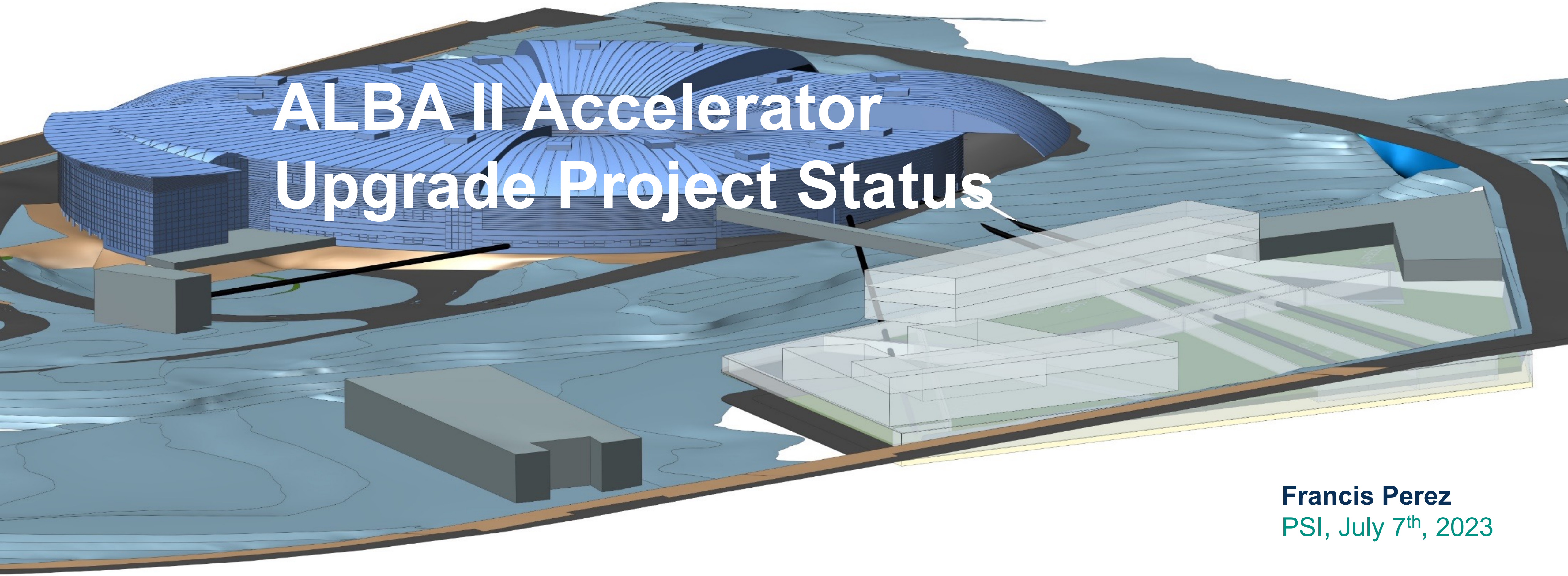
ALBA II Accelerator Upgrade Project Status



Francis Perez
PSI, July 7th, 2023

ALBA is the Spanish Synchrotron Radiation Facility

National Public institution with funding 50%/50% from the **Spanish** *Ministerio de Ciencia e Innovacion* and the **Catalan** *Department de Recerca i Universitats*

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

National and international (28%) staff

National and international (40%) users

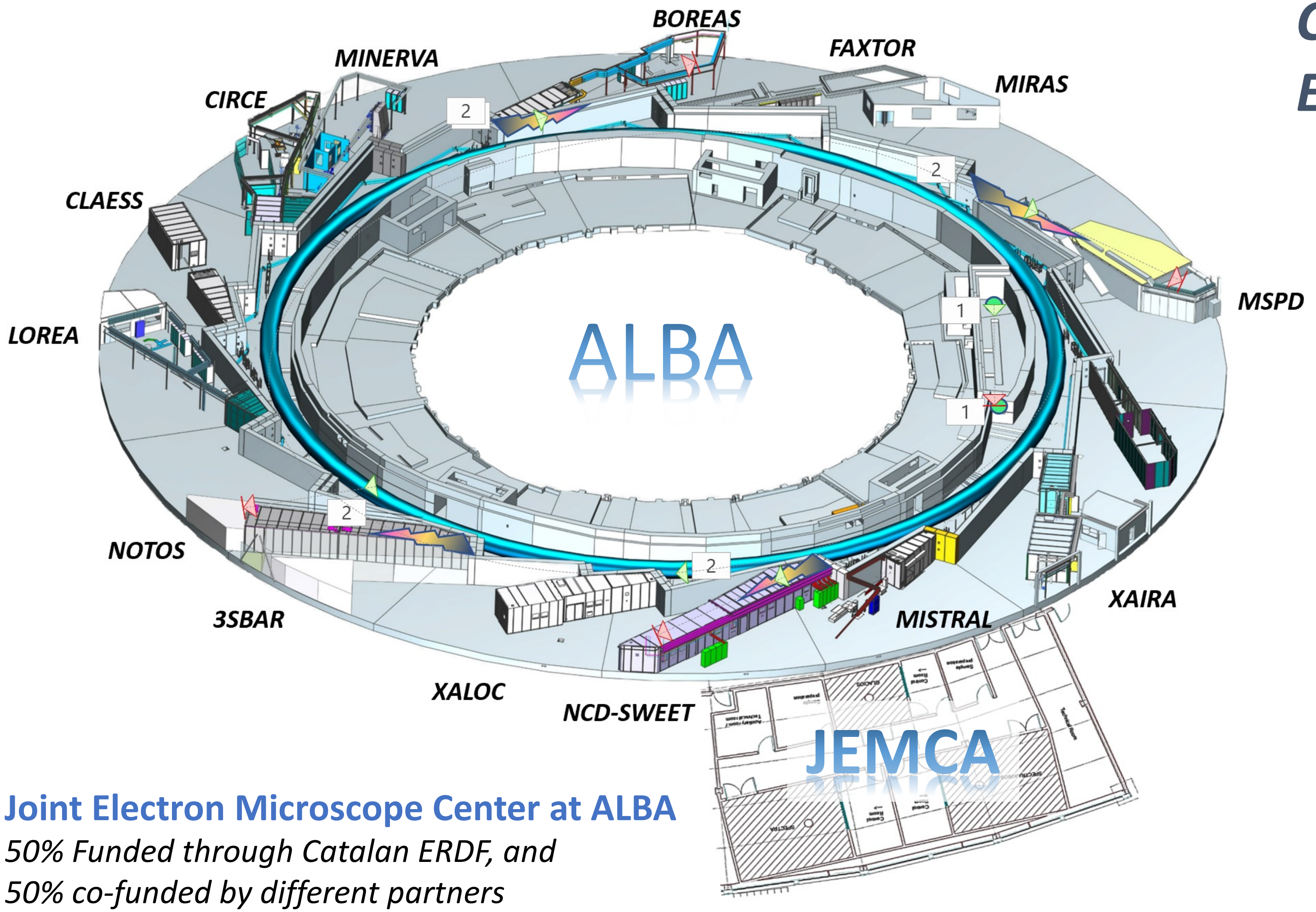
National and international collaborations

Generalitat de Catalunya
Departament de Recerca i Universitats

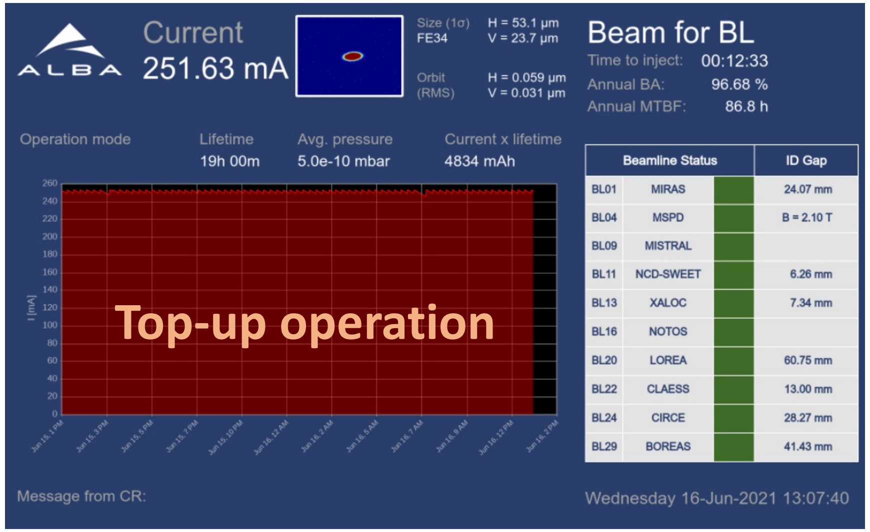
ALBA key parameters

e- Energy = 3 GeV
C = 268.8 m
Emittance = 4.4 nmrad

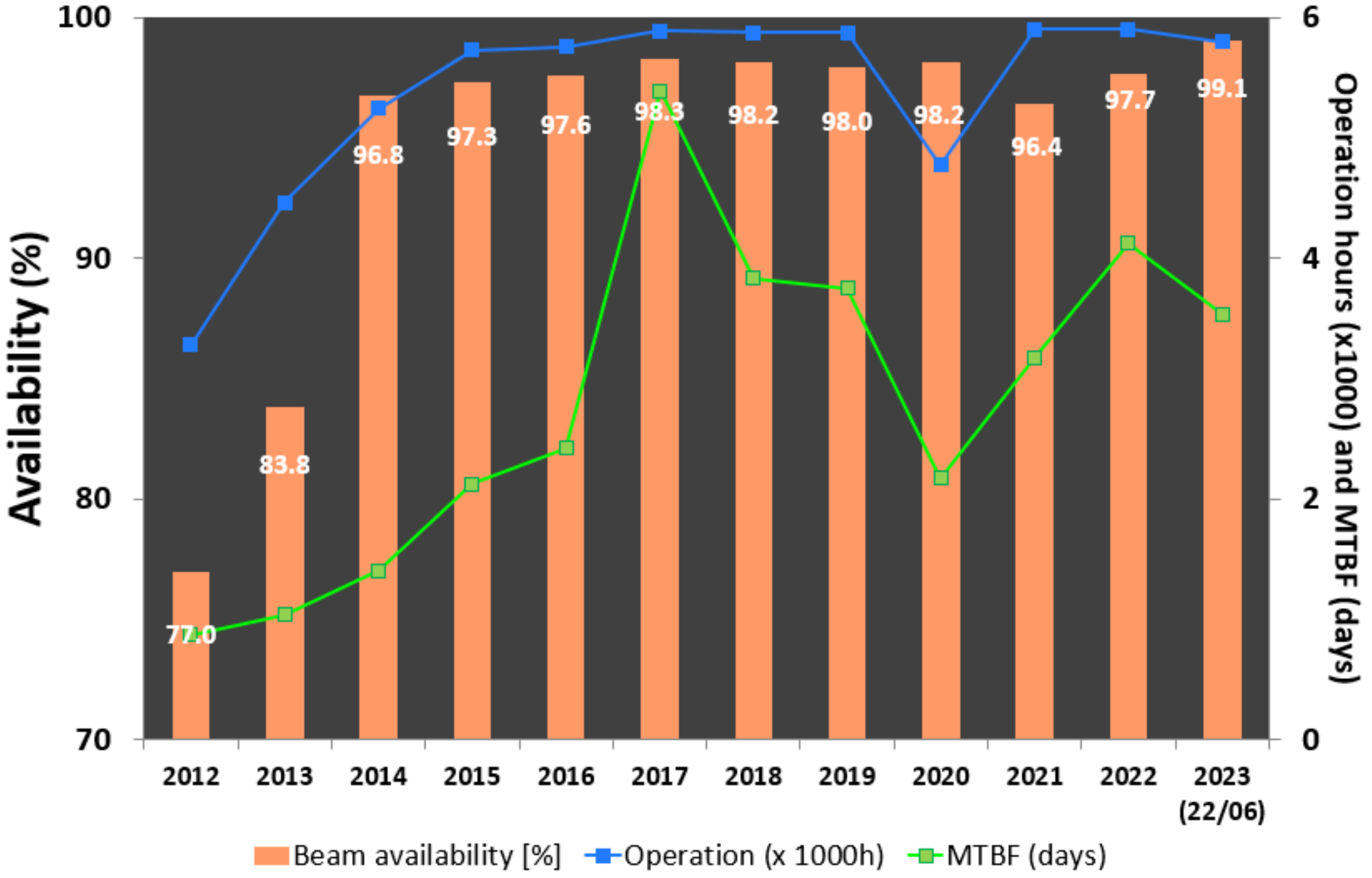
10 operating BLs
2 in commissioning
2 in construction
2 for acc. diagnostics



Joint Electron Microscope Center at ALBA
50% Funded through Catalan ERDF, and
50% co-funded by different partners



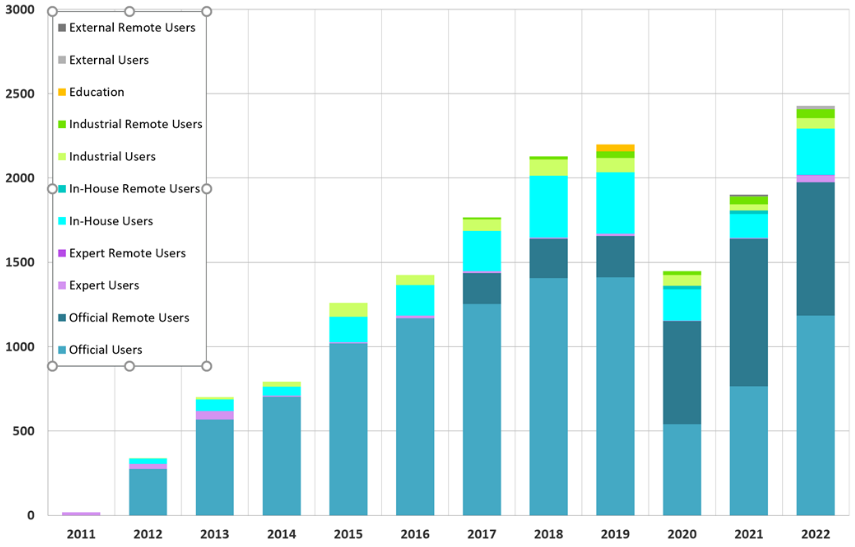
In operation since 2012



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)

In operation since 2012

2400+ user visits
450+ yearly experiments



70+ companies using our instruments

Academic

Joint academic and industrial

Private

Competitive and free access
Public results

Direct access covering operational costs
Results can be confidential

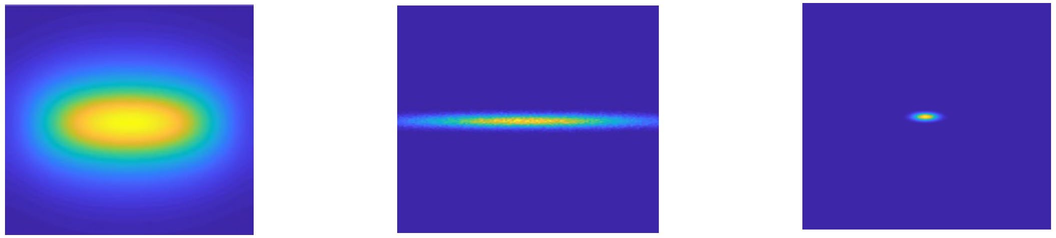
2700+ publications

500+ industrial experiments

Why the upgrade?

