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Polarized gun and ERL R&D for eRHIC

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DISCLAIMER

Polarized Gun and ERL R&D for eRHIC

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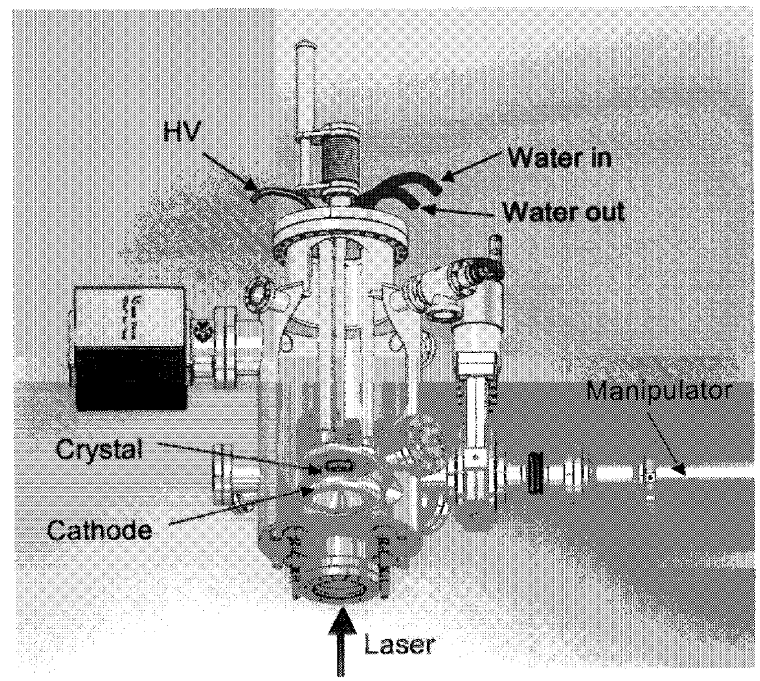
The State-of-the-Art in Polarized Electron Sources

- At Jefferson Laboratory charge density and charge lifetime during electron beam delivery are over $2x10^5$ C/cm^2 and 200 C, respectively. A 200 C charge lifetime at 2 mA corresponds to 10^5 seconds. In a more recent result, charge lifetimes of about an order of magnitude larger were achieved by a load-lock gun with a larger cathode area (Poelker).

Question: How to reach 50 mA polarized beam with decent lifetime?

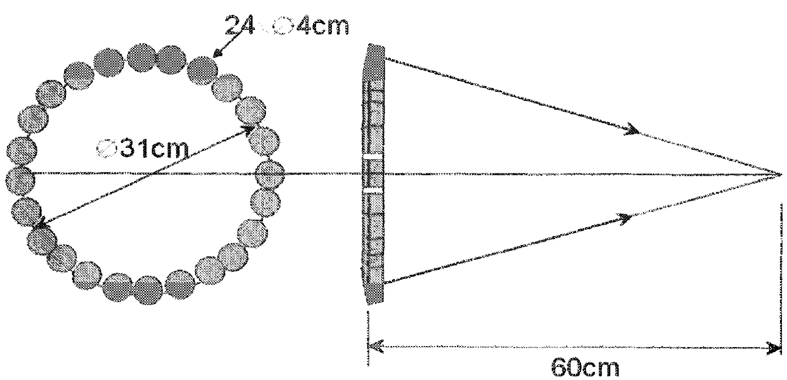
- MIT/Bates is pursuing a large area cathode with cooling aimed at 50 mA.
- Current state-of-the-art in superlattice cathodes is >1 mA
  Lifetime Measurements of High Polarization Strained Superlattice Gallium Arsenide at Beam Current >1 Milliamp Using a New 100kV Load Lock Photogun, J. Grames, et al, Proceedings of PAC07
- Funneling beams is an old technique Beam-Dynamics Design and Performance of the RF Deflector in the Los Alamos Single-Beam Funnel Experiment, F. W. Guy, et al, Proceedings PAC 91.

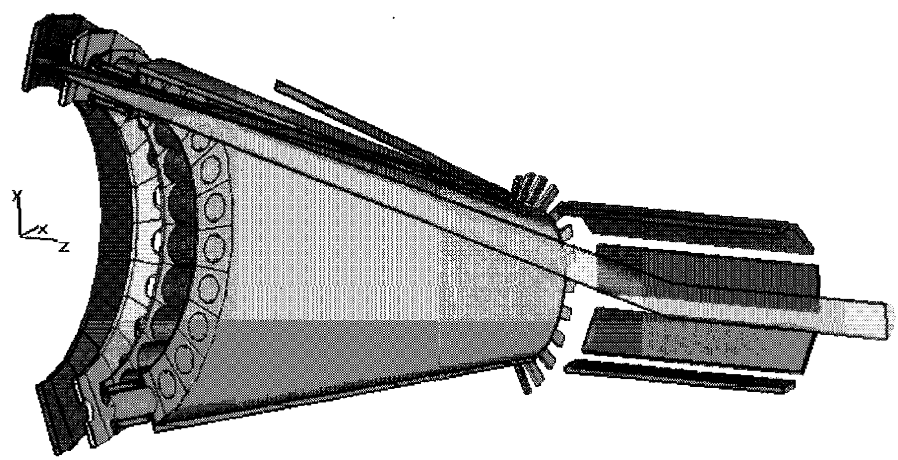


MIT Phase I design
G. Tsentalovitch

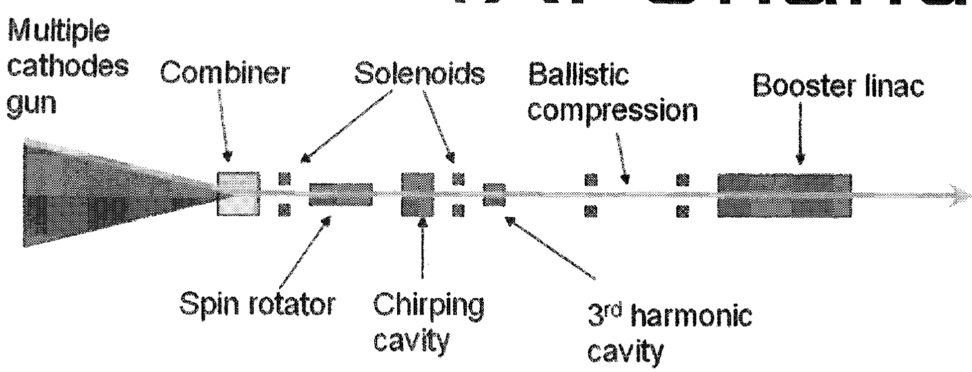
The "Gatling Gun" funnel approach (V. Litvinenko)

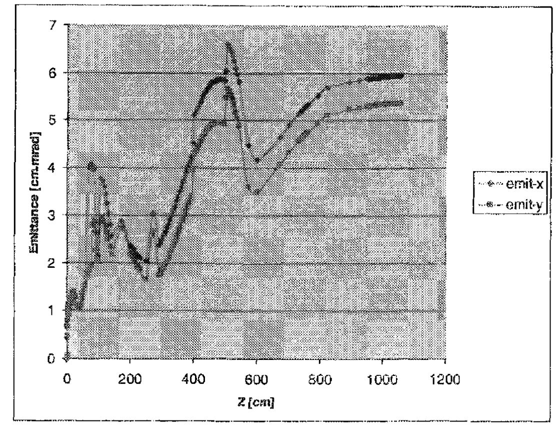
- A "safe" approach is to assume currently demonstrated performance (~2 MA) per cathode, and funnel beams from multiple cathodes.



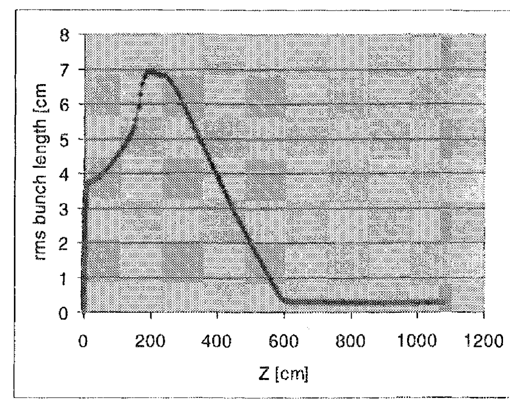


Beam Dynamics of the Gatling Gun (X. Chang)

