Simulation, Generation, and Characterization of a High Brightness Electron Source

Presented by

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Collaborators

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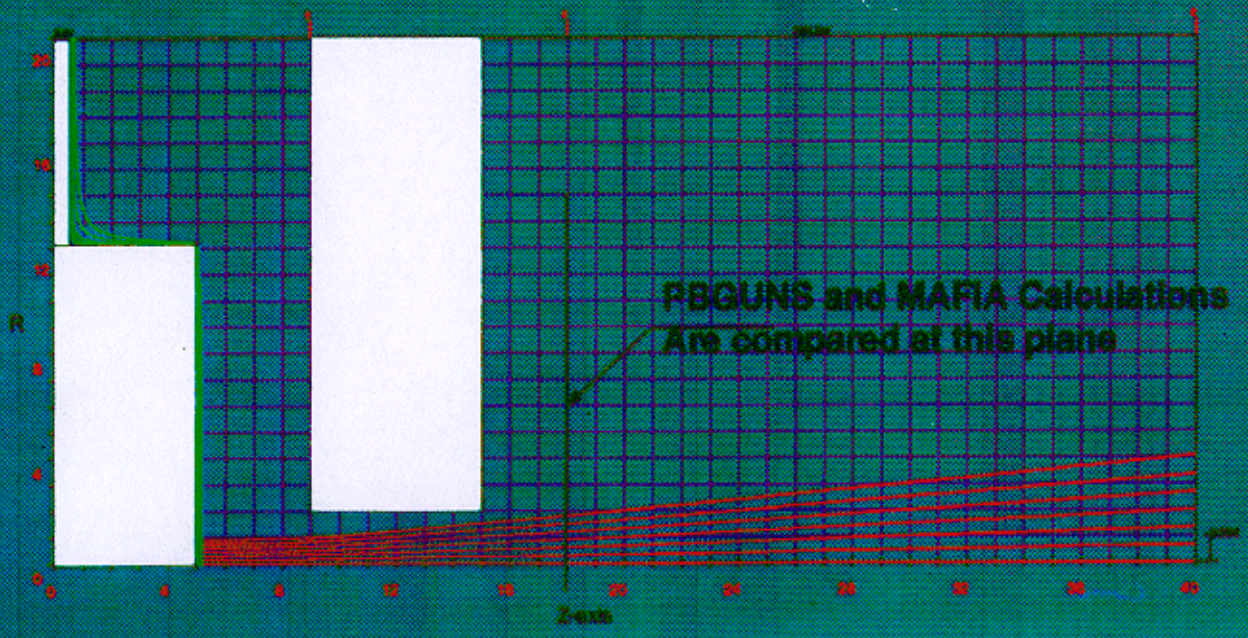
Simulations

- Used MAFIA and PBGUNS
- 1 MV across 1 mm gap, .25 mm emitting spot, .5 mm anode hole
- Emittance as a function of current and pulse duration
- Investigated effect of a 1 eV random initial energy
  - Contributes .17 π mm-mrad to total emittance
- Total beam emittance of .39 π mm-mrad for 100A, 10ps bunch
- Longitudinal energy spread of 0.15% for 100A, 10ps bunch
- Investigated effect of curving the cathode to provide collimation or beam waist

