XBOX status and measurements

Matteo Volpi
on behalf of XBox team

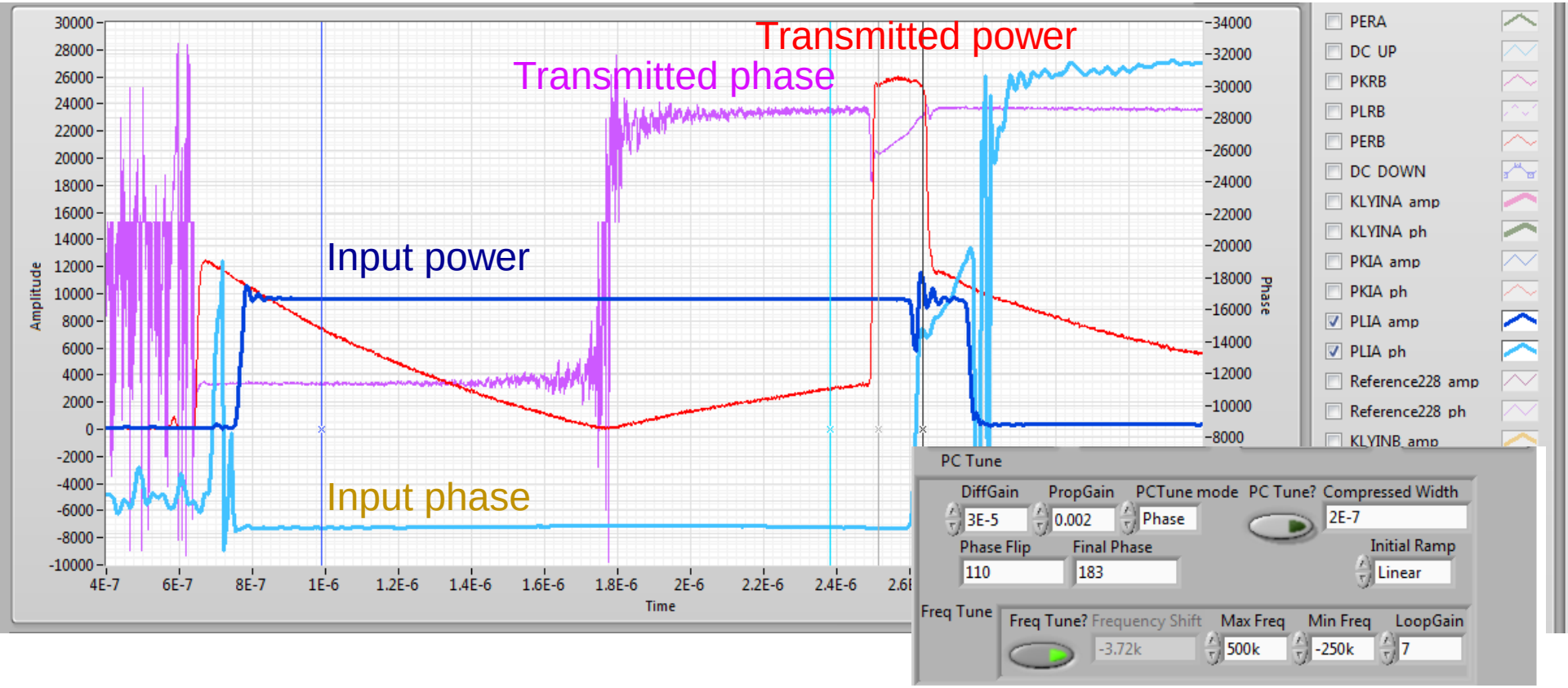
CLIC Project Meeting
03-10-2017

Outline

- Lots of activity since the last report
  - Control room
  - We installed two spare klystron => conditioning of line 1 and 2
  - Add 500kg of lead => **resolve radiation interlocks**
  - **We collect about 4 billions of pulses** (run up to **200Hz** rep. rate stable)
  - All the systems are operated 24h => uptime > 85%
  - Test stands are full operational and testing CLIC prototype structures
  - Developing new tools => **frequency tune**
- X-band and S-band testing facilities
  - Xbox1 - 1 test stand – **Pulsing soon**
  - Xbox2 - 1 test stand - **OPERATIONAL**
  - Xbox3 - 4 test stands - **4 OPERATIONAL**
  - Sbox - 1 test stand – **OPERATIONAL**
- Summary and future plan

Frequency tune for high rep. rate

- We introduce a frequency shift algorithm to tune the pulse compressors after an RF interruption (BDs for example)
  - Algorithm based on the phase slope
- Consequence: at high repetition rate **we keep the PCs well tuned**
  - Need high power chillers to stabilize the PCs temperature (**arrived**)

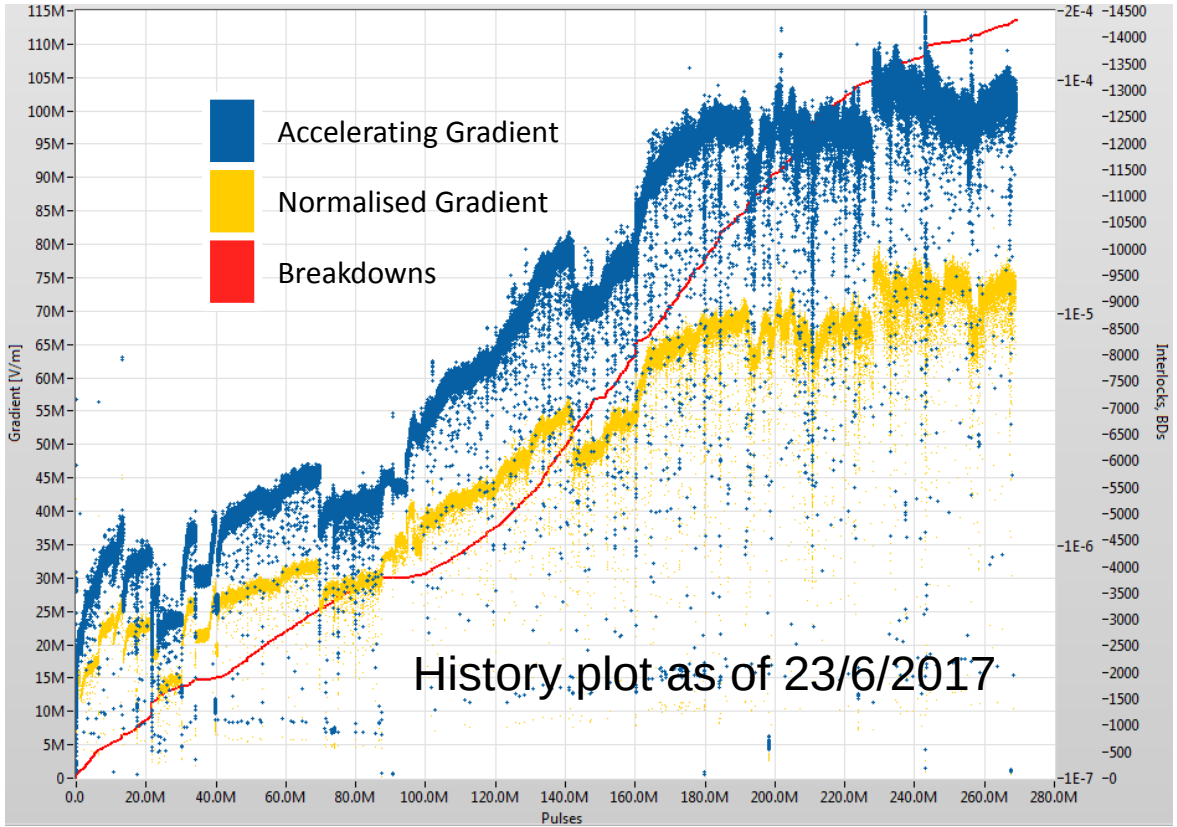


Xbox-1@CTF2 Ongoing test: *2017-* TD26CC-N2

- Switched to diode detectors which improved stability
- Issues with klystron:
  - Stopped pulsing on 23/6/2017
  - New klystron has been installed, will start again soon
- Reached 95 MV/m at 50ns pulse

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

New XL5 klystron installed in modulator.
Waiting the CPI team.



