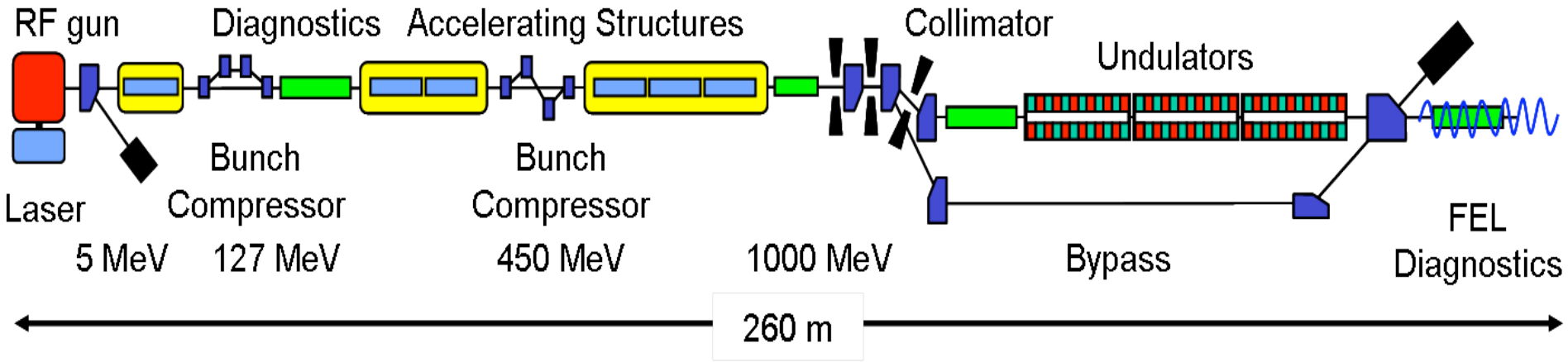
FLASH LLRF
& 9mA experiment

M.Grecki for LLRF team

Operating parameters

- Bunch Charge: 3 nC
- Bunch repetition time: 3 MHz
- Number of bunches: 2400
- Beam energy > 700MeV
- RF pulse length (flattop): 800 μs

FLASH



- ACC456 – the main playground of 9mA experiments for LLRF
  - High gradient modules
  - Equipped with piezos (ACC5 & ACC6)
  - Controlled by DSP based system

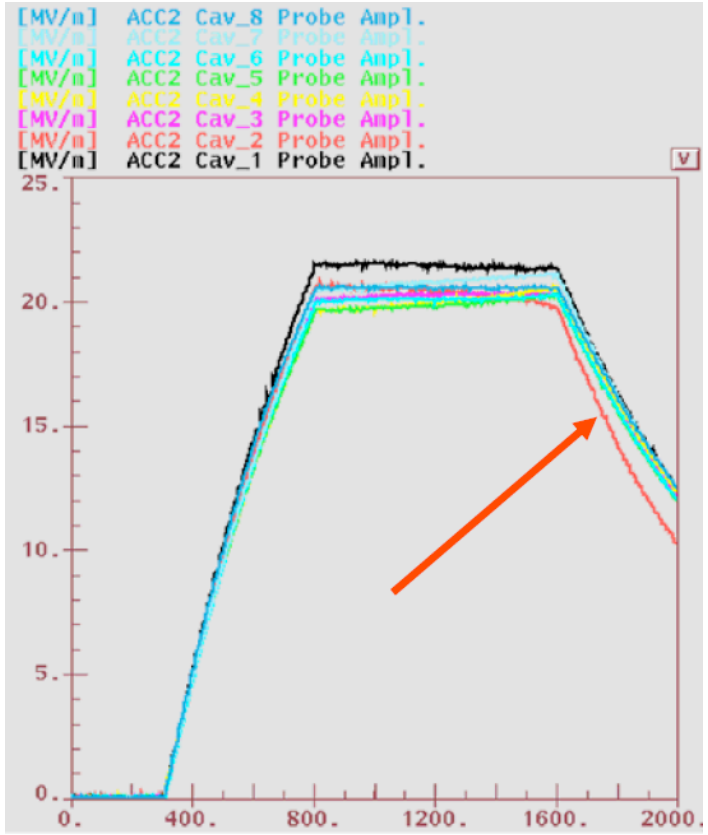
Required LLRF control

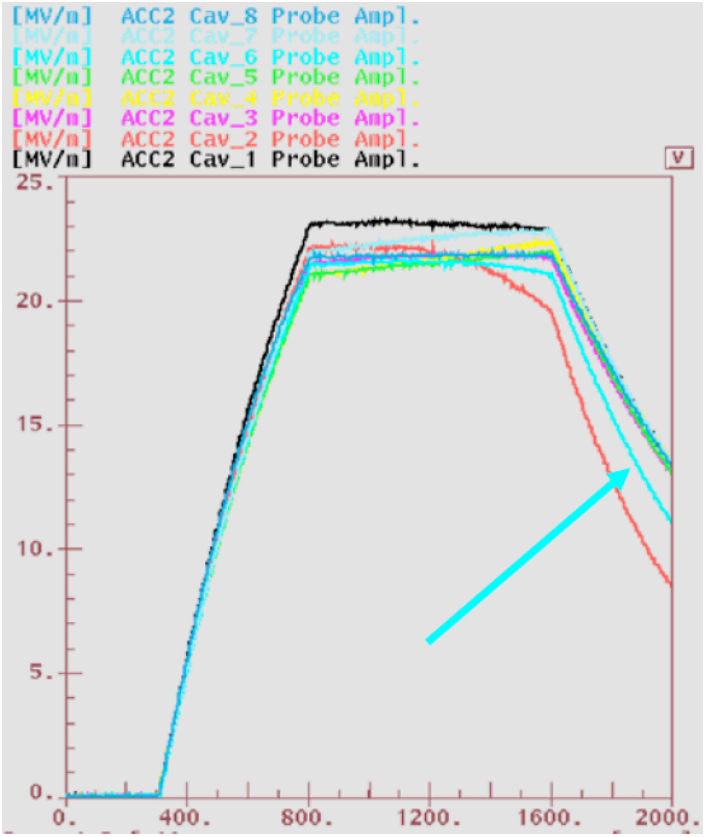
- Pushing machine up to the limits requires exception detection that is only partially present and cannot be implemented in current DSP based LLRF controller
  - No real time quench detection for individual cavities (it exist for vector sum)
  - No klystron linearization
  - No real time beam loading compensation from toroid measurement
  - Slow convergence of AFF algorithm

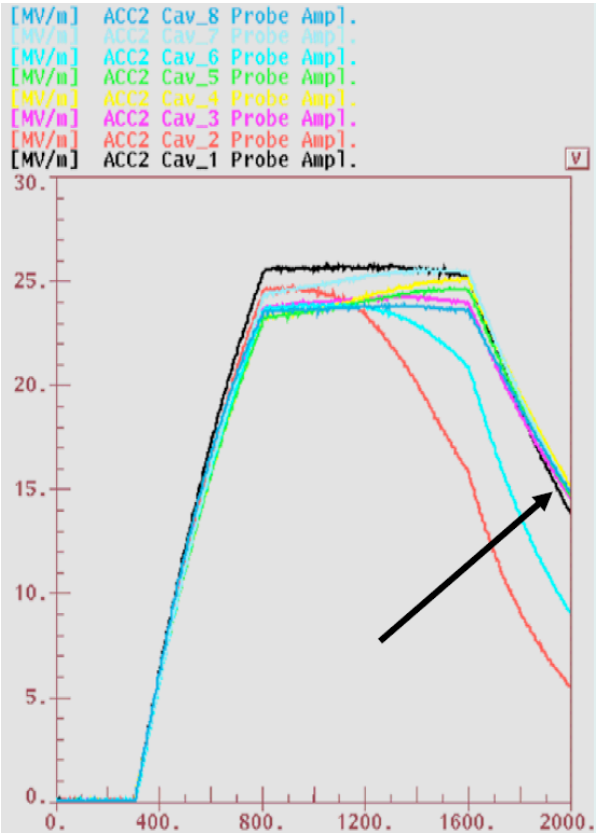
Expected problems

- MPS interlocks and recovery procedure
- Cavity quenching during long pulses with high gradient
- Klystron saturation
- Lorentz force detuning of the cavities during long pulses with high gradient (poor flatness of the field leading to beam losses)
- High rate of klystron trips – recovery automation

Cavity quenches at FLASH (ACC2)

