High Q Cavities for the Cornell ERL Main Linac

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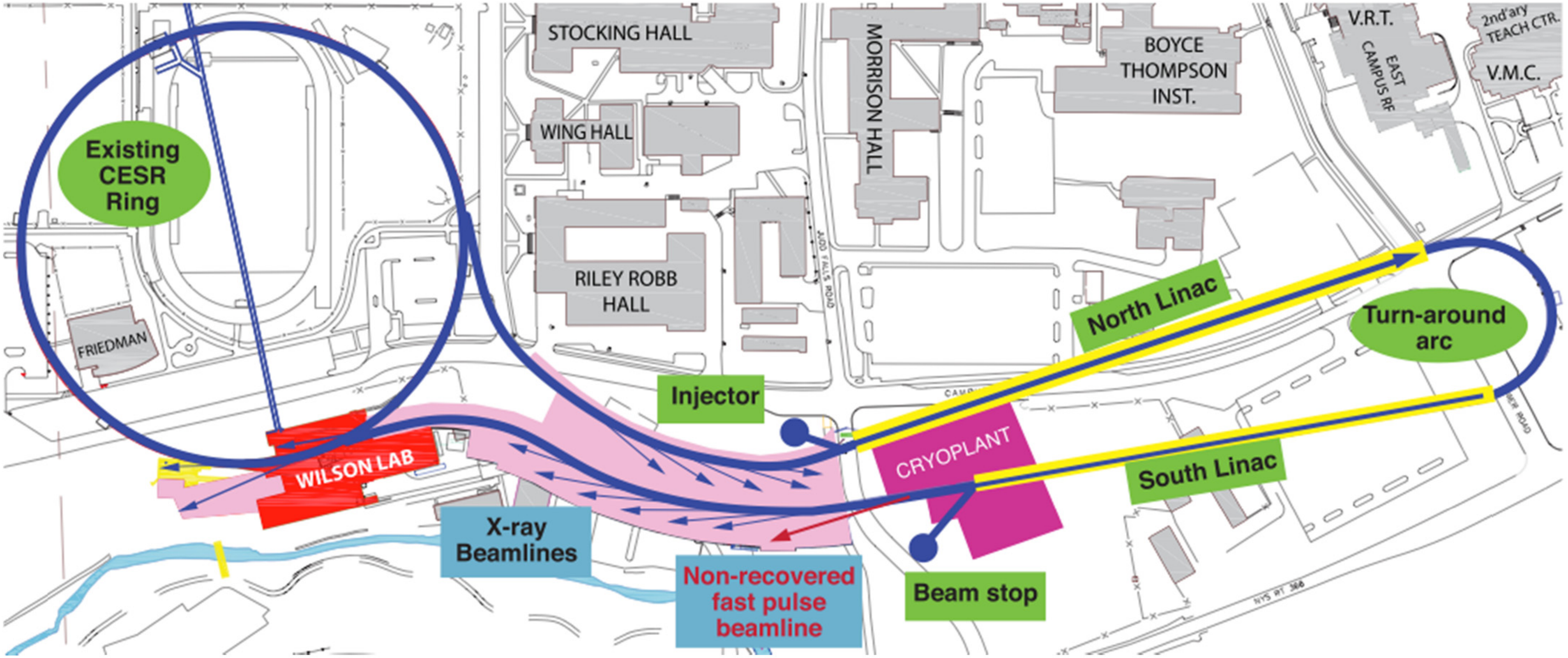
Cornell ERL Layout

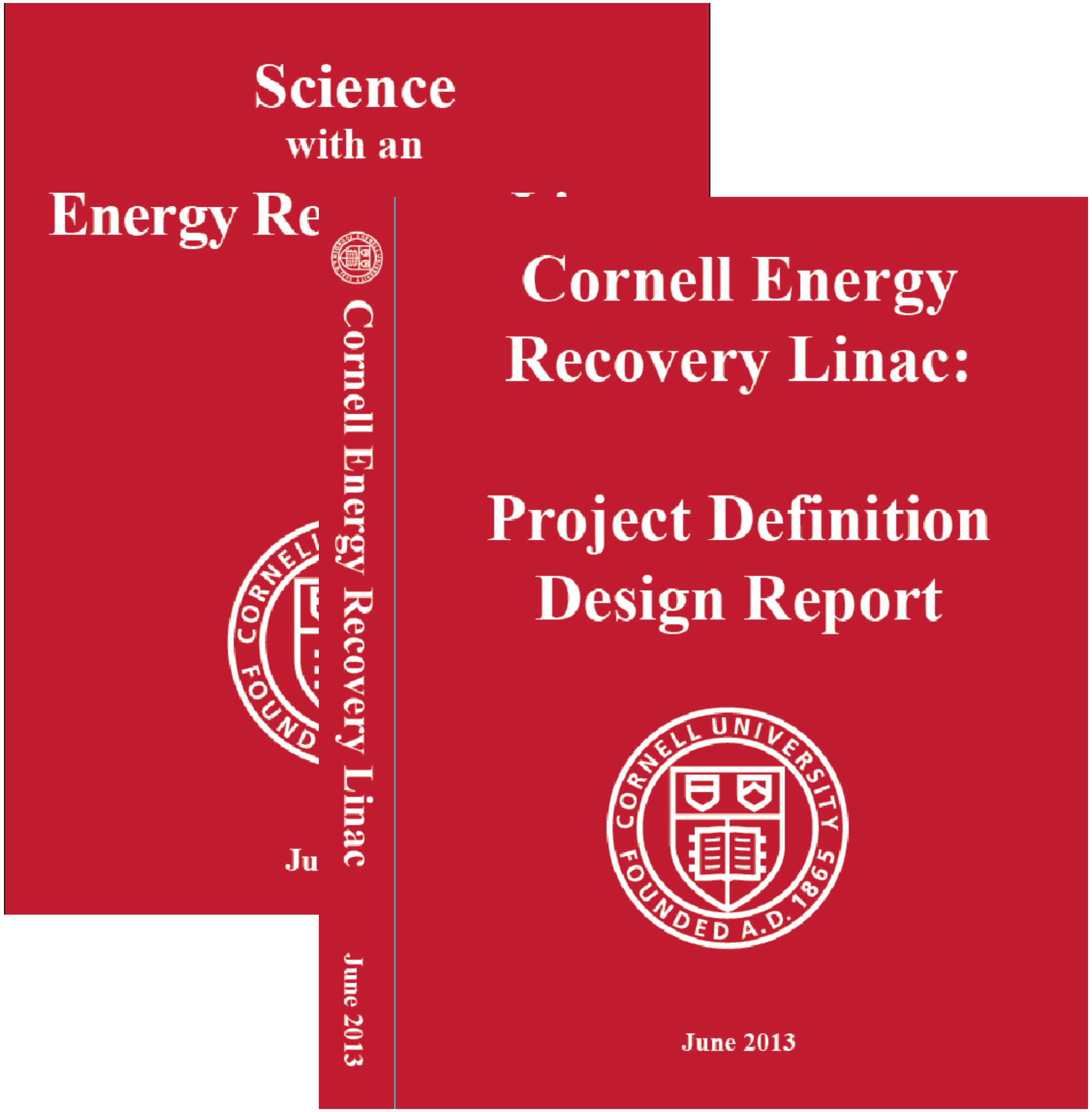
5 GeV, 100 mA CW beam , 8 pm emittance, 2 ps bunches



