Coupler exchange under local cleanroom conditions with the subsequent successful teststand operation of a cryomodule

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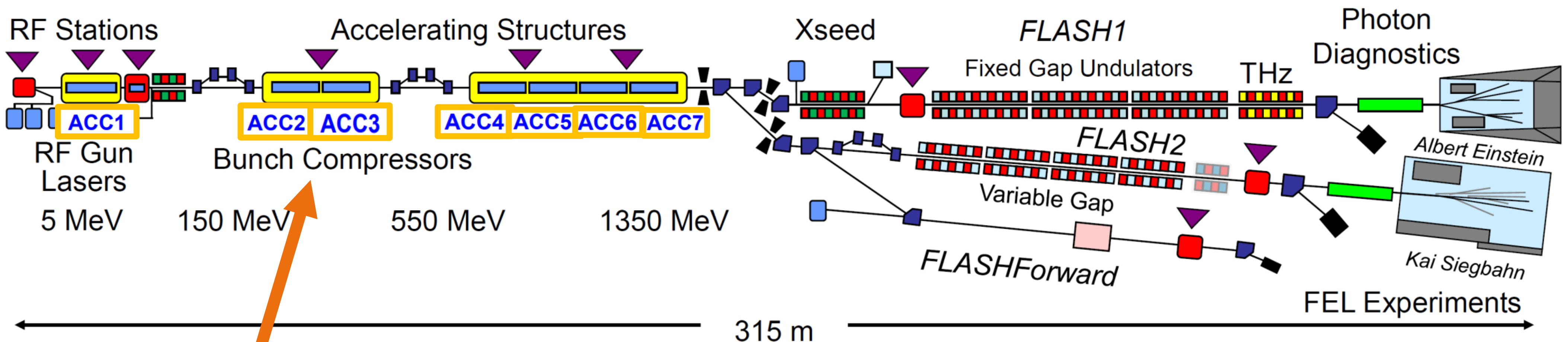
HELMHOLTZ

FLASH.
Free-Electron Laser in Hamburg

DESY.

