New SRF Cavity Geometry for High-Current Applications

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Speaking on behalf of

the BNL-AES-JLAB collaboration

Abstract

CW applications at high-current, such as Energy-Recovery Linacs (ERL) call for new cavity designs, optimized for High-Order Mode (HOM) damping. We report the design of a 703.75 MHz 5-cell elliptical beta=1 cavity which is specifically designed for very high current (over one ampere average current) applications.

The cavity is characterized by large iris apertures, 17 cm in diameter, and large beam tube diameter of 24 cm. All HOMs couple well out of the cavity into the beam pipe, where they will be damped by ferrite absorbers. This design has been pioneered for a single cell cavity for the Cornell 500 MHz storage-ring. The 5-cell cavity is the first one designed specifically for ERL applications. The cavity and cryomodule are being manufactured by Advanced Energy Systems. The work is a collaboration of BNL, AES and Jefferson Laboratory.

Ilan Ben-Zvi

The objective: Provide high-brightness, high-power electron beams.

10 mA is happening at JLAB, but 100-1000 mA requires a few new elements. We work on the development of

- Ampere class photoinjector
- Ampere class ERL cavity
- ERL to test the two elements above

Ampere-class defined: 3000 mA ≥I >300 mA

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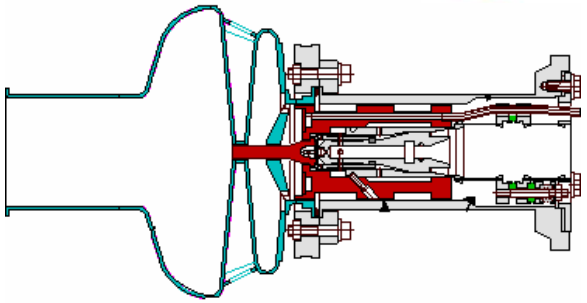
Motivation

- Ultra-high power FELs
- High flux and brightness ERL light-sources
- High luminosity electron-hadron colliders
- Electron cooling of hadron colliders
- Compton X-ray sources
- THz sources