Evolution of Synchrotron Radiation Sources

Representation of photon beam on sample →



‘60s — 1st Gen

‘70s — 2nd Gen

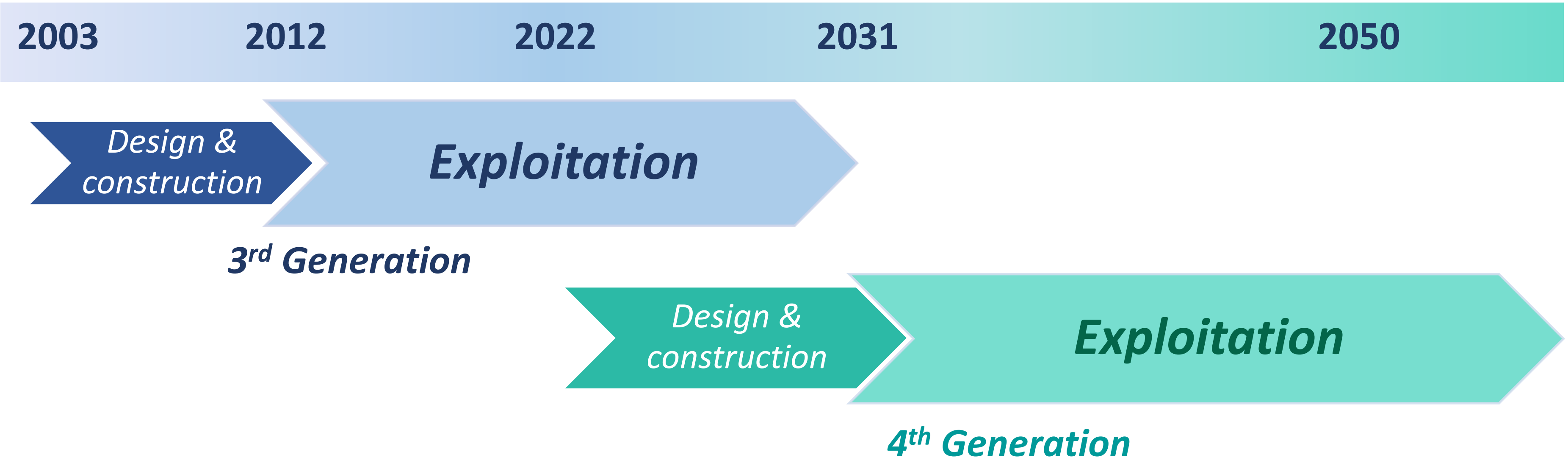
‘90s — 3rd Gen

‘20s — 4th Gen

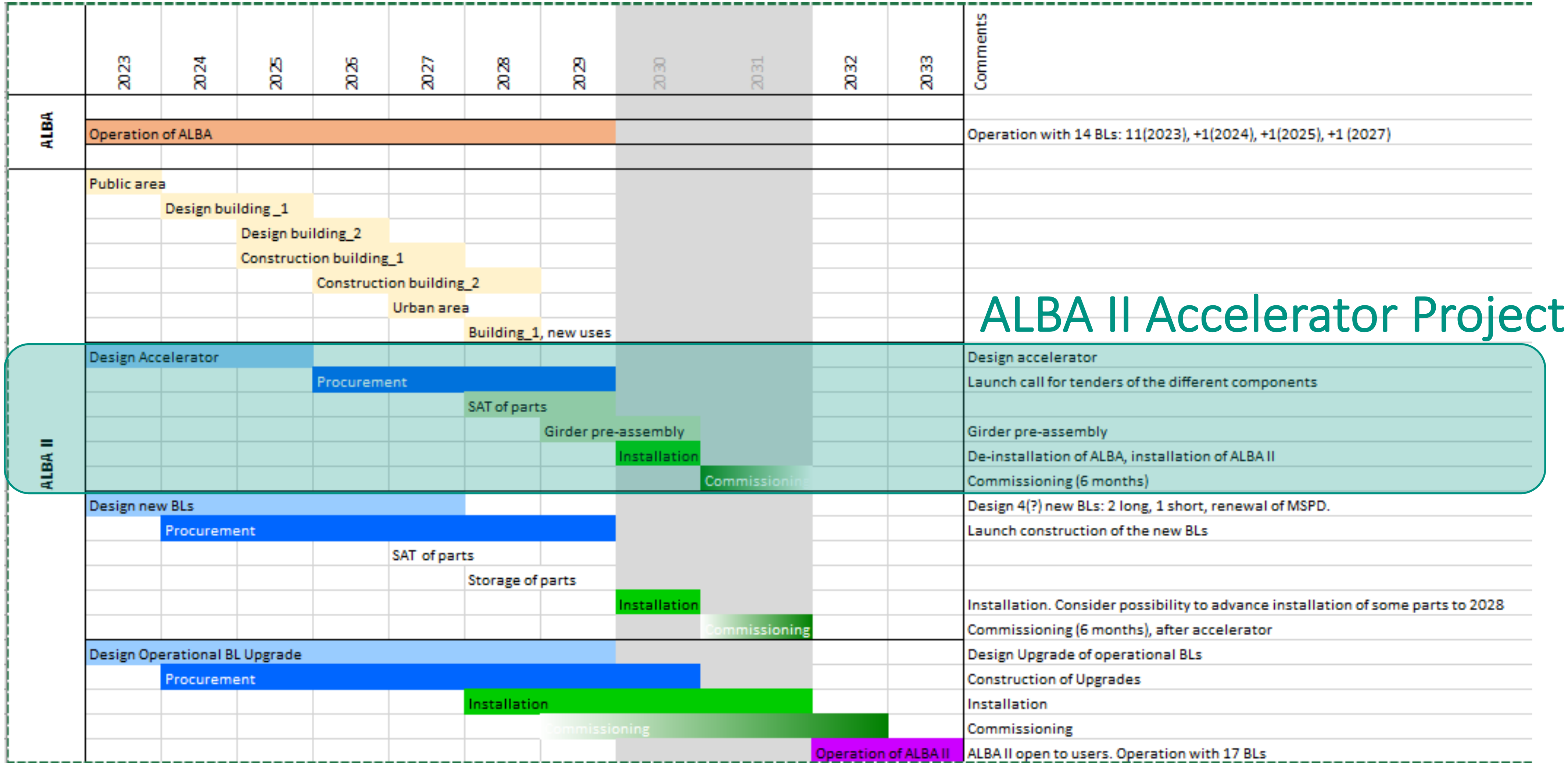
- Increase in Brilliance
- Increase in Resolution Power
- Increase in Coherence
- Increase in Data management capacity

To produce new science beyond the ’50s

Evolution of ALBA to the 4th Generation ALBA II



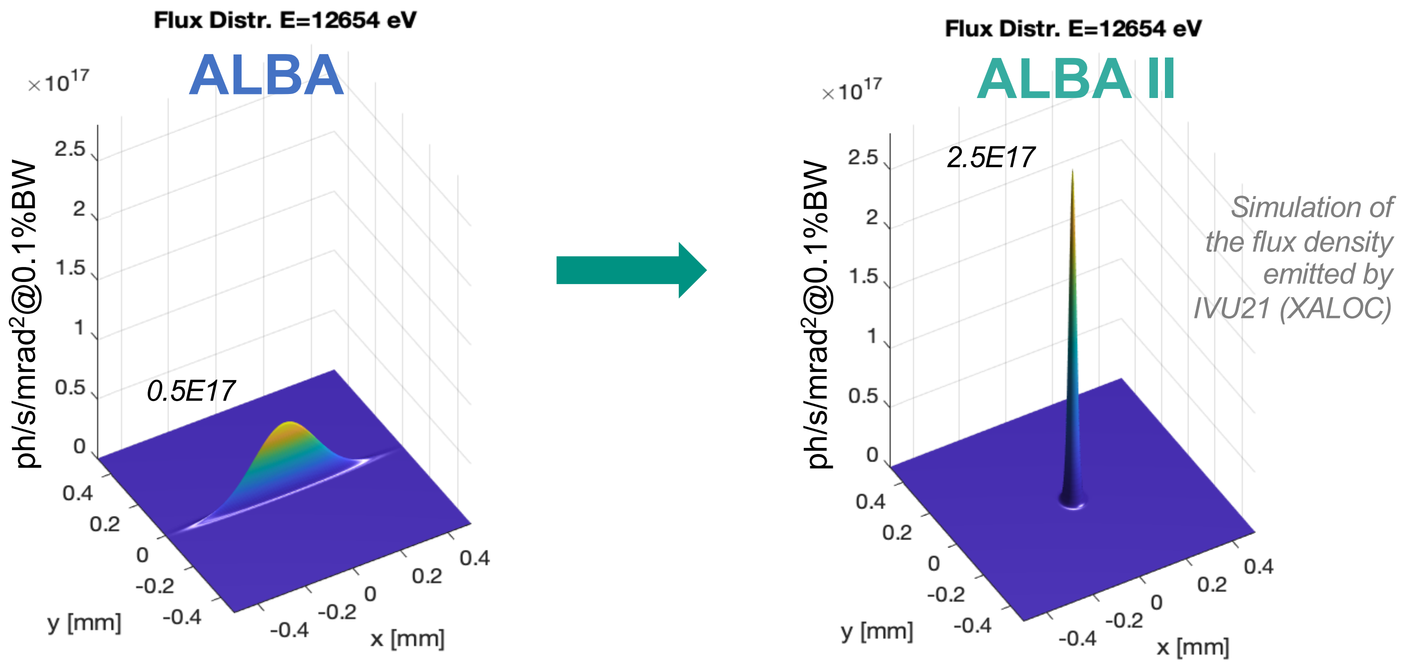
ALBA II Upgrade baseline



Objective

Upgrade the 3rd Generation ALBA Storage Ring

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



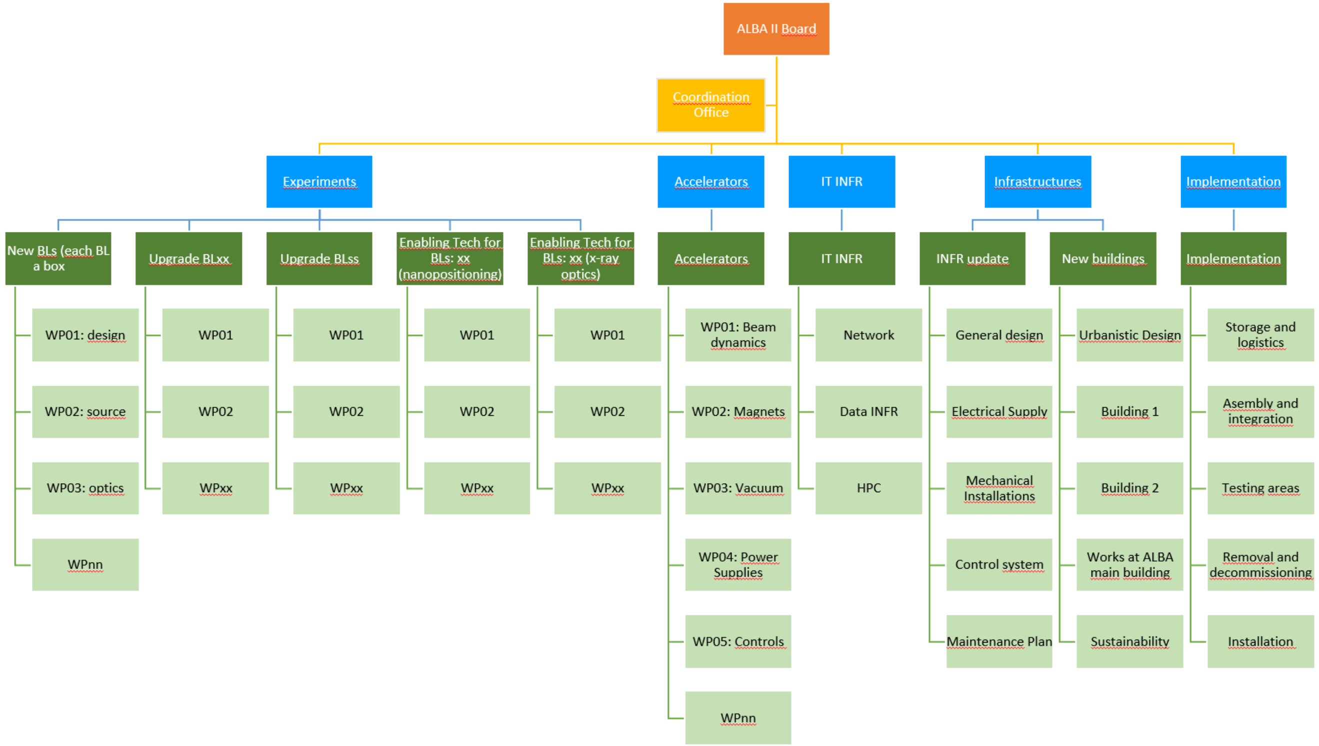
with the aim of doing it as efficiently as posible,

in terms of cost and time.

