Status of the Installation and High Power Test of the 1st Prototype at CERN

Lee Millar[1,2] on behalf of the Xbox team

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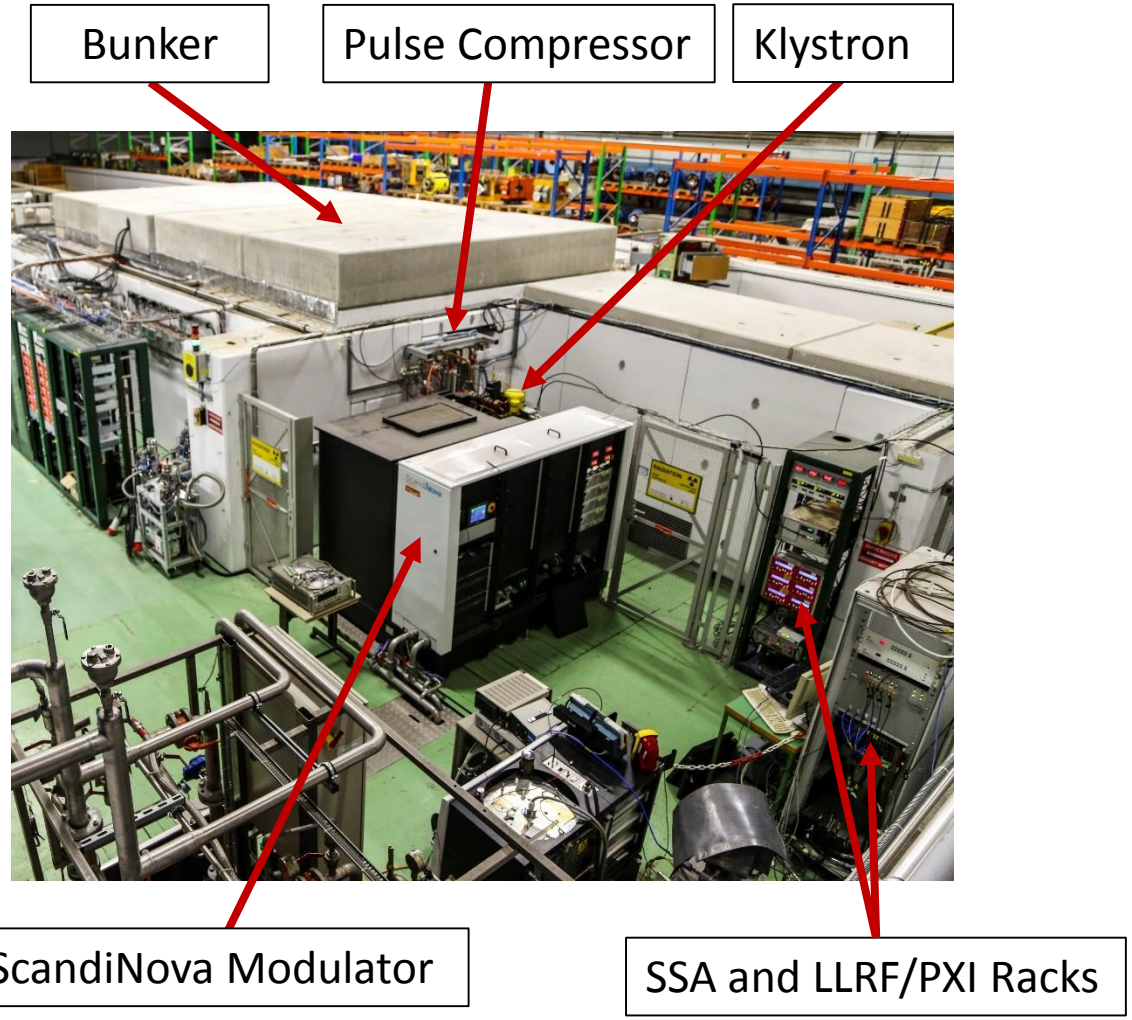
Polarix-TDS Review Meeting

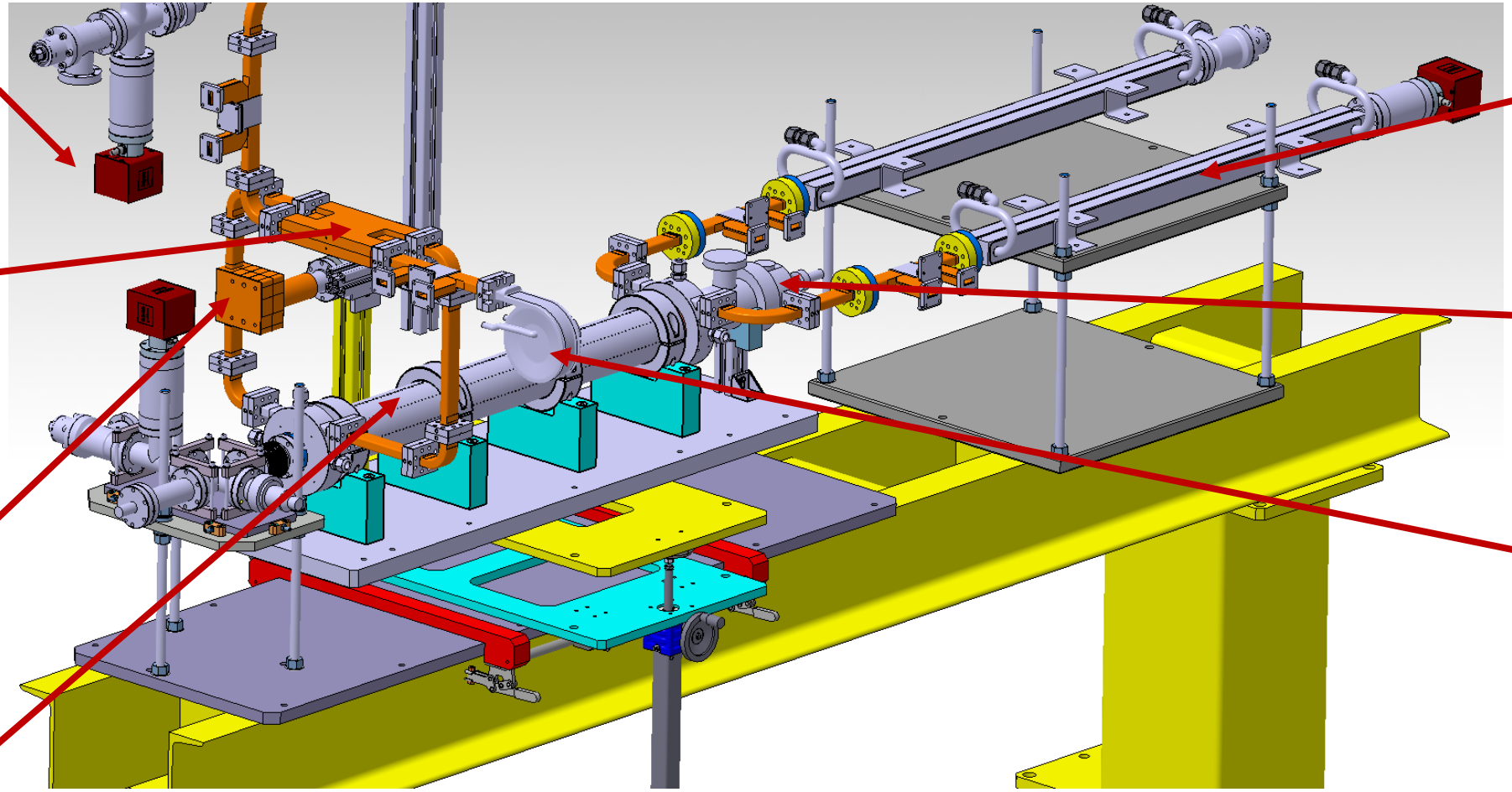
20/02/2019

Xbox-2 Overview

- 50MW CPI VKX-8311A Klystron.
- ScandiNova Modulator.
- 1.5µs pulse length.
- 50Hz rep rate.
- Currently equipped with BOC (Barrel Open Cavity) pulse compressor and Tsinghua university's Correction Cavity Chain (CCC).
- Most recently tested the T24PSI1 and T24PSI2 structures in 2018.



