Radiofrequency for ALBA-II

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(presented by F. Perez)

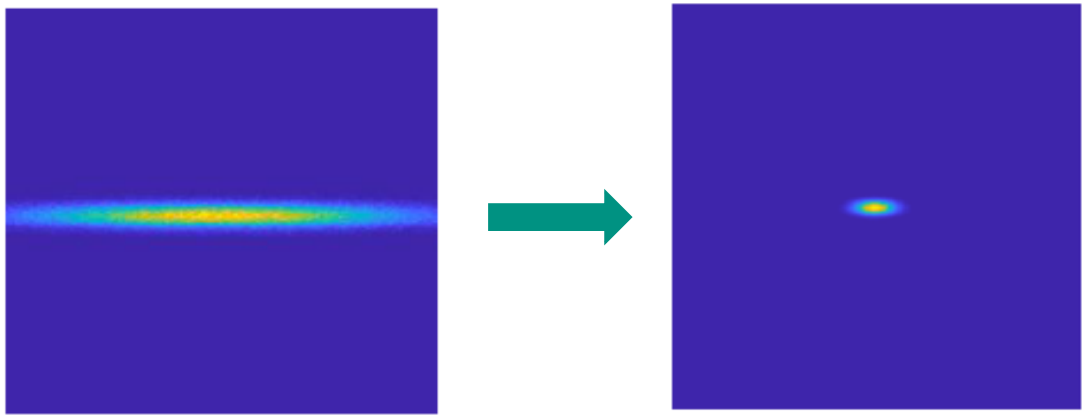
11/10/2022

Outline

- ALBA-II General Overview
- ALBA-II Radiofrequency system
  - Main system
  - 3rd harmonic system
    - SSPA transmitter
    - DLLRF
    - Cavity

ALBA-II 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)

