AITANA

MATTER AND TECHNOLOGY

IFIC High-Gradient Radiofrequency Laboratory

IFICs accelerators group

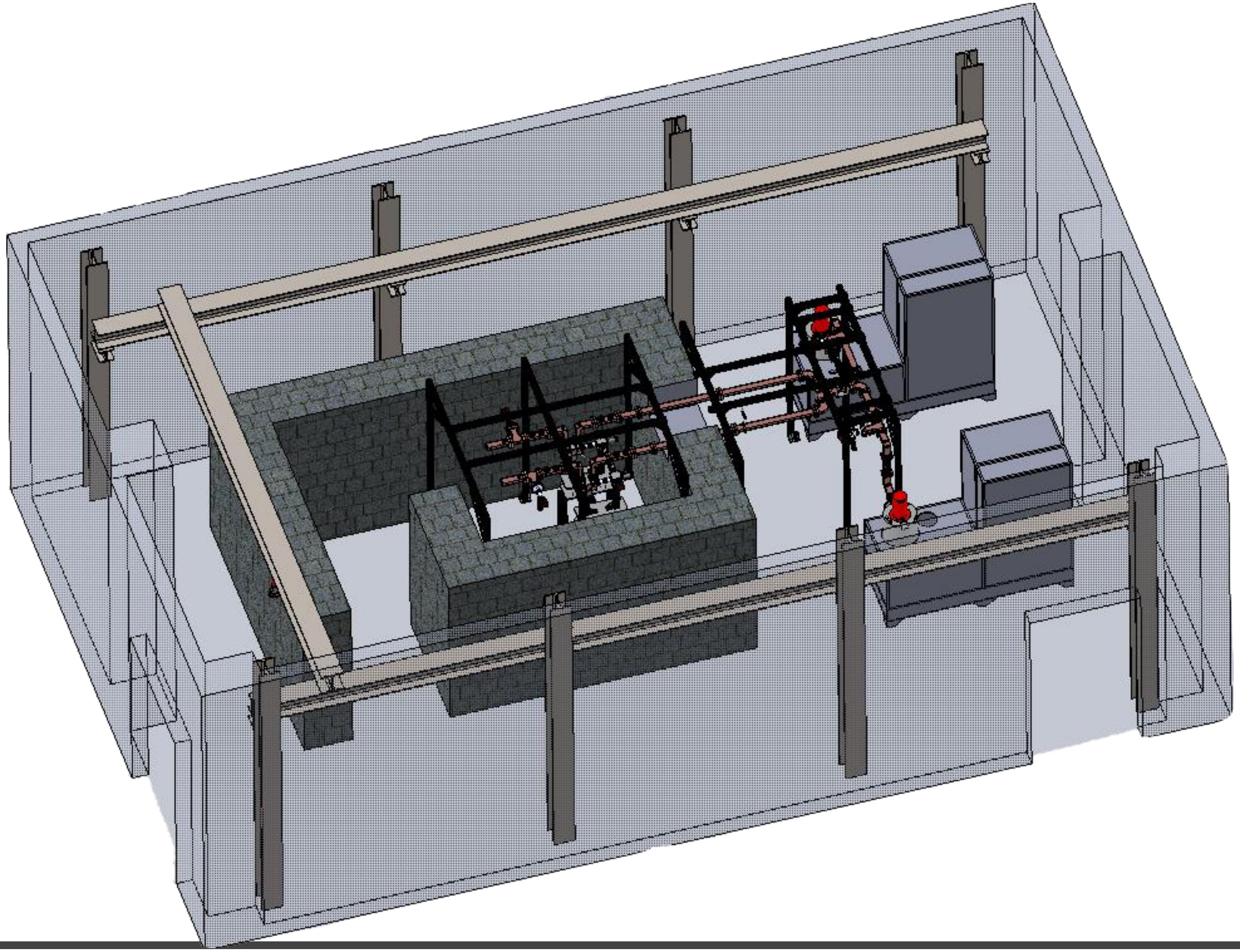
HTS Cavity Meeting

VNIVERSITAT DE VALÈNCIA

IFIC INSTITUT DE FÍSICA CORPUSCULAR

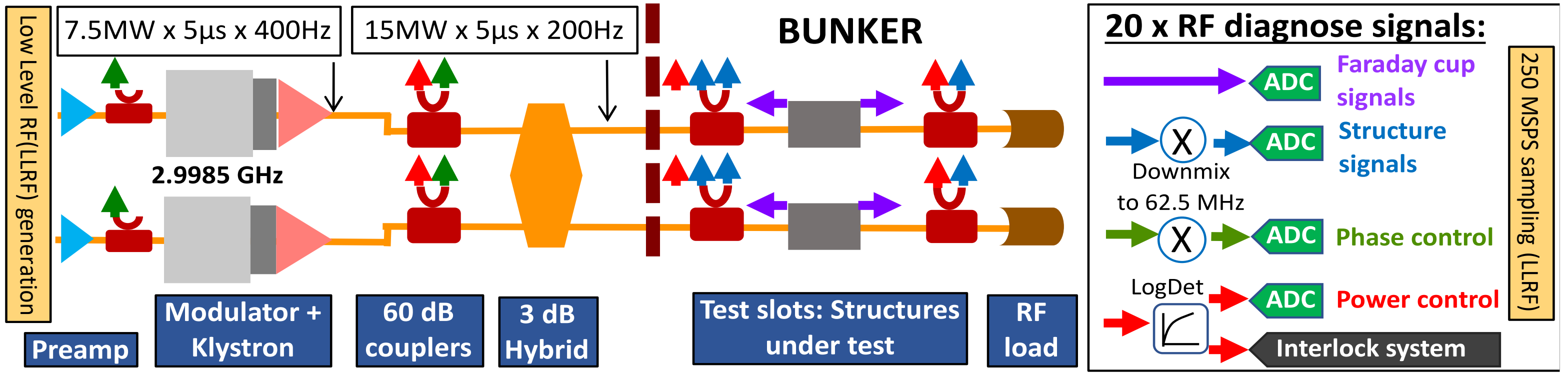
CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

IFIC HG RF Laboratory

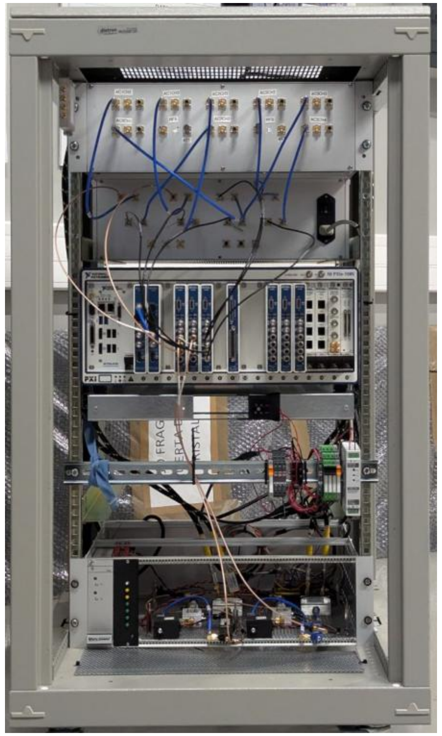


- High-gradient normal conducting RF cavities research topics at S-Band (2.9985 GHz) frequency.
- Very similar to the Xbox-3 test facility but for a central frequency of 2.9985 GHz.
- 2 x pulsed power klystron+modulator (to 7.5 MW, 5 us pulse, **400 Hz**)