The electron gun

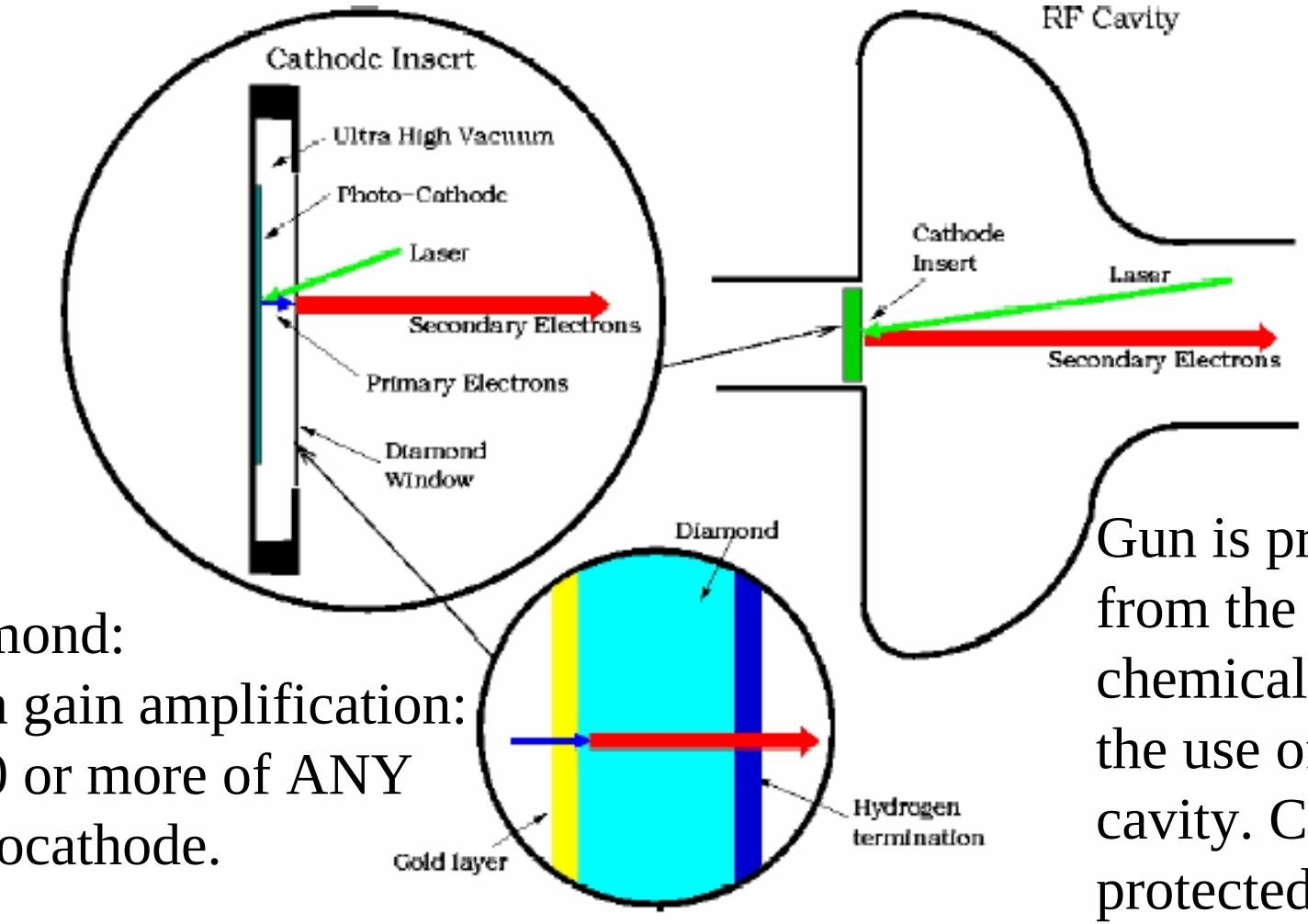
- We have an operational SRF gun, initial results gave 0.5 nC pulses.
- FZR demonstrated a gun with demountable cathode.
- The advantages of CW SRF photoinjectors are obvious.
- Question: How to provide an efficient cathode?



Photocathode and laser system: Arguably the critical challenge

- Cathode quantum efficiency – tied to the laser size and complexity.
- Cathode lifetime (contamination) and vacuum requirements.
- Gun contamination by cathode materials.
- Complicated load-lock mechanisms.
- Thermal emittance, promptness.

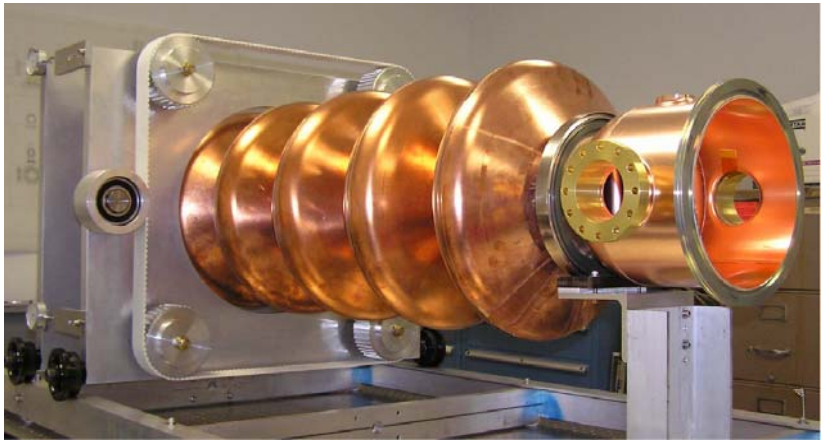
Schematic Arrangement of the System



Diamond:
High gain amplification: x100 or more of ANY photocathode.

