Optimized electron injectors based on DC Guns with NEA photocathodes

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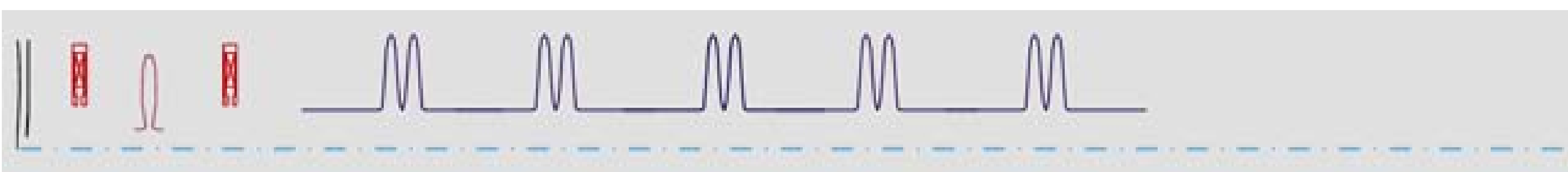
Material prepared by I. Bazarov and C. Sinclair

ERL Injector development at Cornell

- 500-750 kV DC gun with NEA photocathode
- Emittance compensation solenoid
- Conventional drift bunching
- SRF acceleration in five 2-cell cavities, designed to minimize emittance growth
- Variable coupling allows operation from 5 MeV at 100 mA to 15 MeV at 33 mA (limited by 500 kW of available RF power



Schematic view of the axially symmetric injector, from the HVDC gun (left) through SRF accelerator and downstream drift

Design Goals

- 100 mA average current in a 1300 MHz train of 2-3 ps duration pulses (77 pC/bunch)
- Normalized emittance approaching 0.1 μm-rad, dominated by the thermal emittance of the photocathode
- 100 hour operating lifetime at 100 mA
- Operation with 1 nC bunch charge at reduced repetition rate and increased emittance

Injector design optimization

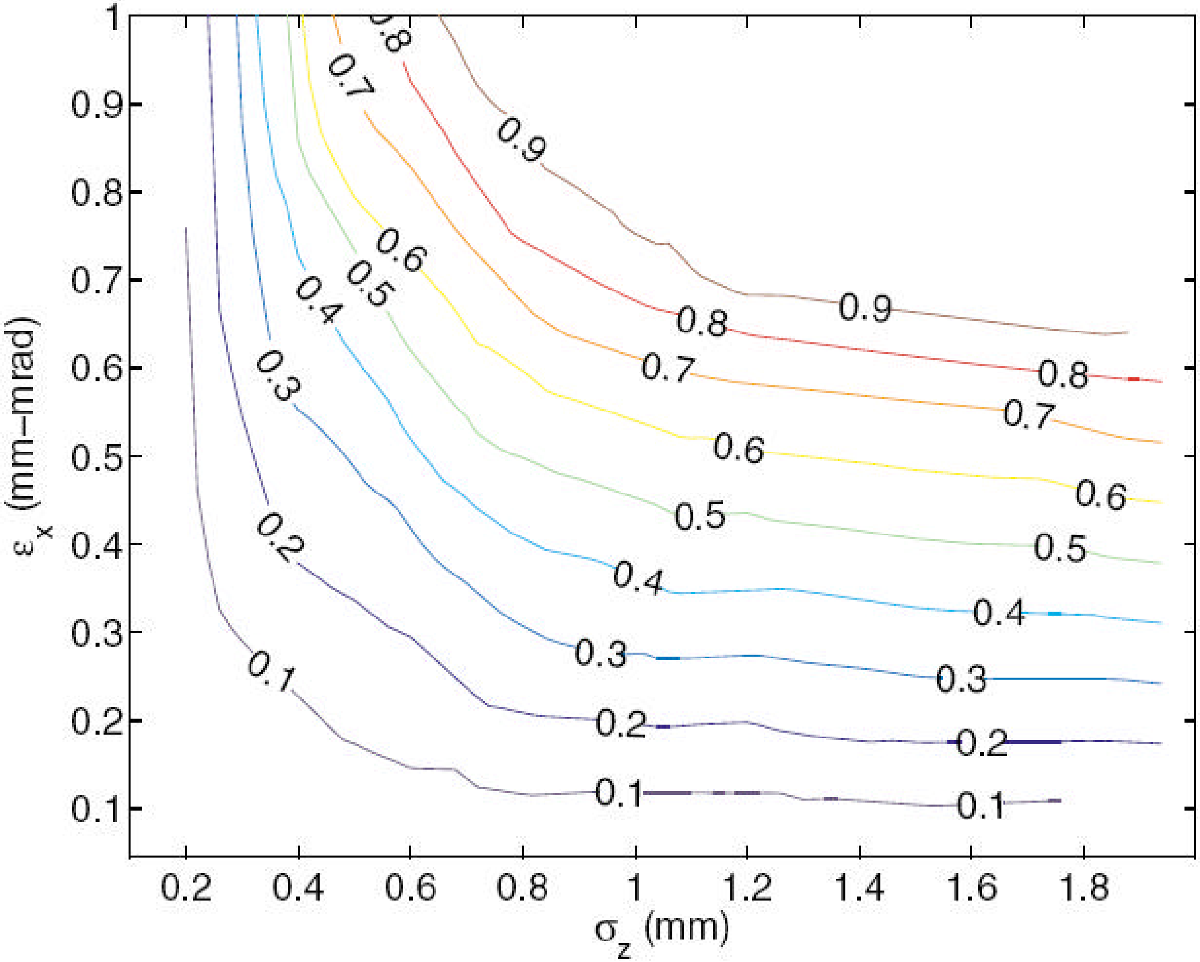
- A genetic algorithm based optimization of the injector was done, using 22 decision variables and incorporating realistic constraints on element sizes and locations
- Decision variables included field strengths, some RF phases, element locations, and optical profiles at the photocathode
- Runs started with relatively few microparticles (a few thousand) for a few hundred generations to obtain feasible solutions

