SPS Crab cavity LLRF

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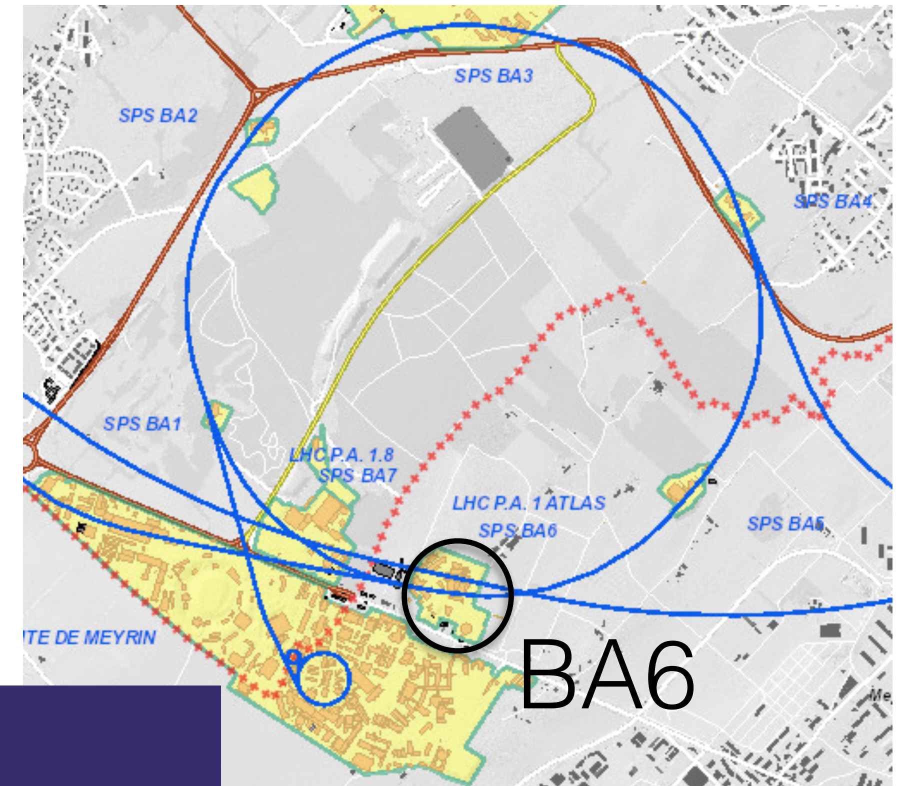
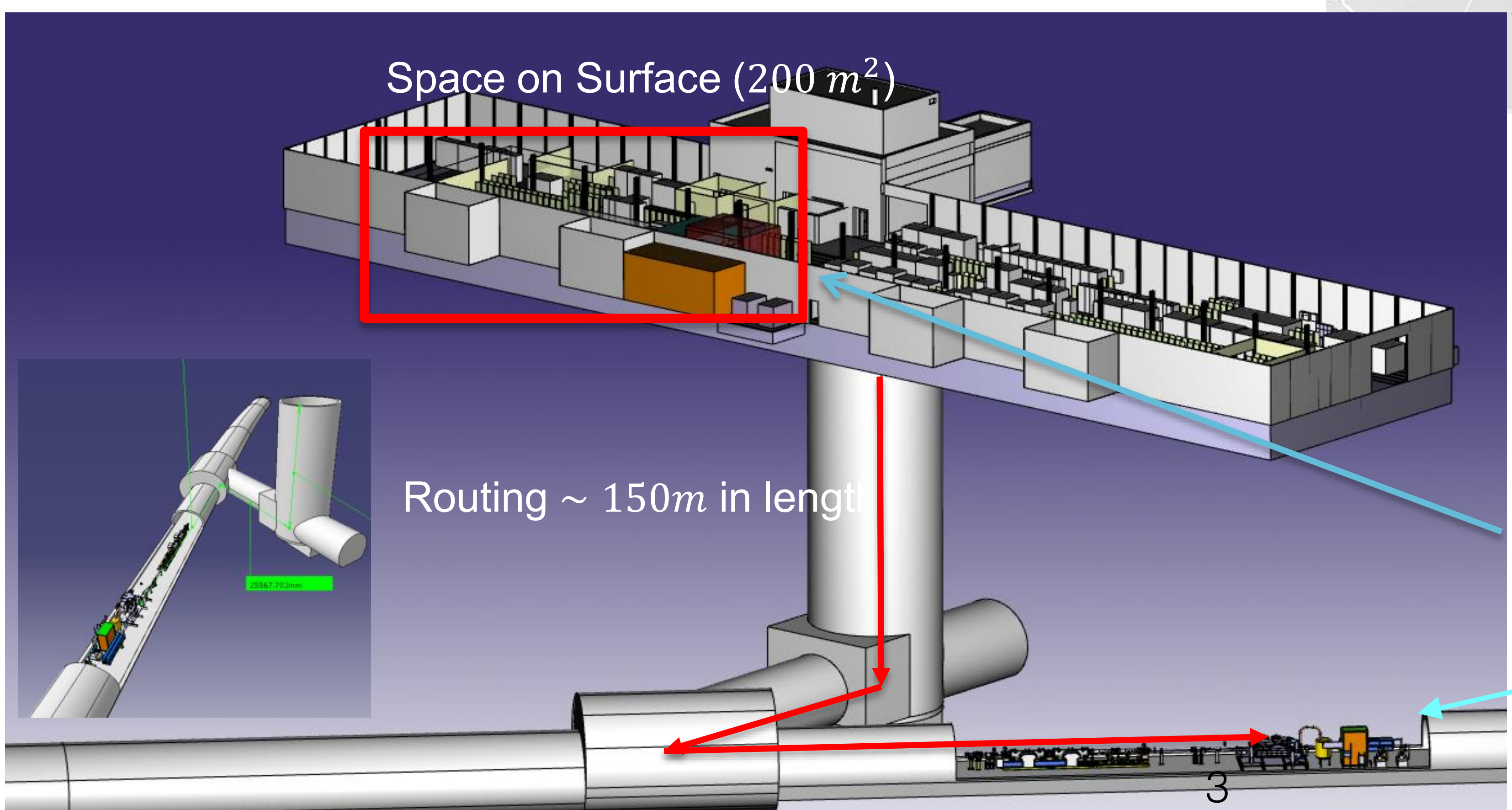
Contents

