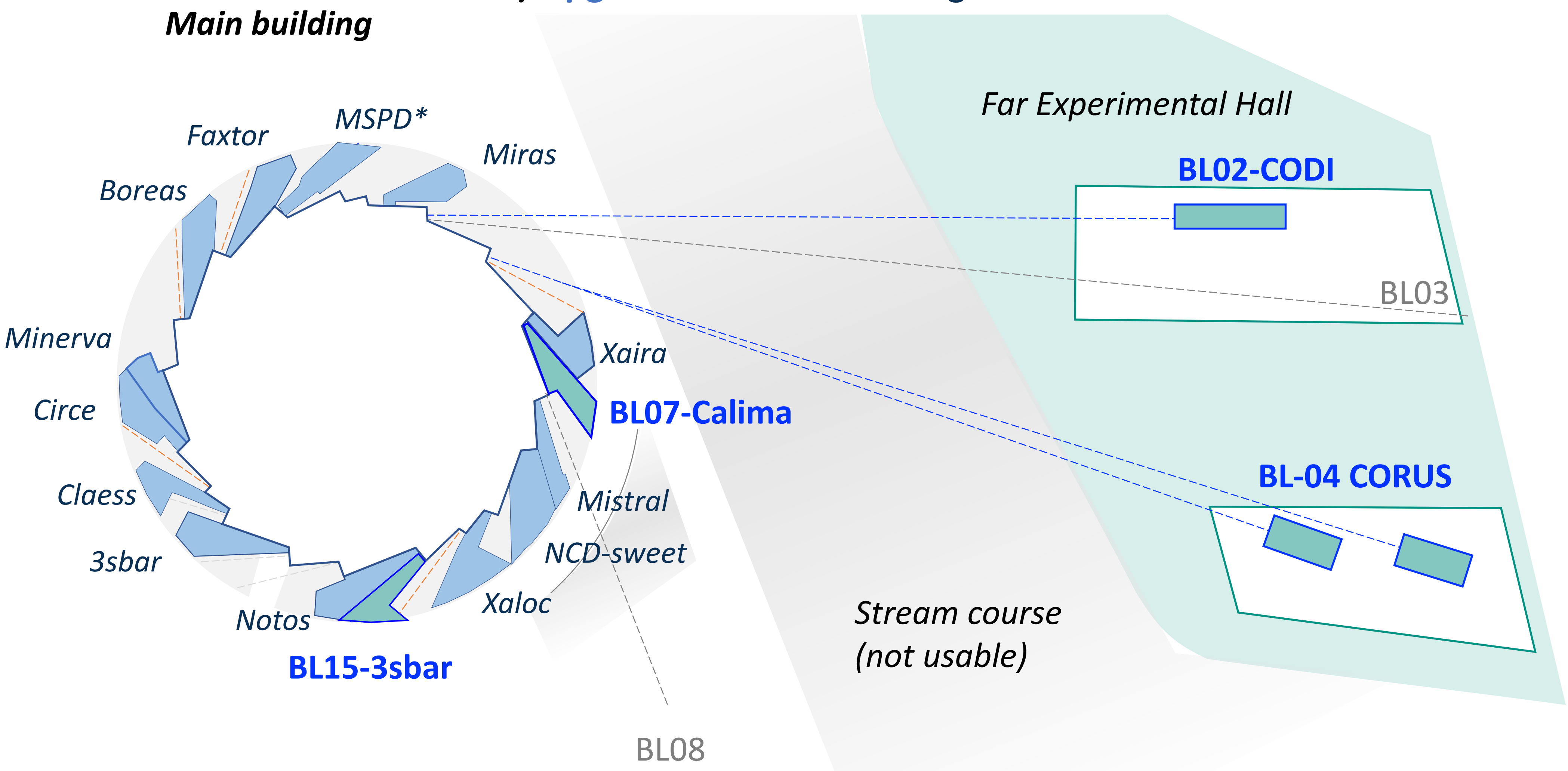
…



# ALBA-II Beamline program

**A)** Construction of **4 new beamlines**

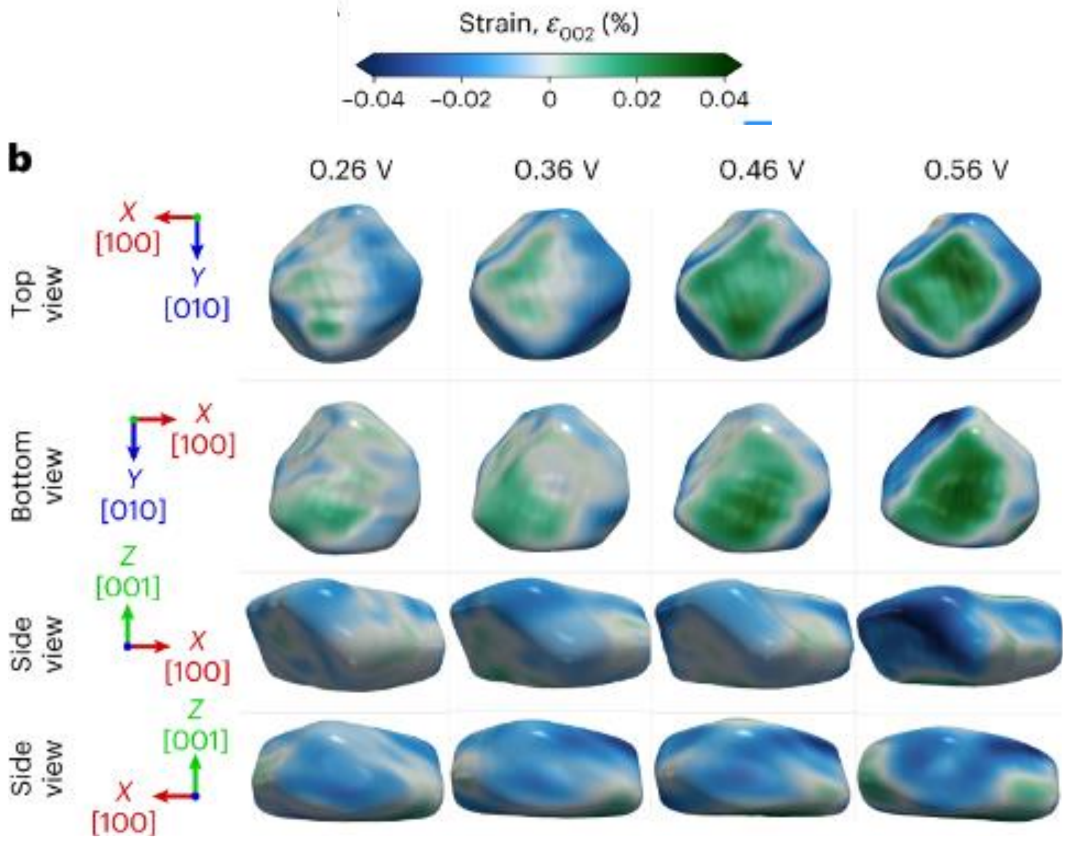
**B)** **Upgrade** of the 13 existing beamlines of ALBA



# 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<br>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)<br>One