ALBA II Upgrade

Five Programs:

- Experiments
  - BLs upgrades
  - New BLs
- **Accelerators**
  - **Accelerator Project**
- IT Intrastructures
- Conventional Infraestructures
  - Upgrade infrastructures
  - New Buildings
- Implementation



Optimization parameters

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

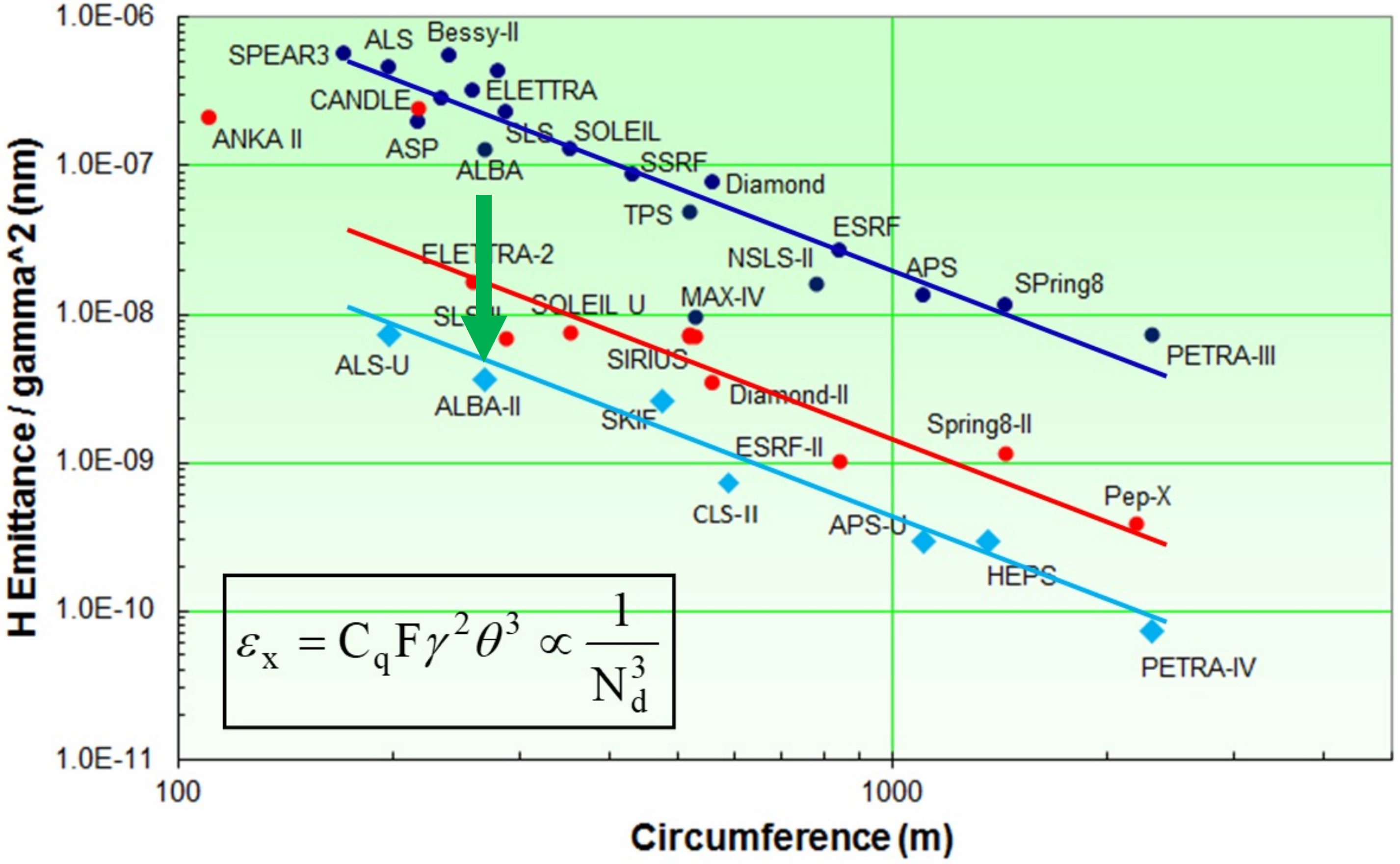
- **Keep** existing **ID beamlines** → preserve 16 cells and source points.
- Bending beamlines can be relocated.

- **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.

ALBA Physicists

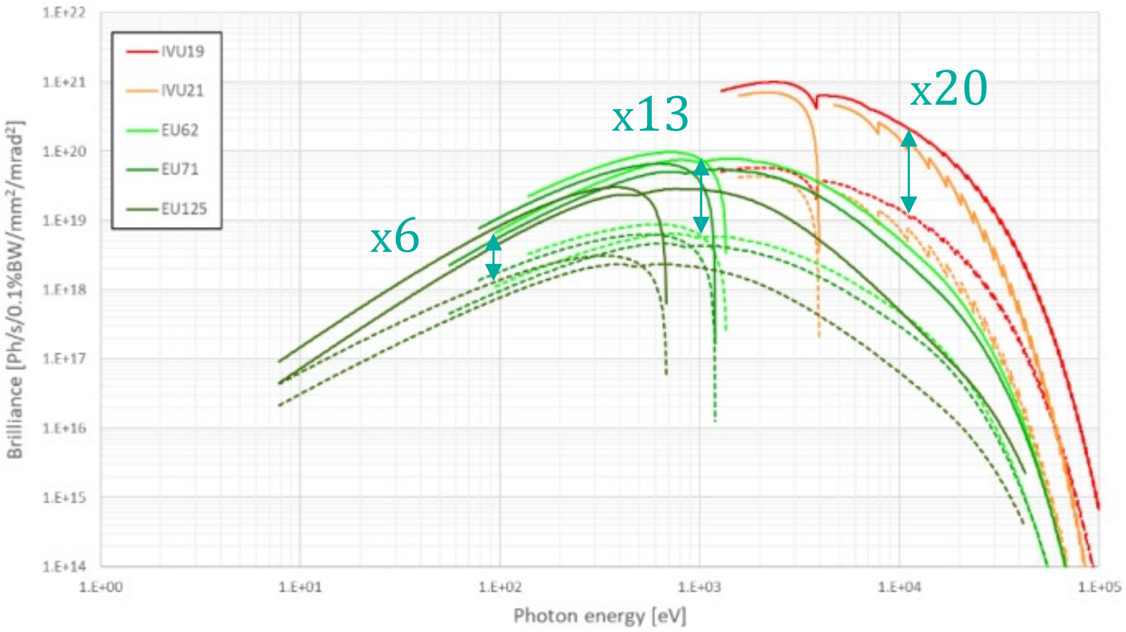
Goal: Reduction of emittance by a factor 20 ≈ 200 pmrad



Reproduced from: R. Bartolini "Overview of ongoing 4th generation light source projects worldwide", 7th DLSR Workshop (2021)

