Injector and Main Linac

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Outline

- Introduction
- Injector status
- Main Linac status
- Next steps

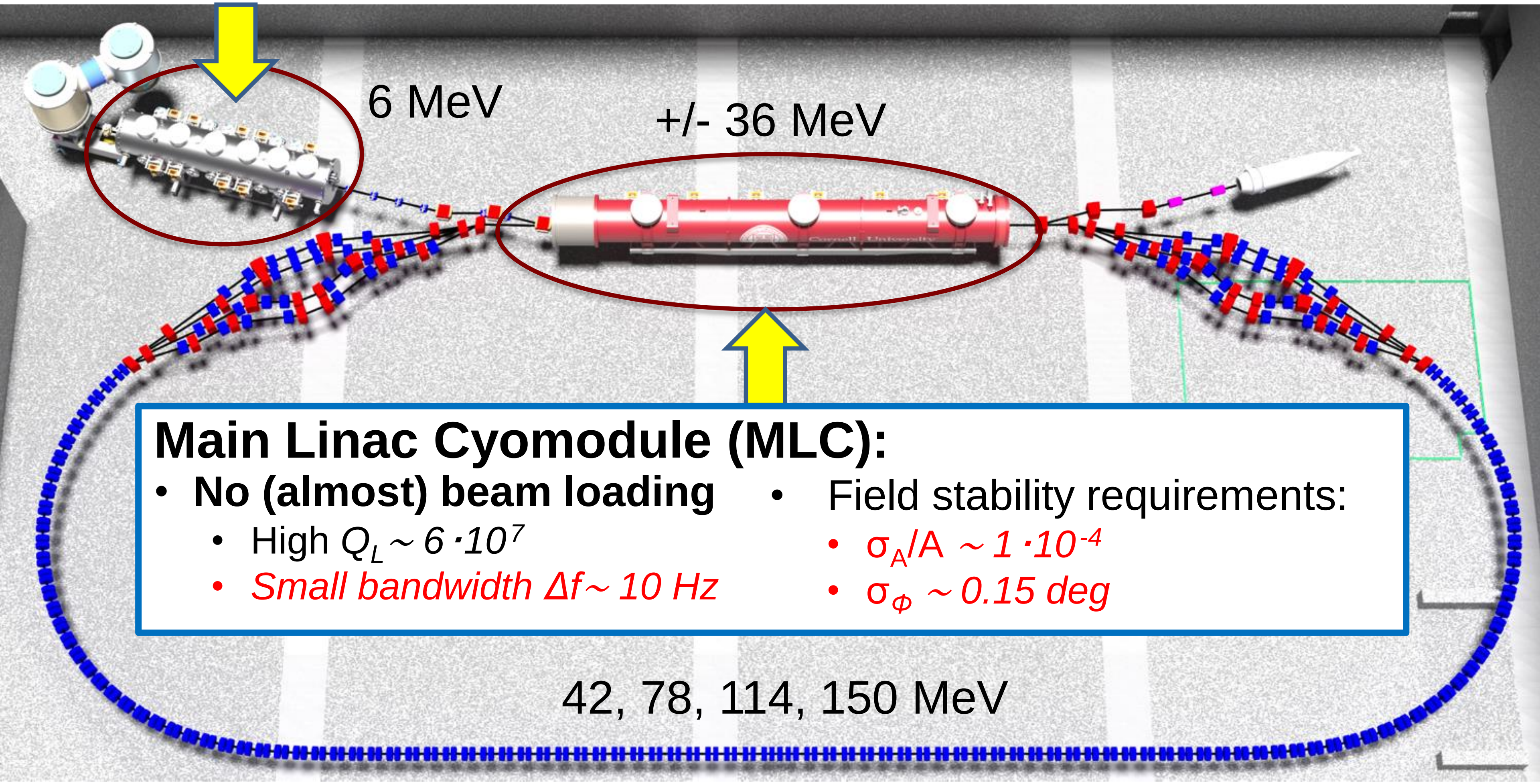
Introduction

Injector Cyomodule (ICM):

- **High beam loading**
  - Small $Q_L \sim 5 \cdot 10^4$ to $4 \cdot 10^5$
  - *Large bandwidth $\Delta f \sim$ 2 to 13 kHz*

Field stability requirements:

- $\sigma_A/A \sim 1 \cdot 10^{-3}$
- $\sigma_\Phi \sim 1$ deg



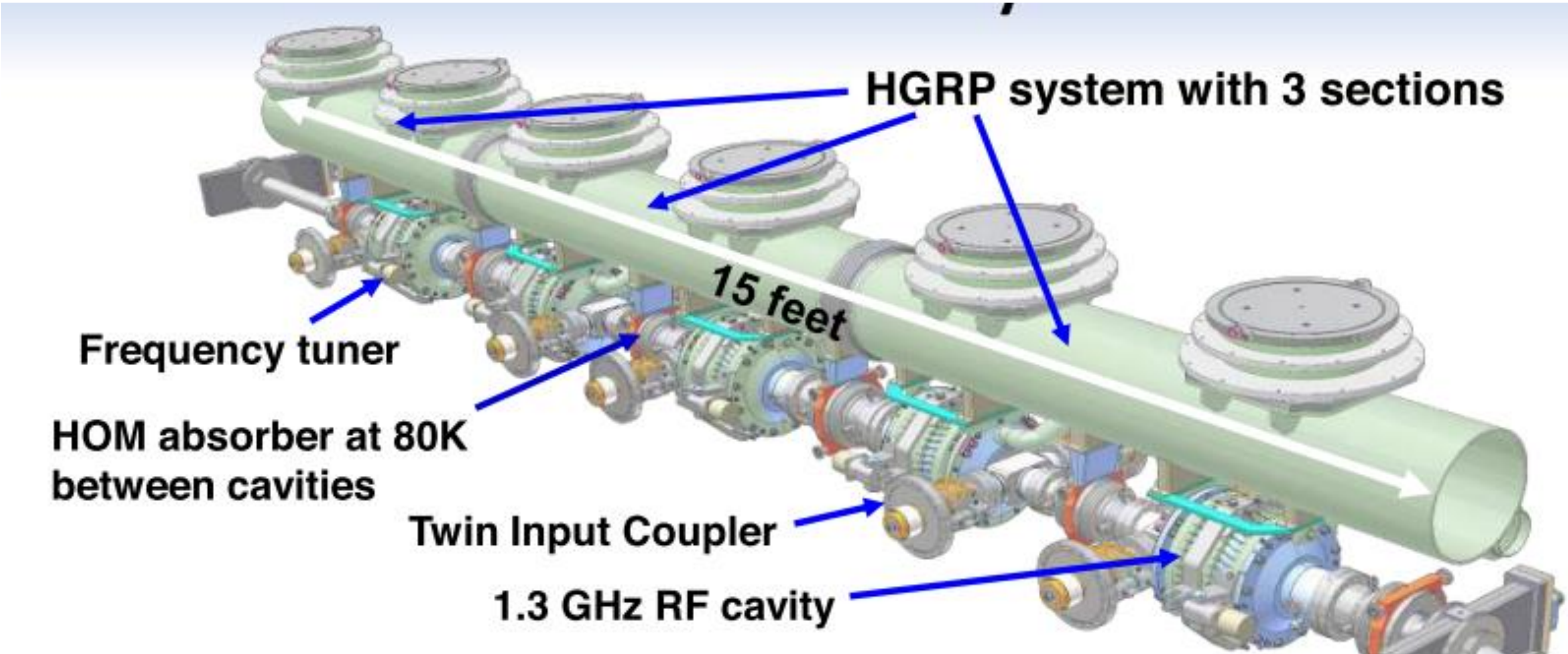
Main Linac Cyomodule (MLC):

- **No (almost) beam loading**
  - High $Q_L \sim 6 \cdot 10^7$
  - *Small bandwidth $\Delta f \sim$ 10 Hz*
- Field stability requirements:
  - $\sigma_A/A \sim 1 \cdot 10^{-4}$
  - $\sigma_\Phi \sim 0.15$ deg

