XFEL Accelerator Modules: Crash Test

L. Lilje

ILC Main Linac SCRF Meeting
FNAL
22.4.2008

Disclaimer

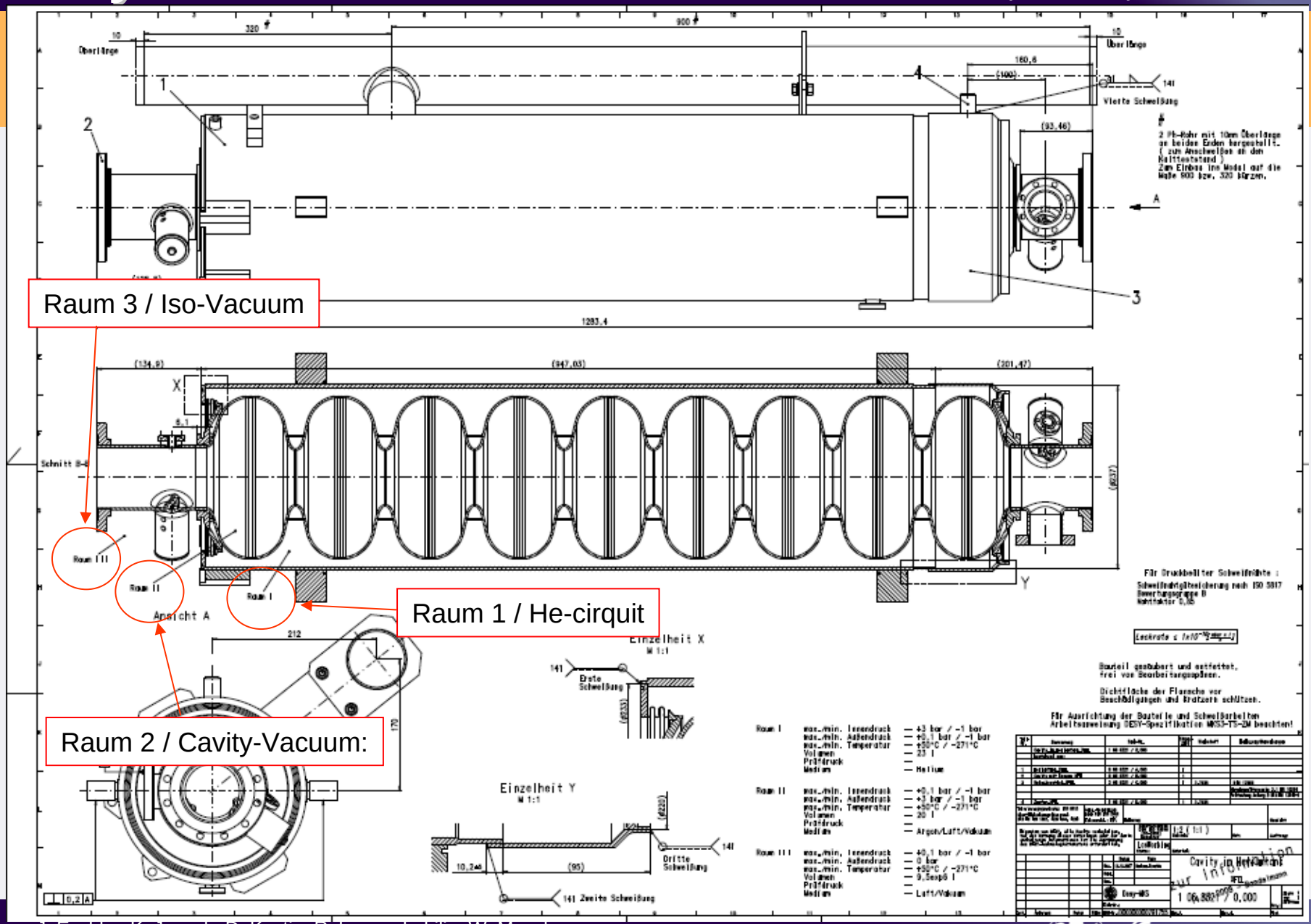
- Data was provided by
  - W. Maschmann, J. Eschke, R. Lange, K. Jensch, D. Kostin, L. Lilje
- Additional data from Chechia C26 pressure test by
  - C. Albrecht and A. Labanc
- This is very preliminary!
  - E.g. some calibrations are under review

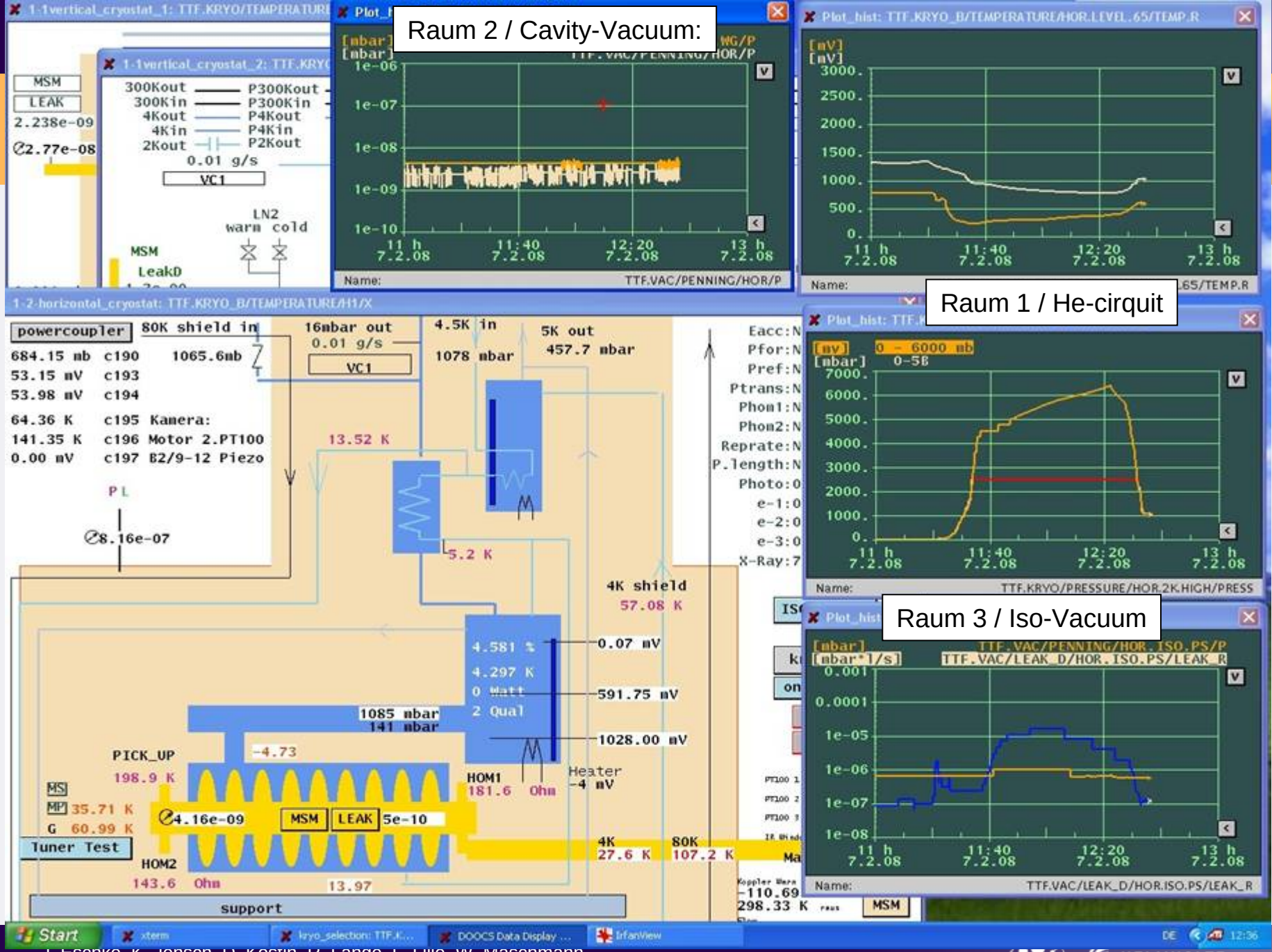
Motivation for the Module Crash Test

- Test has to fulfill several objectives
- Main Objectives
  - Demonstrate compliance with high pressure vessel codes
    - » In other words: Demonstrate that - even in case of a major problem (e.g. accident) occurs - the problem remains contained to the cryostat
  - Crosscheck of numerical calculations for heat influx, pressure drops etc.
  - Demonstrate that selected safety measures are effective
    - » E.g. safety valves positioned correctly, relief valve pressure limits correct etc.
- Additional Objectives
  - Crosscheck interlock philosophy
  - Understand which parts of the module would really need to be replaced (cavities, couplers, motors, piezos etc.)
  - Improve understanding of interplay of the various components
  - Develop simple series pressure tests
- Pre-test of individual cavity in CHECHIA
  - Pressure in cold conditions
  - Coupler venting

