Pressure and Venting Tests

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Slides based on a summary by K. Jensch (DESY)

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 pressure drops
  - 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

Sequence of tests in Module Crash Test

Venting	Condition	Cavity	Coupler	Tuner	Cryo	BPM	Vacuum	Remark
Iso slow	2K, 30 mbar RF Off			Check Piezo	Measure losses		Measure	Helium Rate and Level tbd.
Coupler slow	2K, 30 mbar RF Off		Perfomance Reprocessing		Measure losses		Measure	Nitrogen Rate and Level tbd.
Cavity slow	2K, 30 mbar RF Off	Performance Detuning Reprocessing			Measure losses		Measure	Nitrogen Rate and Level tbd.
Iso fast I	2K, 30 mbar RF Off	Performance Detuning Reprocessing	Ceramic rupture	Tuner motors	Pressure increases, He Pipe rupture, MLI integrity	Ceramic rupture	Measure Leaks	Controlled, Rate tbd, Nitrogen
Iso fast II	2K, 30 mbar RF Off	Performance Detuning Reprocessing	Ceramic rupture	Tuner motors	Pressure increases He Pipe rupture MLI integrity	Ceramic rupture	Measure Leaks	Catastrophic, Air
Coupler fast	2K, 30 mbar RF Off	Performance Detuning Reprocessing	Ceramic rupture		Pressure increases He Pipe rupture		Measure Leaks	Controlled, Rate tbd, Nitrogen
Cavity fast I	2K, 30 mbar RF Off	Performance Detuning Reprocessing	Ceramic rupture		Pressure increases He Pipe rupture	Ceramic rupture	Measure Leaks	Controlled, Rate tbd, Nitrogen
Cavity fast II	2K, 30 mbar RF Off	Performance Detuning Reprocessing	Ceramic rupture		Pressure increases He Pipe rupture	Ceramic rupture	Measure Leaks	Catastrophic, Air
Cavity fast III	2K, 30 mbar RF On	Performance Detuning Reprocessing	Ceramic rupture		Pressure increases He Pipe rupture	Ceramic rupture	Measure Leaks	Controlled, Rate tbd, Nitrogen
Cavity fast IV	4.5K, 1.7 bar, RF Off	Performance Detuning Reprocessing	Ceramic rupture		Pressure increases He Pipe rupture	Ceramic rupture	Measure Leaks	Air, **Need to block 2 safety valves** (VD1R130 and VS1R90)

Motivation for Pressure ant Venting tests in CHECHIA

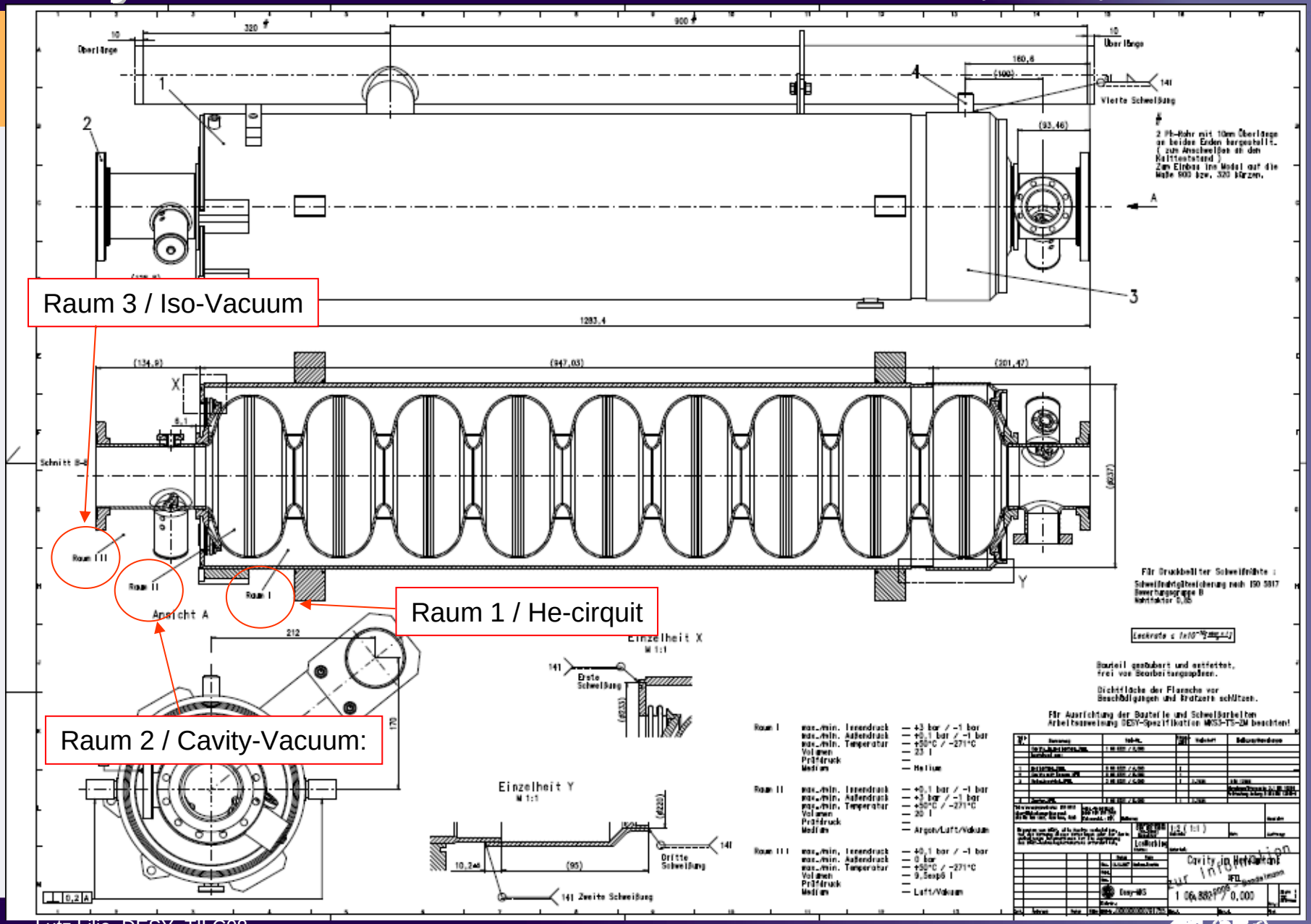
- Safety regulations are taking into account the current ‘wisdom‘ included in simulations
  - Based on several worst case scenarios
  - Benchmarking in operating conditions (cold modules) of these simulations is needed
- In parallel, development of a simple pressure test for the series is highly desirable
  - Pressure test of the He vessel to simplify overall pressure test for the XFEL accelerator system
    - » In my words: If test on individual units e.g. cavity is successful, lower pressure on the He system for XFEL is required.
- Venting of the coupler vacuum
  - Preparation for crash tests
    - » would like to escalate the desaster level in a reasonable way to maximise information from test
  - Check whether ceramic breaks in a fast vent with nitrogen