Injector Cryomodule

http://www.classe.cornell.edu/Research/SRF/SrfNews2010.html

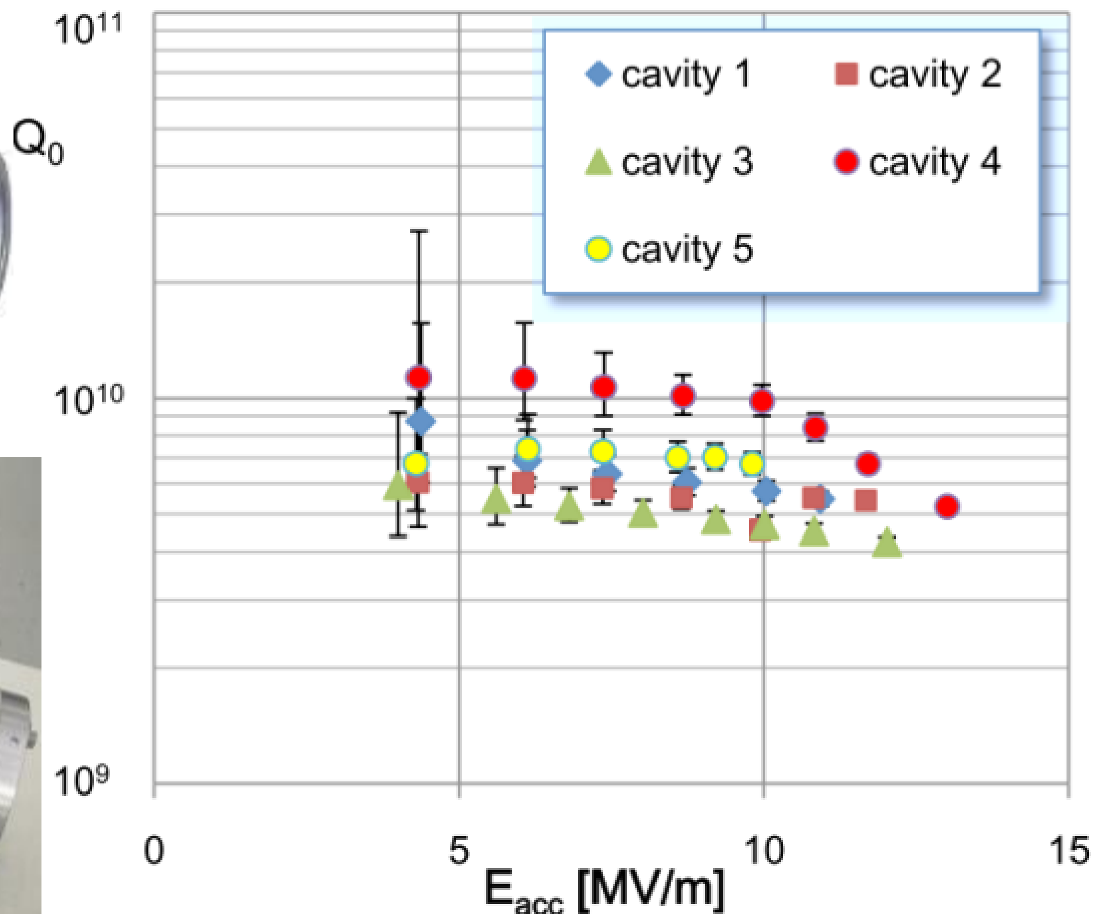
ICM and parameters



- Number of 2-cell cavities 5
- Acceleration per cavity 1 – 3 MeV
- Accelerating gradient 4.3 – 13.0 MV/m
- R/Q (linac definition) 222 Ohm
- Qext $4.6\times10^4 – 4.1\times10^5$
- Total 2K / 5K / 80K loads: 30W / 60W / 700W

- Number of HOM loads 6
- HOM power per cavity 40 W
- Couplers per cavity 2
- RF power per cavity 120 kW
- Amplitude/phase stability 10^{-3} / 0.1° (rms)
- ICM length 5 m

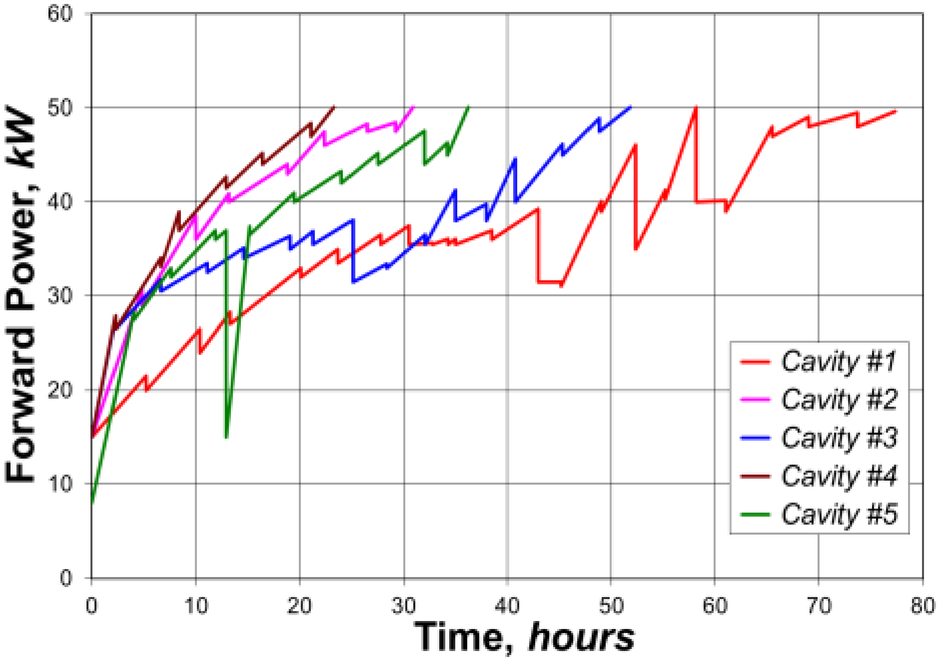
ICM past performances in L0E



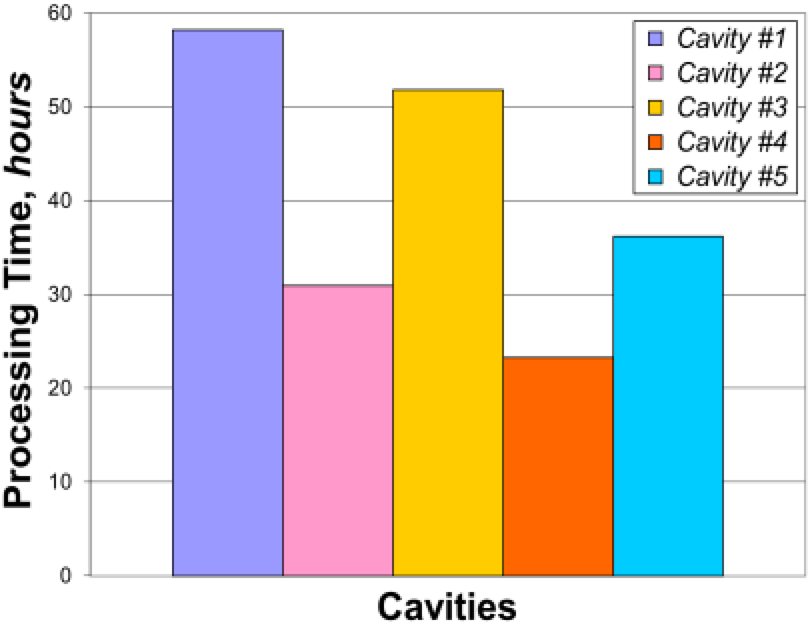
Intrinsic quality factor Q vs. accelerating field Eacc of the injector SRF cavities at 1.8K after rework of the cryomodule.

Coupler Pulse Processing

Pulse processing (1.5 msec, 50 Hz) of new couplers installed in the injector cryomodule



Processing history



Time required to reach 50 kW

ICM status

- Injector Cryomodule (ICM):
  - Installed in L0E.
  - Completed 4K cooldown on 06/09/2016.
  - Performed 2K pump-down for system check on 06/15/2016. Returned to 4K operation.
  - Currently operating at 4K.
  - LLRF connections in progress.

ICM in L0E

ICM status

- Injector Cryomodule (ICM):
  - Helium vessel to insulation vacuum leak:
    - This leak has existed since 2009 L0 installation. Installed active pumping turbo and successfully operated ICM without issue.
    - For the L0E ICM installation, vacuum vessel is actively pumped with two 150 L/s turbo pumps and activated charcoal bags mounted in vacuum vessel.
    - At room temperature:
      - Base Pressure: 1e-5 torr.
      - Leak rate: ~6e-5 torr-liter/sec.
    - At 4K operation:
      - Base pressure: 4e-7 torr.

ICM status

- Klystrons:
  - Installed on L0E Mezzanine
  - All power, water, instrumentation, LLRF connected.
  - RF waveguide 98% installed. Final component installation in progress.

- Initial RF power testing is tentatively scheduled to start the week of 08/01.

120kW Klystrons in L0E

Injector, Next steps

After turn RF on ,,,

- LLRF system check.
- Coupler conditioning.
- Measure Q vs E.
- HOM calibration.
- Check HP helium gas cooling (needs operating couplers at high forward power).
- coordinate with gun staff and others to get 1 mA through the injector to the dump.

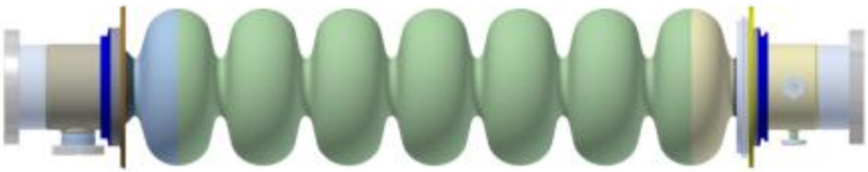
Main Linac Cryomodule

Image; moving MLC to Wilson lab, Mar2015.

