X-Band test stand and accelerating structure testing status

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Outline

- **The Xboxes**
- **Xbox-1\Dogleg experiment**
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    - Breakdown analysis
    - Run with the CLIC pulse shape
    - Beam loading experiment
- **Xbox-2**
  - T24_open
    - Full history
    - Breakdown analysis
    - Radiation issues
- **Conditioning stage of the RF structures under test**
- **Xbox-3**
  - Status and plans
- **Conclusions**

The Xboxes

CPI 50MW 1.5us klystron
Scandinova Modulator
Rep Rate 50Hz

Current test:
Dogleg beam-loading experiment, **TD26CC#1** (in CTF3 LINAC)

Previous tests:
TD24R05 (CTF2, 2013)
TD26CC#1 (CTF2, 2013)
T24 (Dogleg, 2014-15)

CPI 50MW 1.5us klystron
Scandinova Modulator
Rep Rate 50Hz

Current test:
T24_OPEN (in halves)

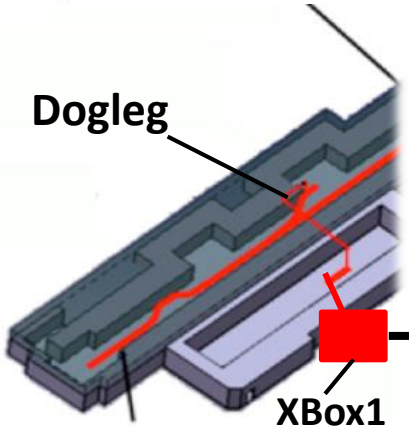
Previous test:
CLIC Crab cavity (2014-15)

4x Toshiba 6MW 5us klystron
4x Scandinova Modulators
Rep Rate 400Hz

LLRF, pulse compressors and waveguide network to be completed at the beginning of 2016

Medium power test:
3D printed Ti waveguide X-band RF valve (Xbox-3A)

Dogleg Experiment



12 GHz RF:
- ✓ 90 MW RF power
- ✓ Up to 50 Hz rep. rate

XBOX1
12 GHz RF

35 m low loss waveguide

Beam:
- ✓ CTF3 Drive Beam modified
- ✓ 3GHz beam at ~1.2 A
- ✓ Pulse length up to 250 ns
- ✓ Energy ~125 MeV at structure
- ✓ Up to 25 Hz pulse rep. rate

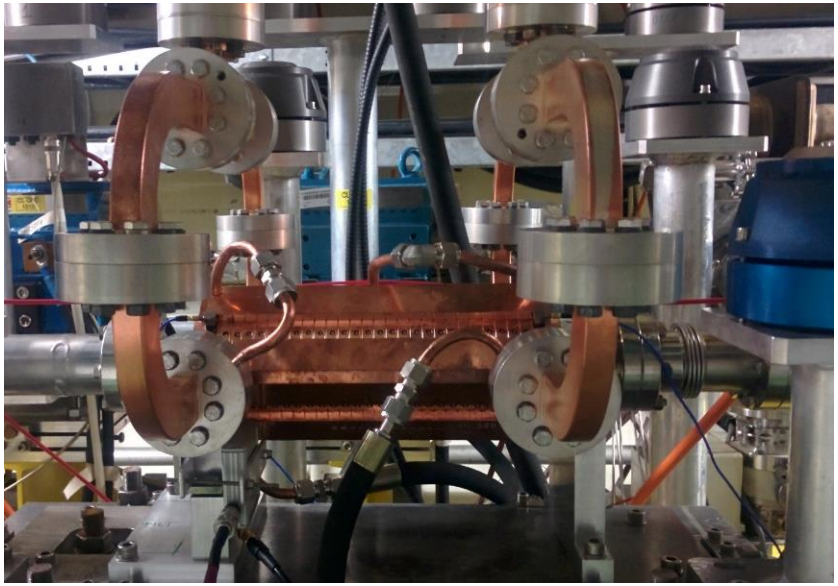
MKS02
3 GHz RF

High Gradient Accelerating Structure

Gun

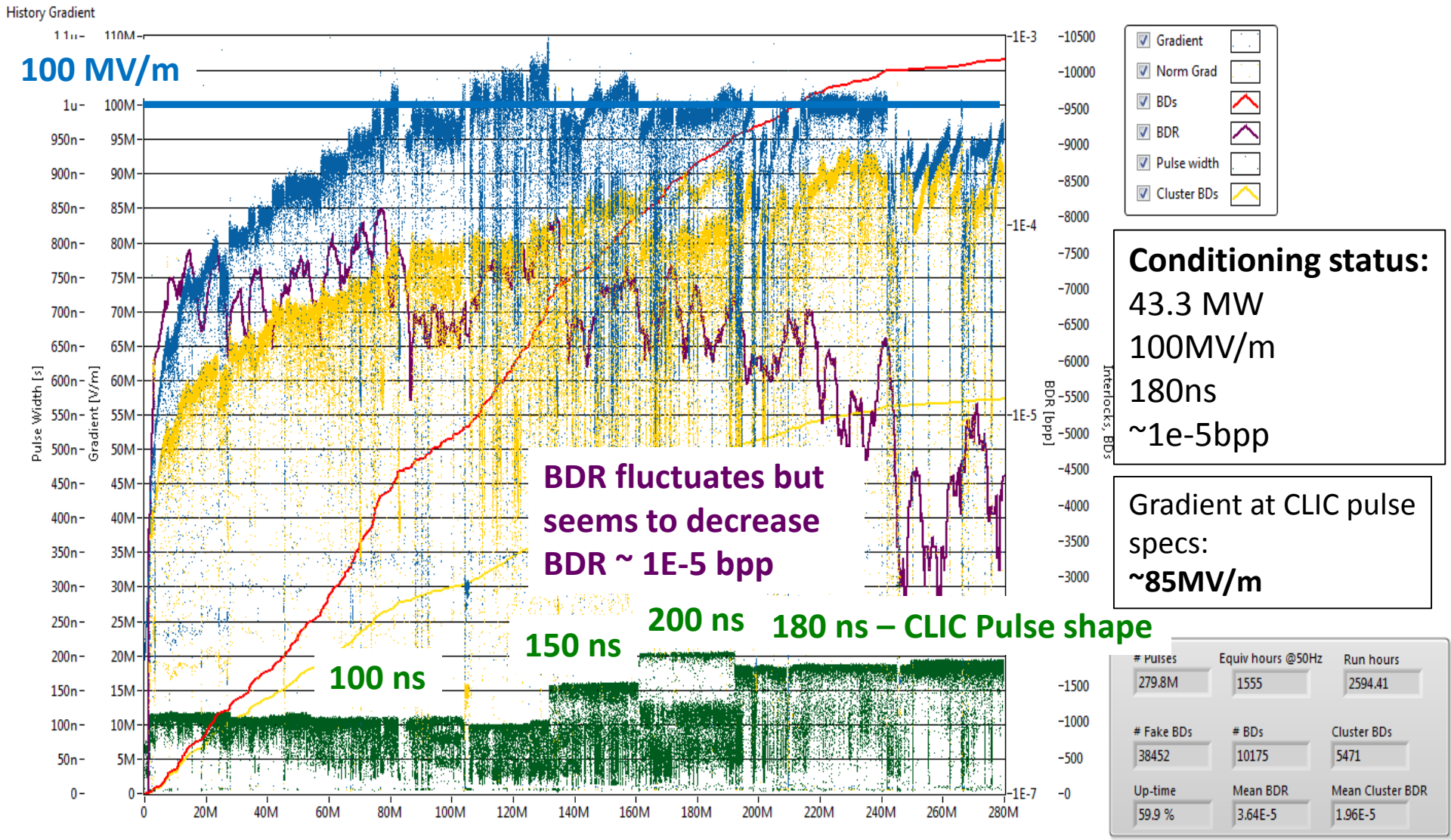
MKS03 **MKS05** **MKS06** **MKS07**

Xbox-1/Dogleg: TD26CC_N1



- TD26CC_N1, tested at Xbox-1 in 2013, was accidentally vented during an unknown period of time.
- The structure was re-baken out at 650 °C and installed in the CTF3 Linac for the **Dogleg experiment**
- Need of reconditioning

