High Brightness Injector Development and ERL Planning at Cornell

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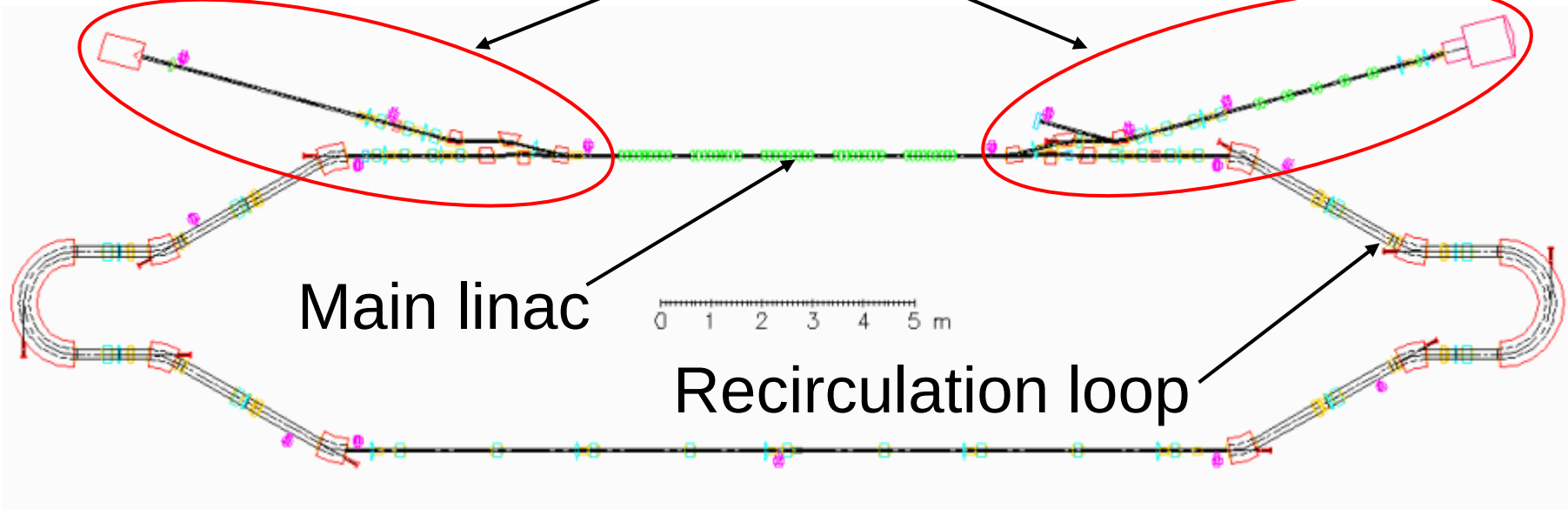
Background

- During 2000-2001, Cornell, with much help from JLab, prepared an NSF proposal to build a 100 MeV ERL to resolve technical issues prior to proposing an ERL-based hard X-ray light source
- In February 2005, the NSF funded Cornell to build the injector portion of the original proposal
- Construction of a fully coherent hard X-ray source is on NSF's long range MRE plan
- In 2006, New York funded Cornell for studies and work related to completing the proposal for the full light source

Proposal vs. funded

Merger, precision diagnostics, and dump

Gun, buncher, and SRF accelerator



Two stages – Operate gun and diagnostics in gun laboratory, then operate complete injector (5 to 15 MeV) in the L0 area of Wilson Lab

Injector Specifications

- Average current – 100 mA
  (77 pC/ bunch, 1300 MHz repetition rate)
- Variable final energy – 5 to 15 MeV
- Beam power – 575 kW average
- Bunch length – < 2 ps, rms
- Transverse emittances – < 0.1 μm-rad (normalized, rms)
- Photocathode operational lifetime – 100 hours

Injector Optimization

We developed a genetic algorithm based computational optimization of our injector, which showed that we should be able to make very small emittance beams.

(Bazarov et al., Phys. Rev. ST-AB 034202 (2005))

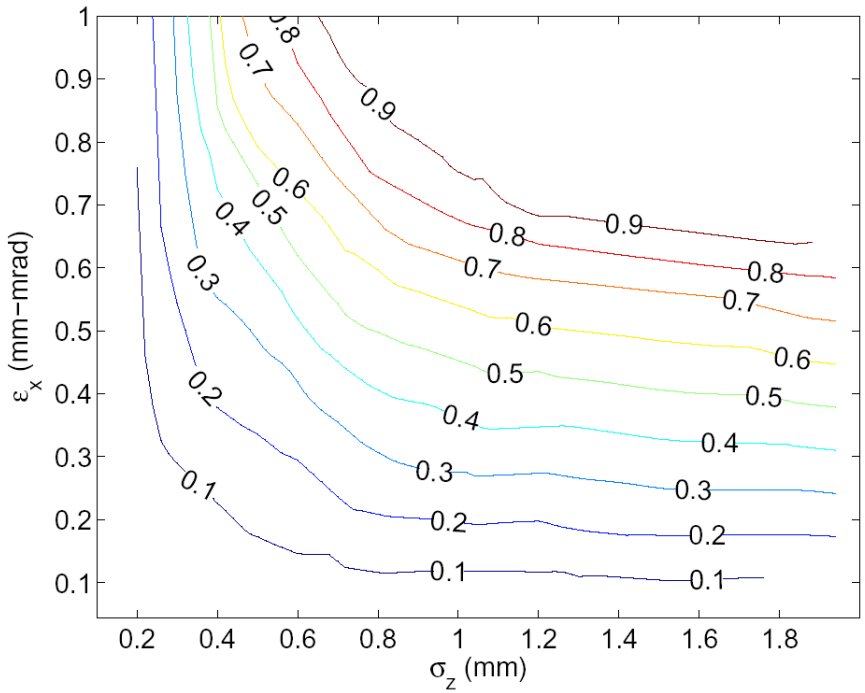


FIG. 10: Transverse emittance vs. bunch length for various charges in the injector (nC).

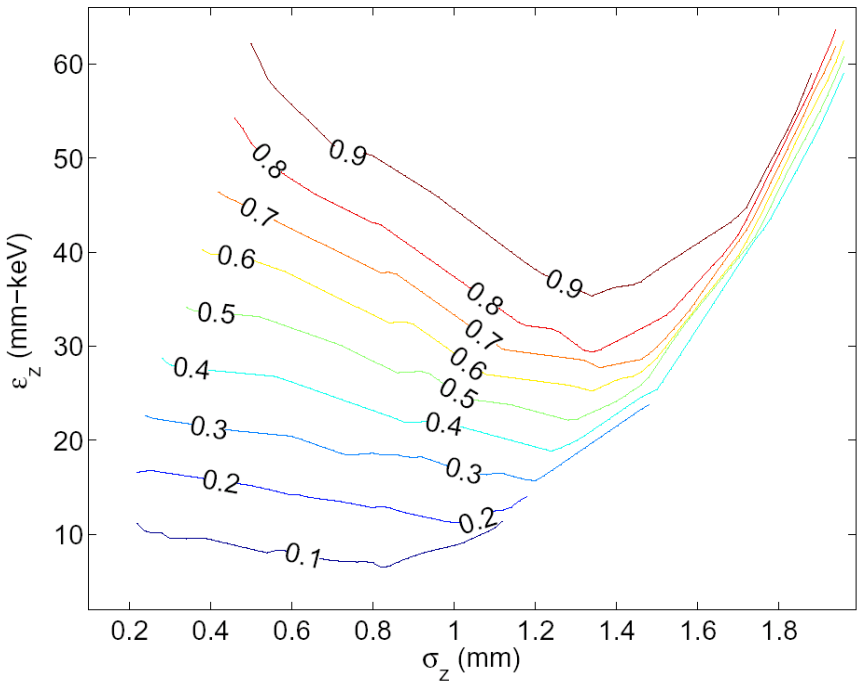


FIG. 11: Longitudinal emittance vs. bunch length for various charges in the injector (nC).

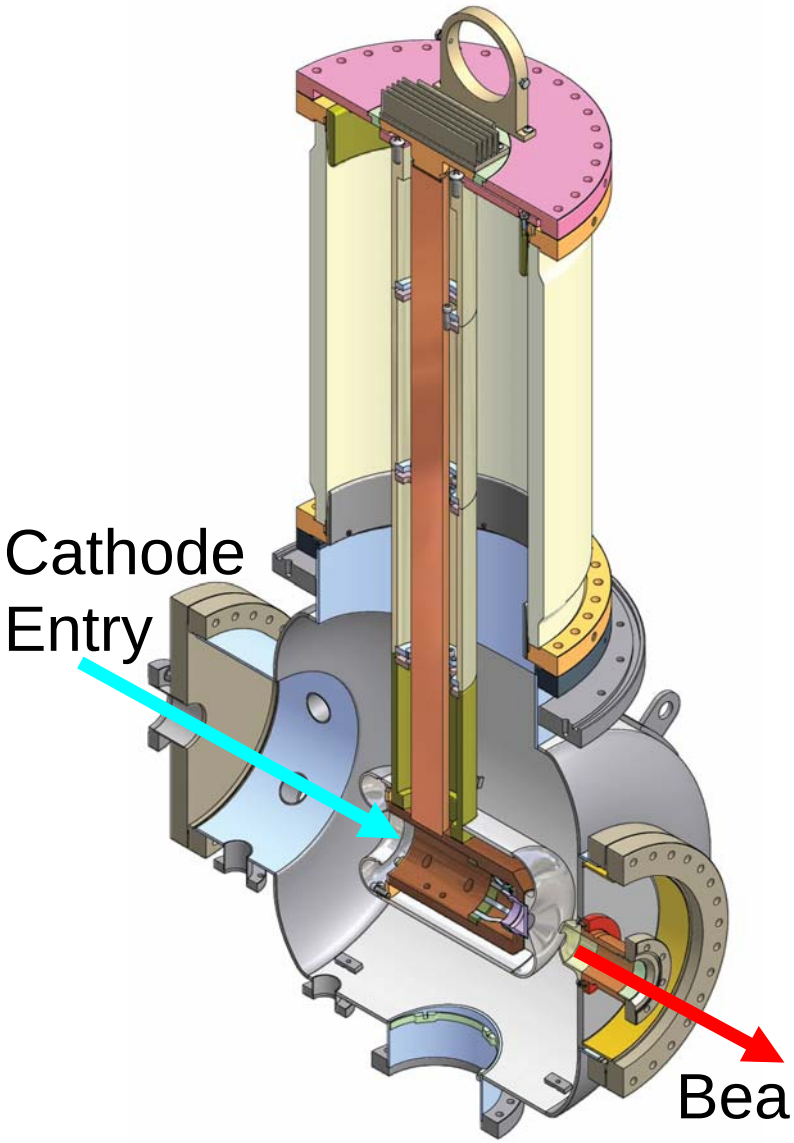
Injector Optimization

- Optimum transverse emittance is dominated by the cathode thermal emittance – this is a tremendous advantage for NEA photocathodes, and implies emittance reduction with cathode cooling
- Emittance compensation works just fine for the DC gun case
- Gentle (adiabatic?) bunching is preferred
- Solutions are insensitive to small parameter variations