C26 Test at 2K and 295K

- Test at 2K with max. pressure of 6.1bar
  - Safety authority took part
- Two tests at 295K up to 6.2bar
  - First warm test canceled because a leak in He circuit of the cryostat
- 1 Test at 2K a. 4K
  - Check the field flatness and tuning

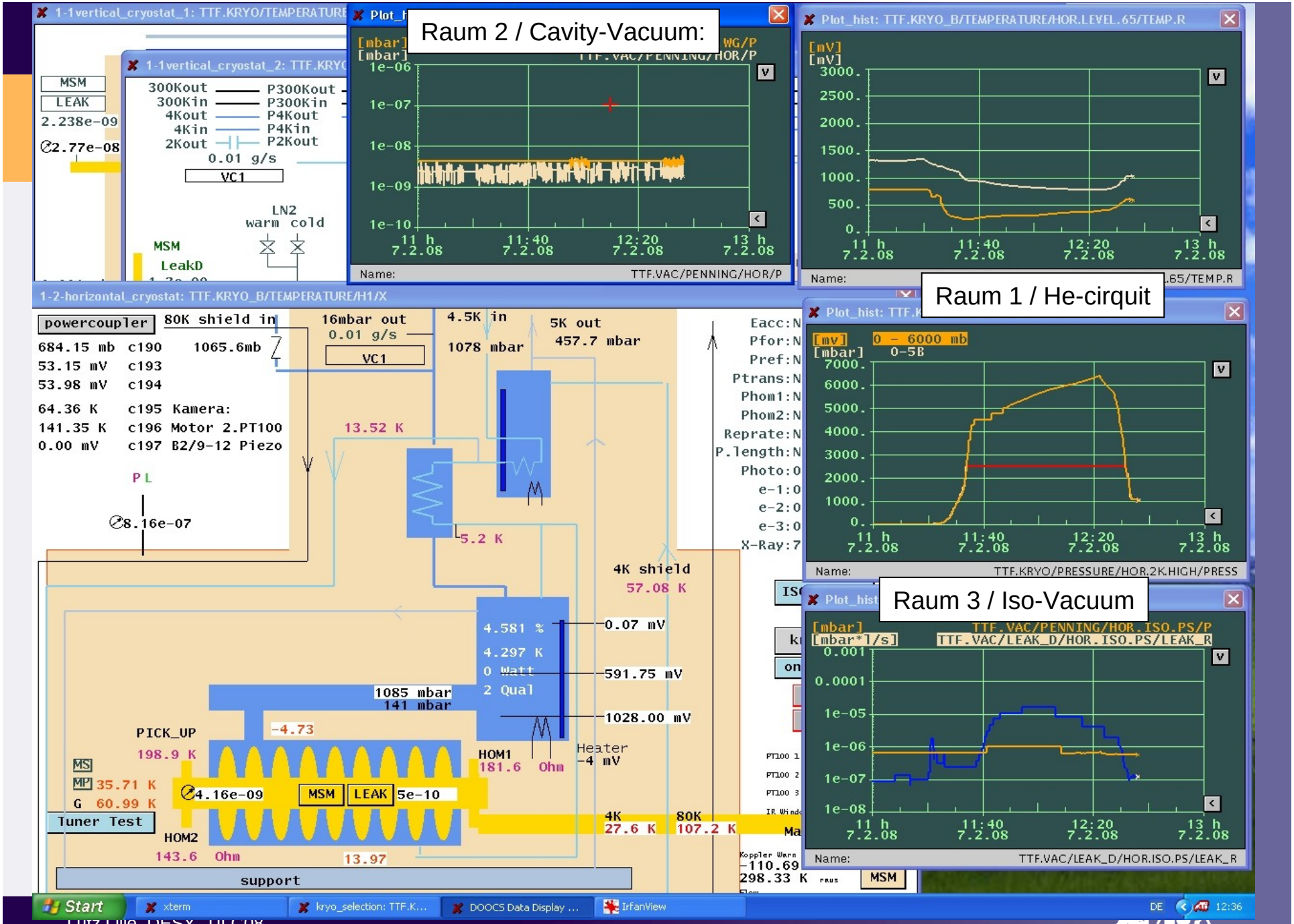
Cavity with He-Vessel – XFEL version

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

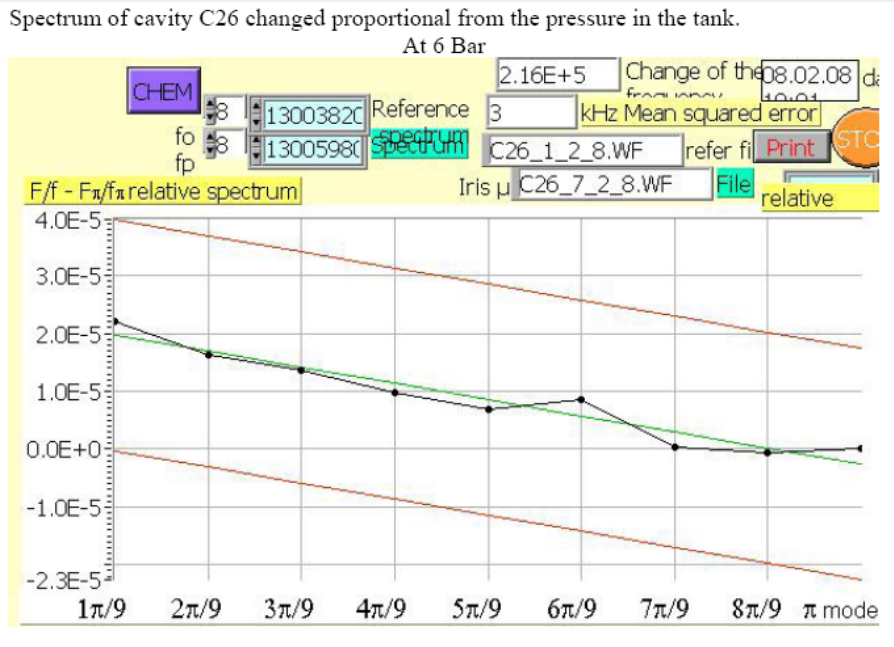


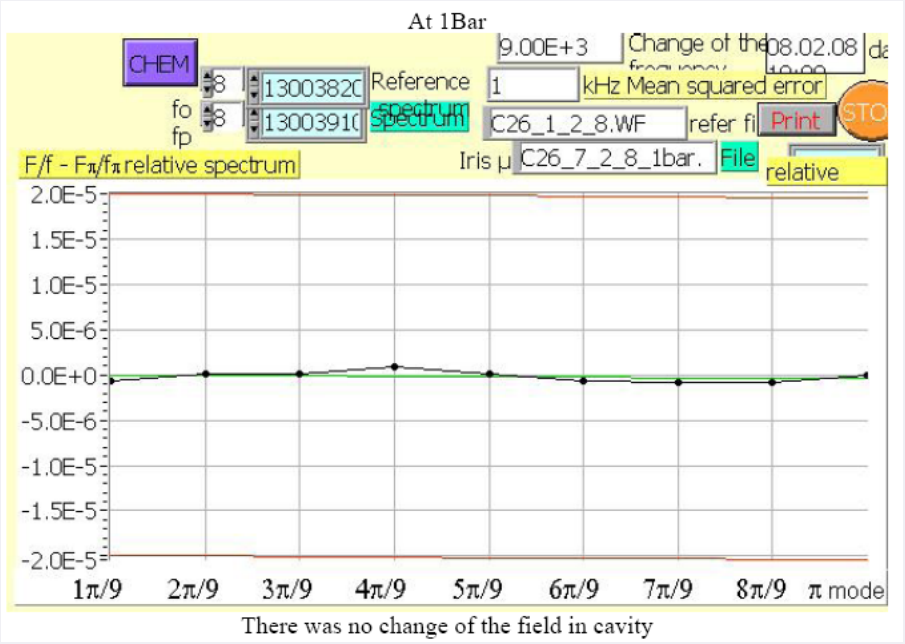
First Cold Test at 2K

- ***Test procedure:***
  - Cavity stable at 2K/31mbar – fr off-resonance
  - Pressure on 2K circuit up to 4,0bar
  - Cavity for 1/2h under pressure
    - during this time the pressure go up to 6,1bar
  - No increase of pressure or leak rate
    - higher leak rate due to surface desorption – no leak!
  - Pressure on 2K circuit down to 1,0bar
    - Frequency and field flatness checked at different pressures
    - Frequency identical at 1,0bar before and after the pressure test.
    - No impact at the filed flatness
    - No plastic deformation at the Cavity, Tunersystem or He-Vessel


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:
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
P L
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.KRYO/PRESSURE/HOR.2K.HIGH/PRESS
[mv]
0 - 6000 mb
[mbar]
0-5B
7000.
6000.
5000.
4000.
3000.
2000.
1000.
0.
Name: TTF.KRYO/PRESSURE/HOR.2K.HIGH/PRESS
Plot_hist
[mbar]
TTF.VAC/PENNING/HOR.ISO.PS/P
[mbar*l/s]
TTF.VAC/LEAK_D/HOR.ISO.PS/LEAK_R
0.001
0.0001
1e-05
1e-06
1e-07
1e-08
Name: TTF.VAC/LEAK_D/HOR.ISO.PS/LEAK_R
Koppler Warm
-110.69
298.33 K
MSM
Start
xterm
kryo_selection: TTF.K...
DOOCS Data Display ...
IrfanView
DE
12:36

