CONDITIONING OF THE FIRST MASS PRODUCTION POWER COUPLERS FOR THE ESS ELLIPTICAL CAVITY

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Abstract

In the framework of the European Spallation Source (ESS), the CEA Saclay is in charge of the delivery of 9 medium beta (beta = 0.67) and 21 high beta (beta = 0.86) cryomodules. Each cryomodule is composed of 4 cavities equipped with RF (Radio Frequency) power couplers (704.42 MHz, 1.1 MW maximum peak power, repetition rate=14 Hz, RF pulse width > 3.1 ms) [1]. Ten prototype power couplers have been manufactured to validate the design and the performance [2]. Currently the mass production of the 120 couplers started and the six first pre-series medium beta couplers have been successfully conditioned. This result allowed launching the production of the remaining 30 medium beta couplers. In this poster, we describe the architecture of the coupler, the main features of the manufacturing and the infrastructure developed at CEA to prepare the couplers: cleaning methods, assembly in a cleanroom, bake-out with a furnace and test bench for the conditioning at high RF power. Some results obtained during the RF conditioning of the first mass production medium beta couplers are also presented.

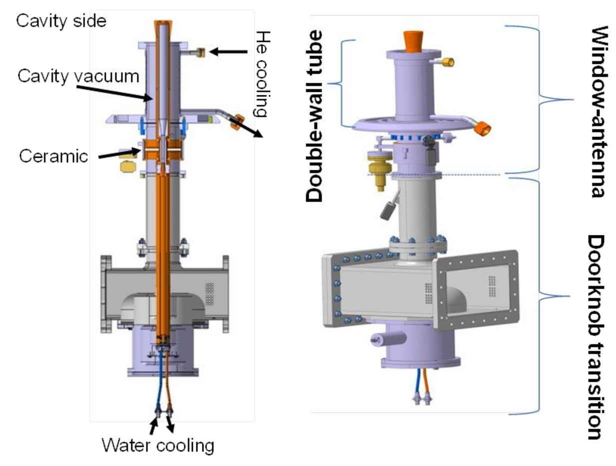
1. ESS couplers: presentation

- **Features of the couplers**

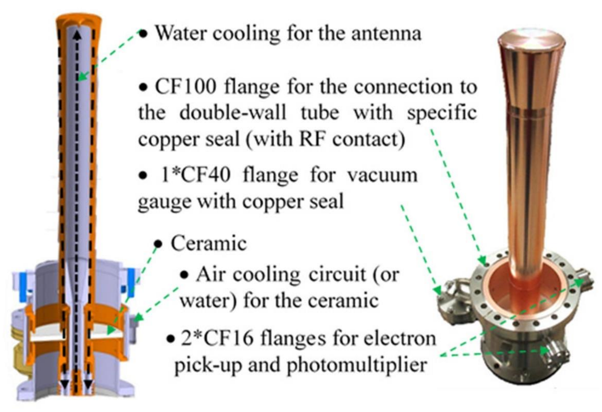
Features	Value
●RF frequency	704.42 MHz
●Repetition frequency	14 Hz
●Incident RF power	1.1 MW
●RF pulse width in full reflection (all phases)	500 µs
●RF pulse width in travelling wave	3.6 ms
●Voltage withstand (voltage between internal conductor and external conductor)	±10 kV

- **Architecture of the couplers**

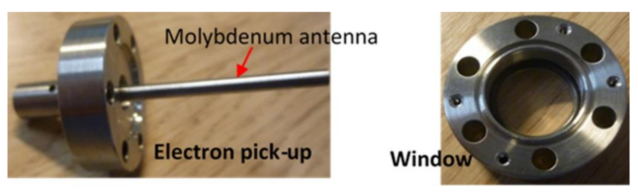
— Single window with antenna + double-wall tube + doorknob transition
— Couplers common to medium and high beta cavities (except the length of the double-wall tube)



