Module Tests

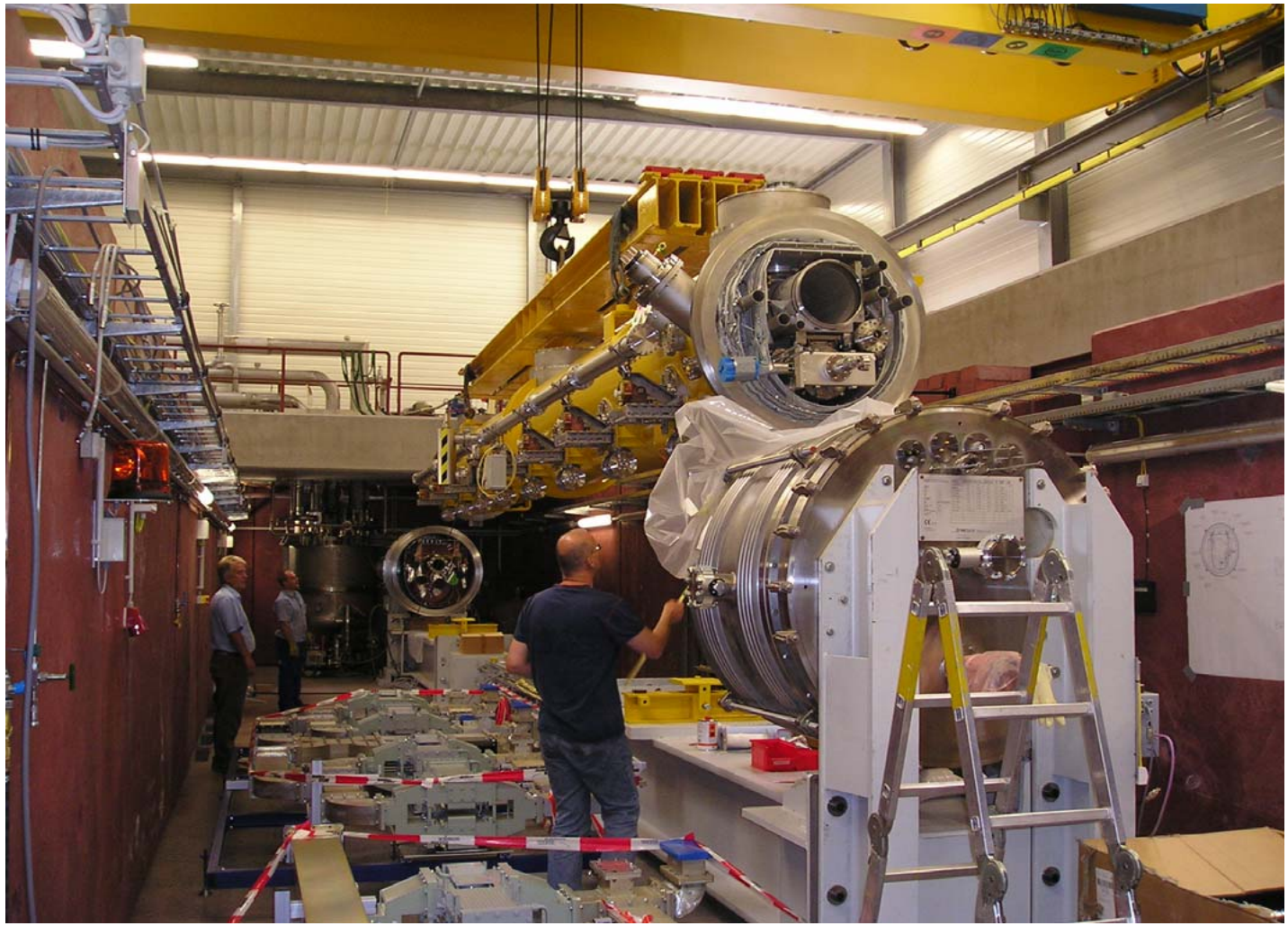
TTC Meeting

23-April-2007 FNAL

R. Lange –DESY-

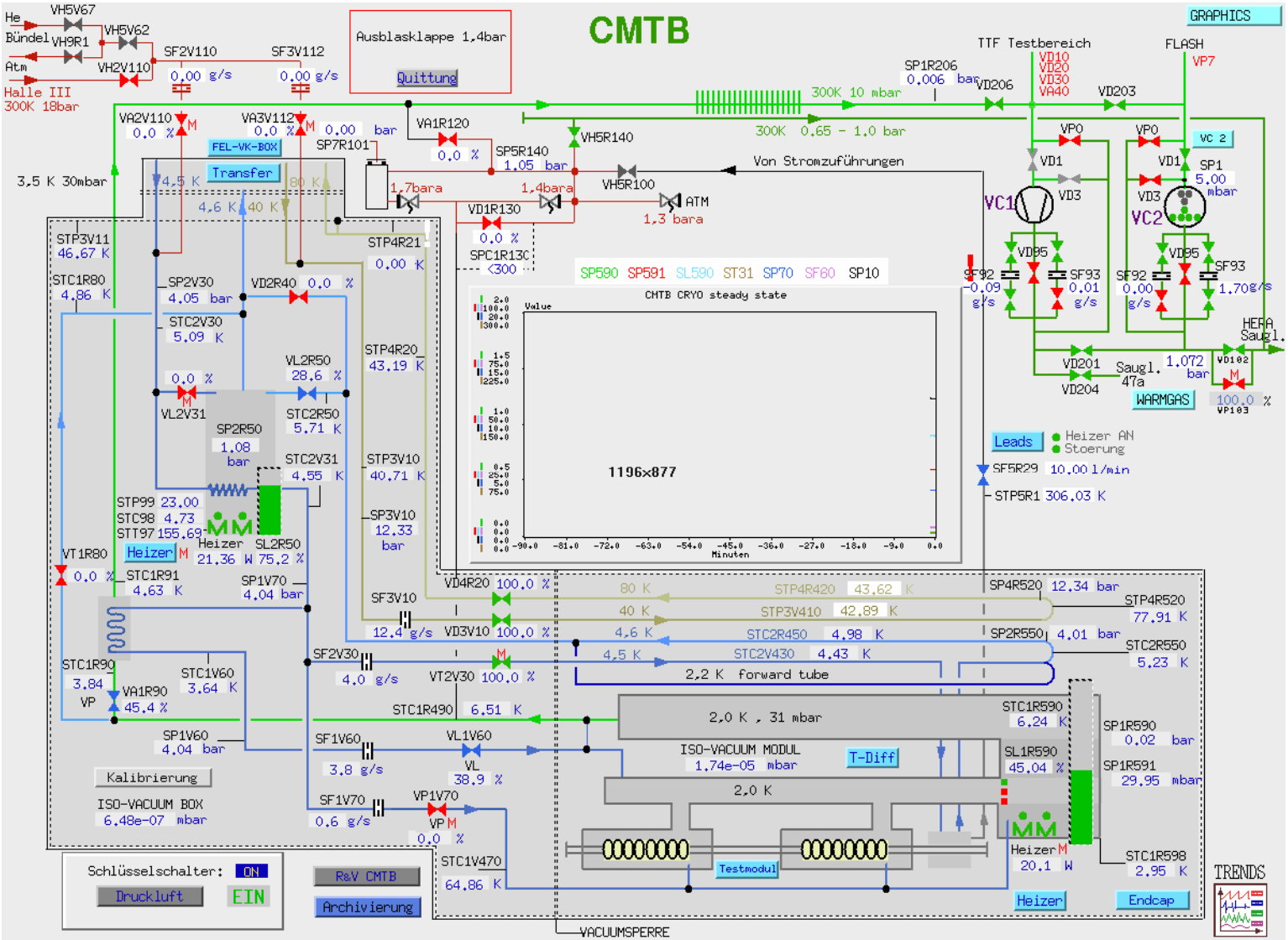
- Module 6 Test
- Module 7 Test
- Future Tests

M6 Transport to CMTB



Module 6 on CMTB

CMTB Cryogenic



Acknowledgements

- Many people have contributed to the overall design and test effort

- Thanks for transperencies to A. Bertolini, D. Kostin, A. Bosotti, R. Paparella, K. Jensch, L. Lilje

Aims for Module 6 of Type III

- **TESLA program**
  - Equipped with 8 cavities operational at 31.5 MV/m (all CHECHIA tested)
  - TTF2/FLASH compatibel ➔To be installed at FLASH position ACC6
  - Long time 10Hz 500/800µs high gradient operation in TTF2/FLASH

- **Investigate main coupler behavior**
  - Processing time warm and cold →storage, assembly, disassembly
  - Heat sinks 4K, 40/80K

- **Test program cavity frequency tuning**
  - Slow tuning →new motor
  - Fast tuning → double piezo system

- **Industrial Assembly and Design Study for XFEL Modules**
  - Introduce Industry/ILC
  - Introduce laser tracking system for alignment by DESY
  - Check all DESY procedures for preparation, assembly, installation
  - Partly joined by TÜV Nord

Aims for Module 6 of Type III on CMTB

- **Comprehensive test on the new cryomodule test stand**
  - **Main coupler processing**
  - **Thermal cycling → keep alignment, leak tightness**
  - **Vibration measurements**
  - **Cryo/RF performance measurement**
  - **Piezo tests**
  - **LLRF test**

