Activities on accelerators in Spain

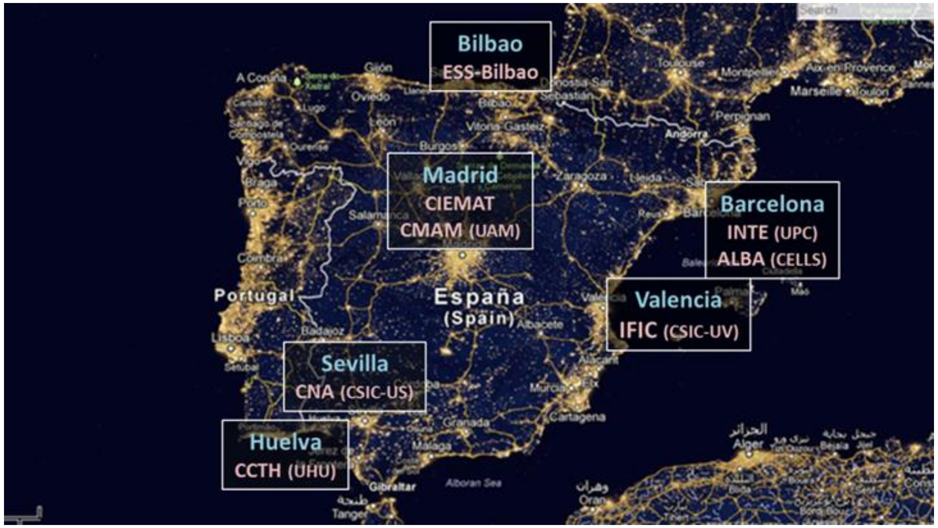
Francis Perez
ALBA Accelerator's Head

on behalf of

CONECTA: Spanish Coordination on Accelerator's Science and Technology

CONECTA

Spanish Accelerator Facilities and Groups



- ALBA - 3rd Generation Light Source - Barcelona
- CNA - Centro Nacional de Aceleradores – US - Sevilla
- CMAM - Centro de Microanálisis de Materiales – UAM - Madrid
- CIEMAT Accelerator Group - Madrid
- IFIC Accelerator Group - CSIC-UV - Valencia
- INTE - Institute of Energy Technologies – UPC - Barcelona
- ESS Bilbao - Bilbao
- CCTH - Centro Científico Tecnológico Huelva – UHU - Huelva

CONECTA

Coordination of the activities of the Accelerator community in Spain

SCOPE

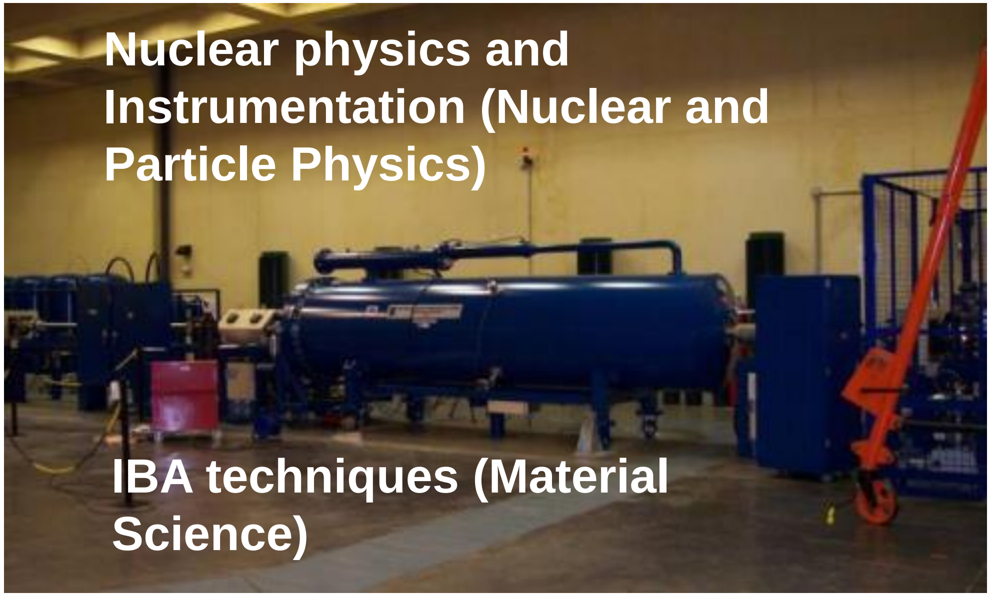
- Contribute to the **implementation of R&D Plans**
- Provide technical consultancy
- Provide support to **education and training**
- Help to coordinate the rationalization of the available resources
- Help to consolidate and recognize professional careers
- Serve as consultant to the industry, in coordination with official bodies
- Provide knowledge and support to the Spanish participation in **international collaborations**
- Gather the needs on accelerator technologies on different scientific fields

MINISTERIO DE EDUCACION Y CIENCIA

Parque Tecnológico Cartuja'93, Avda.Thomas Alva Edison nº 7, E-41092 – Sevilla. Spain
Phone: +34.95.4460553, Fax: +34.95.4460145 cna@us.es

Joaquin Gomez - CNA

3MV Tandem accelerator



Cyclotron
18 MeV (p), 9 MeV (d)

Irradiation (Space technology

Radiopharmaceutical production (Molecular Imaging)

Cincuenta Aniversario
1968 2018
UAM Universidad Autónoma de Madrid

Belonging to UAM
Located in the Cantoblanco Campus
In operation since March 2003
11 M€ of technological investment

CMAM Research Fields
- Archaeometry
- Biophysics
- Energy Related Materials
- Ion-Solid Interactions
- Nuclear Physics
- Photonics

Open facility with competitive access

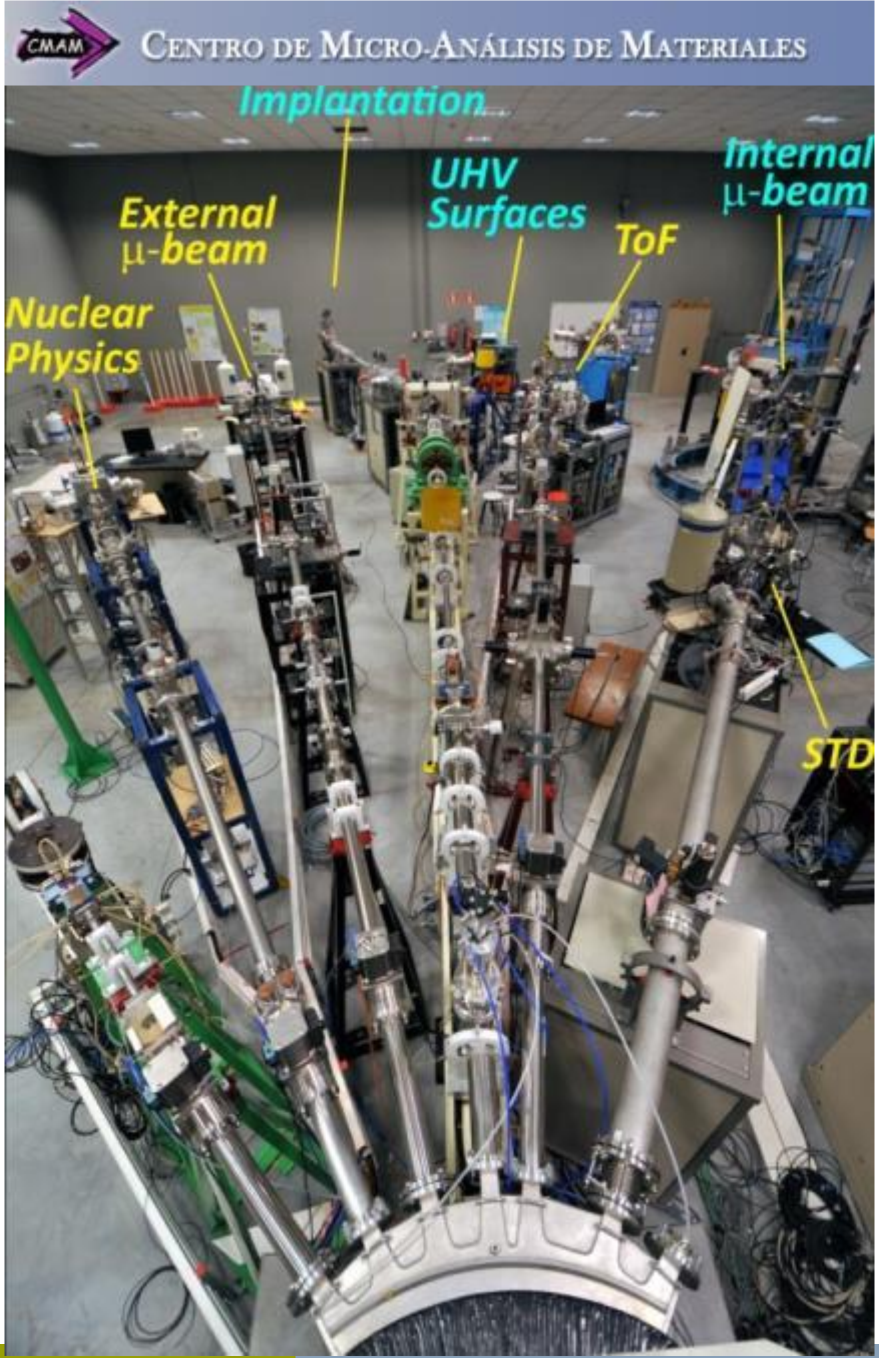
Beamtime periods and deadlines 2018:

Period 00	Period 02	Period 04	Period 06	Period 08	Period 10	Period 12
08 January - 16 February	19 February - 06 April	09 April - 18 May	21 May - 06 July	09 July - 21 September	24 September - 02 November	05 November - 21 December
deadline 5 Dic. 17	deadline 17 Jan. 18	deadline 7 Mar. 18	deadline 25 Apr. 18	deadline 30 May. 18	deadline 4 Jul. 18	deadline 26 Sep. 18

Accelerator & Beamlines

***Tandem accelerator, 5MV*, HVEE.**
The first, High Current, Tandetron Accelerator using the Coaxial Cockcroft-Walton power supply system to reach 5MV.

