ALBA Synchrotron Light Source Magnet Power Supplies System

José Ávila, on behalf of Power Supplies group

26/05/2023

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- Overview of ALBA Synchrotron Magnet Power Supplies System
- Status of ALBA Synchrotron Magnet Power Supplies System
- ALBA Power Converter Projects
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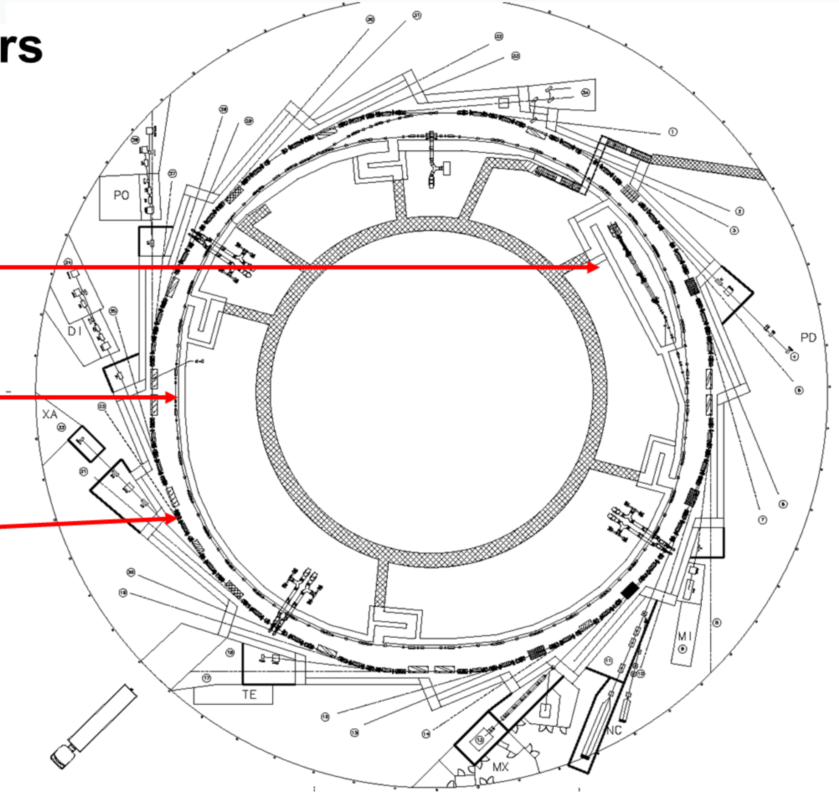
Overview

