News from X-box1

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On behalf of the CLIC structure test team

HG2013, Trieste

X-box1 status about one year ago

- *XL5 klystron repaired twice and in working condition*
- *Modulator installed, calibrated and ready for use*
- *High-power rf network fully installed including pulse compressor and structure under test (CERN T24)*

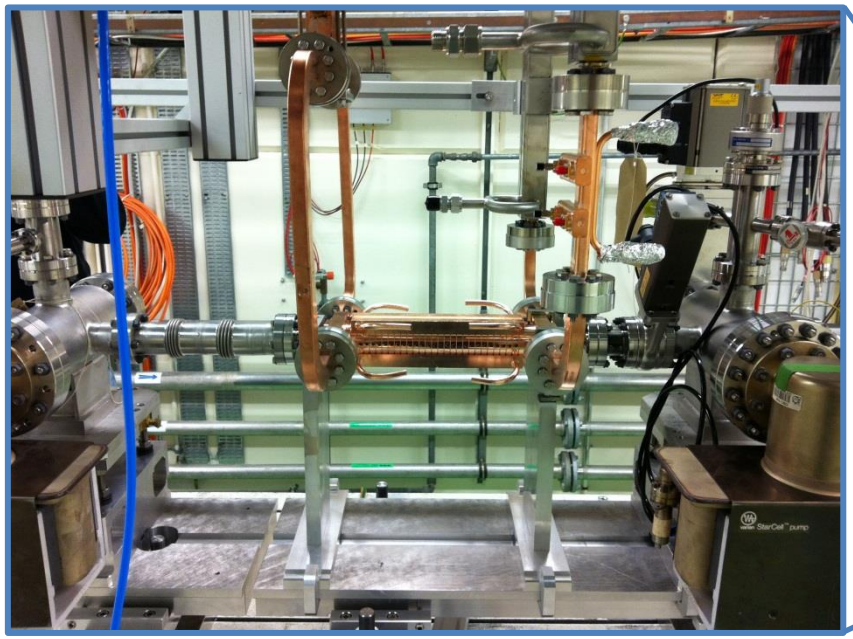
- *No controls, no diagnostics and no interlock software*
- *Klystron conditioned up to full peak power (50MW), but only 300ns pulse width*
- *All high-power rf components including pulse compressor unconditioned and of prototype status*

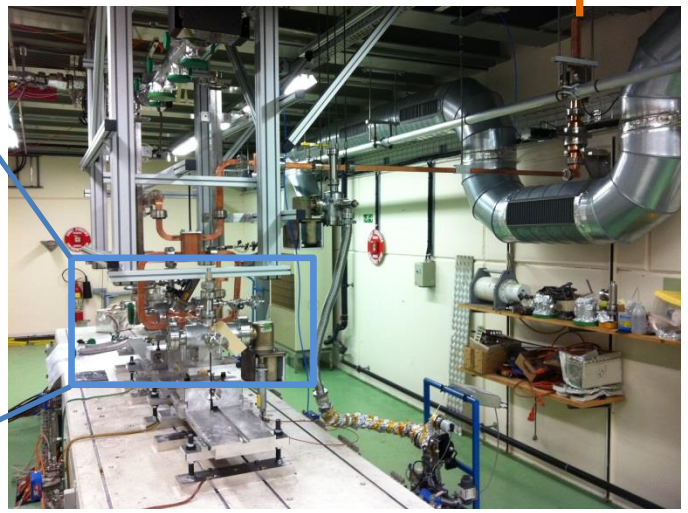
➔ *Lots of work ahead!*

The final X-box1 layout

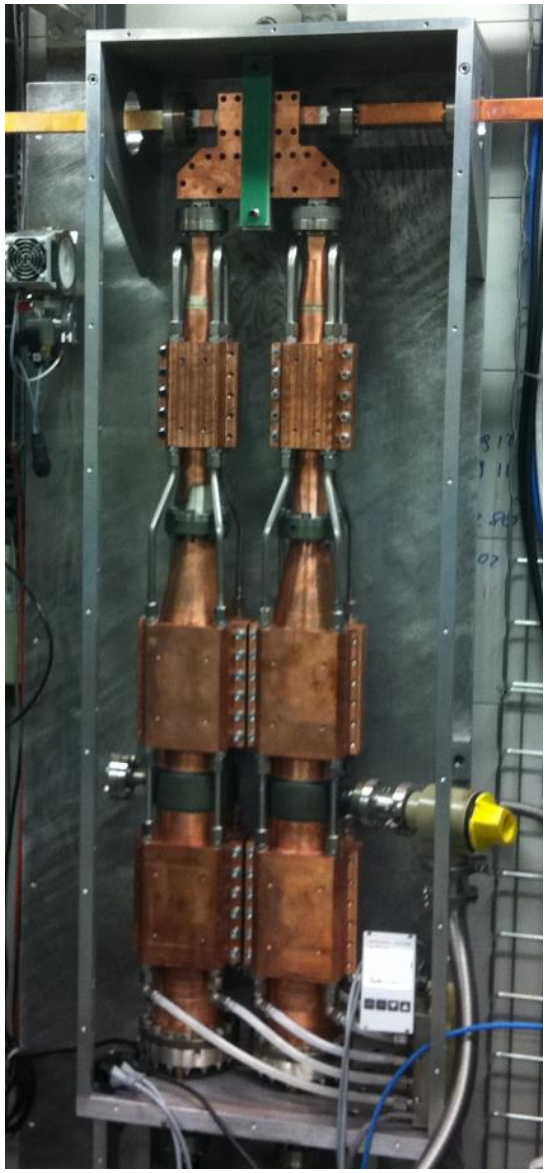
Clockwise from top-left:

- Modulator
- Pulse compressor
- DUT + connections
- Accelerating structure



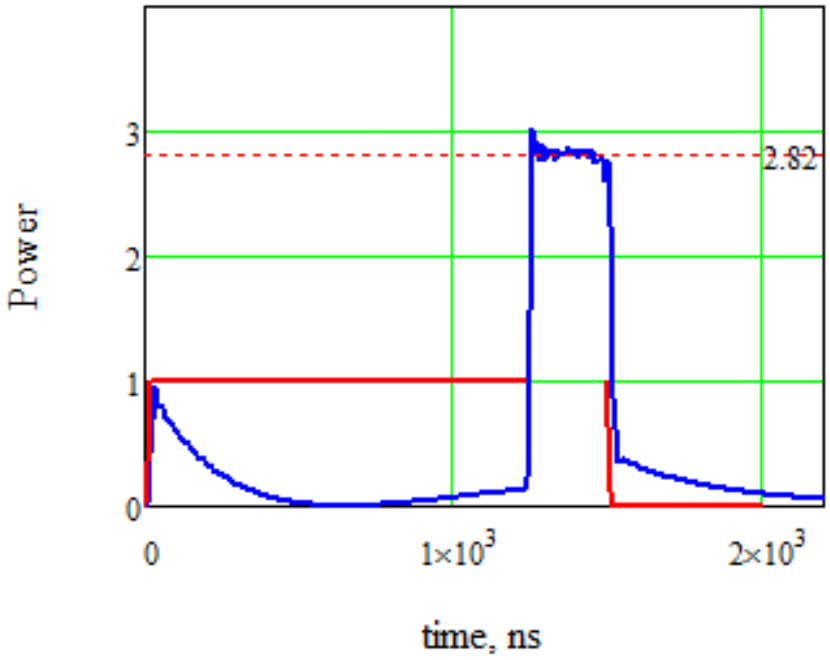


The pulse compressor after installation



Pulse compressor with temp. stabilization installed in test stand

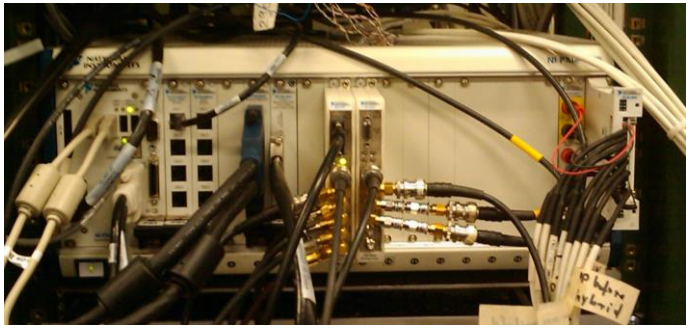
- Power gain of 2.82 calculated from rf performance measured at low power after installation and tuning in 12GHz test stand (under vacuum)
- $Q_{loaded} = 2.375 \times 10^4$, Beta = 4.27, $Q_0 = 1.31 \times 10^5$
- 5% power loss in compressor
- Temperature stabilization better than 0.1K
- LLRF phase programme controlled by AWG and analogue phase shifter (~25MHz BW)



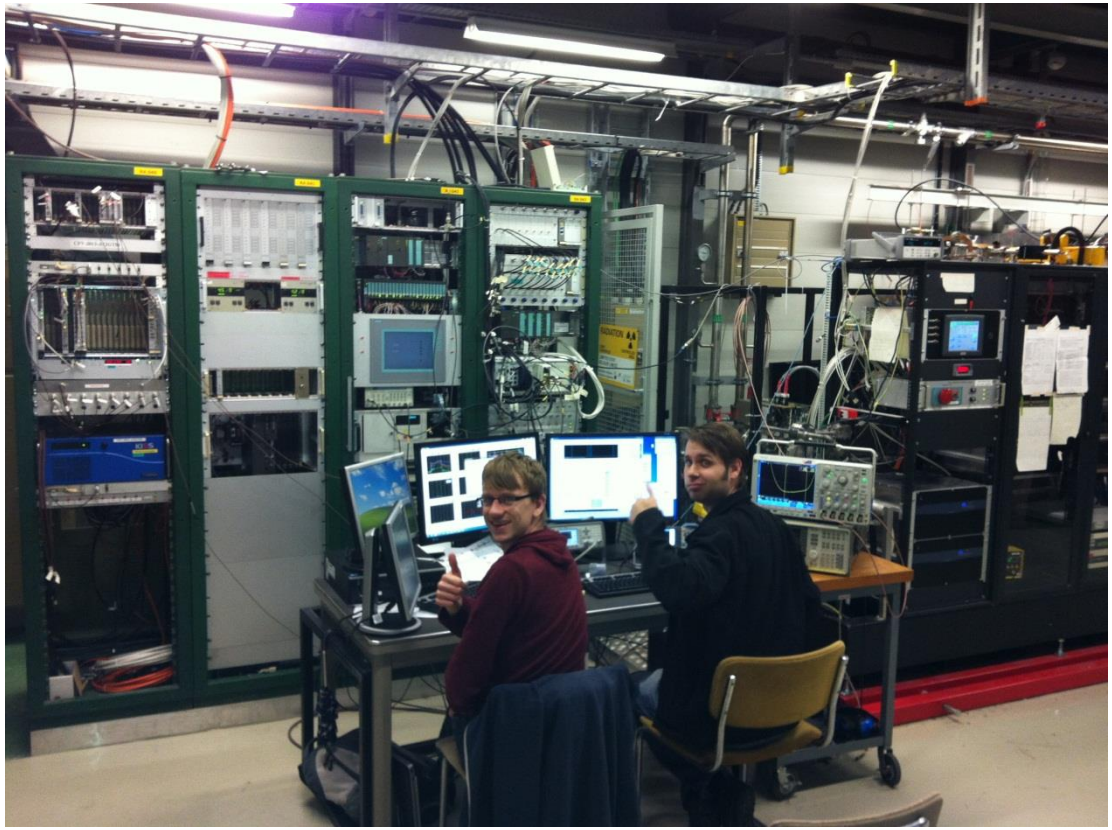
The X-box1 RF layout

Due to the delays caused by the klystron repairs, the conditioning software based on the CERN control system could not be finished ➔ Urgent need for control, interlock and feedback systems!

➔ Decision to use a National Instruments PXI based system for all X-box1 controls and DAQ



- 8ch 250MSps/s 14 bit ADCs for RF (log detectors) and DC sampling, one FPGA for 4chs used for interlocking on reflected power and DC spikes
- I/Os for temp. gauges and interlock signals
- Stepper motor control and encoder read back
- Ion pump current readout for all pumps



The new X-box1 control and DAQ software (September vers.)

50dB log detector into 14bit 250MSps/s ADC for controls

Last interlock event display (plus two previous pulses)

Interlock levels, calibration etc.

Power, DC, beta history

Single shot FN-plot

All at 50Hz rep. rate! 400Hz possible!

Screenshot of X-Box1 controls (Recent version)

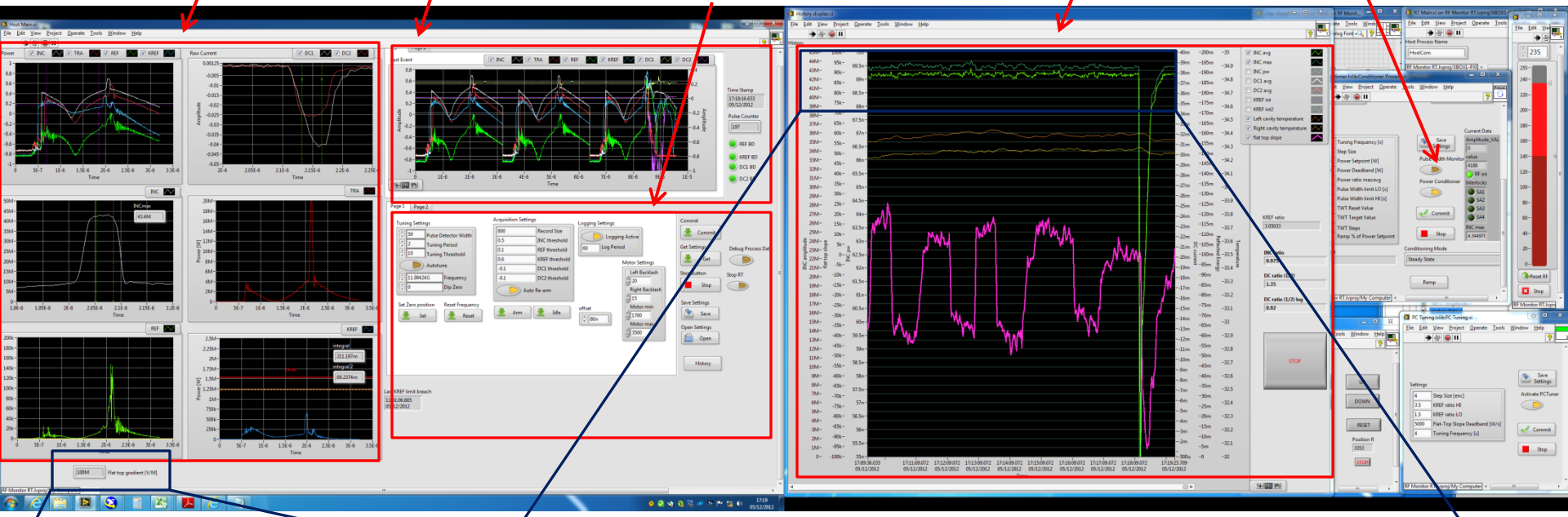
50dB log detector into 14bit 250MSps/s ADC for controls

