

# SPS Crab cavity LLRF

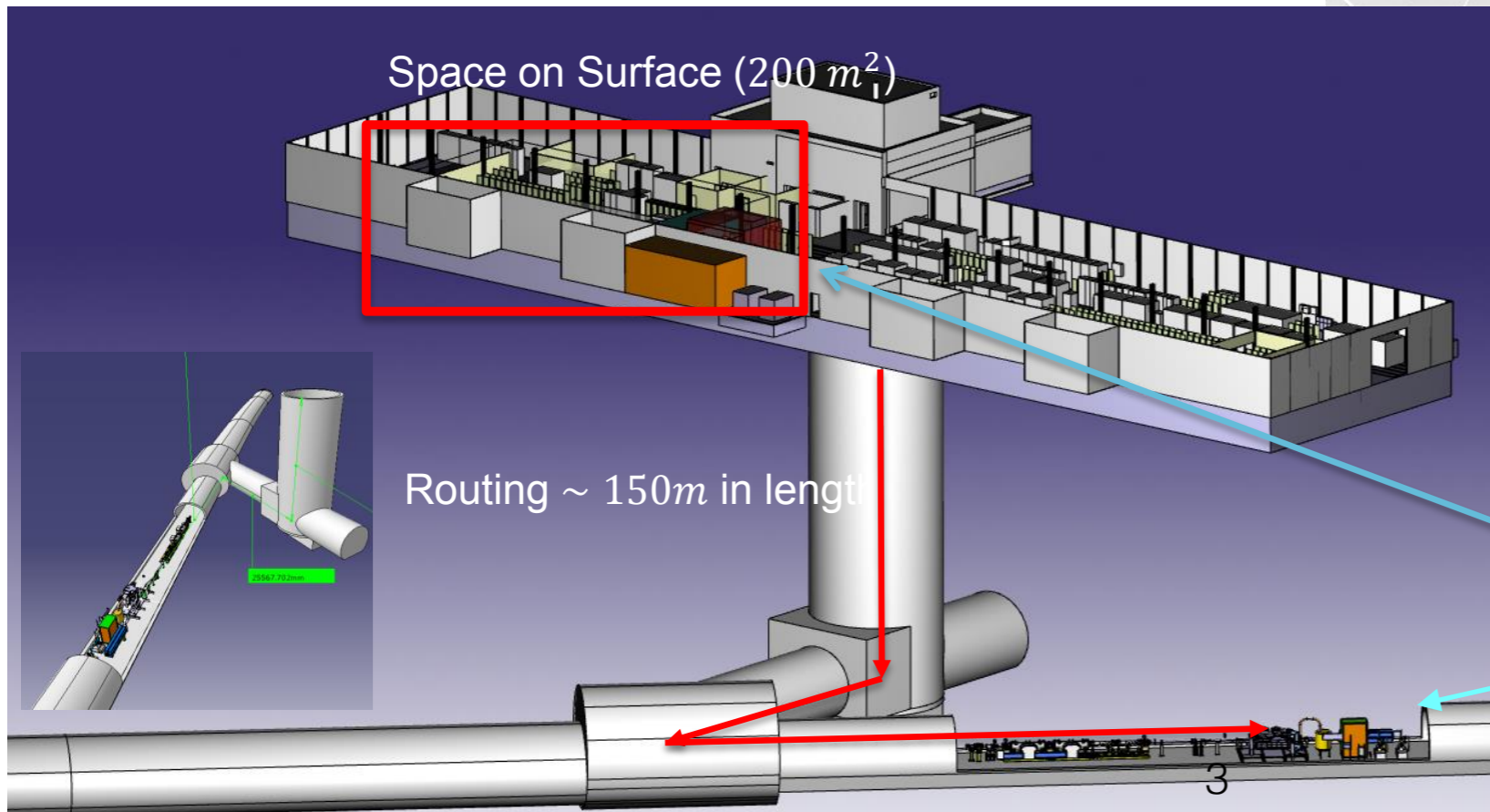
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# Contents

