Electron-beam simulations: electron-gun emission and residual fields from measured profiles

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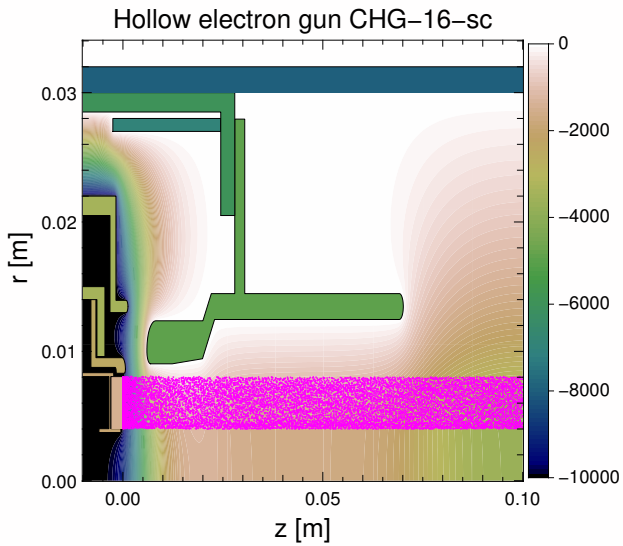
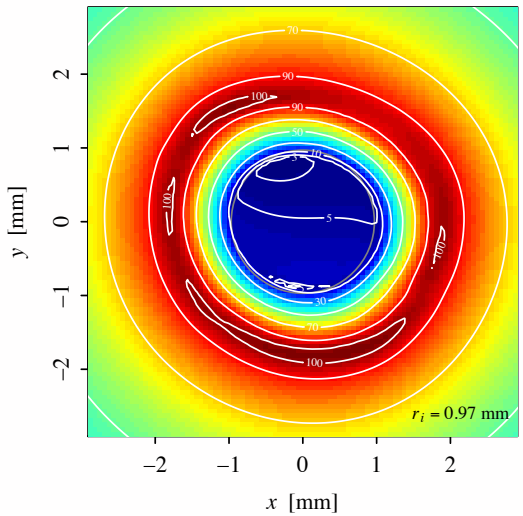
Fermilab

