SRF Test Results and Current Status of the Low Energy Superconducting Linac for RAON

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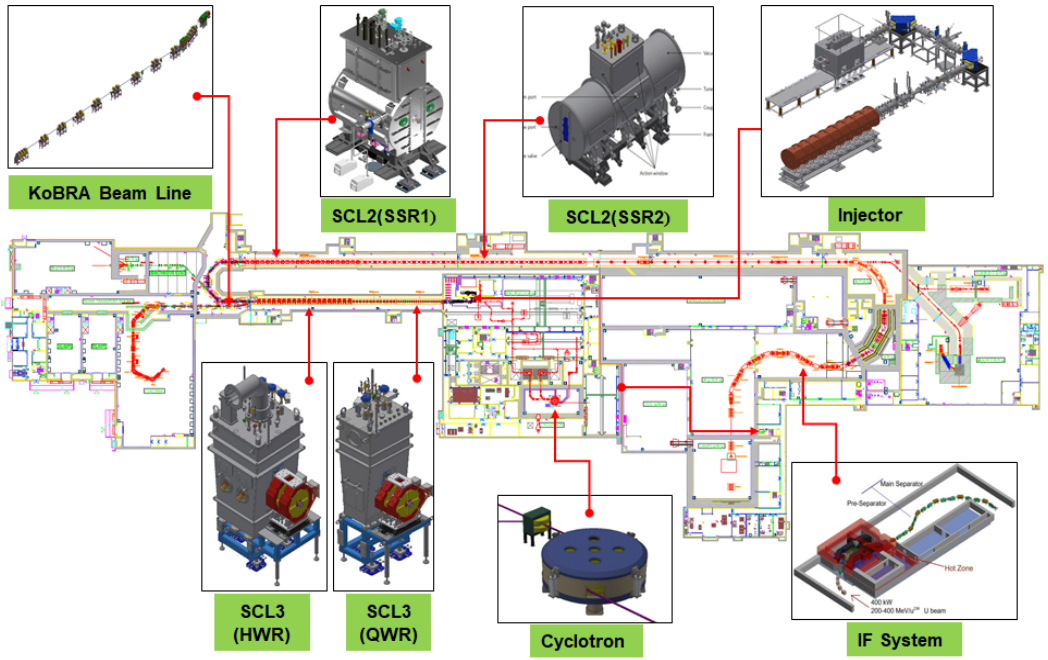
Overview of the Low Energy Superconducting Linac

RAON

▢ The low energy superconducting linac(SCL3) is composed of 22 of QWR, 13 HWR-A(2 HWRs), and 19 HWR-B(4 HWRs) cryomodules.



Module Type	Cavity Type	# of modules	# of cavities per module	# of cavities
QWR	QWR(81.25MHz)	22	1	22
HWRA	HWR(162.5MHz)	13	2	26
HWRB	HWR(162.5MHz)	19	4	76
Total Sum				124

Status of the Low Energy Superconducting Linac

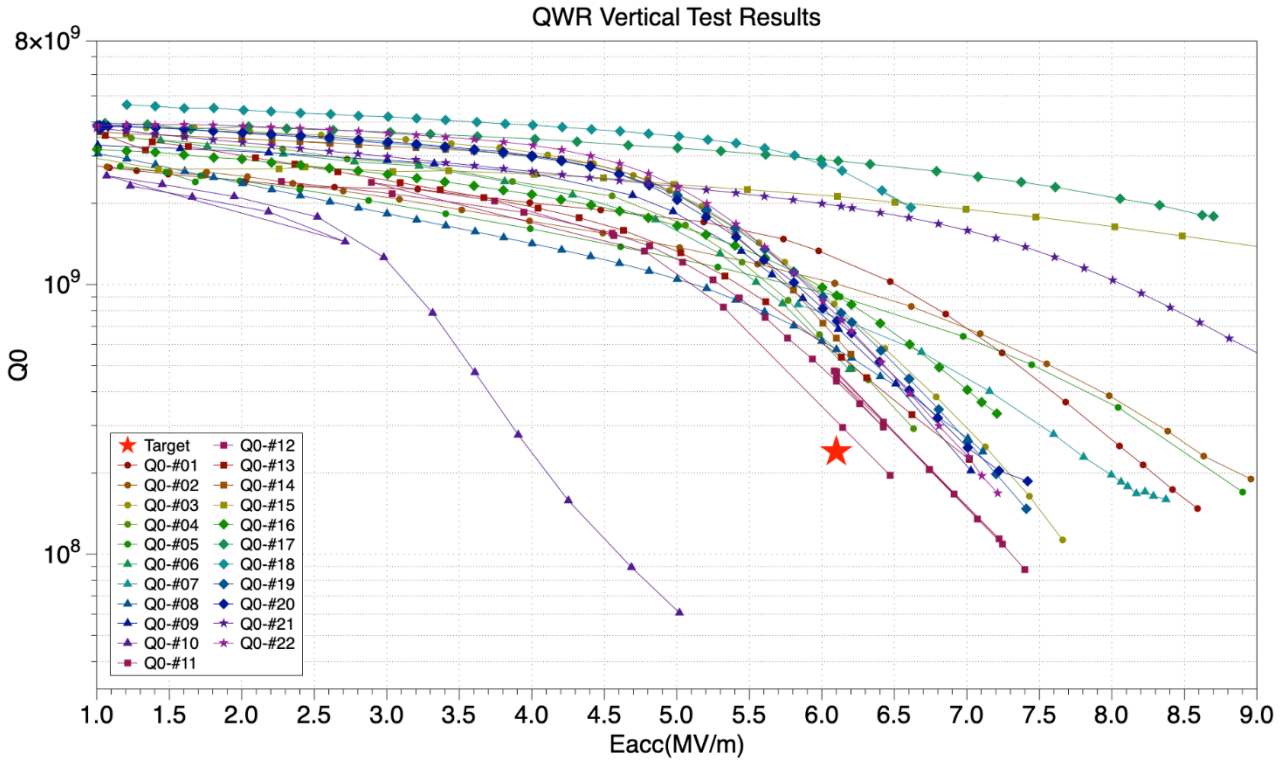
- Installation was finished at the end of the last year 2021.
- The first cool-down started at 7th September, 2022. (50% completed)
- RF conditioning and control test are in progress for 6 QWRs to check initial status of the stability of LHe and external disturbances. Cryogenic team and RF team are in collaboration for seeking the source of microphonics.

