Spanish Contribution to CLIC

Reports from ALBA, CIEMAT and IFIC

CLIC Meeting #30

Fernando Toral (CIEMAT)

Juan Fuster (IFIC & Univ. de Valencia)

Francis Perez (ALBA Synchrotron - CELLS)

Outline

1. IFIC-CSIC - contract KE 2638/BE/CLIC
2. CIEMAT – contract KE2679/BE/CLIC
3. ALBA – contract KE 2715/BE/CLIC

IFIC-CSIC – contract KE 2638/BE/CLIC

WP1: Drive Beam (DB) Stripline Beam Position Monitors (BPM) of the CLIC module at CLEX at CERN	**WP2:** Contribution to the XBOX laboratory tests at CERN and HG-RF laboratory at IFIC: Data Acquisition System of an operational control system
WP3: Contribution to the XBOX laboratory tests at CERN and HG-RF laboratory at IFIC: Mechanics and Subsystems	**WP4:** Contribution to the XBOX laboratory tests at CERN and HG-RF laboratory at IFIC: Beam Dynamics aspects

CERN-CLIC contract

- **CERN-CLIC KE contract. Objective**: learn and contribute to the development of the CLIC BPM monitors with the BI group and mostly to the XBOXs systems and transfer know-how to Valencia HG-RF facility
  - 1 WP to contribute to the CLIC Beam Position Monitors:
    - **WP1**: R&D and testing at CTF3 **fully accomplished by 2016**
  - The development work for XBOX and Val HG-RF facility is structured in 3 WPs
    - **WP2:** the electrical setup of an XBOX and in particular the real time control system and Low Level RF (LLRF) is copied and adapted to the facilities at IFIC in Valencia.
      - **Low-level RF design and construction, High-power RF, Laboratory RF equipment**
    - **WP3:** the mechanical setup of an XBOX is copied and adapted to the facilities at IFIC in Valencia.
      - **Mechanical designs, Vacuum systems, Cooling systems**
    - **WP4:** Contribution to the laboratory tests, analysis of the results and RF analysis including relevant beam dynamics aspects, linac optimization and future developments of HG accelerator structures in the XBOX facilitiy at CERN and in the HG-RF lab at IFIC.
      - **High-gradient physics studies:** RF conditioning, breakdown studies, dark current measurements.

  - **Objectives at the XBOXs accomplished beyond the expectations.**
  - **Objectives at the Val HG-RF facility attained to high degree**. Suffered delays in the delivery of equipment. **Commissioning of the facility ongoing.**

CERN-CLIC contract

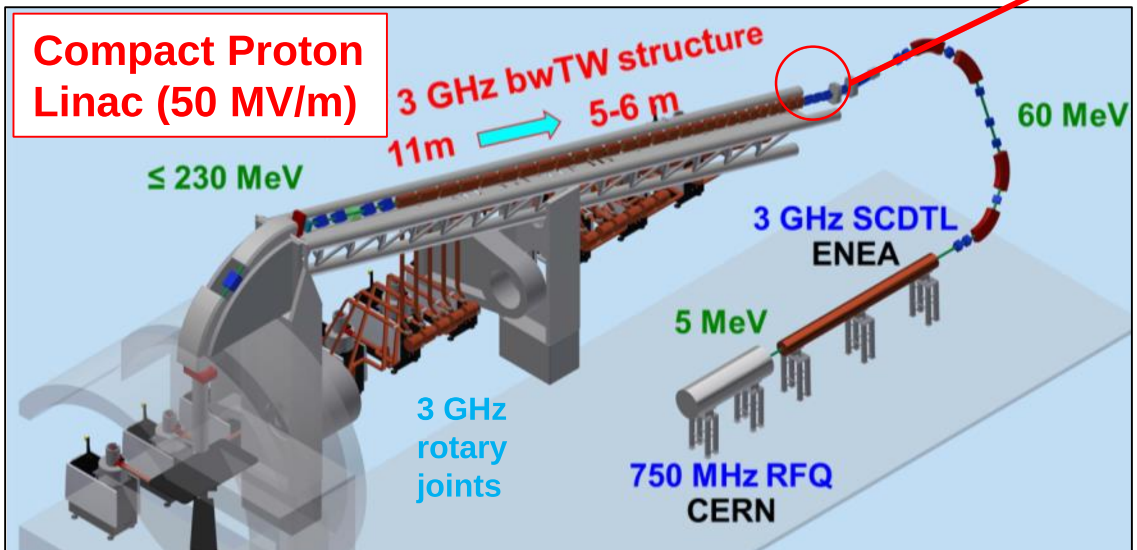
- **Related concurrent financing:**
  - **ERDF funds** to construct the laboratory and purchase equipment.
  - **Marie Curie – IF (H2020) :** D. Esperante, grant to develop the system and upgrade it.
  - **Marie Curie – ITN-OMA (H2020)** : A. Vnuchenko. Optimization of Medical Accelerators.
  - **CompactLight-XLS INFRADEV (H2020): Use of high-gradient for “Free Electron Laser” facilities**
  - **New CLIC-KE contract:** Val HG-RF lab power upgrade, commissioning, first operations and XBOXs support. **Contract agreement accepted by both parties. Currently waiting for last CERN/CSIC signatures!!**

High-Gradient in hadron therapy accelerators

This work is developed within the framework of a Knowledge and Transfer (KT) project thanks to a collaboration agreement between IFIC and CERN:

- **KT "High-Gradient accelerating structures for proton therapy"**
- KE2638/BE/CLIC "Development of accelerator science and technologies associated with the CLIC accelerating structure design"

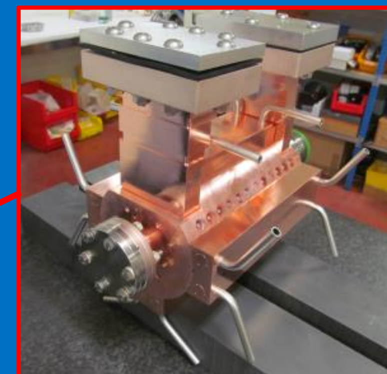
The scope of this project is the **design, construction and high-power test of two high-gradient prototype 3 GHz accelerating** structures at 76 MeV and 213 MeV of a proton linac destined for the TULIP (Turning Linac for Proton therapy) project.



TULIP: Single room facility for tumours irradiation by proton beam, with **fast-controlled energy and beam current variations** for "spot-scanning" and "multi-painting" techniques.

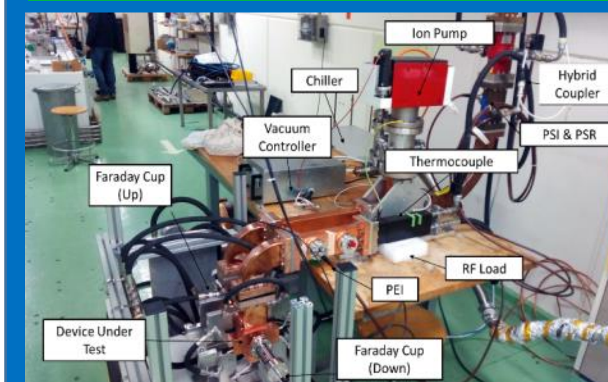
KT structure

First prototype produced following the CLIC standard procedure.



