X-band test facilities at CERN

CLIC workshop 2019

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Outline

1. Xboxes past year tests
   - Structures
   - Components

2. Main technical issues

3. Future plans
   - Upgrade of Xbox2
   - Upgrade of Xbox1 and connection to CLEAR
   - Master schedules

CPI 50MW 1.5us klystron
Scandinova Modulator
Rep Rate 50Hz
Beam test capabilities

Previous tests:
2013 TD24R05 (CTF2)
2013 TD26CC-N1 (CTF2)
2014-15 T24 (Dogleg)
2015-16 TD26CC_N1(Dogleg)

Ongoing test:
June 2017 TD26CC_N2

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

Previous tests:
2014-15 CLIC Crab Cavity
2015-2016 T24_OPEN
2016 TD26CC_N3
2017 T24_PSI_N1
2018 T24_PSI_N2

Ongoing test:
Dec2016- TD26CC_N3

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

Previous tests:
2017:TD24_SiC_N1
2017: T24_PSI_N1&N2
2018: TD24_SiC_N2; Phase shifter; Power variable splitter

Ongoing test:
T24_N4&N5; TD24_BO&UBO

Last year tests

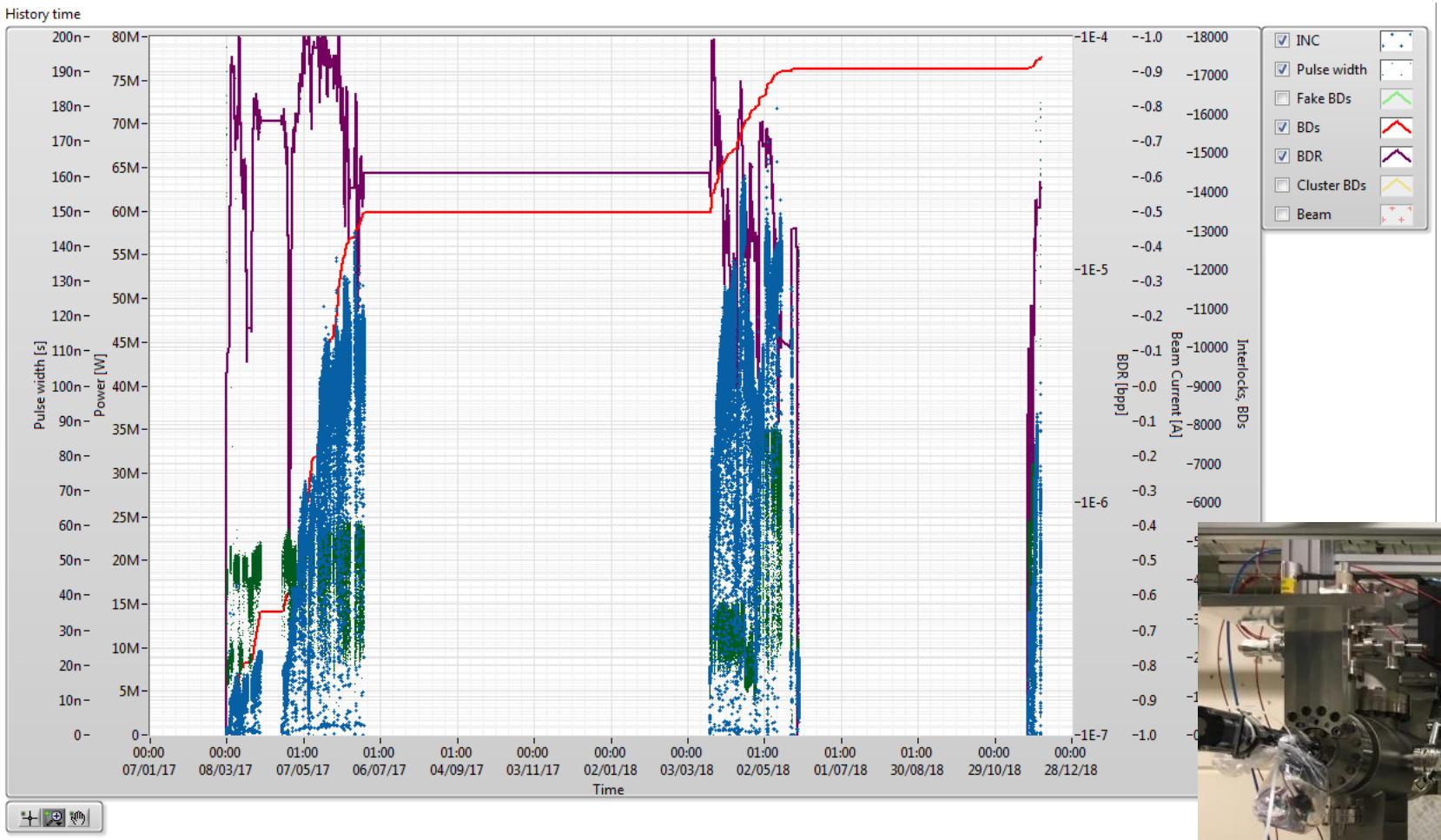
STRUCTURES

Baseline CLIC prototypes with and without damping features, new assembly solutions, ARIES-TNA program

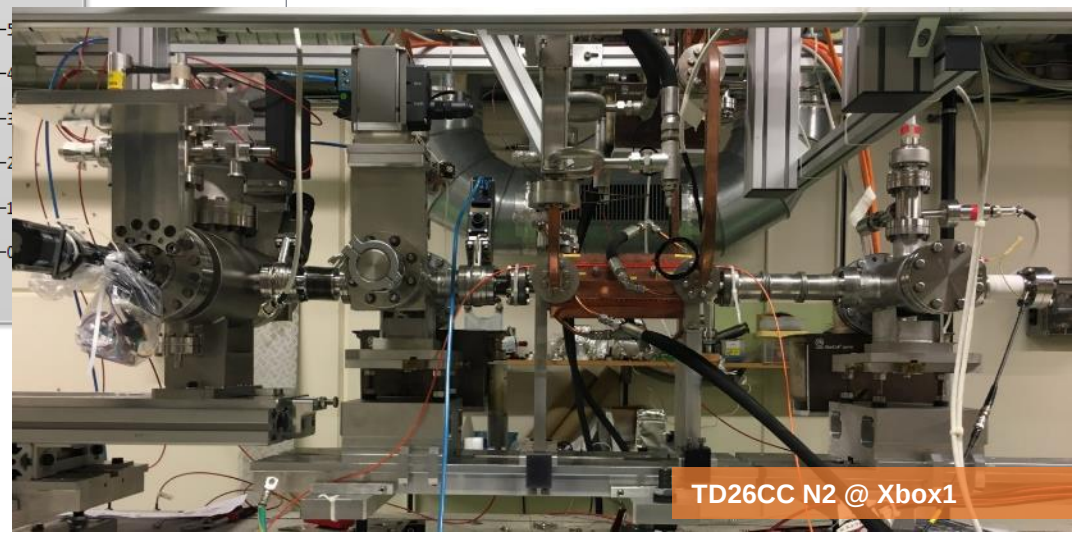
COMPONENTS

Components needed for operating the facilities but also for a first stage 380 GeV, klystron machine.