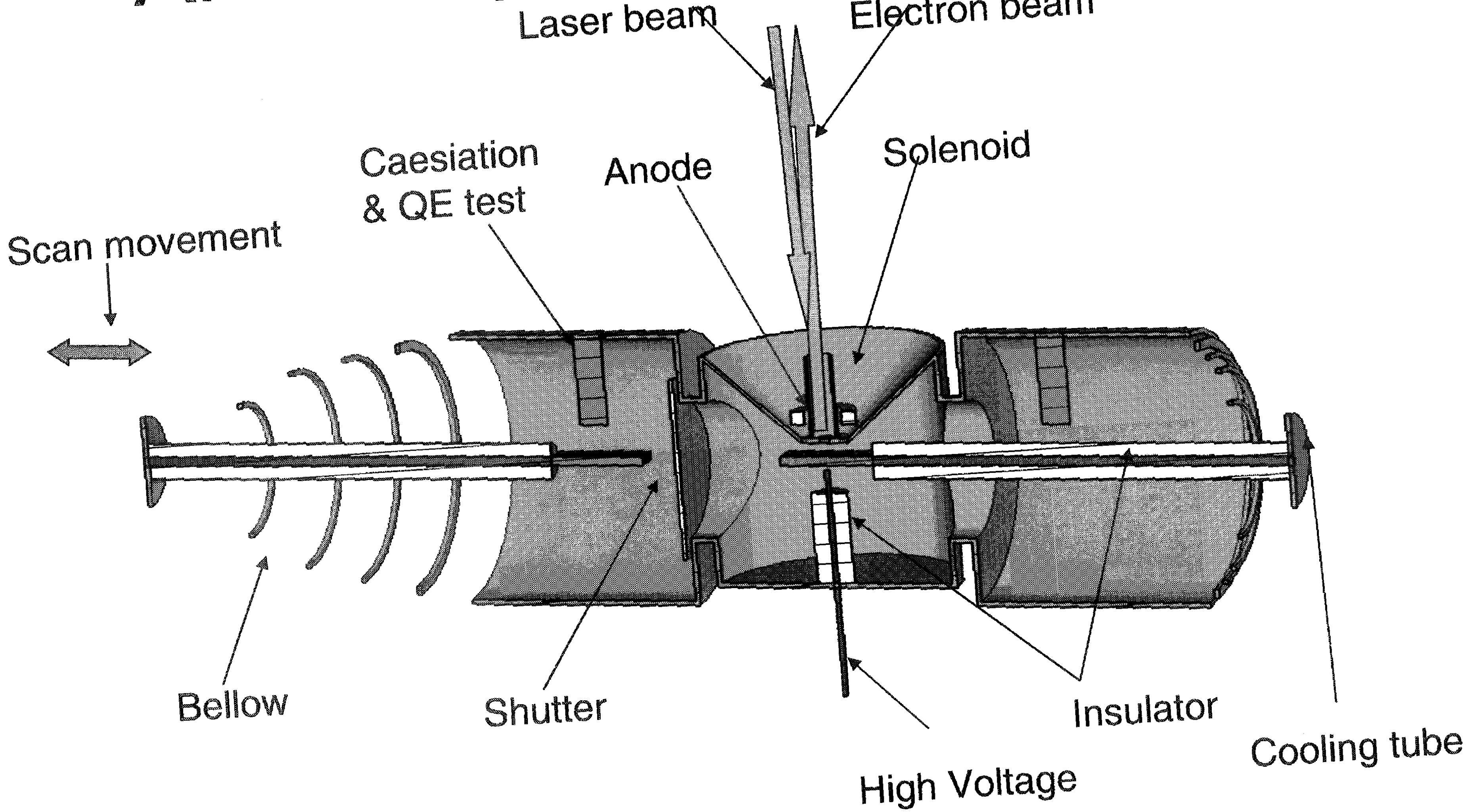




Parameter	Units	Value
Bunch charge	nC	5
Laser spot diameter	mm	8
Laser longitudinal distribution		Gaussian
Laser transverse distribution		Uniform
Laser pulse length	nS (FWHM)	0.5
Accelerating voltage	kV	200
Cathode-anode gap	cm	3
Integrated solenoid field	kG-cm	2.1



Another possible approach

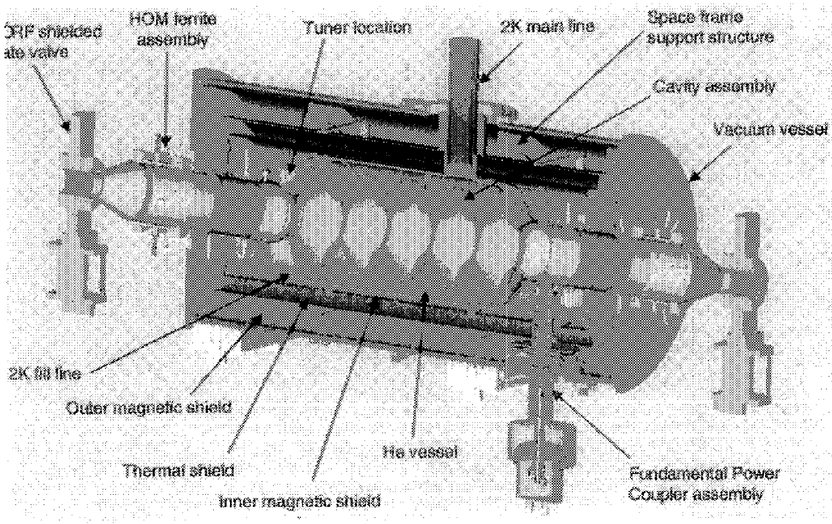


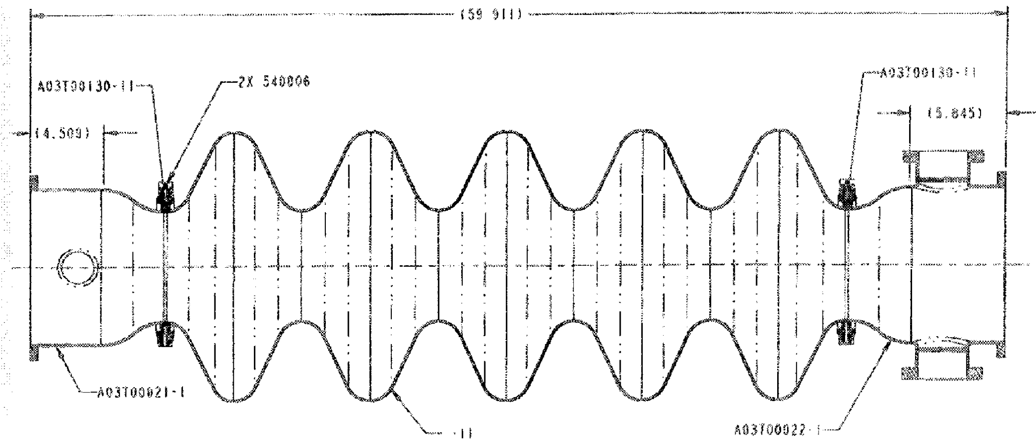
The ERL: The challenge of HOM (Higher Order Modes)

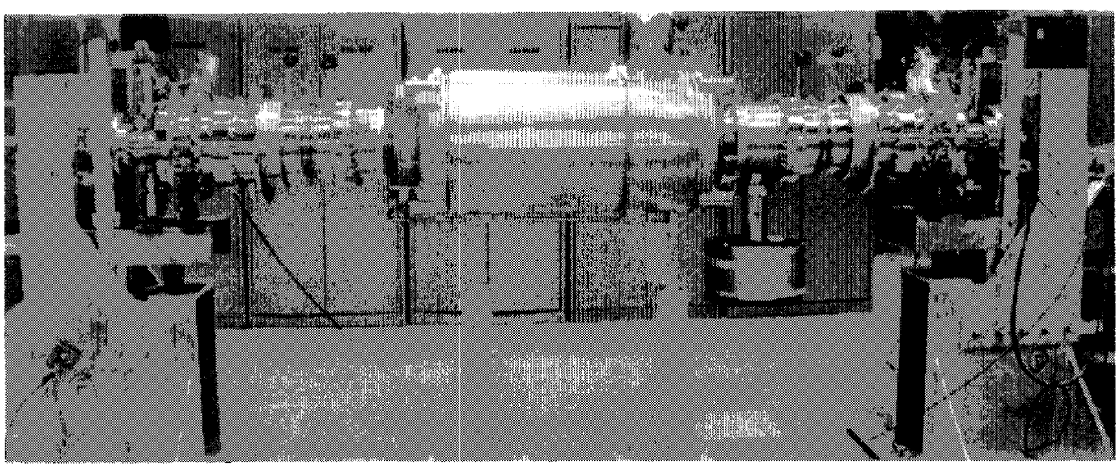
$$P_{HOM} = 2\, I \theta \kappa_{\lambda}$$

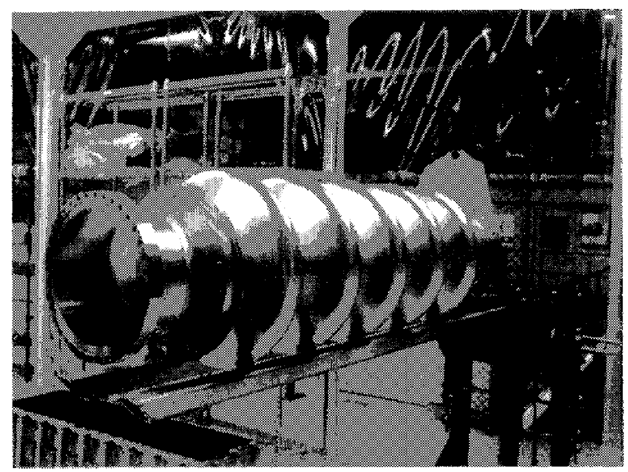
$$k_l \approx \frac{\Gamma(0.25)\, Z_0 \chi}{4\pi^{2.5}} \frac{1}{\alpha \sqrt{\dfrac{\delta N}{\sigma}}}$$