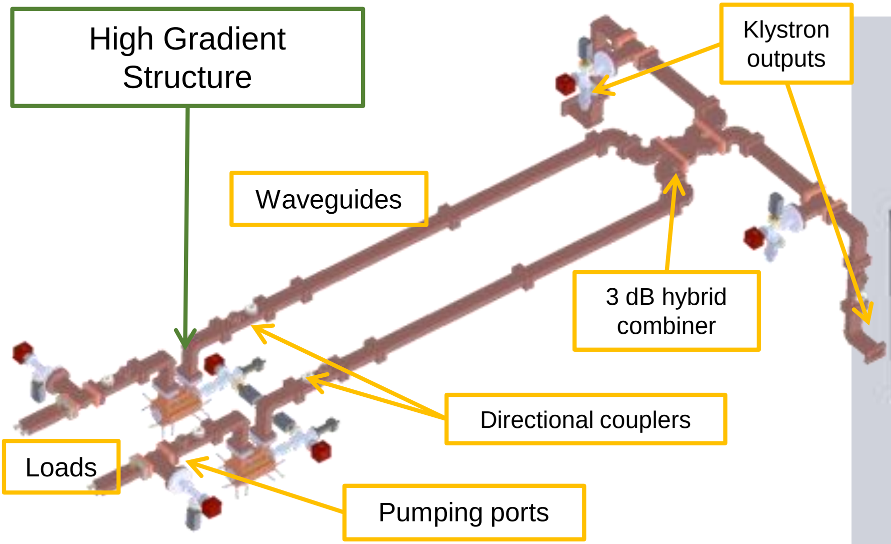
Recently tested in CTF3 (CLIC Test Facility). Another one will be tested at IFIC.

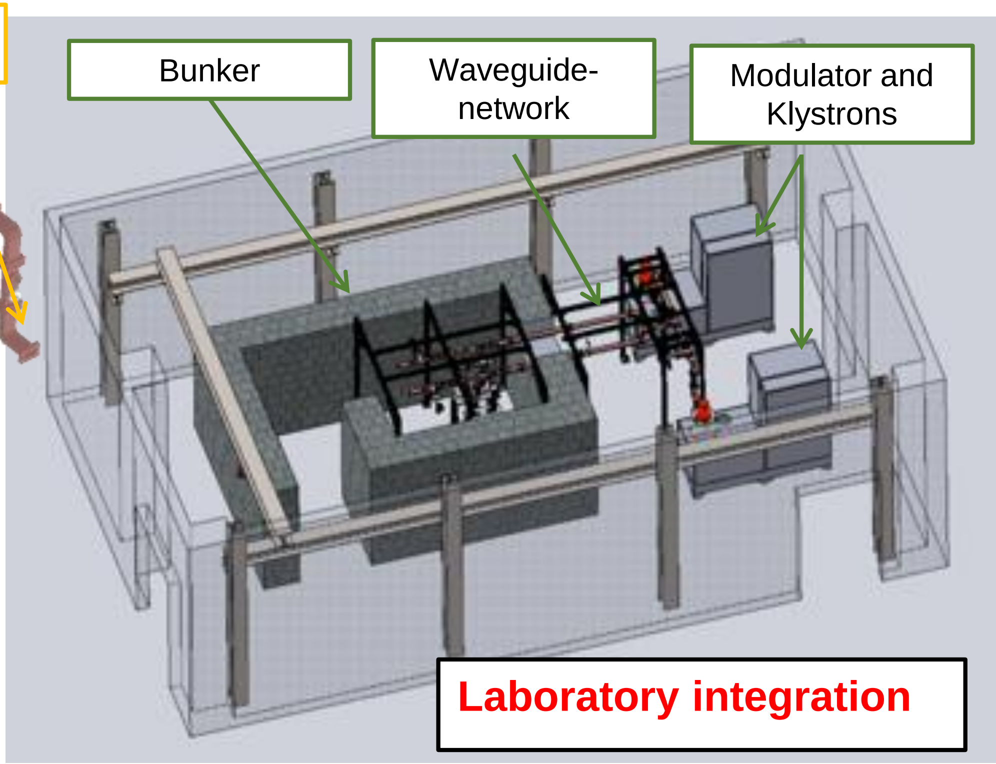
Vacc = 60 MV/m reached!!



Setup built at CTF3

High-Gradient RF laboratory





High-power S-Band (3 GHz) waveguide network:

- 2 test slots
- 40 MW peak
- High repetition rate 400 Hz
- Ultra-high Vacuum (10^{-9} mbar)

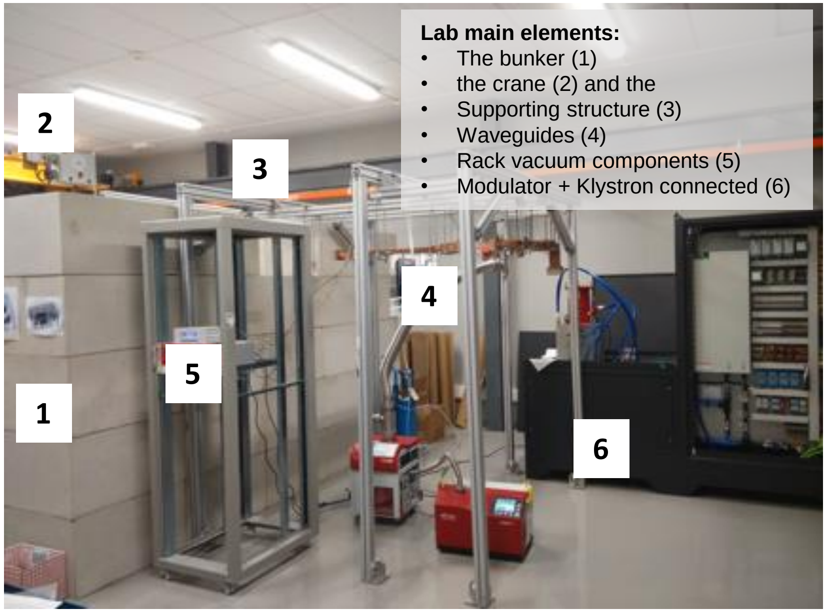
Aim: High-gradient research topics at 3 GHz => **RF testing, breakdown studies and dependencies, structures RF conditioning, studies of High-Power performance, Surface field emission, development of alternative diagnostics and analysis techniques**

Design and development of RF components and technology

Prospects for Val HG-RF facility:

- R&D High-gradient accelerators for hadrontherapy applications:
  - Testing and conditioning of HG cavities and high-gradient phenomena studies
  - Design and development of HG cavities for hadrontherapy linacs
  - High-energy proton imaging in hadron-therapy
- Other applications: Very High Energy Electron (VHEE) linacs for radiotherapy, cargo-scanning, FELs, compton sources…

Laboratory commissioning and tasks performed



High-power modulator technological development in Spain (JEMA)

<u>Val HG-RF specs:</u>

Pulsed High Power RF (HPRF) in S-Band (2.9985 GHz) :

- 2 x pulsed power klystron+modulator (7.5 MW, 5 us pulse, 400 Hz)
- High power waveguide RF network that allows power combining: enables to test 2 structures at a time, 5 us pulse, 200 Hz rep rate

<u>Tasks</u>:

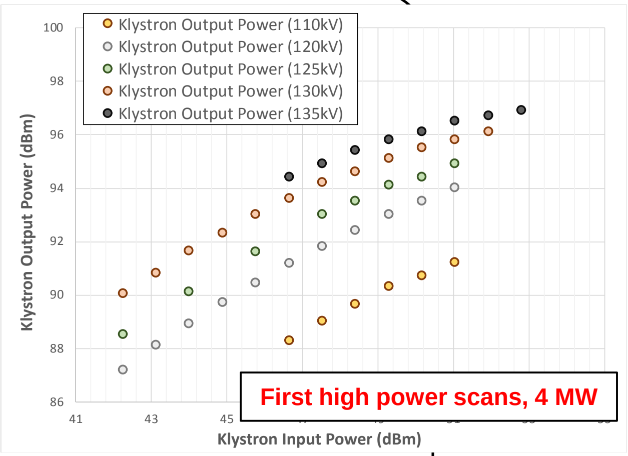
- Completely new Low level RF (LLRF) design. All components already built
- High power RF components being tested
- Commissioning ongoing

<u>Tasks done at XBOXs:</u>

- Design an construction of Xbox-3 LLRF equipment
- Commissioning of Sbox
- Construction and commissioning of Sbox
- Technical support for LLRF and mechanical installations

Laboratory commissioning and tasks performed

Commissioning ongoing:



- First tests started early 2018

- **All LLRF components built and readily available**
- Readout under commissioning
- **First klystron+modulator pulsed to 4 MW!!**

- **Next modulator to be delivered in June. To be installed in July**
- BOC Pulse Compressor to be requested on loan to CERN-CTF3 and installed for after summer
- U. of Valencia agreed to invest and rebuild/condition the bunker.

