ALBA II Accelerator Upgrade Project

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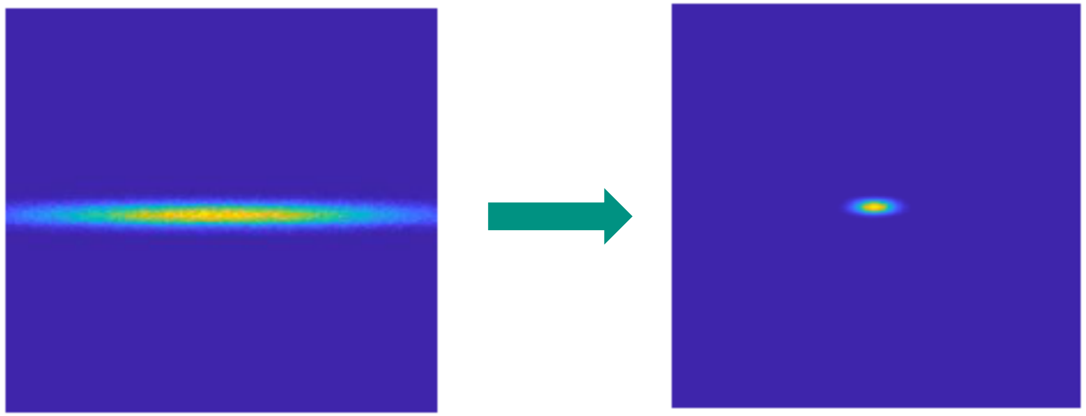
September 8th, 2022
X AUSE Conference & V ALBA User's Meeting

Objective

Upgrade the 3rd Generation ALBA Storage Ring
to a **4th Generation** Ultra Low Emmittance Ring: **ALBA II**



with the aim of doing the 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)

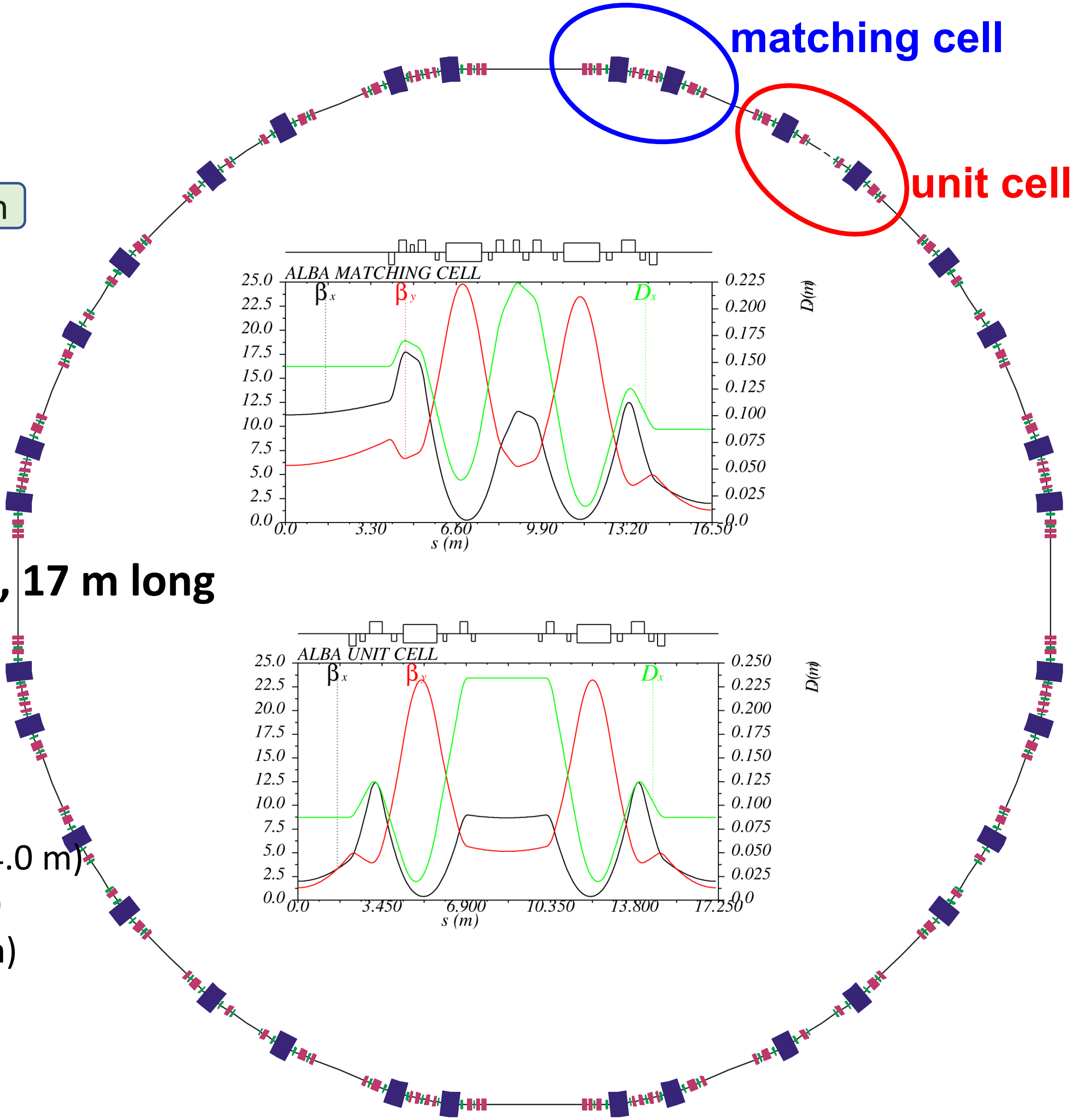
Present lattice

- 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)