Geometry for Simulation

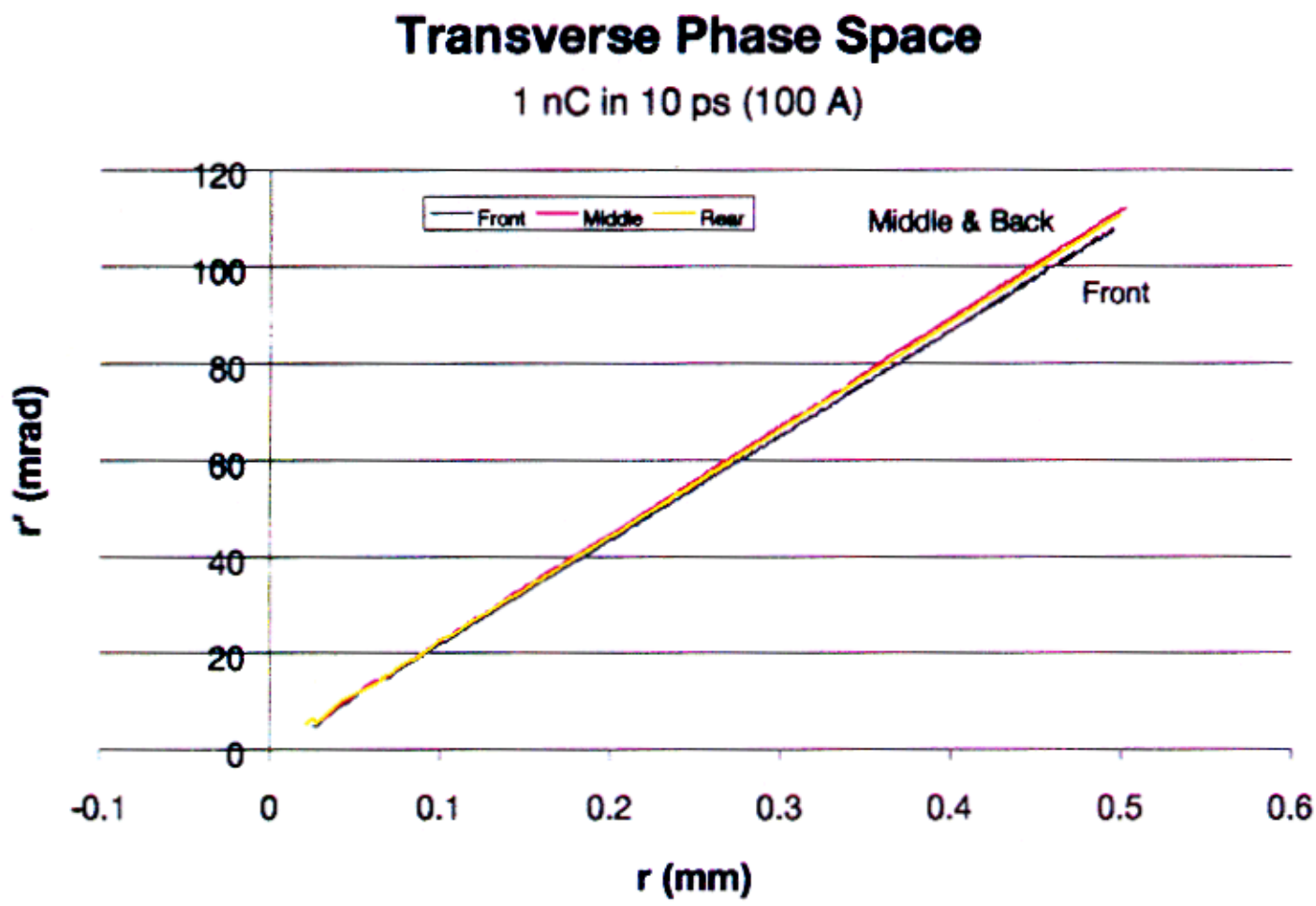
- 1 mm gap
- .5 mm radius anode hole
- .25 mm emitting spot, uniform current density
- 1 MV potential, 1 GV/m gradient



Current	Charge	Bunch length	Emittance	Brightness
A	nC	ps	π mm mrad	$\frac{A}{(mm-mrad)^2}$
100	1	10	0.16734	3571
100	0.3	3	0.0882	12854
100	0.1	1	0.062	26014
100	0.03	0.3	0.0728	18868
500	0.5	1	0.207	11668
250	0.25	1	0.132	14348
50	0.05	1	0.0386	33557
10	0.01	1	0.0446	5027

