



X-Box Status Update

AMELIA EDWARDS on behalf of the X-box team

CLIC project meeting

30 September 2020

Current Status of X-Band Test Stands



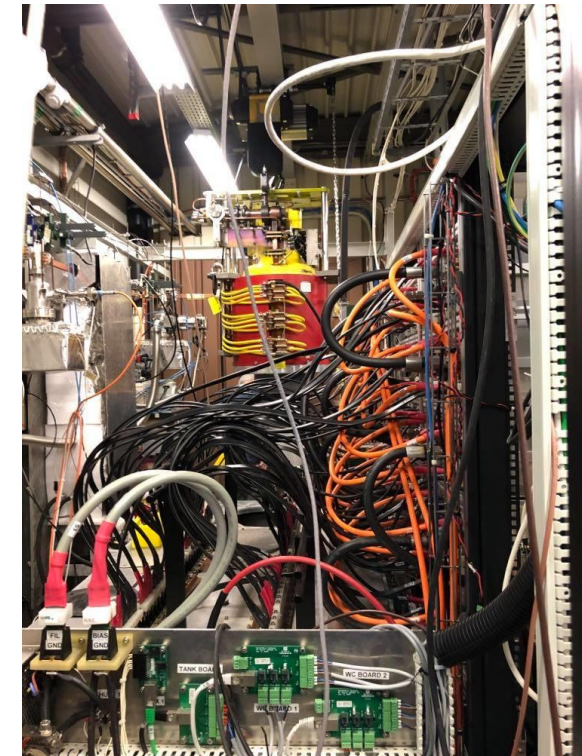
Line	DUT	Power (MW)	Running?
Xbox 1	WG Connection to CTF3	Diode Mode	No
Xbox 2	Super-structure	36/33	Yes
Xbox 3 Line 1	Reversed T24	27.1	Yes
Xbox 3 Line 2	Reversed T24	27.1	Yes
Xbox 3 Line 3&4	Shipped to Melbourne, Australia	N/A	No

X-Box 1



- Waveguide connection into CLEAR was installed and is under vacuum
- Received a repaired 50MW klystron earlier this year and was installed before lockdown
- Diode testing ongoing (380kV)
- LLRF and Software upgrade close to completion
 - Entire upgrade of low level RF and software
 - Aim to make all test stands as similar as possible
- After RF conditioning the klystron will be sent to Frascati

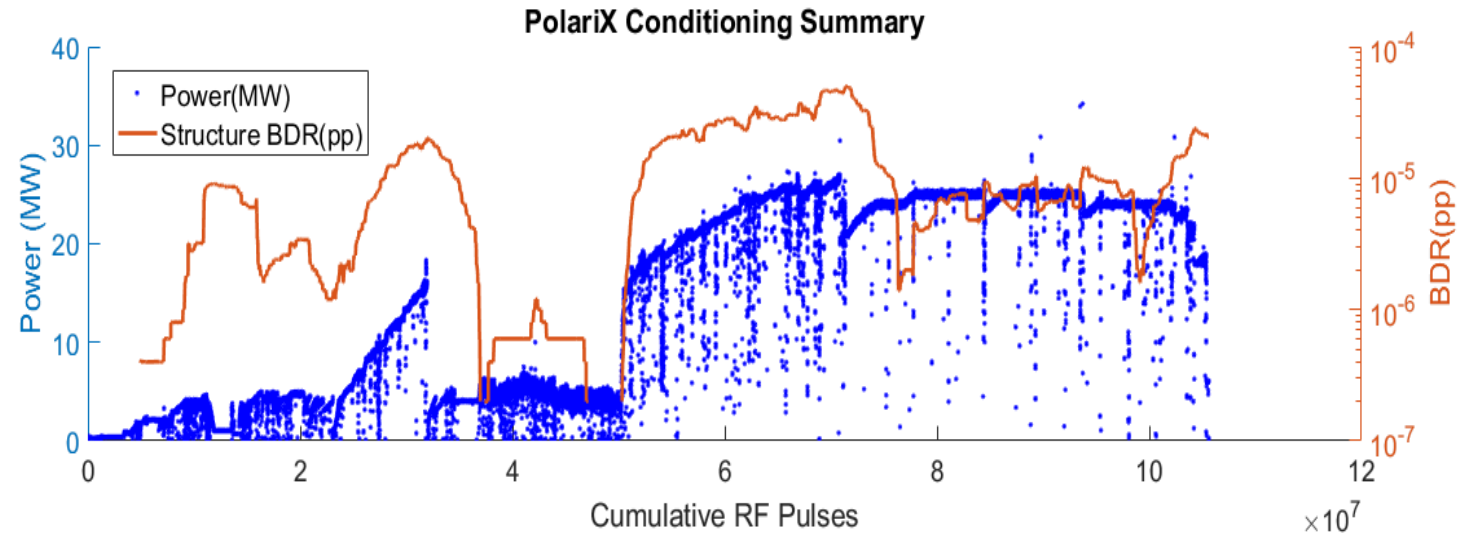
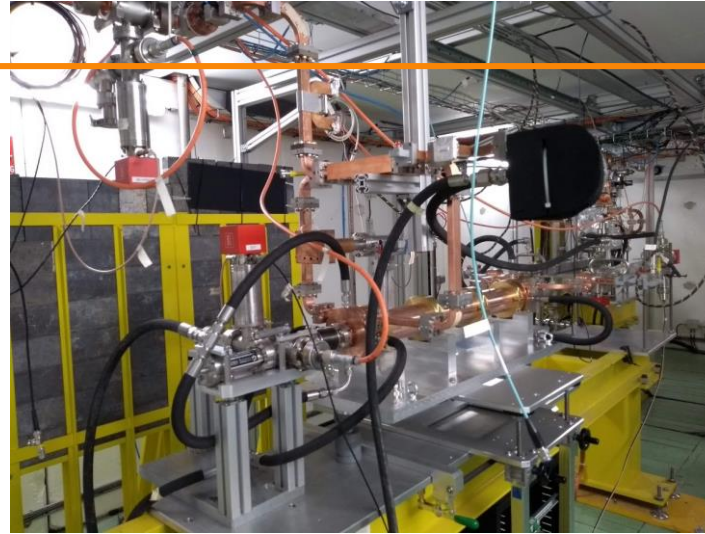
Repaired 50MW klystron during installation in CTF2 – Feb 2020



X-Box 2 – PolariX Transverse Deflecting Structure



- PolariX Transverse Deflecting Structure for DESY's FLASH forward experiment. Made by PSI.
- Installed with phase shifter between inputs to change the polarization of the field.
- PolariX conditioned up to **26.5MW @ 100ns** in one polarization.
- Other polarizations could not be tested due to issues with the high power phase shifter
- **No clear structure limit emerged, the phase shifter and time constraints limited the conditioning of the structure.**
- Structure arrived at DESY and installed in FLASHforward beam line is has been operating since September 2019. Input power 6MW.