- **First tests of components expected 4thQ of 2018**

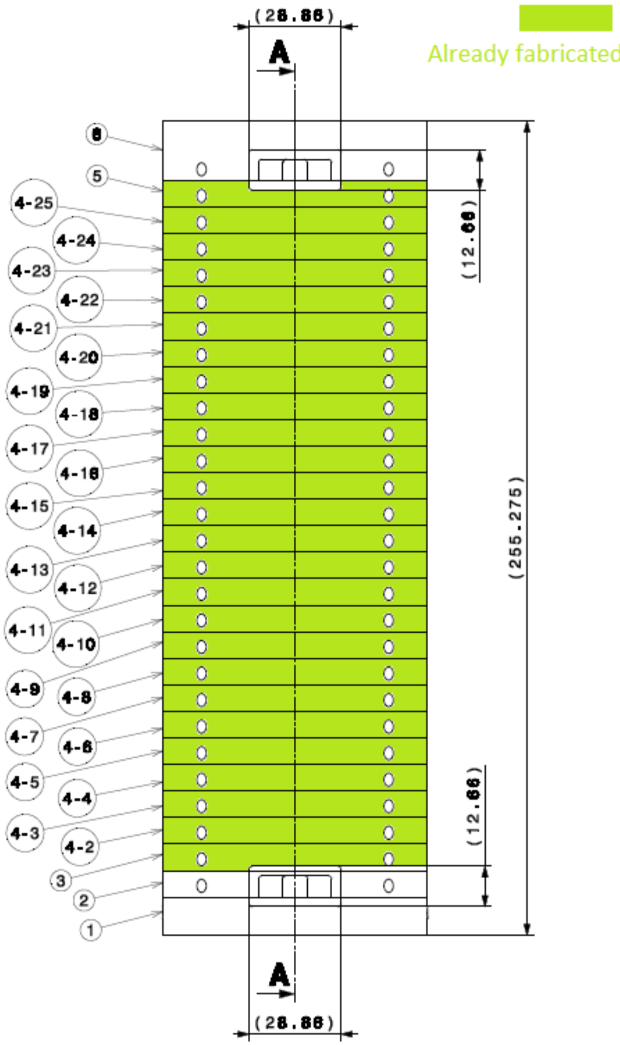
CIEMAT – contracts KE 2679/BE/CLIC

WP1: Accelerating structure for CLIC main linac	**WP2:** Dipole with longitudinally variable field for CLIC damping rings

WP1
Progress on fabrication of an Accelerating Structure for CLIC

Daniel Gavela, Fernando Toral (CIEMAT)
N. Catalan-Lasheras, A. Solodko, J. Souza (CERN)

Fabrication of discs (status)



- **26 central discs fabricated,** currently stored in individual membrane boxes.
- **Fabrication of 3 extreme discs** (RF couplers and beam connections) ongoing.

CLIC

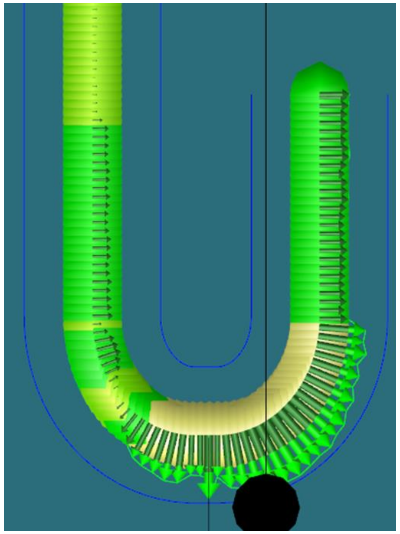
GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA, INDUSTRIA Y COMPETITIVIDAD
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Some comments about discs fabrication

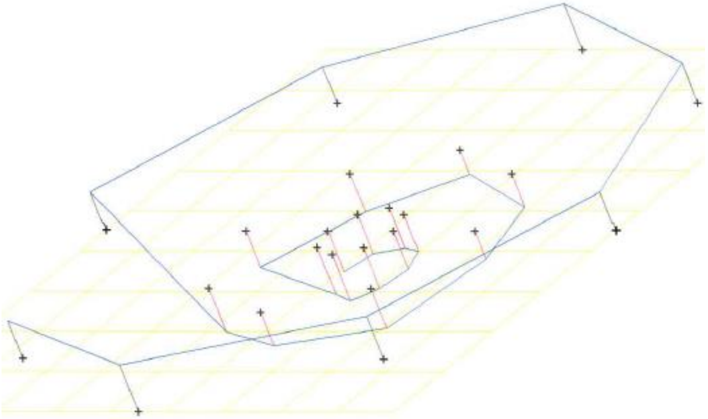
- Final machining step performed on an **ultra-precision machine**, diamond tool (Nanotech, at **DMP, Spain**)

- **Milling** (no turning) of iris area with shape specs achieved. **Advantage -> no step at transition between milled and turned areas**

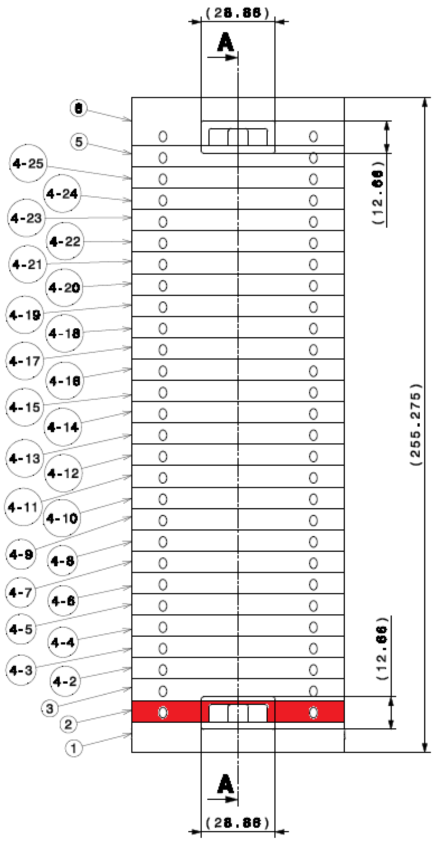
- Some drawing specs are not achievable in a reasonable time or failure rate. These are the **one-micron-tolerances (flatness, paralelism and external diameter**). Certain deviations from these tolerances have been accepted in some discs, especially <u>on flatness errors that will be completely eliminated with the bonding pressure.</u>

