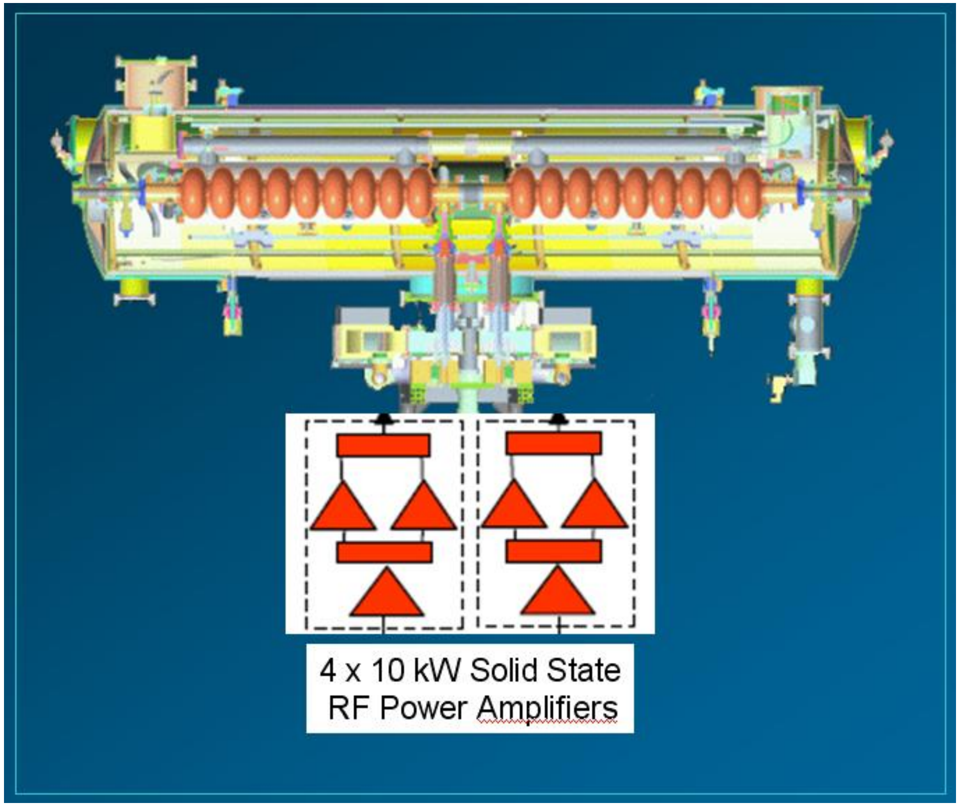
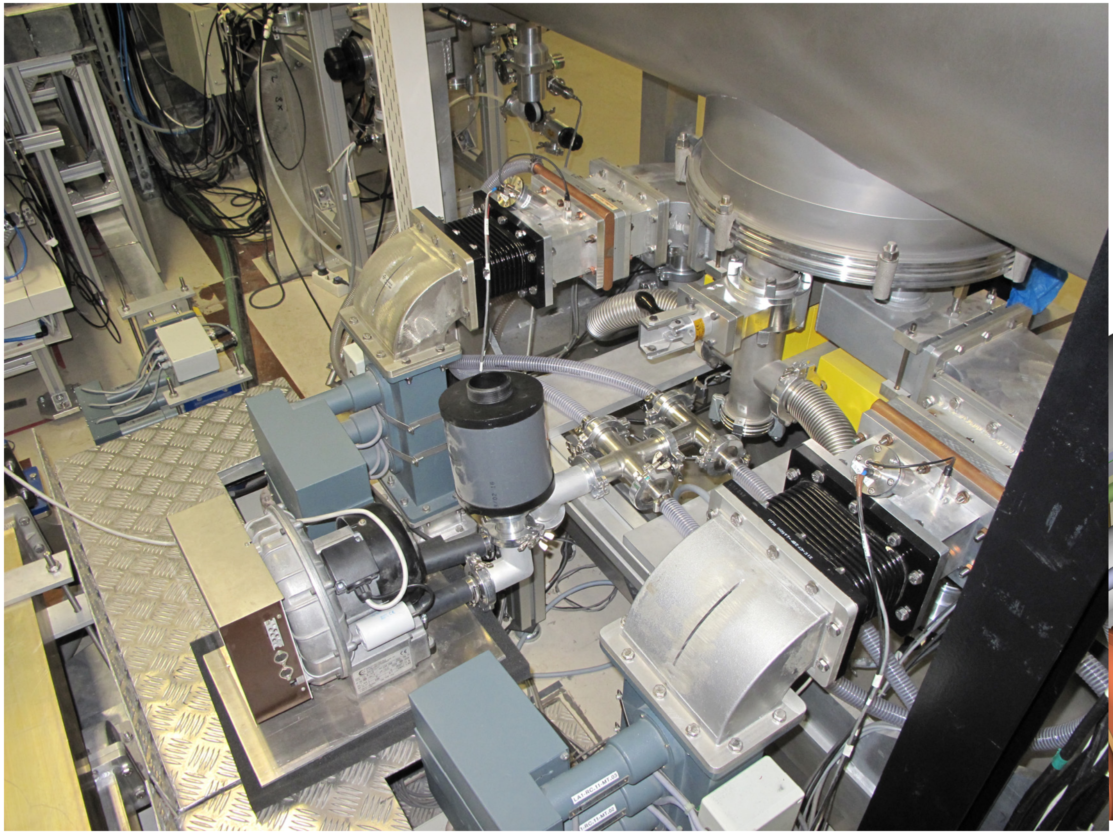
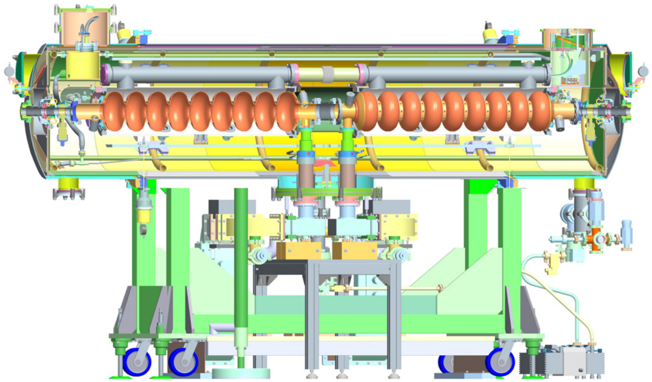
MATCHING the 20 kW SSPA to ELBE

