



Xbox Status

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on behalf of Xbox Team

CLIC WORKSHOP 2018

CERN, Switzerland



Test Stands specifications

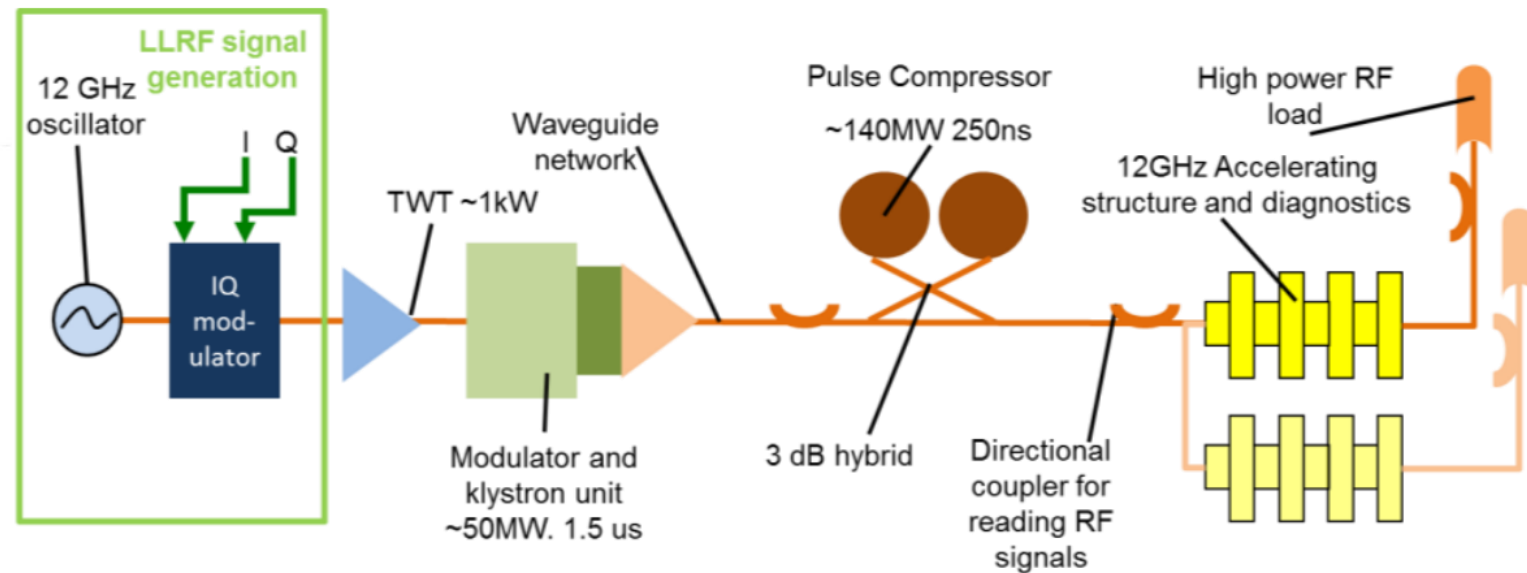
- The required input power to commission CLIC structures is typically 40-60MW and a 250ns flat pulse.
- The speed of conditioning depends on the number of pulses, therefore, high pulse repetition rates are preferred.
- XBOX 1 and XBOX2 use a single 50MW klystron and pulse compressor to test one structure, although up to two structures could be tested.
- Scandinova modulator, CPI klystron, pulse compressor factor ≈ 3



450kV, 350A, 1.5 μ s, 50Hz

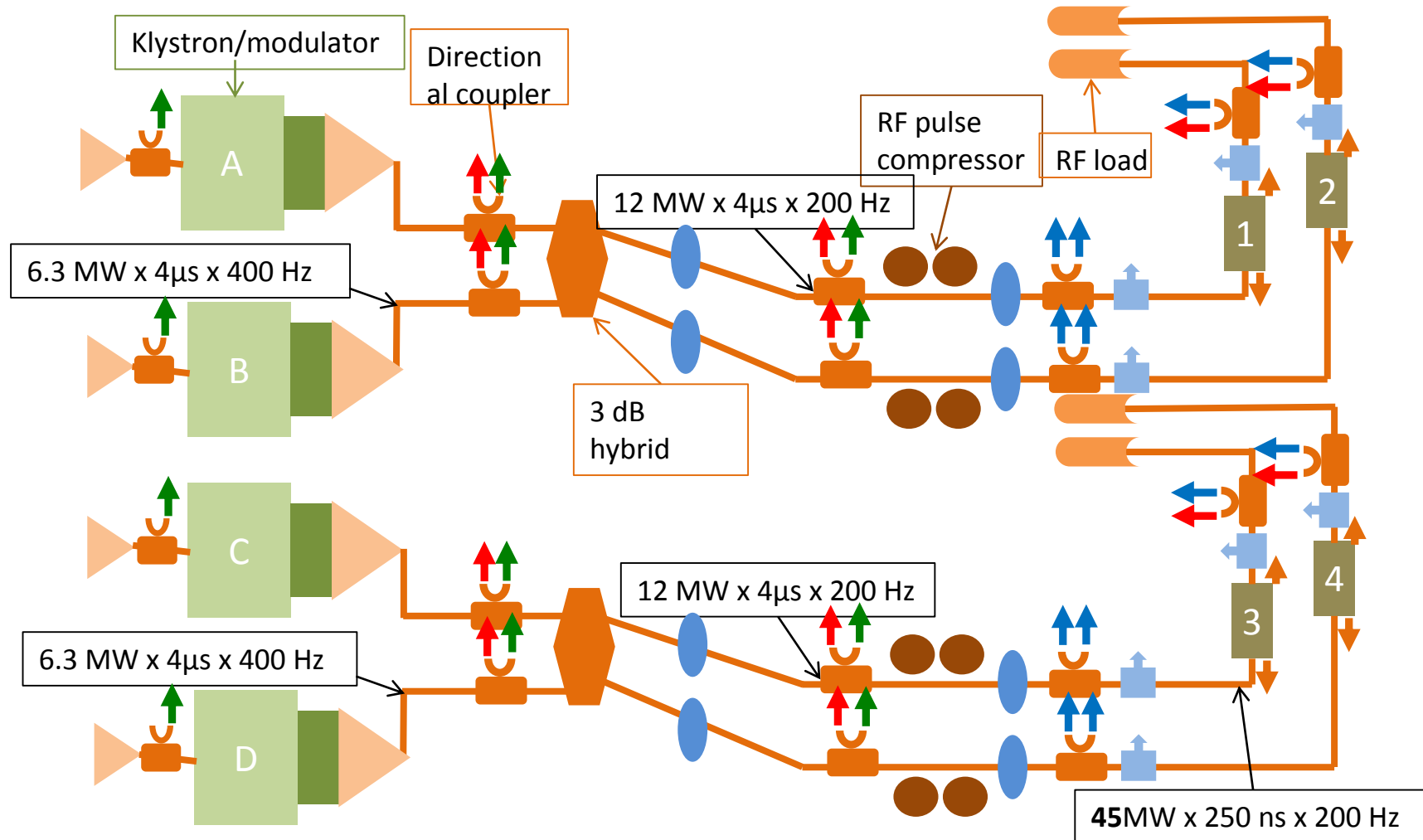


50MW



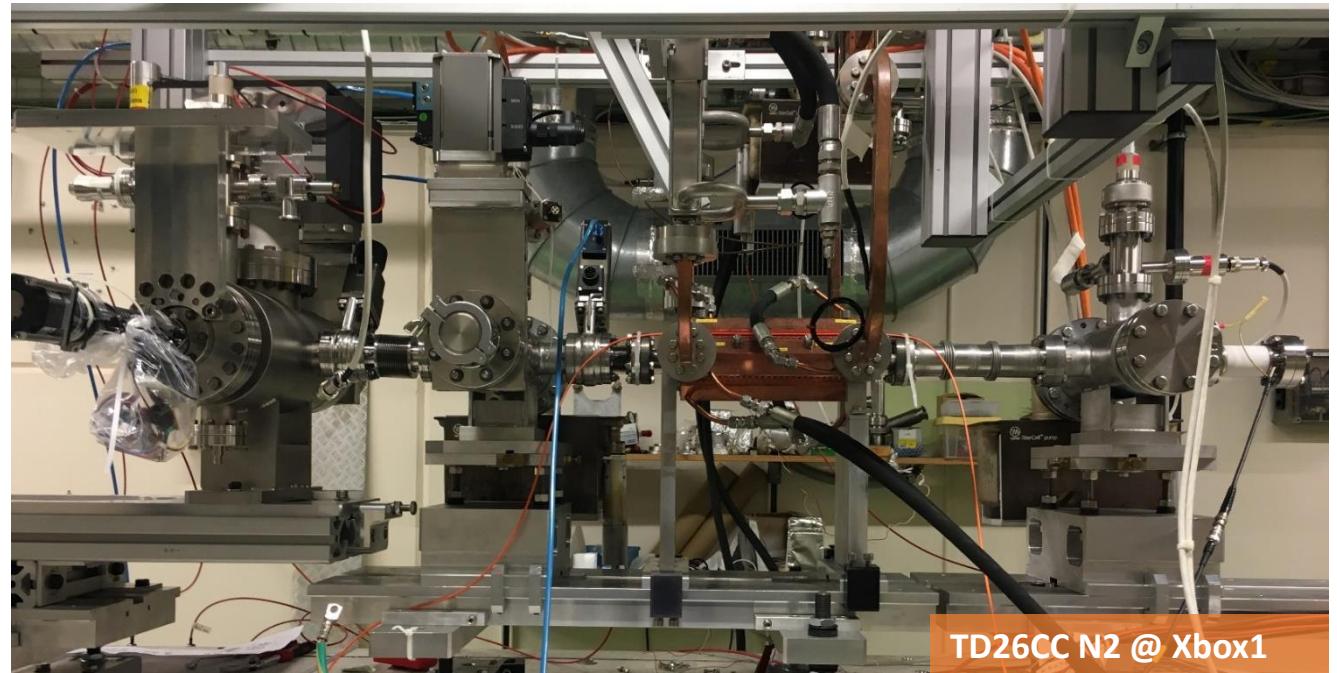
Test Stands specifications

- XBOX3 combines the power of two smaller klystrons with a higher rep. rate $\leq 400\text{Hz}$ to test two structures.
- Scandinova modulator, 6MW Toshiba klystron and pulse compression with a compression factor ~ 4

