High power RF windows and coupler R&D

INFN-LNL

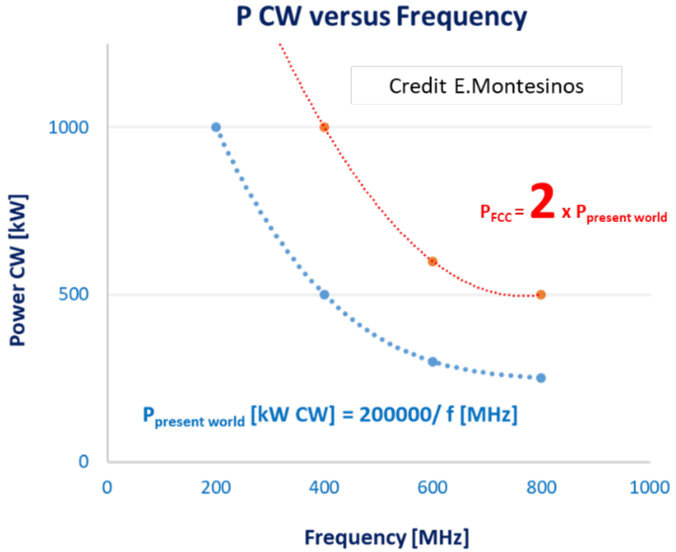
INFN LNL
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

CONTESTO: FCC

FCC coupler needs are roughly twice the present state of the art on power couplers.

FCC

Room for R&D



SRF	SRF
High gradient	High gradient
400 MHz	800 MHz
1 MW CW	500 kW CW
Waveguide disk window	Coaxial disk window
No doorknob, WG to coaxial transition instead	No doorknob, WG to coaxial transition instead
Water cooled antenna	Water cooled antenna

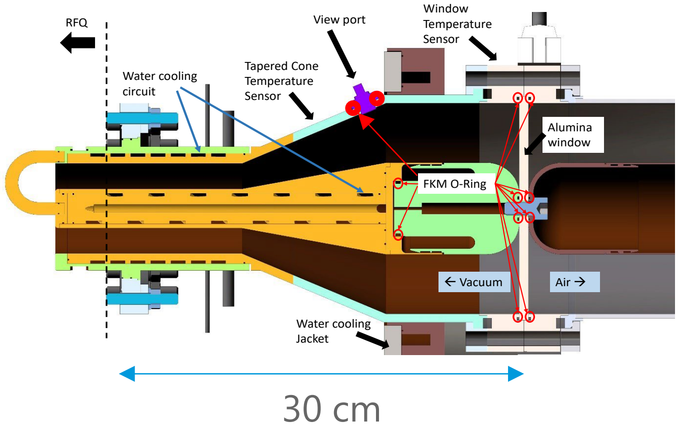
CERN WWFPC#6 meeting, 2-3 July 2024, CERN, Geneva eric.montesinos@cern.ch, CERN FPC status and perspectives 48

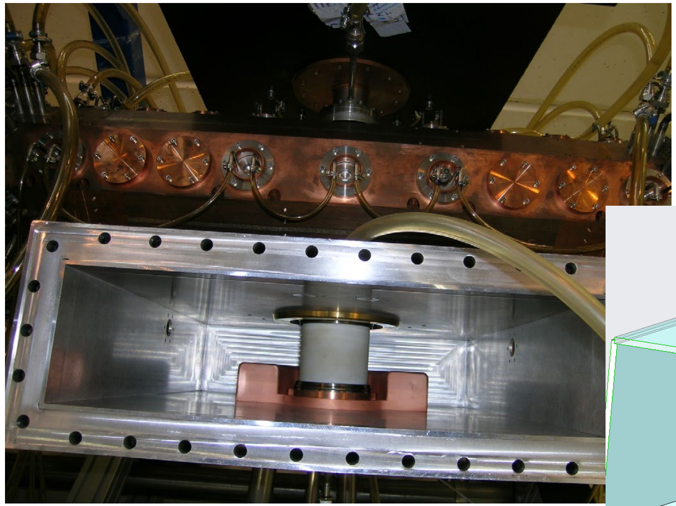
CONTINUITA'