Xbox-1/Dogleg: TD26CC_N1 - full history



Conditioning status:
43.3 MW
100MV/m
180ns
~1e-5bpp

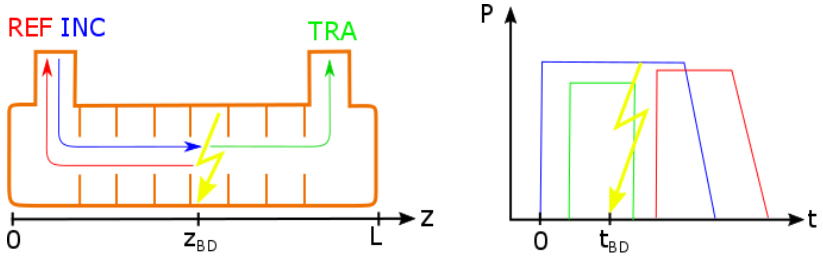
Gradient at CLIC pulse specs:
~85MV/m

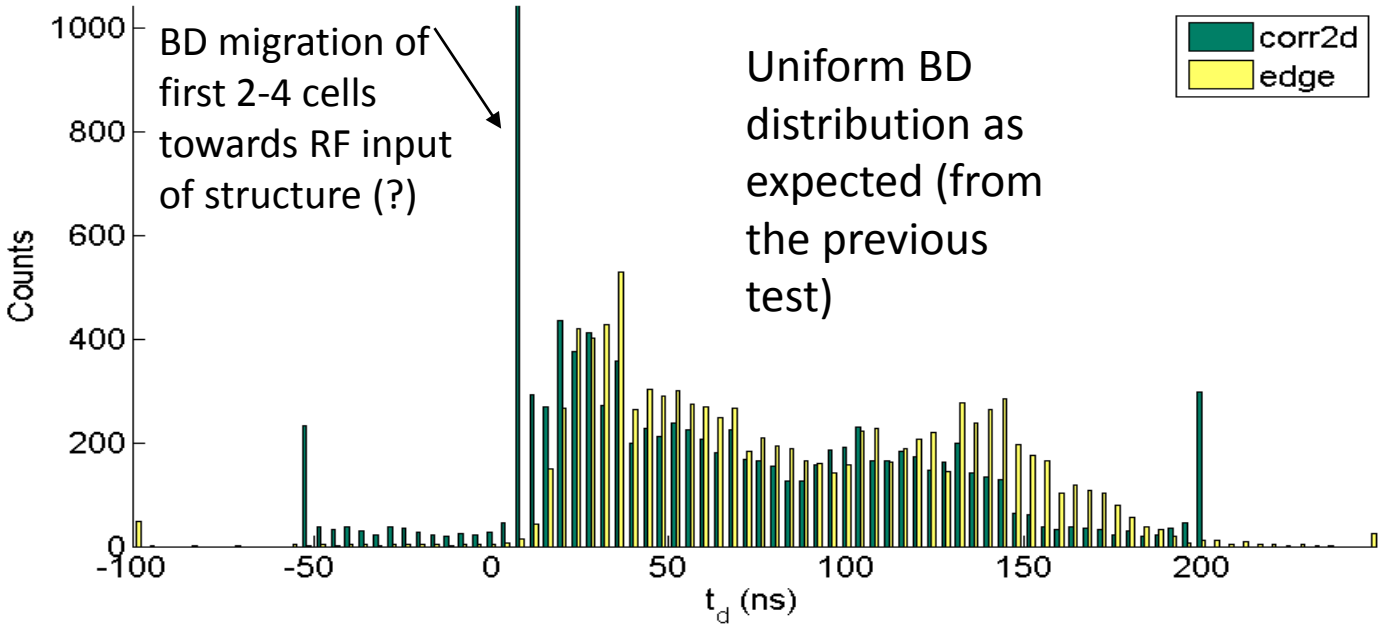
# Pulses	Equiv hours @50Hz	Run hours
279.8M	1555	2594.41
# Fake BDs	# BDs	Cluster BDs
38452	10175	5471
Up-time	Mean BDR	Mean Cluster BDR
59.9 %	3.64E-5	1.96E-5

Xbox-1/Dogleg: TD26CC_N1 - BD analysis

- Strong effort in breakdown localization techniques and diagnostics

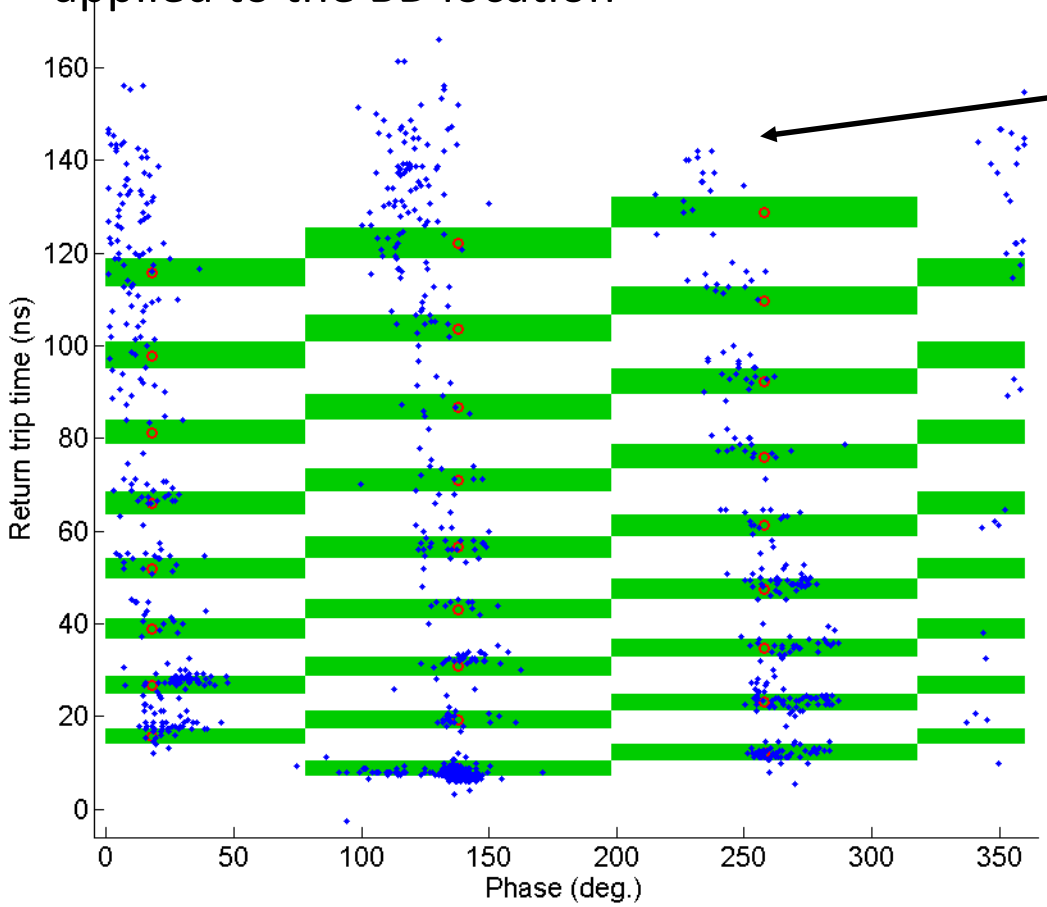
- The two methods used show similar results
  - **Edge:** Falling edge of TRA and rising edge of REF
  - **Correlation:** Correlation in tails of INC and REF





Xbox-1/Dogleg: TD26CC_N1 - BD analysis

- Phase of the signals is also used to locate the BD
- 3 phase groups are clearly visible separated by around 120° → corrections applied to the BD location



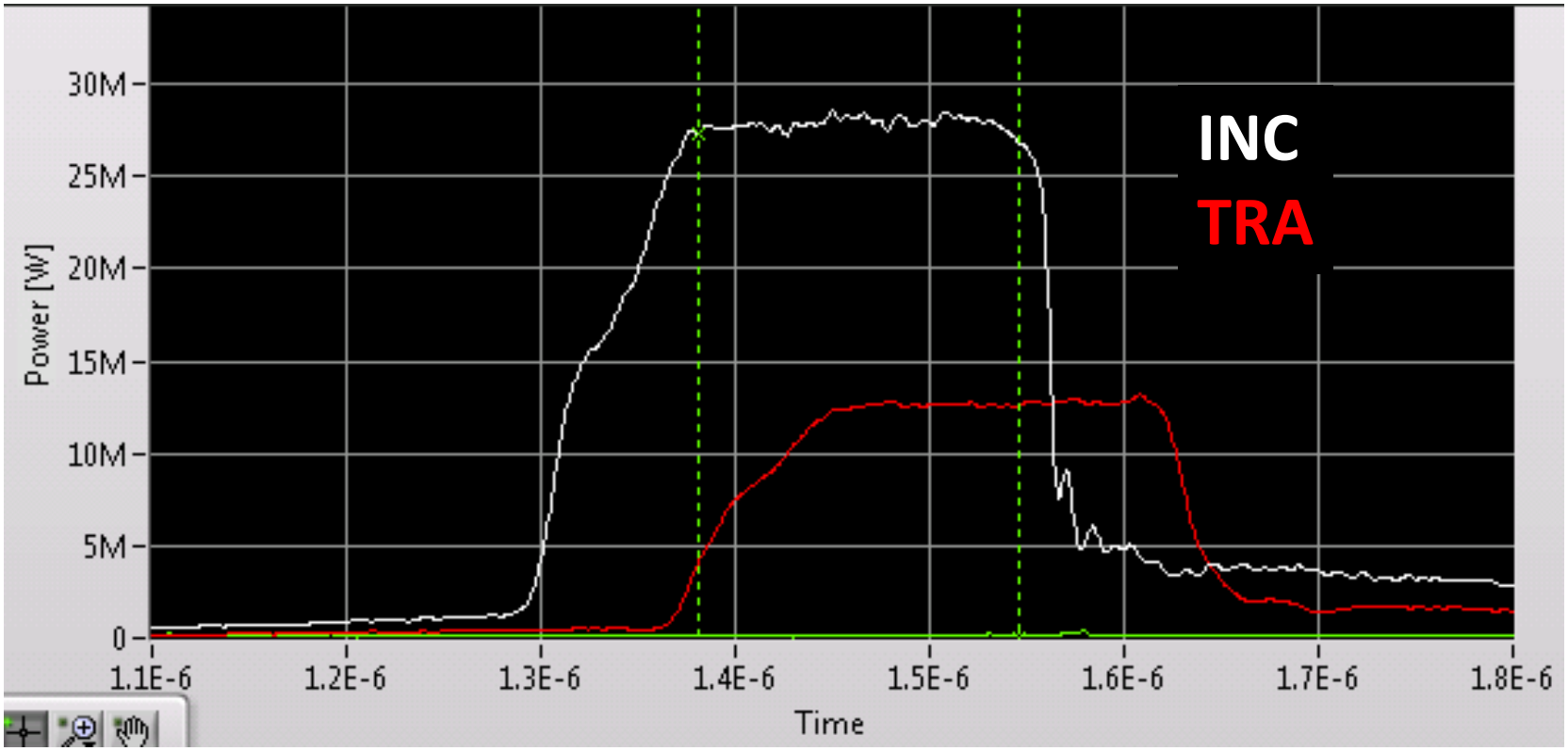
Slope can be due to phase drift cause by cell detuning

Filtering criteria:
- Stable phase
- Small correlation fit error

Good performance (no evidence of hot cells)