XBox2 and XBox3 @ X-Band facility

Xbox2-3 status, all 5 lines operational

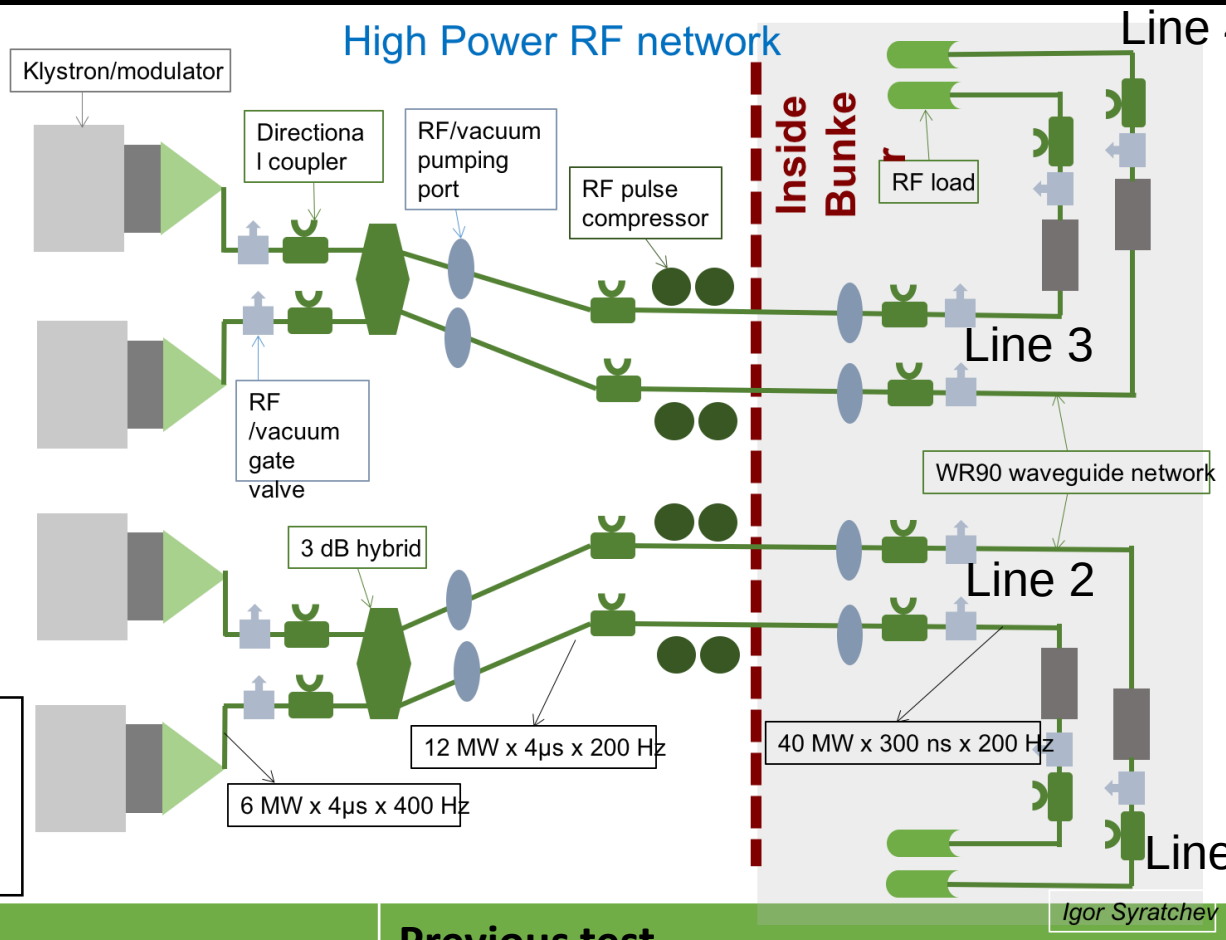
XBox2

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

Since *Dec2016 we tested*
TD26CC-N3
Nowadays PSI N1 is installed on XBox2

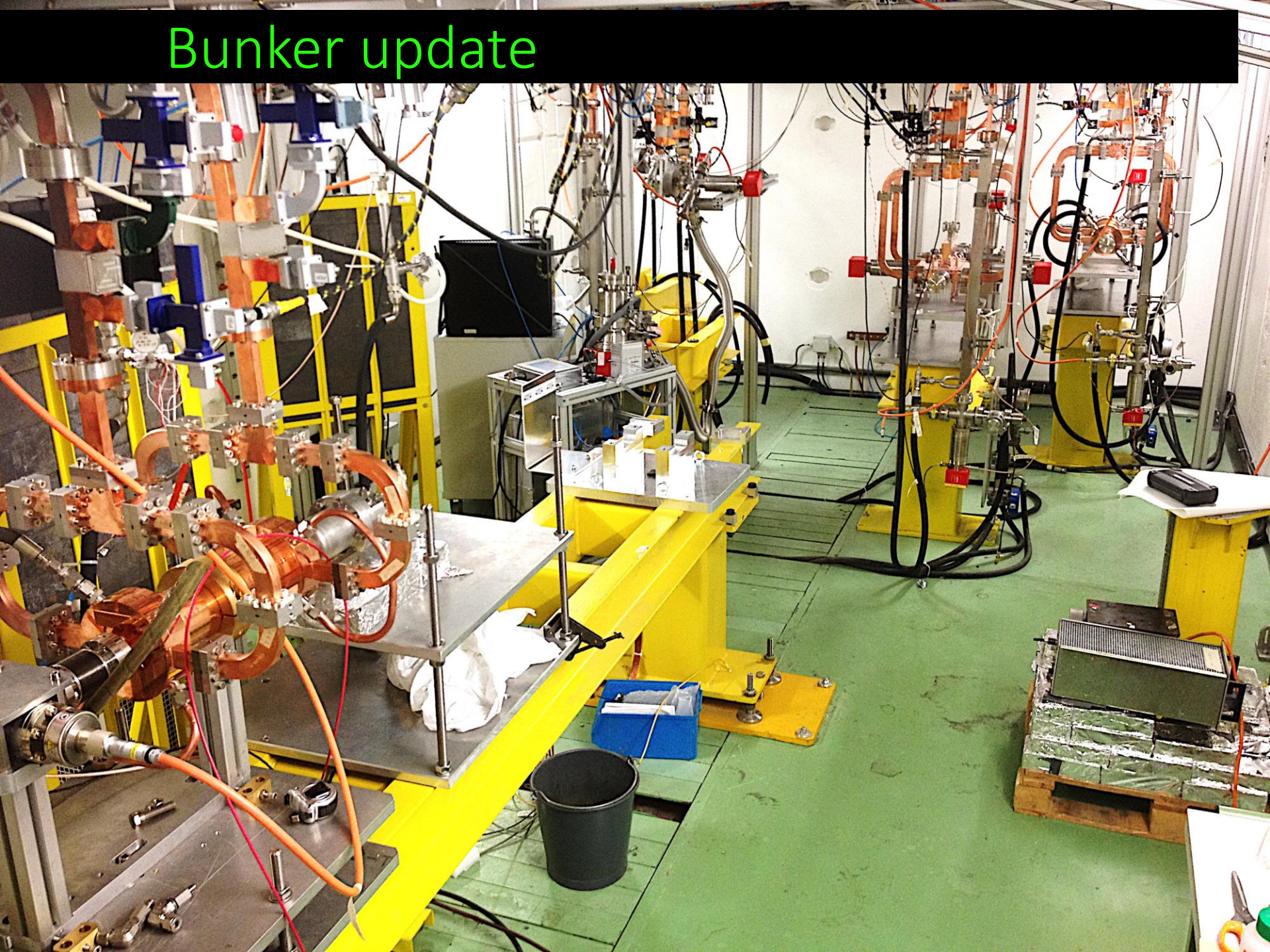
XBox3

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

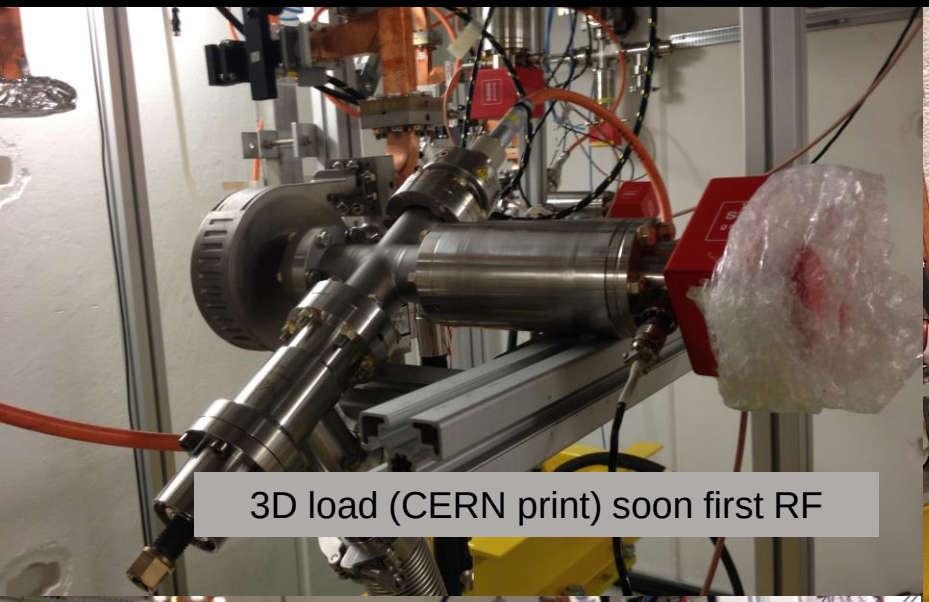


XBox3	Next test	Previous test
Line 1	3D-printed Ti load (UK)	Line conditioning
Line 2	3D-printed Ti load (CERN)	Line conditioning
Line 3	TD24 R05 SIC N2	TD24 R05 SIC N1
Line 4	T24 PSI N2	T24 PSI N1=> move to XBox2 (high power)

