ICFA ERL Workshop
Jefferson Laboratory
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Working Group 1 summary

Ilan Ben-Zvi & Ivan Bazarov

Sincere thanks to all WG1 participants: Largest group, very active participation.
This summary cannot reflect all talks!

Working Group Subjects

- Technology Choices
- Beam Dynamics at the gun / injector
- Cathodes and photoemission
- Lasers
- Joint issues:
  - Diagnostics (low energy, limited space)
  - Beam dynamics (merger…)

Photoinjector Technology Issues

	DC Gun	Normal RF	SRF Gun
Max Gradient (achieved)	4.3 MV/m	6 MV/m	32 MV/m
Max Gradient (planned)	> 7 MV/m	10 MV/m	> 20 MV/m
Max current (demonstrated)	10 mA	128 mA at 25% DF	1 mA
Max current (planned)	100 mA	1000 mA	500 mA
Issues	Field emission Vacuum Ion back bombardment	Thermal Management Vacuum	Thermal management Contamination of SRF cavity

Three ERL programs funded use DC Gun technology

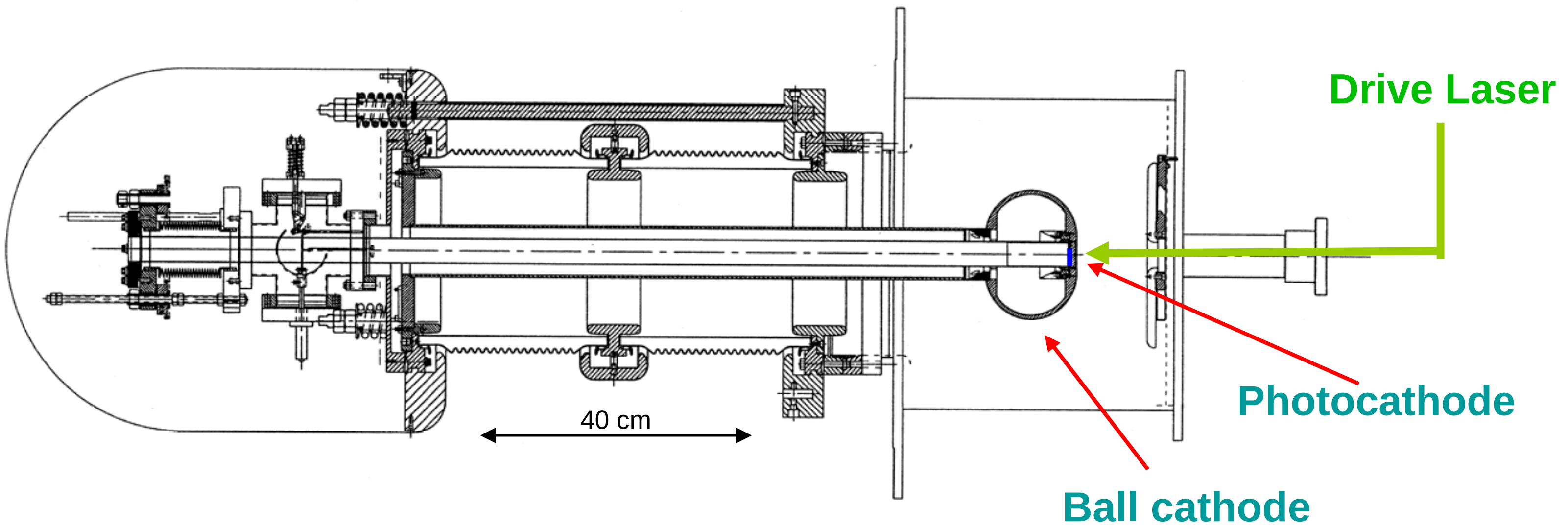
- Cornell
- Daresbury ERLP
- JLab 10kW FEL

