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राजा रामन्ना प्रगत प्रौद्योगिकी केन्द्र, इंदौर

Government of India
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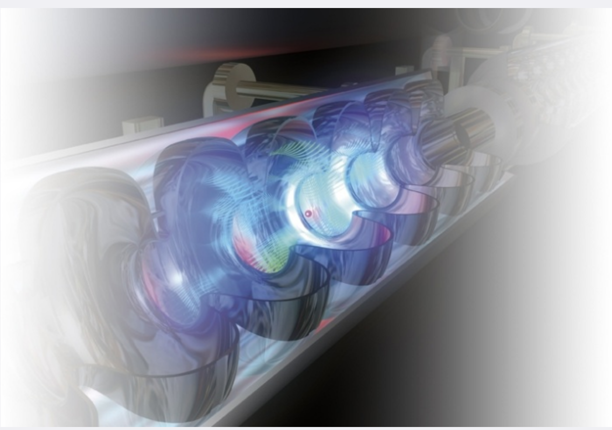
Raja Ramanna Centre for Advanced Technology, Indore

University of Delhi
दिल्ली विश्वविद्यालय

High Pressure Vessel Code Test of Module 3*



Hans Weise (for Rolf Lange et al.)

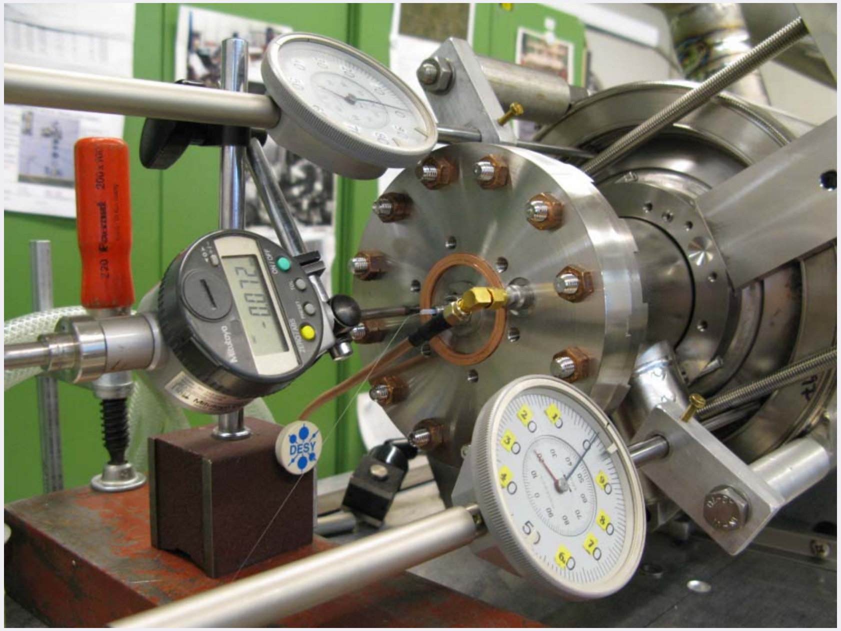
TESLA Technology Collaboration Meeting
New Delhi, October 20th – 23th, 2008

Pressure test of cavity and He vessel

Motivation:
Development of a pressure test for the 800 XFEL cavities as part of a safety acceptance.

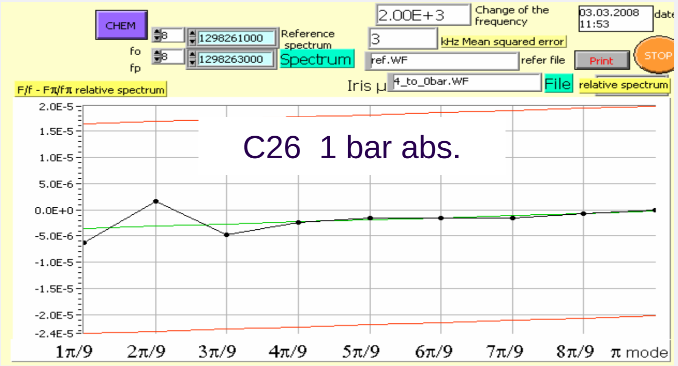
- max. possible pressure inside He vessel is 4 bar rel.
- pressure vessel regulations require 4 x 1.43 = 5.72 bar
- pressure test with 1 bar abs. in the cavity requires 6.72 bar, i.e. 7 bar abs. during a test

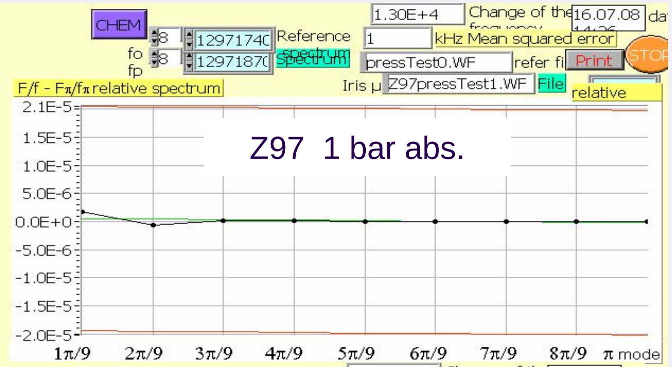
Goal:
Do the pressure test with water at warm temperature and check for plastic deformation of cavities.



Two cavities were tested:
C26 1350 ºC oven treatment
Z97 800 ºC oven treatment
wall thickness of both cavities is 2.5 mm

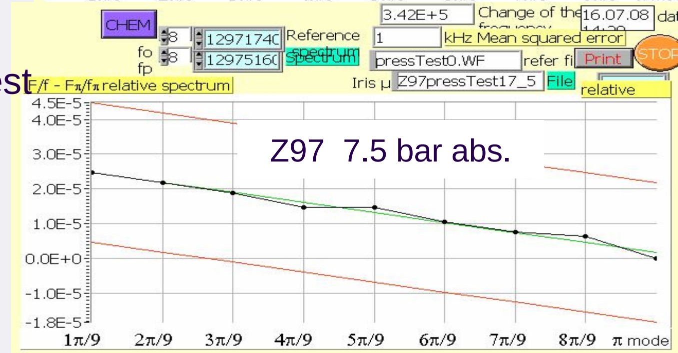
Pressure test and plastic deformation?