- 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

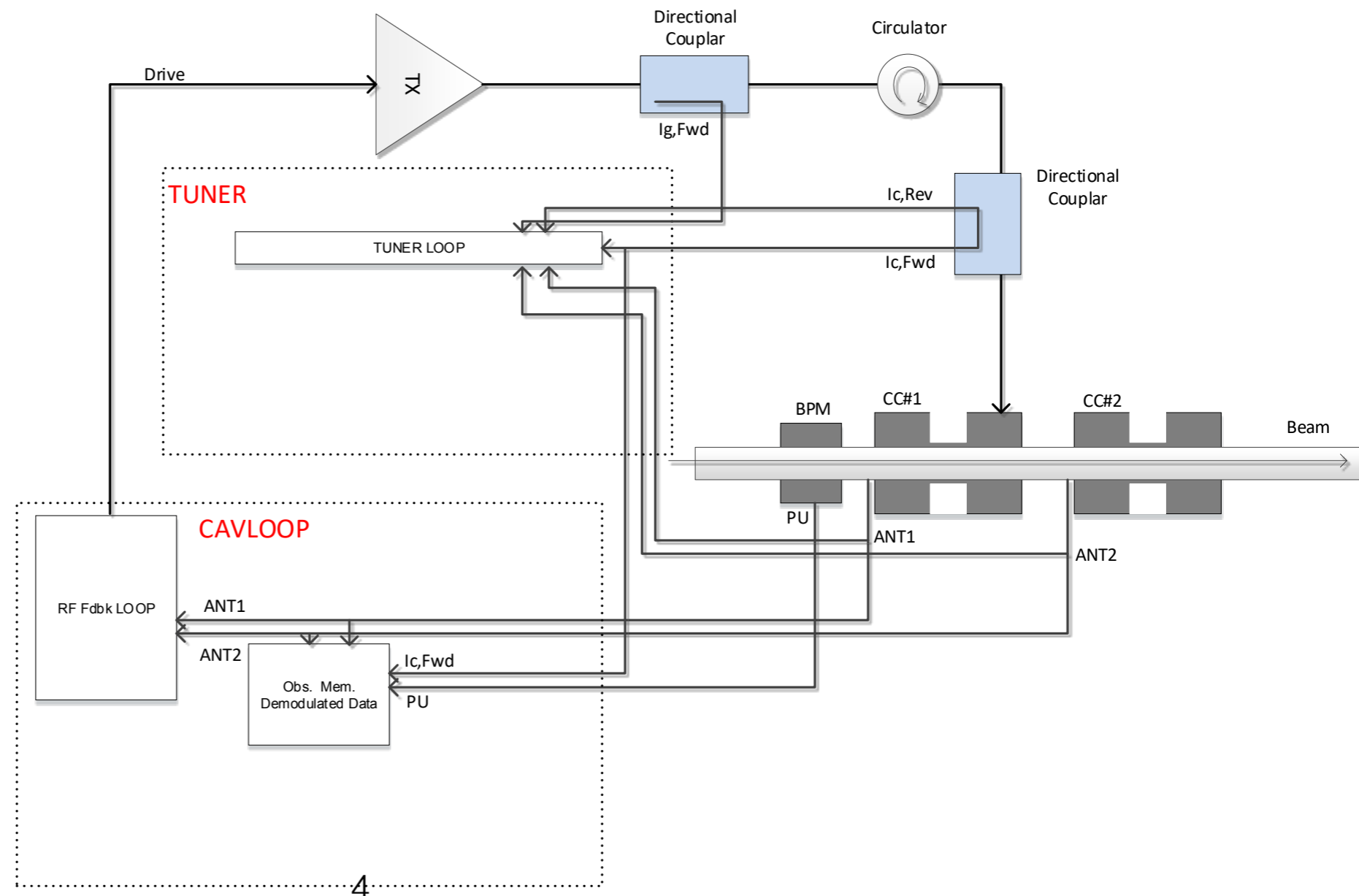


Faraday Cage

Crab Cavities (CCs)

