LARGE SCALE TESTING OF SRF CAVITIES AND MODULES

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IFJ PAN Krakow IKC for the XFEL

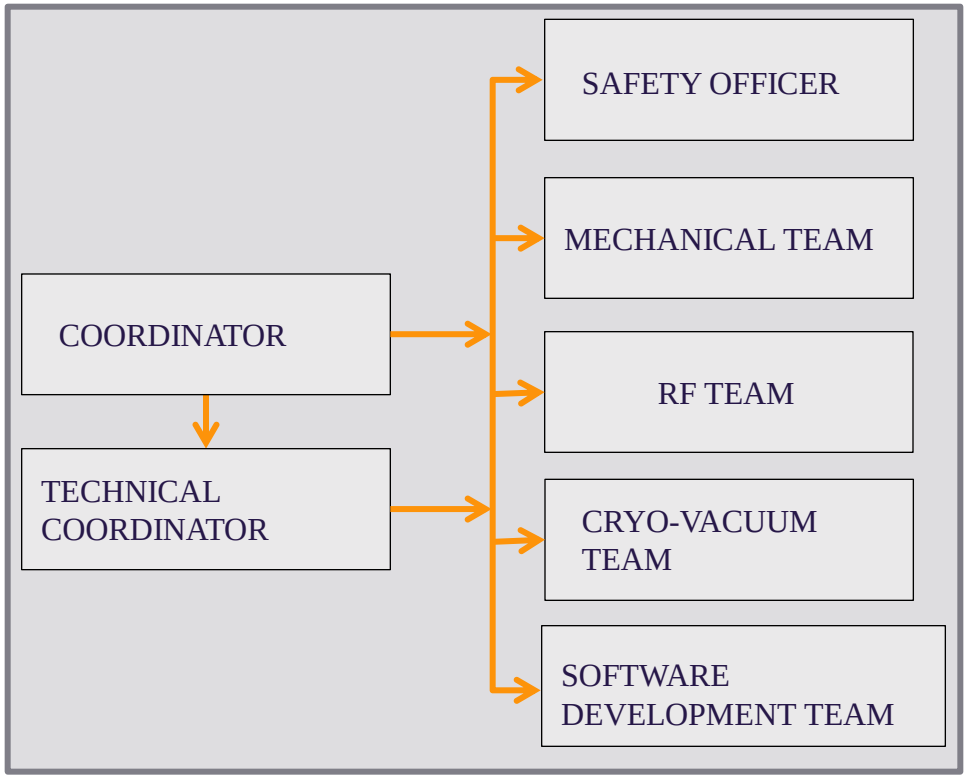
Introduction – IFJ PAN

Institute of Nuclear Physics (IFJ) located in Kraków, Poland was founded in 1955 on the initiative Prof. Henryk Niewodniczański. After reorganization in 2004 the full name is **The Henryk Niewodniczański Institute of Nuclear Physics Polish Academy of Sciences (IFJ PAN)**.

For Cavities and Cryomodules tests are involved :

- AMTF Technical Coordinator
- 18 engineers
- 24 technicians

Currently the work is organized on two shifts



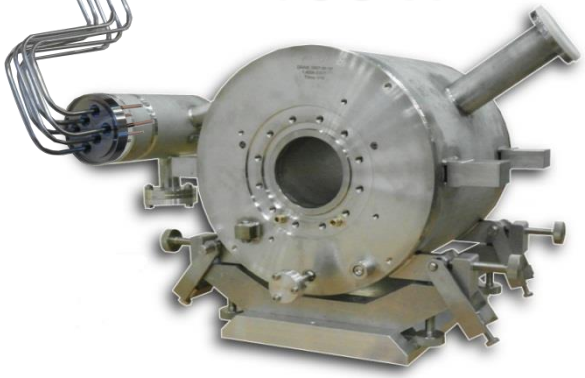
Organizational structure of the IFJ-PAN Team performing cavity and cryomodule test at DESY

What and how many

In December 2010 IFJ PAN signed the agreements with XFEL Company and National Centre for Nuclear Research, Świerk – Poland for performance of qualification tests:

103 x

103 x



840 x

103 x

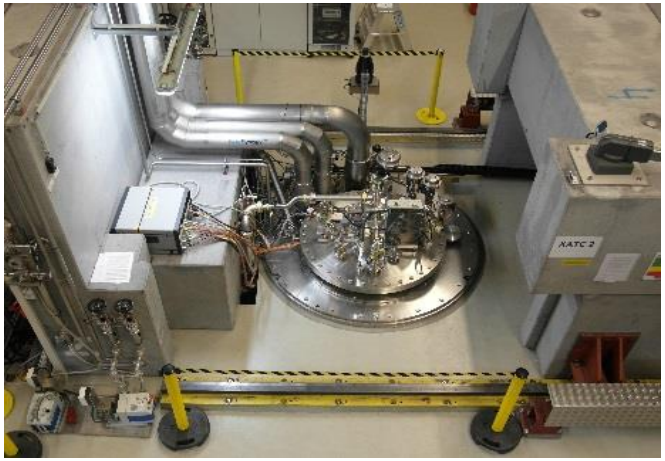
Accelerator Module Test Facility – AMTF Hall

Location: DESY campus at Hamburg

AMTF HALL is equipped with:

- Two cryostats
- Preparation area for cavities (6 Inserts)
- Three test stands for cryomodules
- Preparation areas for cryomodules
- Storage areas for cavities and cryomodules