- LLRF scheme in BA6
- LLRF status
- LLRF features (to be tested)
- LLRF test plans for next MDs

SPS BA6

- LLRF controls are located in Faraday Cage at BA6.
- Crab cavities are in the SPS tunnel underneath the faraday cage

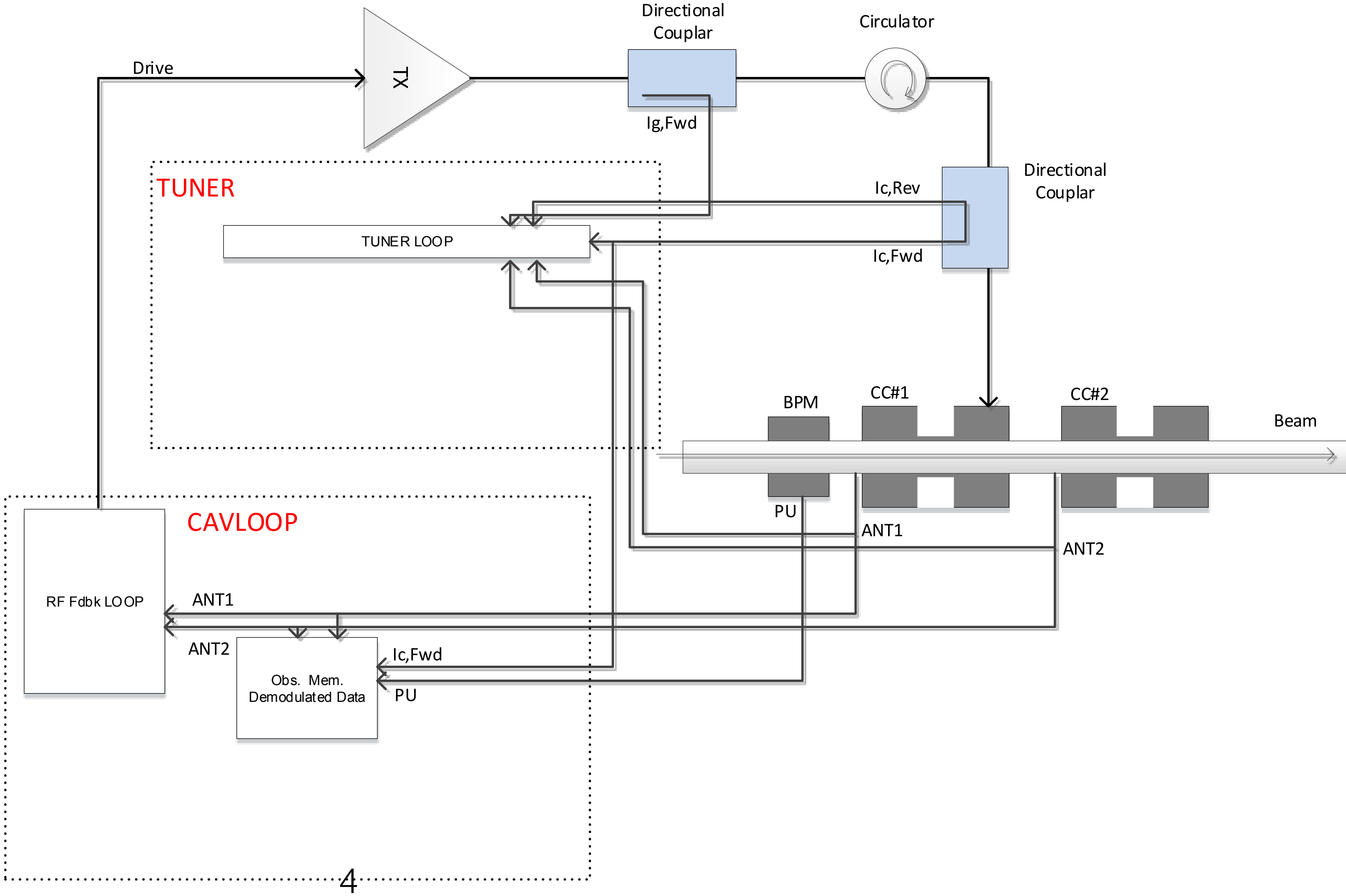




LLRF scheme

- Diagram of the LLRF schemes for SPS crab cavity: Tuner loop plus RF feedback

CC2 CC1



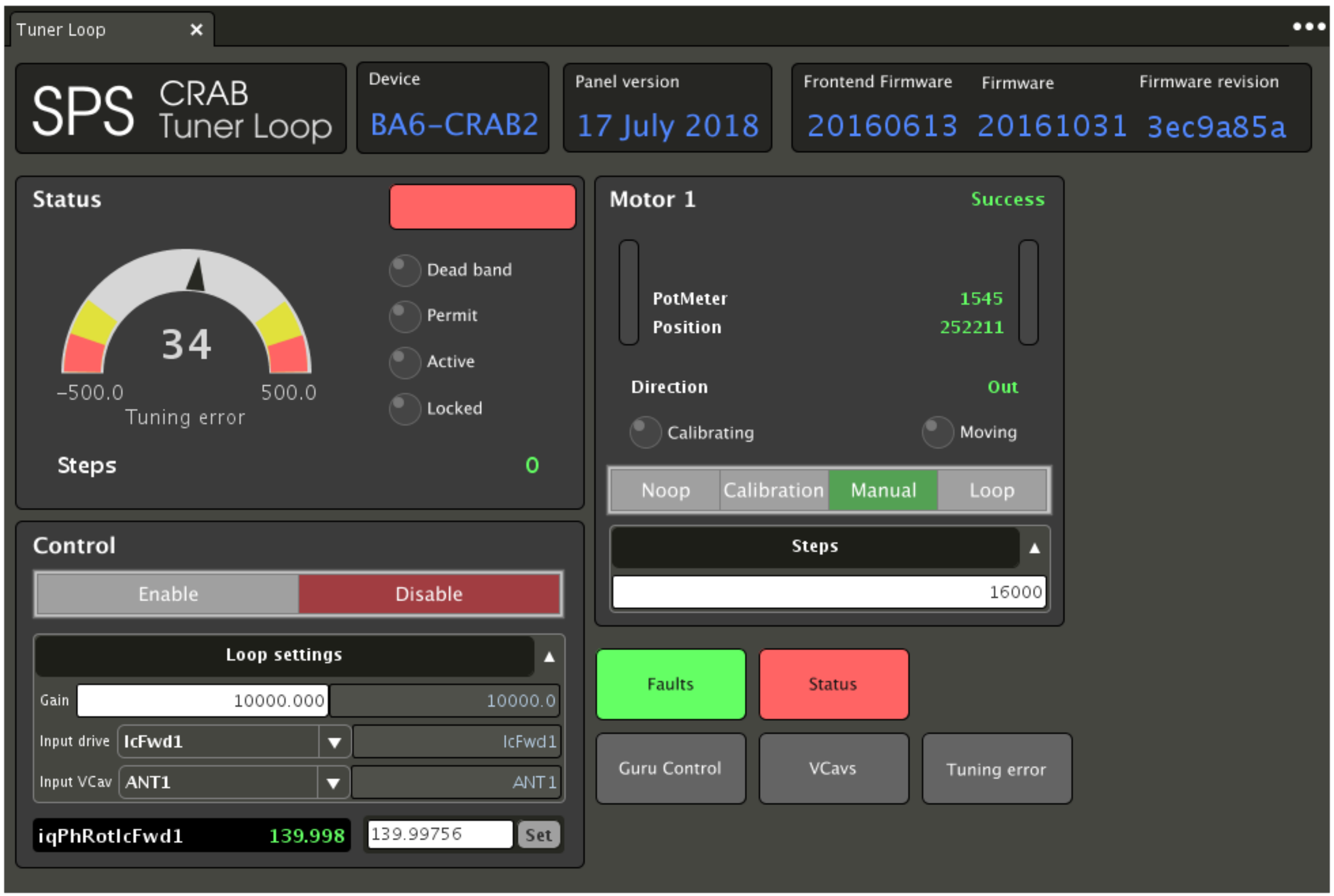
LLRF modules

Tuner Loop module
Adapted from L4

vity Loop module