Free-Electron Laser FLASH

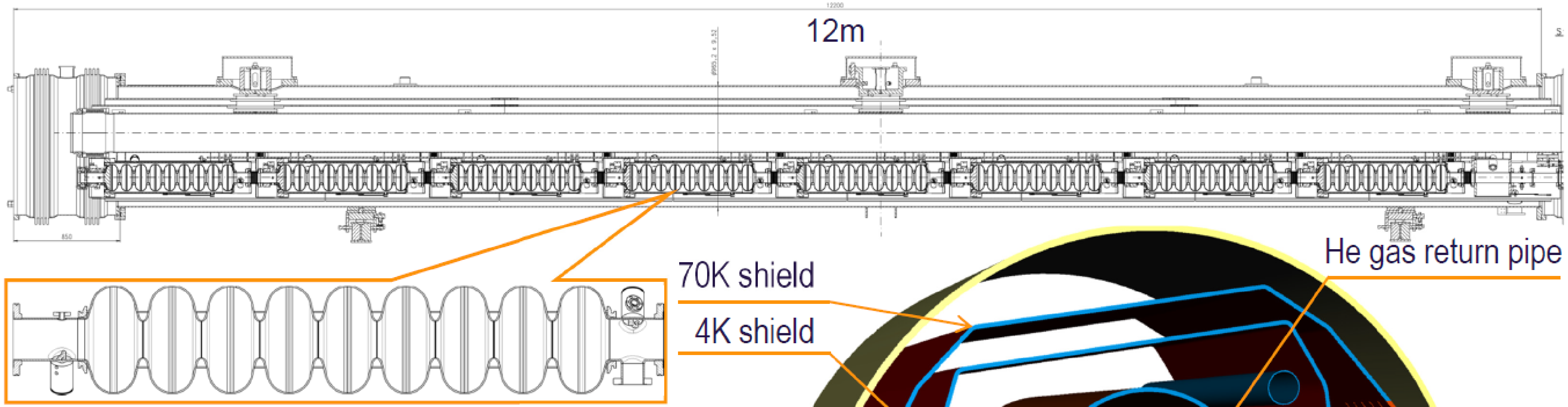


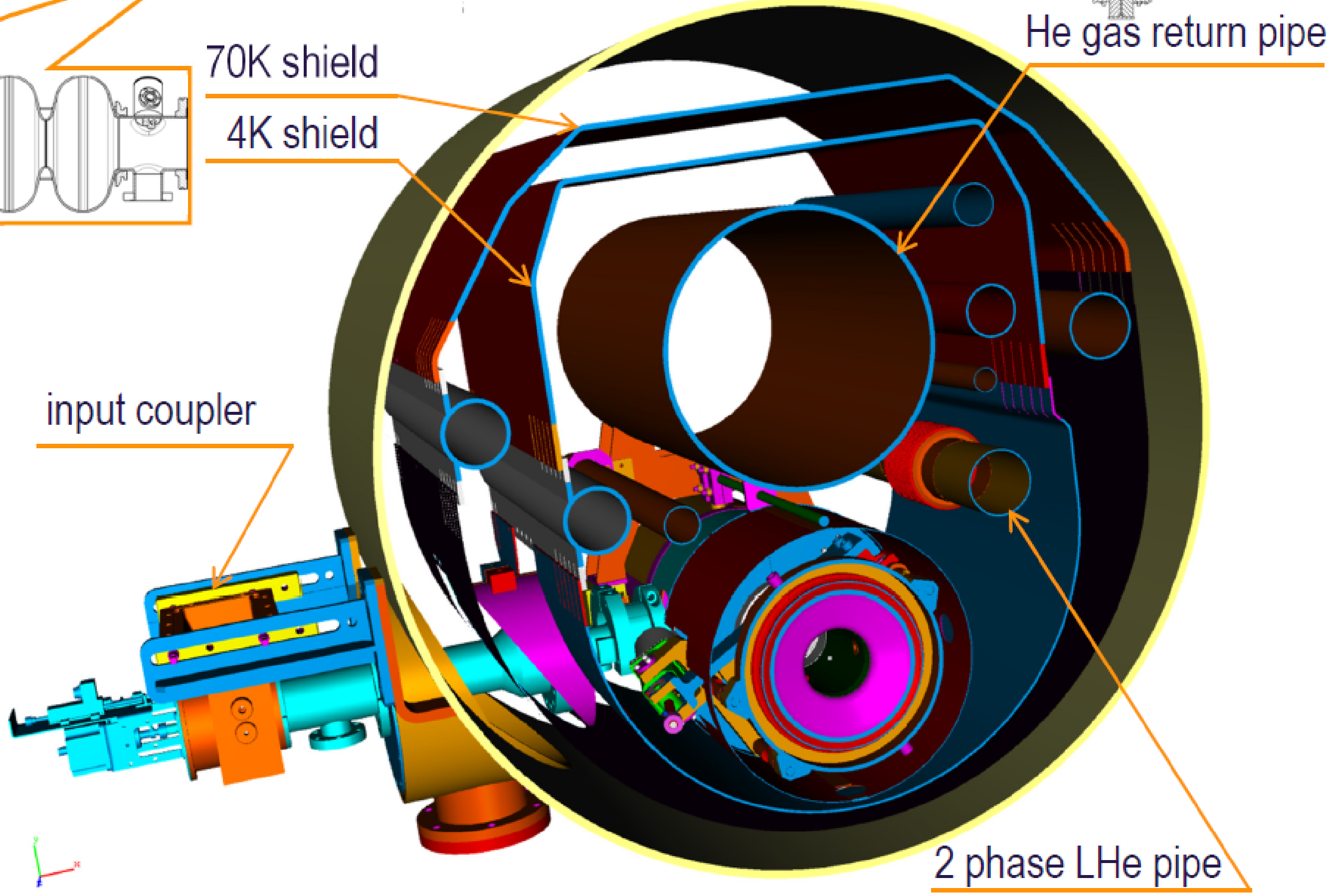
Energy upgrade
FLASH2020+

position	module	type	assembled	coupler type	cold window	warm window
ACC1	3***		Dec. 2009	TTF III	Cylindrical	Cylindrical
ACC2	PXM2.1		Sep. 2021	TTF III	Cylindrical	Cylindrical
ACC3	PXM3.1		Sep. 2021	Eu-XFEL	Cylindrical	Cylindrical
ACC4	4	III	Jul. 2001	TTF II	Cylindrical	Plane, WG
ACC5	5		Jun. 2007	TTF III	Cylindrical	Cylindrical
ACC6	6		May 2006	TTF III	Cylindrical	Cylindrical
ACC7	PXFEL1		Jun. 2009	TTF III	Cylindrical	Cylindrical

Our hero!

Cryomodule - parameters

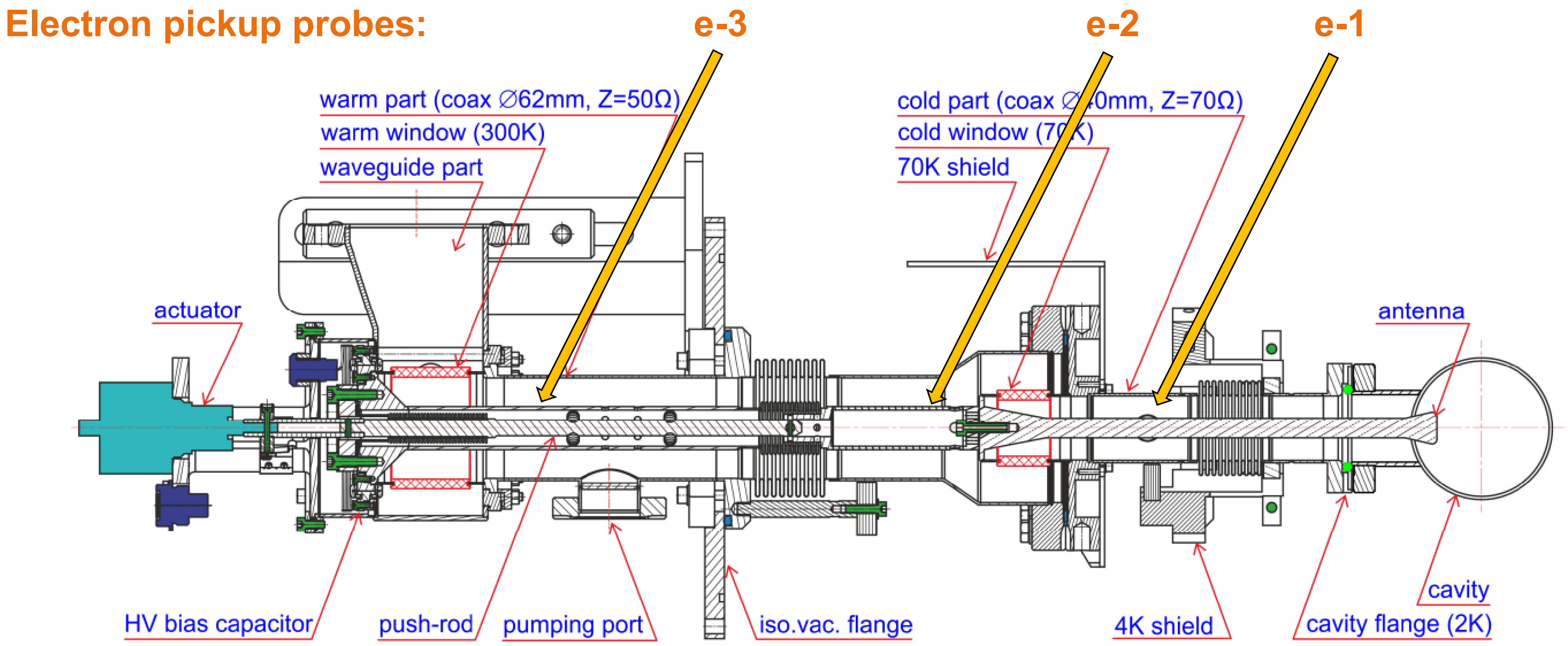




Cavity type	TESLA
Number of cavities	8
Cavity length	1.038 m
Operating frequency	1.3 GHz
R/Q	1036 Ω
Accelerating Gradient	20..35 MV/m
Quality factor	10^{10}
Q_{ext} (input coupler)	4.6×10^6
Operating temperature	2 K

LHe cooling 2K / 31mbar
HERA cryoplant is used

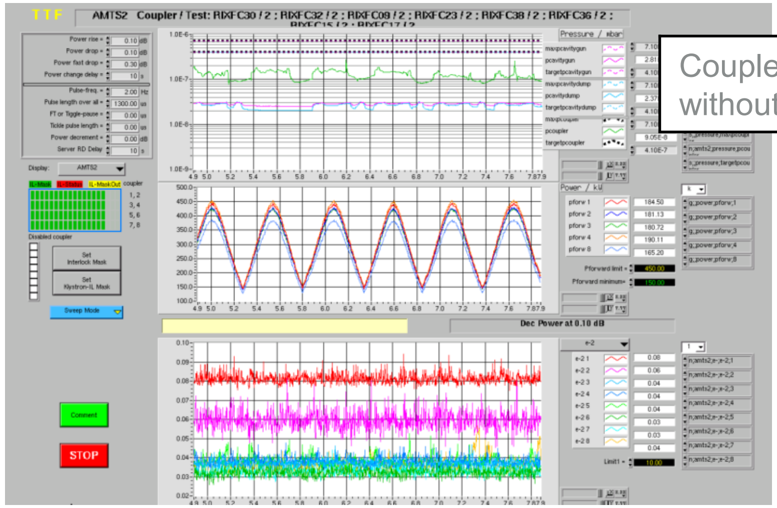
Eu-XFEL Fundamental Power Coupler (FPC)



