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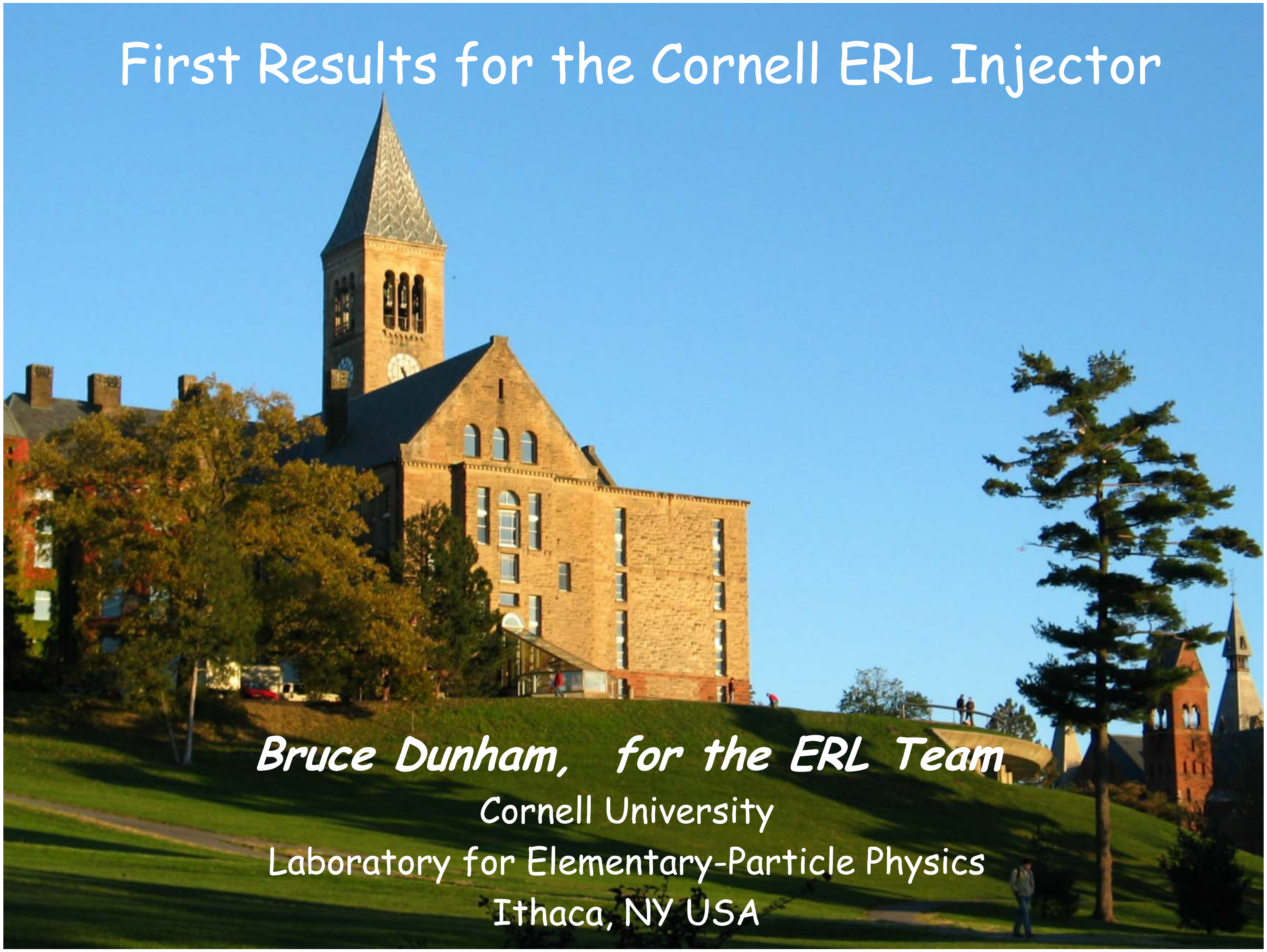

First Results for the Cornell ERL Injector

Bruce Dunham, for the ERL Team

Cornell University

Laboratory for Elementary-Particle Physics

Ithaca, NY USA

Cornell University

ERL Team

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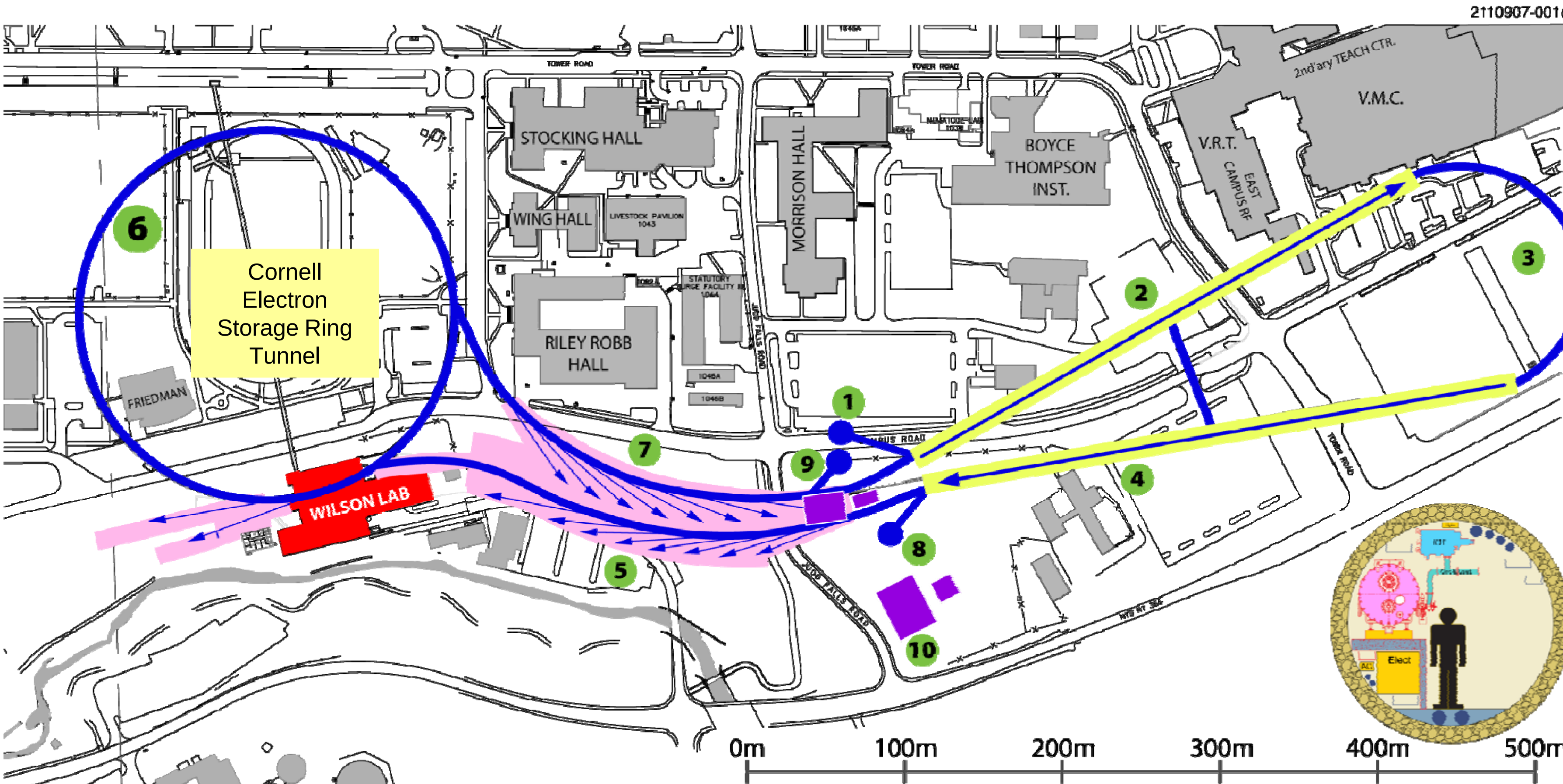
- T. Wilksen

