Status of the Diamond RF systems

Chris Christou

on behalf of the RF group

Agenda

- Statistics and reliability
- IOT update
- Cavity performance management
- Beam current upgrade
- S-band gun
- SR RF projects
- Injector RF projects

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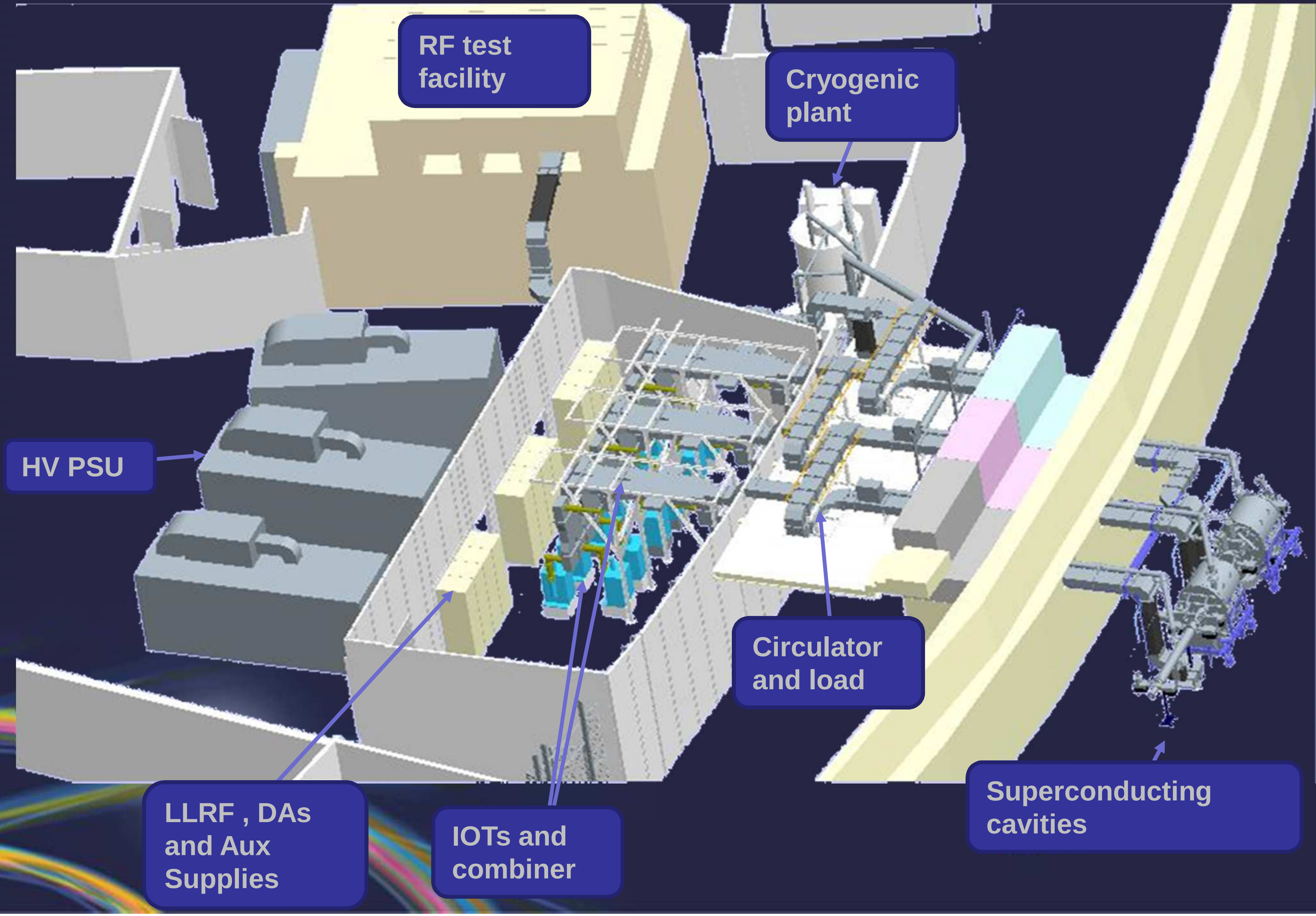
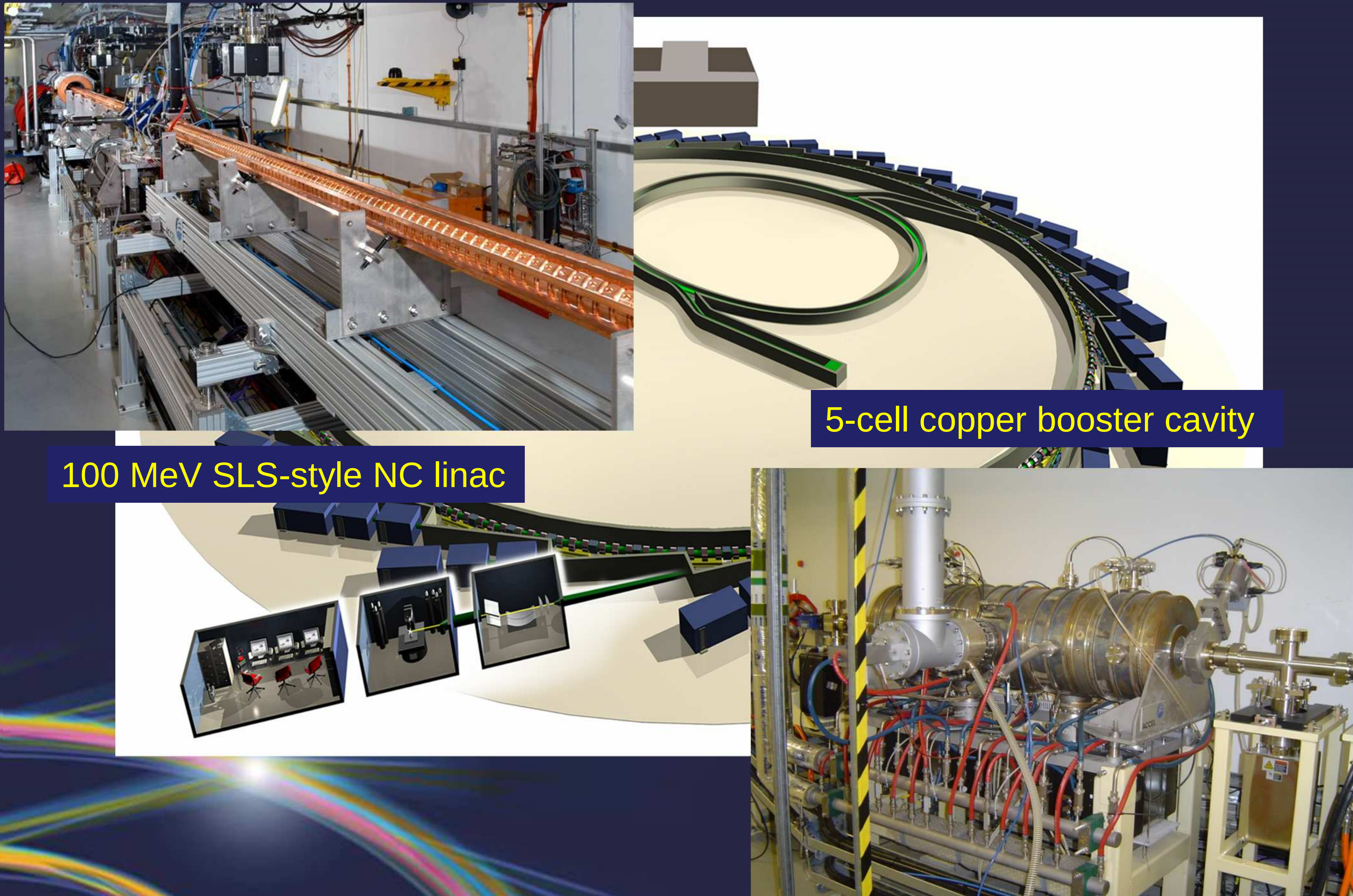
SR RF Systems