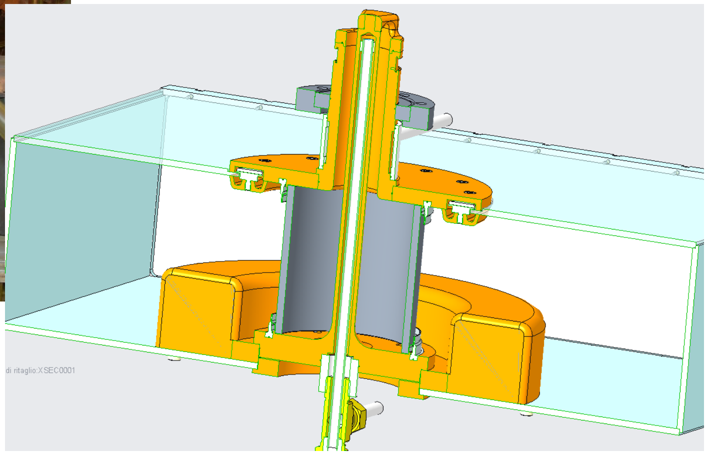
High power couplers for IFMIF, ESS, Dones, ANTHEM

All RF cavities (normal or superconducting) are fed by RF power couplers (rated about 200 kW each).

At LNL now a set of high-power RF amplifier - operating at high duty cycle and CW at 80, 175 and 352 MHz, with power level in the 100-200 kW range - open the possibility of high-power tests in realistic conditions.







MERITO SPECIFICO

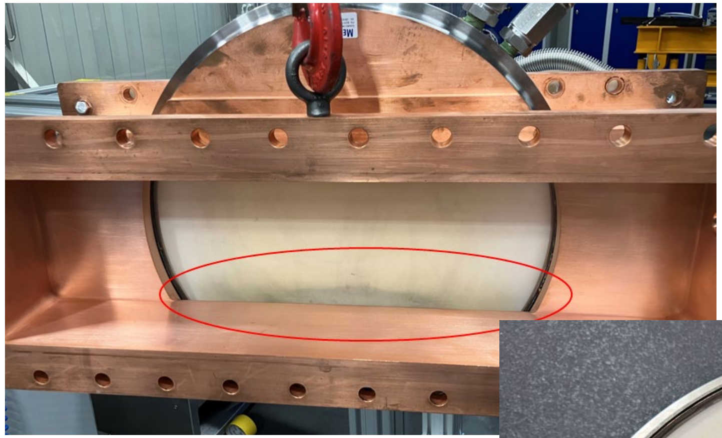
RF design and MP studies.

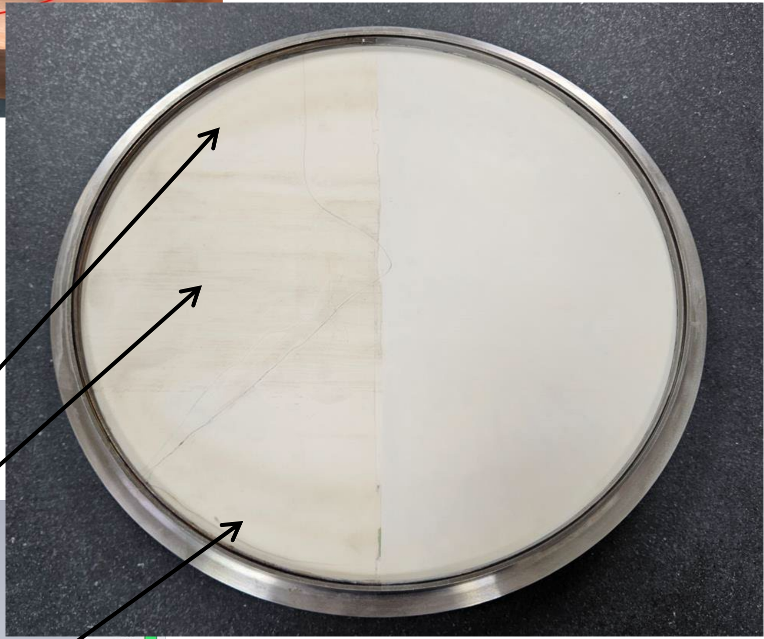
CST studies of MP has been performed using SEY of alumina and copper from paper of CERN and DESY.