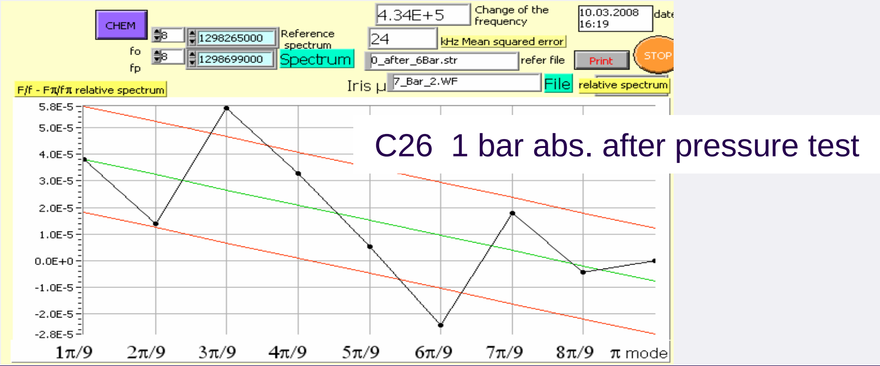


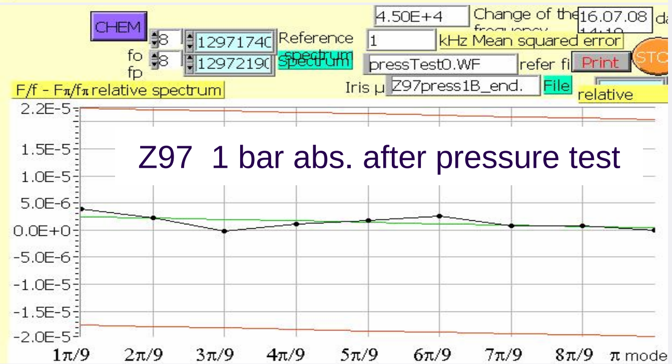


C26 1350 ºC oven treatment
clear deformation after pressure test

Z97 800 ºC oven treatment
no deformation after pressure test
modes unchanged
field flatness unchanged







Accelerator Module 3* at CMTB

Motivation for the ‘destructive’ tests

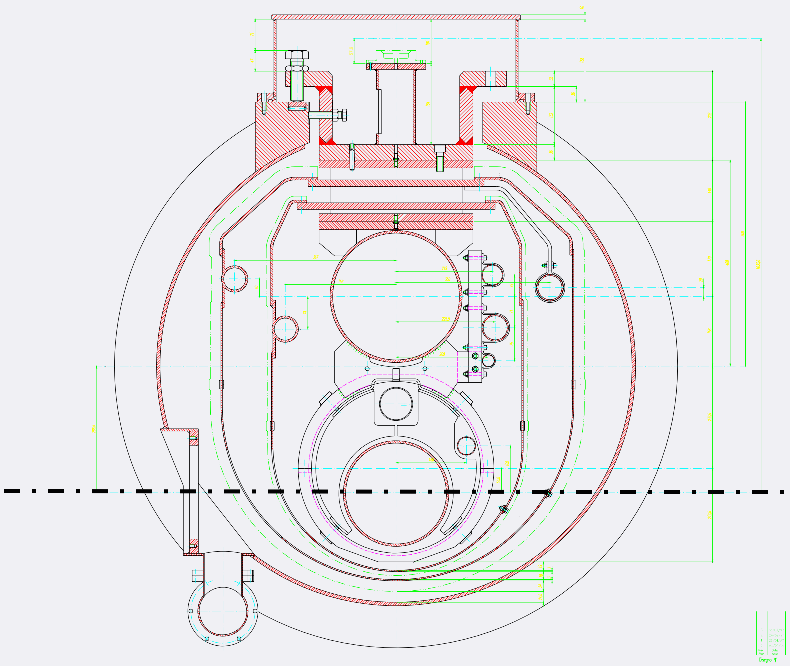
Investigate fault conditions during cryogenic operation of the XFEL modules

Study insulation and beam pipe vacuum system …

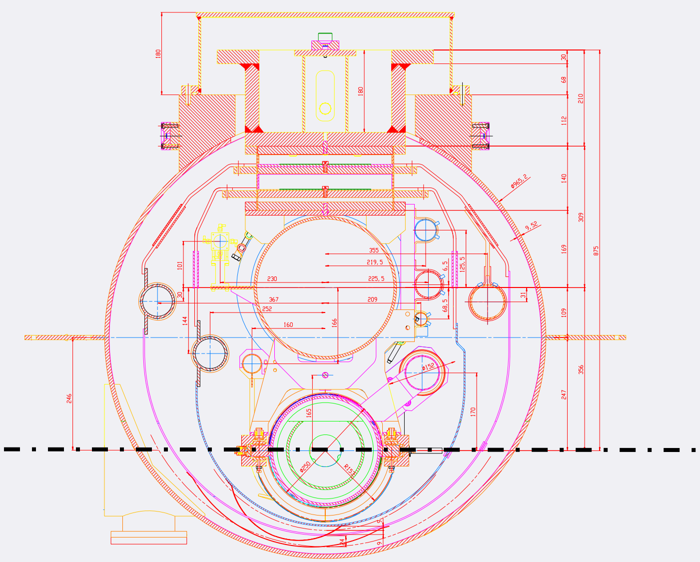
- The worst case is a total breakdown of the vacuum systems during the cool down operation at XFEL:
  - The thermal shields pipes are under maximum pressure
  - The cavity are completely filled with liquid He at 4.3 – 4.5K (1.1 – 1.3bar)
- What happens if the same event occurs under steady state operation at 2K/31mbar?
- Possible faults are:
  - Venting of the beam pipe from the connection in the cryo boxes
  - Venting of the insulation vacuum from the connection in the cryo boxes – DN 100
- Detailed report published by B. Petersen:
  - *“EXPERIMENTAL TESTS OF FAULT CONDITIONS DURING THE CRYOGENIC OPERATION OF A XFEL PROTOTYPE CRYOMODULE* “, International Cryogenic Engineering Conference ICEC22, July 2008, Seoul/Korea

Module 3* is an old type II module

(big vacuum vessel and sliding cavities)



Type II vacuum vessel
diameter 1089 mm



XFEL Type vacuum vessel
diameter 965.2 mm

M3* test sequences

In total 8 tests were carried out on module 3* at CMTB:

- Test 1 – **slow venting isovac.** with He (He-leak) - 2K operation
- Measurement: cavity performance and cryo loses / Max. pressure isovac.: 10E-5mbar up to 2 mbar
- Test 2 – **slow venting coupler vac.** with N2 - 2K operation
- Measurement: cavity performance. and cryo loses / Max pressure coupler vac. < 600 mbar
- Test 3 – **slow venting beam pipe vac.** with N2 – 2 K operation
- Measurement: cavity performance and cryo loses / Max. pressure beam pipe vac. 6*10E-6 mbar
- First warm up 300K and cool down again:
- Test 4 and 5 – **fast venting isovac.** with air – 2 K operation
- Second warm up to 300K (repair He-leak 2K-area / isovac) and cool down again:
- Measurement: cavity performance and cryo loses
- Test 6 – **fast venting beam pipe vac.** with air – 2 K operation
- Third warm up to 300K and cool down again
- Measurement: cavity performance and mech. detuning of cavities
- Test 7 – **fast venting beam pipe vac.** with air – 4,5 K operation
- Measurement: cavity performance and mech. detuning of cavities
- Test 8 – **fast venting isovac.** with air – 4,5 K operation
- Measurement: Diff.-pressure isovac. / Temp. development of vac.vessel

