

RF Progress at Diamond Light Source

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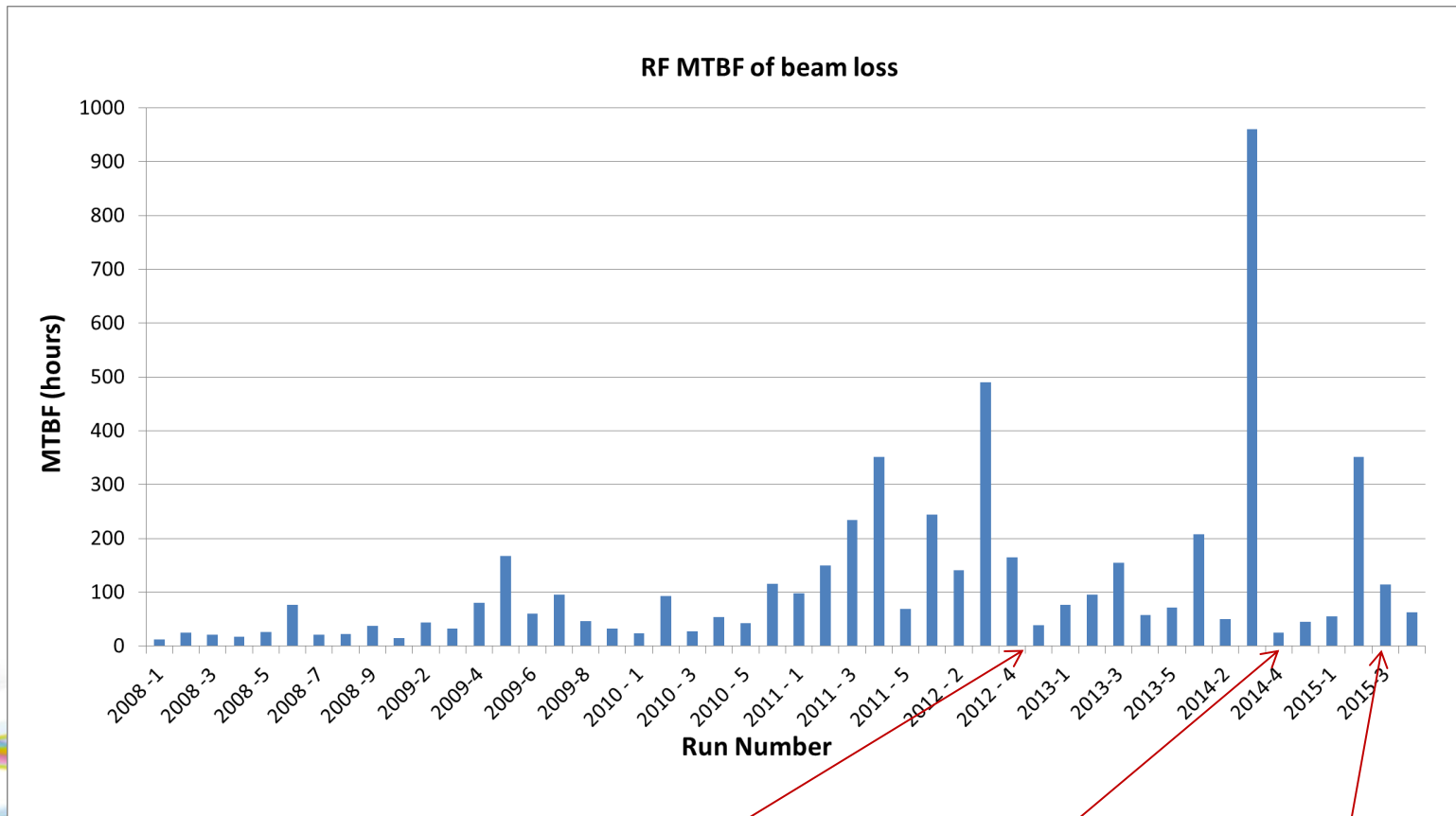
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Agenda

- Storage Ring RF Performance
- Major Cavity Failures
- Effort to Understand and Improve RF System
- Future Plans