ALBA accelerators

LINAC
100 Mev

BOOSTER
100 MeV – 3 GeV

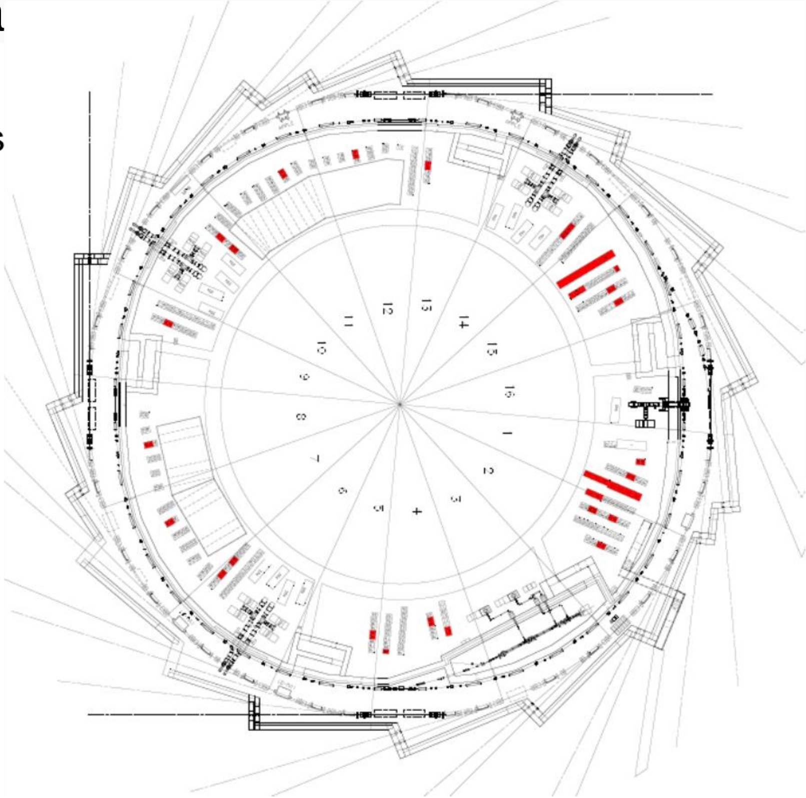
STORAGE RING
3 GeV



Overview

- Distribution in Service Area

Distribution of Power Supplies
in the Service Area



Overview

- Storage Ring Power Supplies

MAGNET	QUANTITY		Power Supply	Nº PS	SPARE	Voltage (V)	Current (A)	OUTPUT POWER (kW)
DIPOLES	33		Hazemeyer Ariane 750-600	1	0	750	600	450
QUADRUPOLES	112	16 (Q200)	Hazemeyer Ariane 15-200	88	8	15	200	3
		48 (Q260)						
		24 (Q280)						
		24 (Q500)	Hazemeyer Ariane 25-225	24	2	25	225	5,625
SEXTUPOLES	120	4 families x 8 magnets (S150A)	Hazemeyer Ariane 100-215	4	1	100	215	21,5
		2 families x 16 magnets (S150B)	Hazemeyer Ariane 190-215	2	0	190	215	40,85
		2 families x 24 magnets (S220A)	Hazemeyer Ariane 350-215	2	1	350	215	75,25
		1 family x 8 magnets (S220B)	Hazemeyer Ariane 125-215	1	0	125	215	26,875
CORRECTORS	208	Horizontal	OCEM (PSI/DLS)	88	6	±60	±12	0,2
		Vertical	OCEM (PSI/DLS)	88	6	±60	±12	0,2
		Skew	OCEM (PSI/DLS)	2	0	±60	±5	0,2
TRIM COILS	32		CAENels FAST-PS 3030-900	32	3	30	30	0,9

Overview

- Booster Power Supplies

MAGNET	QUANTITY		Power Supply	Nº PS	SPARE	Voltage (Vpeak)	Current (Apeak)	OUTPUT ACTIVE POWER (kW)
DIPOLES	40	40 coils	Bruker Dipole ALBA	1	0	±1000	750	95
		40 coils	Bruker Dipole ALBA	1	0	±1000	750	95
QUADRUPOLES	60	16 (series connection 8+8)	Bruker Quad V1&2 ALBA	2	0	±100	180	3,5
		8	Bruker Quad H2 ALBA	1	0	±200	180	5,6
		36	Bruker Quad H1 ALBA	1	0	±750	180	24,5
SEXTUPOLES	16 (series connection 8+8)		Bruker Sextupole ALBA	2	0	±60	±8	0,45
CORRECTORS	72		Bruker Corrector ALBA	72	4	±10	±6	0,25

Overview

- LINAC-Booster Transfer Line

MAGNET	QUANTITY		Power Supply	Nº PS	SPARE	Voltage (V)	Current (A)	OUTPUT POWER (W)
DIPOLES	2	type 1	Bruker LT1 ALBA	1	0	20	180	3600
		type 2	Bruker LT2 ALBA	1	0	12	12	150
QUADRUPOLES	9		Bruker 20/15 LT-QUAD	9	1	20	15	300
CORRECTORS	8		Bruker LT-CORR	8	2	±2	±2	4

- Booster-Storage Ring Transfer Line

MAGNET	QUANTITY	Power Supply	Nº PS	SPARE	Voltage (V)	Current (A)	OUTPUT POWER (W)
DIPOLES	2	Bruker 60/180 BT ALBA	2	0	60	180	10800
QUADRUPOLES	7	Bruker MON 15/170	7	1	15	170	2500
CORRECTORS	8	Bruker 12/6 Corrector ALBA	8	2	±10	±6	60

Overview

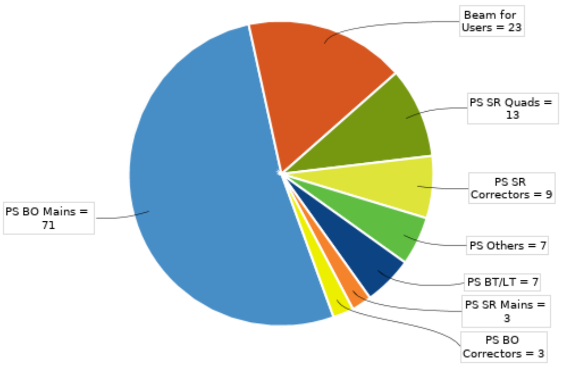
- ID Correctors

MAGNET	QUANTITY	Power Supply	Nº PS	SPARE	Voltage (V)	Current (A)	OUTPUT POWER (W)
CORRECTORS	20	CAENels FAST-PS 2020-400	20	5	±20	±20	400
CORRECTORS	20	OCEM (PSI/DLS)	20	4	±60	±12	200

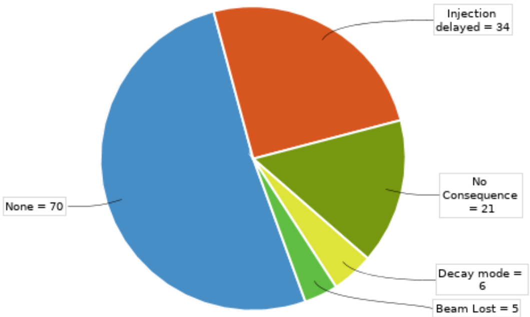
- OCEM ID Correctors to be replaced by CAENels Power Supplies
- To gain stock for SR Correctors!

