Upgrades and EM simulations for the Diamond SR HP Amplifiers

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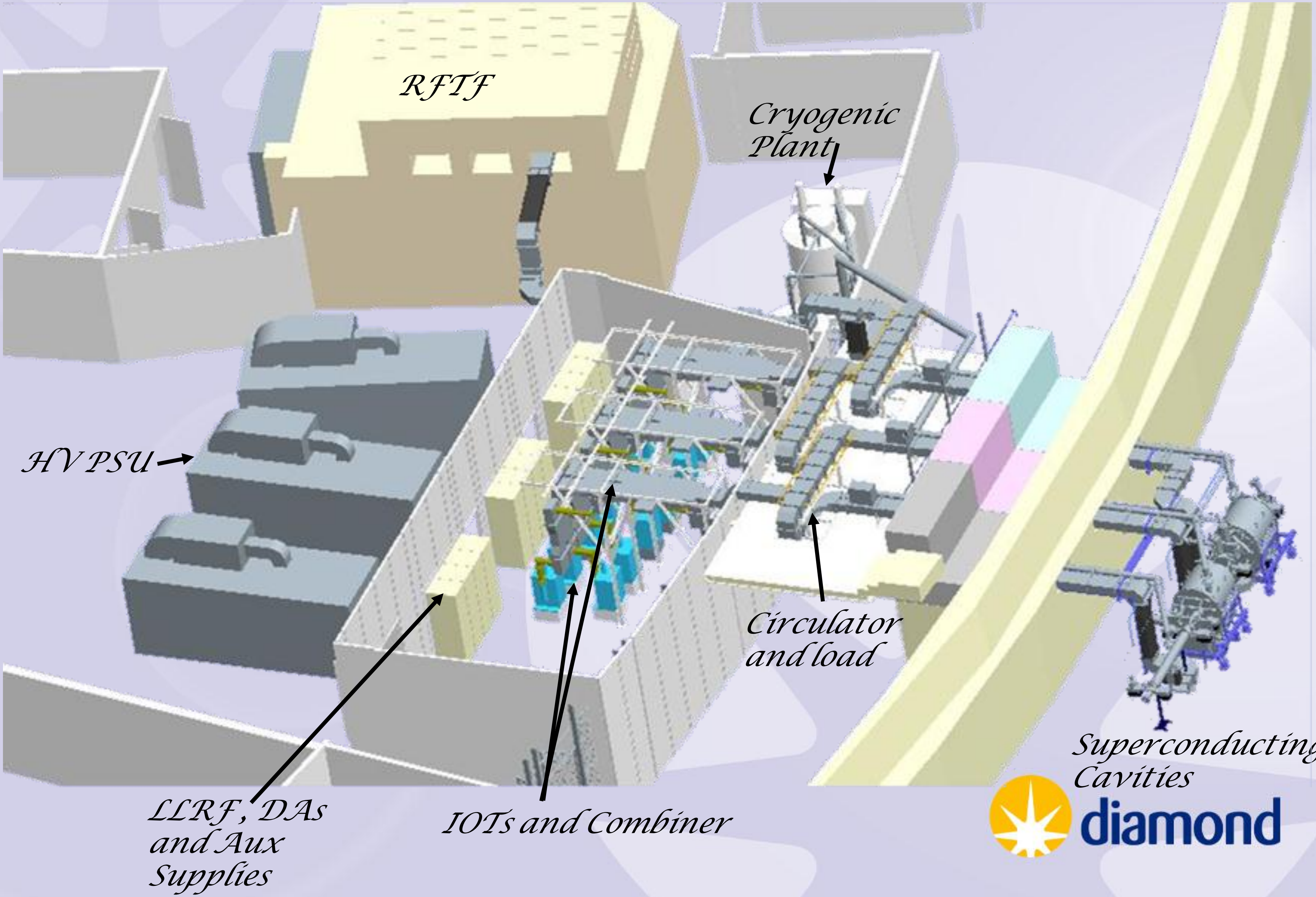
on behalf of the SR RF Group

SR RF Systems



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Most upgrades driven by need to improve reliability

Main issues:

- Cavity failure
- Frequent cavity trips
- Early IOT failure rate
- Spurious arc
- Increasing beam current

Early years: MTBF: ~ 40 hrs
2012 (year to date) > 335 hrs

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Change of IOTs

Original IOT: TH793 (TED)

12 IOT failures: Average filament hours on failure: 4500

New Tender:

IOTD2130 (E2V) or TH793-1 (new TED IOT)

TH793

IOTD2130

Main differences:

- Single output cavity
- No body current connection
- Modified cooling circuit
- Tuning and installation
- Circuit dimensions

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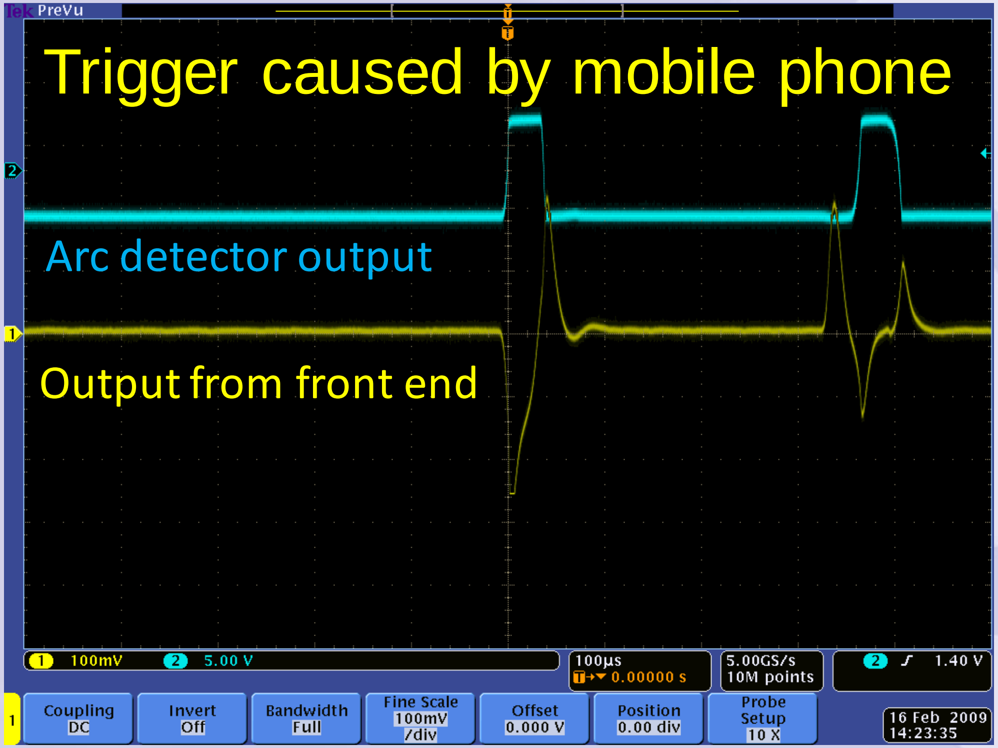
ARC Detector modifications

