Technology Challenges for SRF Guns as ERL Source in View of BNL Work

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What are we building?

- R&D ERL operating at 703.75 MHz, 0.5 A
- SCRF technology for both the injector and accelerating Linac

- Operating plan
  - Generate and accelerate electrons with normalized emittance of < 50 μmrad, energy ~ 20-40 MeV (1-2 passes)
  - Decelerated the electron beam to few MeV and recover the energy back into the RF field
- Test the concepts for very high current ERL with multiple operating modes,
  - 351.875, 0.5 A, 1.4 nC/bunch
  - 9.383 MHz, 0.2 A, 21nc/bunch (RHIC freq, application to electron cooling)
  - 1-20 Hz, start-up mode


Ripp Bowman 3-7-05
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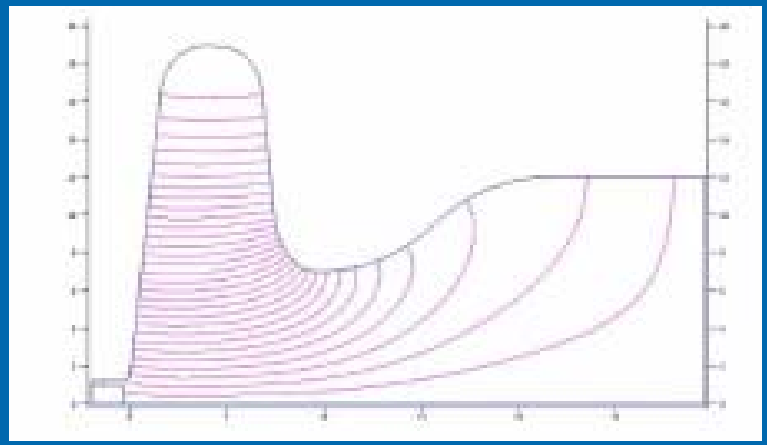
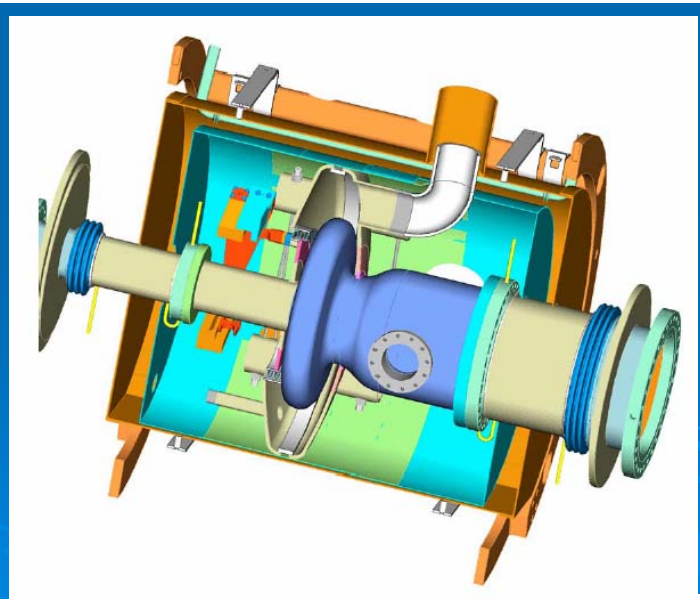
Challenges

- SCRF Gun Design
  - Geometry optimization for best emittance
    - Cathode recess, solenoid requirements
  - Choke Joint design for retractable cathode
  - Cathode insertion method and geometry concern
- Photocathode, CsK_2Sb
  - Lifetime due to vacuum conditions
  - Operation at cryogenic temperatures
  - Secondary emission, capsule design
- Laser, 2^{nd} or 3^{rd} Harmonic of Vanadate
  - multiple repetition rates desired
  - 10's Watts of Laser power required
  - Stability
  - Pulse shape and duration
  - Not commercially available

