Dark Current Measurements at Lab G

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Argonne

MUCOOL/MICE Collaboration Meeting
Illinois Institute of Technology
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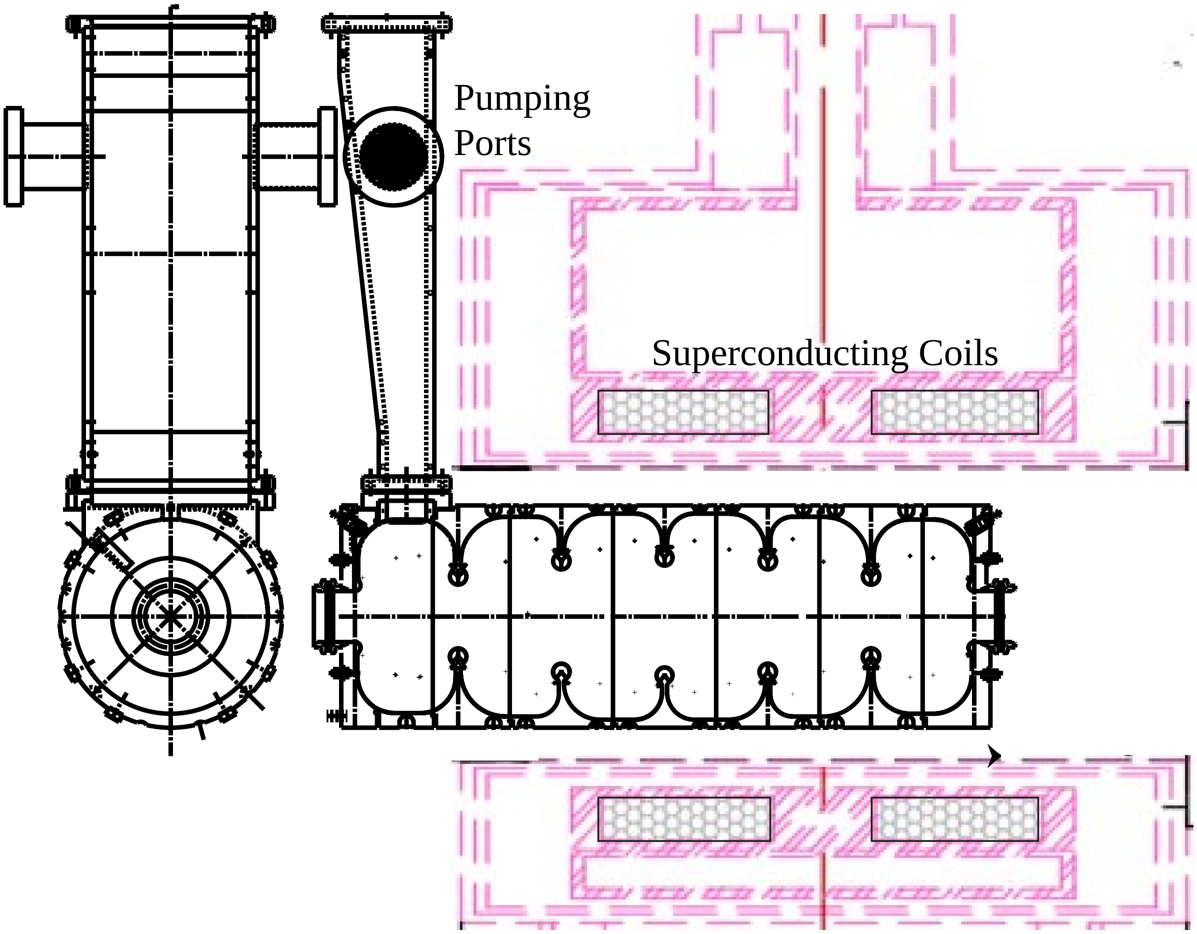
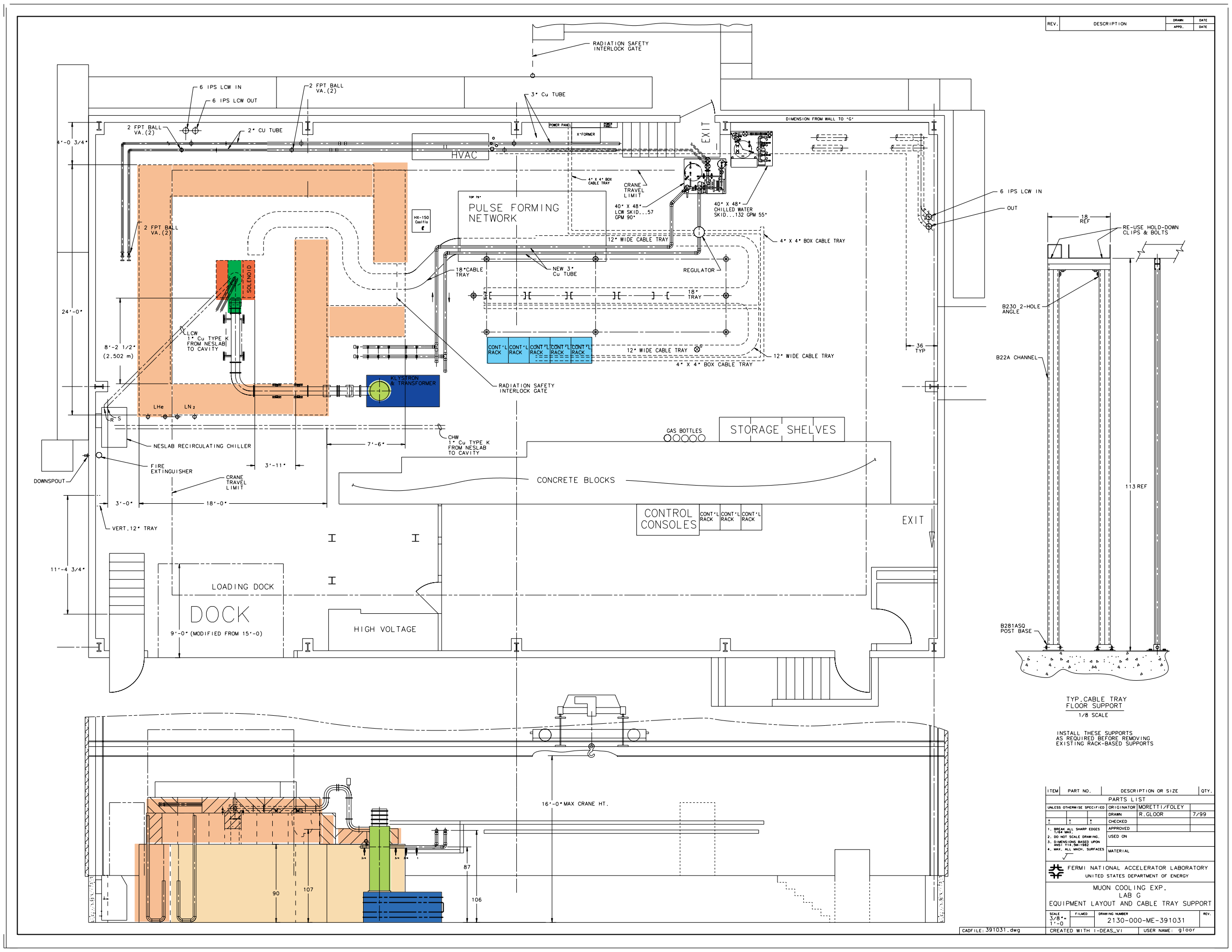
Muon Collaboration

The Cavity / Magnet assembly . . .

