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Accelerators in a new light

Development of automated RF conditioning on CLARA

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On behalf of conditioning automation team at Daresbury Laboratory

Contents

- The CLARA accelerator
- Motivation for automated conditioning
- Implementation
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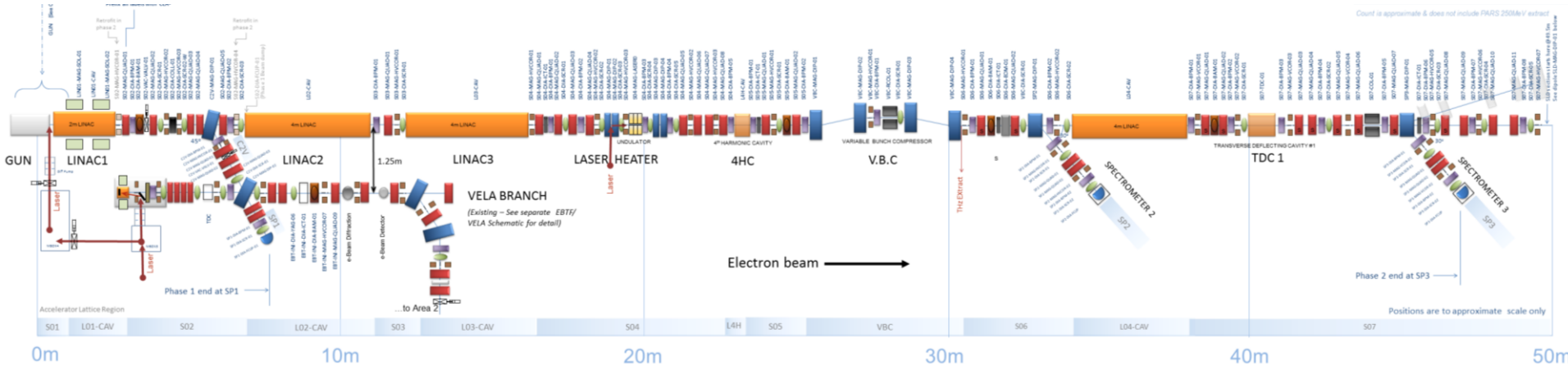
CLARA

- S-band linear acceleration up to 250 MeV
- Bunch charge 20-250 pC
- High repetition rate up to 400 Hz
- Electron bunch lengths 250-850 fs
- FEL wavelengths in the UV



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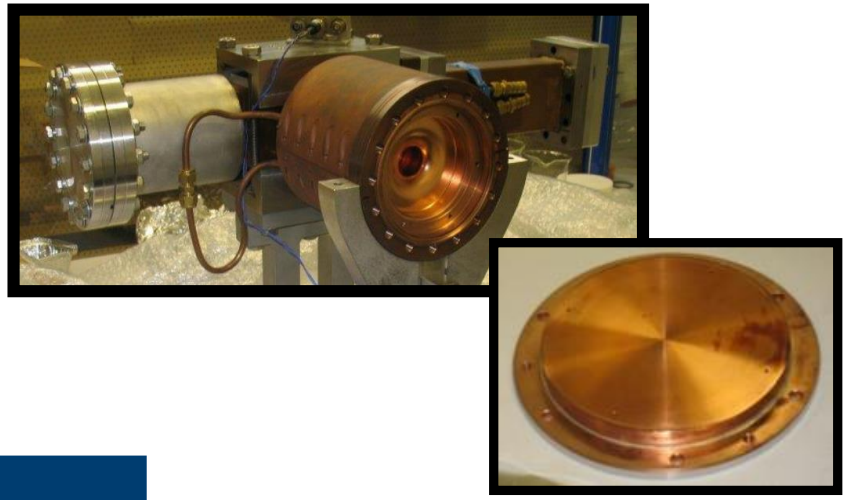
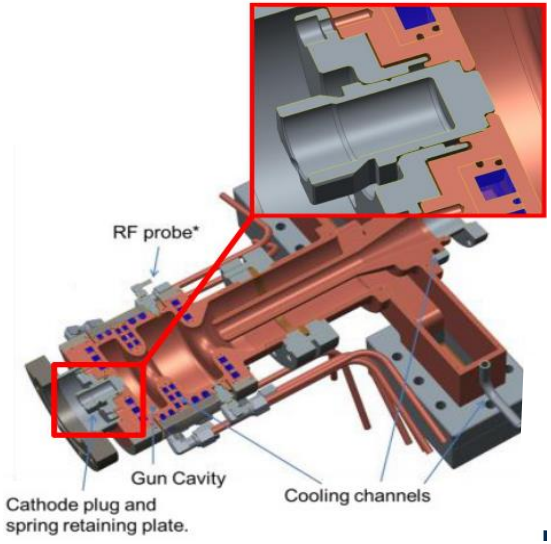
CLARA RF structures

- CLARA has 8 normal conducting RF structures
- A new photoinjector has been designed to replace the old one.
- Both operate with solenoids around the cavity



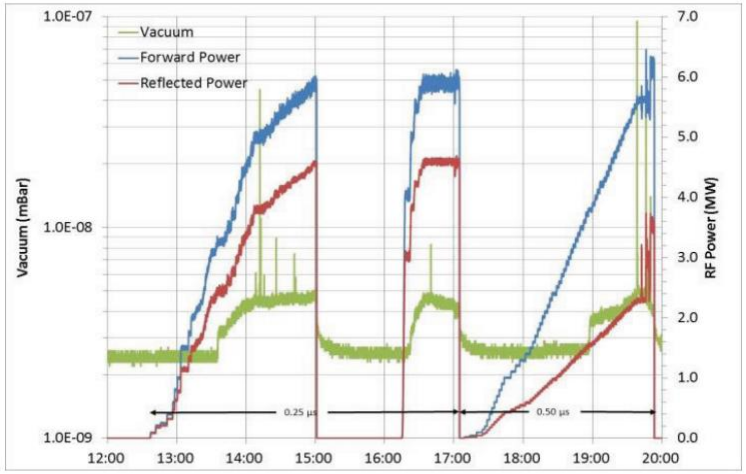
	Old Photoinjector	New Photoinjector
Gradient	~90 MV/m	120 MV/m
Repetition rate	10 Hz	400 Hz
Probe	No	Yes
Load-lock	No	Yes
Coupler	Single feed coaxial	Dual feed coaxial “H coupler”

