Performance of the Cornell ERL Main Linac Prototype Cryomodule

Fumio FURUTA
Cornell University

On behalf of
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CLASSE facilities are operated by the Cornell Laboratory for Elementary Particle Physics (LEPP) and the Cornell High Energy Synchrotron Source (CHESS) with major support from the National Science Foundation.

Outline

- Cornell ERL
- Module components
  - Cavities, VT and HTC results
  - Magnetic shielding
  - Couplers
  - HOM absorbers
- MLC cool down
- Summary

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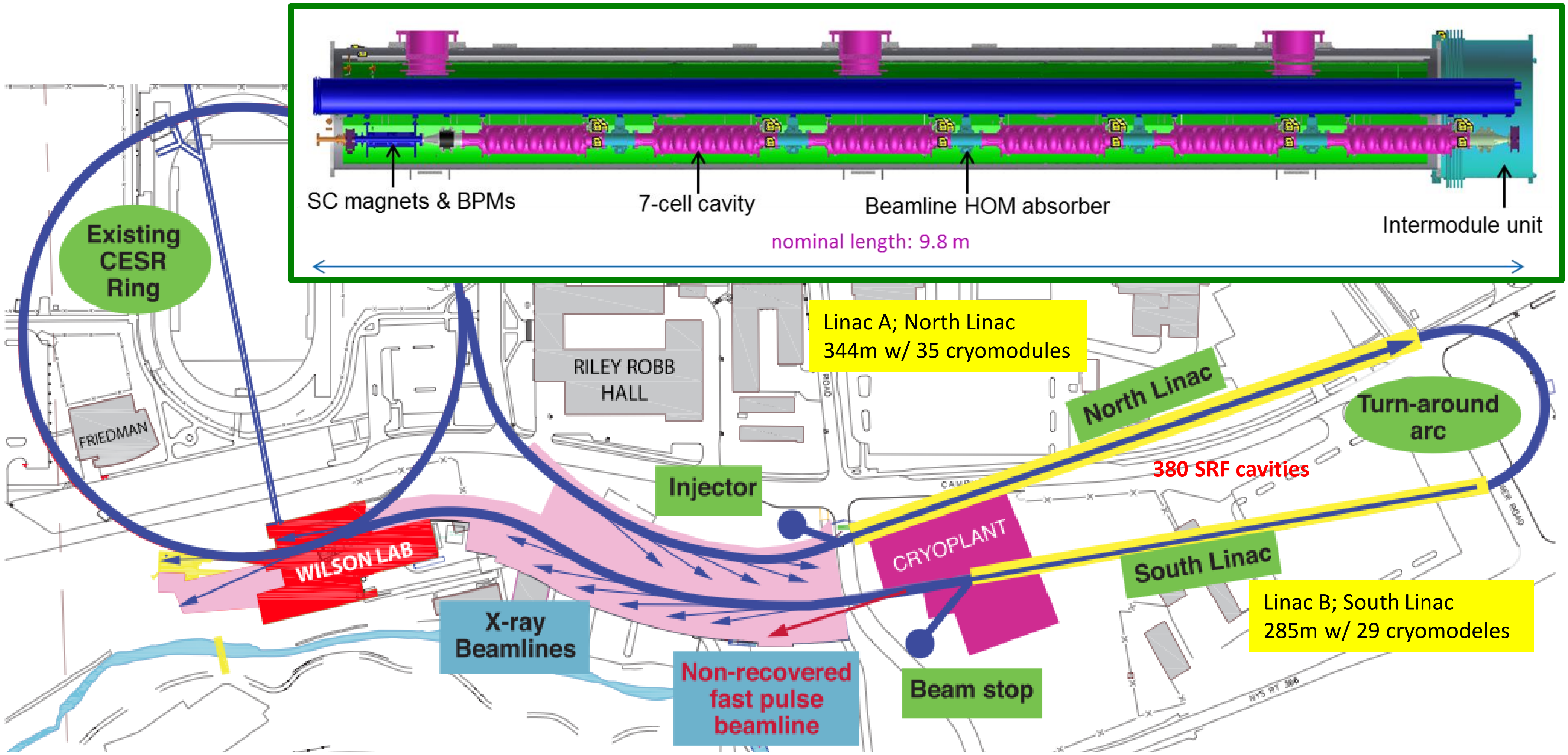
Cornell ERL and MLC

5 GeV, 100 mA, 8 pm emittances, 2 ps bunch length,

16 MV/m cw , Q > $2*10^{10}$, 200 W HOM power per cavity,



PDDR: https://www.classe.cornell.edu/Research/ERL/PDDR.html

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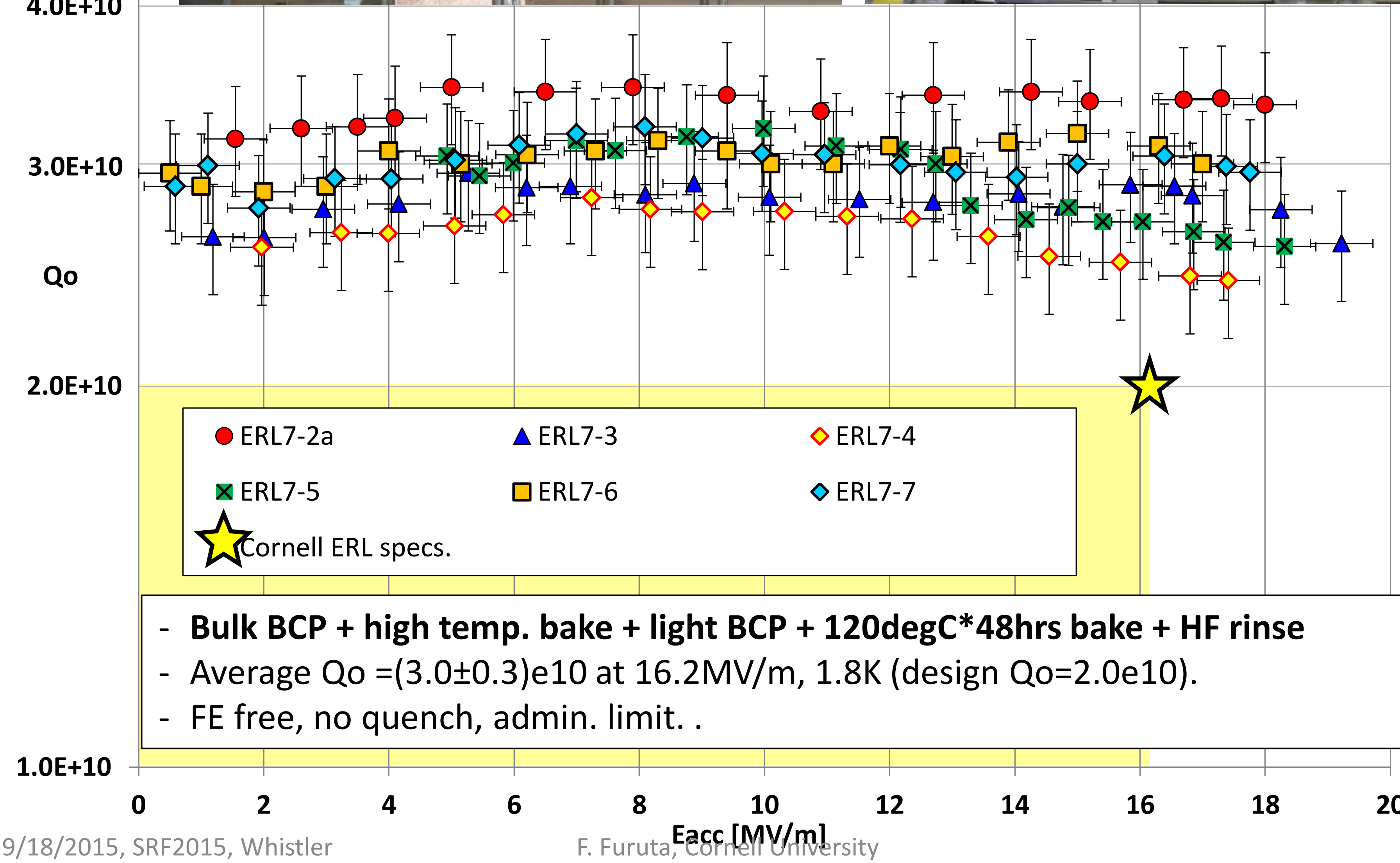
ERL 7-cells VT at 1.8K



- **Bulk BCP + high temp. bake + light BCP + 120degC*48hrs bake + HF rinse**
- Average Qo =(3.0±0.3)e10 at 16.2MV/m, 1.8K (design Qo=2.0e10).
- FE free, no quench, admin. limit. .

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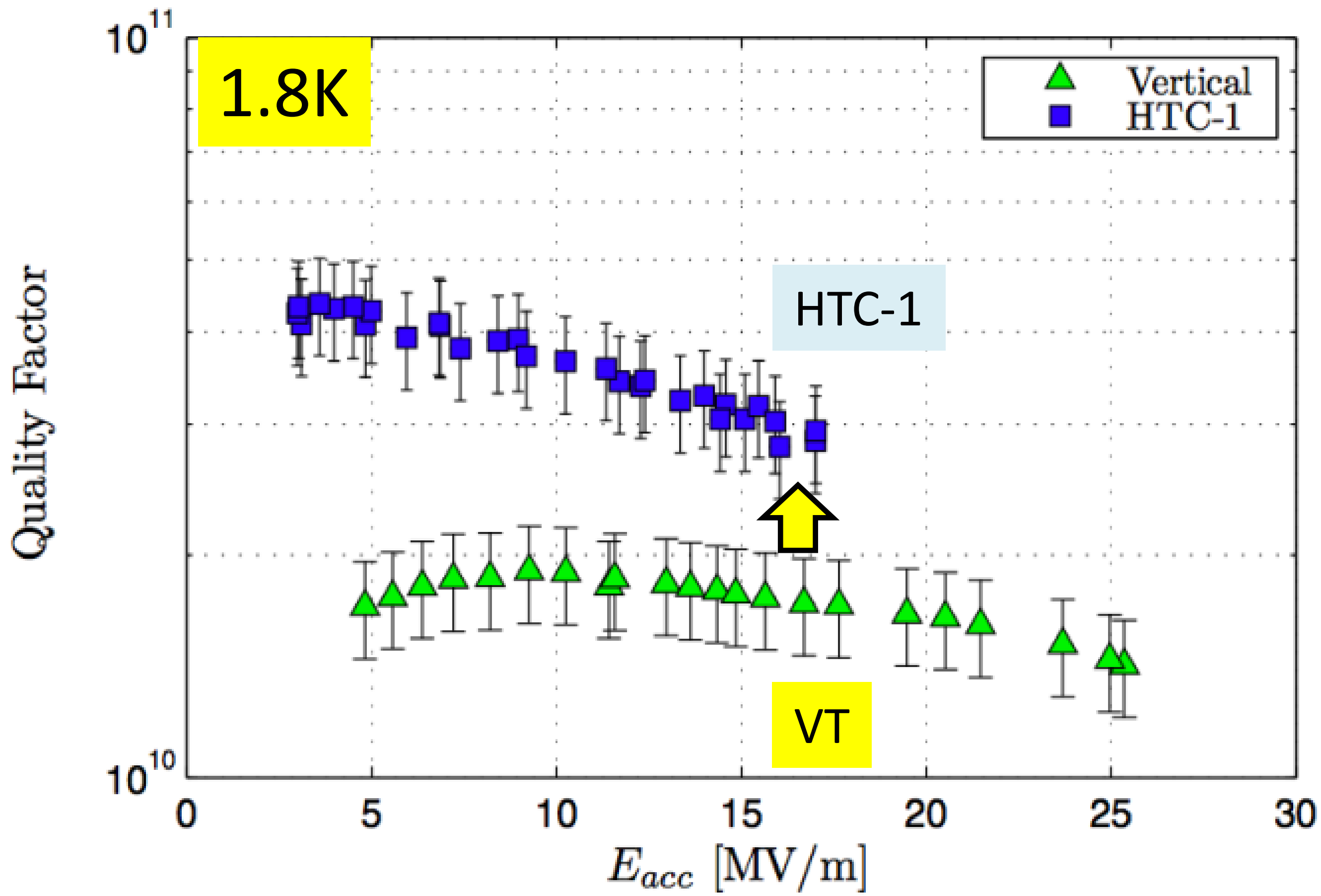
1) Better mag. Shielding in HTC