X-Box 2 – Super-Structure Conditioning



Power Splitter

Phase Shifter

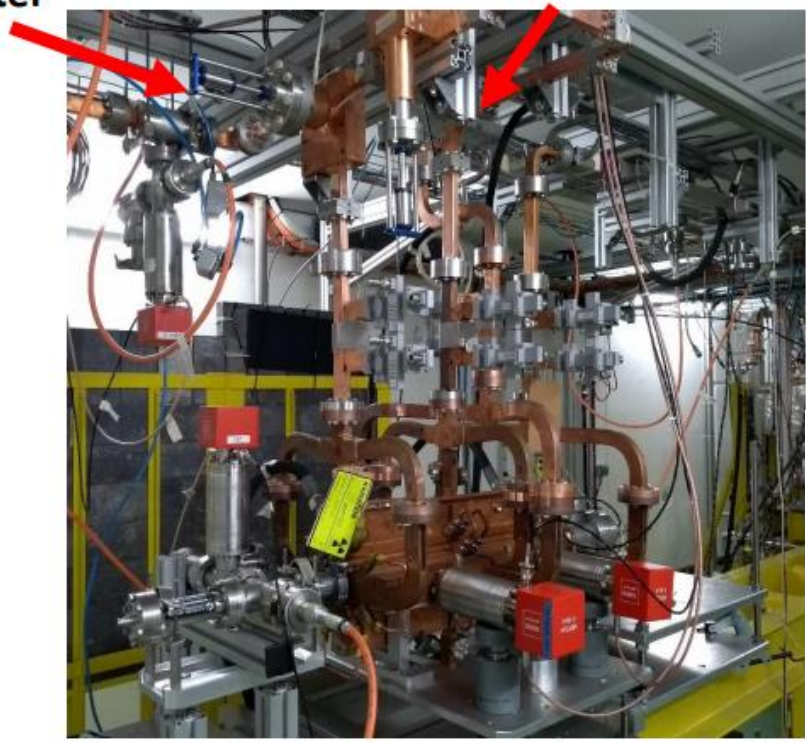
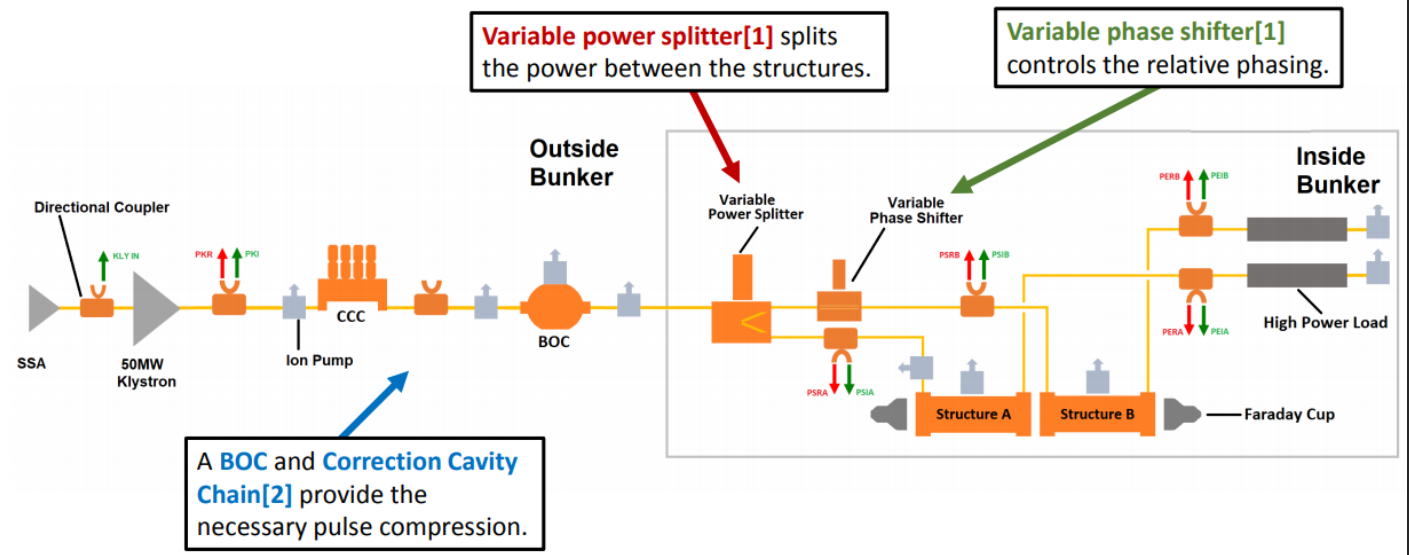


Figure: Current XB2 installation.

- The combination of power splitter and phase shifter are set for an even split between the structures
- In reality the split is approximately 45%:55%
- The gradient in each structure is virtually the same
- Structure B is lagging in phase by about 90 degrees so it isn't phased exactly for a synchronous beam
- The phase shifter has not been moved since installation
- Wakefield monitors installed and have been collecting data since May – the hardware is as close as possible to the setup in CLEAR



X-Box 2 – Super-Structure Conditioning

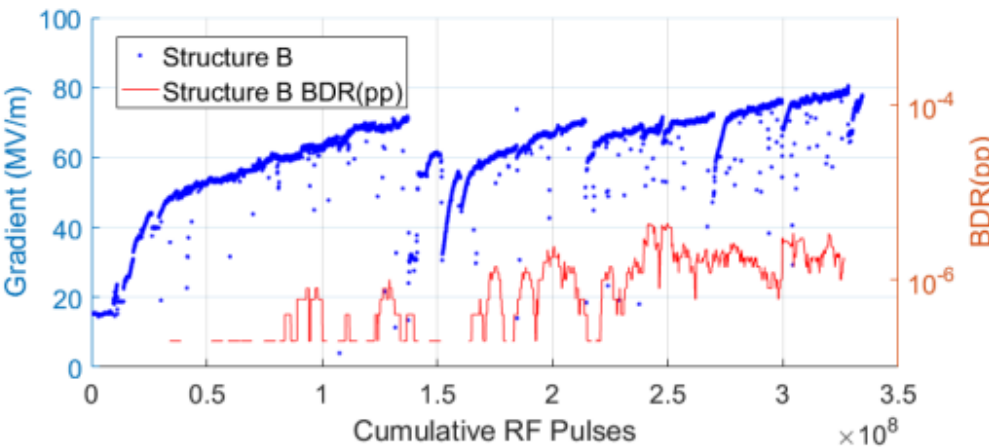
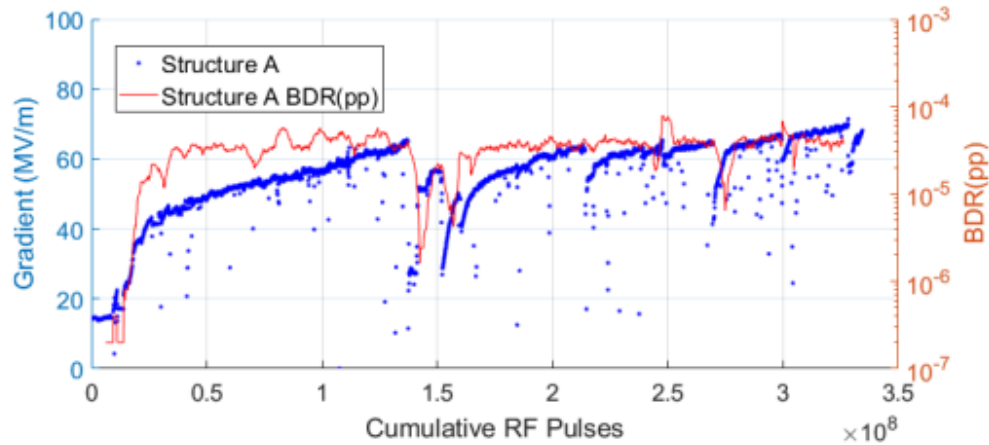


Figure: Conditioning history of the CLIC SS.