Outline

- **An ERL at Cornell**
- **The ERL Injector Prototype Project**
  - Overview
  - DC Photoemission Gun/Laser
  - Superconducting RF
  - Beam Diagnostics
- Results and Prospects

ERL at Cornell



1. Injector
2. Linac 1
3. 2.5 GeV turnaround
4. Linac 2
5. X-ray beam-lines
6. 5 GeV turnaround
7. X-ray beam-lines
8. Beam dump

Goals of the Cornell ERL Project

- Phase I: Build, test injector, LINAC modules; resolve machine issues. Engineering studies for Phase II (in process; $30M NSF & NY State)
- Phase II: Build a high energy (5 GeV) ERL x-ray facility at Cornell as an upgrade to CESR. (5 year construction, no funding yet)

ERL Injector Prototype

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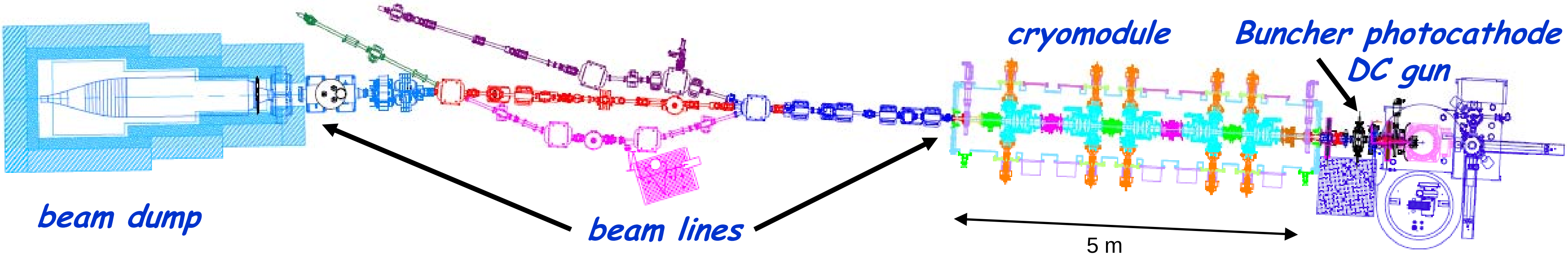

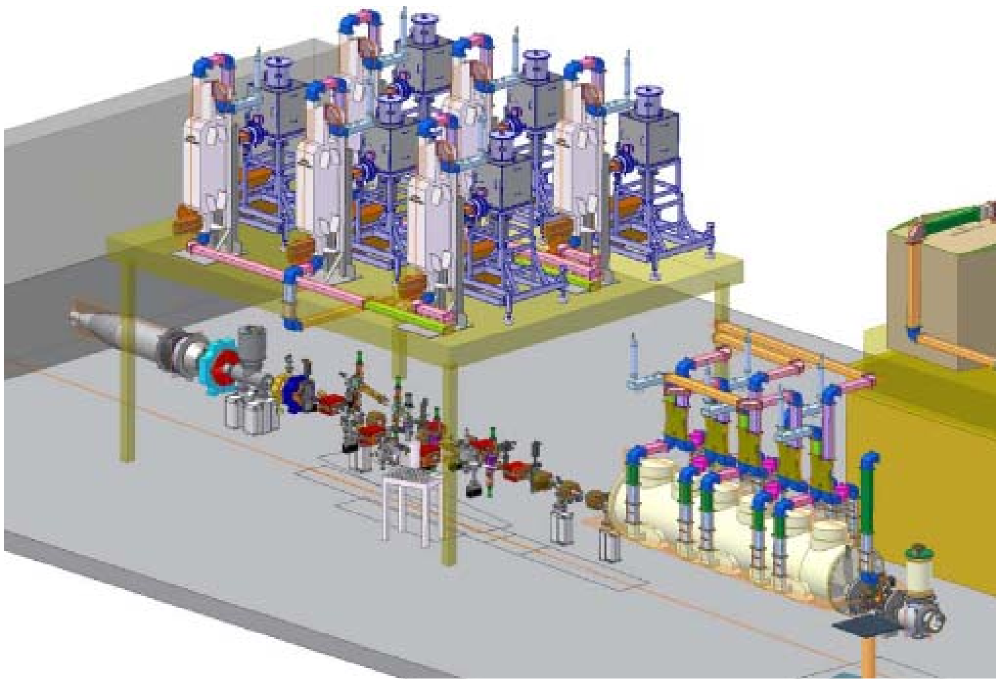

Parameters:

100 mA avg current (5 MeV)

33 mA avg current (15 MeV)

77 pC / bunch at 1.3 GHz

< 2 μm emittance

< 2-3 ps bunch length

Demonstrate:

Cathode longevity

Low emittance

RF controls

Parameter sensitivity

reliability

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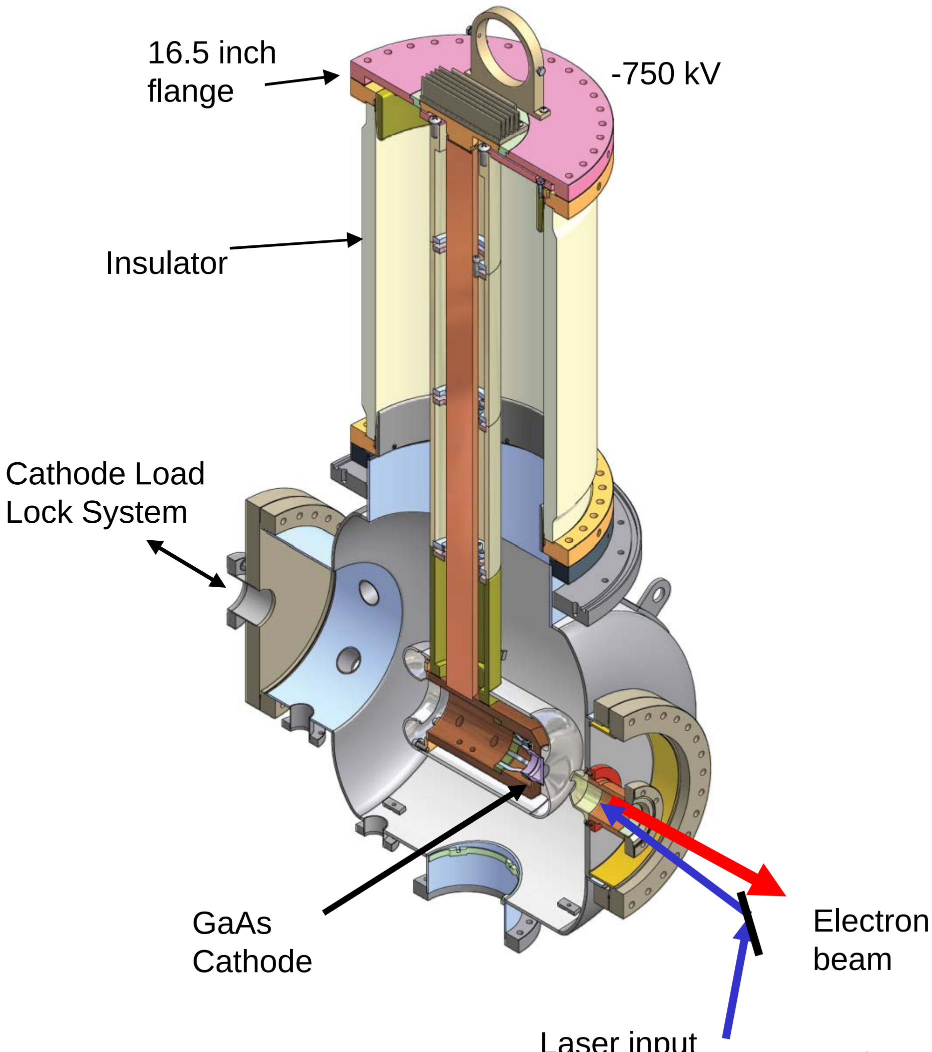
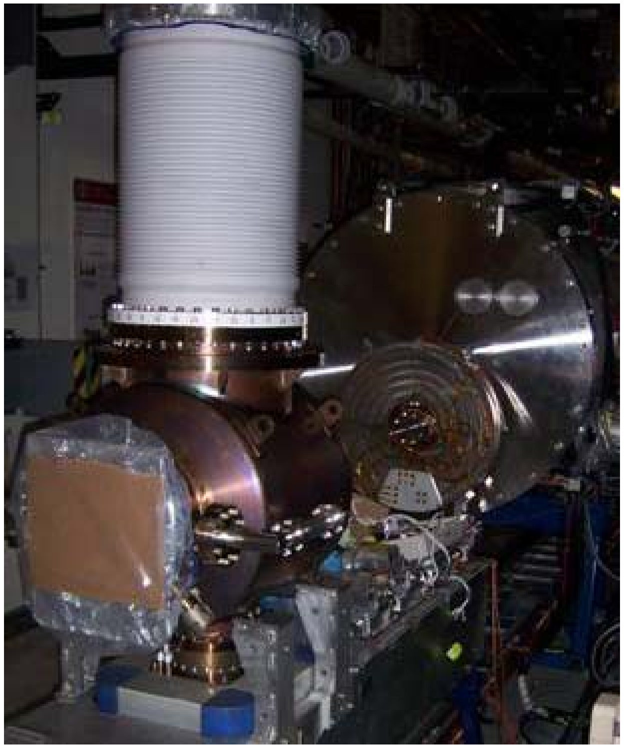
The Photoemission DC Electron Gun

