Magnet section activities at ALBA

Jordi Marcos on behalf of ID, Magnets and Front Ends section

29 September 2022

Outline

- Effect of Covid-19 pandemics
- Magnetic measurement activities at ALBA
- Upgrade plans at ALBA
- Magnetic measurement group reorganization
- Conclusions

Outline

- **Effect of Covid-19 pandemics**
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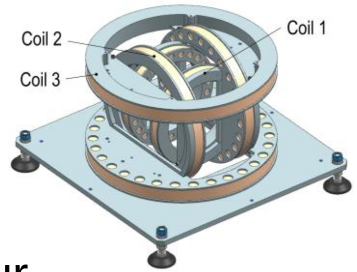
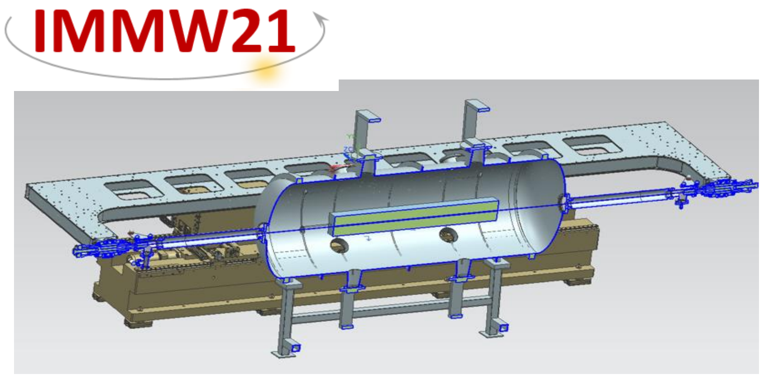
Effect of Covid-19 pandemics

- As a consequence of the **Covid-19 outbreak**, there has been a **drastic reduction** in the number of **requests for ALBA magnetic measurements lab** from **external companies/institutions**:
  - It has **reduced** from **2-3 requests/year** down to **1 single request in 3 years**.

- At an **internal level**, **Covid-19** forced us to **concentrate on high priority activities** (daily operation, construction of new beamlines) and to **put on hold lower priority projects**:
  - 3D Helmholtz coils.
  - Adaptation of Hall probe bench for cryogenic measurements under vacuum.





- After recovery of some normality by **mid-2021**, our focus has displaced to **ALBA upgrade-related activities** (more about this later on).

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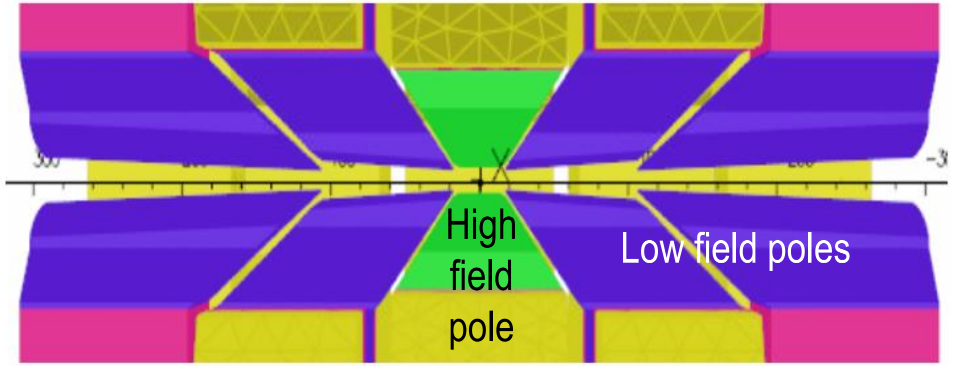
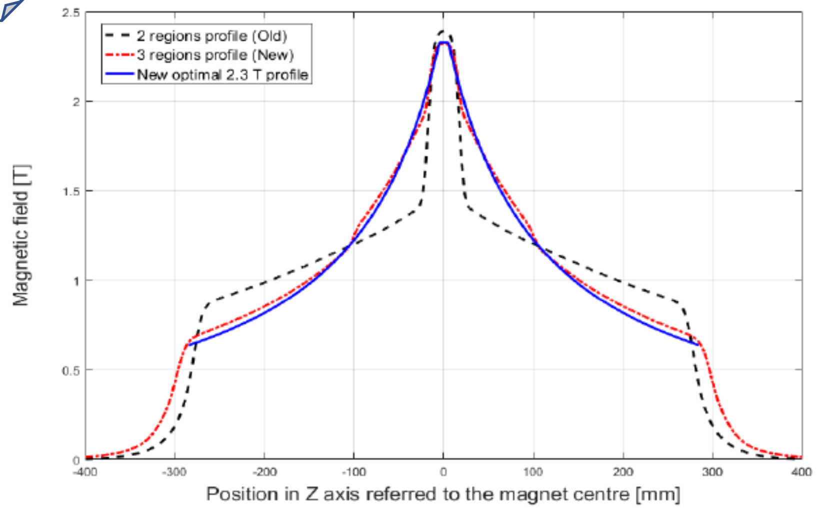
Magnetic measurement activities at ALBA

- Characterization of **Permanent Magnet longitudinal gradient dipole** for **CIEMAT**.
- Prototype of main bending magnets for **CLIC Damping Rings**:
  - **Hyperbolic field profile** along **longitudinal direction** will allow to **minimize electron beam emittance**
  - **Combined function magnet**: dipolar and quadrupolar fields

Papadopoulou *et al*, Phy. Rev. Accel. Beams. 22, 091601 (2019)
M. A. Domínguez *et al*, IEEE Trans. Appl. Supercond. 28, 1 (2018)



Drawings courtesy of M.A. Domínguez (CIEMAT)



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clic

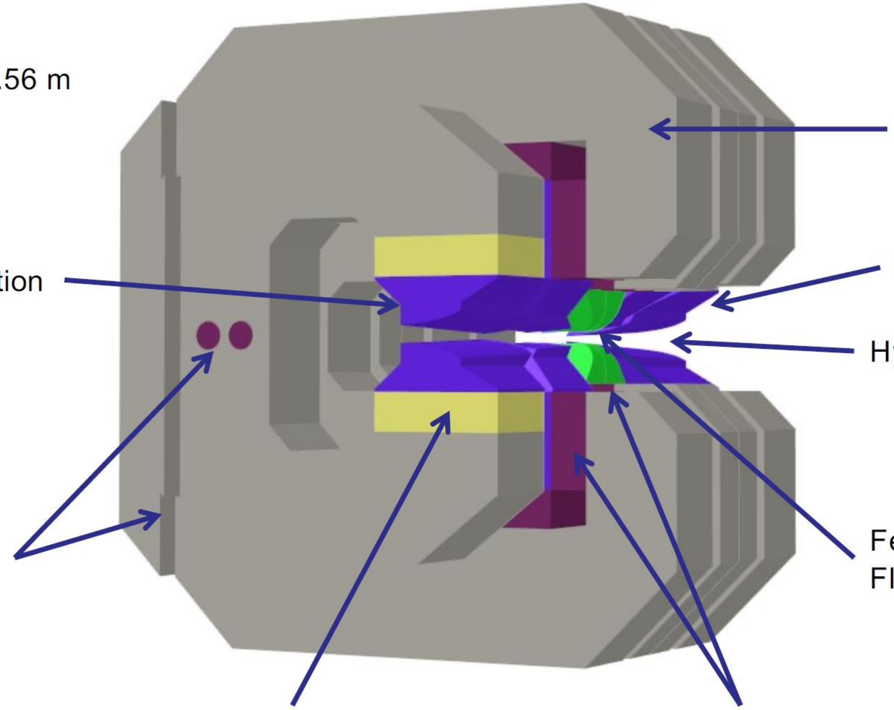
Magnetic measurement activities at ALBA

CLIC DRs Main Bending Magnet (Prototype)

Combined Function:
Longitudinal gradient with trapezoidal shape (2.3 T Peak)
Transverse gradient 11 Tm

Dimensions:
0.65 x 0.68 x 0.56 m

Weight: 1.2 T



Drawings courtesy of M.A. Domínguez (CIEMAT)

