Status of superconducting module development suitable for cw operation: ELBE cryostats

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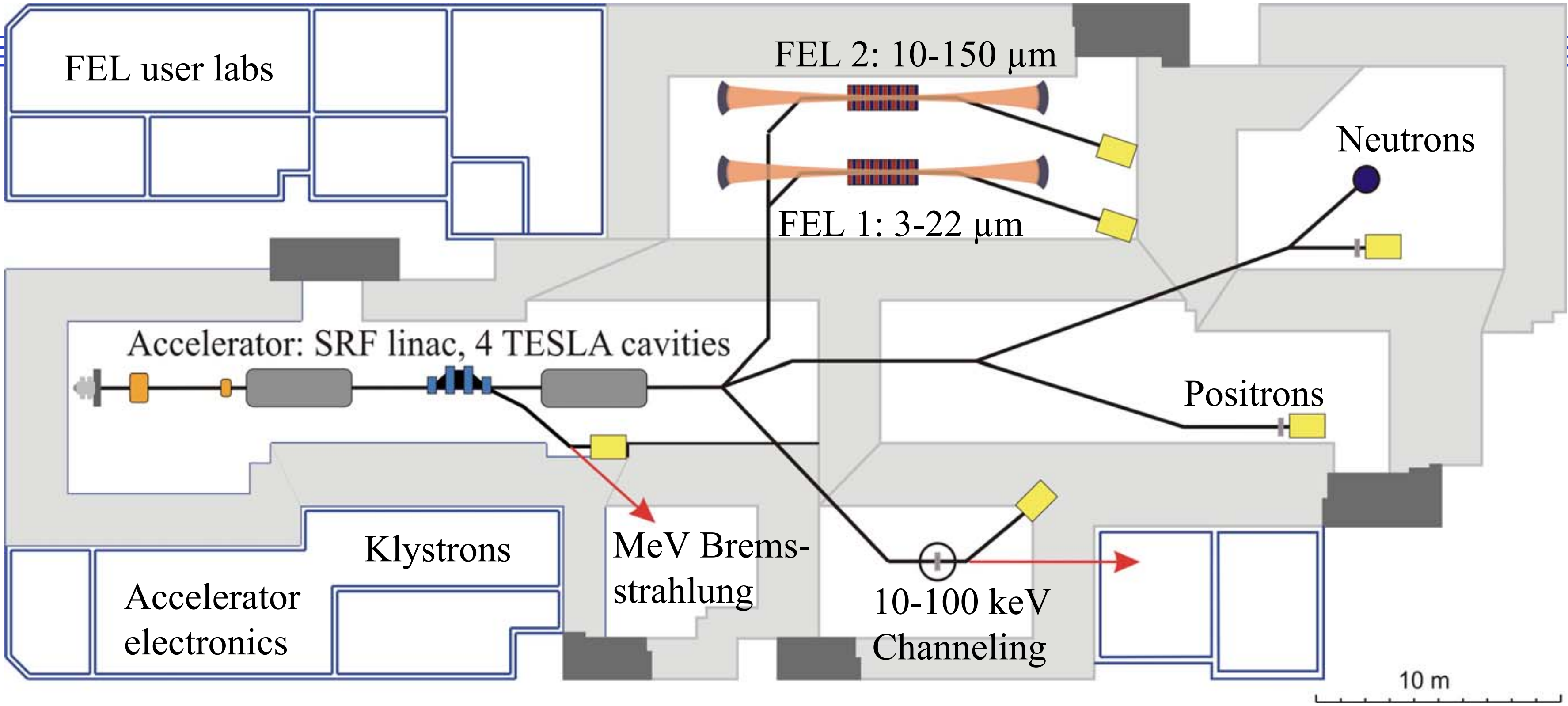
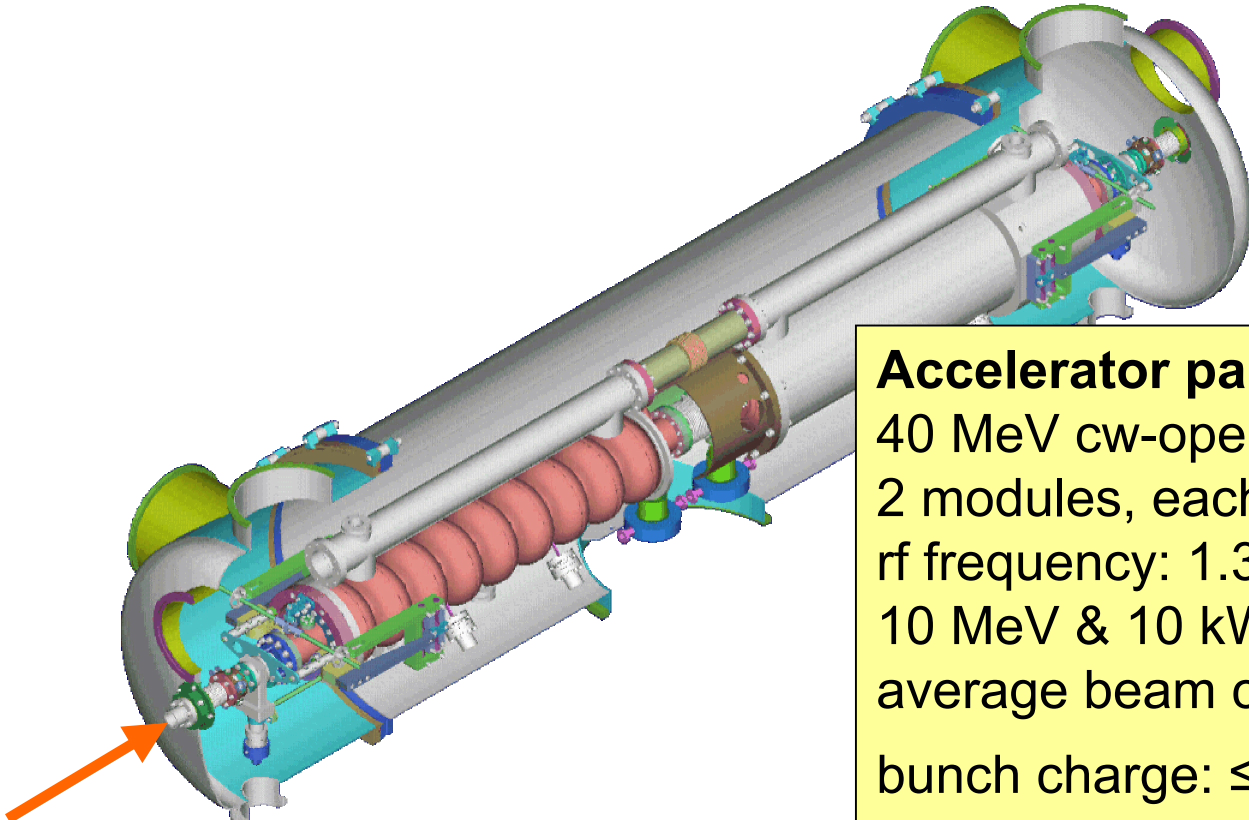
The radiation source ELBE