d from SPS 800 MHz
and L4
mware modified

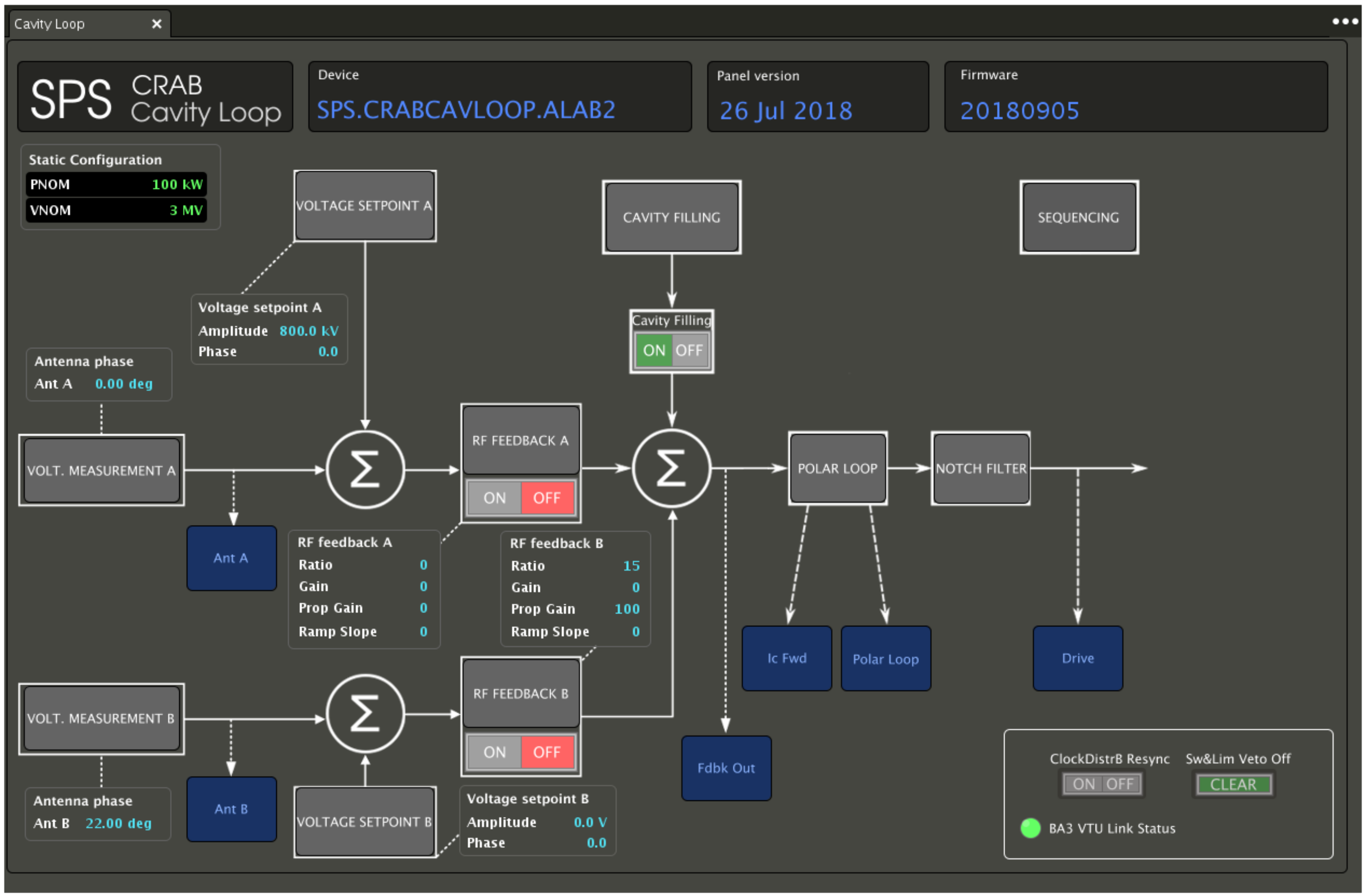
GUI panel: Tuner controls

- GUI panel for Tuner control : adapted from Linac4. The CC tuner acts by deforming the deflecting gap. Its response is VERY slow (below 1/10 Hz).



GUI panel: RF feedback

- GUI panel for RF feedback: created for SPS CCs. We have a PI controller, for each cavity.



Status LLRF for SPS CCs

Tuner Loop

- Tuner control :