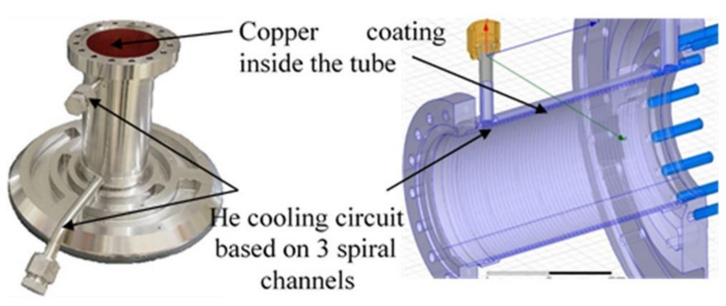
- **Window**



— Bulk copper for the antenna and the chokes; stainless steel 304L for the other parts
— Brazing except for the antenna (electron beam welding)
— Electro-polishing on the antenna
— TiN coating (10 nm ± 5 nm thickness) on the vacuum side of the ceramic
— Copper coating (30 µm ± 10 µm thickness) on the RF surfaces of stainless steel
— Diagnostic equipment: Electron pick-up, view port with a photomultiplier for arc detection on the vacuum side of the ceramic, IKR070 vacuum gauge from Pfeiffer

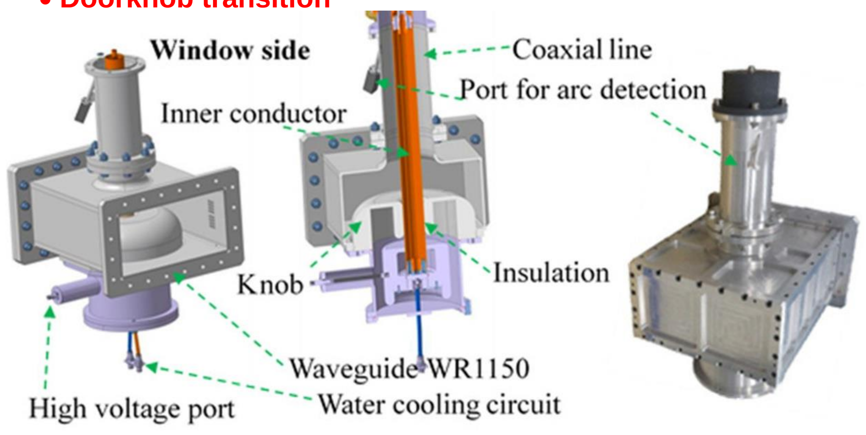


- **Double-Wall tube**



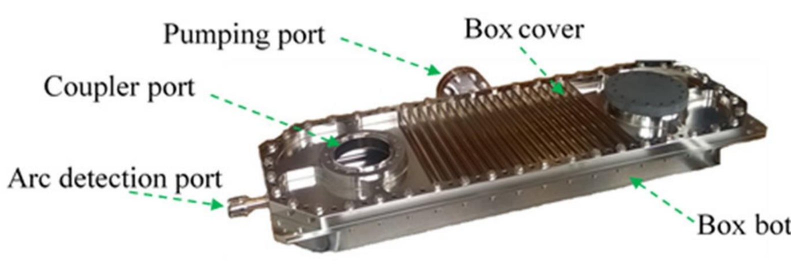
— Stainless steel 316L
— 2 walls assembled by a shrink-fitting method
— Welding for all parts
— Copper coating (10 µm -3 µm/ +2 µm thickness)

- **Doorknob transition**

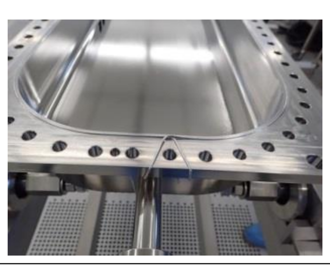


— Bulk copper for the inner conductor, aluminum for the waveguide box and the outer conductor. Stainless steel for some parts
— Port for a photomultiplier (arc detection on the air side of the ceramic)
— High voltage connector for antenna biasing (max 10 kV)
— Water cooling circuit in the inner conductor

- **Test box**



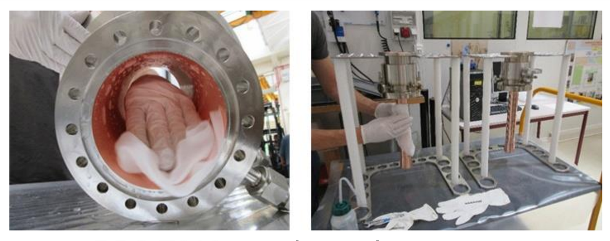
— Stainless steel 316L
— Vacuum tight thanks to an aluminum wire between cover and bottom
— Port for photomultiplier to detect electrical arcs. Pumping port (CF63)