HTC has much better mag. shielding than VT dewar.

R_{res} was reduced from 11nOhm (VT) to 3.2nOhm (HTC-1)

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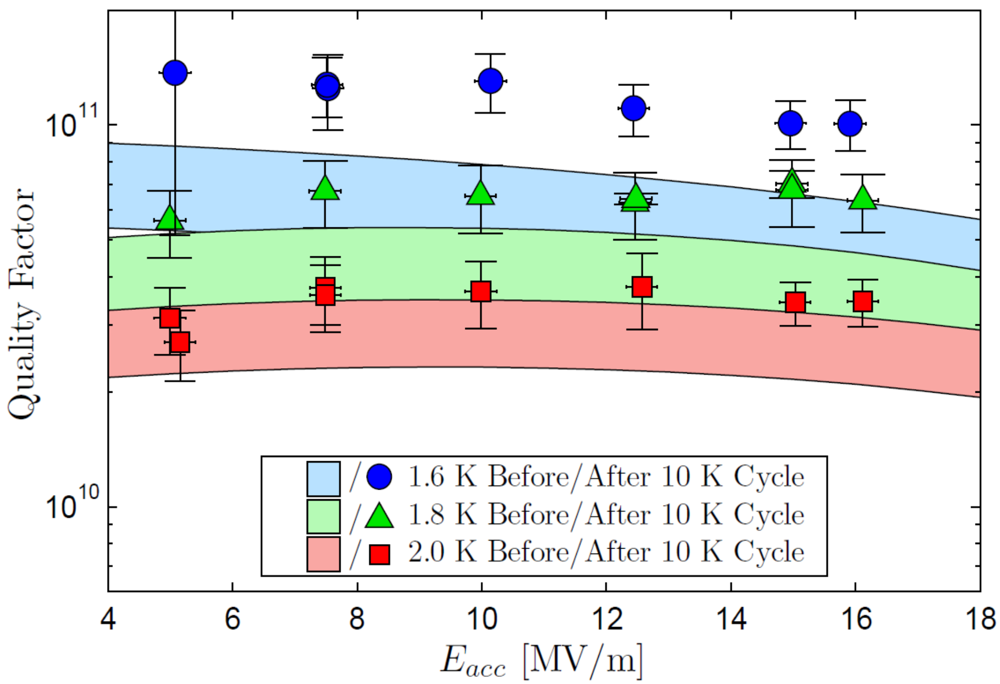
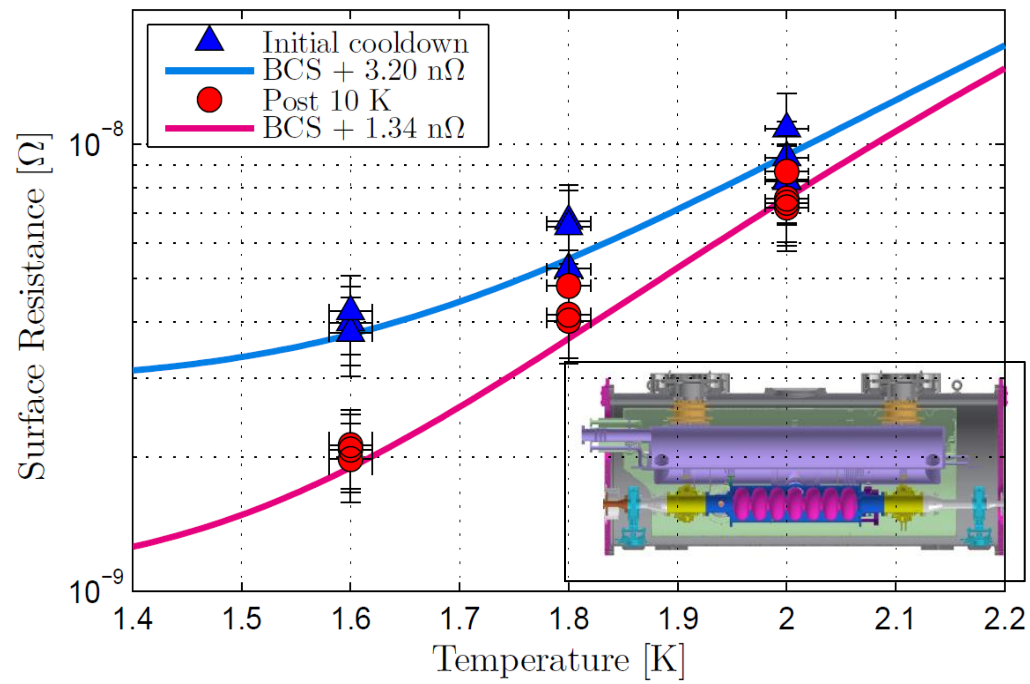
2) Thermal cycle to above Tc is beneficial





Initial Cooldown at 16.2 MV/m

Q_0(2.0 K) = 2.5 x 10^{10}

Q_0(1.8 K) = 3.5 x 10^{10}

Q_0(1.6 K) = 5.0 x 10^{10}

R_{res}=3.2nΩ

10 K thermal cycle at 16.2 MV/m

Q_0(2.0 K) = 3.5 x 10^{10}

Q_0(1.8 K) = 6.0 x 10^{10}

Q_0(1.6 K) = 10.0 x 10^{10}

R_{res}=1.3nΩ

- Slow cool down rate through Tc; ~0.4K/h
- Small cavity temp. gradient; ~0.2K

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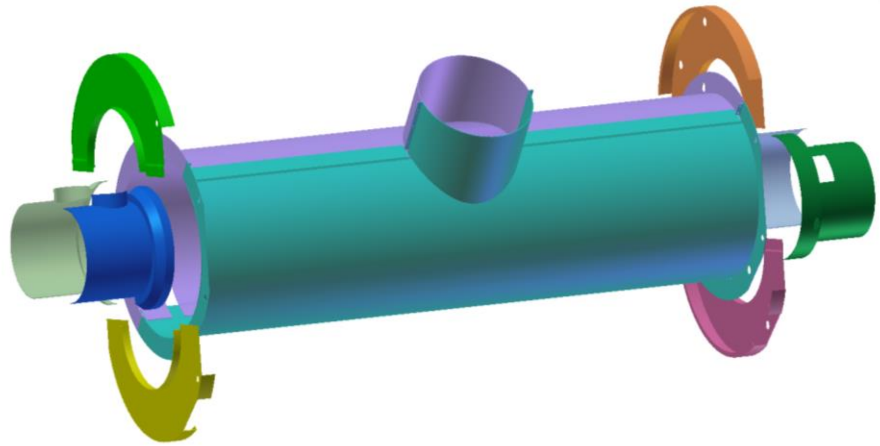
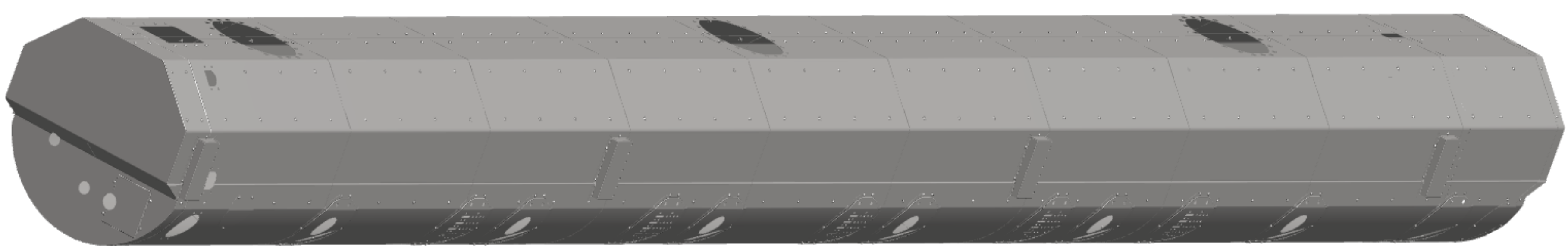
Magnetic shielding