TD26CC_N2 @ xbox1

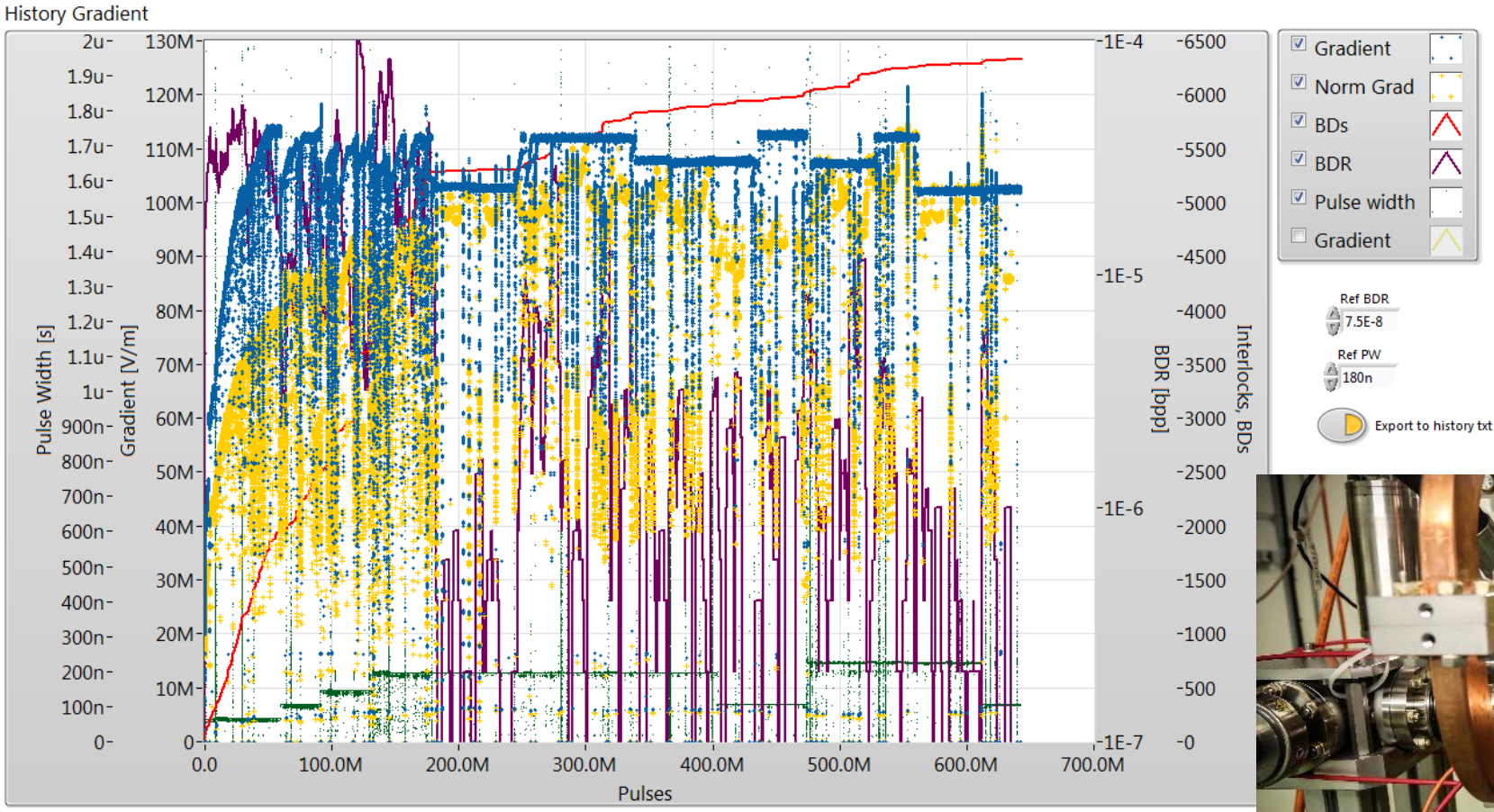


	TD26CC_R05_N2
Max gradient	60 MV/m
Max pulse length	100 ns

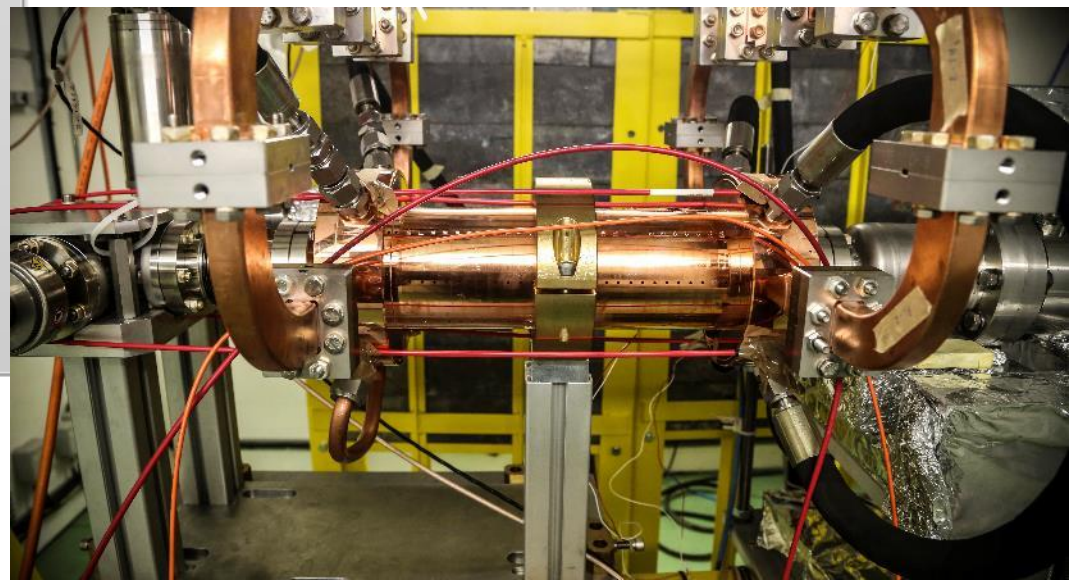


Suffers from klystron and modulator failure and periodic maintenance of CLEAR

T24_PSI_N2@XBOX2

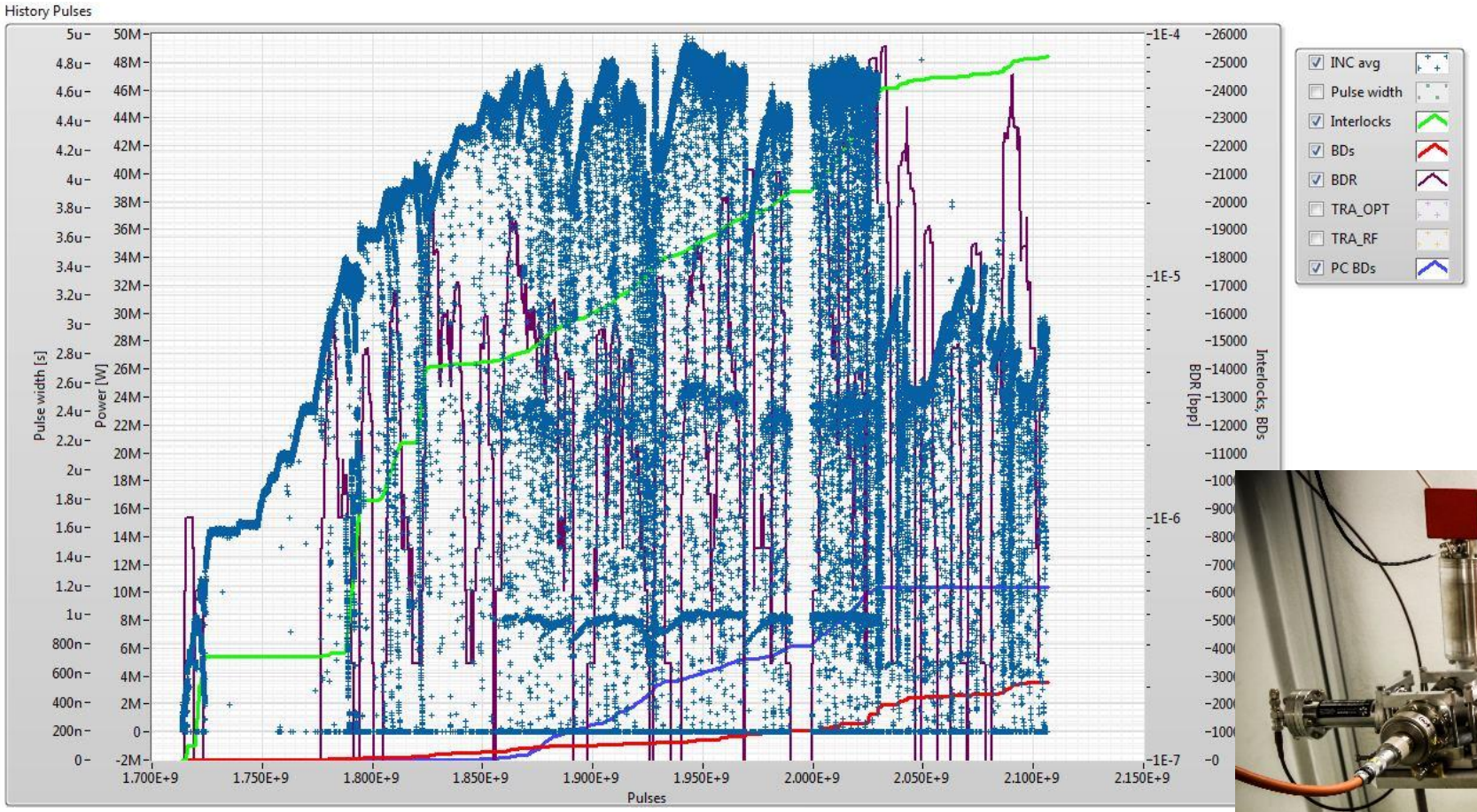


	T24_PSI_N2
Max gradient	113 MV/m
Max pulse length	200 ns



See "High-gradient test results" by L. Millar

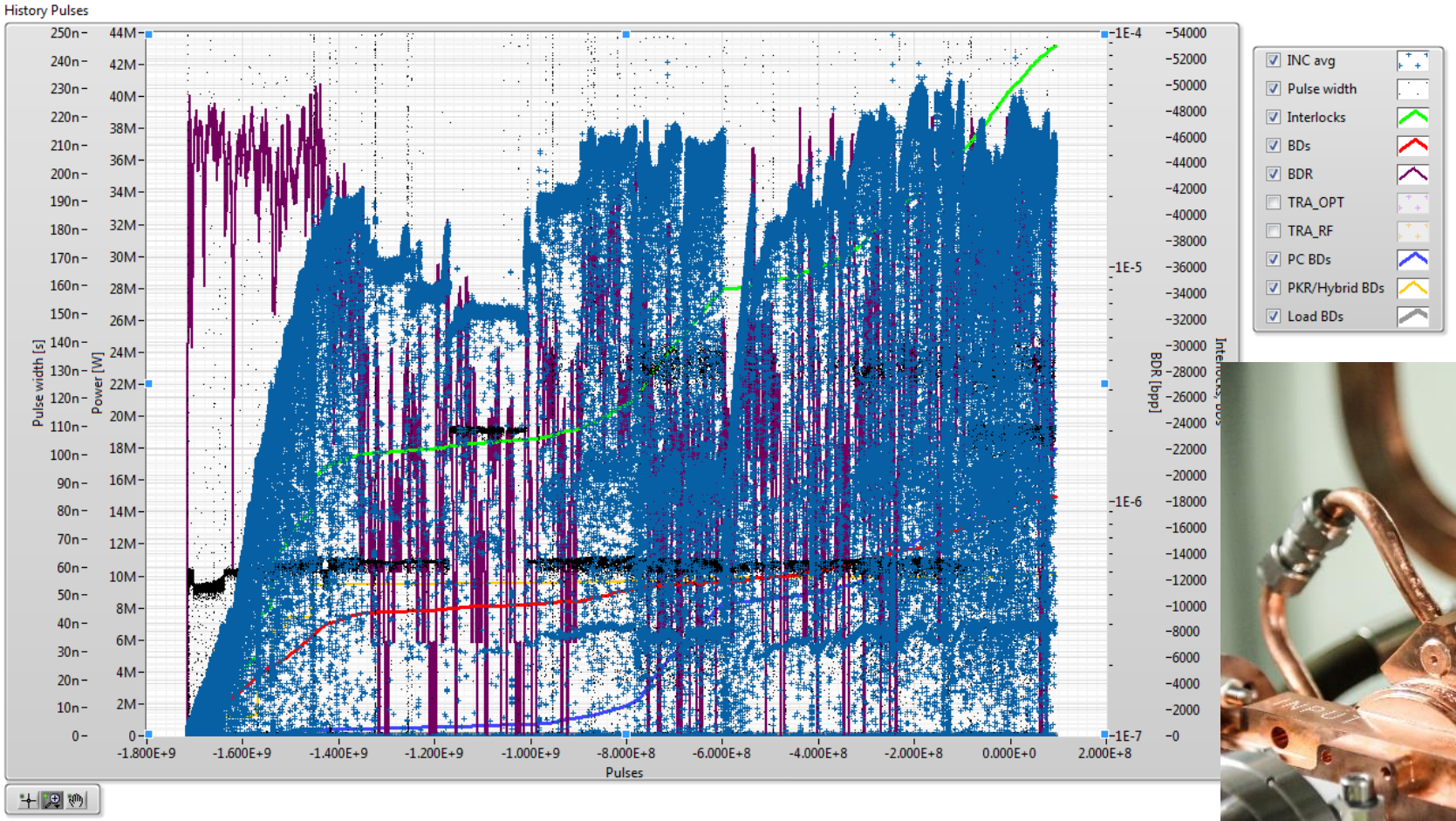
TD24SiC_N2 @ xbox3



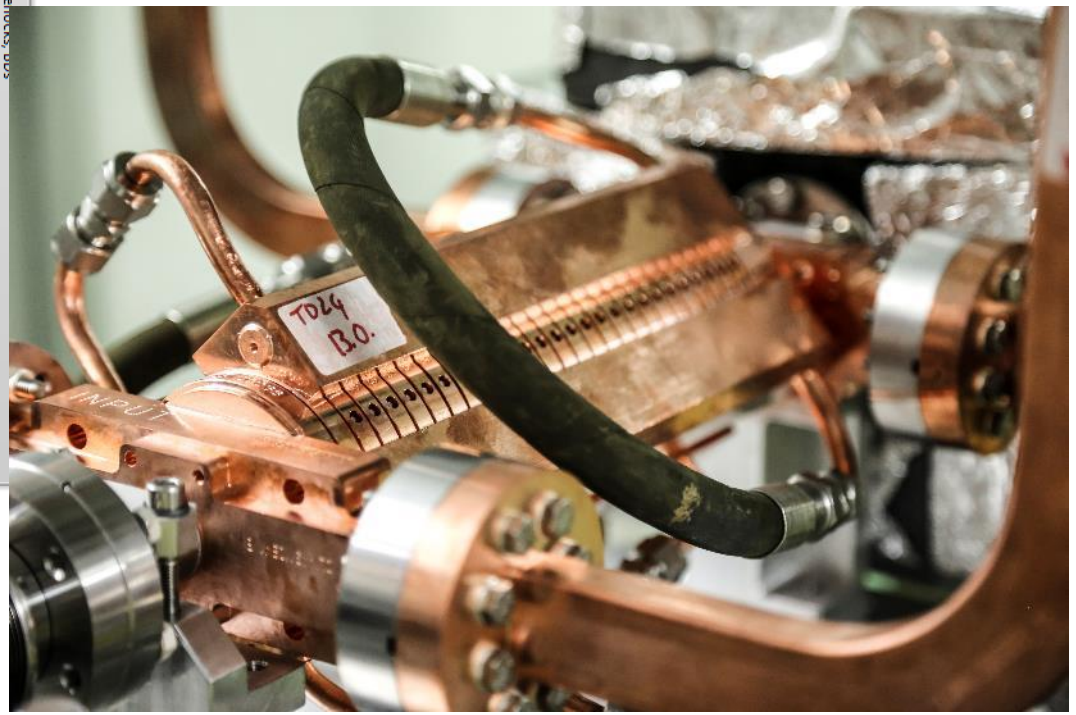
	TD24_SiC_N2
Max gradient	110 MV/m
Max pulse length	50 ns