- First beam in April 2001
- Nuclear physics experiments are running since January 2002
- Channeling radiation since September 2003
- FEL 1 since May 2004
- Second Cryomodule since February 2005

ELBE radio-frequency electron accelerator

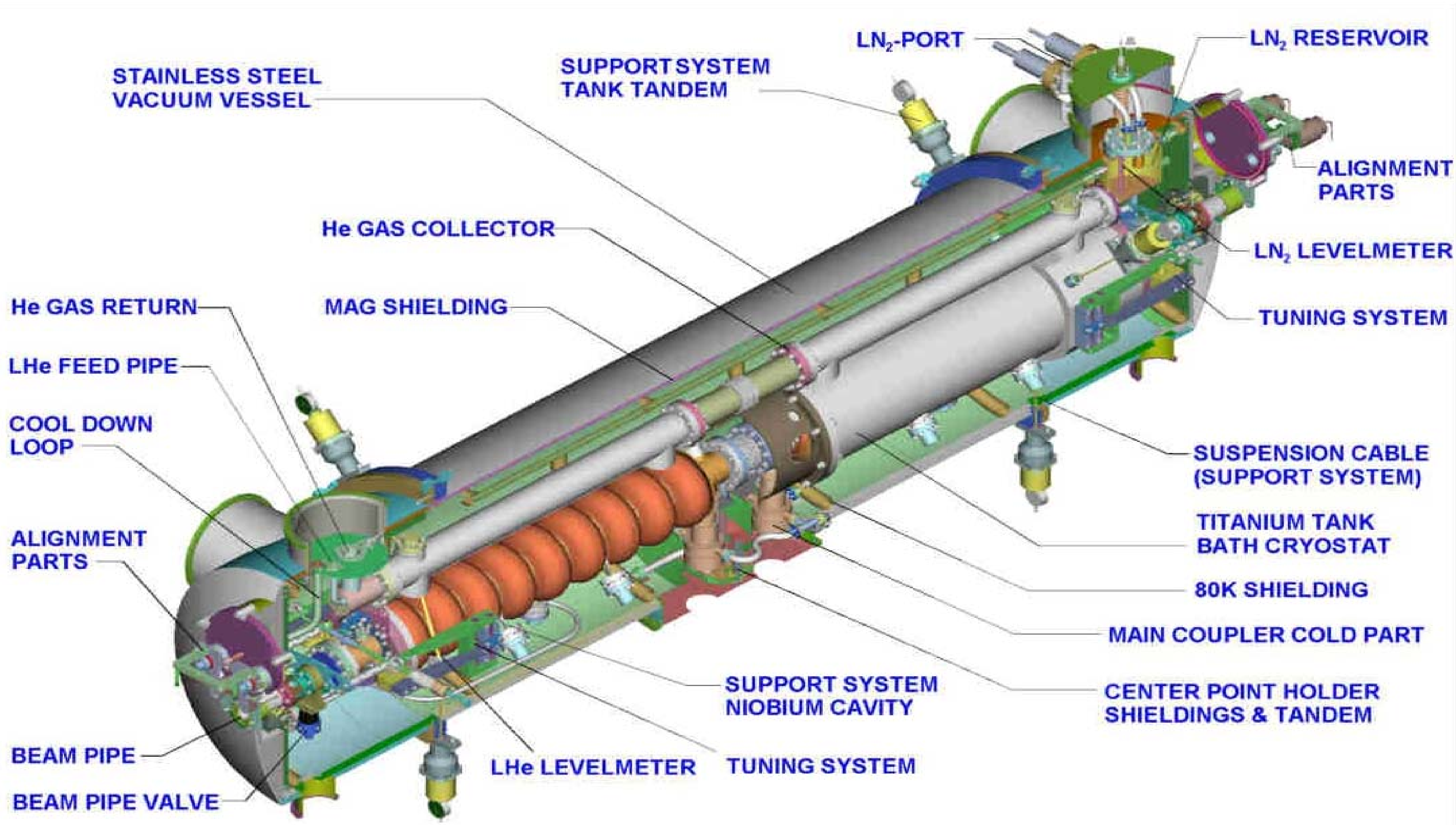


$250\ keV\ , 1mA\ , \beta = 0.74$

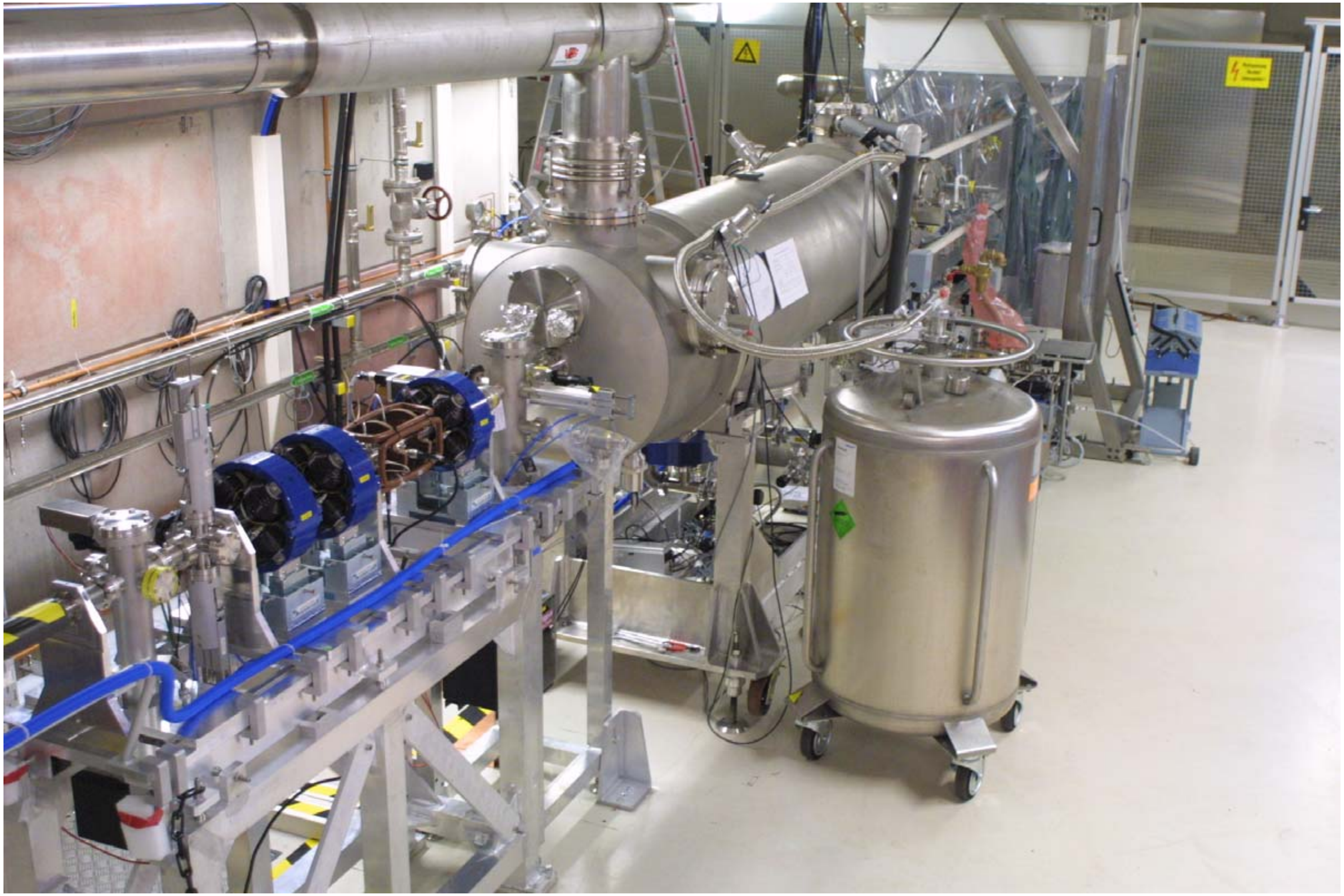
7 MeV @ 10 MV/m for
optimum beam capture

Accelerator parameters:
40 MeV cw-operation
2 modules, each 2 TESLA cavities
rf frequency: 1.3 GHz
10 MeV & 10 kW rf power per cavity
average beam current: ≤ 1 mA
bunch charge: ≤ 77 pC
pulse frequency: 260, 26 … 0.01 MHz
variable pulse trains