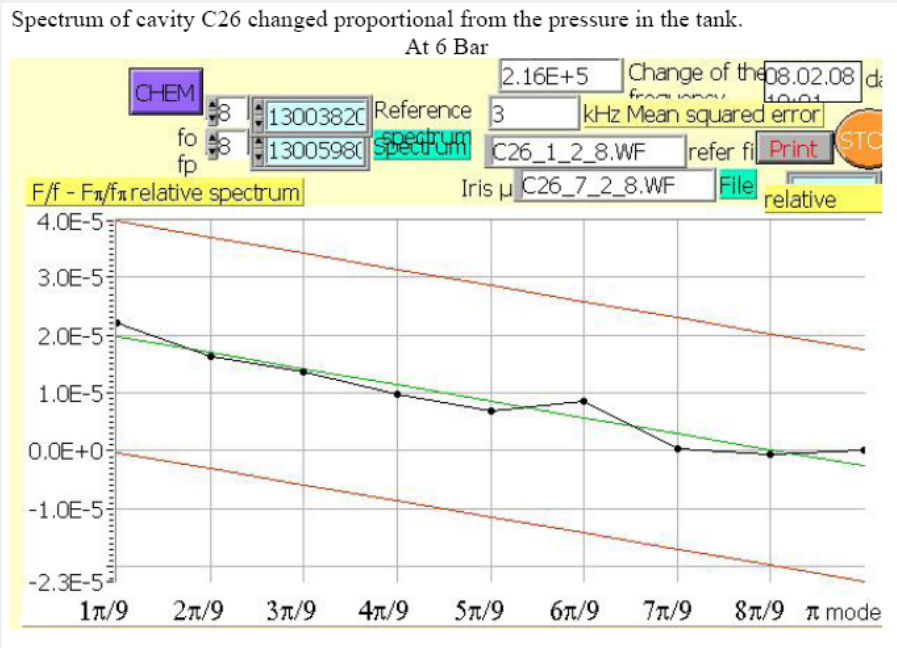
Cavity with He-Vessel – XFEL version

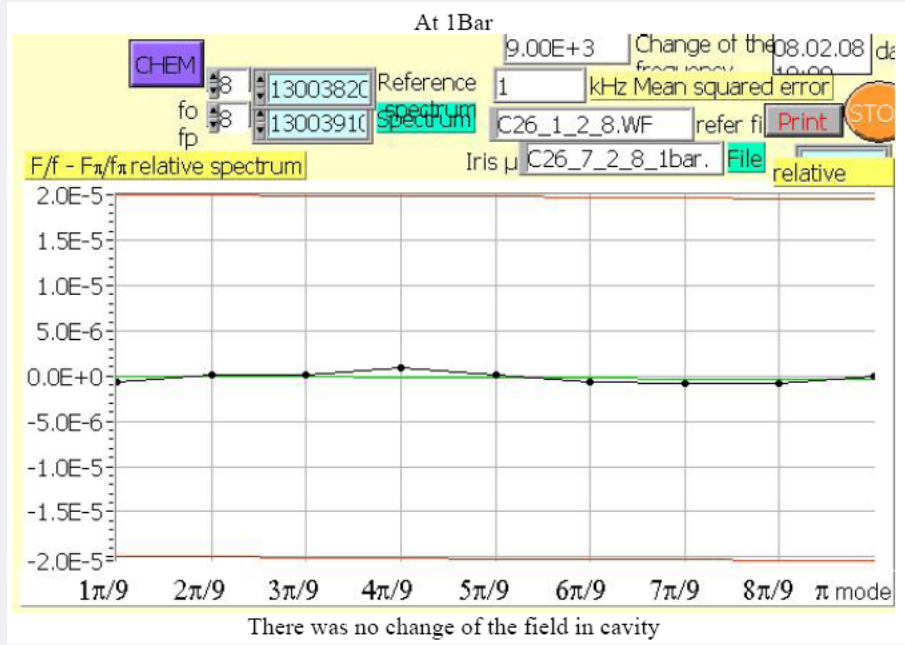
The European X-Ray Laser Project XFEL X-Ray Free-Electron Laser




Raum 2 / Cavity-Vacuum:
Raum 1 / He-cirquit
Raum 3 / Iso-Vacuum
1-1vertical_cryostat_1: TTF.KRYO/TEMPERATURE
1-1vertical_cryostat_2: TTF.KRYO
MSM
LEAK
2.238e-09
2.77e-08
300Kout
300Kin
4Kout
4Kin
2Kout
P300Kout
P300Kin
P4Kout
P4Kin
P2Kout
0.01 g/s
VC1
LN2
warm cold
MSM
LeakD
Plot_hist: TTF.VAC/PENNING/HOR/P
[mbar]
1e-06
1e-07
1e-08
1e-09
1e-10
11 h 7.2.08
11:40 7.2.08
12:20 7.2.08
13 h 7.2.08
Name: TTF.VAC/PENNING/HOR/P
Plot_hist: TTF.KRYO_B/TEMPERATURE/HOR.LEVEL.65/TEMP.R
[mV]
3000.
2500.
2000.
1500.
1000.
500.
0.
Name: TTF.KRYO_B/TEMPERATURE/HOR.LEVEL.65/TEMP.R
1-2-horizontal_cryostat: TTF.KRYO_B/TEMPERATURE/H1/X
powercoupler
80K shield in
684.15 mb c190 1065.6mb
53.15 mV c193
53.98 mV c194
64.36 K c195 Kamera:
141.35 K c196 Motor 2.PT100
0.00 mV c197 B2/9-12 Piezo
16mbar out
0.01 g/s
VC1
4.5K in
1078 mbar
5K out
457.7 mbar
13.52 K
5.2 K
8.16e-07
4K shield
57.08 K
4.581 %
4.297 K
0 Watt
2 Qual
0.07 mV
591.75 mV
1028.00 mV
1085 mbar
141 mbar
PICK_UP
198.9 K
-4.73
HOM1
181.6 Ohm
Heater
-4 mV
MS
MP 35.71 K
G 60.99 K
4.16e-09
MSM
LEAK
5e-10
Tuner Test
HOM2
143.6 Ohm
13.97
4K
27.6 K
80K
107.2 K
support
Eacc:N
Pfor:N
Pref:N
Ptrans:N
Phom1:N
Phom2:N
Reprate:N
P.length:N
Photo:0
e-1:0
e-2:0
e-3:0
X-Ray:7
Plot_hist: TTF.
[mV]
[mbar]
0 - 6000 mb
0-58
7000.
6000.
5000.
4000.
3000.
2000.
1000.
0.
Name: TTF.KRYO/PRESSURE/HOR.2K.HIGH/PRESS
Plot_hist
[mbar]
[mbar*l/s]
TTF.VAC/PENNING/HOR.ISO.PS/P
TTF.VAC/LEAK_D/HOR.ISO.PS/LEAK_R
0.001
0.0001
1e-05
1e-06
1e-07
1e-08
11 h 7.2.08
11:40 7.2.08
12:20 7.2.08
13 h 7.2.08
Name: TTF.VAC/LEAK_D/HOR.ISO.PS/LEAK_R
-110.69
298.33 K
MSM
Start
xterm
kryo_selection: TTF.K...
DOOCS Data Display ...
IrfanView
DE
12:36

Cavity Spectrum under Overpressure – 2K

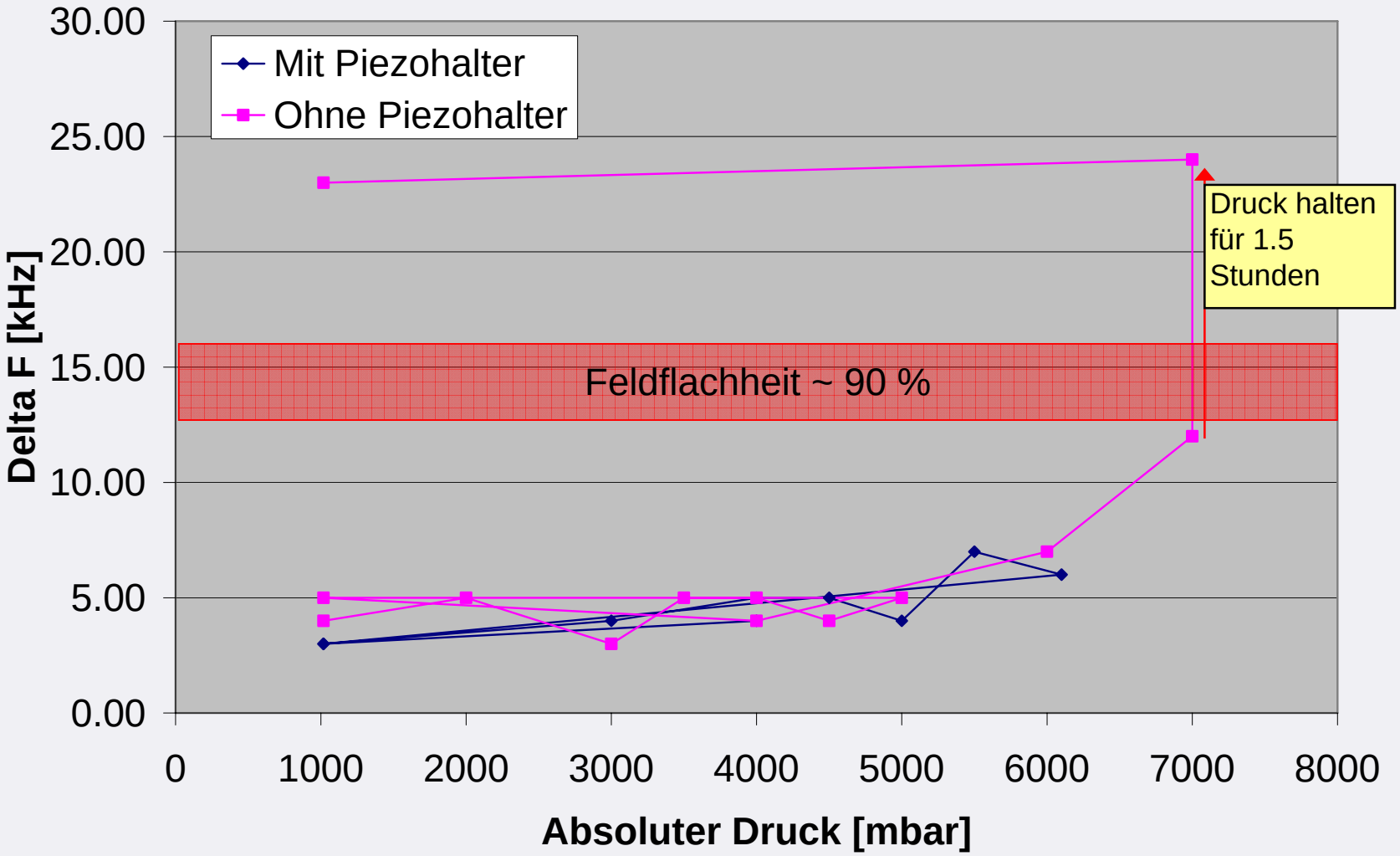




6bar at 2K

Return to 1bar at 2K

Change in the Frequency under Overpressure – 300 K



Preliminary Assumptions for Pressure Tests

4 x 1,43 = 5,72 bar (5,8)

Draft Version

Prüflaboratorium für Druckgeräte
Prüfbericht zur Entwurfsprüfung
von Druckgeräten / Druckgeräteteilen

TÜV NORD

Prüflabor Hamburg

Auftrags-Nr.: 8103790683	Prüfbericht-Nr.: STK1P0971702	
HERSTELLER / INVERKEHRBRINGER	**EINSTUFUNG**	
Deutsches Elektronen-Synchrotron	Prüfgrundlage	97/23/EG (PED, DGRL)
Notkestr. 85	Regelwerk	EN 13445
22607 Hamburg	Kategorie IV Modul	B, Diagramm 2
Tel.: ++49(0)40/8998-0, Fax: -3282	Art des Druckgerätes	unbefeuertes Druckgerät

TECHNISCHE DATEN

Prüfgegenstand: XFEL-Cavities mit Helium-Tank			Herstell-Nr. unbekannt	
Hauptzeichnung: 1_06_8316_0_000 v. 08.11.07			Baujahr ab 2008	
Druckraum		**Cavities / He-Tank**	**Raum II**	**Raum III**
Min./max. zulässiger Druck	PS [bar]	-1 / 3,0	0 / 0	0 / 0
Min./max. zul. Temperatur	TS [°C]	-271 / 50	0 / 0	0 / 0
Volumen	V [L]	Unbekannt	0	0
Fluid	-	Helium	-	-
Prüfdruck (erstmalig)	PT [bar]	5,8	0,0	0,0
Medium (Gasdruckprüfung)	-	Luft	-	-
Schweißnahtwertigkeit	%	85	0	0
Fluidgruppe		2	0	0
Korrosionszuschlag	[mm]	0	0	0

ERGEBNIS:

Die Prüfung erfolgte in Übereinstimmung mit den Anforderungen der Richtlinie 97/23/EG und den o.g. Prüfgrundlagen und ergab keine Beanstandungen.