→ And our hope

→ Conclude from these test, we are on the right way for our XFEL module design

Overview test duration M6 CMTB

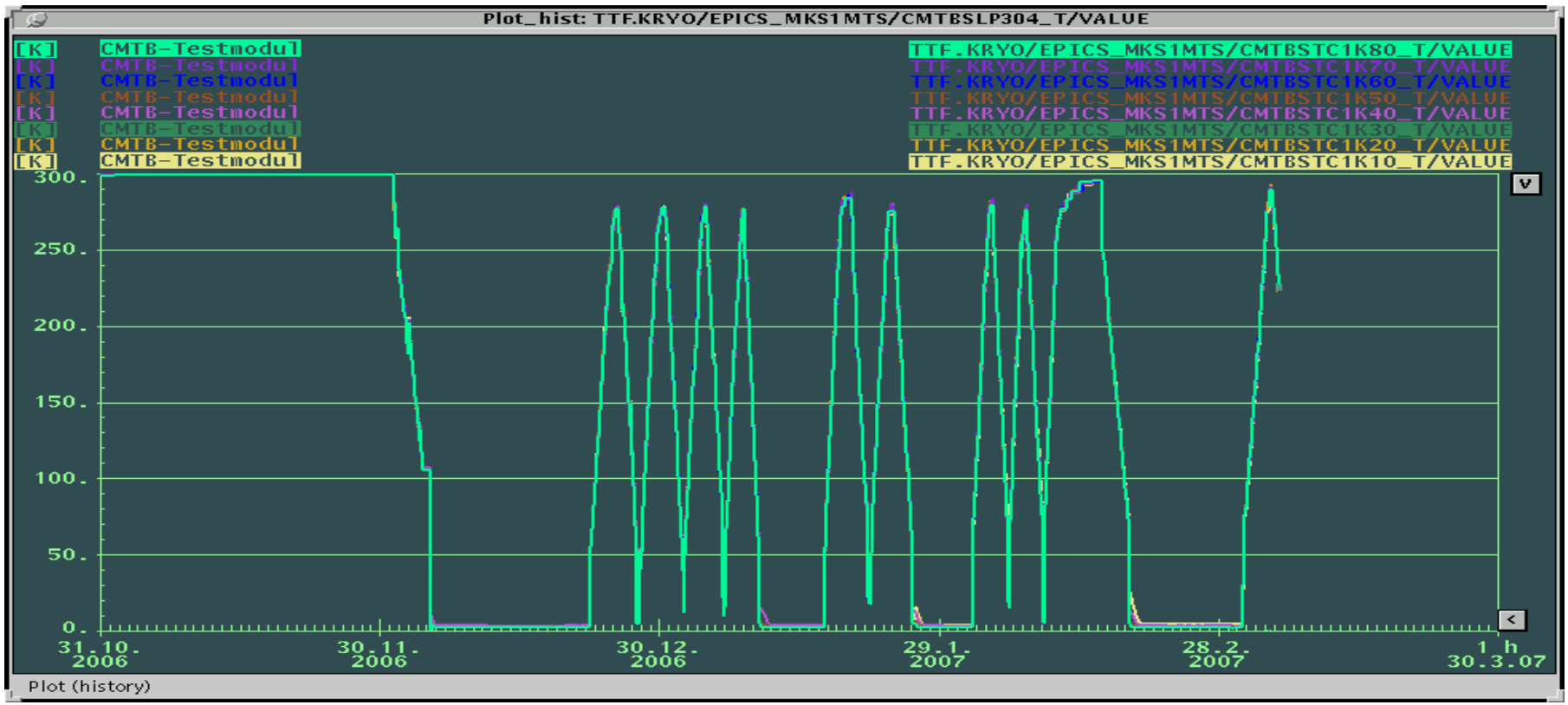
-Test start scheduled for Mid Aug-06

Start 14-Nov-06 (with delay)

-Planned 10 thermal cycles with performance checks after 1, 2, 5, 10

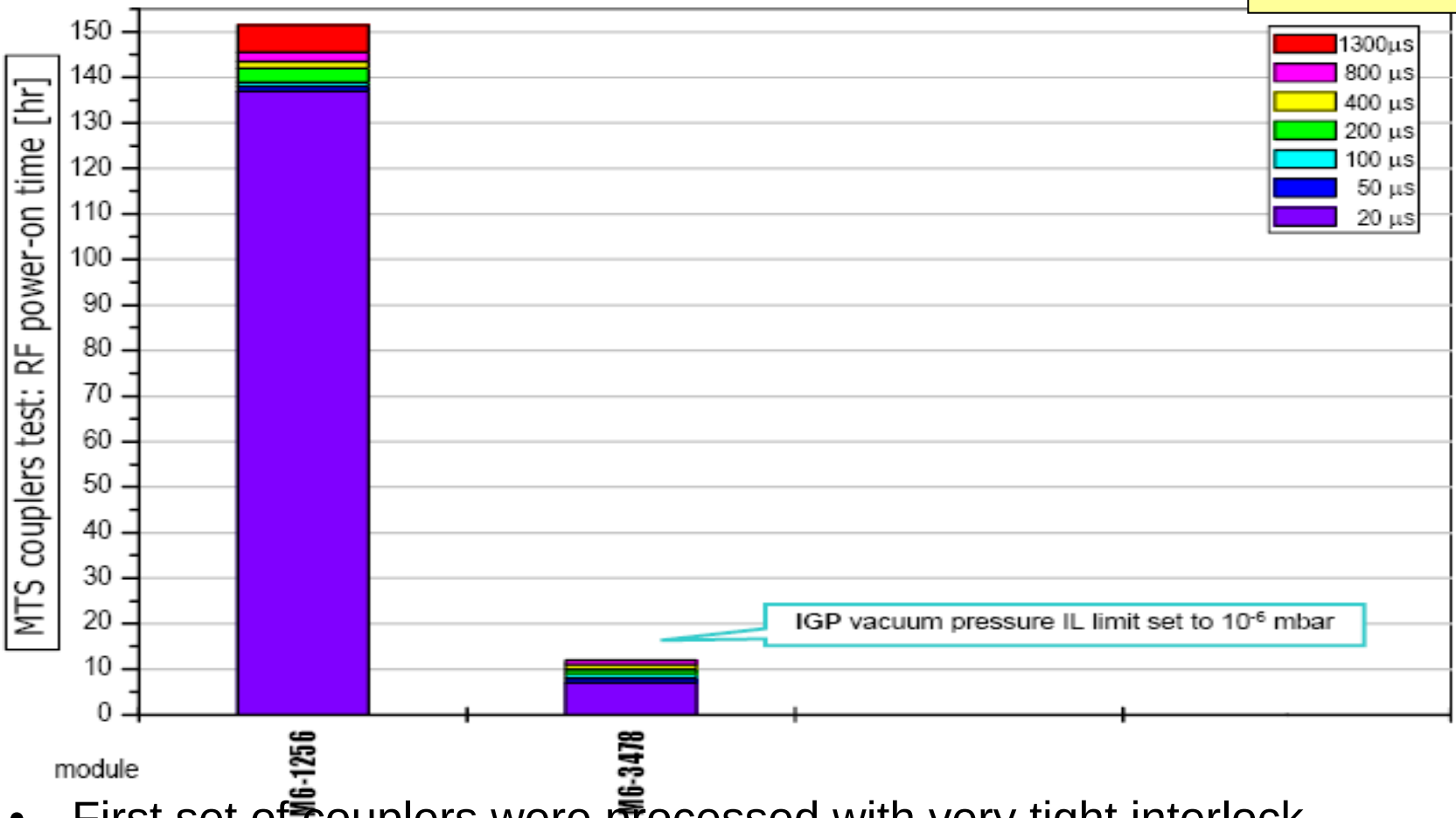
Performed 11 thermal cycles (checks after 1, 5, 7, 11)

-Test finished 20-Mar-07 with removal Module 6



RF power rising time for different pulse lengths during the couplers conditioning:

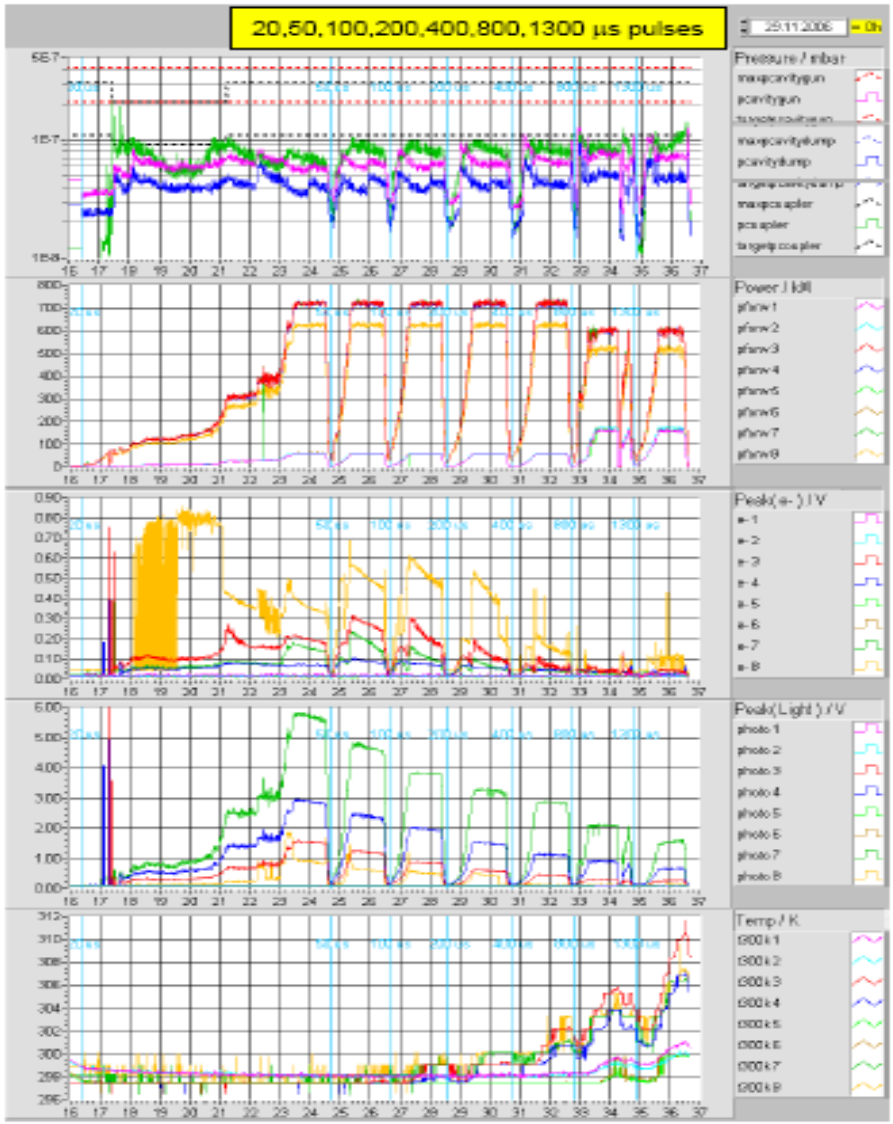
D. Kostin



- First set of couplers were processed with very tight interlock thresholts
- For the second set interlock thresholts were relaxed
- Their conditioning times comparable to recent CHECHIA experiences

Second Set of Couplers

D. Kostin



Input RF couplers 3,4,7,8 warm conditioning

Setting of the higher IGP (pumping speed 60 l/s) vacuum pressure interlock limit (7V: 10^{-6}mbar) as well as conditioning the couplers at higher pressure (like at horizontal cavity cryostat test stand: 1..3x10^{-7} mbar) allows for shorter couplers conditioning time.

The IGP IL limit was initially set to 5V: 7x10^{-8} mbar, at Horizontal test stand it is set to 7.5V: 2x10^{-6} mbar.

Tests

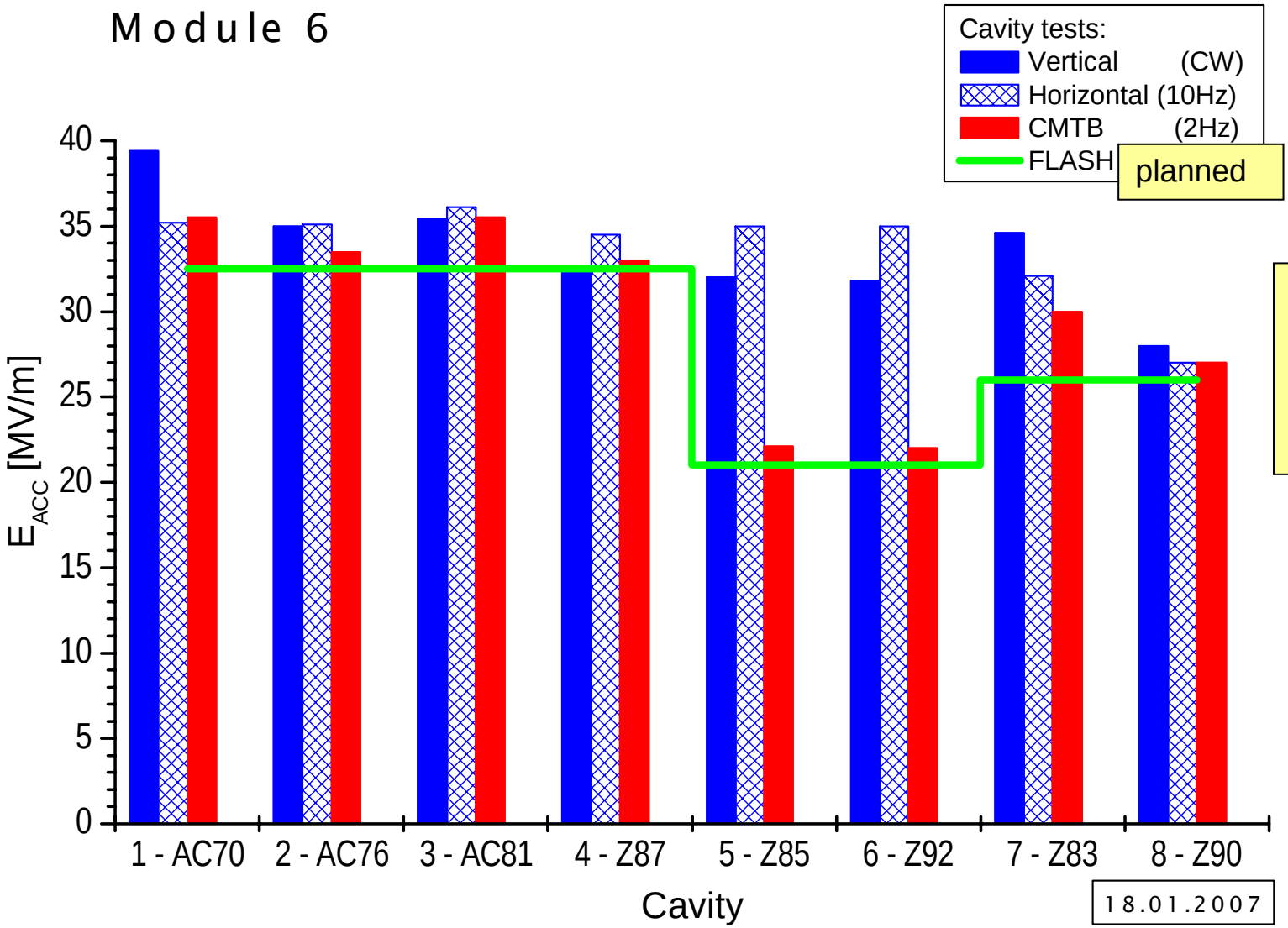
- M6 on CMTB
  - TTF type 3 module
  - Heat load static (expected value)
    - 40 /80 K: 80 Watt +/- 5 (75 Watt)
    - 4 K: 13 Watt +/- 2 (13 Watt)
    - 2 K: 3.5 Watt +/-1.5 (2.8 Watt)
    - Note: 2 Endcaps lead to higher loss!
  - No leaks occurred in 11 thermal cycles
  - RF performance
    - Coupler processing very smooth
    - 2 cavities degraded
  - Piezo tests
  - Alignment over thermal cycles
  - Vibration measurements
  - (LLRF tests)

Cryogenic tests

- **TTF type 3 module**
  - Heat load static (expected value)
    - 40 /80 K: 80 Watt +/- 5 (75 Watt)
    - 4 K: 13 Watt +/- 2 (13 Watt)
    - 2 K: 3.5 Watt +/-1.5 (2.8 Watt)
    - Note: 2 Endcaps lead to higher loss!
  - Module dynamic losses 20 / 22 / 25 MV/m
    - **40 /80 K:20.9 / 22.5 / 24.3 Watt (~3.5 W/coupler@25 MV/m)**
    - **4 K: <1 / <1 / 1 Watt**
    - **2 K: 2.81/ 3.57 / 5.13 Watt (see also Q(E) below)**
  - No leaks occurred in 11 thermal cycles

Cavity Performance

(courtesy D. Kostin – DESY)