1

Current Power:

Structure A – 36MW Structure B – 33MW

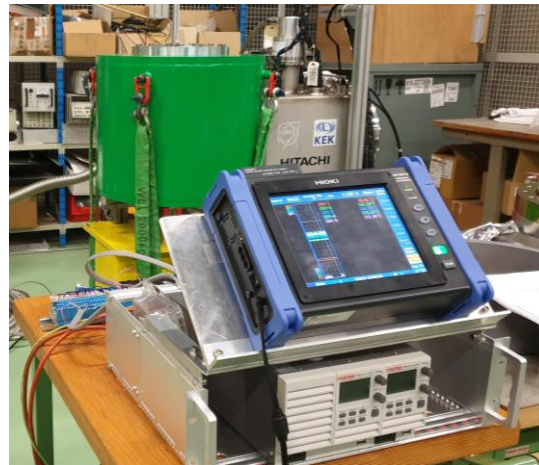
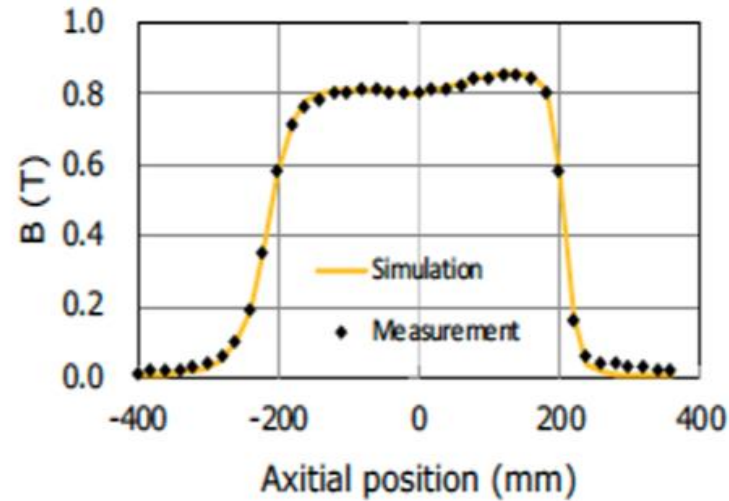
Future Plans:

- Move the phase shifter position to study difference in dark current
- The BOC will be removed and sent to PSI for installation
- SLED pulse compressor will be installed and can be tested with correction cavities
- Data collection and analysis from WFMs

X-Box 2 – Superconducting Solenoid



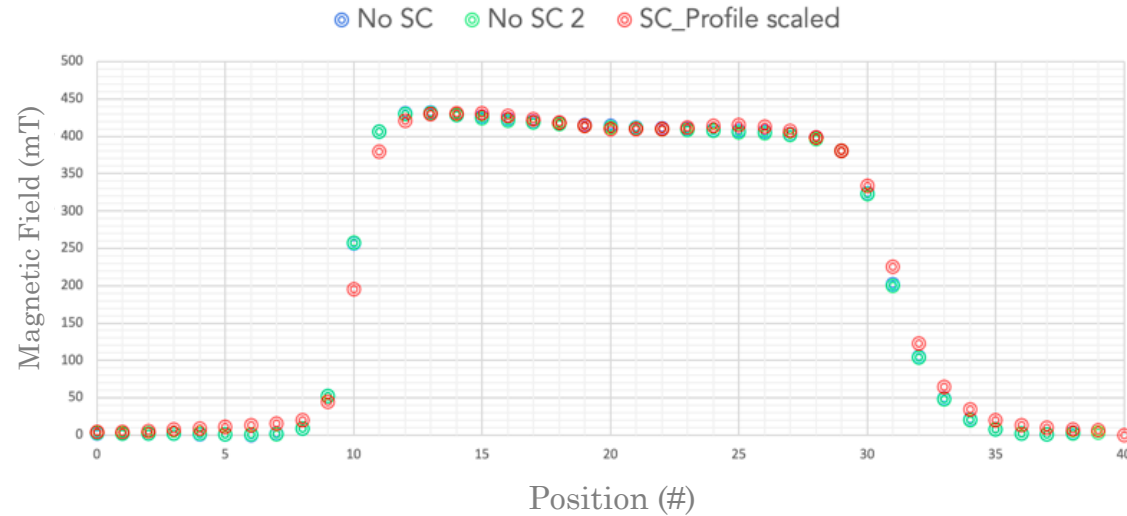
- In February 2019, a novel MgB_2 solenoid built for the 50MW X-band klystron by the CLIC-KEK collaboration was tested at the manufacturer Hitachi.
- After acceptance by KEK, the solenoid arrived at CERN last April from KEK
- The prototype MgB_2 superconducting magnet demonstrated a significant electric power saving at an operation temperature of 20 K with an AC plug power consumption of less than 3 KW for klystron solenoid (compared to 20kW)



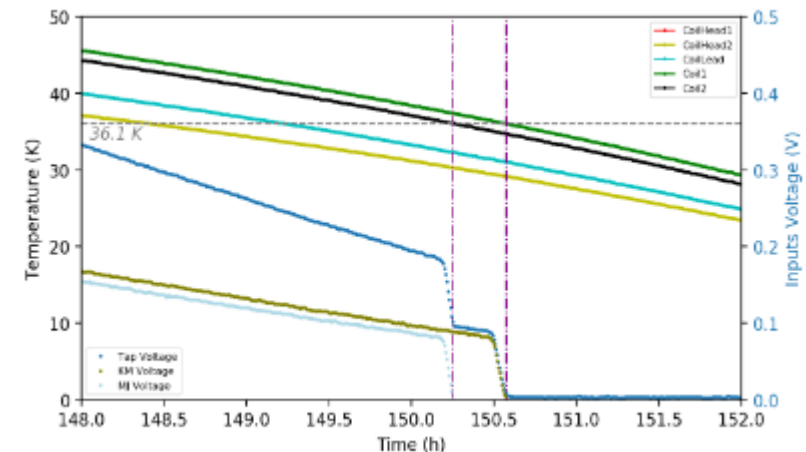
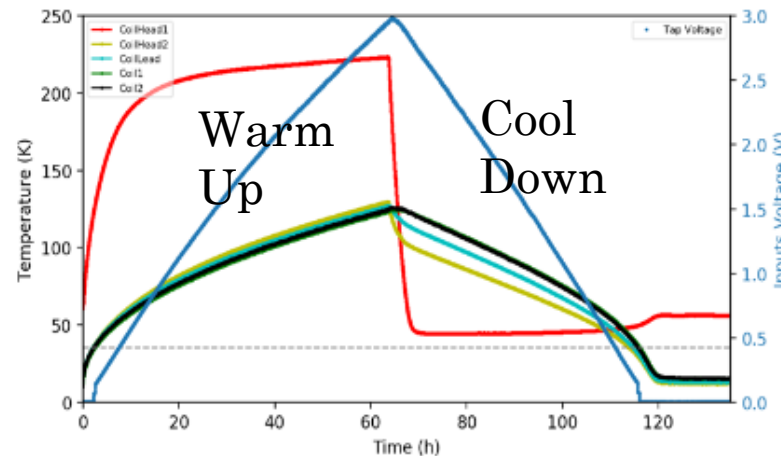
X-Box 2 – Superconducting Solenoid