Planned Installation



Installation of RF Network

Additionally installed are the new BOC and Correction Cavity Chain.

Currently seven high power directional couplers are installed as in the arrangement pictured right.

3dB Hybrid used instead of splitter to facilitate reflection measurement (direction dependent on phase).

Planned to collect the following RF Signals for analysis:

- PKI (Klystron Pulse)
- PCI (Correction Cavity Chain Pulse)
- PSI/PSR (Structure incident and reflected)
- PRI (Power reflected to spiral load)
- PEI1/2 (Transmitted power to each load for delta phase measurement)

Note: KLY IN used for diagnostics, not general operation.

Additional channels are use for interlocking via log detectors (amplitude information only): PKR, PER1/2…

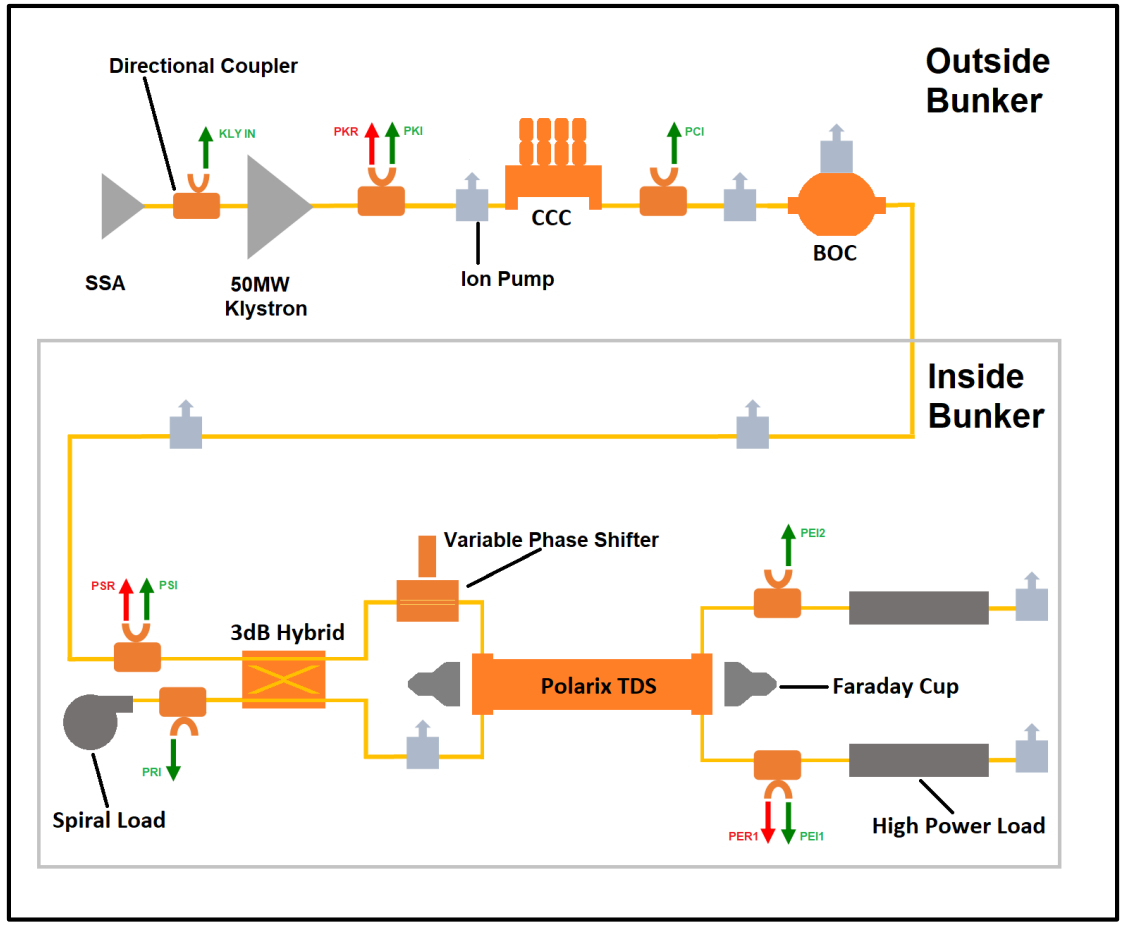
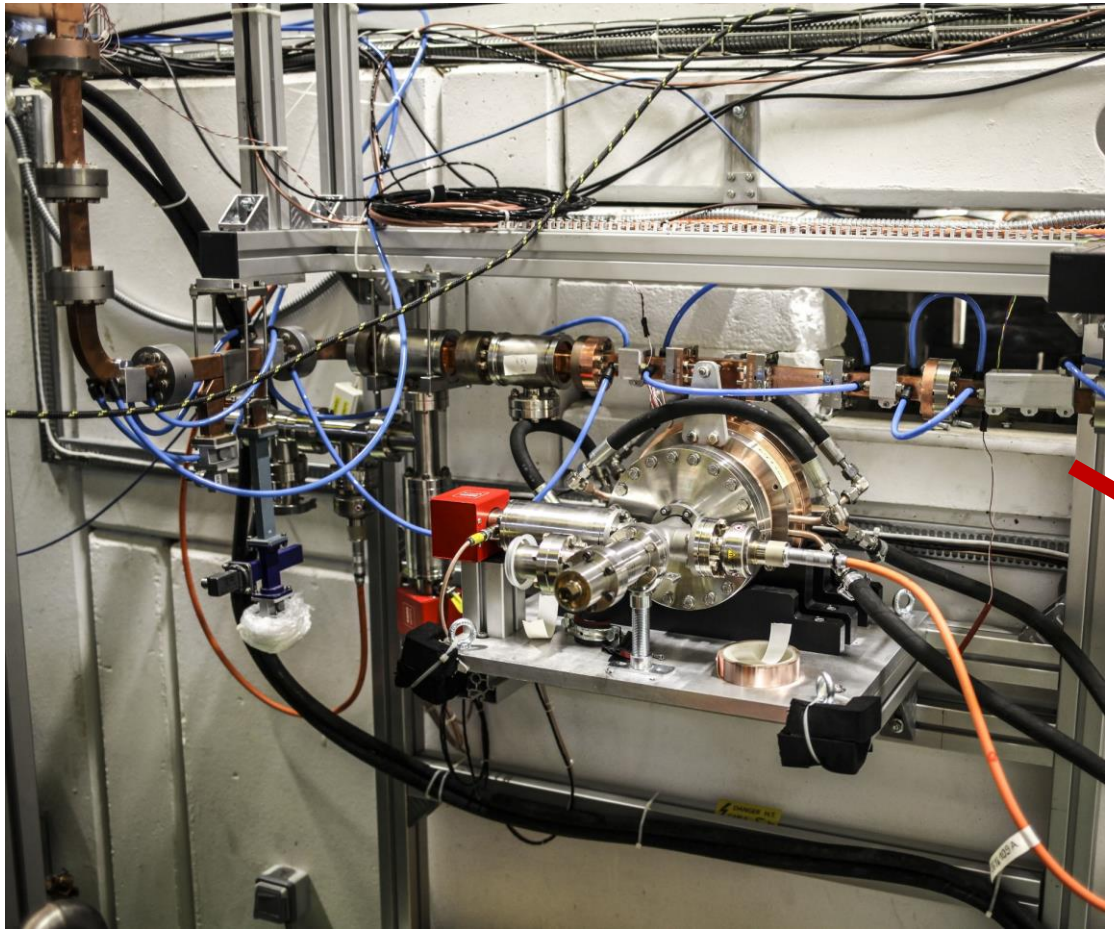
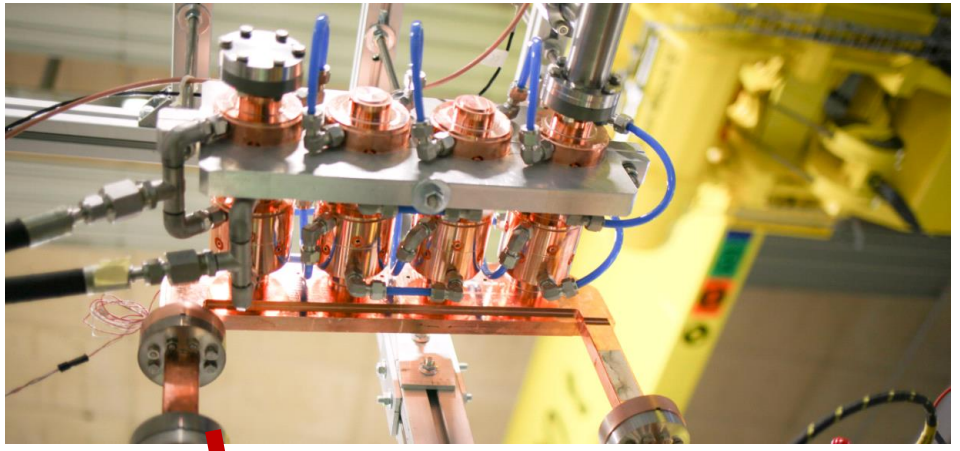
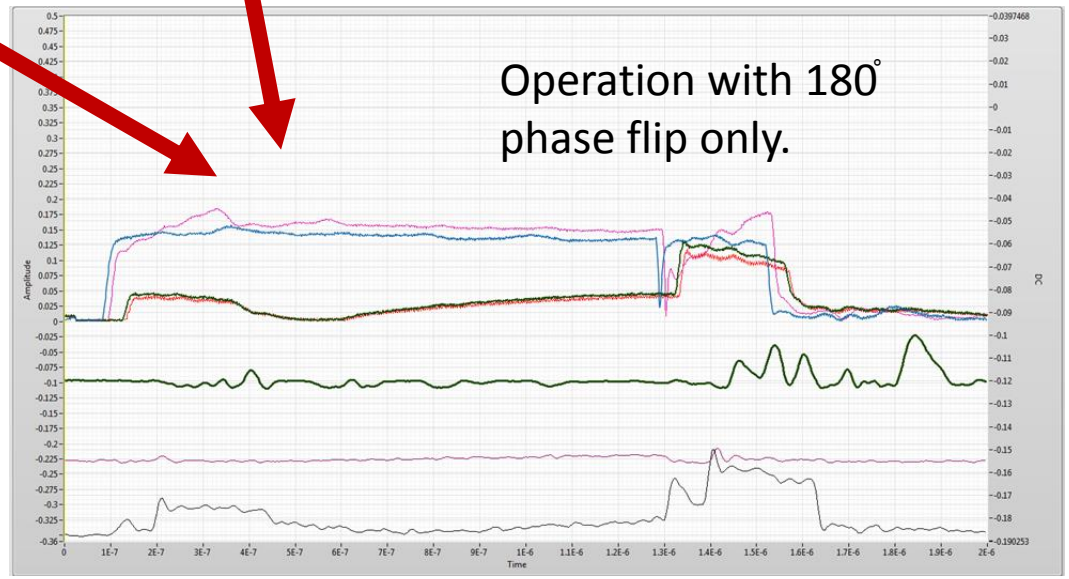