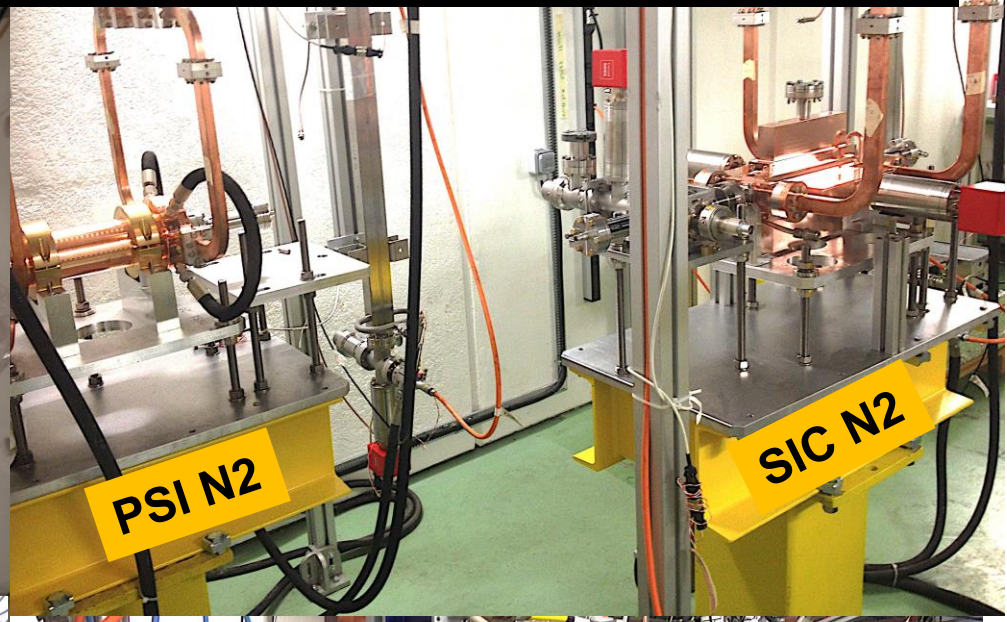
Bunker update

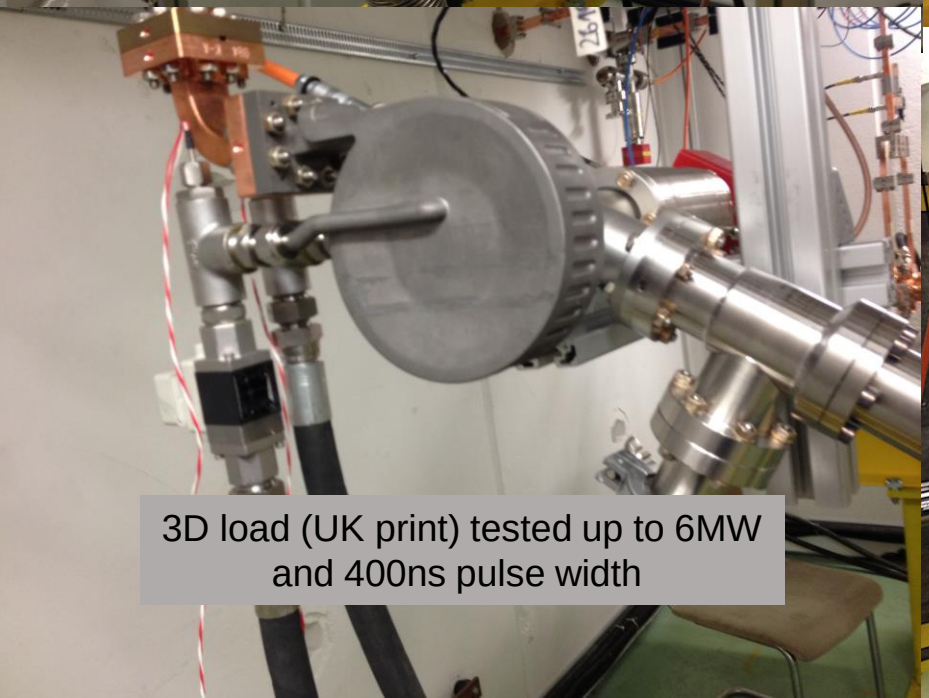


Bunker update

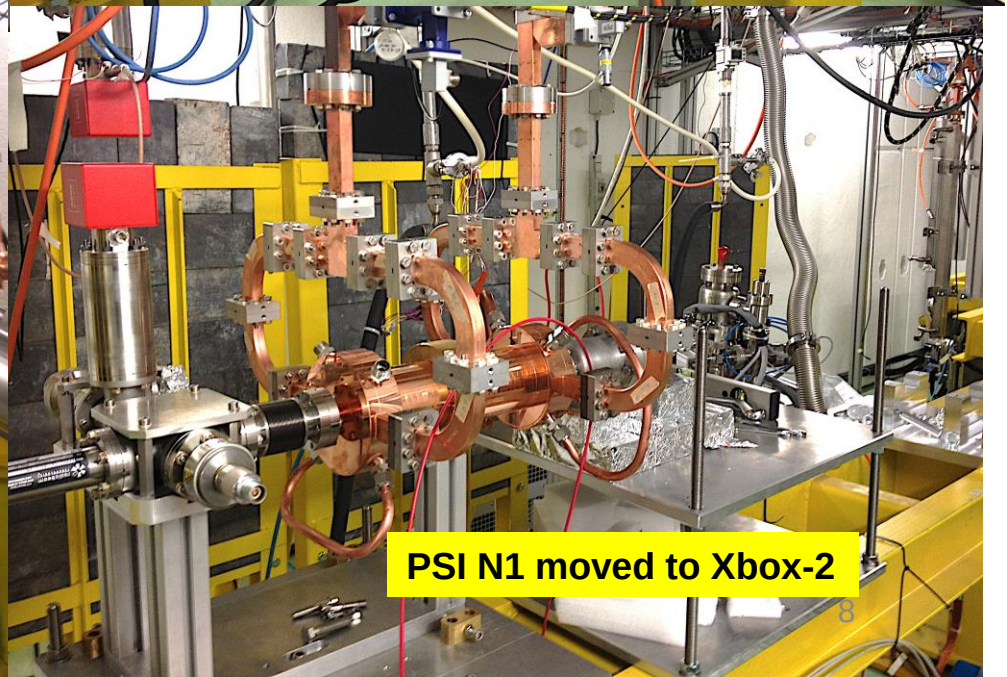


3D load (CERN print) soon first RF

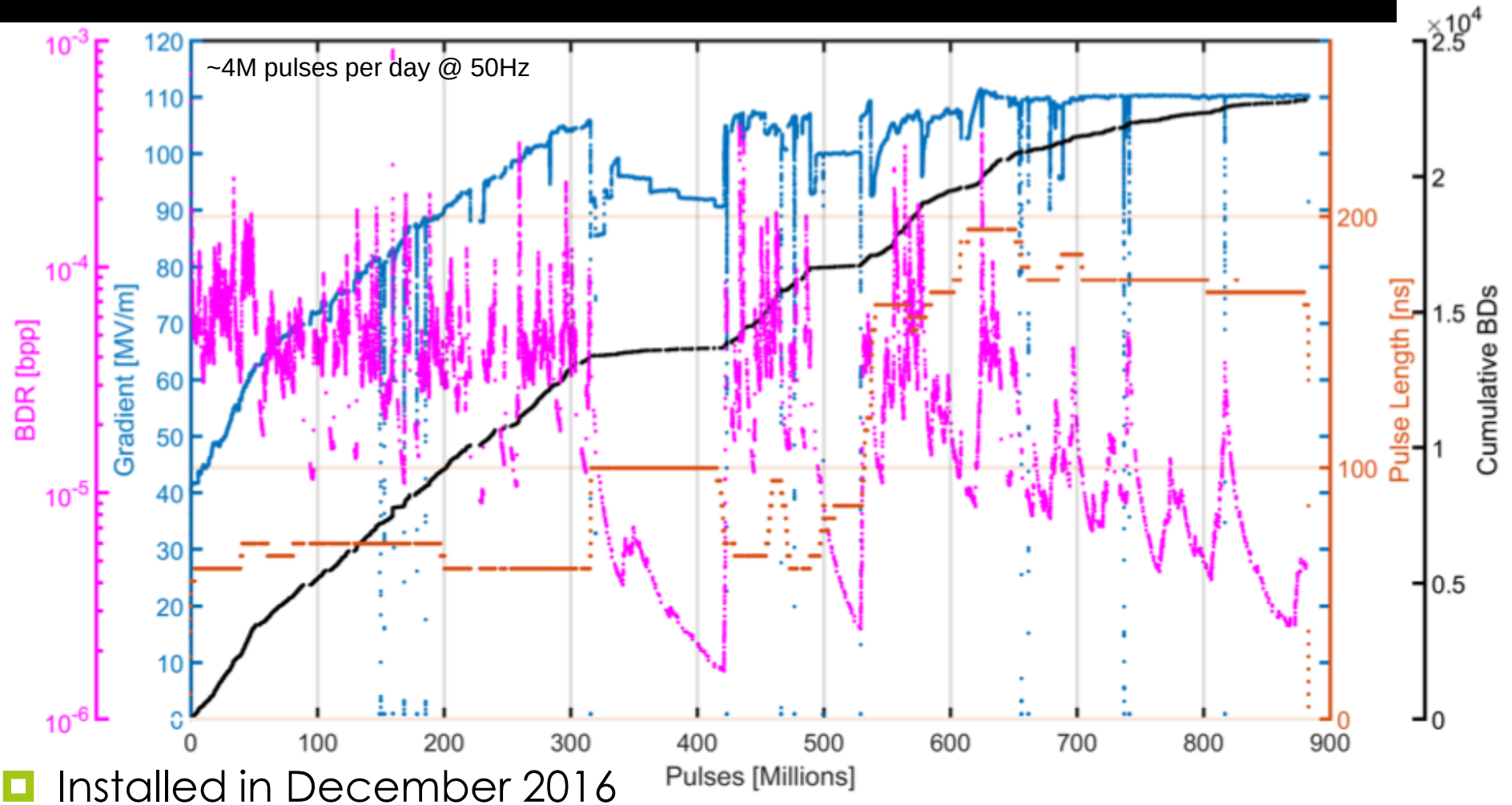




3D load (UK print) tested up to 6MW and 400ns pulse width



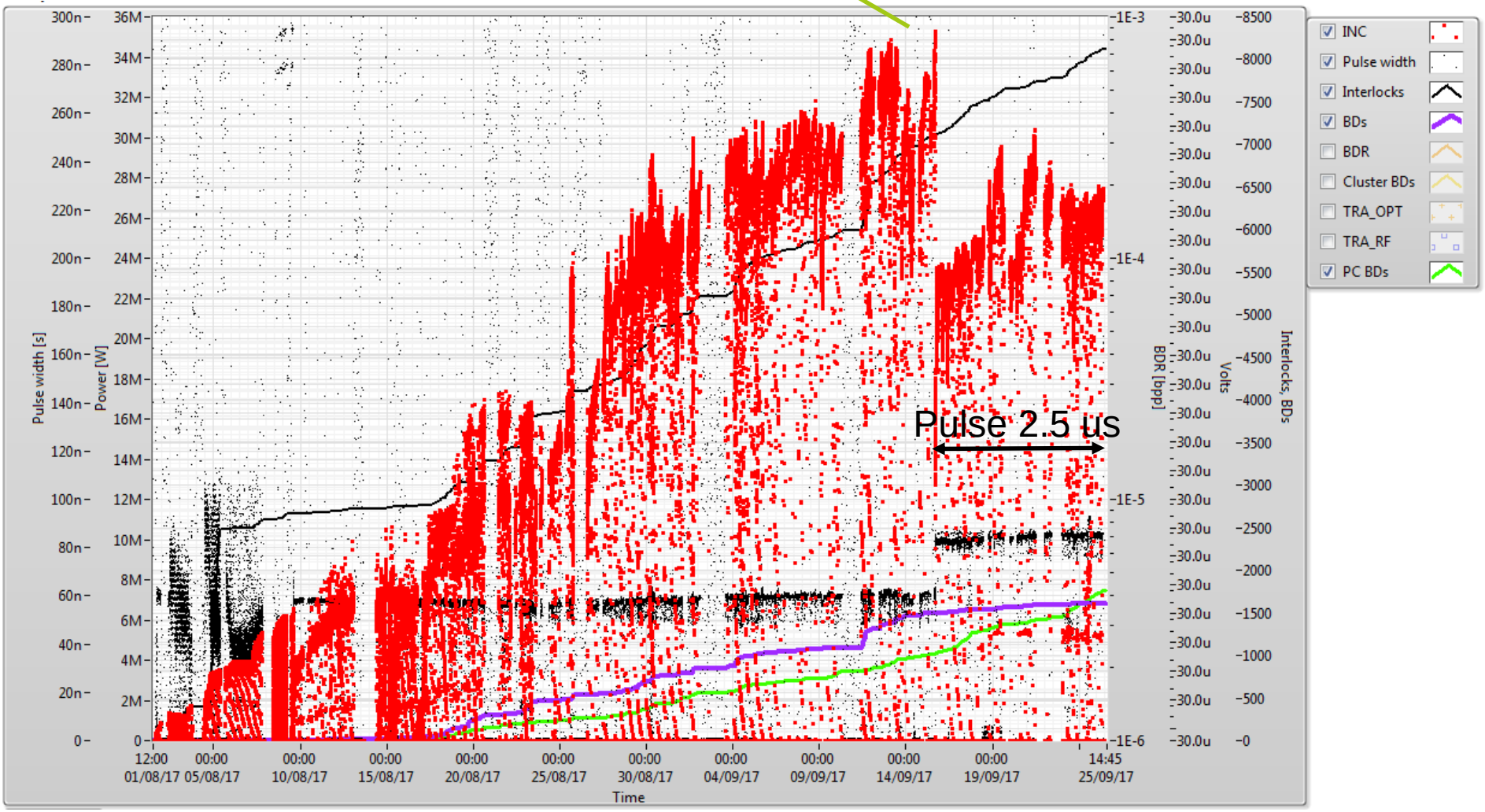
Xbox-2 TD26CC-N3



- Installed in December 2016
  - The structure has been conditioned to its maximum gradient of **113 MV/m**.
  - After 160 days of conditioning, the structure was switched onto a **CLIC-style pulse**. The structure was still reducing in BDR
  - The structure was able to reach a BDR of 2e-6 bpp after 50 days