Hinweis Die Prüfergebnisse beziehen sich ausschließlich auf den beschriebenen Prüfgegenstand und nur auf die druckbeanspruchten Bauteile. Eine auszugsweise Vervielfältigung des Prüfberichtes ohne schriftliche Freigabe des Prüflaboratoriums ist nicht zulässig.

Die in der Anlage genannten Prüfvermerke sind zu beachten.

Ort: Hamburg **Datum:** 29.01.2008 **Prüflaboratorium für Druckgeräte der TÜV NORD Systems GmbH & Co. KG**

- Entwurf -

TÜV Nord Systems, STK
Große Bahnstraße 31
D-22525 Hamburg
Tel. +49-(0)40/8557-2870
Fax +49-(0)40/8557 1901 2786
e-mail uklinger@tuev-nord.de

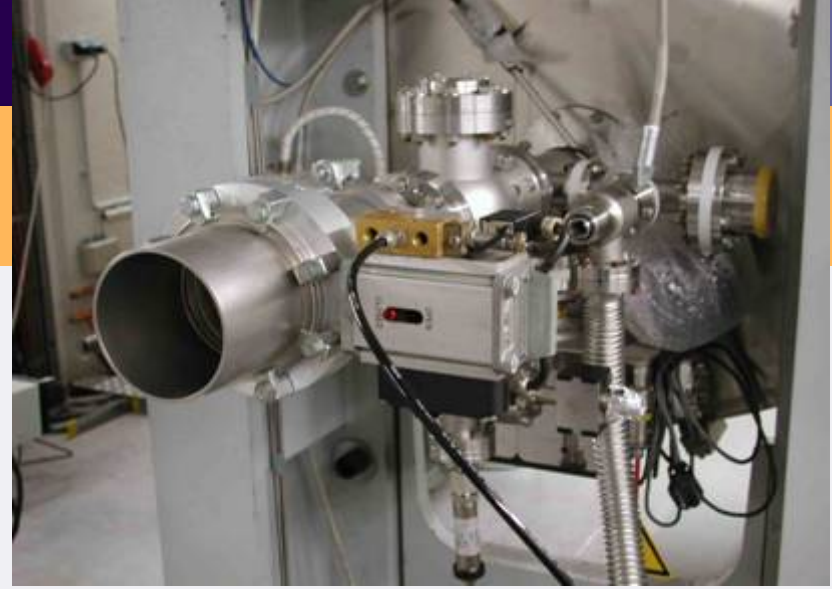
Dipl. Ing. U. Klinger
Benannte Stelle, Kennummer 0045

Proposed Sequence of Venting Tests

(decided meeting 23-April-08 10:00 Jensch, Lange, Maschmann)

Venting	Condition	Cavity	Coupler	Tuner	Cryo	Vacuum	Remark
Iso slow performed	2K, 30 mbar RF Off			Check Piezo	Measure losses	Measure	Helium Rate and Level tbd.
Coupler slow performed	2K, 30 mbar RF Off		Perfomance Reprocessing		Measure losses	Measure	Nitrogen Rate and Level tbd.
Cavity slow performed	2K, 30 mbar RF Off	Performance Detuning Reprocessing			Measure losses	Measure	Nitrogen Rate and Level tbd.
Iso fast cancelled	2K, 30 mbar RF Off	Performance Detuning Reprocessing	Ceramic rupture	Tuner motors	Pressure increases	Measure Leaks	Controlled, Rate tbd, Nitrogen
Iso fast 2 2 times performed	2K, 30 mbar RF Off	Performance Detuning Reprocessing	Ceramic rupture	Tuner motors	Pressure increases	Measure Leaks	Catastrophic, Air
Coupler fast cancelled	2K, 30 mbar RF Off	Performance Detuning Reprocessing	Ceramic rupture		Pressure increases	Measure Leaks	Controlled, Rate tbd, Nitrogen
Cavity fast 1 cancelled	2K, 30 mbar RF Off	Performance Detuning Reprocessing	Ceramic rupture		Pressure increases	Measure Leaks	Controlled, Rate tbd, Nitrogen
Cavity fast 2 Next test In kw 18	2K, 30 mbar RF Off	Performance Detuning Reprocessing	Ceramic rupture		Pressure increases	Measure Leaks	Catastrophic, Air
Cavity fast 3 To be cancelled	2K, 30 mbar RF On	Performance Detuning Reprocessing	Ceramic rupture		Pressure increases	Measure Leaks	Controlled, Rate tbd, Nitrogen
Cavity fast 4 Probably Test in kw 19	4.5K, 1.7 bar, RF Off	Performance Detuning Reprocessing	Ceramic rupture		Pressure increases	Measure Leaks	Nitrogen, Need to block 2 safety valves VD1R130 and VS1R90