  — SM18: Tuner Loop worked well at very low cavity field in both the vertical test-stand and the DQW. The TX was a 200 W solid-state amplifier.

  — First 4 MDs: large fluctuations (more than one BW, at a 1 second rate) on cavity field at 4K, likely caused by He ebullition (?). This is out of the range of tuner loop compensation

  — MD5: 2K Cryo temperature

  cavity field < 800kV: Loop works OK on CC2

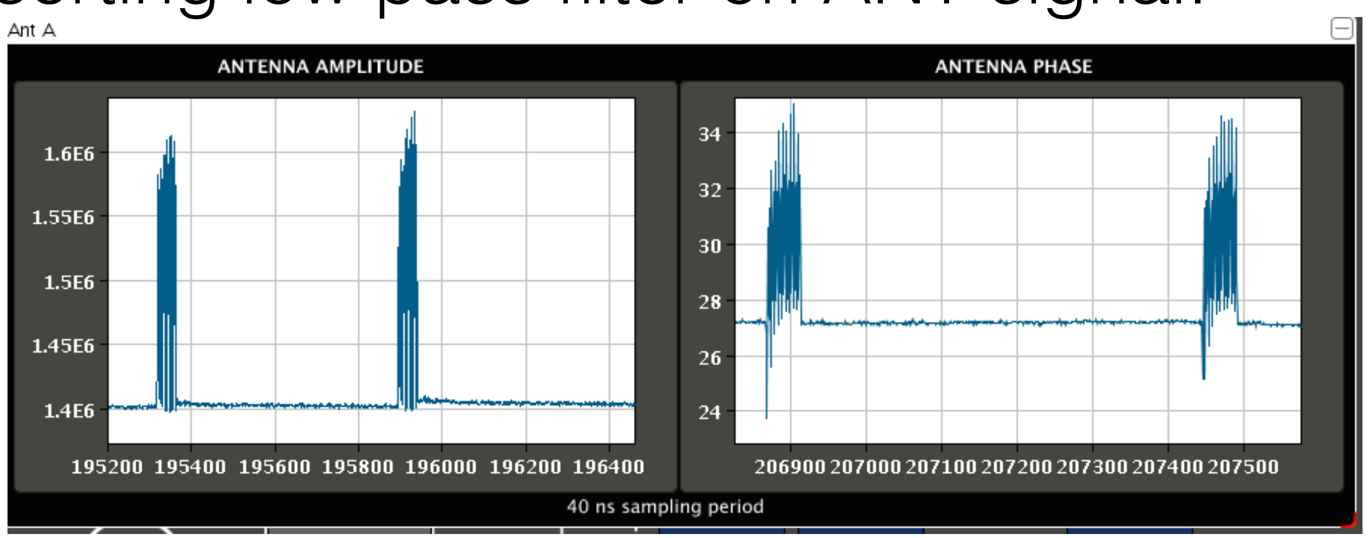
  cavity field > 800kV: cannot use Loop (large fluctuation in measurement signals)