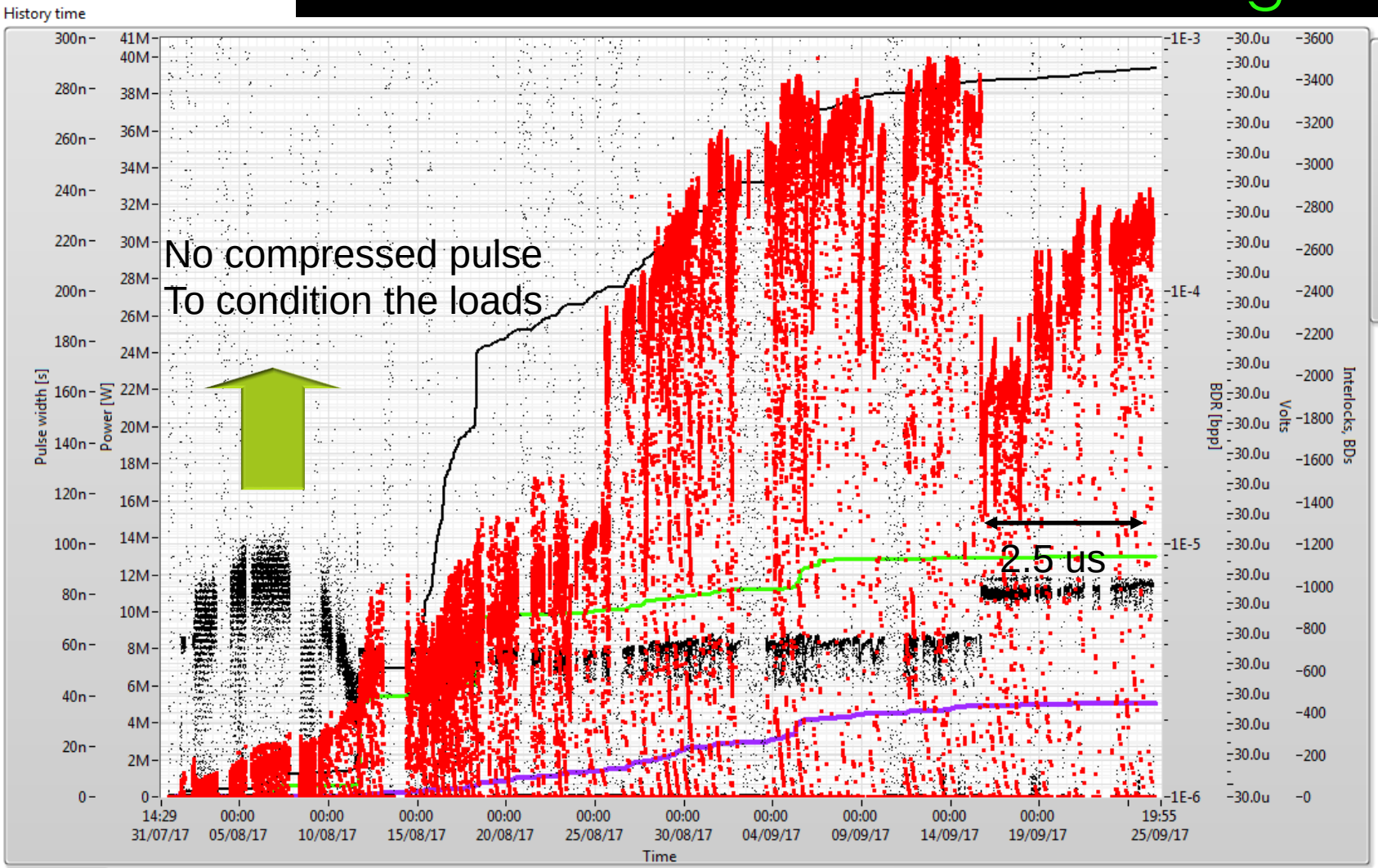
XBox3 - Line 1 conditioning

Klystron close to the saturation=> we expect about 40MW
~ 5MW missed due to the cable+attenuator calibration => power measured directly inside the bunker



8500 interlocks in two months, mostly due to the load activity.
Max flat top 80ns with 2.5us of input pulse at the klystron

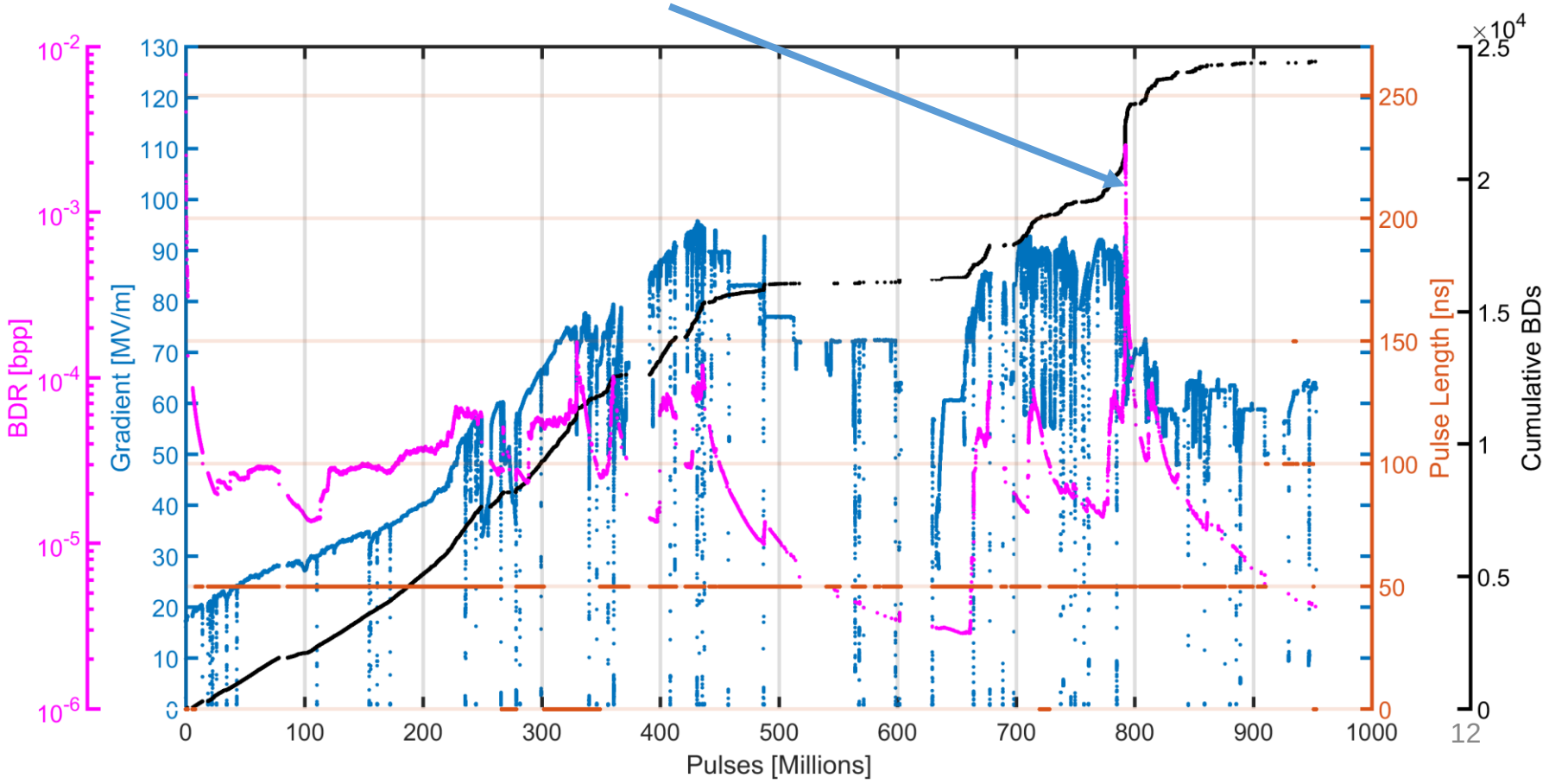
XBox3 - Line 2 conditioning



- Less interlocks than line 1, better load
  - These two lines are ready for testing the CLIC components
  - We are waiting a repaired klystron to replace the unstable one before test structure on these lines (Dec2017)