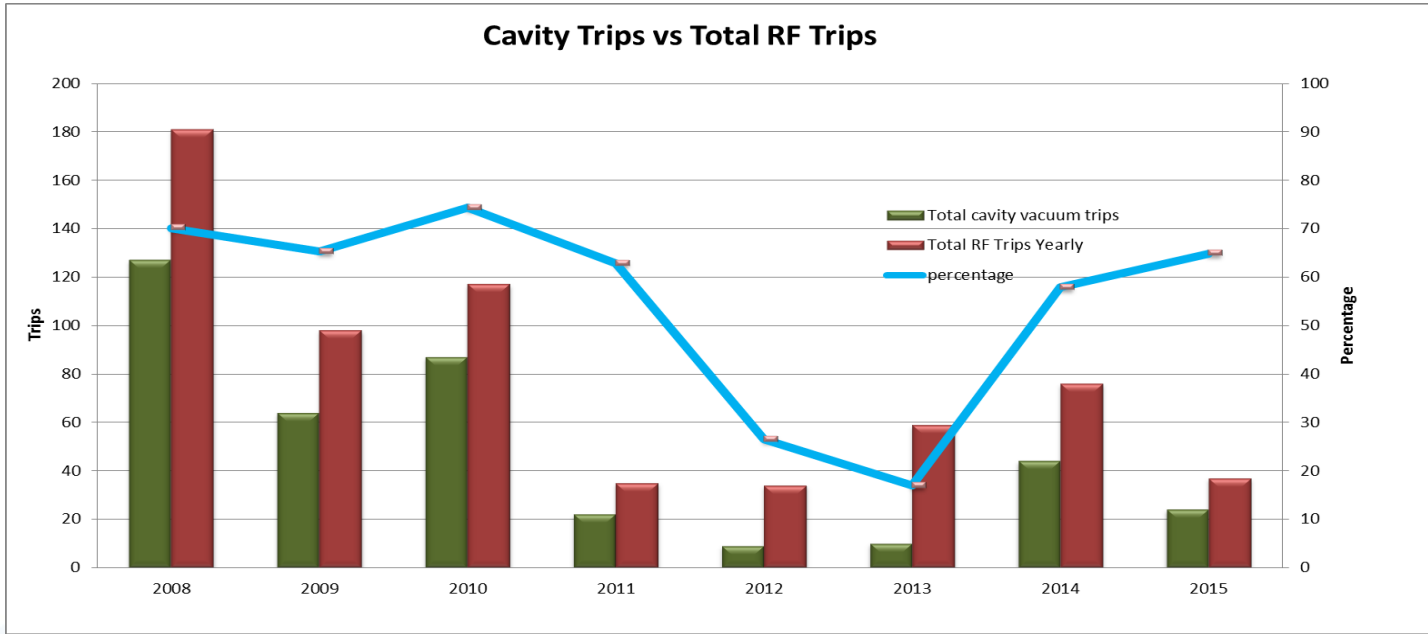
Storage Ring RF MTBF over the Years



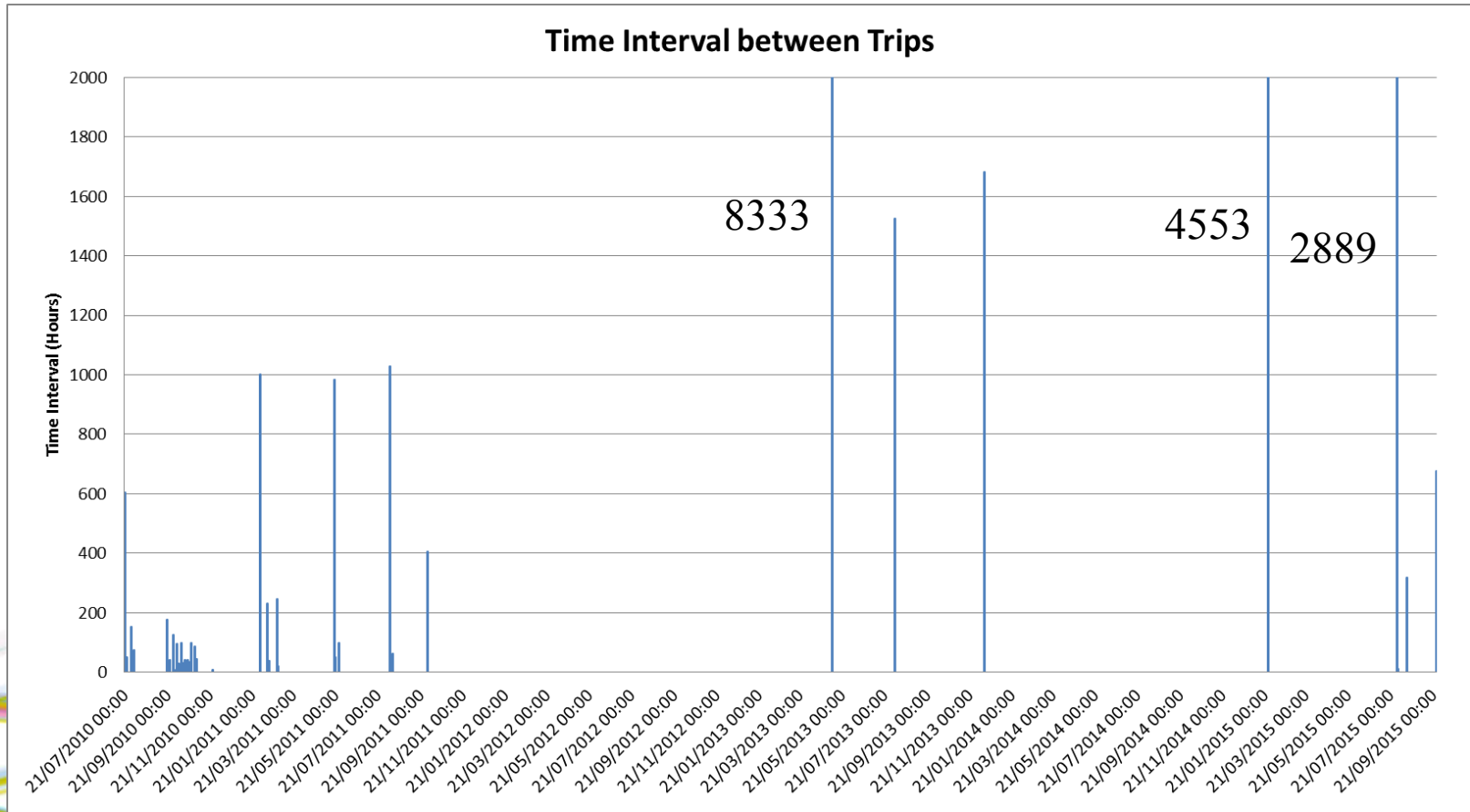
Cavity 1 & 2 swap

Cavity 2 failure

Cavity 4 failure

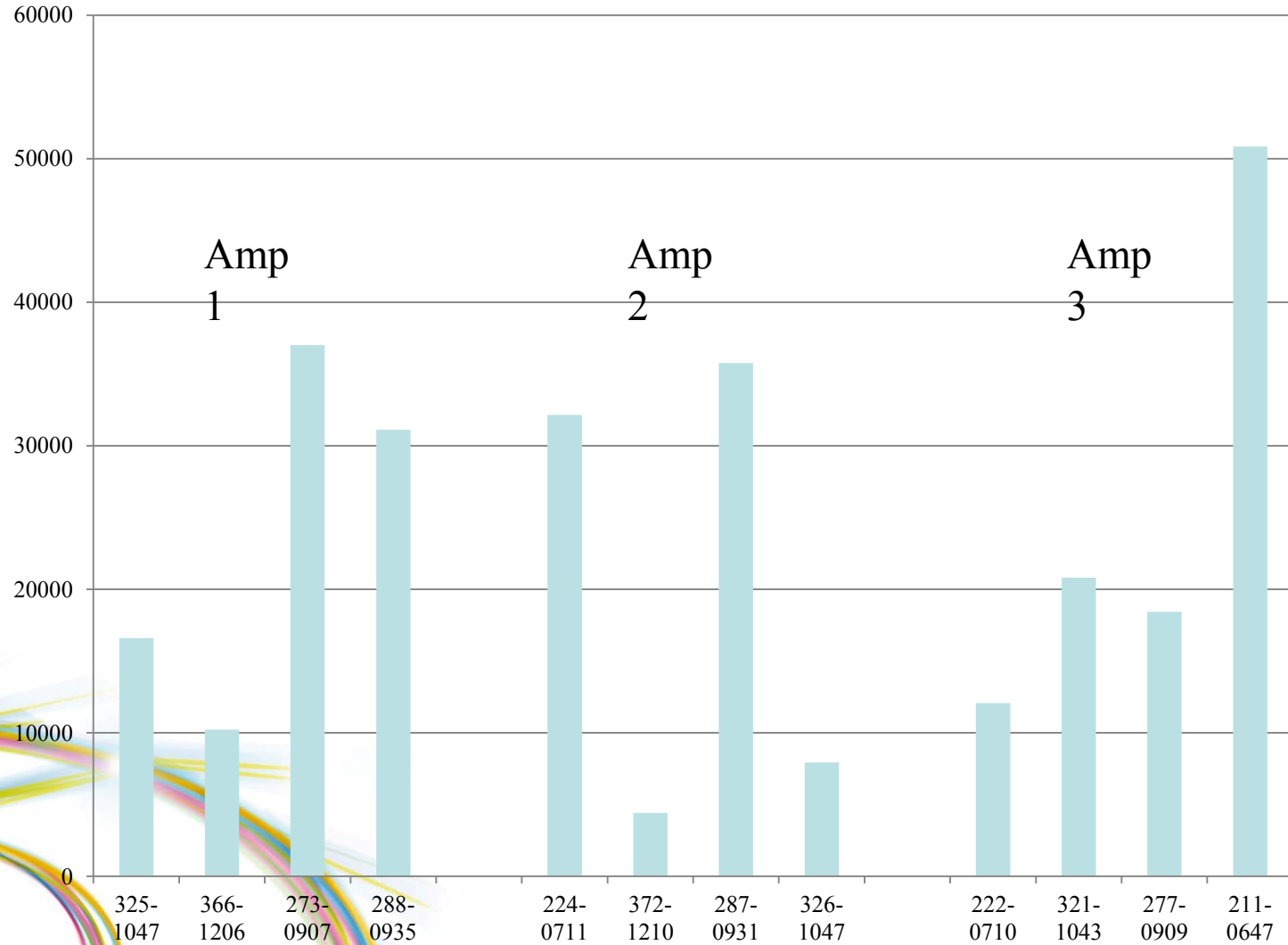


Cavity 3 Performance since Installation



Once good operation is established performance can be maintained

IOT Performance



IOT performance

E2v IOT Operating Hours

- 16 IOTs have provided >360,000 filament hours
- 1 x IOT > 50,000 hours

Operational Failures

- One ‘proper’ failure during operation – broken output ceramic- coincided with broken circulator
- 2 x removed as tripping at start up as precaution
- 1 x removed for grid outgas

