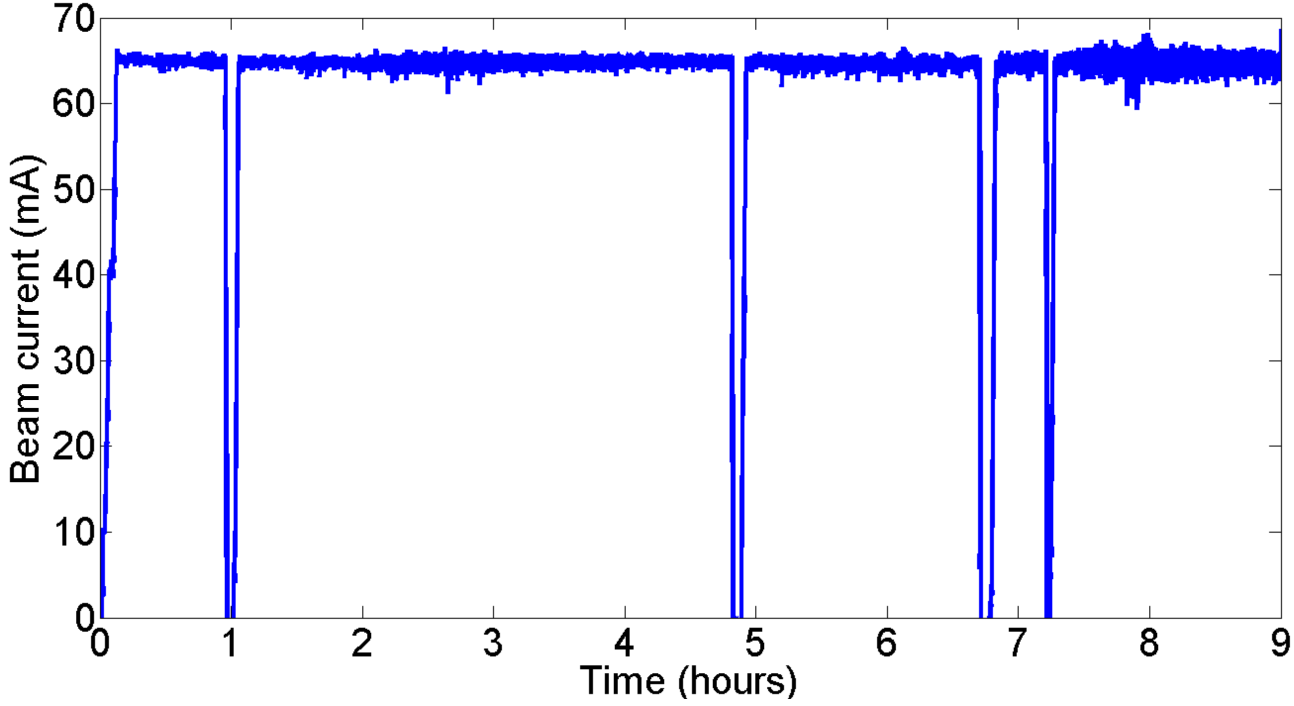
Cornell ERL Update



Cornell ERL Timeline

A Possible Apparatus for Electron Clashing-Beam Experiments (*).

M. Tigner

Laboratory of Nuclear Studies, Cornell University - Ithaca, N. Y.

(ricevuto il 2 Febbraio 1965)

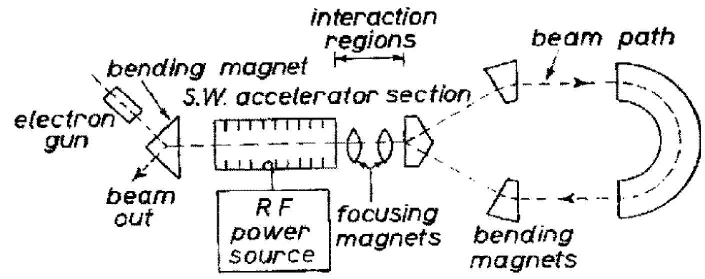
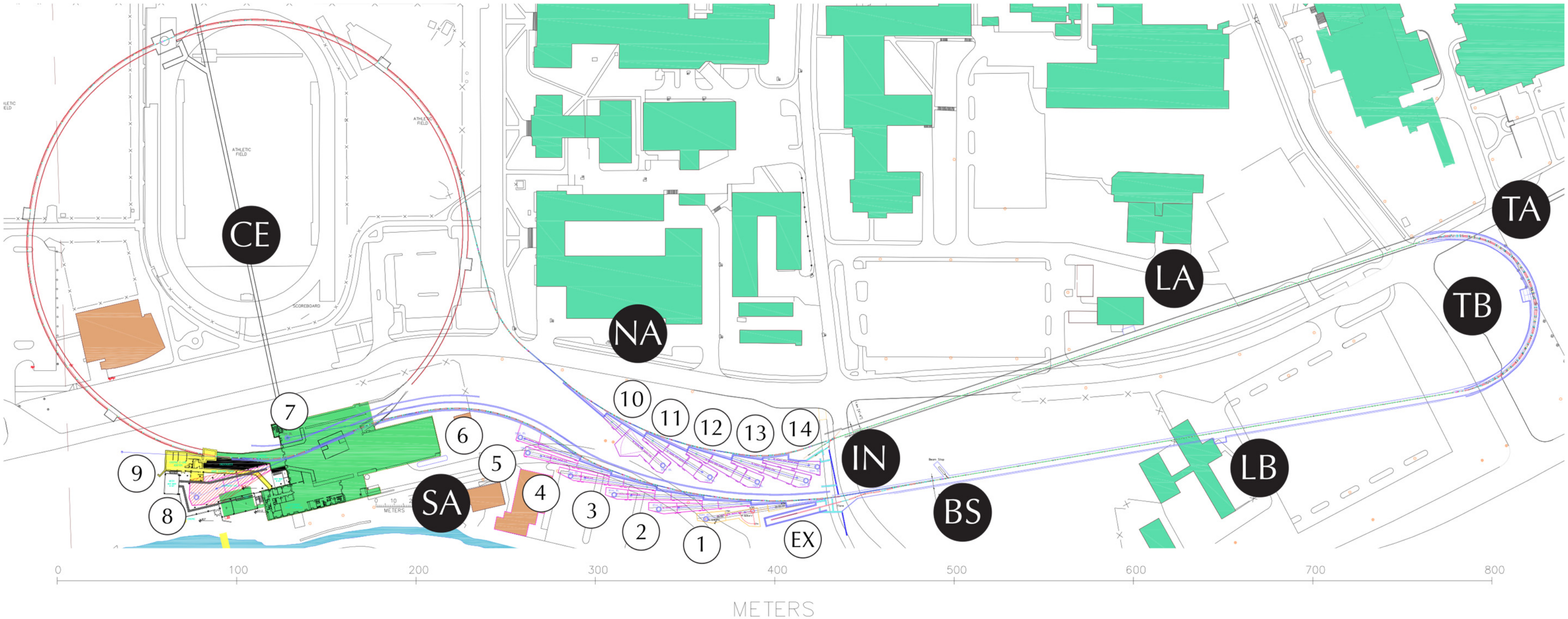
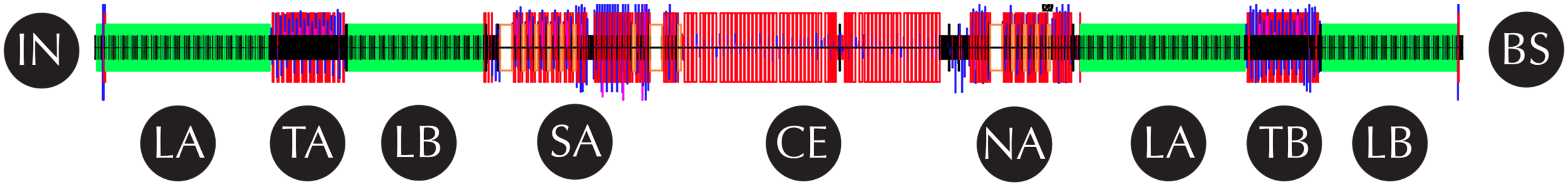


Fig. 3.

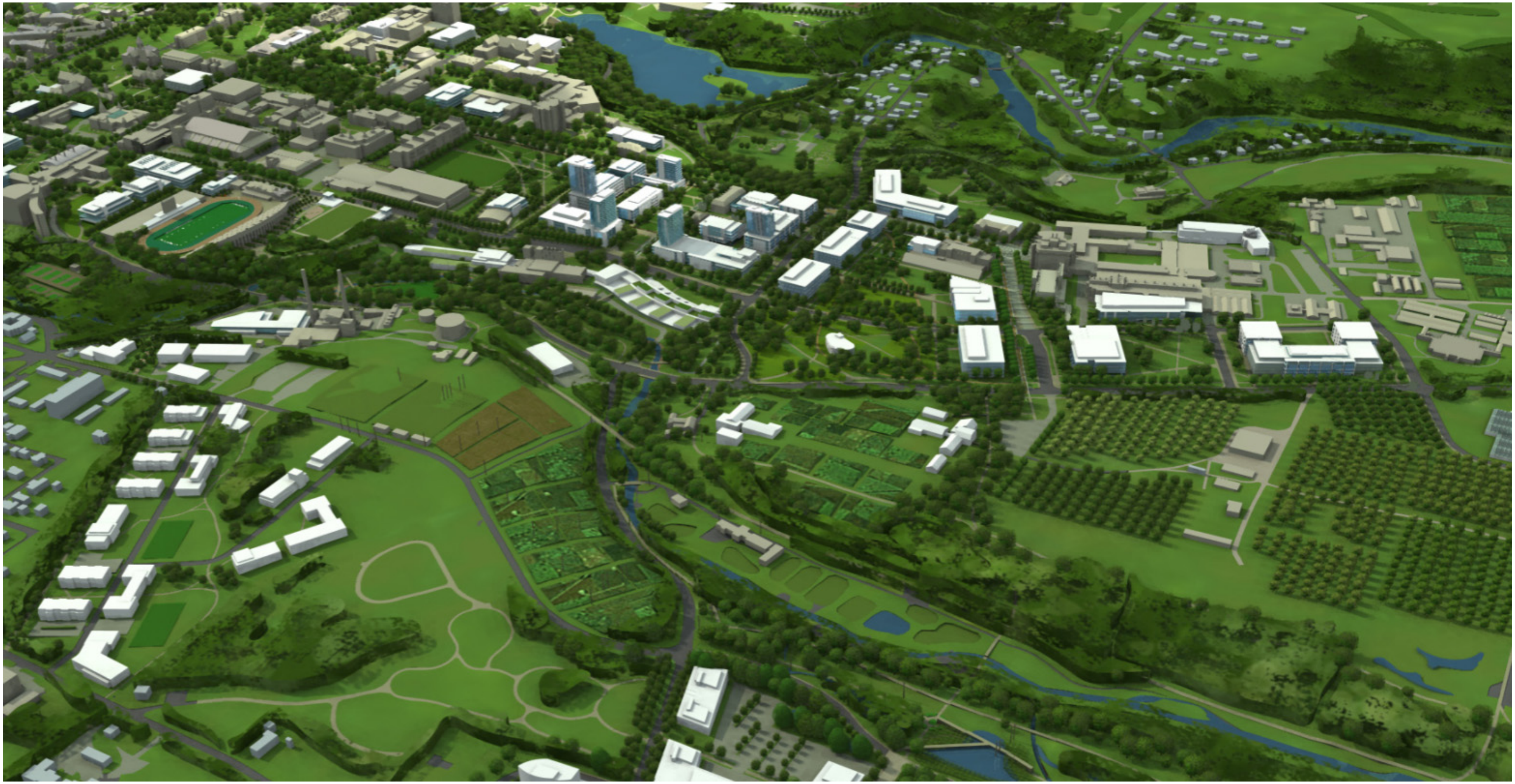
1999: Tigner suggests a coherent hard x-ray ERL light source is feasible.
2000: First x-ray Science Workshop for an ERL at Cornell
NSF encourages proposal
2001: Cornell & JLab ERL `white' paper. Phase 1a proposed.
2005: NSF funds Phase1a: 5-yr R&D on injector, linac modules, machine issues.
2006: Six x-ray Science Workshops for an Energy Recovery Linac at Cornell
2006: Conceptual engineering studies for Phase II (NY State + CU support)
2008: NSF Light Source Panel recommends that the NSF
should build & steward a coherent light source.
2010: NSF funds Phase 1b: 4 year continued R&D).
ERL civil construction design study completed.
2011: XDL-2011 Workshops completed.
ERL technical design report (PDDR) completed, reviewed.
ERL draft Environmental Impact Statement ready for submission.
2012: Critical ERL Phase 1b milestones achieved