Cavity Spectrum



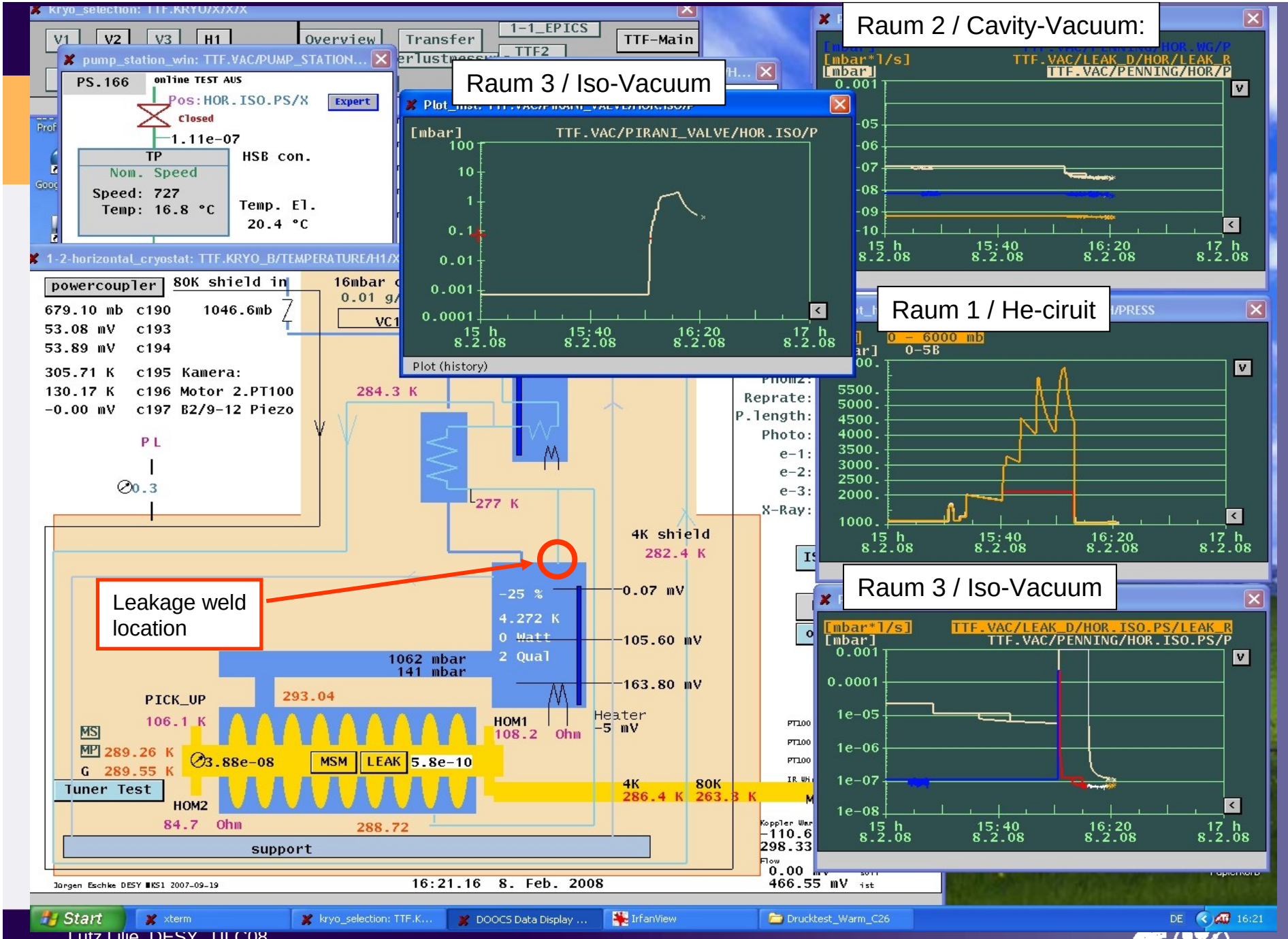


2K at 6bar

2K at 1bar

First Warm Test at 290K

- ***Test procedure:***
- Cavity 290K/1000mbar
- Pressure on 2K circuit in steps up to 6,0bar
- Cavity under different pressure conditions
  - **2,0bar – okay**
  - **3,2bar – okay**
  - **4,5bar – okay**
  - **5,9bar – okay**
  - **~6,0bar – increase of pressure and leak rate in the insulation vacuum**
- Pressure on 2K circuit down to 1,0bar
- Frequency ~140kHz higher on 1,0bar before pressure test.
- Check of filed flatness at 290K in CHECHIA difficult - Gennuadi
- Leak was located
  - 2K supply line from the Level vessel (weld),
  - not at the cavity or He-Vessel.

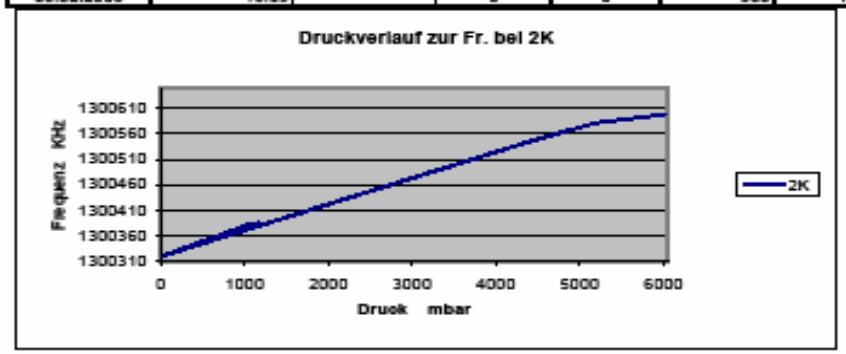

Raum 2 / Cavity-Vacuum:
Raum 3 / Iso-Vacuum
Raum 1 / He-ciruit
Raum 3 / Iso-Vacuum
Leakage weld location
pump_station_win: TTF.VAC/PUMP_STATION...
PS.166
online TEST AUS
Pos:HOR.ISO.PS/X
Expert
Closed
1.11e-07
TP
Nom. Speed
Speed: 727
Temp: 16.8 °C
HSB con.
Temp. El.
20.4 °C
Plot (history)
[mbar] TTF.VAC/PIRANI_VALVE/HOR.ISO/P
[mbar*l/s] TTF.VAC/LEAK_D/HOR/LEAK_R
[mbar] TTF.VAC/PENNING/HOR/P
[mbar*l/s] TTF.VAC/LEAK_D/HOR.ISO.PS/LEAK_R
[mbar] TTF.VAC/PENNING/HOR.ISO.PS/P
1-2-horizontal_cryostat: TTF.KRYO_B/TEMPERATURE/H1/X
powercoupler
80K shield in