Figure: Bunker Arrangement showing fast RF channels.

BOC and Correction Cavity







Data Acquisition

Additional channels required significant software upgrades and a redesign of the LLRF system:

- Mixing crate redesigned to use an IF of 200MHz, sampled at 800MS/s. (Previously 400MHz interleaved and sampled at 1.6GS/s)
- 8 “slow” channels (250MS/s) for Log det. Signals, Faraday cups, BLMs.
- Temperature recorded via RTD, now through an NI TB-4357 to increase no. channels to 20.
- Vacuum data also logged at each NEXTorr.
- Radiation dose rate date available and regularly analysed.
- Faraday Cups to measure upstream/downstream dark current and breakdown current.

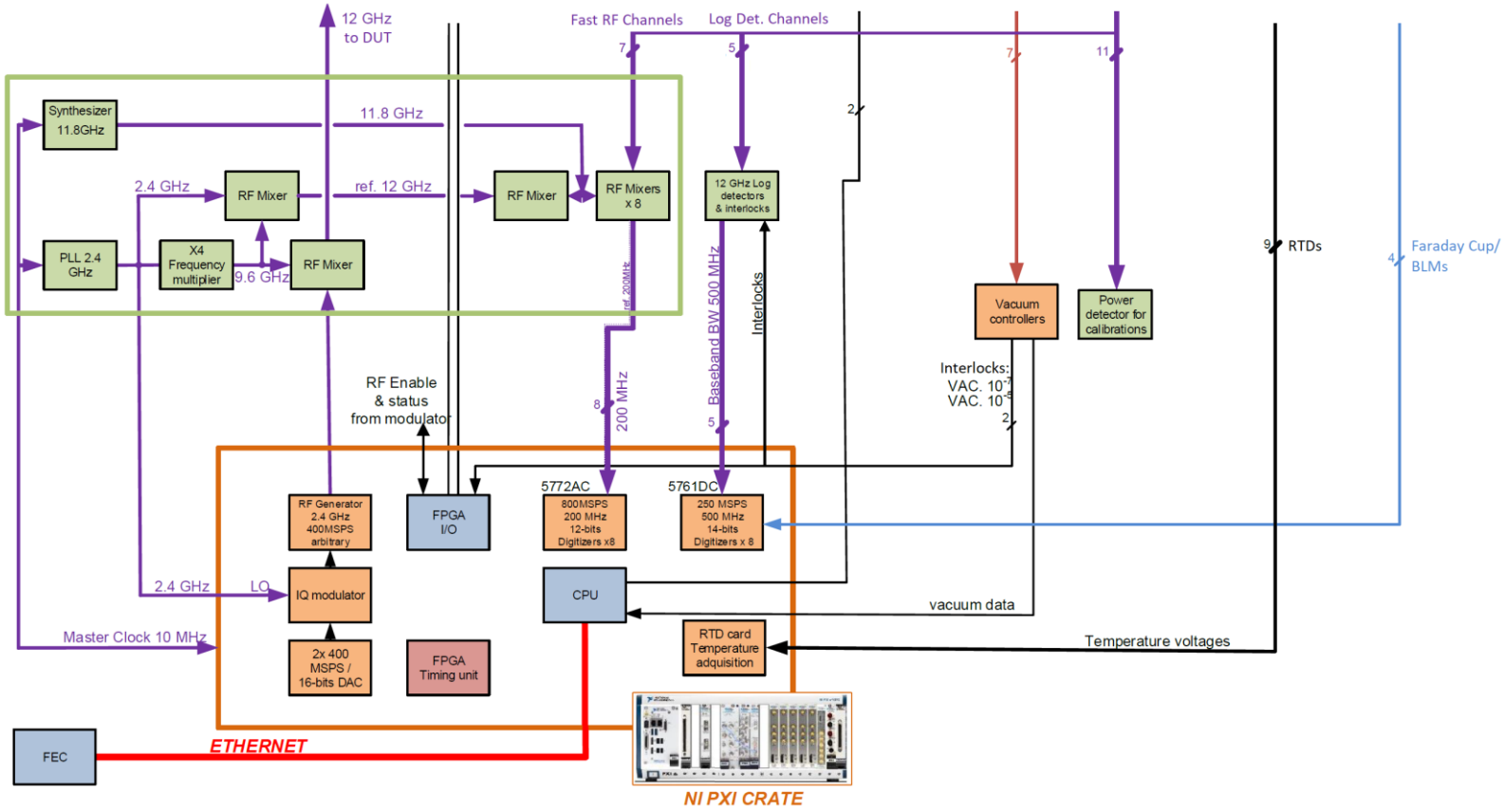
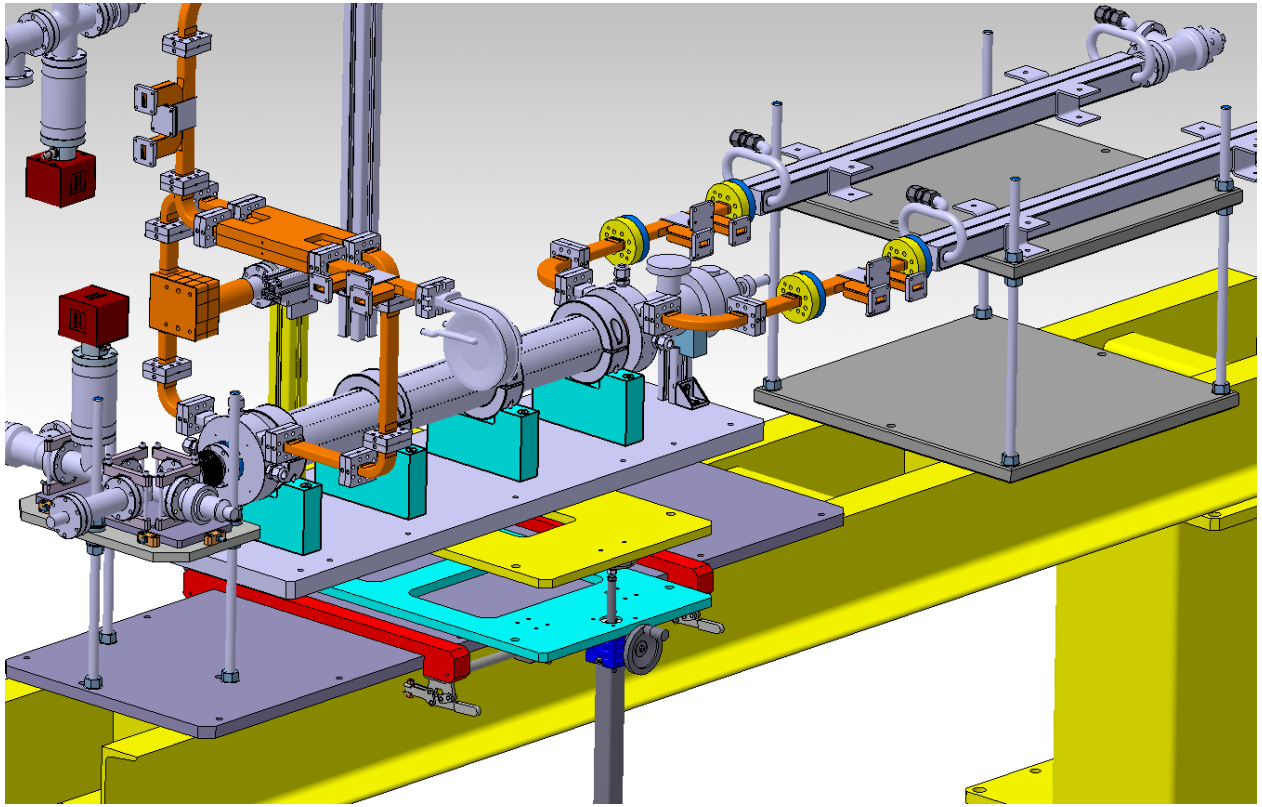


Figure: XB2 Upgraded LLRF system.