See “High-gradient test results” by L. Millar

TD24 BO in 2018 @ xbox3

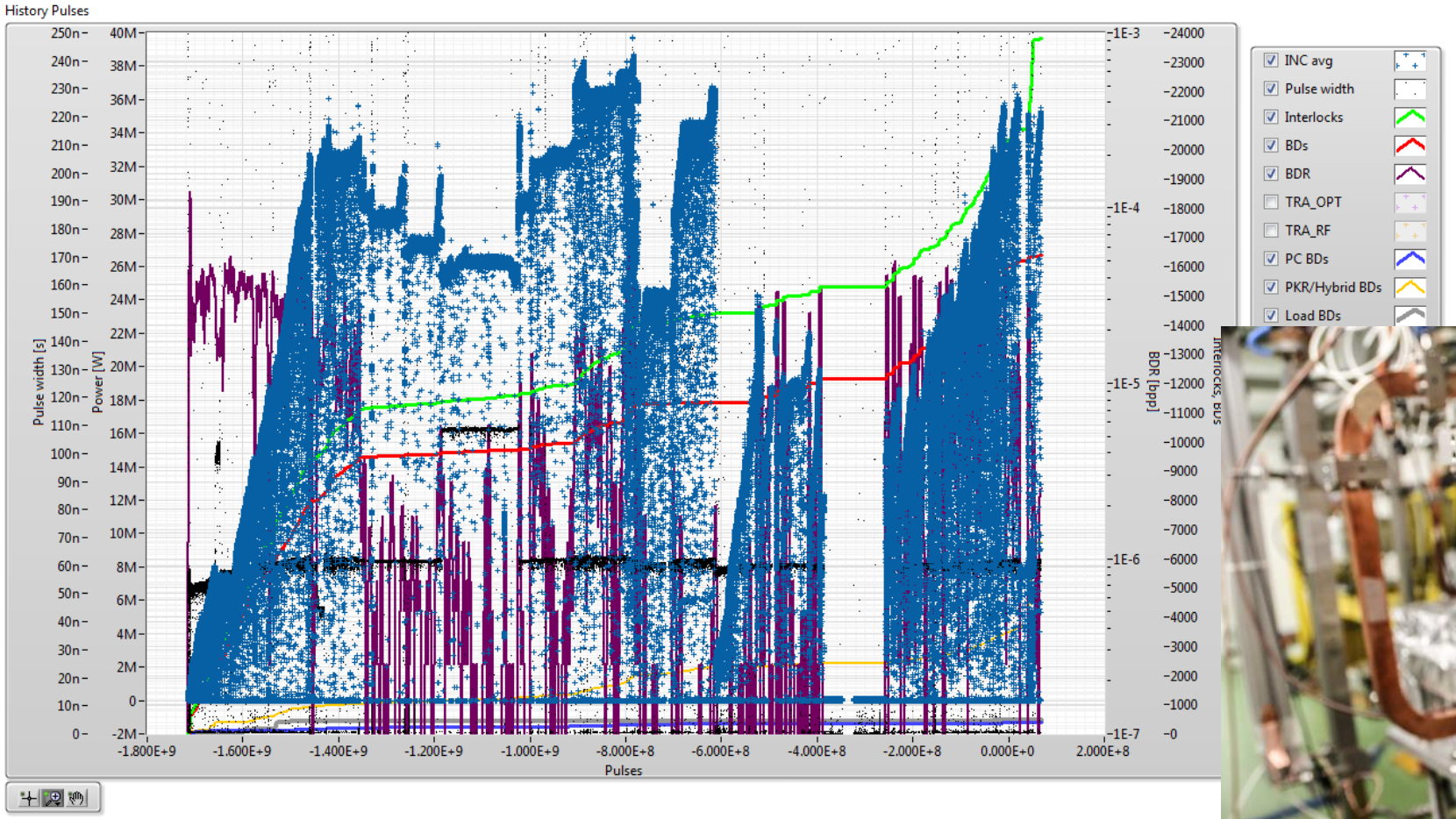


	TD24_N1 (BO)
Max gradient	97 MV/m
Max pulse length	60ns

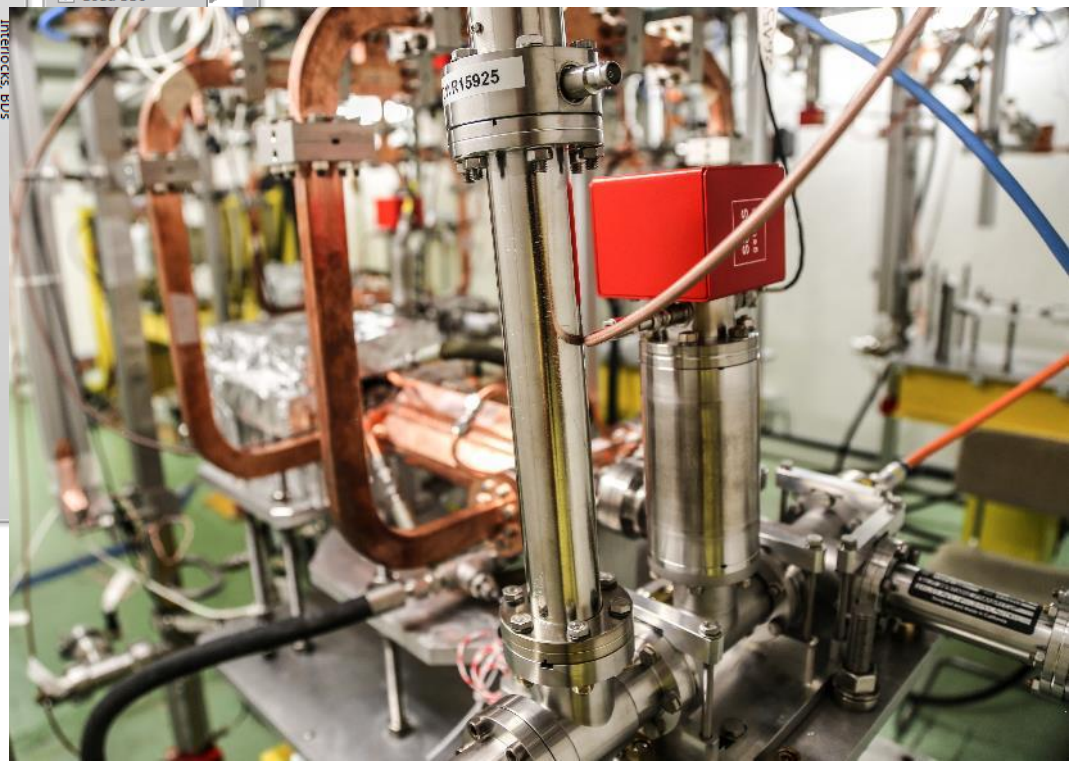


See "High-gradient test results" by L. Millar

TD24 UBO in 2018 @ xbox3

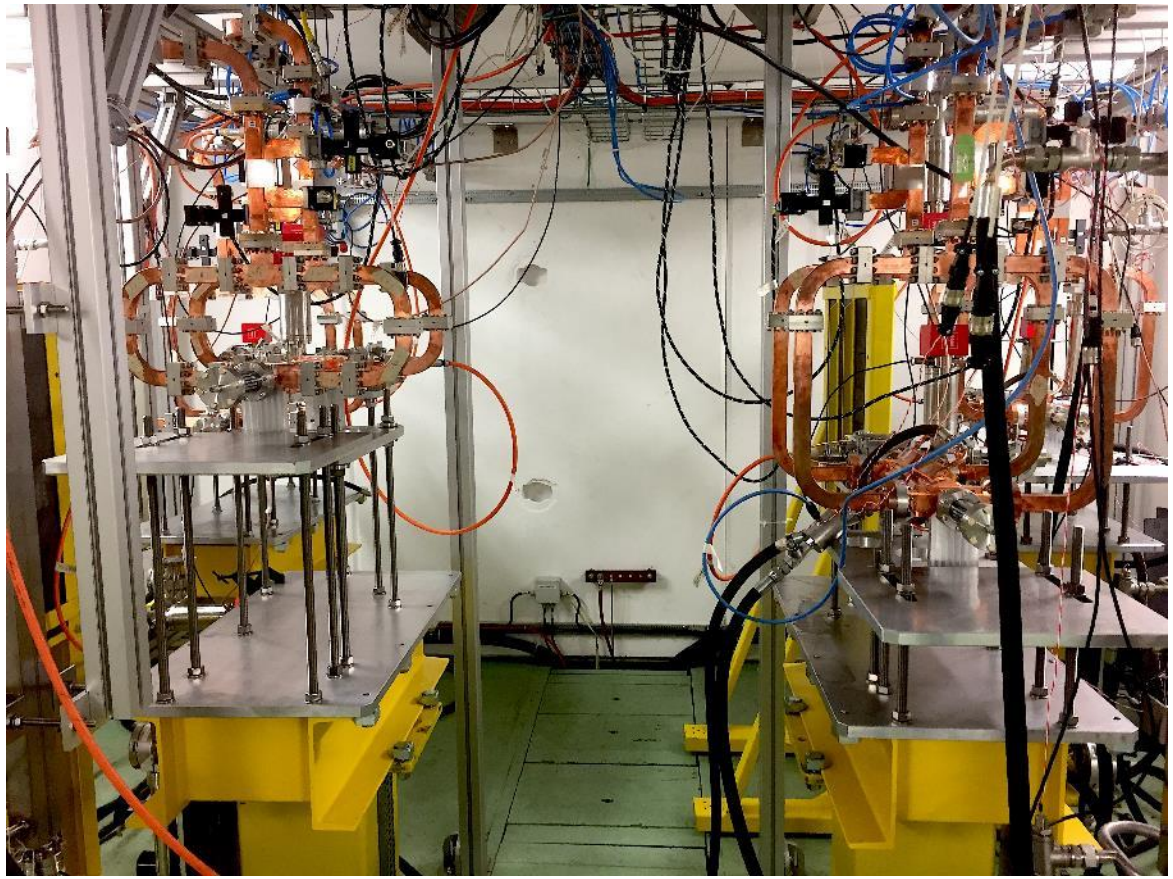


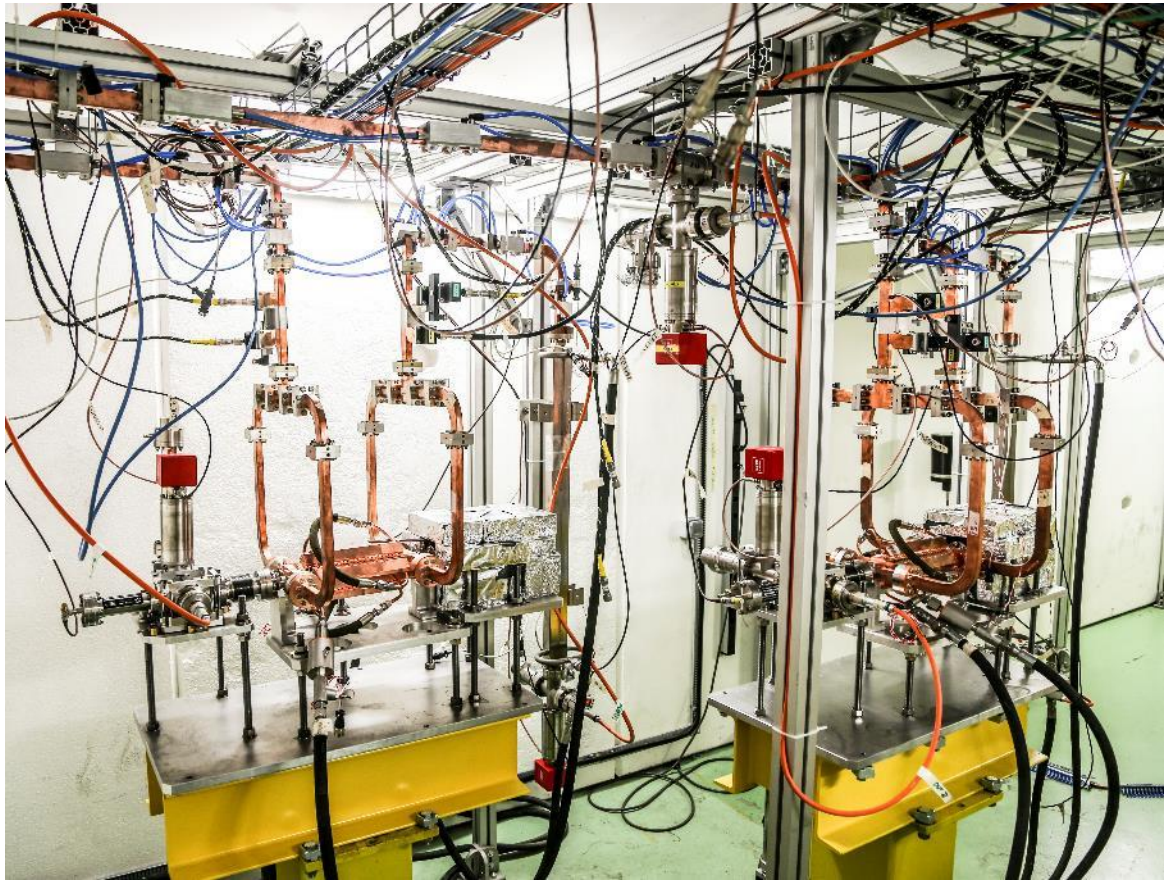
	TD24_N1 (UBO)
Max gradient	95 MV/m
Max pulse length	60ns



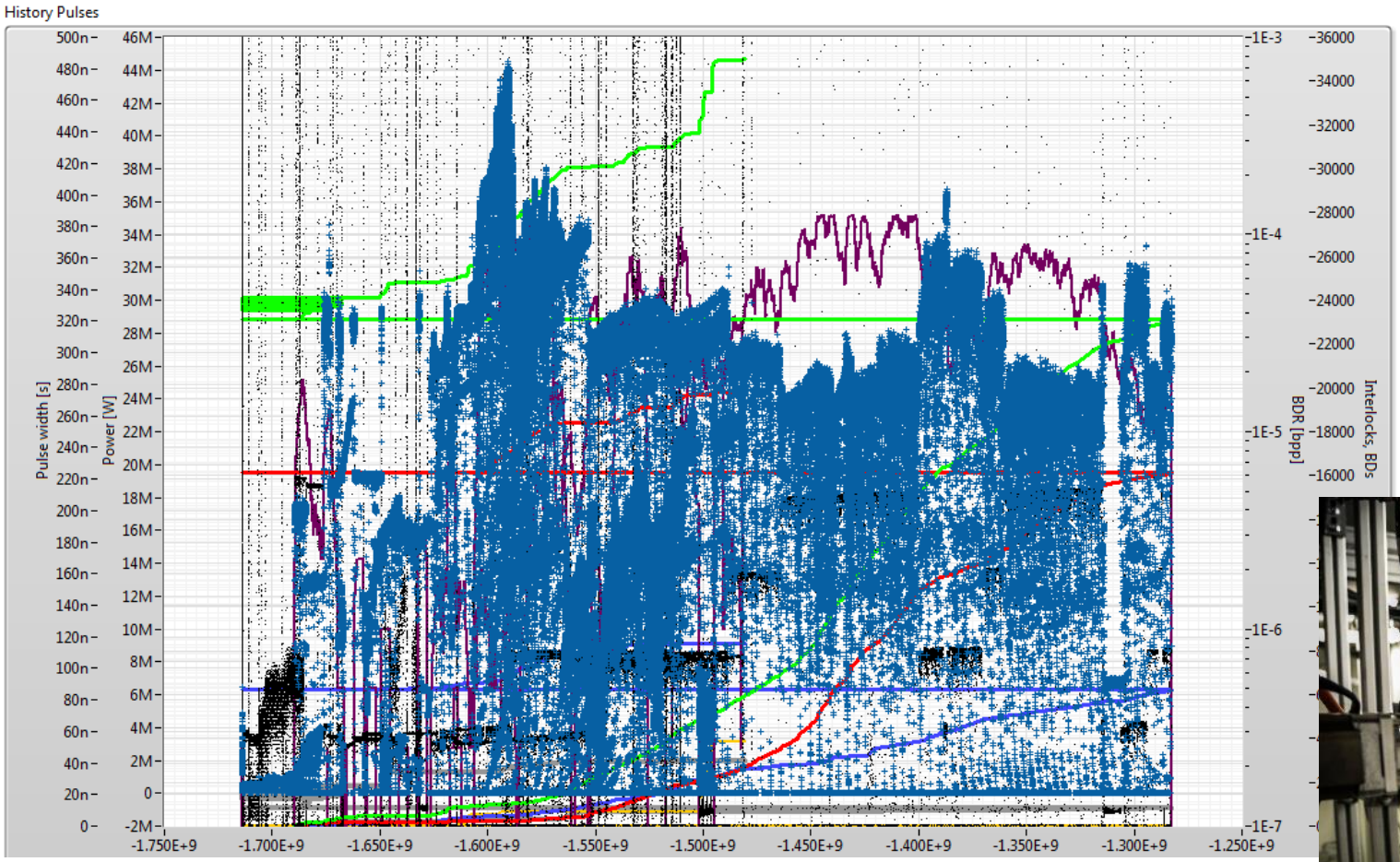
See "High-gradient test results" by L. Millar