Injector Elements

- Photoemission electron gun, 750 kV maximum cathode potential, NEA GaAs or GaAsP cathode, 1300 MHz laser system
- Normal conducting single cell 1300 MHz buncher
- Cryomodule with five 2-cell SRF cavities
- Precision controlled high power RF systems
- Merger magnet system
- Precision diagnostic beam line
- Full power beam dump

750 Photoemission Gun



This gun design incorporates a number of novel features, such as a resistive coated ceramic, photocathode cooling, a cooled beryllium anode, and over 20 m^3/sec of hydrogen pumping speed

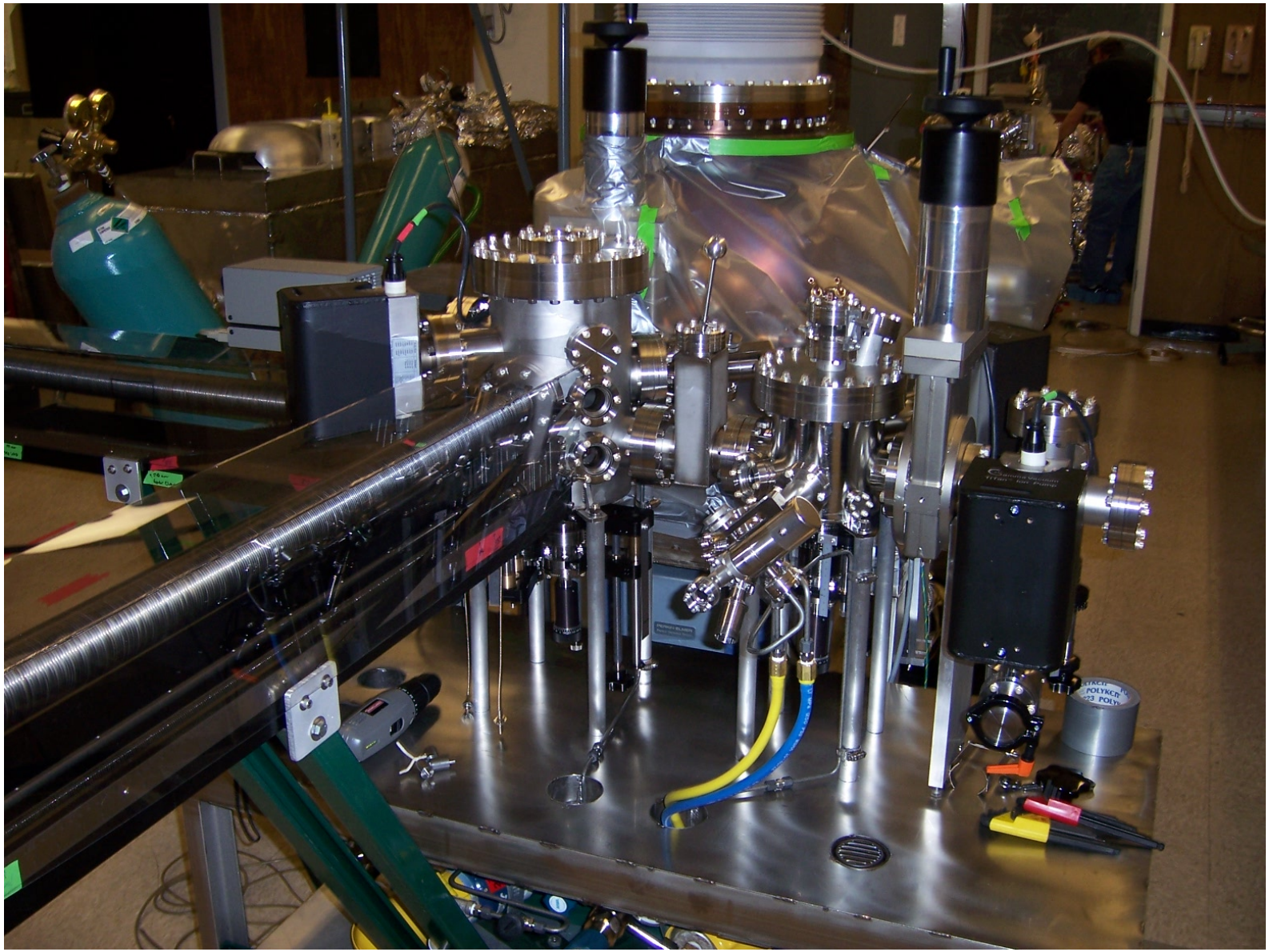
The gun was assembled without touching any cathode electrode surface

Gun Ceramic from CPI

Cathode Electrode Assembly

SF_6 Tank Installation

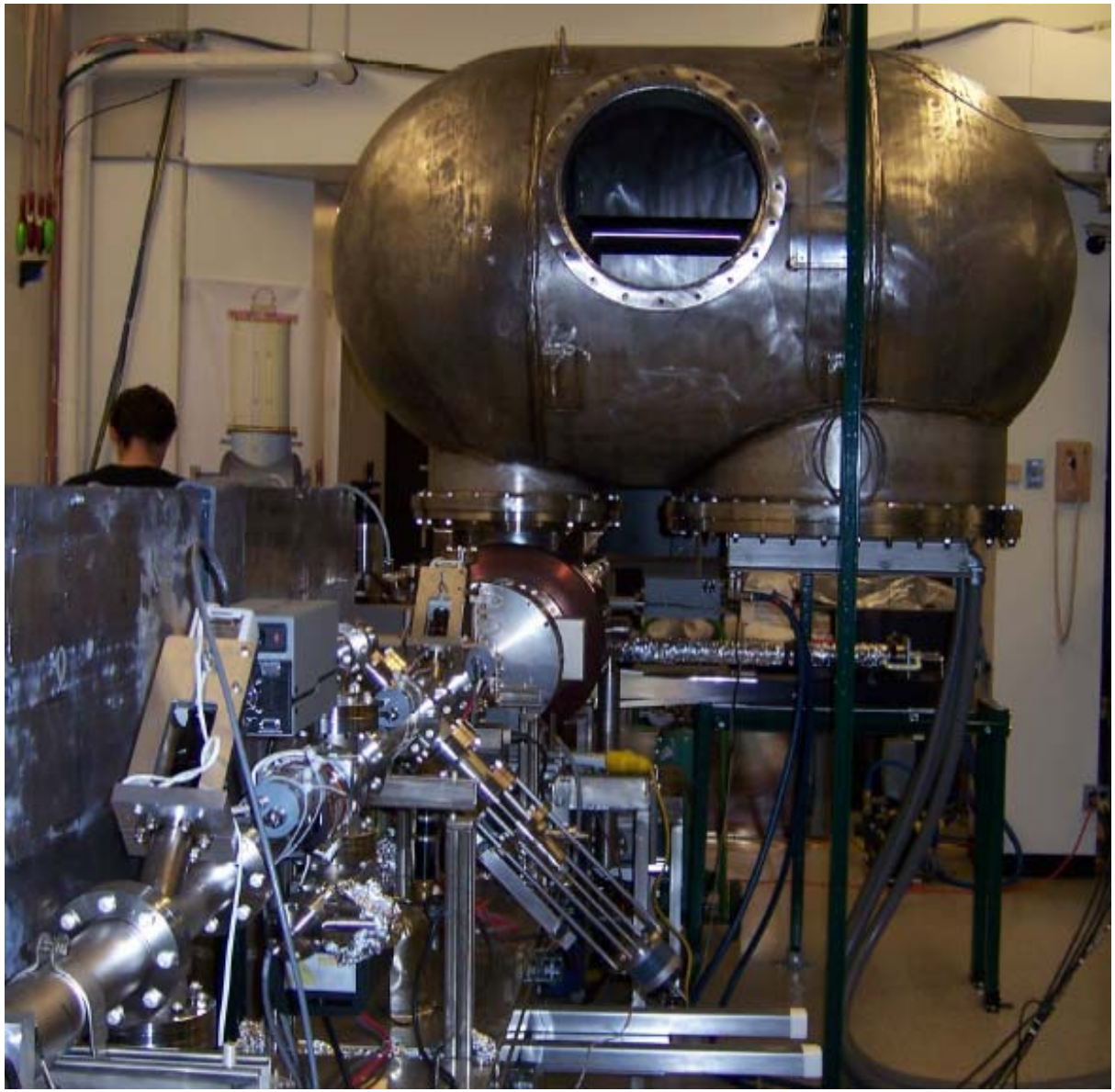
Photocathode Load Lock and Preparation System