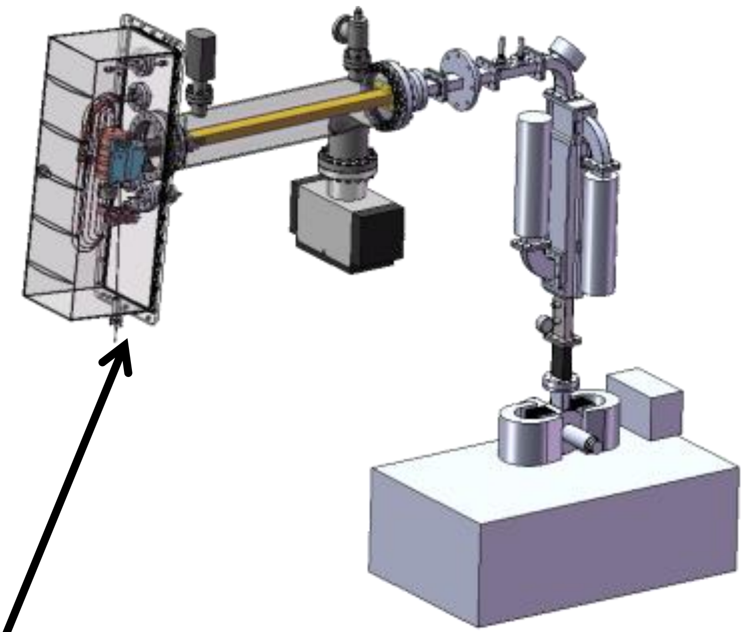
Experimental stations.
Four beamlines with seven experimental stations, including two micro-beams.)



Institut de Tècniques Energètiques inte
UNIVERSITAT POLITÈCNICA DE CATALUNYA

Microtron project at the INTE-UPC

- Design and construction of an electron accelerator with beam recirculation of the **race-track microtron (RTM**) type.
- Quite **compact machine**: the accelerator head dimensions are 60 x 20 x 12 cm approximately.
- Experiments on **material irradiation** with electron beam, **industrial radiography**, **cargo inspection**



Main characteristics	
Beam energies	6, 8, 10, 12 MeV
Energy gain per turn	2 MeV
Injection energy	25 keV
Operating frequency	5712 MHz
Pulse duration	3 µs
Pulse repetition frequency	1 – 200 Hz
Pulse beam current	5 mA

- **Permanent magnets (NdFeB) in-vacuum**
- **Energy switch by change of the extraction orbit**
- **On-axis E-gun with off-axis cathode**

3D image of the interior of the accelerator head / vacuum chamber

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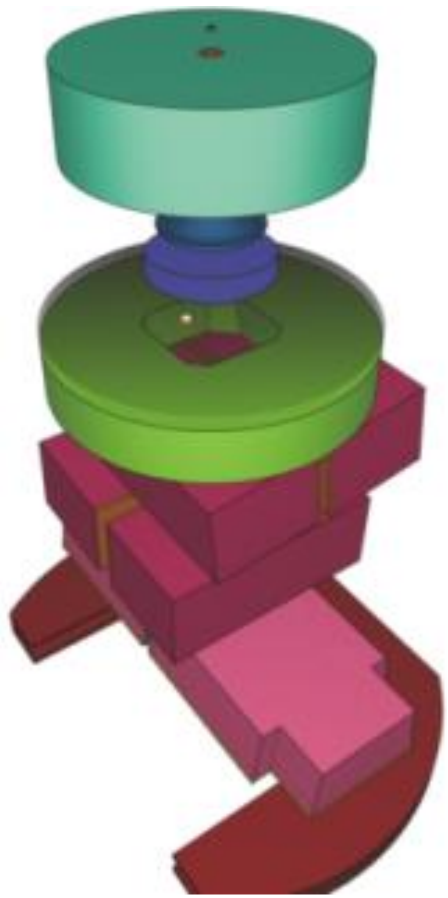
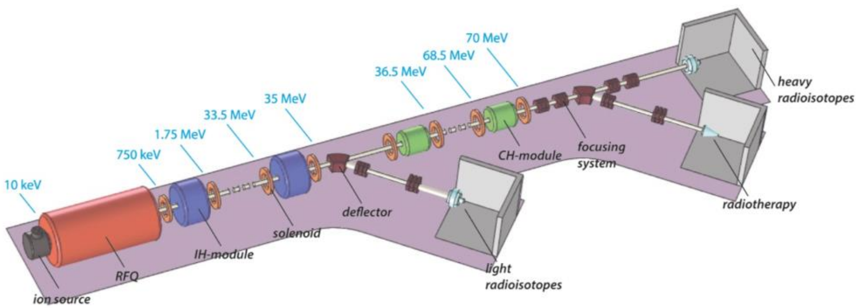
PRIMO - Advanced tool for linac simulation



- PRIMO is a software tool for the Monte Carlo simulation of most Varian models of **clinical linacs**.
- The dose distribution in voxelized patients, or homogeneous phantoms, is also determined. Tools to perform the analysis of these distributions (e.g., dose volume histograms, gamma index) are included.
- It includes a graphical user interface similar to those found in commercial treatment planning systems.
- In collaboration with Universitätsklinikum, Essen
- **Freely available at**
  http://www.primoproject.net

Centro Científico Tecnológico Huelva (CCTH)

Ismael Martel



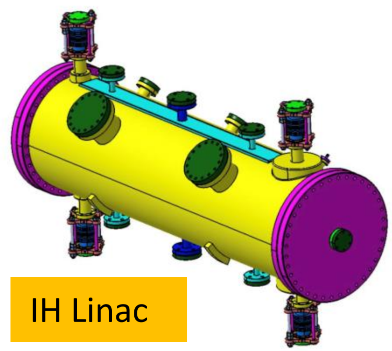
ICH15 – Facility layout

Proyecto ICH15 (CDTI, ITC-20151186)

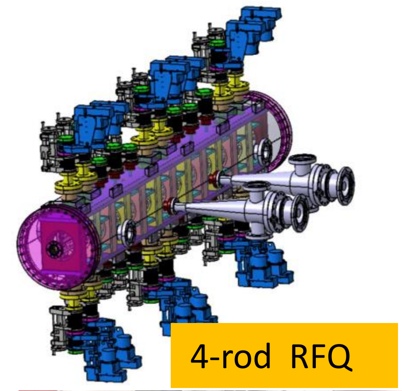
Design of a 70 MeV IH+CH CW **proton linac for radioisotope production and therapy** (uveal tumour). Freq.= 200 MHz.

I= 5 mA , E= 30 MeV & 70 MeV production beam lines

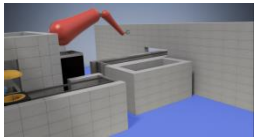
I = 1 uA, E= 70 MeV radiotherapy beam line

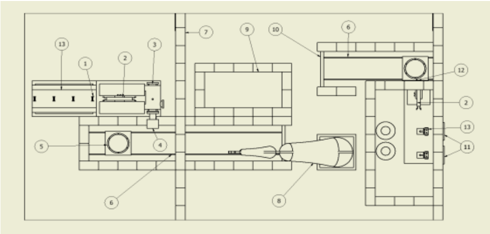


IH Linac

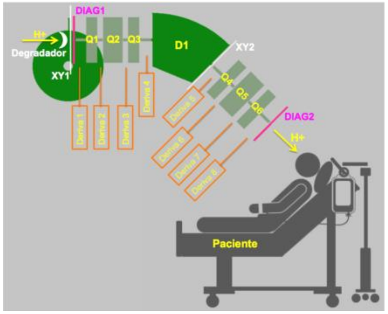


4-rod RFQ





30 & 70 MeV radioisotope production



70 MeV radiotherapy

RFQ & IH prototypes being tested at CCTH – Huelva

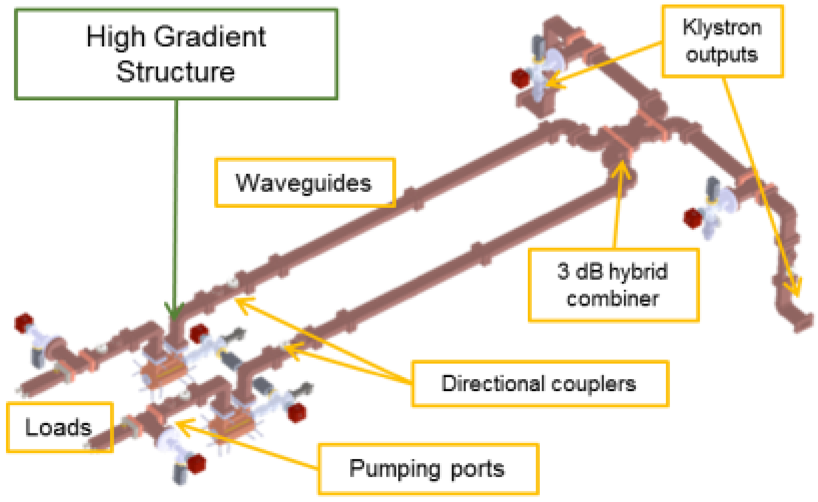
Accelerator R&D, IFIC

http://gap.ific.uv.es/

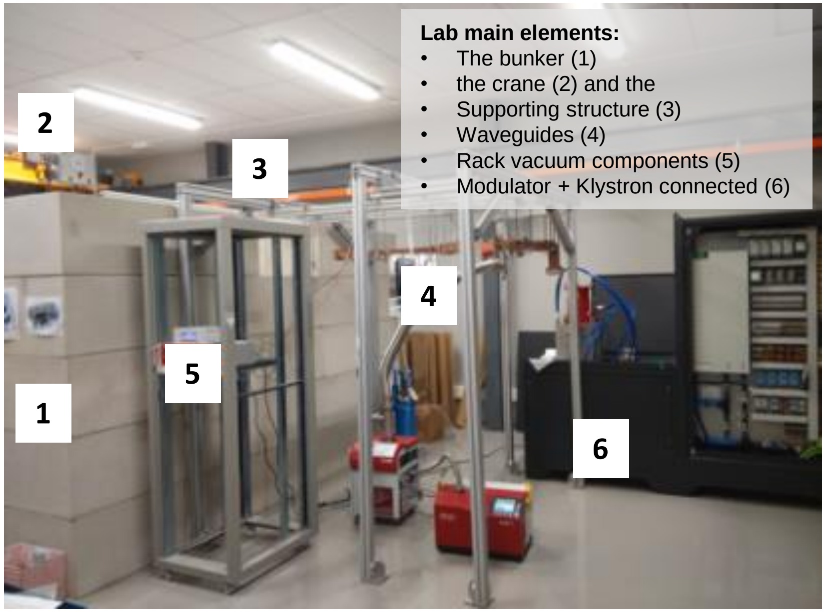
COLLABORATIONS

- **ERDF funds** to construct HG-RF 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.