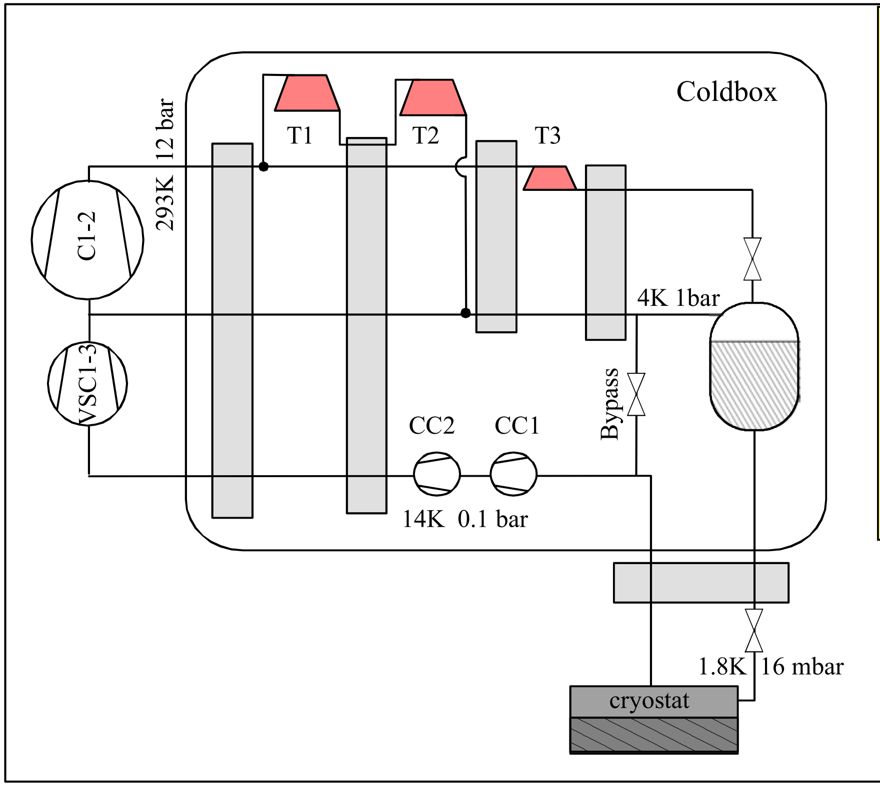
ELBE cryomodule design



ELBE cryomodule



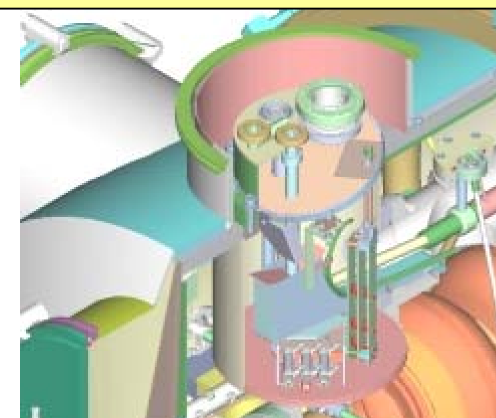
ELBE cryogenics



Problems at beginning:
- pressure instability
- interference between p and He level (valve) control

Solutions:
- increased He flow in CC via bypass,
- level control with heater in modules feed-forward control from gradients

Helium plant 220 W @ 1.8 K
p control with cold compressors CC1, CC2

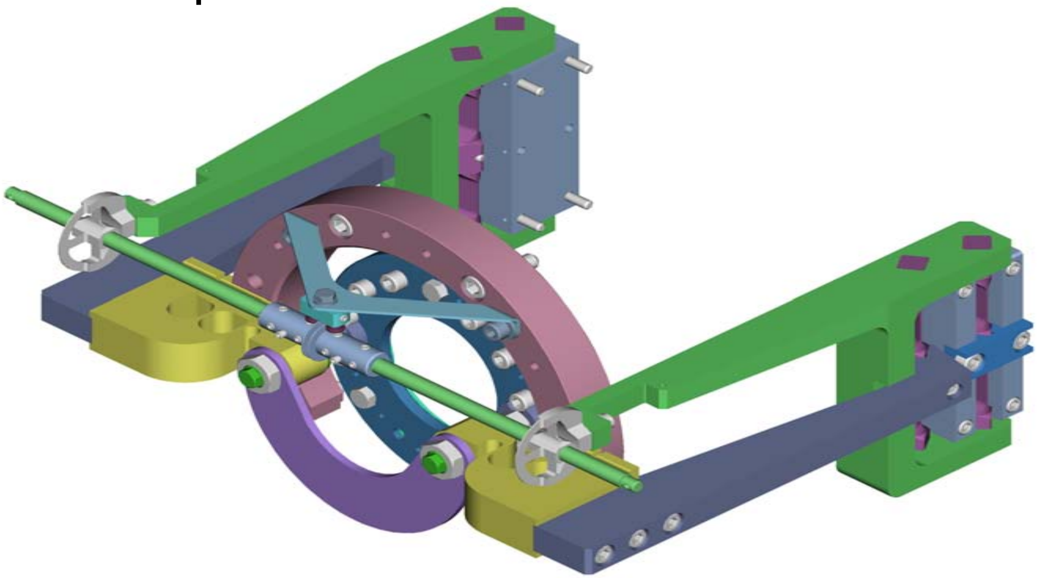


Cryostat pot heater

Now: stable operation of the two cryomodules

ELBE tuning system

"slow" spindle/lever system
due to cw fast Lorentz-force
compensation not needed



Tuning range
- mechanical: ±0.37 mm
- frequency: ± 116 kHz

Tuning resolution
- mechanical: 3 nm
- frequency: 1 Hz

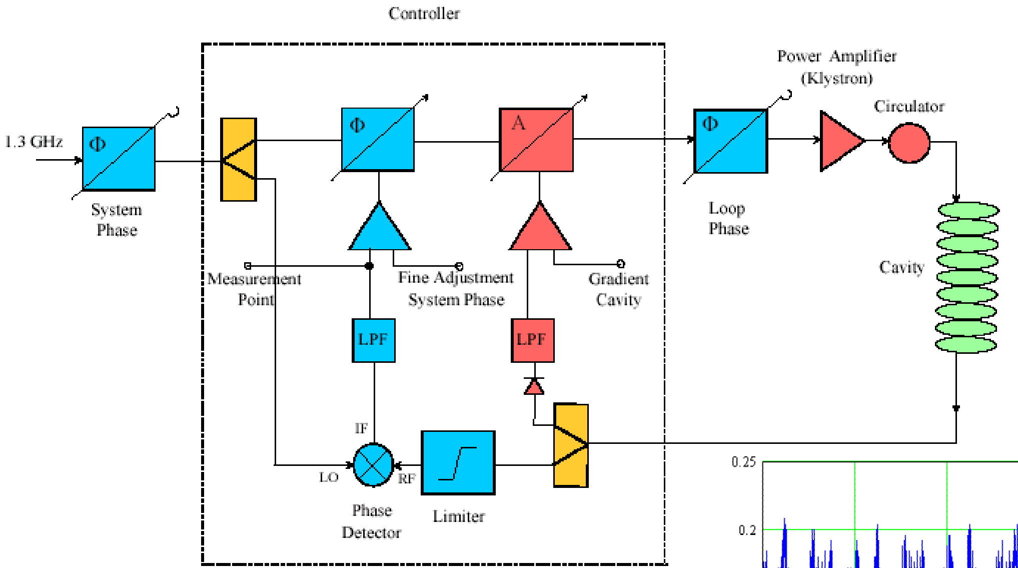
Transfer
- 156 nm/motor turn
- 2.3 steps/nm