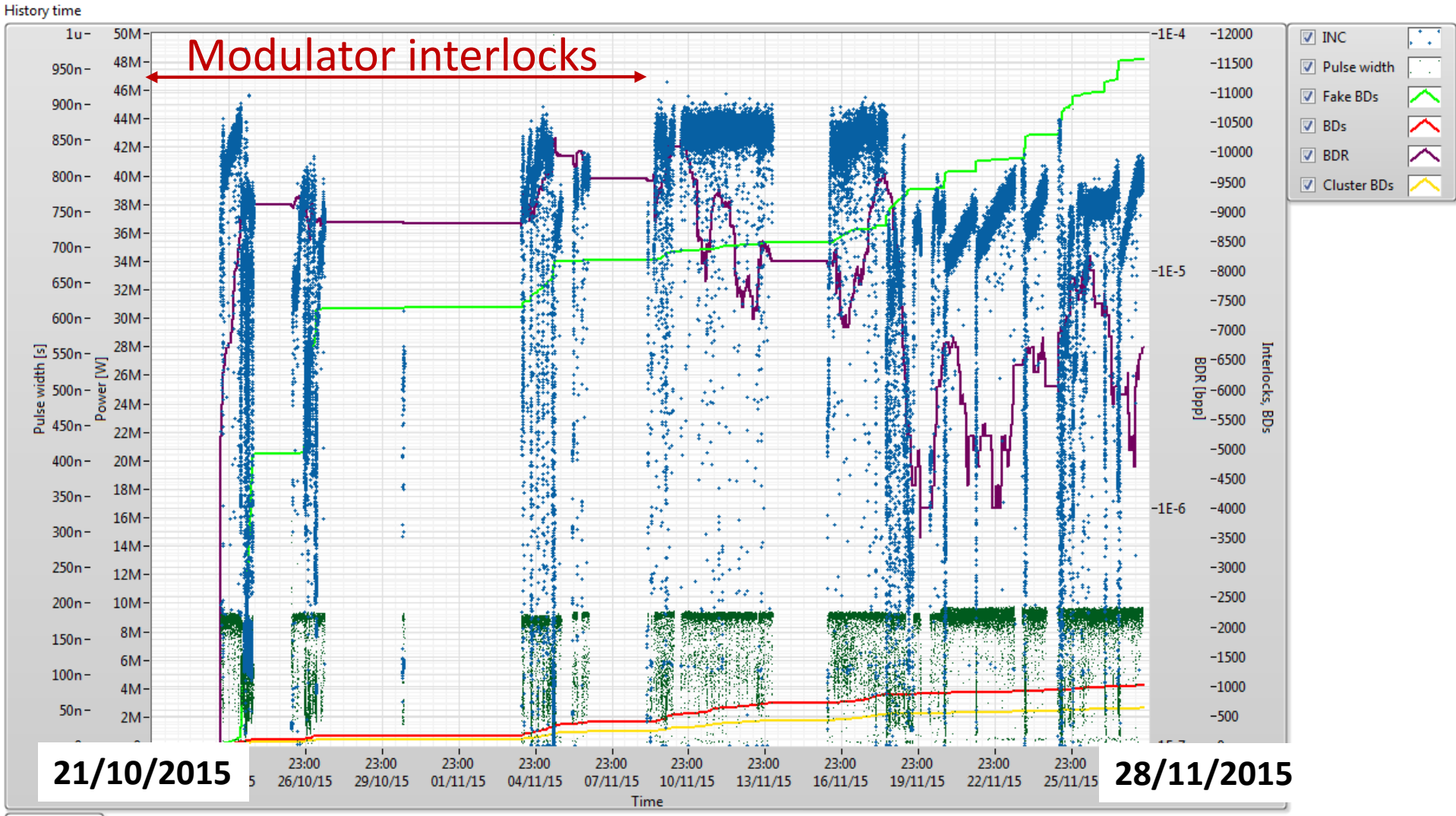
Run with CLIC pulse shape

- CLIC Pulse shape since mid of October to prepare for the beam arrival



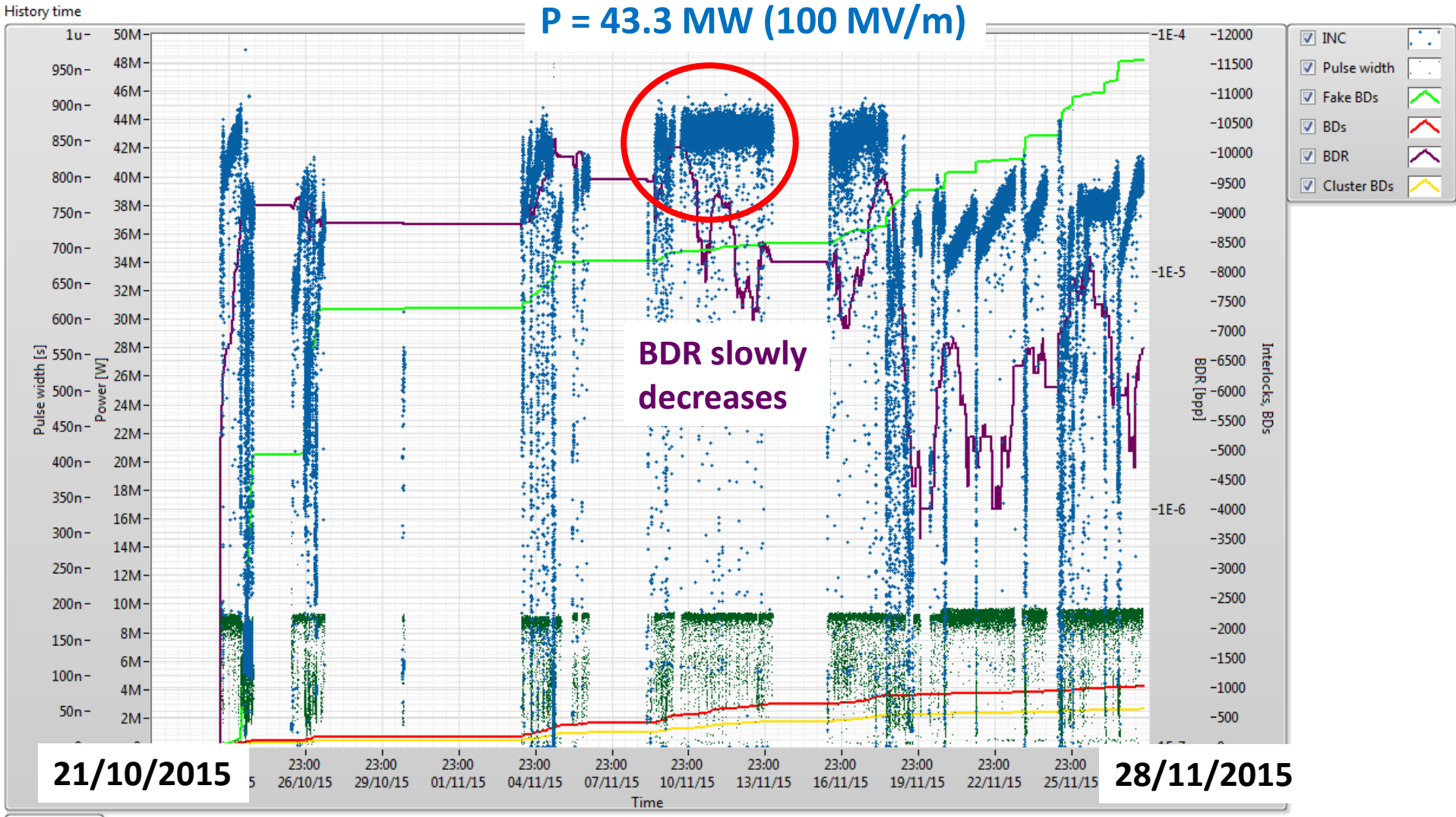
Run with CLIC pulse shape

- Problems with many modulator interlocks → solved



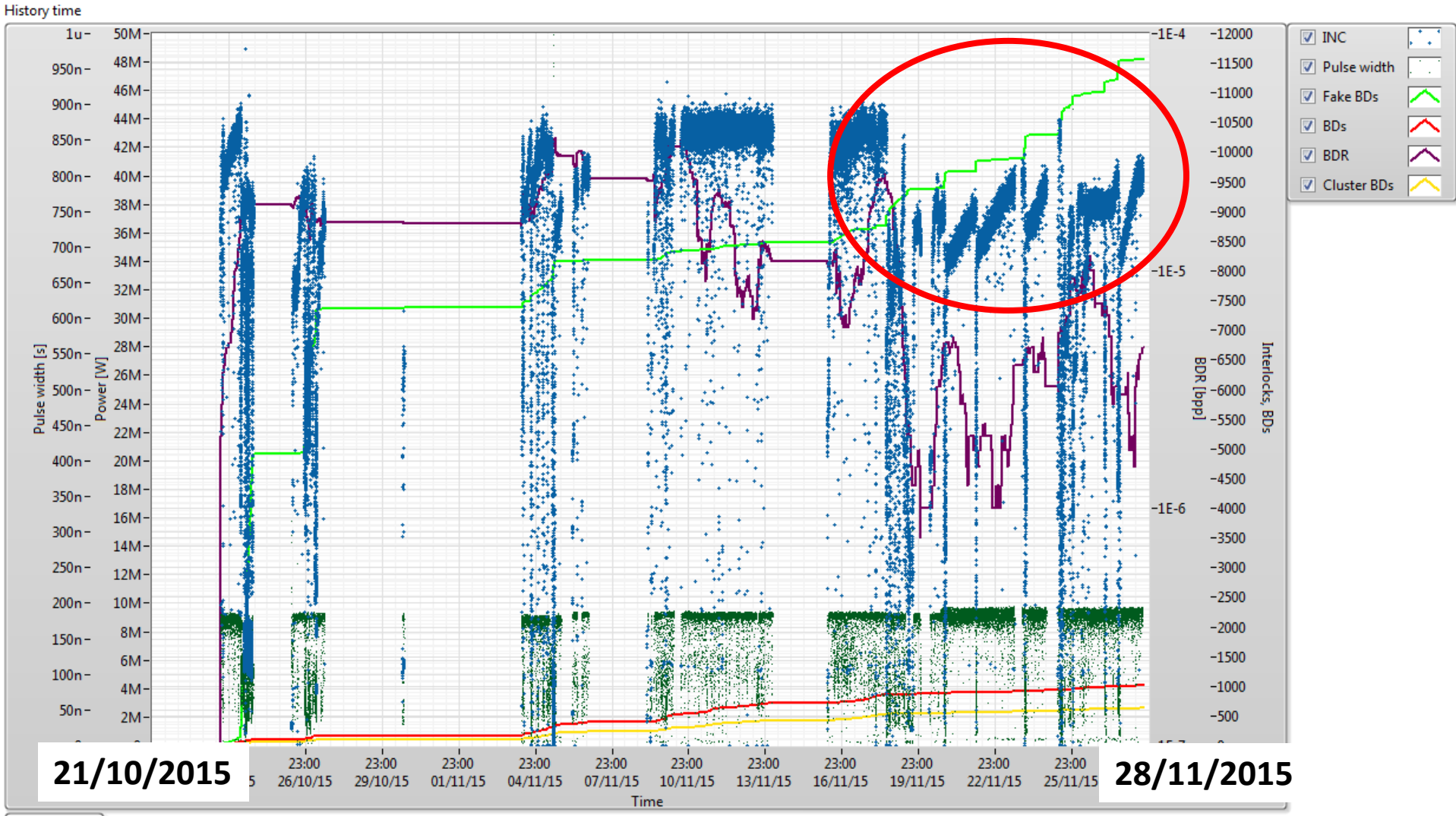
Run with CLIC pulse shape

- Smooth Run after at 43.3 MW averaged incident power (100 MV/m)