- 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





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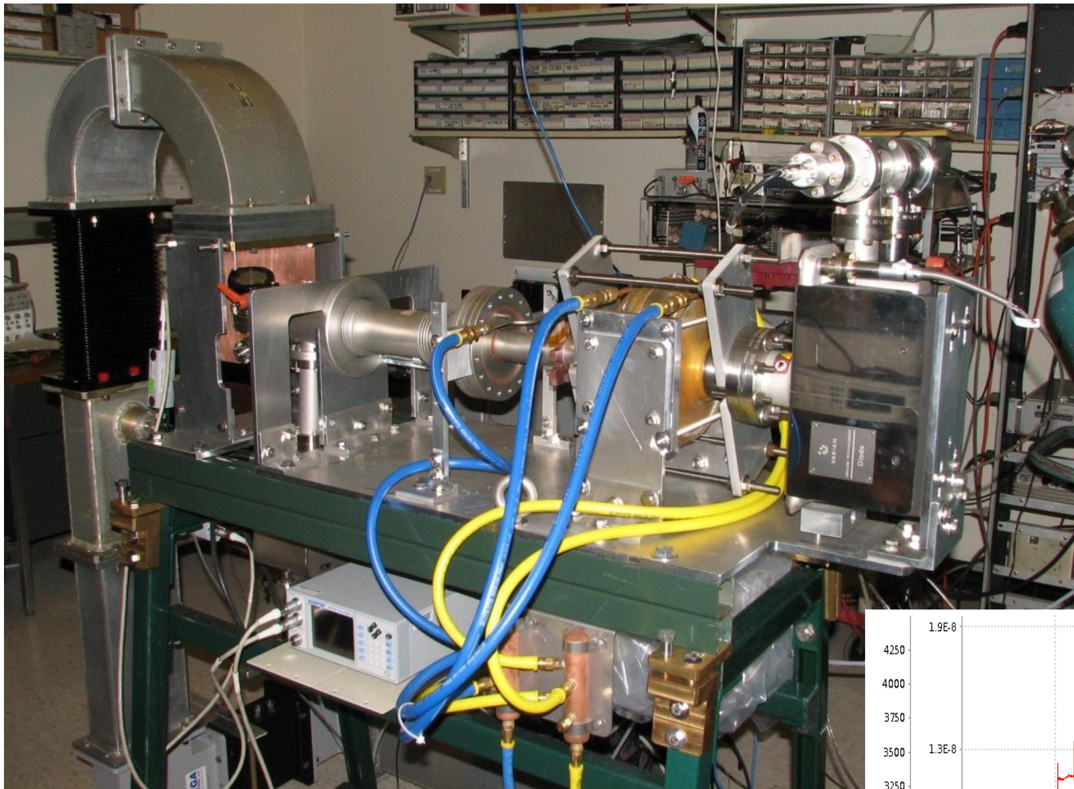
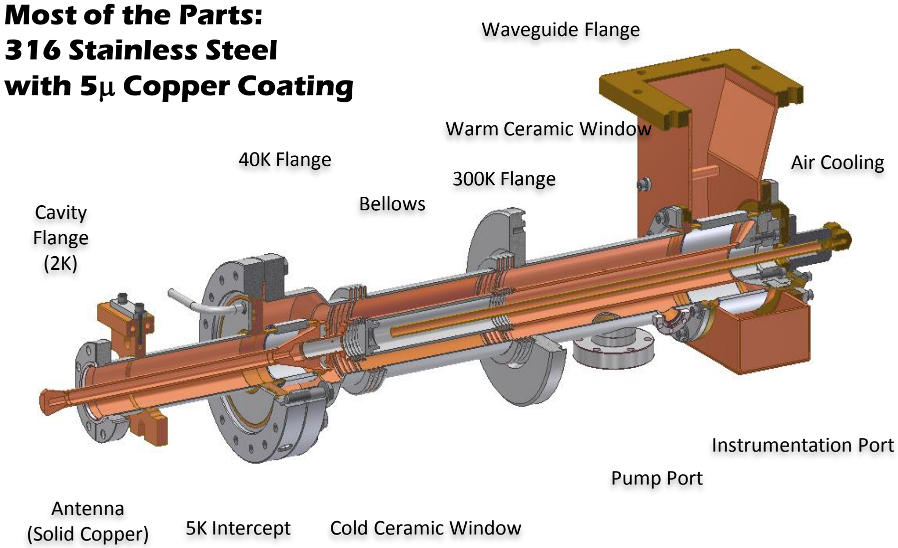
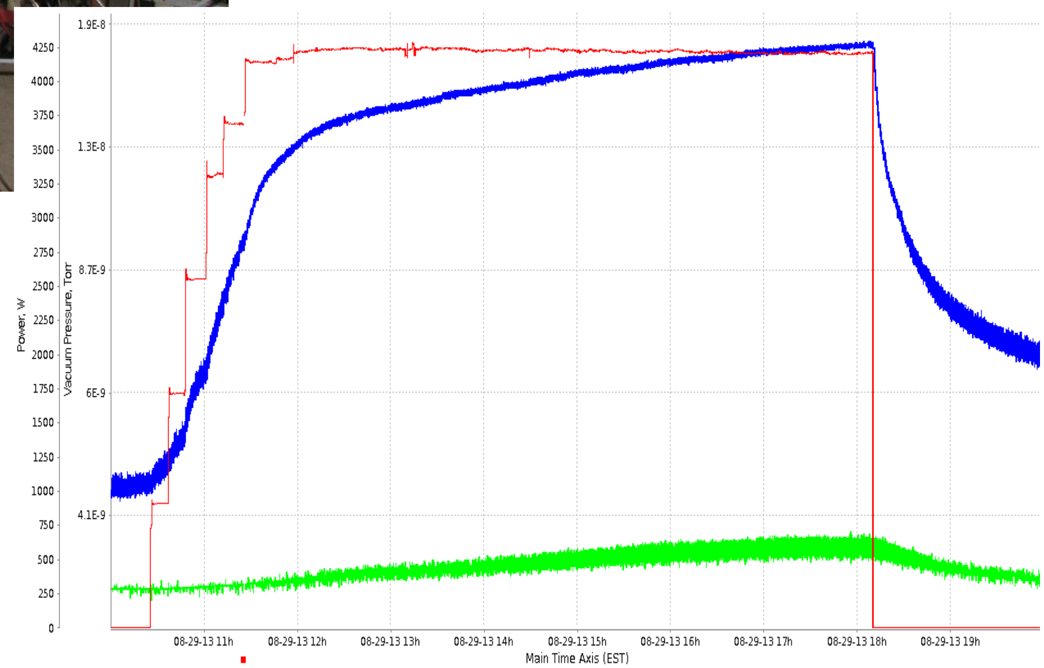
Main Linac Input Coupler Testing



Most of the Parts:
316 Stainless Steel
with 5μ Copper Coating





- Power rating: 5 kW CW
- Qext: 6e7
- Designed by Cornell
- Built by CPI

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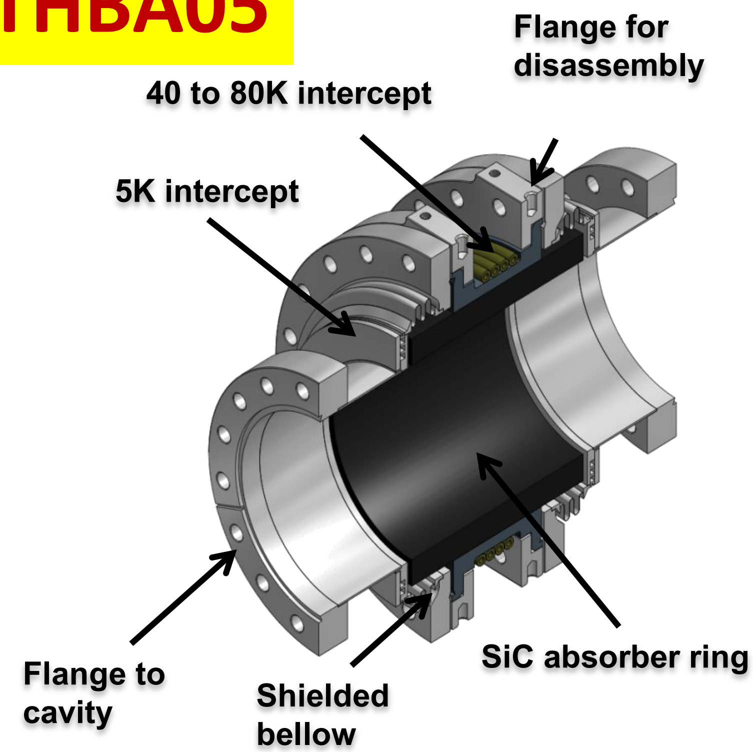
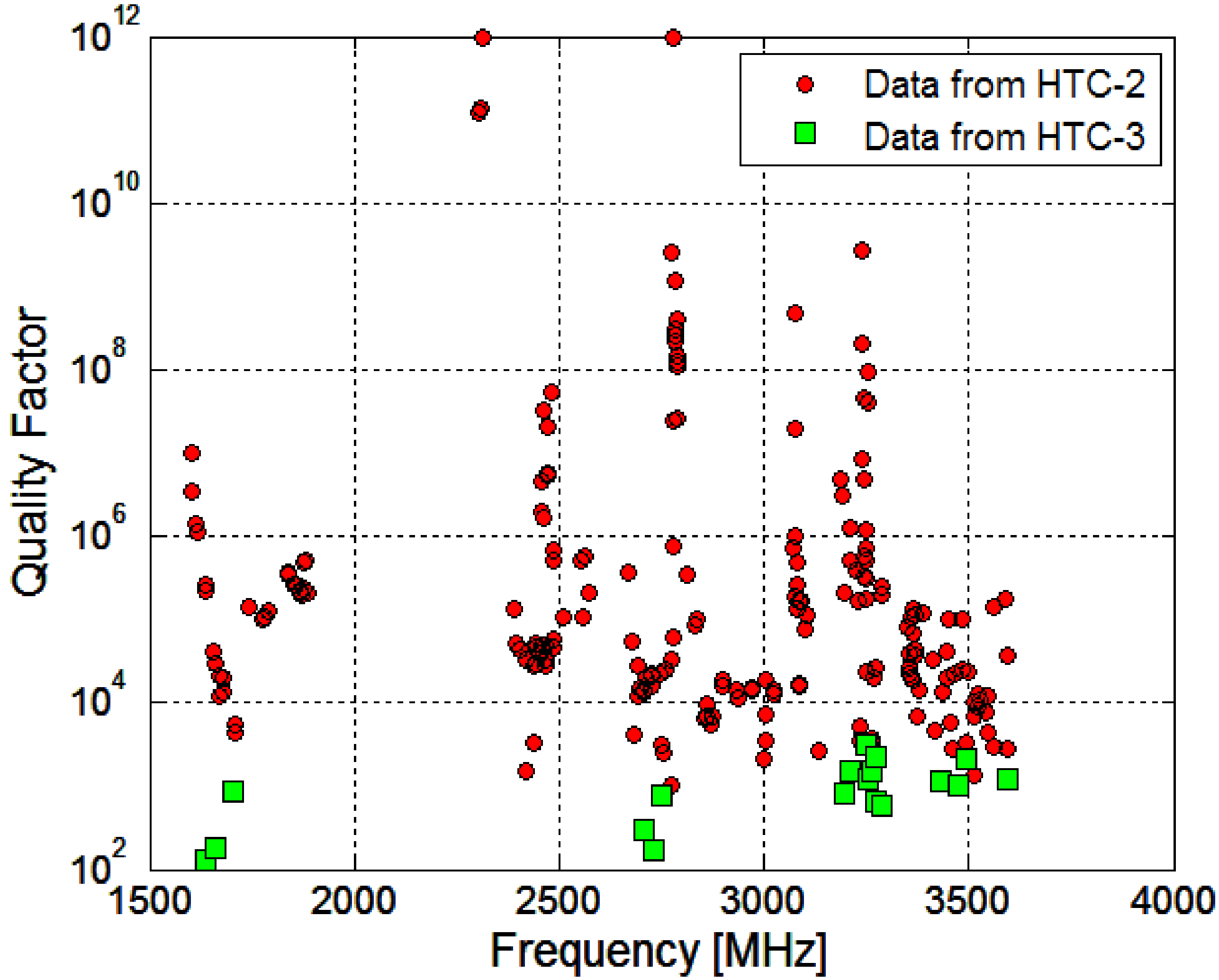
HOM Absorbers