- Cool-down and magnetic measurements at CERN confirmed the original performance
- Becomes super-conducting at 31.6K and we work at 16K so we operate safely below the quench limit
- It also demonstrated a very high stability and operational margin which should guarantee reliable operation when working on the klystron.
- Currently we are preparing an appropriate interlock system
- Expecting to install at Xbox2 in October



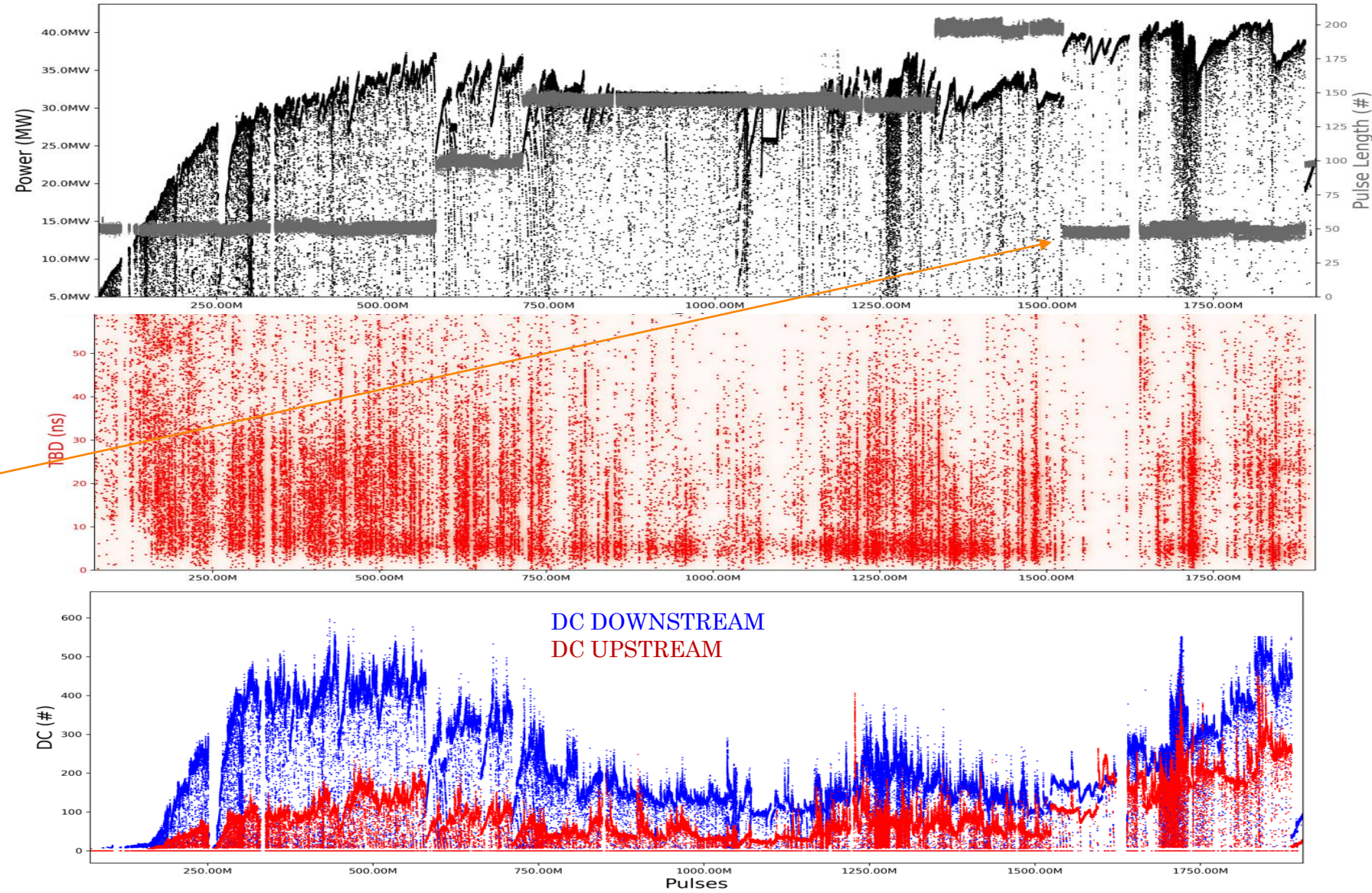
Comparison of Non-Superconducting and Superconducting Solenoid



X-Box 3 Line 1 - T24N5



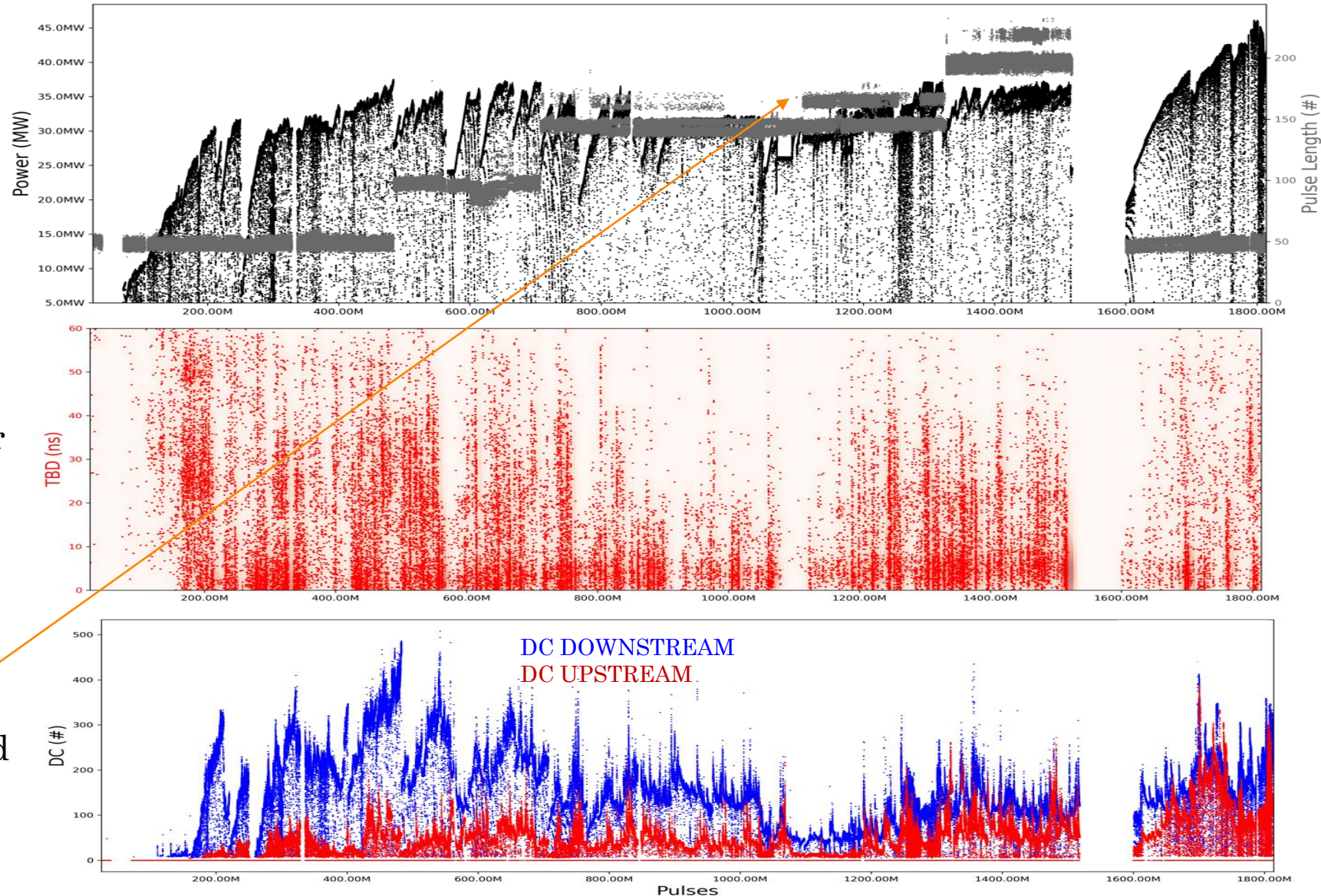
- Total BDs – 37,358
- $100\text{MV/M} = 38.5\text{MW}$
- After reaching nominal (100MV/M) at 200ns compressed pulse length we reduced the pulse length to 50ns and tried to increase the gradient even further
- Max Power – 42MW
- Eventually we were approaching the maximum power of the test stand