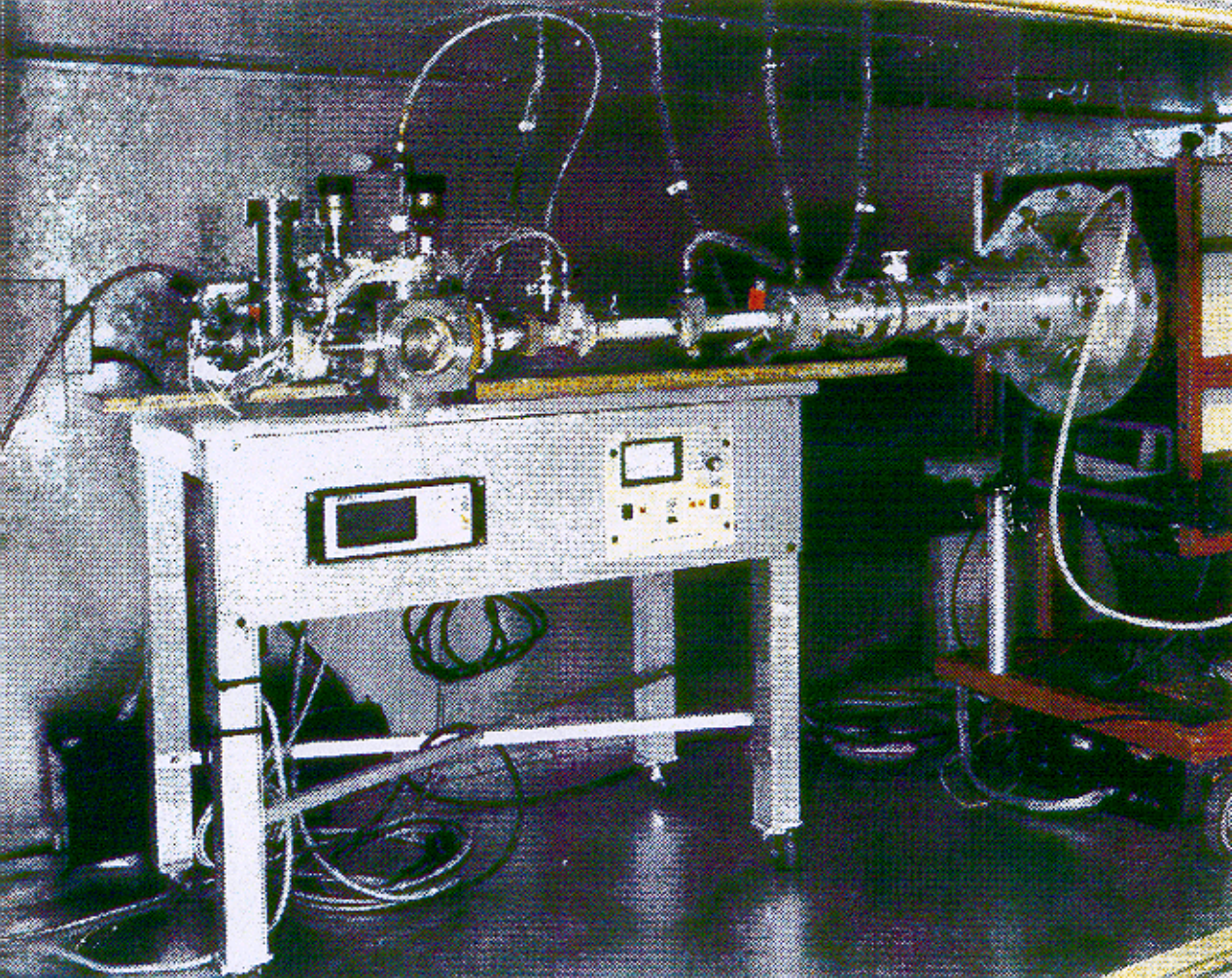
Thermal and Space Charge Contributions

Current	Charge	Initial Energy	Emittance
A	nC	eV	π mm mrad
100	1	0	0.251
100	1	1	0.287
100	1	10	0.597
100	1	100	1.704
10	0.1	0	0.023
10	0.1	1	0.171
10	0.1	10	0.530
10	0.1	100	1.682