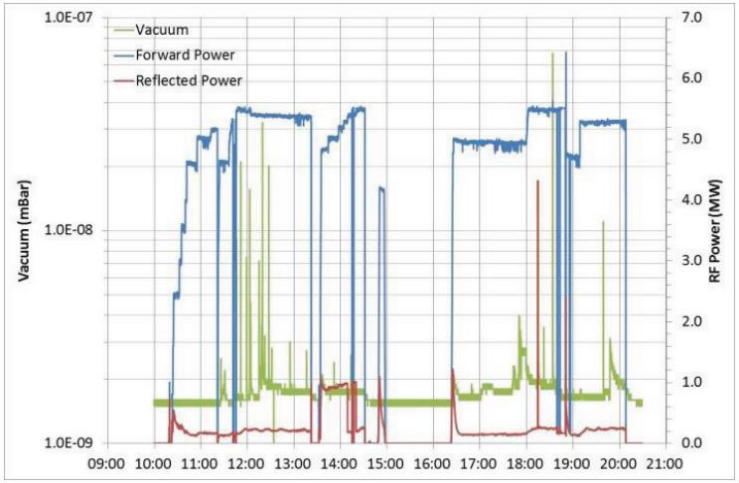


Motivation

- Repeatability and speed of conditioning
- Minimise damage to high gradient structures
- Move towards unmanned operation

2013 conditioning of VELA photoinjector





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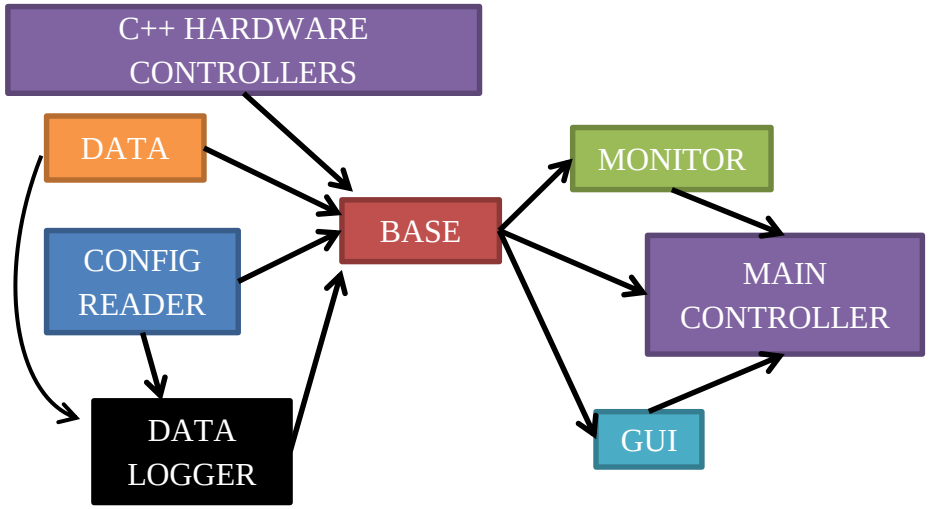
Implementation

- Python script with C++ API with EPICS control system
- Increase power at constant rate
- Switch off power when breakdown detected
- Keep breakdown rate under given value



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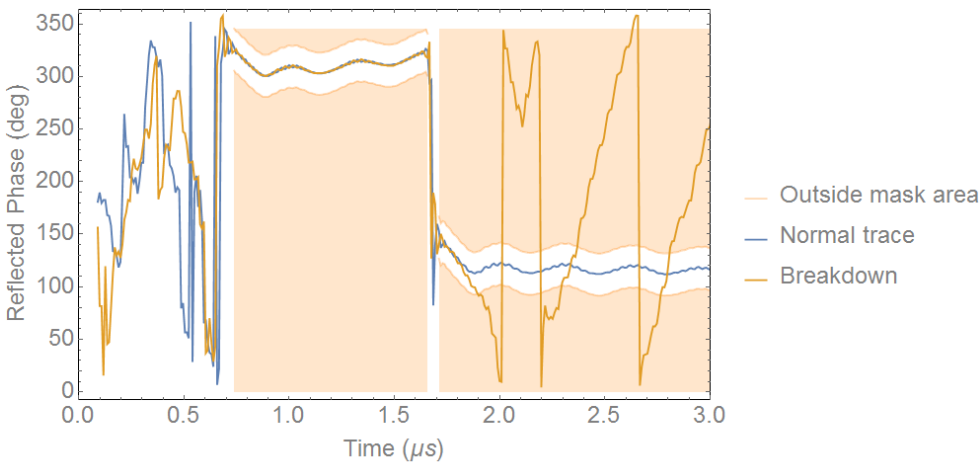
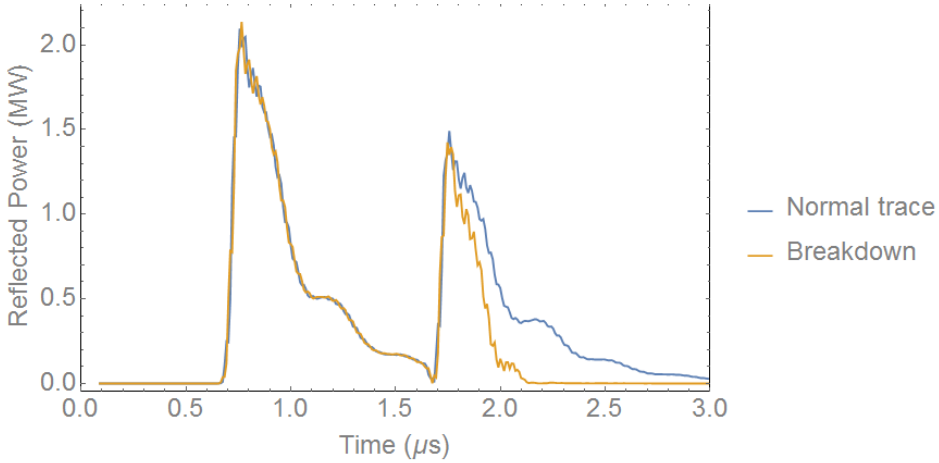
Breakdown detection