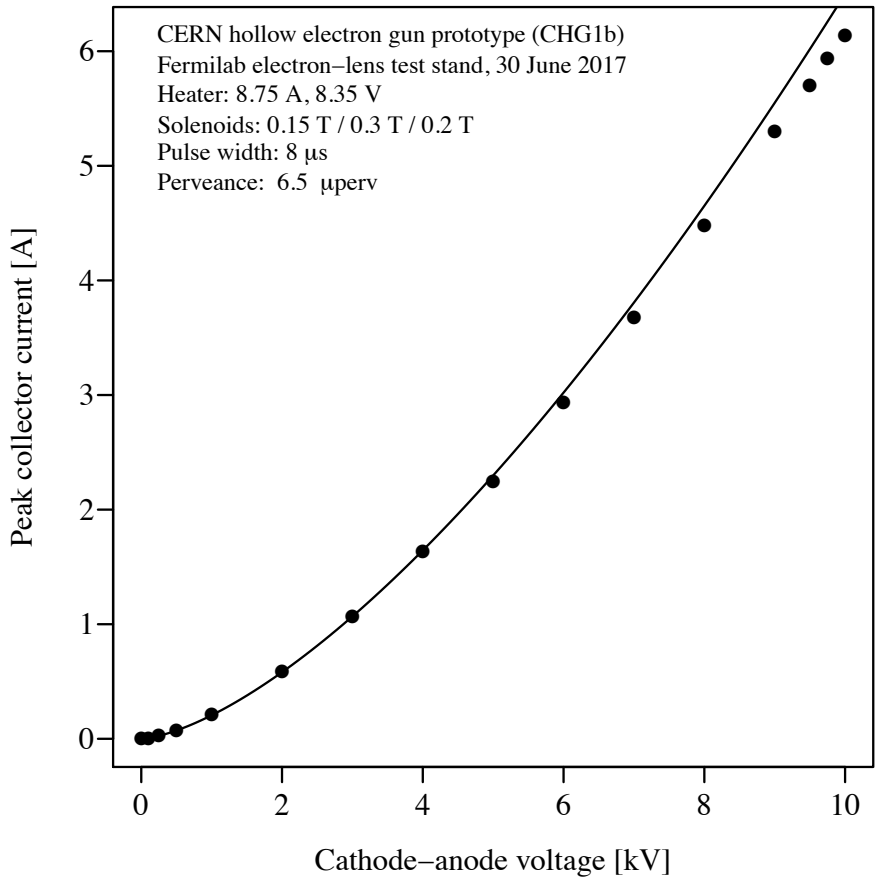
LHC e-lens meeting
26 Jan 2018

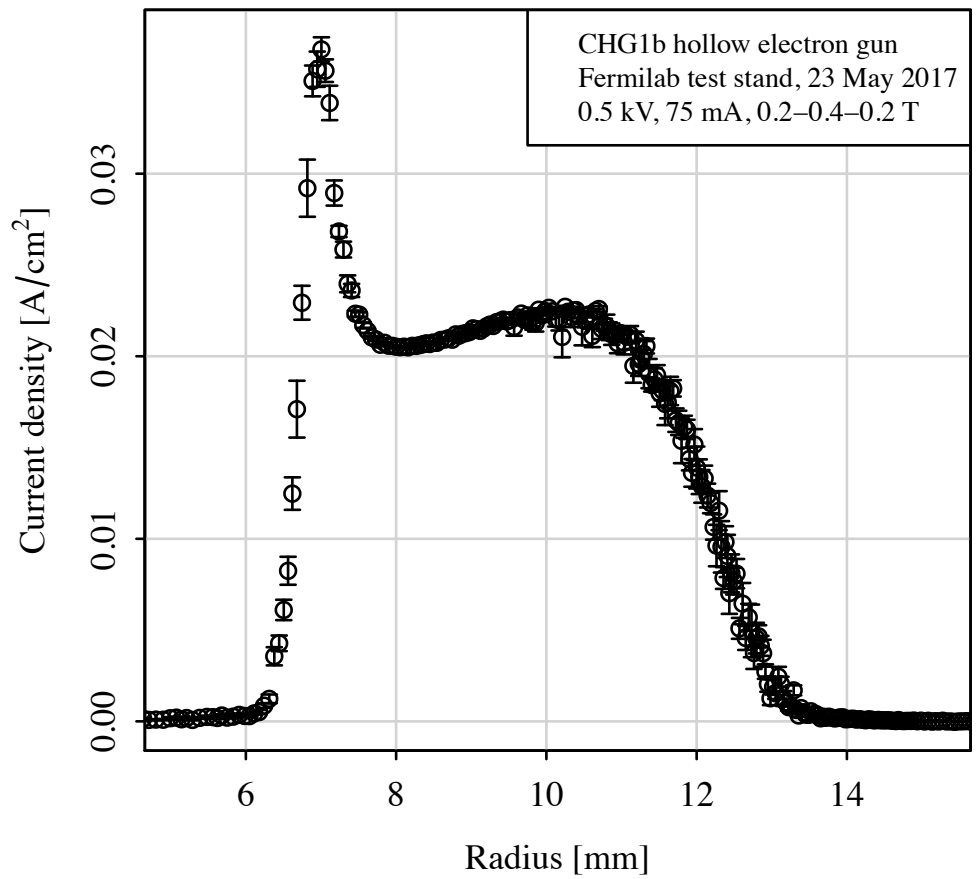




Calculation of electron gun yield and current-density distribution

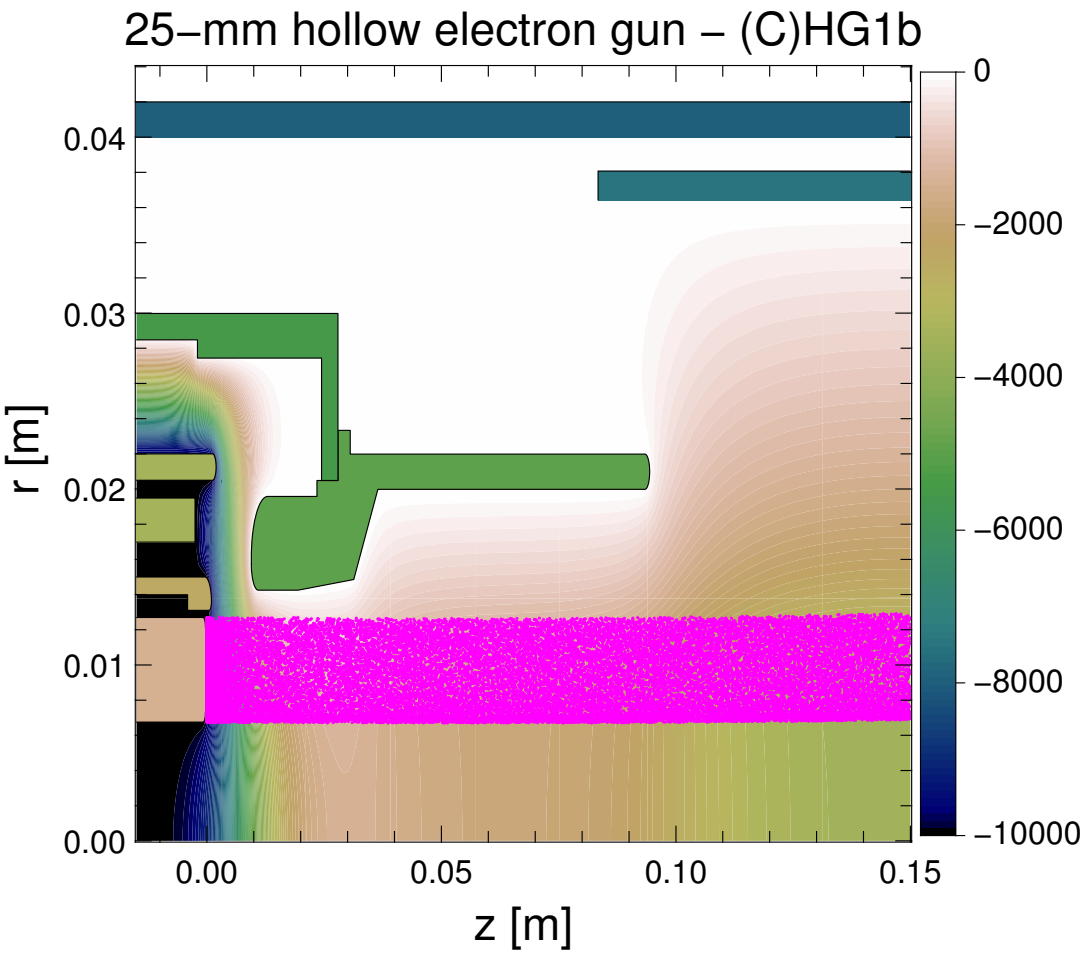
Measured performance of CHG1b 25-mm e-gun

