DE LA RECHERCHE À L'INDUSTRIE

ESS ELLIPTICAL HIGH-BETA CAVITY PACKAGE TEST RESULTS

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SLHIPP-8

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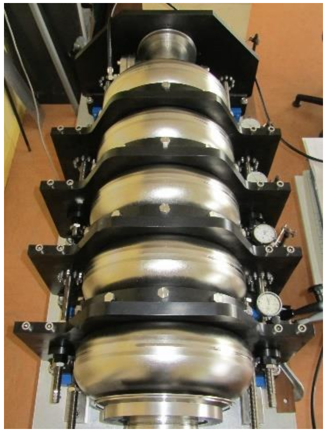
INTRODUCTION AND MOTIVATION OF THE TEST

- **First test of ESS elliptical cavity equipped with a power coupler**
  - Collaboration between :
    - CEA: High beta Cavity. coupler and Cold Tuning System (CTS)
    - FREIA: Test stand (cryostat. control system…)
    - ESS: RF source (modulator and klystron)

- **The test of HB elliptical cavity has the goals of verifying:**
  - the cooling procedures.
  - the power coupler conditioning and performance with the cavity.
  - the cavity performance with the coupler.
  - the cold tuning system (CTS) ability and performance.
  - the LLRF ability and performance.
  - the high power RF amplifier ability and performance in combination with the cavity and LLRF.

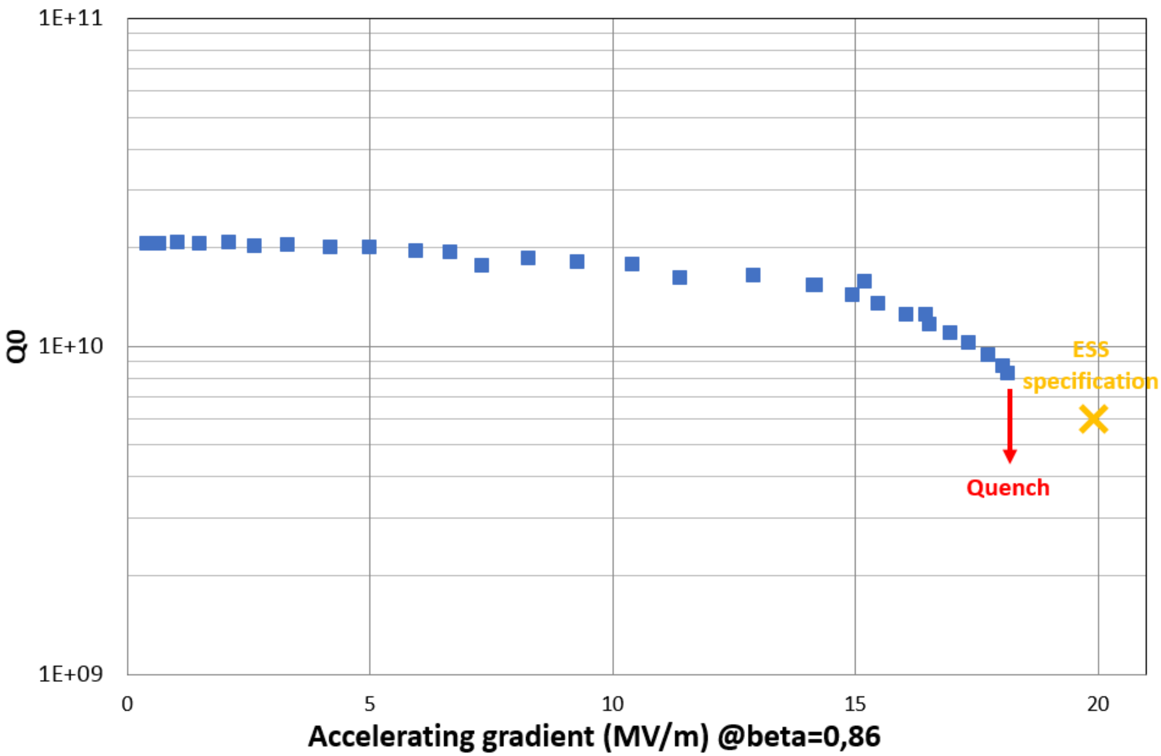
PREPARATION OF CAVITY AT CEA

- **Field flatness tuning → chemical treatment → clean room assembly → test in cryostat vertical (CV) at CEA**



Field flatness tuning stand

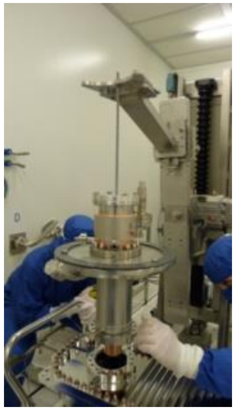
Cavity preparation for CV test



- **Degradation of the cavity performance during a baking**
  - adequate for this test (find the same performance with coupler)

PREPARATION OF POWER COUPLER AT CEA

❶



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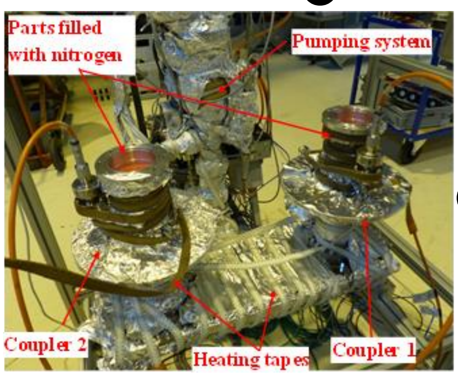

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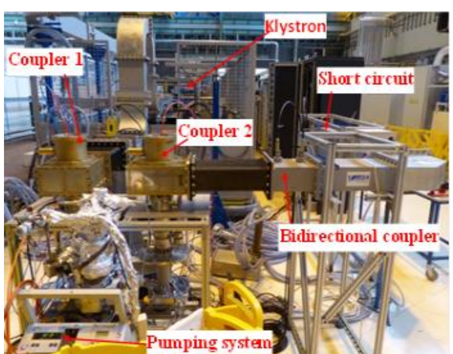
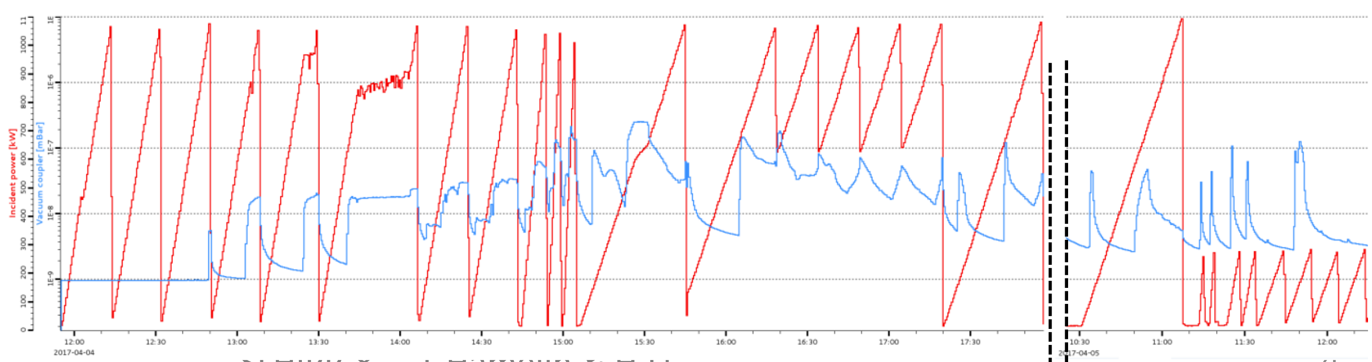