DC Gun Technology

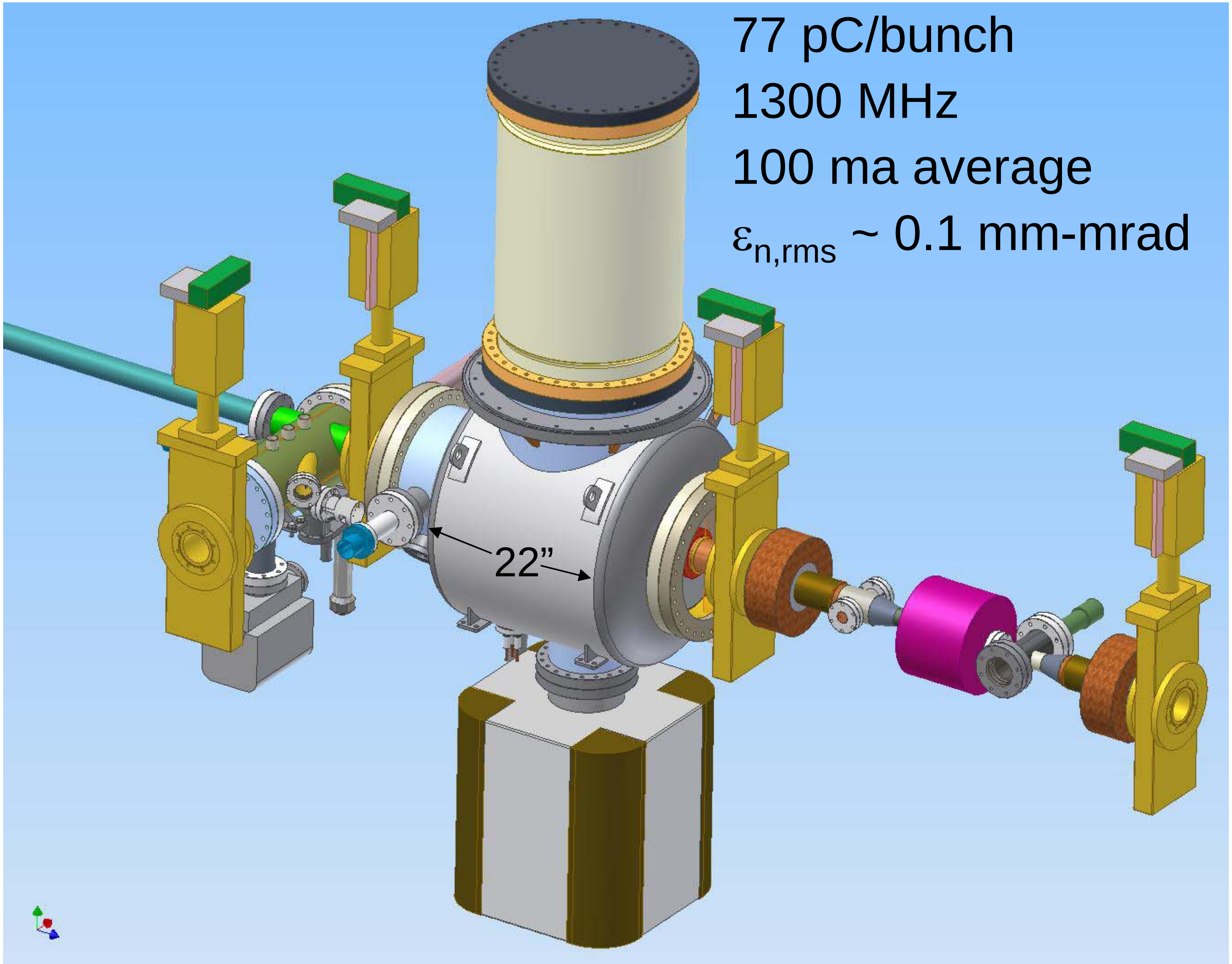
- Best yet demonstrated
  - 350 kV gun with GaAs cathode operating up to 9.1 mA (122 pC/bunch at 74.85 MHz) at JLab (n.b. – gun processed to 435 kV for 350 kV operation)
- Planned
  - Operate JLab gun at 500 kV, 10 mA average
  - Duplicate JLab gun at ERLP (Daresbury) 6.5 mA
  - Add JLab gun to 750 MHz SRF booster (AES), 100 mA average
  - New gun design, 500 to 750 kV, at Cornell, 100 mA average

JLab GaAs 350 kV DC Photocathode gun demonstrated performance

- 9.1 mA CW (energy recovered)
- Over 400 C between re-cesiations
- 5.5kC delivered with single GaAs wafer



Cornell University 500-750 kV gun in development



RF Injector Programs

Normal-Conducting Guns

- Boeing RF Gun (128 mA at 25% df and Retired but Still the State-of-the-Art)
- LANL/AES RF Gun
- “LUX” Gun (proposed)
- Field Emission Gated Gun (proposed)