ALBA-II lattice

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

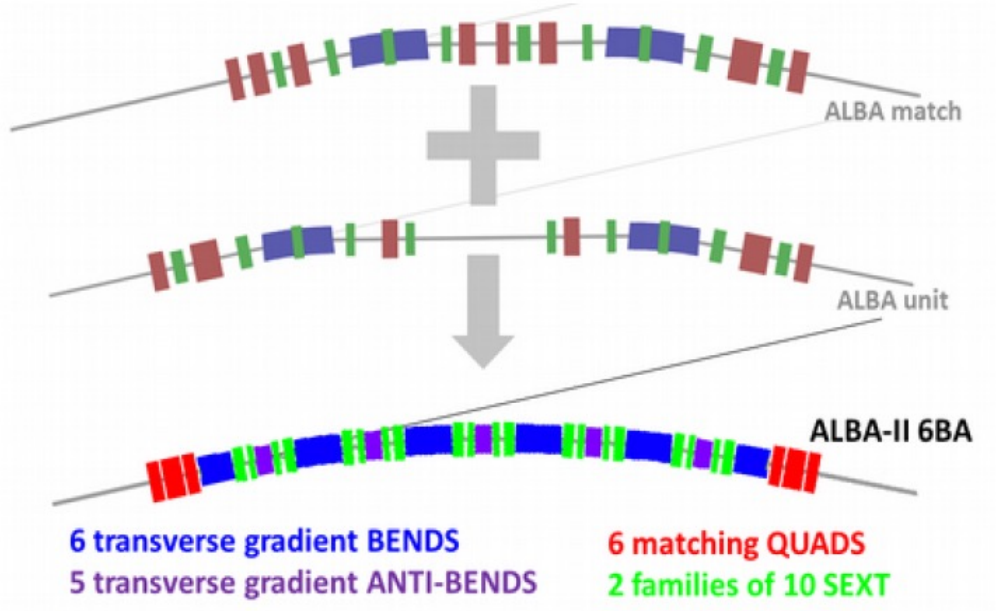
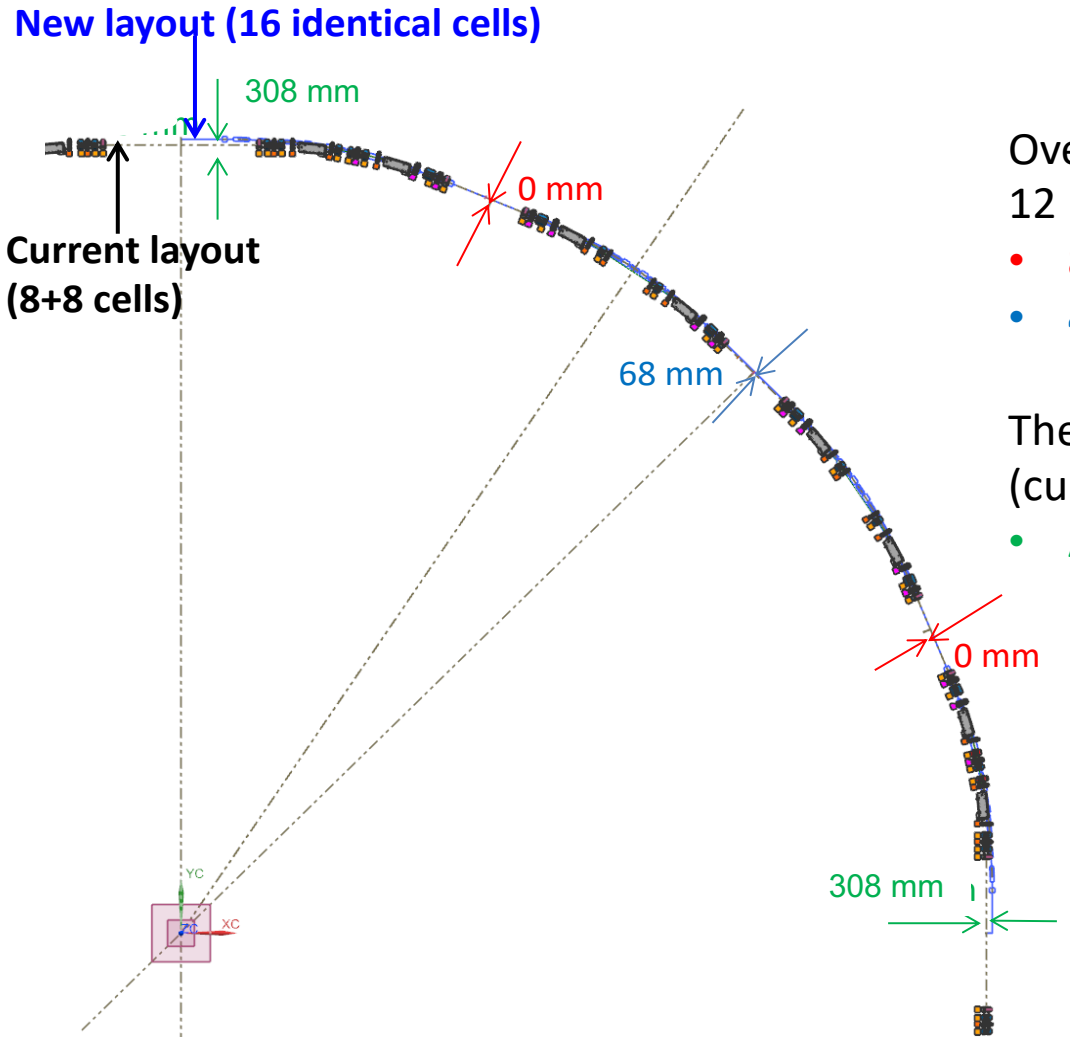


Figure 1: In ALBA-II, the two types of DBA cell (8 matching cells plus 8 unit cells) of the current lattice are replaced by 16 identical 6BA+anti-bend cells.

	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.	$8.9 \cdot 10^{-4}$	$0.8 \cdot 10^{-4}$
Energy spread	$1.0 \cdot 10^{-3}$	$1.1 \cdot 10^{-3}$
Energy loss/turn	1023 keV	843 keV
Damping times	4 / 5 / 3 ms	3 / 6 / 6 ms