Cornell ERL


CE
NA
LA
TA
TB
LB
IN
BS
SA
EX
1
2
3
4
5
6
7
8
9
10
11
12
13
14
0
100
200
300
400
500
600
700
800
METERS

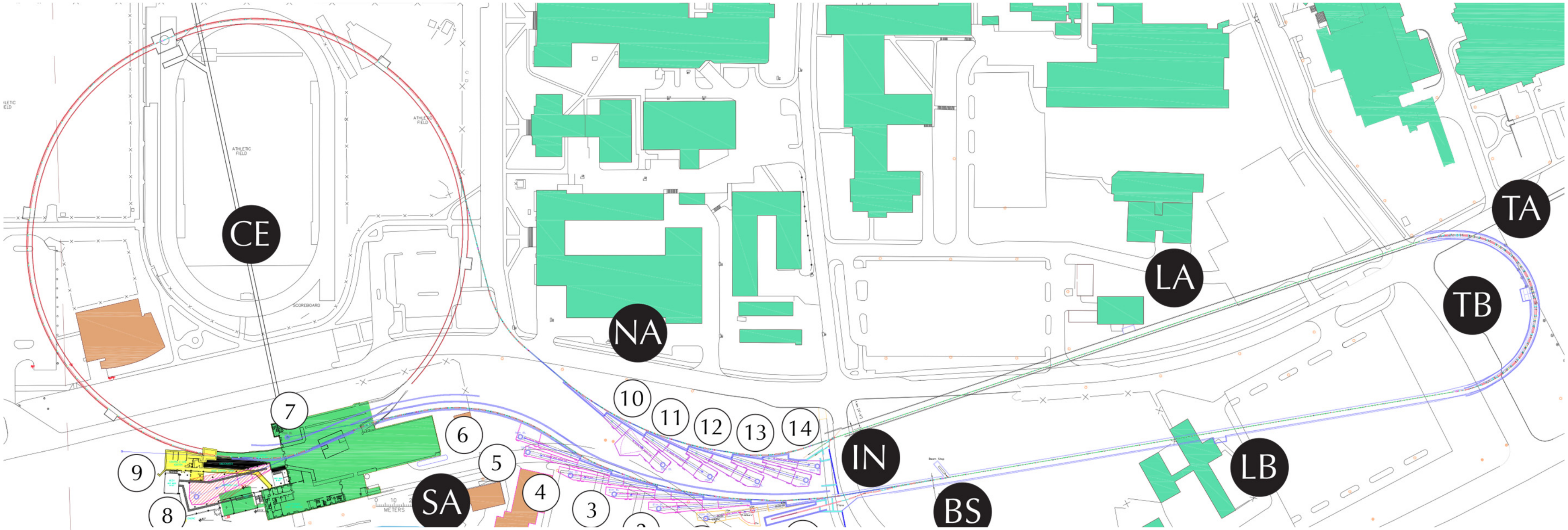

IN
BS
LA
TA
LB
SA
CE
NA
LA
TB
LB

Cornell Master Plan



[www.masterplan.cornell.edu]

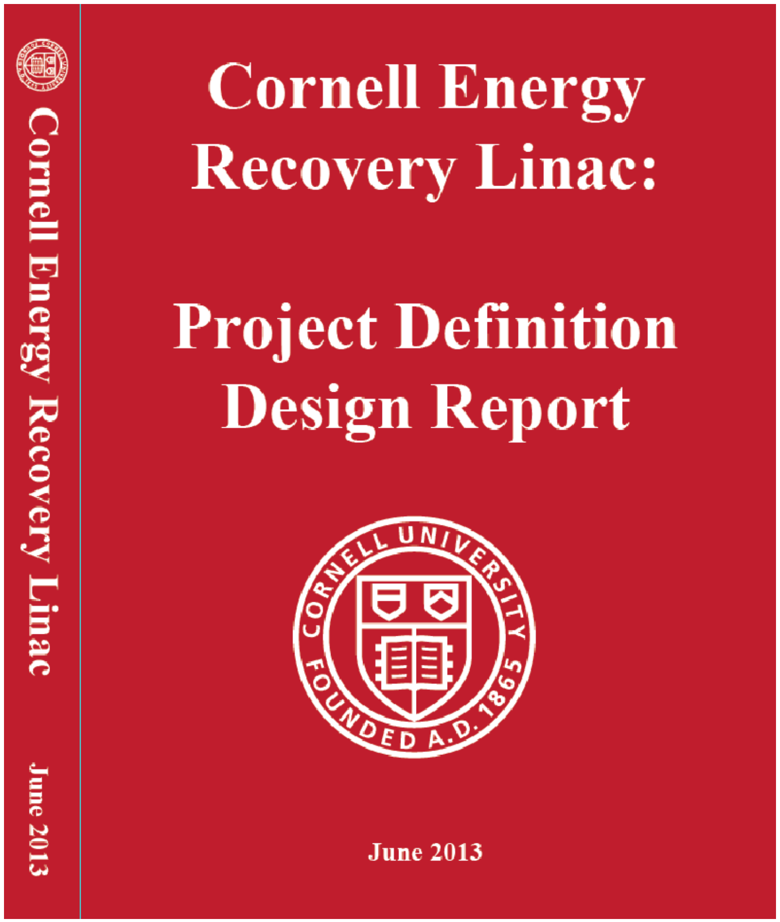
Cornell ERL Parameters

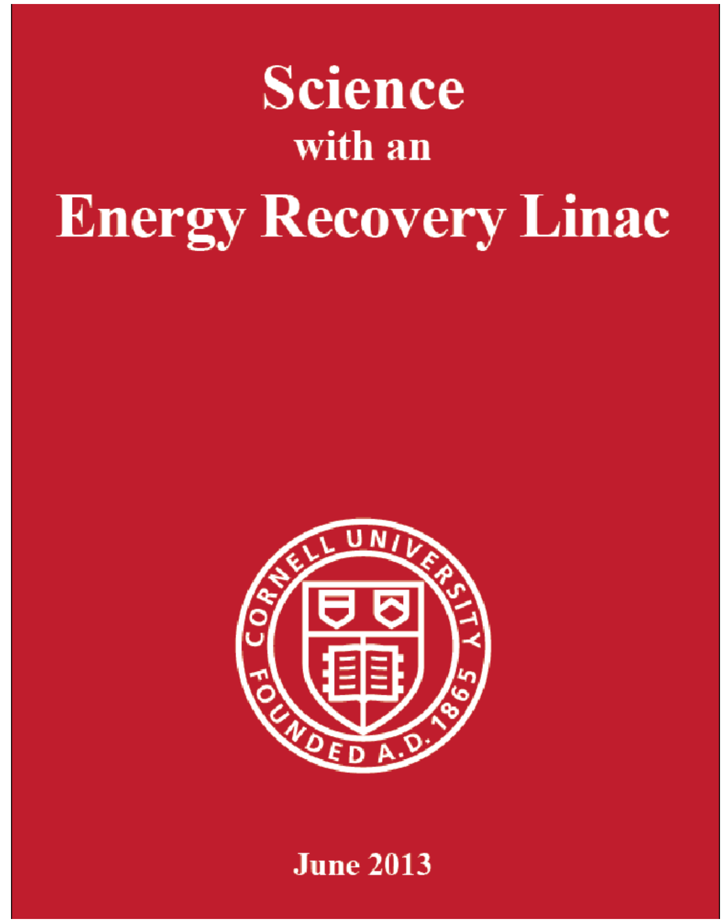


Operating Modes	A *High Flux*	B *High Coherence*	C *Short Bunch*	Unit
Energy	5	5	5	GeV
Current	100	25	25	mA
Bunch Charge	77	19	19	pC
Repetition Rate	1.3	1.3	1.3	GHz
ϵ_x (SA/NA)	31/52	13/34	21/66	pm
ϵ_y (SA/NA)	25/26	10/10	14/14	pm
σ_z/c (SA/NA)	2.1/2.1	1.5/1.5	1.0/0.1	ps
σ_δ (SA/NA)	1.9/1.9	0.9/1.0	9.1/9.3	10^{-4}