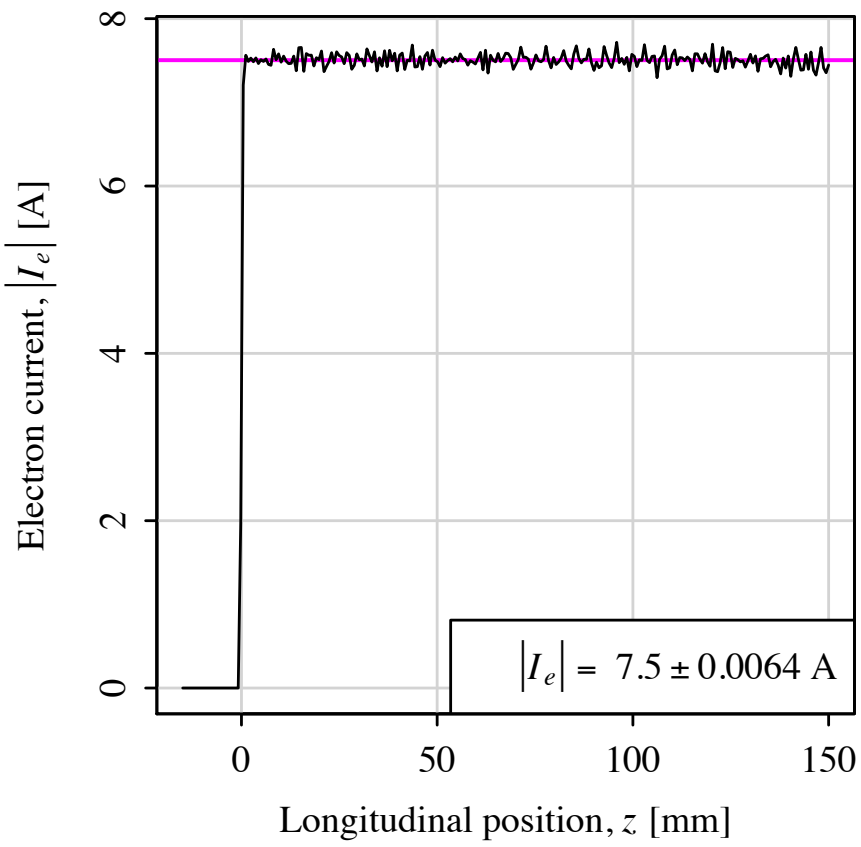




Data file: CHG1b_170523_8p75A_2–4–2kG_500V_75mA_hires.txt.gz

Warp simulation of existing (C)HG1 25-mm e-gun





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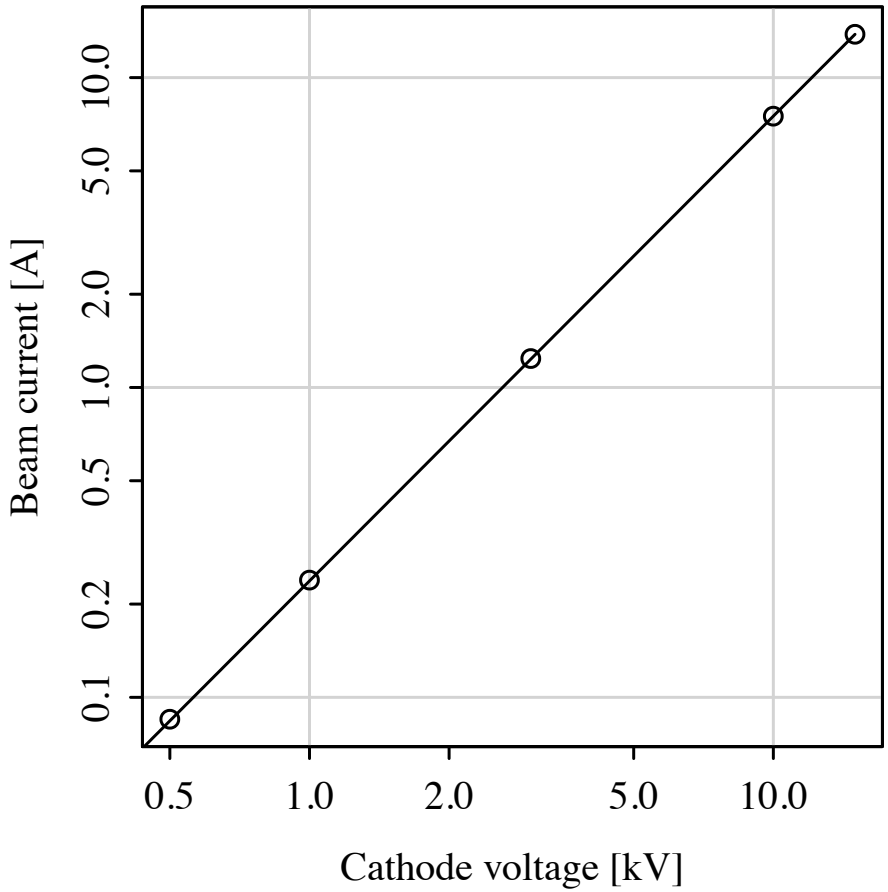
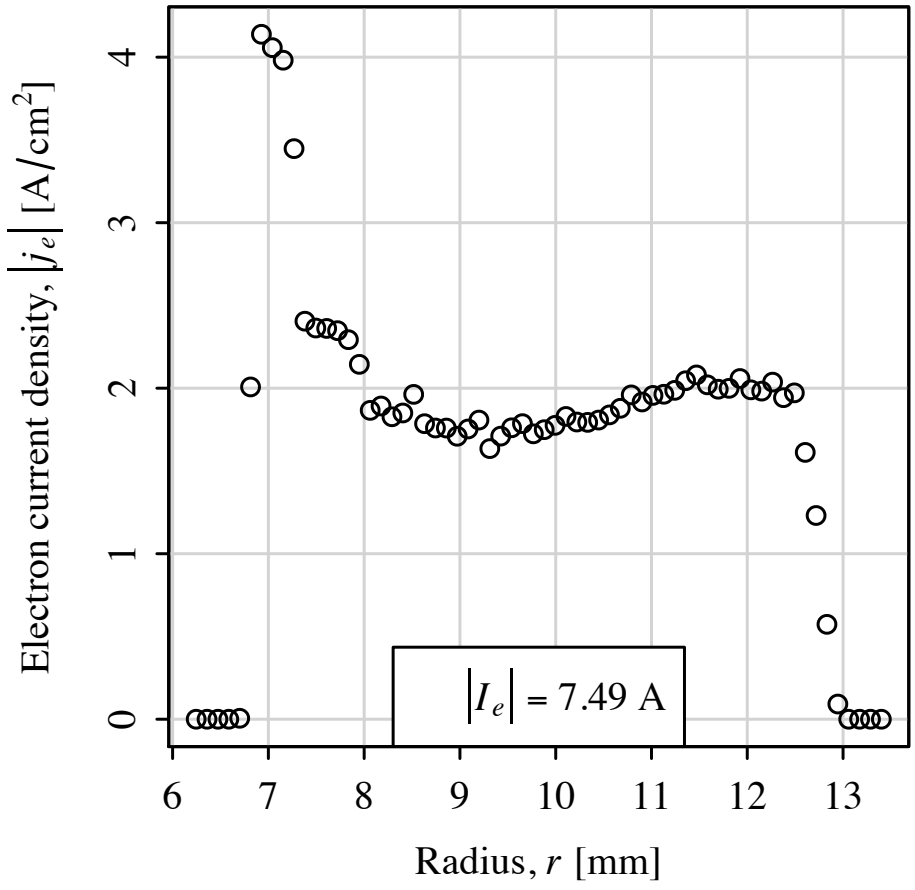
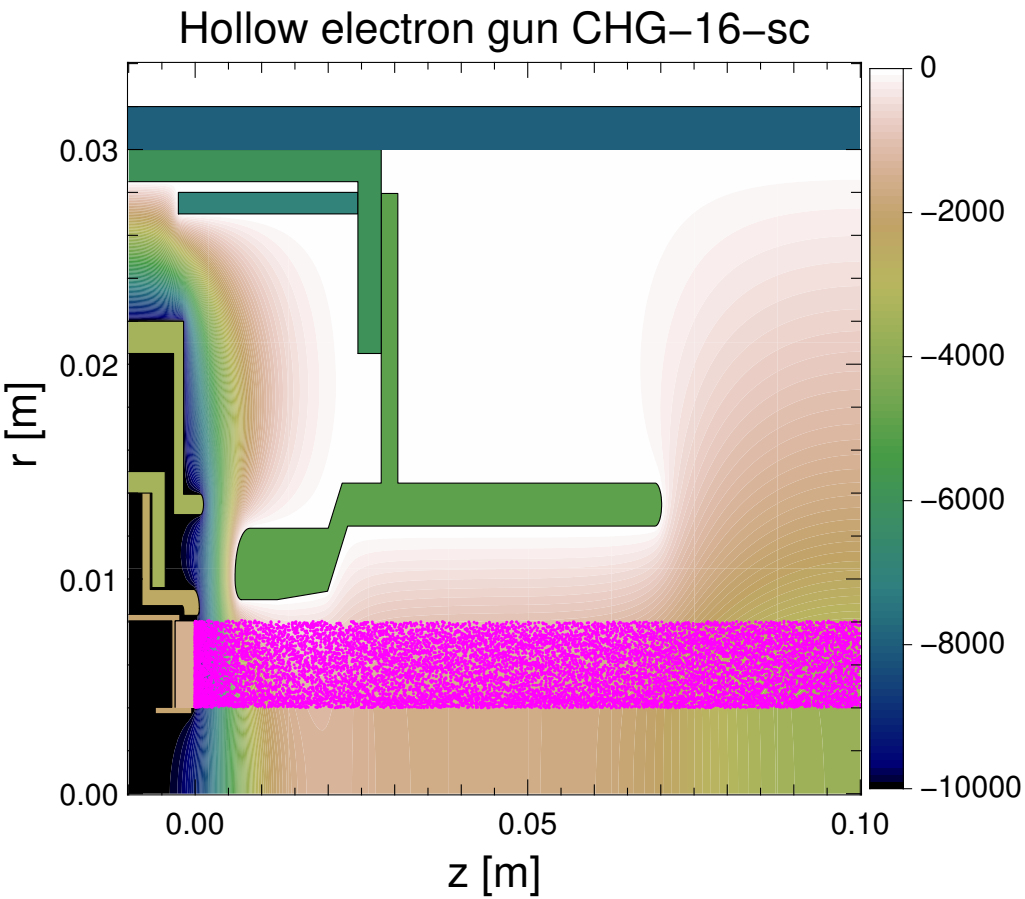