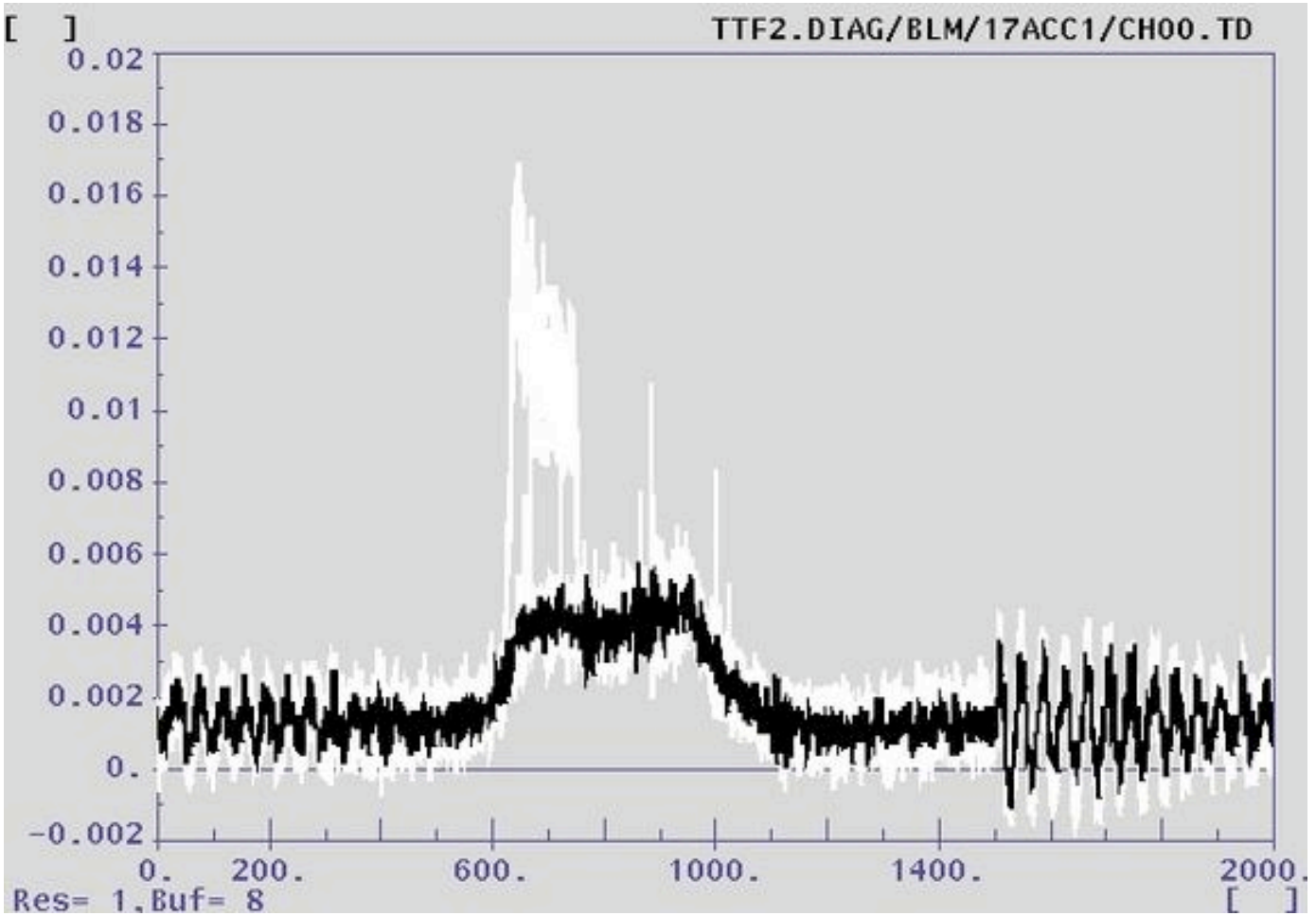






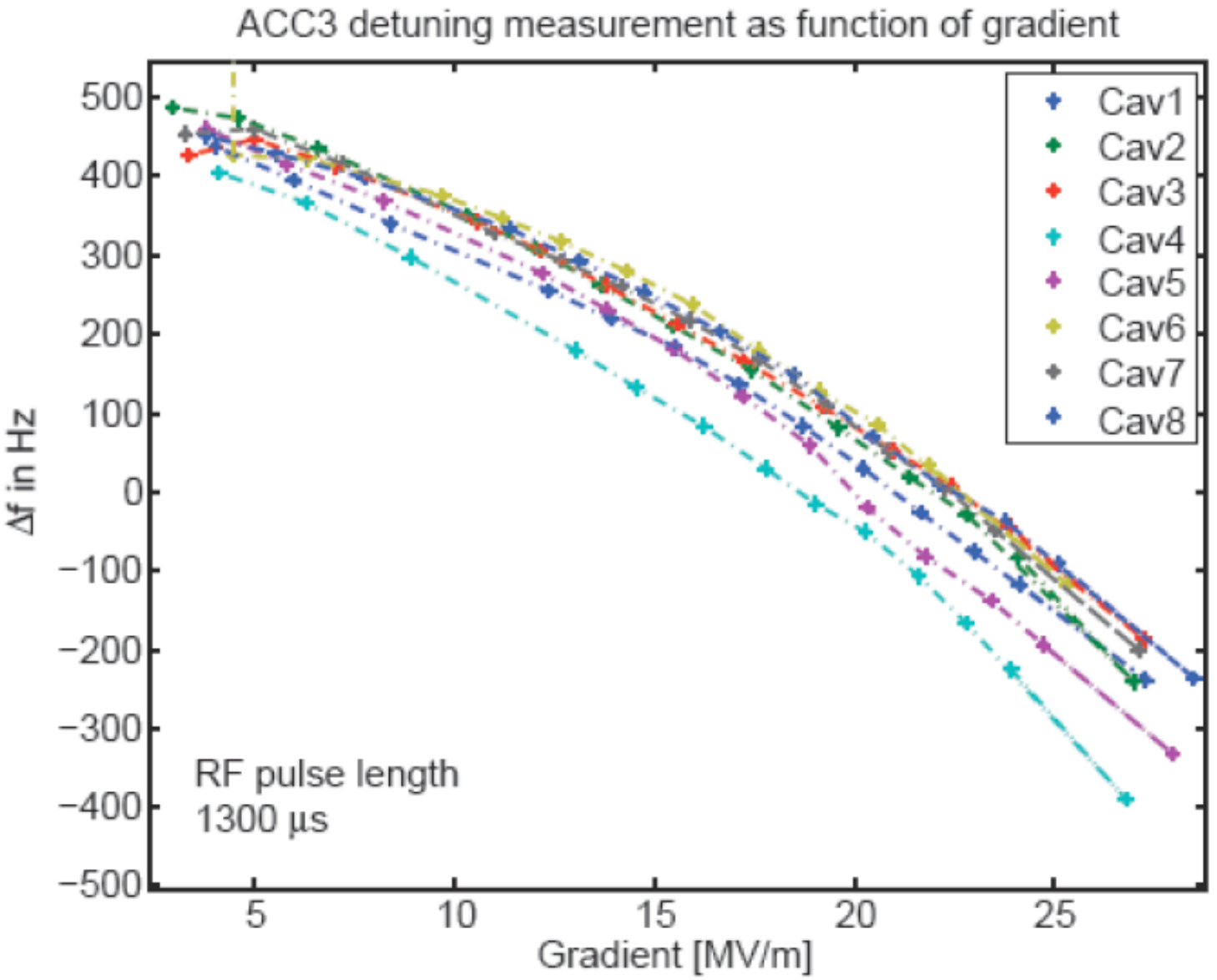
- #1 – 19 MV/m, cavity 2
- #2 – 21 MV/m, cavity 6
- #3 – 24 MV/m, cavity 1