~200 W HOM power/cavity

CW operation, Q(1.8 K) = 2×10^{10} @ 16.2 MV/m

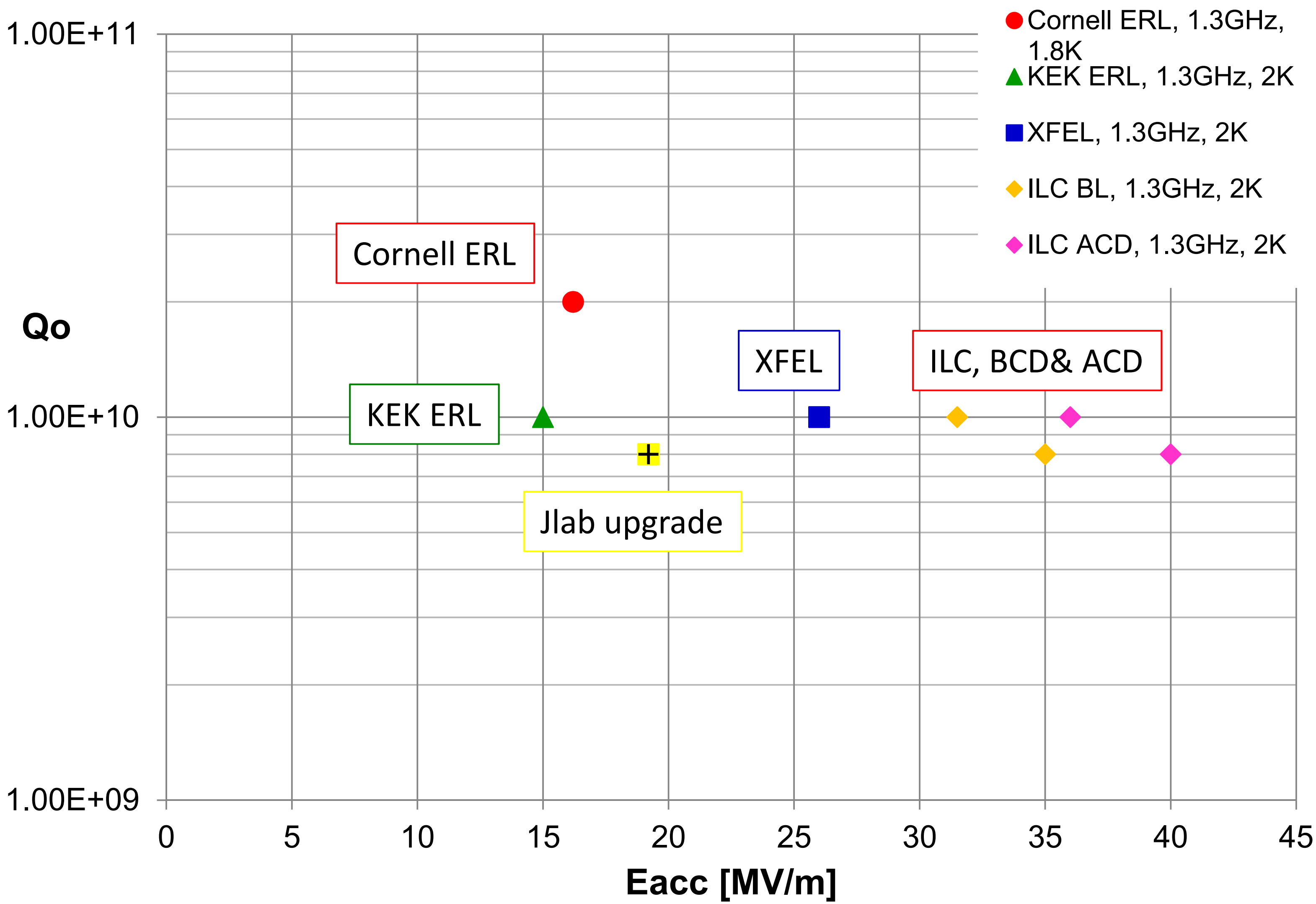
ERL documentation: (1) Science, (2) Generic design



- Science case gathered in international workshops
- Design report
  - 530 pages between conceptual design and engineering design
  - Access at

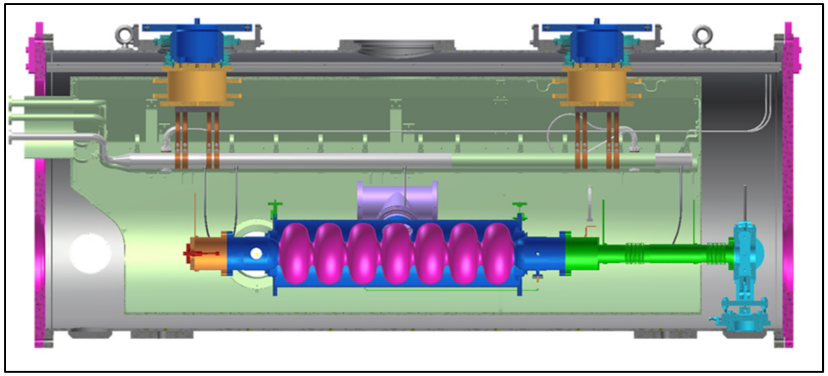
www.classe.cornell.edu/ERL/PDDR

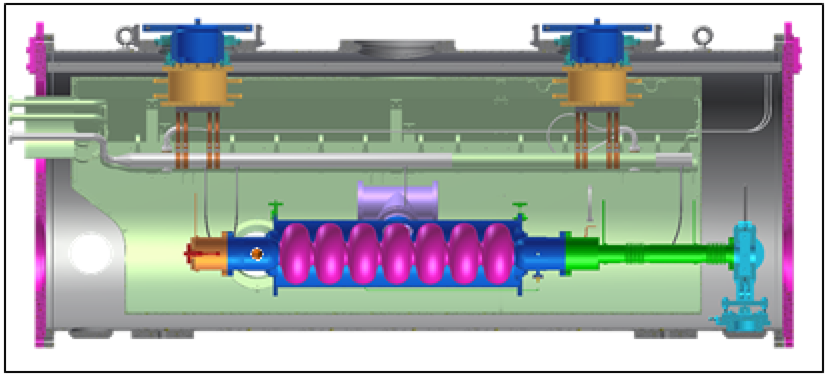
Cornell Cavity Specs

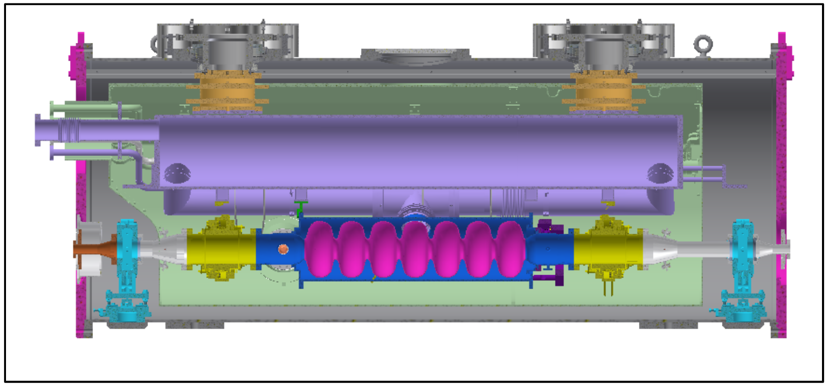


HTC Tests

- HTC-1: Follow vertical assembly procedure as closely as possible
- HTC-2: Include side mounted, **high power RF input coupler**
- HTC-3: Full cryo-module assembly:high power RF input coupler and **beam line HOM loads**