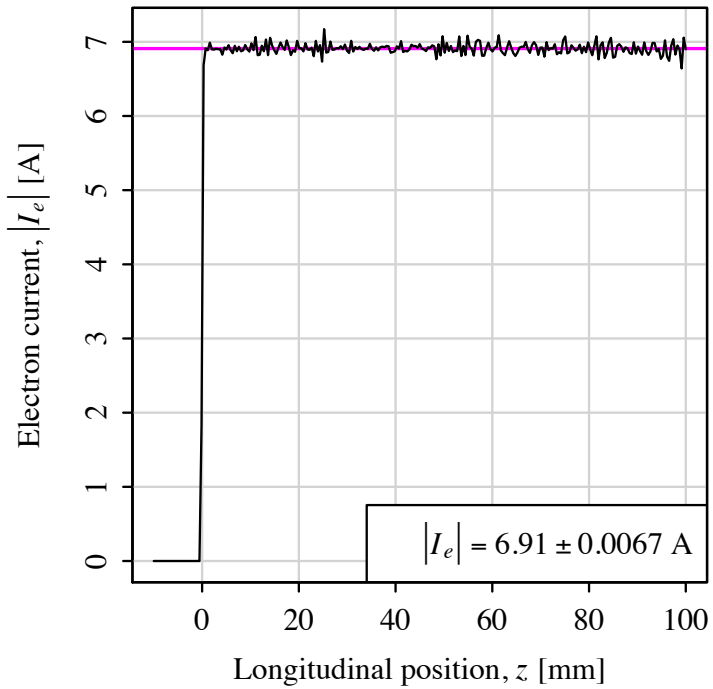


Predicted perveance is 7.5 uperv (vs. 6.5 measured)

Current-density distribution shows inner peak and sharp outer edge at 0.15 m downstream of cathode (measurements were taken at 2.8 m)

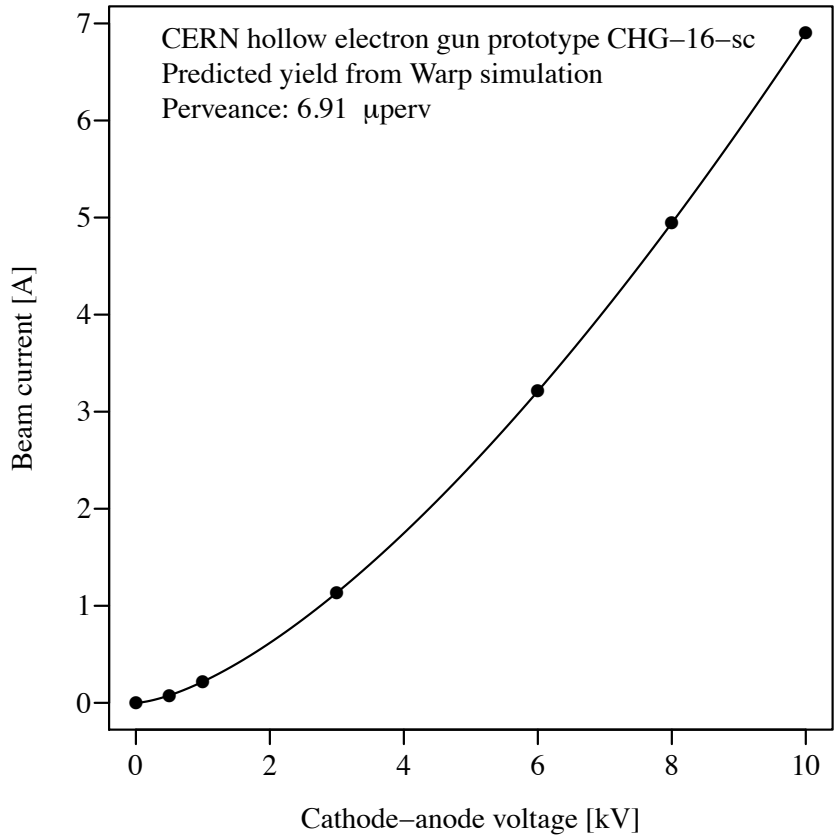
New CHG-16-sc e-gun with 16-mm scandate cathode

