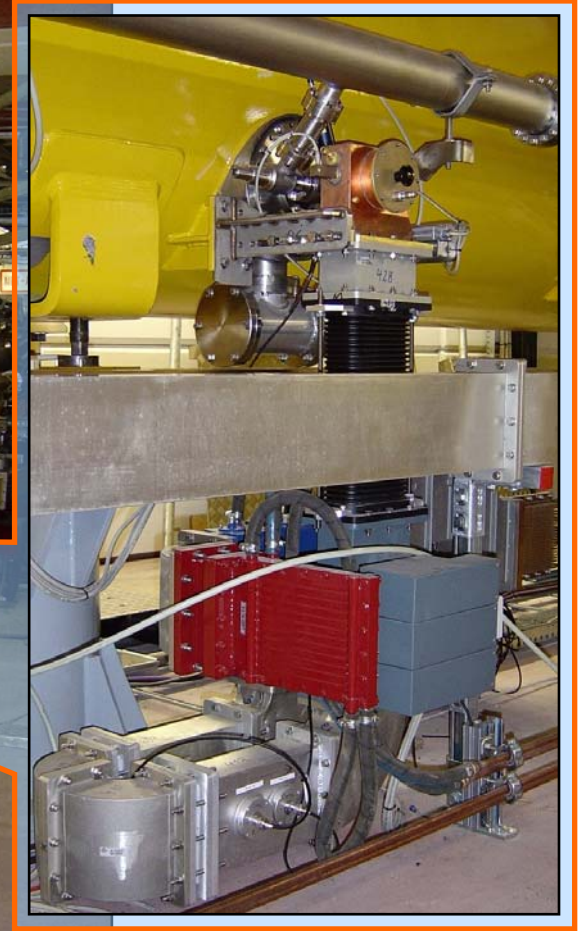
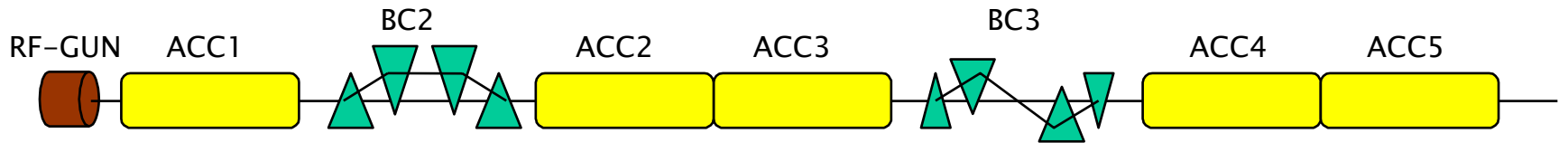


TESLA Cavities and RF Power Couplers in the VUV-FEL LINAC Modules

Overview

- ★ VUV–FEL LINAC Accelerating Modules
- ★ VUV–FEL LINAC RF Power Couplers
- ★ VUV–FEL LINAC Cavities
- ★ Conclusion

VUV-FEL LINAC



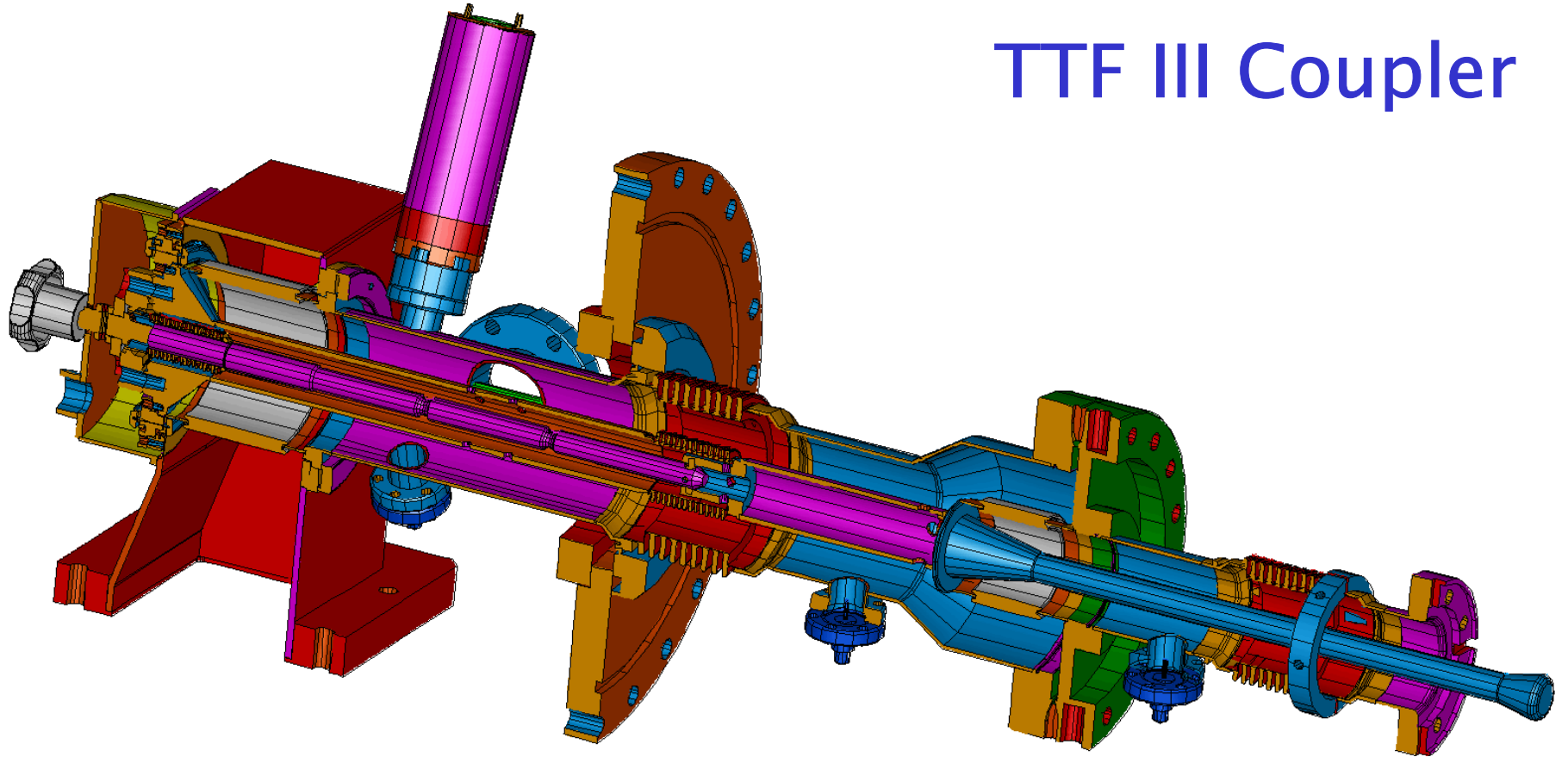
Accelerating Modules

Five accelerating modules were installed into the TTF tunnel as a part of the VUV FEL Linac
Each module has 8 superconducting cavities and RF power input couplers

position	module	assembled	coupler type	cold window	warm window
ACC1	2*	Jan. 2004	FNAL/TTF III	Conical/Cyl.	Planar/Cyl
ACC2	1*	Mar. 2000	FNAL/TTF II	Conical/Cyl.	Planar
ACC3	3*	Feb. 2003	TTF II	Cylindrical	Plane, WG
ACC4	4	Jul. 2001	TTF II	Cylindrical	Plane, WG
ACC5	5	Mar. 2002	TTF III	Cylindrical	Cylindrical