Maximum load: 3000 N

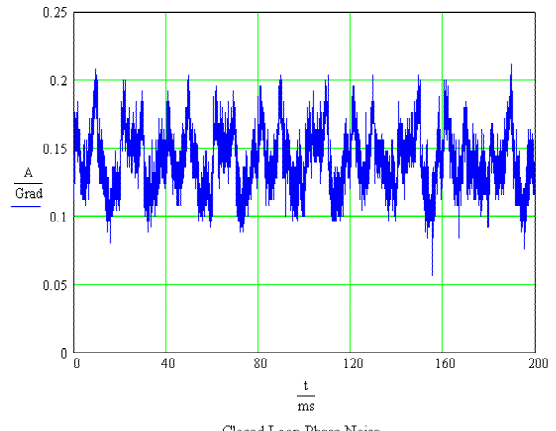
Lorentz-force detuning: 50 Hz @ 7 MV/m
compensation "by hand" during gradient ramp up

RF control

10 kW CPI VKL 7811 ST klystron for each cavity, in cw operation
analog low-level rf control, phase & amplitude loop



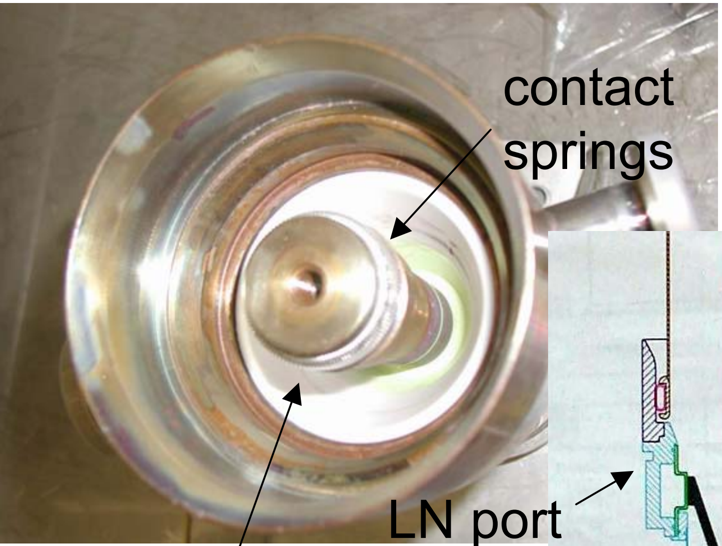
separate for each cavity:
- gradient
- phase
- power meas. values (tuning)

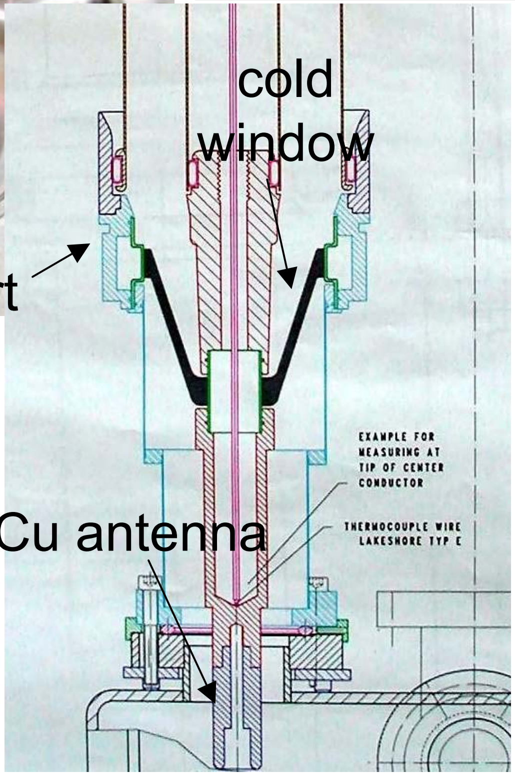


Safety system
Gradient loop error:
- detuned cavities
- beam loading etc.

