Crab Cavity Results

Ben Woolley

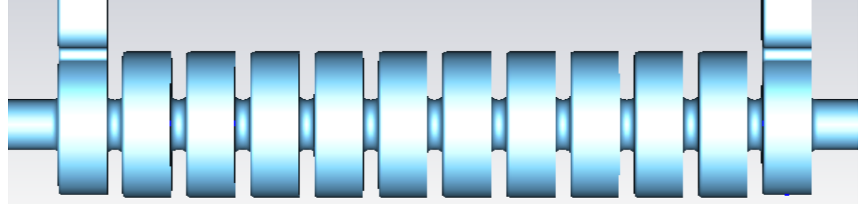
&

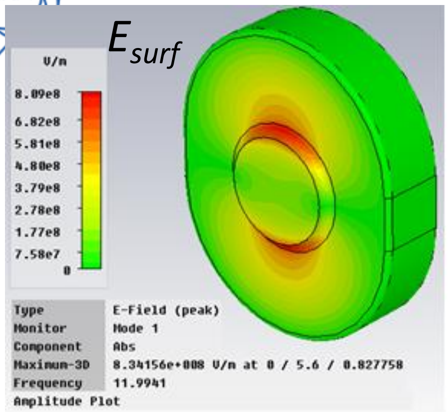
The Xbox team

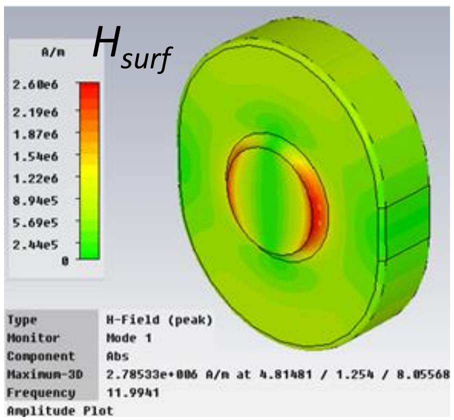
Outline

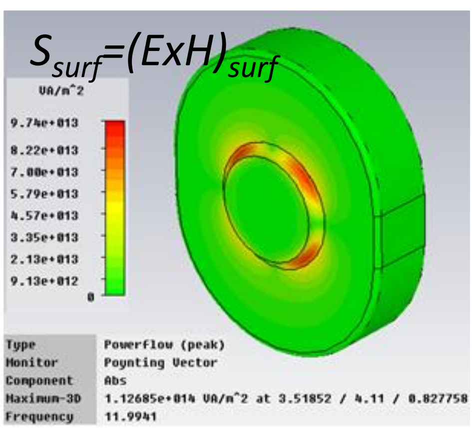
- Crab cavity RF Design
- Fabrication
- Tuning
- High power testing: Xbox-2
- Conditioning and Performance
- Breakdown locations
- Future testing

RF Design





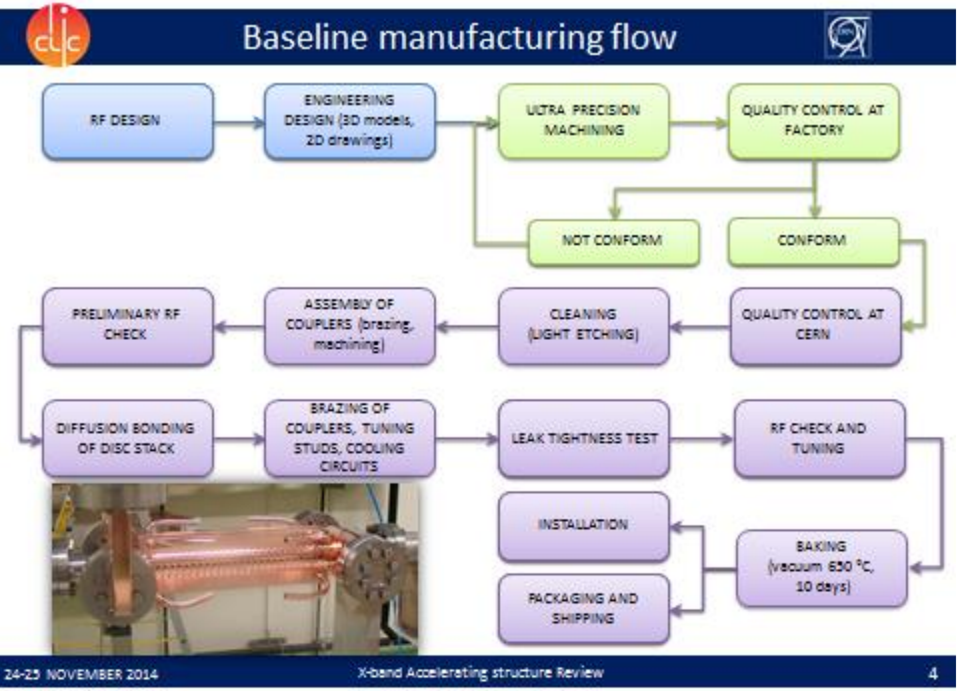




- Peak electric and magnetic fields of the dipole mode are located 90 degrees from each other on the iris
- Surface Poynting flux S_{surf} is however at 45 deg to both E and H
- Location of the breakdown on the iris provides critical information about the role of magnetic field in breakdown.
- The cavity has a large Sc but relatively low E and H fields at the surface so this also provides an independent verification of new theories.

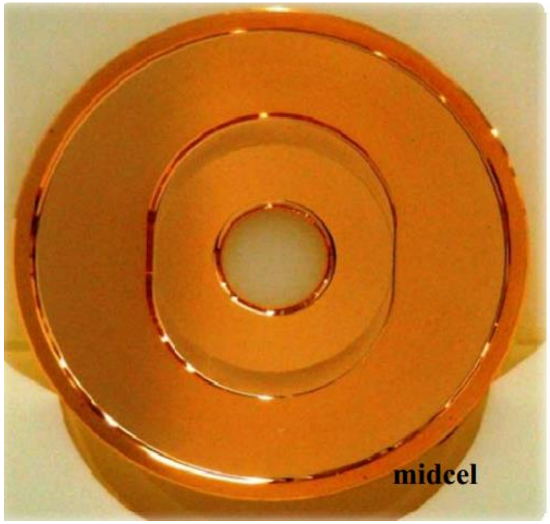
Property	Crab cavity	CLIC_G
Mode	120° , 11.9942 GHz	120° , 11.9942 GHz
Q	6247	6100-6265
V_{group}	-2.9 %c	1.66-0.83 %c
Kick	2.55 MV	NA MV
Gradient	26 MV/m	100 MV/m
Power	**13.35** MW	42 MW
E_{surf}	103 MV/m	190 MV/m
H_{surf}	348 kA/m	410 kA/m
ΔT (200ns)	26 K	21 K
Sc	3.32 W/mm^2	3.8 W/mm^2

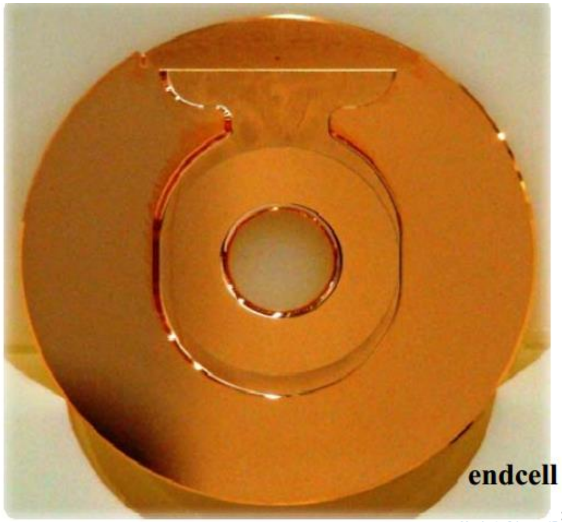
Fabrication



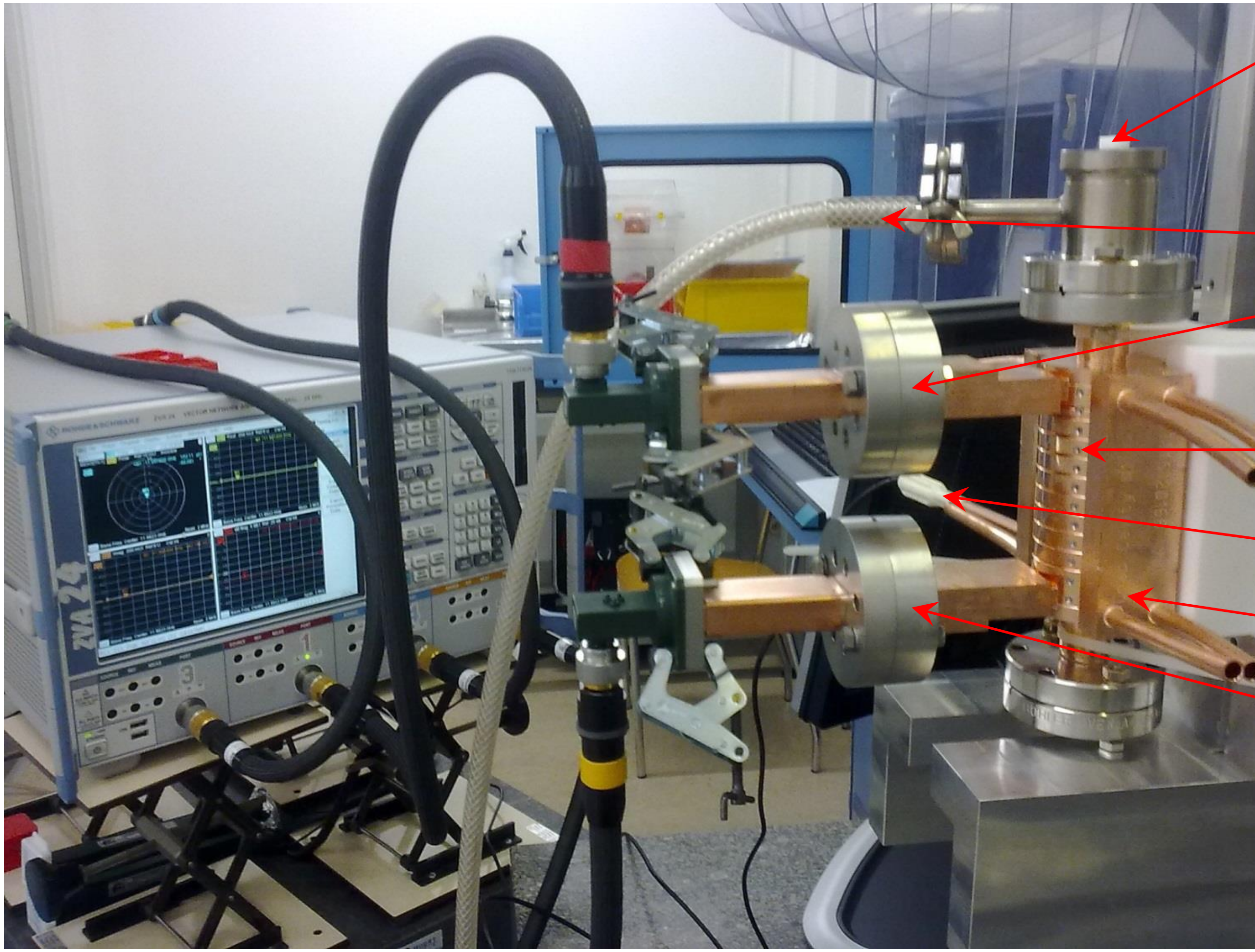
Manufactured with normal CERN techniques:

- Discs ultra-precision machined at VDL
- Stacking and alignment performed at CERN or Bodycote.
- Coupler brazing and bake out at Bodycote.