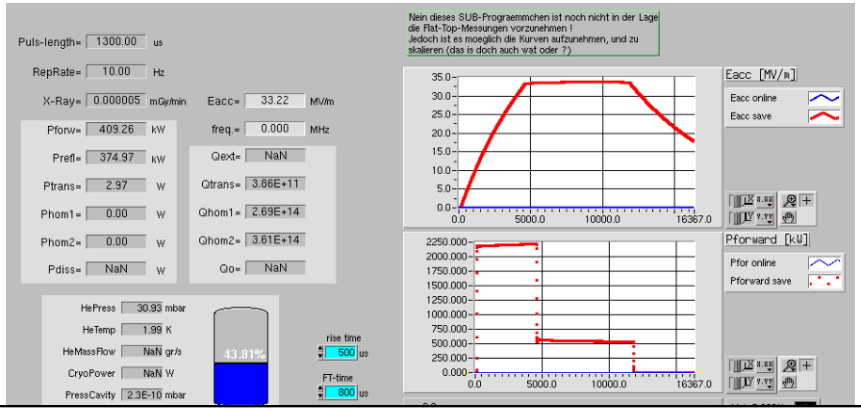
Eu-XFEL Fundamental Power Coupler consists of warm, cold and waveguide main parts. Coaxial coupler is made of copper and copper plated(10/30µm) stainless steel with alumina TiN coated ceramic windows. Motorized antenna tuning (±10mm) allows for Q_{ext} adjustment (10^6..10^7).

Our hero – the way of PXM3.1 from teststand to FLASH

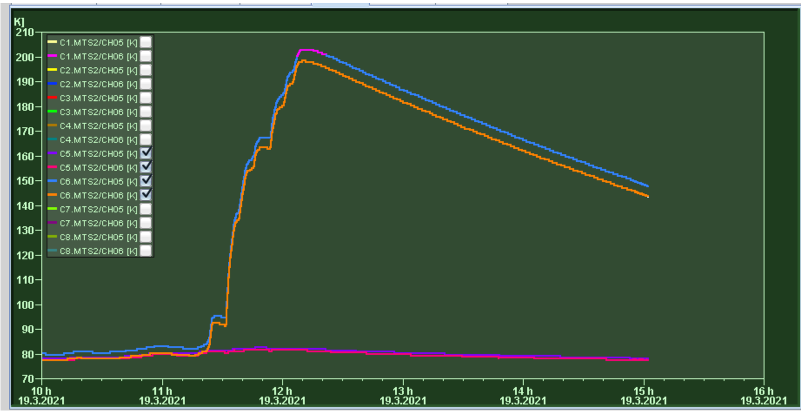
First coupler conditioning and power rise of coupler 6



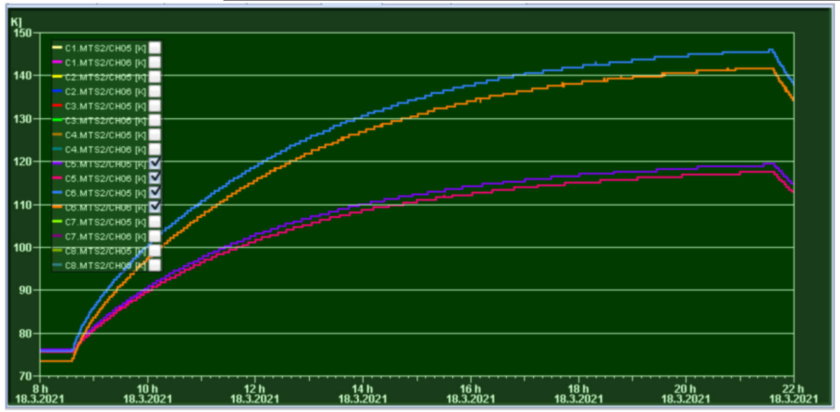
Coupler contitioning was performed without any special issues.



- During first power rise at 2K, an increase at T70K shield was noticed.
- Due to this cavity was set to high gradient for few hours in order to check coupler overheating. The temperature limit at 70K shield was set to 200K.



Overheating off-resonance !