VUV-FEL LINAC RF Power Couplers

TTF III Coupler

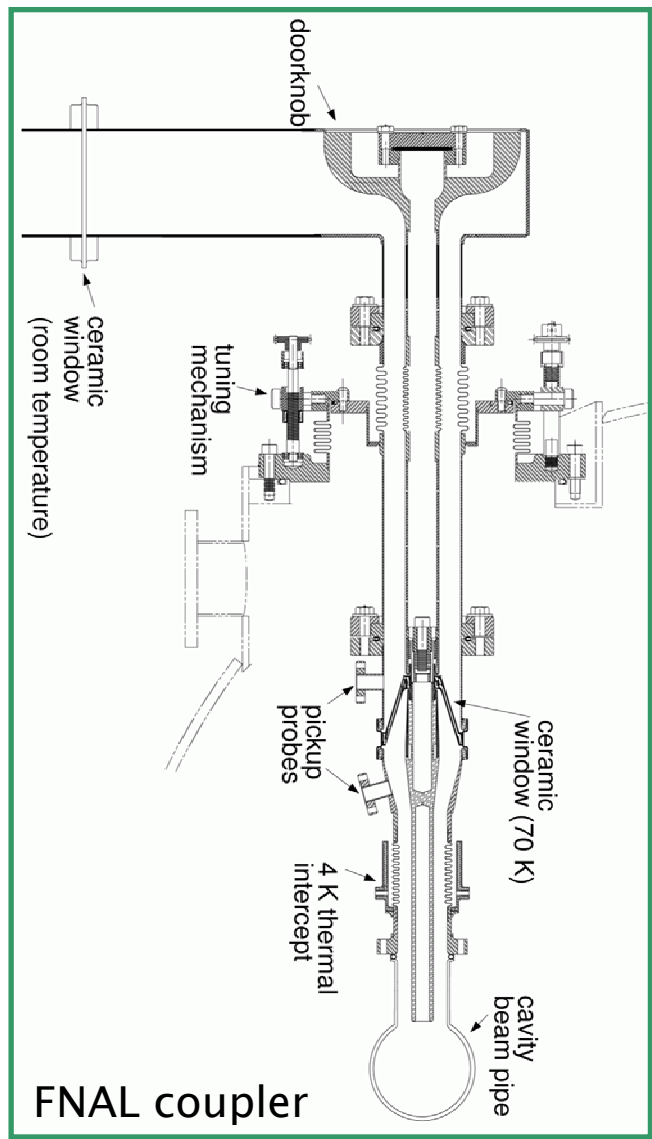
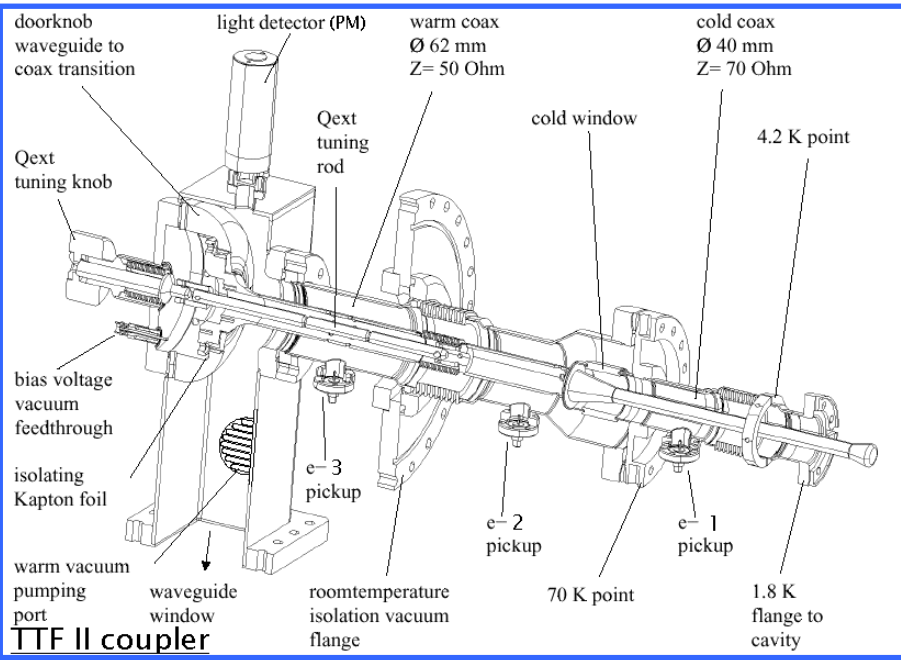
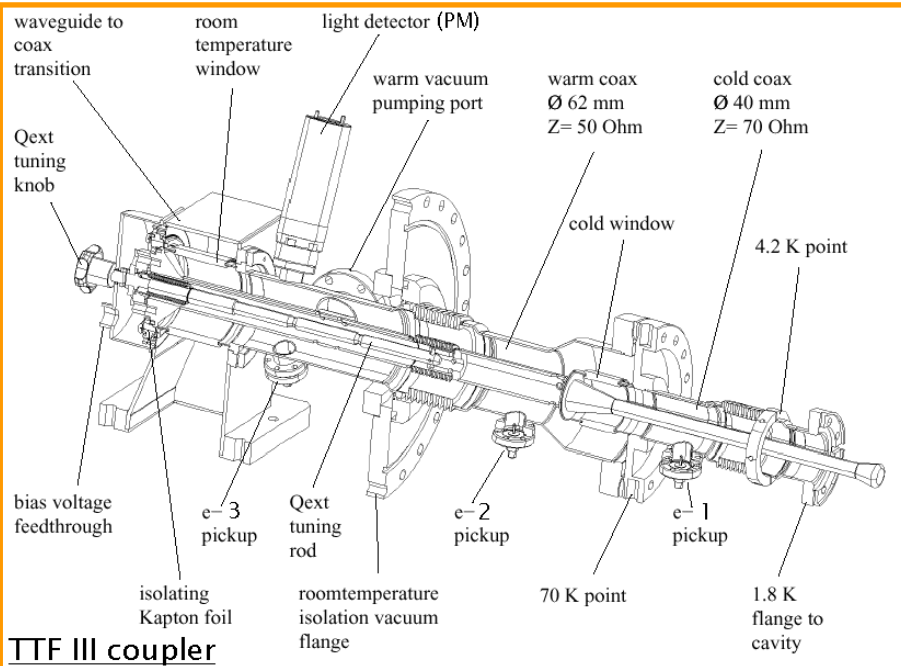