High-Gradient RF laboratory



High-power S-Band (3 GHz)



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 techniquesDesign 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…

Luis García-Tabarés - CIEMAT

The Electrical Engineering Division at CIEMAT

STRUCTURE

ELECTRIC ENGINEERING DIVISION (33 people)

- ACCELERATOR TECHNOLOGY UNIT (16 people)
- ELECTROMECHANICAL TECHNOLOGY UNIT (9 people)
- POWER SYSTEMS UNIT (6 people)

FACILITIES

Main Offices

Energy & Superconductivity

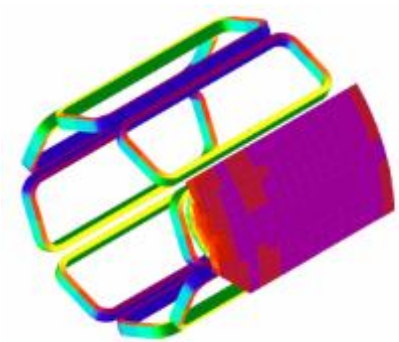
Assembly Hall

Electrical Engineering Division: Areas, Projects and Collaborations

ACCELERATORS	POWER SYSTEMS
Large Facilities ↓	**Storage ↓**
E-XFEL	SH2
FAIR	
LHC Hi-Lumi (CERN)	
CTF3/CLIC (CERN)	
FCC (CERN) & EuroCirCol	
ILC	
IFMIF	**Generation ↓**
TIARA	UNDIGEN+
Small Accelerators ↓	SEA-TITAN
AMIT CYCLOTRON	

Accelerator Technology Unit: Activities & Capabilities

- **Calculations**: Electromagnetic, thermal and mechanical analysis and beam dynamics simulations.
- **Engineering design:** 3-D modeling, fabrication techniques, drawings.
- **Prototyping**: Fabrication and assembly of magnets, RF structures and other accelerator components, including complete compact accelerators.
- **Testing**: Two vertical cryostats, one cryocooler and low power RF measurements.

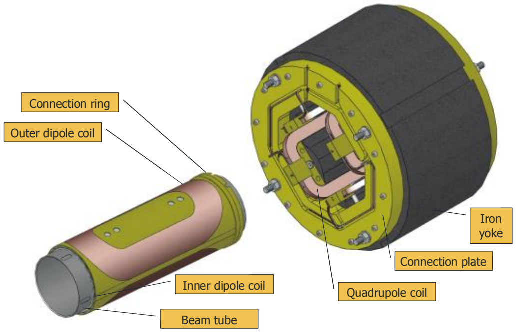


GOBIERNO DE ESPAÑA | MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD | Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

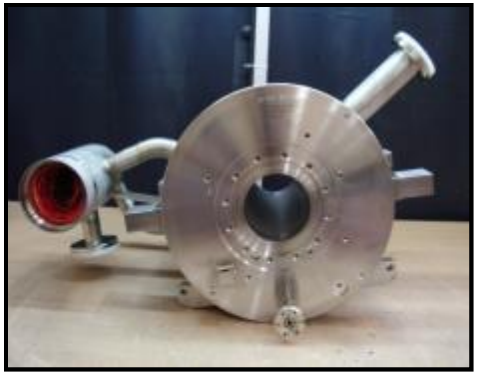
Accelerator R&D activities: CIEMAT

Accelerator Technology Unit: Relevant Projects (I)

CONTRIBUTION TO THE E-XFEL PROJECT (European Free Electron Laser):

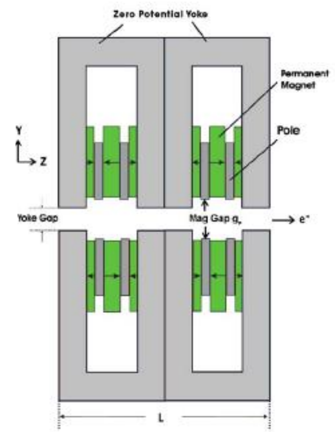


101 Electronic Control Racks



103 Combined Superconducting Magnets

101 Moving Tables

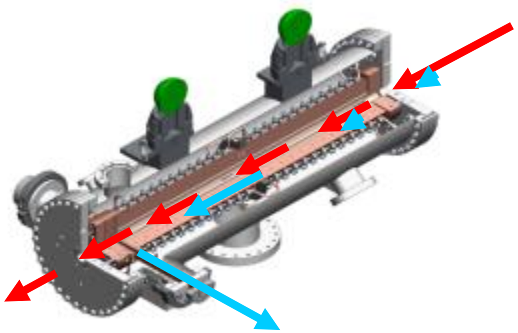


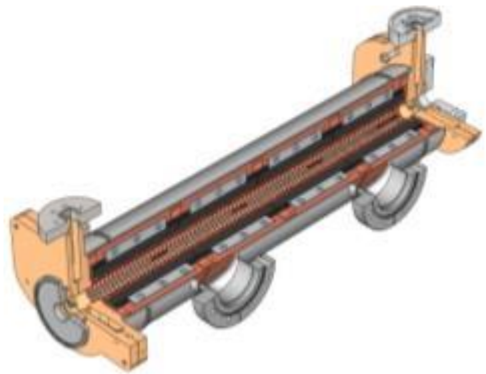
3 Phase Shifters

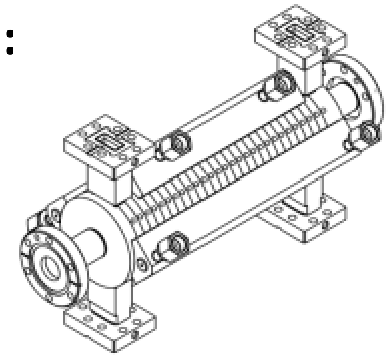
Accelerator R&D activities: CIEMAT

Accelerator Technology Unit: Relevant Projects (II)

CONTRIBUTION TO THE CLIC PROJECT (Compact LInear Collider):



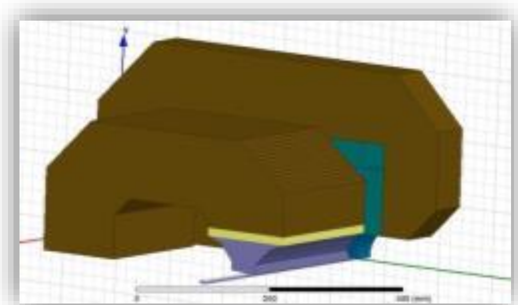




1 Accelerating Sructure

12 Power Extraction Transfer Structures for CTF3

1 Double Length Power Extraction Transfer Structure



1 Damping Ring Gradient Dipole

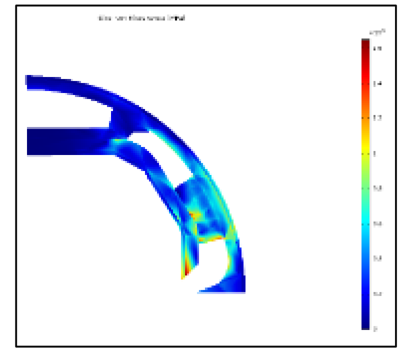
Accelerator R&D activities: CIEMAT

Accelerator Technology Unit: Relevant Projects (III)

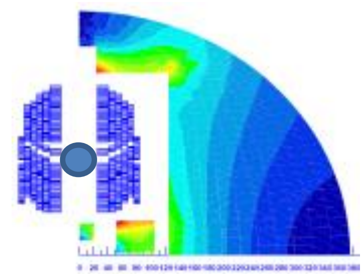
CONTRIBUTION TO THE LHC-HiLumi & FCC (Future Circular Collider) PROJECTS:

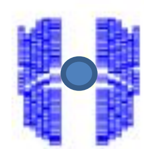
Radiation resistant high aperture SC Sextupole

Combined Corrector Dipole for LHC-HL



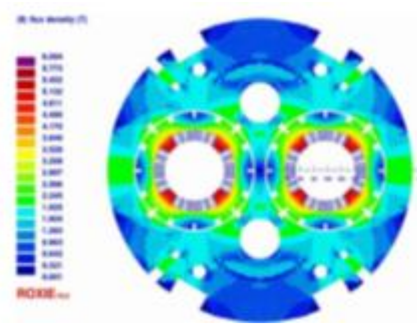
Participation in the FCC Vacuum Beam Screen Design





Analysis of the Common-Coil option for the FCC main Dipoles

Radiation resistant high aperture SC Octupole

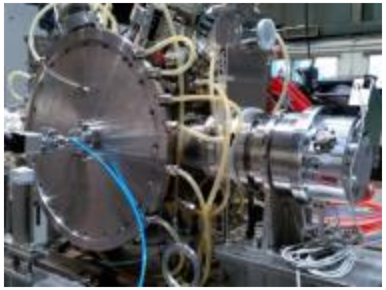


Participation in the development of 2 Quadrupoles for LHC-HL

Accelerator R&D activities: CIEMAT

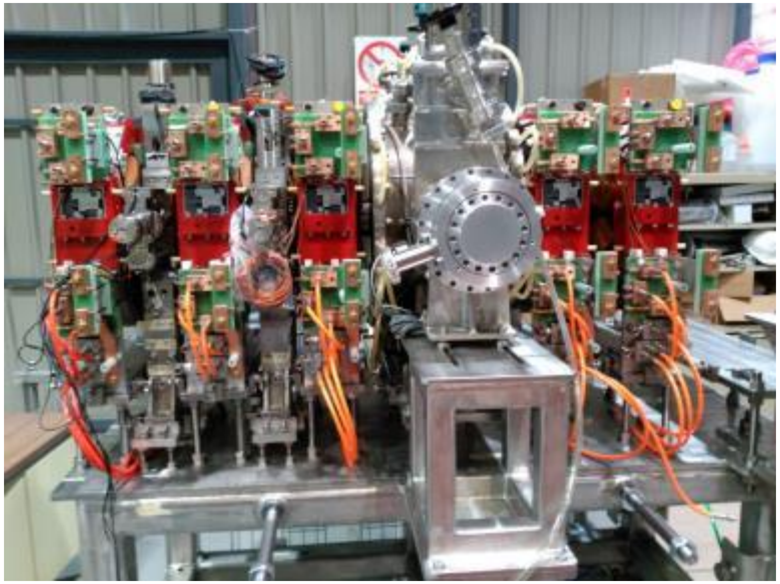
Accelerator Technology Unit: Relevant Projects (IV)