Aluminium wire seal

2. Cleaning

— Window: manual cleaning with absolute ethanol (surfaces, under chokes, all the ports with microfiber swabs). Antenna cleaned with RBS T310
— Double-wall tube: cleaning in an ultrasonic bath with Tickopur R33. If oxidation marks present, manual cleaning with RBS T310



RBS T310 on tube and antenna

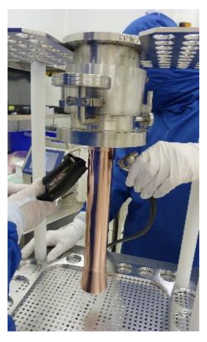
— Electron pick-up in a beaker filled with absolute ethanol and in ultrasonic bath

Electron pick-up in ultrasonic bath

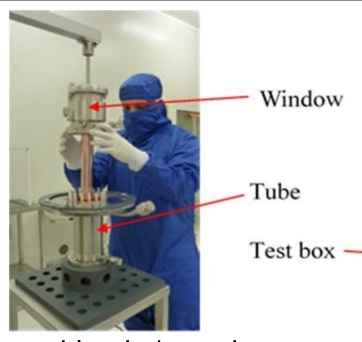
3. Assembly

— Assembly in ISO5 cleanroom
— Particle counting (no particle > 0.3 µm)
— Leak test performed
— Use of rails to move the couplers

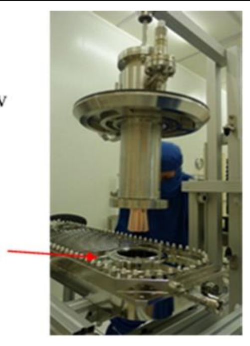
Rails



Particle counting



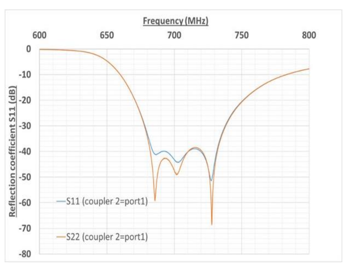
Assembly window-tube



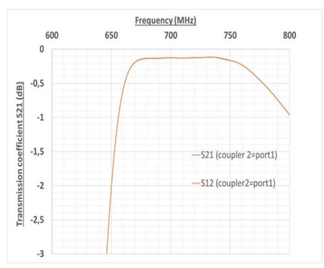
Assembly coupler-test box

4. Bake-out

— Validation of the assembly with RF measurements

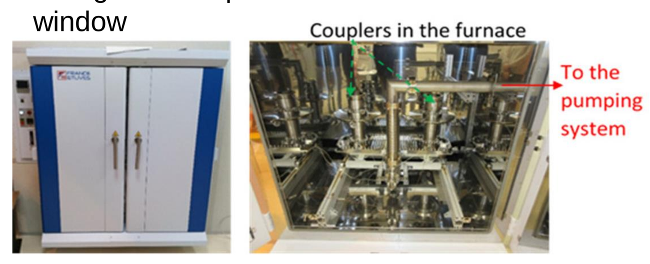


Reflection coefficient

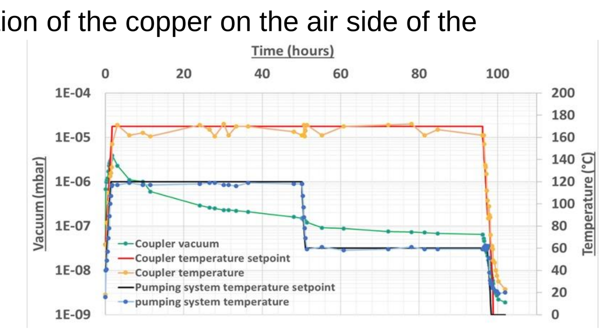


Transmission coefficient

— Couplers baked out for 4-5 days at 170°C in a furnace, the pumping system at 120°C for 2 days then 60°C
— Nitrogen atmosphere in the furnace to limit the oxidation of the copper on the air side of the window