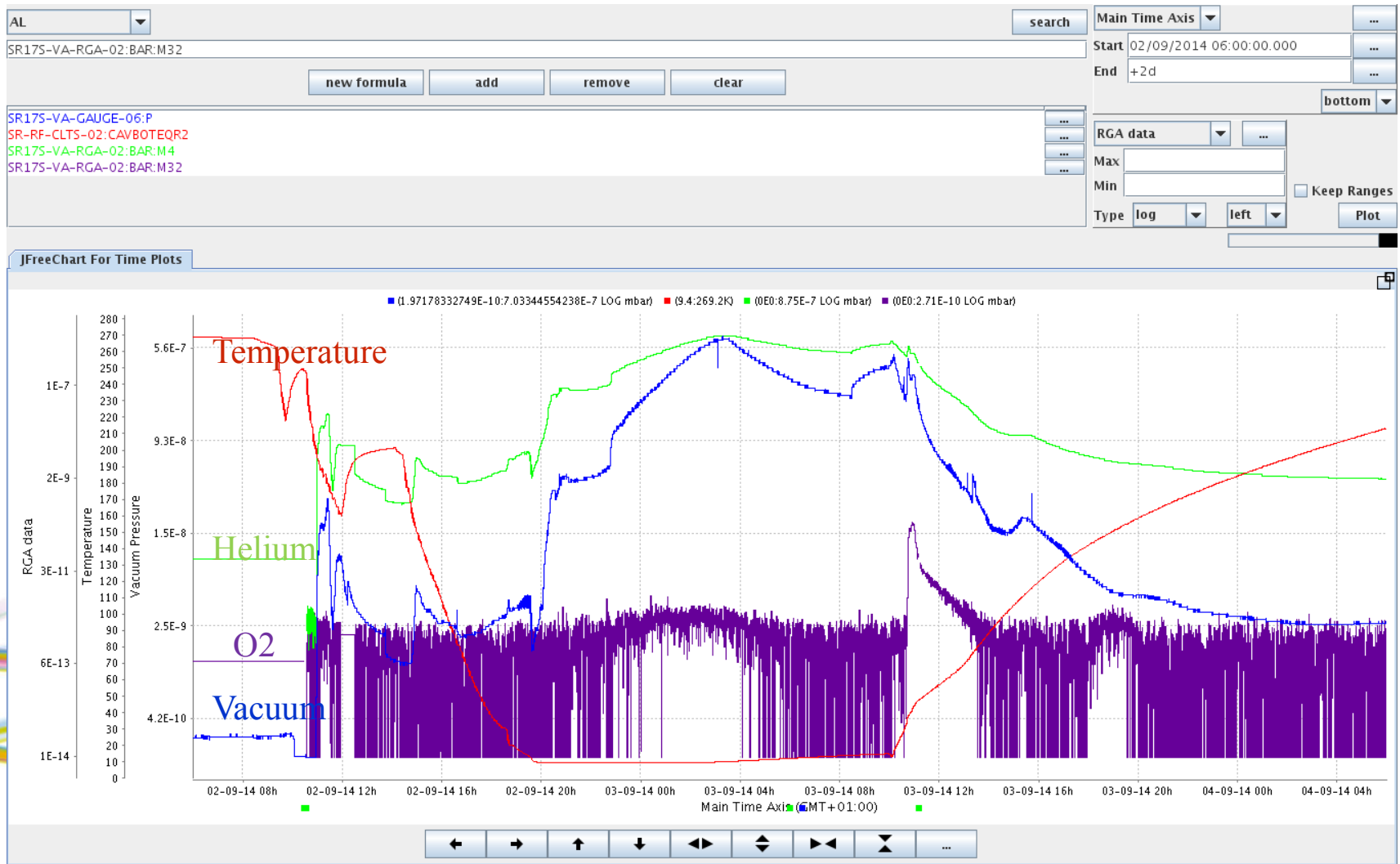
Conditioning Failures

- 1 x failure due to collector contamination
- 1 x failed due to wiring fault

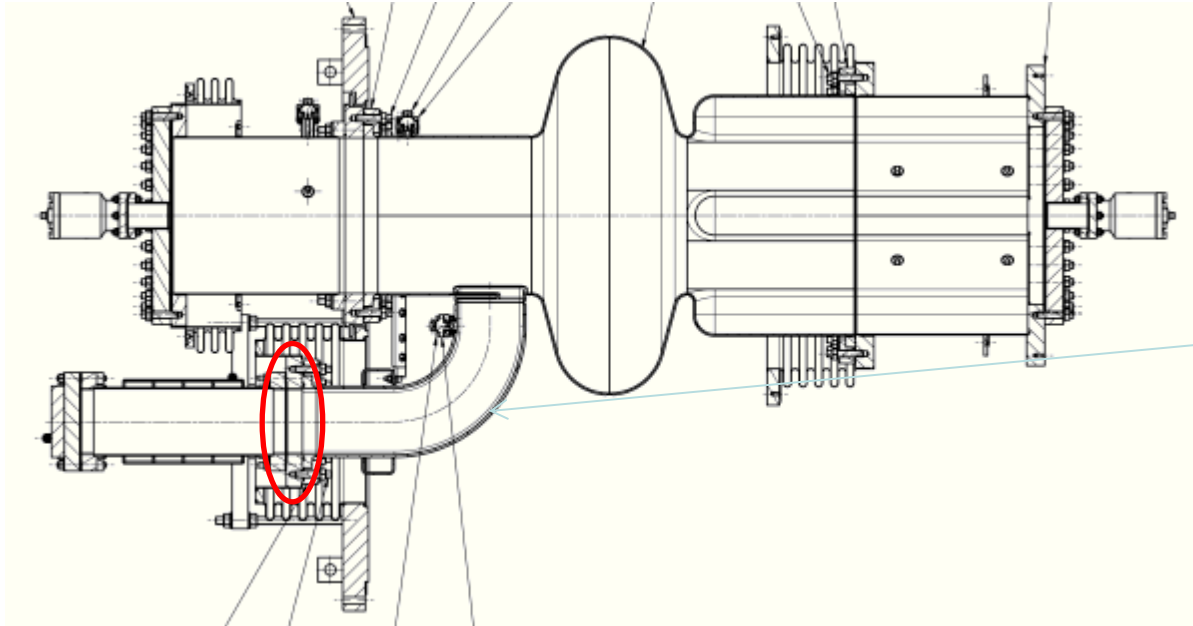
Current Investigations

- Hi Ion pump current – failed during HP coupler calibration

Cavity 2 Failure during Cool-down



Investigation at RI



Leak rate $2 \times 10^{-8} \text{mbar} \cdot \text{l/s}$

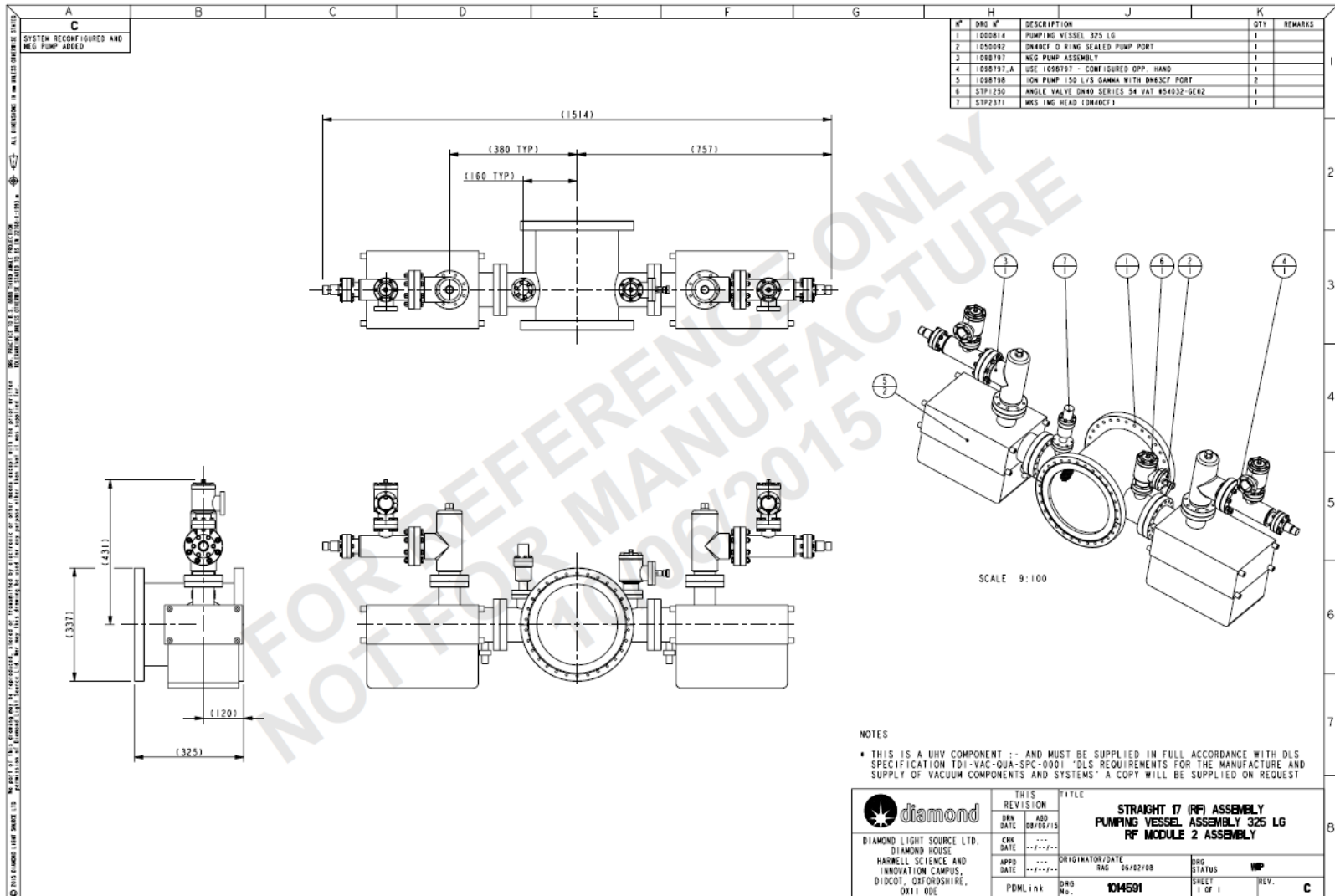
Repair and modification plan:

Add AB sensor along niobium waveguide bend.

Add TSPs with isolation valve on RBT side.

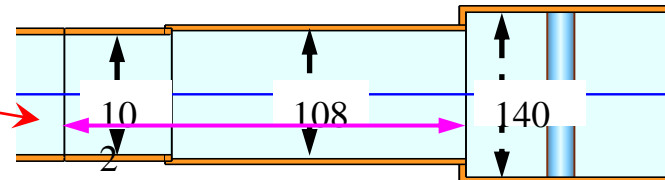
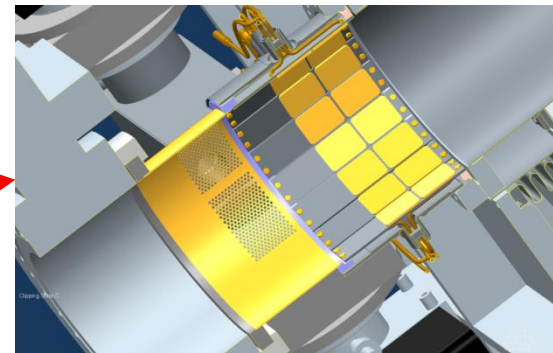
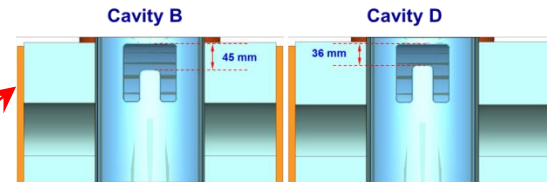
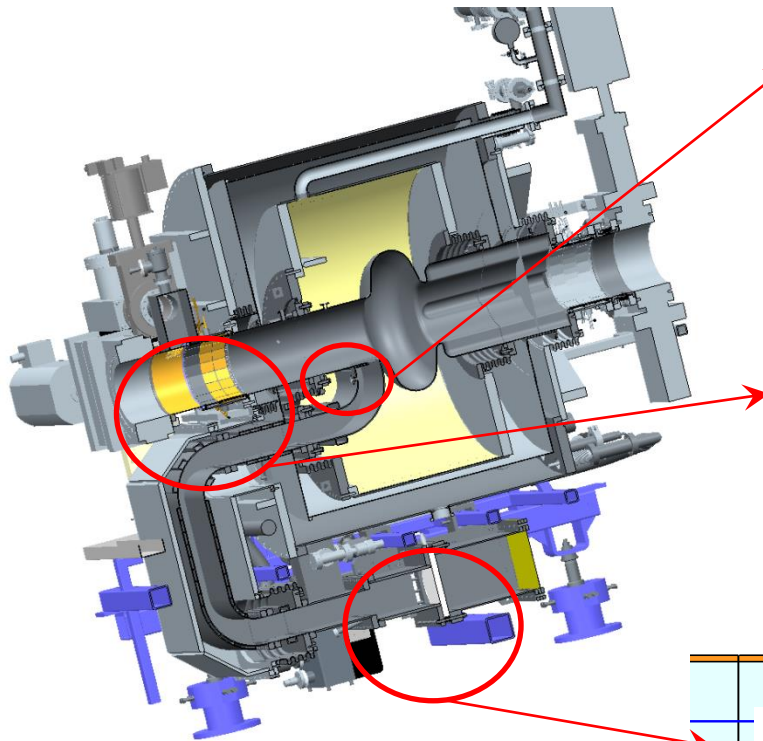
Modify helium fill tube to achieve more uniform cooling.

Cavity 2 Modification



Cavity 4 Modifications

1. HOM loads at RBT side
2. Shanghai Coupler tongue
3. CLS Pump out box ($Q_e \sim 1.5 \times 10^5$)
4. TSPs with isolation valve on RBT side
5. Position sensors on two sides
6. New LN2 flow controller



Cavity 4 RF Window Leak

Cavity 4 was rushed through the FAT to replace cavity 2 last September.

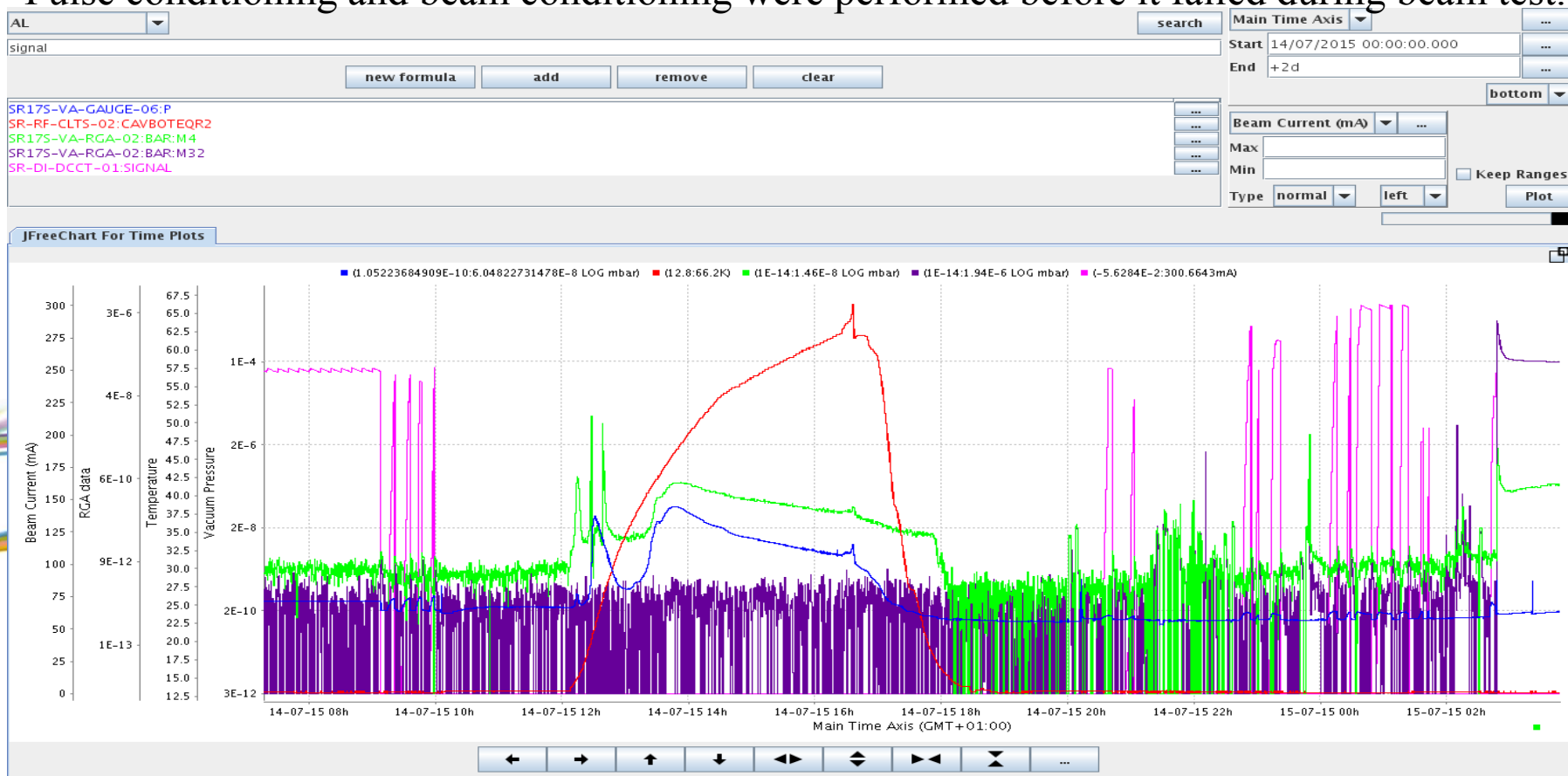
It suffered many fast vacuum trips from the start.