X-Box 3 Line 2 - T24N4



- Total BDs – 31,383
- $100\text{MV/M} = 38.5\text{MW}$
- After reaching nominal (100MV/M) at 200ns compressed pulse length we reduced the pulse length to 50ns and tried to increase the gradient even further
- Identical to T24_N5 (previous slide)
- Max Power = 44MW
- This is a problem with the of the analysis software and can be ignored



X-Box 3 Line 1 – T24 Reversed Structures



Breakdowns were concentrated in the beginning parts of the structure in the tests of T24#5 and T24#4 at Xbox3 Line1 and Line2

Not see many breakdowns in the end cells which have higher field

Flip the structure and retest it at high power → “42T” (reversed T24)

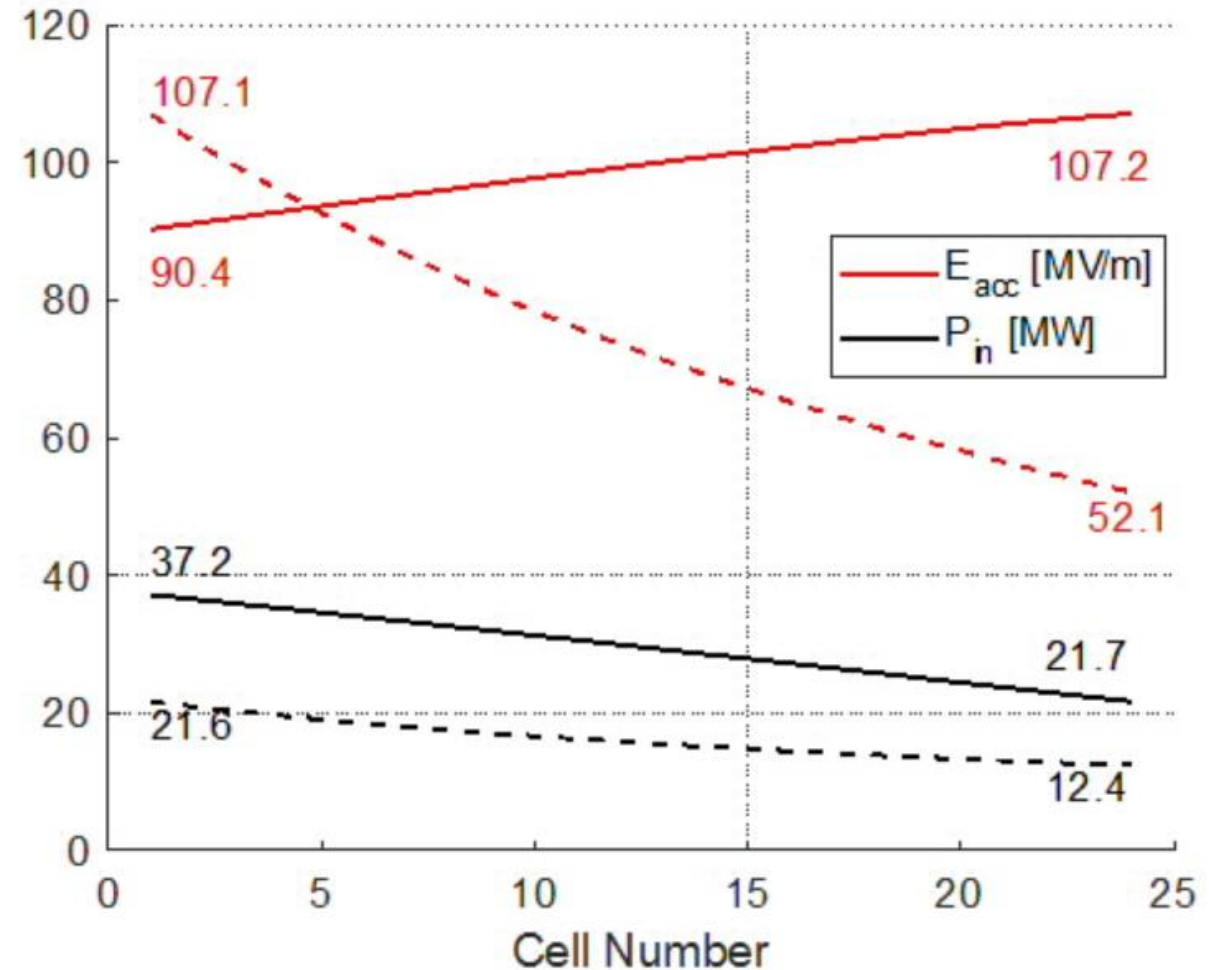
To reach high gradient in the beginning parts of the reversed structure (end cells of T24)

T24 (solid line):

average gradient of 99.43 MV/m @ **38.5 MW**
gradient along structure: 90.4 MV/m—107.2 MV/m

Reverse T24 → “42T” (dash line):