- High power waveguide RF network that allows power combining enables to test 2 structures at a time at up to 15 MW, 5 us pulse, 200 Hz repetition rate
- Running on Ultra-High vacuum (10^{-9} mbar)

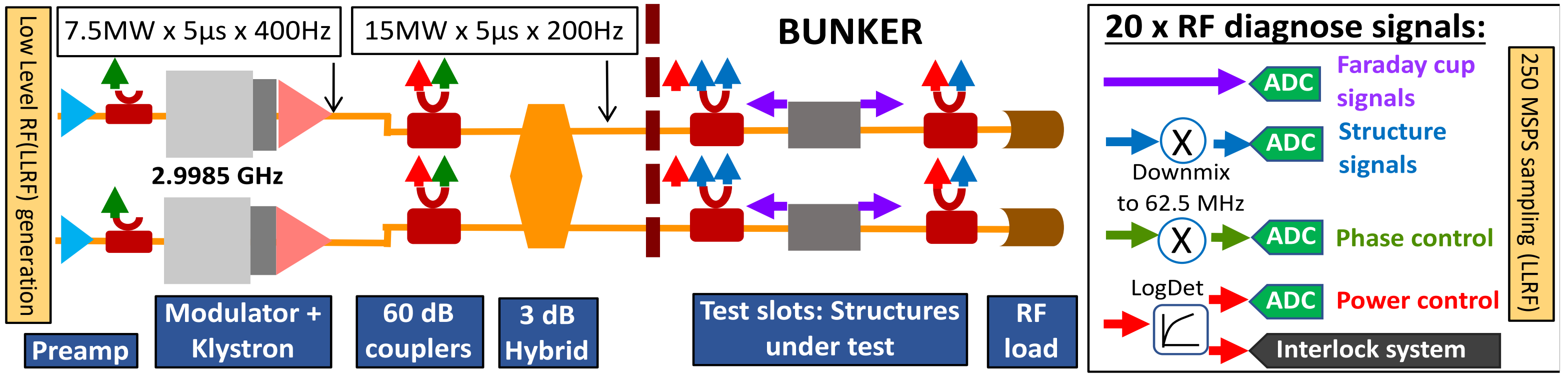
LLRF



- **LLRF** is based on National instruments PXI.
- 2 RF generators (0.2 – 4.4 GHz), 6 ADC cards with 4 channels each (max 250 MS/s) – 24 input channels, timing control and other subsystems integration.
- LLRF includes Power distribution, Down mixing, hardware interlock and communication interfaces
- Modulated pulses are preamplified in 2 SSAs from Microwave Amp, prior injecting them to the klystrons.