Magnet characteristics	
e-beam energy [GeV]	2.98
Peak field [T]	2.4
Iron length [mm]	560
Central gap [mm]	12.7
GFR diameter [mm]	10
Deflection angle [deg]	4
Sagitta [mm]	5.06
Trans. Gradient [T/m]	~11

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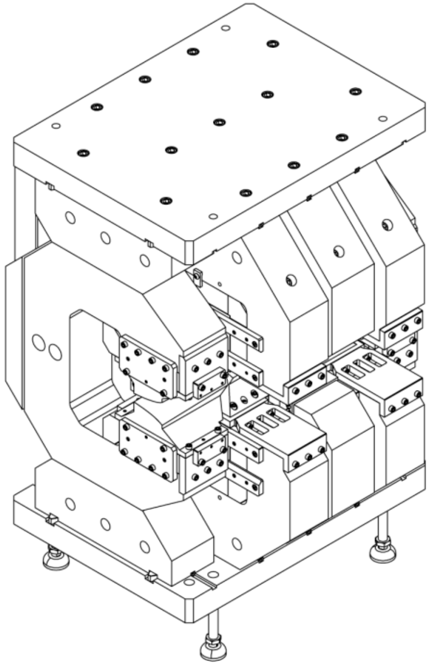
Magnetic measurement activities at ALBA

- **Requested measurements:**

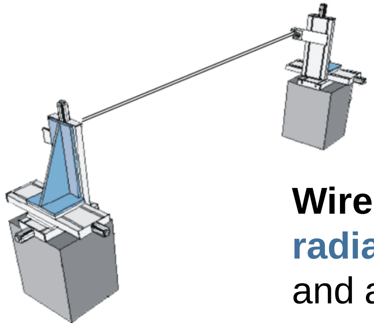


Field map within magnetic midplane → Conventional Hall probe bench

Integrated field quality along straight lines → Rotating coil bench

No coil available with the required dimensions
(∅ <12mm , length >600mm)

→ Flipping coil with **eccentric pieces**



Wire supporting pieces defining a **radial coil** with a **width of 7.6mm** and an **offset of 1.8mm**

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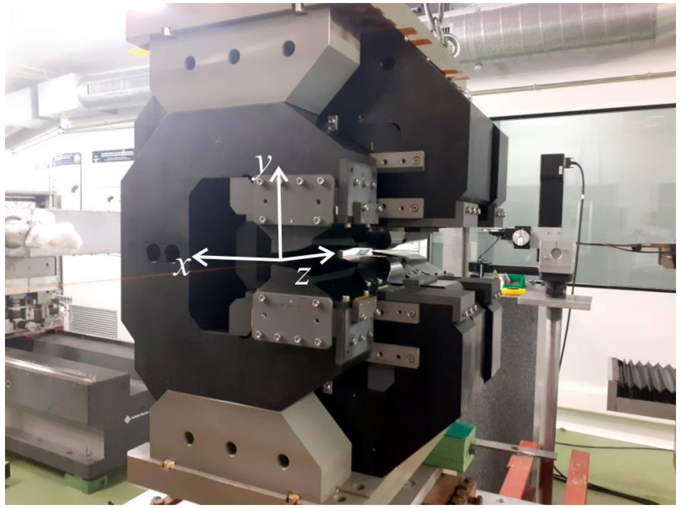
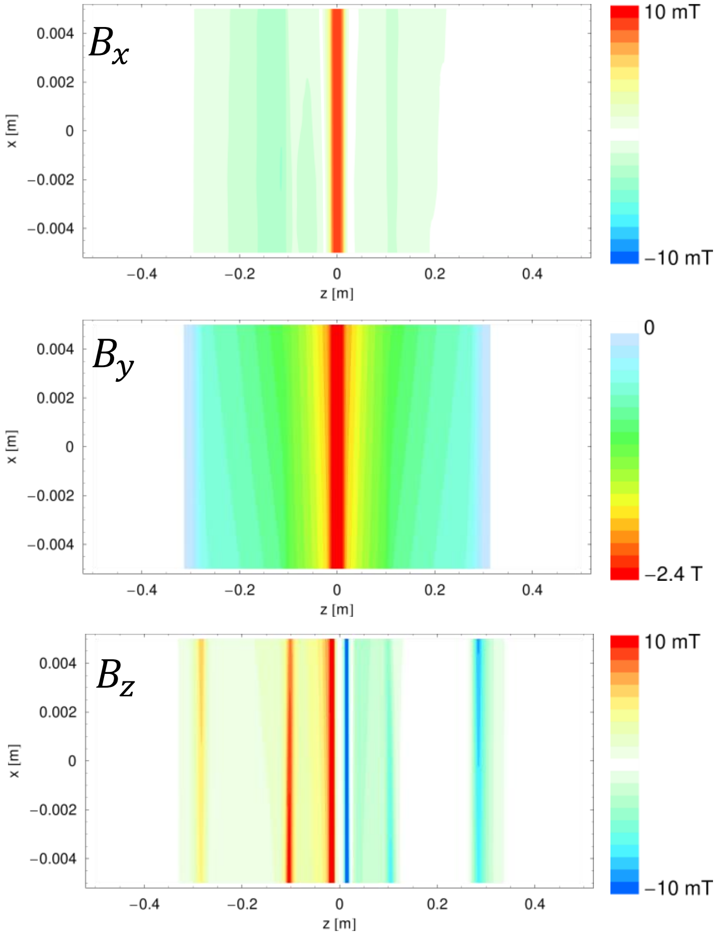
CLIC

Magnetic measurement activities at ALBA

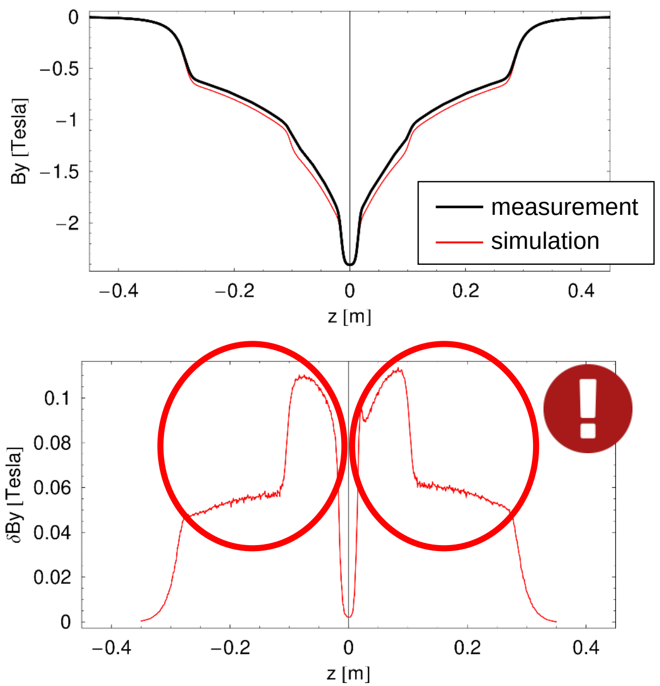
- **Results**

Hall probe field mapping





Magnetic field profile along z at $x=y=0$

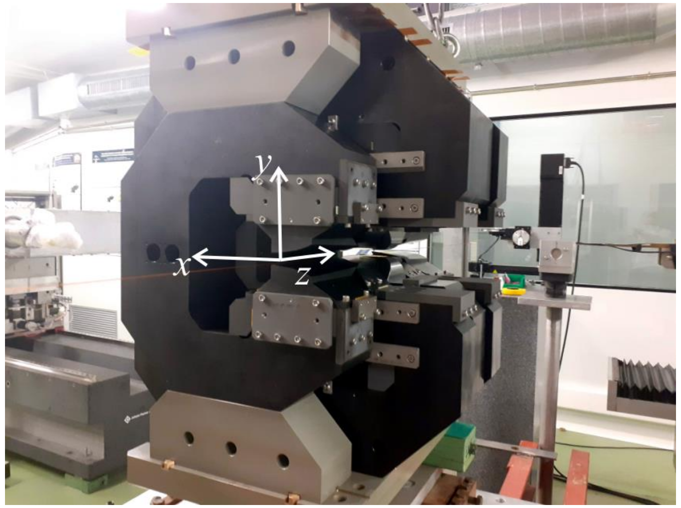


5-6% field defect in **medium and low field poles**, most likely due to **change of Armco poles properties upon machining**