Transverse Phase Space
1 nC in 10 ps (100 A)
Front
Middle
Rear
Middle & Back
Front
120
100
80
60
40
20
0
r' (mrad)
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
r (mm)

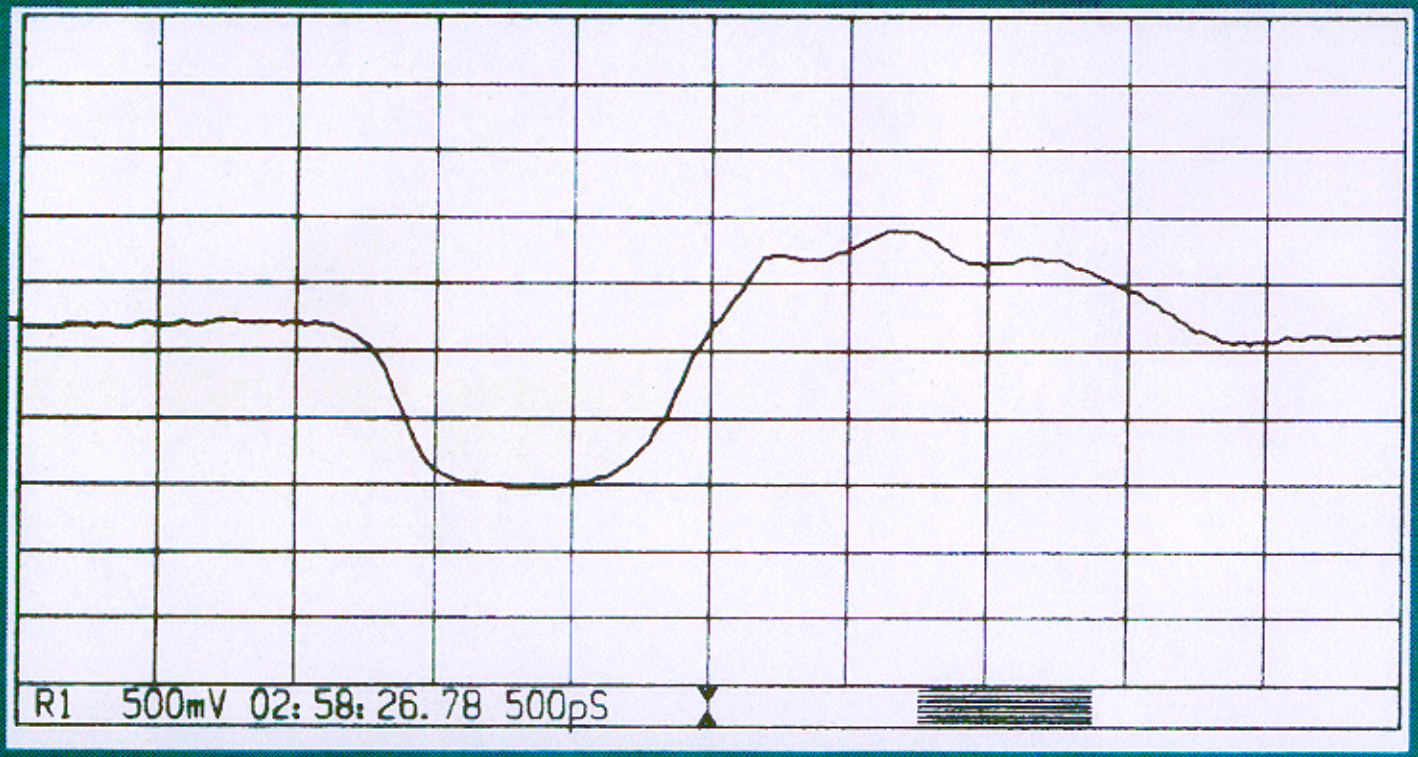
Measurements

- Experimental Arrangement
- Pulser provides 1 ns voltage pulse with 100ps rise and fall
- Dark Current
  - 10 pC at 650 MV/m
  - Fowler-Nordheim plot gives $\beta = 30$ for a well conditioned surface
- Photoemission using KrF excimer
  - Charge has a linear dependence on laser energy
  - Field dependence