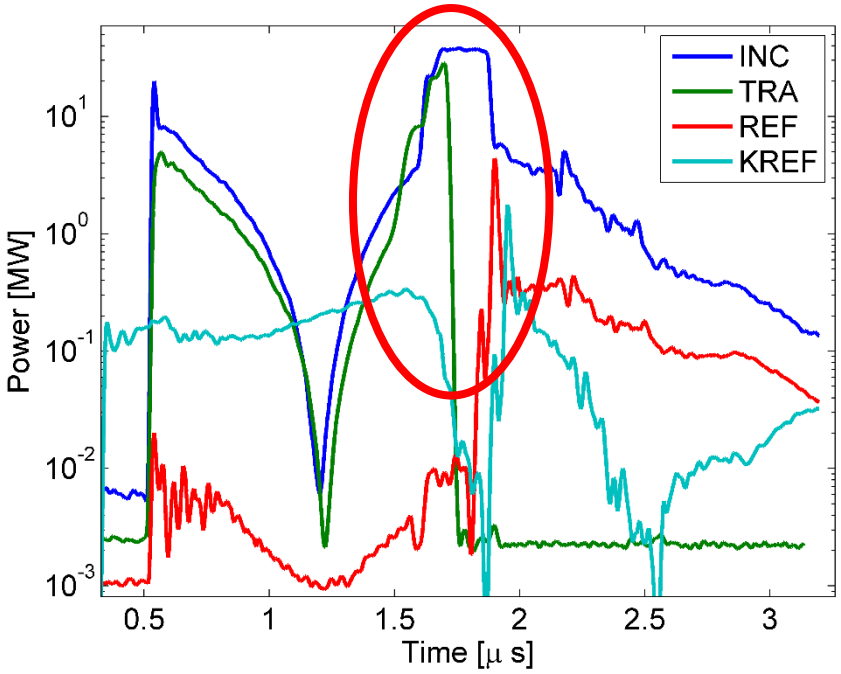
Run with CLIC pulse shape

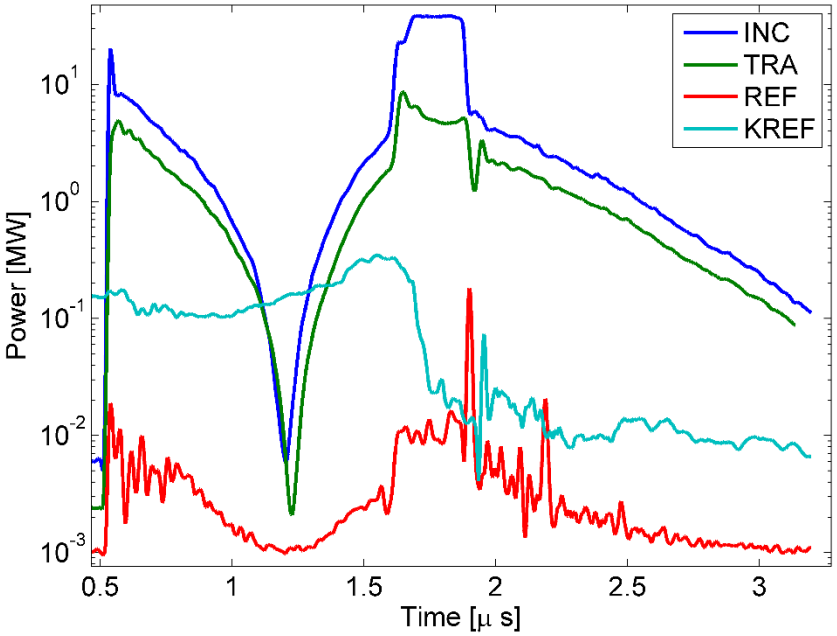
- Problems with breakdowns in the area around the Pulse compressor → **Conditioned with less power, around 39 MW**



Beam loading experiment

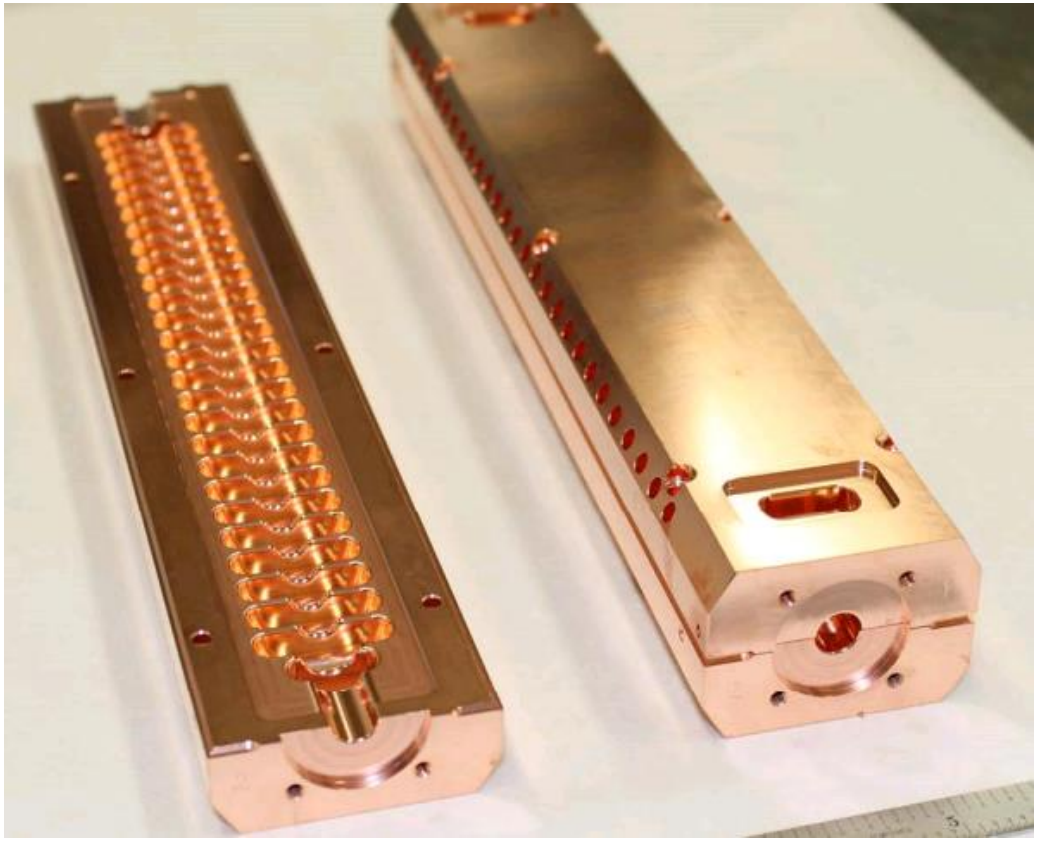
- Beam set-up by Frank at 26/27 November 2015
- Change the phase and delay of the klystron to match the beam (initially beam was decelerated)