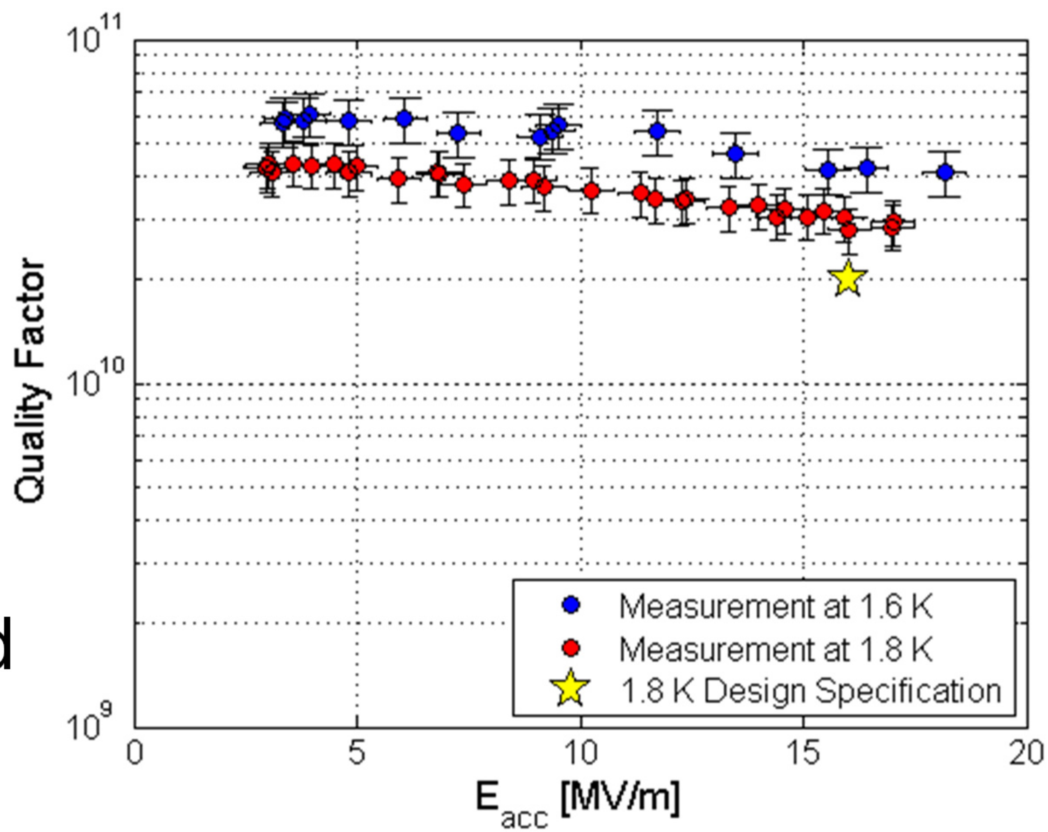






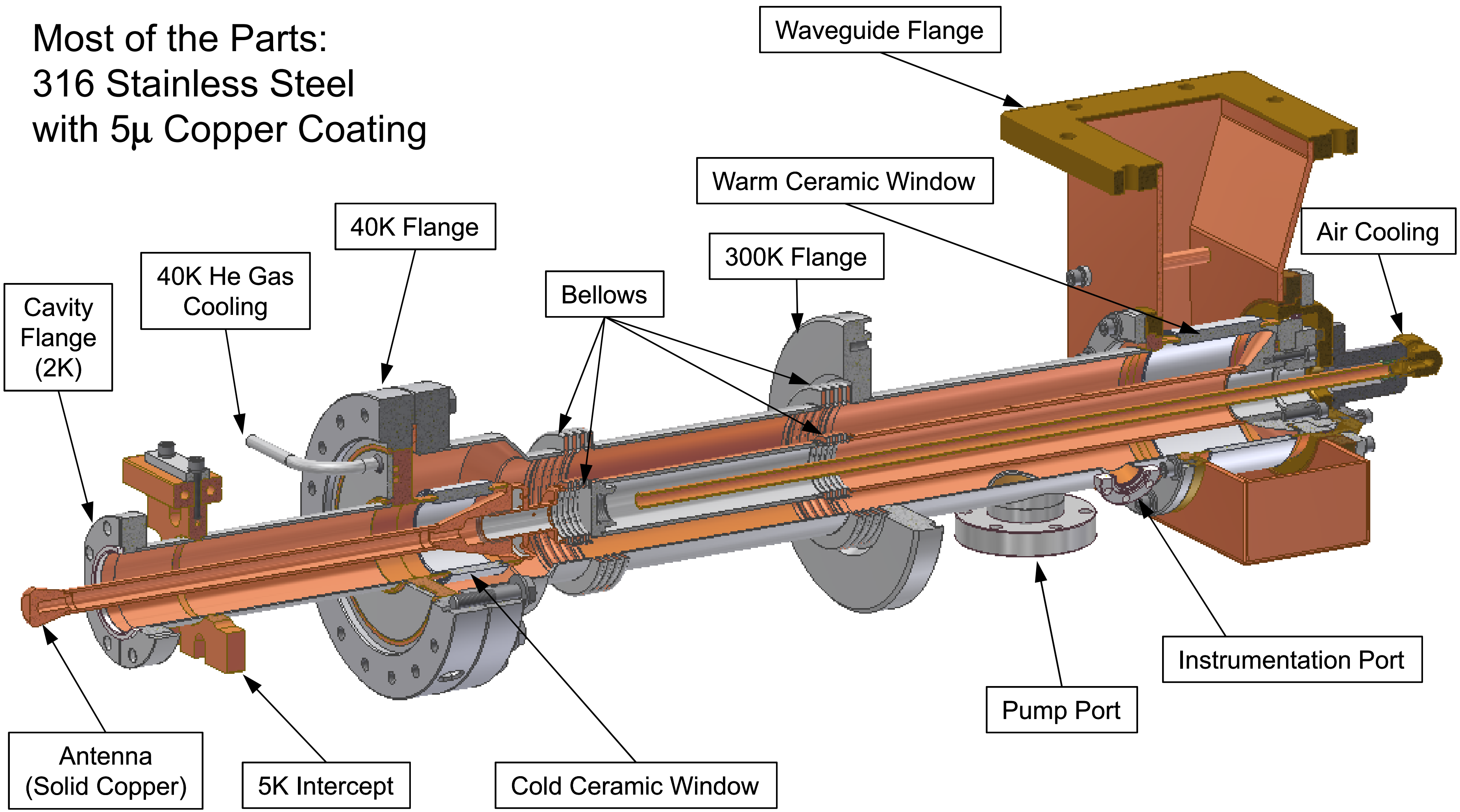
HTC-1: Results

- Cavity exceeded Q specification at 1.8 K by 50%, reaching 3×10^{10}
- Q(1.6 K, 5 MV/m) = 6×10^{10}
- Exceeded gradient specifications
- RF-based and calorimetric-based Q measurements yielded consistent values