❹

- Coupler cleaning ❶ → clean room assembly of 1 pair of coupler on coupling box ❷ → baking at 170°C during ~100h ❸ → RF conditioning ❹

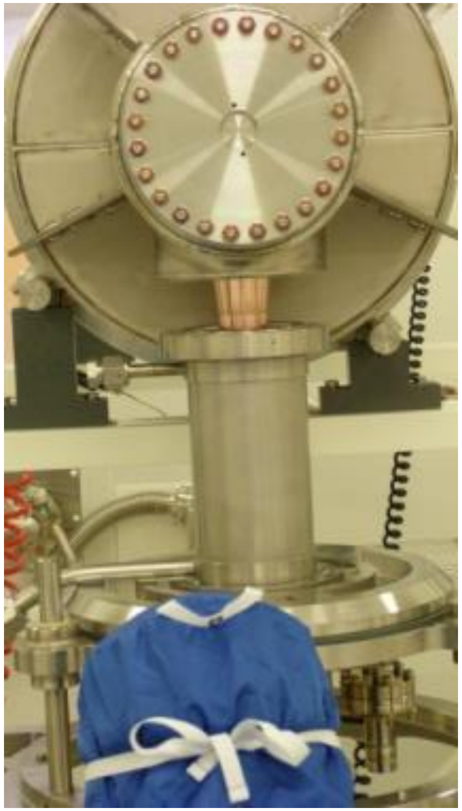
Conditioning sequence	Traveling wave(TW)	Standing wave (SW)
RF power ramps	From 15 kW to 1100 kW	From 15 kW to 300 kW to 1100 kW
RF pulse repeat rate	From 1 Hz to 14 Hz	From 1 Hz to 14 Hz
RF pulse length	From 50 µs to 3600 µs	From 50 µs to 3600 µs to 500 µs
Configuration	On load 50 Ω	On short circuit: 2 positions to have an electric field on ceramics at maximum and minimum levels



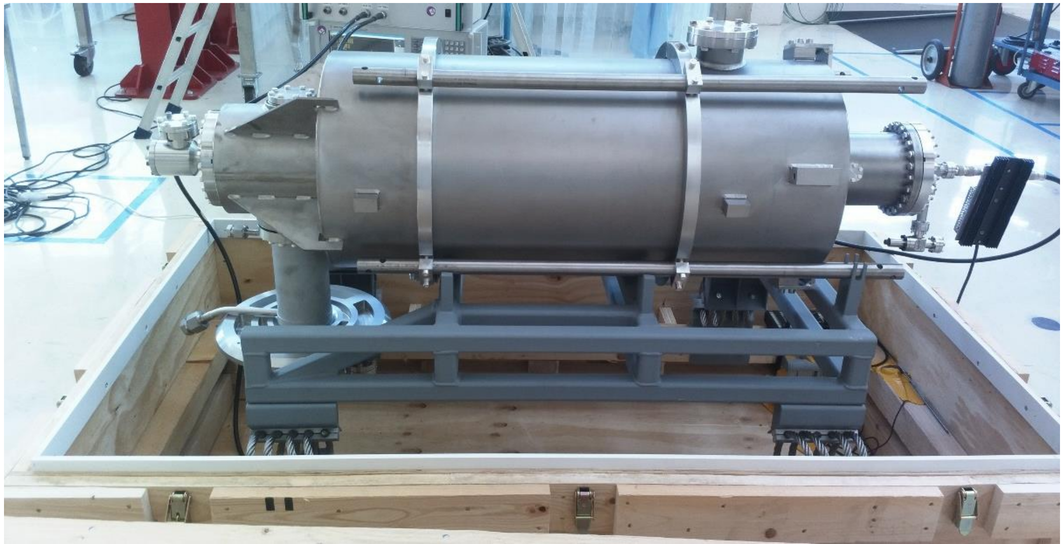
CAVITY AND COUPLER ASSEMBLY AT CEA

- **Coupler assembly on the cavity in clean room**

Coupler-cavity assembly stand



Coupler assembly on the cavity



Packaging of the coupler-cavity for Uppsala

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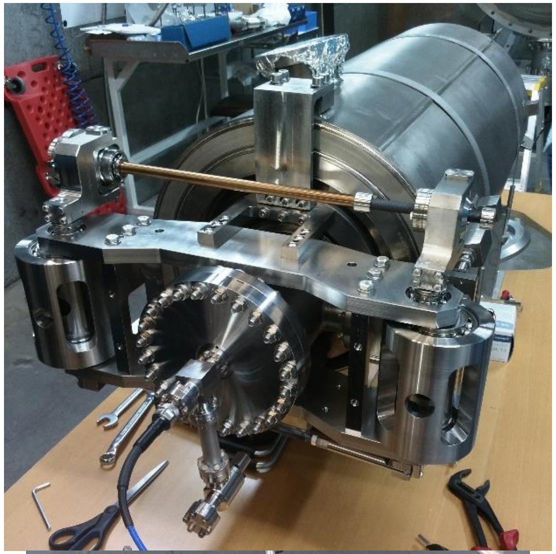
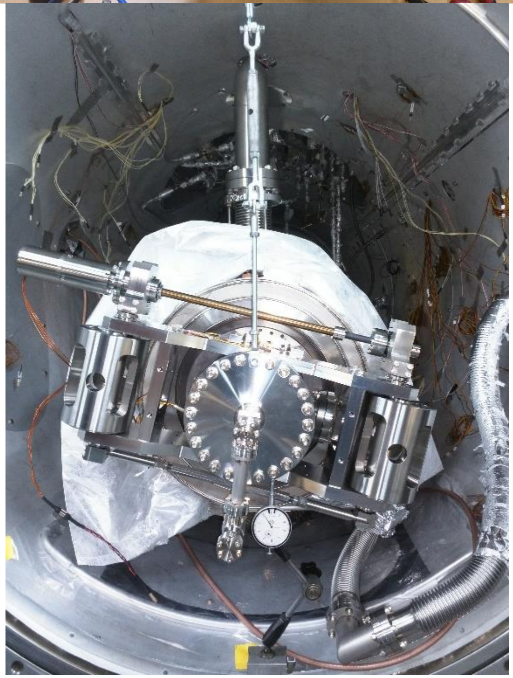
FREIA