Current Status:



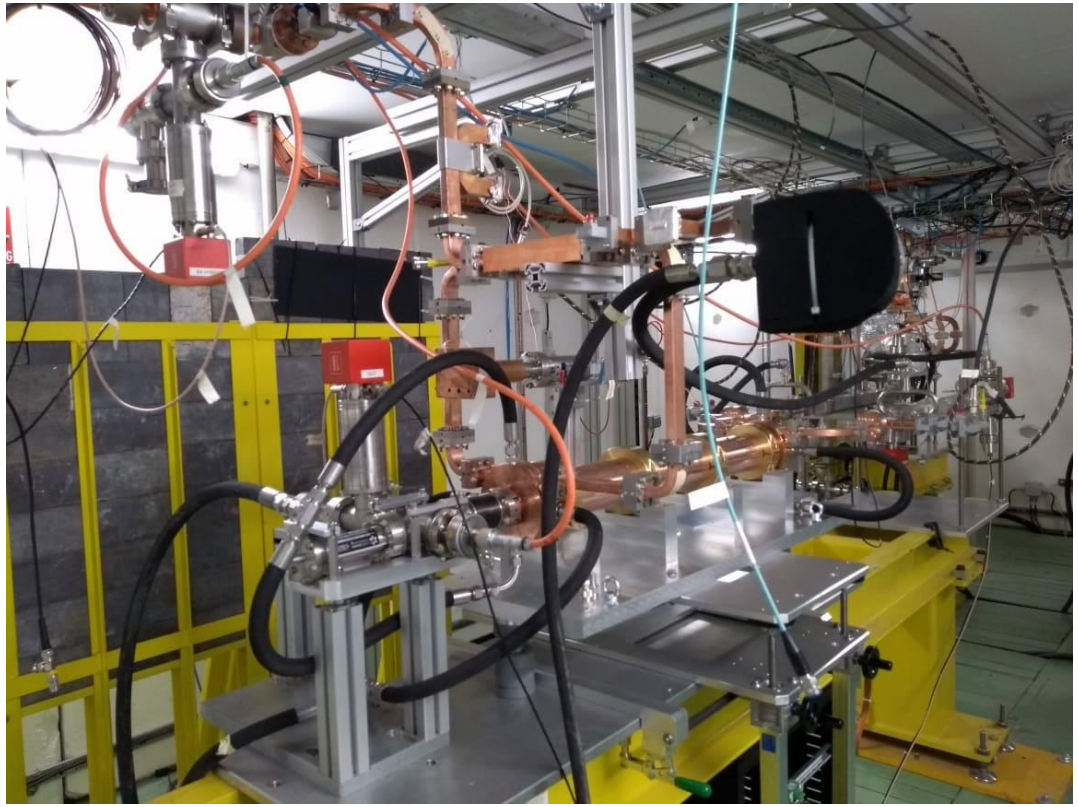


Figure: Planned installation (left) and Polarix TDS in the XB2 bunker(right).

Summary of Installation Status:

- Mixing crate upgraded and additional cables pulled. ✓
- Software upgraded to acquire additional channels. ✓
- Structure installed and waveguide network under vacuum. (Currently at ≈ 10^{-9} mbar and dropping) ✓
- Output arms characterised for delta phase measurement. ✓
- Cooling water circuit completed and running. ✓
- Final cable calibrations for accurate phase and power measurement. **-In progress**
- Measurement and installation of three waveguide to coax adaptors for DCs. **-In progress**
- Add two additional RTDs . **-In progress**

Pulsing planned to commence tomorrow.