AMTF Hall - Cavity



Vertical Cryostat

Radiation protection shielding

Cavity preparation area

Cavity storage area

Cavity incoming check area

Clean room

AMTF Hall - Cryomodule

Unloading of the cryomodule after transport – see **POSTER MOPP021**

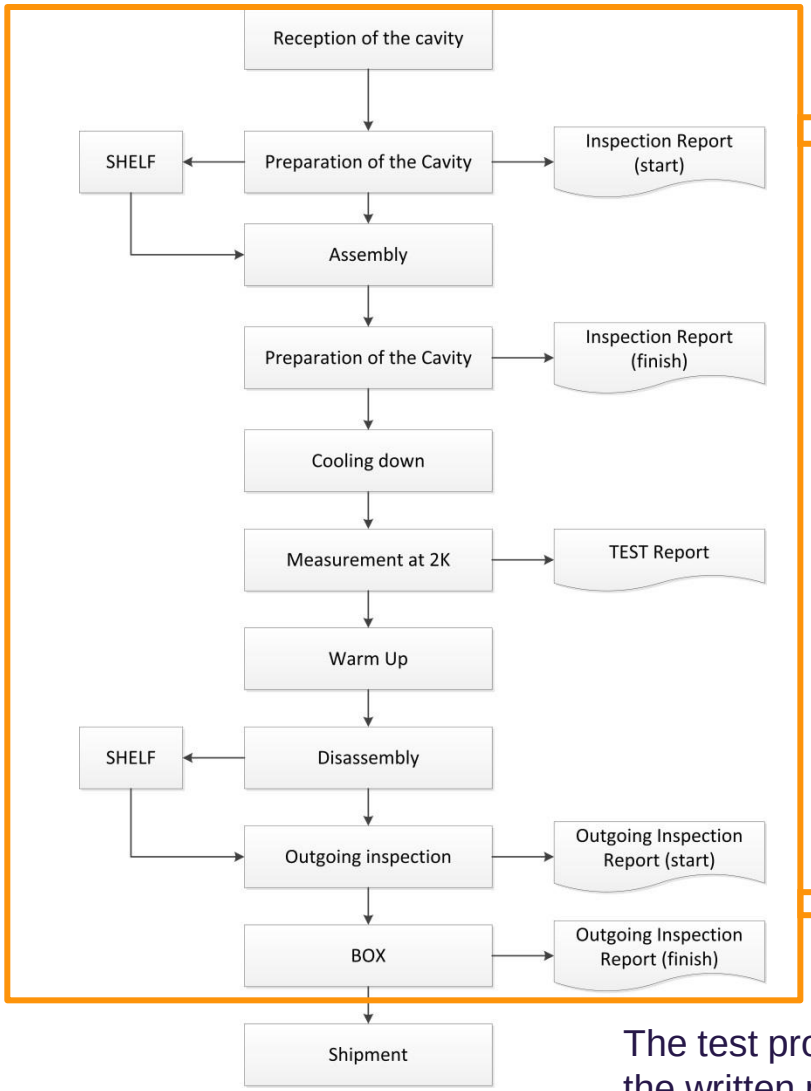
Cryomodule preparation area

Cryomodule test stand

Cryomodule test stand – module inside

Cryomodule test stand – front view

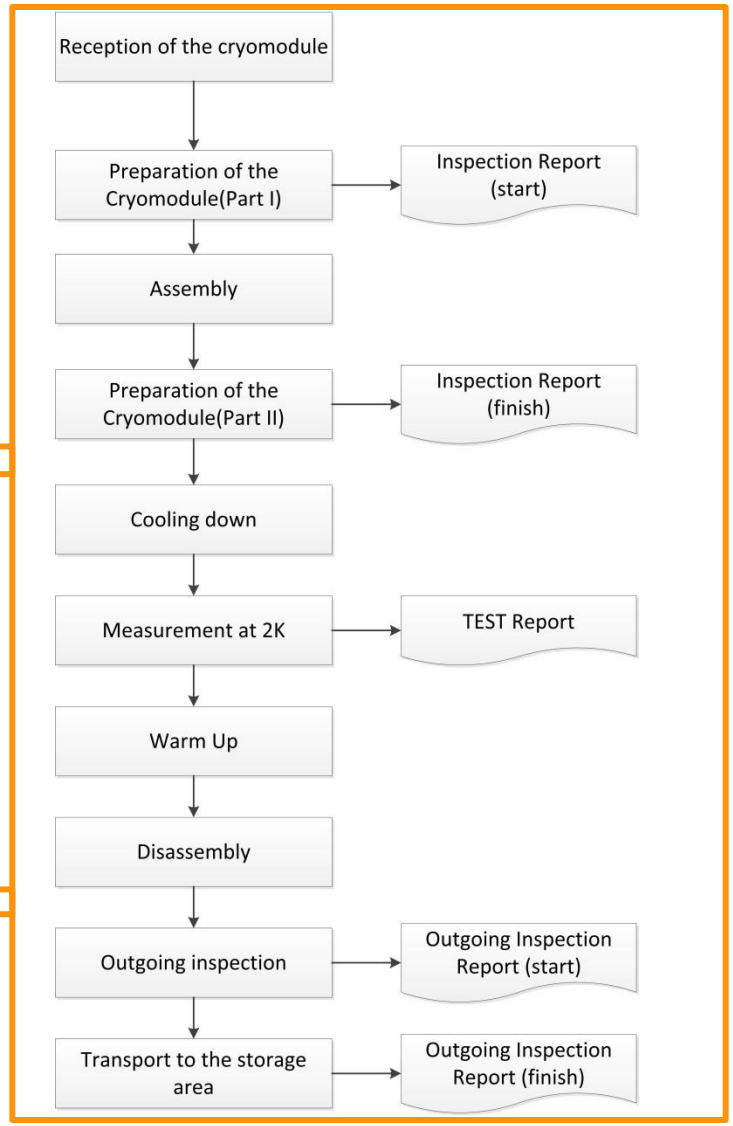
TEST - What does it mean ?



Cavity test main flow diagram

Cryomodule test main flow diagram

TEST



The test program is realized according to the written procedures

Preparation and assembling



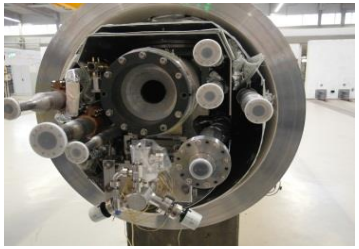

Main tasks:

- Incoming checks
- Assembling Cavity to the Insert
- Connecting Cavity to the vacuum line (in cleanroom conditions)
- Tuning of Fundamental Mode Rejection Filters of both HOM couplers + Cables connection
- Leak check of the Cavity
- Transport of the Insert to the cryostat + vacuum connection




Preparation and assembling





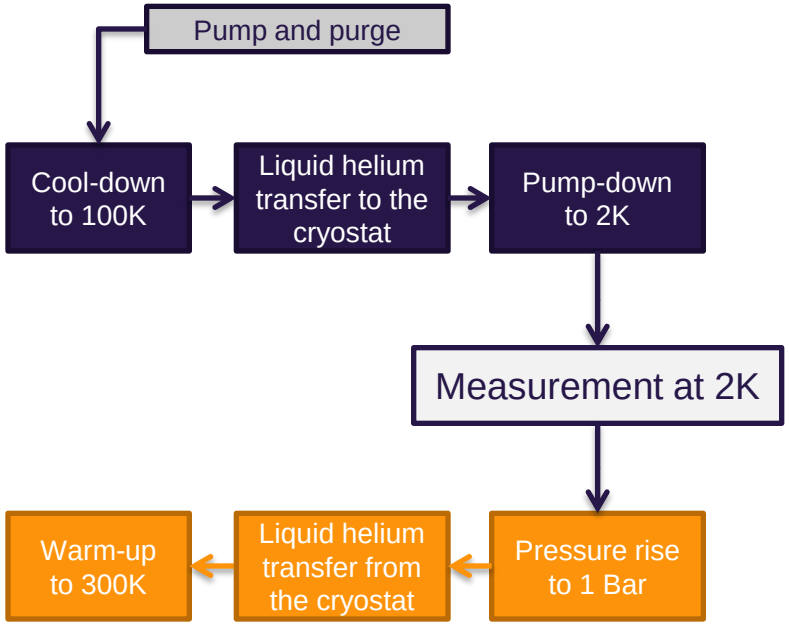
Main tasks:

- Unload the cryomodule from the truck
- Incoming checks
- Load the cryomodule to the movable support
- Assembling Cryomodule at the test stand
- Connecting Cryomodule beam line to the test stand under clean room conditions
- Leak check of beam line interconnections and mass spectroscopy of the beam line
- Connecting of the waveguides
- Connecting of all electrical cables
- Connect of all cryomodule process pipes to the test stands
- Leak check of cryomodule vessel (ISO-VAC)
- Leak check of cryomodule cryogenic lines
- Assembly and isolating thermal shields
- Pumping down of isolation vacuum


Cool down and Warm up

XATC1, XATC2

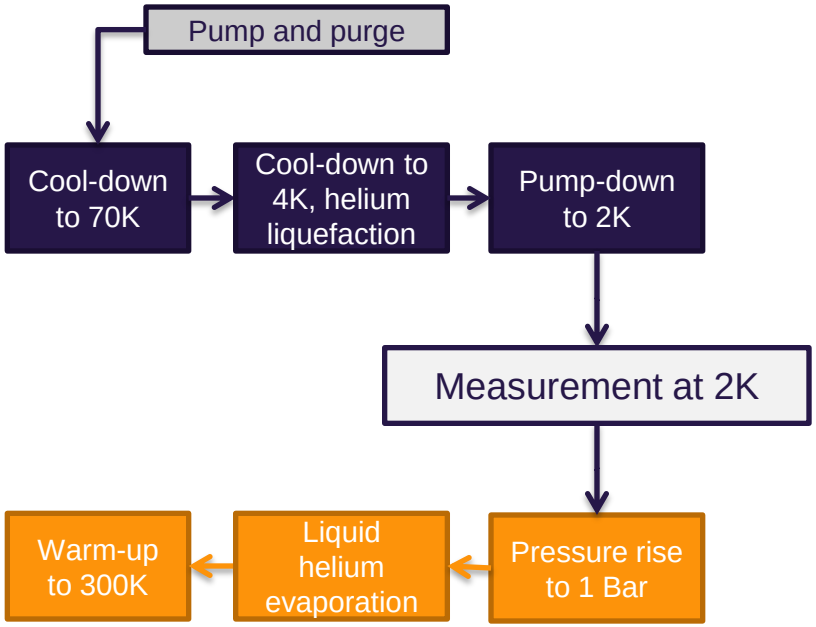
- Pump and purge manual
- Cool-down to 4K, liquid helium transfer and warm-up **process automatized** by use of SNL scripts
- Pump-down to 2K manual



Cryogenics operation sequence for vertical cryostat

XATB1, XATB2, XATB3

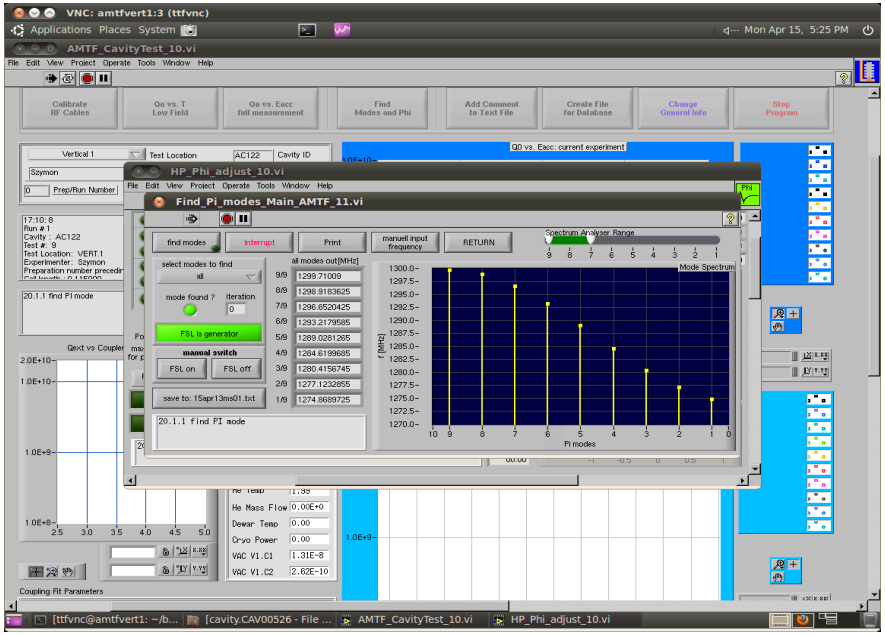
- Pump and purge manual
- Complete cool-down and warm-up **process performed manually** by cryo-operators