Four structures testing in Xbox3

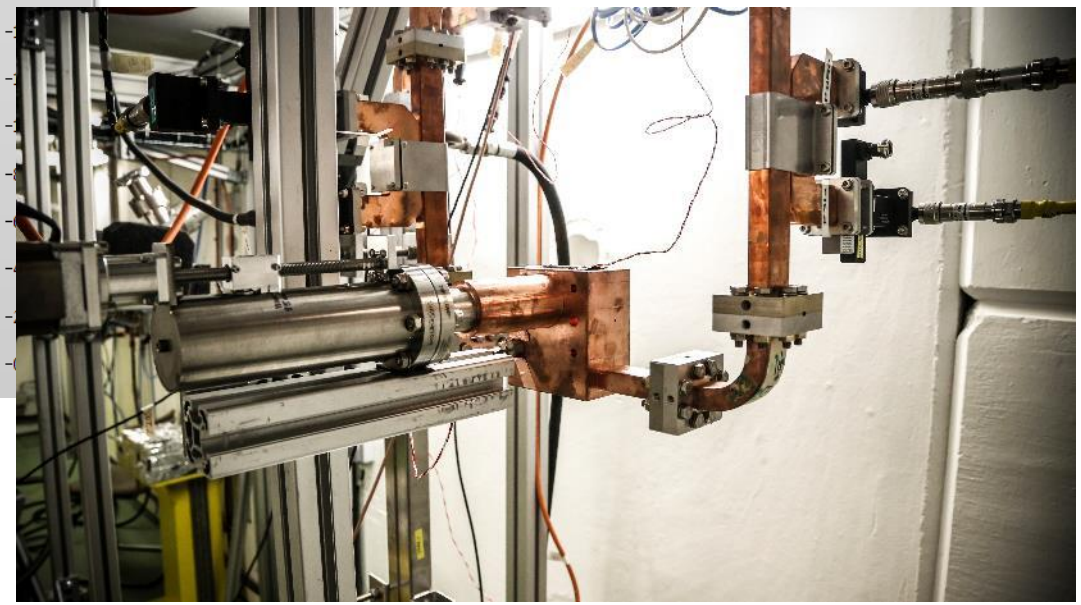




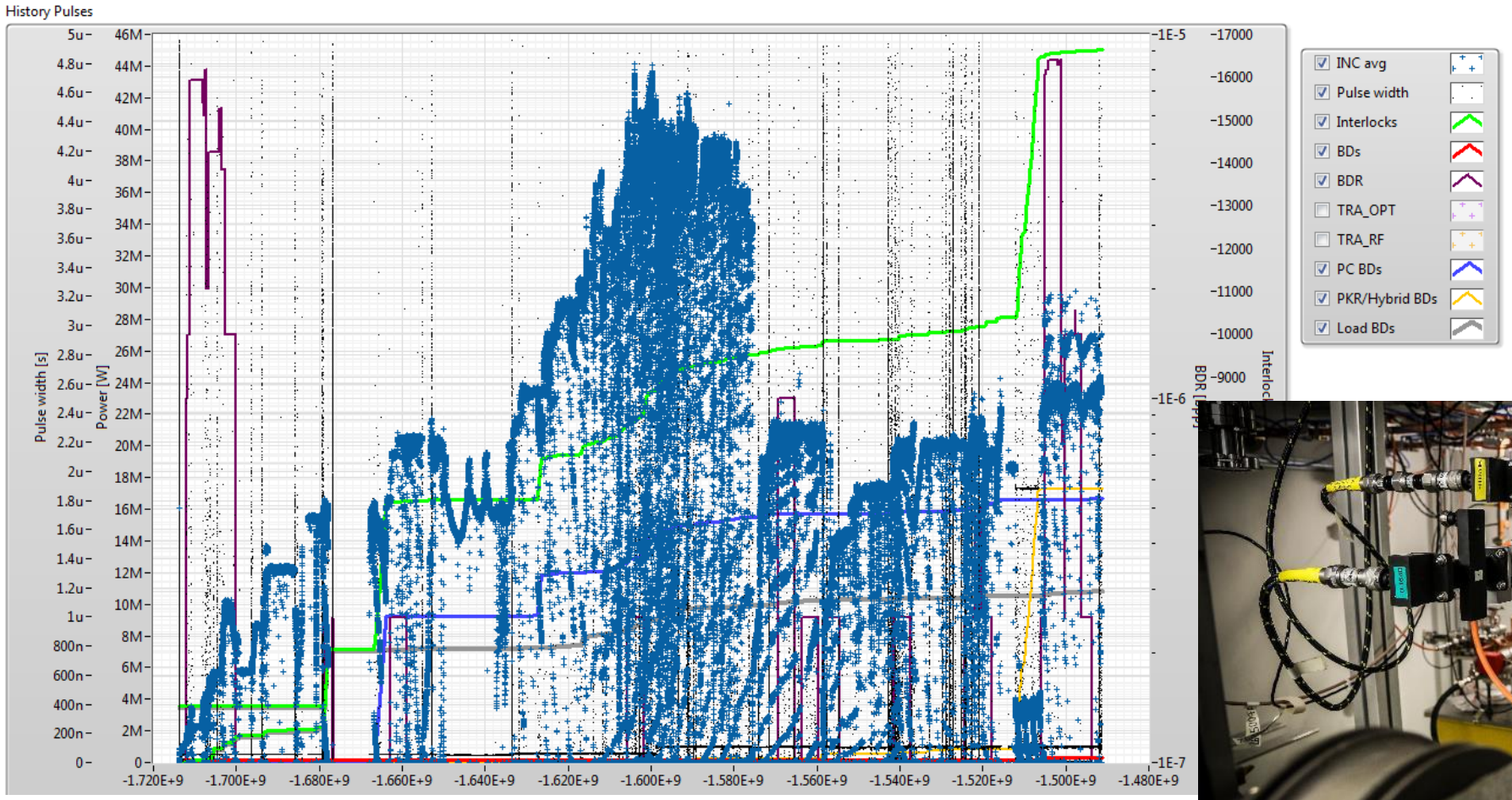
Phase Shifter in line 1



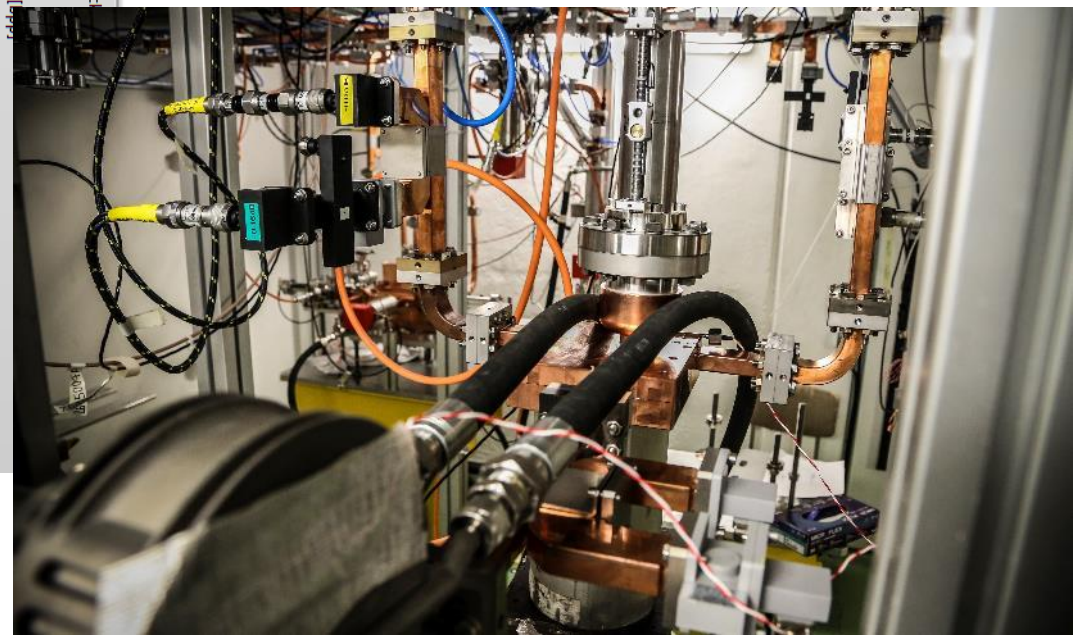
	Phase Shifter #1
Max peak power	42
Max pulse length	50



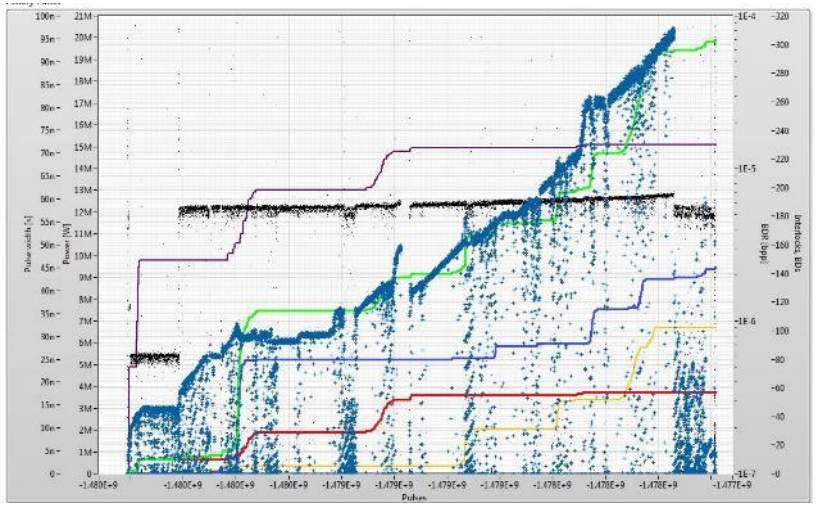
Power splitter in line 2

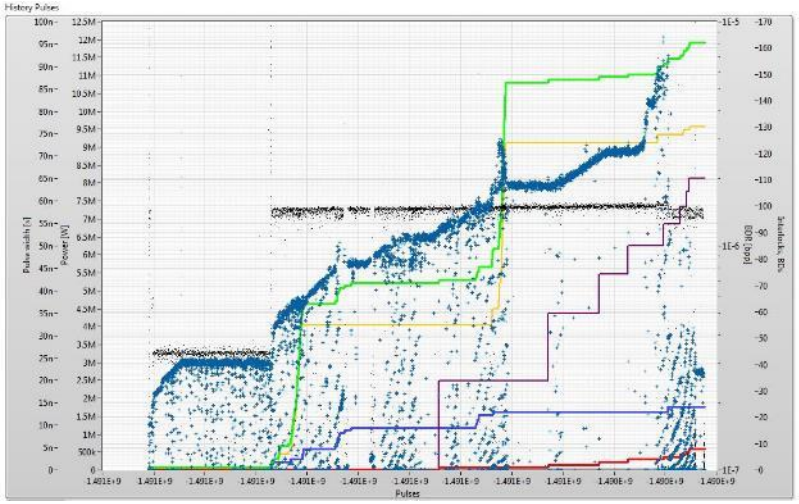


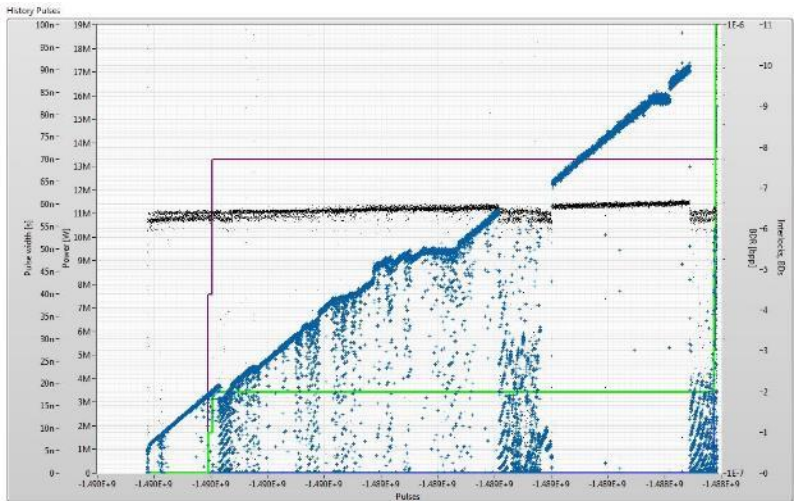
	Variable power splitter
Max peak power	42
Max pulse length	50