Andree Arnold + Hartmut Büttig for the ELBE team

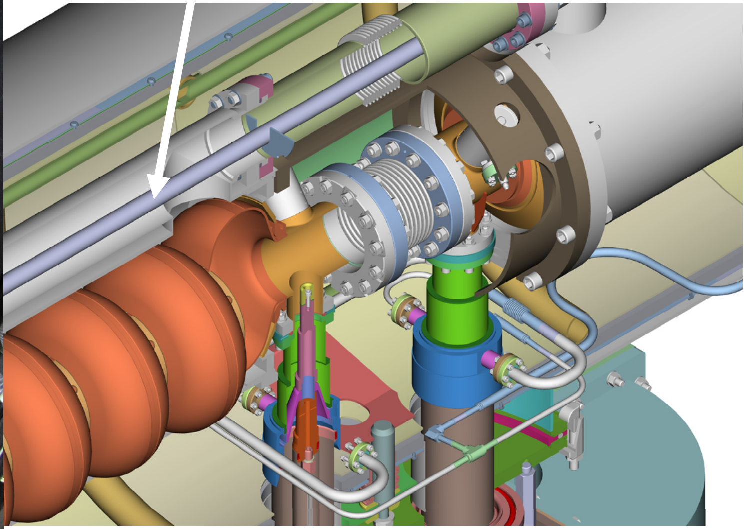


Remarks on Cavity Bandwidth



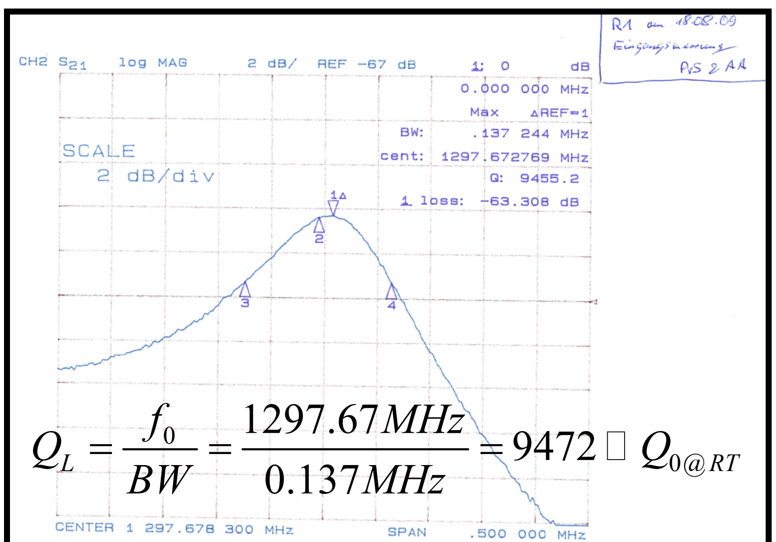


Antennas with fixed tip !

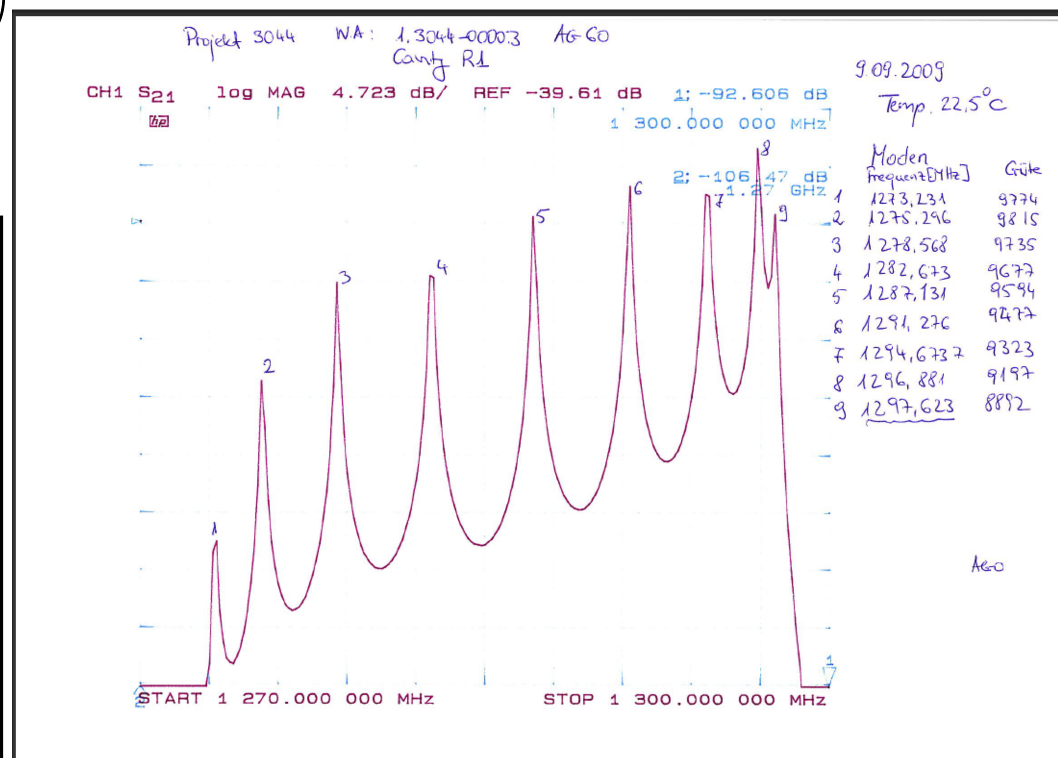


Warm Cavity Measurements – Passband & Field Profile

$$Q_0 = \left(1 + \underbrace{\frac{Q_0}{Q_{FPC}}}_{\beta_{FPC}} + \underbrace{\frac{Q_0}{Q_{HOM}}}_{\beta_{HOM}} + \underbrace{\frac{Q_0}{Q_{Pickup}}}_{\beta_{Pickup}} \right) Q_L \approx Q_L$$