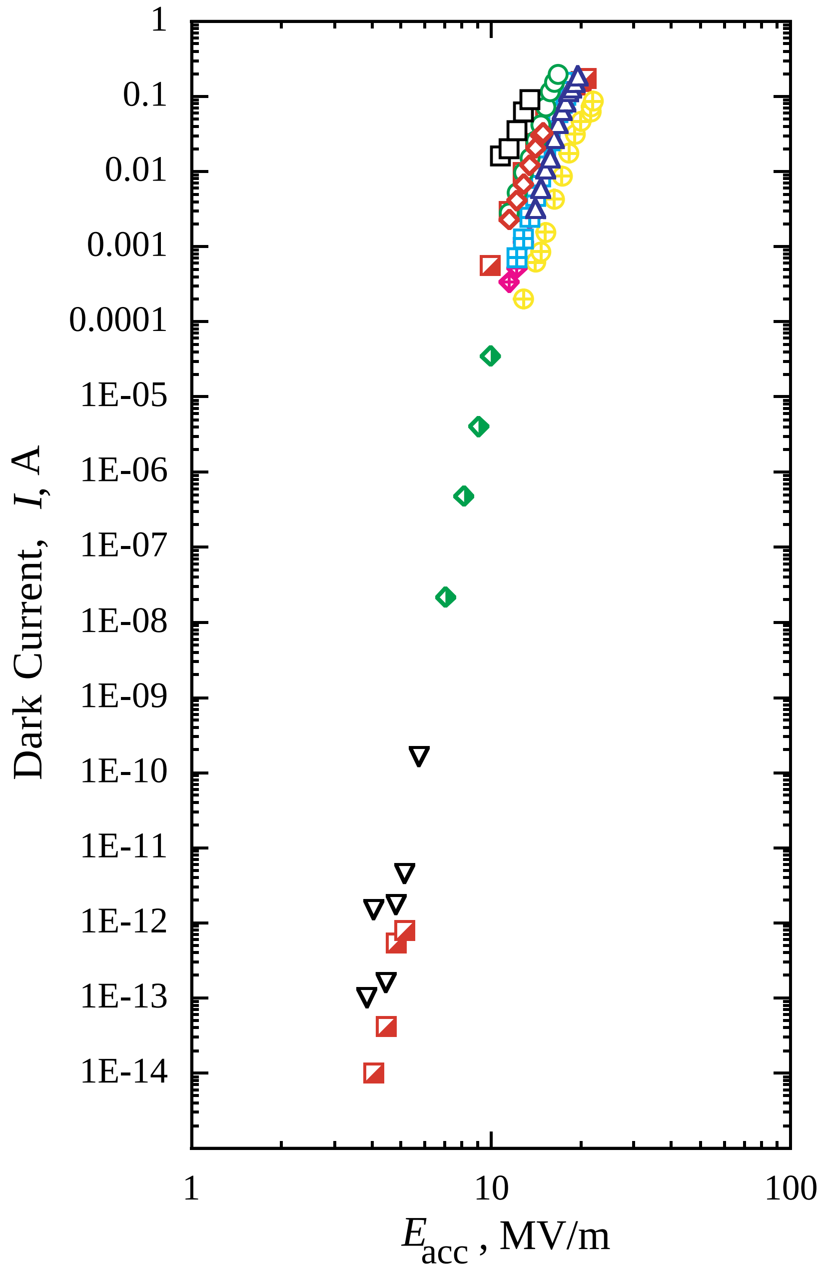


. . . sits in Lab G.


PULSE FORMING NETWORK
HVAC
STORAGE SHELVES
CONCRETE BLOCKS
CONTROL CONSOLES
LOADING DOCK
DOCK
HIGH VOLTAGE
EXIT
FERMI NATIONAL ACCELERATOR LABORATORY
MUON COOLING EXP.
LAB G
EQUIPMENT LAYOUT AND CABLE TRAY SUPPORT
2130-000-ME-391031

We have shown experimentally that:

1) Dark currents are the source of our x ray and background problems.



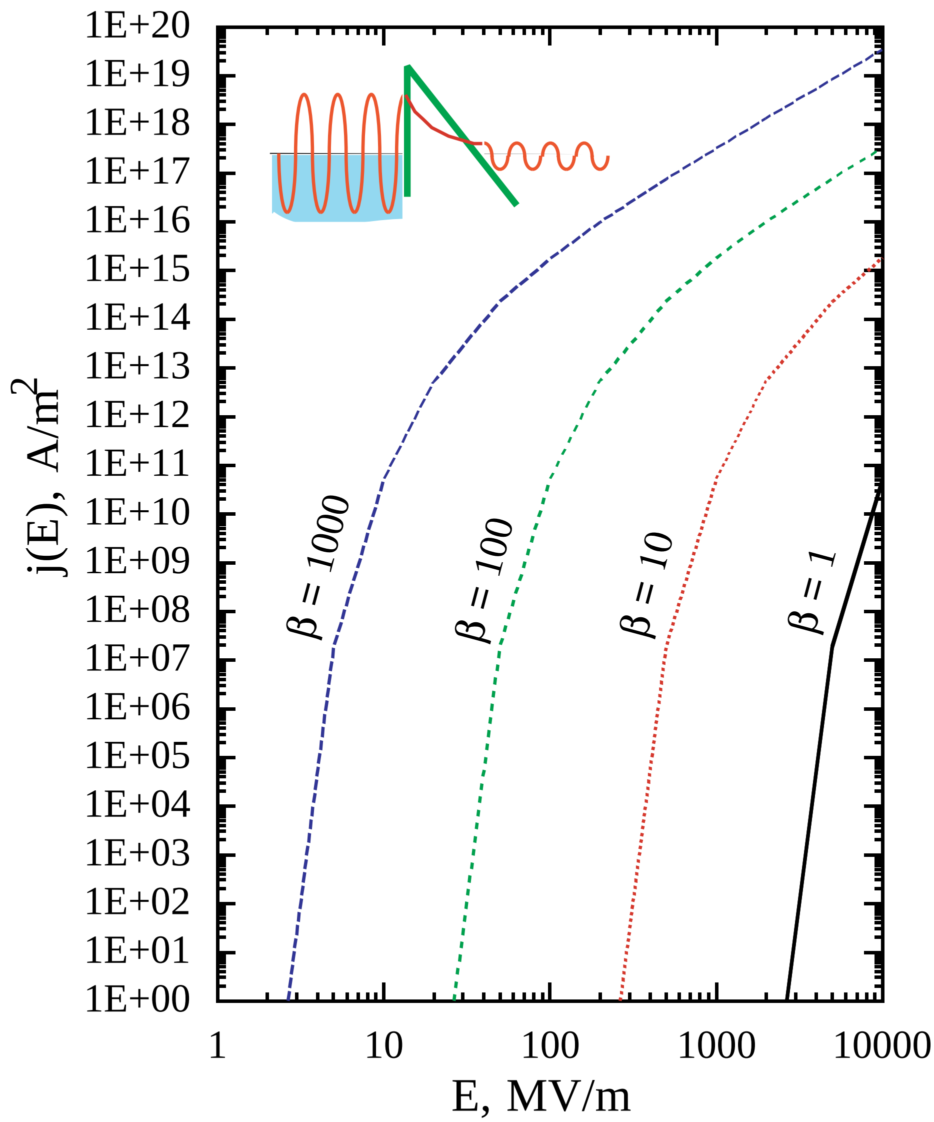
- Fowler Nordheim emission is described by the expression.