Low energy superconducting linac at tunnel

RF system at gallery

Vertical Test Results for QWRs

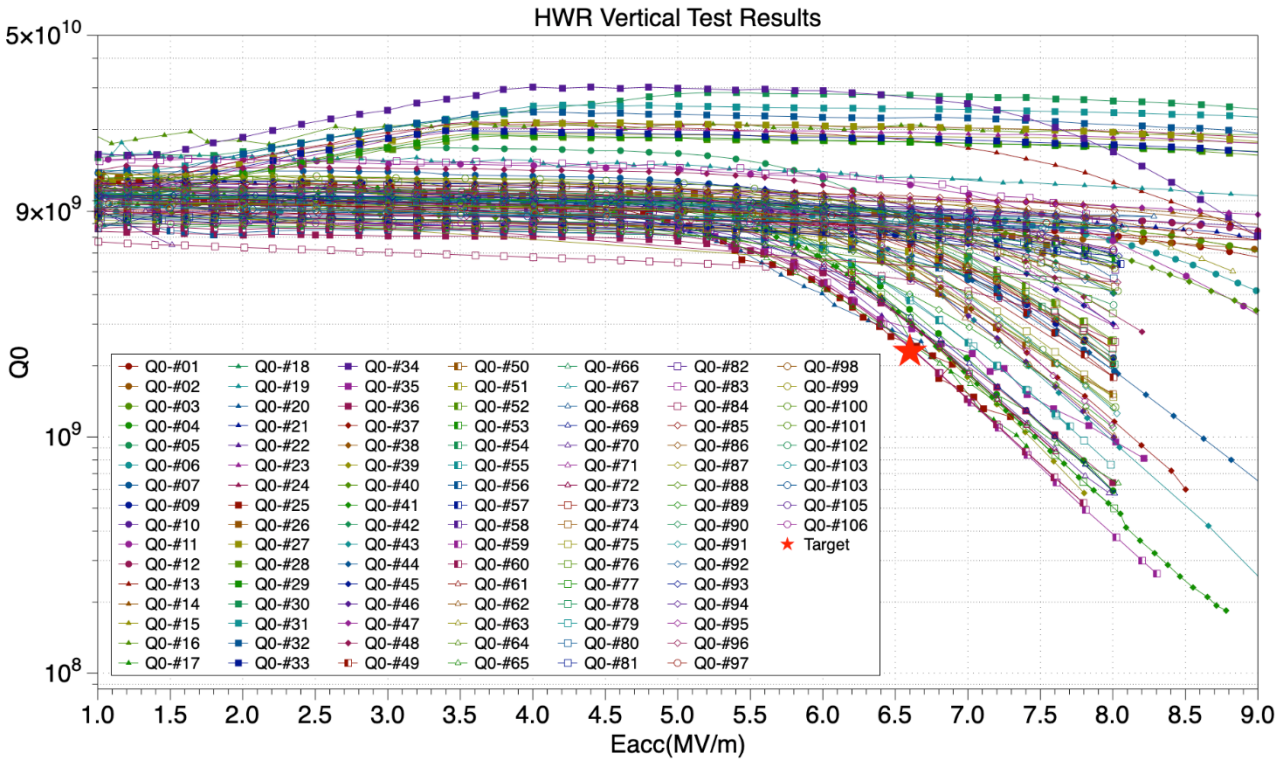
	QWR
β_{opt}	0.047
f [MHz]	81.25
L_{eff}	173.5
R/Q [Ω]	469
E_p/E_{acc}	5.7
B_p/E_{acc} [mT/(MV/m)^2]	10.4
E_{acc} [MV/m]	6.1
V_{acc} [MV]	1.06
QR_s	18.1



$$Target\ Q_0 = 2.3\times10^8\ at\ E_{acc} = 6.1 MV/m$$

Vertical Test Results for HWRs

	HWR
β_{opt}	0.12
f [MHz]	162.5
L_{eff}	221.5
R/Q [Ω]	295
E_p/E_{acc}	5.2
B_p/E_{acc} [mT/(MV/m)^2]	9
E_{acc} [MV/m]	6.6
V_{acc} [MV]	1.46
QR_s	36.8



$$Target\ Q_0 = 2.3\times10^9\ at\ E_{acc} = 6.6MV/m$$

Horizontal Test Procedure

Installation in the bunker

- Cavity frequency check & tuner operation test
- Leak test and vacuum pumping for cavity
- Leak test and Purging cryogenic pipes
- Connecting cryogenic lines, signal cables, DC bias, RF transmission lines, etc.

Cool-down

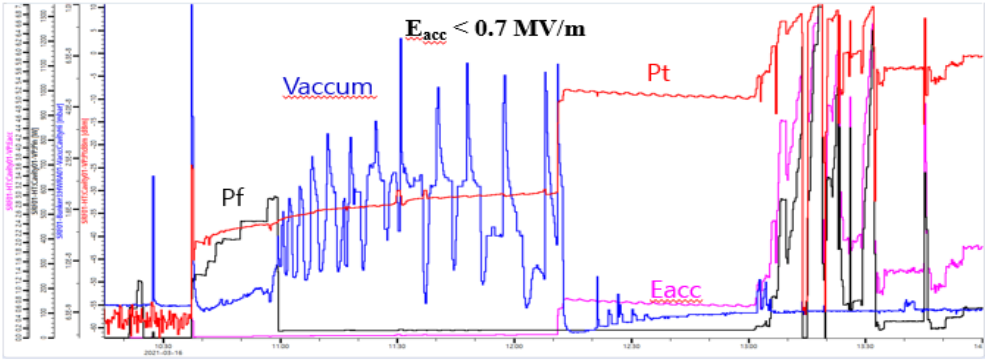
- Thermal shield cool-down by LN2
- Cavity cool-down through cool-down line