- End of M3* test at CMTB – M3* disassembled to check for damage

Pressures He-circuits

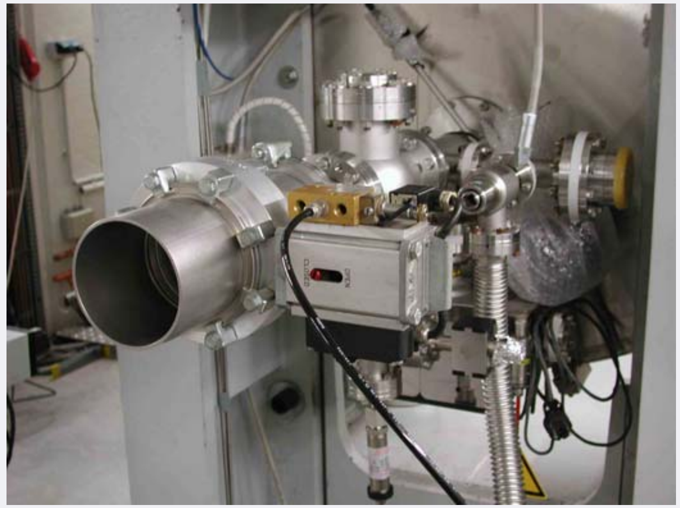
	P max 2 K area	P max 4 K area	P max 70 K area	Time of venting	Cryo-operating
First venting coupler vacuum - with N2 25.03-27.03.08	**No pressure increase**	**No pressure increase**	**No pressure increase**	**150 min** **Pmax = > 600 mbar**	Test at 2 K operation 4 K valves open 40/70 K valves open 2 K valves open
First venting Beampipe - with N2 27.03-28.03.08	**Part 1 :32,5 mbar** **Part 2 : 40 mbar**	**No pressure increase**	**No pressure increase**	**Test 1:** **500l >60 min** **Test2: 1600l>90min**	Test at 2 K operation 4 K valves open 40/70 K valves open 2 K valves open
First venting Isovac. fast - with air 18.04.2008	**2,169 bar**	**15,49 bar**	**16,14 bar**	**111,76 sec.** **up to 1000 mbar**	Test at 2 K operation 4 K valves closed 40/70 K valves closed 2K valves 10 % open
Sec. venting Isovac. fast - with air 21.04.2008	**2,134 bar**	**15,41 bar**	**16,40 bar**	**> 105 sec.** **up to 1000 mbar**	Test at 2 K operation 4 K valves closed 40/70 K valves closed 2K valves close
First venting Beampipe fast - with air 29.04.08	**1,964 bar**	**4,20 bar**	**12,63 bar**	**ca.11 sec.** **up to 1000 mbar**	Test at 2 K operation 4 K valves open 40/70 K valves open 2K valves closed
Worst case: Sec. venting Beampipe fast – with air 08.05.2008	**2,347 bar**	**4,37 bar**	**12,40 bar**	**ca.11 sec.** **up to 1000 mbar**	Test at 4.5 K operation 4 K valves open 40/70 K valves open 2K circuit closed
Worst case: Third venting Isovac. fast - with air 09.05.2008	**2,443 bar**	**16,13 bar**	**17,52 bar**	**64,33sec.** **up to 1000 mbar**	Test at 4.5 K operation 4 K valves closed 40/70 K valves closed 2K circuit closed

Pressures Vacuum-circuits

	P max Beampipe	P max Couplersys.	P max Isovaksys.	To be broken	Detectet
First venting couplerpipe - with N2 25.03-27.03.08	**No pressure increase**	**> 600 mbar Start: 3 * 10-8mbar**	**No pressure increase**		
First venting Beampipe Slow - with N2 27.03-28.03.08	**Pressure increase only on the venting side**	**No pressure increase**	**No pressure increase**		**Pressure increase detected after warm up Saefty valve open beampipe >2087 mbar. Change saefty.-alve**
First venting Isovac. fast - with air 18.04.2008	**3*10-3 mbar Start: 2 * 10-7 mbar**	**9*10-6 mbar Start: 2 * 10-8mbar**	**>1000 mbar Start: 8 * 10-4 mbar**		**Suspect of beam pipe leak** (approved during disassembly – Leak on BPM feedthrough)
Sec. venting Isovac. fast - with air 21.04.2008	**2*10-3 mbar Start: 1,3 * 10-6 mbar**	**1*10-7 mbar Start: 5 * 10-8mbar**	**>1000 mbar Start: 9 * 10-5 mbar**		
First venting Beampipe fast - with air 29.04.08	**>1000 mbar Start: 2 * 10-7 mbar**	**No pressure increase**	**9*10-6 mbar Start: 3 * 10-6 mbar**		
Sec. venting Beampipe fast - with air 08.05.2008	**>1000 mbar Start: 2 * 10-7 mbar**	**No pressure increase**	**1*10-5 mbar Start: 3 * 10-6 mbar**		
Third venting Isovac. fast - with air 09.05.2008	**9*10-3 mbar Start: 9 * 10-4 mbar**	**3*10-6 mbar Start: 3,6 * 10-8 mbar**	**>1000 mbar Start: 3 * 10-6 mbar**		

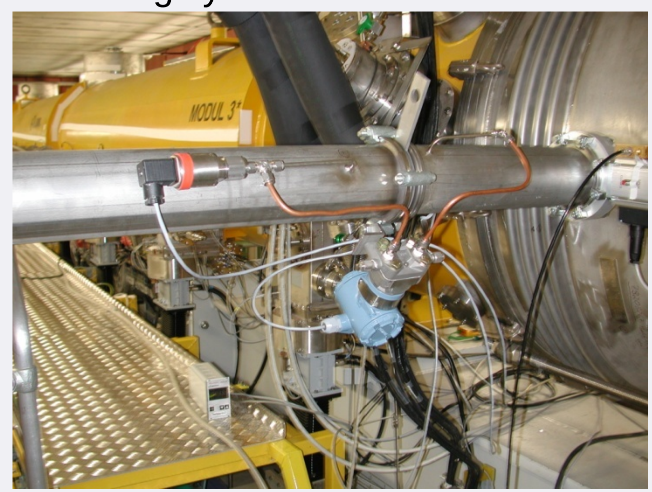
Venting system coupler, cavity and iso-vacuum