Gun is protected from the cathode chemicals, enabling the use of an SRF cavity. Cathode is protected from gun.

The Ampere-Class ERL Cavity



Copper model of the
703.75 MHz high-current
ERL cavity.
The niobium cavity is under
construction

Objectives:

1. Low loss factor
2. High BBU threshold

Principles:

1. Low frequency elliptical cavity
2. Large iris (17 cm diameter)
3. Huge beam tube (24 cm dia.)
4. External ferrite HOM dampers

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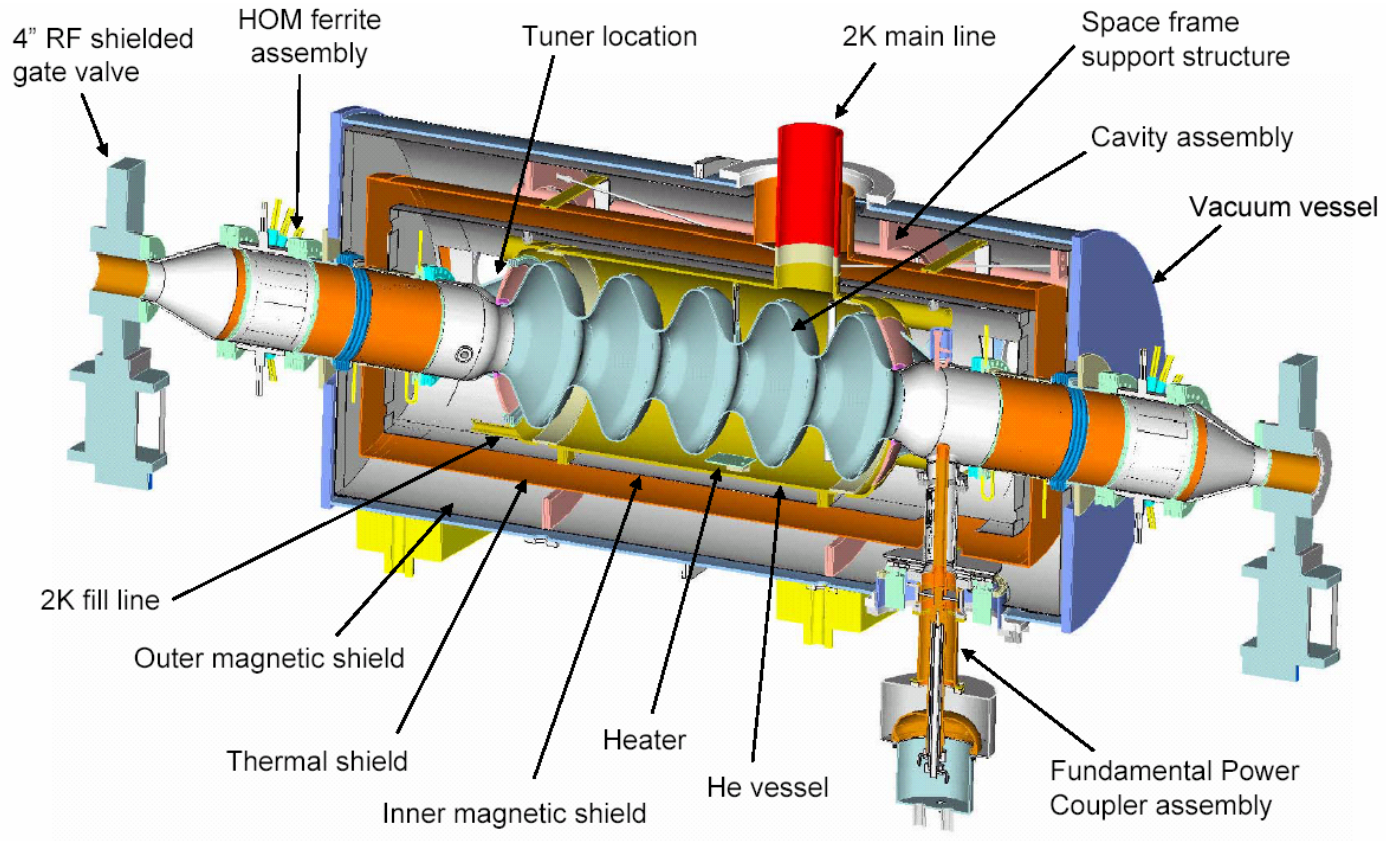
Cryomodule design passed Final Design Review