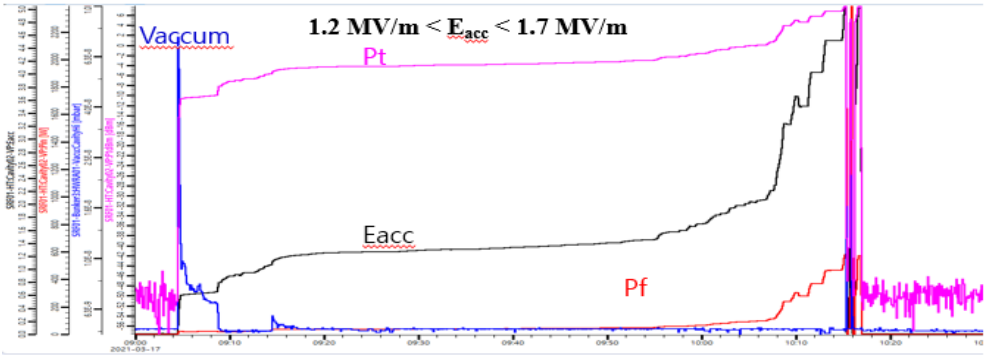
4 K Test

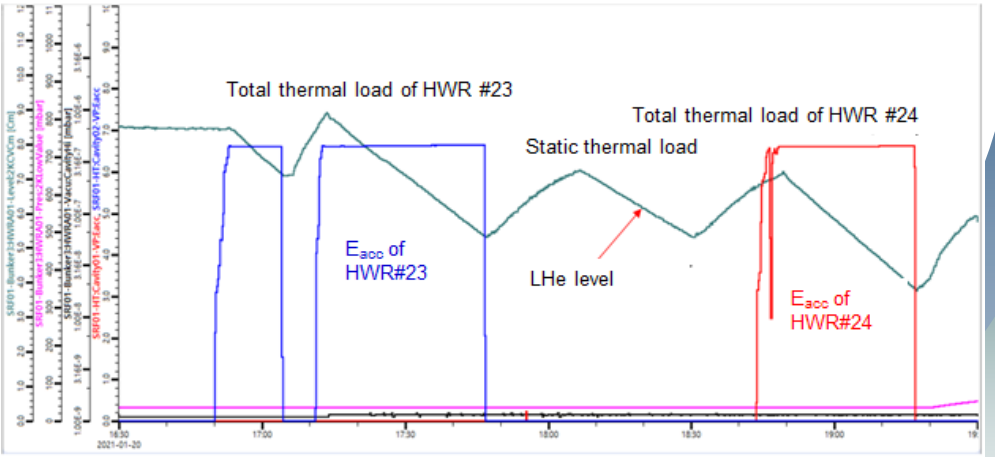
- Cable calibration
- MP conditioning
- Static and total thermal load measurement (Fig. 6)
- Field emission conditioning with pulsed RF power, if necessary

2 K Test

- 2 K pump-down: df/dp measurement (2~3MV/m)
- Q_{ext} measurement with vector network analyzer
- Static and total thermal load measurement
- LFD (Fig. 10) & tuner operation test
- RF control test