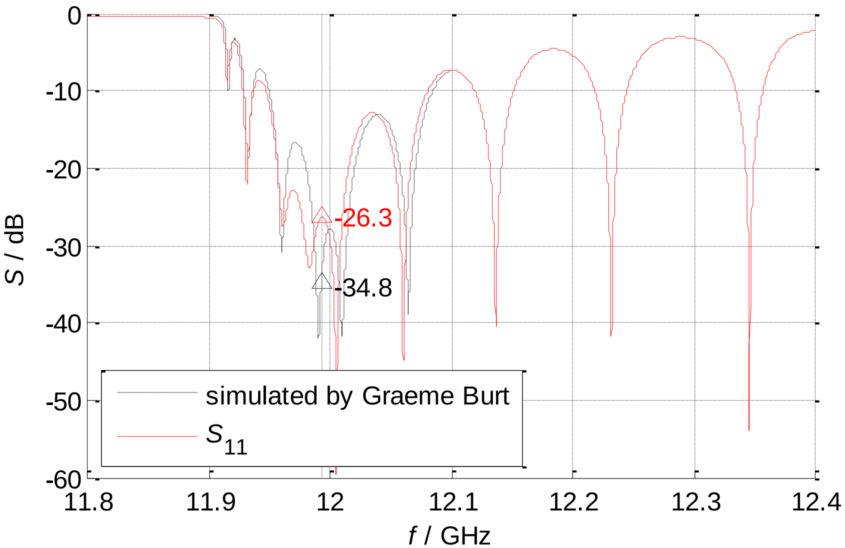


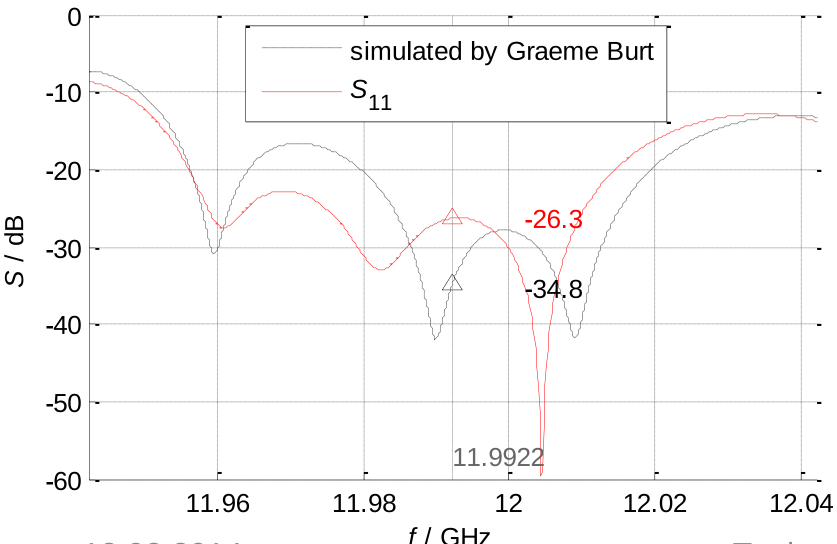
Tuning


centring V guiding the wire for bead-pull measurements
nitrogen supply
input (chosen and marked)
tuning pins (4 per cell)
temperature sensor
cooling block
output (marked)

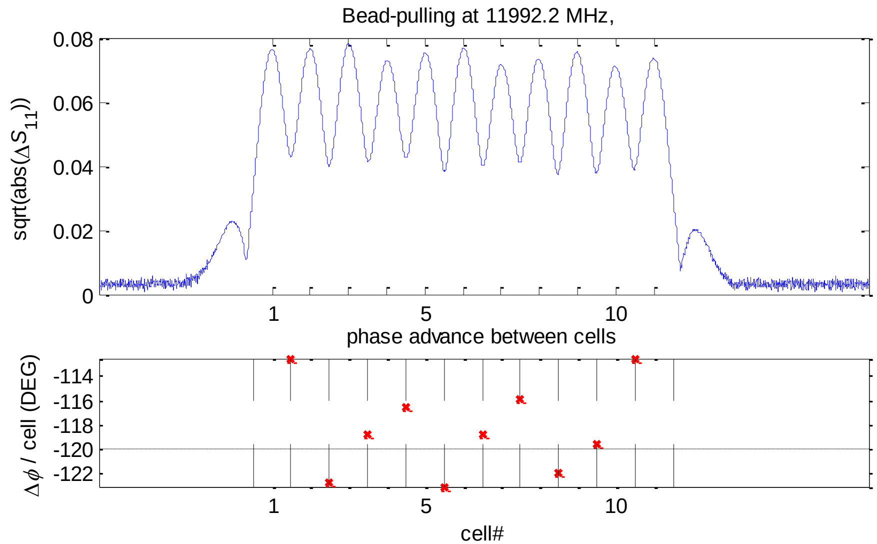
Before Tuning

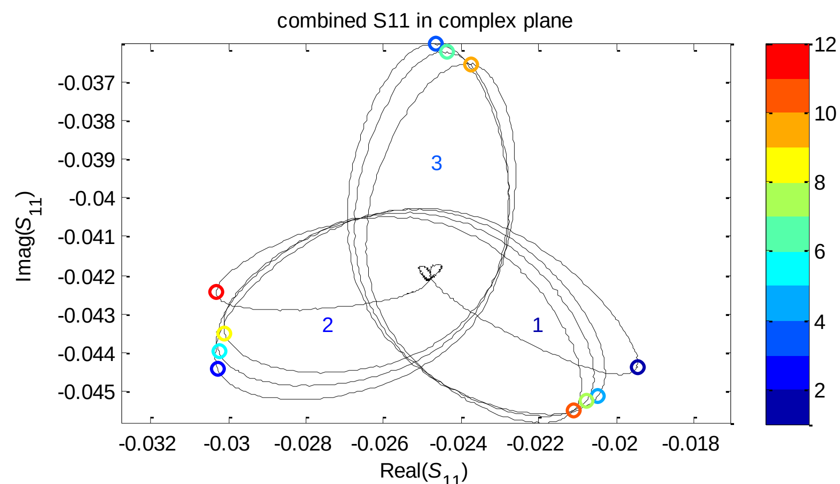
input reflection





bead-pull @ 11.9922 GHz





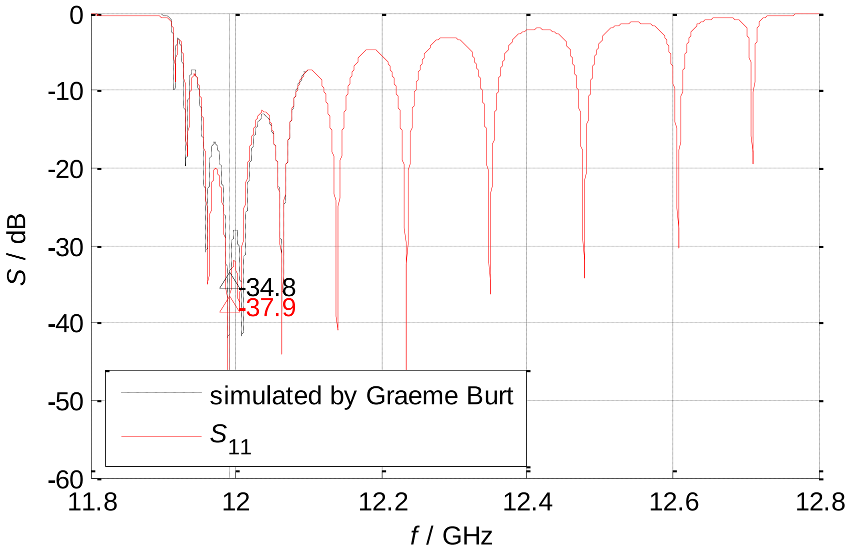
Tuning - E. Daskalaki, A. Degiovanni, C. Marrelli, M. Navarro Tapia, R. Wegner, B. Woolley

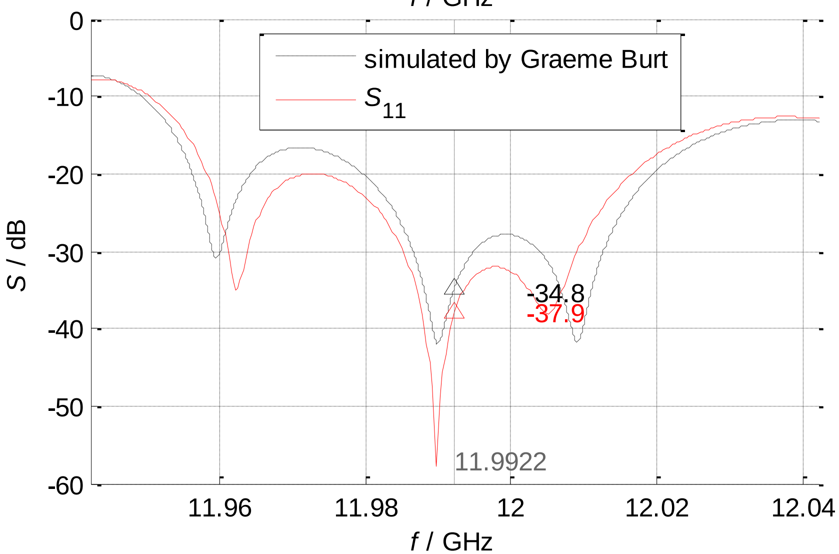
cell	tuning record of |ds11|*sign(df) (mU)													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 in														
2														
3														
4														
5														
6														
7														+4.8
8												+9.6	+14.0	
9											-8.9			-3.4
10									+7.0	+4.0				
11					+7.4	+12.0								
12 out	+8.1	+10.2	+12.3	+8.7			-7.5	-3.2						

cell	tuning record of |ds11|*sign(df) (mU)												
	15	16	17	18	19	20	21	22	23	24	25	26	**sum**
1 in											+9.8		**+9.8**
2										+10.5		+9.9	**+20.4**
3								+6.2	+21.7				**+27.9**
4					+5.3		+3.8						**+9.1**
5				+6.4		+3.1							**+9.5**
6	+5.0		+5.7										**+10.7**
7	+7.0	-3.4											**+8.4**
8													**+23.6**
9													**-12.3**
10													**+11.0**
11													**+19.4**
12 out													**+28.6**