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Cavity parameters

Property	Units	Value
Frequency	MHz	703.75
E_p/E_a	-	2.0
H_p/E_a	mT/(MV/m)	5.8
R/Q	Ω	404
Geometrical factor	Ω	225
Cell-to-cell coupling	%	3
Expected unloaded Q	-	$2x10^{10}$
Dynamic power loss	Watt	44
External Q	-	$3x10^{7}$
Max. amplifier power	kW	50
1st Mechanical resonance	Hz	96
Lorentz detuning	$Hz/(MV/m)^2$	1.5
Loss factor	V/pC	1.2

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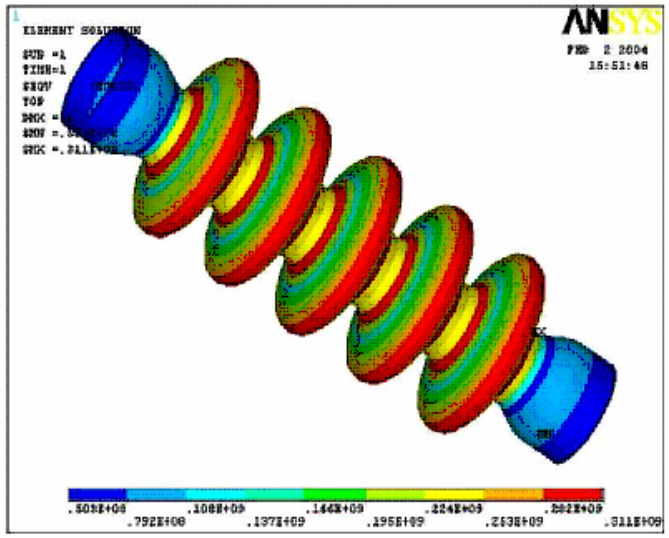
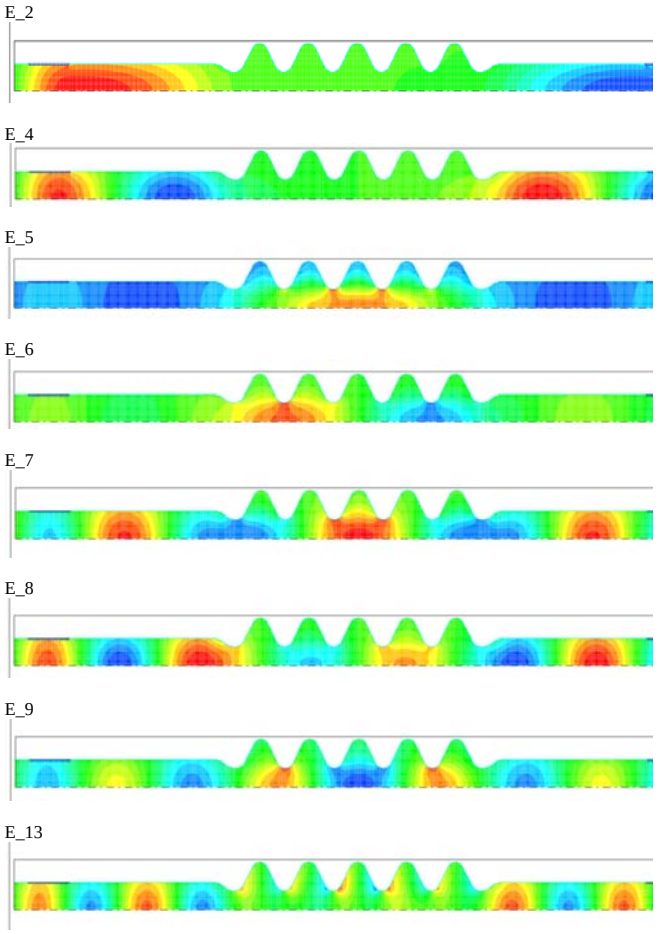
Detailed Computer Simulation