Beam losses



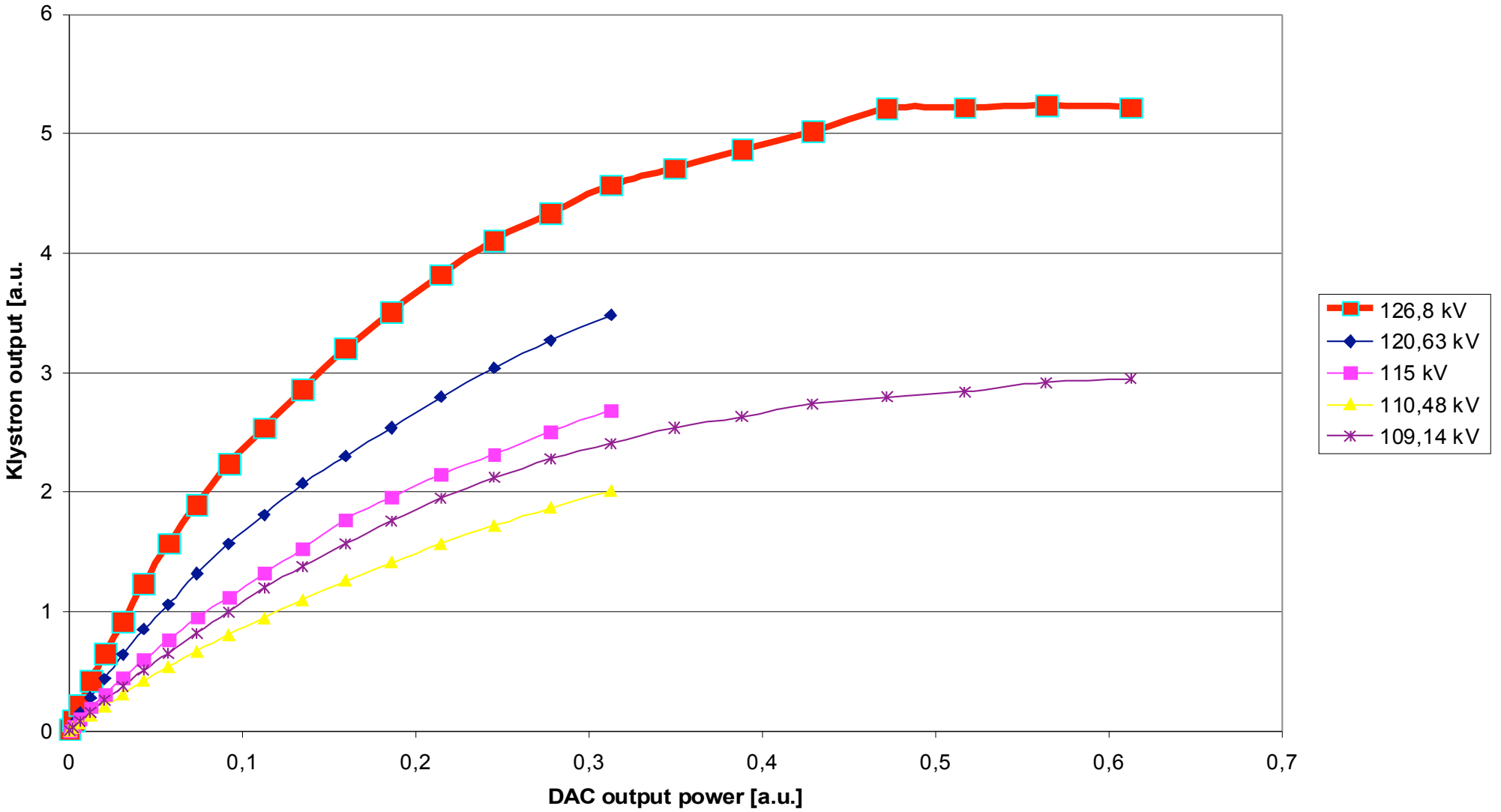
Field instability lead to beam losses that triggers BIS and disables RF operation

Lorenz force detuning

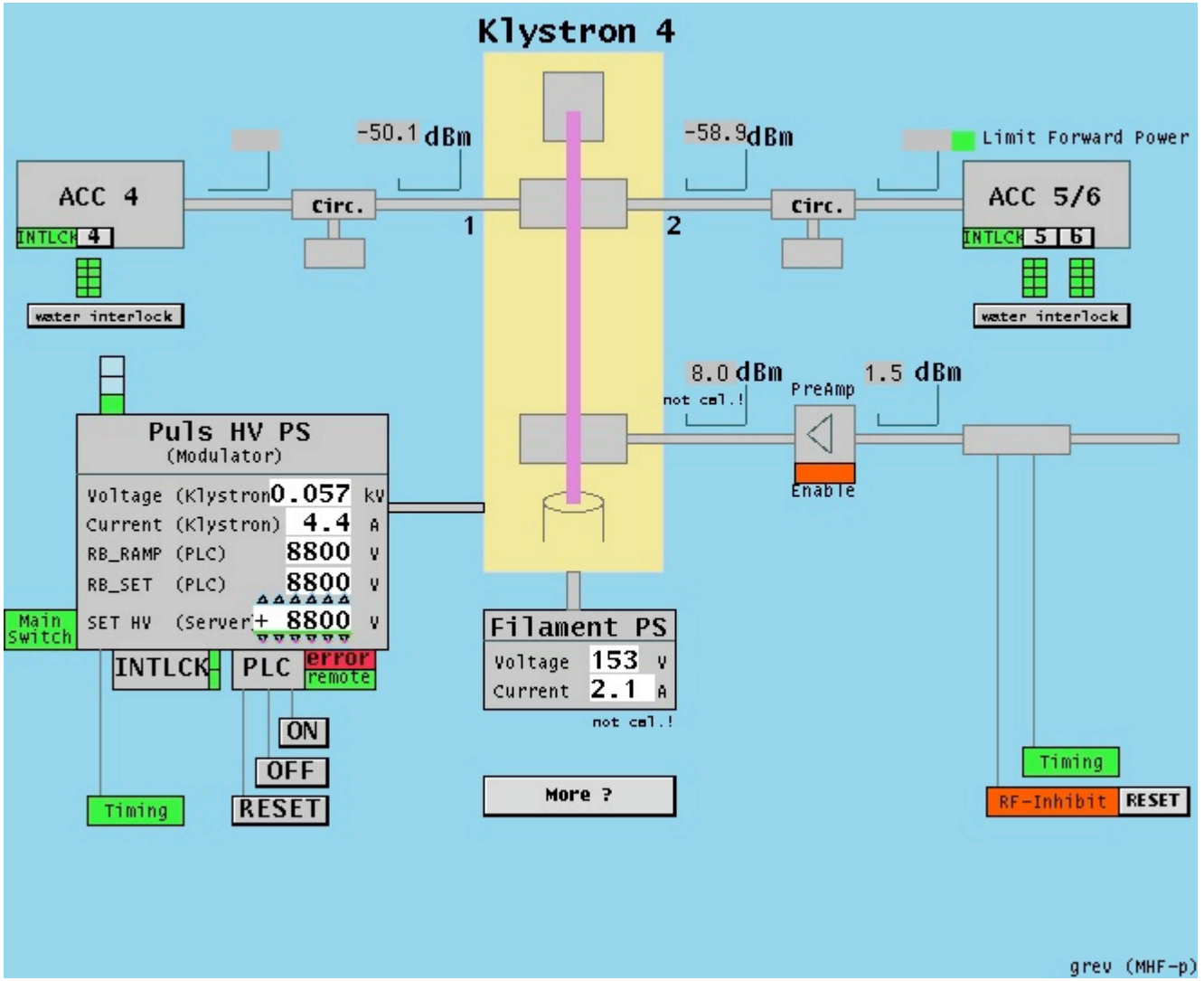


Klystron nonlinearity

Klystron output power vs. LLRF controller DAC output power characteristic.
VUV-FEL klystron 3.



Klystron



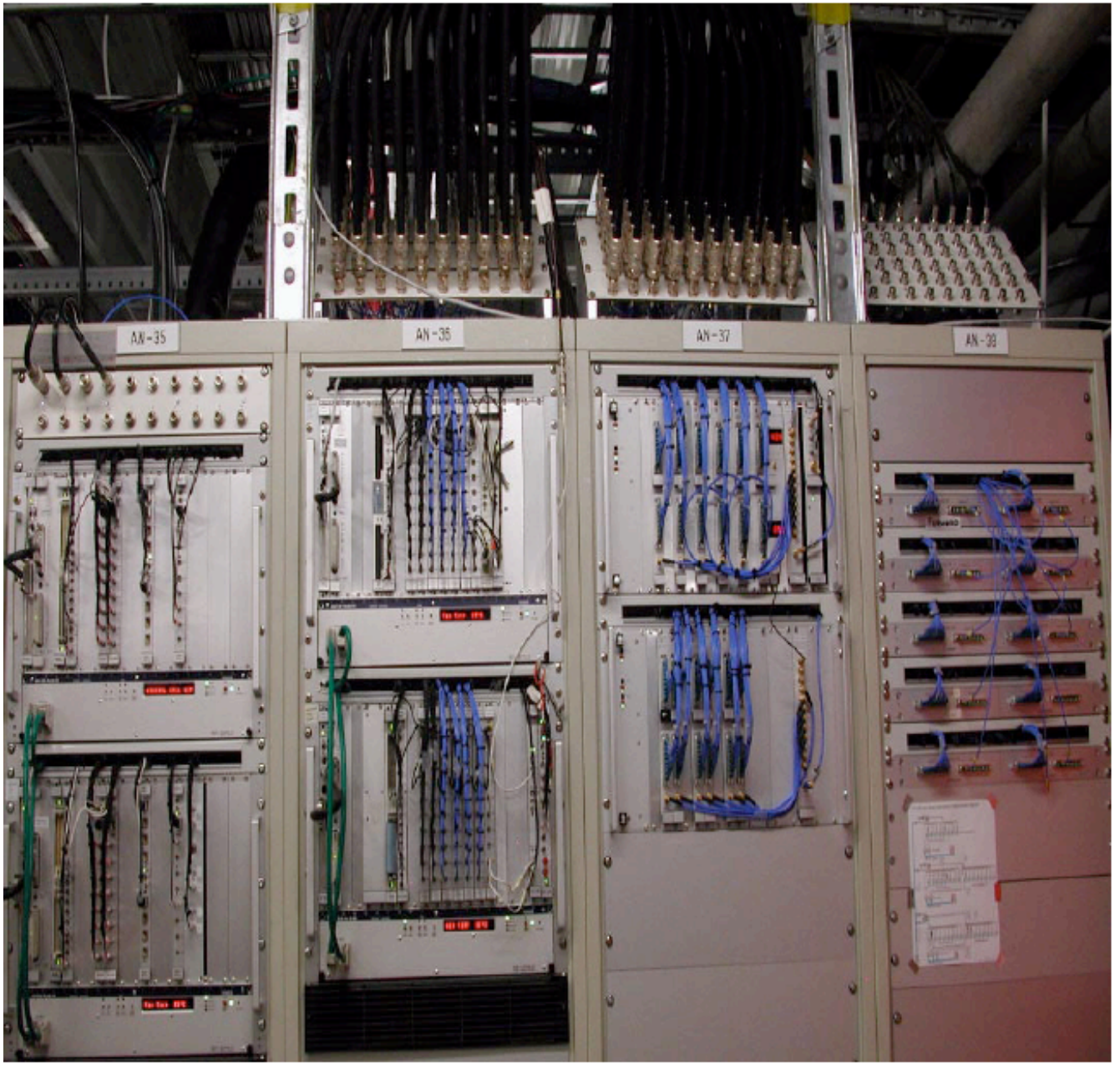
Difficulties: Kly. 4 high voltage tripped -> 6:30 h - 7:08 h -> 0.5 h down