Suspected false trips from Waveguide Circulator and RF Load arc detectors.

Confirmed susceptibility to false trips:

- Mains cable
- PCB
- EMI
- Excessive circuit gain



Solution:
Reduced Sensitivity
Gain: 10M → 200k
Energy for trigger: 1 – 2 J

No more trips

Spark Box

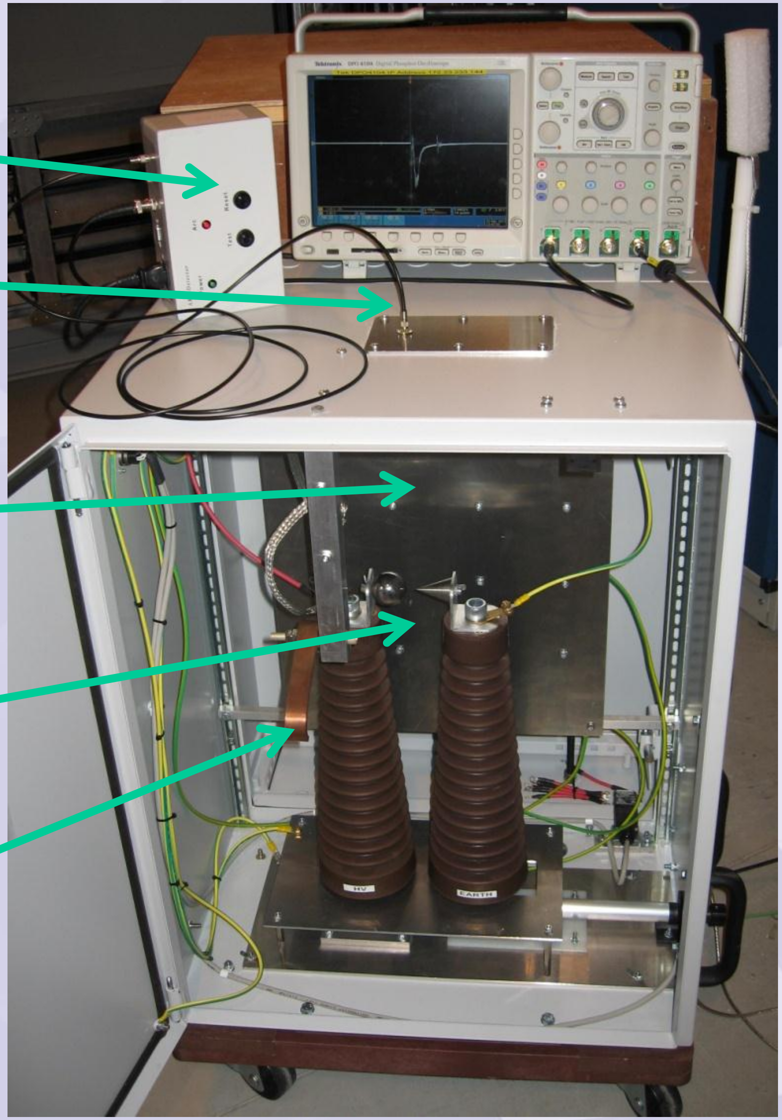
ARC detector

Optical fibre

Capacitor mounting plate

Adjustable Spark gap

Safety shorting bar



- In-house design and build
- Output voltage can be changed by adjusting the spark gap
- The spark energy is determined by the number of HV capacitors linked together
- Output of original arc detector saturates even with very weak sparks. A gain of 10k is enough to detect sparks of 0.1 Joule energy

Glycol Change

Investigation of IOT failure revealed Blackened collector

Diamond IOT after 1300 hrs

Broadcast IOT with 8 years service

Cause: Suspected lack of cooling

Chemical change to Glycol used introduced Silicone. Silicone prevents wetting of collector surface reducing cooling.