Qext was pushed very low to 9×10^4 by using stub 1&3 of the 3-stub tuner.

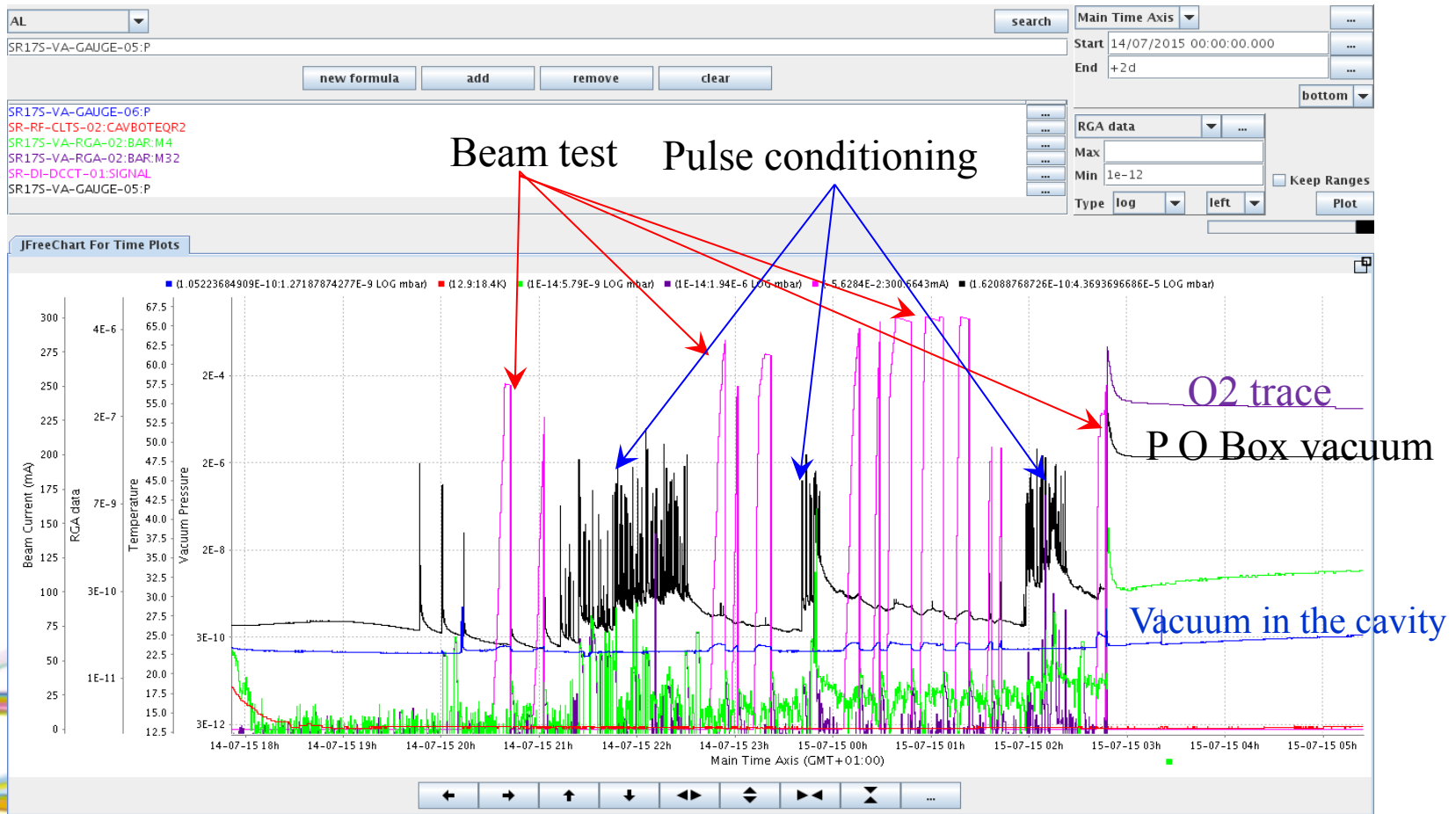
Stronger and more lasting out gas even at low power level when both stub 1&3 were pushed in.

Recurrent trips on pump out box vacuum limited beam current to 250mA.

Pulse conditioning and beam conditioning were performed before it failed during beam test.



Cavity 4 RF Window Leak



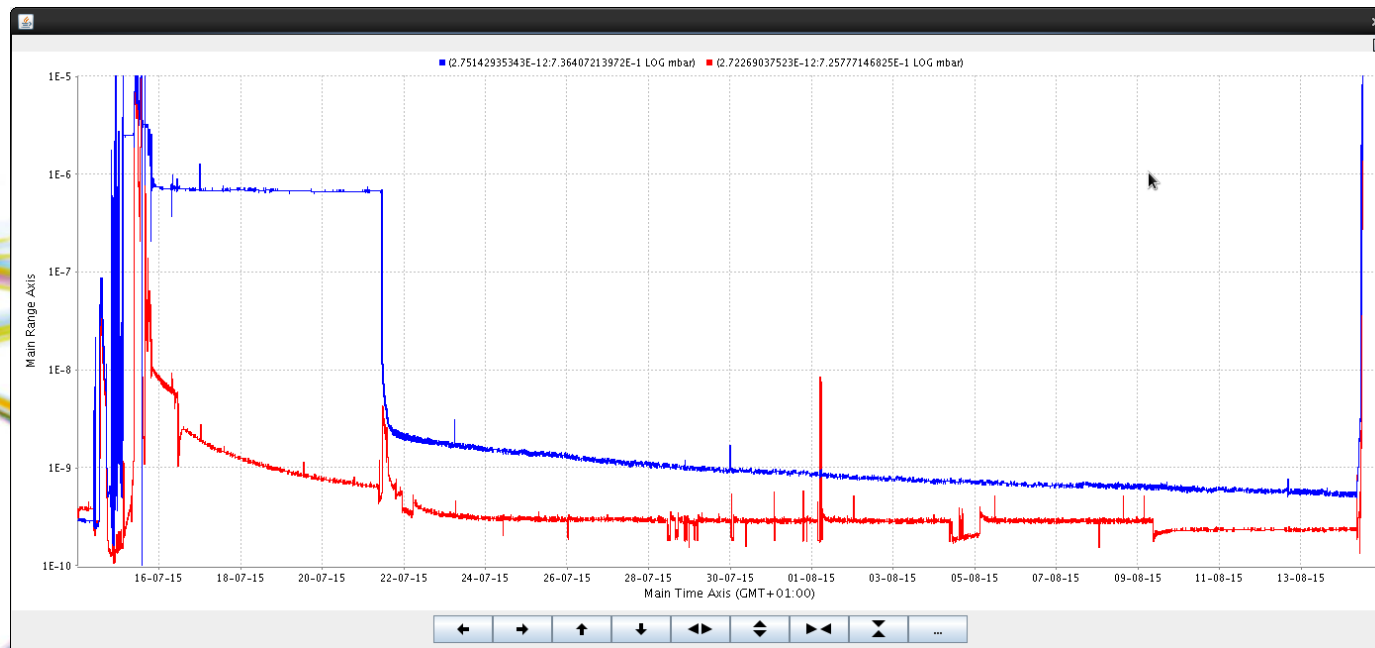
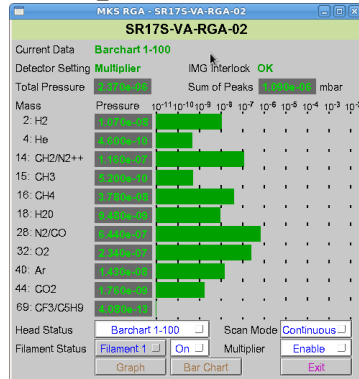
Vacuum at valve box went up to 10^{-5} mbar at pump out box.
No big change inside the cavity.

Cavity 4 RF Window Leak

Vacuum sealant was applied to the RF window.

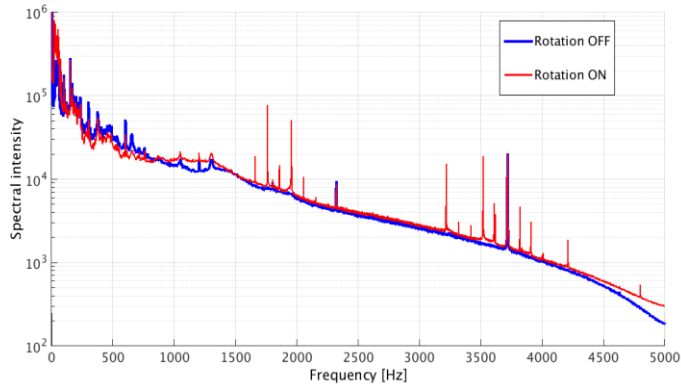
Cavity was detuned and kept cold during the rest of the run for more than 4 weeks.

Plan to swap RF windows using a clean room of RAL Space.



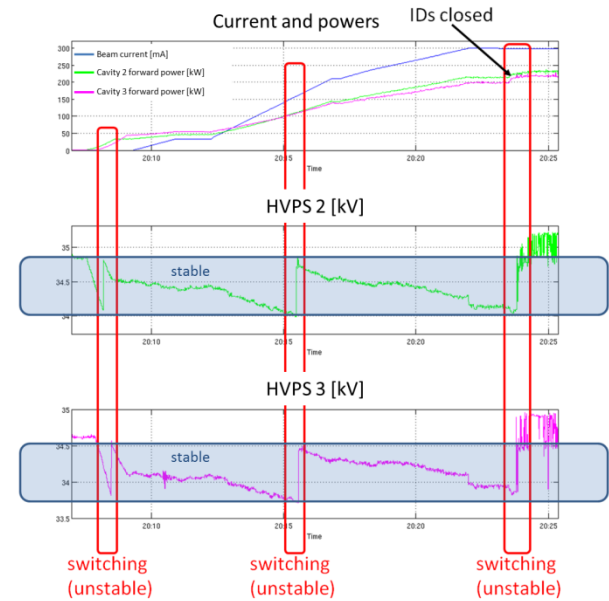
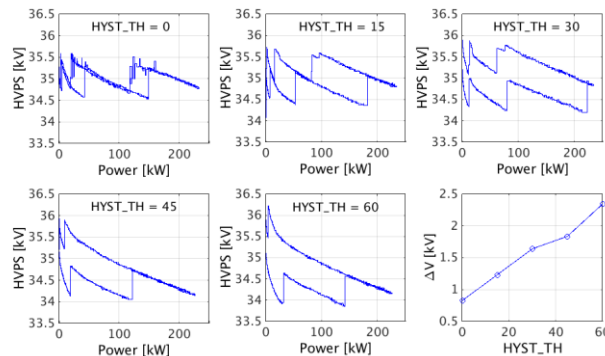
Elimination of high frequency noise