CONTRIBUTION TO THE IFMIF (International Fusion Irradiation Facility) PROJECT:

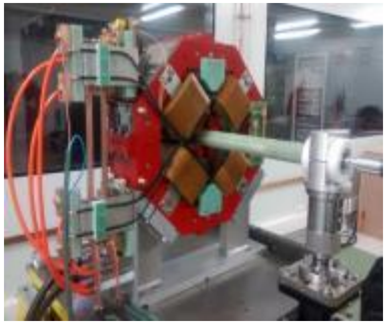


2 RF Buncher Cavities

2 Collimation Scrapers



Integration activities in the MEBT



13 Combined Resistive Magnets

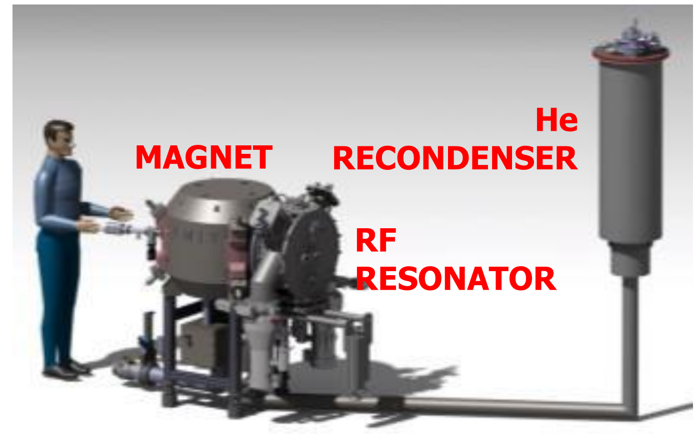
Beam Position Monitors

Accelerator R&D activities: CIEMAT

Accelerator Technology Unit: Relevant Projects (V)

THE AMIT PROJECT: A Compact Superconducting Cyclotron for Radioisotope Production

GENERAL	
Cyclotron Type	Classical
Energy	>8.5 MeV
Current	>10 μA
MAGNET	
Type	Low Tc Superconductor
Configuration	Warm Iron
Superconductor	NbTi
Central Field	4 T
Focusing type	Radially decreasing (1.5%@extraction radius)
RF SYSTEM	
Configuration	One 180º Dee
Peak Voltage	60 kV
RF frequency	~ 60 MHz
ION SOURCE	
Type	Internal
Ions	H^-
EXTRACTION	
Extraction	Stripping foil at 110 mm
Target	Nitrogen gas (^{11}C) , ^{18}O enriched water (^{18}F)
Position	External



General lay out of the accelerator (up) and complete superconducting magnet (down)

ESS-Bilbao

The Spanish Contribution to the ESS

Public consortium of Central and Basque Governments; bringing knowledge and added value in particle accelerators and neutron scattering science and technologies; by leveraging its in-kind contribution to the European Spallation Neutron Source, in Lund (Sweden).

Mario Pérez, ESS-Bilbao

52 employees
age average: 40

29% women **71% men**

Qualification

- **27% PhD**
- **13% Post Graduate Degree**
- **44% Master's Degree**
- **8% Bachellor**
- **8% Technician**

Headquarters

Poligono Ugaldeguren III
Zamudio (Bilbao)

R&D Center

Parque Tecnológico
Zamudio (Bilbao)

AWF

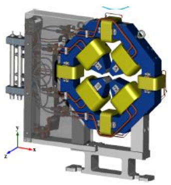
Polígono Industrial Júndiz
Vitoria-Gasteiz

Madrid Satellite

Instituto de Fusión Nuclear
Madrid

In-Kind Contributions to ESS

MEBT

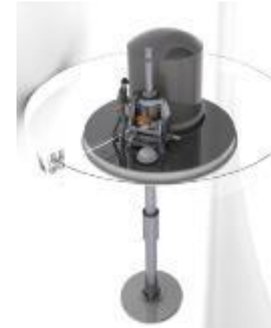


Accelerating element: complete subsystem that goes after the RFQ and integrates: design, manufacturing, diagnostics, control, assembly and testing.

RF Systems

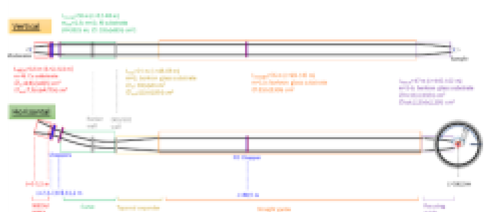
RF chains: 1 for RFQ and 5 for DTL. Composed by klystrons, modulators, loads, waveguides, interlocks and LLRF

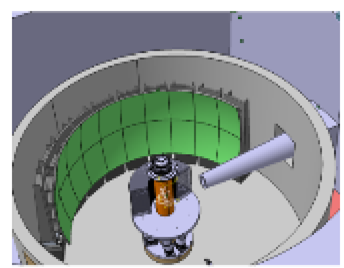
TARGET



The spallation process takes place when the accelerated proton beam hits the Tungsten bricks of the 11-tonne target wheel. This will produce neutron brightness for scientific experiments across multiple disciplines.

MIRACLES INSTRUMENT



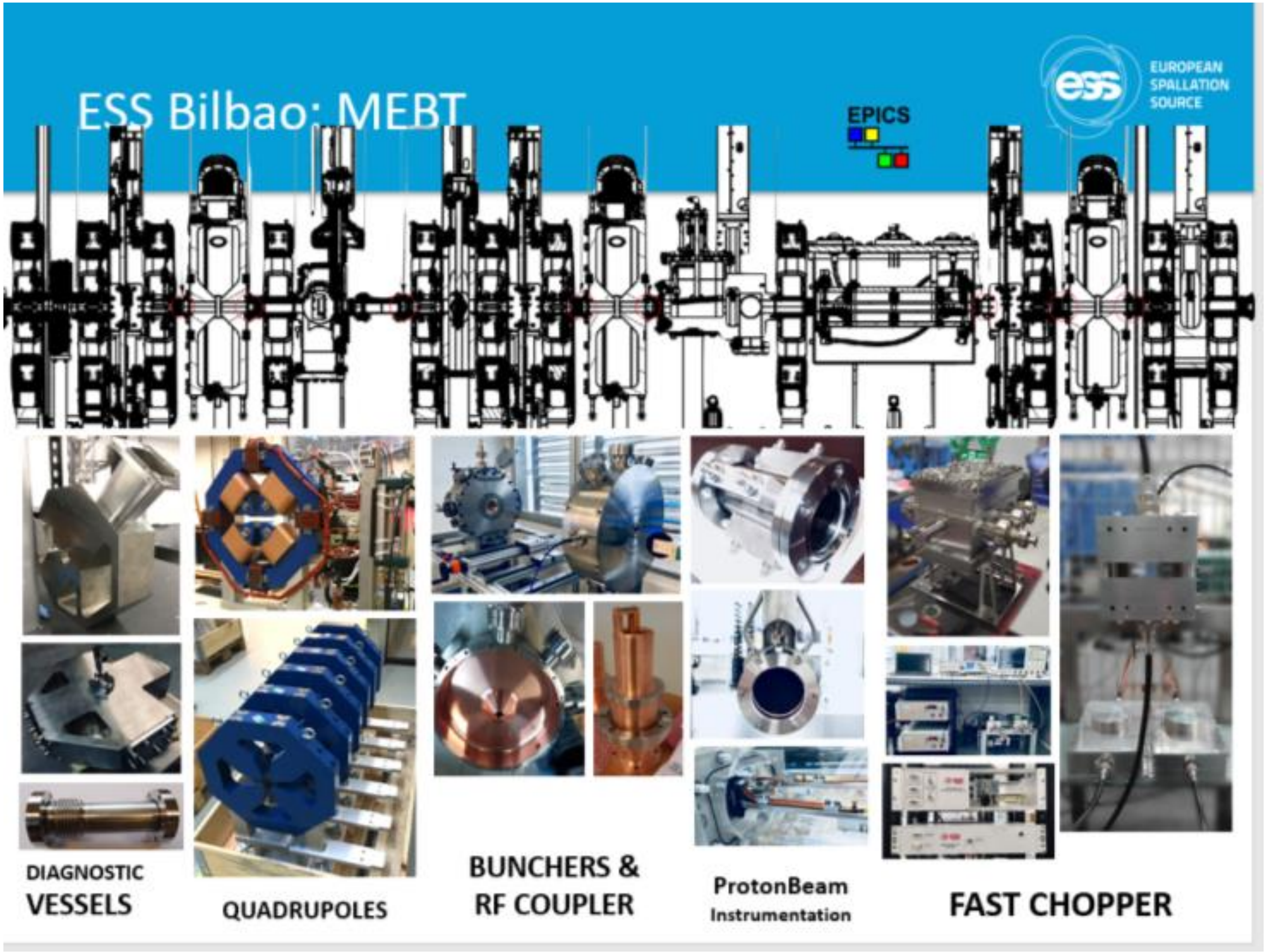


Time-of-Flight backscattering instrument for polymer science, energy materials, and magnetism studies.
Prime contractors: design, manufacturing, assembly &cold commissioning