# LLRF scheme

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



# LLRF modules



Tuner Loop module  
Adapted from L4

Cavity Loop module  
Adapted from SPS 800 MHz  
and L4  
firmware modified

# GUI panel: Tuner controls

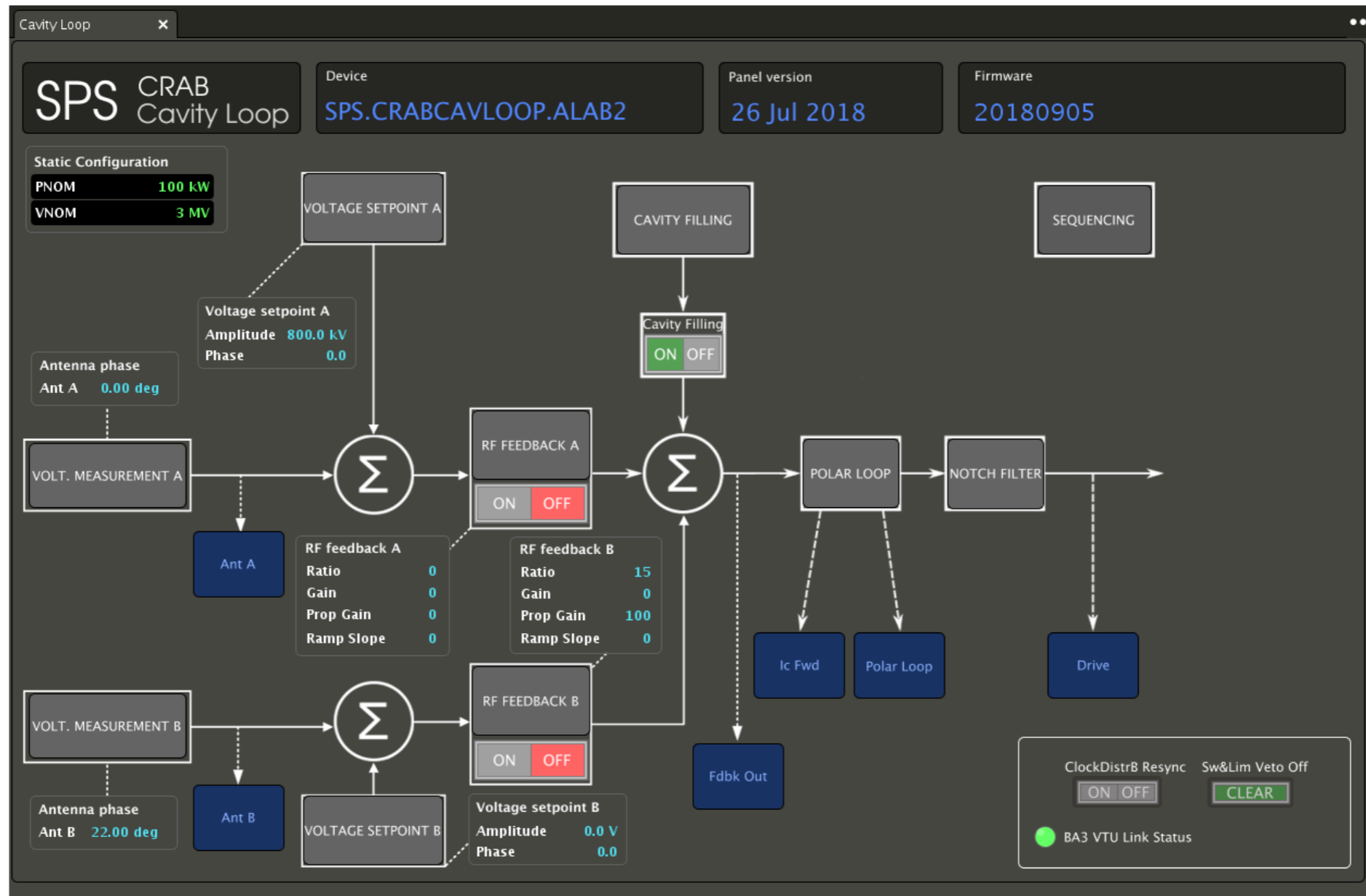
- GUI panel for Tuner control : adapted from Linac4. The CC tuner acts by deforming the deflecting gap. Its response is VERY slow (below 1/10 Hz).

The screenshot displays the 'Tuner Loop' GUI interface. At the top, it shows system information: 'SPS CRAB Tuner Loop', 'Device: BA6-CRAB2', 'Panel version: 17 July 2018', 'Frontend Firmware: 20160613', 'Firmware: 20161031', and 'Firmware revision: 3ec9a85a'. The main interface is divided into several sections:

- Status:** Features a semi-circular gauge for 'Tuning error' with a needle pointing to 34. The gauge has a scale from -500.0 to 500.0. To the right are radio buttons for 'Dead band', 'Permit', 'Active', and 'Locked'. Below the gauge is a 'Steps' counter showing 0.
- Motor 1:** Shows a 'Success' status. It includes a vertical slider for 'PotMeter Position' (value 1545) and a 'Direction' indicator (value 252211). Radio buttons for 'Calibrating' and 'Moving' are present. A mode selector at the bottom has 'Manual' selected, with other options being 'Noop', 'Calibration', and 'Loop'. Below this is a 'Steps' slider ranging from 0 to 16000.
- Control:** Contains an 'Enable/Disable' toggle (currently 'Disable' is active). Below it is a 'Loop settings' section with a 'Gain' input field set to 10000.000. There are dropdown menus for 'Input drive' (set to 'IcFwd1') and 'Input VCav' (set to 'ANT1'). At the bottom, a display shows 'iqPhRotIcFwd1' with a value of 139.998 and a target value of 139.99756, with a 'Set' button.
- Buttons:** A row of buttons includes 'Faults' (green), 'Status' (red), 'Guru Control', 'VCavs', and 'Tuning error'.