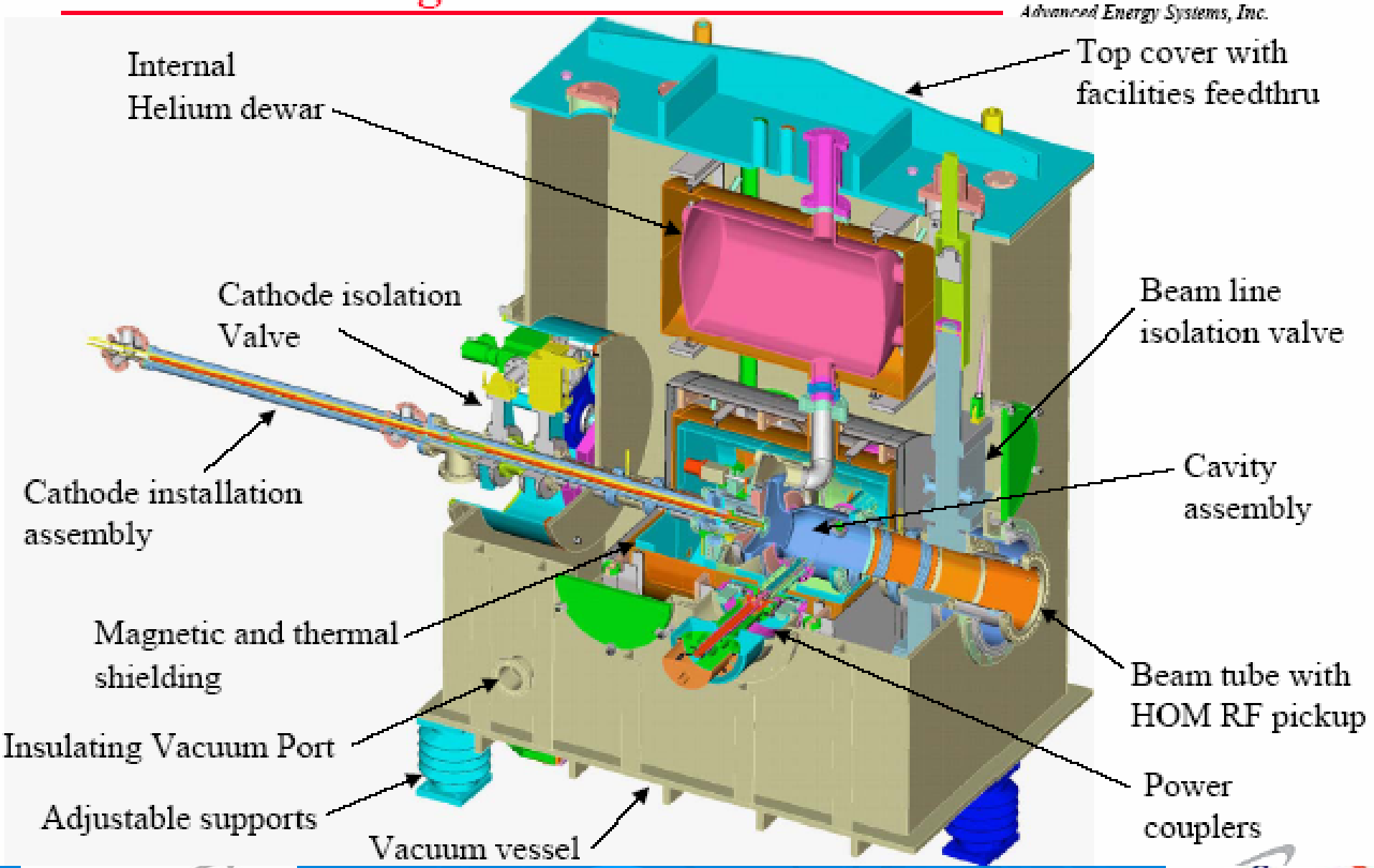
SCRF Gun Design

- 703.75 MHz ½ cell Niobium photoinjector
  - Retractable CsK_2Sb photocathode
  - 1MW RF power producing ~2 MeV electrons at 0.5 A
  - RF focusing provided by recessed cathode
  - Optional Solenoid and bucking coil