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

  where A_{FN}, B_{FN}, β_{FN}, are constants, ϕ is the work function of the material, and the emitter area is A_e.

- Over a narrow range of accelerating fields this looks like E^n.

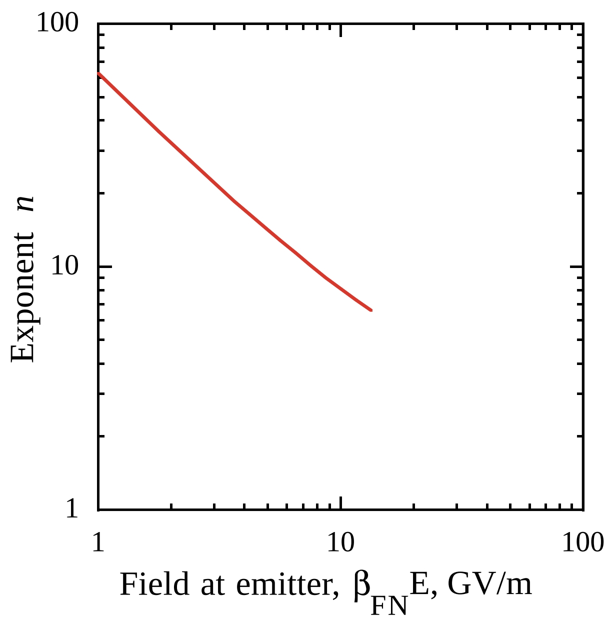
2) Dark currents come from Fowler Nordheim field emission.



3) The emitters seem to be small points which have

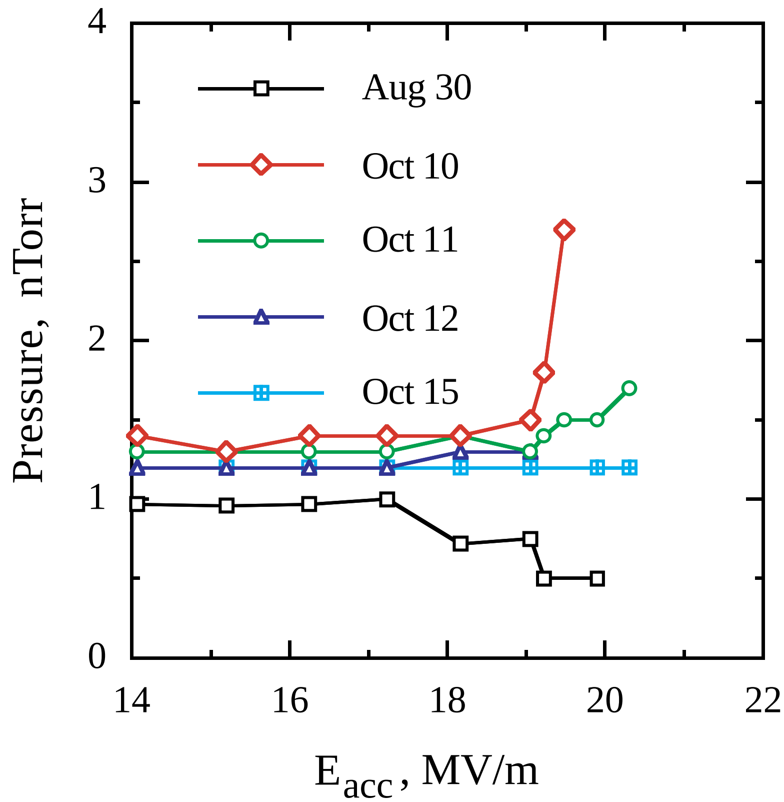
- Electric fields of 3-10 GV/m

  We can measure it remotely from E^n.