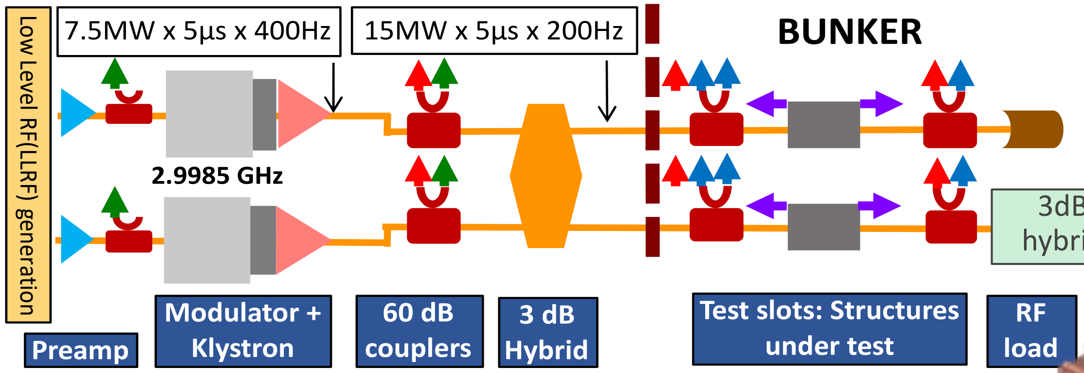


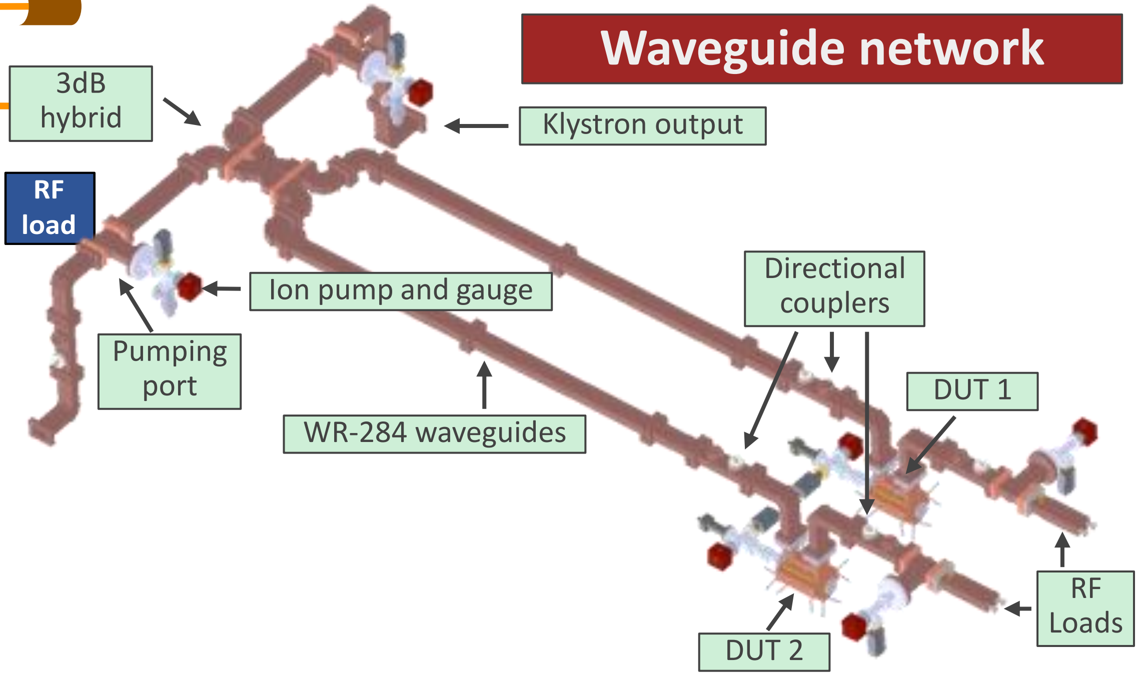
Klystrons and Modulators



- JEMA Modulators produce voltage pulses up to 145 kV and 5 us flattop
- Two CPI Klystron VKS-8262G, central frequency 2.9985 GHz and maximum output power 7.5 MW in 5 us pulse.

