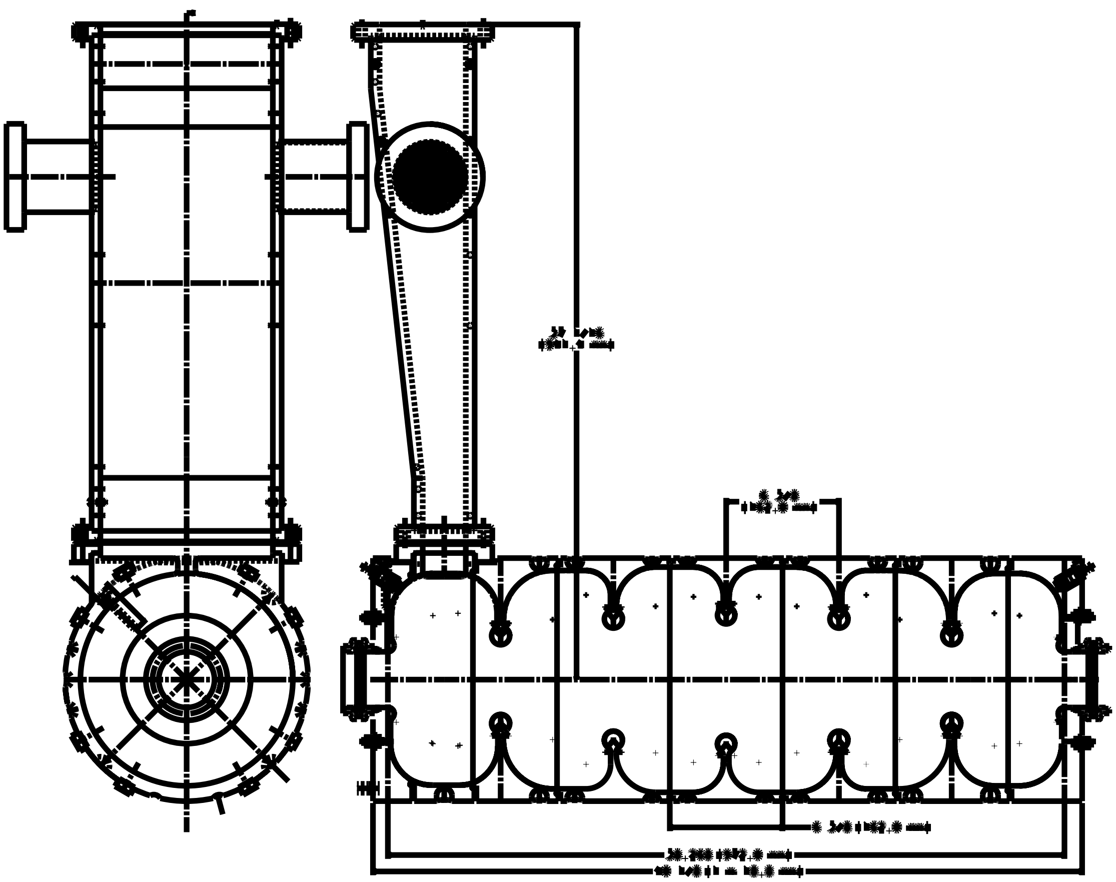
Preliminary Lab G Dark Current Results

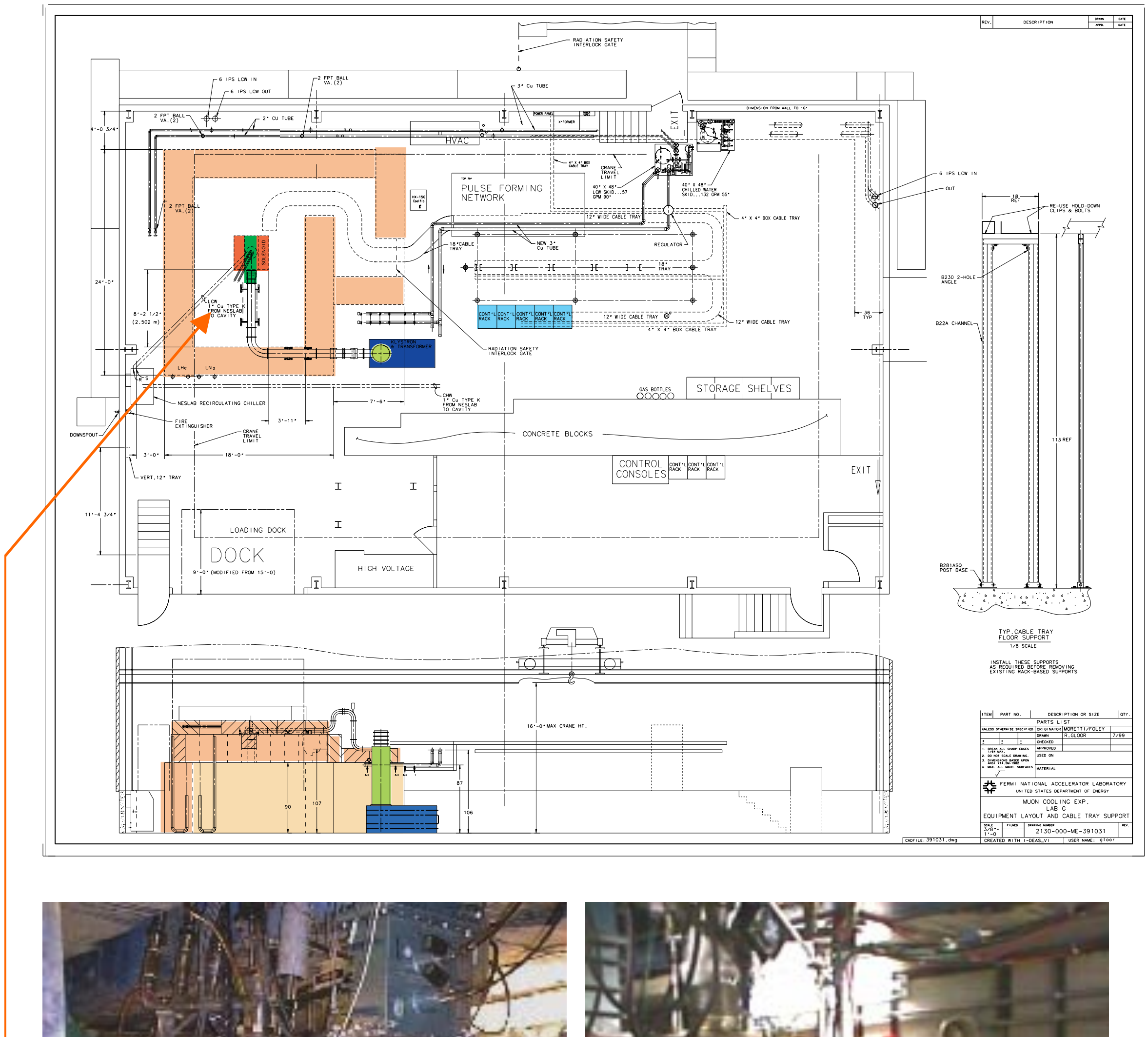
J. Norem ANL
S. Geer, A. Moretti, M. Popovic, Z. Qian, V. Wu Fermilab
L. Ducas, D. Errede U of IL.
N. Solomey, Y. Torun IIT

10/11/01

We are studying an open cell cavity which operates at 805 MHz.



The Cell is mounted in a magnet in Lab G.



Measurements use a variety of traditional instrumentation to look at dark currents and X rays.