A Prototype eRHIC Cavity





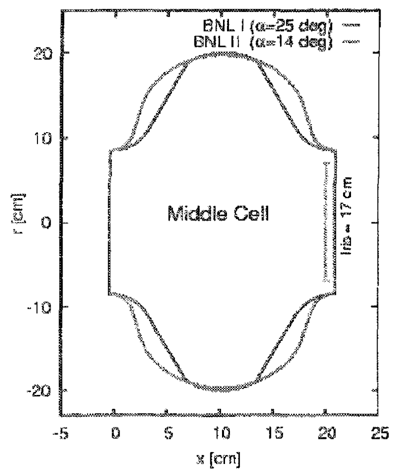


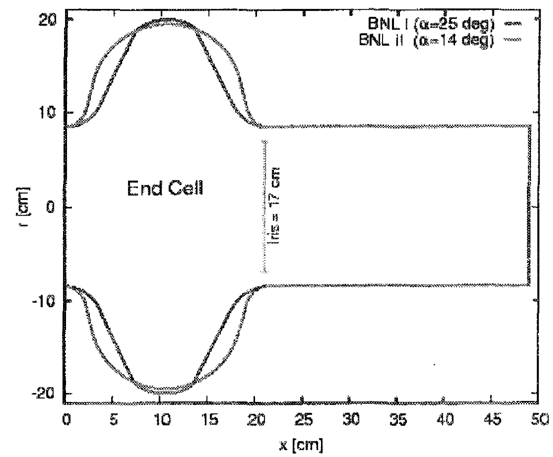


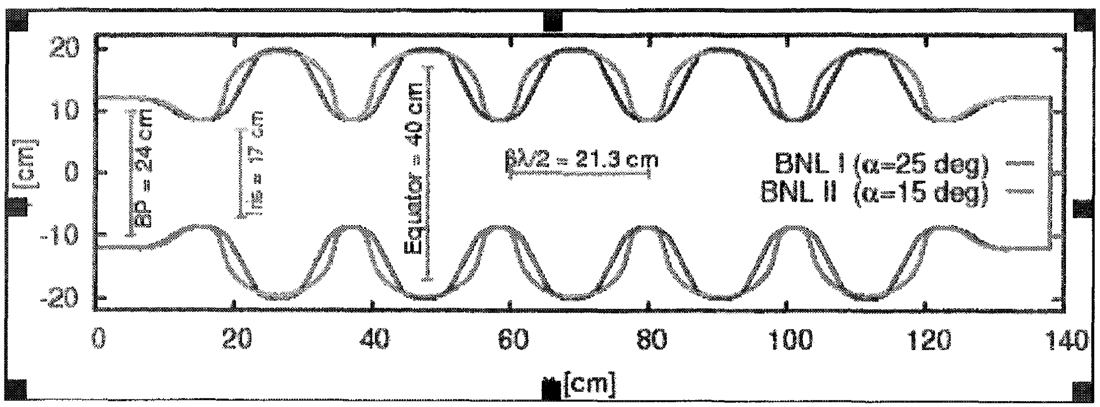
Cavity Parameters

Parameter	Unit	BNL 1(HC)	BNL 2 (HC)	CEBAF(HG)	TESLA(HG)
Frequency	[MHz]	703.75	703.75	1497	1300
Number of cells	-	5	5	7	9
$(R/Q) * G$	$[\Omega^2]$	9×10^4	9.69×10^4	2.1×10^5	2.8×10^5
E_p/E_a	-	1.97	2.36	1.96	1.98
H_p/E_a	$[mT/MV/m]$	5.78	4.76	4.15	4.15
Cell to cell coupling (k_{cc})	-	3%	4.68%	1.89%	1.87%
Sensitivity Factor ($\frac{N^2}{\beta k_{cc}}$)	-	8.3×10^2	5.3×10^2	2.6×10^3	4.1×10^3
Field Flatness	-	97.2%	97.3%	97.5%	95 %
Lorentz detuning coeff.	$[Hz/(MV/m)^2]$	1.28 (UnStiff)	NE	2	1

New Cavity Design
(R. Calaga)

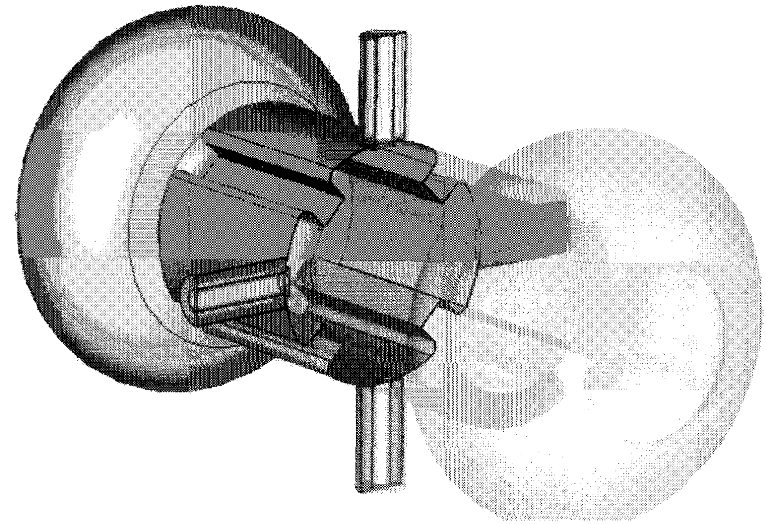


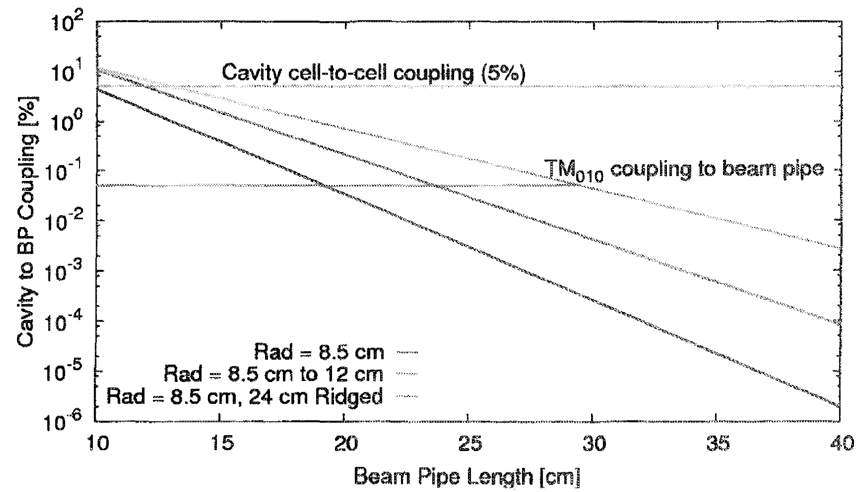




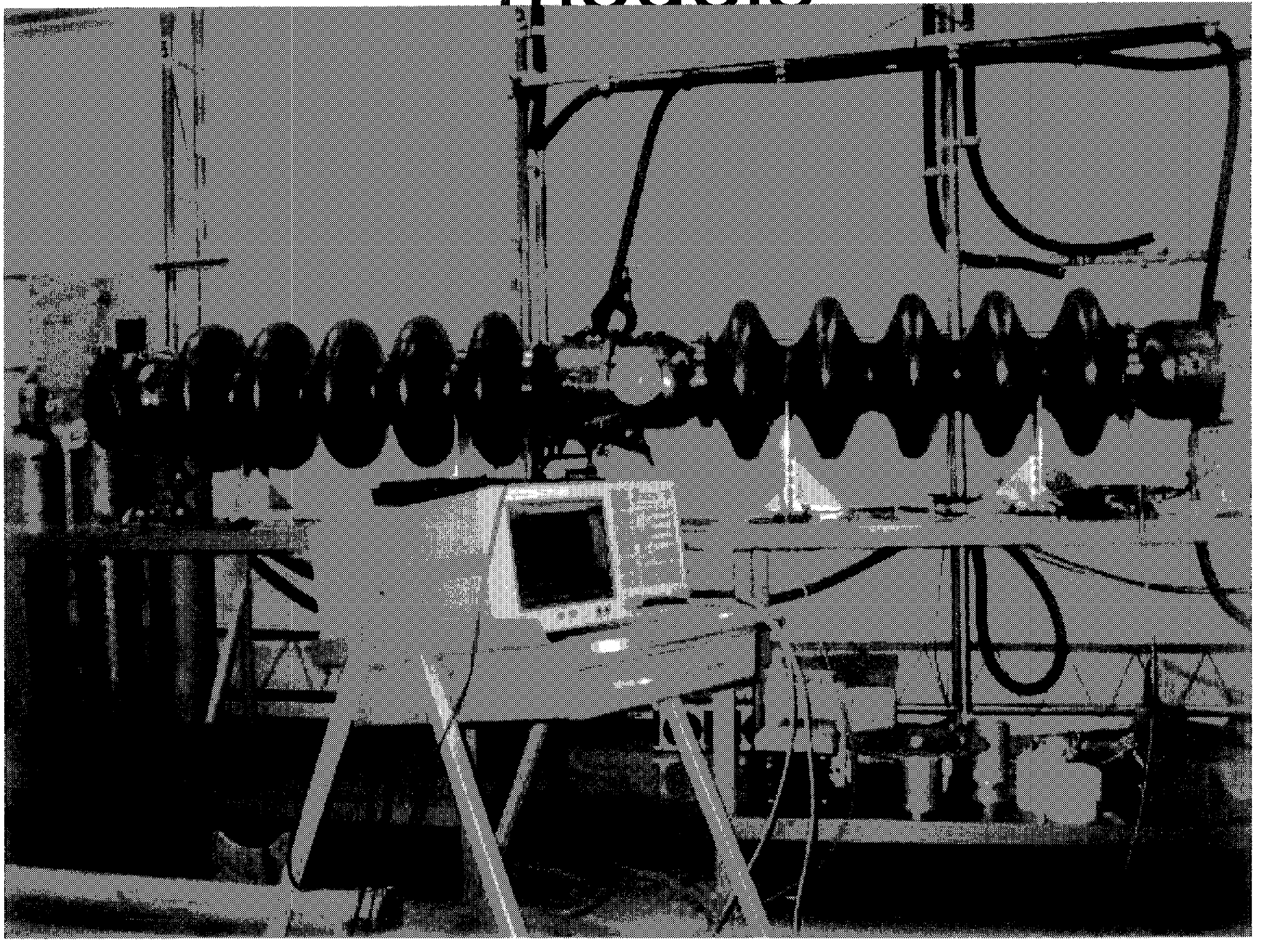
The goals of the new design

- Reduce peak surface magnetic field.
- Reduce stiffness.
- Apply new ideas in HOM damping.
- Reduce ration of evanescent fundamental to propagating HOM in beam tubes.