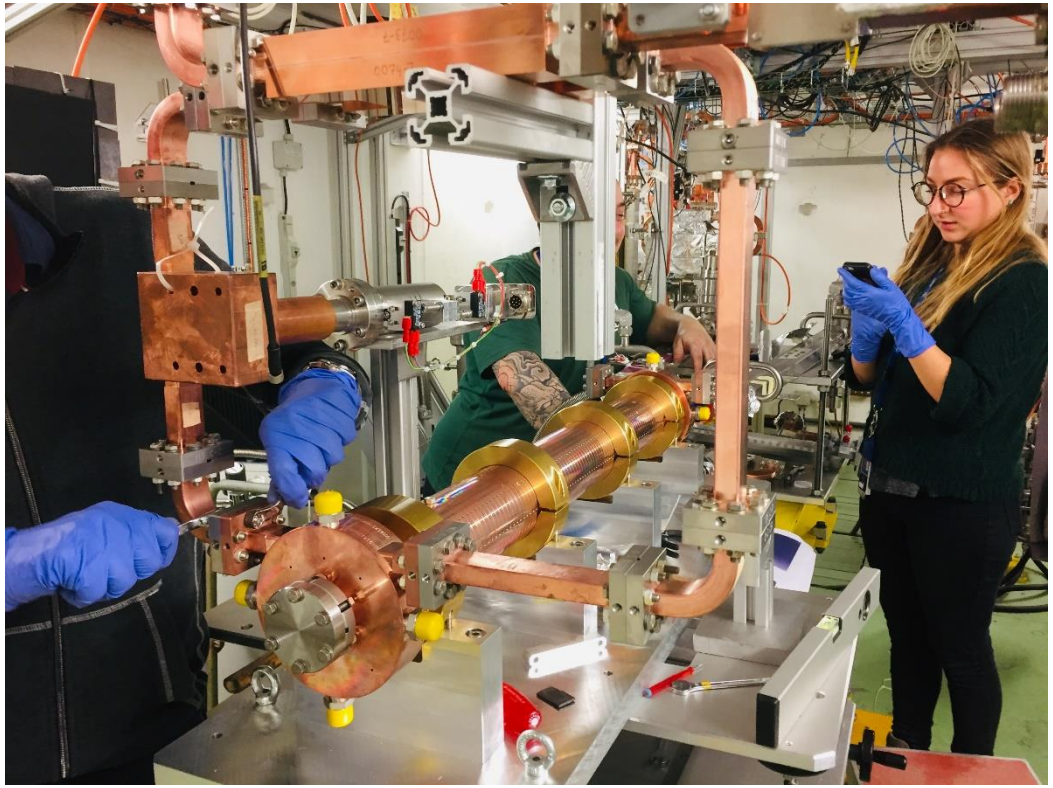


Figure: Installation of the Polarix TDS in XB2.

Thank you. Questions?

Summary Of Signals

Fast RF Channels:

- PKI (Klystron Pulse)
- PCI (Correction Cavity Chain Pulse)
- PSI/PSR (Structure incident and reflected)
- PRI (Power reflected to spiral load)
- PEI1/2 (Transmitted power to each load for delta phase measurement)
- Reference Channel

RTD Channels:

- Structure In
- Structure Out
- Load 1 + Load 2
- Spiral Load
- BOC
- CCC
- Waveguide Network x 2

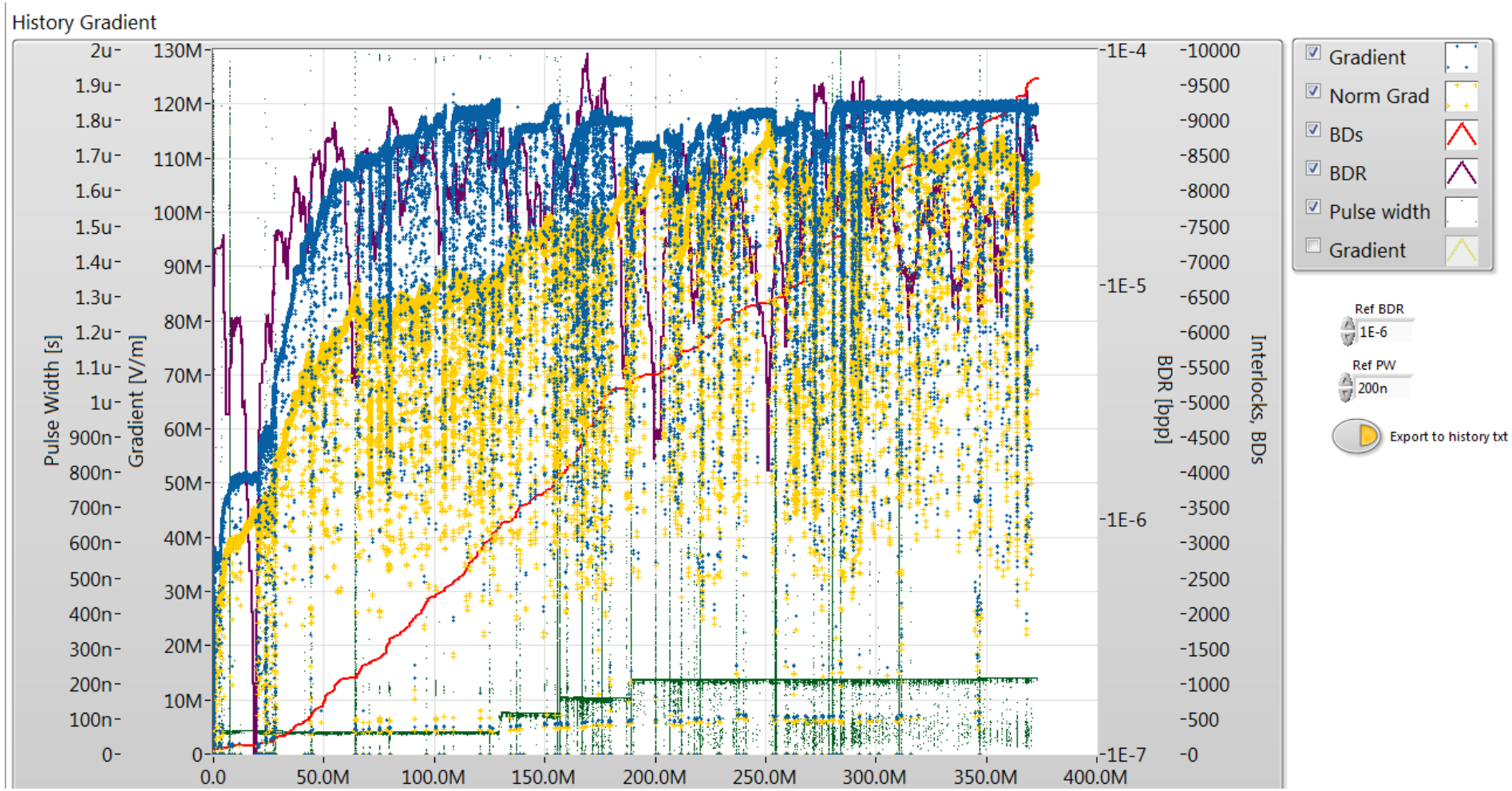
Slow Channels:

- DC UP (Upstream Faraday Cup)
- DC DOWN (Downstream Faraday Cup)
- PKR (KlystronPER1 /PER2 (Reflections from loads)
- reflected)
- 3 x Spare (possibility to add BLMs/additional RF signals).

