S1.1 & S1.2 Performance

Target Workshop, 7/1/13

Edward Overton

Summary

1. Reminder – Performance Analysis

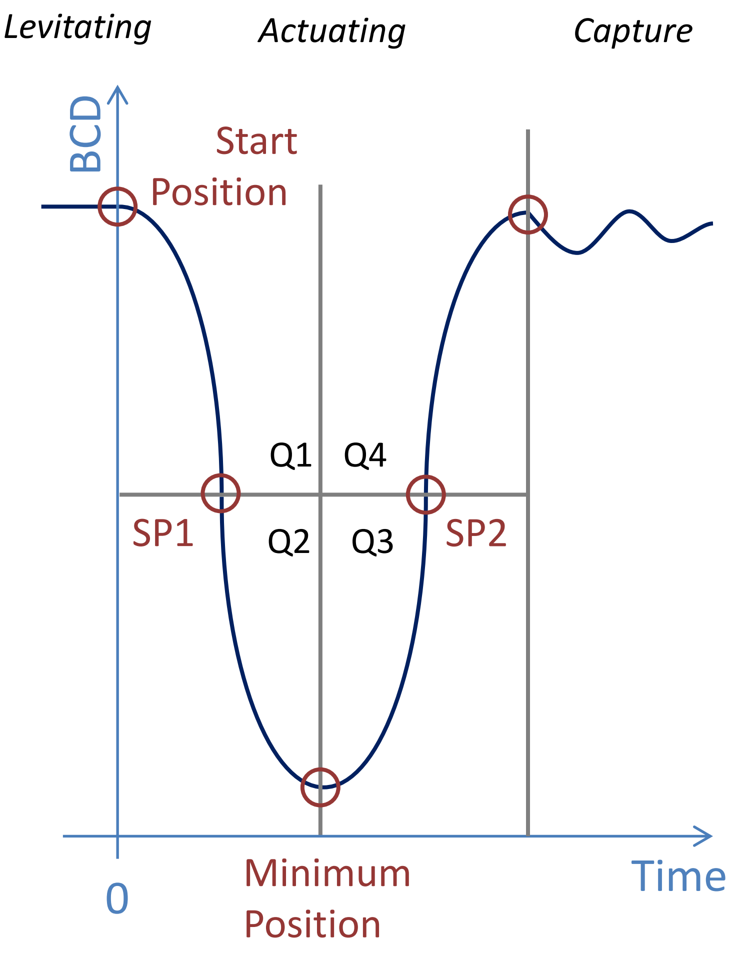
2. Performance
   1. S1
   2. S1.1
   3. S1.2

3. History of R78 Targets (> T2.5)

4. Possible Further Analysis

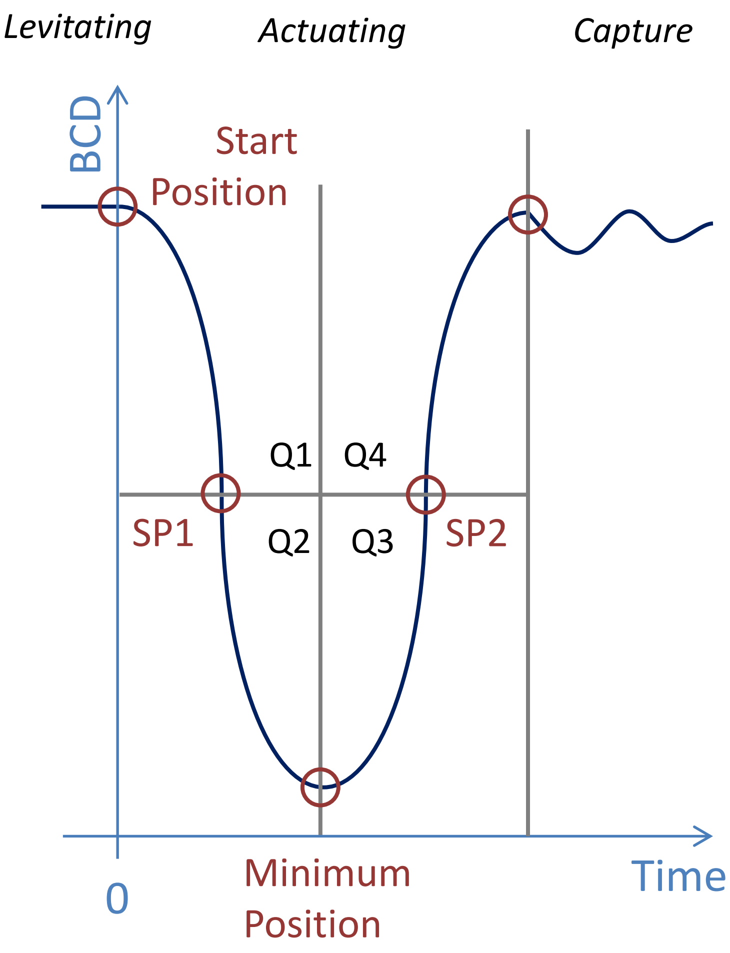
5. Additional Slides:
   1. Acceleration / Starting Position plots for T2.6 – S1.2.

Reminder: Performance Monitoring



- Acceleration (to SP1):
  - Calculated from the time the controller begins powering on the coils.
  - Calculated to the SP1, the first point the controller switches acceleration.
- Starting Position:
  - Determined by the point in capture the target stopped at in the previous actuation.
  - The stop condition is when the bearing friction (F_s) exceeds the restoring force from the magnetic potential (V):
    - $F_s > | - dV/dx |$
    - $F_s > 2Bx$ (if ~parabolic, $V = Bx^2$) – Note x is distance from centre of well, not the BCD, B is proportional to the field strength.
  - On a single actuation the position will be somewhere between $\pm F_s/2B$.
  - Over many actuations the width of the distribution of different starting positions will be: F_s/B.
    - A larger width indicates a larger friction.
    - Increasing the coil current increases B and will reduce the width.

Reminder: SP2, Corrections and 'Gaps'

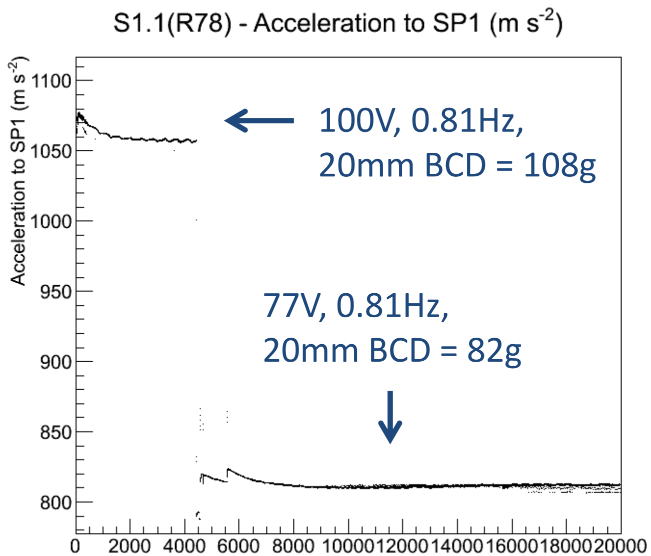


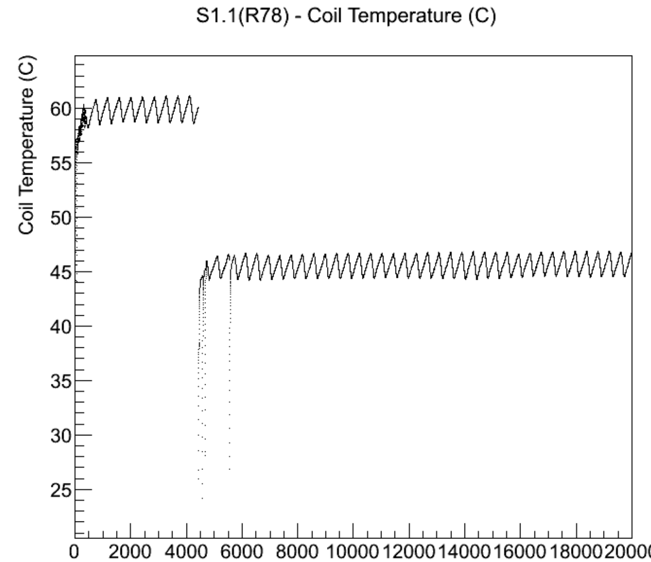
- Capture Corrections:
  - If the target is caught in outside the operational range (64.5 +- 0.75mm) then the controller will move target to the correct location. This normally takes +1s so there is a time 'Gap' in the data.
  - In High friction cases, the Gaps can exceed 10s, I verified this by watching the GUI during actuation.
- SP2 Corrections:
  - SP2: Switch point 2, the second point where the controller reverses the force.
  - If a capture correction occurs regularly the controller will automatically adjust SP2 one step towards the optimal location.
  - Seeing a lot of capture corrections indicates that the controller is struggling to find an optimum location. eg: due to a wide start position.
- Neither of these has any use in ISIS as the target operation tends to be stop/start at different depths!

S1 Thermal Performance

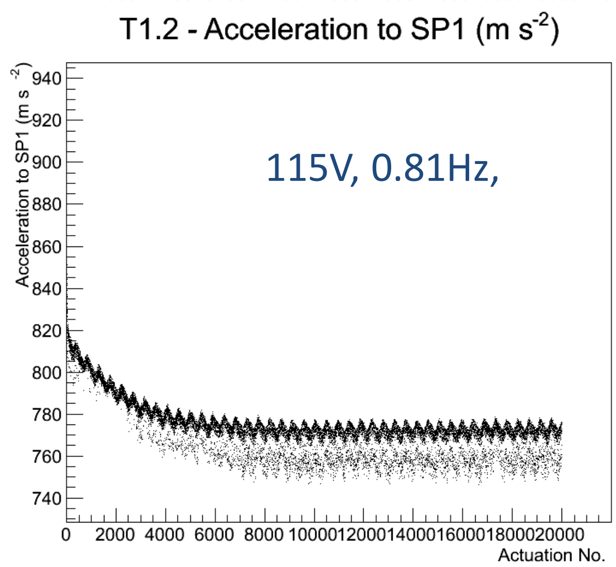
- The improved winding / cooling of S1 enables S1.1 to run at lower voltages and coil currents:

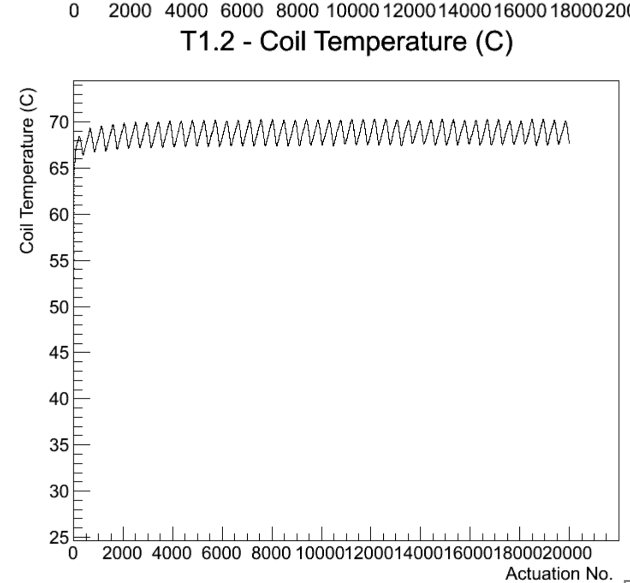
S1.1 →





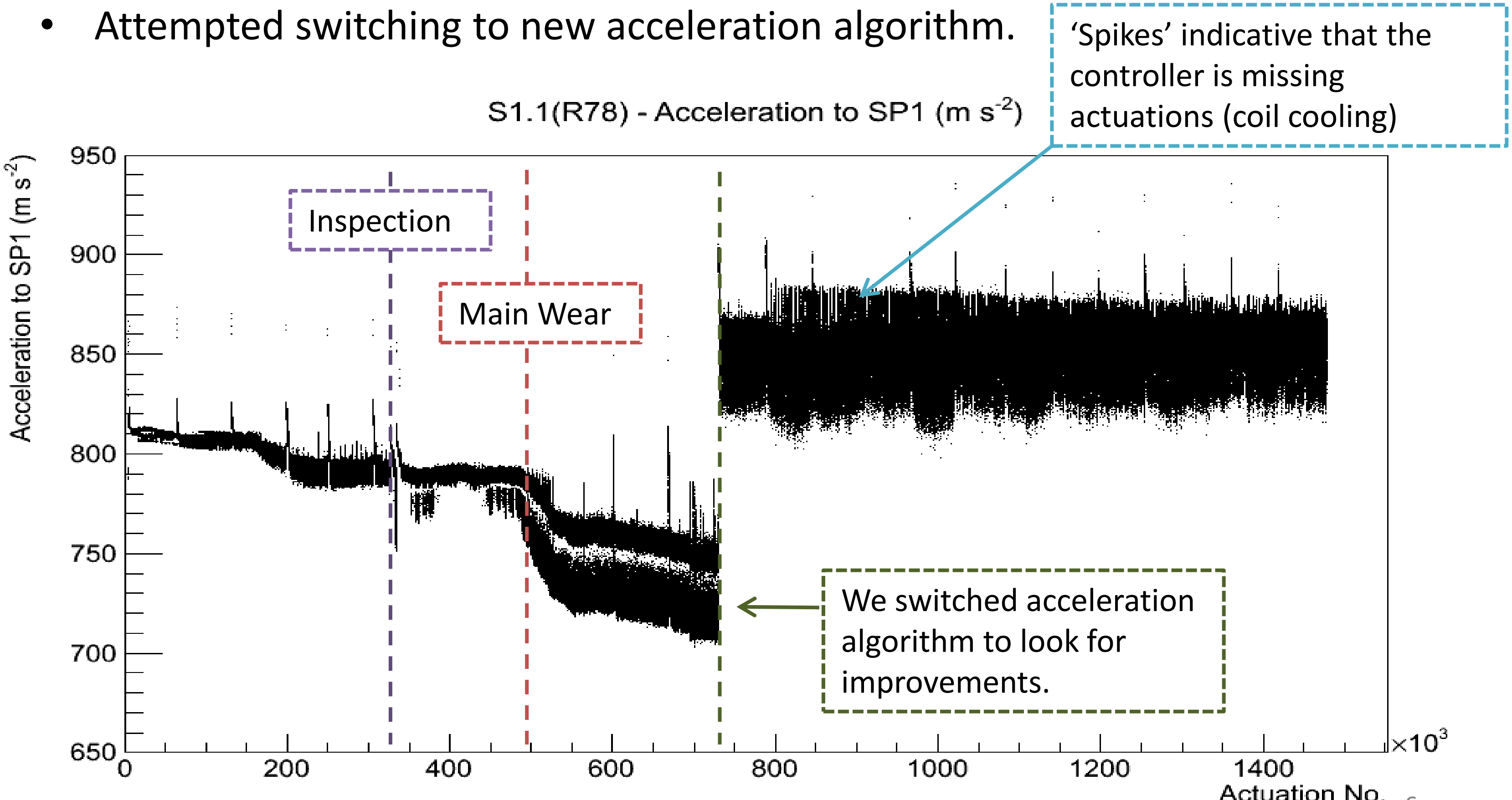
T1.2 →



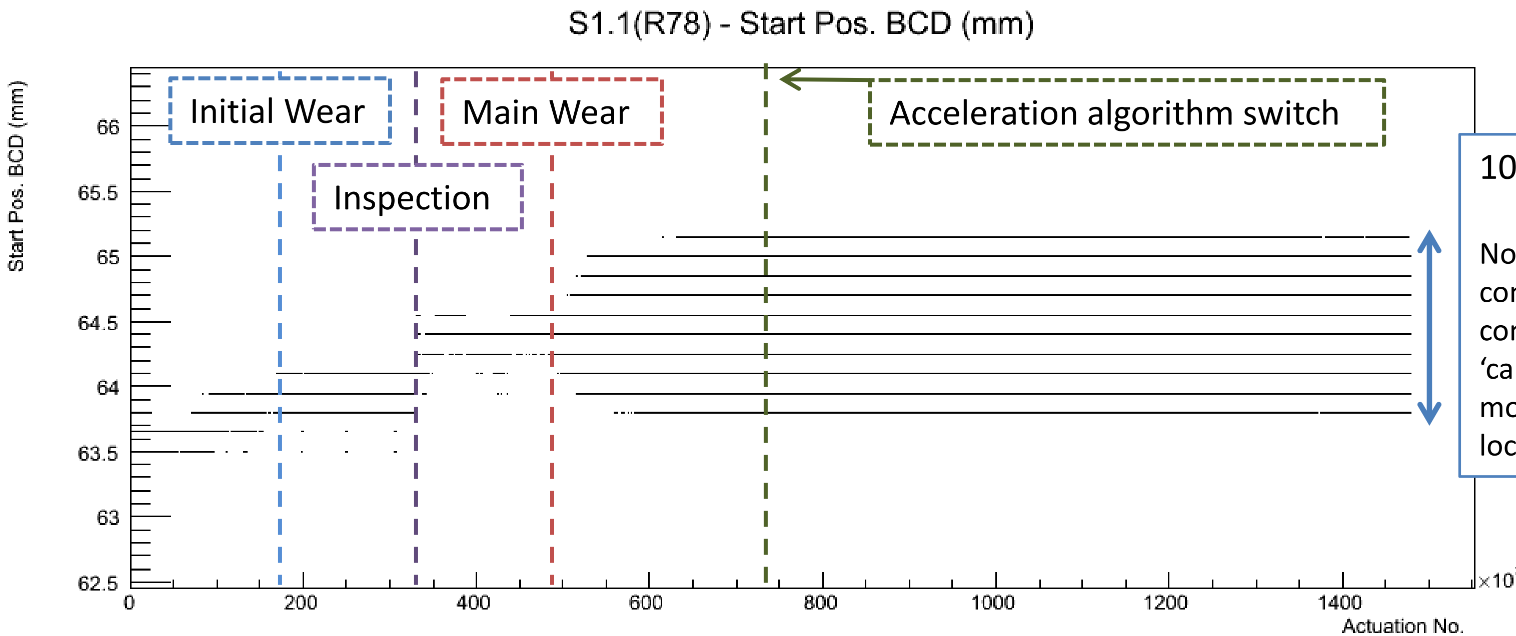


S1.1 Test Performance

- Begun testing on 25/9/12,
- Around 300K there were lots of capture corrections, reduced rate to 0.24Hz.
  - Modification of index calibration helped reduce the problems.
  - Target was dropped just before Inspection (measured 7ms^{-2} of deceleration)
  - Partial Inspection, checked vane for damage / dust.
- By 800K the acceleration had dropped substantially.
  - Decided there was little to gain from running.
  - Attempted switching to new acceleration algorithm.

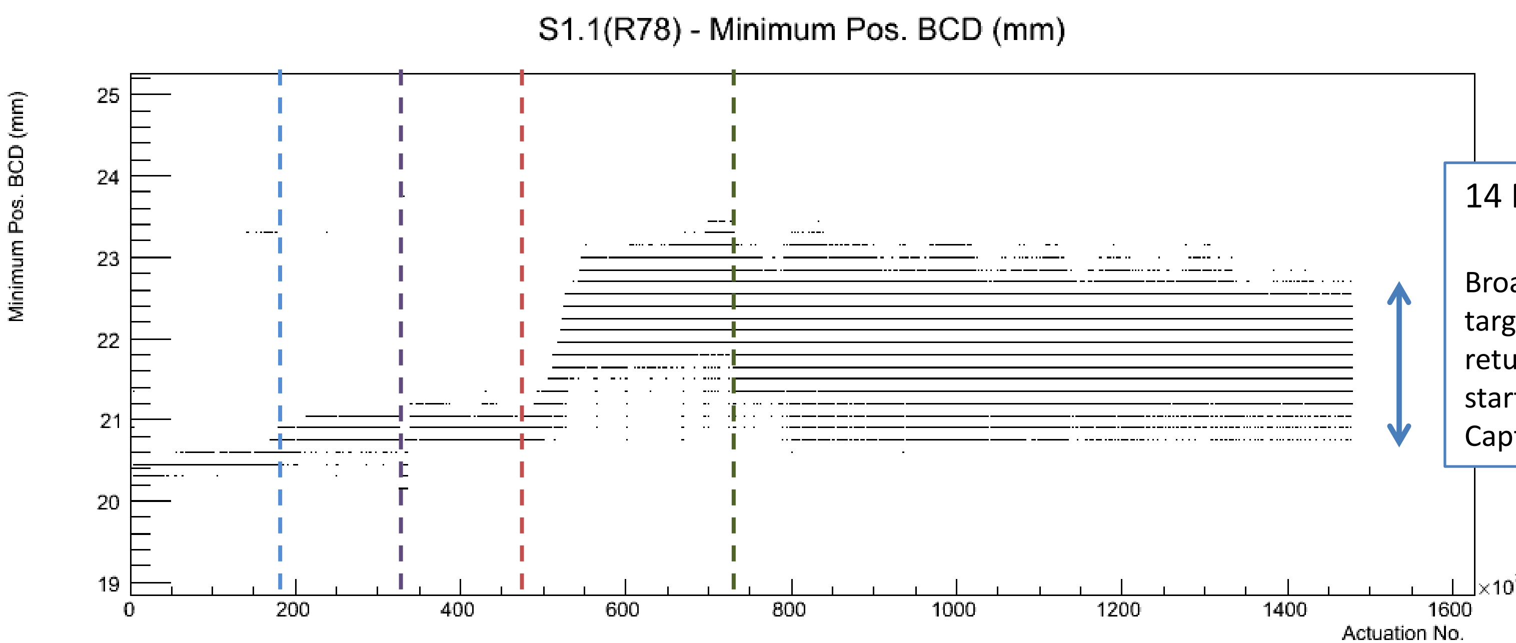


S1.1 Test Performance



10 Positions = 1.5mm

Note: Limited to 1.5mm by control. If outside controller initiates a 'capture correction' to move to correct starting location.