Venting systems for Coupler-, Cavity- and Iso-vacuum

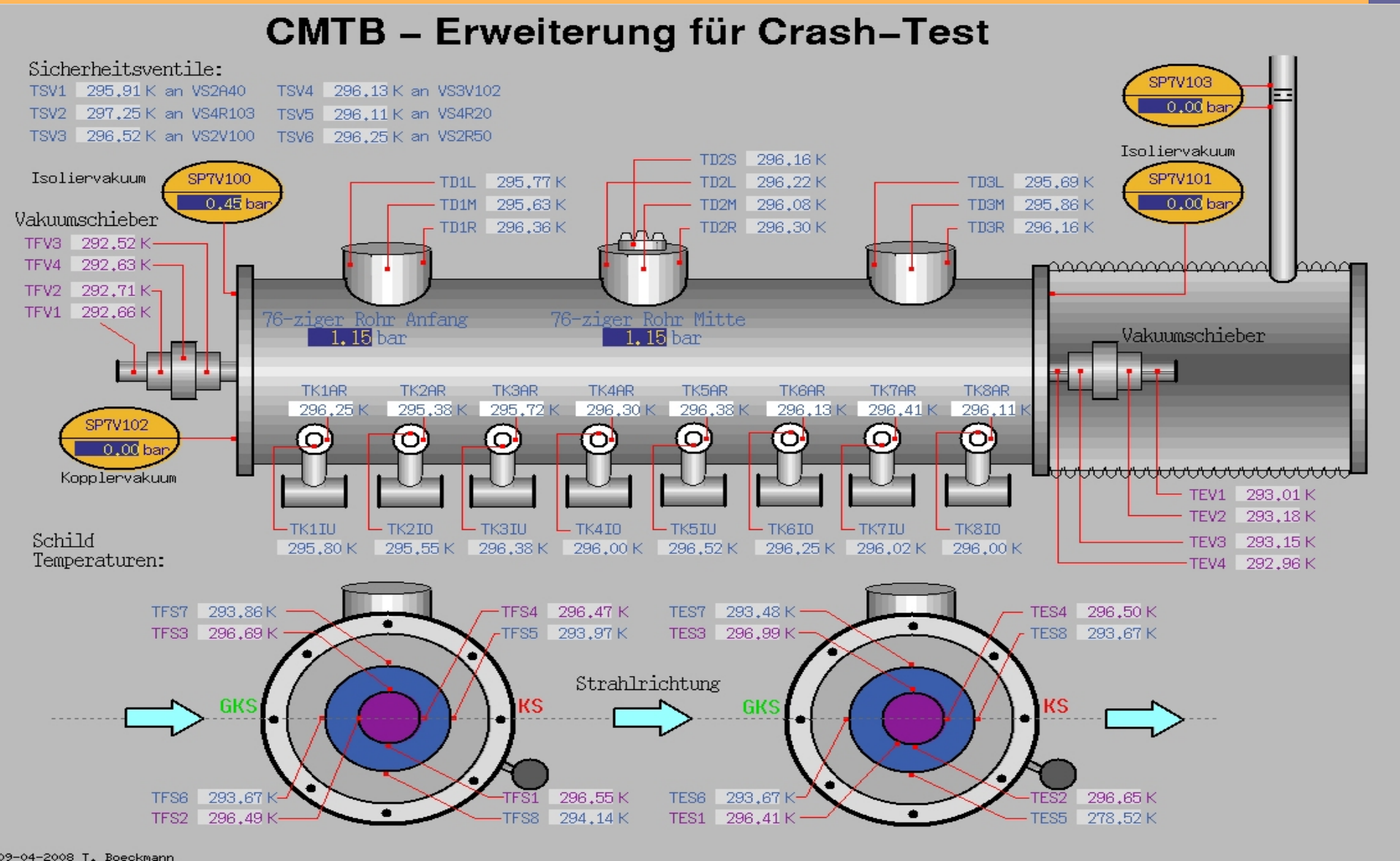


Venting system beam-pipe-vacuum DN 100

Venting system coupler-vacuum DN 100

Venting system isovacuum DN 100

Additional Sensors for Crash Test



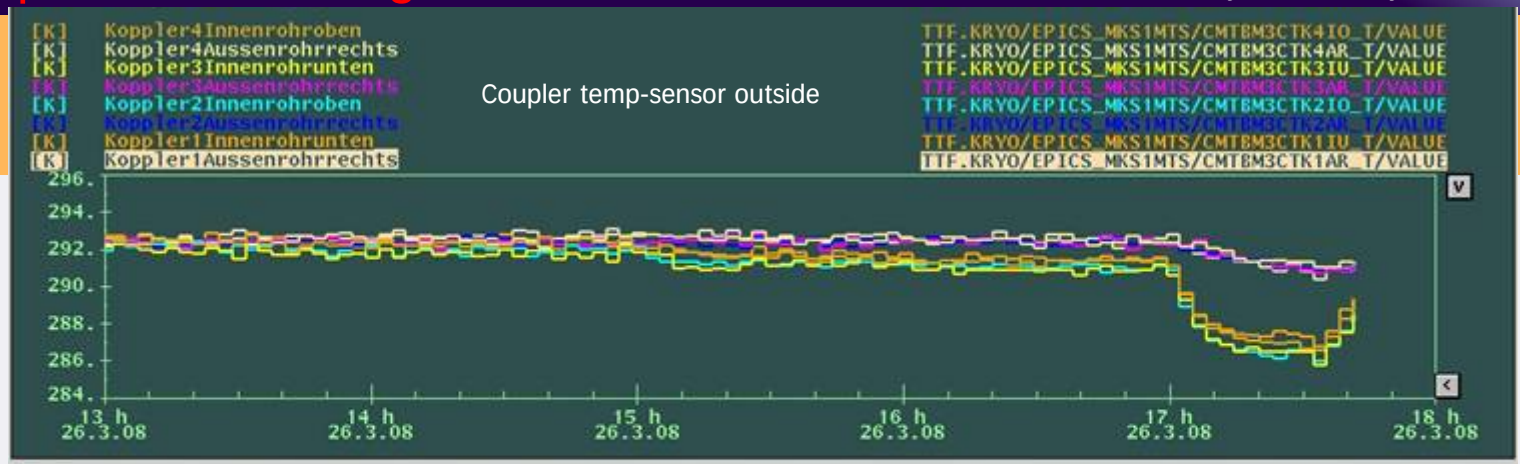
09-04-2008 T. Boeckmann

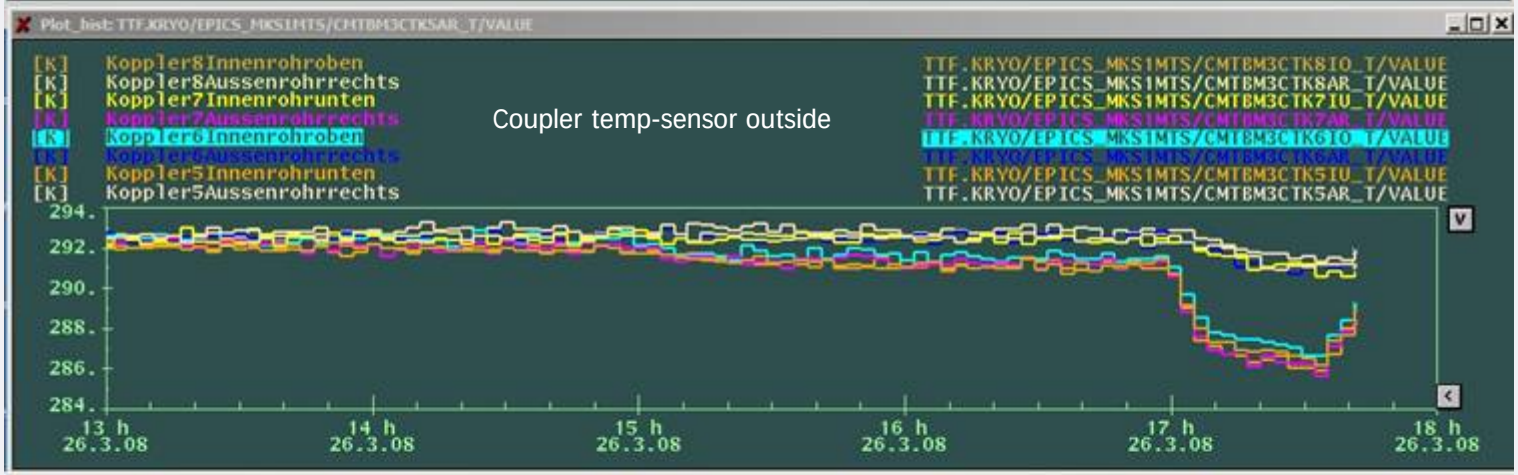
Slow Isolation Vacuum Venting with Helium

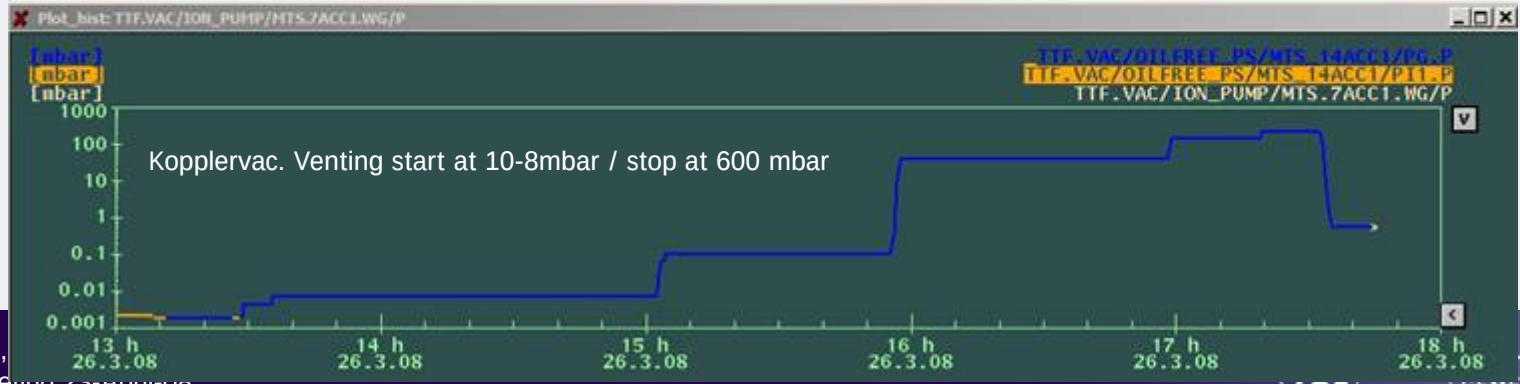
	TTF 2003 Iso 1*10-6	03.2008 Iso 3*10-5	03.2008 Iso 7*10-5	03.2008 Iso 2*10-4
4,3 K circuit	14 W	14,43 W	22,7 W	58 W
2 K circuit	< 3,5 W	3,3 W	3,84 W	12,47 W
40/80 K circuit	75 W	125,6 W (endcaps!)	112 W (endcaps!)	43,3 W

Preliminary!

Koppler slow-venting with N2 at 2 K







Cryo-losses : isolation-vac.: 6 – 7 * 10-5 mbar / coupler-vac. vented!

	Design TDR	Couplervac. 10-8 mbar	Couplervac. 10-1 mbar
4,3 K circuit	**21 W**	**22,70 W**	**23,77 W**
2 K circuit	**4,2 W**	**3,84 W**	**4,07 W**
40/80 K circuit	**115 W**	**112 W ! Flow 12,20 g/sec**	**108,66W! Flow 11,56 g/sec**

Preliminary!

Slow venting beampipe-vac.at 2 K operation

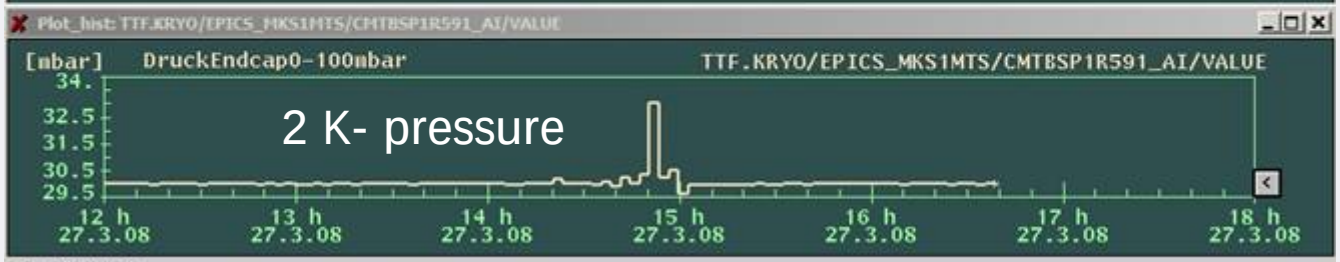
- First step venting ca. 500 l with N2 (27.03)
- Overnight-break:
  - measure kryo-losses
- Second step venting ca. 1600 l with N2 (28.03)
- Warm up complete modul
- Check of safety valves beampipe