Cryogenics operation sequence for cryomodule test stand

Measurements at 2K

- Cavity performance test in 2K(QvsE measurement)
- HOM spectra measurements

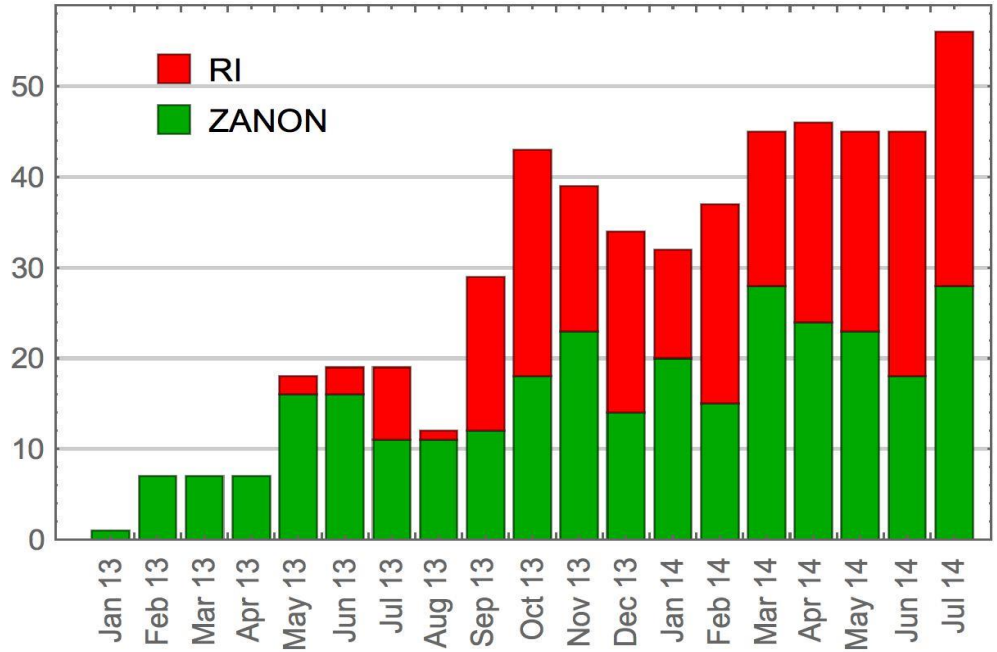


Vertical test application

Vertical acceptance tests (Status Jul 31, 2014)

- Analysis of vertical acceptance tests includes
  - Series Cavities + “ILC HiGrade”-Cavities
  - NO infrastructure commissioning tests

- So far delivered: 404 cavities
- Total RF tested: 382 cavities



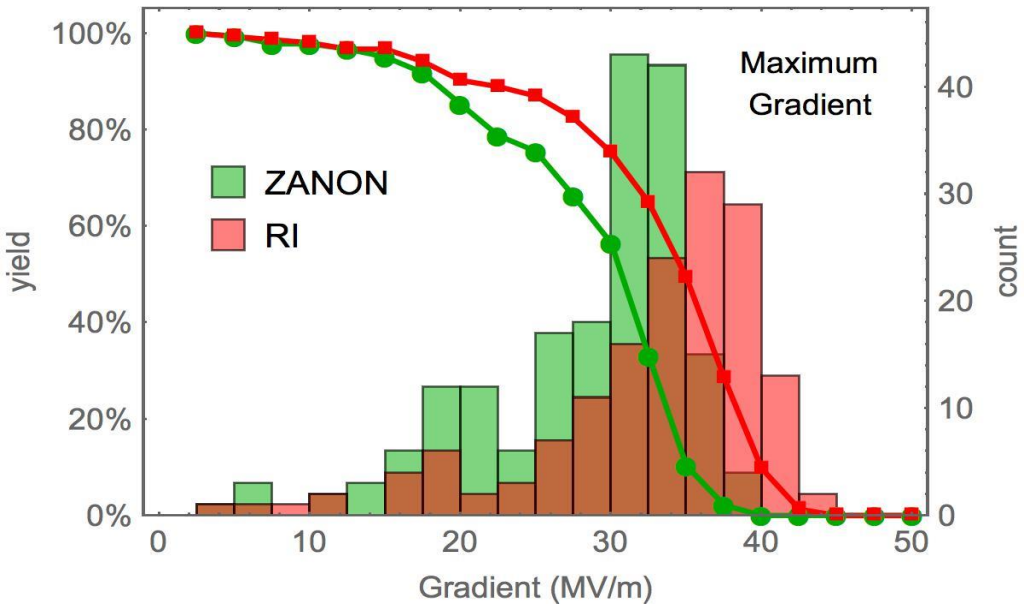
Average:
> 9 tests per week
since Oct 2013
(full operation of AMTF)