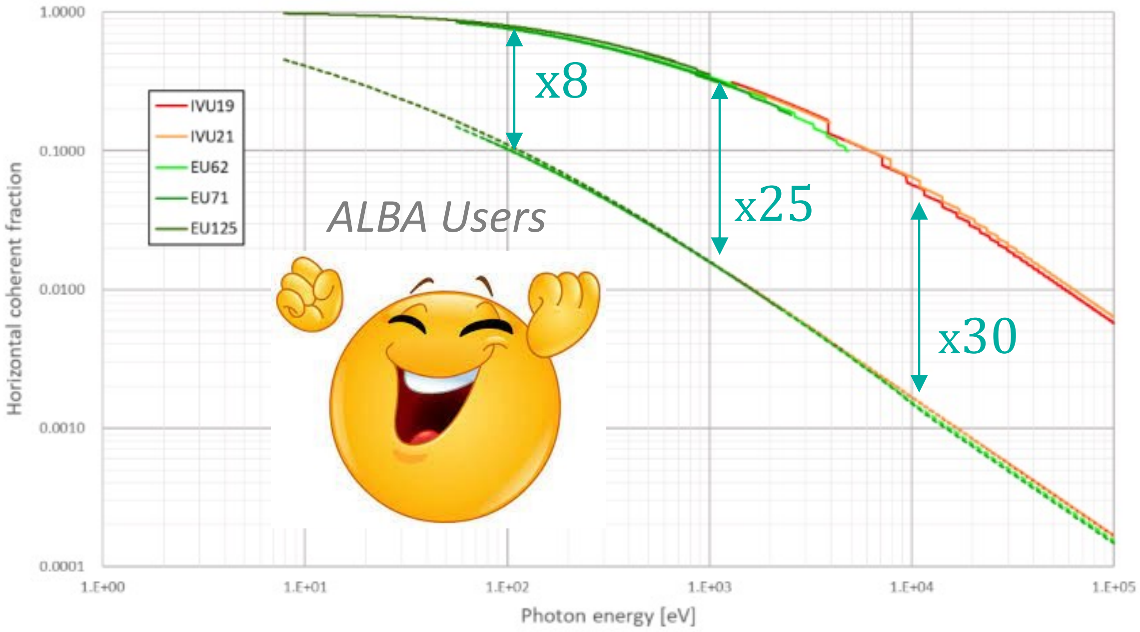
IDs radiation: from ALBA to ALBA II

Brilliance



100 eV 1 keV 10 keV

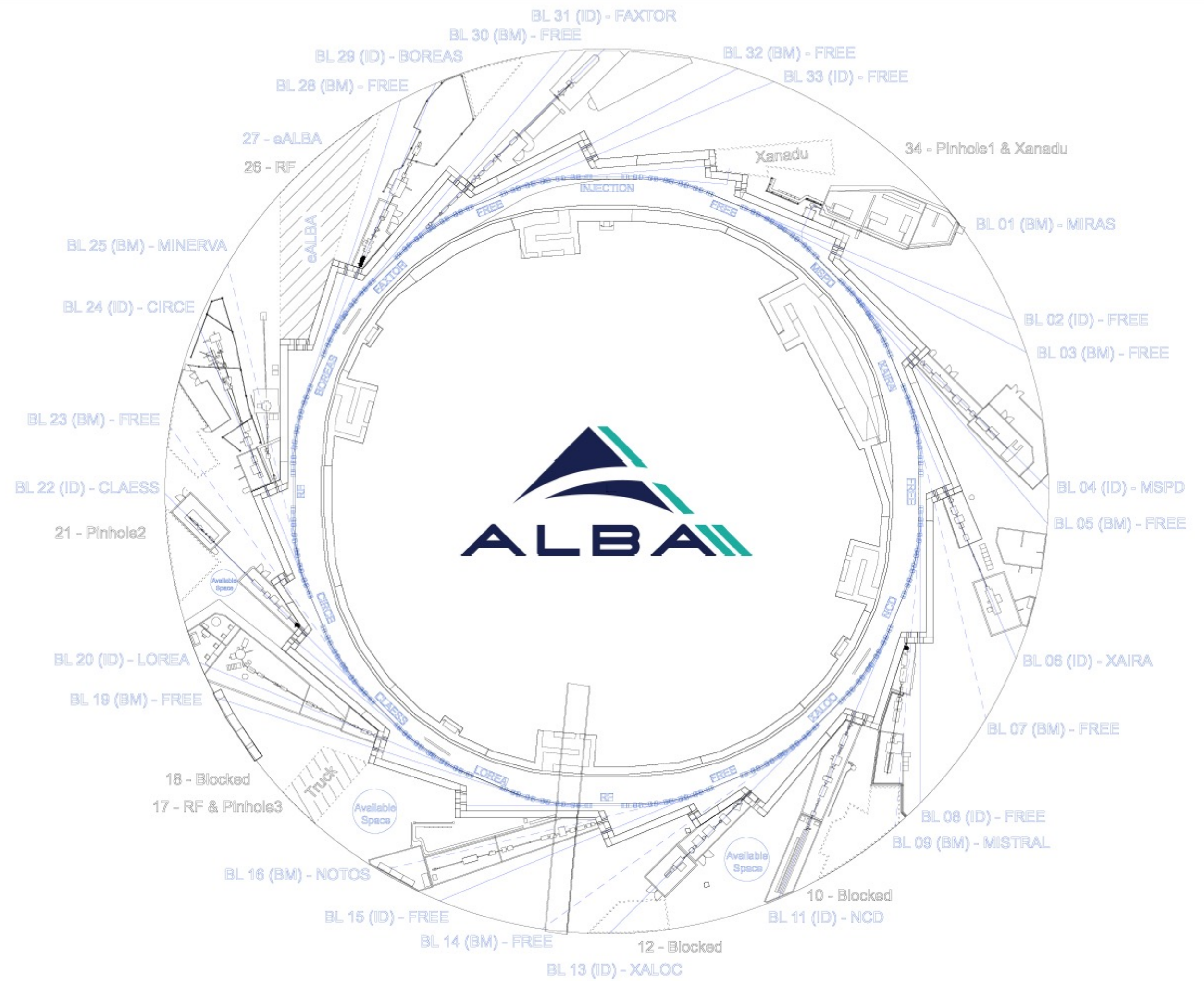
Horizontal Coherent fraction

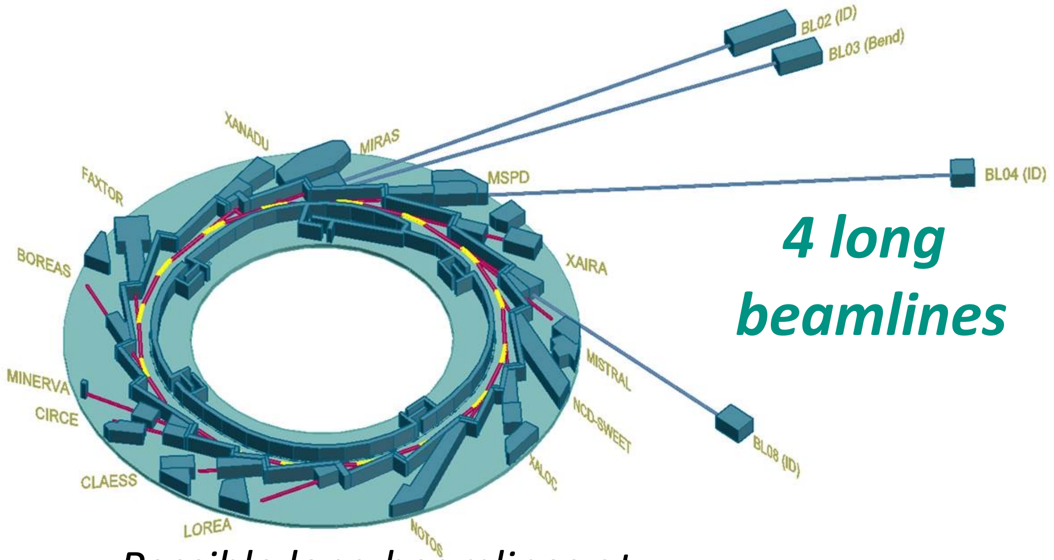


100 eV 1 keV 10 keV

vs. Photon Energy

Implementation



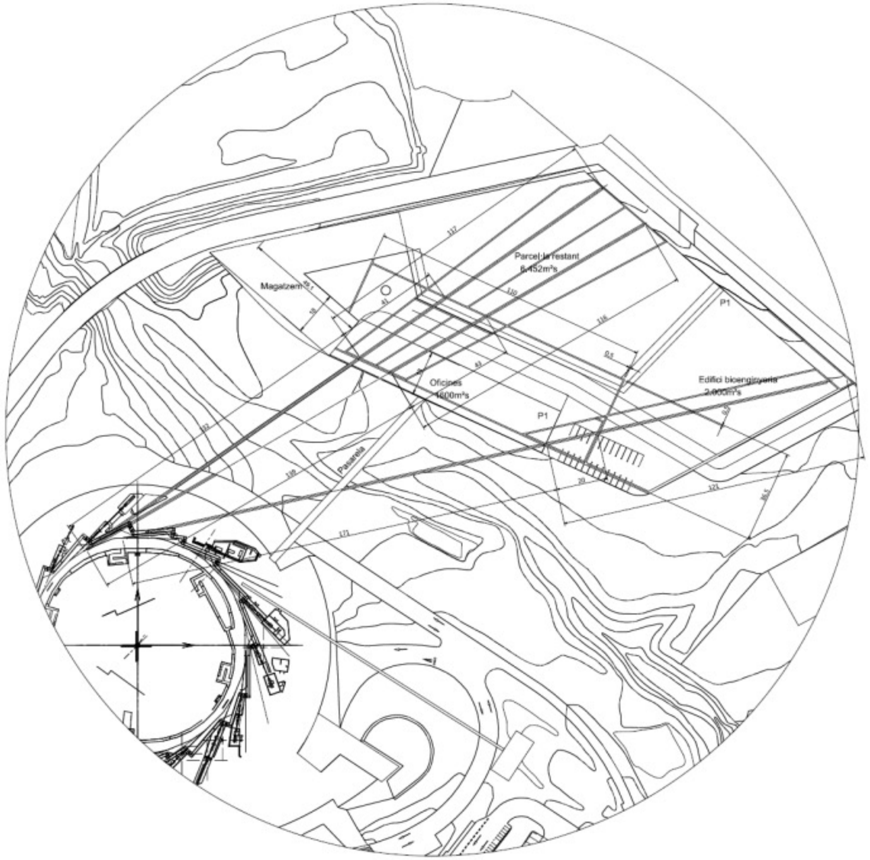


4 long beamlines

Possible long beamlines at BL02-ID , BL03-Bend, BL04-ID, BL08-ID

13	***ID beamlines***
13	***Bending beamlines***
1	***IR beamline***
1	***Visible diagnostics***
2	***XR pinhole diagnostics***

ALBA II Long Beamlines technologies being defined now



150 – 300 m long beamlines

Figure 1-1 – Layout of the four long BLs

Process:

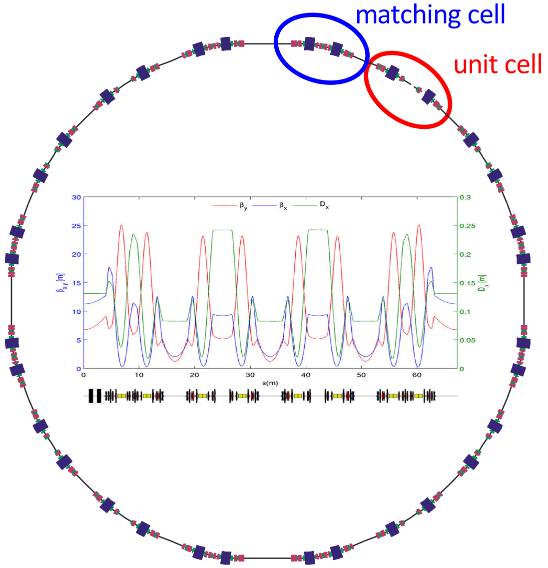
- Call to scientific community
- Pre evaluation, focusing on 3 proposals
- Proposals received on May'23
- Evaluation in progress
- Decision to be taken in July'23

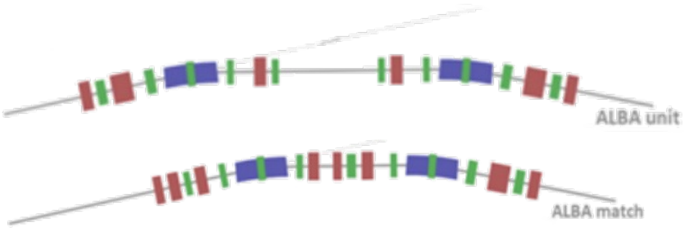
Applications, among others:

- Ptychographic tomography
- High resolution imaging of materials
- Coherence diffraction
- Spectroscopy
- Resonant Inelastic Scattering
- Coherent imaging and Spectroscopy
- Resonant Soft X-ray Scattering (RSoXS)
- Scanning Transmission X-ray Microscopy (STXM)
- Ptychography

The upgrade

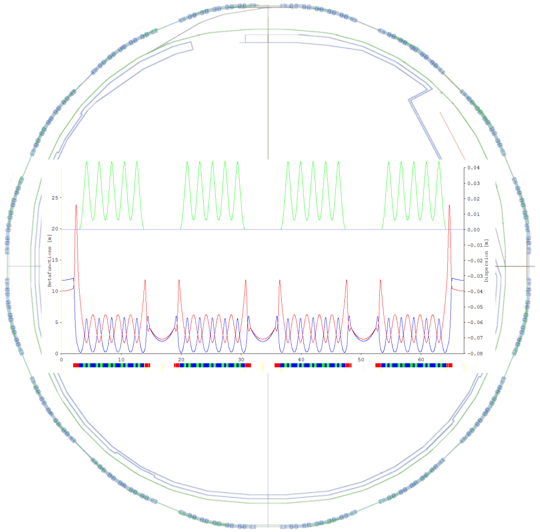
ALBA Physicists

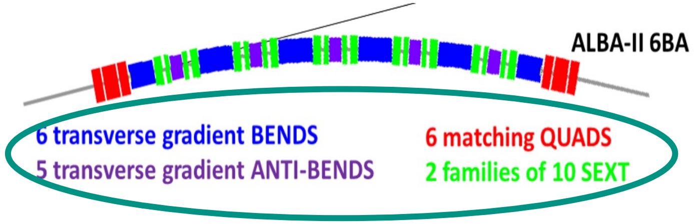




	ALBA	ALBA II
Energy	**3 GeV**	**3 GeV**
Circumference	268.8 m	268.8 m
Symmetry	4-fold	4-fold
Lattice	8×2-DBA cells	16×6BA cells
Emittance	**4.5 nm·rad**	**185 pm·rad**
Nº of cells	8+8	16
# of straights	4 / 12 /8	16
Straight length	7.8 / 4.0 / 2.3m	4.0 m

÷25





Cell's length comparison

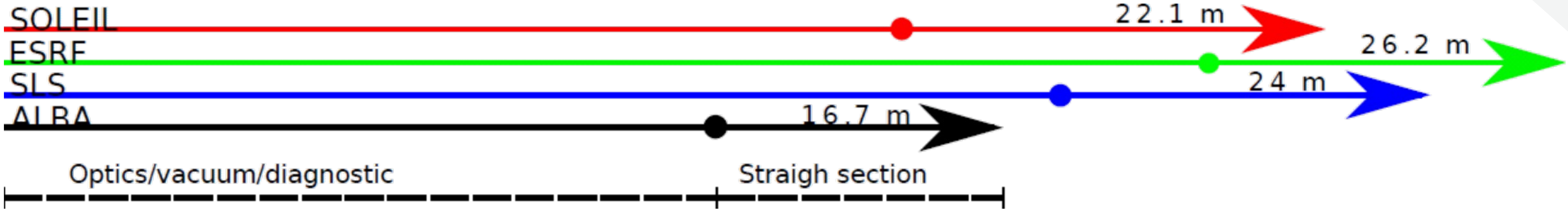
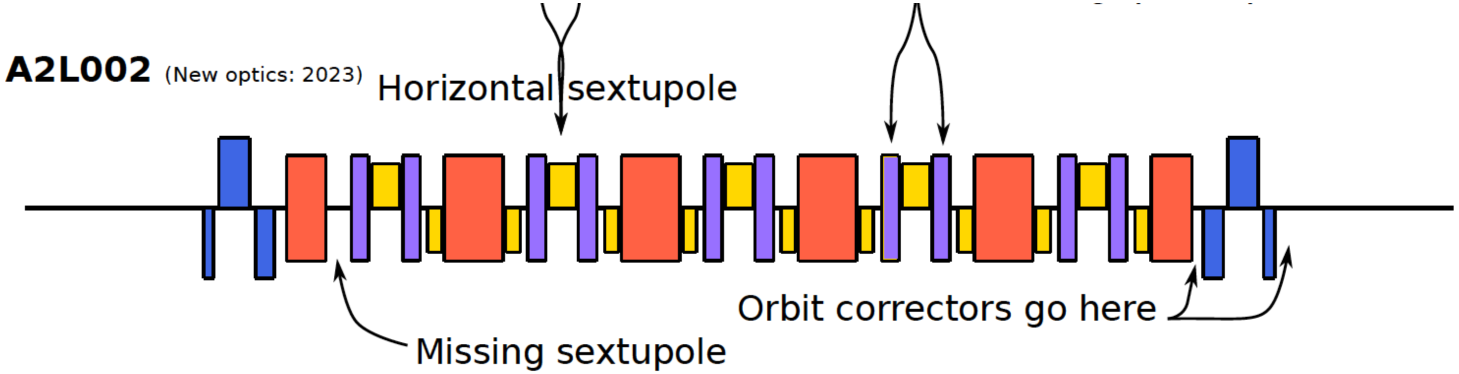


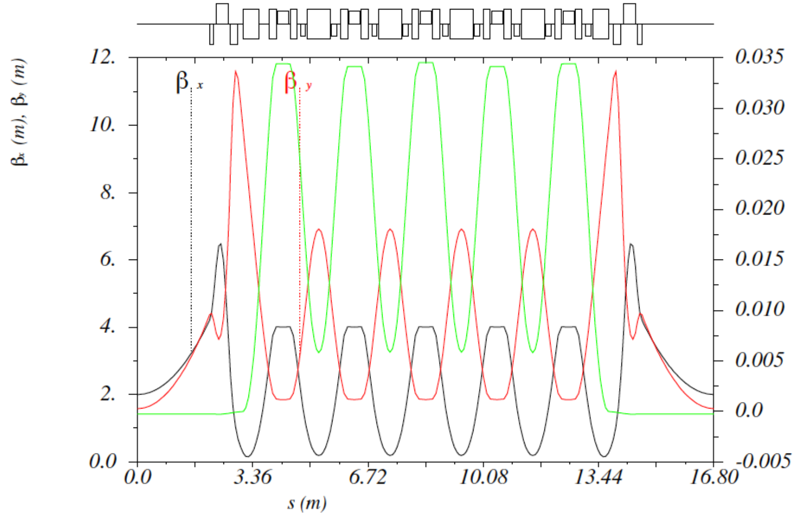
diagram courtesy of M. Carlà (ALBA Acc. Division)

Space requirements for ALBA II are **particularly tight**:

- 16 straight sections in 268m → **16.7m per cell**
- In ALBA II every straight section will be **4m**
- The space left for magnets/diagnostics/vacuum is 16.7m – 4m = **12.7m**