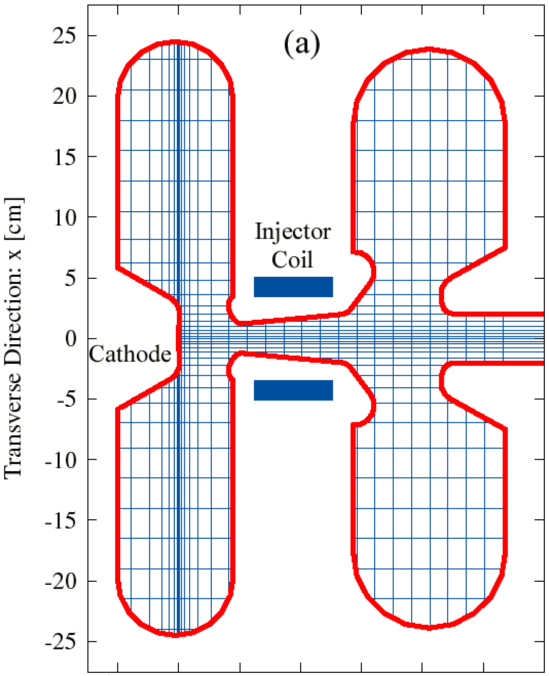
SRF Guns

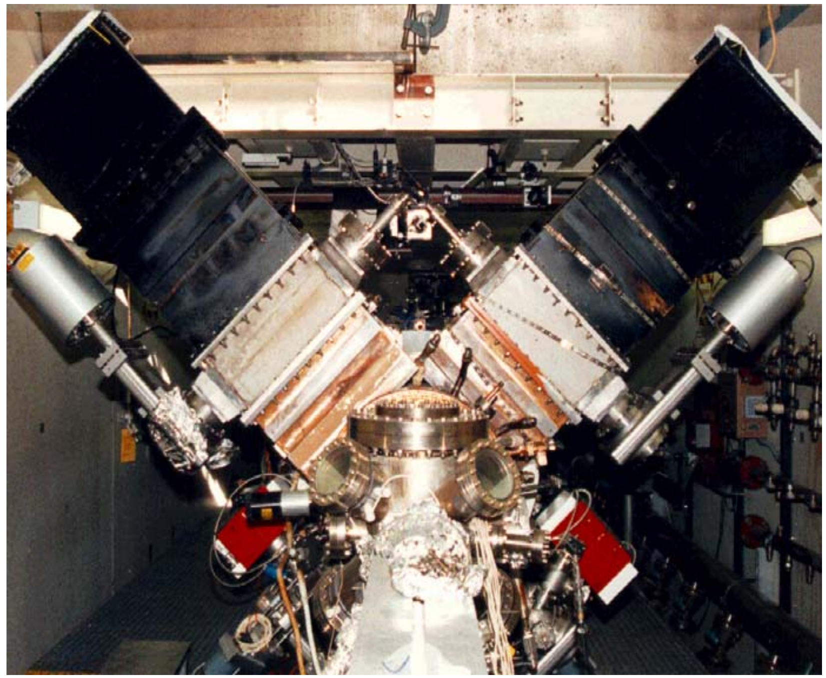
- Rossendorf 1 ½ and 3 ½ cell SRF Gun
- BNL/AES/JLab ½ cell 1.3 GHz gun
- University of Peking DC+SRF gun
- AES/BNL SRF Gun, ½ cell 703.75 GHz

Hybrid Guns

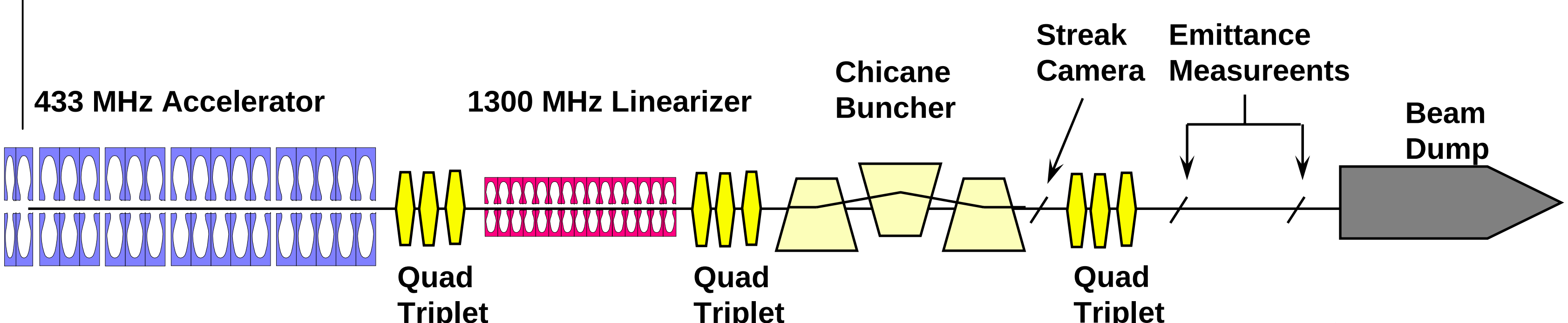
- LANL NC Injector and SCF Booster Cavity

The Boeing Gun: Still the Demonstrated State-of-the Art





Gun Type	NCRF
Injector and ERL	
RF Frequency (MHz)	433
PRF (MHz)	27
Charge/Bunch (nC)	4.75
Current (mA)	32 (132 Peak)
Injector Energy (MeV)	5
Transverse RMS Normalized Emittance (	~ 7
Longitudinal RMS Emittance (keV-psec)	
RMS Bunch Length (psec)	
RMS Energy Spread (%)	~ 3
ERLP Energy (MeV)	N/A
ERL Energy Goal (MeV)	N/A
Electron Gun	
DC Gun Voltage (kV)	N/A
Gun Accelerating Field (MV/m)	
Cathode Material	CsKSb
Drive Laser FWHM Pulse Length (psec)	53
Laser Wavelength (nm)	527
Laser Power at 5% QE (W)	
Booster Accelerator	
Type	N/A
Geometry (Cavities x Cells)	1 x 1.5 + 1 x 3
Couplers per Cavity / Type	2 / WG
Coupler Power (kW)	
Status	**Retired**