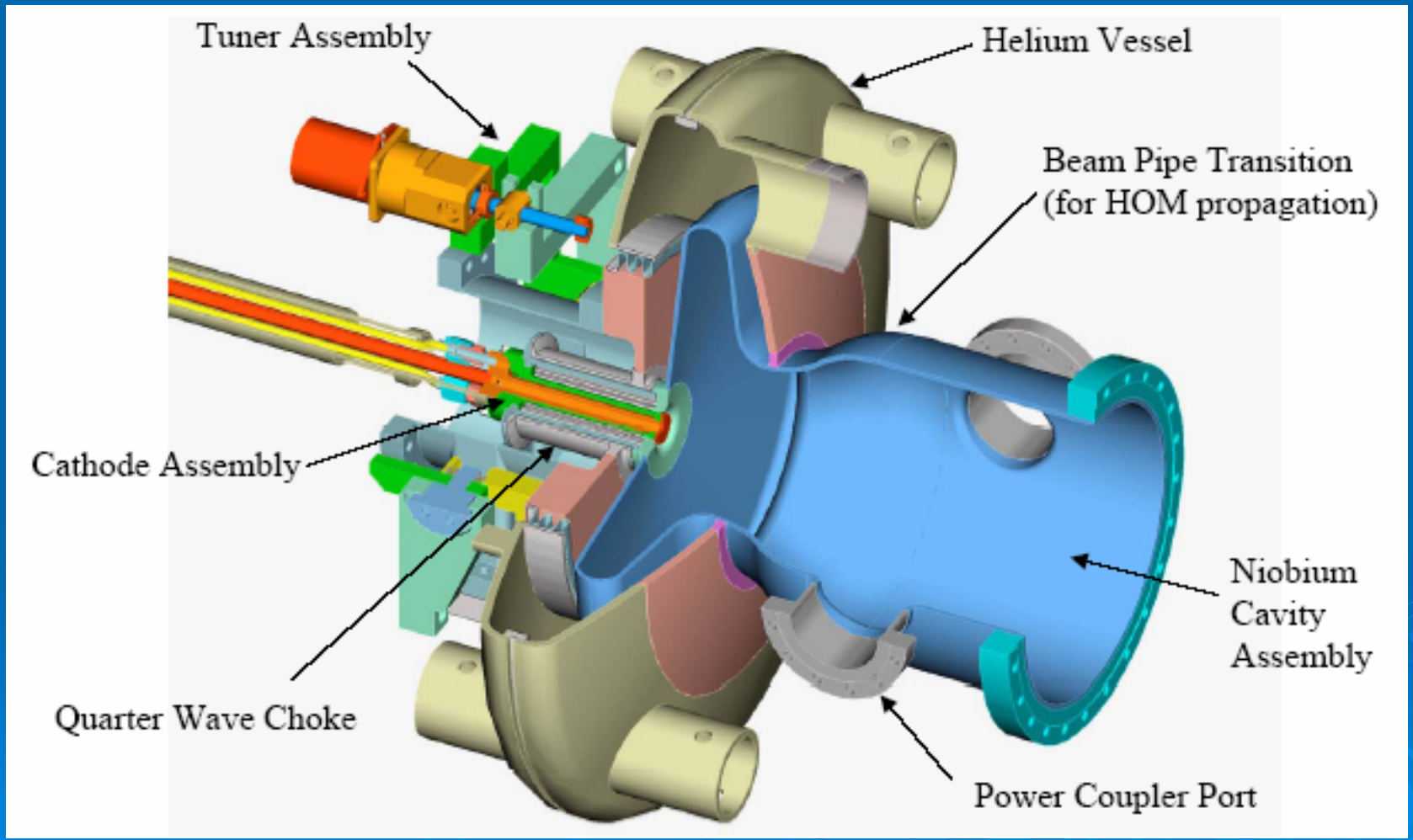




General Arrangement

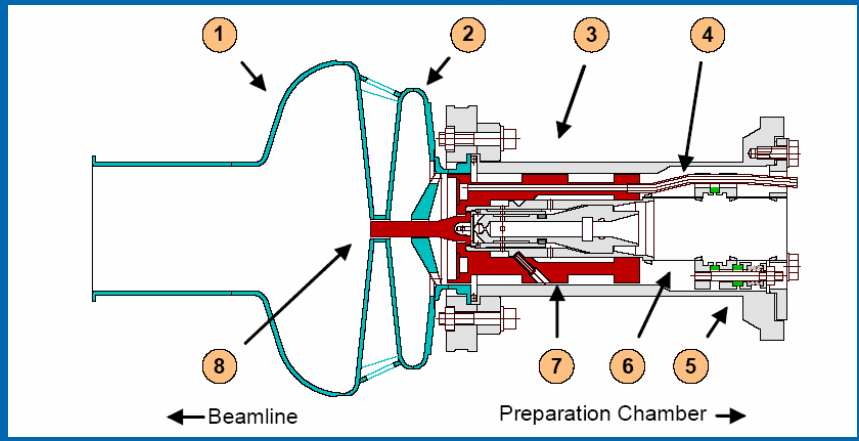


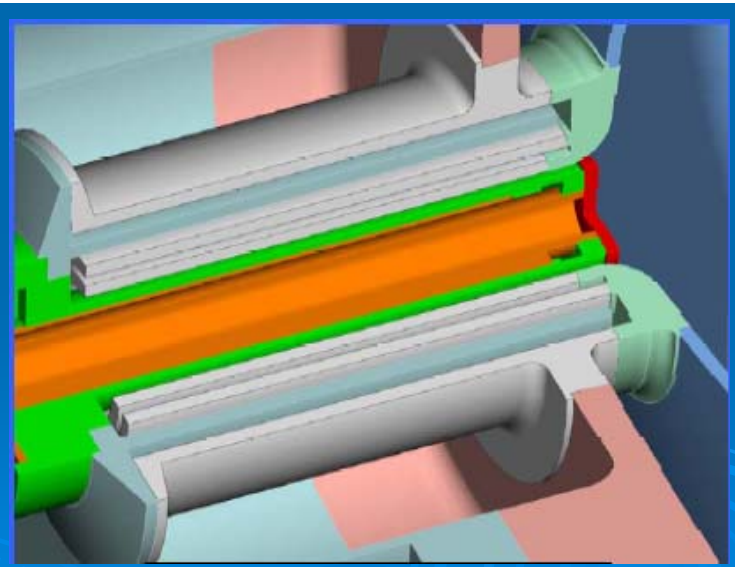
SCRF Photoinjector



Quarter wave choke joint

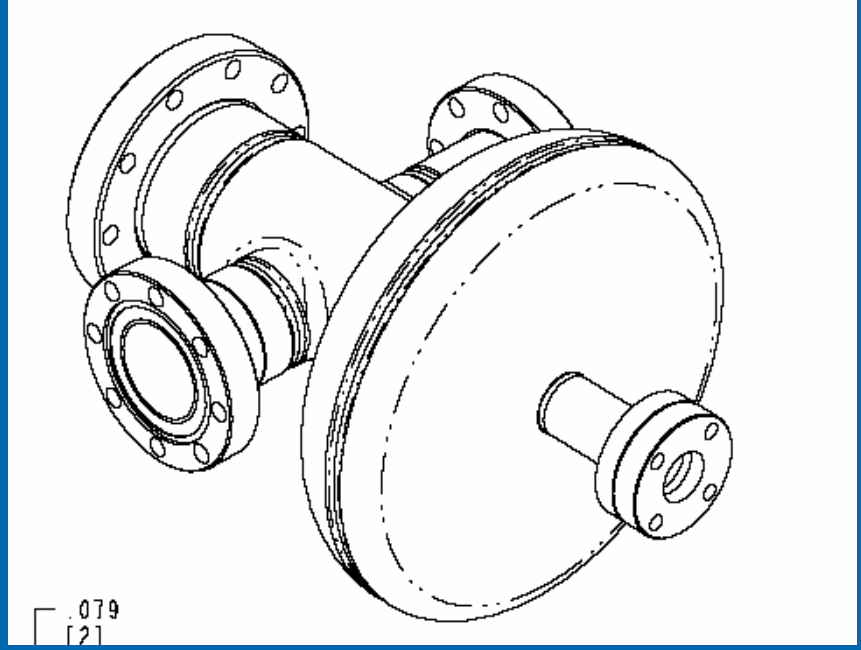
- Considered option of incorporating FZR choke joint
- Alternate, Tunnel Dust quarter wave choke selected to simplify design and fabrication