The lattice

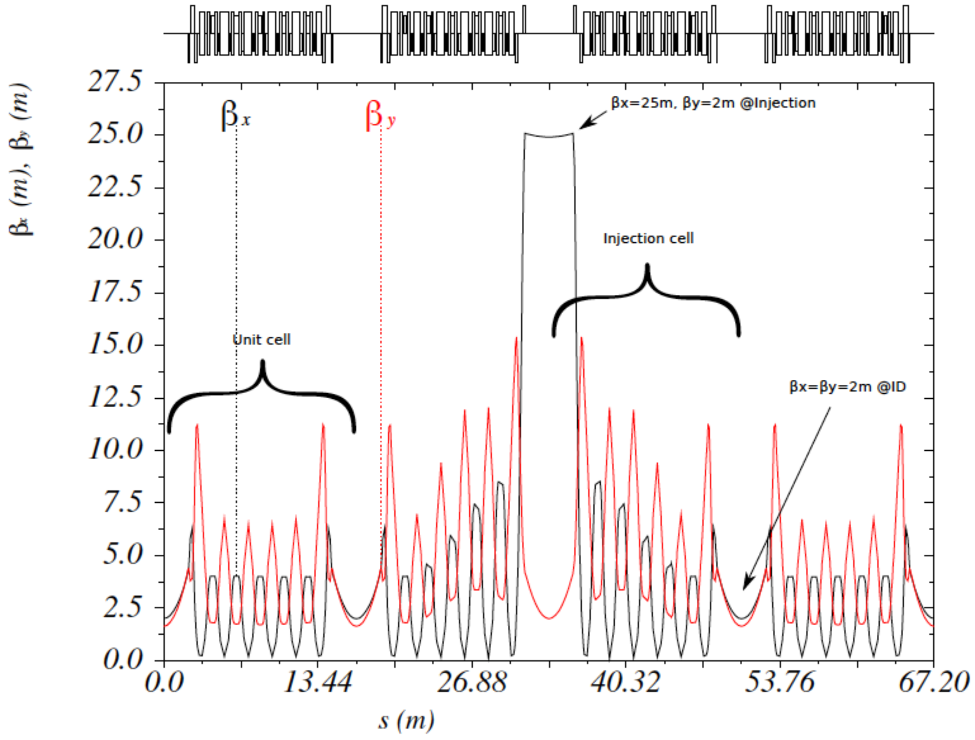




- **16 identical cells, 14 families of sextupoles (5 SH + 9 SV)**

- **Natural emittance: 185 pm**
- α_c: $9.6 \cdot 10^{-5}$
- Energy loss: 1.0 MeV/turn
- $\beta_{x/y}$ at ID: 2 m
- Q_x/Q_y: **45.15 / 14.38**
- **Chromaticity: -89 / -58**

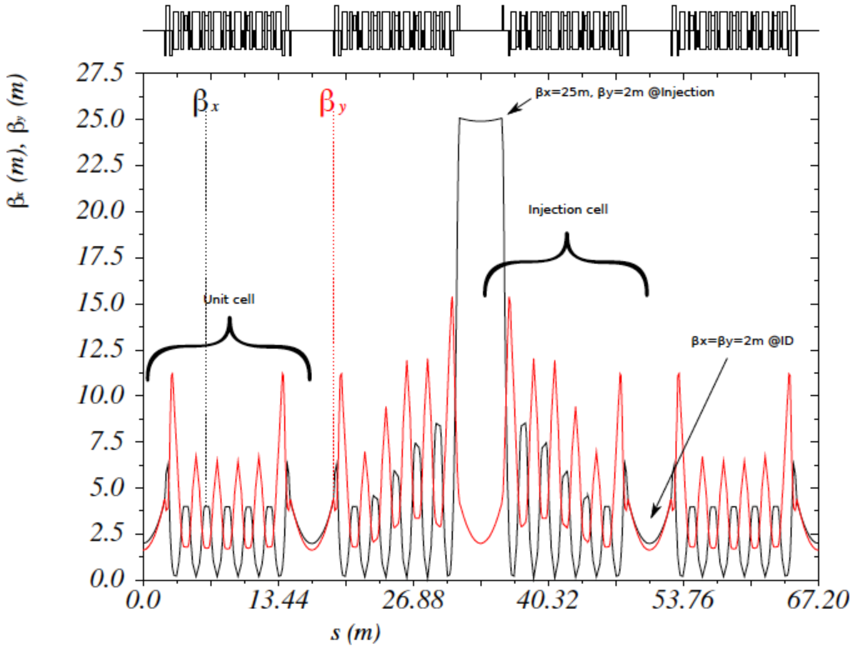
Injection cell

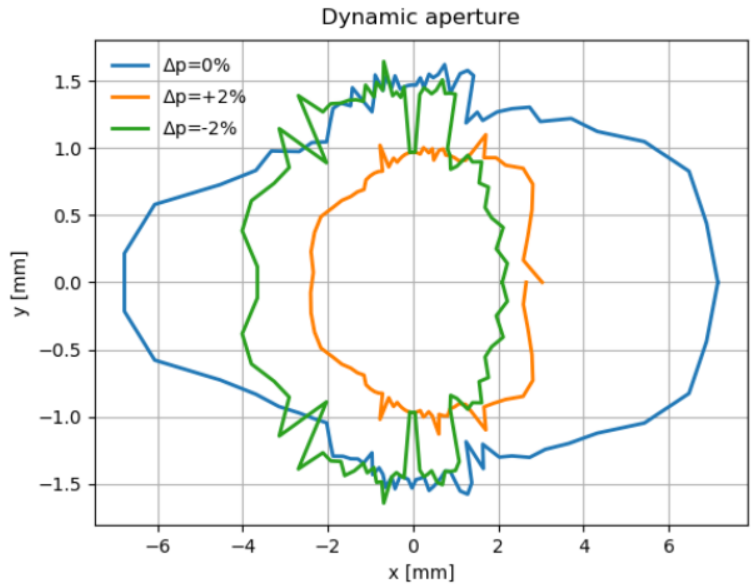


- **Quadrupoles in the injection cells are detuned** to increase β_x in the injection straight
- 3% change of gradient in the injection cell arc is enough to achieve β_x=25m at the kicker
- **Natural emittance increases ∼20pm** (only 2 cells are affected)

Dynamic aperture

Work in progress

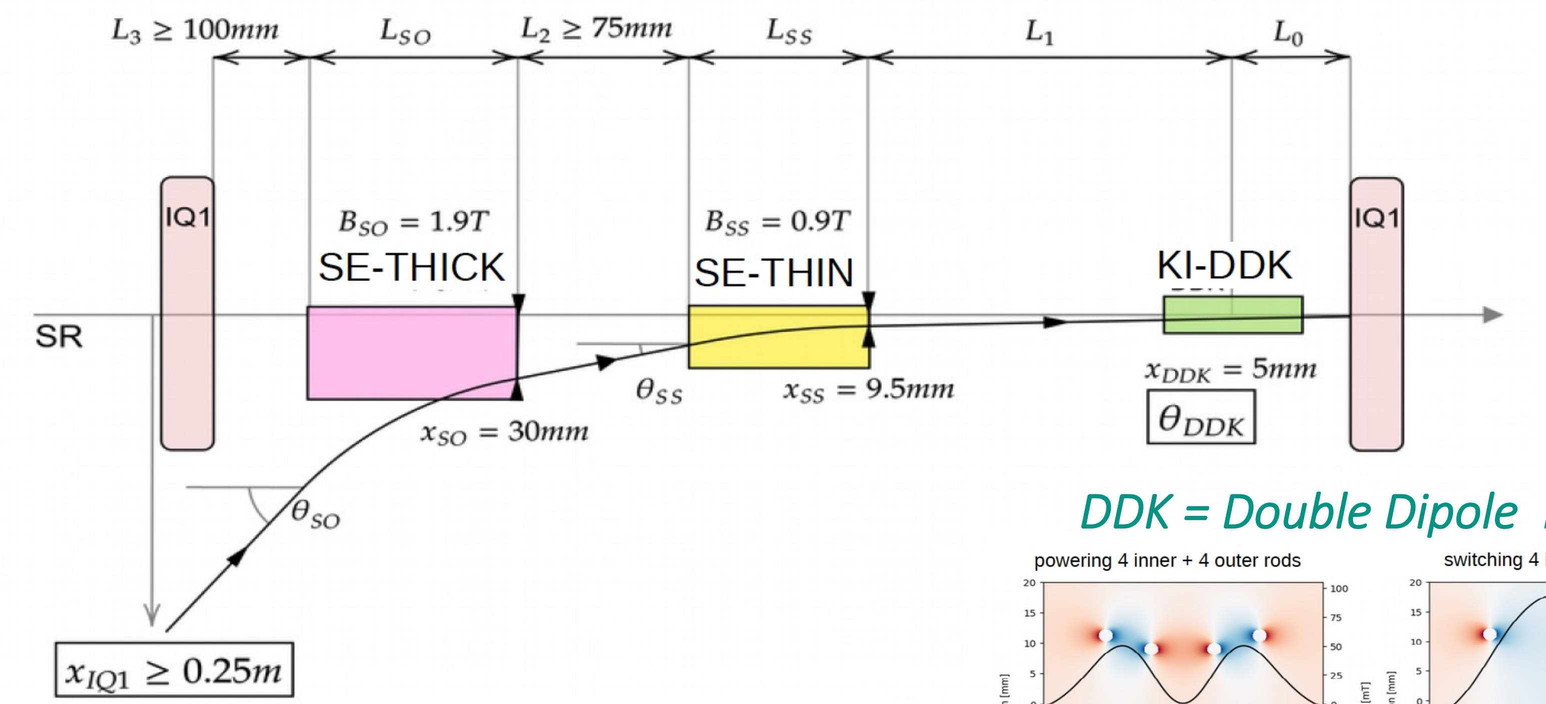




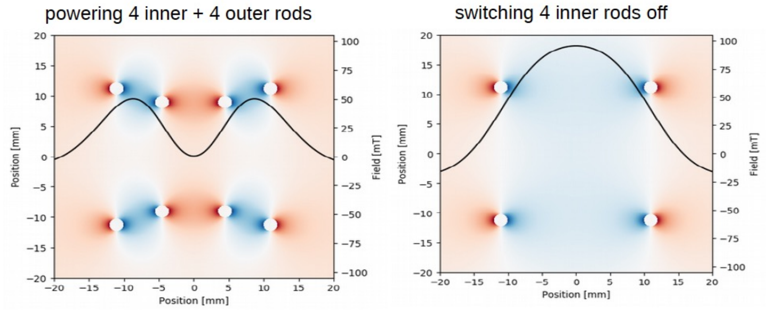
- **14 families of sextupoles** for the unit cell (5 SH + 9 SV)
- **plus 4 SH + 4 SV** close to the injection are **independent** (2 on each side of the injection straight)
- The missing SV after the injection is reintroduced (is one of the 4 independent SV)
- In a first attempt **only on-energy dynamic aperture is optimized** (NSGA2)

Injection concept

The ALBA-II lattice is very tight, all the injection elements have to fit in a **4 metres straight section**.
The beam from the booster is injected off-axis and a **multipole pulsed kicker** reduces its large oscillations within the dynamic aperture.

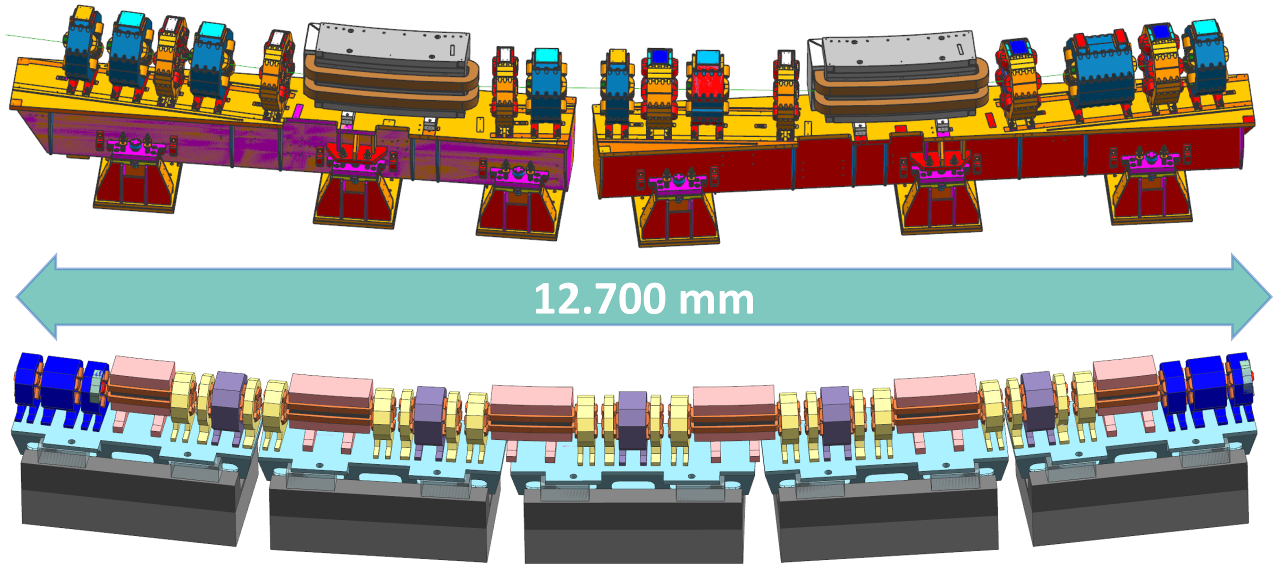


DDK = Double Dipole Kicker



Magnets: from ALBA to ALBA II

Cell Architecture



ALBA
Total magnet equivalent length: 6.180 mm
Compactness:
6,18/12,7 = **49 %**

ALBA II
Total magnet equivalent length: 10.130 mm
Compactness:
10,13/12,7 = ***80 %***

ALBA Engineers

ALBA II magnet requirements

- **Primary set of requirements** (**field/gradient strengths** and **lengths**) from Beam Dynamics (original lattice with modified triplet, Dec'22):