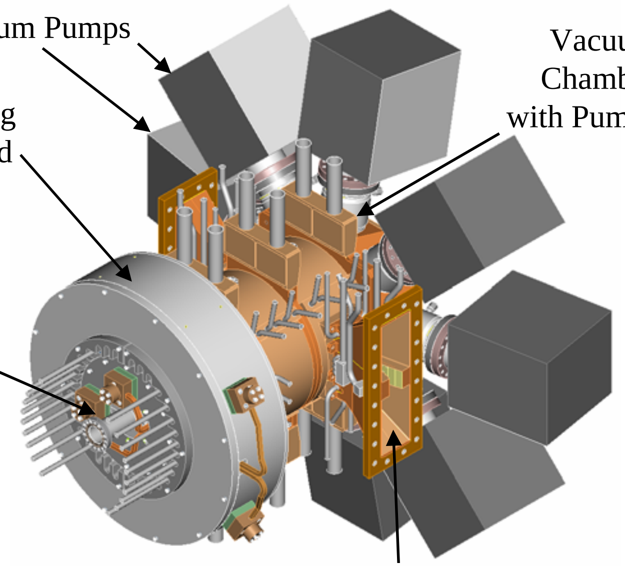


Dowell

Material Courtesy David Dowell and John Adamski

BOEING®

100 mA Normal-Conducting Injector



700 MHz
100 mA

Objectives & Comments

- Design and fabricate a 100 mA-capable Normal-Conducting Injector for delivery to Los Alamos (1 A potential @ 350 MHz)
- Demonstrate CW thermal performance at 7 MV/m (no cathode)
- Demonstrate 100 mA beam performance (not yet funded)

Projected Parameters

Frequency	700	MHz
Energy	2.54	MeV
Current @ 33.3 MHz*	100	mA
Bunch Charge*	3	nC
Transverse Emittance	6	mm-mrad rms normalized
Longitudinal Emittance	145	keV-psec rms
Energy Spread	0.5	%
Bunch Length		psec rms

* > 100 mA-capable but no cathode at present.

Todd

Schedule

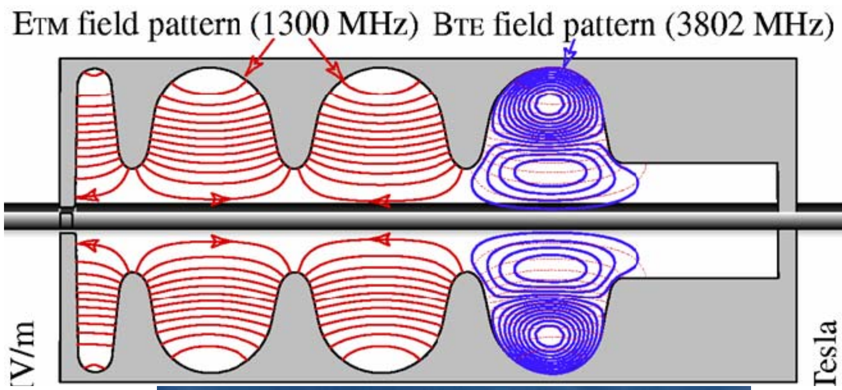
- Design fully developed
- Drawings completed - explicitly include all machining and process steps
- AES fabrication operations - complete 7/05
- AES stack tune - complete 8/05
- AES stack braze - complete 9/05
- AES deliver cavity to LANL – 9/05
- Thermal test complete ~ 12/05
- Beam test possible by ~ 6/07