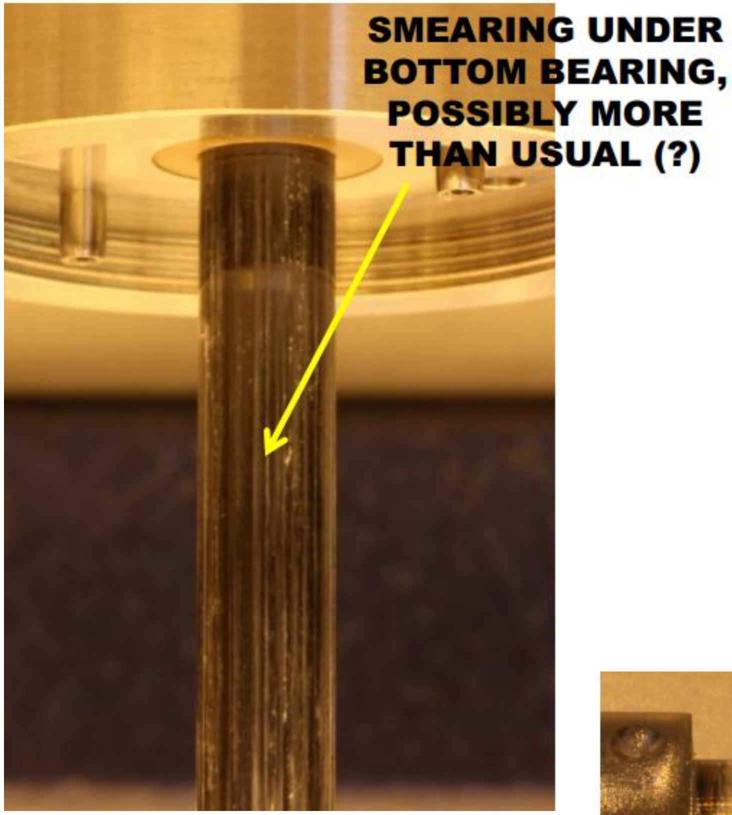


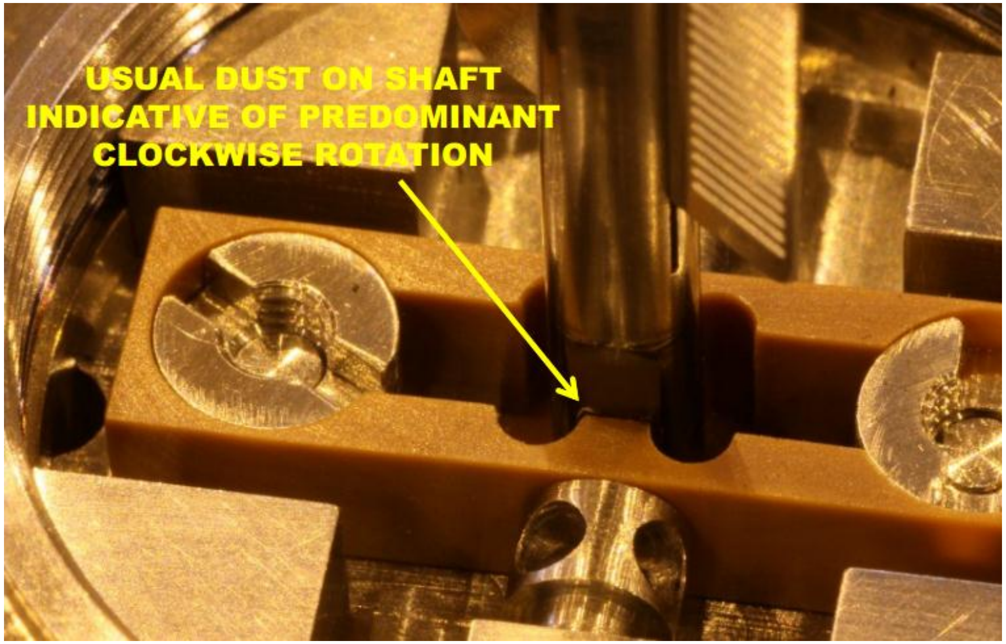
14 Positions = 2.1mm

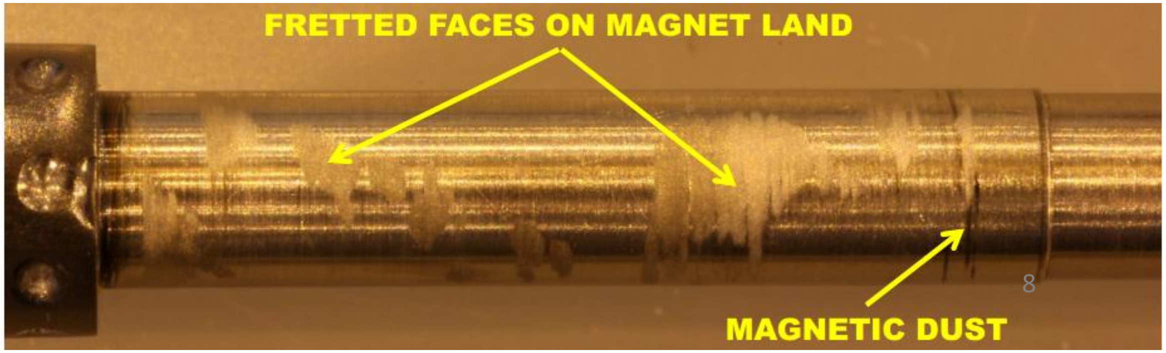
Broader than 1.5mm, target is less likely to return to acceptable starting location => Capture correction.

S1.1 Inspection

- The anti-rotation baring normal dust build-up indicative of clockwise rotation
- Quite a lot of smearing under bottom bearing (possibly more than usual?)
- Vacuum Bore was unusually dirty (dark dust)
- Signs of fretting caused by loose magnets and vane, possible caused the dark dust. Not a problem in ISIS, Magnets are glued to shaft.







S1.1r2 & Calibration Modifications

- S1.1r2 was a re-run of the S1.1, using the same bearings and shaft.

- Before starting the controller was robustified against the issues seen in S1.1:

  - Increased Capture / Hold Current 50%, using the large amount of thermal headroom available. Will reduce the width of the Starting Position. Also makes capture corrections more forceful (less chance of a stick).

  - Adjusted the index calibration to move the position recognised by the controller to the centre of the magnetic potential. Will reduce the likelihood of the target being caught outside the allowed start region reducing the number of capture corrections.
    Note: we are not accelerating at maximum force, the coil switch points are not in the optimum location (by only 1% or so).

- The S1.1r2 performance degraded quickly and the test was terminated after 80k actuations.

S1.2 Test Performance

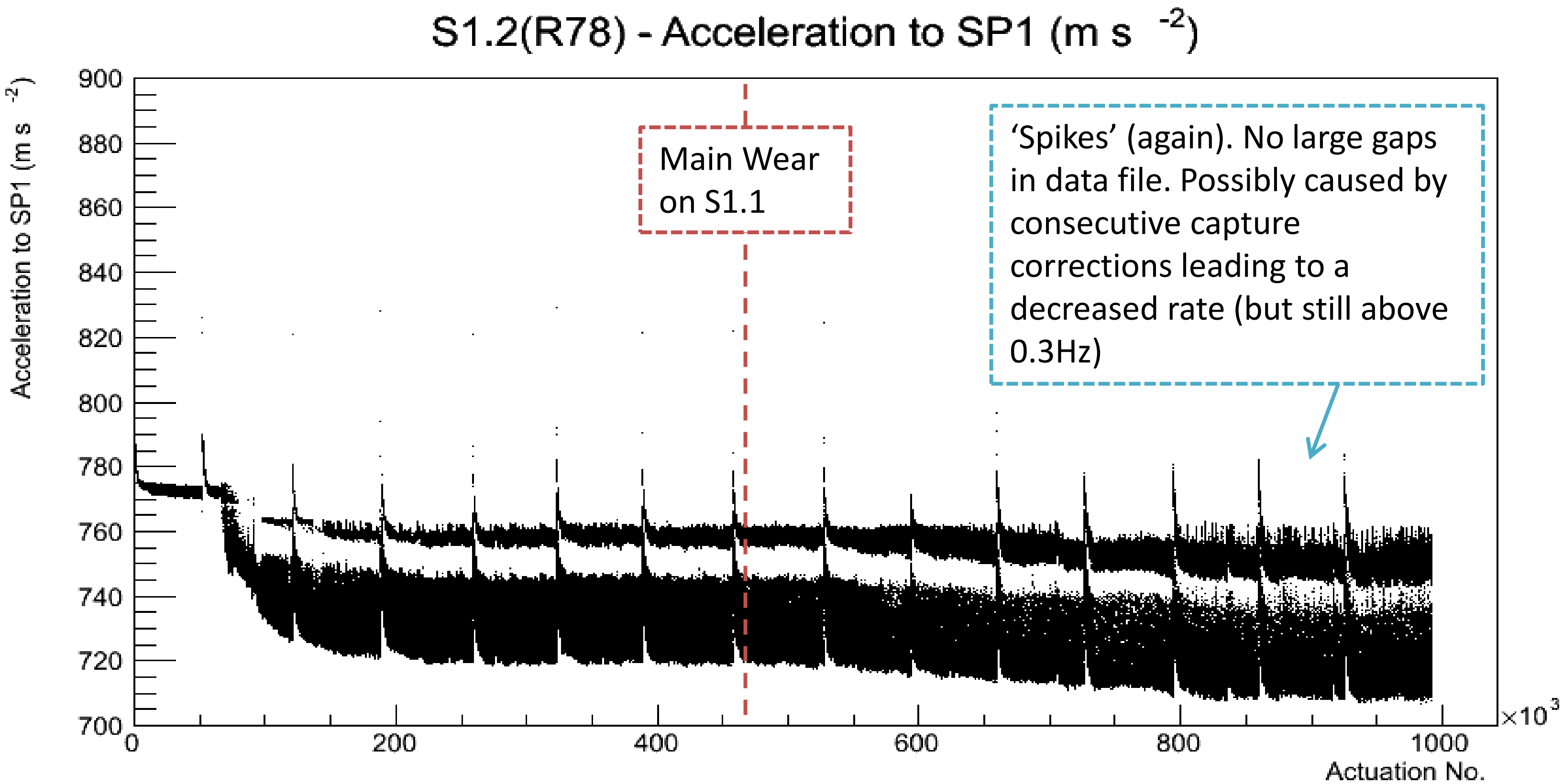
- S1.2 is currently setup in R78 under vacuum (chillier and power electronics off for Christmas).

- So far completed 1M actuations:

	S1.2		S1.1 (comparison)	
	Last Shift	Total	Last Shift	Total
Actuations:	67.1K	992.5 K	120.4K	966.3 K
Quadrature Count errors:	0	0	0	71
Fiber ADC errors:	0	0	0	3
BPS errors (during actuation):	0	0	0	1
(R78) Gaps > 3s & < 10s:	0	24	1738	16224
(R78) Gaps > 10s:	2	28	410	3478
(R78) SP2 Corrections:	0	25	1298	10458
(R78) Capture Over/Under shoots:	22/1724	9486/11210	16786/2085	88823/90908

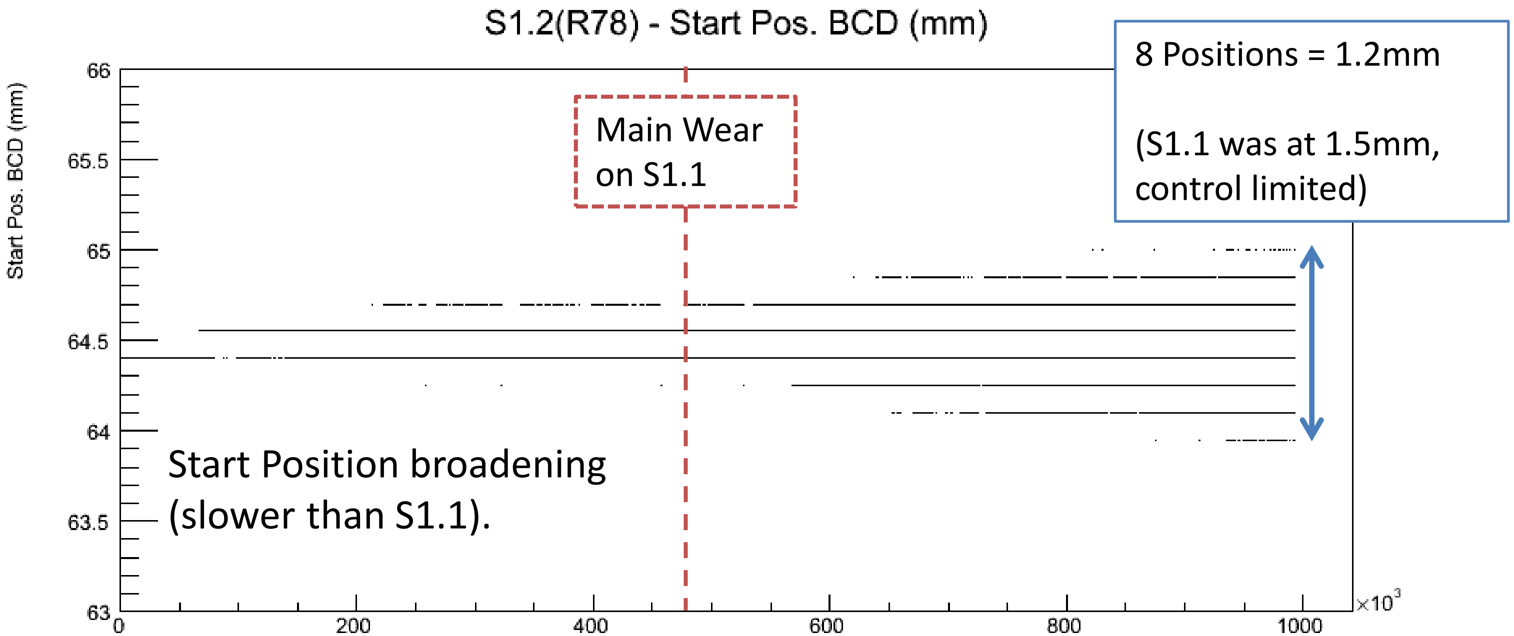
- For a similar age, now seeing less capture corrections, less gaps and less SP2 corrections.
  - Appears that the robustification has helped.
- No sign of quadrature problems