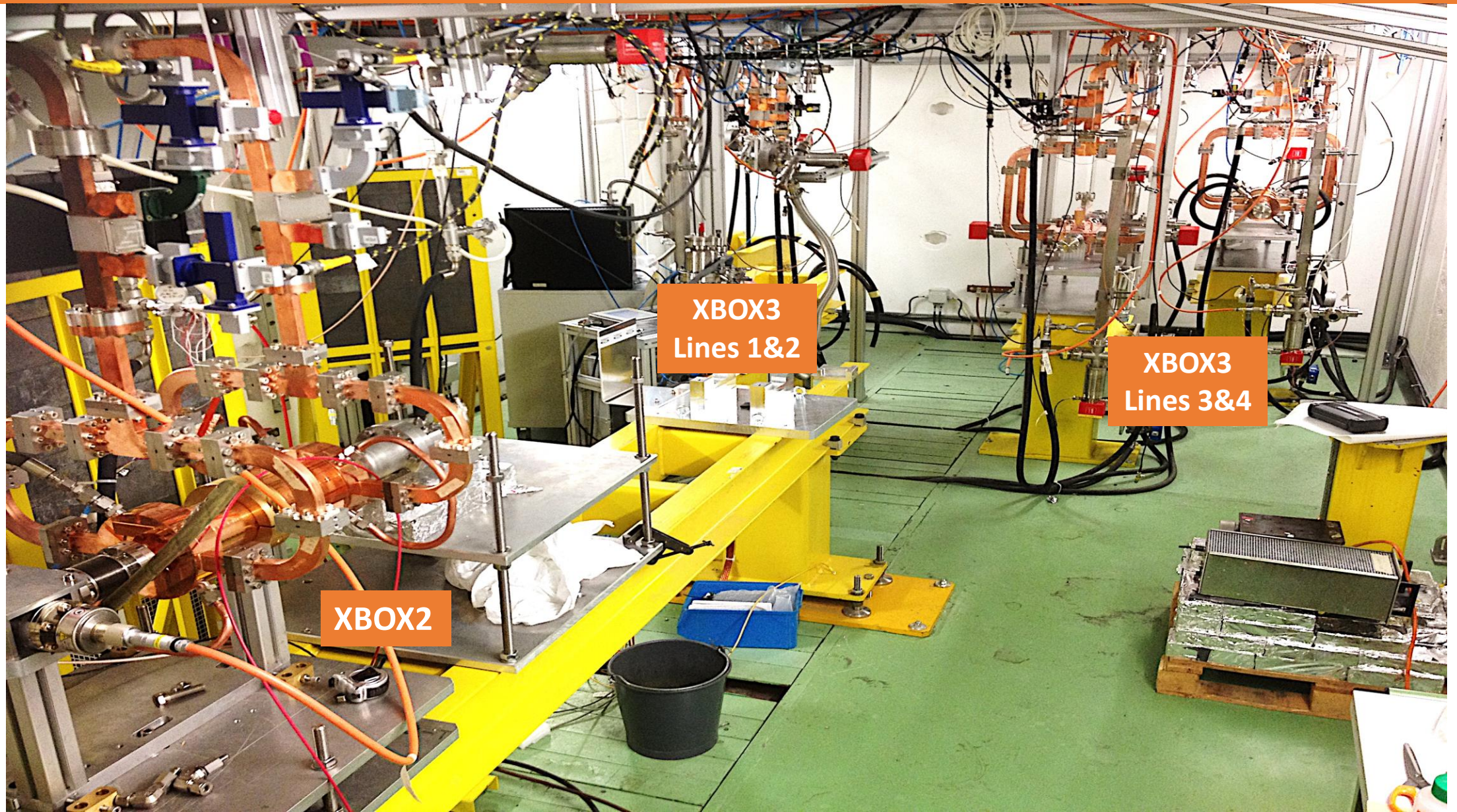


XBOX1 @ CTF2

- After dog-leg experiment, XBOX1 was reconnected to CTF2 and TD26CCN2 structure was installed.
- June 2017: Stopped pulsing due to a problem in the klystron.
- Installation of new klystron.
- Klystron and modulator test performed.
- Installation of the spectrometer from XBOX2.
- Restarting in February after yearly maintenance.
- Reconnection to CLEAR this year



The Bunker



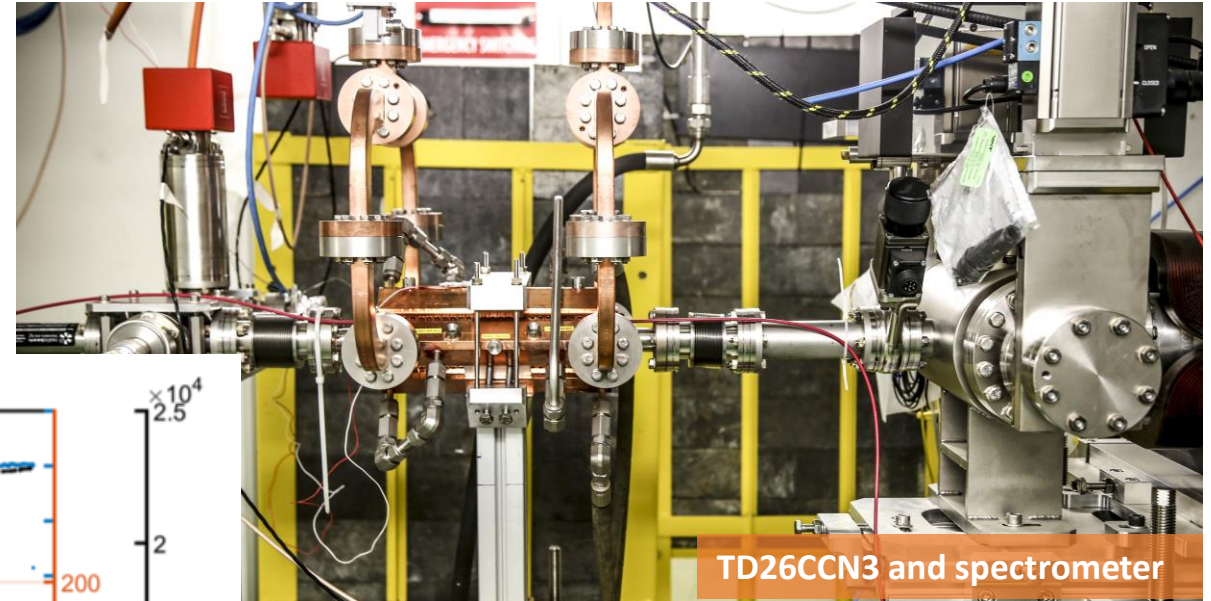
XBOX2

XBOX3
Lines 1&2

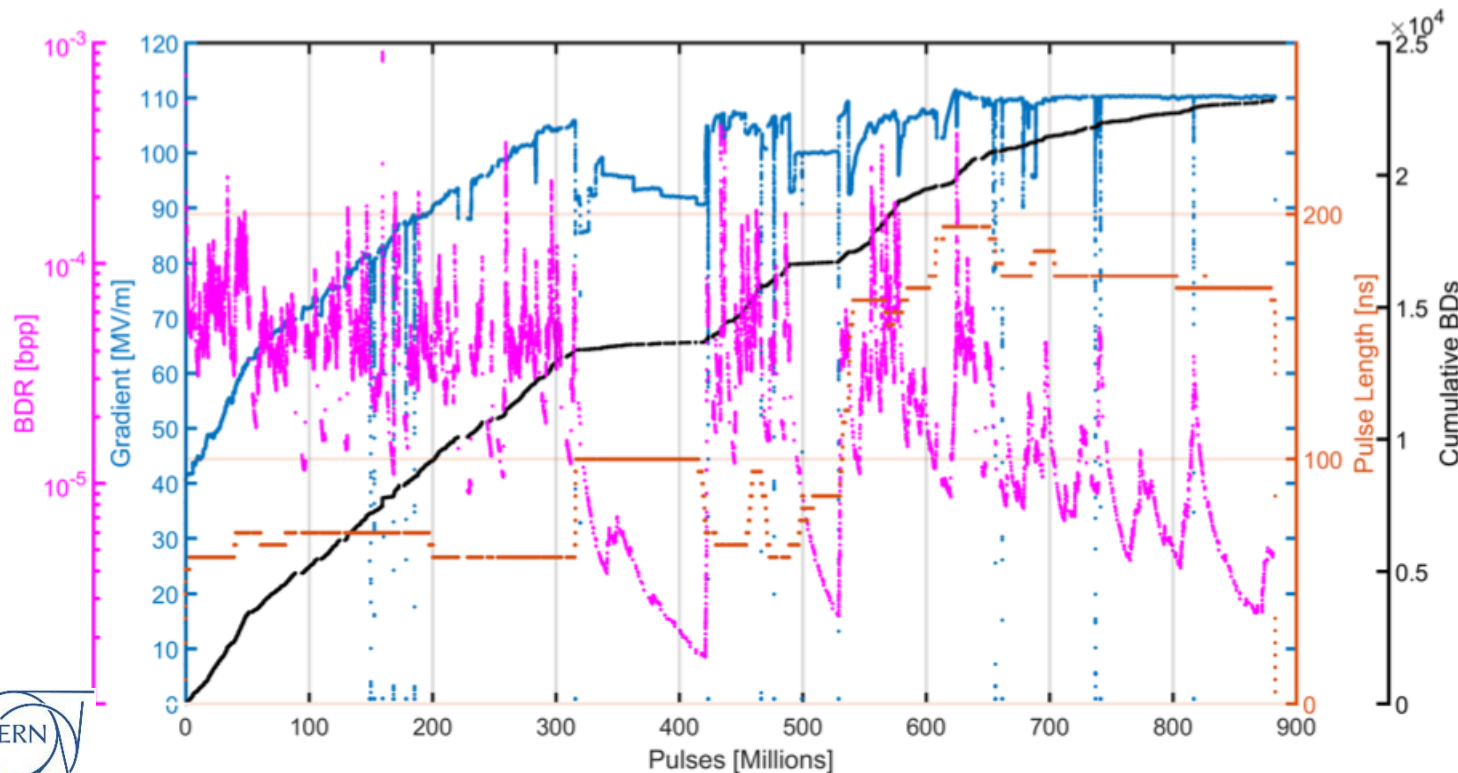
XBOX3
Lines 3&4

XBOX2

- Dec2016 – Sep2017: TD26CCN3
 - Reached a maximum gradient of 113MV/m@60ns
 - After 160 days of conditioning, switched to a CLIC pulse.
 - After 50 days it reached a BDR of 2E-6bpp.



TD26CCN3 and spectrometer



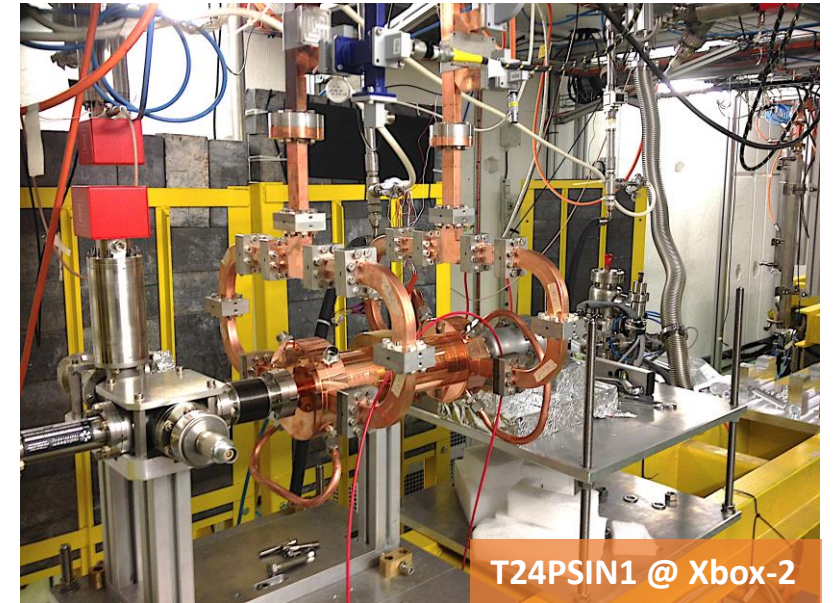
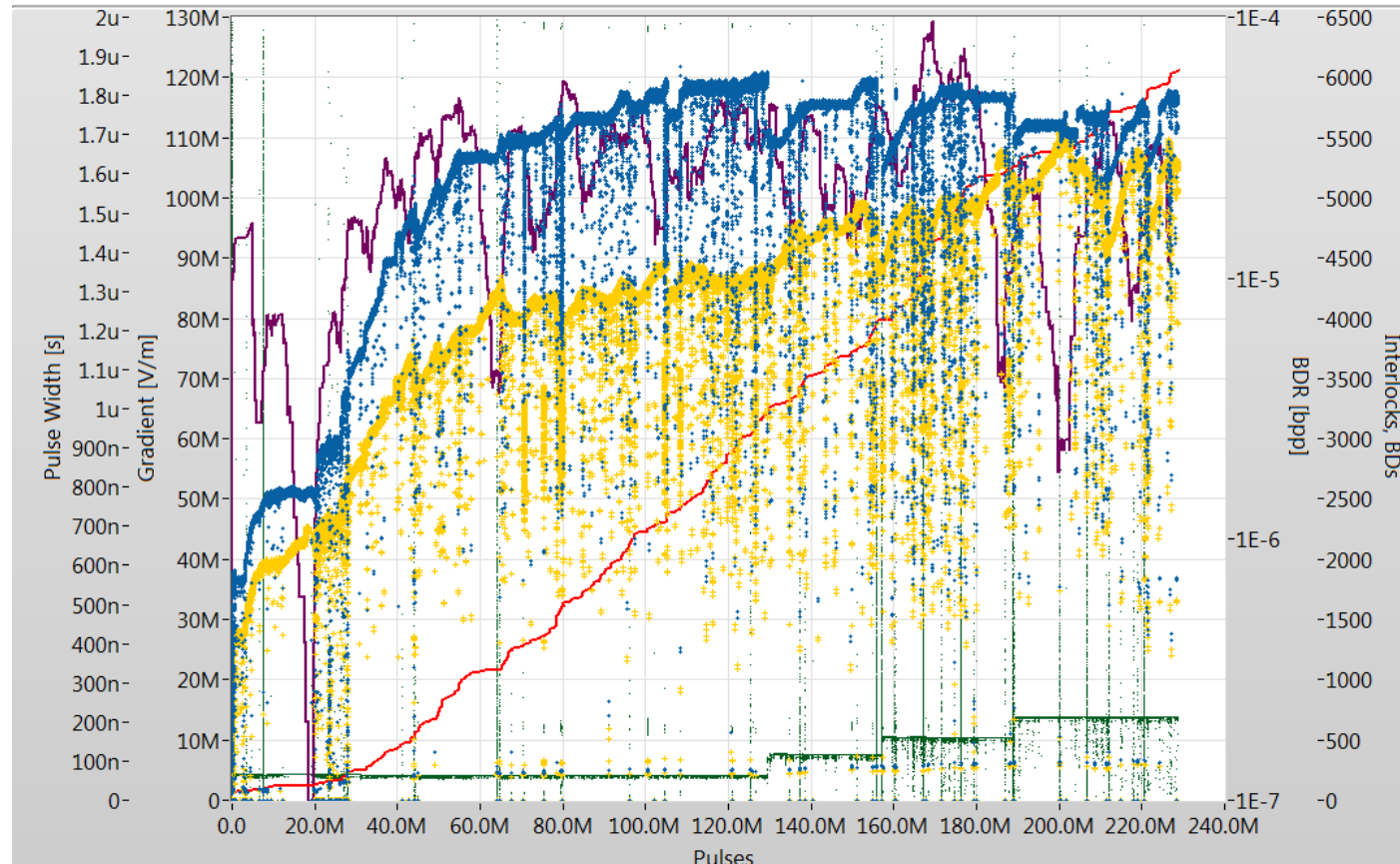
~4M pulses per day @50Hz