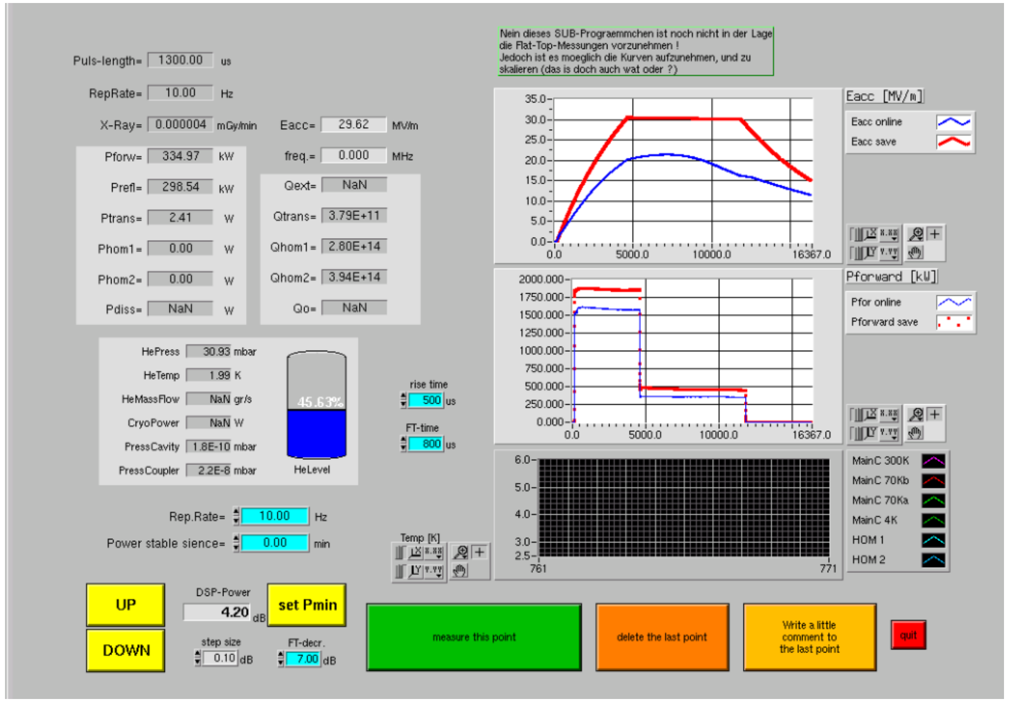


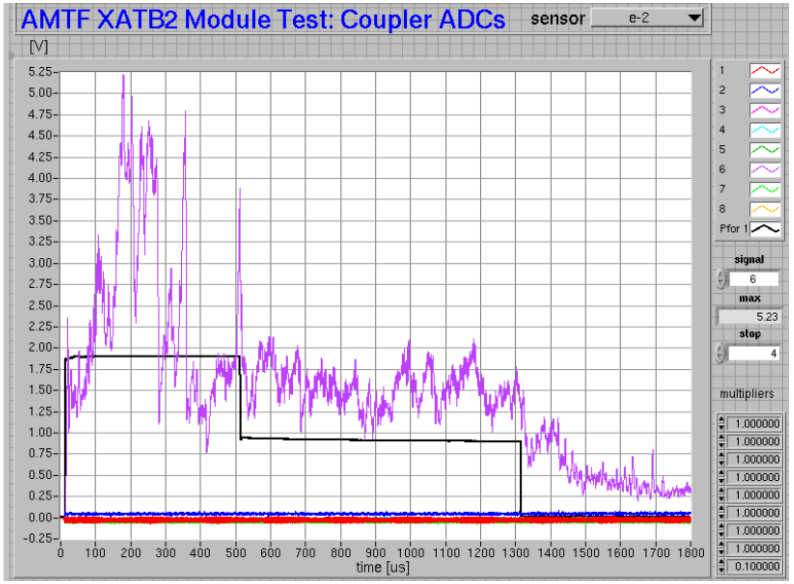
Overheating on-resonance !

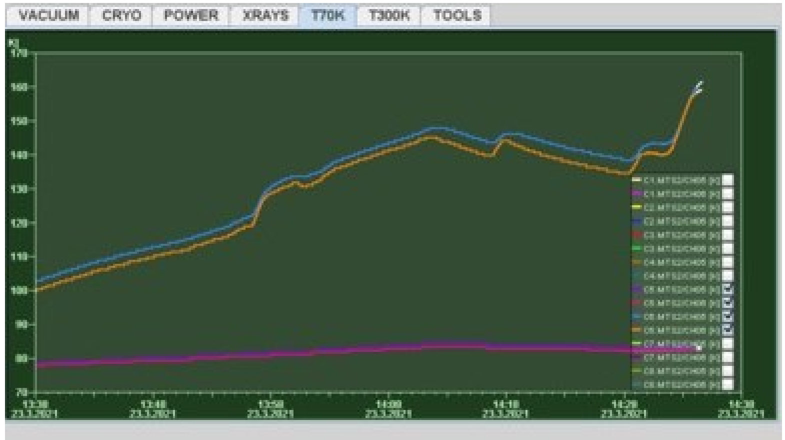
Max acc. gradient 33.2 MV/m

Overheating of coupler 6 noticed at 70K shield! No problems with other couplers noticed.

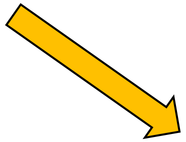
Second power rise – coupler 6 overheating







- Second electron sensor (e-2) disabled and then masked in the technical interlock
- Constant huge discharge in the coupler observed

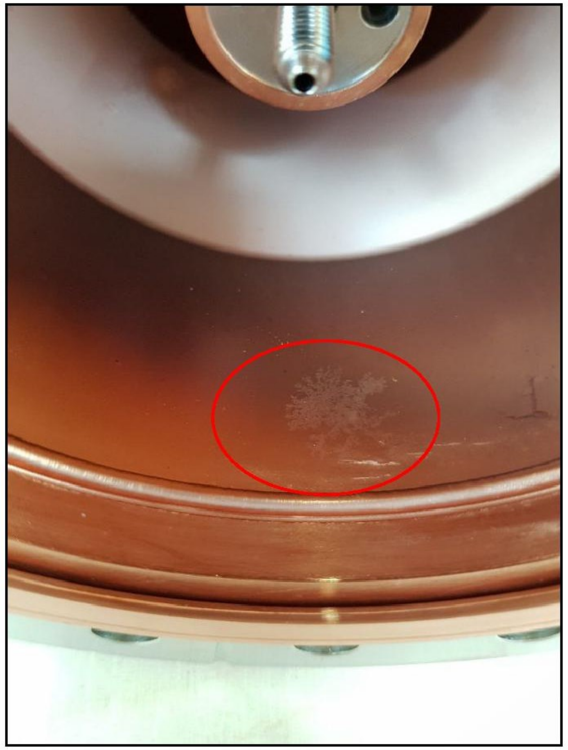


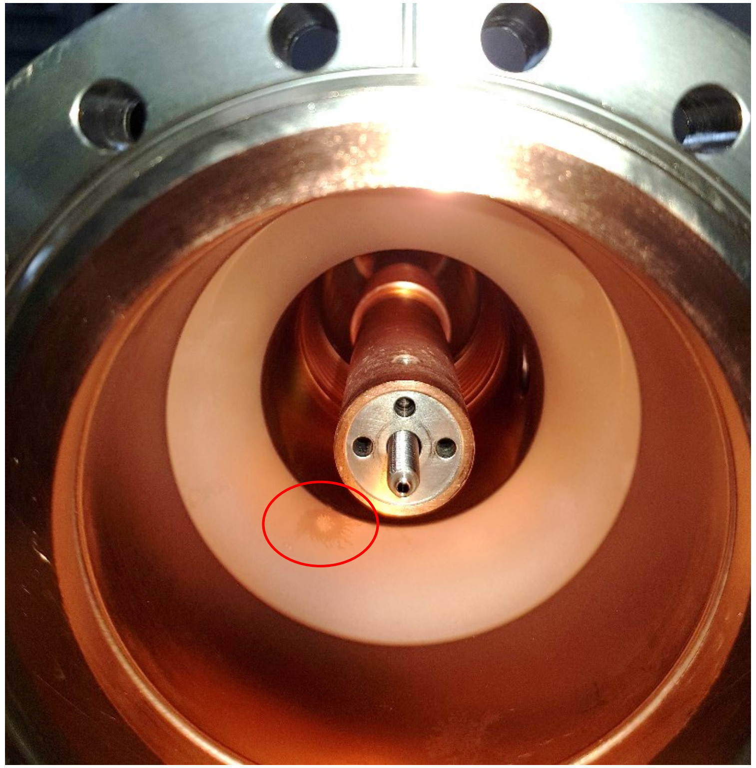
Decision : WARM PART of coupler 6 had to be exchanged under local cleanroom conditions in the teststand.