microphonics
open loop: 0.97 deg rms
closed loop: 0.02 deg rms

ELBE rf power coupler





overheated in coupler tests with 8 kW full reflection

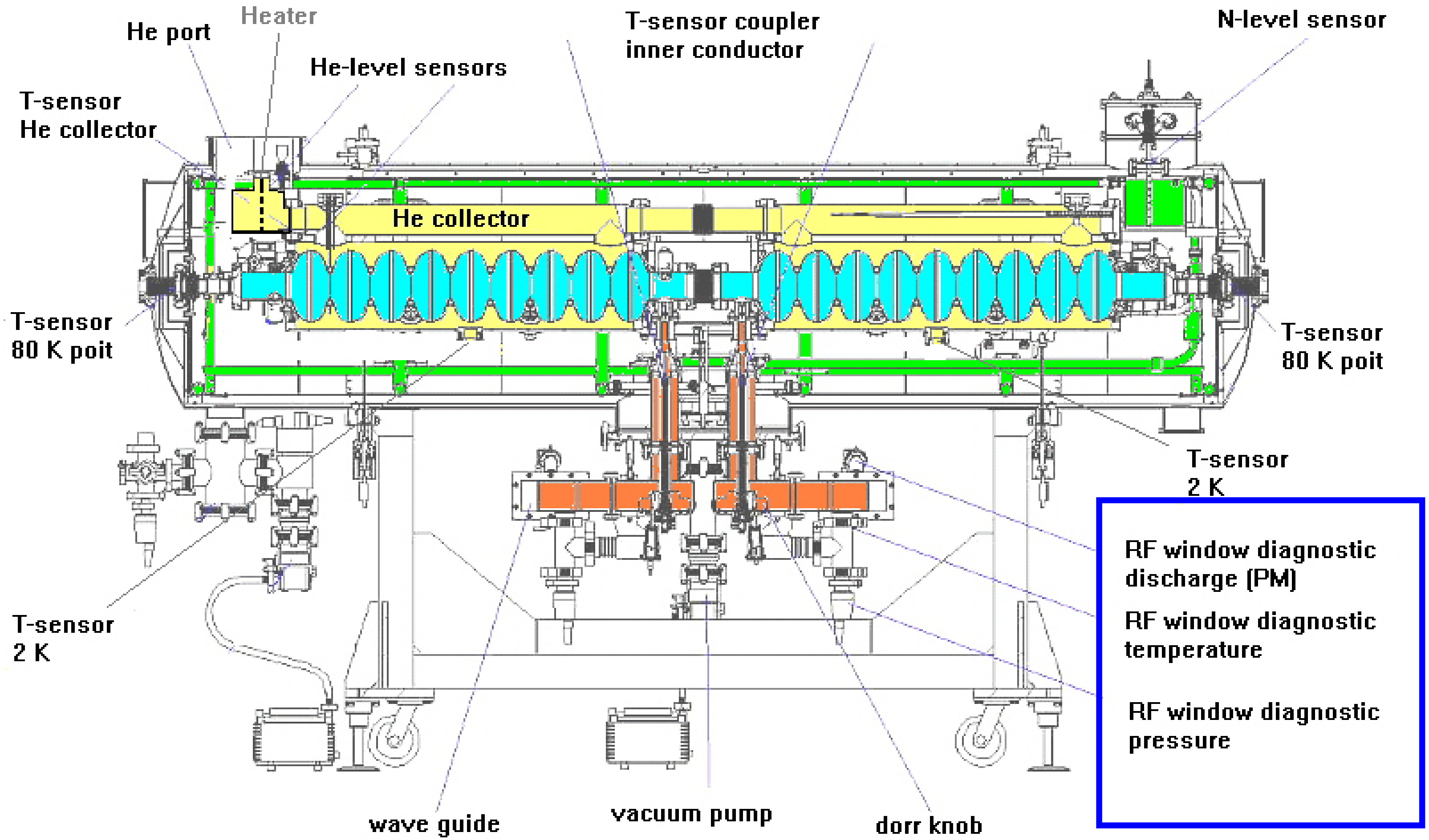
Coupler design for 10 kW cw using the TTF conical insulator, T.Kimura/HEPL-Stanford & J.Stephan

three-stub waveguide tuner
for BW adjustment
RT planar window in waveguide
REXOLITHE
position at E-field waist
conical cold window at 70 K
ceramics
Coupling is matched for 1 mA beam current at 10 MV/m