Last interlock event display (plus two previous pulses)

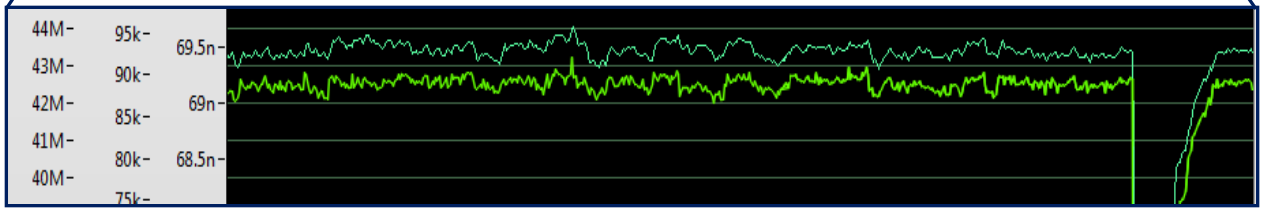
Interlock levels, calibration etc.

Configurable history plot

Controls for tuning, power, motors etc.

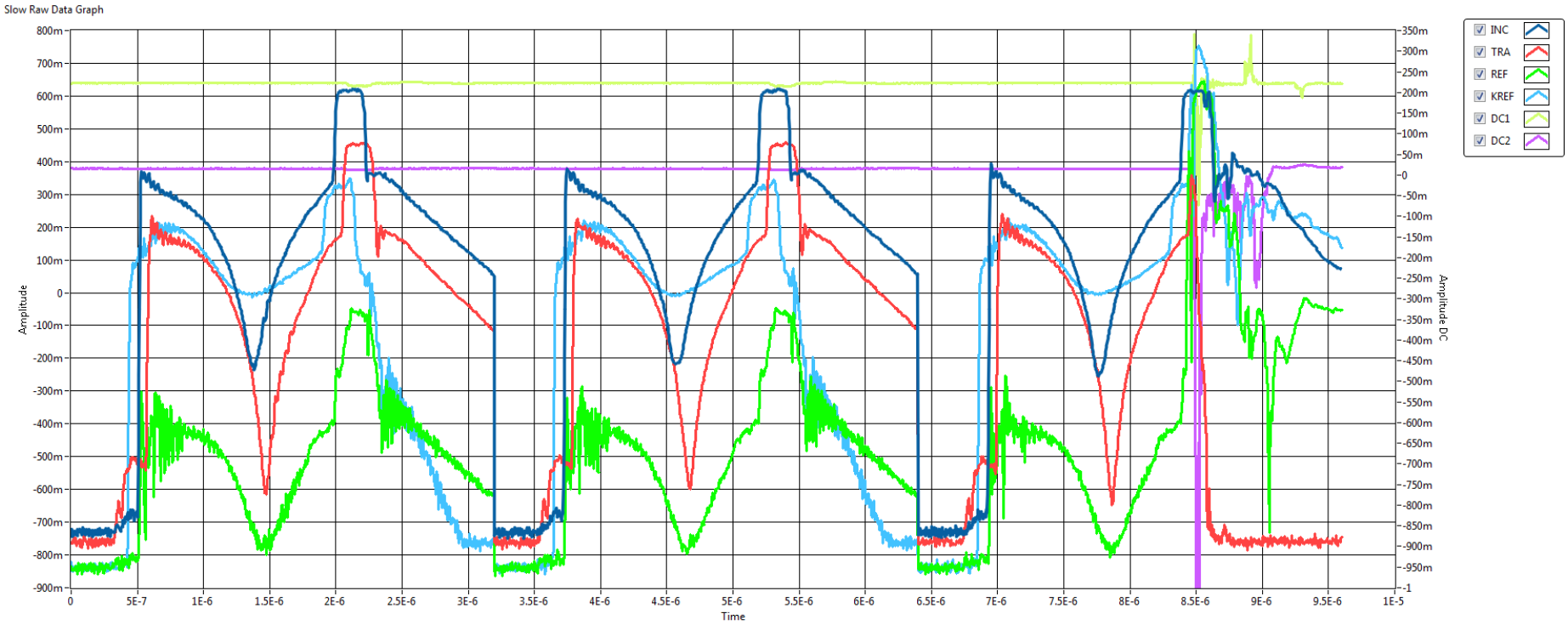


Real-time gradient display



Power history plot (peak and average)

X-band log detectors



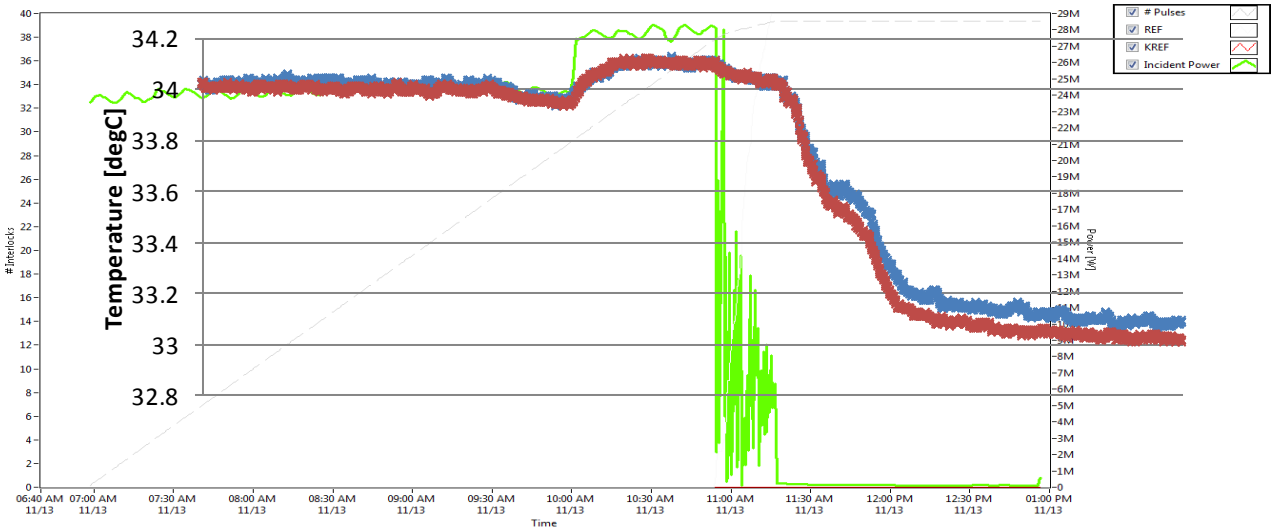
Hittite HMC662 8-30GHz log power detector, approx. 50dB dynamic range