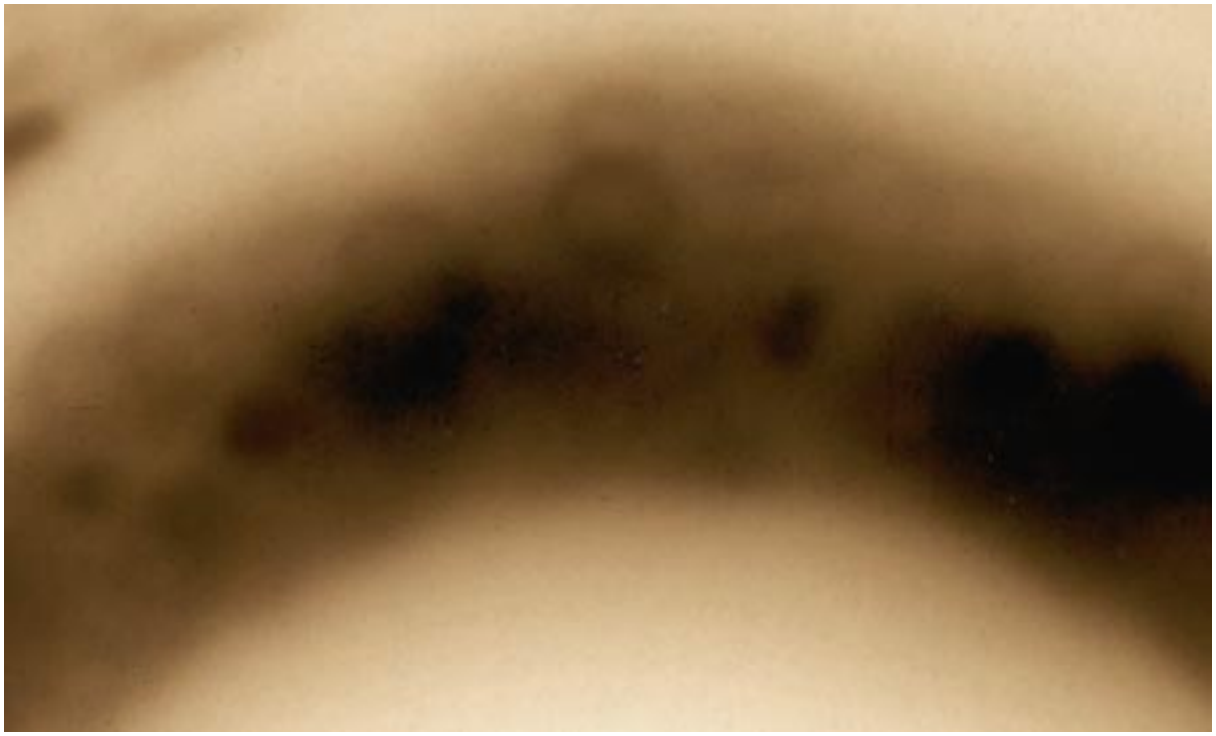
- Mechanical tension: 10,000 - 60,000, psi
- a high emitter density on irises.
- Overall emission dominated by a few sources.

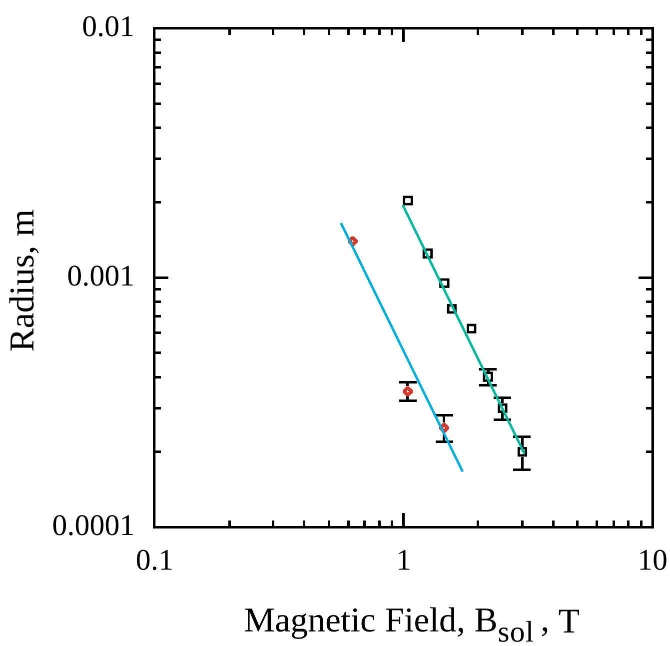
- Vacuum seems unrelated to dark currents.

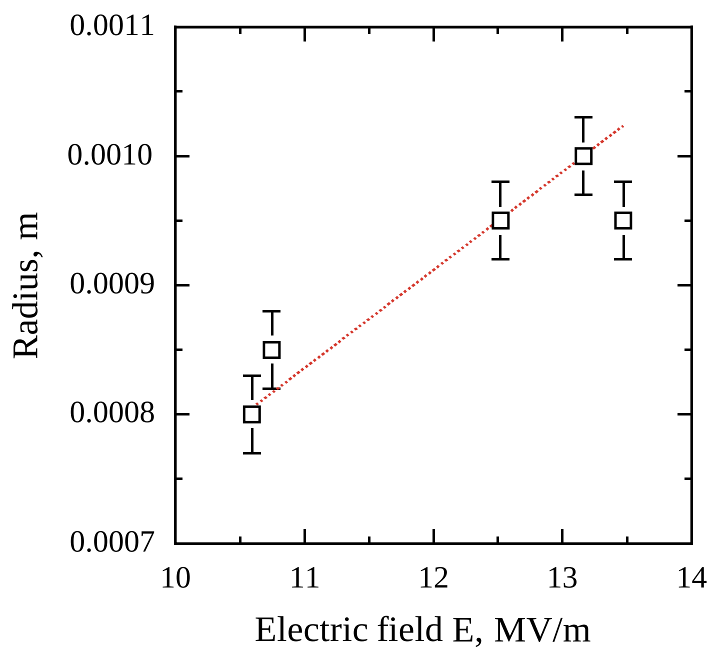


4) Magnetic fields perturb the dark currents

- Ring beams are seen, perhaps for the first time in HEP.