XBOX2

■ Oct2017: T24PSI-N1

- Moved from XBOX3 as it reached the line power limit (45MW)
- Reached 119MV/m@50ns.
- Switched to longer flat pulses: 118MV/m@200ns

History Gradient

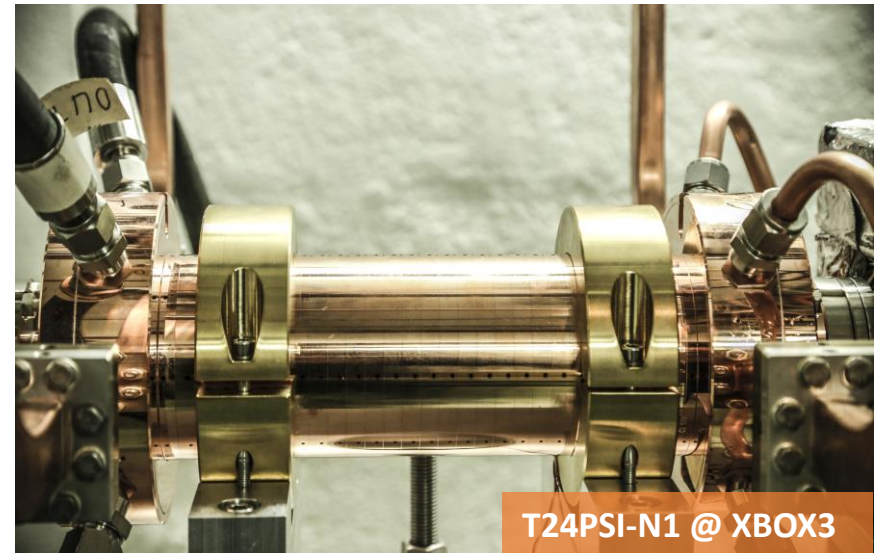
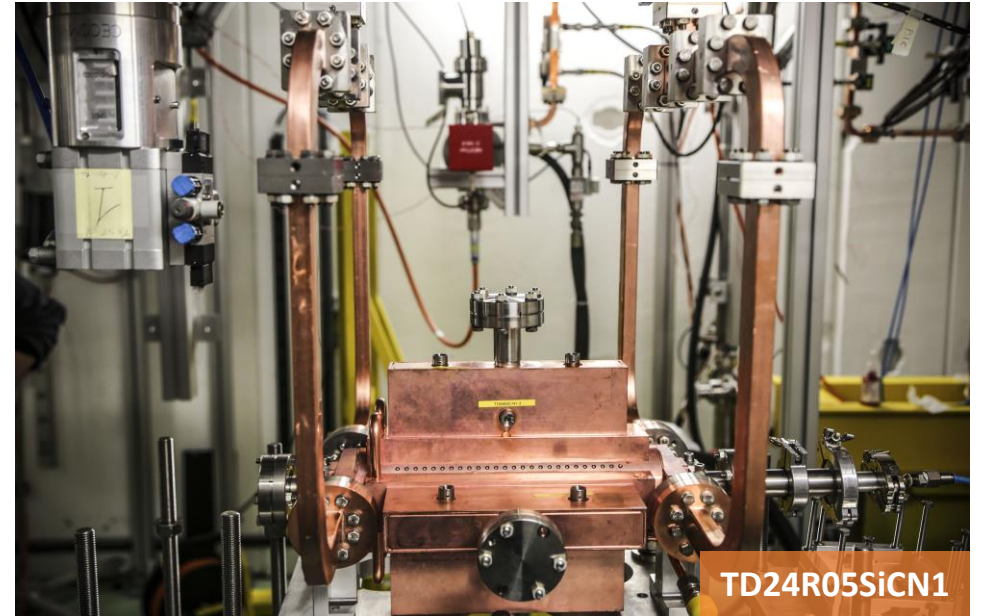


- Accelerating Gradient
- Normalized Gradient
- Breakdowns
- BD rate
- Pulse length

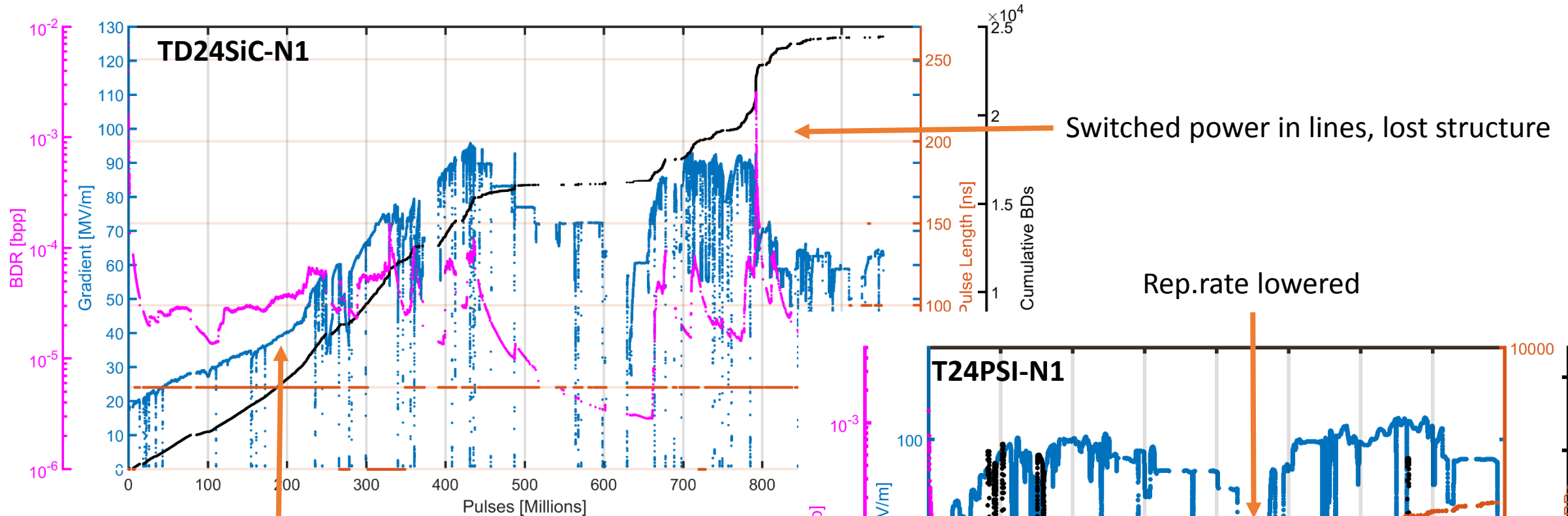
~80% Availability

XBOX3CD

- TD24R05SiCN1 (line 3) and T24PSI-N1 (line4)
 - Many **operational lessons** learned.
 - Conditioning during 5 months.
 - ~ 900M pulses in each line.
- Slow conditioning due to software algorithm.
- Running up to 300Hz. Needed more powerful chillers to maintain tuning temperature of the pulse compressor at 400Hz.
- SiC structure lost due to a hot-cell which developed and drove down the power as a consequence of a bug in the code when running a high rep. rate that switched the power between the two lines.