Venting system
beam-pipe-vac DN 100

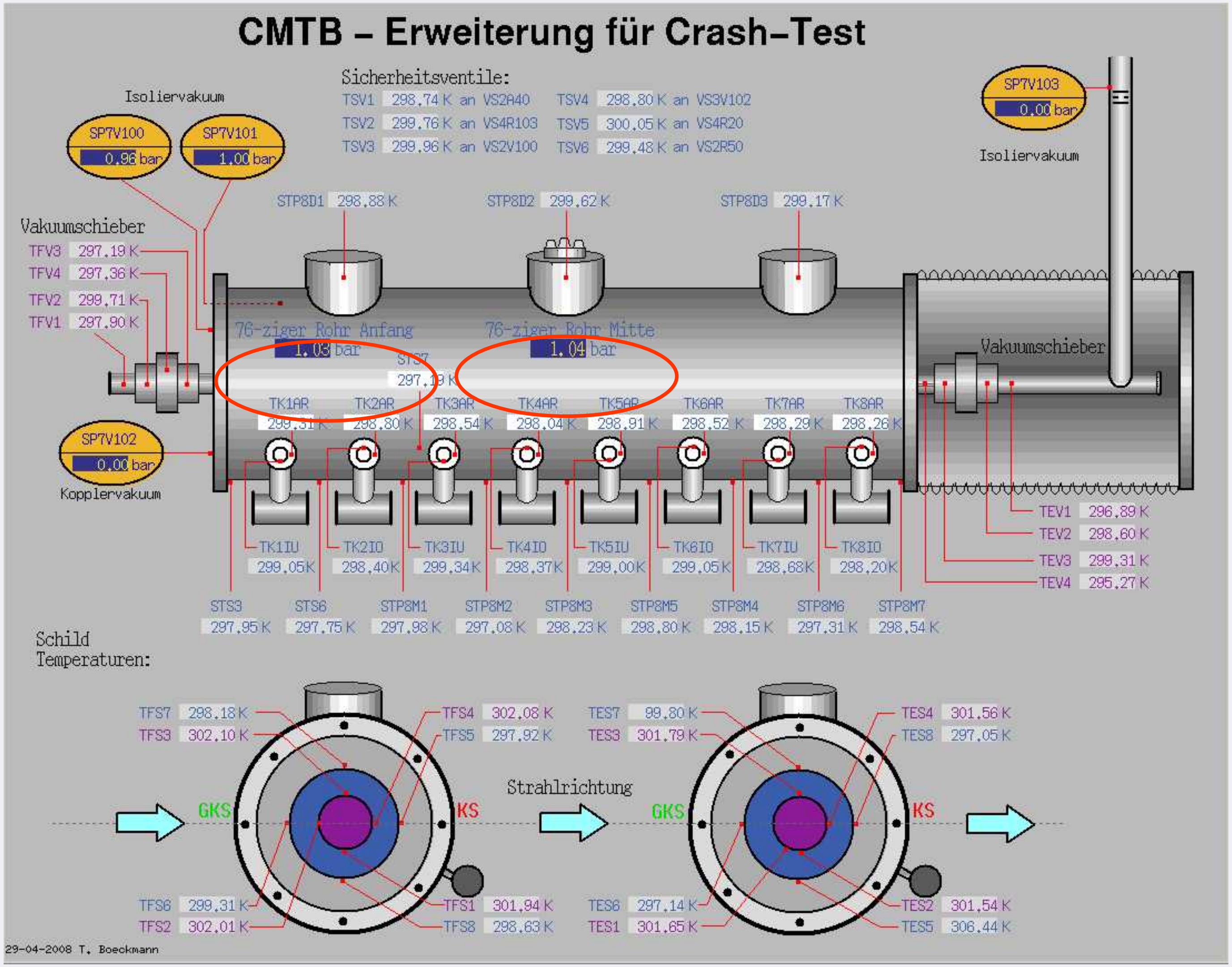


Venting system coupler-vac DN 100

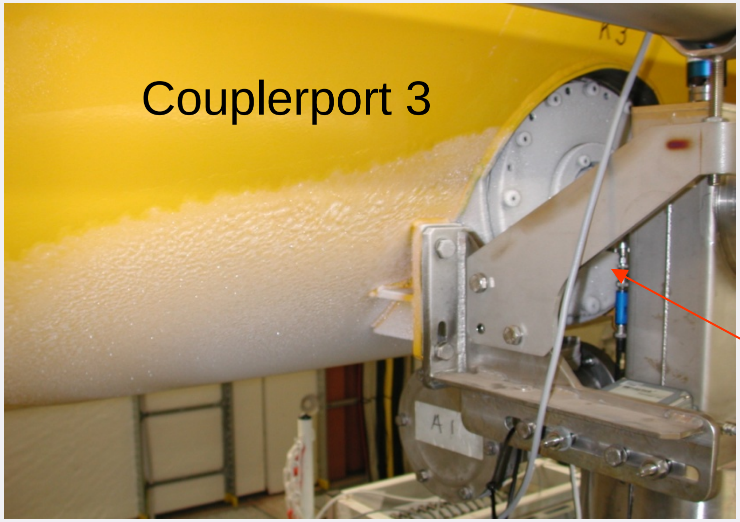
Venting system Iso.-vac DN 100



Additional sensors on M3*

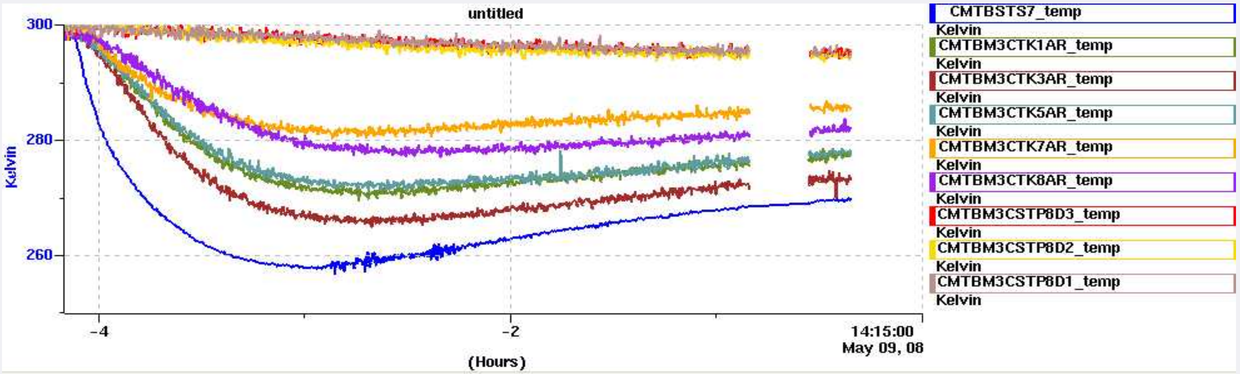


Cold areas after Iso.-Vac venting

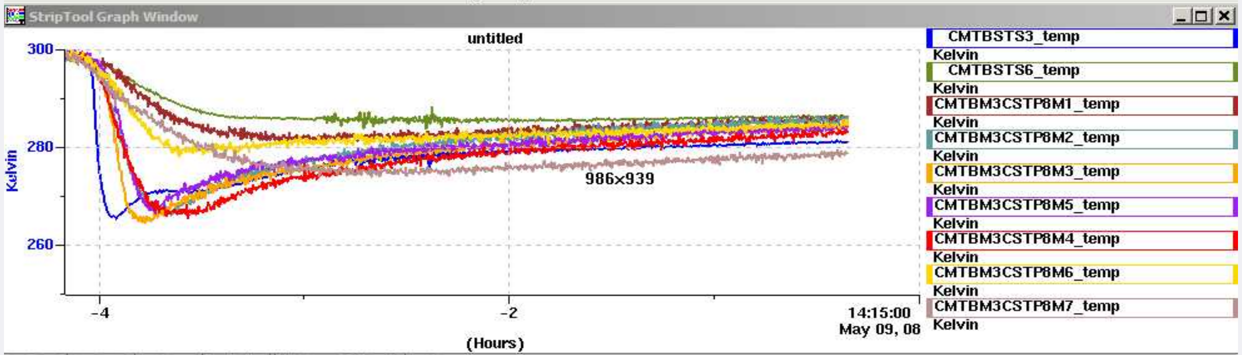


Position of the additional
Temp.-sensors on the coupler flanges

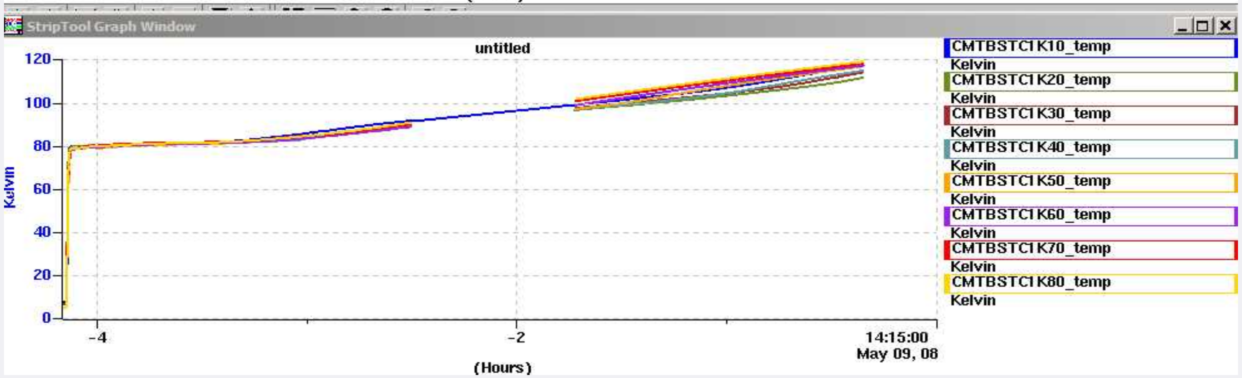
Temperature over 4 hours after Iso.-Vac venting