Choke Joint Testing

- Leverage SCRF technology at BNL by modifying our 1.3 GHZ fully SCRF gun to accept a modified QW choke joint
  - Allow us to investigate maximum field in cavity
  - Study multipacting
  - Preliminary testing of diamond sample
  - Possible investigation of CsK_2Sb photocathode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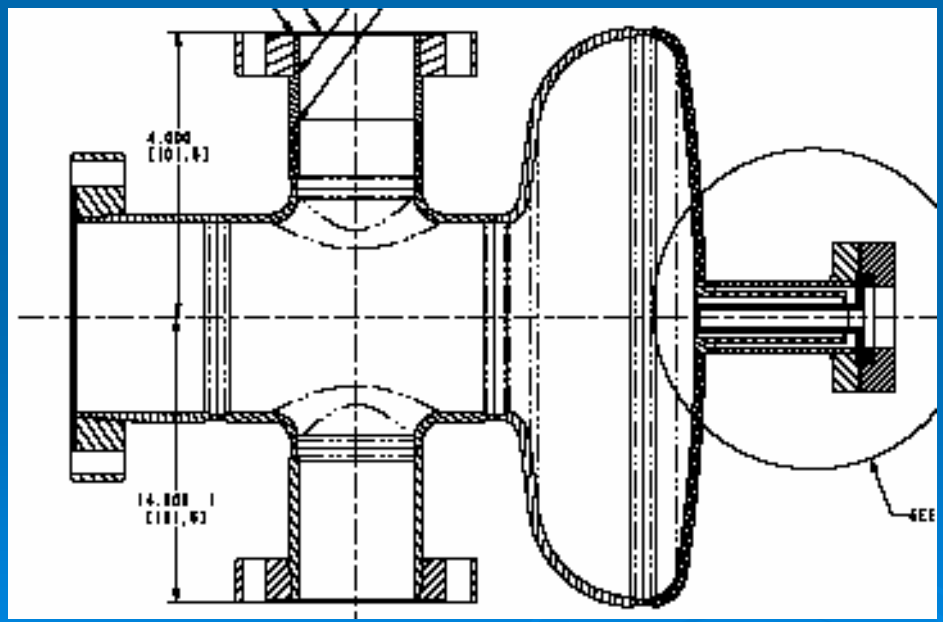
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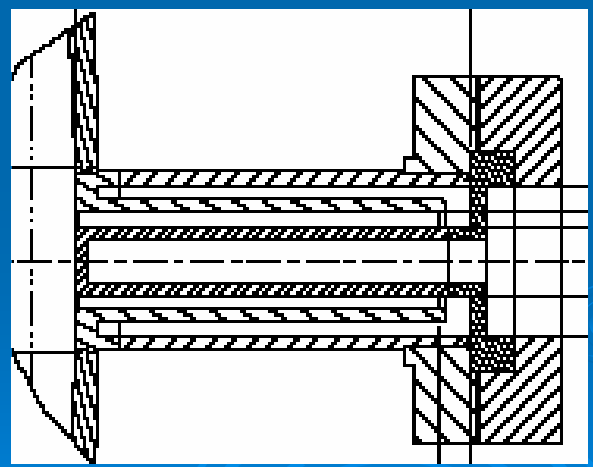
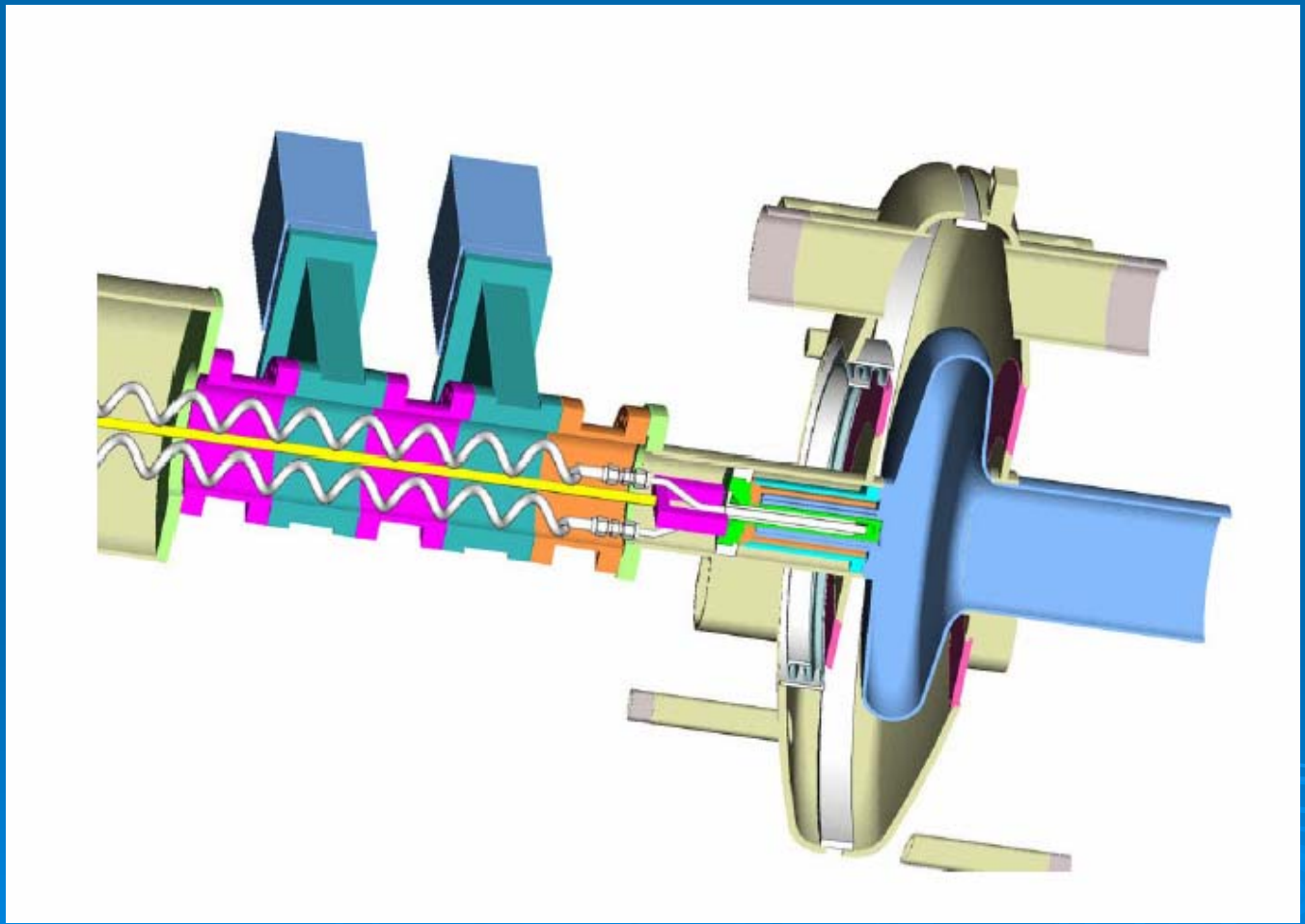