Status

- Some Statistics. PS Incidents 2020



2020 PS Incidents by Component

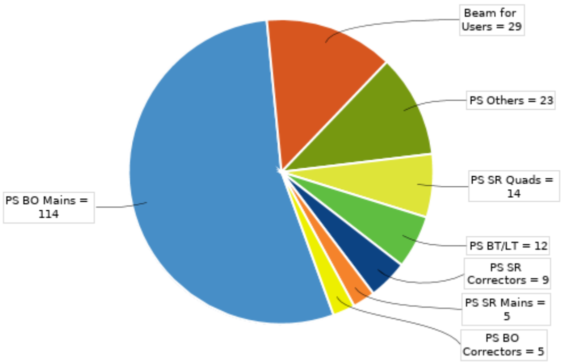


2020 PS Incidents beam consequences

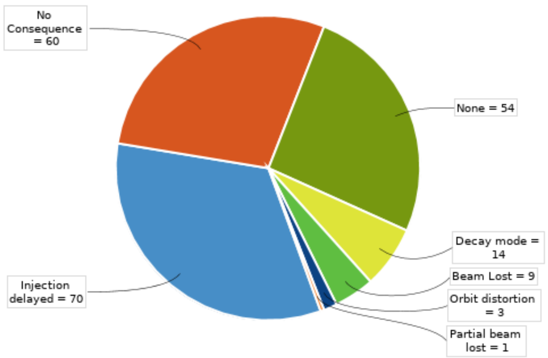
- 136 reported PS Incidents
  - 5 Beam losses
  - 34 Injection delays + 6 Decay modes

Status

- Some Statistics. PS Incidents 2021



2021 PS Incidents by Component

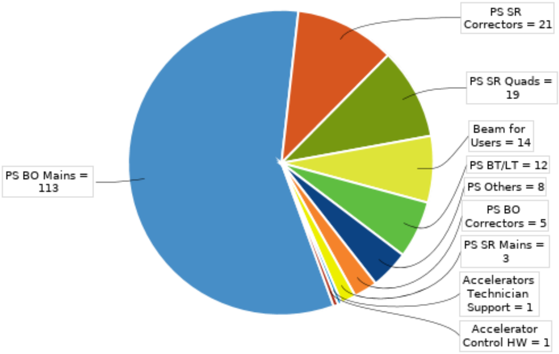


2021 PS Incidents beam consequences

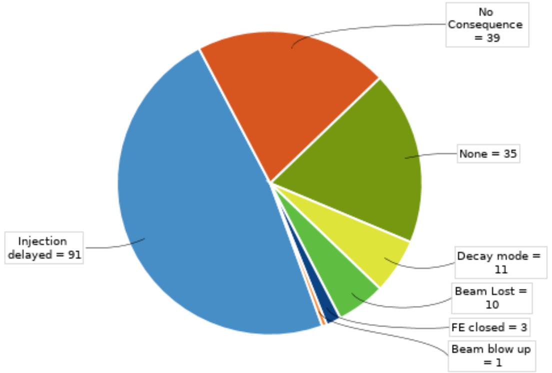
- 211 reported PS Incidents
  - 10 Beam losses
  - 70 Injection delays + 14 Decay modes

Status

- Some Statistics. PS Incidents 2022



2022 PS Incidents by Component



2022 PS Incidents beam consequences

- 190 reported PS Incidents
  - 11 Beam losses
  - 91 Injection delays + 11 Decay modes