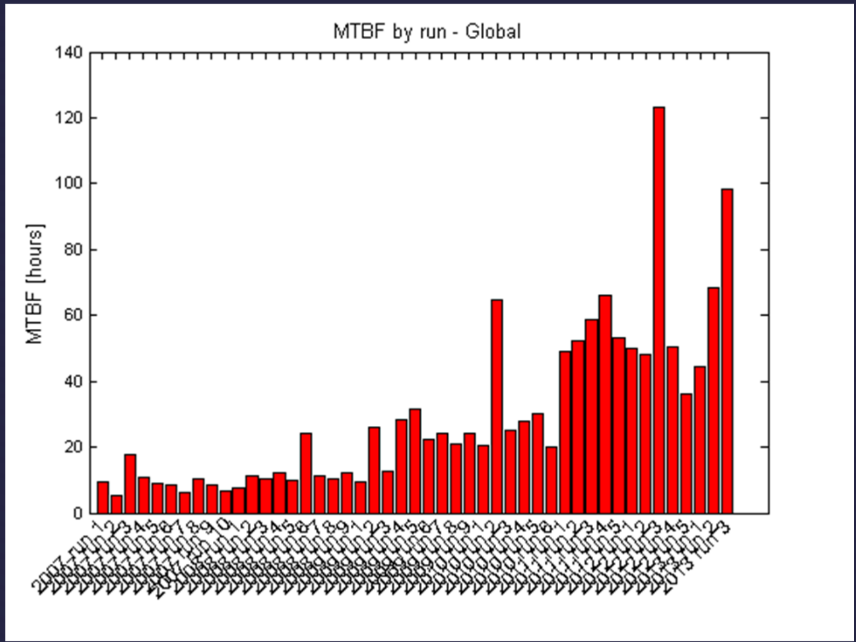
Other RF Systems

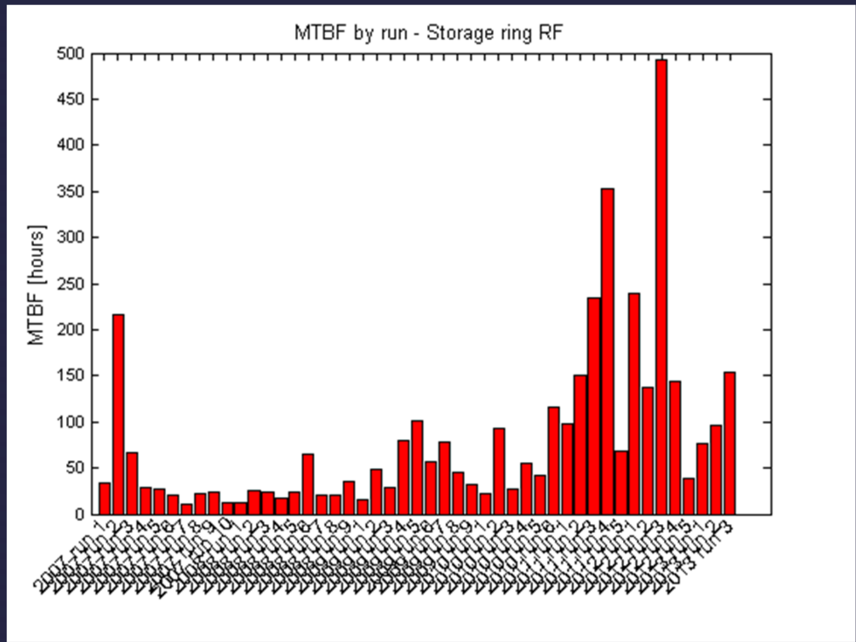


5-cell copper booster cavity

100 MeV SLS-style NC linac

Machine reliability





Steps in global machine reliability with

1: Introduction of top-up
2: Change in RF conditioning regime

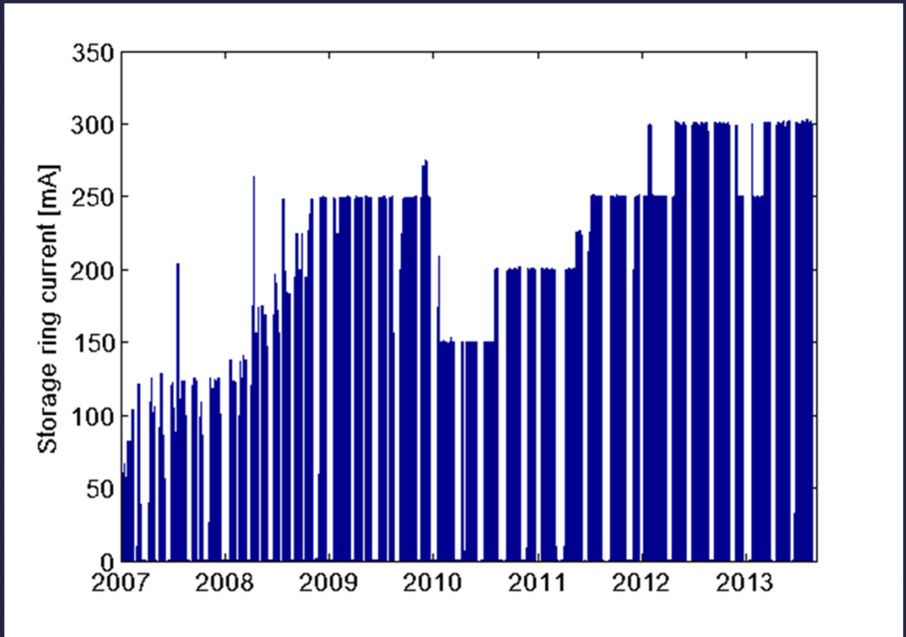
Cavity change in late 2012 for replacement of second damaged cavity