Chemical analysis of alternative glycols

Heated detergent wash prior to glycol change

New glycol mix in operation

DowCal10 changed for ThermoCal

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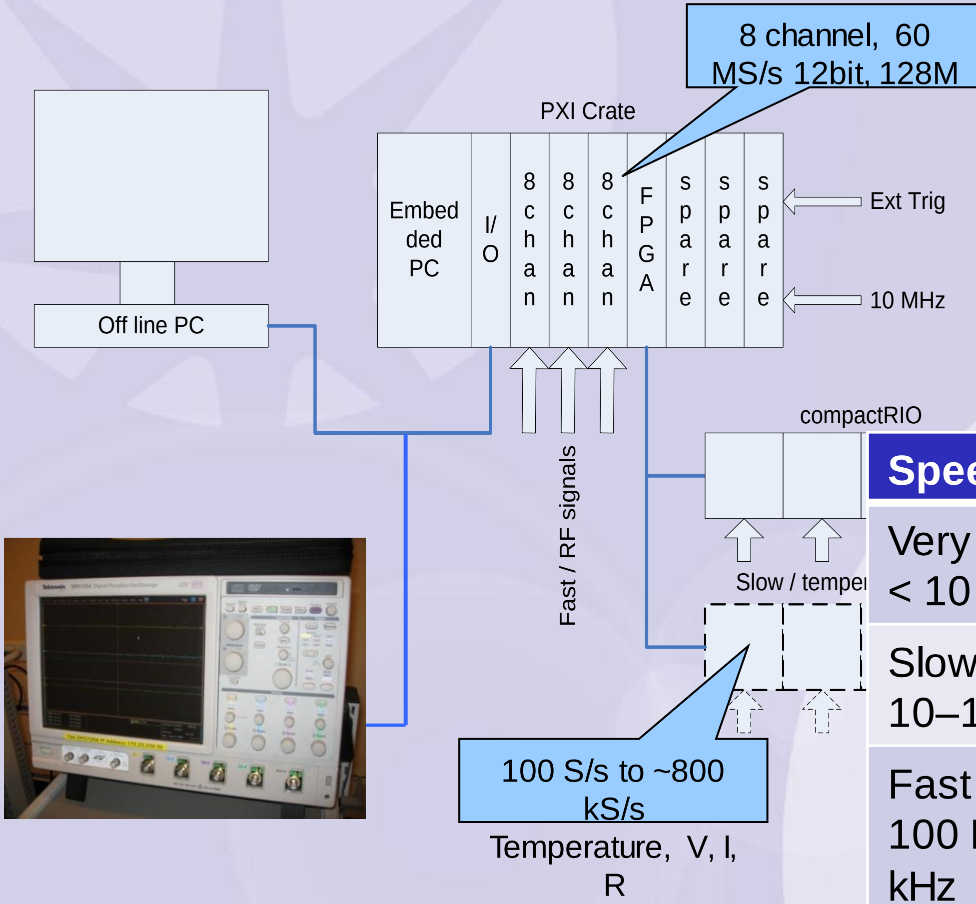
NI PXI Data Acquisition



Speed	Examples	Hardware
Very Slow < 10 Hz	EPICS PVs	VME / IOC
Slow 10–100 Hz	Temperatures Cryogenics	NI Compact RIO
Fast 100 Hz -800 kHz	Vacuum Analogue voltage / current	NI Compact RIO
Very fast ≤ 60 MHz	Cavity voltage RF power etc	PXI Scope Cards
RF Waveforms	500 MHz waveforms Pulses and fast rise times	Typical oscilloscope ≥ 1 GHz

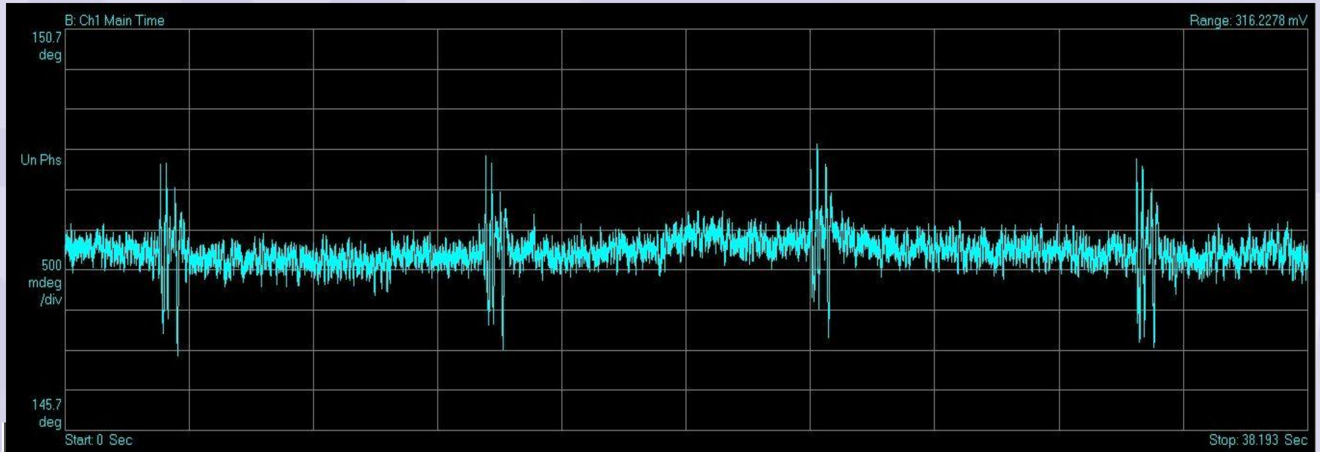
plus

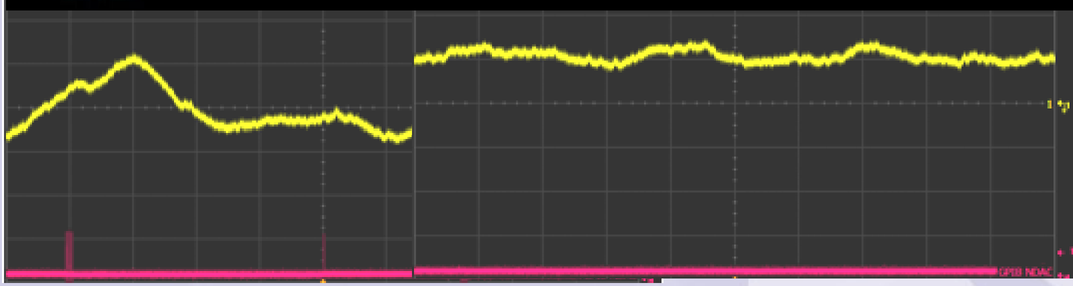
3 off G64 Canberra X-ray monitors
ION Chamber based monitoring
One installed per cavity

Master Oscillator Modification

IFR (Aeroflex) 2040

Phase glitches observed when communicating with MO





Before After

GPIB interface located on 5 Volt PCB supply track.

Current pulse causes voltage drop (0.0008 V) producing noise.

In house investigation:
Circuits modified to supply GPIB circuitry directly from PSU and with additional decoupling capacitors.