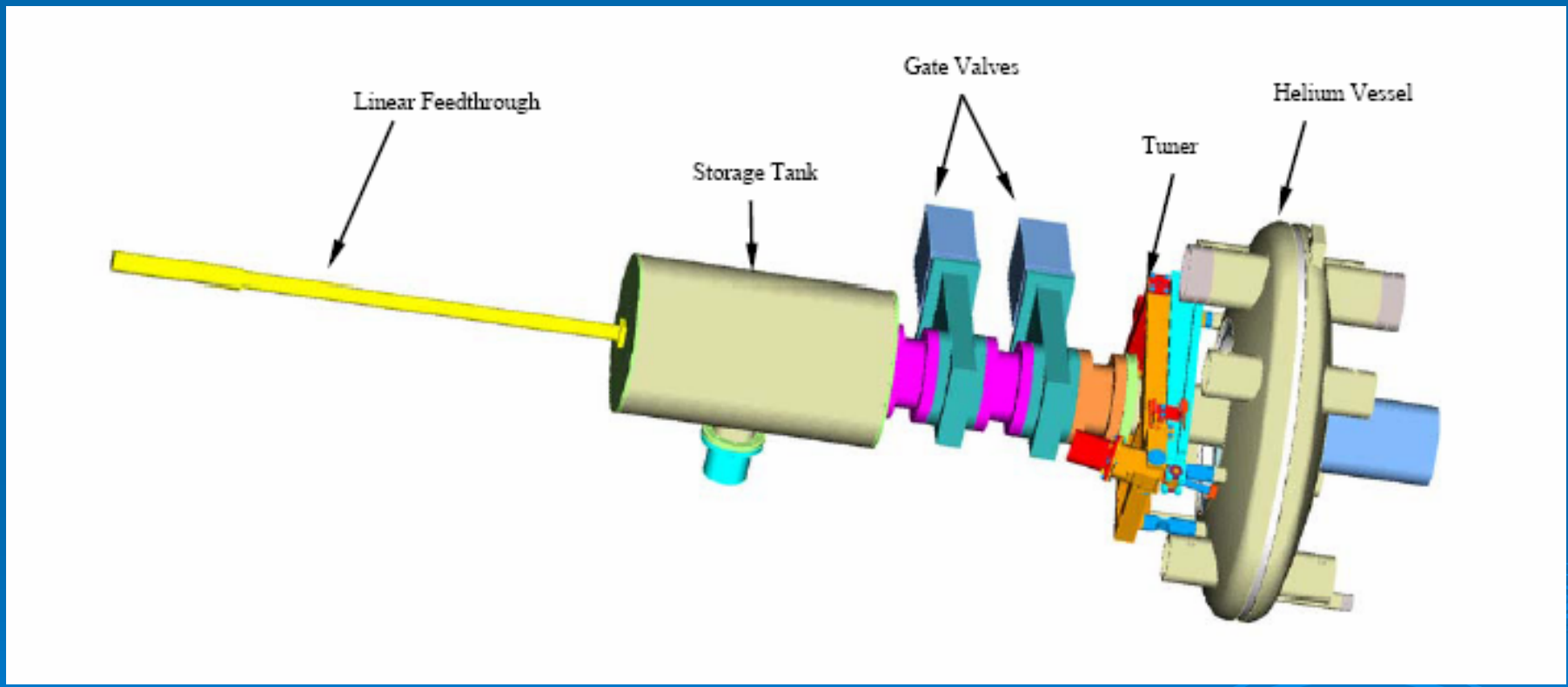
CsK_2Sb photocathode in SCRF Guns

- Issues:
  - Lifetime of photocathode affected by vacuum level
  - Cesium contamination of SCRF cavity
  - Thermal isolation
  - Interface of cathode to gun
- Solutions:
  - No vacuum degradation during operation like NC gun
  - Secondary emitter capsule
  - Actively cooled cathode stalk
  - Proper design and engineering