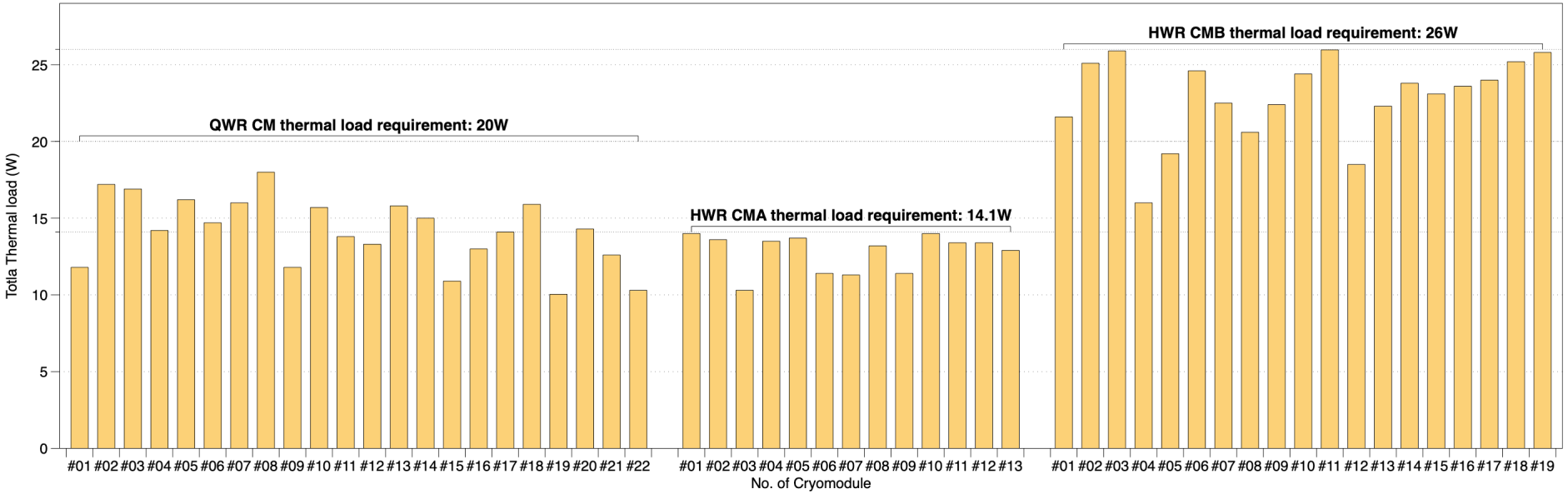


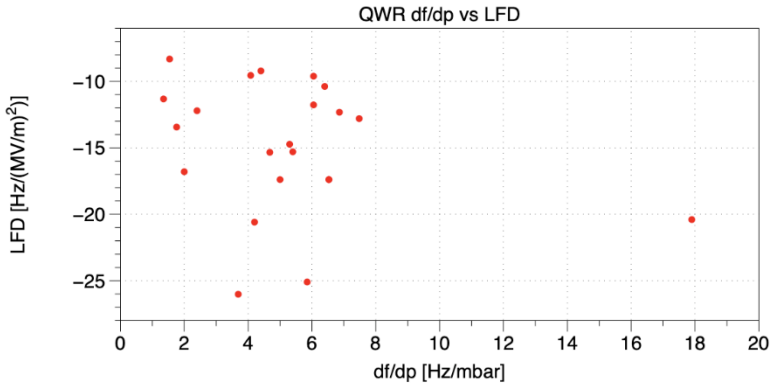


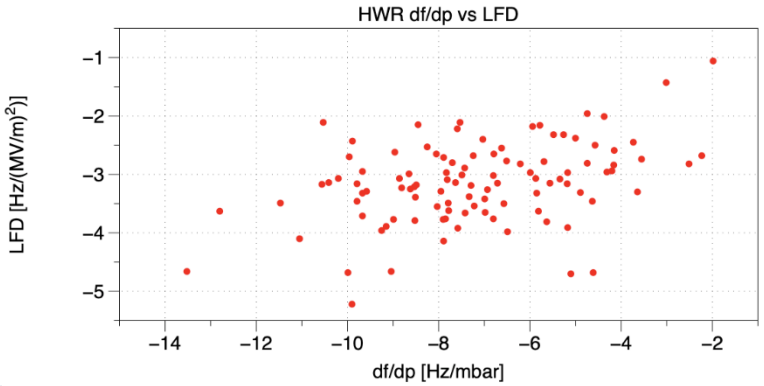


Horizontal Test Results for QWRs and HWRs

- Thermal load requirement
  - QWR CM:20W, HWR CMA: 14W, HWR CMB: 26W
  - QWR operation : 6.1MV/m @ 4.5K, HWR operation : 6.6MV/m @ 2.05K

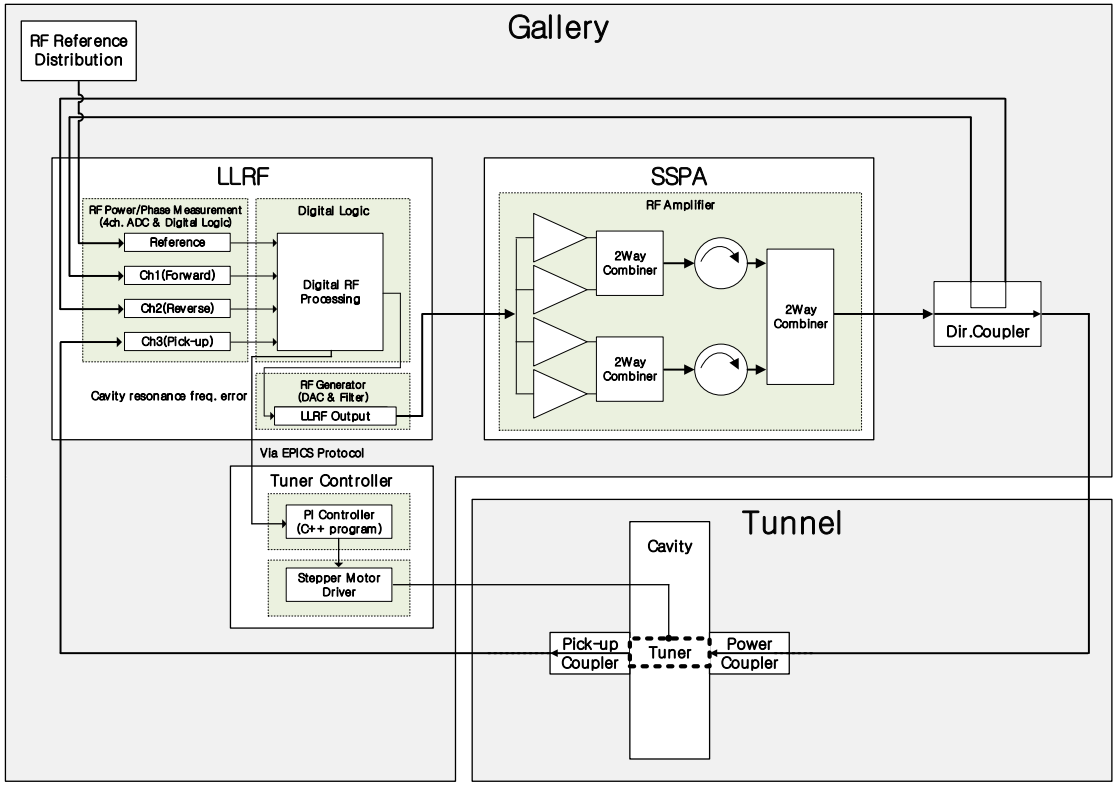






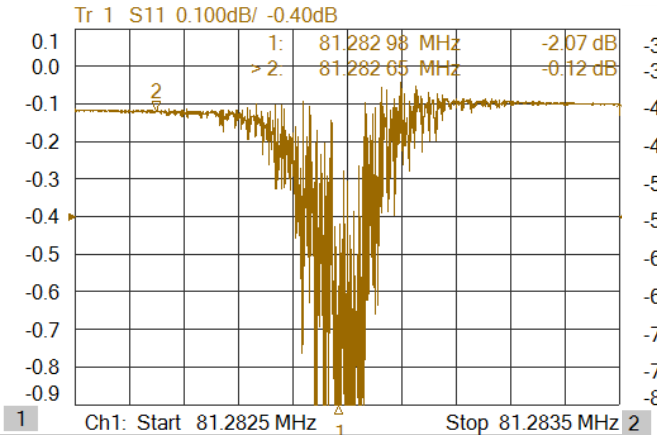
RF System for QWRs and HWRs

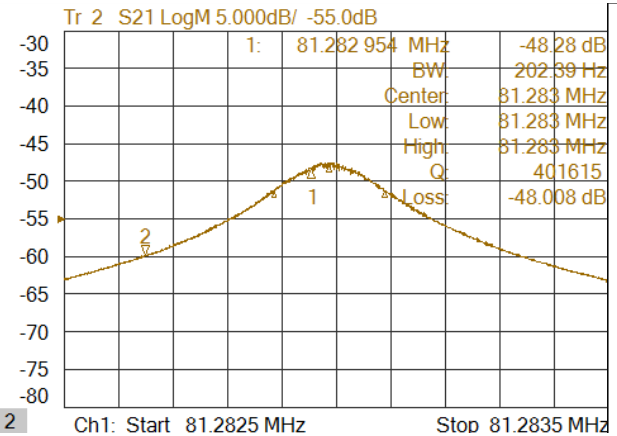
- QWR(81.25MHz 4kW) SSPA 22ea, HWR(162.5MHz 4kW) SSPA 102ea
- LLRF regulates RF amplitude and phase of the pick-up signal. Also, it supports SEL mode for RF conditioning and initial RF start-up.
- Tuner control server is in the LLRF rack. The server sends instruction to the motor driver in the cryomodule control rack.