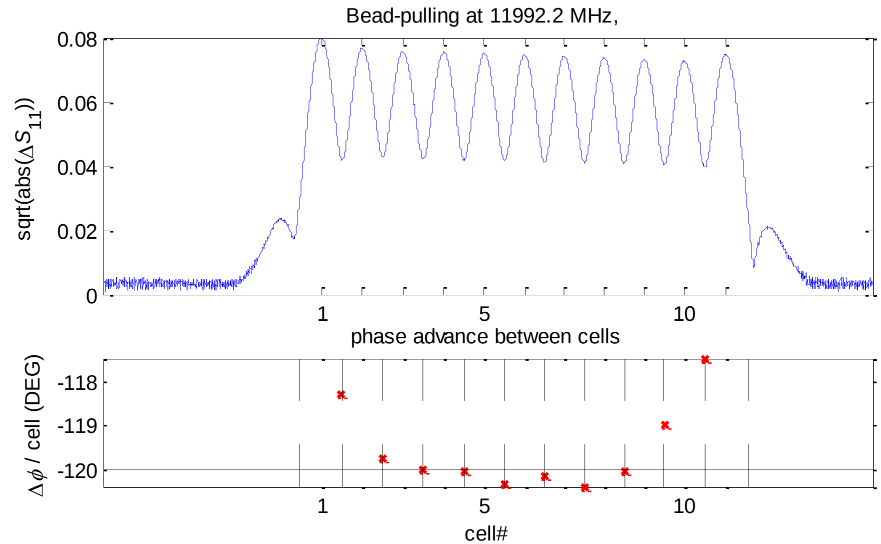
Tuning Results

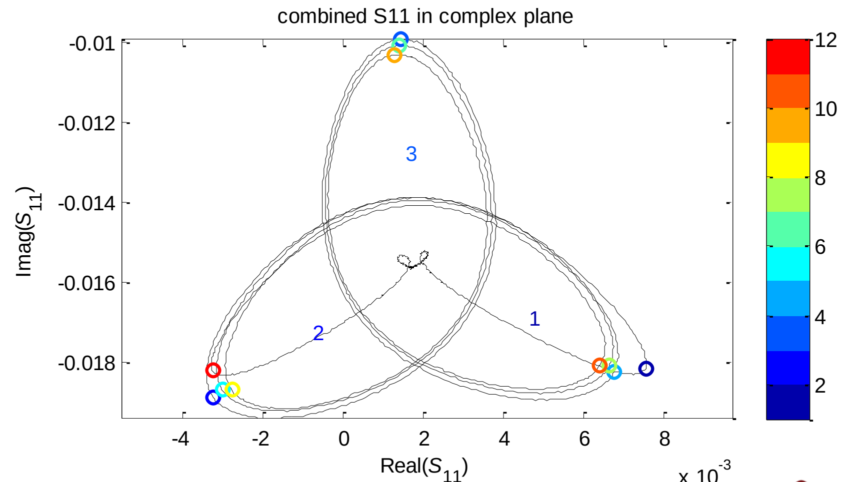
input reflection





bead-pull @ 11.9922 GHz

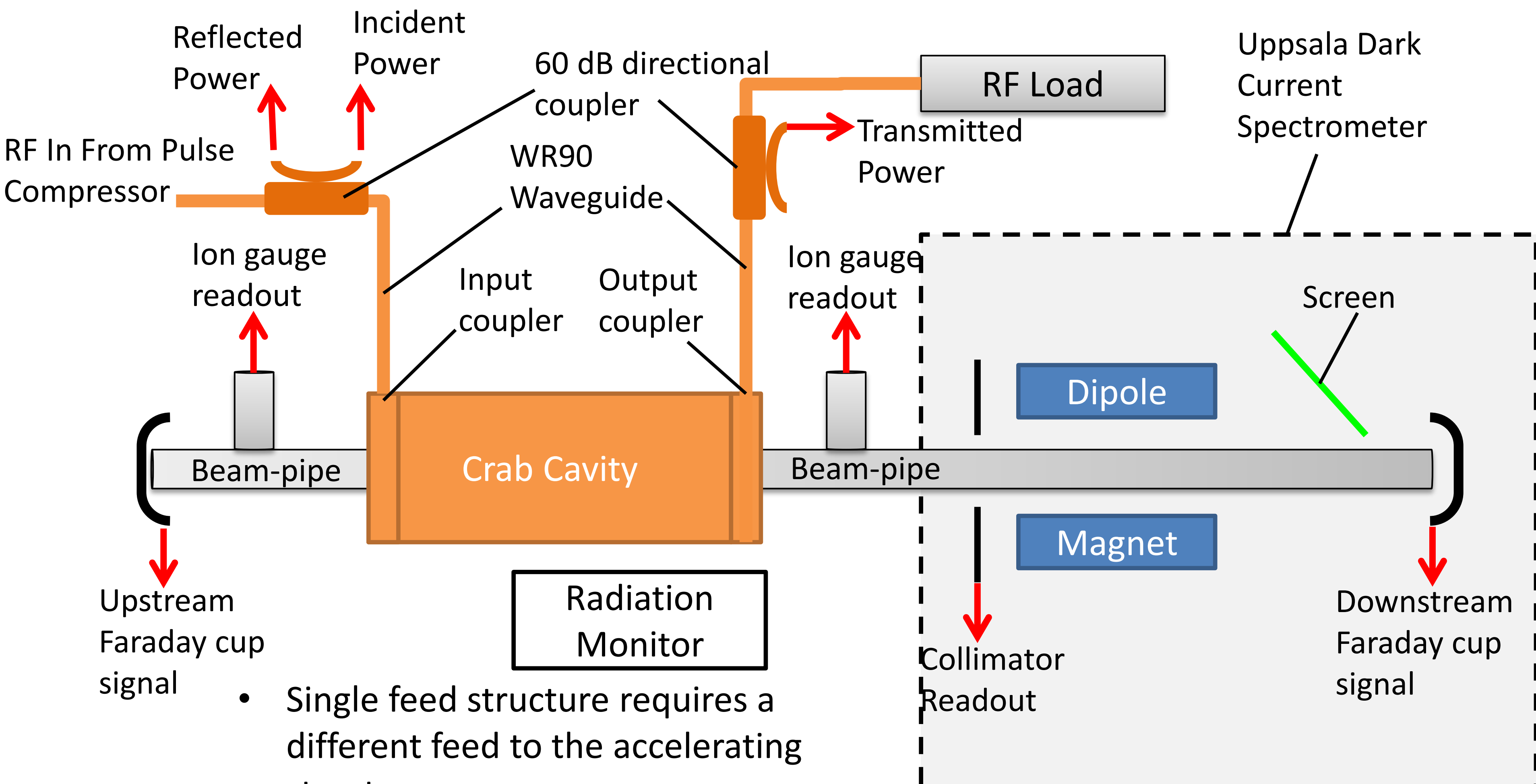




Xbox-2

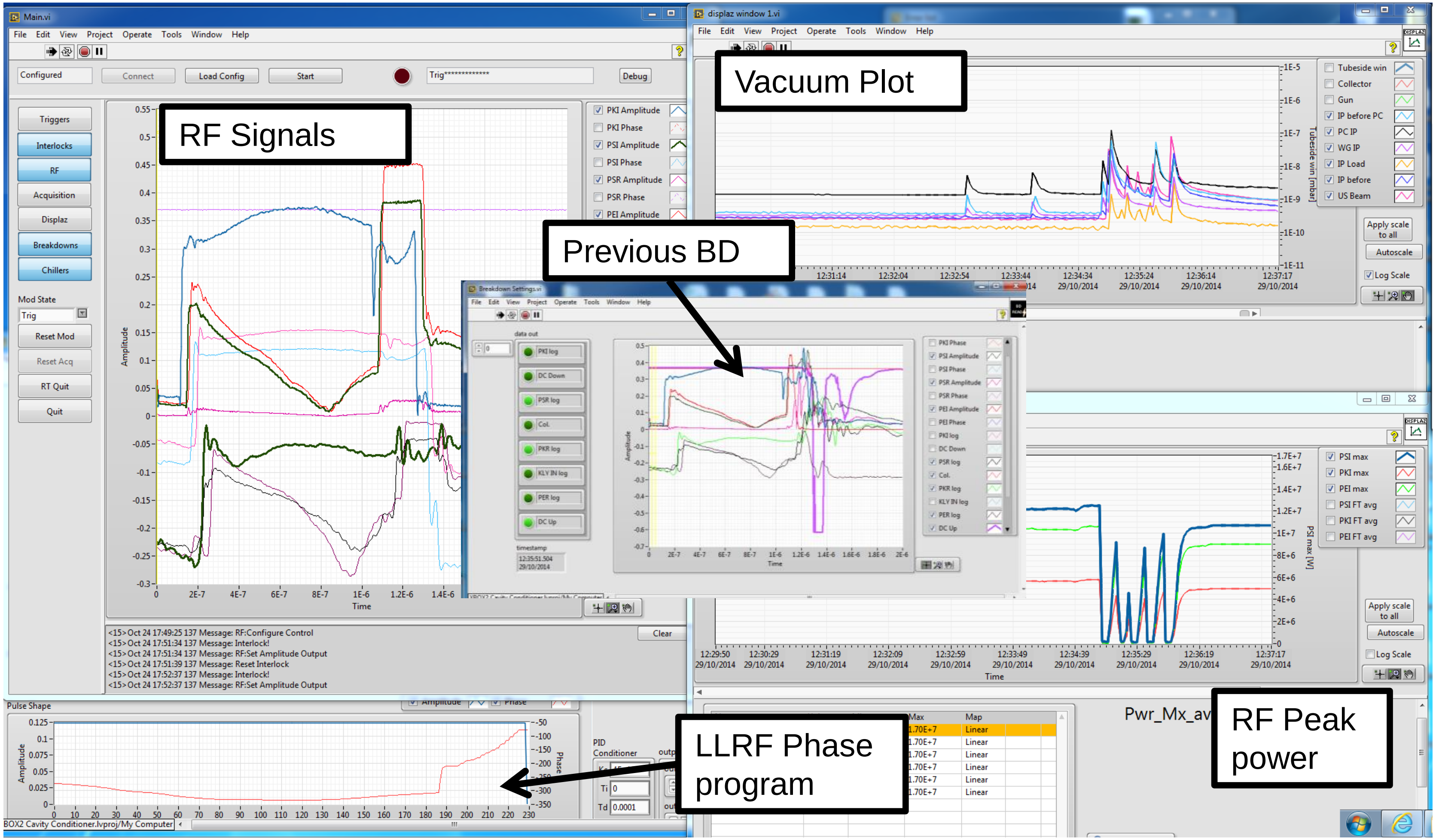
- Scandinova Modulator
- Klystron (50MW, 1.5us pulse) For Crab cavity test: SLAC XL5 klystron
- Pulse compressor (250ns, ratio ~3)
- Stainless steel load