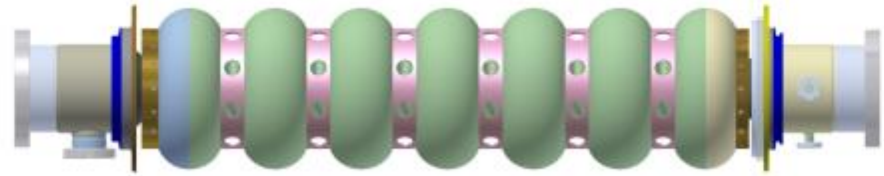
7-cell cavities and MLC parameters

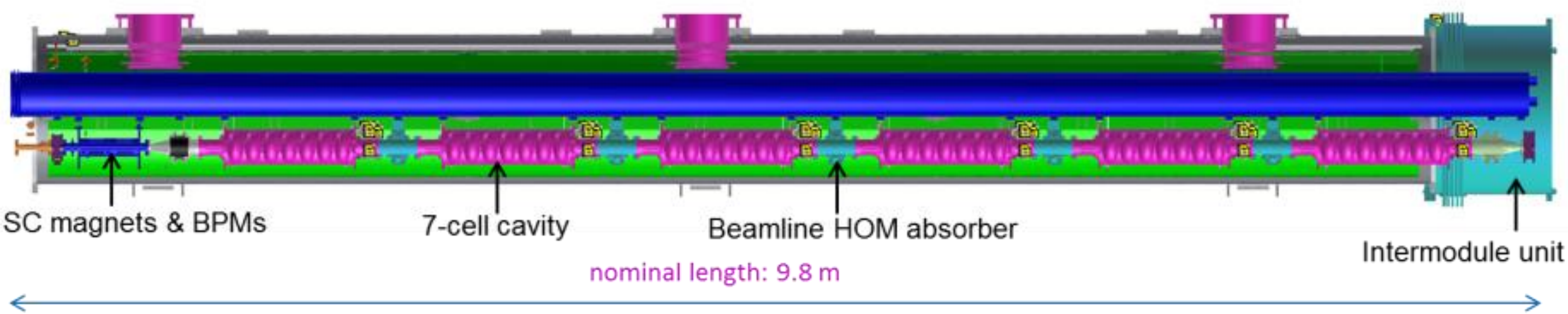
CBETA

Un-stiffened Cavity



Stiffened Cavity





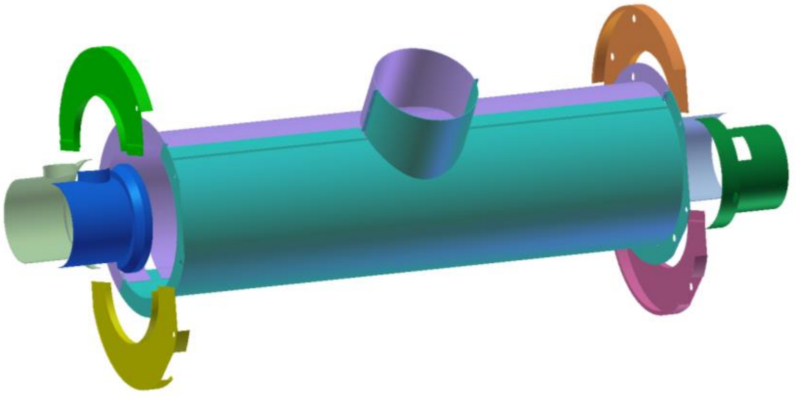
- Number of 7-cell cavities 6
- Acceleration gradient 16.2 MV/m
- R/Q (linac definition) 774 Ohm
- Qext 6.5×10^{7}
- Total 2K / 5K / 80K loads: 76W / 70W / 1500W

- Number of HOM loads 7
- HOM power per cavity 200 W
- Couplers per cavity 1
- RF power per cavity 5 kW
- Amplitude/phase stability 10^{-4} / 0.05° (rms)
- Module length 9.8 m

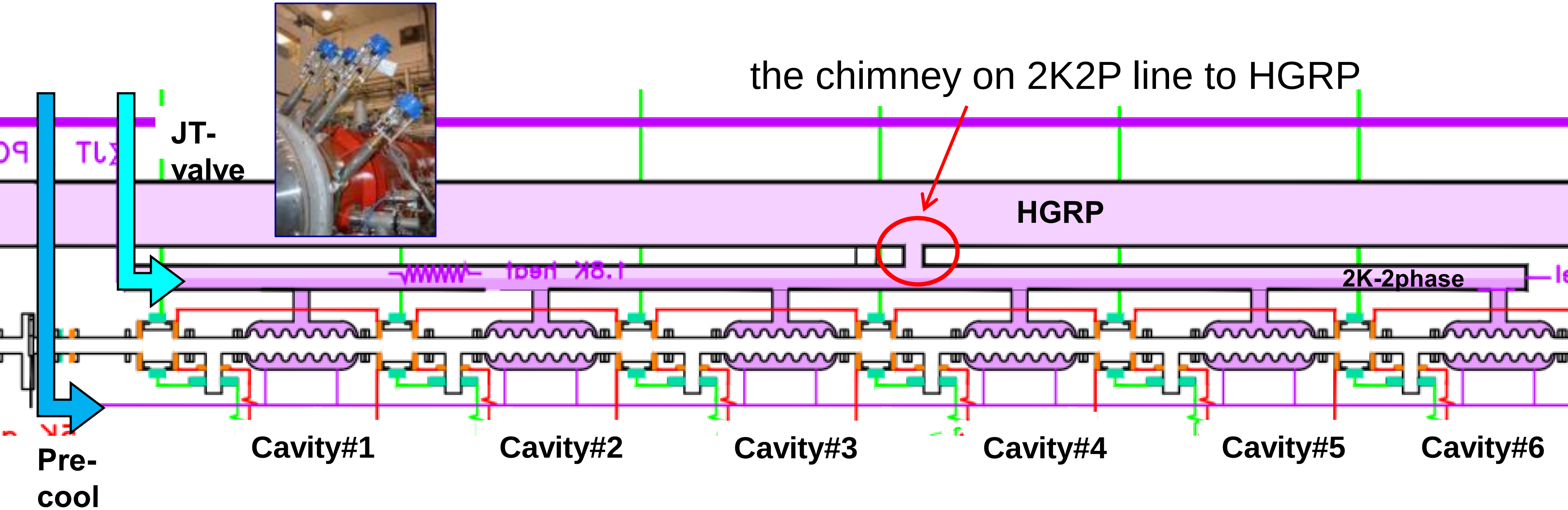
Magnetic shielding

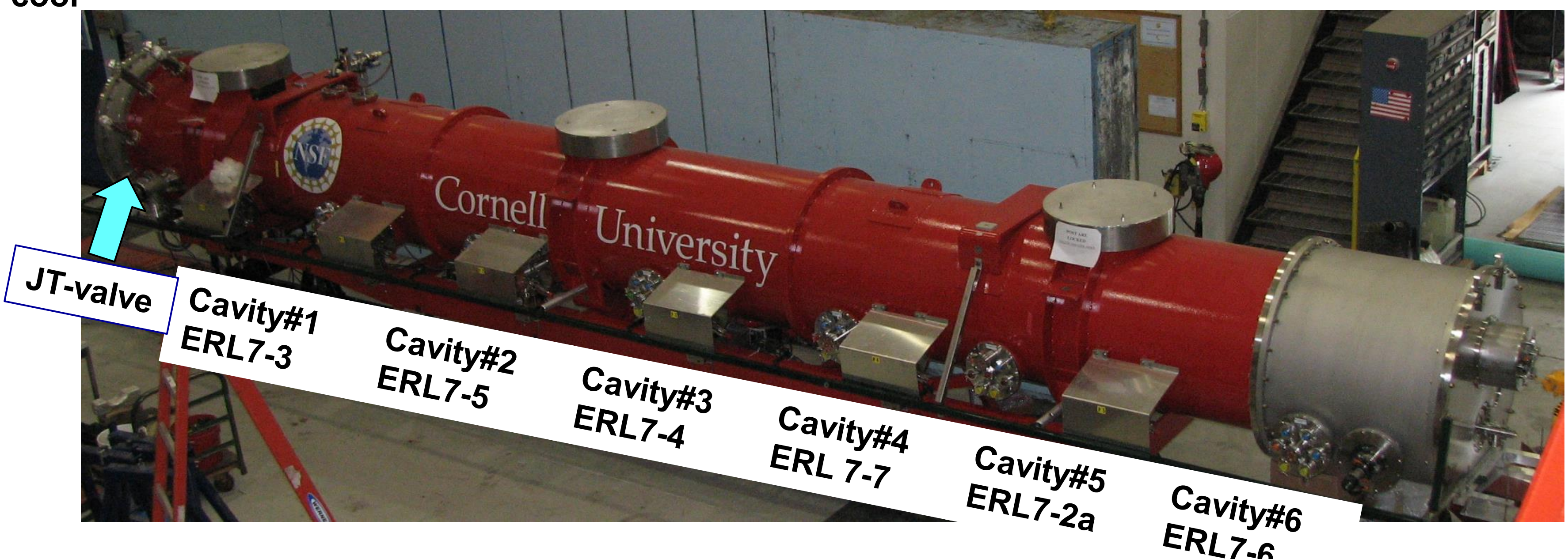
Three layers of magnetic shielding:

- Vacuum Vessel (carbon steel)
- 80/40 K magnetic shield enclosing the cold mass
- 2 K magnetic shield enclosing individual cavities