small detector mounted on robot arm<br>Multielement SDD |



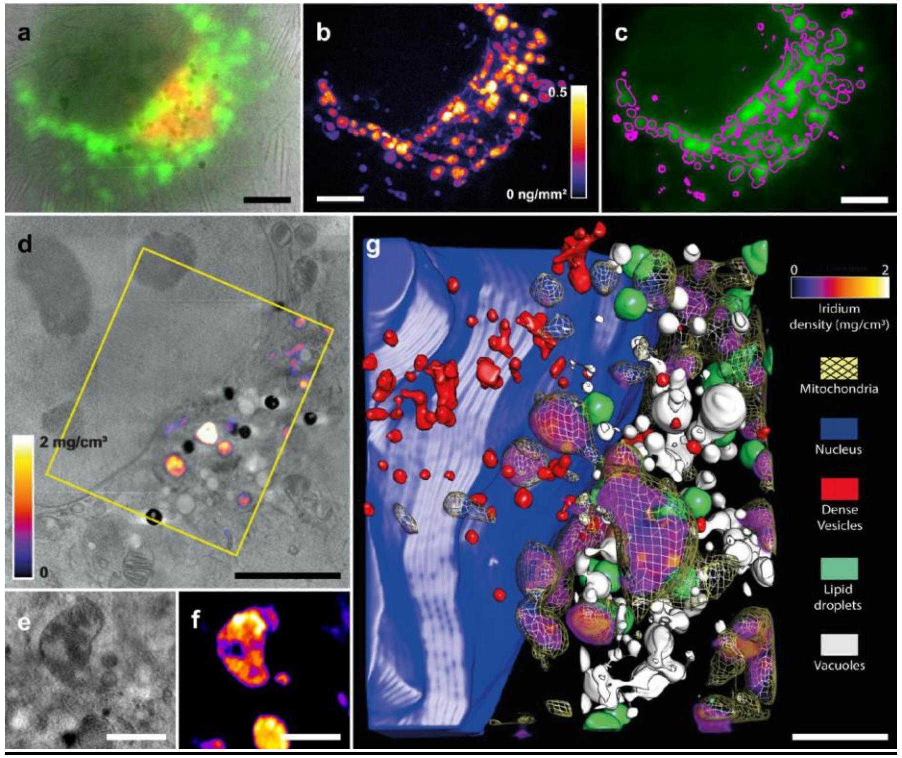

*3D reconstruction and Evolution of strain in a Pt nanoparticle as varying electrode potential. Useful for the design of strain-engineered nano-catalysts*

*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.