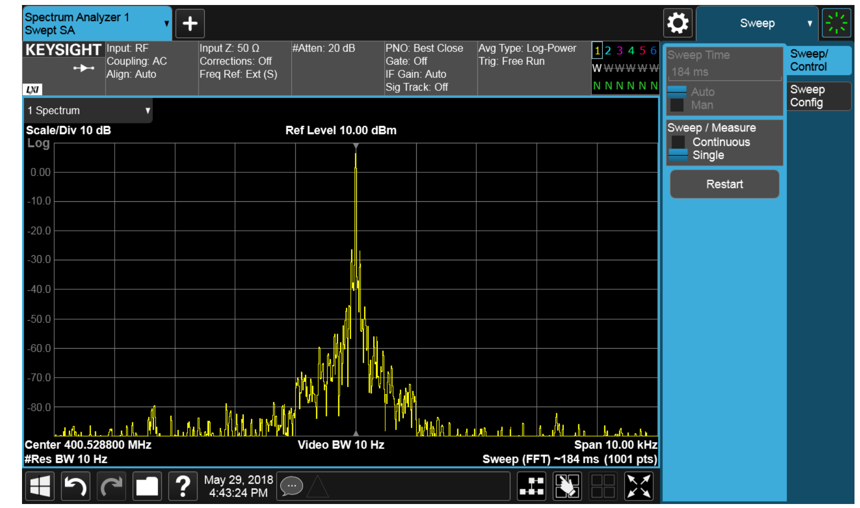
  CC1 could not operate

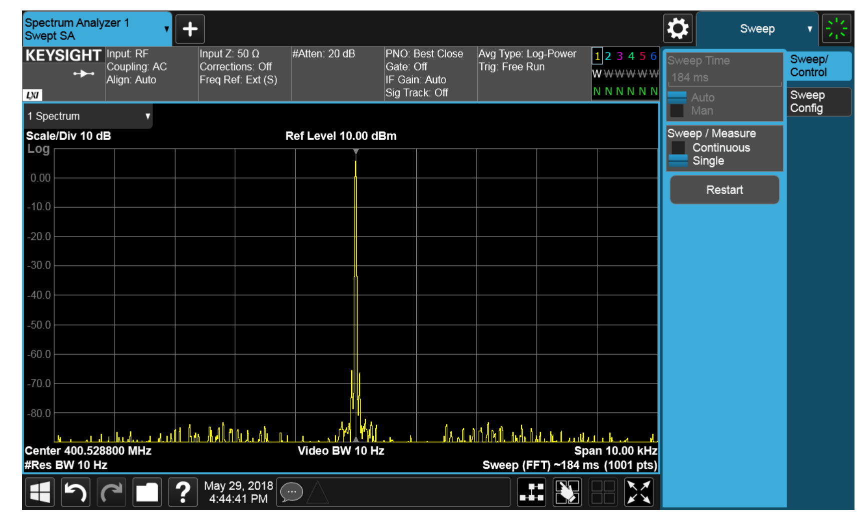
RF feedback (FDBK) Loop

— First 4 MDs : fdbk control can regulate the fields in presence of the large tune variations.

We see a direct coupling of beam passage in the ANT used by fdbk: should be reduced by inserting low pass filter on ANT signal.







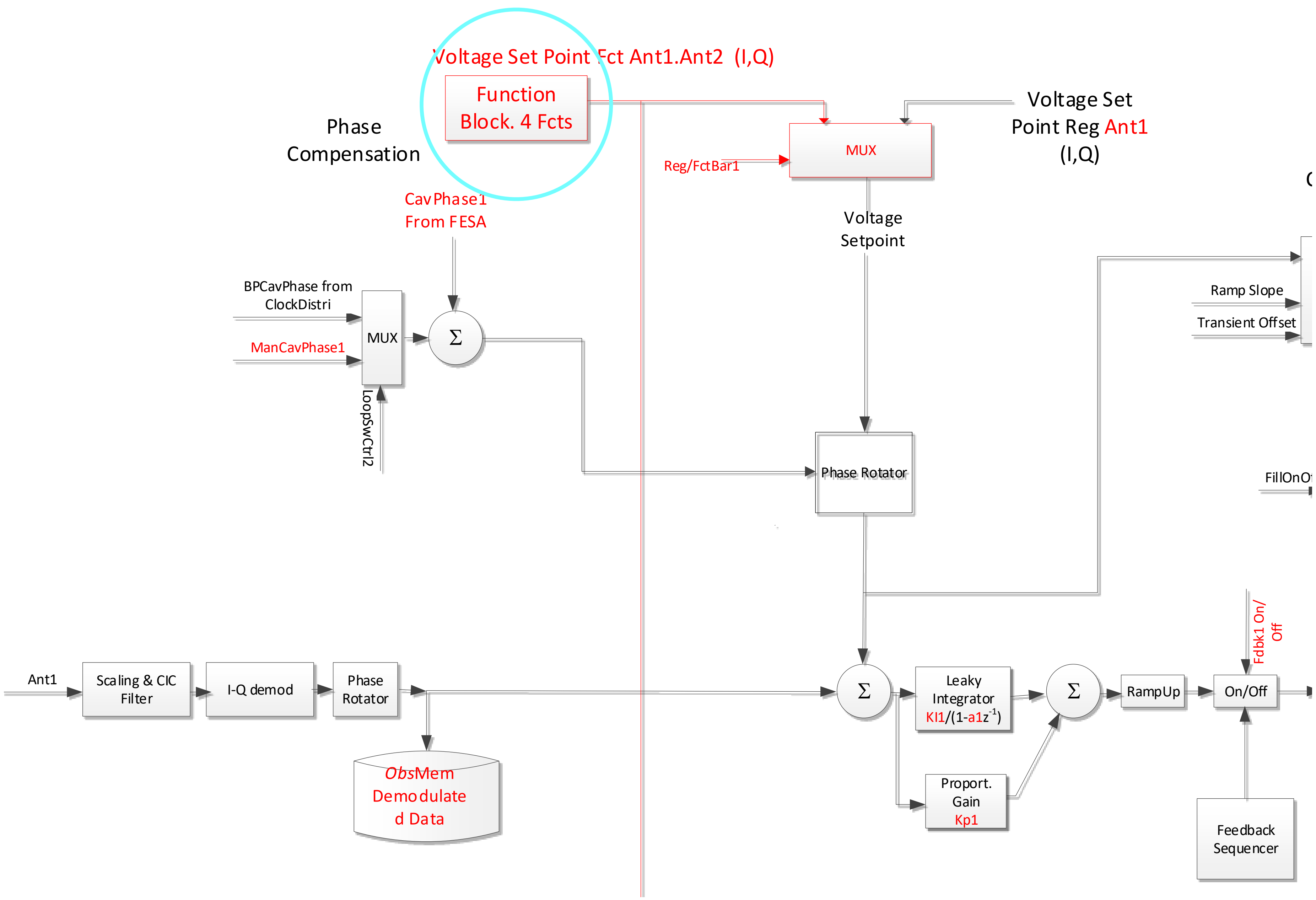
— Setting up FDBK is not easy due to the non-linearity of IOT amplifier. Nominal transmitter power is 100 kW, while we operate around 1-2 kW. So the fdbk phase/gain must be adjusted as we increase the field. Tedious…

— MD5: operate close to the multipacting level of the cavities. Therefore transients in TX drive have dramatic effects->Trip cavity.