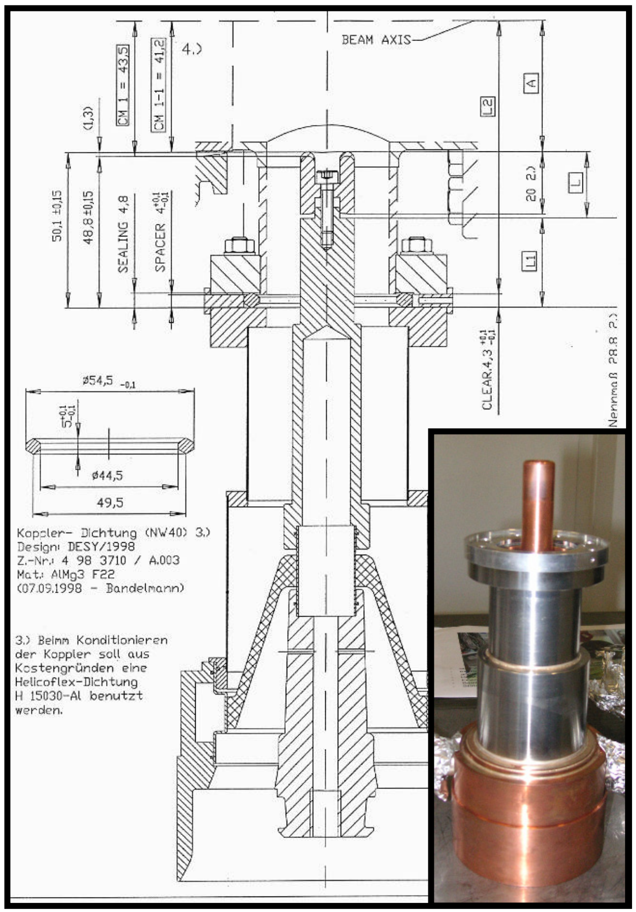


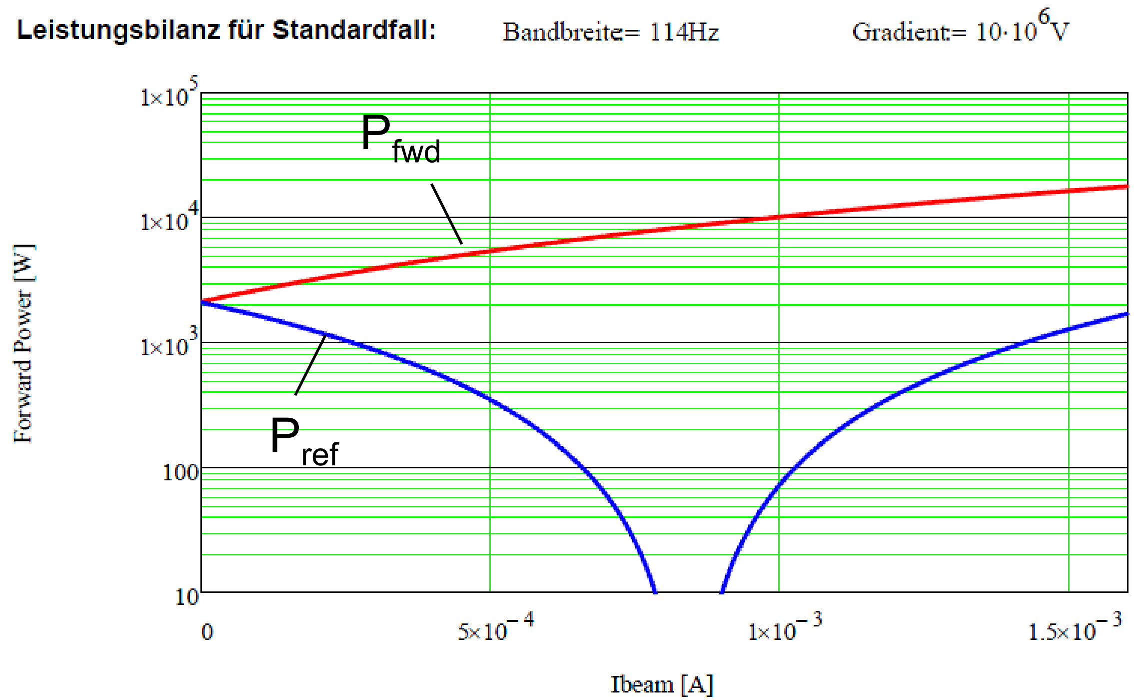
$$Q_L = \frac{f_0}{BW} = \frac{1297.67\,MHz}{0.137\,MHz} = 9472 \approx Q_{0@RT}$$



Optimal FPC coupling for beam matching - adjusted by antenna tip

$$Q_{HK} \approx \frac{V_{acc}}{2 \cdot I_{beam} \cdot r_s} = \frac{10MV}{2 \cdot 850\mu A \cdot 518\Omega} = \boxed{1.136 \cdot 10^7} \sim Q_L \rightarrow BW = f_0 / Q_L \boxed{= 114Hz}$$

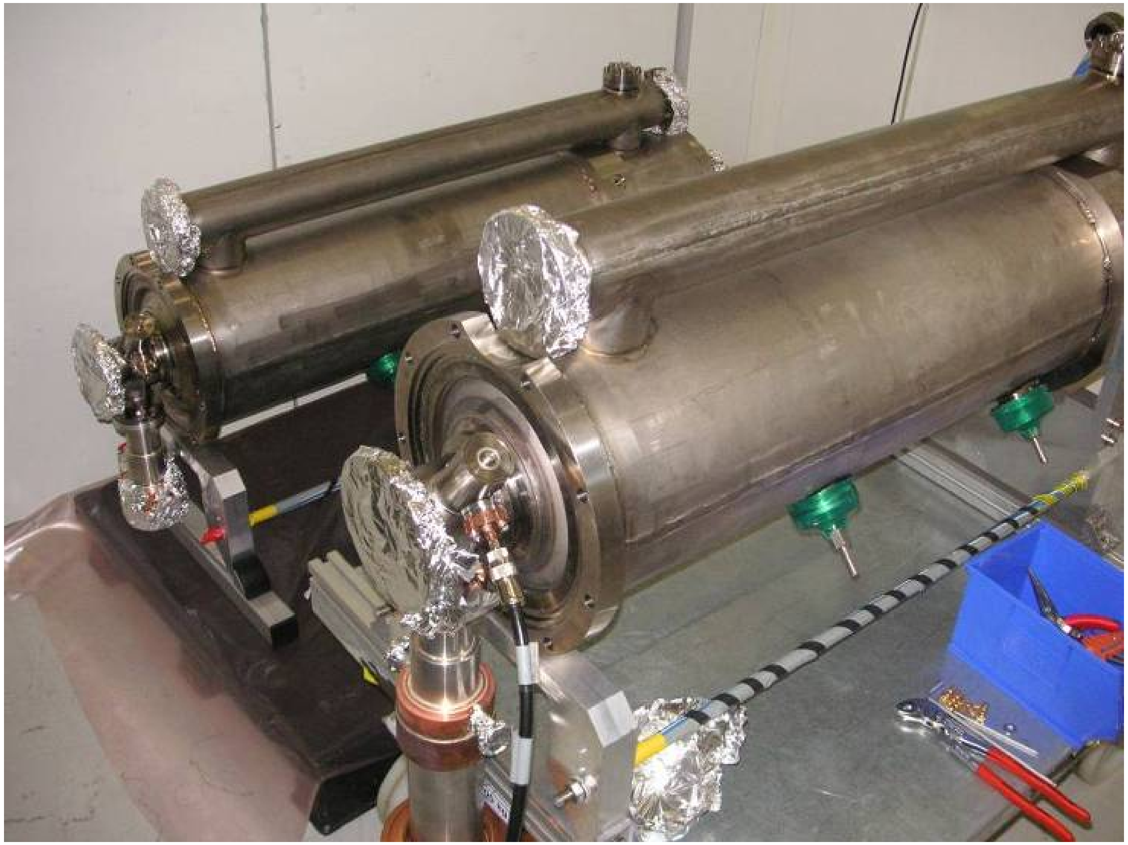


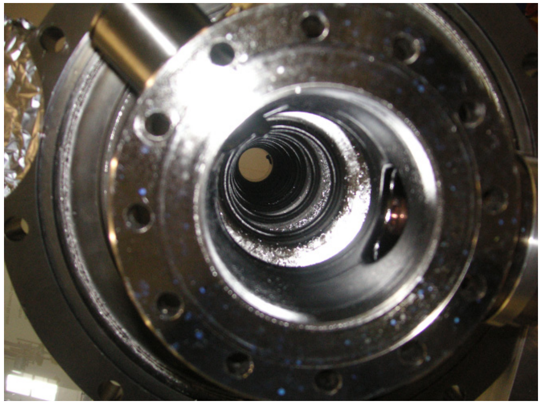


Note: the higher BW – the lower effect of detuning caused by micro phonics and LHe pressure fluctuations