Los Alamos
NATIONAL LABORATORY

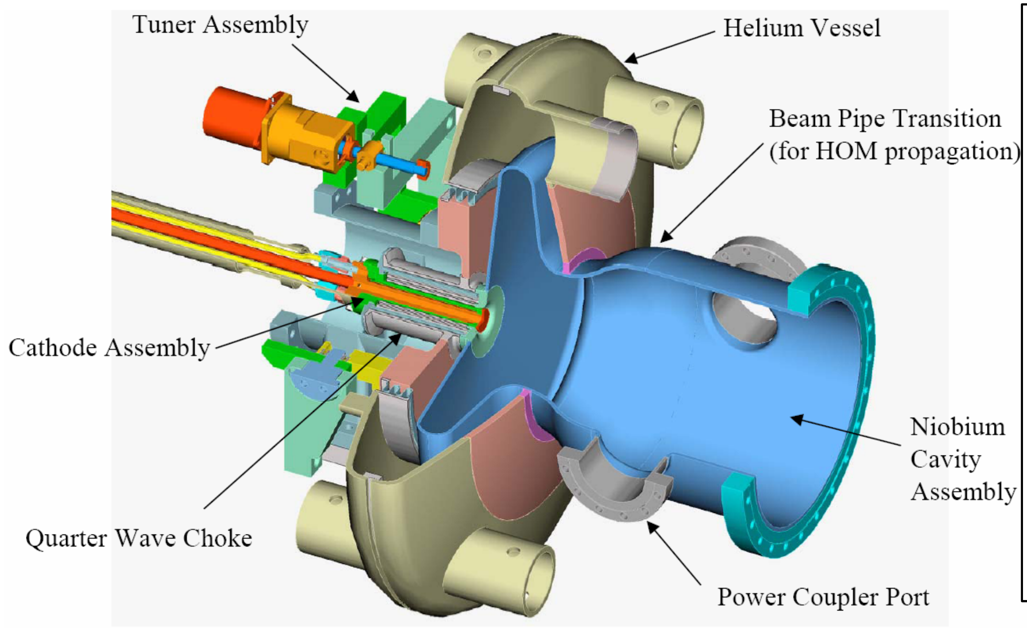
Rossendorf 1.3 GHz 3.5 Cell SRF Gun

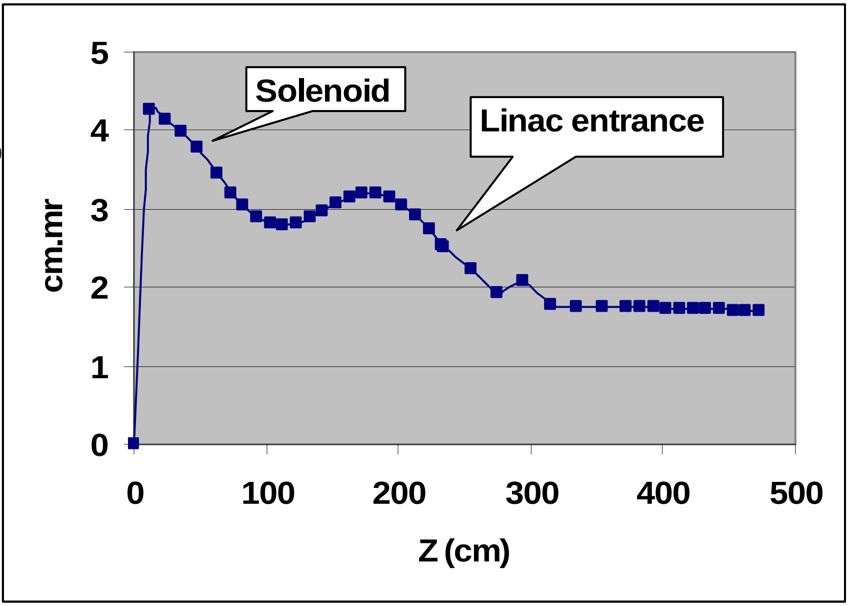
Cavity: Niobium 3+½ cell
(TESLA Geometry)
Choke filter
Operation: T = 1.8 K
Frequency: 1.3 GHz
HF power: 10 kW
Electron energy: 10 MeV
Average current: 1 mA
Cathode: Cs_2Te
thermally insulated, LN_2 cooled
Laser: 262 nm, 1W
Pulse frequency: 13 MHz & < 1 MHz
Bunch charge: 77 pC & 1 nC