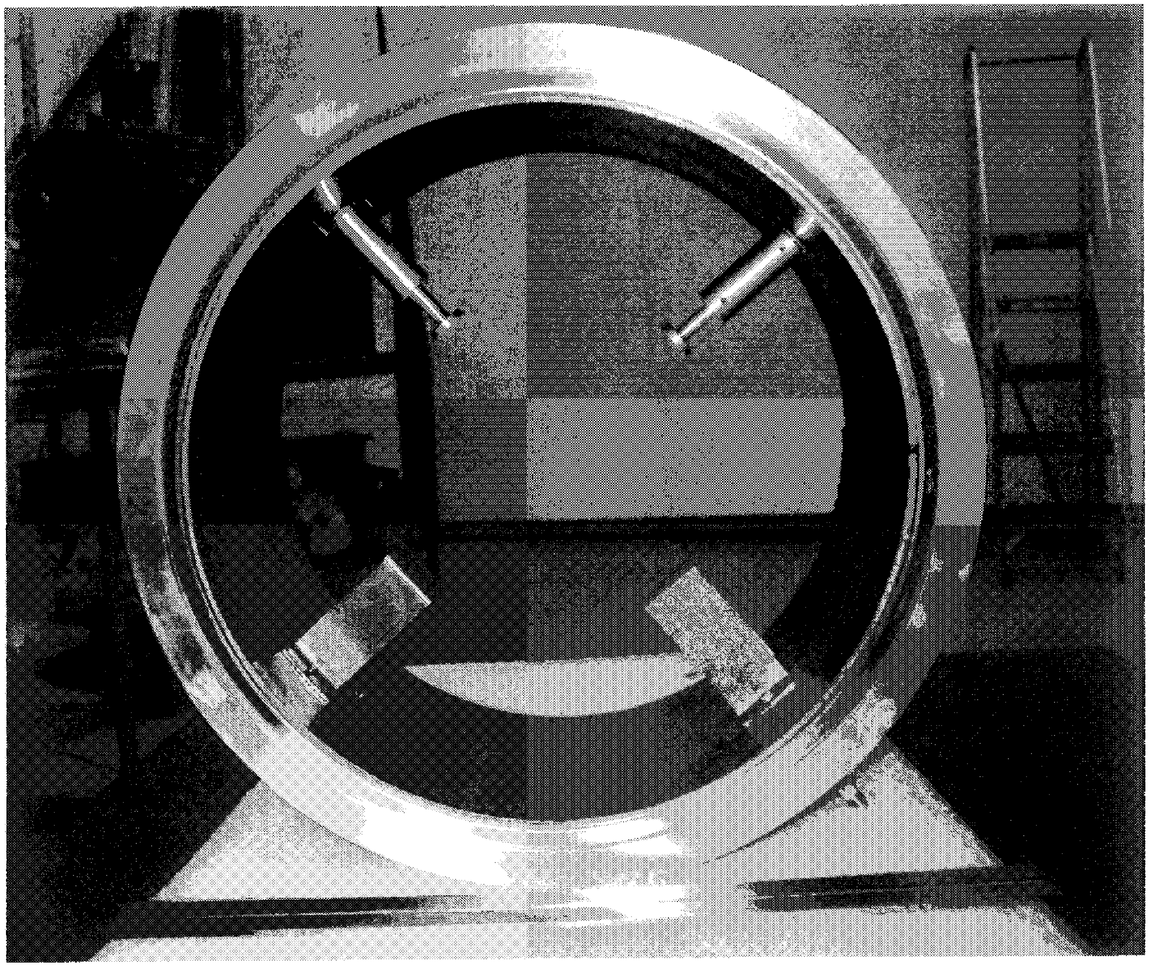




Measurements on copper models



HOM probes insert



HOM damping

- All HOMs couple well to the beam tube.
- The fundamental is attenuated in the tube.
- Thus one can preferentially damp the HOMs.
- In BNL I, this damping is done with ferrites.
- In principle, one can use pick-up probes in the beam tube to damp the HOMs.
- Thus, one may combine the advantages of the probes with the attenuation of the fundamental achieved in the BNL I cavity.

Preliminary damping measurements (Harald Hahn)

f [MHz]	Q (ECX)	R/Q [Ω]	Q (wo)	Q{left}	Q{right}	Q {BPM}
808.06	870	0.06	24880	8120	8300	8700
808.69			23750	8680	6300	17500
809.26			23350	8750	?	9330
824.33	330	0.76	19500	11500	8860	11750
					2100	8440
845.85	143	4.3	14900	3270	?	3760
866.1		43.91	11400	1453	1075	2780
882.9		74.35	12250	2330	1700	3120
900.79		13.76	8850	276	4700	6910
958.82		0.01	32700	22100	28600	30350
958.98		0.01	34800	33100	32300	
964.23		0.62	16100	5200	23700	18400
965.51		? 13.14	29900	26160	18400	
973.55		? 13.44	3470	1540	1720	2870
977.58	921	6.5	21100	9520	9500	10300
984.33			2030	960	1214	1850
995.01	331	0.1	11200	1600	1390	9200
999.56			4050	1599	740	1128

Coupling of the fundamental to the HOM probes

The purpose of the dampers is the reduction of HOMs, but they interact unavoidably with the fundamental mode.
As a result, the damper has an “external Q”. The unloaded O_0 of the cavities is ~28500 at resonance.
A direct way of measuring Q_X consist in establishing critical coupling in the respective cavity and finding the S21 to the damper, from which follows

$$Q_x = Q_0 / S_{21}{}^2$$

The measured results are listed in Table 3.3, with the Q_X of the dampers around .
Values at this level indicate low power loading of the notch filters. At 20 MV/m a Q of 10^8 corresponds to 10 kW.

Damper	(linear)	(left)	(linear)	(right)
top	22.46 E-3	0.55 E8	20.86 E-3	0.63 E8
front	13.38 E-3	1.54 E8	21.25* E-3	0.61 E8
Probe back	11.55 E-3	2.06 E8	8.413 * E-3	3.9 E8
Probe down	9.62 E-3	3.0 E8	12.67 E-3	1.7 E8

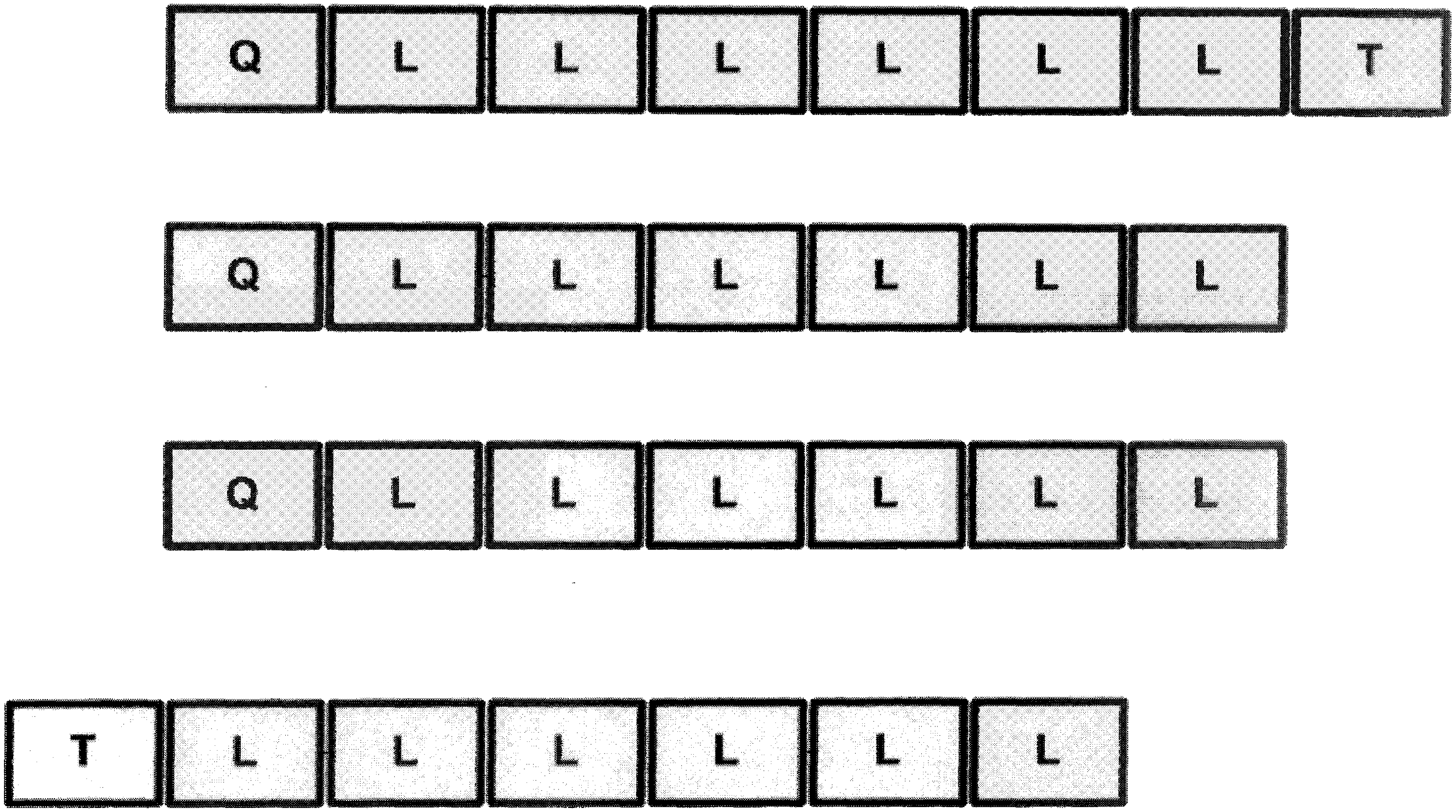
Cross coupling of the two cavities

- Cross coupling between cavities must be considered in the design of the RF control system.
- Cross coupling is given as the signal level in the neighboring cavity with respect to the level of the excited cavity.
- The result of the measurement:
  - without spacer (cavities connected directly) 27 dB
  - with the addition of the 5 in. spacer, 42 dB.