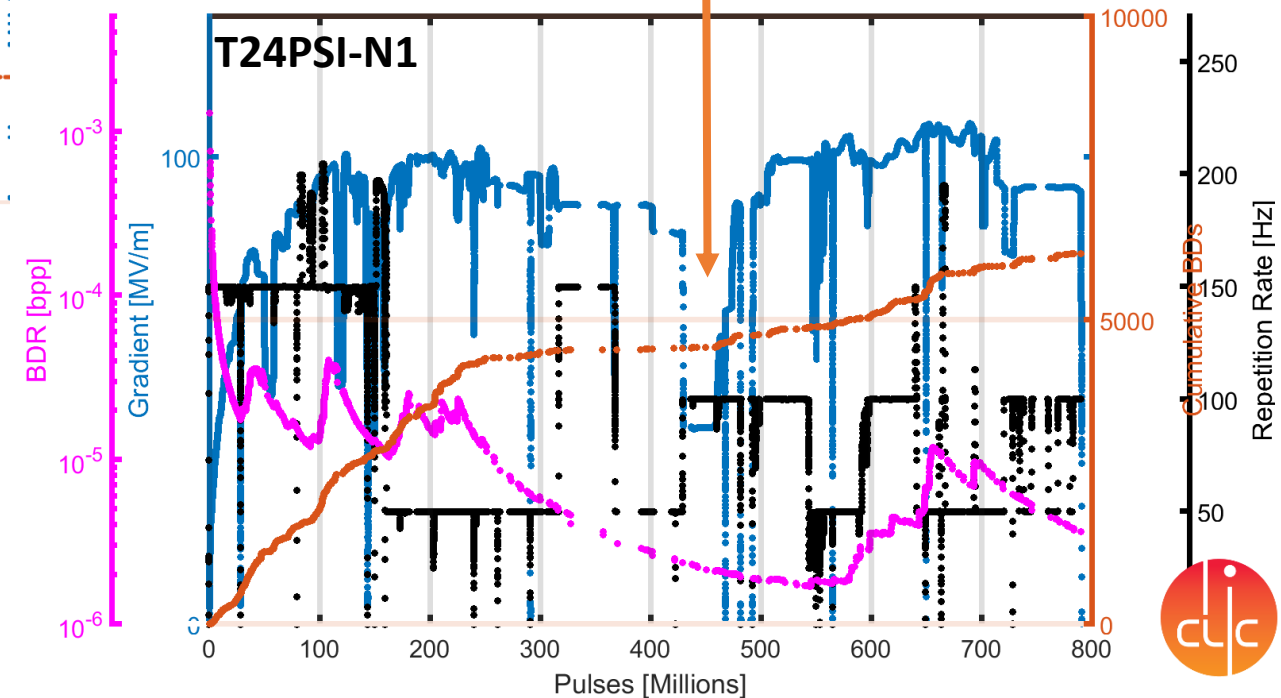
XBOX3CD



Switched power in lines, lost structure

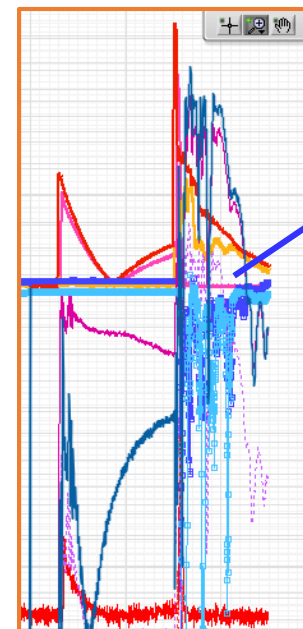
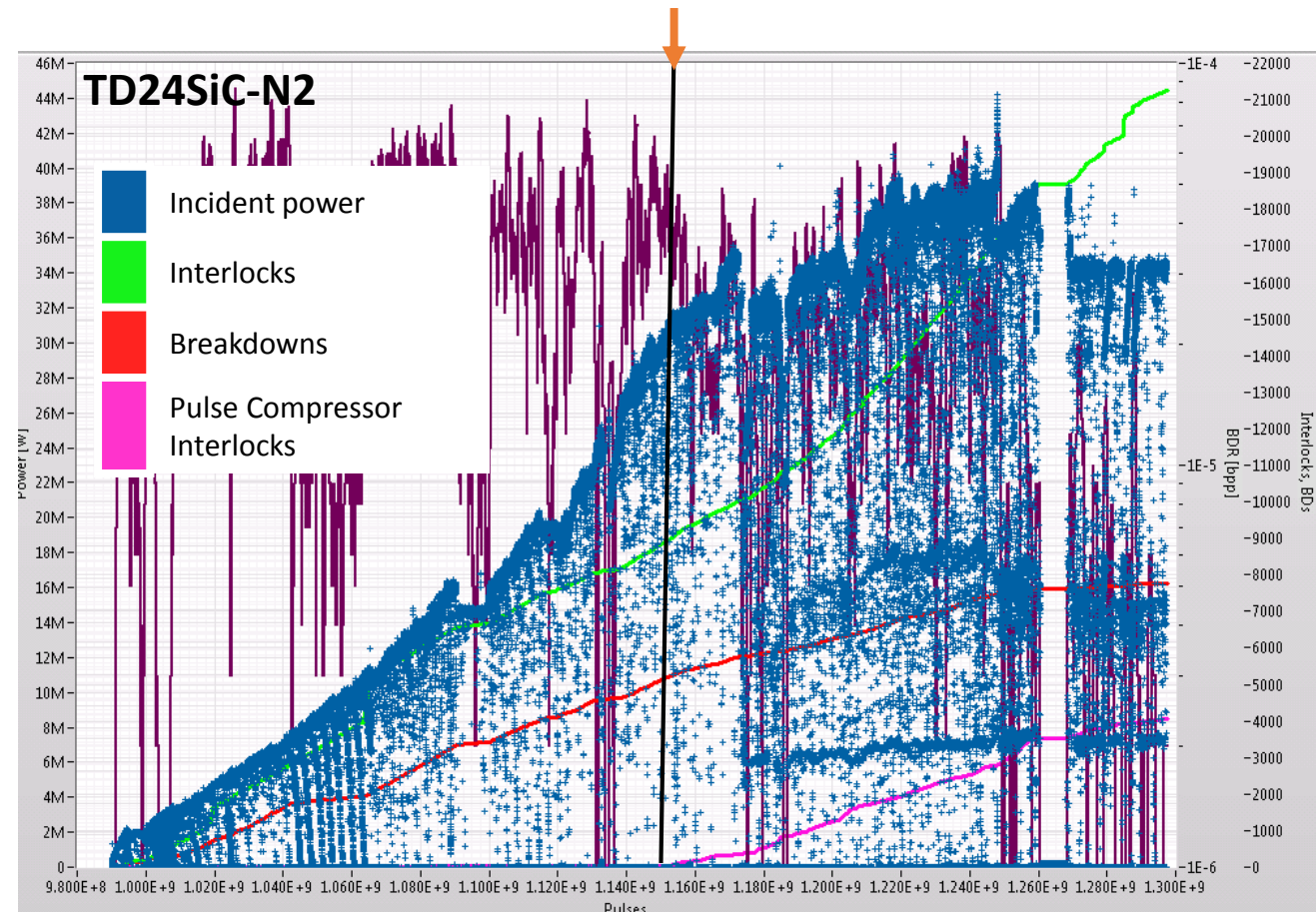
Rep.rate lowered

Slow conditioning due to algorithm

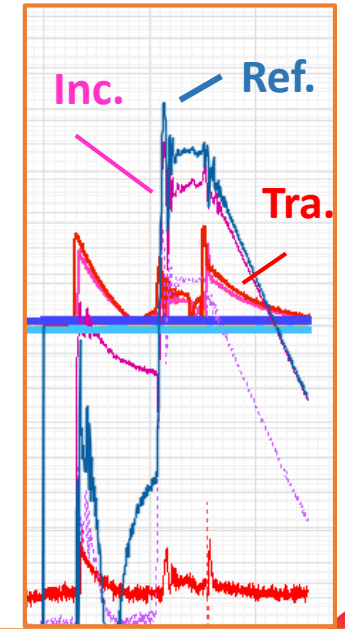


XBOX3CD

- Since Oct2017: TD24SiC-N2 and T24PSI-N2
 - 3 months and ~ 310M pulses in each line
 - New high power chillers installed for conditioning at 400Hz.
 - Commissioning limited by conditioning of Pulse Compressor



BD in the structure

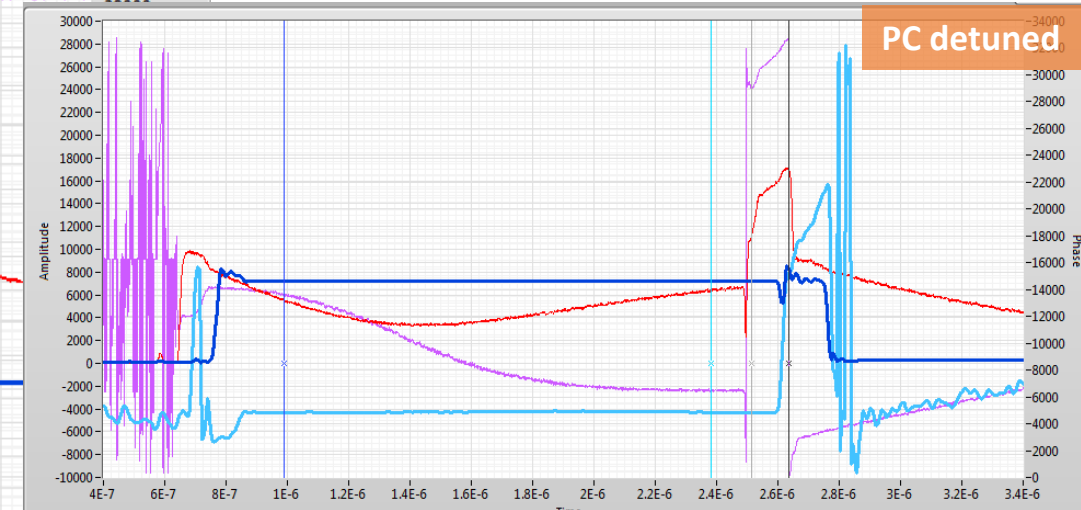
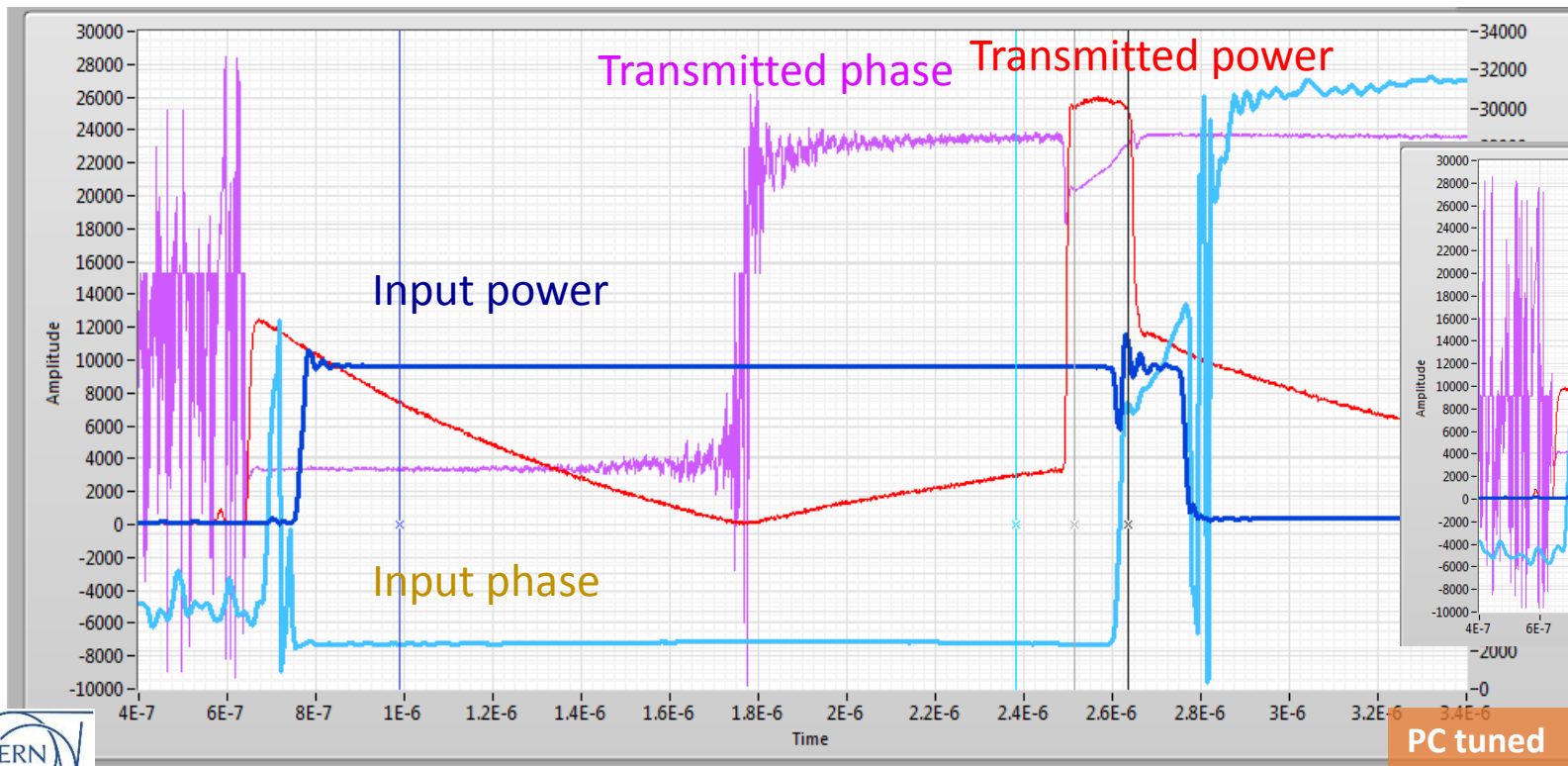
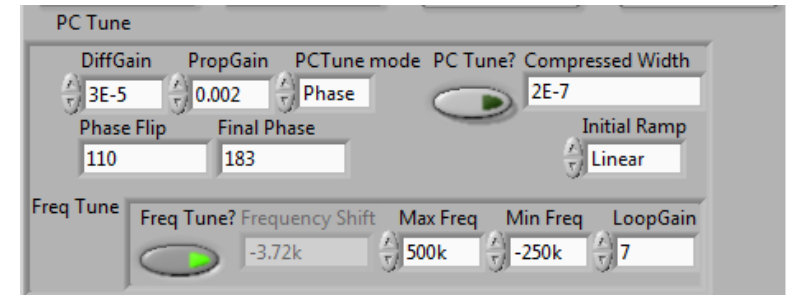