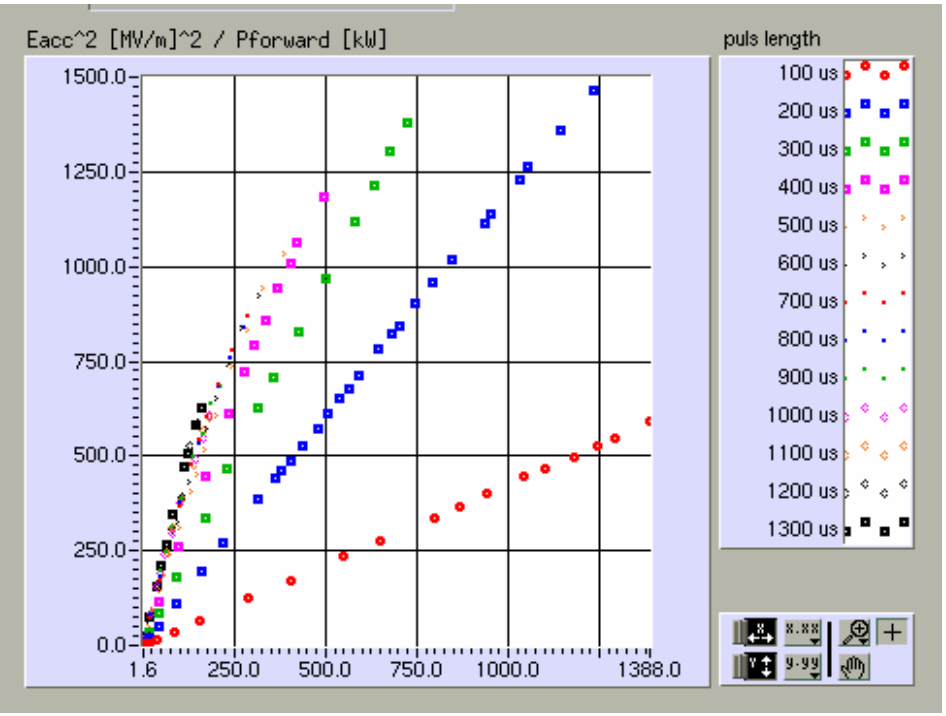


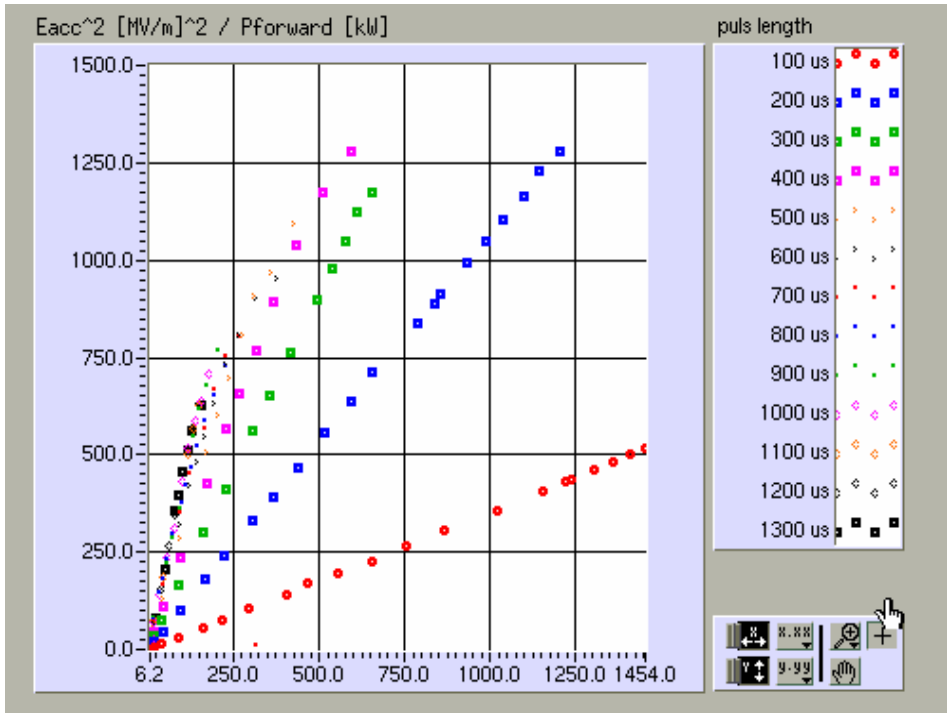
Average gradient: 28 MV/m

HPP on Cavity 5 +6

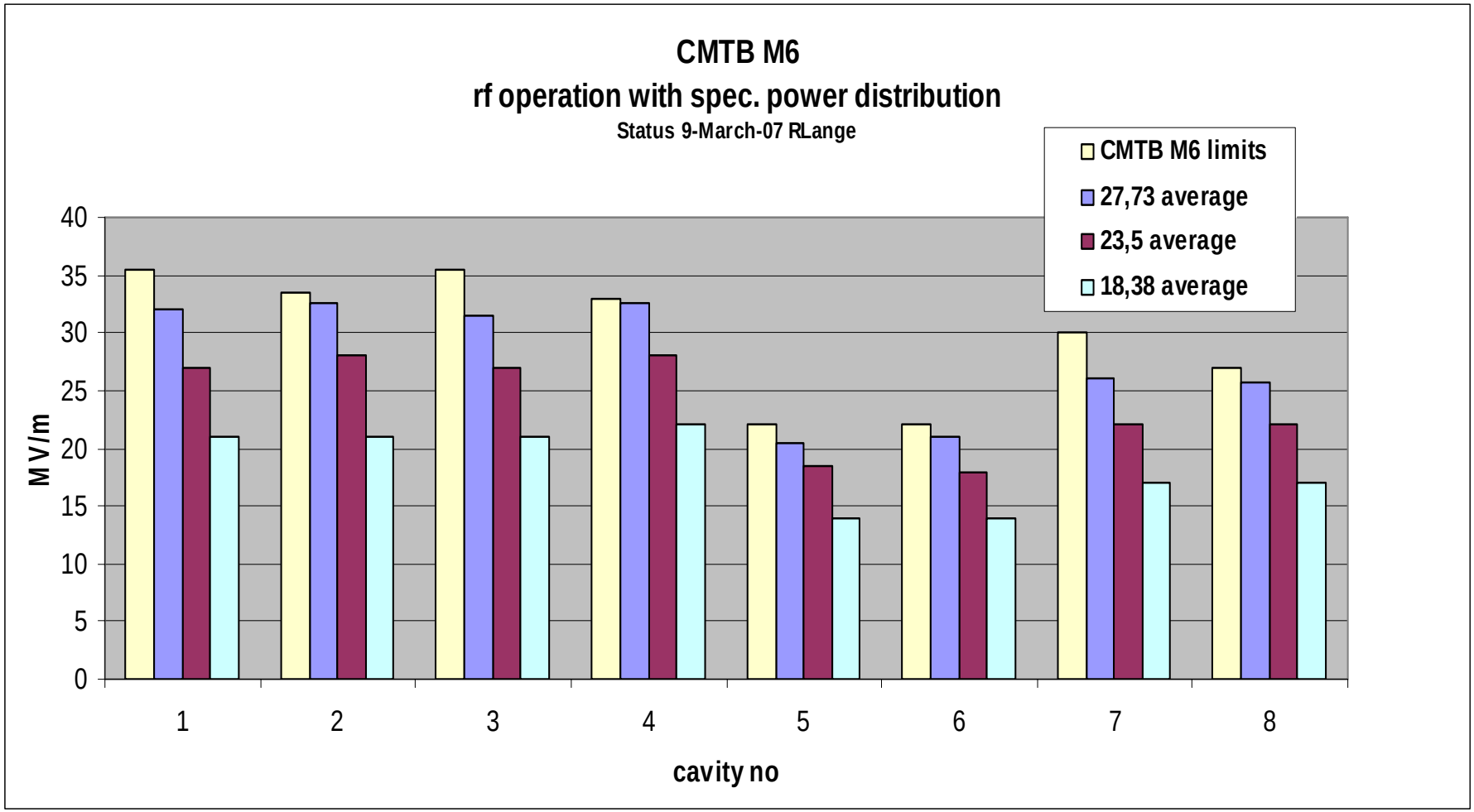
D. Kostin

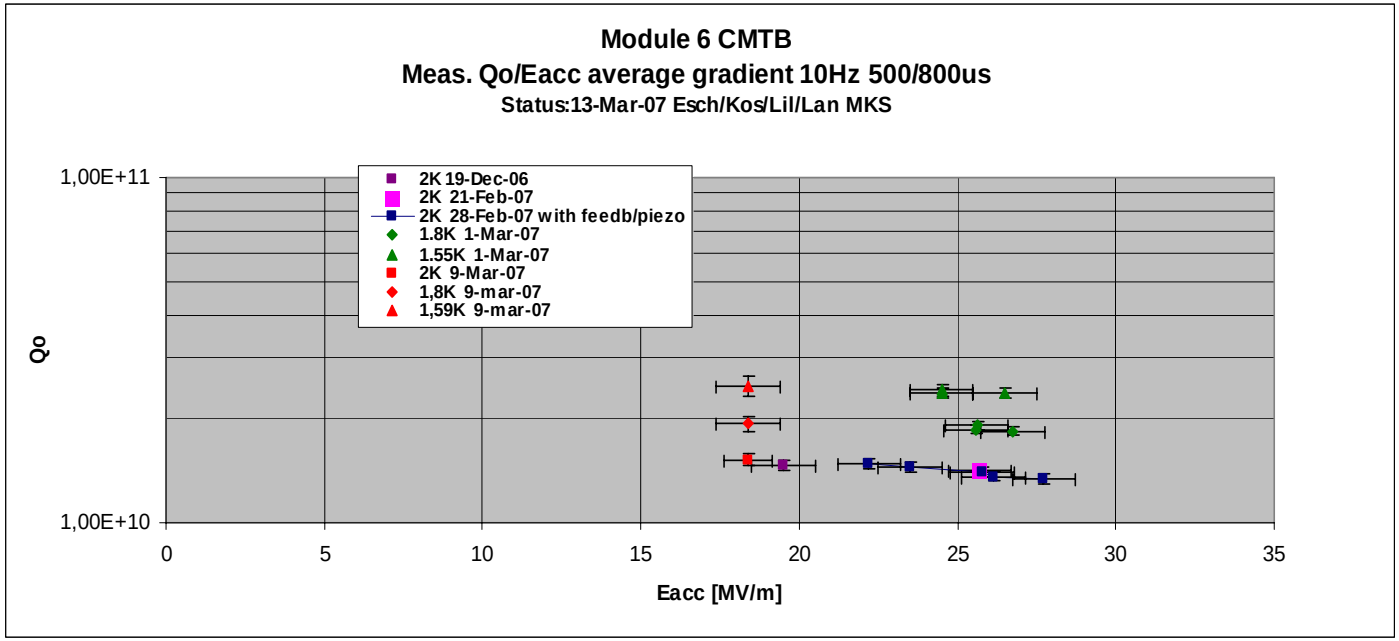
- For short pulses up to 300 us gradient is high >30 MV/m
- Radiation levels are relatively low
- This hints to a thermal quench