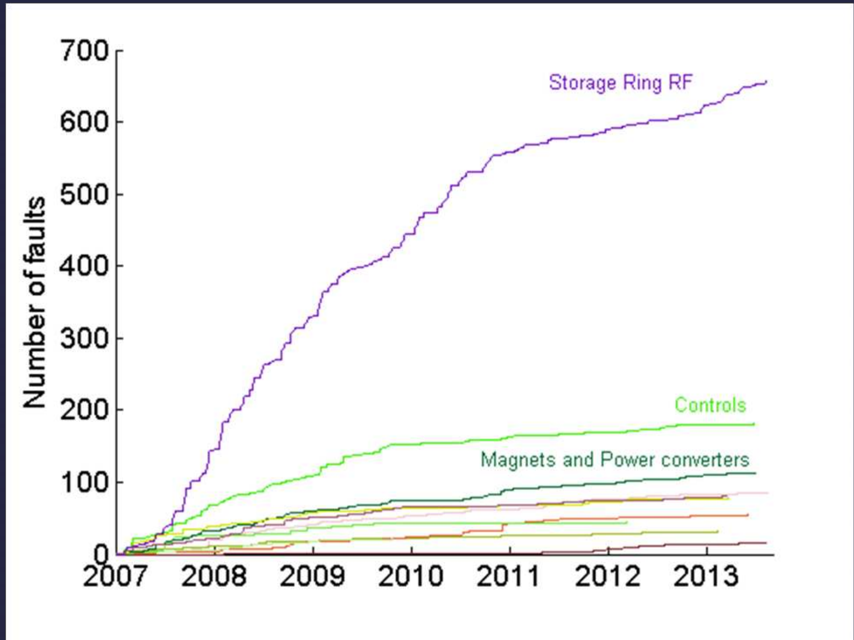
- RF reliability falls sharply (mainly amplifier faults)
- Recovered by mid-2013: tube conditioning and interlock review

Last run:

3 x cavity 2 trips
1 x cavity 3 trip
3 x filament 2/4 supply faults in quick succession at weekend

Machine reliability

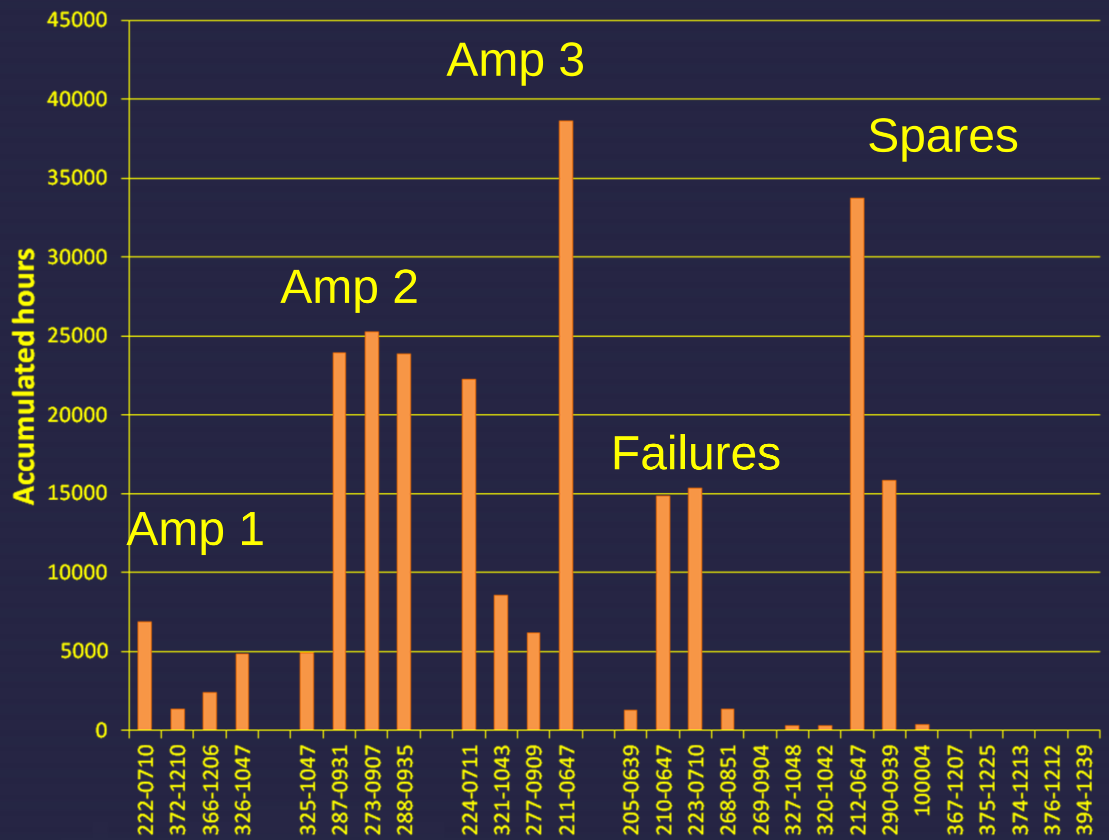




Beam current intimately related to the state of the RF cavities

- Cavity warm-up incident at end of 2009 required the exchange of both cavities
  - First swap in 2010
    - 150 mA operation with one cavity before replacement installed
  - Second swap in 2012
    - Old cavity taken out and new cavity installed in single shutdown
    - Brief period at 250 mA, now back to 300 mA
- Current increase to 350 mA planned for October 2013
  - Three stub tuner adjustment required

IOT performance



Newer tubes **do** arc more

- Programme of IOT conditioning
- Evaporation of emissive material from loaded cathode?
- Tube failure has double impact
  - failure
  - burn-in
- Are we approaching end-of-life for multiple tubes?

Problem of arcing over 2012/2013 following IOT swaps

2/1	2/2	2/3	2/4	3/1	3/2	3/3	3/4
7	0	0	1	1	3	2	1

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IOT performance

E2v IOT Operating Hours

- 16 IOTs have provided >286,000 filament hours
- Average IOT cost £1/hr
- Average >17,000 hours/IOT
- 6 x IOTs > 25,000 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

- Trial of alternative L3 IOT started
- Upgrade IOT cooling circuit >standby pump
- Design of water reject load completed