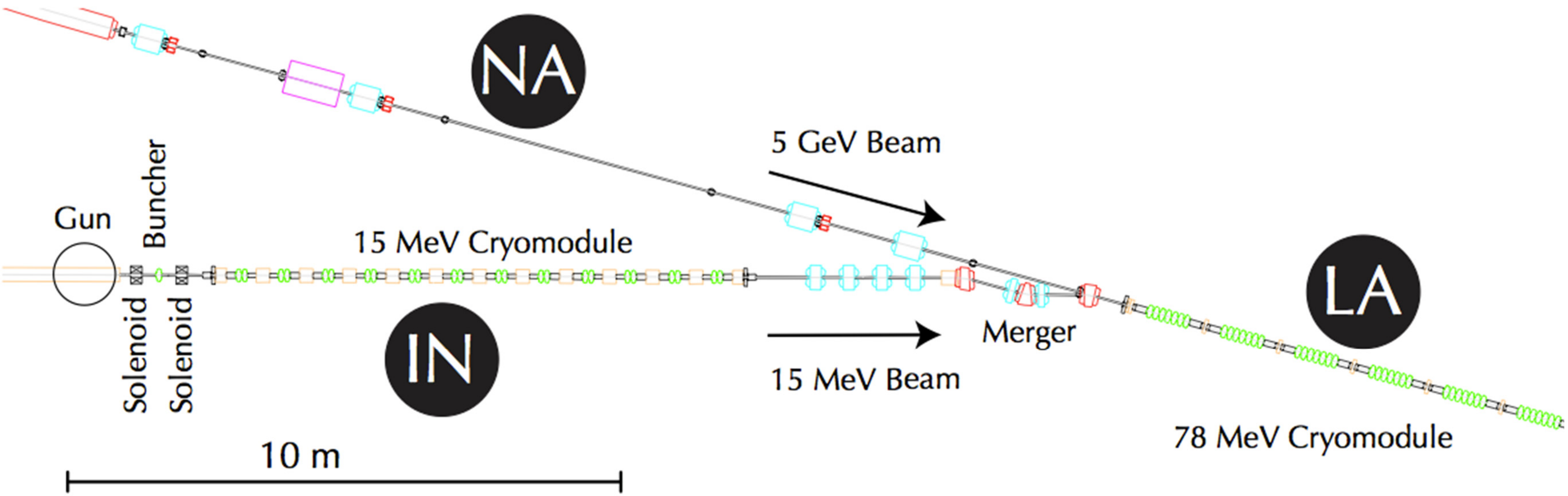
Cornell ERL PDDR

www.classe.cornell.edu/ERL/



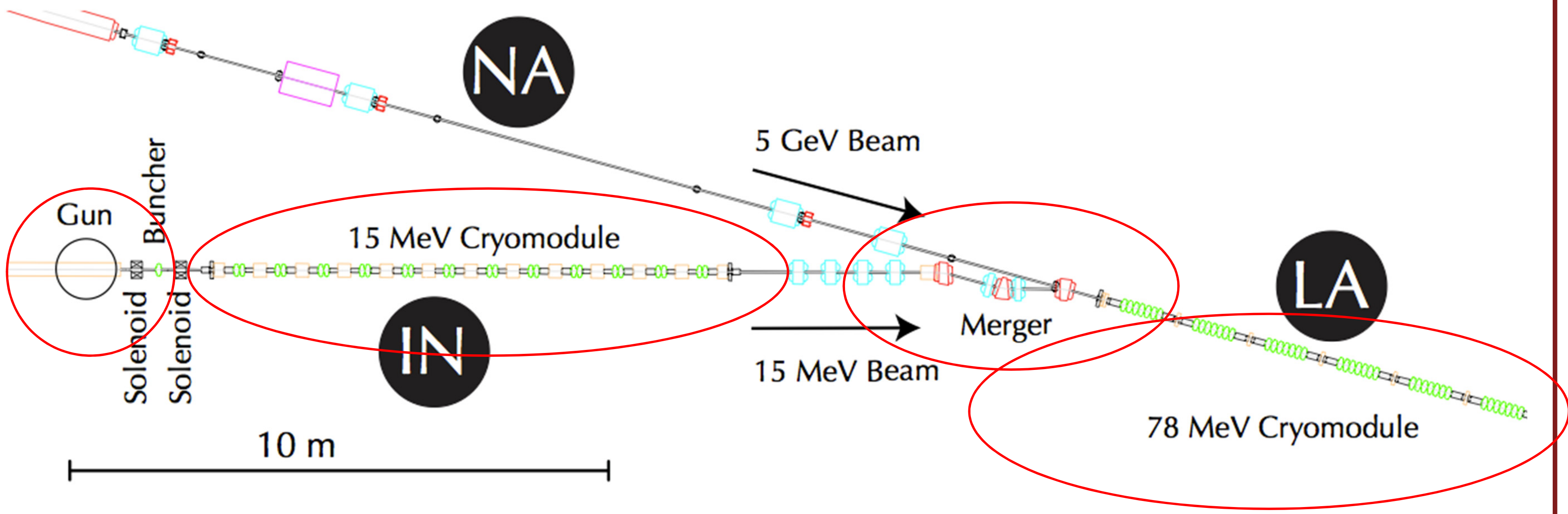


Critical components

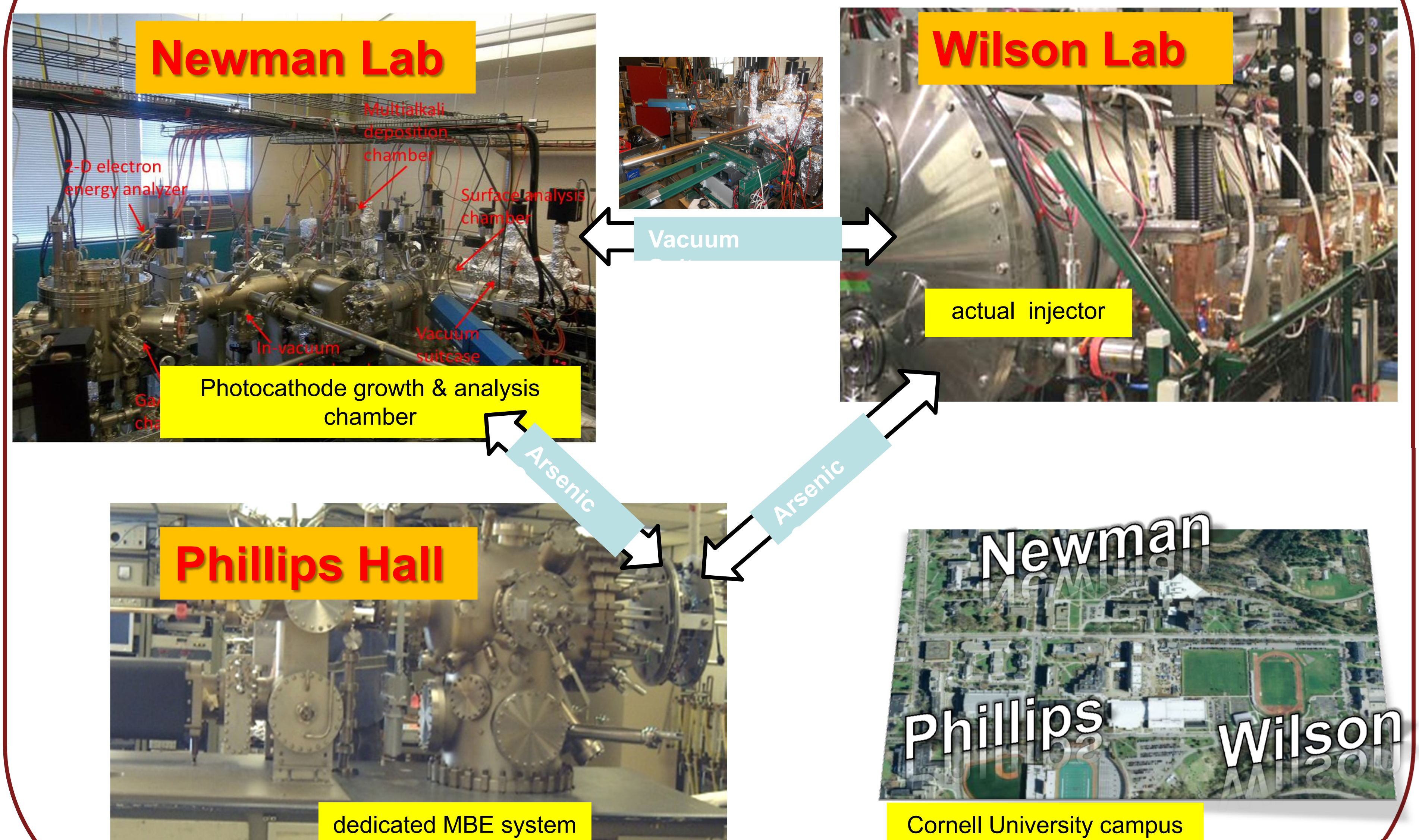


Critical components

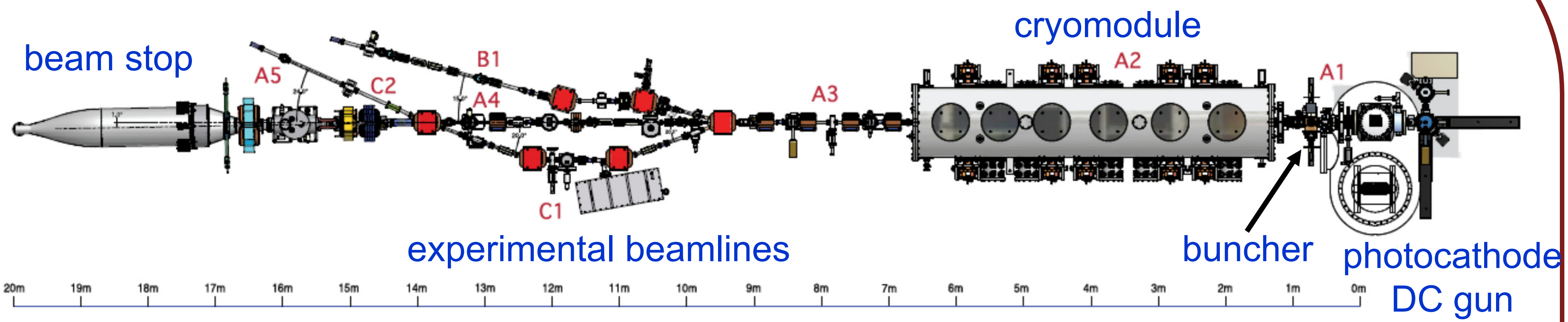
Phase 1a & 1b

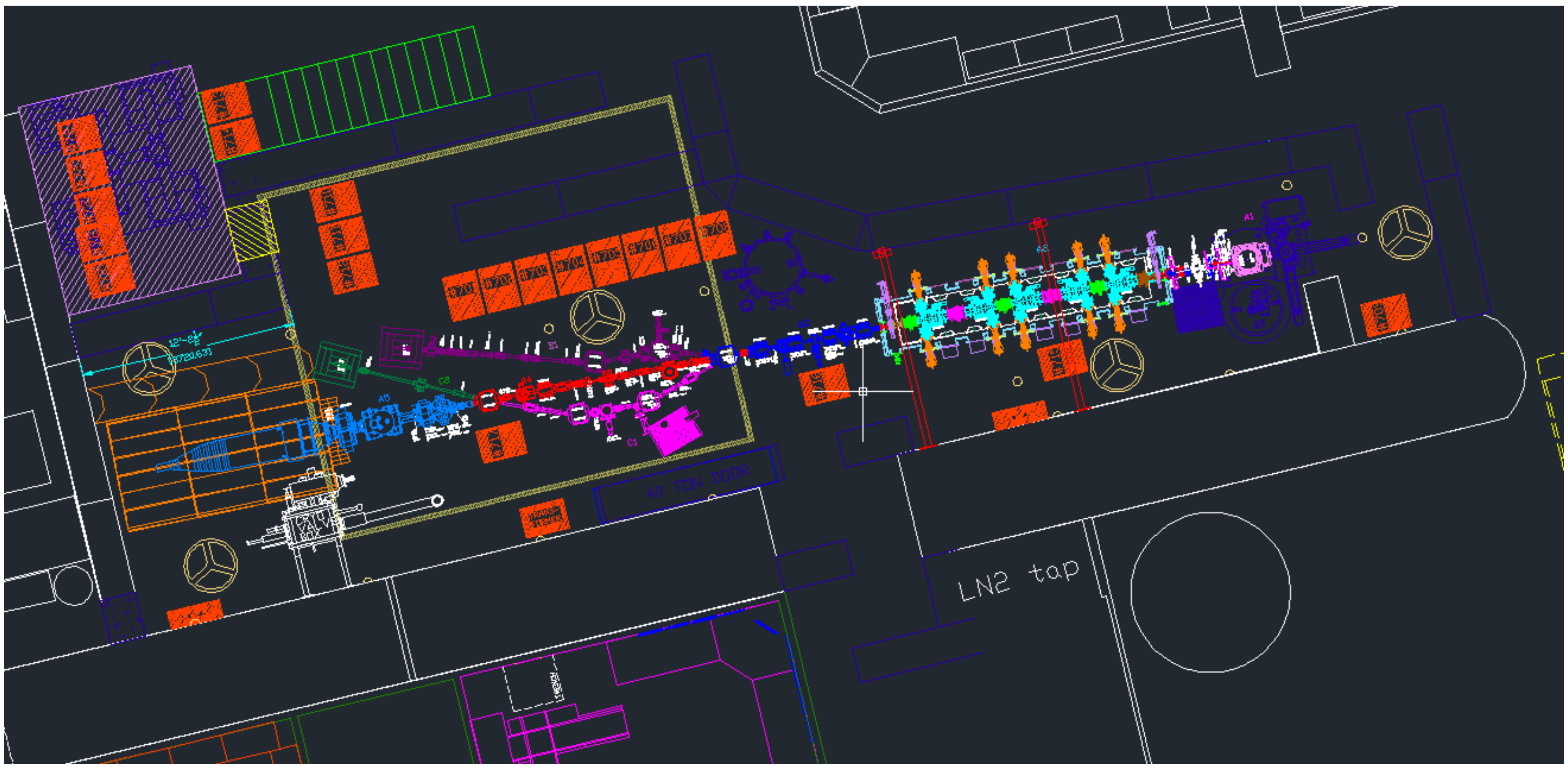


Photocathode Facilities at Cornell



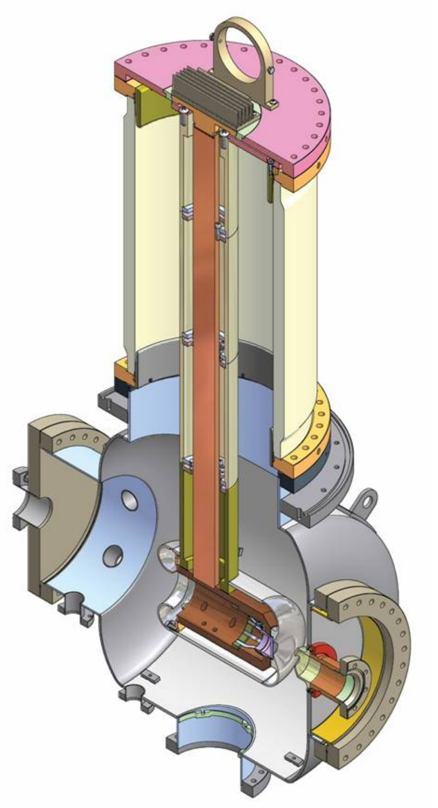
Prototype ERL injector