CTS AND DOORKNOB ASSEMBLY AT FREIA



Assembly and adjustment of the CTS



Implementation of the cavity and the coupler in the cryostat

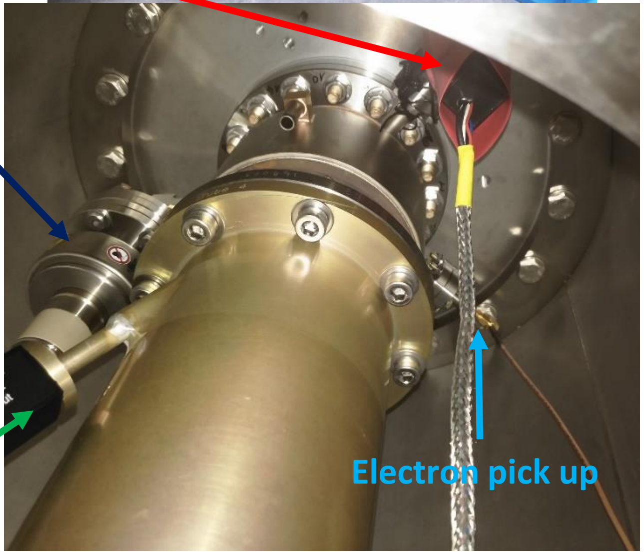
Assembly of the doorknob

Vacuum Photomultiplier

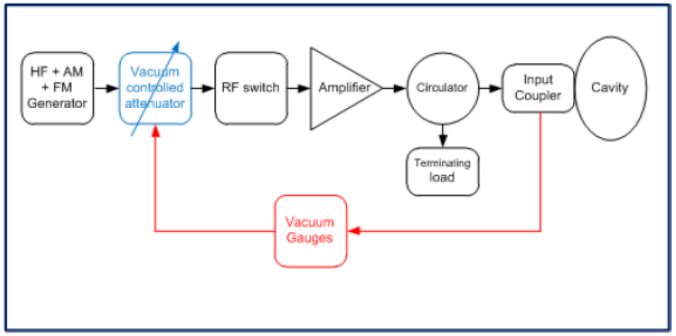
Vacuum gauge

Implementation of the coupler security signals

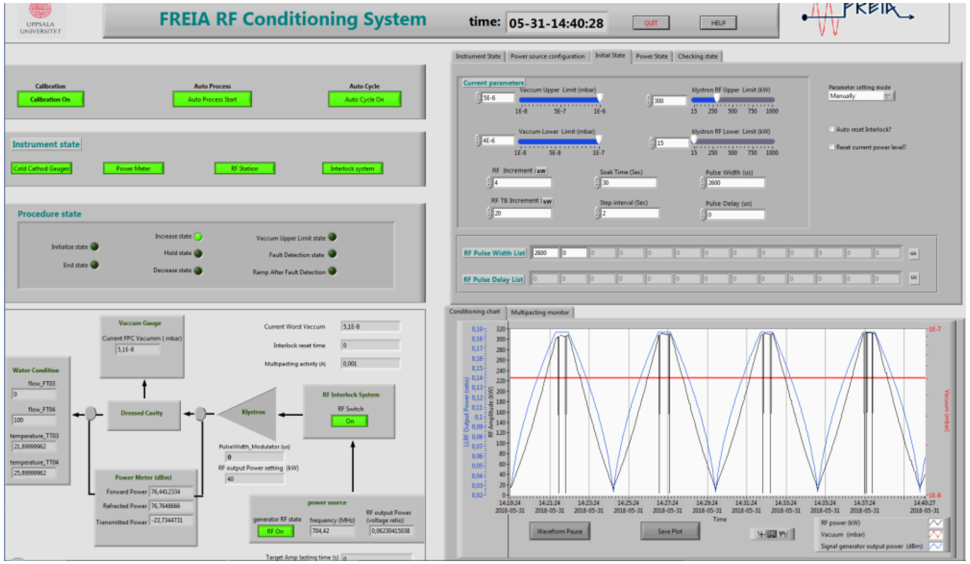
Air Photomultiplier



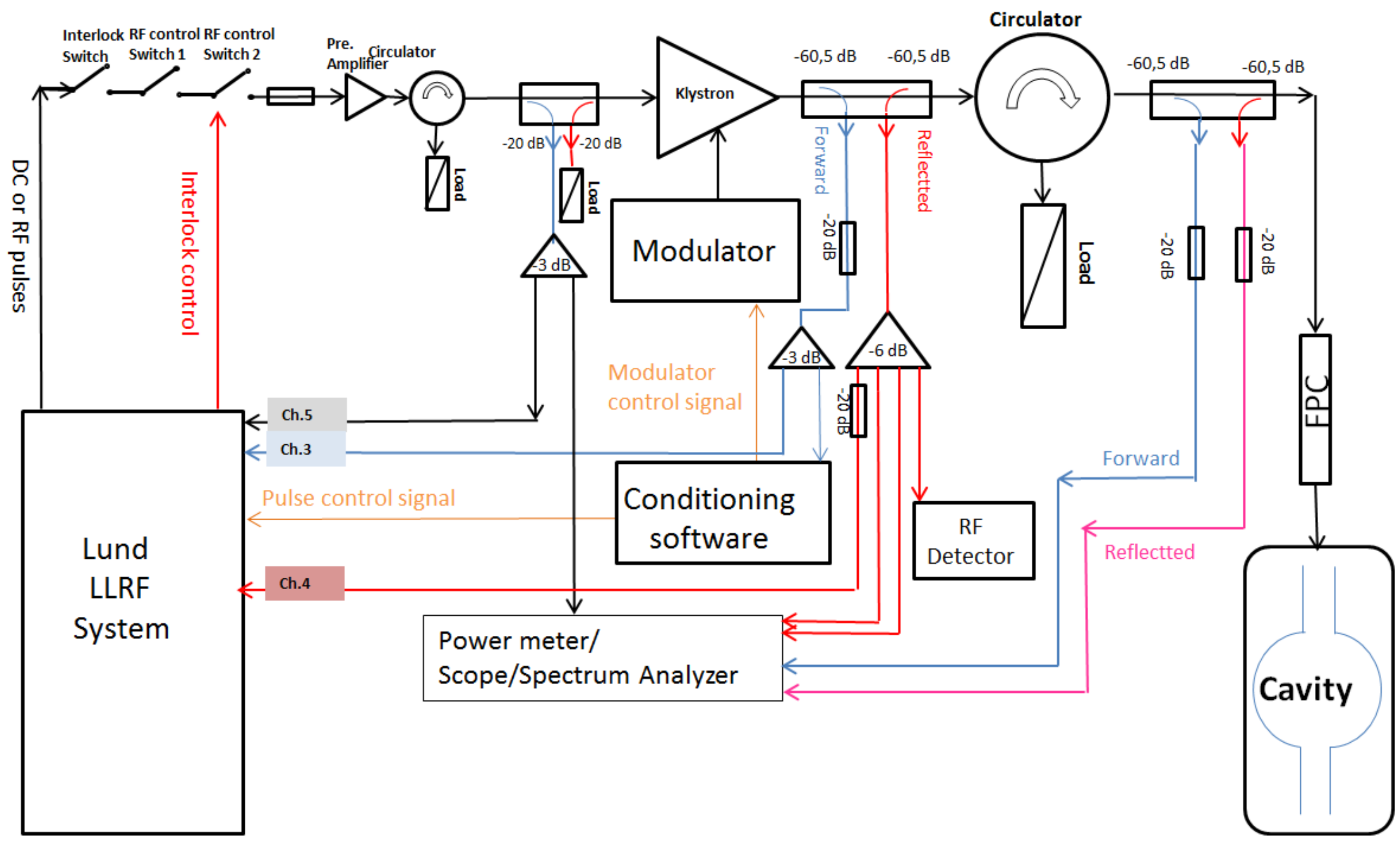
- FREIA conditioning program
  - ✓ Conditioning software has been tested with ESS spoke cavity
  - ✓ Several repetition rates has been implemented (1Hz, 2Hz, 3.5Hz, 7Hz, 14Hz)
  - ✓ Key paremeters setting are following CEA's suggestion,like interlock thresholds and vacuum thresholds.



