High gradient test results from X-BOX1

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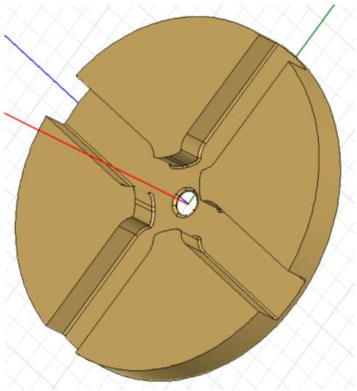
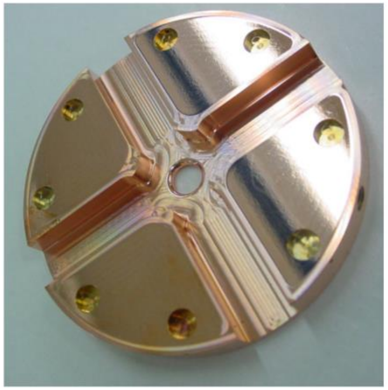
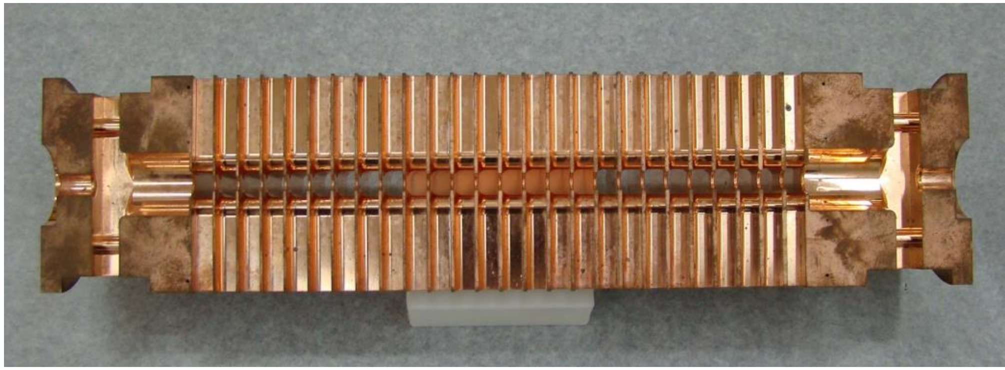
RF Processing of CLIC Structures

- High accelerating gradient 100MV/m → 200-300MV/m surface fields.
- Long conditioning period needed >2000hrs to reduce breakdown rate toward 3×10^{-7} for CLIC.
- The established method:
  - Start with short pulse length (50ns).
  - Ramp to nominal power(100MV/m, ~42MW) keeping BDR~10^{-5}.
  - Increase pulse length by 50ns, drop gradient by ~10% and repeat.





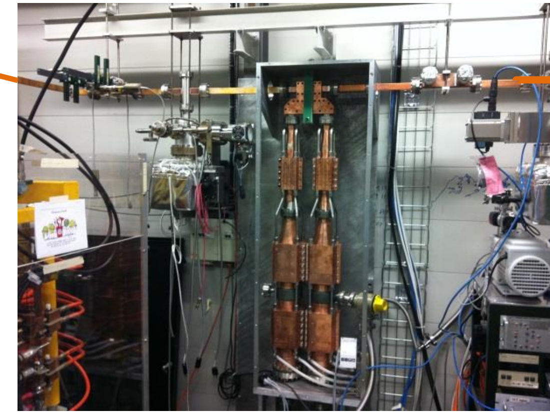
A. Grudiev, W. Wuensch, CERN



Xbox-1 Layout

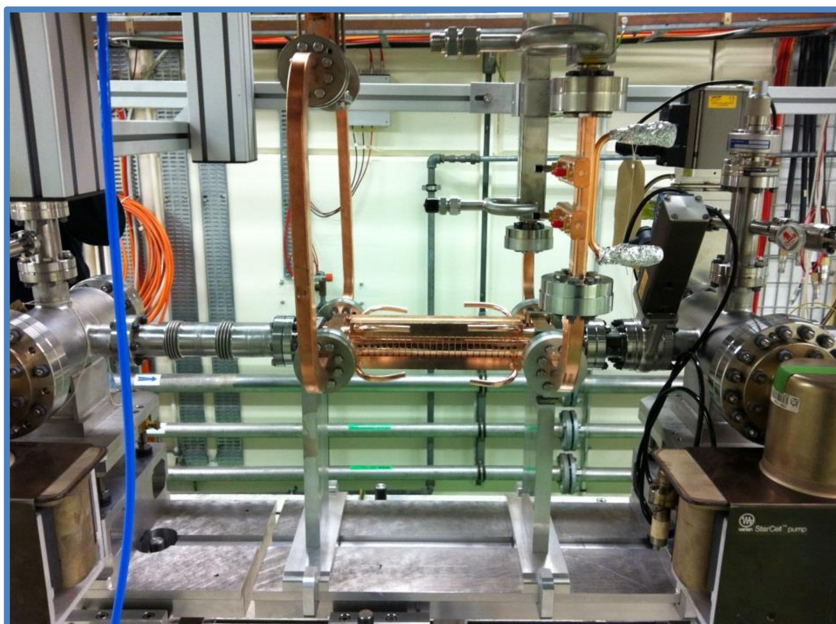
Clockwise from top-left:

- Modulator/klystron (50MW, 1.5us pulse)
- Pulse compressor (250ns, ratio 2.8)
- DUT + connections
- Acc. structure (TD26CC)