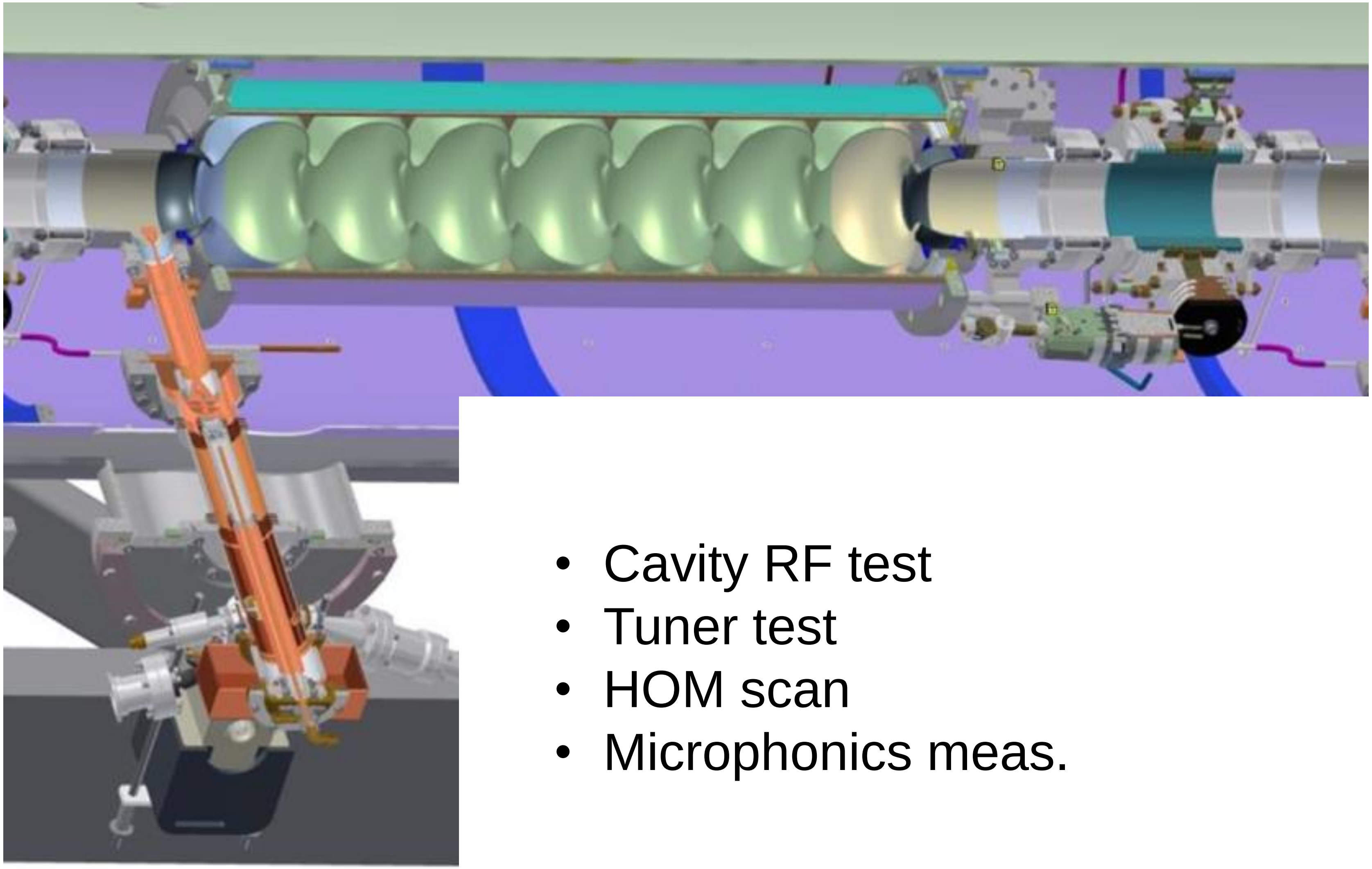


MLC Cooling schematic



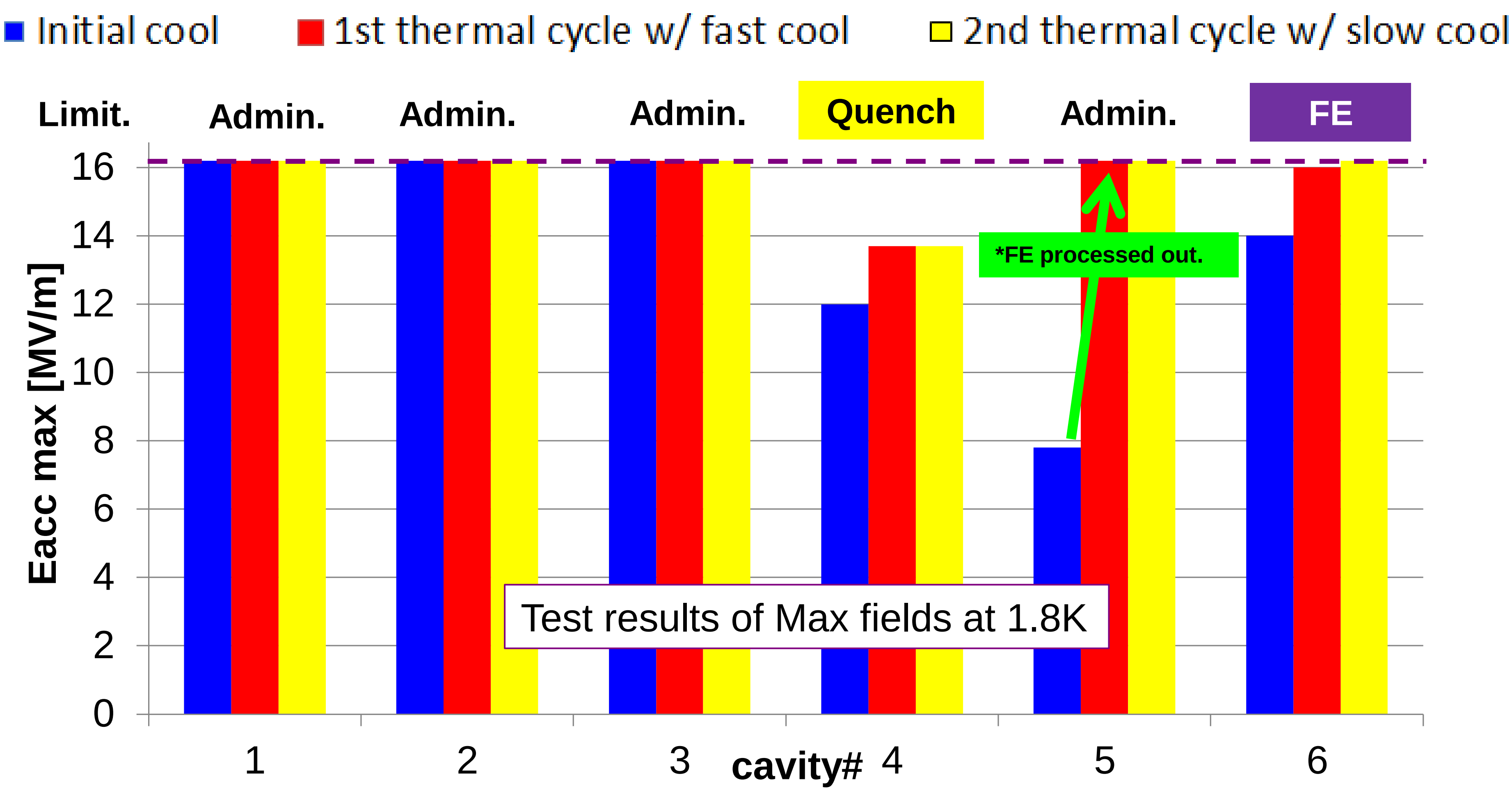


MLC test



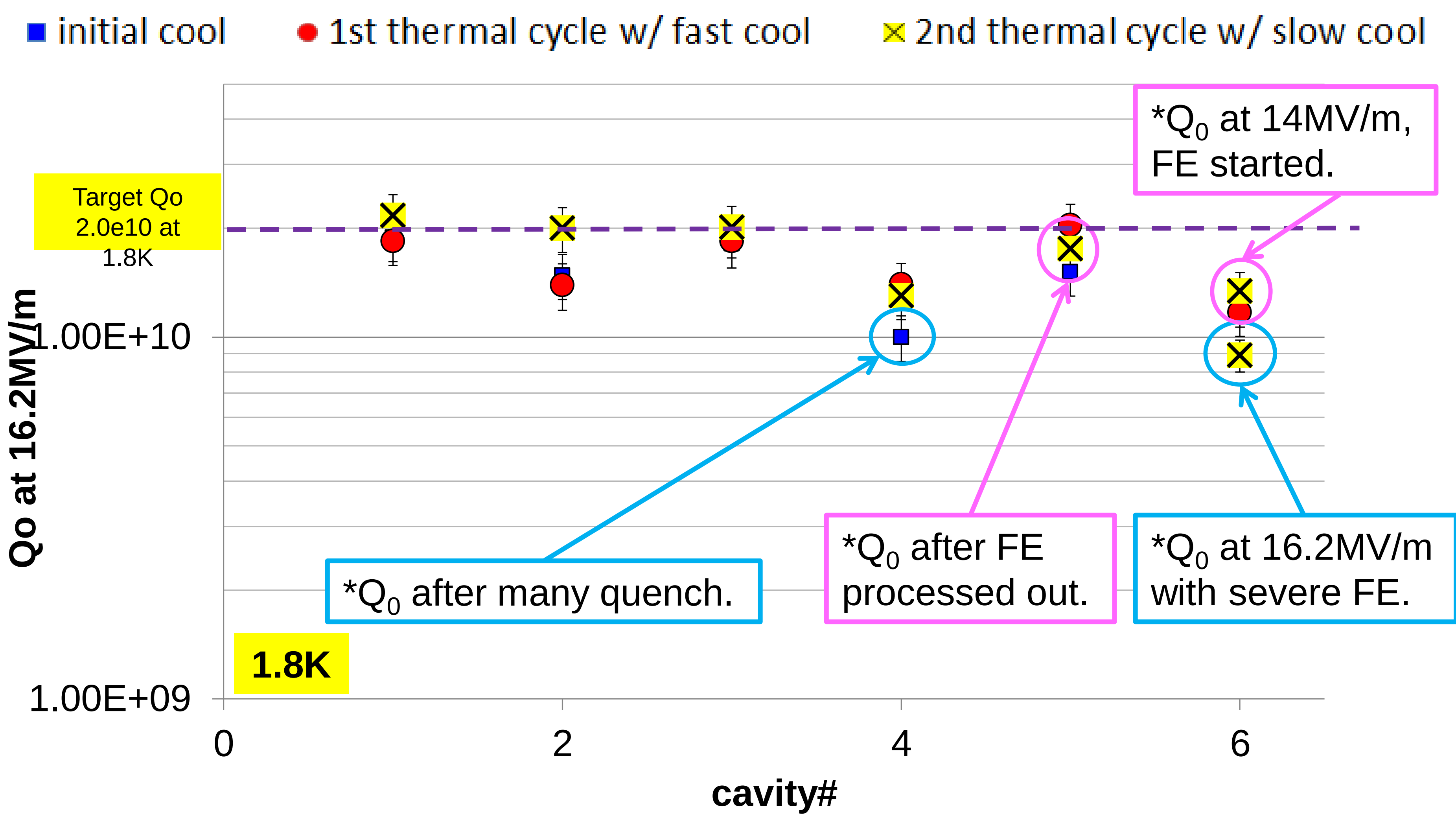
- Cavity RF test
- Tuner test
- HOM scan
- Microphonics meas.

MLC cavity RF test



- 5 of 6 cavities had achieved MLC design gradient of 16.2MV/m at 1.8K in MLC.