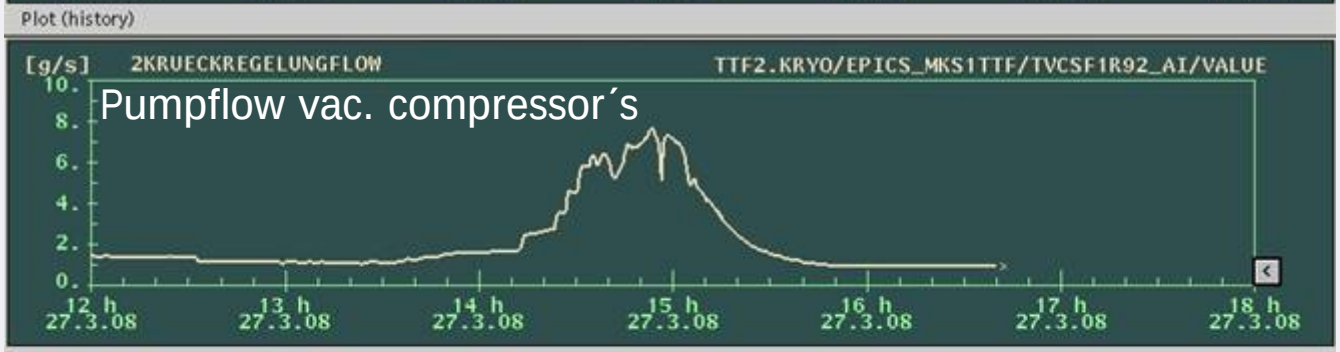
Slow venting beampipevac. with N2

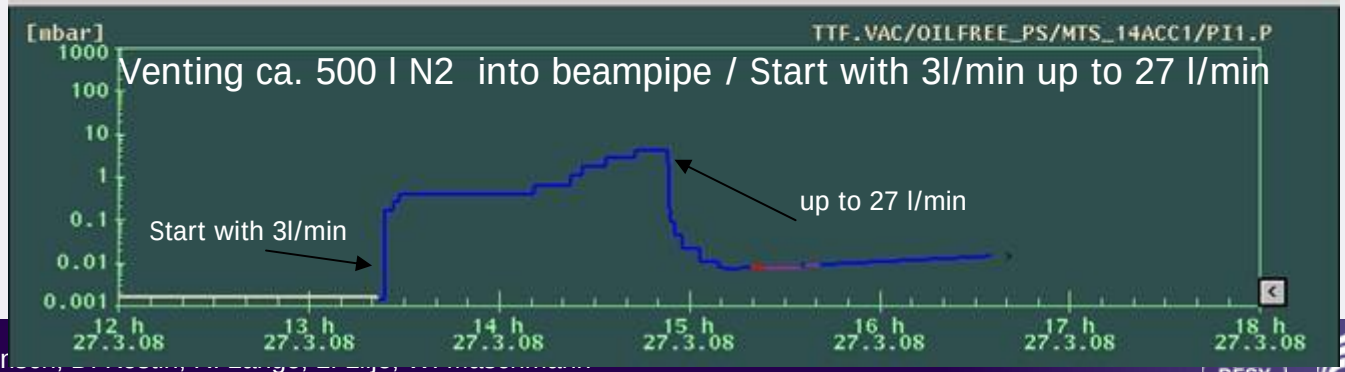
Steps	Pressure Beampipe Feedcap	He-Flow Vacuum-compressor	2K pressurse
Venting beampipe with ca. 500 l N2	**5,5*10-7 mbar**	**Exept to 8 g/sec**	**max. 32,5 mbar**
Overnight – break	**5,5*10-7 mbar**	**Normal 1,15-1,2g/sec**	**30 mbar**
Venting beampipe with ca. 1600 l N2	**5,5*10-7 mbar**	**Exept to 12/sec**	**max. 40 mbar**

Preliminary!