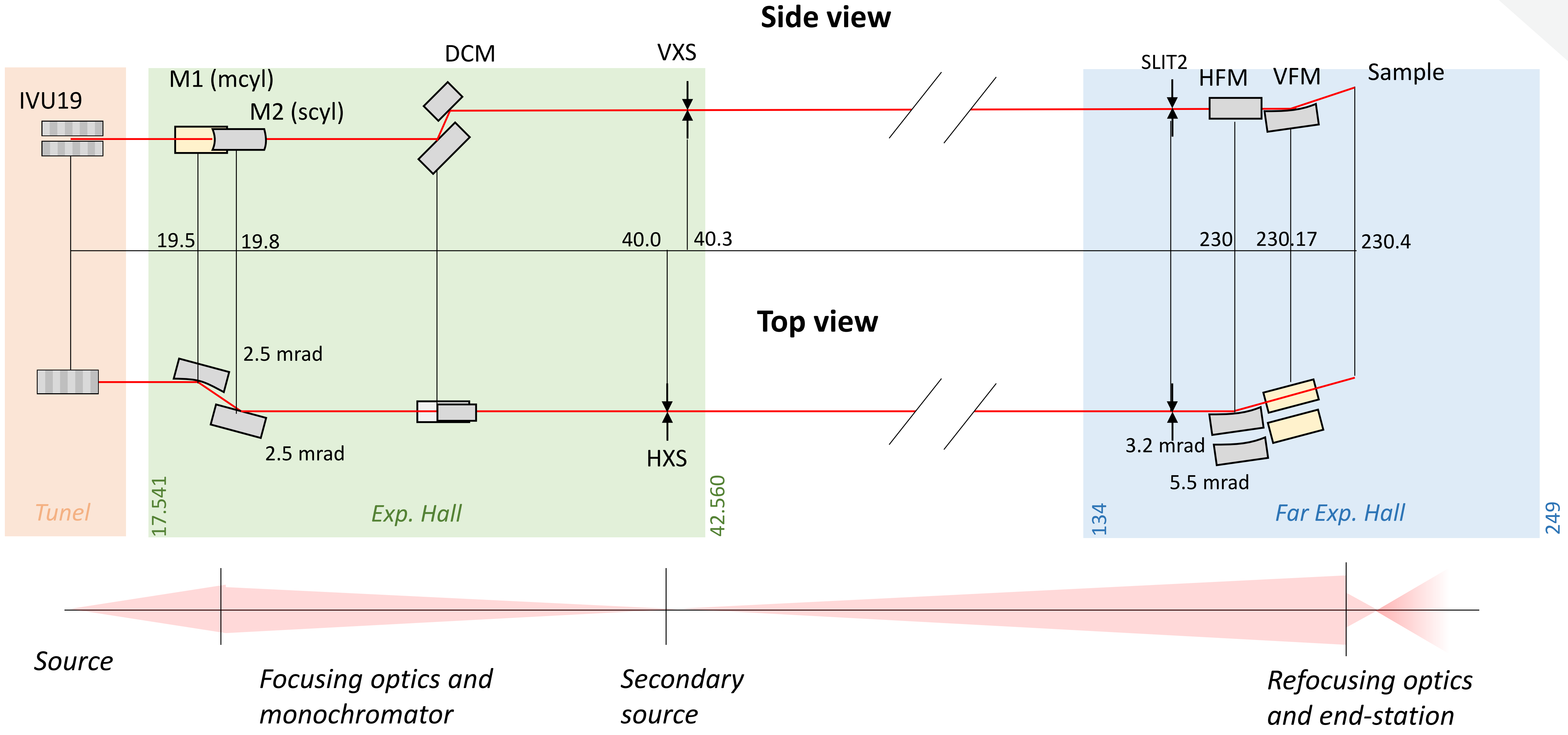
| | Corus |
|---|---|
| **Source** | In vacuum undulator (IVU19) |
| **Energy Range** | 10 - 27 keV (DCM + MLM) |
| **Spot Size** | 20-50 nm |
| **Technique** | 3D-nanoXRF, XANES (STXM)<br>Holo-tomography (Full Field) |
| **Features** | LN2 cryogenics, 180º Rotation, XY mapping<br>UHV, Visible microscope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