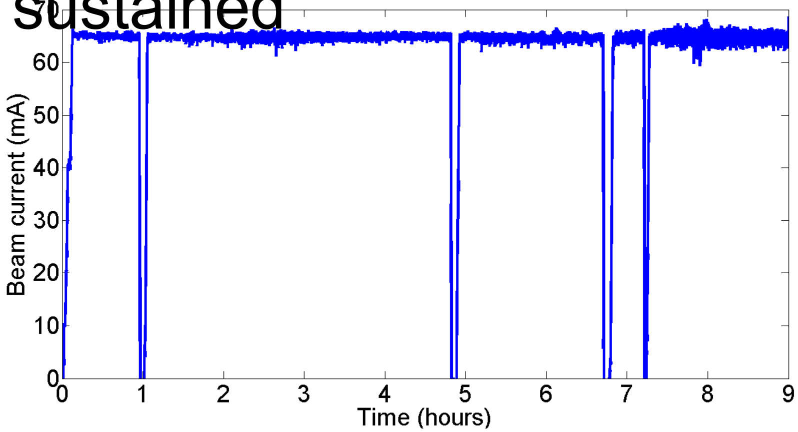




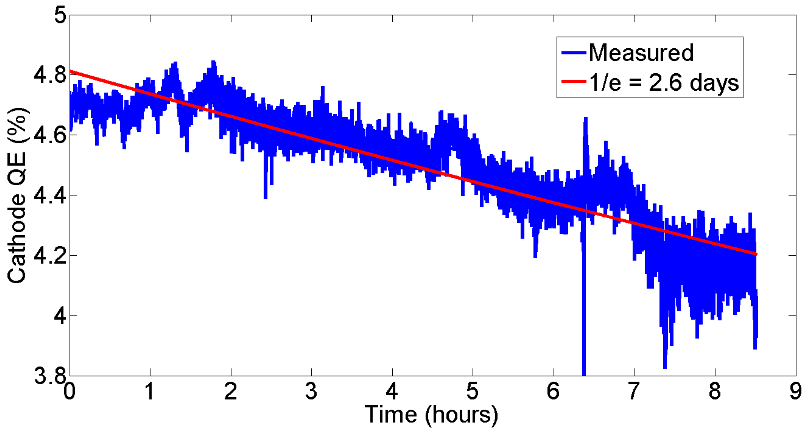
Cornell Injector Record Current at 4 MeV

Highest current ever NaK_2Sb Cathode: 75 mA, 65 mA sustained





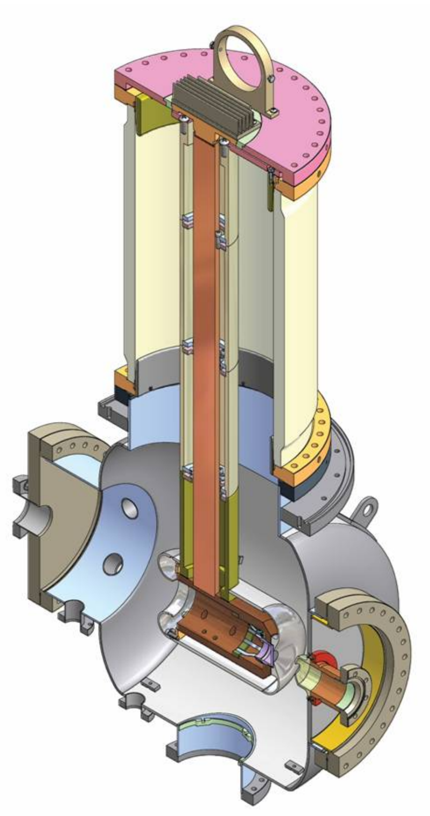
May 24, 2013



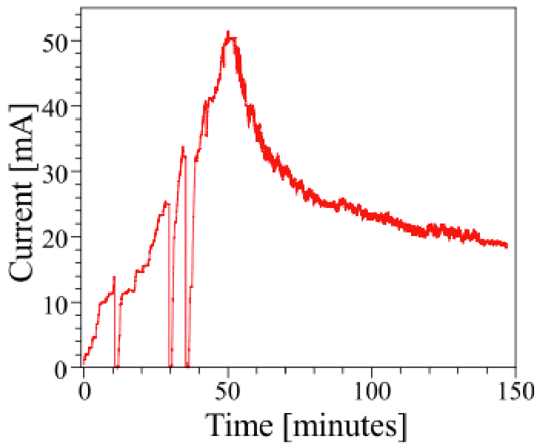
Dunham et al., Appl. Phys. Lett., 102, 034105 (2013)

Cornell Injector Record Current at 4 MeV

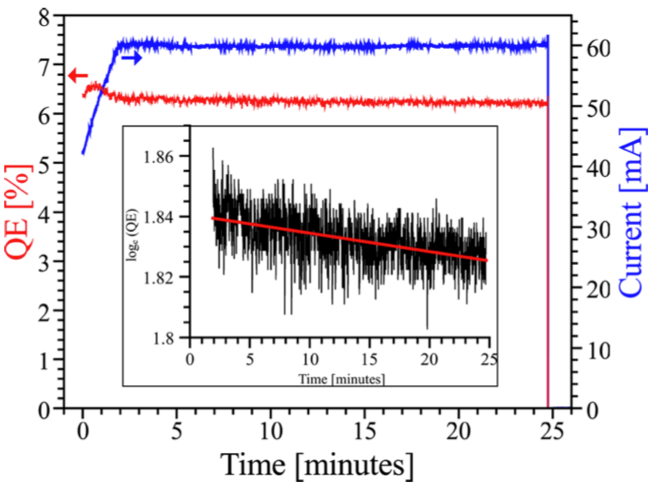
More records:



GaAs: 52 mA

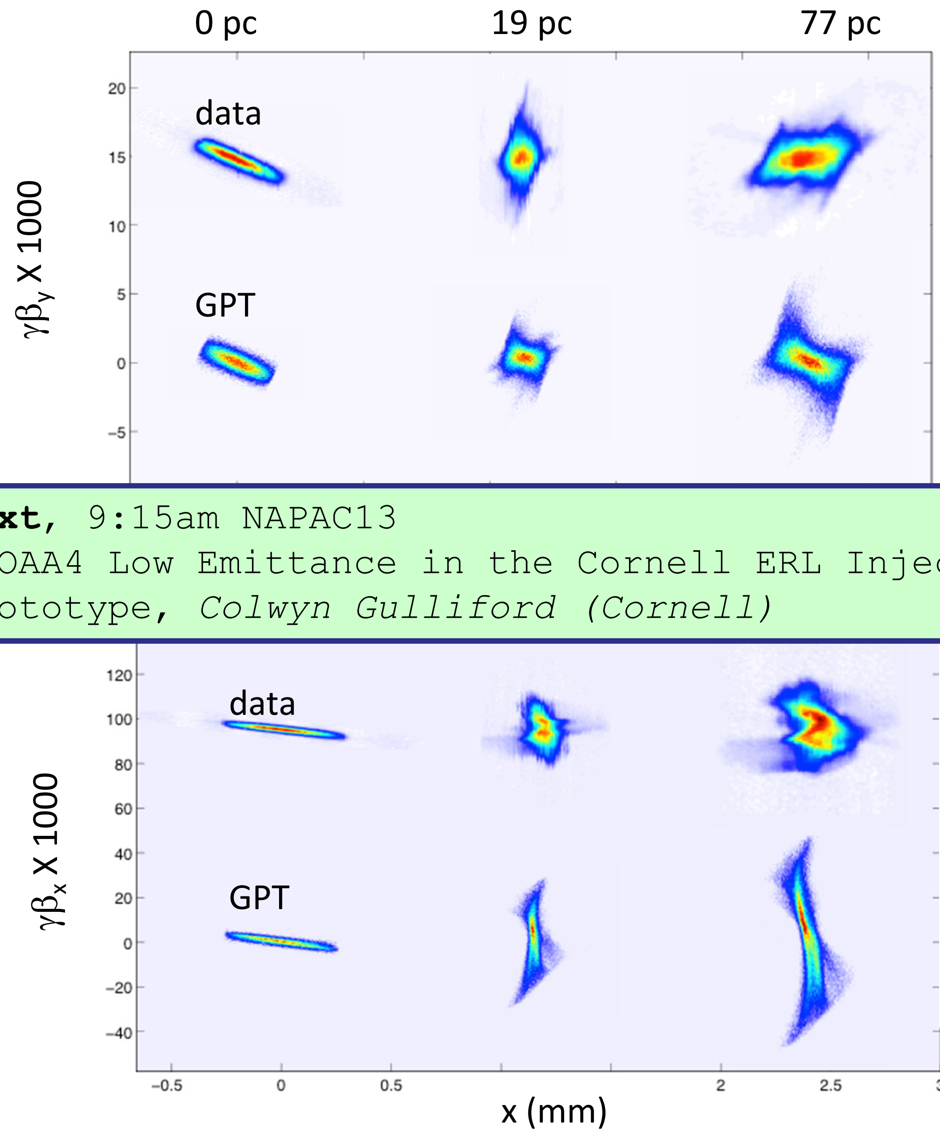


CsK$_2$Sb: 60 mA



Dunham et al., Appl. Phys. Lett., 102, 034105 (2013)

Phase space measurements and simulation



Next, 9:15am NAPAC13
WEOAA4 Low Emittance in the Cornell ERL Injector Prototype, *Colwyn Gulliford (Cornell)*

Projected Emittance for 19 (77) pC at 8MeV:

(y, p_y)

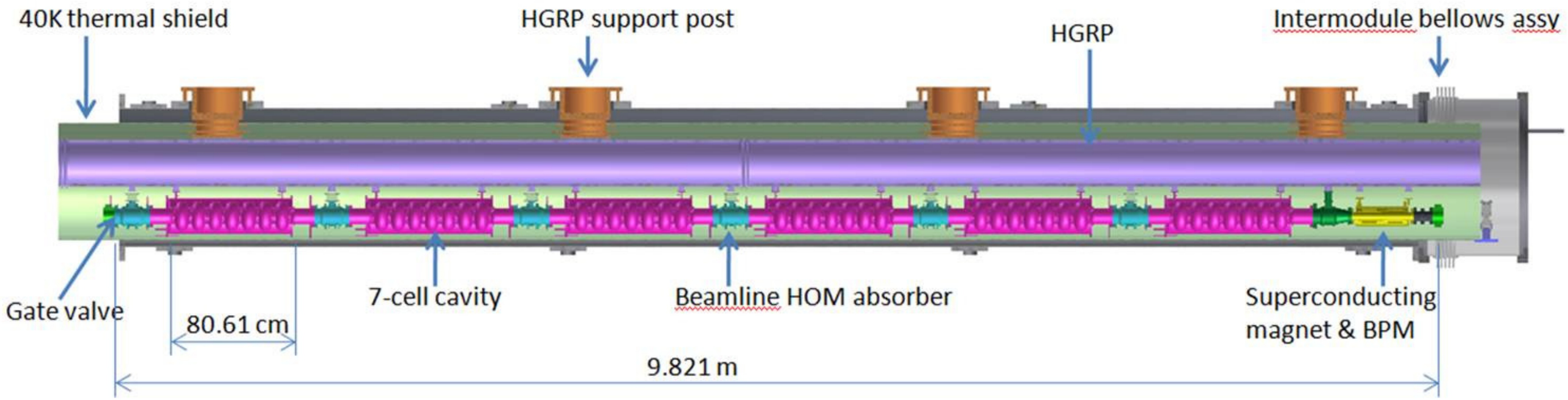
Data Type	enorm(100%) [microns]	enorm(90%) [microns]
Projected (EMS)	0.20 (0.40)	0.14 (0.29)
GPT	0.16 (0.37)	0.11 (0.25)

(x, p_x)

Data Type	enorm(100%) [microns]	enorm(90%) [microns]
Projected (EMS)	0.33 (0.69)	0.23 (0.51)
GPT	0.31 (0.72)	0.19 (0.44)

Gulliford et al., Phys. Rev. ST Accel. Beams 16, 073401 (2013)

Main Linac Cryomodule (MLC) Prototype

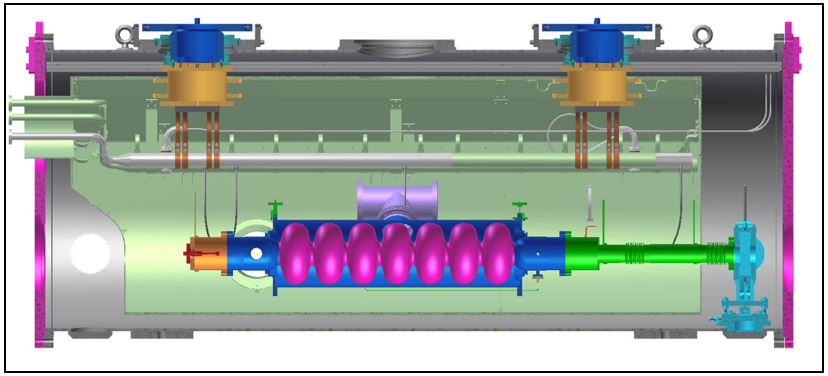


- Completed fabrication and RF test of 6 main linac SRF cavities
  - Statistics of high Q_0 cavity preparation
- Fabrication of full ERL main linac prototype cryomodule
  - Fabrication of input couplers, tuners, beamline HOM absorbers, cryomodule components…
  - Start string assembly summer 2013
  - Start cold mass assembly late 2013
  - Module completion by summer 2014

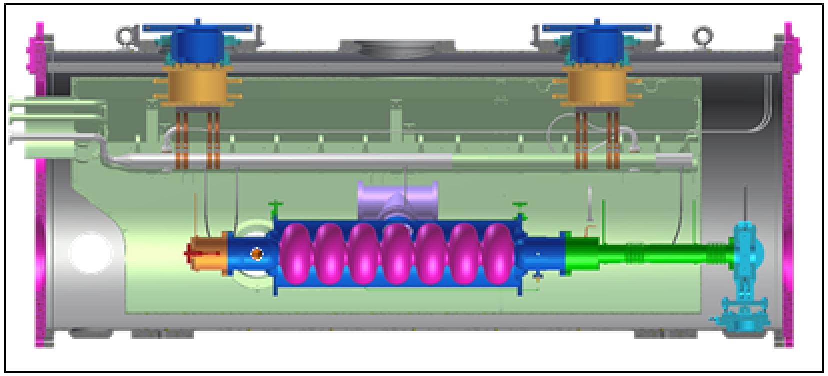
First high current (>100 mA), CW SRF linac cryomodule worldwide!

Cornell Horizontal Test Cryomodule (HTC)

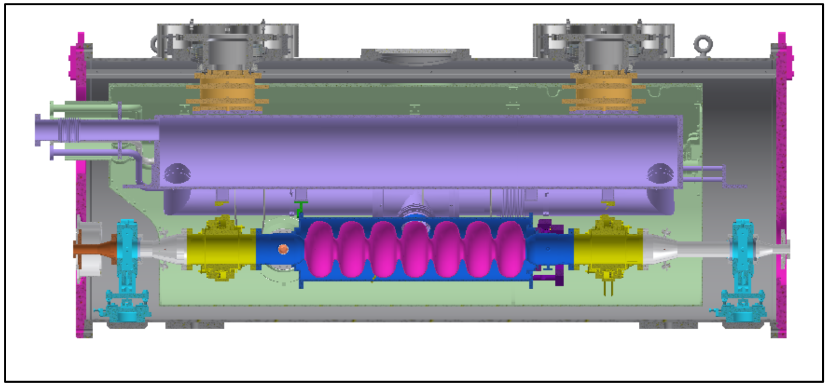
- HTC-1: Follow vertical assembly procedure as closely as possible