Beam Transformer

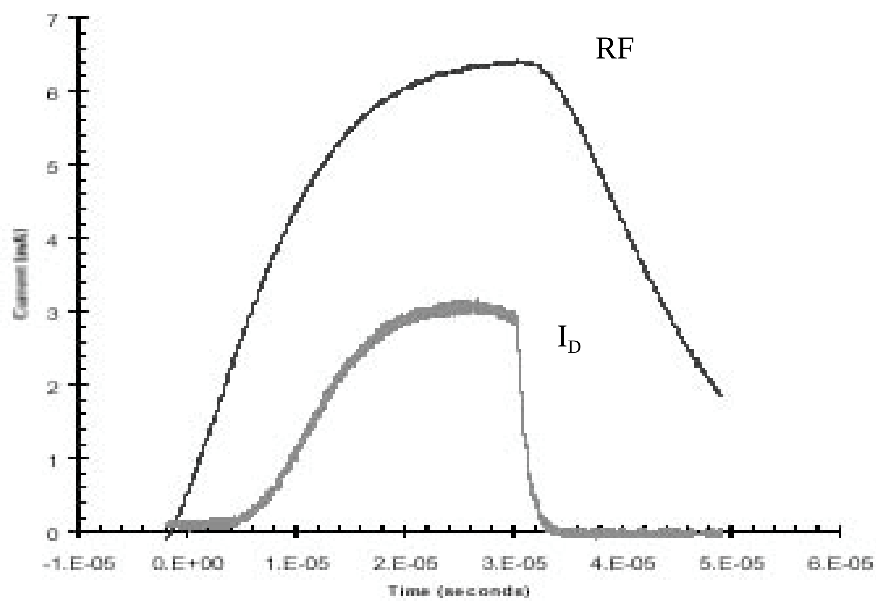
Thermoluminescent detectors

Scintillator / Photomultiplier tubes

Polaroid sheet film

A permanent magnet spectrometer

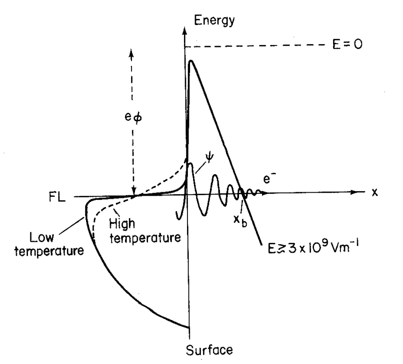
At low power, the pulse is triangular, rising until the rf shuts off. With longer pulses, or higher powers the current seems to saturate. This rf pulse was longer than usual.