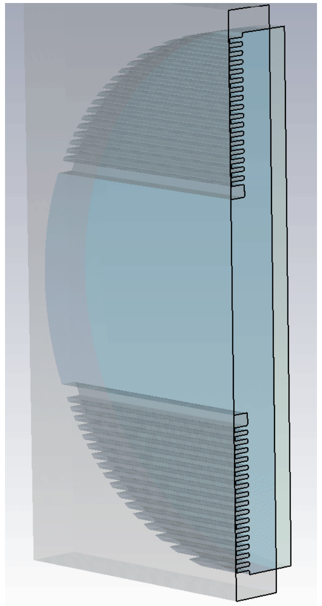
Electron multiplication studied with and without space charge (procedure follows SNS studies performed by G. Toby [3] and Langellotti [0]).

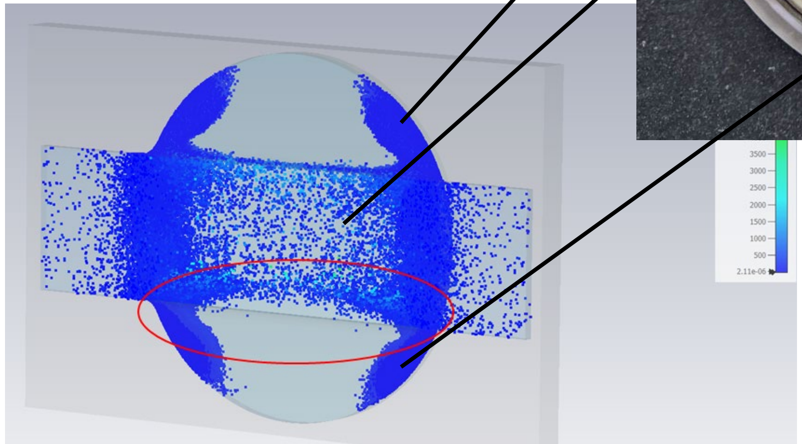
The method is validated by recognizing the colored MP zone observed on the alumina and the highest reaction at 300 kW.

The method has been validated also in the framework of IFMIF programme.