- HVPS module rotation is visible on the beam
- Infrared beamlines claim this pollutes their spectra



- Rotation lines can be removed
- Only remaining lines are mechanical vibration
- Vibration lines eliminated by water flow control

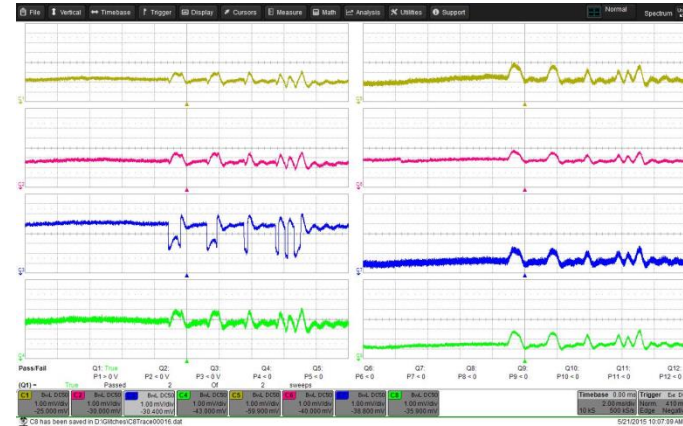
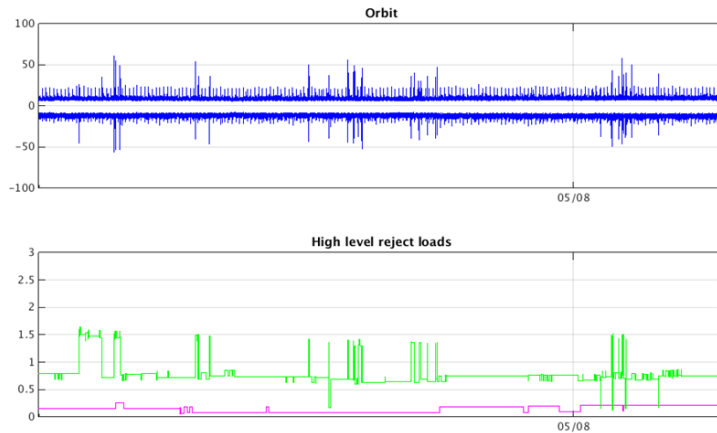
- Firmware modified to introduce user-controlled dead-band to HVPS switching
- Global stability is ensured over the complete range of Diamond operation



- Removing module PWM results in steps in IOT voltage which may cause global stability issues
- Must expand range of HVPS non-switching operation

Beam Glitches and IOTs

Beam is occasionally kicked by tens of microns – could be a problem for MPS interlock

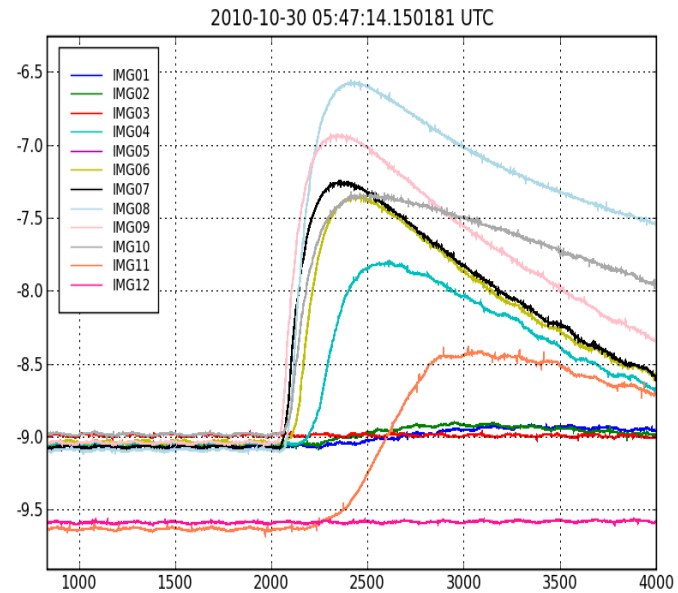
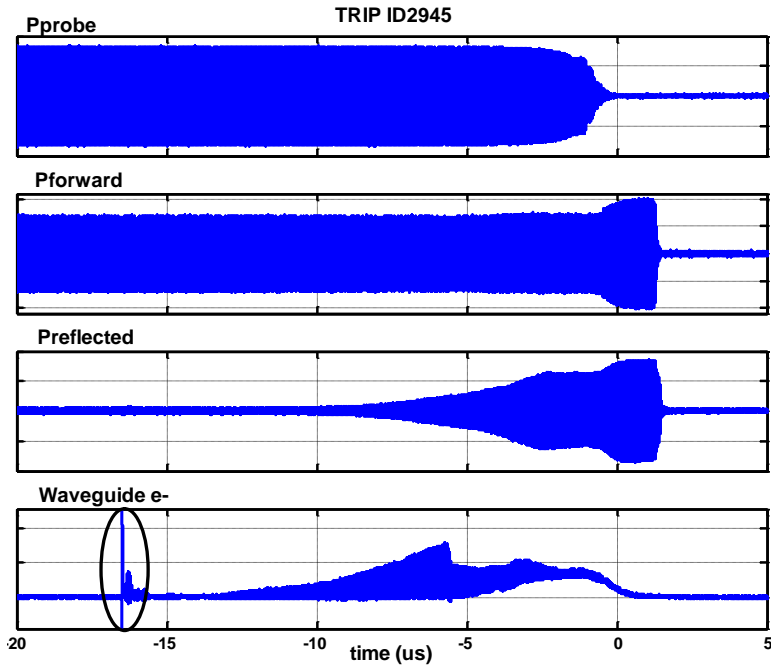


Beam kicks correlate with changes in combiner reject power

One IOT steps output by ~1%, all others react through LLRF

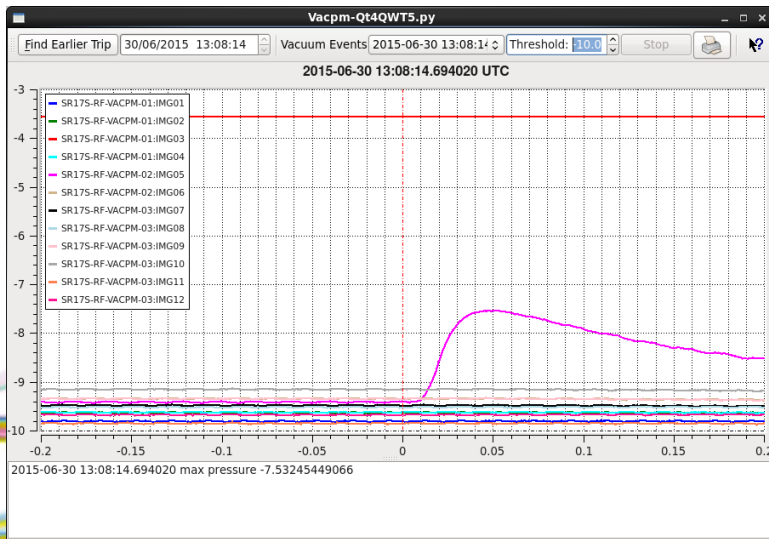
- Common voltage to all four IOTs in one amplifier – no individual IOT voltage steps
- Drive amplifier power remains constant – fault is at the IOT
- Effect vanished when all IOTs were transferred at cavity change – not a tube fault
- Appears to be a power supply issue
 - Grid bias voltage supply is the most likely candidate
 - Plan to test bias voltage stability with HVPS at zero voltage

Observation of Fast Vacuum Trip

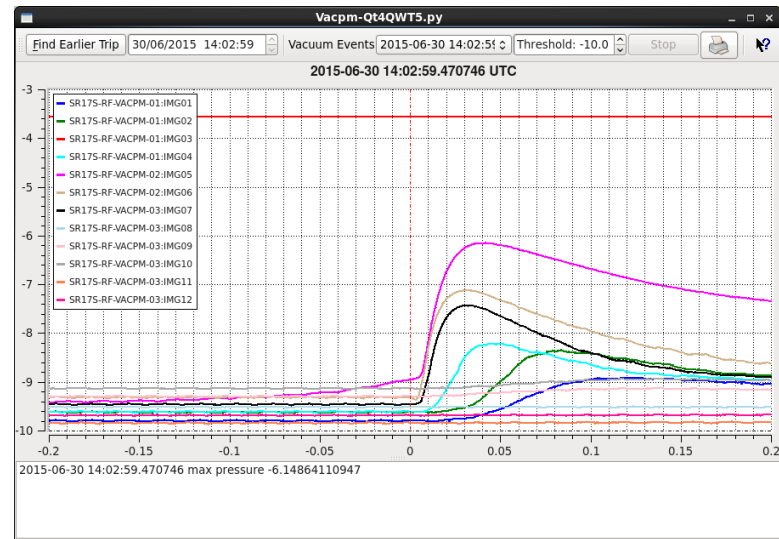


3-stub Tuner Position and Cavity Trips

- Cavity 4 trip problem was cured by reducing voltage from 1.0MV to 0.8MV
 - Some loss of beam lifetime but interlock levels were cleared
 - Required change in 3-stub tuner position to maintain good coupling
- As a test, a beam trip was provoked by overloading cavity with the two 3-stub tuner configurations
 - Followed same procedure in both cases