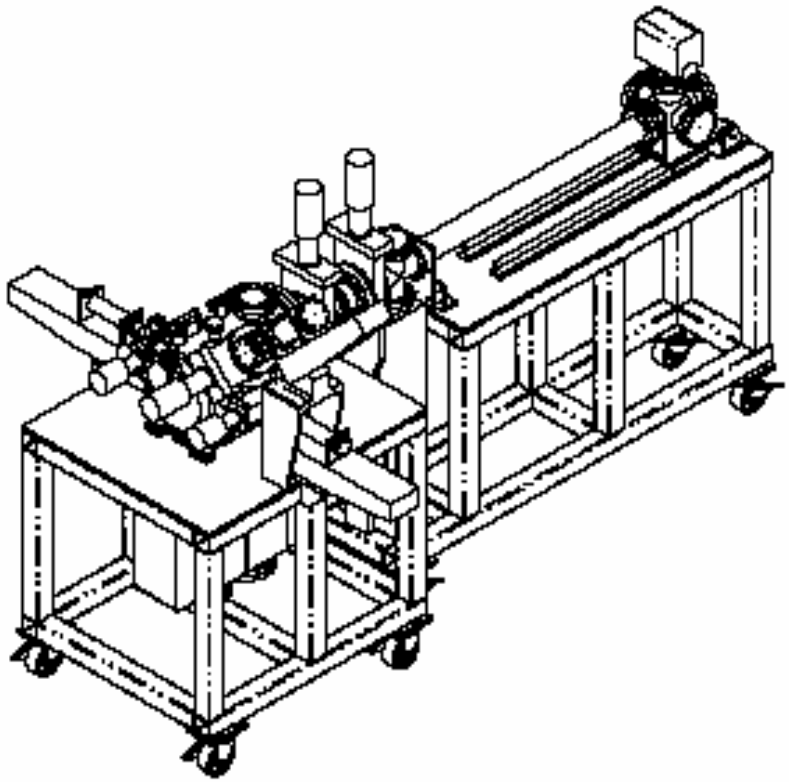
Photocathode inserted in Cavity

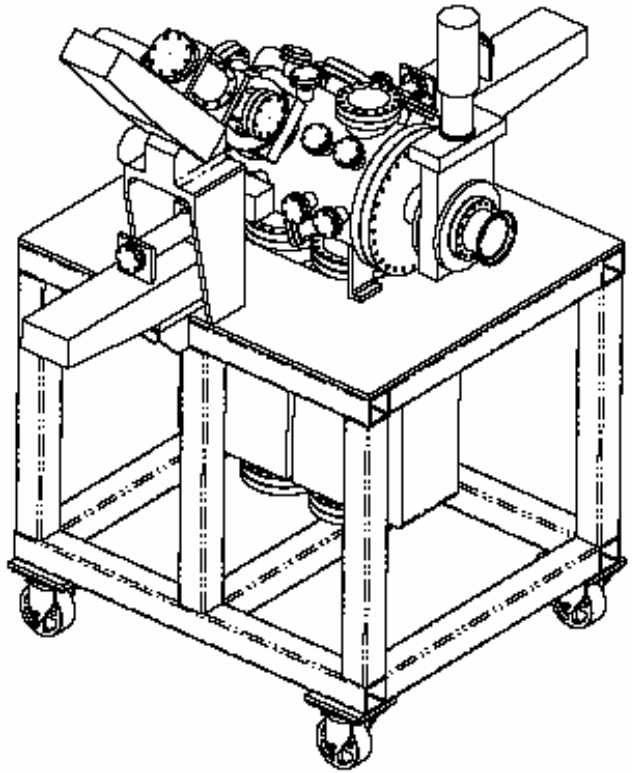


Cathode insertion device



Photocathode deposition system



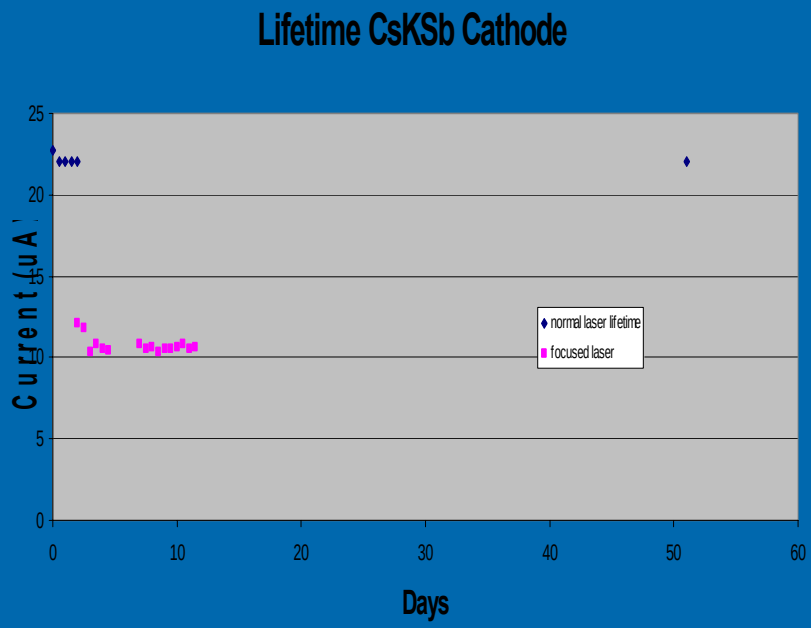


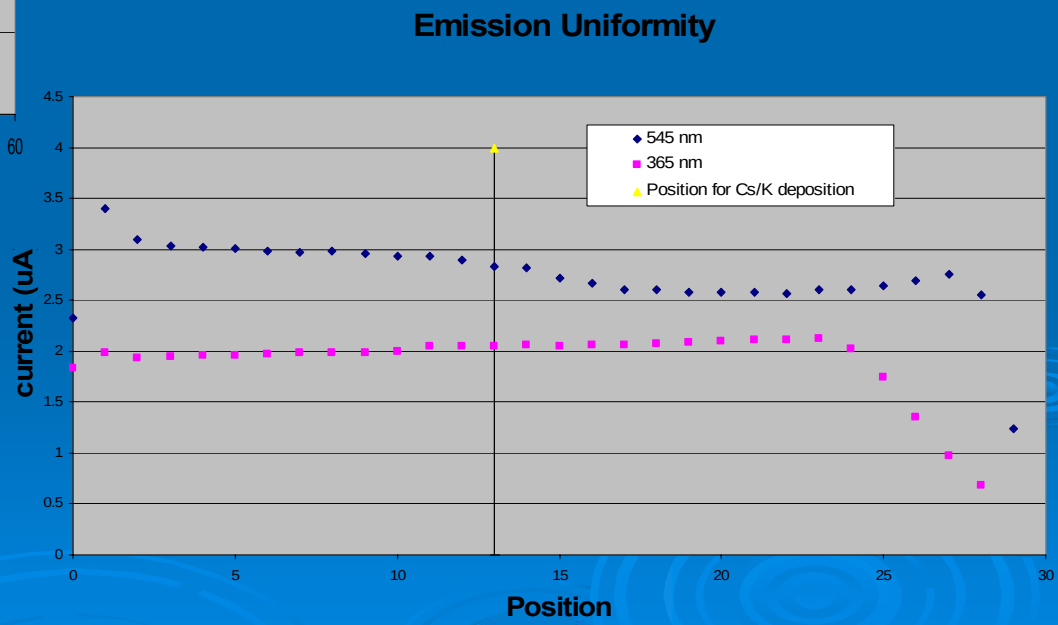
CsK_2Sb photocathode

- Lifetime studied under UHV conditions
- Current density comparable to ERL requirements studied
- High Charge per bunch testing planned
- Recipe optimization being completed

Laser Wavelength	CsK_2Sb QE	Desired current	Laser power required
532 nm	3%	200 mA/ 500mA	15 W/ 38W
355 nm	9%	200 mA/ 500mA	8 W/ 17 W

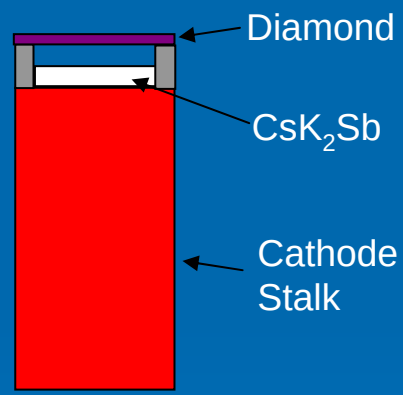
CsK_2Sb study





Diamond Capsule

- Dual benefits
  - Electron amplification
  - Protects gun from cathode and cathode from gun

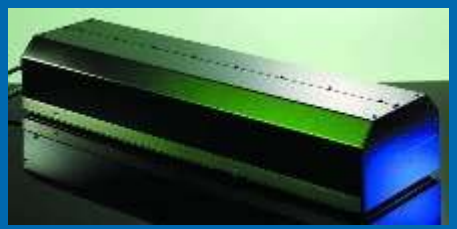


Capsule challenges

- Develop method of bonding diamond to metal for UHV capsule