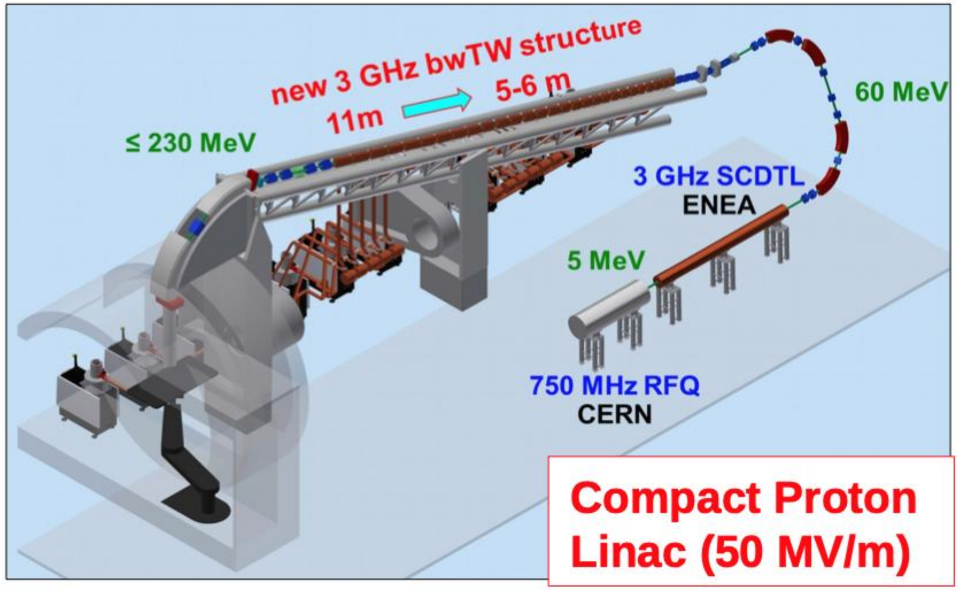
Waveguide network



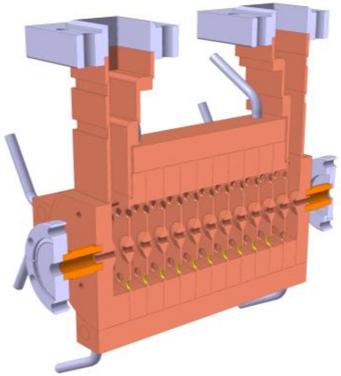


Ultra-High vacuum (10^{-9} mbar)

TULIP: Backward Traveling Wave (BTW)



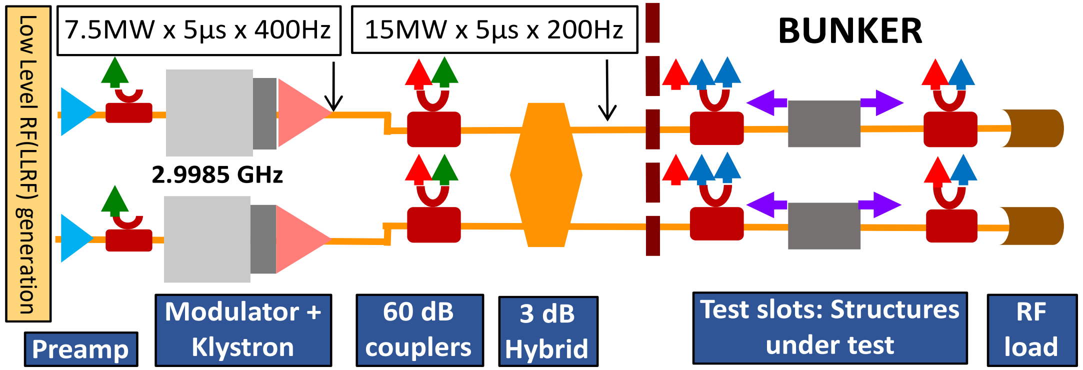
- TULIP (TUrning LInac for Protontherapy) project: Conceptual design of a compact linear proton therapy machine
- HG accelerating structure designed to reach an accelerating gradient of **50 MV/m** for protons



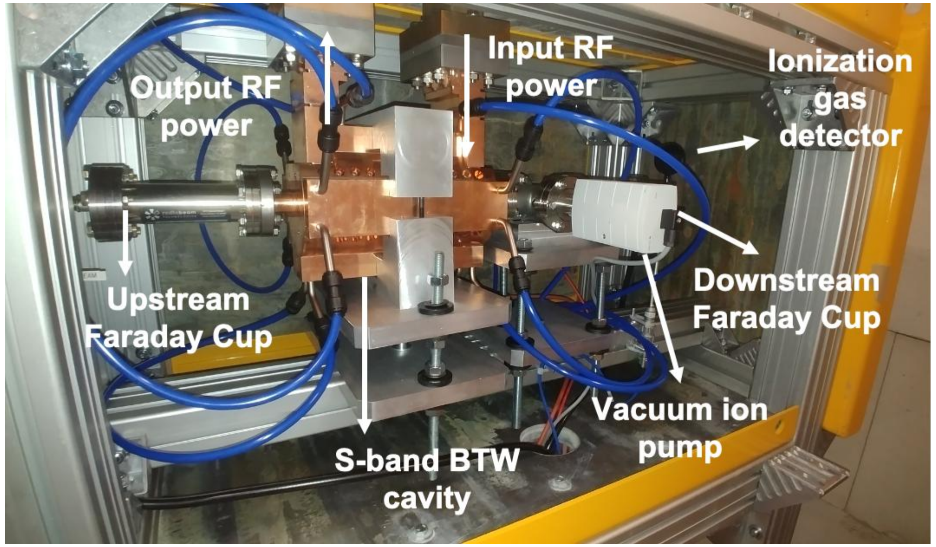
- Frequency: 2.9985 GHz mode with $5\pi/6$ phase advance