Oct 1, 2008 B. Dunham

Cornell University

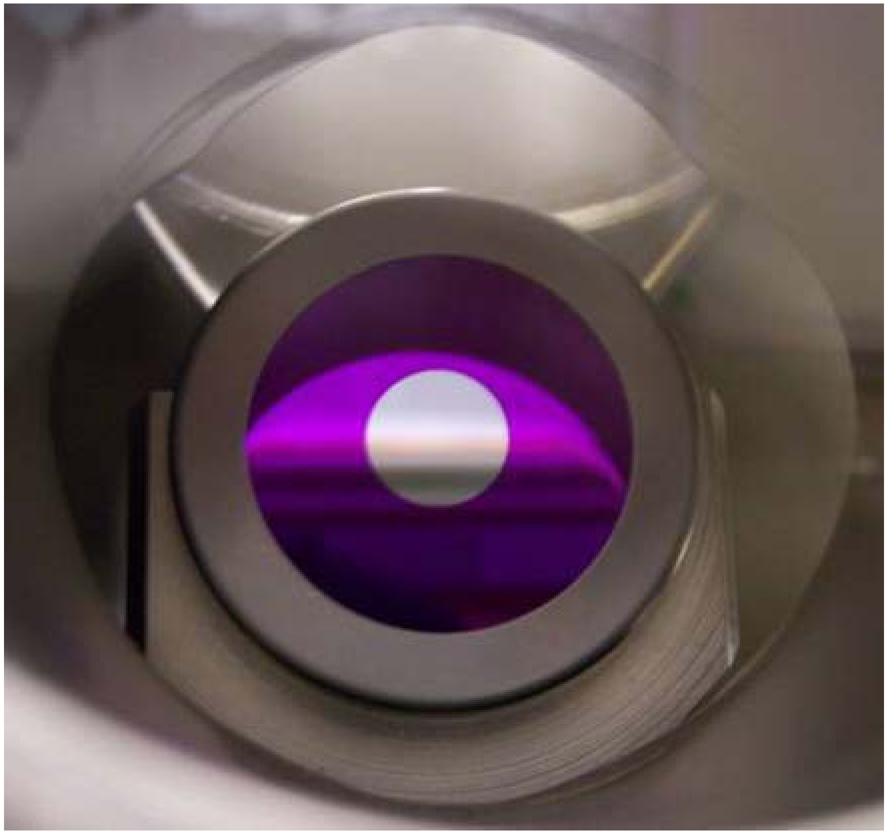
DC Photocathode Gun Design





Basic design has been used in GaAs polarized electron sources for decades (@ 100 kV).

Photoemission from GaAs



GaAs is still our cathode of choice . . .

- good quantum efficiency (QE)

- low thermal emittance (cold)

- fast time response (@520 nm)

But . . .

- need extreme UHV (< $1x10^{-11}$ Torr)

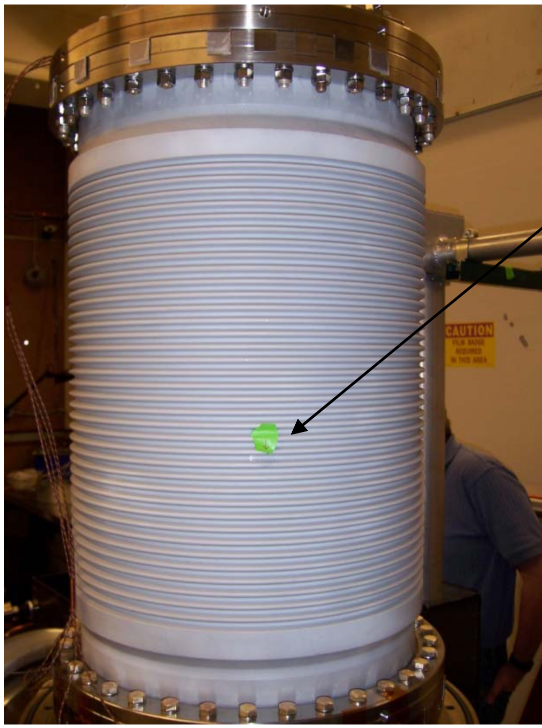
- limited lifetime

- minimum thermal emittance near bandgap (where the QE is lowest)

- thermal emittance degrades at higher QE

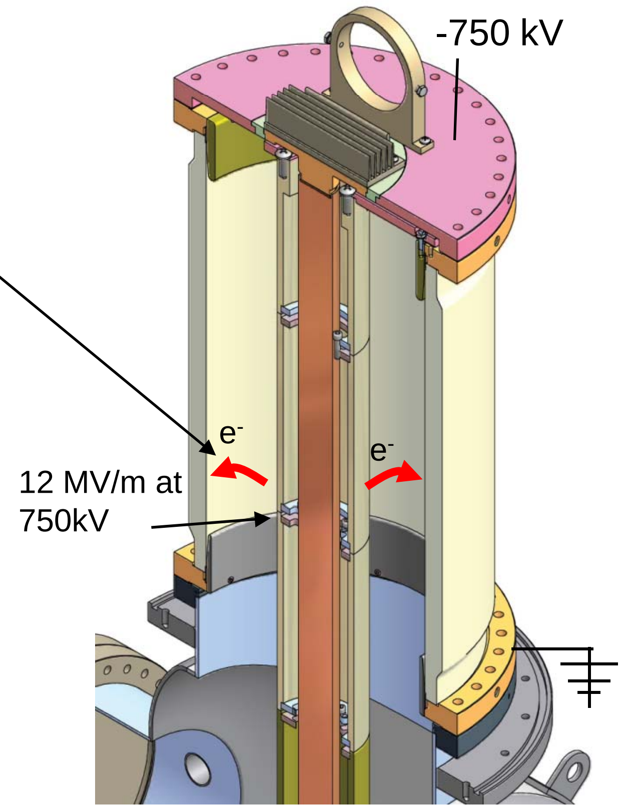
. . . We are willing to try other cathodes