679.10 mb c190 1046.6mb
53.08 mV c193
53.89 mV c194
305.71 K c195 Kamera:
130.17 K c196 Motor 2.PT100
-0.00 mV c197 B2/9-12 Piezo
284.3 K
277 K
4K shield
282.4 K
-25 %
4.272 K
0 Watt
2 Qual
0.07 mV
105.60 mV
163.80 mV
1062 mbar
141 mbar
PICK_UP
106.1 K
293.04
HOM1
108.2 Ohm
Heater
-5 mV
MS
MP 289.26 K
G 289.55 K
3.88e-08
MSM
LEAK 5.8e-10
Tuner Test
HOM2
84.7 Ohm
288.72
4K
286.4 K
80K
263.3 K
support
Reprate:
P.length:
Photo:
e-1:
e-2:
e-3:
X-Ray:
16:21.16 8. Feb. 2008
Jürgen Eschke DESY MKS1 2007-09-19
Start
xterm
kryo_selection: TTF.K...
DOOCS Data Display ...
IrfanView
Drucktest_Warm_C26
DE
16:21

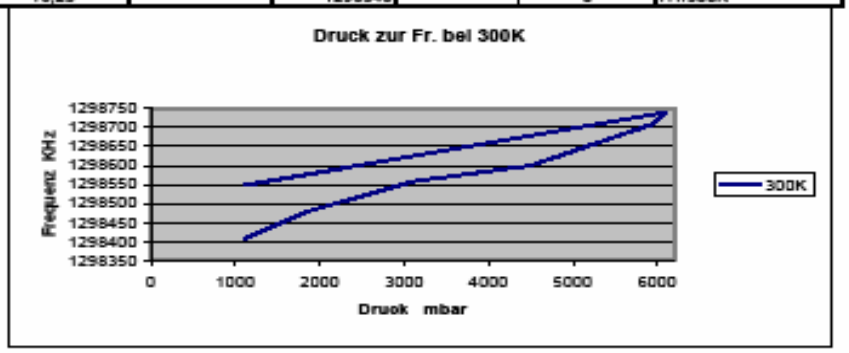
Frequenzverlauf bei Drucktest C26 im H1

Datum:	Uhrzeit	delta mV	Steps	Position	Temp.	Druck	Piezo-Span.	delta Span.	Frequenz	delta Fr.	Feldstärke	Wo
		(HP 54501)			Kelvin	mbar	mV	KHz	GHz	KHz	MV/m	
			0	0	300				1298400			Werkstatt
01.02.2008	15:55		0		5	1160			1300385			Erster Kalttest
01.02.2008	15:33			264000	5	1159			1300019		0	Erster Kalttest
07.02.2008	9:10		0	0	5	1070			1300383		0	Zweiter Kalttest
07.02.2008	10:35		0	0	2	32			1300321		0	Zweiter Kalttest
07.02.2008	11:35		0	0	2	4500			1300550		0	Zweiter Kalttest
07.02.2008	11:55		0	0	2	5200			1300582		0	Zweiter Kalttest
07.02.2008	12:10		0	0	2	6010			1300598		0	Zweiter Kalttest