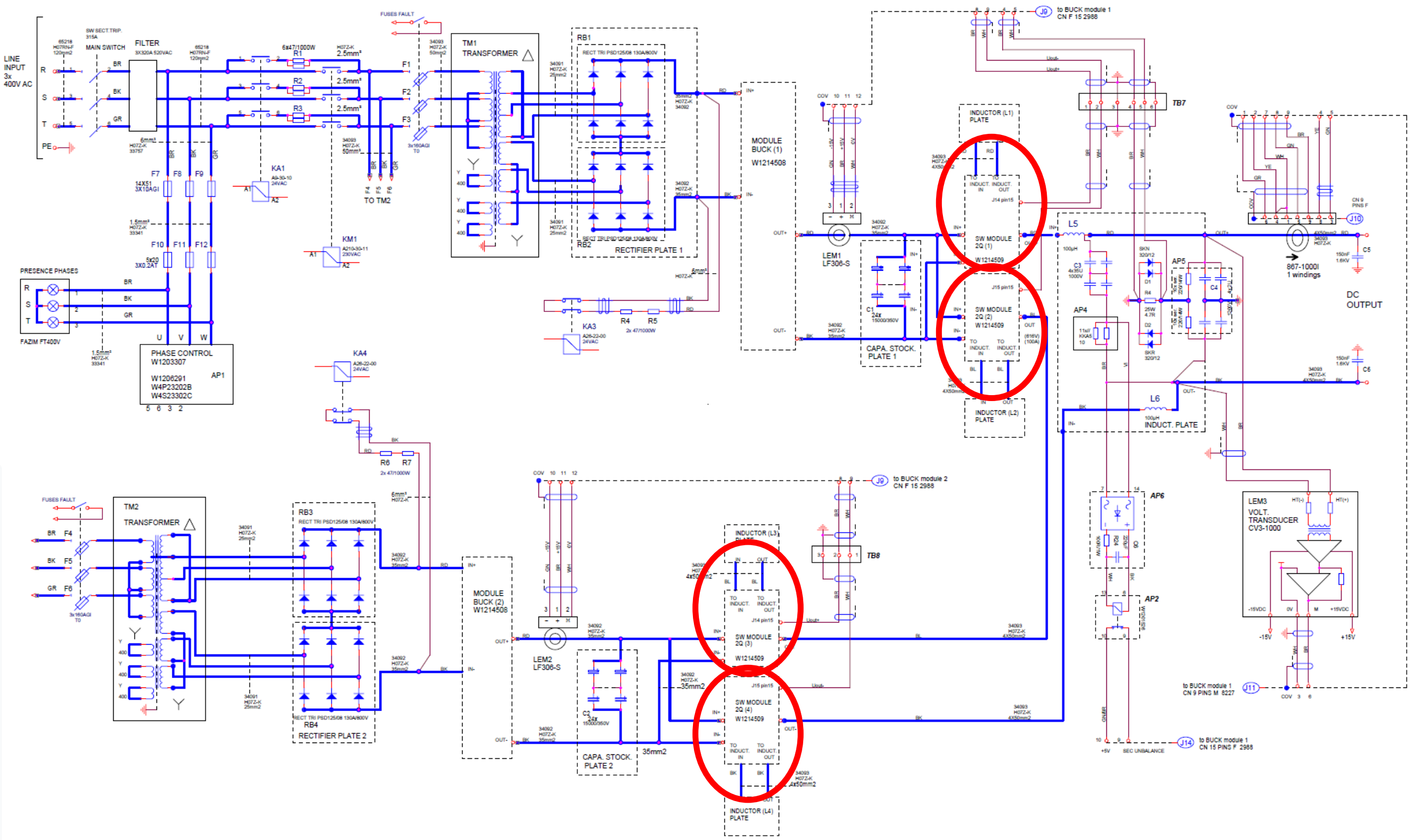
Projects

- From the main concern reported in POCPA'18…

  - Booster Dipole Power Supplies:
  - Two Main Problems
    - 1) very low lifetime of 2Q modules under the stress of top-up operation. Power and thermal cycling.
    - 2) Large difficulties to make failure diagnostics when the control/regulation boards are involve.

Projects

- From the main concern reported in POCPA’18…



x2
(BO-DIP1, BO-DIP2)

Projects

- … with the following approach:

1) Try to obtain the best of the current design.
   1) Management of module to balance top and bottom IGBT ✗
   2) Better IGBT with same packaging ✗
   3) Improve thermal contact (thermal compounds) ✗
   4) DC warm-up (since October 2018) ✓

2) Find a permanent solution
   1) New design ✓
      - Booster Dipole In-house 2Q module (short term)
      - Procurement of New Booster Mains Power Supplies (mid-term)

Projects

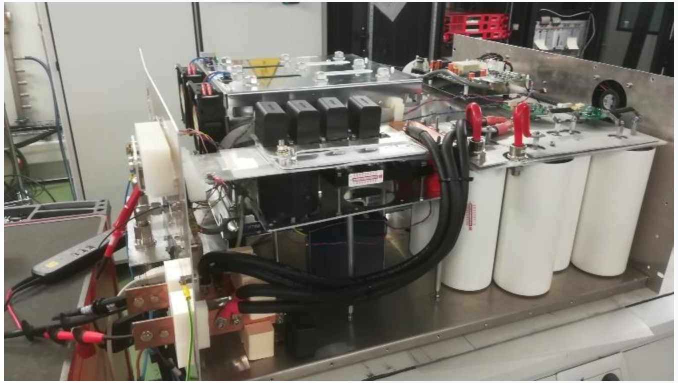
Booster Dipole In-house 2Q module

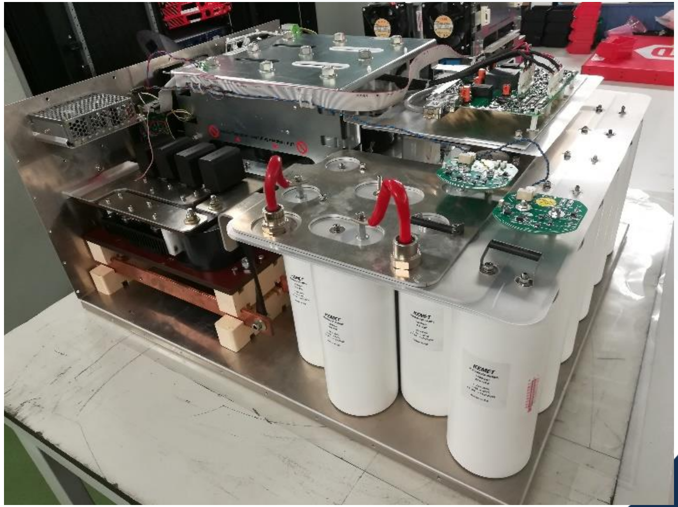
- Based on IGBT Stack from Semikron (IGB-8-424-P1F9-1BH-WA)
- Full internal development:
  - Mechanical Design
  - Ancillary Electronics
    - Opto-Electric adaption (IGBT driver)
    - Interlock management
    - Output Voltage sensing
  - Internal cabling
  - Testing
  - Commissioning