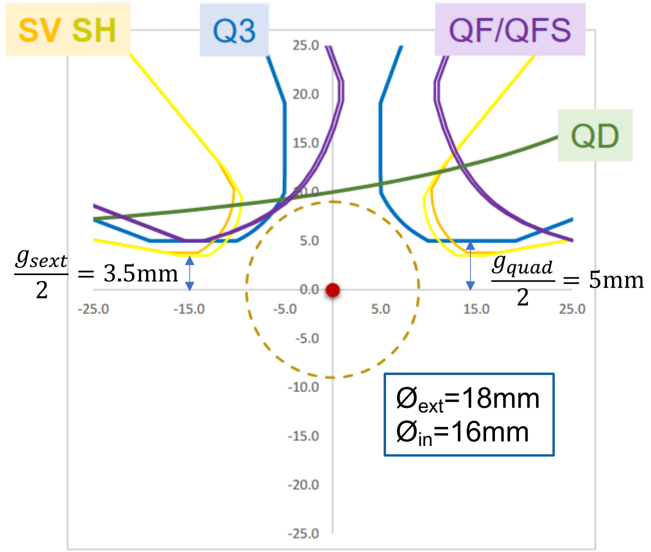
cell center

straight section

Distances between magnets' **effective lengths**

Yoke-to-yoke distances will be **larger** by at least **1cm**

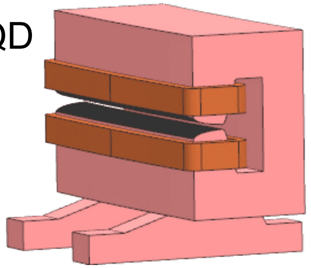
A2L001b					
Magnet description	Types	Length [m]	Field [Tesla]	Gradient (K_1) [T/m]	2nd order grad (K_2) [T/m²]
Bending with transversal gradient	QD	0.8669	**1.009**	-15.41	
	QDS	0.6310	0.819	2.03	
Antibending with transversal gradient	QF	0.2972	-0.394	70.05	
	QFS	0.2972	-0.425	70.05	
Quadrupoles	Q1	0.1000		-89.75	
	Q2	0.3500		91.97	
	Q3	0.2000		**-108.22**	
Sextupoles	SH	0.1042			**4936**
	SV	0.1823			-4084



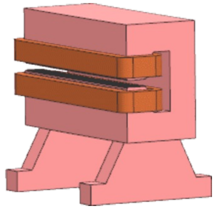
Preliminary designs

- By Feb’23 a **preliminary set of 3D models** for **all main magnet types** was available:

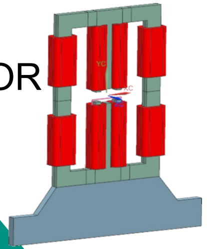
QD



QDS

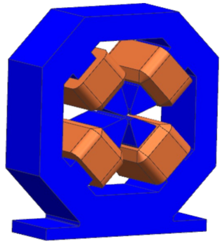


COR

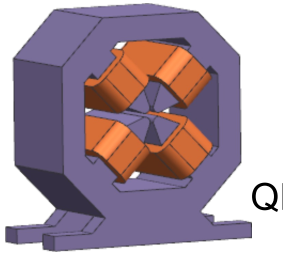


A2L001b

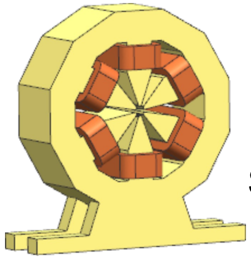
Magnet type	Bore diameter [mm]	Min. pole vertical distance [mm]	Effective Length [mm]	Iron Length [mm]	Width [mm]	Height [mm]	Current [Amp·turn]	Efficiency [%]
QUAD (Q3)	20	10	200.0	190.6	484	484	5000	90
ANTIBEND QF/QFS	27.8	10	297.2	282.5	540	540	5860	91
BEND QD	20	12.2	867	833.4	310	470	8130	99
BEND QDS	20	12.2	631	602.6	227	342	6573	99.8
SEXTUPOLE (SH)	24	7.0	104.2	96.2	514	514	2450	95
SEXTUPOLE (SV)	26	7.6	182.0	174.0	514	514	2460	98
CORRECTOR (COR)		25	85.0	20	262	430	1500/2000	----



Q3



QF



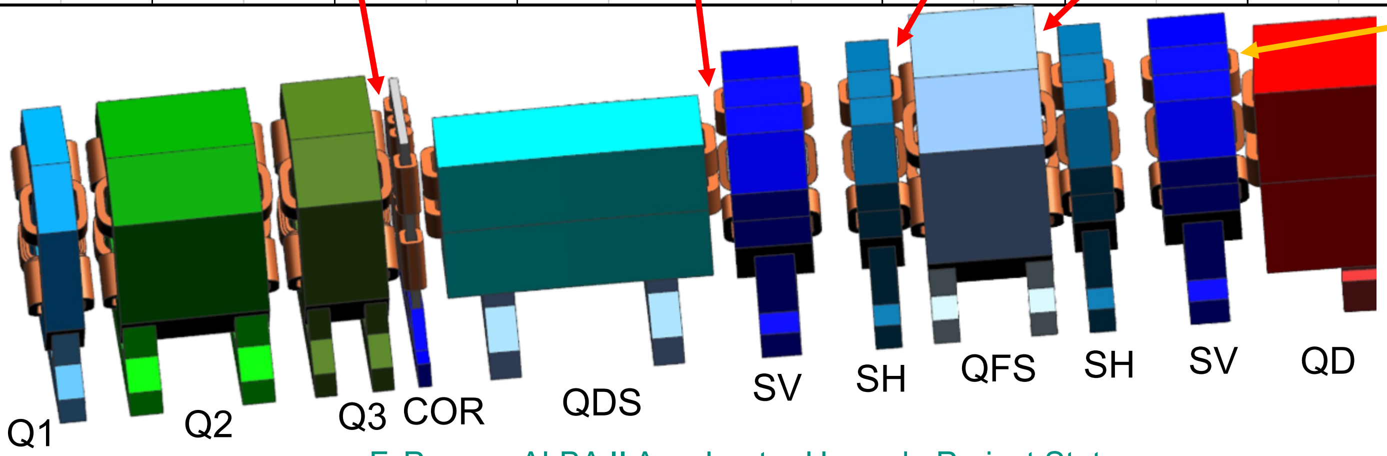
SV

After several iterations

		Q1		Q2		Q3		COR		QDS		SV		SH		QFS		SH		SV		QD	
Iron	Q1			81.6	56.1																		
Coil				56.1	30.6																		
	Q2	81.6	56.1			80.5	55.0																
		56.1	30.6			55.0	29.5																
	Q3			80.5	55.0			54.7															
				55.0	29.5				10.2														
	COR					54.7				64.2													
							10.2				11.2												
	QDS							64.2				58.2											
									11.2				2.2										
	SV									58.2				108									
											2.2				64								
	SH											108				51.35							
													64				5.85						
	QFS													51.35				51.35					
															5.85				5.85				
	SH															51.35				108			
																	5.85				64		
	SV																	108				60	
																			64				4
	QD																			60			
																					4		

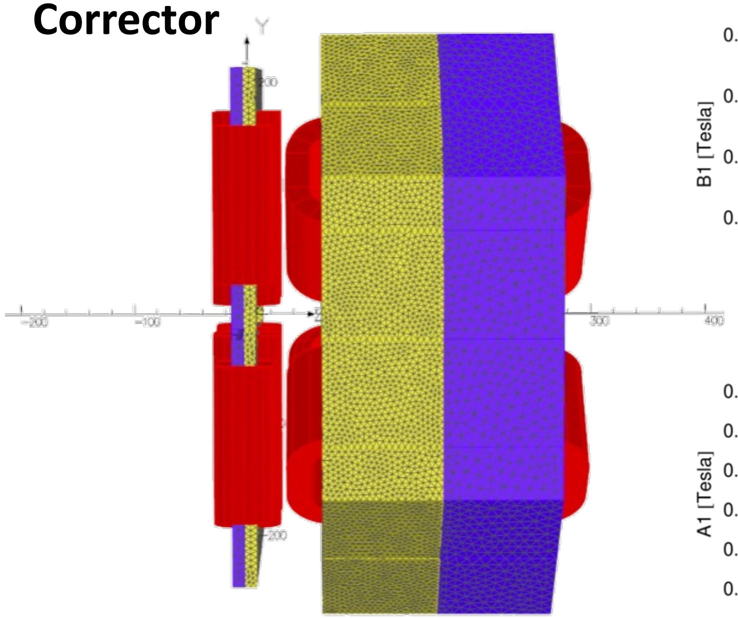
iron-to-iron
Average: 72mm
Min: 51mm
Max: 108mm

coil-to-coil
Average: 23mm
Min: 2mm
Max: 64mm

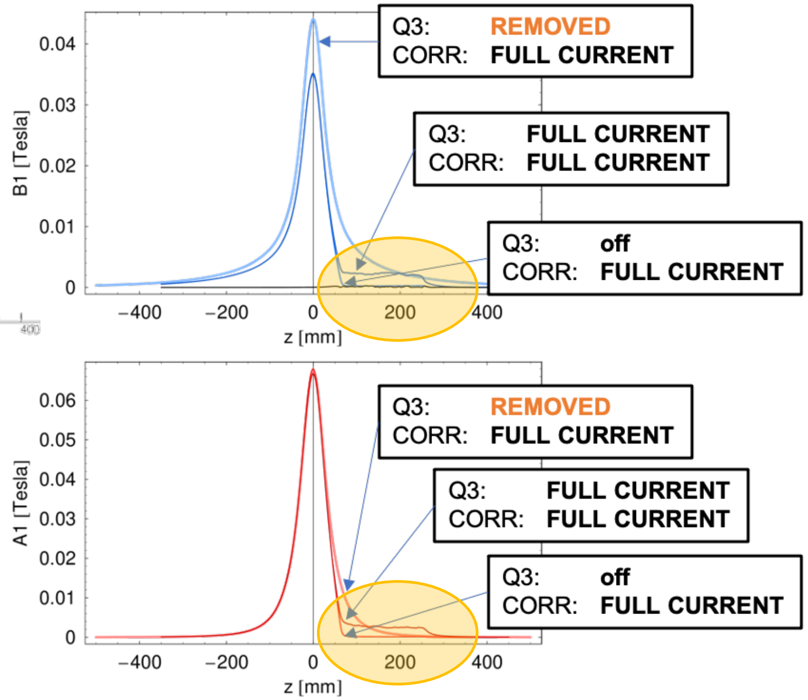


Preliminary designs

In addition, magnetic cross-talk



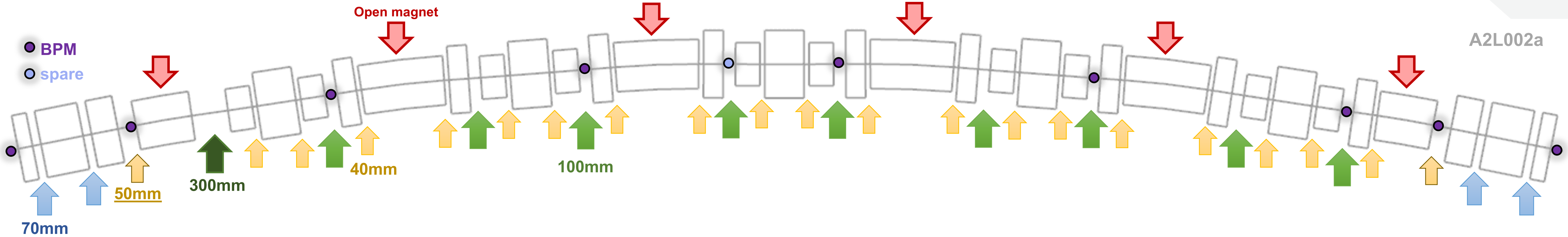
yoke to yoke = 54.7 mm
coil to coil = **5.7 mm**

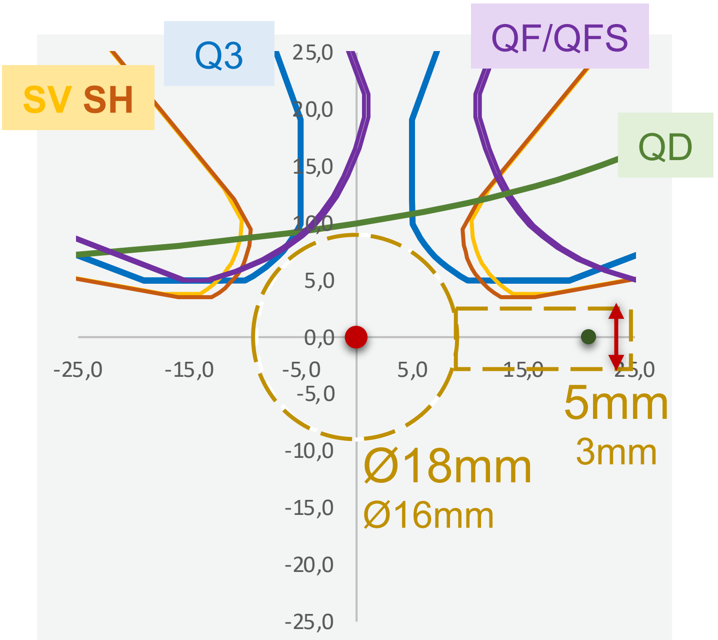


		Specs	CORR	CORR+Q3
A1	[T·mm]	*>5*	6.06 ✓	5.84 ✓
B1	[T·mm]	*>5*	5.24 ✓	3.58 ✗
A2	[T]	*<0.005*	0.0003 ✓	0.0017 ✓
B2	[T]	*<0.005*	0.0006 ✓	---- ✓
A3	[T/m]	*<2.2*	0.21 ✓	3.15 ✗
B3	[T/m]	*<1.8*	0.37 ✓	3.47 ✗