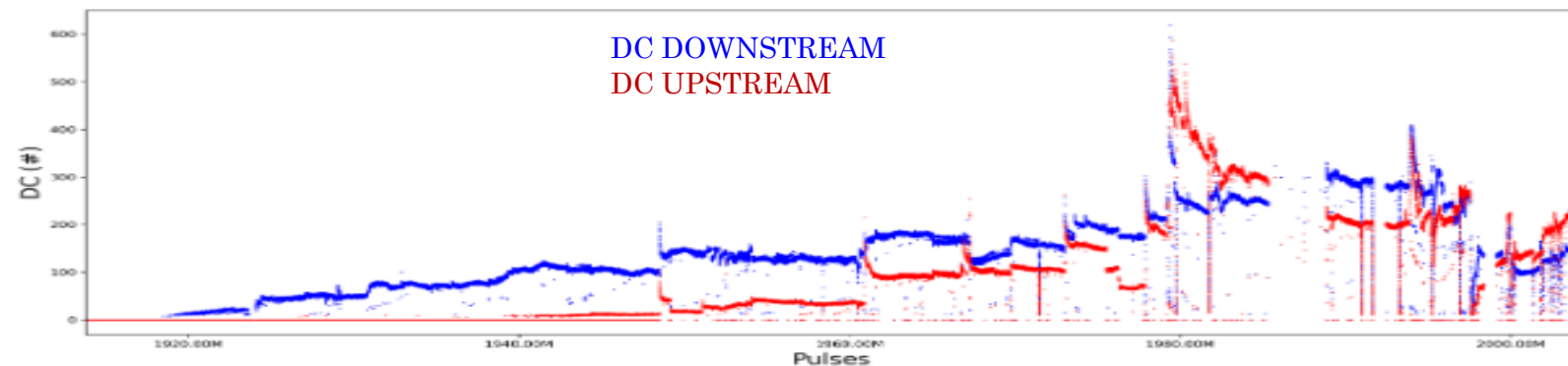
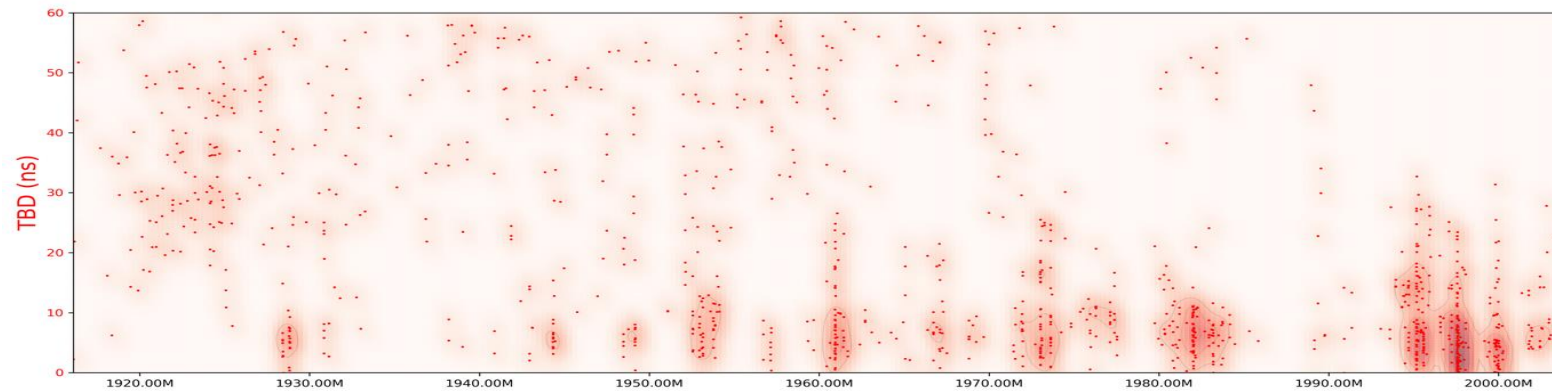
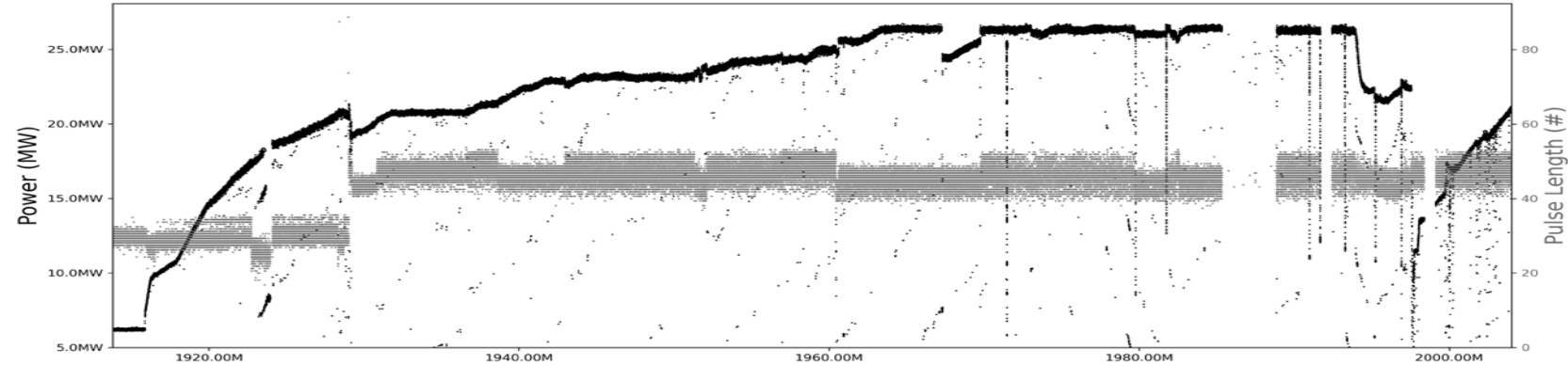
average gradient of 75.05 MV/m @ **21.4 MW**
gradient along structure: 107.1 MV/m--52.1 MV/m