- RF traces
  - Phase of reflected signal from cavity
  - Amplitude of reflected signal from cavity
  - Phase of cavity probe signal
  - Amplitude of cavity probe signal
- Dark current
- Pressure spikes in cavity vacuum





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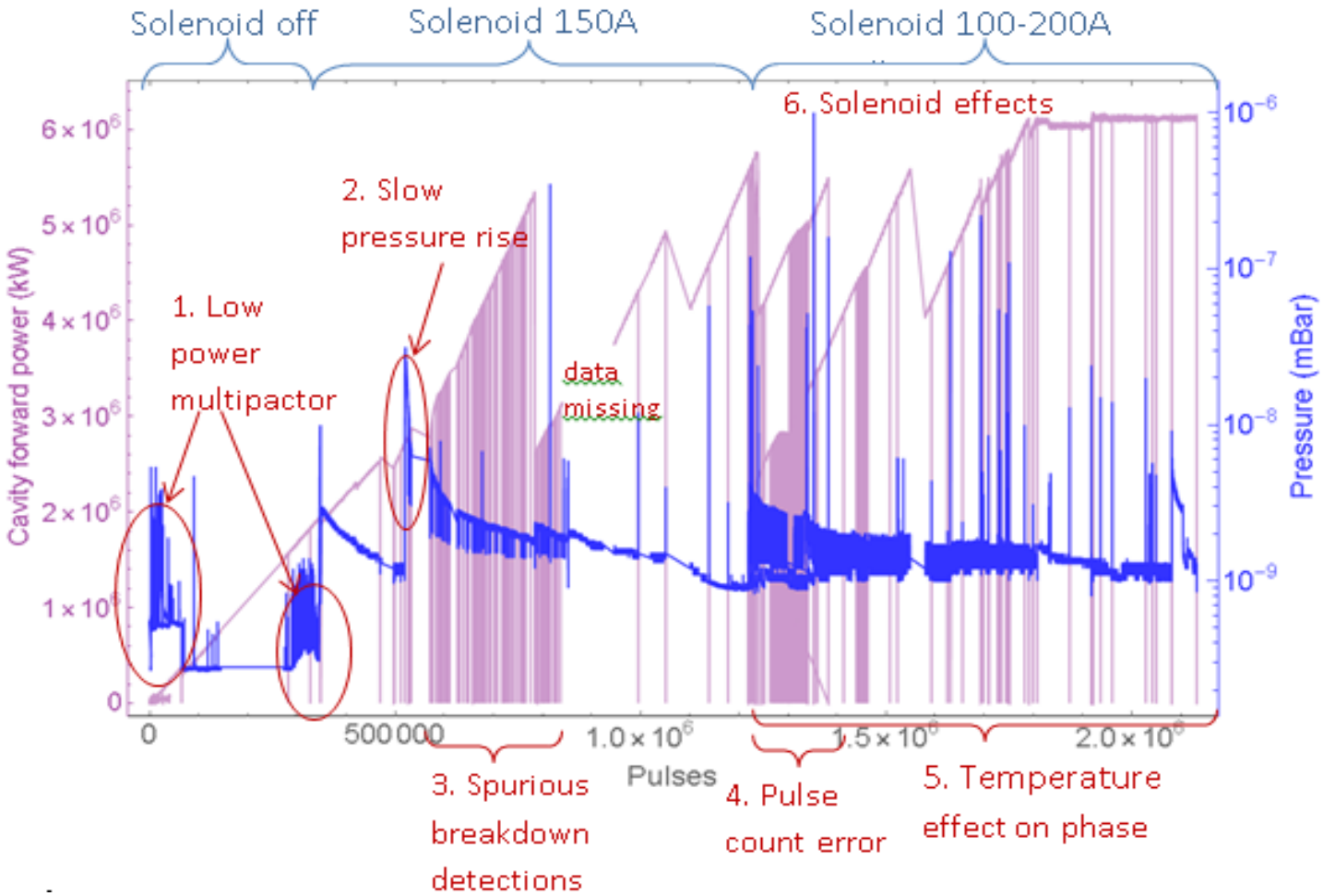
Technical issues..

- LLRF system is I-tech Libera
- Timings of measured RF traces are not repeatable, at 100 Hz is impossible to match a set of traces.
- New software upgrade implementing now, we will have access to raw trace data as single output, perform our own I/Q demodulation.

