Keine Angst vor hohen Frequenzen

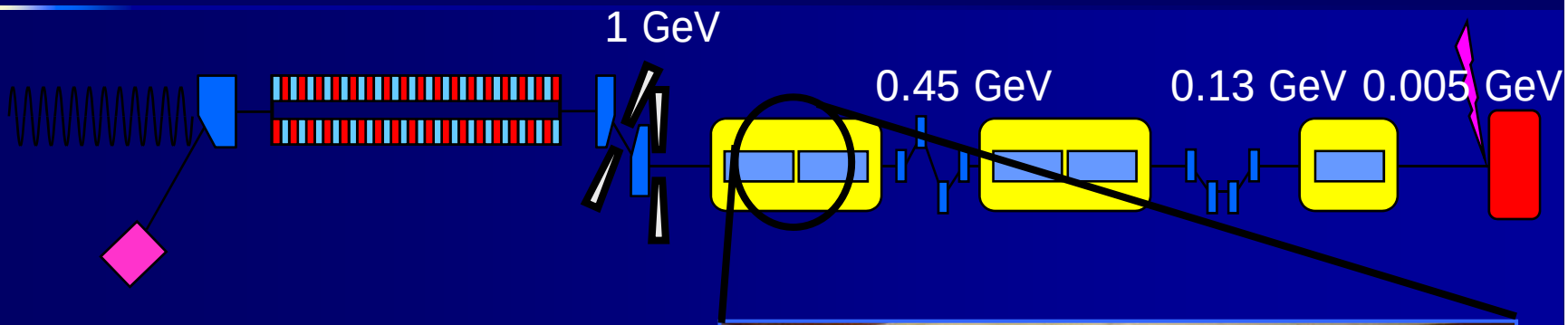
Markus Hüning

Schichtgängerausbildung 2007

Überblick

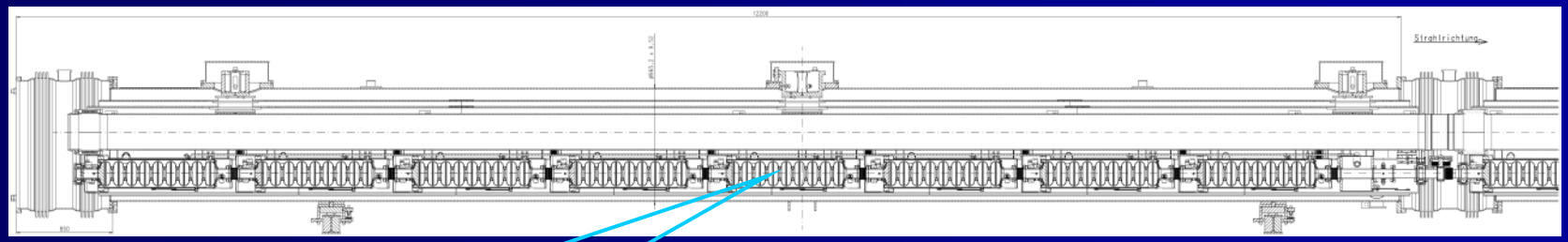
- FLASH
- Beschleunigungsmodule
- Überblick über unsere Cavities
- Die HF-Einkoppler
- Allgemeines zur HF-Erzeugung
- HF-HP-HV: Die HF-Stationen
- LLRF: Kleine Pegel grosse Wirkung
- Bedienung
- Bilder

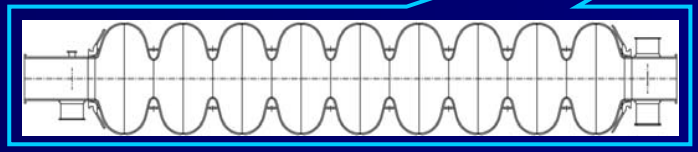
FLASH

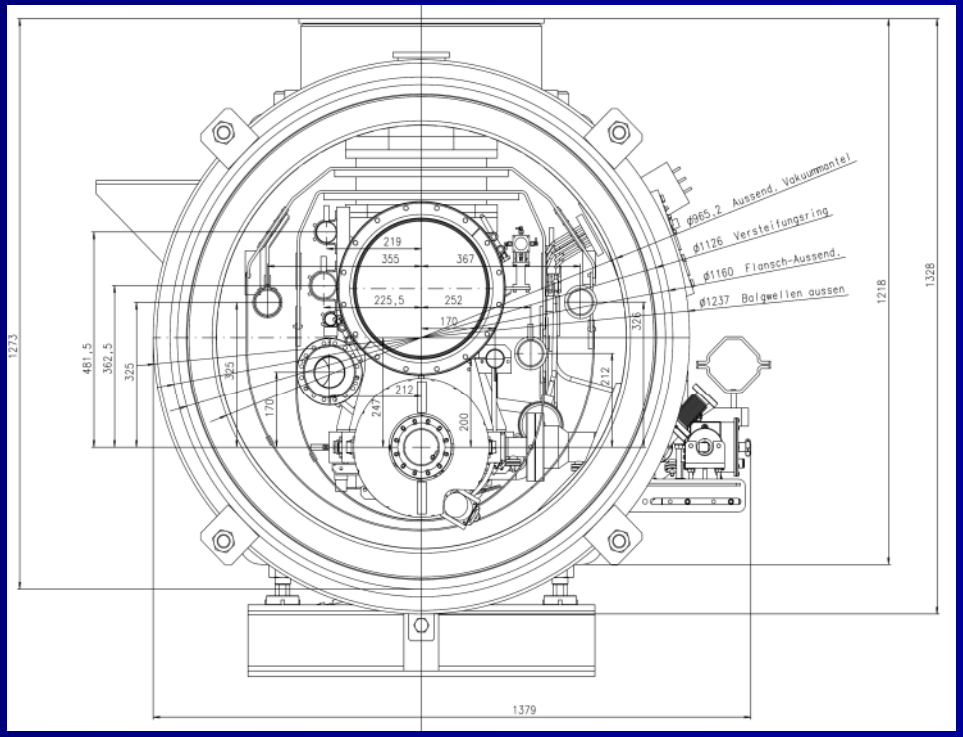


6 Kryomodule mit je 8 Cavities zur Beschleunigung der Elektronen
Gesamtenergie bis zu 1 GeV $\rightarrow$ 6.5nm FEL
100x bessere Auflösung als mit sichtbarem Licht
Strahlleistung 1MW (peak) bzw 10kW (avg)

Innenleben eines Moduls







Number of cavities	8
Cavity length	1.038 m
Operating frequency	1.3 GHz
R/Q	1036 Ω
Operating temperature	2 K
Accelerating Gradient	23..35 MV/m
Quality factor	10^{10}
Q_{ext} (input coupler)	3×10^6

(D. Kostin, MHF-SL)

ACCELERATING CAVITIES

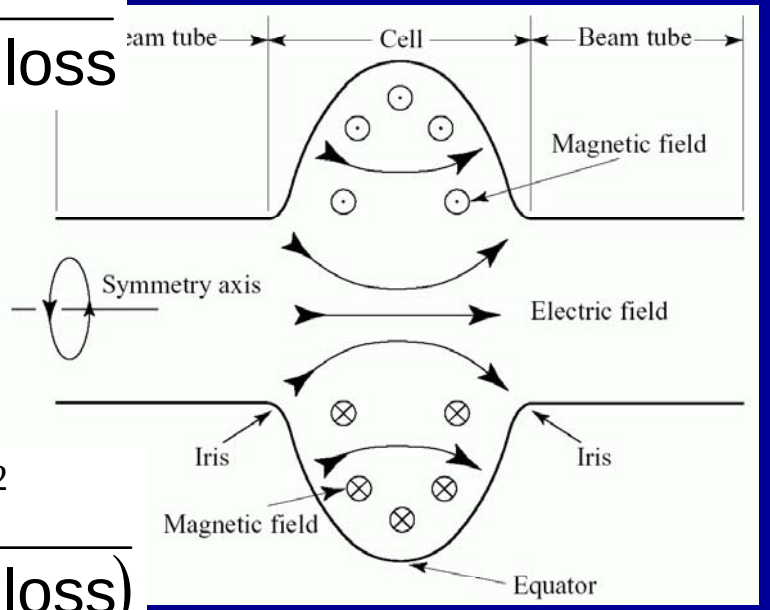
1.Quality factor

$$Q_0 = 2\pi f_0 \frac{\text{stored energy}}{\text{time - averaged power loss}}$$

$$Q_0 = 2\pi \frac{\text{stored energy}}{\text{energy lost per cycle}}$$

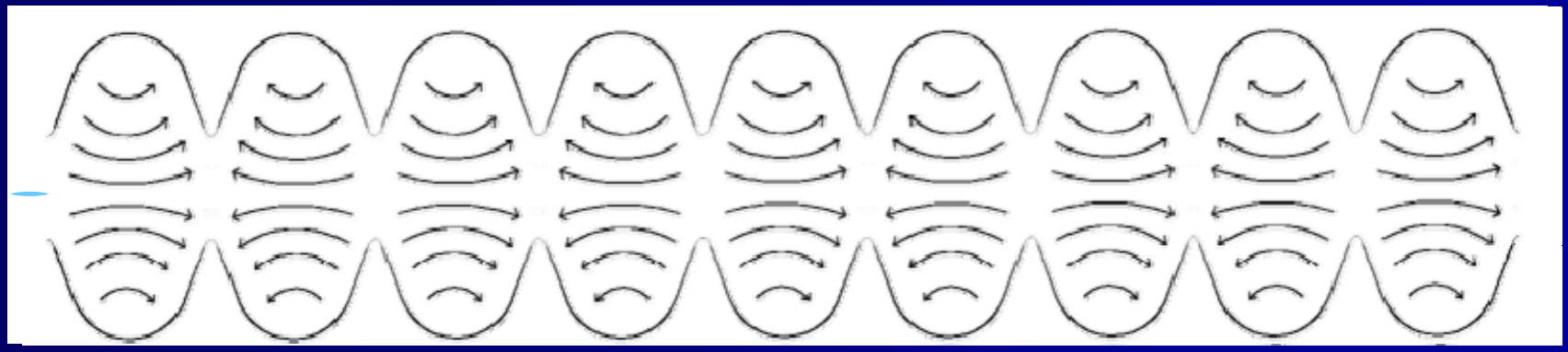
1.Shunt impedance

$$R_{sh} = \frac{(\text{accelerating voltage})^2}{2 \times (\text{time - averaged power loss})}$$