Proposed solution

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

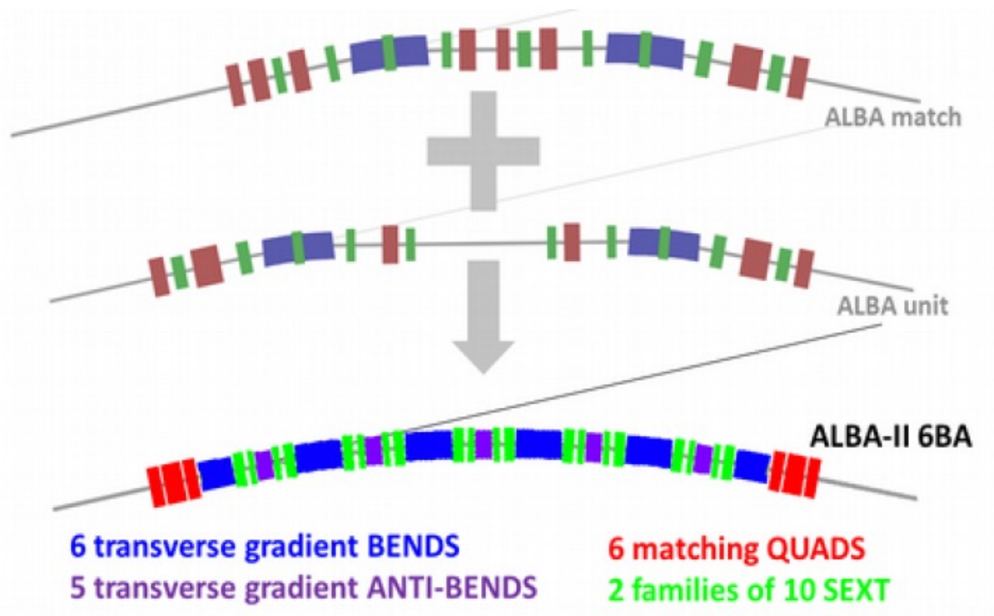


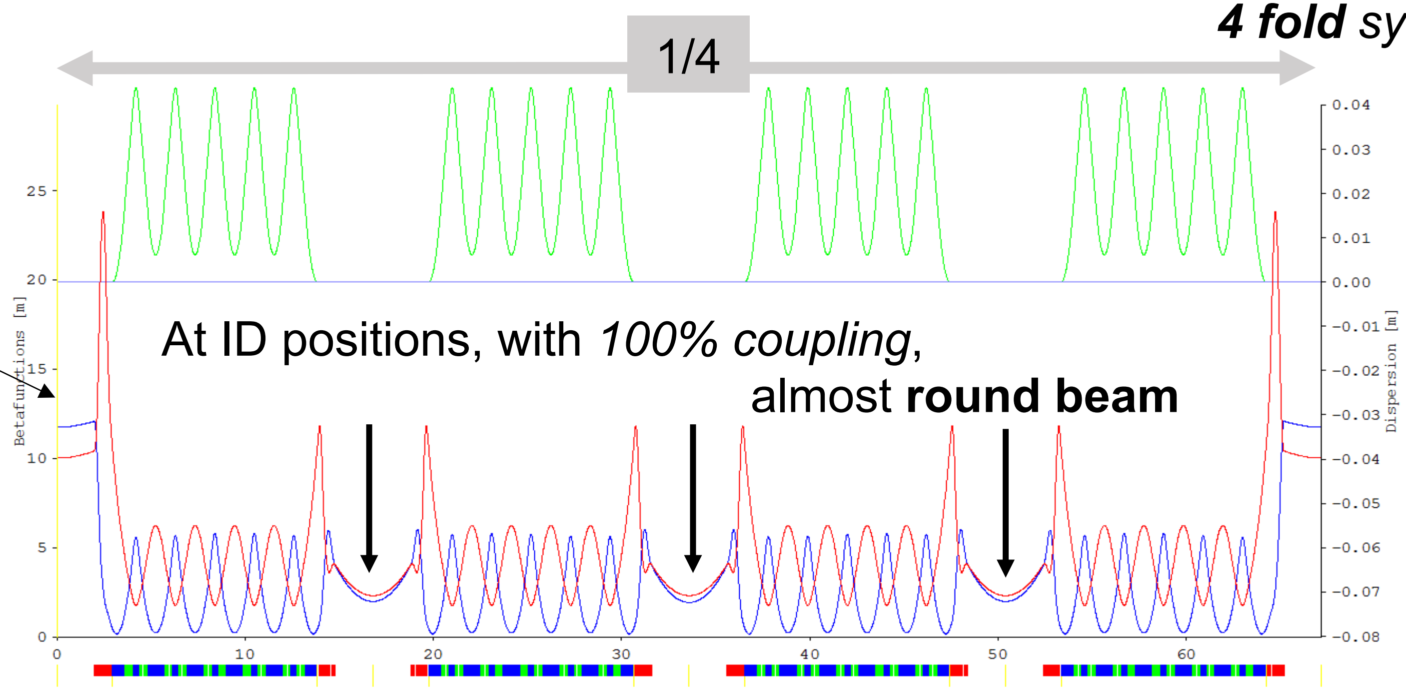
Figure 1: In ALBA-II, the two types of DBA cell (8 matching cells plus 8 unit cells) of the current lattice are replaced by 16 identical 6BA+anti-bend cells.

	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.	$8.9\cdot10^{-4}$	$0.8\cdot10^{-4}$
Energy spread	$1.0\cdot10^{-3}$	$1.1\cdot10^{-3}$
Energy loss/turn	1023 keV	843 keV
Damping times	4 / 5 / 3 ms	3 / 6 / 6 ms

The 6BA lattice

4 fold *symmetry*

High beta required for Injection

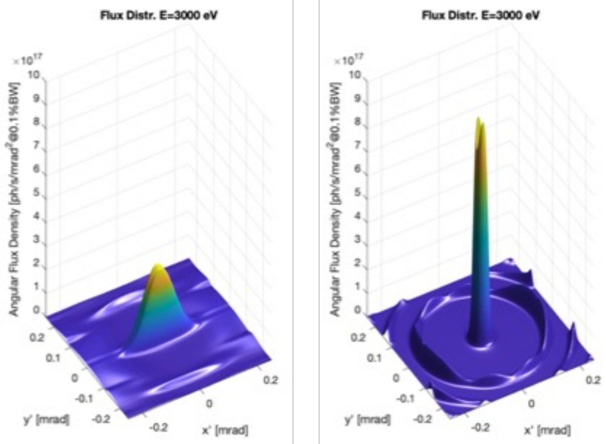


Transversal beam size comparison:

At ID position, today:

σ_x = 127 um ; σ'_x = 47 urad

σ_y = 5.2 um ; σ'_y = 4,4 urad



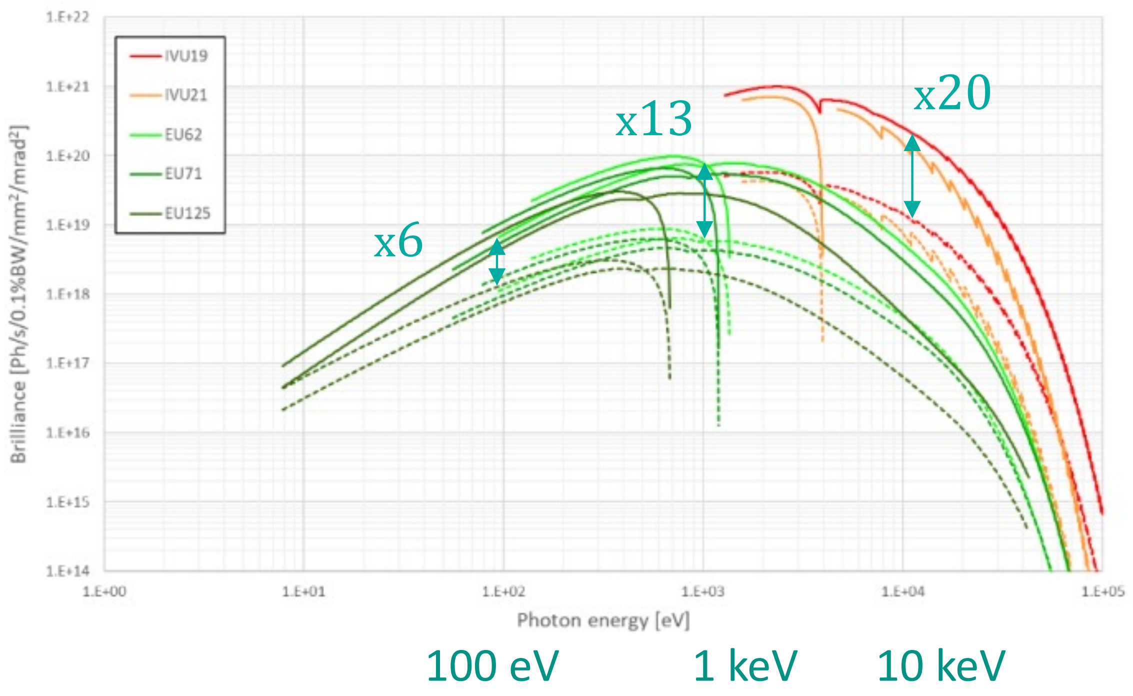
At ALBA II ID position,
with *100% coupling*, almost **round beam**:

σ_x = 14.0 um σ'_x = 7.1 urad

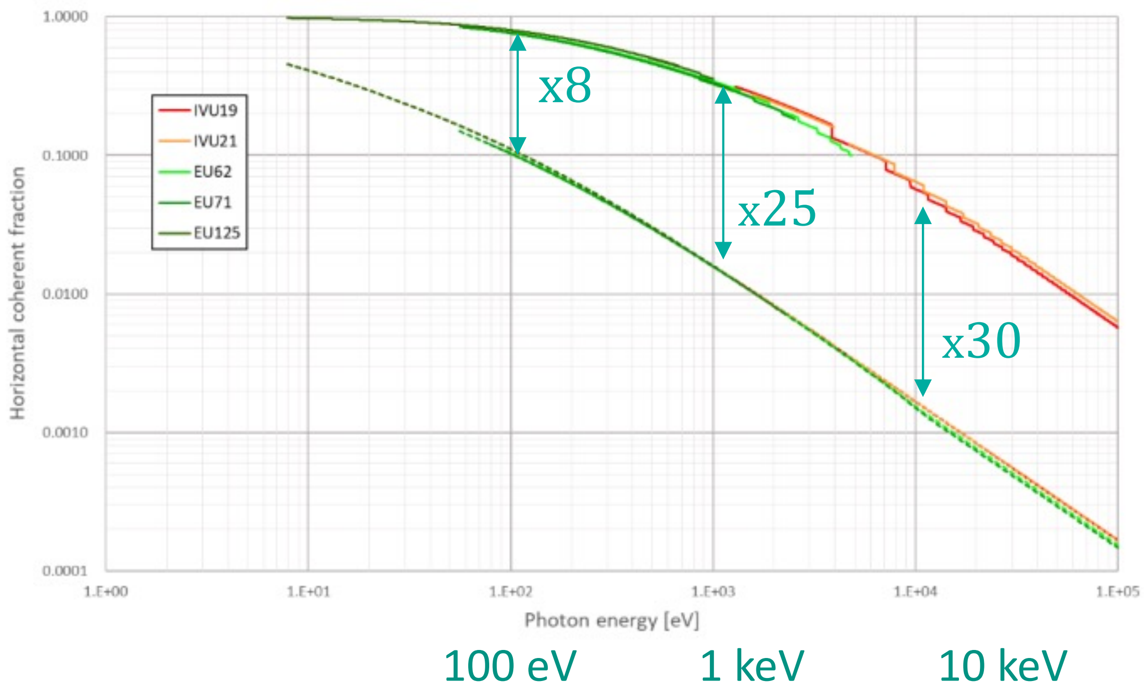
σ_y = 15.1 um σ'_y = 6,6 urad

Comparison of some ALBA IDs

Brilliance

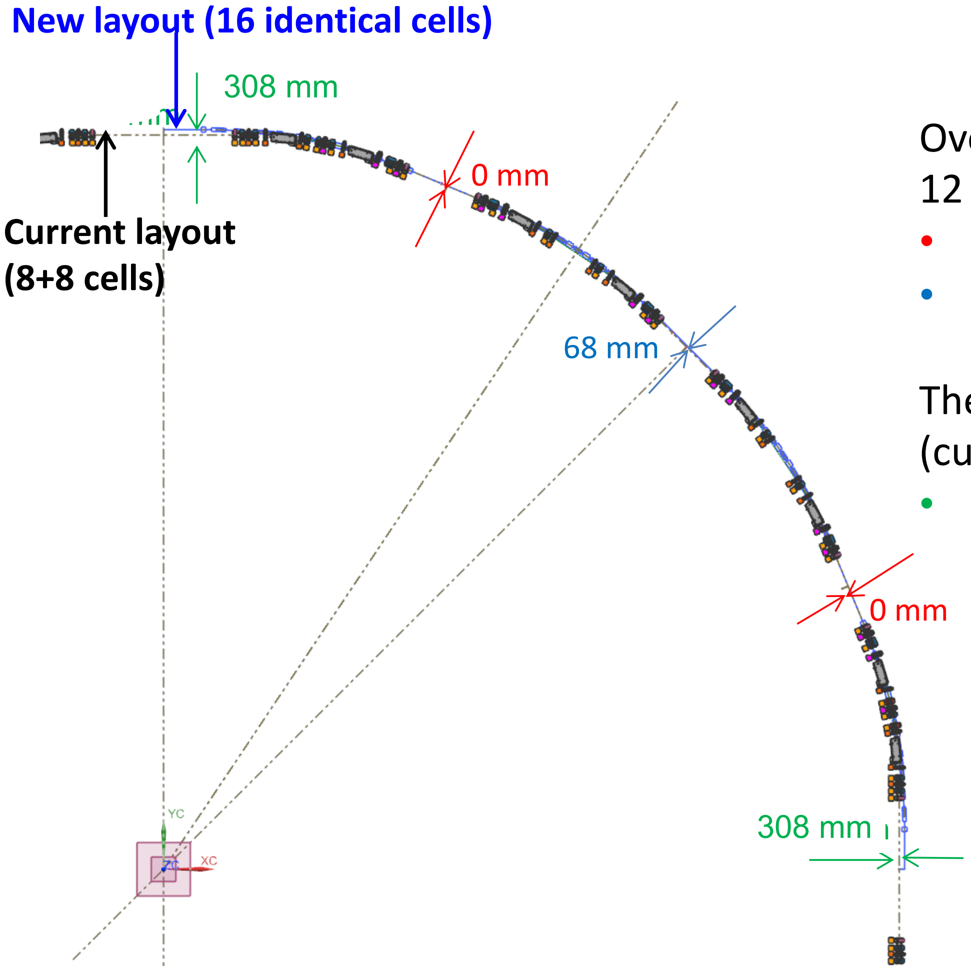


Horizontal Coherent fraction



vs. Photon Energy

Straigth sections for IDs



Over the source points of the present 12 Medium Straight Sections:

- **8 would be preserved**
- **4 radially shifted by 68 mm**

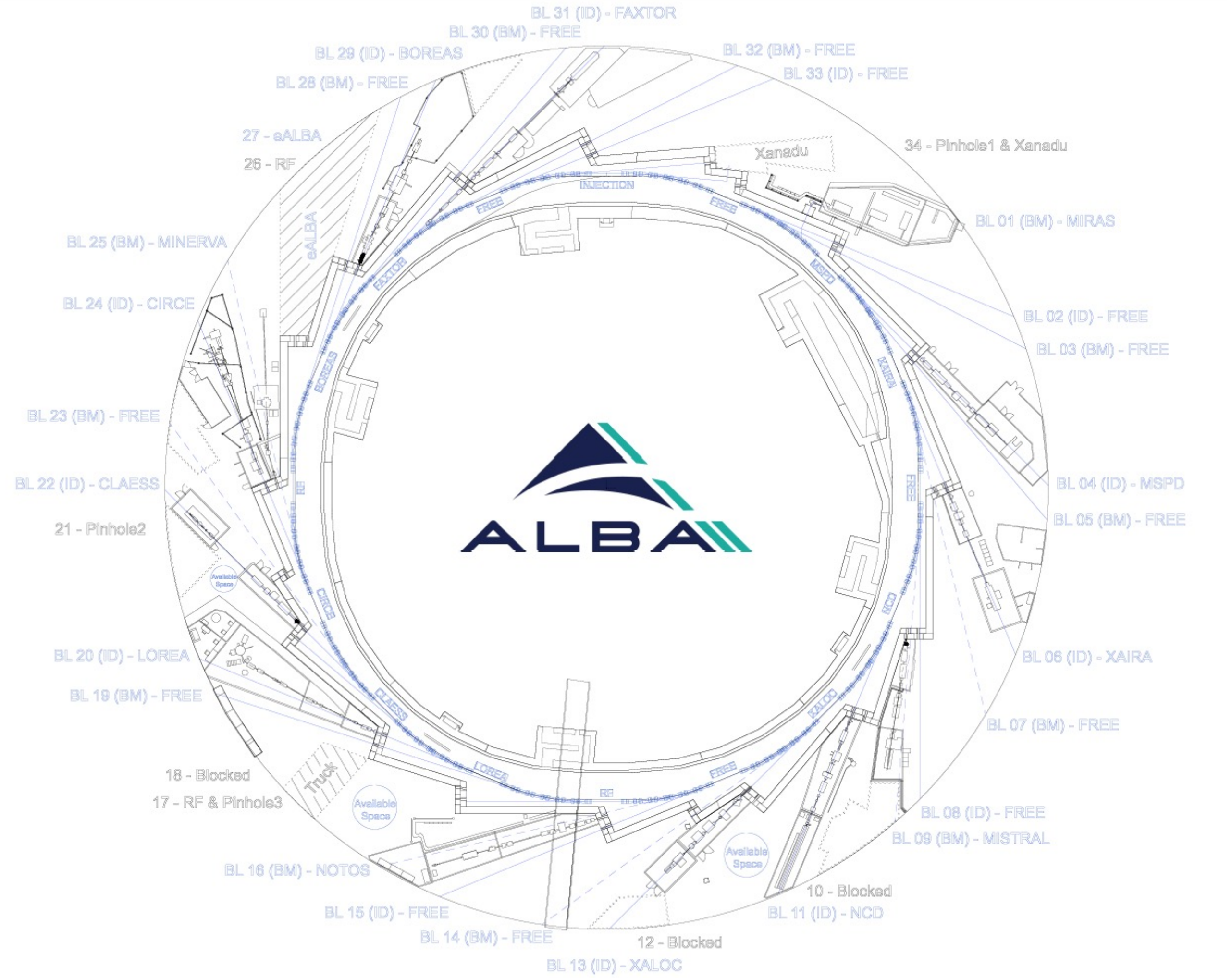
The present 4 Long Straight Sections (currently not used yet for BLs):