Janssen



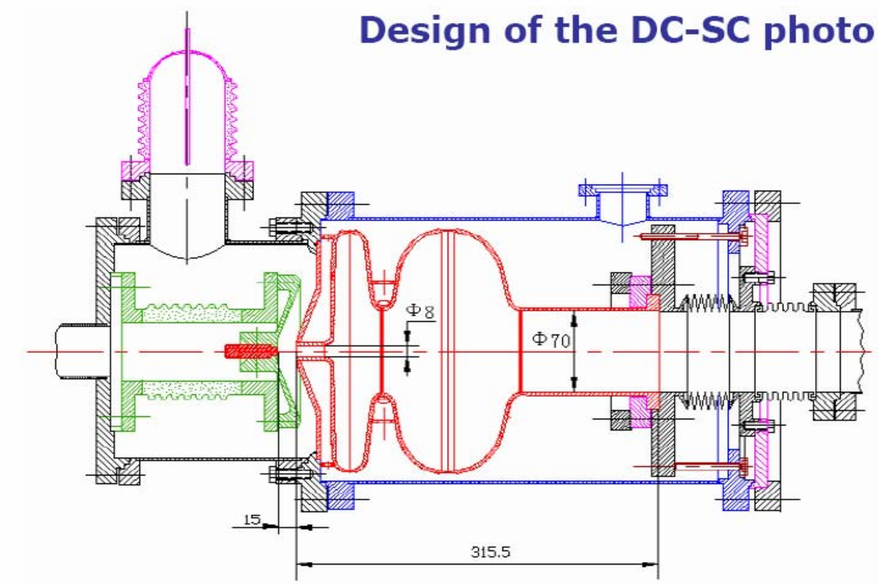
AES/BNL 703.75 MHz Gun





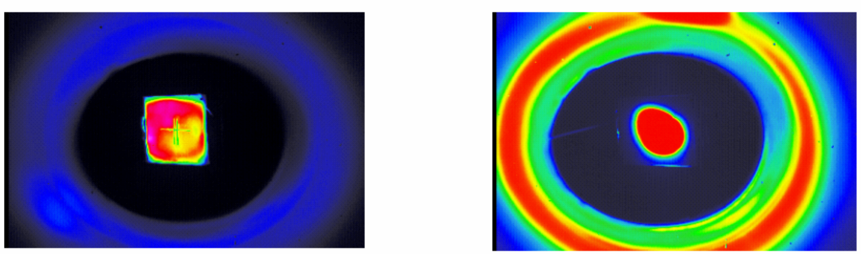
Burrill

Peking University DC-SRF Gun



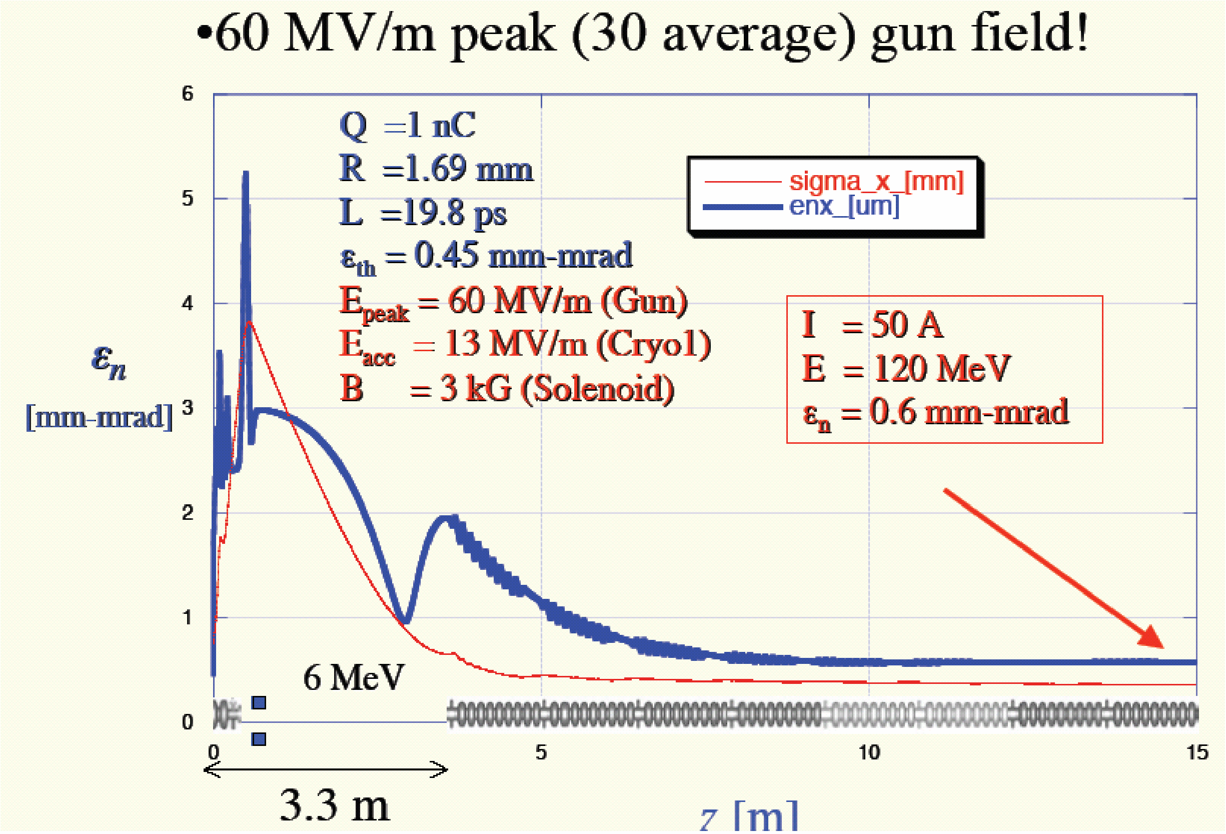
Lu

Beam image



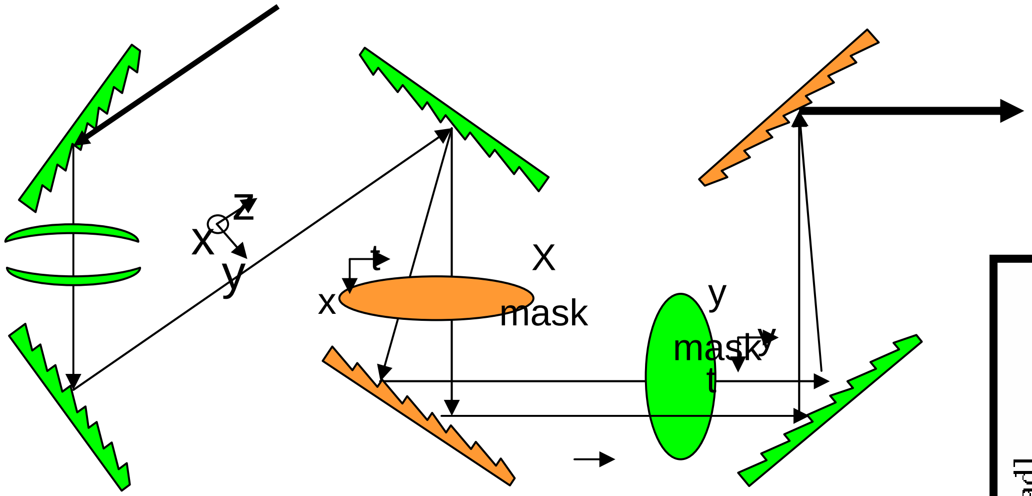
Beam Dynamics

Emittance compensation applied to SRF gun:

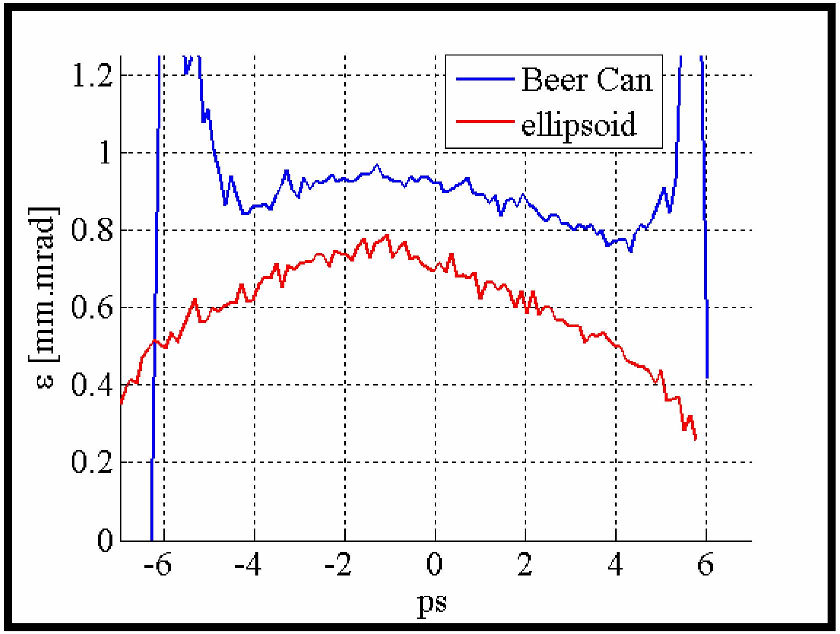


Rosenzweig, Ferrario

Ellipsoid Charge Distribution



Limborg-Deprey



Emittance compensation works for all!

Emittance compensation can be achieved despite
reduced flexibility in solenoid positioning

	Q [nC]	Rms bunch Length (compressed)	Ex [mm-mrad]	Cathode material(&)	Band Peak field
RF	1 / 0.2	2.8 ps / 1.7 ps	0.72 / 0.3 (**)	Copper, 700 meV	S-Band [120 MV/m]
DC	1/ 0.1	3ps / 3ps	0.8 / 0.14 (**)	GaAs 35 meV	[15 MV/m] (Average)