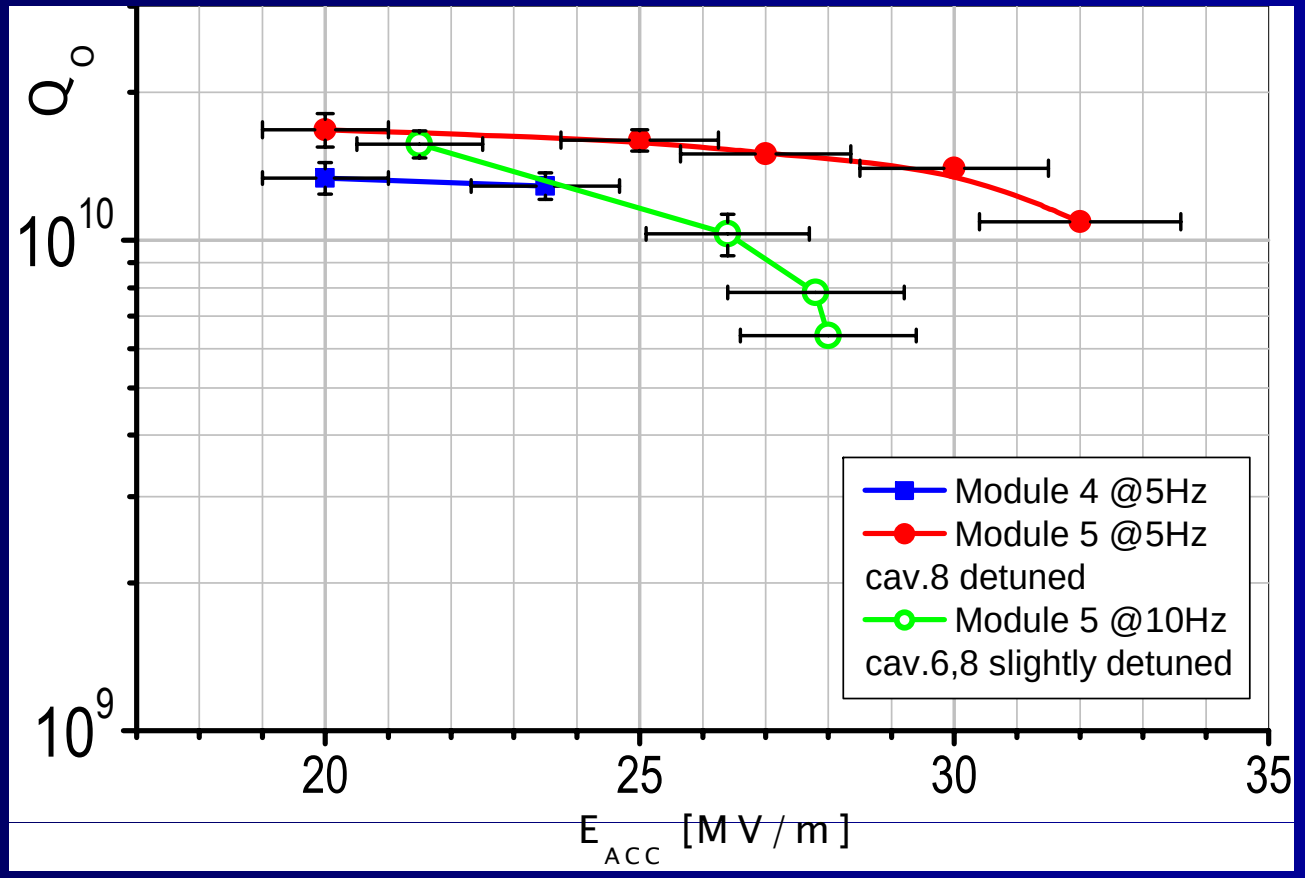


9-Cell Cavity

9 Zellen
1.3 GHz
Π-Mode
R/Q 520 Ω

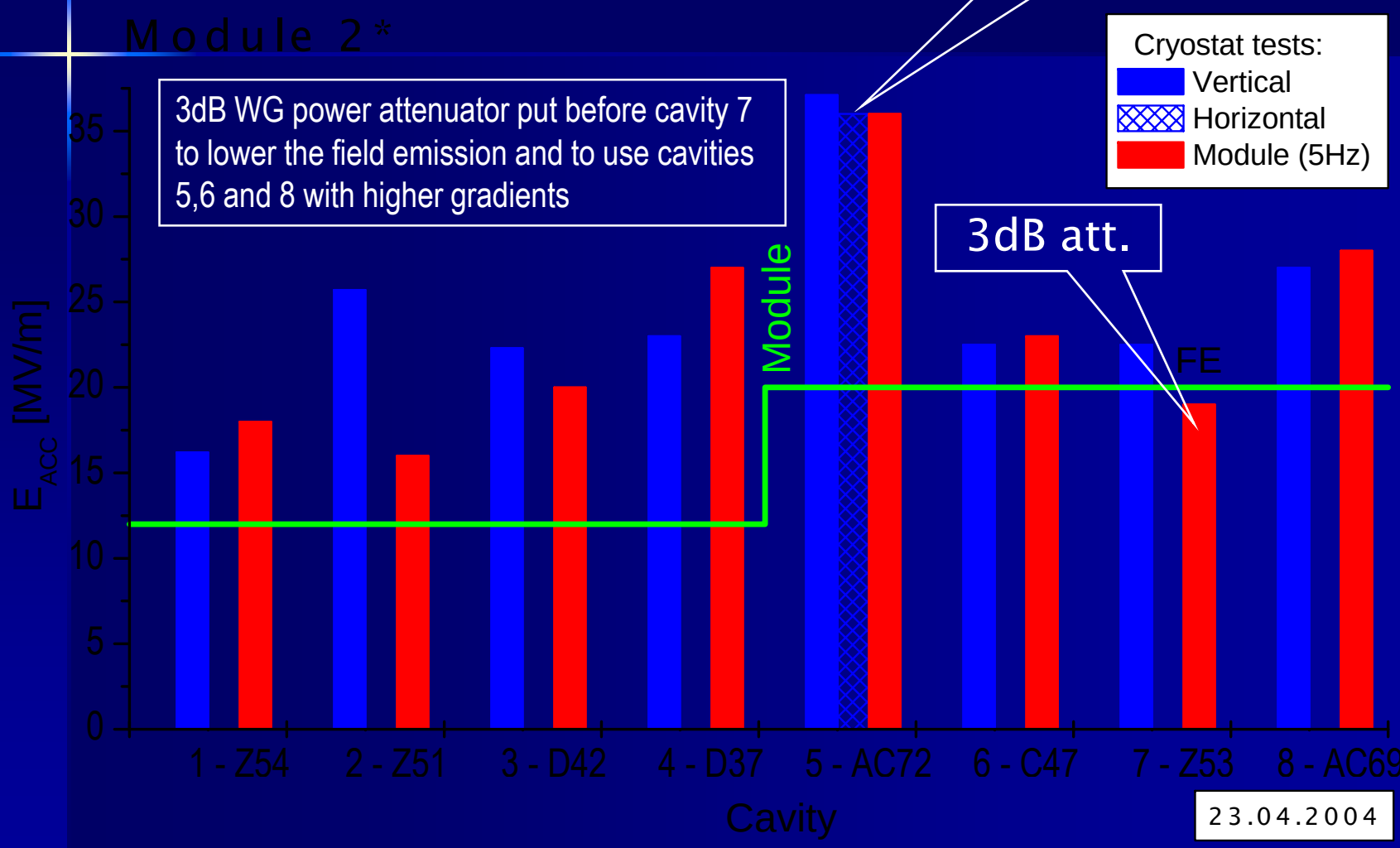


Cavity Messungen



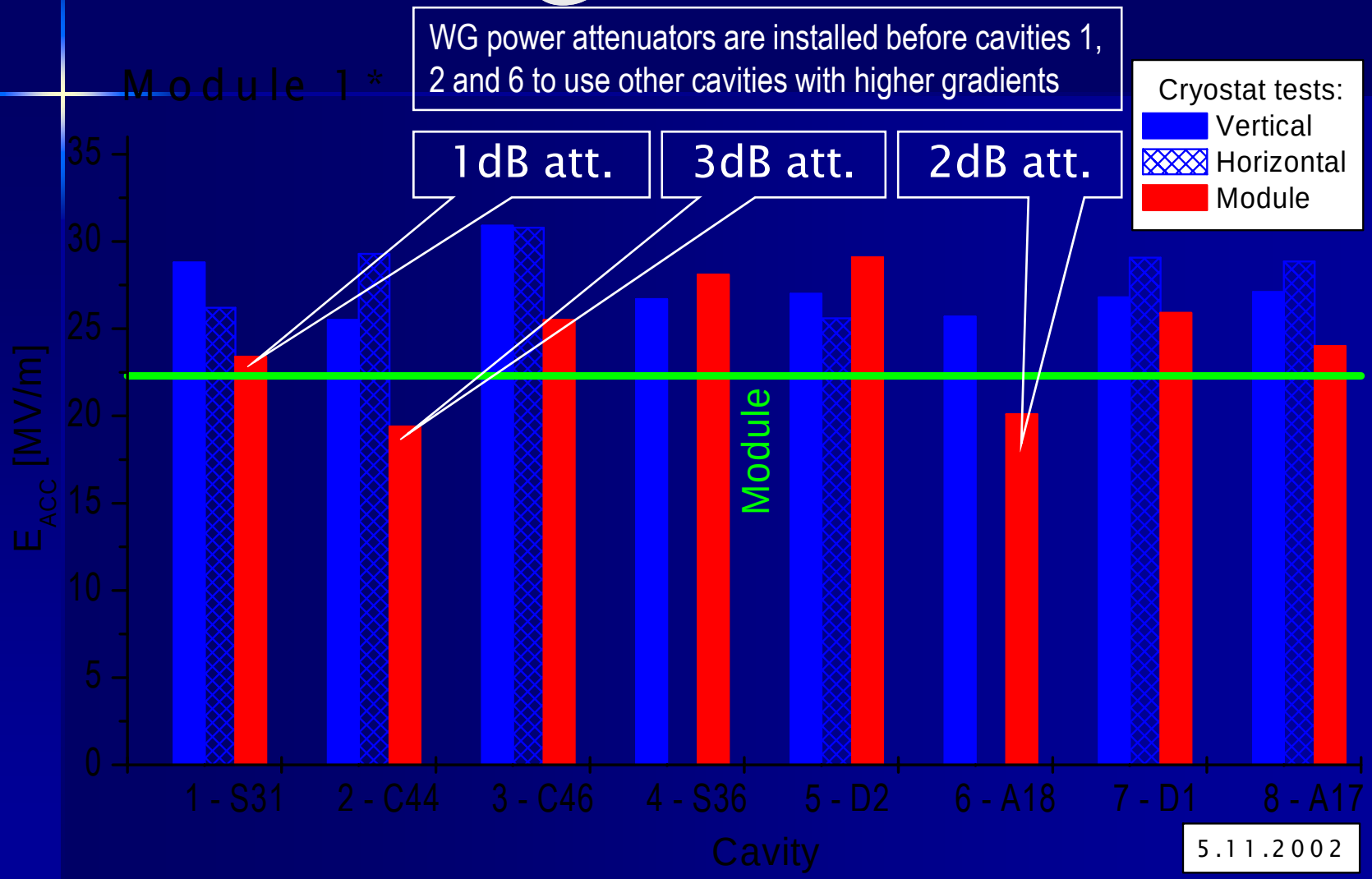
D. Kostin

Cavities @ ACC1



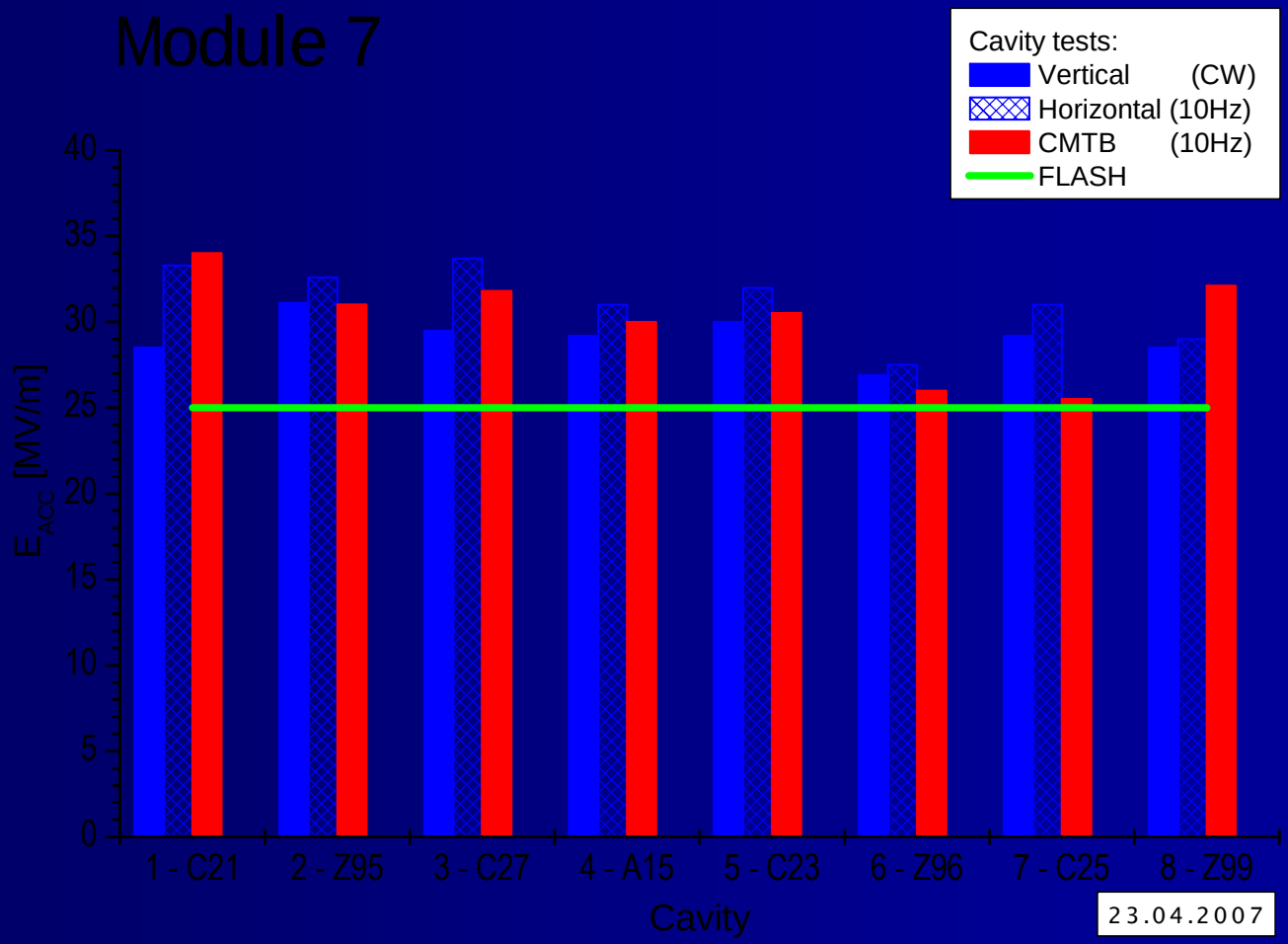
D. Kostin, MHF-SL

Cavities @ ACC2



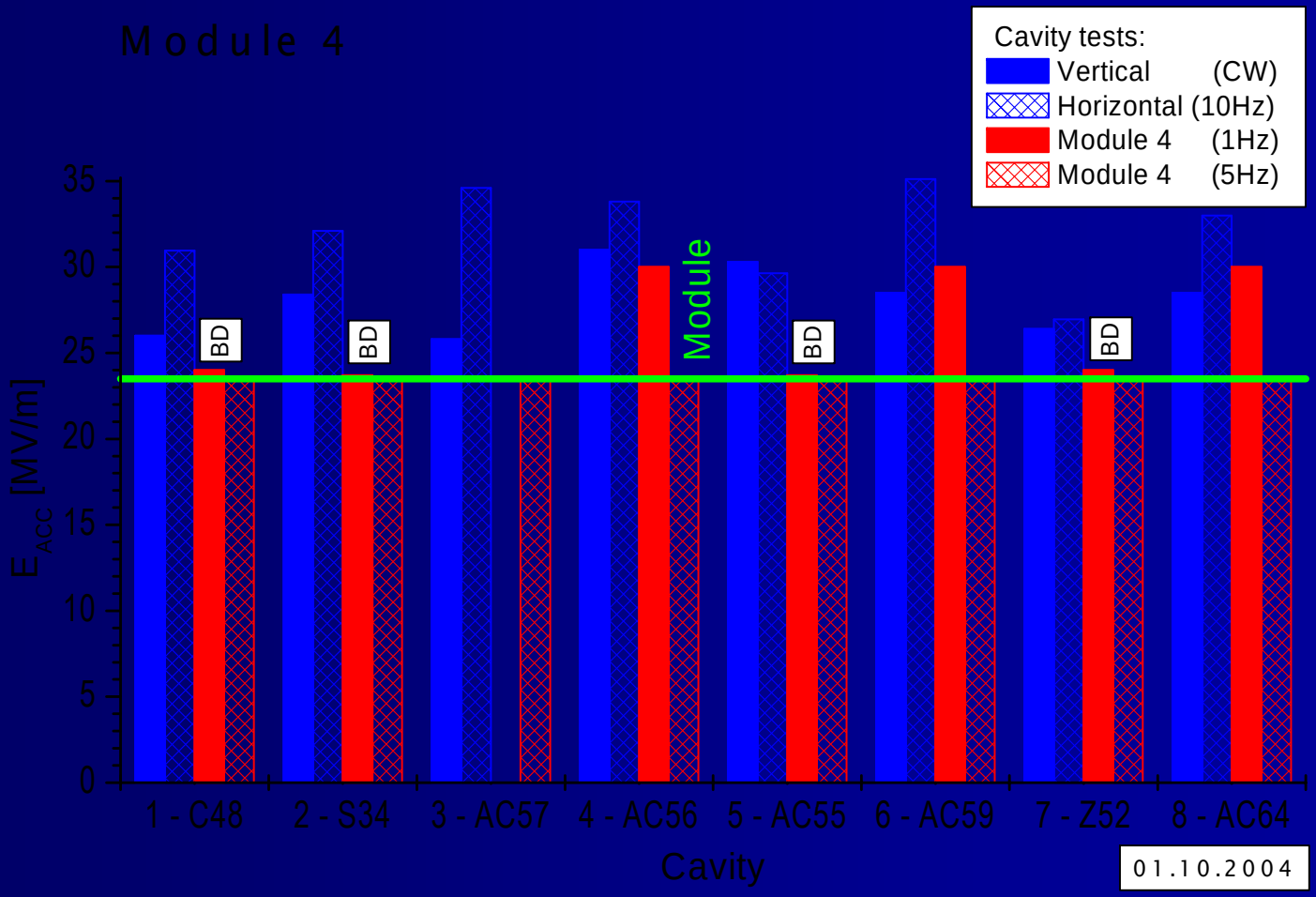
D. Kostin, MHF-SL

Cavities @ ACC3



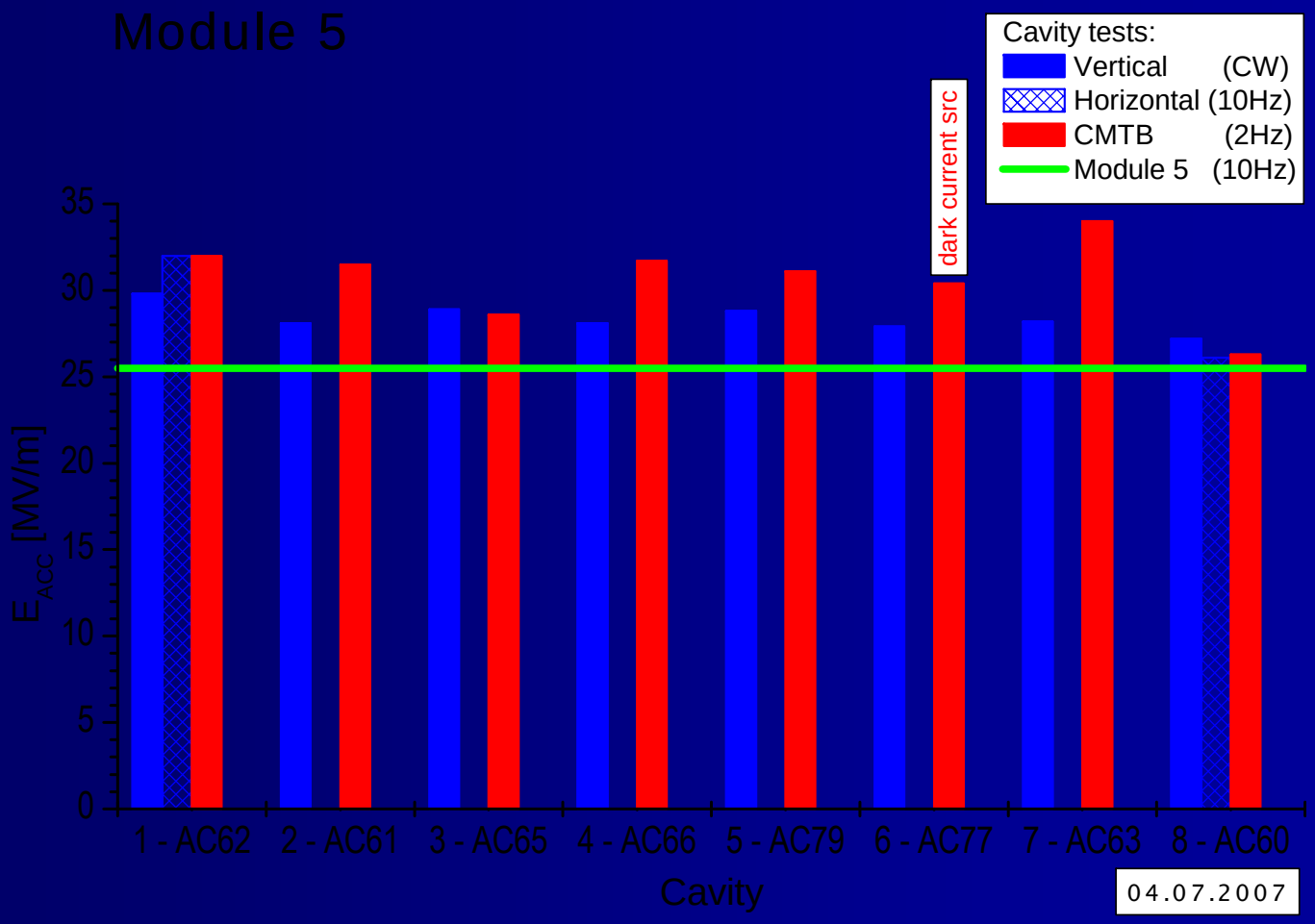
D. Kostin, MHF-SL

Cavities @ ACC4



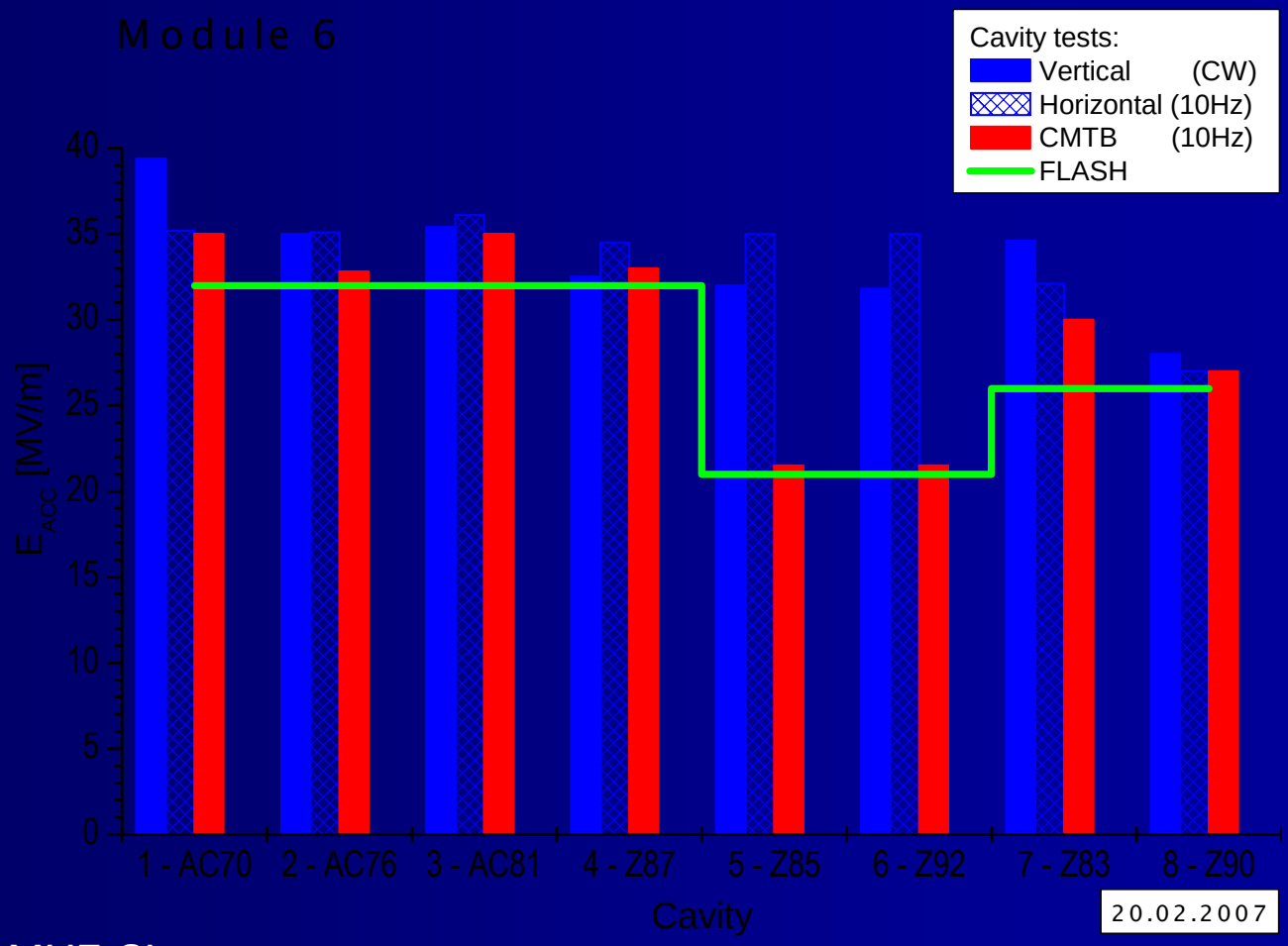
D. Kostin, MHF-SL

Cavities @ ACC5



D. Kostin, MHF-SL

Cavities @ ACC6

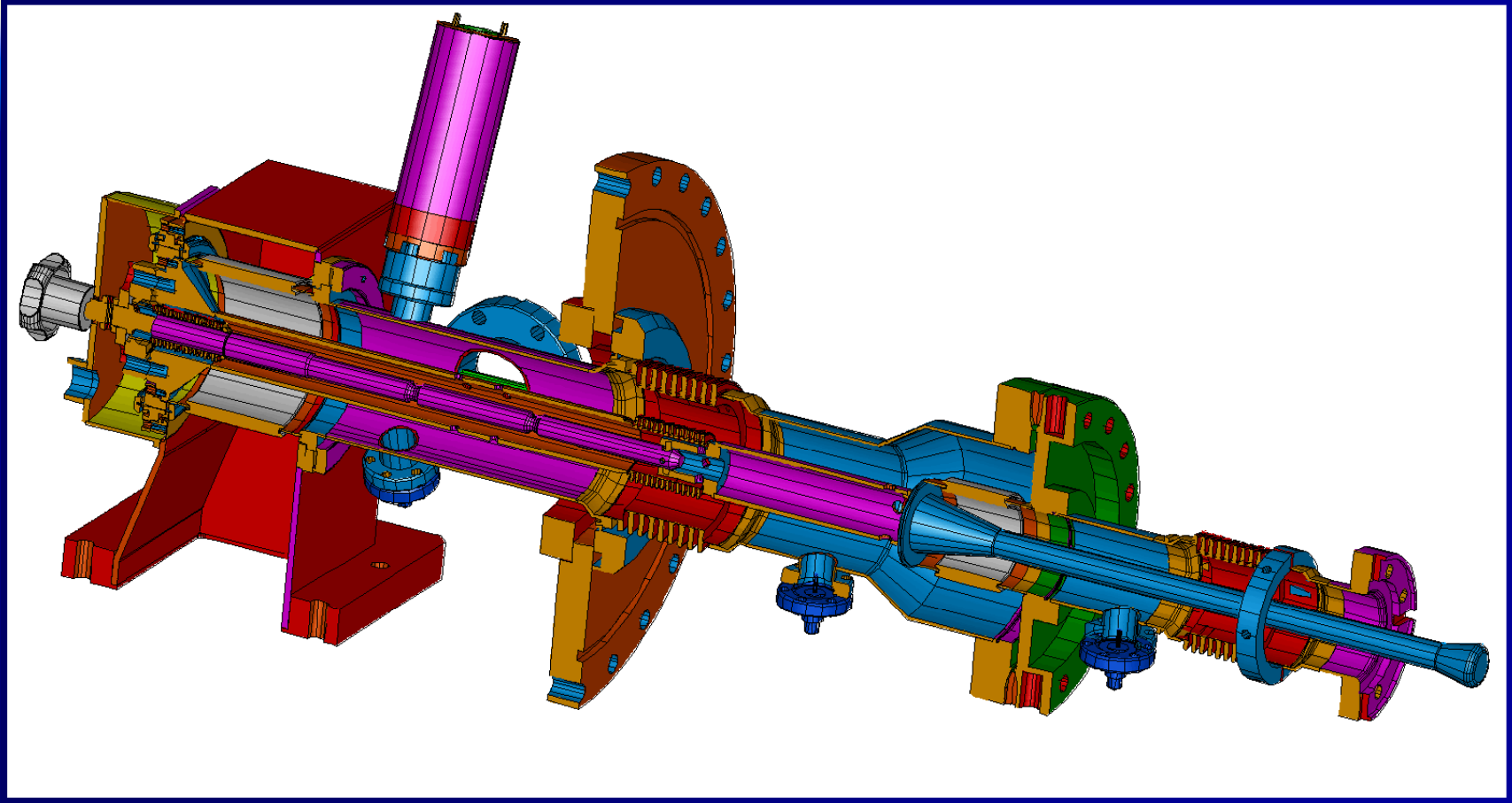


D. Kostin, MHF-SL

Situation in FLASH

module	cavity	E_{acc} [MV/m]	attenuator [dB]	comment
ACC1	1, 2, 3, 4	13	—	capture section, lower gradient
	5, 6, 8	20	—	
	7	14	3	too high FE
ACC2	3, 4, 5, 7, 8	23	—	limited at 24 .. 25 MV/m
	1	21	1	quench
	2	16	3	quench
	6	18	2	quench
ACC3	1 ... 8	25	—	limited at 25.5 MV/m
ACC4	1 ... 8	23	—	limited at 23.5 MV/m
ACC5	1 ... 8	25	—	limited at 26.0 MV/m
ACC6	1 ... 4	32	XFEL type RF power distribution	limited at 33.0 MV/m
	5, 6	21		limited at 22.0 MV/m
	7, 8	26		limited at 27.0 MV/m

TTF III Coupler



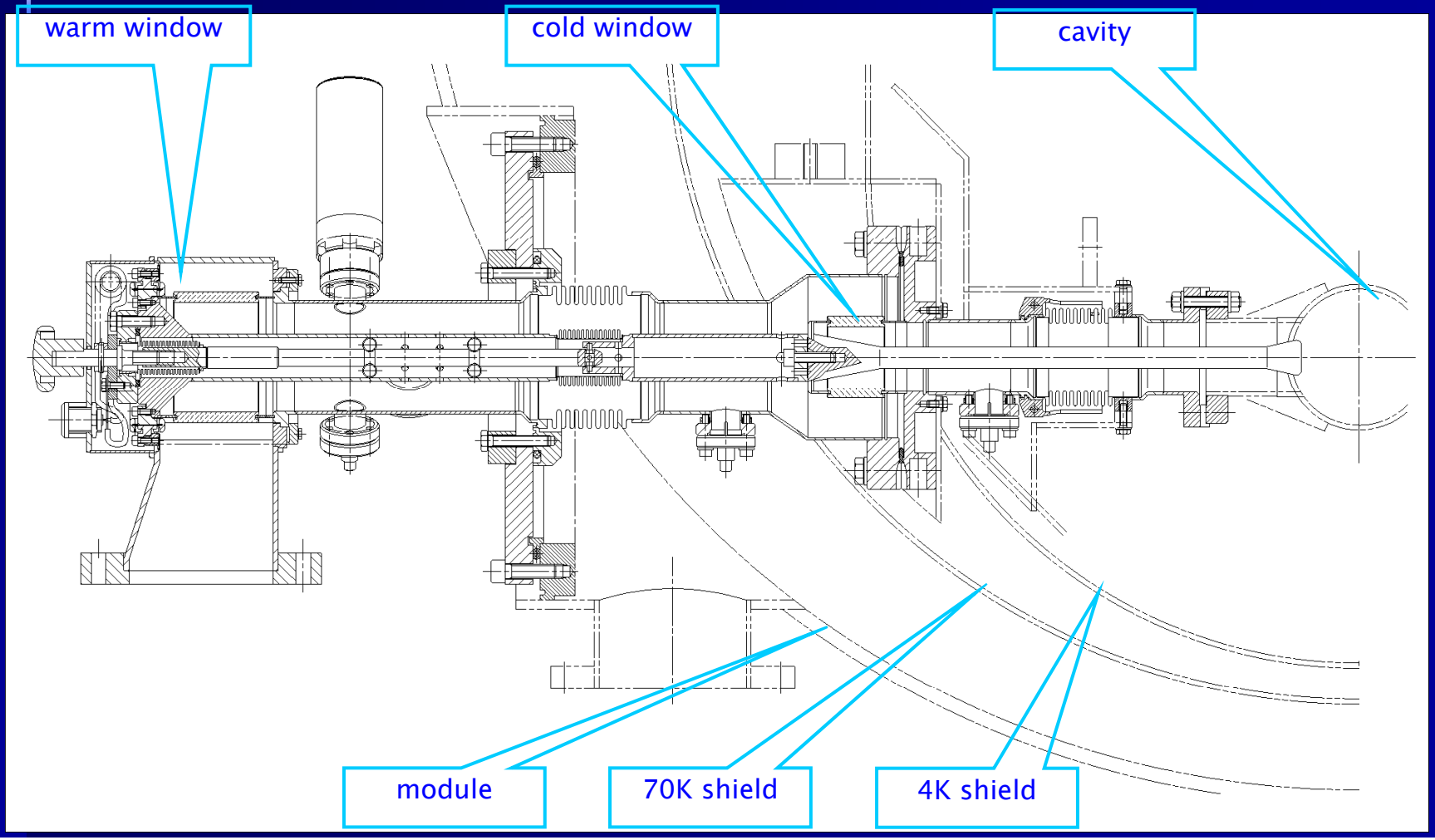
Einkoppler

Schwierigkeiten:
- HF-Einkopplung
- Kalt-Warm-Übergang
- Vakuumtrennung
- mech. Bewegung beim Abkühlen
- ...