Couplers in the furnace



Temperature cycle

5. Conditioning test stand

— Couplers conditioned by pair
— RF signals checked during the conditioning:
  — The incident power at the output of the klystron (PKDIR),
  — The reverse power at the output of the klystron (PKREV),
  — The incident power at the input of the couplers (PIDIR),
  — The reverse power at the input of the couplers (PIREV),
  — The incident power at the output of the couplers (PTDIR),
  — The reverse power at the output of the couplers (PTREV),
  — The image of the RF power in the coupler thanks to the electron pickup (80dB coupling, PuRF1, PuRF2).
— Vacuum signal checked:
  — The vacuum of each coupler thanks to the IKR070 gauges set up on the vacuum ports (VAC1, VAC 2),
  — The vacuum of the pumping system with a IKR070 gauge. This gauge is close to the input of the pumping port of the test box.
— Signals for electrical activity:
  — Detection of electrical arcs with photomultipliers on the air side of the ceramic (PMA1 and PMA2) and also on the vacuum side (PMV1 and PMV2). In the coupling box thanks to a photomultiplier set up on the test box (PMB)
  — The multipactor effect with the electron pick-up of each coupler (DC bias of 48 V) thanks to the signals PUE1 and PUE2
— Water: flowmeter and temperature probes (water input and output)
— Couplers temperature: probes set-up on the window and on the box

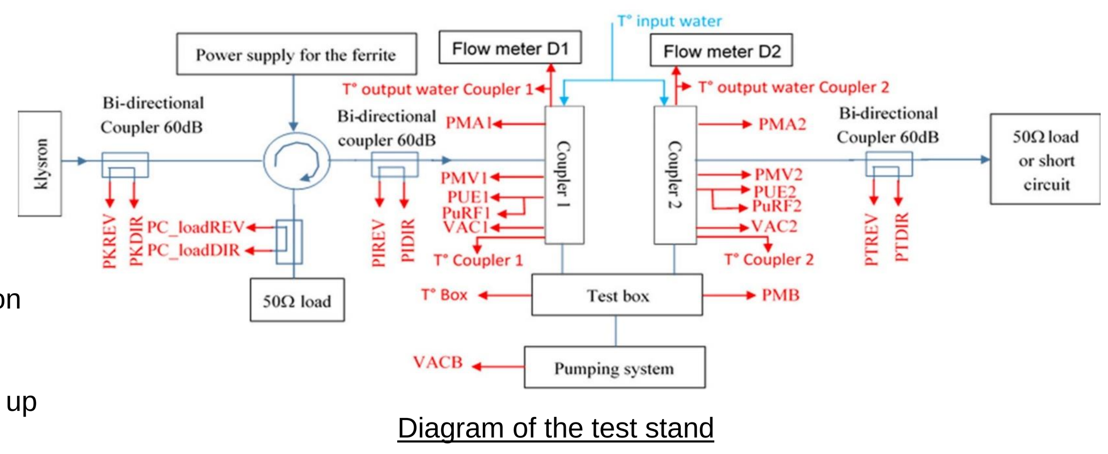
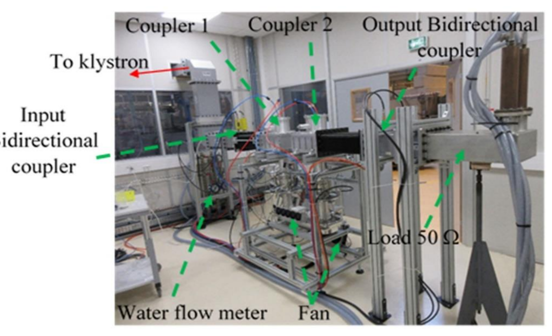
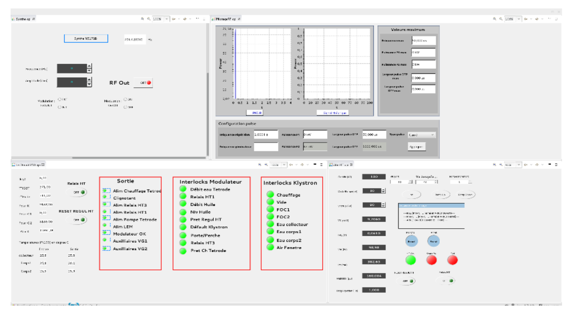