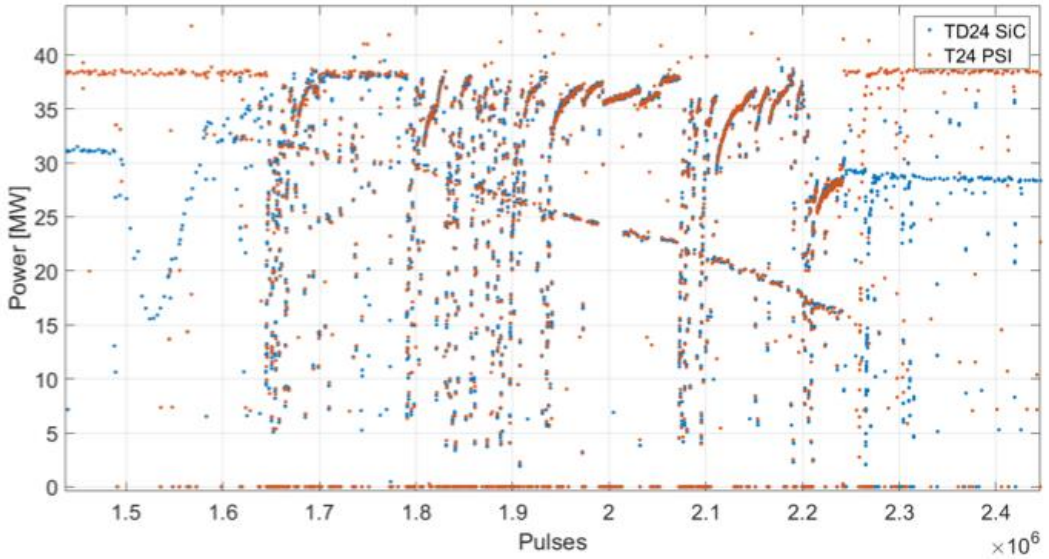
TD24 R05 SIC N1 (Xbox-3 Line 3)

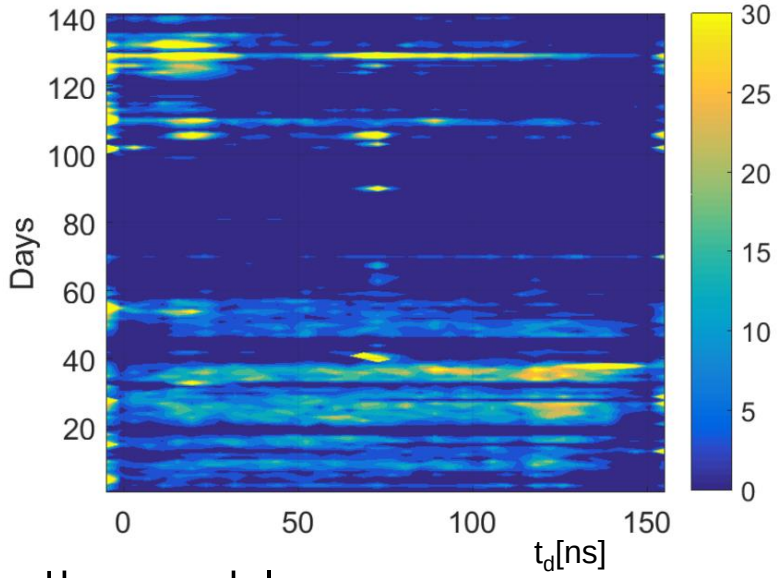
- SiC structure experienced a rough conditioning but lead to many operational lessons.
  - It was found that the structure was conditioning slowly not due to the structure but due to the algorithm.
  - The structure was unfortunately lost due to a hot-cell which developed and drove down the power.



TD24 R05 SIC N1 (Xbox-3 Line 3)

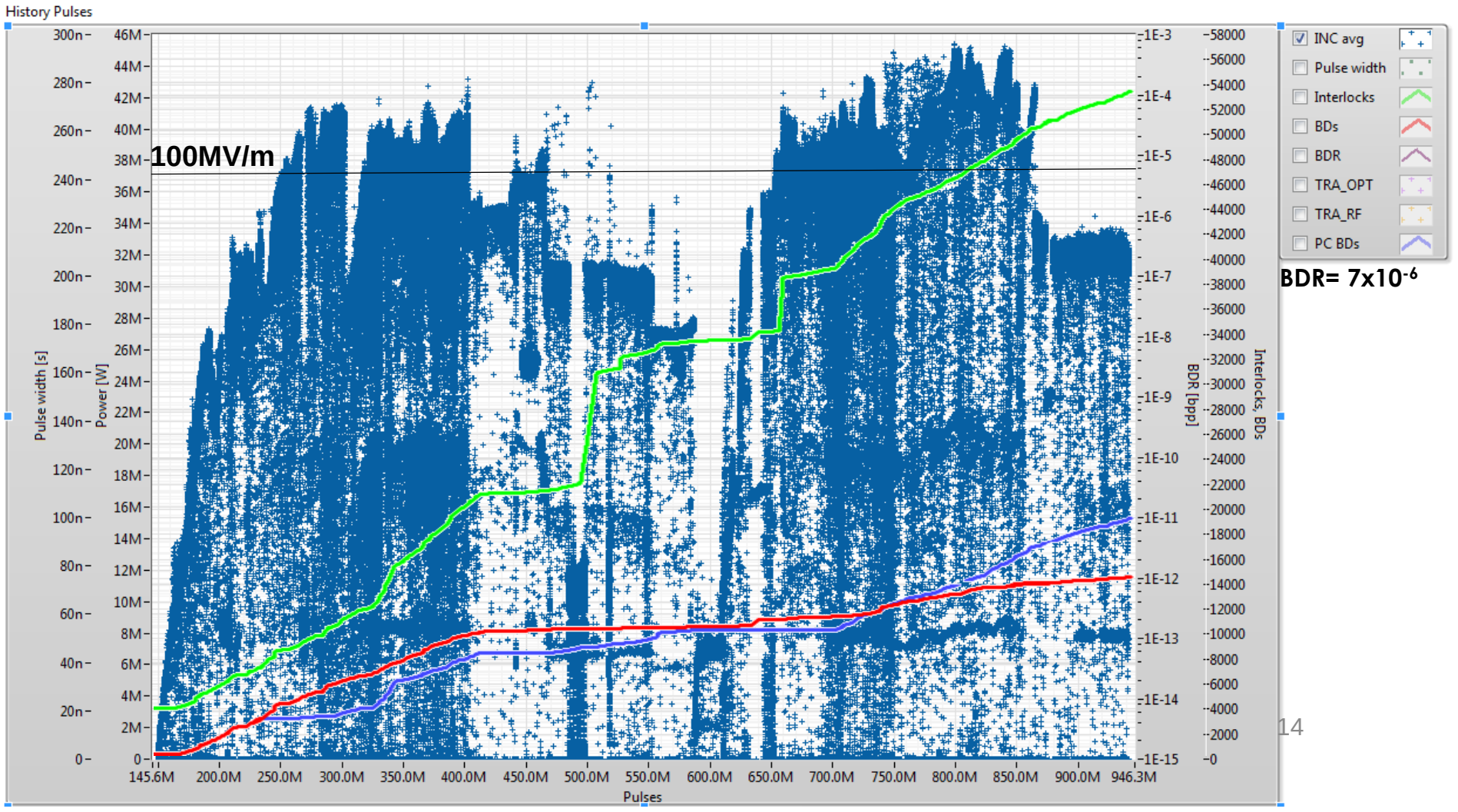
- High density of breakdown at the first cells.
  - Conditioning algorithm went confused when run at high repetition rate ≥ 200Hz
  - Power level for PSI was sent to SiC line, and vice versa.