Warm part exchange

Visual surface irregularities on warm part after first dismounting of the warm part

- Heating spots on the outer and inner conductor as expected after dismounting the warm part



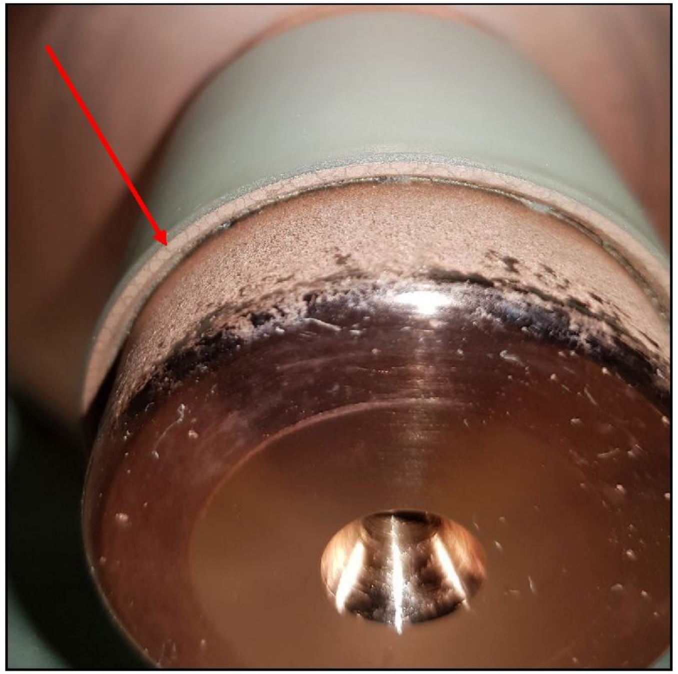


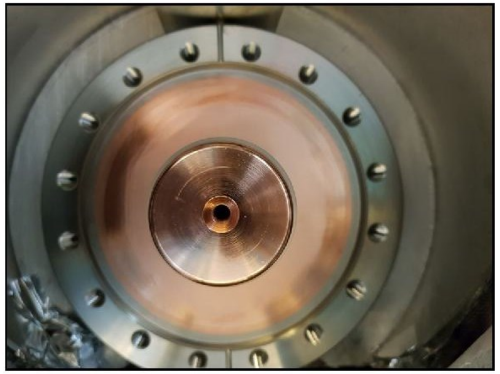
Warm part
before module test
without any
visual irregularities

Visual inspection of cold part

Visual surface irregularities on cold part

- Metalized copper layer detected on the frontal area (nearby the brazed seam)
- The copper surface and the superficies surface of the ceramic is heavily discolored and tarnished



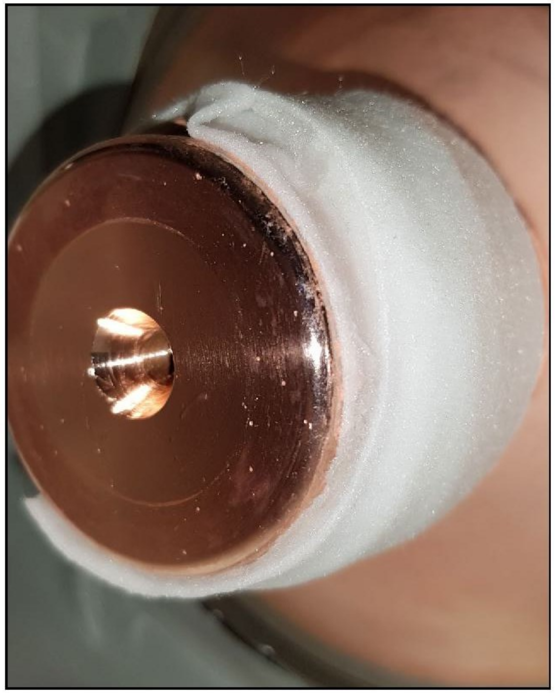


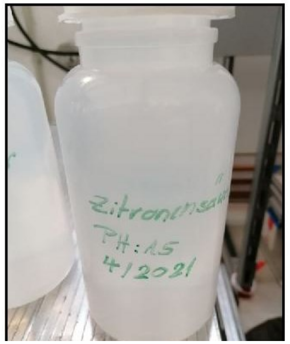
Cold part
before module test
without any
visual irregularities

Cleaning of cold part

Cleaning procedure of the copper surfaces and the ceramic superficies surface

- The copper surface and the superficies surface of the ceramic have been cleaned by citric acid

