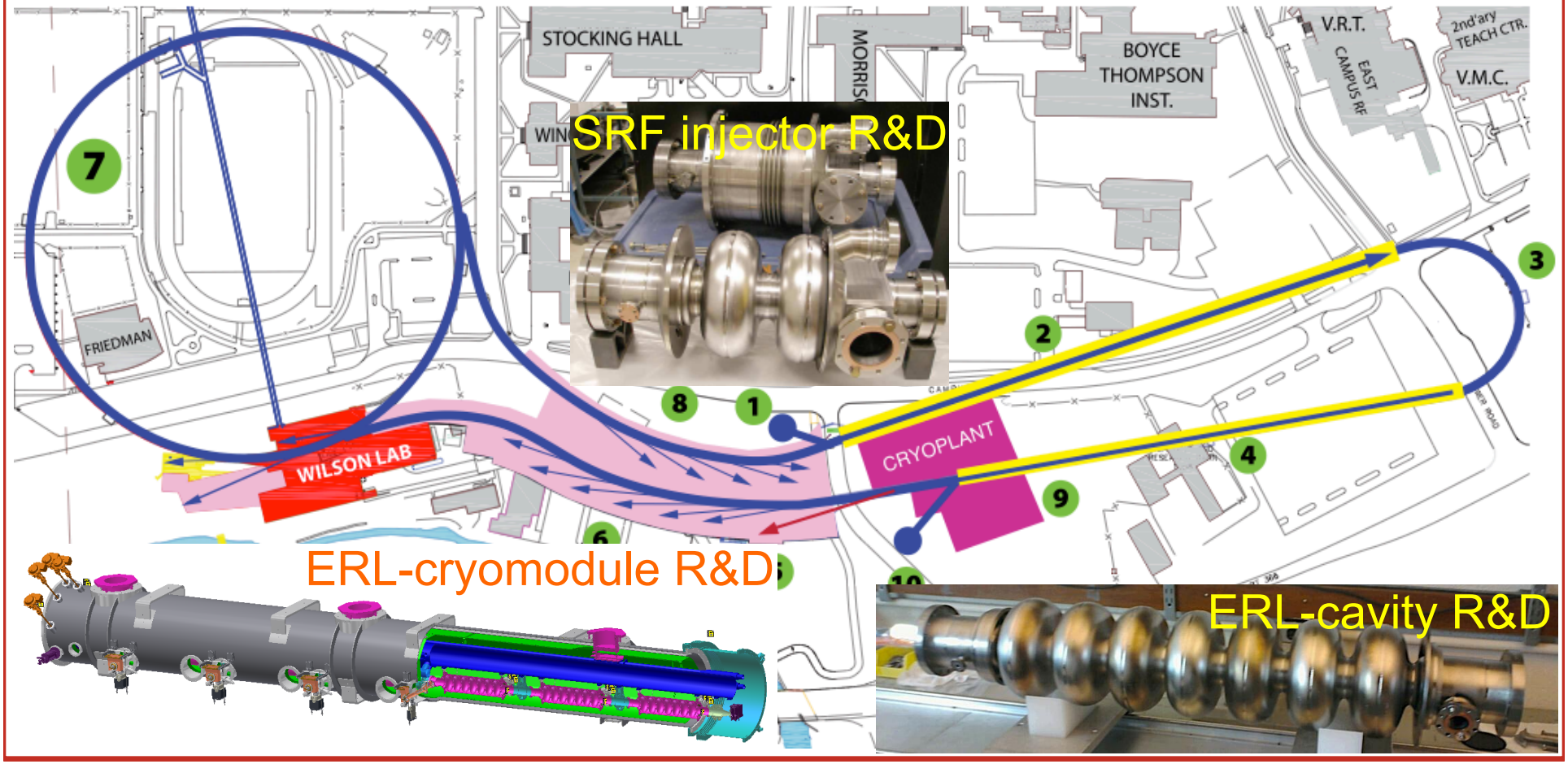
Welcome to Cornell for the 1st TTC topical meeting: CW SRF

Georg Hoffstaetter
Cornell Physics Dept. / CLASSE
Cornell's SRF and ERL team



Cavity Design (KEK, JLAB, Cornell, Berkeley, Fermilab)

SRF Guns (HZDR, HZB)

Low Beta and Transversal Cavities (Fermilab, APS, IHEP, IMP)

CW cavity operation (Cornell, JLAB, HZB, Fermilab)

Cavity high Q treatment procedures (Fermilab, JLAB, Cornell, HZB)

Couplers (Cornell, KEK, Fermilab)

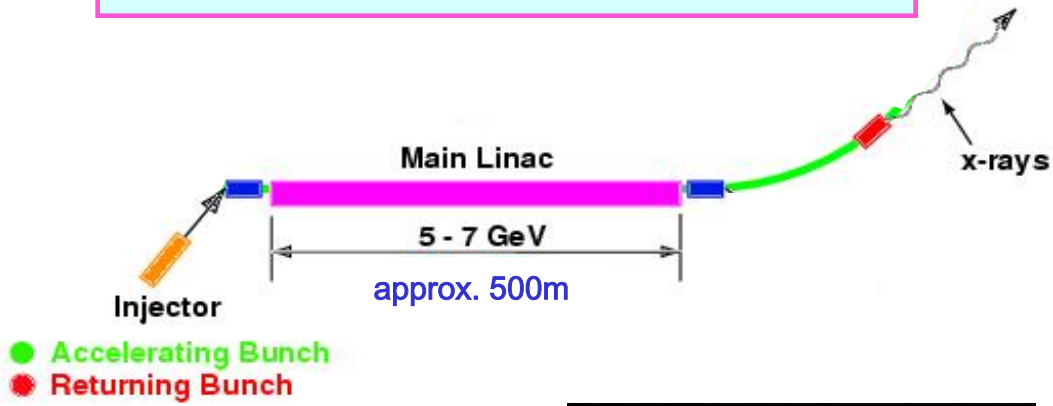
HOM Absorbers (Cornell, KEK, JLAB, DESY, APS)

Cryomodules (Daresbury, Berkeley, Cornell, Fermilab, JLAB, KEK, DESY)

Principle of an X-ray ERL

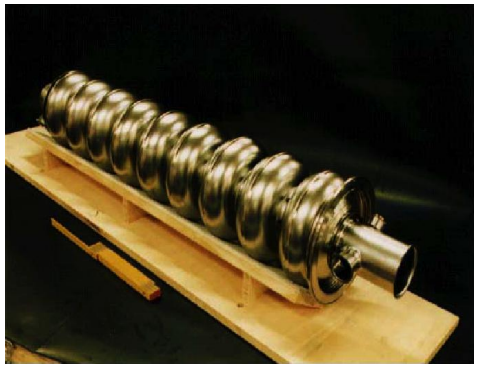
- Narrower and less divergent beams
- More coherent beams
- Shorter pulses

5GV*100mA = 0.5GW
(good size power plant)



Challenges:

- Low emittance, high current creation
- Emittance preservation
- Beam stability at insertion devices
- Accelerator design
- Component properties, e.g. SRF



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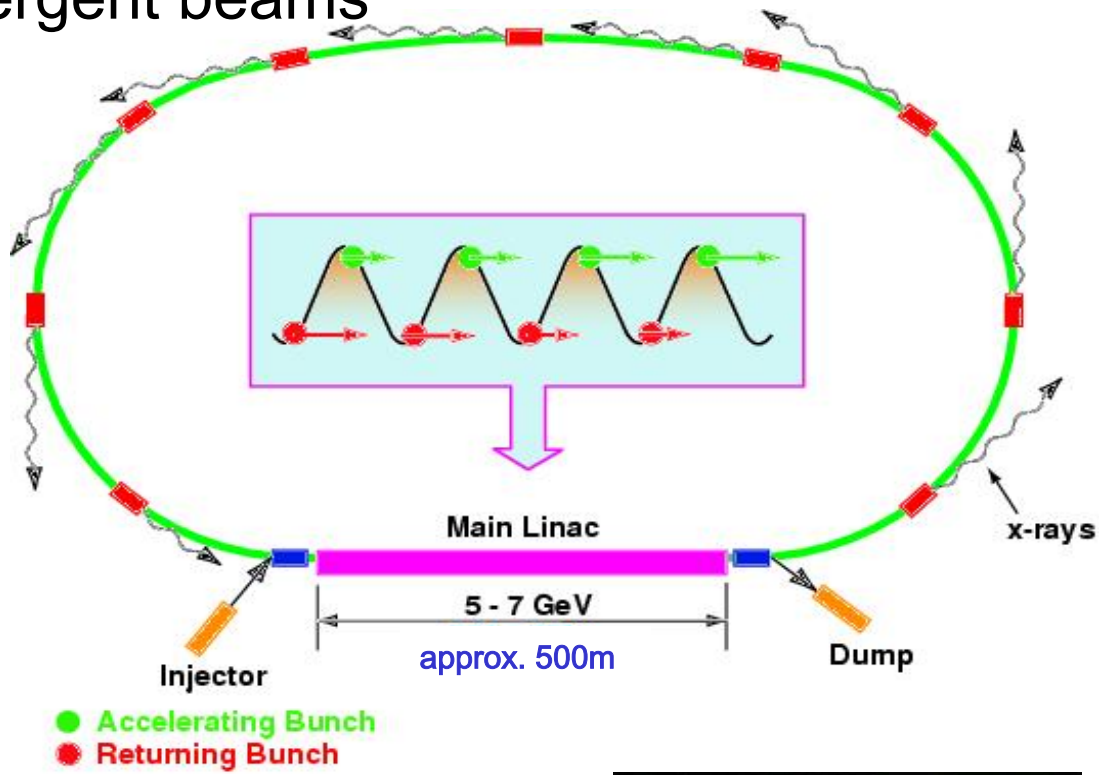

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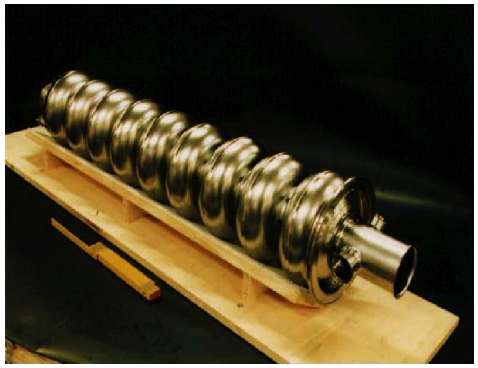
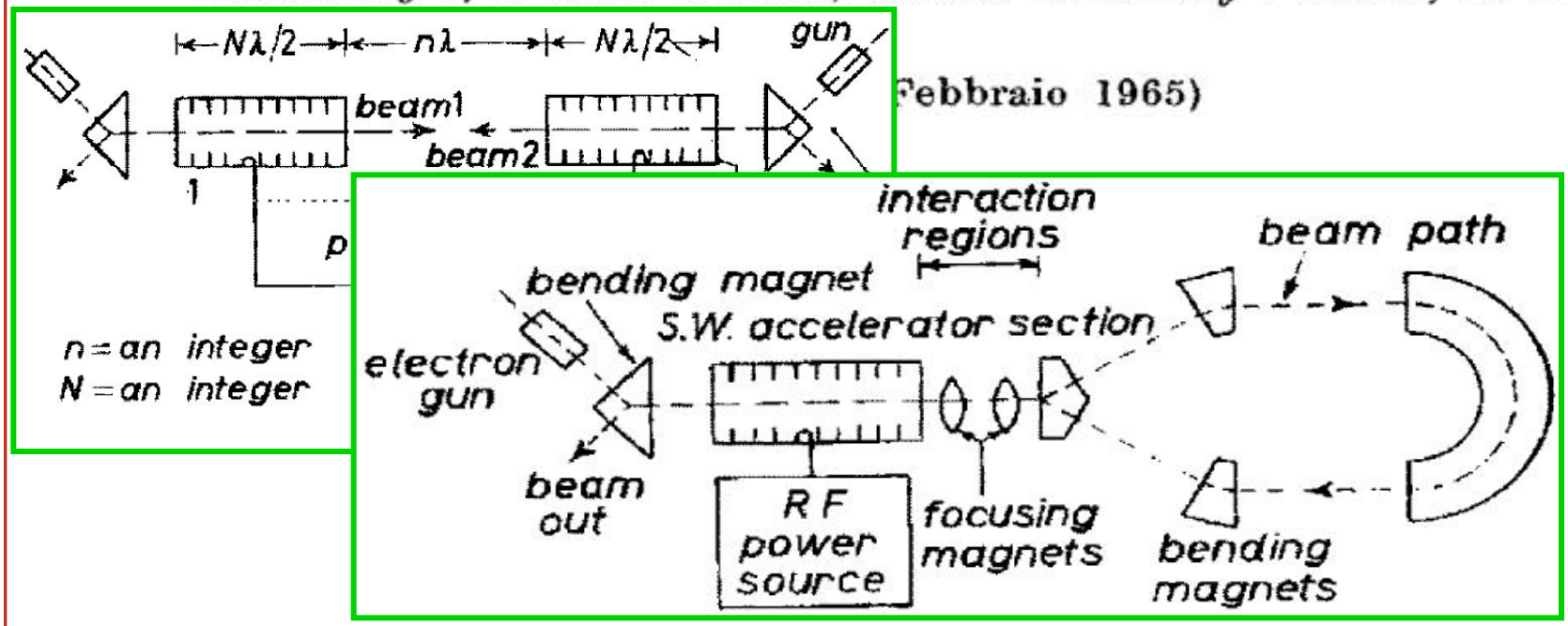