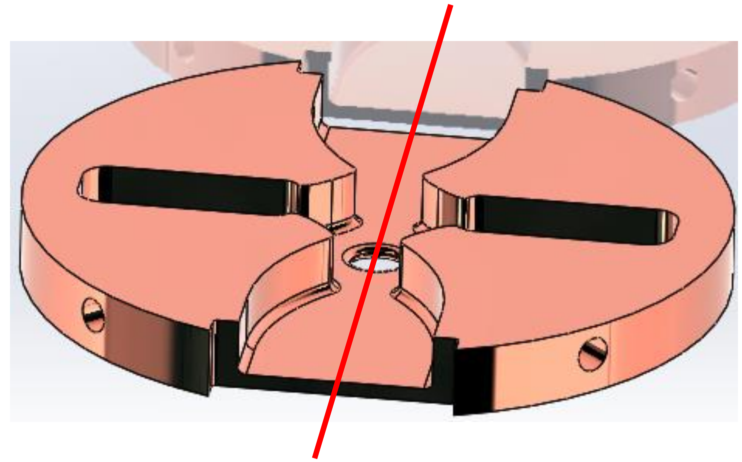


Disk Iris
3D metrology
OK
< +- 2 um



Disc CLIAAS120229: the most difficult one



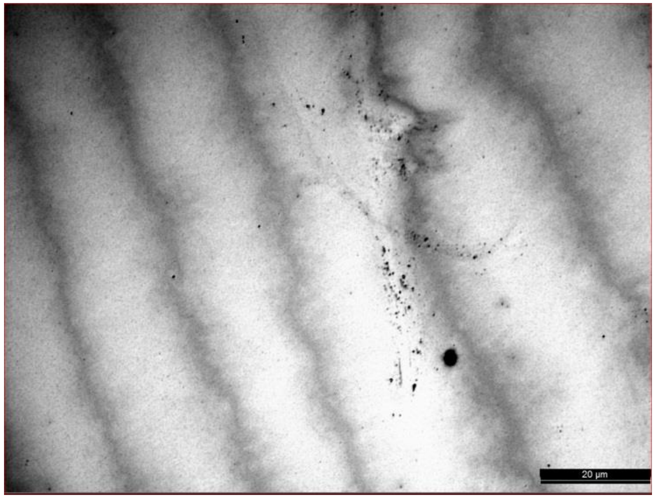


Two massive halves joined by a thin section, with 0,001 total flatness spec

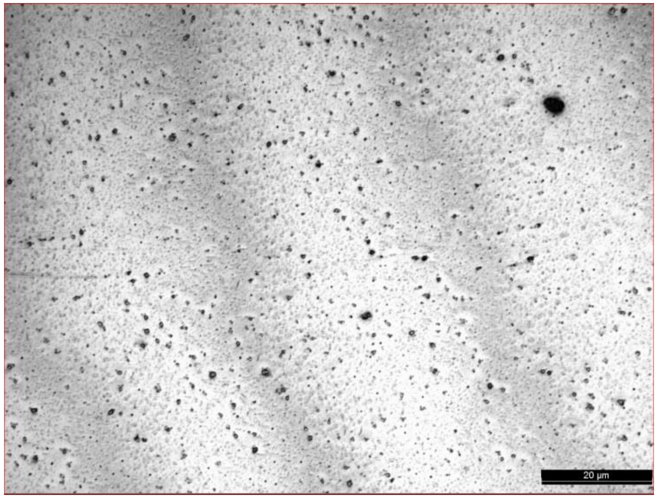
- On one hand: impossible to get a flatness even close to the target
- On the other hand: too much curving of the thin section can affect waveguide performance
- **What kind of dimensions to specify and measure, and what tolerances to apply is under study and discussion**

Bonding furnace validation

- **Four validation tests** have been performed on two candidate furnaces
- **First furnace** was not accepted due to apparition of some (very few) new particles with **Mg and Ca content**
- **Second furnace** (fully metallic with graphite heater) shows generalized contamination of **small (about 1 µm) particles**.
- The origin of that contamination is **under study** (possibly ocurring at furnace venting time / influence of parts set-up at the furnace).



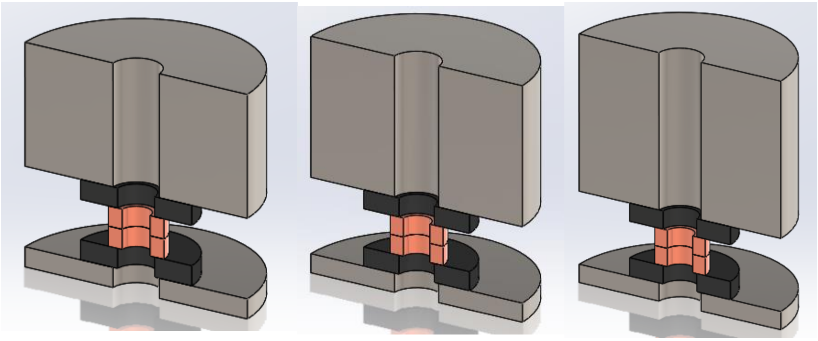
First furnace



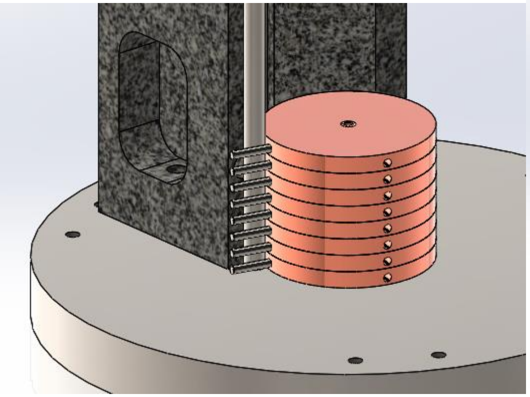
Second furnace

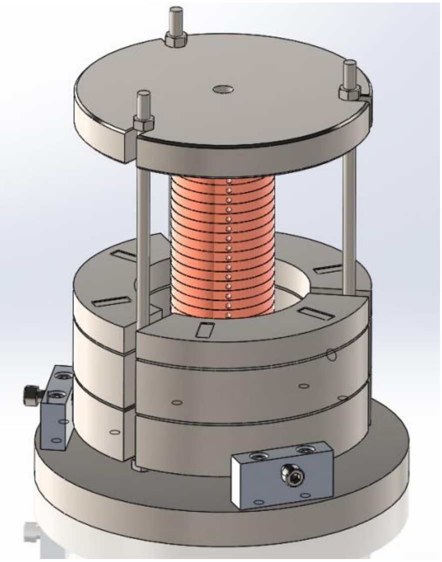
Bonding tests and tooling

- **Bonding test no.1**: ϕ30 mm discs, 3 different bonding pressures.
- Analysis of shape change, bonding quality and grain diffusion
- Target: validation of furnace conditions to get a good bonding and the effect of different bonding pressures

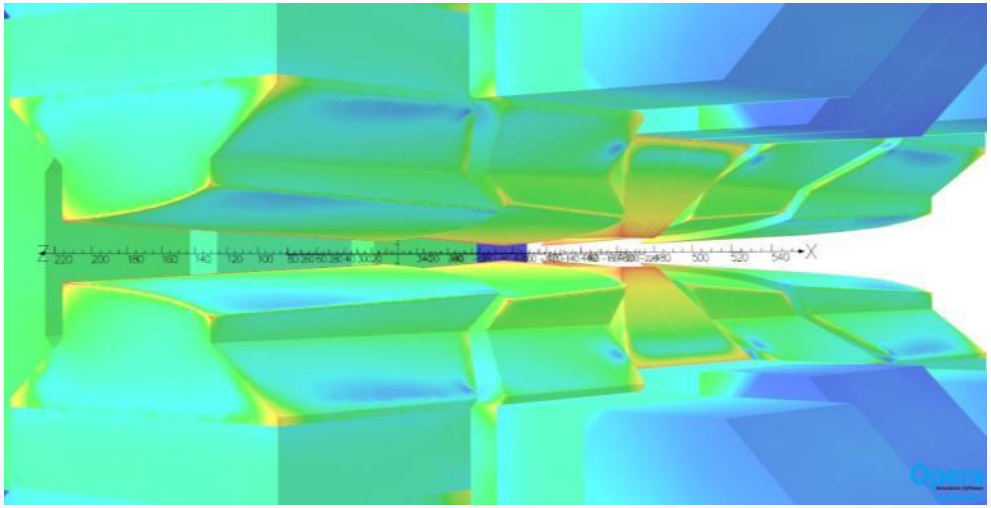


- **Bonding test no.2**: Real diameter discs.
- Final alignment and pressure applying tooling
- **Tooling currently under detailed design and fabrication**