Beta test: VELA gun conditioning



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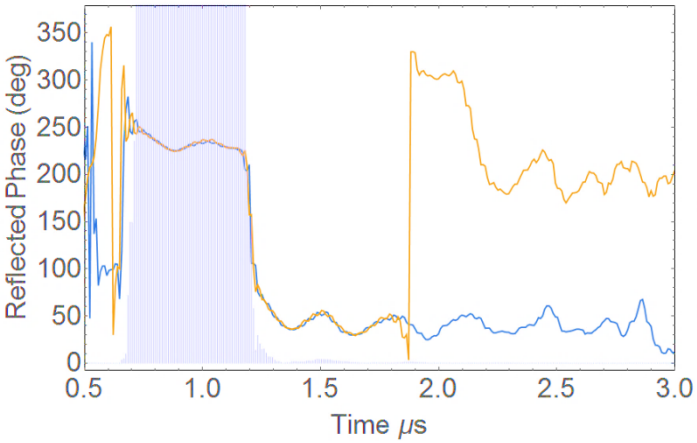
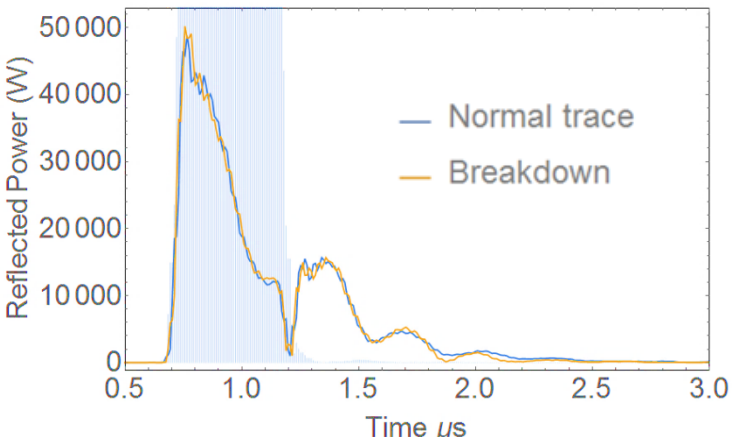
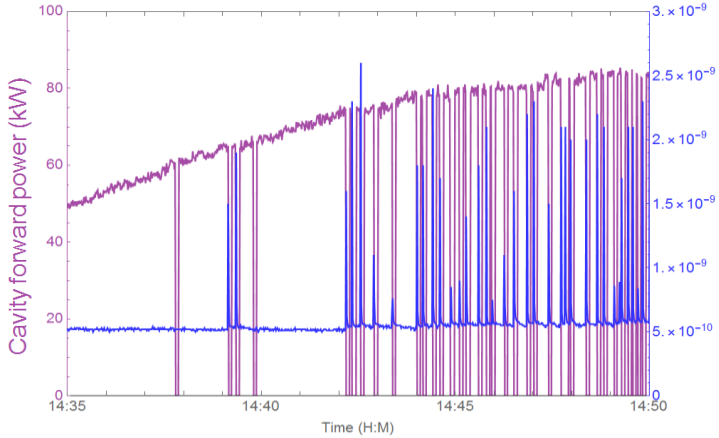
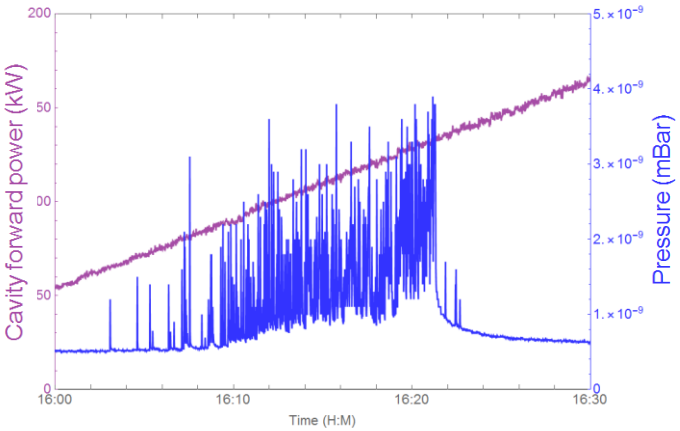
Low power multipactor

Two bands of soft multipactor at 100 kw and 1.7 MW peak forward power









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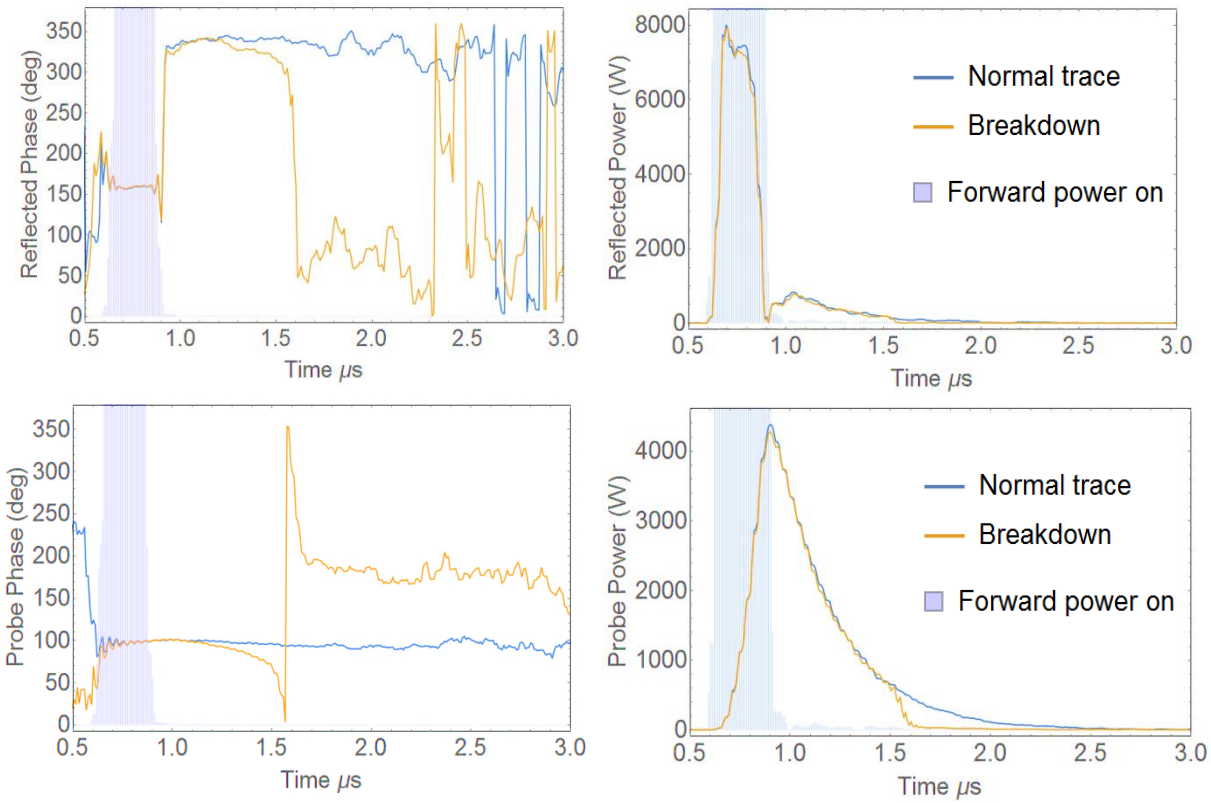
Low power multipactor in new CLARA gun