The performance of rf cavities at high power is determined primarily by field emission from cavity surfaces. This field emission creates currents which:

- Produce x-ray doses which limit the accelerating field
- produce backgrounds for our μ cooling exp.

The currents seem to be generated by **Fowler-Nordheim field emission** from localized sources on the cavity surface. These currents are the result of tunneling thru the surface potential with the help of an external field. The picture is,



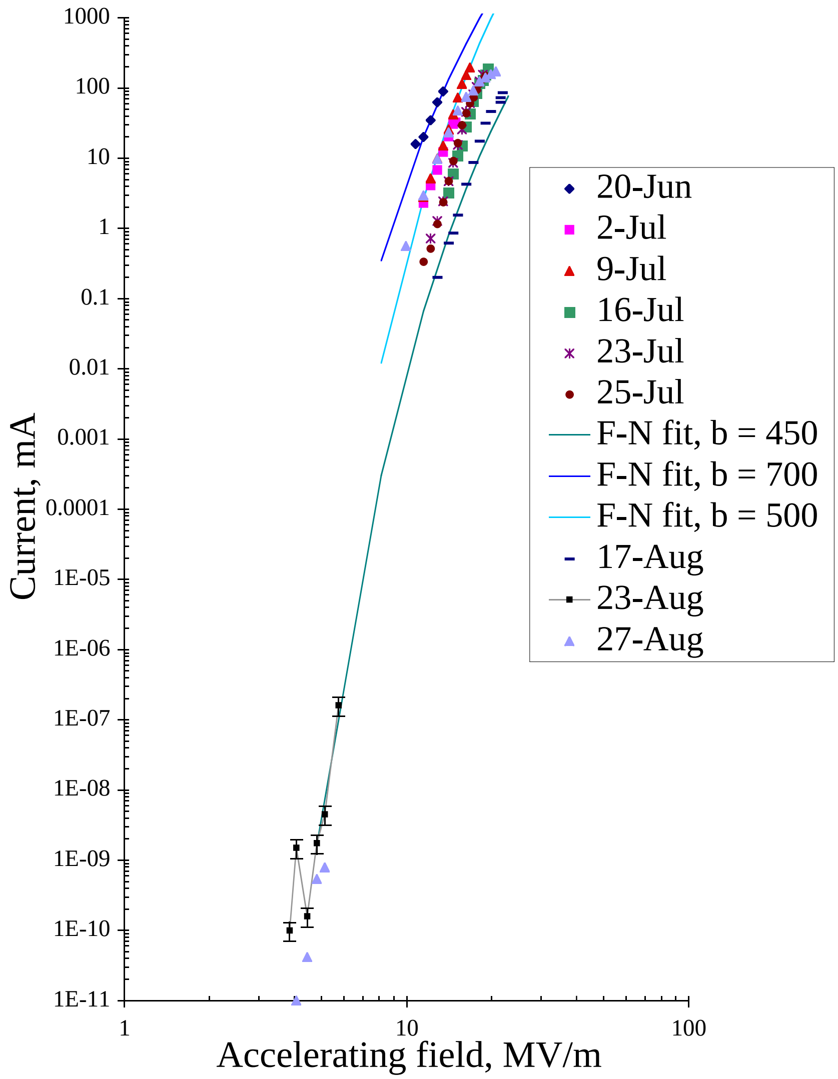
The equation that describes this is,

$$I(E) = \frac{A_{FN} A_e (\beta_{FN} E)^2}{\phi} \exp\left(\frac{B_{FN} \phi^{3/2}}{\beta_{FN} E} \right)$$