RF Coupler Specifications

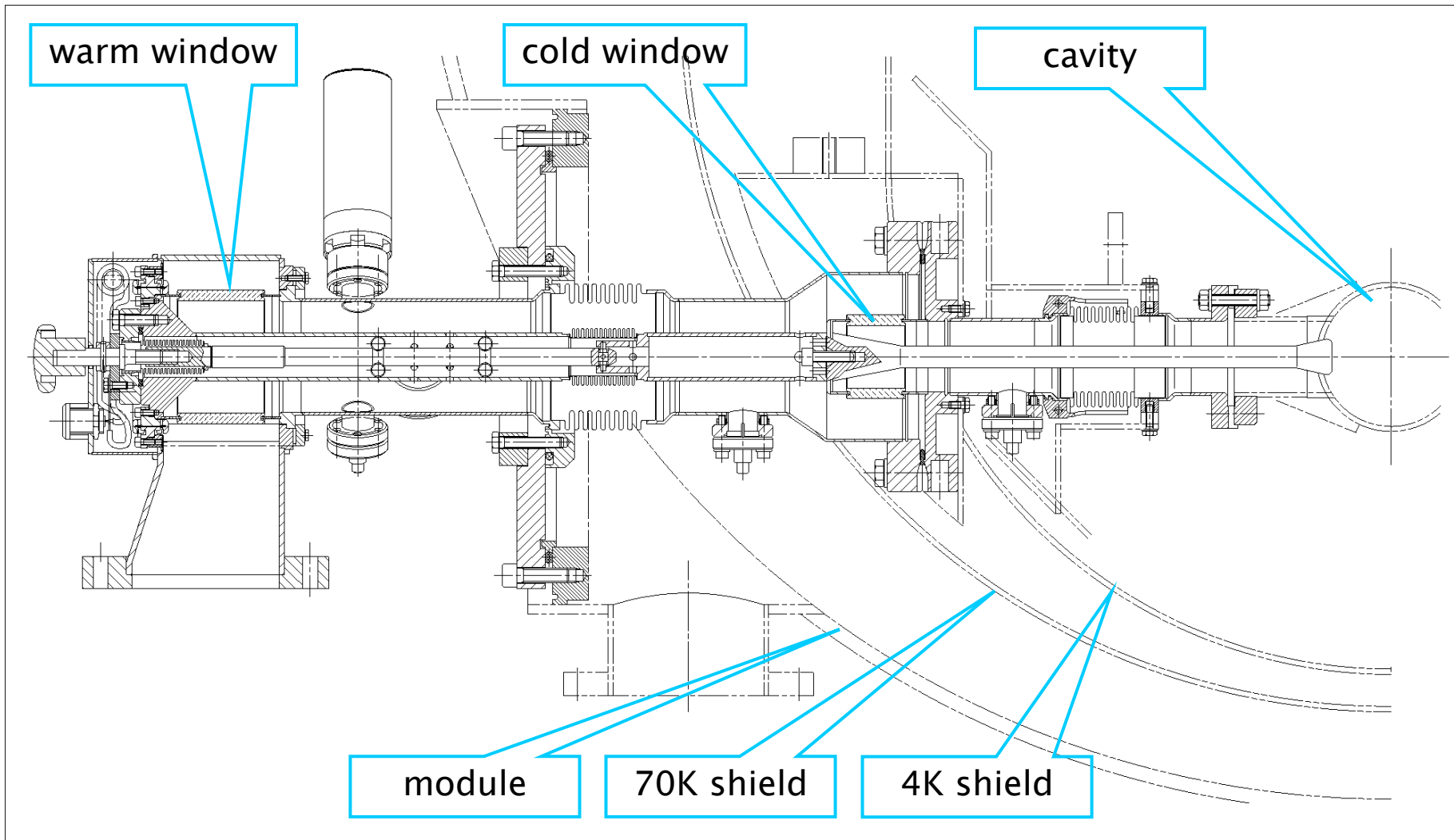
frequency	1.3 GHz
operation	pulsed: 500 μ sec risetime, 800 μ sec flat top with beam
two windows, TiN coated	<ul style="list-style-type: none"> • safe operation • clean cavity assembly for high Eacc
2 K heat load	0.06 W
4 K heat load	0.5 W
70 K heat load	6 W
isolated inner conductor	bias voltage, suppressing 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 (Q_{ext})	adjustable ($10^6 - 10^7$)	fixed ($3 \cdot 10^6$)	adjustable ($10^6 - 10^7$)

RF Coupler Types



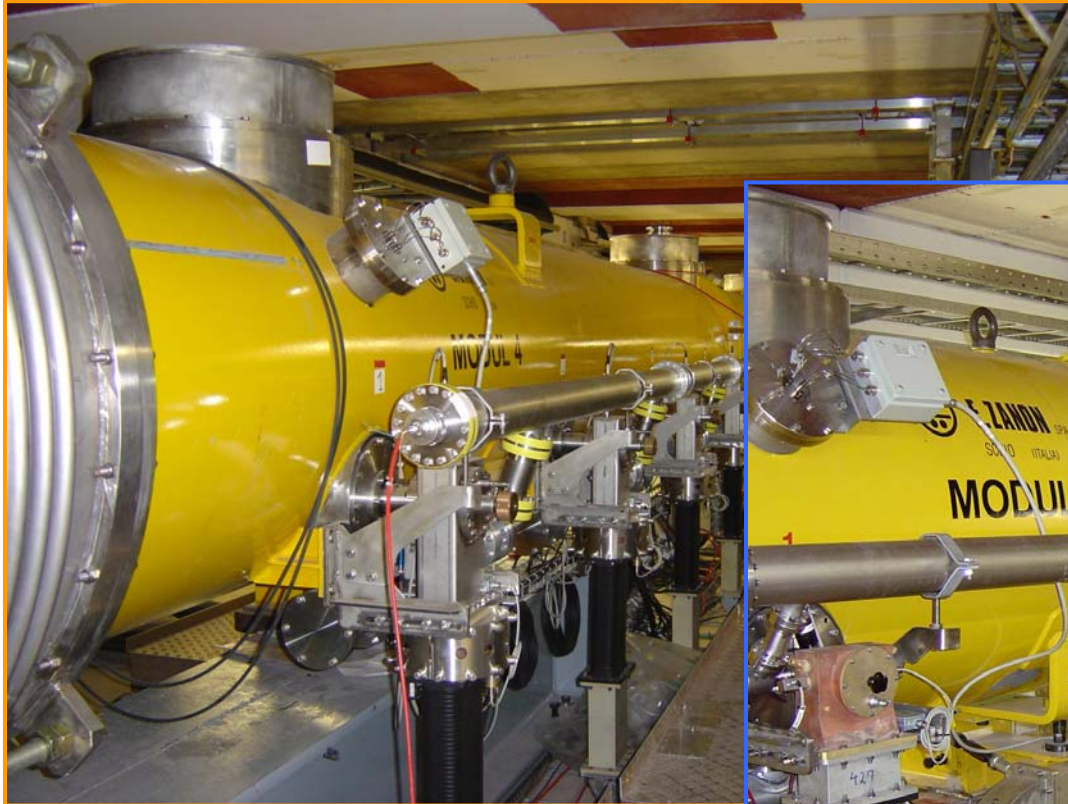
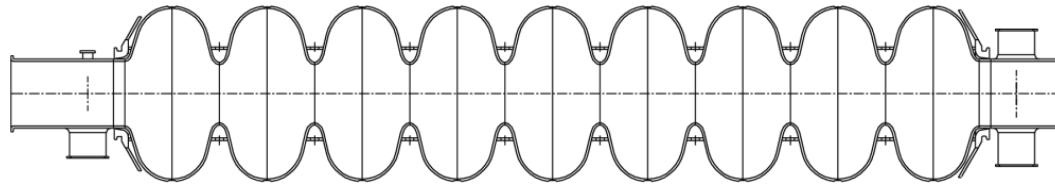
RF Coupler in Module