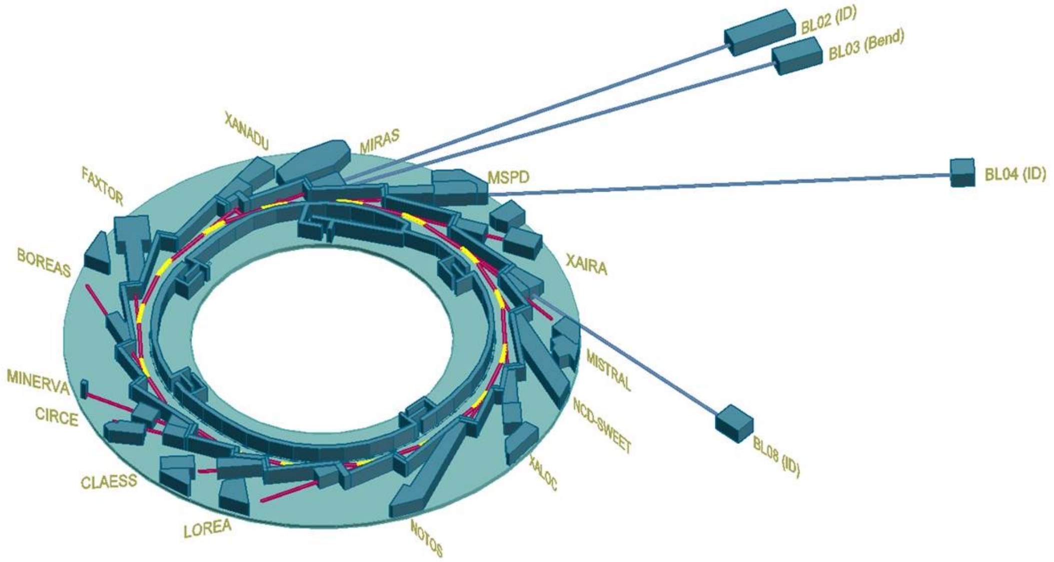
- **All radially shifted by 308 mm**
  With high betas (β_x=11,7 ; β_y=10,0)

*But **3 will be used for the Accelerator**:*

- *1 for Injection*
- *2 for RF*

Implementation





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

ID Ports

Straight	BL		Comments
SR01	2	FREE	
SR02	4	MSPD	68mm displacement
SR03	6	XAIRA	
SR04	8	FREE	308mm displacement / Large Beta
SR05	11	NCD	
SR06	13	XALOC	68mm displacement
SR07	15	3SBar	
SR08	17	RF	& Pinhole3
SR09	20	LOREA	
SR10	22	CLAESS	68mm displacement
SR11	24	CIRCE	
SR12	26	RF	
SR13	29	BOREAS	
SR14	31	FAXTOR	68mm displacement
SR15	33	FREE	
SR16	0	INJECTION	

3x FREE
10x IN USE
3x ACCELERATOR

Bending Ports

BM	BL		SuperBend	Comments
SR02_QD_3 ?	1	MIRAS		
SR02_QD_1	3	FREE	Ok	
SR03_QD_1	5	FREE		Limited space due to MSPD
SR04_QD_2	7	FREE		
SR05_QD_1	9	MISTRAL		
	10	Blocked		NCD
	12	Blocked		Xaloc
SR07_QD_2	14	FREE		
SR08_QD_2	16	NOTOS	Ok (-2.5º)	Superbend requires to move BL 480mm
	18	Blocked		Truck entrance
SR09_QD_4	19	FREE	Ok	
	21	Blocked		CLAESS – Used for Pinhole2
SR11_QD_2	23	FREE		
SR12_QD_2	25	MINERVA		
	27	Blocked		eALBA
SR13_QD_3	28	FREE	Ok	
SR14_QD_4	30	FREE	Ok	
SR15_QD_4	32	FREE	Ok	
	34	Blocked		Pinhole1 + Xanadu

9x FREE
4x IN USE
6x BLOCKED

Implementation

- **Magnets**
  - ~ **600 magnets**
  - **With power supplies**
  - **Some, permanent magnets?**
- **Vacuum chambers**
  - ~ **270 m vacuum chambers**
  - **SS, Cu, NEG coated**
- **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**
  - **…**

Label Units	Length [m]	Field [T]	Gradient (K_1) [T/m]	Second order gradient (K_2) [T/m^2]
Q1	0.20000		-104.36262	
Q2	0.35000		82.66465	
Q3	0.20000		-33.50837	
IQ1	0.20000		41.78267	
IQ2	0.35000		-66.15815	
IQ3	0.20000		86.56011	
QF	0.29913	-0.37424	70.00000	
QD	0.84977	1.02457	-15.76108	
QFS	0.29913	-0.36306	70.00000	
QDS	0.68523	0.72782	-0.03471	
SH	0.12253			4632.01822
SV	0.18896			-4137.73557

ALBA II Enabling Technology Project

The Ministry gave CELLS a grant of 7.5 M€, for "*the development of advanced technologies for ALBA II*".

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ESPAÑA PUEDE.

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ORDEN DE LA MINISTRA DE CIENCIA E INNOVACIÓN POR LA QUE SE CONCEDE AL CONSORCIO PARA LA CONSTRUCCIÓN, EQUIPAMIENTO Y EXPLOTACIÓN DEL LABORATORIO DE LUZ SINCROTRÓN (CELLS) LA SUBVENCIÓN NOMINATIVA PREVISTA EN LOS PRESUPUESTOS GENERALES DEL ESTADO PARA 2021 CON UN IMPORTE ACTUALIZADO DE SIETE MILLONES QUINIENTOS VEINTISIETEMIL TRESCIENTOS SESENTA EUROS (7.527.360,00 €) CON CARGO A LA APLICACIÓN PRESUPUESTARIA 28.50.460D.74903 (MECANISMO DE RECUPERACIÓN Y RESILIENCIA) Y SE ESTABLECEN LAS CONDICIONES DE LA CONCESIÓN.

Plan de Recuperación, Transformación y Resiliencia

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ALBA II Enabling Technologies 2022- 2025

PROYECTO: "DESARROLLO DE TECNOLOGÍA AVANZADA PARA ALBA-II"

El proyecto de una fuente de luz de sincrotrón de 4ª generación está basado en tecnologías avanzadas, muchas de las cuales se están actualmente desarrollando en el mundo, obedeciendo a las necesidades de los varios proyectos de nuevos sincrotrones y de renovación de los actuales.