ALBA-II straight sections for IDs



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

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

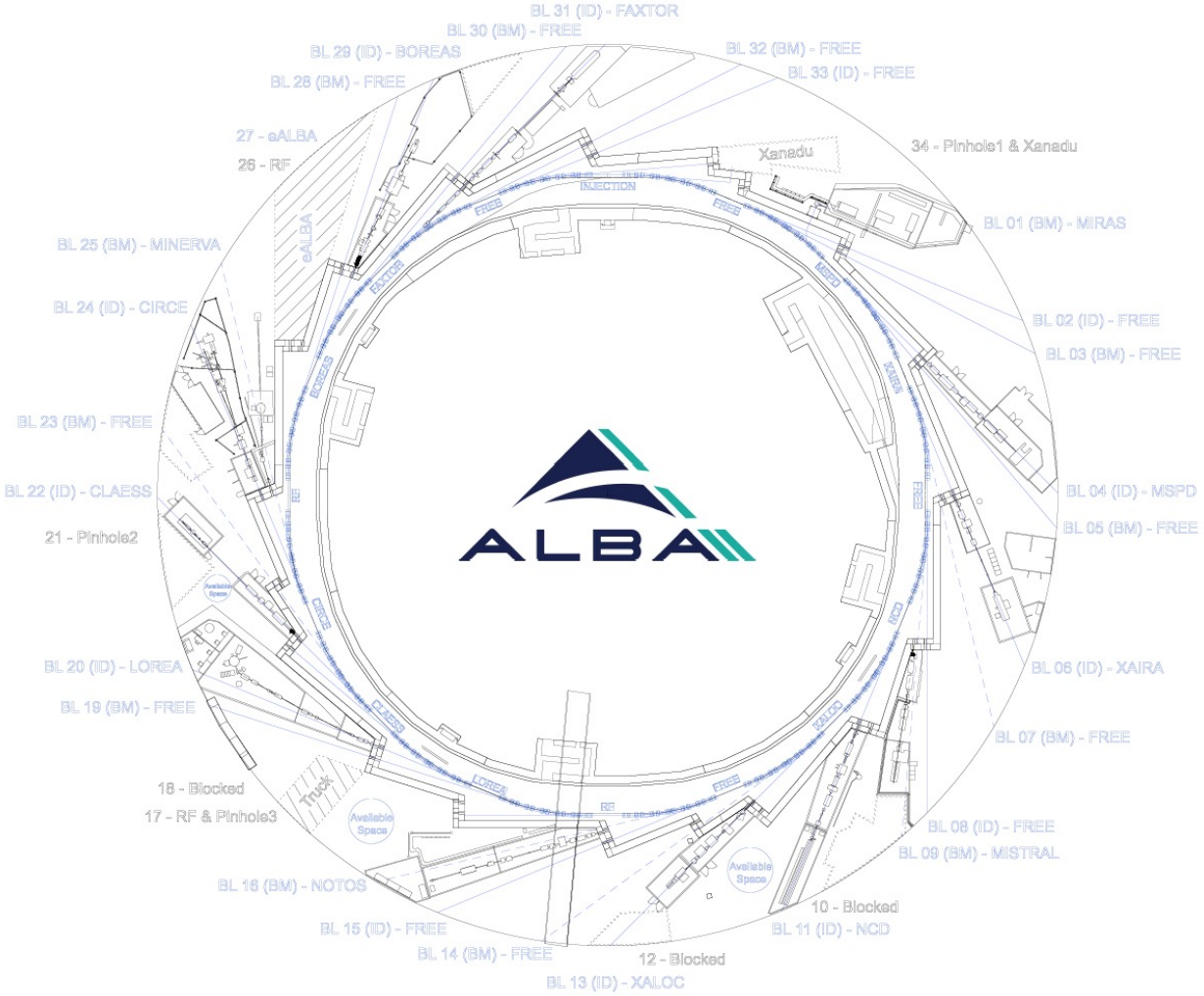
The present 4 Long Straight Sections (currently not used yet for BLs):