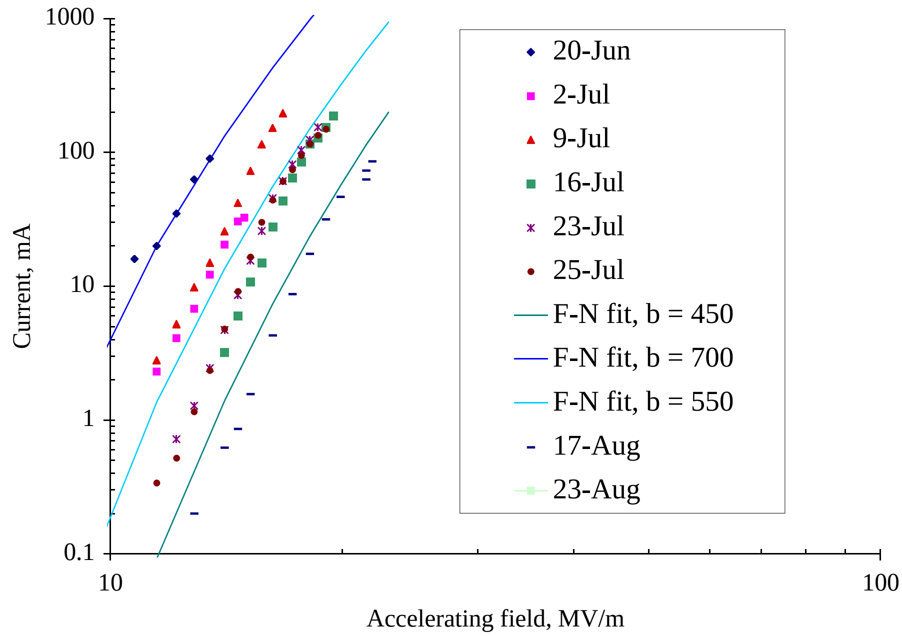
where A_{FN} and B_{FN} are constants, A_e is the emitting area, E is the electric field, ϕ is the work function of the material and β is the field enhancement factor.

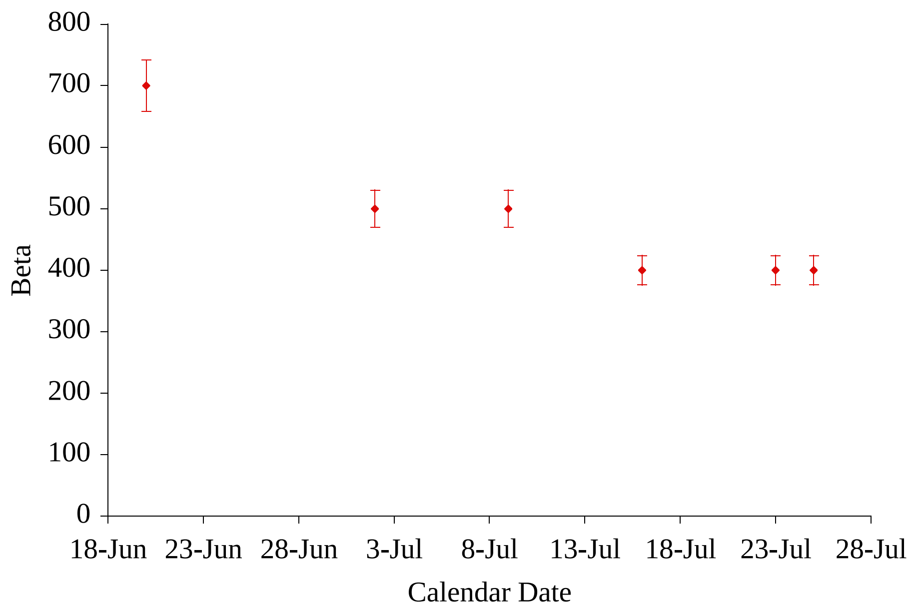
Lab G Results

- The emission we see follows a Fowler-Nordheim curve over many orders of magnitude - but with large β.
- Our data shows no evidence of plasma enhanced emission, but this process may occur during breakdown
- We may be seeing the Child-Langmuir limit.