BD in the pulse compressor



Frequency shift tool

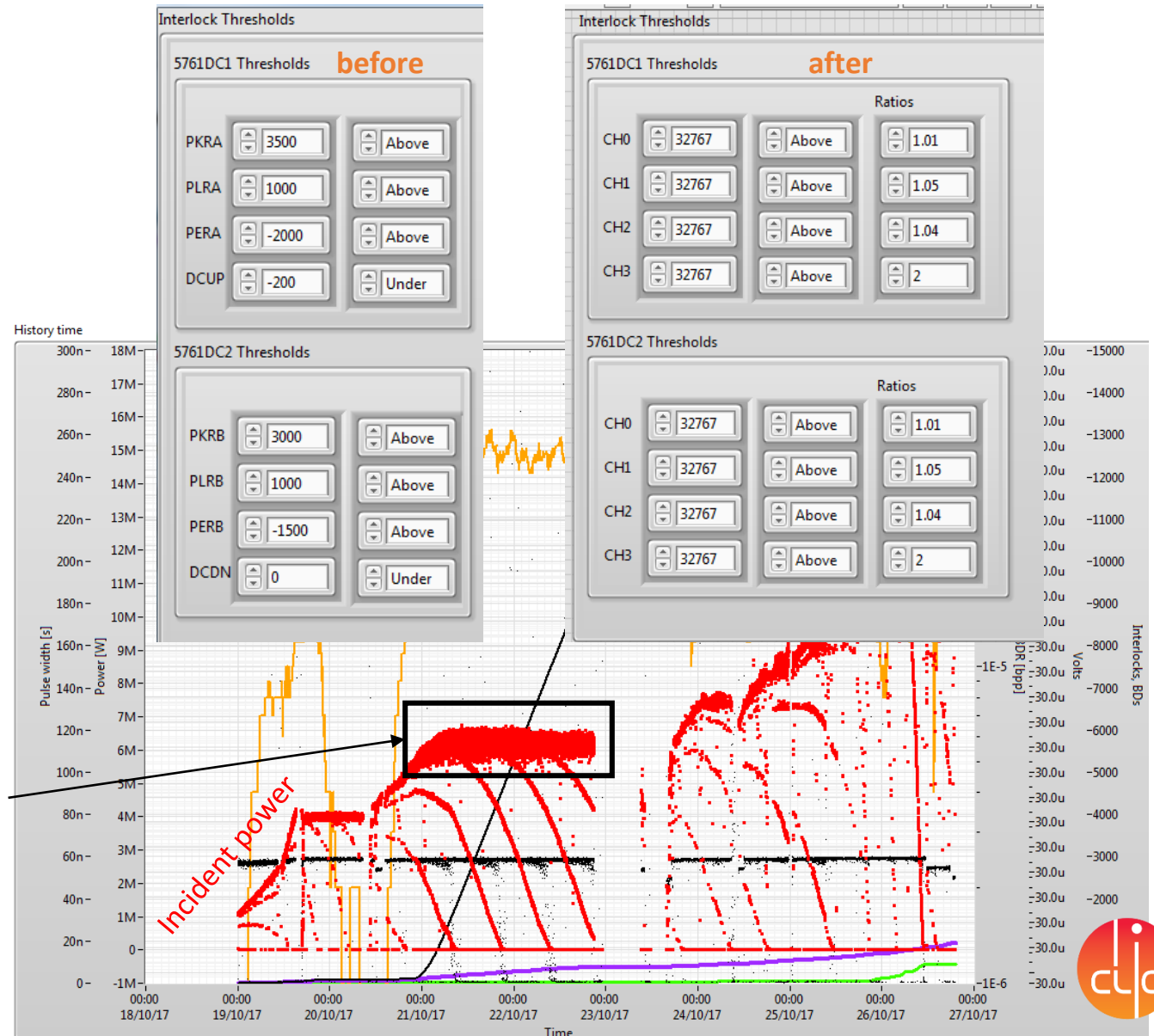
- New frequency shift tool for rapid tuning of the pulse compressor after a power lost (BD).
 - Before the tuning frequency was achieved by changing the temperature on the chillers connected to the cavities of the PC
 - Calculates de correct transmitted phase and corrects the frequency.
 - Up to 1MHz shift



Power ratio instead of fixed threshold

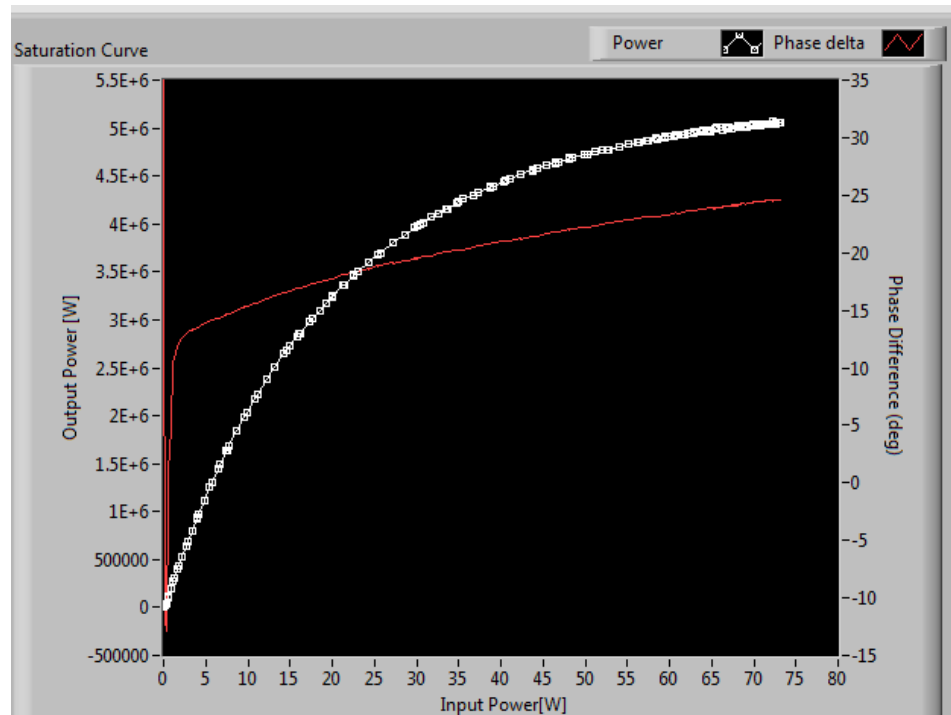
- The software interlock system is based on power thresholds to interlock in case of high reflected power at various points along the line.
- These values had to be increased during commissioning while the incident power in the line increased.
- A new tool has been introduced, it calculates the ratio between the current pulse and the previous one and compares it to a given value.
- This allows a more automatic operation of the Xboxes while protecting the line.

Unattended period (weekend):
Reflected power continuously reaching a threshold, wouldn't allow the incident power to increase.

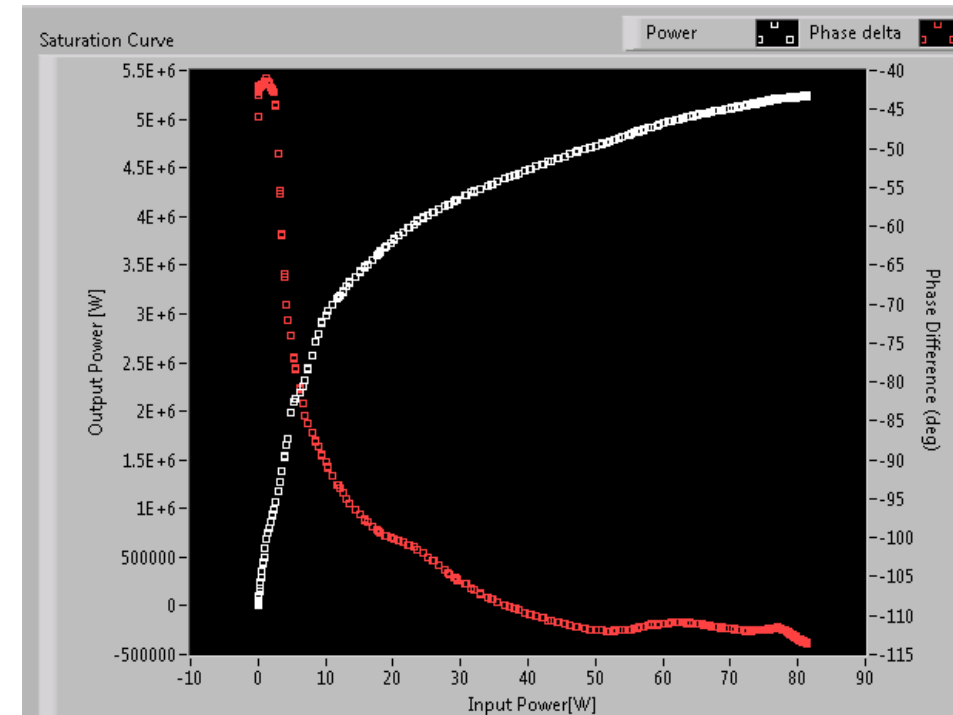


XBOX3AB

- Installation of the klystrons and pulse compressors.
- Klystron A has an unstable phase, therefore, we are waiting for a spare klystron to start conditioning structures (2months).
- New waveguide cooling system, also in CD and XBOX2.
- Conditioning of the lines and installation and testing of 3D printed loads.