Crab Cavity Diagnostics

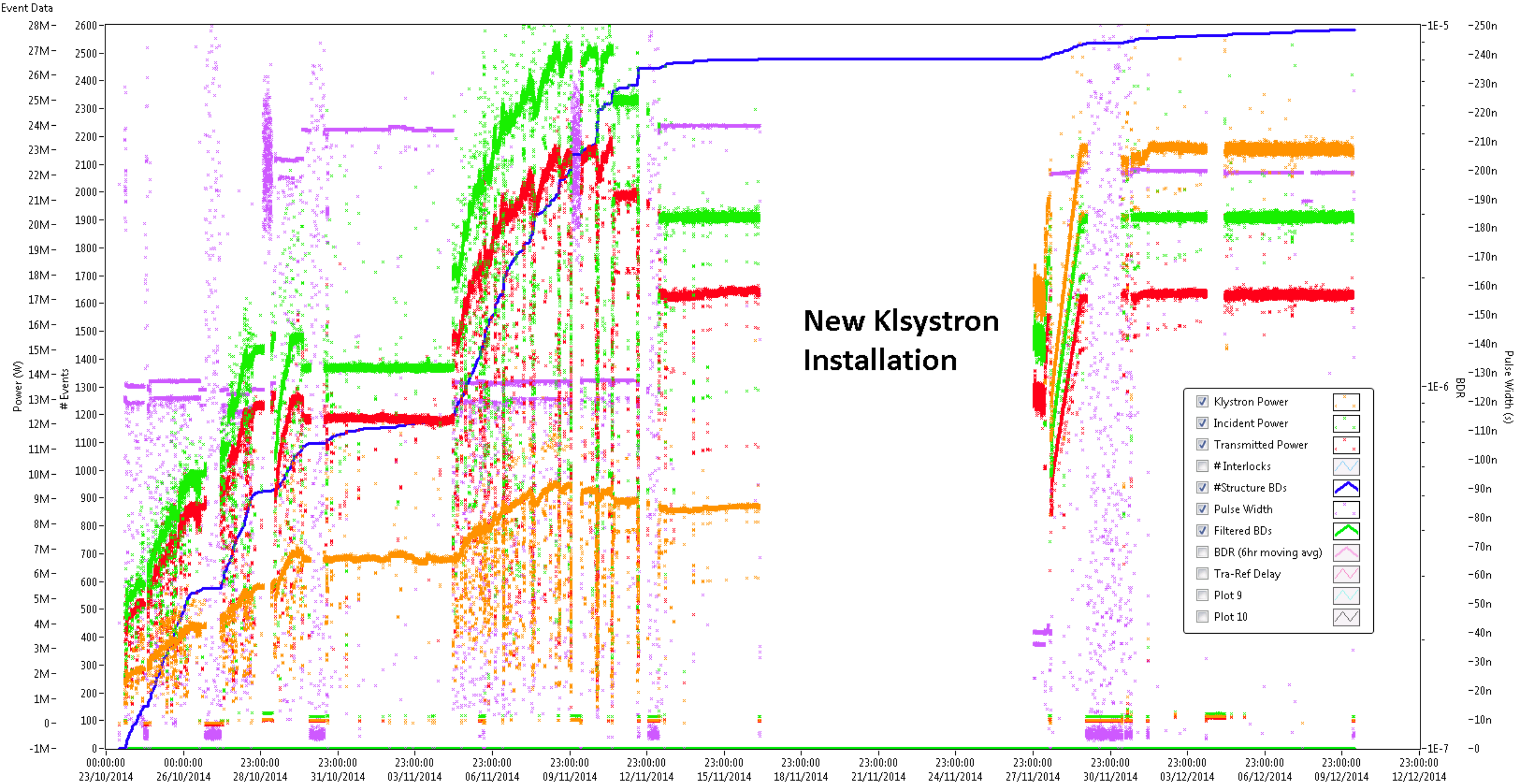


- Single feed structure requires a different feed to the accelerating structures.
- We can take advantage of extra diagnostics with the Uppsala dark current spectrometer.

Xbox2 Operator Display

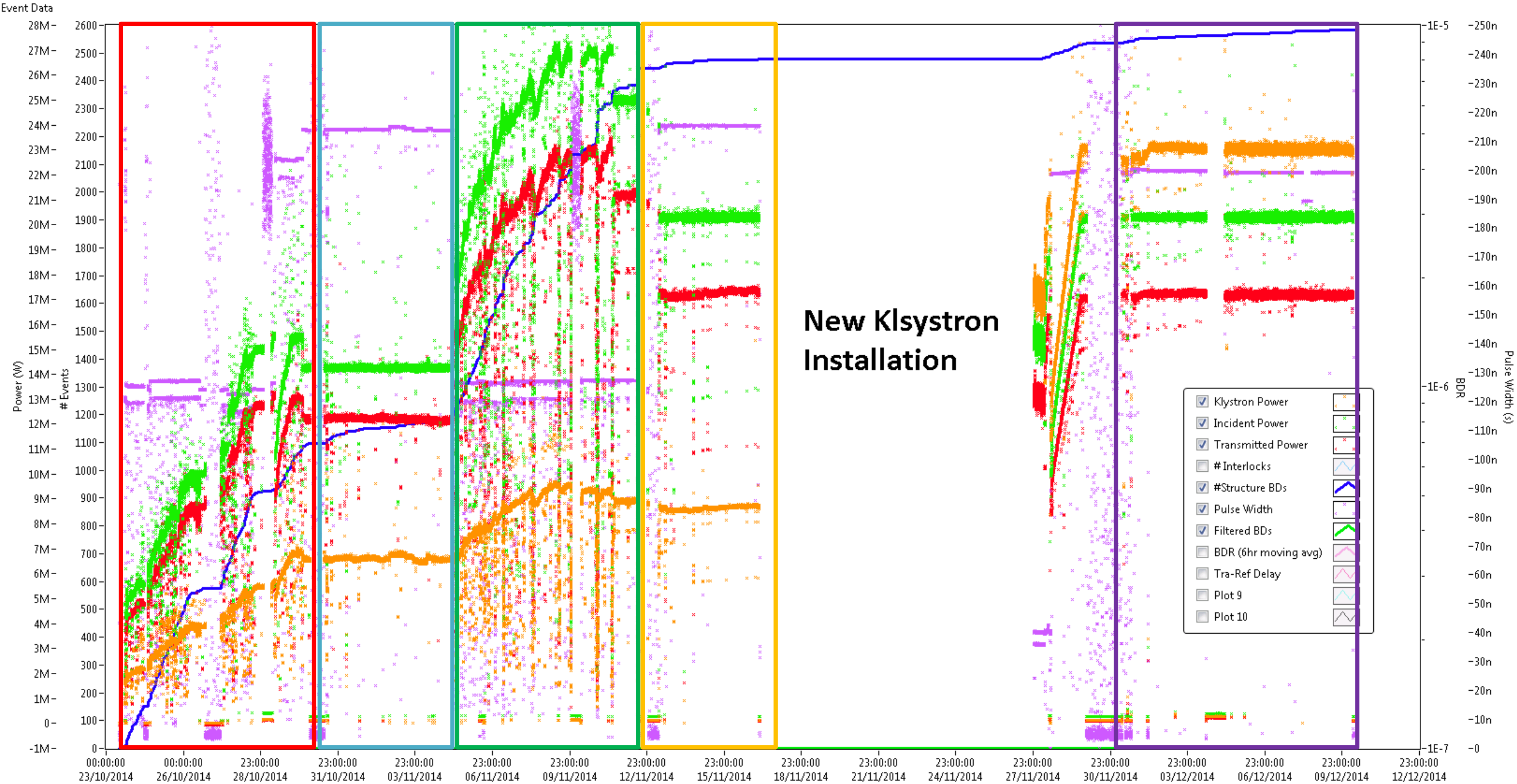


Results



- 23rd October – 10th December
- Almost 2600 recorded breakdowns
- New klystron allowed the pulse compressor to be turned off

Results



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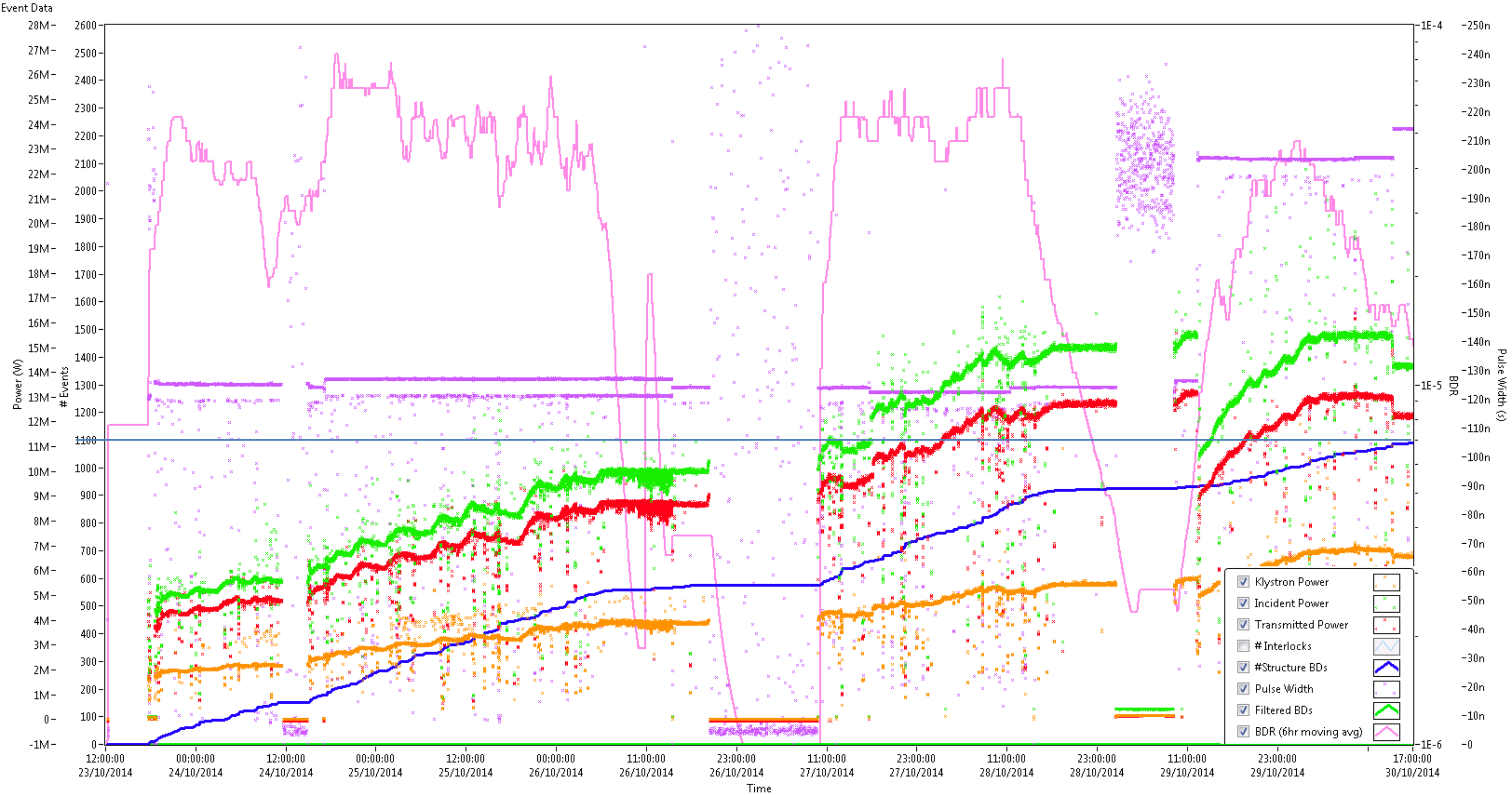
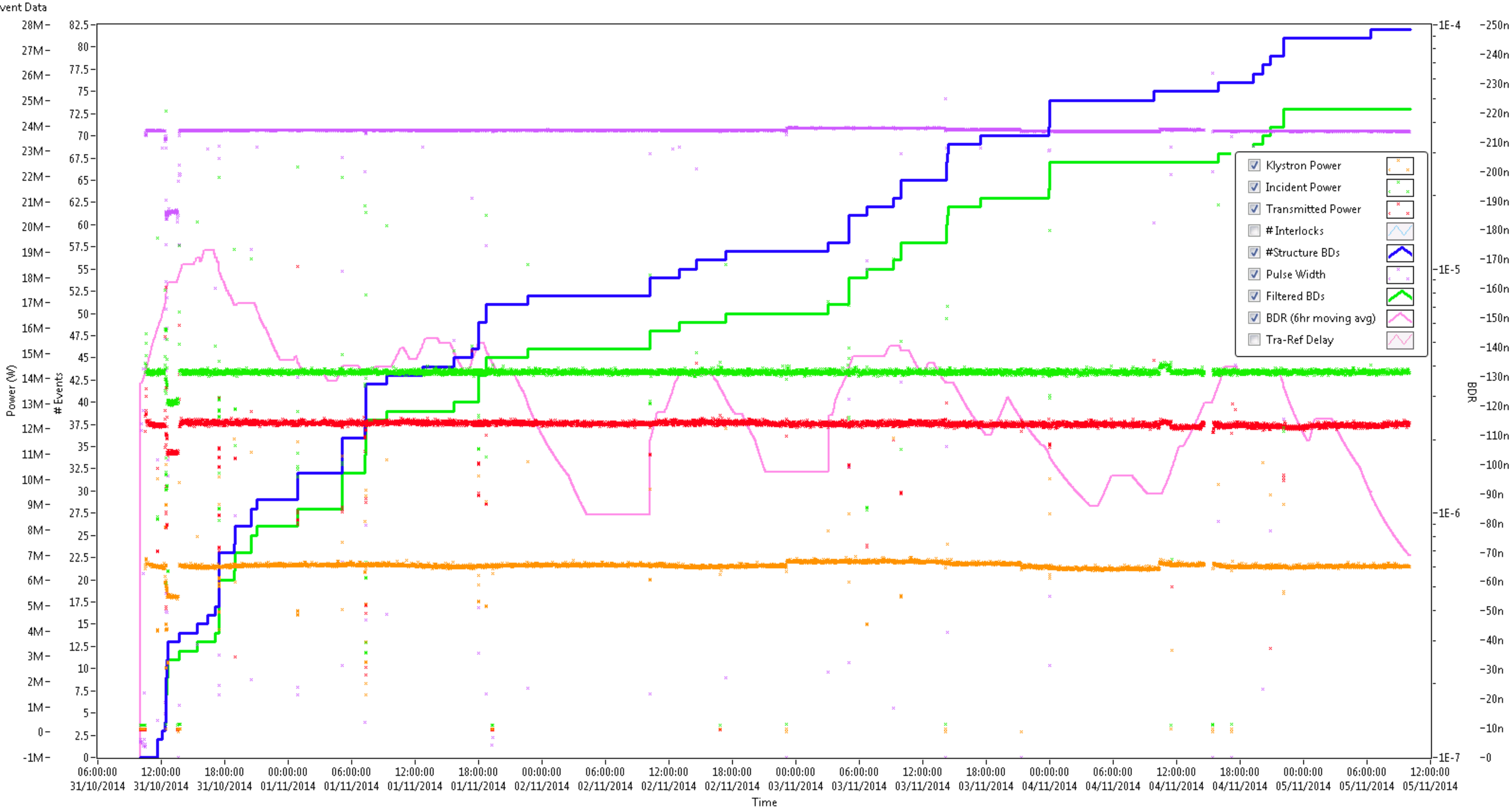
- Almost 2600 recorded breakdowns
- New klystron allowed the pulse compressor to be turned off