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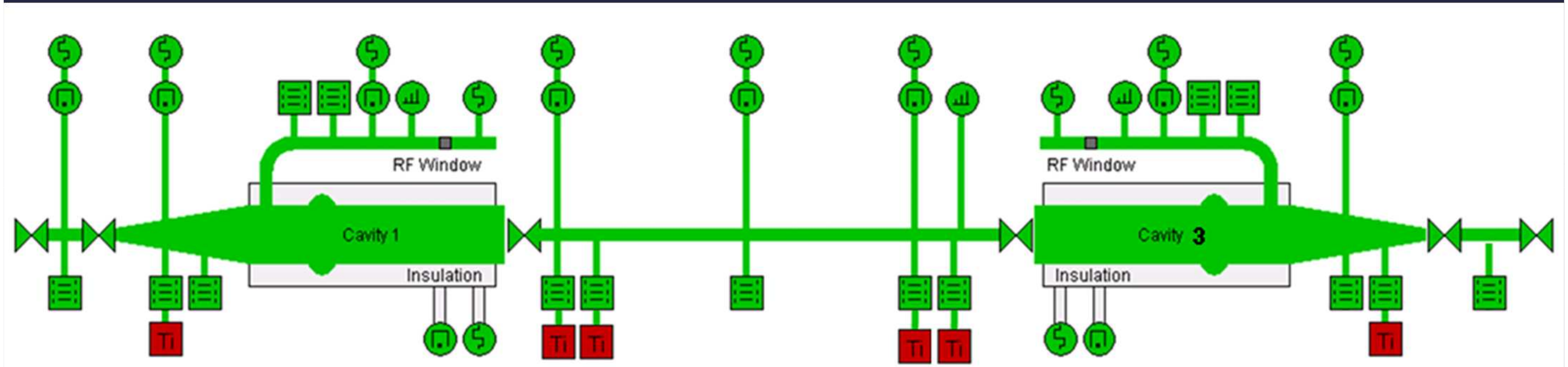
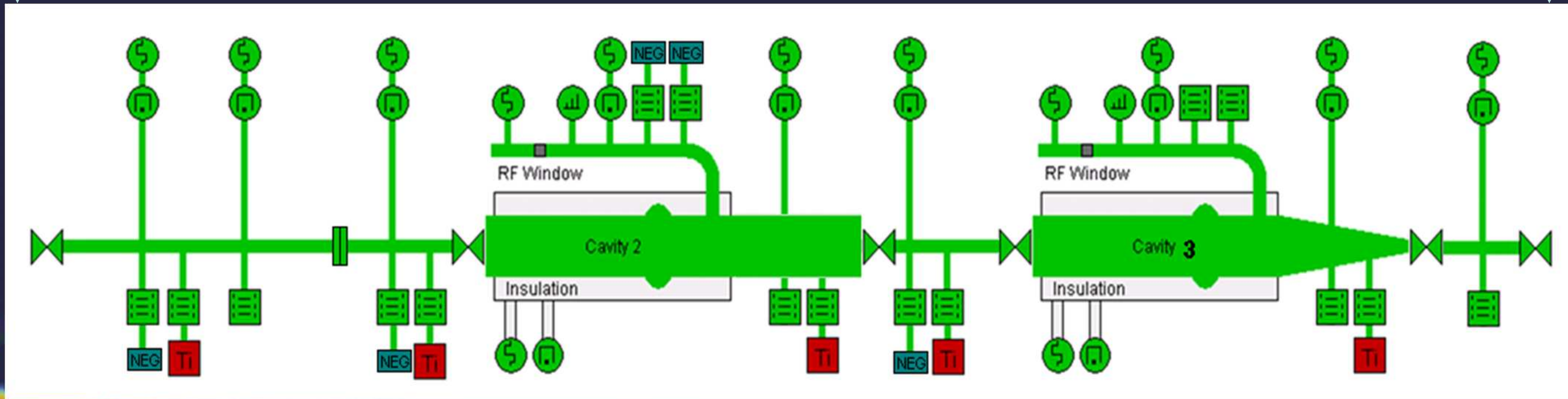
Cavity performance management



New vacuum configuration for RF straight after replacement of cavity 1 with cavity 2



Combined use of NEG and TSP to pump hydrogen
NEG cartridges are regenerated every shutdown.
TSPs are fired every week during MD time.
Typical vacuum level at 1.8e-10 to 5e-10 mbar @300mA.

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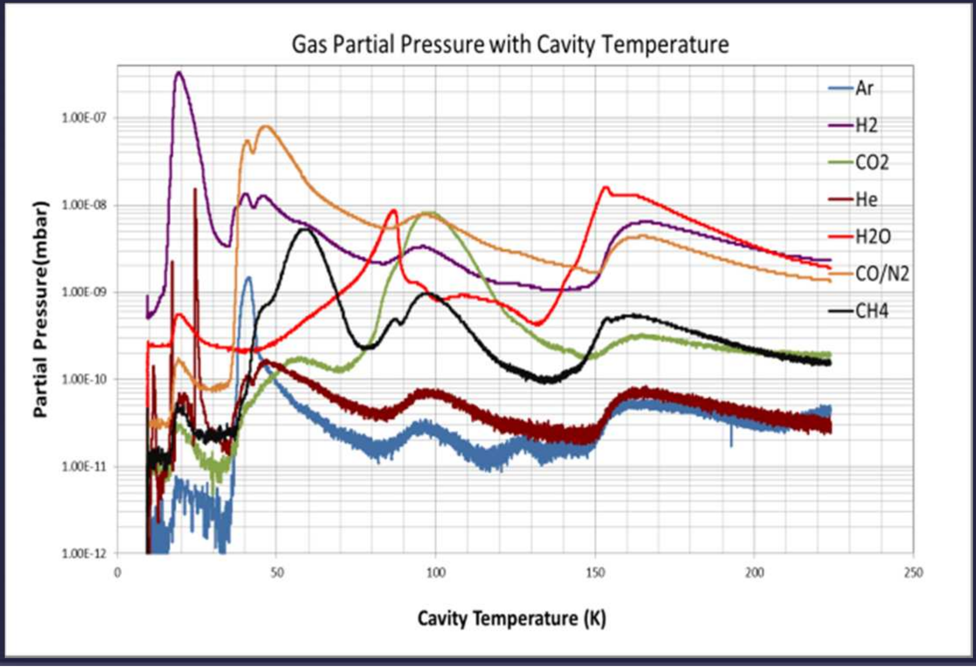
Conditioning strategy

- Cavities are fully warmed up each shutdown
- RF windows are baked each shutdown
  - Taken to 120°C and held for three days
- Cavities are partially warmed up to 50K several times each run
  - Reducing in frequency from weekly to every three/four weeks through 2013
- Pulse conditioning every week in run-time
  - 2.5 MV peak voltage
  - 10% duty cycle (10ms/100ms)
- Pulse conditioning with detuned cavity every week in run-time
  - Detune angle scanned to sweep standing wave in waveguide

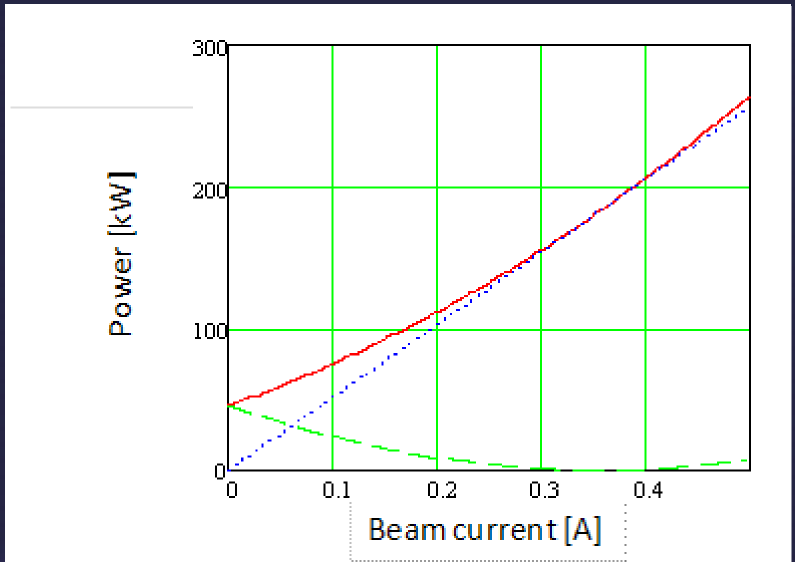
Cavity 1 repair

- Removed from the tunnel in 11/2012
- Replaced with cavity 2
- Moved into RFTF
- Repaired helium level sensor
- Conditioned and tested
- Held as a spare cavity