Insulator Design



Manufactured by CPI, Beverly, MA

- Large size to keep field gradients low
- Field emitted electrons can build up on the insulator and punch thru
- External SF_6
- High mechanical stresses due to SF_6 pressure and bakeouts
- Difficult to find suppliers
- Braze difficulties due to large size



Maximum voltage so far 440kV. Operating at 250-300 kV now until a spare is obtained

750 kV HV power supply

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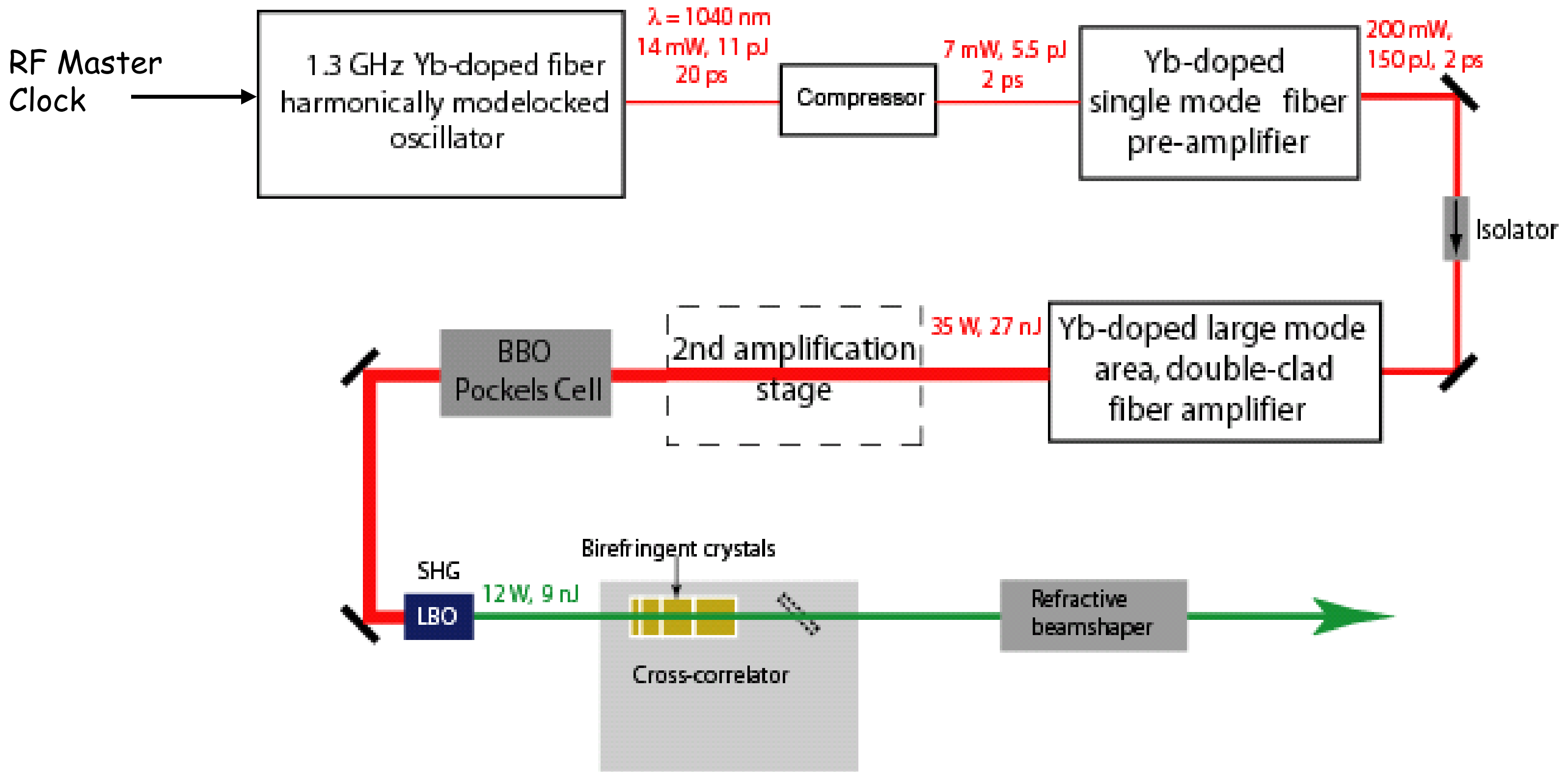
750 kV, 100 mA supply

Kaiser Systems, Beverly, MA

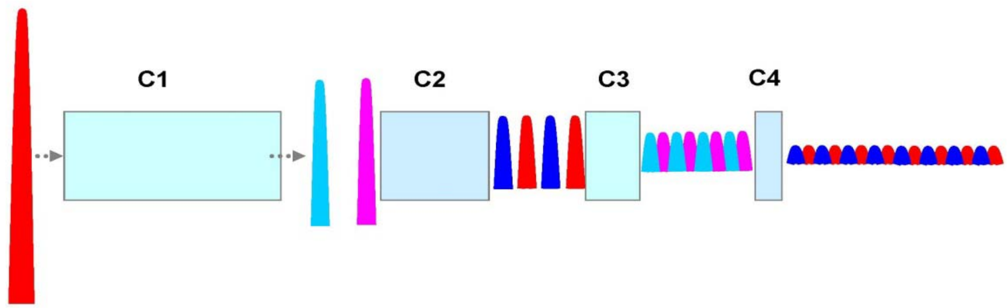
Custom floating ammeter to measure field emission current during processing