MLC cavity Q_0 at 16.2MV/m, 1.8K



- 4 of 6 cavities had achieved design Q_0 of 2.0E+10 at 1.8K.

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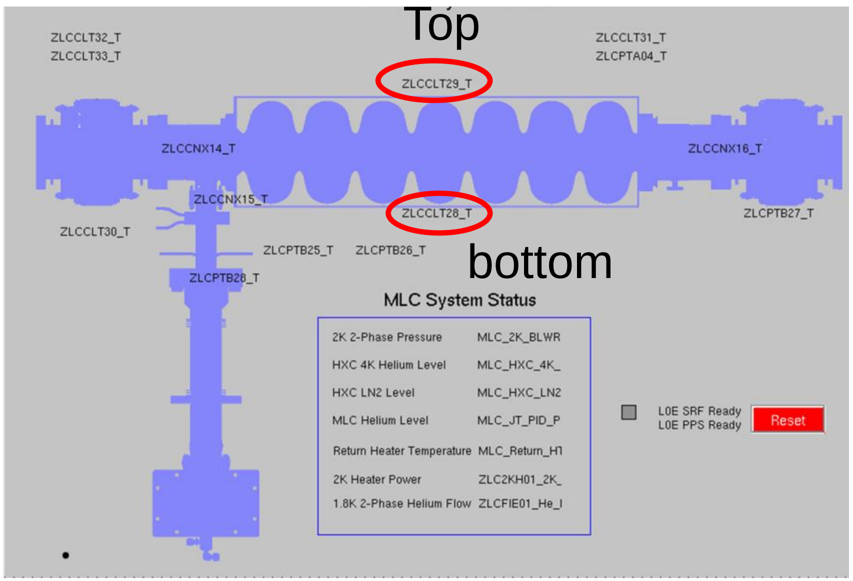
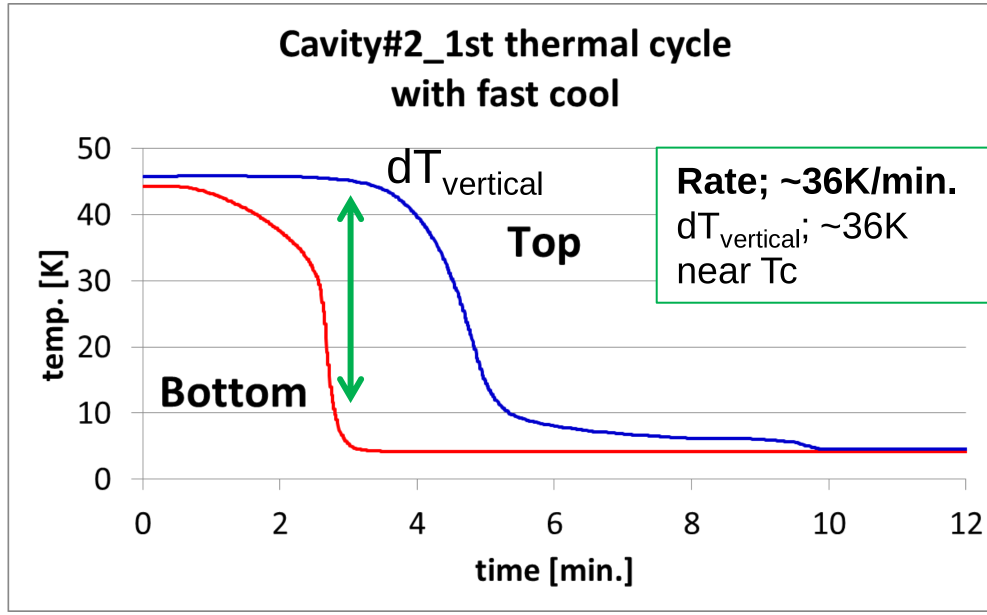
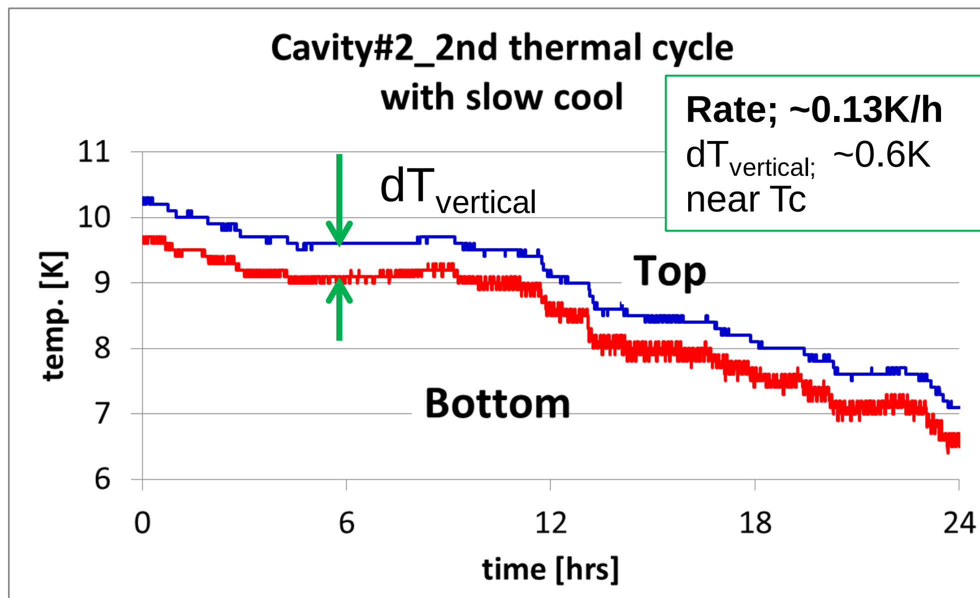
Thermal cycles on MLC