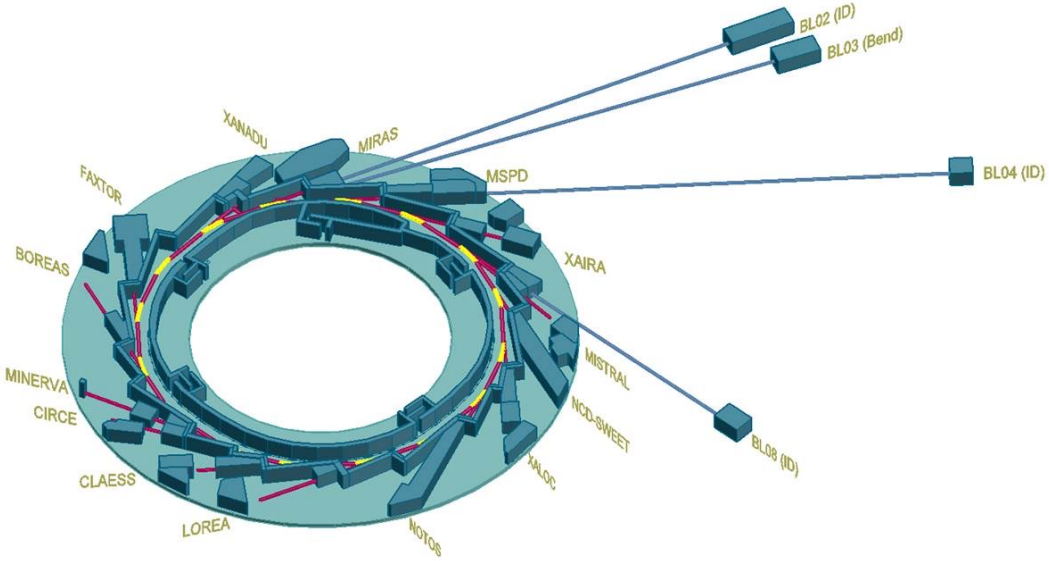
- **All radially shifted by 308 mm**

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

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

ALBA-II implementation





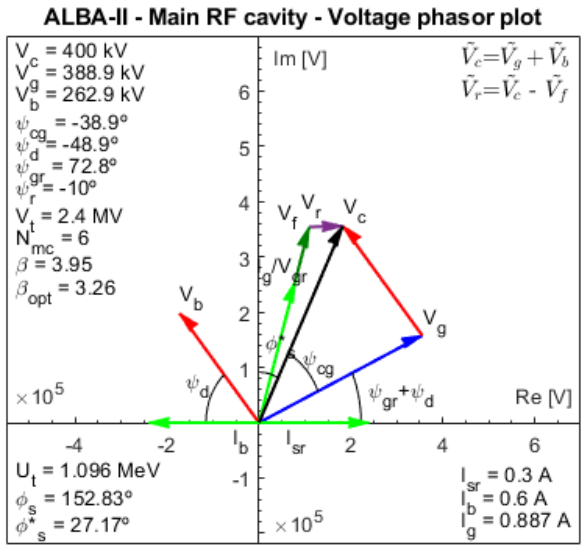
Possible long beamlines at
BL02-ID , BL03-Bend, BL04-ID, BL08-ID

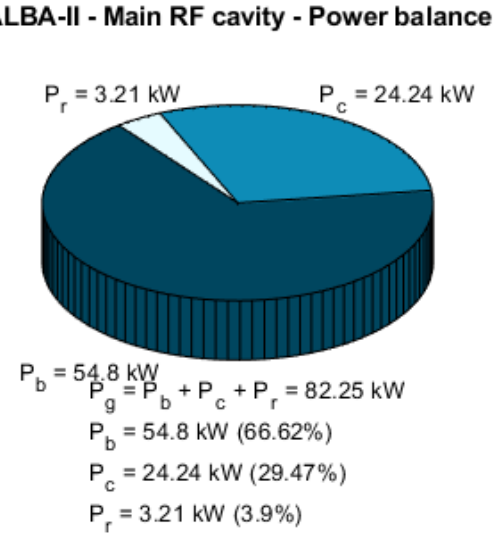
ALBA-II Implementation

- **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 SSPA and 3rd Harmonic Cavity**
  - **New Diagnostics equipment**
  - **New Insertion Devices**
  - **…**

ALBA-II Main System

- 500 MHz EU HOM cavities.
- IOT based transmitter replaced by SSPA.
- Main RF parameters:

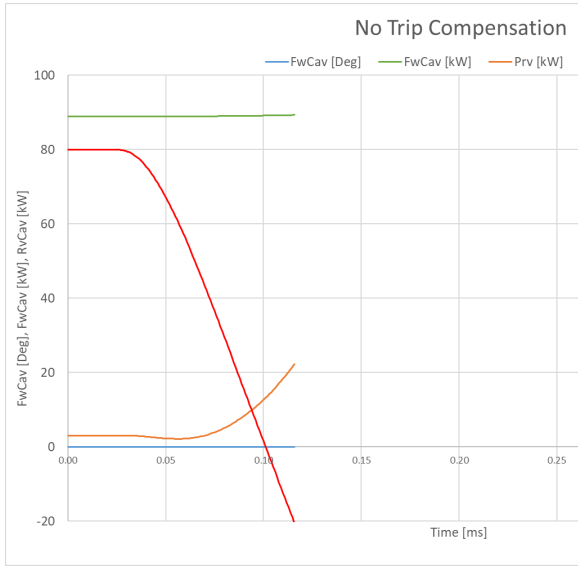


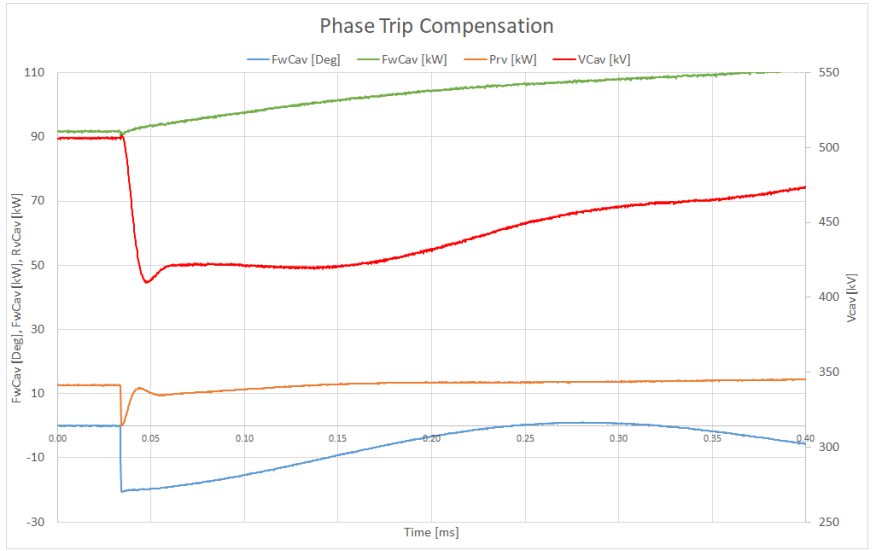


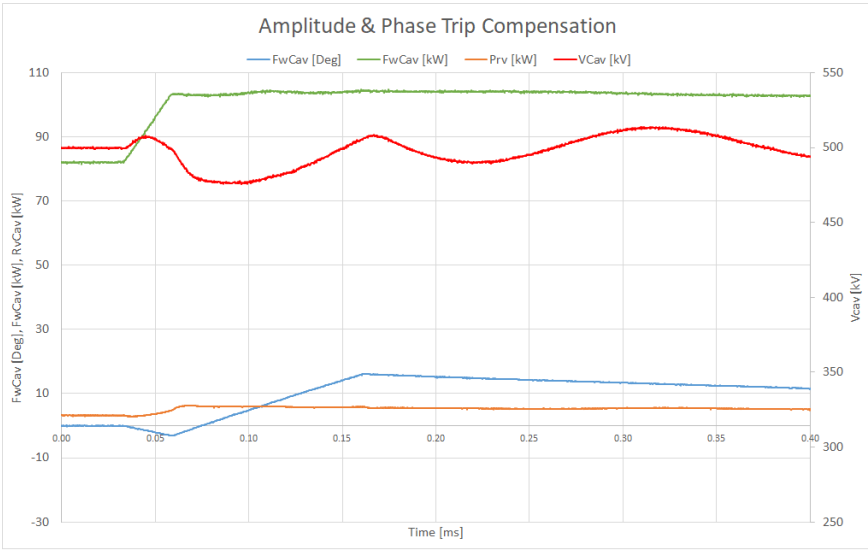
	ALBA	ALBA-II
Average current	250 mA	300 mA
Harmonic number	448	448
Natural bunch duration	15.8 ps	5.5 ps
Main voltage	3 MV	2.4 MV
Number of main cavities	6	6
RF acceptance	2.75 %	8 %
Natural synchrotron frequency	8.5 kHz	2.5 kHz
Transmitter power	90 kW	82 kW
Synchronous phase	160 Deg	153 Deg