- HTC-2: Include side mounted, High-power input coupler

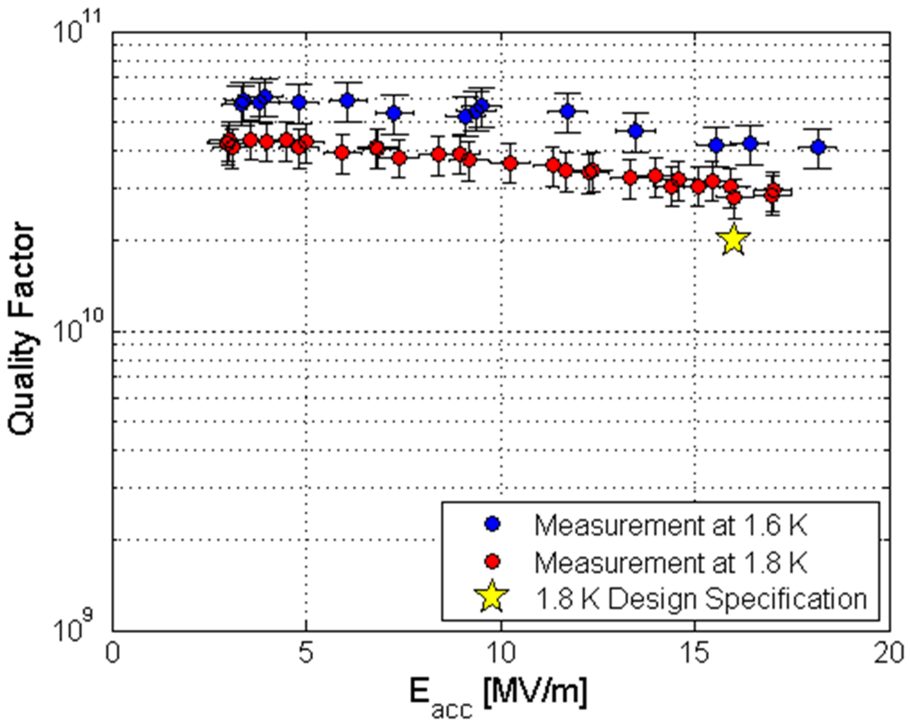


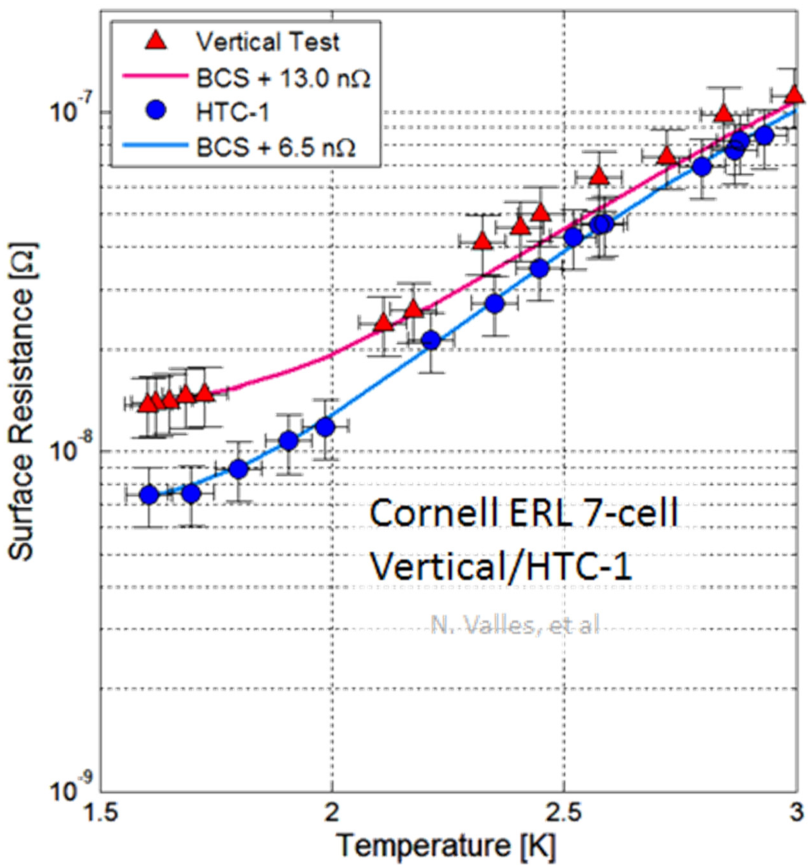
- HTC-3: Full cryomodule assembly-high power RF input coupler and HOM absorbers



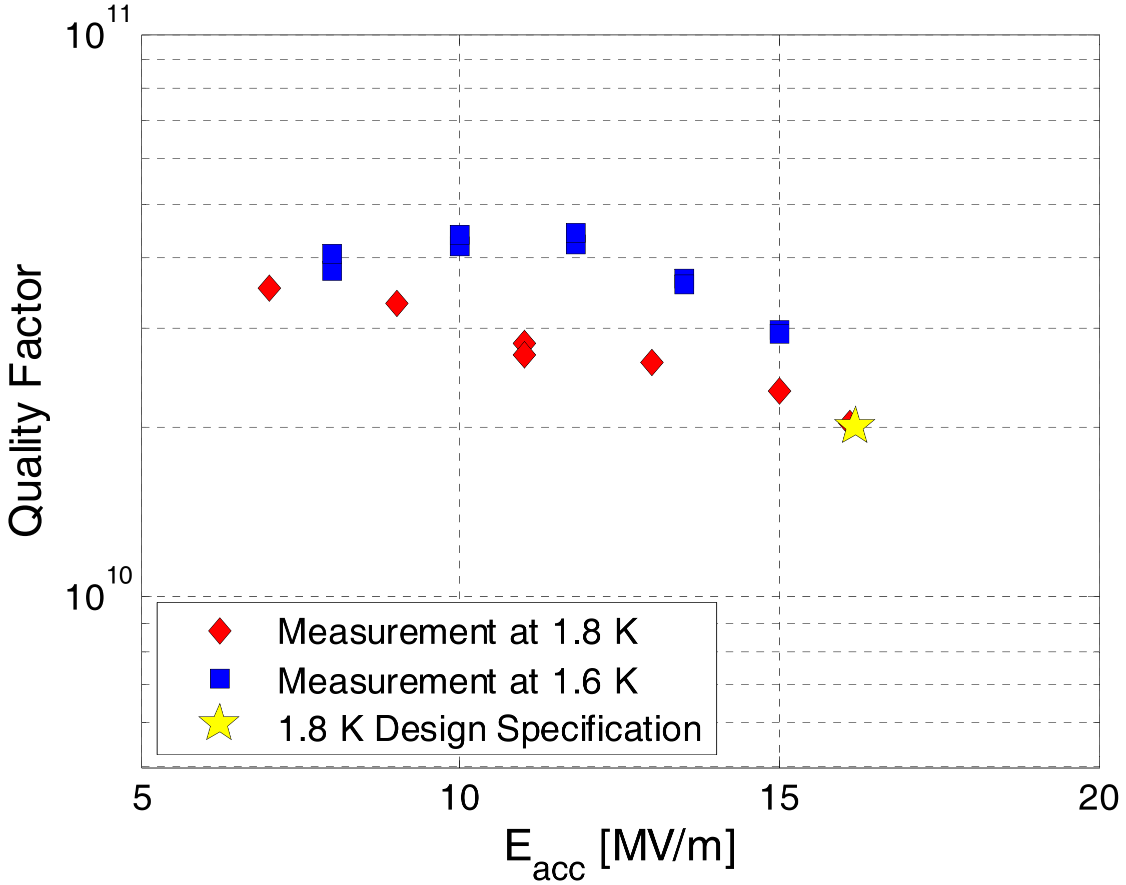
HTC-1: Cavity only

Record Q_0 in a horizontal cryomodule:
6 x 10^{10} (at 5 MV/m, 1.6 K)



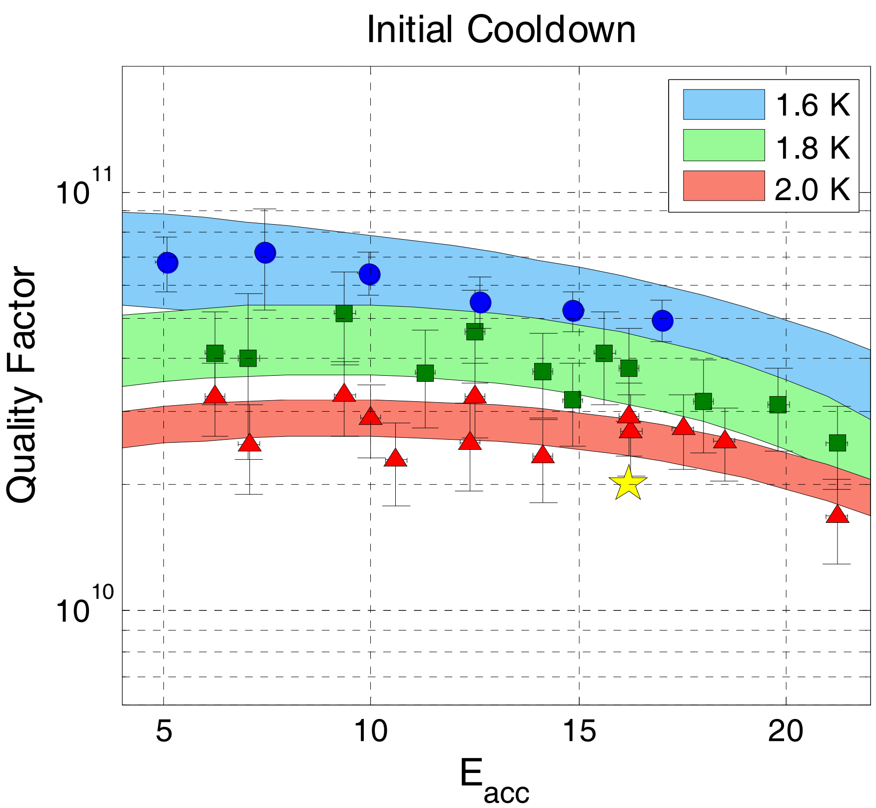


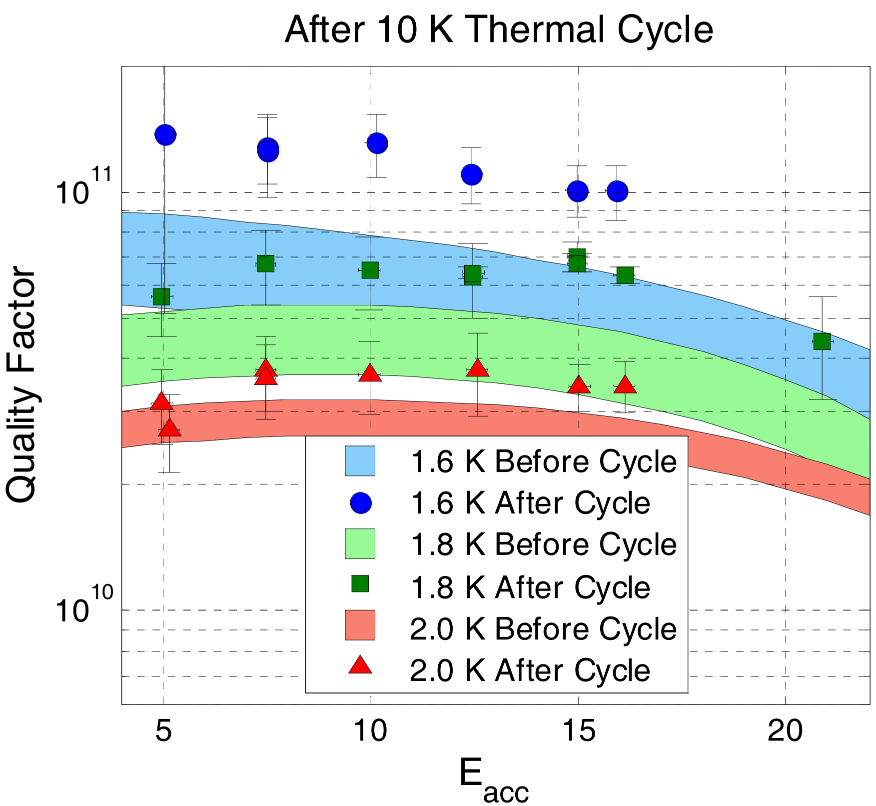
HTC-2: Cavity + Coupler



HTC-3: Cavity + Coupler + HOM Absorbers

New Record in a horizontal cryomodule:
Q_0 > 10^{11} (at 16.2 MV/m, 1.6 K)