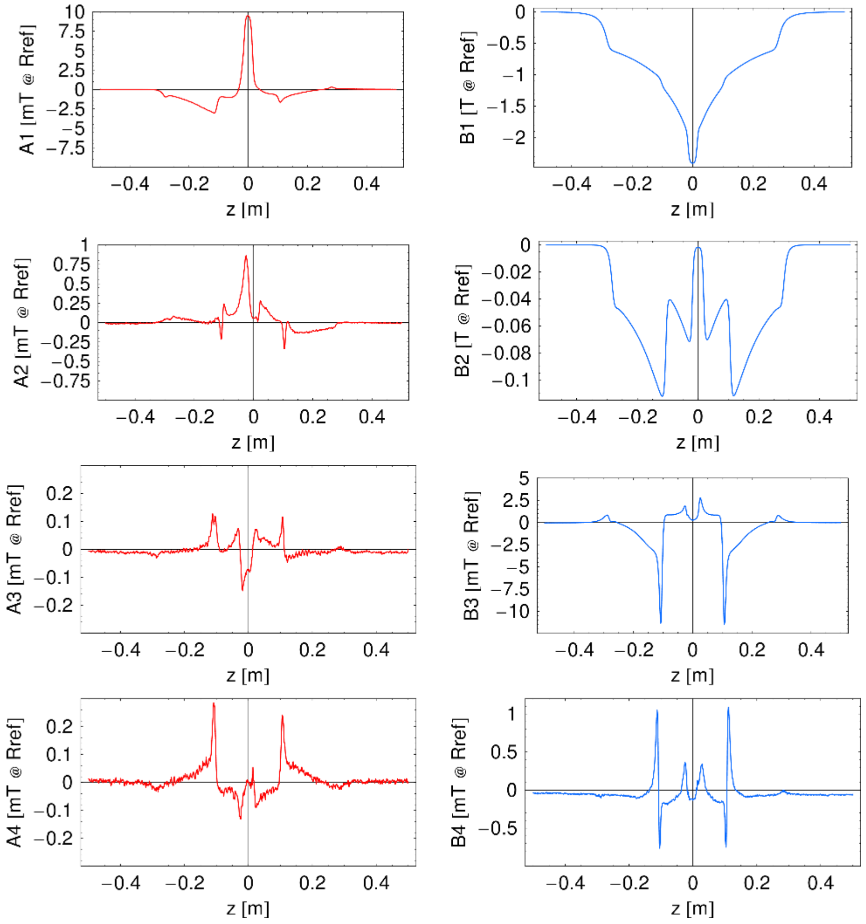
Magnetic measurement activities at ALBA

- **Results**

Hall probe field mapping



Computed multipoles at R_{ref}=5mm



Polynomial adjustment of field map data:

$$B_y(x,z) = \sum_{n=1}^{4} B_n(z)\left(\frac{x}{R_{ref}}\right)^{n-1}$$

$$B_x(x,z) = \sum_{n=1}^{4} A_n(z)\left(\frac{x}{R_{ref}}\right)^{n-1}$$

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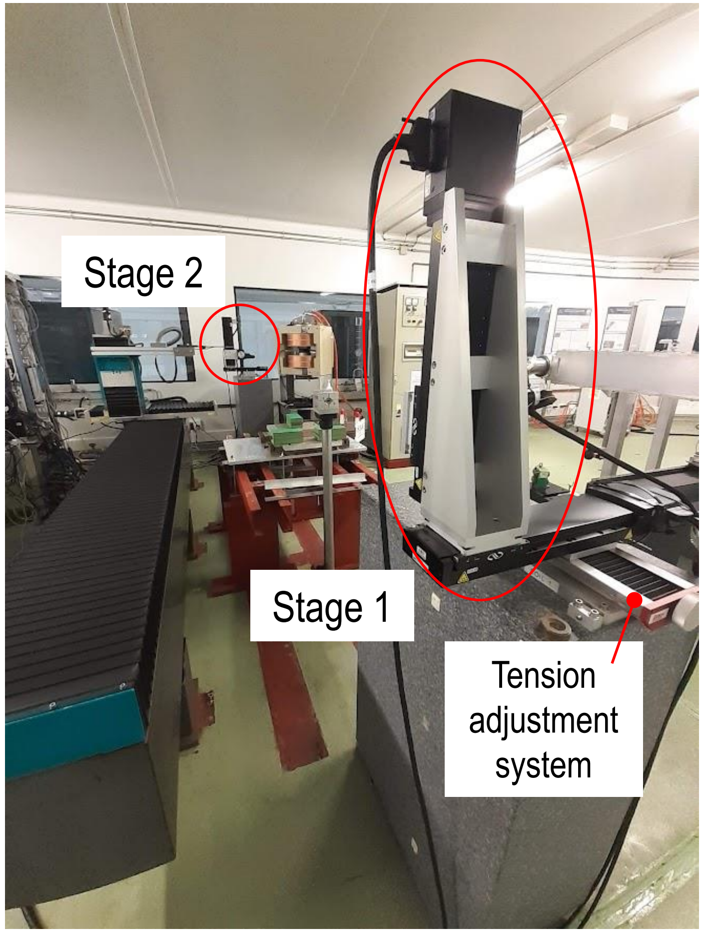
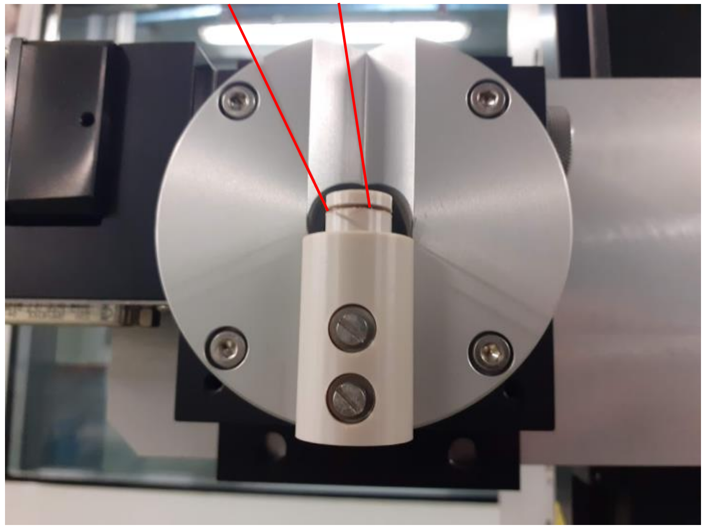
Magnetic measurement activities at ALBA

- **Results**

Flipping coil measurements

- **Flipping coil** at ALBA used to determine **residual field integrals of IDs** → it is **not intended to measure large field integral values** with a **high accuracy**.
- We decided to give it a try ("just in case") **to complement Hall probe data**.