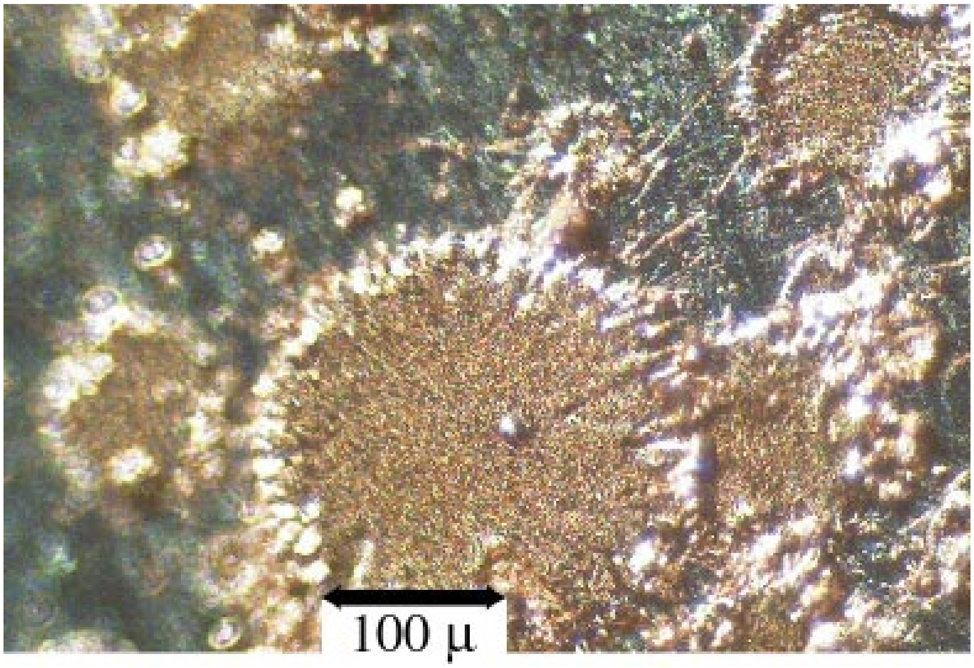






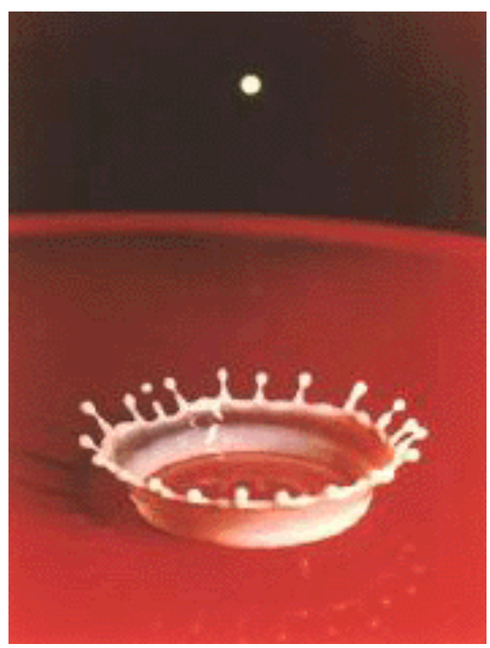
5) Emitters could be formed from copper spattered on walls during breakdown

- Self perpetuating mechanism?

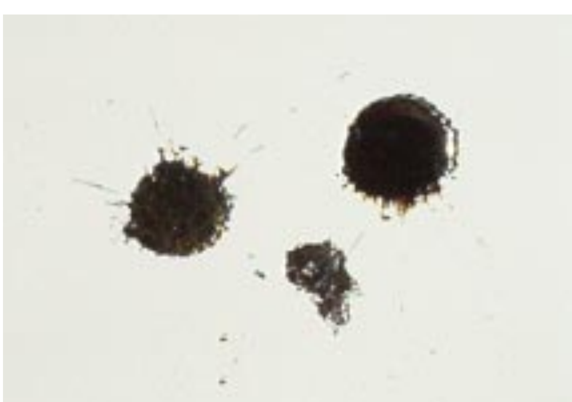


This looks like . . . .

Milk

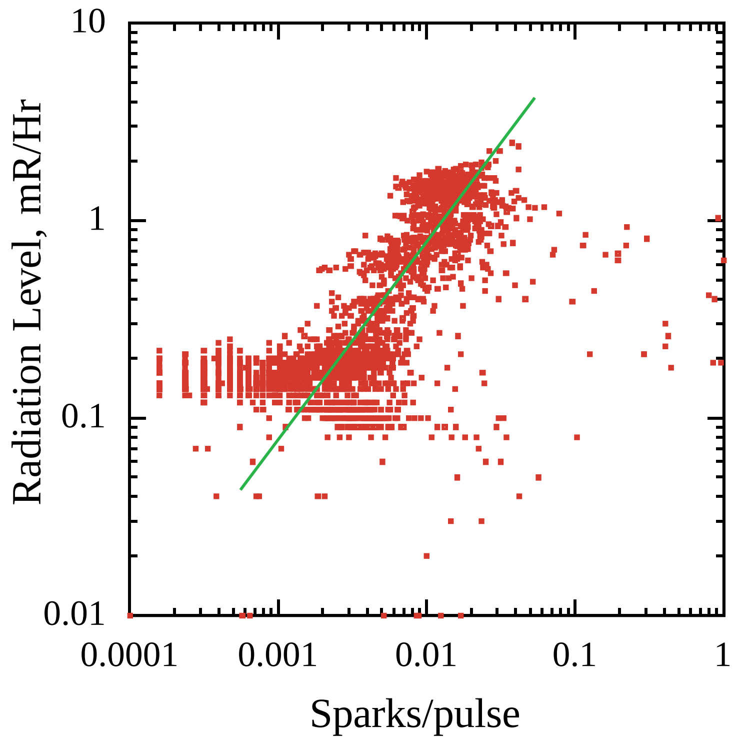


. . . or solder splashes.



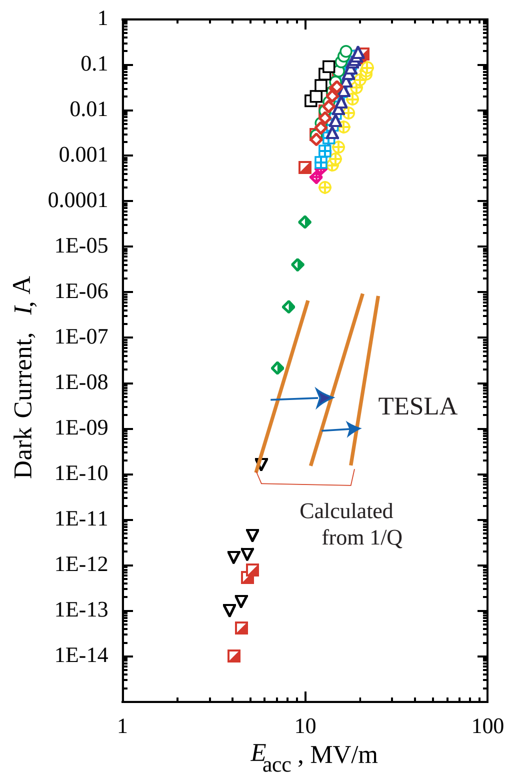
6) Breakdown is related to dark currents.

- Dark currents proportional to sparking rate
- Emitters snapping in 50,000 psi could cause breakdown.



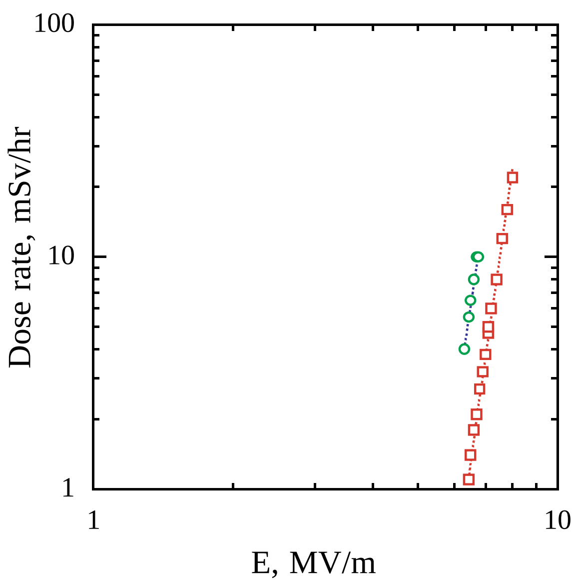
7) All accelerating structures seem to have similar problems.