Fiber Laser Description

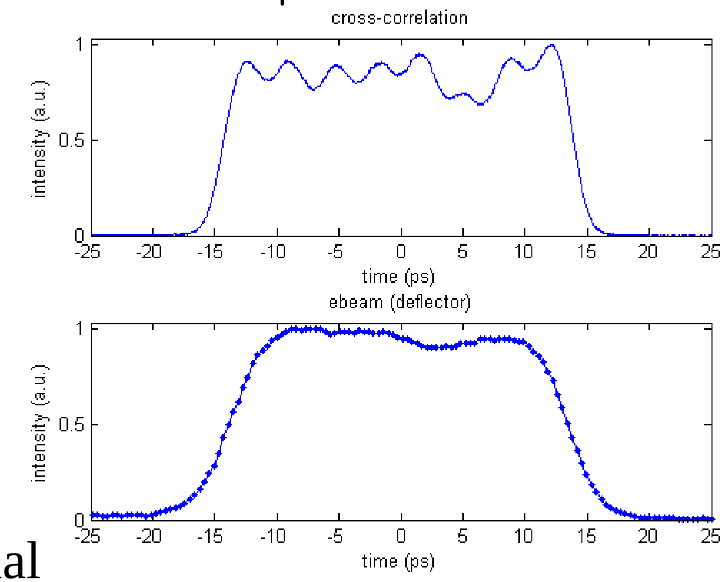


For a 10% QE cathode, one needs ~2 Watts to reach 100 mA

Laser Shaping – Beer Can Distribution



Measured longitudinal laser profile

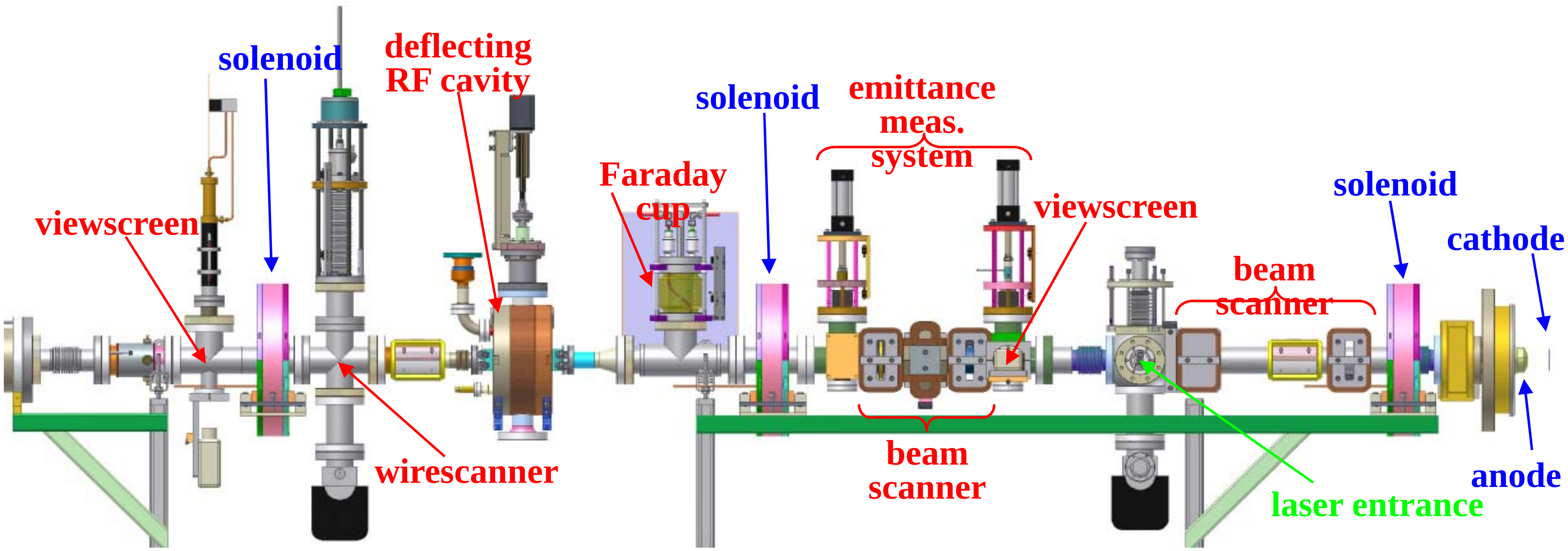


Measured longitudinal electron beam profile

We use an ‘optical pulse-stretcher’ to get 20-40 p flat-top pulses from a 2 ps laser (DPA – divided pulse amplifier)

Gauss to flat top transformation using a commercial aspheric lens (Newport Corp)

Beamline for characterizing the phase space from the gun



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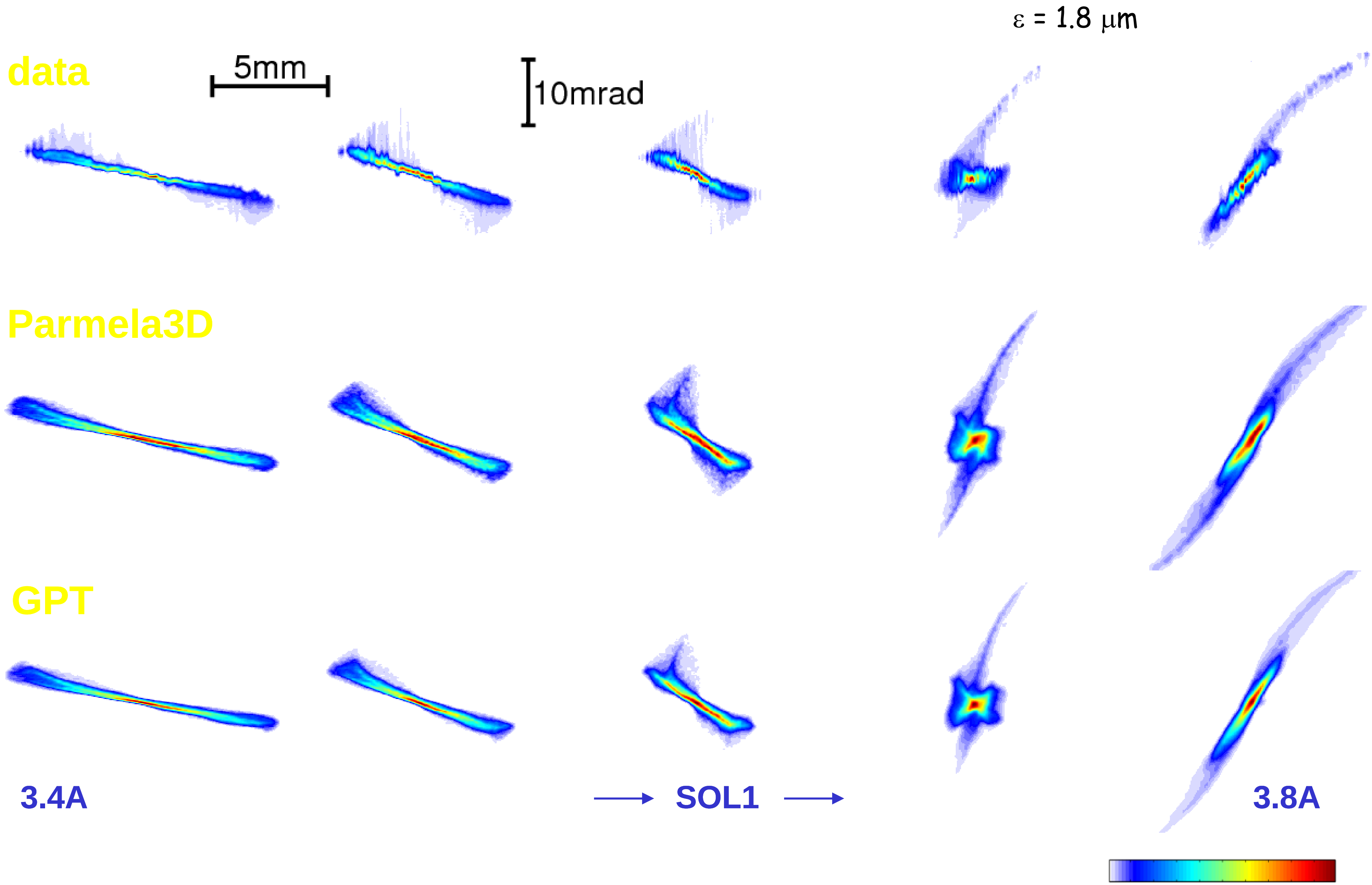
Emittance data at 250kV, 80 pC



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The RF and Superconducting RF Systems