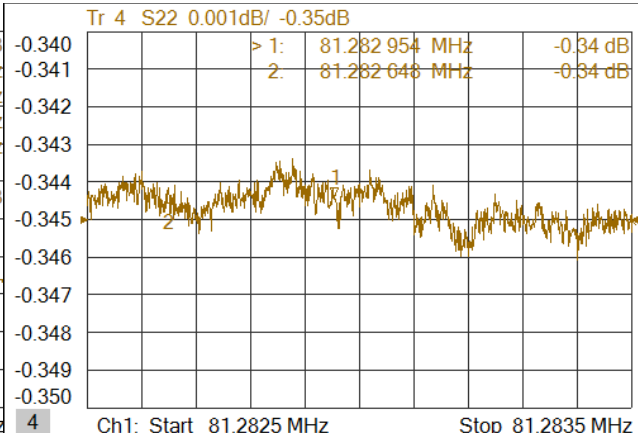


QL Measurement Results (QWR#01-#06)

- Loaded Q measurement results using VNA after cooling down (QWR#01-06)





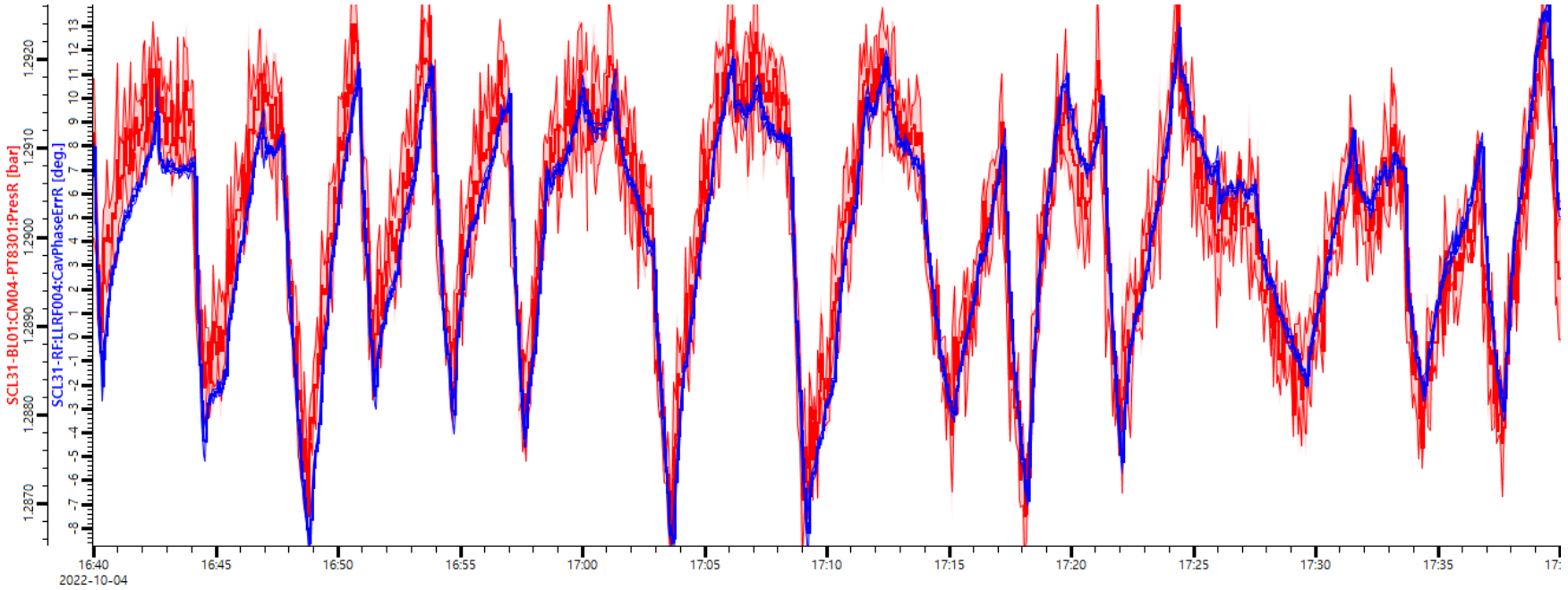


QWR CM number	#01	#02	#03	#04	#05	#06
Freq [MHz]	81.275	81.2829	81.275	81.2829	81.281	81.281
QL	6.78E+05	4.57E+05	5.07E+05	4.02E+05	6.95E+05	4.63E+05
Qt	9.56E+10	7.14E+10	1.13E+11	1.03E+11	9.49E+10	1.15E+11
Control BW[Hz]	120	178	160	202	117	176

Frequency drift vs Helium Pressure(QWR#04)