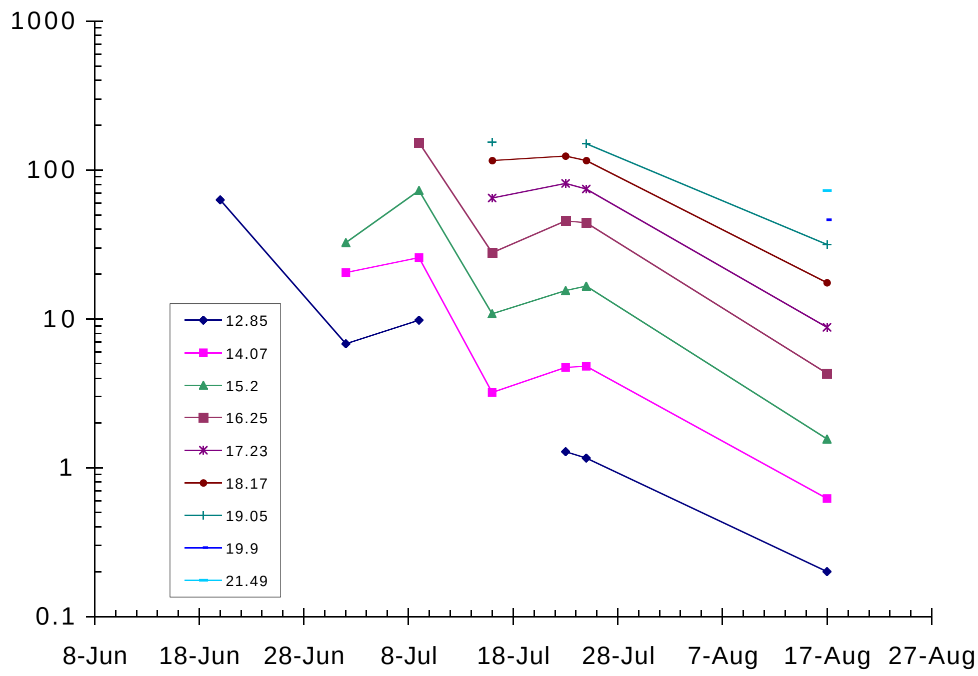


We see conditioning, in the form of reduced values of β with time.



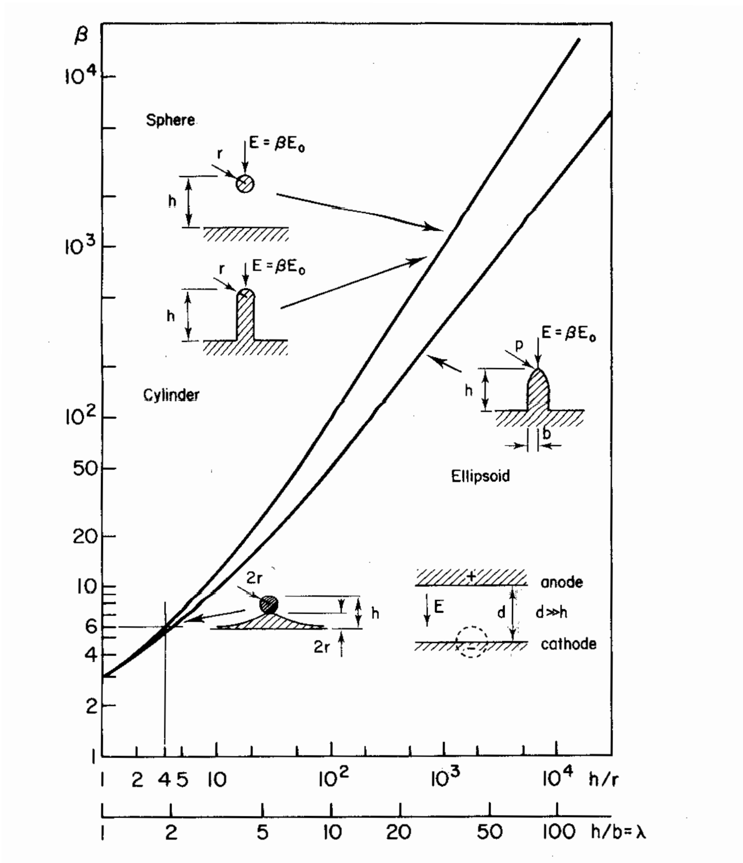


The conditioning did not proceed in a linear manner, and when the coil was turned on the conditioning had to be started again.



The very high β values – in the range of 400 – 600, are seen by others. But the β values should not be this large.

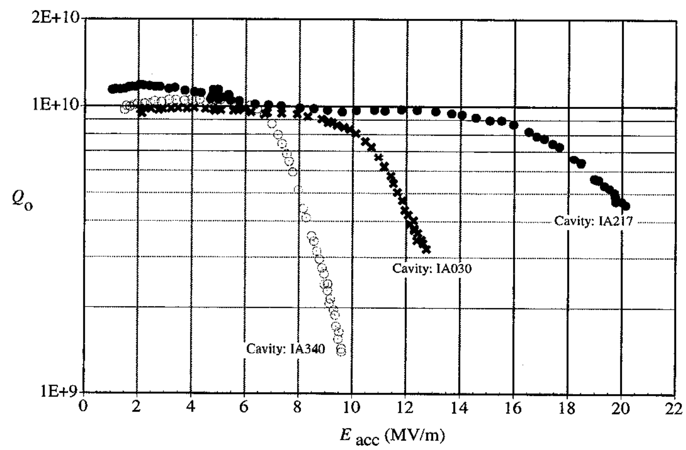
- If "hairs" of some sort produce this amplification of the field, these hairs would have to be ~ 100 times longer than their diameter, which would be highly unphysical and easily destroyed. A variety of other shapes (ridges, sharp points, cones) may be more physical.