HTC-2: No HOM Absorbers

HTC-3: With HOM Absorbers



Beamline HOM absorbers strongly damp dipole HOMs to under Q ~ 10^4

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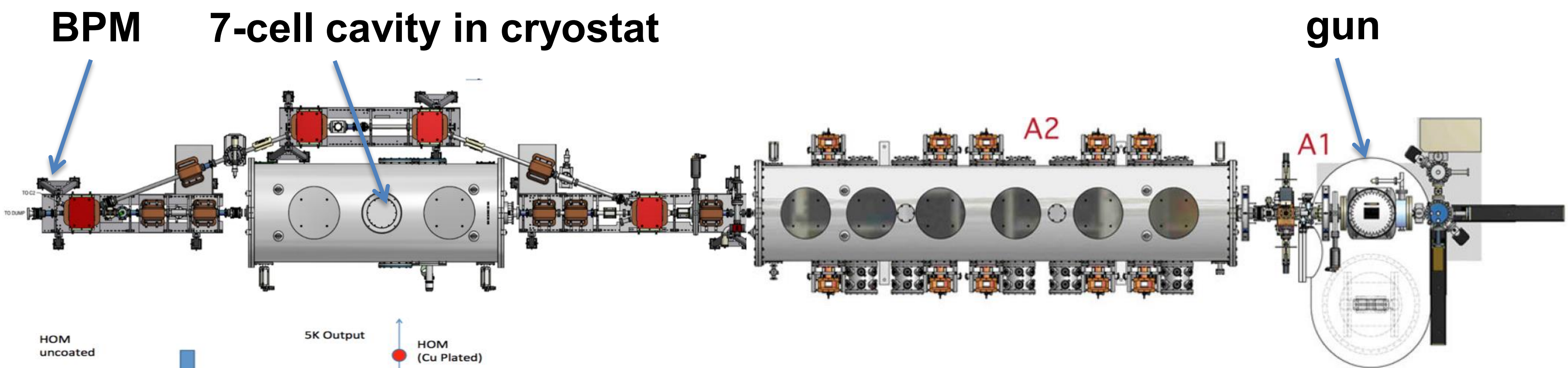
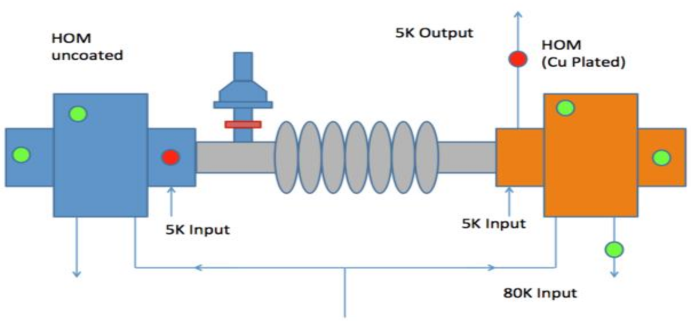
HOM Absorbers beam test





Current, bunch length	ΔT (beam pipe behind Abs.) coated/uncoated	ΔT (80K gas temp) coated/uncoated	ΔT (80K absorber temp) coated/uncoated	ΔT (5K flange next to cavity) coated	ΔT, beam pipe to cavity coated/uncoated
25 mA, 3.0 ps	0.075/0.075	1.14/0.82	1.02/0.975	0.007	0.076/-.005
40 mA, 3.4 ps	0.2475/0.335	2.95/2.16	2.72/2.53	0.021	0.179/0.009
40 mA, 2.7 ps	0.2975/0.425	3.00/2.22	2.772/2.63	0.027	0.203/0.014

THBA05

- No charge-up of the HOM ceramics observed
- HOM heating was less than expected

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MLC assembly at Newman lab

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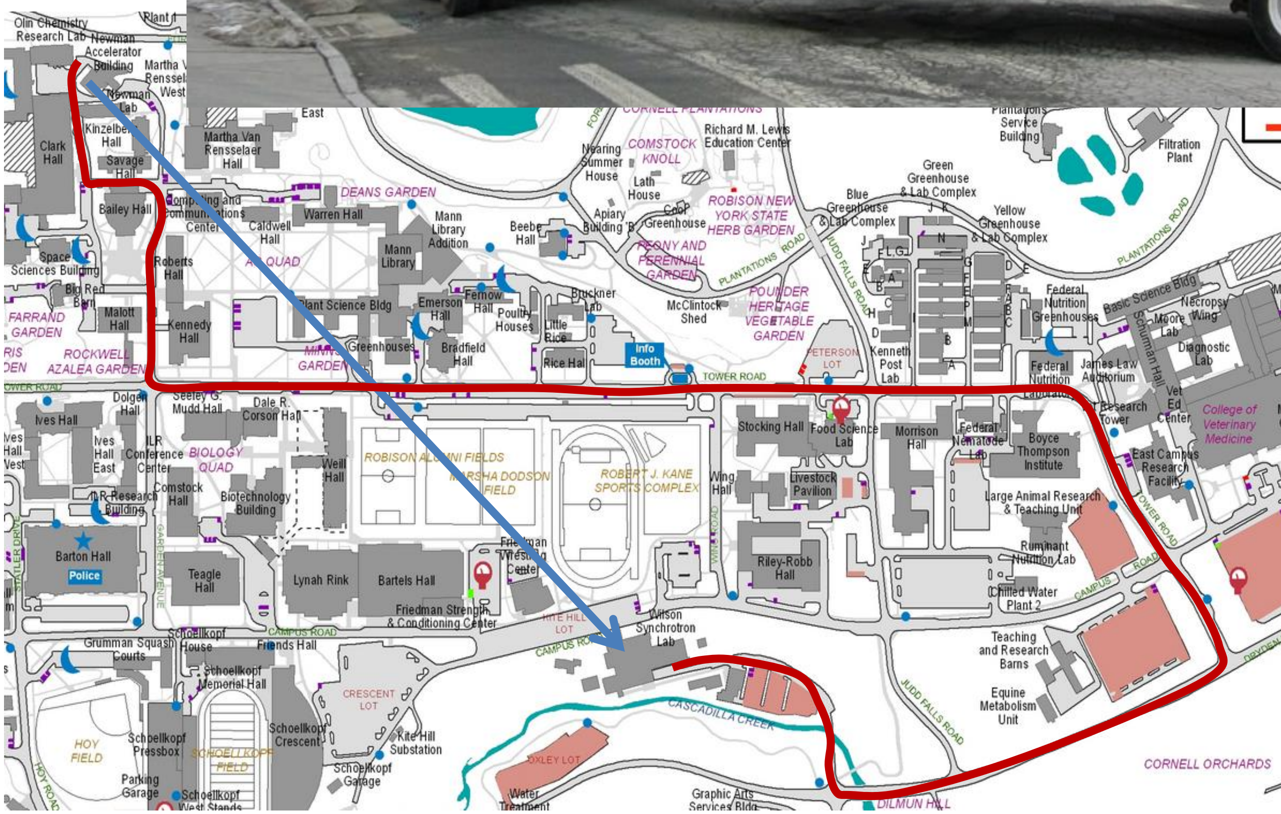
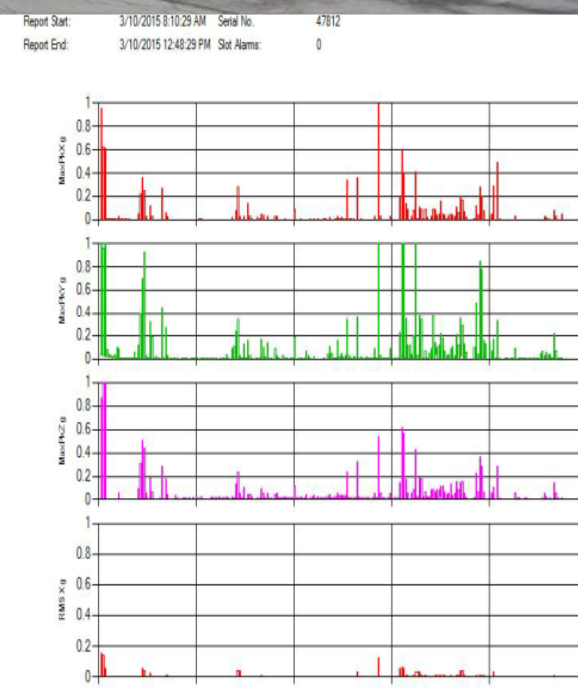
Moving MLC to Wilson lab