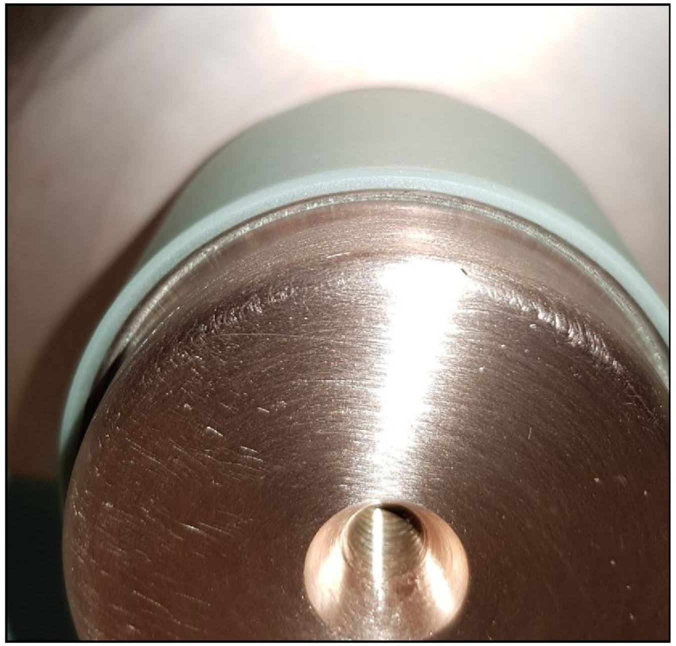


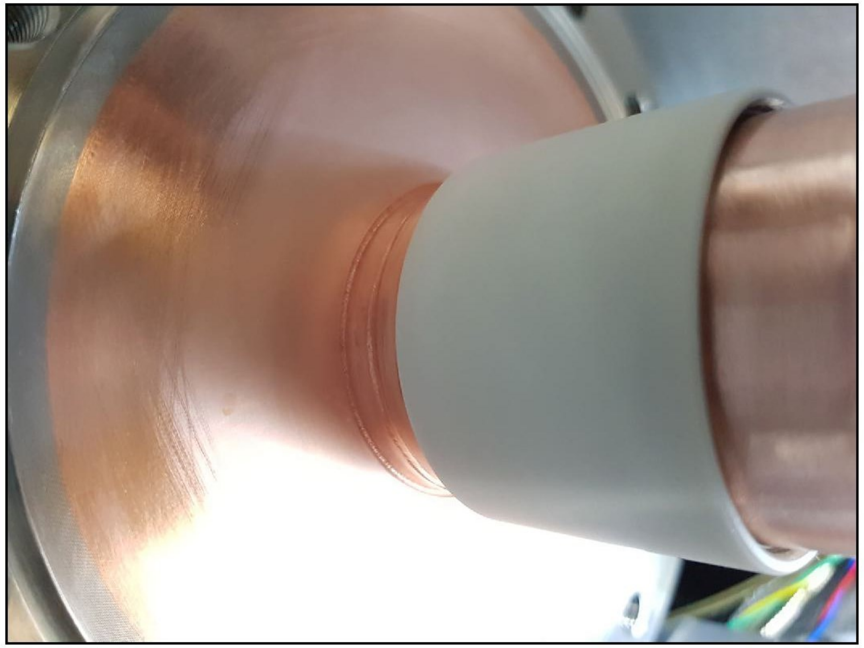


Cold part after cleaning

Impression of the cold part after cleaning and re-grinding procedure of the ceramic

- Metalized copper layer completely removed
- The copper surface and the superficies surface of the ceramic have been cleaned by citric acid

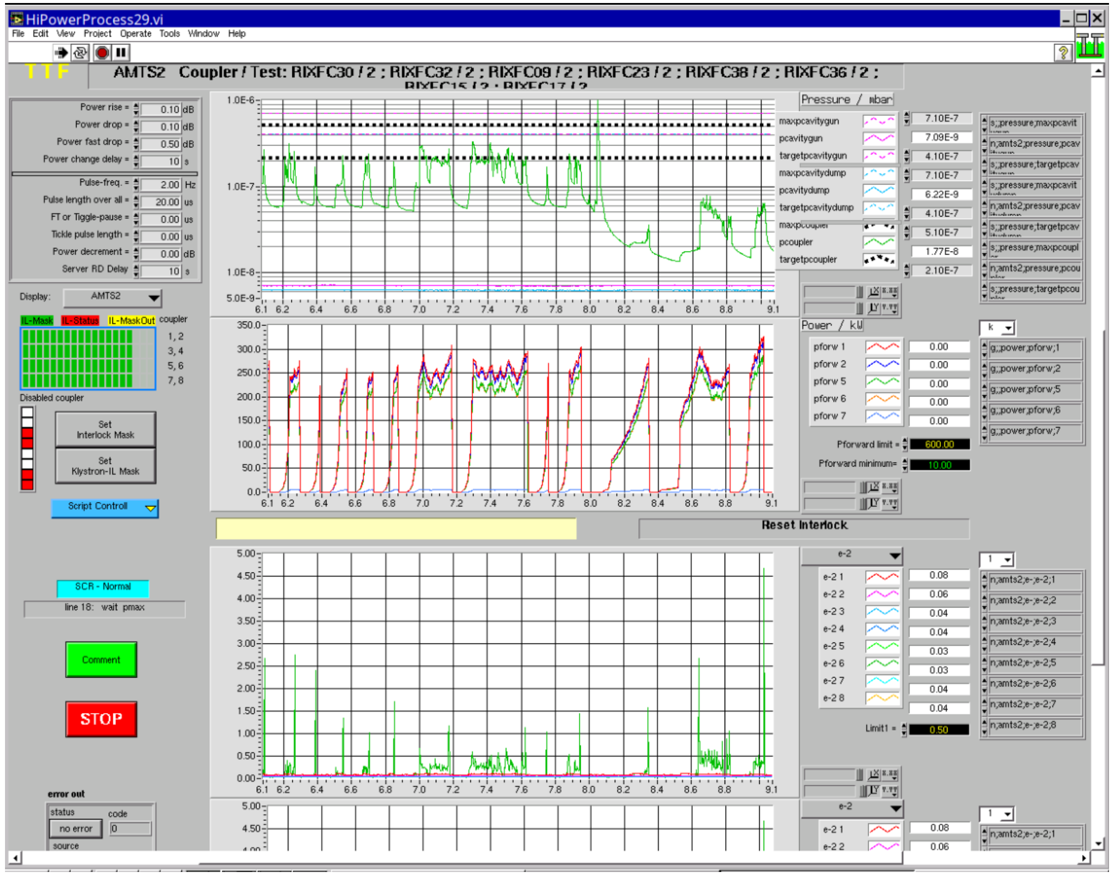


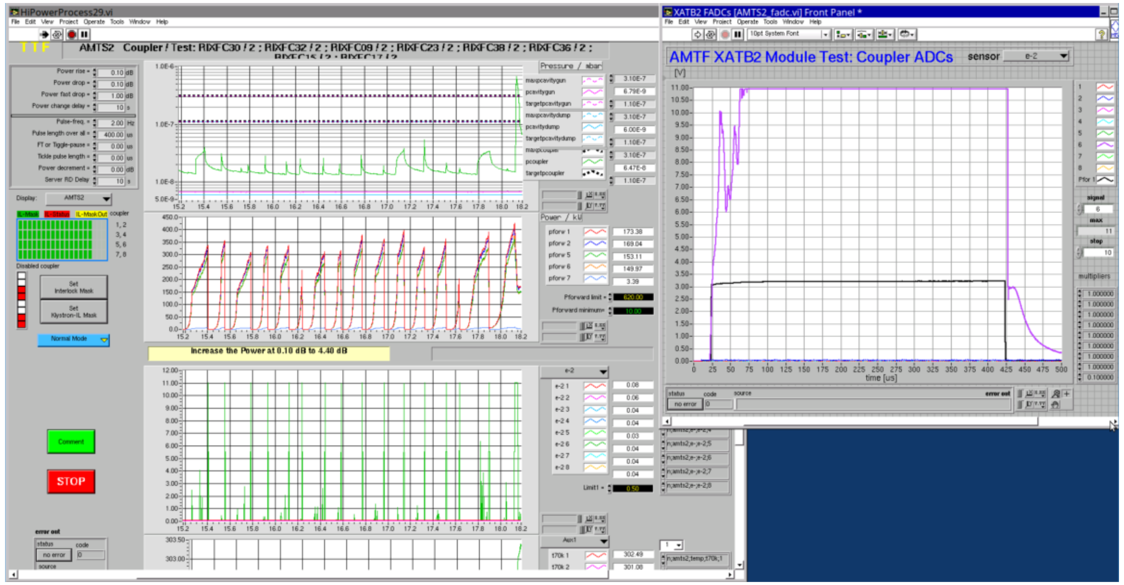


Decision : Connection of a new WARM PART on position 6 and re-conditioning

Second conditioning of coupler 6

- Second electron sensor (e-2) disabled and then masked in the technical interlock
- It just influenced increasing the coupler vacuum pressure and temperature at T70K shield
- Spontaneous discharge observed
- Coupler not conditionable