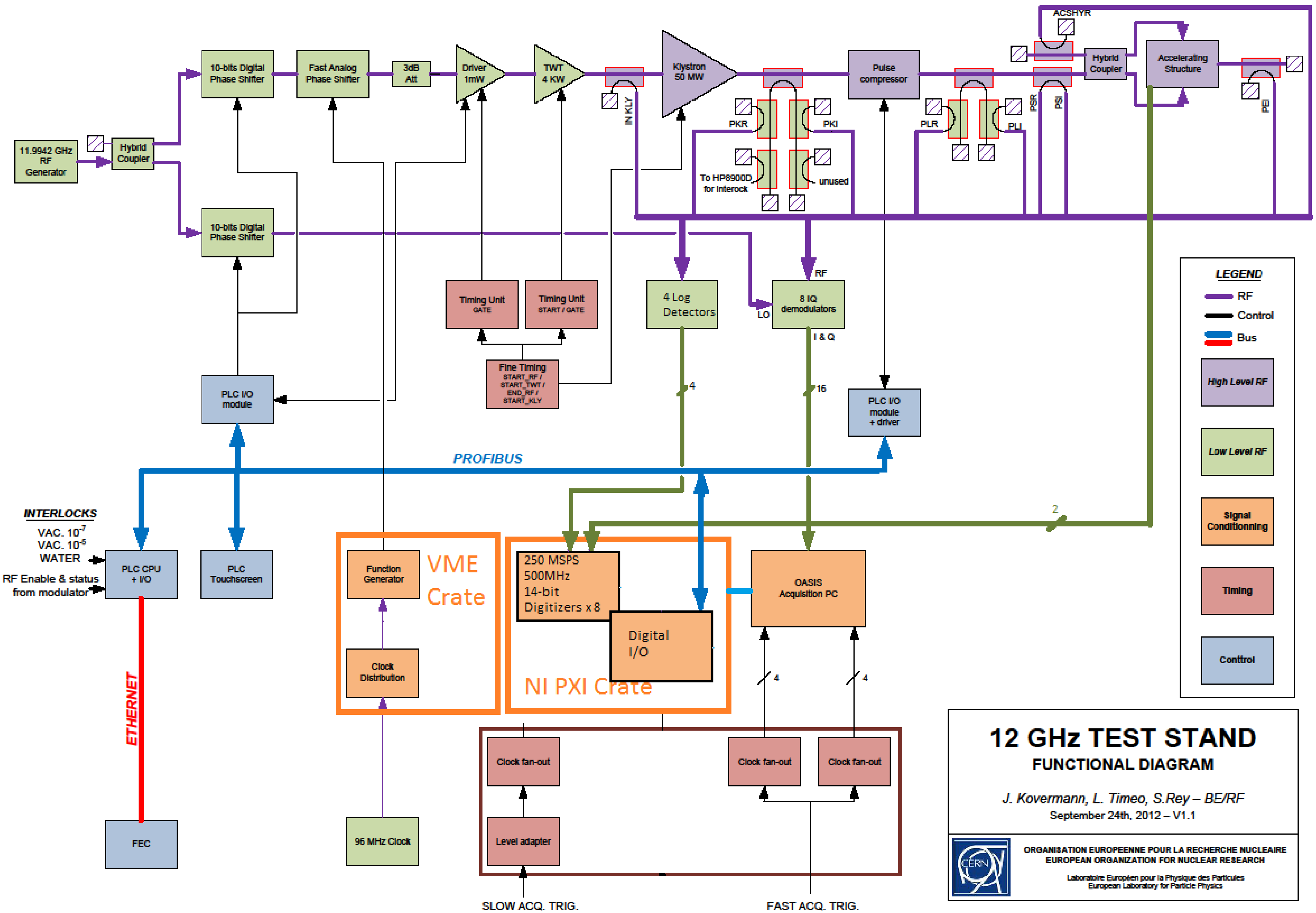


Gallery

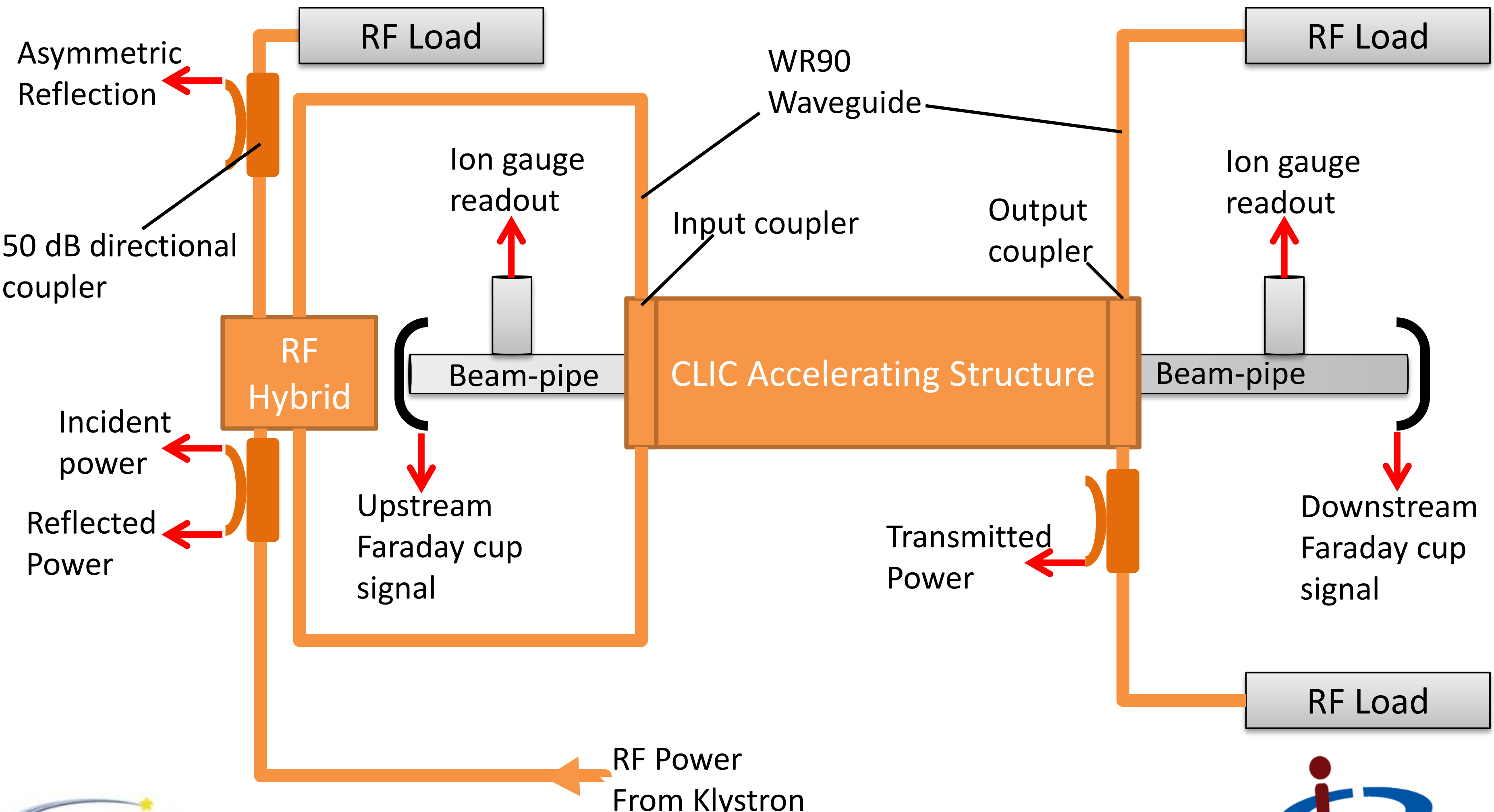
Bunker



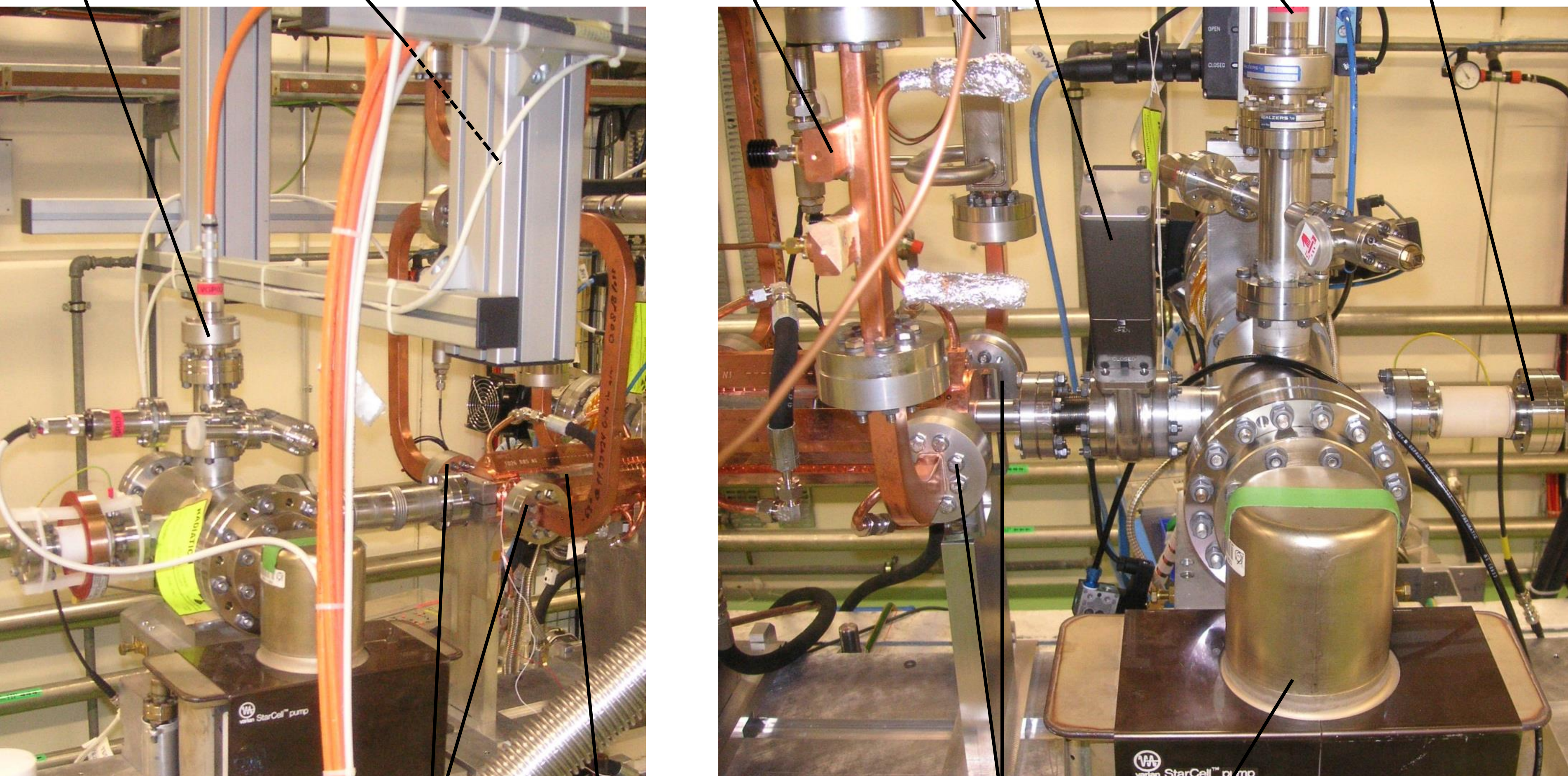
System Layout and diagnostics



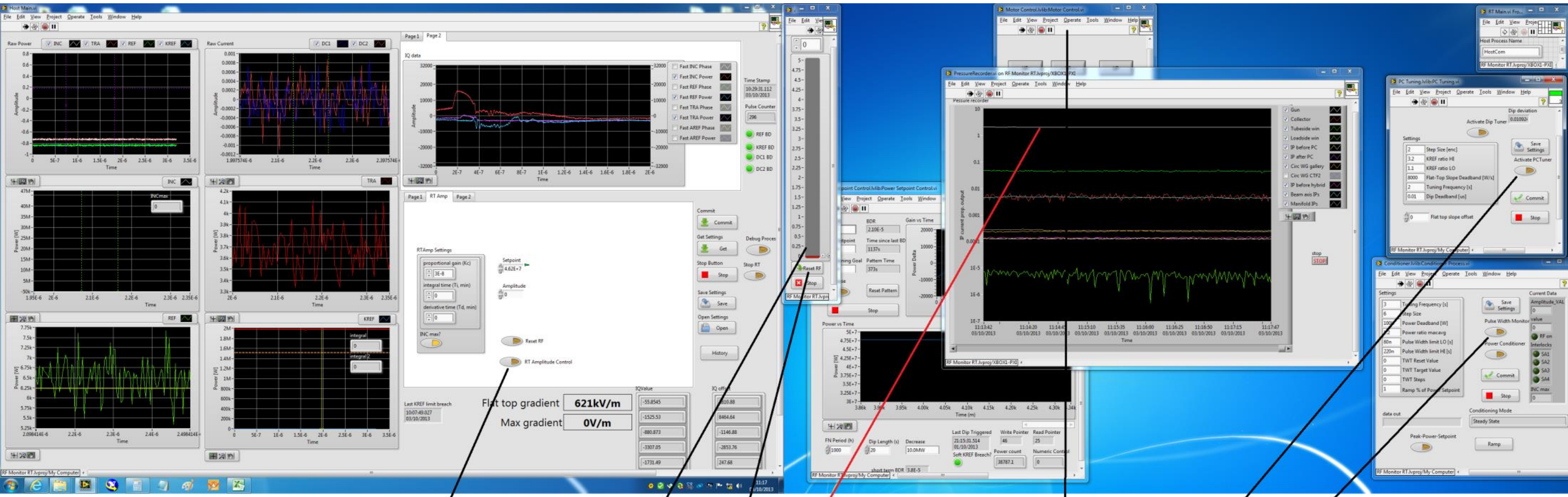
Accelerating Structure Diagnostics



Accelerating Structure Diagnostics



Operator display



2. Toggle and then turn OFF RT amplitude control

3. press Reset RF

1. Turn OFF Pulse Width Monitor

8. Increase voltage of attenuation in Amplitude Control.vi

4. Reset and Trig the modulator at 250 V

5. Deactivate PC tuner

9. If tuning is good activate PC tuner (press Set Zero position when dip is good)