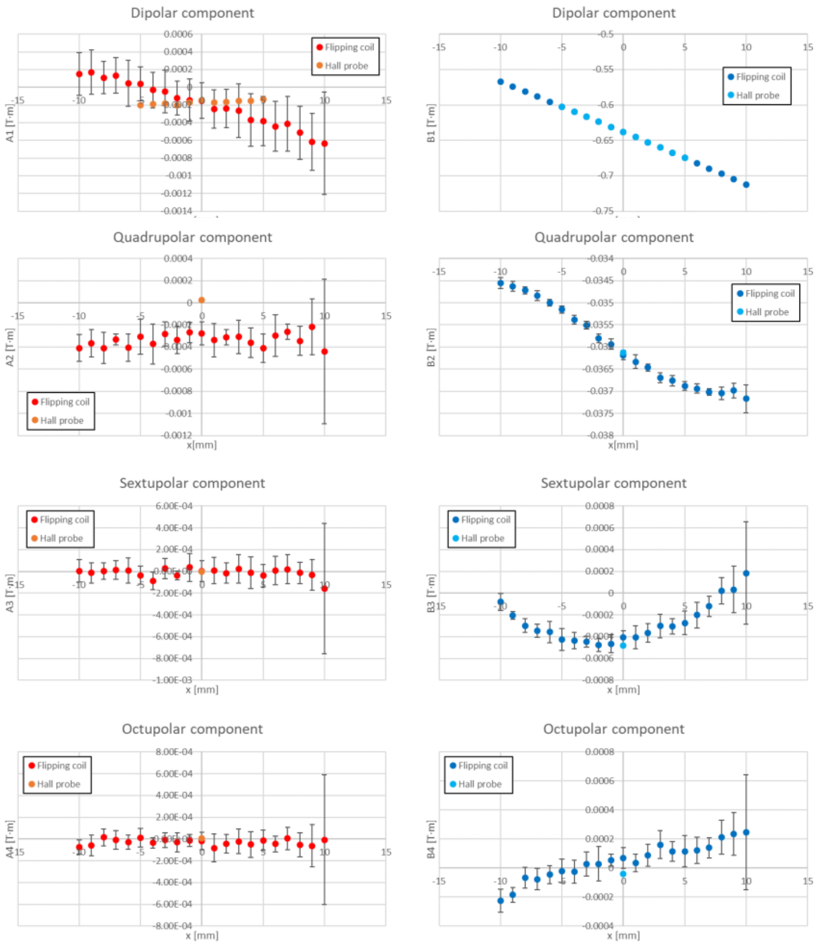
- **New support pieces** defining a coil **displaced wrt the rotation axis**.
- Support pieces made of **PEEK**.
- **5 turns** coil with **0.1mm** Cu wire.
- Exact values of **coil parameters calibrated** by comparison with **Hall probe data** (**coil width**) and **self-consistency** of B_1 and B_2 when measuring at different horizontal positions (**coil offset**)

Magnetic measurement activities at ALBA

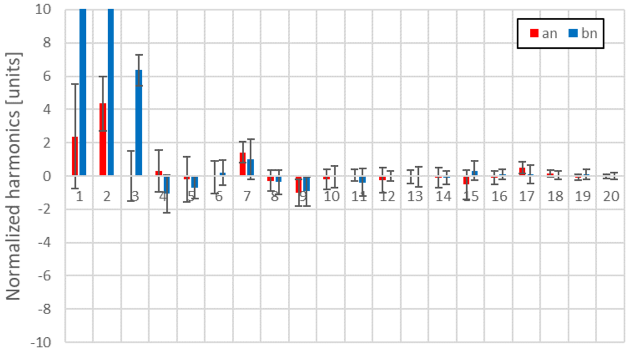
- **Results**

Flipping coil measurements

Integrated multipoles at R_{ref}=5mm



- Acquisition system of **Flipping coil** adapted in order to acquire **flux data along the continuous rotation of the wire**.
- Measurements at **different horizontal positions** within GFR.
- **Good agreement** between **Hall probe** and **Flipping coil** results.
- **Good magnetic field homogeneity**, with high order multipoles **smaller than 2 units**.



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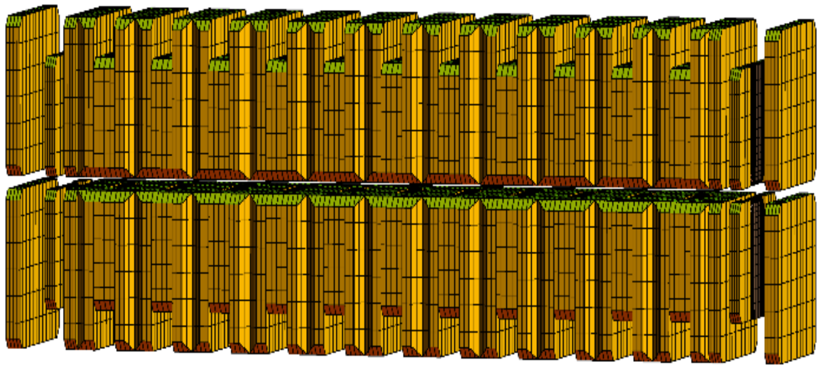
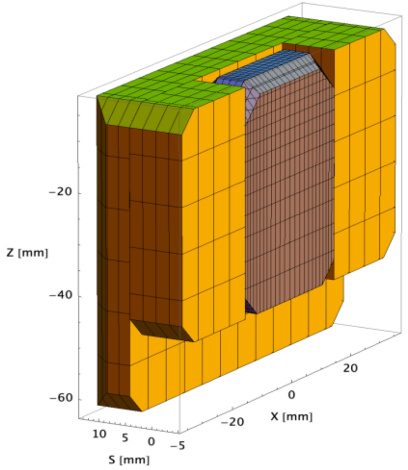
Magnetic measurement activities at ALBA

- **Insertion Device** for **FAXTOR beamline** at **ALBA** (fast X-ray microcomputed tomography at high resolution).
- **In-vacuum multipole wiggler MPW54**

ID characteristics	
Magnetic configuration	Planar hybrid
Period length [mm]	54
PM blocks	NdFeB (B_r=1.25T)
Iron poles	Vanadium Permendur
Number of periods	5.5
Magnetic length [mm]	362
Minimum magnetic gap [mm]	5.2
Maximum peak field [T]	2.5
Maximum K	11.5





5½ periods wiggler RADIA model (courtesy of AVS)

Magnetic measurement activities at ALBA

- **Manufacturing** contract was awarded to **AVS company**:
  - **US division** of the company (AVS|US, former ADC) took care of the **magnetic structure assembly and tuning** and its **integration into the vacuum chamber**.
  - **Spanish headquarters** of the company took care of the **mechanical support structure** and the **final integration of the whole device**.

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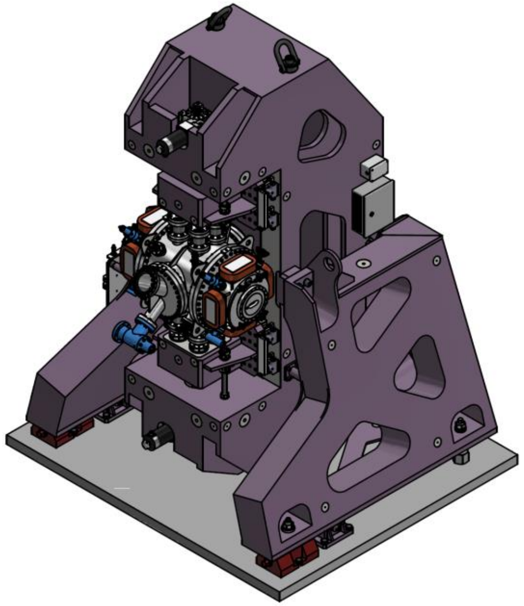
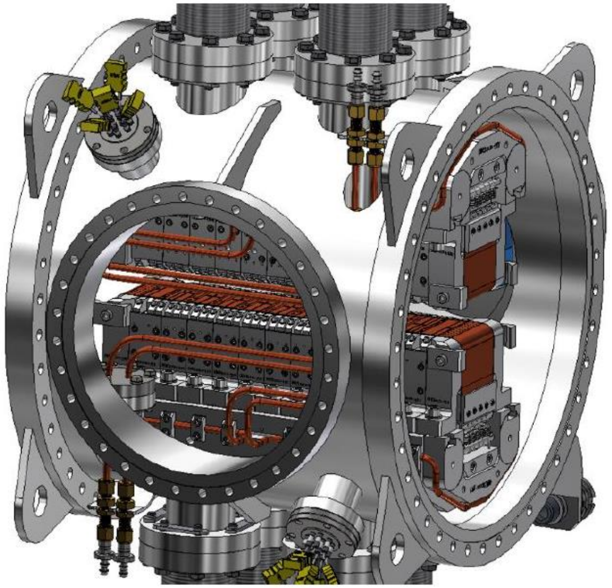