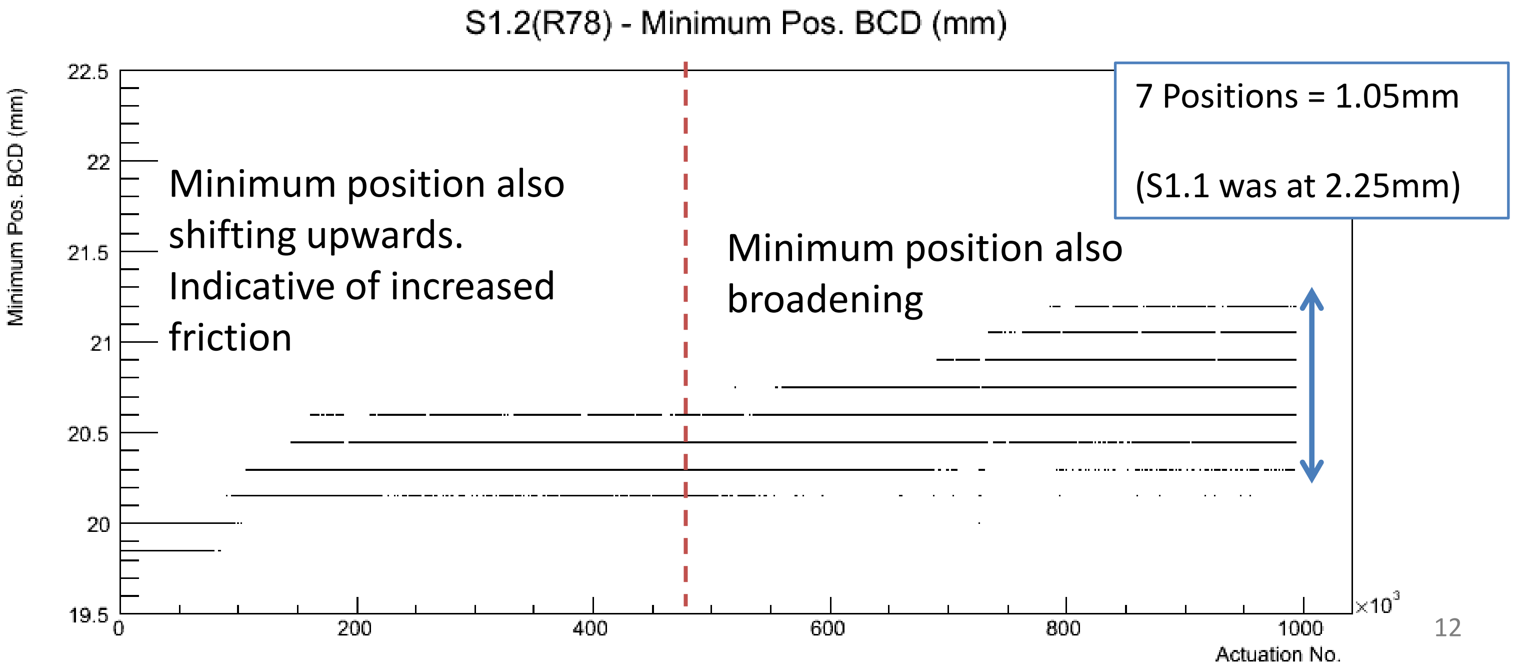
S1.2 Test Performance



- S1.2 started 30m/s/s below S1.1, probably due to the calibration.
- Decline in acceleration around 60k difficult to specify exact amount due to double banding.
- Acceleration appears more stable than S1.1.
- There is a slight slope, indicating a gradual drop over time

S1.2 Test Performance





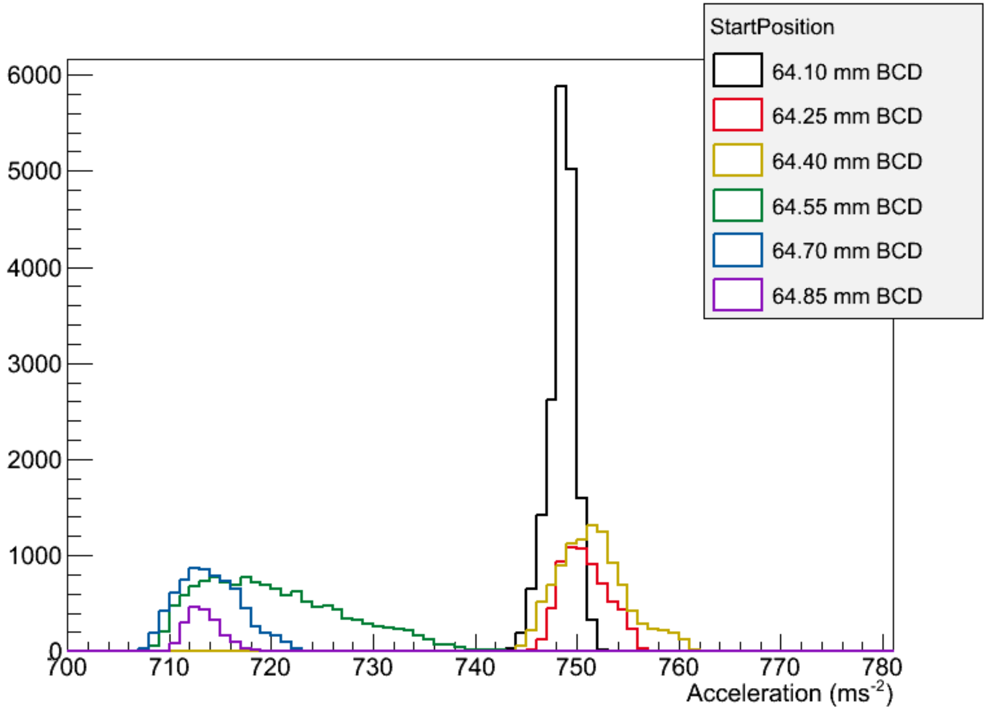
History of Targets (R78)

Test	Performance Notes (1mm wide start position)	Total Actuations (K)
T2.6	Degraded around 400K	1,100
T2.7	Degraded around 700K	1,300
T2.8	Degraded around 100K	1,000 + 1,500
T1.1	Degraded around 2,700K	3,200
T1.2 (Ti)	Degraded from 400k -> 1,000K*. Then improved. (wear in?)	2,000
T1.3 (Ti)	Degraded from 100K* (higher acceleration ~850m/s/s). Improved after switching to ~760m/s/s. Still good with new algorithm (@850m/s/s).	5,000
S1.1	Degraded around 500K	1,500
S1.1r2	Degraded around 5K**	80
S1.2	Degraded around 600K**	> 1,000

* 0.6 mm width (never reached 1mm..)

** 0.66mm (Capture current increased 50%).

Further Analysis: Acceleration Band Splitting



- On the acceleration plots, a double band normally forms.
- So far, looking at S1.2 this appears to be caused by different starting locations.
- The acceleration calculation in incredibly simple:
  - $a = 2s/t^2$

It is possible this is caused by dead time when the coils switch:

- If this happened near the start of the actuation (low velocity) then: $a = 2s/(t+d)^2$
- => For the acceleration drop (750-715) and t of 7.8ms, the time d can be estimated: 1.9us.

Further Analysis: Target Waveforms

- To help with target diagnostics, it would be useful to improve the analysis to also include the waveform data collected. This will be especially useful with the new control software where the controller and waveform data are collected to the same place. Here's some ideas:

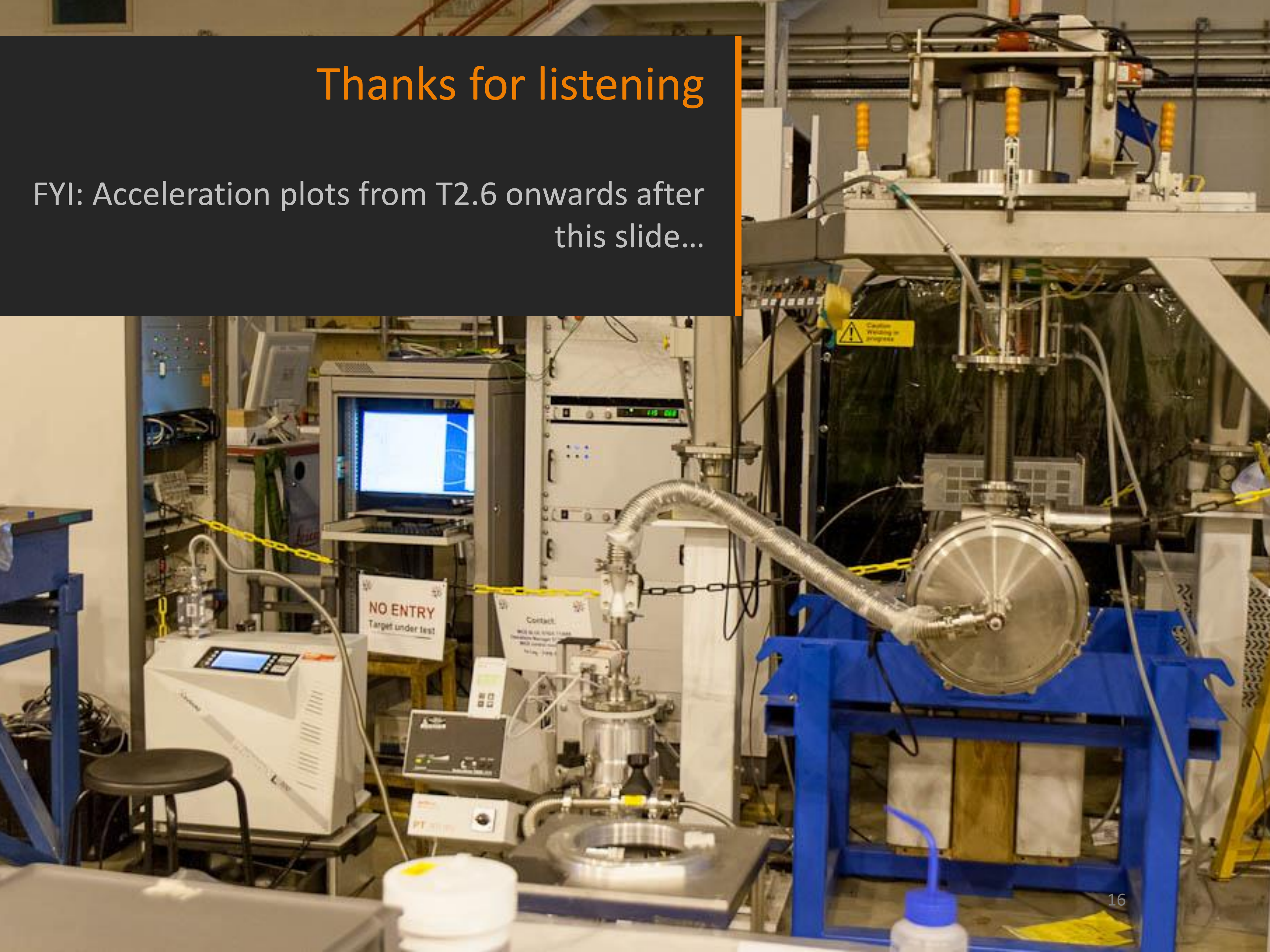
1. (Old) Use the acceleration in different quadrants to try and calculate the friction.
   - Slightly trickier than first thought.
   - Looking for small (1-10%) changes by summing large numbers.
   - The coil current is not linear across the actuation.

2. (New-ish) Look at the energy loss during the capture of the target.
   - Can provide good indicator of friction at beginning of test
   - Should not be too difficult.
   - Need to fit a oscillation with decaying amplitude to the capture region.
   - Need to reliably find the capture region.

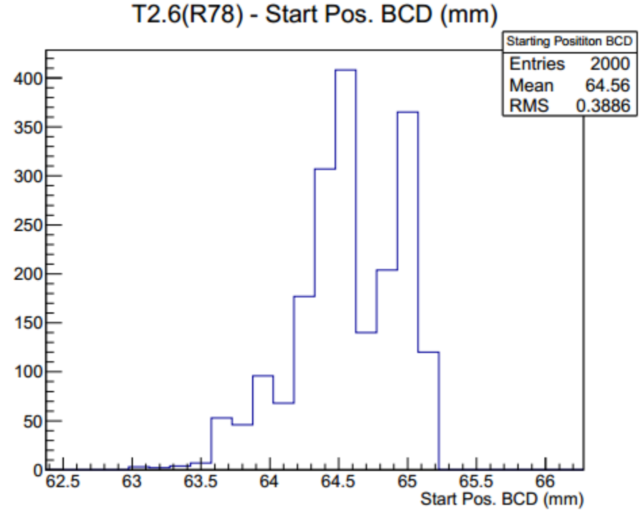
3. (Old) Look for quadrature glitches:
   - Need to intelligently scan the actuation, looking for glitches where the target appears to moves in the opposite direction.