Temperature
of coupler 1 - 8

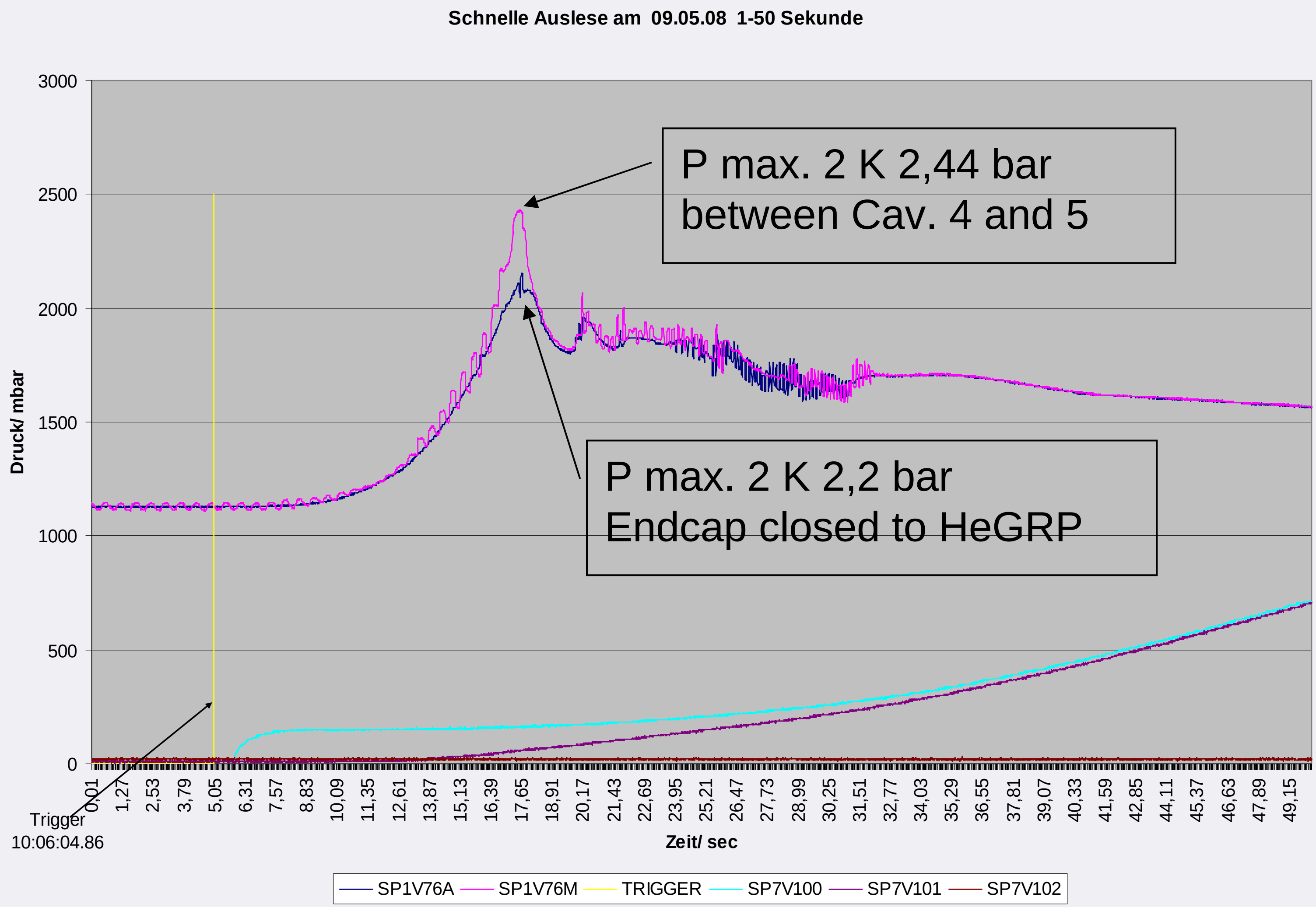


Temperature bottom
of vac.-vessel

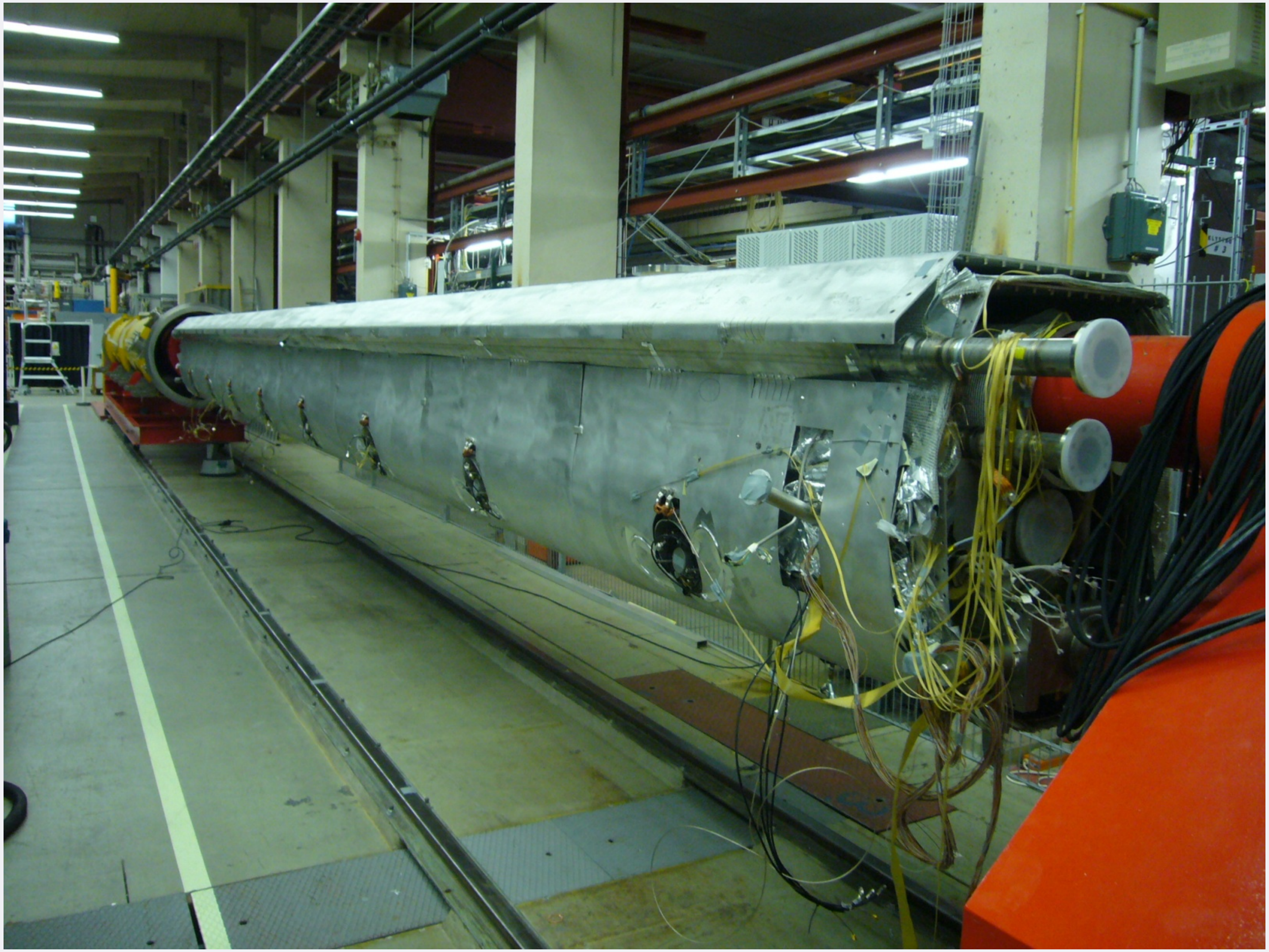


Temperature
of Cav. 1 – Cav. 8