Diagram of the test stand



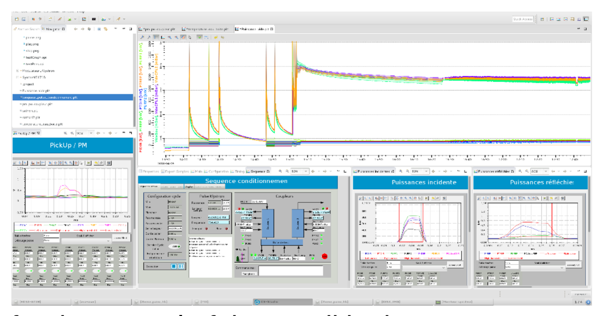
RF test stand



GUI for the control of the klystron

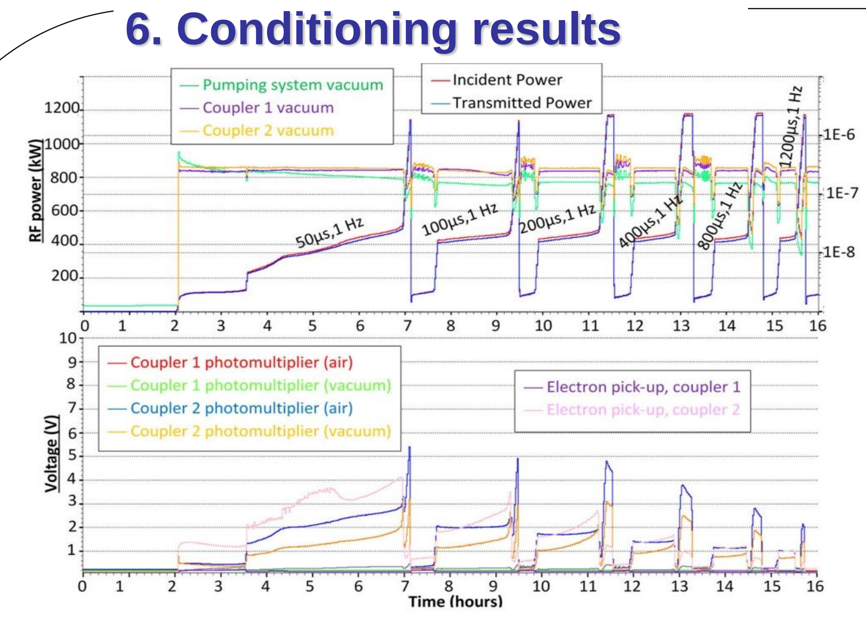
Conditioning principle:
— RF power ramps from around 10 kW to 1.1 MW (pulse width from 50µs to 3.6ms), increase step by step (usually 1 kW per second)
— RF power switched off when
  — Outgassing with a vacuum level exceeding a hardware threshold defined at 1x10^{-6} mbar
  — Presence of electrical arcs whose intensity is greater than around 3 lux (photomultiplier),
  — Presence of electrons whose intensity is greater than 8 mA (detected with the pick-up electron).

Conditioning sequence:
— Conditioning in travelling wave at 1 Hz
— Conditioning in travelling wave at 14 Hz
— Conditioning in standing wave at 1 Hz
— Conditioning in standing wave at 2 Hz, 4 Hz, 8Hz
— Conditioning in standing wave at 14 Hz.
The automated handling of all the conditioning sequences, the interlocks and the data recording are controlled with EPICS