WP2
Design of a Dipole with Longitudinal Variable Field using Permanent Magnets for CLIC DRs



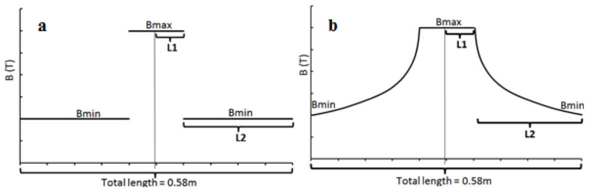
M. A. Domínguez, F. Toral (CIEMAT), H. Ghasem, P. S. Papadopoulou, Y. Papaphilippou (CERN)

Magnet Overview

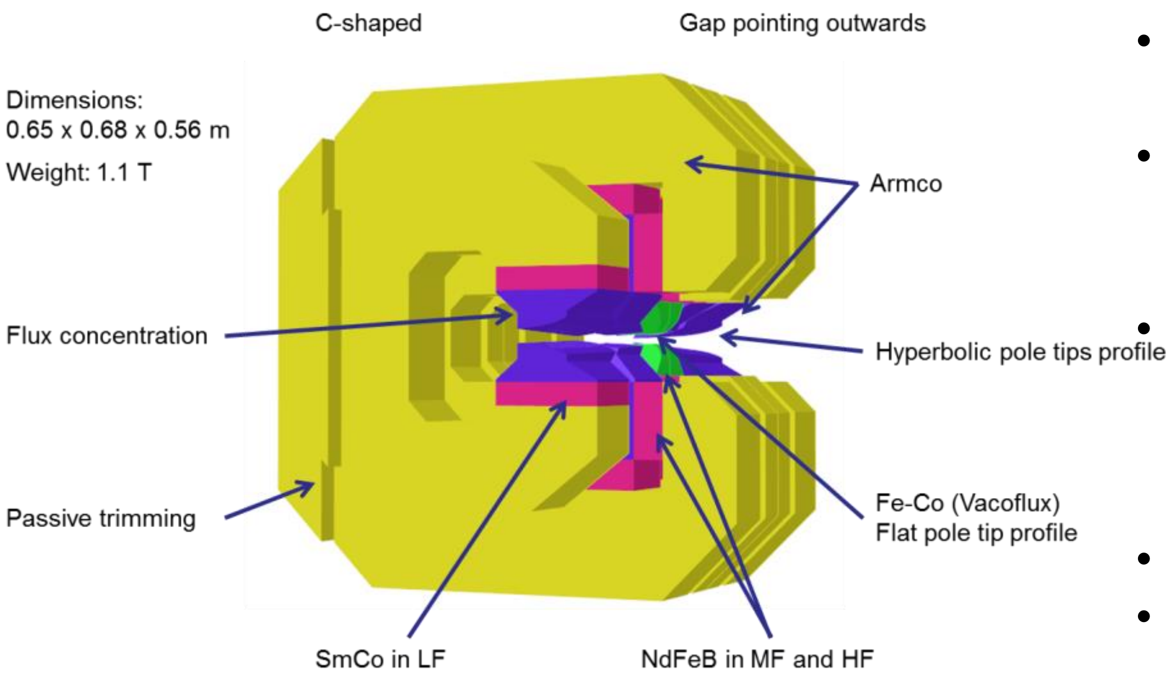
- Ciemat contribution to CLIC Damping Rings:
  - Design and production of 90 **combined function dipoles with longitudinal variable field**
- Field provided by **permanent magnets**
- **Combined function dipoles**: dipolar (bending) and quadrupolar (focusing/defocusing) field
- **Longitudinal gradient**: reduces the horizontal emittance
- **Four different cases** were analysed: finally the most complicated and effective one is achieved (Trapezium profile case 1)
- **The magnetic design phase is completed,** achieving a higher field peak (2.3T vs 1.7T) and a better emittance reduction factor (F_{TME}=7 vs F_{TME}=4) than the ones originally demanded in the technical specifications

TABLE I
TECHNICAL SPECIFICATIONS

Good field region radius [mm]	5			
Field harmonics [units 1E-4]	~1			
Transverse gradient [T/m]	11			
Magnet length [m]	0.58			
Aperture diameter [mm]	13			
	Step profile	Trapezium profile		
		Case 1	Case 2	Case 3
# of dipoles	96	90	90	90
Dip. field [T·m]	0.625	0.667	0.667	0.667
Bmax [T]	1.7666	1.7666	1.7666	1.7666
Bmin [T]	0.8737	0.7791	0.7508	0.7146
L1 [mm]	65.858	3.352	13.836	26.488
L2 [mm]	224.142	286.648	276.164	263.512



Magnet Overview



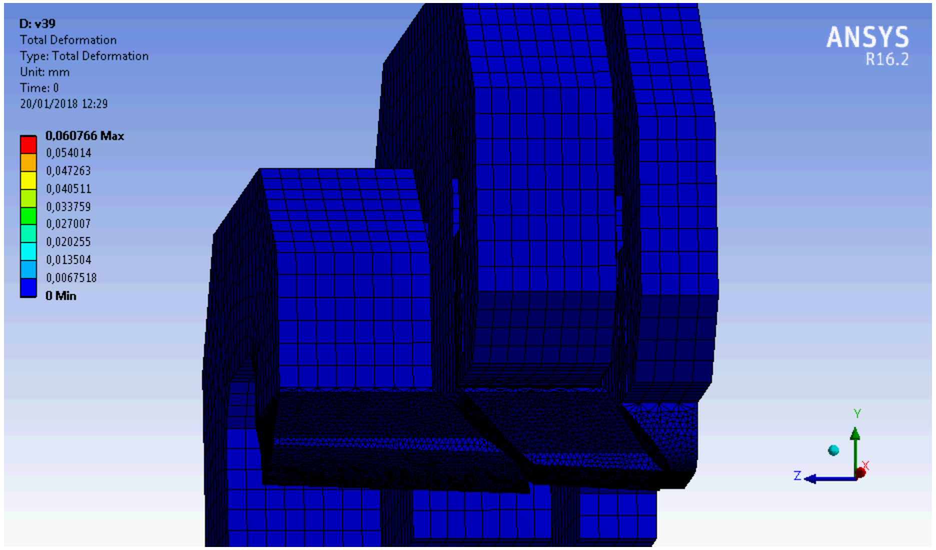
- Fixed field provided with **permanent magnets**
- Max Temp variation ±0.1ºC => **No specific temperature** compensation
- Taking into account radiation tolerance, volume and weight, maximum remanent magnetization, cost,…:
- **SmCo** in the low field region
- **NdFeB** in the high field region

- C-shaped magnets: efficient use of space
- Gap is pointing outwards to ease synchrotron radiation evacuation
- Yoke made of pure iron (Armco). Average field below 1T
- **High saturatio**n in the high field region pole => Fe-Co (Vacoflux) preferred