- No evidence that the structure itself was the problem.
- **Code is already fixed and it is ready to test news structures at high repetition rate ≥ 200Hz**

T24 PSI N1 (XBox3 -Line 4)



BDR= 7x10^{-6}

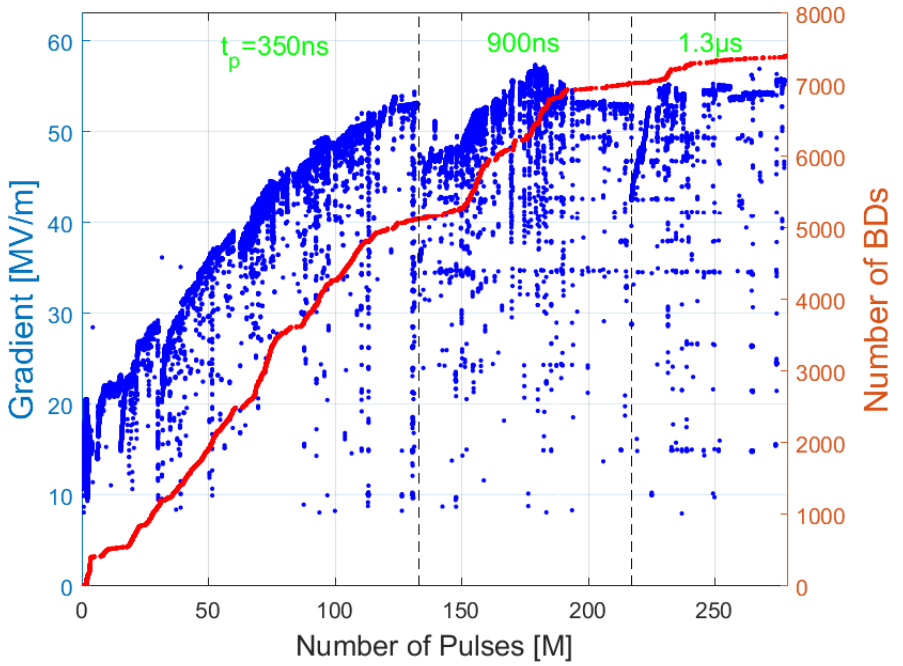
- Structure conditioning dominated by the pulse compressor and load
  - Maximum power expected in XBox3 is about 47MW
  - We moved the structure to XBox2 that can run up to 60MW

S-box S-band (2.9985 GHz) CTF2

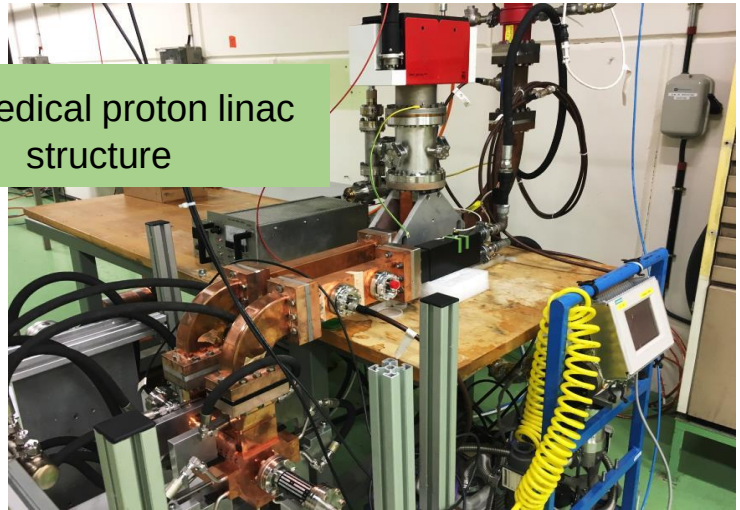
- Medical proton linac structure (**BTW**) funded by the Knowledge and Transfer (KT) group at CERN.
- Second structure is ready for test
  - Line limited in power need to change modulator.
- Valencia is opening a S-Band (HGRF) facility and it will host BTW structure.
  - Modulator factory tests (done)
  - Test with klystrons (RF) soon

	Target	Achieved results
Power	**28 MW**	**26 MW**
Gradient	**50 MW/m**	**56 MV/m**
T_pulse	**1.5 µs**	**900 ns**

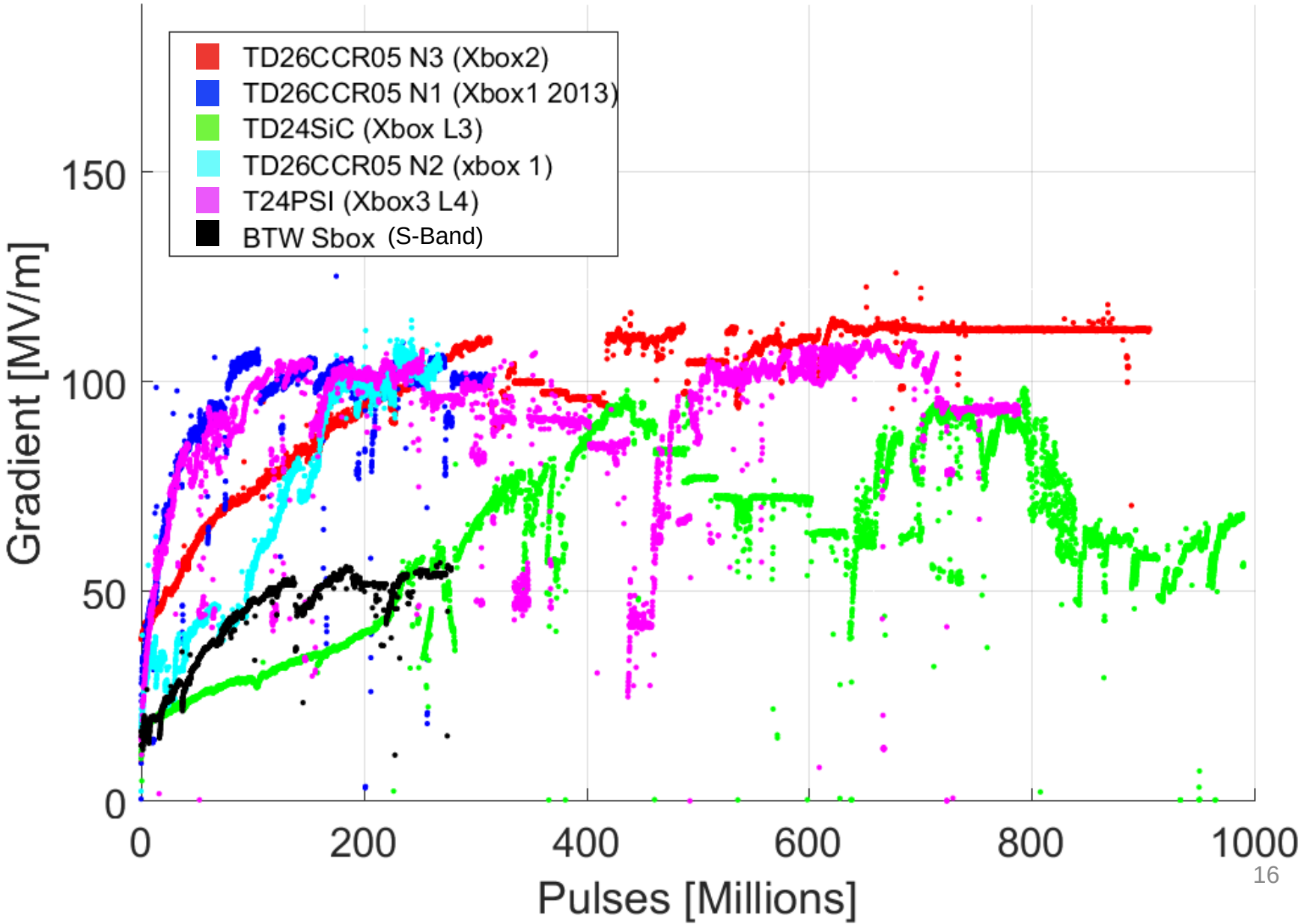
Backward Travelling Wave (BTW) structure tested at Sbox since November 2016.