LLRF hardware in FLASH

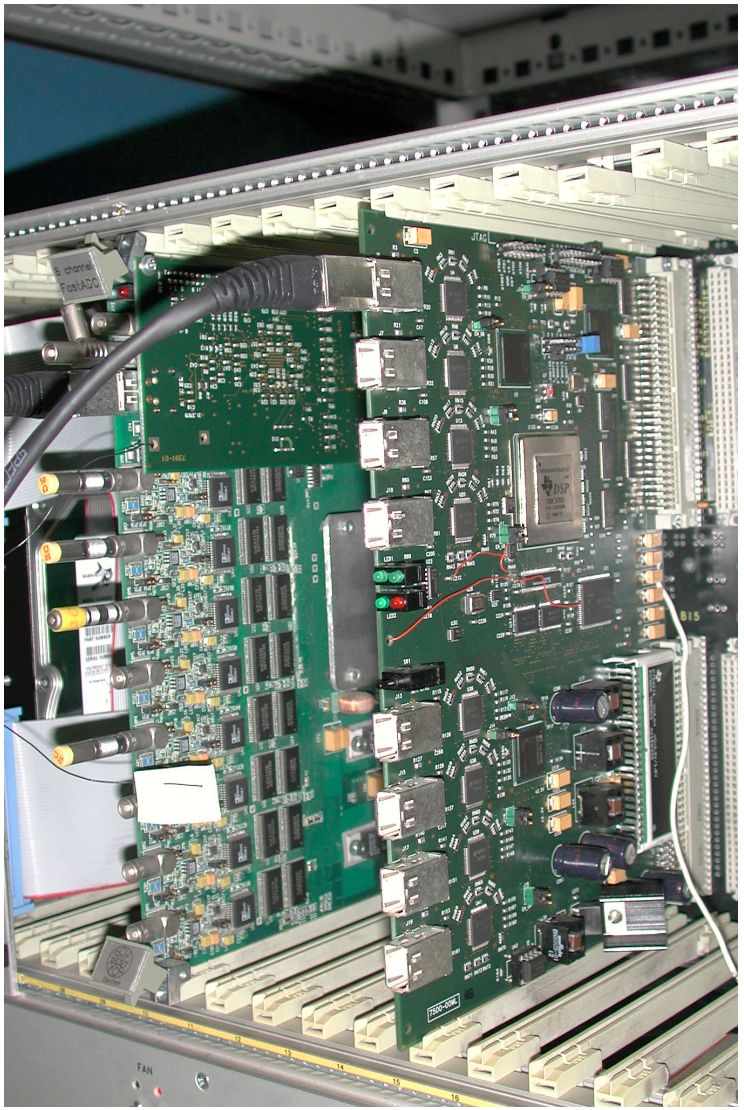
ACC23

&

ACC456

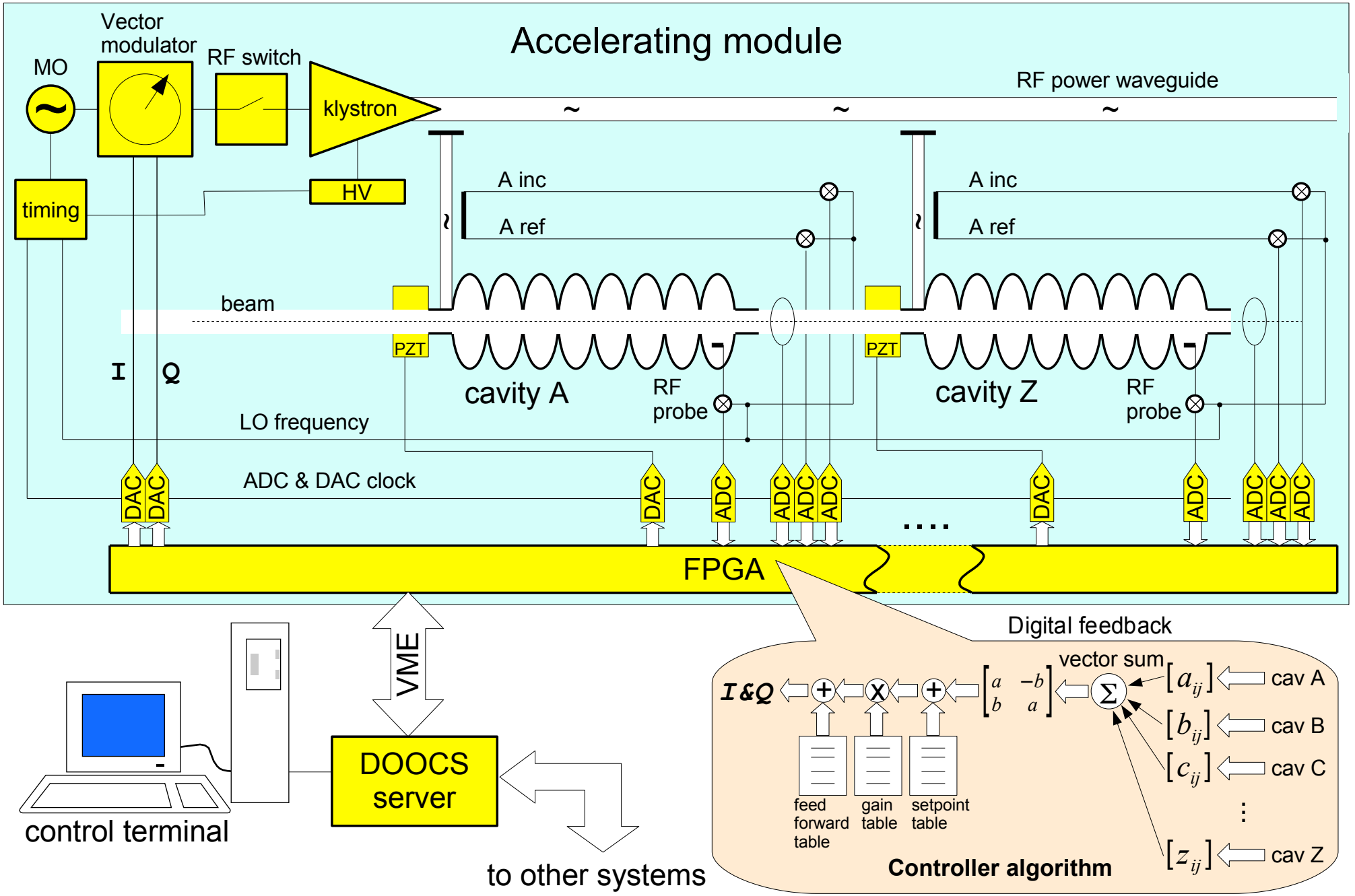


C67 (Model 2002)



- 1x C67 DSP for up to 32 cavities
- 8x Gigalink Interface (4x8ADC, DAC)
- 1 MHz sampling, 5 us latency