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Fast IOT Fault Detection and Isolation

Purpose

- IOT breakdown is single largest amplifier fault
- Fault on one IOT isolates HV for all 4 IOTs
- Typically 10-15 trips per year (6 in 2011)

  8 IOTs in operation
- Recovery is fast – but beam is lost

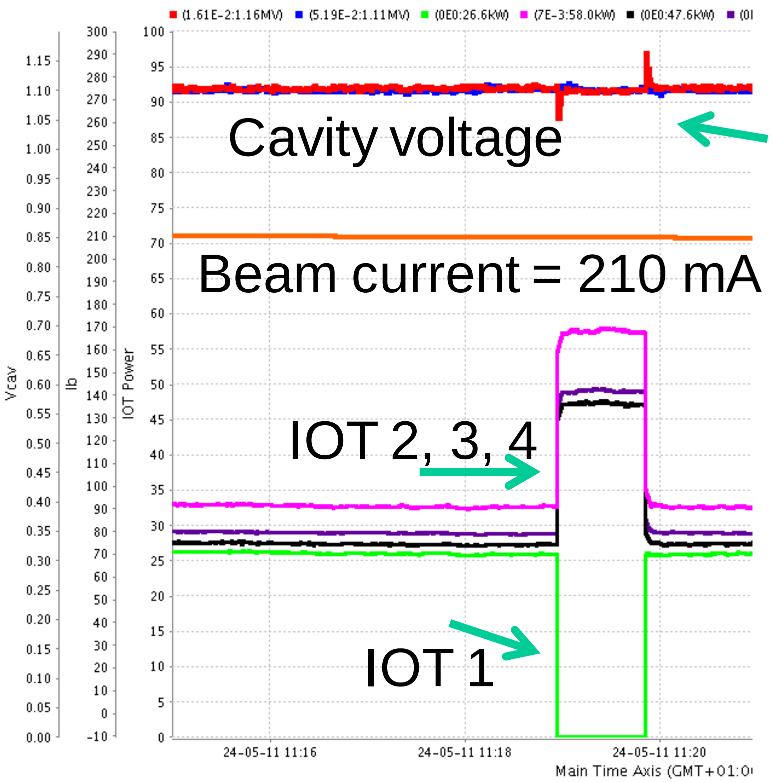
Possible solution

- Detect IOT fault **(μs)**
- Isolate IOT HV **(dissipated energy < 9J)**
- Maintain beam –> **Other IOTs to ramp up**
- Re-instate IOT -> **Other IOTs ramps down**

Fast IOT Fault Detection and Isolation

Successful First Test of Principle

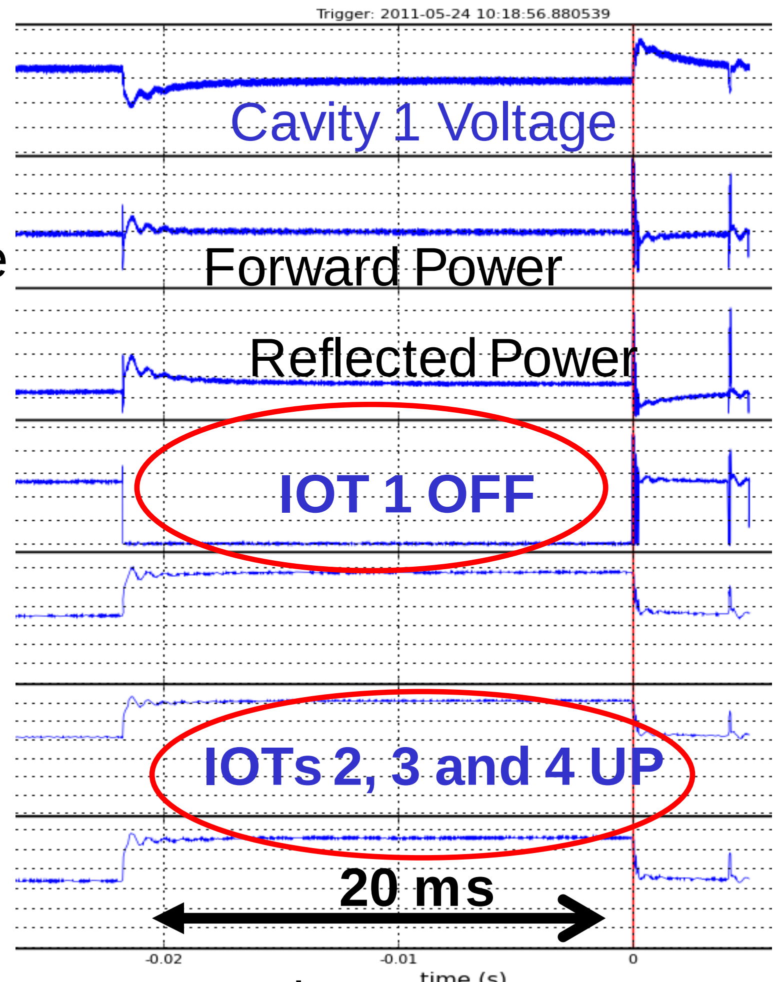
Close up of IOT turn OFF and ON



Small voltage disturbance during switching

IOT power

Note IOT 1 turned off and IOTs 2,3 and 4 compensate



Preparation:

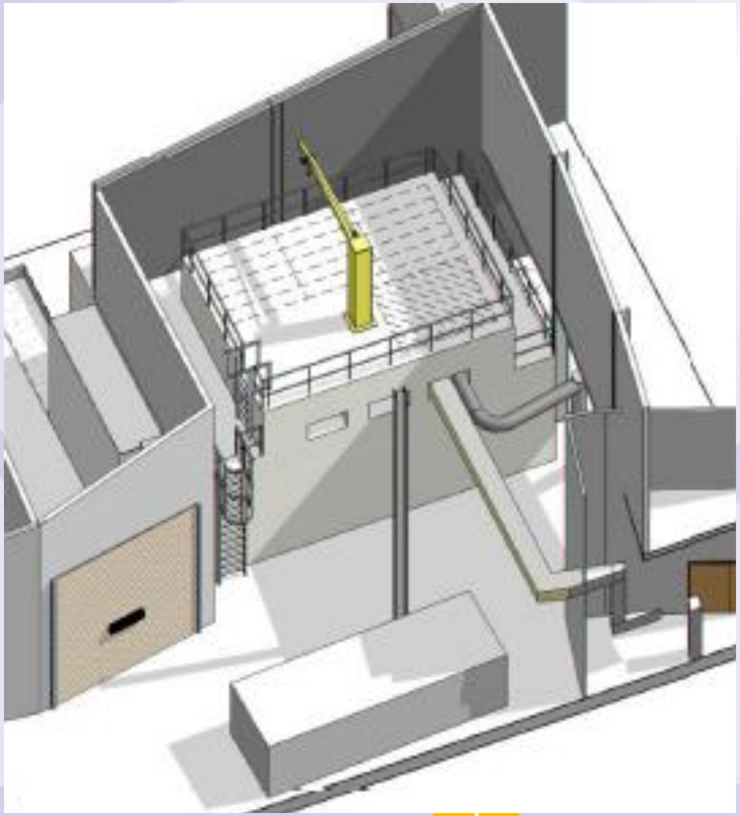
Quench Detector turned OFF

Reflected power trip turned off

Further work needed to maintain beam at high power operation

RF Test Facility

- Shielded high power cavity conditioning area
- Full PSS control
- 300 kW RF power from any of the 3 amplifiers
- Integration into the Liquid Helium Refrigerator
- Full cavity control system



The Reject Loads

- The present load uses a mixture of 40% Glycol and 60% Water – Glycol to be eliminated.
- The new load will use pure water – required for IOTs

Design Goal

- **Co-axial 6-1/8” line size; modification of existing loads**
- **Well matched to the input transmission line**
  S11 < -30dB @499.654 ± 2 MHz
- **Able to handle 80 kW**

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Dielectric Properties of Water & Glycol

	40% Glycol-Water Mixture @25°C	Pure Water @25°C
Dielectric Constant (ε')	56	78
Loss Tangent ($\tan\delta$)	~0.2	~0.024♣

Glycol-Water Mixture

- Impedance matching is easier for short loads
- Very good absorber of RF Power
- ⇒ Fast attenuation leading to compact design

Water

- Impedance matching is relatively difficult
- Not very good absorber of RF power (vs Glycol-Water mixture)
- ⇒ Slow attenuation leading to larger length

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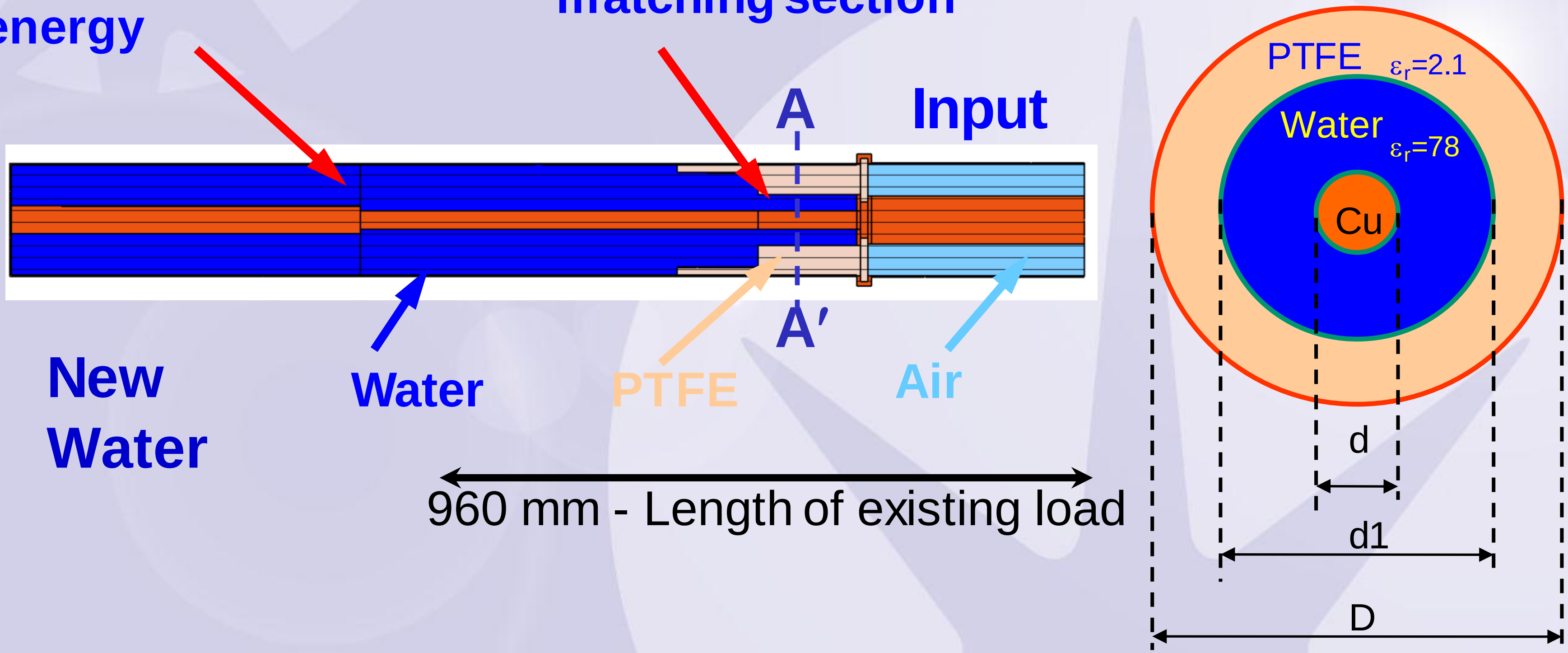
♣ *Technique of Microwave Measurements* edited by C G Montgomery, Rad. Lab. Series Vol. 11