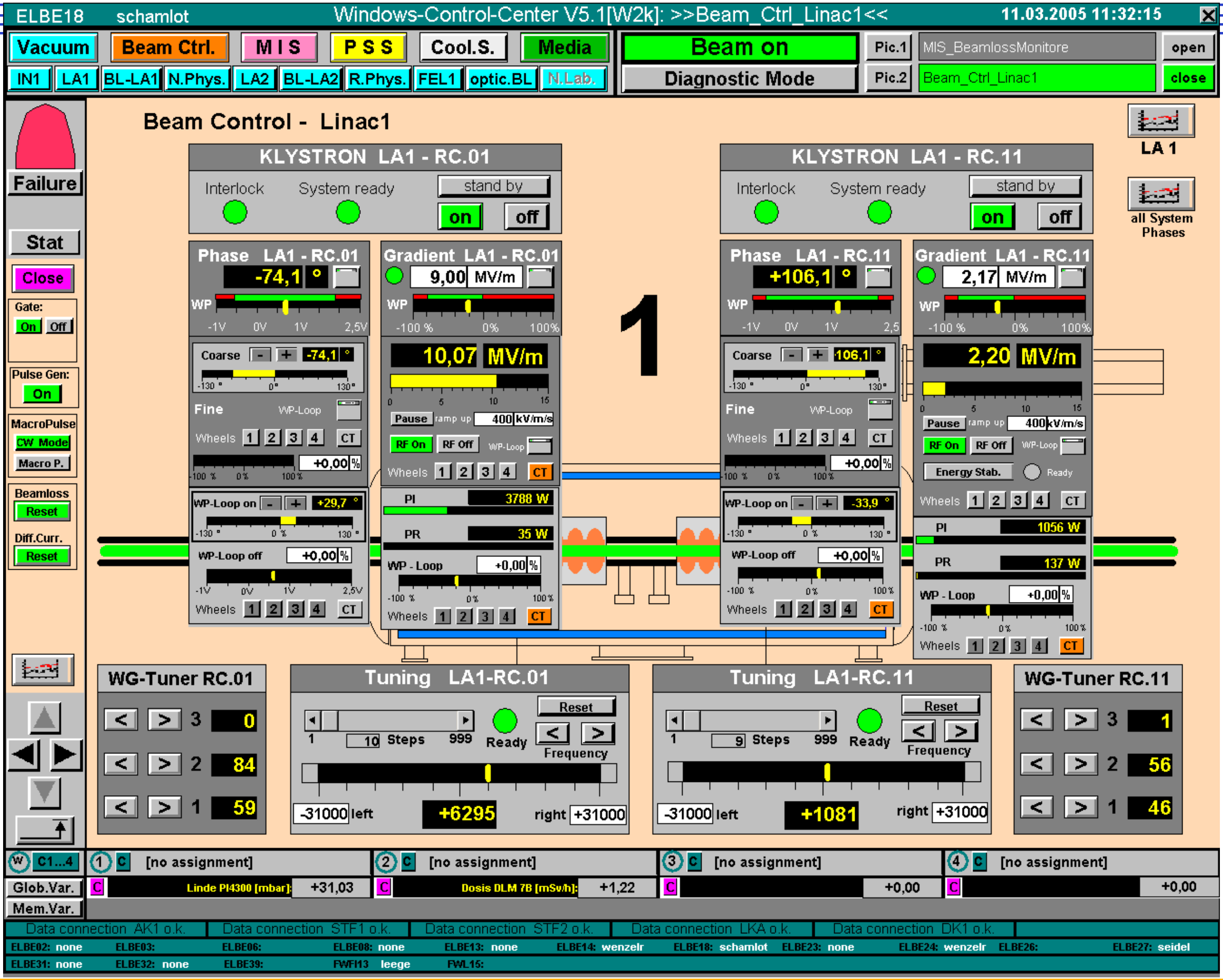
BW = 114 Hz

$Q_L = 1.2 \times 10^7$

ELBE cryomodule diagnostics



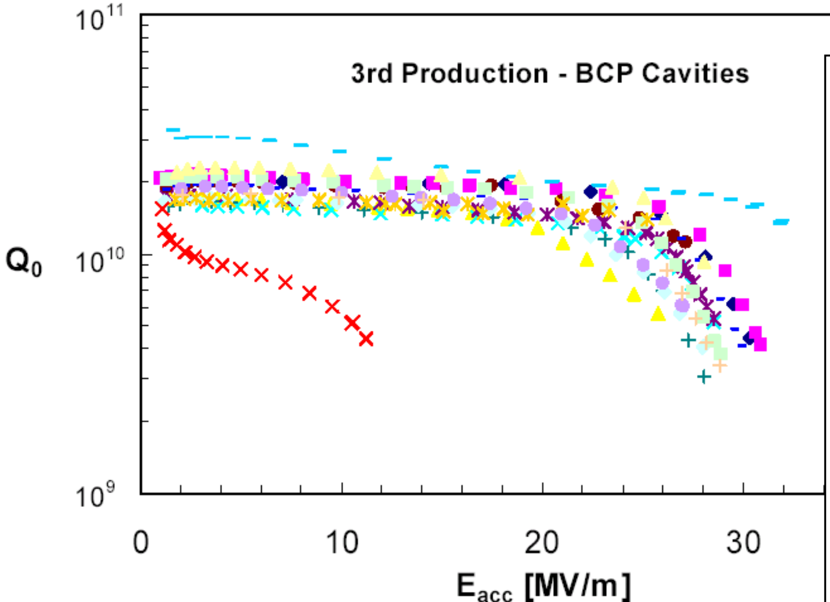
RF control



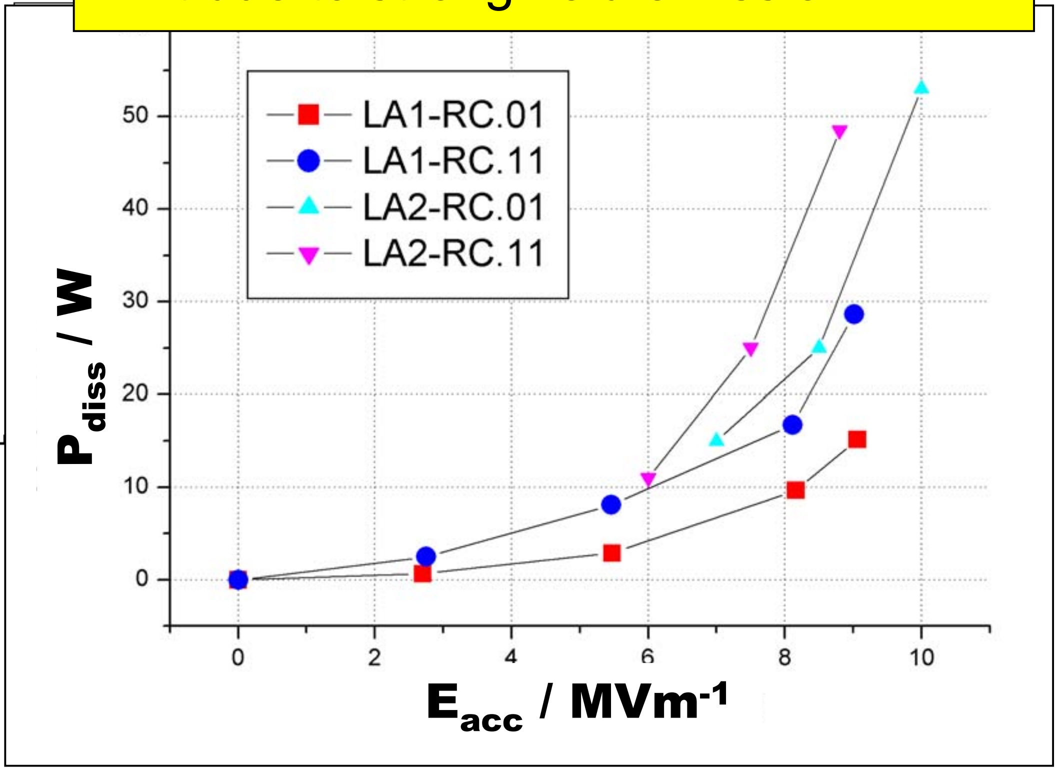
ELBE18 schamlot
Windows-Control-Center V5.1[W2k]: >>Beam_Ctrl_Linac1<<
11.03.2005 11:32:15
Vacuum
Beam Ctrl.
M I S
P S S
Cool.S.
Media
Beam on
Diagnostic Mode
Pic.1
Pic.2
MIS_BeamlossMonitore
Beam_Ctrl_Linac1
open
close
IN1
LA1
BL-LA1
N.Phys.
LA2
BL-LA2
R.Phys.
FEL1
optic.BL
N.Lab.
Failure
Stat
Close
Gate:
Pulse Gen:
MacroPulse
CW Mode
Macro P.
Beamloss
Reset
Diff.Curr.
Beam Control - Linac1
KLYSTRON LA1 - RC.01
KLYSTRON LA1 - RC.11
Interlock
System ready
stand by
on
off
Phase LA1 - RC.01
-74,1 °
Gradient LA1 - RC.01
9,00 MV/m
10,07 MV/m
Phase LA1 - RC.11
+106,1 °
Gradient LA1 - RC.11
2,17 MV/m
2,20 MV/m
Coarse
Fine
WP-Loop
Wheels
CT
WP-Loop on
WP-Loop off
Pause
ramp up
400 kV/m/s
RF On
RF Off
Energy Stab.
Ready
PI
3788 W
PR
35 W
1056 W
137 W
WP - Loop
1
LA 1
all System Phases
WG-Tuner RC.01
WG-Tuner RC.11
Tuning LA1-RC.01
Tuning LA1-RC.11
Reset
Steps
Ready
Frequency
-31000 left
+6295
+1081
right +31000
[no assignment]
Glob.Var.
Mem.Var.
Linde PI4300 [mbar]
+31,03
Dosis DLM 7B [mSv/h]
+1,22
+0,00
Data connection AK1 o.k.
Data connection STF1 o.k.
Data connection STF2 o.k.
Data connection LKA o.k.
Data connection DK1 o.k.