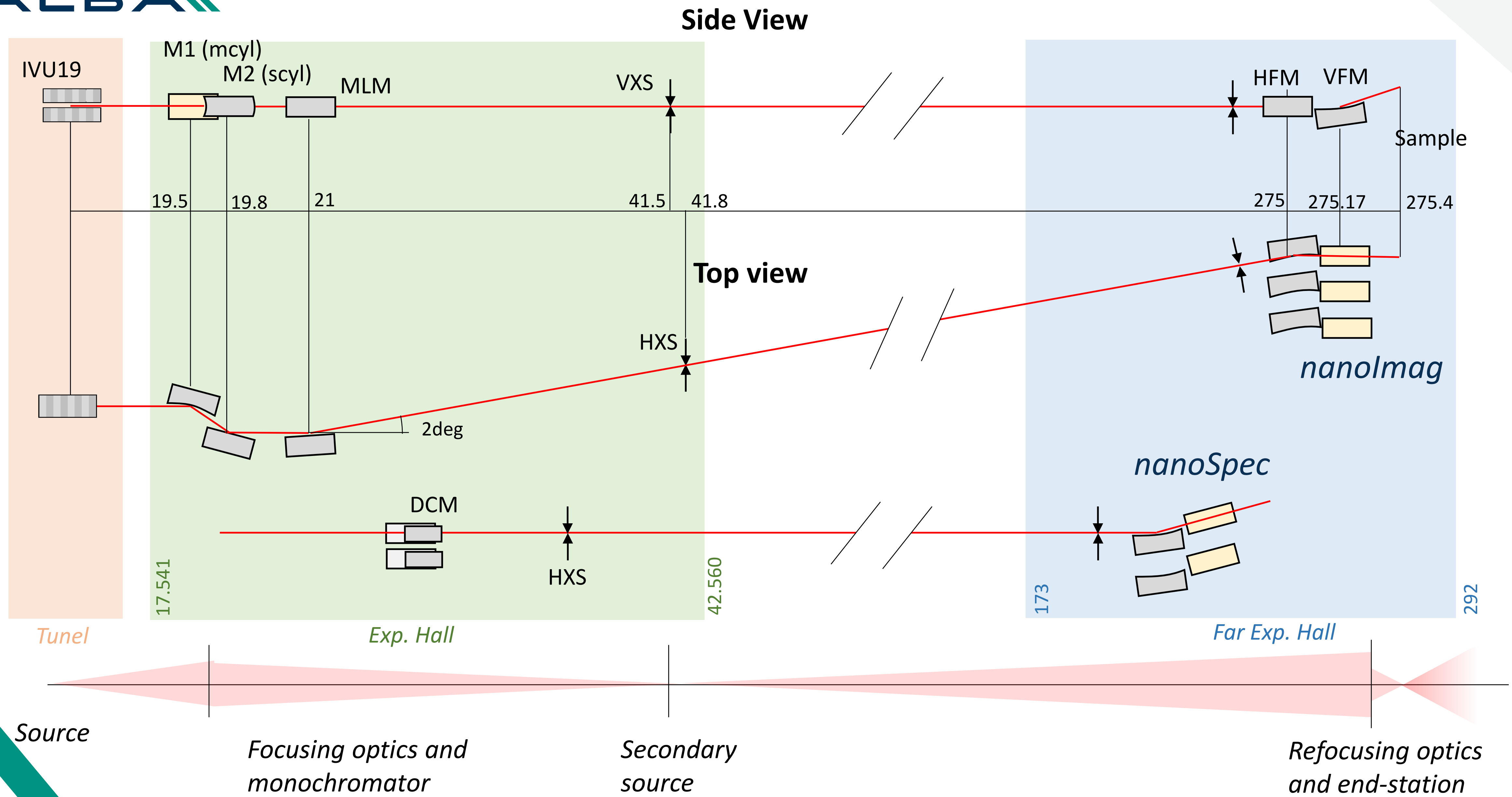

*Determination of intra-cellular location of Ir in breast cancer cells. Imaging at nm-resolution with chemical sensitivity.*