LLRF features for CCs

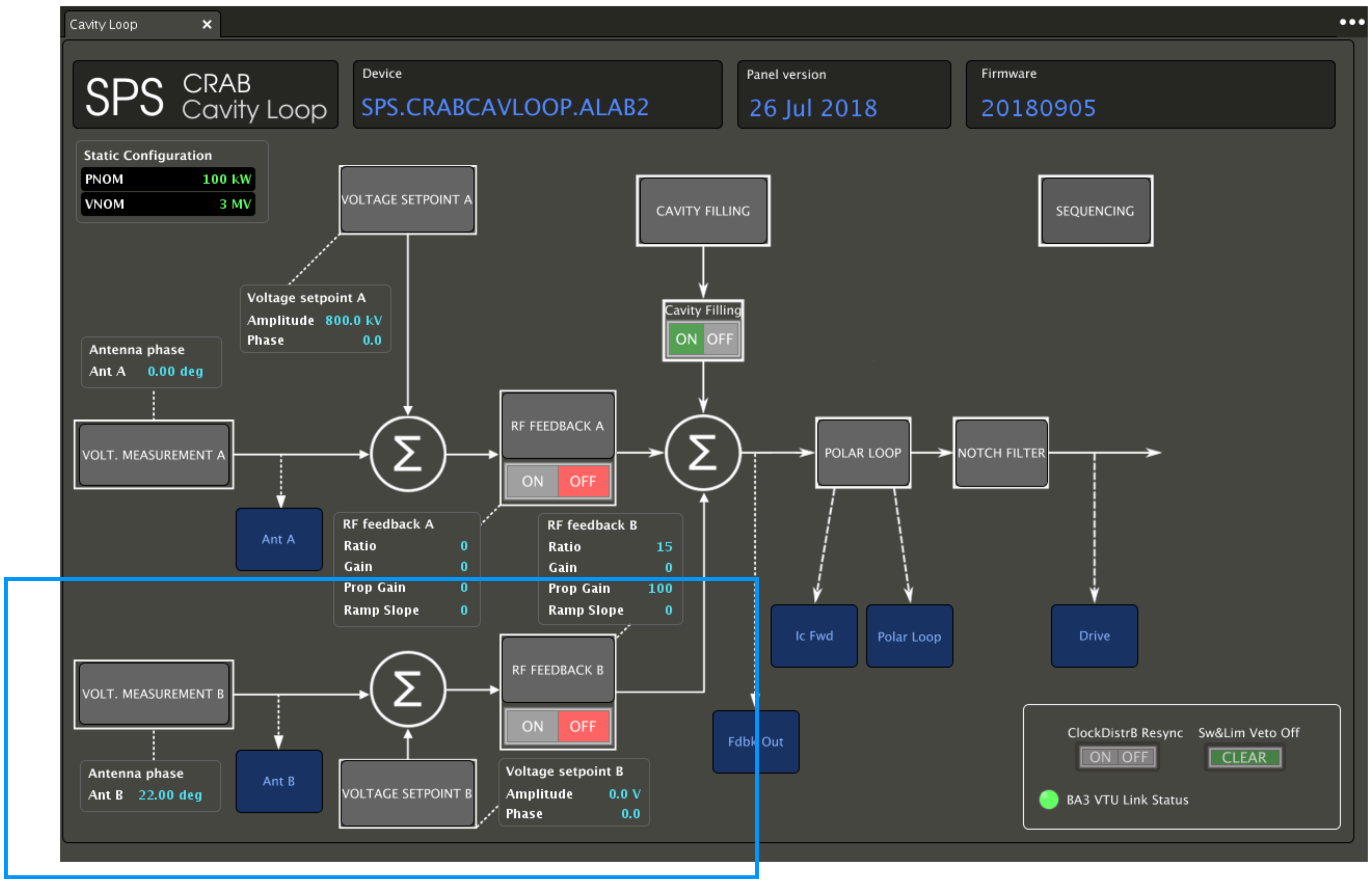
Function for voltage set-point

- Voltage set-point (Amp/Phase) can be changed by function.
  - Cavity phase scan w.r.t beam centre (Done : MD1-4)
  - Counter-phasing both CCs (to be tested this year?)