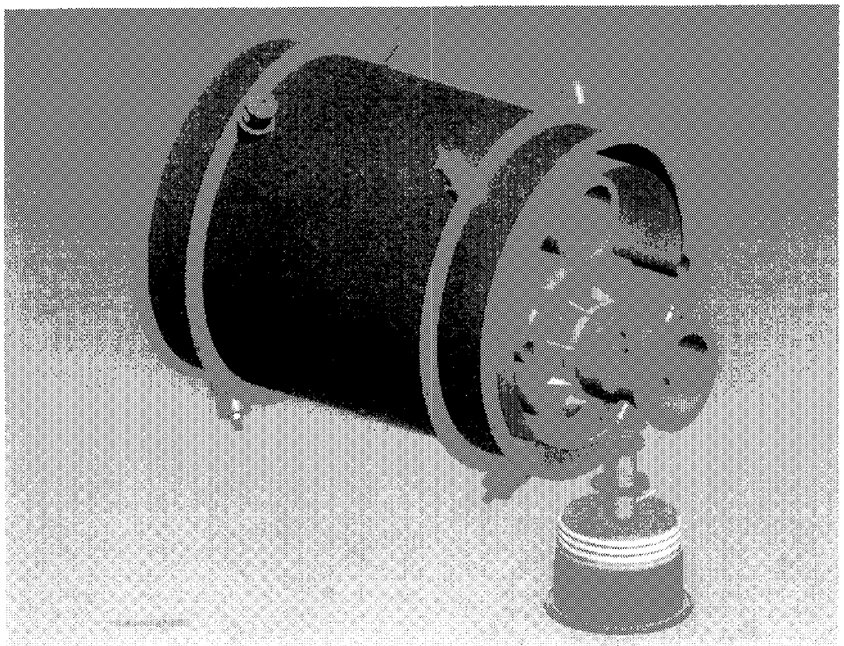
Really modular cryomodule?

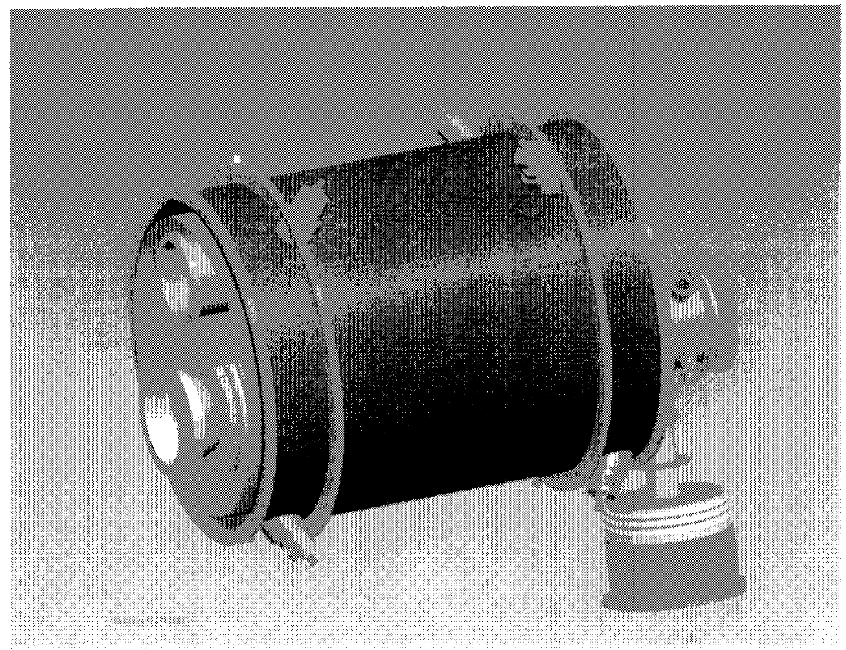
- For efficient real-estate gradient, keep the linac at 2K all along the machine.
- For easy assembly, alignment, interconnections and removing HOM power, assemble a single cavity in a cryomodule unit, to be designated as an "L" unit.
- Quadrupole units , or "Q" units, will house quadrupole lenses, helium connections and beam instrumentation.
- A termination unit, or "T" unit, connects to romm temperature at each end.