➔ Eases operation and PC tuning at all power levels

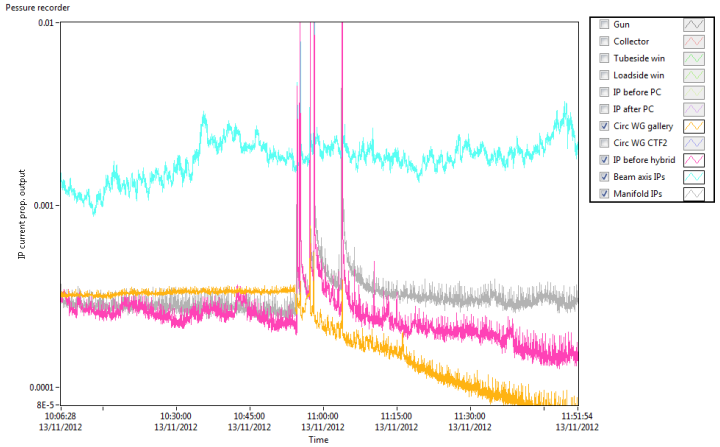
➔ Good resolution of reflected power signals without saturation effects during BDs

Some early operation experience

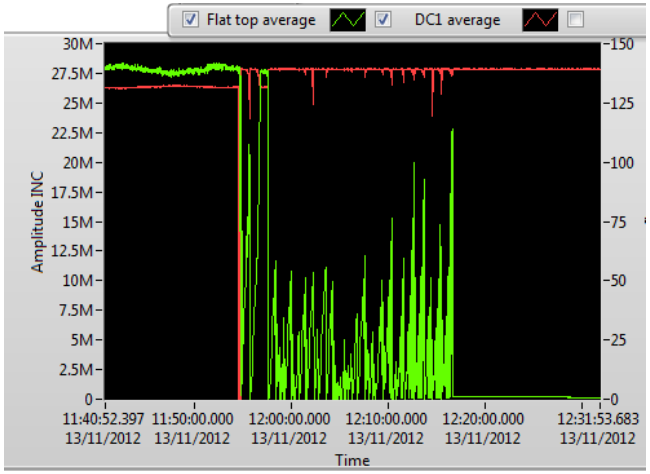
Started routine conditioning of T24 structure beginning of November 2012, but needed to resolve problems with RF jitter and the stability of the pulse compressor



Breakdown: RF off, PC cools down and detunes, RF ramped back without flat top (peak power overshoot), next breakdown due to high peak fields, RF off again, PC cools down even more, and so on…



Vacuum history of BD cluster



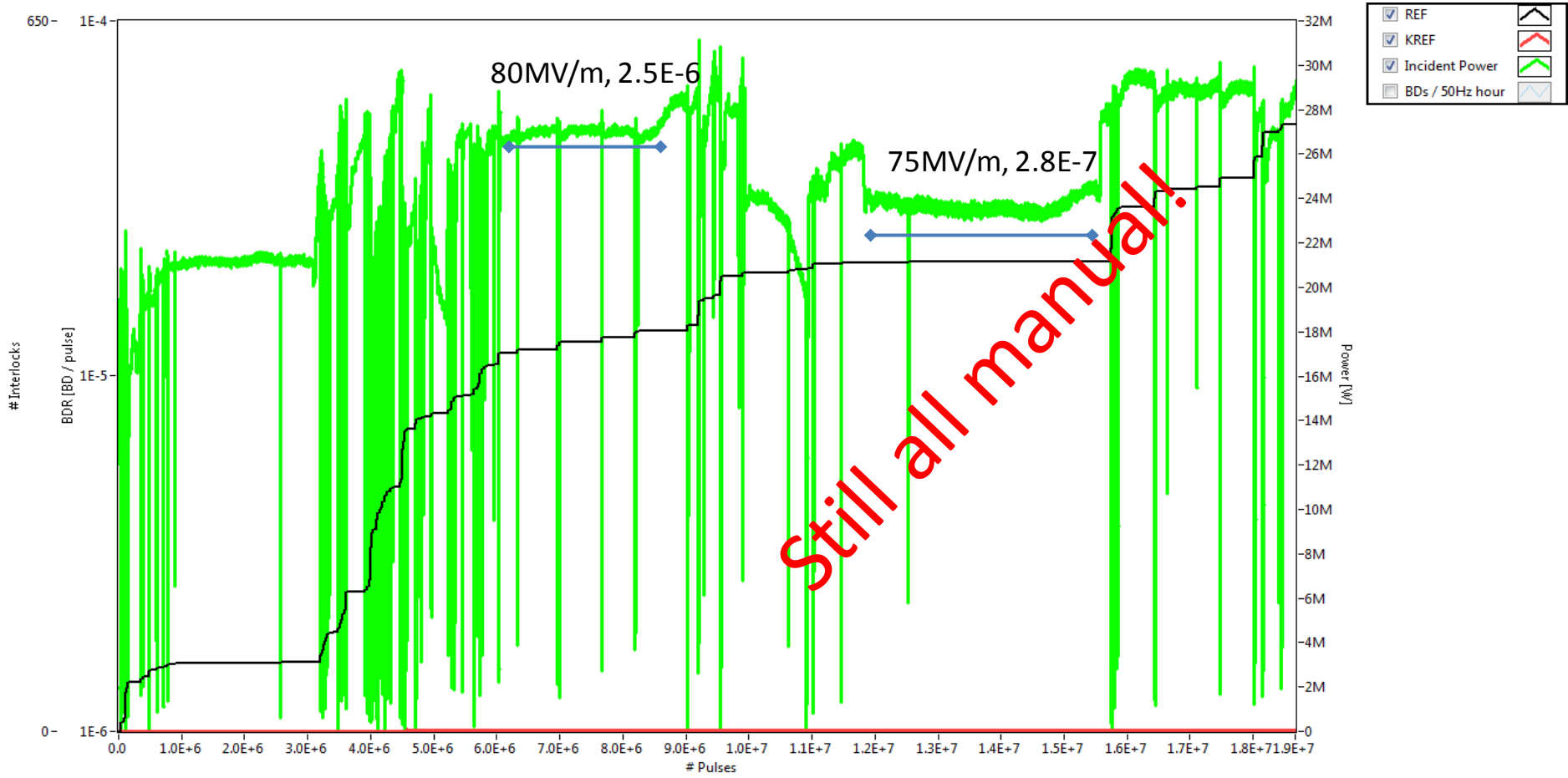
Power/DC history of BD cluster

T24 structure status

Started conditioning at 170ns flat top, 50Hz, max. gradient ~83MV/m at pulse compressor compatible BDR