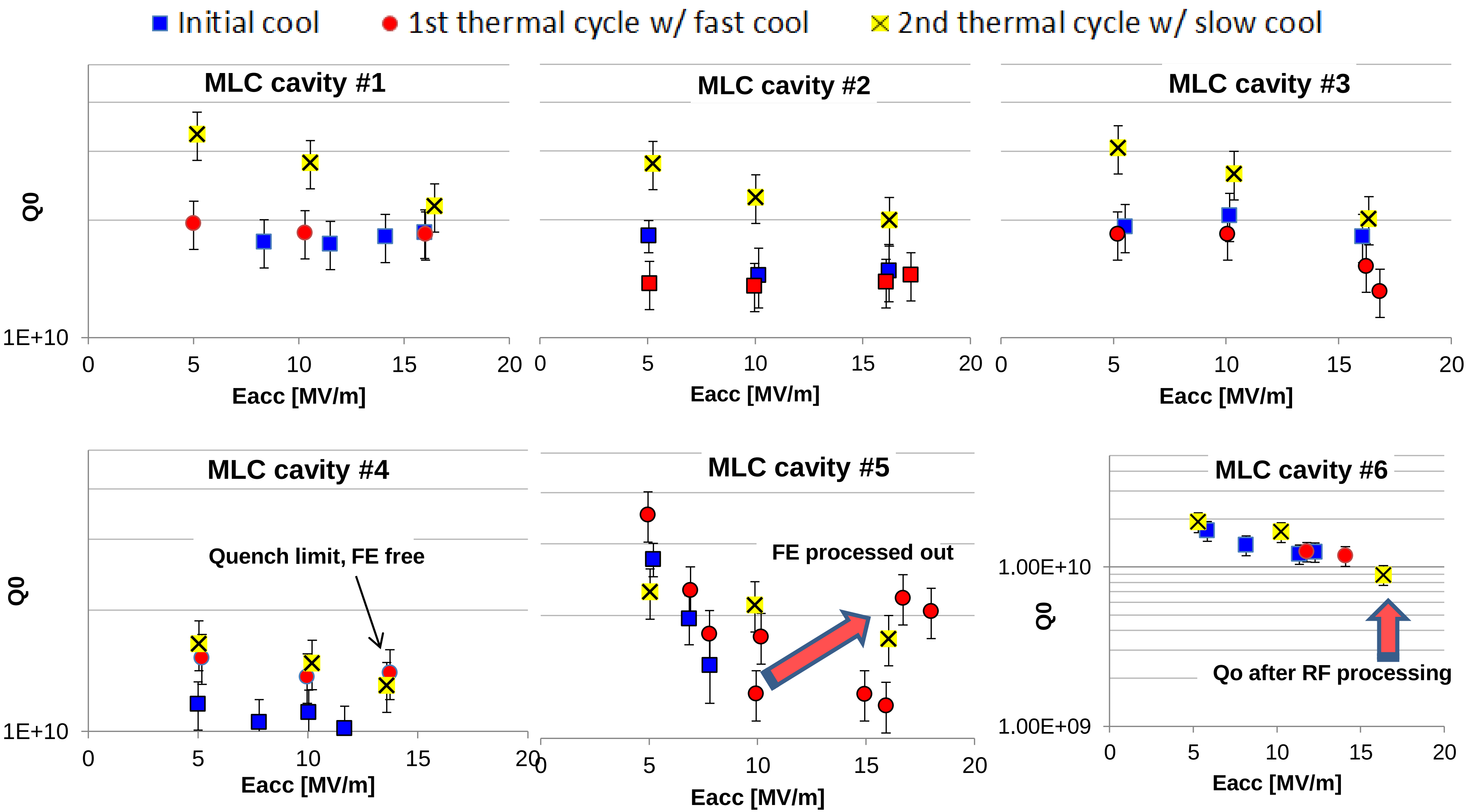


- Plot shows the temp. profiles on top and bottom of Helium tank.
- To pass through the Tc
  - Fast cool down w/ large dT ; ~**10min.** for 6 cavities.
  - Slow cool down w/ small dT ; ~**20hrs** for 6 cavities.





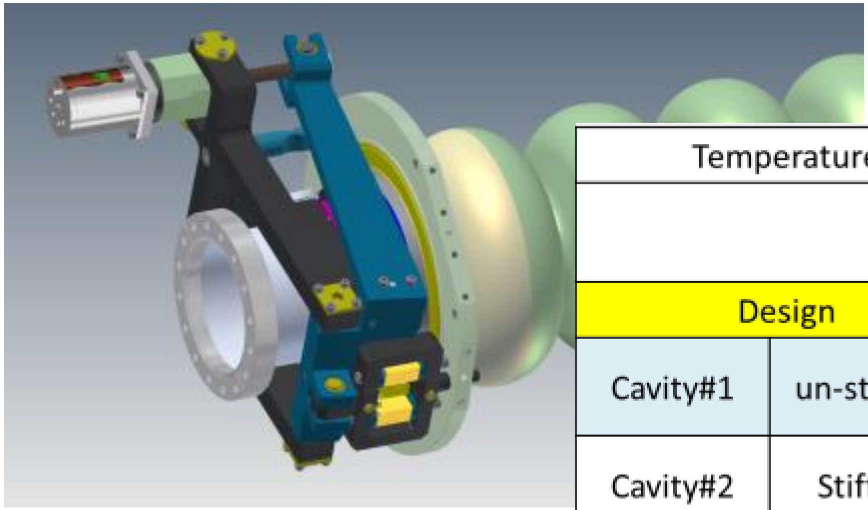
Impact of thermal cycling



Thermal cycle with small temp. gradient over cavity improved Qo.

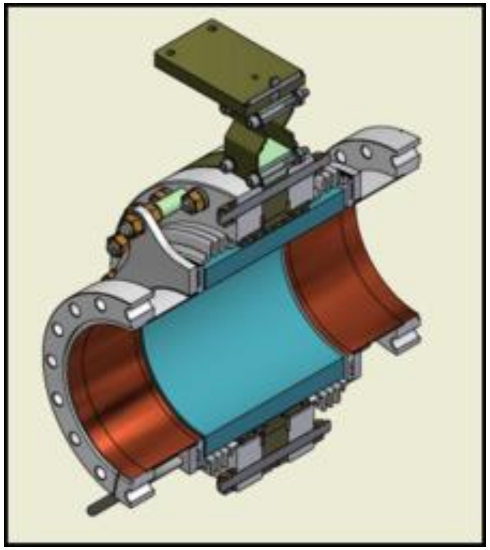
MLC tuner test

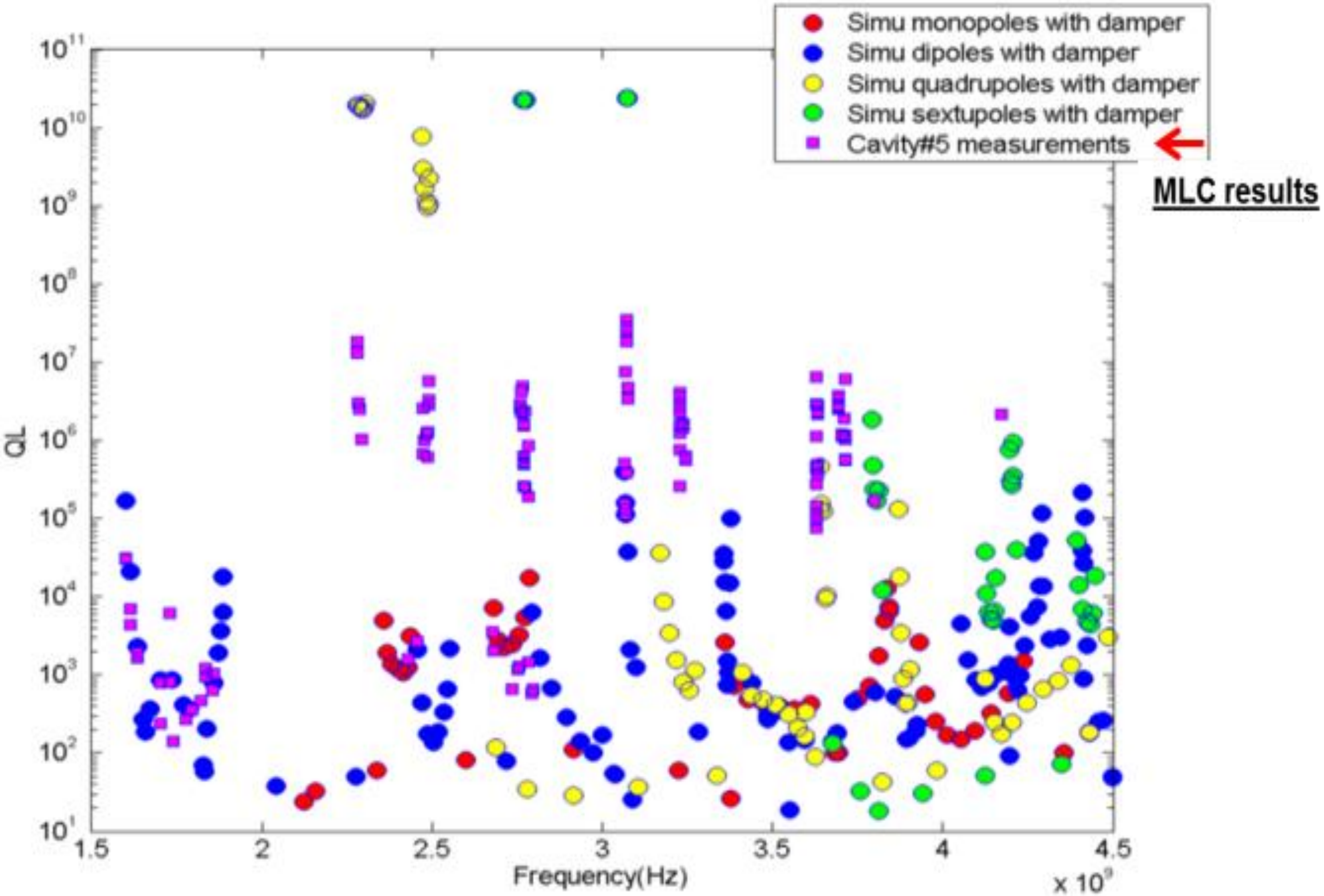
Tune has been done on all six cavities in 1.8K, successfully.