Cornell history: The ERL principle

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

M. TIGNER

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

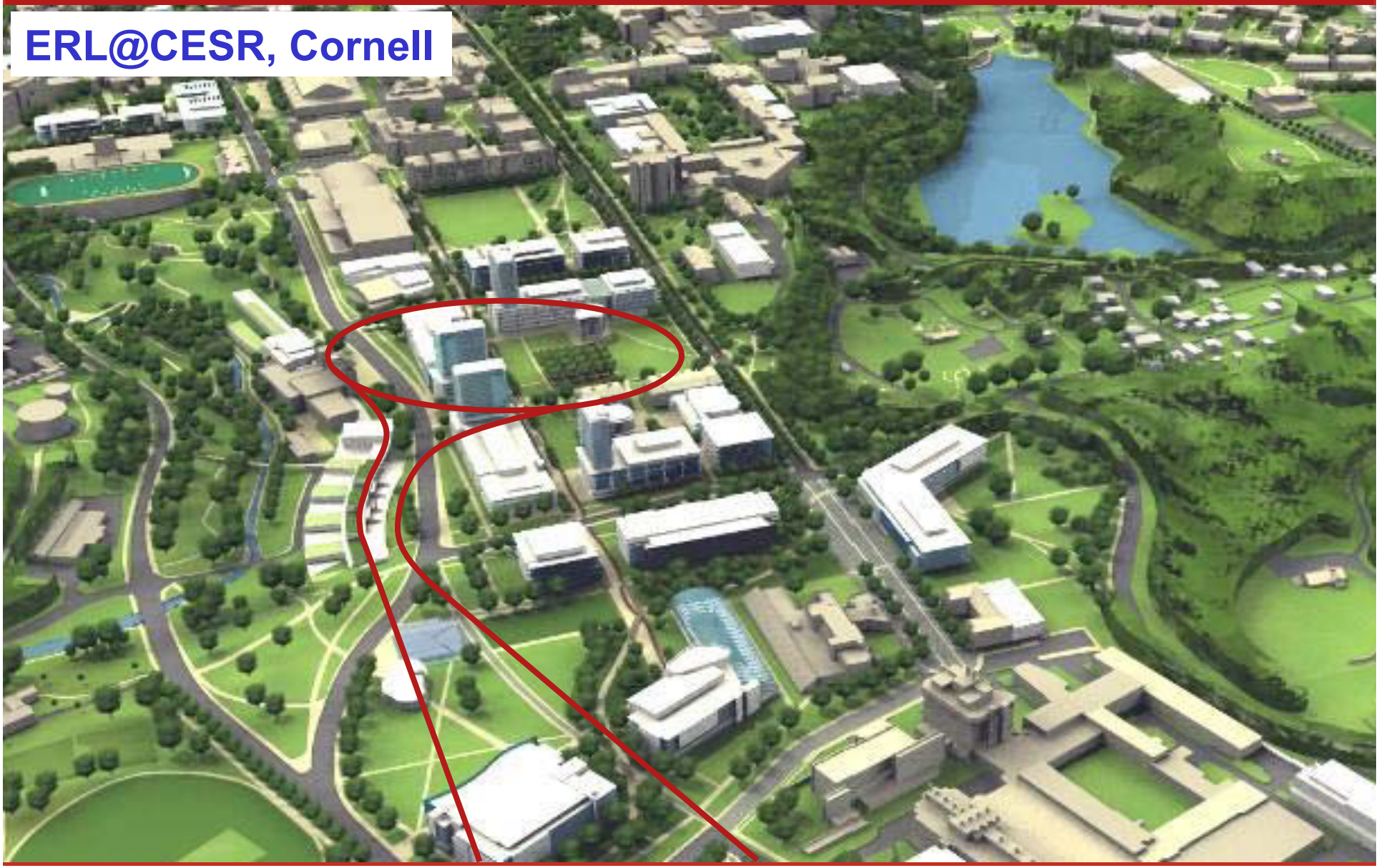


Energy recovery needs continuously fields in the RF structure

- Normal conducting high field cavities can get too hot.
- Superconducting cavities used to have too low fields.

ERL on Cornell's campus as extension of CHESS

CLASSE

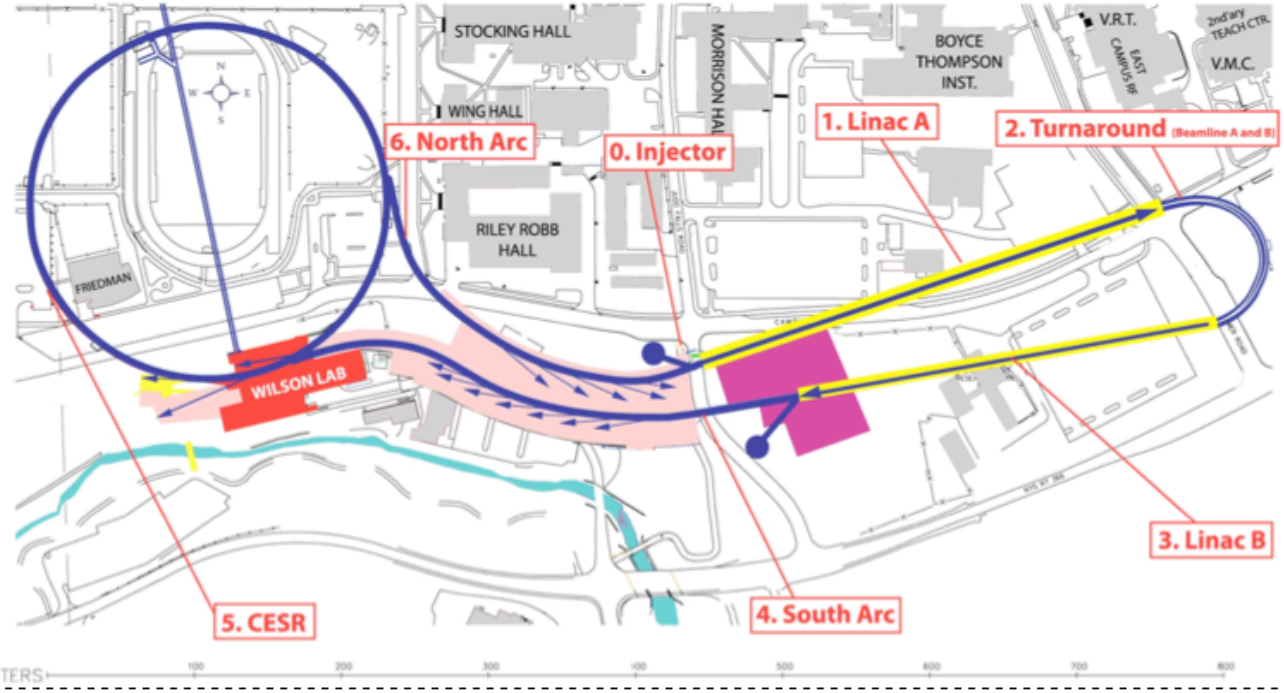


Conrell Energy Recovery Linac
Project Design Definition Report (PDDR)

Editors: Georg Hoffstaetter, Sol Gruner, Maury Tigner

Contributors: I. V. Bazarov, S. A. Belomestnykh, D. H. Bilderback, M. G. Billing, J. D. Brock, B. W. Buckley, S. S. Chapman, E. P. Chojnacki, Z. A. Conway, J. A. Crittenden, D. Dale, J. A. Dobbins, B. M. Dunham, R. D. Ehrlich, M. P. Ehrlichman, K. D. Finkelstein, E. Fontes, M. J. Forster, S. W. Gray, S. Greenwald, S. M. Gruner, C. Gulliford, D. L. Hartill, R. G. Helmke, G. H. Hoffstaetter, A. Kazimirov, R. P. Kaplan, S. S. Karkare, V. O. Kostroun, F. A. Laham, Y. H. Lau, Y. Li, X. Liu, M. U. Liepe, F. Loehl, L. Cultrera, T. Miyajima, C. E. Mayes, J. M. Maxson, A. Meseck, A. A. Mikhailichenko, D. Ouzounov, H. S. Padamsee, S. B. Peck, M. A. Pfeifer, S. E. Posen, P. G. Quigley, P. Revesz, D. H. Rice, U. Sae-Ueng, D. C. Sagan, J. O. Sears, V. D. Shemelin, C. K. Sinclair, D. M. Smilgies, E. N. Smith, K. W. Smolenski, Ch. Spethmann, C. Song, T. Tanabe, A. B. Temnykh, M. Tigner, N. R. A. Valles, V. G. Veshcherevich, Z. Wang, A. R. Woll, Y. Xie, Z. Zhao

Special Thanks: Chris Mayes is acknowledged for tireless editorial help and layout organization, and Sherrie Negrea for language editing.



Out for comments by selected advisors.

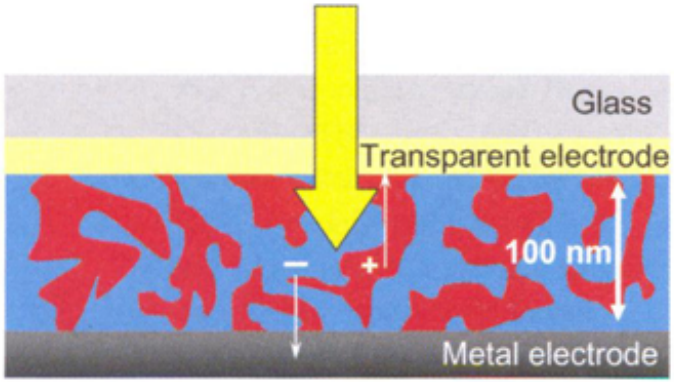
530 pages between conceptual design and engineering design.

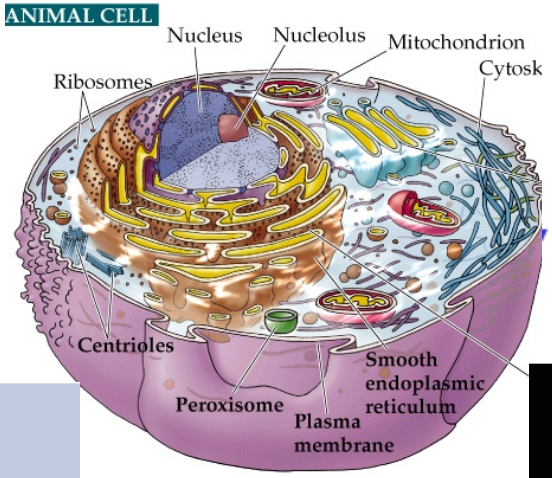
Getting ready for suitably timed submission to the NSF.

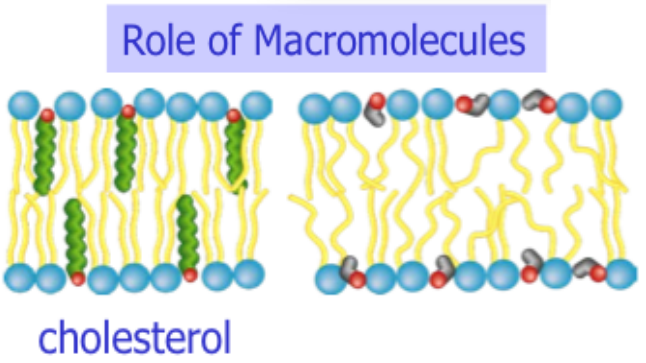
Interest in ERLs for Light Sources

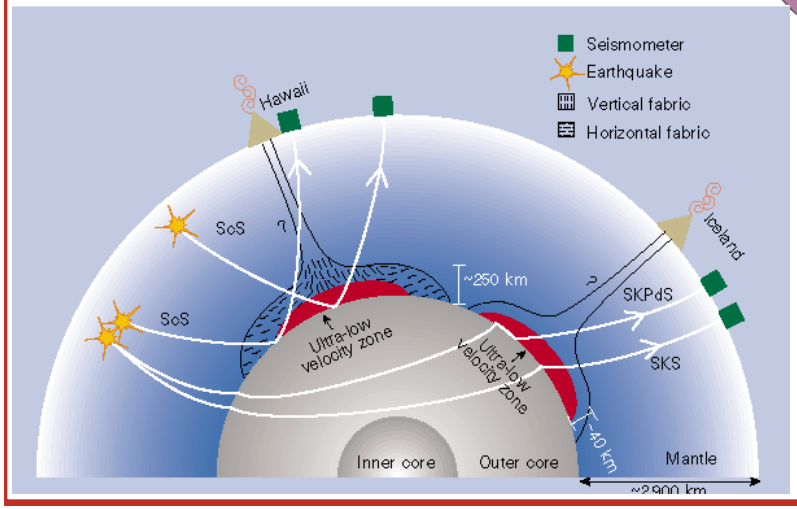
CLASSE

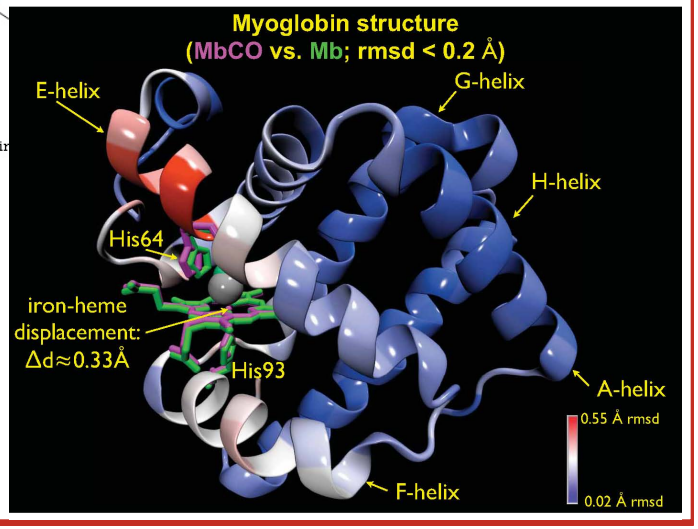
Progress in the
science case for X-ray ERLs