Worst case scenario: Iso.-Vac. venting with air at 4.5K with closed valves



70 K shield during the disassembly



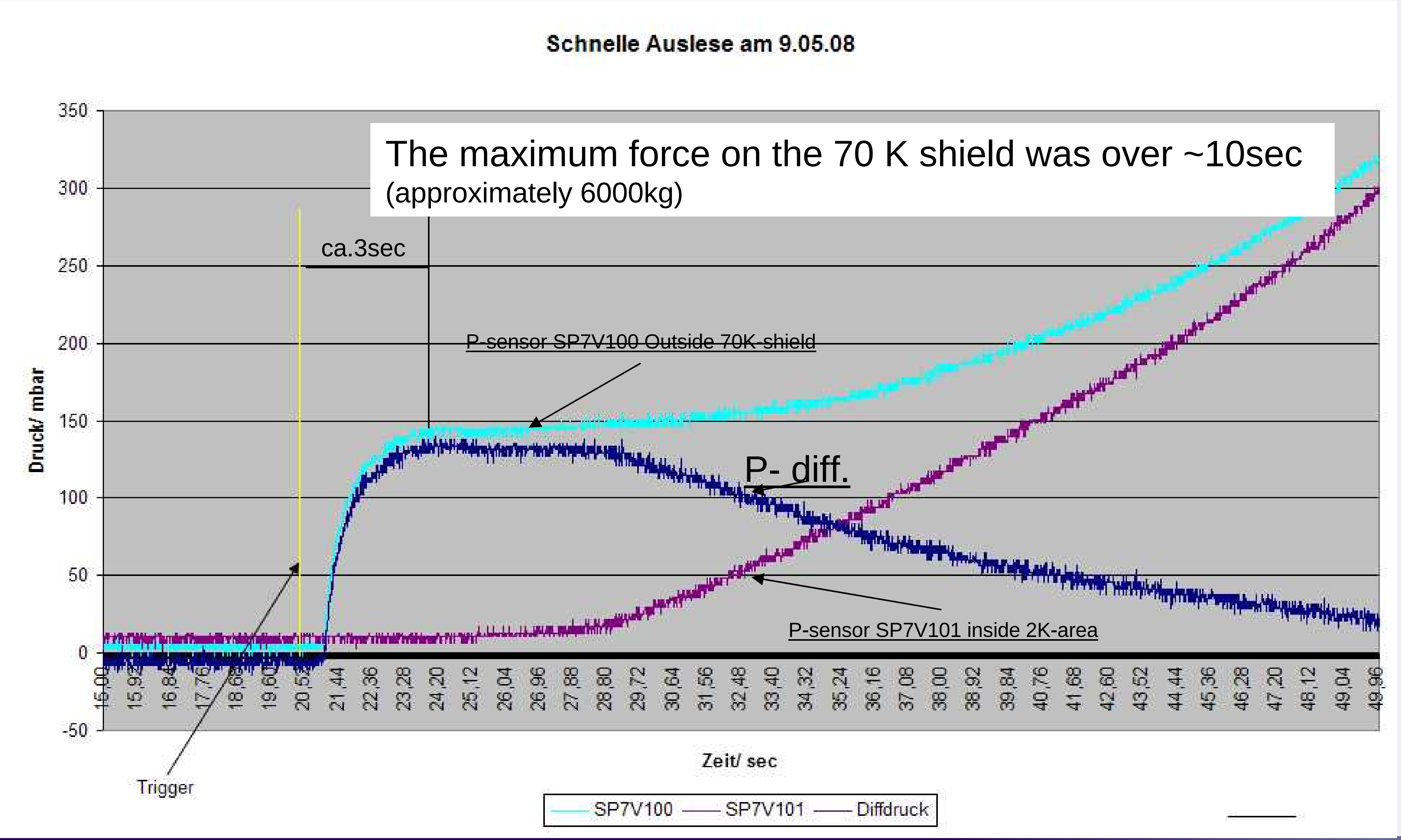
Performance and Damages after Venting Tests