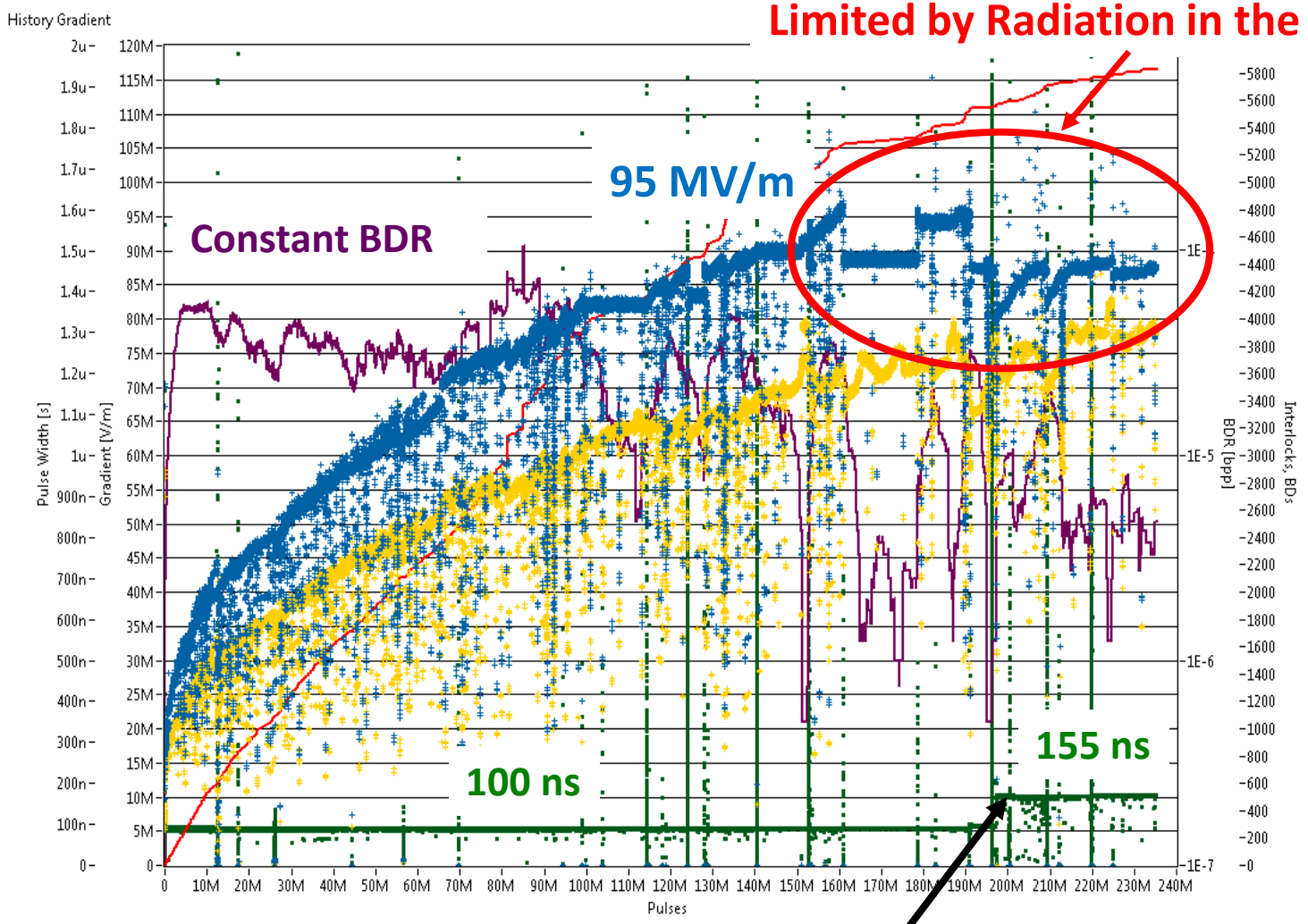
- Time only to set-up the interlocks: threshold of the Transmitted energy increased (still lot of margin compared to unloaded BDs)
- Run on this weekend is scheduled

Xbox2: T24_open



X-band structure in halves designed by CERN and built by SLAC (A. Grudiev, H. Zha, V. Dolgashev)