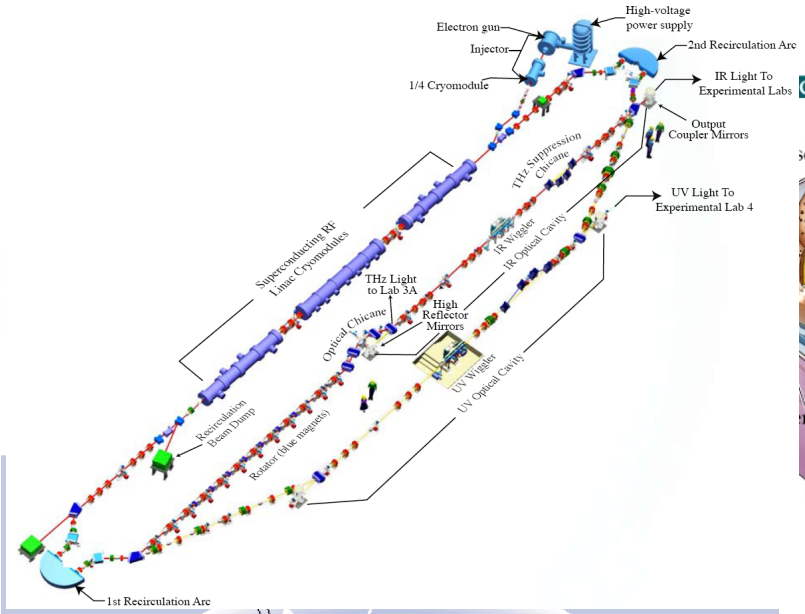


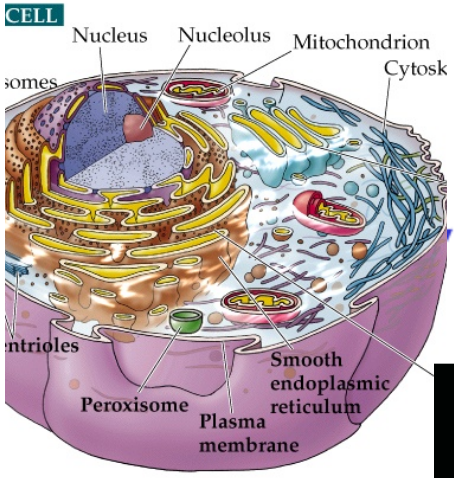


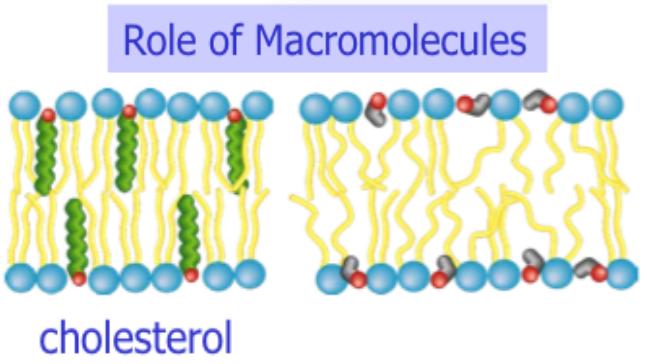


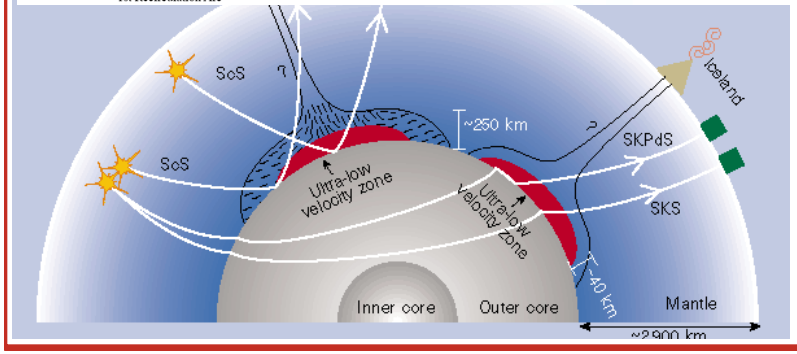
Interest in ERLs for Light Sources

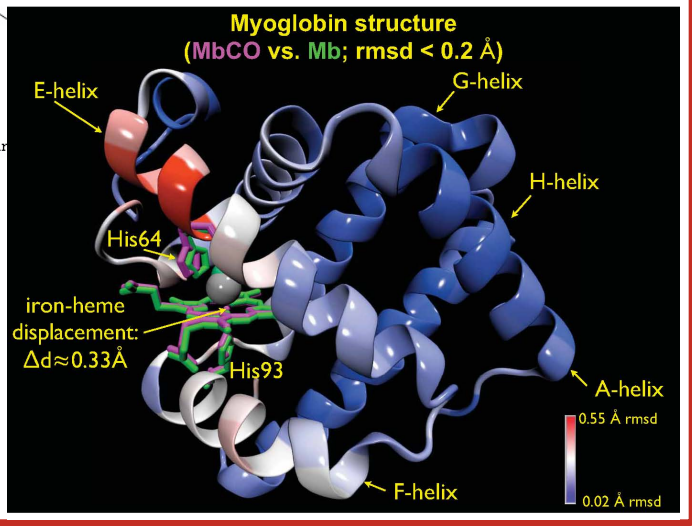
Operations at JLAB





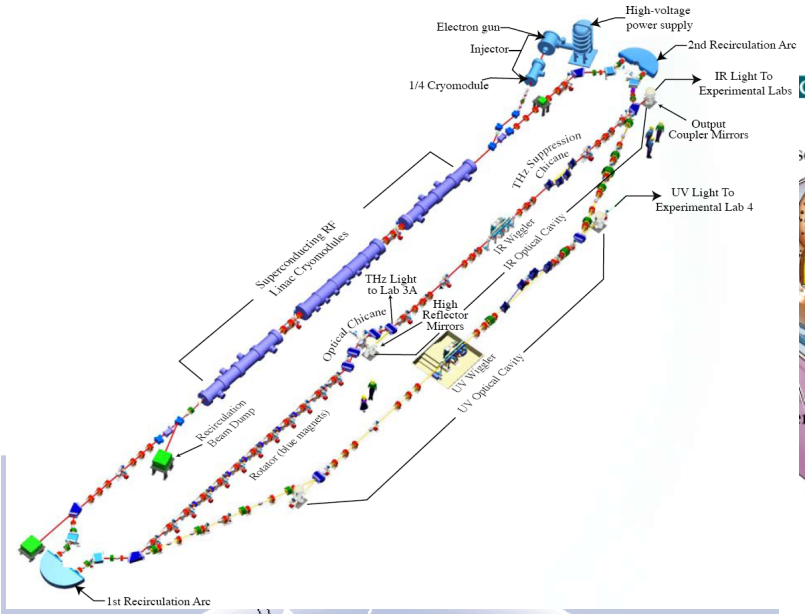


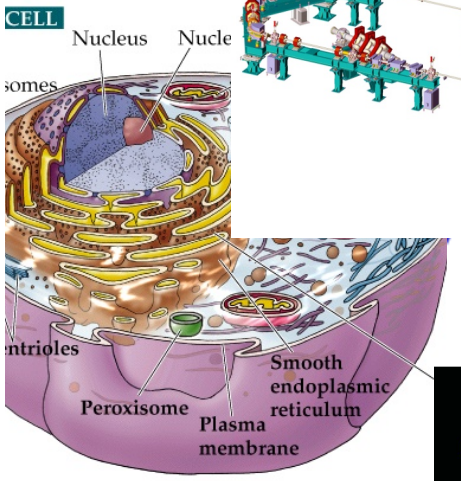


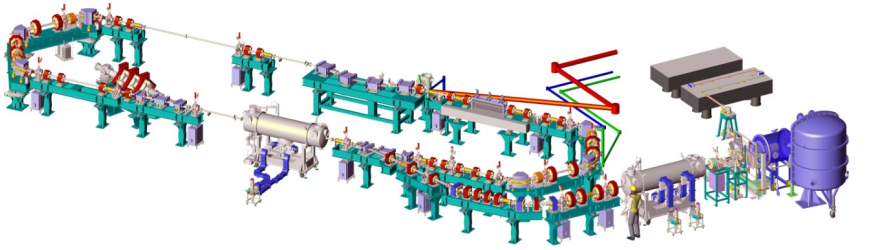


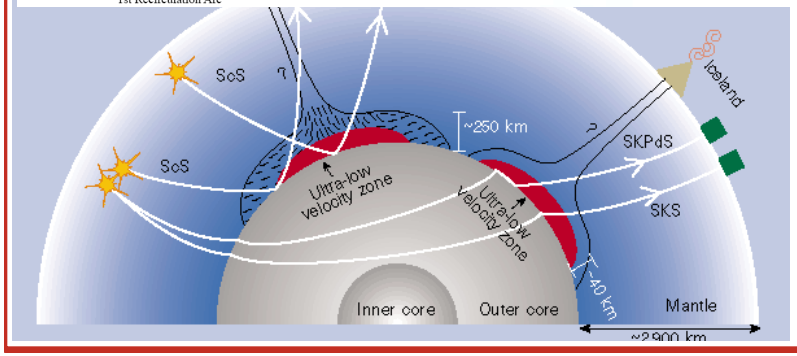
Interest in ERLs for Light Sources

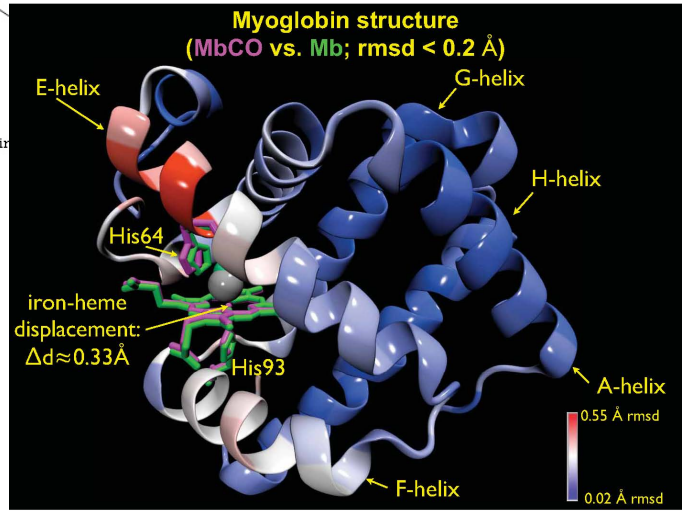
Operations at JLAB, Daresbury,





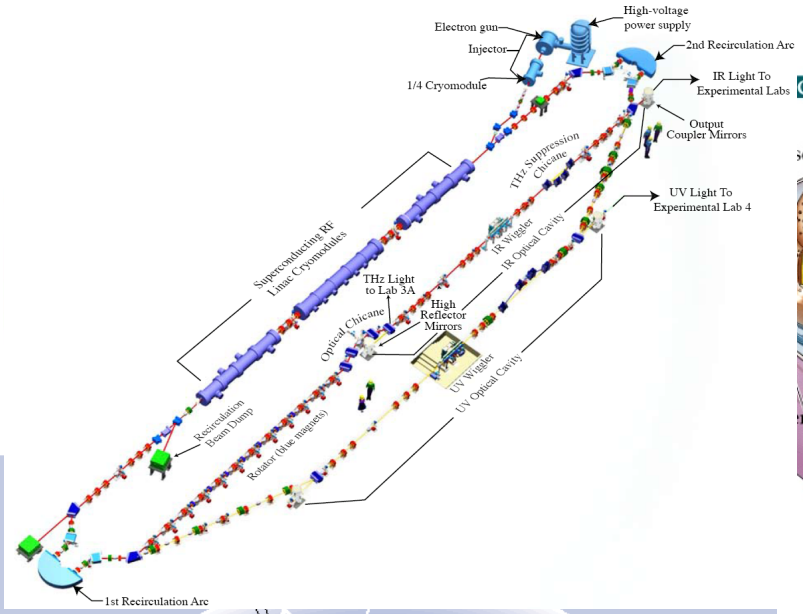


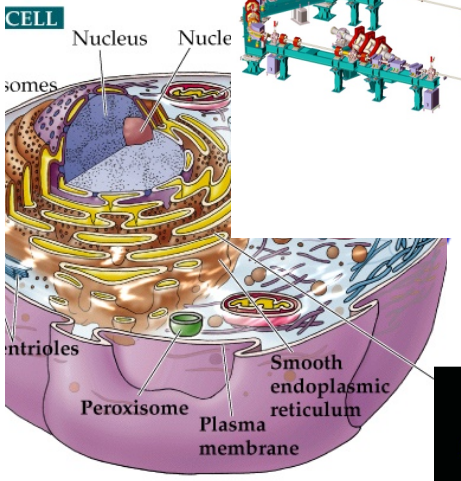


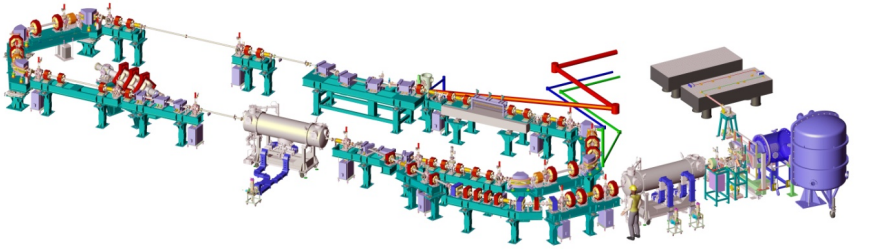


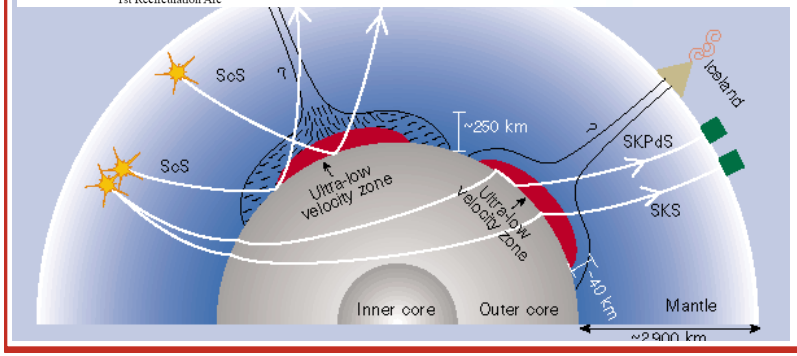
Interest in ERLs for Light Sources

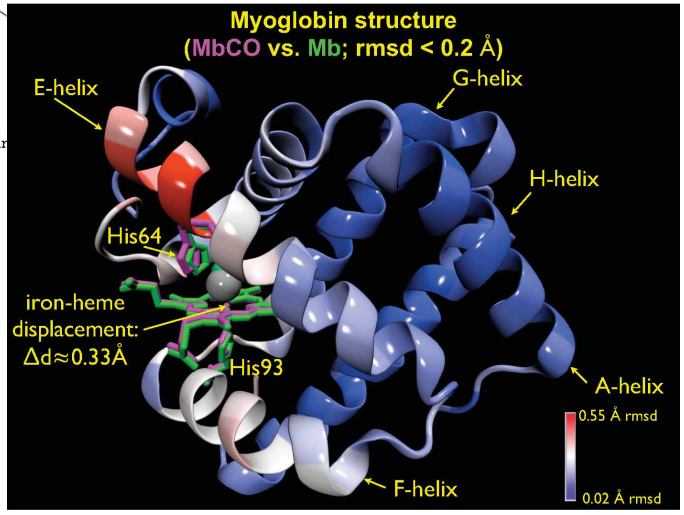
Operations at JLAB, Daresbury, BINP





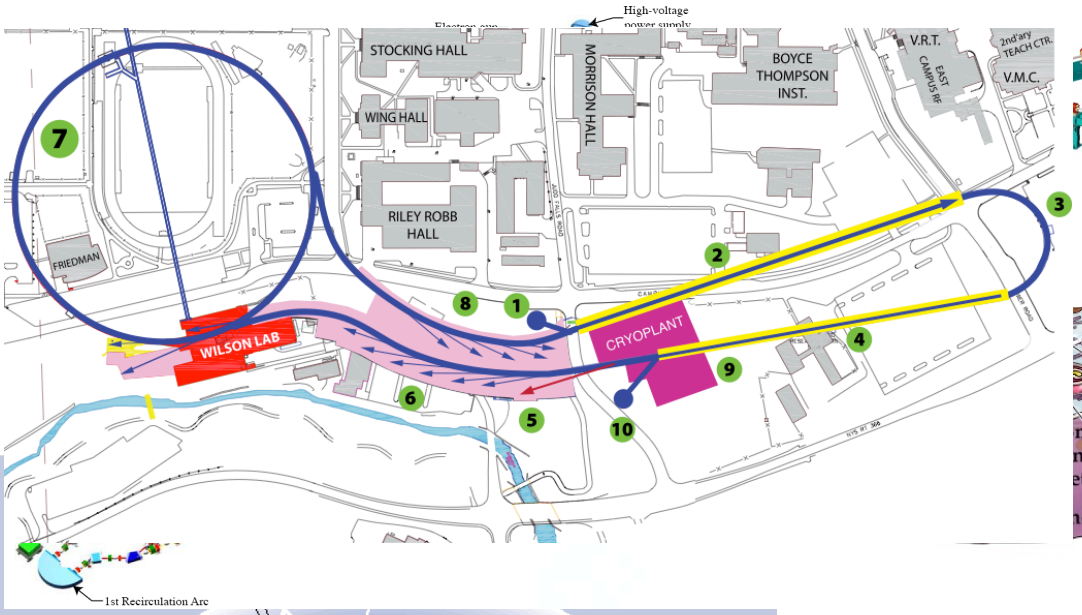


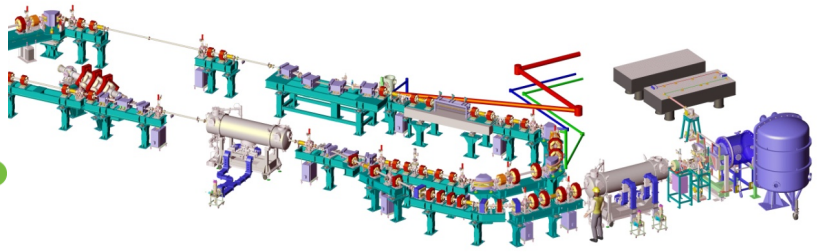


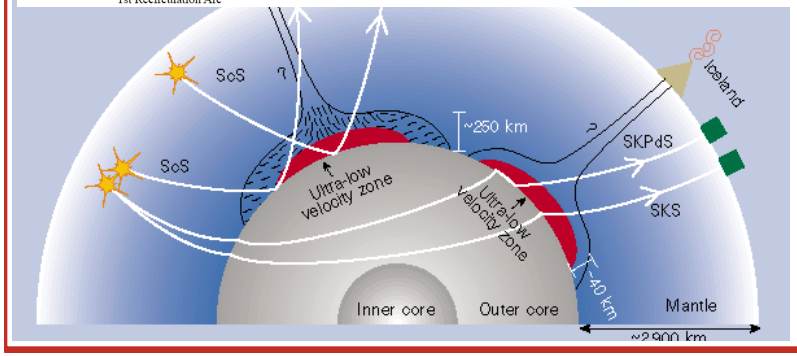


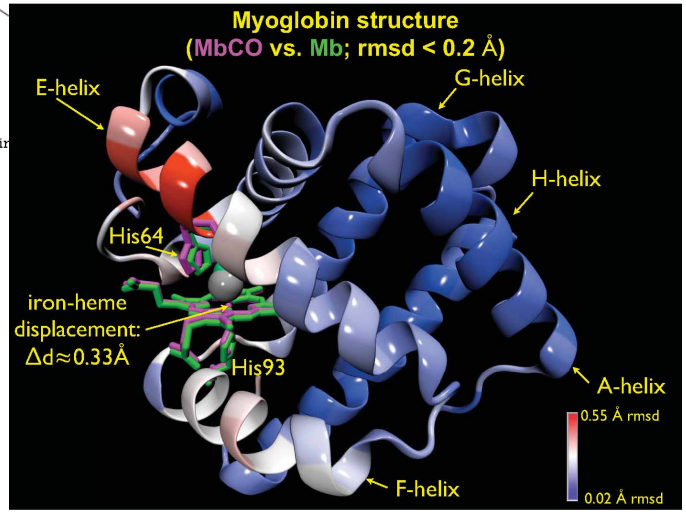