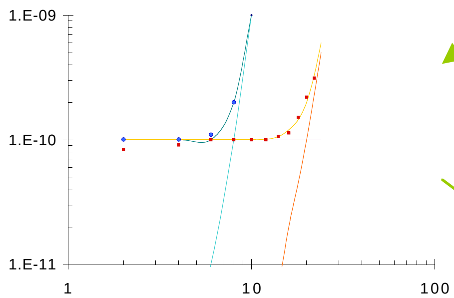
- Inclusions or other surface perturbations would also change the average β values.

In many experiments, improvement in **cleanliness** seems to produce improvements in dark currents - superconducting rf technology made great progress this way.

Padamsee, Knobloch and Hayes
Fig 12.1

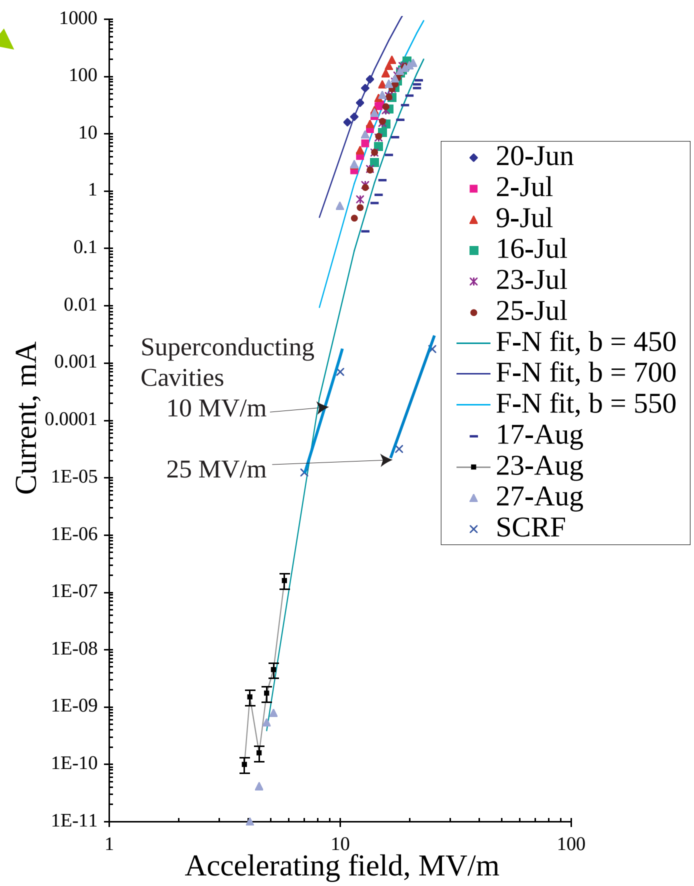


losses go like 1/Q . . .



- SCRF field emission is consistent with Lab G measurements.

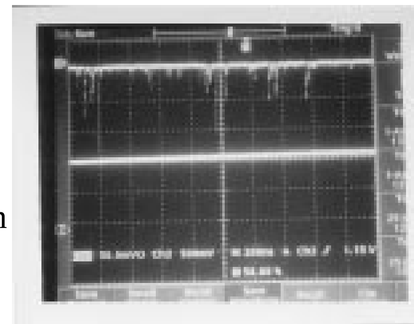
- We should be able to get comparable gains from surface treatment.



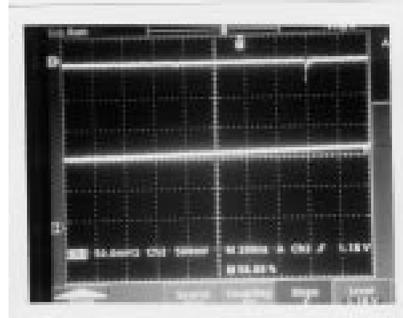
The very low current data was obtained by counting electrons in a given time. Typical traces are shown.