# 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



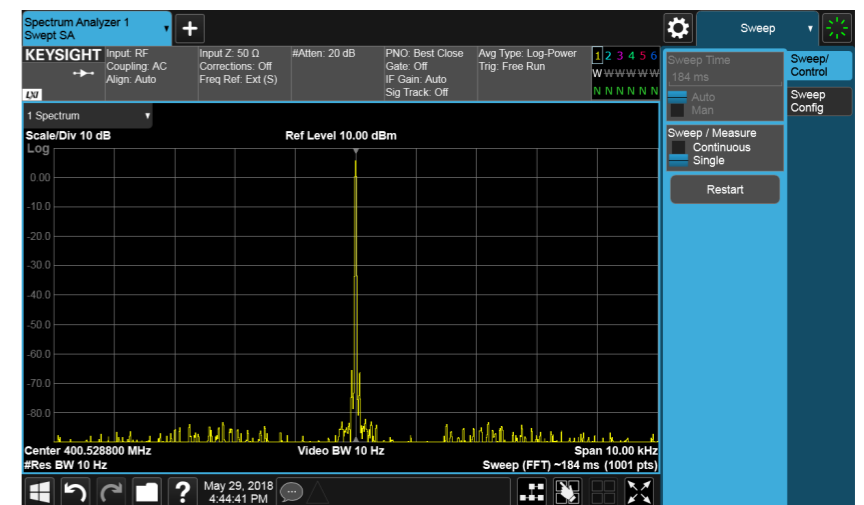
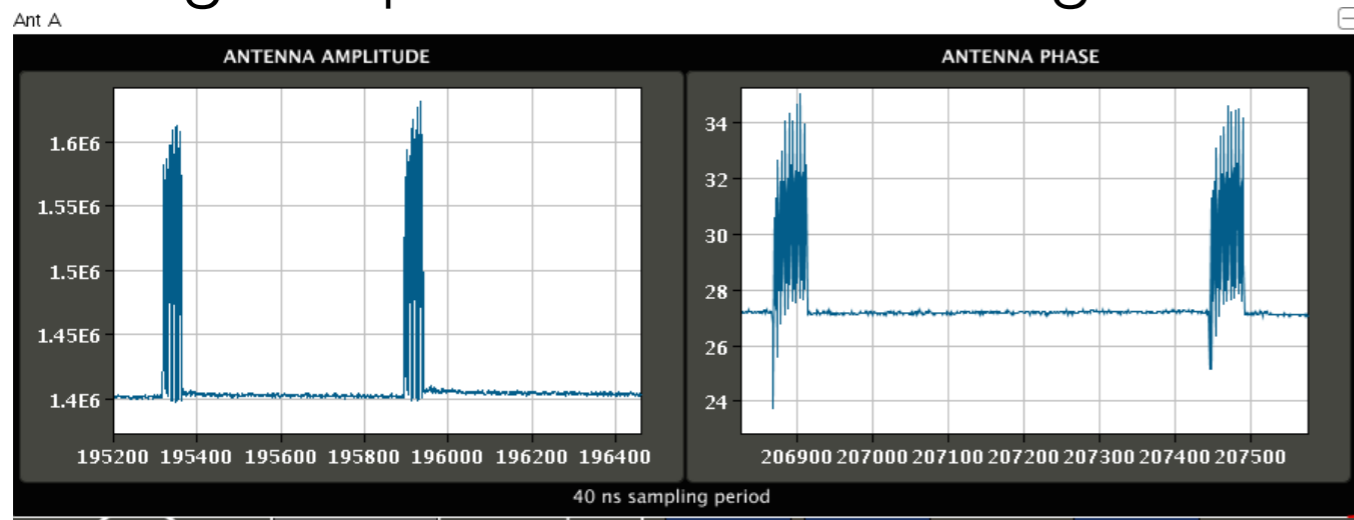
# Tuner Loop

- 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  $< 800\text{kV}$ : Loop works OK on CC2
    - cavity field  $> 800\text{kV}$ : 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.



