HL-LHC Low Level RF

SM18 RFD CryoModule tests

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Objectives for SM18 test stand

- LLRF objectives (RFD C2)
  - Commissioning of newly installed LLRF (additional HW to BA6)
  - New RF front-end (ease RF calibration, LLRF setting-up)
  - New Polar-Loop (PL): gain/phase loop around amplifier
    - Linearize amplifier gain and phase (wrt to power)
    - Restore open-loop phase for Fdbk
  - New TunerLoop firmware and software
  - Partial software migration to non-multiplex (keeping SPS timing)
- Preparation for BA6 MDs
  - Gaining experience on RFD cavities
  - Migration to non-multiplex and CW operation (RF ON/OFF sequence)
  - Deployment/Debugging of new feature in SM18 rather than in BA6
- LLRF as a tool for SRF (cryomodules validation)
  - Voltage ramp up to 3.4MV (SEL or Driven loop)
  - Measurement of the cavity parameters

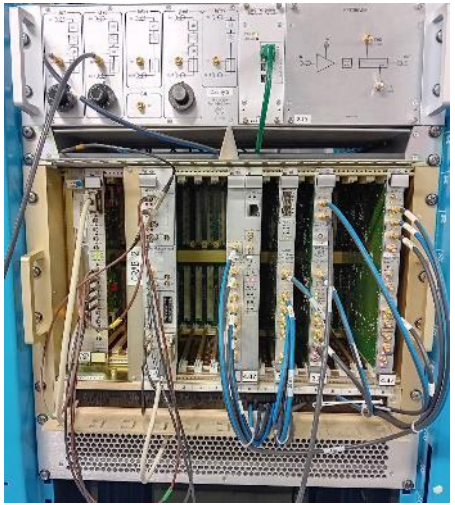

Fig – LLRF Hardware

Summary on RFD C2 tests

- RF Front-end module commissioned
  - RF calibration (LLRF acq based on power sensors)
  - Ease calibration (decoupling LLRF and cable/cavity calib)
- TunerLoop module commissioned
  - Heritage from L4
  - Multiple firmware issues solved (metastability, CDC, improved prevision for low level signals)
  - New software commissioned (FESA, inspector)
- Self-Excitation Loop (SEL) commissioned
  - Operational even w/o circulator
  - Fine tuning (phase) necessary for smooth switch over to DrivenLoop
  - Operation with short pulses (10ms) → 3.7MV
- Switch&Limit commissioned
  - Drive chain calibrated at 1MV (1.5kW)
  - Very dependent on amplifier gain non-linearity (Polar-loop will compensate for it)

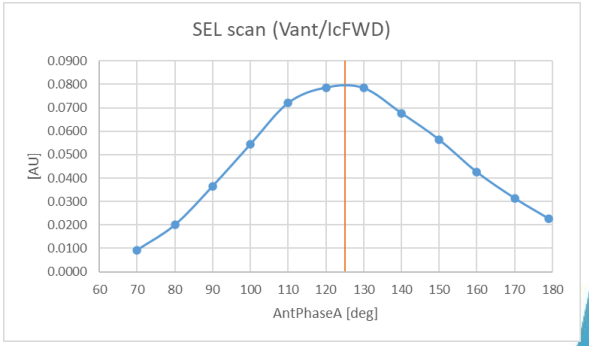

Fig – Phase scan for SEL

Summary on RFD C2 tests

- DrivenLoop commissioned
  - Impossible w/o circulator
  - Low ponderomotive oscillations if well on tune (Stable TunerLoop operation is necessary)
- RF Feedback commissioned
  - Total loop group delay RFD C2: 1600ns
  - Proportional gain used only: Gp=40 (32dB impedance reduction, theoretical max value Gp=120)
  - HL-LHC target : 1200ns, Gp=150
  - Missing controls added (AC coupler, Setpoint, etc.)
  - New software commissioned (FESA, inspector)
- PolarLoop (PL) commissioned
  - Non-optimal settings to cope with 60dB coupler
  - Phase loop working fine (Gain = 0.5)
  - Gain loop issue to be investigate (Gain=0.005)
  - Gain loop operational with SEL
  - Automatic operation with >600W, >600kV

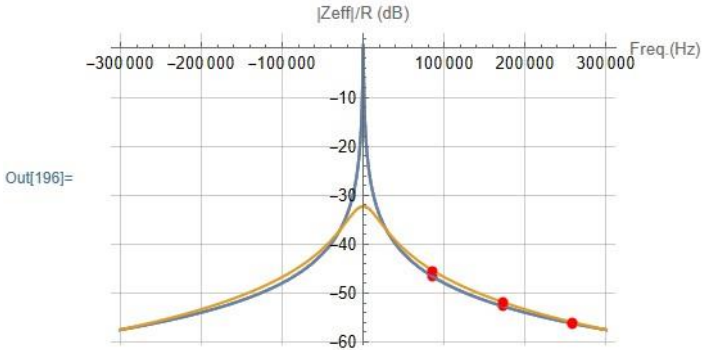

Fig – Cavity impedance with & w/o feedback

Summary on RFD C2 tests

- RF noise similar to BA6
  - Dominated by RF receiver noise (Clock, LO, ADC)
  - Fdbk gain of 32dB
  - Peaking due to the PolarLoop around 70kHz (to be investigate)

Fig – PN in open-loop

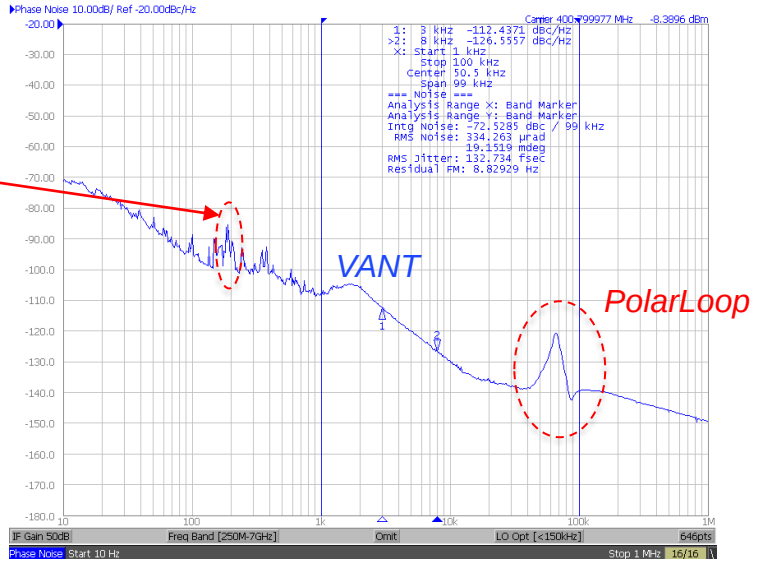

Fig – PN in close-loop (PL+FDBK)

Next steps, SM18

- LLRF commissioning on 2nd Cavity (sept 2024)
  - 50dB forward coupler? (IgFWD, IcFWD)
- Migration to CW operation
  - Non-multiplex operation, decoupled from SPS timing
  - More efficient for SM18 tests and SPS MD's
  - RF on/off sequence
  - Mainly a software task (try minimizing firmware changes)
  - Firmware change to switch over from SEL to DrivenLoop
- Consolidation of the controls
  - Units, conversion factors, acquisition, etc.
  - Automatic phase scan?
- We need to minimize the work on the VME platform
  - Priority must be put on final hardware (MTCA)