Counting Individual Electrons
in 2 microseconds

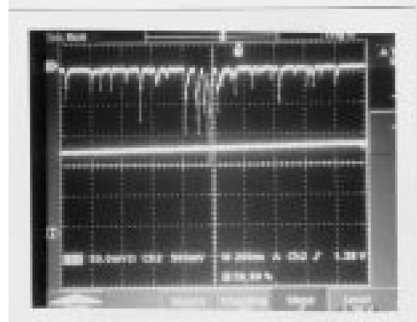
0.5 MW
4.06 MV/m
~1.5 pA



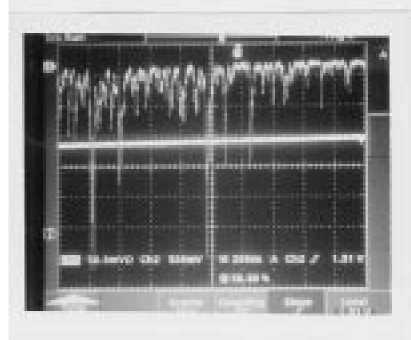
0.6 MW
4.45 MV/m
~0.16 pA



0.7 MW
4.81 MV/m
~1.6 pA



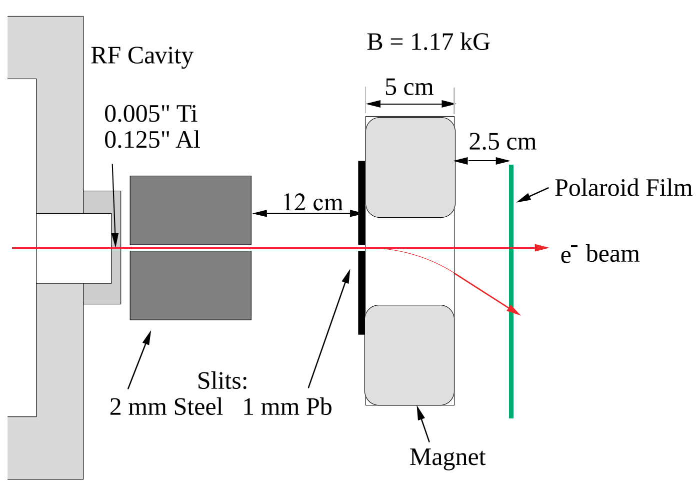
0.8 MW
5.14 MV/m
~4.5 pA

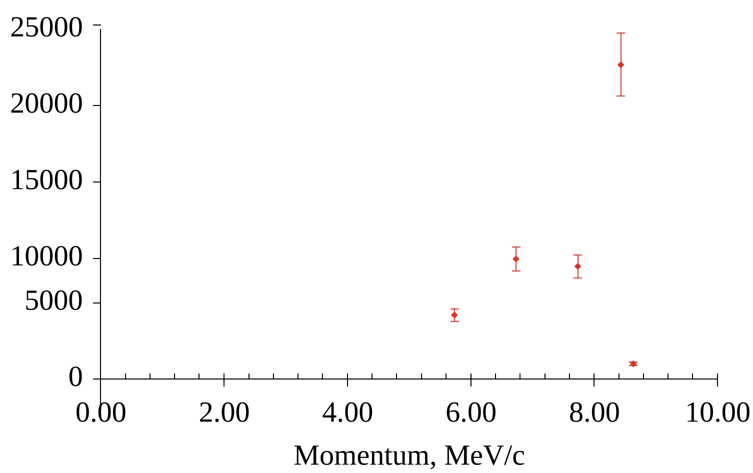


The low power “blip” at 0.5 MW was real on one day but did not reappear on the next.

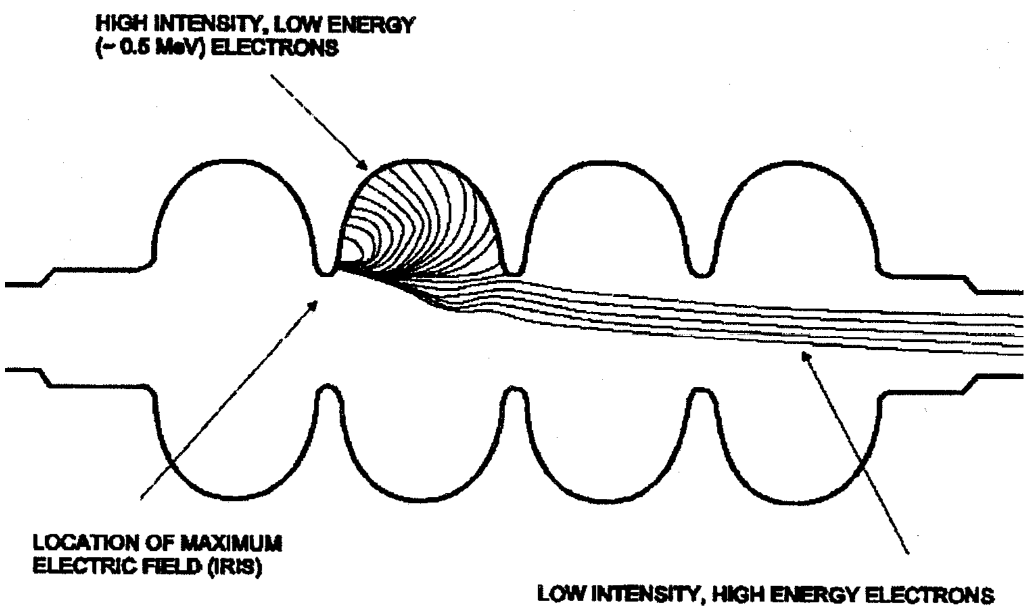
A magnetic spectrometer was used to measure the momentum of the electrons. The maximum momentum measured was 60% of the *El*, where a calculation gives the result of 59.9%. This implies that a significant fraction of the beam traverses the whole length of the cavity.