Projects

Booster Dipole In-house 2Q module

- 2 modules built up to now:
    - V1 prototype
        - Beam of last run of 2020 during 3 weeks (until it failed)
        - Beam of run 2 and run 3 of 2021 (no problems found)
    - V2 pre-series
        - Successfully working in BO-BEND system since January’23
        - Design considered as final an validated
- **x3 V2 series modules to be built in 2023**





Projects

Procurement of New Booster Mains Power Supplies

- Started in fall 2019
- Public tender (turn-key approach)
- Available Budget 1.2M€
- Tender type definition, administrative conditions and technical specifications review took some time
- … and at the end of the review, ALBAII entered the scene
  - Redo technical specification, affecting the key parameter of IGBT power/thermal cycles
- Public tender finally published on 31/07/2022

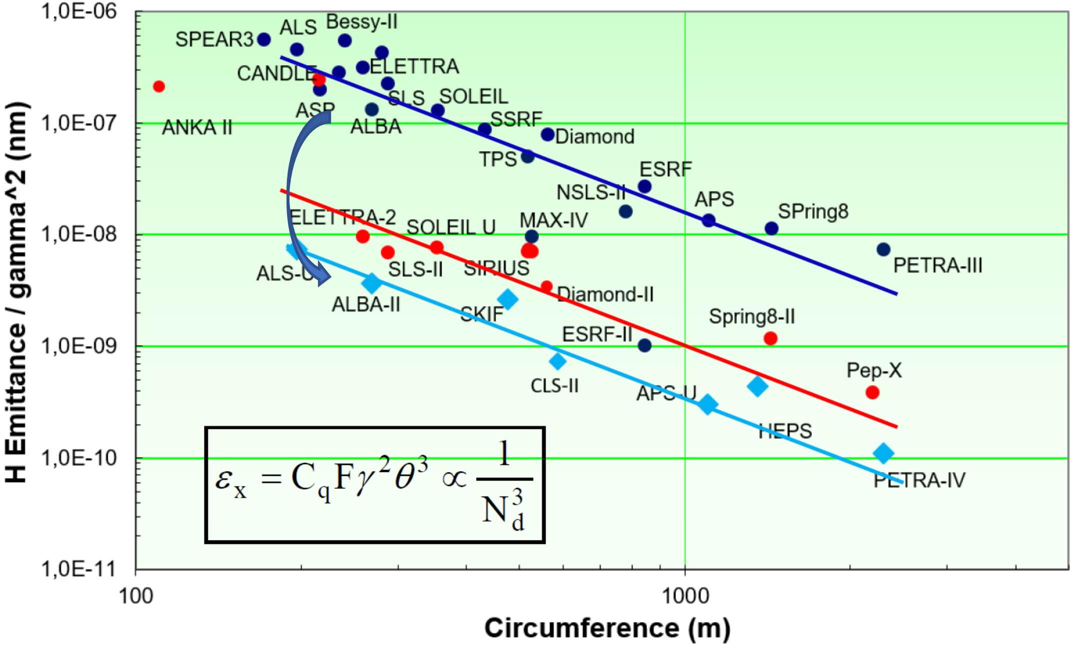
Procurement of New Booster Mains Power Supplies

- Award criteria:
  - Subjective:
    - Tools for preventive and/or corrective maintenance
  - Objective:
    - Economic issues (Purchase cost, installation cost, integration cost, eventual spare parts)
    - Power/thermal cycles
    - Warranty Extension
- Two bidding offers: OCEM (IT), JEMA (SP)
- Awarded to OCEM, 825.660€

Procurement of New Booster Mains Power Supplies

- Project Plan
  - Contract signed - 20/04/2023 (0m)
  - Kick-off Meeting - 19/05/2023 (1m)
  - Preliminary Design Report – December’23 (8m)
  - Critical Design Report – April’24 (12m)
  - New location adaptation – 2024-2025
  - Delivery of the Supplies – April’26 (36m)
  - Power-up of the Supplies – June’26 (42m max)
  - SAT & CoA – August’26 / January’27 (48m max)

ALBA II



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

ALBA II. Motivation for upgrade

- **To reduce the emittance of a Synchrotron. What is needed?**

To make a long story short, one basically has to **split the bending action** among a **larger number of dipoles** → **<u>Multi-bend achromat</u>** (**MBA**) concept

Equilibrium emittance scaling law: $\varepsilon_x \approx \mathcal{F}\frac{C_q\gamma^2}{J_x}\varphi^3 \propto \gamma^2\varphi^3 \propto \frac{1}{N_d^3}$