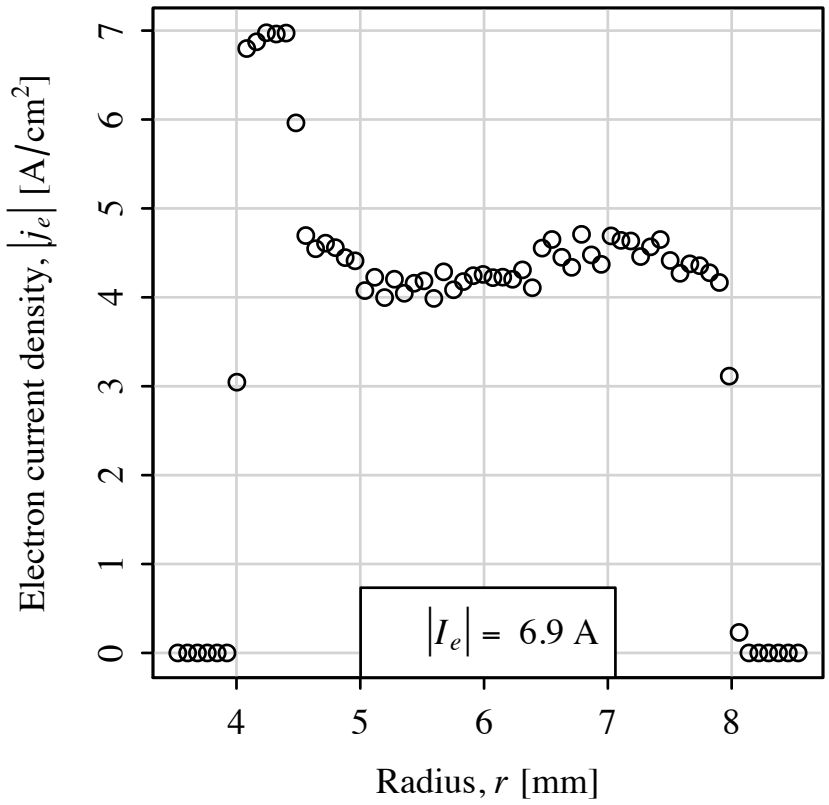




Simulated new e-gun using geometry from construction drawings

Predicted yield and current-density distribution



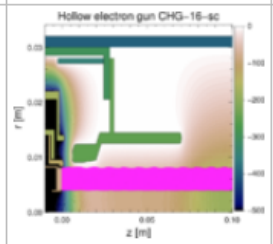
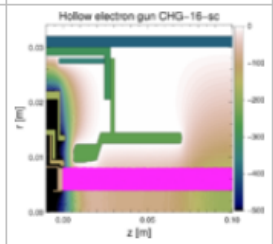
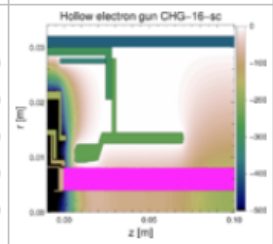
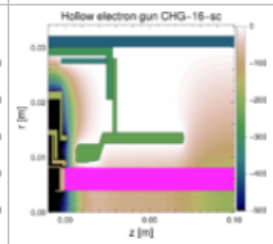
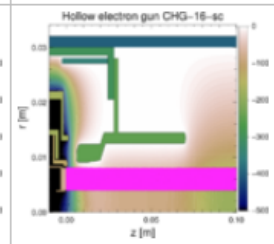
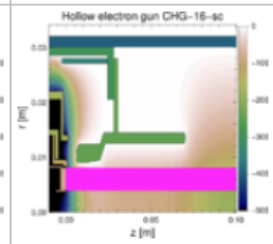
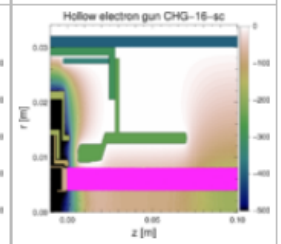
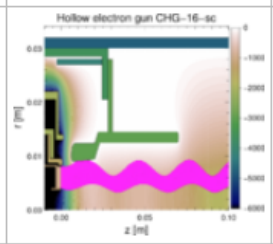
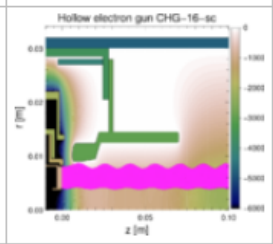
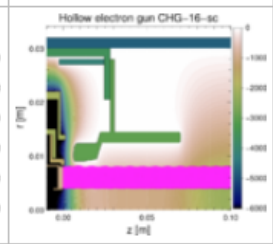
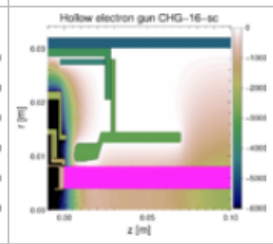
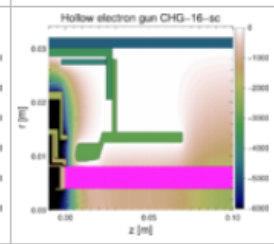
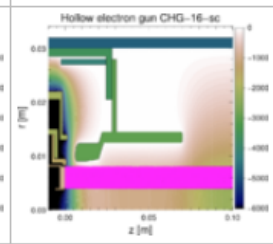
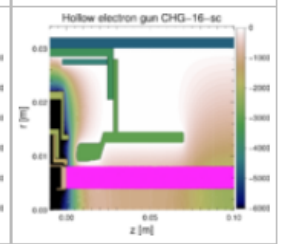
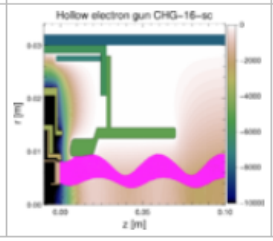
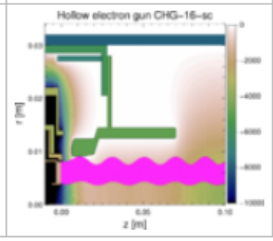
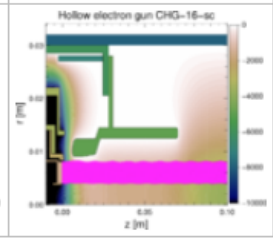
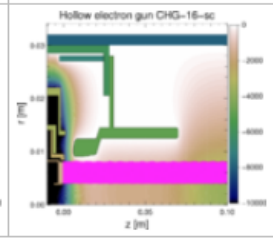
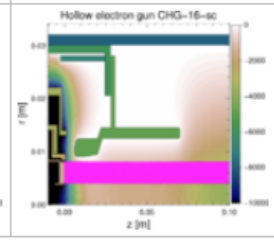
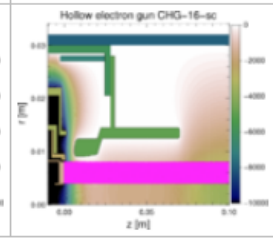
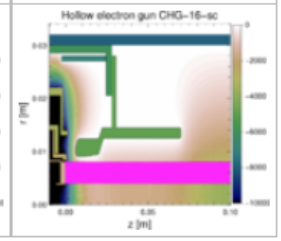


Predicted perveance is 6.9 uperv

Scaled geometry should give same perveance as CHG1b, but cathode is flat and anode shield is farther.

Current-density distribution shows is similar to CHG1b

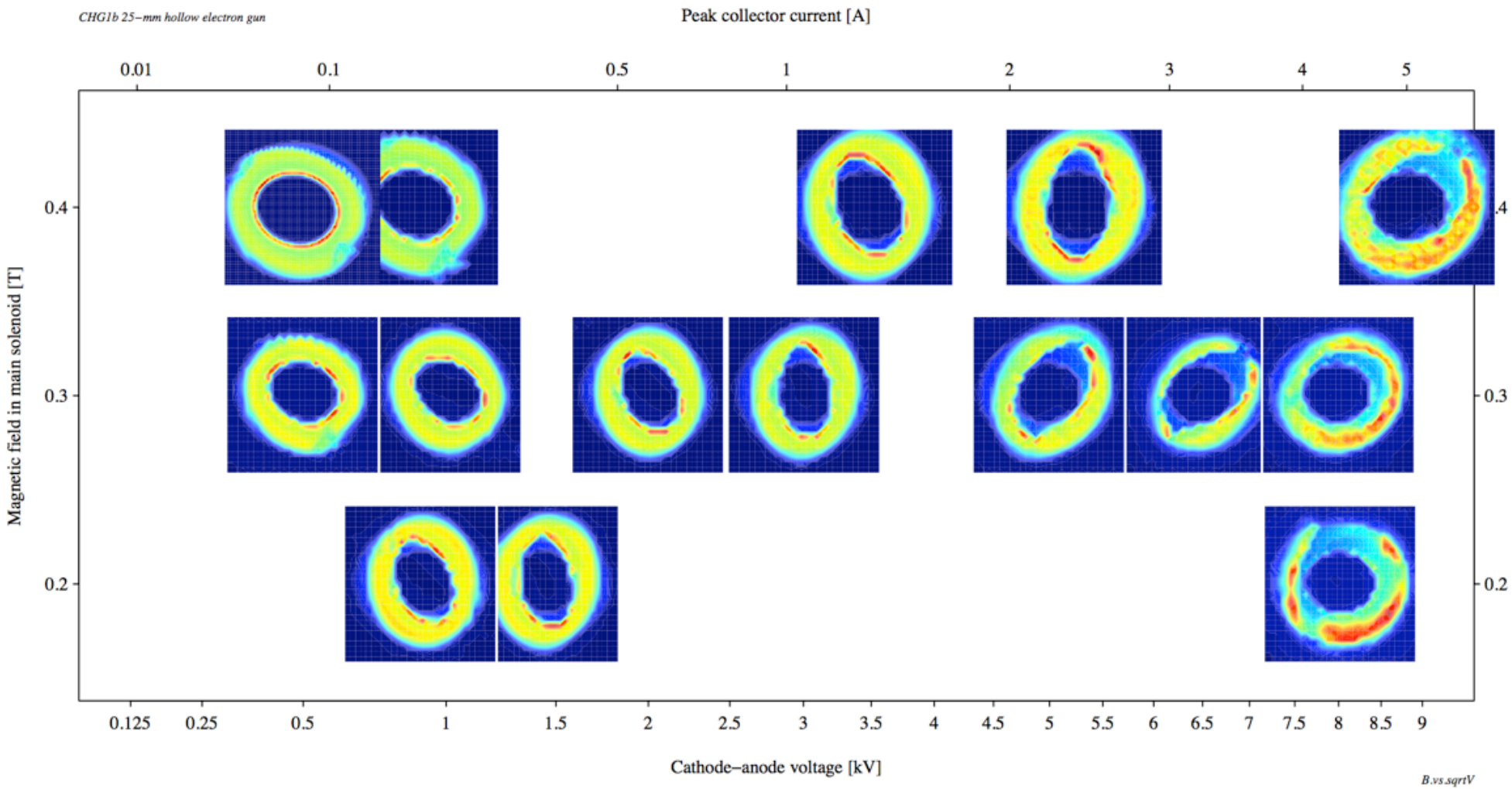
Emission vs. voltage and magnetic field (Warp calc.)