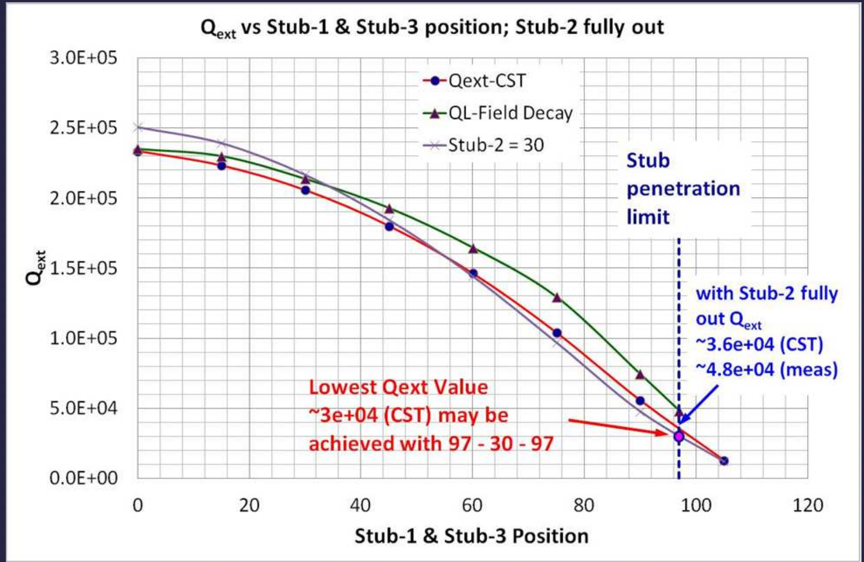


Beam current upgrade

- Desire for storage ring beam current to be raised
  - Radiation shielding is rated for 500 mA operation
- 500 mA operation requires a third cavity and lower external Q

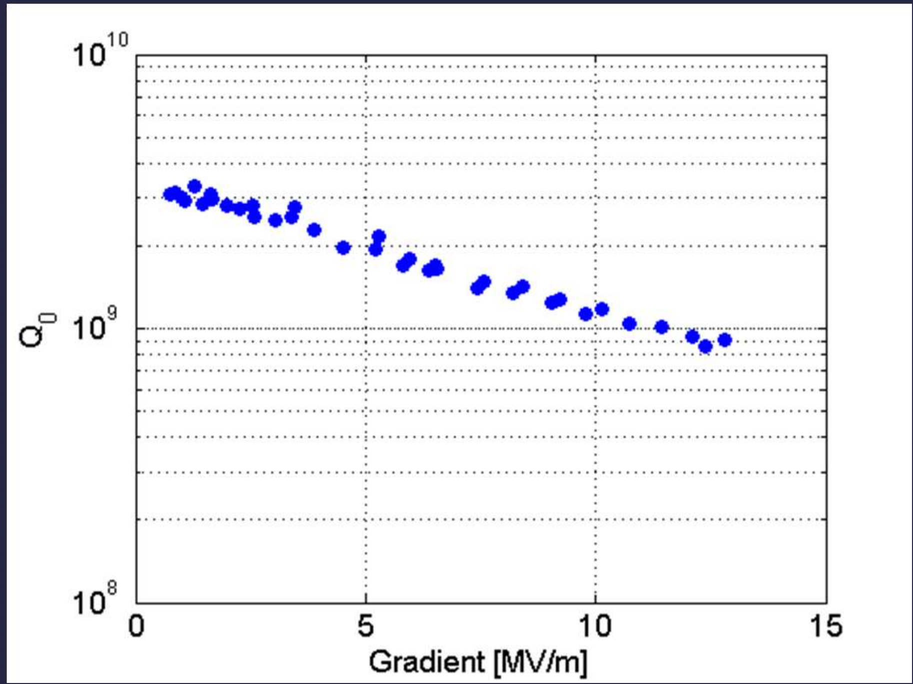


Typical three cavity configuration
1.4MV, Q_0 = 6e8, Q_{ext} = 1.2e5



Detailed three-stub tuner modelling is ongoing

Cavity 4 procurement



Cavity 4 contract placed with RI Research Instruments GmbH
Use SSRF coupler tongue design and CLS pump-out box to give $Q_{ext} = 1.2x10^5$
Vertical test at Cornell University carried out in July 2013

- Rapid conditioning to full field
- Q_0 exceeded specification
  - $Q_0 > 1x10^9$ at $V_{acc} < 6.67$ MV/m
  - $Q_0 > 5x10^8$ at $V_{acc} < 9.33$ MV/m

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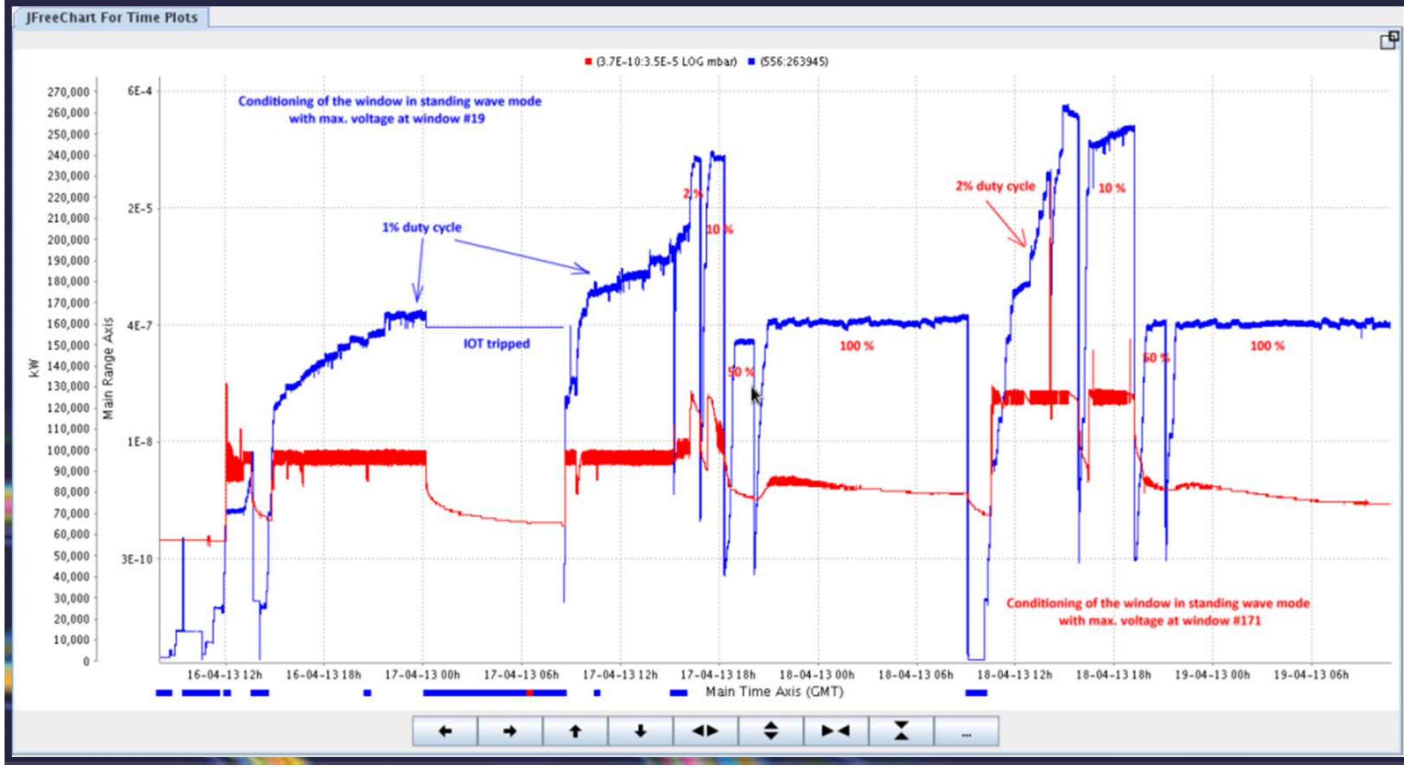
Cavity 4 window test