X-Box 3 Line 1 Reversed T24N5



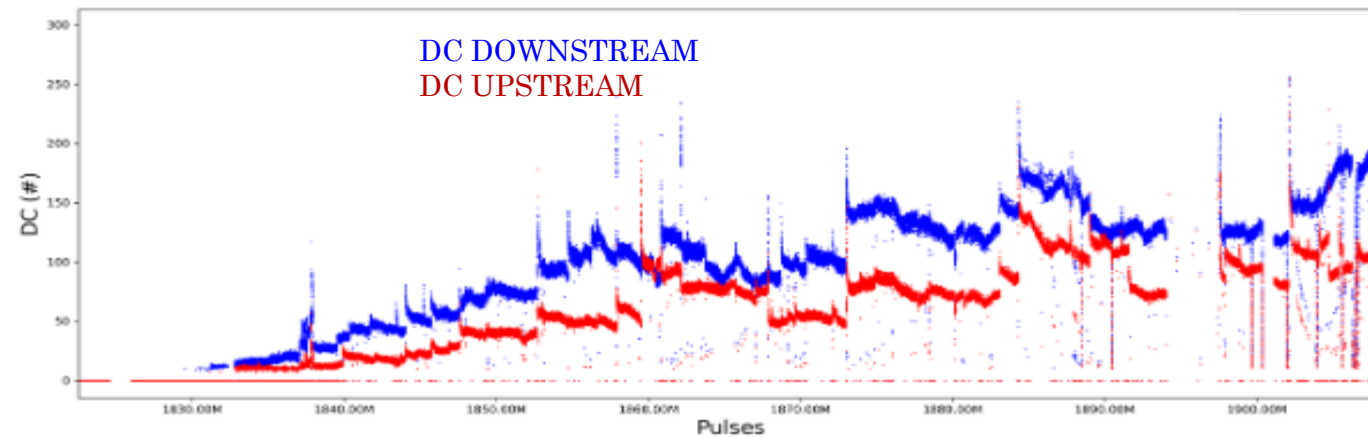
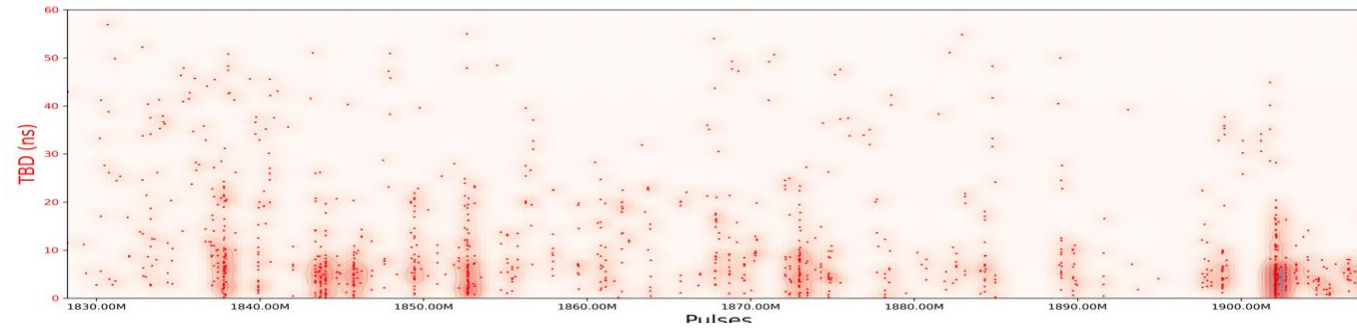
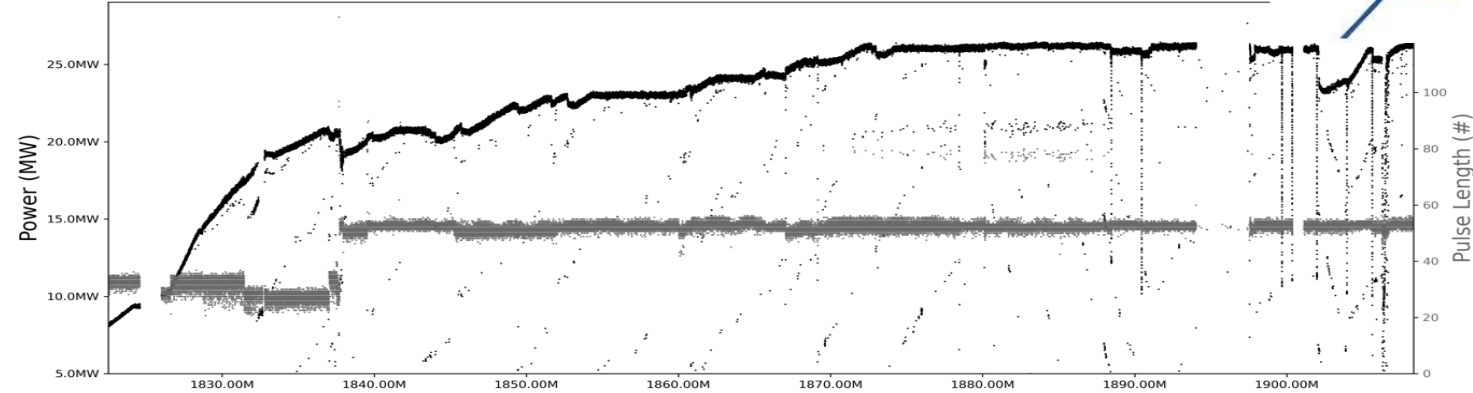
- Started pulsing in May 2020
- RF Conditioning began at 5MW, 50ns compressed pulse
- 100MV/M in the first cell = 21.4MW
- Quickly conditioned up to 27.1MW which is 120MV/M



X-Box 3 Line 2 Reversed T24N4



- Started pulsing in May 2020
- RF Conditioning began at 5MW, 50ns compressed pulse
- 100MV/M in the first cell = 21.4MW
- Quickly conditioned up to 27.1MW which is 120MV/M



X-box3 Line 3 & 4



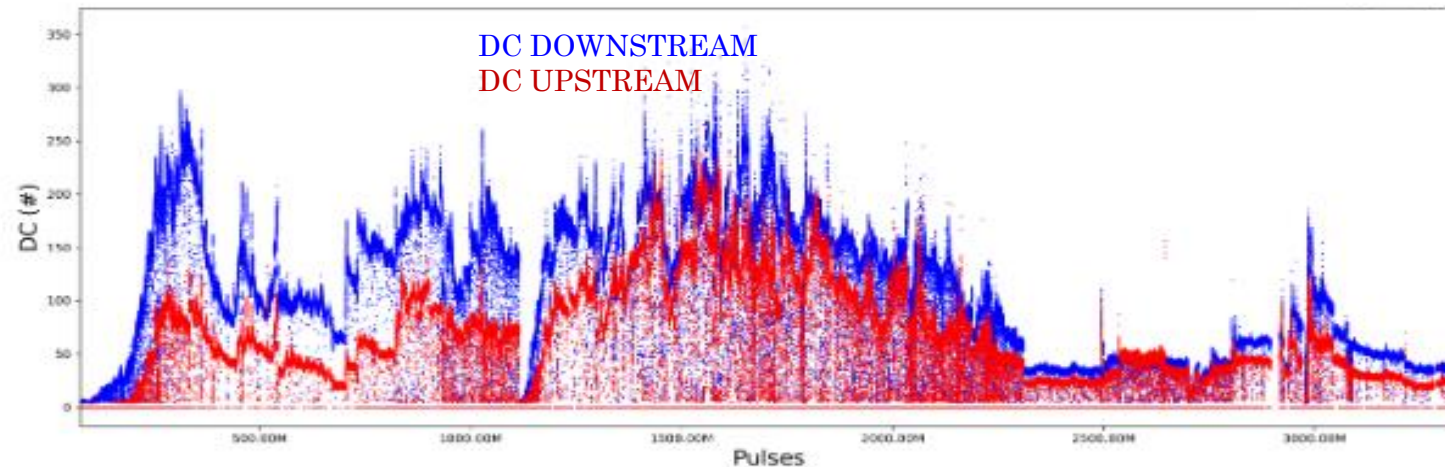
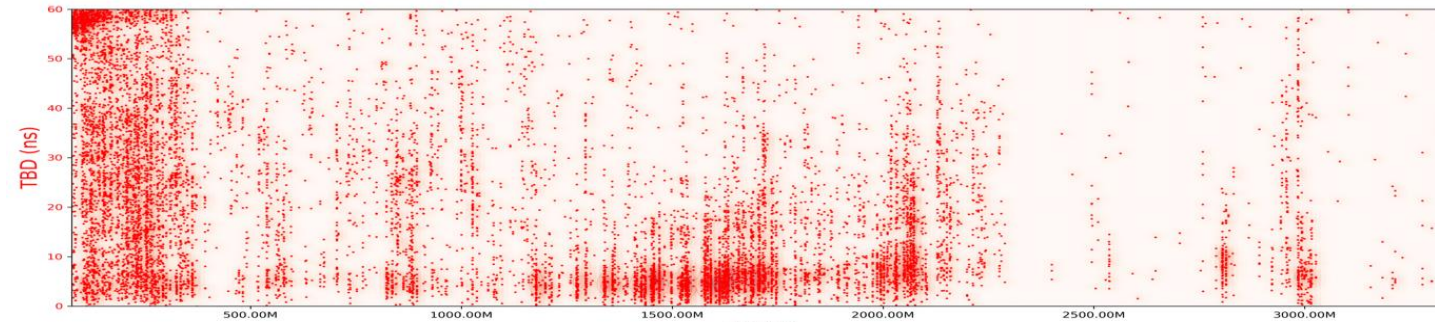
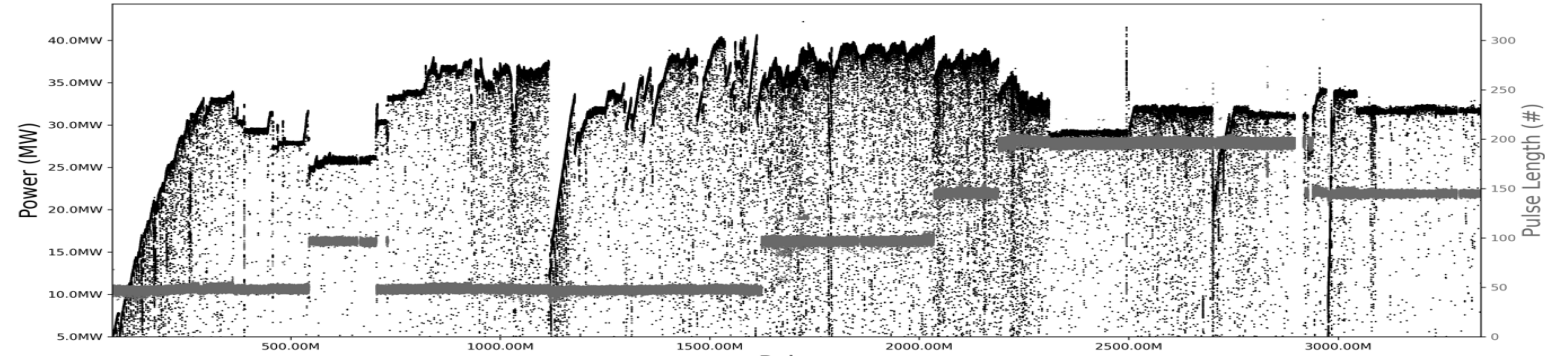
XBOX-OZ HAS
LEFT THE
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X-Box 3 line 3 TD24 Baked Out