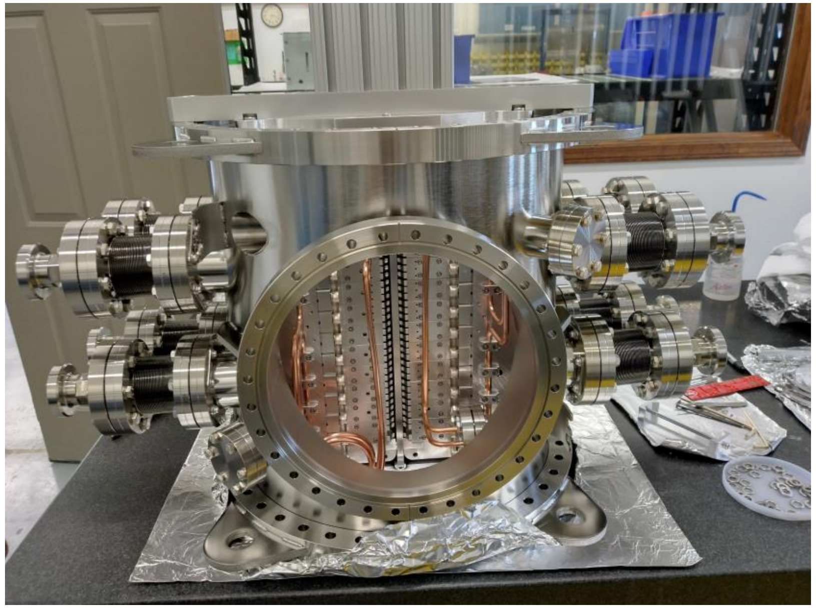


Magnetic measurement activities at ALBA

- **AVS|US assembled** and **shimmed** the **individual magnet arrays**, and afterwards transferred them to a **temporary support carriage** to determine and adjust their **combined effect at different gaps**.
- Once **within specs**, the arrays where **mounted inside the vacuum chamber**, and the assembly shipped to **AVS headquarters** for its **integration into the final support structure**.

Single array tuning

Combined arrays on temporary carriage

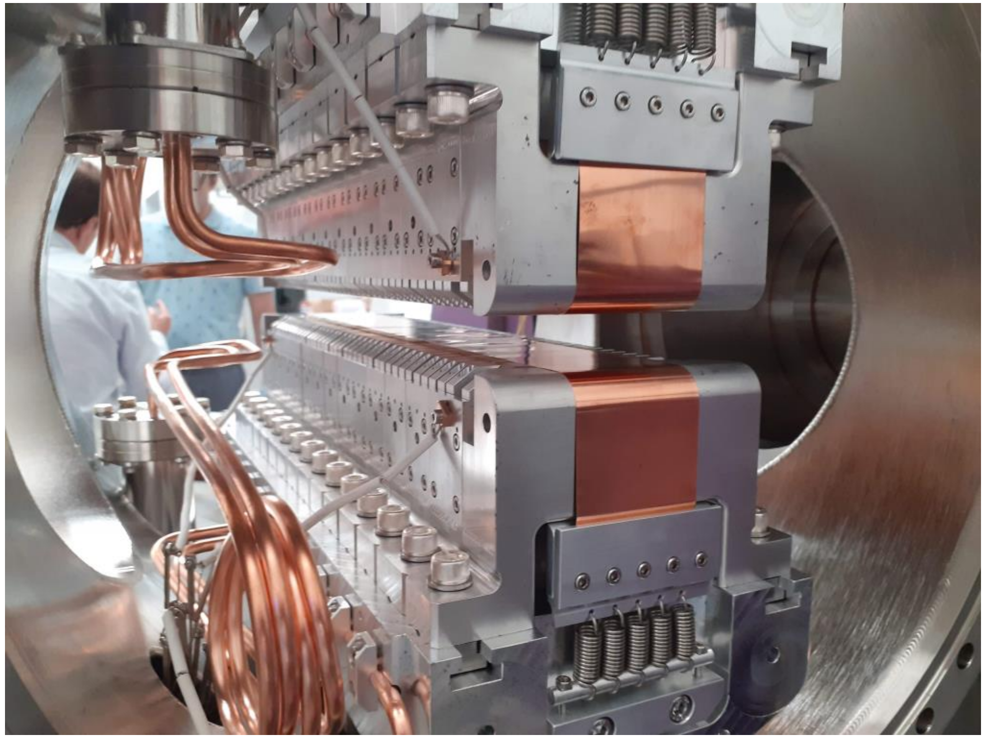


Assembly into vacuum chamber prior to shipping

Magnetic measurement activities at ALBA

- **Final integration** at **AVS (Spain)** has already taken place, and the **FAT** of the **mechanical aspects** of the device was carried on the **21—22 of Sept ‘22**.

Assembled ID at AVS headquarters



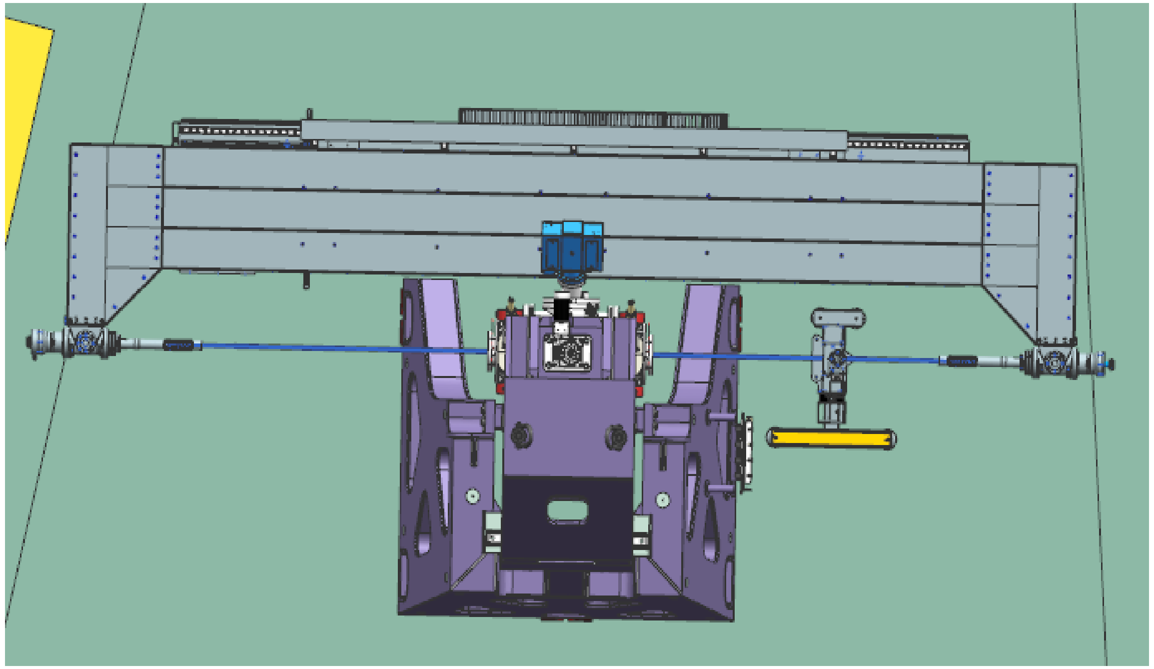
Detail of magnet arrays inside vacuum chamber

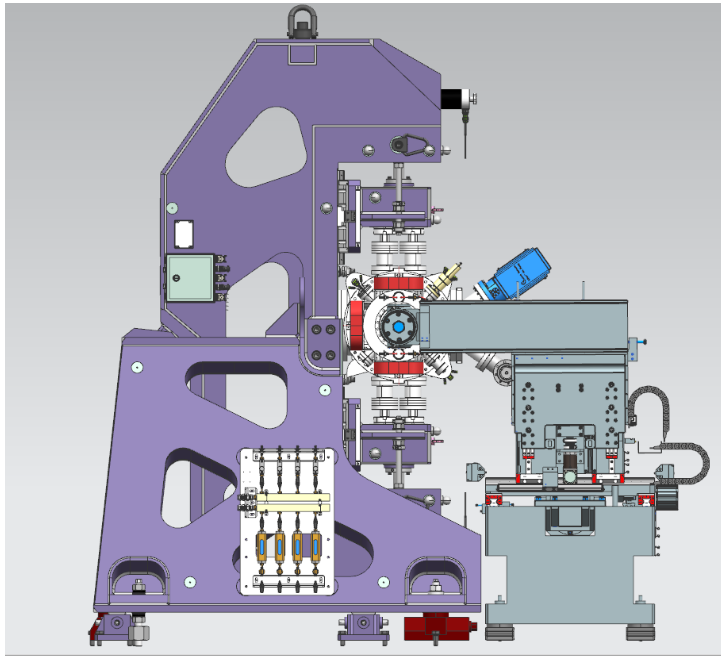
Magnetic measurement activities at ALBA

- **Final adjustments of the magnetic structure** (relative alignment between magnet arrays, optimization of magic fingers for integrated multipole correction, verification of correction coils, etc) will be carried out at **ALBA magnetic measurements laboratory** using our dedicated **Hall probe bench for closed structures**