Mar. 2015





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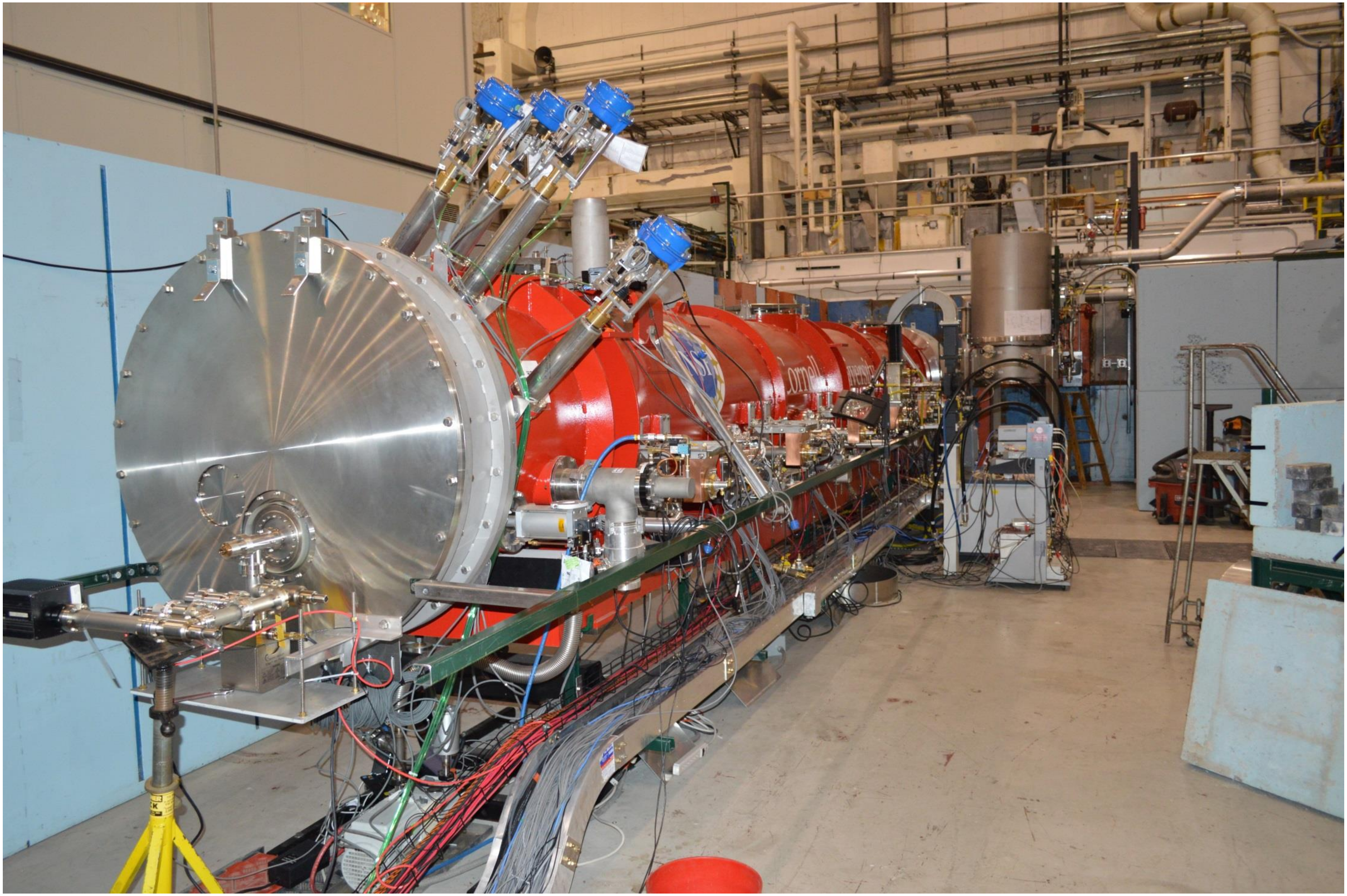
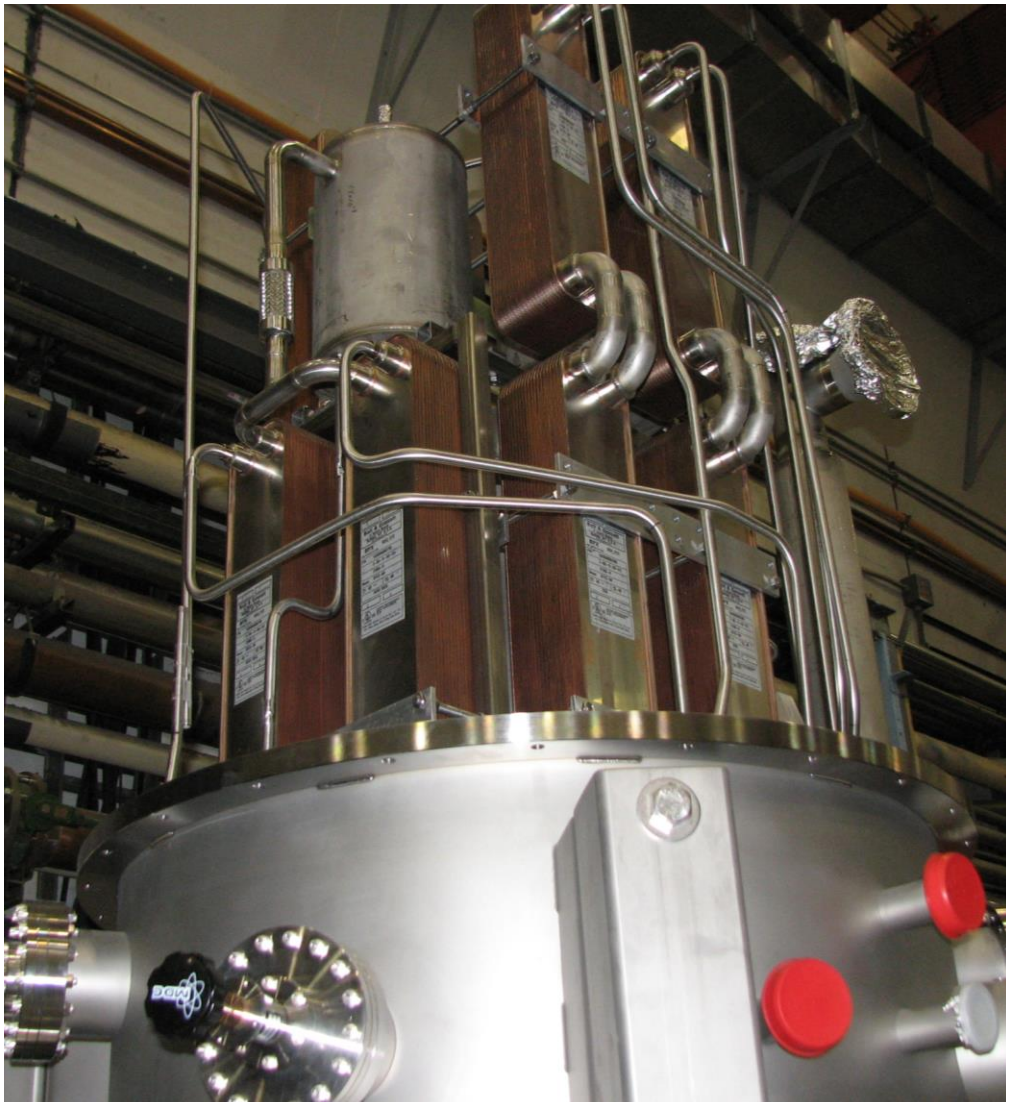
MLC in Wilson L0E