Small Gap, Permanent Magnet Dipole

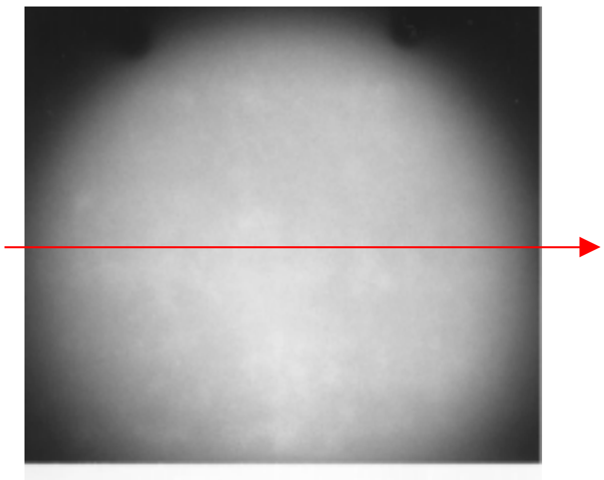


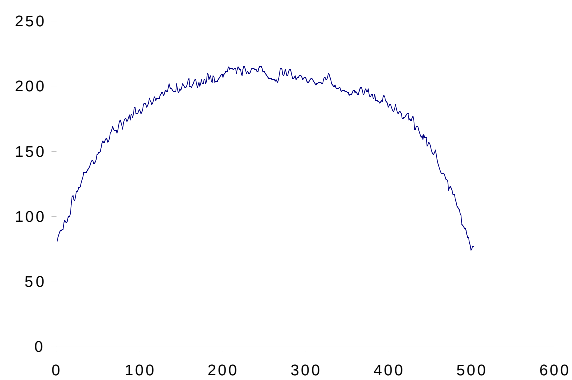


The transmission of dark currents in rf cavities has been calculated for the case with no applied magnetic field.



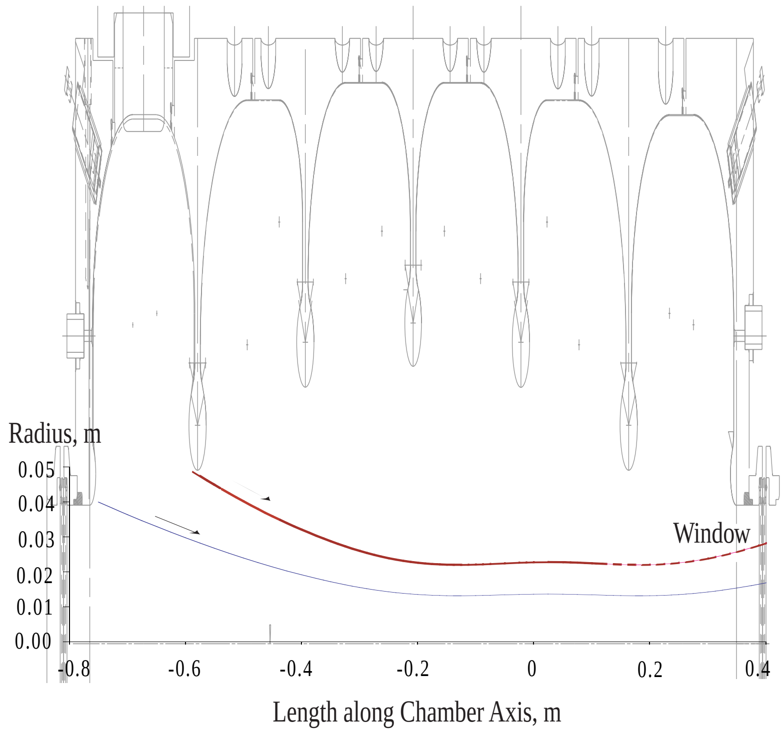
We see a smooth distribution





The power in the beam was sufficient to melt the plastic cover of the window.

With the magnetic field on we see a number of effects which imply that the dark current electrons and copper ions tend to ride magnetic field lines into the window, which developed a leak and some internal copper deposition.



A variety of effects complicate this picture, the magnet and cavity axes were not aligned, and we do not know the charge, source point, mass or initial velocity of the copper particles, and since the emission depends on electric field like $E^{20} – E^{23}$, the process is very sensitive to geometry.

The diameter of the burned ring is about 3.3 cm, consistent with simple tracking results.

We are not done yet. There are a number of continuing problems which we are trying to nail down.