IMMW19 INTERNATIONAL MAGNETIC MEASUREMENT WORKSHOP

IMMW20 International Magnetic Measurement Workshop 4th – 9th June 2017, Diamond Light Source





Outline

- Effect of Covid-19 pandemics
- Magnetic measurement activities at ALBA
- **Upgrade plans at ALBA**
- Magnetic measurement group reorganization
- Conclusions

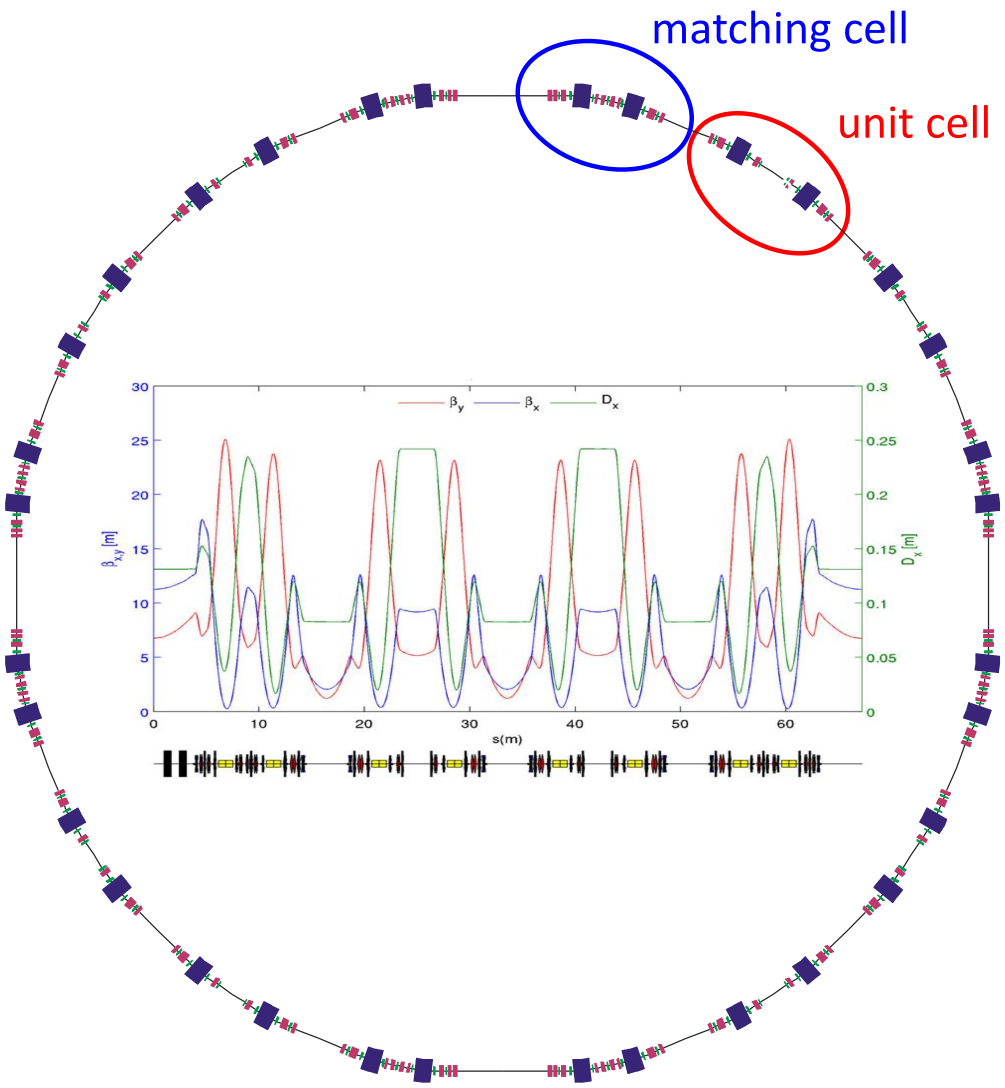
Upgrade plans at ALBA

- ALBA lattice

  8+8 DBA-like cells

Parameters	
Energy	**3 GeV**
Circumference	268 m
Symmetry	4-fold
Emittance	**4.5 nm·rad**
Nº of cells	8+8
Nº of straights	4 / 12 /8
Straight length	7.8 / 4.0 / 2.3m

ALBA in operation for users since **2012**



Upgrade plans at ALBA

- **ALBA II constraints/requirements**
  - **Keep beam energy** @ 3GeV
  - **Keep the tunnel** → SR with similar compact circumference
  - **Keep existing ID beamlines** → preserve 16 cells and source points
  - **Dipole** beamlines **can be relocated**
  - **Keep injector** (present Booster $\epsilon_x^{Booster}$=10nm·rad)
  - **Keep infrastructures** (as much as possible)
  - Straight sections ~4m with $\beta_x \sim \beta_y$ ~2m
  - **Reduce SR emittance by more than factor 10** (**<400pm·rad**)

Upgrade plans at ALBA

- Proposed solution:
  - From 2×8 double-bend lattice (DBA)
  - To 1×16 **multi-bend lattice (6BA)**

IPAC21 contribution (WEPB074)