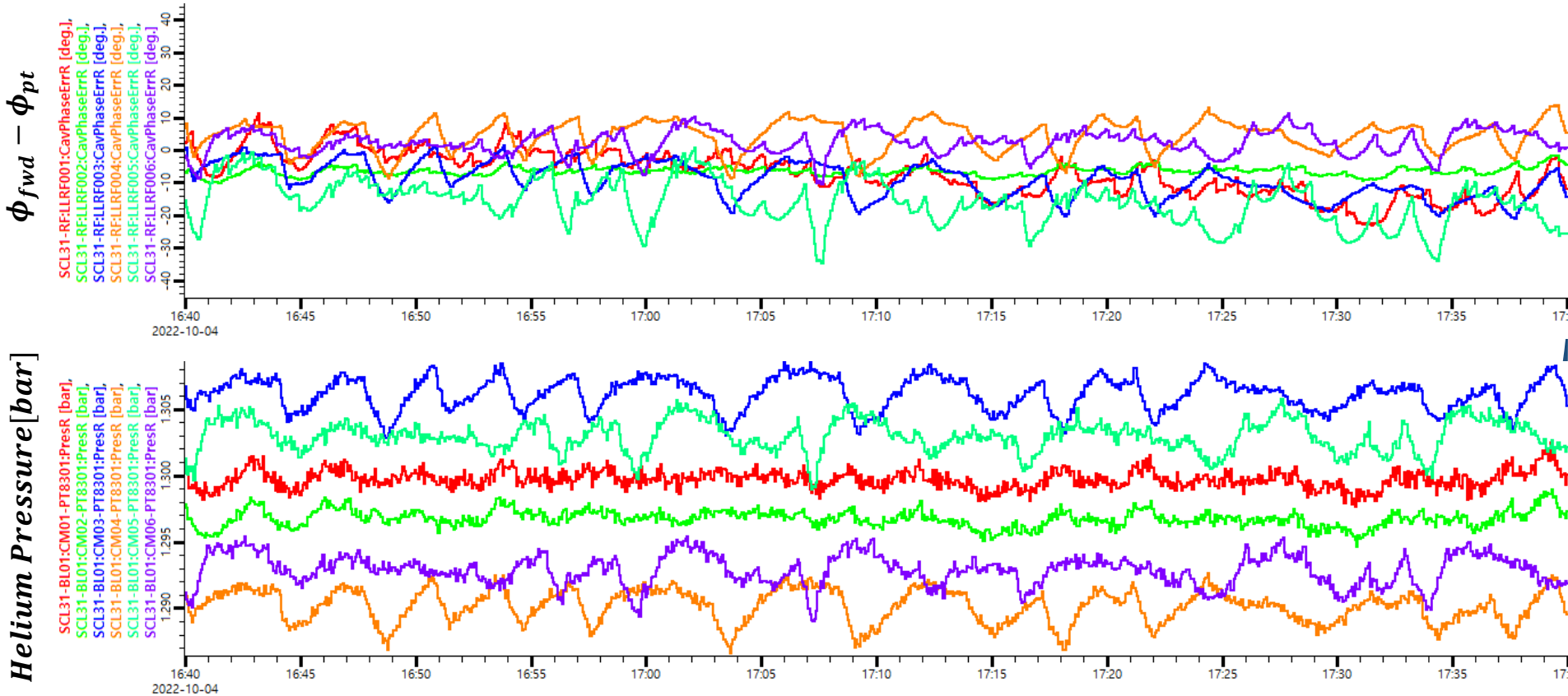
- Checking the resonance frequency drift caused from the fluctuation of helium pressure. (in GDR mode with amplitude/phase feedback)
- Linac is in cool-down mode(50% complete), we expect that helium pressure will be more stabilized after the end of cool-down. (Helium pressure = 1.287~1.292mbar)

$Helium\ Pressure[bar]$ $\phi_{fwd} - \phi_{pt}$(QWR#04)



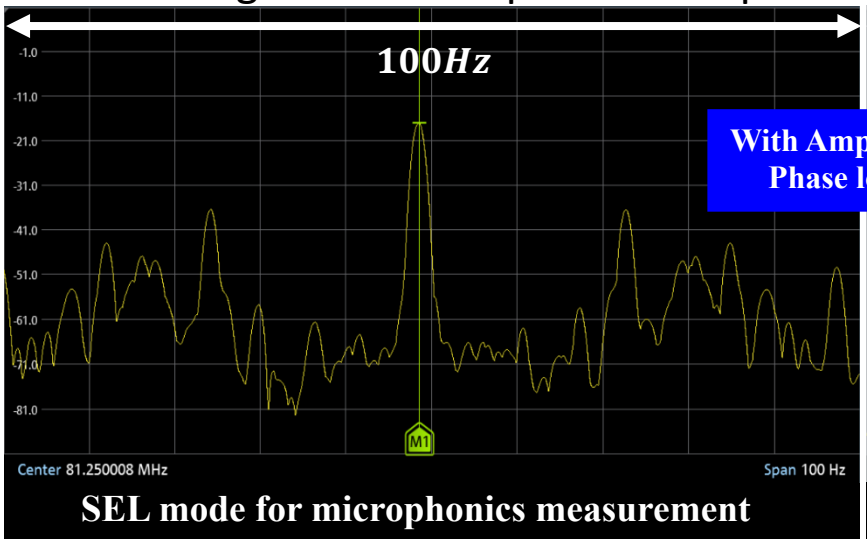
Frequency drift vs Helium Pressure(QWR#01-#06)

- Checking the resonance frequency drift caused from the fluctuation of helium pressure. (in GDR mode with amplitude/phase feedback)
- Linac is in cool-down mode(50% complete), we expect that helium pressure will be more stabilized after the end of cool-down.



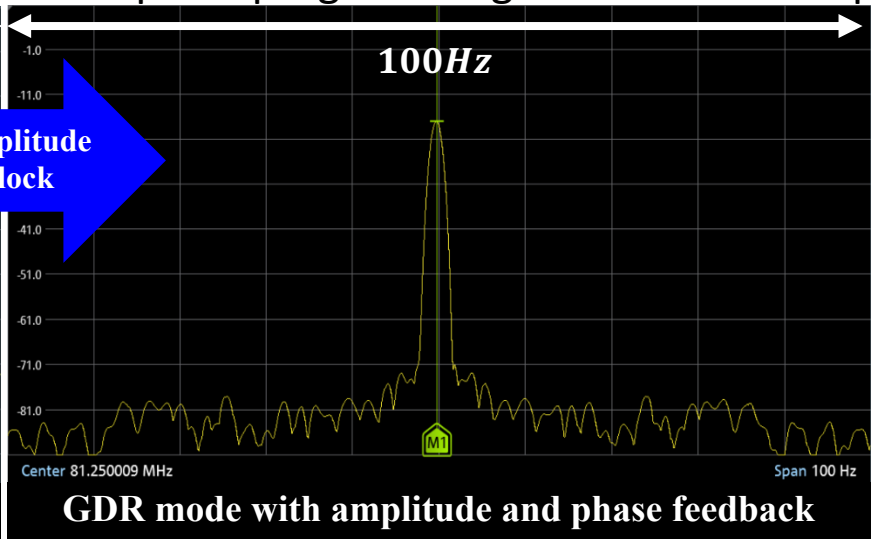
Microphonics Measurement(QWR#01-#06)

- Microphonics can be monitored when LLRF operates in SEL mode.
- LLRF can regulate the amplitude and phase of the pick-up signal using PID feedback loop.