Linac structure

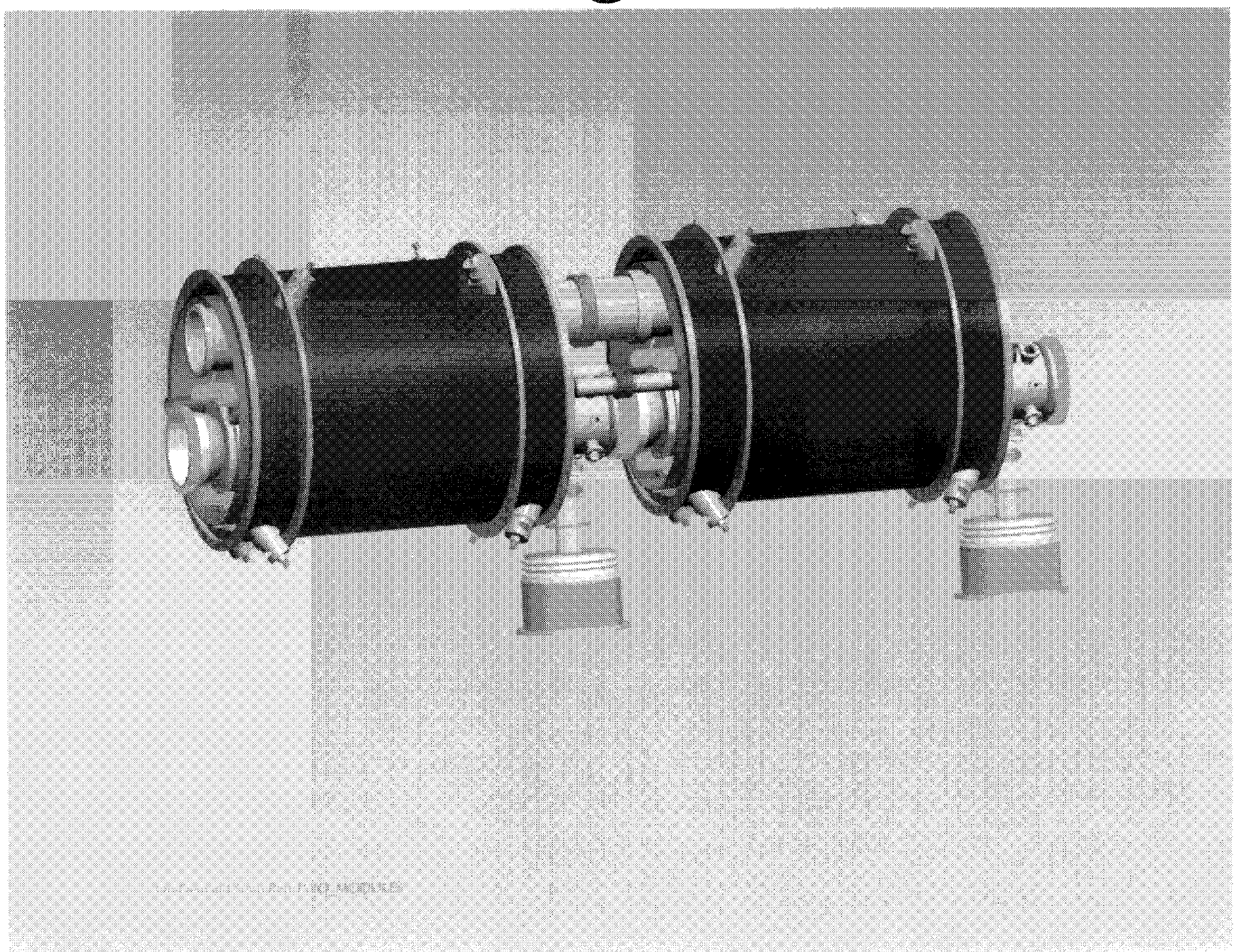


A single L unit

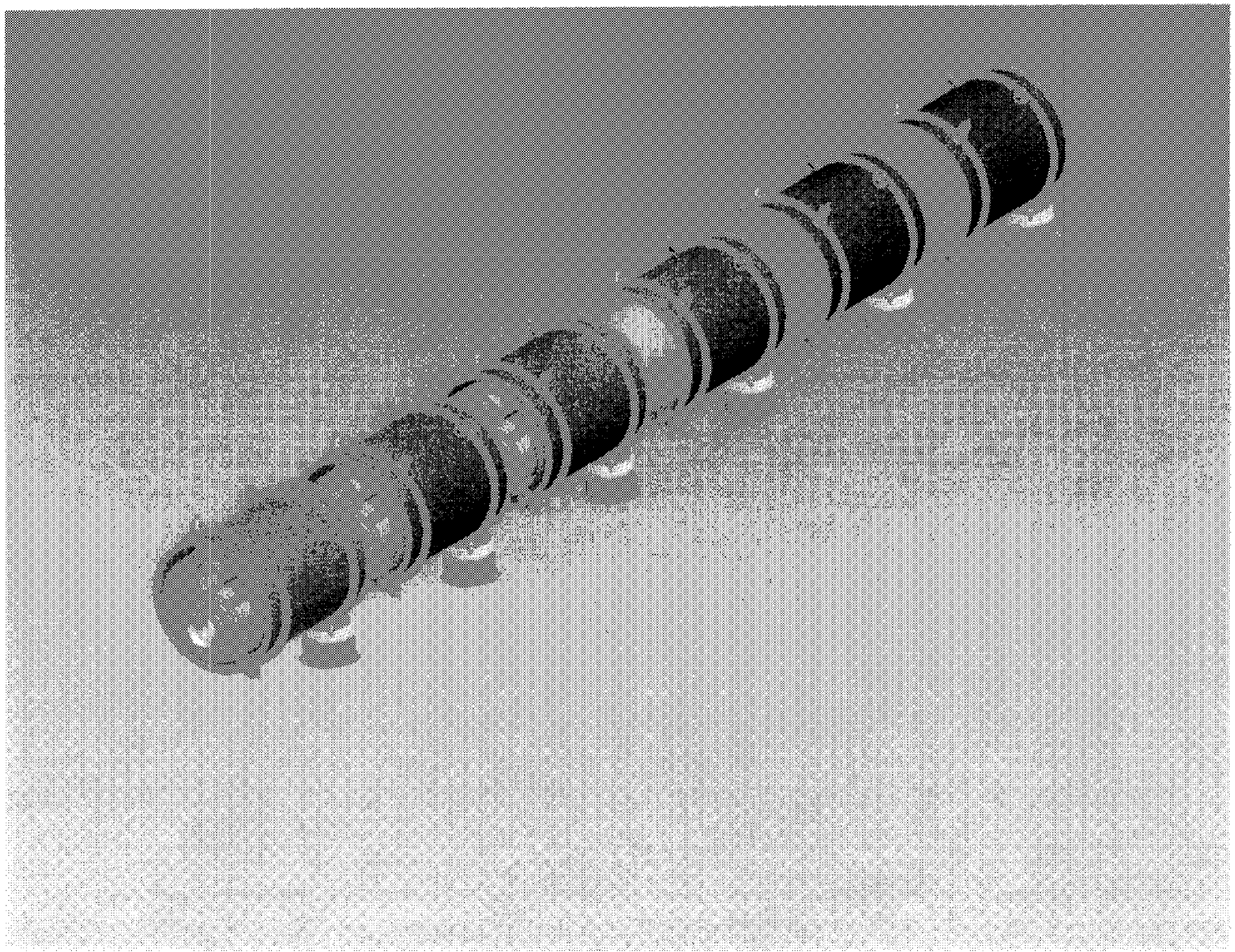




Connecting two L units



A string of "L" units, some joined



Work on 704 MHz connections

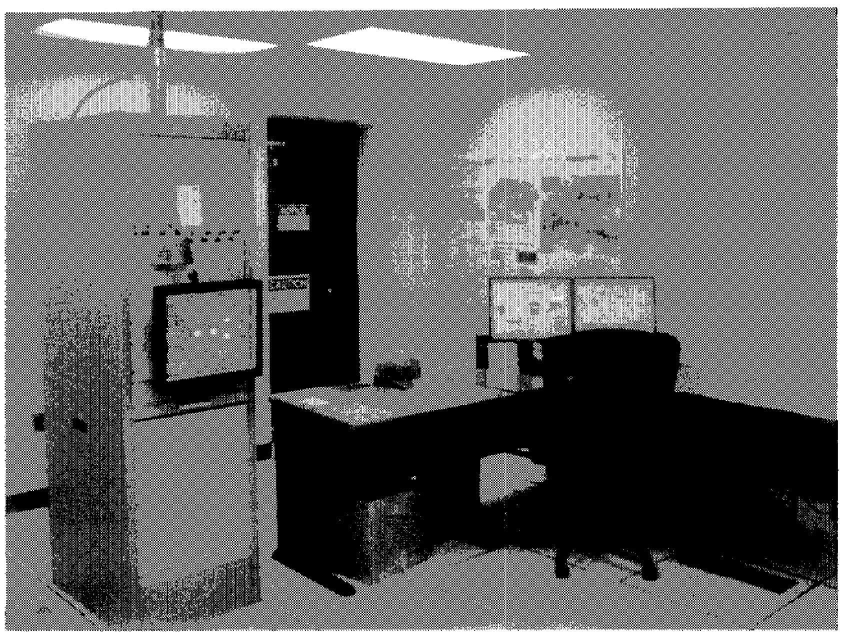
"Dry-tent" technique at Berkeley's ALS

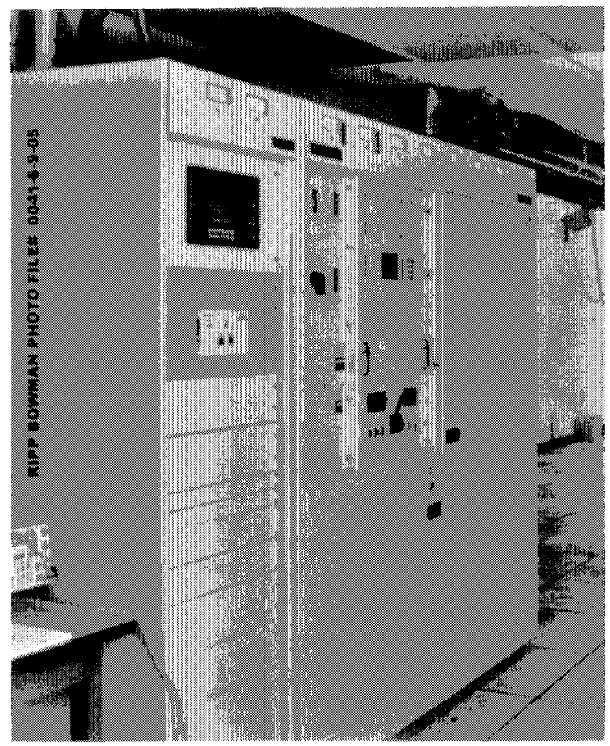
R&D ERL

- eRHIC will have a very high current (as the current is multiplied by the number of passes)
- It is important to investigate accelerator physics issues in a high-current ERL:
  - Bean breakup
  - Generation of HOM power
  - Coherent radiation effects
  - Non-intercepting diagnostics
- For these reasons, and others, we are constructing the R&D ERL.