A DISTRIBUTED SEXTUPOLES LATTICE FOR THE ALBA LOW EMITTANCE UPGRADE

G. Benedetti, M. Carlà, U. Iriso, Z. Martí, F. Pérez
CELLS-ALBA Synchrotron, Cerdanyola del Vallès, Barcelona, Spain

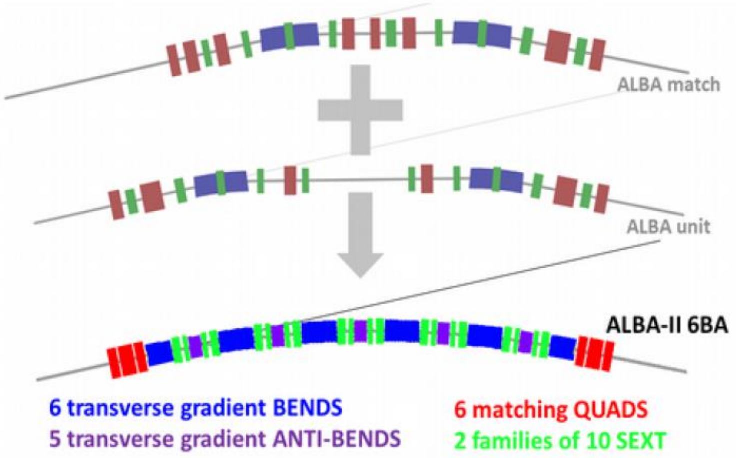


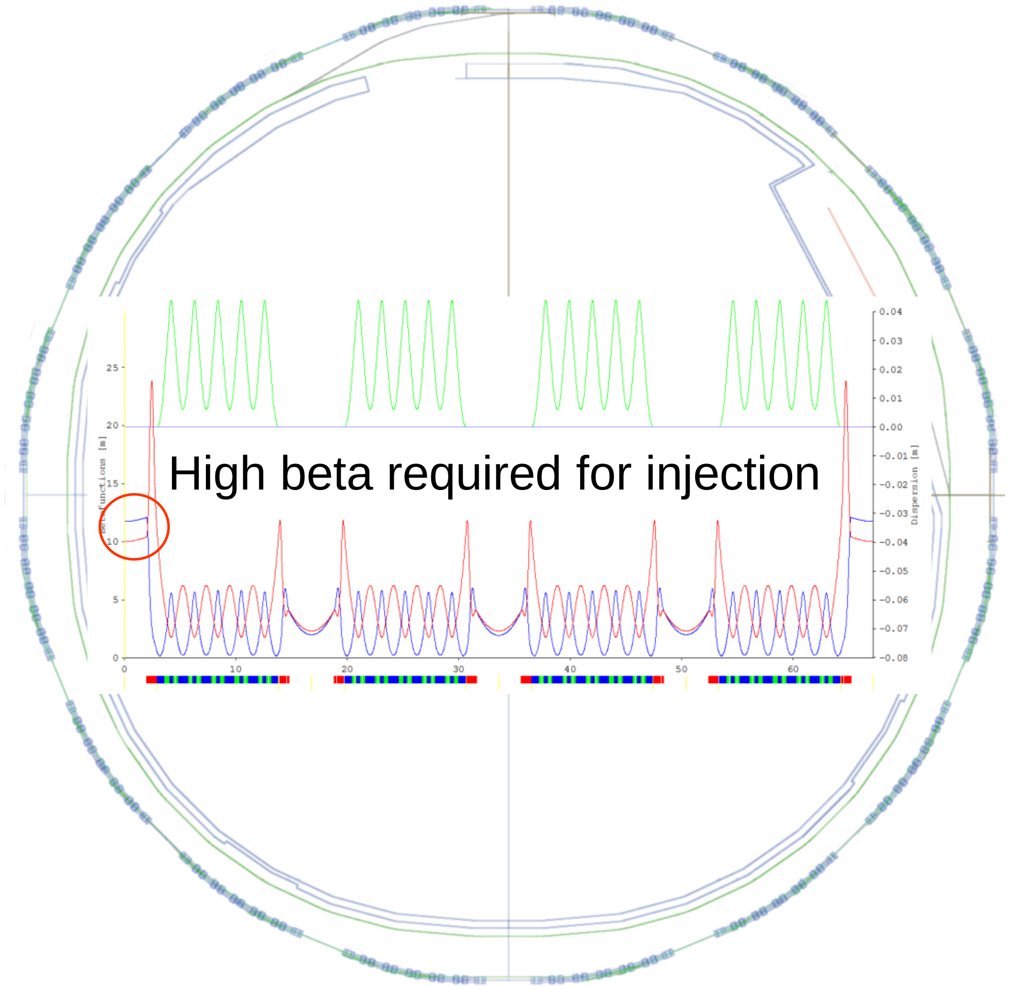
Figure 1: In ALBA-II, the two types of DBA cell (8 matching cells plus 8 unit cells) of the current lattice are replaced by 16 identical 6BA+anti-bend cells.

Upgrade plans at ALBA

- ALBA II lattice

  16 6BA cells

Parameters		
	ALBA	ALBA II
Energy	**3 GeV**	**3 GeV**
Circumference	268.8 m	268.8
Symmetry	4-fold	4-fold
Emittance	**4.5 nm·rad**	**140 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



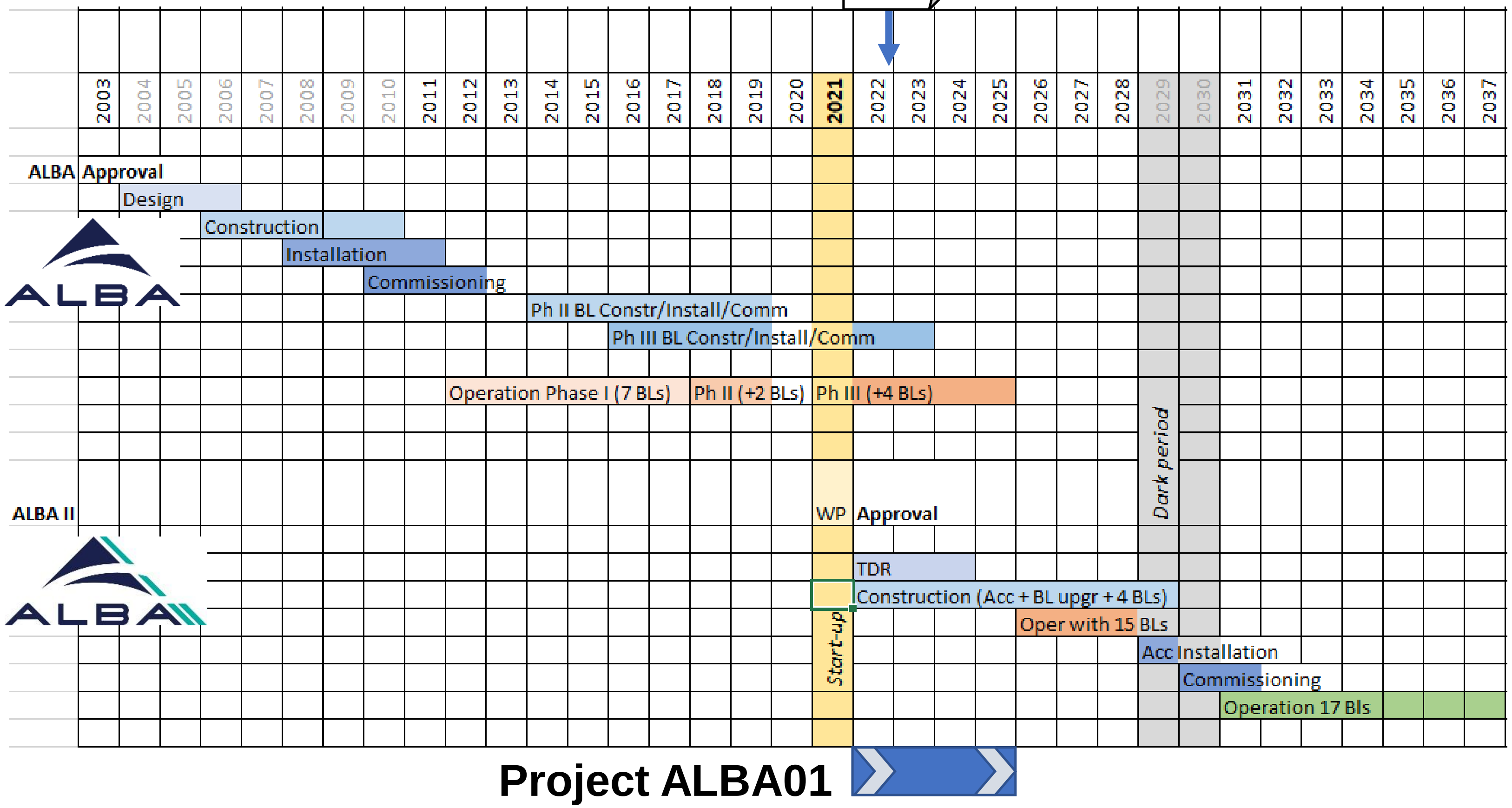
Upgrade plans at ALBA

- The **tentative cost** for the upgrade is **120M€**, to be added to ALBA budget along **10 years** (increase of **30%** on average)
- The upgrade project **is still not funded**, but we have received the **approval (Dec 2020) from our Governing Body** to start a **design study**
- The project's **White Paper** is foreseen to be issued by the **end of 2022**
- In parallel, a **4-year** project (**ALBA01**) devoted to the development of prototypes and funded with **7.5M€** is already **ongoing**
  - Development of **magnets**, **vacuum chambers**, **girders**, **IDs** and **nanopositioning systems** for BL optics & instrumentation

Upgrade plans at ALBA

- **Tentative ALBA II timeline**

ALBA II White Paper (Dec ‘22)



Project ALBA01

“Enabling advanced technologies for ALBA II”

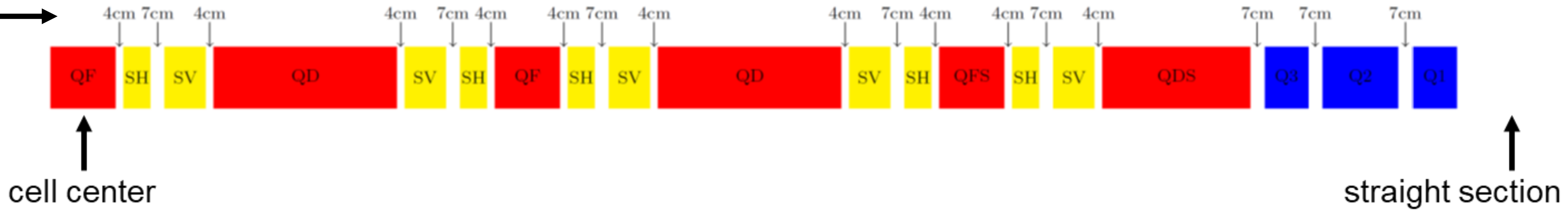
Upgrade plans at ALBA

- **ALBA II** lattice is based in **16 identical 6BA cells**, with **9 magnet types**, for a total of **592 individual magnets** (currently 264 magnets at ALBA SR)