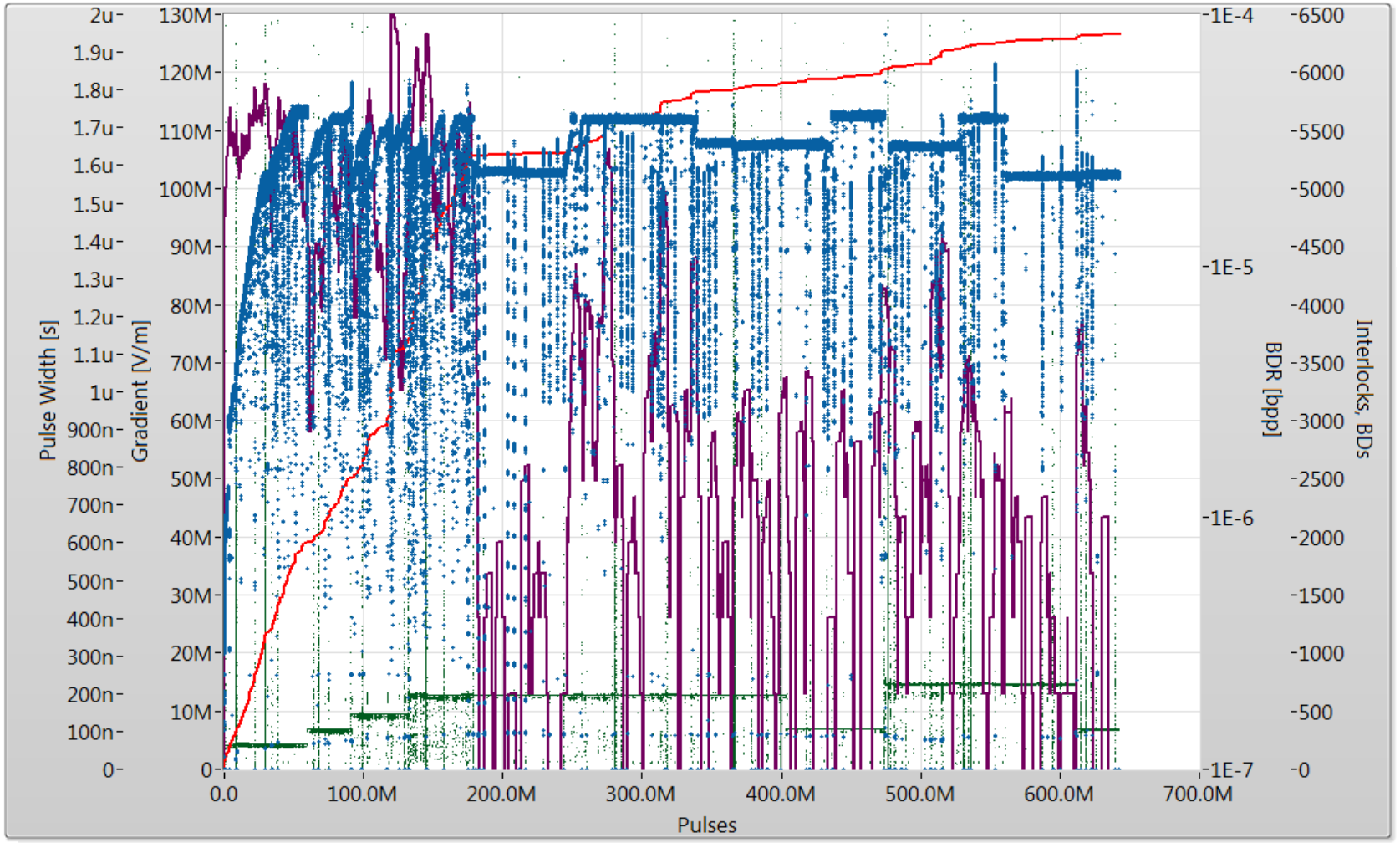
Vacuum Readings:

- Klystron (internal)
- CCC
- Line 1
- BOC
- Line 2
- Before Hybrid
- Structure Input
- Load 1
- Load 2
- Waveguide Network

Bonus Slides: Conditioning Curve for PSI1 IN XB2



Bonus Slides: Conditioning Curve for PSI2 in XB2



See: "Behavior of High Gradient RF Structures During Long-Term Operation" talk by Lee Millar at Workshop on Mechanisms of Vacuum Arcs (Mini MeVArc) 2018

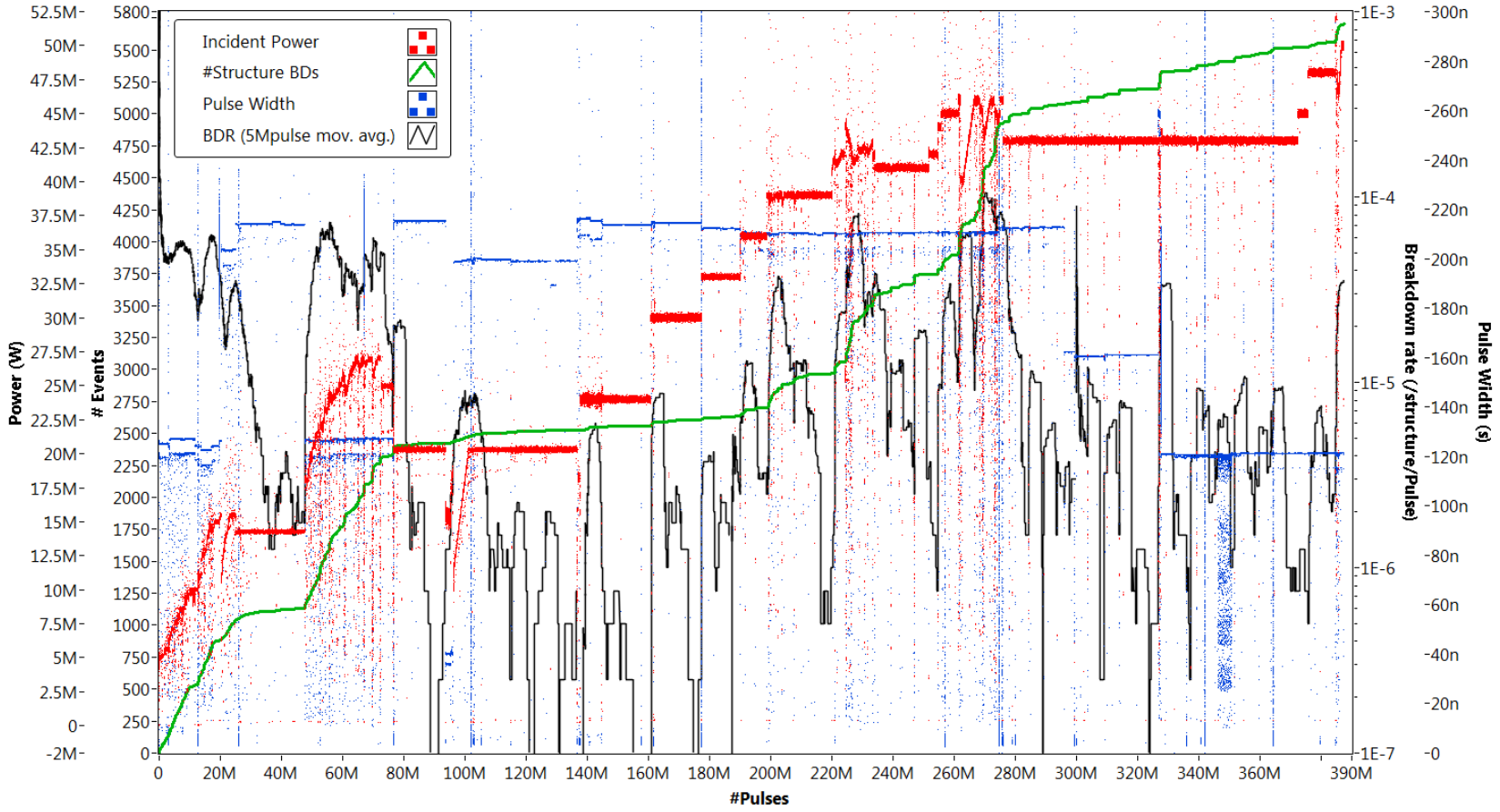
Bonus Slides: Conditioning Curve – CLIC Crab Cavity

Another deflecting structure tested in XB2. Structure saw almost 390 million pulses with over 5700 breakdown events.