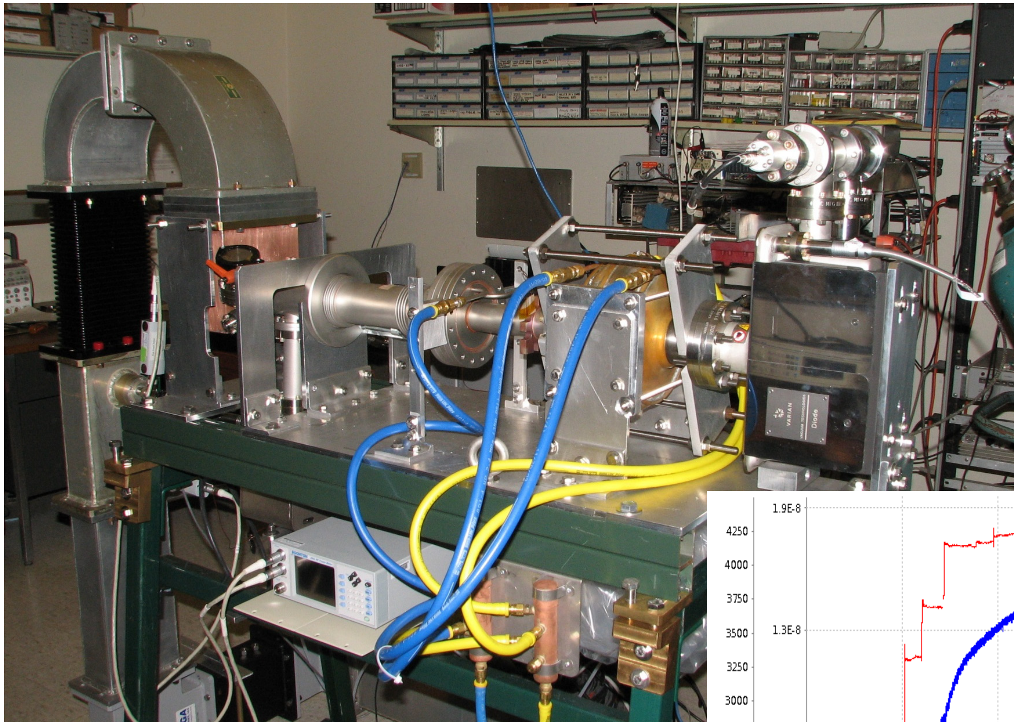


Main Linac Input Coupler

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



Main Linac Input Coupler Testing

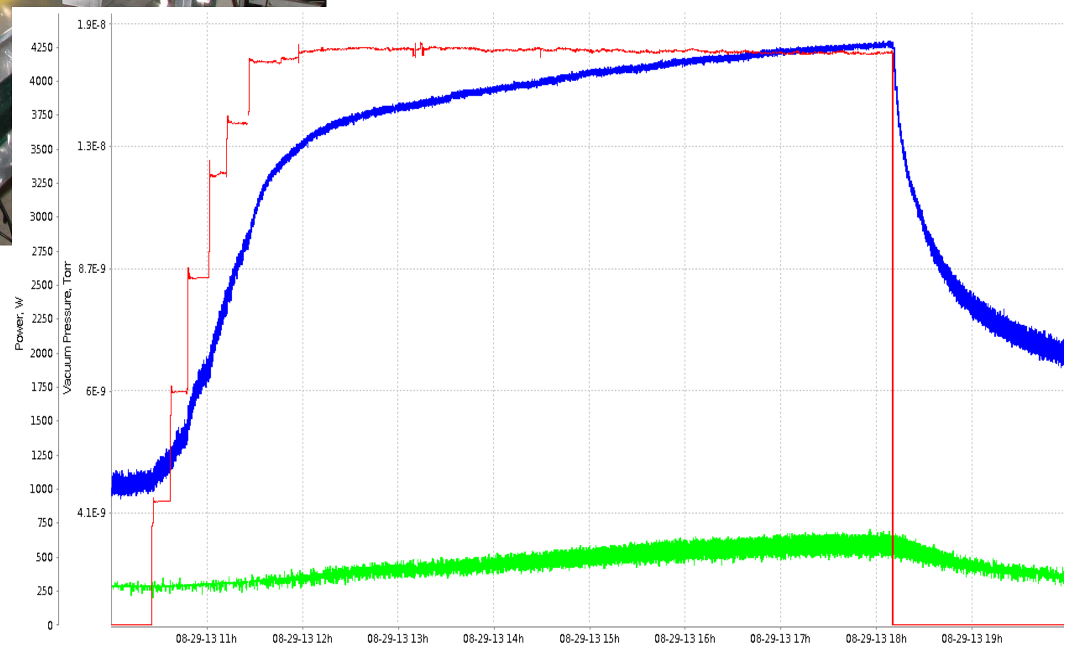


Power rating:
5 kW CW

Headroom for 10 kW

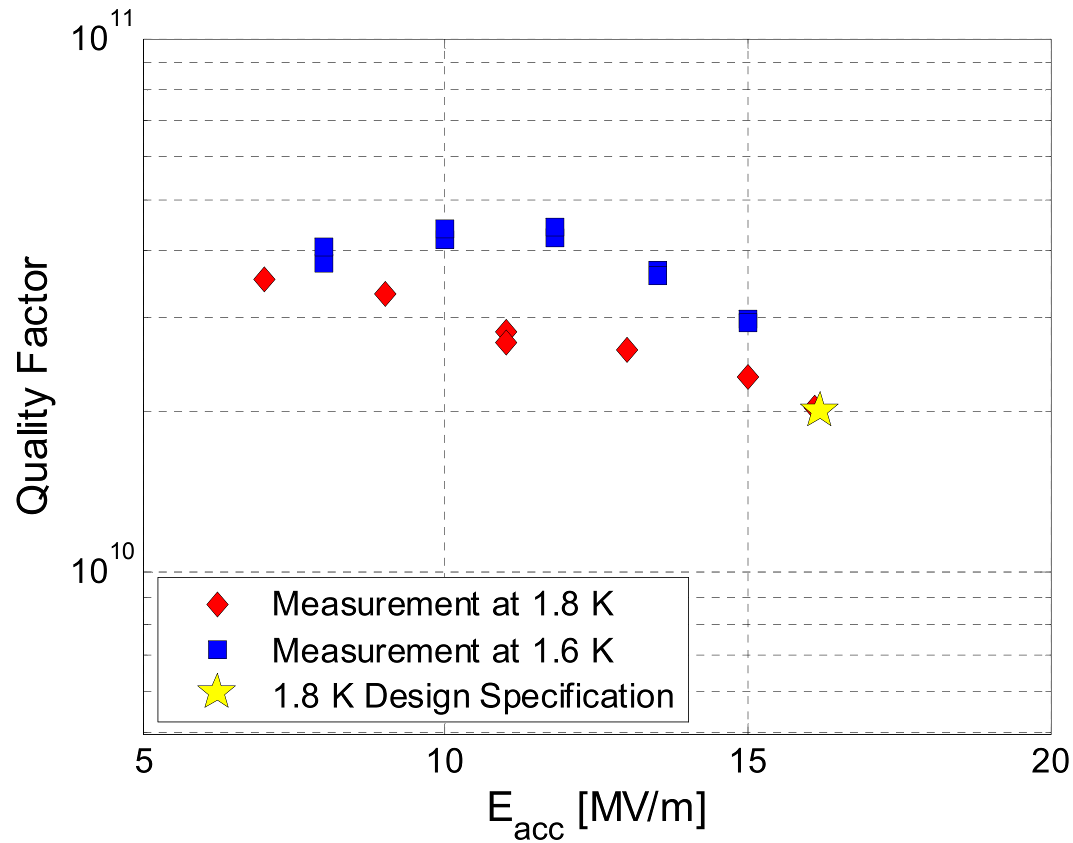
Designed by Cornell

Built by CPI

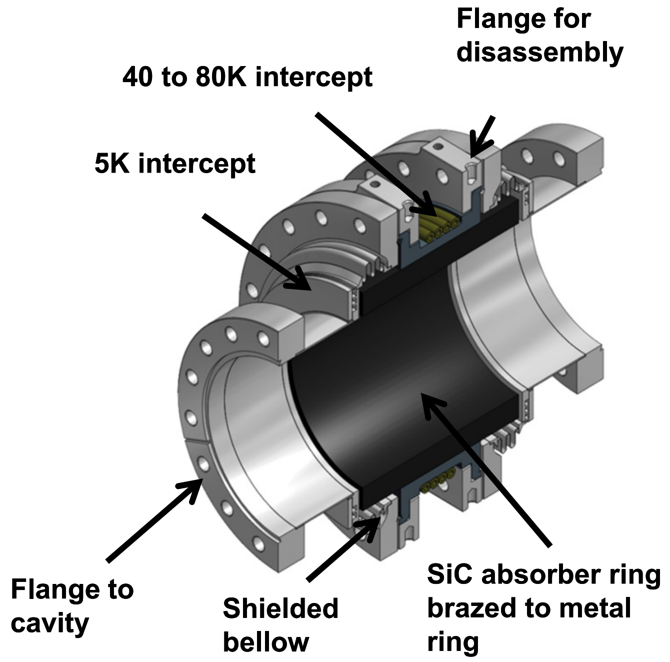


HTC-2: Results

- Quality factor, gradient specifications achieved
- Administrative limits prevented higher field measurements (not limited by quench)
- Lower Q (than HTC-1) due to high radiation levels