ALBA-II Main System

- **Novel Trip Compensation (TC)**
  - **Amplitude and phase response allows to decrease main RF voltage and still survive a cavity trip.**
  - **Secondary phase rotation to avoid oscillations.**







No TC → Beam lost

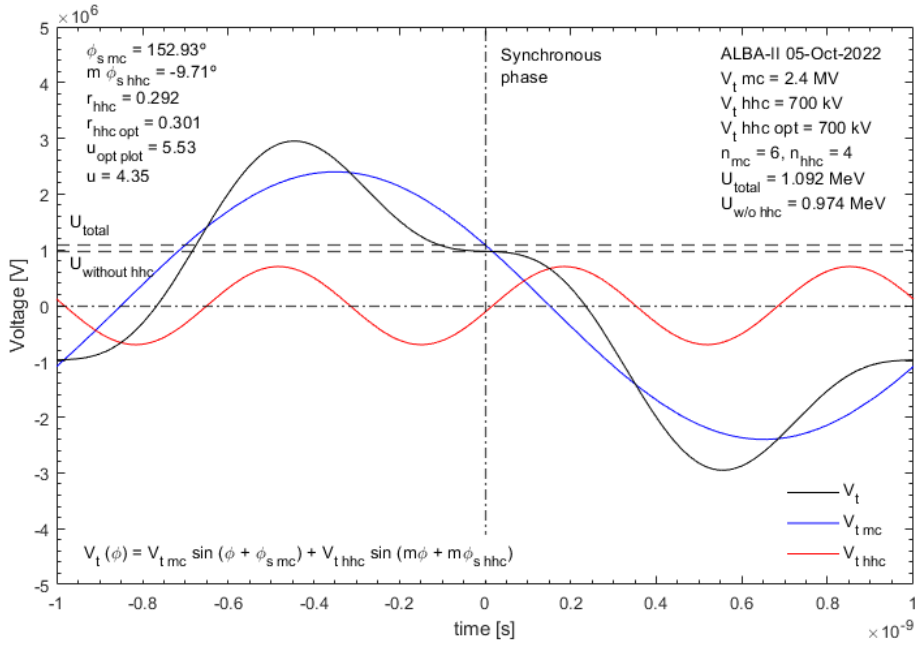
Phase TC → large voltage oscillations

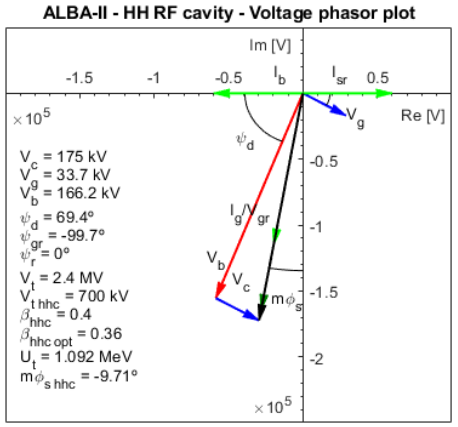
Phase & Amplitude TC → more stable voltage

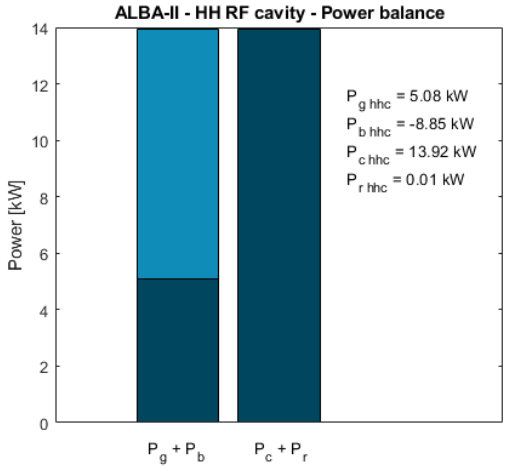
ALBA-II Harmonic System

- **A 3rd harmonic system is needed for lifetime improvement by means of bunch lengthening.**

	ALBA-II
Number of harmonic cavities	4
Total harmonic voltage	700 kV
Coupling factor	0.4
Harmonic synchronous phase	-10 Deg
Harmonic transmitter power (300 mA)	5 kW / cavity
Beam power (300 mA)	-9 kW / cavity
Lengthening factor	4.4
Bunch duration	24.2 ps
Lifetime (transversal full coupling)	17.2 h







ALBA-II Harmonic System

- 1.5 GHz SSPA transmitter prototype.
  - Manufactured by COMMTIA Systems S.A., Spain.
  - Gallium Nitride transistor.
  - Individual circulator for every transistor.
  - FAT performed on 06/10 successfully.