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

# BL02-CoDI: Optical layout

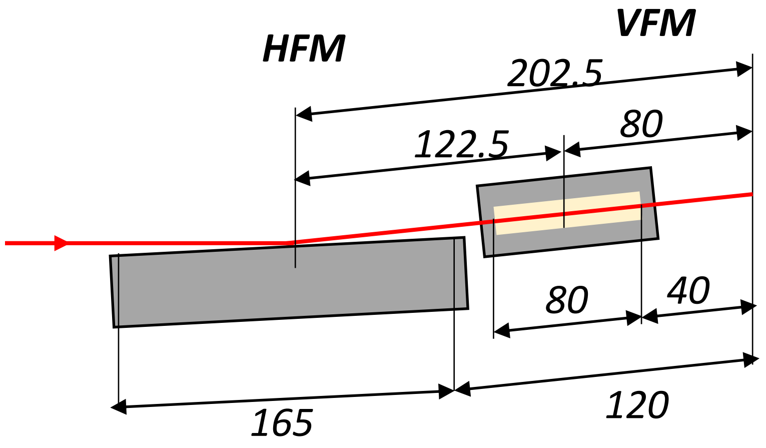


# BL04-CORUS: Optical layout



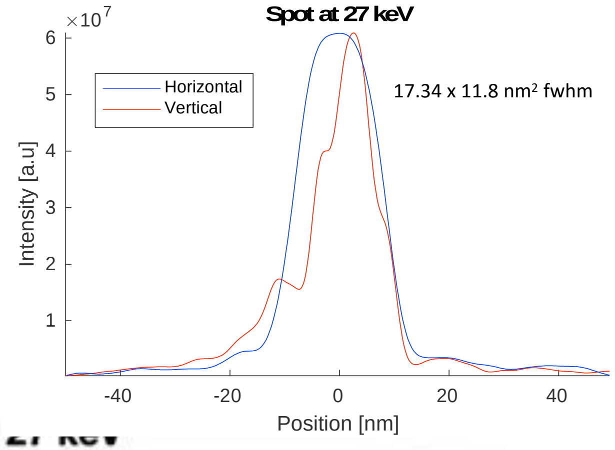
# A challenge: Nanofocusing KB optics

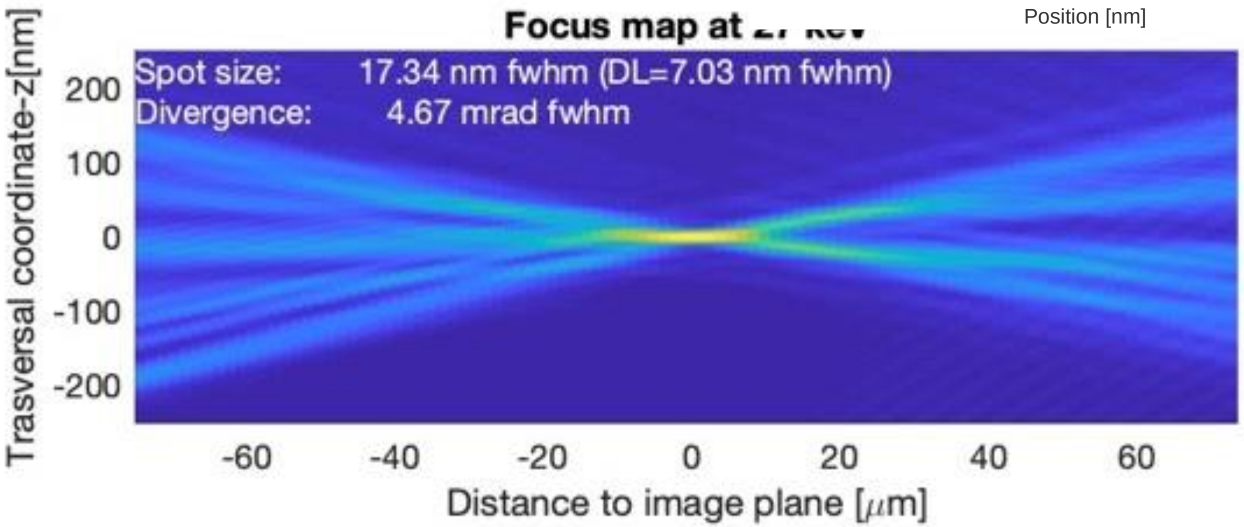
The intended nanoprobes represent a challenge, first in optics