Un proyecto como ALBA II necesita un estudio de viabilidad que incluya la construcción de prototipos de los sistemas que se desarrollan por primera vez y la evaluación de su compatibilidad recíproca.

Design and prototype construction of

- Magnets
- NEG Coated vacuum chambers
- Pulsed magnets
- Girder for arc assembly tests

Nano-positioning lab

Superconducting Undulator

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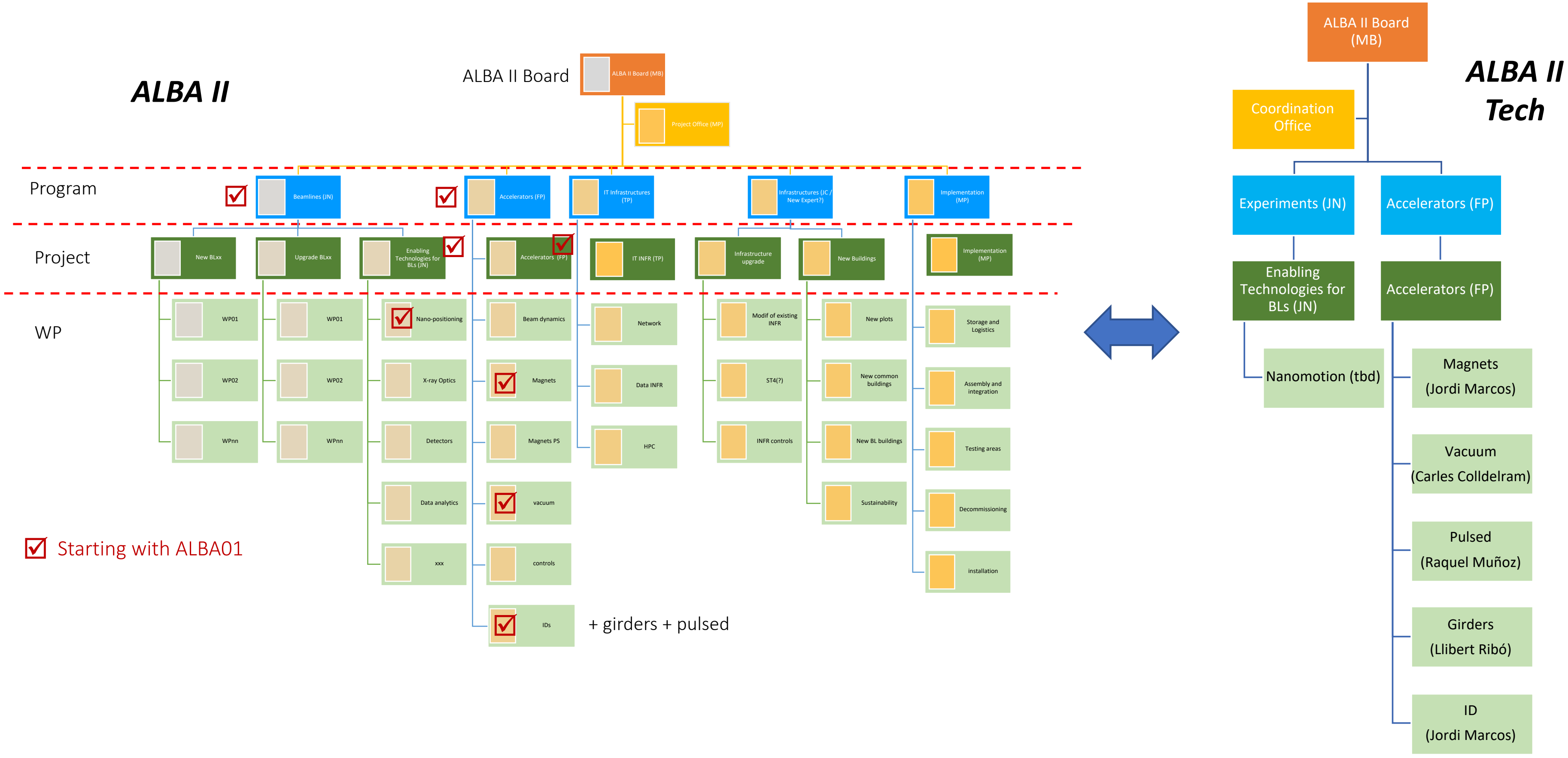
ALBA II Enabling Technologies 2022- 2025

The structure of project has been implemented such that will fit in the future ALBA II structure



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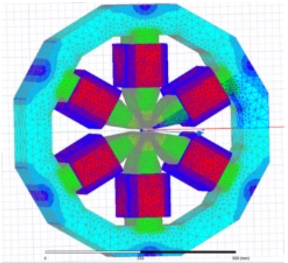
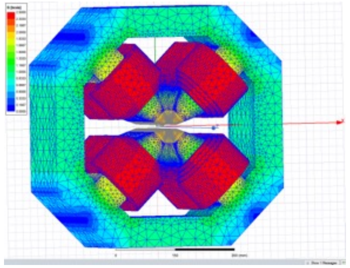
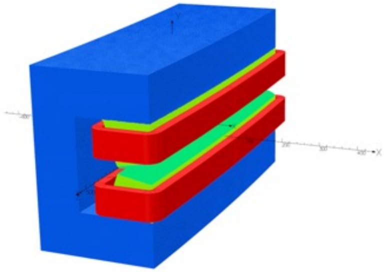
WP1 - Magnets

1) Magnets design







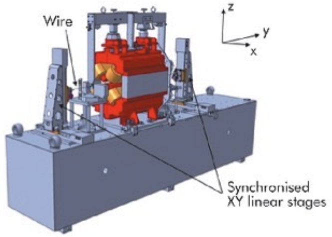
2) Prototypes definition

Description	Magnets
Quadrupoles (EM)	Q1, Q2, Q3
Sextupoles (EM)	SH, SV
Antibends (EM)	QF, QFS
Bends (EM)	QD, QDS
Bends (PM)	QD, QDS
Superbend (PM)	QD superbend

Increasing COMPLEXITY

Prototypes	Description	Qty
Sextupoles	1xSH + 1xSV (EM)	2
Quadrupoles	1xQ1 + 1xQ2 + 1xQ3 (EM)	3
Antibends	1xQF/QFS (EM)	1
Bends	2xQD (EM+PM) +2xQDS (EM+PM) + 1 superbend (PM)	5
Total		**11**

3) Upgrading the Mag Lab



Stretched wire measurement bench

WP2 - Vacuum

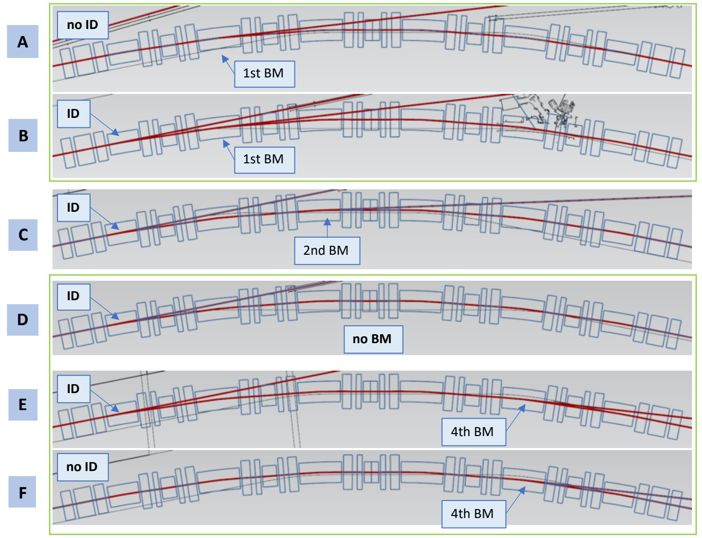
1) Reviewed requirements

- ***Ultimate pressure:*** A good portion of the Synchrotron radiation will be absorbed on the vacuum chamber walls generating a significant PSD outgassing.
  - Dynamic Pressure
  - Space
  - It should reach up to 1e-9 mbar or lower.
- ***Synchrotron Radiation* heat power removal:** All the heat power deposited on the vacuum chamber sides located at these narrow segments shall be removed.
  - Absorber Space
  - Direct Cooling on the chamber
- ***Image current:*** The vacuum chamber shall allow a proper image current low impedance circulation along the ring.
  - Chamber geometries
  - Transitions