Parameter	value
Loop control time (s)	1
Pulse repeat rate (Hz)	1,2,3.5,7,14
Vacuum upper limit (mbar)	5e-6
Vacuum lower limit (mbar)	2e-6
RF upper limit (KW)	1000 (for pulse less then 500us) 300 (for pulse less then 500us)
RF lower limit (KW)	1
Initial pulse length (µs)	50
pulse length step	50 µs. 100µs,. 200 µs,. 300µs,. 400 µs,. 500µs,. 800 µs,. 1,.5 ms,. 2 ms,. 2.6 ms

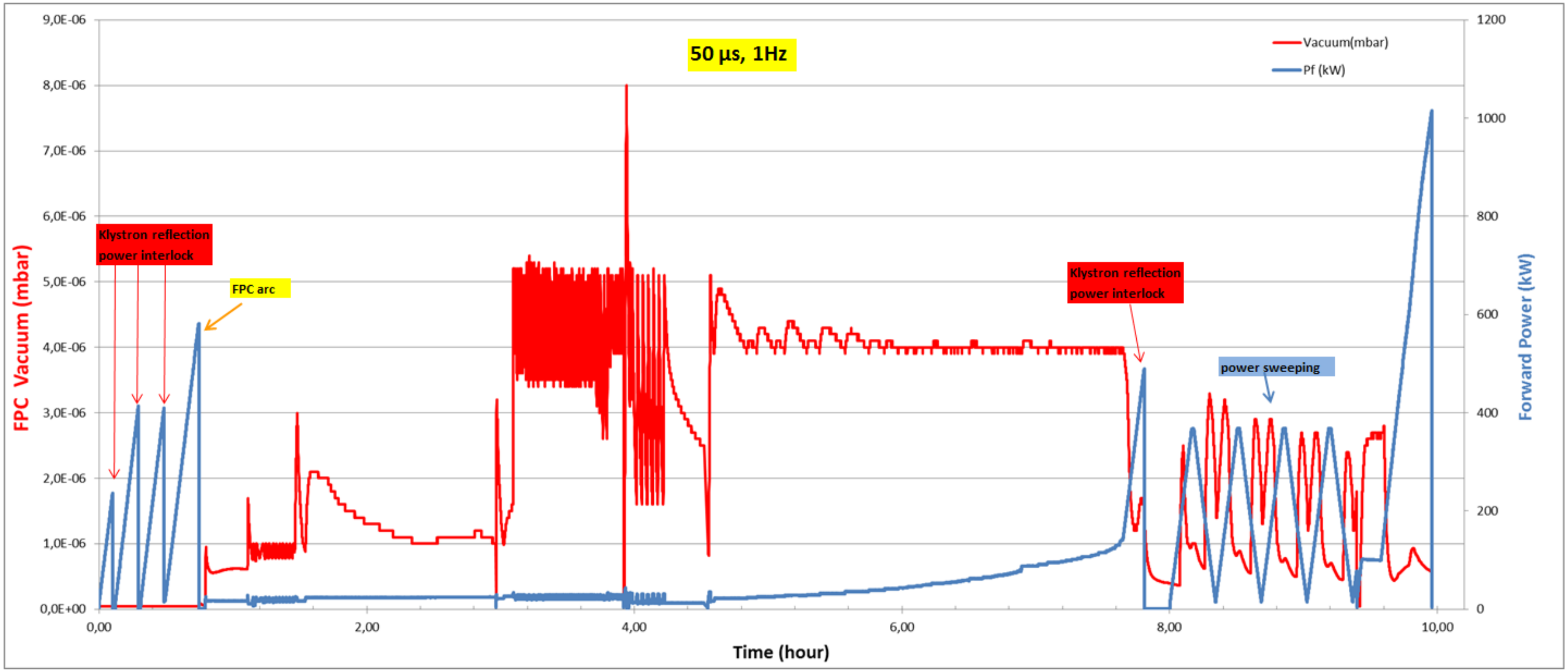


FPC CONDITIONING BLOCK DIAGRAM



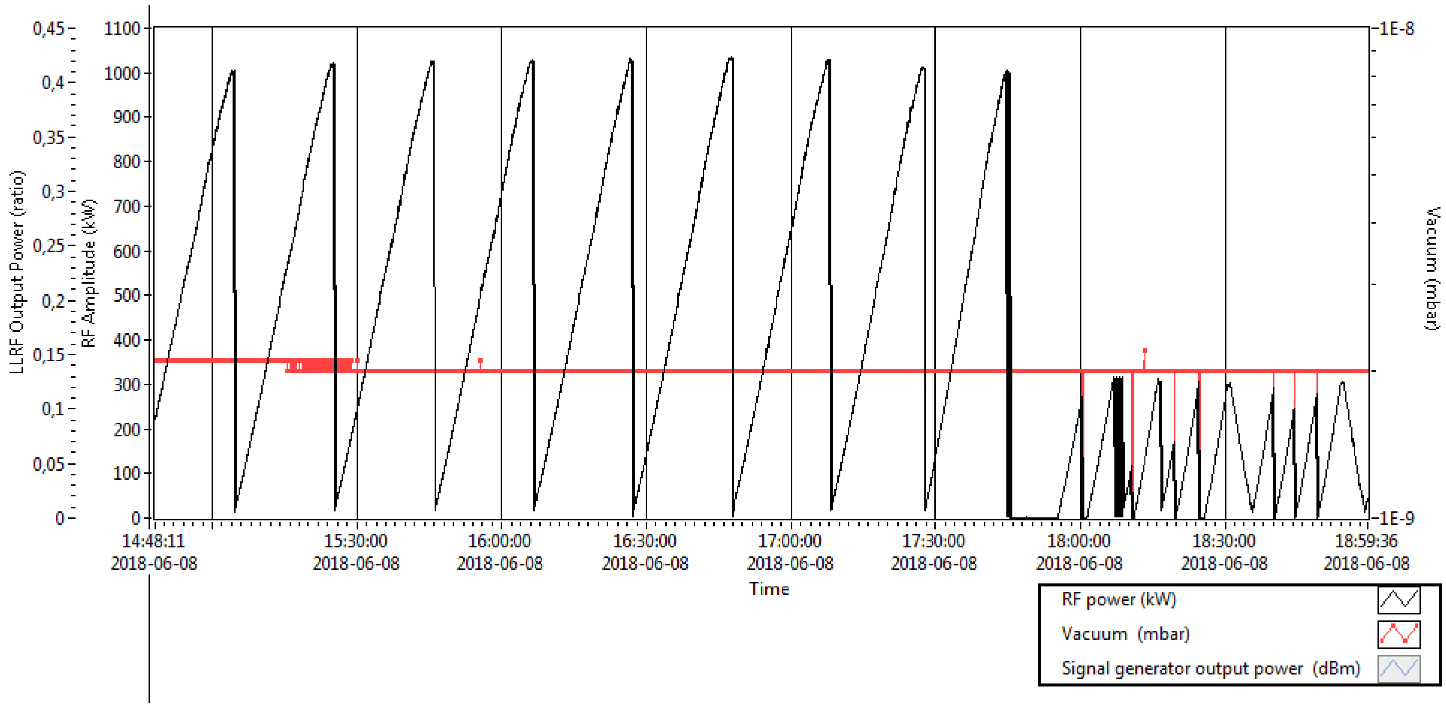
FPC WARM CONDITIONING

- Warm conditioning of FPC took 20 hours in total (effective conditionig time)
  - ✓ A lot of outgassing happend at low power with short pulses, 10 hours was spend at 50us phase
  - ✓ Several repetition rates has been implemented for 500 us pulses (1Hz, 2Hz, 3.5Hz, 7Hz, 14Hz)
  - ✓ 300kW power with 2.6 ms pulses is reached

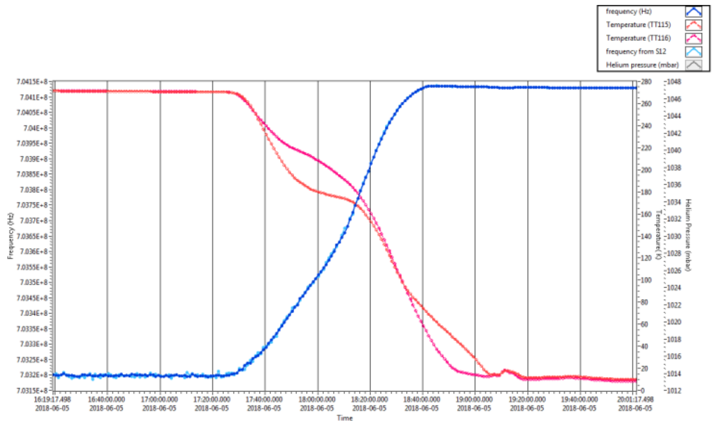


FPC COLD CONDITIONING

- Cold conditioning of FPC took 9 hours in total (effective conditionig time)