optimization, continued

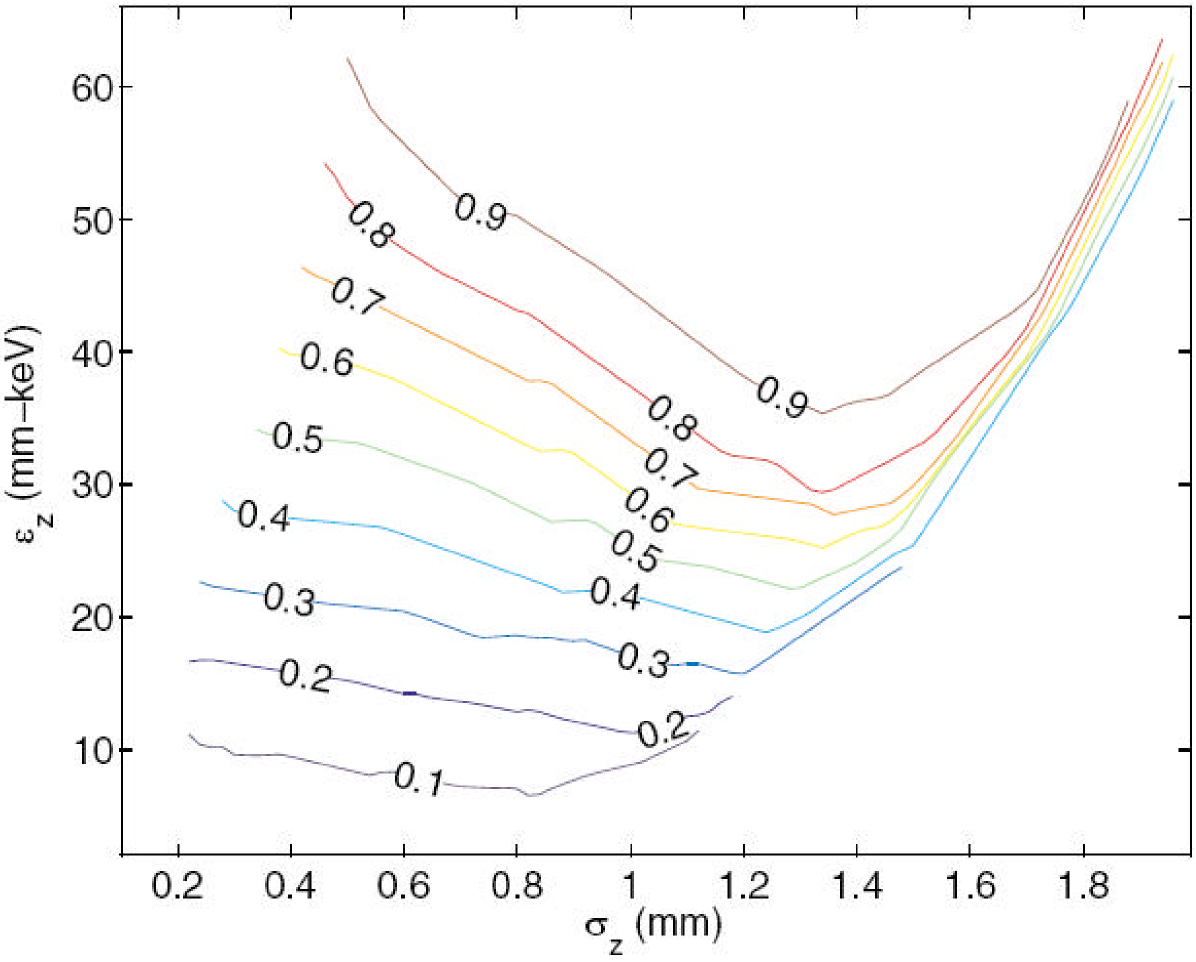
- Optimization completed by significantly increasing the number of microparticles and reducing the mesh sizes, using the results from the first several hundred runs
- Optimized results are robust, and do not show high sensitivity to reasonable changes in decision variables