2) First layout considerations

Types	#	SS	BM
Type A	1	-	1st
Type B	3	ID	1st
Type C	5	ID	2nd
Type D	1	ID	-
Type E	5	ID	4th
Type F	1	-	4th

Lattice #	SS (before)	BL		BM (which dipole)	BL		Lattice type
Lattice 1	Injection	-	-	1st	BL01	MIRAS	Type A
Lattice 2	Free	BL02	Free	1st	BL03	Free	Type B
Lattice 3	Superconducting Wiggler SCW30	BL04	MSPD	1st	BL05	Free	Type B
Lattice 4	In-vacuum undulator IVU19	BL06	XAIRA	2nd	BL07	Free	Type C
Lattice 5	Free	BL08	Free	1st	BL09	MISTRAL	Type B
Lattice 6	In-vacuum undulator IVU21	BL11	NCD	-	-	-	Type D
Lattice 7	In-vacuum undulator IVU21	BL13	XALOC	2nd	BL14	Free	Type C
Lattice 8	Free	BL15	Free (3Sbar)	2nd	BL16	NOTOS	Type C
Lattice 9	RF	BL17	Pinhole3	4th	BL19	Free	Type E
Lattice 10	APPLE II helical undulator	BL20	LOREA	4th	BL21	Pinhole2	Type E
Lattice 11	Multipole Wiggler	BL22	CLAESS	2nd	BL23	Free	Type C
Lattice 12	APPLE II helical undulator	BL24	CIRCE	2nd	BL25	MINERVA	Type C
Lattice 13	RF	-	-	4th	BL28	Free	Type F
Lattice 14	APPLE II undulator	BL29	BOREAS	4th	BL30	Free	Type E
Lattice 15	Multipole Wiggler (5 poles in-vacuum)	BL31	FAXTOR	4th	BL32	Free	Type E
Lattice 16	Free	BL33	Free	4th	BL34	Pinhole1 and Xanadu	Type E



3) Stablishing collaborations with Max IV

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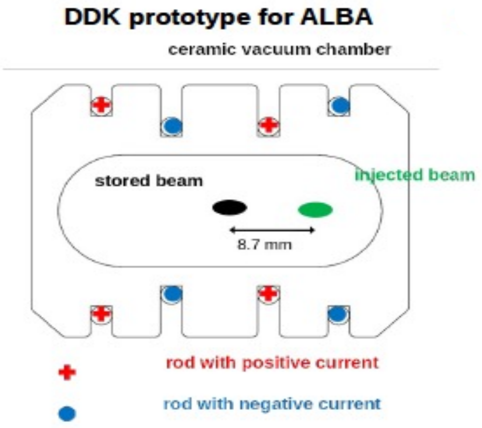
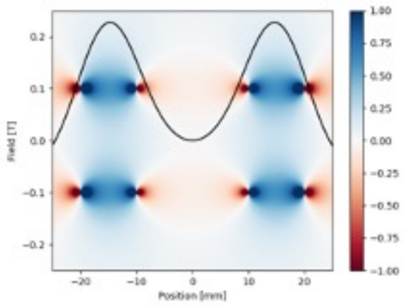
WP3 – Pulsed Magnets

1) Design done: Novel topology adopted → Double Dipole Kicker (DDK)

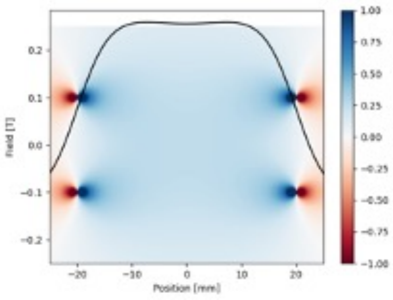


powering 4 inner + 4 outer rods



Sextupole-like kicker, zero field on axis

switching 4 inner rods off



Dipole field for on-axis injection during commissioning

2) Call for tender published in July

3) Stablishing collaboration with SIRIUS

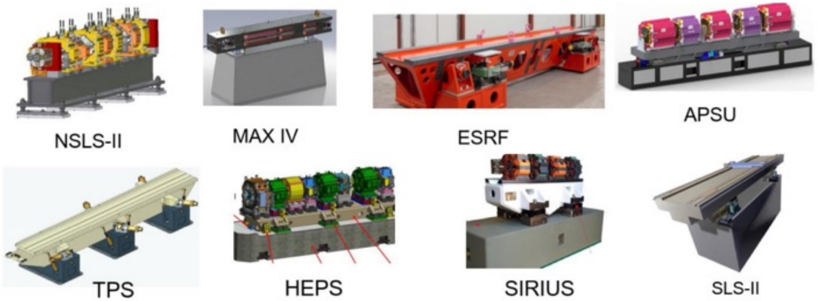
TECHNICAL SPECIFICATIONS

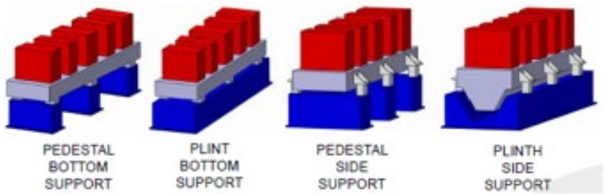
FOR THE SUPPLY OF ONE (1) DOUBLE DIPOLE KICKER AND TWO(2) PULSER UNITS FOR THE ALBA SYNCHROTRON LIGHT SOURCE OF THE CELLS

Dossier number: xx/21

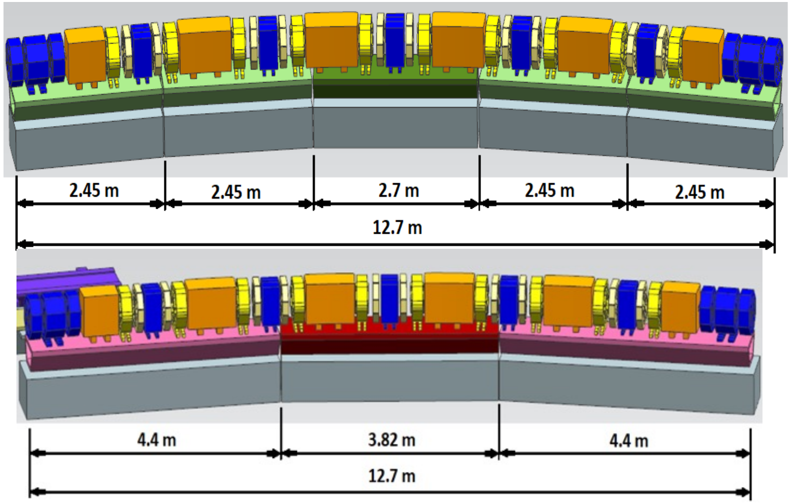
WP4 - Girders

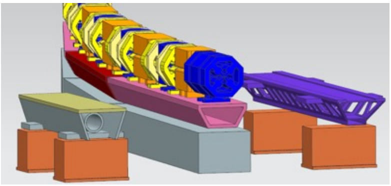
1) **Preliminary Research:** evaluating alternatives from other projects.