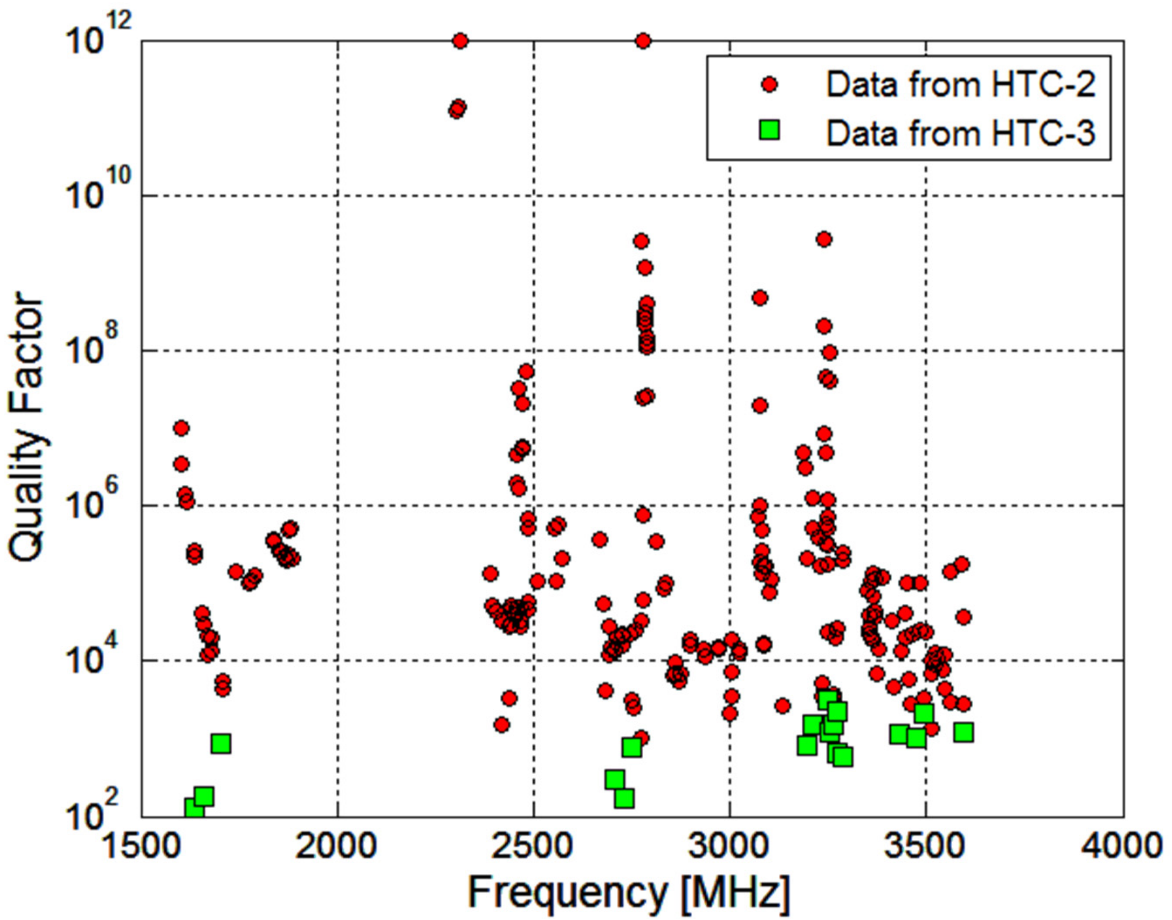


HOM Damping in the HTC



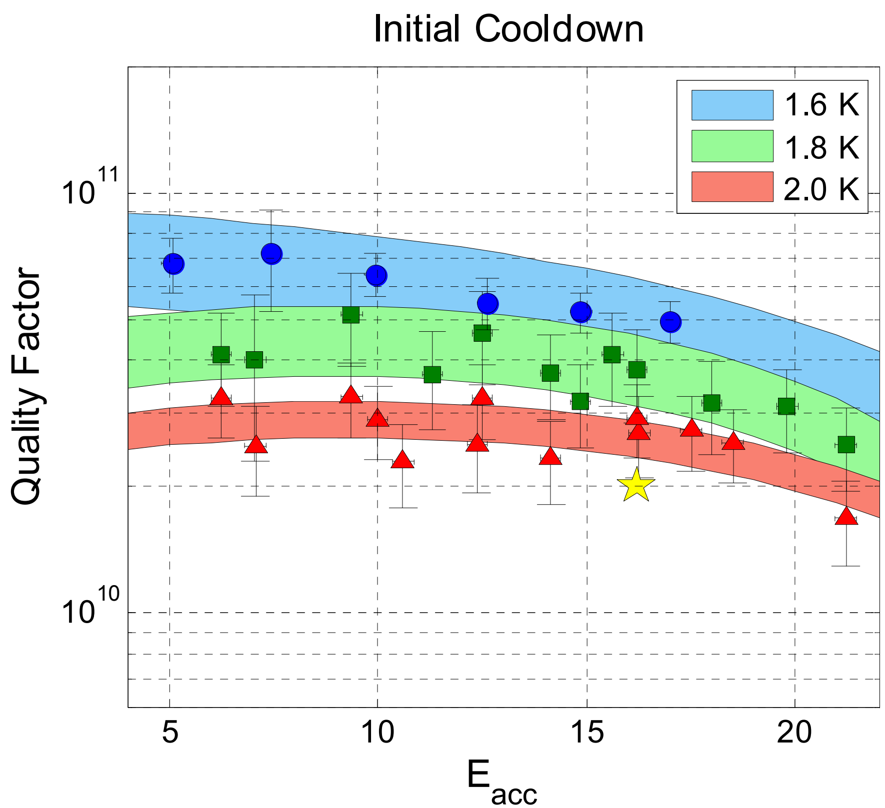
HTC-2: No HOM Absorbers

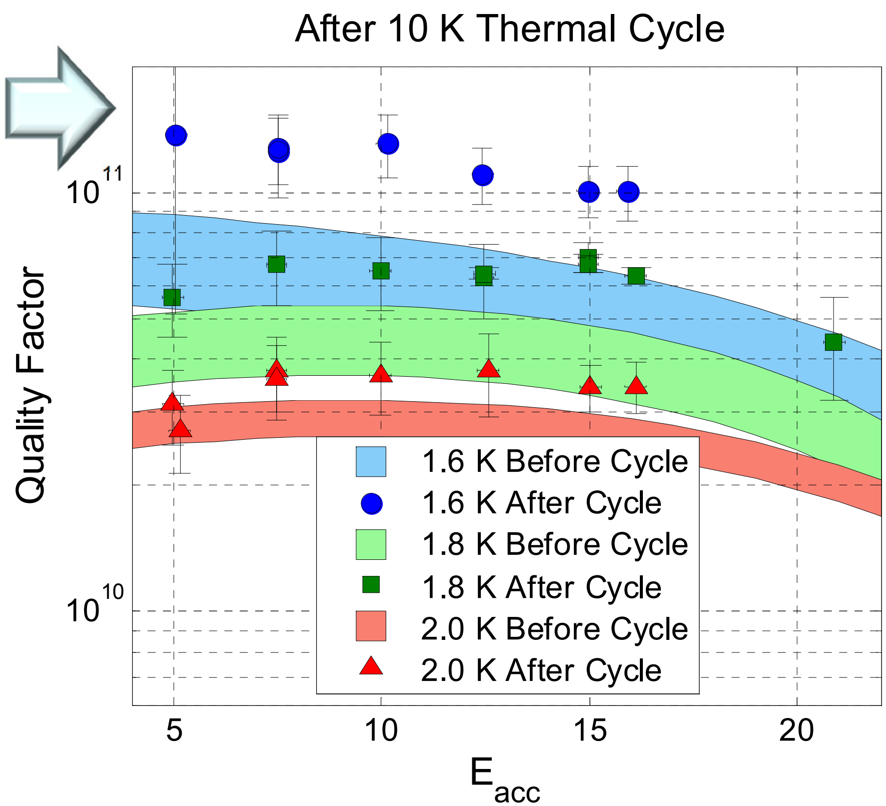
HTC-3: With HOM Absorbers



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

HTC-3: Results





Initial Cooldown at 16.2 MV/m

$Q(2.0\ K) = 2.5 \times 10^{10}$

$Q(1.8\ K) = 3.5 \times 10^{10}$

$Q(1.6\ K) = 5.0 \times 10^{10}$

10 K thermal cycle at 16.2 MV/m

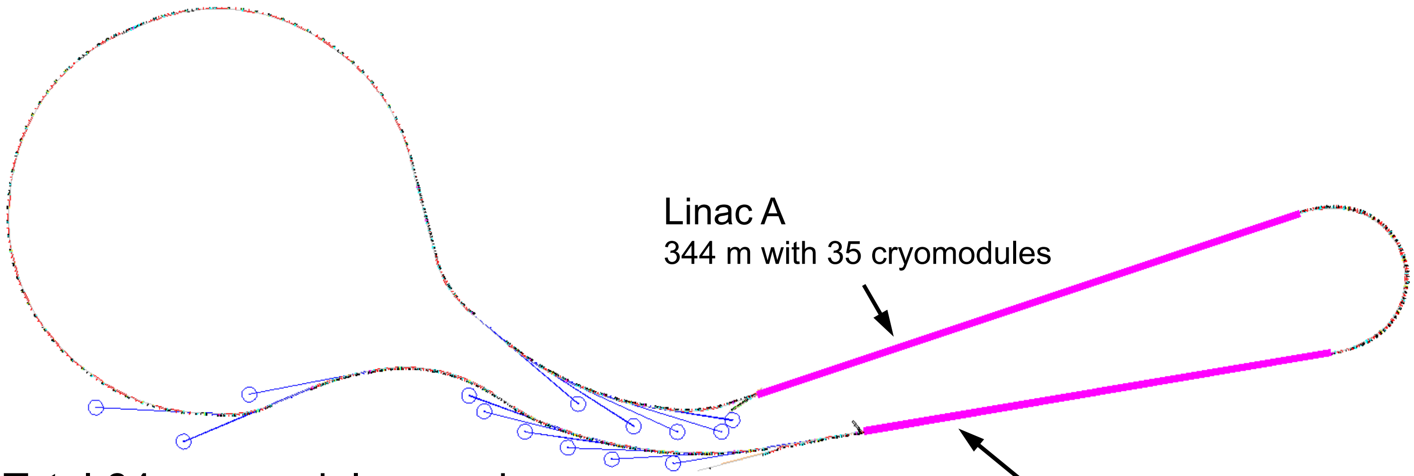
$Q(2.0\ K) = 3.5 \times 10^{10}$

$Q(1.8\ K) = 6.0 \times 10^{10}$

$Q(1.6\ K) = 10.0 \times 10^{10}$

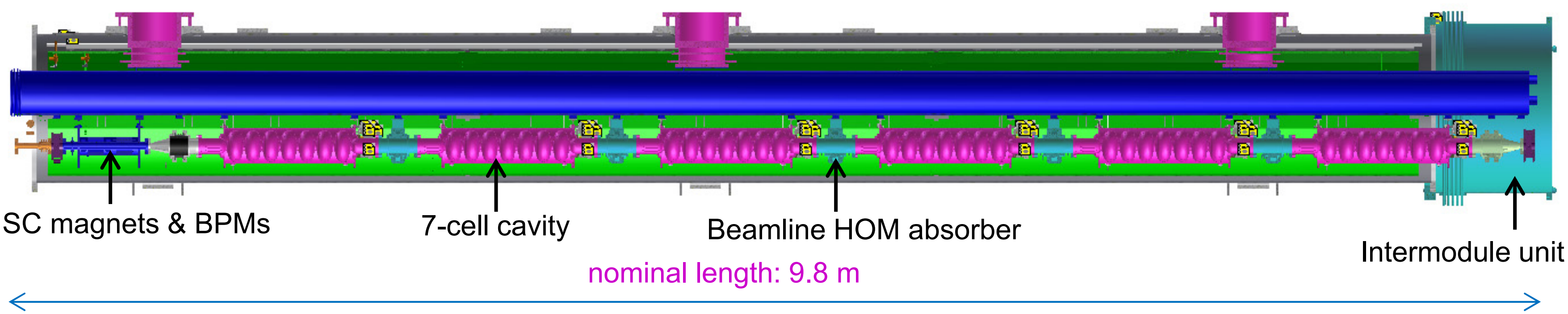
Are we (just) lucky?