C_q: constant

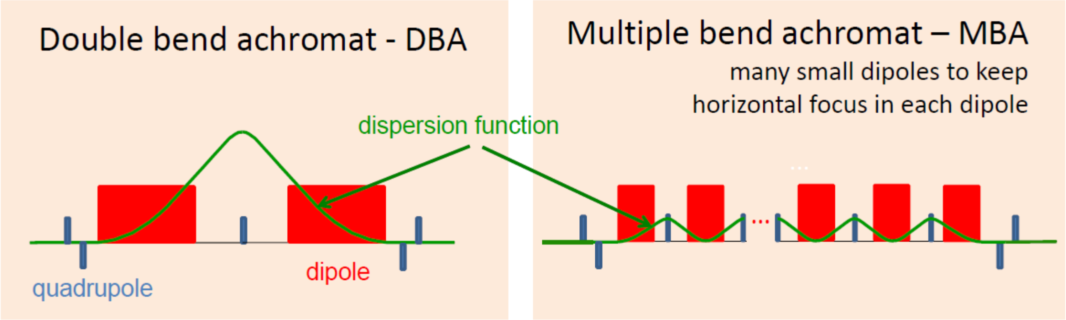
J_x: Robinson partition number

$\mathcal{F}$: lattice scale factor

γ: Lorentz factor

φ: deflection angle per bending

N_d: number of bendings

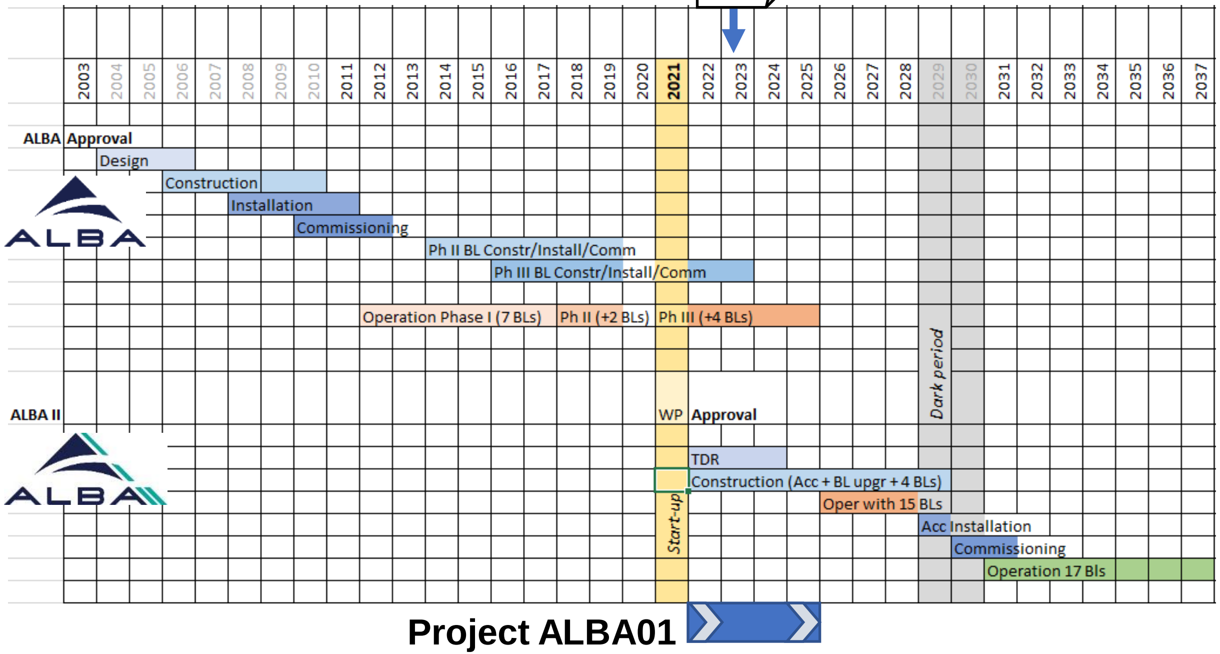


Reproduced from: Liu Lin "Towards Diffraction Limited Storage Ring Based Light Sources", IPAC17, Copenhagen (2017)

ALBA II. Project Description

- **Tentative ALBA II timeline**

ALBA II White Paper (Spring '23)

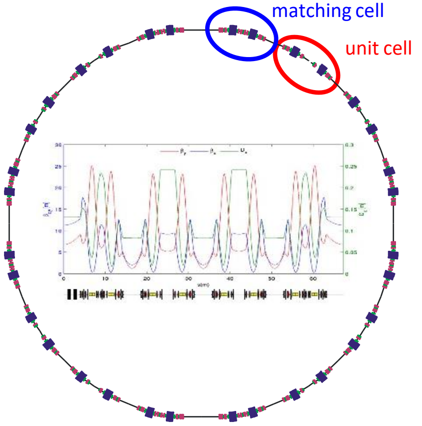


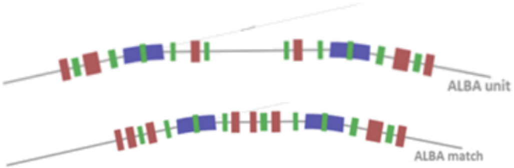
Project ALBA01
"Enabling advanced technologies for ALBA II"

ALBA II. Project Description

- **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**)