Temperature		1.8K			
		Before tuned [MHz]	**After Tuned** [MHz]	Tuning range	df/dp
Design		1299.700	1300.0000		
Cavity#1	un-stiffened	1299.525	1300.0000	+470kHz	38 Hz/torr (29 Hz/mbar)
Cavity#2	Stiffened	1299.724	1300.0000	+270kHz	15 Hz/torr (11 Hz/mbar)
Cavity#3	Un-stiffened	1299.650	1300.0002	+340kHz	46 Hz/torr (35 Hz/mbar)
Cavity#4	Stiffened	1299.615	1299.996	+381kHz	17 Hz/torr (13 Hz/mbar)
Cavity#5	Un-stiffened	1299.677	1300.000	+323kHz	33 Hz/torr (25 Hz/mbar)
Cavity#6	Stiffened	1299.554	1299.939	+385kHz	19 Hz/torr (14 Hz/mbar)

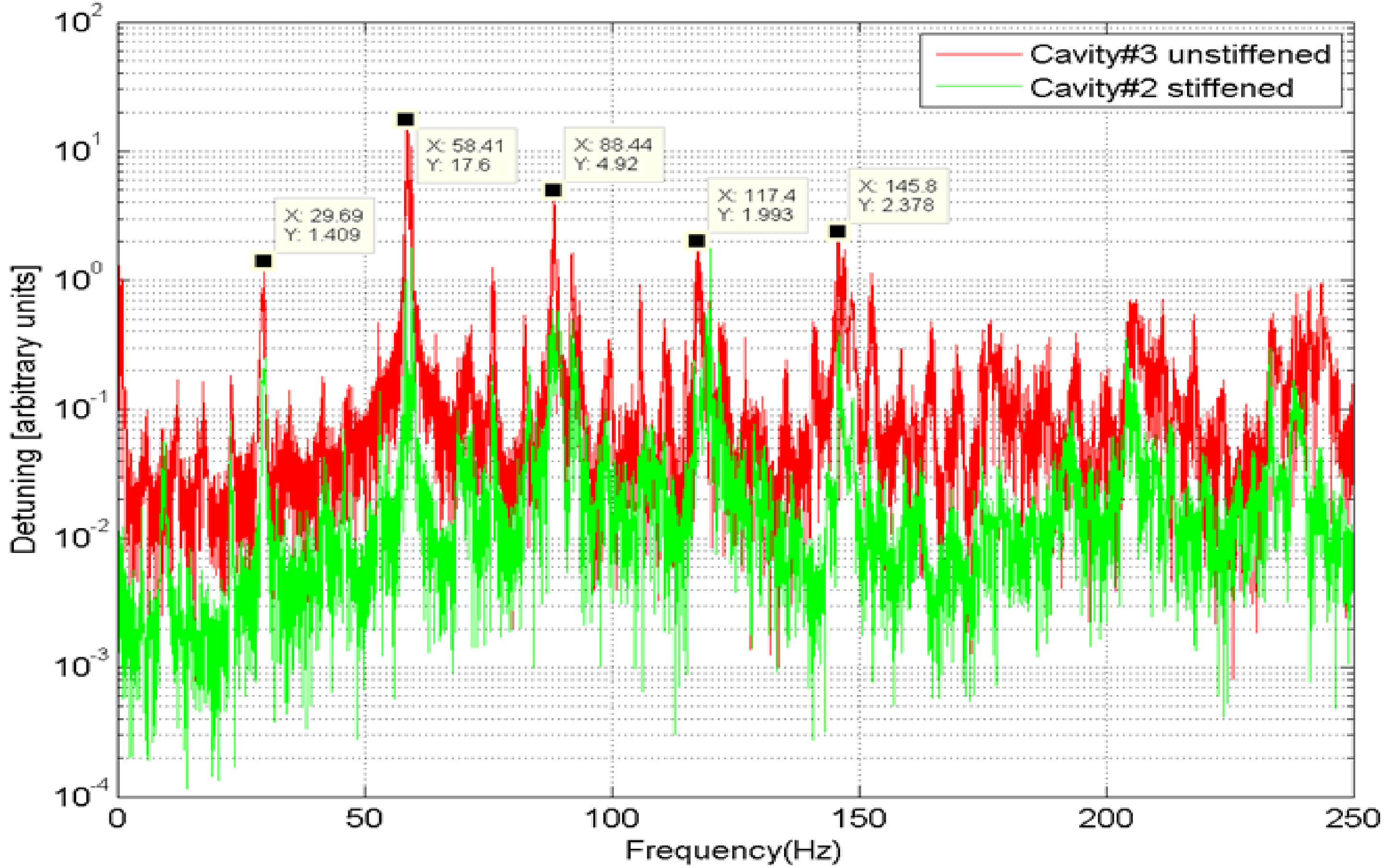
HOM scan analysis





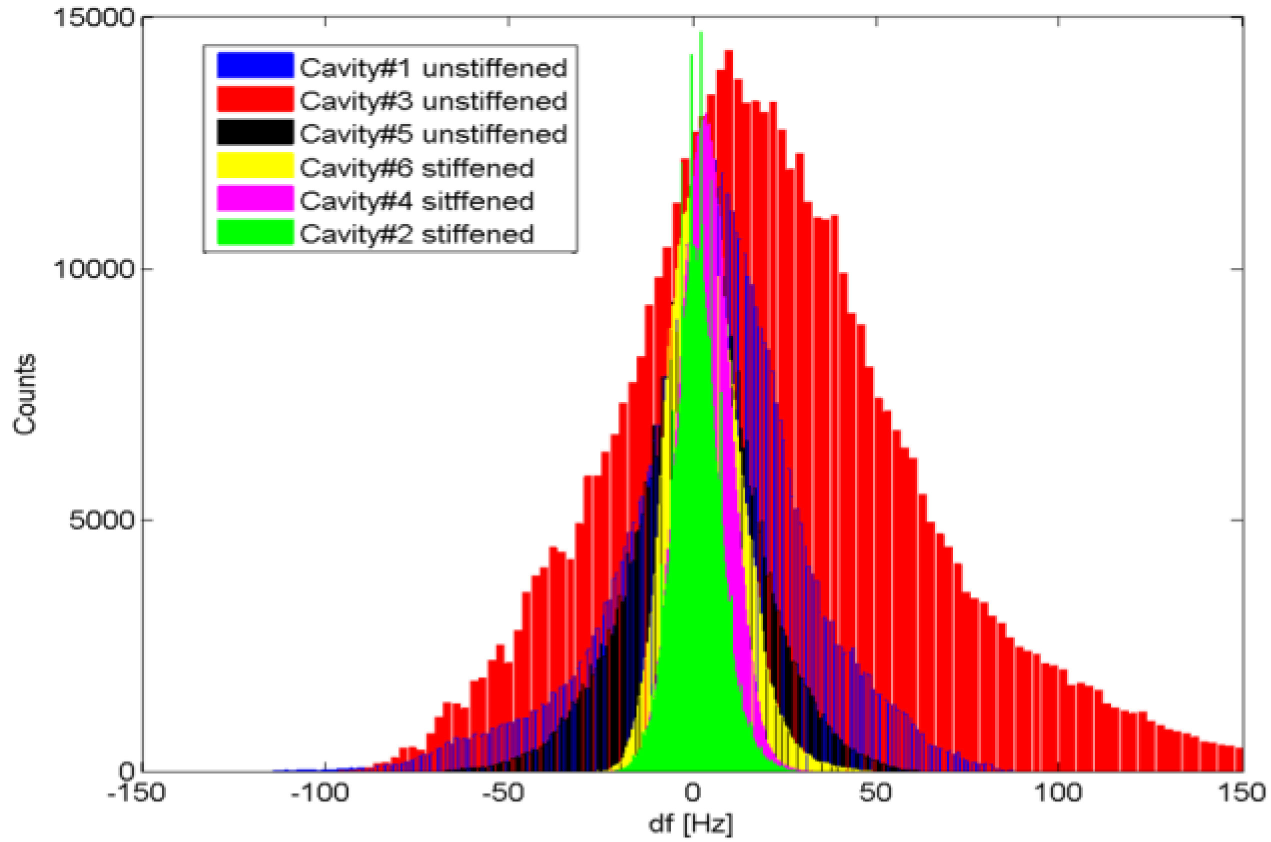
Dipole HOMs on MLC were strongly damped below Q~10^4.
Consistent with HTC and simulation results.

Microphonics meas. (1)



- Preliminary results of mechanical vibration peaks on MLC.
- stiffened and un-stiffened cavities had similar peak.