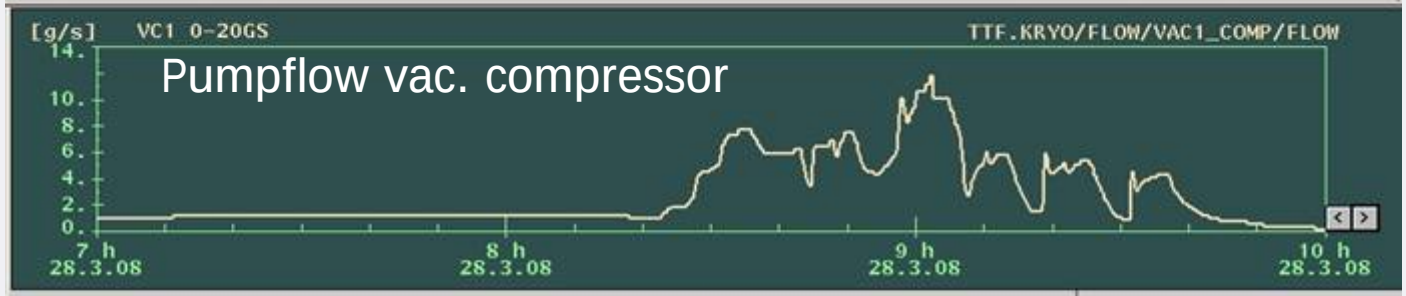
First slow venting beampipe 27.03.2008

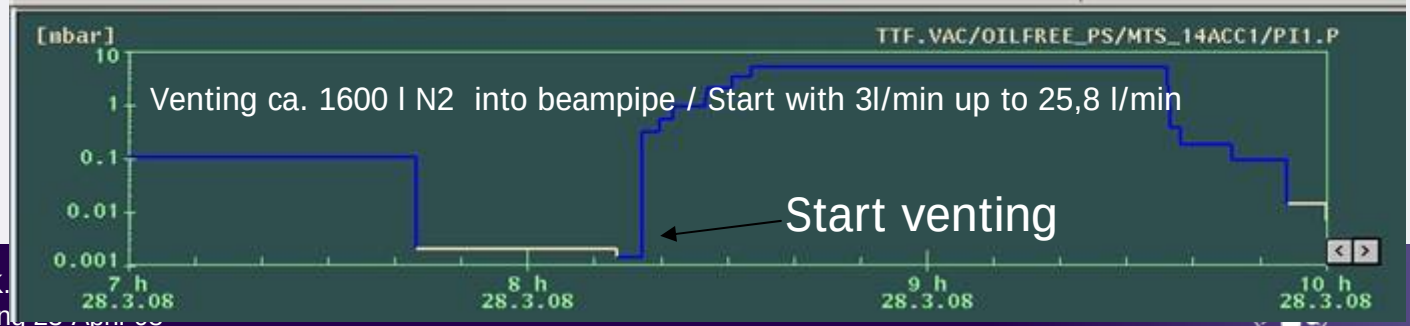






Second slow venting beampipe 28.03.2008

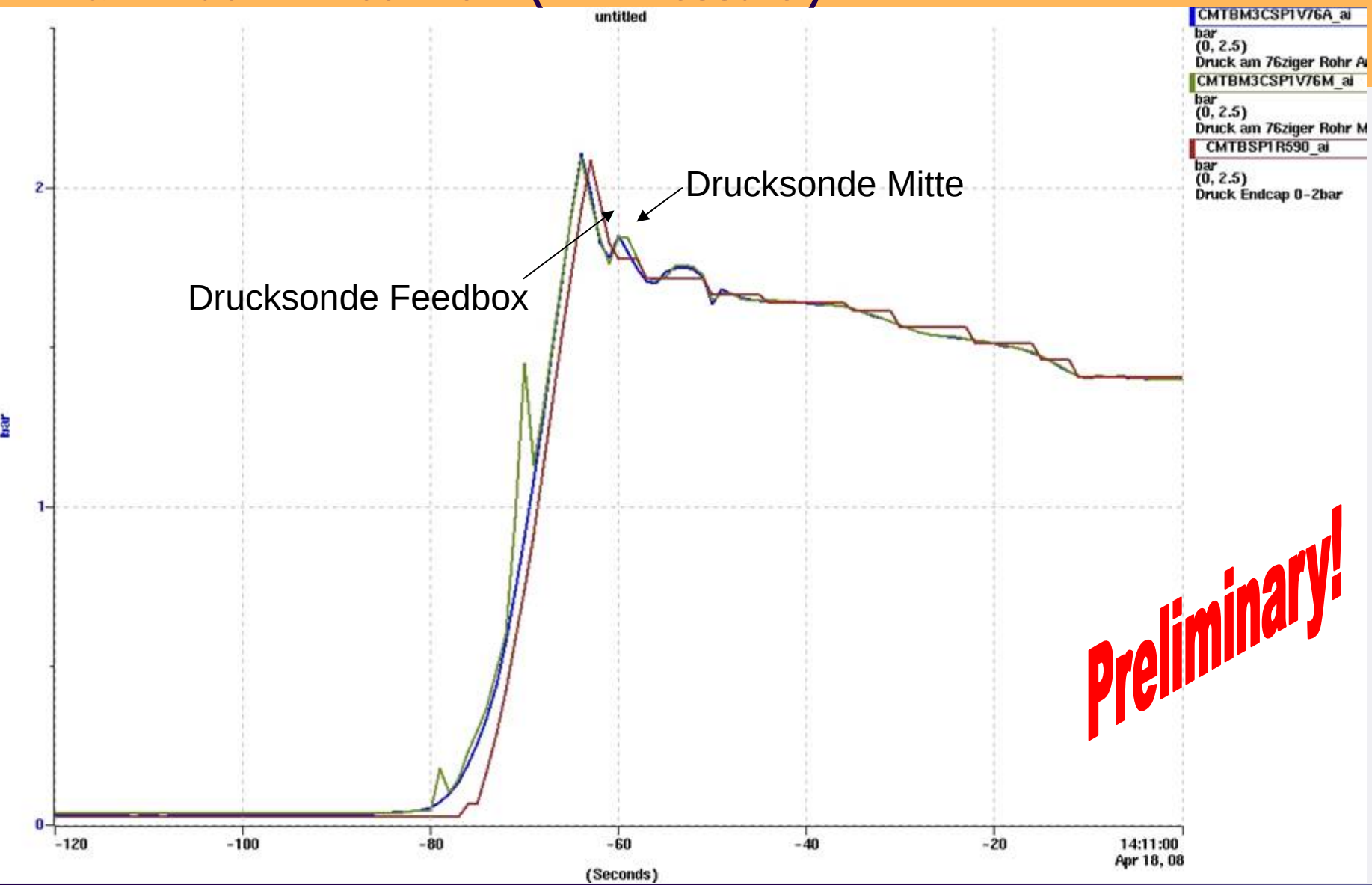




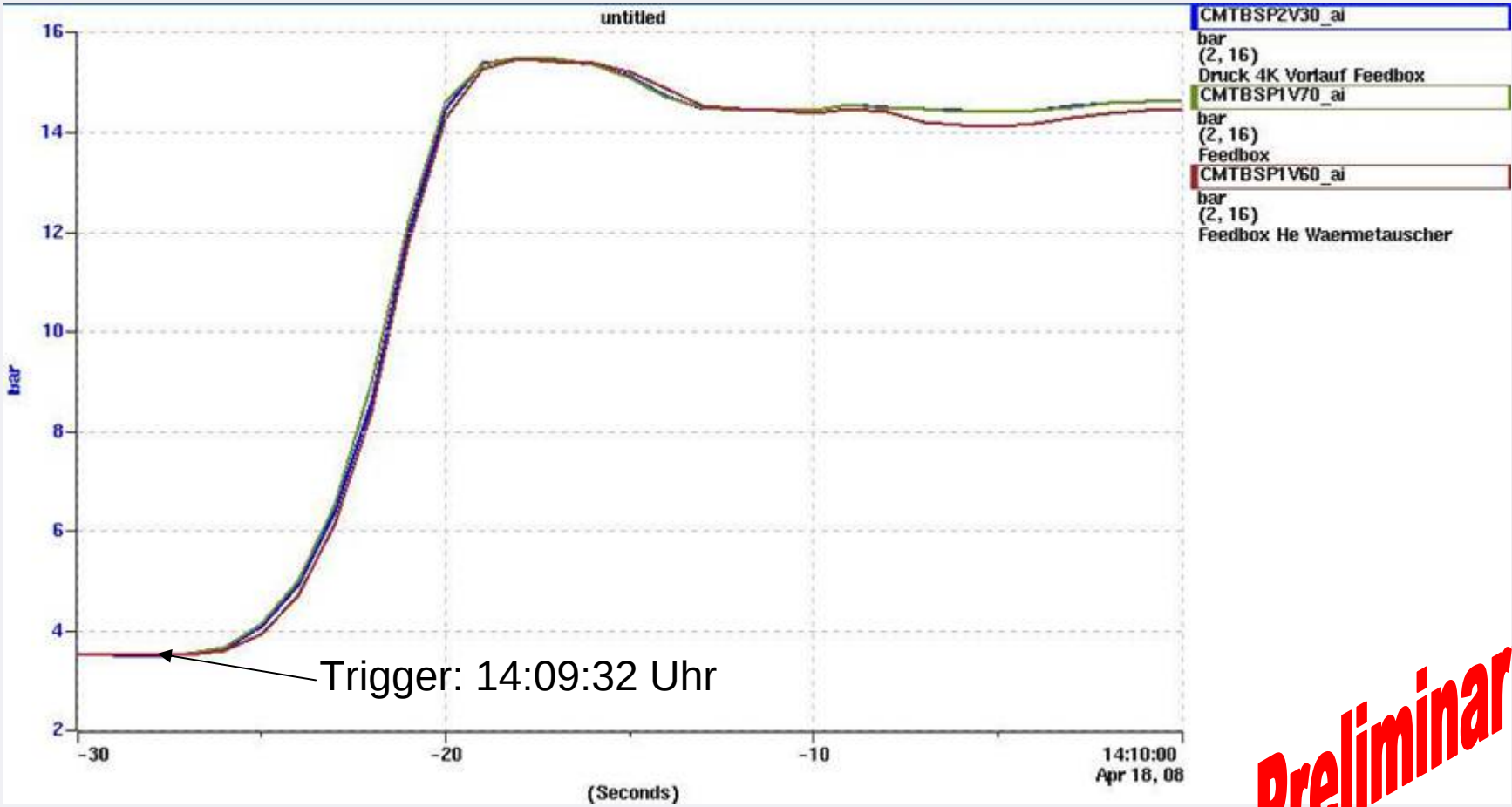
Fast Venting Procedure: Isolation-Vacuum

- First venting test 18.4.2008 14:09
  - This was really loud...
  - Valve open for approximately 3 minutes
  - pump on iso-vac after roughly 30 minutes
- Stable 2 K operation after a few hours in the evening
- Weekend
- RF operation on monday morning
  - RF performance did not change
- Second venting test 21.4.2008 15:07:31
  - Valve open for approximately 3 minutes
  - no pumping of isolation vacuum
- Warmup
- Repair
  - Small Leaks
    - 2K to Iso: existed before crash, replace Indium on 300 mm pipe
  - get temperature readout on 300 mm pipe operational

Max. Druck im 76ér Rohr (2 K Pressure)

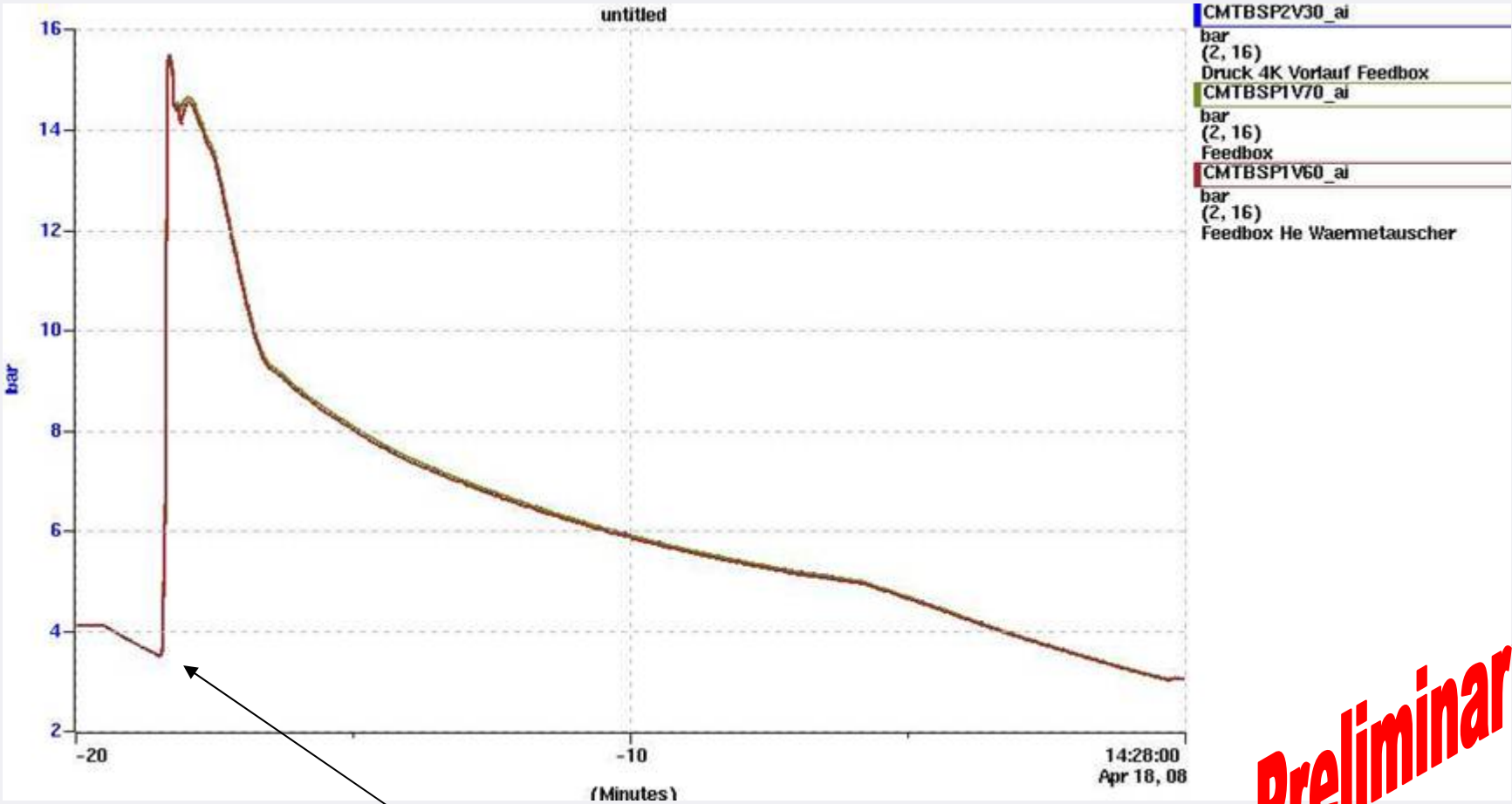


Max. Pressure in 4 K - System



Preliminary!

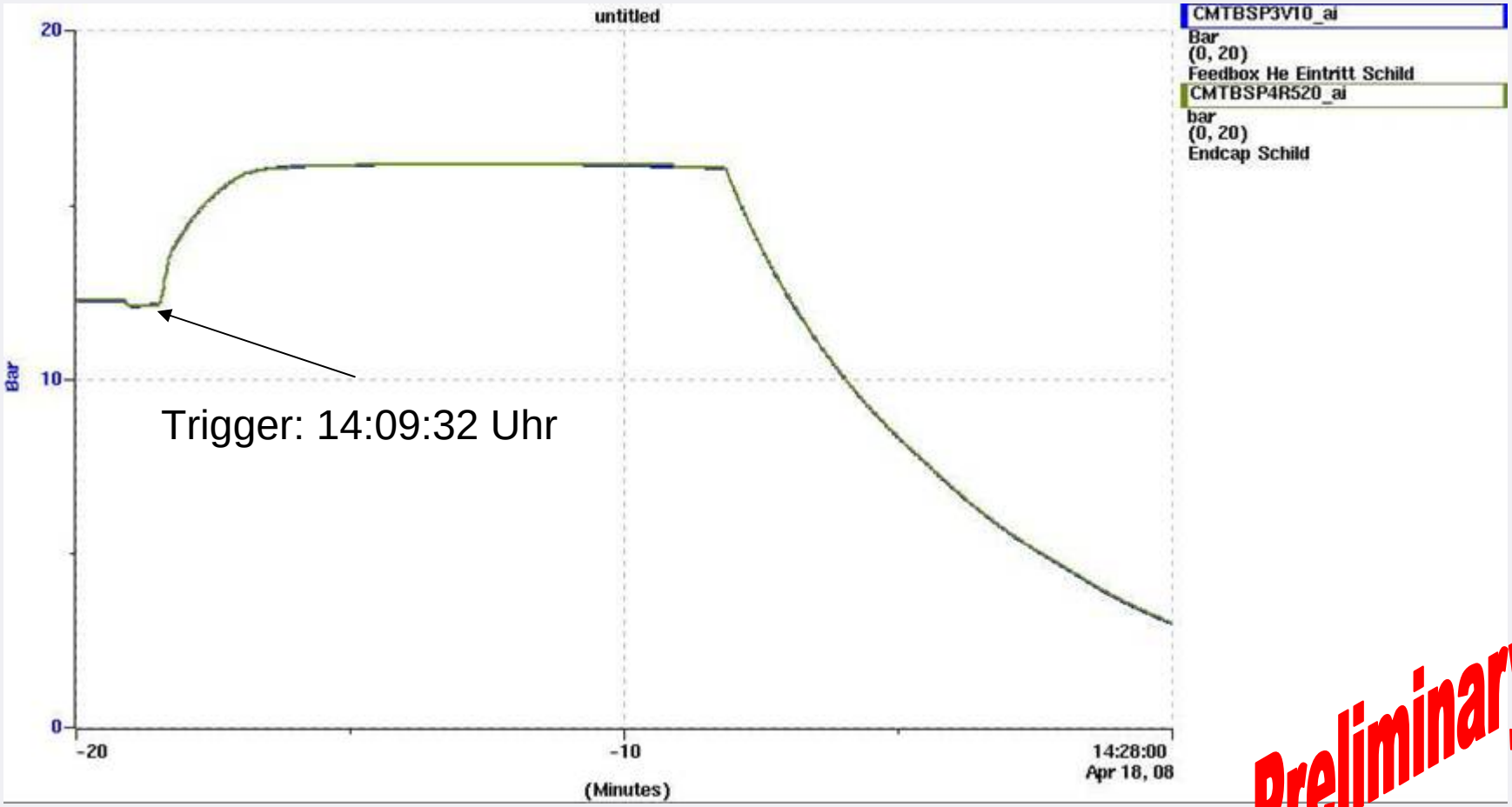
Max. Pressure in 4 K - System



Trigger: 14:09:32 Uhr

Preliminary!