Thanks for listening

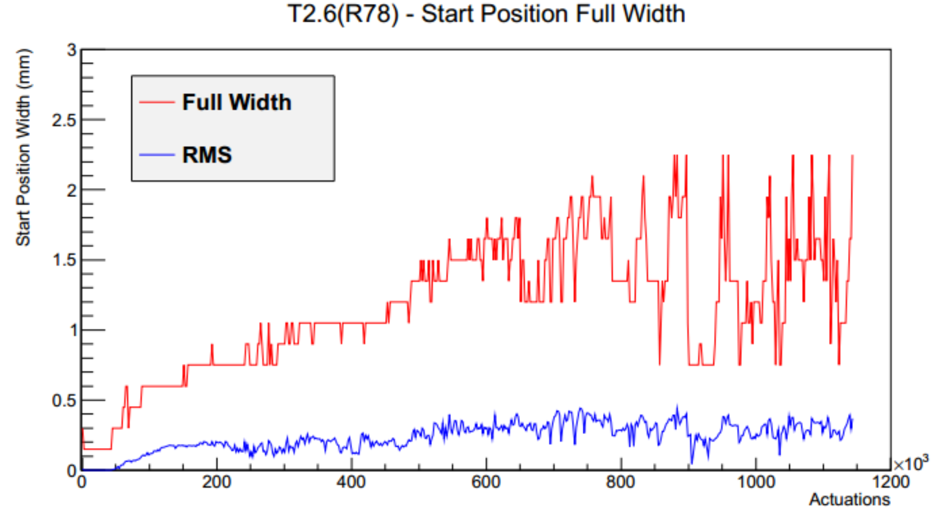
FYI: Acceleration plots from T2.6 onwards after this slide…



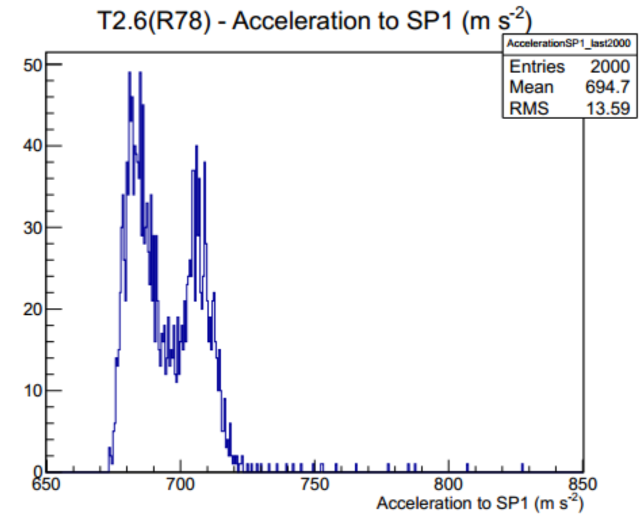
Archive Plots: T2.6



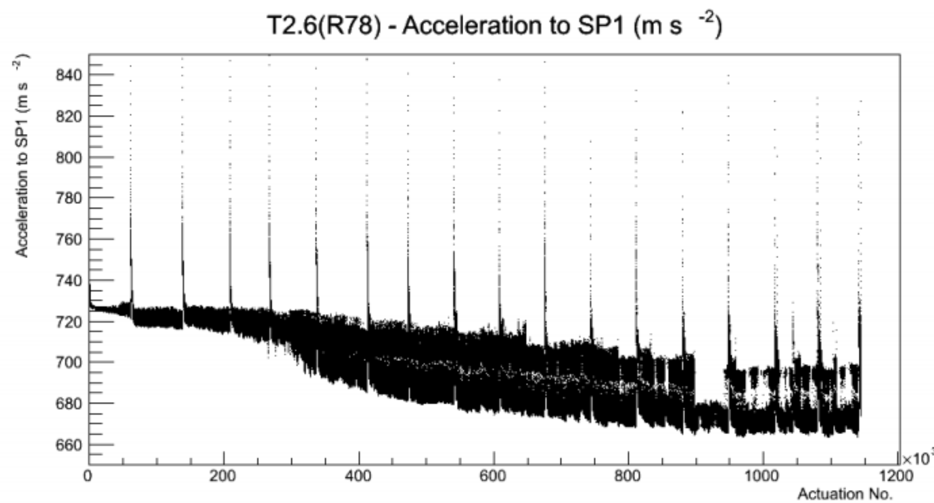
Starting position for the last 2000 actuations.



Starting position width over time.

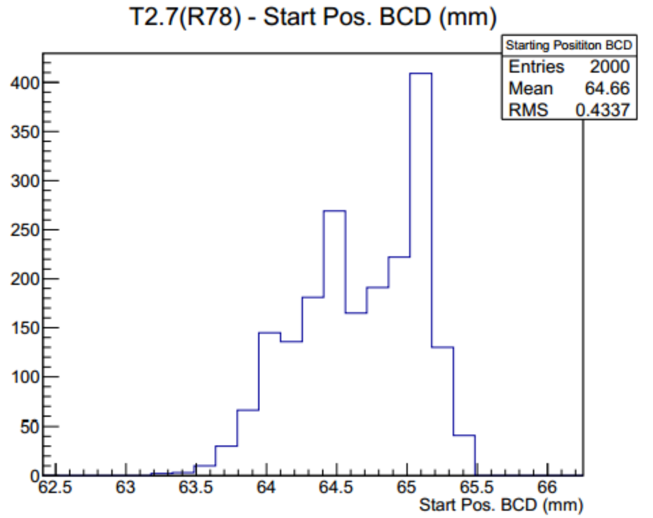


Acceleration for the last 2000 actuations.

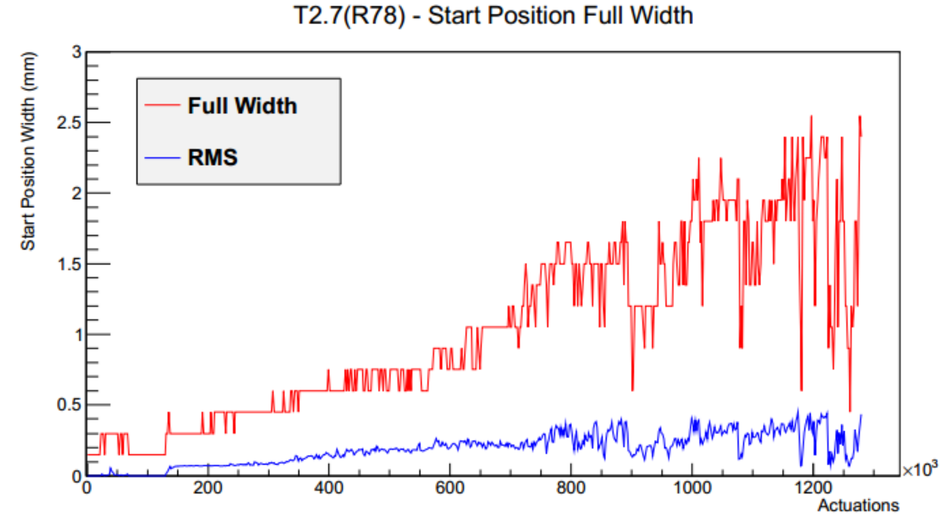


Acceleration over time.

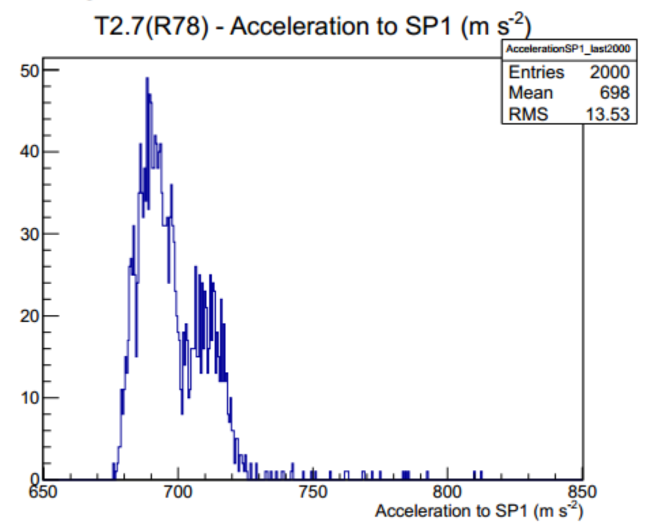
Archive Plots: T2.7



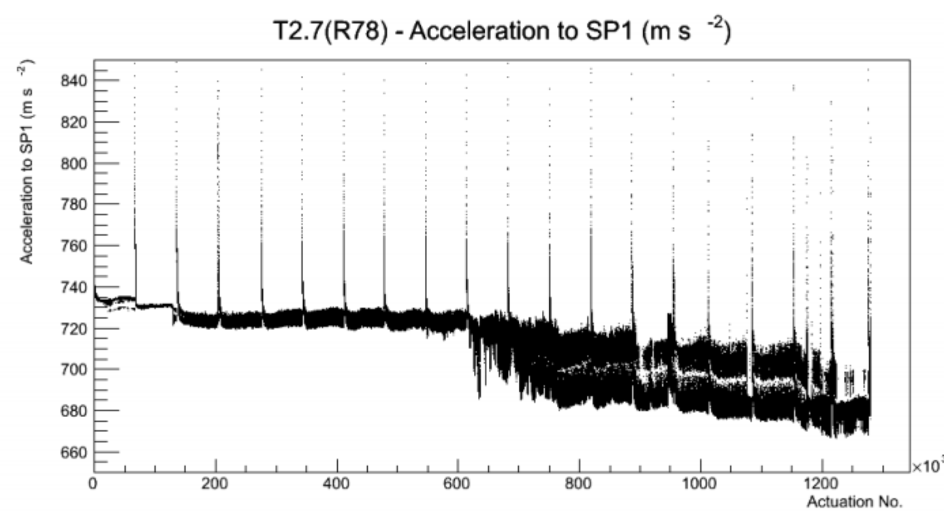
Starting position for the last 2000 actuations.



Starting position width over time.

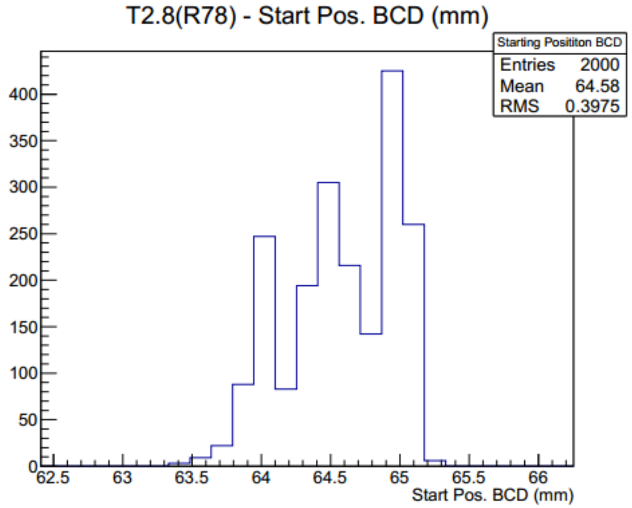


Acceleration for the last 2000 actuations.

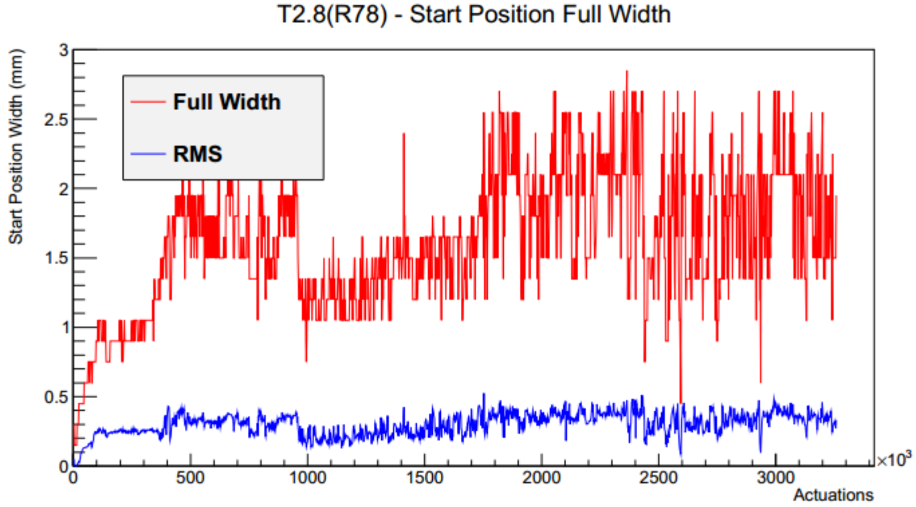


Acceleration over time.