ELBE module - cavity properties

TESLA cavities



cavity operation at ELBE: Gradient limit due to strong field emission



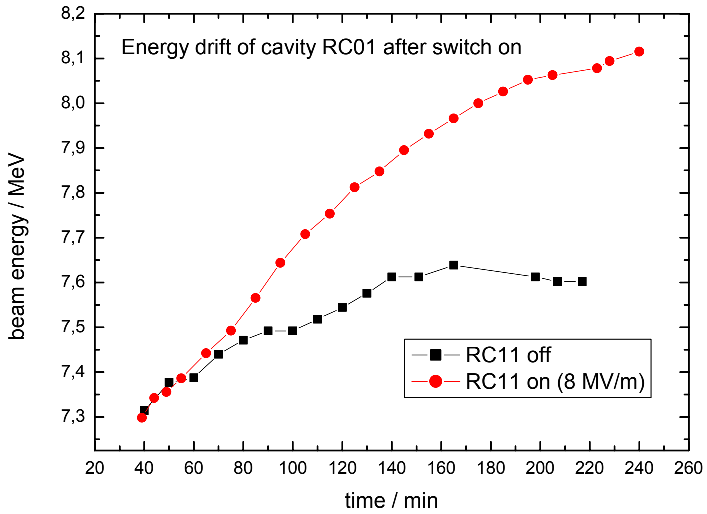
ELBE cavities vertical test at DESY before tank welding etc.:

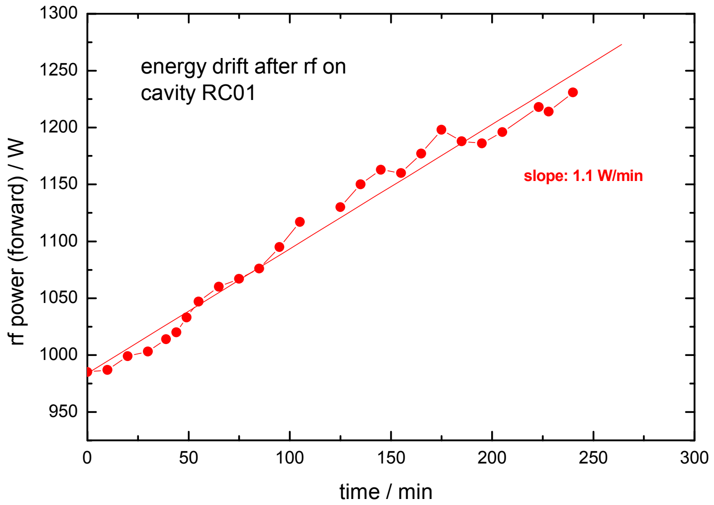
$Q_0 = 2 \times 10^{10}$, E_{acc} = 15... 25 MV/m

Reason: welding, assembling, storage, couplers?

ELBE module – energy drift

We observed an energy growth with time after switching on gradient set values and pick-up signals are constant





the source is in the module, it is not rf control,
temperature increase with the same time scale,
connected with cw operation of TESLA cavities at ELBE?

ELBE cryomodule - summary

- ELBE cryomodules are suitable for cw-operation @ 10 MV/m & 1 mA
  most of module parameters better/equal to design specifications
  common He pressure control with cold compressors,
  separate He level control (heater) in each module,
  analog phase and amplitude rf control for each cavity,
  sophisticated coupler/window diagnostics,
- Higher gradients:
  1. limit due to field emission in cavities, difficult to reach 20 MeV,
     extended quality management for next module
  2. At ELBE: capacity limit of the cryogenic plant,
- Higher current (rf power):
  1 mA (10 kW) seems near to the limit of the rf power couplers,
- Energy drift:
  cw-operation causes 1 MeV energy drift within first hours,
  source is in module (temperature effect) , no rf control

Acknowledgment

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LL RF control: F.Gabriel

RF and couplers: H. Büttig, R. Schurig, A. Büchner

Diagnostics: D. Pröhl, F. Herbrand, R. Jainsch, J. Claussner, A. Schamlott

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Operation: U. Lehnert, P. Michel, P. Evtoushenko, J. Voigtländer

DESY Hamburg **(A. Matheisen ...),** ***HEPL Stanford, ACCEL, TU Dresden***