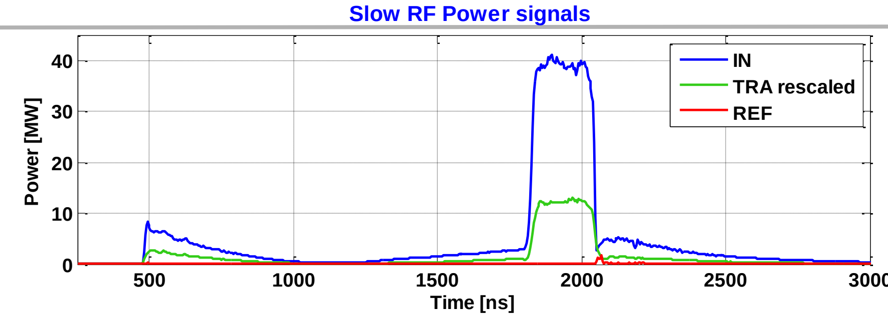
6. Tune pulse compressor to cold state (step 1000 then back to 20)

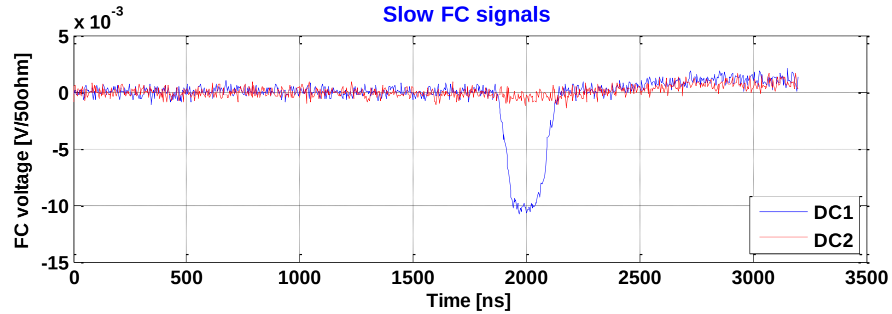
7. Ramp modulator voltage while checking gun vacuum level

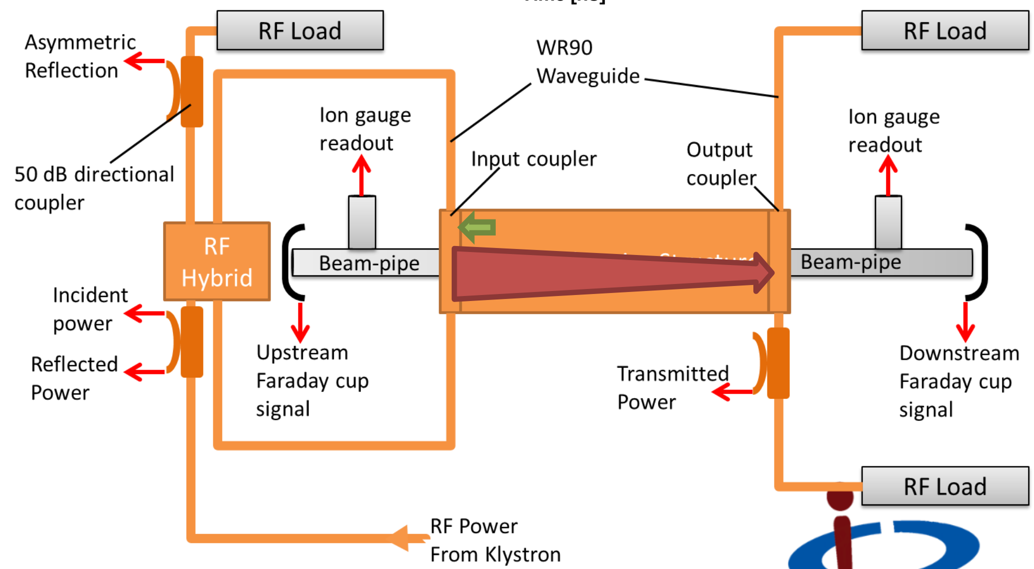
10. Switch ON pulse width monitor(1) and RT amplitude control(2)

BD Detection: Normal Pulse

- Transmitted pulse follows the incident pulse but with ~4dB of attenuation.
- Reflected signal is ~20dB lower than incident pulse.
- Only a few mV seen on the faraday cups. DC2-Upstream sees 1/10 of the signal compared to downstream.