Interest in ERLs for Light Sources

Operations at JLAB, Daresbury, BINP
Designs at Cornell









Interest in ERLs for Light Sources

CLASSE

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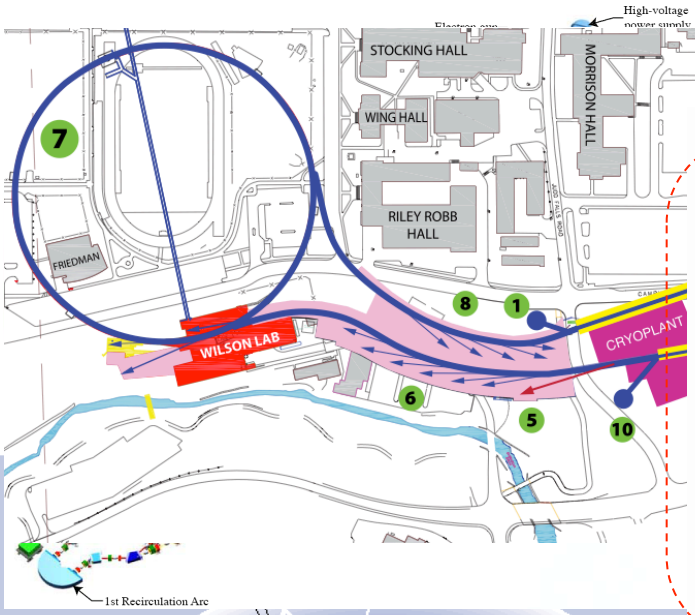
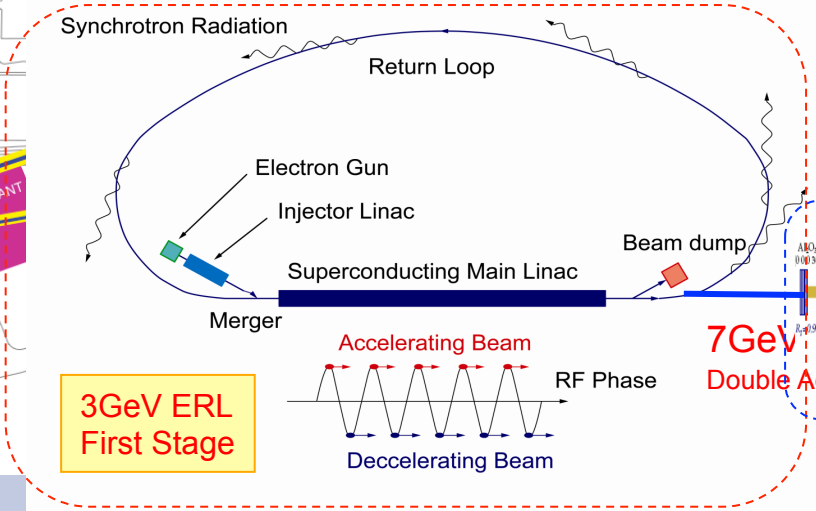
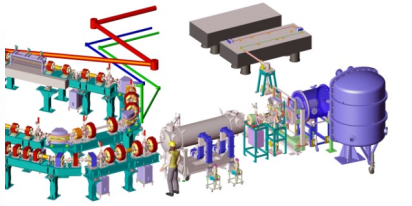
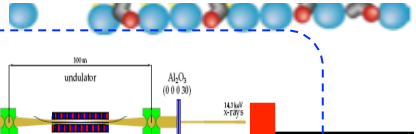
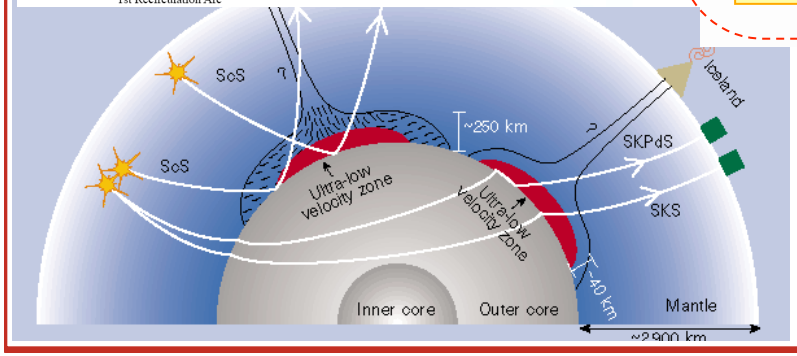


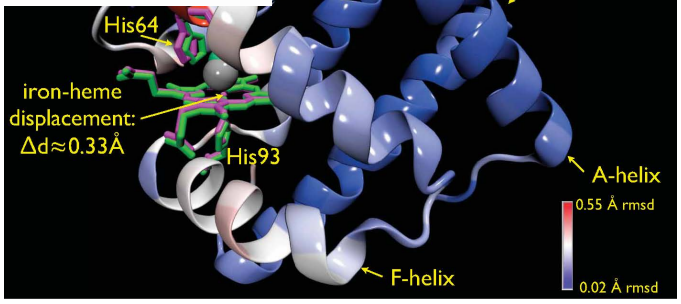






XFEL-O Second Phase





Interest in ERLs for Light Sources

Operations at JLAB, Daresbury, BINP
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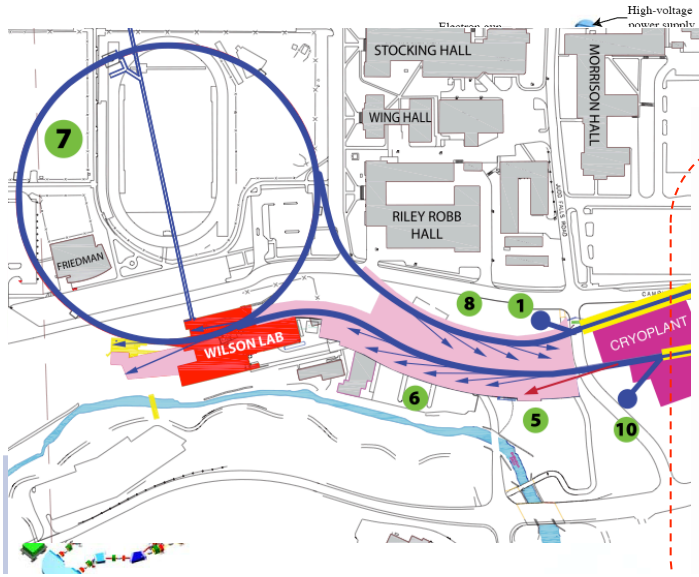

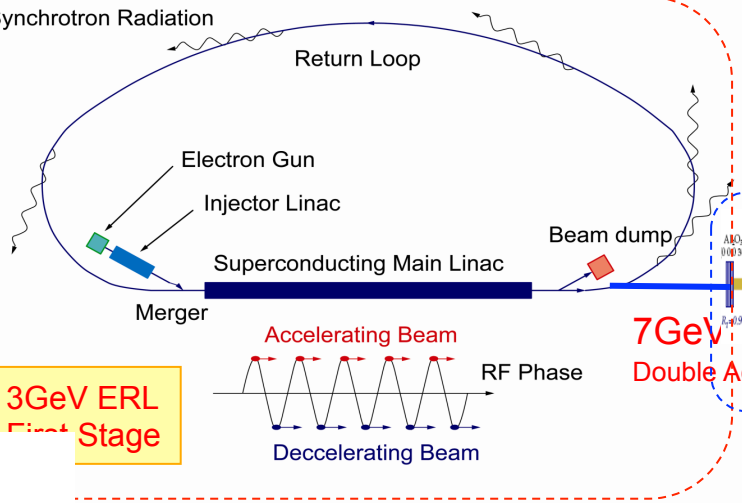

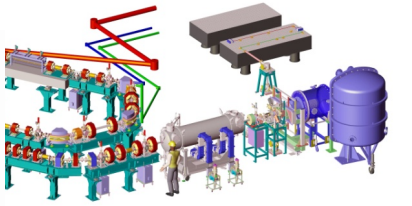

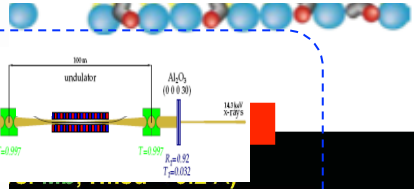

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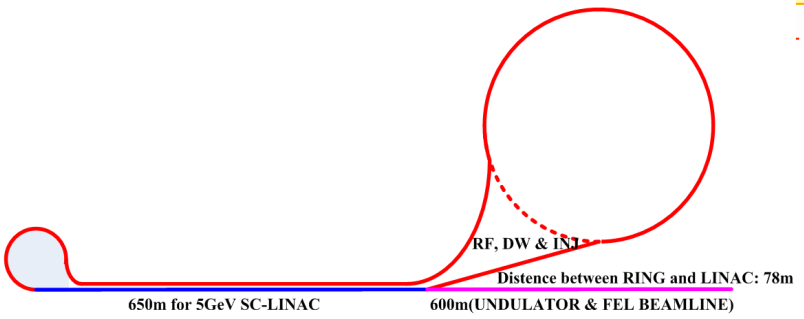
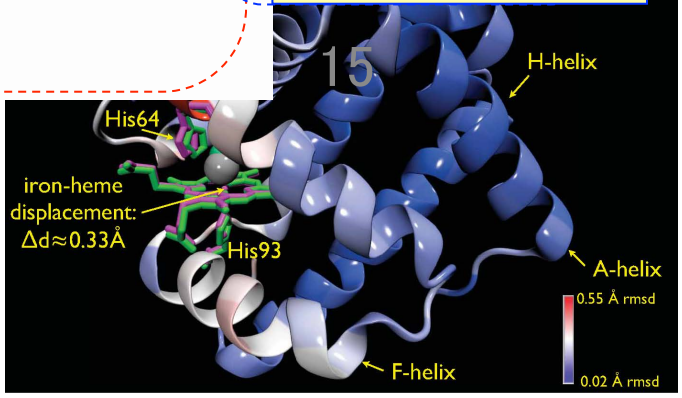
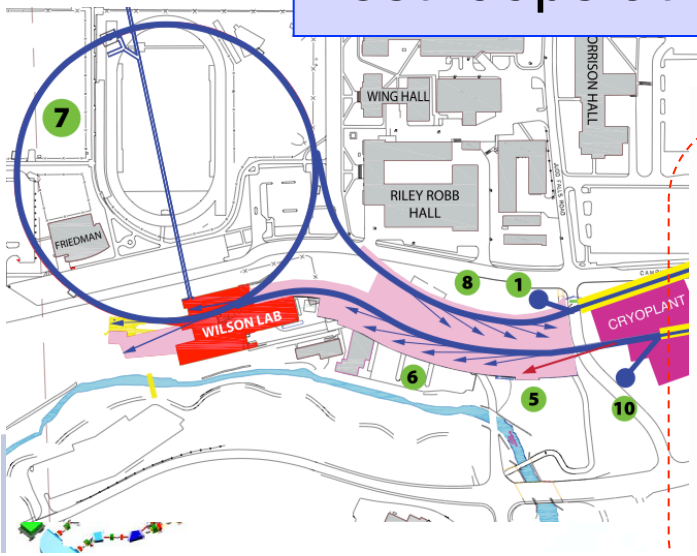
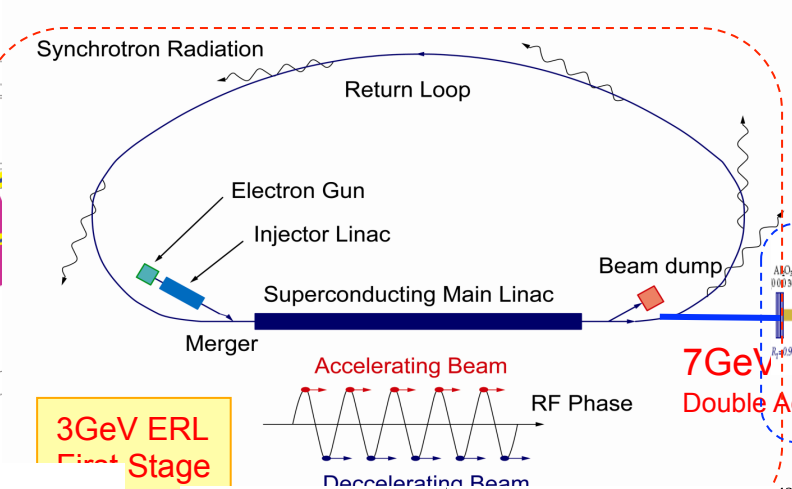