Xbox2: T24_open – full history



Changed pulse length to 155ns

Conditioning status:
34 MW
87 MV/m
155 ns
4e-6 bpp

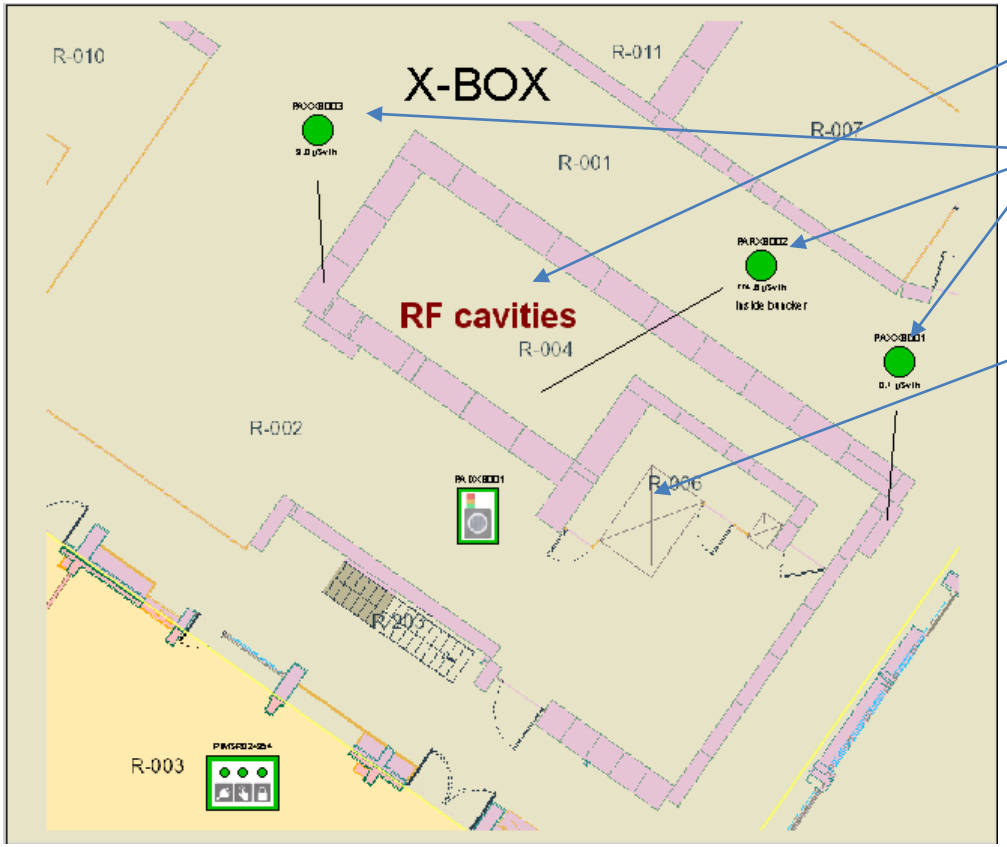
Gradient at CLIC pulse specs:
~74 MV/m

# Pulses	Equiv hours @50Hz	Run hours
235.1M	1306	2007.31

# Interlocks	# BDs	Cluster BDs
5889	5828	3577

Uptime (%)	Mean BDR	Mean Cluster BDR
65	2.48E-5	1.52E-5

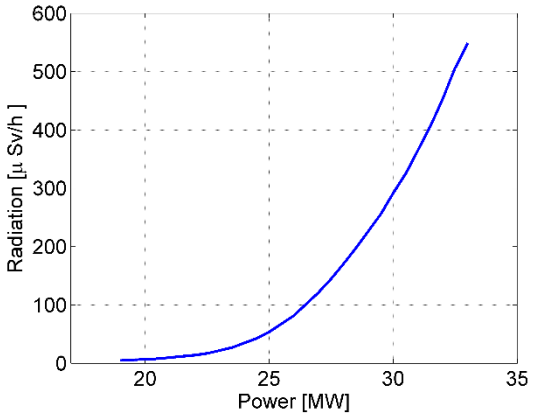
Xbox2: T24_open – Radiation issues



Bunker\RF structure

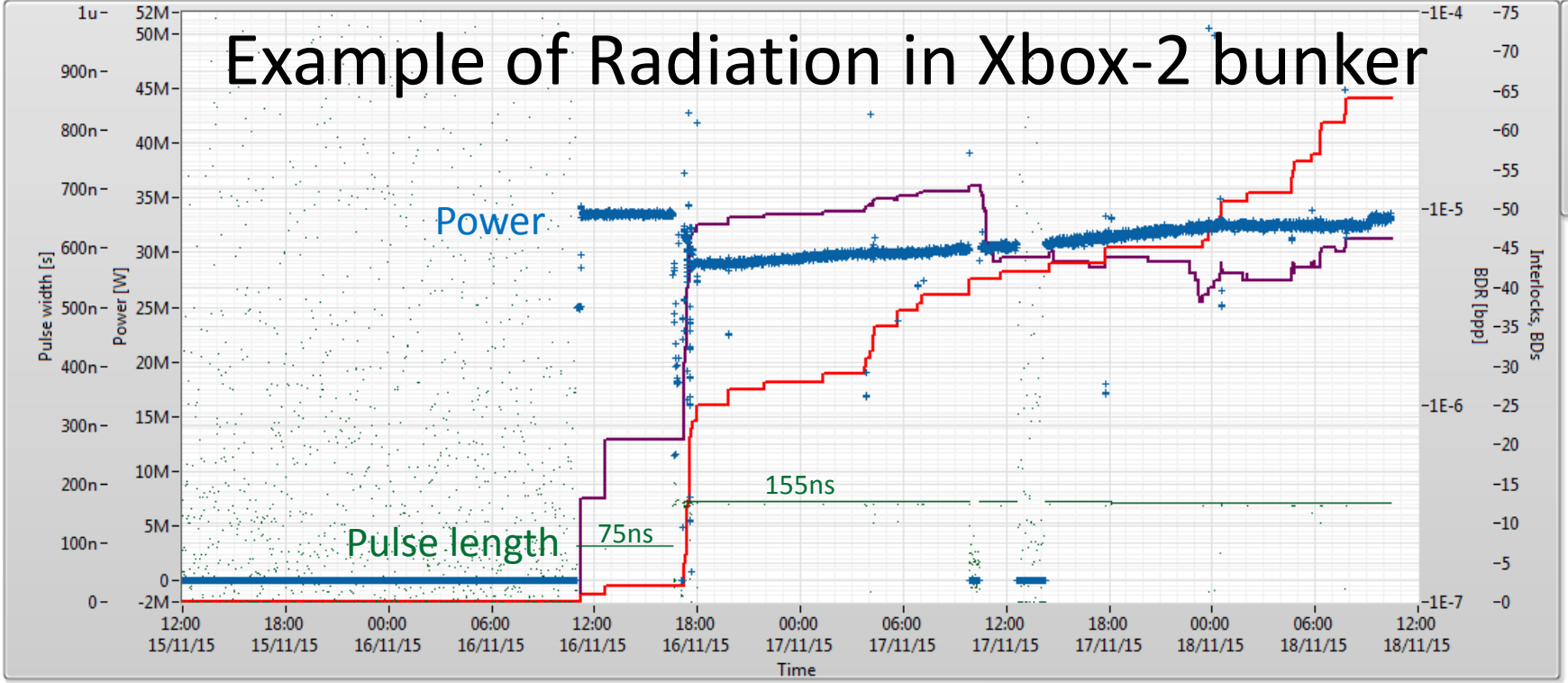
Radiation detectors

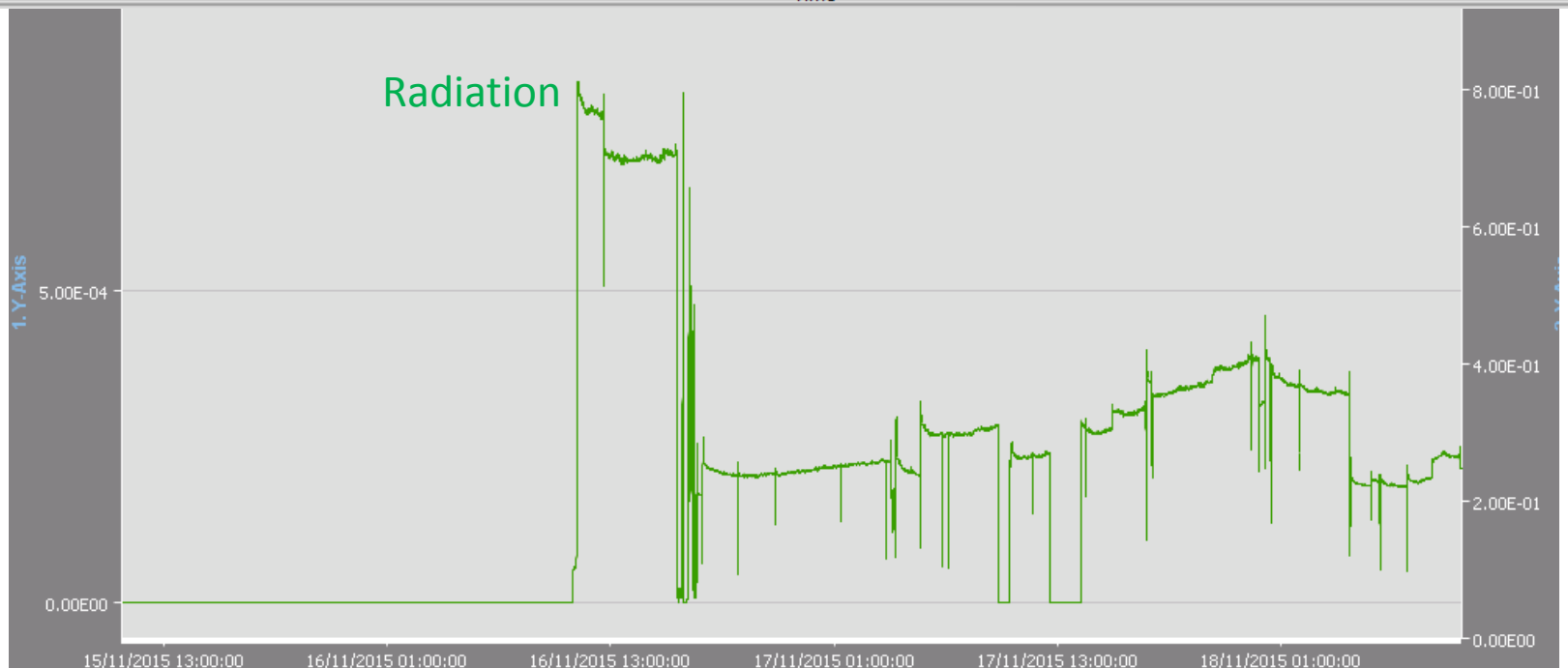
Klystron\Modulator\PC



- Unpredictable behaviour of the radiation with BDs → limits power level
- Survey by the Radioprotection group to identify possible sources of radiation → Faraday Cup, Collimator
- **Short term solution:** shielding them locally with led
- **Long term solution:** enhance the roof of the bunker (20 cm more concrete)

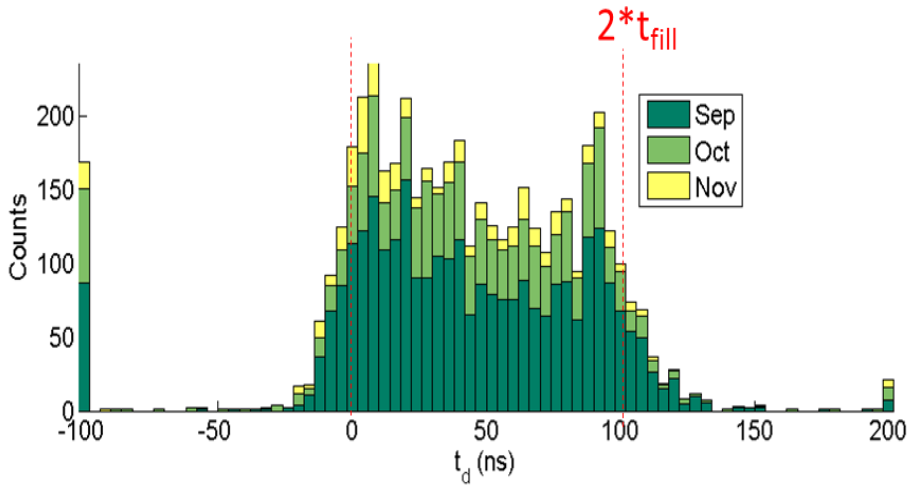
Example of Radiation in Xbox-2 bunker

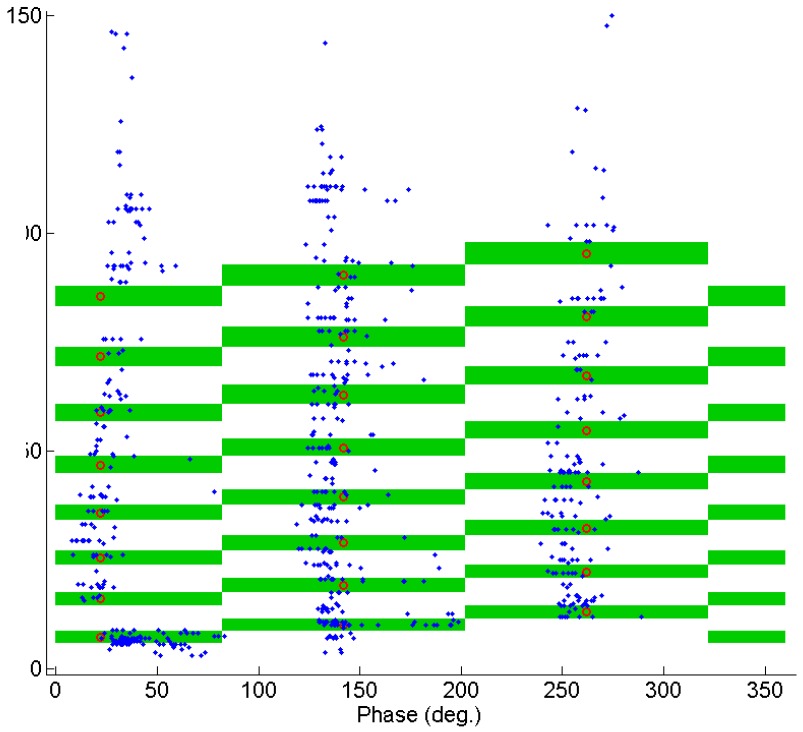




Xbox-2: T24_open - BD analysis

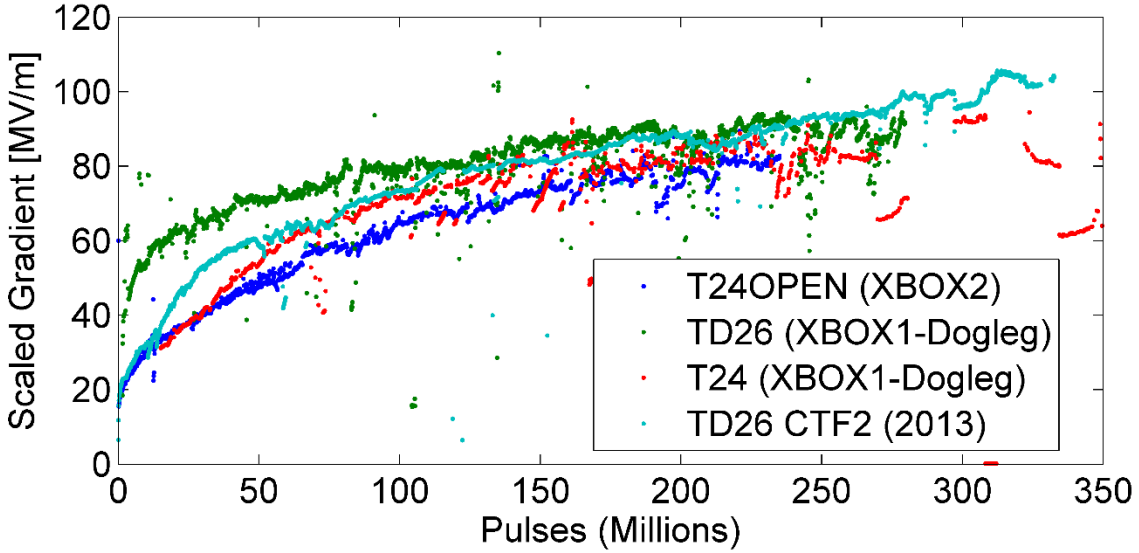
- Same BD analysis applied using the amplitude and the phase of the recorded signals