Warm Cavity Measurements

Optimal FPC coupling adjusted by antenna tip, done with RI



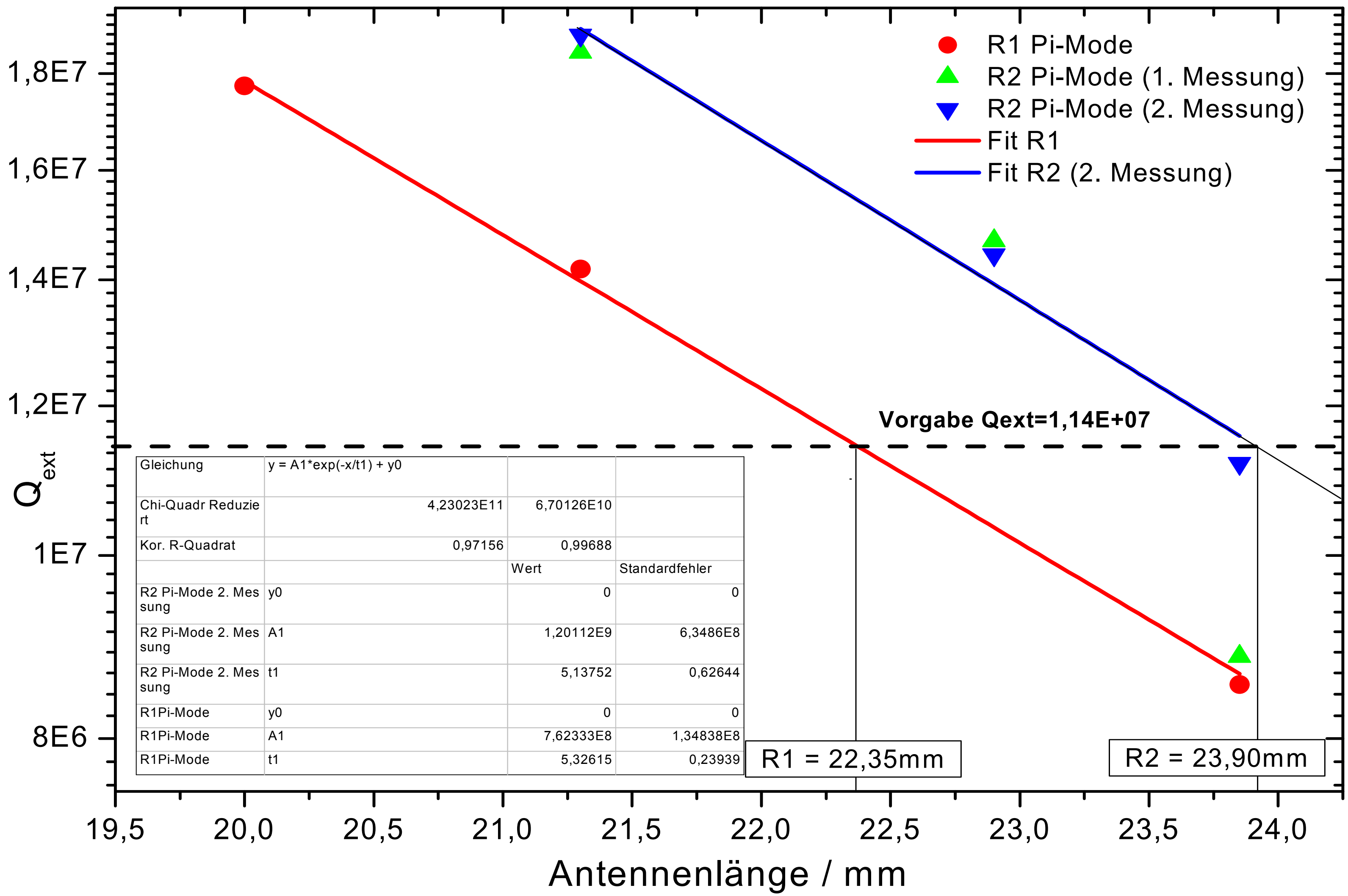


$$\beta_{FPC} = \frac{P_{FPC}}{P_d} = \frac{S_{21}^2}{1 - S_{11}^2 - S_{21}^2}$$

$$Q_{FPC} = \frac{Q_{0@RT}}{\beta_{FPC@RT}} = \frac{Q_{0@2K}}{\beta_{FPC@2K}}$$

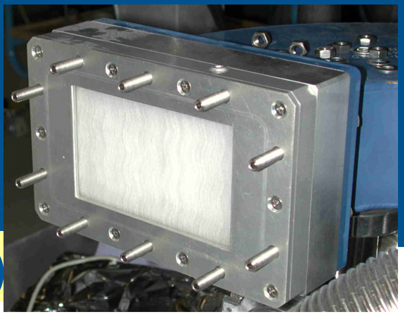
Warm Cavity Measurements

Optimal FPC coupling adjusted by antenna tip, done with RI



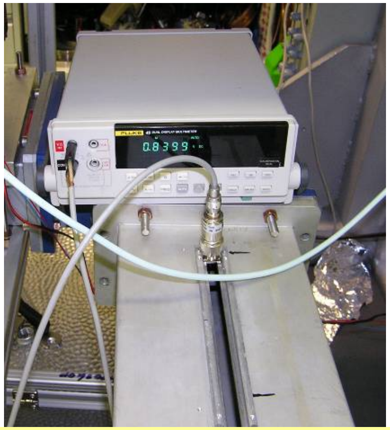
Gleichung	y = A1*exp(-x/t1) + y0		
Chi-Quadr Reduziert	4,23023E11	6,70126E10	
Kor. R-Quadrat	0,97156	0,99688	
		Wert	Standardfehler
R2 Pi-Mode 2. Messung	y0	0	0
R2 Pi-Mode 2. Messung	A1	1,20112E9	6,3486E8
R2 Pi-Mode 2. Messung	t1	5,13752	0,62644
R1Pi-Mode	y0	0	0
R1Pi-Mode	A1	7,62333E8	1,34838E8
R1Pi-Mode	t1	5,32615	0,23939

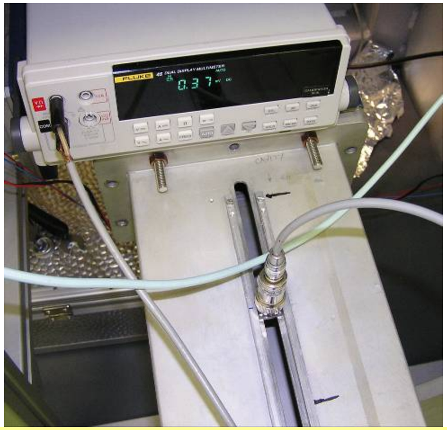
Position of the Waveguide Window (Warm window)

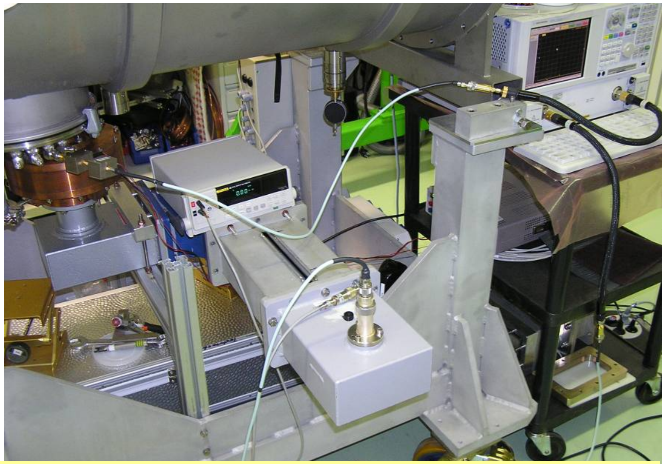


- Dielectric losses → warm window need to be in a voltage minimum
- During cooldown, coupling switched from weakly coupled ($\beta \ll 1$) to over coupled ($\beta \gg 1$) → standing wave in the waveguide moved by $\lambda_{guide}/4$
- Window position at max. voltage @ final waveguide setup
- Setup: NWA, 1.3 GHz Amp., slotted waveguide, detector diode, multimeter
- Distance between min. and max. is $\lambda_{guide}/4=8cm$

$$\lambda_{guide} = \lambda_{freespace} \frac{1}{\sqrt{1-\left(\frac{c}{2af}\right)^2}} \approx 32cm$$

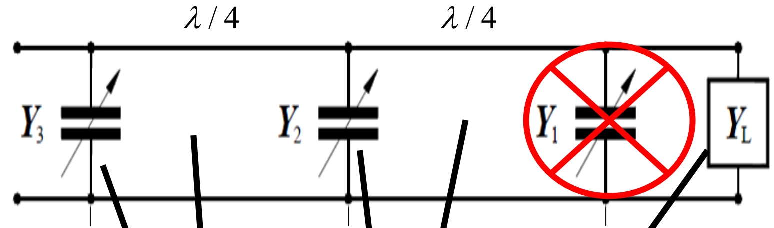






Position of the WG-window was optimized for abt.120 Hz cavity bandwidth

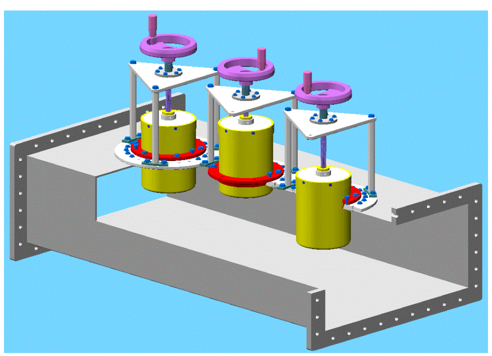
3-Stubtuner Impedance Matching is used to shift the cavity bandwidth