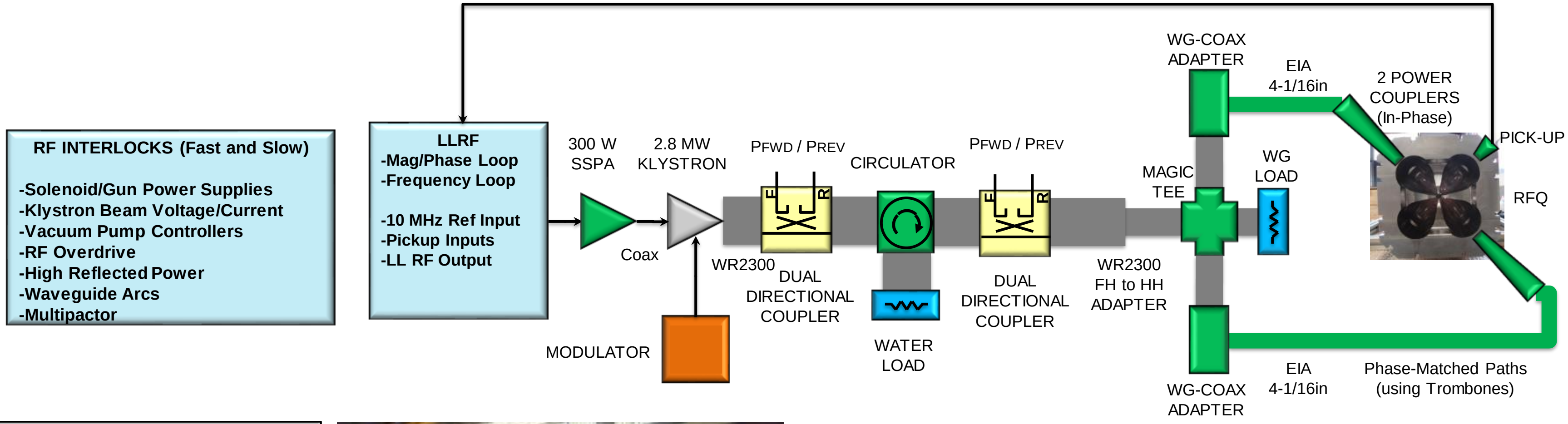
EUROPEAN SPALLATION SOURCE

EUSKO JAURLARITZA GOBIERNO VASCO

In-Kind Contribution - MEBT



In-Kind Contribution – RF Systems



Parameter	Specification
Power Supply	110kV, 50A (pulsed)
Frequency	352.2 MHz
Peak RF Power	2.8 MW
Average RF Power	151.2 kW
Collector Dissipation Capability	420 kW
Pulse width	up to 1.8 ms
PRF	up to 50 Hz

Klystrons

Modulators

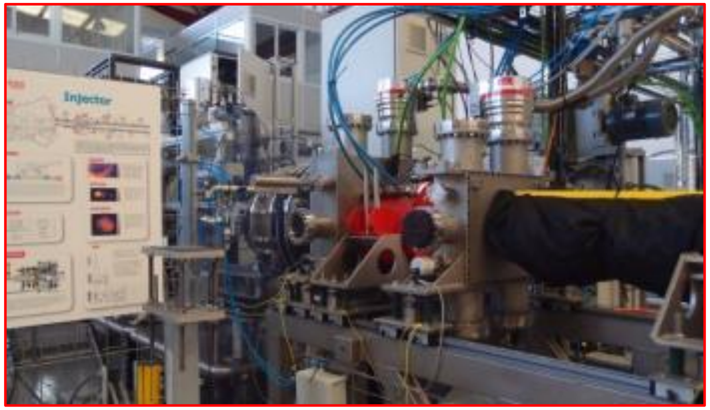
Marx Generator – Direct Modulator mixed topology

Pulses feature outstanding rise/fall time and flatness characteristics

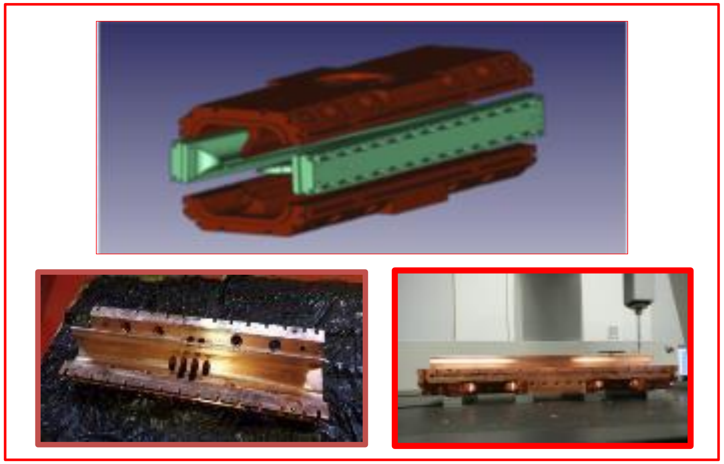
Parameter	Specification
Output Voltage	120 kV (pulsed)
Output current	60 A
Pulse Width	1.81 ms (adjustable)
Pulse Repetition Rate	2 - 50 Hz
Peak Power	7.2 MW
Average Power	648 kW
Duty Cycle (%)	9%
Input Voltage	30 kV (50Hz)
Efficiency	> 90%

ESS-Bilbao In-House Projects

ECR: H+ source; 45 KeV; 50 mA



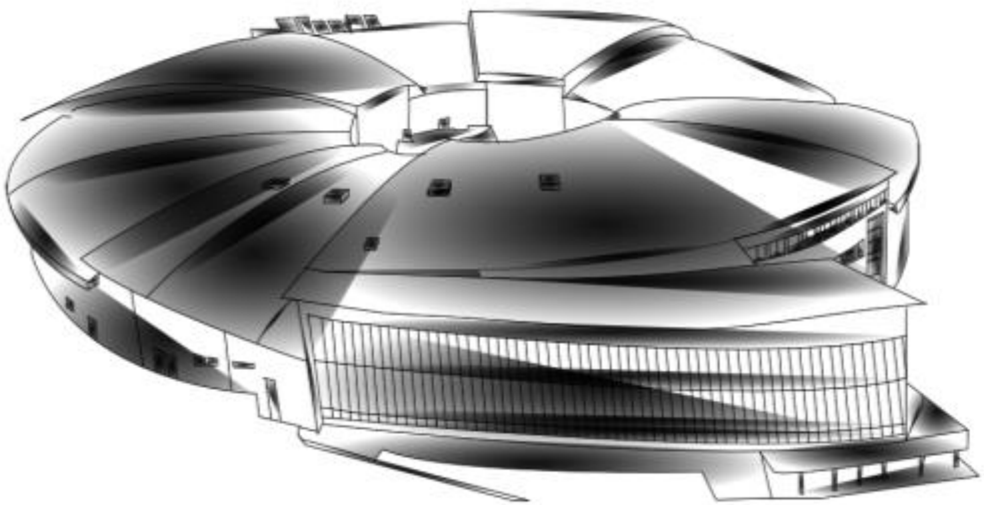
LEBT: Low Energy Beam Transport
Focusing and beam diagnostics