  - ✓ Cold conditioning was complected at 2K
  - ✓ Same procedure as warm conditioning was adopted
  - ✓ Two frequencies were used for the cold conditioning (slightly lower and higher frequency than the resonant frequency)
  - ✓ 300kW power with 2.6 ms pulses is reached



FREQUENCY CHECKING

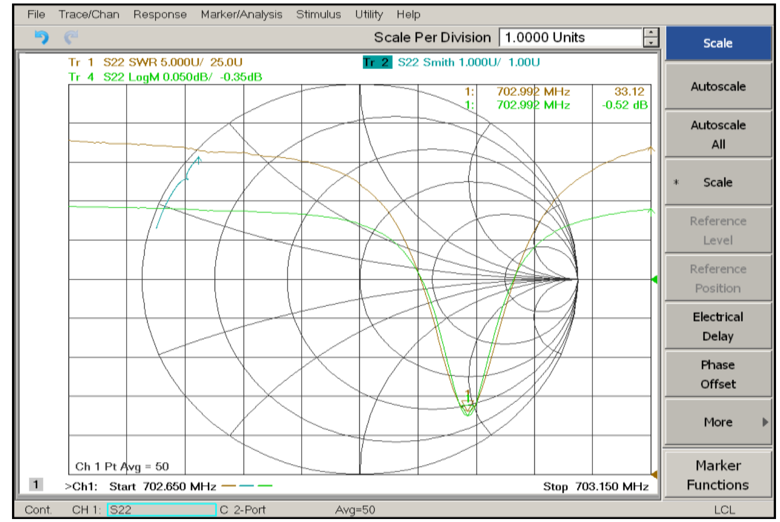


- Frequency checking during cool down to study the cavity behavior
  - ✓ Key frequencies at certain temperature
  - ✓ Frequency shift

Parameter	Frequency (MHz)		
	300K	**4K**	**2K**
Π mode	702.991	704.120	704.081
Frequency shift (compare to 300K)	0	1.129	1.09

Qext FOR FPC

- The Qext for FPC has been studied both at room temperature and cold with different medthod.
  - ✓ Good agreement of result is found
  - ✓ Qext of FPC is close to the expectation

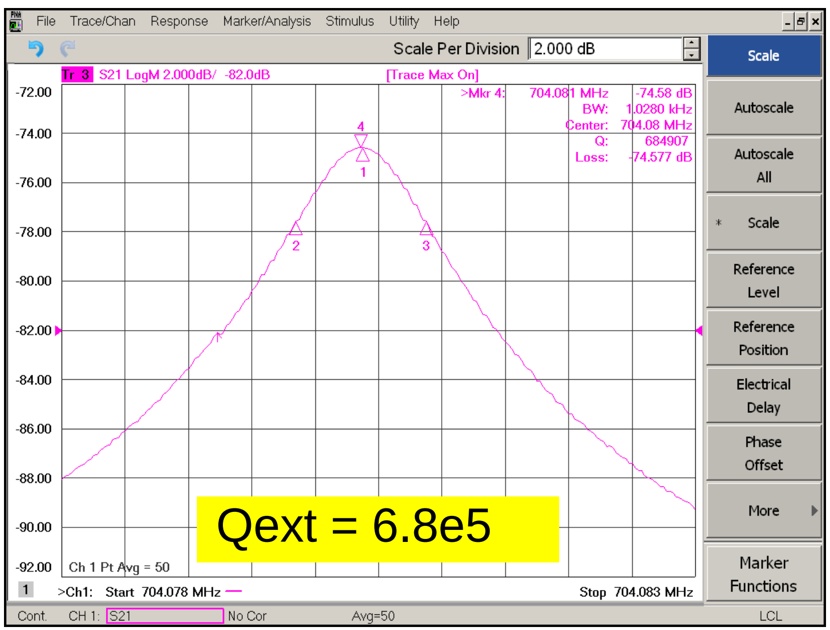


SWR measurement at 300K

✓ The external quality factor of the port of input power can be calculated by the standing wave ratio (SWR).