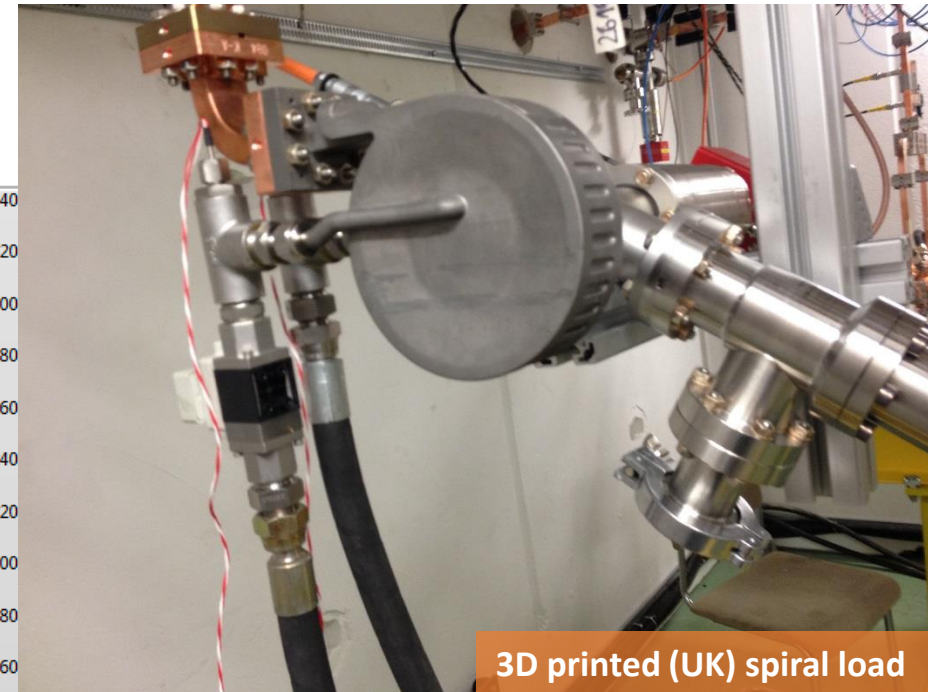
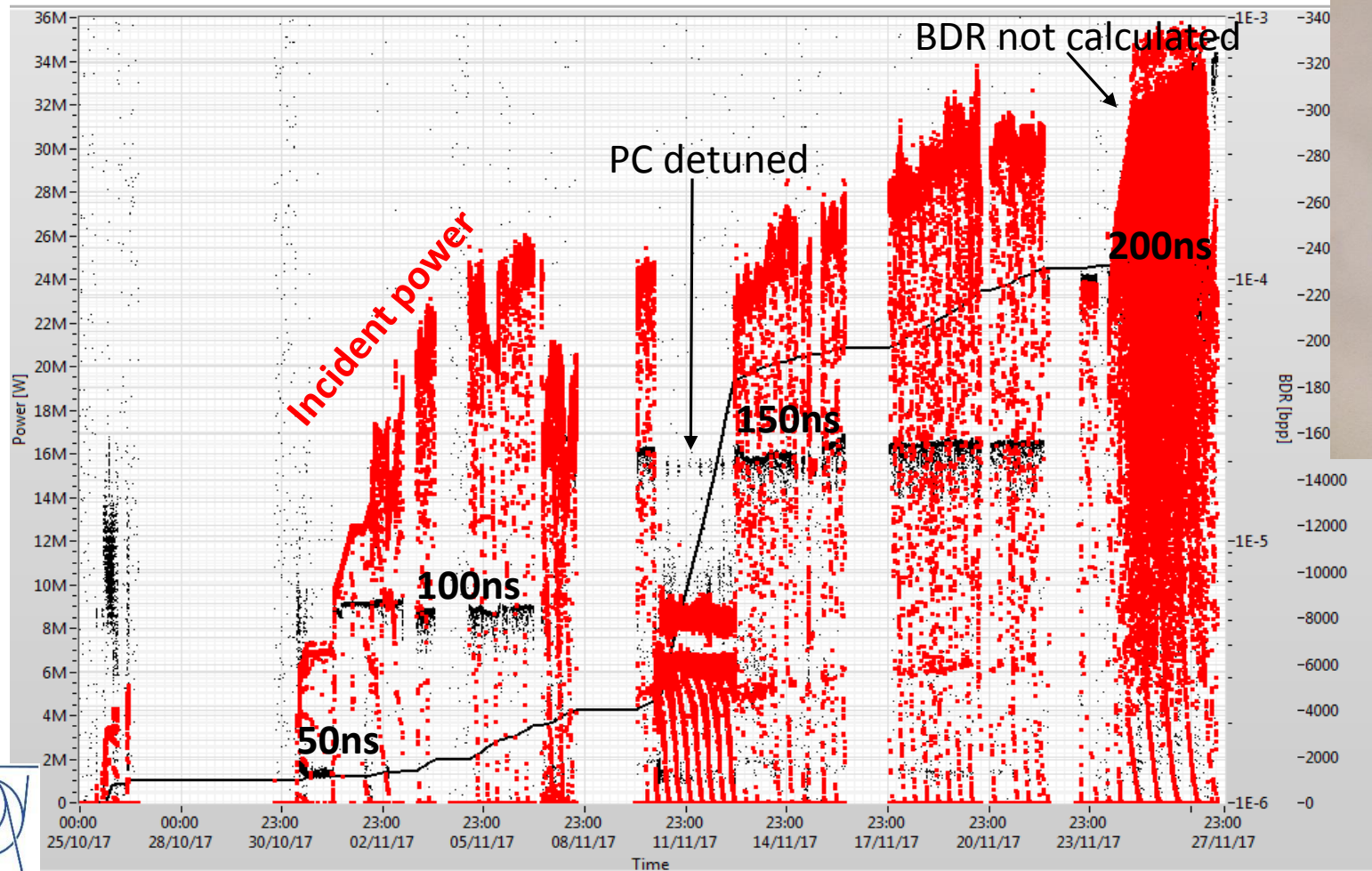
Klystron B



Klystron A

XBOX3AB – Line 1

- Oct2017: Spiral load
 - Few problems with the new software tools (solved)
 - Reached 32MW@200ns.



3D printed (UK) spiral load

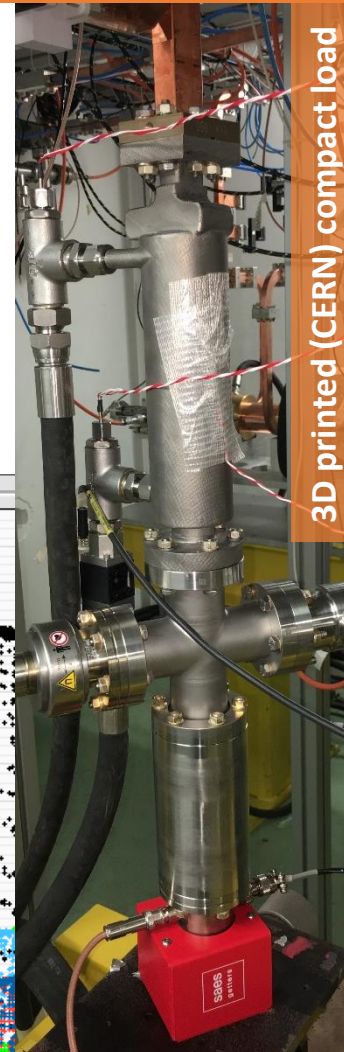
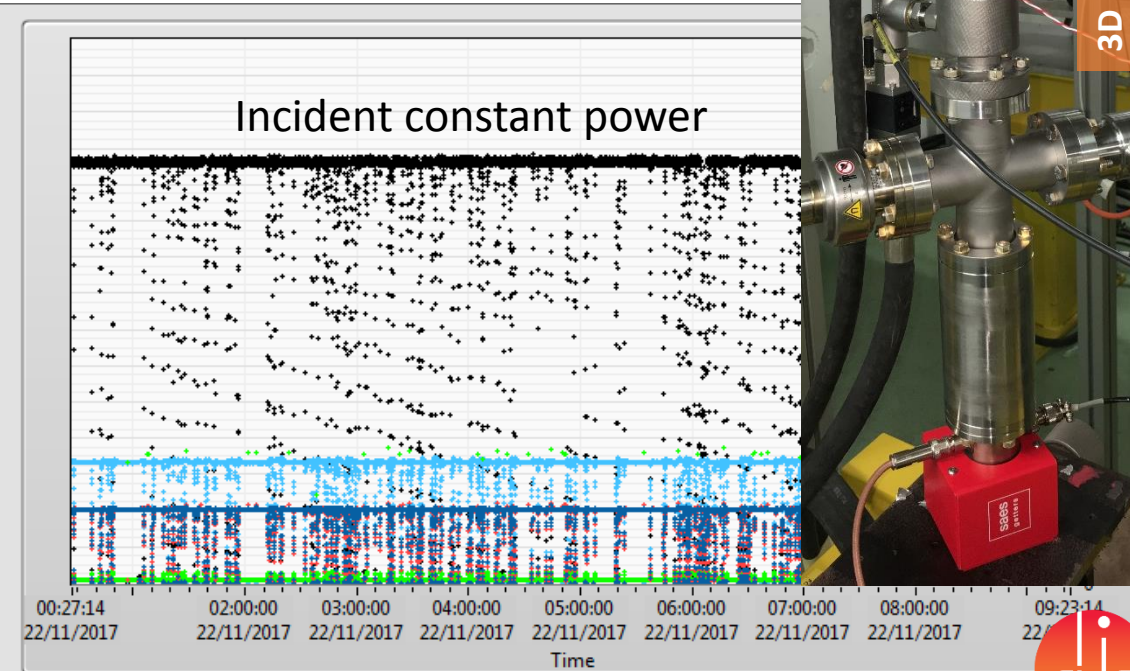
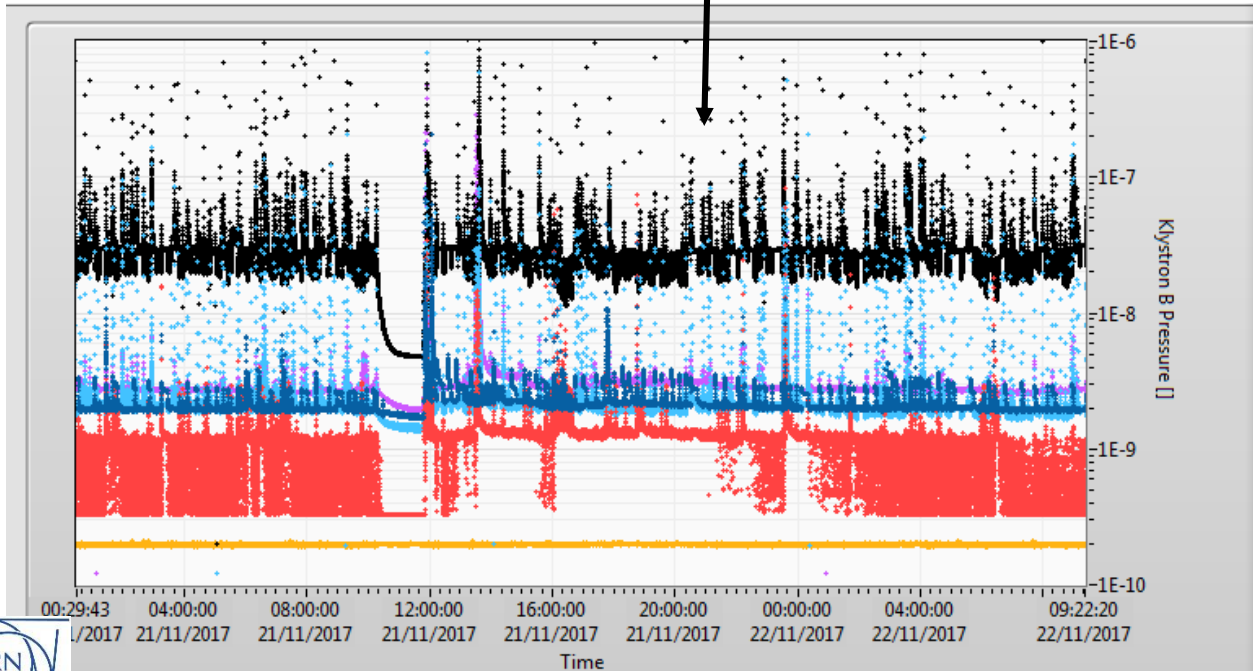
XBOX3AB – Line 2

- Oct2017: Compact load

- High baseline pressure, thus ramping slow.
- Pressure** in the load will not improve with further conditioning at constant power.
- Analysis of pressure vs. peak power and rep. rate to be done.