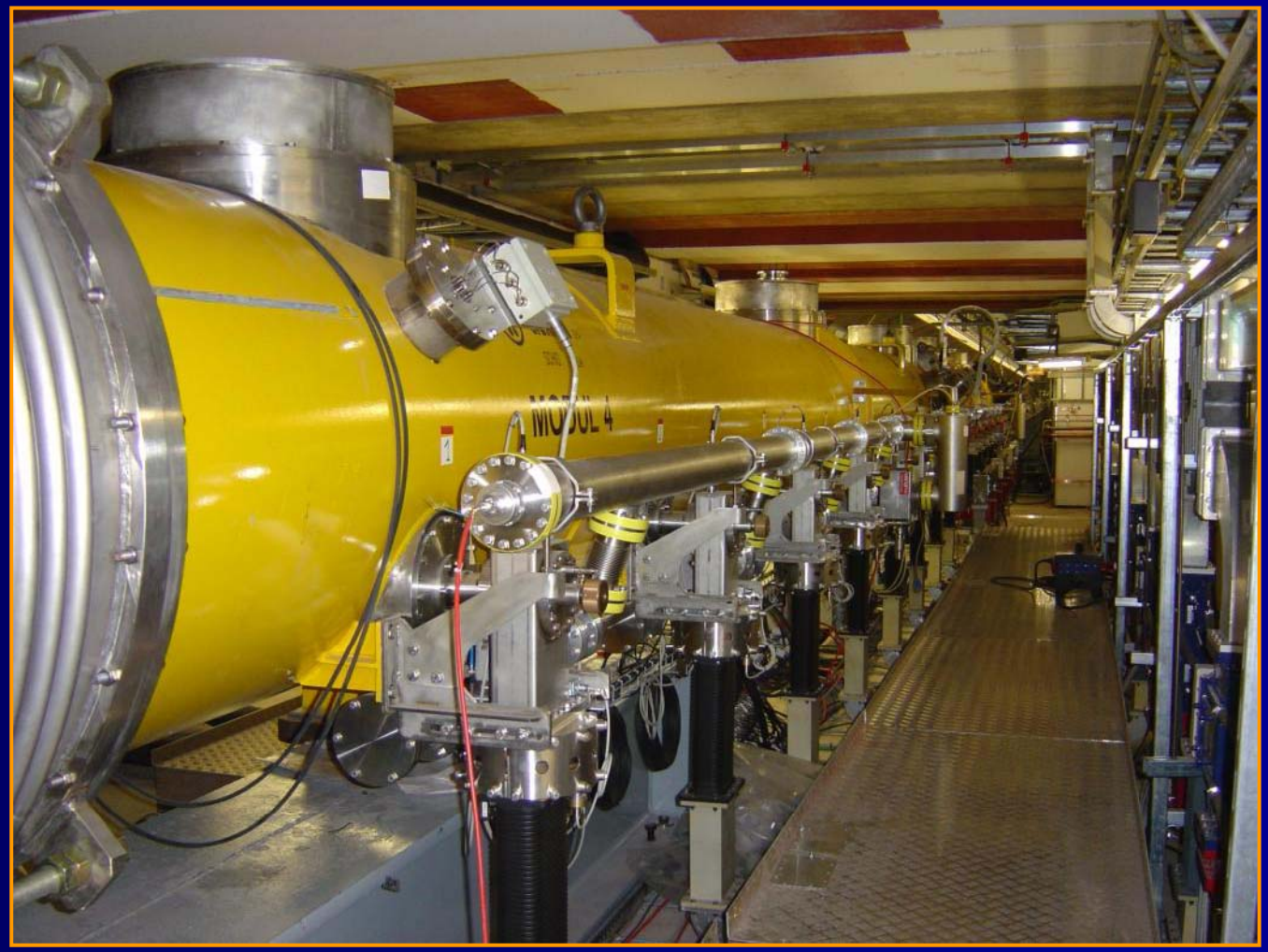
frequency	1.3 GHz
operation	pulsed: 500 µsec risetime, 800 µsec flat top with beam
two windows, TiN coated	■ safe operation ■ clean cavity assembly for high Eacc
2 K heat load	0.06 W
4 K heat load	0.5 W
70 K heat load	6 W
isolated inner conductor	bias voltage, suppressing multipacting
diagnostic	sufficient for safe operation and monitoring

	TTF	**TESLA** 9cell / upgrade	**XFEL**
Peak power + control margin	250 kW	250 kW / 500 kW	150 kW
Repetition rate	10 Hz	5 Hz	10 Hz
Average power	3.2 kW	3.2 kW / 6.4 kW	1.9 kW
Coupling (Qext)	adjustable (10^6 - 10^7)	fixed ($3*10^6$)	adjustable (10^6 - 10^7)

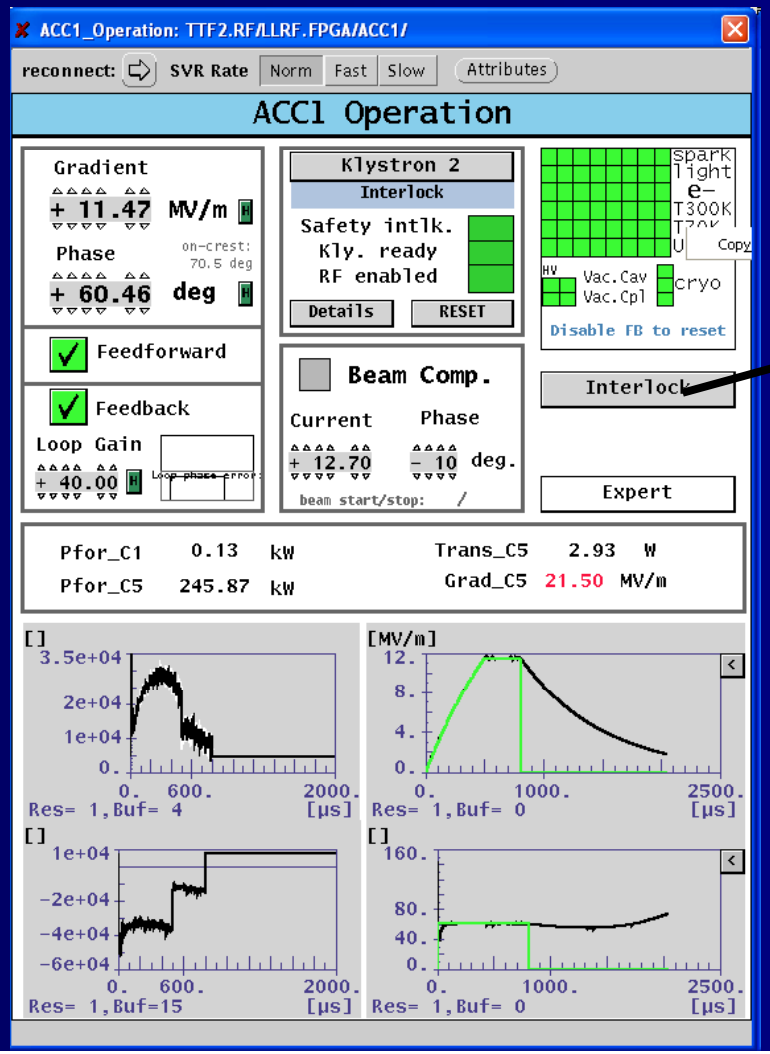
Schnittzeichnung

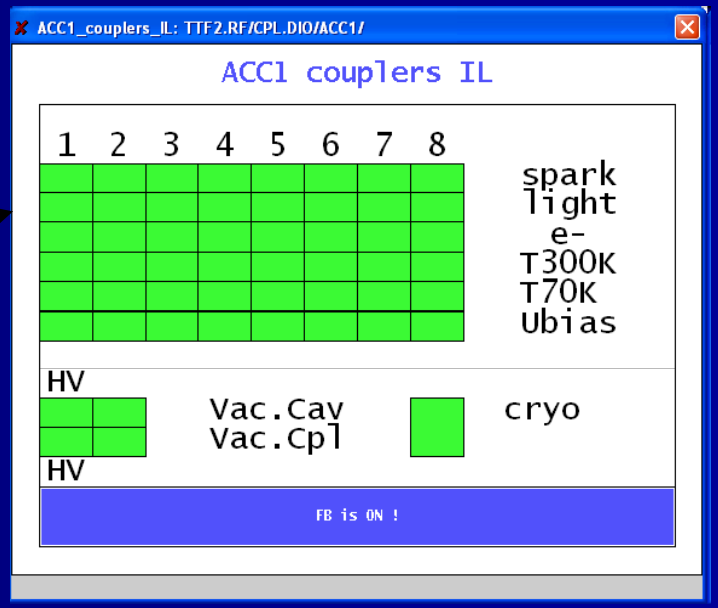


Im Tunnel



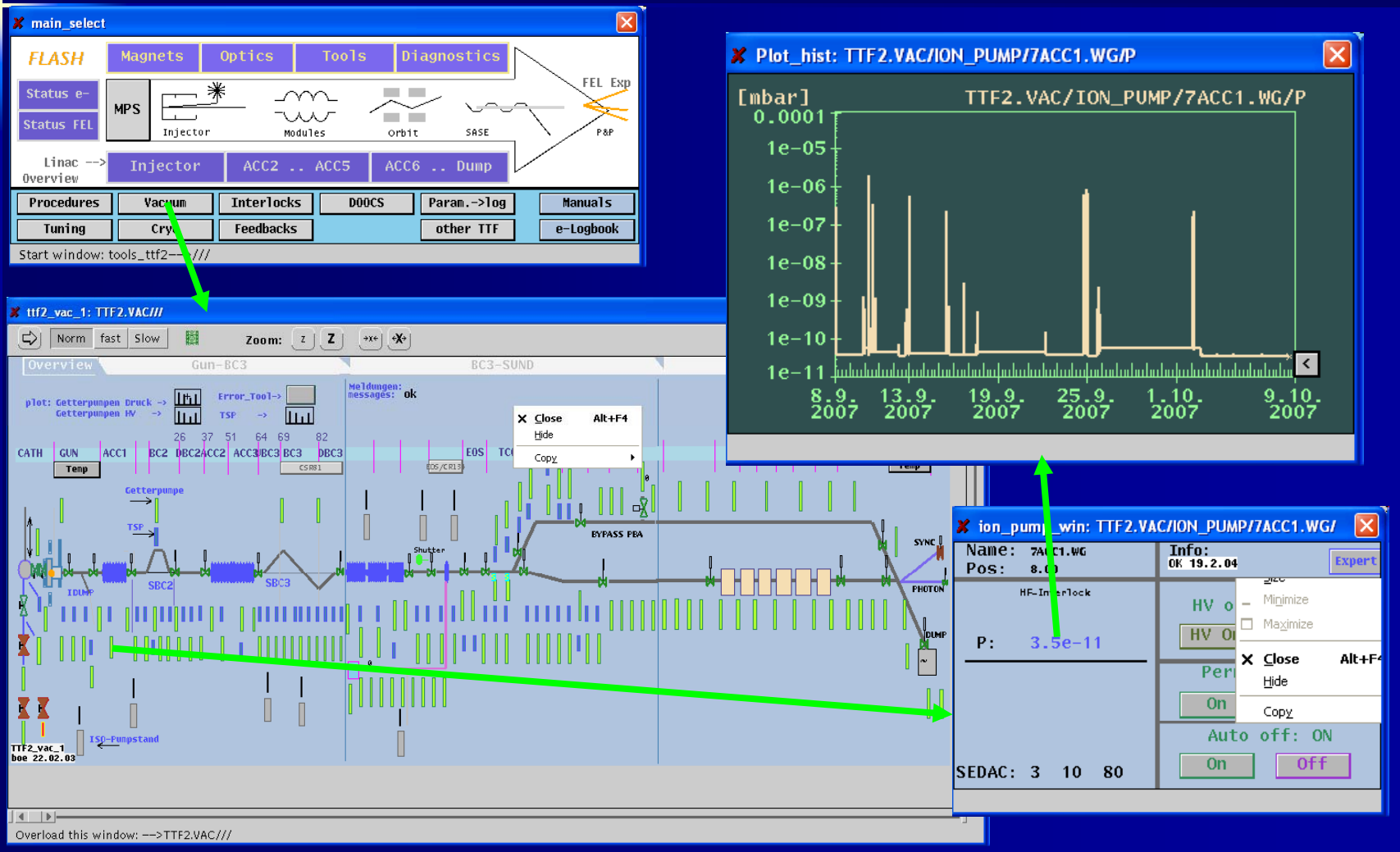
In DOOCS





Feedback MUSS AUS sein,
bevor RESET gedrückt wird

Vakuumanzeige

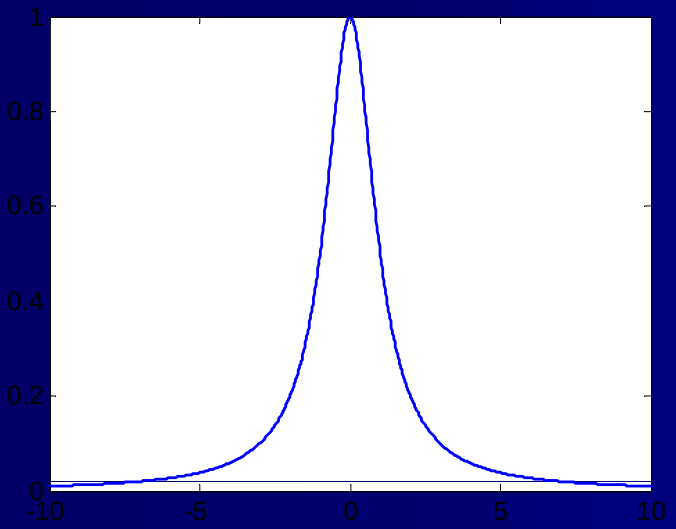


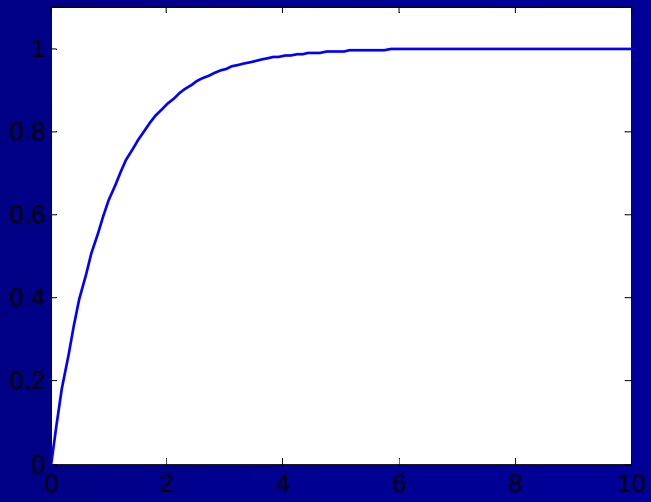
Resonanzkurve

Güte:

$$Q = \frac{\omega_0}{2\omega_{1/2}}$$

$$Q = \frac{1}{2}\omega_0\tau$$





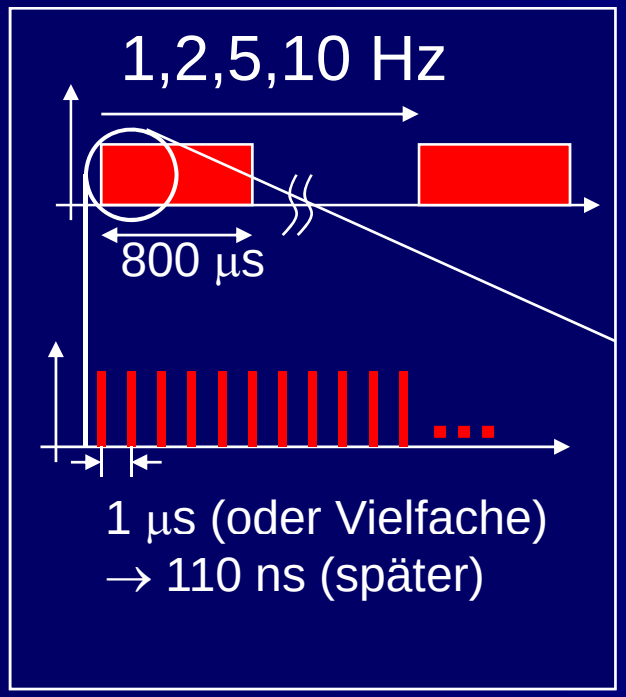
Im Falle von FLASH:

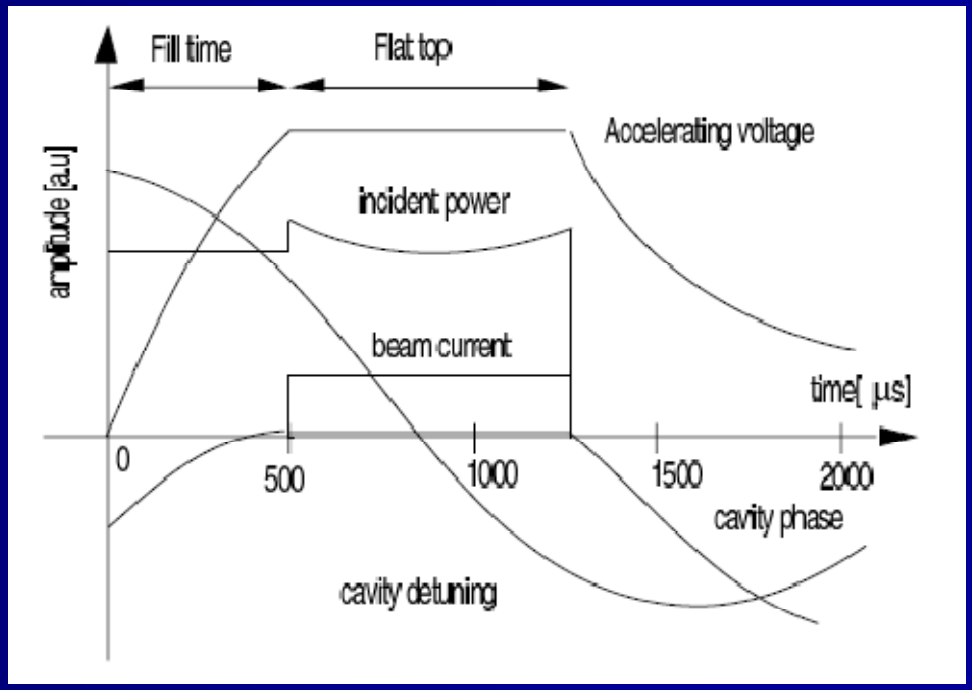
Q_0 = 10^{10}!

$f_{1/2}$ = 0.04 Hz

τ = 24 s

Die Pulsstruktur





Ankopplung an Klystron senkt die Güte

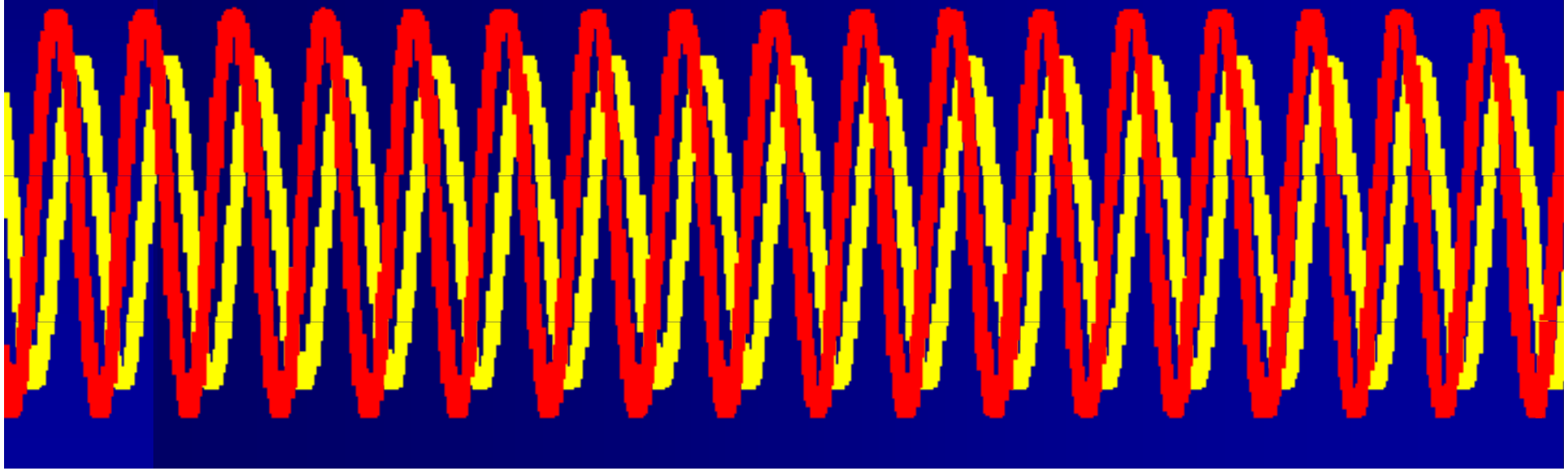
- Füllzeit wäre viel zu lang
- HF-Leistung für den Strahl könnte nicht nachgeliefert werden
- für gegebene Spannung, R/Q und Strom gibt es eine optimale Güte

$$Q_{L,opt} = \frac{U}{2(R/Q)I\cos(\varphi)}$$

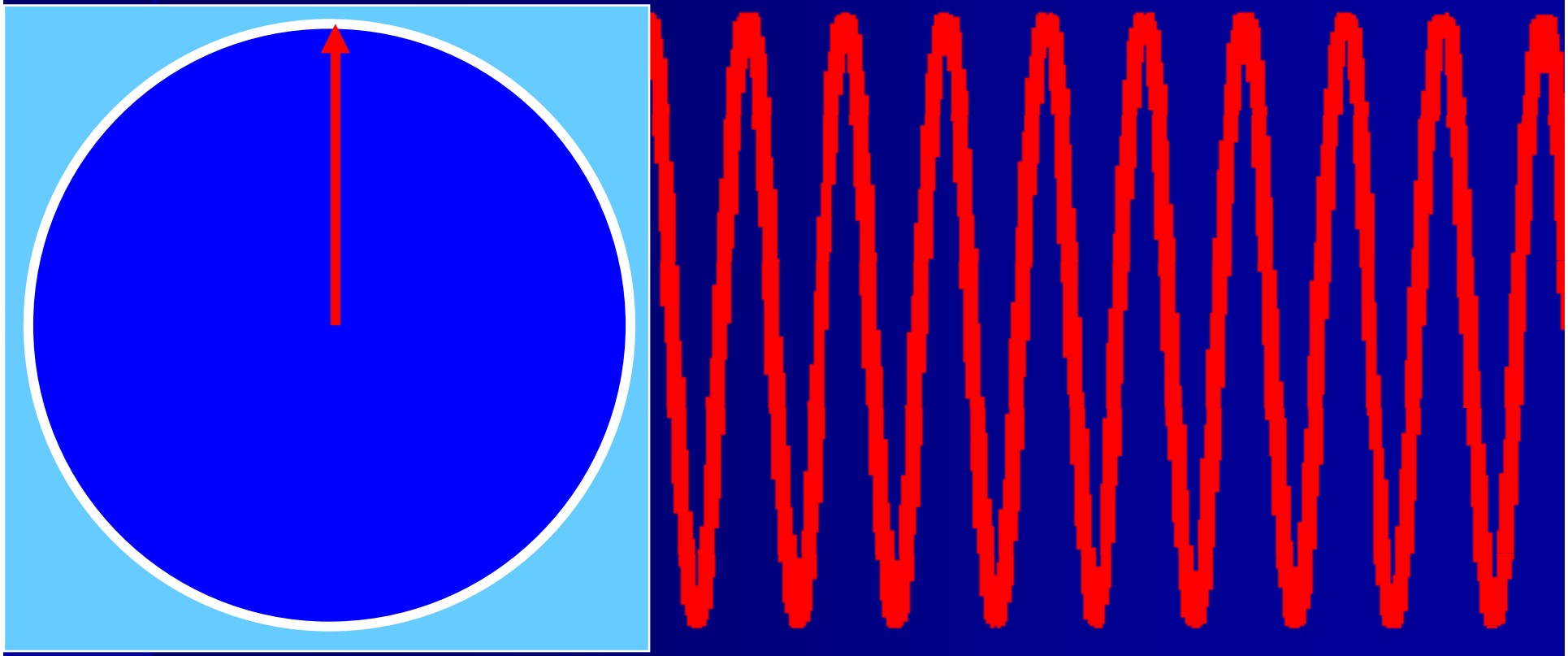
- Bei FLASH benutzen wir die Güte für 8mA, d.h. 3E6 (das ist das Erbe von TESLA)
  Zeitkonstante ~ 700μs

Welche Größen sind relevant?