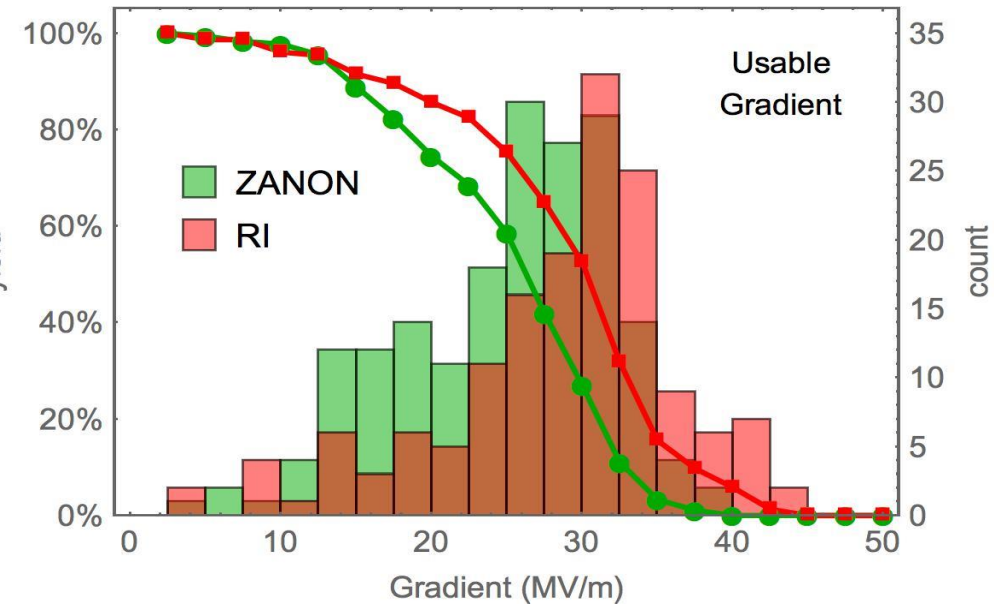
Vertical RF test conditions + acceptance criteria

- **Cavity "full equipped" refers to**
  - Dressed with He-tank (except of "HiGrade" cavities)
  - Equipped with fixed High Q-antenna, Pick-up and two HOM-antennas
- Only Q(E)-measurement at 2K + fundamental mode frequencies
  - All cavities checked for Q-disease by parking at 100K
- Definition of **usable gradient**:
  - Gradient of Quench or
  - Gradient at Unloaded $Q_0 < 1x10^{10}$ or
  - Gradient at X-ray level: upper detector > $1x10^{-2}$ mGy/min; lower detector > 0.12 mGy/min (empirical limit from FLASH cavities for different detector locations)
- **Acceptance criteria**:
  - OLD: Usable gradient **>26 MV/m** (10% margin for 23.6 MV/m design gradient)
  - NEW: Usable gradient **>20 MV/m** (after analysis of retreatment results for optimized number of tests and energy gain

Yield of gradients: “As received”

- Yield of usable and maximum gradient of **339 cavities “as received”** (EZ: 185; RI:154)





Average **maximum** gradient:

(30.4 ± 7.6) MV/m

EZ: (28.4 ± 7.1) MV/m
RI: (32.4 ± 7.6) MV/m

given errors are standard deviation

Average **usable** gradient:

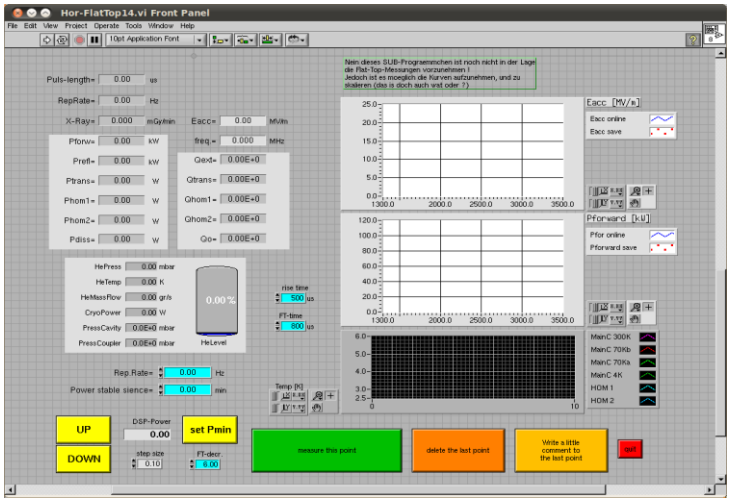
(26.6 ± 7.6) MV/m

EZ: (24.8 ± 7.0) MV/m
RI: (28.6 ± 7.9) MV/m

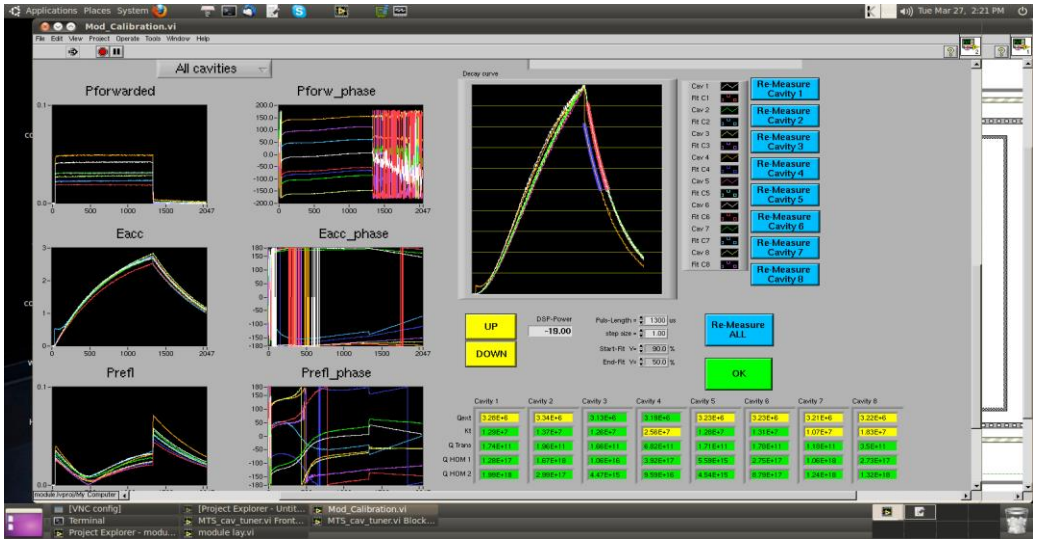
Detailed vertical test analysis see **Poster THPP021**

Measurements at 2K

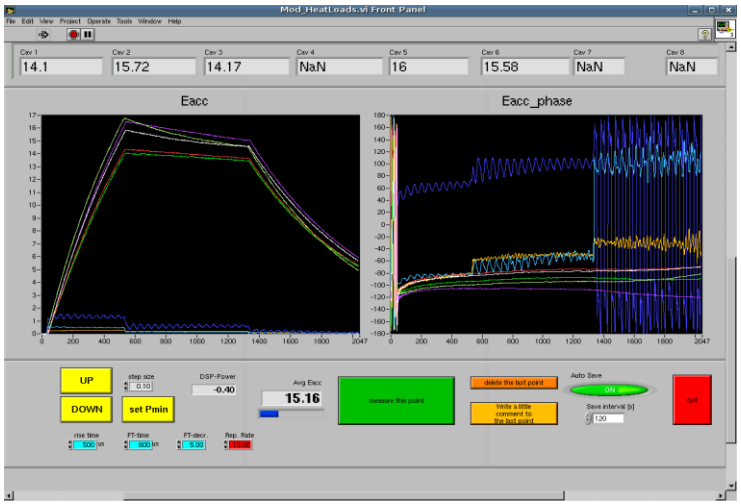
- Cold cables calibration
- Spectra measurement
- Cavities tuning
- HOM spectra measurements
- Couplers tuning
- Cavities calibration
- Cavities Flat-top measurement
- Heat Loads Measurements
- LLRF => **Talk by J. Branlard WEIOA06**



Cavity Flat – top application



Cavities calibration application



Heat Loads application

Module testing

- **Sorting of cavities for string assembly** according to
  - **gradient**
  - **mechanical constraints**
- **RF power constraints**
  - Equal RF power to cavity pairs
  - Module: Maximum gradient 31 MV/m by available RF power
  - Module: Allowed gradient spread ± 20% of average gradient
- Seven modules tested so far (XM-2 to XM5)
- Operational gradient determined by
  - worse cavity of pair
  - 0.5 MV/m below quench limit
  - empirical radiation limit of > 10^{-2} mGy/min at both endcaps
  - above power limit