Initial Conditioning



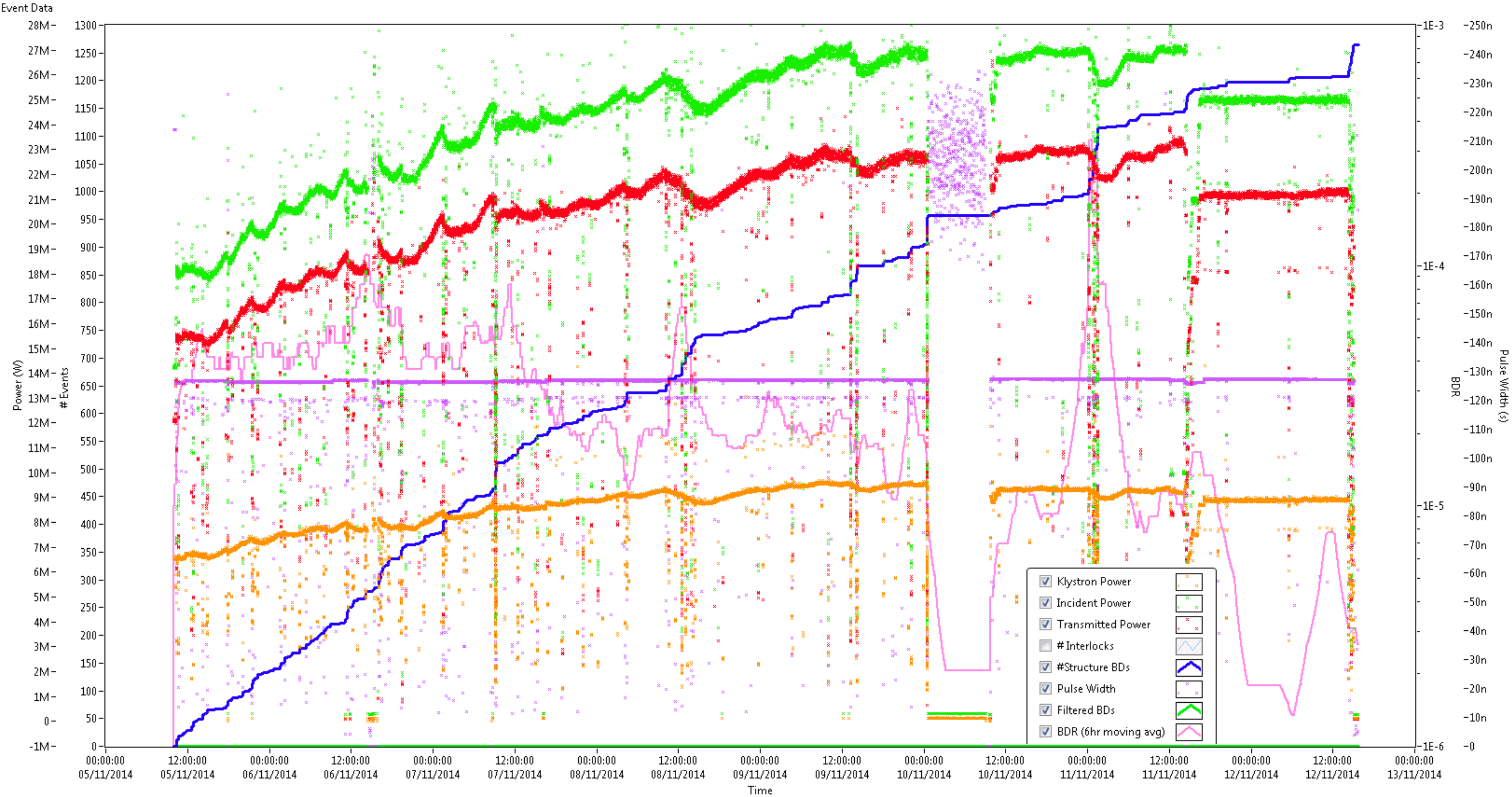
- 23rd October – 30th October
- Almost 1100 recorded breakdowns
- Constant BDR ~5e-5

Nominal performance



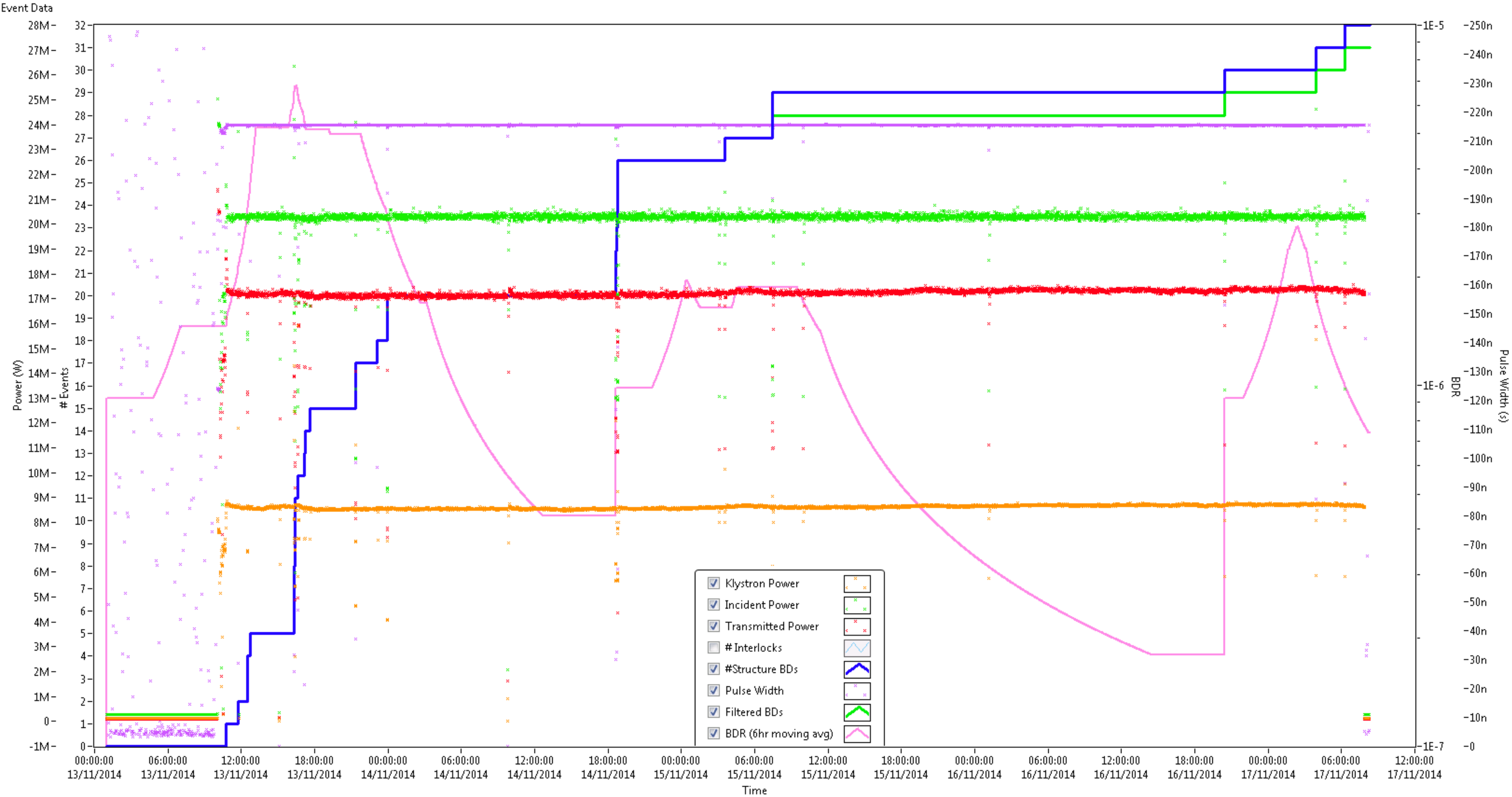
- 31st October – 5th November
- 82 (73 when filtered by eye) recorded breakdowns
- Overall BDR 3.4e-6 but if we discount first 36 hours BDR 1.3e-6

How high?