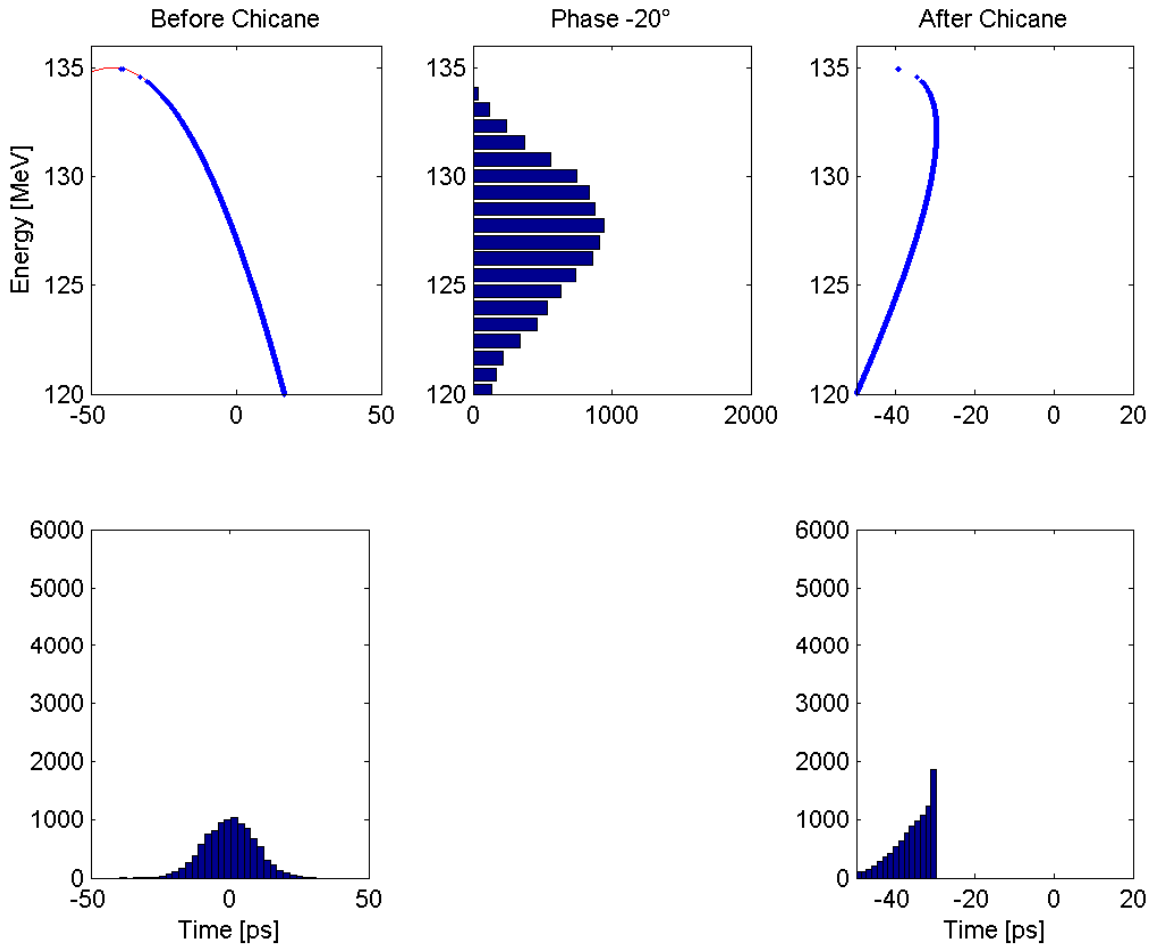
- Amplitude
- Phase $\rightarrow$ Referenz!
- Frequenz = Δphase/zeit



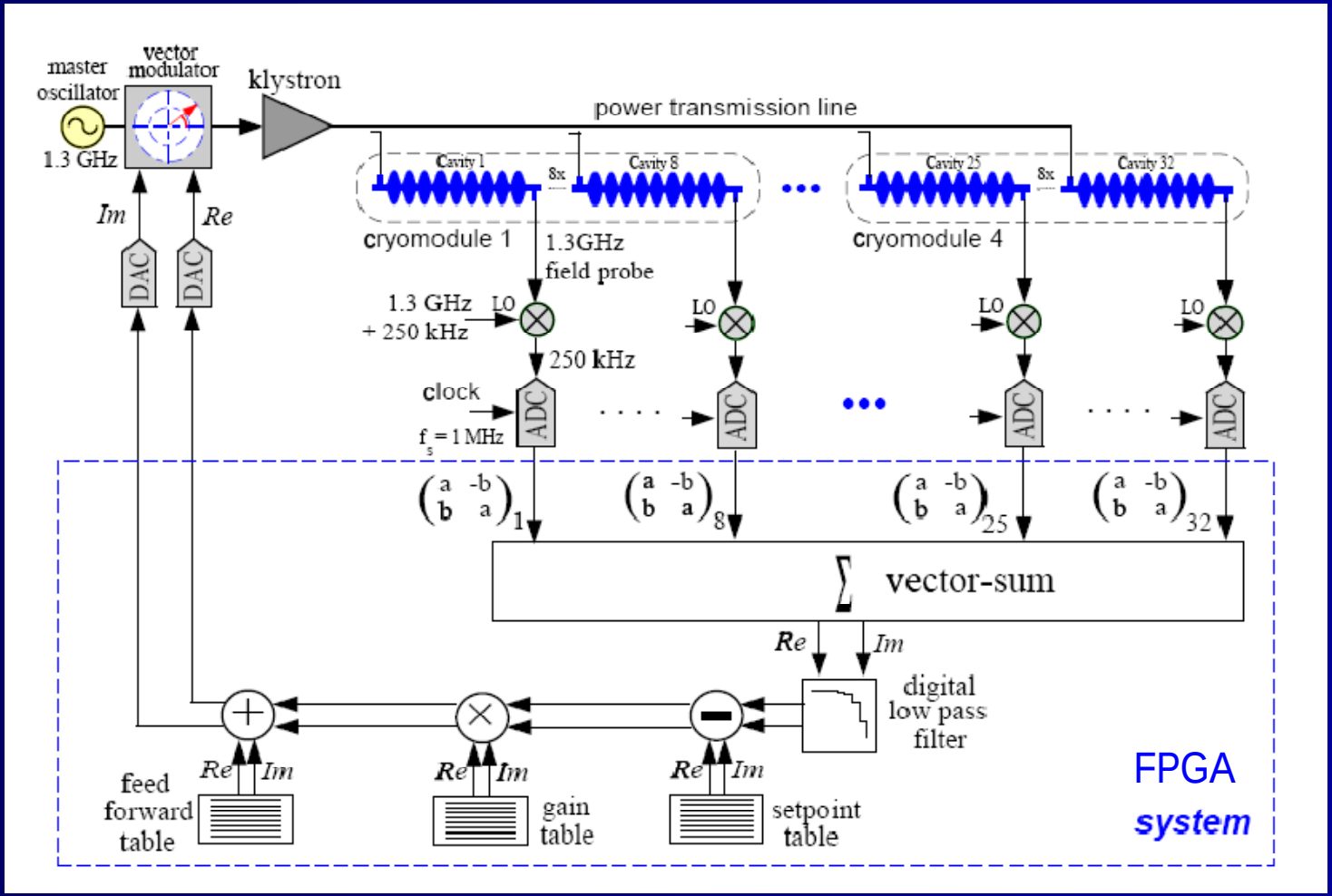
Darstellung als Vektor



Die Wechselwirkung von HF und Bunchkompressor



Allgemeines zur HF-Erzeugung



Das Multibeamklystron

Figure 3.4.2: *The Thomson TH1801 multibeam klystron.*

	Design	Measurement
Operation Frequency	1300 MHz	1300 MHz
RF Pulse Duration	1.5 ms	1.5 ms
Repetition Rate	10 Hz	5 Hz
Cathode Voltage	110 kV	117 kV
Beam Current	130 A	131 A
HV Pulse Duration	1.7 ms	1.7 ms
No. of Beams	7	7
Microperveance	3.5	3.27
No. of Cavities	6	6
Max. RF Peak Power	10 MW	10 MW
RF Average Power	150 kW	75 kW
Efficiency	70%	65%
Gain	48 dB	48.2 dB
Solenoid Power	4 kW	6 kW

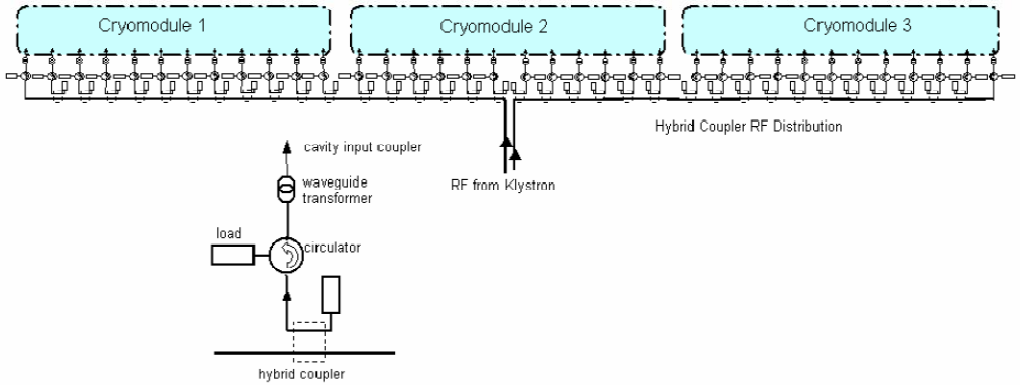
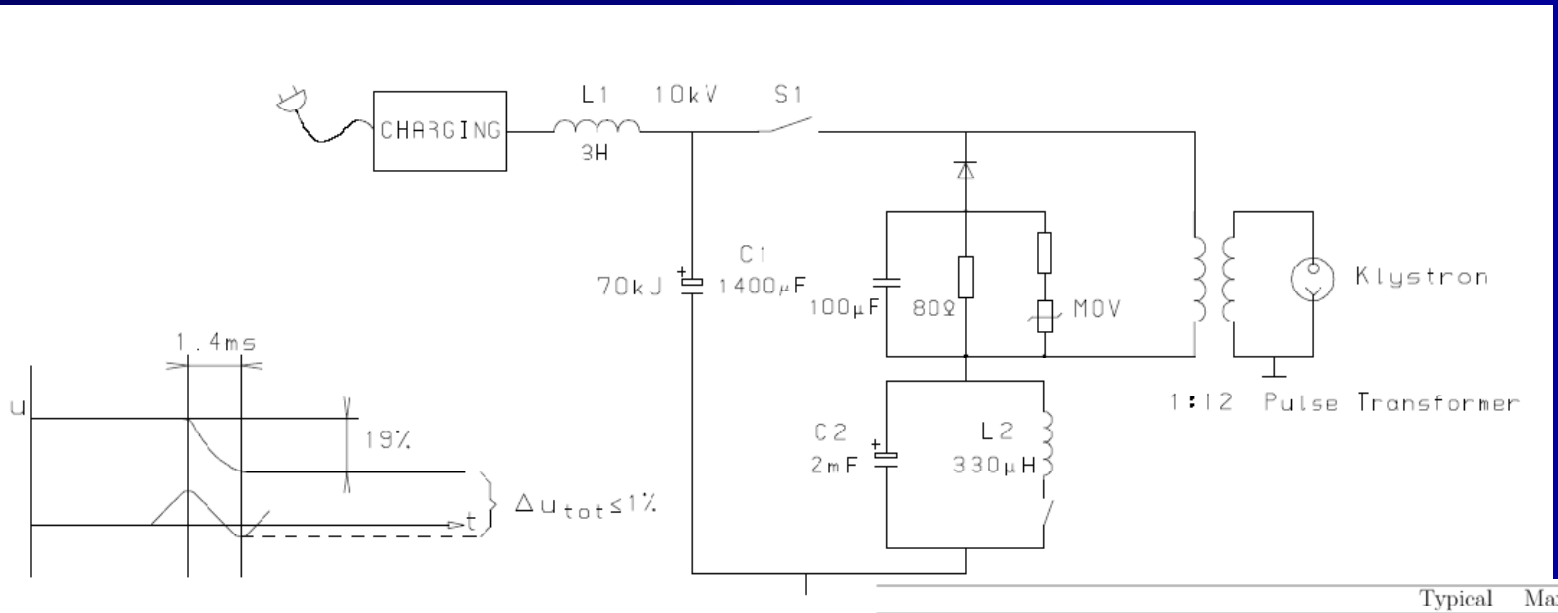


Figure 3.4.5: *RF waveguide distribution of one RF station.*

Quelle: TESLA TDR

Bouncer Modulator



Keine Spielchen mit dem Timing!

	Typical	Maximum
Klystron Gun Voltage	115 kV	120 kV
Klystron Gun Current	130 A	140 A
High Voltage Pulse Duration (70% to 70%)	< 1.7 ms	1.7 ms
High Voltage Rise and Fall Time (0 to 99%)	< 0.2 ms	0.2 ms
High Voltage Flat Top (99% to 99%)	1.37 ms	1.5 ms
Pulse Flatness During Flat Top	< ±0.5%	±0.5%
Pulse-to-Pulse Voltage fluctuation	< ±0.5%	±0.5%
Energy Deposit in Klystron in Case of Gun Spark	< 20 J	20 J
Pulse Repetition Rate for 90% of the Modulators	5 Hz	5 Hz
Pulse Repetition Rate for 10% of the Modulators	10 Hz	10 Hz
Transformer Ratio	1 : 12	
Filament Voltage	9 V	11 V
Filament Current	50 A	60 A

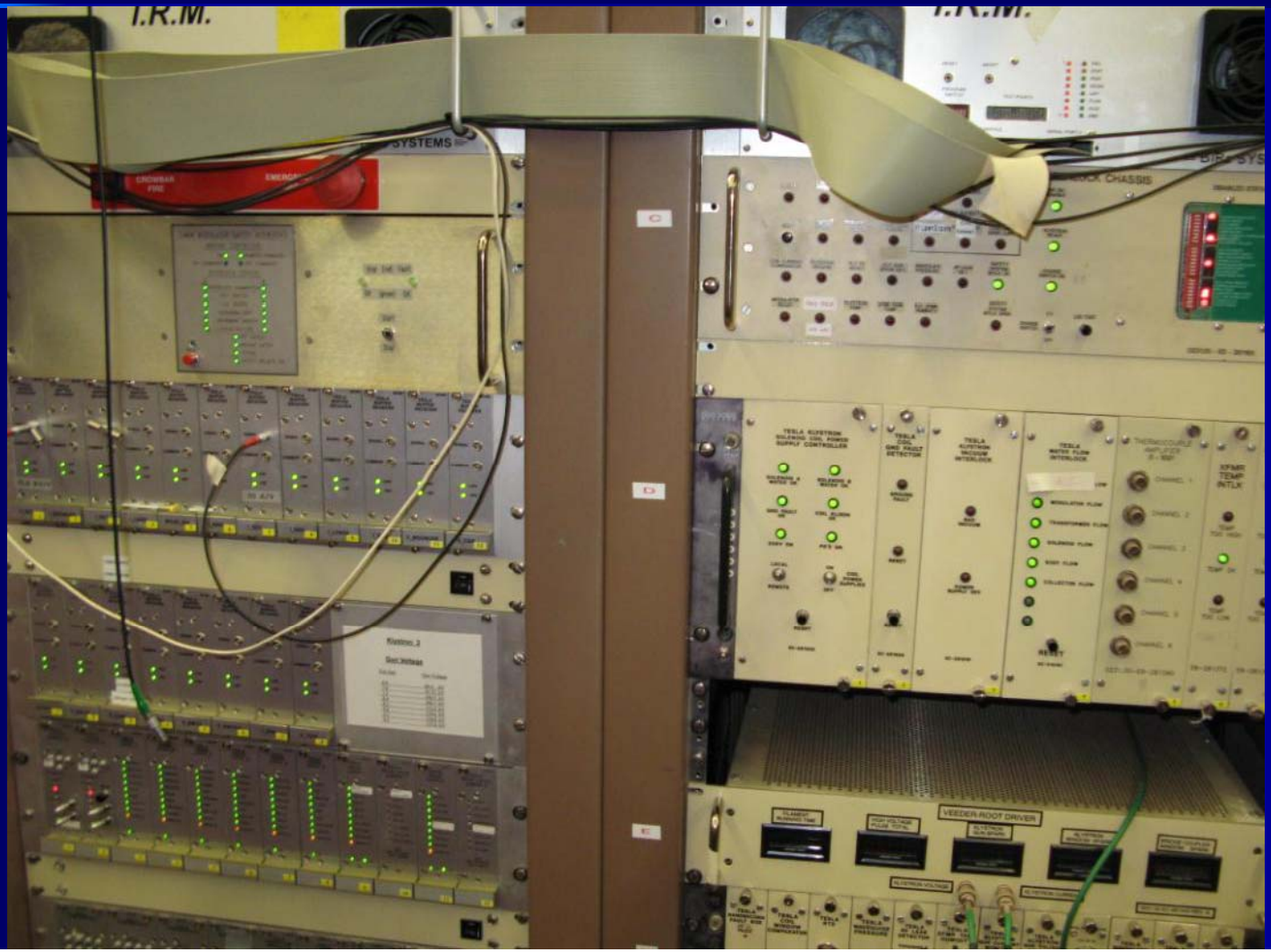
Table 3.4.2: *Modulator requirements.*

Modulatoren

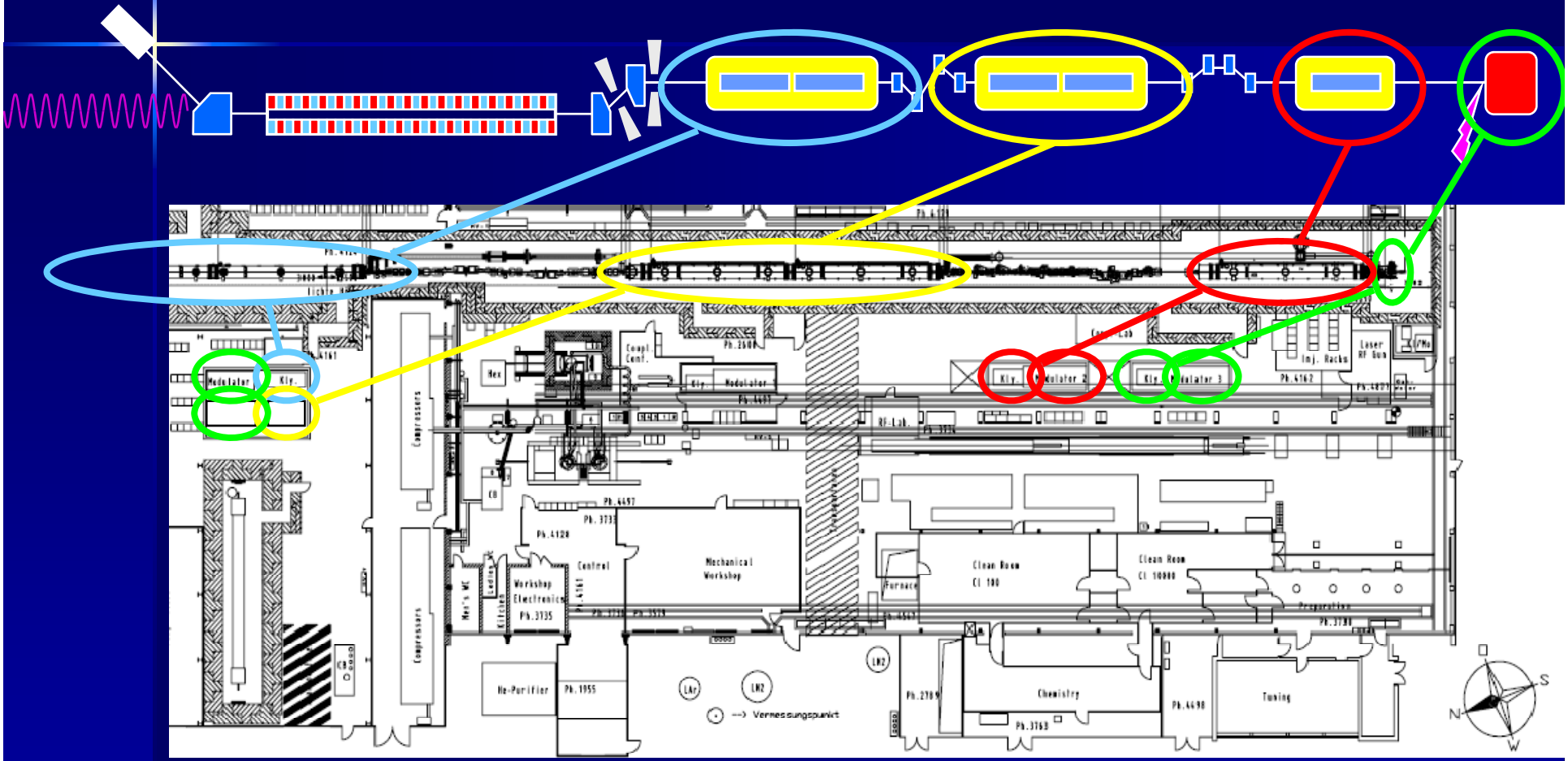
H2.2
(Halle 2)

Modulator 2 (Halle 3)

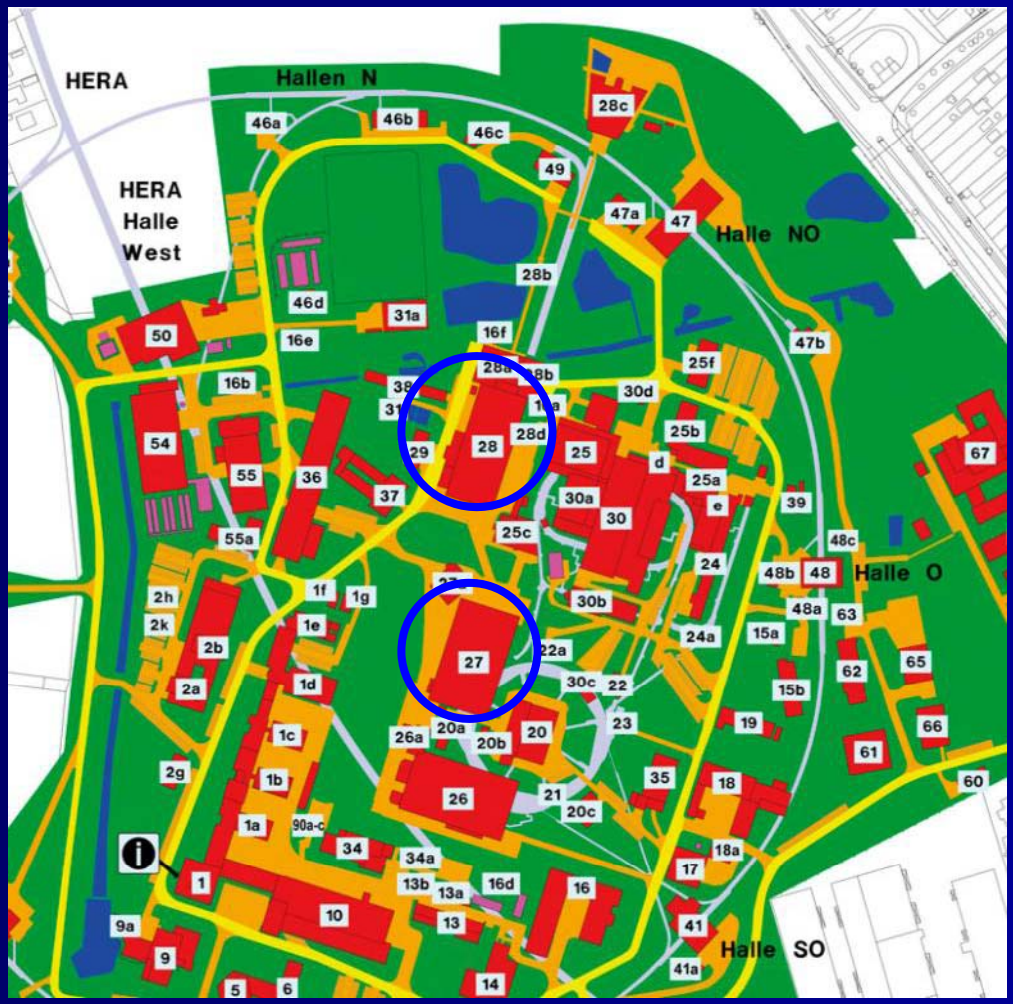
Lokale Bedienung Fermilab-Modulatoren



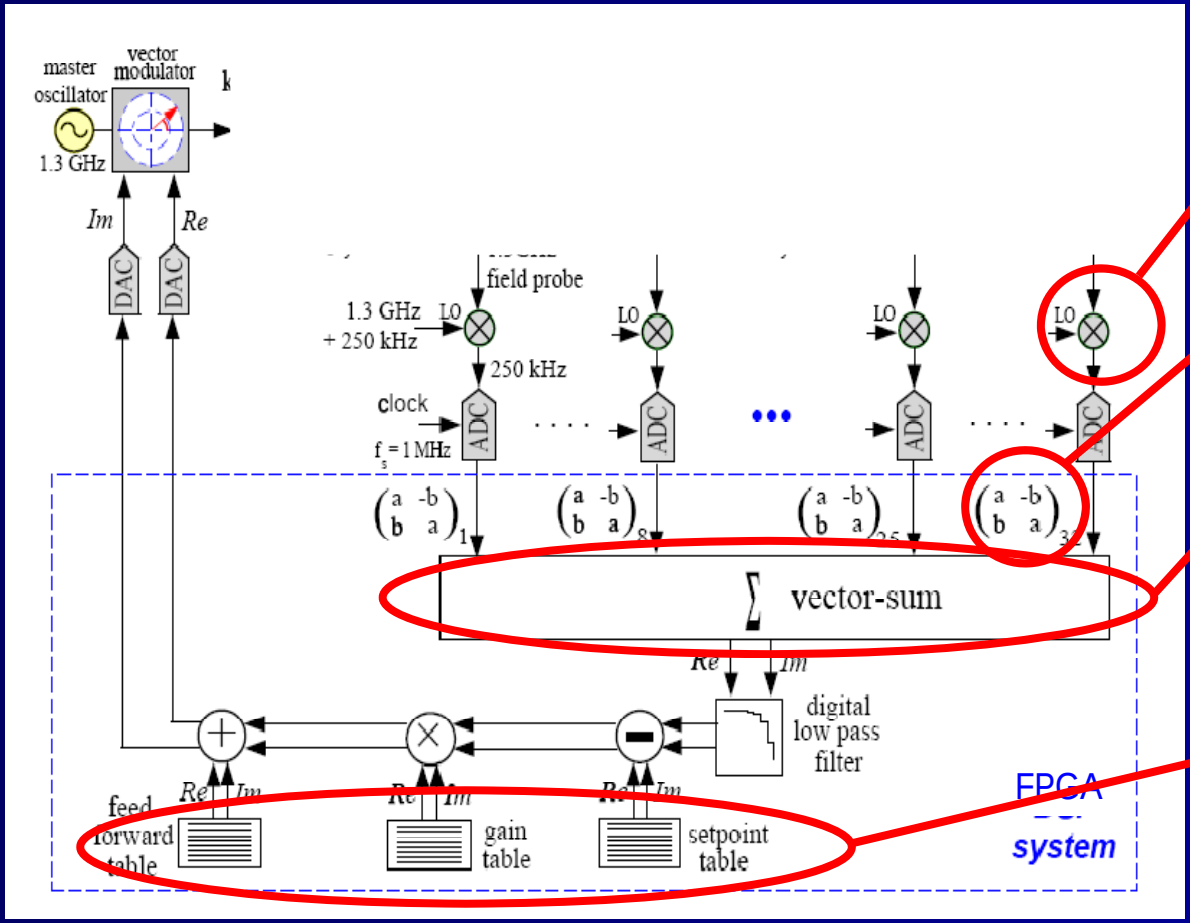
In Halle 3


Modulator
Kly.
Compressors
Mechanical Workshop
Control
Workshop Electronics
Ph.3735
Clean Room
Cl 100
Clean Room
Cl 10000
Furnace
Chemistry
Tuning
He-Purifier
Ph.1955
Ph.3768
Ph.4498
Laser RF Gun
Inj. Racks
RF-Lab.
Ladies
Men's WC
Kitchen
LAr
LN2
--> Vermessungspunkt
N
S
W