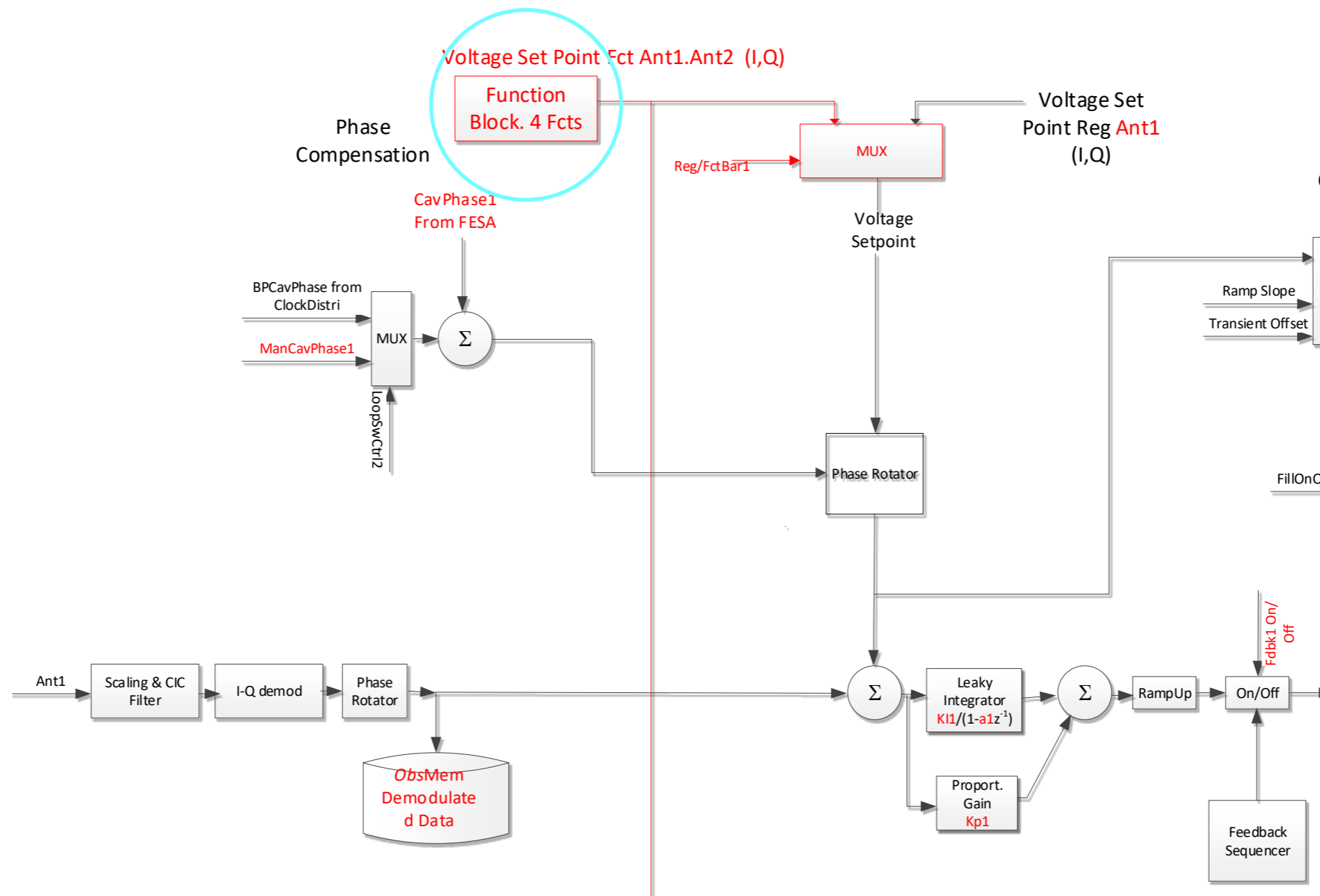
— Setting up FDBK is not easy due to the non-linearity of IOT amplifier. Nominal transmitter power is 100 kW, while we operate around 1-2 kW. So the fdbk phase/gain must be adjusted as we increase the field. Tedious...