Since 6th of November 2012: 19Mps (~100 50Hz*hrs), 500BDs, 1PC BD

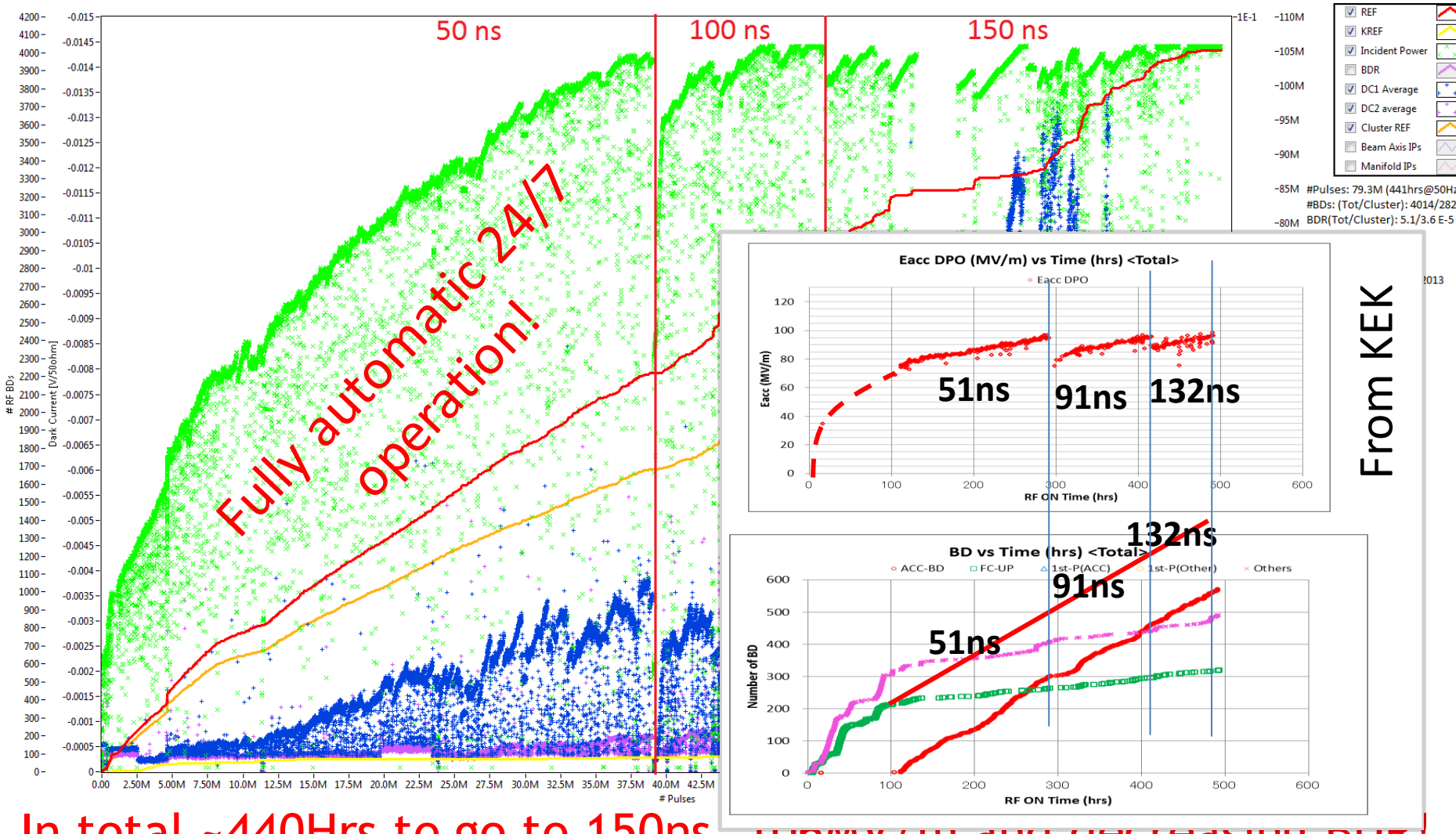
Since 20th of November 2012: Decided to go to 50ns conditioning, but BDR stayed high



➔ Replaced T24 structure by TD24R05 structure (no damping mat.)!

New TD24R05 structure status (from January 2013)

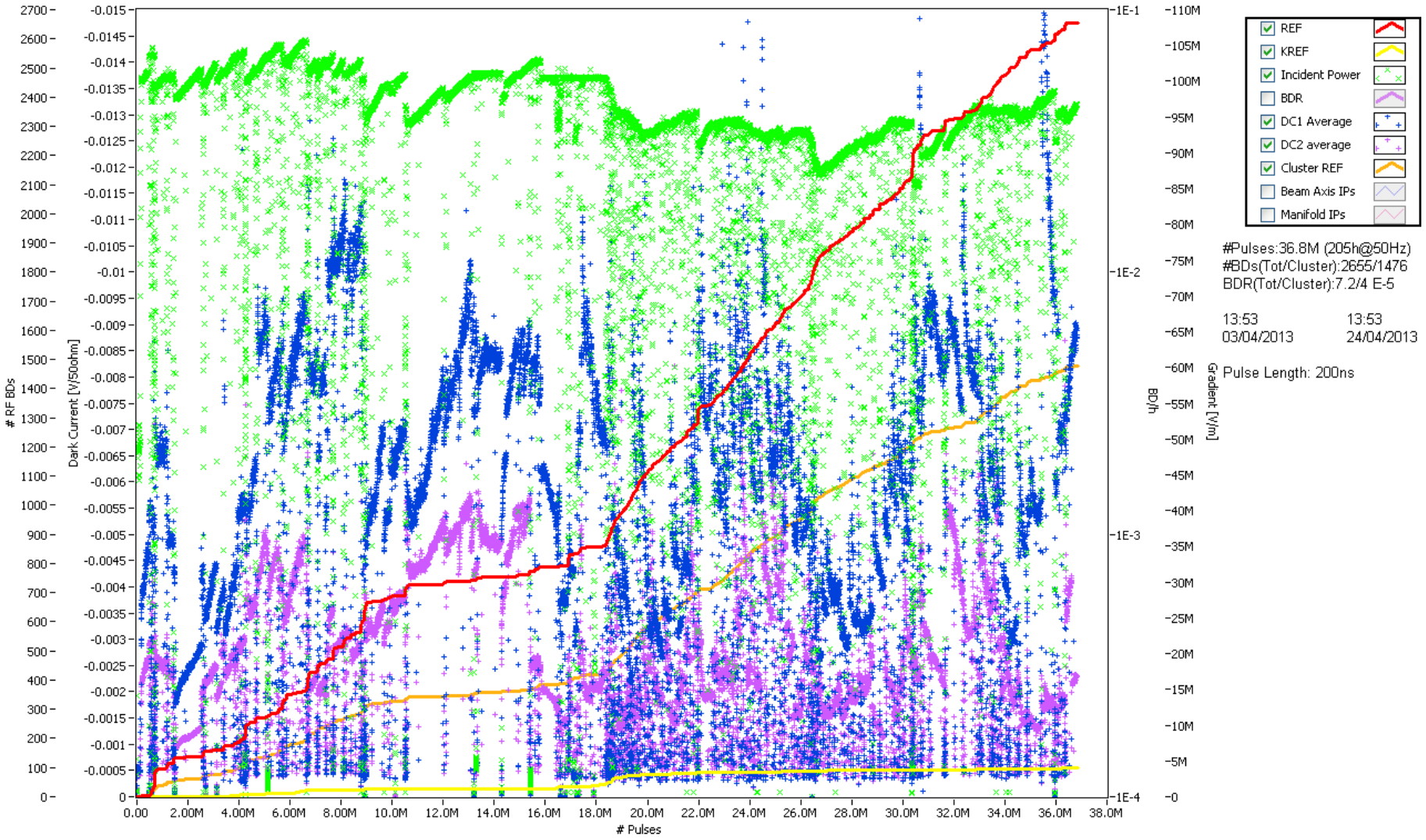
Implemented AGC and pulse compressor stabilization routine. Started at 50ns pulse width.
New long-time conditioning software now keeps BDR constant:



In total ~440Hrs to go to 150ns, 106MV/m and decreasing BDR!