Initial Cooldown at 16.2 MV/m

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

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

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

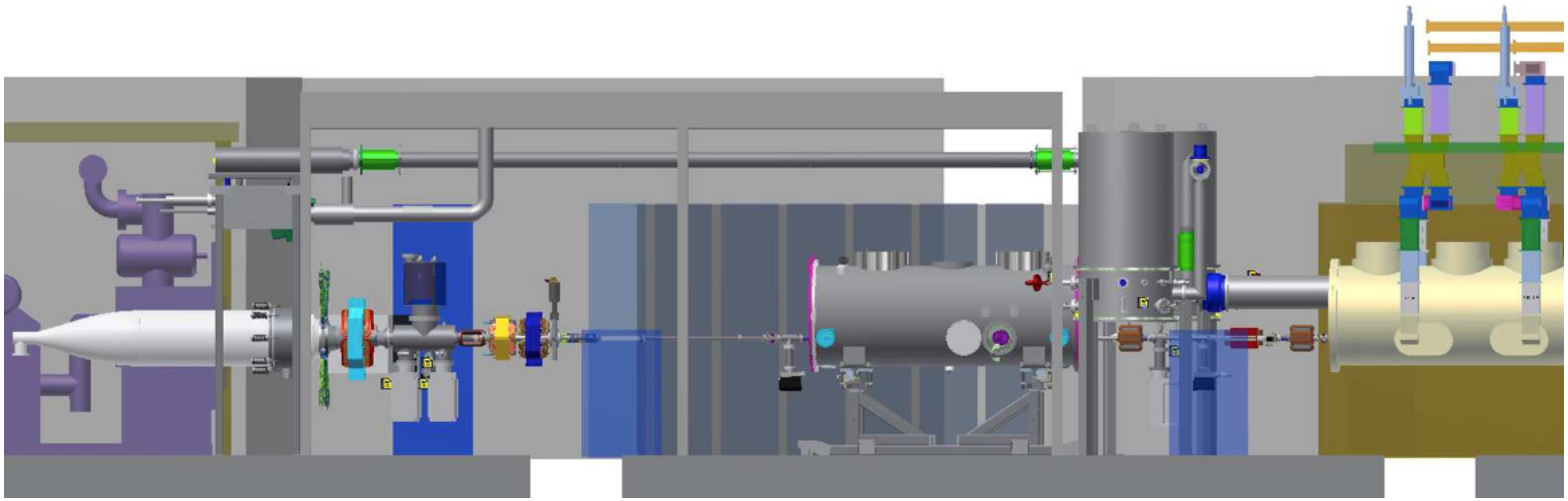
10 K thermal cycle at 16.2 MV/m

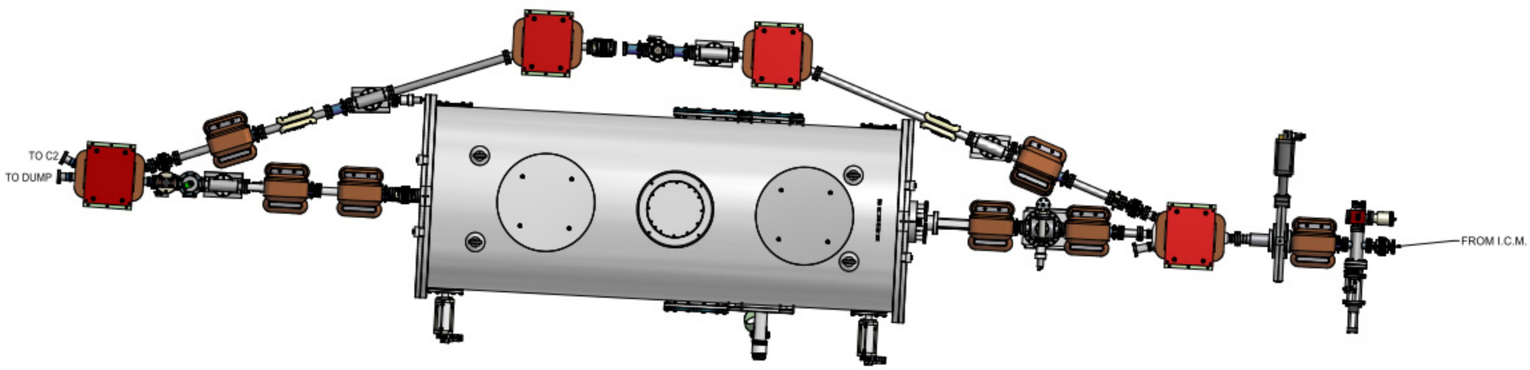
Q(2.0 K) = 3.5 x 10^{10}

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

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

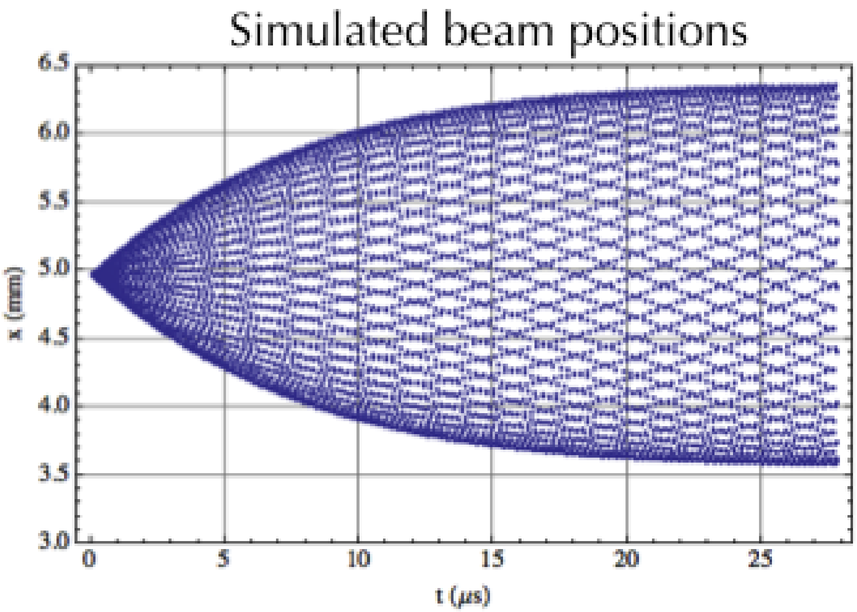
HTC is now in the Prototype ERL Injector



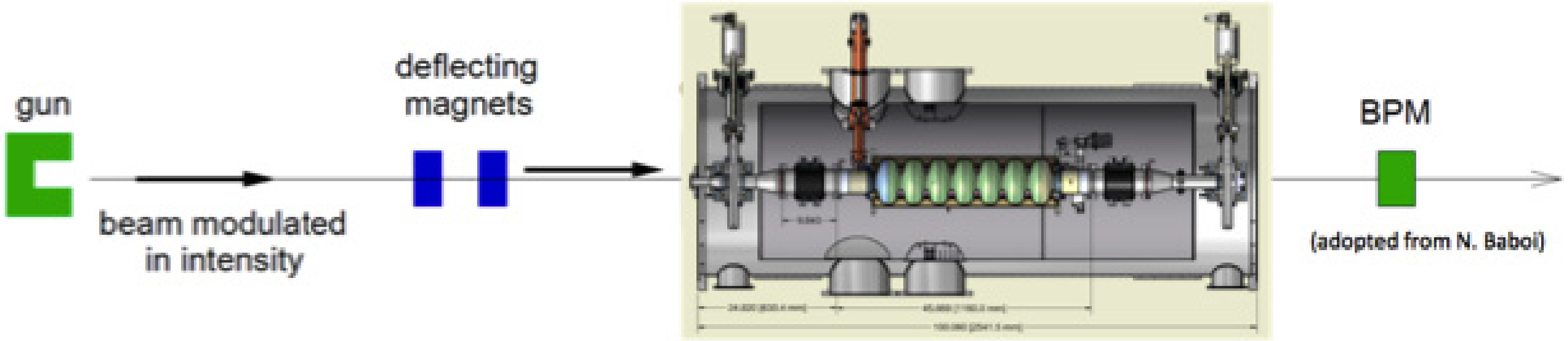


HTC is now in the Prototype ERL Injector

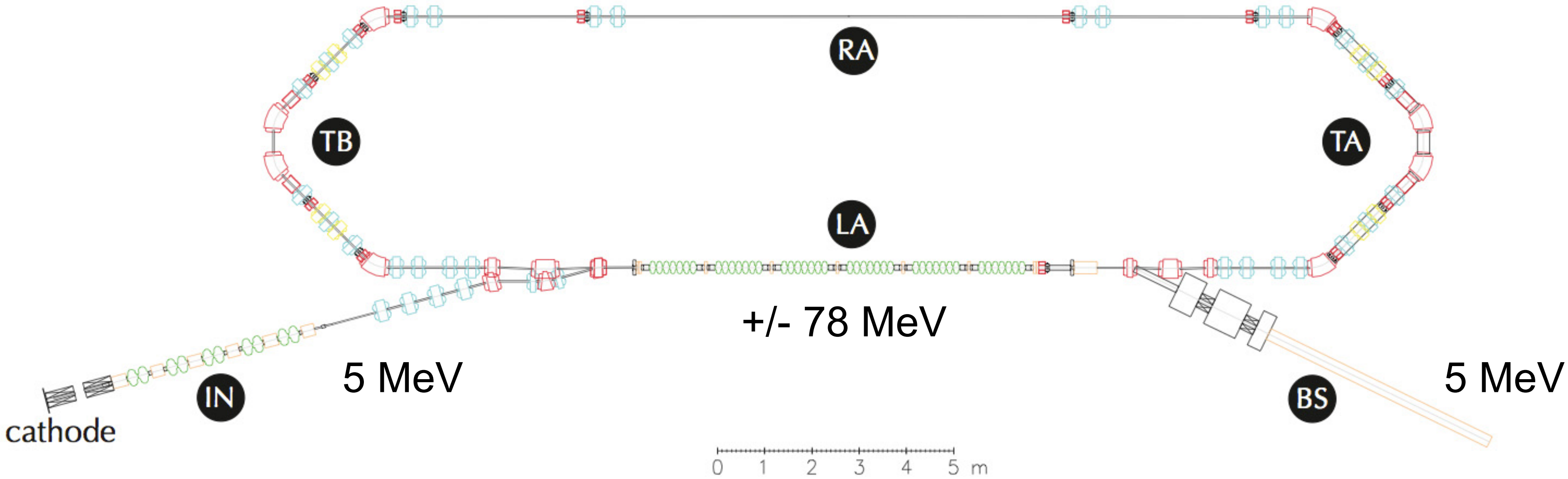
- Parameter directly related the BBU threshold can be measured directly by **resonantly exciting Higher Order Modes with a charge modulated beam**.
- Measuring the beam positions at some distance downstream
  $\Rightarrow$ **R/Q of HOM** from beam position oscillation amplitude
  $\Rightarrow$ **Q of HOM** from the decay of oscillations after modulation is turned off



$$\Delta_{\mathrm{BPM}} \approx \frac{c}{\pi} a_{\mathrm{mod}}\, x_{\mathrm{offset}}\, d_{\mathrm{BPM}}\, q_0\, f_{\mathrm{b}}\, \frac{e}{\mathcal{E}} \frac{(R/Q)_\lambda Q_\lambda}{f_\lambda}$$