$$Qe=(1+SWR)QL$$

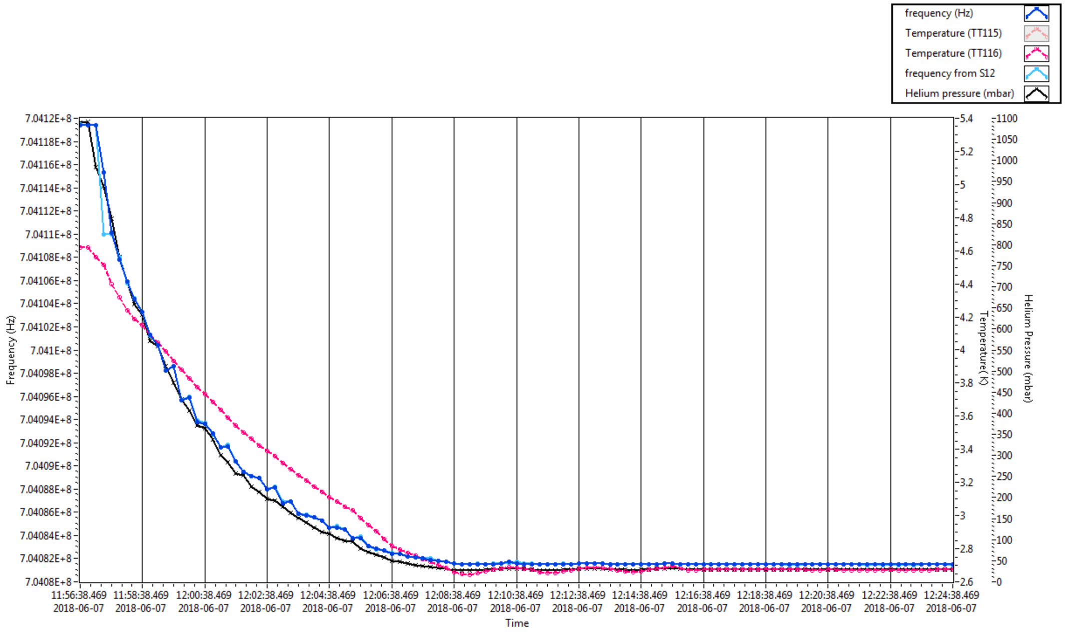
Test run	SWR	Qe
1	29.1	$5.7*10^5$
2	32.3	$6.3*10^5$
3	35.6	$7*10^5$
4	33.1	$6.5*10^5$
5	26.5	$5.2*10^5$
6	28.4	$5.6*10^5$



S21 measurement at 2K

FREQUENCY SENSITIVITY TO PRESSURE

- Checking the cavity frequency shift as a function of helium pressure during cool down from 4.2 K (~1080mbar) to 2 K (~30mbar)



Frequensy sensitivity test rerult of HB elliptical package

Frequency sensitivity to Pressure= 37 Hz/mbar

PASSBAND MEASUREMENT

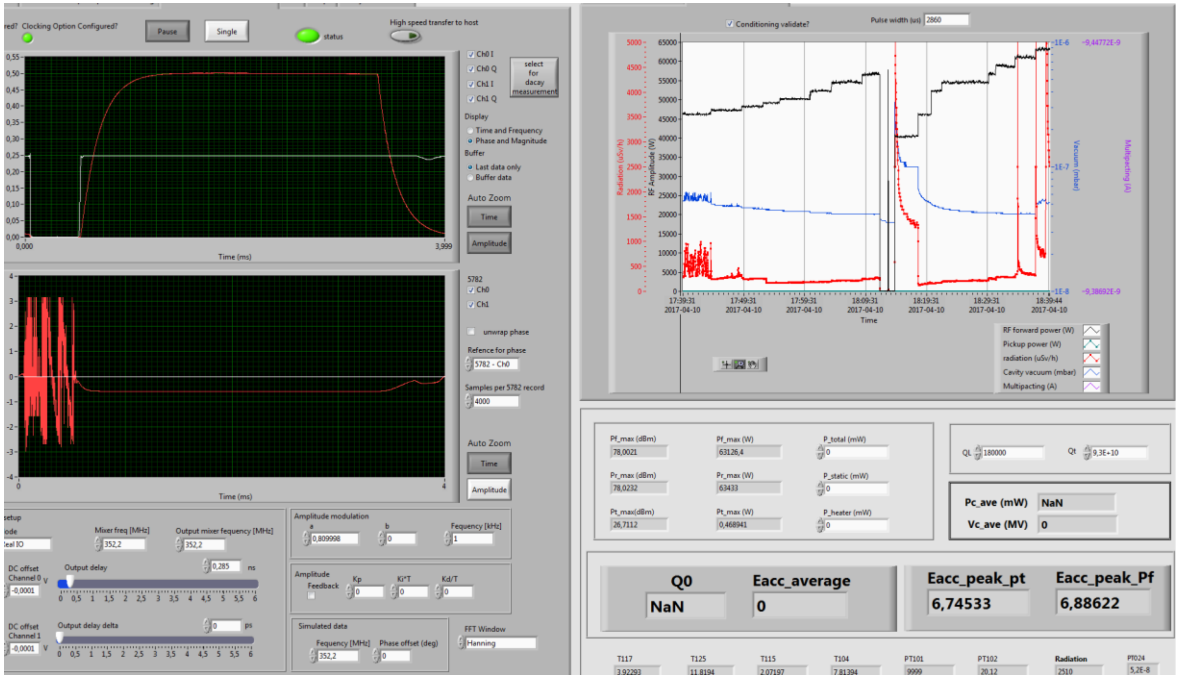
- Frequency of fiest passband was studed at different temperature

Parameter	Frequency (MHz)		
	300K	**4K**	**2K**
Π mode	702.991	704.120	704.081
4Π/ 5 mode	701.761	702.889	702.848
3Π/ 5 mode	698.464	699.592	699.551
2Π/ 5 mode	694.370	695.494	695.454
Π/ 5 mode	691.104	692.227	692.187

Frequency distance between nearest HOM and the nominal frequency is >1.2 MHz

CAVITY CONDITIONING AND TEST

- Cavity package conditioning and test will use FREIA pulse SEL.
- Test program base on Labview will be applied. which has successfully implemented on the spoke packege.
- 2.6 ms pulse with 14Hz repetition rate will be used.
- Major multipacting regions and FE regions will be found



Contorl screem of pulse SEL at FREIA

CONCLUTION

- Test stand and software for HB elliptical cavity test are tested and ready.
- Conditioning of FPC has successfully finished.
- RF test of the HB elliptical cavity is under going.