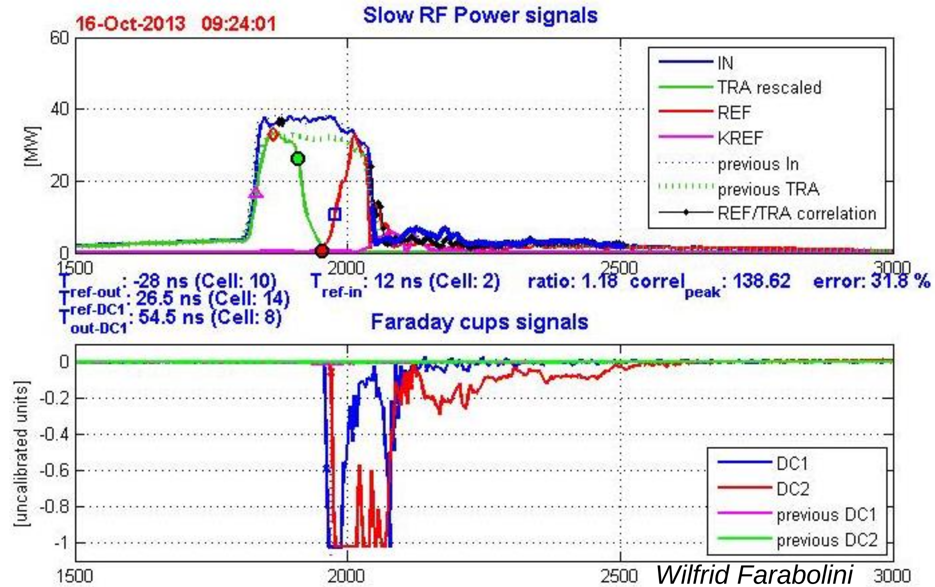


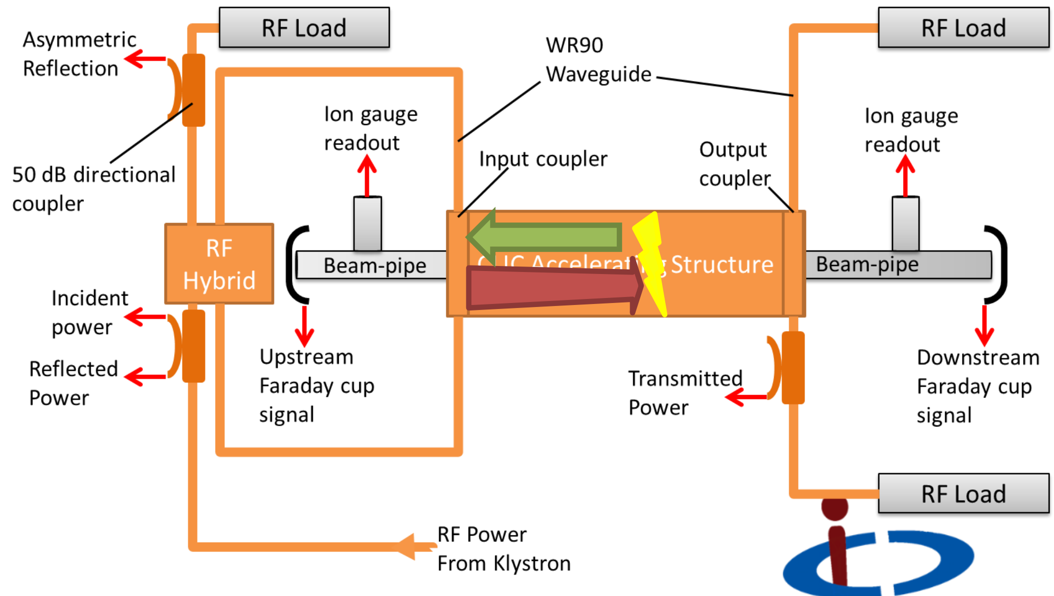




BD Detection: Breakdown

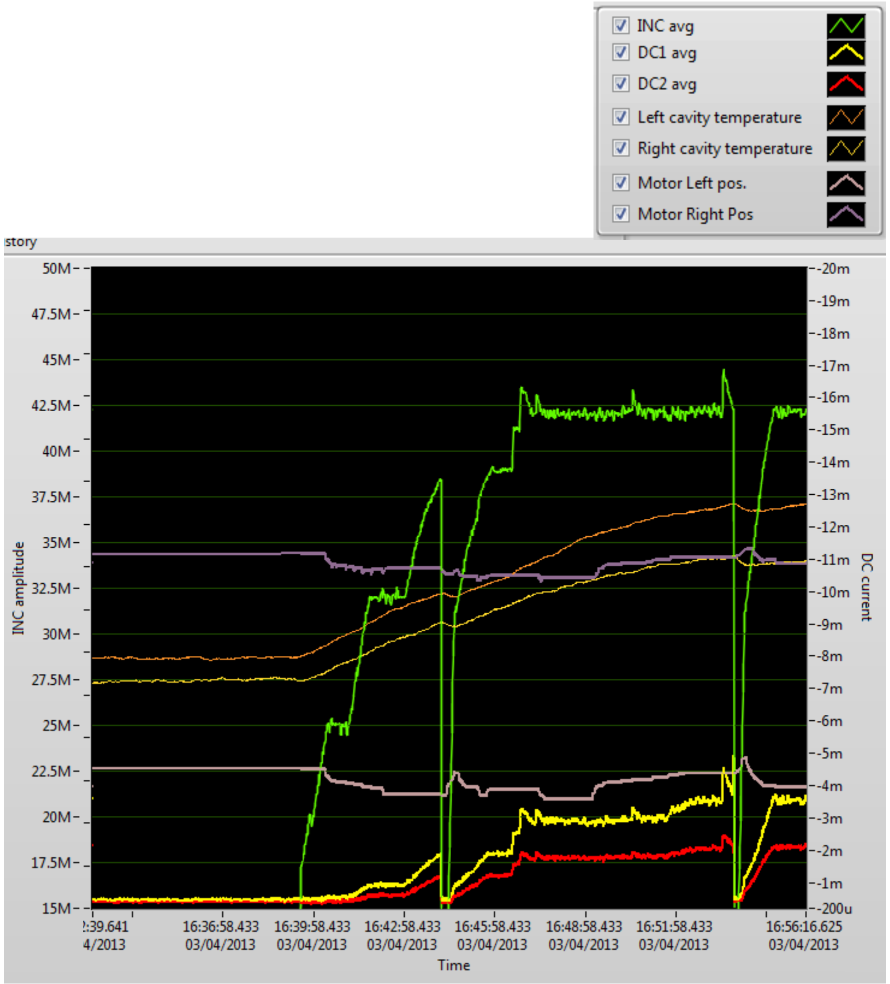
- Transmitted pulse drops as the arc is established.
- Reflected power increases to the same order as the incident pulse.
- Faraday cup voltages are saturated: 100-1000x increase in charge emitted.
- We can use the difference in time between the transmitted power falling and the reflected power increasing to find the BD cell location.
- The phase of the reflected signal is used to pinpoint cell location.