The High Power Co-axial Load

Extra length to absorb remaining energy

Impedance matching section

Enlarged Section at A-A′



New Water

Water

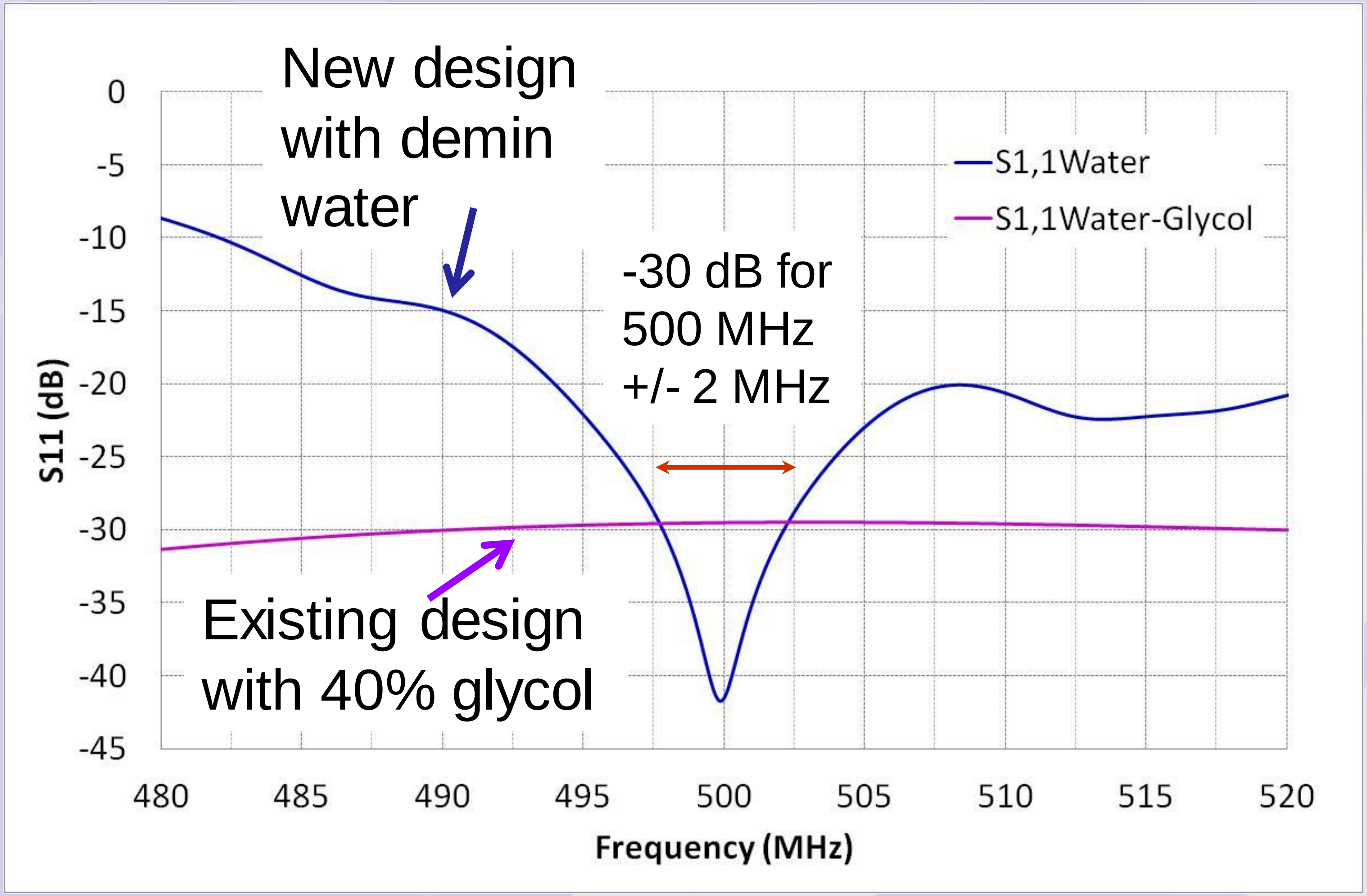
PTFE

Air

960 mm - Length of existing load

Diameters and lengths of the PTFE cylinders are changed in steps for impedance mathcing and to reduce power density