Number of RF cells	**12**
Geometric β	0.38
RF Ph. Adv.	150 deg
Total length	189.84 mm
Pin @ 50 MV/m	20.16 MW
Pout @ 50 MV/m	11.24 MW
Filling Time	220 ns

Bunker

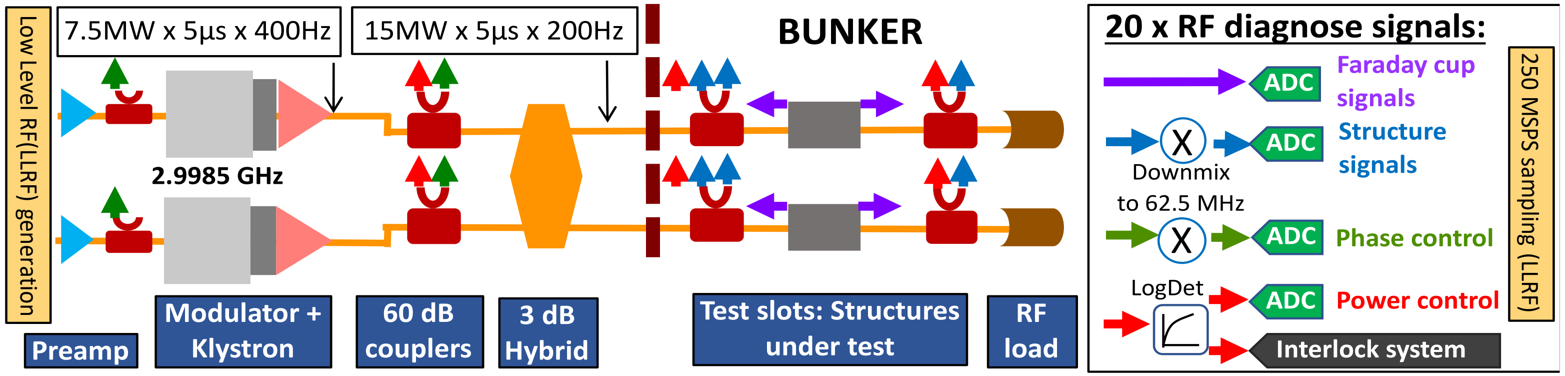


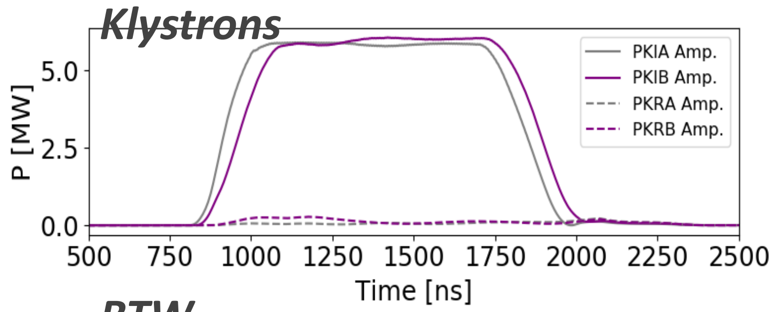
Low Level RF(LLRF) generation
7.5MW x 5μs x 400Hz
15MW x 5μs x 200Hz
BUNKER
2.9985 GHz
Preamp
Modulator + Klystron
60 dB couplers
3 dB Hybrid
Test slots: Structures under test
RF load

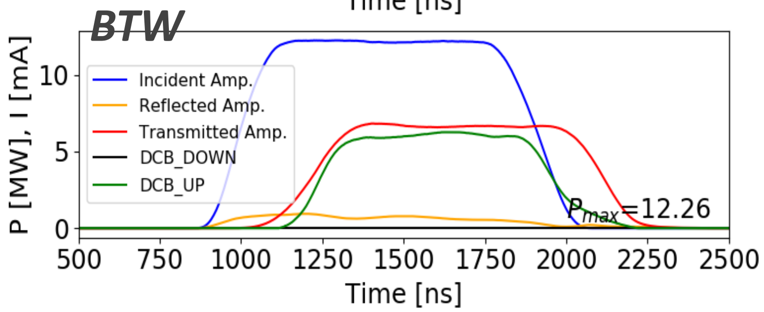


Output RF power
Input RF power
Ionization gas detector
Upstream Faraday Cup
Downstream Faraday Cup
Vacuum ion pump
S-band BTW cavity