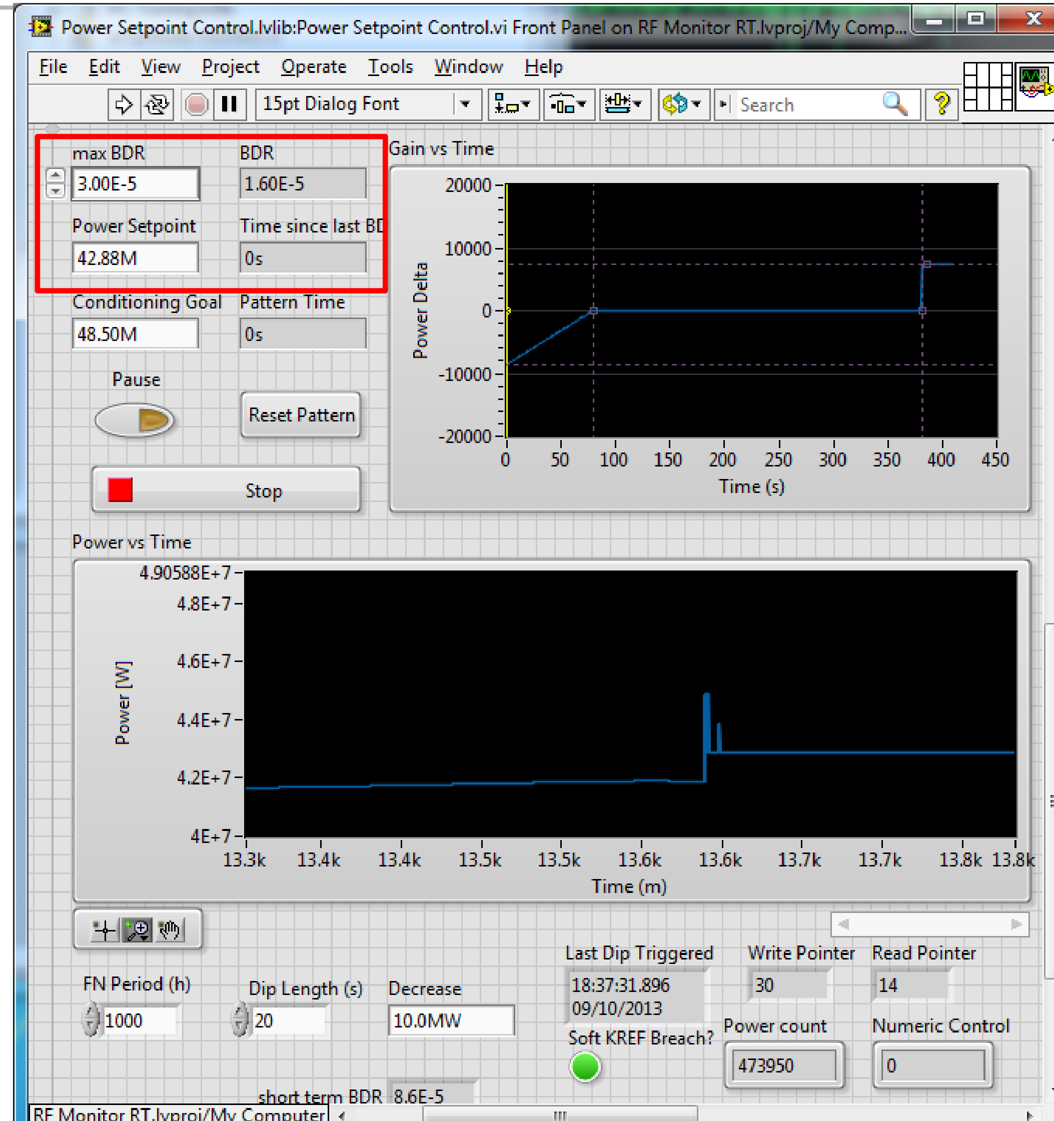
Breakdown: Steps taken

- We stop the next pulse from occurring and wait 2 seconds to let the vacuum level recover.
- All the signals are logged to file for later analysis.
- Over 20-30 seconds we ramp the power from zero back to the power set-point.