Oct 1, 2008

B. Dunham

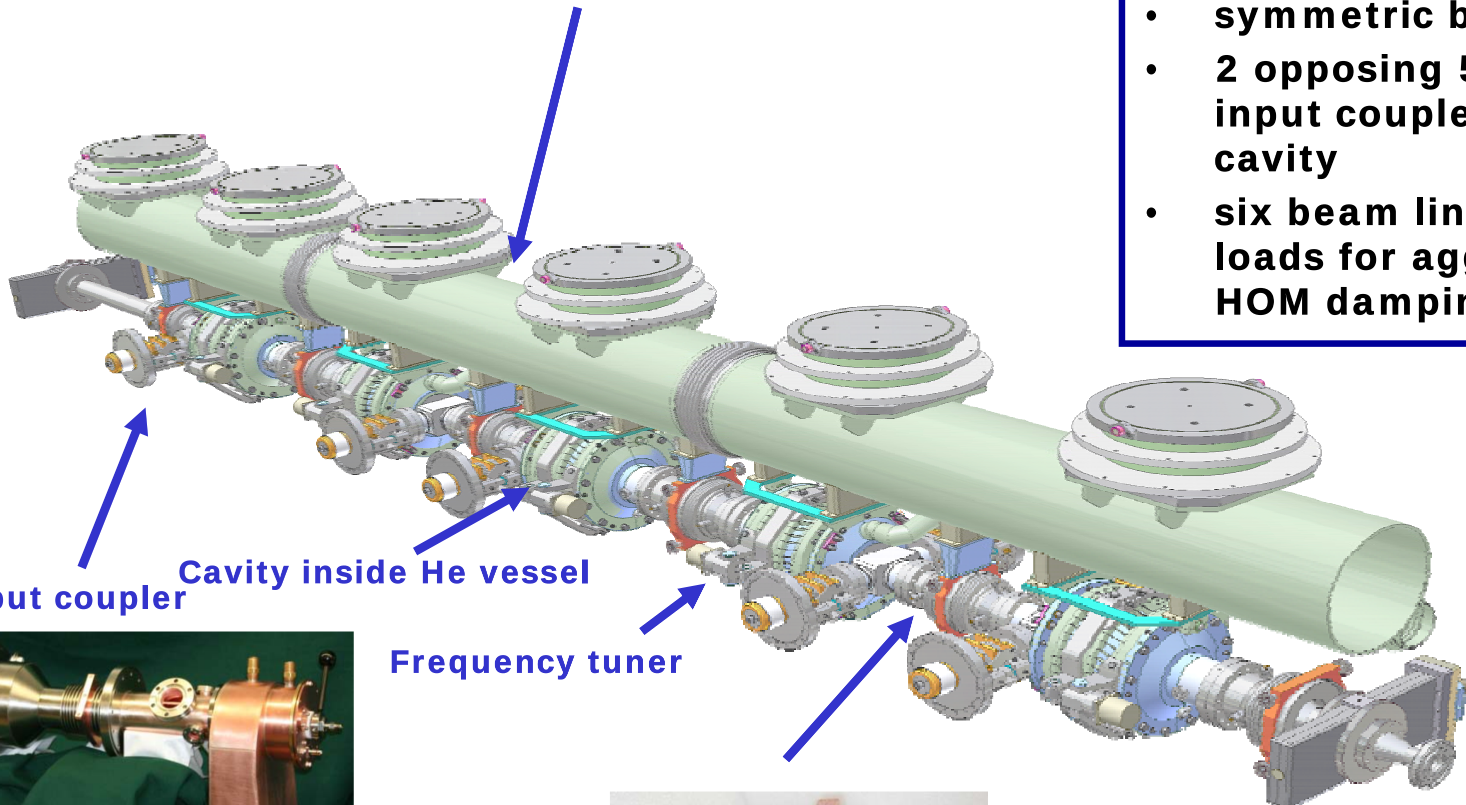
RF and SRF - Major challenges

- **High RF power transfer to beam for acceleration of high current beam ⇒ input coupler challenge: 1 MeV per cavity * 0.1 A = 100 kW**
- **High beam loading needs to be compensated very accurately for injectors ⇒ RF control challenge.**
- **Emittance preservation ⇔ reduce beam-cavity interaction effects, small transverse kick fields, high RF field stability.**
- **Strong damping of HOMs (monopole, dipole and quadrupole) is essential for emittance preservation and to reduce monopole HOM power.**
- **CW cavity operation at higher fields ⇒ cryogenic power ⇒ cryostat design challenge.**

ERL injector cryomodule

- five 2-cell cavities
- symmetric beam line
- 2 opposing 50 kW input couplers per cavity
- six beam line HOM loads for aggressive HOM damping

2K He gas return pipe

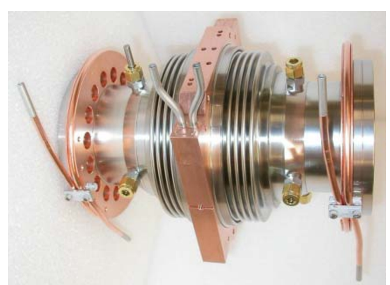


RF input coupler

Cavity inside He vessel

Frequency tuner

Manufactured by CPI,
Beverly, MA



HOM absorber

Manufactured by Cornell,
Accel

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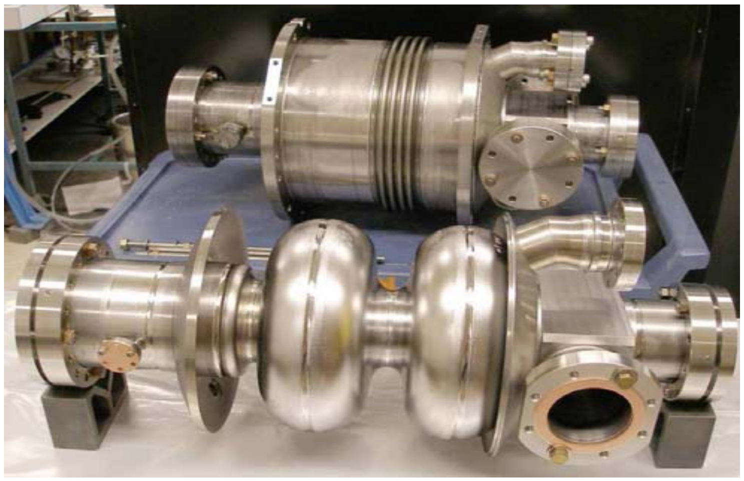
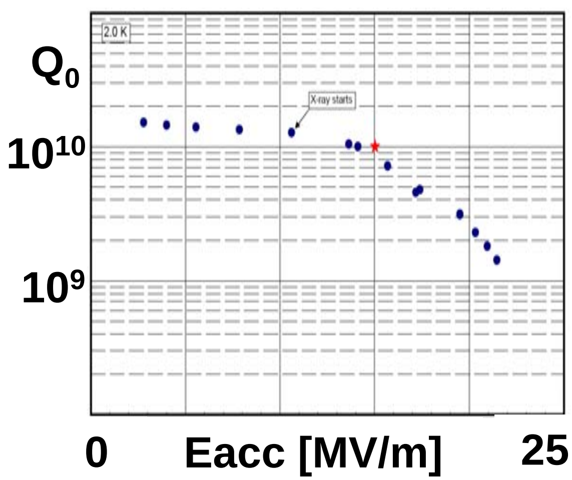
Injector cavity parameters





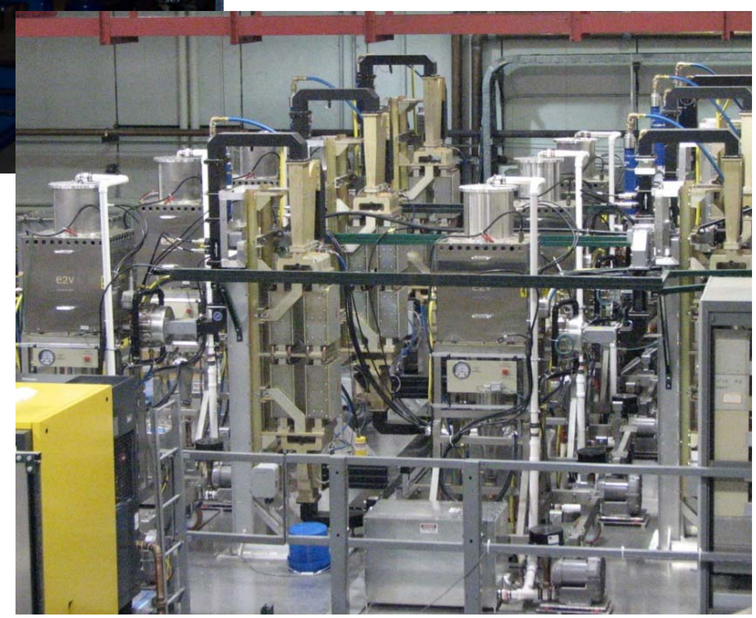
Vertical test data

cavity frequency	1300 MHz
cells per cavity	2
R/Q per cavity	222 Ω
acc. voltage per cavity	1 to 3 MV
acc. gradient	4.6 to 13.8 MV/m
Q_0	$> 1 \cdot 10^{10}$
Q_{ext}	$> 4.6 \cdot 10^4$ to $4.1 \cdot 10^5$
active cavity length	0.218 m
total cavity length	0.536 m