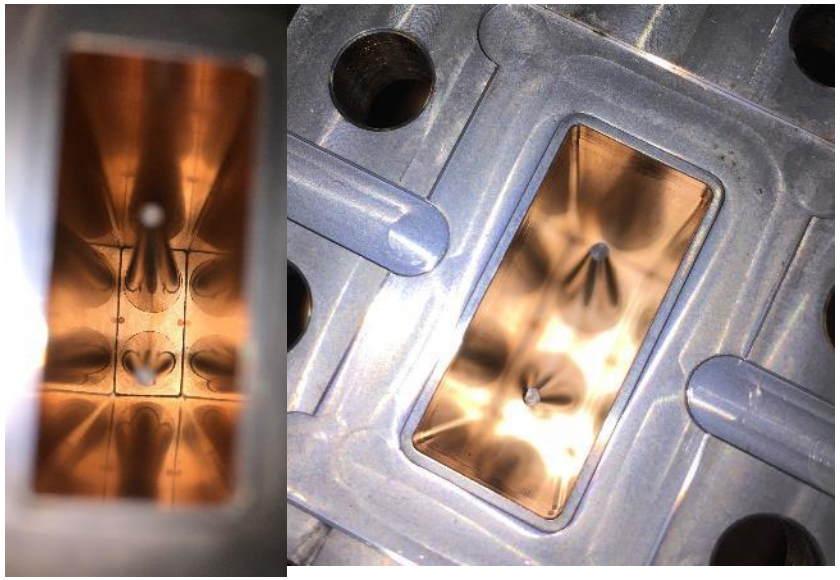


Terminators





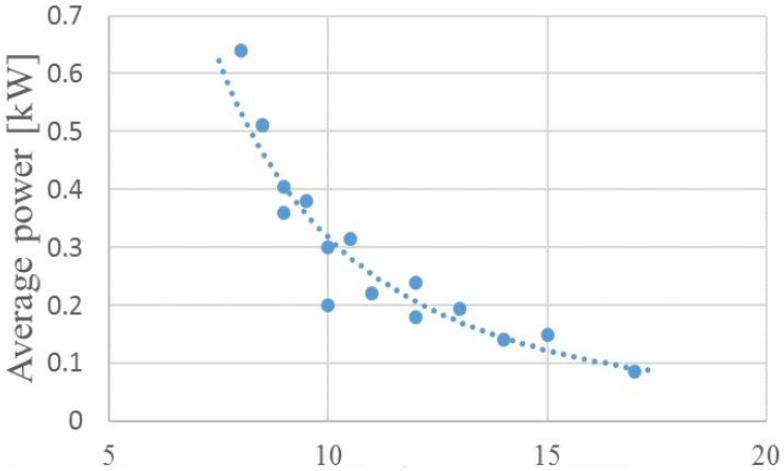


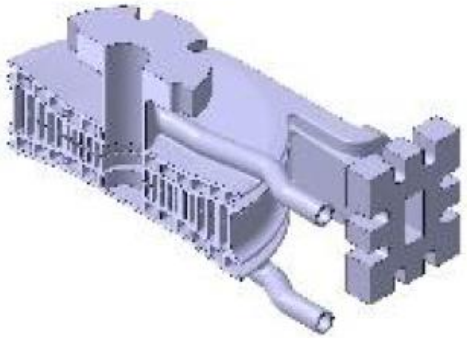


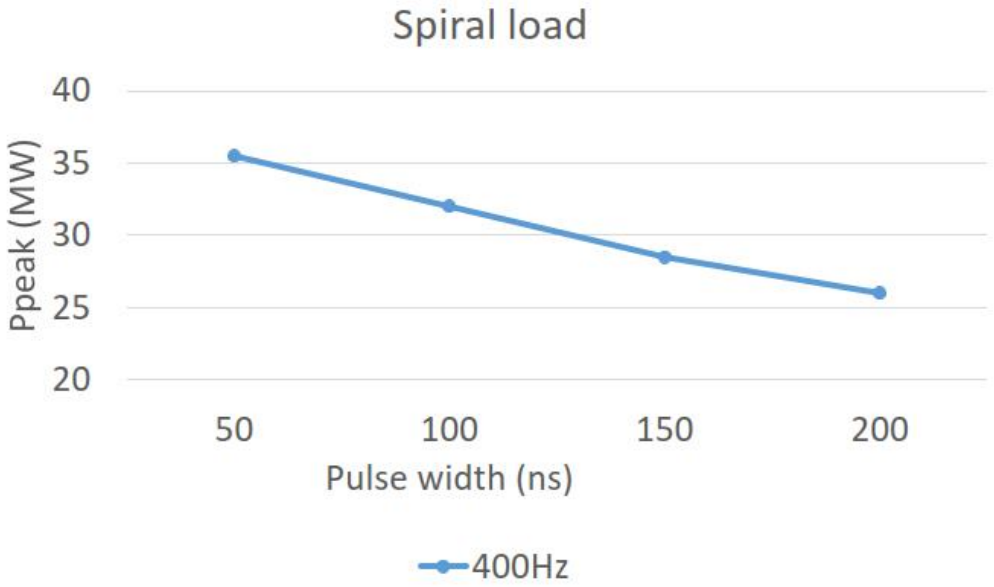
Looking for low average power loads to terminate hybrids fourth port

Y. Cuvet, A. Grudiev, C. Serpico

Additive manufacturing loads final results

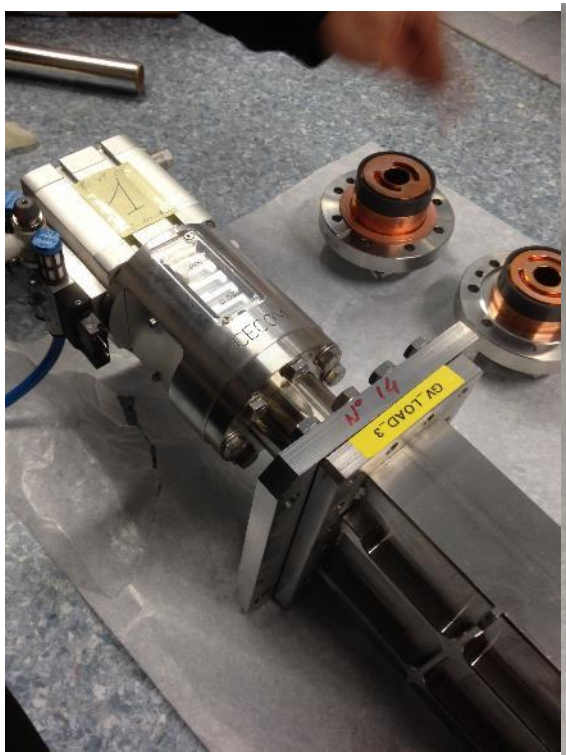


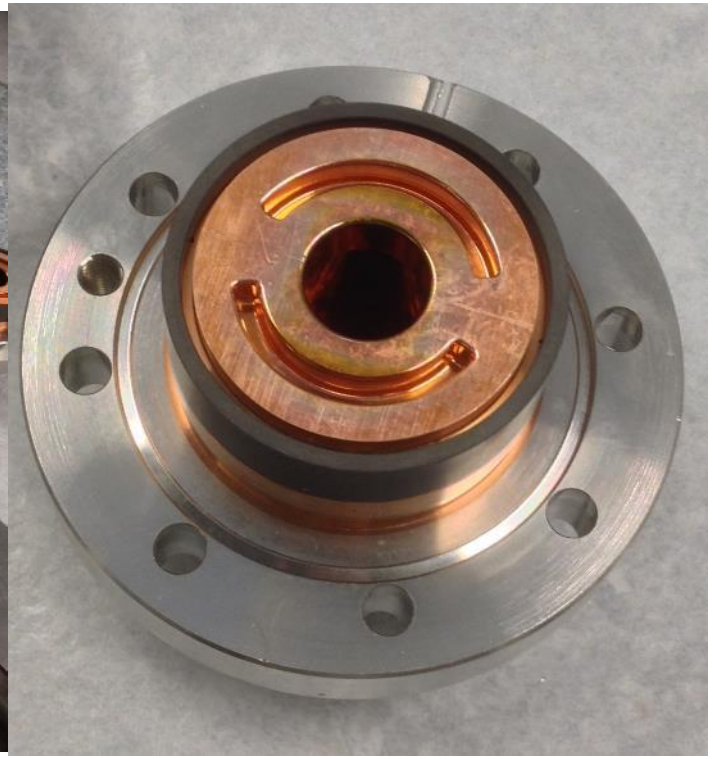




HIGH POWER CONDITIONING OF X-BAND RF COMPONENTS,
N. Catalan-Lasheras et al., IPAC2018

Gate valves





Originally design and build for routine operation. Failed at 7 and 35 MW due to multipacting
Visible burning marks at 35MW
Working on a high power window

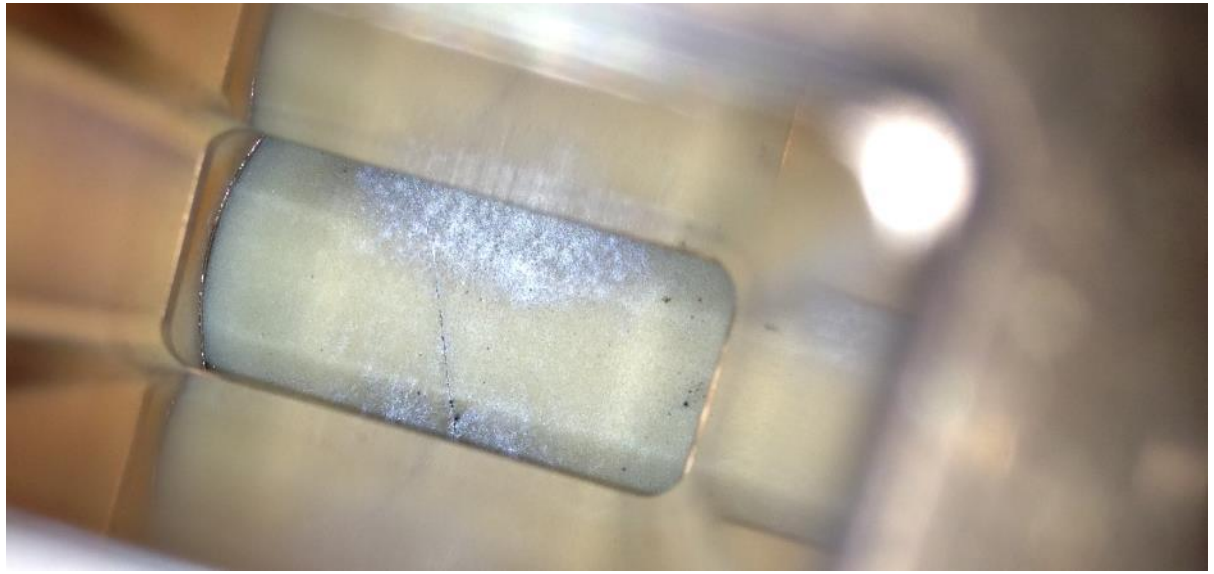
Main technical issues

Many small issues with conditioning algorithm, software improvements typically solved in one or two days

Most time consuming activities affecting the availability of Xboxes

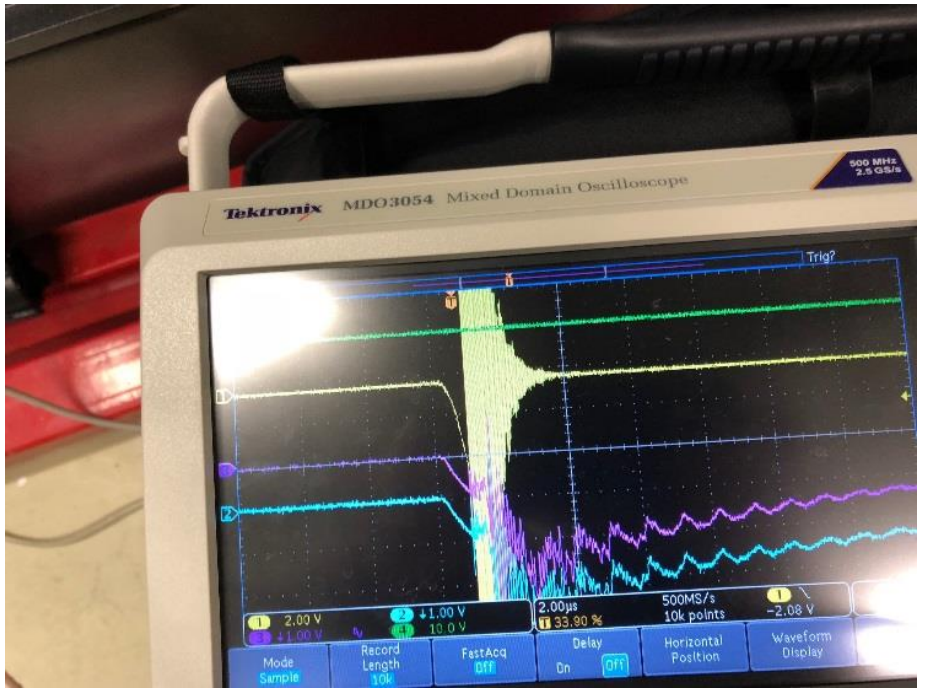
- Installation of new structures
- Regular maintenance and factory tests
- Radiation
- Klystrons failures