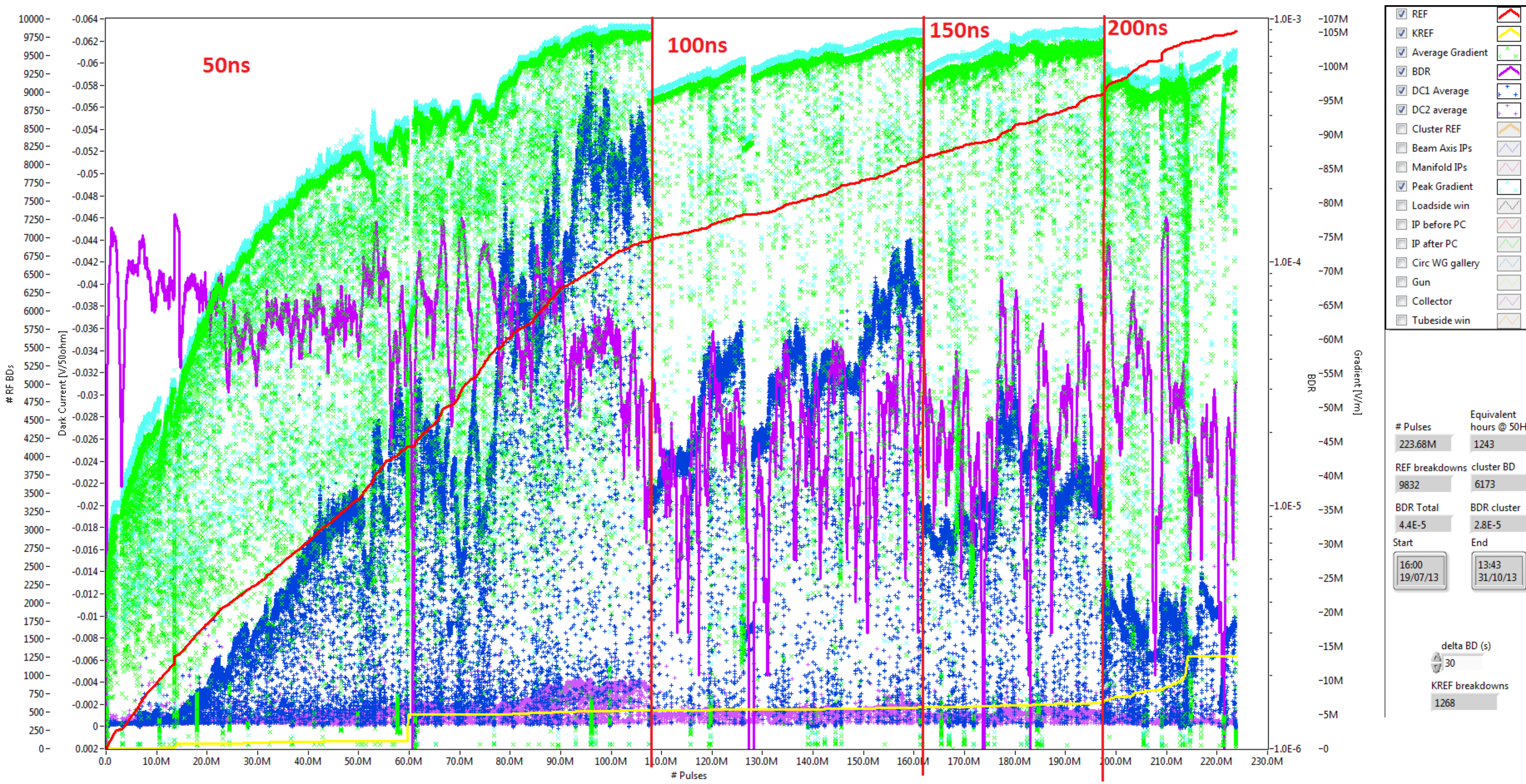


Cavity Conditioning Algorithm

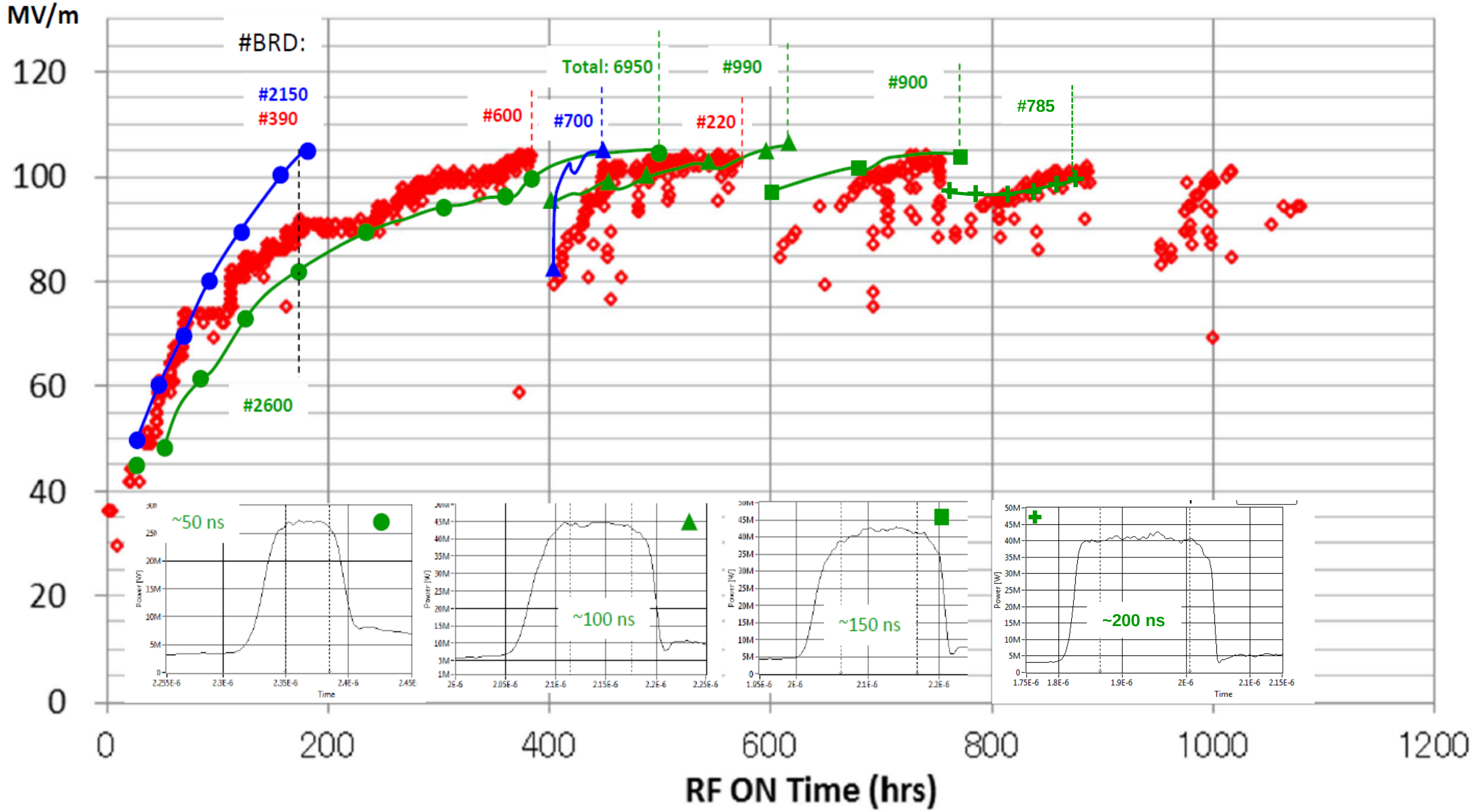
- Automatically controls incident power to structure.
- Short term: +10kW steps every 6 min and -10kW per BD event.
- **Long Term**: Measures BDR (1MPulse moving avg.) and will stop power increase if BDR too high.



Results: TD26CC



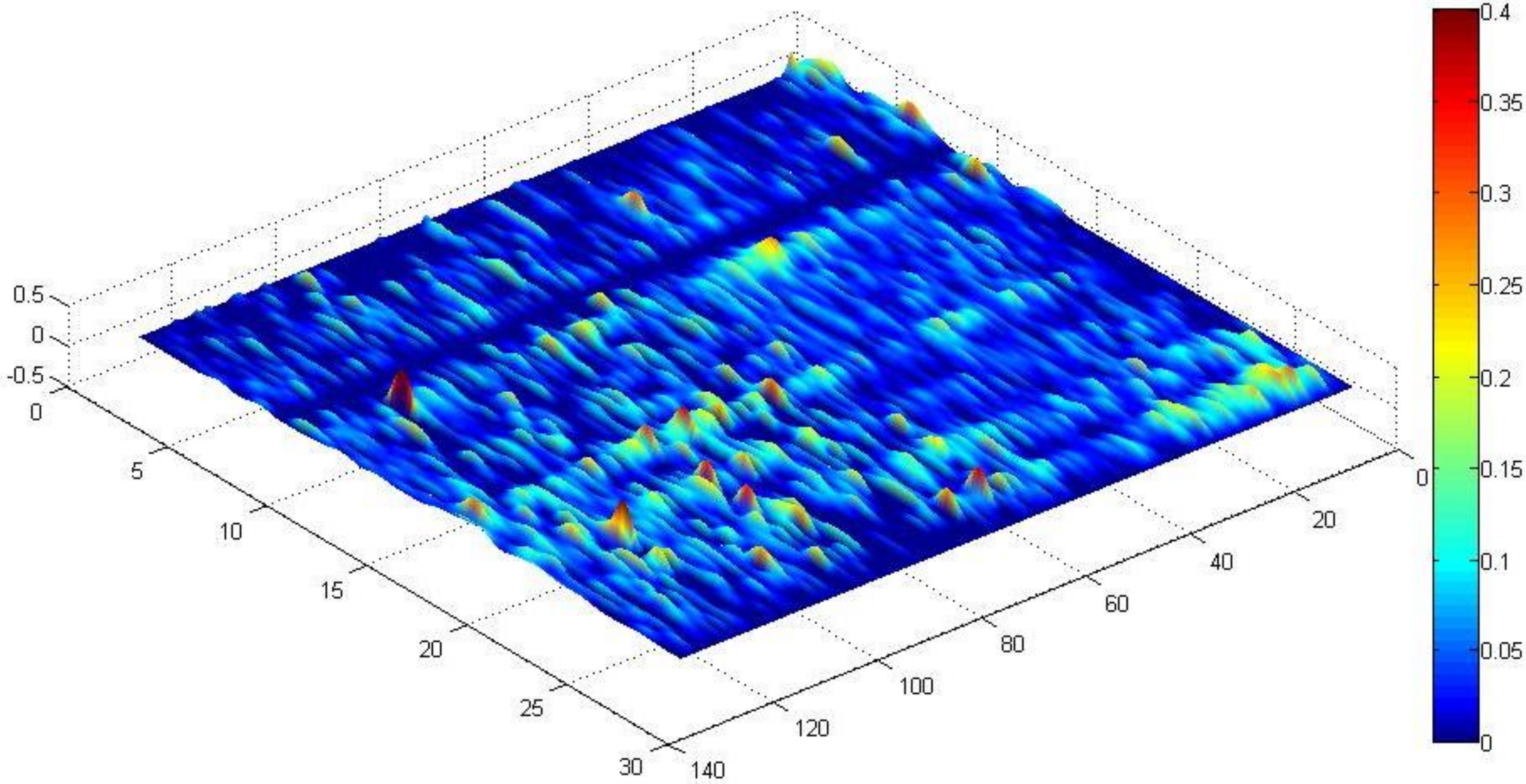
Comparison of the TD24R05(KEK); TD24R05(CERN) and TD26R05CC (CERN) processing histories.