Performed well above the operating limit of 13.35 MW: **43MW, 200ns flat-top, BDR 3e-6**.

Peak power reached**: 51 MW, 100 ns flat-top, BDR 3e-5**.

For a detailed post mortem analysis see: “High Power Crab Cavity Testing” talk by Ben Woolley delivered at EuCARD-2 3rd Annual Meeting, Malta.



Bonus Slides: History of Component Performance

Phase Shifter

- Tested up to 42MW at 50ns flat top pulse length.
- Reached 30MW for 100ns before installation of new device.

Spiral Load.

- Operated from 50-200 ns up to 200Hz.
- Tested to 35.5 MW (Maximum available in the line) for 50nsa nd 25MW for 200ns.
- The maximum average power put into the load was 2.1 kW.

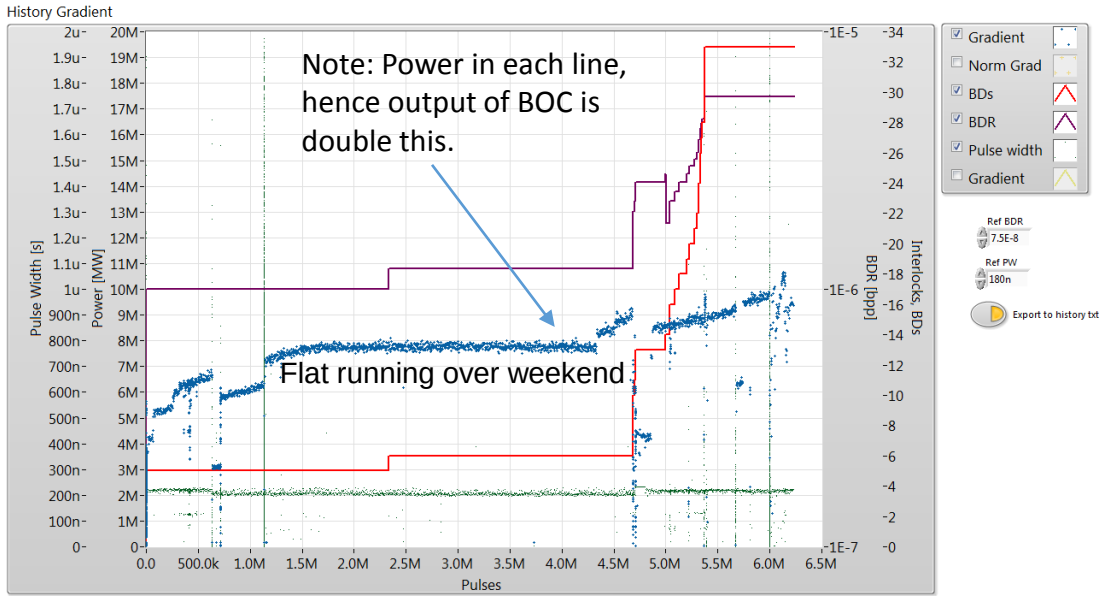
BOC

- Previously reached 20MW compressed pulse for 250ns. Limited by vacuum activity in load, not breakdowns.

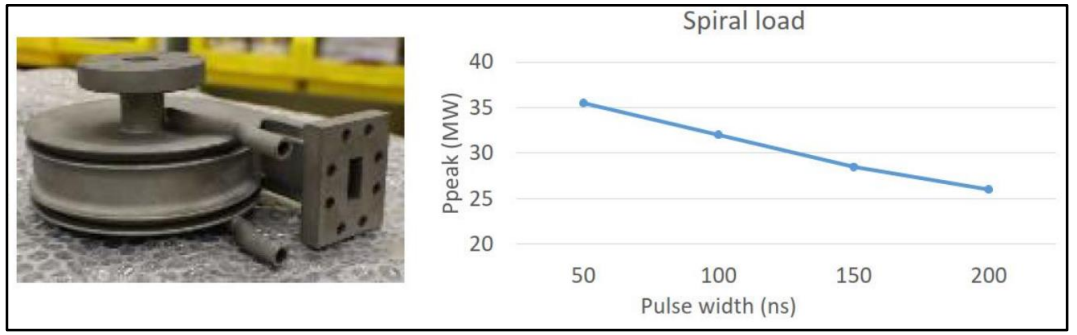
Stainless Steel Loads

- Operated from 50-200 ns up to 200Hz.
- Tested to 35.5 MW (Maximum available in the XB3 line at time of testing) for 50ns and at 25MW for 200ns.
- The installed loads recently saw 10MW each for 250ns, limited by vacuum activity in he new one.

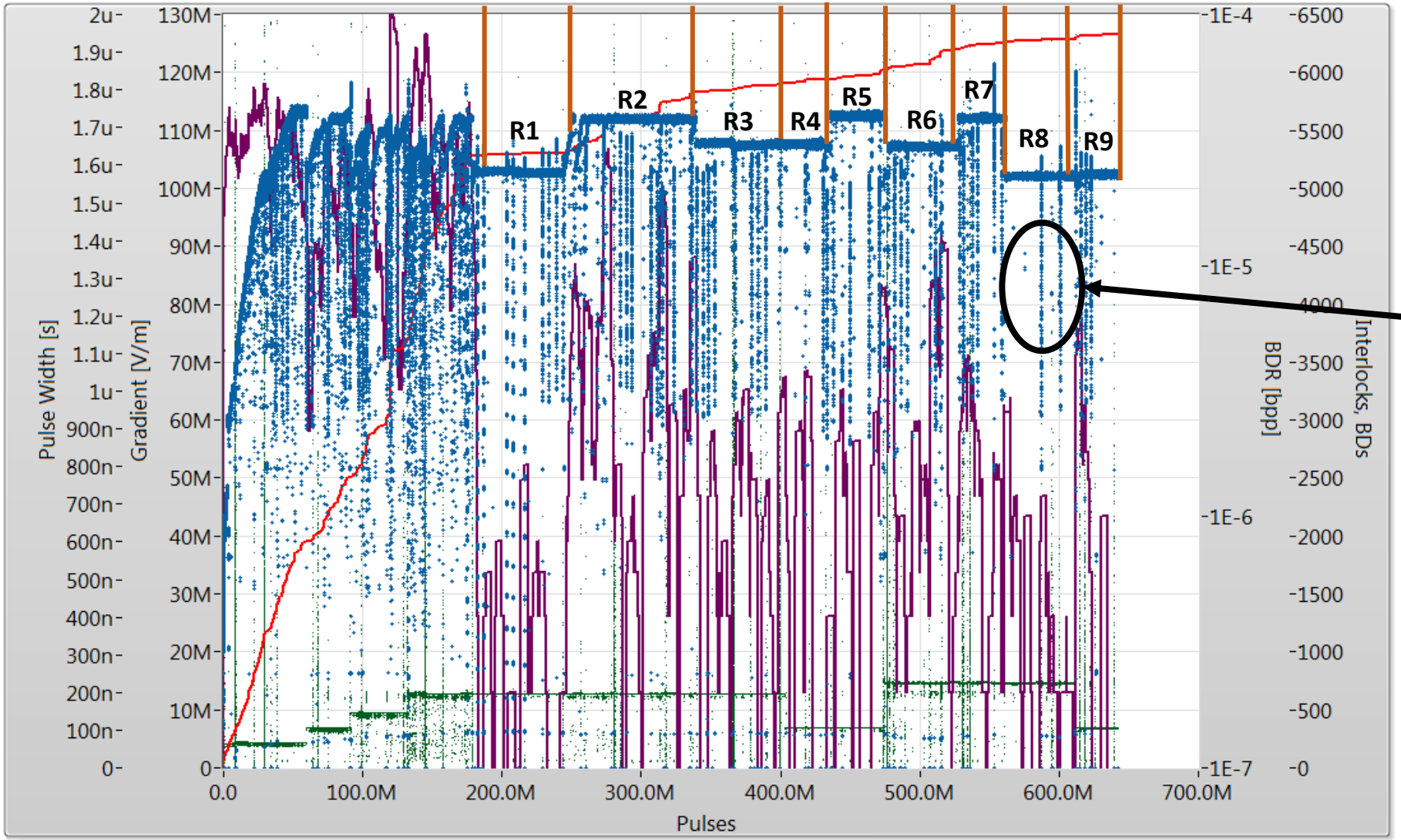
See: “X-band test facilities at CERN” by Nuria Catalan Lasheras at CLIC workshop 2019