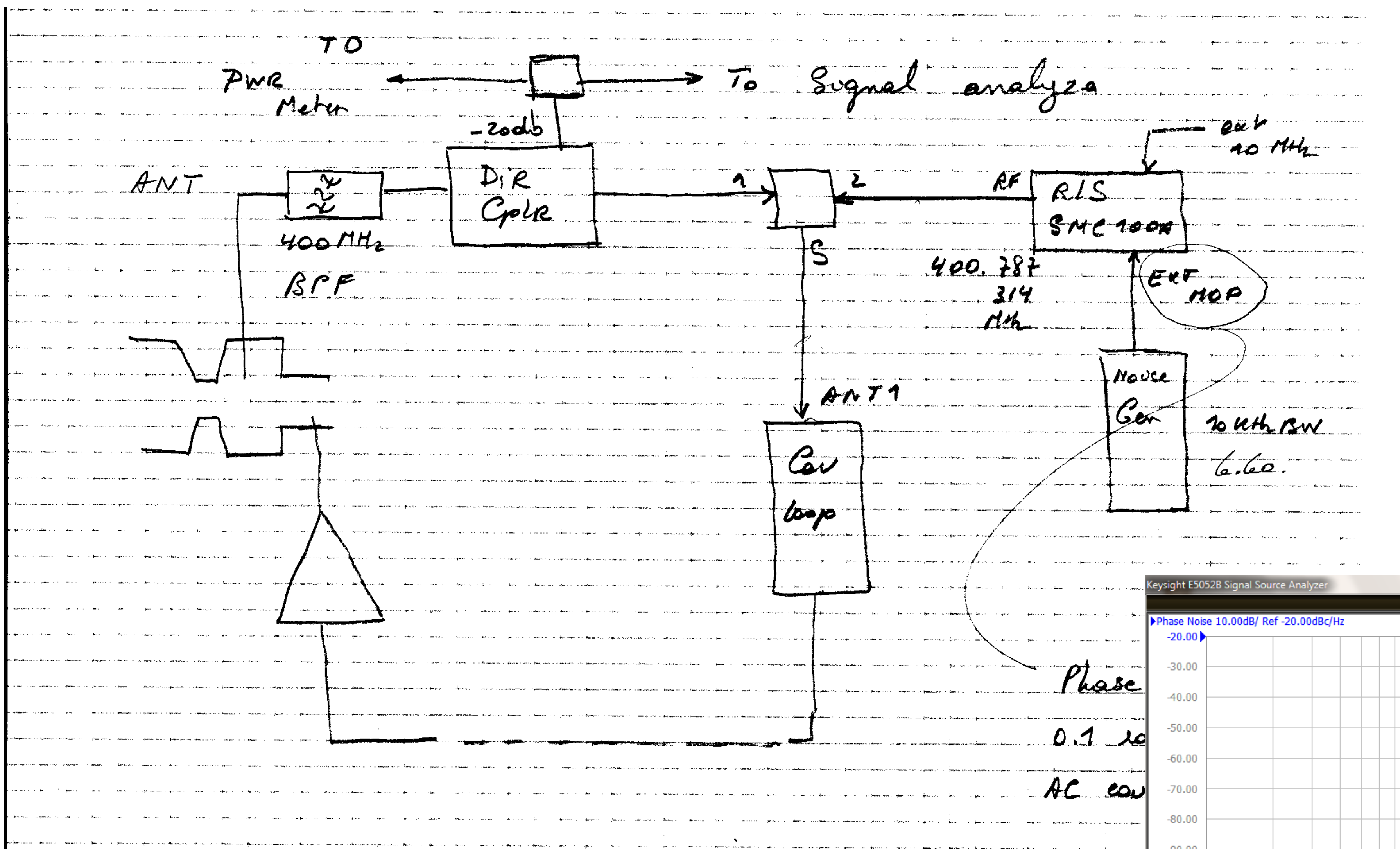
Coupled feedback system

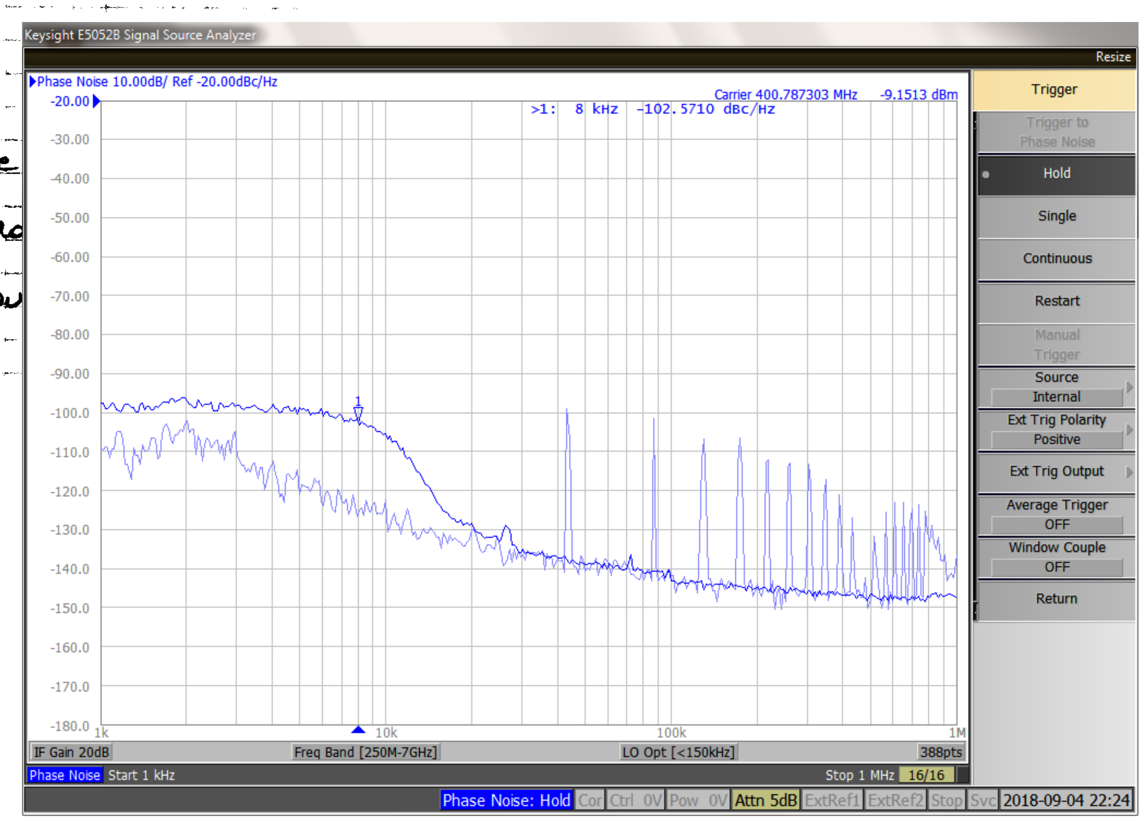
- Coupled feedback system: keep the two crab voltages equal by monitoring the difference. (Tested this year?)