Main frequency	1.5 GHz
Bandwidth	5 MHz
Total power	5.0 kW
Gain	> 65 dB
Transistor drain efficiency	72.0 %
Transmitter efficiency	52.0 %

ALBA-II Harmonic System

- 1.5 GHz DLLRF prototype developed.
  - Struck Innovative Systeme (SIS):
    - uTCA.4
    - SIS8300KU
    - SIS8864
    - DWC8VM1
  - 10 ADC, 2 DAC + direct output modulator, 64 GPIO, 125 MHz clock rate, …
  - Complete rack with LO generation crate, Plunger motor controller, GPIO patch panel, PSU, …
  - Call for Tender published on 09/22 for main and harmonic DLLRF.

ALBA-II Harmonic System

- **Harmonic EU Cavity according to ALBA Active Design.**
  - **2015: ALBA team started the design of an active 1.5 GHz normal conducting cavity for CLIC Damping Ring and ALBA 3rd Harmonic.**

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).

  - **2018: ALBA, with EU funds, started the construction of a prototype.**

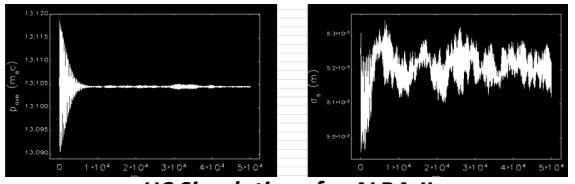
The **prototype construction** was co-funded by ALBA and the European Regional Development Fund (ERDF) within the Framework of the Smart Growth Operative Programme 2014-2020.

  - **2020: Agreement between ALBA, HZB and DESY for testing the cavity.**

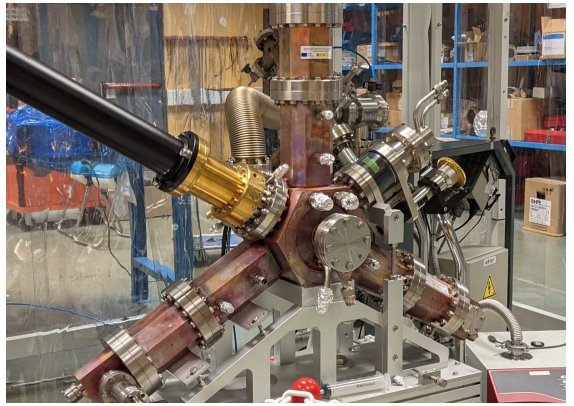
The **prototype tests** were co-funded by ALBA, HZB and DESY through the collaboration agreement RCN-CIN202100124 (2020-2023).

ALBA-II Harmonic System

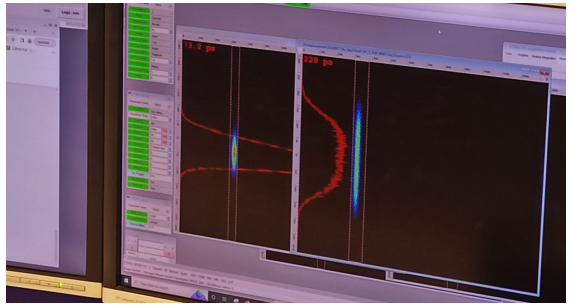
- **Harmonic EU Cavity according to ALBA Active design.**
  - **Jul 2021: Elegant simulation started for ALBA-II**
    - **See I. Bellafont talk 11/10 3rd session.**
  - **Dec 2021: SAT at ALBA facility.**
    - **See J. Ocampo talk 12/10 1st session.**
  - **Sep 2022: Tested at Bessy II with beam.**
    - **See A. Matveenko talk 11/10 4th session.**