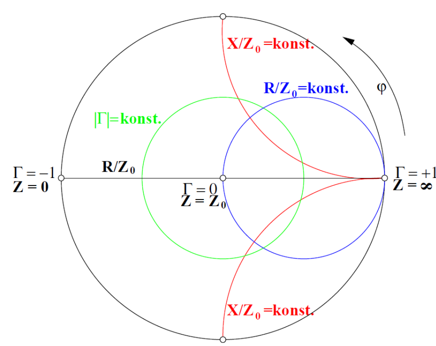


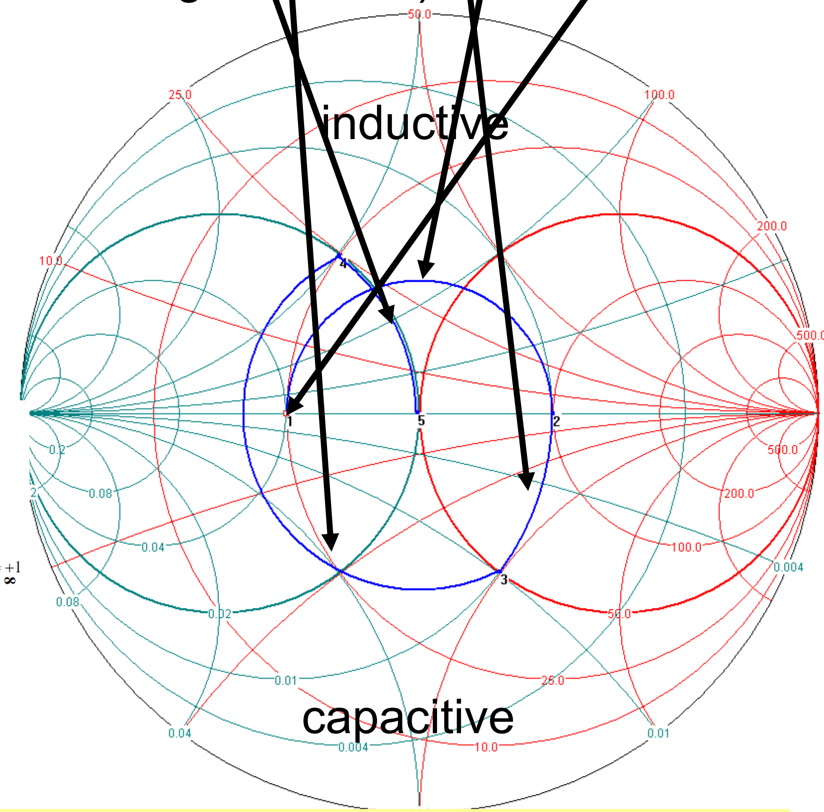
- Coupling factor of FPC is fixed e.g. 114 Hz (no moveable parts)
- To compensate mech. tolerances and to match the generator for different beam currents a matching network (3-stub waveguide tuner) is needed
- Example for twice the current:

$$Q_{HK} \approx \frac{V_{acc}}{2 \cdot 2 \cdot I_{beam} \cdot r_s}, \quad \beta_{HK} = 2\frac{Q_0}{Q_{HK}}, \quad BW = 2 f_0 / Q_L$$

- half the impedance seen by generator

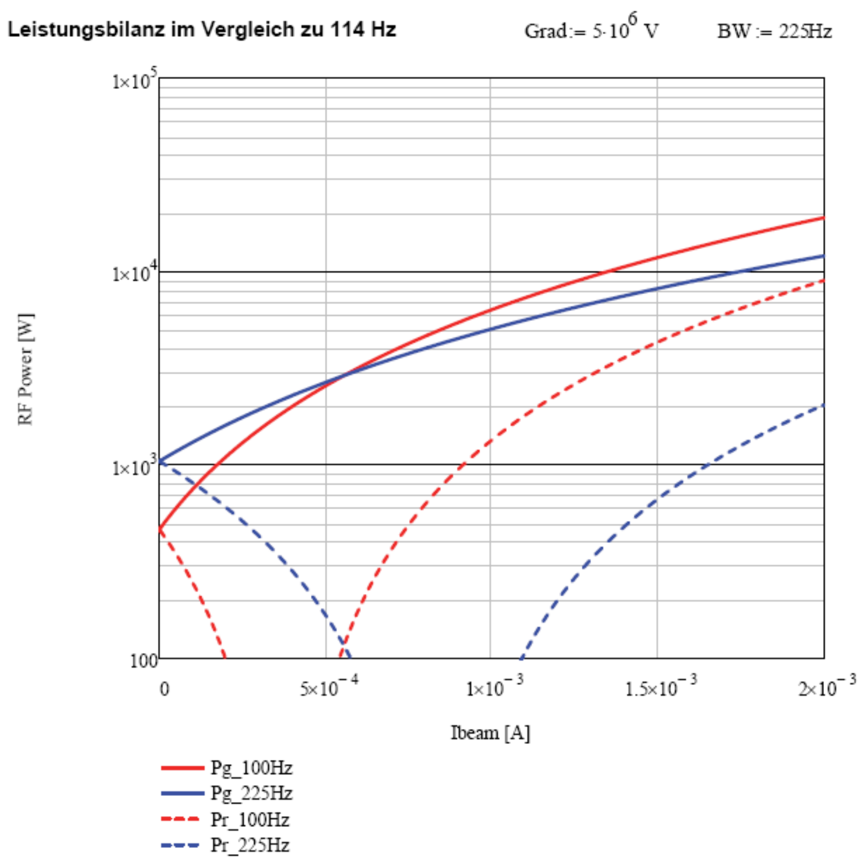




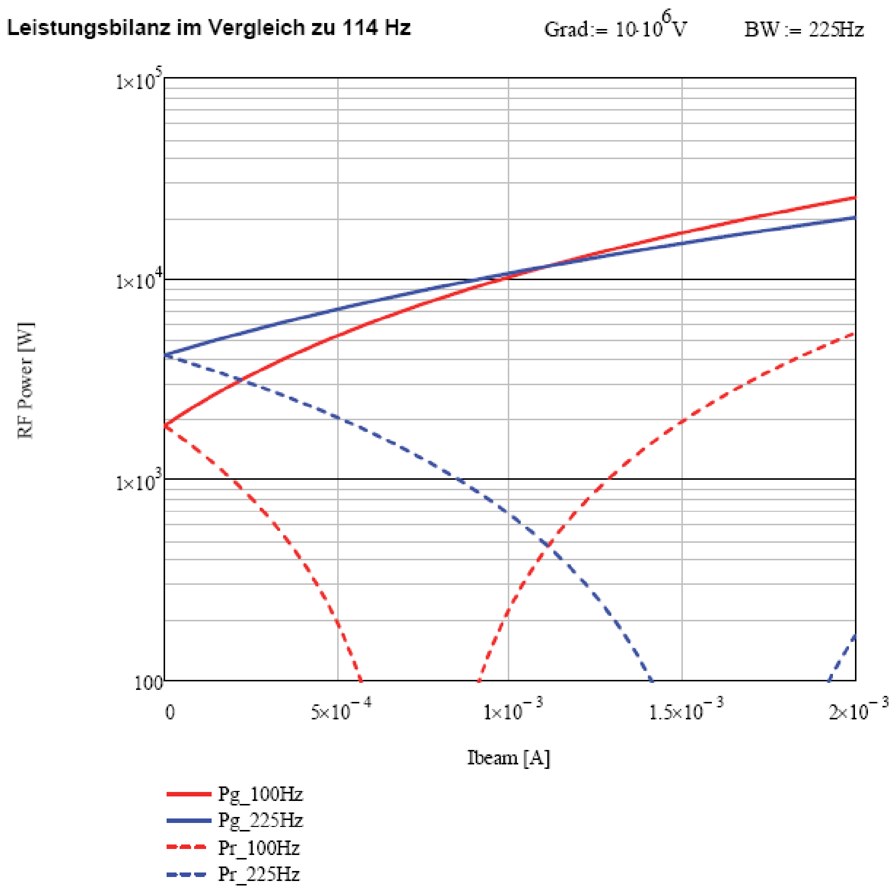


Problem: By changing the cavity bandwidth with the 3-Stubtuner one shifts the Standing wave pattern in the „WG-cavity“ between antenna and 3-Stubtuner !