Working on it…

Vacuum system layout





Beam dynamics lattice layout

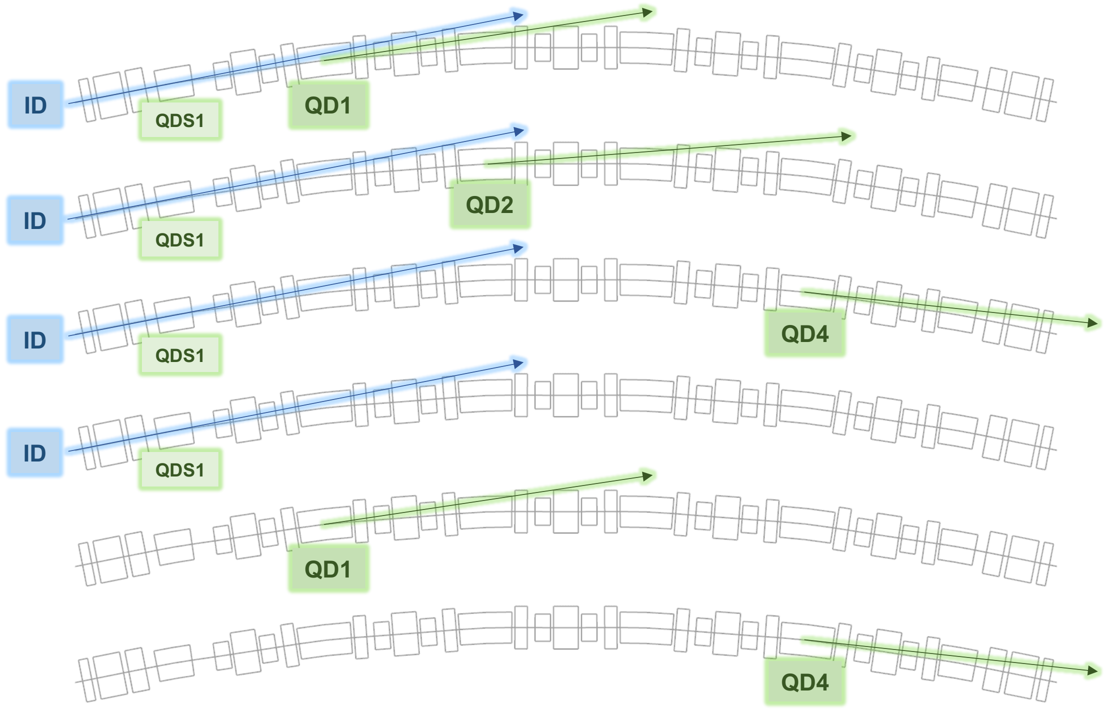
Distance between magnets

40, 70 and 100 mm – Compact spaces

Magnets apertures

BPM positions layout

Vacuum system layout



The **6 types of cells** and the **light extractions locations**

Type A: ID + QD1 (3x)

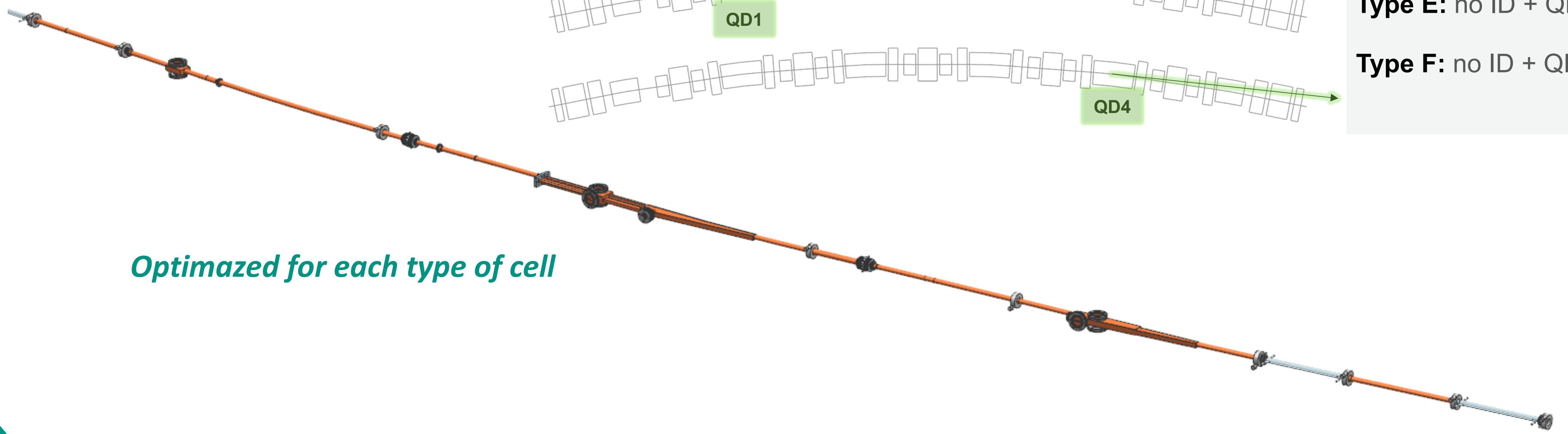
Type B: ID + QD2 (5x)

Type C: ID + QD4 (5x)

Type D: ID + no BM (1x)

Type E: no ID + QD1 (1x)

Type F: no ID + QD4 (1x)

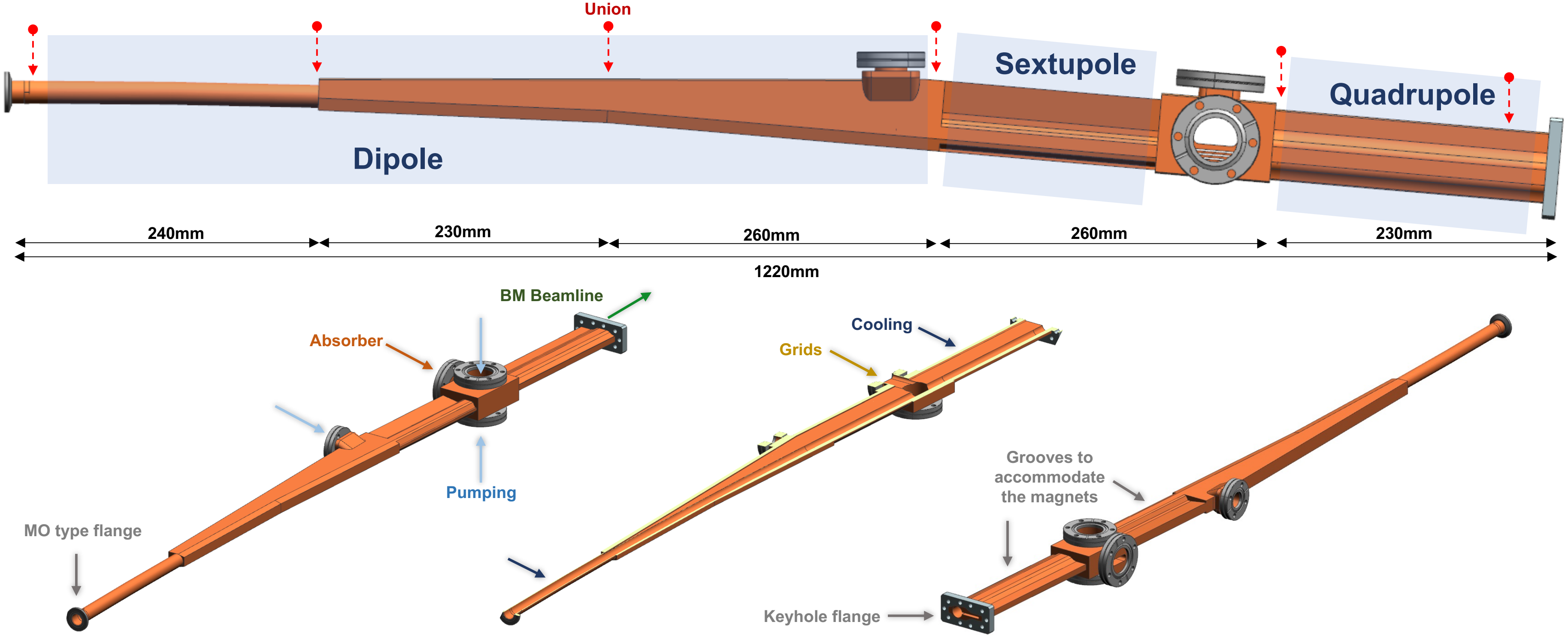


Optimazed for each type of cell

Vacuum system design concept

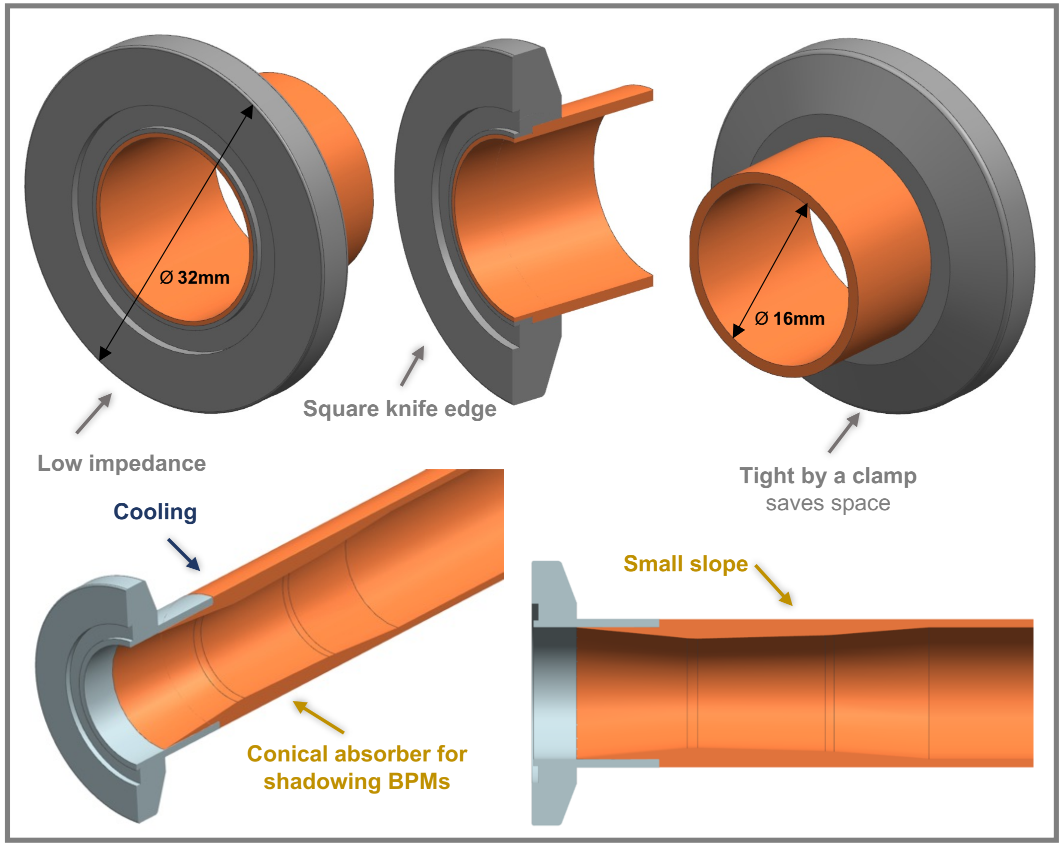
Hybrid approach

- **NEG coated copper** chambers
- Conventional chambers with **antechambers** and **absorbers**
- Stainless steel for BPMs and correctors chambers



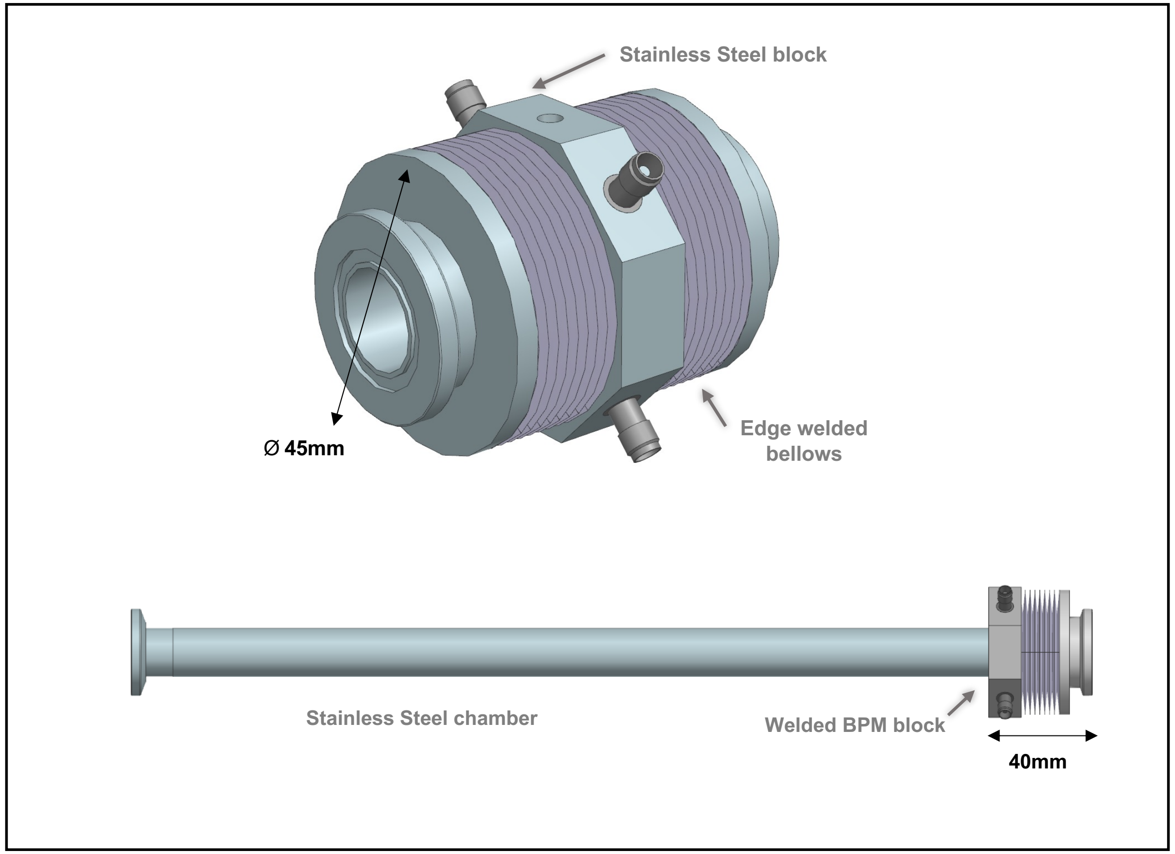
Vacuum system design concept

MO type flanges



Y. Suetsugu, KEK,"Application of a Matsumoto-Ohtsuka-type vacuum flange to beam ducts for future accelerators", 2005
R.Seraphim, "Vacuum system design for the Sirius storage ring", IPAC2015

Integrated bellows



RF System

- Main RF **high power components reused** for ALBA-II.
- RF main voltage must provide enough **RF acceptance** and **redundancy** in case of a cavity trip.