Stub 3 in

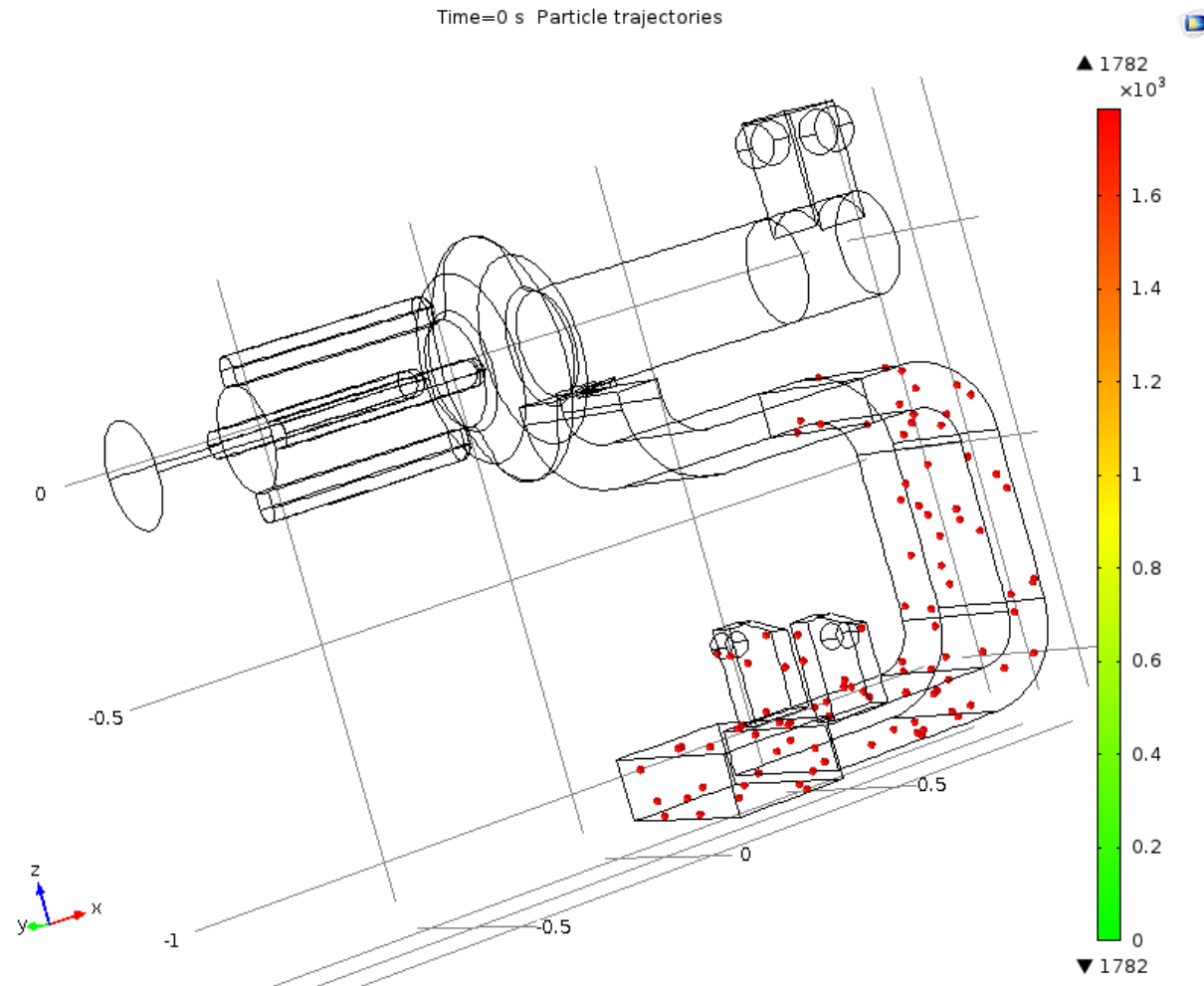


Stub 3 out

Pressure profiles correspond to standing wave pattern and do not signify different processes

Simulation of Gas Deposition on Cold Surfaces

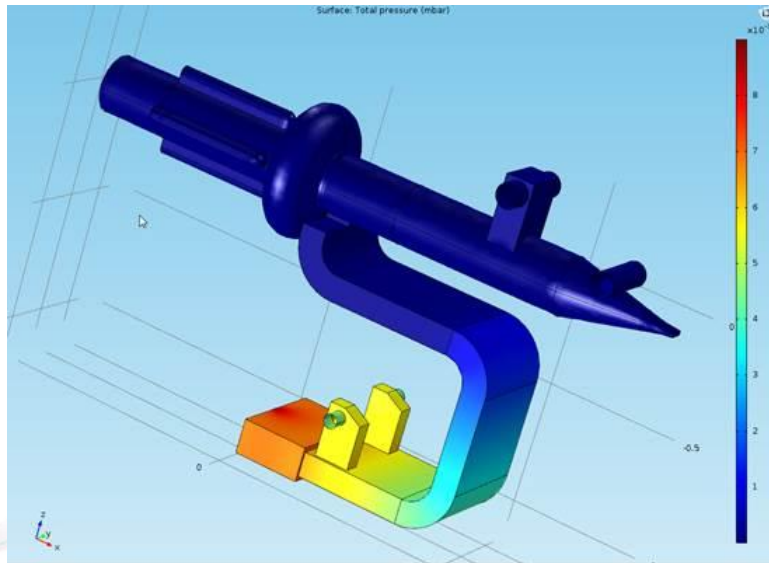
Courtesy of Matthew Cox



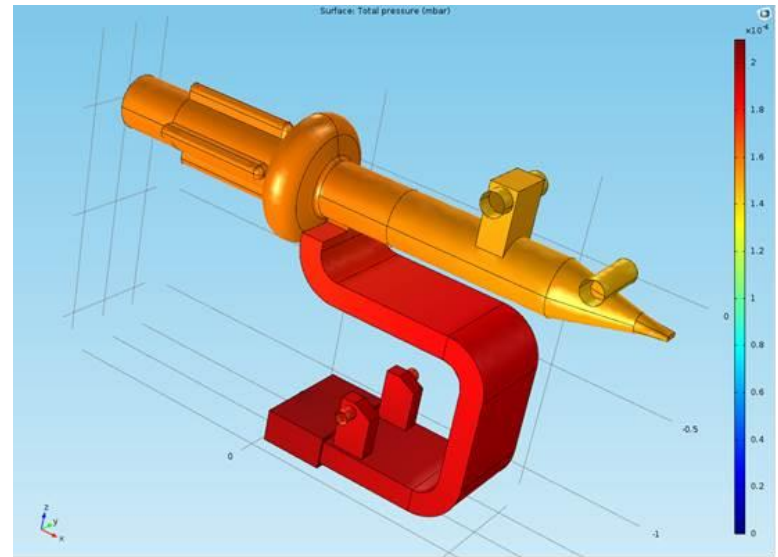
Simulation of Gas Deposition on Cold Surfaces

Courtesy of Matthew Cox

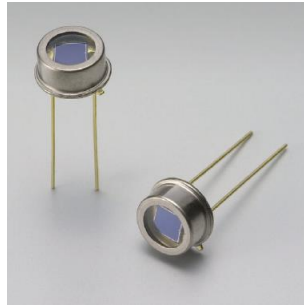
Nitrogen



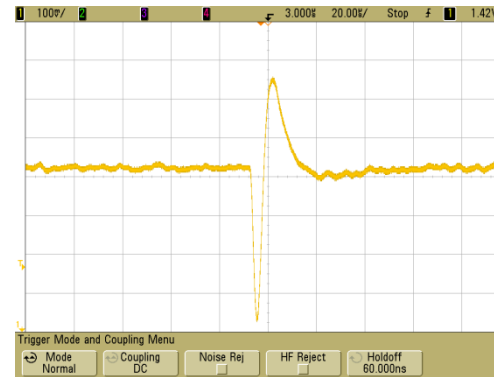
Helium



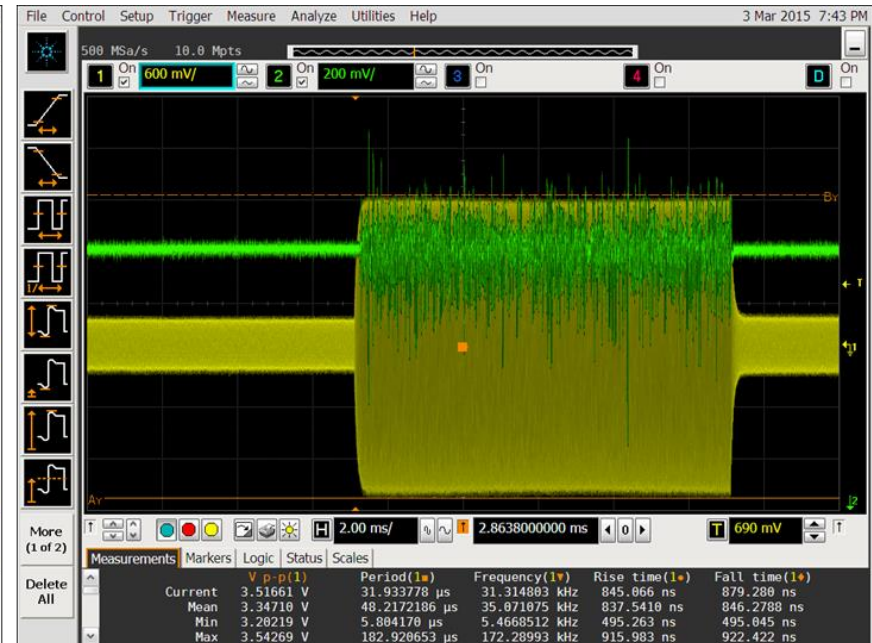
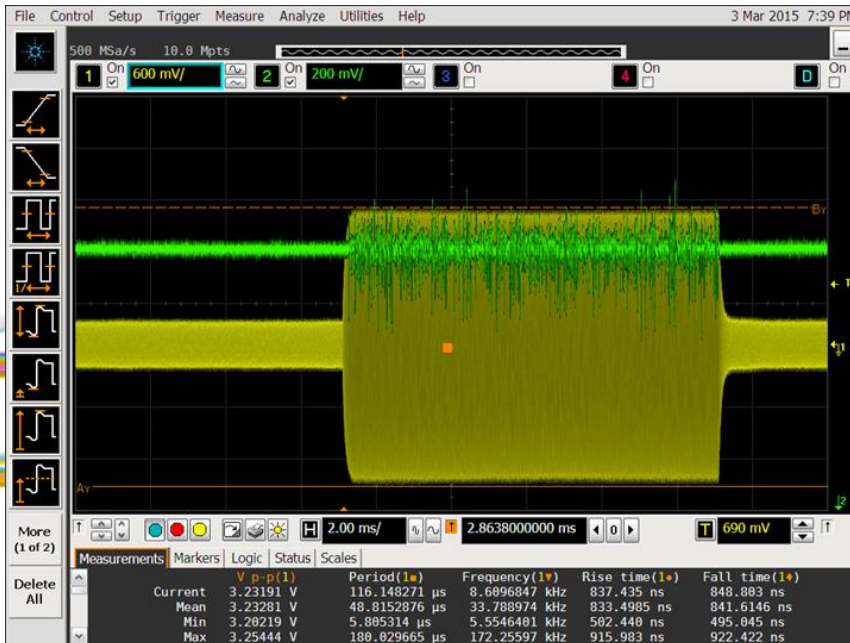
PIN Diode X-ray Detector



Hamamatsu S1223



Single radiation event



Radiation during pulse conditioning at different peak cavity voltage

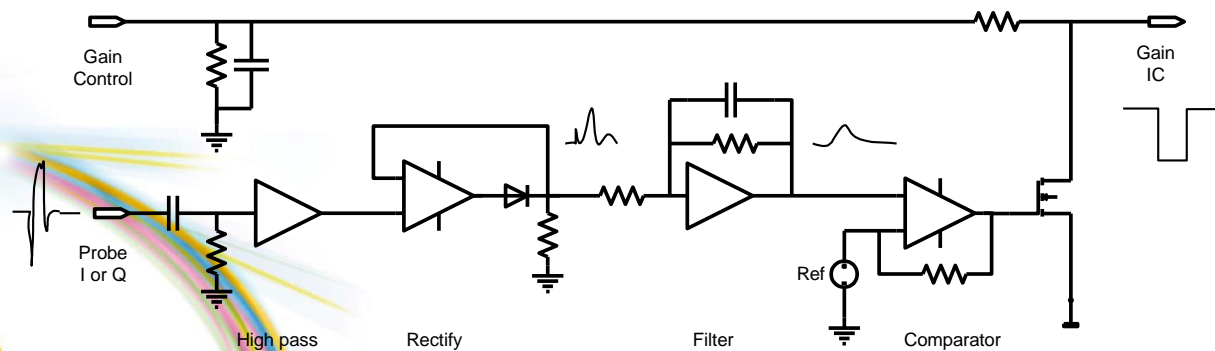
Cavity Probe Blips

Problem:

- fast rise-time spikes causing loss of RF signal on cavity HF pickup (and spare probes). Up to 4 blips/day/probe.
- LLRF interprets this as reduction in cavity volts and pushes up the forward power to compensate, causing a beam trip in some circumstances.