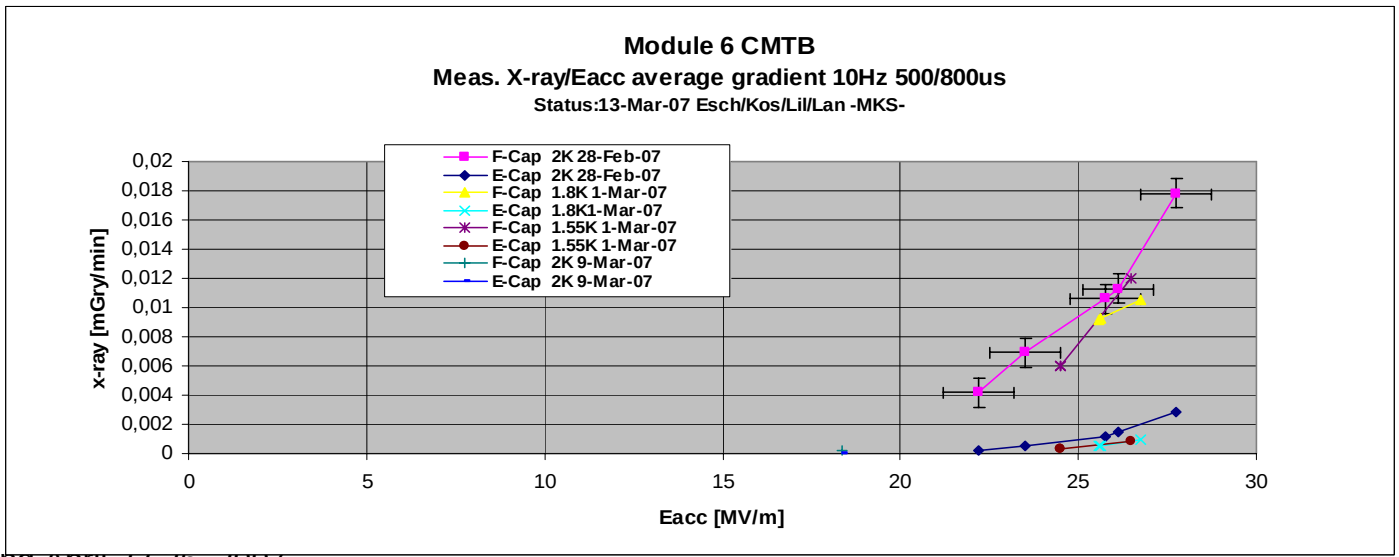




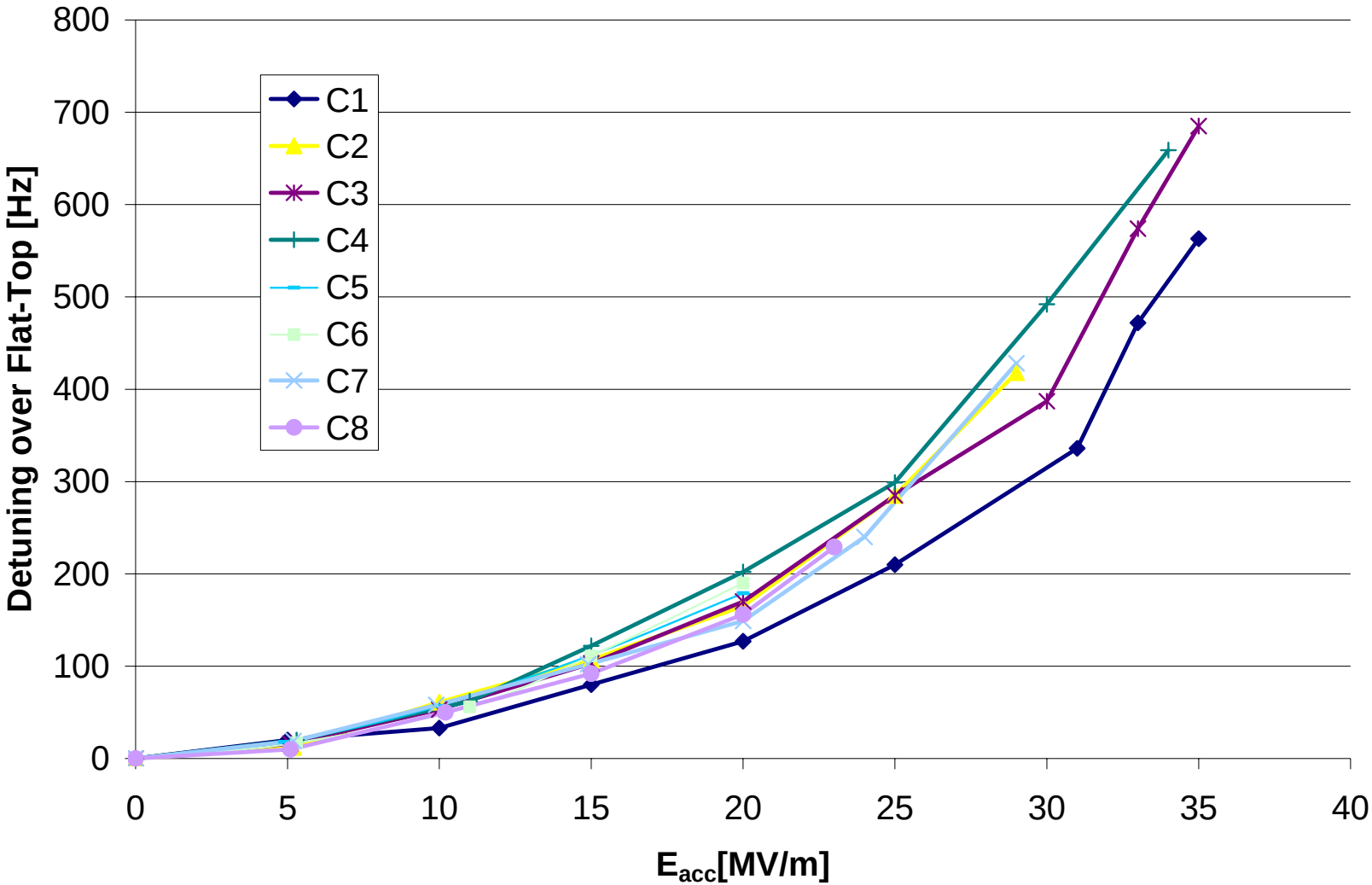
M6 RF Tests with special power distribution