Distances between magnets' **effective lengths**

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

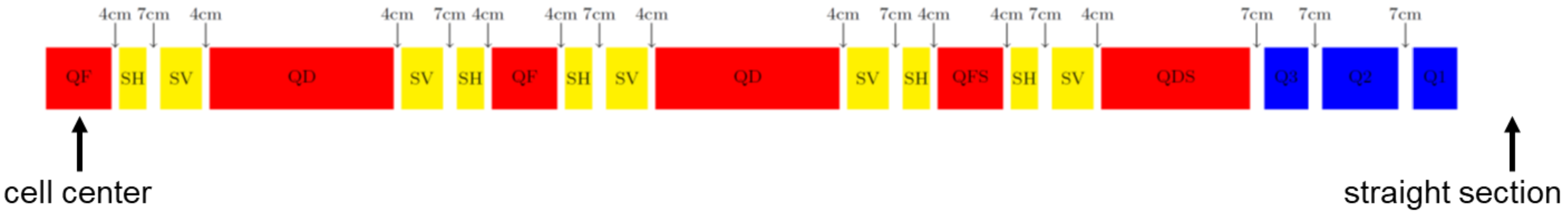
Half 6BA unit cell



Magnet description	Types	# per cell	# in SR
Bend with trans grad	2 (QD, QDS)	6	96
Antibend with trans grad	2 (QF, QFS)	5	80
Quadrupoles	3 (Q1, Q2, Q3)	6	96
Sextupoles	2 (SH, SV)	20	320
Total	**9**	**37**	**592**

Upgrade plans at ALBA

- **Beam dynamics group** has defined a **primary set of requirements** (**field/gradient strengths** and **lengths**) for the magnets of ALBA II lattice:



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	0.2000		-31.54	
	Q2	0.3500		83.16	
	Q3	0.2000		**-109.83**	
Quadrupoles (injection)	IQ1	0.2000		44.70	
	IQ2	0.3500		-69.61	
	IQ3	0.2000		89.71	
Sextupoles	SH	0.1042			**4936**
	SV	0.1823			-4084

Relationship between gradients and pole-tip field:

- quadrupoles: $B_{tip} \simeq K_1\, r$
- sextupoles: $B_{tip} \simeq K_2\, r^2$

Different current settings for quadrupoles adjacent to injection straight (and equivalent straights)

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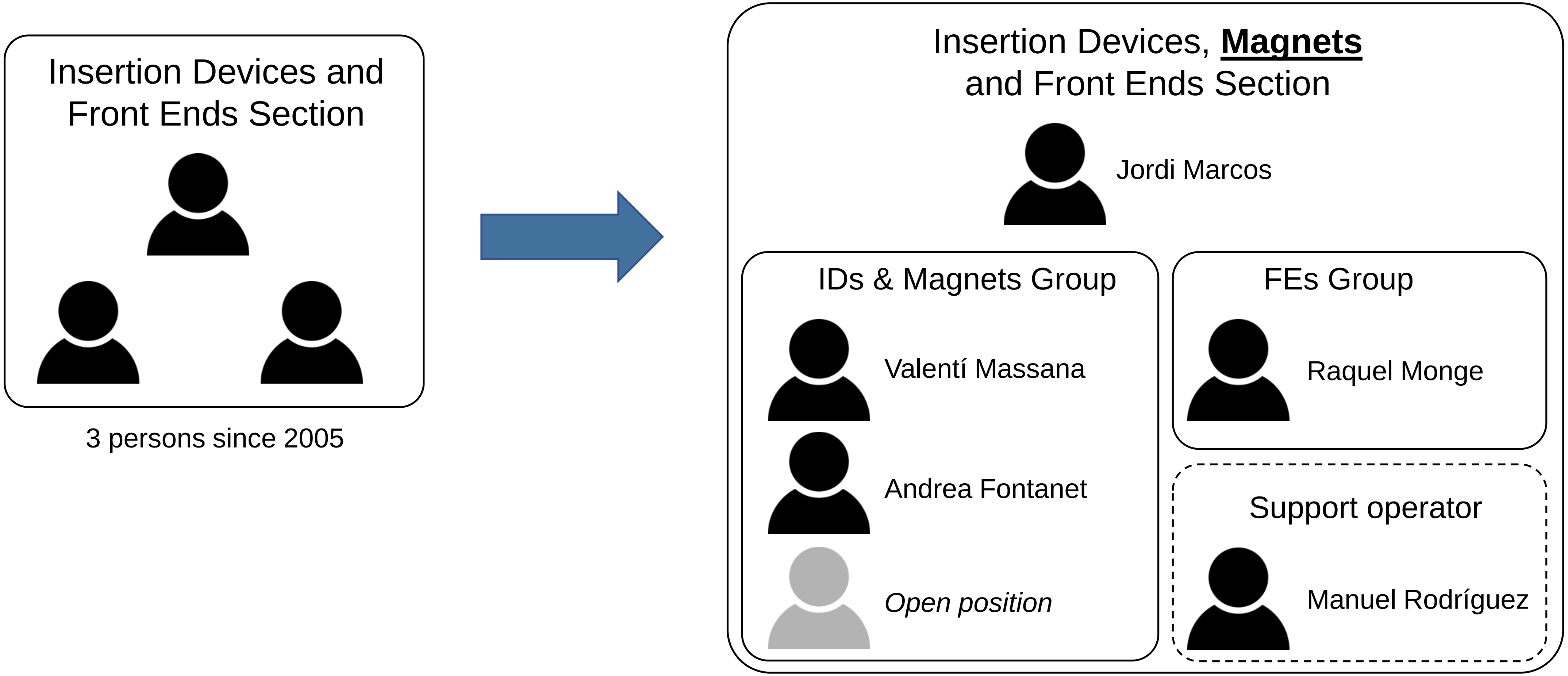
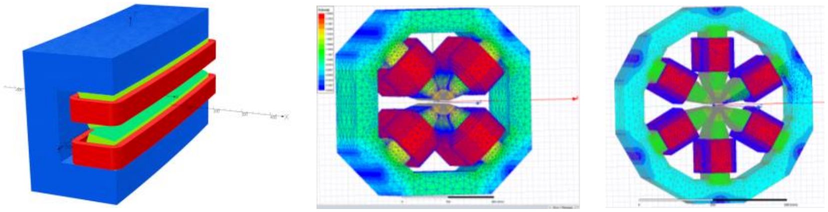
Magnetic measurements group reorganization

- By the **end of 2021** our section was **reorganized** in order to face upcoming challenges:



Magnetic measurements group reorganization

- **Responsibilities** of **IDs & Magnets Group**:
  - Maintenance of IDs already installed at ALBA.
  - Design, follow-up and test/acceptance of IDs for new Beamlines (~1 ID each 2 years).
  - Operate and upgrade magnetic measurements lab (internal and external requests).
  - **Design of prototypes for ALBA II** magnets (2022-2025):
    - Design work already started.
    - CFTs to be launched **before end of 2023.**



  - **Definition of strategy** for the **procurement** and **characterization** of ALBA II series magnets:
    - Magnets **manufacturing** will be **completely outsourced** (details of the company validation procedure still to be defined).
    - Approach to the validation/characterization of magnets **still to be devised**.

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Conclusions

- Since last IMMW21, the volume of activity at ALBA magnetic measurements lab has decreased. Despite of this, some new measurement modes have been tested with encouraging results.
- One year ago the ID & FE section at ALBA underwent a complete renewal in order to face ALBA upgrade challenges, and to take care of all the aspects of ALBA II magnets procurement, validation and characterization
- We are confident that at the time of IMMW22 (by 2024) we will be able to show you some interesting advances regarding ALBA II magnets design and procurement/verification strategy (at least we hope so).

Questions?