Modulatoren



Kleiner Pegel grosse Wirkung: Die LLRF



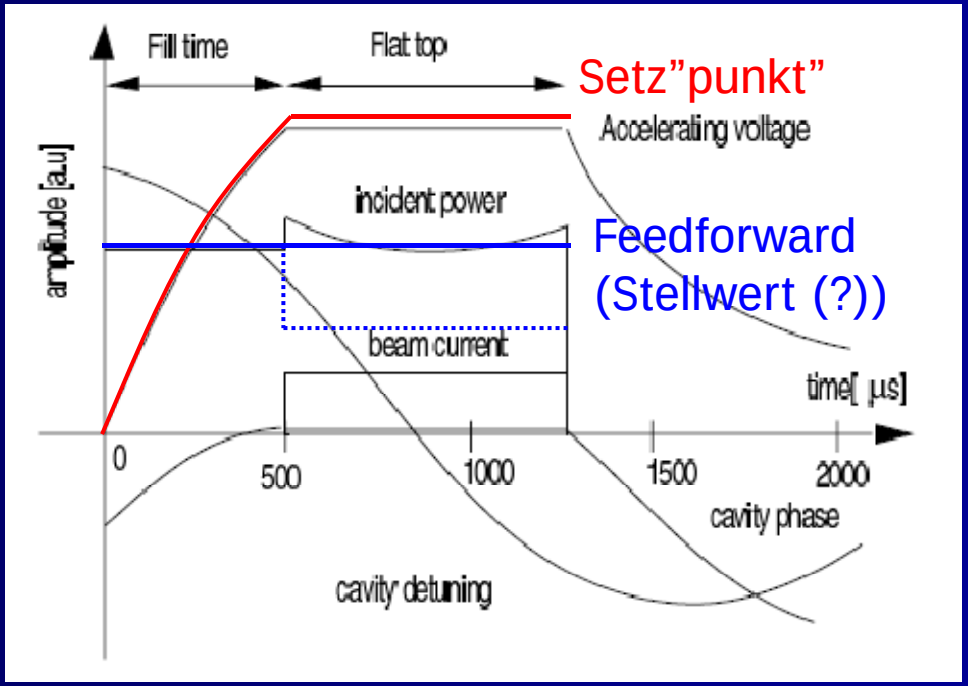
Mischer: misst Amplitude und Phase zu Referenz

Kalibrationsfaktor: Amplitude und Phase zu Strahl

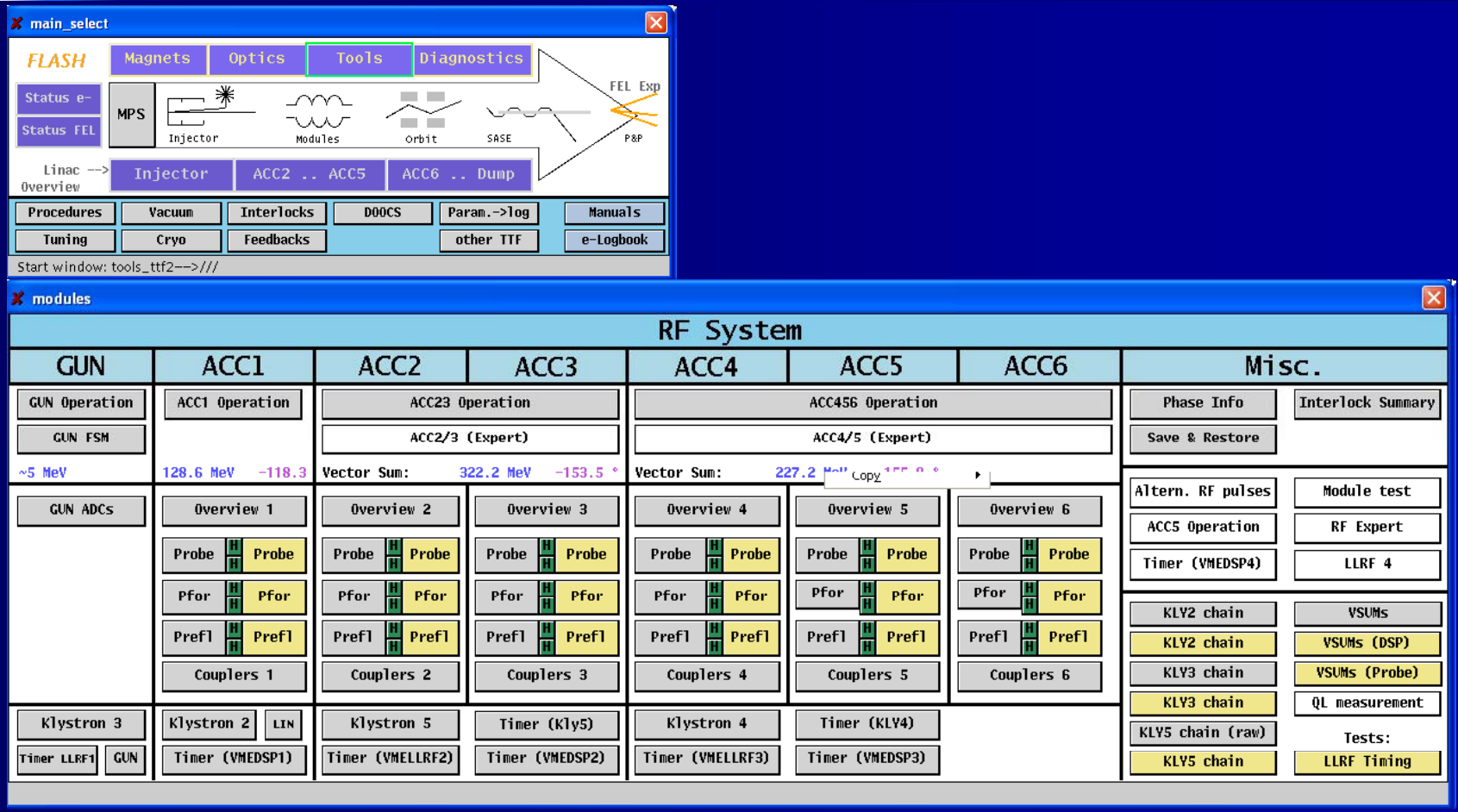
Vektorsumme: phasenrichtiges Aufsummieren von 8, 16 oder 24 Cavities

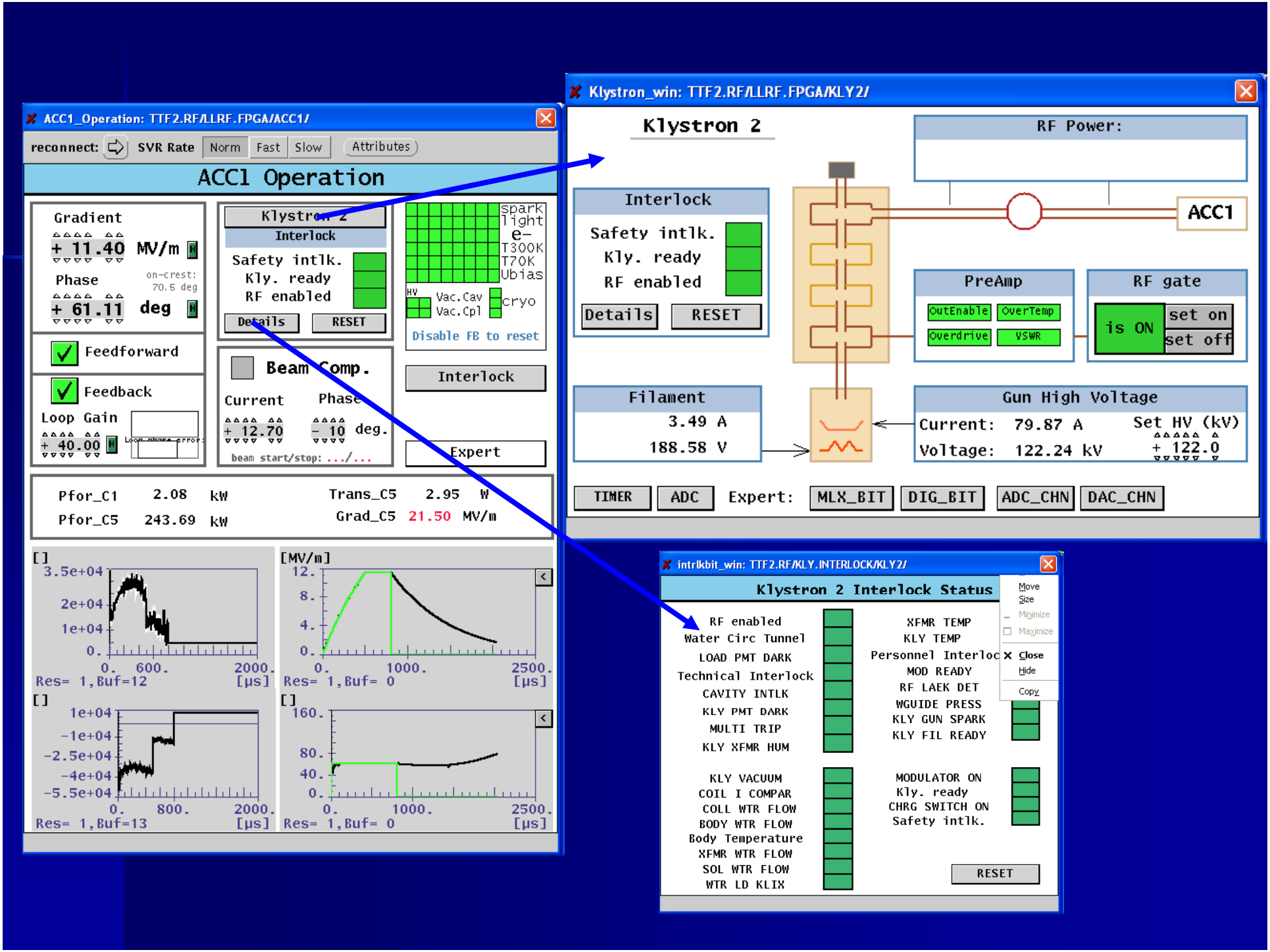
Setzpunkt und Feedforward als Tabelle→

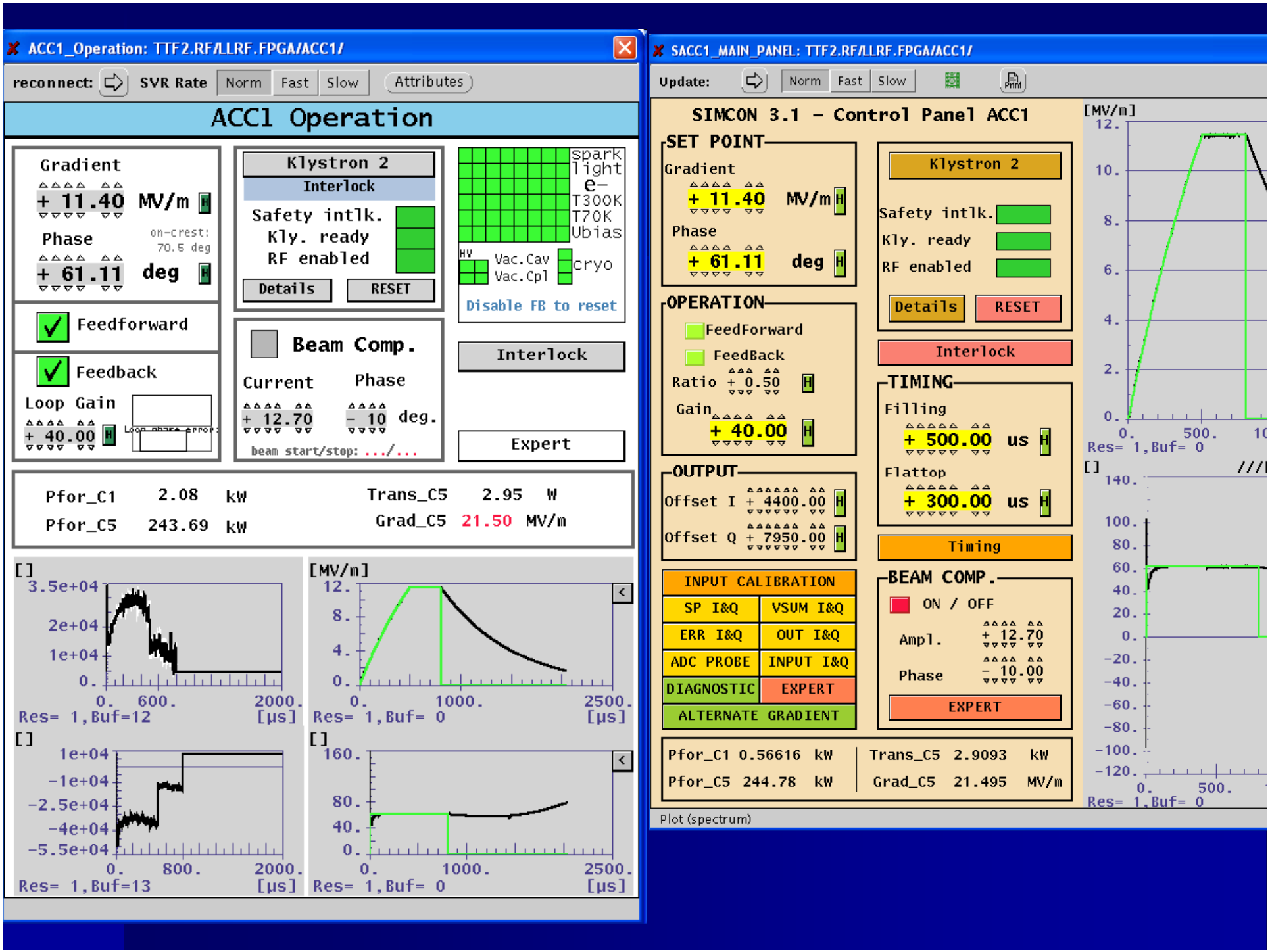
Tabelle: Einträge für jede Microsekunde des Pulses