Comparison of match of original load to new design



Improved match at 500 MHz but narrow band

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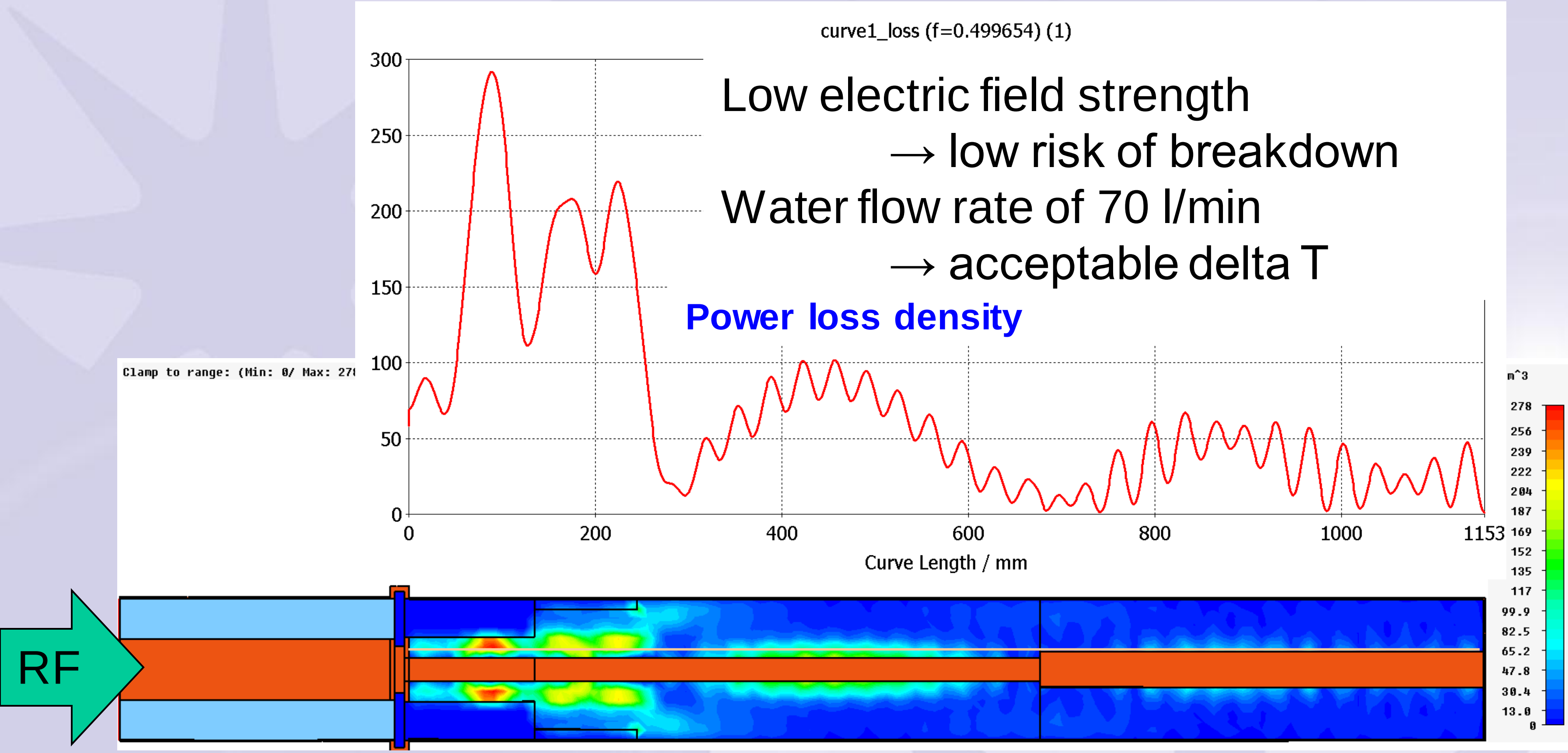
Power loss density along the length

Low electric field strength
→ low risk of breakdown
Water flow rate of 70 l/min
→ acceptable delta T

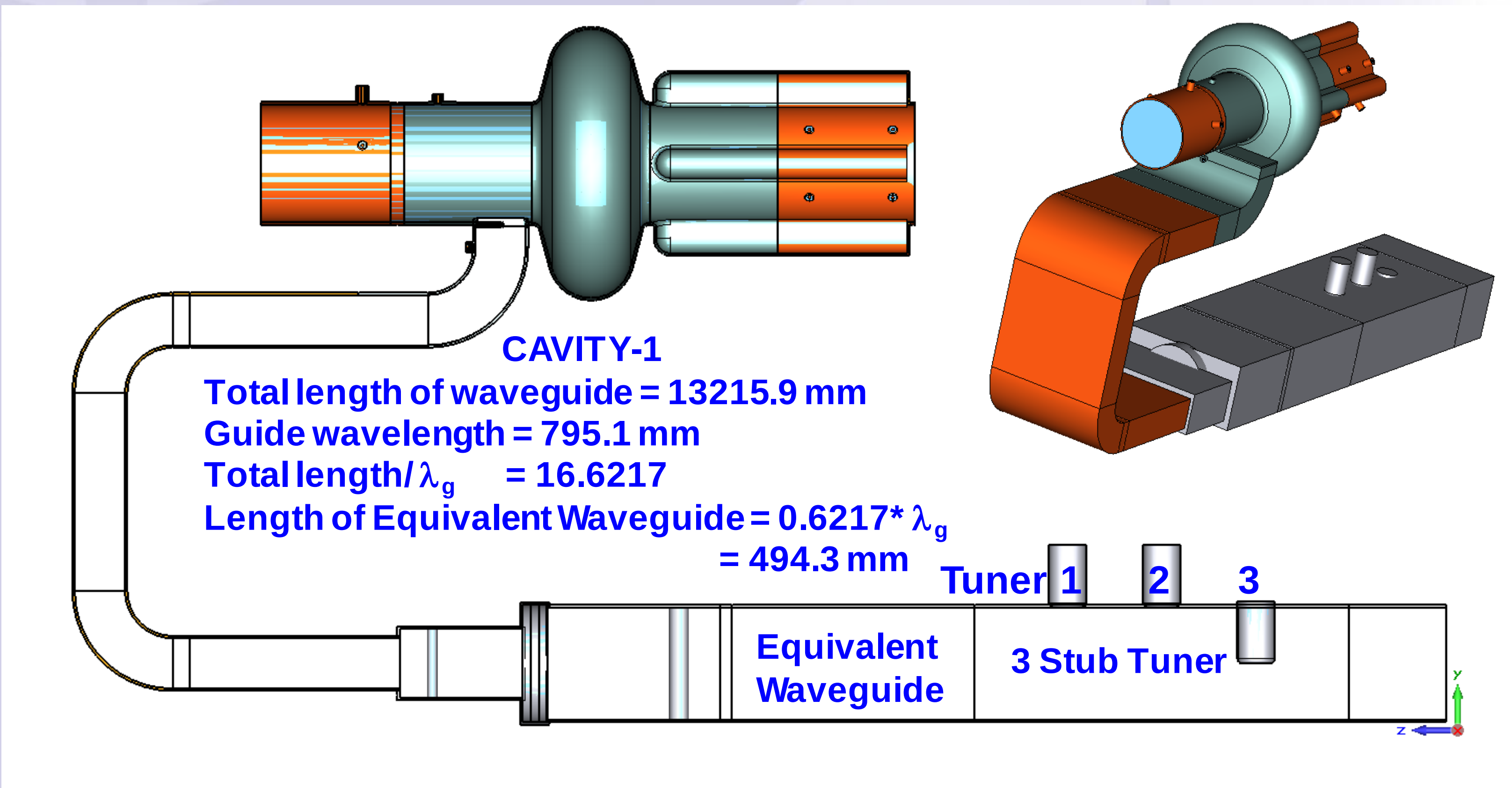


Further work to include:

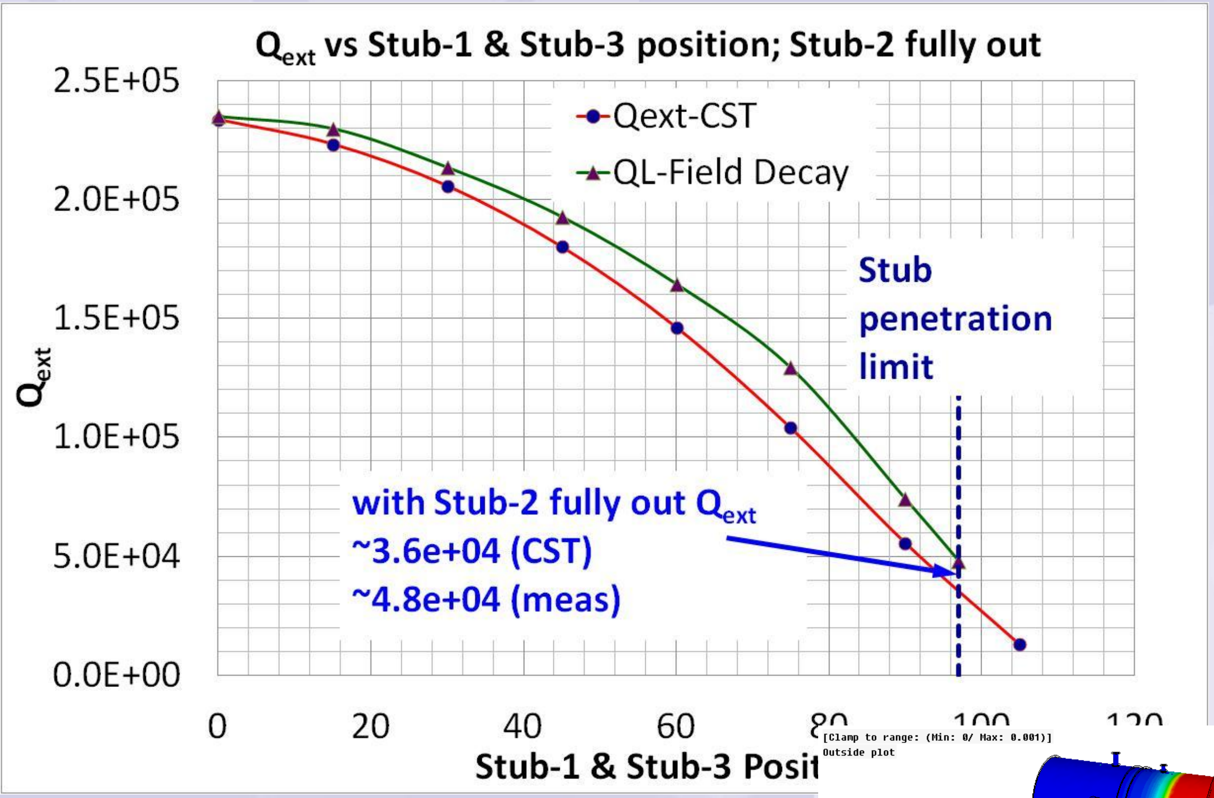
- Tolerance analysis
- Variation in match with water temperature
- Mechanical design
- Build of Prototype

Optimisation of 3-Stub Tuner

- To match the cavities when operated at non-optimum conditions → Higher / Lower Qext
- Experimental optimisation:
  - Takes too long due to long time constants 24-48 hrs
  - Reduced risk due to high electric field regions
  - Minimization of critical thermal loads and mechanical fatique

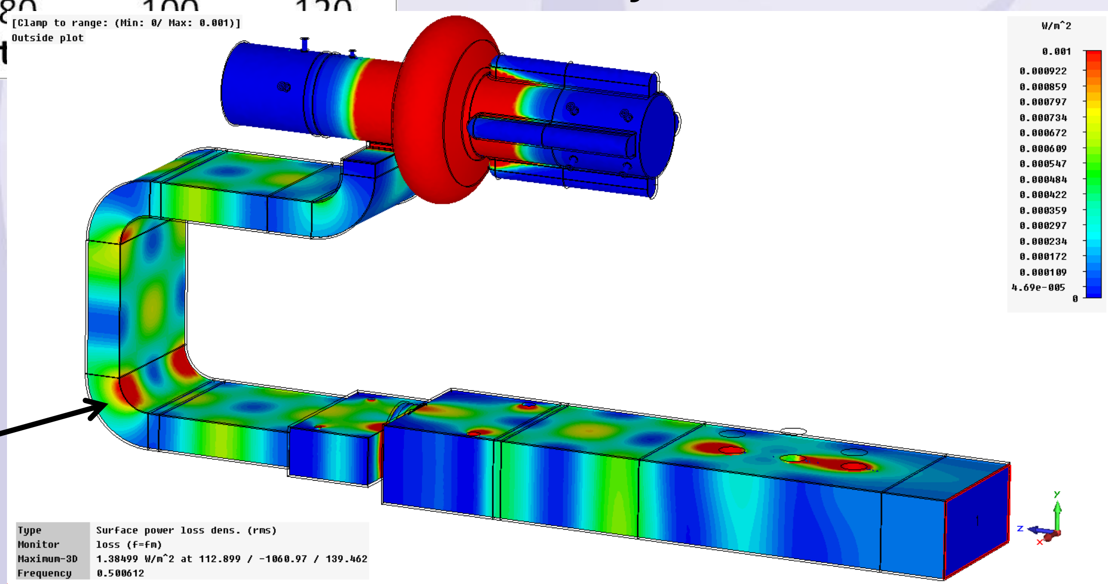


Optimisation of 3-Stub Tuner



Comparison between simulation and measurement

Surface power loss density W/m^2



Hotspots indicate regions with high heat loads

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Thank you for your attention