Conditioning in RFTF
- March: Window for Diamond
- June: Window for Pohang

Travelling wave to 300 kW CW

Standing wave to 160 kW CW, 240 kW pulsed

Cavity and window at RI for integration into cryostat
- On site at Diamond end 2013
- Contract completion early 2014



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Cryogenic issues for high current operation

Assume 500 mA with three installed CESR cavities

- Cold Box load is 82% of capacity with 2-cavity 300 mA operation and 1.8 MV on cavity in RF test facility
- Must consider the following factors for 500 mA operation
  - Beam heating of third cavity
  - Change in configuration of multichannel lines
  - Increased beam heating of two installed cavities
- Capacity of installed cryogenic system is 500 W

- Gas storage space for cool-down of all three cavities will also be an issue

- *Can we maintain the RF Test Facility?*
- *Can we place the new cavity remote from the RF straight?*
- *Cryogenic higher harmonic cavity?*

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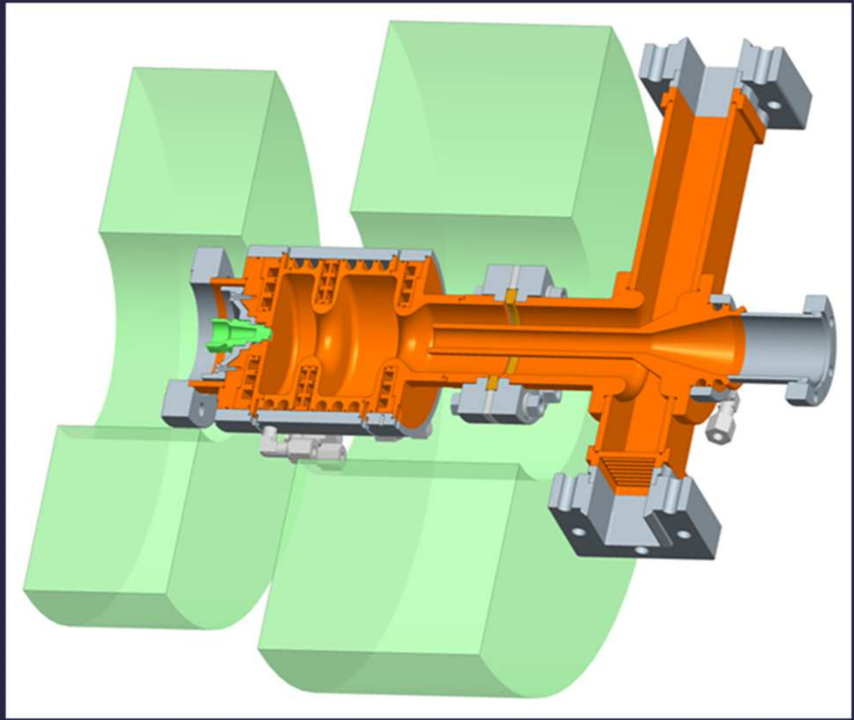
S-band photocathode gun design

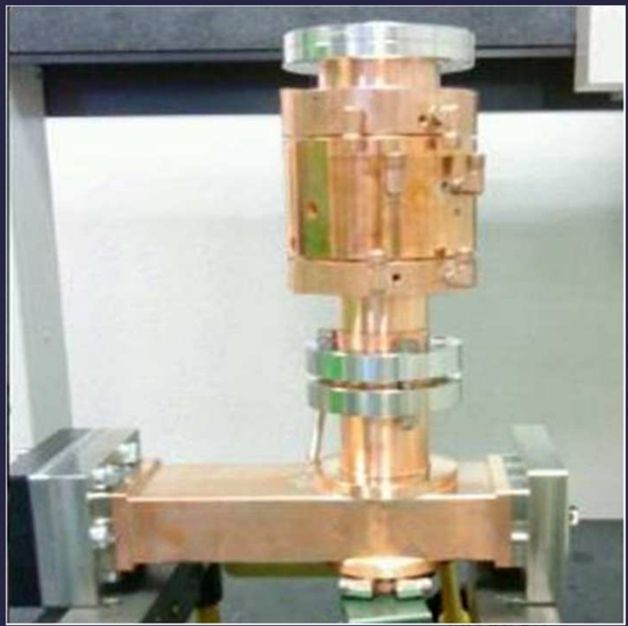
Based on DESY PITZ design philosophy
Designed for operation up to 1 kHz reprtition rate

- 1.5 cell design
- Coaxial coupler
  - Preserves gun symmetry
- Extensive cooling for high repetition rate operation
- Transverse emittance
  - < 1 mm.mrad for Q = 1 nC
  - < 0.5 mm.mrad for Q < 0.25 nC
- Single focusing solenoid and bucking solenoid
  - Flexible position for tuning
- Removable cathode



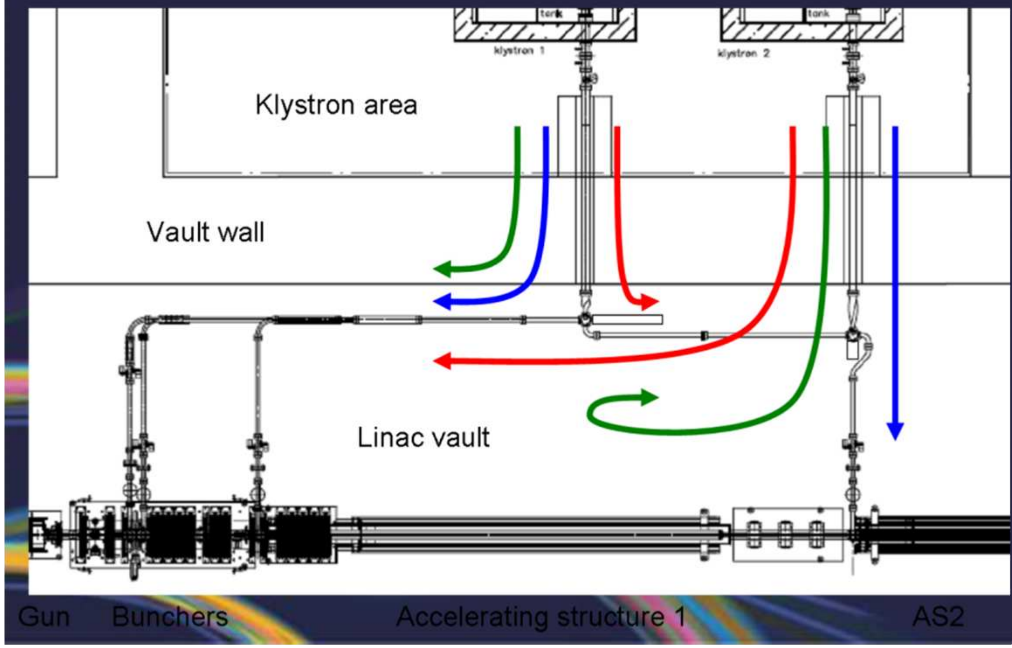
Manufactured at FMB Berlin and delivered in 2012
Requred frequency tuning by cathode insertion
Second iteration under construction
Tune by cavity length trim before brazing