- Develop method of attaching CsK_2Sb cathode to stalk and subsequently to Diamond assembly, all under UHV conditions
- Test modified capsule in 1.3 GHz SCRF gun

Laser Options

Laser Wavelength	CsK_2Sb QE	Desired current	Laser power required
532 nm	3%	200 mA/ 500mA	15 W/ 38W
355 nm	9%	200 mA/ 500mA	8 W/ 17 W



Coherent Paladin, 8W, 355 nm, 80 MHz 15 ps pulse length

7 ps	pulse width
1064 nm, 1053 nm, 1047 nm	wavelength
20 MHz – 2.5 GHz	repetition rate
800 mW @ 1064 nm	output power
1% / °C	power stability
TEM_{00}	spatial mode
1.1	M^2

New Laser Option

50 W	output power
40 MHz – 60 MHz	repetition rate
1 µJ	per pulse
< 800 fs	pulse width
1 MW	peak power
1030 nm	wavelength
1.1	M^2 (TEM_{00})

Diamond Amplification option

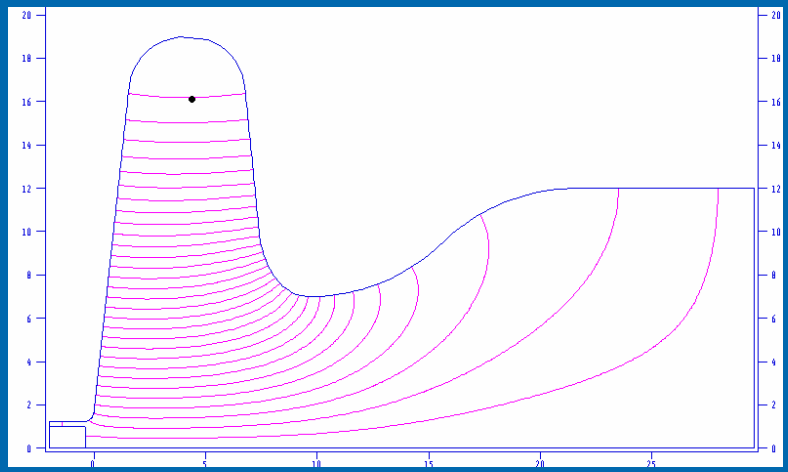
Laser Wavelength	CsK_2Sb QE	SEY	Desired Current	Laser Power to Cathode
532 nm	3%	0	0.5 A	38 W
532 nm	**3%**	**50**	**0.5 A**	**0.7 W**
355 nm	9%	0	0.5 A	17 W
355 nm	**9%**	**50**	**0.5 A**	**0.35 W**