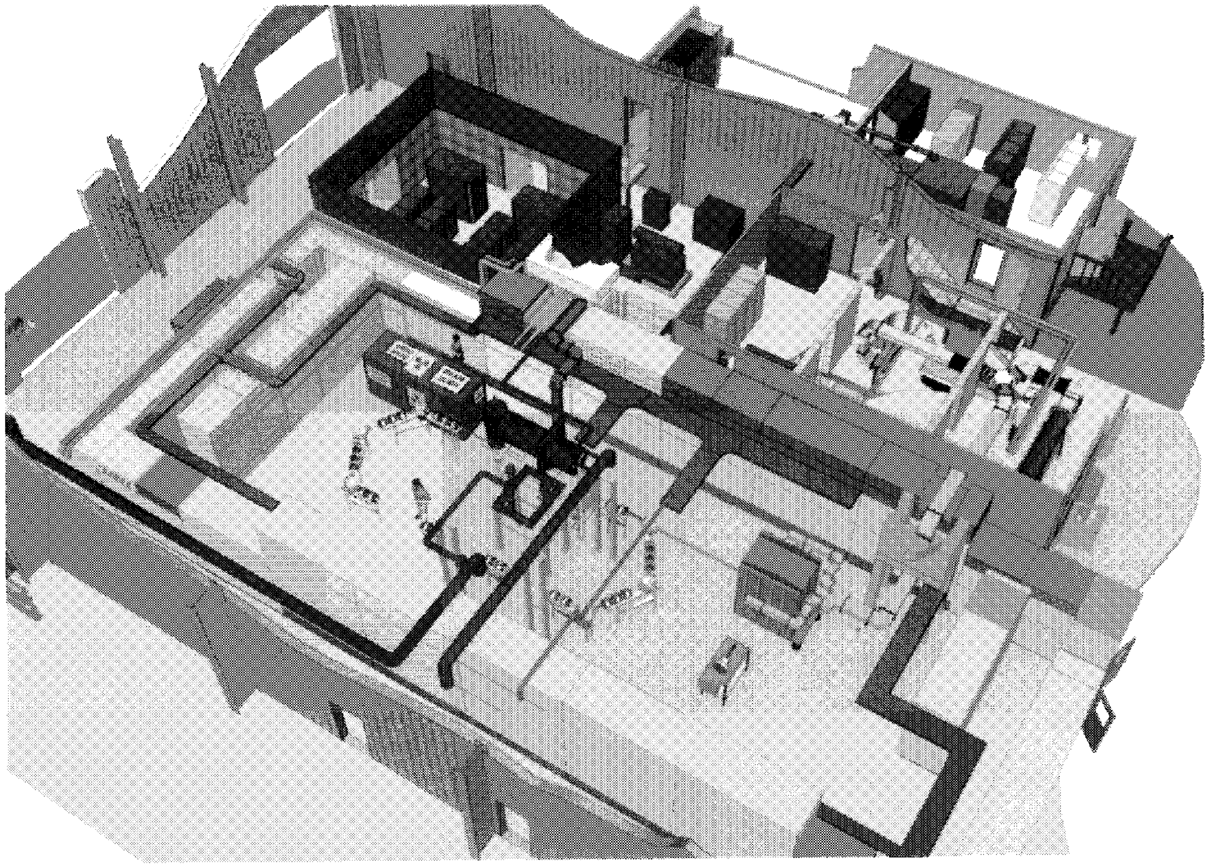
Status of the R&D ERL

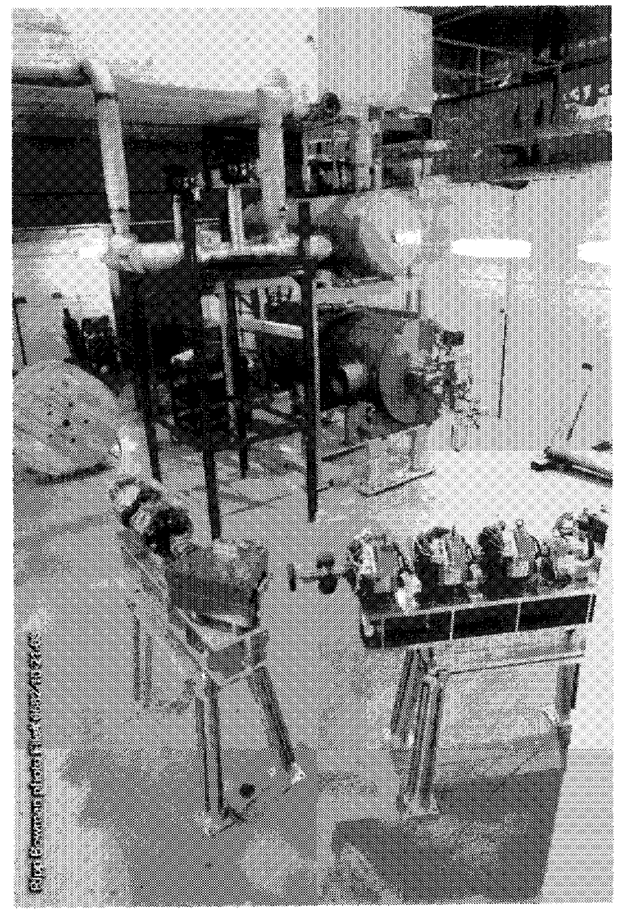
- The ERL is in an advanced stage of construction
- Beam will be generated next year





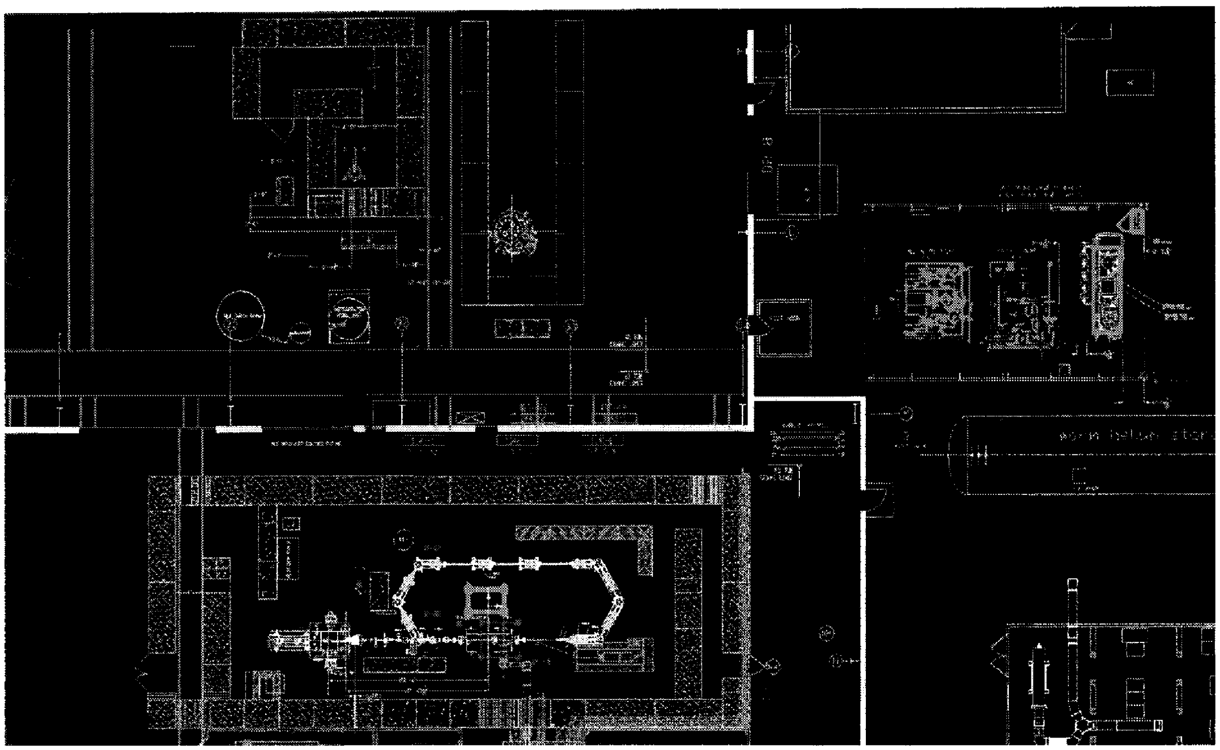
The R&D ERL layout

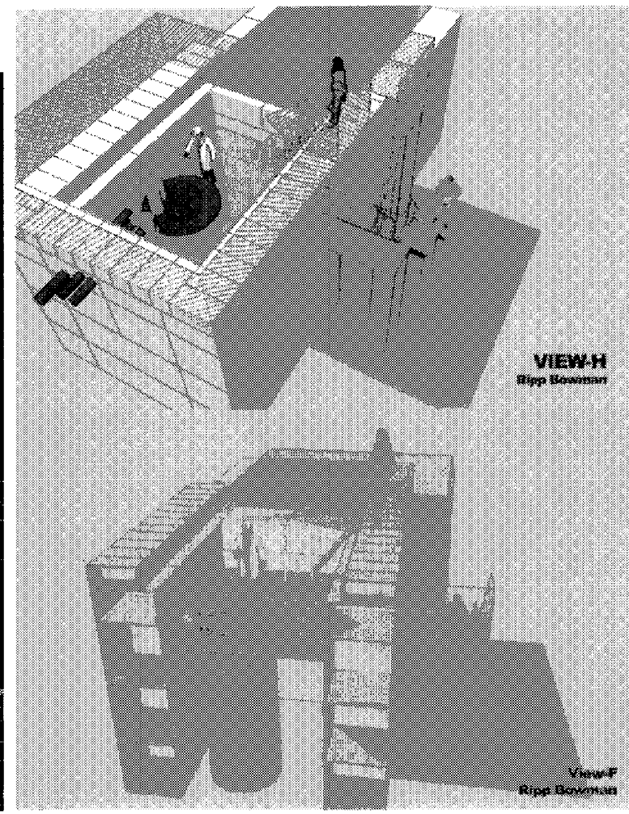




The R&D ERL and VTF Layout

- Dewar 38" diameter 96" working depth RF systems from 56 – 1300 MHz
- LHe refrigerator with 360 W capacity, 1000 gallon storage dewar
- Liquid ring pump for operation to 1.8K