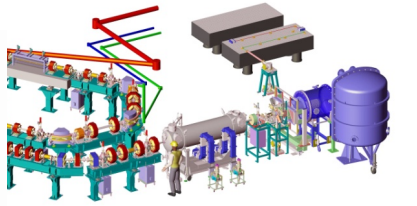


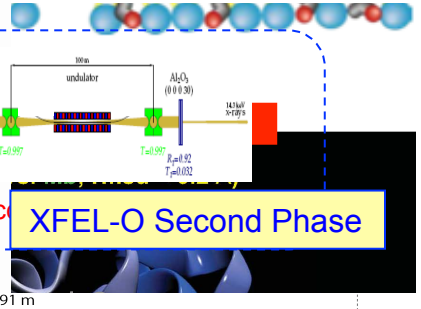
Interest in ERLs for Light Sources

Operations at JLAB, Daresbury, BINP
Designs at Cornell, KEK/JAEA, BAPS
Test loops at KEK



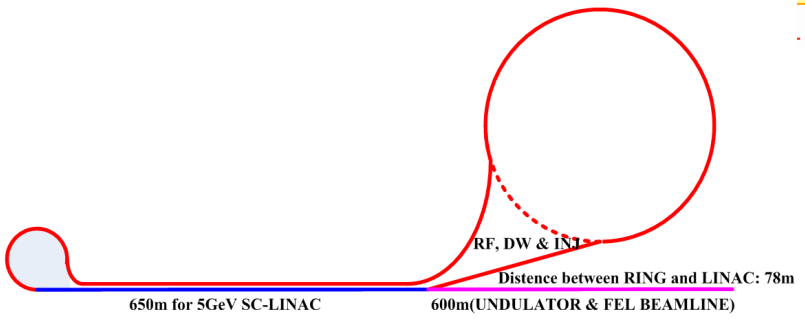


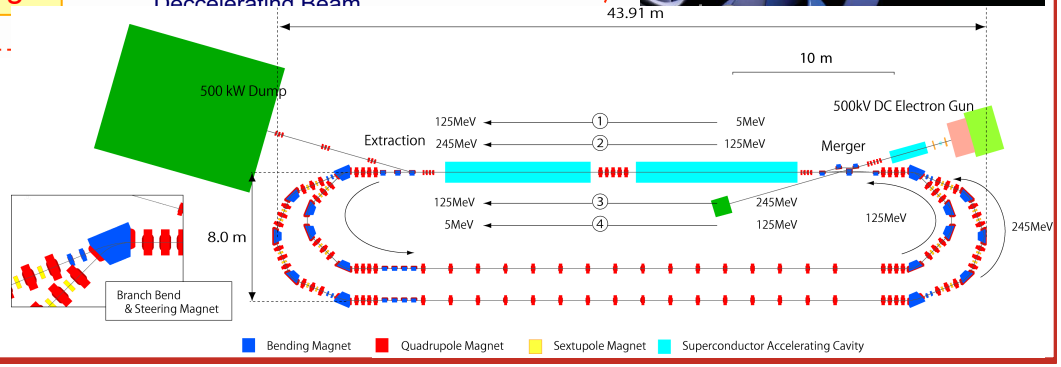




3GeV ERL First Stage

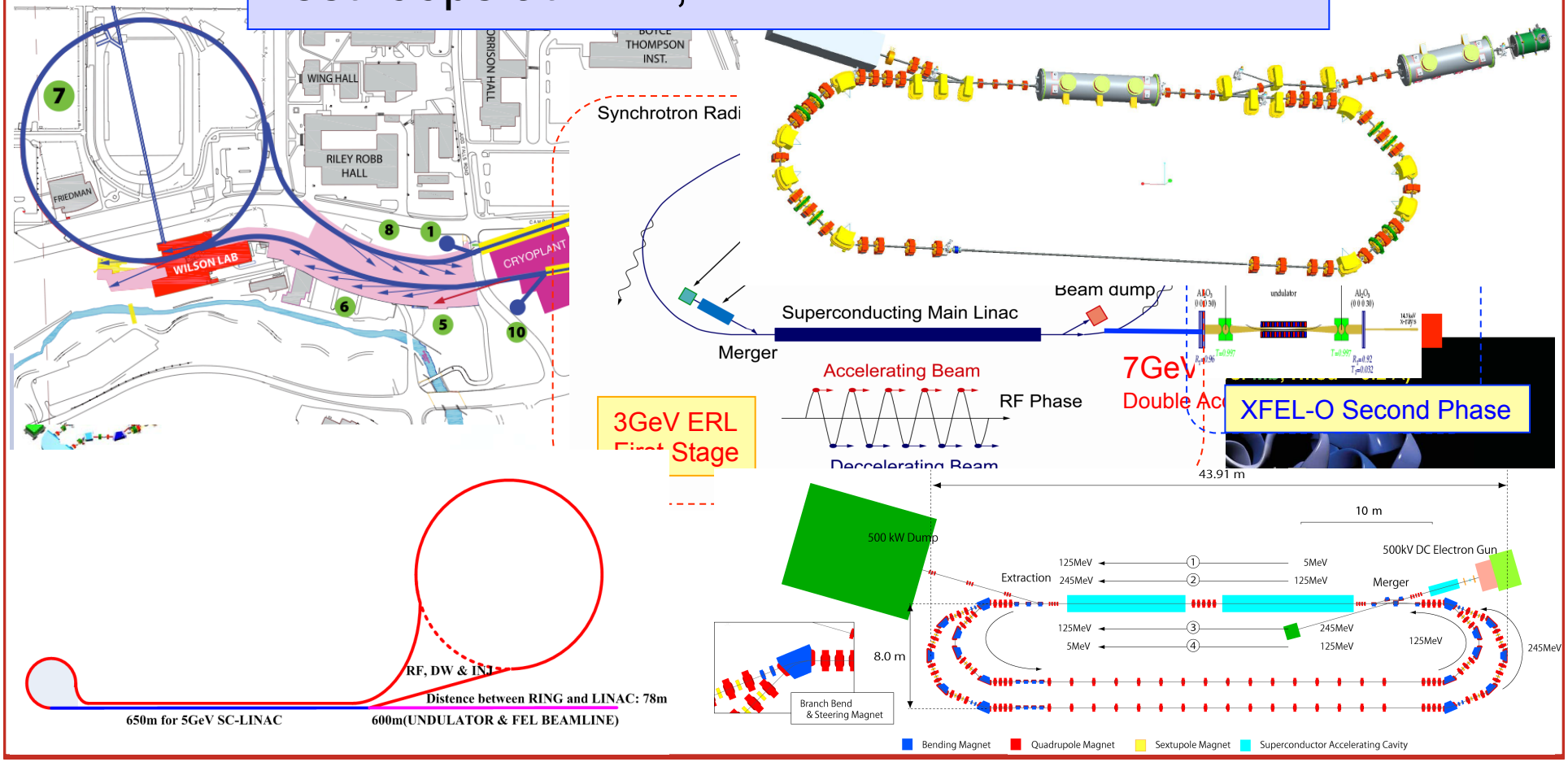
7GeV Double Ac





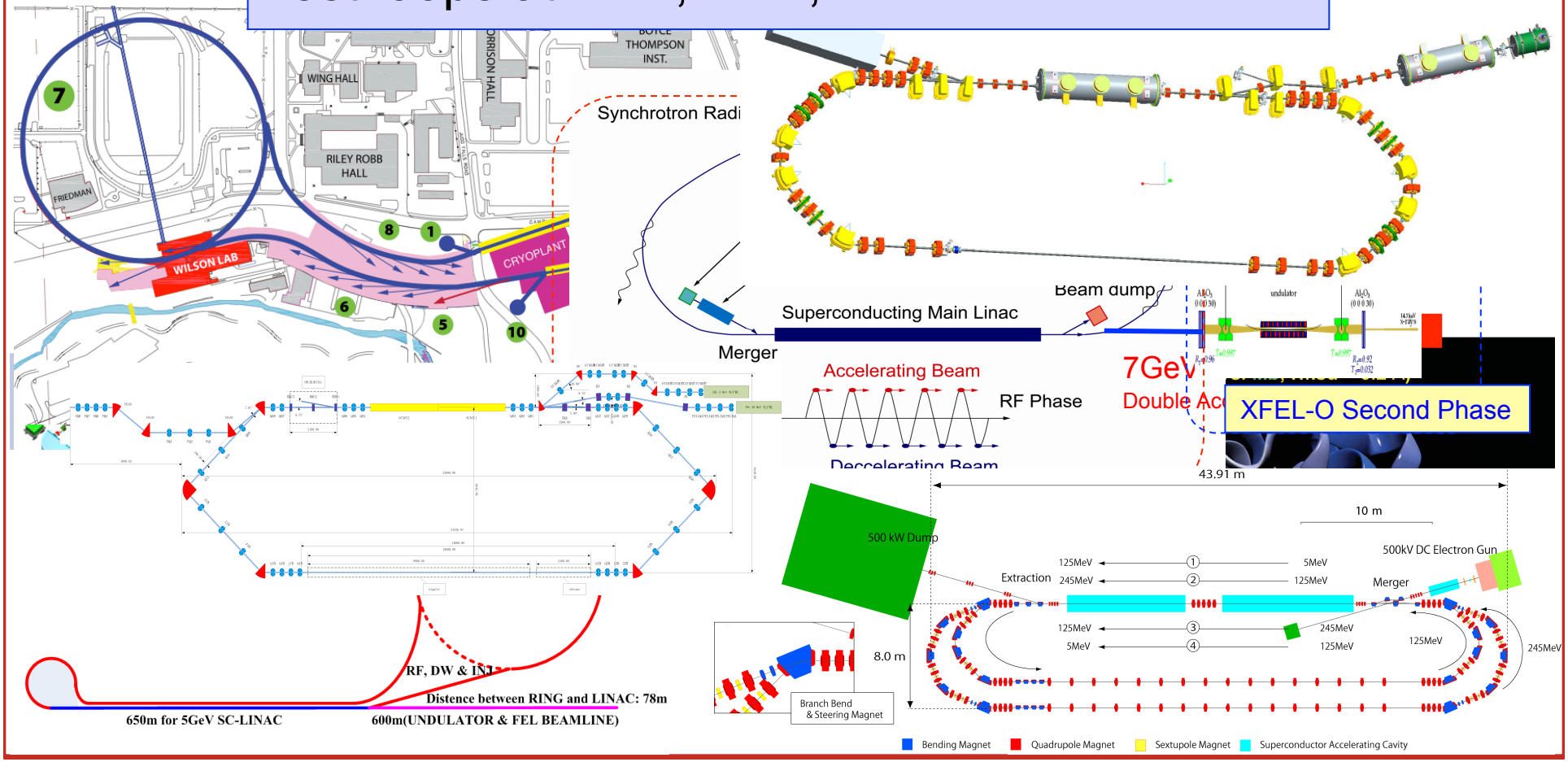
Interest in ERLs for Light Sources

Operations at JLAB, Daresbury, BINP
Designs at Cornell, KEK/JAEA, BAPS
Test loops at KEK, HZB



Interest in ERLs for Light Sources

Operations at JLAB, Daresbury, BINP
Designs at Cornell, KEK/JAEA, BAPS
Test loops at KEK, HZB, IHEP



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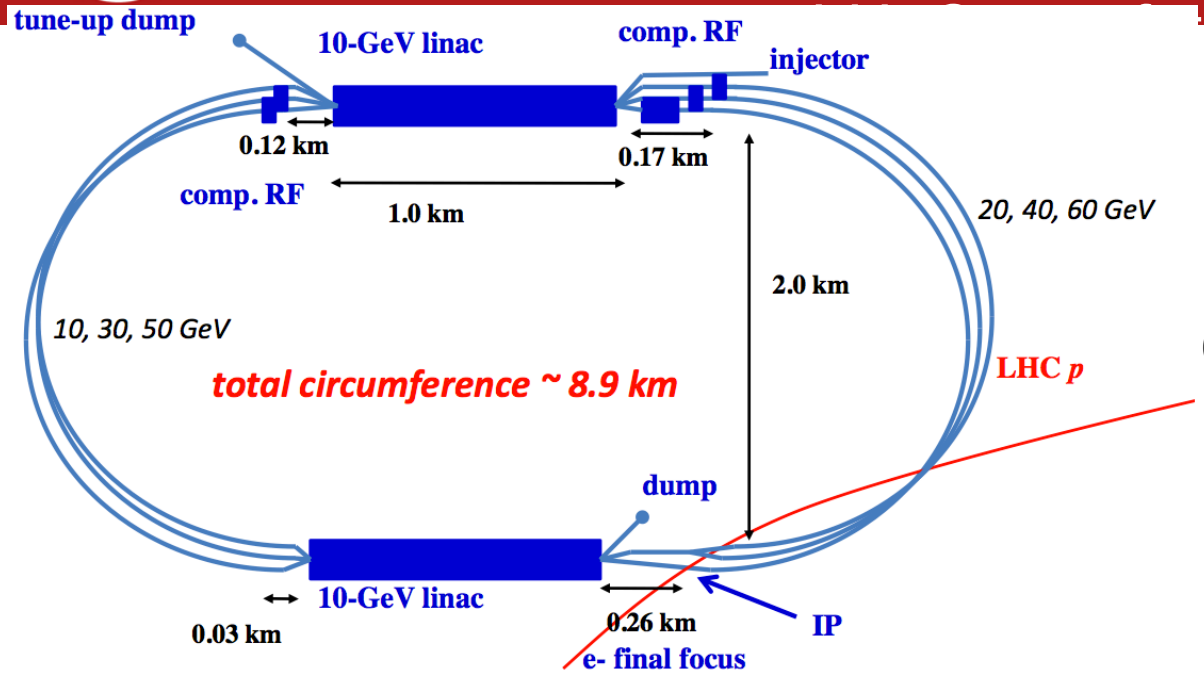
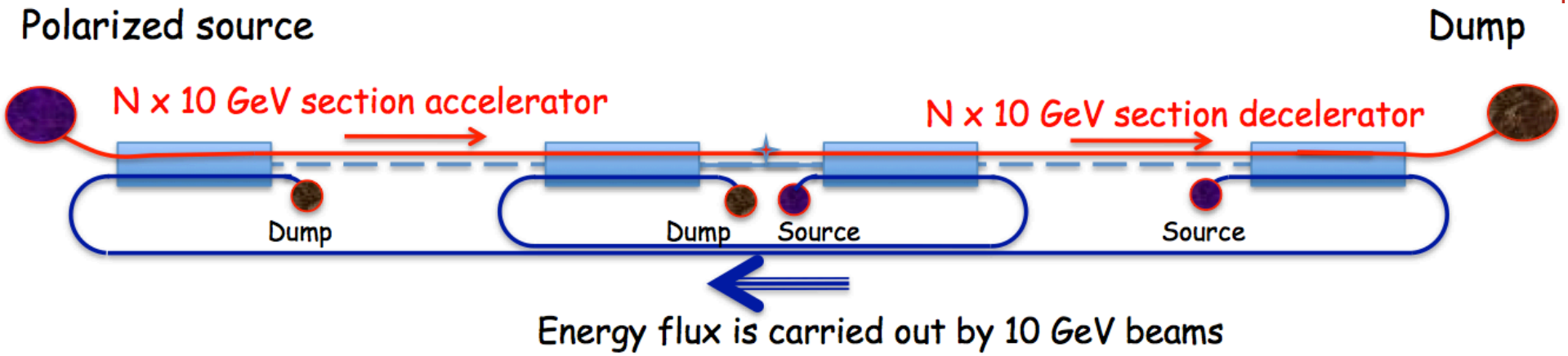
ERLs for High-Energy Physics