300 kV, 100 mA Power Supply

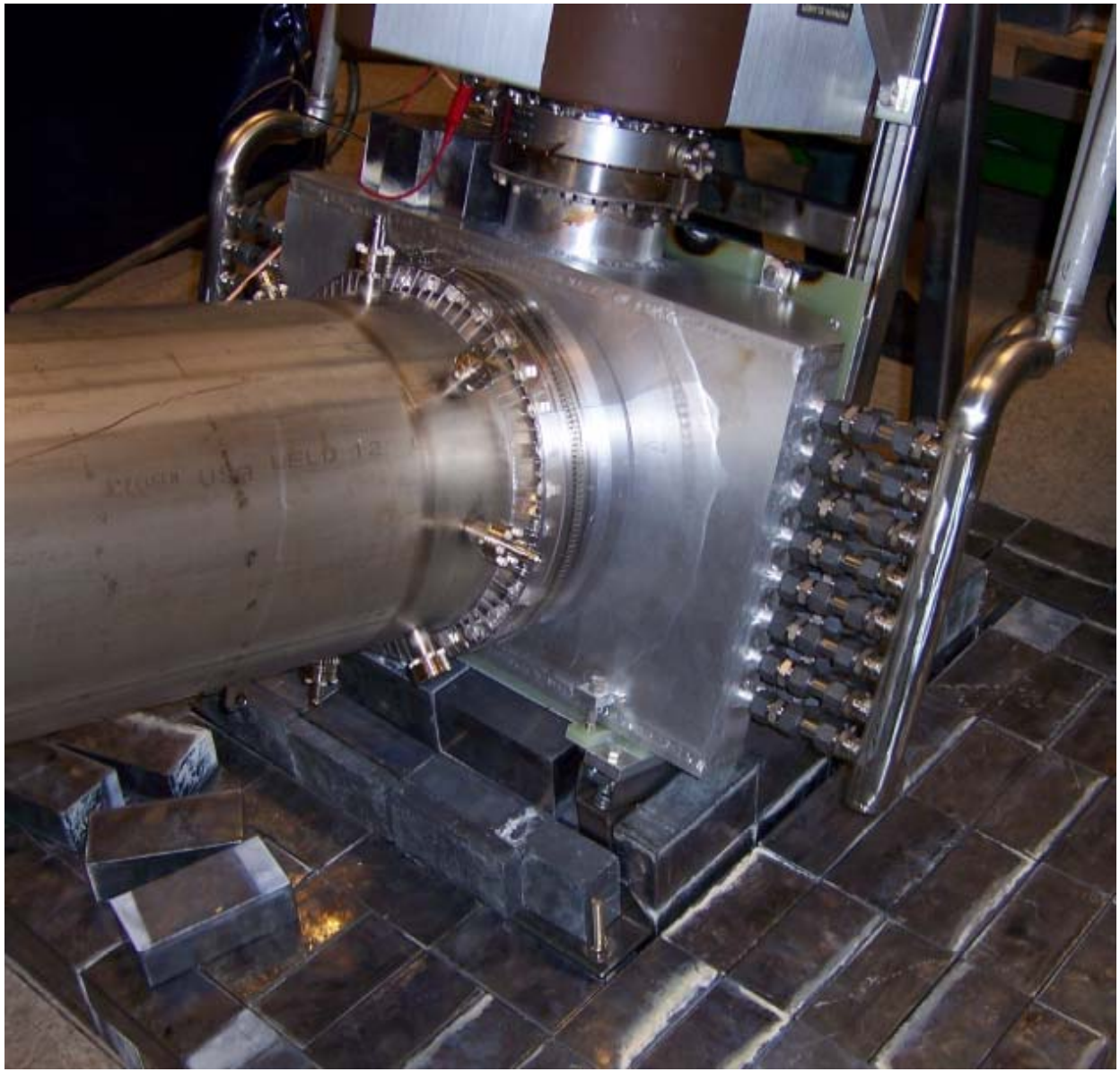
Gun and Power Supply in Tank

Beam Line looking toward Gun



Beam Dump during assembly

Starting the shielding

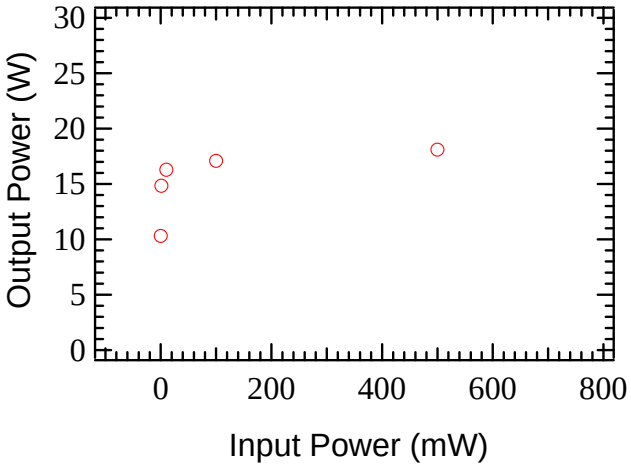


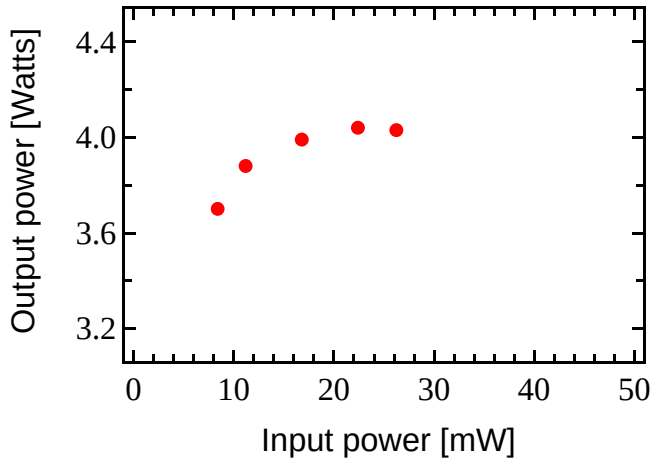
Lasers

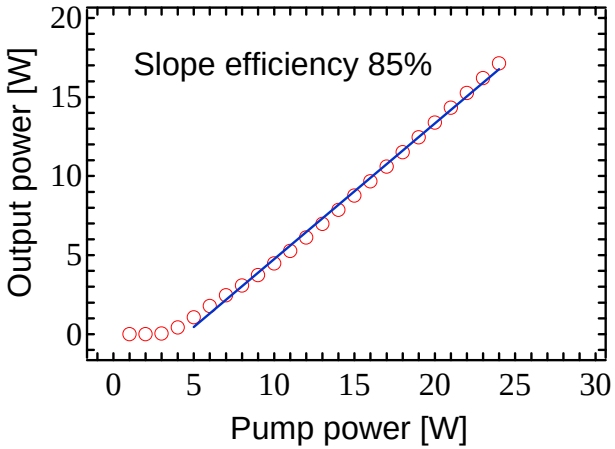
- With our CW argon ion laser, the present setup will allow us to study
  - Photocathode thermal emittance
  - Photocathode operational lifetime at high average current
- Adding a laser with RF time structure and additional diagnostics, we will study
  - Emittance as a function of bunch charge
  - Temporal structure of the bunches
- 50 MHz, and 1300 MHz frequency doubled Yb fiber lasers in development with A&EP

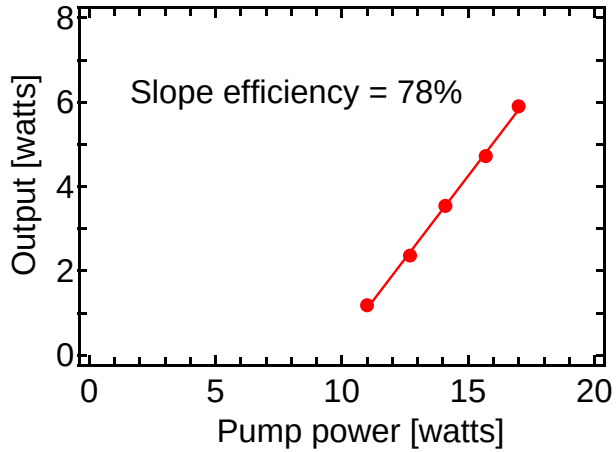
Laser Development

- 50 MHz fundamental frequency mode-locked Yb fiber oscillator
- Harmonic mode-locking to reach 1300 MHz
- Yb fiber amplifier(s) to reach ~ 130 W in the IR. (100 nj/pulse)
- Frequency multiplication in LBO to give > 20 W in the green after pulse shaping
- Initial transverse shaping with aspherics, temporal shaping with pulse stacking
- Pattern control with BBO Pockels cell