TD24R05 structure status

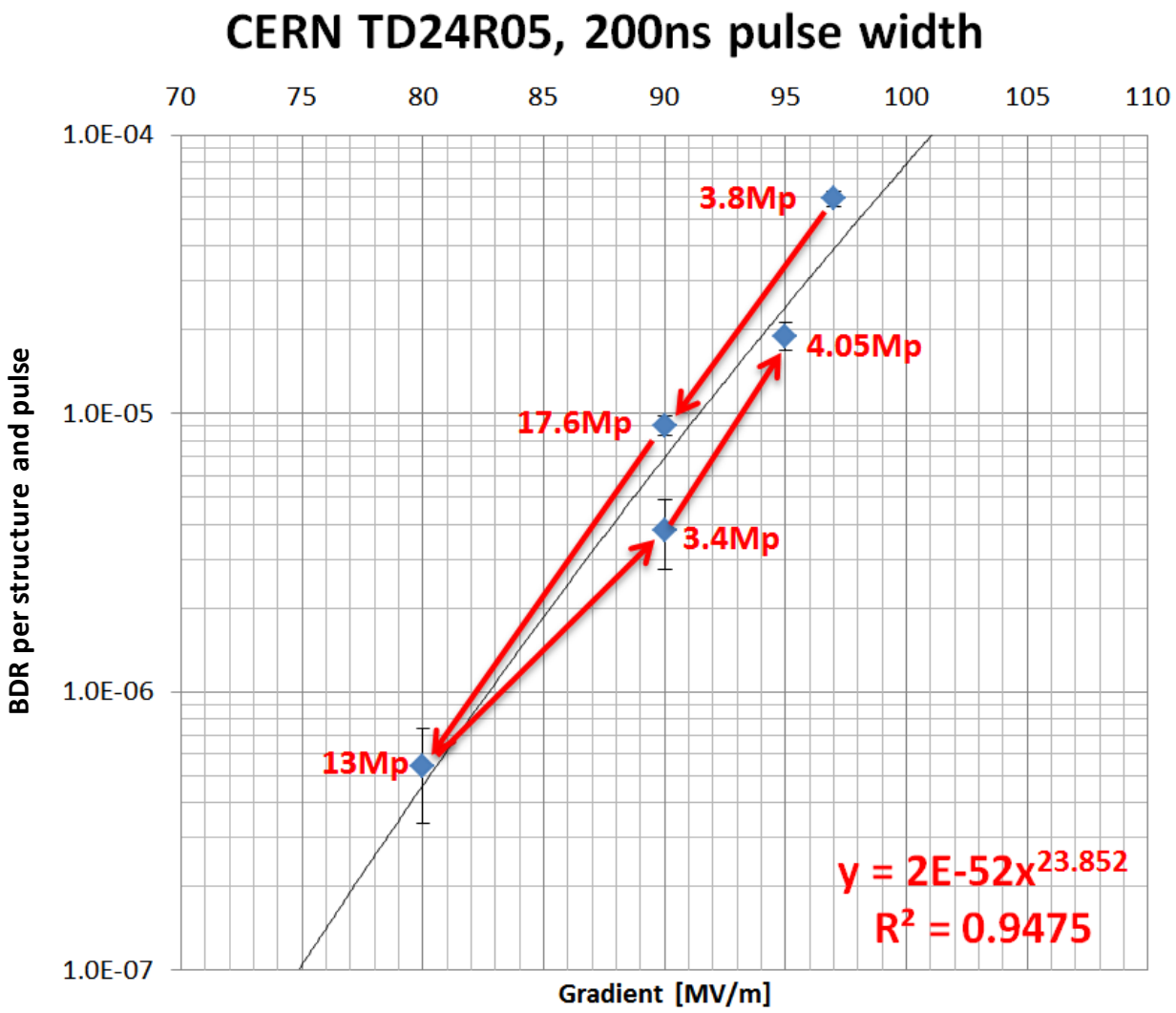
Later processing at 200ns pulse width:



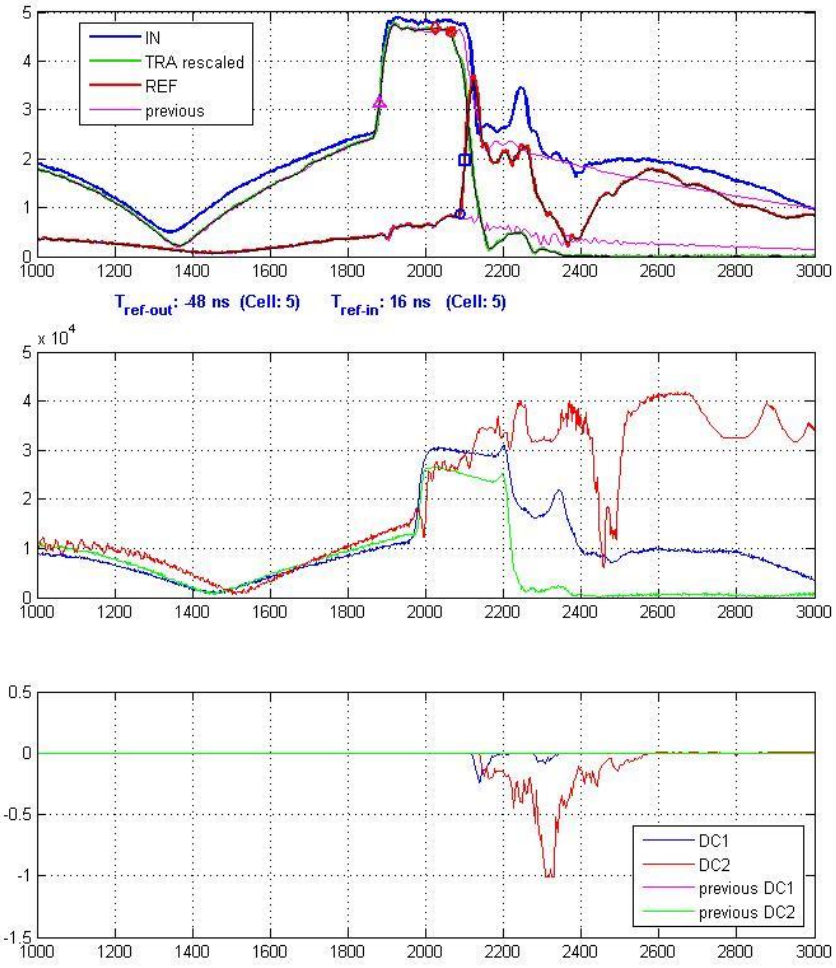
Operation beyond 95MV/m and 200ns pulse width turned out to be difficult, probably due to a 'hot cell' ➔ Data analysis by W. Farabolini