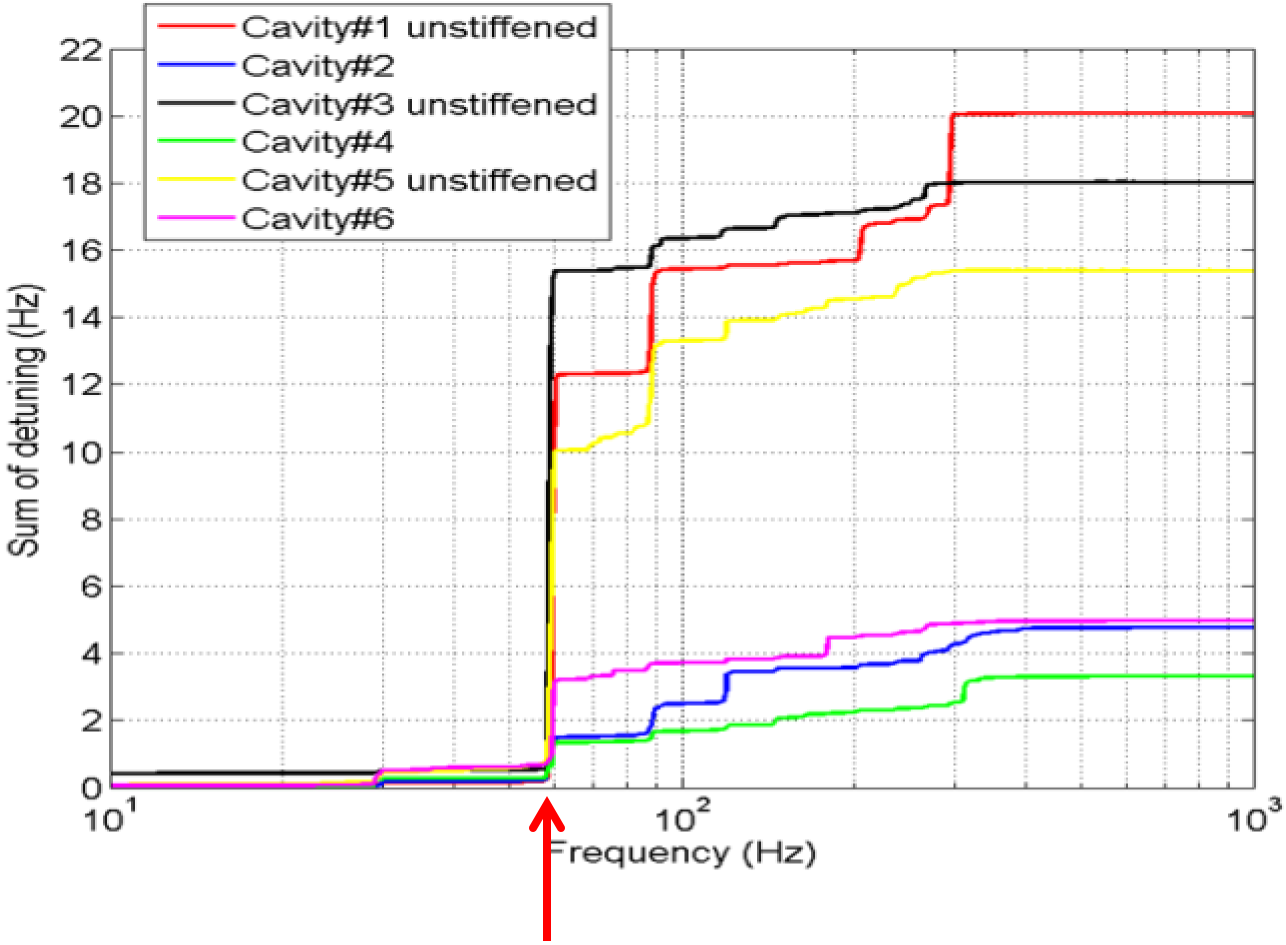
Microphonics meas. (2)



Initial measurements showed,

- Stiffened cavities had ~30Hz detuning, Un-stiffened cavities had ~150Hz detuning (ERL design ~20Hz, CBETA 50~100Hz).
- MLC had no optimization against detuning when these data were taken.

Microphonics meas. (3)



- the vibration peak of ~60Hz seemed to make high gain on detuning on un-stiffened cavities.
- Identification of vibration source, vibration-elimination or isolation are needed.

Identify and isolate the vibration sources

Measured with Cavity#2 (stiffened)

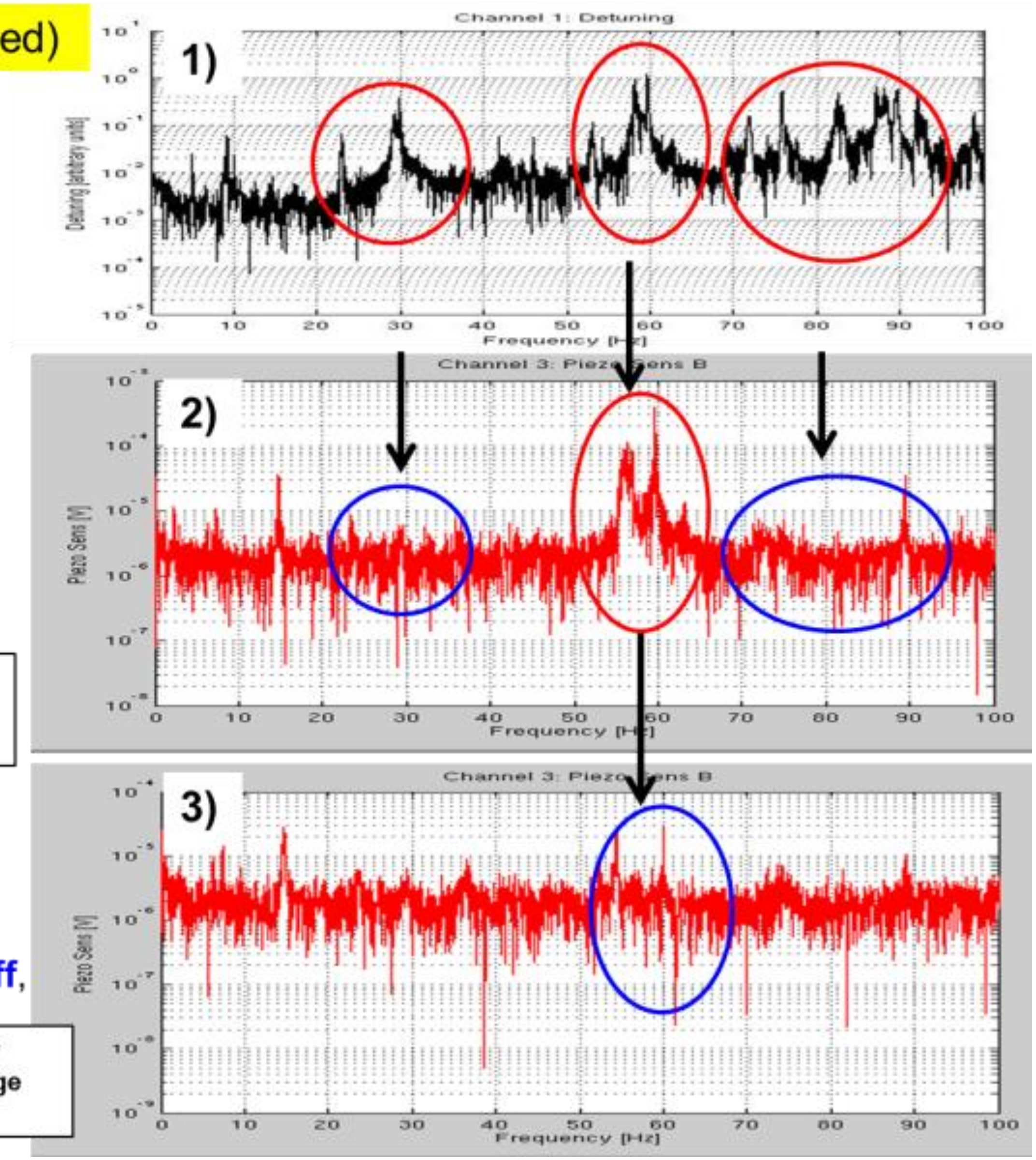
1) Pump Skid ON
80K flow was 7.5 g/s (high flow)
5K flow was 1.8 g/s

2) Pump skid Off
80K flow was 2.425 g/s (low flow)
5K flow was 1.6 g/s
Insulation vacuum turbo pumps ON valve Open.

measurements were done by directly measuring the voltage on the piezo B sensor

3) Pump skid Off
80K flow was 2.425 g/s(low flow)
5K flow was 1.6 g/s
Insulation vacuum turbo pumps off, valve shut.

measurements were done by directly measuring the voltage on the piezo B sensor



Main Linac, Next steps

- Cooling down to 1.8 K again, re-instate running conditions.
- Run LLRF and analyse free run data.
- Analyse pressure sensor data (1.8 K system)

	Cajon Ultra Torr; Caj
Transient Response (time constant):	8 msec

- Take more accelerometer data.
- Add pneumatic dampers to pump-skids and other vibrations generators.
- Measure HOM spectra of the remaining cavities.

Summary

- Injector and Main Linac are commissioned, tested, and ready for CBETA.

- Some optimization remains for the MLC.

- Injector cryomodule will be turned RF on next week, the week of Aug. 1st. LLRF system check, coupler conditioning, Qo meas., and HOM meas. are planed.

- Main Linac Cryomodule is maintained at 4K currently, waiting cool down to 1.8K again. more optimizations for LLRF and microphonics are planed.