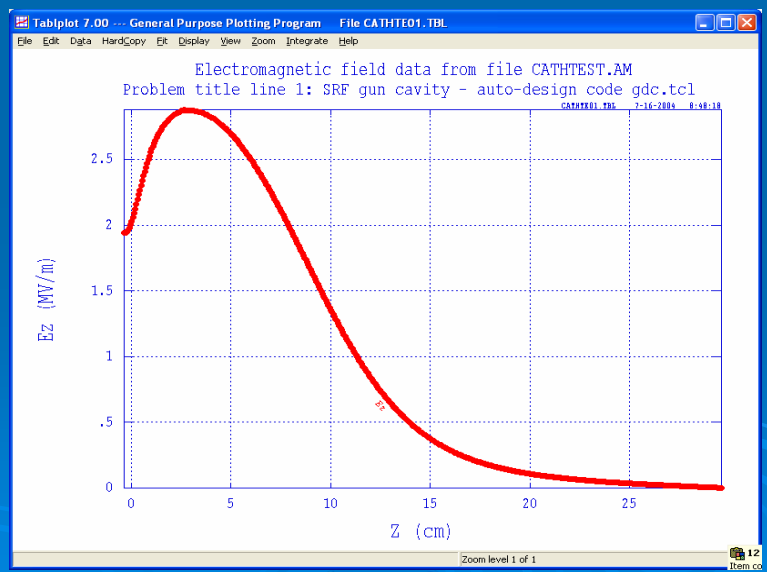
Conclusions

- SCRF Gun design for high average current c.w. operation is proceeding well
- Numerous challenges before arriving at a turn-key system
  - All the key pieces are in place
  - Research is actively engaged in all aspects
- Expect to begin ERL operation in 2007

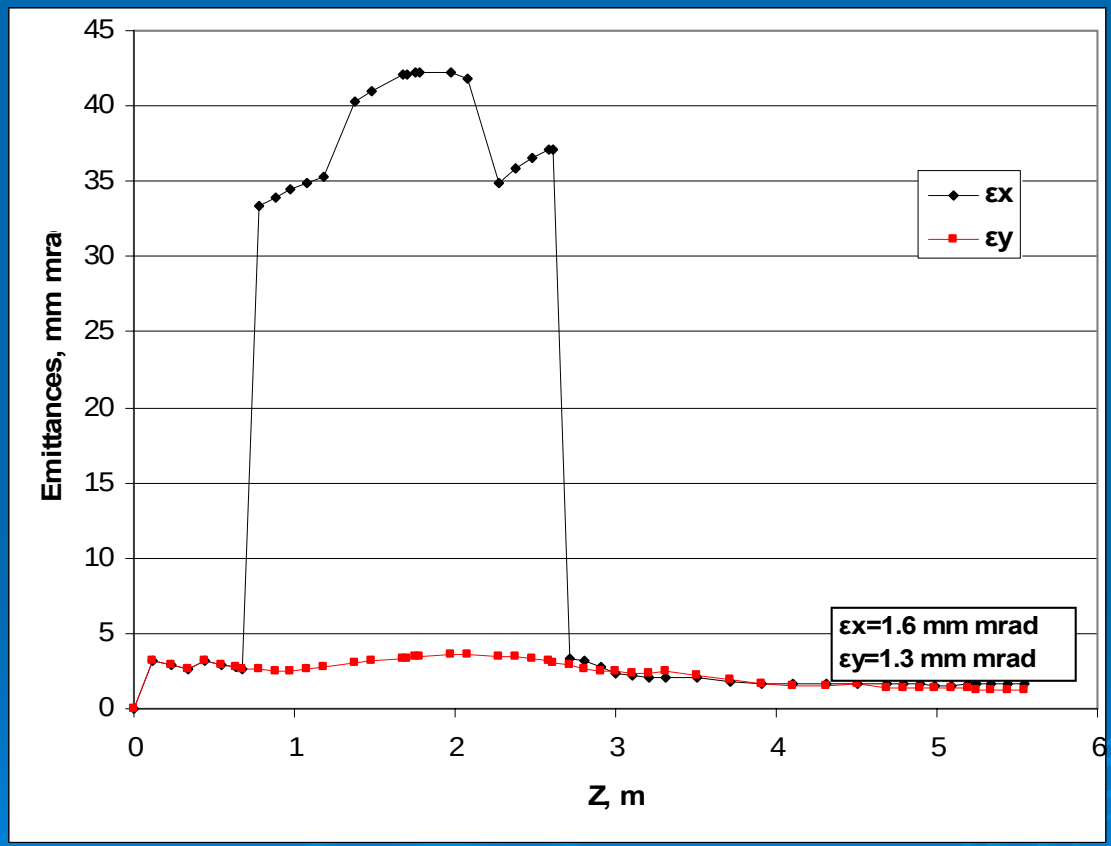
Gun Simulations

- Optimization with respect to cathode recess, gun cell length, beampipe diameter and implications on the injections section of the ERL must be considered.





Emittance from Gun to Linac Entrance



Conclusion

- By using a short half cell SRF cavity with cathode recess and a Z bend system, one can make both transverse emittance and longitudinal emittance very small for the ERL project.
- The initial launch phase can also be raised close to optimum for the diamond cathode.
- Wake fields must be considered.

Current Cavity Geometry