	0.05 T	0.1 T	0.2 T	0.3 T	0.4 T	0.5 T	1.0 T
0.5 kV, 78 mA							
6 kV, 3.22 A							
10 kV, 6.91 A							

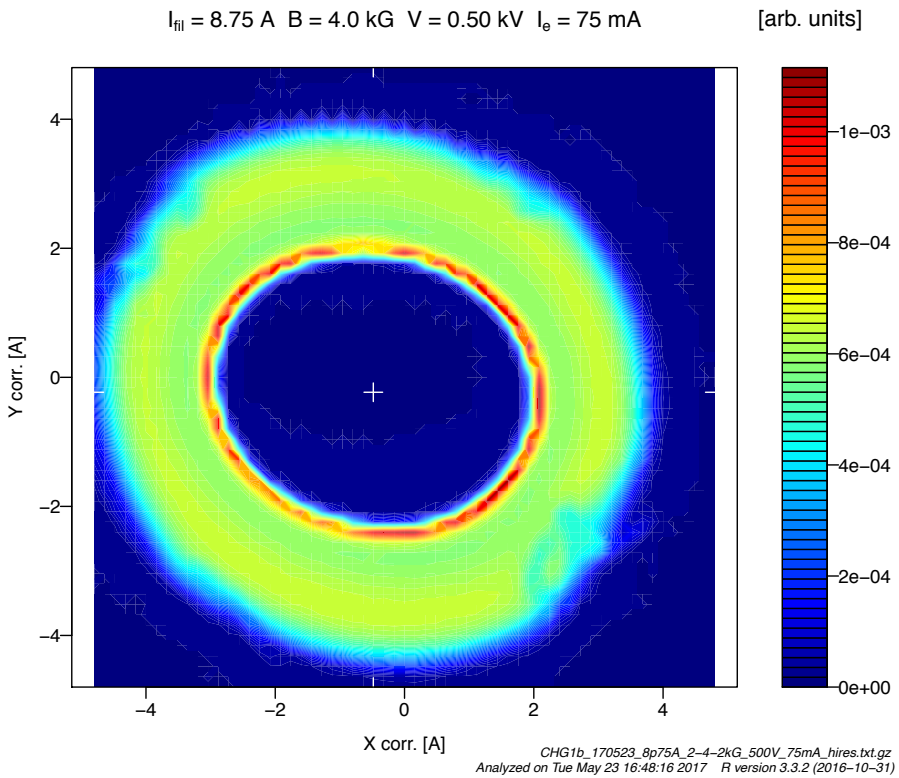
Examples show minimum magnetic field to avoid scalloping

Calculation of residual electric fields from measured profiles

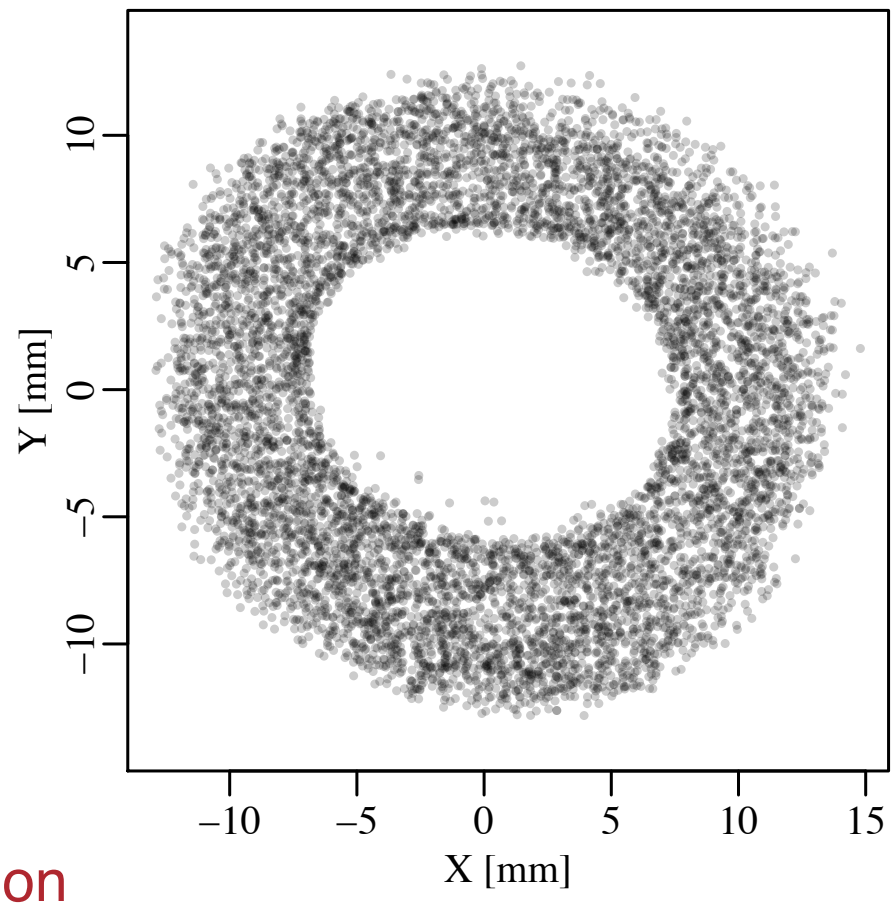
CHG1b measured profile evolution



Generation of particle distributions



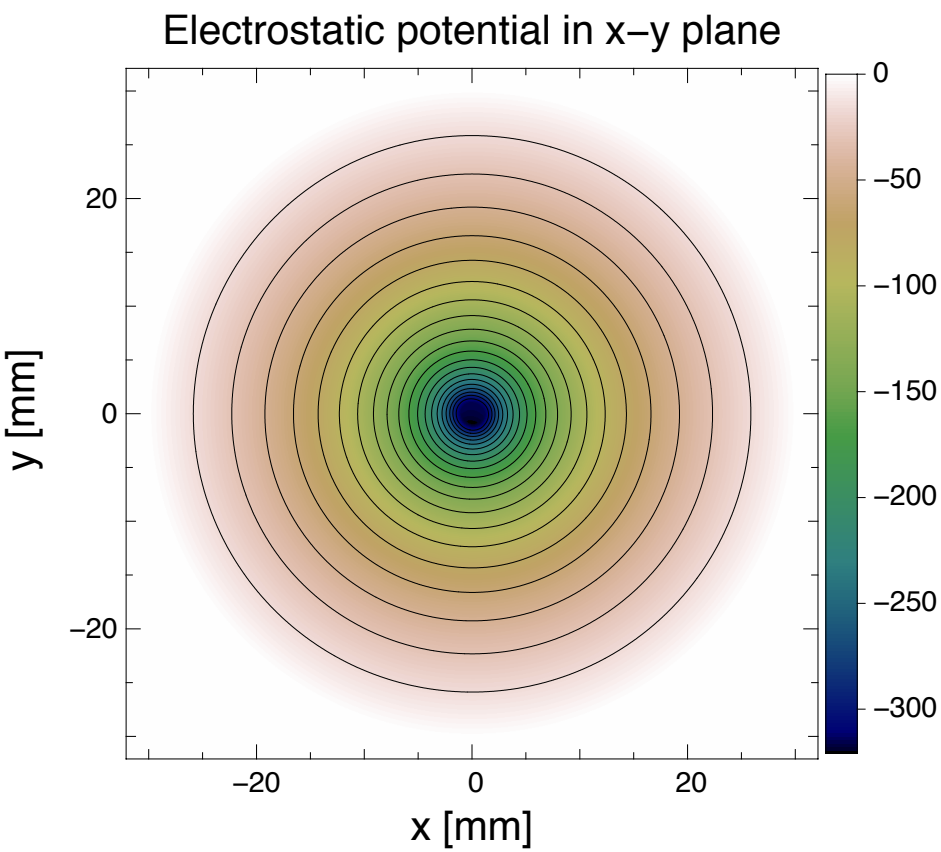
From measured profile...