10.10.2013

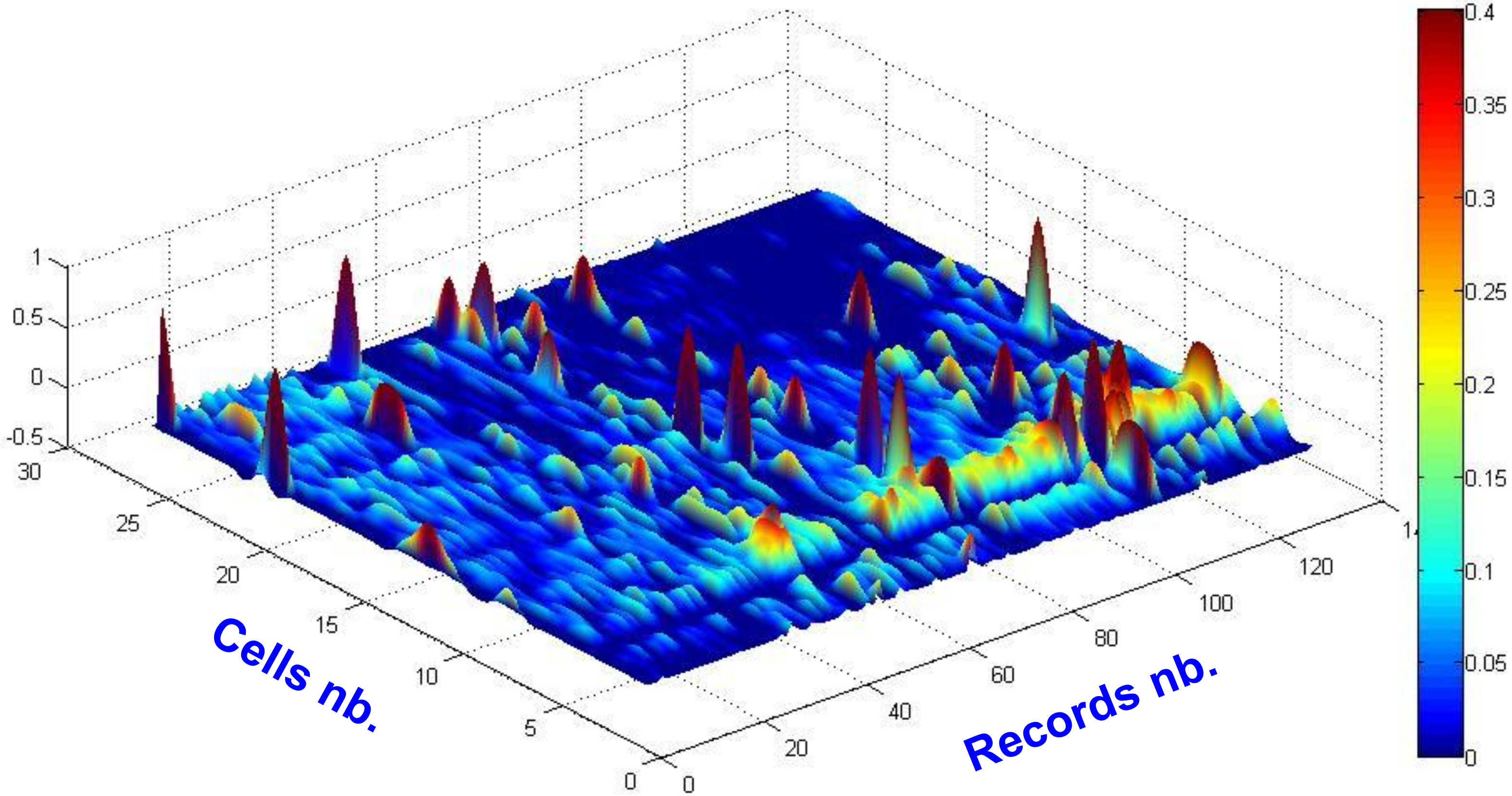
*50Hz vs. 60 Hz included

Results: TD26CC BD Location



Corrupted files and no powered periods have been removed from the record

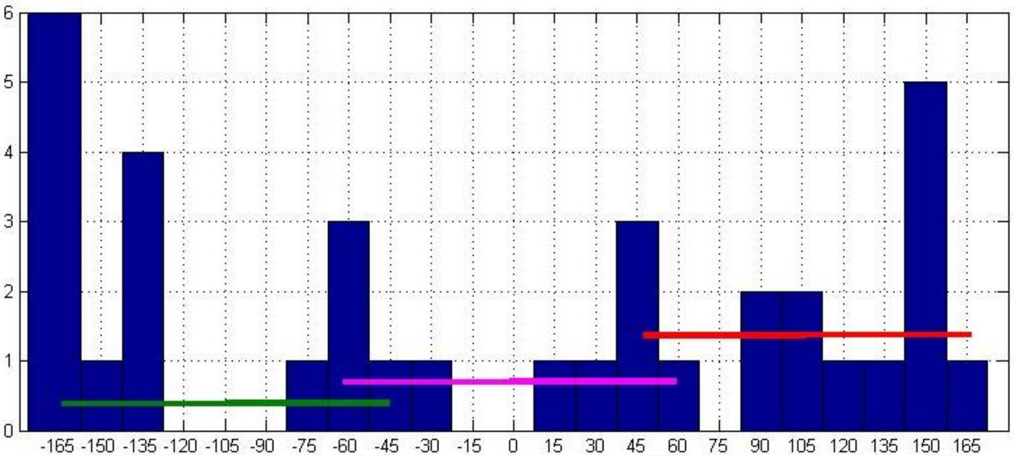
Results: TD24R05 BD Location

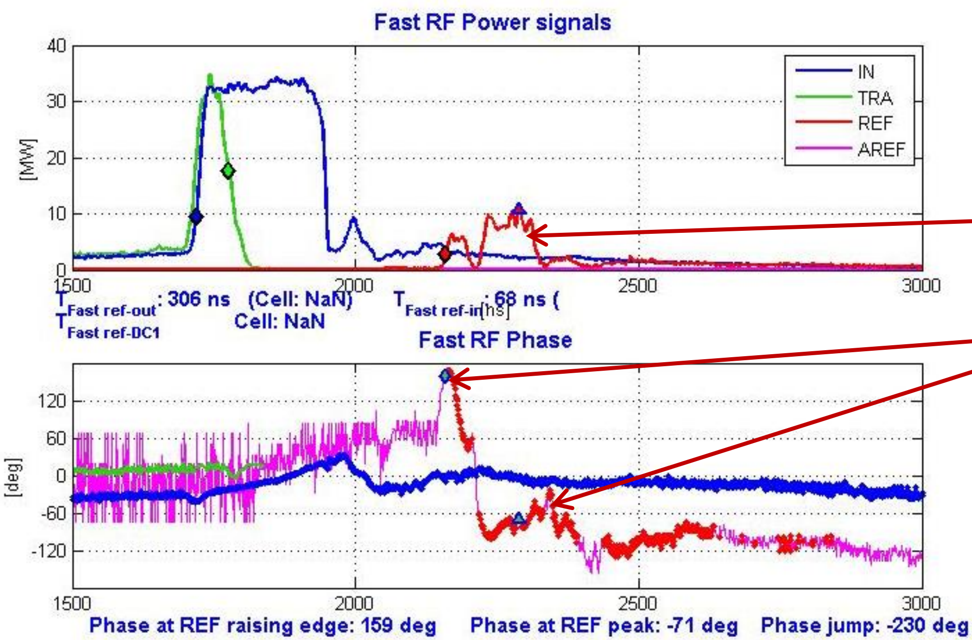


Hot cells (5 and 6) have appeared from record #50

The very high peak values are an artifact of the normalization (if only 2 BDs during a record these cells will result very active)