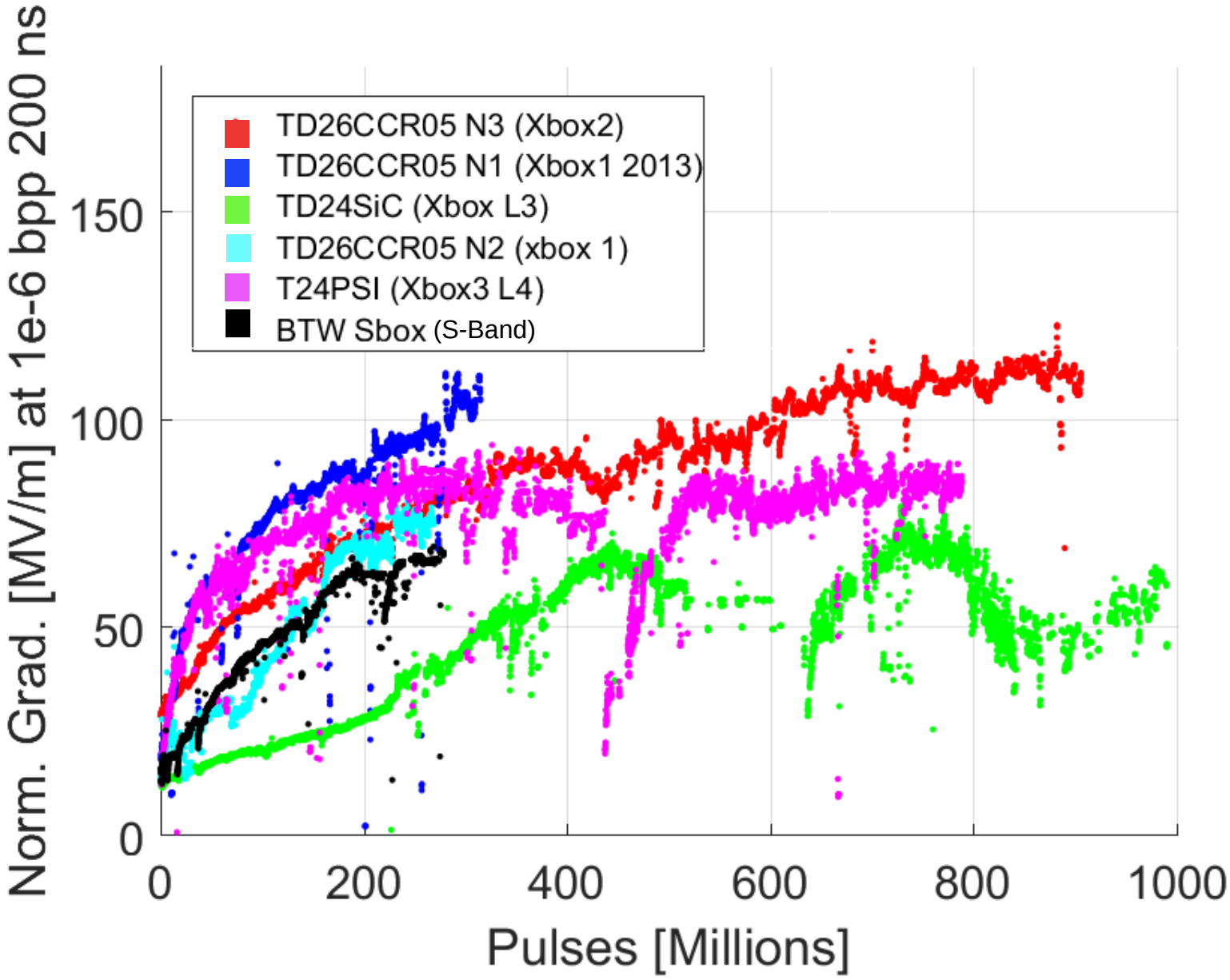
KT medical proton linac structure



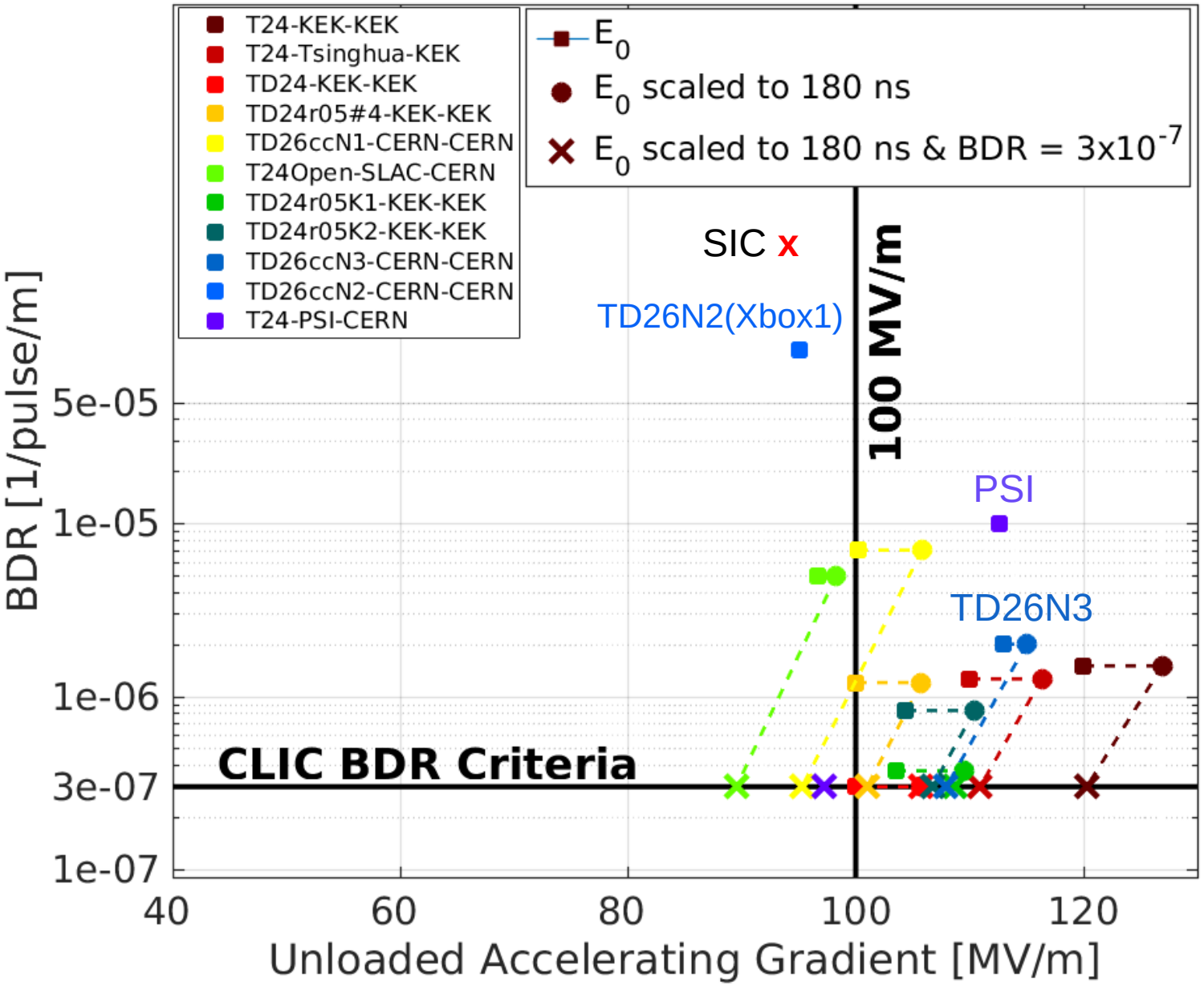
Gradient summary plot



Scaled gradient summary plot

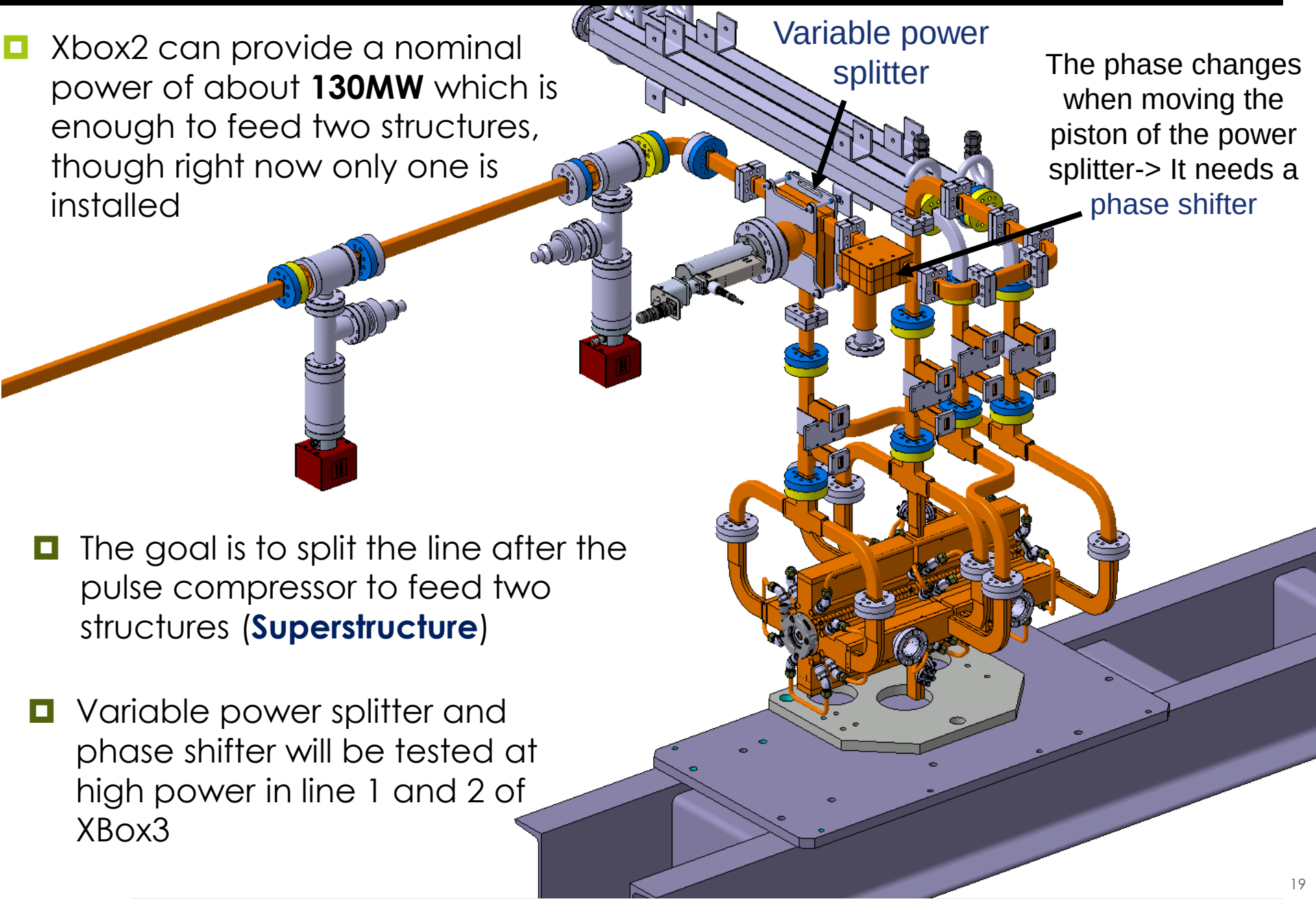


BDR comparison



XBox2 upgrade

- Xbox2 can provide a nominal power of about **130MW** which is enough to feed two structures, though right now only one is installed



- The goal is to split the line after the pulse compressor to feed two structures (**Superstructure**)
- Variable power splitter and phase shifter will be tested at high power in line 1 and 2 of XBox3