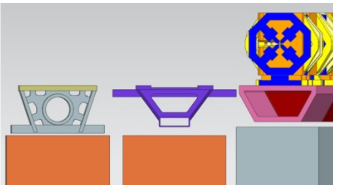


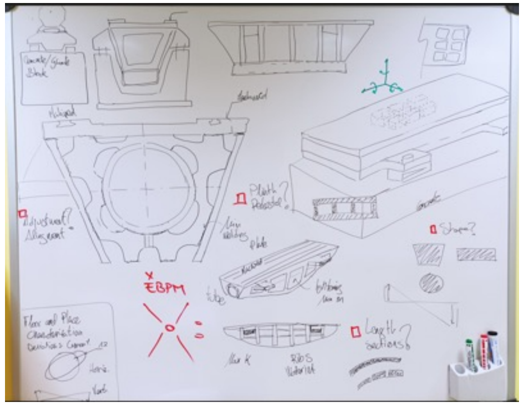


2) **First general concept designs**









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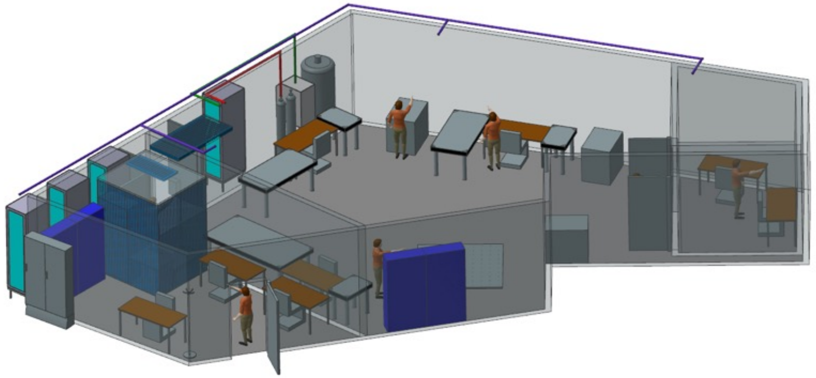
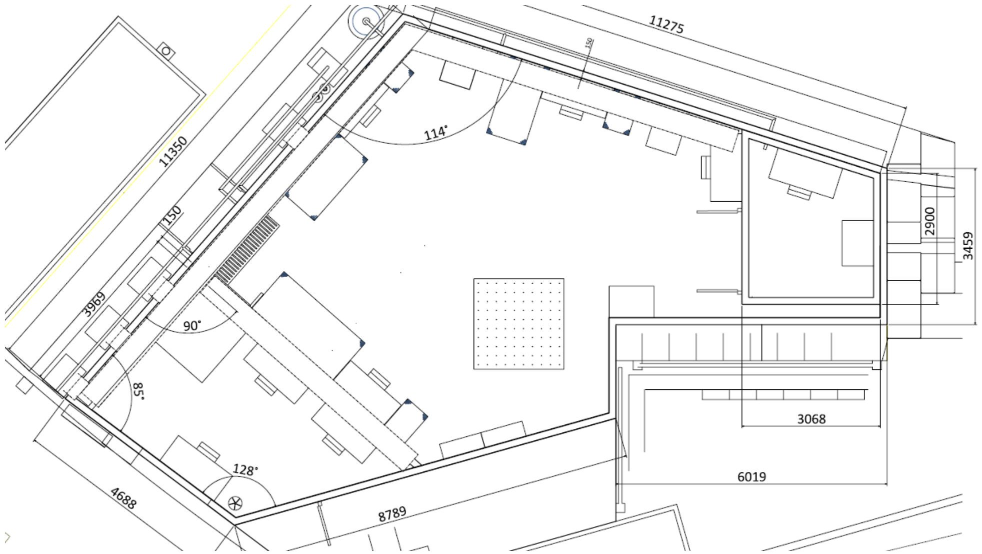
WP5 – Nanoposition Lab

Working on:

1. **Spaces** definition and detailing
    - Construction solutions
    - Services & Network
    - Conventional and Mechanical installations
2. **Material**:
    - Furniture, benches, tools, tooling list…
3. **Instrumentation** and controllers definition

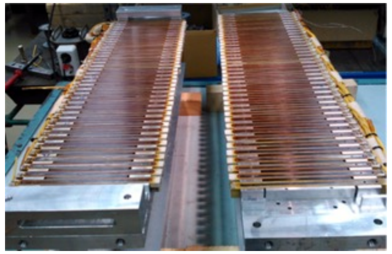




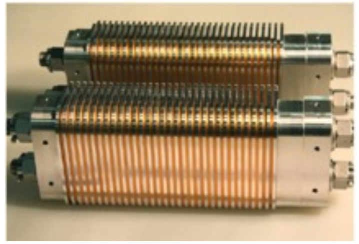
WP6 – Superconducting Undulator

1) Reviewing state of the art.

Budker Institute of Nuclear Physics

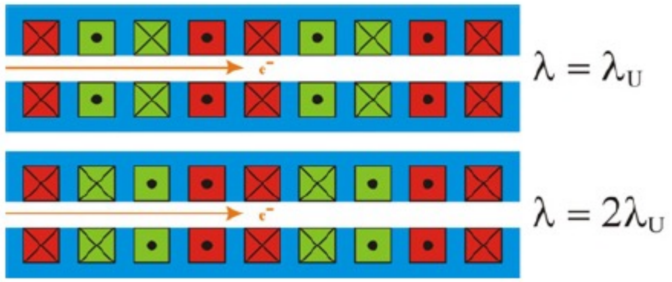


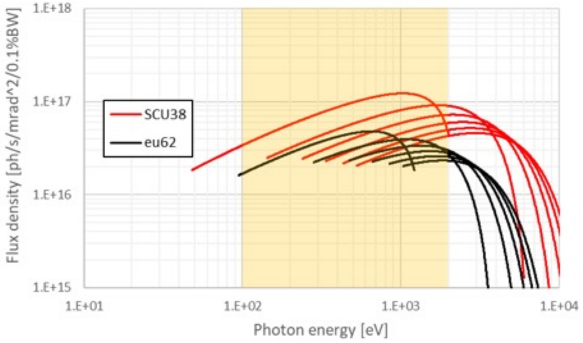
BiLFINGER

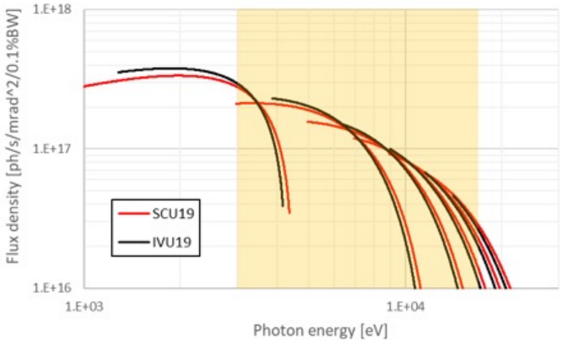


Argonne NATIONAL LABORATORY

2) Analyzing best case for ALBA II requirements.







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Conclusions

- ALBA II is feasible:
  - emmittance ~ 150 - 200 pmrad
  - betas X,Y ~ 2.0 - 2.5 m
- Up to 26 beamlines are feasible:
  - 13 IDs
  - 13 Bendings
    - Some of these bending positions can be used for up to 3T superbend.
- Prototyping for the Acceleraror Upgrade has started.

Thanks!