Linac cryomodule for the ERL



Total 64 cryomodules, each:

- six packages of 7-cell cavity/Coupler/tuner
- a SC magnets/BPMs package
- five regular HOMs/two taper HOMs



MLC Milestones

- Dec ‘12 – Design completed
- Jan ‘13 – Order 6 remaining input couplers (6 month fab)
- Feb ‘13 – 3 unstiffened cavity built, testing started
- Apr ‘13 – Award vacuum vessel PO (6 month fab) & HGRP (6 month)
- July ‘13 – Production of 3 stiffened cavities started
- Sept. ‘13 – In-house fabrication of string components complete (tuners, HOMs, tapers…)
- Nov. ‘13 – Begin string assembly in clean room
- March ‘14 – Begin cold mass assembly and instrumentation (outside clean room)
- End of ‘14 – MLC ready for testing

7-cell cavity production

All cavities were designed, built and tested at Cornell

Un-stiffened cavities (#2, #3, #4)

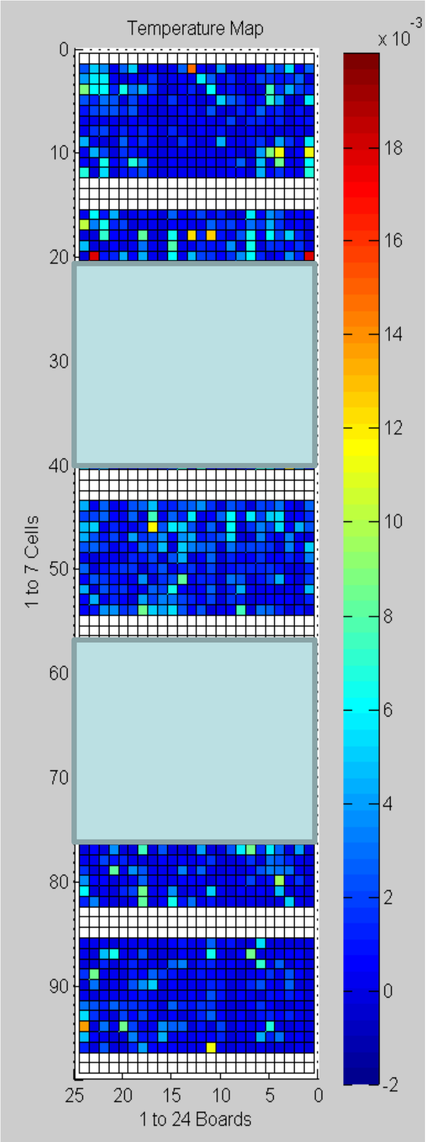
ERL 7-cell surface preparations

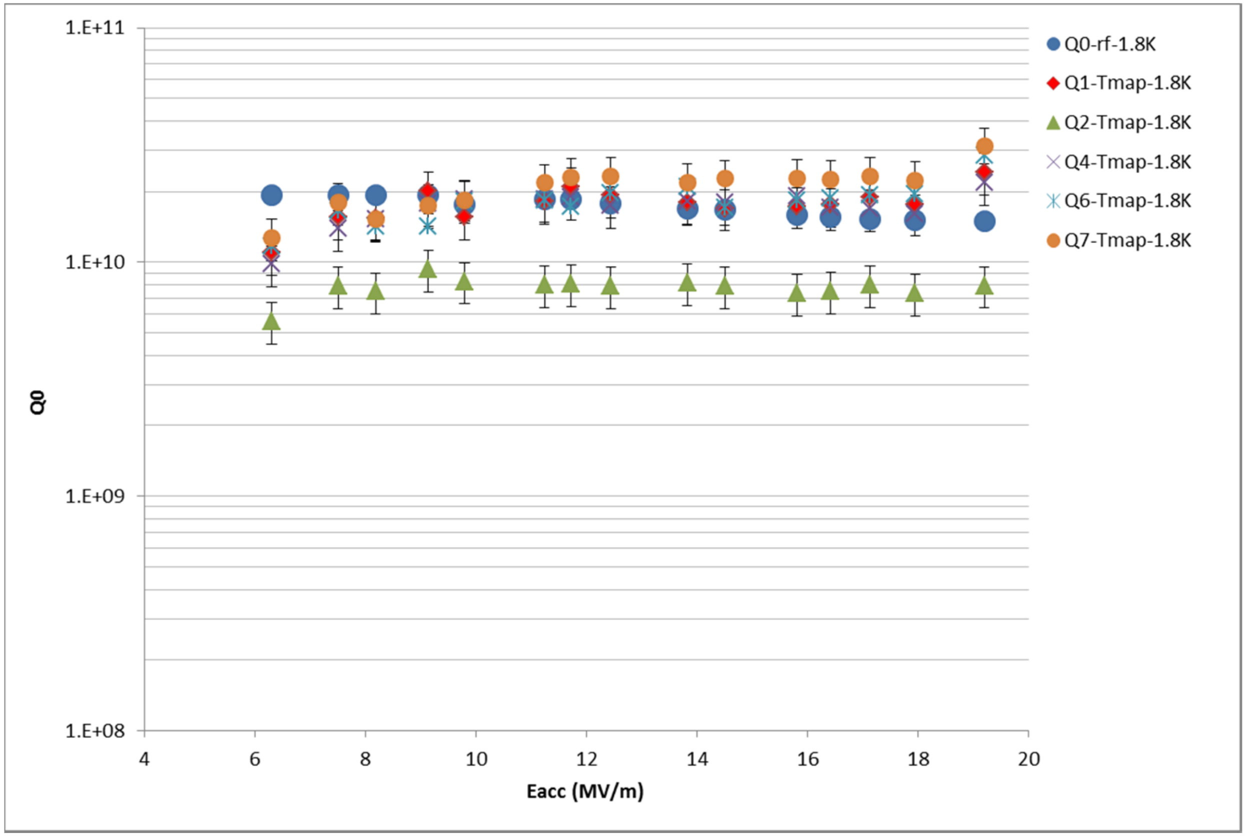
1. Bulk BCP (140um)
2. Degassing in TM furnace (650C*4days)
3. Freq. and flatness Tuning
4. Final BCP (10um)
5. 120C bake in TM furnace (120C*48hrs)
6. HF rinse
7. VT w/ T-map