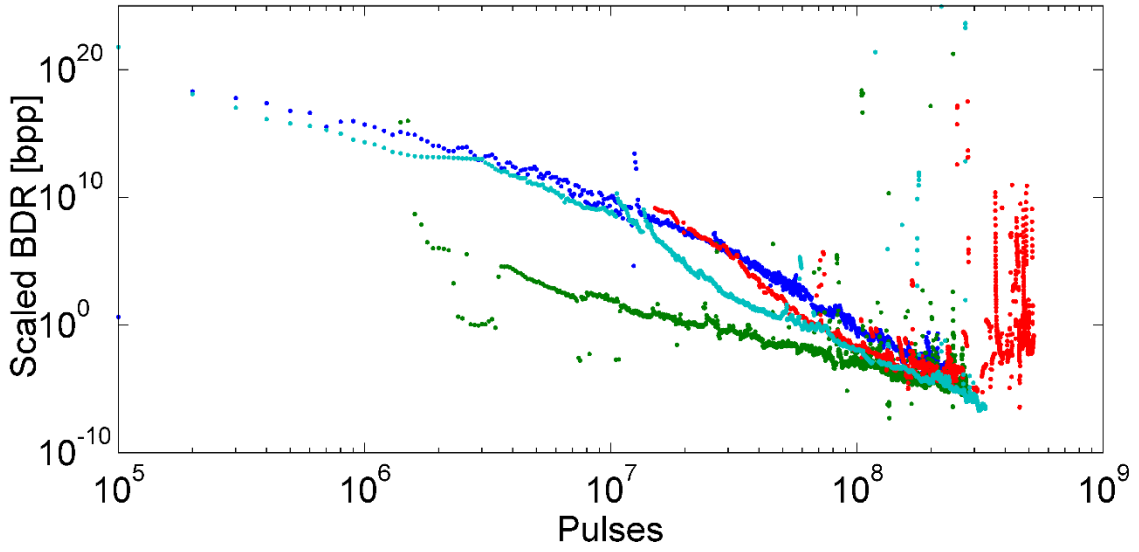




Good performance (no evidence of hot cells)