- SCRF sees the same level of dark currents

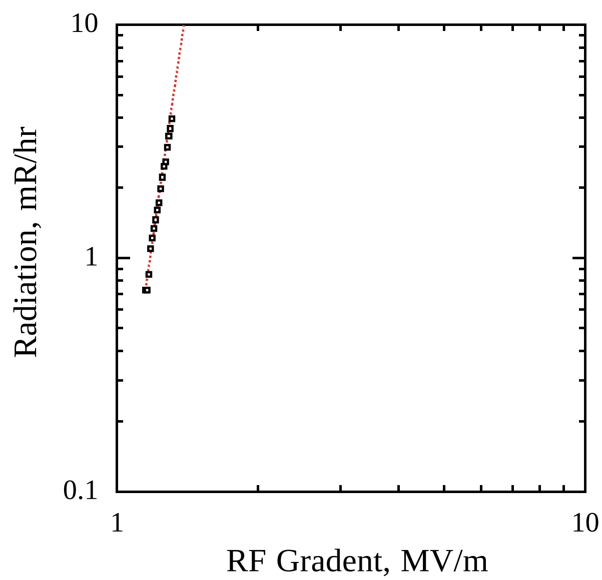


- We can also look at 200 MHz structures

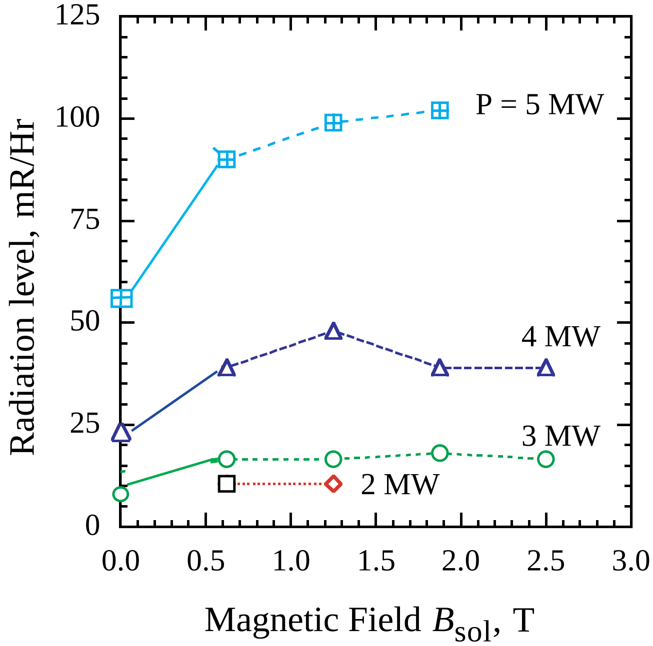
ISIS Linac



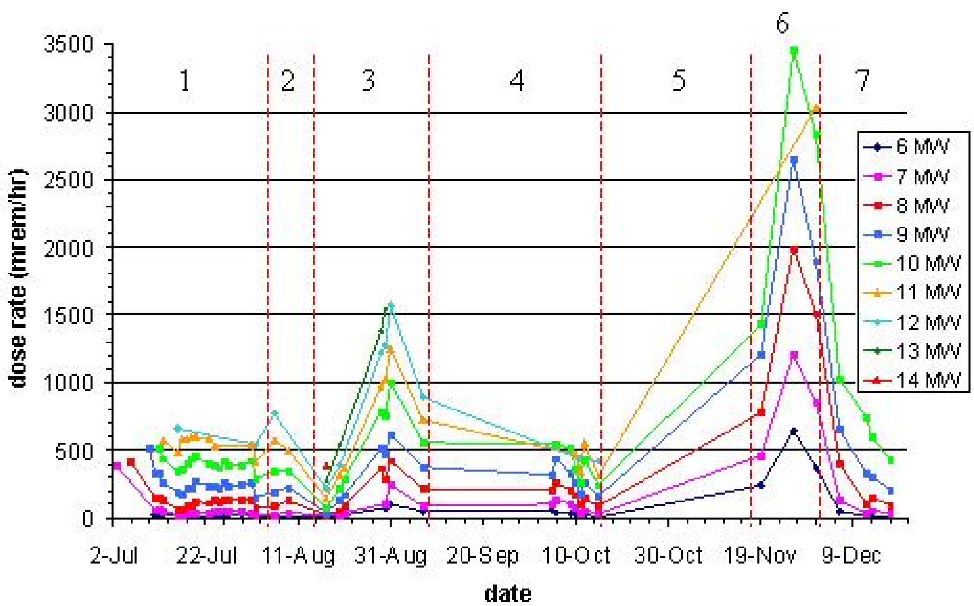
IPNS Linac



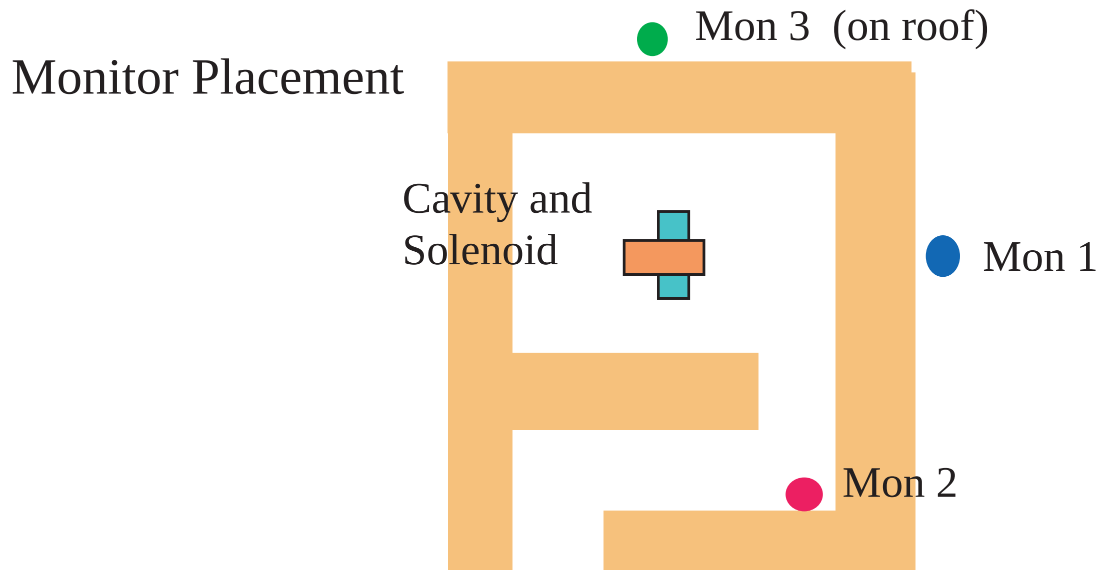
8) We are sorting out I(B)dependence.