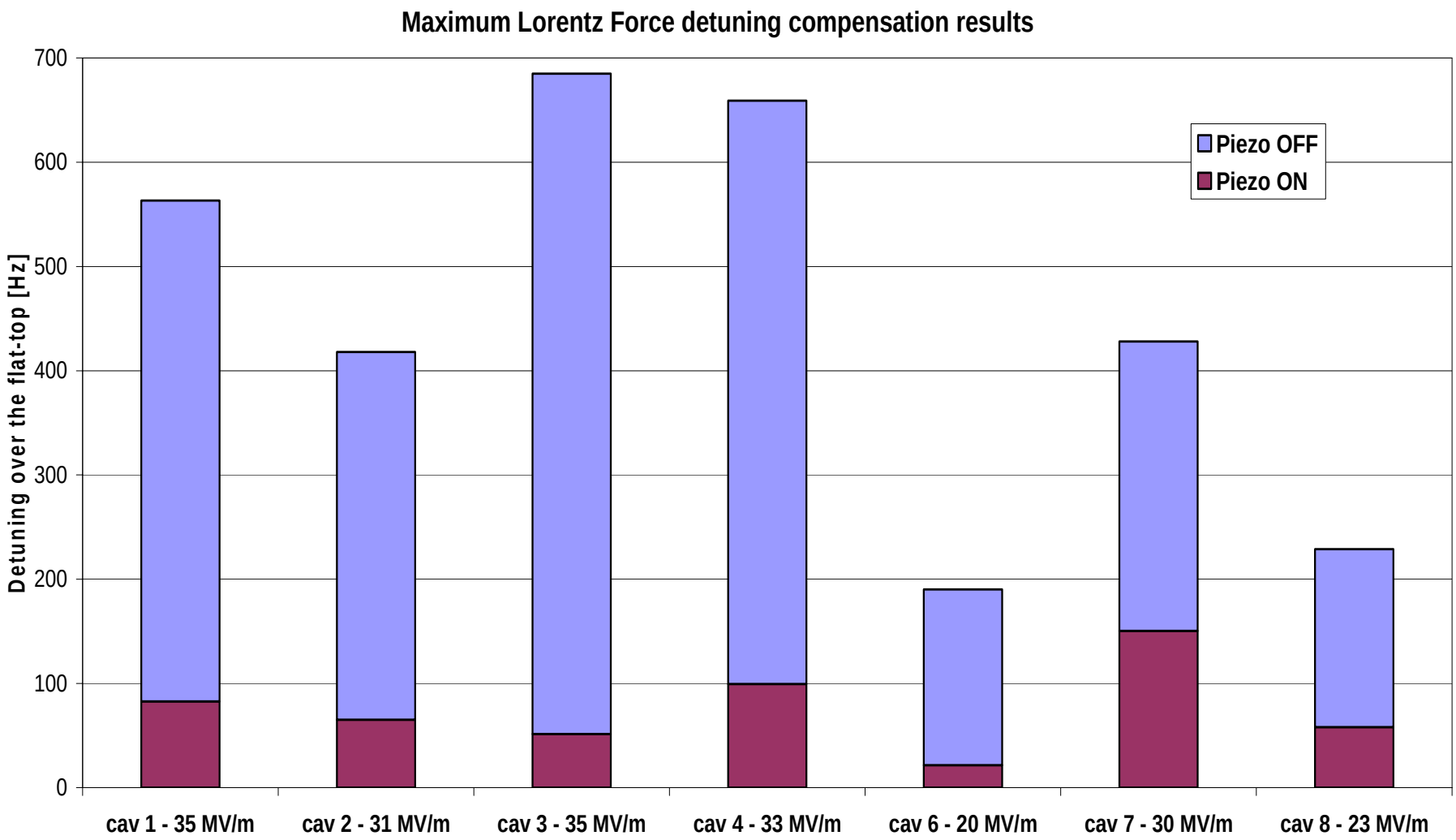

Module 6 CMTB
Meas. Qo/Eacc average gradient 10Hz 500/800us
Status:13-Mar-07 Esch/Kos/Lil/Lan MKS
2K 19-Dec-06
2K 21-Feb-07
2K 28-Feb-07 with feedb/piezo
1.8K 1-Mar-07
1.55K 1-Mar-07
2K 9-Mar-07
1,8K 9-mar-07
1,59K 9-mar-07
Qo
1,00E+11
1,00E+10
0
5
10
15
20
25
30
35
Eacc [MV/m]


Module 6 CMTB
Meas. X-ray/Eacc average gradient 10Hz 500/800us
Status:13-Mar-07 Esch/Kos/Lil/Lan -MKS-
F-Cap 2K 28-Feb-07
E-Cap 2K 28-Feb-07
F-Cap 1.8K 1-Mar-07
E-Cap 1.8K1-Mar-07
F-Cap 1.55K 1-Mar-07
E-Cap 1.55K 1-Mar-07
F-Cap 2K 9-Mar-07
E-Cap 2K 9-Mar-07
x-ray [mGry/min]
0,02
0,018
0,016
0,014
0,012
0,01
0,008
0,006
0,004
0,002
0
0
5
10
15
20
25
30
Eacc [MV/m]

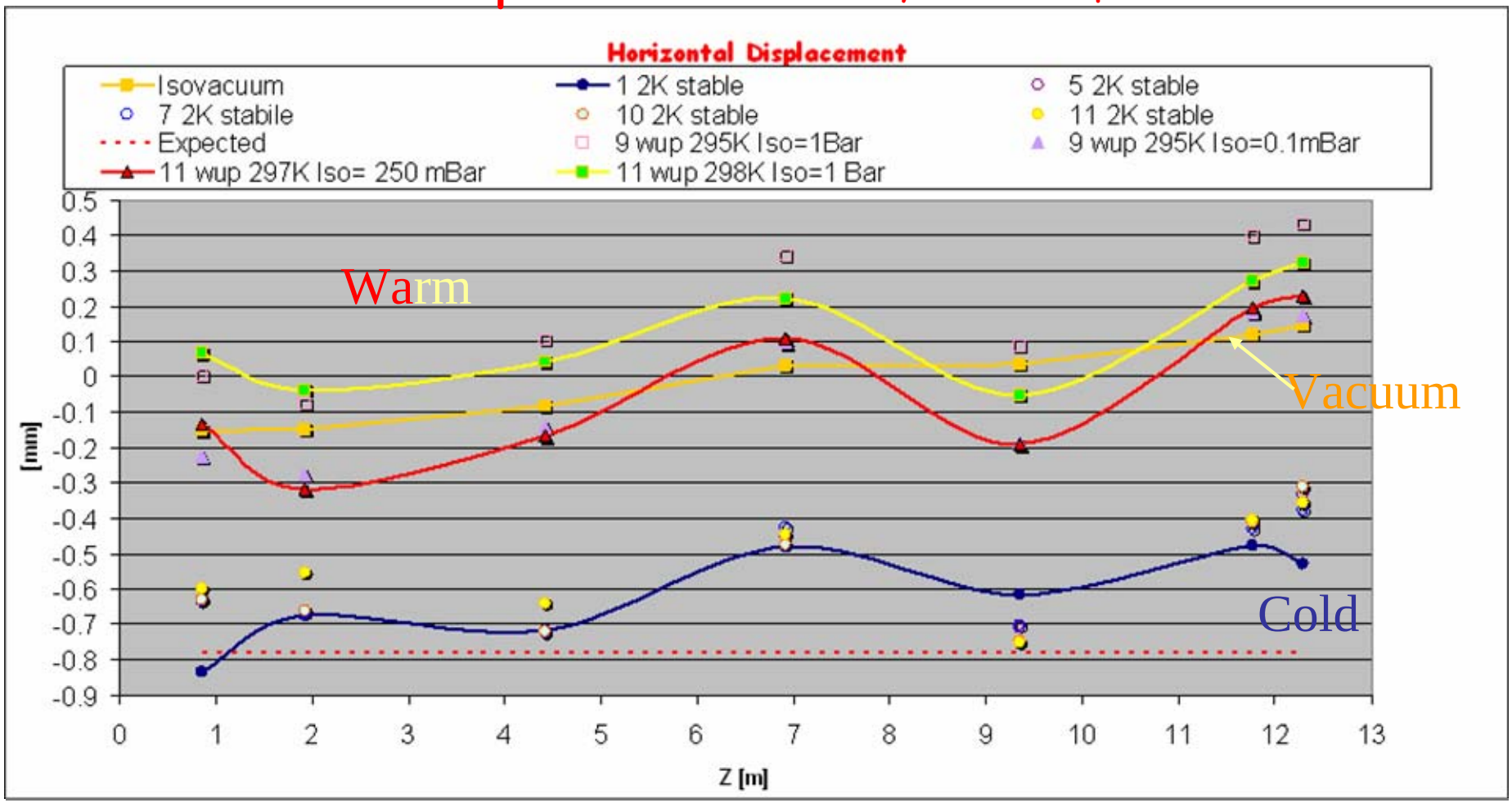
Lorentz Force Detunings in Module 6



Compensated Detuning per Cavity

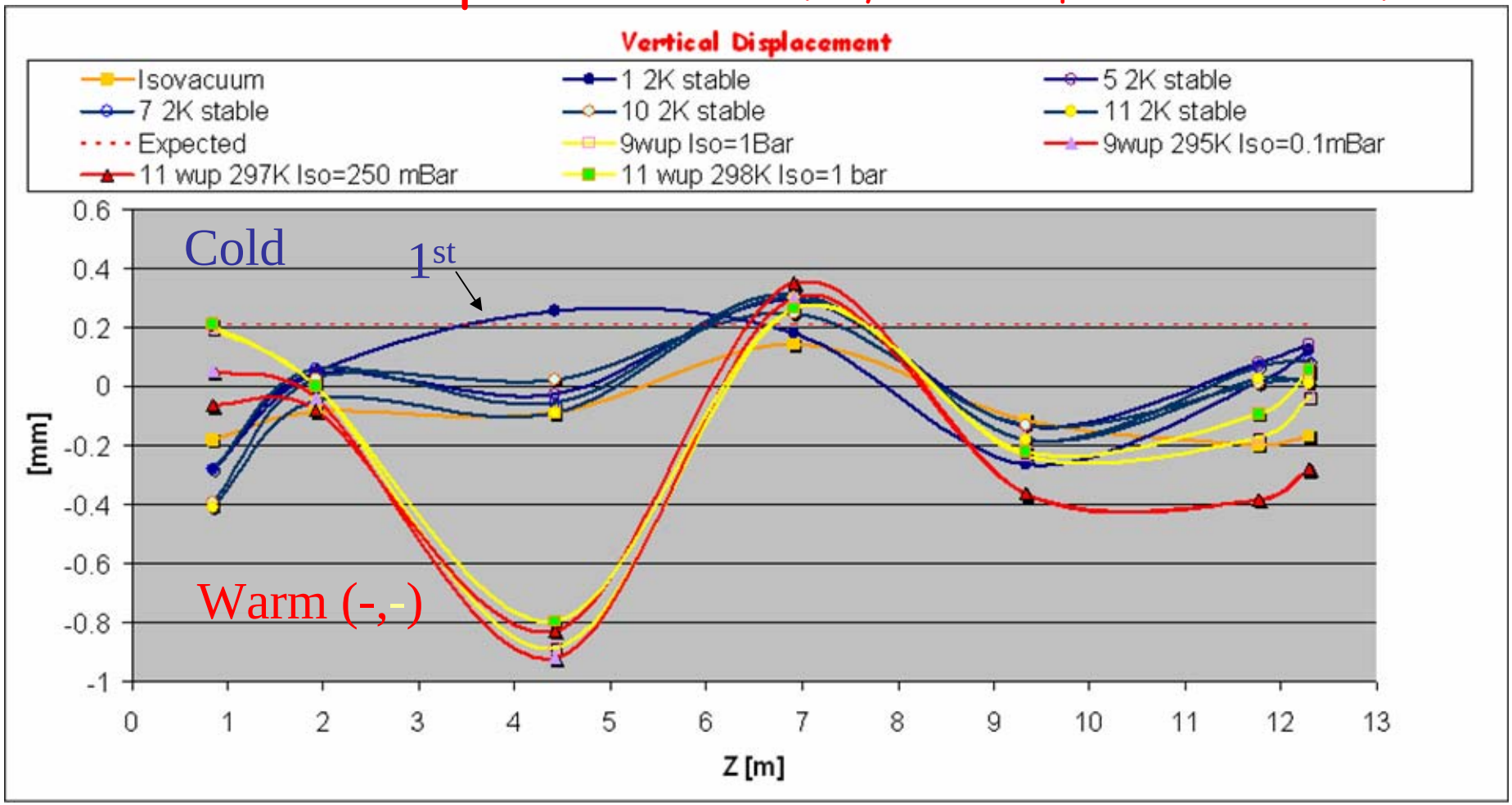


Cooldown and Warmup data for different cycles: Horizontal Displacements (only stable T points considered)