RF structures conditioning





Gradient scaled at 200 ns and 1e-6 bpp

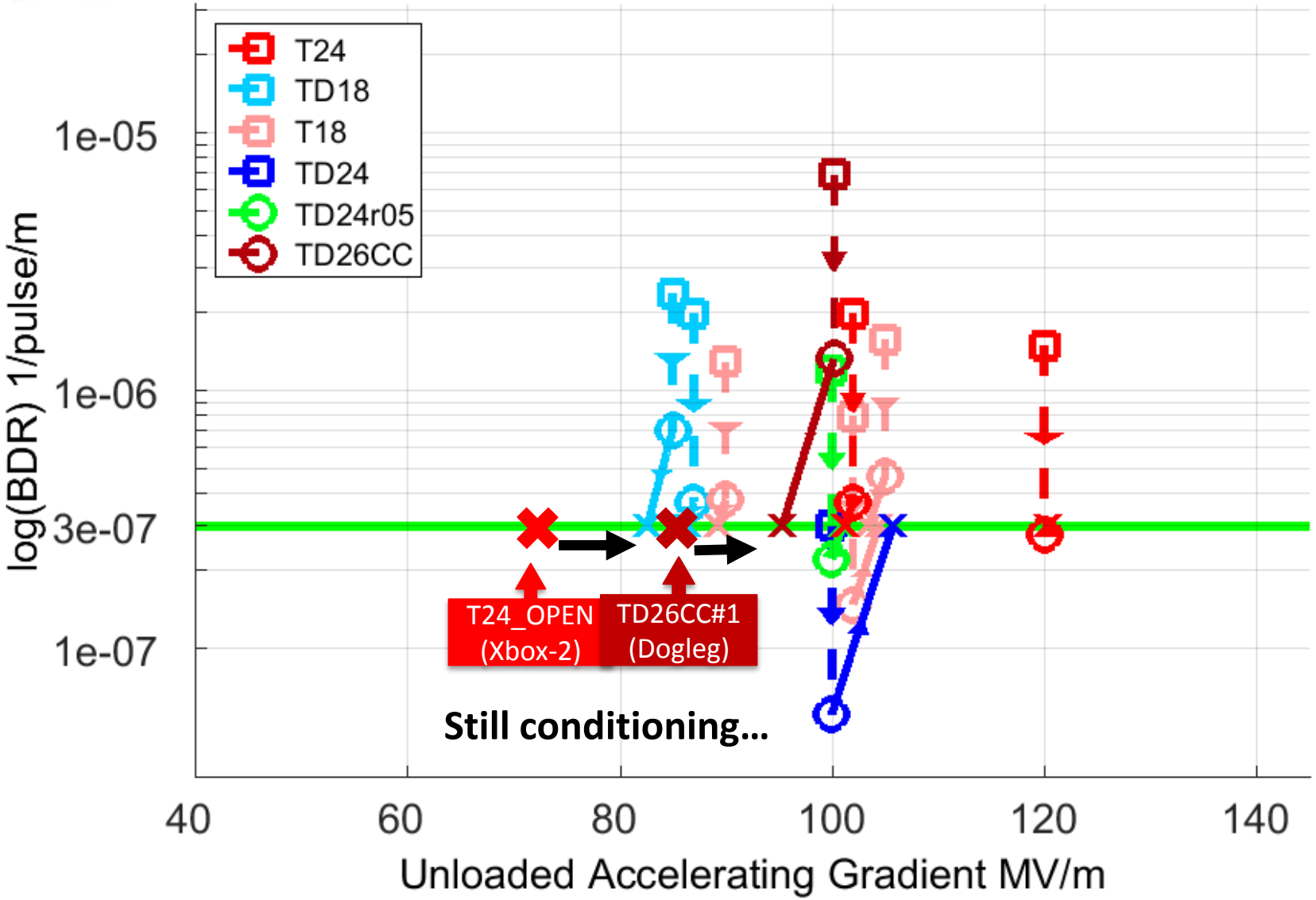
BDR scaled at 200 ns and 100 MV/m

Good conditioning of the accelerated structures

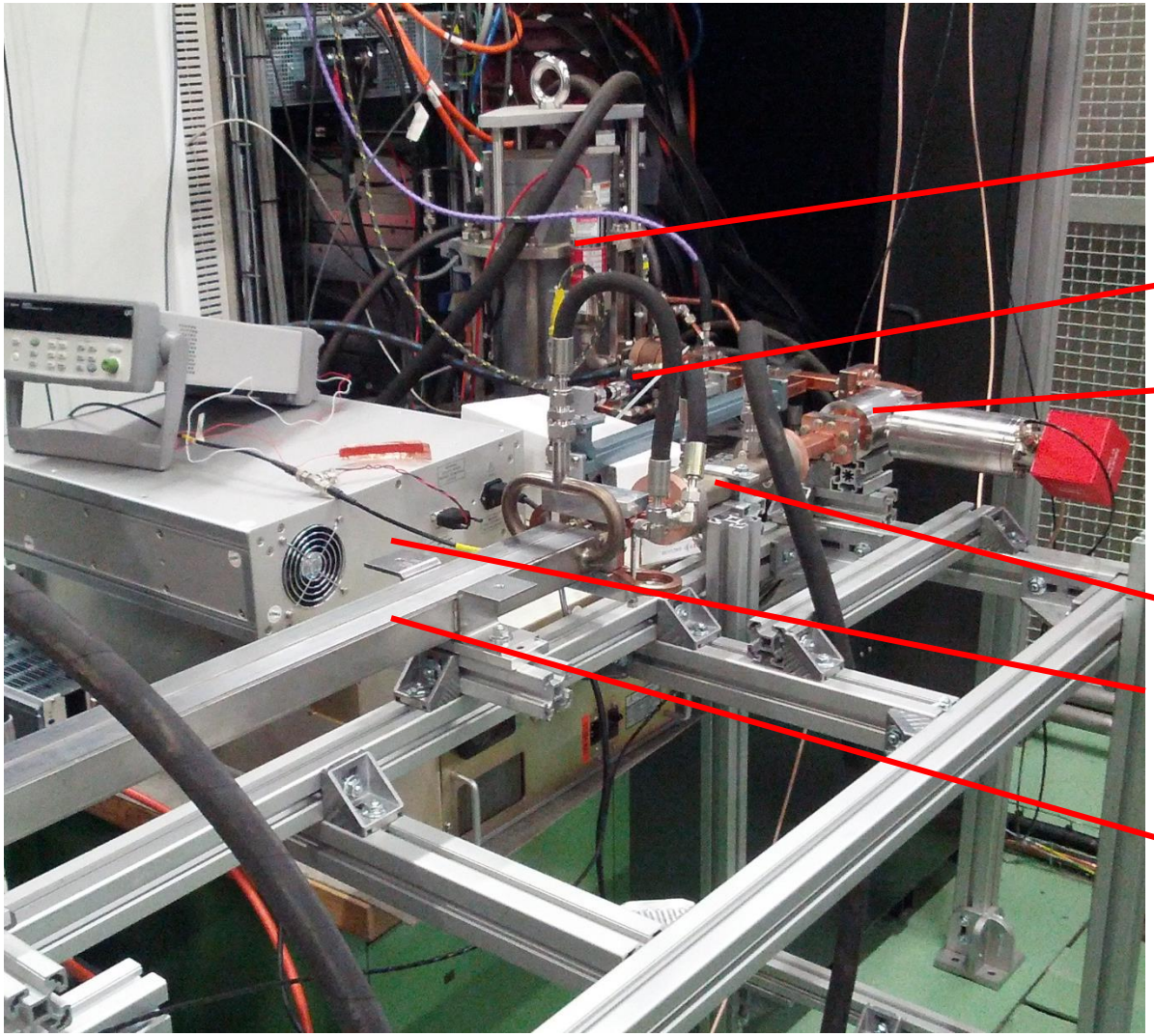
Similar like previous structures

TD26 almost recovered to the old condition stage

Summary of tested structures



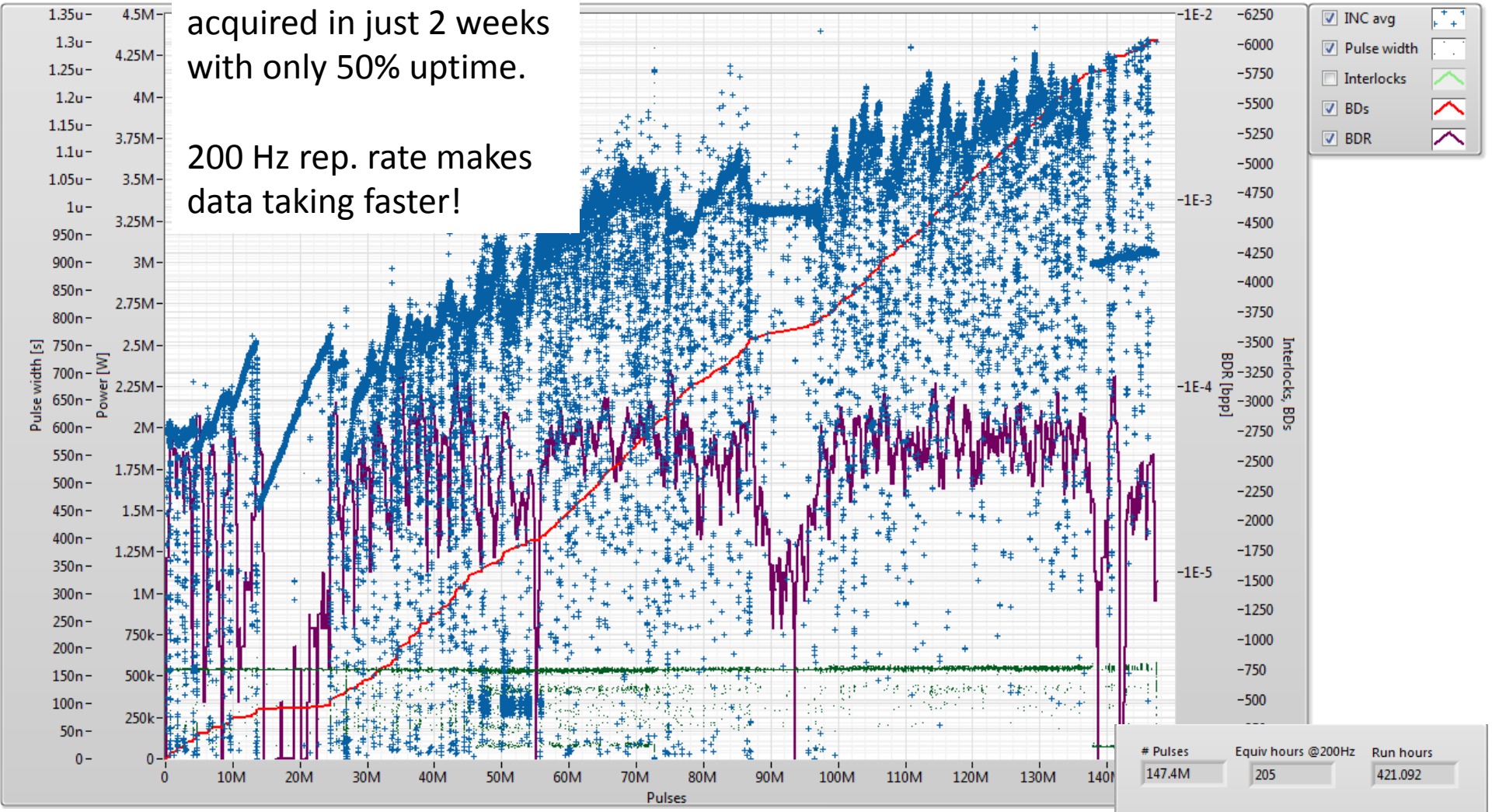
Xbox-3A


6.5-7MW Klystron
Directional Coupler
Vacuum Port
3D Printed Waveguide
Solid state 320W amplifier
RF Stainless Steel Load

3D Printed waveguide results

~150 Million Pulses acquired in just 2 weeks with only 50% uptime.

200 Hz rep. rate makes data taking faster!



Xbox-3 Status and plans

Klystron/Modulators

- All 4 klystron/modulator units from Toshiba/Scandinova have been installed and tested in diode mode
- Klystron A has been tested with RF up to 7.25MW output power ~2us pulse width
- New water pump delivered to be installed in the next few weeks to increase cooling capacity such that Xbox 2 and 3 can run simultaneously
- 4, 400W solid state pre-amps ordered to arrive by end of January. (We have already tested one prototype at CERN, performance is good.)

Waveguides + High power RF components

- All high power waveguide components are due to arrive early January
- New RF valve design tested performance is much improved
- Pulse compressors will be later.. (Delay of 1-2 months due to leaking waveguide components)
- Support beams are in place for the waveguide system

LLRF and Controls

- PXI crates are purchased and at CERN. Control software is being developed (from X-box 2 code) to increase rep. rate to 400Hz and to switch between 2 channels @ 400 Hz
- LLRF mixing crates are under fabrication with 90% of components already at CERN
- All crates should be finished by end of January.

Commissioning to start in February

Conclusions

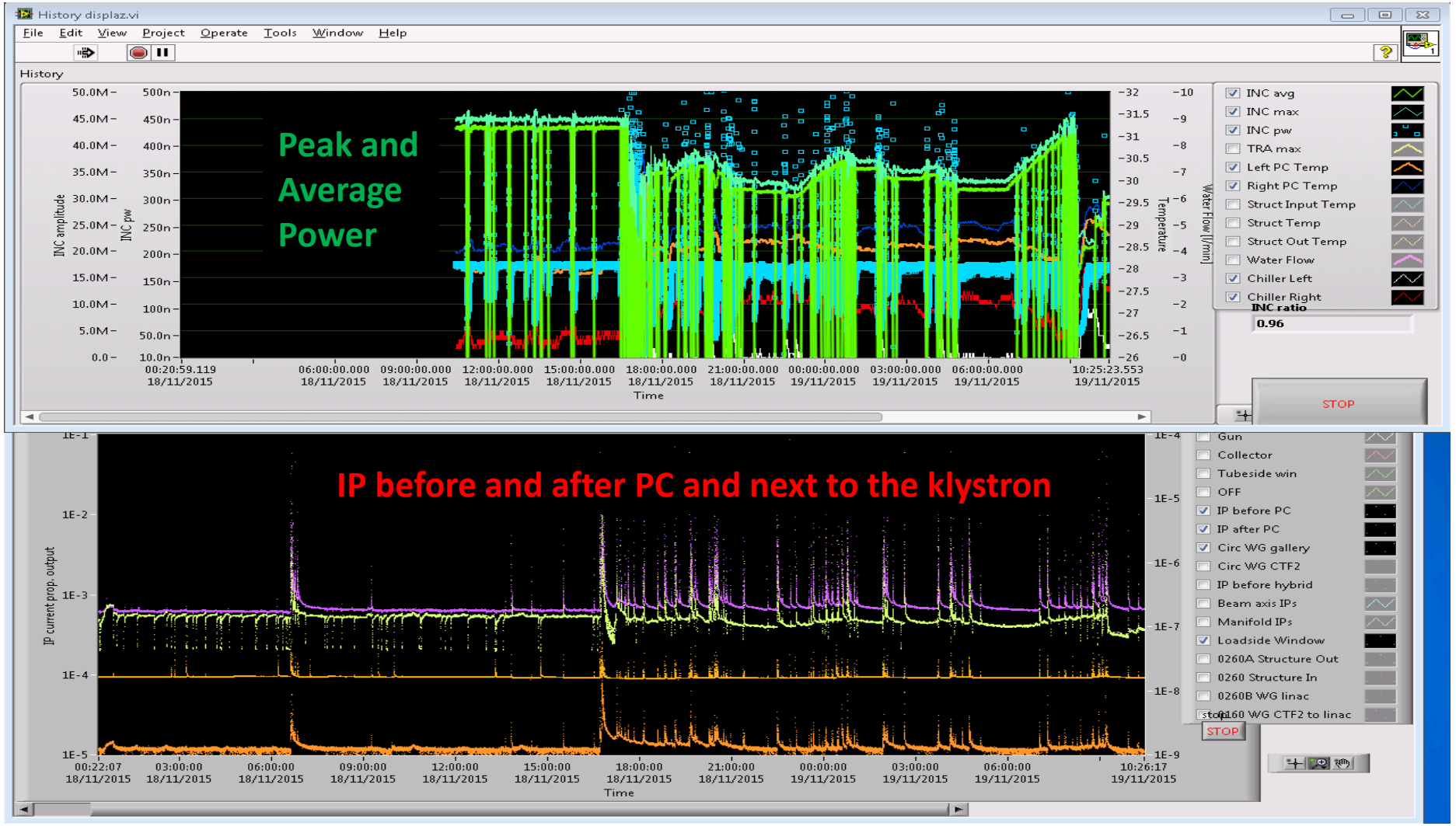
- Xbox 1 and 2 are running at full capabilities to perform the required high-power tests for the CLIC prototypes
- Xbox 3 all components will be here by the end of January → commissioning to start in February
- Dogleg experiment with Xbox-1 and CTF3 beam will study the beam loading effect on the breakdown rate
- Data analysis is ongoing for a better understanding of the BD phenomena in real cavities
- Two test stands running with different structures → possibility of testing different operating strategies

Thank you for you attention

Extra Slides

Run with CLIC pulse shape

- **Problems with breakdowns in the area around the Pulse Compressor**



Run with CLIC pulse shape

- **Some issues with the TWT amplifier (50 Hz not optimum ?) → induce a BD or interlock. Quite frequent lately → important to be solved**