Mechanical design

- Forces (analytically calculated with VW method):

	LF	MF	HF
Y axis	5272 N	5957 N	5425 N
Z axis	1047 N	1210 N	0 N (symmetry)



- Maximum Stress: 69 Mpa

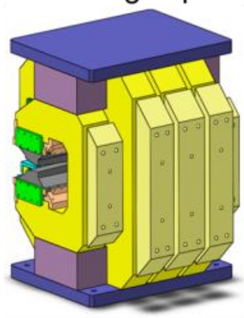
- Max. Deformations:
  - Y axis: 0.06 mm
  - Z axis: 0,009 mm

- **Including these deformations in the Opera model, the multipole values are still kept within the desired values**:

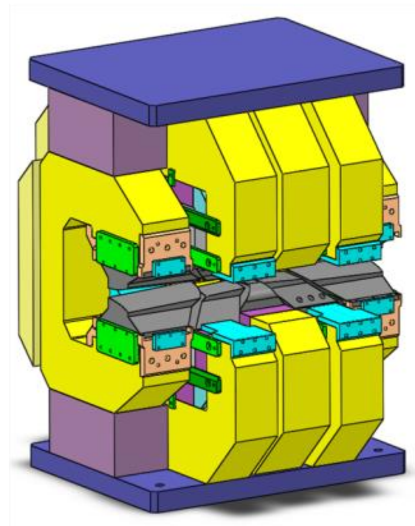
	b1	b2	b3	b4	b5	b6	b7	b8	b9	b10
Base	10000	-567.9	5.5	2.1	-0.1	-0.1	-0.0	0.0	-0.0	0.0
Def	10000	-567.7	5.6	2.0	-0.2	-0.2	-0.1	0.0	-0.0	0.0

Mechanical design

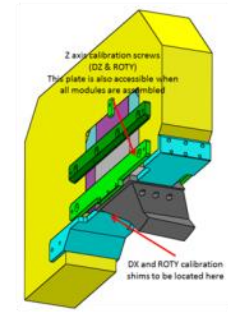
Field trimming implementation



how the ±5% field trimming will be implemented

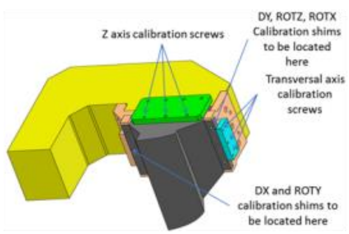


Medium Field module



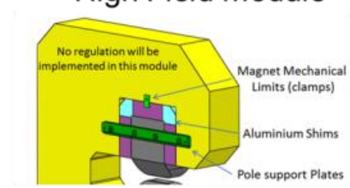
magnets and poles fixation and the pole tip regulations

Low Field module



magnets and poles fixation and the pole tip regulations

High Field module



No regulation will be used in the high field module.

Designed in collaboration with PROACTIVE R&D

This is the present design phase. **The different modules will be mounted attached to the upper and lower support plates.** Firstly, these plates will be fixed to the high field module and then the rest of the modules will be mounted laterally**. A keyway will be machined in the support plates and modules, and a key installed to serve as a guide during the mounting phase**. Transversal rods will be used to control the approximation due to the considerable attracting forces appearing between the modules.

ALBA – contract KE 2715/BE/CLIC

WP1: Test with beam of the CLIC DR Stripline	**WP2:** Beam impedance and collective effects simulations and measurements
WP3: Beam size measurements, simulations and instrumentation development	**WP4:** Design Study of an active 1.5 GHz RF System

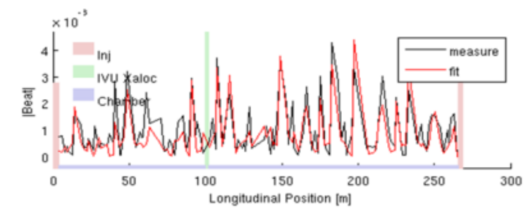
ALBA - WP2: Beam impedance and collective effects simulations and measurements

The main objective of this work package is to collaborate in the development of simulating tools and benchmark the results in a real accelerator similar to the Damping Ring, i.e. ALBA Storage Ring.

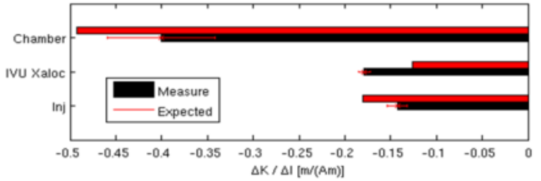
This work package has been **completed during 2015 and 2016**, with visits to each other institute, join simulations and join beam tests at ALBA. The results of the collaboration concluded in **three papers**:

Beam-based Impedance Characterization of the ALBA Pinger Magnet.
U. Iriso, T.F. Günzel (ALBA-CELLS), E. Koukovini-Platia, H. Bartosik, G. Rumolo (CERN). IPAC 2015.
accelconf.web.cern.ch/AccelConf/IPAC2015/papers/mopje027.pdf

Utilizing the N beam position monitor method for turn-by-turn optics measurements.
A. Langner (CERN & Hamburg U.) , G. Benedetti, M. Carlà, U. Iriso, Z. Martí (ALBA
J. Coello de Portugal, R. Tomás (CERN).
Phys. Rev. Accel. Beams 19 (2016) no.9, 092803.



Local transverse coupling impedance measurements in a synchrotron light source from turn-by-turn acquisitions.
M. Carlà, G. Benedetti, T. Günzel, U. Iriso, and Z. Martí.
Phys. Rev. Accel. Beams 19 (2016) , 121002.



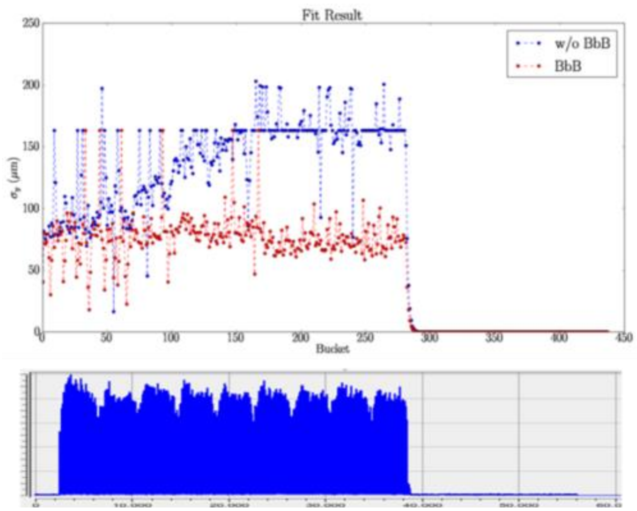
ALBA - WP3: Beam size measurements, simulations and instrumentation development

The main objective of this project is to collaborate in the development of instrumentation of bunch by bunch transverse beam size diagnostics and to test this instrumentation in a real accelerator similar to the Damping Ring, i.e. ALBA Storage Ring.

This work package has been **completed during 2015 and 2016**, with visits to each other institute and join beam tests at ALBA. Two different instrumentation and diagnostics setups have been tested:

- *Fast gated camera for bunch by bunch transverse beam size measurement*
- *“Speckle” measurement tests, using nanoparticles*

The results of the collaboration concluded in **two papers**:



Transverse beam profile reconstruction using synchrotron radiation interferometry
L. Torino and U. Iriso. Phys. Rev. Accel. Beams 19 (2016), 122801.