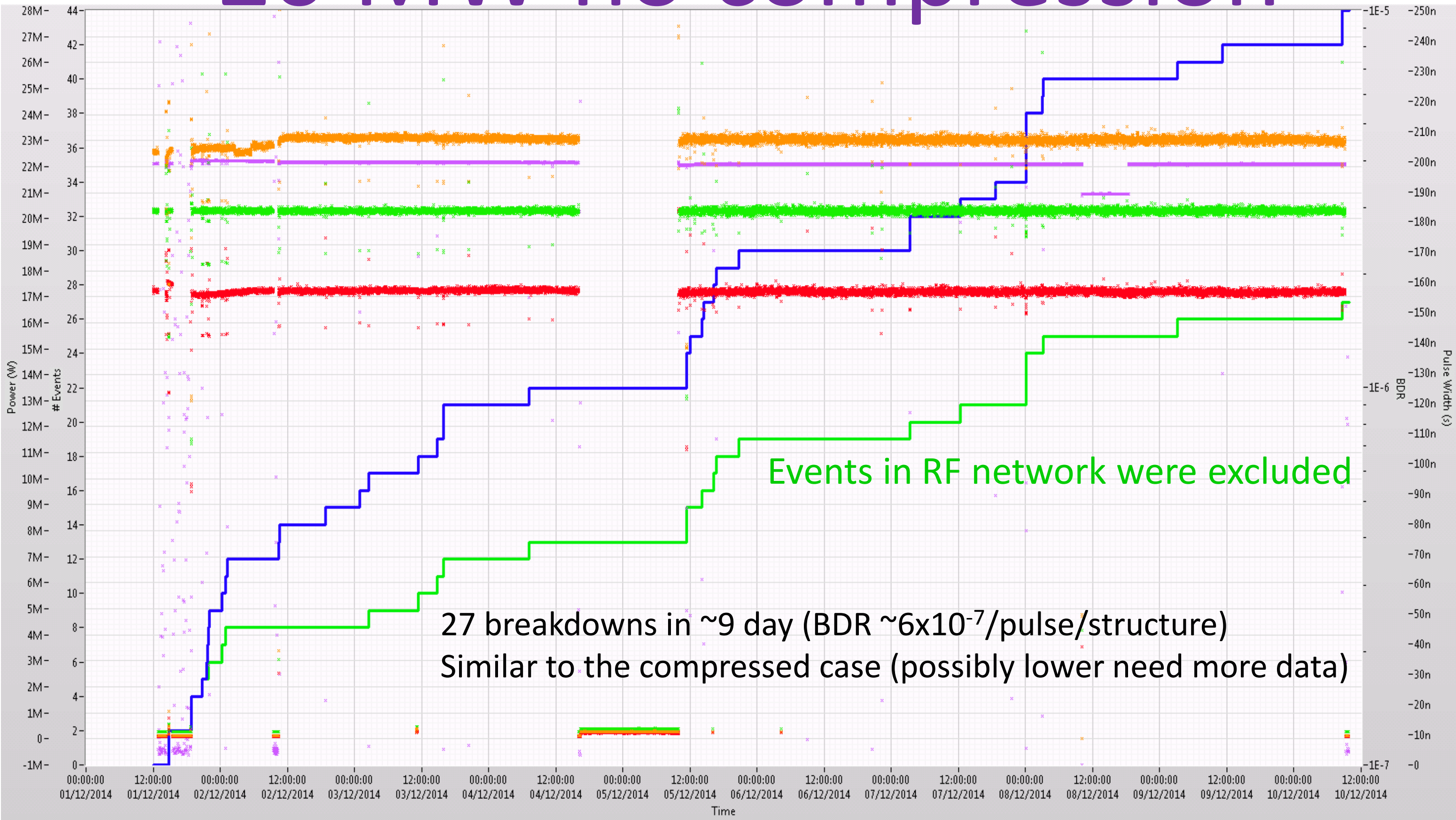
- Pulse width 125ns
- 5th November – 12th November
- About 1250 recorded breakdowns
- BDR stable/decreasing ~3e-5 until 27 MW reached… Then oscillates by 1.5 orders of magnitude

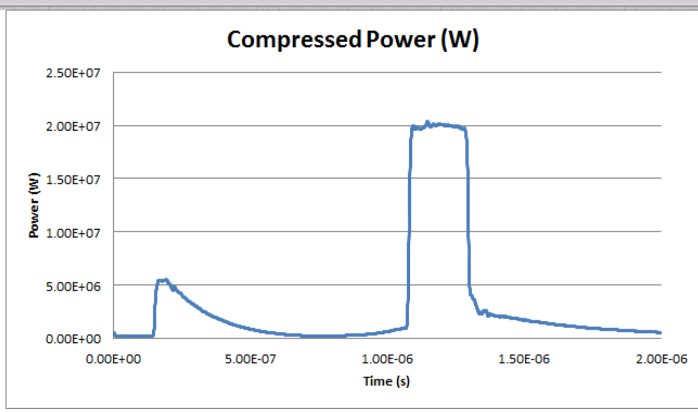
20MW Performance

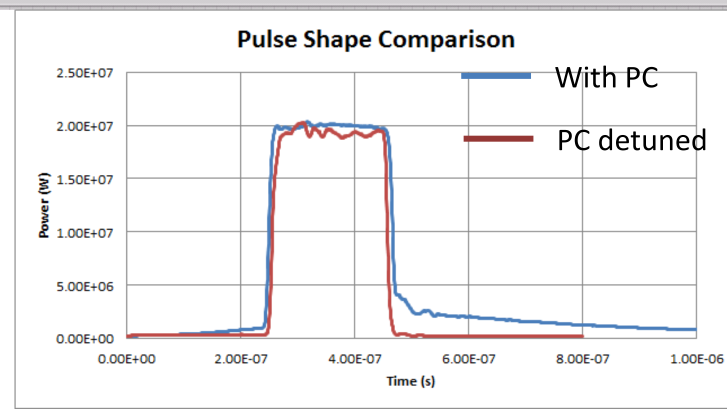


- Pulse width 215ns
- 13th November – 17th November
- About 31 recorded breakdowns
- Overall BDR 1.8e-6 but if we discount first 36 hours BDR ~7e-7