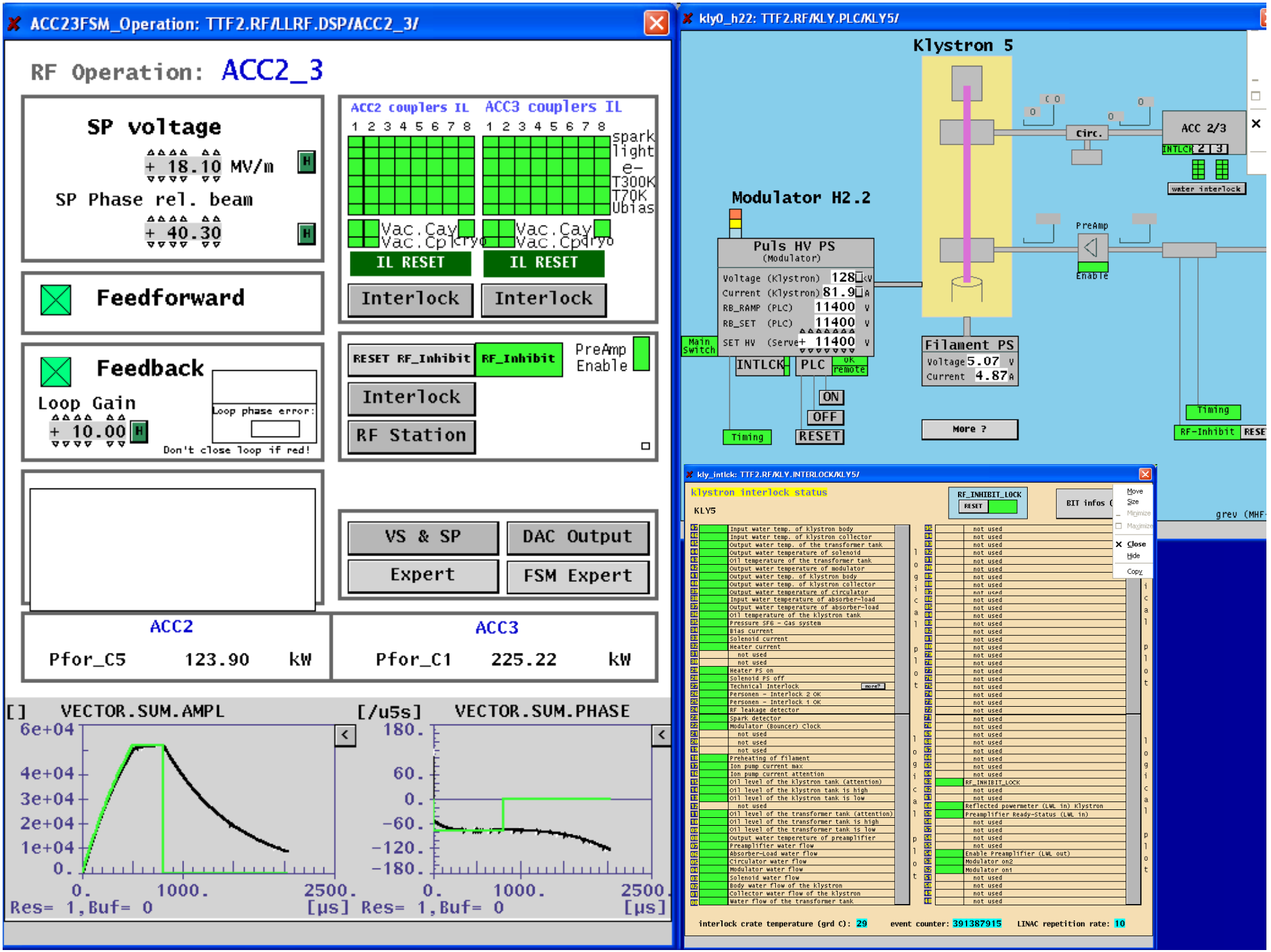


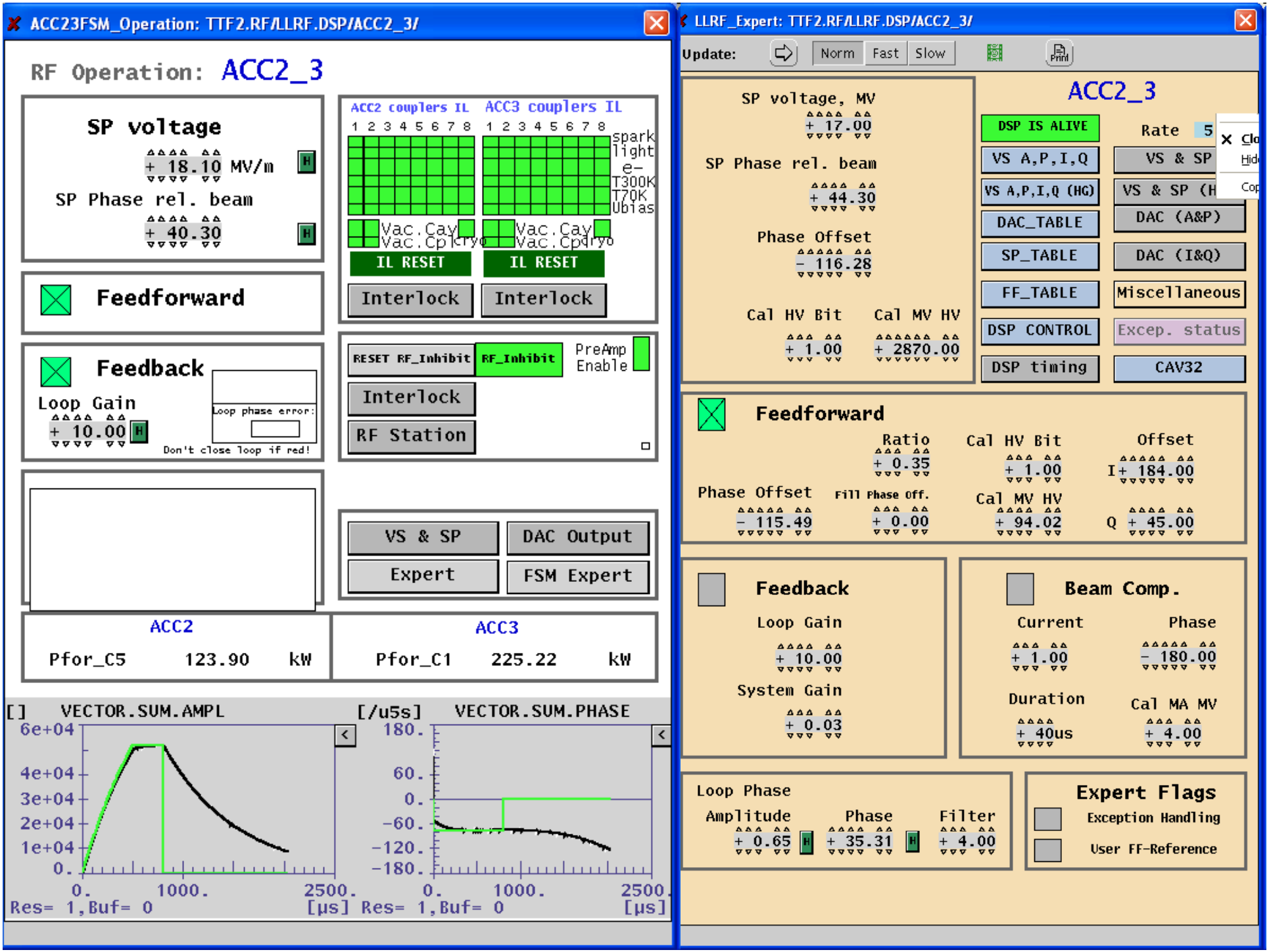
DOOCS

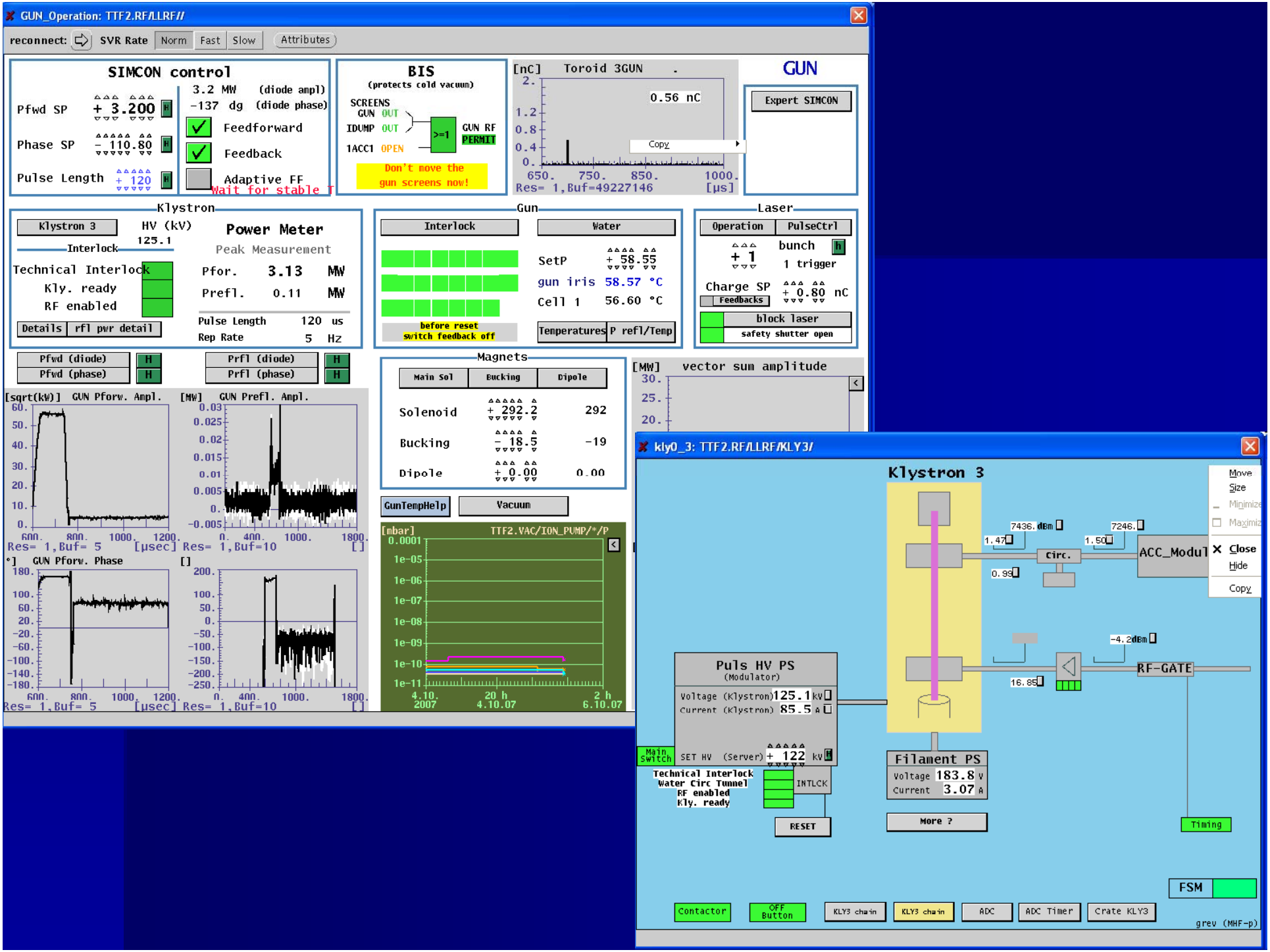

main_select
FLASH
Magnets
Optics
Tools
Diagnostics
Status e-
Status FEL
MPS
Injector
Modules
Orbit
SASE
FEL Exp
P&P
Linac --> Overview
Injector
ACC2 .. ACC5
ACC6 .. Dump
Procedures
Vacuum
Interlocks
DOOCS
Param.->log
Manuals
Tuning
Cryo
Feedbacks
other TTF
e-Logbook
Start window: tools_ttf2-->///
modules
RF System
GUN
ACC1
ACC2
ACC3
ACC4
ACC5
ACC6
Misc.
GUN Operation
GUN FSM
~5 MeV
ACC1 Operation
128.6 MeV -118.3
ACC23 Operation
ACC2/3 (Expert)
Vector Sum: 322.2 MeV -153.5 °
ACC456 Operation
ACC4/5 (Expert)
Vector Sum: 227.2
Copy
Phase Info
Interlock Summary
Save & Restore
Altern. RF pulses
Module test
ACC5 Operation
RF Expert
Timer (VMEDSP4)
LLRF 4
GUN ADCs
Overview 1
Overview 2
Overview 3
Overview 4
Overview 5
Overview 6
Probe
Pfor
Prefl
Couplers 1
Couplers 2
Couplers 3
Couplers 4
Couplers 5
Couplers 6
KLY2 chain
KLY2 chain
KLY3 chain
KLY3 chain
KLY5 chain (raw)
KLY5 chain
VSUMs
VSUMs (DSP)
VSUMs (Probe)
QL measurement
Tests:
LLRF Timing
Klystron 3
Timer LLRF1
GUN
Klystron 2
LIN
Timer (VMEDSP1)
Klystron 5
Timer (VMELLRF2)
Timer (Kly5)
Timer (VMEDSP2)
Klystron 4
Timer (VMELLRF3)
Timer (KLY4)
Timer (VMEDSP3)

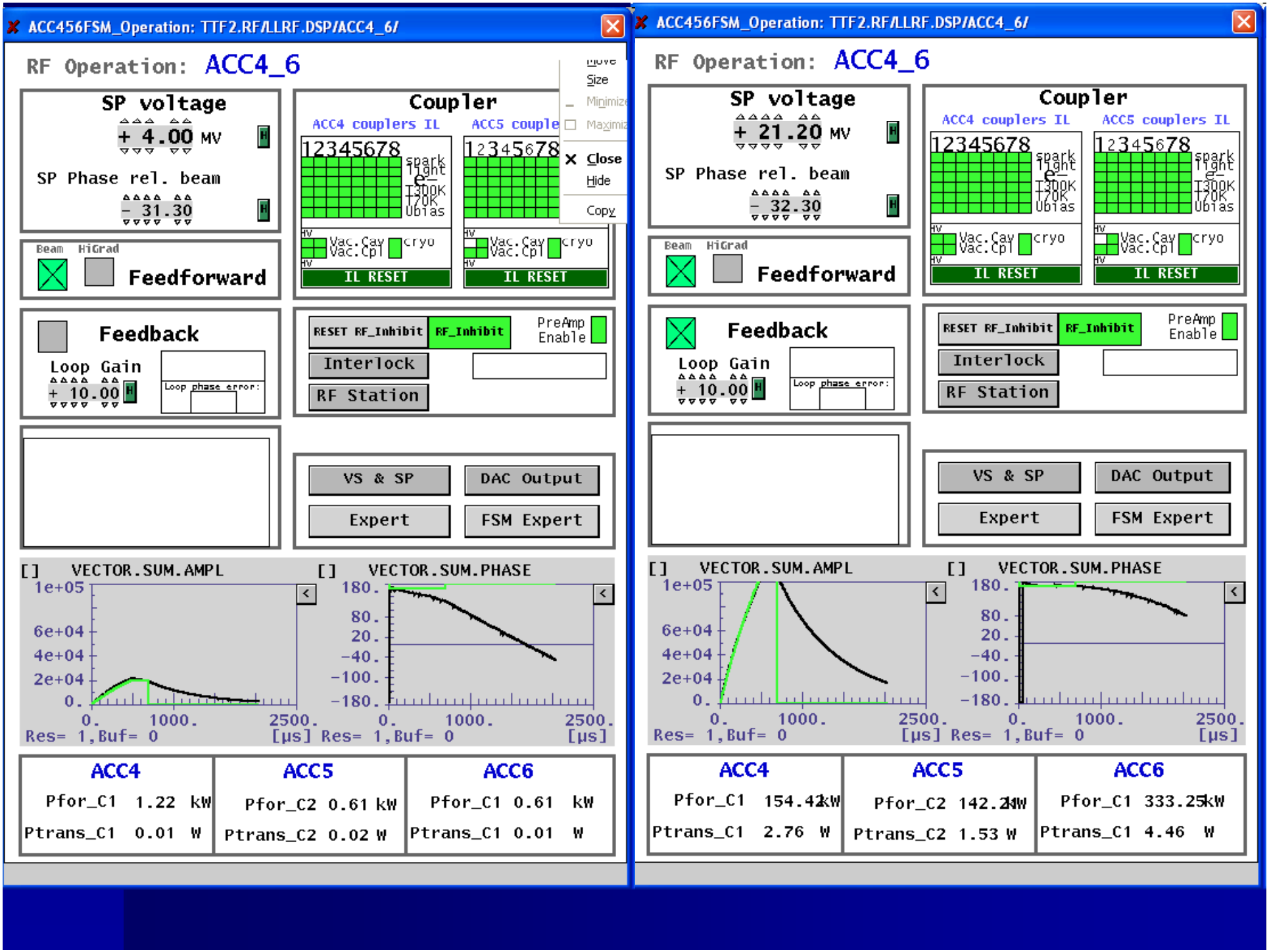

ACC1_Operation: TTF2.RF/LLRF.FPGA/ACC1/
reconnect:
SVR Rate
Norm
Fast
Slow
Attributes
ACC1 Operation
Gradient
+ 11.40
MV/m
Phase
on-crest:
70.5 deg
+ 61.11
deg
Feedforward
Feedback
Loop Gain
+ 40.00
Klystron 2
Interlock
Safety intlk.
Kly. ready
RF enabled
Details
RESET
Beam Comp.
Current
Phase
+ 12.70
- 10
deg.
beam start/stop: .../...
spark
light
e-
T300K
T70K
Ubias
HV
Vac.Cav
Vac.Cpl
cryo
Disable FB to reset
Interlock
Expert
Pfor_C1 2.08 kW
Pfor_C5 243.69 kW
Trans_C5 2.95 W
Grad_C5 21.50 MV/m
[]
[MV/m]
Res= 1,Buf=12
Res= 1,Buf= 0
Res= 1,Buf=13
Res= 1,Buf= 0
[µs]
Klystron_win: TTF2.RF/LLRF.FPGA/KLY2/
Klystron 2
RF Power:
Interlock
Safety intlk.
Kly. ready
RF enabled
Details
RESET
ACC1
PreAmp
OutEnable
OverTemp
Overdrive
VSWR
RF gate
is ON
set on
set off
Filament
3.49 A
188.58 V
Gun High Voltage
Current: 79.87 A
Voltage: 122.24 kV
Set HV (kV)
+ 122.0
TIMER
ADC
Expert:
MLX_BIT
DIG_BIT
ADC_CHN
DAC_CHN
intrlkbit_win: TTF2.RF/KLY.INTERLOCK/KLY2/
Klystron 2 Interlock Status
RF enabled
Water Circ Tunnel
LOAD PMT DARK
Technical Interlock
CAVITY INTLK
KLY PMT DARK
MULTI TRIP
KLY XFMR HUM
KLY VACUUM
COIL I COMPAR
COLL WTR FLOW
BODY WTR FLOW
Body Temperature
XFMR WTR FLOW
SOL WTR FLOW
WTR LD KLIX
XFMR TEMP
KLY TEMP
Personnel Interloc
MOD READY
RF LAEK DET
WGUIDE PRESS
KLY GUN SPARK
KLY FIL READY
MODULATOR ON
Kly. ready
CHRG SWITCH ON
Safety intlk.
RESET
Move
Size
Minimize
Maximize
Close
Hide
Copy

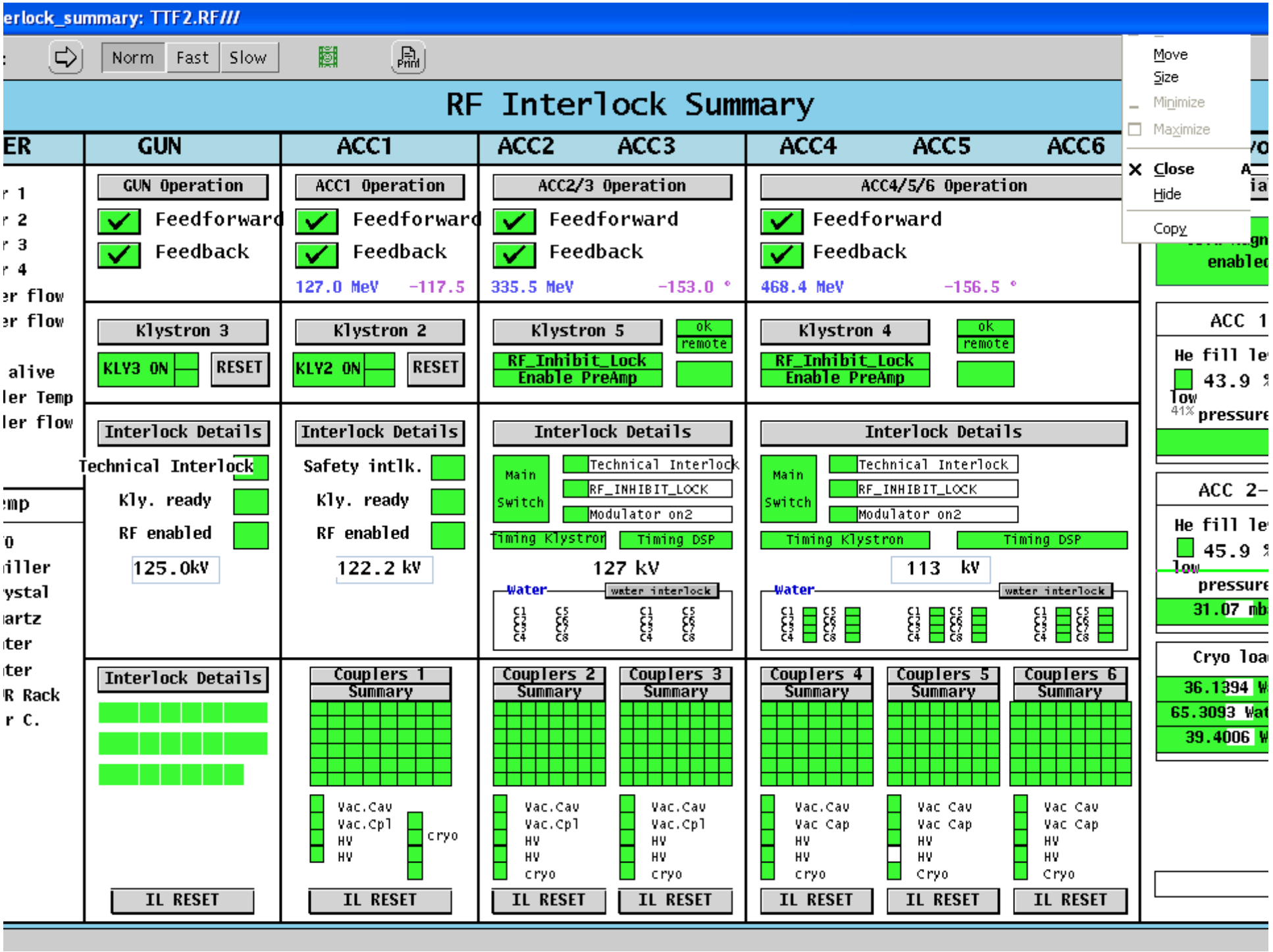

ACC1_Operation: TTF2.RF/LLRF.FPGA/ACC1/
reconnect:
SVR Rate
Norm
Fast
Slow
Attributes
ACC1 Operation
Gradient
+ 11.40
MV/m
Phase
+ 61.11
deg
on-crest: 70.5 deg
Feedforward
Feedback
Loop Gain
+ 40.00
Klystron 2
Interlock
Safety intlk.
Kly. ready
RF enabled
Details
RESET
Beam Comp.
Current
+ 12.70
Phase
- 10
deg.
beam start/stop: .../...
spark
light
e-
T300K
T70K
Ubias
HV
Vac.Cav
Vac.Cpl
cryo
Disable FB to reset
Interlock
Expert
Pfor_C1 2.08 kW
Pfor_C5 243.69 kW
Trans_C5 2.95 W
Grad_C5 21.50 MV/m
[MV/m]
Res= 1,Buf=12
Res= 1,Buf= 0
Res= 1,Buf=13
[µs]
SACC1_MAIN_PANEL: TTF2.RF/LLRF.FPGA/ACC1/
Update:
Norm
Fast
Slow
Print
SIMCON 3.1 - Control Panel ACC1
SET POINT
Gradient
+ 11.40
MV/m
Phase
+ 61.11
deg
OPERATION
FeedForward
FeedBack
Ratio + 0.50
Gain
+ 40.00
OUTPUT
Offset I + 4400.00
Offset Q + 7950.00
INPUT CALIBRATION
SP I&Q
VSUM I&Q
ERR I&Q
OUT I&Q
ADC PROBE
INPUT I&Q
DIAGNOSTIC
EXPERT
ALTERNATE GRADIENT
Klystron 2
Safety intlk.
Kly. ready
RF enabled
Details
RESET
Interlock
TIMING
Filling
+ 500.00
us
Flattop
+ 300.00
us
Timing
BEAM COMP.
ON / OFF
Ampl.
+ 12.70
Phase
- 10.00
EXPERT
Pfor_C1 0.56616 kW
Pfor_C5 244.78 kW
Trans_C5 2.9093 kW
Grad_C5 21.495 MV/m
Plot (spectrum)


ACC23FSM_Operation: TTF2.RF/LLRF.DSP/ACC2_3/
RF Operation: ACC2_3
SP voltage
+ 18.10 MV/m
H
SP Phase rel. beam
+ 40.30
H
Feedforward
Feedback
Loop Gain
+ 10.00
H
Loop phase error:
Don't close loop if red!
ACC2 couplers IL
ACC3 couplers IL
1 2 3 4 5 6 7 8
spark
light
e-
T300K
T70K
Ubias
Vac.Cav
Vac.Cplcryo
Vac.Cav
Vac.Cpdryo
IL RESET
IL RESET
Interlock
Interlock
RESET RF_Inhibit
RF_Inhibit
PreAmp Enable
Interlock
RF Station
VS & SP
DAC Output
Expert
FSM Expert
ACC2
Pfor_C5 123.90 kW
ACC3
Pfor_C1 225.22 kW
[] VECTOR.SUM.AMPL
6e+04
4e+04
3e+04
2e+04
1e+04
0.
0. 1000. 2500.
Res= 1,Buf= 0
[/u5s] VECTOR.SUM.PHASE
180.
60.
0.
-60.
-120.
-180.
0. 1000. 2500.
[µs] Res= 1,Buf= 0
[µs]
kly0_h22: TTF2.RF/KLY.PLC/KLY5/
Klystron 5
Modulator H2.2
Puls HV PS
(Modulator)
Voltage (Klystron) 128 kV
Current (Klystron) 81.9 A
RB_RAMP (PLC) 11400 V
RB_SET (PLC) 11400 V
SET HV (Serve+ 11400 V
Main Switch
INTLCK
PLC
OK
remote
ON
OFF
RESET
Timing
Filament PS
Voltage 5.07 V
Current 4.87 A
More ?
Circ.
ACC 2/3
INTLCK 2 3
water interlock
PreAmp
Enable
Timing
RF-Inhibit
kly_intlck: TTF2.RF/KLY.INTERLOCK/KLY5/
klystron interlock status
KLY5
RF_INHIBIT_LOCK
RESET
BIT infos
Move
Size
Minimize
Maximize
Close
Hide
Copy
Input water temp. of klystron body
Input water temp. of klystron collector
Output water temp. of the transformer tank
Output water temperature of solenoid
Oil temperature of the transformer tank
Output water temperature of modulator
Output water temp. of klystron body
Output water temp. of klystron collector
Output water temperature of circulator
Input water temperature of absorber-load
Output water temperature of absorber-load
Oil temperature of the klystron tank
Pressure SF6 - Gas system
Bias current
Solenoid current
Heater current
not used
not used
Heater PS on
Solenoid PS off
Technical Interlock
more?
Personen - Interlock 2 OK
Personen - Interlock 1 OK
RF leakage detector
Spark detector
Modulator (Bouncer) Clock
not used
not used
not used
Preheating of filament
Ion pump current max
Ion pump current attention
Oil level of the klystron tank (attention)
Oil level of the klystron tank is high
Oil level of the klystron tank is low
not used
Oil level of the transformer tank (attention)
Oil level of the transformer tank is high
Oil level of the transformer tank is low
Output water temperature of preamplifier
Preamplifier water flow
Absorber-Load water flow
Circulator water flow
Modulator water flow
Solenoid water flow
Body water flow of the klystron
Collector water flow of the Klystron
Water flow of the transformer tank
not used
RF_INHIBIT_LOCK
Reflected powermeter (LWL in) Klystron
Preamplifier Ready-Status (LWL in)
Enable Preamplifier (LWL out)
Modulator on2
Modulator on1
logical plot
interlock crate temperature (grd C): 29
event counter: 391387915
LINAC repetition rate: 10

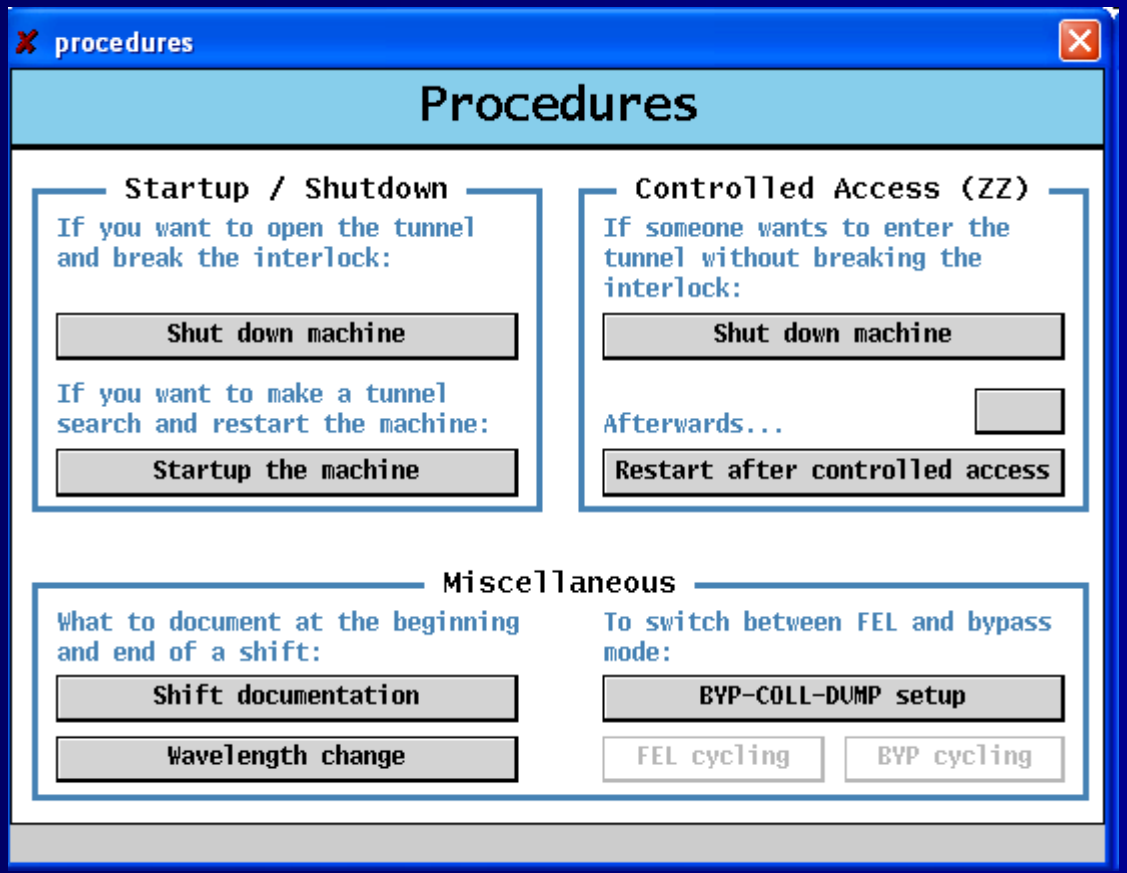

ACC23FSM_Operation: TTF2.RF/LLRF.DSP/ACC2_3/
RF Operation: ACC2_3
SP voltage
+ 18.10 MV/m
SP Phase rel. beam
+ 40.30
ACC2 couplers IL
ACC3 couplers IL
1 2 3 4 5 6 7 8
spark
light
e-
T300K
T70K
Ubias
Vac.Cav
Vac.Cplcryo
Vac.Cav
Vac.Cpdryo
IL RESET
IL RESET
Interlock
Interlock
Feedforward
Feedback
Loop Gain
+ 10.00
Loop phase error:
Don't close loop if red!
RESET RF_Inhibit
RF_Inhibit
PreAmp Enable
Interlock
RF Station
VS & SP
DAC Output
Expert
FSM Expert
ACC2
Pfor_C5 123.90 kW
ACC3
Pfor_C1 225.22 kW
[] VECTOR.SUM.AMPL
6e+04
4e+04
3e+04
2e+04
1e+04
0.
0. 1000. 2500.
Res= 1,Buf= 0
[/u5s] VECTOR.SUM.PHASE
180.
60.
0.
-60.
-120.
-180.
0. 1000. 2500.
[µs] Res= 1,Buf= 0 [µs]
LLRF_Expert: TTF2.RF/LLRF.DSP/ACC2_3/
Update:
Norm
Fast
Slow
Print
SP voltage, MV
+ 17.00
SP Phase rel. beam
+ 44.30
Phase Offset
- 116.28
Cal HV Bit
+ 1.00
Cal MV HV
+ 2870.00
ACC2_3
DSP IS ALIVE
Rate 5
VS A,P,I,Q
VS & SP
VS A,P,I,Q (HG)
VS & SP (H
DAC_TABLE
DAC (A&P)
SP_TABLE
DAC (I&Q)
FF_TABLE
Miscellaneous
DSP CONTROL
Excep. status
DSP timing
CAV32
Feedforward
Ratio
+ 0.35
Cal HV Bit
+ 1.00
Offset
I+ 184.00
Phase Offset
- 115.49
Fill Phase Off.
+ 0.00
Cal MV HV
+ 94.02
Q + 45.00
Feedback
Loop Gain
+ 10.00
System Gain
+ 0.03
Beam Comp.
Current
+ 1.00
Phase
- 180.00
Duration
+ 40us
Cal MA MV
+ 4.00
Loop Phase
Amplitude
+ 0.65
Phase
+ 35.31
Filter
+ 4.00
Expert Flags
Exception Handling
User FF-Reference