we have lost some of the layers from the insulation in the venting area

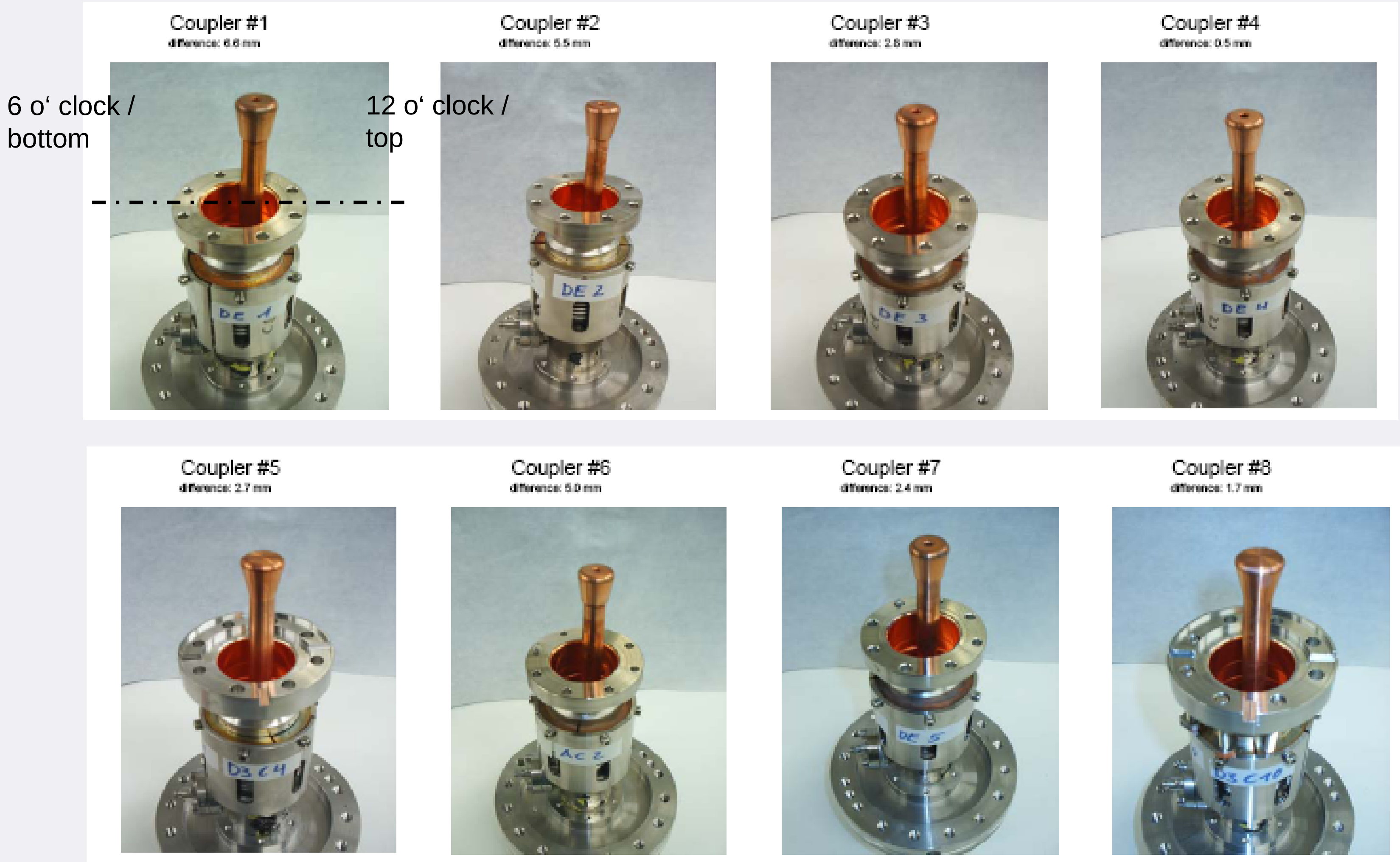
we see a ‘small’ deformation in the 70K shield, the extruded aluminium pipe is bent

- Xray started at ~4-5MV/m up-to 120mGray/min (~11MV/m)
- Missing of some cables with temp.sensors in He-circuit (HeGRP)
- No detuning of the cavity frequency and field flatness
- All tuner drive systems work after all these Iso.-Vac ventings
- ***We see no mechanical defects/effects on the cavities, couplers and the magnet!!!!!!!!!!***

Diff-pressure Vac.-vessel vs. internal shields over 30 s



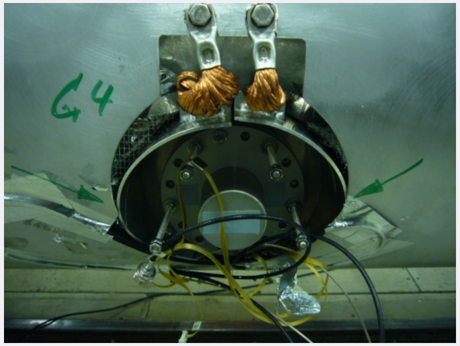
Module 3* cold coupler parts after disassembly