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

# LLRF features for CCs

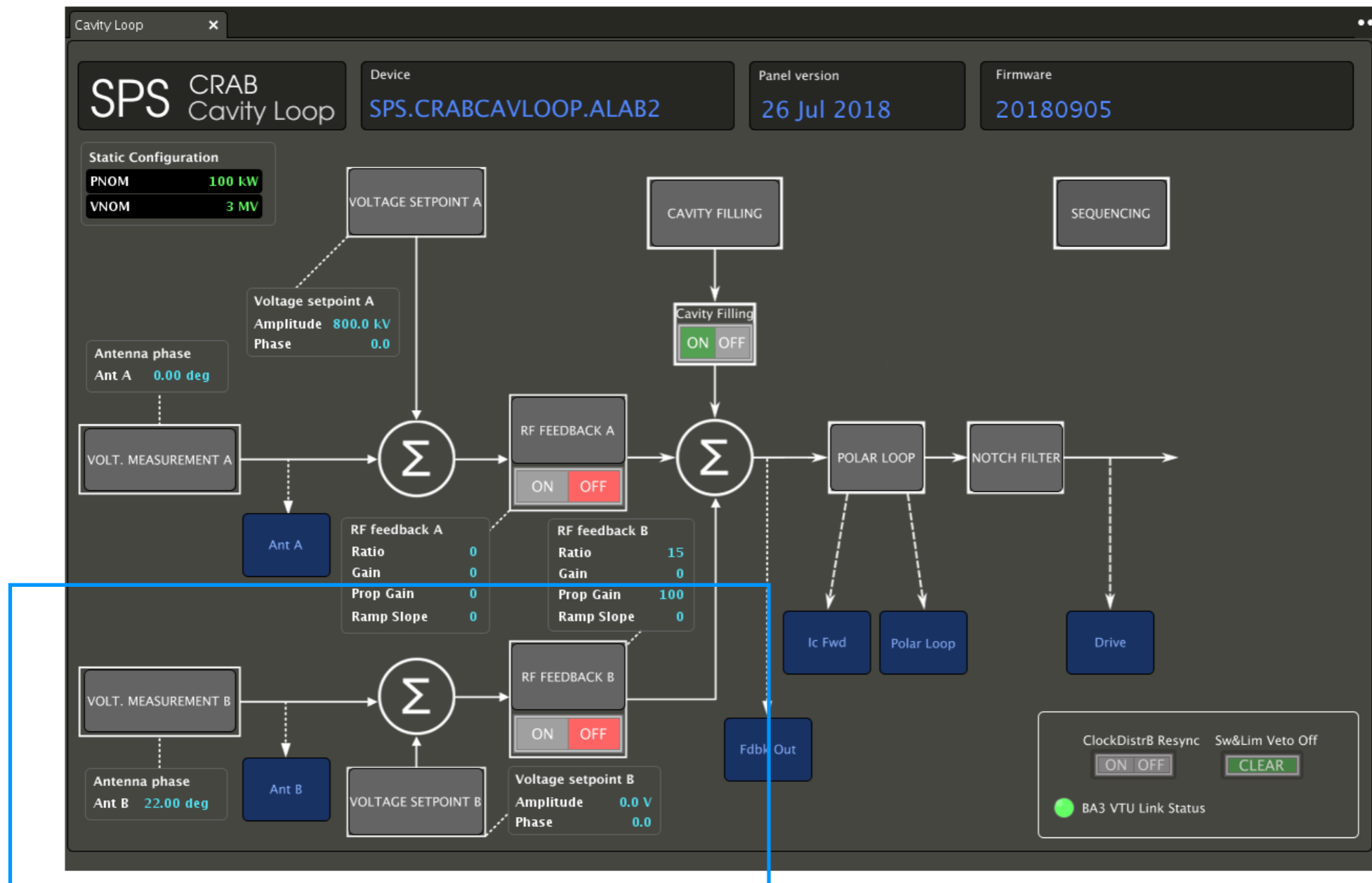
# Function for voltage set-point

- 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?)