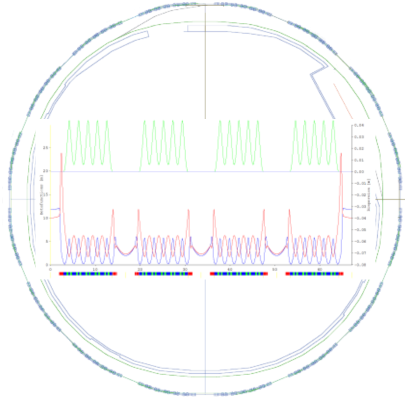
ALBA II. Project Description

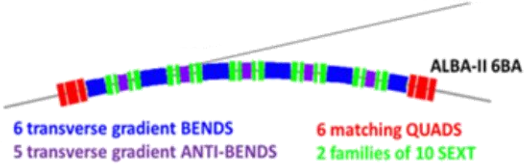




	ALBA	ALBA II
Energy	**3 GeV**	**3 GeV**
Circumference	268.8 m	268.8
Symmetry	4-fold	4-fold
Lattice	8×2-DBA cells	16×6BA cells
Emittance	**4.5 nm·rad**	**140 pm·rad**
Nº of cells	8+8	16
# of straights	4 / 12 /8	16
Straight length	7.8 / 4.0 / 2.3m	4.0 m

÷30





Benedetti et al. *"A distributed sextupoles lattice for the ALBA low emittance upgrade"*, **IPAC21, WEPB074**

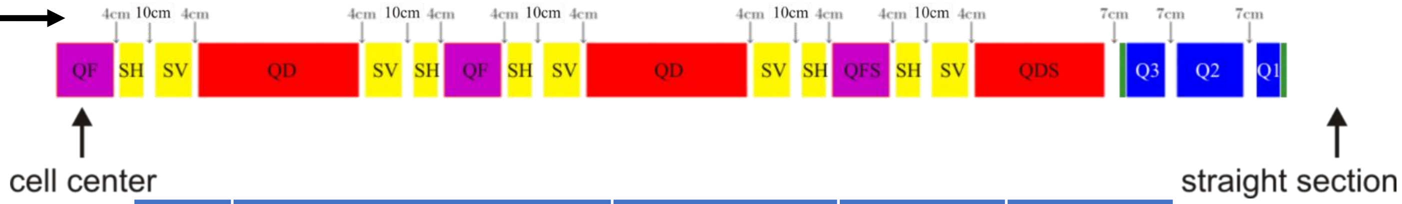
ALBA II. SR Magnets Design

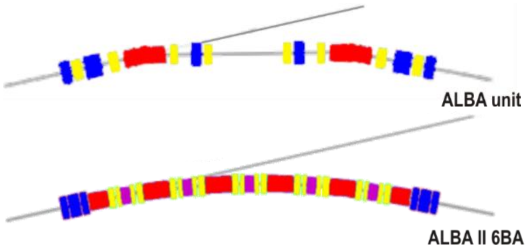
- **ALBA II** lattice is based in **16 identical 6BA cells**, with **10 magnet types**, for a total of **656 individual magnets** (currently 264 magnets at ALBA SR)

Distances between magnets' **effective lengths**

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

Half 6BA unit cell



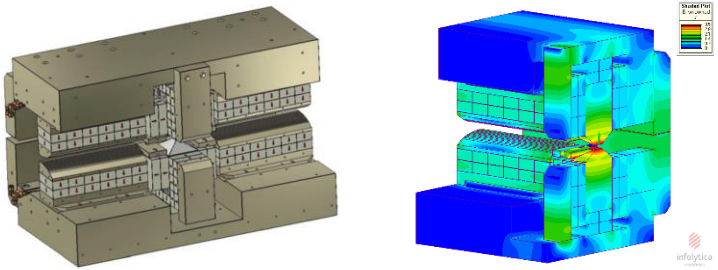


Code	Magnet description	Types	# per cell	# in SR
(red)	Bend with trans grad	2 (QD, QDS)	6	96
(magenta)	Antibend with trans grad	2 (QF, QFS)	5	80
(blue)	Quadrupoles	3 (Q1, Q2, Q3)	6	96
(yellow)	Sextupoles	2 (SH, SV)	20	320
(green)	Fast Correctors	1 (COR)	4	
	Total	**10**	**41**	**656**
	Integrated Correctors	WIP	~17	~272

928 PS!

ALBA II. SR Magnets Design

- Adopted conventional EM technology for the baseline design of **ALBA-II SR magnets**, maximum priority to it.
- To **explore in parallel more innovative designs** (e.g. **hybrid EM-PM magnets**) for QD and QDS magnets.
- One **clear candidate** to introduce PM are the modified QD dipoles (**superbends**) that will be necessary to feed dipole BLs requiring photon energies **above 4keV**.