RF HP Pulses





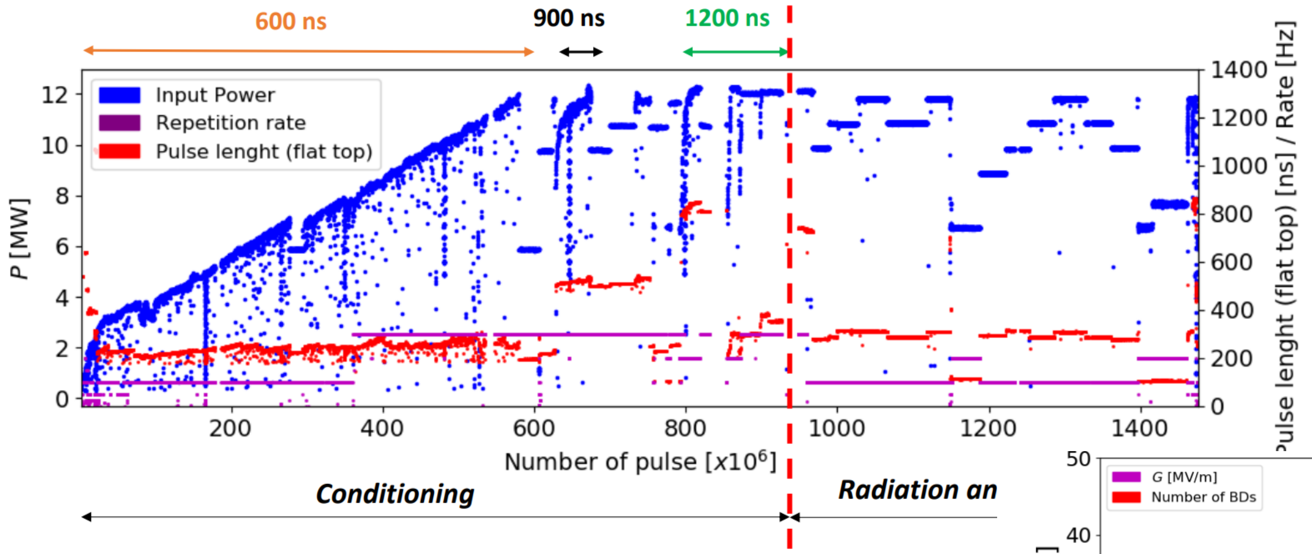


- Timeline
  - Commissioning of the facility in June 2019.
  - Started testing the BTW structure in October 2019.
- Conditioning.
  - Explore the limitations of the accelerating gradient and study the BD and dark current phenomena.
- Reached maximum power allowed by current set-up in September 2021 (600 ns pulse length) and October 2021 (1200 ns pulse length).

Structure Conditioning

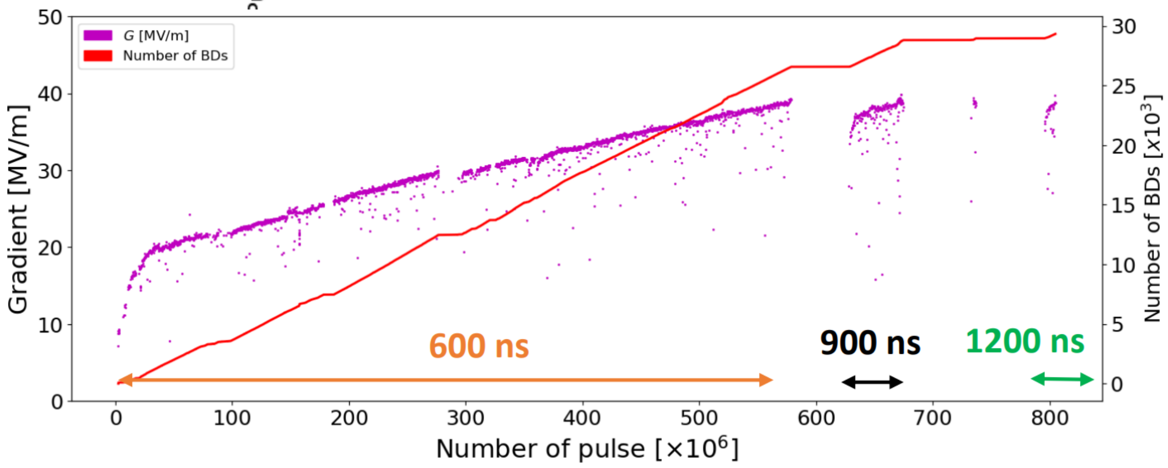
- **Maximum power 12 MW** in ~570M pulses (short pulse length).