EU-HOM NC cavity

WR1800

ALBA Main RF IOT based transmitters

Upgrade to SSPA

Parameter	Value	Unit
Frequency	499.654	MHz
Number of cavities	6	-
Voltage	2.4	MV
RF acceptance	7	%
Loses per turn (bare lattice)	1.028	MeV
Transmitter power (300 mA)	90	kW
Momentum compaction (α_c)	9.6·E-5	-
Synchrotron frequency*	2.25	kHz
Bunch length (σ)*	6.96	ps

* w/o harmonic system

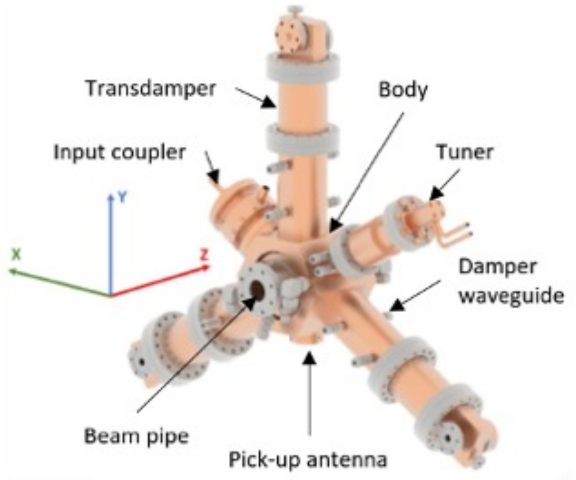
Short bunches lead to small lifetimes due to high Touschek effect (for ALBA $\sigma = \sim 17$ ps)

RF System
3rd Harmonic Active Cavity

The **prototype design** was co-funded by ALBA and the CERN through the collaboration agreement KE2715/BE/CLIC for the Development of CLIC Damping Ring Technologies (2015-2018).

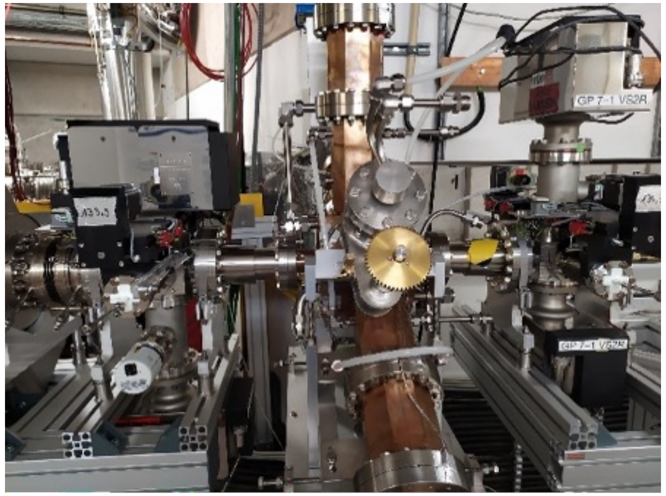
The **prototype construction** was co-funded by ALBA and the European Regional Development Fund (ERDF) within the Framework of the Smart Growth Operative Programme 2014-2020.

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



Designed

Prototyped

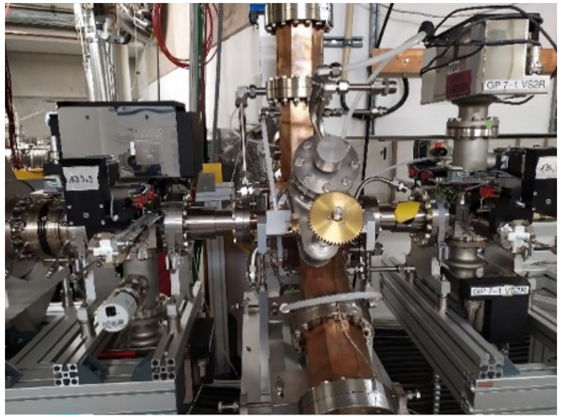


Installed at BESSY II

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).

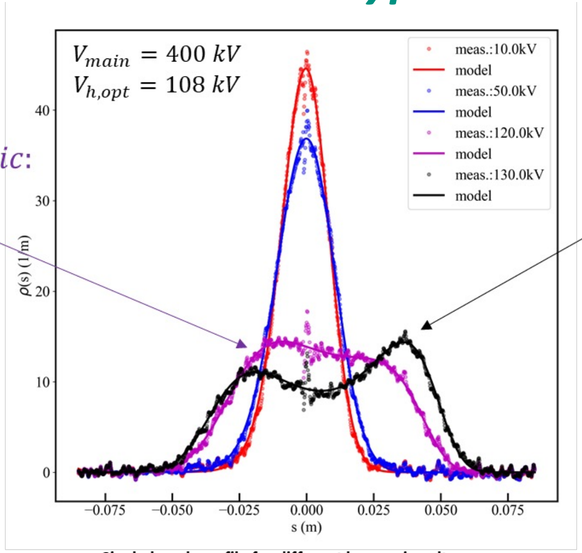
Cavity



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

Ayuda **ICTS-MRR-2021-02-CELLS** financiada por:

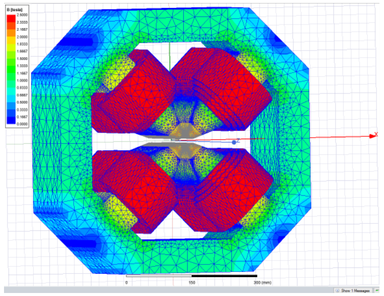
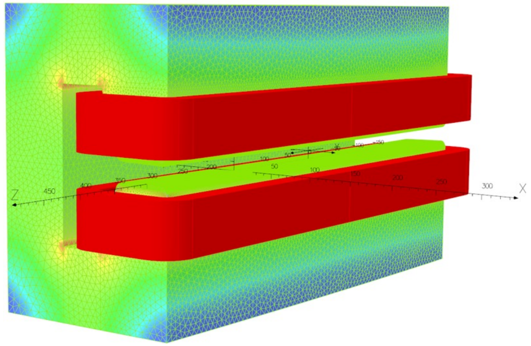
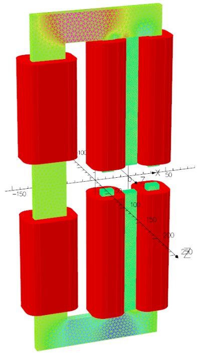
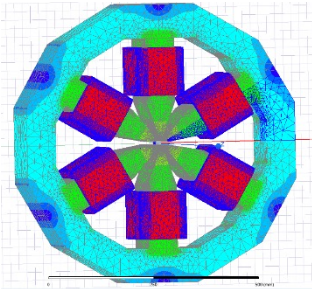
GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Plan de Recuperación, Transformación y Resiliencia

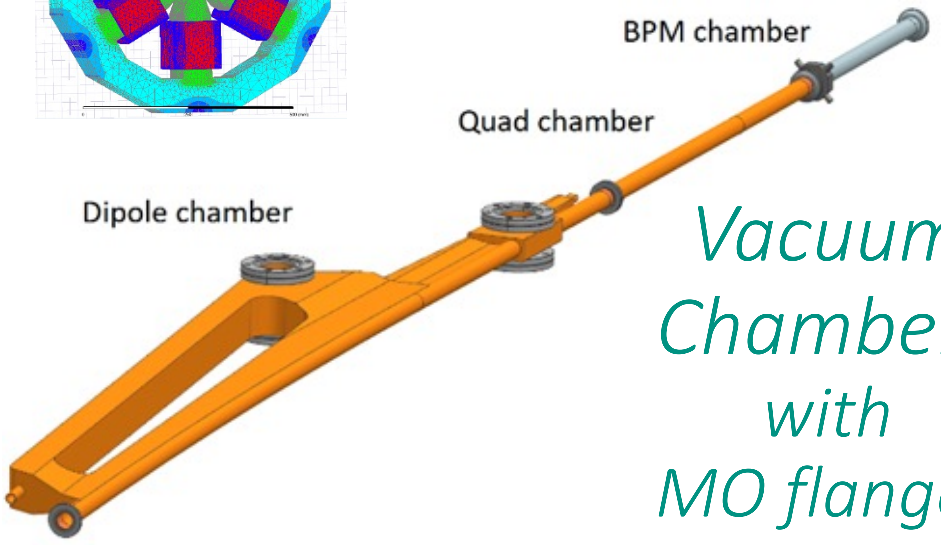
Financiado por la Unión Europea NextGenerationEU

Prototypes

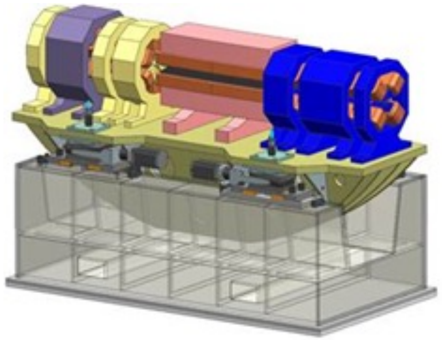
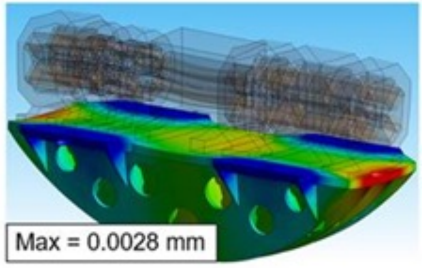
2022-2025

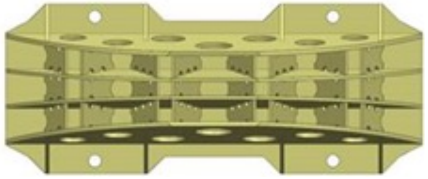





Magnets



Vacuum Chambers with MO flanges

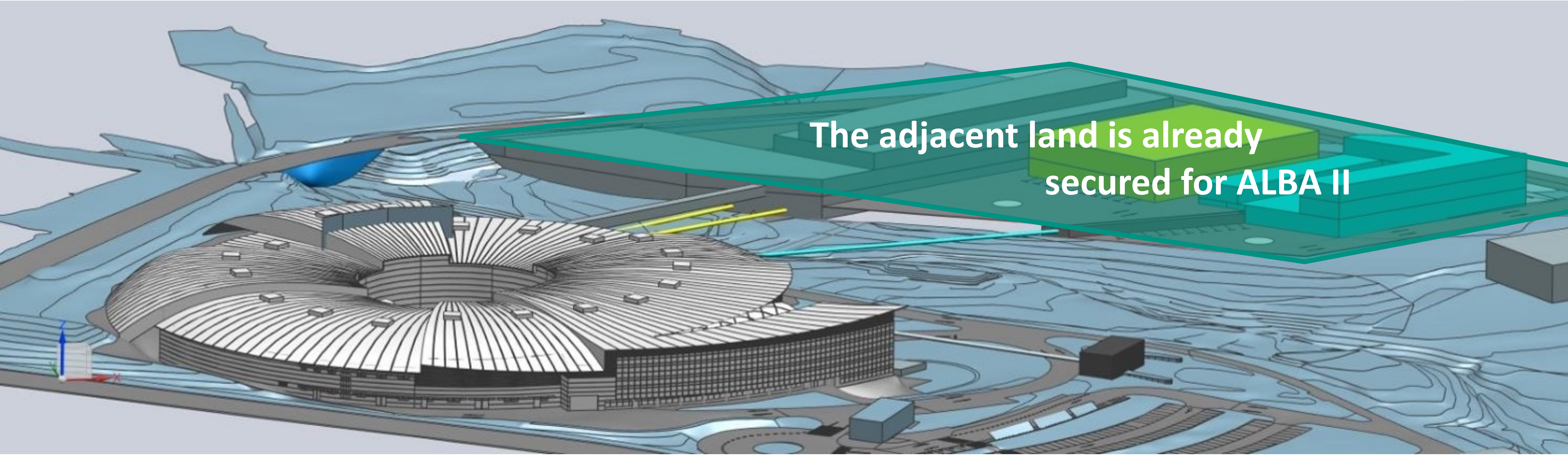
1st eigenmode = **124 Hz** Deformation < **3 um**

Girders

DDK: Double Dipole Kicker

SCU: Superconducting Undulator

Upgrade Project



The upgrade ALBA II also includes:

- **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.

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Thanks!