Klystron problems

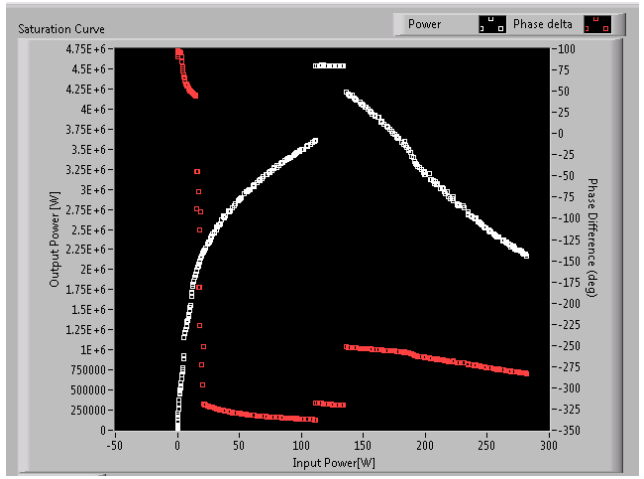


Klystron went up to air when we vented RF waveguide line to change structure
Visual inspection of klystron showed broken window

CPI klystron serial #3 , removed recently due to gun arcs and increased vacuum pressure in gun
Ion pump on gun breaking down above 3kV
Tube sent back to CPI for evaluation for repair

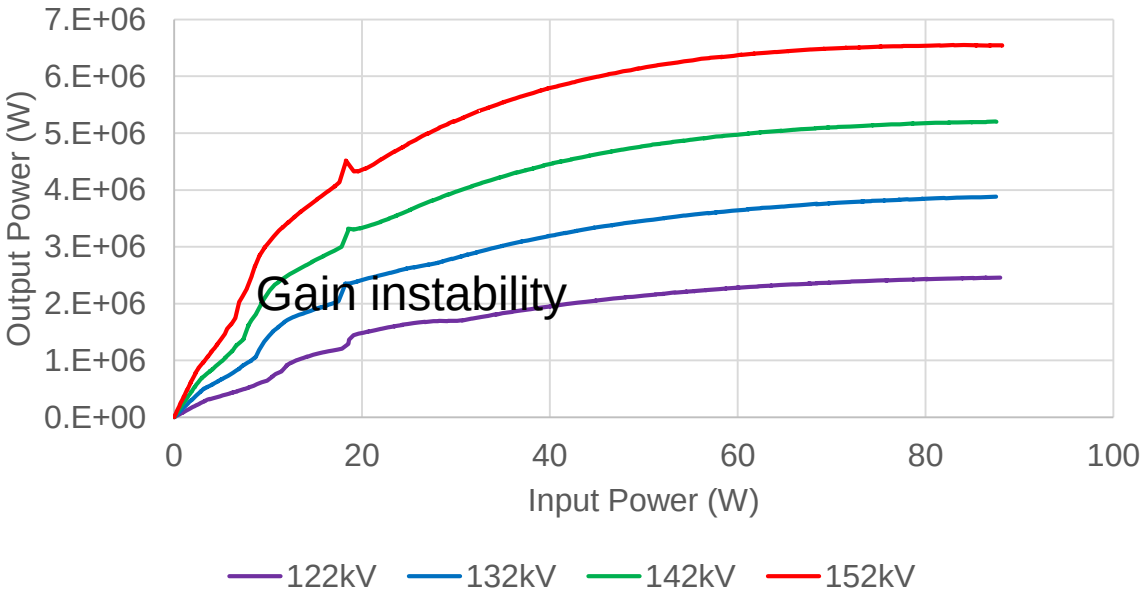


Klystron E37113 serial number 2

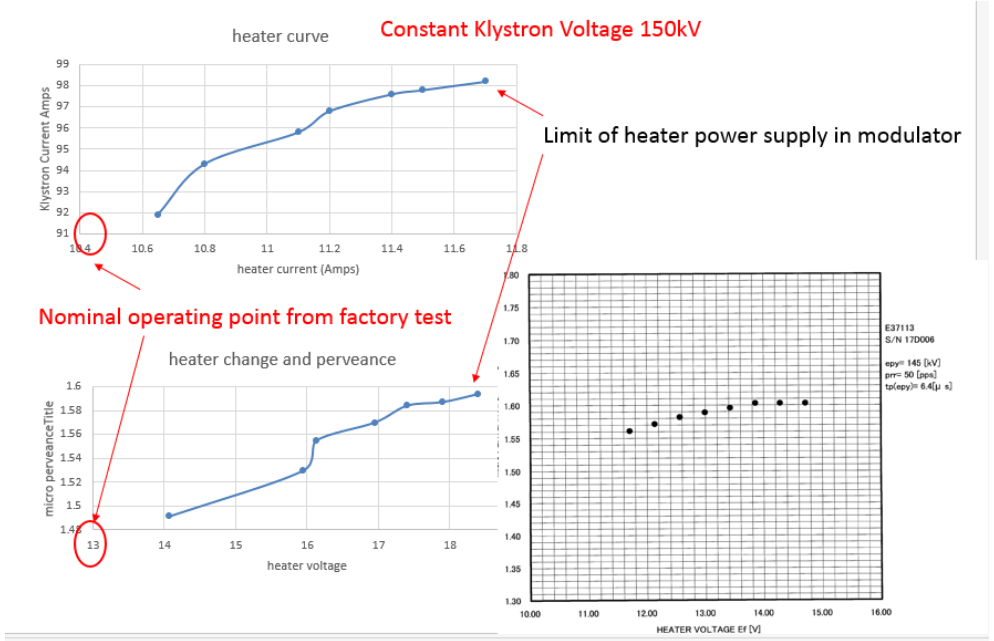


White trace P_in versus P_out

Red trace output phase

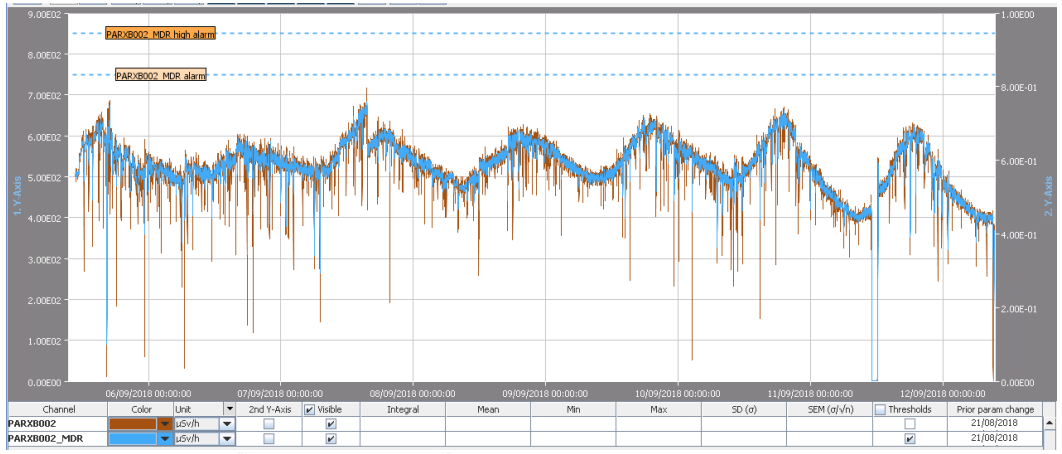


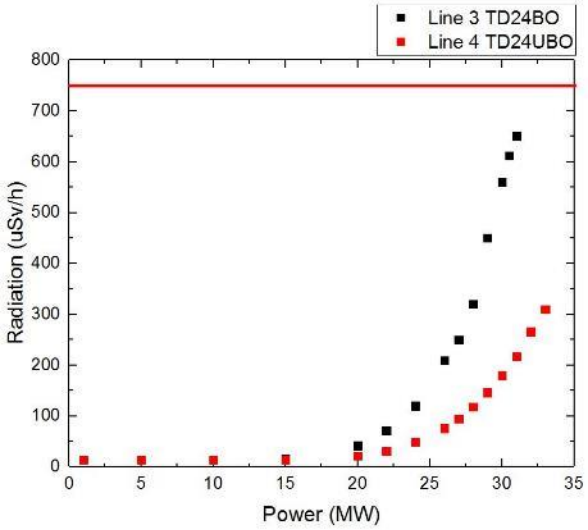
Perveance change

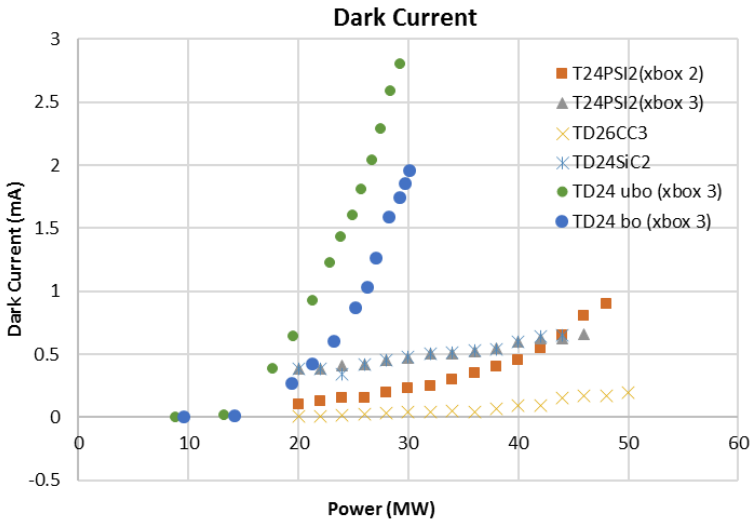


Radiation in the Xbox2/3 bunker

- Radiation needs to be verified
  - for all new structures
  - for any new layout in the shielding
- Radiation measured inside the bunker and threshold applied
- Interesting changes with temperature
- Needs to be updated regularly to accommodate changes







See "Radiation measurement and simulation" by M. Boronat

On-going and future plans

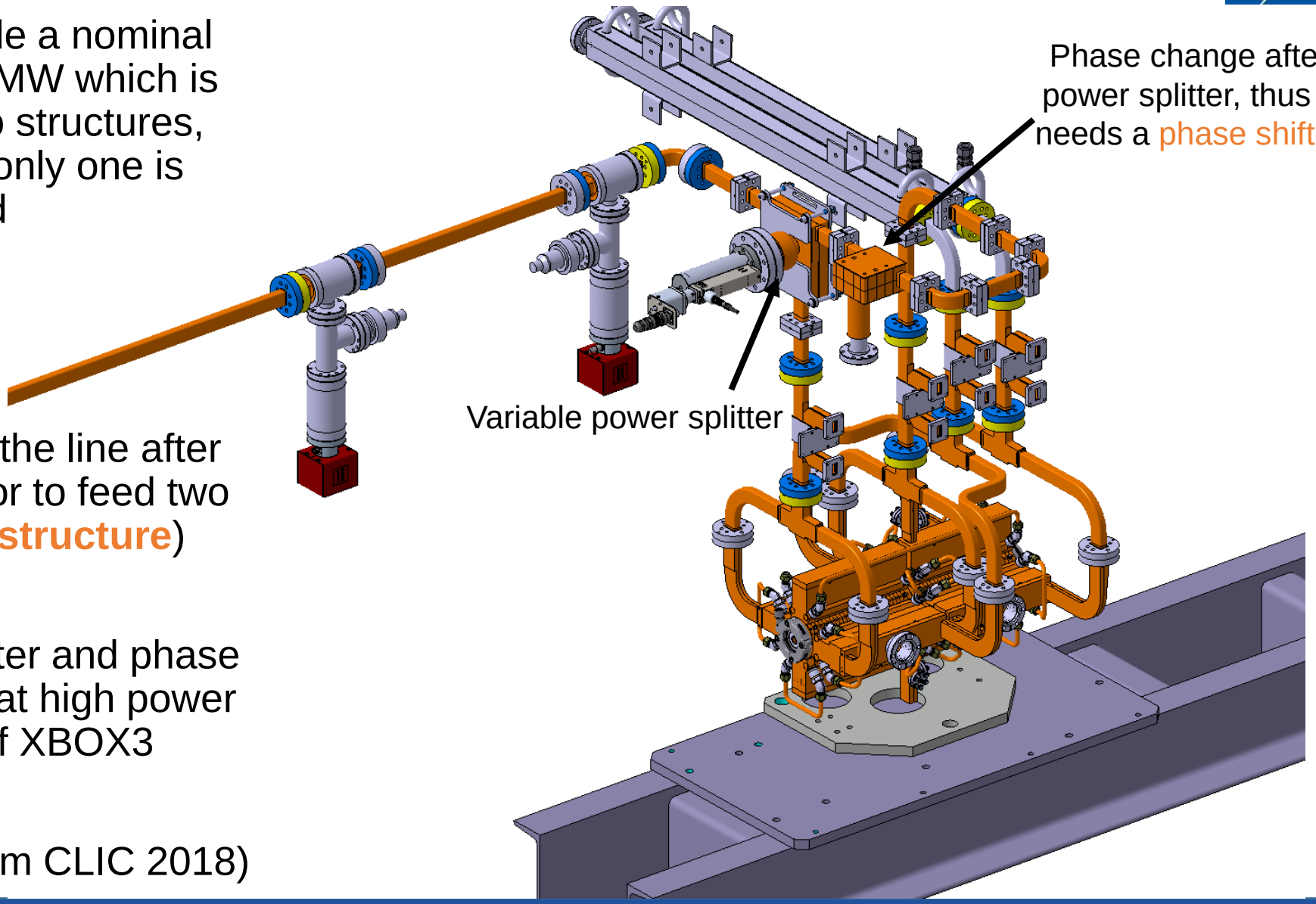
Xbox2 upgrade

- XBOX2 can provide a nominal power of about 130MW which is enough to feed two structures, though right now only one is installed