Detailed results published – Bazarov and Sinclair, Phys. Rev. ST-AB **8**, 034202 (2005)

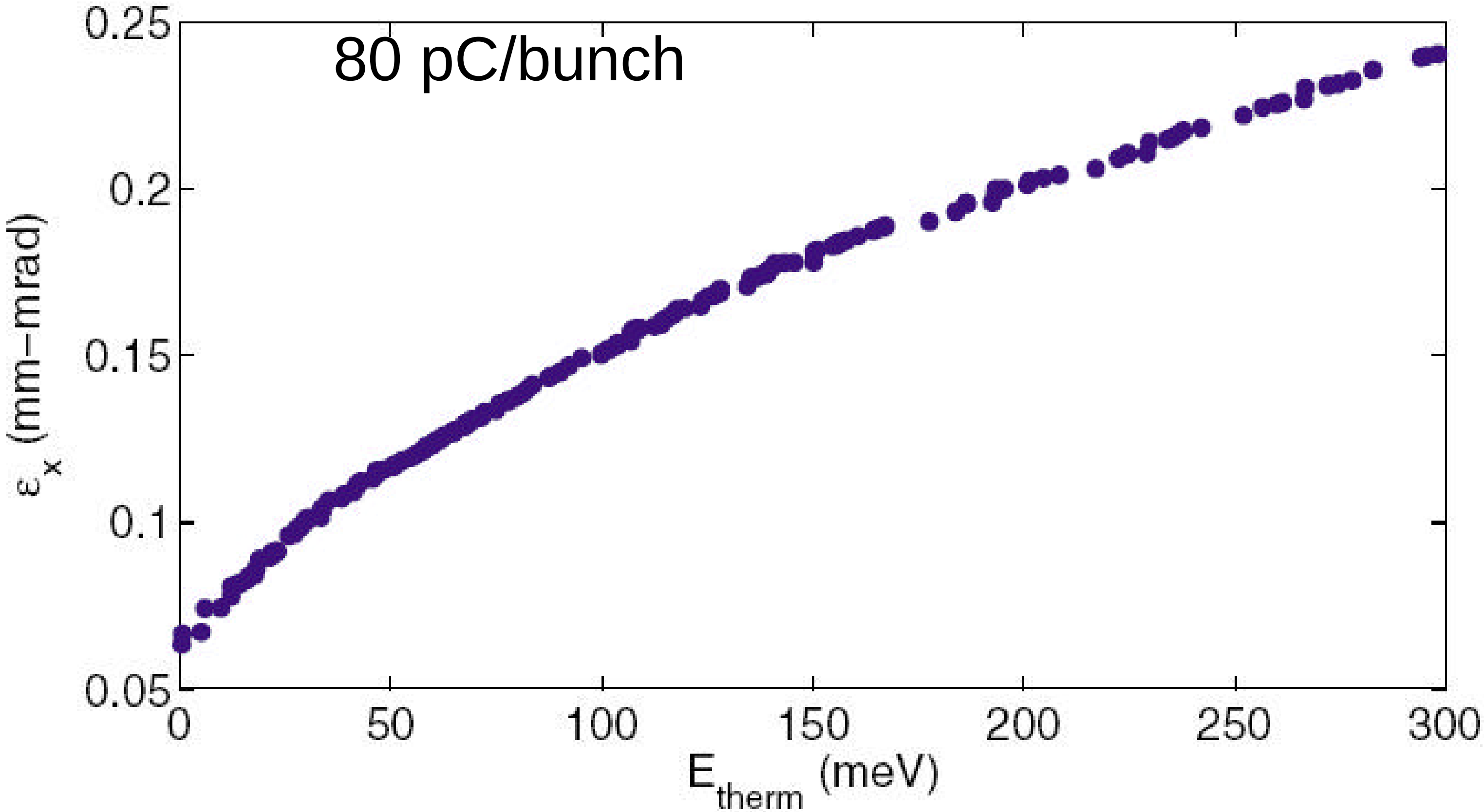
Normalized rms transverse emittance versus bunch length for various bunch charges