Process summary ERL cavities

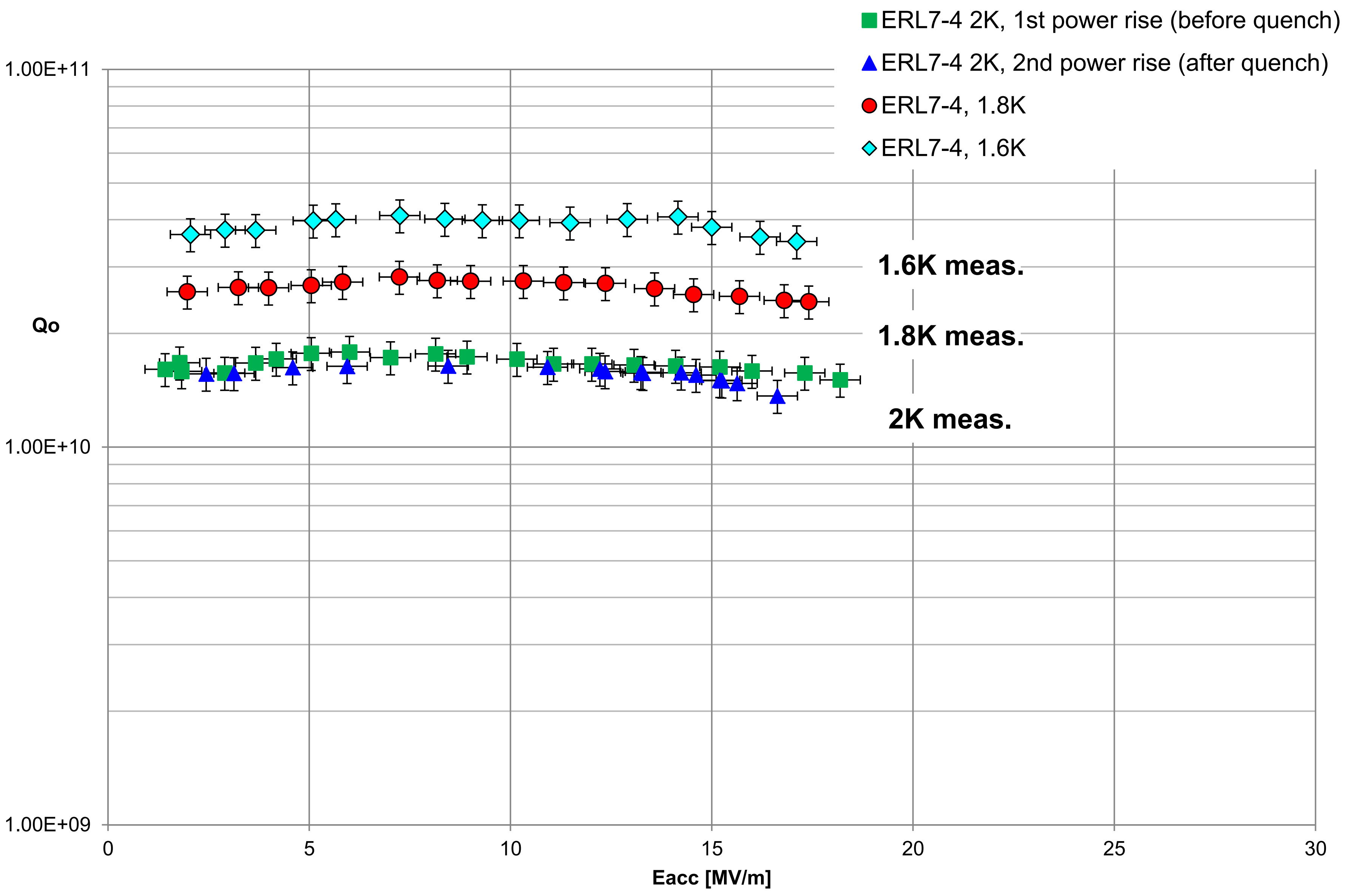
	ERL7-1 (HTC)	ERL7-2	ERL7-3	ERL7-4
Bulk BCP	140um (witness sample)	135±10 um (cavity equator)	138±5 um (cavity equator)	132±7 um (cavity equator)
Degassing	Jlab, 650C*10hrs	TM-furnace 650C*4days	TM-furnace 650C*4days	TM-furnace 650C*4days
tuning	88%	94%	91%	92%
Final BCP	10 um	10 um	10 um	10 um
120C bake	On insert	TM-furnace	On insert	TM-furnace
HF rinse	No	Yes	Yes	Yes
VT 1st (1.8K)	17MV/m, 1.6e10 (No T-map , old insert)	17MV/m, 1.53e10 w/ T-map	Limited by FE w/ T-map	17.4MV/m, 2.4e10 w/ T-map
Re-process	-BCP(10um) -120C bake(in clean room, old set-up) -HF rinse	-Cavity length is too long, re-built & re-test are planed	Re-process to cure FE -BCP(10um) -120C bake(TM-furnace) -HF rinse	
	HTC3, 16.2MV/m, 6.0e10 @1.8K		17MV/m, 2.8e10 No T-map (PC down)	