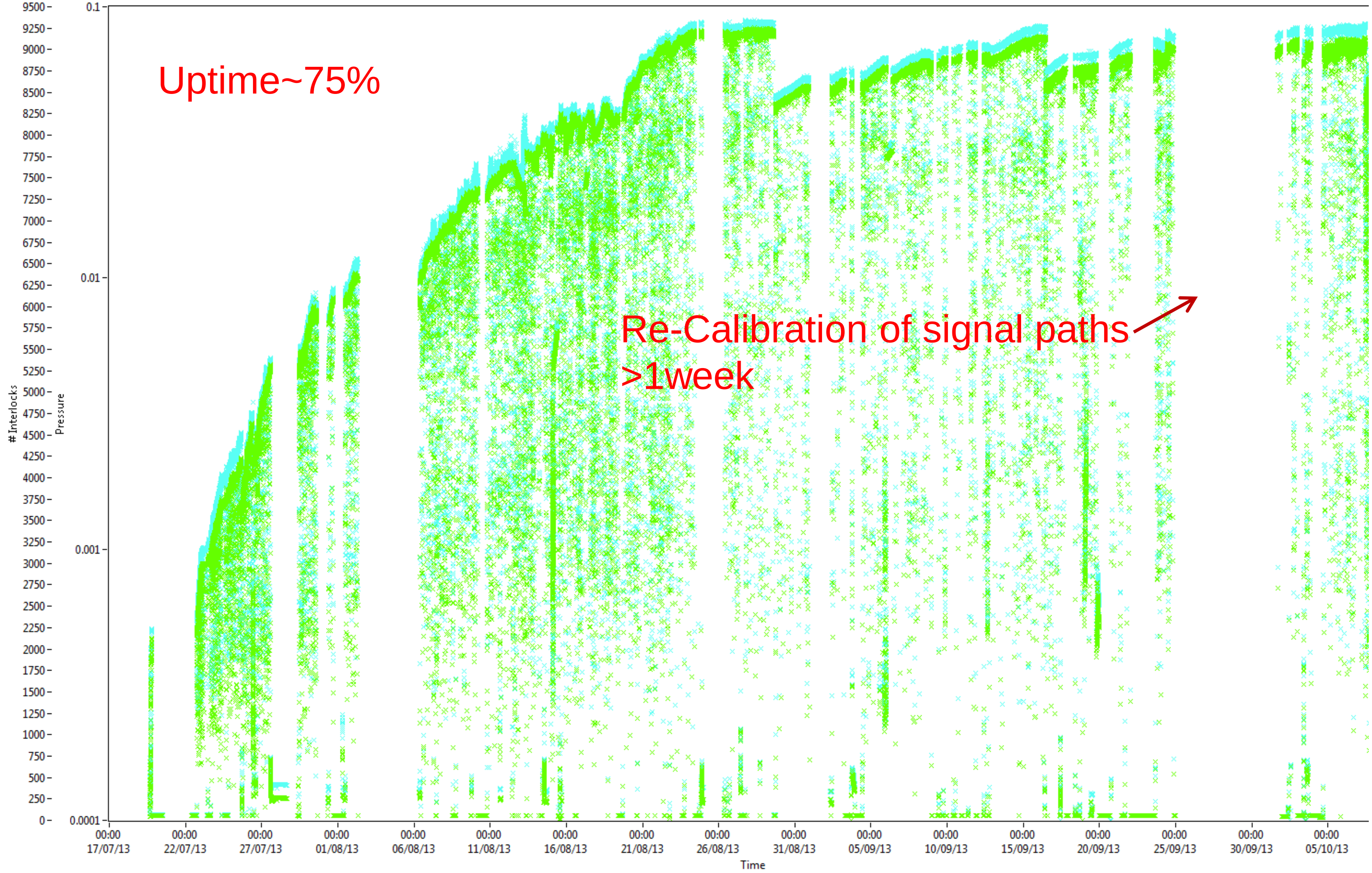
Initial Phase Measurements



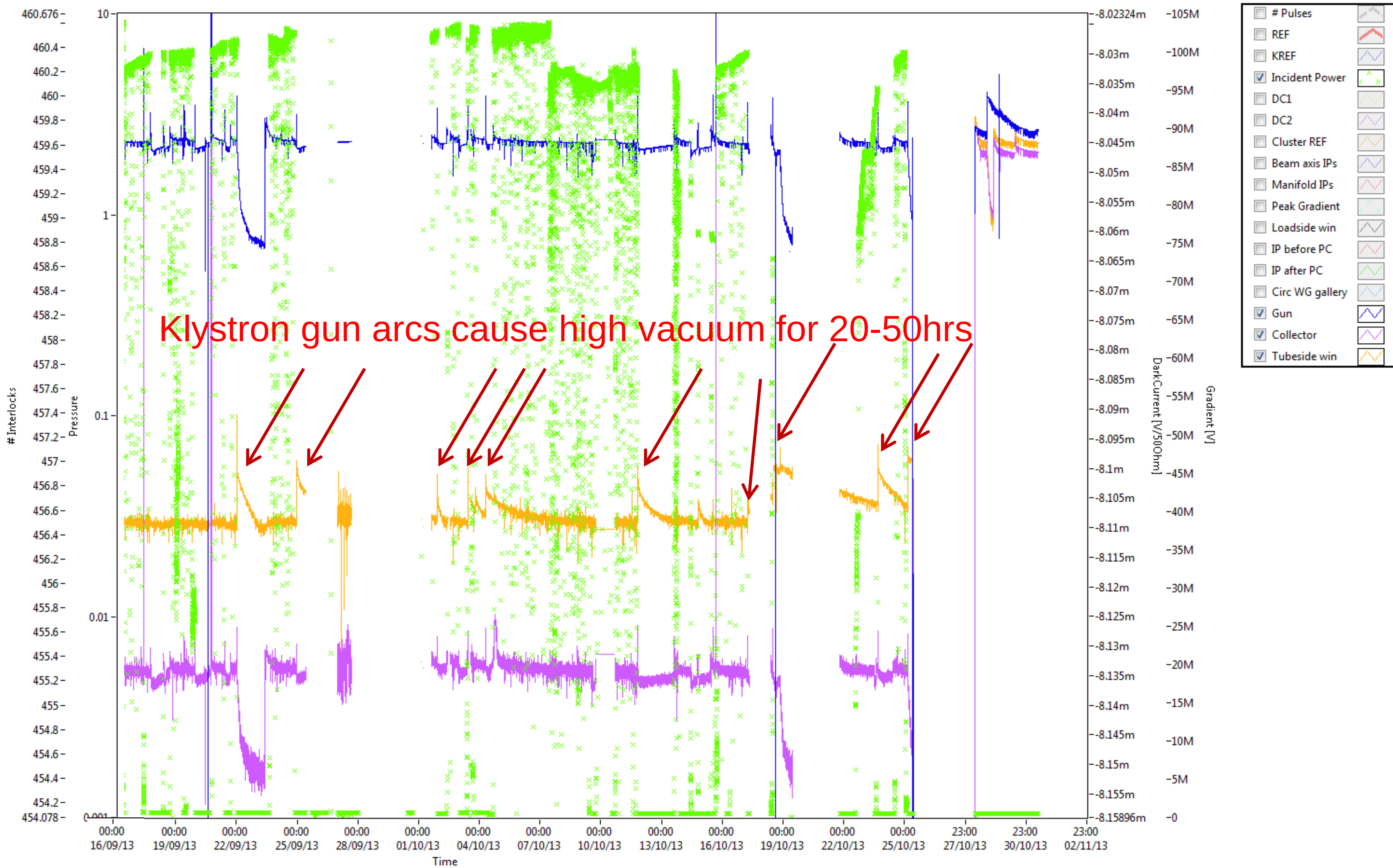


- We expect to see reflected phase grouped into 3 bins separated by 120°. Need more data to reaffirm this.
- Accurate reflected phase measurement should take into account the incident phase fluctuation.
- About 25% of BDs see a drift in position:
  - REF pulse is split in 2 parts that shows 2 different phases
  - Phase drifts about 240º from raising edge to peak REF (1st and 2nd REF pulses).
  - The drift is always negative→ BD arc is moving towards the input.

Results: TD26CC UP-TIME



Results: TD26CC UP-TIME



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Xbox-1: Future Developments

- Try to solve the issue with the klystron arcs.

- Continue to develop phase measurement analysis.
  - Increase accuracy.
  - BD cell locations.
  - BD drifts.

- Dynamic range on DC measurements to be increased along with faster sampling. (Use logarithmic amplifier or split signal in two with low and high dynamic ranges respectively.)

- Soon to have installation of dark current energy spectrometer → Should give better indication of the energies involved in accelerating electrons and ions during a BD.

- Quicker/better method of calibration to be devised (less downtime).

Thank you for your attention!

Extra Slides

Summary

- Phase signals are opening a very interesting new field of investigations
- Still some improvements in signal acquisition to be performed
- Many BDs show REF phase drifts (more or less by steps of 120^{o} and 240^{o}): BD#: 1-2-5-7-13-15-17-20-34-35
- These BDs are mainly associated to location drift from BD ignition to BD extinction
- Some stable location BDs are mainly associate with no RF drifts, BD#: 8-9-18-26
- When REF phase drifts it is always decreasing
- INC phase is also affected after a BD, this effect is to be subtracted from the measured REF phase
- New BD diagnostics would help in BD evolution understanding (optical or RF plasma probes)

Future LLRF Generation and Acquisition for X-band test stands