SRF	1 / 0.1(*)	5.7 ps/ 2.7 ps	0.8 / 0.23 (**)	"metallic" 184 meV	L-Band [60MV/m]

(*) scaled
(**) limited by thermal emittance
(&) Copper and GaAs use measured values,
but SRF gun uses generic metallic cathode
number for thermal emittance (0.3 mm-mrad per 1 mm full radius)

RF and DC guns computations are based on optimum emission pulse
"3D-ellipsoid", whereas SRF gun computation uses "beer can"

Cathodes for ERLs

- 100 mA +
  - **Cs:GaAs (demonstrated 9 mA CW, DC JLab FEL)**
  - **K_2CsSb (demonstrated 128 mA at 25% d.f., NCRF Boeing)**
  - Cs_3Sb

- 10 mA +
  - Cs: GaAs (polarized), and Cs2Te

- 1 mA +
  - Metals, Dispenser cathodes

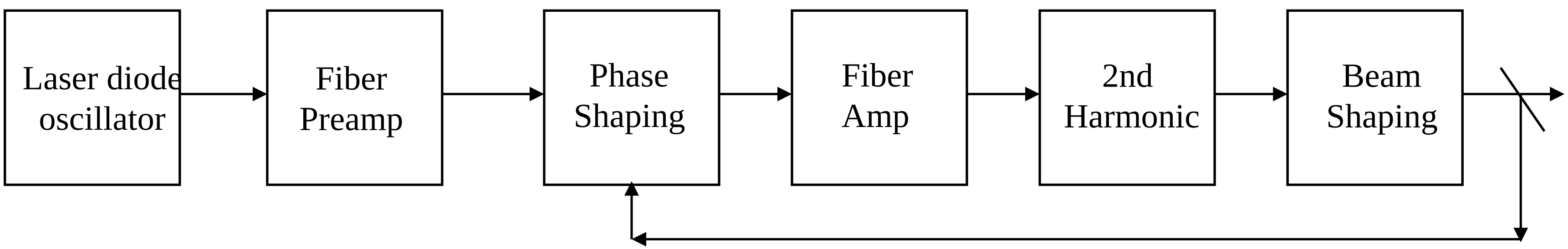
- Technologies to watch (not demonstrated in injectors yet)
  - Cs dispenser cathode, Cs:GaAsP, Cs:GaN, and Diamond