CLASSE

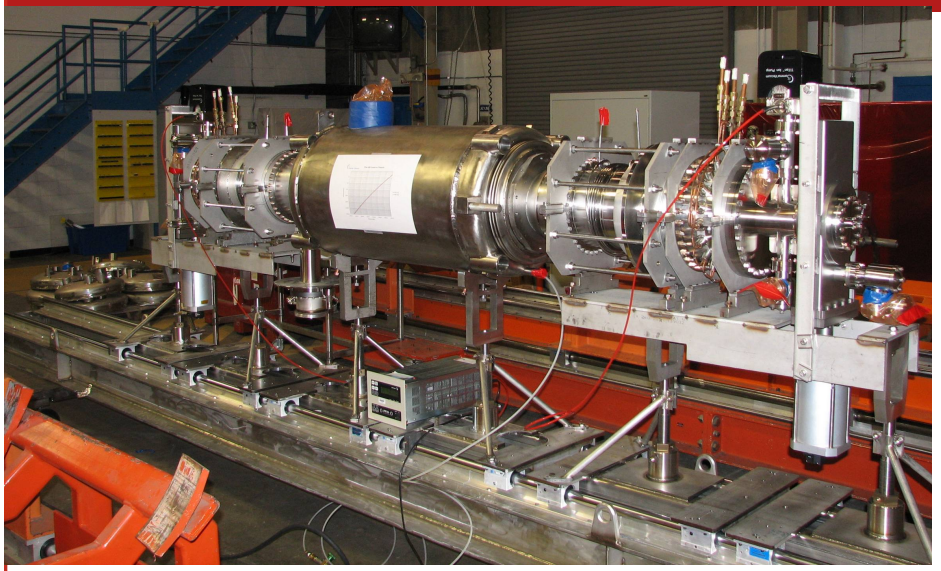


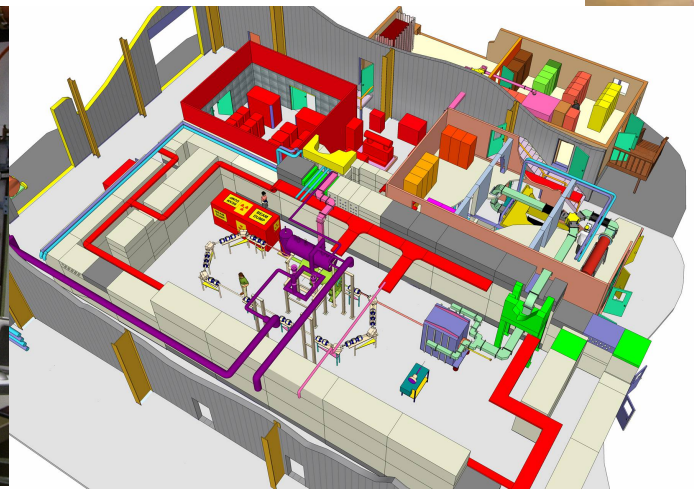
60GeV electrons on LHC protons



For 140GeV electrons on LHC protons

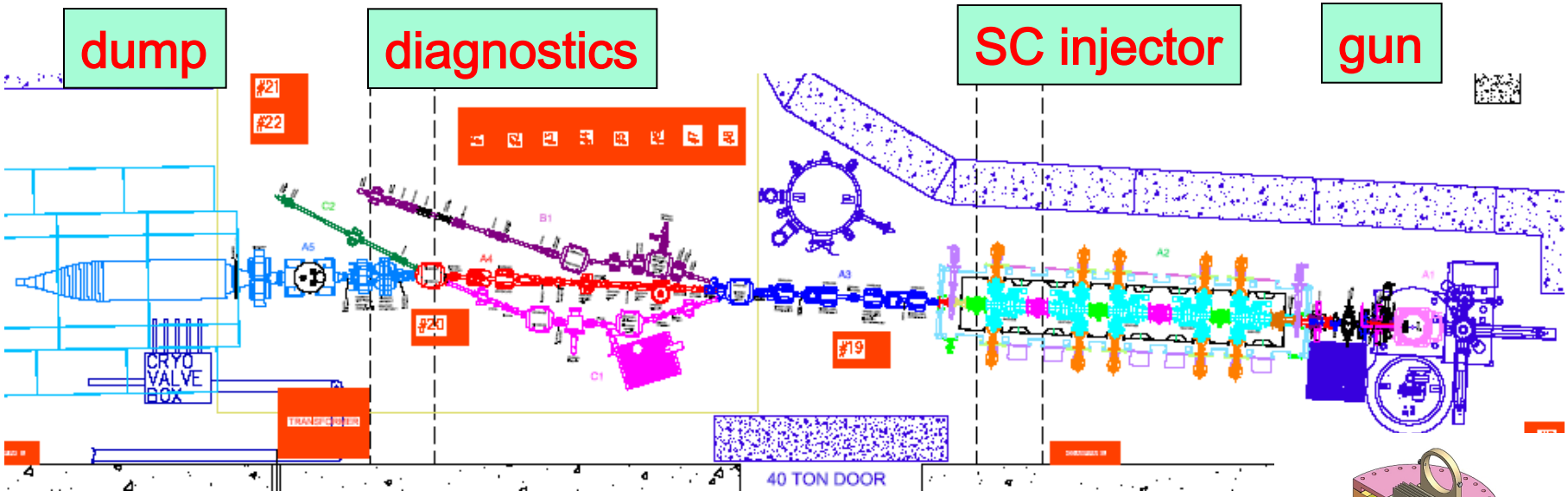
BNL test ERL for e-RHIC (and more)



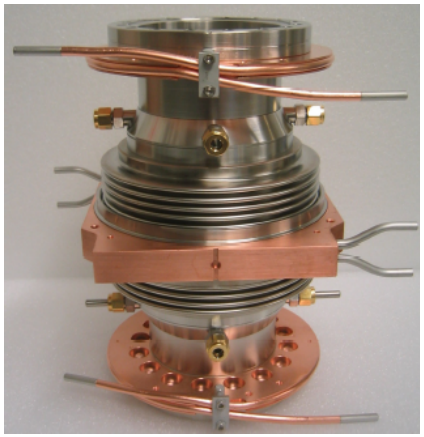


- 5 cell SRF cavity, 17 cm iris, 24 cm beampipe
- 703.75 MHz, 20 MV/m @ Q_o=1e^{10}
- Ferrite Dampers for HOMs at room temp.
- No trapped HOMs

Cornell Injector prototype: Verification of beam production

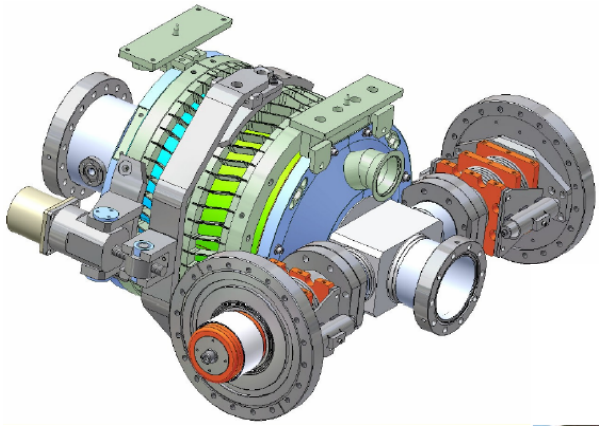


HOM absorb.