HC Simulations for ALBA-II

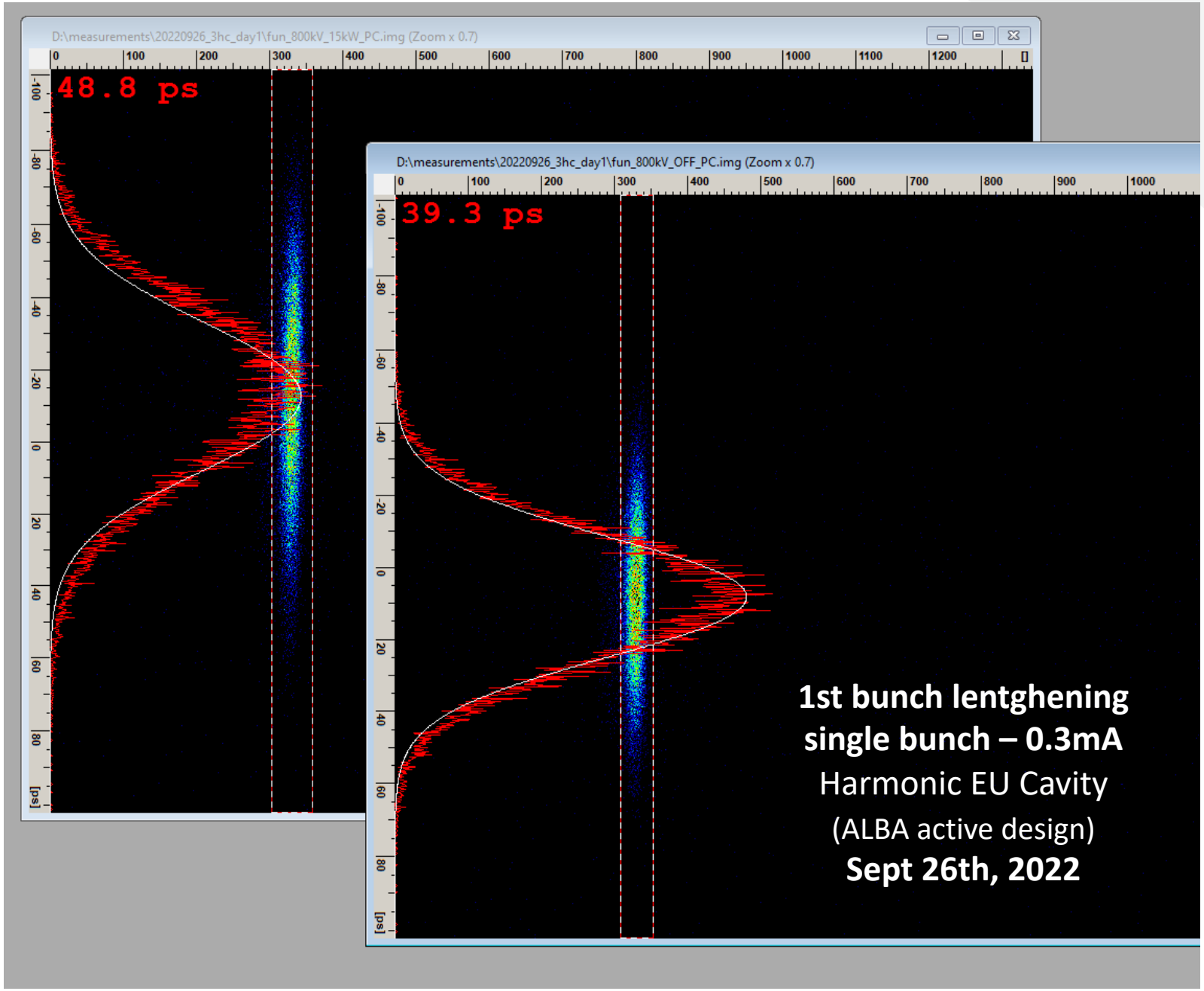


ALBA 3HC design and construction



ALBA 3HC comissioning results

Thanks!


D:\measurements\20220926_3hc_day1\fun_800kV_15kW_PC.img (Zoom x 0.7)
48.8 ps
D:\measurements\20220926_3hc_day1\fun_800kV_OFF_PC.img (Zoom x 0.7)
39.3 ps
1st bunch lentghening
single bunch – 0.3mA
Harmonic EU Cavity
(ALBA active design)
Sept 26th, 2022