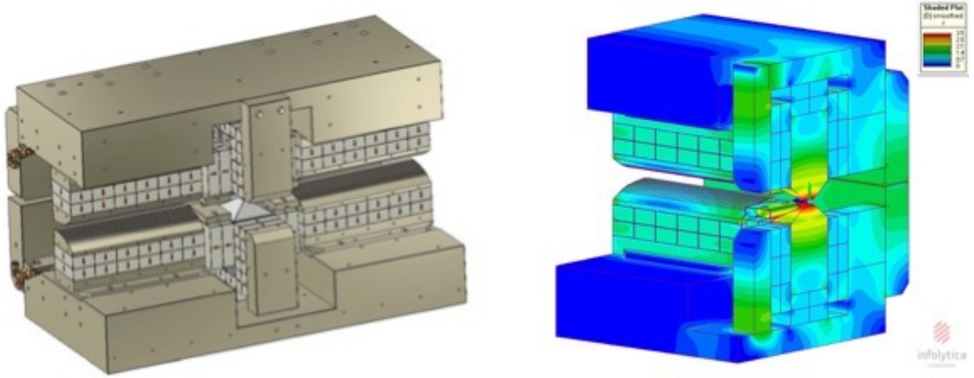
Beam sizes at emission points

			Medium straights									
	Emit (pm rad)	*Coupling*	***Betx (m)***	***Bety (m)***	***Dx (m)***	***D'x (m)***	***X rms (um)***	***X' rms (urad)***	***Y rms (um)***	***Y' rms (urad)***		
ALBA	*4550*	*0,5%*	***2,05***	***1,20***	***0,083***	***0,000***	127,3	47,1	5,2	4,4		
			Dipole (at the middle)									
			Betx (m)	**Bety (m)**	**|Alfax|**	**|Alfay|**	**Dx (m)**	**D'x (m)**	**X rms (um)**	**X' rms (urad)**	**Y rms (um)**	**Y' rms (urad)**
			0,30	25,10	0,00	0,00	0,033	0,0061	49,5	123,3	23,9	1,0
			Low betas straights									
	Emit (pm rad)	Coupling	**Betx (m)**	**Bety (m)**	**Dx (m)**	***D'x (m)***	**X rms (um)**	**X' rms (urad)**	**Y rms (um)**	**Y' rms (urad)**		
ALBA-II	140	100%	1,98	2,30	0,00	*0,000*	14,0	7,1	15,1	6,5		
			High betas straights									
			Betx (m)	**Bety (m)**	**Dx (m)**	**D'x (m)**	**X rms (um)**	**X' rms (urad)**	**Y rms (um)**	**Y' rms (urad)**		
			11,74	10,02	0,0	0,0	34,0	2,9	31,4	3,1		
			Dipoles 2, 3, 4, 5 (at the middle)									
			Betx (m)	**Bety (m)**	**|Alfax|**	**|Alfay|**	**Dx (m)**	**D'x (m)**	**X rms (um)**	**X' rms (urad)**	**Y rms (um)**	**Y' rms (urad)**
			0,23	6,24	0,00	0,00	0,0061	0,00	8,4	20,8	24,8	4,0
			(at the ends)									
			Betx (m)	**Bety (m)**	**|Alfax|**	**|Alfay|**	**Dx (m)**	**D'x (m)**	**X rms (um)**	**X' rms (urad)**	**Y rms (um)**	**Y' rms (urad)**
			1,24	4,63	2,5579	3,3691	0,0167	0,0501	21,9	61,7	21,4	16,2
			Dipoles 1, 6 (at the middle)									
			Betx (m)	**Bety (m)**	**|Alfax|**	**|Alfay|**	**Dx (m)**	**D'x (m)**	**X rms (um)**	**X' rms (urad)**	**Y rms (um)**	**Y' rms (urad)**
			0,23	7,14	0,602	4,6435	0,0041	0,0257	6,6	38,0	26,5	17,7
			(at end1)									
			Betx (m)	**Bety (m)**	**|Alfax|**	**|Alfay|**	**Dx (m)**	**D'x (m)**	**X rms (um)**	**X' rms (urad)**	**Y rms (um)**	**Y' rms (urad)**
			0,45	10,57	1,2969	6,2825	0,00	0,00	6,6	24,4	32,3	19,4
			(at end 2)									
			Betx (m)	**Bety (m)**	**|Alfax|**	**|Alfay|**	**Dx (m)**	**D'x (m)**	**X rms (um)**	**X' rms (urad)**	**Y rms (um)**	**Y' rms (urad)**
			1,19	4,63	2,4527	3,3687	0,0162	0,051	21,3	62,5	21,4	16,2

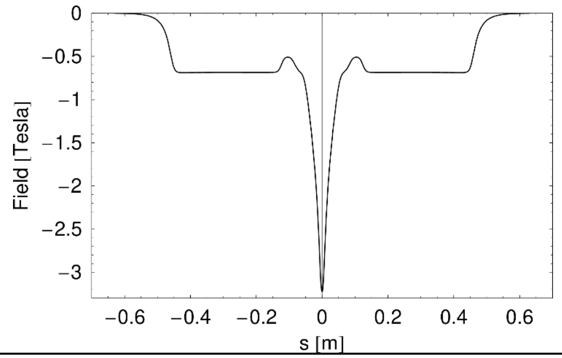
The 6BA lattice has a main bending of 1T *(<1,4T of ALBA)*

Propose to add:

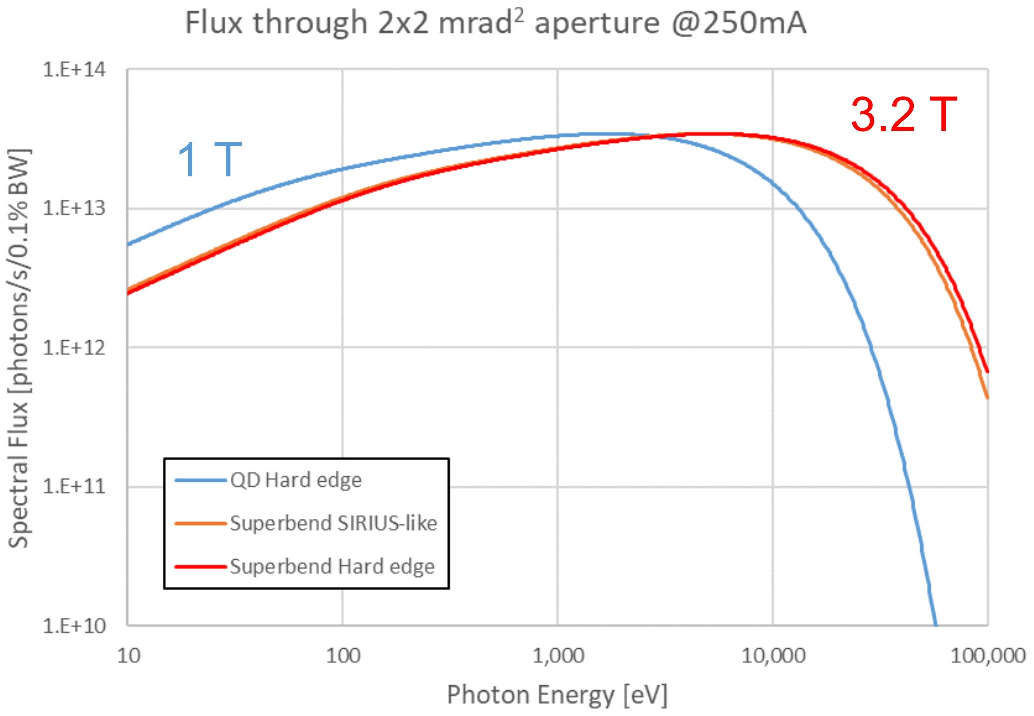
Superbend: 3.2 T combined permanent magnet



SIRIUS superbend



Bendings emission comparison



For beamlines $E_{ph} \lesssim 2$ keV

it is more favorable the 1T bending

Possible sources

- 13 IDs
  - 12 small betas
  - 1 high betas

- 13 bendings
  - Keep the bending beamlines MISTRAL & MINERVA with 1T bending
  - Move NOTOS to a 3T bending
  - 4 more possible with 1T bending
  - 5 more possible with either 1T or 3T bending

- MIRAS
  - Could be maintained in the same position, but the mechanical desing of the extraction from the SR has to be investigated.

Accelerator’s Investment