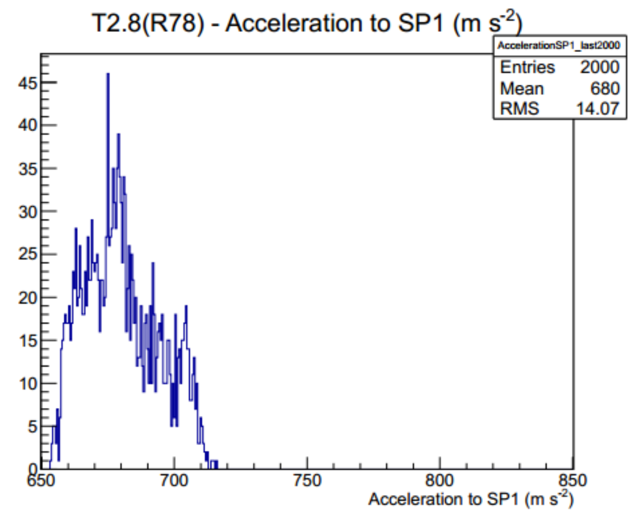
Archive Plots: T2.8



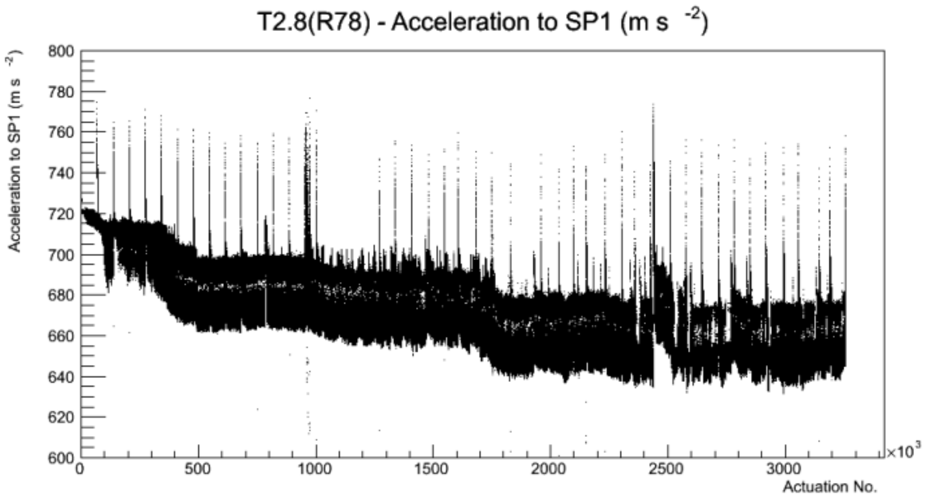
Starting position for the last 2000 actuations.



Starting position width over time.

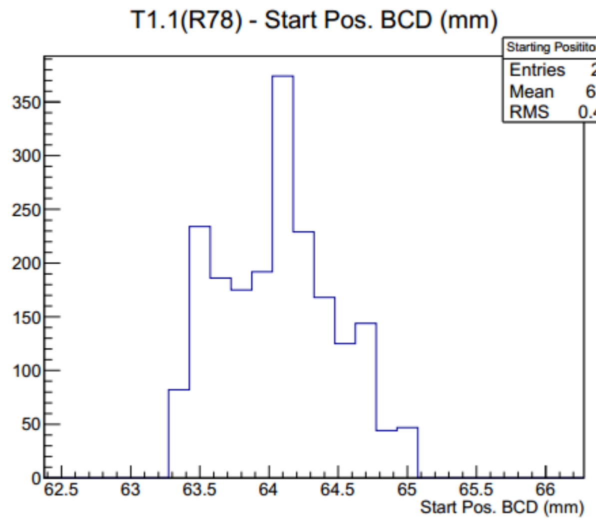


Acceleration for the last 2000 actuations.

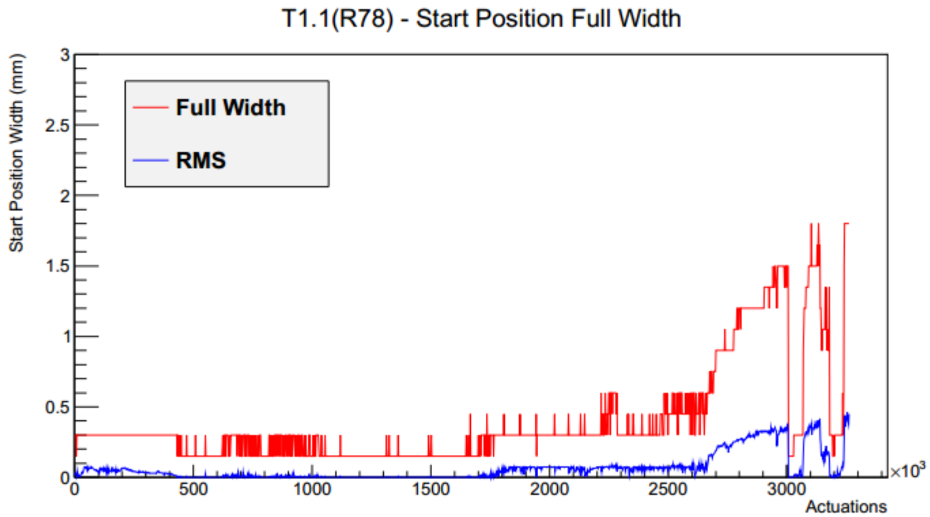


Acceleration over time. Normalised to a temperature 68C using the temperature data collected by the system.

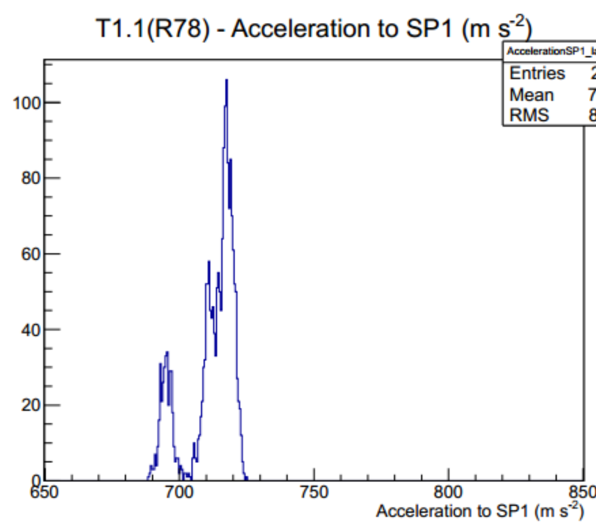
Archive Plots: T1.1



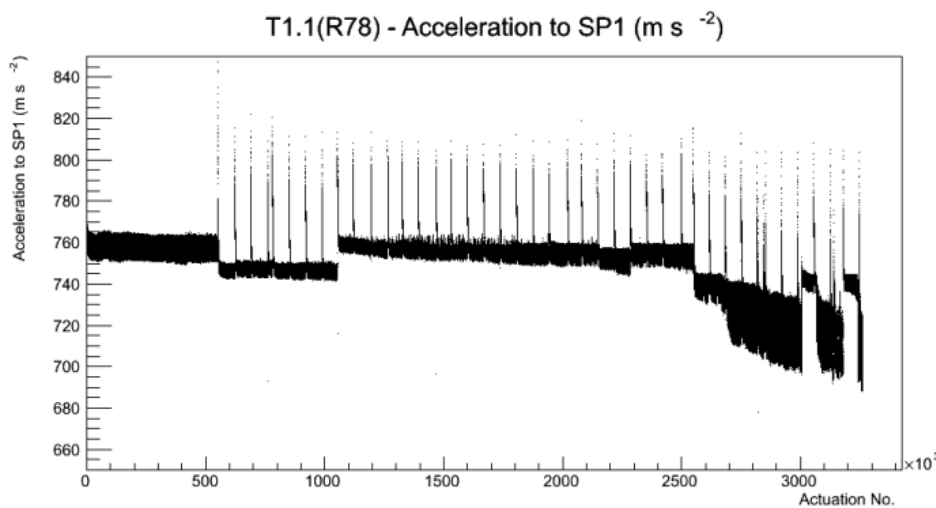
Starting position for the last 2000 actuations.



Starting position width over time.

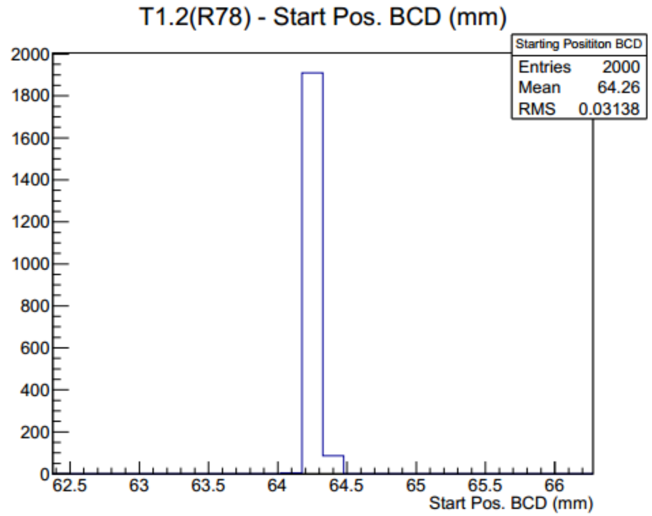


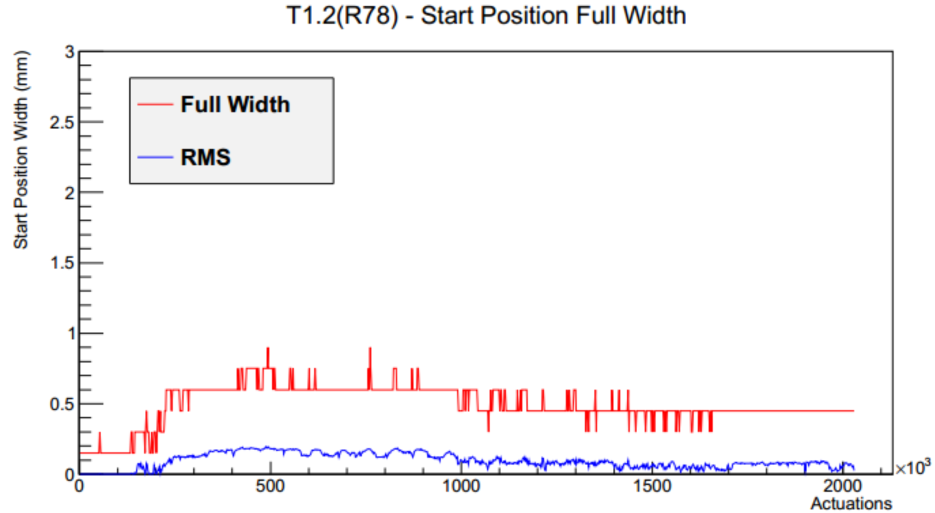
Acceleration for the last 2000 actuations.



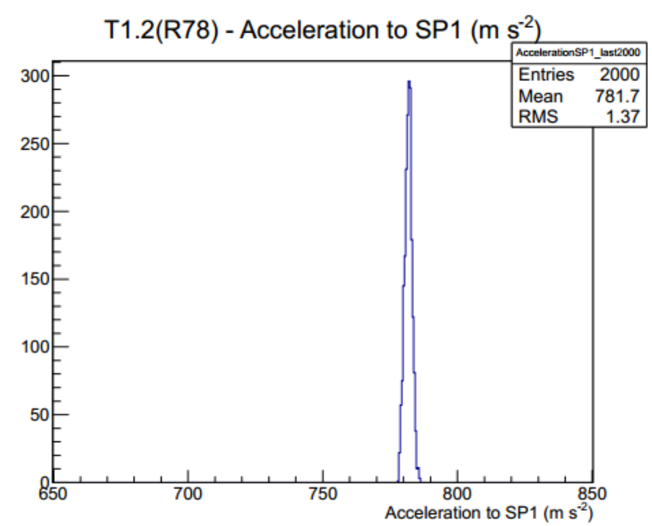
Acceleration over time. Normalised to a temperature 68C using the temperature data collected by the system.