300K Druoktest

Datum:	Uhrzeit	delta mV	Steps	Position	Temp.	Druck	Piezo-Span.	delta Span.	Frequenz	delta Fr.	Feldstärke	Wo
		(HP 54501)			Kelvin	mbar	mV	KHz	GHz	KHz	MV/m	
08.02.2008	15:20		0	0	300	1109			1298409		0	H1/300K
08.02.2008	15:30		0	0	300	1850			1298479		0	H1/300K
08.02.2008	15:46		0	0	300	3110			1298558		0	H1/300K
08.02.2008	15:49		0	0	300	4500			1298600		0	H1/300K
08.02.2008	15:51		0	0	300	5950			1298710		0	H1/300K
08.02.2008	16:03		0	0	300	6100			1298740		0	H1/300K
08.02.2008	16:09		0	0	300	1100	16,25		1298548		0	H1/300K

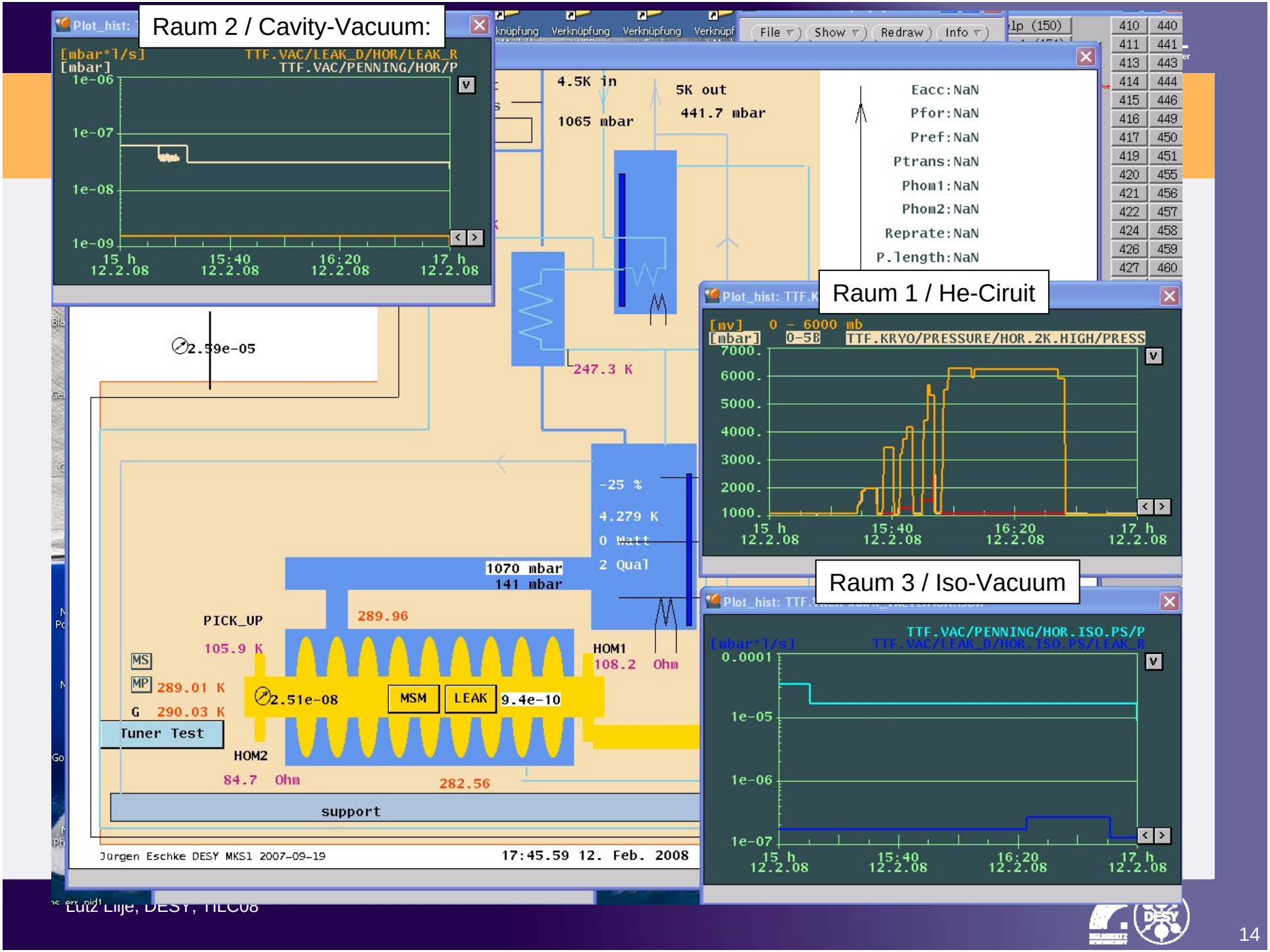




Clemens Albrecht

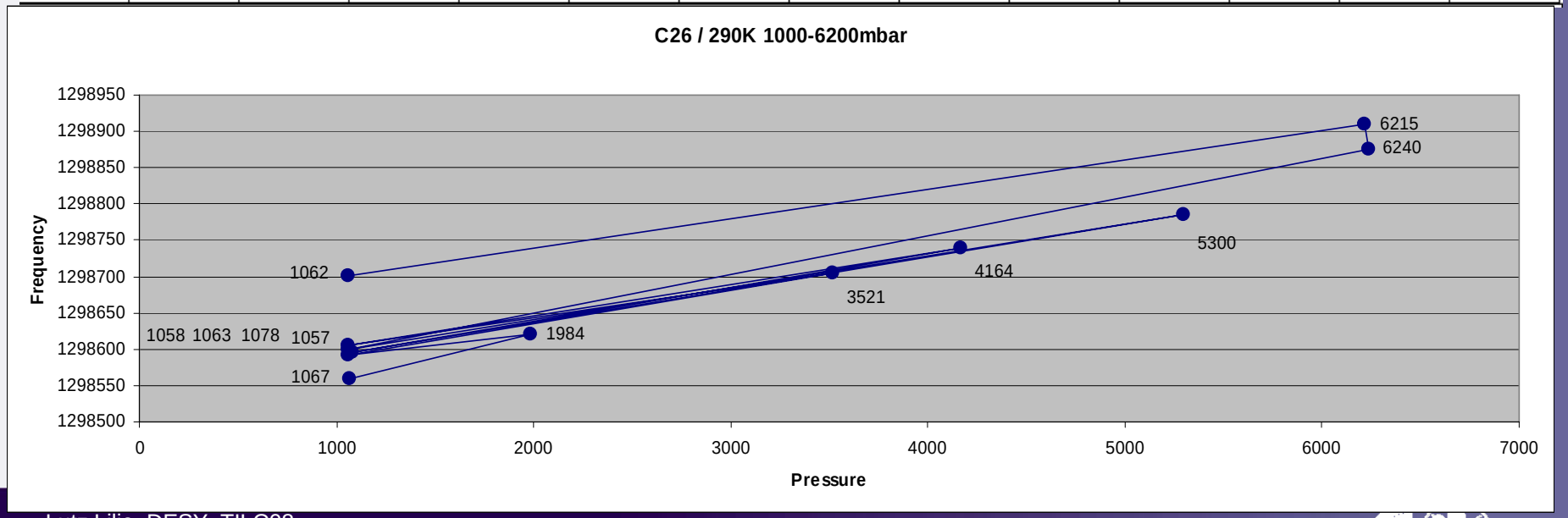
Second Warm Test at 290K

- ***Test procedure:***
- C26 ~290K
  - Raum 1: 1,0bar / Frequency measured
  - Raum 2: ~3x10E-8mbar
  - Raum 3: ~1,6x10E-5mbar
- He-Raum (1) in steps to impress with warm He:
  - 2,0 bar / Frequency measured
  - 1,0 bar / fr measured
  - 3,45 bar / fr measured
  - 1,0 bar / fr measured
  - 4,2 bar / fr measured
  - 1,0 bar / fr measured
  - 5,3 bar / fr measured
  - 1,0 bar / fr measured
  - 6,2 bar / fr measured