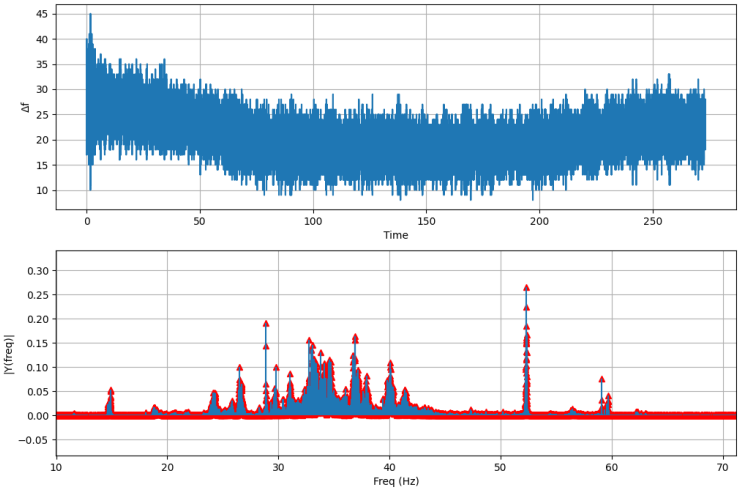


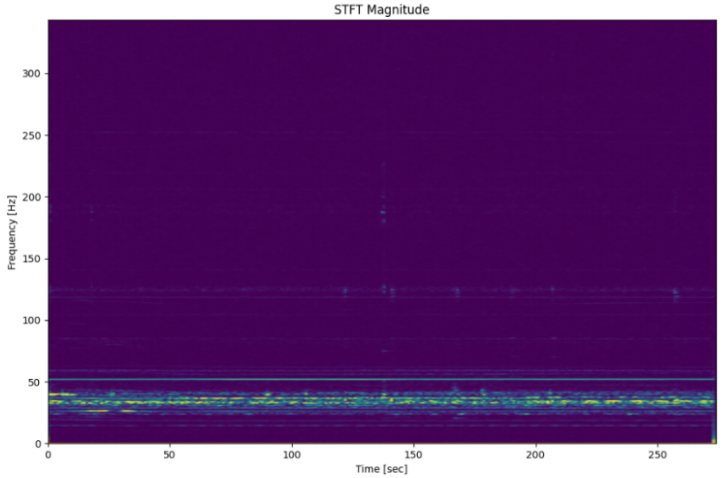
SEL mode for microphonics measurement

With Amplitude Phase lock



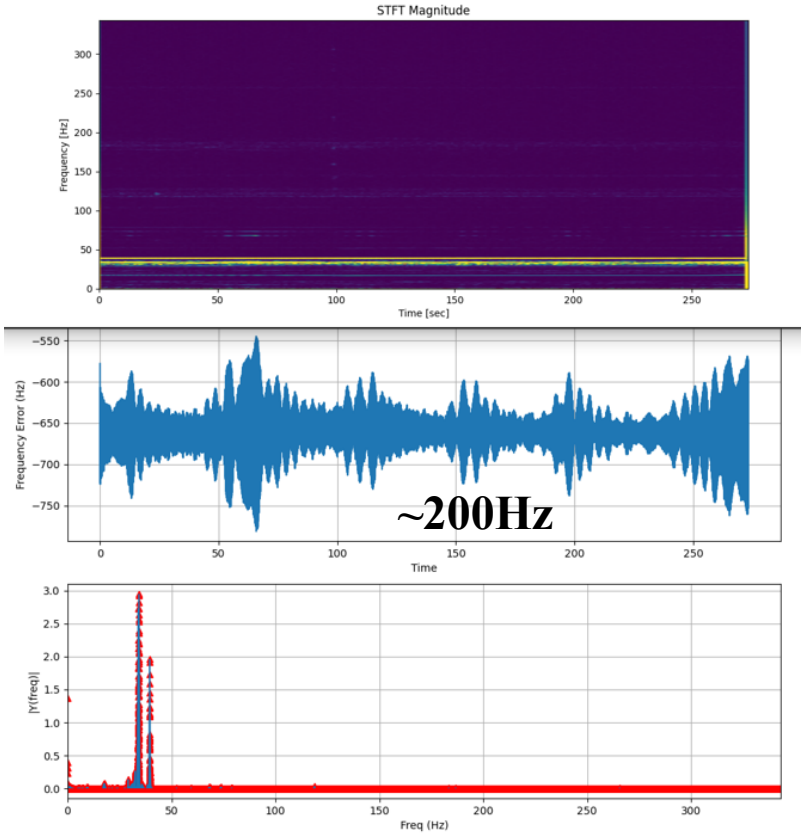
GDR mode with amplitude and phase feedback

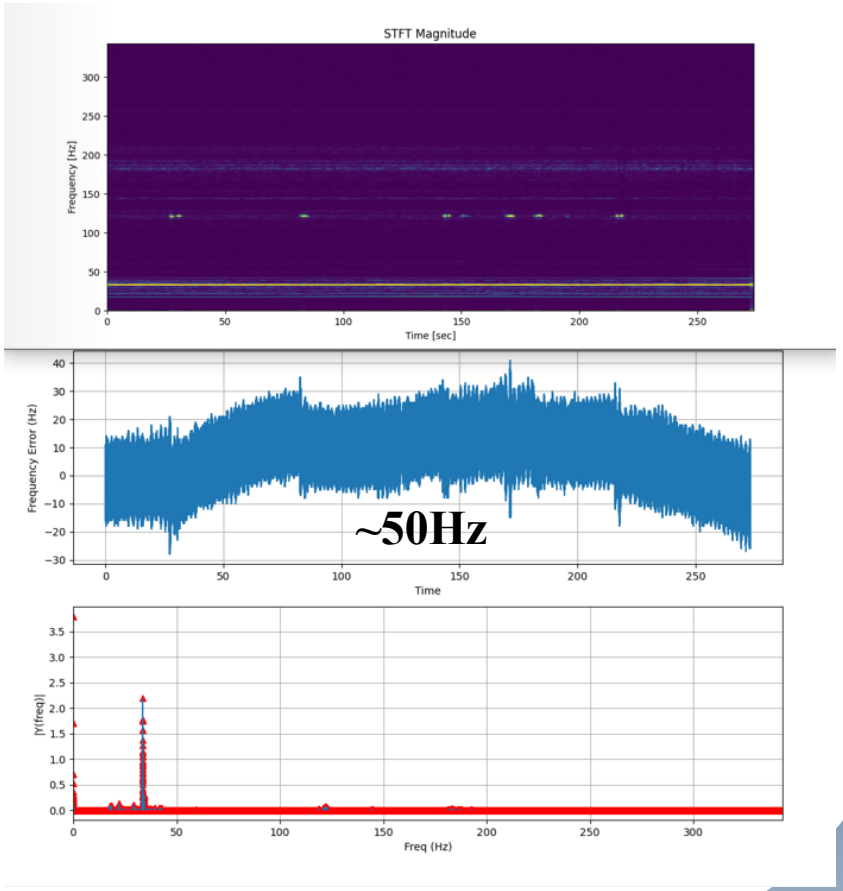




Microphonics Mitigation(1)