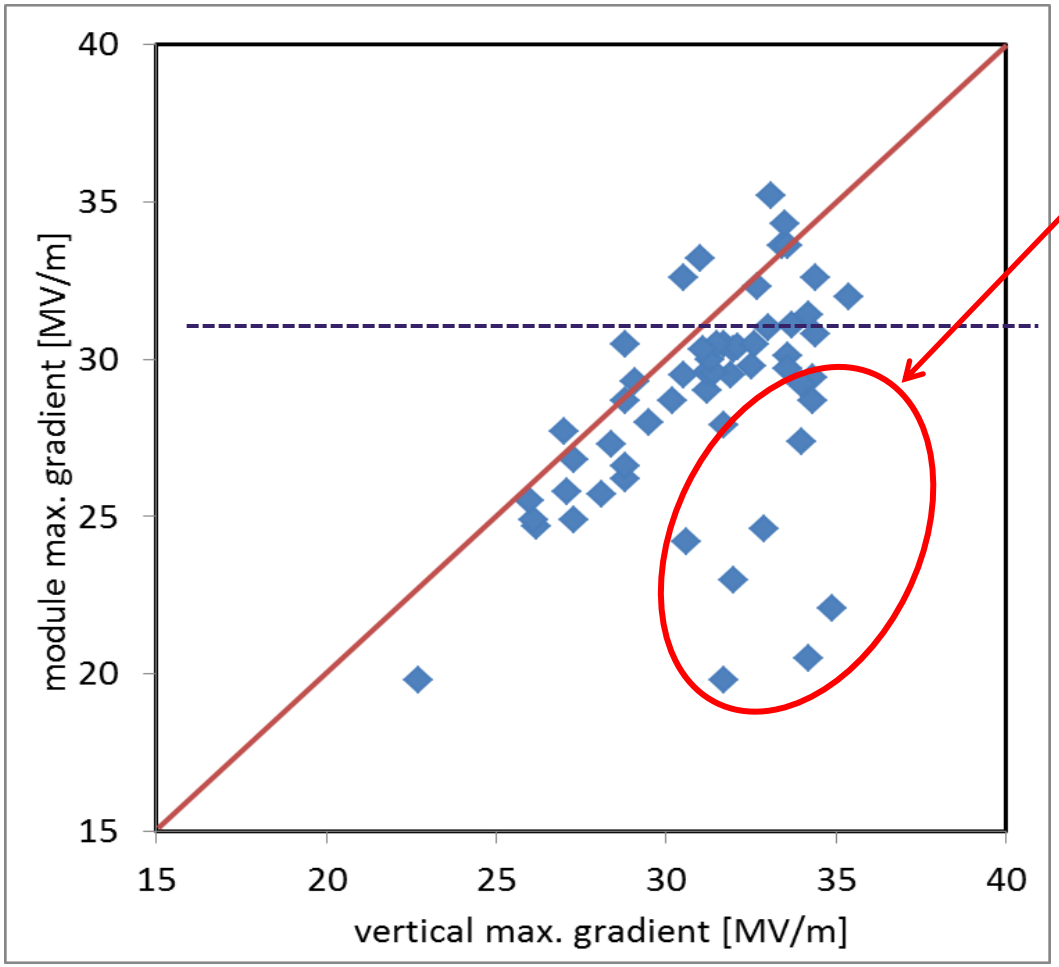
Summary of results

	average max. gradient **module** [MV/m]	average max. gradient **vertical** [MV/m]	Average operational gradient **module** [MV/m]	Average usable gradient **vertical** [MV/m]
XM-2	27.2	28.1	24.5	26.5
XM-1	28.2	30.8	25.1	29.4
XM1	30.3	32.5	27.6	29
XM2	27.7	32.7	25.5	28.6
XM3	30.4	32.0	28.8	29.3
XM4	28.6	33.3	23.8	30.5
XM5	27.8	28.9	24.9	26.9

All results above XFEL specs. 23.6 MV/m

Vertical vs. module performance

- Comparison of maximum vertical vs. module gradient



Few cavities show significant performance reduction

From individual max. gradient

to operational module gradient:

~20% reduction

Summary

- In total 840 cavities and 103 cryomodules are foreseen to test
- Testing of the cavities established, 382 tested - Status Jul 31, 2014
- Testing of the cryomodules started, 7 cryomodules tested - Status Jul 31, 2014
- Cavity and Cryomodule testing and all work flows at AMTF are well established
- Cavities and Cryomodules acceptance test performance are in average above specification
- Testing in large scale requires development of many test procedures, software improvements and trainings. It is also a big logistic challenge. This have been succeed with help of DESY experts.

I strongly invite You to look posters:

- A New Type of Waveguide Distribution for the Accelerator Module Test Facility of the European XFEL
- **TUPP019** - Qualification of the Titanium Welds in the XFEL Cryomodule and the CE Certification
- **THPP022 (TALK + POSTER!)** - Efficiency of High Order Modes Extraction in the European XFEL Linac

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- and others
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Thank You !!!