  - 6,2 bar for a 1/2h / fr measured
  - 1,0 bar / fr measured
- Above 6,2 bar fr ~100kHz higher on 1,0bar before pressure test.
- Up to 5,3bar steps no fr shift vs. 1.0bar measurements.
- None detection of pressure or leak rate increase in the cavity or insulation vacuum


Raum 2 / Cavity-Vacuum:
Raum 1 / He-Ciruit
Raum 3 / Iso-Vacuum
[mbar*l/s]
TTF.VAC/LEAK_D/HOR/LEAK_R
[mbar]
TTF.VAC/PENNING/HOR/P
1e-06
1e-07
1e-08
1e-09
15 h 12.2.08
15:40 12.2.08
16:20 12.2.08
17 h 12.2.08
4.5K in
1065 mbar
5K out
441.7 mbar
Eacc:NaN
Pfor:NaN
Pref:NaN
Ptrans:NaN
Phom1:NaN
Phom2:NaN
Reprate:NaN
P.length:NaN
File
Show
Redraw
Info
[mv] 0 - 6000 mb
[mbar] 0-5B
TTF.KRYO/PRESSURE/HOR.2K.HIGH/PRESS
7000.
6000.
5000.
4000.
3000.
2000.
1000.
2.59e-05
247.3 K
-25 %
4.279 K
0 Watt
2 Qual
1070 mbar
141 mbar
PICK_UP
105.9 K
289.96
HOM1
108.2 Ohm
MS
MP 289.01 K
G 290.03 K
2.51e-08
MSM
LEAK
9.4e-10
Tuner Test
HOM2
84.7 Ohm
282.56
support
Jürgen Eschke DESY MKS1 2007-09-19
17:45.59 12. Feb. 2008
TTF.VAC/PENNING/HOR.ISO.PS/P
[mbar*l/s]
TTF.VAC/LEAK_D/HOR.ISO.PS/LEAK_R
0.0001
1e-05
1e-06
1e-07