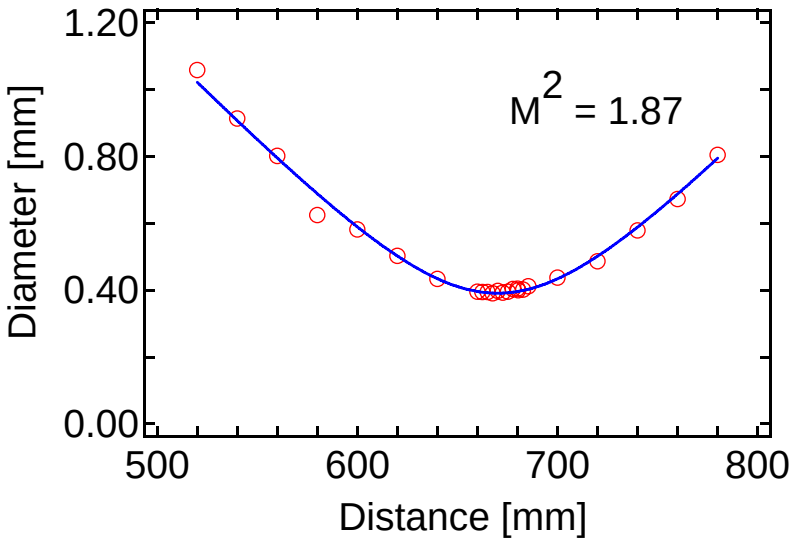


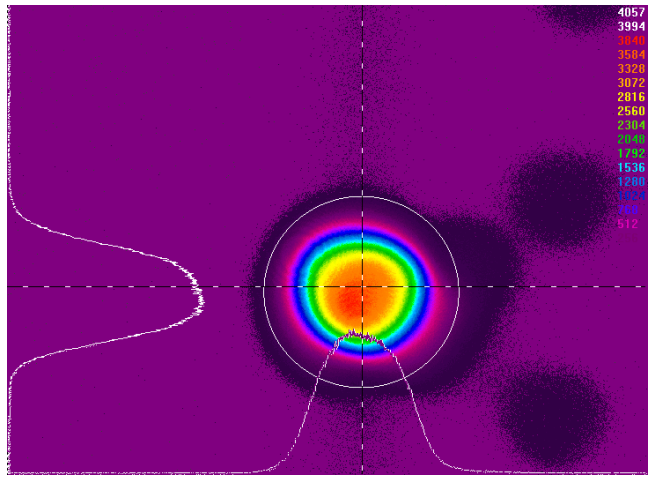


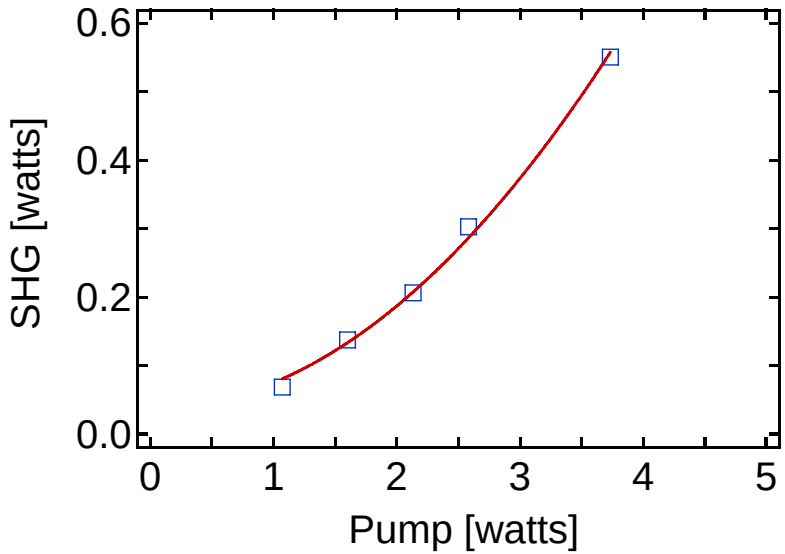


Simulation with Liekki Application designer

First measurements On amplifier

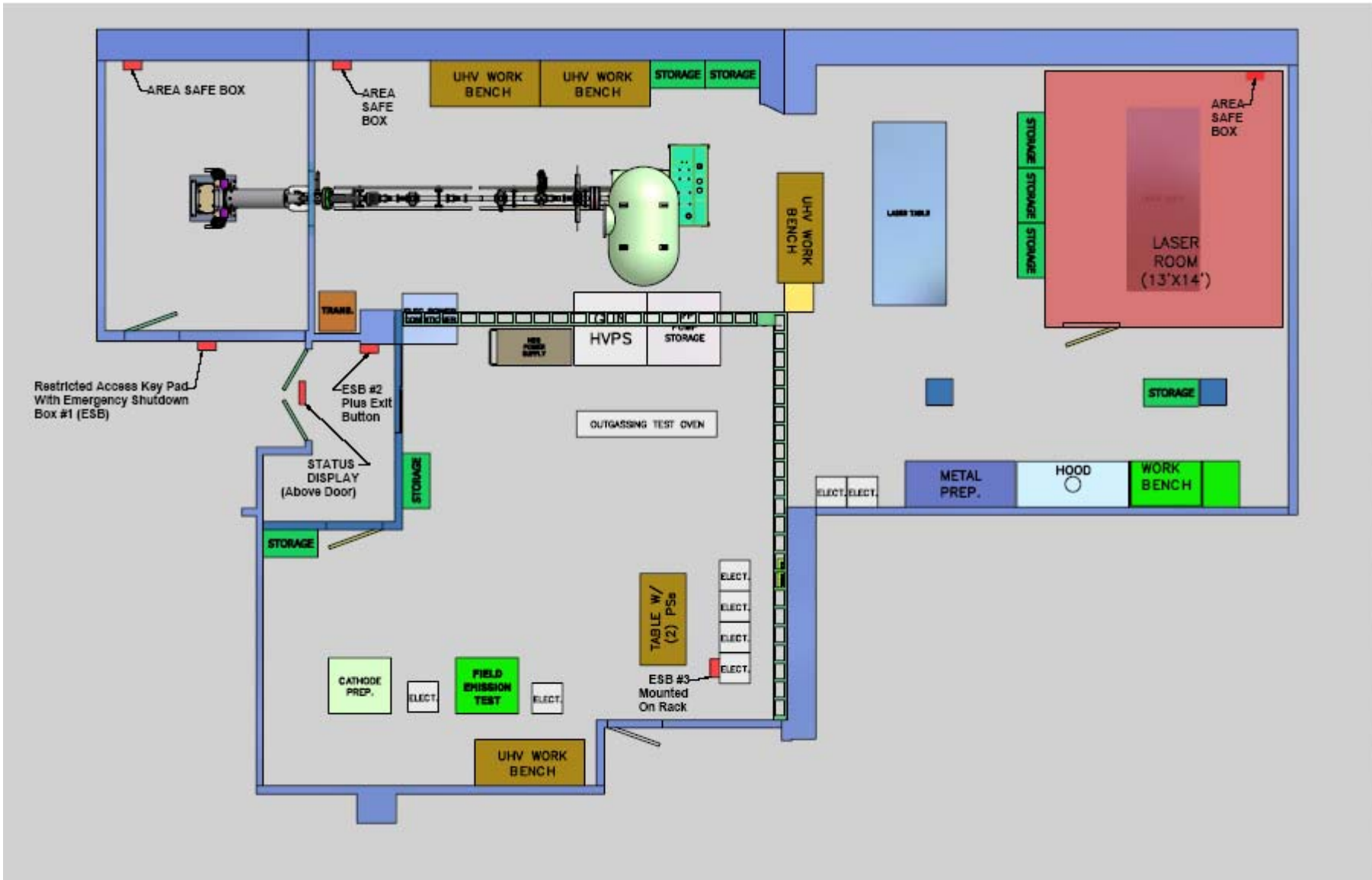






15 mm LBO doubler
Non-critical phase matched
5 cm focal length

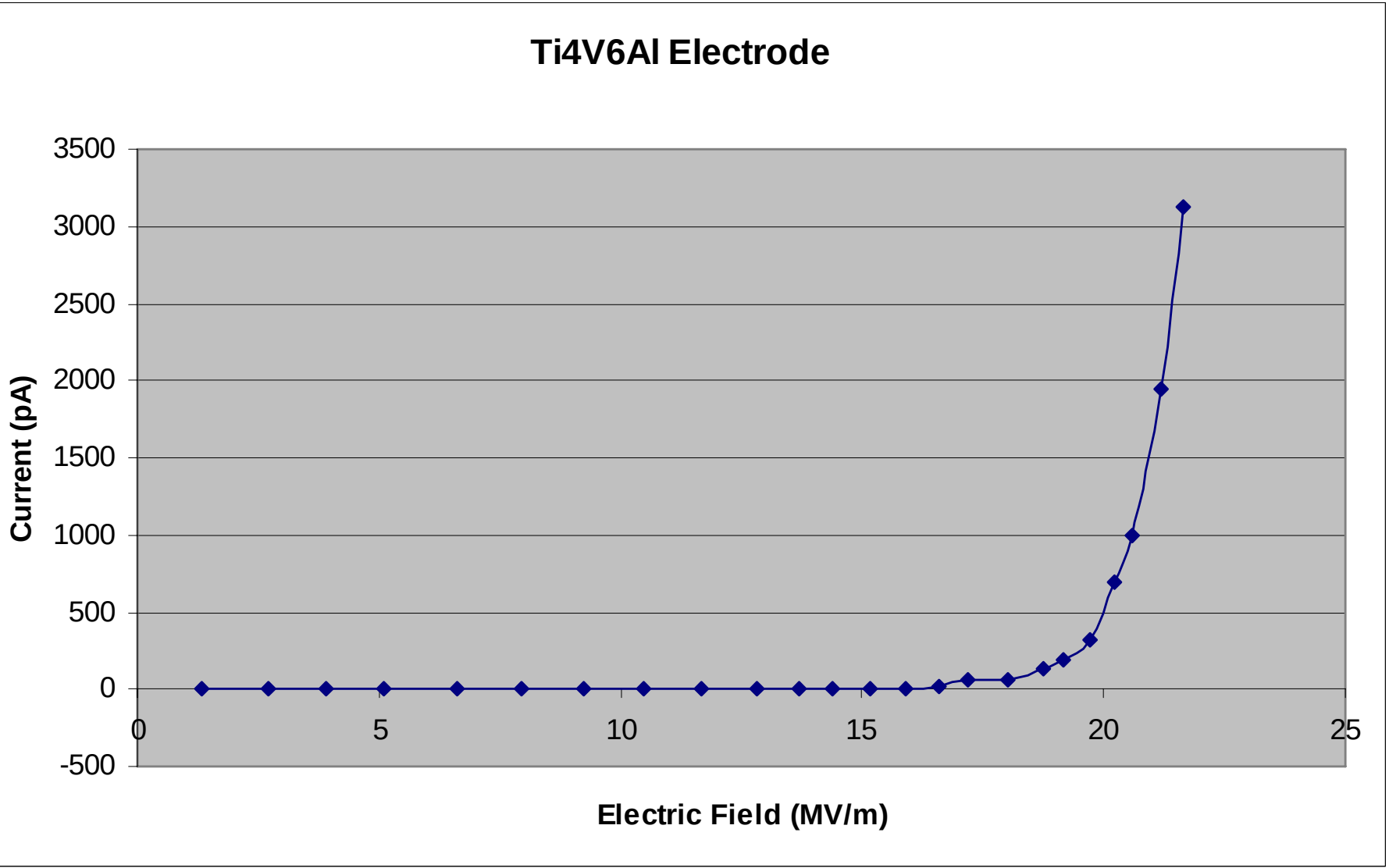
Plan View – Gun Test Lab



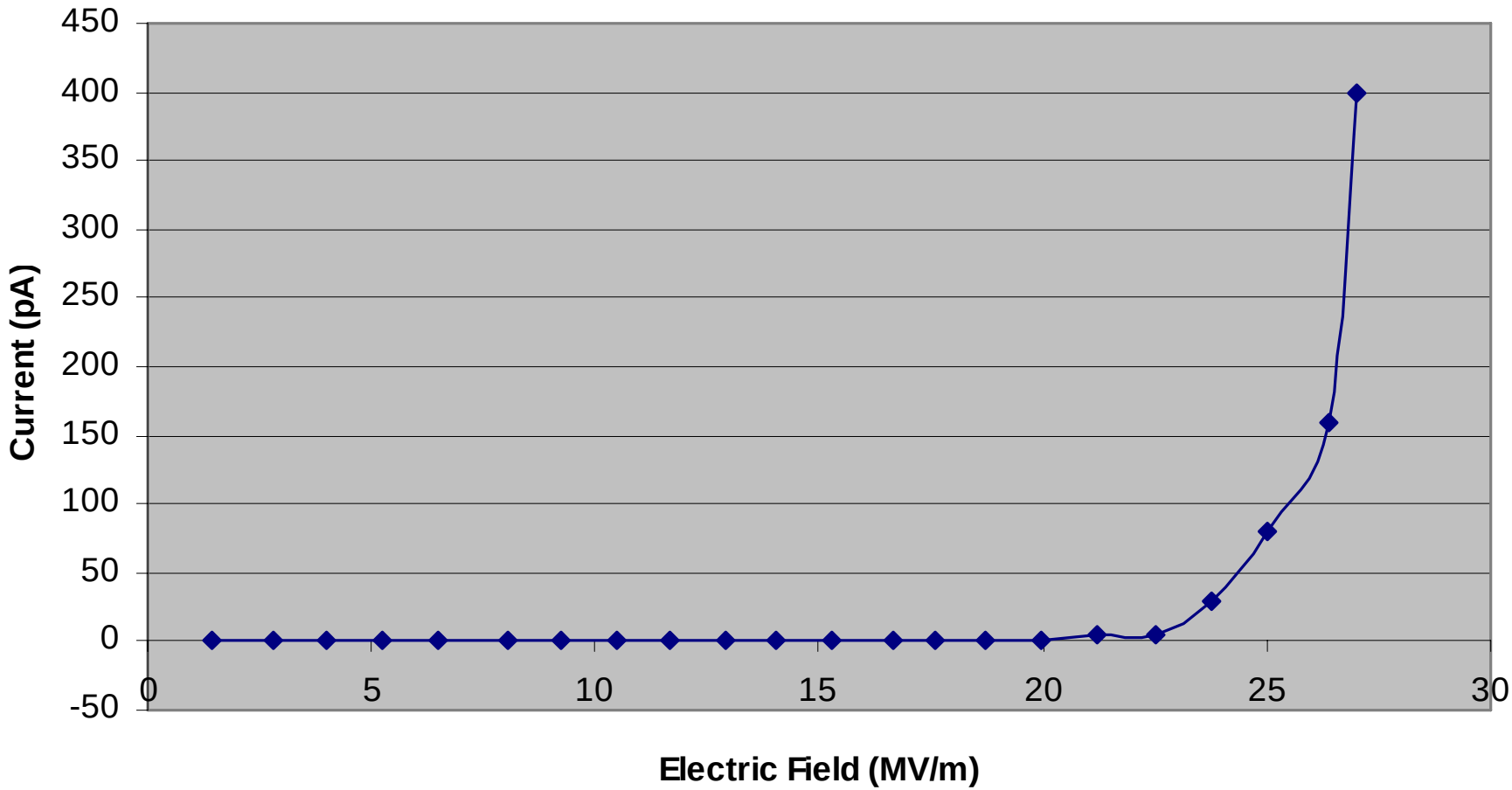
Additional Activities

- Outgassing studies
  - Best result to date, following VIRGO prescription, is an outgassing rate of ~ 2 x 10^{-13} torr-liter/sec-cm^2
- Photocathode preparation
  - Routinely prepare ~ 17% QE photocathodes on both GaAs and GaAsP wafers
- Field emission reduction
  - Evaluated 316 LN, Ti4V6Al, and GCIB treated materials
  - Have achieved “zero” emission up to 20-22 MV/m

Bare Ti4V6Al Electrode



GCIB treated 304 SS