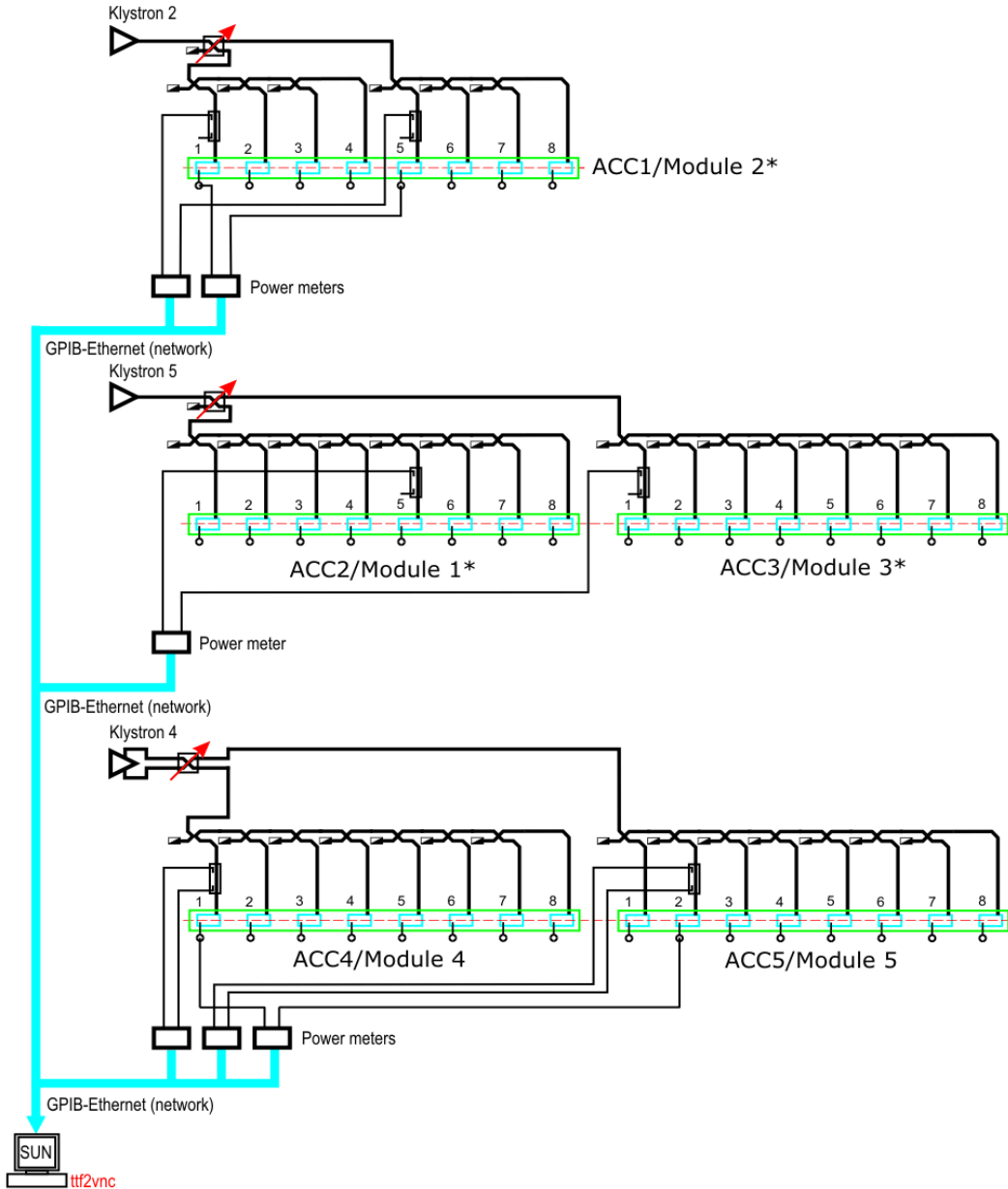
RF Couplers Performance

- ◆ Total of 40 RF power couplers connected to the superconducting cavities in the VUV FEL linac, eight in a module.
- ◆ All couplers in the VUV FEL linac could be processed and operated up to the cavity performance limits.
- ◆ The parallel processing of 8 respectively 16 couplers at the modules is slower than that at the test stands or in the horizontal cryostat.
- ◆ RF power couplers were tested up to 1 MW of pulsed power at 1.3 ms pulse length 2 Hz at the test stand.
- ◆ RF power couplers operated ~350000 hours*coupler.
- ◆ Last coupler design TTF III has simplified assembly as well as better performance, conditioning time is shorter.
- ◆ TTF III couplers are tested together with cavities at gradients of 35 MV/m (600 kW) 5 Hz without degradation of cavity or coupler.

VUV-FEL LINAC Cavities



TTF II RF test: Power distribution/measurement diagram



RF Test

RF Power Calibration

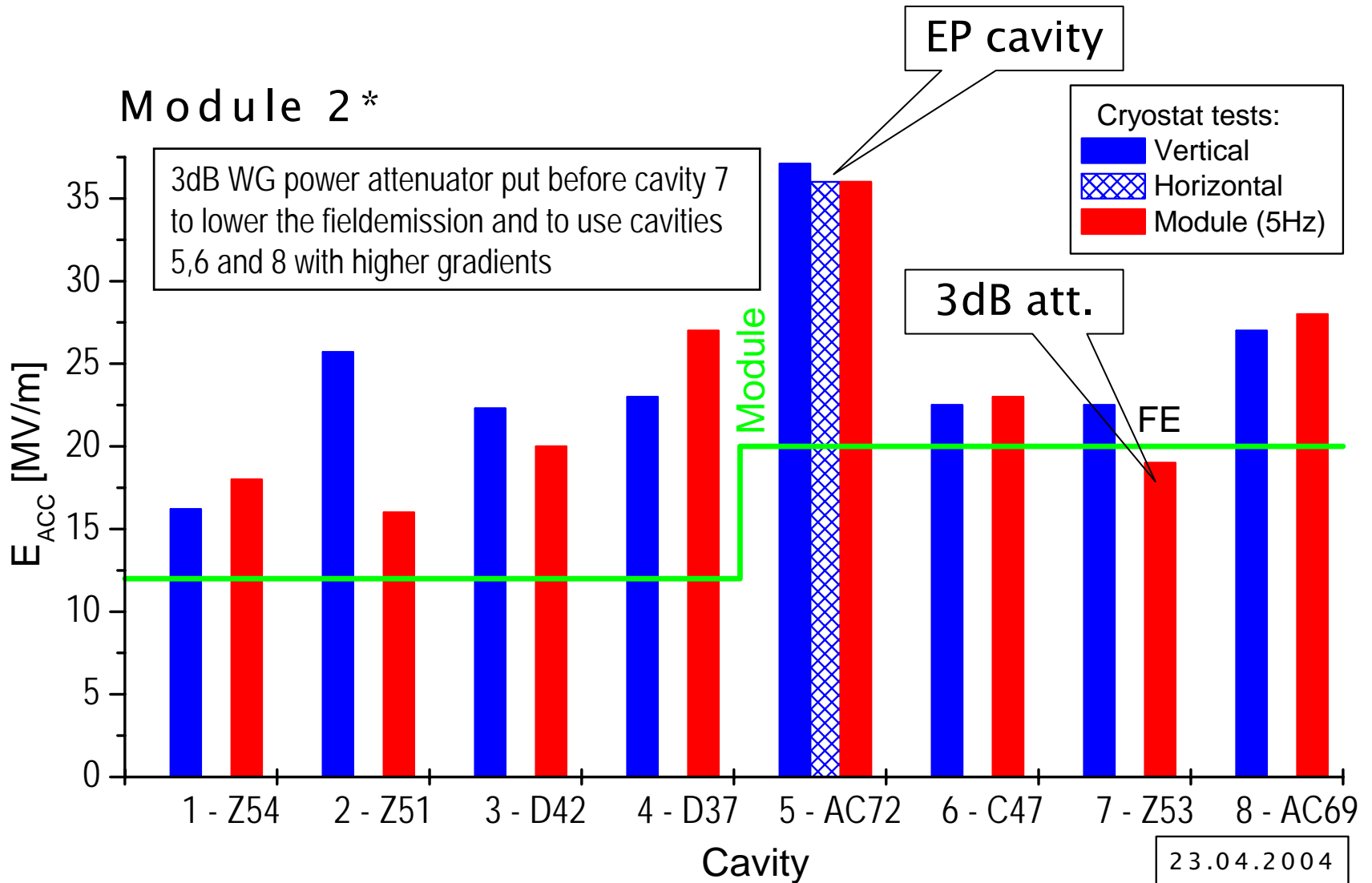
$$E_{ACC} = \frac{\sqrt{4 \frac{R_{sh}}{Q} Q_{load} P_{for}}}{L_{cavity}} \times \left[1 - e^{-\frac{\pi f_0 t_{fill}}{Q_{load}}} \right] =$$