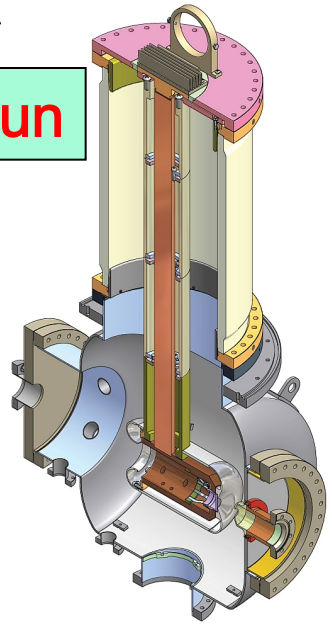


CW coupler

Dressed cavity

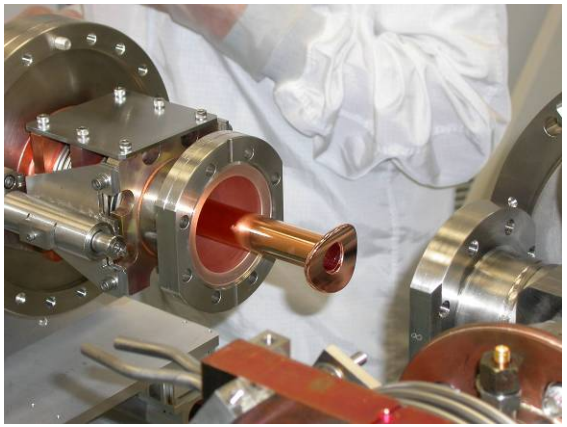


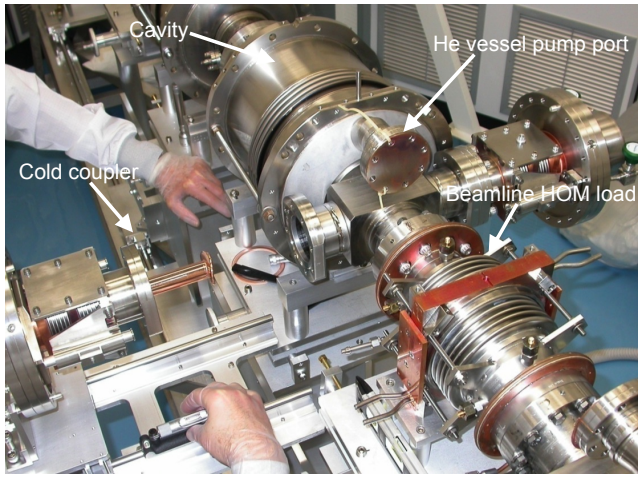
gun

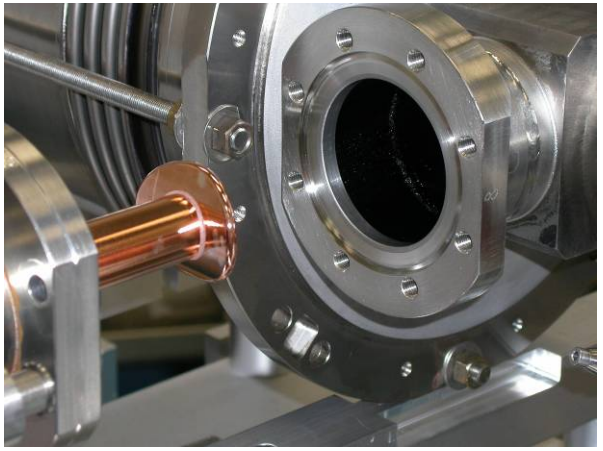


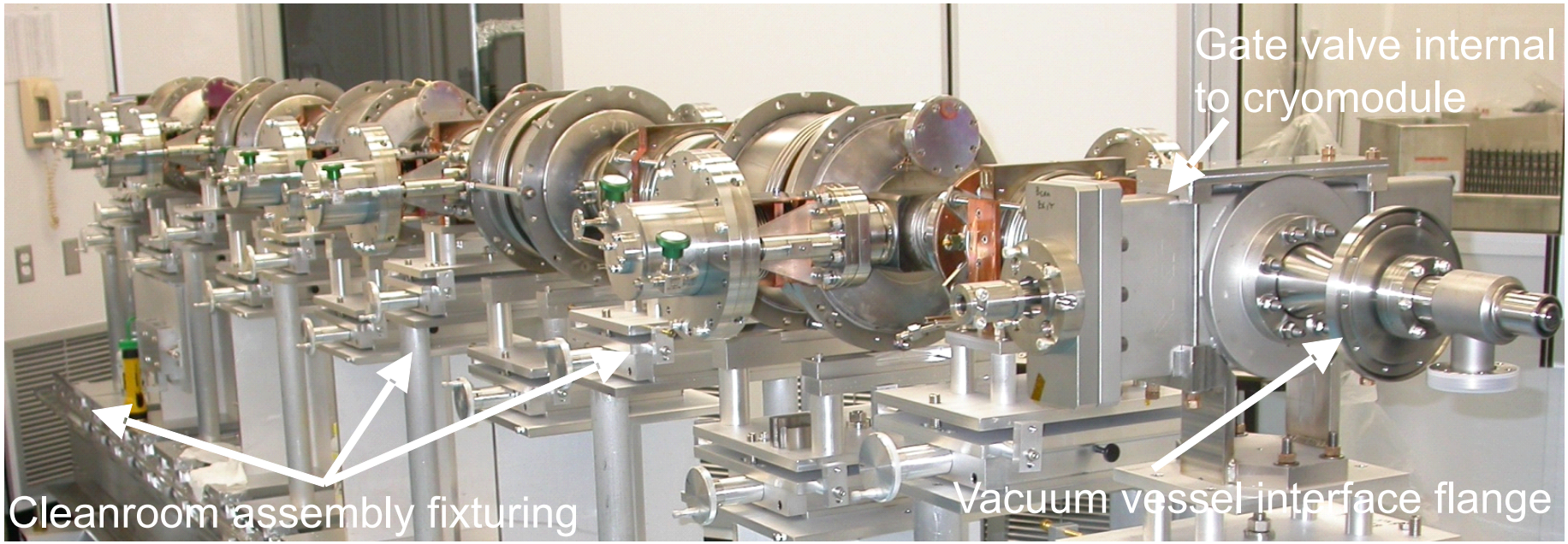
Beamline String Assembly

Attach cold couplers to beamline string

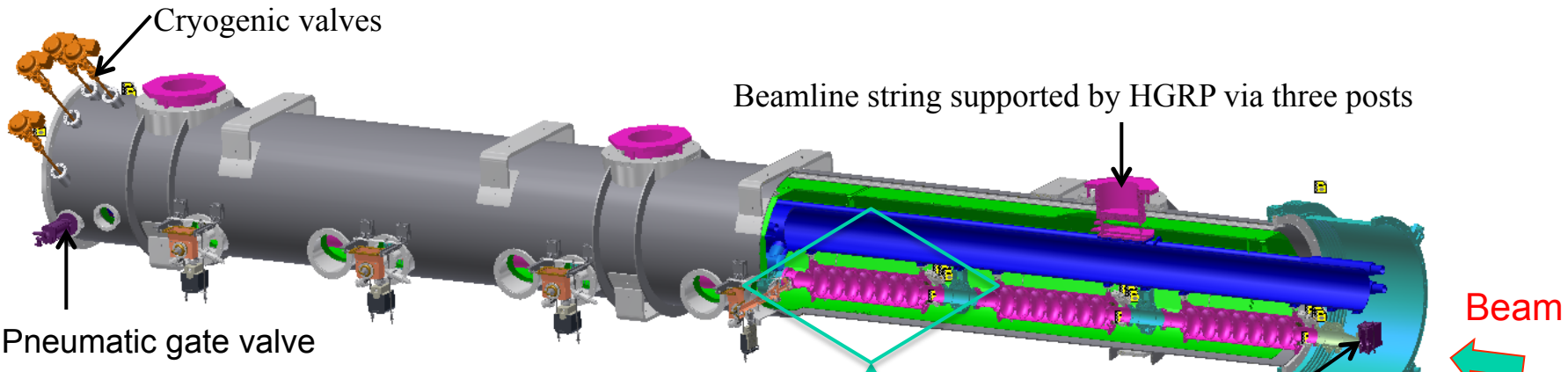






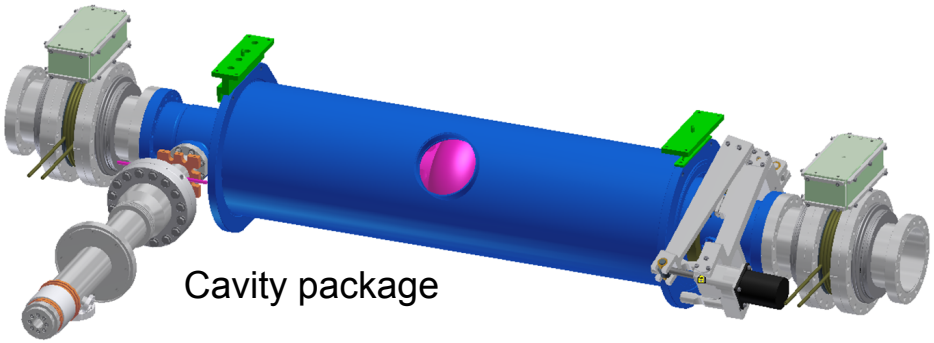


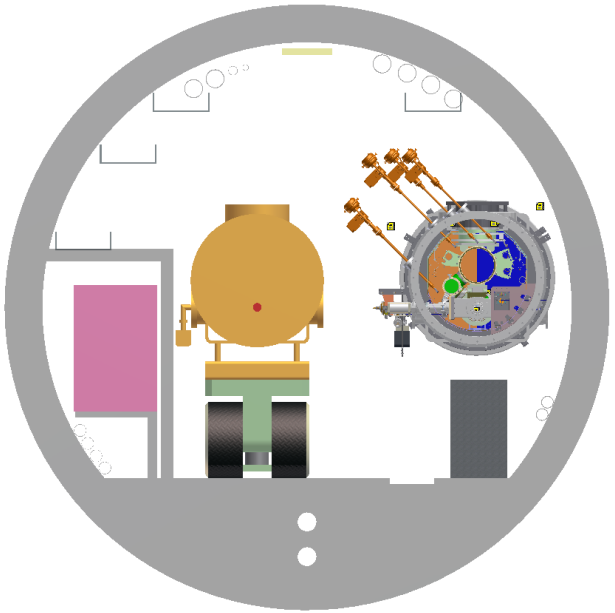
Test the of CW cryomodule Test was cut with funding cuts



A full ERL cryomodule is built for

- Realistic costing of this cost-driving item
- Dark current and radiation background in tunnel
- Study HOMs of the 6-cavity combination
- Study reproducibility of low-loss cavities
- Study microphonic vibrations that increase needed RF power
- Prepare industrialization of ERL linacs





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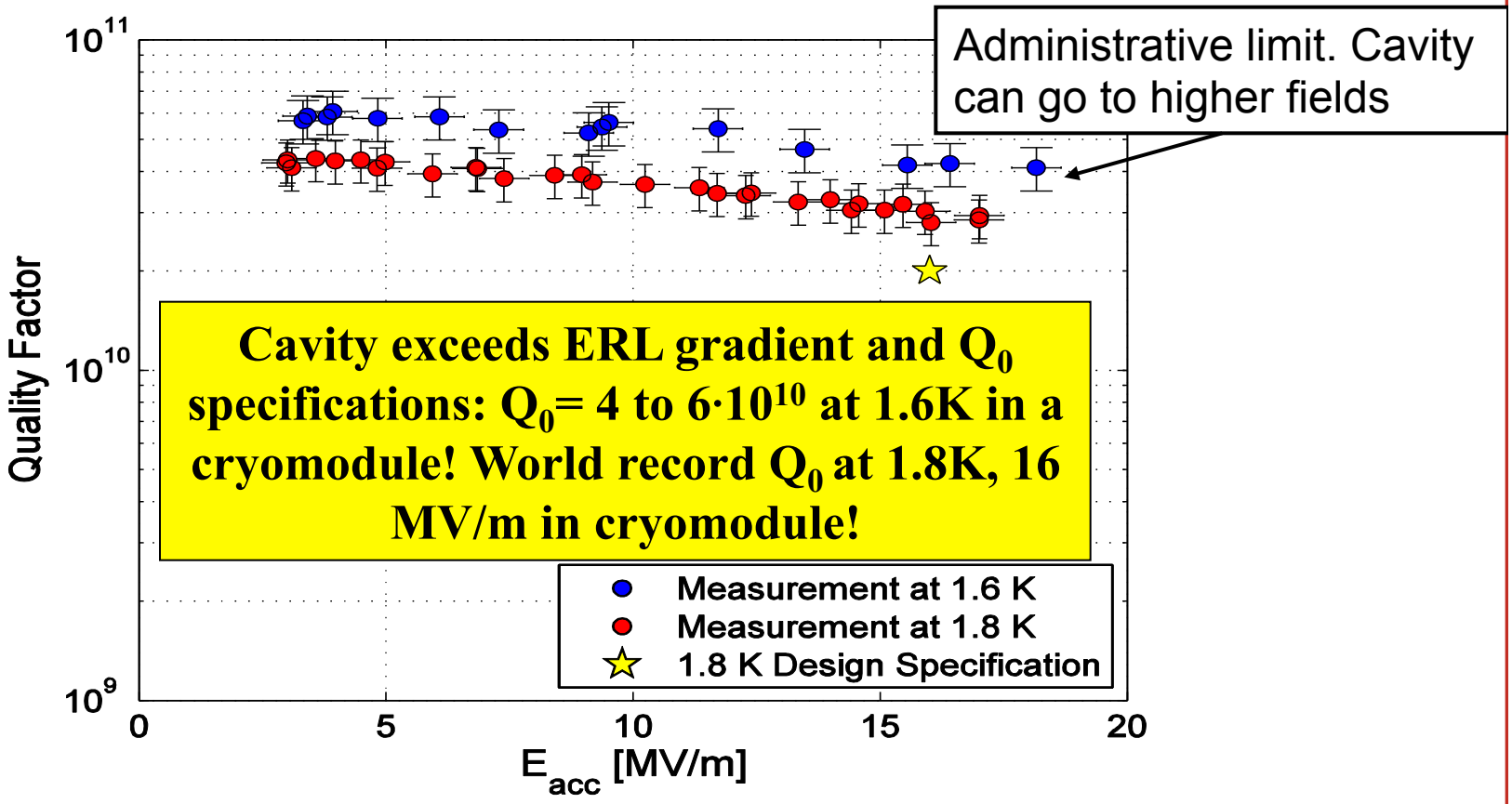
Low-loss SRF cavities for CW linacs: High Q0

CLASSE

Cavity surface was prepared for high Q_0 while keeping it as simple as possible: bulk BCP, 650C outgassing, final BCP, 120C bake



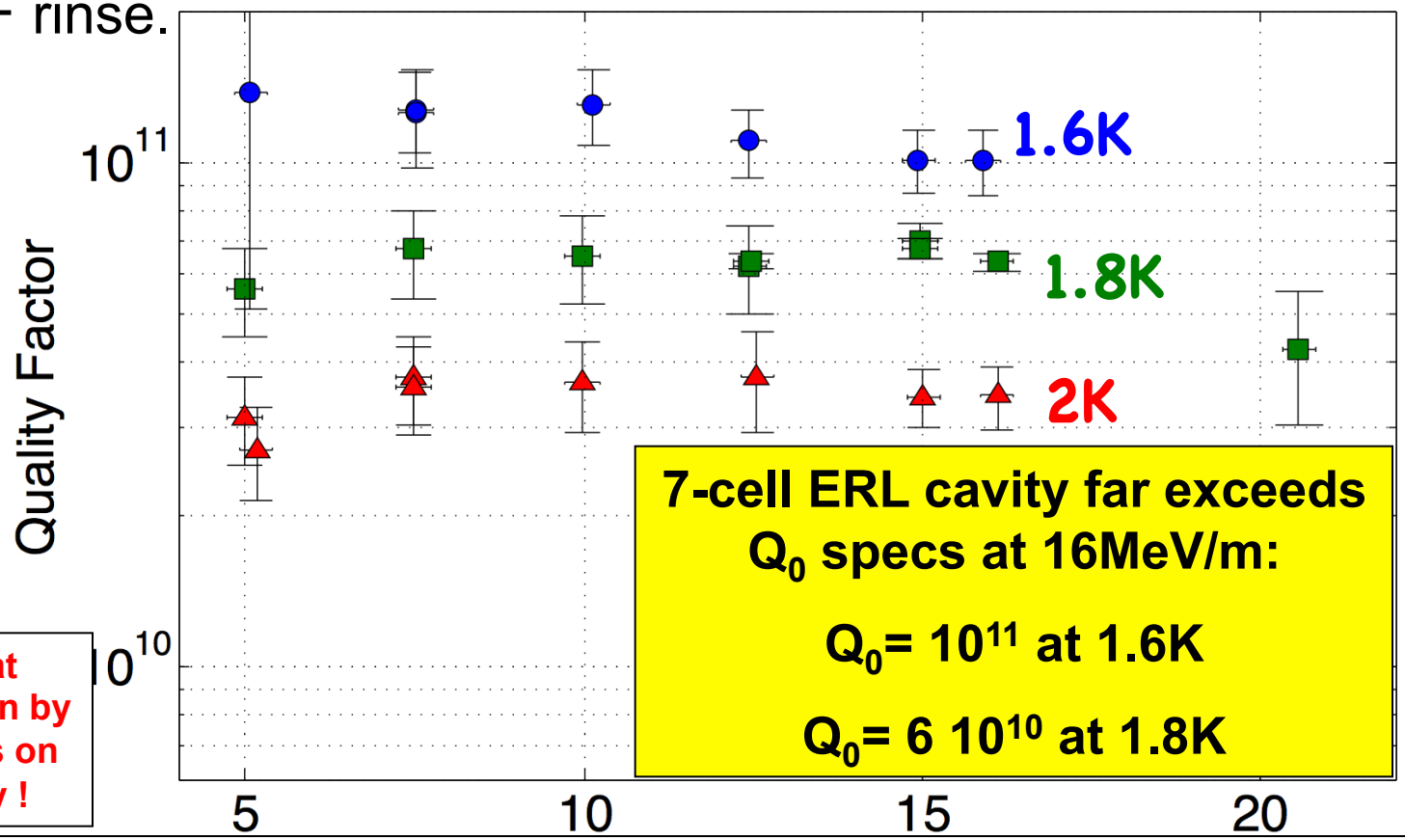
The achievement of high Q is relevant not only to Cornell's ERL but also to Project-X at Fermilab, to the Next Generation Light Source, to Electron-Ion colliders, spallation-neutron sources, and accelerator-driven nuclear reactors.

Cornell University

Low-loss SRF cavities for CW linacs: High Q0

CLASSE

Cavity surface was prepared for high Q_0 while keeping it as simple as possible: bulk BCP, 650C outgassing, final BCP, very uniform 120C bake, HF rinse.



7-cell ERL cavity far exceeds Q_0 specs at 16MeV/m:

$Q_0 = 10^{11}$ at 1.6K

$Q_0 = 6\ 10^{10}$ at 1.8K

Details at presentation by Nick Valles on Thursday !

The achievement of high Q is relevant not only to Cornell's ERL but also to Project-X at Fermilab, to the Next Generation Light Source, to Electron-Ion colliders, spallation-neutron sources, and accelerator-driven nuclear reactors.

ERL-readiness milestones

Many milestones, some world records, have been achieved:

Peak bunched-beam current:
75mA with NaKSb / 52mA with GaAs, 65mA stable for 8h, 1/e = 2.6 days.

Smallest normalized thermal emittance: 0.25 mm mrad/mm radius
Smallest normalized emittance after injector at 80pC: 0.5 / 0.3 mm mrad
with normalized bunch core emittance **: 0.3 mm mrad**

This bunch in a 5GeV ERL would produce X-rays brighter than any ring today.
(a 25pmX25pm ERL/USR or a 0.3nmX3pm storage ring, 20 * Petra III)

SRF-cavity: Q of 3.E10 at 16MV/m

Construction of a prototype ERL cryomodule and an improved DC electron source are ongoing.

The injector prototype has already achieved beam sufficient for an ultra-bright x-ray ERL. And further improvements are yet possible.
Now is the time to prepare for construction of an X-ray ERL !