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

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

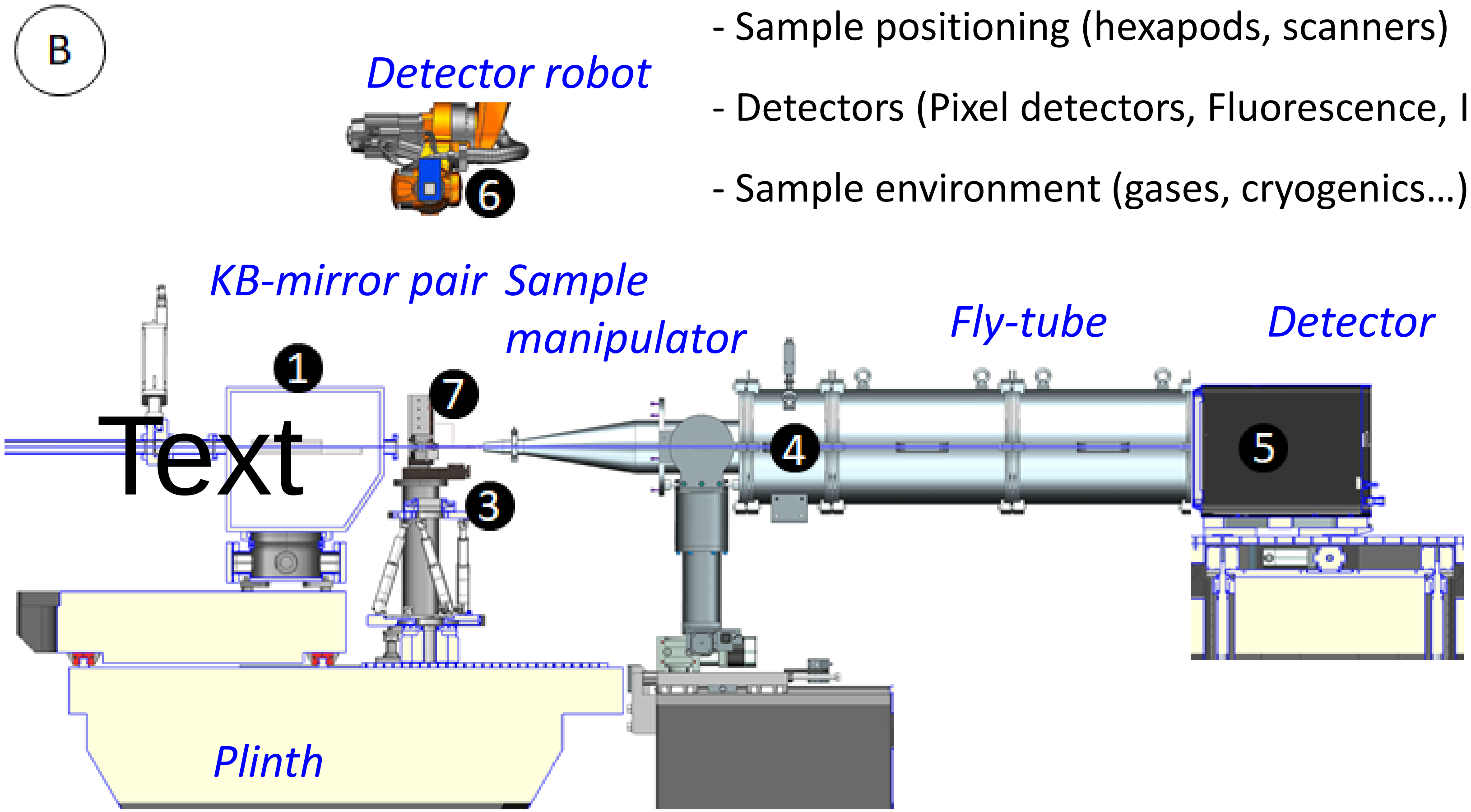


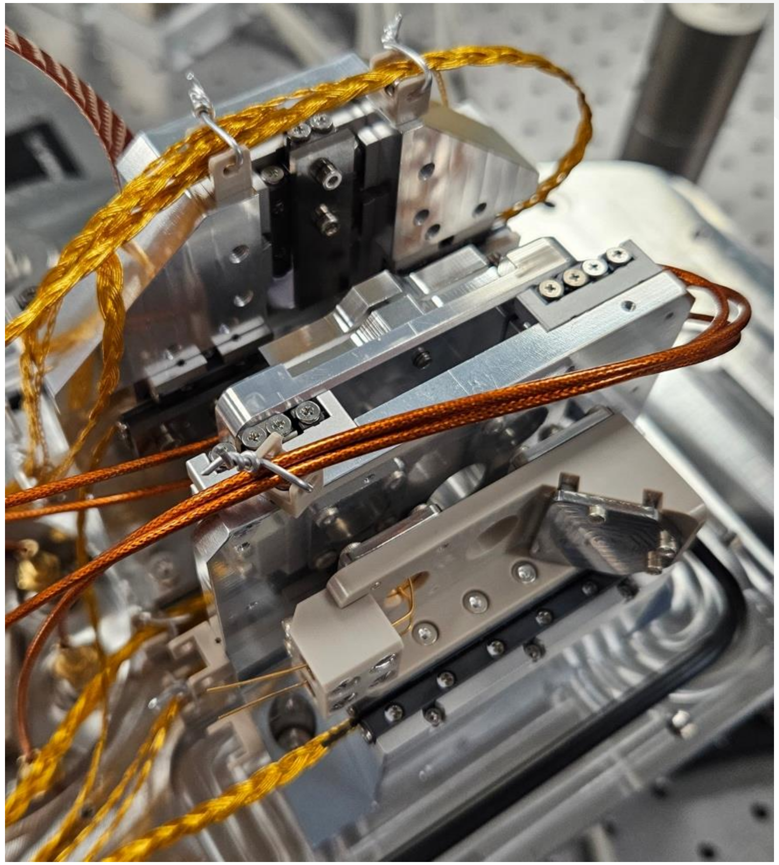



# Endstation (CoDI)

**Endstations for CoDI (and Corus) include**

- Sample positioning (hexapods, scanners)
- Detectors (Pixel detectors, Fluorescence, Izero)
- Sample environment (gases, cryogenics…)



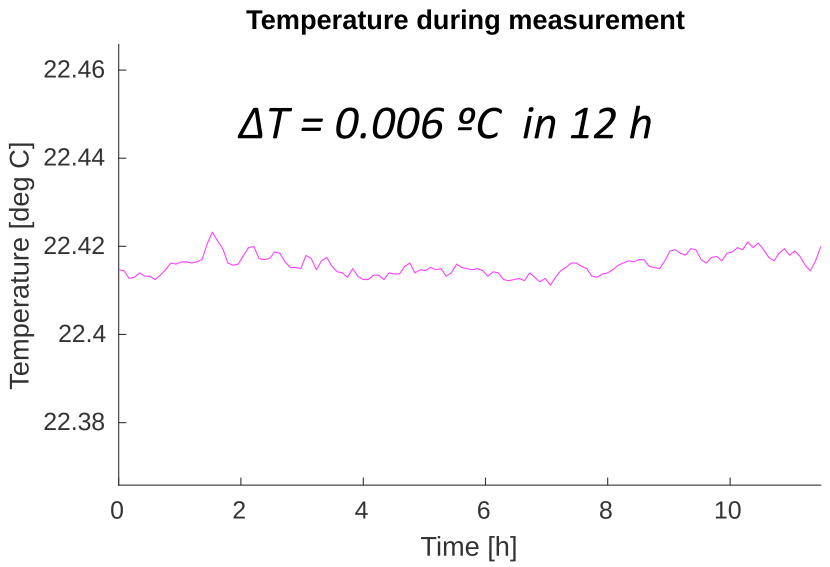
Lightweight, speed and compactness are required.

Watchmaker mechanics.