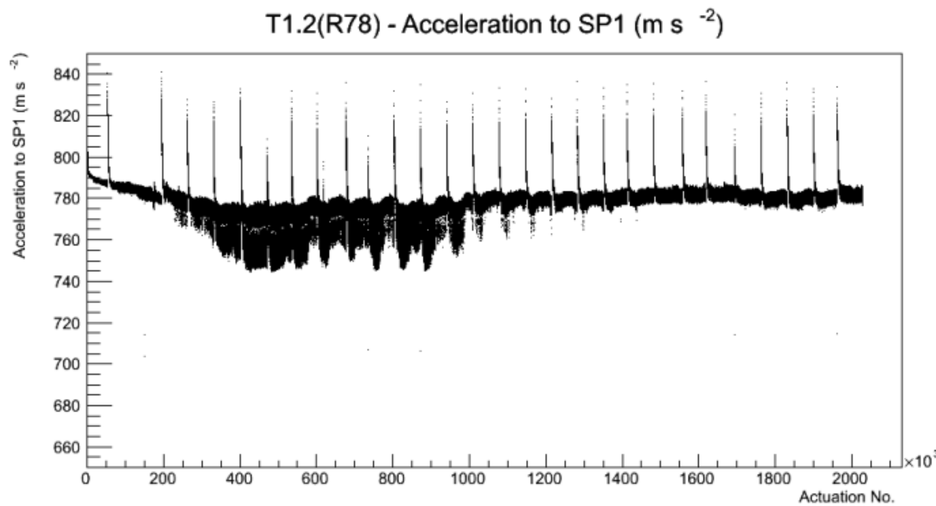
Archive Plots: T1.2





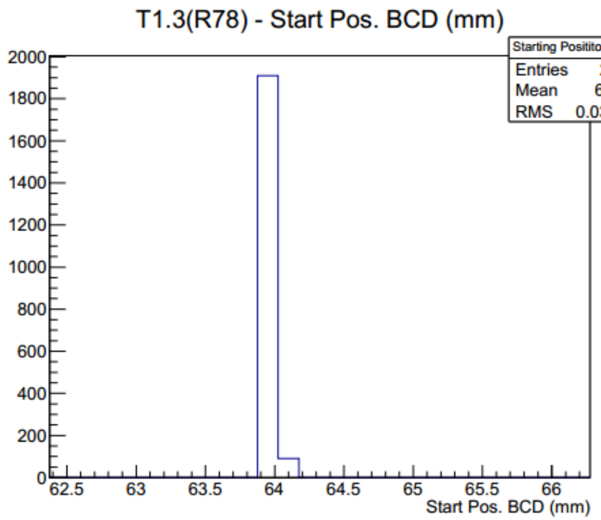
Starting position for the last 2000 actuations. Starting position width over time.



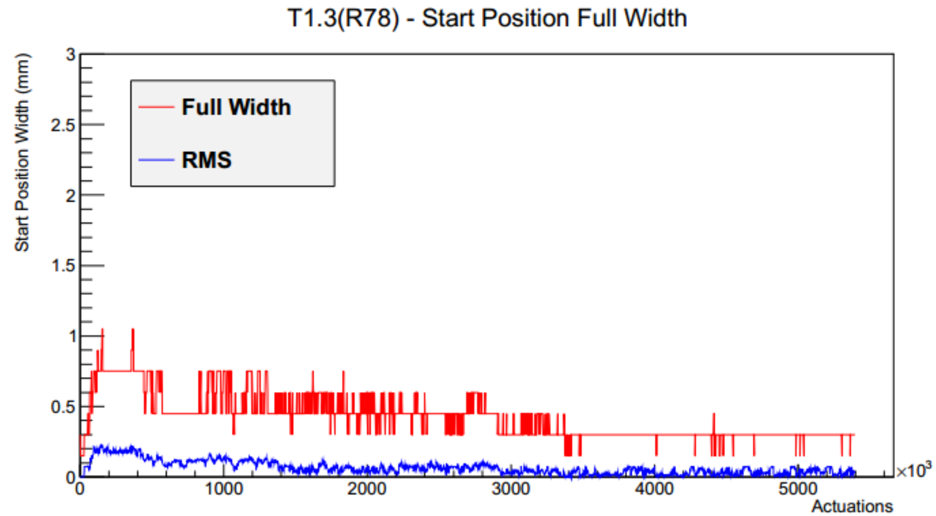


Acceleration for the last 2000 actuations. Acceleration over time. Normalised to a temperature 68C using the temperature data collected by the system.

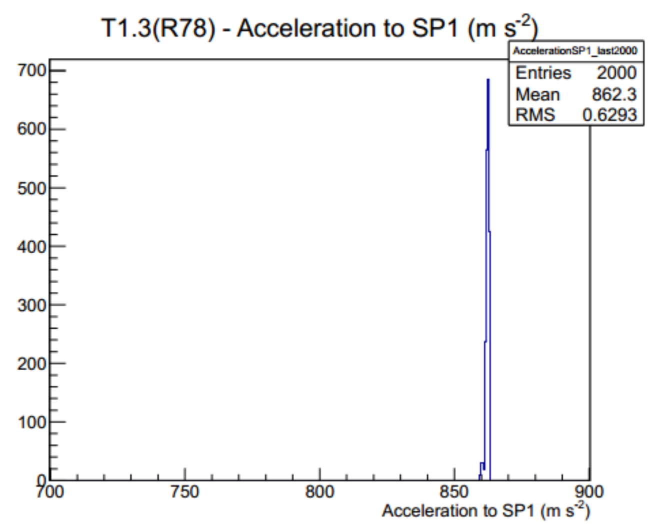
Archive Plots: T1.3



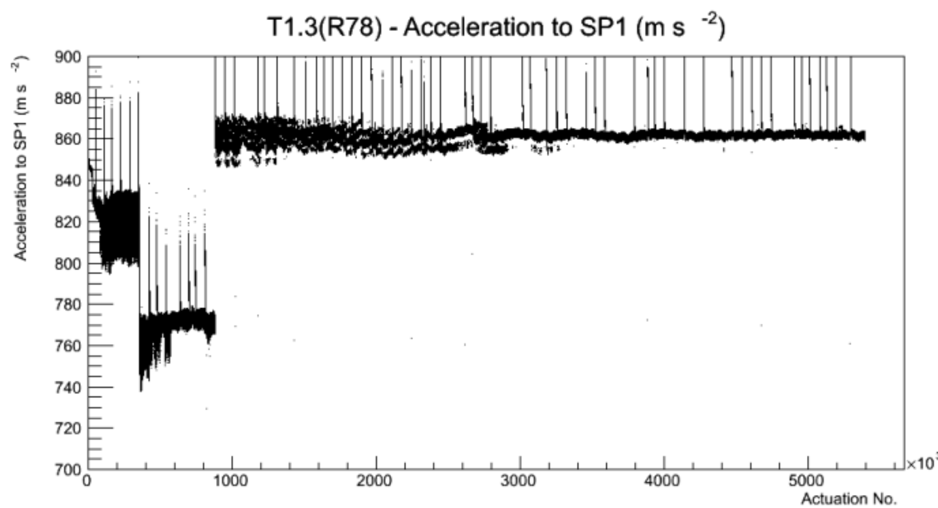
Starting position for the last 2000 actuations.



Starting position width over time.

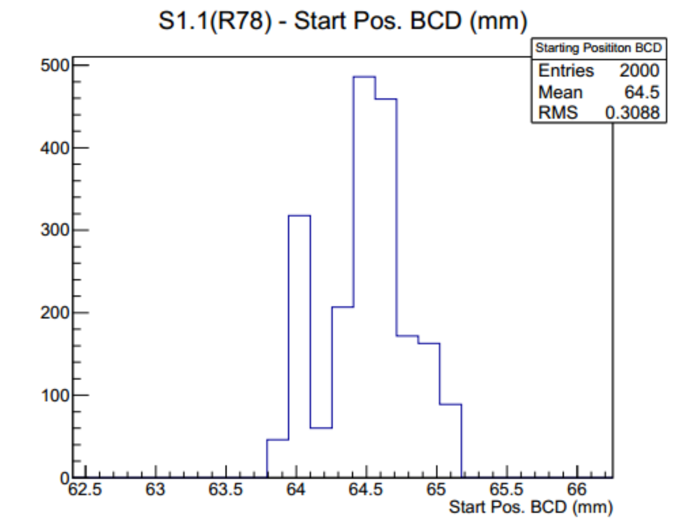


Acceleration for the last 2000 actuations.

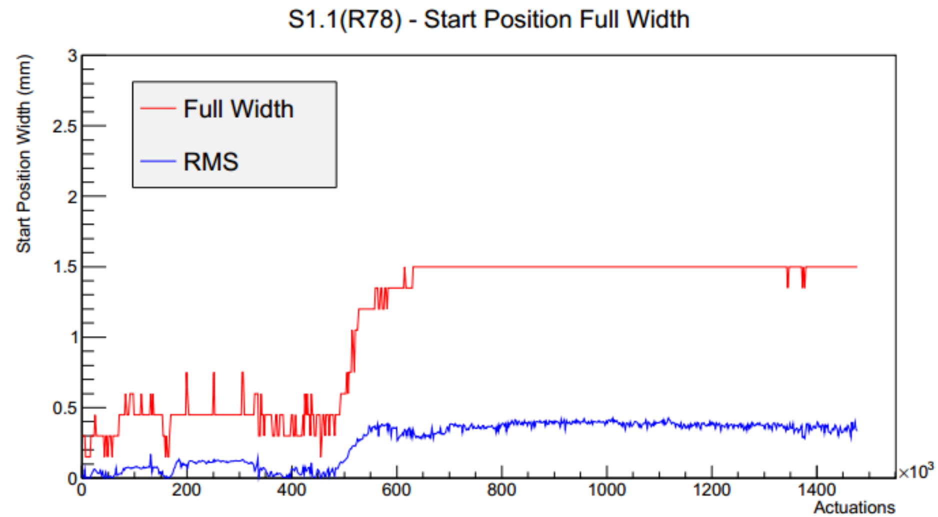


Acceleration over time. Normalised to a temperature 72C using the temperature data collected by the system.

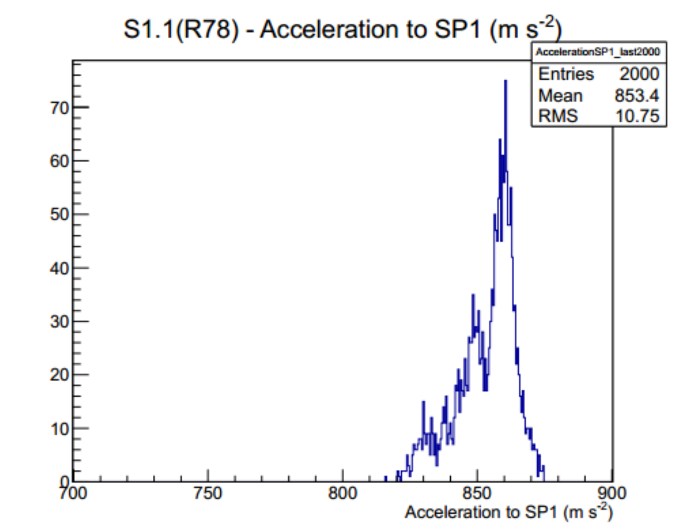
Archive Plots: S1.1



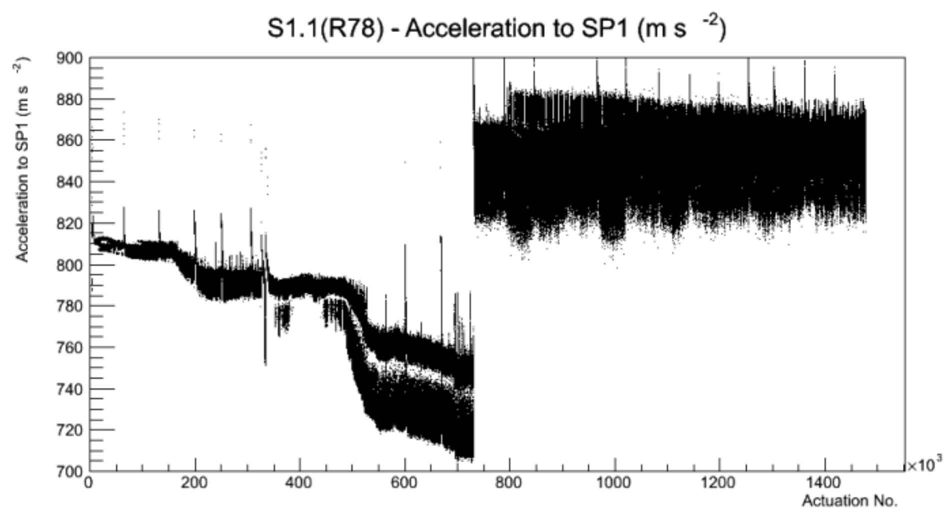
Starting position for the last 2000 actuations.