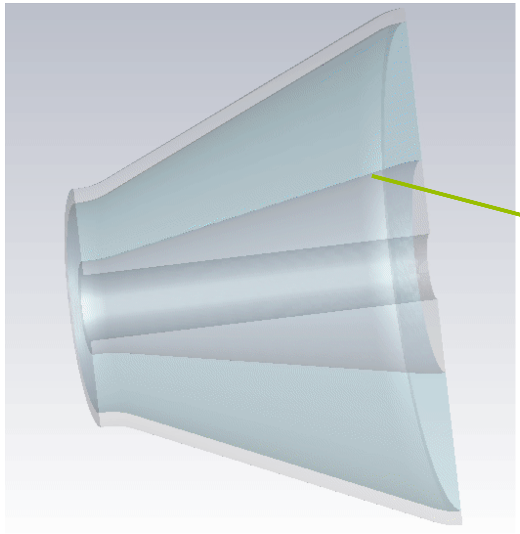


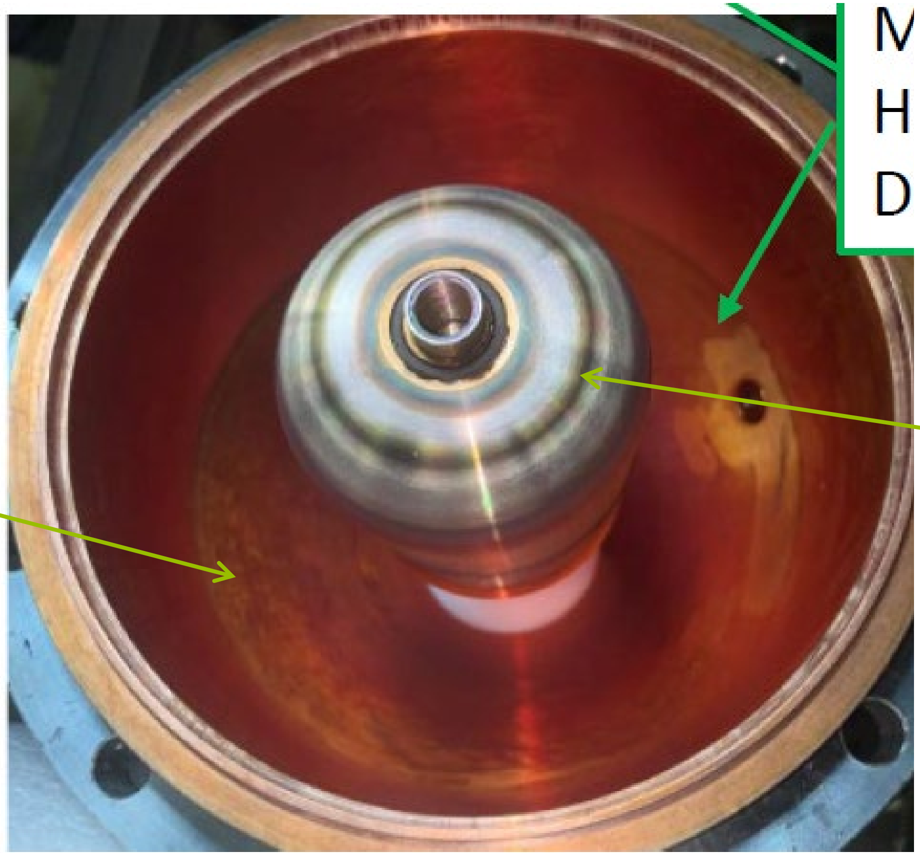


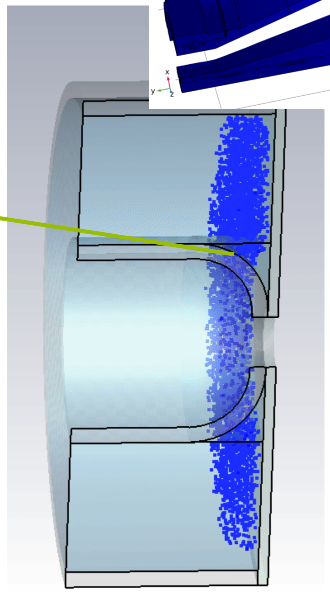
MERITO SPECIFICO

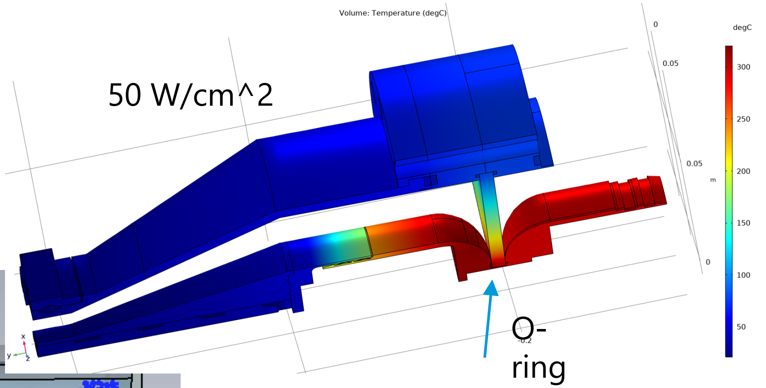
RF design and MP studies.

The simulated power surface density is consistent with observation on the anchor most damaged (rainbow color)









MERITO SPECIFICO

Alumina Coating and vacuum.

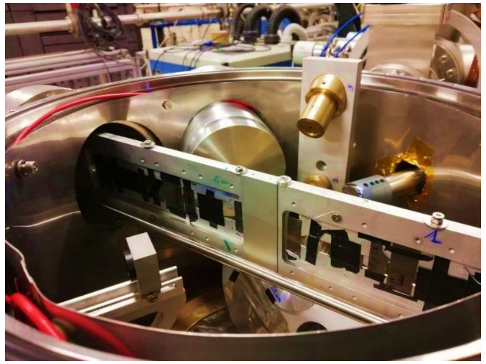
Sample description:

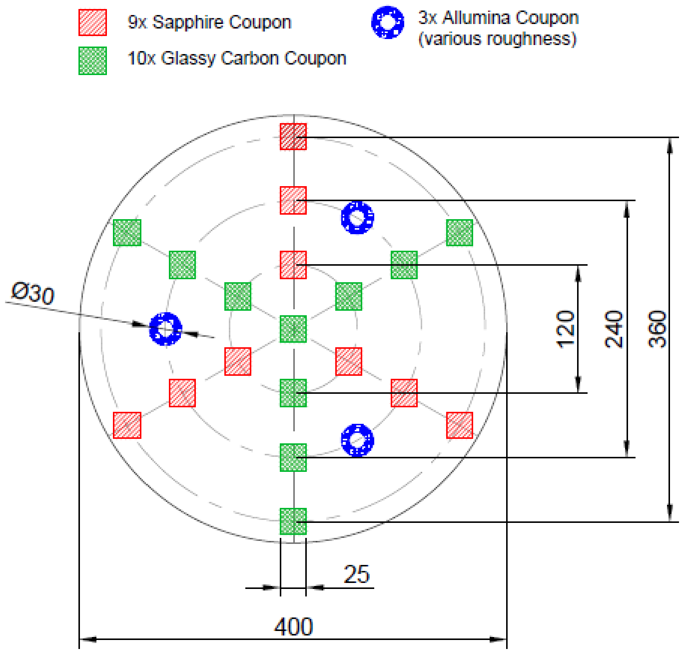
- Glassy carbon thickness: 2mm
- Sapphire thickness: 0.5mm
- Alumina samples if available at LNL.

Interested analysis:

- RBS and NRA for areal density and composition using glassy carbon substrates (@LNL).
- Roughness and further resistivity measurements on sapphire substrates (@LNL).
- SEY on Alumina substrates (@CERN or LNF).

Then we want to apply same calibration and qualification approach to multiple vendors.





Merito specifico

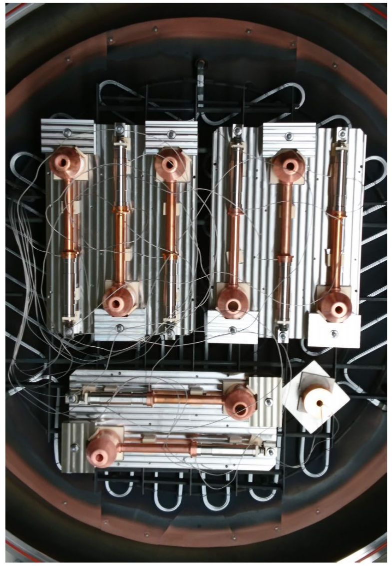
Active Brazing Alloys as alternative to make MoMnO+Ni metallization

LNL has long experience on traditional brazing techniques (IFMIF RFQ, ESS DTL).

Ordered at ITALBRASS/Kyocera a set of alumina disks (diam=25 mm, thickness=4mm) and ABA paste.

First test of brazing small samples on the small LNL vacuum furnace. Then actual geometries on the big vacuum furnace.

After brazing, the same samples will be used to characterize the SEY at different roughness values (1.6um and smoothest), provided that the coating thickness is the same→good input for simulations.



Brazing alloys Italbrass:

- paste CB10 (B-Ag64,8CuTi 780/805)
- Wire Cb4 (70.5Ag, 26.5Cu, 3Ti filo)

Both have an higher content of Ti, which is important for ceramic-metal bonding.

KYOCERA

DEGUSSIT AL23

2023.04.03

Material Type: Aluminium oxide (α-Al_2O_3)