Decision : Exchange of cold and warm part of coupler 6 while coupler and beam vacuum is vented and then repeat the module test

Cold part replace

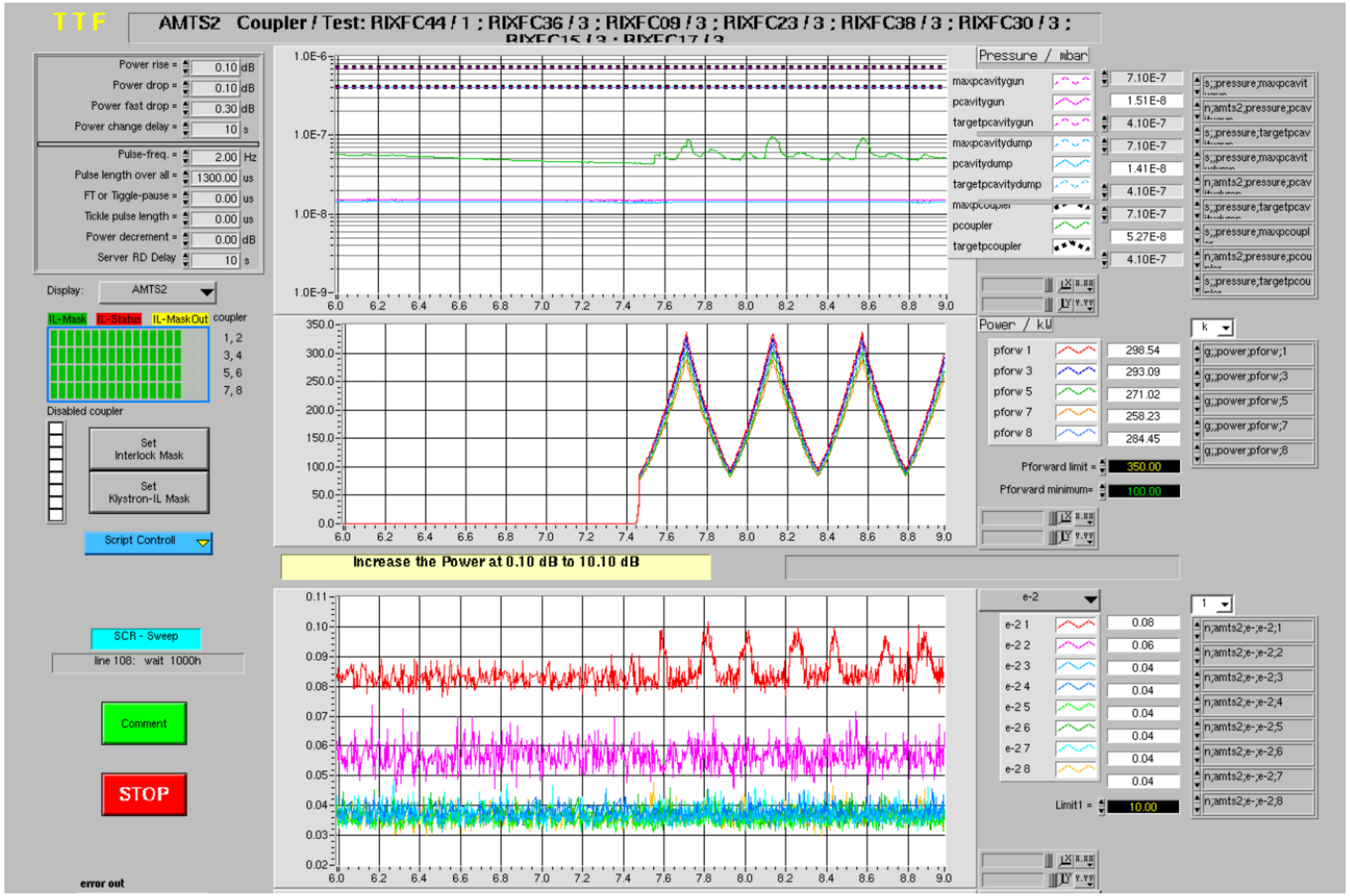
Exchange outside of the teststand

Preparation work:
- Warm parts of fundamental power couplers disassembled
- Disassembly of cryomodule 80K and 8K shield isolation
- Local cleanroom used for this challenge
- String vented with N2 before the replacement of the cold part

Decision : Re-conditioning and new test at 2K.

Third warm coupler conditioning

Successful !!!