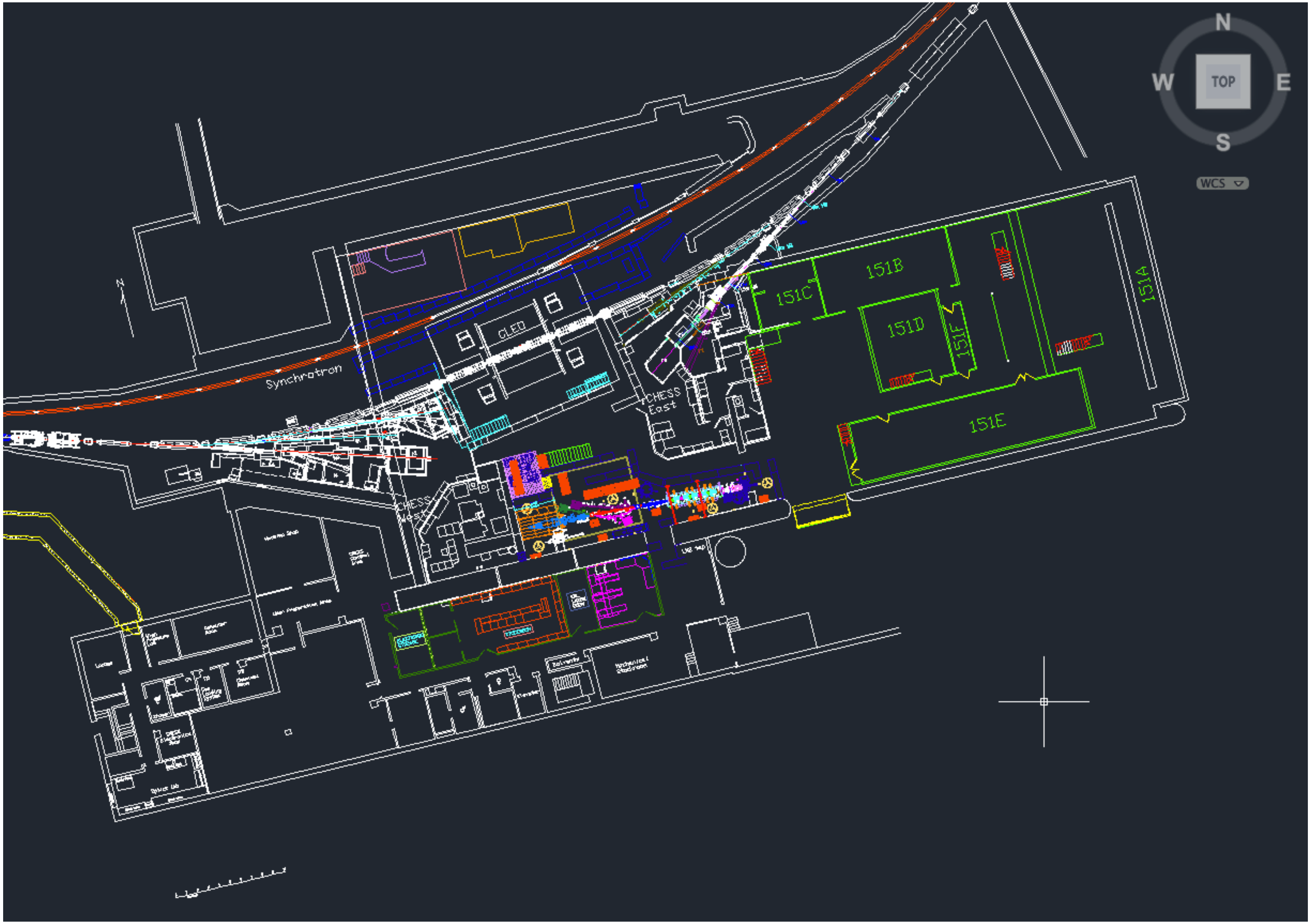


Cornell High-power recirculation loop

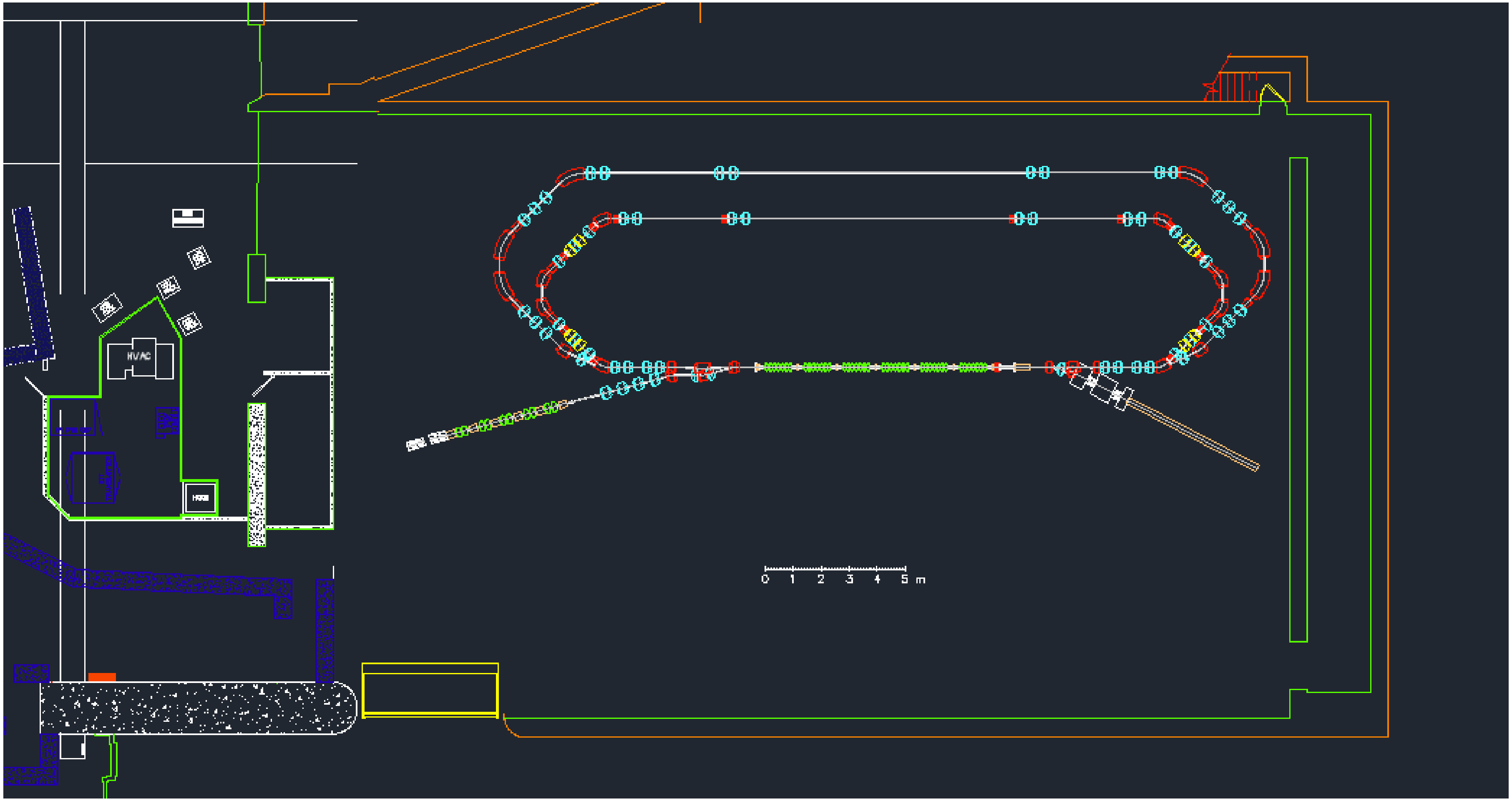


Energy	83	MeV
Current	100	mA
Emittance x, y	0.3	mm-mrad
Frequency	1.3	GHz
Bunch charge	77	pC

Cornell High-power recirculation loop



Cornell High-power recirculation loop



Studies with the loop

High current

- Halo sources in high-power beams
- Halo development in high-power beams
- Particle-Loss mechanisms
- Collimation of beam halos
- Detection of beam halos
- Particle-loss detection for machine and personnel safety
- Radiation background, material damage, and demagnetization under particle loss

Studies with the loop

<u>CW operation</u>

- SRF operation dominated by dynamic heat load
- SRF field control at highest precision
- Active and passive microphonics control in SRF cryostats
- Evaluation of high-precision cavity production, incl. Q_0, Q and R/Q of HOMs, coupler kicks, alignments, and straightness.

<u>Low emittance</u>

- Space-charge dominated beams (in the injector region)
- High-density beams in high-energy accelerators (emittance preservation, error fields, element alignments and imperfections)
- High-brightness beam diagnostics

Cornell ERL R&D Summary

Cathode Laboratory

Grow and characterize robust, low MTE cathodes for ERL use

Prototype ERL injector

Record 65 mA from NaKSb cathode 8 hours at 4 MeV (May 24)
Record 52 mA (briefly) from GaAs
Emittance targets after the merger achieved
Emittance measurement system was replaced by HTC over the summer
Will now push for 100 mA

Horizontal Test Cryomodule (HTC)

Record $\mathbf{Q_0 > 10^{11}}$ (at 16.2 MV/m, 1.6 K)
Now in the injector for high current and HOM studies

Main Linac Cryomodule (MLC)

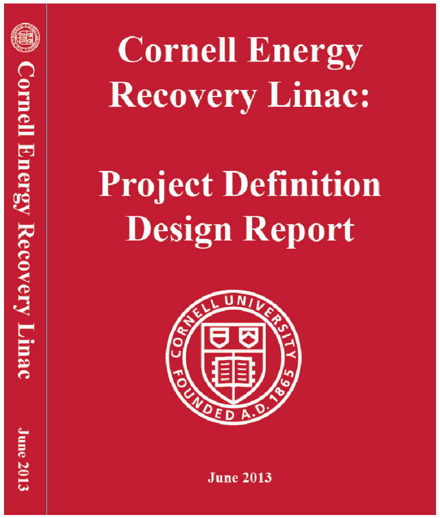
All cavities fabricated in-house
All components ordered
Summer 2014 completion

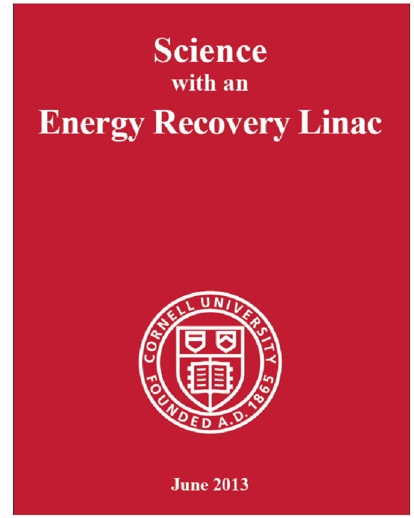
Future: High-power Recirculation Loop

Test injector, merger, MLC in an ERL configuration

Cornell ERL PDDR

www.classe.cornell.edu/ERL/





This work is supported by the National Science Foundation grant DMR-0807731