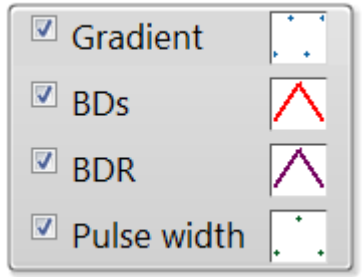


Figures: Preliminary conditioning of the BOC (above) and summary of spiral load (below).



Bonus Slides: PSI2 Conditioning Summary



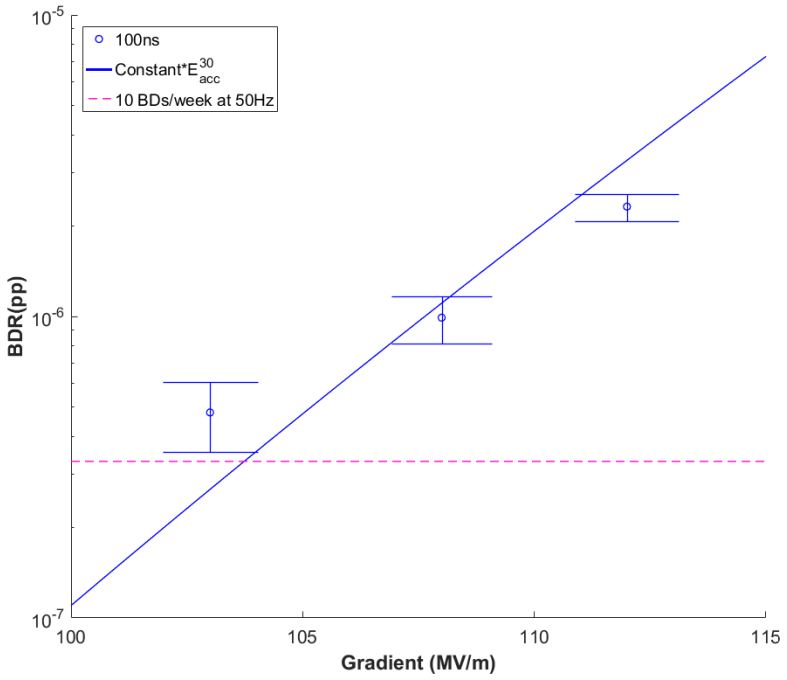


NB: Regular power drops due to dark current measurements. (See Jan Paszkiewicz talk at CLIC workshop 2019)

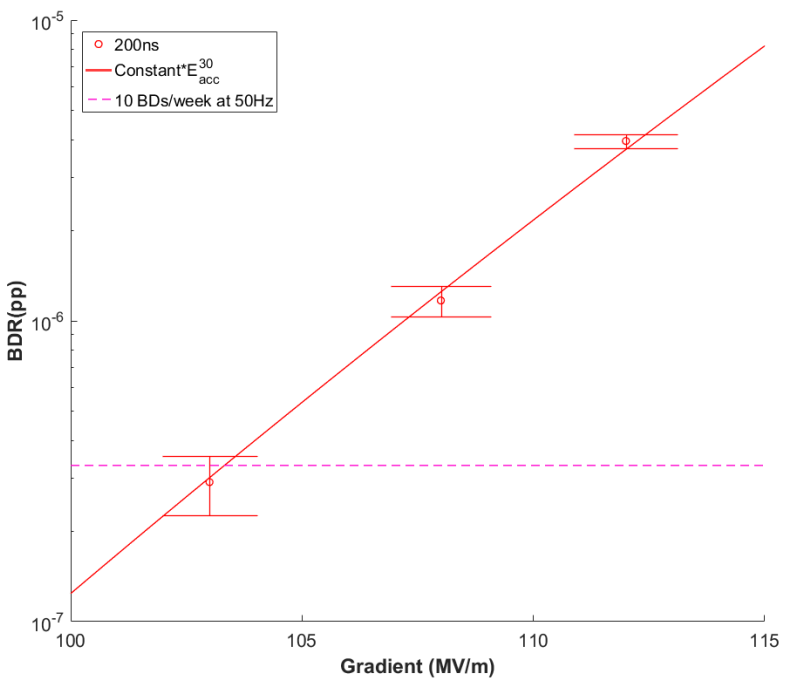
Run	Gradient (MV/m)	Pulse Length (ns)	Pulses (millions)
1	103	200	68
2	108	200	64
3	112	200	91
4	108	100	32
5	112	100	41
6	108	CLIC	54
7	112	CLIC	34
8	103	CLIC	37
9	103	100	31

Bonus Slides: PSI2 BDR Results of Flat Runs

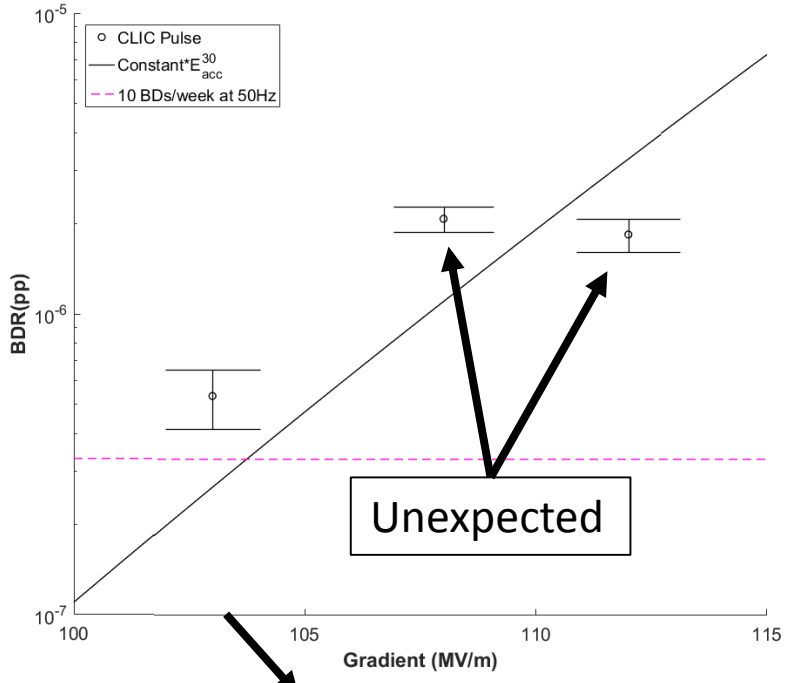
100ns Pulse



200ns Pulse



CLIC Pulse



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2	108	200	64	7	112	CLIC	34
3	112	200	91	8	103	CLIC	37
4	108	100	32	9	103	100	31
5	112	100	41				

$$Proposed\ scaling: BDR \propto {E_a}^{30}$$