RFQ: Radio Frequency Quadrupole
Four-vane, 3 MeV, 3.2 m long, at 352 MHz

RFTX: RF Test Stand

ALBA,
Synchrotron Light Source

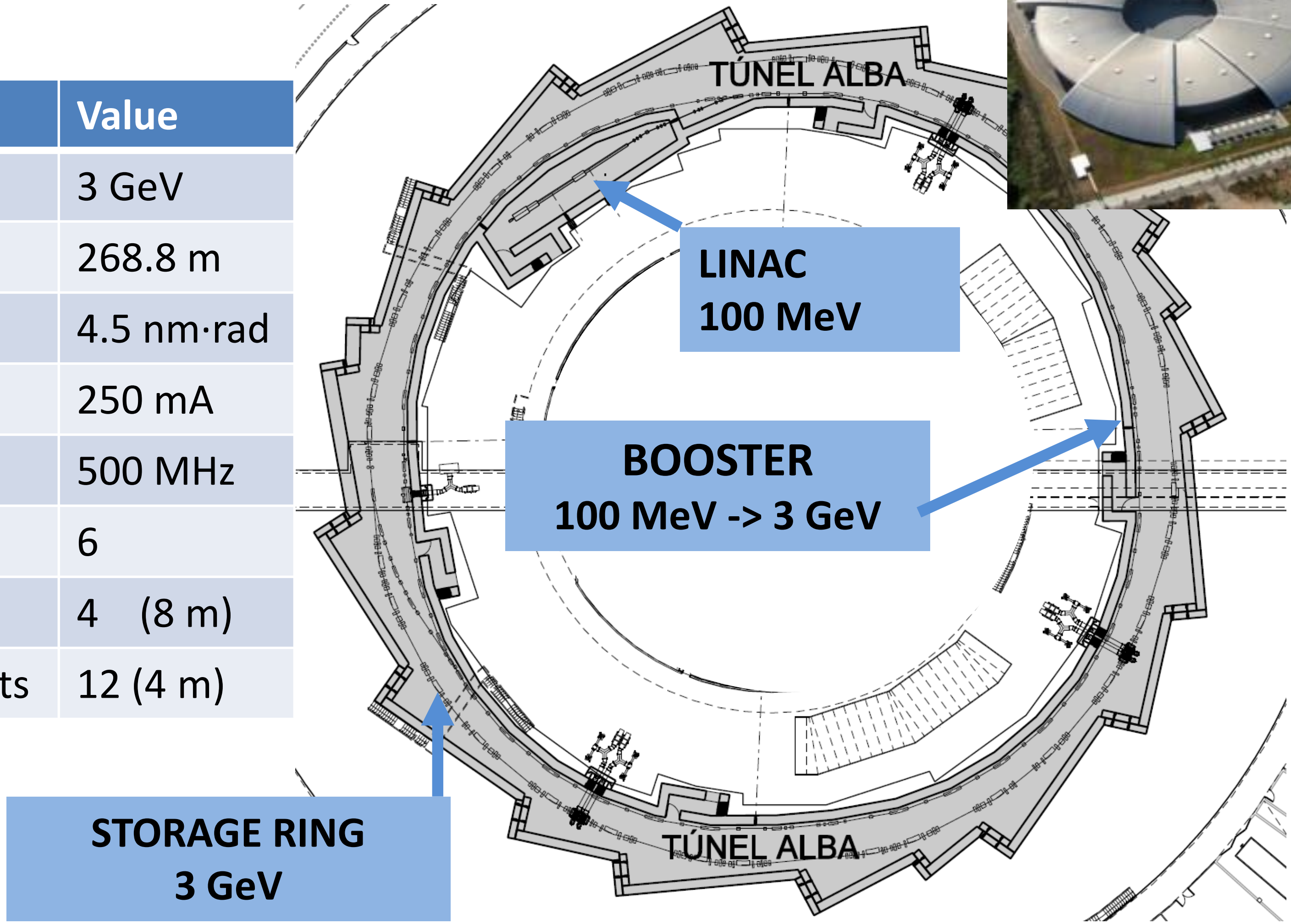


Source: Javier Sanchez Rios

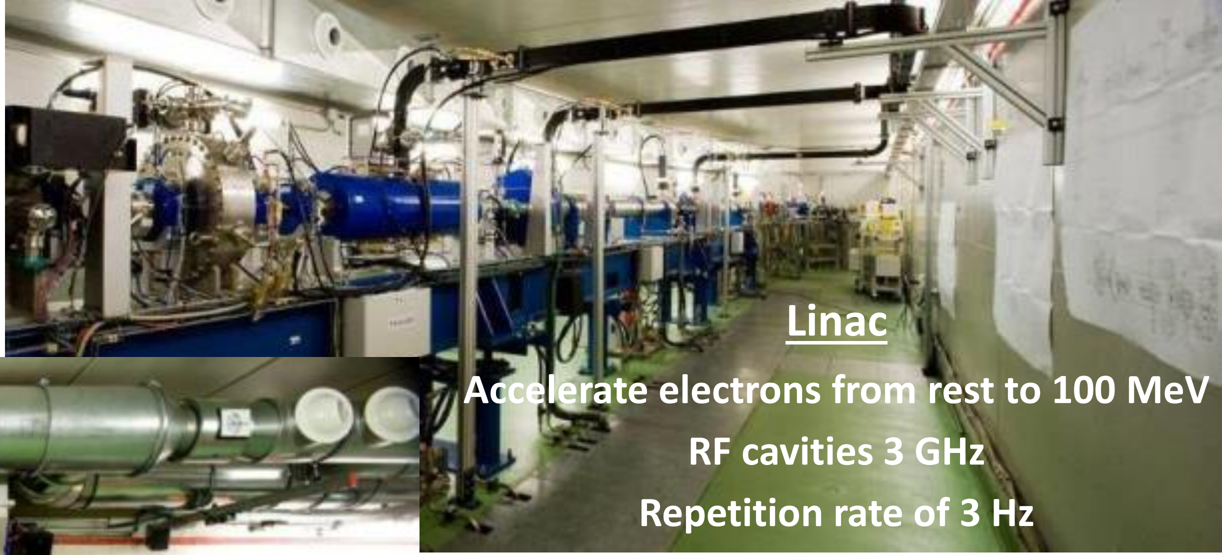
Francis Perez - ALBA

ALBA Accelerators

Parameter	Value
Energy	3 GeV
Circumference	268.8 m
Emittance	4.5 nm·rad
Current	250 mA
RF frequency	500 MHz
# cavities	6
Long straights	4 (8 m)
Medium straights	12 (4 m)



ALBA Accelerators

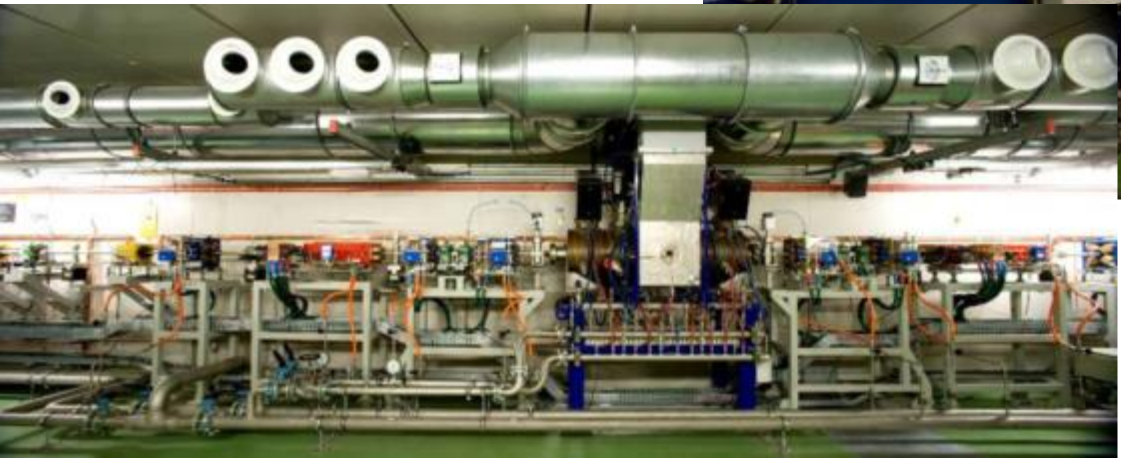


Linac

Accelerate electrons from rest to 100 MeV

RF cavities 3 GHz

Repetition rate of 3 Hz



Booster

Accelerate e- from 100 MeV to 3 GeV

1 x RF cavity at 500 MHz

Repetition rate of 3 Hz

Storage Ring

Keep electrons at 3.0 GeV

Magnets and correctors to keep the orbit (sub-μm)

Vacuum Pumps (10^{-10} mbar)

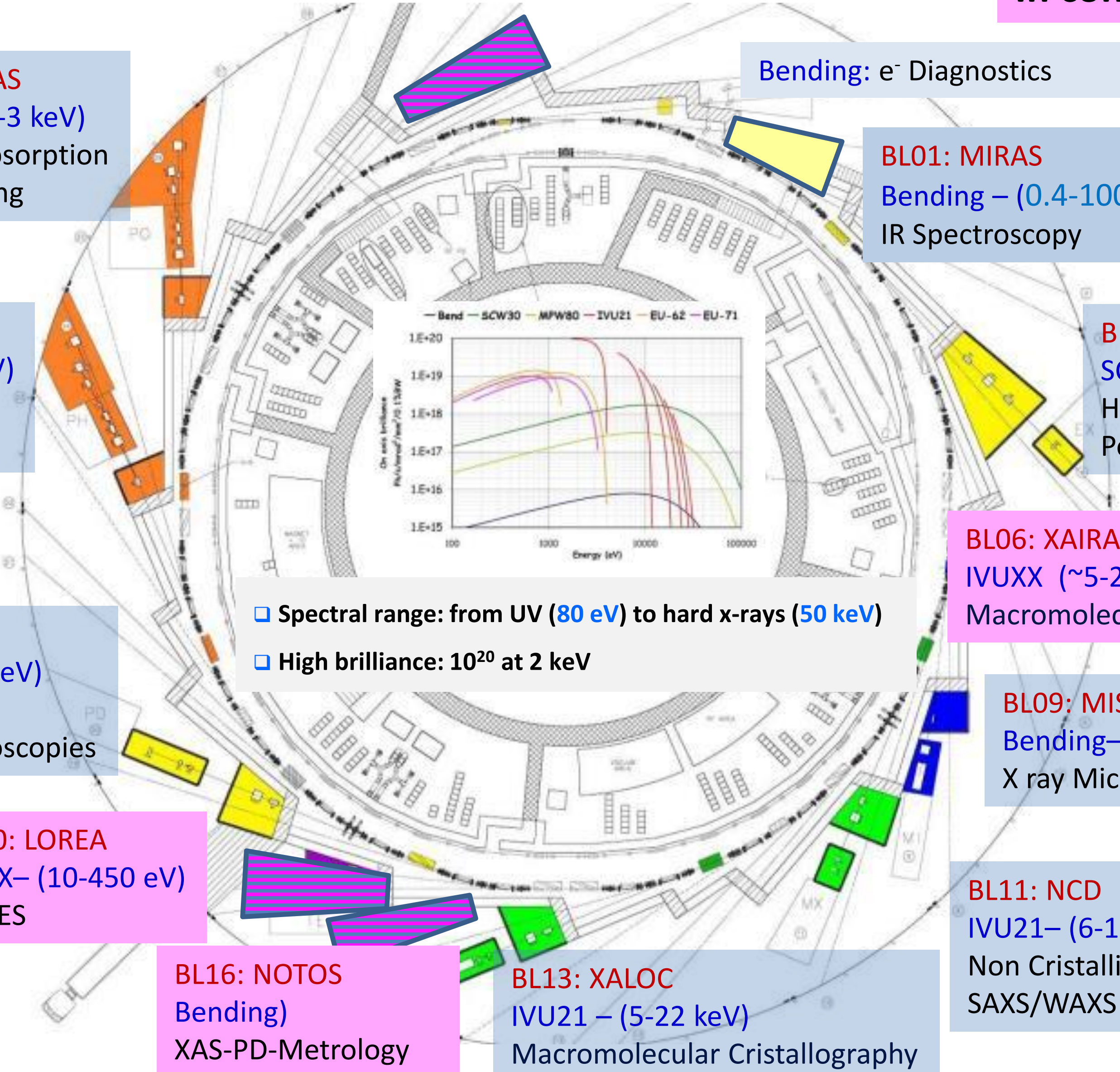
6 x RF cavities at 500 MHz

Circulating current: 250 mA

ALBA BEAMLINES

In operation (8)

In construction (3)



BL29: BOREAS
EU71– (0.08-3 keV)
REsonant Absorption and Scattering

Bending: e⁻ Diagnostics

BL01: MIRAS
Bending – (0.4-100 μm)
IR Spectroscopy

BL24: CIRCE
EU62– (0.1-2 keV)
Photoemission spectroscopies

BL04: MSPD
SCW31 – (8-50 keV)
HP/HR
Powder Diffraction

- Spectral range: from UV (80 eV) to hard x-rays (50 keV)
- High brilliance: 10^{20} at 2 keV

BL06: XAIRA
IVUXX (~5-25 keV)
Macromolecular Cristallography

BL22: CLÆSS
MPW80– (2-63 keV)
Absorption & Emission Spectroscopies

BL09: MISTRAL
Bending– (0.27-2.6 keV)
X ray Microscopy

BL20: LOREA
EUXX– (10-450 eV)
ARPES

BL11: NCD
IVU21– (6-13 keV)
Non Cristalline Diffraction
SAXS/WAXS

BL16: NOTOS
Bending)
XAS-PD-Metrology

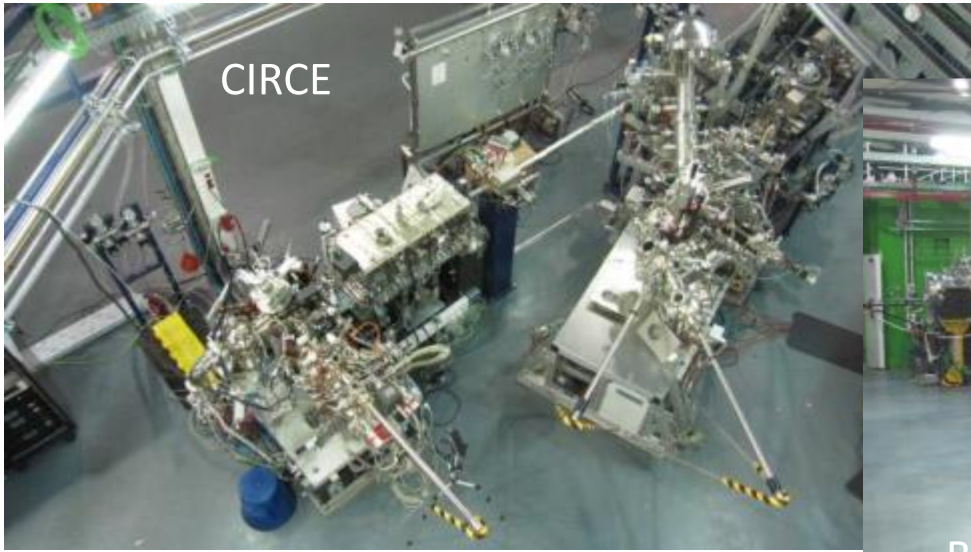
BL13: XALOC
IVU21 – (5-22 keV)
Macromolecular Cristallography