Heat exchanger can



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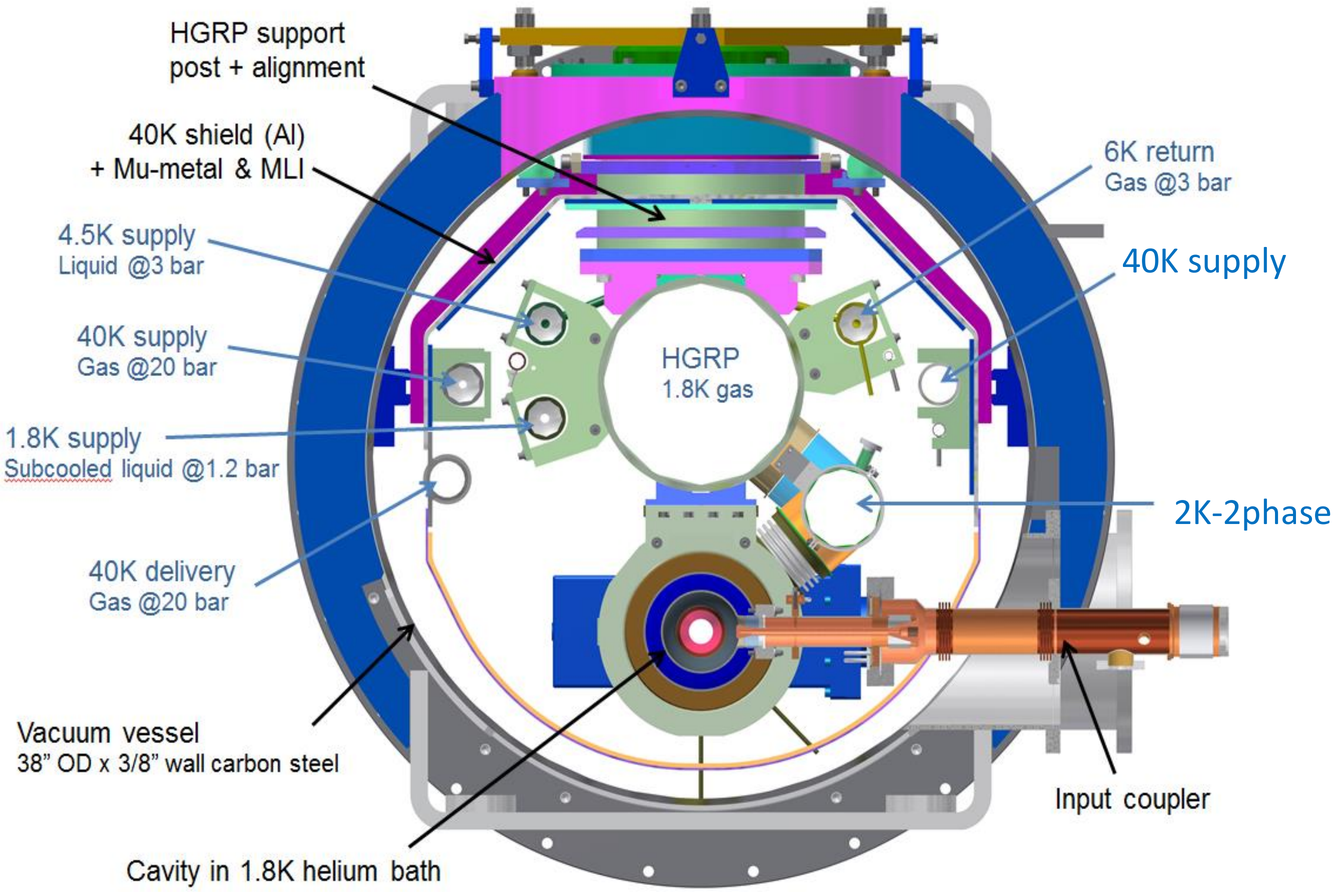
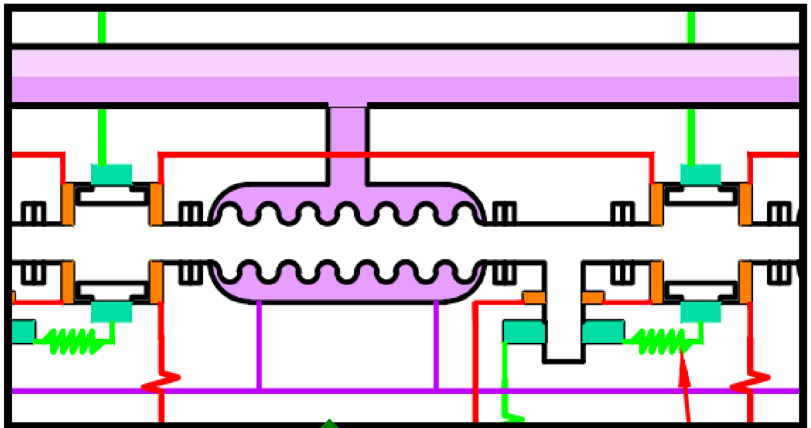
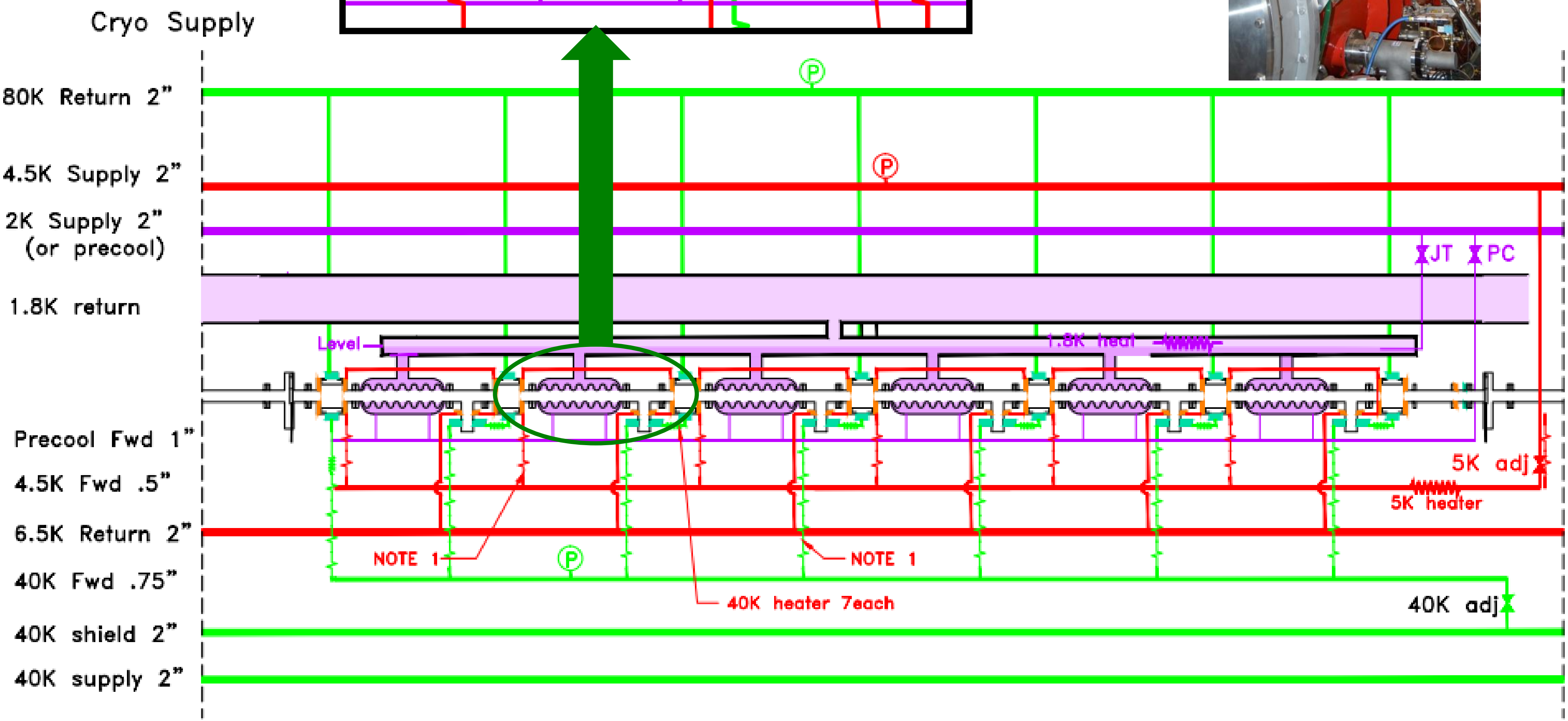
Cryogenic sketch

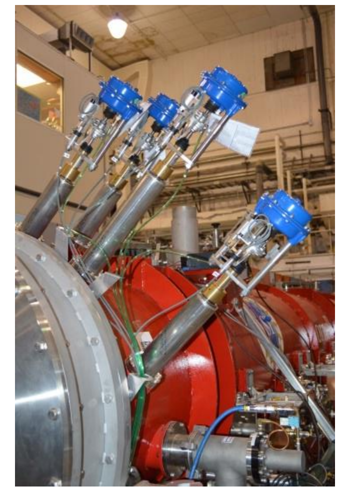


1 line for 2K supply	subcooled liquid @1.2 bar	• 2K helium bath for cavities via 2K-2 phase line • pre-cool gas for cool-down • 90% heat load from RF losses in the cavities
2 lines for 4.5-6K	3.0 bar He liquid Single phase flow	• Thermal intercept for HOM absorbers and couplers • 2/3 dynamic heat load
3 lines for 40-80K	20 bar He gas	• Thermal intercept for HOM absorbers and couplers • 40K thermal shield • 90% heat load from HOM

Prototype MLC Cooling schematic







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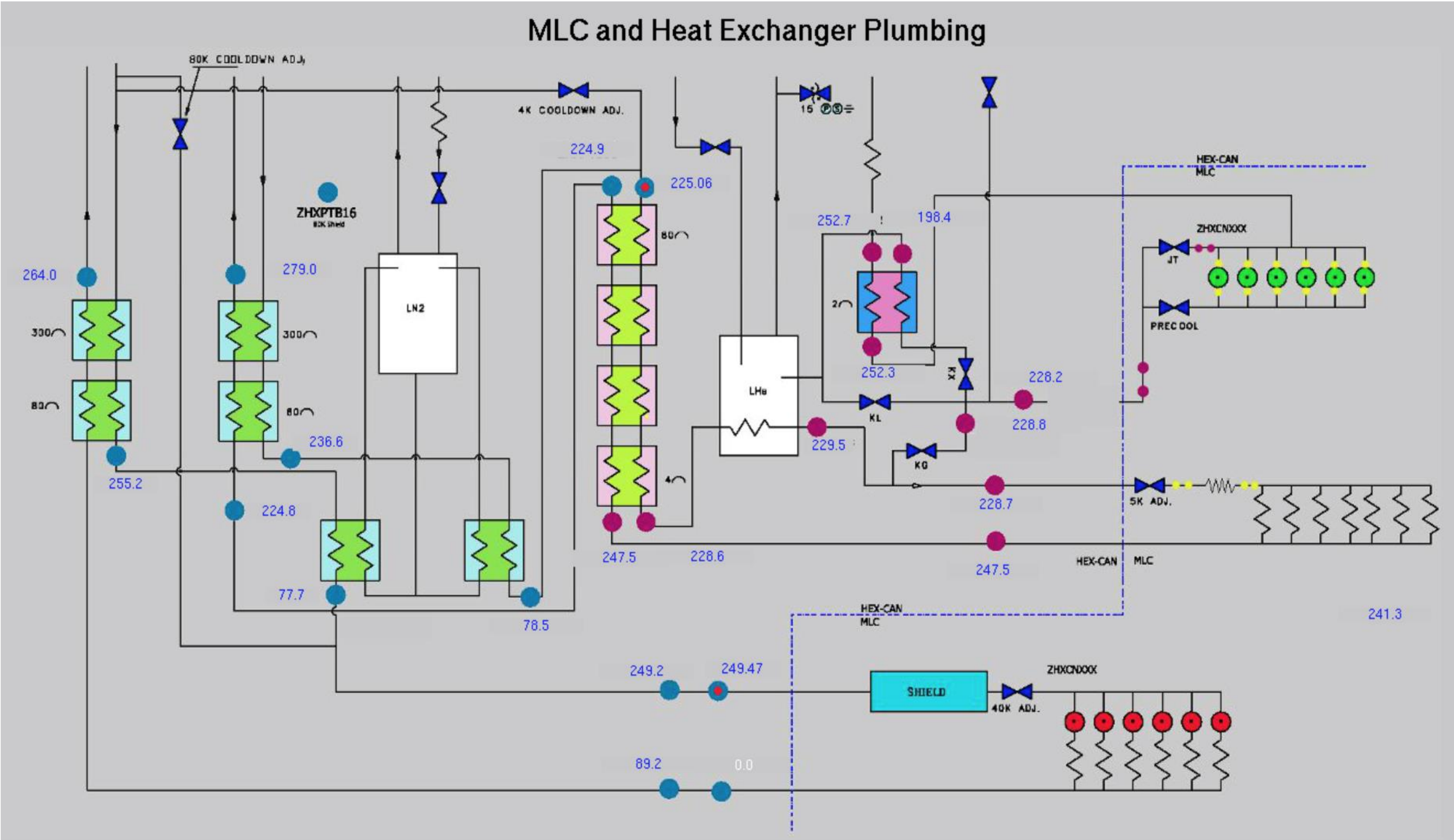
MLC and HXC Plumbing



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MLC Cool down

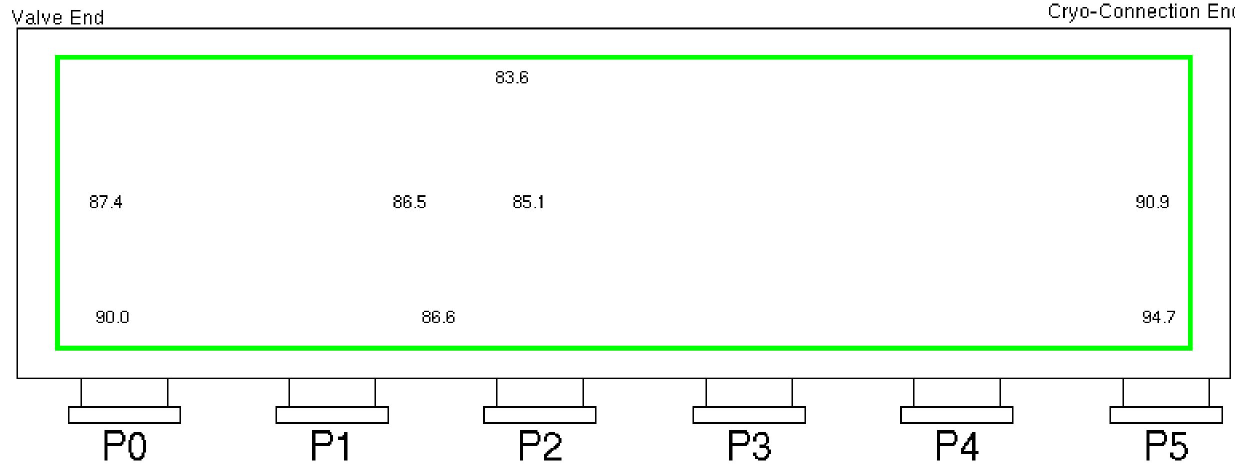
Cool down target;