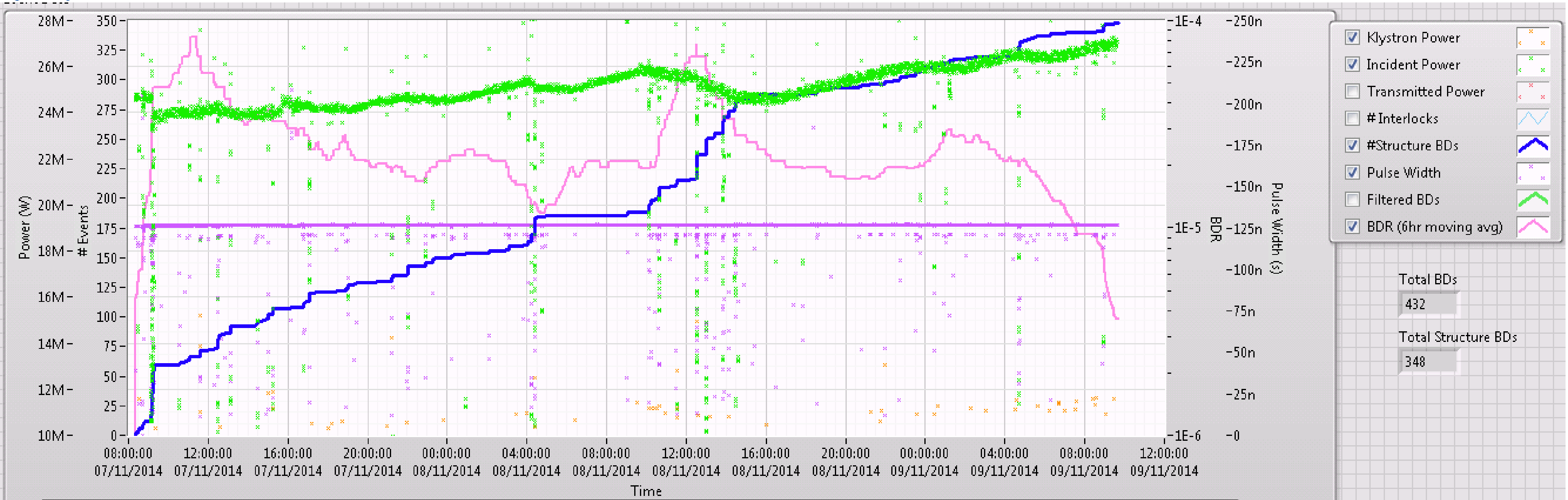
20 MW no compression

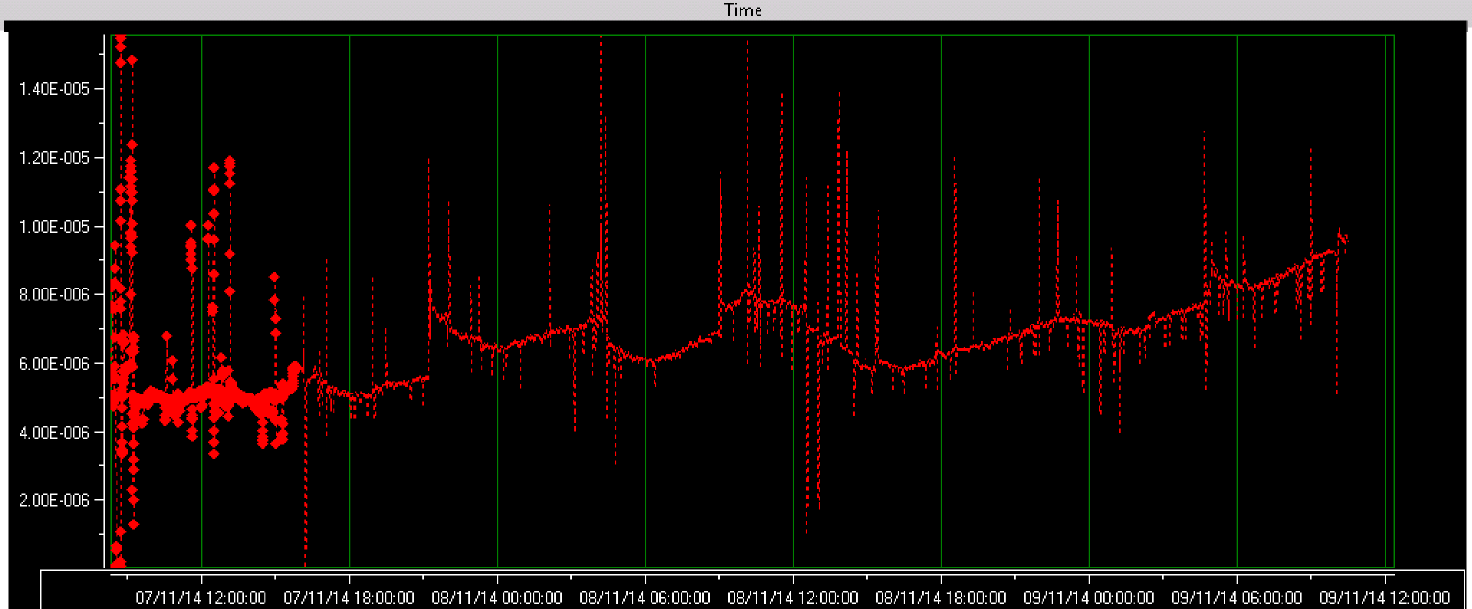






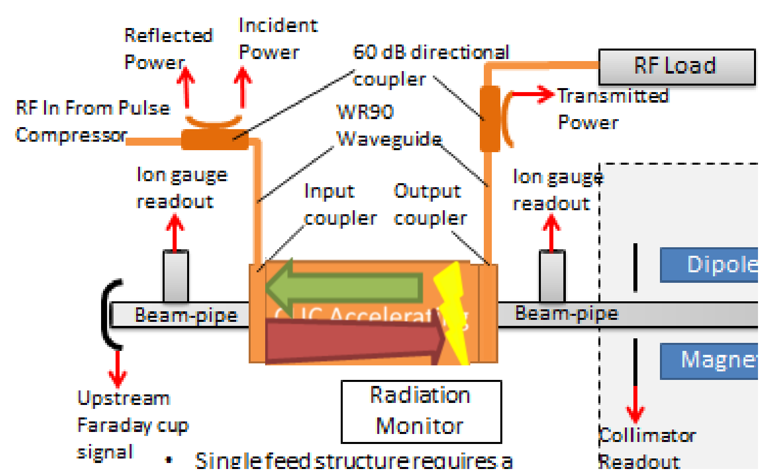
Radiation Monitor





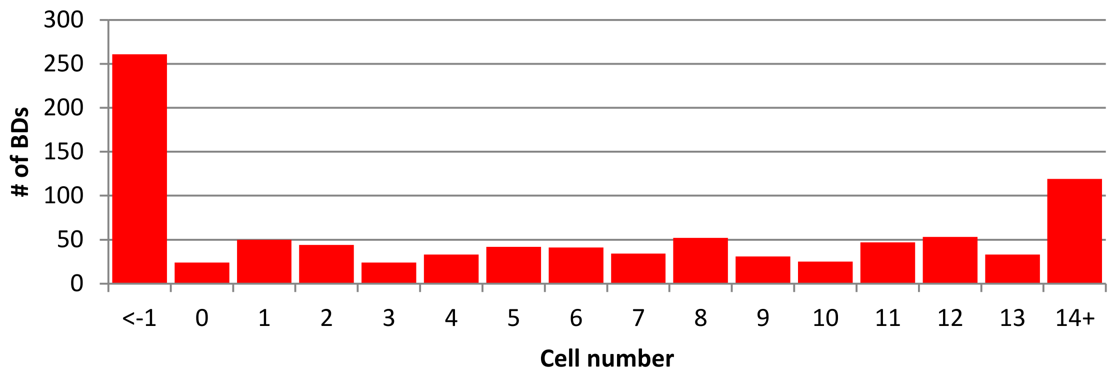
BD detection + cell location

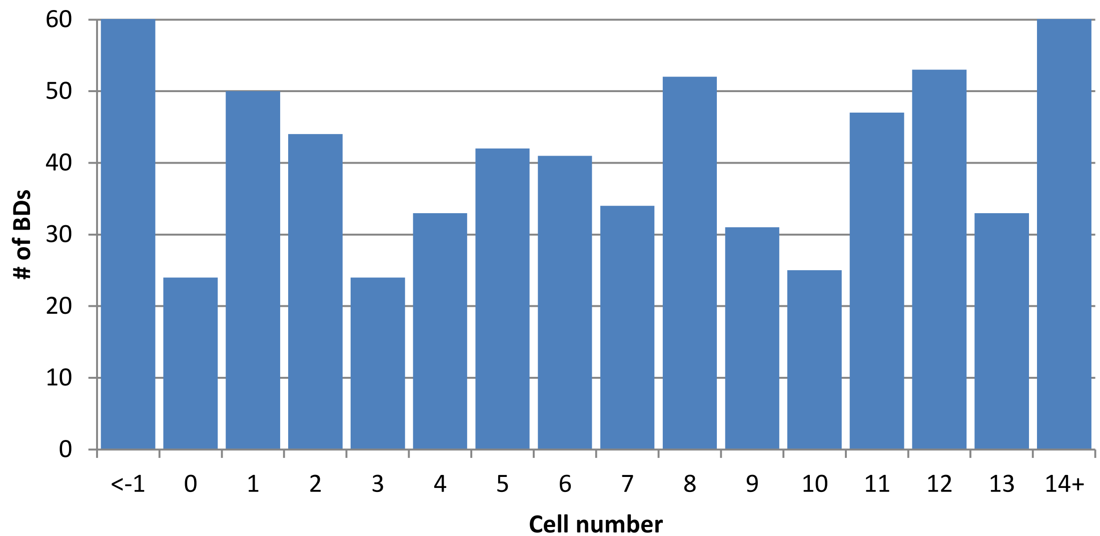
- Transmitted pulse drops as the arc is established.
- Reflected power increases to the same order as the incident pulse.
- We can use the difference in time between the transmitted power falling and the reflected power increasing to find the BD cell location.
- The phase of the reflected signal is used to pinpoint cell location.



Preliminary BD cell results

Transmitted drop minus Reflected rise times

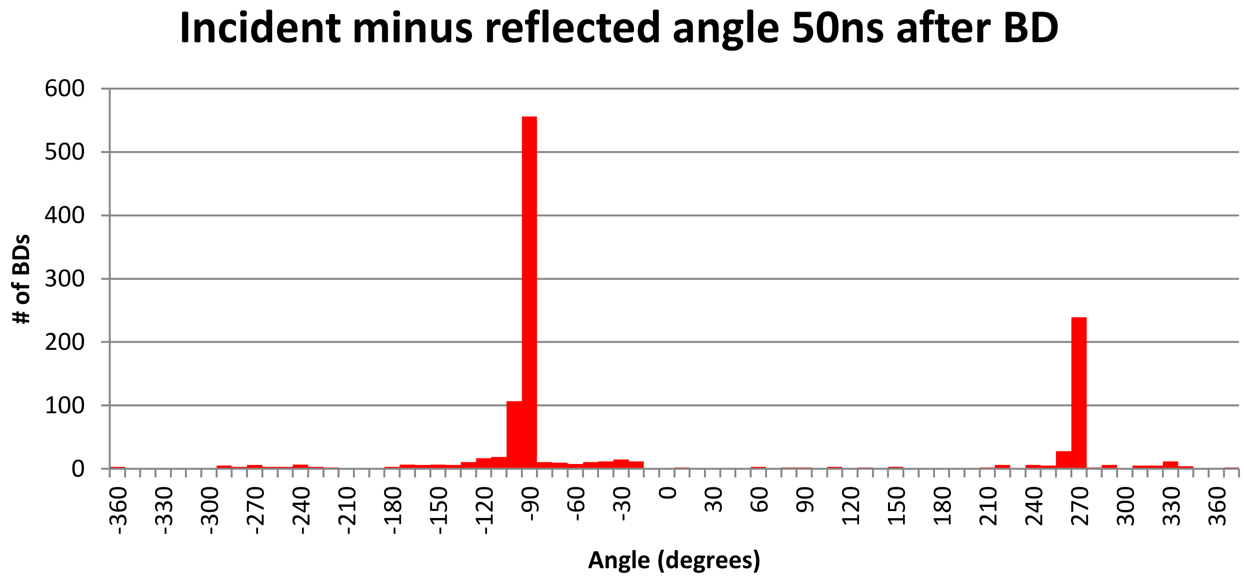


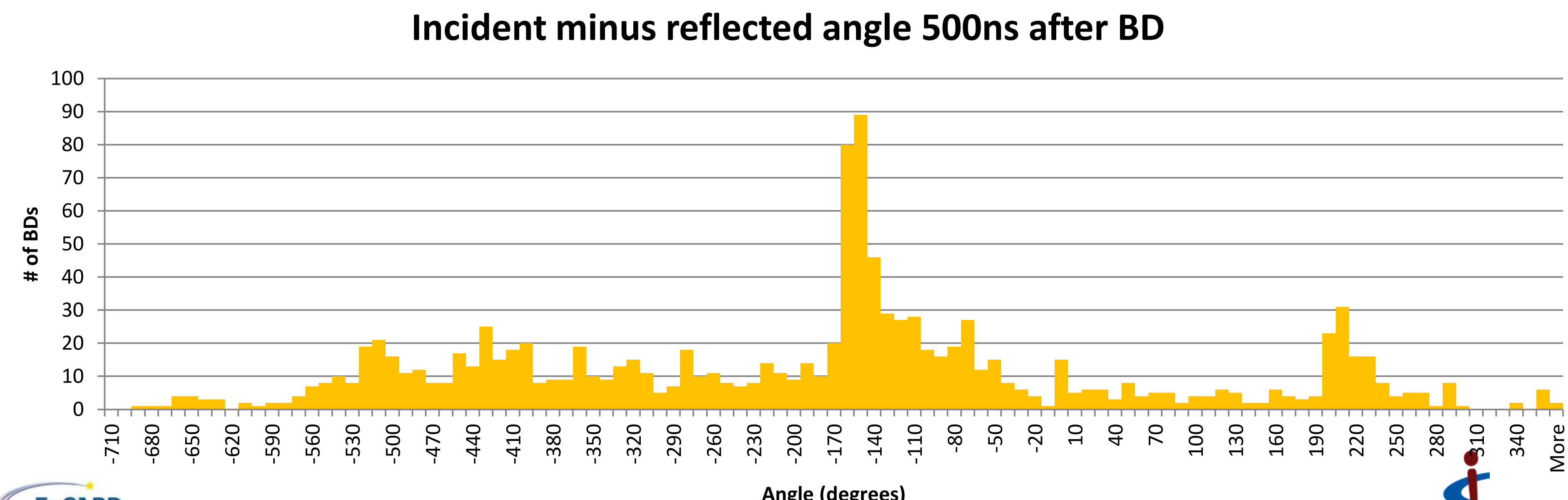


- Relatively flat distribution (possibly a standing wave pattern at every 3rd cell?)
- However large number of events ‘outside’ the structure needs further analysis.
- Fast group velocity; 2.9%c for the crab vs 1.8-0.6%c for accelerating structures increases the errors.