Comp. Pulse	Inc. Power
50ns	23MW
200ns	17MW

Load pressure @ 23MW

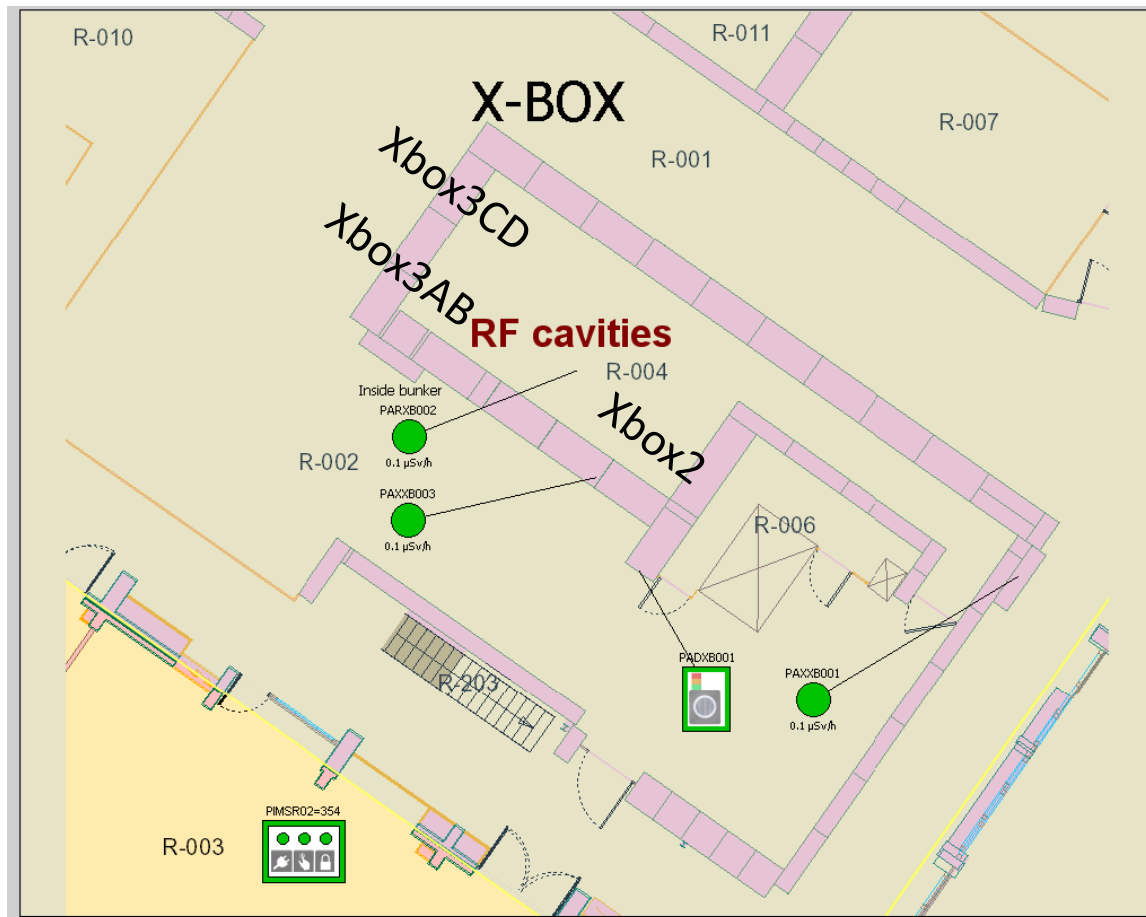


3D printed (CERN) compact load

2PKIA ampcursor Blue mean []

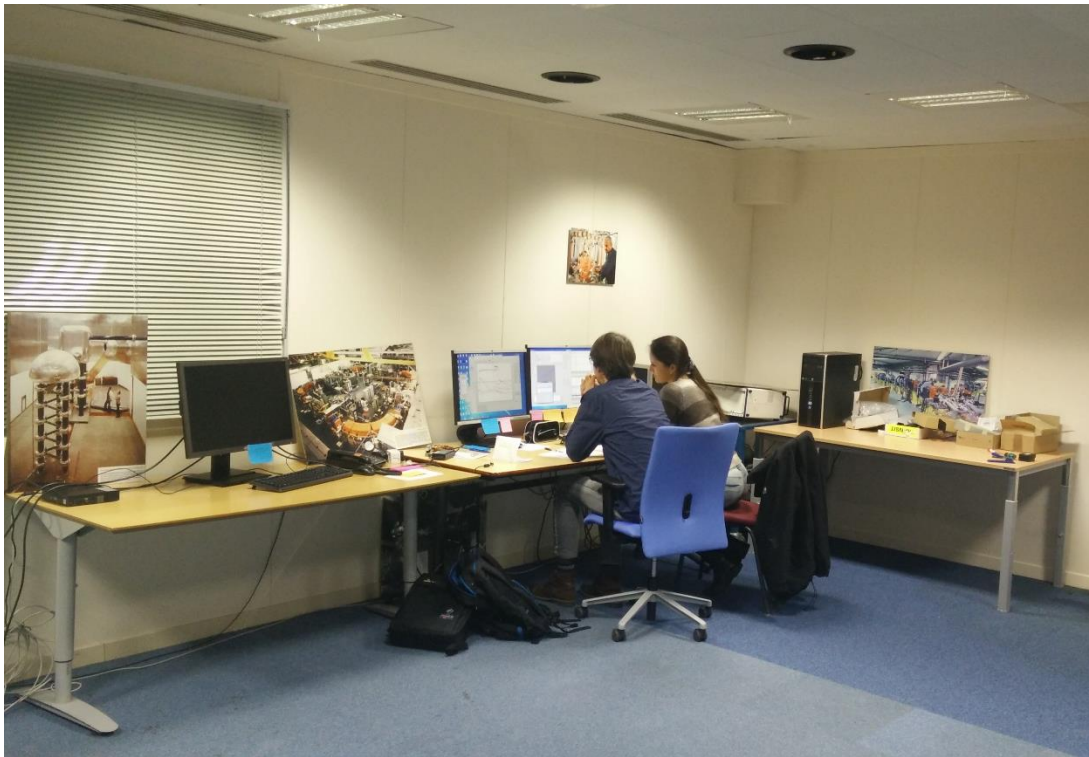
Radiation

- Exceeding the radiation limits interlocks the system
- We tried to solve the problem by removing the spectrometer from XBOX2 and shielding the downstream faraday cups with 500Kg of lead



New Control room

- Since summer 2017, located in front of the testing facilities.
- All Xboxes can be operated from the control room, including XBOX1@CTF2.
- Meeting room.



Conclusions

- **Six** operational lines, 24h operation.
- Since last WS: 3 structures tested, 4 structures and 2 loads currently under test.
- Installation of new klystron in XBOX1. Installation of spectrometer after the structure.
- Installation of spare klystrons and pulse compressors in lines 1 and 2.

- New waveguide cooling system and high power new chillers.
- New software tools for a more **autonomous** operation (freq. shift and ratio threshold).
- Radiation protection added.

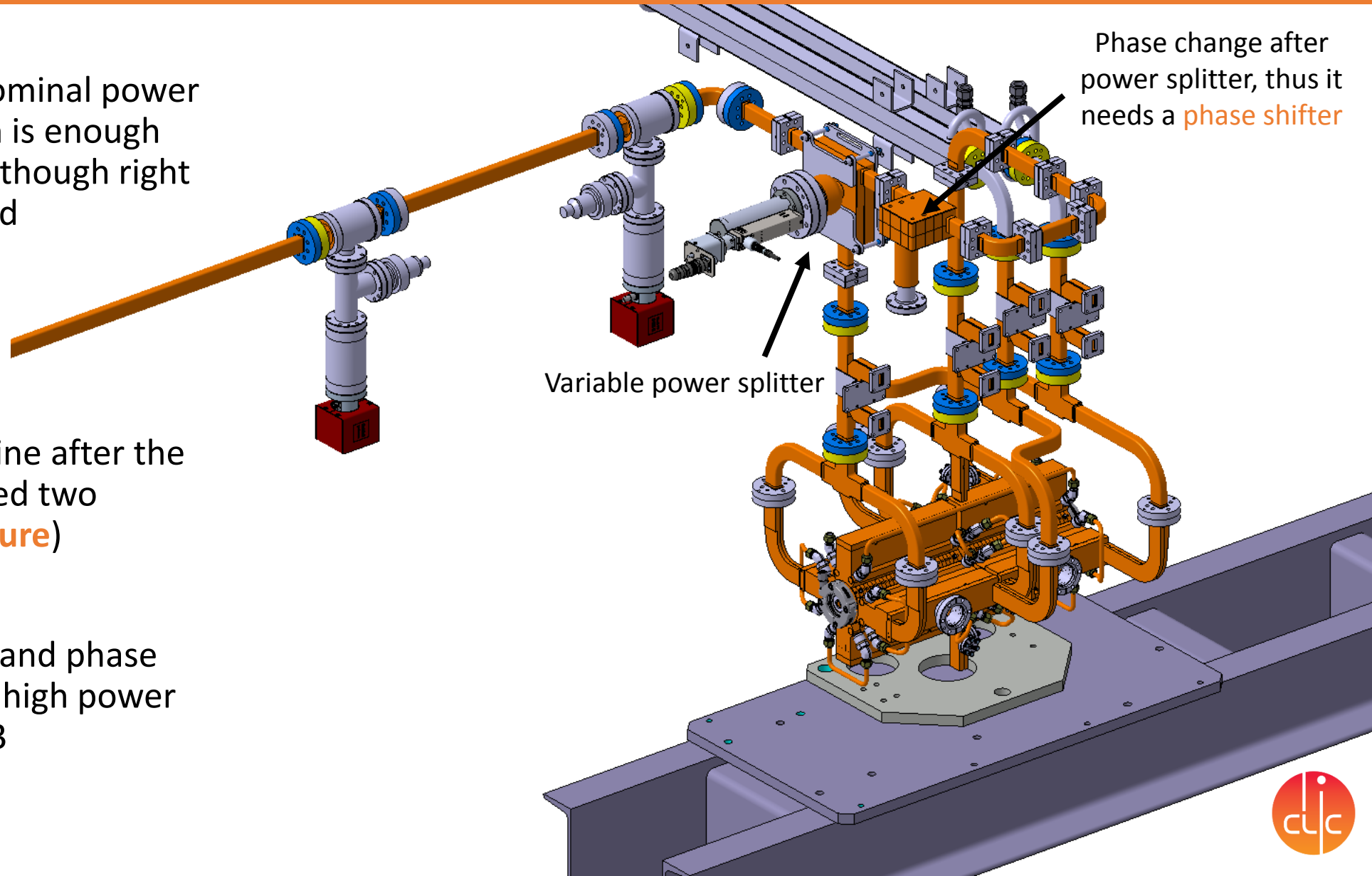
- New **control room**.

Future plans

	Current test	Next test	Next
Xbox 1	TD26CC N2	To be continued	Test with beam from CLEAR
Xbox 2	T24 PSI N1	T24 PSI N2	TD26_SiC superstructure
Xbox 3 Line 1	3D-printed Spiral load	Power Splitter	Change klystron and test TD26R1 structures
Line 2	3D-printed Compact load	Phase Shifter	
Line 3	TD24 R05 SIC N2	Change PC	
Line 4	T24 PSI N2	TD24 R05 SIC N2	Unbaked/Baked TD24