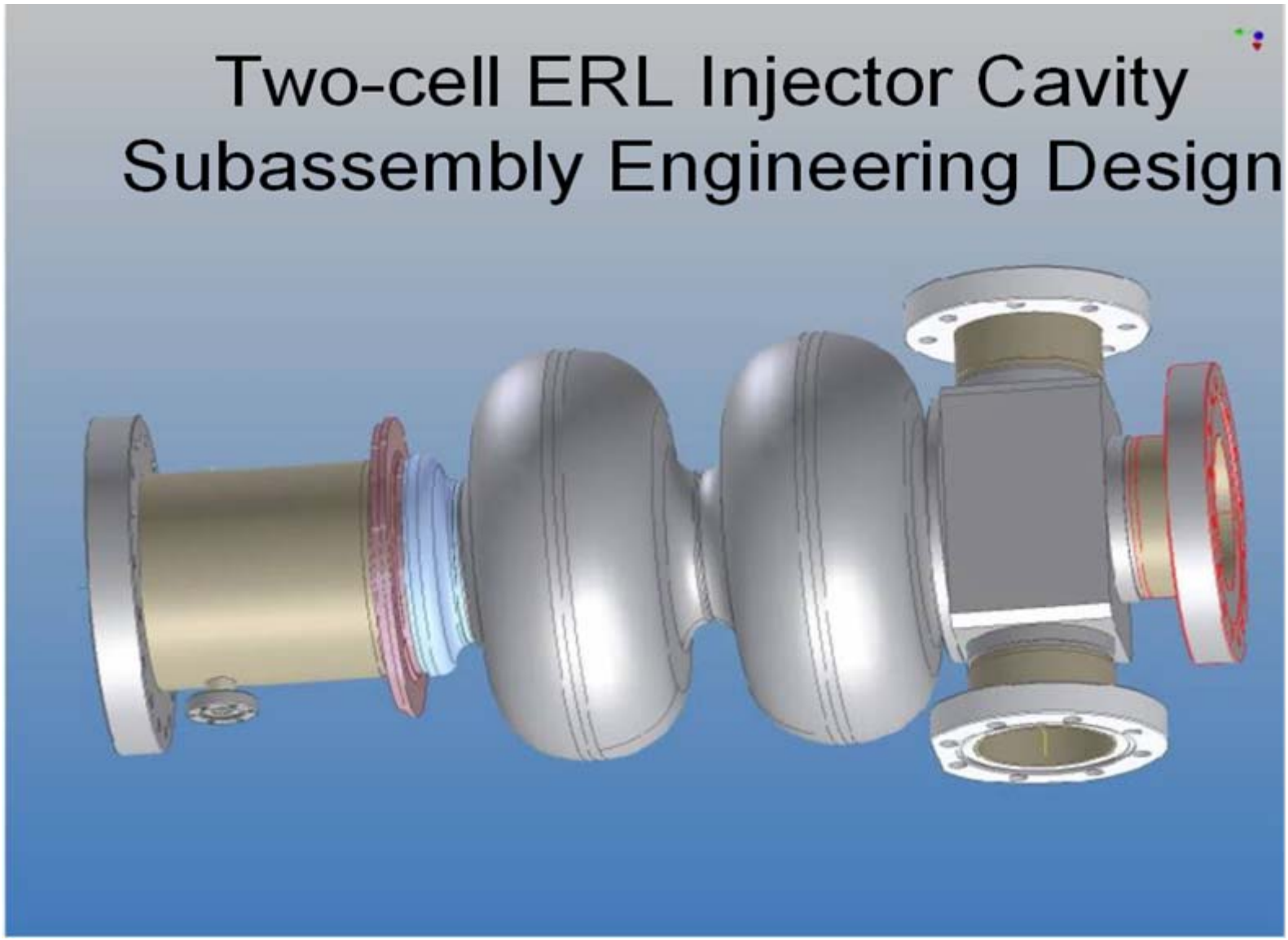
Ion Back Bombardment

- A very bright undergrad student has been modeling ion creation and back bombardment in the gun
- We have been using sputtering of cesium fluoride as a surrogate for what is degrading the cathode quantum efficiency under ion bombarment
- I can almost explain the QE degradation as due solely to sputtering of the NEA activation layer
- We have detailed predictions we can test with our gun

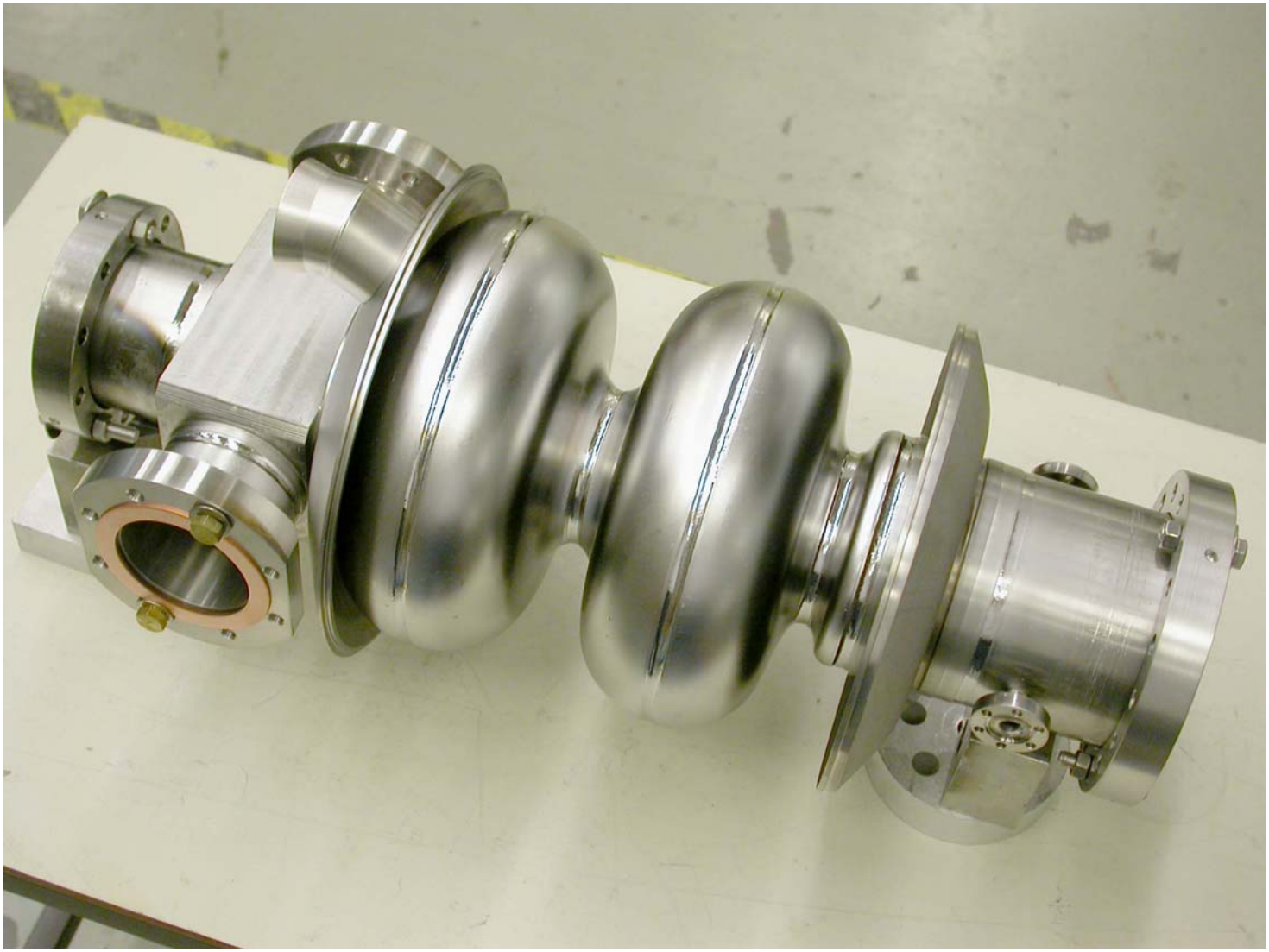
Current Status

- Gun, preparation system, beam line, and dump are all assembled and baked
- We have been plagued by a series of leaks ion the preparation system, and most recently, in the gun
- We see strong field emission at relatively low voltages on the gun, and so far, have not been able to process through this
- I am starting to survey the local bridges