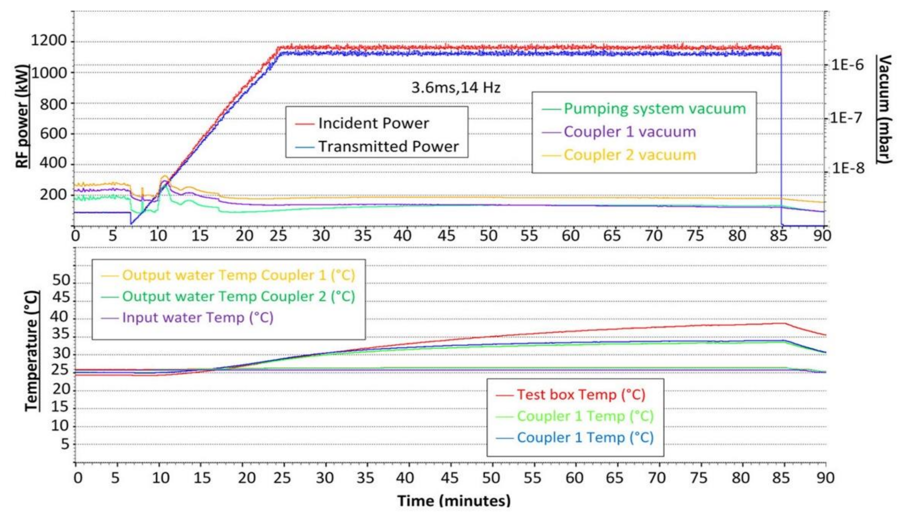


GUI for the control of the conditioning sequence

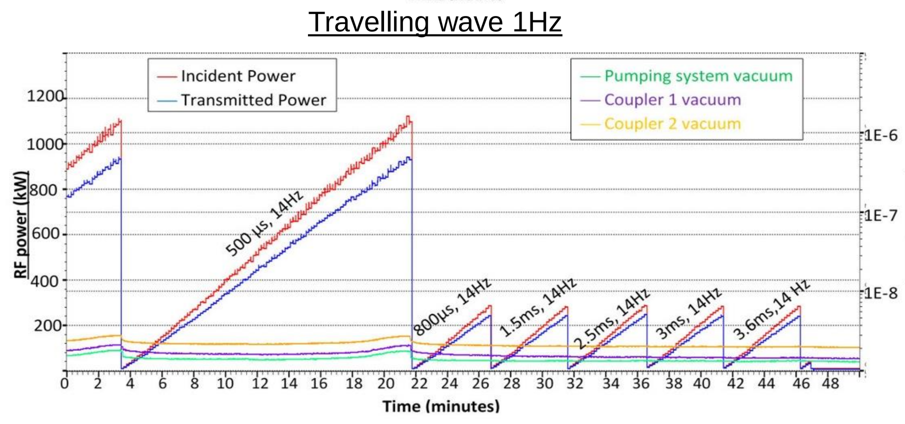
6. Conditioning results



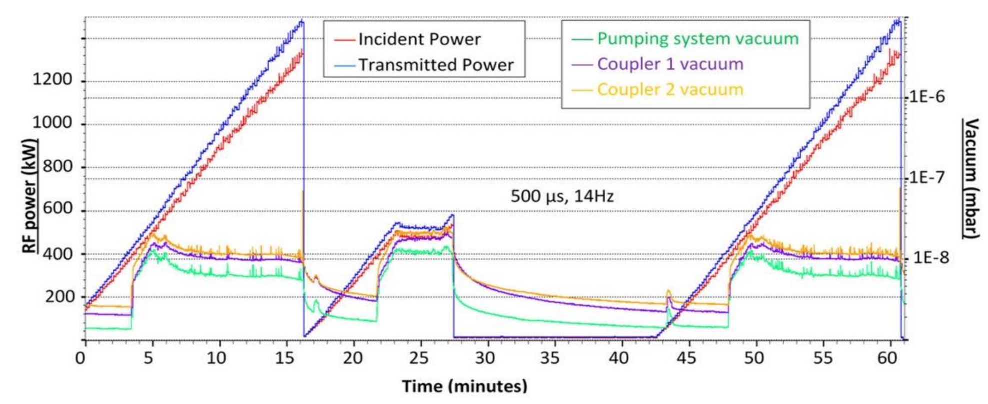
Travelling wave 1Hz



Travelling wave 14Hz



Standing wave 14Hz (1st position of the short circuit)



Standing wave 14Hz (2nd position of the short circuit)

— Conditioning of the 3 first couplers pairs
— In standing waves: 2 positions of short circuit, the first one gives a maximum of electric field close to the ceramic. The second position allows a minimum of electric field close to the ceramic.
— Duration of conditioning: 167 hours for the 1st pair, 86 hours for the 2nd pair, 233 hours for the 3rd pair.
— Acceptance requirements: maximal outgassing pressure lower than 2x10^{-8} mbar without electron activities and electrical arc phenomena on the full RF power range in the following ramps
  — travelling wave (14 Hz, 3.6 ms, 1.1 MW max followed by a power plateau at 1.1 MW for 1 hour),
  — standing wave (14 Hz, 500 µs, 1.1 MW max) for the 2 positions of the short circuit,
  — standing wave (14 Hz, 3.6 ms, 300 kW max) for the 2 positions of the short circuit

Conclusion

— Successful conditioning of the six first pre-series couplers ⇒ validation of the different manufacturing processes and launching of the rest of the series couplers.
— Four pre-series couplers are currently assembled on the first series cryomodule.
— Start of the conditioning of the next series couplers.

References

[1] C. Arcambal et al., "Status of the power couplers for the ESS elliptical cavity prototypes", in Proc. SRF'2015, Whis-tler, Canada, Sep. 2015, paper THPB078, pp. 1309-1312.
[2] C. Arcambal et al., "Conditioning of the power couplers for the ESS elliptical cavity orototypes", in Proc. IPAC'2017, Copenhagen, Denmark, May 2017, paper MOPVA044, pp. 957-959.