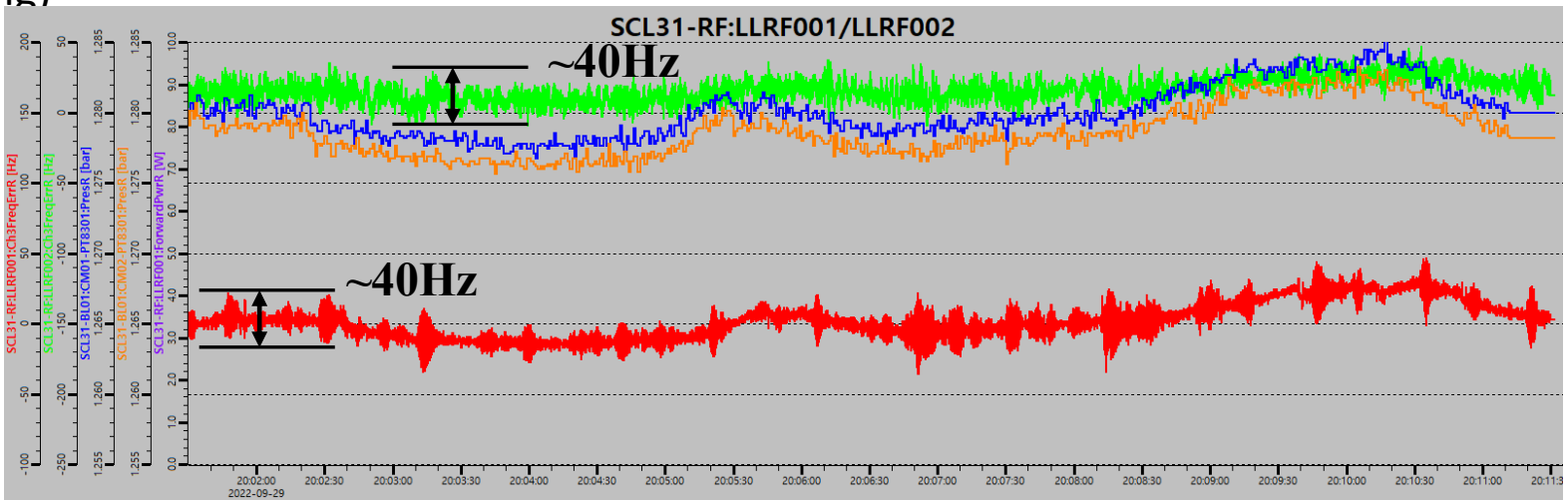
▢ After reducing the flow-rate from cryoplant, microphonics (at 34Hz) was reduced.(RISP Cryogenic System Team, Dr. Ki, Tae Kyung)

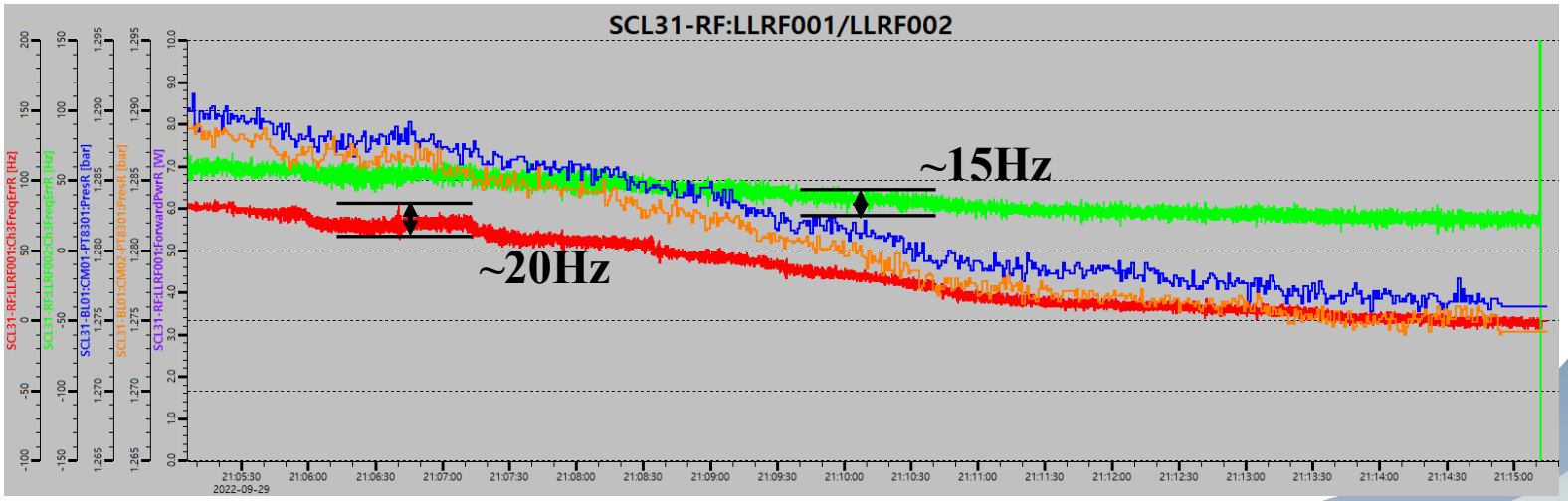




Microphonics Mitigation(2)

▢ After closing a bypass line(VLP valve) from main supply line to 2K pump-down line for HWRs, irregular microphonics (at 34Hz) was removed.(RISP Cryogenic System Team, Dr. Ki, Tae Kyung)





Summary

- All QWR CM, HWR CMA and HWR CMB successfully passed test and were installed at the end of 2021.

- The first cool-down started at 7th September, 2022(50% completed).

- RF conditioning and control test are in progress for 6 QWRs

- After finishing cool-down of the low energy superconducting linac, RF team will start SRF commissioning soon.

Thank you for your attention