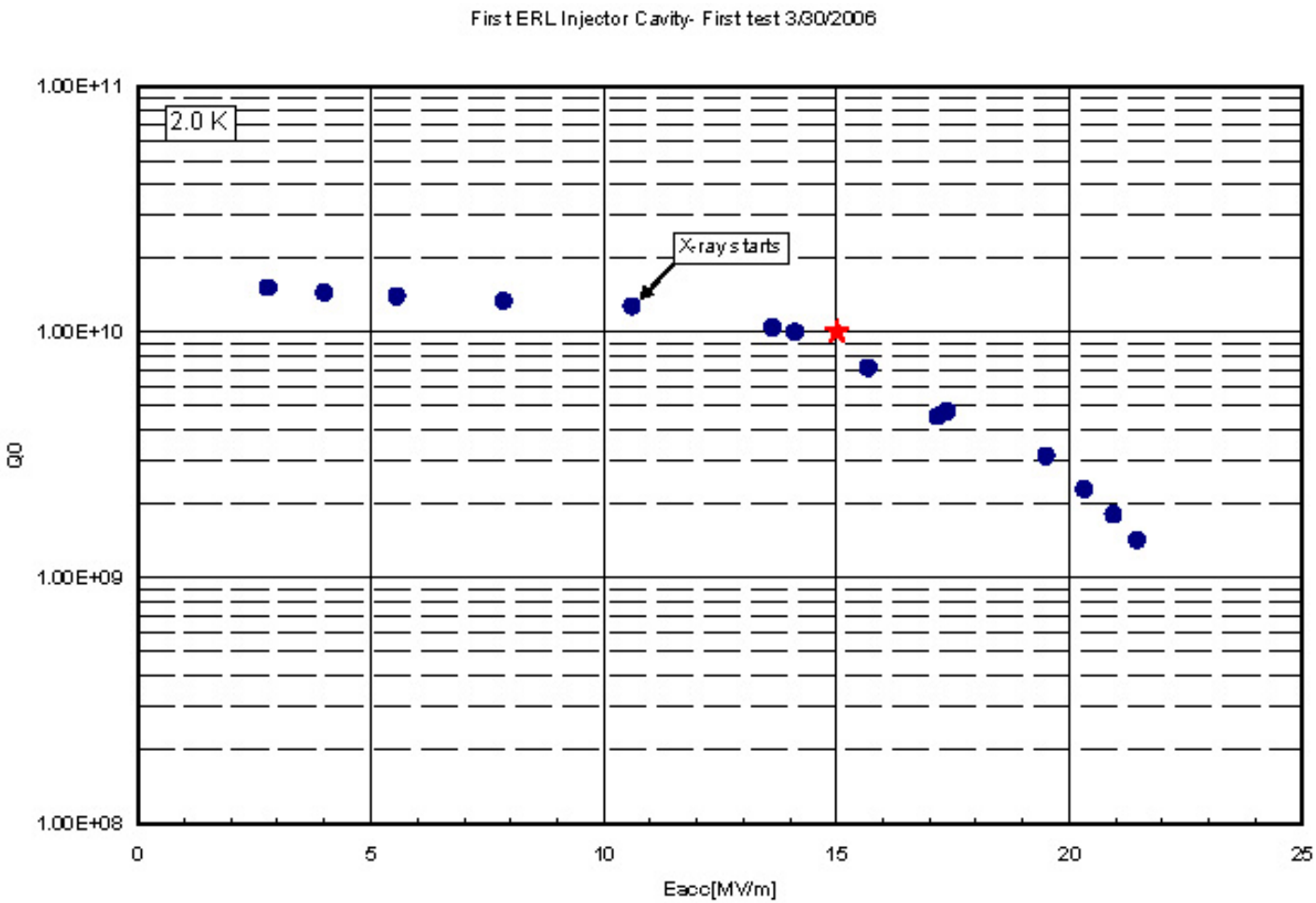
SRF Cavity Design



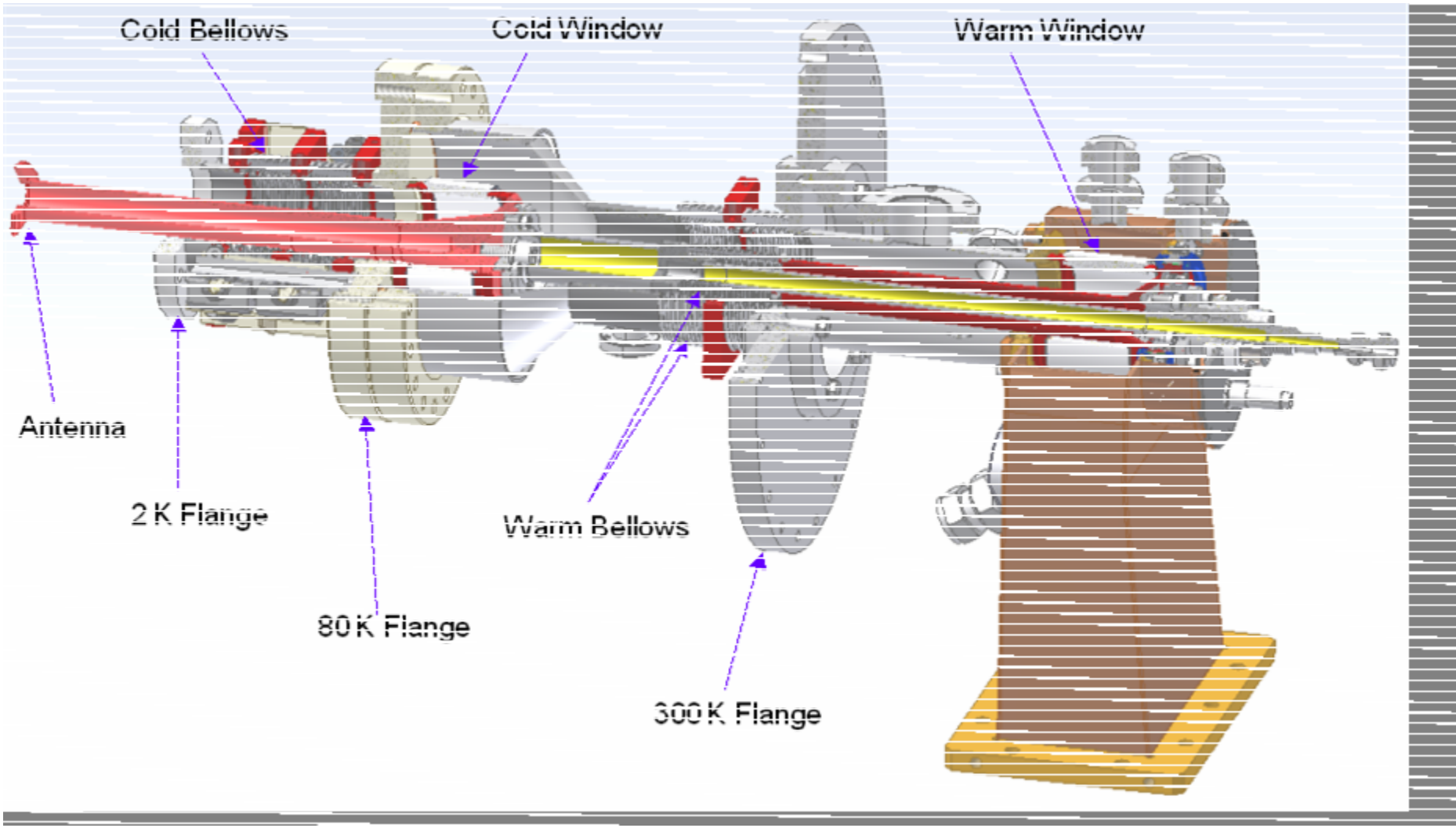
First 2-cell Niobium Cavity Weldment



First Vertical Test

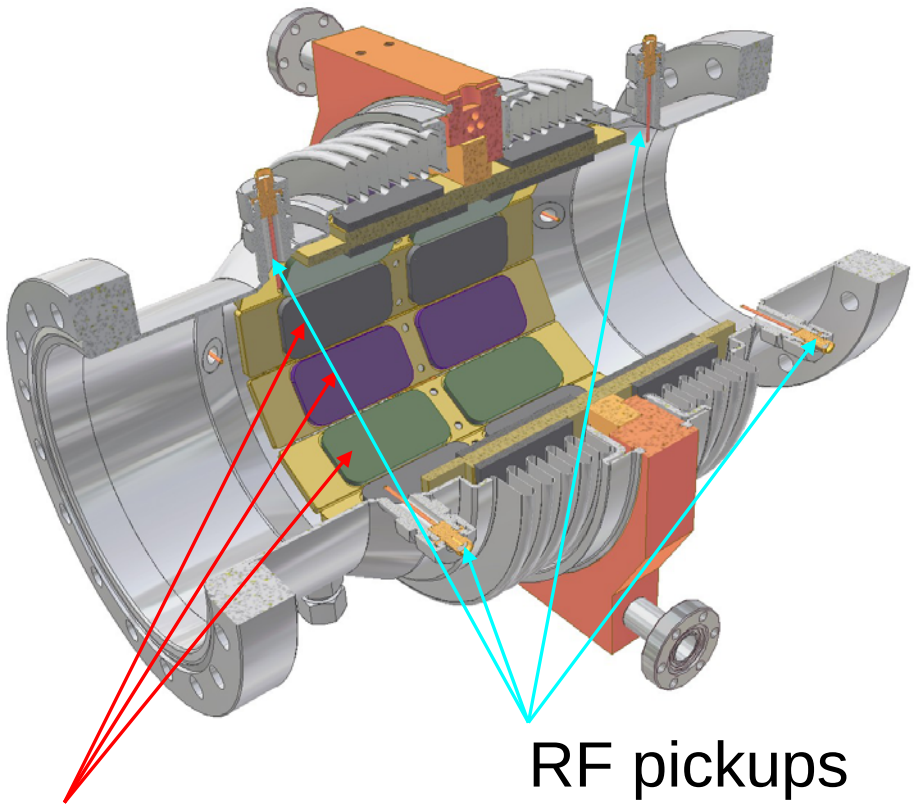


RF Power Coupler Design



RF Power Coupler

HOM Loads

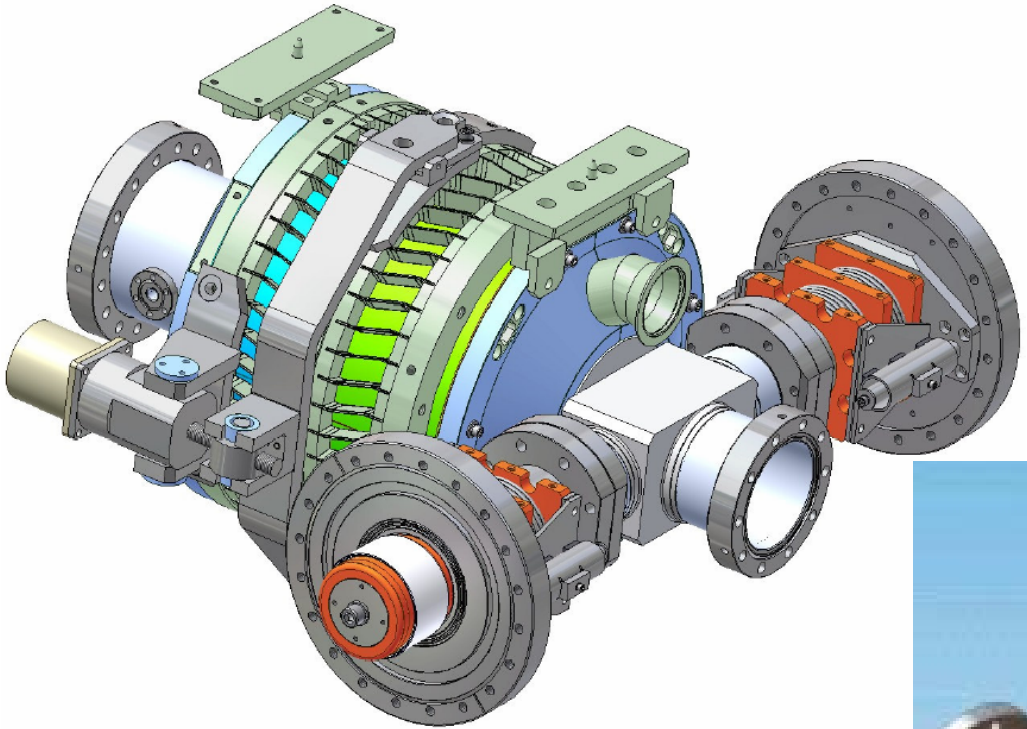


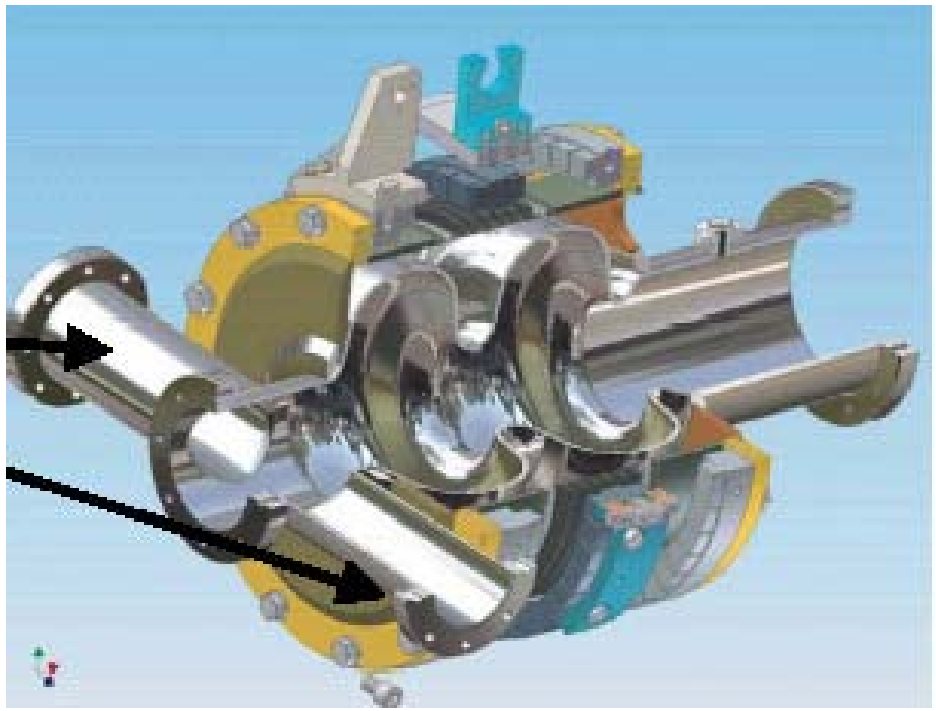
Extensive program to find absorbers over the full frequency range at low temperature completed. Three different materials necessary

Fabrication of first load nearly complete

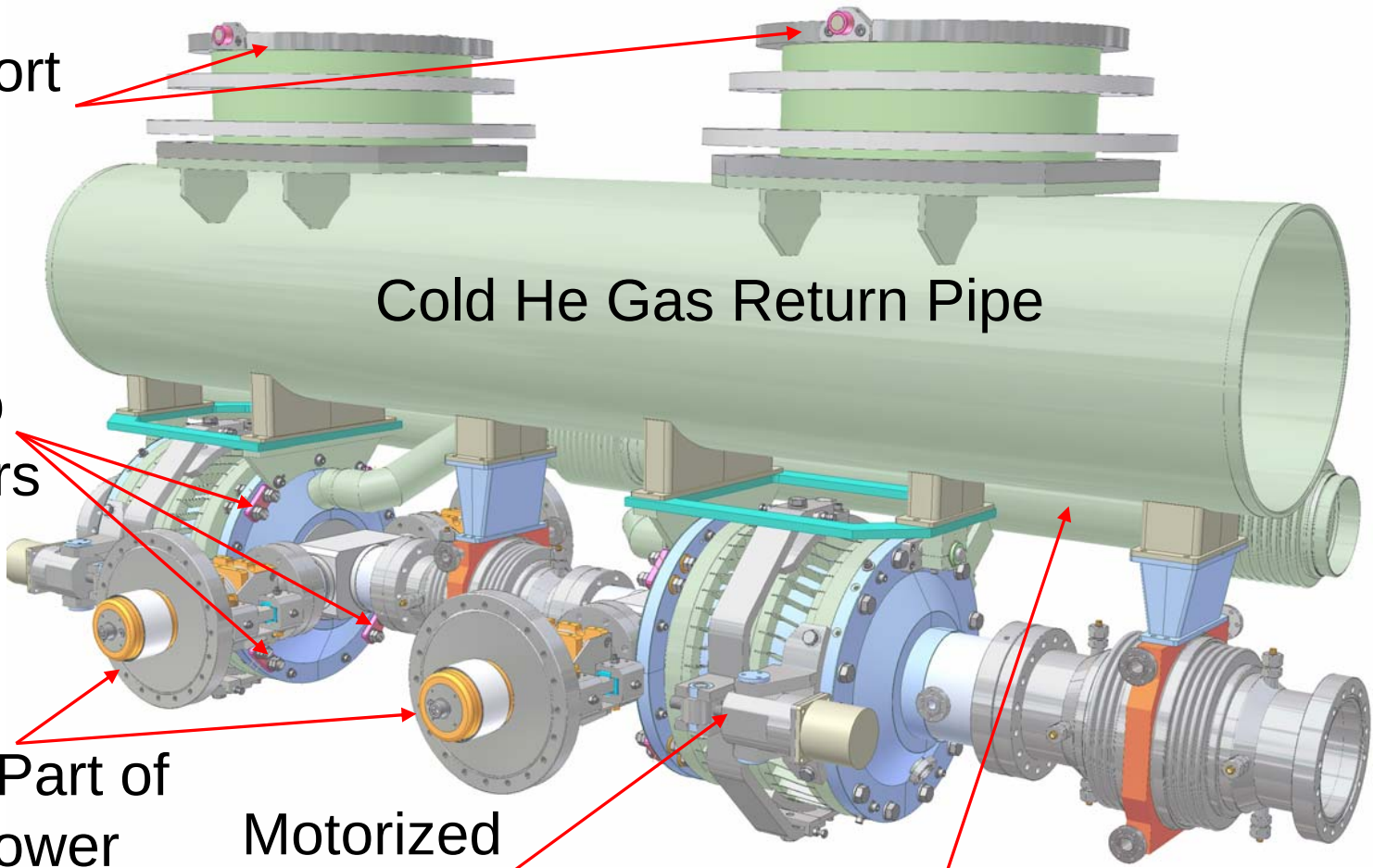
RFP ready to send to vendors for remaining loads

The fully dressed cavity





Cryomodule Design Concept



Cryomodule Status

- Fabrication of five two-cell cavities underway
- First test of RF power coupler pair in July, with procurement of ten more couplers to follow
- First article HOM load test soon, procurement in process
- Blade tuner development underway in collaboration with University of Pennsylvania
- 2K cryogenic plant under construction
- First horizontal test of fully dressed cavity early in March 2007

1300 MHz RF Power Sources

- 16 kW IOT transmitter in house, passed acceptance test. Will be used for:
  - RF power coupler tests
  - Buncher power
  - Transverse deflecting cavity diagnostic
- 160 kW klystron in development at e2v Technologies (England)
  - First tube on pump stand, should begin RF testing in early July
  - First tube delivered in early August
  - Five additional tubes by April, 2007