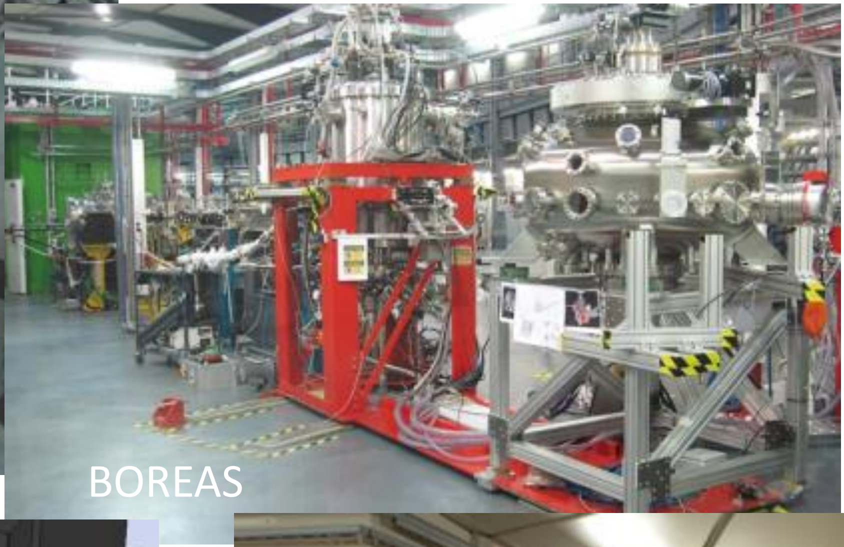
ALBA BEAMLINES

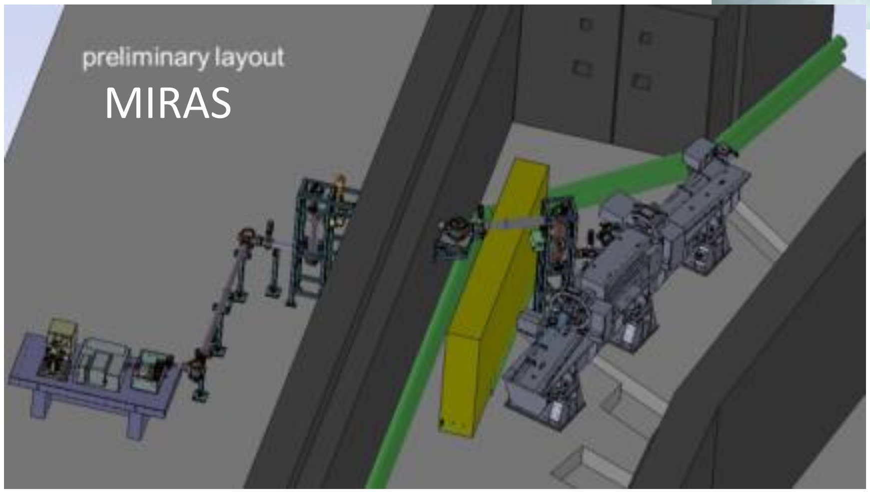
Some pictures

ALBA BEAMLINES

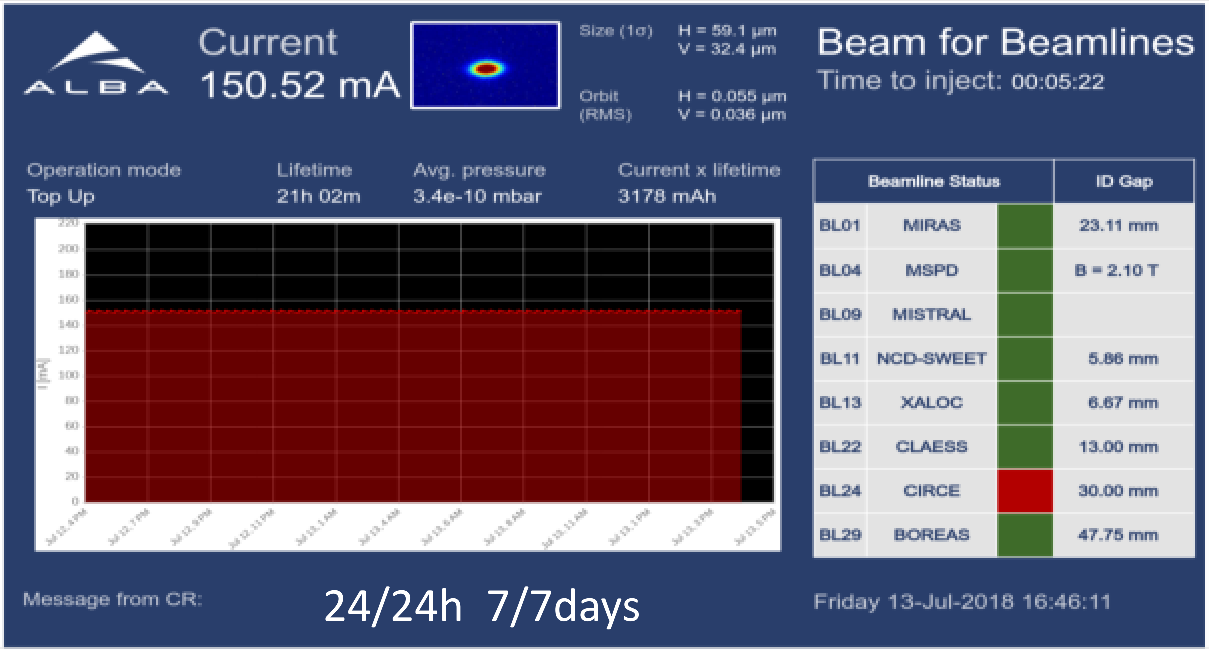
Some pictures

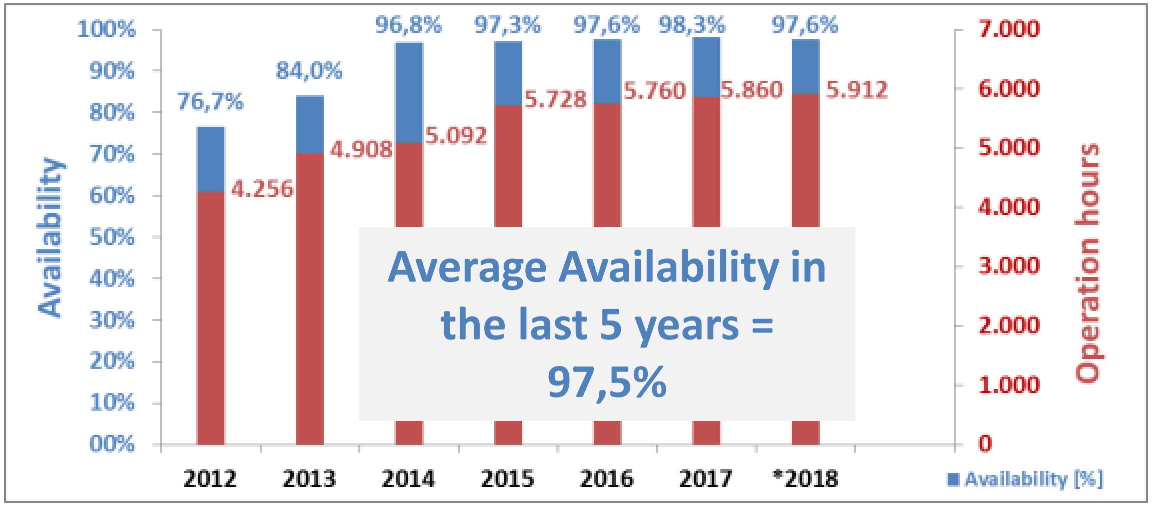






ALBA Operation





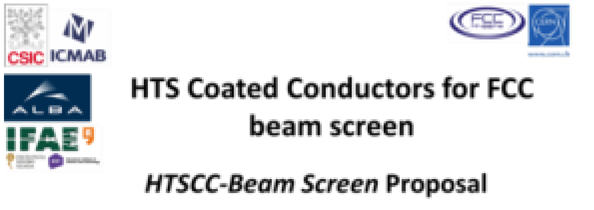
Average Availability in the last 5 years = 97,5%

Active International Collaborations

- *H2020 – XLS - CompactLight*

→ **1st Annual Meeting hosted by ALBA, Dec 2018**

→ **Post Doc**



- KE contract FCC-CERN – HTS-BS-FCC

→ **PhD student**

- EU H2020 Project EuroCirCol

→ **Leader WP4 – FCC Vacuum chamber**

→ **PhD student**

- KE contract CLIC-CERN

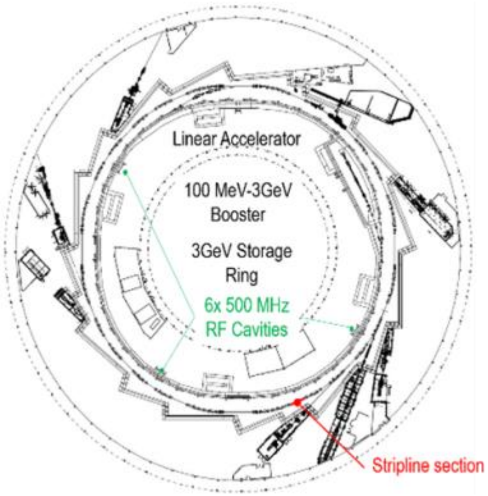
→ **Pulsed Magnets, RF, Diagnostics, Beam dynamics**