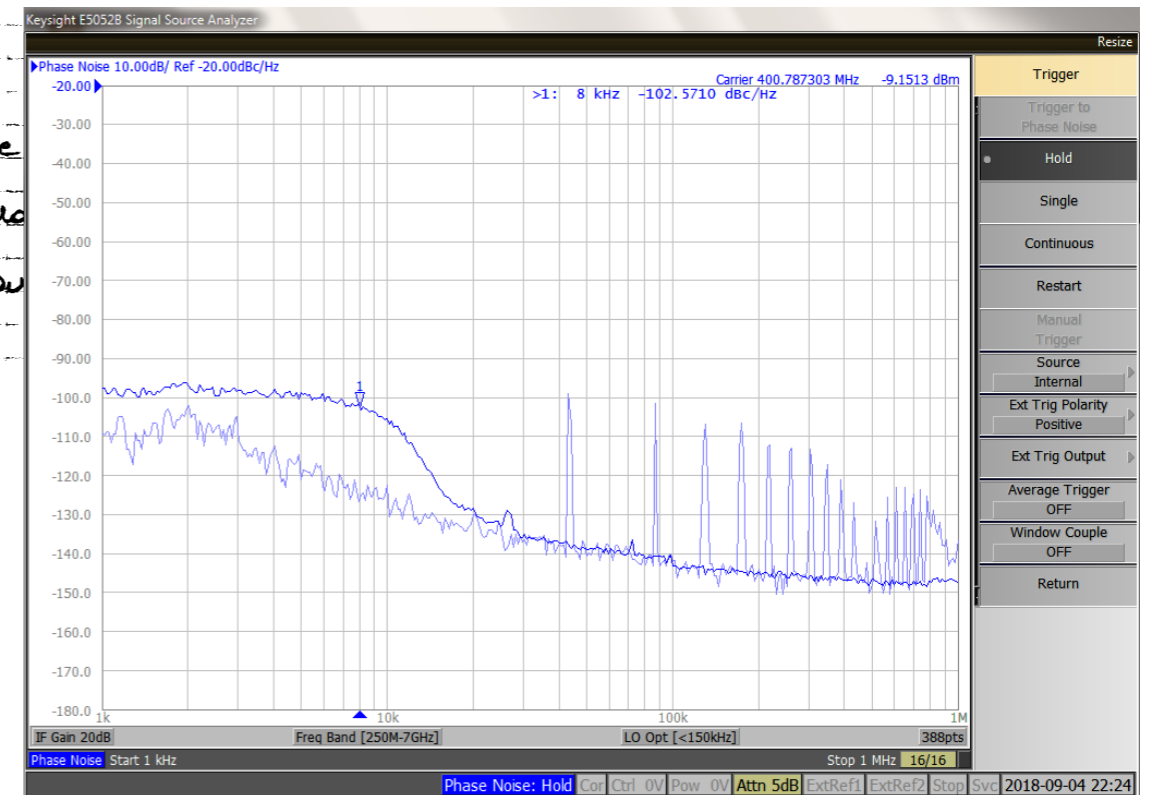
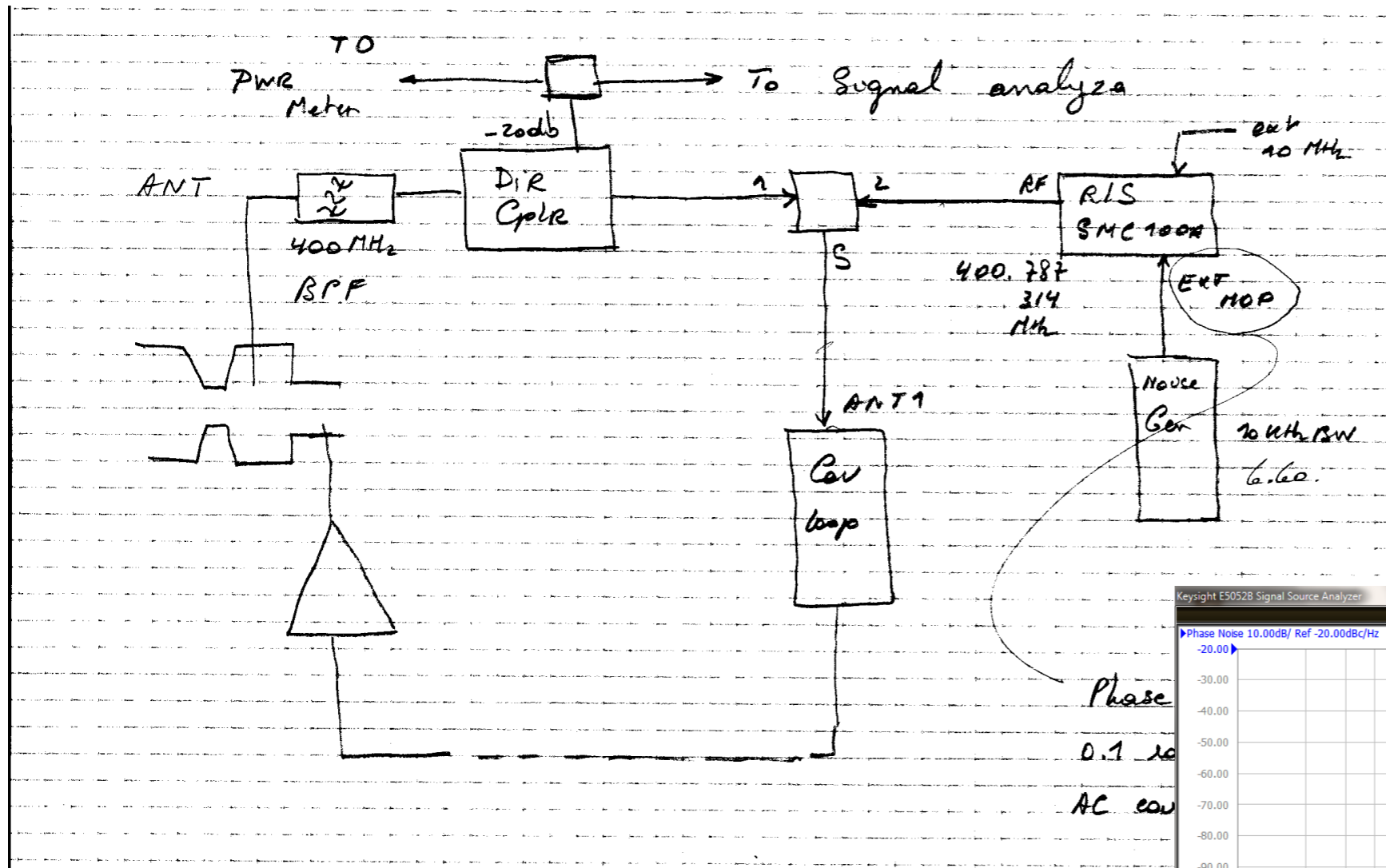
# Coupled feedback system