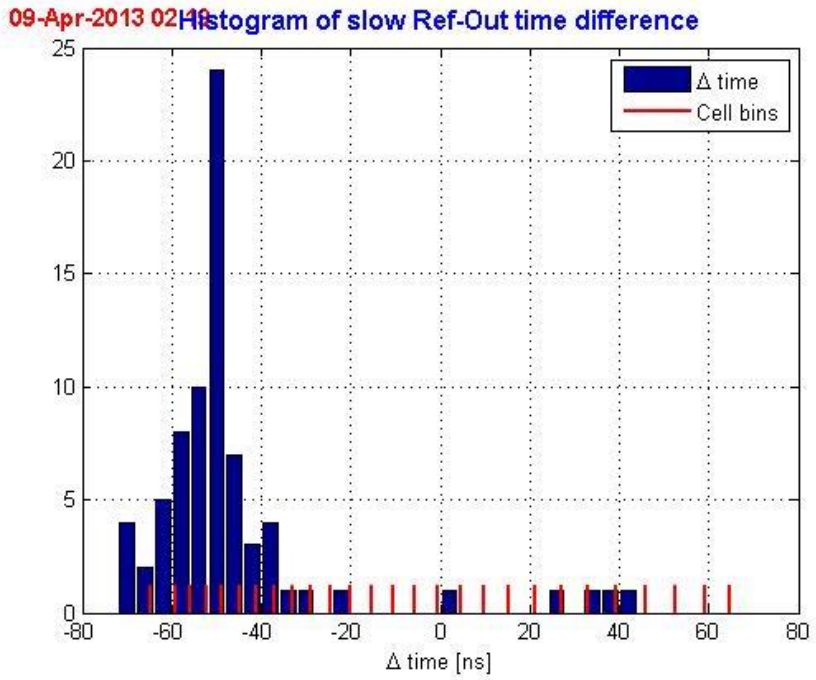
TD24R05 structure status

BDR vs gradient plot:



Breakdown location statistics





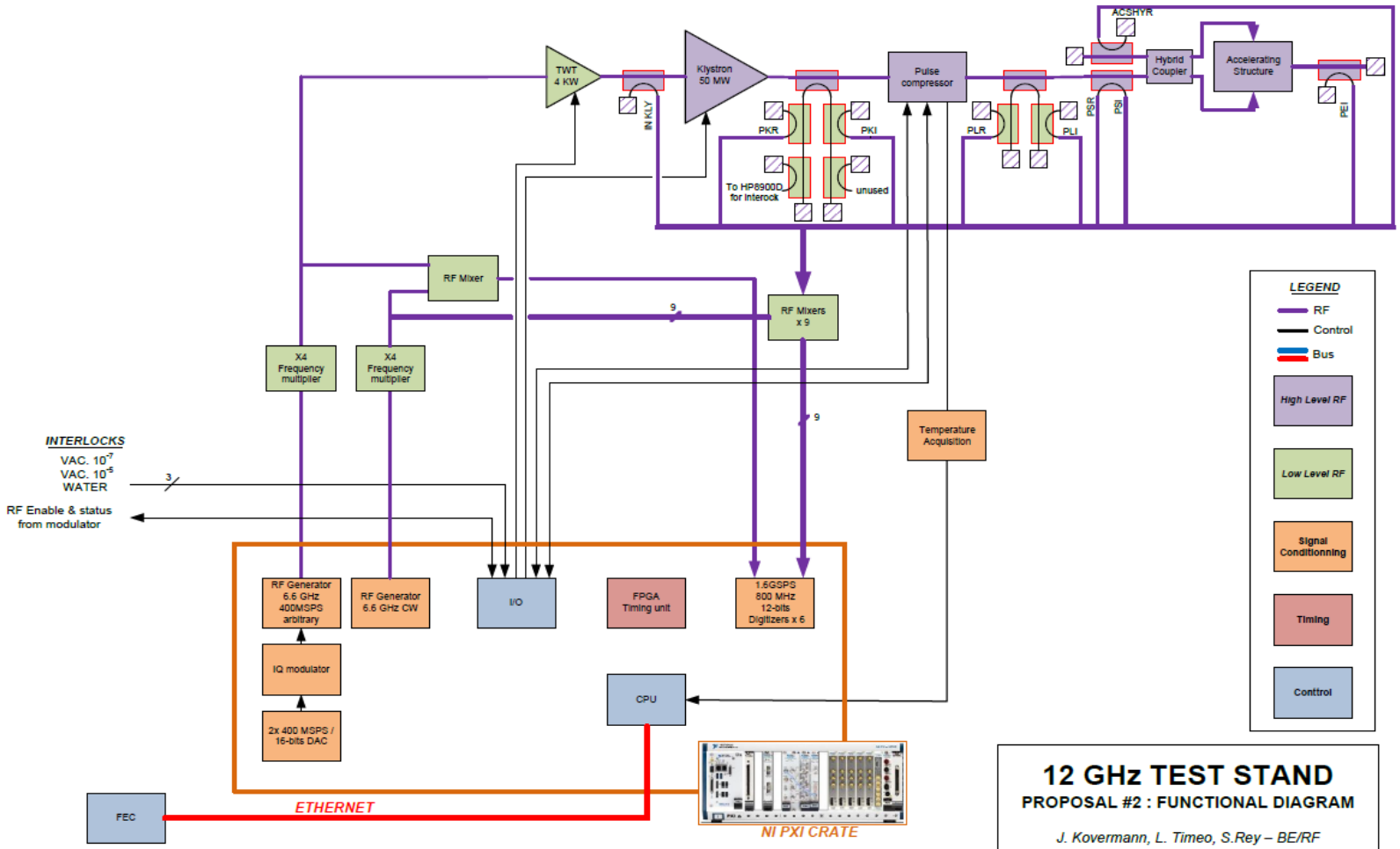
Clear indication of a 'hot cell'…

➔ Structure will be replace during summer shutdown

➔ See Wilfried's talk this afternoon!