LLRF system architecture



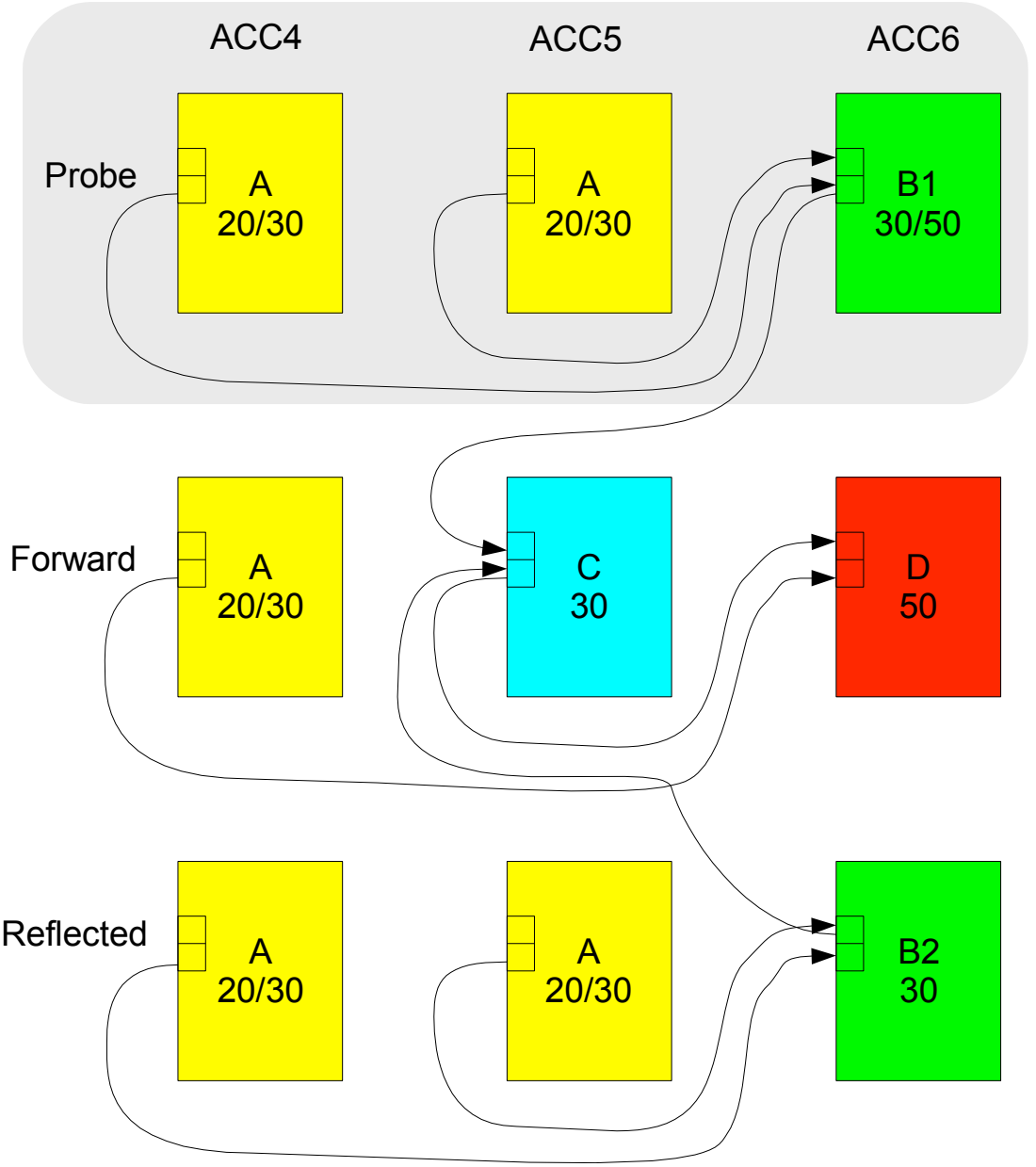
SimCon DSP board

- 10xADC, 8xDAC
- Xilinx Virtex II Pro (20/30/50), PowerPC
- DSP, Tiger Sharc
- SystemACE (Flash memory)
- 2 opto gigalinks
- VME interface
- Ethernet

running in FLASH ACC1

ACC456 controller (Simcon DSP based)

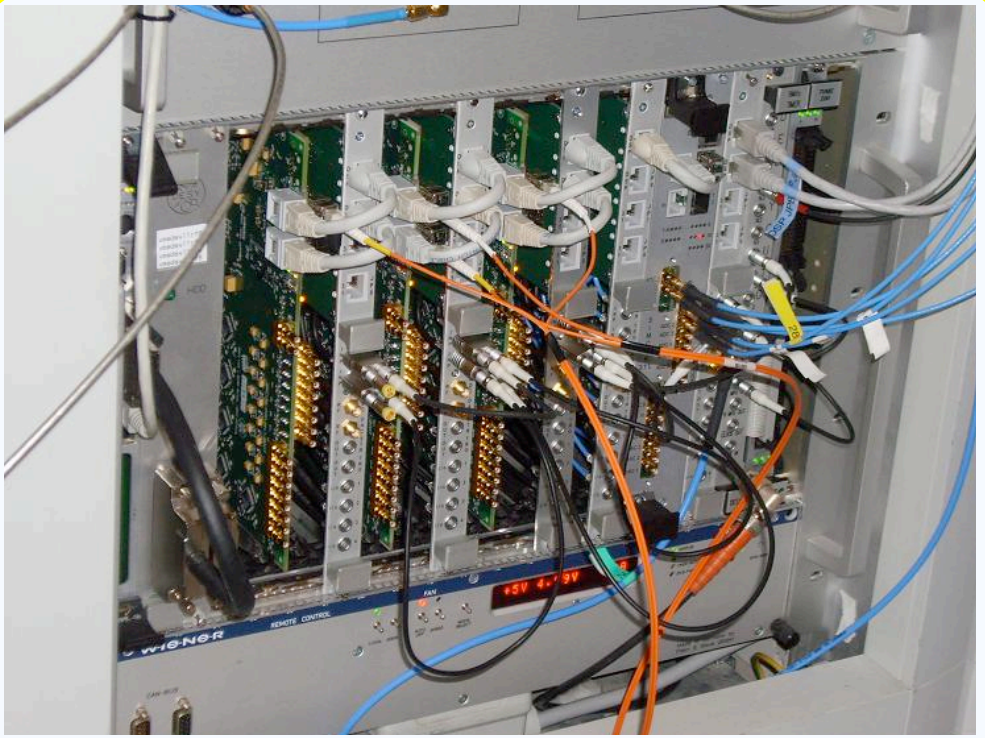
- A,Bx,C,D – type of firmware
- 20/30/50 – Virtex2Pro ...
- optolink
- 2 VME crates needed



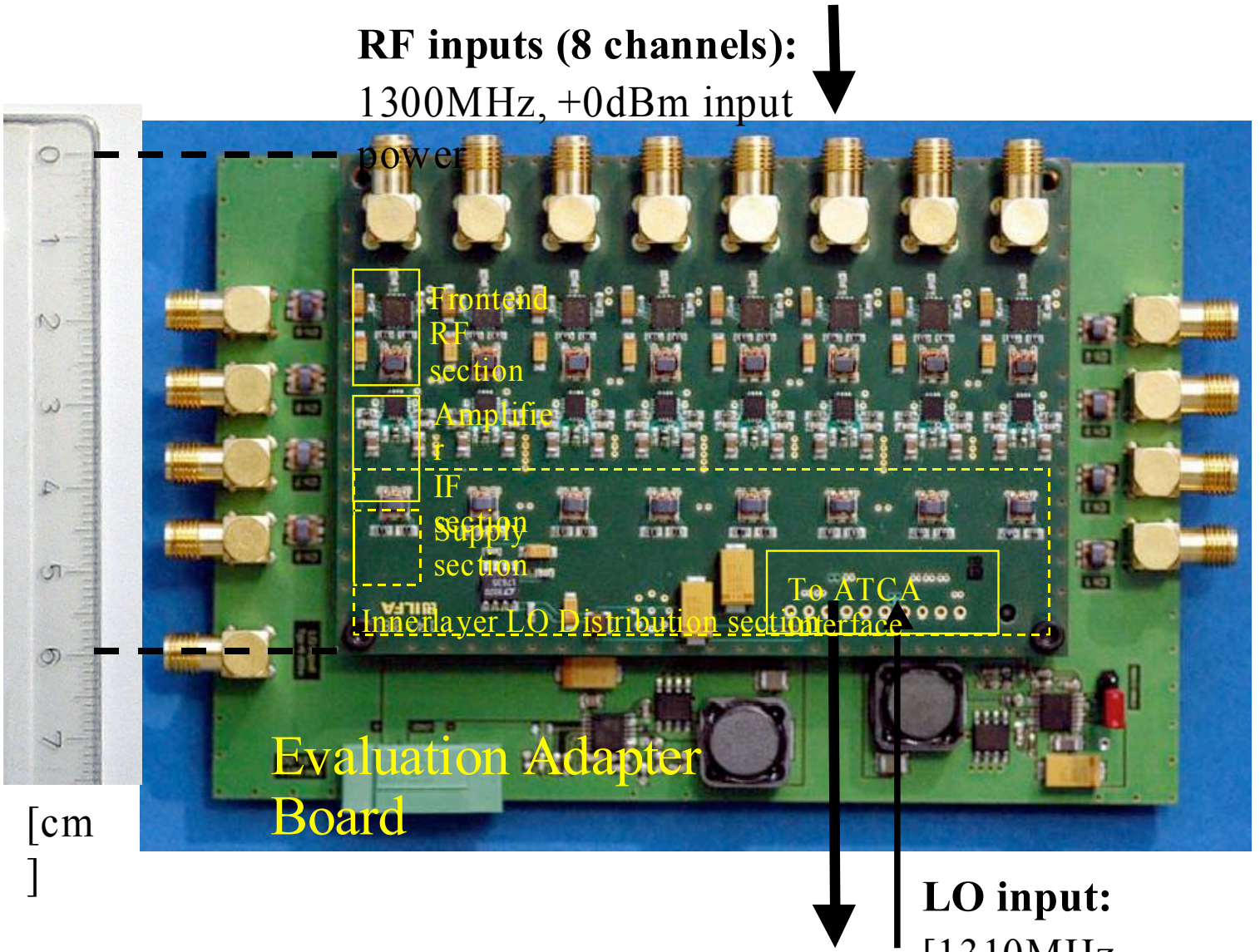
ACC456 controller – assembling (status for 6.01.2009)