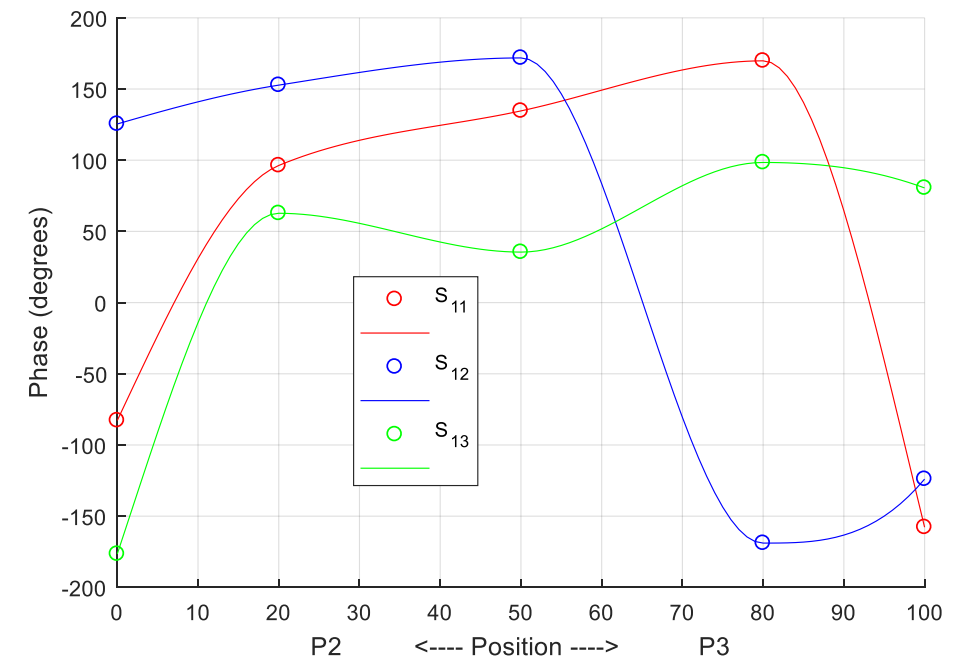
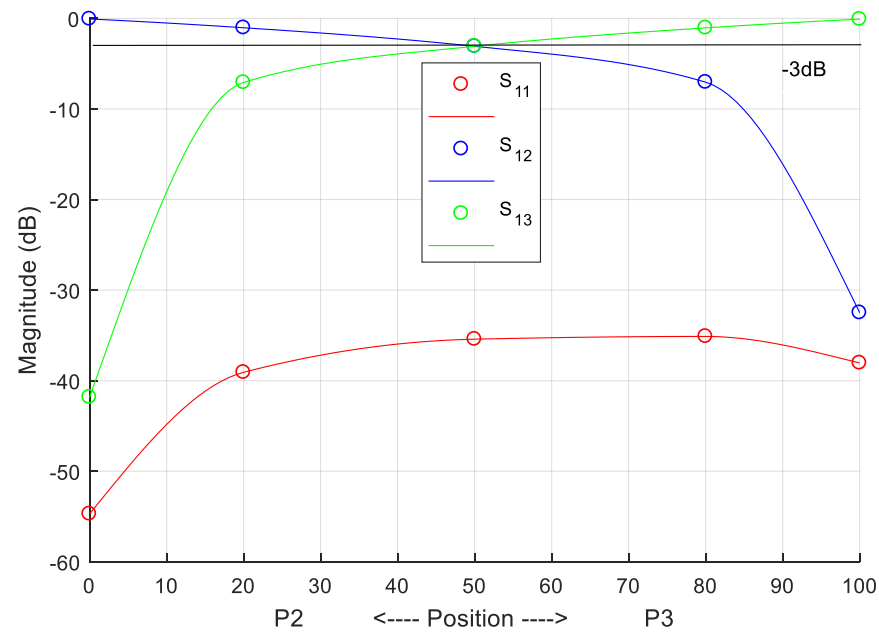
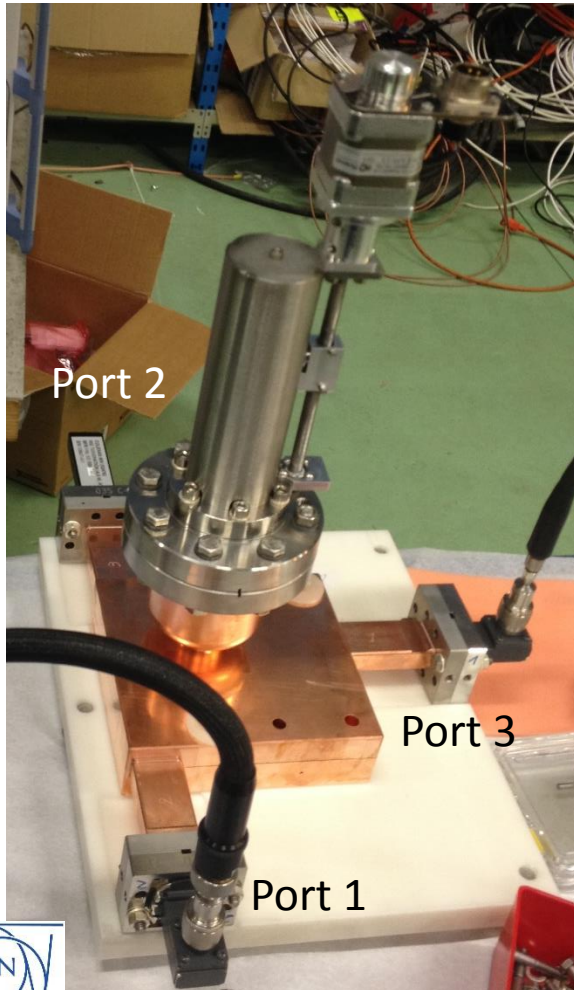
Future plan – XBOX2 upgrade

- 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



XBOX2 upgrade

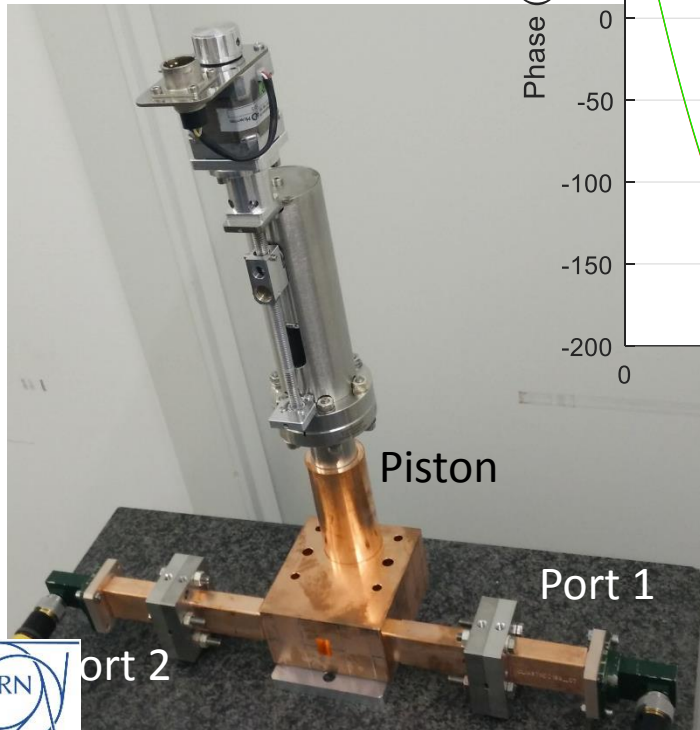
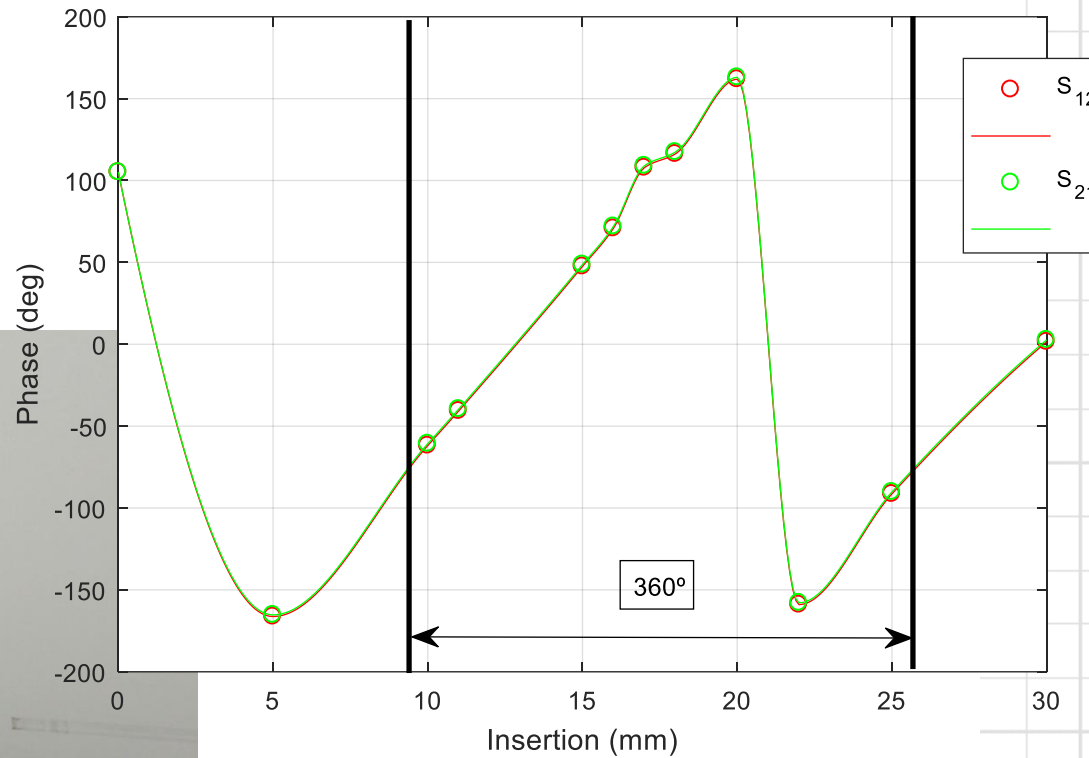
- VNA measurements done to variable power splitter



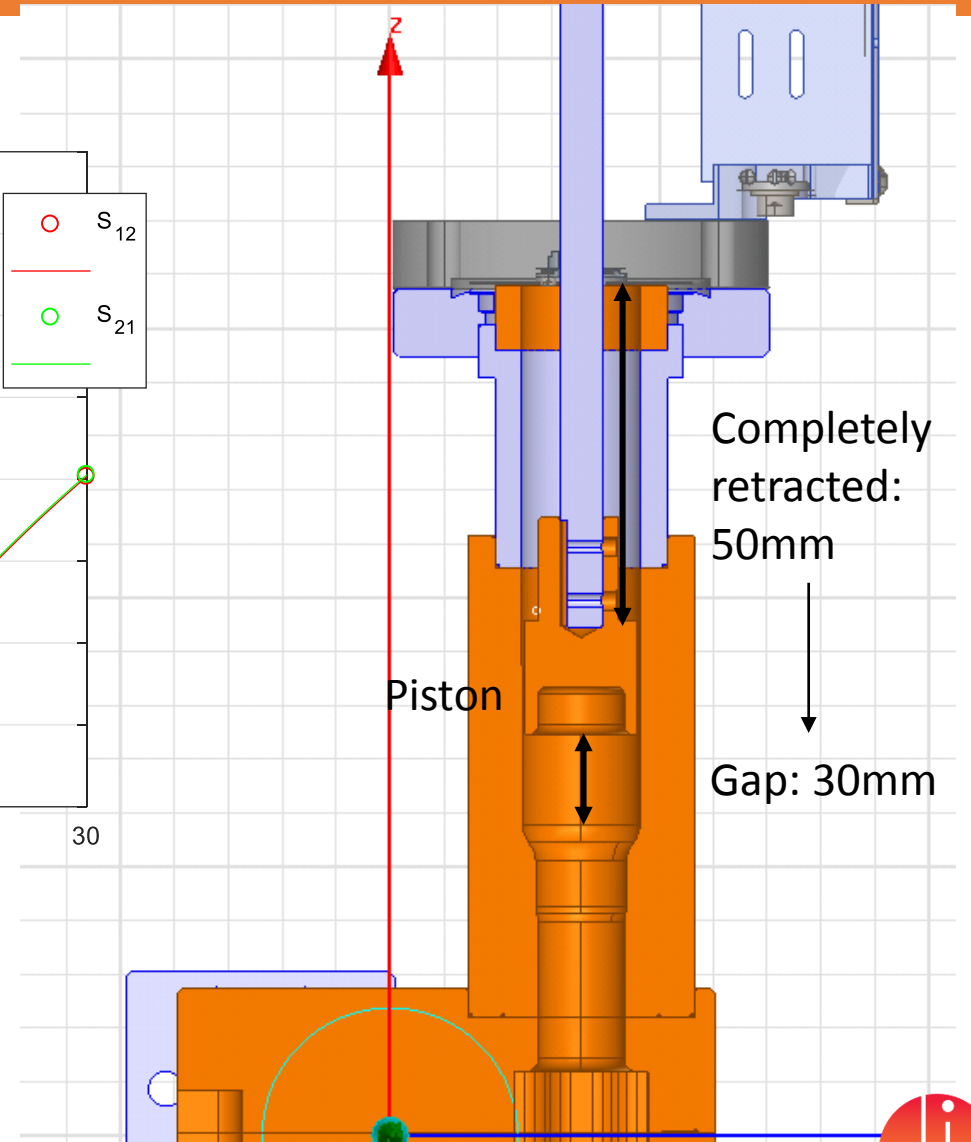
Phase changes when moving the piston

XBOX2 upgrade

- VNA measurements done to variable phase shifter



1mm insertion $\sim 21^\circ$ phase shift
17mm insertion $\sim 360^\circ$ phase shift



Credits

- Many people contribute daily to the operation of the Xboxes, and many of them have also contributed to this presentation either as an inspiration or by pictures/graphs etc.
- I would like to thank Matteo Volpi, Ben Wooley, Jan Paszkiewicz, Anna Vnuchenko, Thomas Lucas, Nuria Catalan Lasheras, and the rest of the **Xbox team**.

Thanks for your attention