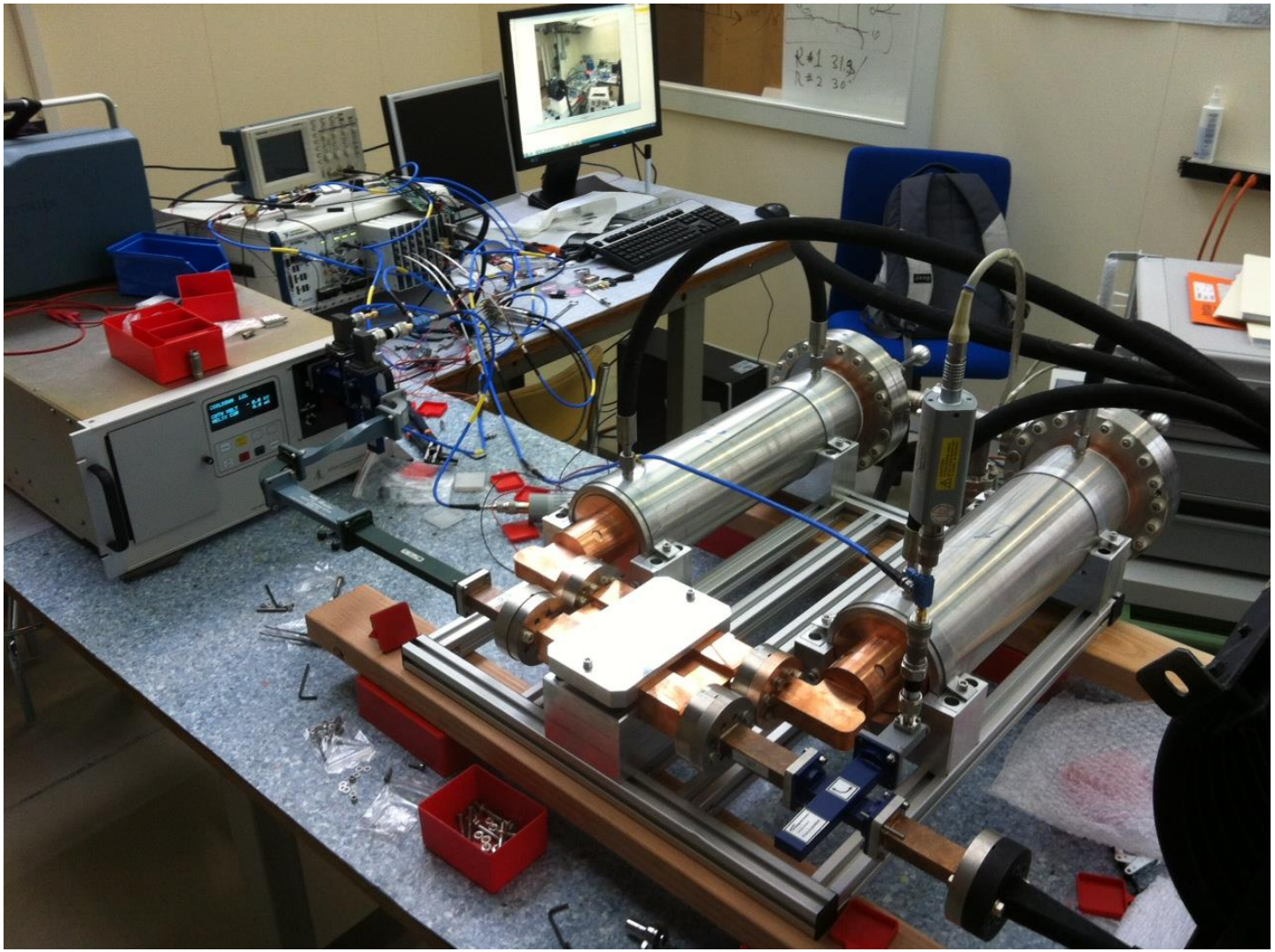
The future X-box1 and X-box2 RF system

The main weaknesses of the Xbox-1 system are the difficult to calibrate and rather non-linear I/Q demodulators and the dependency on the CERN control system (necessary for X-box1 only for the timing but not for the future test stands) ➔ Proposal for an upgrade under evaluation



The future Xbox-1 and Xbox-2 RF system

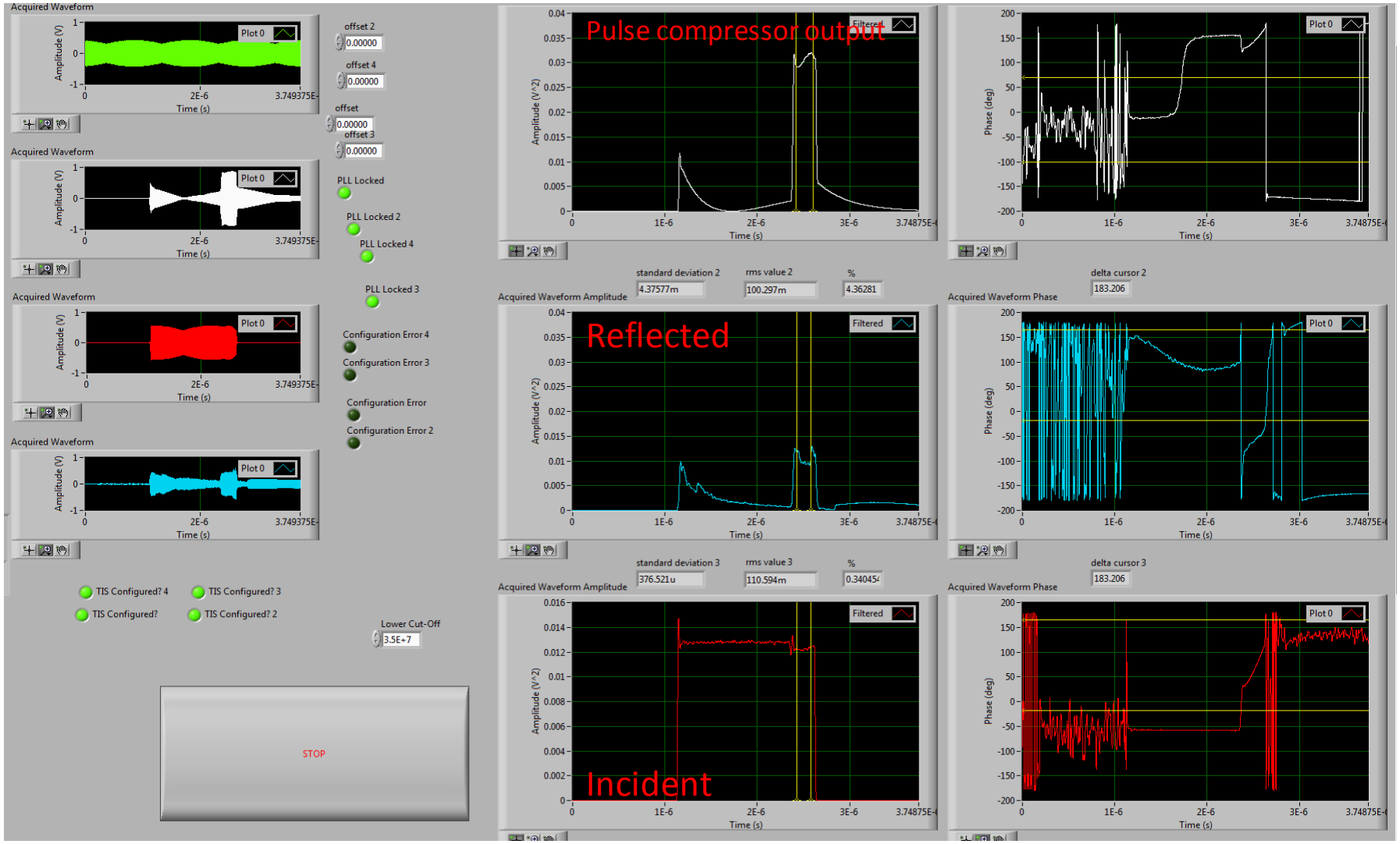
Lab setup of new LLRF concept works (including TWT and pulse compressor)!



Much simpler and far more flexible (and even a bit cheaper…)!

The future Xbox-1 and Xbox-2 RF system

First real (but low power) phase and amplitude signals:



Measured >30dB of dynamic range on rf signals, 1.6Gsps/s (12bit) sampling, 800MHz BW

Conclusion

- *First X-band test stand for 12GHz CLIC accelerating structures has been successfully installed and commissioned!*

- *The system is now running and taking useful data 24/7 with only few user interventions*

- *Two structures – T24 and TD24R05 - have already been tested*

- *A new LLRF control system has been developed for X-Box1 and evolved into a new and already proven LLRF concept for X-Box2*

- *Several new high power testing slots planned at CERN and at collaborators labs*

Thank you!