Lasers

Parameter	Electron cooling ERL	High Current ERL	Polarized e-Source ERL
Current (mA)	500	100	24
PRF (MHz)	28	700	15
Wavelength (nm)	530	530	780
QE(%)	2	2	0.3
Laser System	Yb Fiber MOPA w/SHG	Yb Fiber MOPA w/SHG	Er Fiber MOPA w/SHG
Cathode Power (W)	70	15	30

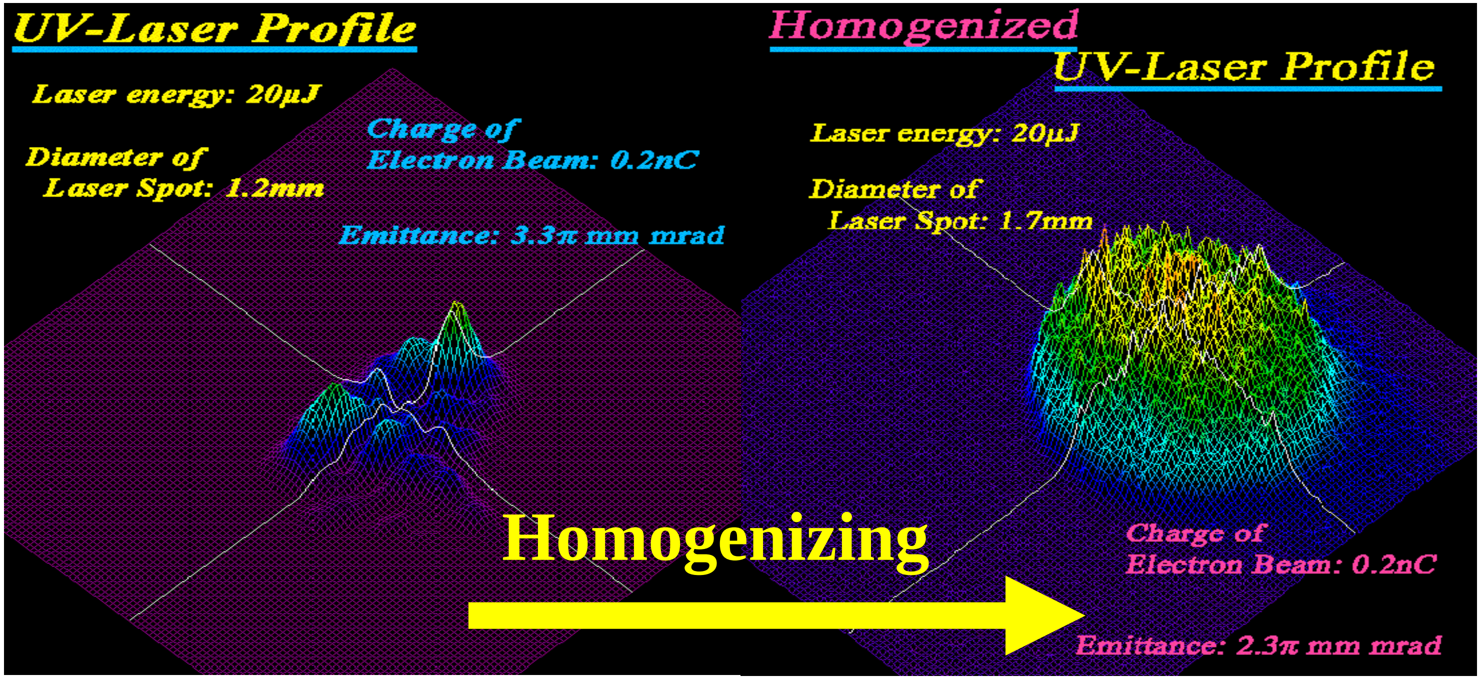
Two photocathodes are under consideration: NEA GaAs and K_2CsSb.
Fiber-based system should suffice, subject to pulse shaping requirements.
The fiber-based system show good promise. Slab-based system alternate option.

DRIVE LASER SCHEMATIC



- Design incorporates possible need for temporal shaping.

Spatial & temporal shaping



Injector key diagnostic requirements

- Most diagnostics must work at low energy (<10 MeV)
- Need to made injector as short as possible (implies compact diagnostics)
- All diagnostics designed for low impedance.
- Want CW capability at full charge and full rep. rate.