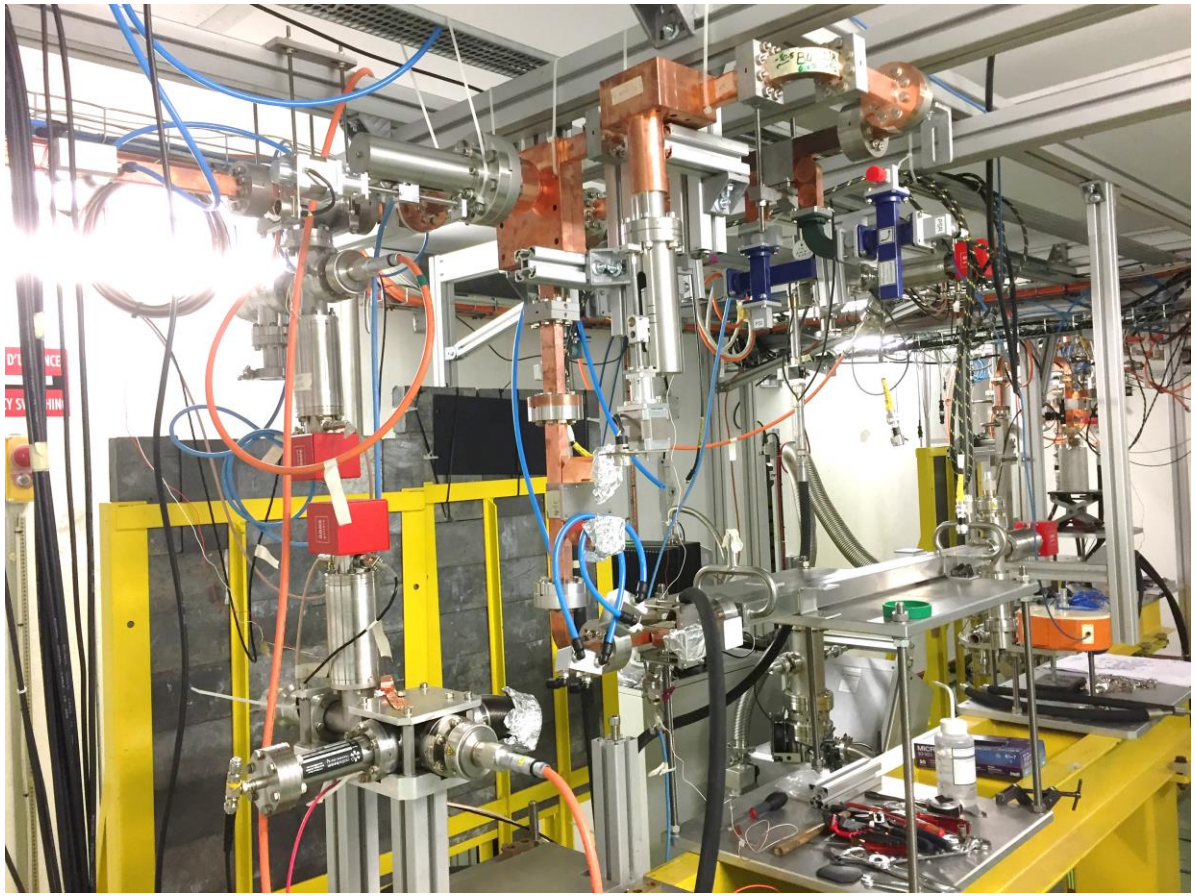
- The goal is to split the line after the pulse compressor to feed two structures (**Superstructure**)

- Variable power splitter and phase shifter will be tested at high power in line 1 and 2 of XBOX3

(From CLIC 2018)

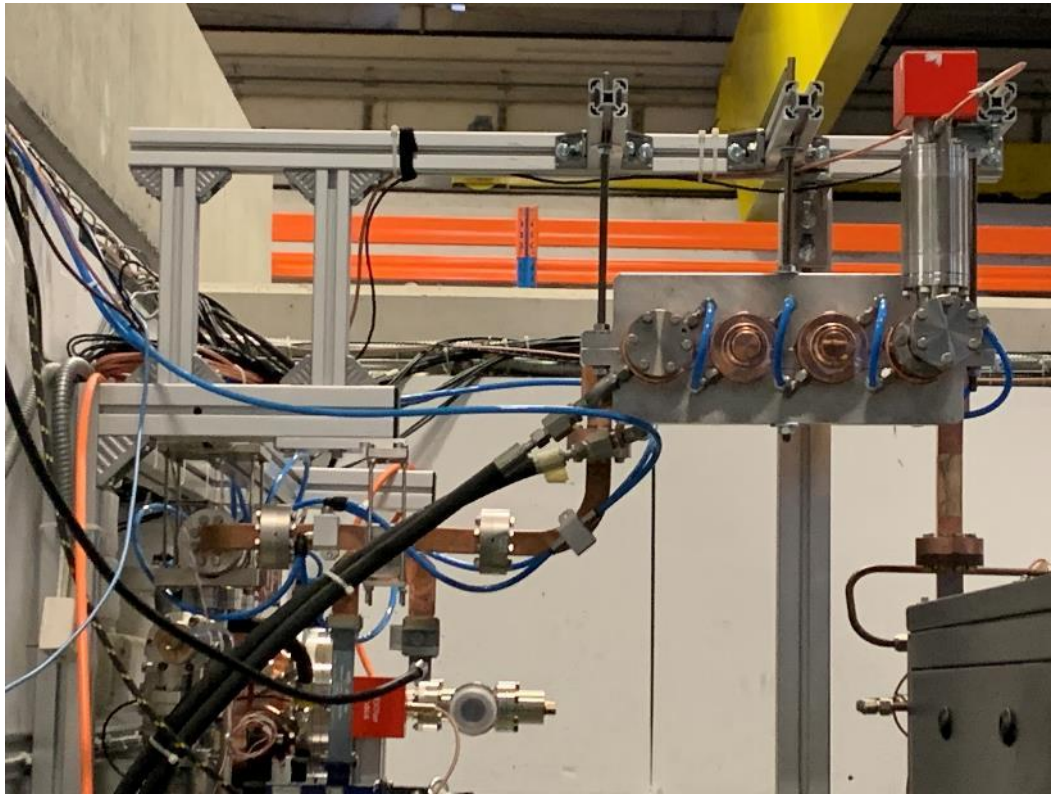


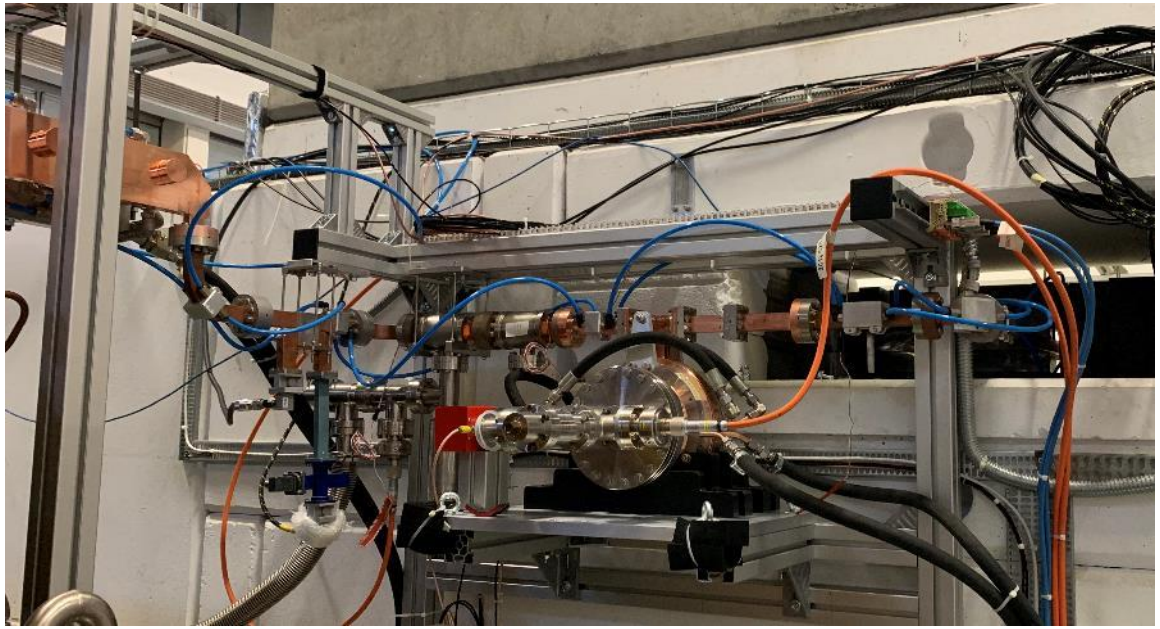
Installation of the RF network

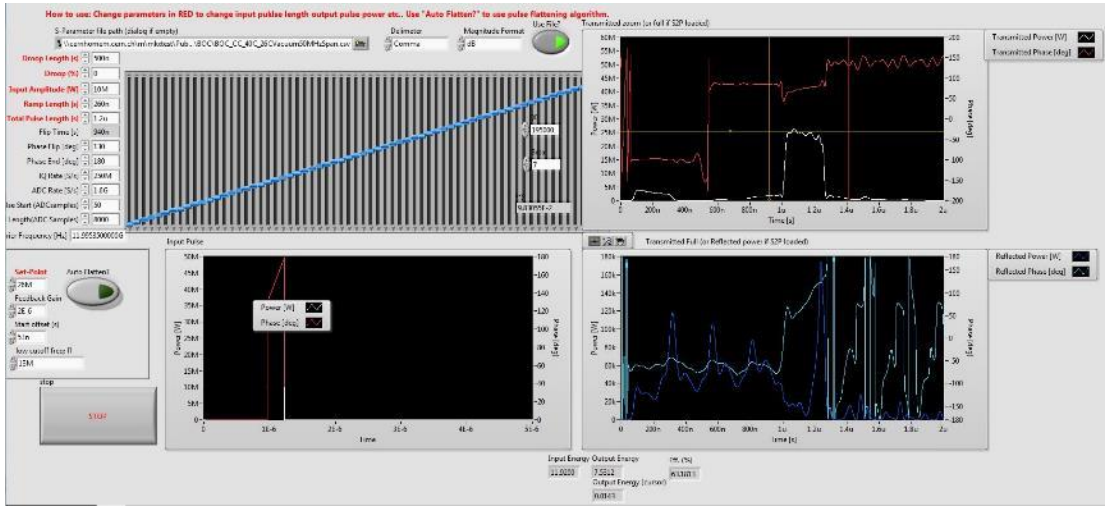


- Conditioning of the line without superstructure to the highest peak power
- Variable power splitter removed du mechanical problems in the piston
  - A 3dB splitter is in place now
  - Does not affect the program
- SLED pulse compressor not expected to reach 120 MW
- Replaced by a BOC pulse compressor provided by PSI