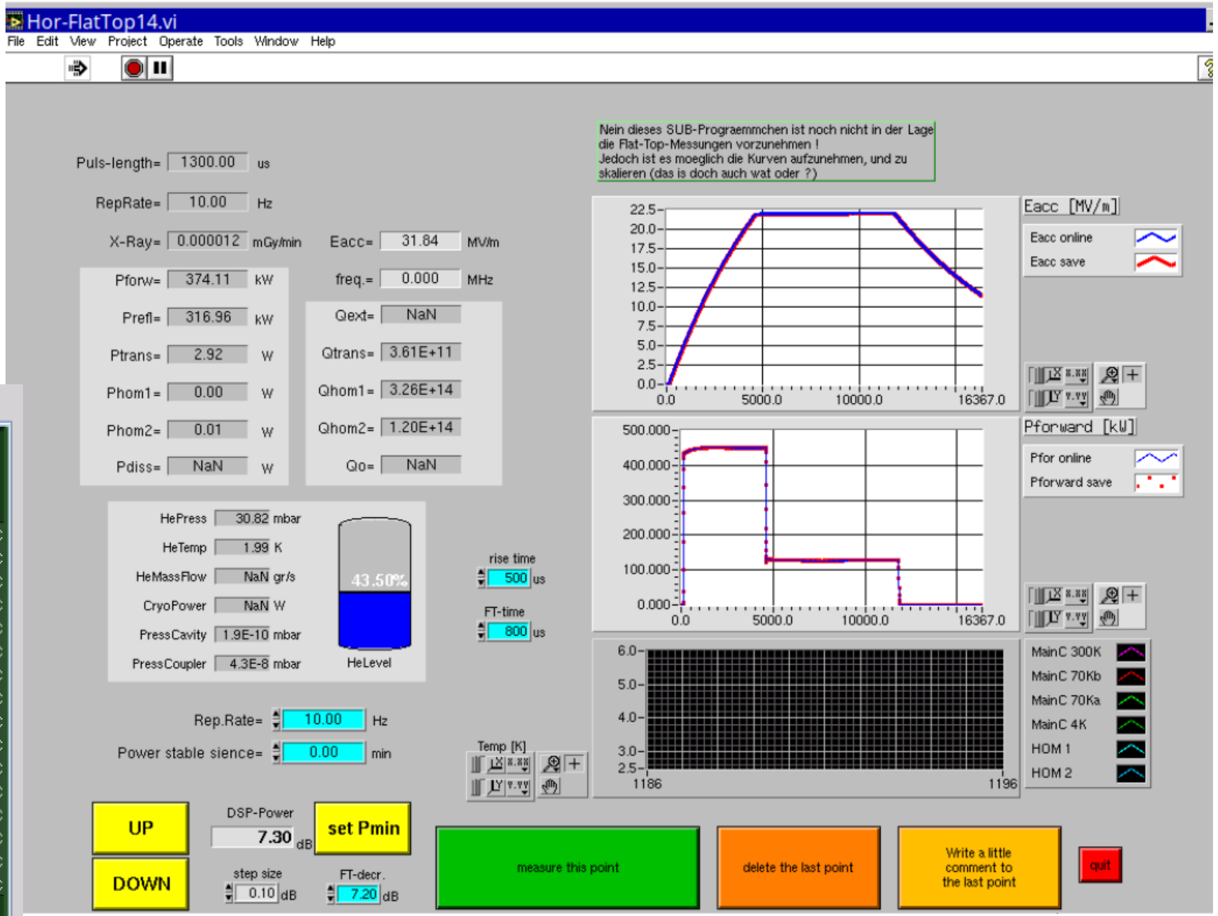


Power rise and off resonance temperature check

Max acc. gradient 32.3 MV/m (before 33.2 MV/m)

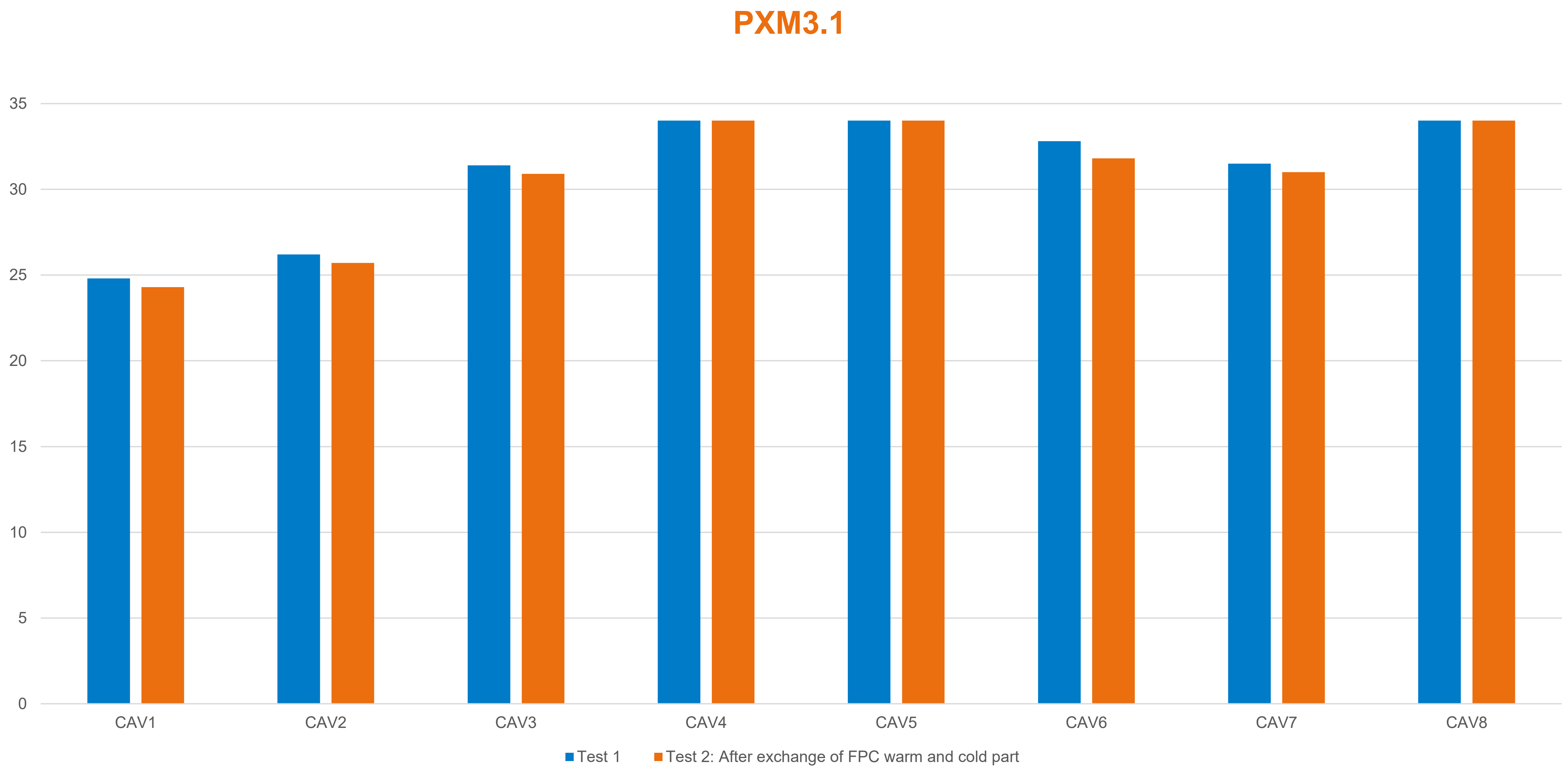
No radiation after the cavity processing!

- Thermal equilibrium at all couplers during the operation off resonance. Temperature reached max. 150K at T70K.
- No overheating OFF resonance!
- No overheating during long test (24h) ON resonance.



Decision : Install the module in the FLASH accelerator.

Operating gradient comparison



PXM3.1 – end of the story

Coupler overheating observed during cold power rise

- No problems during the warm coupler conditioning
- Overheating together with discharge observed
- **DECISION: exchange warm part of FPC in the teststand**

Only warm part exchange + cold part cleaning with the citric acid and re-grinding of the frontal area

- No mistakes of the installation
- In the warm part hot spots
- The color of the copper and on the ceramic changed in the cold part
- Detected copper layer on the frontal area of the ceramic
- Coupler not conditionable
- **DECISION: exchange warm and cold part of FPC under local clean room conditions**

Warm part and cold warm part exchange

- Replacement of the coupler cold part
- Exchange done with the overpressure on the beam vacuum
- No cavity degradation
- No radiation
- **DECISION: Module installation in the tunel**

No further issues with the overheating and discharge in the tunnel in the FLASH observed.

Acknowledgmenets

- Special thanks to Andrea Muhs, Denis Kostin, Lea Steder and Mateusz Wiencek