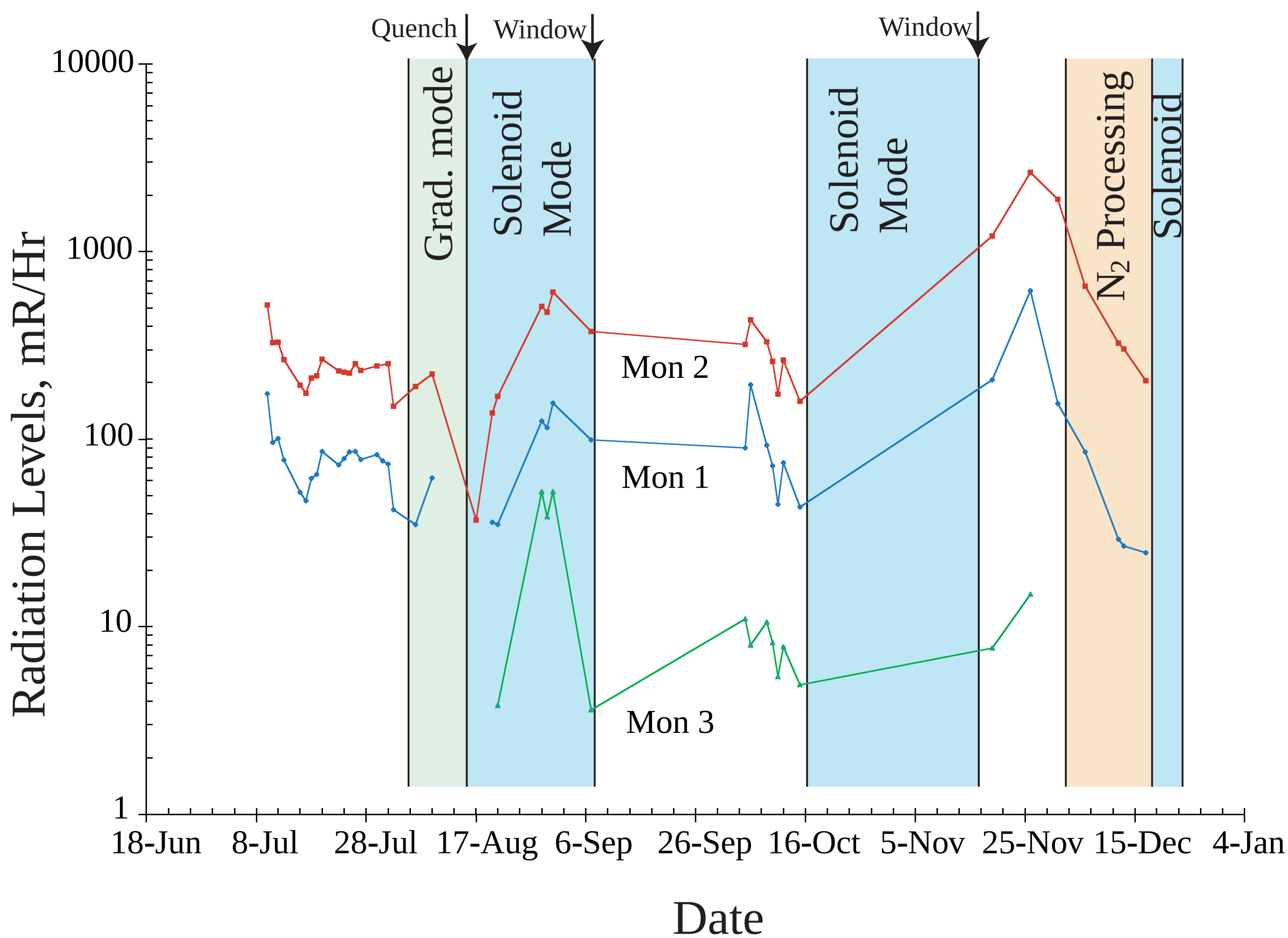


Electron orbits
Diagnostics
Cavity copper
. . . all are f(b)



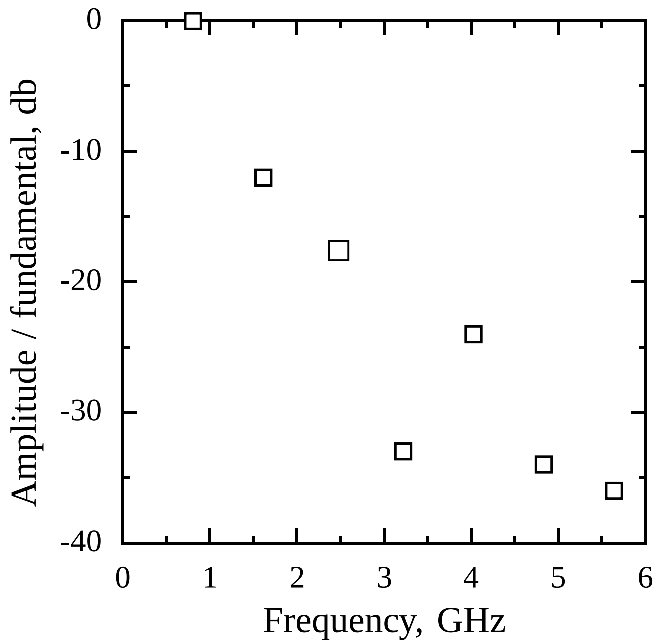
The behavior of monitors over the life of the cavity,