Cornell's Temperature Mapping System

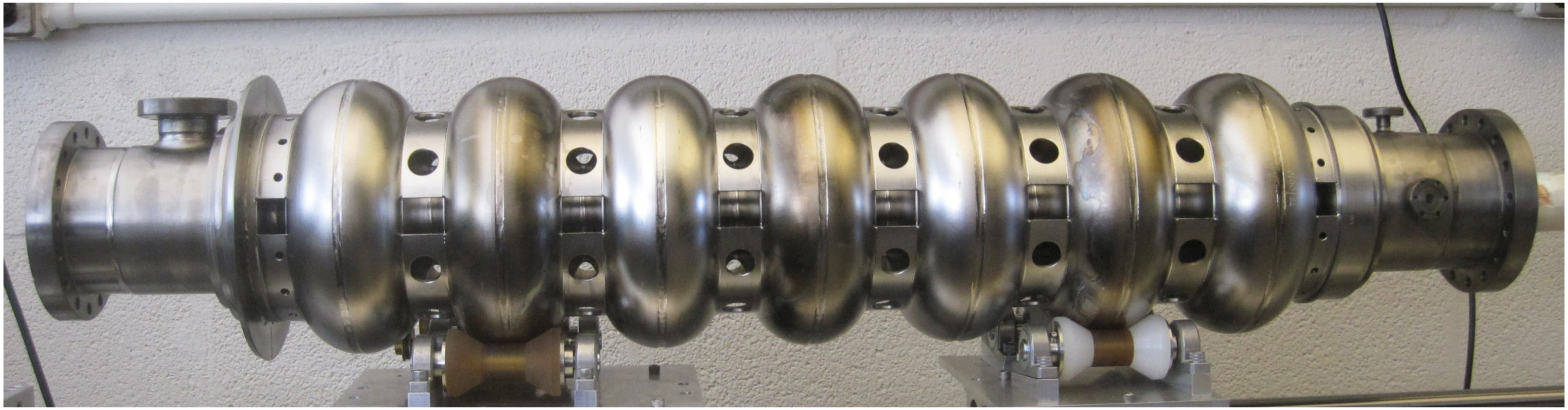




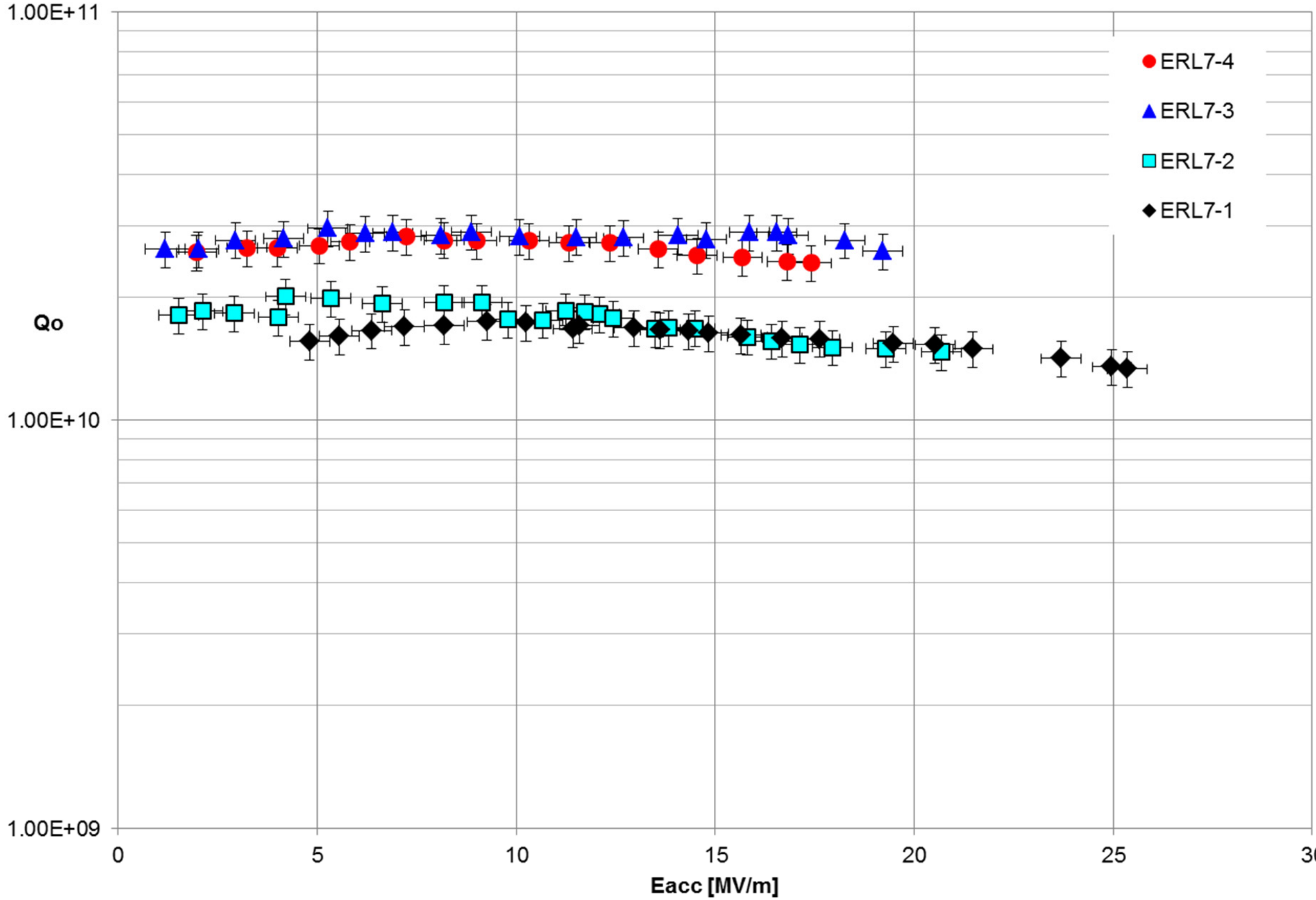
Vertical Test Cavity #4



Cornell ERL Stiffened Cavity



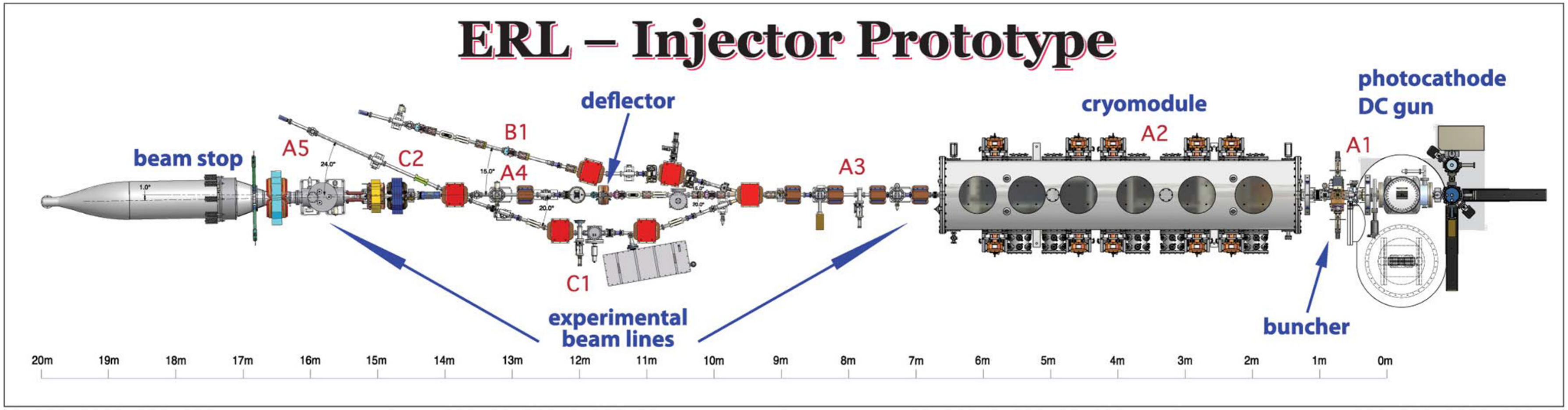
ERL 7-1 to 7-4 Vertical Test Results

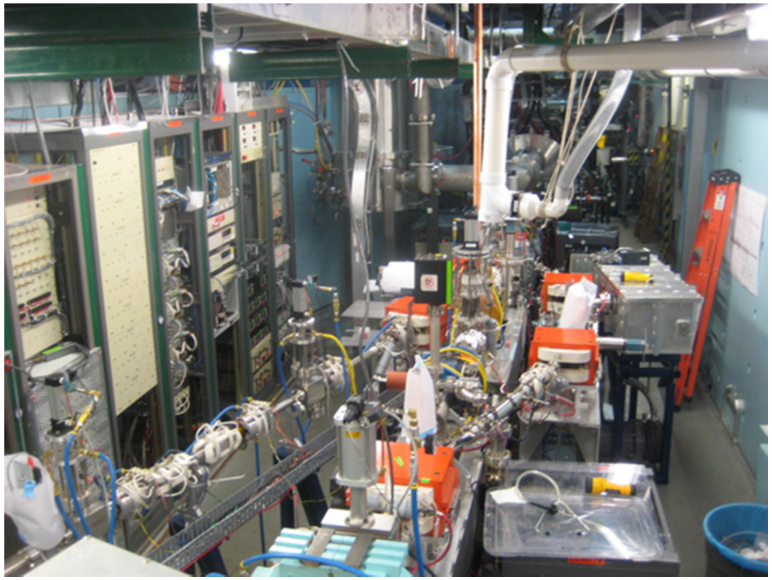


Are we (just) lucky?

Well, at least we are happy!

Cornell ERL Injector

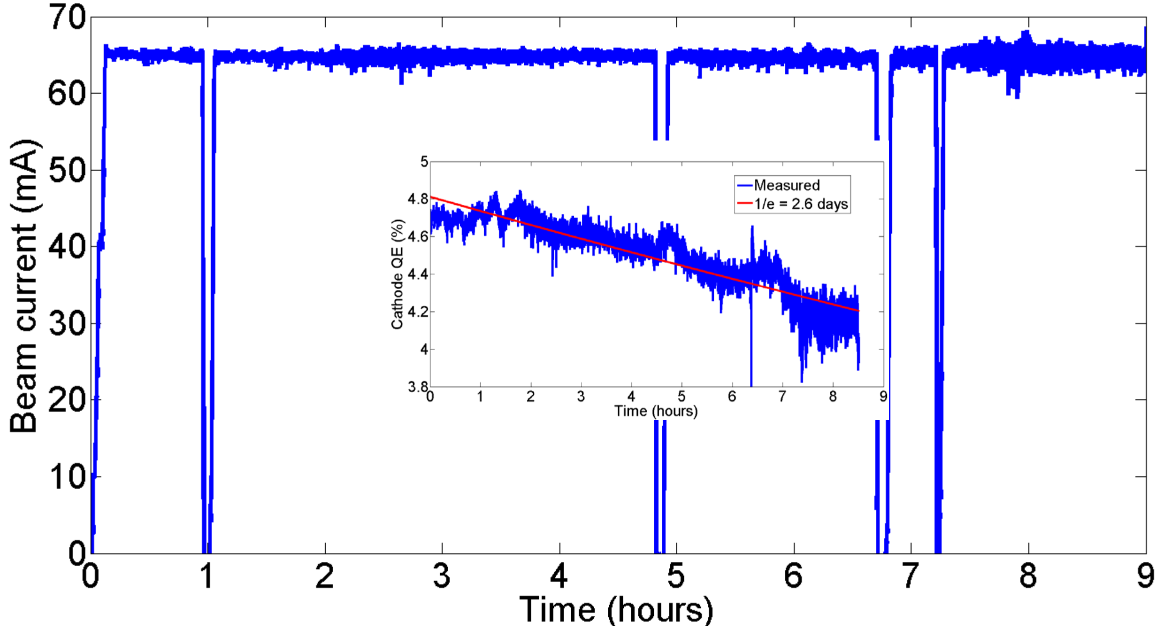




ERL Injector Prototype:
Achievements to date:

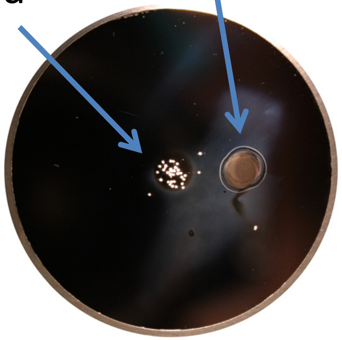
- *75 mA average current @ 4 MeV*
- *0.3 μm emittance @ 77 pC, 8 MeV*

High Currents – Na2KSb



Ion damage limited to the central area

Active area is offset from the center



Front surface of the cathode (CsK_2Sb on Si) after use.

Using a Na_2KSb photocathode, ran over 8 hours at 65 mA (2000 C) with a 2.6 day 1/e cathode lifetime.
Reached as high as 75 mA for a short time.

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The Cornell ERL team