Annex

•Commissariat à l'énergie atomique et aux énergies alternatives
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•T. +33 (0)1 69 08 76 11 | F. +33 (0)1 69 08 30 24
•Etablissement public à caractère industriel et commercial | RCS Paris B 775 685 019

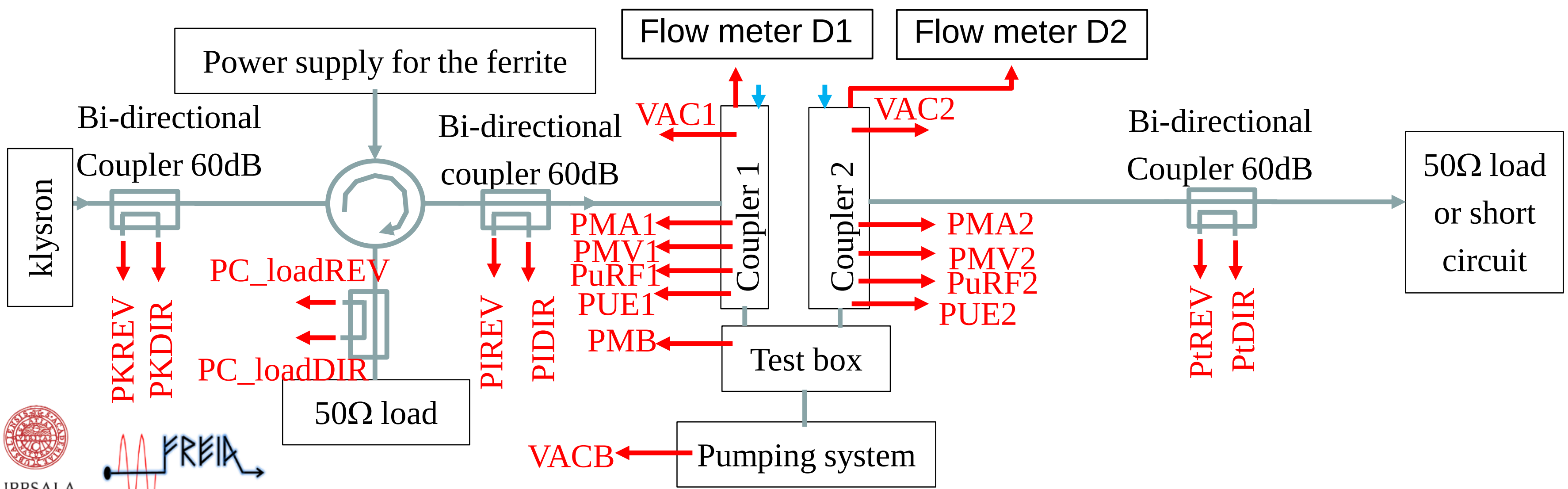
RF CONDITIONING

SECURITY SIGNALS

- Conditioning test stany is instrumented to to ensure the safety of couplers
- 5 arc detectors (photomultiplier PM): 2 by couplers (1 PM on the vacuum side (PMV1 and PMV2) and 1 PM on the air side (PMA1 and PMA2) and 1 for the conditioning box (PMB)
- 2 pick up electrons (current measurement) (1 per coupler) (PUE1. PUE2)

Fast signals: response time < 10µs

- 3 vacuum gauges (IKR070): 1 per coupler (VAC1. VAC2) and 1 for the conditioning box (VACB)
- 5 temperature sensors (PT100): 2 for the hydraulic cooling circuit (1 per coupler). 1 on each coupler closest to the ceramic and 1 for the conditioning box
- 10 RF measurements: 8 measuring the incident and reflected powers by bidirectional couplers (PKREV. PKDIR. PIREV. PIDIR. PTREV. PTDIR) and 2 measuring the power on the electron pickup of each coupler (PuRF1. PuRF2)



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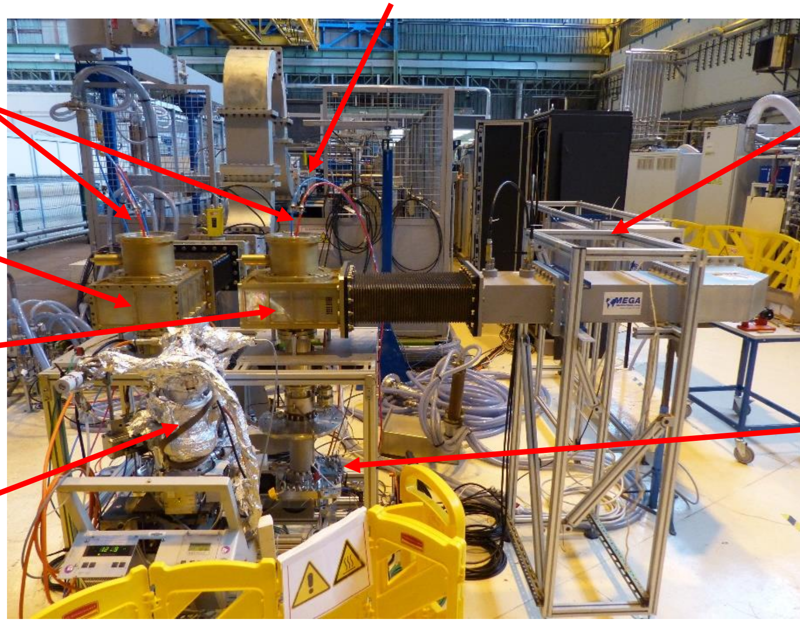
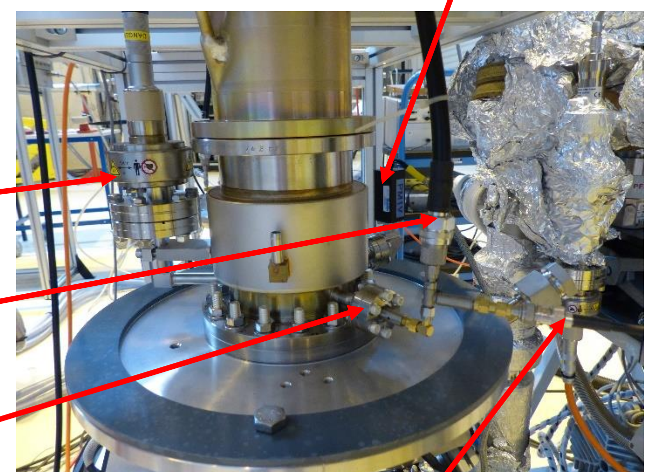
VIEWS OF THE CONDITIONING STAND