$$= k_t \times \sqrt{P_{trans}} \cdot [V/m]$$

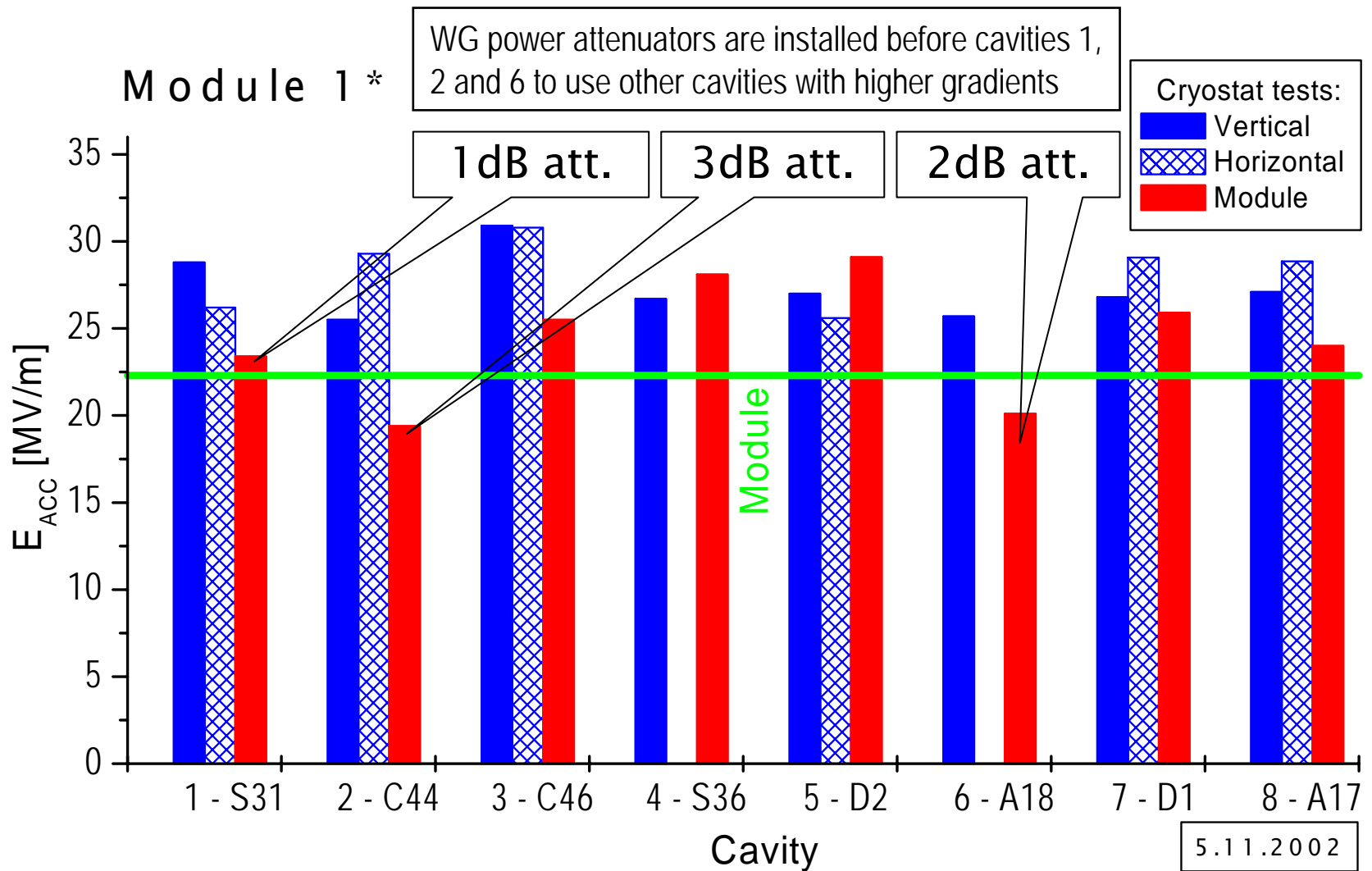
evaluated error margins for accelerating gradients in this test are about $\pm 10..16\%$.

$R_{sh}/Q=1030\Omega$, $L_{cavity}=1.035m$,
 $Q_{load}=3 \times 10^6$, $f_0=1.3GHz$, $P_{for} \approx 5kW$,
 $t_{fill}=1300\mu s$ (for calibration,
 $500\mu s$ for flat-top (FT))