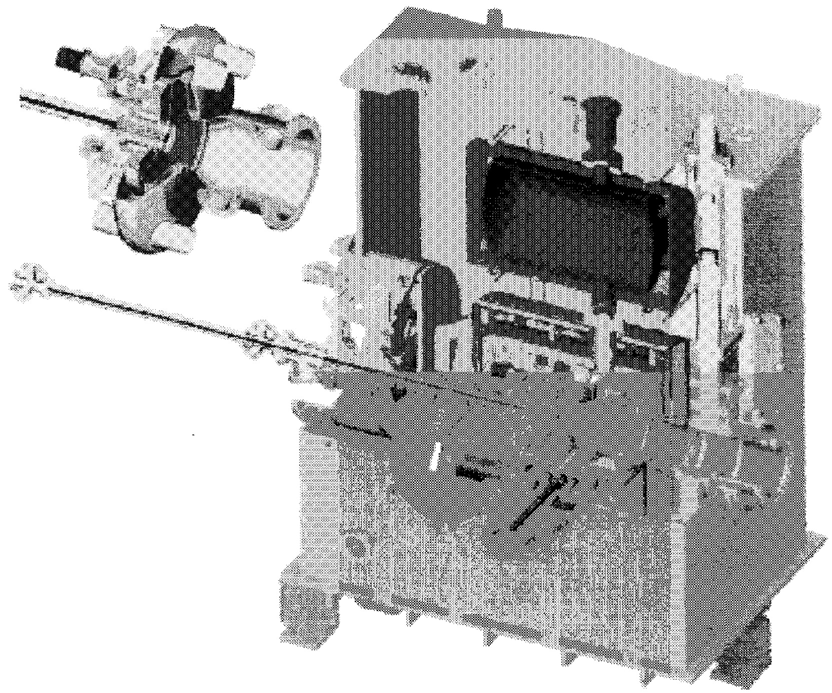


ERL Beam Parameters

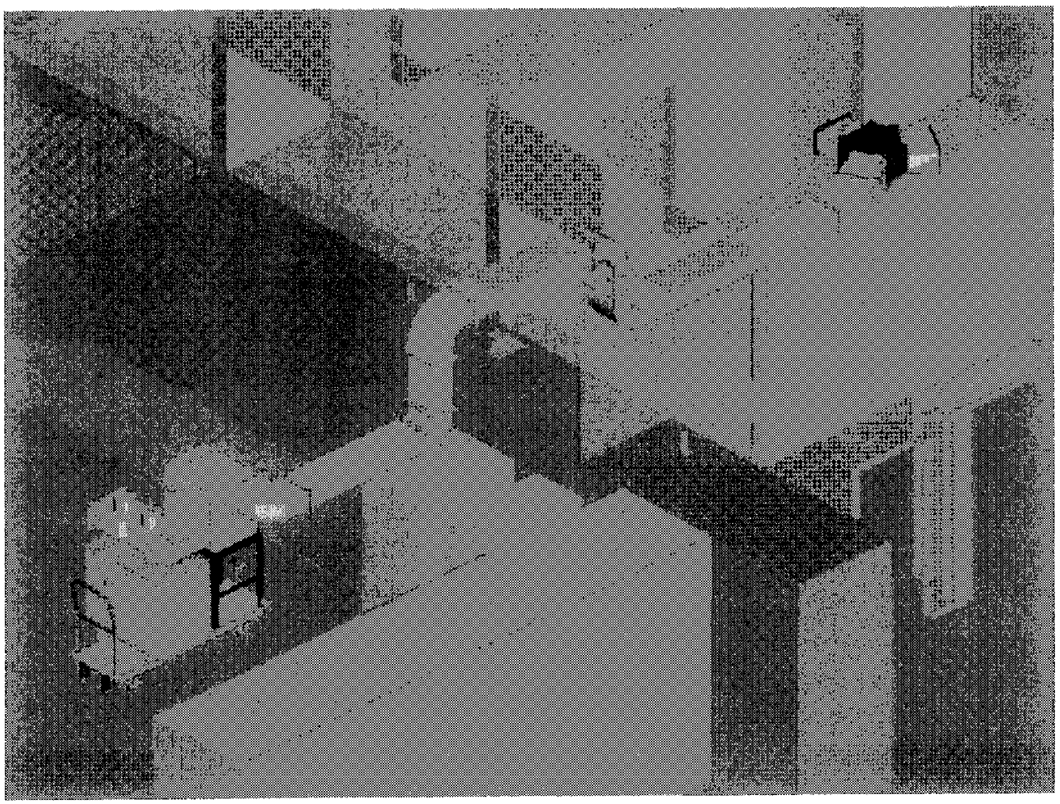
	High Current-A	High Current- B	High charge
Charge per bunch, nC	0.7	1.4	5
Numbers of passes	1	1	1
Energy maximum/injection, MeV	20/2.5	20/2.5	20/3.0
Bunch rep-rate, MHz	704	352	9.383
Average current, mA	500	500	50
Injected/ejected beam power, MW	1.0	1.0	0.15
R.m.s. Normalized emittances ex/ey, mm*mrad	1.4/1.4	2.2/2.3	4.8/5.3
R.m.s. Energy spread, $\delta E/E$	3.5×10^{-3}	5×10^{-3}	1×10^{-2}
R.m.s. Bunch length, ps	18	21	31

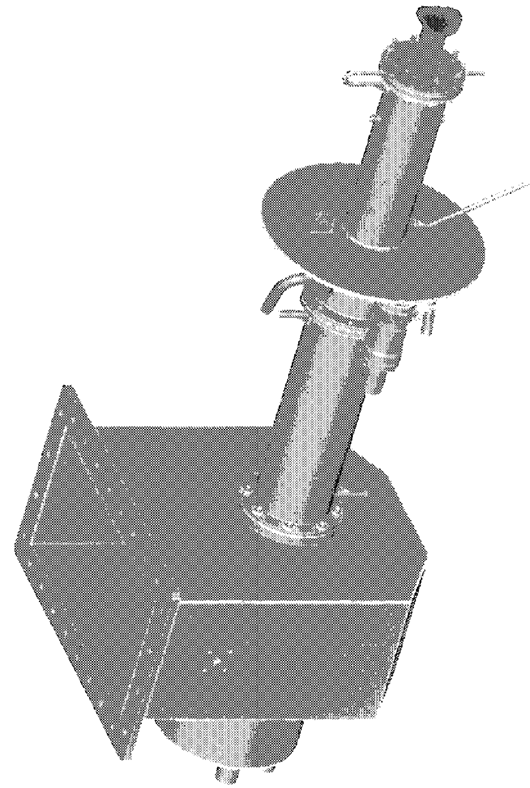
1/2 Cell SRF Injector

- ½ Cell SRF injector
  - Demountable cathode stalk
  - HTS Solenoid
- UHV cathode transporter carts
  - 2 fabricated and delivered
  - Testing to begin soon



0.5 MW CW Coaxial Coupler (one of two) and Conditioning Cart





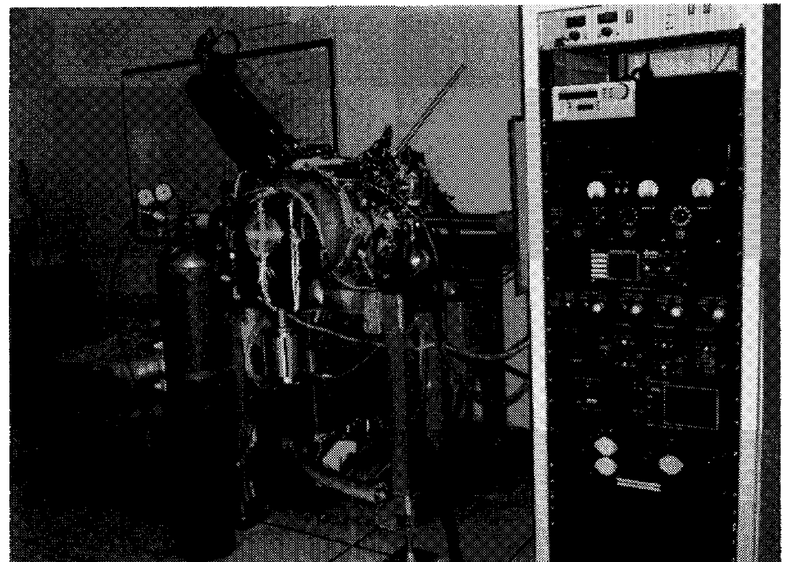
Photocathode Preparation

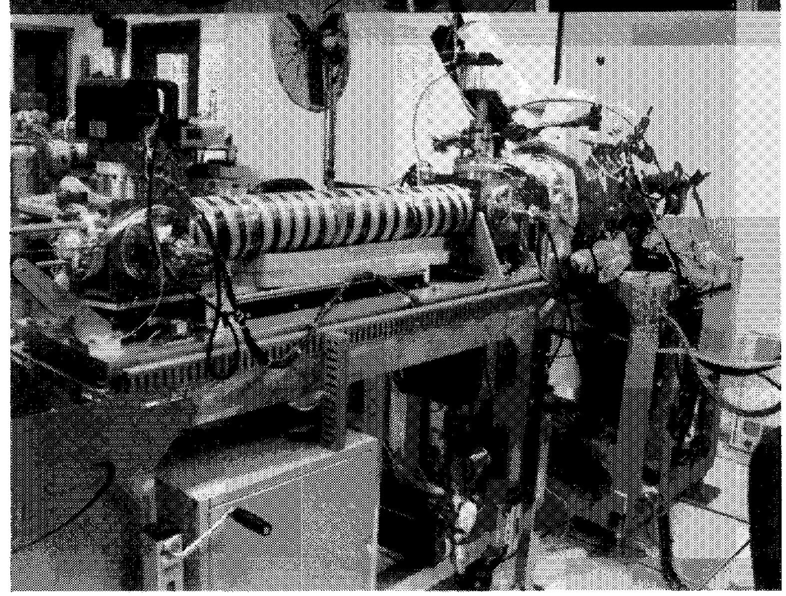
Deposition System in house

- 2 transporter carts delivered
- Base pressure 1x10^{-10} Torr
- System designed to eliminate cross contamination of sources
- Provides for quicker source exchange

Transporter cart

- 2 UHV systems with LN_2 cooling capability
- Baking to improve vacuum



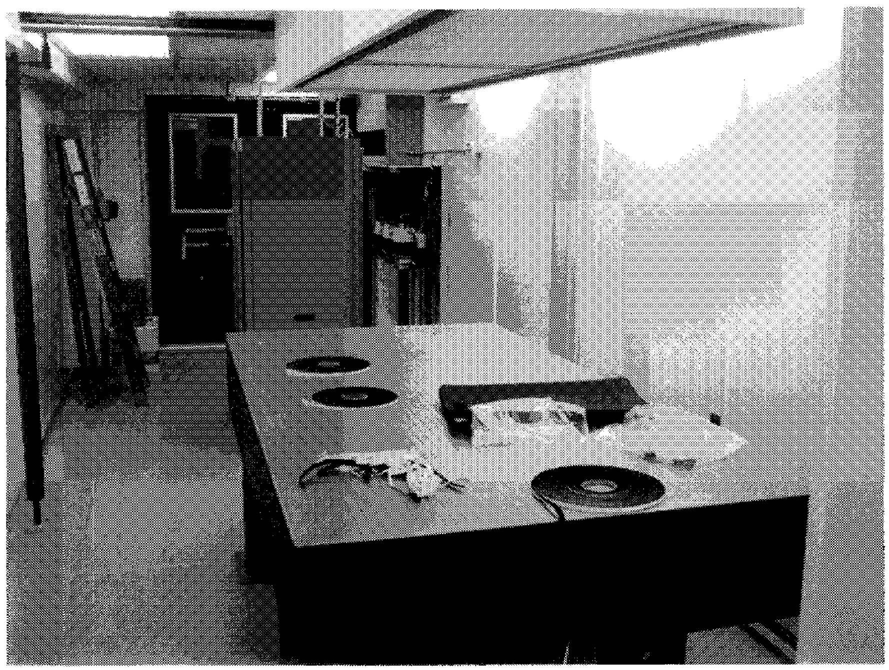


Laser System

- Lumera built a 5 W, 355 nm, 10 ps, 9.38 MHz laser system
  - Designed for BNL needs for generation of 50 mA current
    - We had discussions with vendor about upgrading to system for 500 mA if funding is available
  - Will be operated at 532nm, 355nm, and 266nm
  - Active program for generation of spatial and temporal flat top beams underway with good progress
  - System arrived 4 weeks ago, and should be installed and field tested by end of May.

Laser Room

- Climate controlled, 1C/hour, Humidity Controlled +/- 2%/hour
- HEPA Filters to establish class 1000 area



Injector Fabrication complete	7/09	
Gun VTF testing	8/09	
Hermetic String assembly	10/09	
Cryomodule complete	3/10	
Injector cryomodule conditioning	5/10	
Beam, no ERL (G5)		8/10
Full ERL Test		1/11