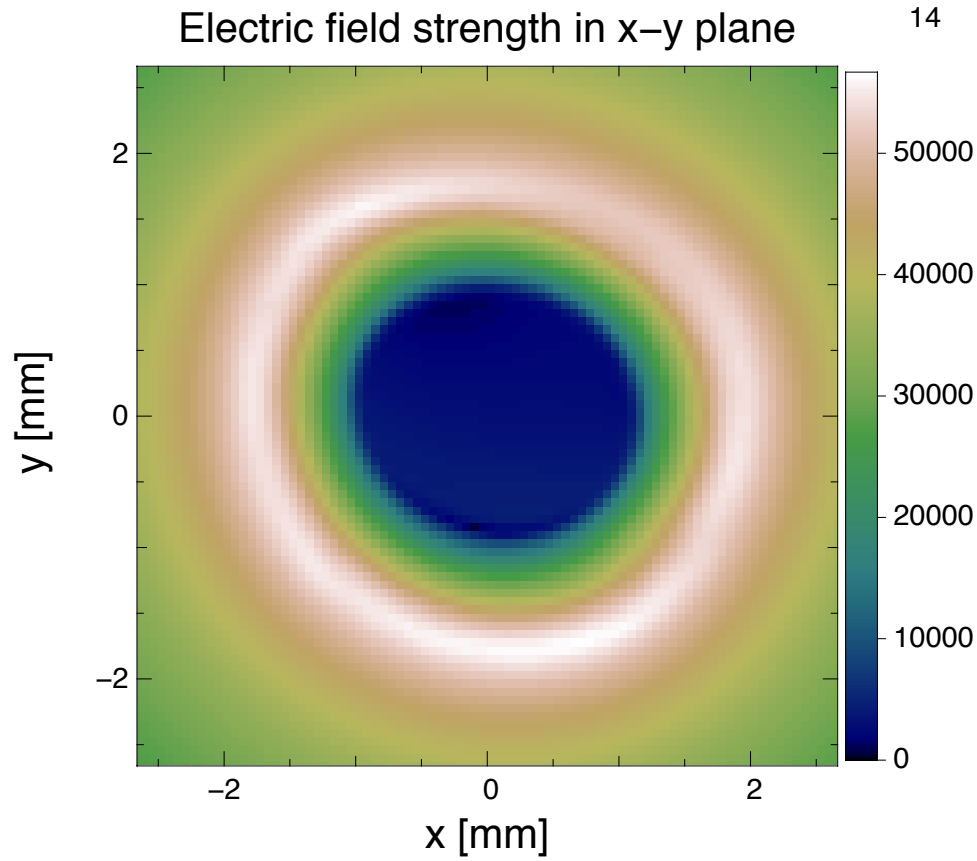


...to particle distribution

Calculation of potentials and fields with boundaries

Particle distributions are entered in Warp to calculate potentials and fields

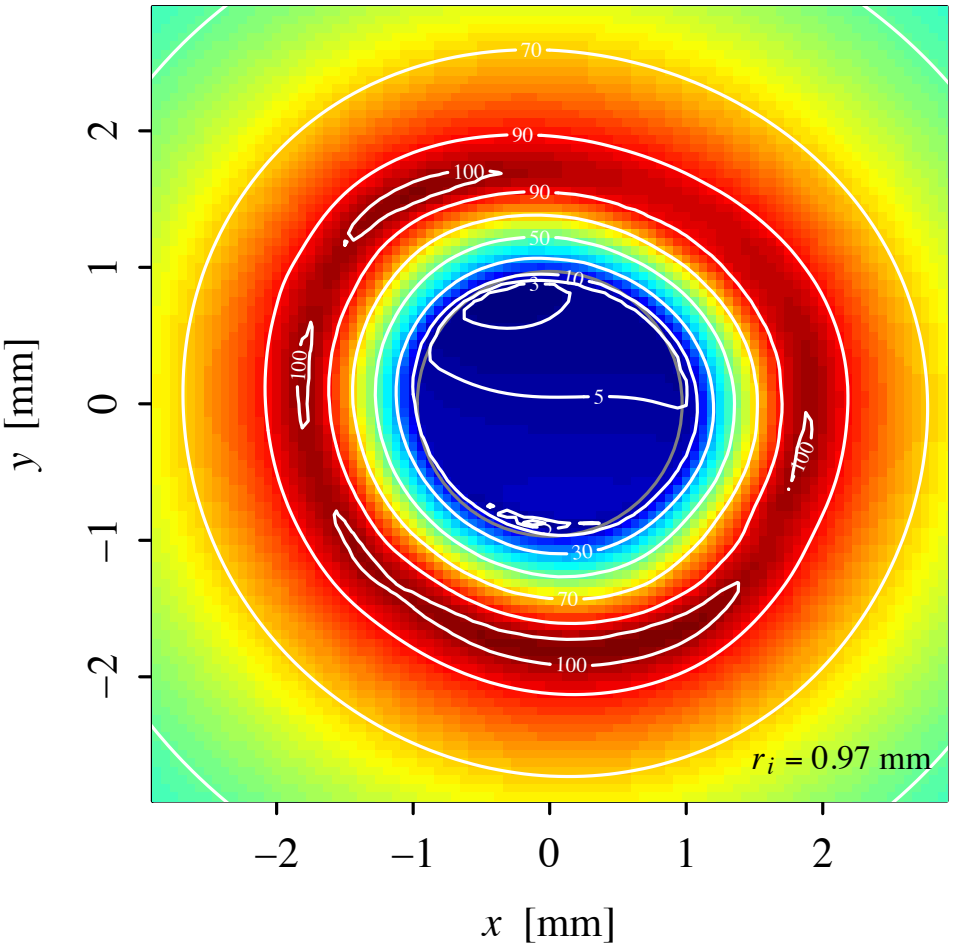


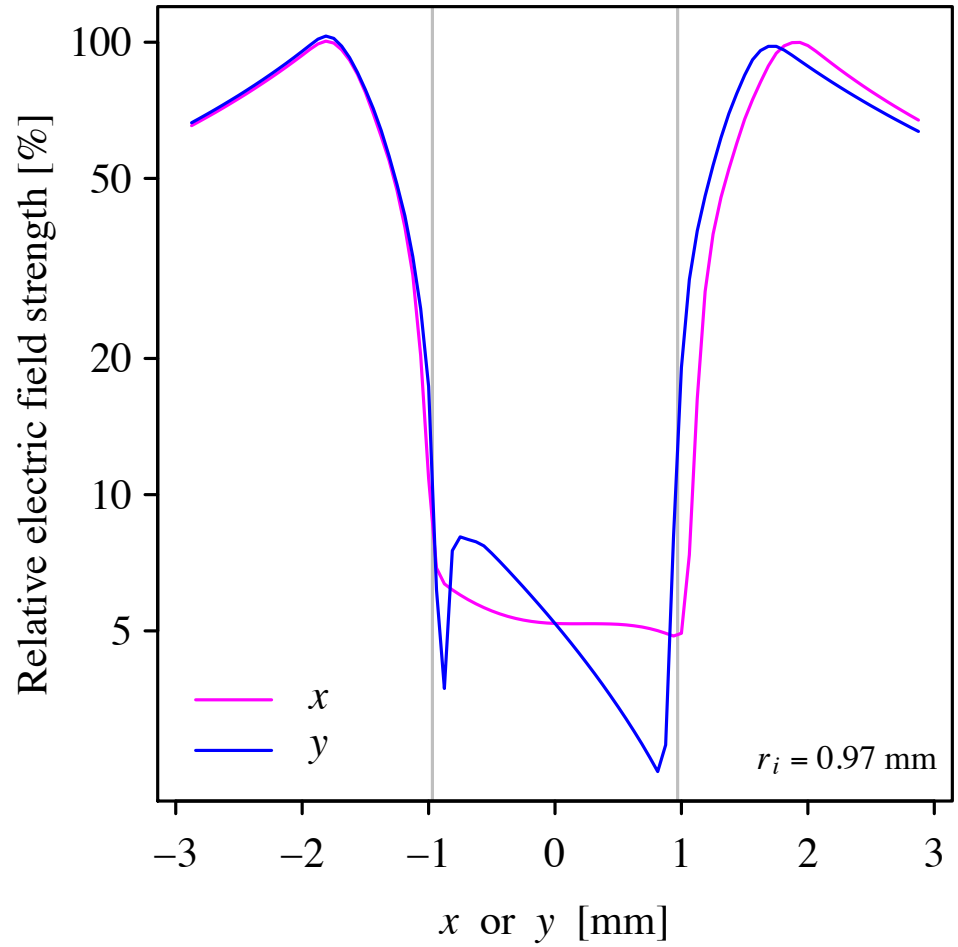


Examples with inner e-beam radius = 0.97 mm and 30-mm inner radius of vacuum chamber

Analysis of field distributions

Calculations are analyzed to estimate field quality in the center

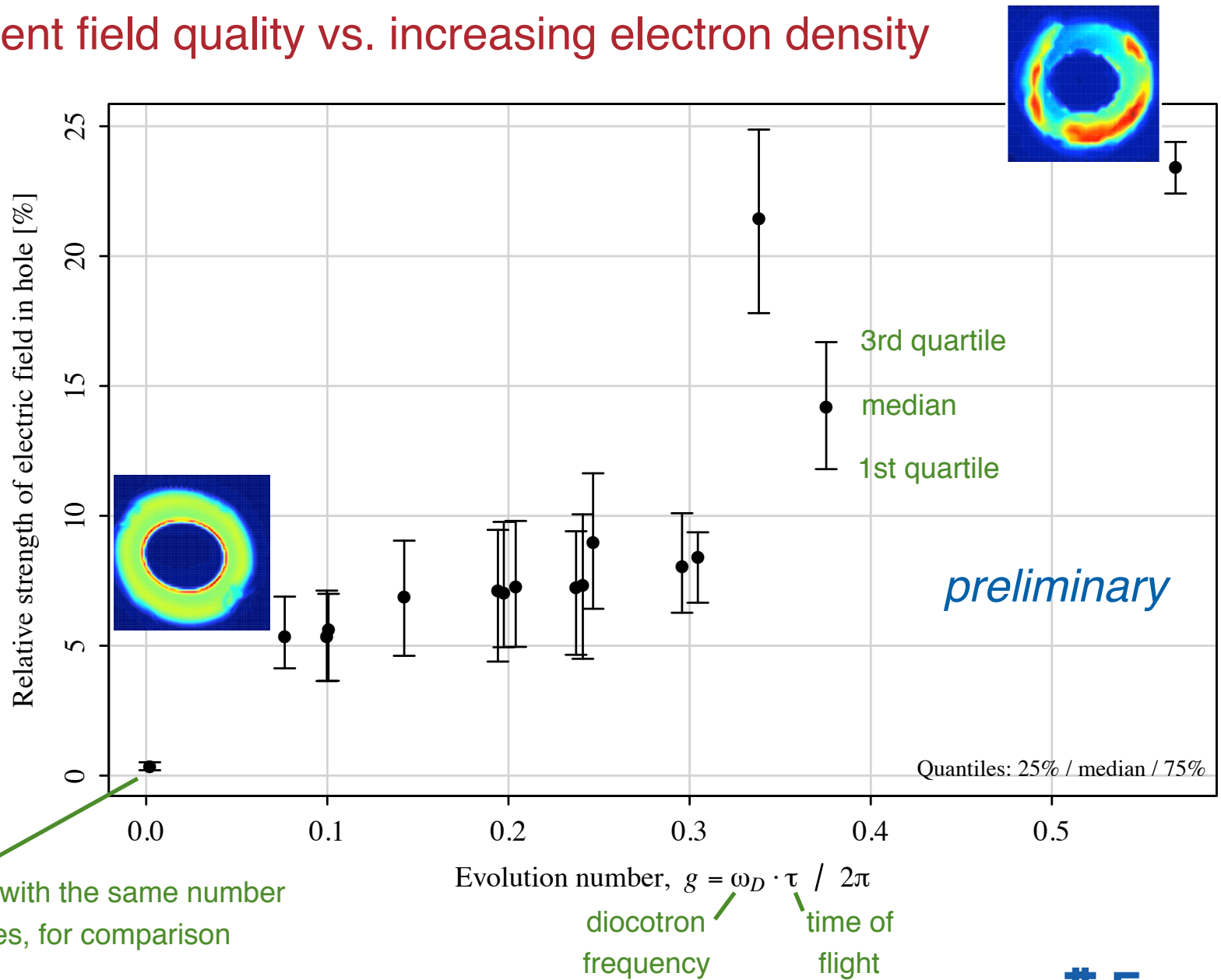




Outputs: mean field, field fluctuations, kick maps for tracking

Electric-field quality vs. evolution parameter

A way to present field quality vs. increasing electron density



Observations

We have reliable tools for electron-gun design

Warp predicts yield to within ~10%. Profile comparison needs full cathode-collector simulation, but preliminary results are good.

UltraSAM has been used successfully in the past.

Direct comparison between Warp, UltraSAM and CST can be done on one of the existing e-guns.

Preliminary estimates of residual E-fields in hole are around 5% of peak using CHG1b measurements, r_i = 0.97 mm, and a 60-mm vacuum chamber.

Caveats: misalignments not fully corrected; calculation is not self-consistent (same velocity for all electrons).

Field map can be implemented in proton tracking codes using general symplectic form (see note FERMILAB-FN-0972-APC).