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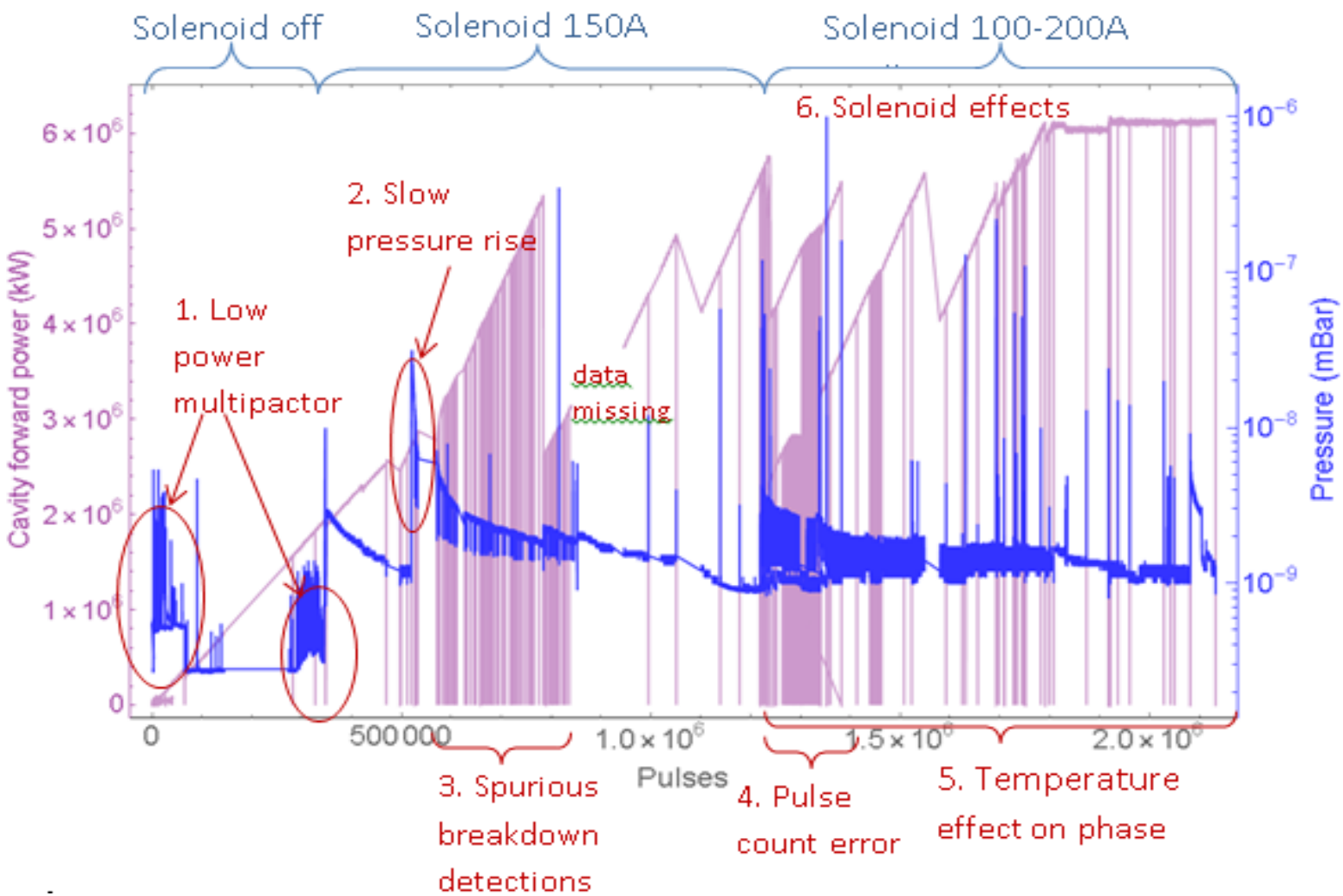

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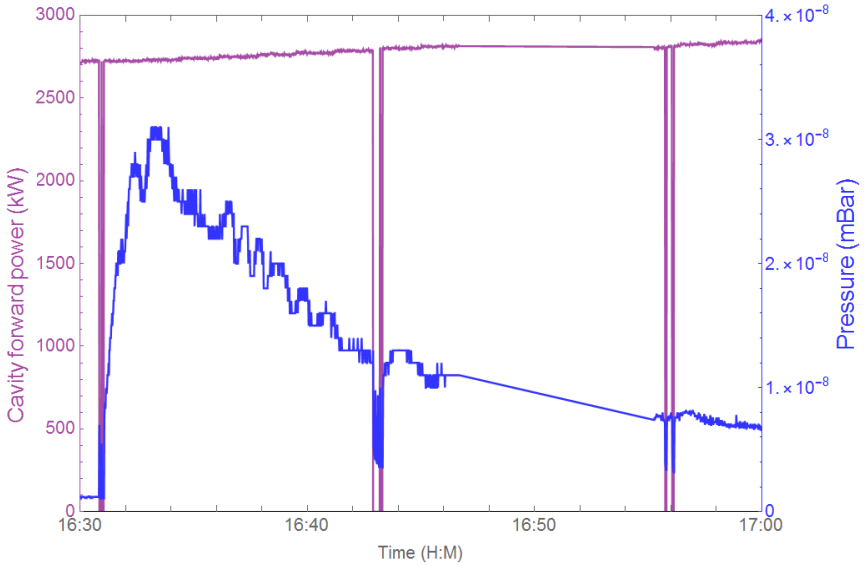
Slow pressure rise



- No change seen in RF traces
- Some kind of localised heating effect?
- Neutral gas outgassing?
- Gauge error?