SRF and RF installation

Cryomodule installed at the ERL injector

Klystron gallery



Cavity string before installation into cryomodule

Cavity Performance

Cavity	CW	Limit	Pulsed	Limit
1	2.8 MV	Cryogenics	4.35 MV	IC
2	2.9 MV	IC	3.75 MV	IC
3	3.5 MV	Cryogenics	3.66 MV	IC
4	3.4 MV	Cryogenics	4.15 MV	Quench
5	3.5 MV	none	5.20 MV	IC
All 5	2.4 MV/12 MV total	Cryogenics		

IC – input coupler vacuum

Beam Diagnostics and Beam Dump

Oct 1, 2008

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Diagnostics

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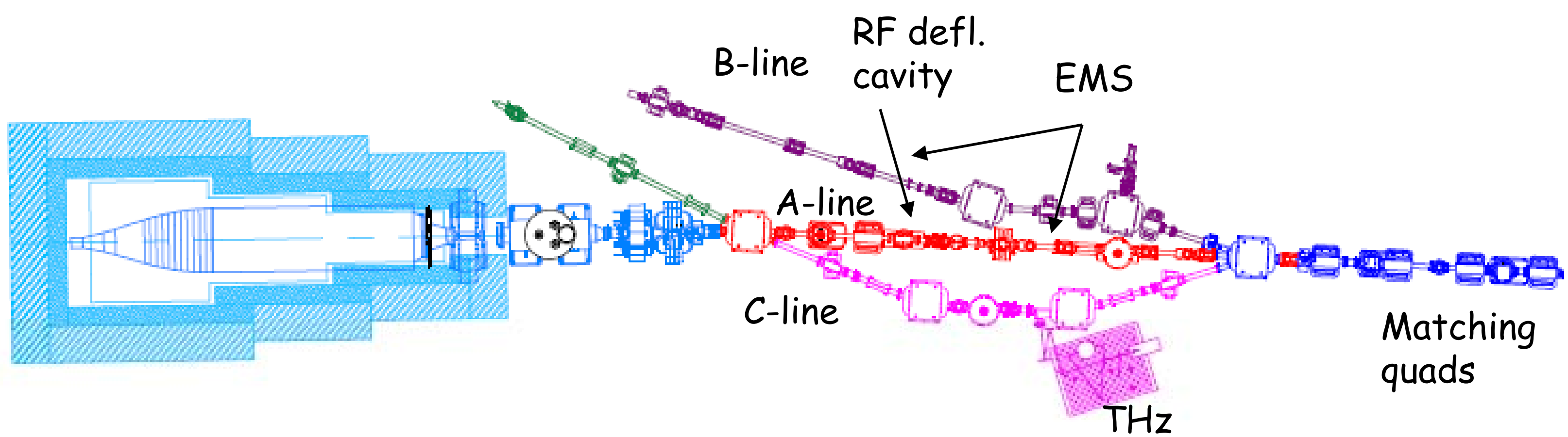


A-line: Full phase space characterization

emittance measurement slits (EMS), bpm's, flying wire, deflection cavity, energy spread, viewers

B-line: Merger studies (low average power)

emittance measurement slits, bpm's, viewers

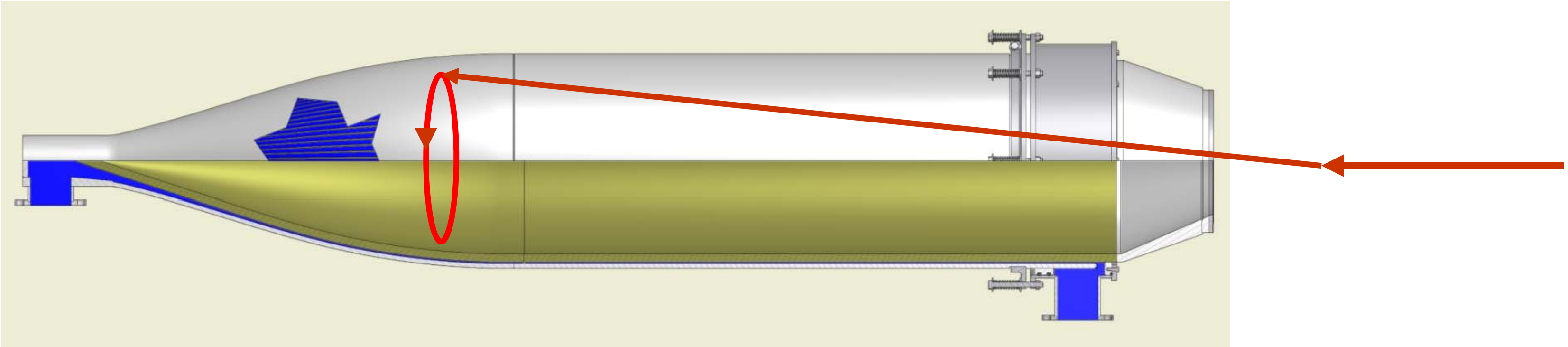
C-line: phase and energy spread/stability, bunch length

THz interferometer, flying wire, bpm's, viewers

Beam Dump

Beam Dump undergoing e-beam welding, manufactured by Metalex, Inc. Due to ship this week

Up to 500 kW average power in the beam for the Phase 1 injector, probably need 1.5 MW for the final ERL design



Before reaching the dump, the 1 mm dia, 500 kW beam is expanded and rastered to reduce the instantaneous power load. Aluminum is used to minimize neutron production

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Results

- All construction (except for dump and final shielding) is complete
- RF and SRF commissioning nearly complete
- Diagnostics commissioning is underway
- Beam through all beamlines, 5 MeV, 50 uA max
- All components ready for 100 mA
- Phase space measurements to begin soon

Acknowledgements

This work is supported by NSF PHY-0131508

Industrial Partners:

Communication and Power Industries (CPI) – DC Gun and RF couplers

e2V – 100 kW klystrons

Accel – HOM loads

Kaiser Systems – 750 kV power supply

Metalex – 500 kW beam dump

Myer Tool – Cryomodule

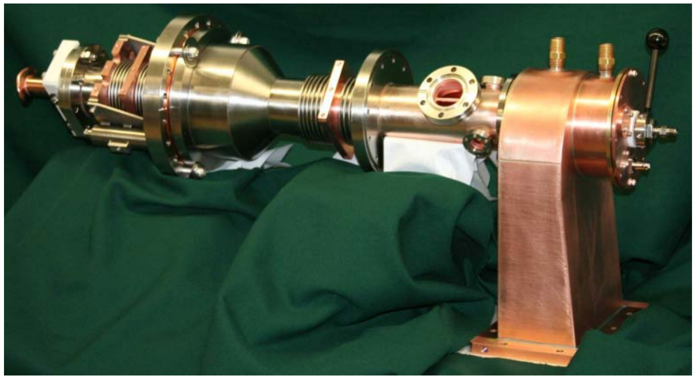
Pritel – Laser oscillator

The next ERL workshop is in Ithaca, NY

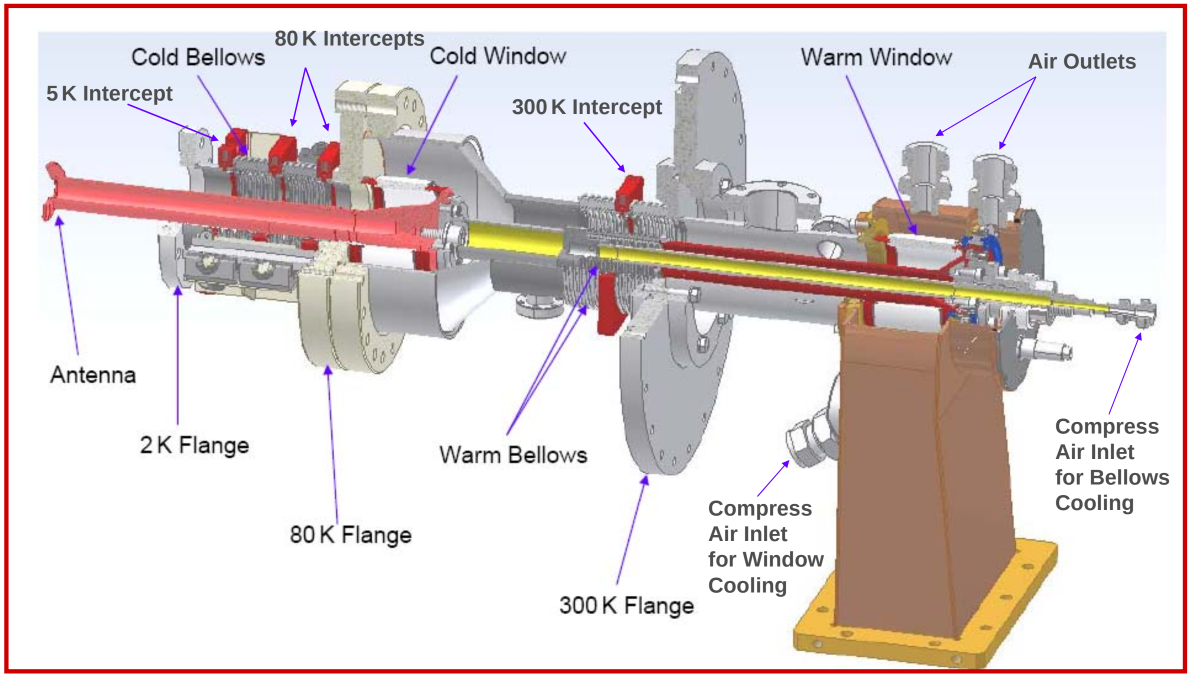
Coupler design highlights

Design features:

- **Design derived from the TTF-III coupler**
- **The cold part was completely redesigned using a 62 mm, 60 Ohm coaxial line for stronger coupling, better power handling and avoiding multipacting**
- **Antenna tip was enlarged and shaped for stronger coupling**
- **"Cold" window was enlarged to the size of "warm" window**
- **Outer conductor bellows design was improved for better cooling (added heat intercepts)**
- **Air cooling of the warm inner conductor bellows was added**

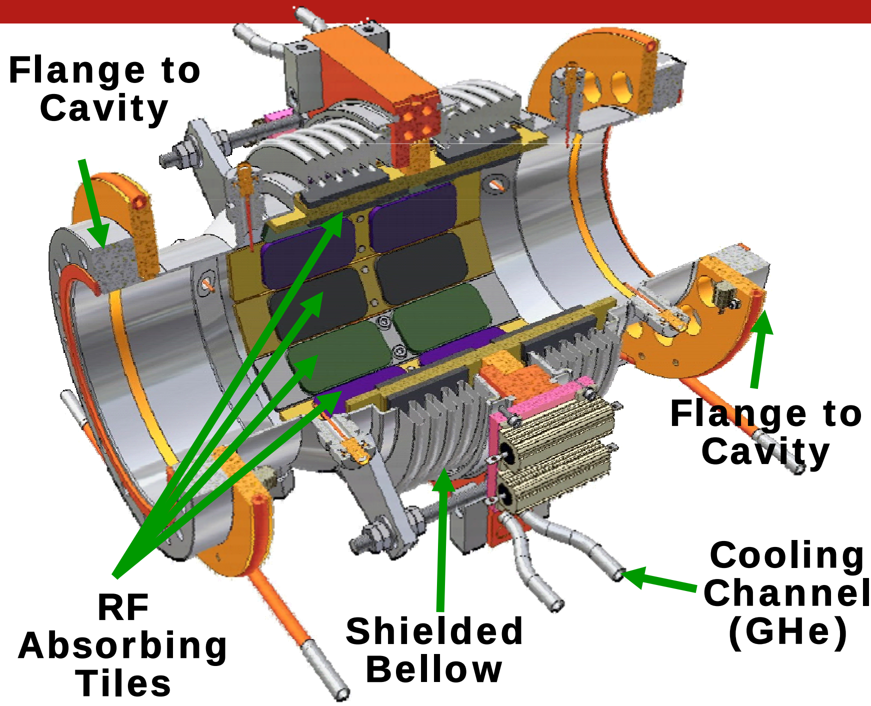


Manufactured by CPI, Beverly, MA

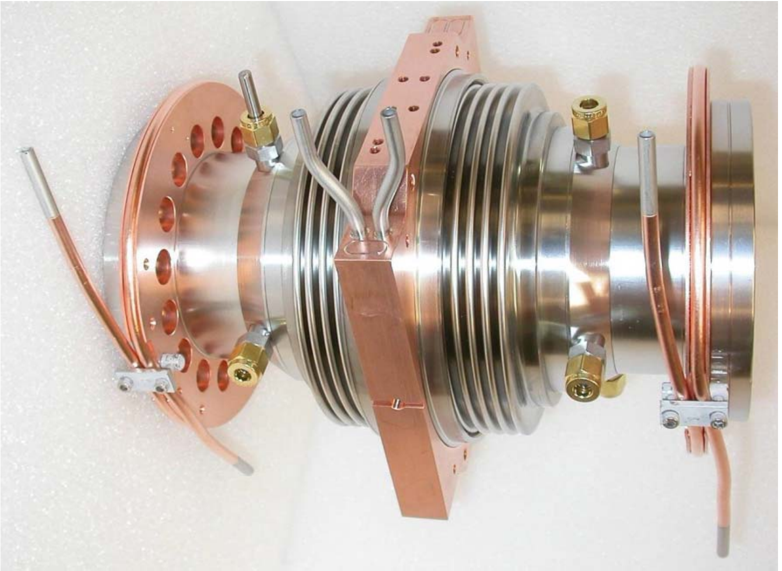


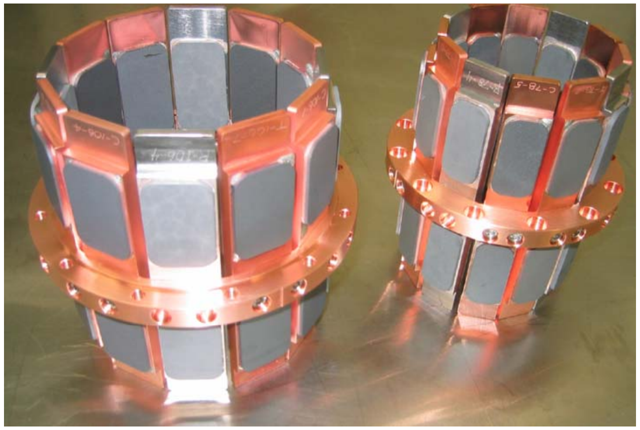
HOM load design

Total # loads	3 @ 78mm + 3 @ 106mm
Power per load	26 W (200 W max)
HOM frequency range	1.4 – 100 GHz
Operating temperature	80 K
Coolant	He Gas
RF absorbing tiles	TT2, Co2Z, Ceralloy



2 proto-types fabricated at Cornell
6 production loads fab'ed by ACCEL





Diagnostics overview

- Beam position resolution: 10 μm (spec)
- Energy spread resolution: 10^{-4}
- Transverse beam profile resolution: 30 μm (viewscreens)
  10 μm (slits)
  30 μm (flying wire)
- Angular spread resolution: 10 μrad
- Pulse length (deflecting cavity&slits): 100 fs
- RF phase angle: 0.5°

Ability to take phase space snapshots of the beam, both transverse planes, and longitudinal phase space