ACC456 controller – assembling (status for 6.01.2009)

ACC456 controller – assembling (status for 9.01.2009)

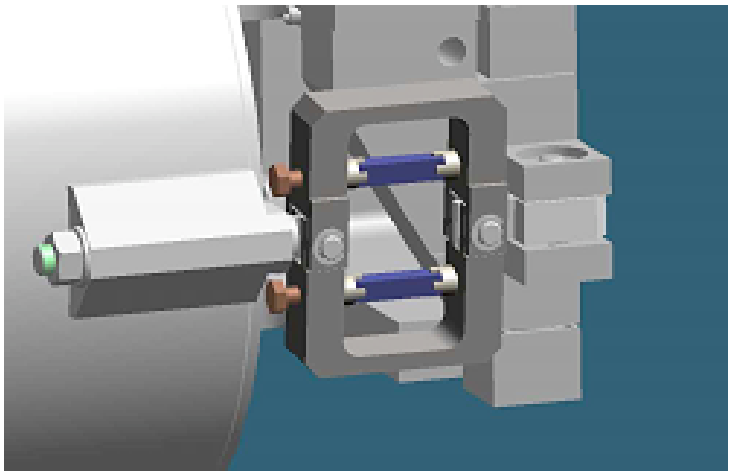


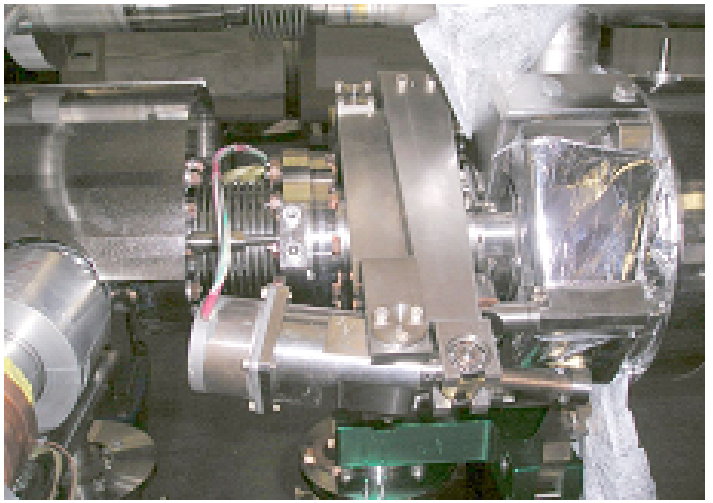
New downconverter (obtained on 20.12.2008)



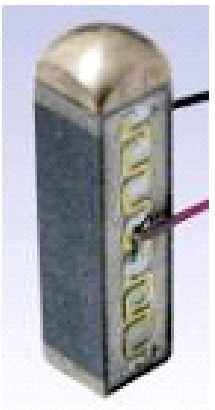
Goal of Piezo Control system

- Drive the piezoelements assembled in fast tuners frames to minimize the Lorentz force and microphonics effects
- On-line frequency detuning calculation
- Microphonics measurement (i.e. diagnostics of cryogenic system)





Dimensions: **10x10x30mm**
Manufacturer: **NOLIAC**



Dimensions: **10x10x36mm**
Manufacturer: **PI**

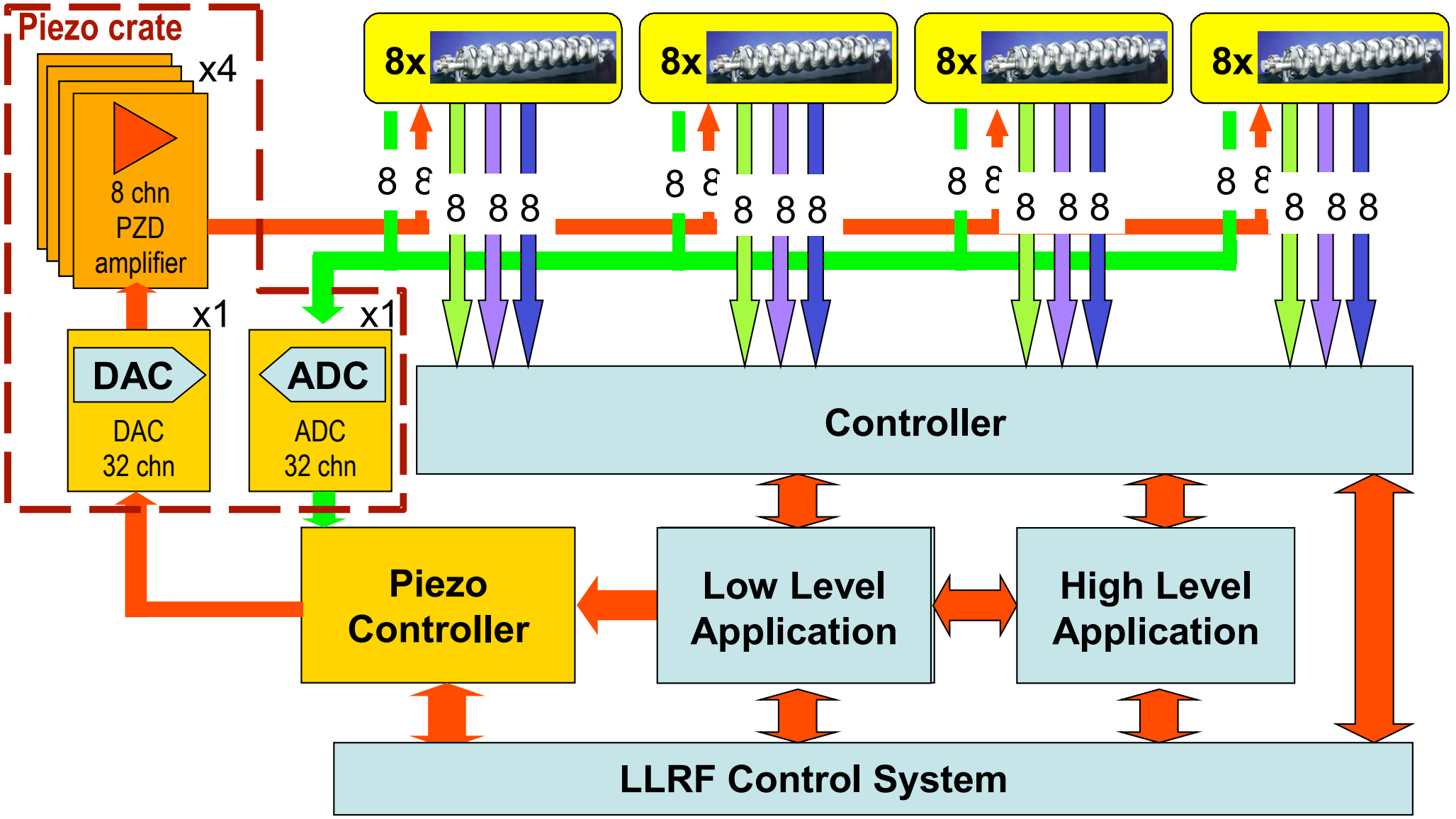
Piezos installed in ACC3,5,6

Producent ratings	Noliac	PI ceramic
Model:	SCMAS/S1/A/10/10/30/200/42/6000	P-888.90
Cells:	8	8
Voltage:	< 200 V	< 120 V
Blocking force:	6 kN	3 kN
Size:	10 mm x10 mm x 30 mm	10 mm x10 mm x 35 mm
Capacitance:	6 μF	12 μF