Frequenzverlauf bei Drucktest C26 im H1

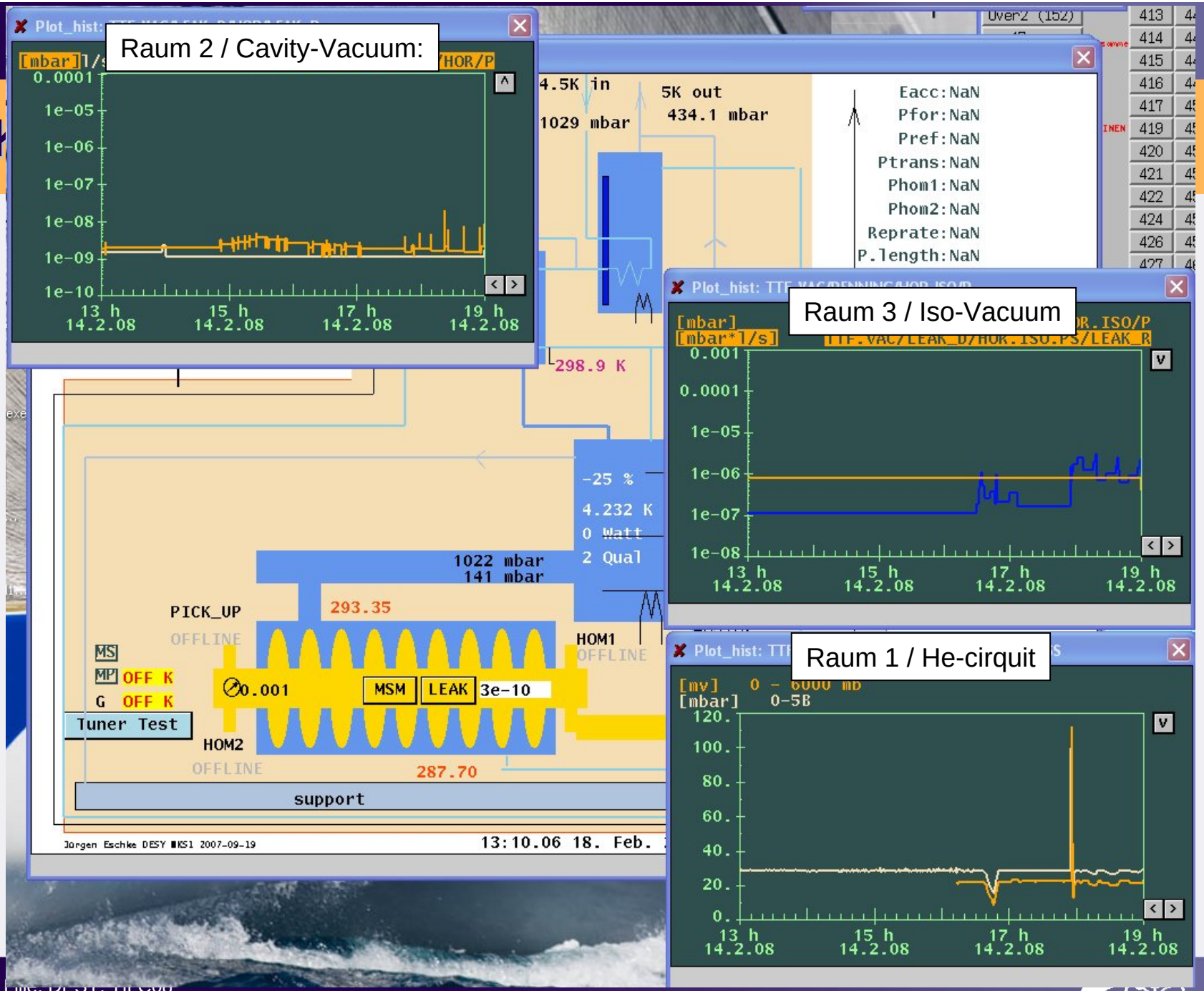
Datum:	Uhrzeit	delta mV (HP 54501)	Steps	Position	Temp. Kelvin	Druck mbar	Piezo-Span. mV	delta Span. KHz	Frequenz GHz		delta Fr. KHz	Feldstärke MV/m	Wo
11.02.2008	09:10		0		300	1070			1298560				
11.02.2008	15:10		0		300	1067			1298560				
11.02.2008	15:25		0			1984			1298620	60			
11.02.2008	15:35		0			1058			1298592	-28			
11.02.2008	15:39		0			3521			1298705	113			
11.02.2008	15:41		0			1063			1298605	-100			
11.02.2008	15:45		0			4164			1298740	135			
11.02.2008	15:48		0			1078			1298595	-145			
11.02.2008	15:52		0			5300			1298785	190			
11.02.2008	15:56		0			1057			1298600	-185			
11.02.2008	15:59		0			6240			1298875	275			
11.02.2008	16:26		0			6215			1298910	35			
11.02.2008	16:36		0			1062			1298702	-208			



Second Cold Test at 2K

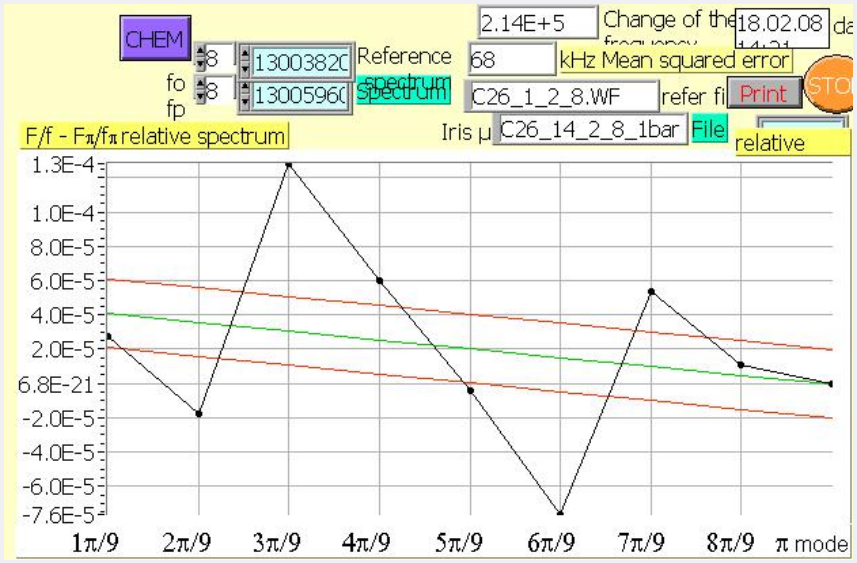
- ***Test procedure:***
- Cavity stable at 2K/31mbar – fr on-resonance
- Frequency and field flatness checked
- Frequency could be tune.
- Field flatness unbalanced – impact from the warm test

2K

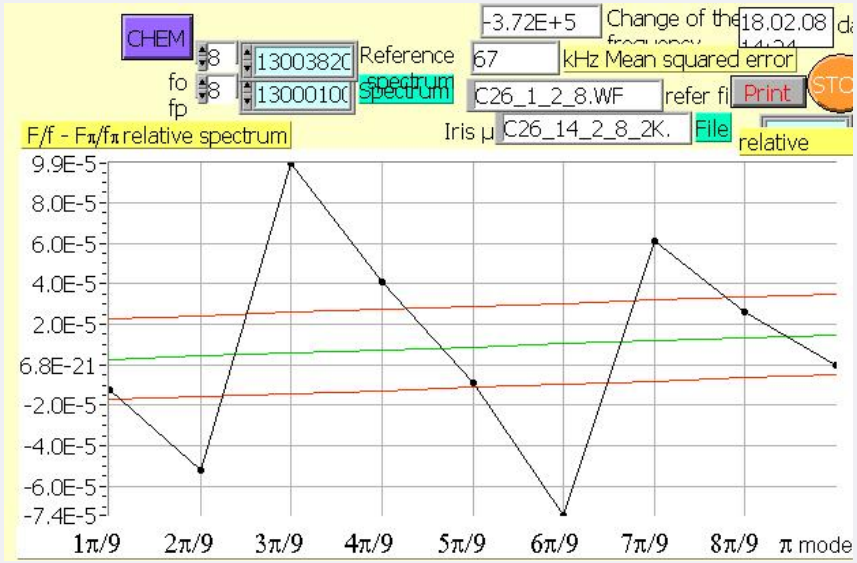

Raum 2 / Cavity-Vacuum:
Raum 3 / Iso-Vacuum
Raum 1 / He-cirquit
4.5K in
1029 mbar
5K out
434.1 mbar
Eacc:NaN
Pfor:NaN
Pref:NaN
Ptrans:NaN
Phom1:NaN
Phom2:NaN
Reprate:NaN
P.length:NaN
298.9 K
-25 %
4.232 K
0 Watt
2 Qual
1022 mbar
141 mbar
PICK_UP
OFFLINE
293.35
HOM1
OFFLINE
MS
MP OFF K
G OFF K
Tuner Test
0.001
MSM
LEAK
3e-10
HOM2
OFFLINE
287.70
support
Jörgen Eschke DESY MKS1 2007-09-19
13:10.06 18. Feb.
[mbar]
[mbar*l/s]
[mv]
[mbar]
13 h
14.2.08
15 h
14.2.08
17 h
14.2.08
19 h
14.2.08