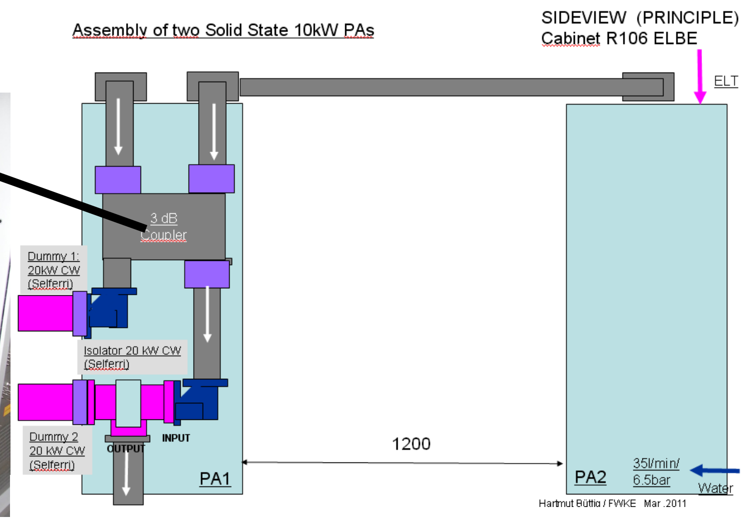
Gradient 5MV/m

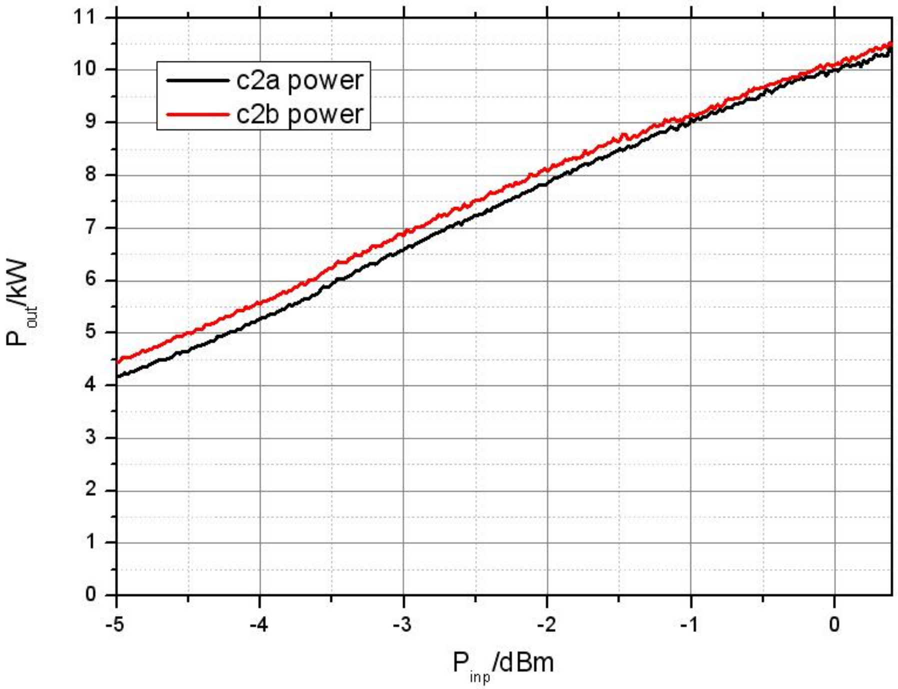


Gradient 10MV/m

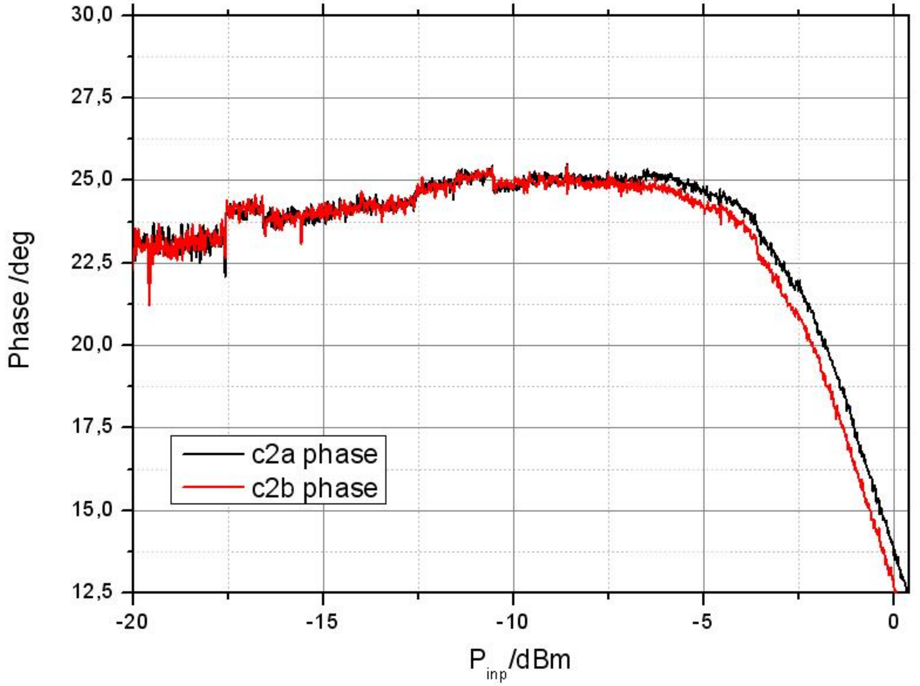


Matching the pairs of amplifiers



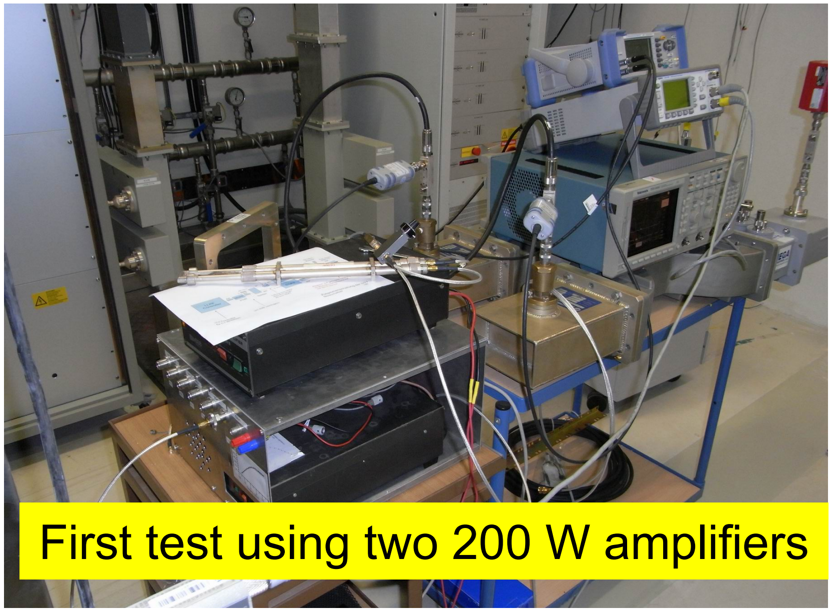


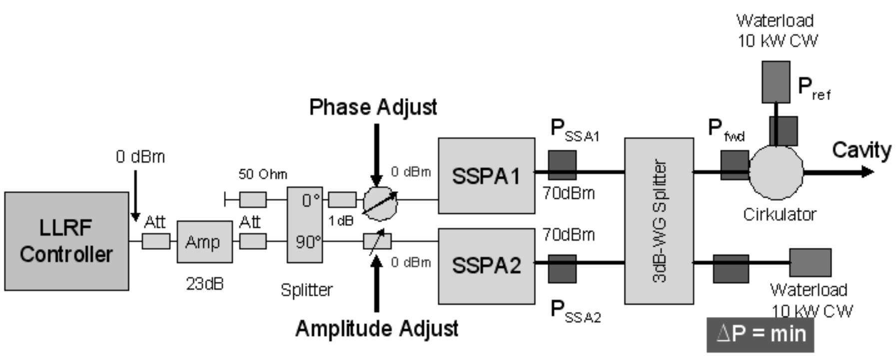
S_{21}

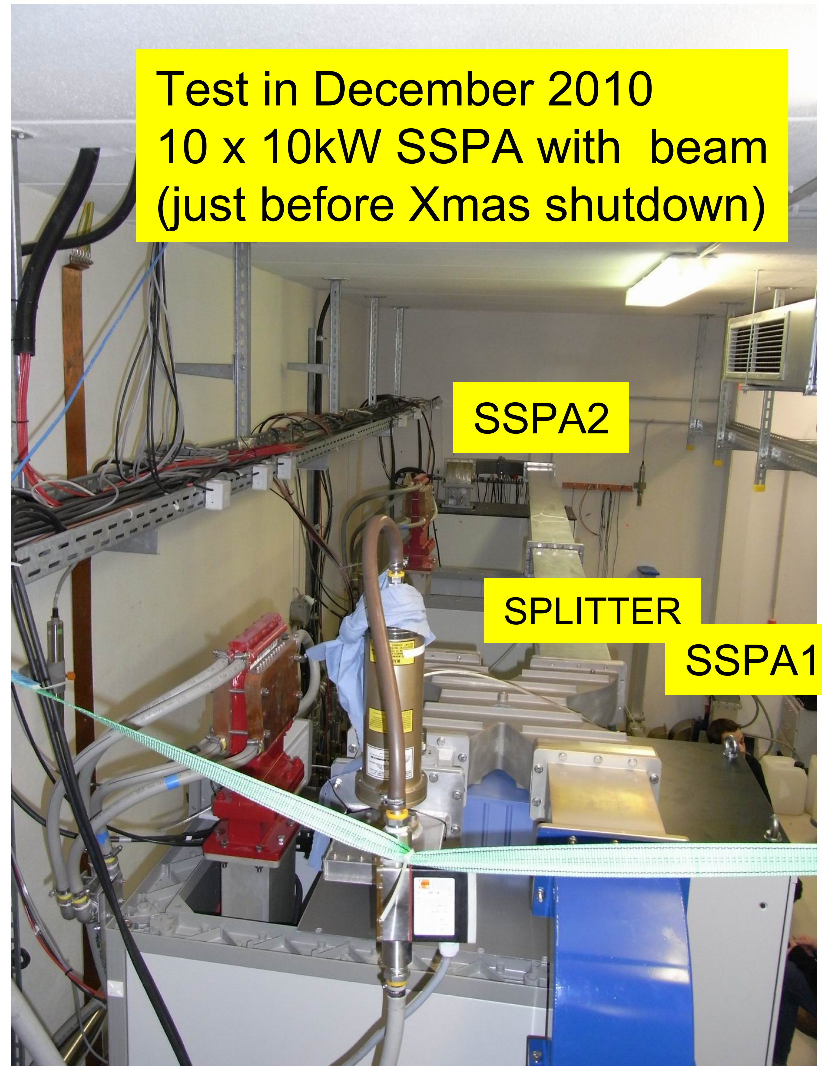


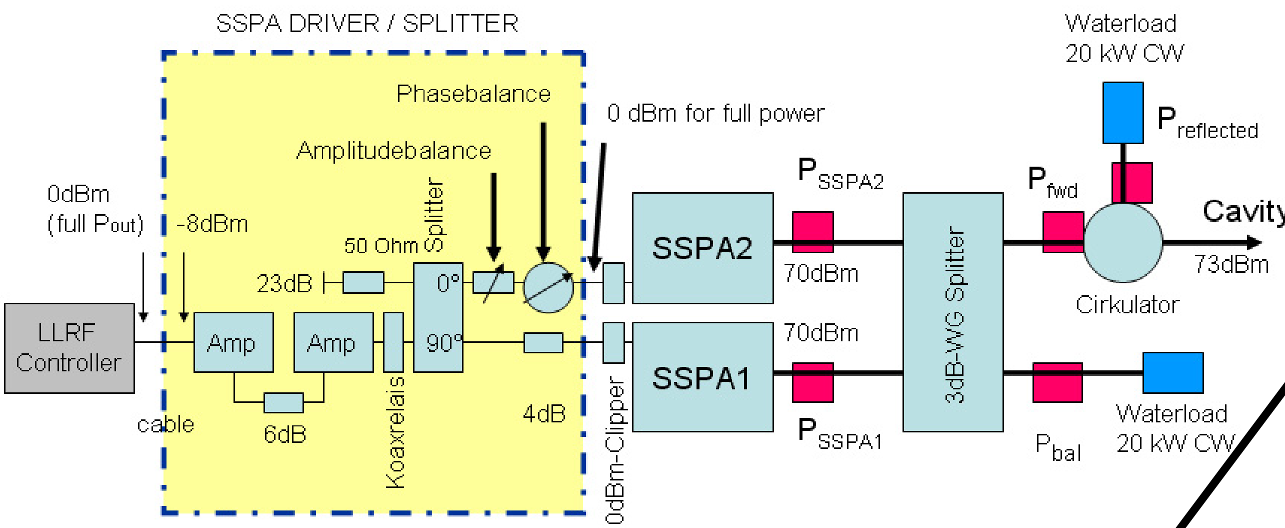
Phase

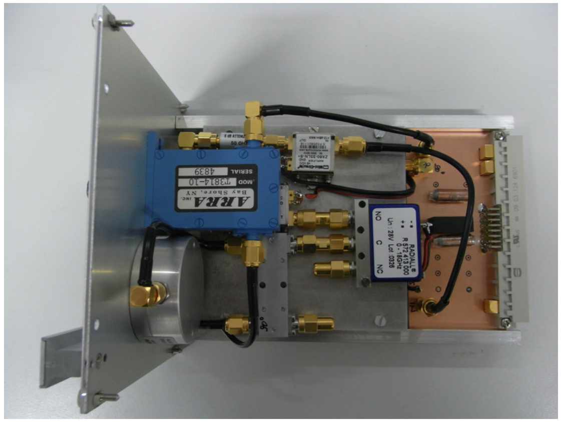
The pair off SSPA driving Cavity C2

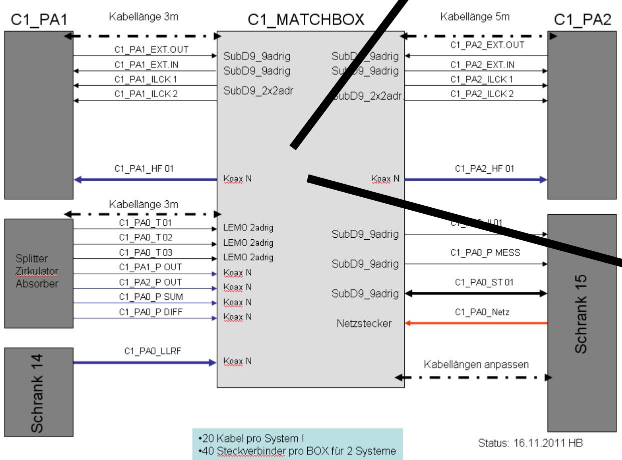

First test using two 200 W amplifiers

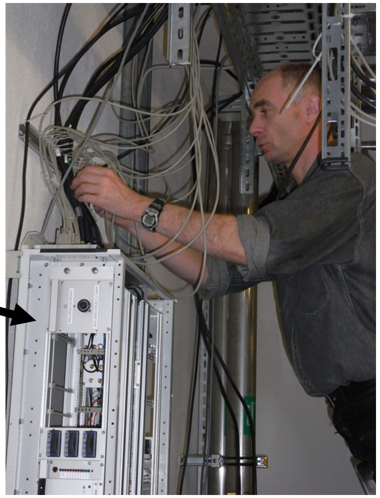

Waterload
10 KW CW
P_{ref}
Phase Adjust
P_{SSA1}
P_{fwd}
Cavity
0 dBm
50 Ohm
0 dBm
SSPA1
70dBm
3dB-WG Splitter
Cirkulator
LLRF Controller
Att
Amp
Att
0°
90°
1 dB