Max. Pressure im 70 K - System



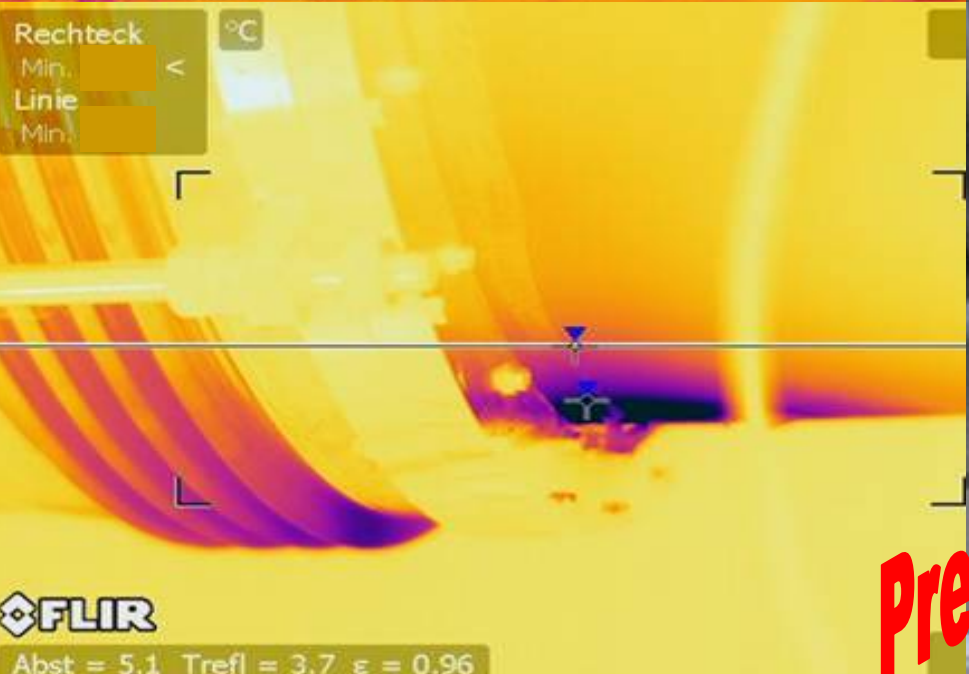
Preliminary!

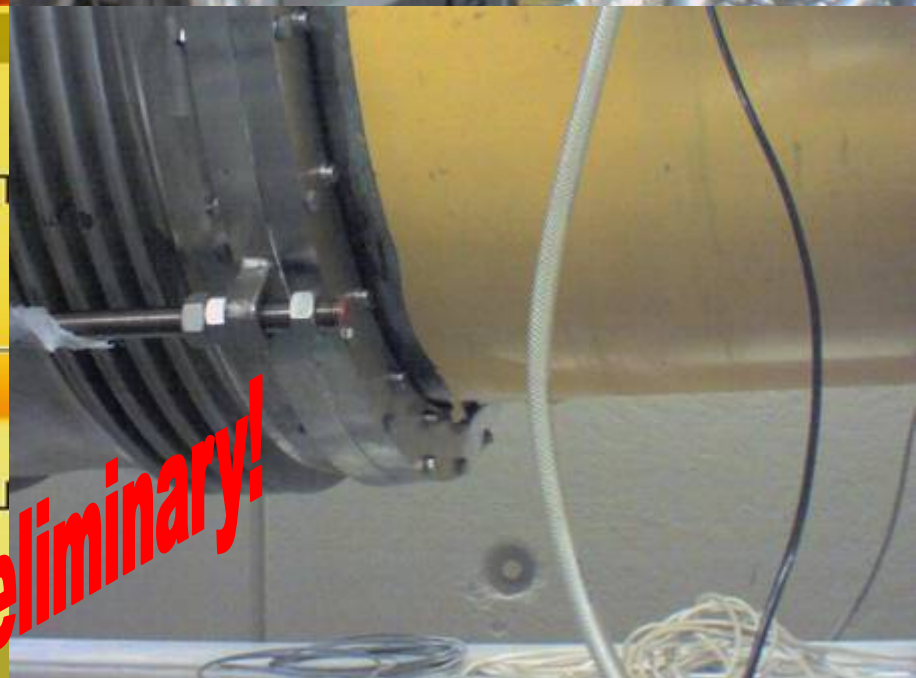
Isovacuum and Beampipevacuum

Preliminary!

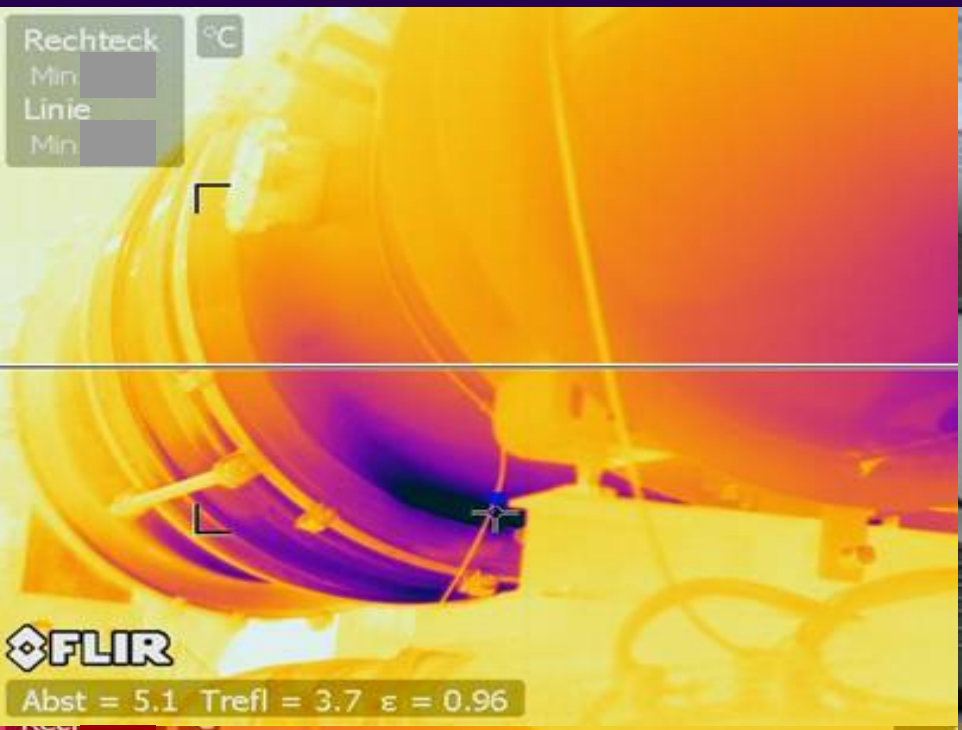
Coupler Temperature Development

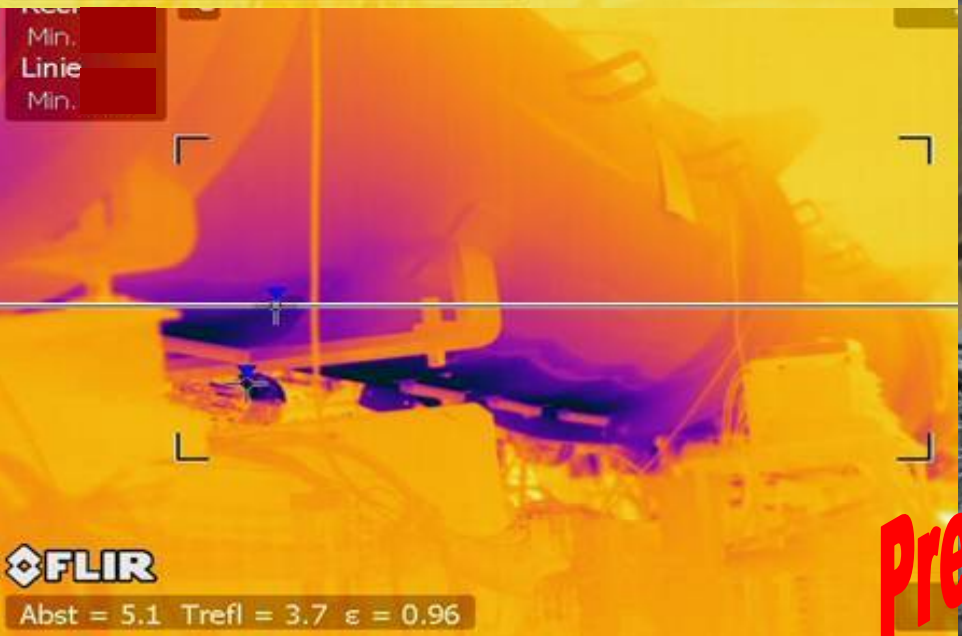
Preliminary!





Preliminary!





Preliminary!