Transverse Beam Size Diagnostics using Brownian Nanoparticle at ALBA.
M. Siano, B. Paroli, M. A. C. Potenza (Università Milano and INFN),
A. Goldblatt, S. Mazzoni, G. Trad (CERN),
U. Iriso, A.A. Nosych, L. Torino (ALBA-CELLS).
IBIC 2016. accelconf.web.cern.ch/AccelConf/ibic2016/papers/mopg73.pdf

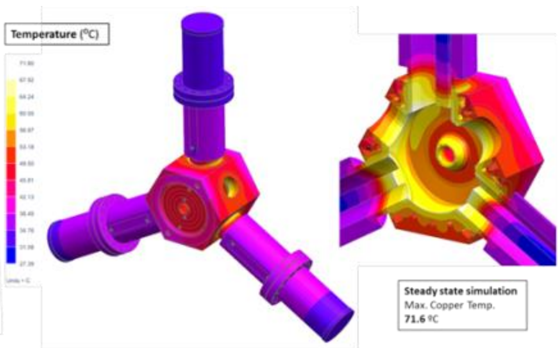
ALBA - WP4: Design Study of an active 1.5 GHz RF System

The aim of this work package is the development of the design of an RF system for the Damping Ring with a beam loading compensation scheme based on the phase voltage control via a digital LLRF. The objective of the work package is to design the cavity and a digital LLRF with active beam loading compensation.

The design of the cavity, including the electromagnetic simulations, the mechanical design and the thermal and stress simulations, **has been completed** with the result of technical specifications for the construction of a prototype cavity. A call for tender for the construction of a prototype will be launched in 2018 using ALBA R&D budget.

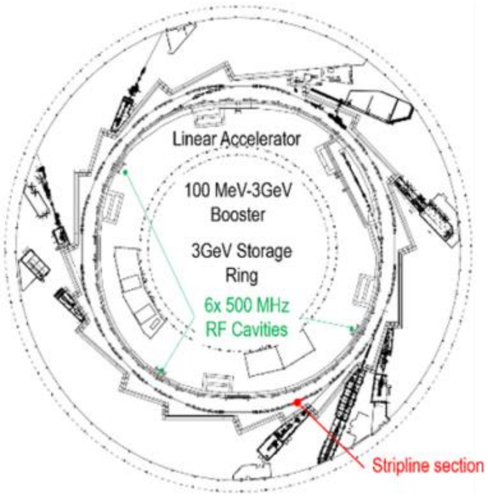
The results of the collaboration is also presented in one paper:

1.5 GHz Cavity Design for the CLIC Damping Ring
and as Active Third Harmonic Cavity for ALBA.
B. Bravo, J.M. Alvarez, F. Perez, A. Salom [ALBA-CELLS].
IPAC 2017.
accelconf.web.cern.ch/AccelConf/ipac2017/papers/thpik0

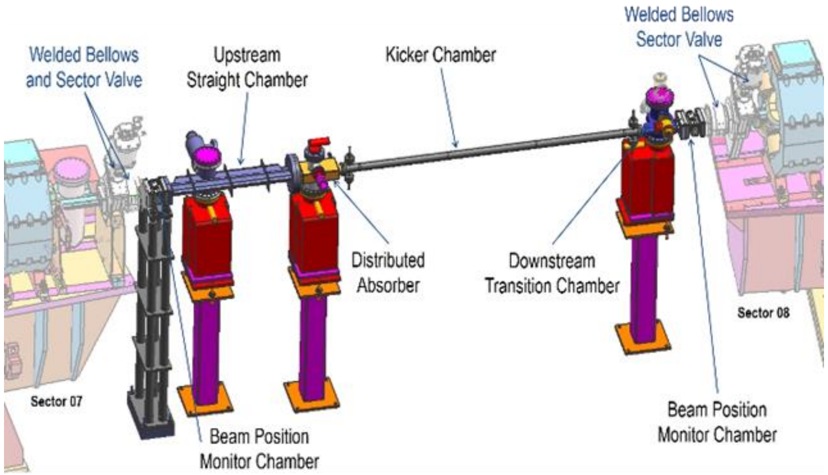


ALBA – WP1: Test with beam of the CLIC DR Stripline

The main objective of this project is to test the stability of the proposed stripline kicker and its pulser in a real accelerator with beam. For that, these elements shall be installed in the ALBA storage ring.



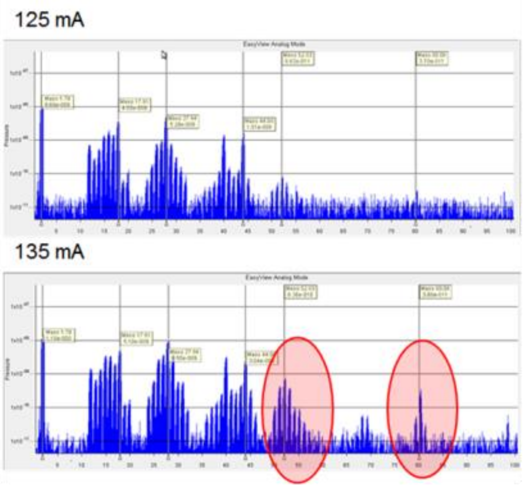
All the preparation work for the installation of the kicker in the ALBA storage ring were performed during 2015 and 2016, including the design and purchasing of transition vacuum chambers and the electronics equipment.



ALBA – WP1: Test with beam of the CLIC DR Stripline

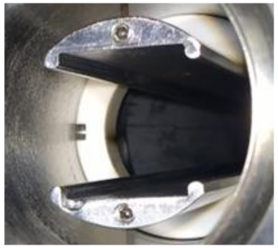
The installation of the Kicker in the ALBA storage ring was done in January 2017, but due to **vacuum problems** was removed after few days of beam conditioning. In March 2017, the Kicker was installed again, and again, it had to be removed due to vacuum problems.

Two reasons have been analysed related to the vacuum problems: the **impact of direct synchrotron radiation in the ceramic supports** and the **finding of the glue "Loctite" in the screws fixing the ceramic supports**.