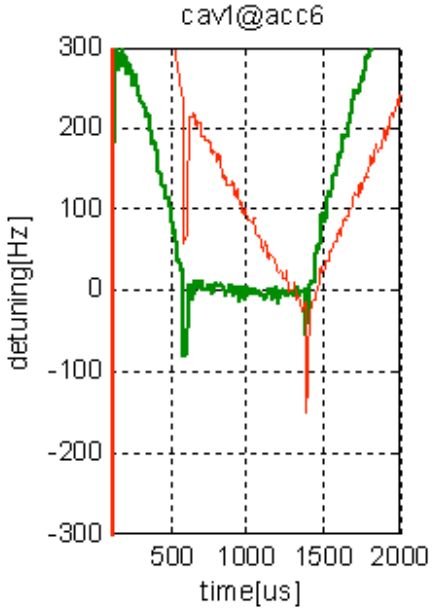
Piezos Capacitance

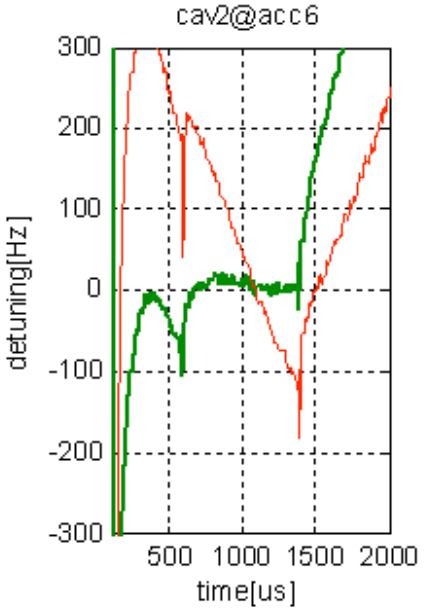
cavity	piezo	model	ACC3/M7	model	ACC5/M5	model	ACC6/M6
1	1	PI	4,93uF	Noliac	2,1uF	PI	4,13uF
	2	-	Unavailable	-	Unavailable	PI	4,45uF
2	1	PI	4,61uF	Noliac	2,22uF	PI	4,4uF
	2	-	Unavailable	-	Unavailable	PI	4,2uF
3	1	PI	4,91uF	Noliac	2,28uF	PI	4,21uF
	2	-	Unavailable	-	Unavailable	PI	4,1uF
4	1	PI	4,6uF	Noliac	3,12uF	PI	3,86uF
	2	-	Unavailable	-	Unavailable	PI	4,2uF
5	1	Noliac	2,6uF	Noliac	2,2uF	PI	4,22uF
	2	-	Unavailable	-	Unavailable	PI	4,28uF
6	1	Noliac	2,13uF	Noliac	2,13uF	PI	3,73uF
	2	-	Unavailable	-	Unavailable	PI	4,41uF
7	1	Noliac	2,22uF	Noliac	2,19uF	PI	4,69uF
	2	-	Unavailable	-	Unavailable	PI	4,41uF
8	1	Noliac	2,21uF	Noliac	2,17uF	PI	4,31uF
	2	-	Unavailable	-	Unavailable	PI	4,2uF

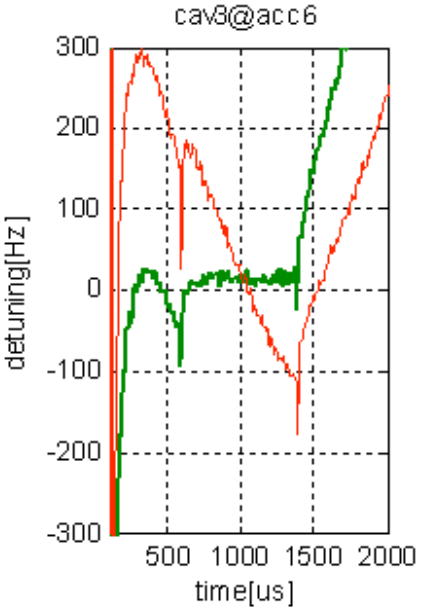
Piezo control

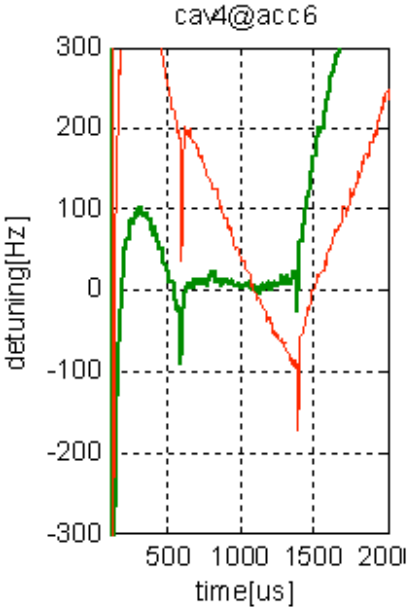


ACC6 (SP = 15 MV/m, Pforw = 220kW, rep = 5 Hz)