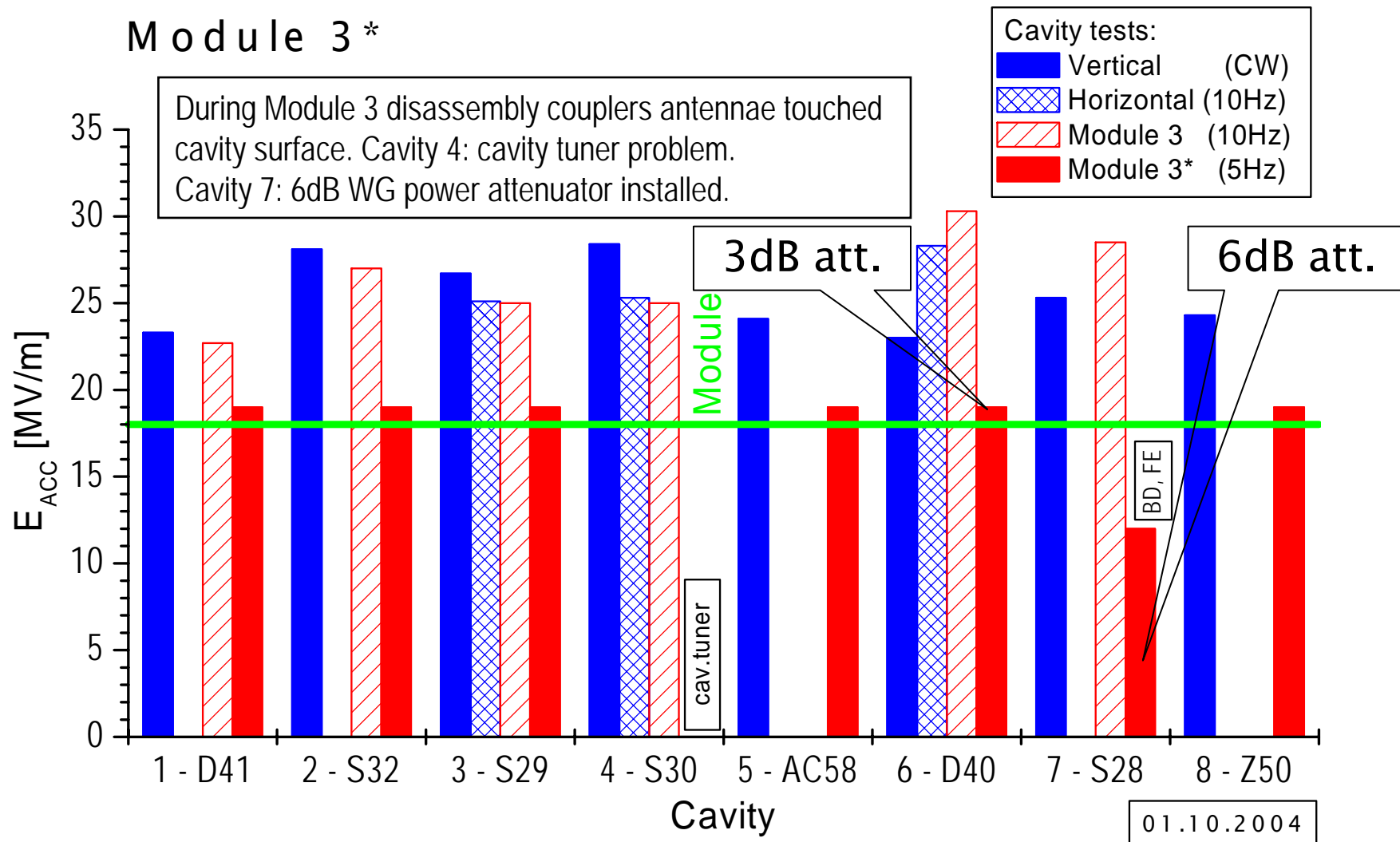
Cavities @ ACC1



Cavities @ ACC2

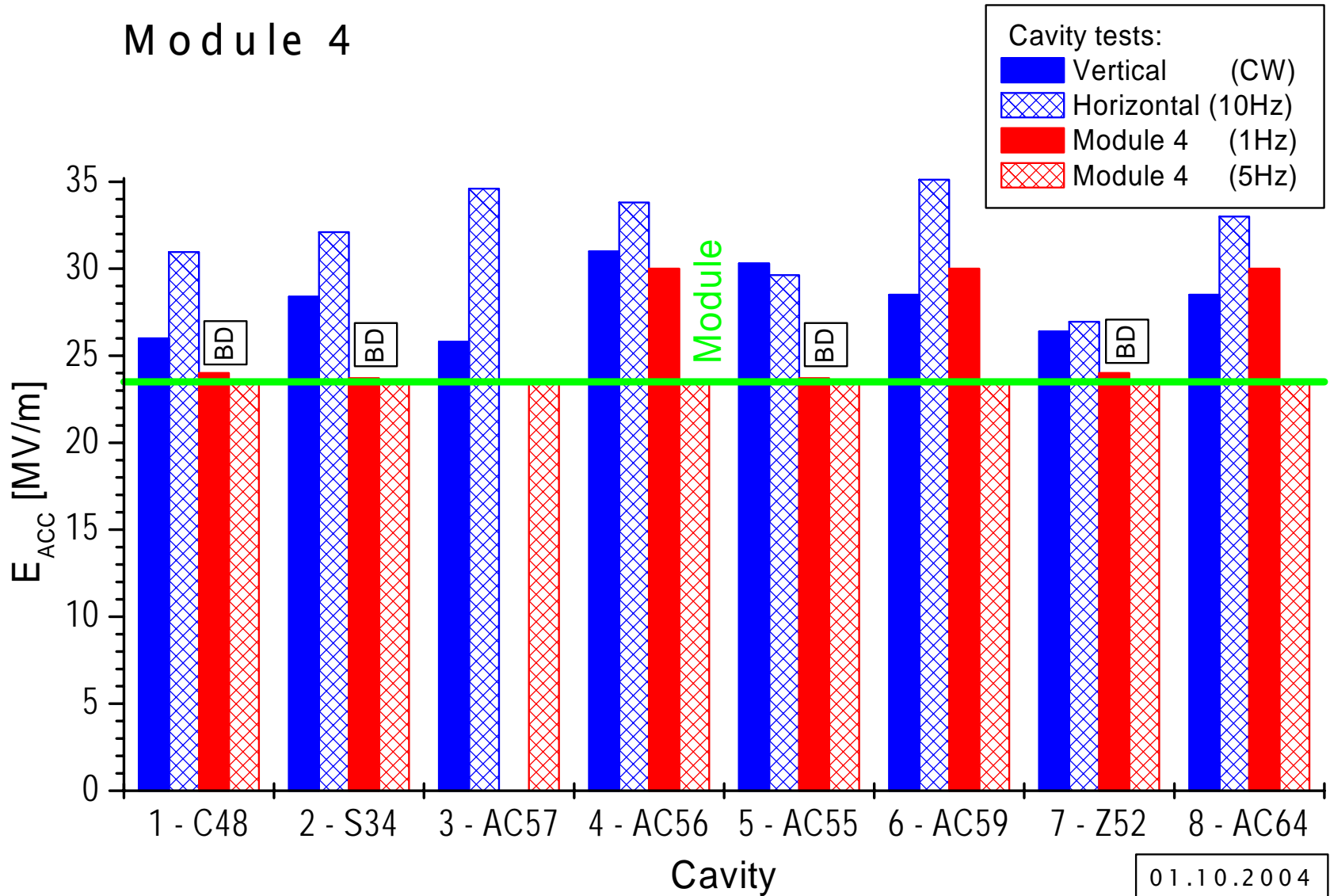


Cavities @ ACC3



Cavities @ ACC4

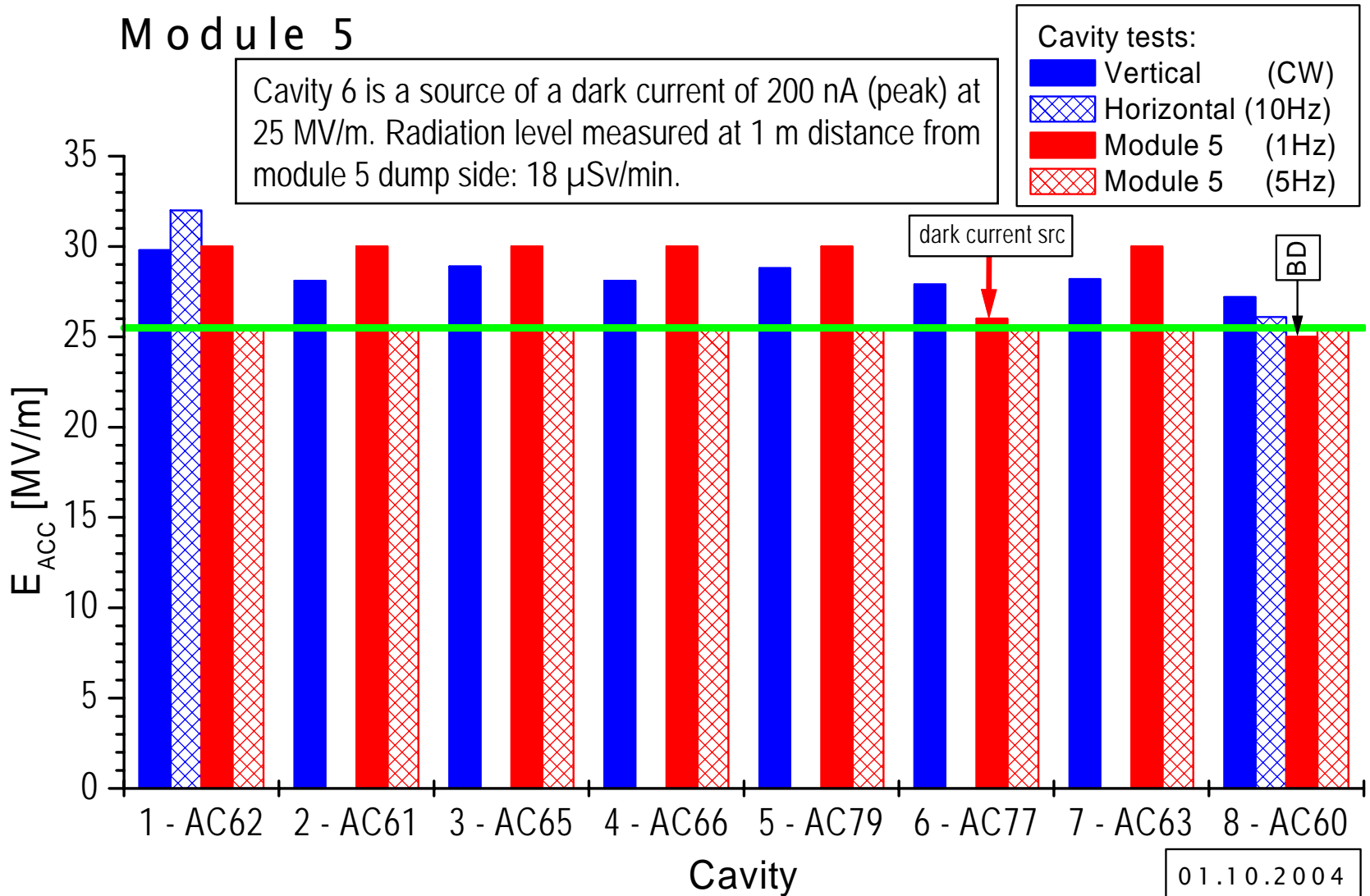
Module 4



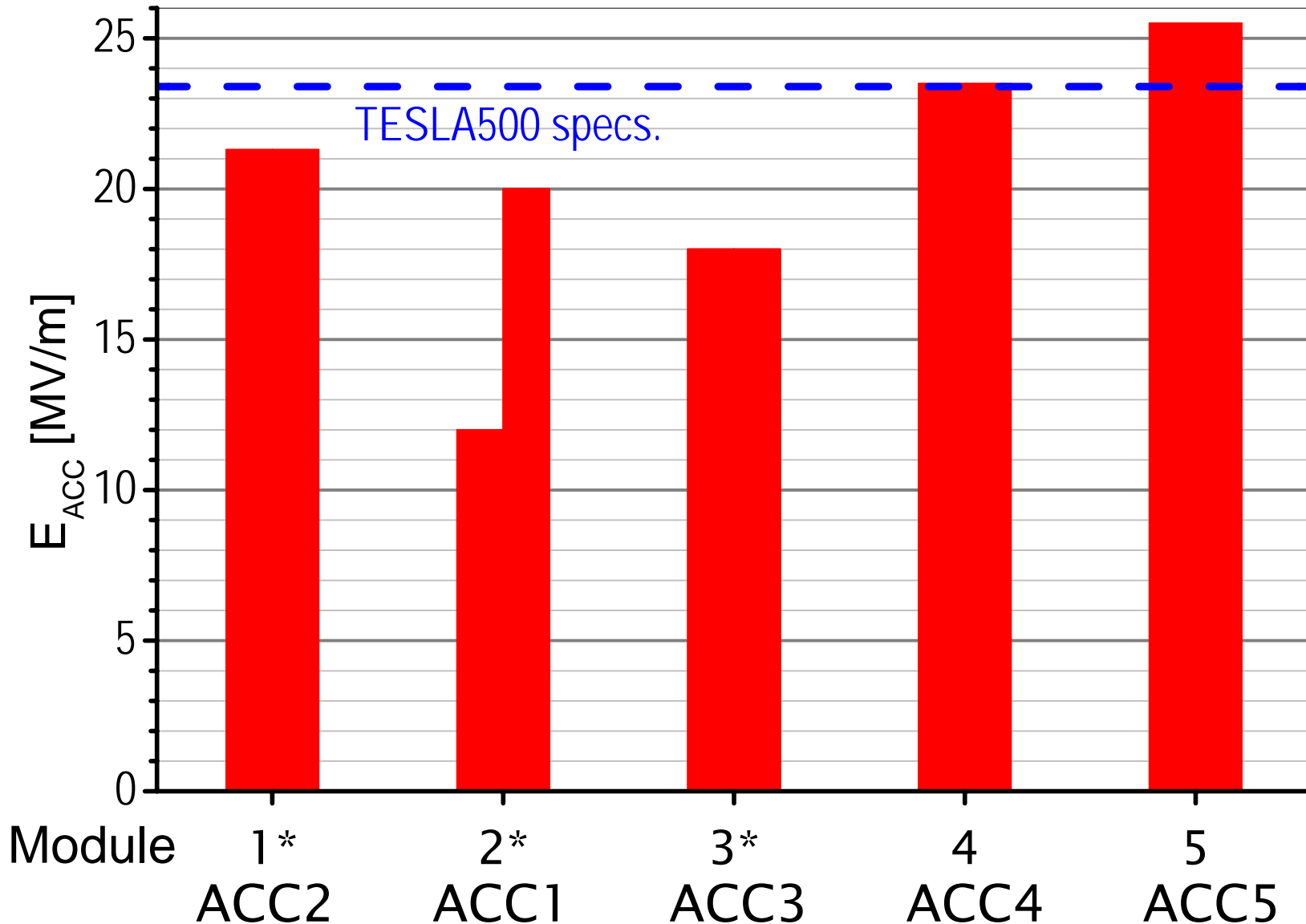
Cavities @ ACC5

Module 5

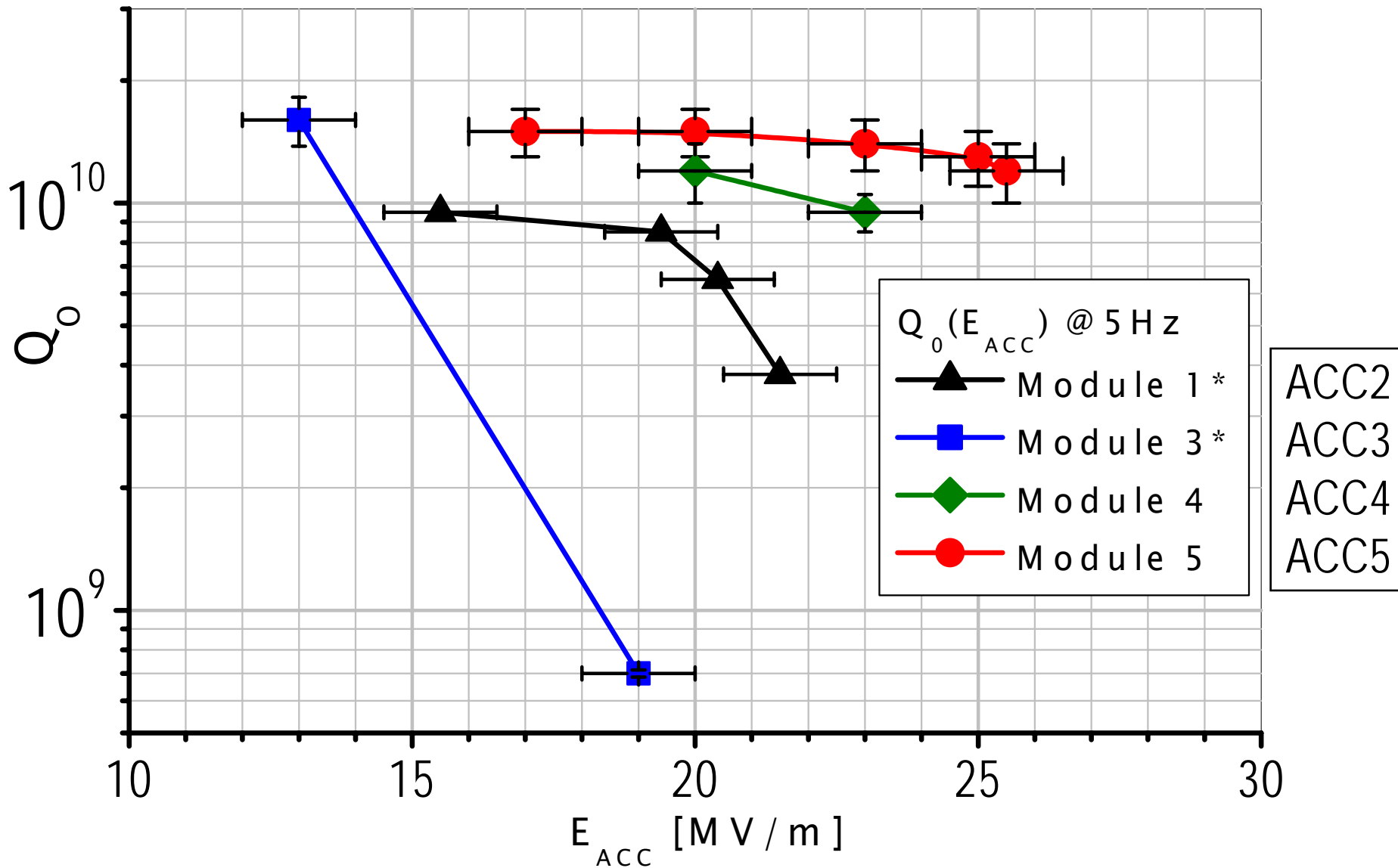
Cavity 6 is a source of a dark current of 200 nA (peak) at 25 MV/m. Radiation level measured at 1 m distance from module 5 dump side: 18 μ Sv/min.



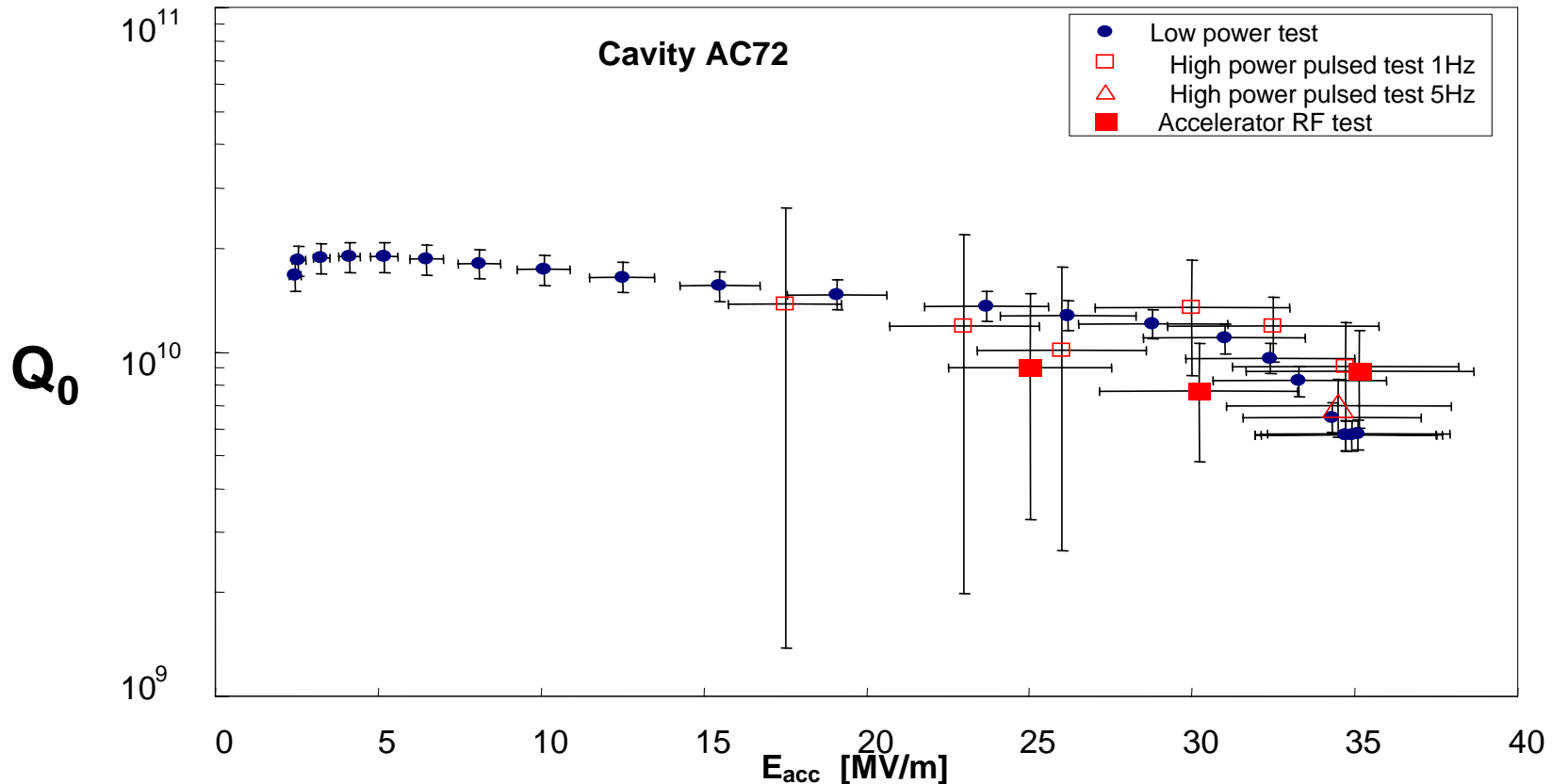
Modules Operating Gradients



Q_0 Measurements



EP Cavity @ ACC1



- Same performance with beam as in previous low and high power tests without beam
- **Very low cryogenic losses** as in high power tests
- Standard X-ray radiation measurement indicates no radiation up to 35 MV/m

Conclusions

- ★ All couplers in the VUV FEL linac could be processed and operated up to the cavity performance limits.
- ★ The last two modules, 4 and 5, fulfill the TESLA500 specifications.
- ★ ACC5 / module 5, tested at the repetition rate of 5 Hz was operating at the accelerating gradient of 25.5 MV/m , 500 + 800 μ s full length flat-top pulse and quality factor of 1×10^{10} .
- ★ ACC5: cavity 6 is a source of a dark current of 200 nA (peak) at 25 MV/m.
- ★ ACC1: cavity 7 is a source of a dark current, up to 10 mGy/min measured on axis.
- ★ All modules have functioned continuously during certain periods of time.
- ★ The beam operation started with all modules.
- ★ Cavity 5 (AC72, EP) tested in Module 2* / ACC1 reached 35 MV/m, confirmed with beam.