70dBm
0 dBm
SSPA2
23dB
Splitter
Amplitude Adjust
P_{SSA2}
Waterload
10 KW CW
ΔP = min

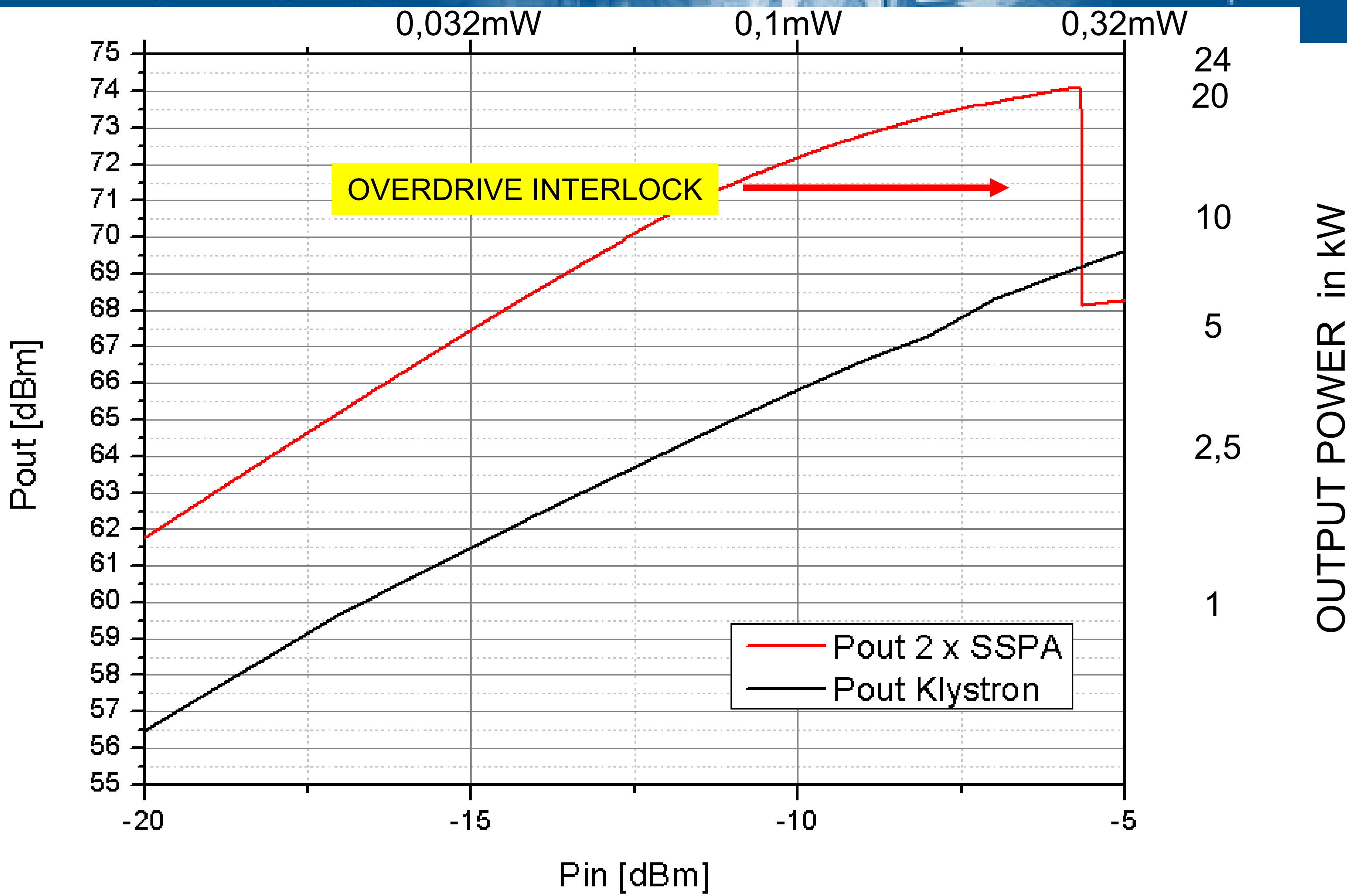

Test in December 2010
10 x 10kW SSPA with beam
(just before Xmas shutdown)
SSPA2
SPLITTER
SSPA1


SSPA DRIVER / SPLITTER
Phasebalance
Amplitudebalance
0 dBm for full power
0dBm
(full Pout)
-8dBm
50 Ohm
Splitter
23dB
0°
90°
LLRF
Controller
Amp
Amp
cable
6dB
Koaxrelais
4dB
0dBm-Clipper
SSPA2
SSPA1
70dBm
70dBm
P SSPA2
P SSPA1
3dB-WG Splitter
P fwd
P bal
Waterload
20 kW CW
P reflected
Cavity
73dBm
Cirkulator
Waterload
20 kW CW




C1_PA1
Kabellänge 3m
C1_MATCHBOX
Kabellänge 5m
C1_PA2
C1_PA1_EXT.OUT
C1_PA1_EXT.IN
C1_PA1_ILCK 1
C1_PA1_ILCK 2
SubD9_9adrig
SubD9_9adrig
SubD9_2x2adr
C1_PA2_EXT.OUT
C1_PA2_EXT.IN