# More challenges

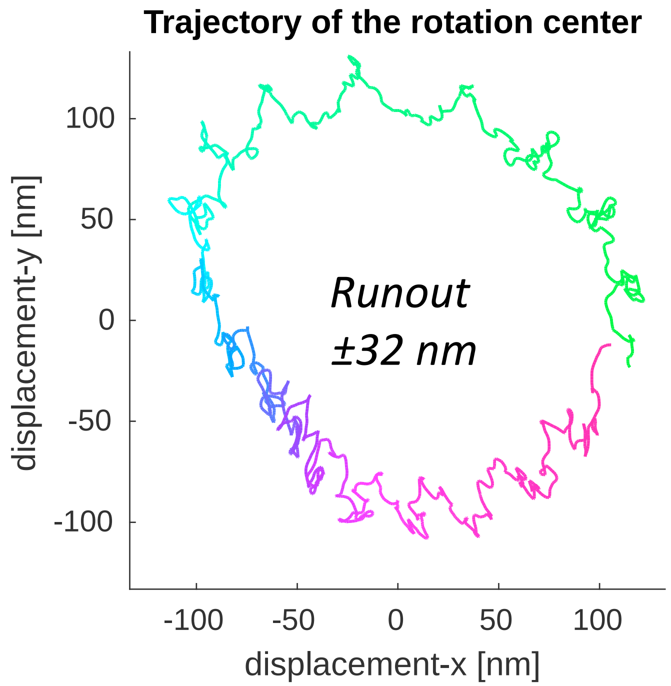
## Nanometer stability

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




## Nanometer positioning accuracy

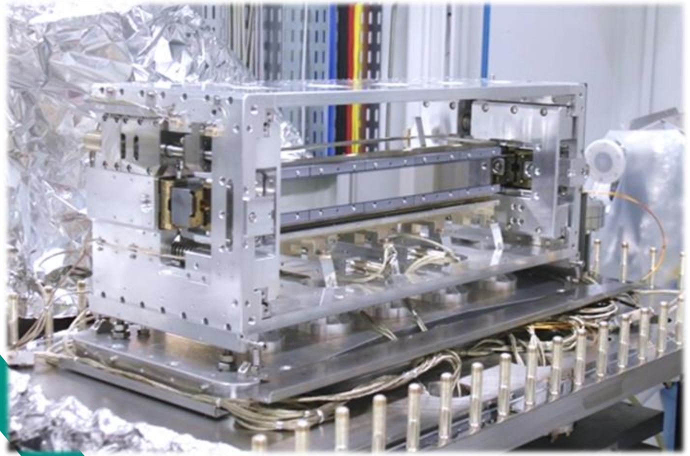
- *Feedback positioning systems*
- *Nanometer resolution*
- *Nanometer guidance errors*
- *Fast actuators*