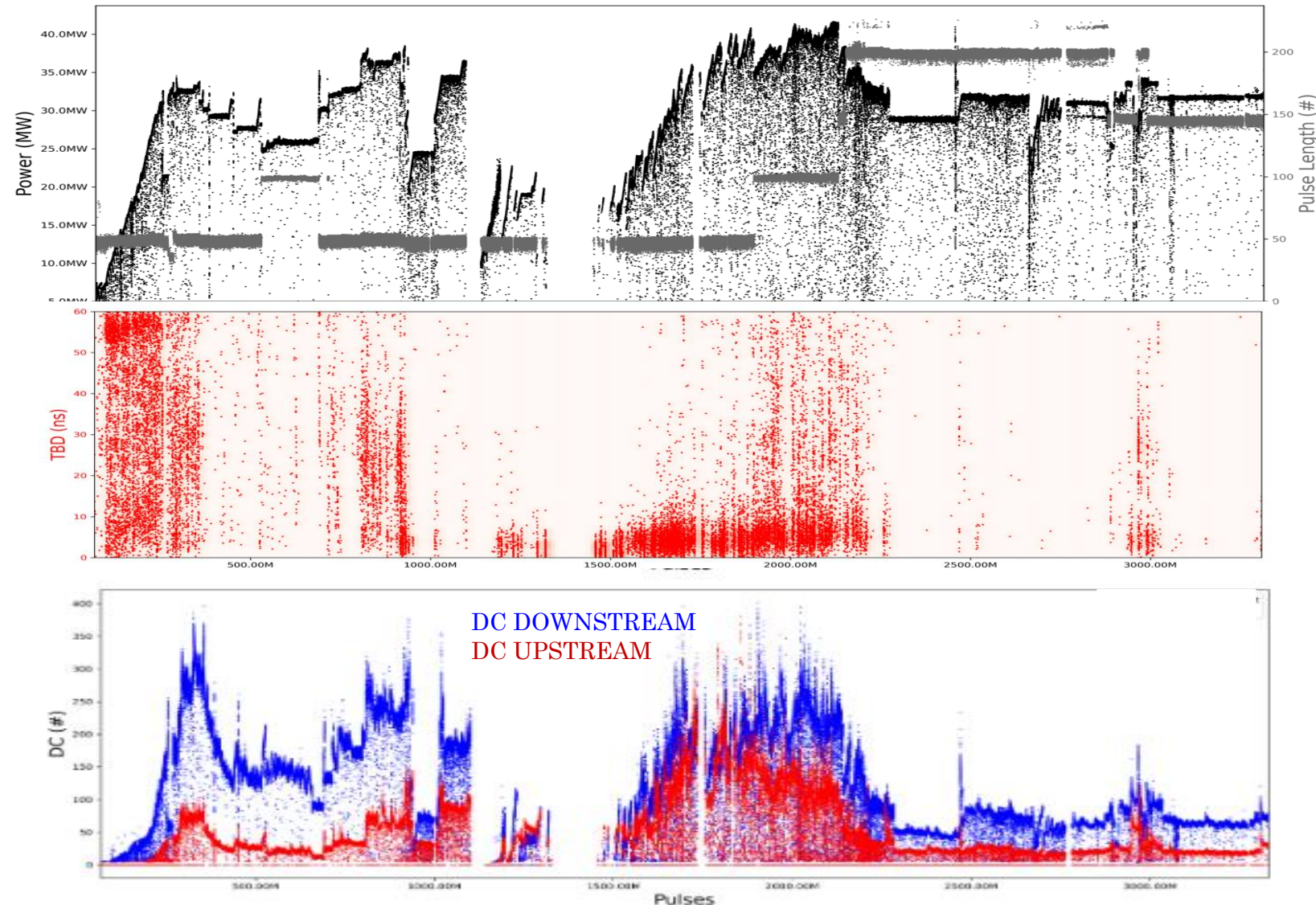
- 100MV/M = 42.2MW
- Structure stored under N₂ for >5 years.
- Recent bake out prior to installation
- Produced more dark current and was limited at times by radiation.
- New pulse compressor had never been to high power.
- **TD24_BO@Line3 reached 40.45 MW which is 97.9 MV/m.**
- Conditioning completed after which we started a period of flat running for BDR analysis
- During flat running the BDR was 89.17 MV/M at 1.066e-5 breakdown/pulse/m for 150 ns



X-Box 3 line 4 T24 Not Baked Out



- 100MV/M = 42.2MW
- Structure stored under N₂ for >5 years.
- No bake out before installation
- Produced more dark current and was limited at times by radiation.
- New pulse compressor had never been to high power.
- **TD24_UBO@Line4 reached 41.5 MW which is 99.2 MV/m.**
- Conditioning completed after which we started a period of flat running for BDR analysis
- During flat running the BDR was 89.13 MV/M, 1.065e -5 breakdown/pulse/m for 150 ns



Summary & Future Work



- Xbox1 - preparing to RF condition repaired 50MW klystron
- Xbox2 - Superstructure is conditioning. We will be moving phase shifter in the next few days to test relative phase changes and their influence on BDR and dark current
- Xbox2 - Swapping from BOC to SLED pulse compressor and installing superconducting solenoid on the klystron
- Xbox3 Line 1&2 – Trying to find ultimate gradient in the reversed T24 structures
- Xbox3 Line 3&4 - On the way to Melbourne University



Thank you!

On behalf of entire X-Box team.

Matteo, Marca, Lee, Xiaowei, Ben,
Alejandro, David, Nuria, Walter, Alexej,
Gerry, Igor, Sergio, Serge, Hikmet, and
Amelia