A. Bosotti

Cooldown and Warmup data for different cycles: Vertical Displacements (only stable T points considered)

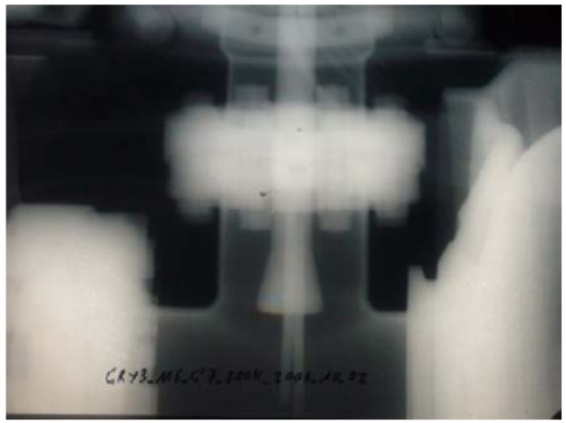


A. Bosotti

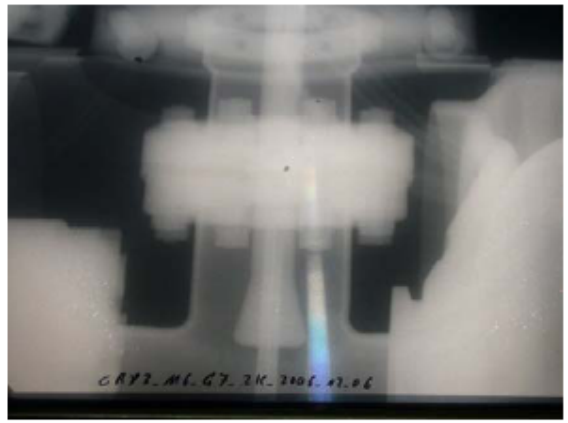
Longitudinal Position: Xray of Coupler Antenna (C7)

(Ansicht Y-Achse)

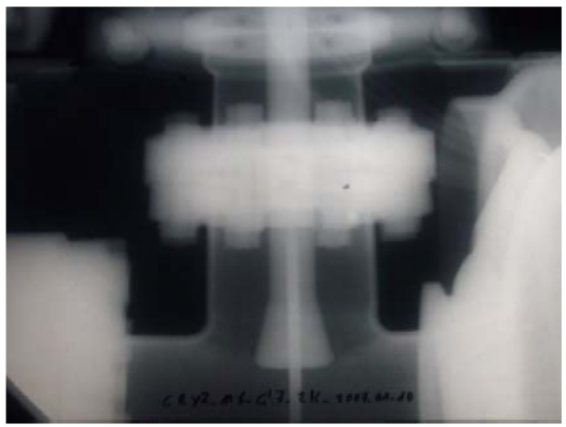
300 K vor 1 therm. Zyklus



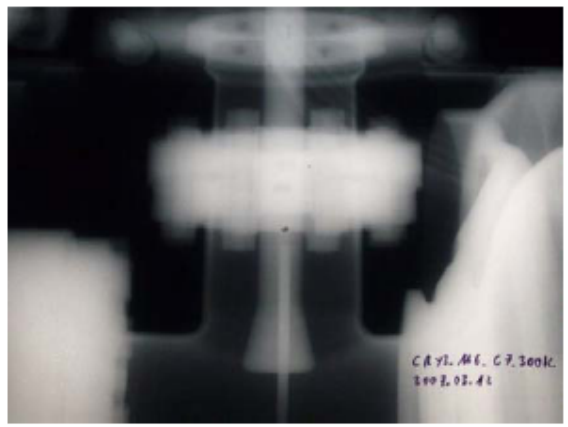
2 K nach 1 therm. Zyklus



2 K nach 5 therm. Zyklus



300 K nach 11 therm. Zyklus



← Beam direction

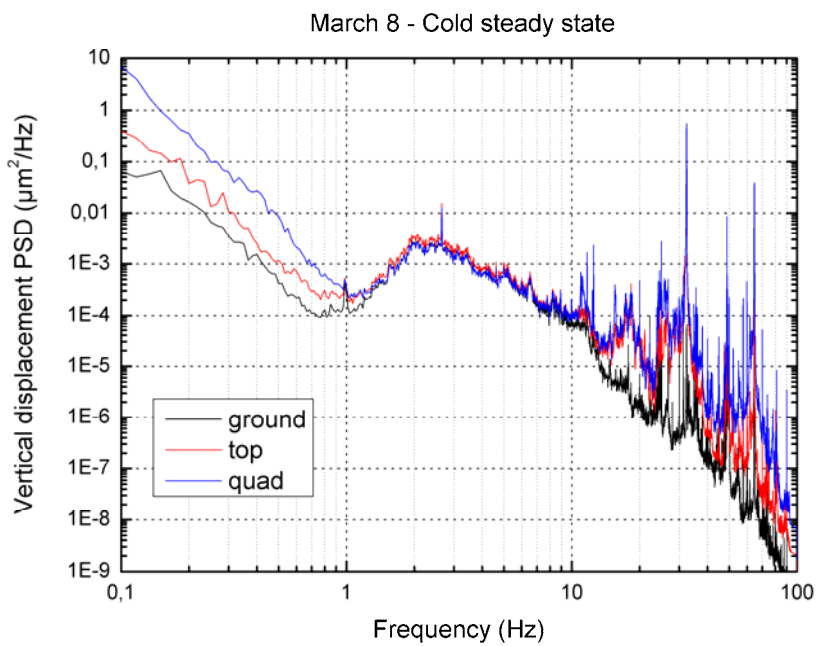
K. Jensch

Summary of the results (from March 20th meeting)

Our results on Module 6 agree with the piezo data (taken during the 1-9th thermal cycles) at frequencies >10 Hz; geophones allow us to push the measurement down to 1 Hz or even below (important for XFEL and ILC linacs)

Quad vibration level seems not affected at all by the RF operation. No differences have been found between no RF/LLRF/high gradient conditions.

Quad vibration level is not affected by the refrigeration system; no difference with warm operation except for a large amplitude ~30 Hz oscillation (+harmonics) that build up in the cold. Not a mechanical resonance of the cold mass/quad structure: no trace in the transfer function measured at room temperature. For ex. Vertical RMS amplitudes ranging from 200 nm to >1 μm have been measured.



Conclusions

Geophone test at 4K

- classic 4.5 Hz industrial geophone can operate at 4K without any loss of sensitivity
- in-situ high accuracy calibration procedure demonstrated
- a new tool for low frequency vibration investigations at cryogenic temperatures

Quadrupole vibration measurements at 4 K

- low frequency (1-100 Hz) quadrupole vertical stability is not affected by high gradient RF operation
- quadrupole vertical stability is not affected by the refrigeration system at frequencies up to 30 Hz; results not conclusive at higher frequency because of the present limitations of the CMTB cryo plant.
- needed comparison with operation in the FLASH linac. Can we keep the geophones aboard Module 6?
- the results will be cross-checked with laser interferometry on Module 8 at the end of the year.