GUN_Operation: TTF2.RF/LLRF//
reconnect:
SVR Rate
Norm
Fast
Slow
Attributes
SIMCON control
Pfwd SP
+ 3.200
Phase SP
- 110.80
Pulse Length
+ 120
3.2 MW (diode ampl)
-137 dg (diode phase)
Feedforward
Feedback
Adaptive FF
Wait for stable T
BIS
(protects cold vacuum)
SCREENS
GUN OUT
IDUMP OUT
1ACC1 OPEN
>=1
GUN RF PERMIT
Don't move the gun screens now!
[nC] Toroid 3GUN
0.56 nC
Copy
Res= 1,Buf=49227146 [µs]
GUN
Expert SIMCON
Klystron
Klystron 3
HV (kV)
125.1
Interlock
Technical Interlock
Kly. ready
RF enabled
Details
rfl pwr detail
Power Meter
Peak Measurement
Pfor. 3.13 MW
Prefl. 0.11 MW
Pulse Length 120 us
Rep Rate 5 Hz
Gun
Interlock
Water
SetP + 58.55
gun iris 58.57 °C
Cell 1 56.60 °C
before reset switch feedback off
Temperatures
P refl/Temp
Laser
Operation
PulseCtrl
+ 1
bunch
1 trigger
Charge SP
Feedbacks
+ 0.80 nC
block laser
safety shutter open
Pfwd (diode)
Pfwd (phase)
Prfl (diode)
Prfl (phase)
[sqrt(kW)] GUN Pforw. Ampl.
Res= 1,Buf= 5 [µsec]
[MW] GUN Prefl. Ampl.
Res= 1,Buf=10 []
°] GUN Pforw. Phase
Res= 1,Buf= 5 [µsec]
[] Res= 1,Buf=10 []
Magnets
Main Sol
Bucking
Dipole
Solenoid + 292.2 292
Bucking - 18.5 -19
Dipole + 0.00 0.00
GunTempHelp
Vacuum
[mbar] TTF2.VAC/ION_PUMP/*/P
4.10. 2007
20 h 4.10.07
2 h 6.10.07
[MW] vector sum amplitude
klyO_3: TTF2.RF/LLRF/KLY3/
Klystron 3
Move
Size
Minimize
Maximize
Close
Hide
Copy
7436. dBm
7246.
1.47
1.50
Circ.
ACC_Modul
0.98
-4.2dBm
RF-GATE
16.85
Puls HV PS
(Modulator)
Voltage (Klystron) 125.1 kV
Current (Klystron) 85.5 A
Main Switch
SET HV (Server) + 122 kV
Technical Interlock
Water Circ Tunnel
RF enabled
Kly. ready
INTLCK
RESET
Filament PS
Voltage 183.8 V
Current 3.07 A
More ?
Timing
FSM
Contactor
OFF Button
KLY3 chain
KLY3 chain
ADC
ADC Timer
Crate KLY3
grev (MHF-p)


ACC456FSM_Operation: TTF2.RF/LLRF.DSP/ACC4_6/
RF Operation: ACC4_6
SP voltage
+ 4.00 MV
SP Phase rel. beam
- 31.30
Coupler
ACC4 couplers IL
ACC5 couple
12345678
spark
light
e-
T300K
T70K
Ubias
HV
Vac.Cav
Vac.Cpl
cryo
IL RESET
Move
Size
Minimize
Maximize
Close
Hide
Copy
Beam
HiGrad
Feedforward
Feedback
Loop Gain
+ 10.00
Loop phase error:
RESET RF_Inhibit
RF_Inhibit
PreAmp Enable
Interlock
RF Station
VS & SP
DAC Output
Expert
FSM Expert
[] VECTOR.SUM.AMPL
1e+05
6e+04
4e+04
2e+04
0.
0. 1000. 2500.
Res= 1,Buf= 0
[] VECTOR.SUM.PHASE
180.
80.
20.
-40.
-100.
-180.
0. 1000. 2500.
[µs] Res= 1,Buf= 0 [µs]
ACC4
Pfor_C1 1.22 kW
Ptrans_C1 0.01 W
ACC5
Pfor_C2 0.61 kW
Ptrans_C2 0.02 W
ACC6
Pfor_C1 0.61 kW
Ptrans_C1 0.01 W
ACC456FSM_Operation: TTF2.RF/LLRF.DSP/ACC4_6/
RF Operation: ACC4_6
SP voltage
+ 21.20 MV
SP Phase rel. beam
- 32.30
Coupler
ACC4 couplers IL
ACC5 couplers IL
Beam
HiGrad
Feedforward
Feedback
Loop Gain
+ 10.00
Loop phase error:
RESET RF_Inhibit
RF_Inhibit
PreAmp Enable
Interlock
RF Station
VS & SP
DAC Output
Expert
FSM Expert
[] VECTOR.SUM.AMPL
1e+05
6e+04
4e+04
2e+04
0.
0. 1000. 2500.
Res= 1,Buf= 0
[] VECTOR.SUM.PHASE
180.
80.
20.
-40.
-100.
-180.
0. 1000. 2500.
[µs] Res= 1,Buf= 0 [µs]
ACC4
Pfor_C1 154.41kW
Ptrans_C1 2.76 W
ACC5
Pfor_C2 142.21kW
Ptrans_C2 1.53 W
ACC6
Pfor_C1 333.25kW
Ptrans_C1 4.46 W

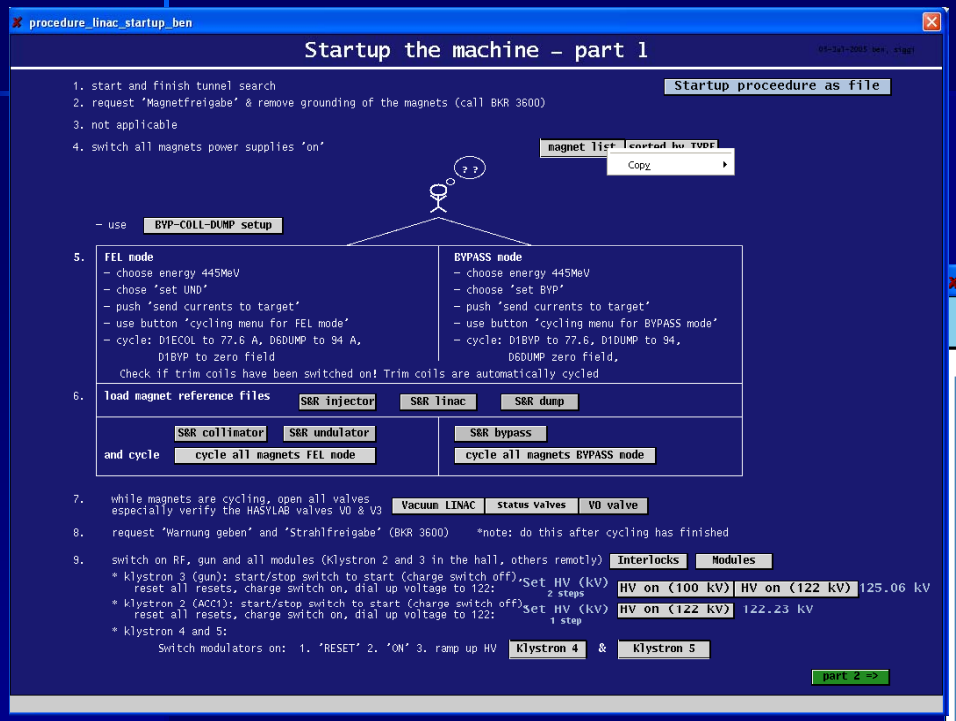

erlock_summary: TTF2.RF///
Norm
Fast
Slow
Print
Move
Size
Minimize
Maximize
Close
Hide
Copy
RF Interlock Summary
ER
GUN
ACC1
ACC2
ACC3
ACC4
ACC5
ACC6
GUN Operation
Feedforward
Feedback
ACC1 Operation
Feedforward
Feedback
127.0 MeV
-117.5
ACC2/3 Operation
Feedforward
Feedback
335.5 MeV
-153.0 °
ACC4/5/6 Operation
Feedforward
Feedback
468.4 MeV
-156.5 °
Klystron 3
KLY3 ON
RESET
Klystron 2
KLY2 ON
RESET
Klystron 5
ok
remote
RF_Inhibit_Lock
Enable PreAmp
Klystron 4
ok
remote
RF_Inhibit_Lock
Enable PreAmp
Interlock Details
Technical Interlock
Kly. ready
RF enabled
125.0kV
Interlock Details
Safety intlk.
Kly. ready
RF enabled
122.2 kV
Interlock Details
Main Switch
Technical Interlock
RF_INHIBIT_LOCK
Modulator on2
Timing Klystron
Timing DSP
127 kV
Water
water interlock
Interlock Details
Main Switch
Technical Interlock
RF_INHIBIT_LOCK
Modulator on2
Timing Klystron
Timing DSP
113 kV
Water
water interlock
Interlock Details
IL RESET
Couplers 1 Summary
Vac.Cav
Vac.Cpl
HV
HV
cryo
IL RESET
Couplers 2 Summary
Vac.Cav
Vac.Cpl
HV
HV
cryo
IL RESET
Couplers 3 Summary
Vac.Cav
Vac.Cpl
HV
HV
cryo
IL RESET
Couplers 4 Summary
Vac.Cav
Vac Cap
HV
HV
cryo
IL RESET
Couplers 5 Summary
Vac Cav
Vac Cap
HV
HV
Cryo
IL RESET
Couplers 6 Summary
Vac Cav
Vac Cap
HV
HV
Cryo
IL RESET
ACC 1
He fill le
43.9
low
41%
pressure
ACC 2-
He fill le
45.9
low
pressure
31.07 mb
Cryo loa
36.1394
65.3093 Wat
39.4006

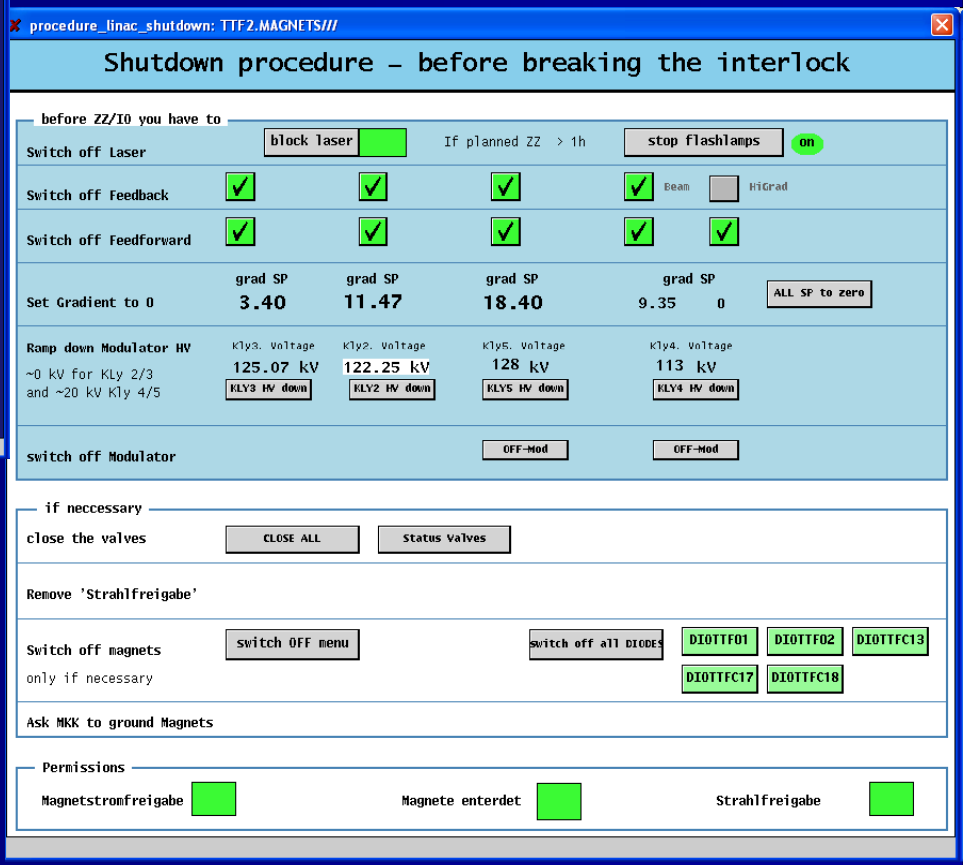
Die wichtigsten Schritte zusammengefasst



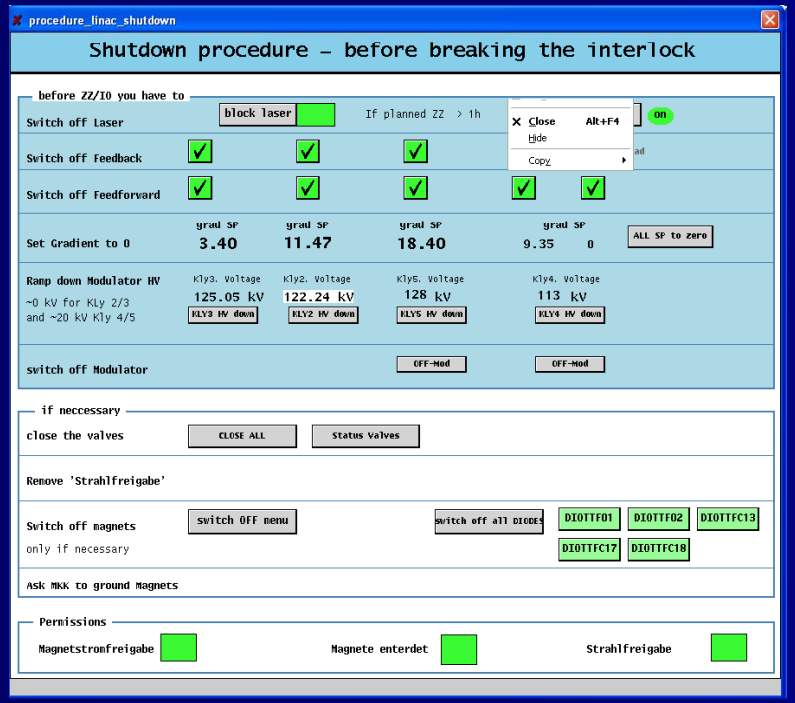
Die Knöpfe hier starten keinen Prozess sondern nur ein neues Fenster! (Sieht man, wenn man die Maus drüberbewegt)

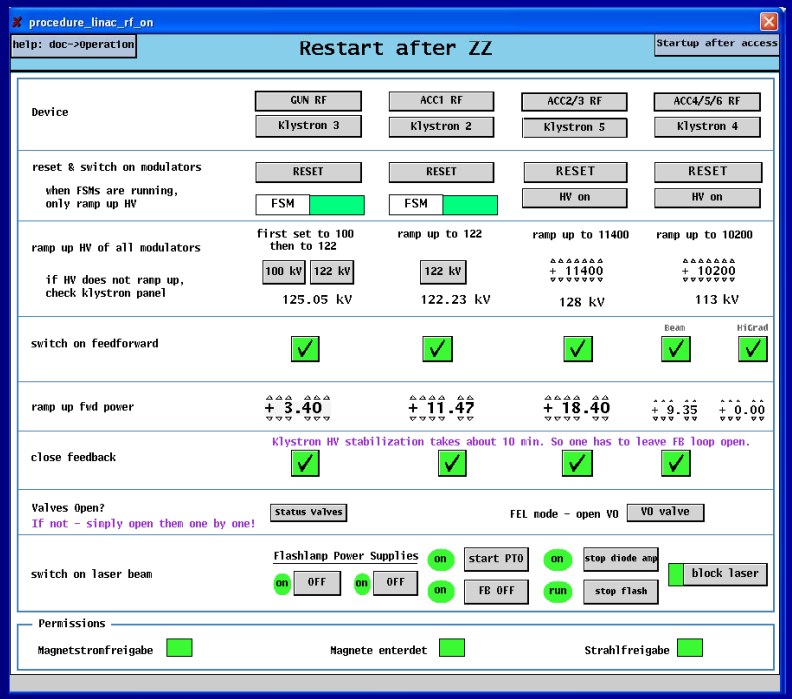
Startup / Shutdown





ZZ / Restart

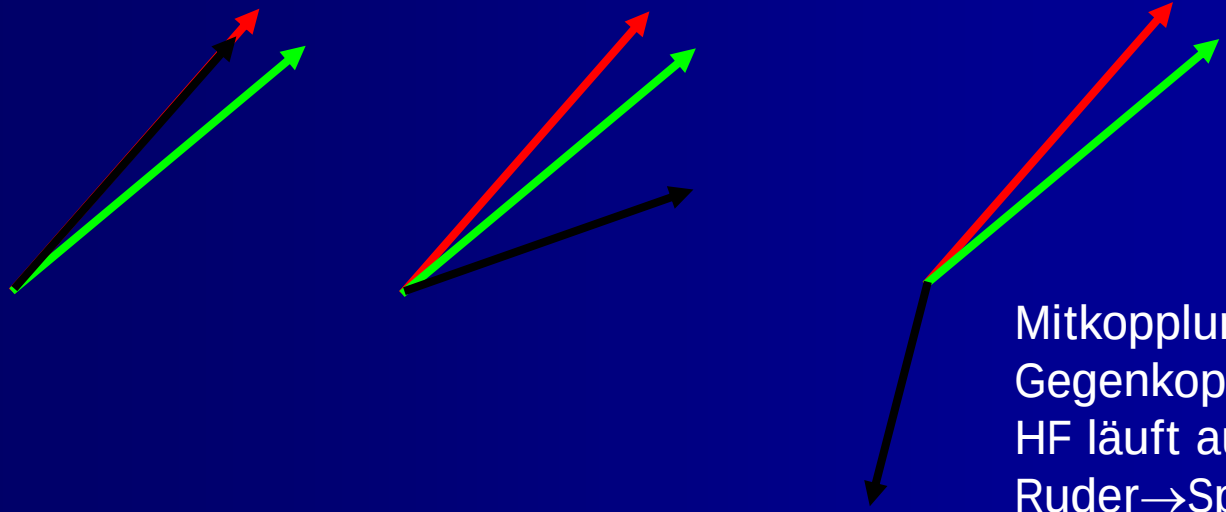

procedure_linac_shutdown
Shutdown procedure – before breaking the interlock
before ZZ/IO you have to
Switch off Laser
block laser
If planned ZZ > 1h
Close Alt+F4
Hide
Copy
Switch off Feedback
Switch off Feedforward
grad SP
Set Gradient to 0
3.40
11.47
18.40
9.35
0
ALL SP to zero
Ramp down Modulator HV
~0 kV for Kly 2/3
and ~20 kV Kly 4/5
Kly3. Voltage
125.05 kV
KLY3 HV down
Kly2. Voltage
122.24 kV
KLY2 HV down
Kly5. Voltage
128 kV
KLY5 HV down
Kly4. Voltage
113 kV
KLY4 HV down
switch off Modulator
OFF-Mod
OFF-Mod
if neccessary
close the valves
CLOSE ALL
Status Valves
Renove 'Strahlfreigabe'
Switch off magnets
only if necessary
switch OFF menu
switch off all DIODES
DIOTTF01
DIOTTF02
DIOTTFC13
DIOTTFC17
DIOTTFC18
Ask MKK to ground Magnets
Permissions
Magnetstromfreigabe
Magnete enterdet
Strahlfreigabe


procedure_linac_rf_on
help: doc->Operation
Restart after ZZ
Startup after access
Device
GUN RF
Klystron 3
ACC1 RF
Klystron 2
ACC2/3 RF
Klystron 5
ACC4/5/6 RF
Klystron 4
reset & switch on modulators
when FSMs are running,
only ramp up HV
RESET
FSM
RESET
FSM
RESET
HV on
RESET
HV on
ramp up HV of all modulators
if HV does not ramp up,
check klystron panel
first set to 100
then to 122
ramp up to 122
ramp up to 11400
ramp up to 10200
100 kV
122 kV
122 kV
+ 11400
+ 10200
125.05 kV
122.23 kV
128 kV
113 kV
switch on feedforward
Beam
HiGrad
ramp up fwd power
+ 3.40
+ 11.47
+ 18.40
+ 9.35
+ 0.00
close feedback
Klystron HV stabilization takes about 10 min. So one has to leave FB loop open.
Valves Open?
If not - simply open them one by one!
Status Valves
FEL mode - open V0
V0 valve
switch on laser beam
Flashlamp Power Supplies
on
OFF
on
OFF
on
start PTO
on
FB OFF
on
stop diode amp
run
stop flash
block laser
Permissions
Magnetstromfreigabe
Magnete enterdet
Strahlfreigabe

Gut & Böse bei der HF

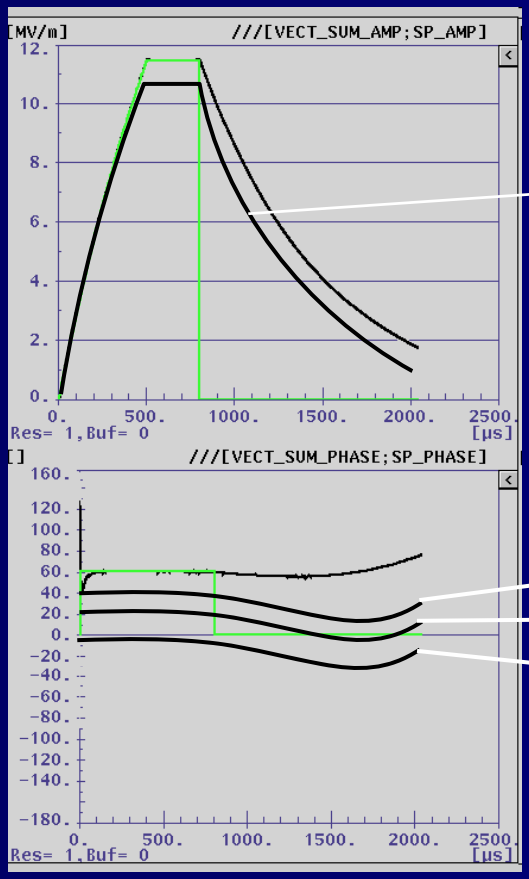
1. Loop Phase

good	bad	ugly



Mitkopplung statt Gegenkopplung: HF läuft aus dem Ruder→Spark!

Woran erkennt man das?