Correction cavities and BOC







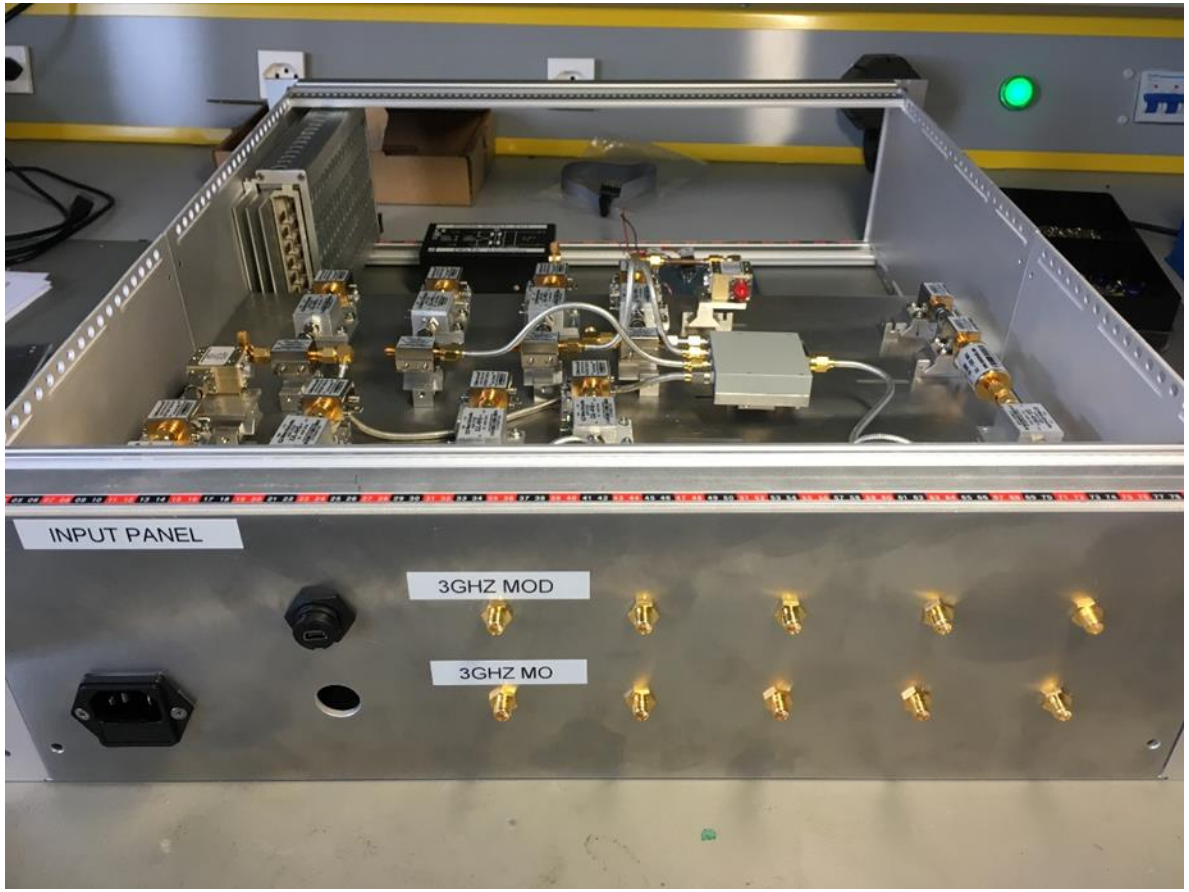
Pulse compressor BOC type designed and built by PSI
Correction cavities built by Tsinghua university

See “X-band pulse compressors at Tsinghua” by Y. Jiang

Xbox1 upgrade

X-Box1 was the prototype – long overdue an upgrade.

- LLRF
  - RF Generation – modulate using one PXI card rather than multiple existing steps in PFN.
  - Data Acquisition – down mix to 200 MHz matching X-Box 2 & 3.
  - IQ sampling to obtain phase and amplitude information.
  - Keeping triggers and 3GHz master oscillator from CTF3 – Timing handled through PXI card replacing old CTF timing cards.
  - Signals split and analysed by CLEAR and X-Boxes in parallel.
  - More channels to account for superstructure with more signals.
- Software to be upgraded and brought in line with X-Box 2 & 3.
- Thorough characterisation of waveguide network and more accurate calibration techniques.



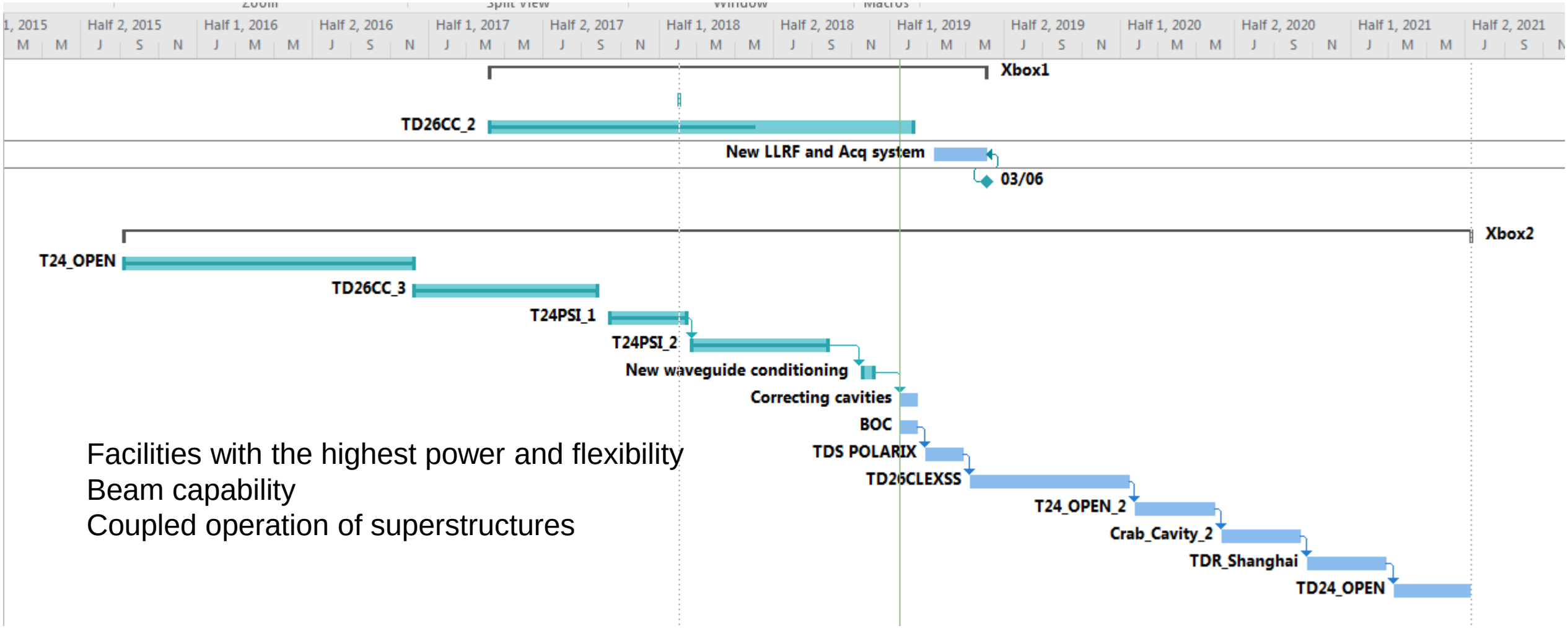
Xbox1 connection to CLEAR

Connecting old 50MW X-Box1 Klystron and pulse compressor to CLEAR

20m of low loss overmoded waveguide from CTF2.

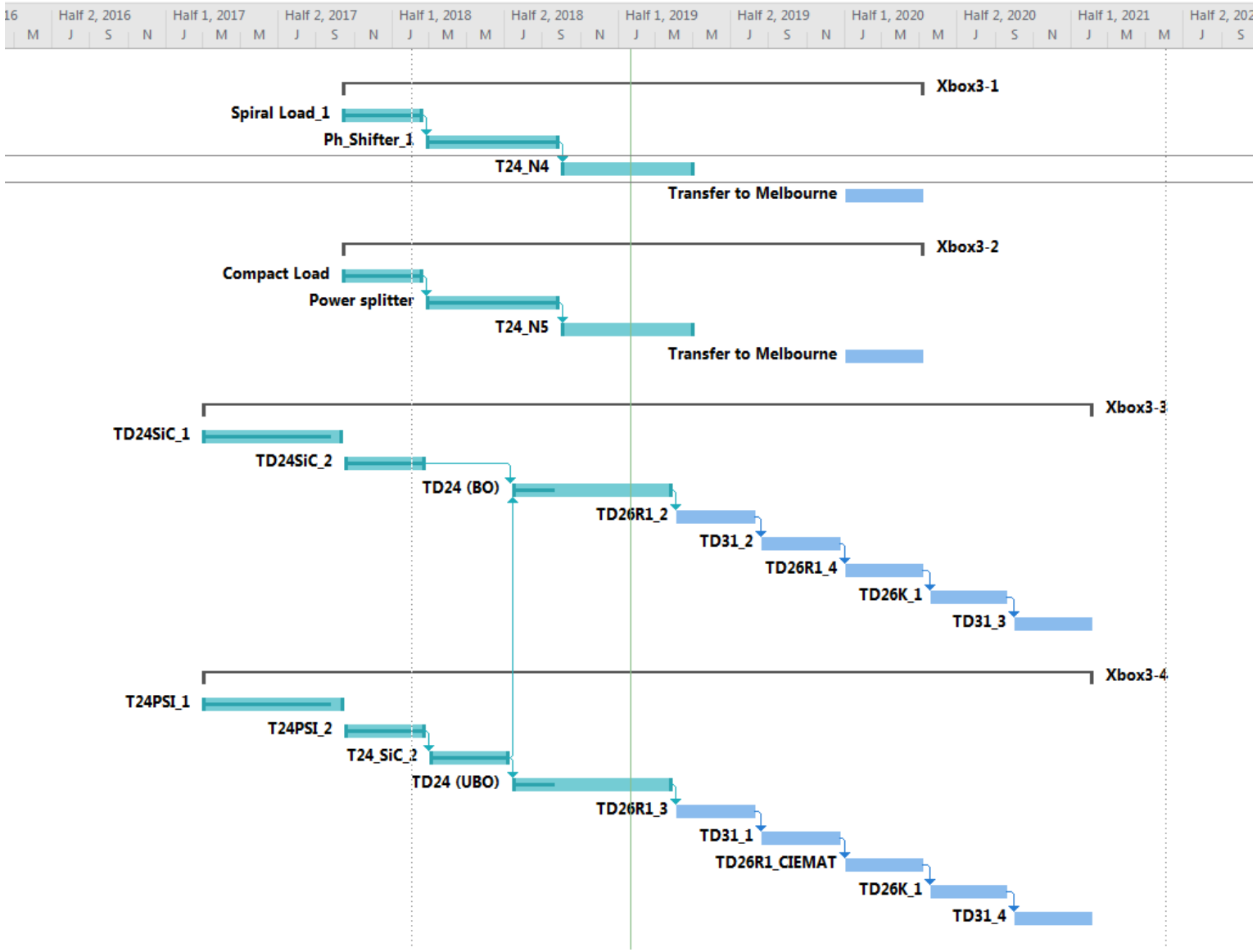
Aim to provide superstructure with ~85MW RF power after losses.

Xboxes1&2



Facilities with the highest power and flexibility
Beam capability
Coupled operation of superstructures

Xbox3



- Xbox3 lines 1 and 2 will be transferred to Australia. Melbourne university
- CLIC program to be continued in 2020
- Fast turnover of prototype tests
- Potential power upgrade thanks to new klystrons

Conclusions

- All facilities working. Six simultaneous testing slots. One more to come.
- New upgrade going on in Xbox2 and planned in Xbox1
- Two Xbox3 testing slots moving to Australia
- Very productive year with lots of tests and improvements going on
- Testing CLIC baseline prototypes as well as new components in high power required for running the Xboxes and for CLIC 380GeV based on Klystrons
- Extended program in X-band thanks to ARIES Trans National Access activities

Thanks!

Xbox 3

Xbox 3C

Klystron E37113 serial number 1

14000 heater hours

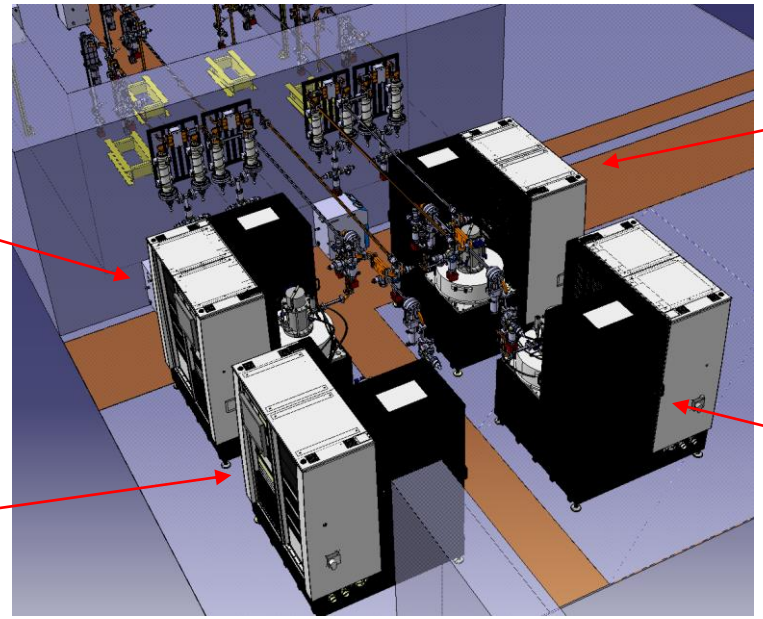
12000 high voltage hours

Xbox 3D

Klystron E37113 serial number 6

heater hours

high voltage hours



Xbox 3B

Klystron E37113 serial number 3R

1000 heater hours

1000 high voltage hours

Xbox 3A

Klystron E37113 serial number 8

60 heater Hours

50 high voltage hours

Spares

Klystron E37113 serial number 7
New

Klystron E37113 serial number 4R
Gun arc from time to time

Broken ready for repair

Klystron E37113 serial number 2
Phase instability (see next slide)
Perveance change (need to increase heating)
6377 heater hours 4723 high voltage hours

Klystron E37113 serial number 5
Broken window (see next slide)
1758 heater hours 1490 high voltage hours