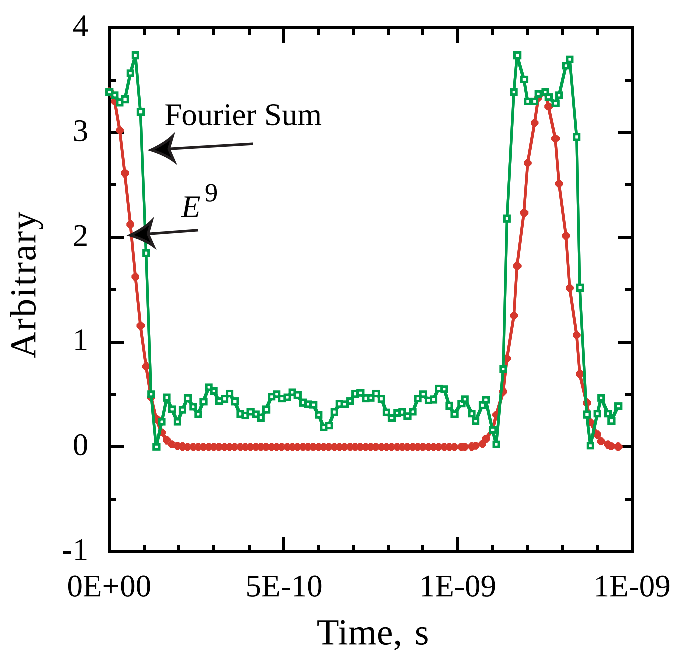


9) Pulse length measurements

Measurements of dark current harmonics with fast pickup



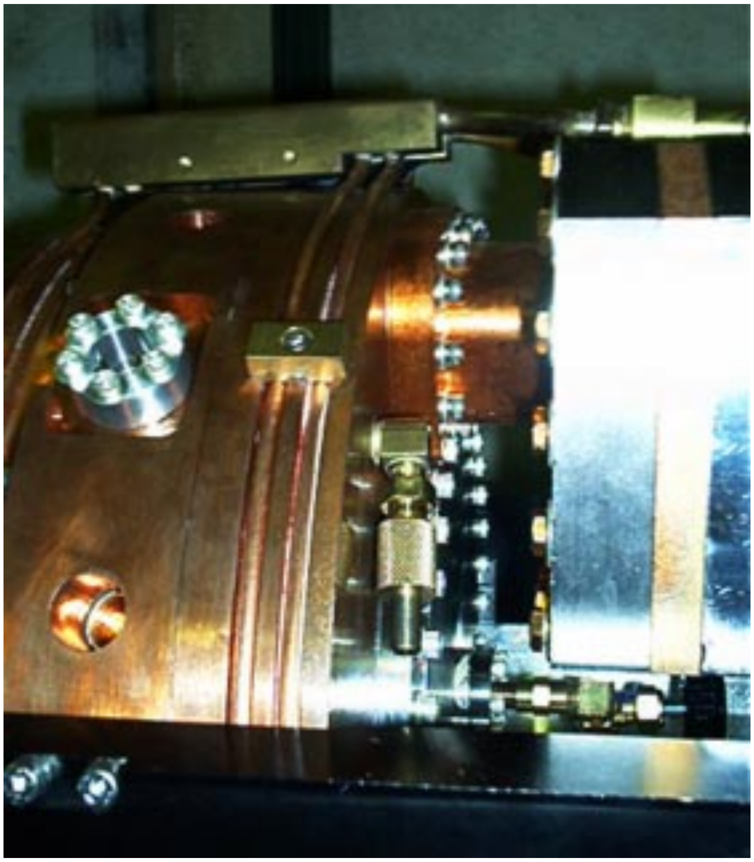
give (many) estimates of pulse shape



What's next -

A) Short Term

1) The LBNL cavity is here, holds vacuum and is ready to install.
   - It's hard to instrument.



2) We will look at:
   - Copper windows
   - Be windows
   - Grids
   - Buttons
   - Instrumentation: APD's, Spectroscopy etc

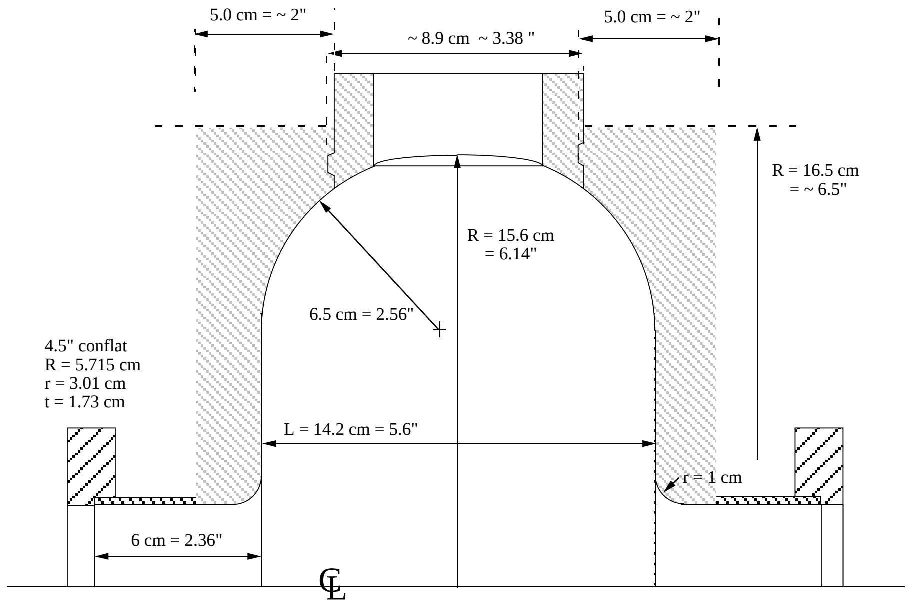
B) Long Term

1) There are large number of possible improvements to test.
   - Vary cleaning and polishing methods
   - High pressure H_20 / Magnetorheological fluids
   - Surface treatments which alter electron emission
   - Discharge cleaning, Gas conditioning
   - In-situ coatings which change typography
   - Low vapor pressure materials
   - High melting point materials
   - Insulators
   - Coatings that reduce adsorbed gases
   - Baking
   - . . .

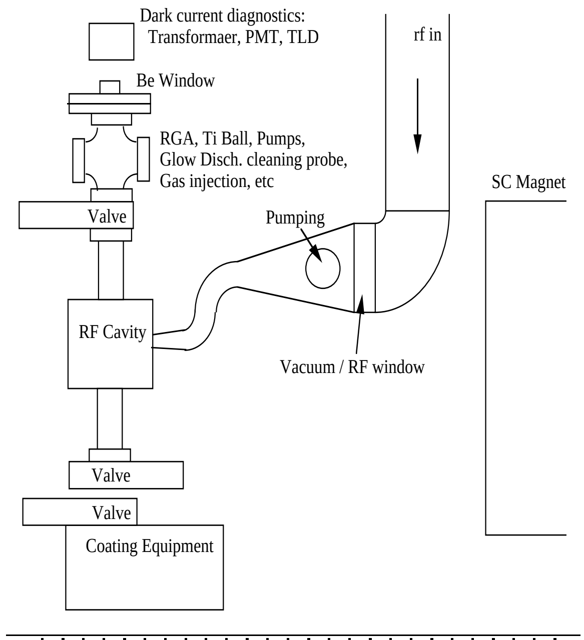
2) We need to be more careful about surfaces.
   - Electropolishing or equivalent
   - Round corners
   - Water Rinsing
   - Clean Rooms
   - Simple cavities, which are easy to work with.

3) Careful attention to
   - Conditioning
   - Instrumentation

The best way to test surface treatments is with a simple cavity which has good access.



which could be run from the existing klystron.



Note that:

> While almost every HEP dollar for the next two generations is being committed to the NLC, which will run miles of copper at very high gradients, **no one in the HEP community is presently looking at this physics in a systematic way**.