- R:100 ns + FT: 200 ns + F:300 ns
- R:100 ns + FT: 500 ns + F:300 ns
- R:100 ns + FT: 800 ns + F:300 ns



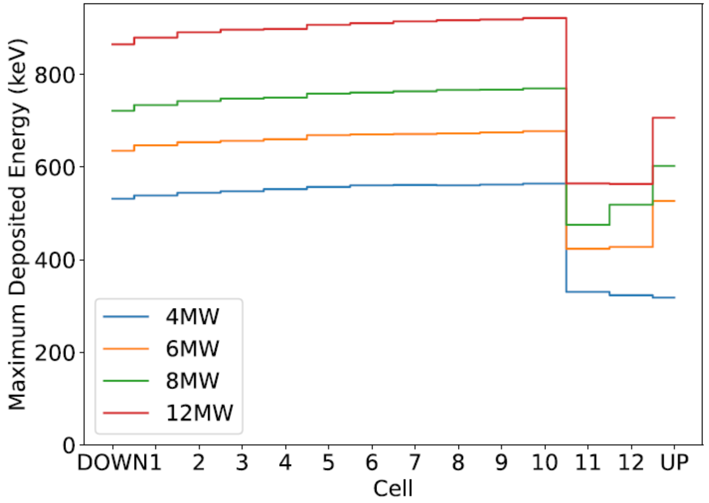
Gradient	50 MV/m
Total length	1.5 μs

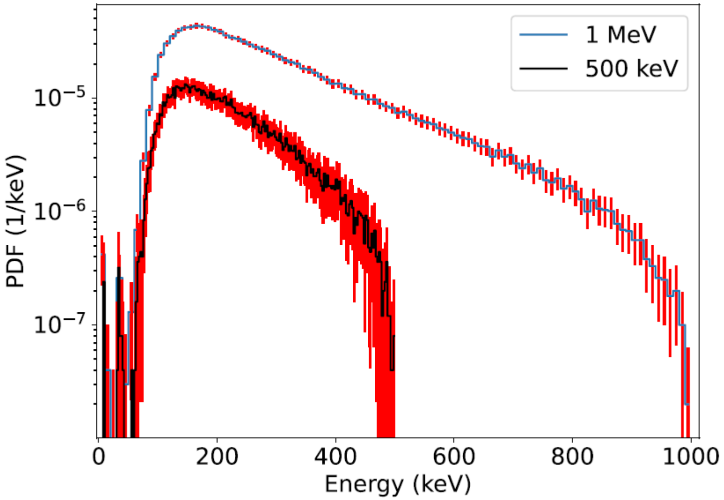
➢ Current set-up capable to reach an accelerating gradient of ~39 MV/m

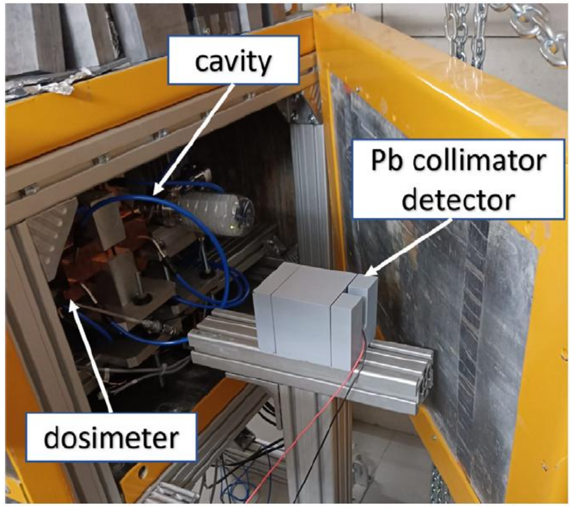


Dark Current Simulation Validation

- A 3D EM model of the BTW RF accelerating cavity was developed in CST-PS in order to study the dark current electron dynamics inside the cavity.
- To estimate the impact of this dark current on the radiation reaching the exterior of the cavity, Monte Carlo simulations were performed using PENELOPE.
- Electrons are light particles, their interaction with the copper walls of the cavity is dominated by bremsstrahlung.