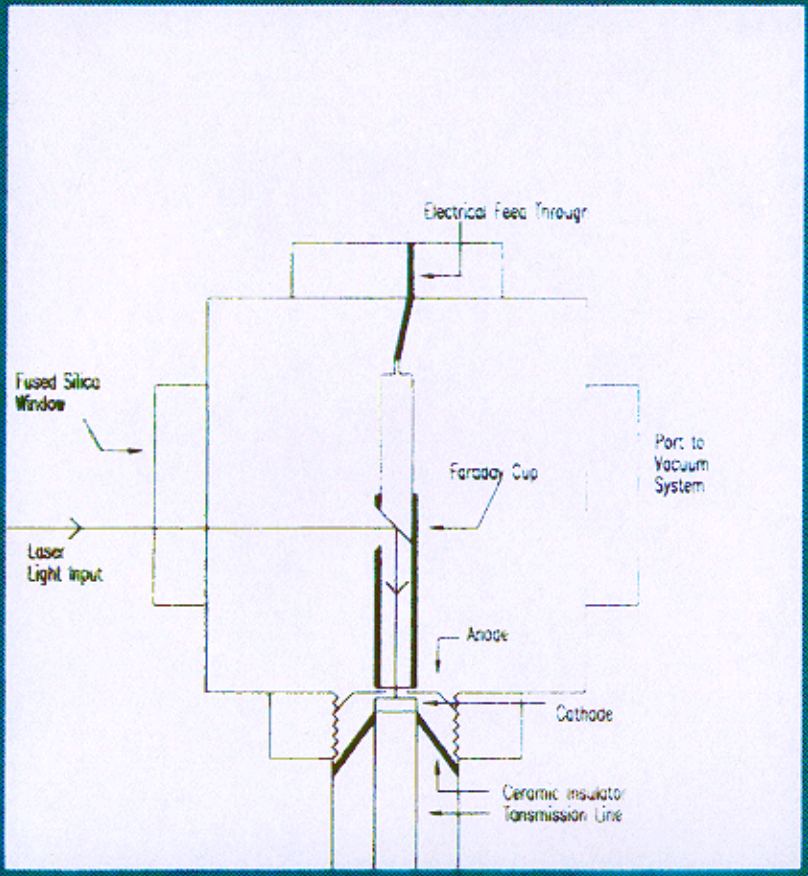


Voltage Trace from MV pulser

1 ns duration, with 100 ps rise and fall

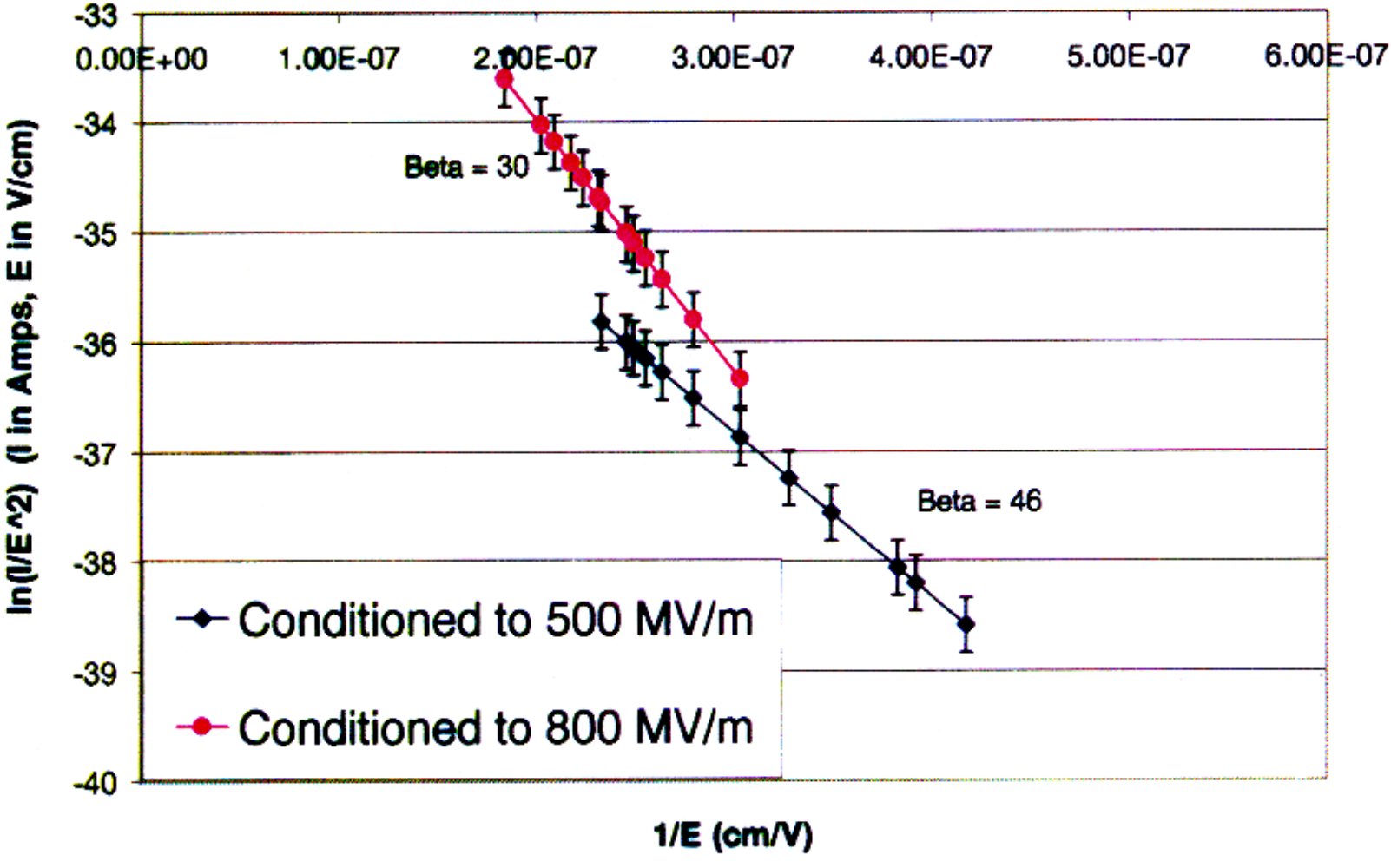


Experimental Arrangement



- Variable electrode spacing
- Faraday cup with mirror surface

Fowler-Nordheim Plot for Cu Cathodes



Field Dependence of Extracted Charge

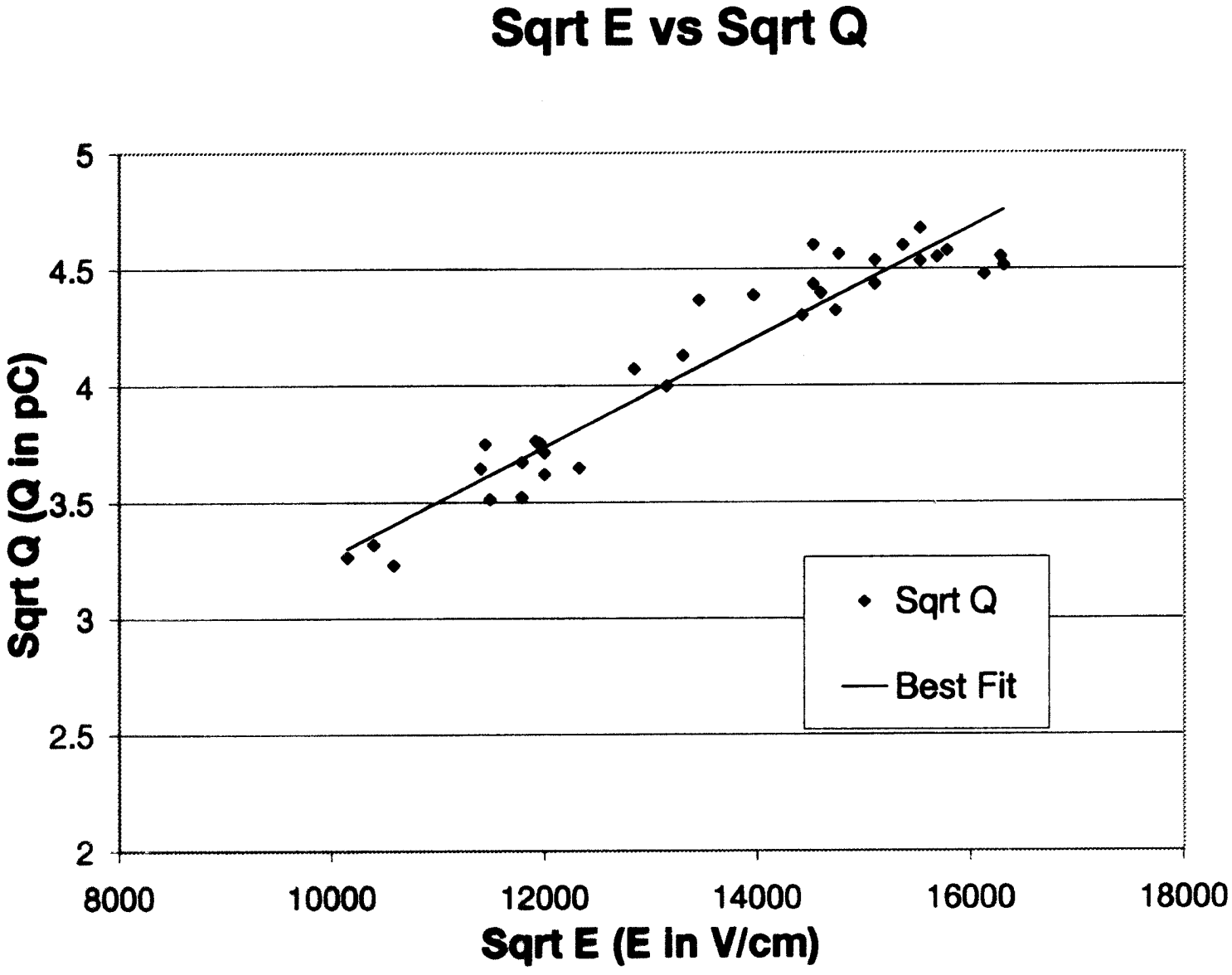
- Investigated the dependence of extracted charge on applied voltage for a constant laser energy.
- For small values of $[h\nu-\phi]$,

$$Q \propto \left(h\nu - \phi + \sqrt{\frac{e\beta E}{4\pi\varepsilon_0}}\right)^2$$

- Plot $Q^{1/2}$ vs $E^{1/2}$

$$\frac{slope}{intercept} = (h\nu - \phi)^{-1}\sqrt{\frac{e\beta}{4\pi\varepsilon_0}}$$

- Yields $\beta = 5$ for $\phi = 4.65$ eV


Sqrt E vs Sqrt Q
Sqrt Q (Q in pC)
5
4.5
4
3.5
3
2.5
2
8000
10000
12000
14000
16000
18000
Sqrt E (E in V/cm)
Sqrt Q
Best Fit

Conclusions and Future Plans

- Simulations show that a pulsed power gun with a 1 GV/m gradient should be able to provide a 1 nC beam in 10 ps with
  - Total emittance of .39 π mm-mrad
  - Energy spread of 0.15%
  - Even better values of total emittance may be possible for shorter pulse durations
- It is possible for a copper cathode to support a field of 1 GV/m without breakdown
- The field enhancement factor for photoemission is lower than than the field enhancement factor for field emission
- Future plans include photoemission with 4th harmonic of NdYAG, measurements of beam emittance and energy spread, and an eventual upgrade to 5MeV