MAFIA:
All modes
well damped

ANSYS:
Cavity very
stiff. Lowest
mode (no
LHe tank)
is ~100 Hz



Other codes used:
BUILDCAVITY / SUPERFISH
ABCI, TDBBU, MATBBU

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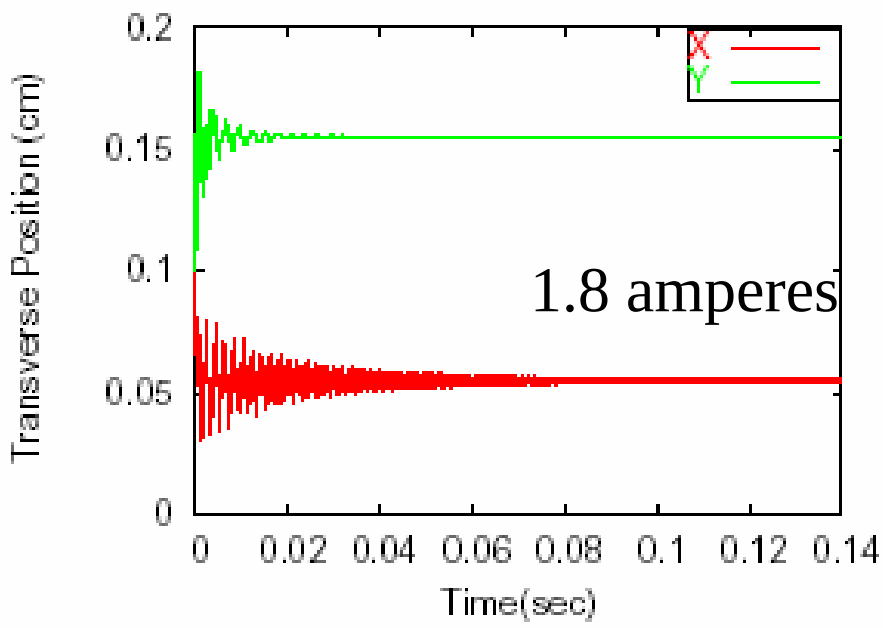
How to make a linac cavity capable of over 1 ampere?

- Good cavity / HOM design, using very large beam ports to guide HOM to ferrite absorbers.
- Design has excellent SRF cavity properties, low loss factor and high BBU threshold

TDBBU:



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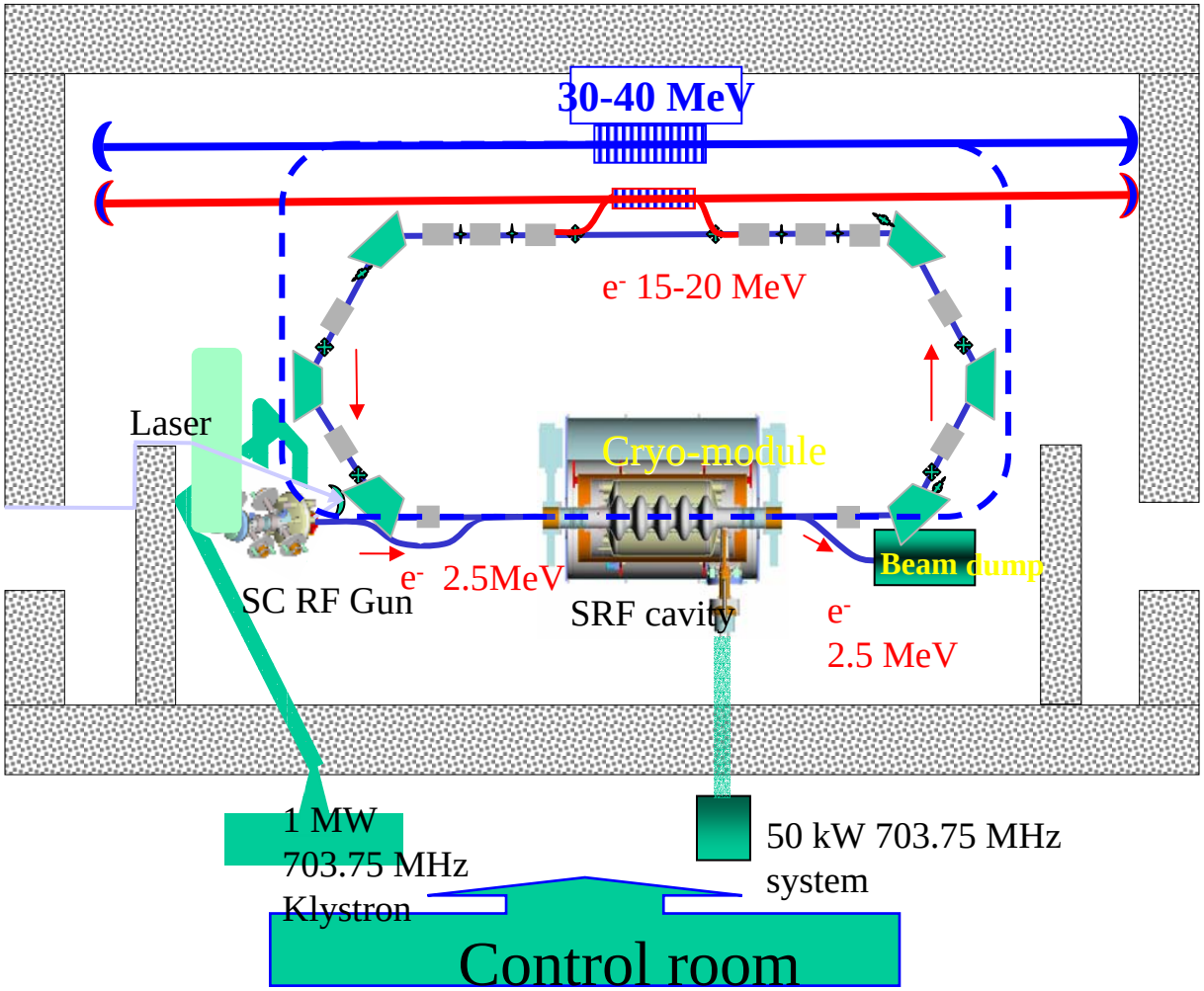
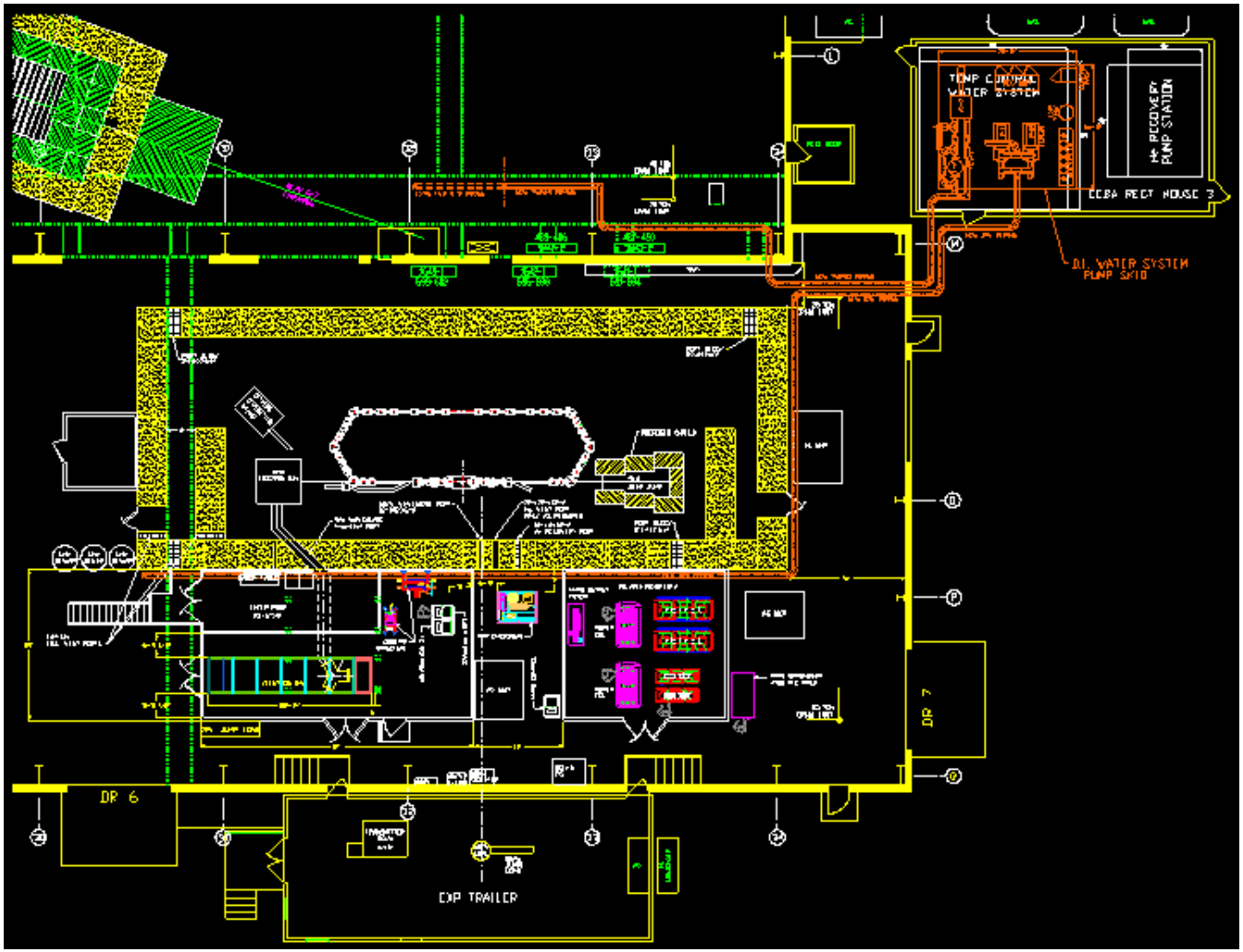
ERL Program

- The components described above will be used to construct a R&D ERL.
- **We plan to start commissioning of the R&D ERL in late 2006/early 2007**
- The prototype ERL will demonstrate the main parameters of the e-beam required for e-cooling
- The prototype will also serve as a test bed for studying issues relevant for very high current ERLs and high power FELs


30-40 MeV
e- 15-20 MeV
Laser
Cryo-module
Beam dump
e- 2.5MeV
SC RF Gun
SRF cavity
e-
2.5 MeV
1 MW
703.75 MHz
Klystron
50 kW 703.75 MHz
system
Control room

Shielding

50 kW amplifier



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Conclusions

- A new SRF β=1 5-cell linac cavity has been designed and is under construction.
- The cavity is aimed at ampere class ERLs.
- SRF tests f the cavity will take place next year.
- Testing of the cavity current performance will be done with the help of
  - Ampere class SRF photoinjector
  - Diamond amplified photocathode
  - ERL incorporating the photoinjector and linac cavity
- The goal of commissioning ERL is late 2006 / early 2007.