Actions taken:

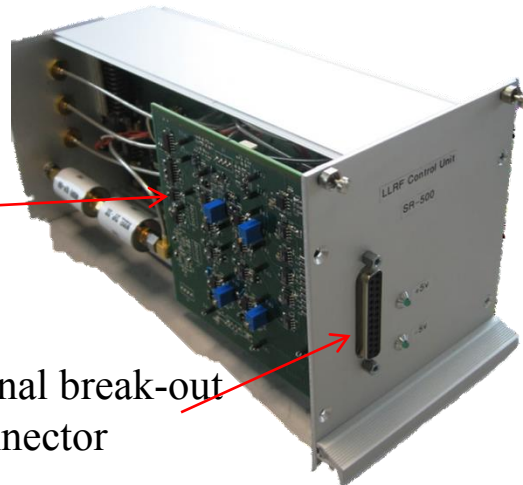
- Addition of filtering in the LLRF to reduce the bandwidth from 1MHz to 50 kHz. This has been successful at preventing trips at low loop gains. No probe blip trips since January 2014.
- Trial of a additional circuitry to detect the blip and reduce the loop gain during the period of the blip (~2 to 6 μ s typically).



Simplified schematic of probe blip detection circuit

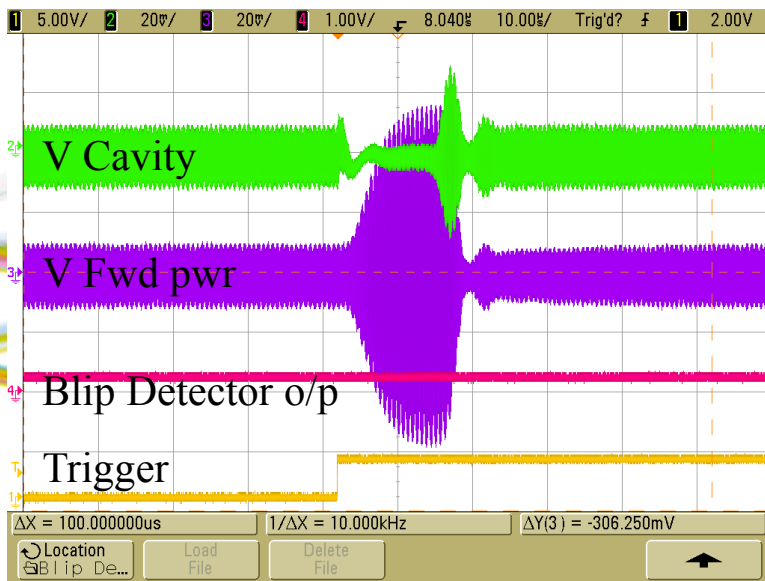
Cavity Probe Blips

Probe blip detector PCB mounted in LLRF module

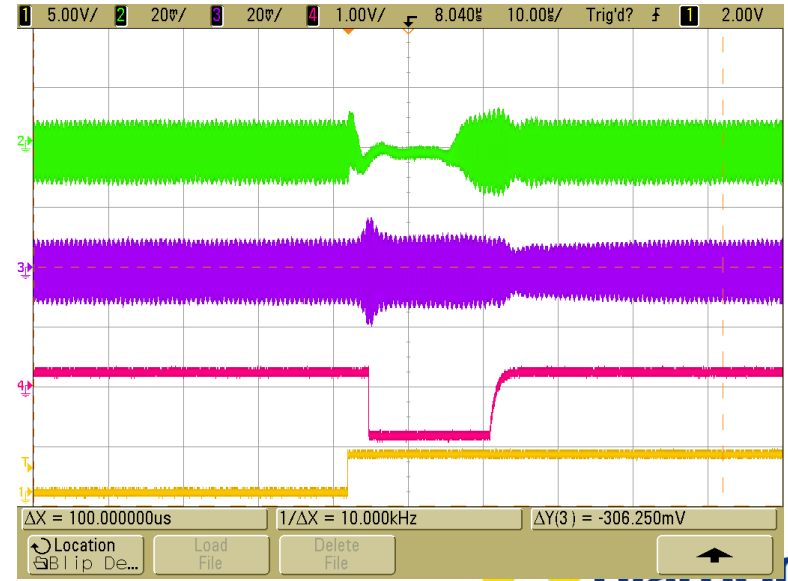


Signal break-out connector

Tests using cavity simulator and blip simulated by blanking probe signal for 10us:



Circuit disabled



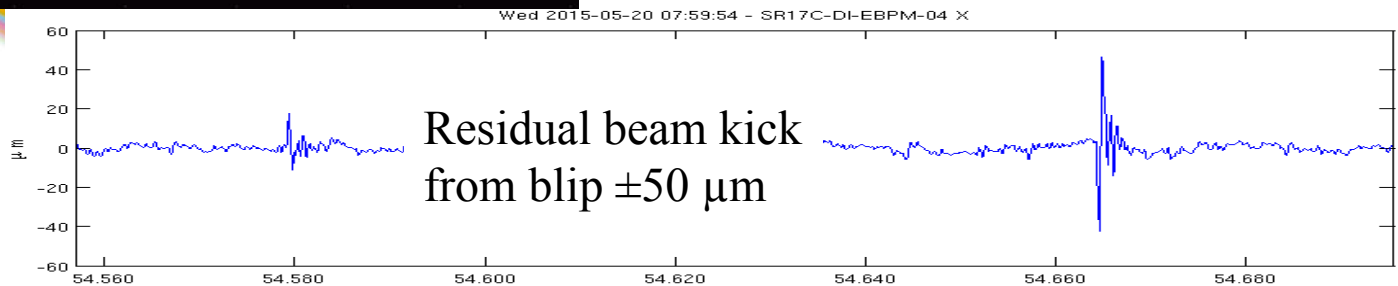
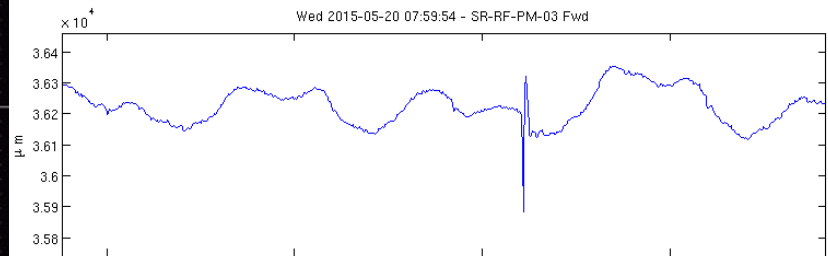
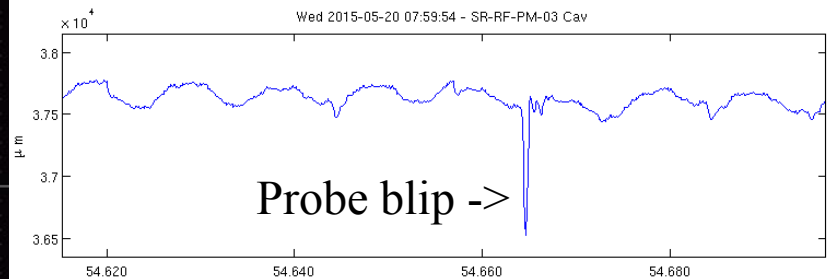
Circuit enabled

Cavity Probe Blips

Storage ring tests @ 300mA with LLRF#3 modified to include blip circuit:



LIBERA box, Cavity , PFwd and beam (X) motion signals:



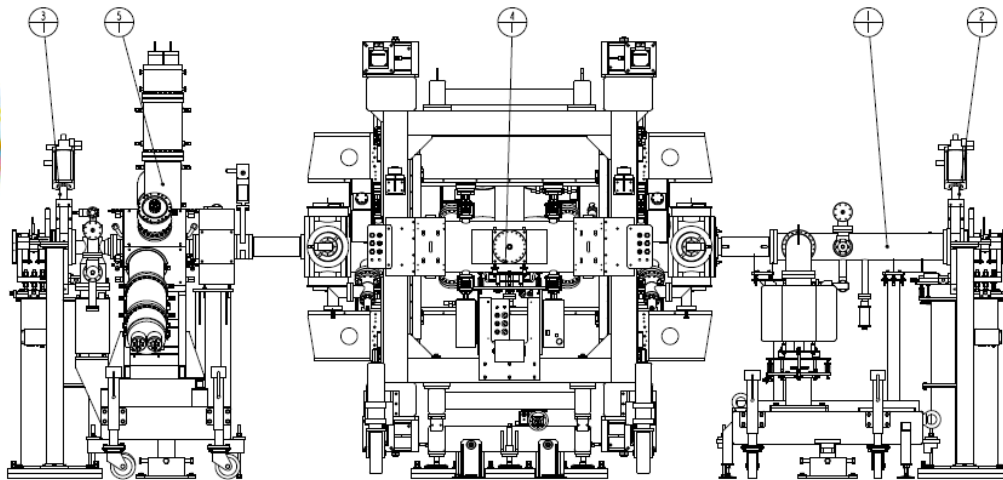
Attack and decay time-constants of gain reduction need optimisation to minimise beam disturbance.