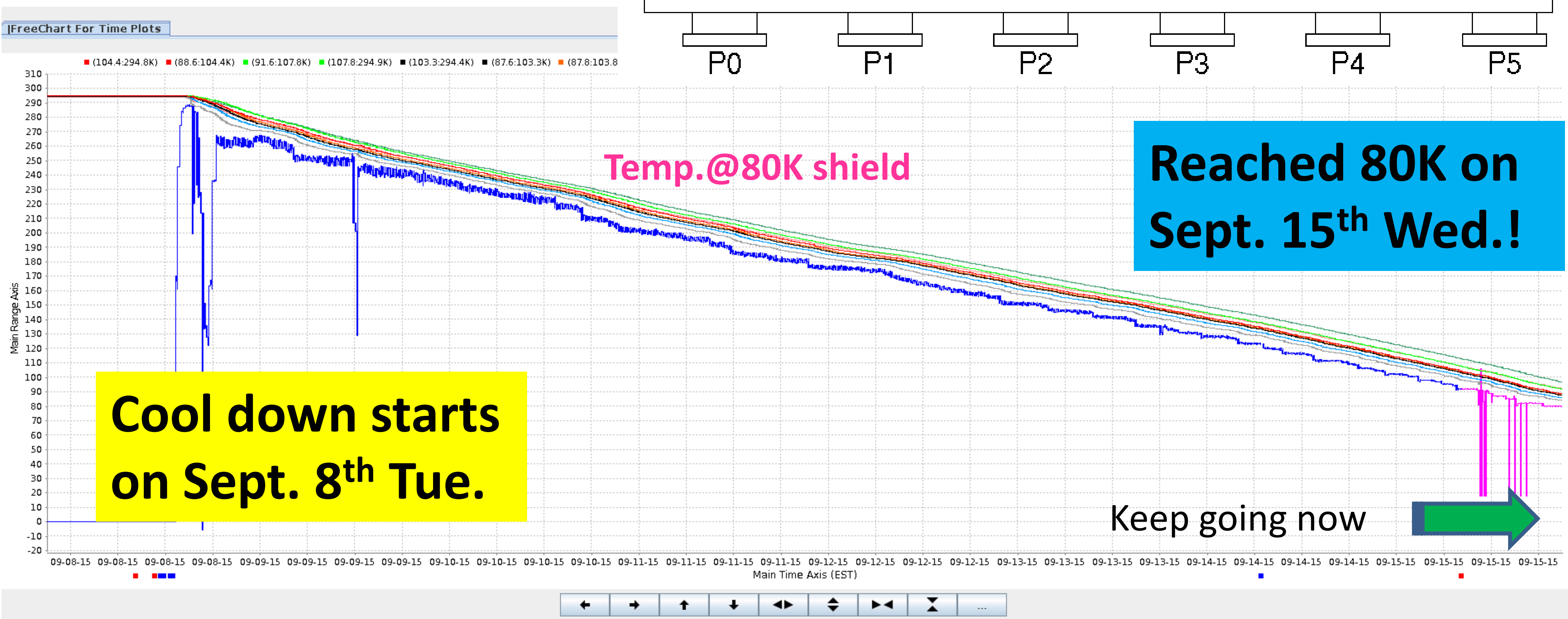
- 4k/h from room temp. to 80K
- dT<20K on 80K shield

Actual

- ~1.3k/h from room temp. to 80K
- dT~15K on 80K shield.

MLC 80K shield temperature





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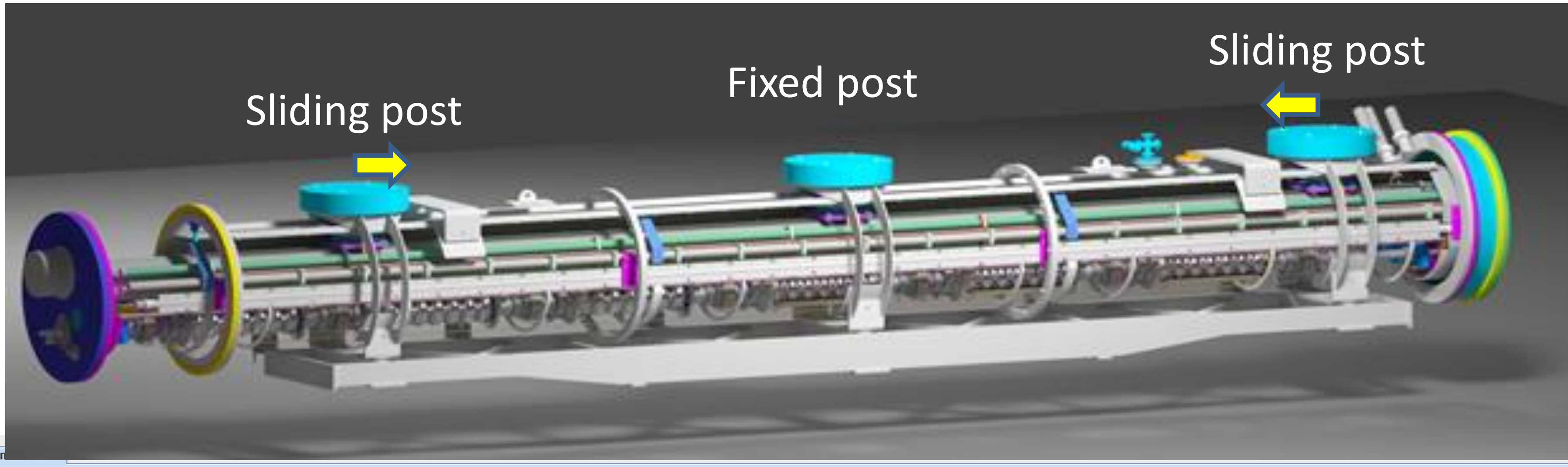
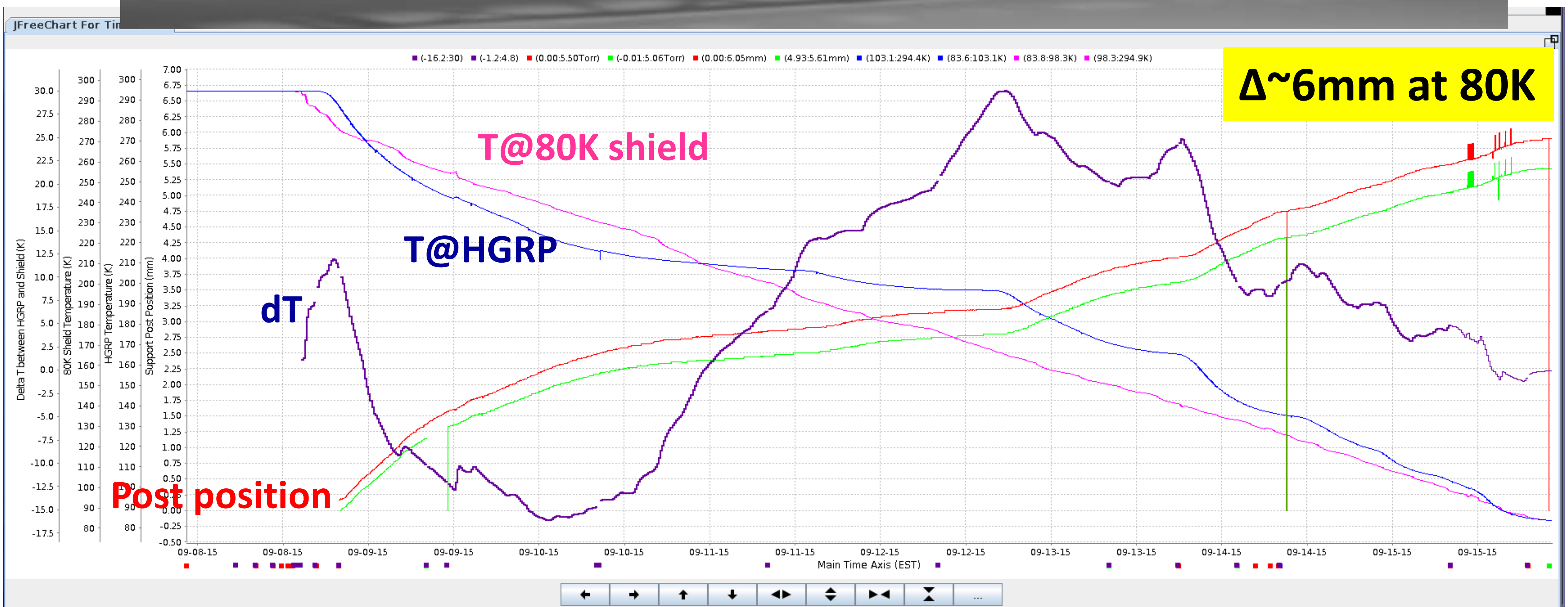
MLC shrinkage during cool down





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MLC Today

A new ELOG entry has been submitted:

Logbook: MLC Message ID: 32

Entry time: Thu Sep 17 14:49:03 2015 (EDT)

Author: Peter Quigley

Type: Routine

Category: General

Subject: MLC Cooldown Status

MLC cooldown is complete!

Pump skid is running and operating for 1.8K.