Preliminary BD cell results

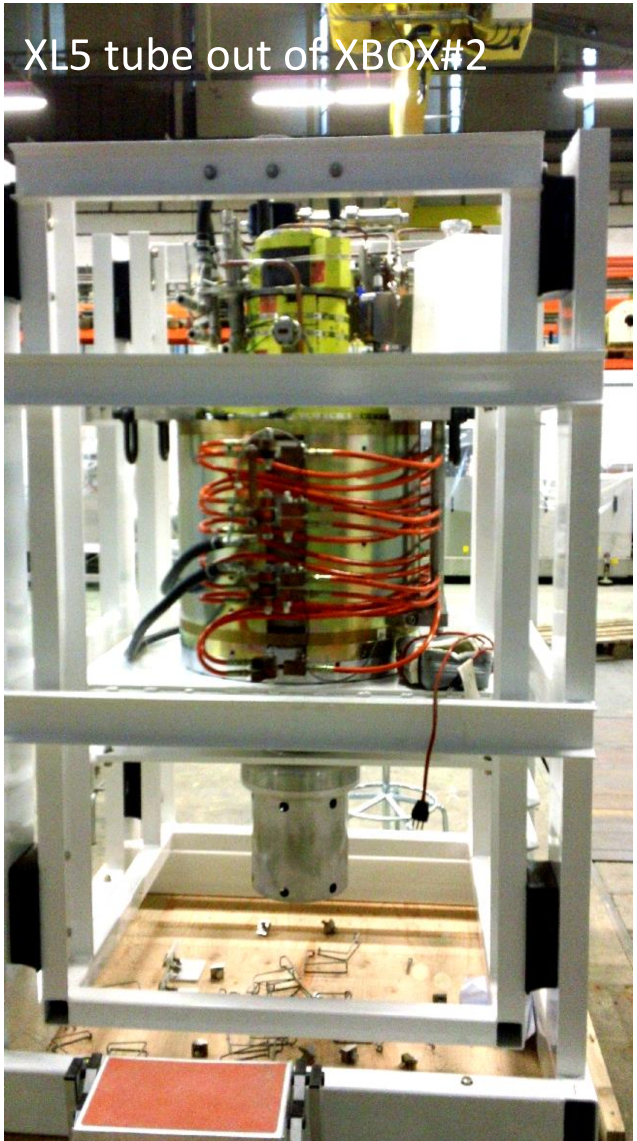
- Shortly after BD there is only a single angle detected..
- At +500ns after the BD there is a large spread supporting the travelling arc hypothesis.



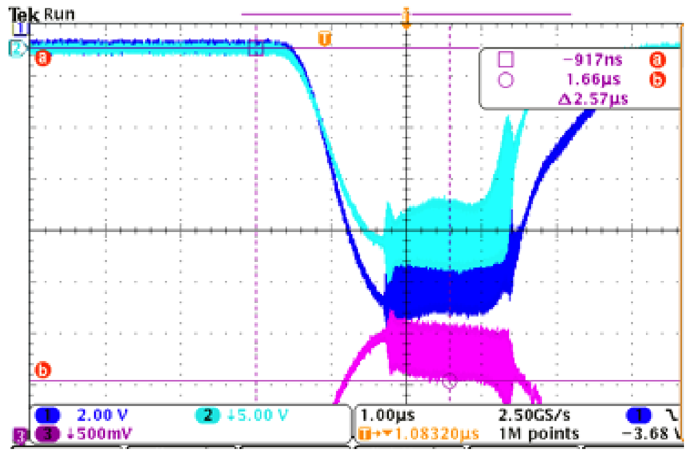


New Klystron: CPI#2

On 17.11.2014 XL5 was replaced by CPI#2

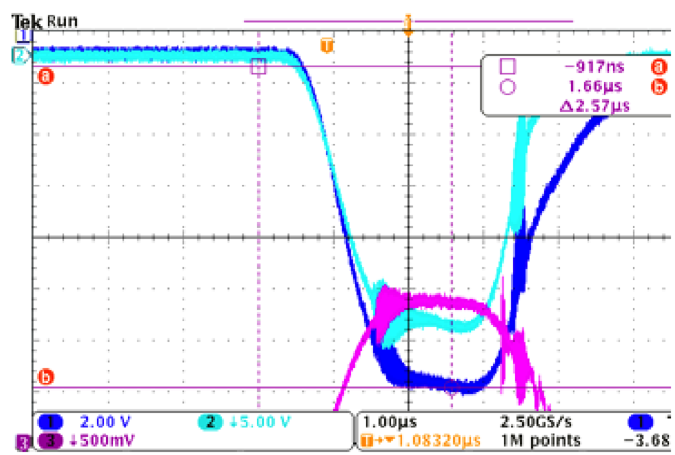


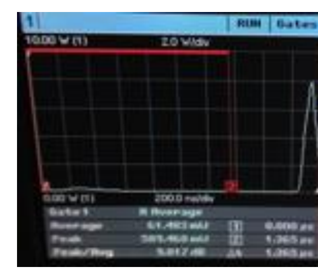
Diode tests (no RF) of CPI#2 tube showed that 0.7 GHz gun oscillations starts at about 240 kV and even generate RF power from the input cavity:



12 GHz pulse from the input cavity

Fortunately, going higher in voltage, the instability zone moves towards the rise/fall time, so the plat top can be used now. Example of the pulse with ~ 5 MW RF peak power expected:

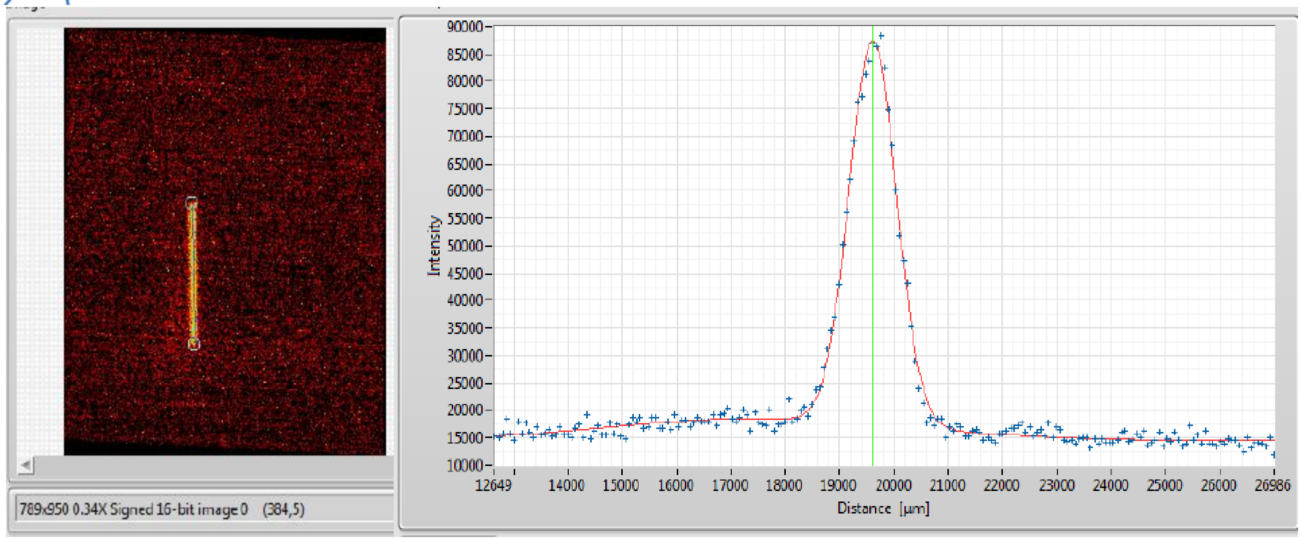




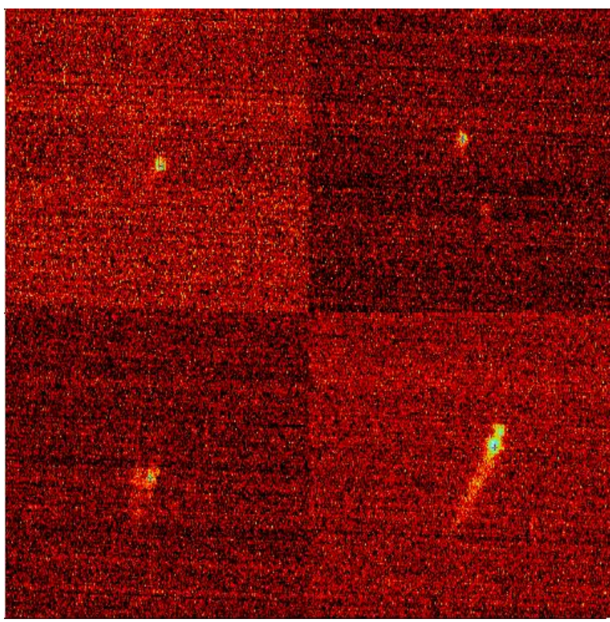
EuCARD

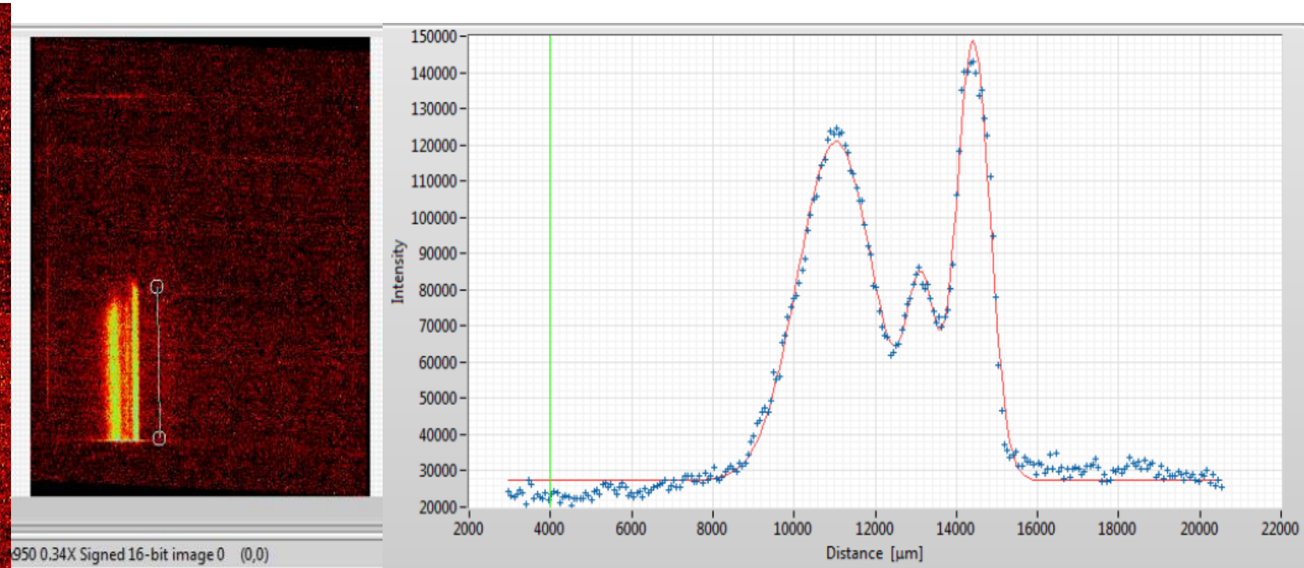
The Cockcroft Institute of Accelerator Science and Technology

Sneak peek: DC spectrometer



- Initial results show a mix of single projections and also many multiple hits on the screen. This suggests some of the electrons are kicked by the deflecting field.
- This effect is seen with both the slit collimator and pin hole collimator.





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Future tests

- Change power and pulse width to get BDR vs power and pulse width plots.
- More detailed analysis of BD distributions in time and cell position.
- Push up power level or pulse width ‘to destruction’….
- Post-mortem to assess the position on the iris where most damage occurs. (E,H,or Sc?)

Summary

- Crab cavity RF design was presented and fabrication described.
- Tuning results were discussed
- Xbox-2 test stand used for the high power test
- Conditioning and Performance of structure evaluated.
- Breakdown analysis showed almost even distribution of breakdowns along the structure.
- Dark current spectrometer results previewed.
- Next steps discussed.

Thank you