C1_PA2_ILCK 1
C1_PA2_ILCK 2
C1_PA1_HF 01
Koax N
Koax N
C1_PA2_HF 01
Kabellänge 3m
Splitter
Zirkulator
Absorber
C1_PA0_T 01
C1_PA0_T 02
C1_PA0_T 03
C1_PA1_P OUT
C1_PA2_P OUT
C1_PA0_P SUM
C1_PA0_P DIFF
LEMO 2adrig
LEMO 2adrig
LEMO 2adrig
Koax N
Koax N
Koax N
Koax N
SubD9_9adrig
SubD9_9adrig
SubD9_9adrig
Netzstecker
C1_PA0_P MESS
C1_PA0_ST 01
C1_PA0_Netz
Schrank 15
Schrank 14
C1_PA0_LLRF
Koax N
Kabellängen anpassen
•20 Kabel pro System !
•40 Steckverbinder pro BOX für 2 Systeme
Status: 16.11.2011 HB




0,032mW
0,1mW
0,32mW
75
74
73
72
71
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
Pout [dBm]
24
20
10
5
2,5
1
OUTPUT POWER in kW
OVERDRIVE INTERLOCK
Pout 2 x SSPA
Pout Klystron
-20
-15
-10
-5
Pin [dBm]

INPUT POWER

Thank you !