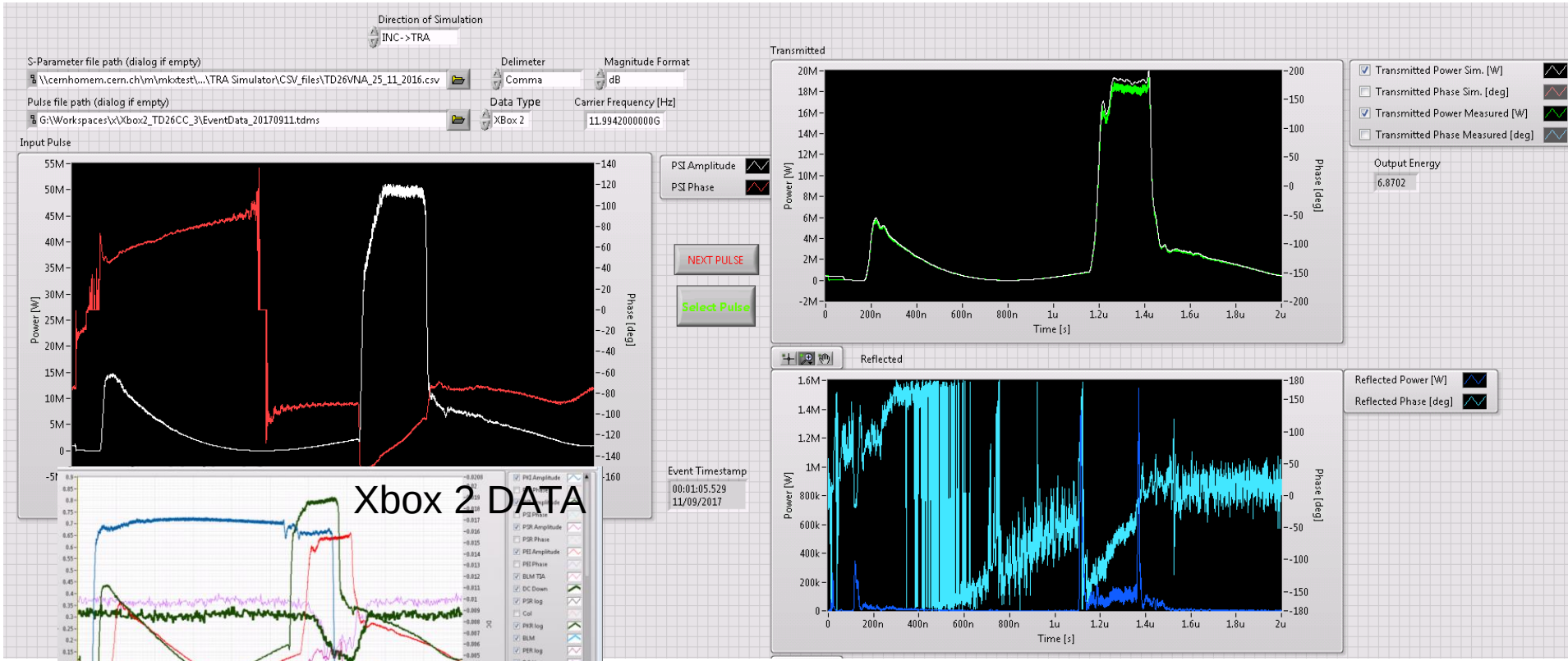
Conclusion and future plan

- We conditioned 3 prototype CLIC structures
  - New structures are already installed in line 3 and 4
  - PSI N1 is moved in XBox2 line to test it at high power
  - Results are in agreement with the previous structures already tested
    - Few operational issues already (resolved) contribute to the demise of TD24R05SIC_N1 structure.
    - No evidence that the structure itself was the problem.
- Two spare klystrons are inserted in modulator C and B.
  - A third repaired klystron is expected to be here by mid-December to replace klystron A
  - Finish installation and start conditioning structures in Line 1-2 in January 2018.
  - At the moment we use line 1 and 2 to test components
    - 3D loads , phase shifter, variable power splitter, halves mock-up
- Upgrade Xbox2 (end 2017 beginning 2018)
  - Two structure testing, variable attenuator
  - Potential upgrade existing modulator to 100Hz

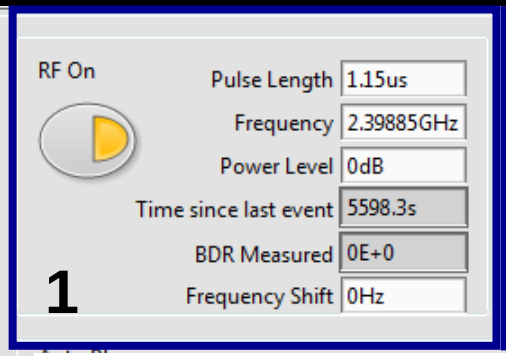
Extra slides

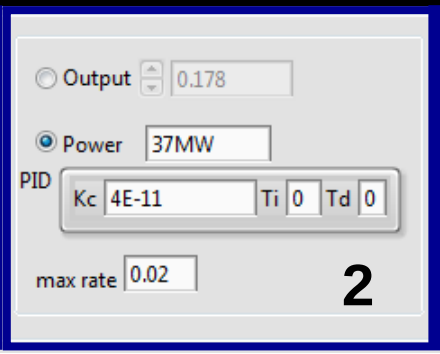
Transmitted power simulation

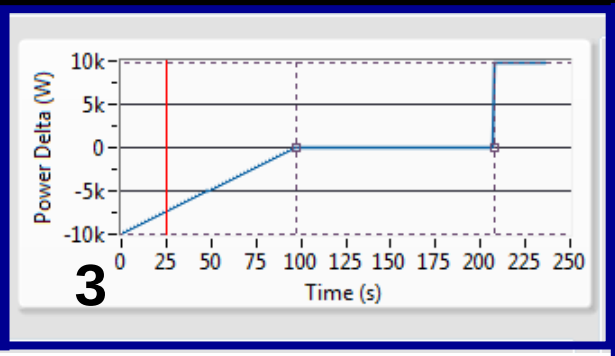
- The S-parameters can be used to simulate the output pulse shape of pulse compressors and structures
  - Input (real waveform) => S-parameters of structures + splitter junctions => transmitted power
  - Control power calibration

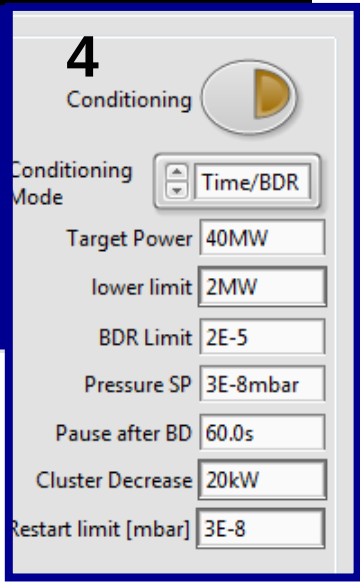


Conditioning control algorithm







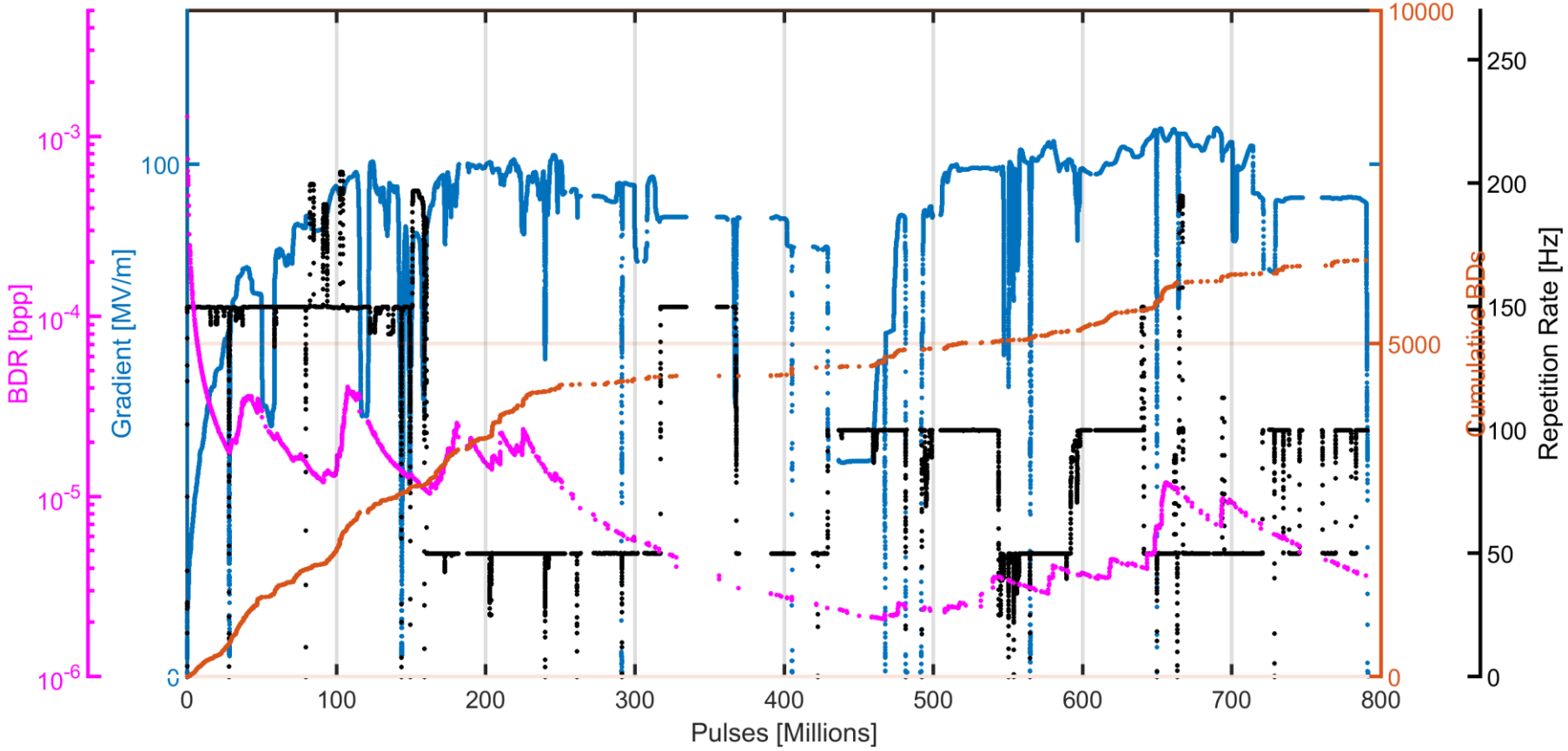


1. Pulse length and LLRF frequency are set:
2. Fast → pulse to pulse
   - PID loop on the incident power to the structure
3. Medium → seconds-minutes
   - increase power by 10kW every few minutes (**cycle loop**) if no BD
   - reduce power by 10kW if successive BDs too close in time
4. Slow → hours
   - **BDR measurement** performed across a moving window of approx. 1M pulses.
   - BDR measurement and stop power increase if it is too high

OR

- Use PID loop using the system pressure as a process variable.
- Increase in pressure results in a reduction of power and vice versa.

T24 PSI N1 (XBox3 -Line 4)



T24 PSI N1 (XBox3 -Line 4)