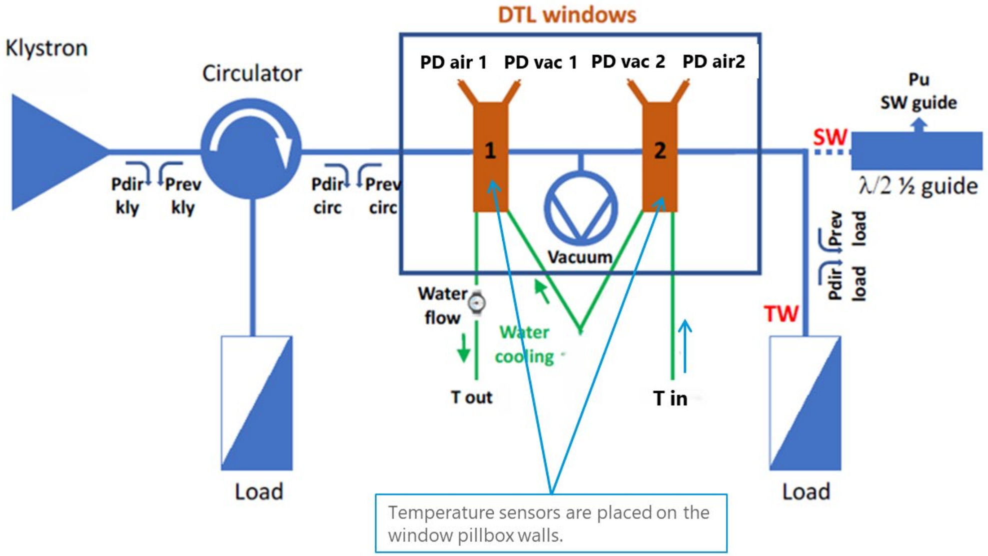
MECHANICAL & PHYSICAL CHARACTERISTICS (TYP.)

Purity		[wt.-%]	>99.5
Density		[g/cm³]	3.70-3.95[1)]
Open porosity		[vol.-%]	0
Average size of crystallites		[μm]	10
Bending strength σ_m DIN EN 843-1		[MPa]	300-350[1)]
Compressive strength		[MPa]	2500
Young's modulus (static)		[GPa]	380
Poisson's ratio		[-]	0.22
Hardness HV1		[-]	1740
Maximum service temperature in air		[°C]	1950
Linear coefficient of expansion	20 - 1000°C	[10^{-6}/K]	8.2
Specific heat 20 °C		[J/(kg*K)]	900
Thermal conductivity	20 °C 1000 °C 1500° C	[W/(m*K)]	34.9 6.8 5.3
Dielectric strength		[kV/mm]	20-30[1)]
Typical colour		[-]	ivory

[1)] Dependent on manufacturing method

Merito specifico

High power testing: procedure already developped



RF high power conditioning is controlled by an automatic routine in python.

We perform RF power ramps from around 10 kW to 1.4 MW. We switch off the RF power when one of the following events occurs:

- Outgassing with a vacuum level exceeding a hardware threshold defined at 1x10-6 mbar,
- Presence of electrical arcs whose intensity is greater than around 2 lux (AFT photodiode"< 25 mV at < 1 Lux")
- Water T outlet – Water T inlet > 0.6 degC (each window by design should give dT ≈ 0.3 degC)

The RF power is increased step by step 1 kW per second). The power increases if the vacuum pressure is lower than a soft threshold placed at 5x10-7 mbar or lower. The soft threshold is defined to allow some dynamic to RF with the initial conditions. If the outgassing is larger than this soft threshold, we decrease the RF power of 10 kW or more if needed, to keep the vacuum lower than the threshold.

A similar soft threshold logic is setup on the light signal level being lower than 65 mV. The analogic signal of the AFT module is acquired on an oscilloscope.

Once the vacuum is correct, RF power can increase. RF power ramps start with repetition rate of 1 Hz. The sequence is the following:

- Conditioning in travelling wave at rep rates 1-2-3.5-7-14 Hz
- For rep rate each configuration, we change the pulse width from short pulse widths ≈25 μs to 3.6 ms doubling the pulses at the end of each power ramp.
- 12 hrs endurance test in travelling wave at 14 Hz – 3.2ms
- Conditioning in standing wave, ramping power at 25-50-100 us 1 Hz and 14 Hz
- 2 hrs endurance test in SW at 100 us – 14Hz
- The test will be carried out at 8 specific phase angles from a variable length short circuit

Possible Collaborations and Budget

CERN.

CEA.

SNS.

INFN-LASA.

INFN-LNF.

Budget 800-1000 k€

- consumable materials (copper, alumina, special brazing materials, chemical coatings...)
- small movable ISO5 clean room for “in-situ” coupler assembly (roughly 70-100 kEuro, depending on the size).

Staff for 3-5 years:

- RF scientist
- 1 Mechanical/Material engineer
- 1 Control scientist
- 1 Electronics technician
- 1 mechanics technician