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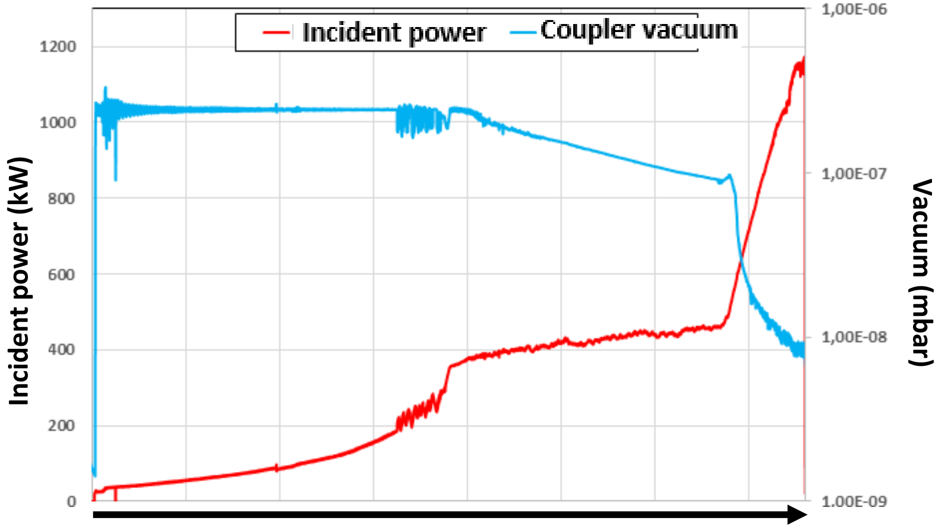
FREIA

RF CONDITIONING

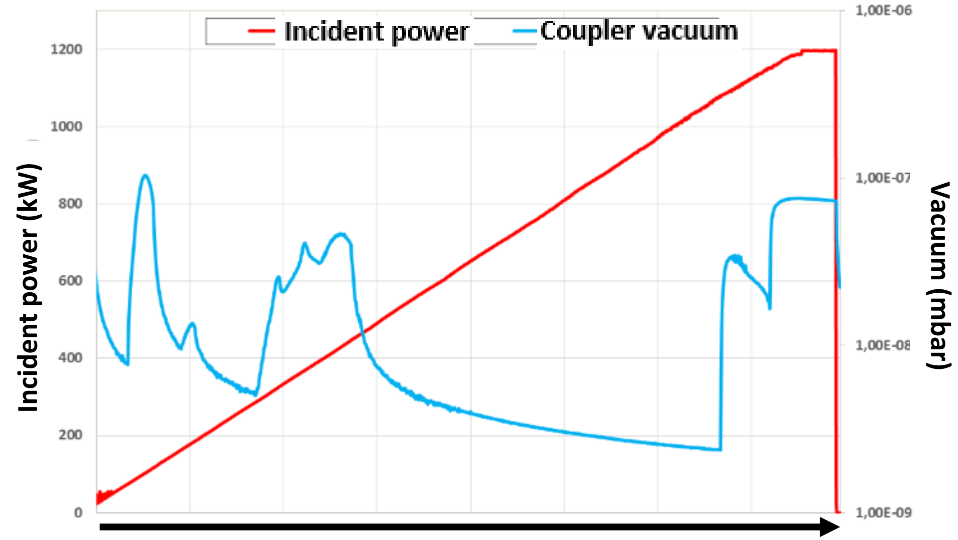
CONDITIONING RESULTS

First ramp

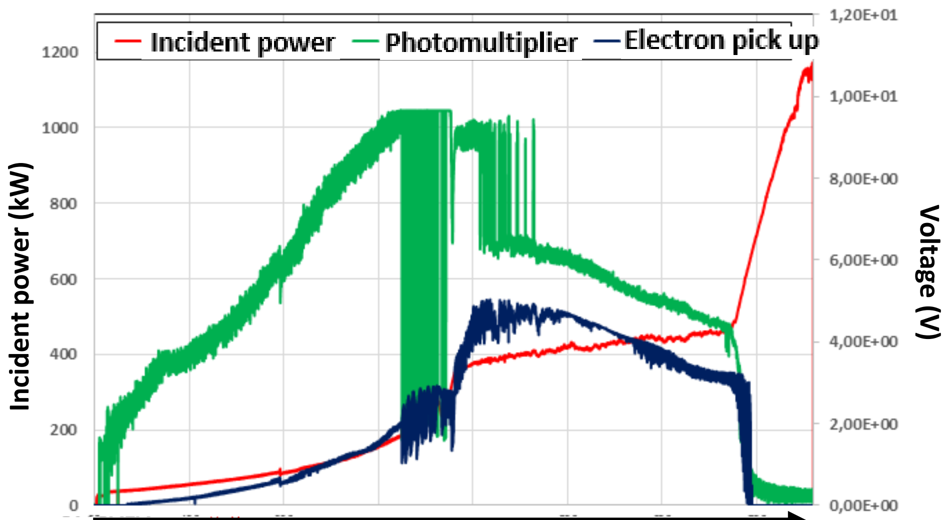


~ 5h00

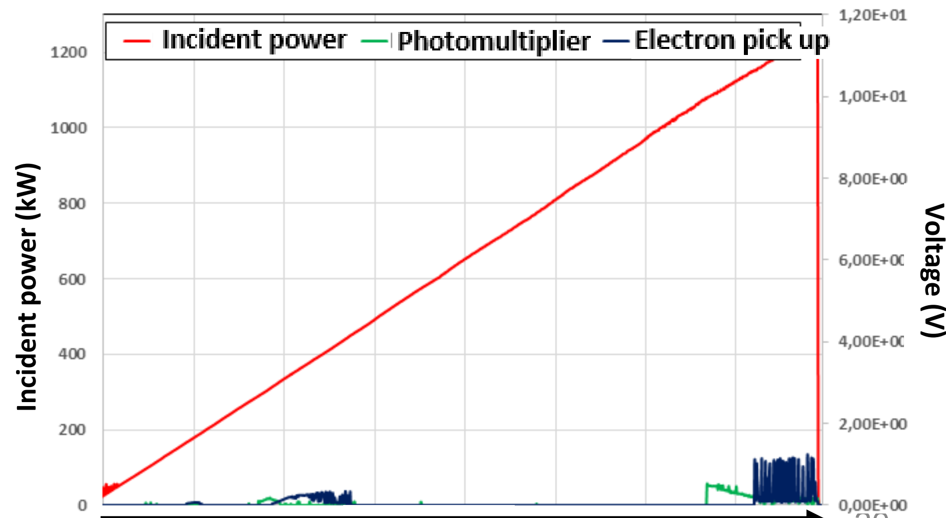
N ramp



~ 20 min



~ 5h00



~ 20 min

The list of tests

Warm test	Cool down	Cold test	Warm up
✓ Central cavity frequency and spectrum of HOM ✓ Qe	Frequency shift due to cool down	✓ Coupler cold conditioning ✓ Cavity conditioning	Frequency shift vs. T
✓ Coupler warm conditioning		✓ Central frequency ✓ Loaded Q and Qe	
		✓ Cavity level profile: let the LHe evaporate to low levels ✓ Effect of CV105 in heat load ✓ Cavity's power limit ✓ Effect of different FPC cooling temperatures in heat load ✓ Max load on the 2K pumps	
		✓ Q0 ✓ Dynamic heat load ✓ Max gradient ✓ Dynamic Lorentz force detuning	
		✓ Stabilization of the cavity field with LLRF using only RF compensation ✓ Dynamic Lorentz force detuning ✓ Tuning range of the slow step tuner	
		✓ Tuner related testing	

CRYO

VNA

SGD signal generator driven

SEL

Lund system

Lund university