# 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

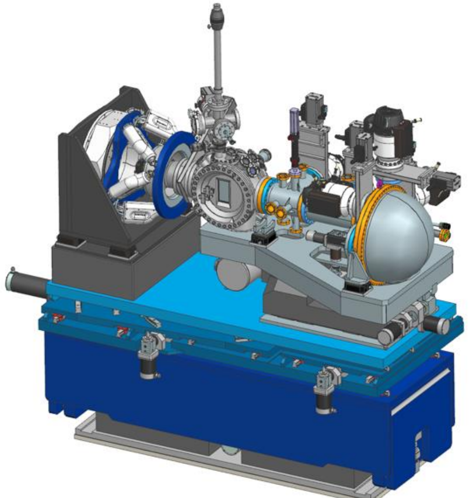


### Infrastructure

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

### Data

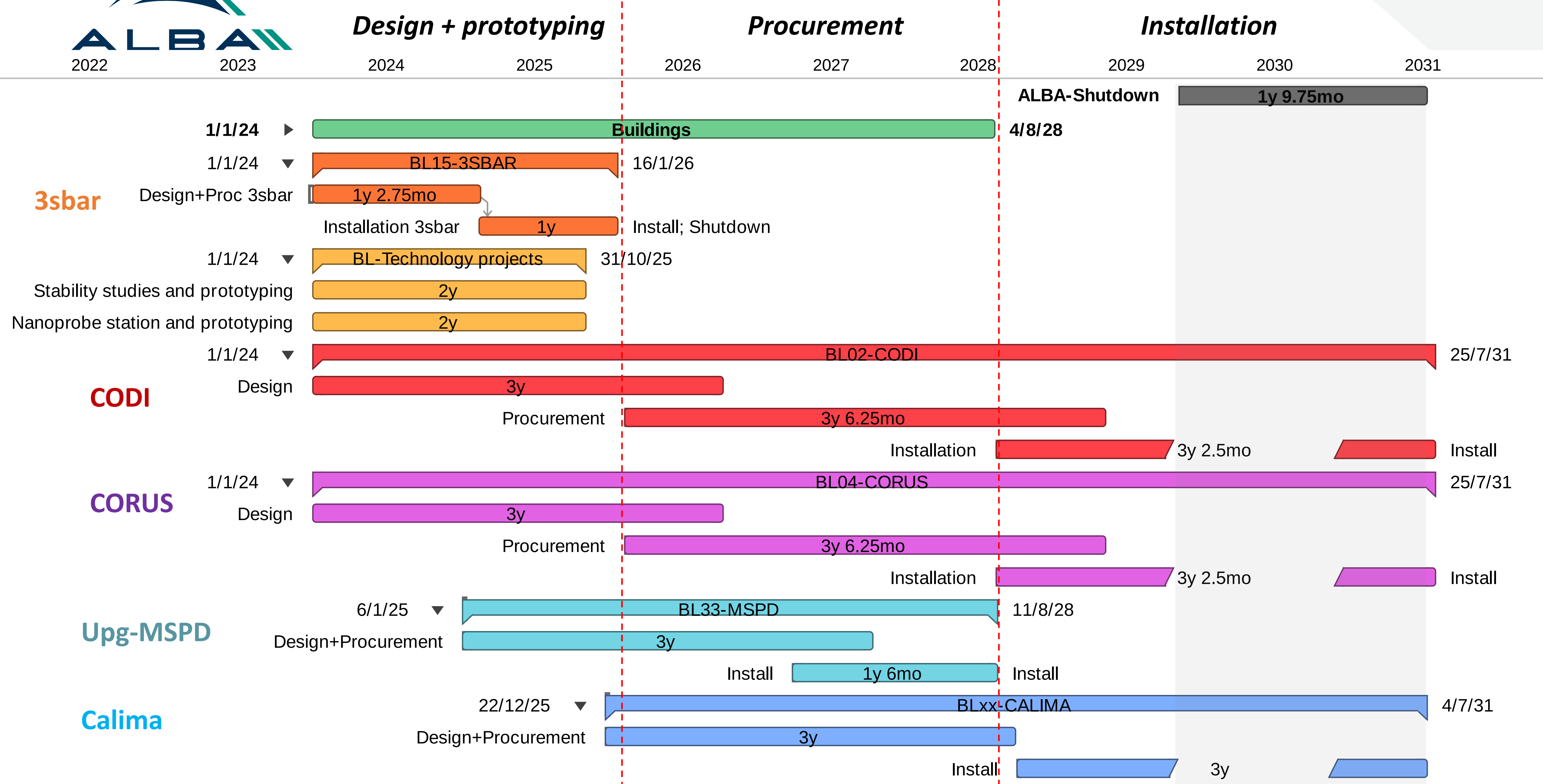
- **High data volume**
    - **Networking**
    - **Storage**
- **Complexity**
    - **Real Time processing**
    - **Data Analysis**



### Endstation

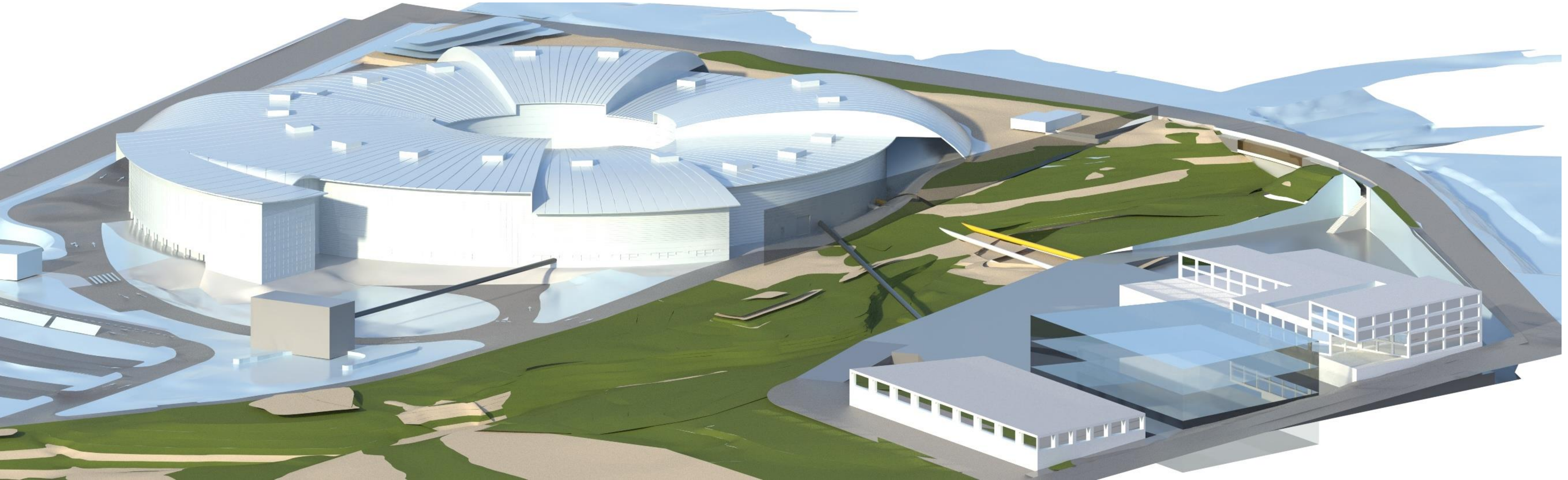
- **Sample manipulator**
    - Hexapodes
    - Goniometers
    - Scanning stages
- **Detectors**
    - Pixel detectors
    - Si drift detectors
    - Izero monitors
- **Sample environment**
    - Gas dosing
    - Cryogenics
    - Heating
    - Sample Exchange robots
    - …

# 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!