S-band photocathode gun commissioning



- High-power test exploits the waveguide switches installed for Diamond linac rescue mode
- Using same klystrons and interlocks as normal Diamond linac
- High-power tests restricted to machine shutdowns
- Modulator repetition rate limited to 5 Hz
- Last conditioning run to 3.5 MW (target 6 MW)

Klystron 2



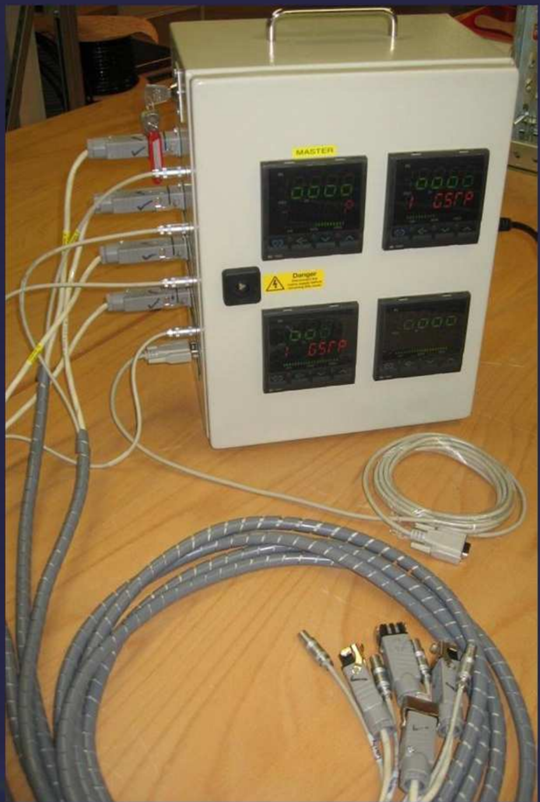
Arc detector upgrade

- Glass multimode fibres are opaque because of radiation in tunnel
  - Replace fibres with “Super Eska” SH8001 POF (SNS, Oak Ridge)
  - 0.2 dB/m loss (5dB over whole 25m length)
  - Installed in August shutdown: now to be evaluated
- AFT arc detector suffers false trips (even with fibre inputs capped)
  - ARC04 under test – probably reduce transimpedance again

‘Cornell’ style too long when fitted to Diamond cavity RF window, fouls on waveguide

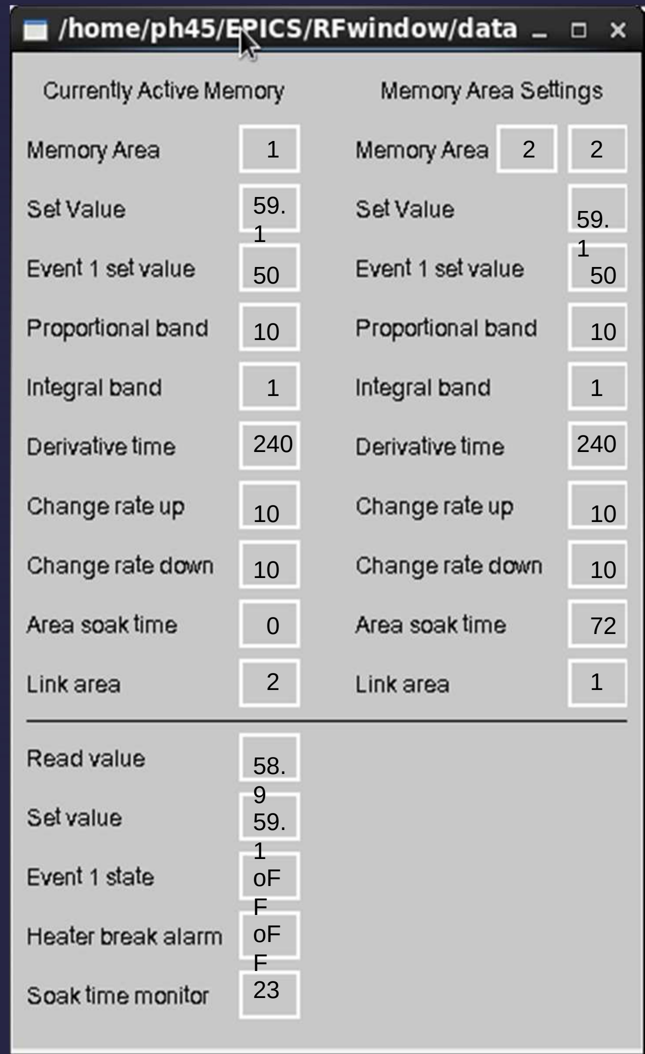
Shorter (100mm) unit produced for Diamond by ET Enterprises UK
Uses 22mm dia. Tube (# 9111B)
Connectors on flying leads reduces size

RF Window Bake-out box



Mechanical relays for heater tape energisation changed to solid state for compatibility with controller SSR’s in series to reduce possibility of relay stuck on

EPICS GUI to monitor temperature, alarm and set parameters (read only)