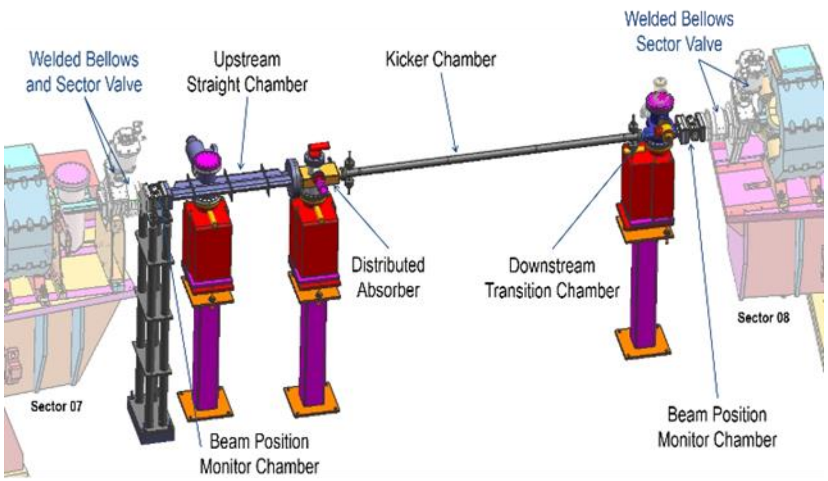
- H2020 - ARIES – Advanced Diagnostics for Accelerators

→ **Fast Feed Back Workshop hosted by ALBA, Nov 2018**

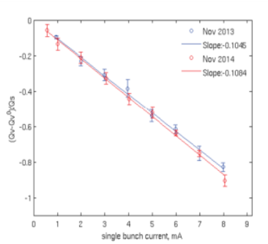
ALBA-CLIC Collaboration
WP1: Test with beam of the CLIC DR Stripline

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.

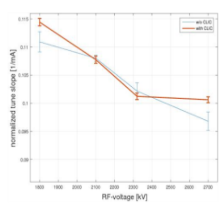




ALBA-CLIC Collaboration
WP1: Test with beam of the CLIC DR Stripline



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.

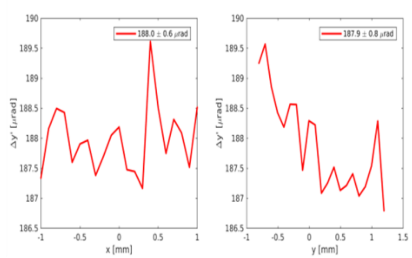
For this reason, the detuning slopes were taken

- 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

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.

The Future Circular Collider study

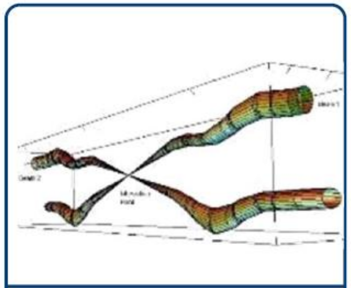
EuroCirCol

Horizon 2020
H2020-INFRADEV-1-2014-1
RIA action, proposal number 654305

Lead: **CEA**
A. Chancé

Co-Lead: CERN
D. Schulte

Arc Design



EIR Design

Lead: **JAI**
A. Seryi

Co-Lead: CERN
D. Schulte

Lead: **CELLS**
F. Perez

Co-Lead: CERN
P. Chiggiato

Cryo Beam Vacuum

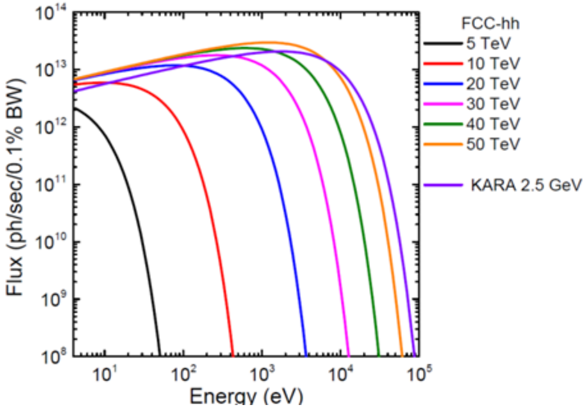
High Field Magnet

Lead: **CERN**
L. Bottura

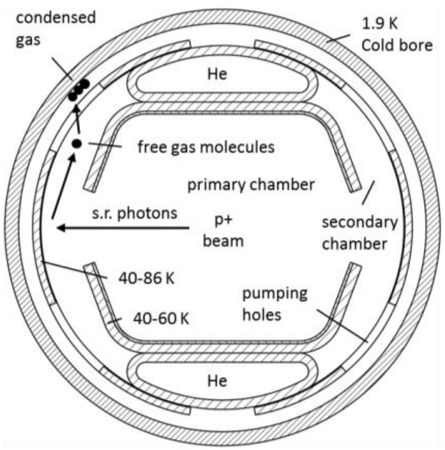
Co-Lead: **TBA**
TBA

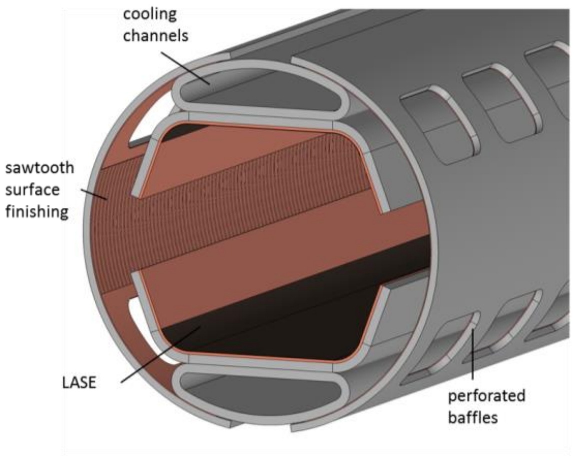
The Future Circular Collider study

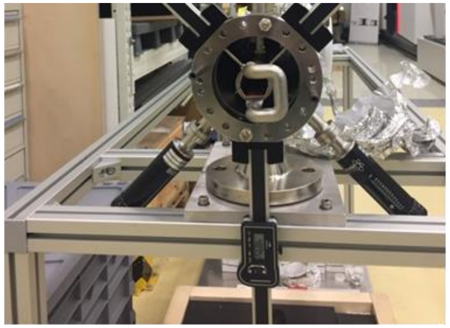
FCC - Vacuum Beam Screen Design

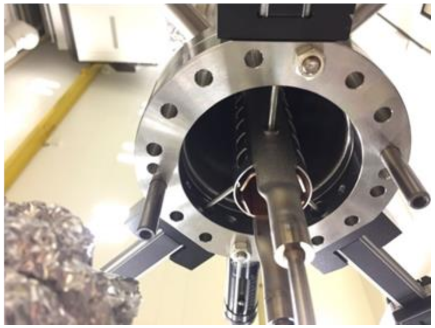


Synchrotron Radiation
as a Light Source





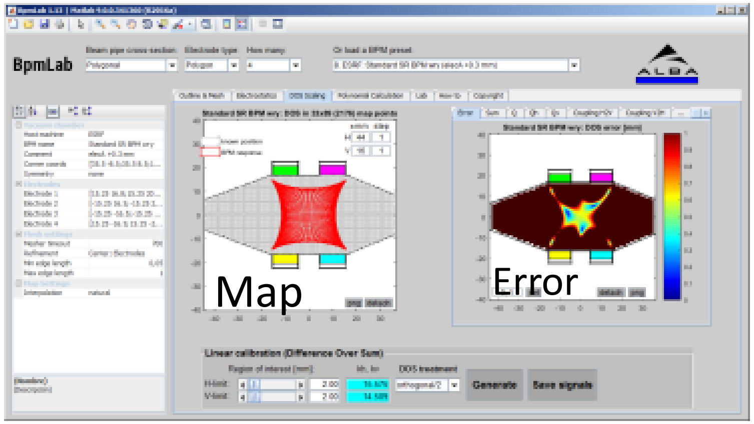




Active contracts (Collaborations)

- ***ESRF - EBS –*** *BPM tool*

ESRF-EBS
EBS Science Workshop



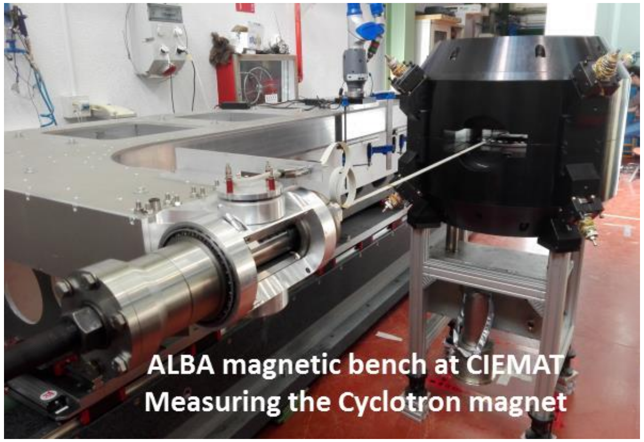
Standard ESRF BPM response with one electrode (right-top) retracted by 300 um

- ***SIRIUS*** **-** *Digital LLRF*

LNLS Brazilian Synchrotron Light Laboratory
sirius

ALBA Magnetic Lab

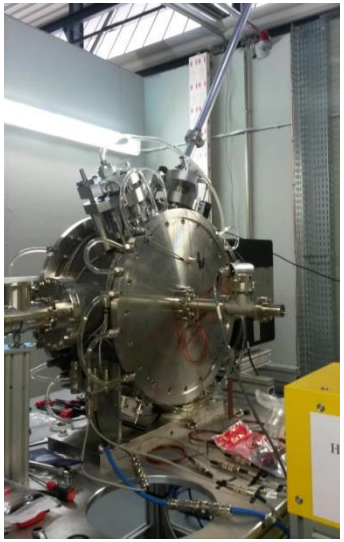
CIEMAT – IFMIF magnets
CIEMAT - SC Cyclotron
Magnet measurements for several companies



ALBA RF Lab

RF transmitter


ALBA Cavity inside the Bunker


CIEMAT
IFMIF Buncher cavity
at *ALBA RF lab* for High
Power Conditioning

CONECTA

As summary, Spanish groups on accelerators have consolidated and are contributing to the development of accelerators in Spain as well as to the new international projects (CLIC, FCC, XFEL, ESS, …).

Thanks for your attention