RGA shows the presence of high masses

Upon opening the stripline,

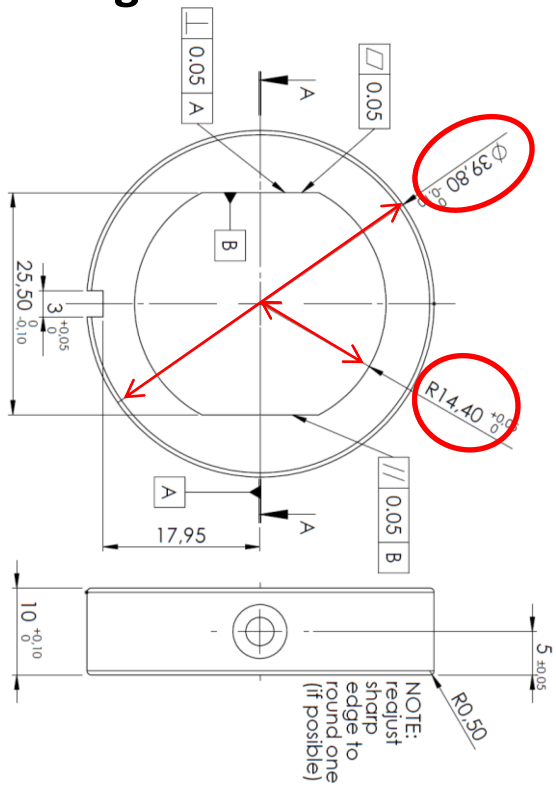


SR on the MACOR rings

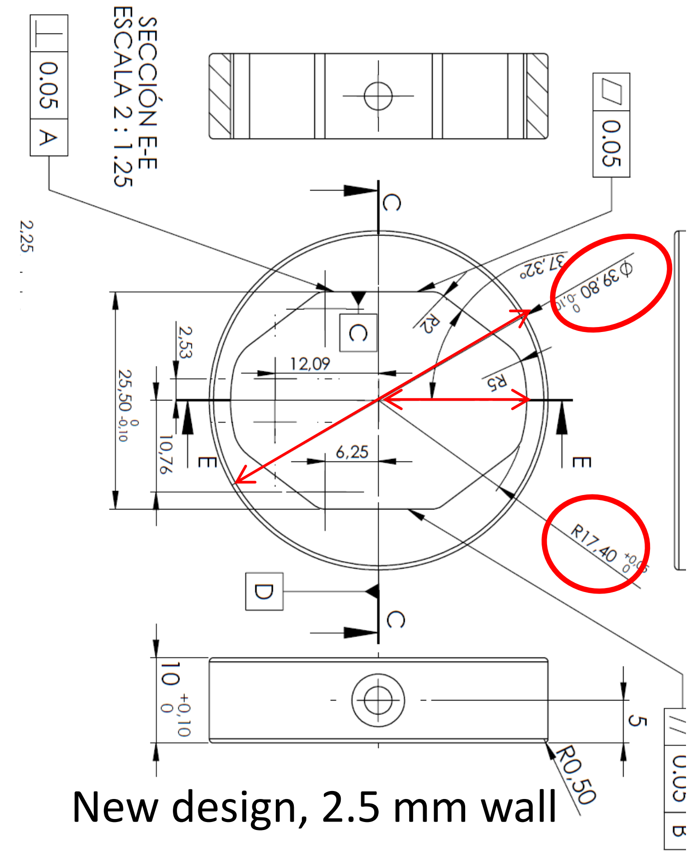
Loctite on the electrodes

ALBA – WP1: Test with beam of the CLIC DR Stripline

- **New design of the MACOR rings with larger clearance in the horizontal plane**



Original design, 5.5 mm wall

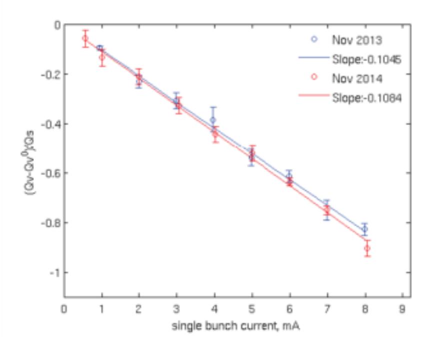


New design, 2.5 mm wall

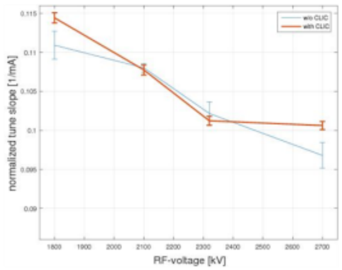
New ceramic supports purchased and **reinstallation performed on January 2018.**

MEASUREMENTS WITH BEAM

Beam Coupling Impedance



The transverse contribution of the stripline has been estimated from the change on TMCI threshold and detuning slope measured before and after the stripline installation,



Normalised tune slope for different RF voltages before and after installation of the stripline

The detuning slopes are sensitive to different machine parameters and the machine reproducibility is one of the main limitations of this method.

For this reason, the detuning slopes were taken

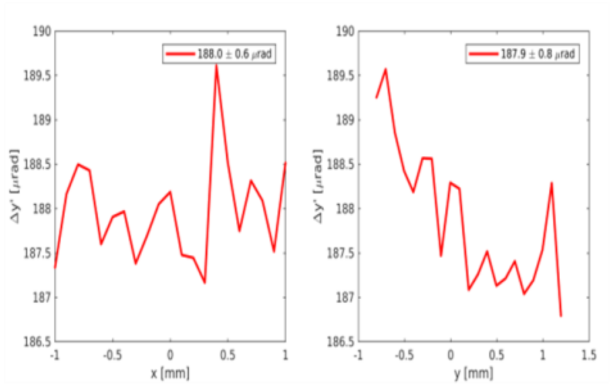
- At different RF voltages (and hence different bunch lengths), and also
- with the in-vacuum undulators open and closed.
- using the nominal ALBA lattice as well as a specifically designed lattice that maximises the beta function at the location of the stripline

Results Z_{eff} =3 .1±15 kΩ/m

Simulation Z_{eff} = 6.2 kΩ/m

ALBA – WP1: Test with beam of the CLIC DR Stripline

Transverse field homogeneity



Kick variation while scanning the beam position in the horizontal (left) and vertical (right) plane, when each electrode is powered to 3.5 kV DC, but of opposite polarity

The stripline kick is determined by measuring the beam angle difference at the entrance and the exit of the stripline, using two pairs of BPMs: two upstream and two downstream of the stripline.

Using the machine corrector magnets, the beam position is scanned in a region 1 mm around the nominal trajectory to determine the field homogeneity.

First results show a variation of ~10^{-3}, and we expect to decrease it further by carrying out a larger number of measurements per position.

The measurements in the figure to the left were limited to 3.5 kV and 10 acquisition/position because partial beam losses due to an incomplete HV conditioning of the electrodes together with the beam.

These results have been presented at IPAC2018:

The Stripline Kicker prototype for the CLIC Damping rings at ALBA: installation, commissioning and beam characterisation
U. Iriso, N. Ayala, M. Carla, T. Günzel, Z.Martí, R. Monge, A.Olmos, F. Perez, M. Pont, M. Quispe. ALBA Synchrotron, 08290 Cerdanyola del Vallès, Spain
M.J. Barnes, C. Belver-Aguilar, Y. Papaphilippou, CERN, Geneva, Switzerland.
IPAC 2018, Vancouver.

ALBA – WP1: Test with beam of the CLIC DR Stripline

During these different tests the following conclusions have been obtained:

- **The vacuum conditioning with beam of the strip line is not well understood**: the outgassing rate is greater than expected and longer measurement periods are needed in order to understand the behaviour.

- **The HV conditioning has successfully performed in the lab, but once installed in the ring and with stored beam, a new HV conditioning has to be performed**. Again, more measuring time with beam it is needed to fully understand the behaviour.

- The impedance of the strip line has been measured, with values compatible with the simulation, but with high error bars**. A new method is being investigated in order to reduce the measurement error**.

- The transverse homogeneity of the strip line has been measured, but at low HV due to the HV conditioning limitations. **Measurements need to be repeated once a proper HV conditioning with beam is performed**.

ALBA – WP1: Test with beam of the CLIC DR Stripline

In this context, the following actions are proposed:

In the timeframe of the present collaboration (until Nov 2018):

a. Install the strip line in the ALBA storage ring in August 2018

b. Perform the following measurements in the period 30/8 – 3/9:
    i. **Repeat the impedance measurement**
    ii. **HV conditioning with beam**
    iii. **Transverse homogeneity measurements**

c. De-install the stripline 4/9

ALBA – WP1: Test with beam of the CLIC DR Stripline

Delays on the development of the pulser due to an error in the manufacturing of the pulser boards have been reported at the beginning of May 2018, with the completion of two pulser foreseen now for September 2018. This delay will make impossible to perform the pulser tests with the stripline installed in the ALBA storage ring before the ending of the present contract (Nov 2018).

Proposal to **extend the present collaboration** in order to complete the following tests:

a. **Investigate the vacuum conditioning with beam** in longer beam time periods, analysing the outgasing rate and measuring with an RGA the outgassing components.

b. **Test the two pulser units with the strip line in the ALBA laboratory**

c. **Install the stripline and the pulser in the ALBA** storage ring and perform the study of the **pulse longitudinal and temporal stability**.

CONCLUSION

The three collaborations are going pretty well, with request to extend some of them

Thanks