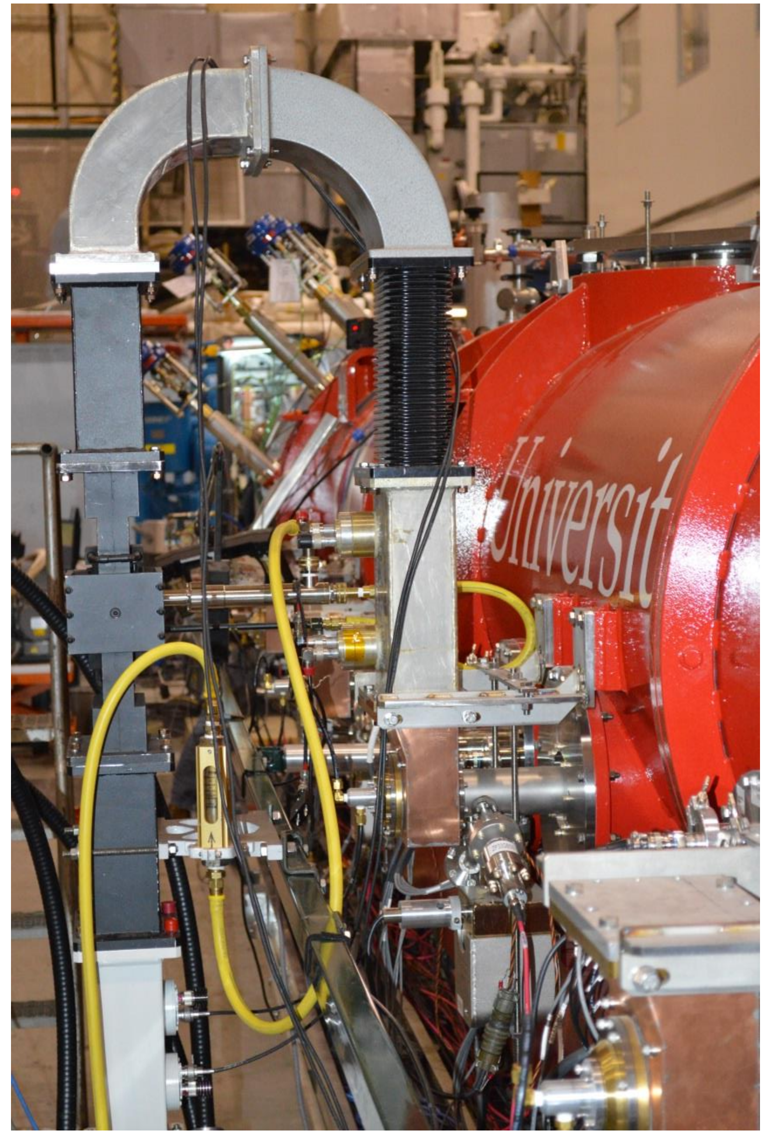
Setup for RF is next.

Details later today.

Alarm Handler is running in CESR Control room.

Peter Quigley for The Team.

MLC cavity RF test prep.



- ERL7-7 will be the 1st cavity to test in MLC.
- ERL7-7 VT results was 3e10 at 16MV/m, 1.8K.

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MLC Milestones

Dec 2012	Design completed
Jan. 2013	Order 6 remaining input couplers (6 month fab)
Feb. 2013	3 unstiffened cavity built, testing started
Apr. 2013	Award vacuum vessel PO (6 month fab) & HGRP (6 month)
July 2013	Production of 3 stiffened cavities started
Sept. 2013	In-house fabrication of string components complete (tuners, HOMs, tapers…)
Jan. 2014	Begin string assembly in clean room
May 2014	Begin cold mass assembly and instrumentation (outside clean room)
End of 2014	Cold mass assembly complete, MLC ready for moving
Mar 2015	Moving MLC from Newman to Wilson
July 2015	Begin MLC installation in Wilson L0E and cool down preparation
Sept. 2015	MLC cool down starts and completed. Cavity RF test will start (2weeks/cavity, Q(E), tuner, HOM, HPC, microphonic, etc..)
End of 2015	Will complete cavity RF test

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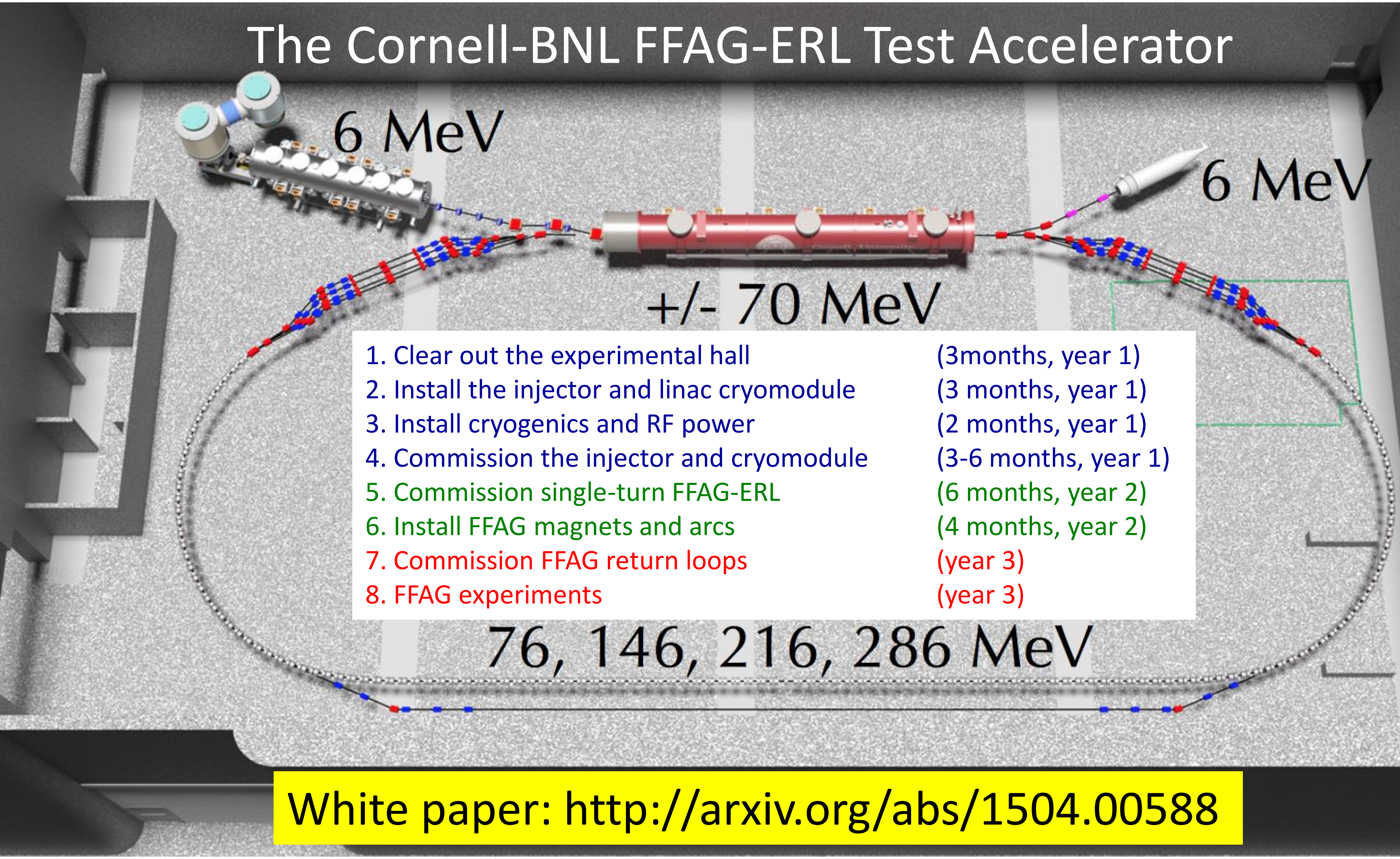
Future

The Cornell-BNL FFAG-ERL Test Accelerator



1. Clear out the experimental hall	(3months, year 1)
2. Install the injector and linac cryomodule	(3 months, year 1)
3. Install cryogenics and RF power	(2 months, year 1)
4. Commission the injector and cryomodule	(3-6 months, year 1)
5. Commission single-turn FFAG-ERL	(6 months, year 2)
6. Install FFAG magnets and arcs	(4 months, year 2)
7. Commission FFAG return loops	(year 3)
8. FFAG experiments	(year 3)

White paper: http://arxiv.org/abs/1504.00588

Summary

- **All MLC components had been tested successfully and assembled into cold mass.**
- **World record high-Q had achieved during HTC 7-cell test,**

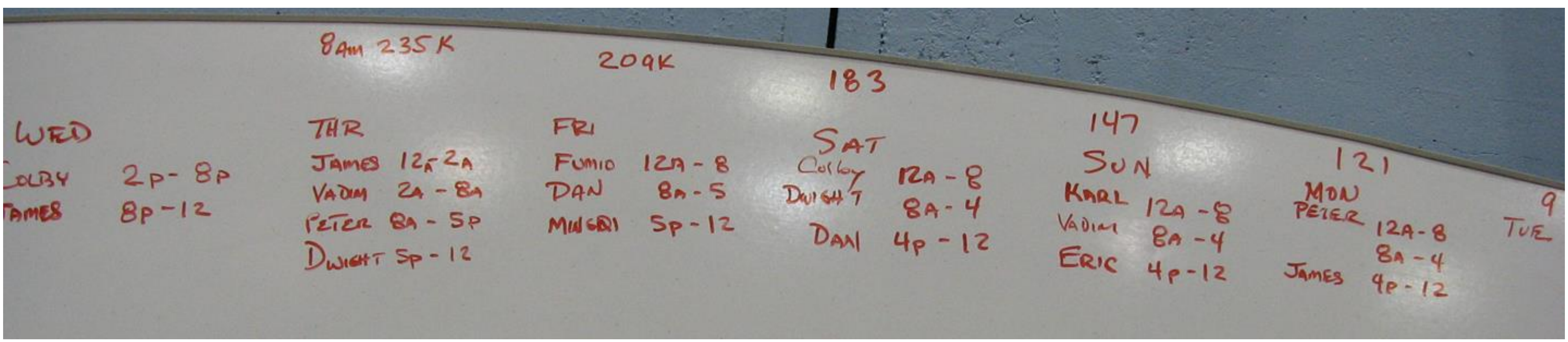
  3.5e10(2K), 6e10(1.8K), 1e11(1.6K)
- **Essences of Cornell's ERL high-Q cavities are**

  1) good mag. shielding

  2) Thermal cycle to above Tc is beneficial
- **MLC cool down starts in Wilson lab on Sept. 8th, completed on Sept 17th, Pump skid is running and operating for 1.8K.**
- **From room temp. to 80K, Cool down rate is about 1.3K, dT over 80K shield is kept ~15K during cool down.**
- **RF test will start after conference, one cavity test at once, 2weeks/cavity.**
- **thermal cycle will be applied to improve Qo.**

Acknowledgement

Paul Bishop, Mitch Bush, John Dobbins, Edwin Foster
Richard Gallagher, Greg Kulina, Gloria Lafave, Jeff Mangus
Jamie Maywright, Jonathan McDonald, Kate Miller,
Tobey Moore, Peter Quigley, Mike Ray, Dan Sabol,
James Sears, Colby Shore, Eric Smith
Vadim Veshcherevich, Dwight Widger



Shift table during room temp. to 80K cool

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