HTS Cavity Meeting

Dark Current Simulation Validation

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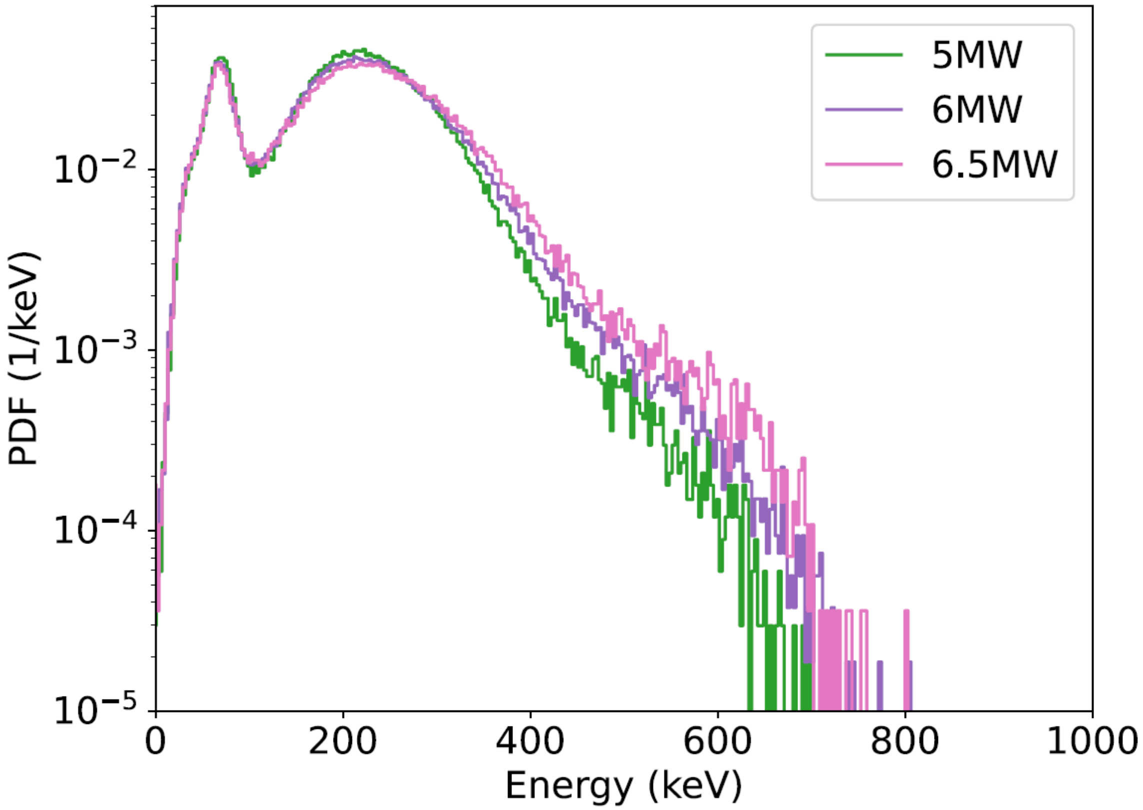


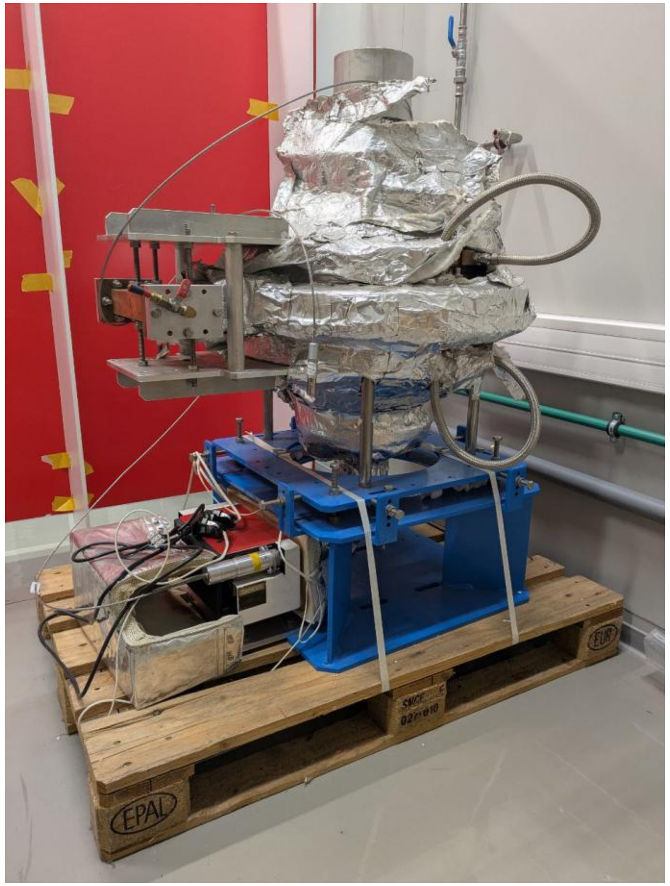
- The maximum energy of the source electrons can be inferred by examining the cut-off energy of the measured spectrum. As seen, the maximum energy of the photons increases with the RF input power, as expected from the simulations performed with CST-PS and PENELOPE
- The measured maximum energy of the electrons is the range of 600– 750 keV which is compatible with the numerical simulations that predicted a range between 550–700 keV.

IFIC HG RF Laboratory: Plans

- Results: P. Martinez-Revieriego et al. Nuclear Engineering and Technology 57 (2025) 103164
- **Energy upgrade for the IFIC HG RF Laboratory: Installation of a pulse compressor.**

Arcing detected on the cathode of one CPI klystron.

High-potting test under consideration – Coordinating with CERN to access their equipment.



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Plan de Recuperación, Transformación y Resiliencia

GENERALITAT VALENCIANA
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LINAC6+

- IFIC, CERN & CIEMAT collaborate in the development of a C6+ and He2+ ions injector of 10 MeV energy in collaboration with industrial partners
- Funding from CDTI by means of Innovative/Pre-commercial Public Procurement process. Main strategic lines of the project:
    - Innovation: Construction of the first phase of a C6+ ion linear accelerator. The equipment will be built by industry. Successful tenderer: AVS (Added Values Industrial Engineering Solutions S.L)
    - Scientific: progress in radiobiological, biomedical and clinical aspects essential for an adequate knowledge of ion radiotherapy
- To be installed at IFIC premises (2024-2029)