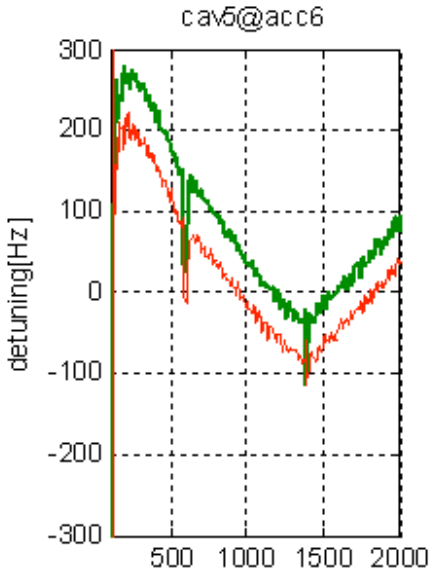


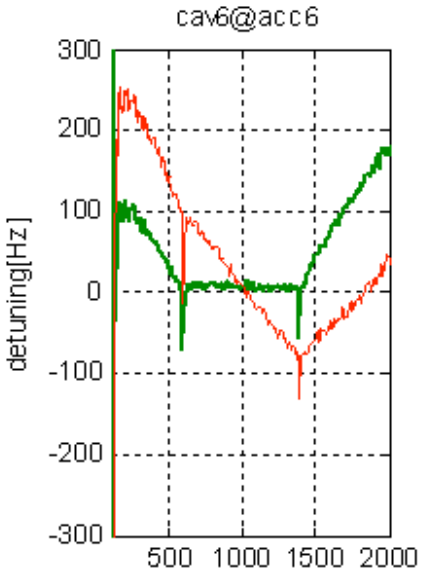


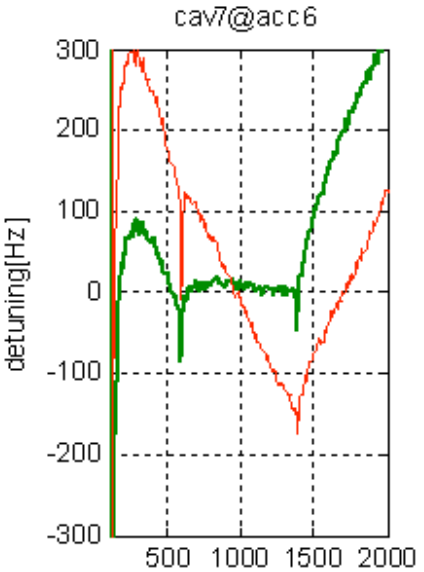


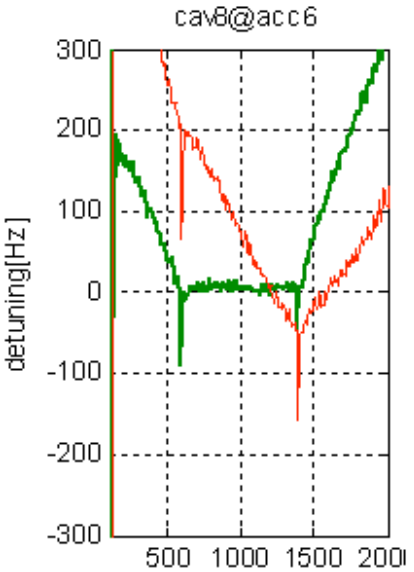


Cav. (1-3)
Amp: 34V
Dly: - 4.1 ms



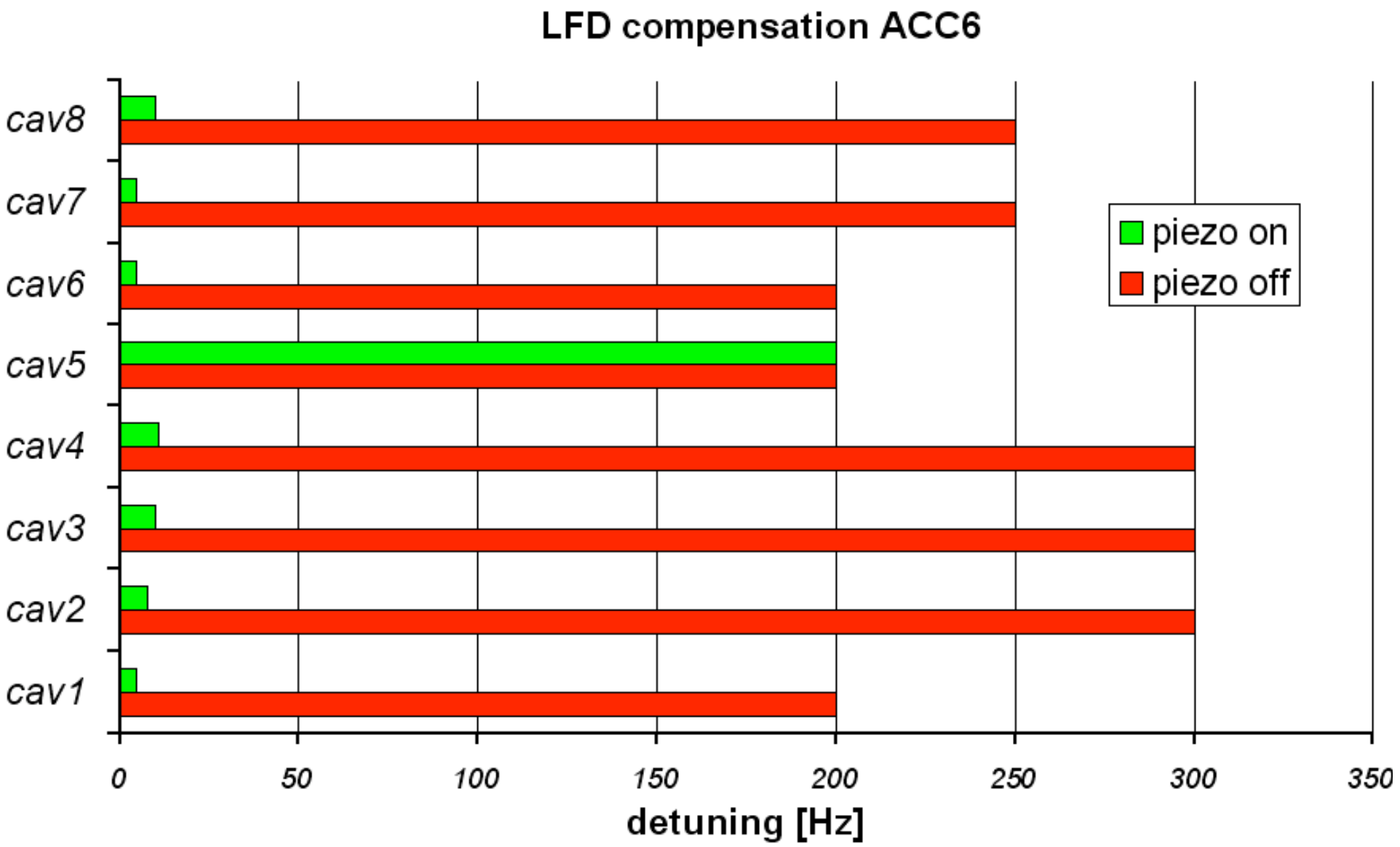




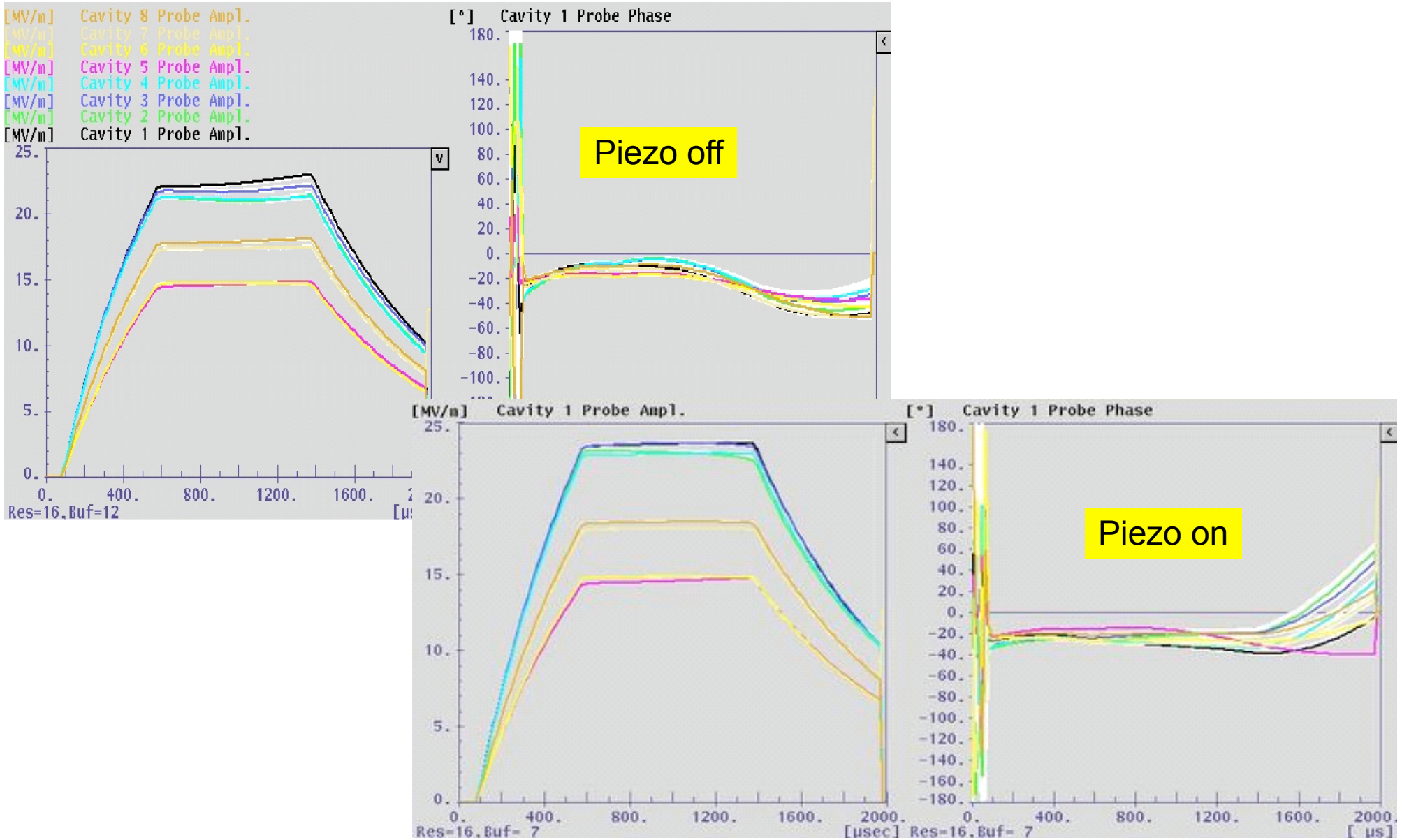


Cav. (4-8)
Amp: 23V
Dly: - 4 ms

ACC6 – LFD compensation results



ACC6 – LFD compensation results



What has been / must be done? (Hardware)

- Installation of SimconDSP based LLRF system in ACC456 as parallel system
  - Cabling (splitting signals) – done
  - Crate with 9xSimconDSP – smaller system with 3 SimCon boards installed
  - Downconverter – obtained, installed and during tests
  - Communication between 9 SimconDSP boards – it was never tested before
  - Piezo control – temporary installation, permanent installation in progress

What has been / must be done? (Software)

- SimconDSP firmware – was tested in FLASH, but not with all required features
  - Beam loading compensation - never tested with high beam loading
  - Loaded Q and detuning measurements – Matlab scripts exist, DSP/FPGA implementation is under development
  - Quench detection - Matlab scripts exist, DSP/FPGA implementation is under development
- DOOCS server - version for simpler system ready
- Matlab scripts for HL algorithms (VS calibration, AFF, klystron linearization, etc.) - ready
- Exception handling (quench detection, klystron trips) – must be worked out