Verdächtig, wahrscheinlich Sättigung

tolerabel

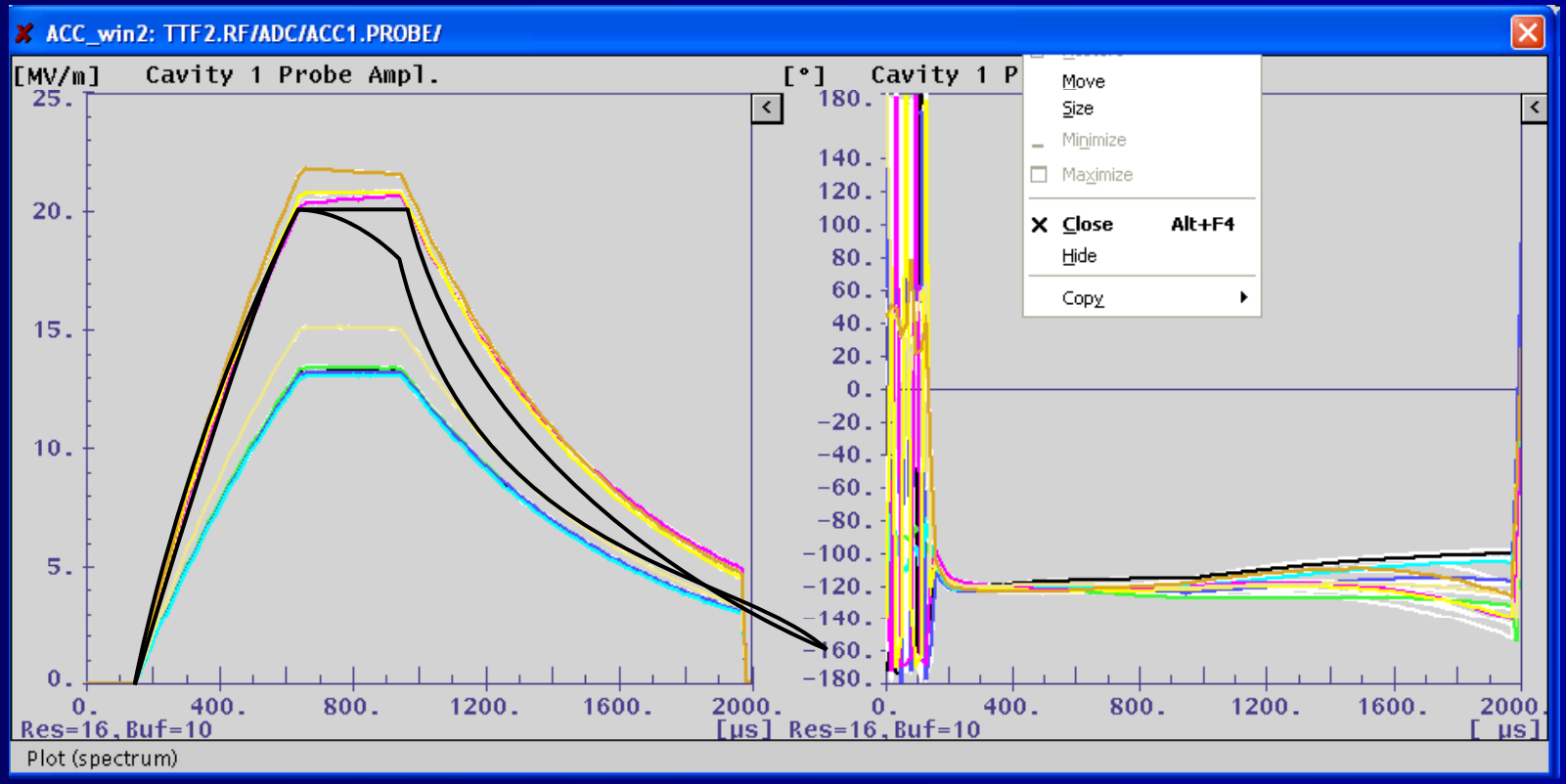
ziemlich übel

gefährlich

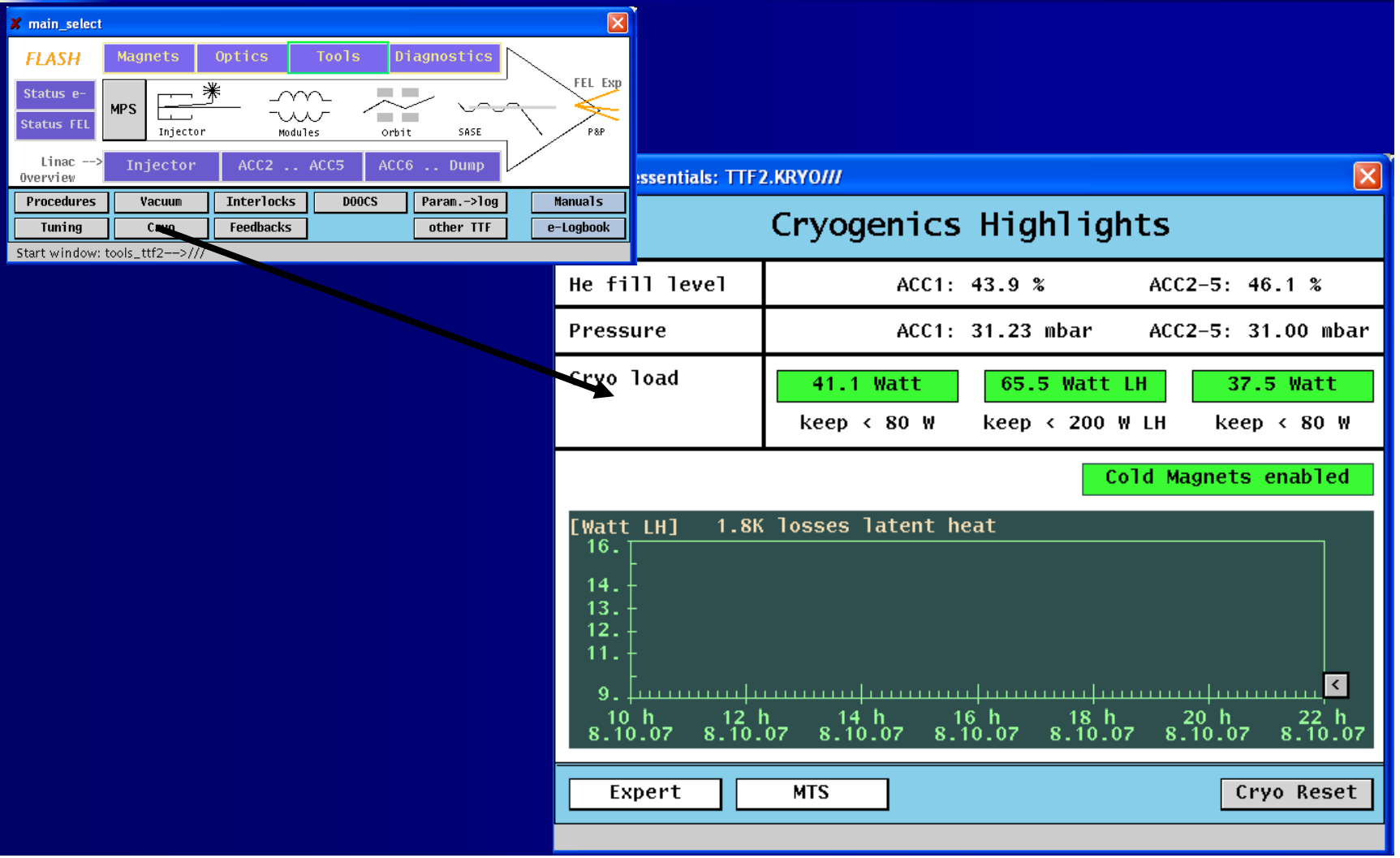
Vorsichtsmassnahmen

- Niemals Klystron einschalten, wenn Feedbackloop geschlossen ist
  (Insbesondere kein Interlock-Reset)
- Warten, bis Klystron-Spannung voll da ist
- Erst Feedforward an, Kurven beobachten, dann Feedback
- Gain schrittweise erhöhen – insbesondere, wenn Einstellungen sich geändert haben könnten
- Phasenscans möglichst nicht bei geschlossener Loop (wenn der Scanbereich gross ist)

Quench


ACC_win2: TTF2.RF/ADC/ACC1.PROBE/
[MV/m] Cavity 1 Probe Ampl.
[°] Cavity 1 P
25.
20.
15.
10.
5.
0.
180.
140.
120.
100.
80.
60.
40.
20.
0.
-20.
-40.
-60.
-80.
-100.
-120.
-140.
-160.
-180.
0.
400.
800.
1200.
1600.
2000.
Res=16,Buf=10
[µs]
Move
Size
Minimize
Maximize
Close Alt+F4
Hide
Copy
Plot (spectrum)

Oder ein Blick auf die Kryo

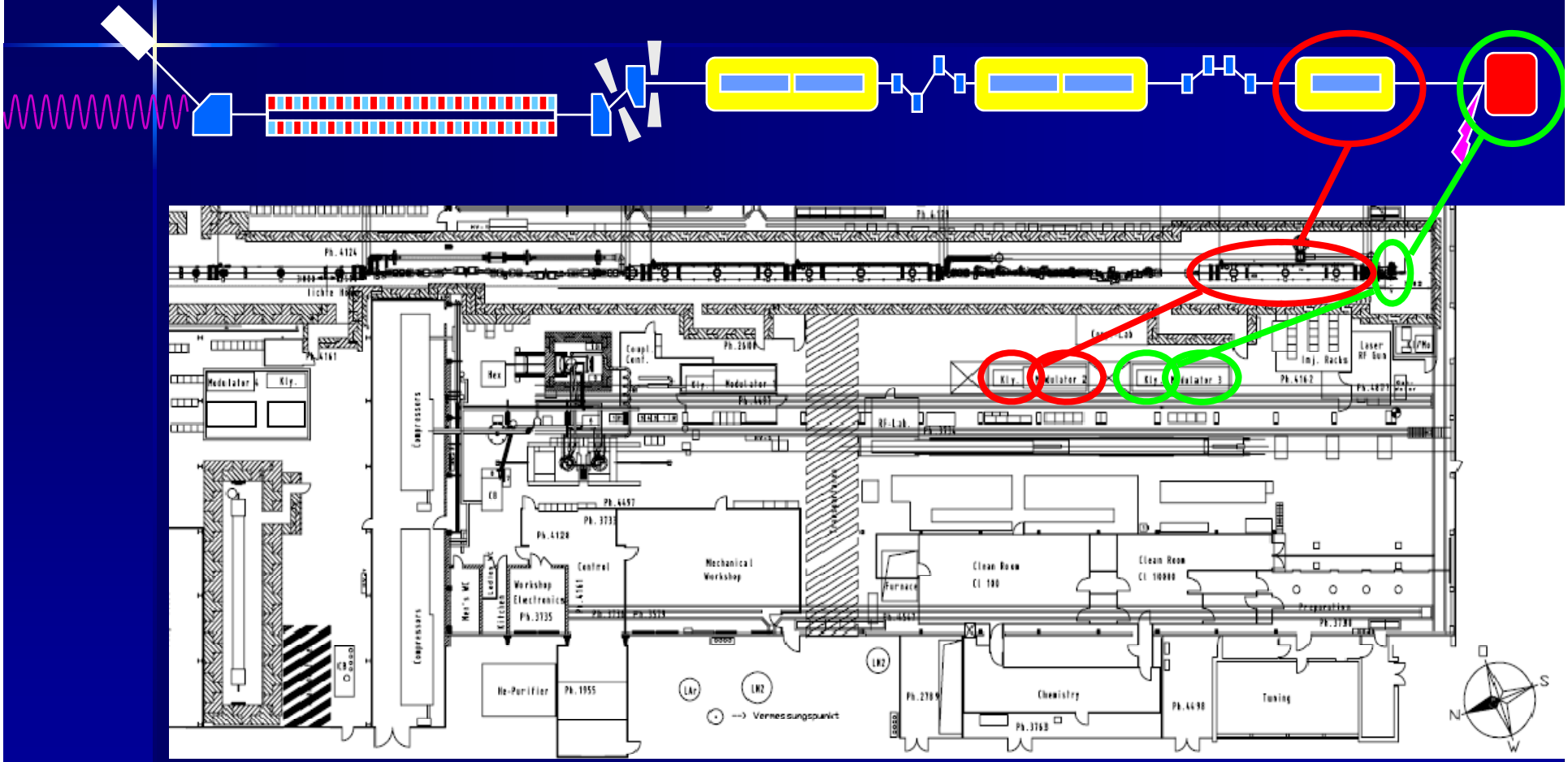


Zum Abschluss

- Kein Übermut aber auch keine Angst!
  - Im Prinzip ist das System durch das technische Interlock geschützt, aber man muss das ja nicht unbedingt ausprobieren
  - Abschalten per Interlock verhindert unmittelbaren Schaden, belastet aber die Komponenten unnötig
- Vor dem Wegfall der Strahlfreigabe Hochspannung herunterfahren!

In Halle 2

In Halle 3

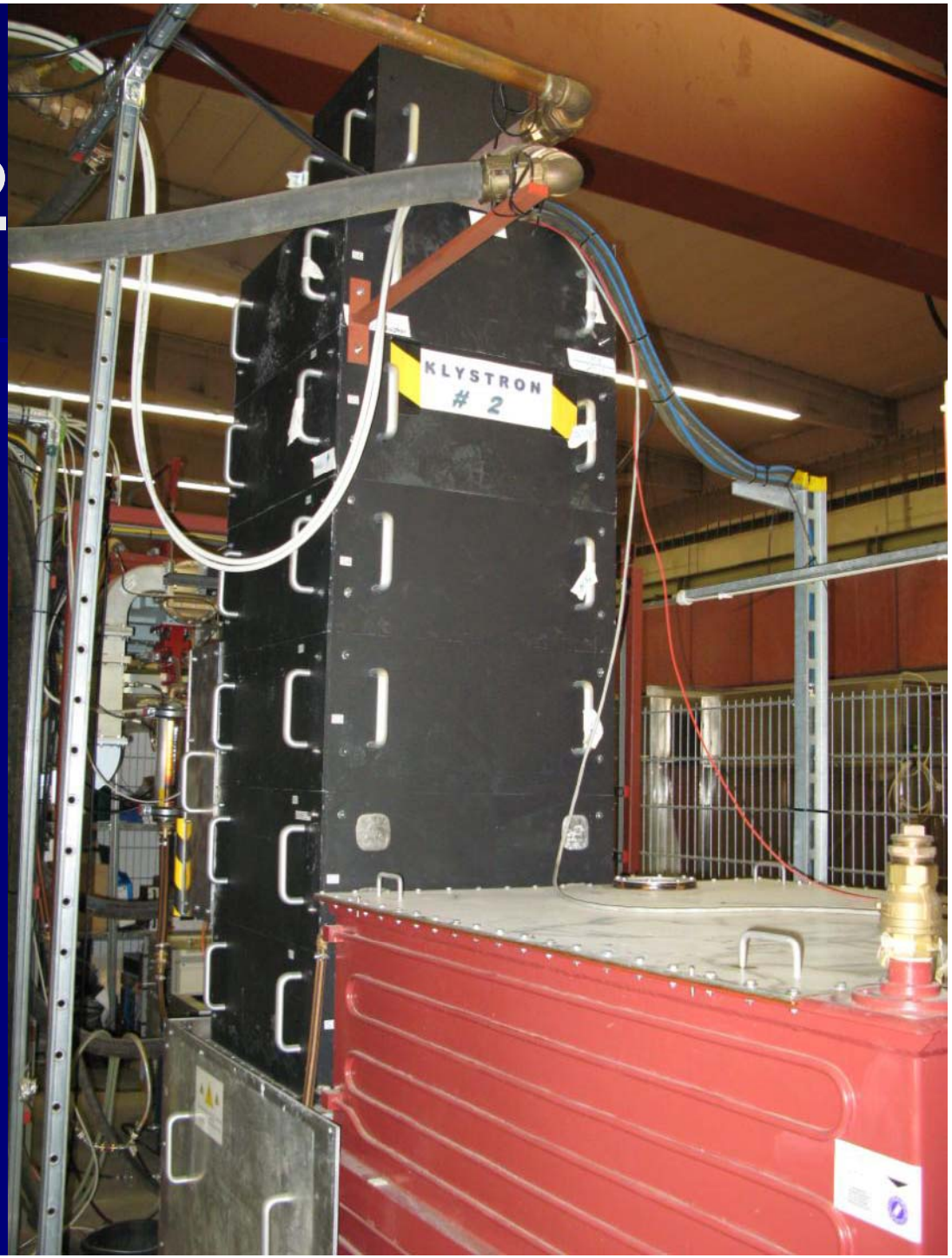

Modulator
Kly.
Compressors
Mechanical Workshop
Clean Room
Cl 100
Clean Room
Cl 10000
Chemistry
Tuning
Laser RF Gun
Inj. Racks
RF-Lab.
Control
Workshop Electronics
Ph.3735
He-Purifier
Ph.1955
Furnace
Ladies
Men's WC
Kitchen
LAr
LN2
--> Vermessungspunkt
N
S
W

Rückseite von Modulator3

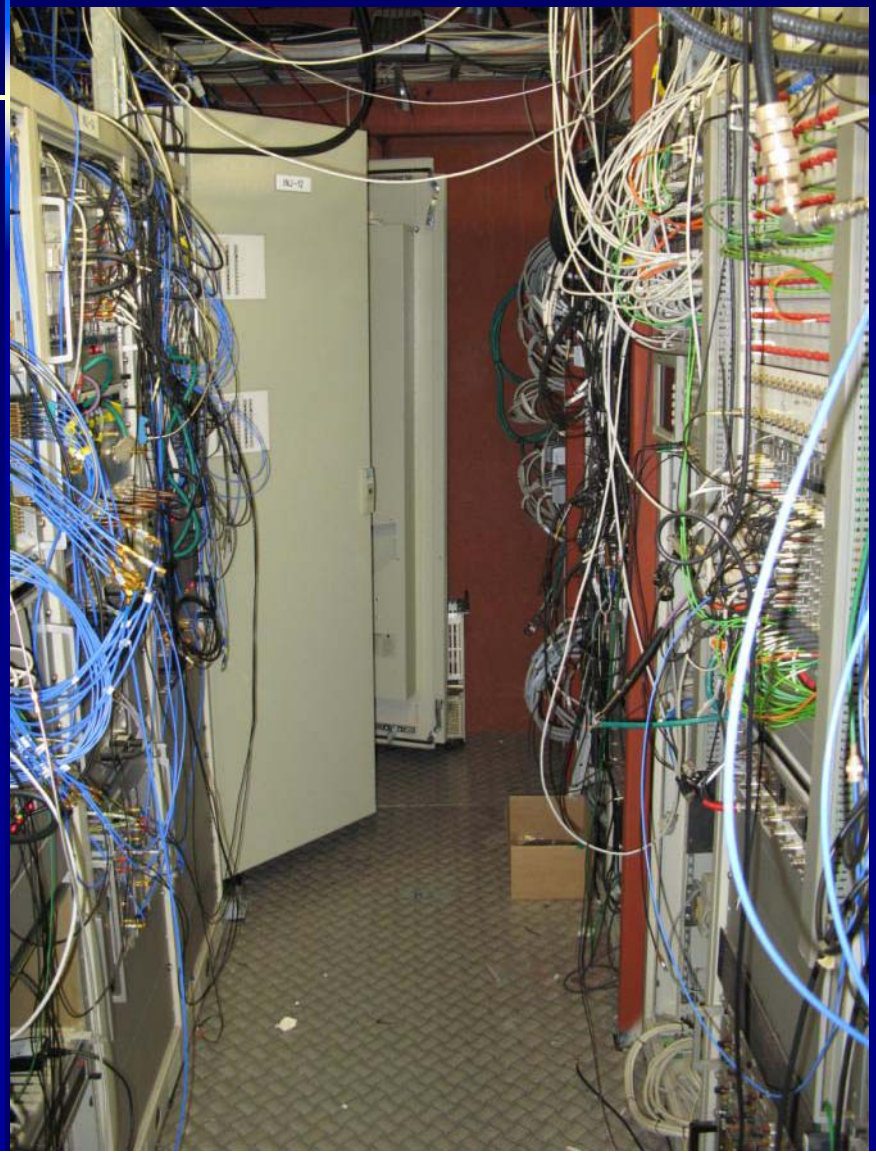
Kly 3

SF6

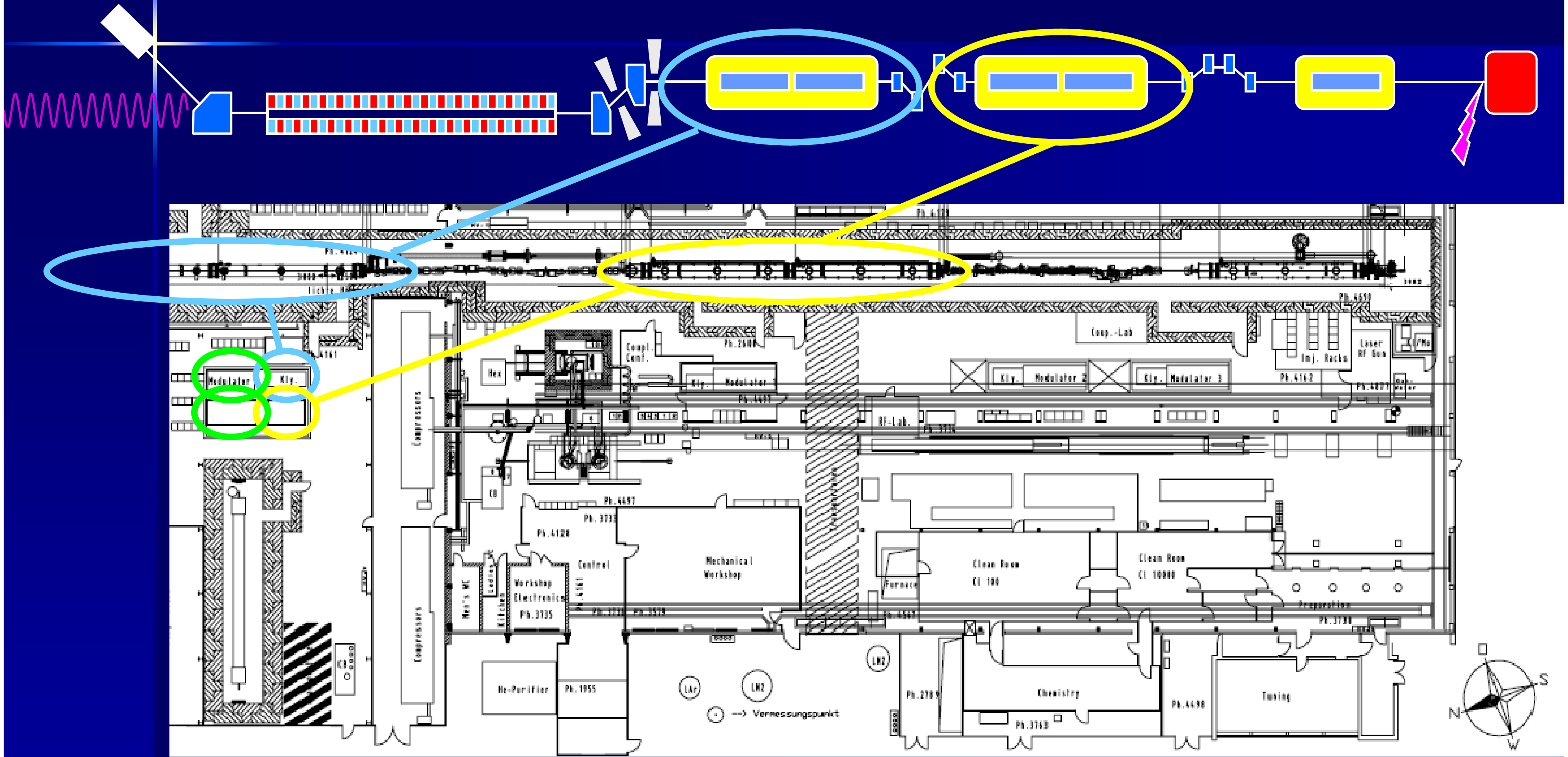
Klystron 2



LLRF + Timing



In Halle 3


Mechanical Workshop
Clean Room
Chemistry
Tuning
Compressors
He-Purifier
Vermessungspunkt

Kly 4&5 Zugang + LLRF

Klystron 4&5