- 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

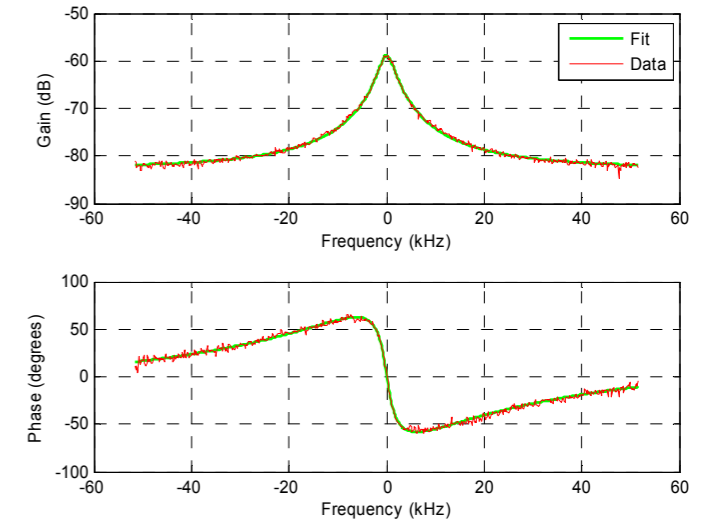
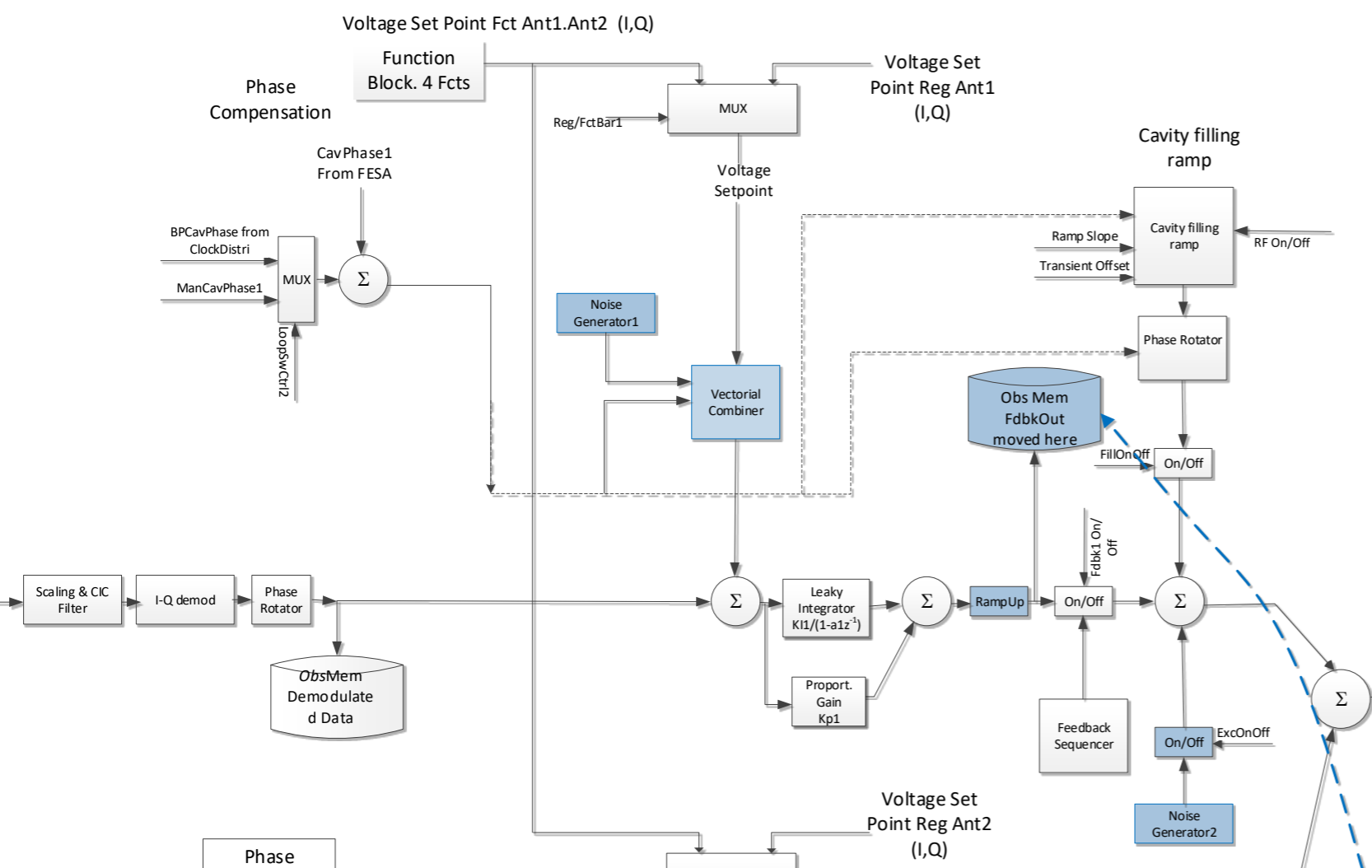


Figure 3: Magnitude and phase response of analog/digital paths.

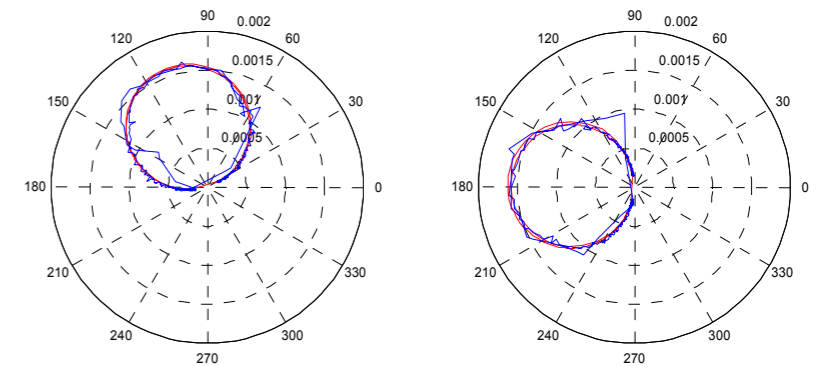


Figure 4: Initial and rotated loop phase.

[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  $>1\text{MV}$
- 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)