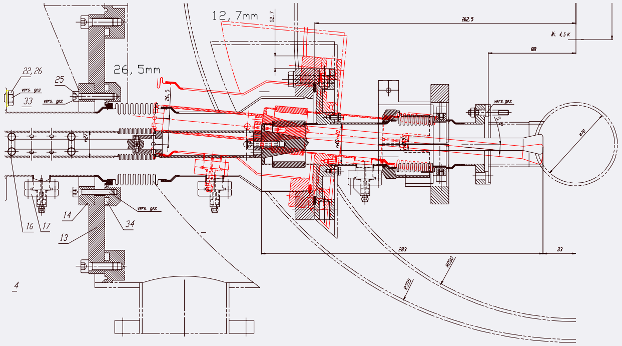


Main coupler antenna: Contact to the cavity surface

- After the dismounting of the couplers' cold part the antennas were bent and copper traces were visible at 6 o'clock on the inner surface of all cavities. **Why?**
- The reason for the copper on cavity 1 was clear - during the module assembly in 2003 the antenna had contact to the cavity – because of an alignment failure of the cold mass in the vacuum vessel
- For all other seven cavities the situation remains unclear.
- The first idea that the coupler was displaced by the deformed 70 K shield was not confirmed – because:
  - During the disassembly of M3* the 70K shield was still in the displaced position
  - The dismounting of the warm coupler part from the cold part was without stress
  - The coupler bellows were not deformed
  - During assembly and disassembly special mounting tools are used which require a pretty precise alignment; there is no hint towards a strong bending of the

Detailed simulations could not explain the bending

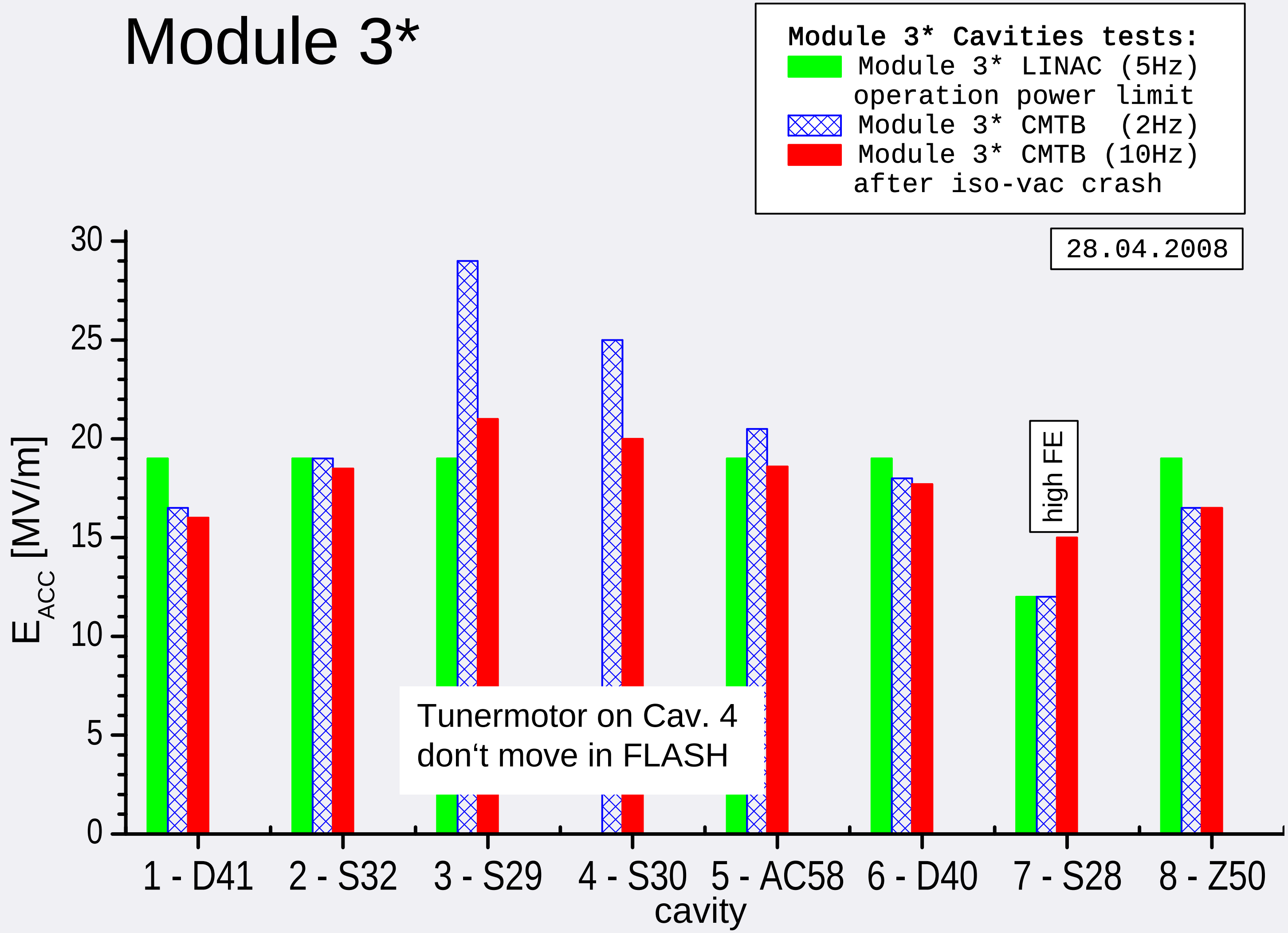




Conclusions

- The calculated values of pressure drops in the He-circuits during venting the beam pipe and insulation vacuum are confirmed
- The cavities' frequency and field flatness was unchanged
- A venting of the beam pipe seems to be "relaxed" because the blast wave needs 3.6 sec over one single accelerator module, i.e. there is sufficient time to close gate valves
- After a venting of the insulation vacuum followed by pump down (no warm-up) the module was operated under 'normal' conditions (rf and cryo-wise)
- The frequency tuners' drive system still works
- The venting of an XFEL unit's (12 modules) insulation vacuum is much more relaxed as compared to the CMTB test because the volume is factor ~12 larger, i.e. the pressure blast less critical
- The deformation of the XFEL module's 70K shield is more relaxed because the expanse of the thermal shield is smaller then for the tested Type II module
- *The contact of the coupler antennas is **not understood** !!???!!!??!!!!*

Last but not least: module 3* performance after Iso.-Vac venting



Many colleagues were involved in the preparation and execution of this fascinating experiment. Thank you!

The experts are ….

Kay Jensch

Rolf Lange

Wolfgang Maschmann

and many others ….

The today's speaker is just the bearer of the message!