Cavity Spectrum at 4 a. 2K

4K



2K



RF on-resonance

Pressure Test: Conclusion and Next Steps

- Pressure Test results
  - At 2K
    - » Until 6.2 bar Cavity and Tuner system only elastic deformations
  - At 295K
    - » Until 5,3bar Cavity and Tunersystem only elastic deformations
    - » Over 5.3bar plastic deformations on the Cavity und Tunersystem
- Next steps:
  - Prepare the Cavity for simple spectrum measurements at 295K
  - Pressure test in the work shop (water)
    - » Measurements at Cavity flanges and the Tunersystem with micrometer to figure out what are the “instable components”
    - » Pressure test with tuner clamps (Pratzen) and disassemble tunersystem
    - » Pressure test for the series will be done with clamps.
  - To retest with a 800°C Cavity under same conditions
    - » C26 is 1400°C treated
  - The goal is to verify if it possible to certified a Cavity/He-Vessel with a simple cheap test at 5.8bar
    - » 4.0bar is the specified max. pressure in XFEL – 4.0x1.43=5.72bar

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 -

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

Draft Version

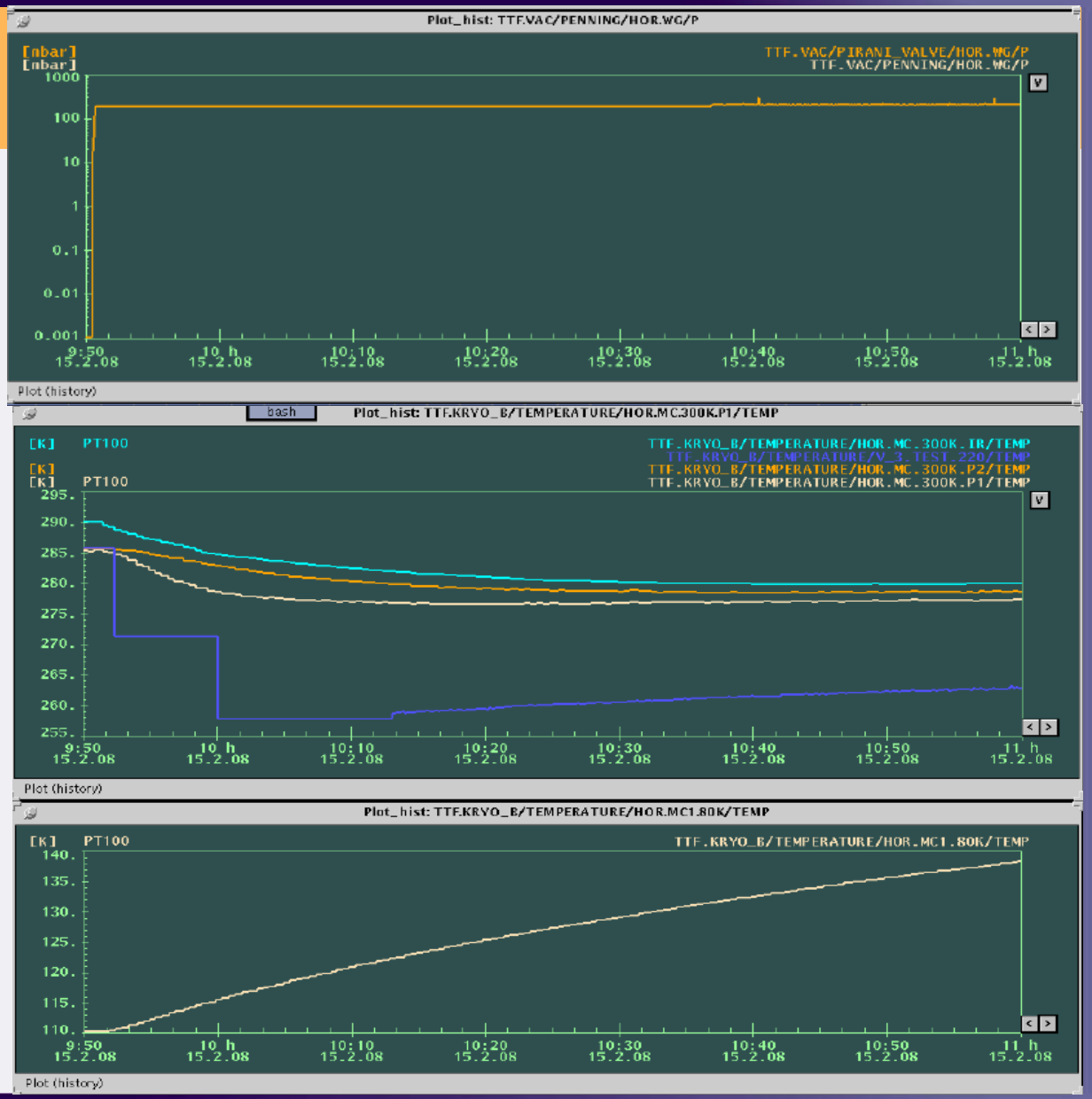
Venting of the Coupler Vacuum

- Preparation for crash tests
  - would like to escalate the desaster level in a reasonable way to maximise information from test
    - » Correct scheduling of tests is important
  - In other words: At which stage are we seriously start destroying things?
- Check whether ceramic breaks in a fast vent with nitrogen
- Results
  - Ceramic does not break
  - No leak occured
    - » Cross-checked after pumpdown

Venting of Coupler Vacuum

- Opening needle valve
- about 1 min for full vent
- Nitrogen, not air
- Gauge calibrated for air

- Results:
- Ceramic does not break
- No leak



Summary and Outlook

- Pressure test
  - No detuning of the cavity in cold
  - Development of a simple pressure test for the series
    - » Warm condition up to ~6 bar
- Venting test
  - Ceramic did not break, no leak
- Module crash test
  - Safety authorities will take part
  - Series of test with careful escalation of level of destruction
    - » Starting this week