Damages, Problems and Operation

- Damages
  - Isolation Vacuum - No damages detected
  - Coupler vacuum - No damages detected
  - Beam pipe - Small Leak to Isolation vacuum developped
  - Temparature measurements - Did not work on 300 mm pipe
  - Safety system behaved as expected
    - Leakage at emergency vent into he return line ‘Saugkreis‘
    - Burst disc - as expected it did what should have done...
- Problems
  - DAQ system problems
    - Temperature readout on first test
    - Fast archiver on second test
- Module could be operated!
  - RF performance did not detoriate
    - was not excellent before
  - Tuner motors moved

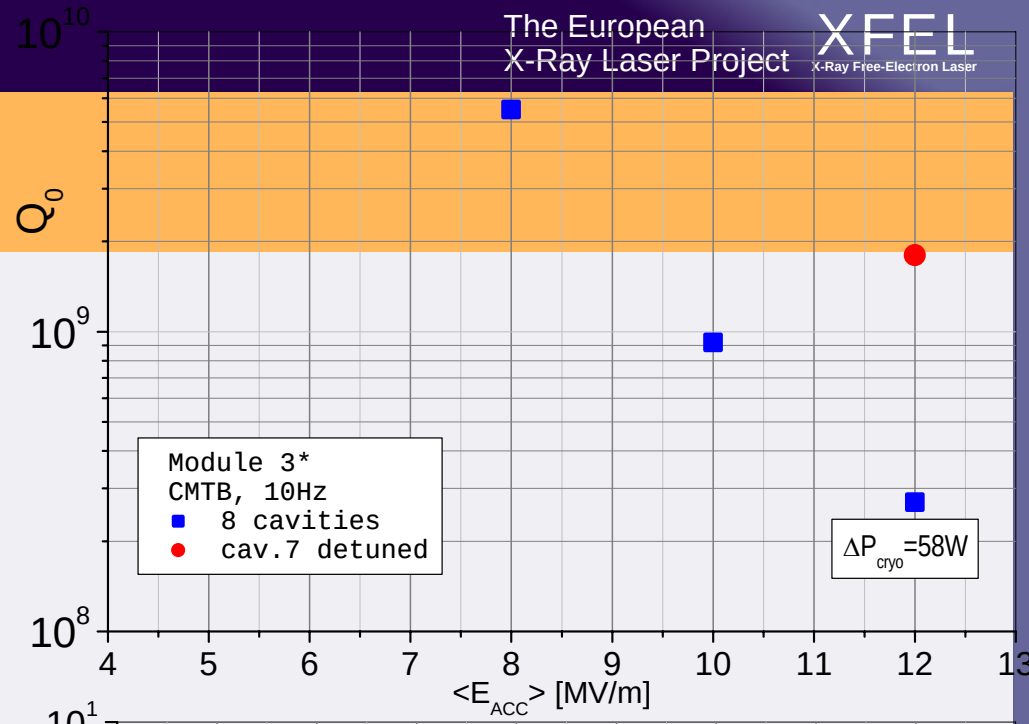
Summary

- Cavity pressure tests
  - 6 bar at 2K without plastic deformation
  - 5 bar at 300 K without plastic deformation
    - 6 bar plastic defomation observed
  - So far soft cavity, next test with 800C cavity
- Several venting tests in cold conditions were performed on a full accelerator module
- ‘Slow‘ Vents of all three vacuum systems
  - Heat loss measurements done, good agreement with simulations
  - Rf performance did not change
  - No damages e.g. leaks
- ‘Fast‘ Vents on Isolation Vacuum
  - Pressure incereases in He circuits measured
  - RF performance did not change
  - Minor damages

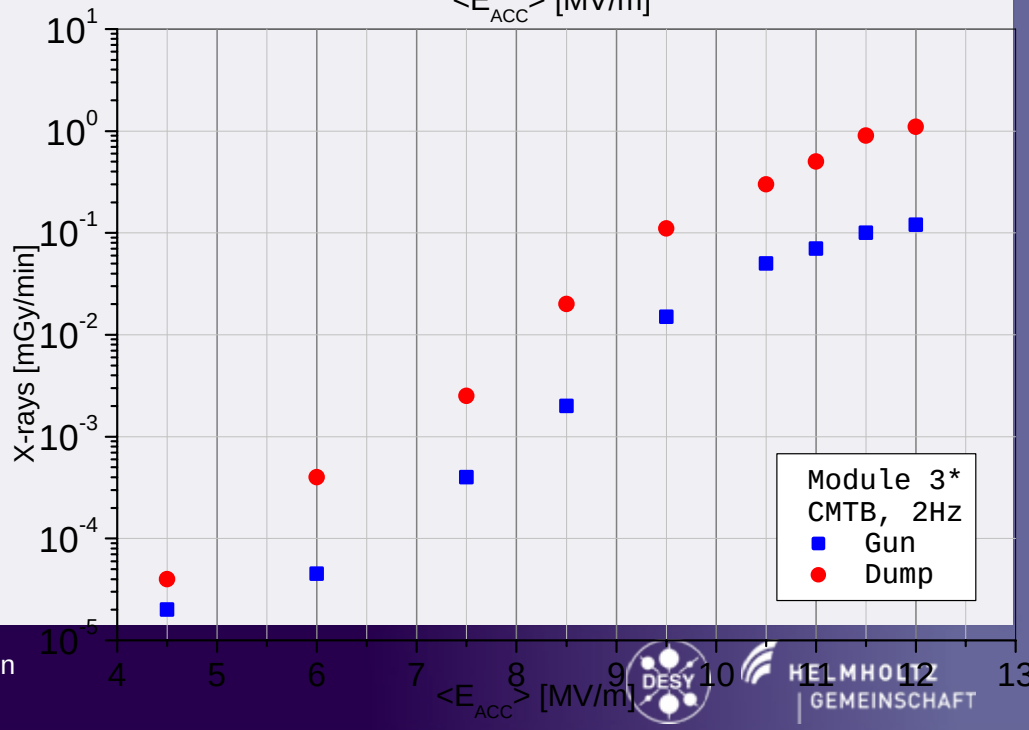
Backup

Module 3*

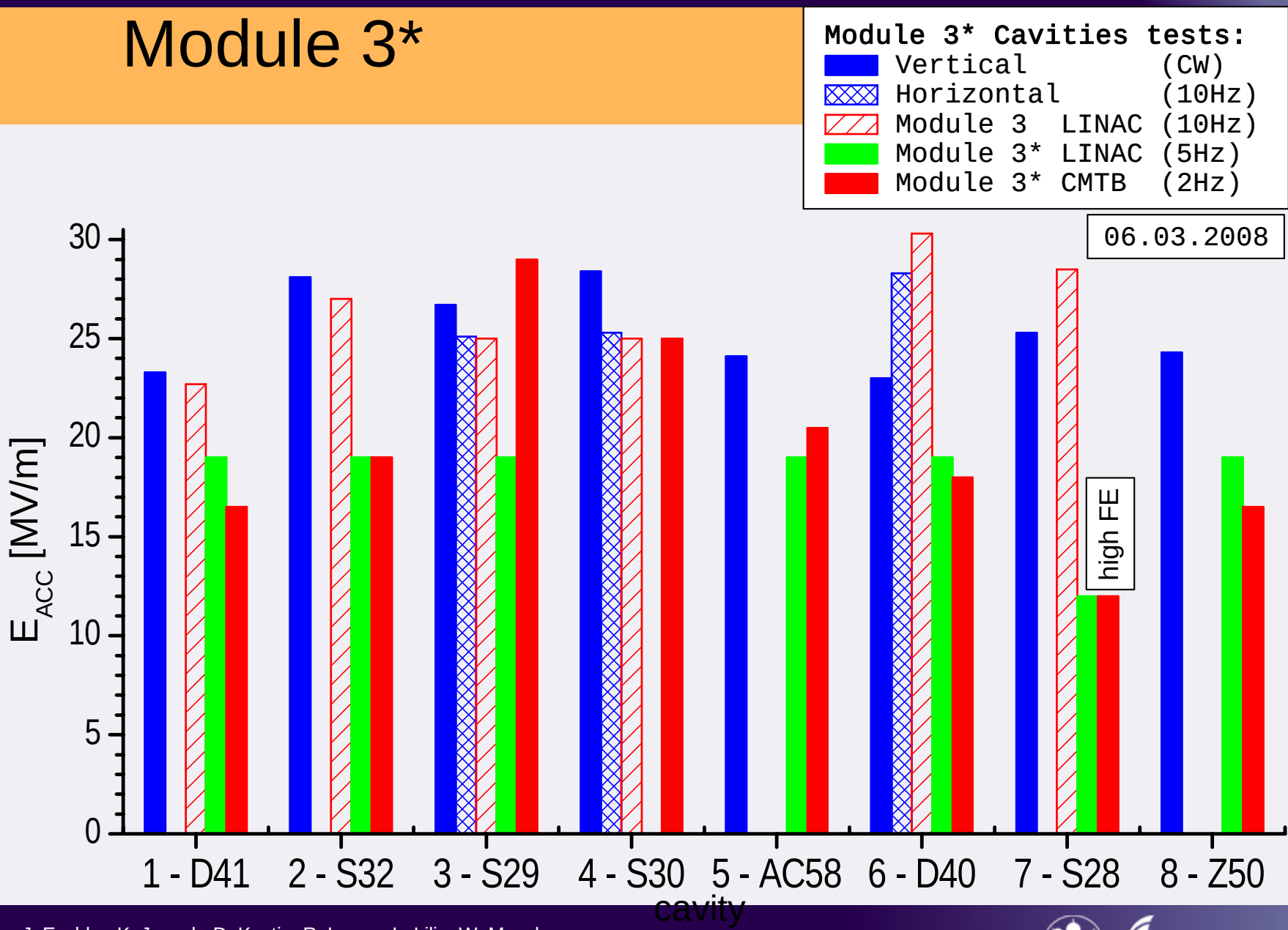
$Q_0(E_{acc})$



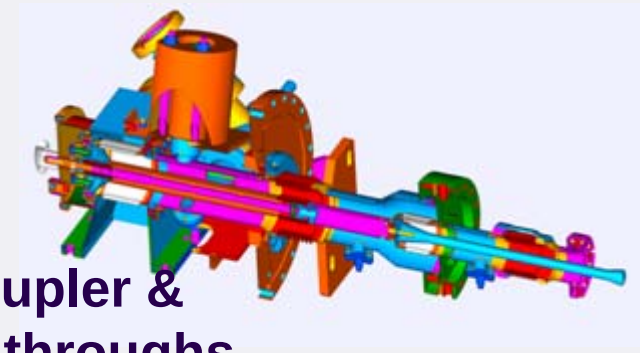
X-rays



Module 3*

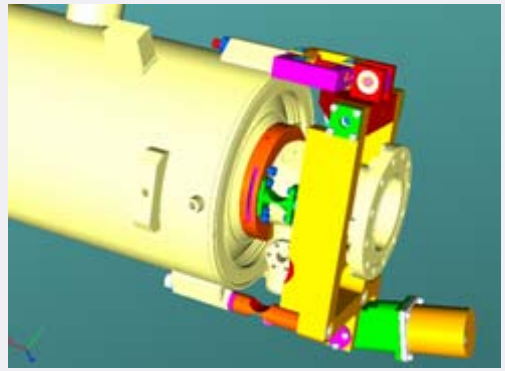

Module 3* Cavities tests:
Vertical (CW)
Horizontal (10Hz)
Module 3 LINAC (10Hz)
Module 3* LINAC (5Hz)
Module 3* CMTB (2Hz)
06.03.2008
high FE
E_ACC [MV/m]
0
5
10
15
20
25
30
1 - D41
2 - S32
3 - S29
4 - S30
5 - AC58
6 - D40
7 - S28
8 - Z50
cavity

XFEL Accelerator Module Components



Coupler &
Feedthroughs

Tuner



Cavities

HOMs

Length quantized n·λ/2 (possibility of ERL)

XFEL Accelerator Module (Cryomodule)