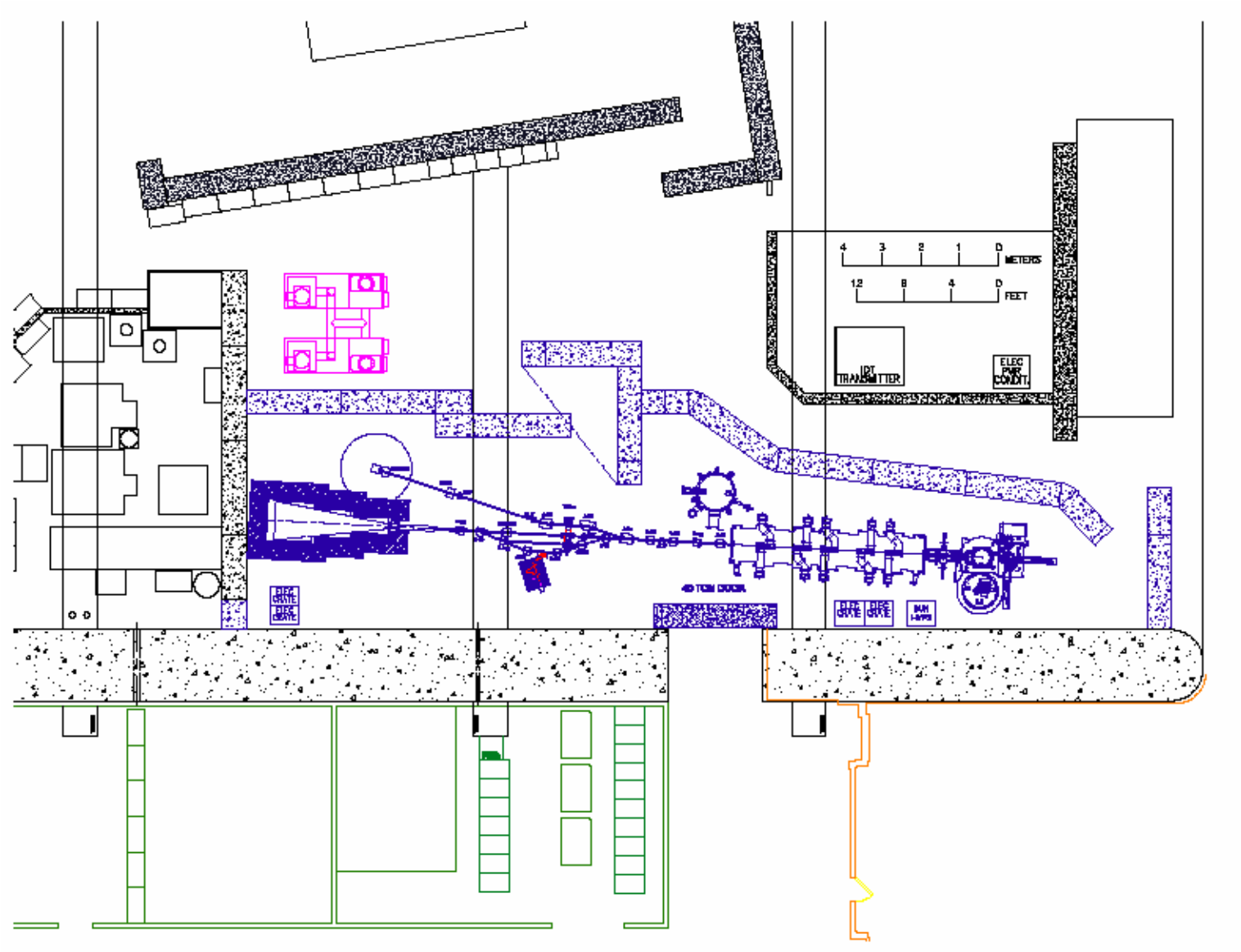
First Klystron on Pump Stand

Klystron Specifications

- > 120 kW CW output with incremental gain > 0.5
- Efficiency > 50% at 120 kW, 0.5 incremental gain
- Small signal gain > 45 dB
- +/- 2 MHz at – 1 dB
- +/- 3 MHz at -3 dB

Seven cavity design required to meet specifications

Injector Layout in L0

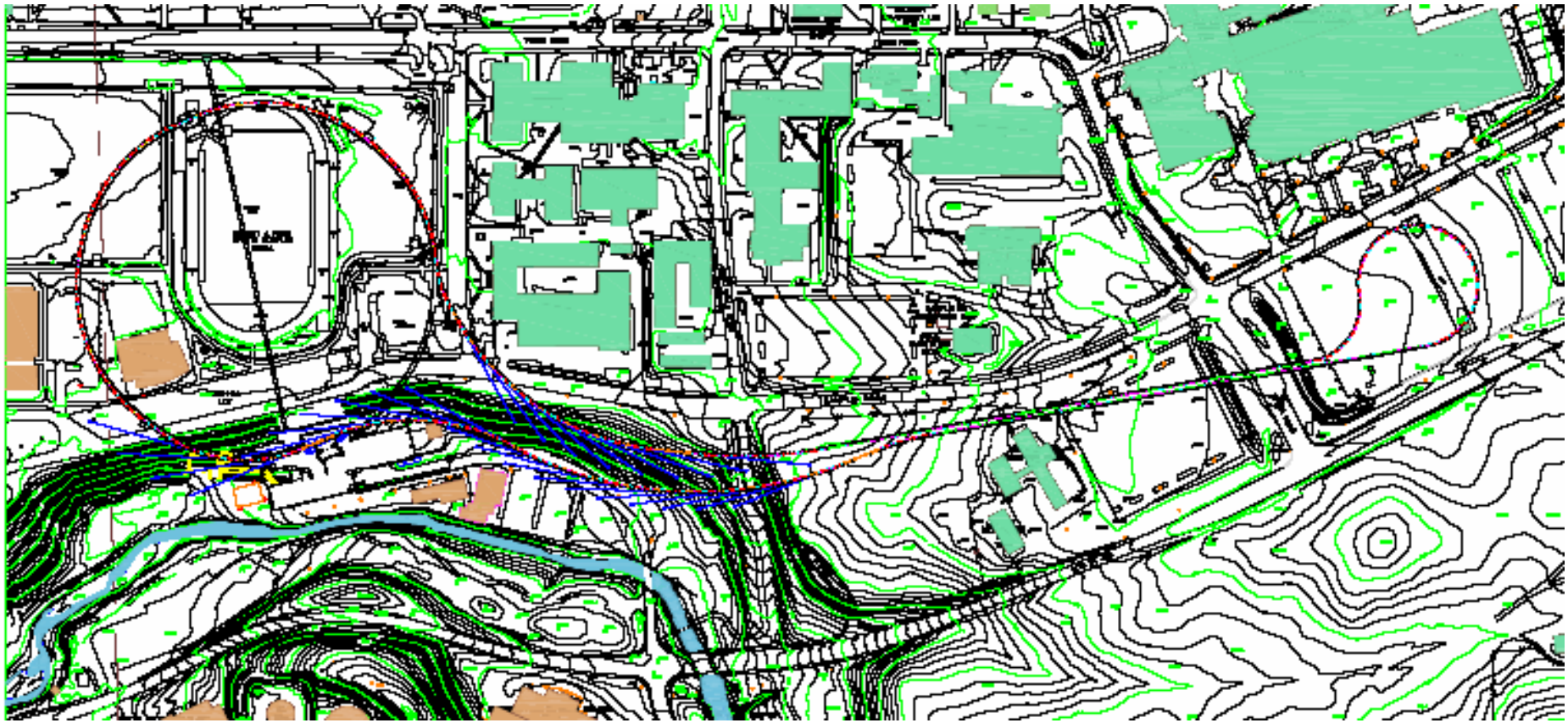


L0 Layout with Mezzanine

Time Line

- 750 kV Gun Power Supply delivered in November 2006
- Gun tests in lab continue through 2007
- Begin clearing area for control room, and starting installation later this year
- Three (at most) horizontal cavity tests will be completed by October 2007
- L0 area ready for installation in November 2007
- Begin beam operations in September 2008

ERL @ CESR



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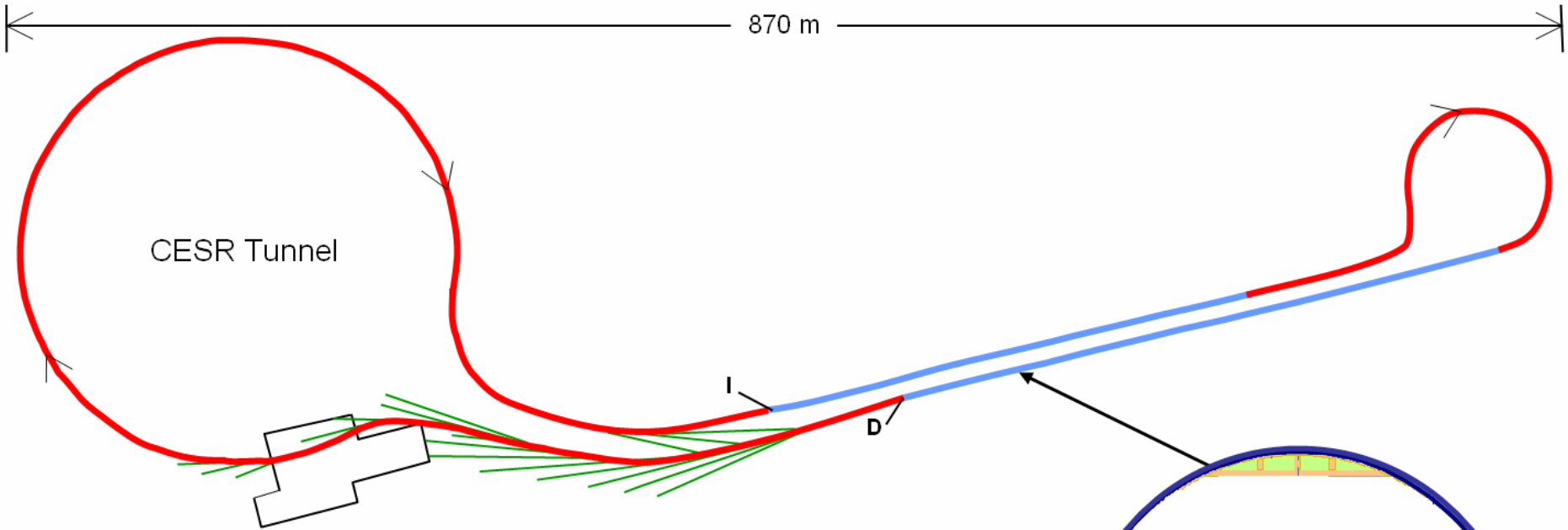
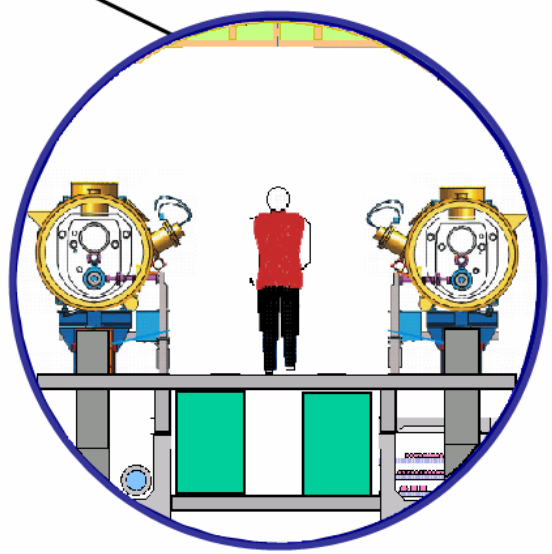


Preliminary layout view of an ERL upgrade to CHESS in the present CESR tunnel. A new tunnel with a return loop will be added to CESR. Electrons are injected into superconducting cavities at (I) and accelerated to 2.5 GeV in the first half of the main linac, then to 5 GeV in the second half. The green lines show 18 possible beamline locations. Electrons travel around the CESR magnets clockwise and re-enter the linac out of phase. Their energy is extracted and the spent electrons are then sent to the dump (D).



Two superconducting linacs in one tunnel accelerate the electrons to 5 GeV. Person shown for scale.

Full Machine Planning

- Detailed lattice design underway, with a total of 18 X-ray beam lines
- Detailed WBS in development, prepatory to developing a full budget and schedule for the full machine
- Test borings of site underway with NYS funds
- Six X-ray workshops held this month, to build the science case for the full machine
- Plan to submit a proposal for a 5 GeV ERL light source in December, 2007
- Construction start in 2011???