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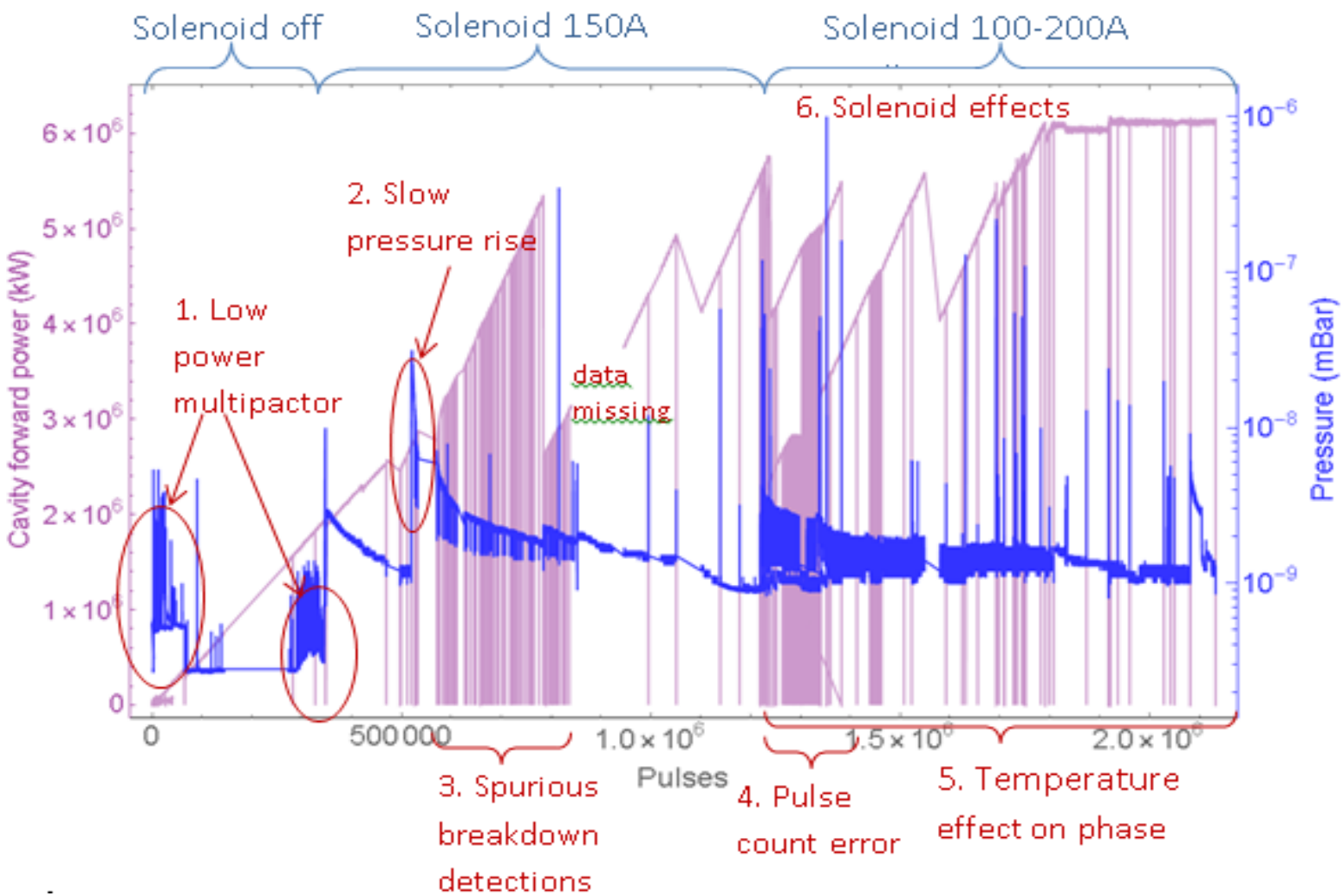

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Spurious breakdown detections

- Forward power drops to zero
- Other traces show noise, which is outside mask.
- Problem with acquisition
- Became more frequent with change in trigger
- Fix involves checking forward signal before others but need to be sure they are the same pulse

Pulse count errors

- Some overlaps in pulse numbering
- Mechanism for changing pulse length needs work

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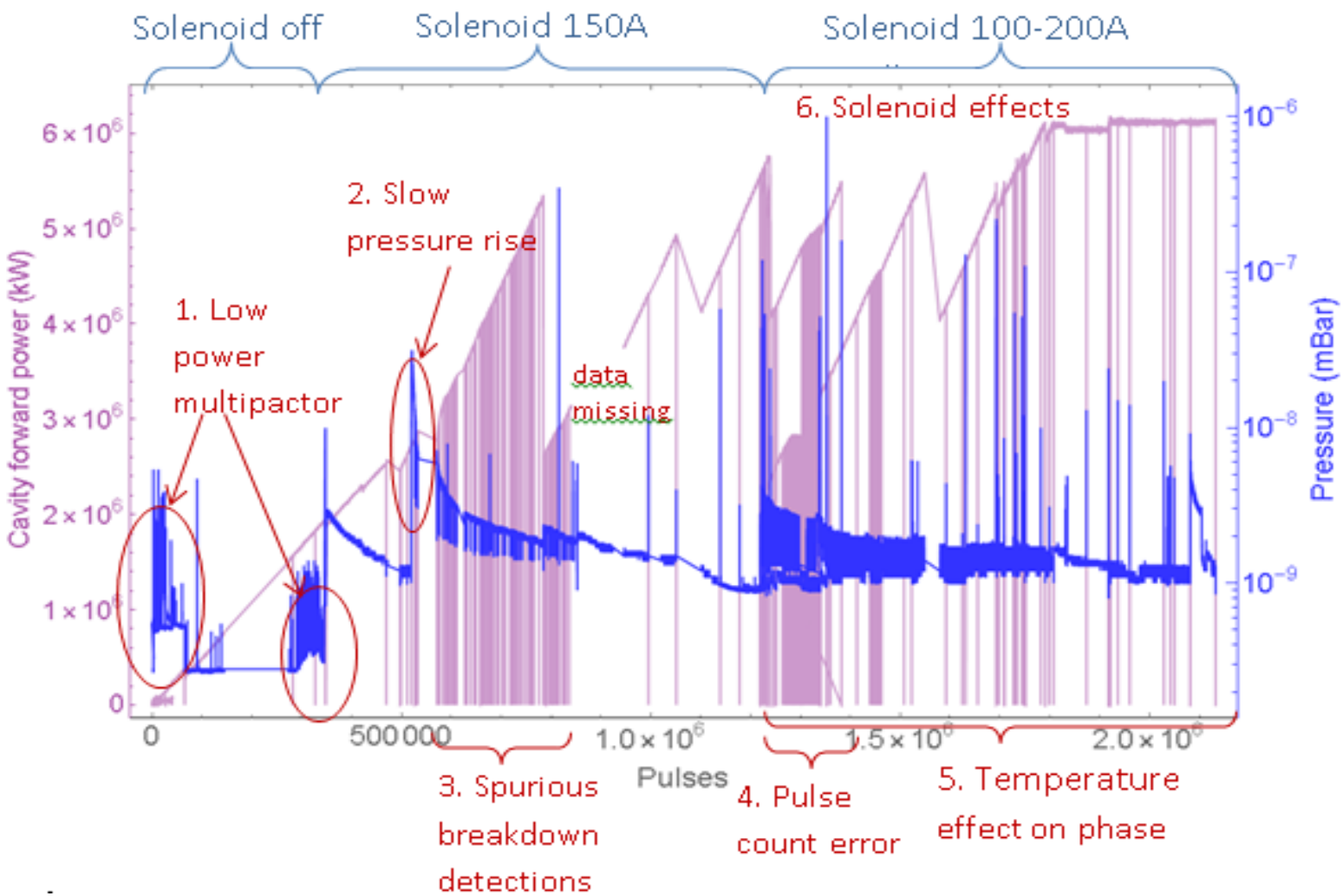