SIRIUS 3.2 Tesla BC magnet (superbend) available at wiki-sirius.lnls.br

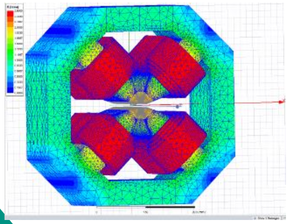
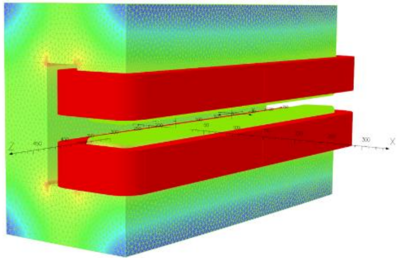
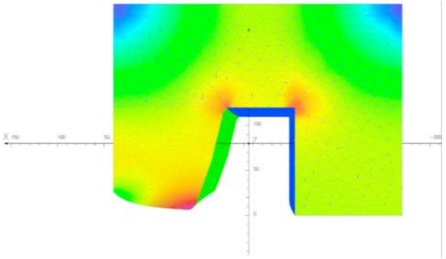
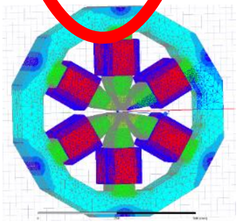
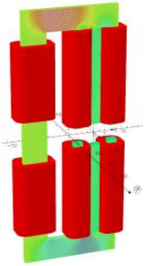
- In relation with this point, ALBA participates in **PerMaLIC** collaboration, sharing the development of **PM designs** with other facilities.

ALBA II. SR Magnets Design

- **Preliminary set of 3D models** for **all main magnet types** (overall dimensions without pole profile optimization):

	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)	36	25	85.0	20	262	430	1500/2000	----

#turns still under design

ALBA II. Power Supplies

- Today's information:
  - 656 DC PS. Rated power depends on final magnet design
  - 272 DC/Freq PS. Rated power & frequency depends on final magnet design

- On the past:
  - Call for tenders for different subsystems (Transfer lines, Booster, Storage Ring)
  - Turnkey approach.
  - 3 Companies
    - Bruker (Now Sigmaphi Electronics) for Transfer Lines and Booster
    - Hazemayer for SR Dipole, Sextupoles and Quadrupoles
    - OCEM – Storage Ring Correctors

ALBA II. Power Supplies

- Yesterday’s Solutions are Today’s Problems
  - Yesterday’s Solutions:
    - Transfer the risk of a new design to an external company
    - Low Manpower needed, only to follow up the companies
    - Low delivery time.
  - Today’s Problems
    - Risk of out of business of a manufacturer.
    - Companies may change their business.
    - The complete know how is in the manufacturer.
    - Design errors that appear after long term in operation. Not covered by warranties.
    - Product obsolescence

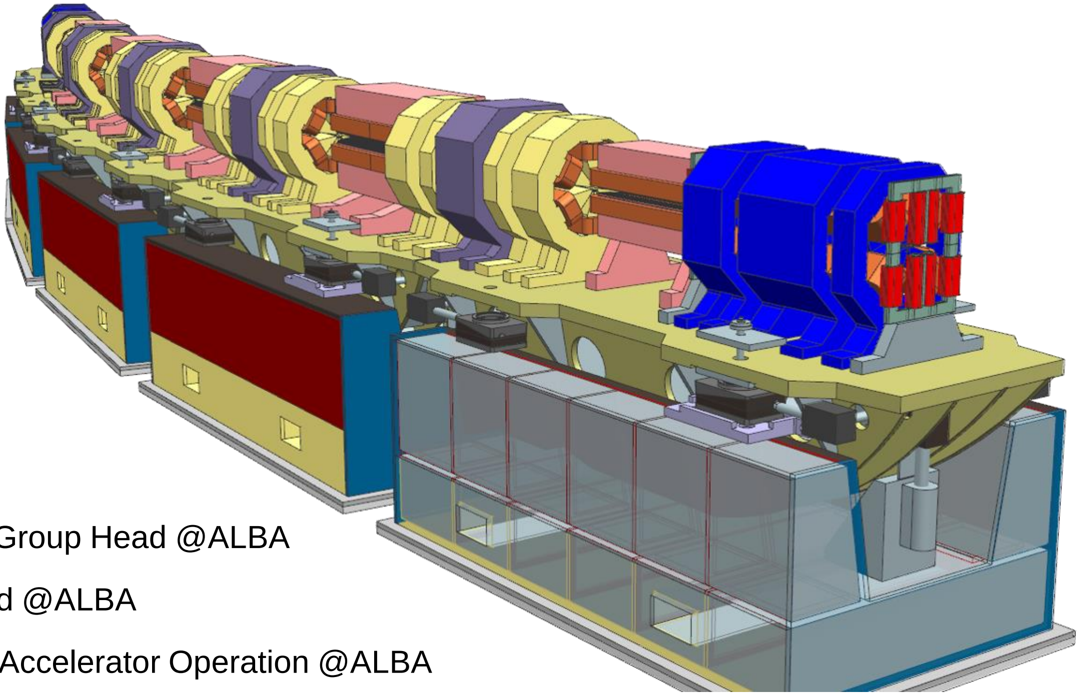
ALBA II. Power Supplies

- We have to take a decision about the approach for ALBA II power supplies
  - Turn-key option (again)
  - In-house design (outsourced manufacturing)
    - Many options here regarding the integration of COTS parts
  - Collaboration with PS Groups from other facilities
    - Unique opportunity!

- Study on-going to estimate costs, times and resources of all possible options.

ALBA II. Power Supplies

Questions?



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