Hybrid normal/superconducting RF

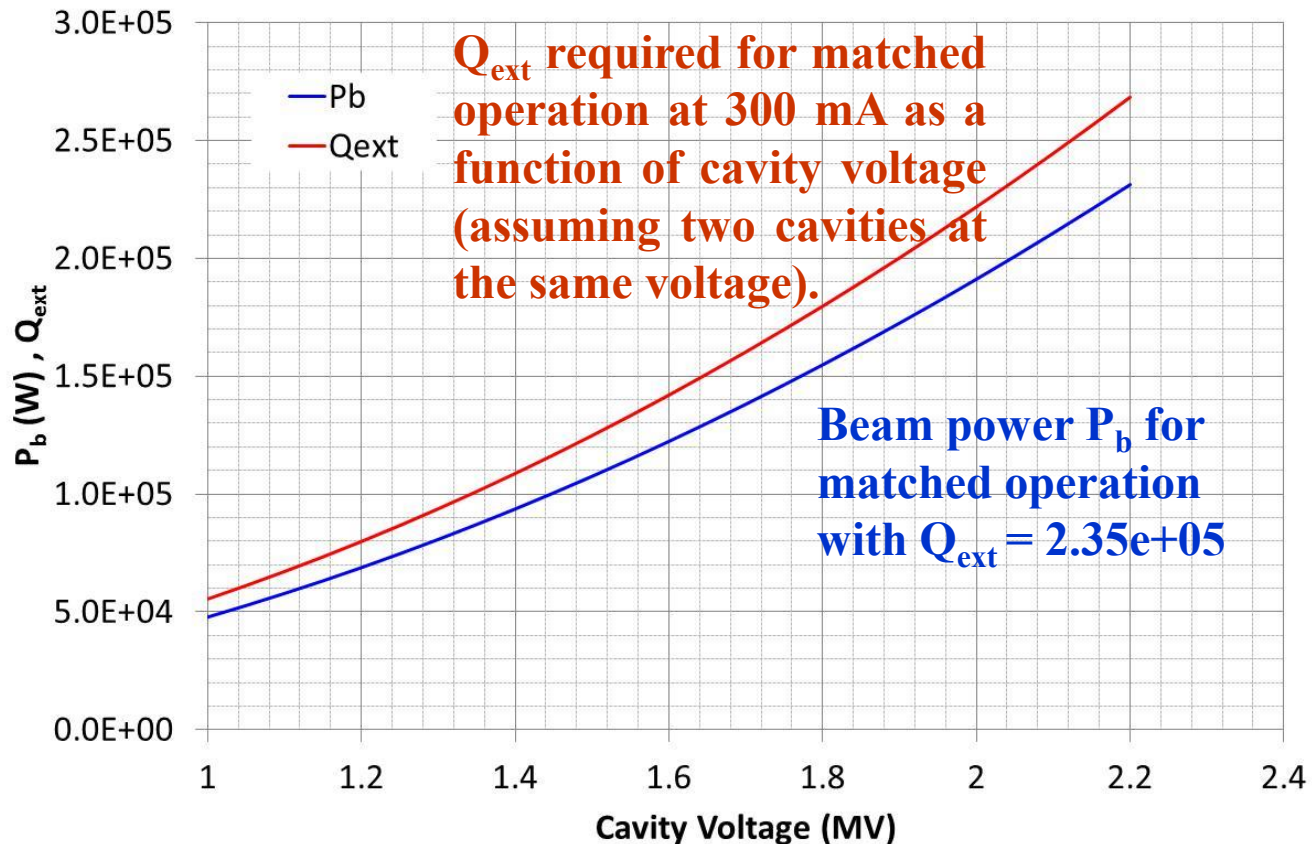
- Cavity failure is a catastrophic event putting Diamond out of action for several weeks
 - Lifetime to failure of cavities is around 6 years
 - A simple cavity repair can take 2 years
 - Currently have 2 working cavities and 2 under repair
 - Cavity 2 UHV leak caused 3 week downtime
 - Cavity 4 had to be rushed into service with knock-on problems
 - One week recovered by extending following run
 - Cavity 4 window failure resulted in 24 hours downtime and extended period of 150mA operation
- We will add two normal conducting cavities to our superconducting cavities
 - Can run at modest voltages and reduce power requirements of present amplifiers
 - Removes common mode of failure of superconducting cavity or cryo system
 - EU HOM-damped cavities as at BESSY and ALBA
 - Requires amplifier modification and new LLRF
 - LLRF to be upgraded to digital system
 - Plan to retrofit digital LLRF to present RF systems

Hybrid normal/superconducting RF

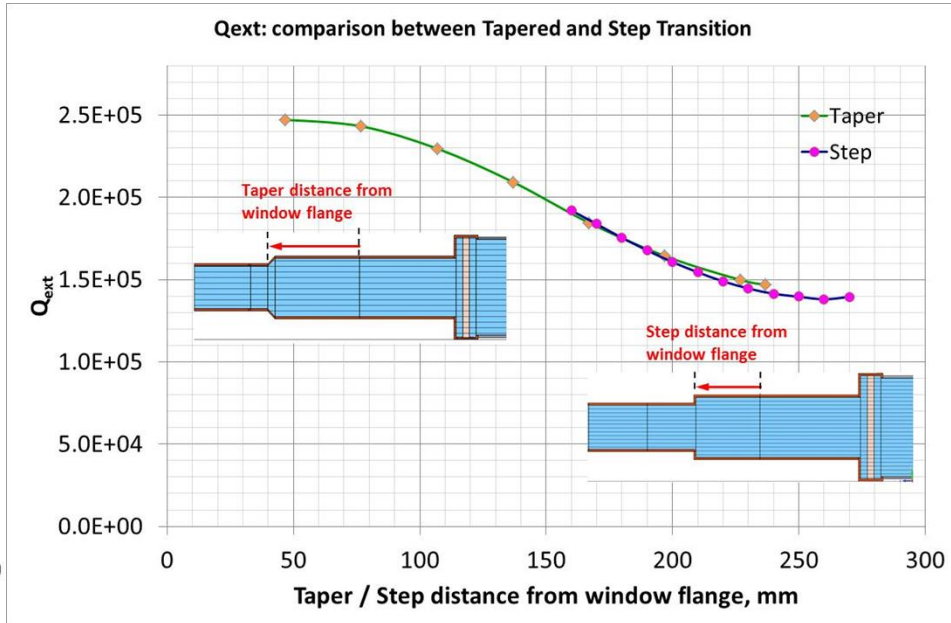
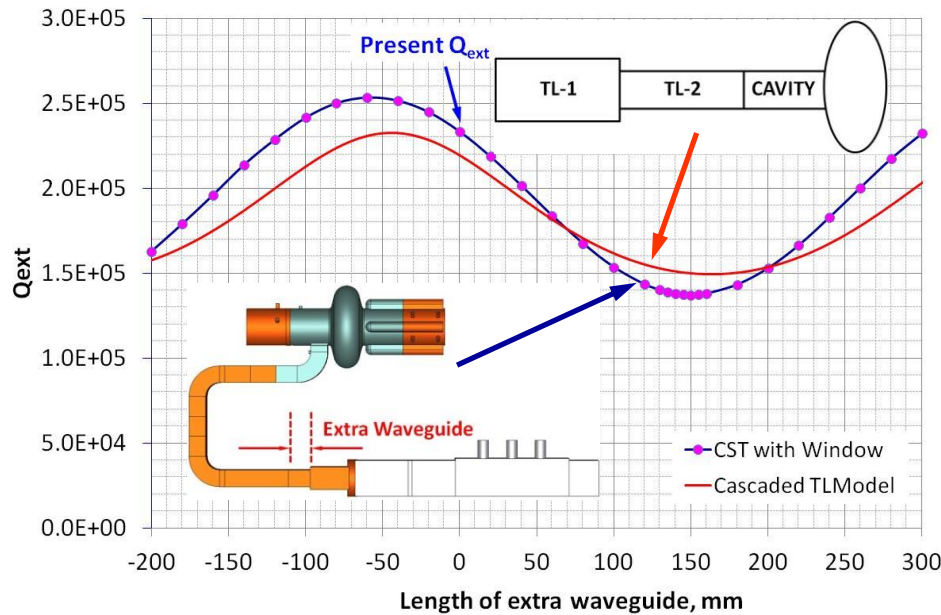
- Location of extra cavities is significant
 - Risk of total RF failure is too high if three superconducting cavities are in the same straight
 - No space for cryostat outside RF straight
 - EU HOM-damped cavities can be placed in many locations
 - Install NC cavities outside the RF straight
 - Install cavities upstream of IDs immediately before and after the RF straight
 - New transmission lines to be installed
 - Use third amplifier for both cavities
 - Currently powering RF Test Facility
 - Investigating amplifier options for RFTF



Modification of Pump Out Box for a Lower Q_{ext}



Modification of Pump Out Box for a Lower Q_{ext}



Review waveguide dimensions

Investigate waveguide construction

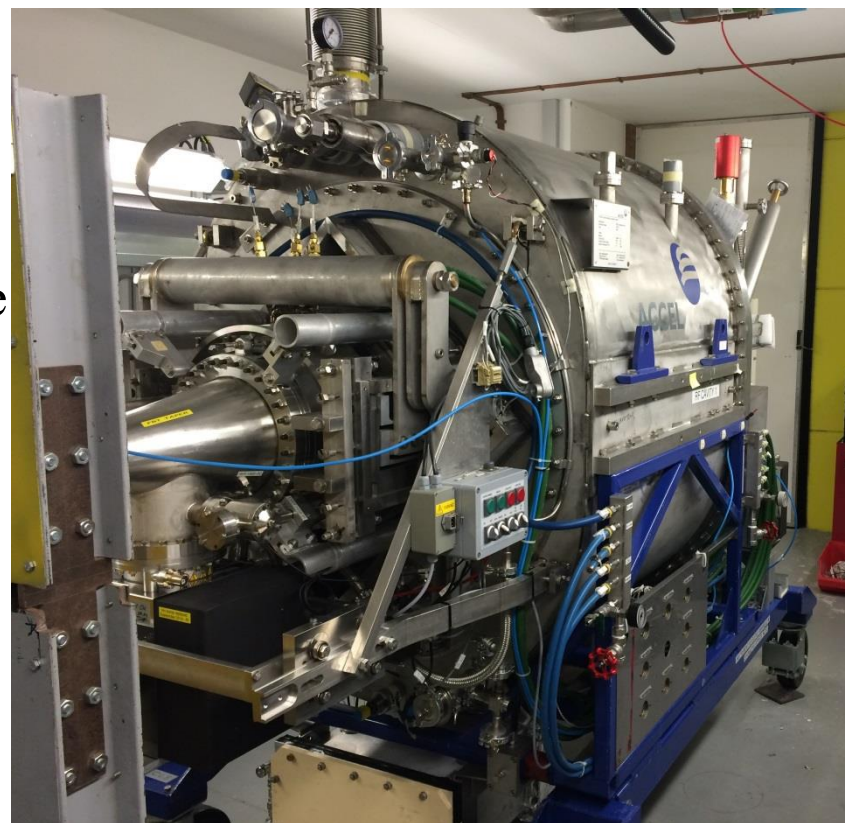
IOT switches

- IOTs are currently protected by switching off HVPS to all four tubes
 - Beam is always dumped for any IOT fault
 - IOTs must be protected locally, not by switching off the HVPS
- Isolate each IOT with a fast-acting MOSFET switch
 - Behlke 50kV solid state switch is under test
 - Can we control it quickly enough?
 - Can we survive the amplifier transients?
 - Is it reliable for continuous use?
- Extra power delivered by normal conducting cavities will allow beam to be preserved at full current with live switching of IOTs
 - IOT power-off tests show that beam is kicked but not lost



Exploitation of RF Test Facility

- Canadian Light Source cavity failed in January 2013
 - Failure of indium seal at feedthroughs
 - He leak to UHV
 - Returned to RI for repair
- Convenient to test cavity in Europe before returning to Canada
 - High power amplifier and cryogenic infrastructure available at DLS RF Test Facility
 - Tested by CLS staff at DLS in January 2015
- Cavity returned to RI and then to CLS in Spring 2015
 - To be installed in RF upgrade



Thank You!!