XFEL Module Meeting, March 20th 2007

Overview test duration and summary M6 CMTB

- **Summary after 11 thermal cycles:**

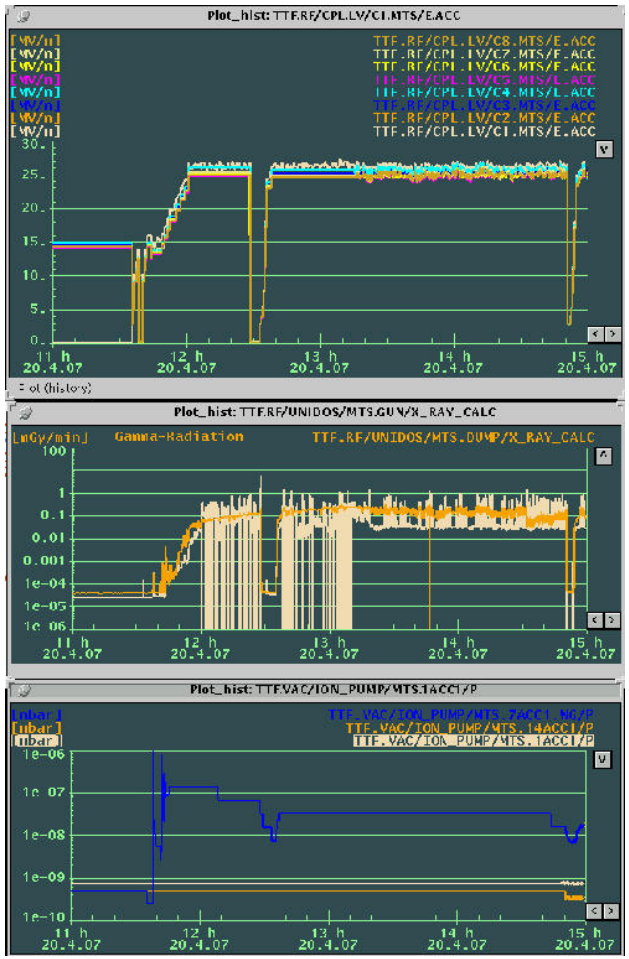
  Warm coupler processing (4 parallel) as expected
  Alignment can be kept

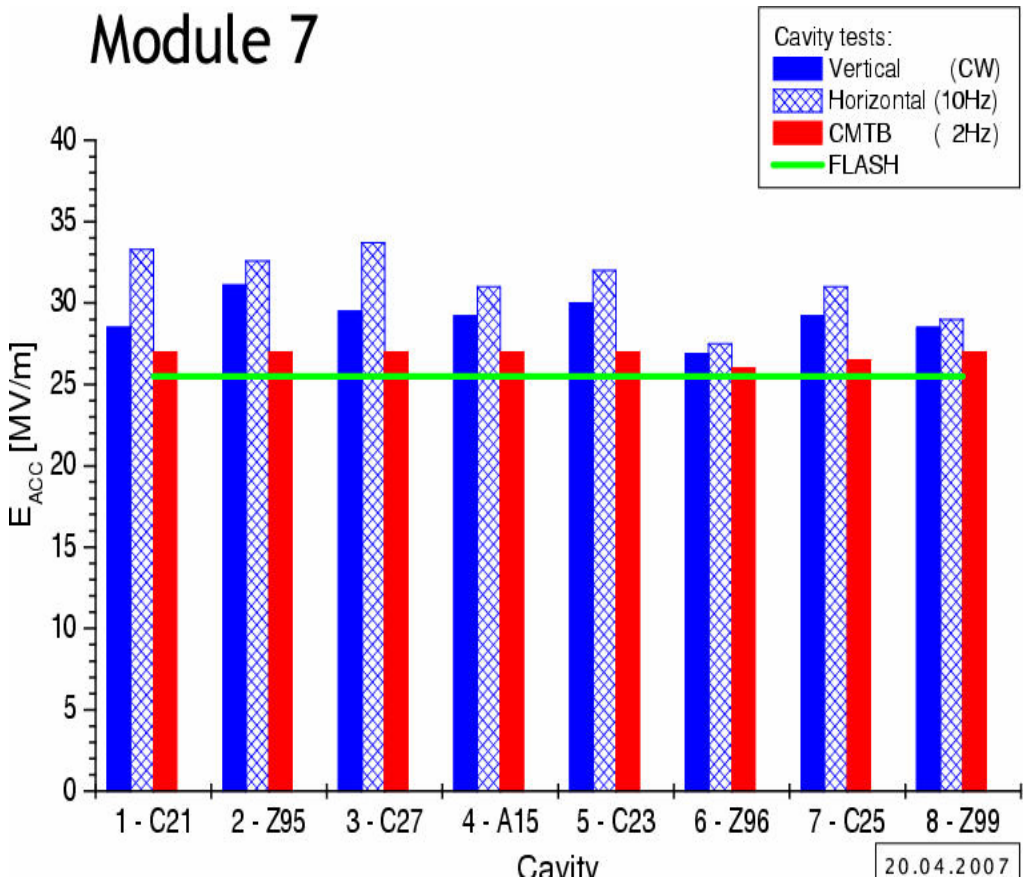
  No leaks

  New tuner motors and double piezos work

➔Basic design appropiated for XFEL-Modules

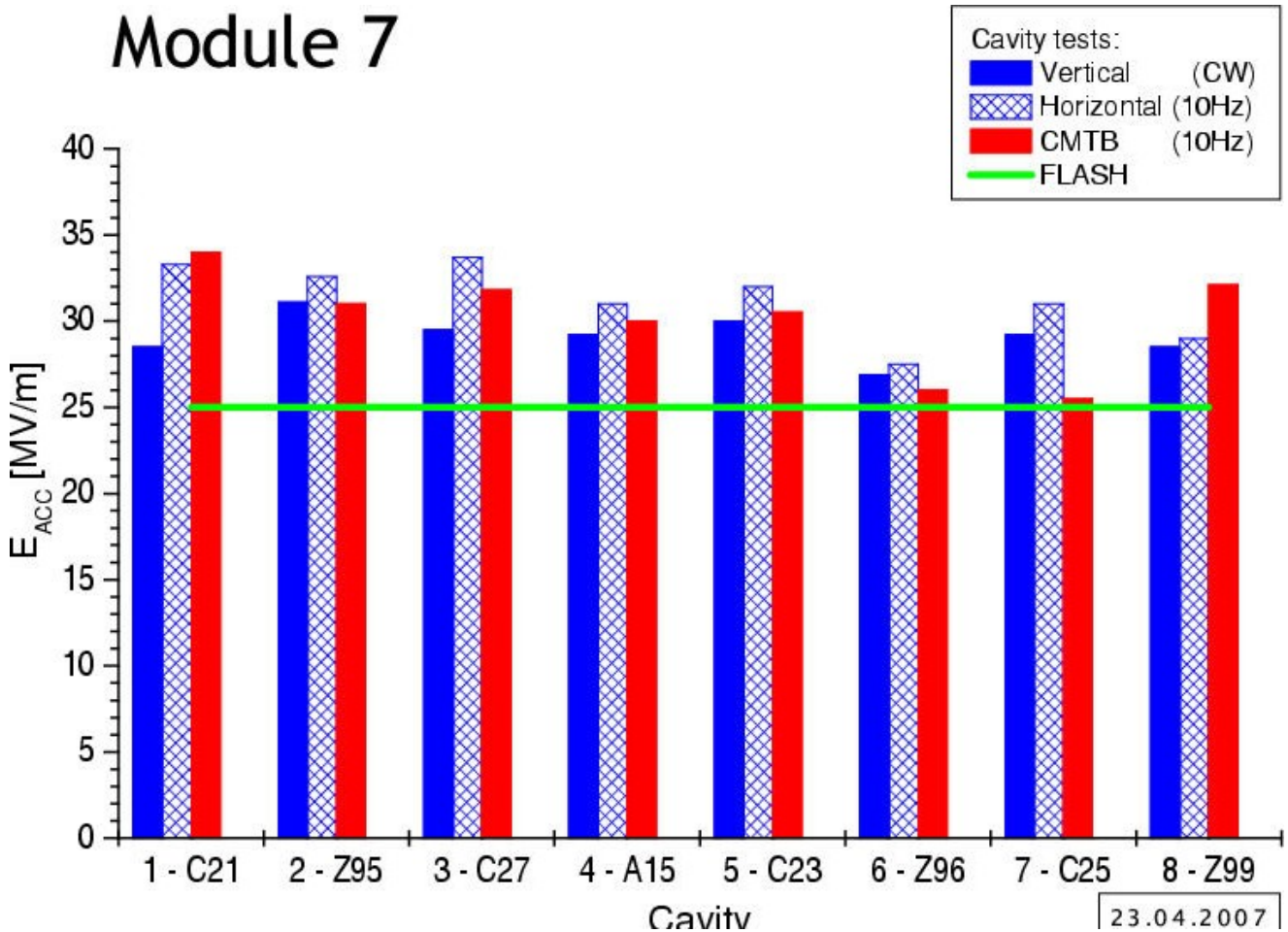
Module 7 on CMTB





Module 7 limits on CMTB

10Hz 500/800us 23-April-07



Conclusion

- CMTB has proven to be essential tool for thorough linac-independent tests of modules
- M6 has passed several important tests
  - Coupler processing
  - Alignment over several thermal cycles
  - Leaktight over several thermal cycles
  - Piezo compensation
  - First comprehensive LLRF
  - Higher vibration amplitudes not caused by the module

- Nonetheless some issues remain
  - Cavity performance degradation (M4, M5 and M7 no degr)
  - Vibration needs more understanding (~30 Hz peak)
- Minor evolutions in design will be tested on M8 (M9)
  - Important step toward a XFEL prototype test

Future Tests

- Destructive test on M3*
- More vibration measurements
  - M7
    - Parallel accelerometer and geophone measurements
    - Continuous measurements
  - M8
    - Laser interferometry on quad
  - FLASH
    - Accelerometers (all modules) and geophones (in M6/ACC6) will be monitored continuously
    - wpm position monitors in M4, M5 and M6 (over ~36m)
- Test on longitudinal positioning of Quad/BPM package
  - On M8/(M9)
- More detailed tests on piezo tuning system
  - Reversed cavity pre-tuning needs full demonstration
- Further LLRF tests