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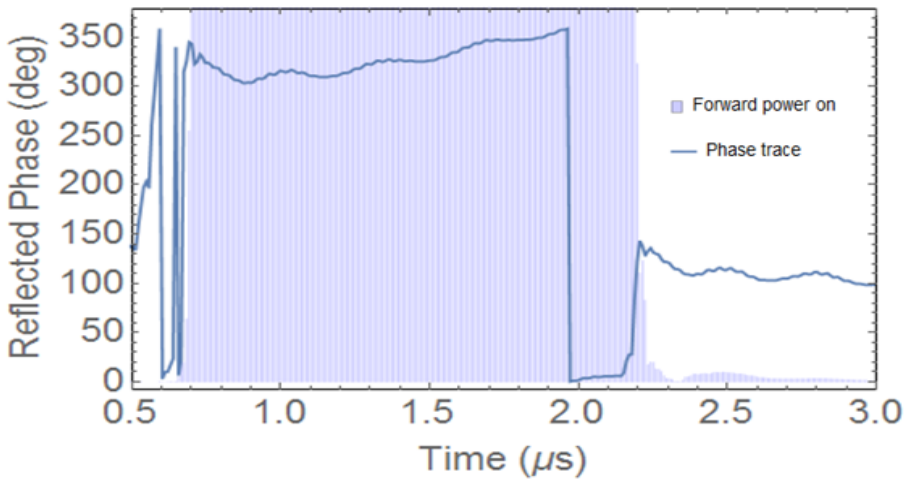
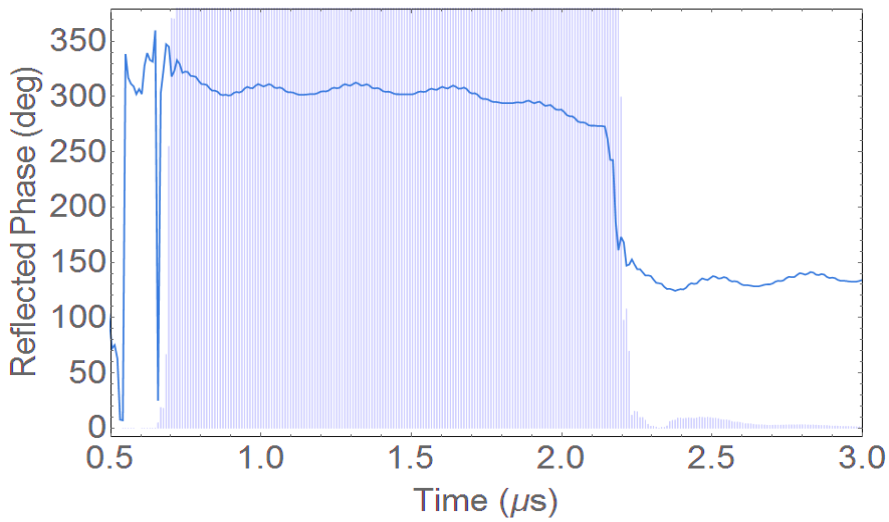
Temperature effect on phase





- At pulse lengths above 2 μs reflected phase varies towards end of the pulse
- This correlates with cavity temperature
- Vicious circle: phase change detected as a breakdown → RF off → no load on water cooling system → less cooling when RF comes back on

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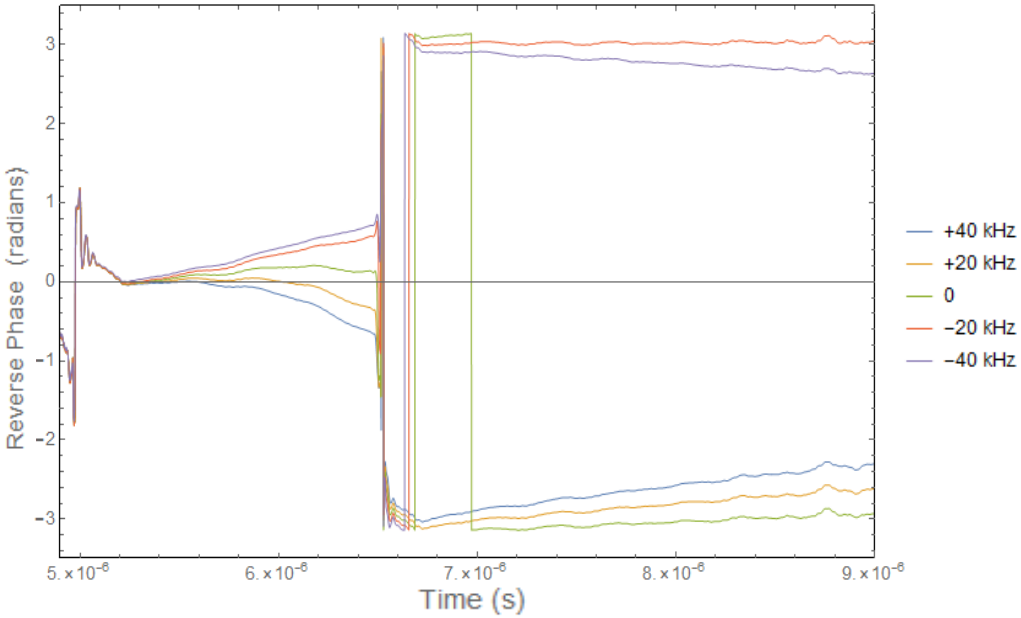
Temperature effect on phase (2)

- Simulated by cavity S11 convolution with forward power pulse in frequency domain
- S11 frequency varied with respect to forward power pulse
- We know 1 ° C temperature change gives ~50 kHz frequency change