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ERL R&D at Cornell

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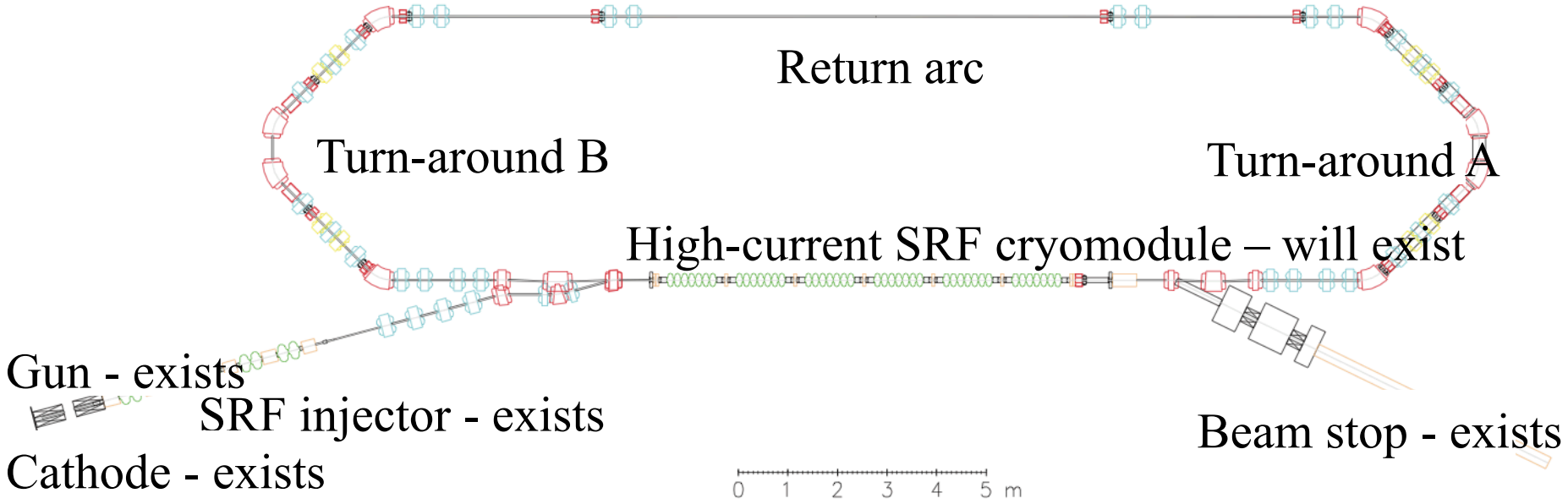

Many R&D challenges have been addressed. Foremost:

- **Can an injector be made to deliver required emittance?**
- **Can the injector operate with acceptable current and lifetime?**
- **Can the main linac operate with acceptable Q_0 and HOM performance at 100 mA?**
- **Can this all be done faster & cheaper than USR alternatives?**

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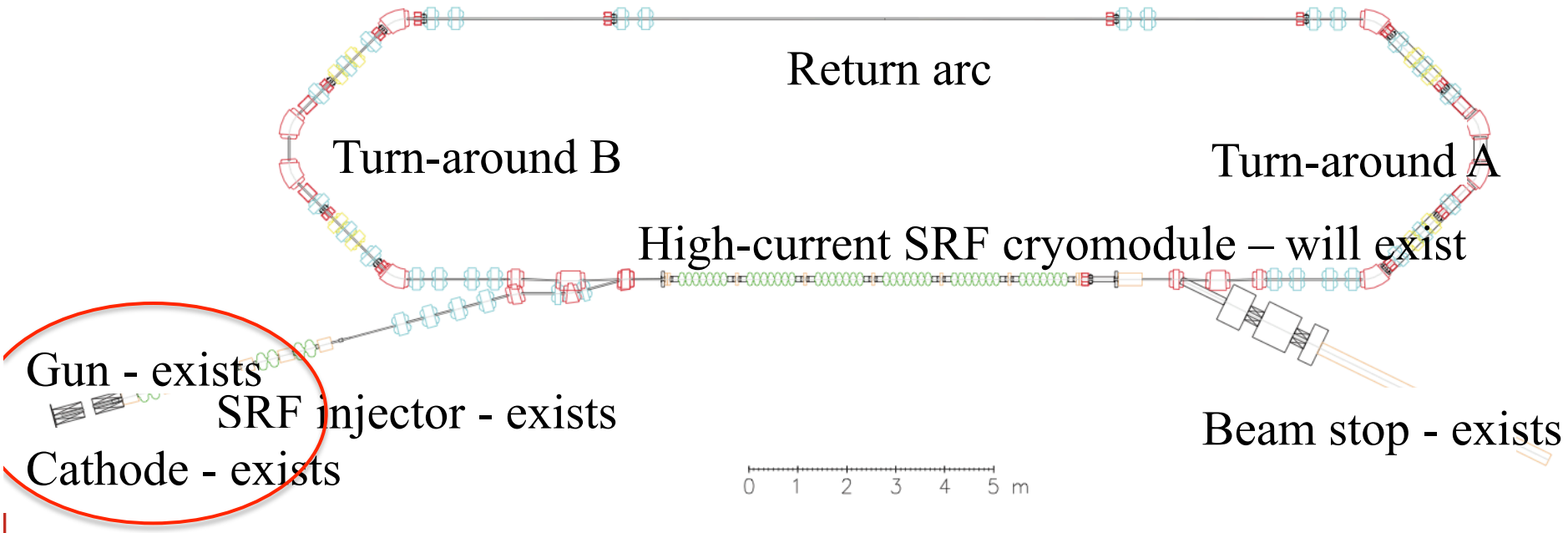
ERL R&D at Cornell

CLASSE



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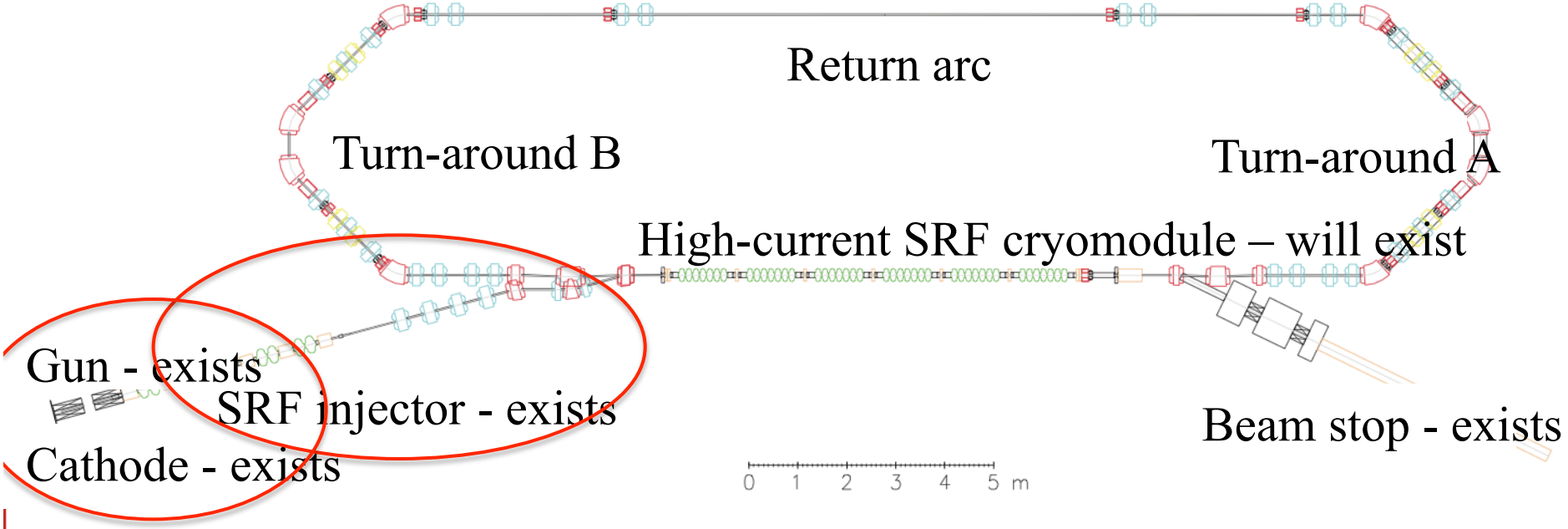
ERL R&D at Cornell



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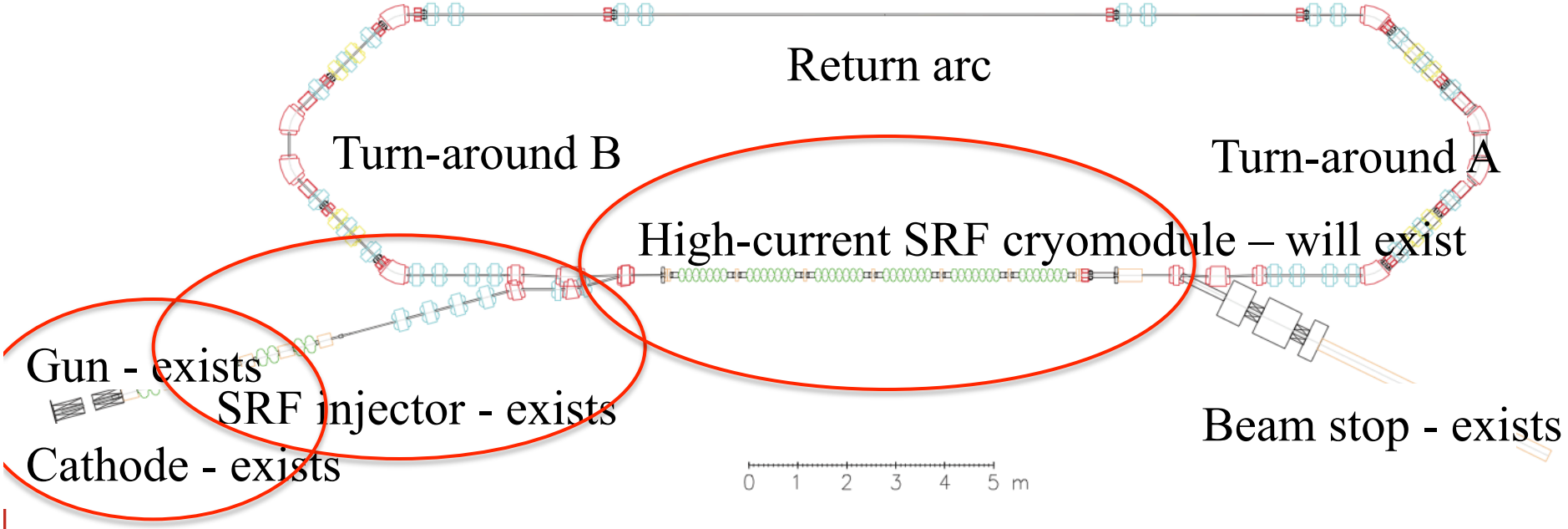

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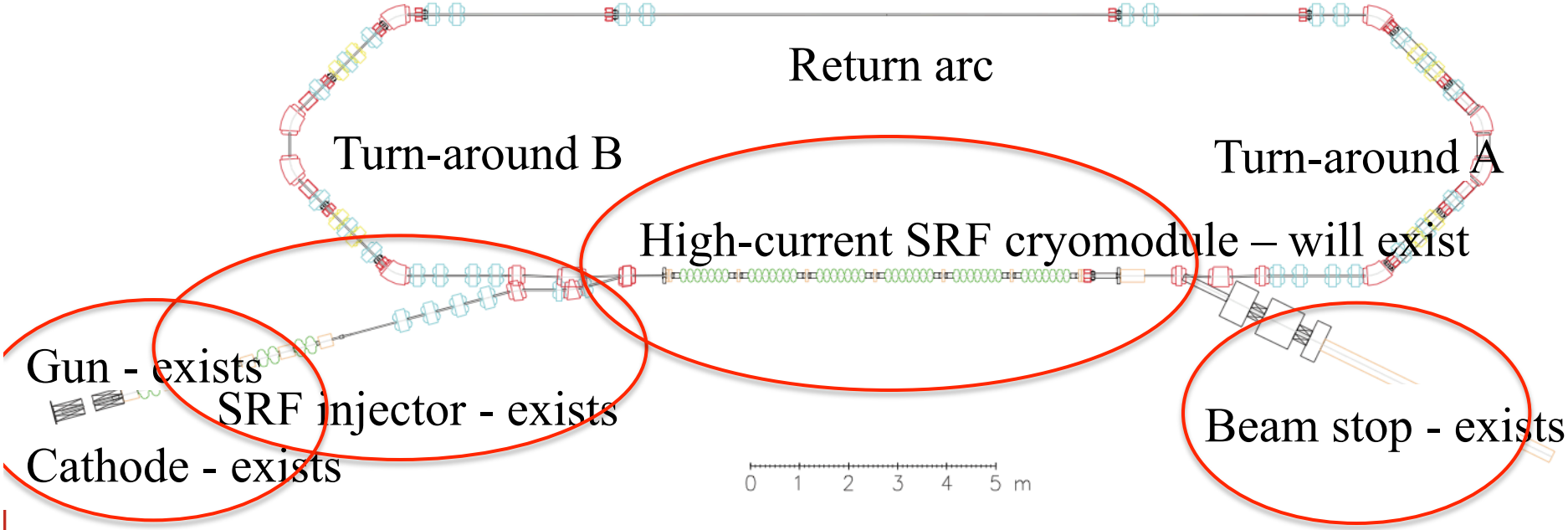
ERL R&D at Cornell for all that's needed for an ERL

CLASSE



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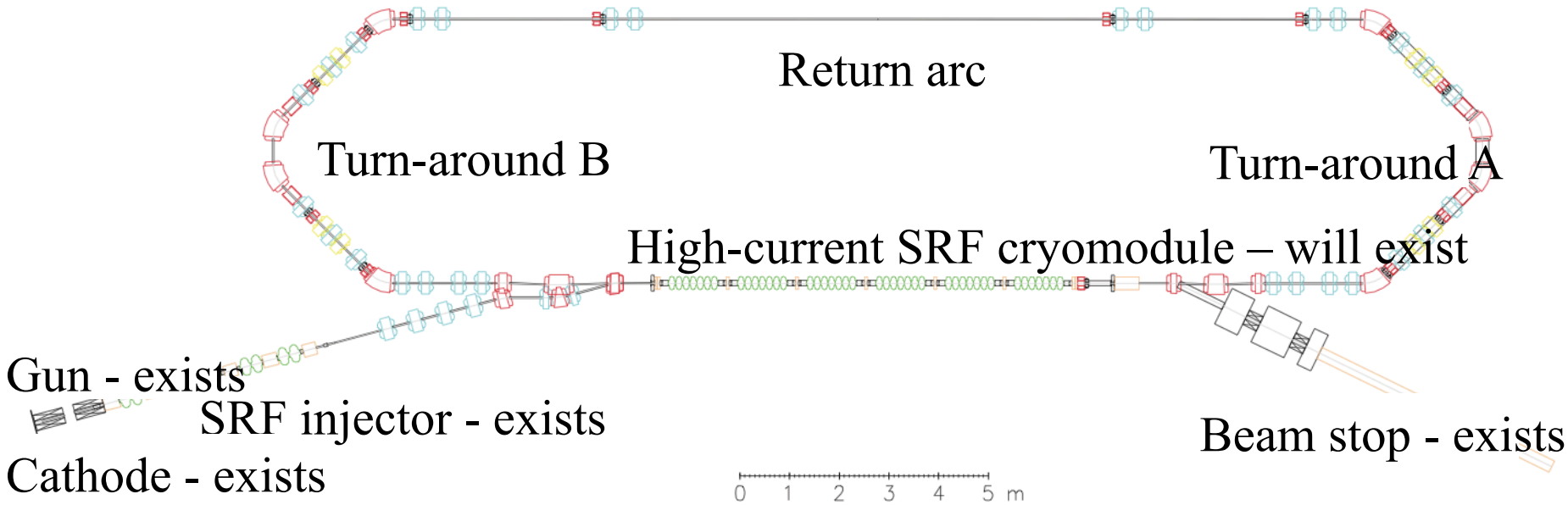
Loop-enabled measurements for high-power/brightness beams



- Beam dynamics measurements, e.g. halo, collimation, beam-instability thresholds, using the ERL principle to allow for large currents …
- Optimized high-current, narrow beam SRF injector
- Ultra-low emittance research, below what has been proposed in the past with advanced cathodes
- Smallest bunch charges usable for FELs
- Disruption of ions in high-power Linacs
- Yielding relevant information for: electron cooling in RHIC, LeHC, and EIC, Linac light sources (e.g. XFELs, XFELO, NGLS), Project X (1MW), SNS (1MW), ESS (5MW), Accelerator Driven Systems (e.g. 15MW SRF beam in China).

Start of TTC topical meeting on CW SRF