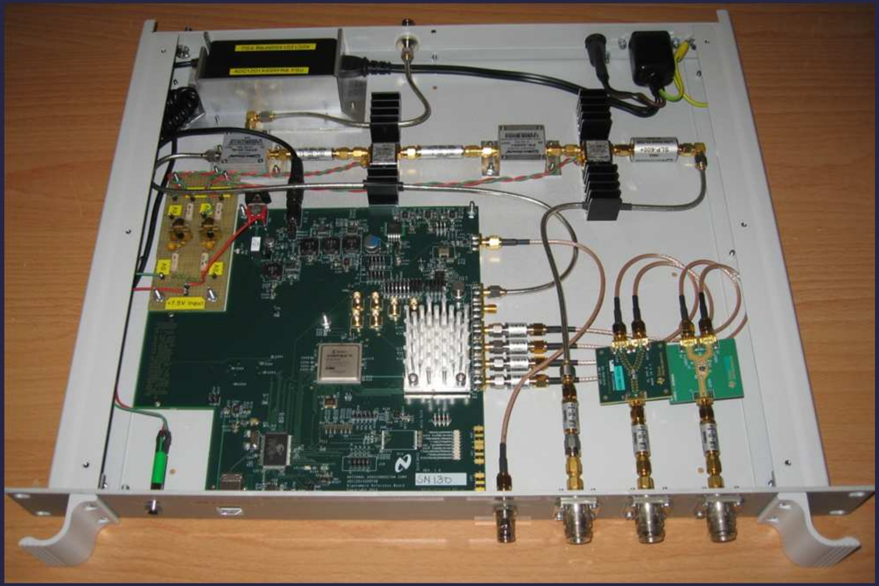


Fast sampling and demodulation

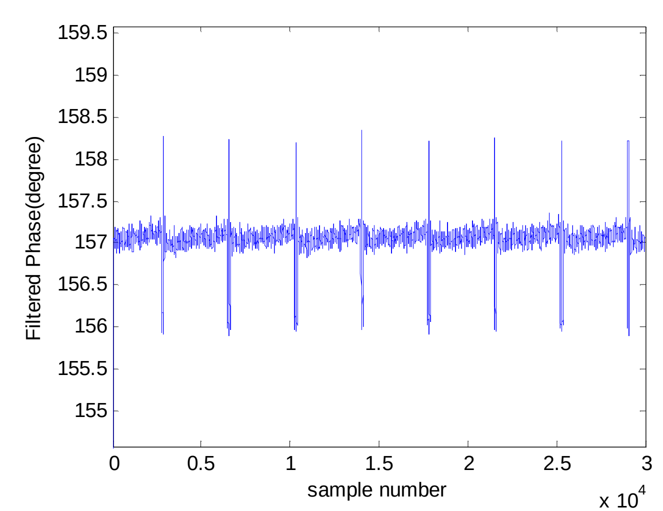
TI ADC12D1800 sampling at 2.0 GSPS .
Sample by sample demodulation

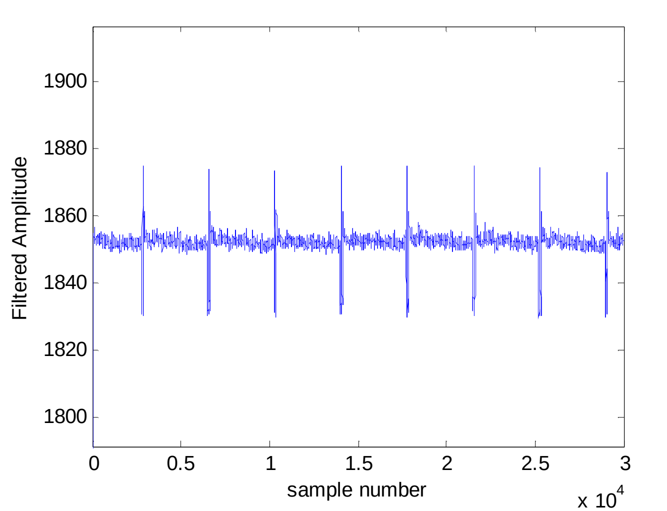
$$\begin{pmatrix} I \\ Q \end{pmatrix} = \begin{pmatrix} \cos n\Delta\varphi & -\cos(n+1)\Delta\varphi \\ -\sin n\Delta\varphi & \sin(n+1)\Delta\varphi \end{pmatrix} \bullet \begin{pmatrix} y_{n+1} \\ y_n \end{pmatrix}$$

$$\Delta\varphi = 90^0$$



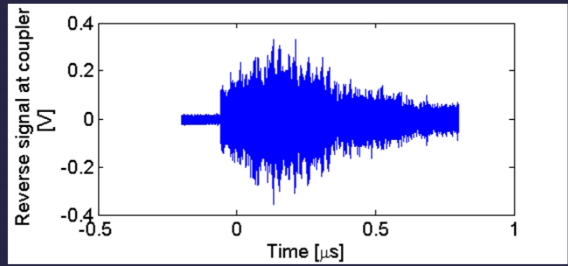
Cavity 2 FBT Near Bottom Probe

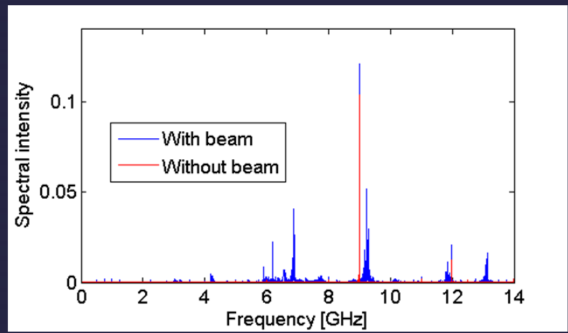


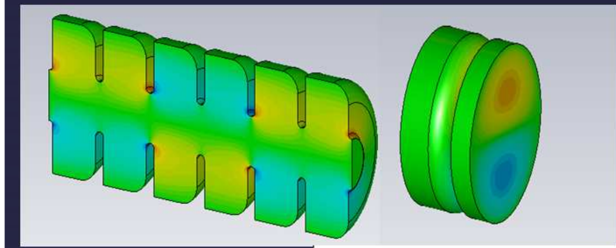


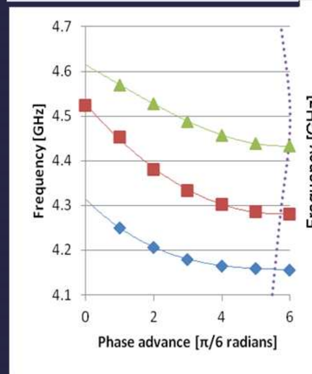
Injector RF projects

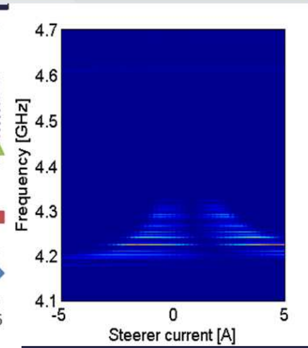
- Linac wakes and HOMs
- Measured during operation
- Excellent match with CST Microwave Studio and Particle Studio models
- Useful for future linacs
- A structure cavity BPM
- Linac as test bed for hardware developments

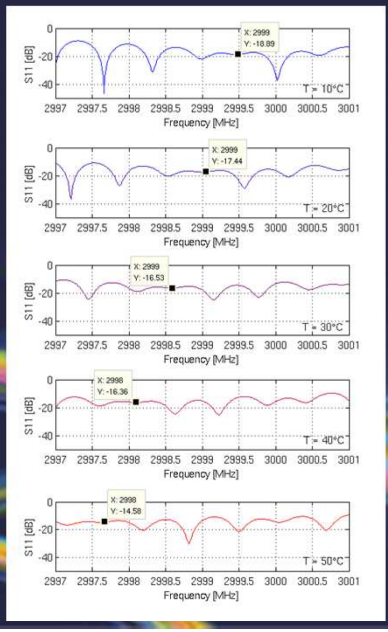












- Temperature control of linac operating frequency
- To support possible changes to storage ring lattice
- 2 MHz span with temperature control
- Demonstrated beam at extremes of frequency

Also general maintenance

- Booster LLRF work
- Linac gun renewal
- …

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The Diamond RF Group

- Chris Christou
- Alek Bogusz
- Pengda Gu
- Matt Maddock
- Peter Marten
- Shivaji Pande
- Adam Rankin
- David Spink
- Alun Watkins

And of course a big “Thank You” to Morten!

Thank you for your attention
Any questions?

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