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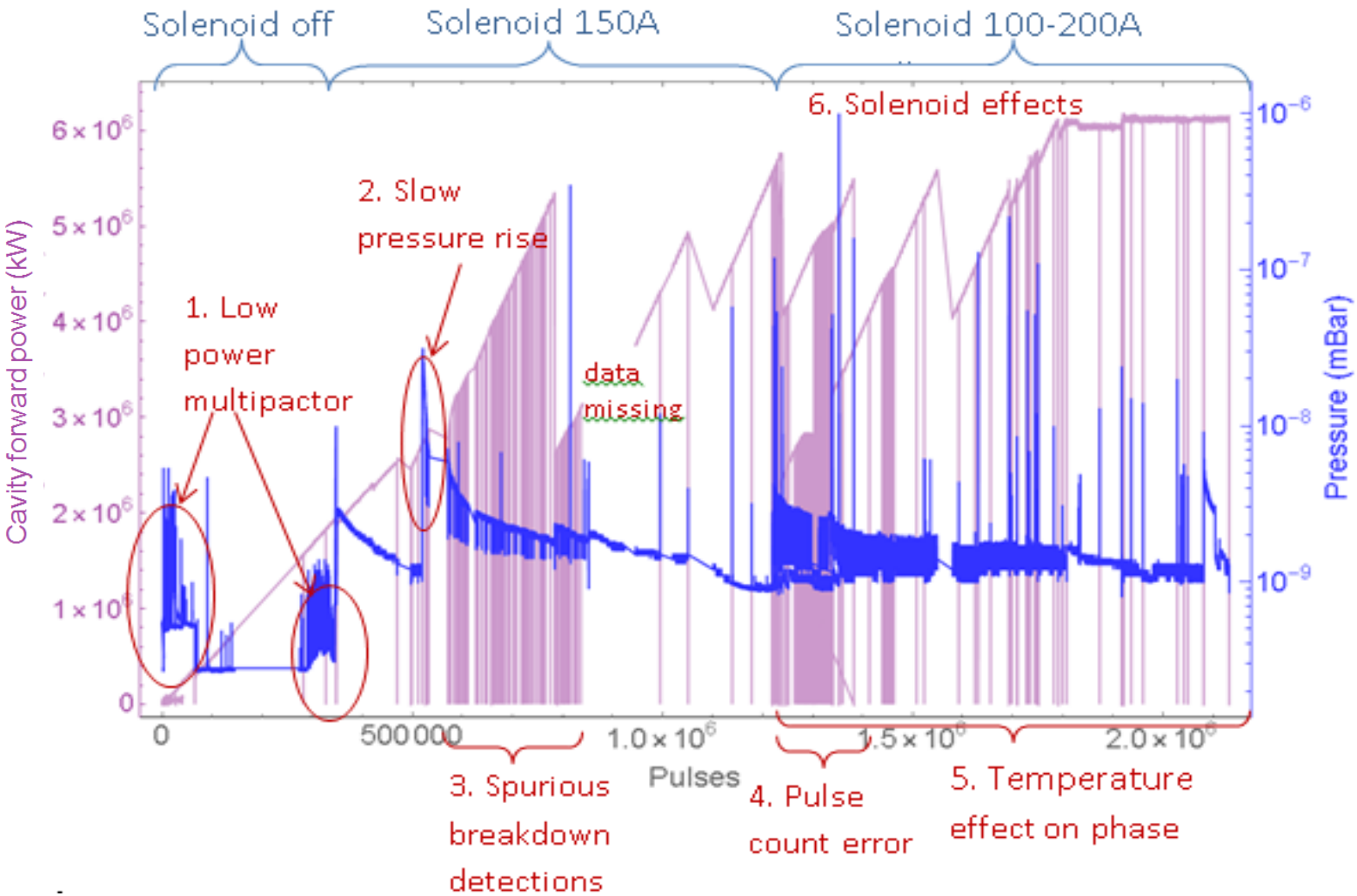

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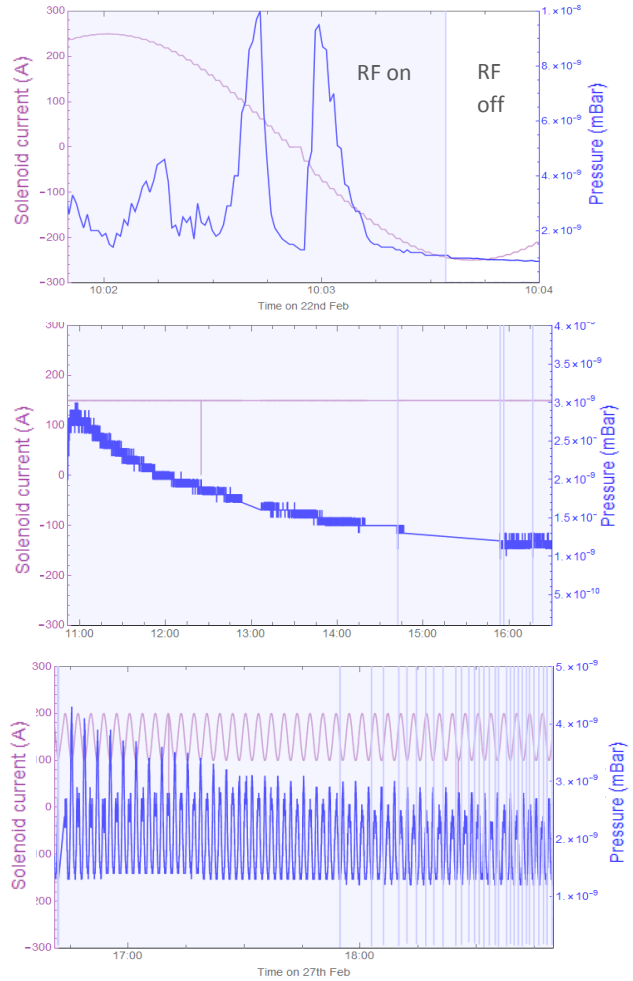
Solenoid effects

- Oscillation from -250 A to + 250 A caused vacuum spikes up to 1 x 10^{-8} mBar.
- Solenoid switch on to 150 A caused pressure increase to 2.7 x 10^{-9} mBar. Which recovered slowly.
- Solenoid oscillation from 100 to 200 A caused decaying oscillation of the pressure.



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Further work

- Implement Libera software upgrade
- Finish digitisation of dark current measurements
- Switch off water cooling PID when RF is off
- Automate pulse length changes
- Study breakdown behaviour with and without solenoid
- Condition CLARA photoinjector!

Acknowledgements

Thank you to my colleagues on this project, particularly Duncan Scott for the work he has put into the programming.

Thanks to the team at the XBOXs for sharing their knowledge and answering my questions on their conditioning process.

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