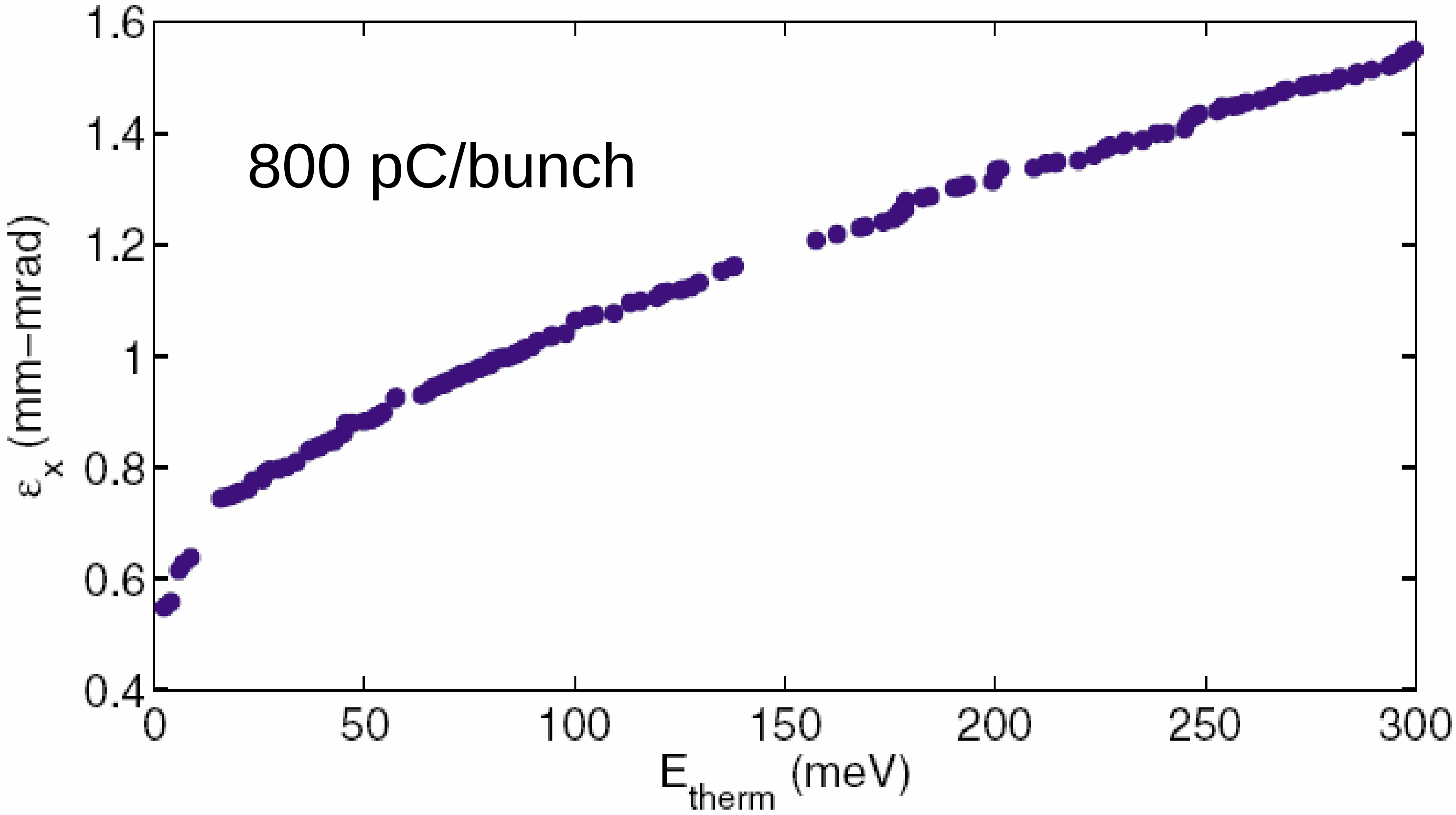


Longitudinal rms emittance versus bunch length for various bunch charges



The optimum emittance depends on cathode thermal emittance even at high bunch charge, contrary to frequent statements otherwise




800 pC/bunch
ε_x (mm−mrad)
1.6
1.4
1.2
1
0.8
0.6
0.4
0
50
100
150
200
250
300
E_{therm} (meV)

What did the optimization change from the original single point design?

- Reduced the optical pulse duration and spot size at the photocathode by about a factor of two
- Shortened the focal length of first solenoid a factor of 1.76
- Moved the buncher closer to the electron gun
- Reduced the field in first SRF cavity nearly a factor of two, and moved its phase about 45^{o} off crest in the bunching sense
- Increased the beam energy by ~ 20%

Conclusions

- Genetic algorithm based optimizations are a powerful tool to improve injector designs
- An optimized very high voltage DC gun based injector, delivering a long pulse (compared to the time to transit the cathode-anode gap) and employing sub-harmonic bunching may prove to be an excellent low emittance injector for the ILC
- We are constructing an ERL injector at Cornell which will be used to validate our optimization results

The Cornell 500-750 kV Photoemission Gun