Starting position width over time.

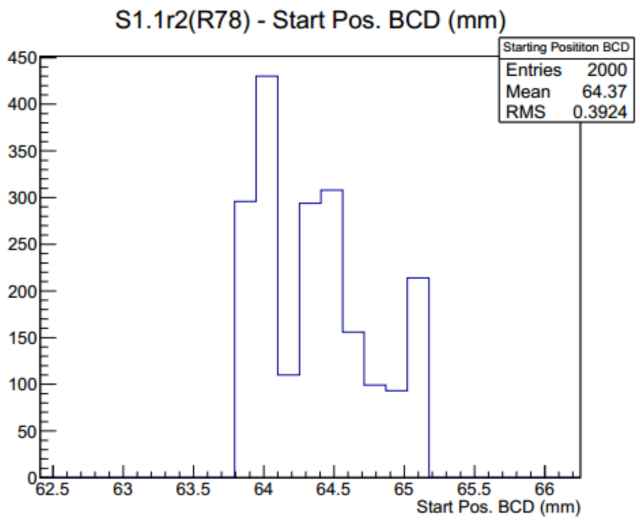


Acceleration for the last 2000 actuations.

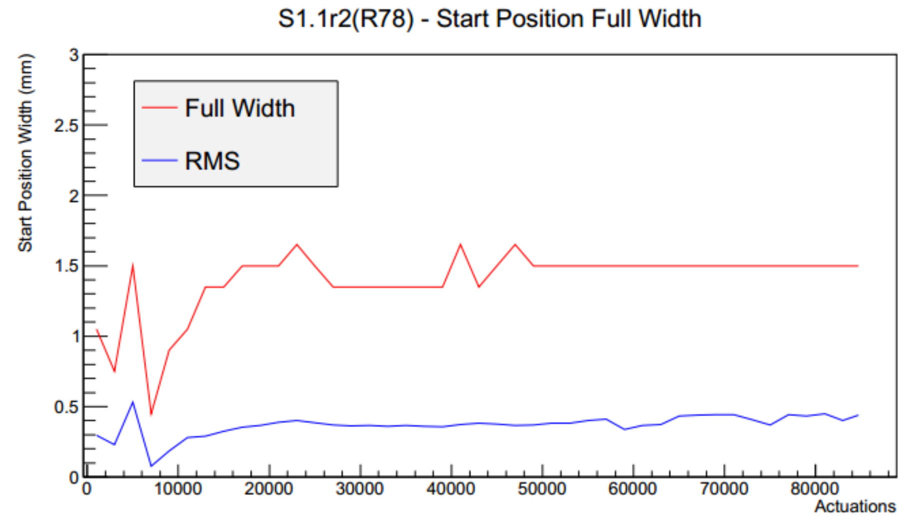


Acceleration over time. Normalised to a temperature 45C using the temperature data collected by the system.

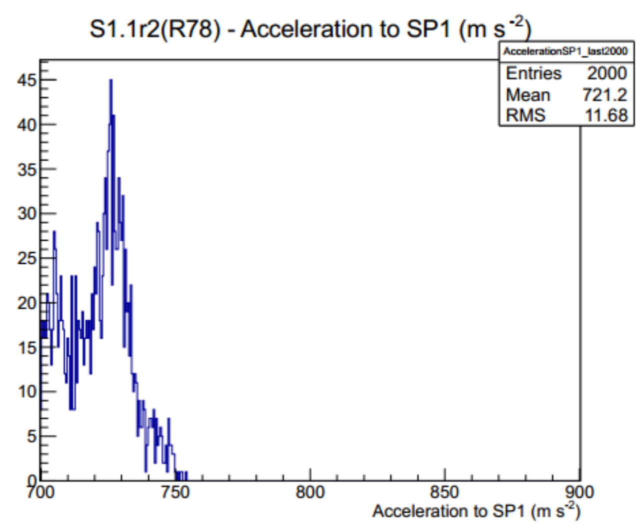
Archive Plots: S1.1r2



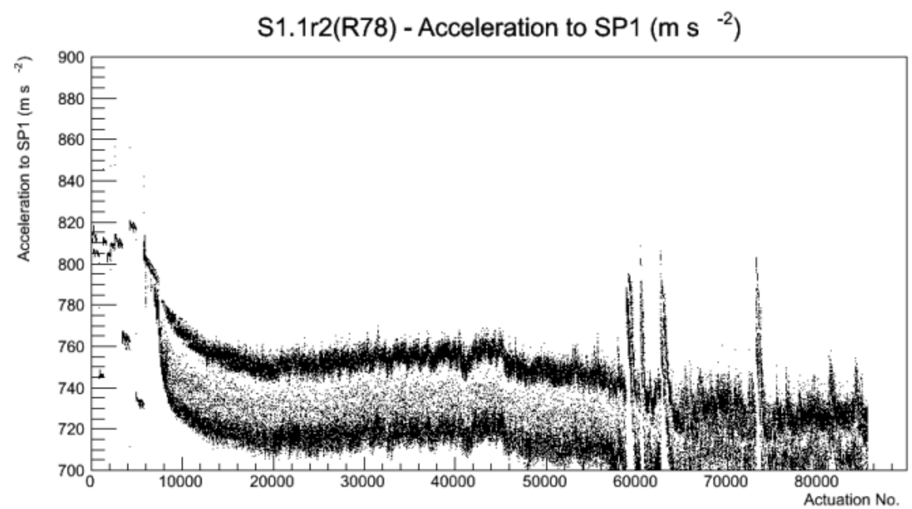
Starting position for the last 2000 actuations.



Starting position width over time.

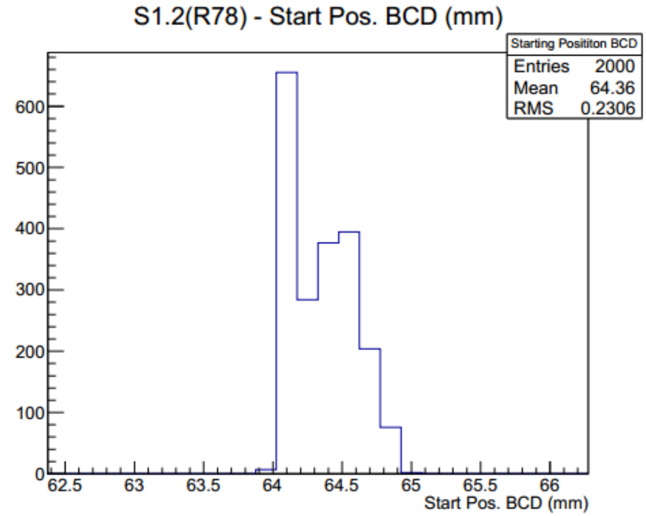


Acceleration for the last 2000 actuations.

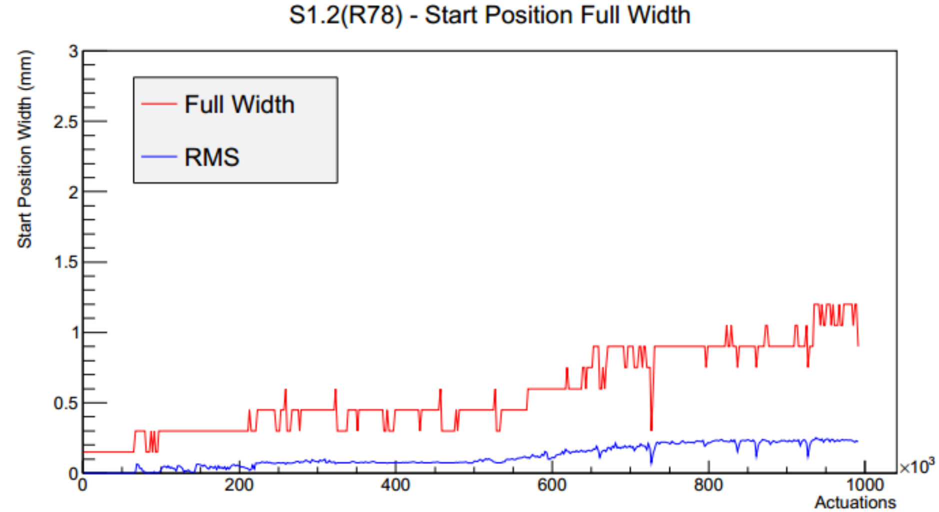


Acceleration over time. Normalised to a temperature 45C using the temperature data collected by the system.

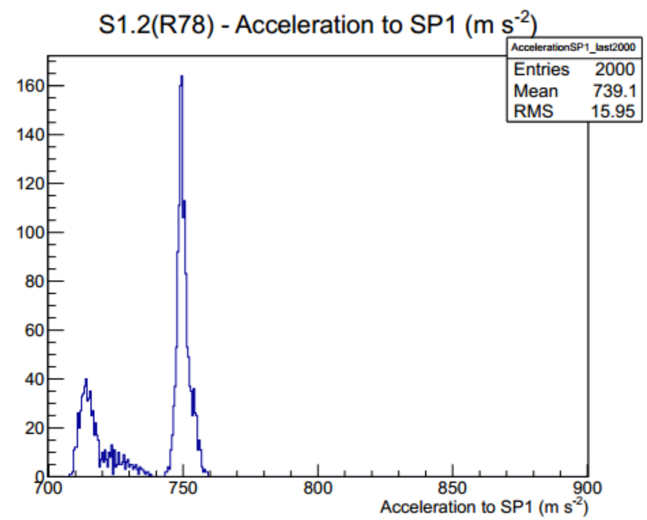
Archive Plots: S1.2



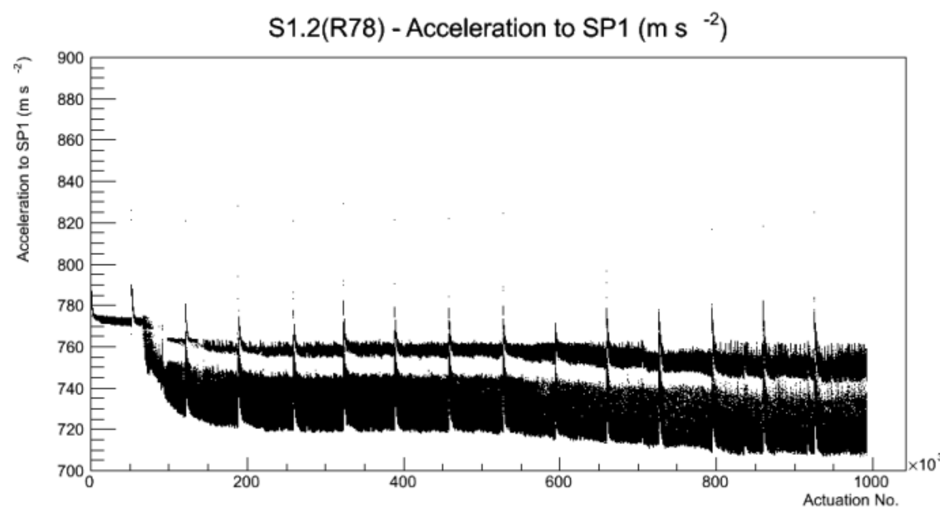
Starting position for the last 2000 actuations.



Starting position width over time.



Acceleration for the last 2000 actuations.



Acceleration over time. Normalised to a temperature 45C using the temperature data collected by the system.