Excitation noise injection

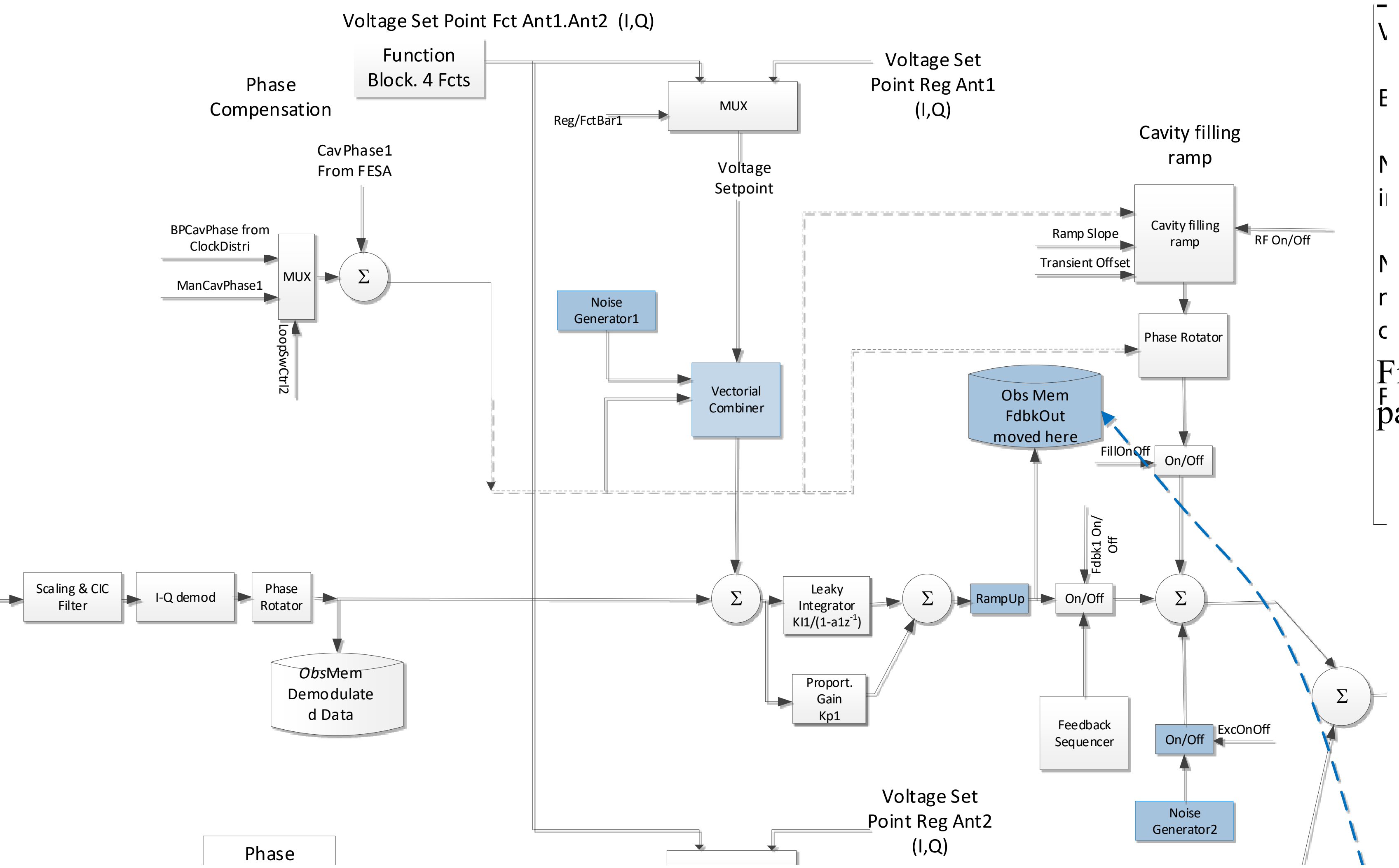
- Phase and amplitude noise (MD5: emittance growth measurements)





Online analysis of LLRF feedback system

- Adapted Python scripts from LHC LLRF system
- Open-loop and close-loop response at nominal TX power



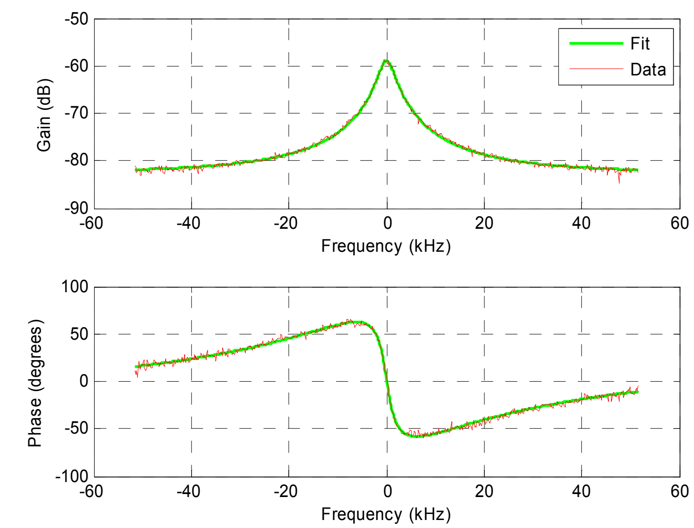


Figure 3: Magnitude and phase response of analog/digital paths.

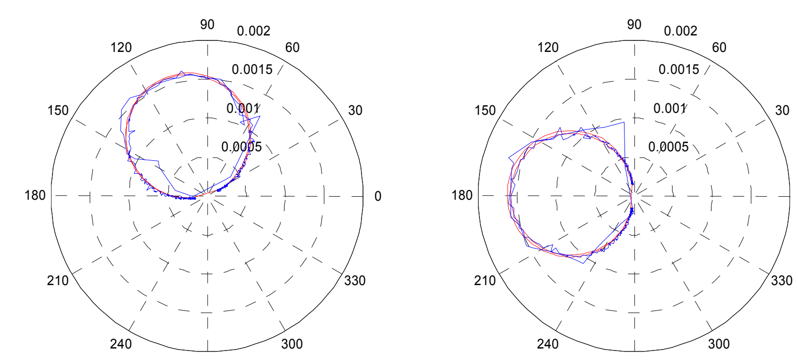


Figure 4: Initial and rotated loop phase.

[1] D.V. Winkle, et. al., Feedback configuration tools for LHC Low Level RF system, PAC09

Plans for next MDs

- Hopefully work with both cavities at >1MV
- Clean injection of amplitude and phase noise for transverse emittance growth measurement.
- Tuner Loop working if we are far enough from multipacting.
- High intensity batches ?
- Filtering of the ANT signal to reject direct coupling with beam passage
- Tighter clamping of demanded TX power to avoid tripping on transients

Excitation noise injection

- Phase and amplitude noise (emittance growth measurements)