Field Emission and Voltage Breakdown

H. Padamsee, Cornell University

Outline of Two Talks/Today and Tomorrow

- Conclusion
  A picture of the evolution from
  field emission -> voltage breakdown

- Evidence that field emission sites arise from
  microparticle contaminants
    RF and DC
    Apparatus used to find/analyze emitters

- Evidence that breakdown sites arise from
  contaminants
    RF and DC
    Apparatus used to find/analyze
    breakdown sites

- The smoking gun
  Intentionally introduced particles that cause
  breakdown
  RF and DC

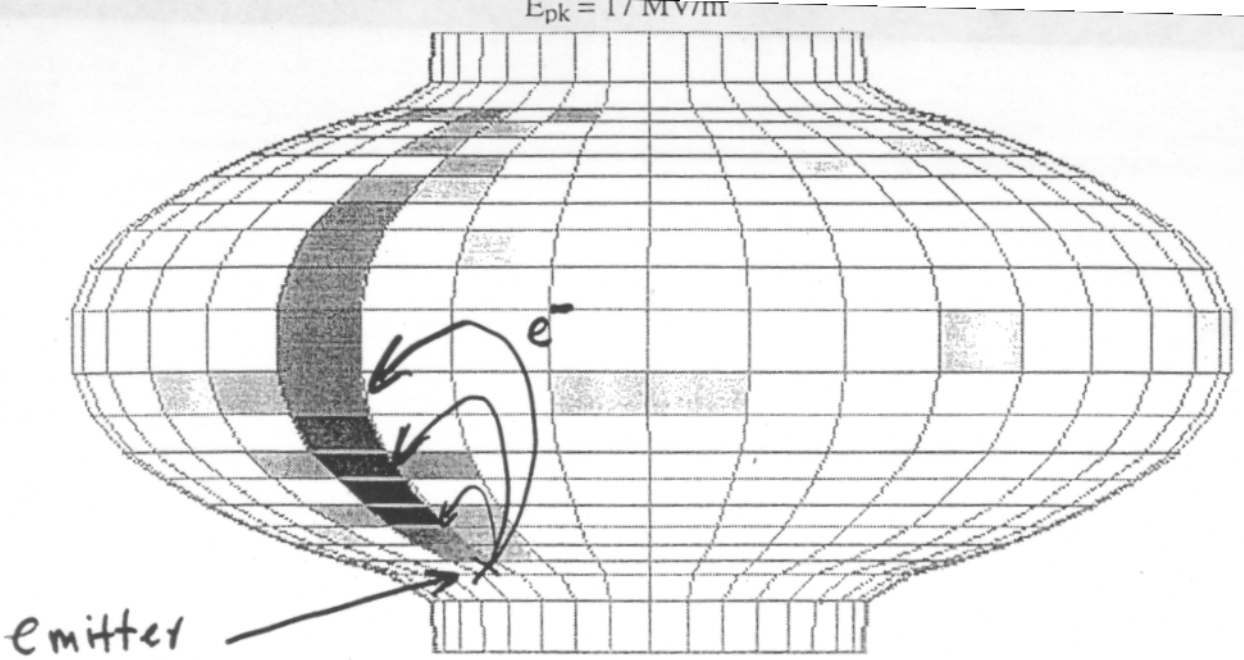
- Evidence that gases are involved in breakdown
  RF and DC

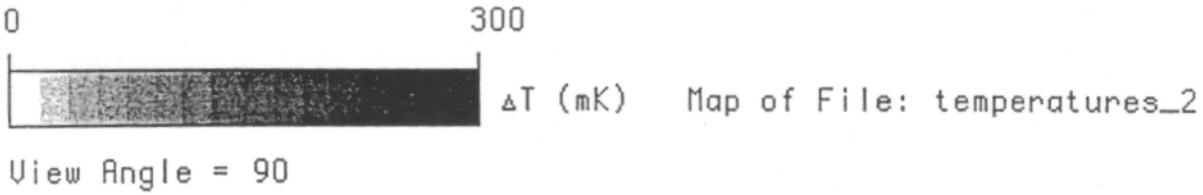
- A numerical simulation of the picture for the evolution of breakdown
  Movie in working group?

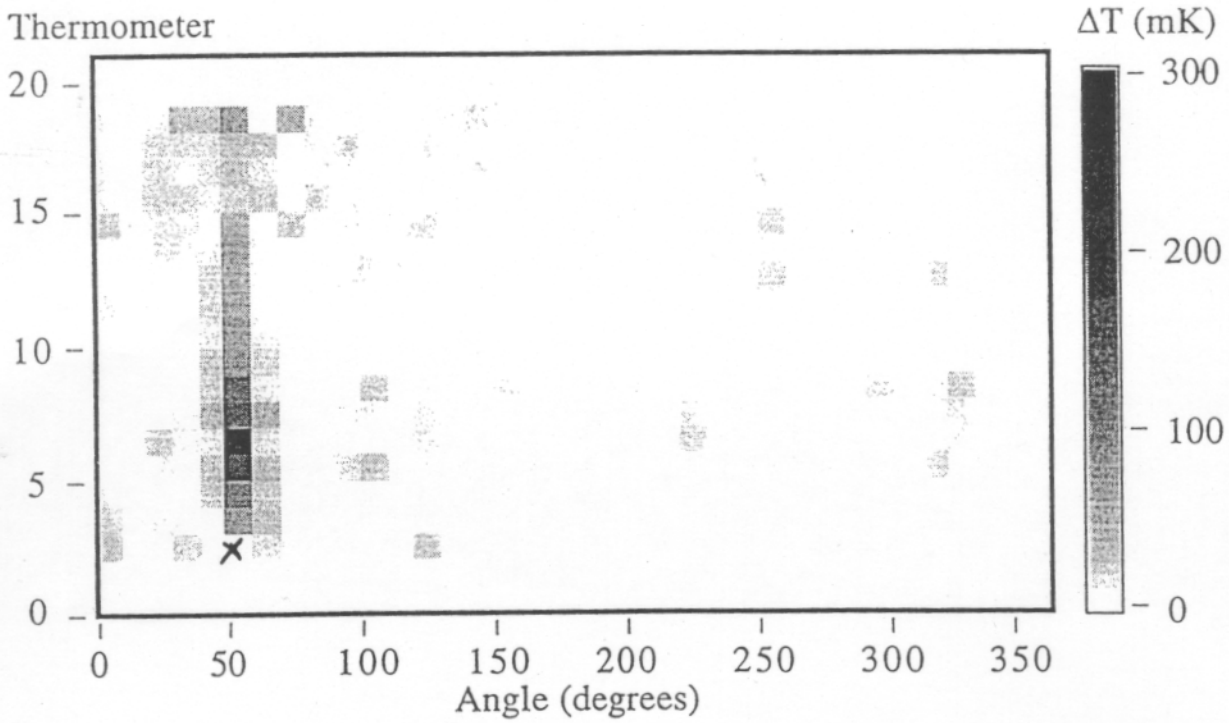
- More about field emitters
  Not all particles are emitters
  Role of Microgeometry
  Role of condensed gas

- What to do?
  Avoid microparticles
  Extensive bake to reduce adsorbed layer
  Avoid exposure to poor vacuum
  => use windows to isolate accelerating structure vacuum

- Evidence that field emission sites arise from microparticle contaminants
  - RF and DC
  - Apparatus used to find/analyze emitters



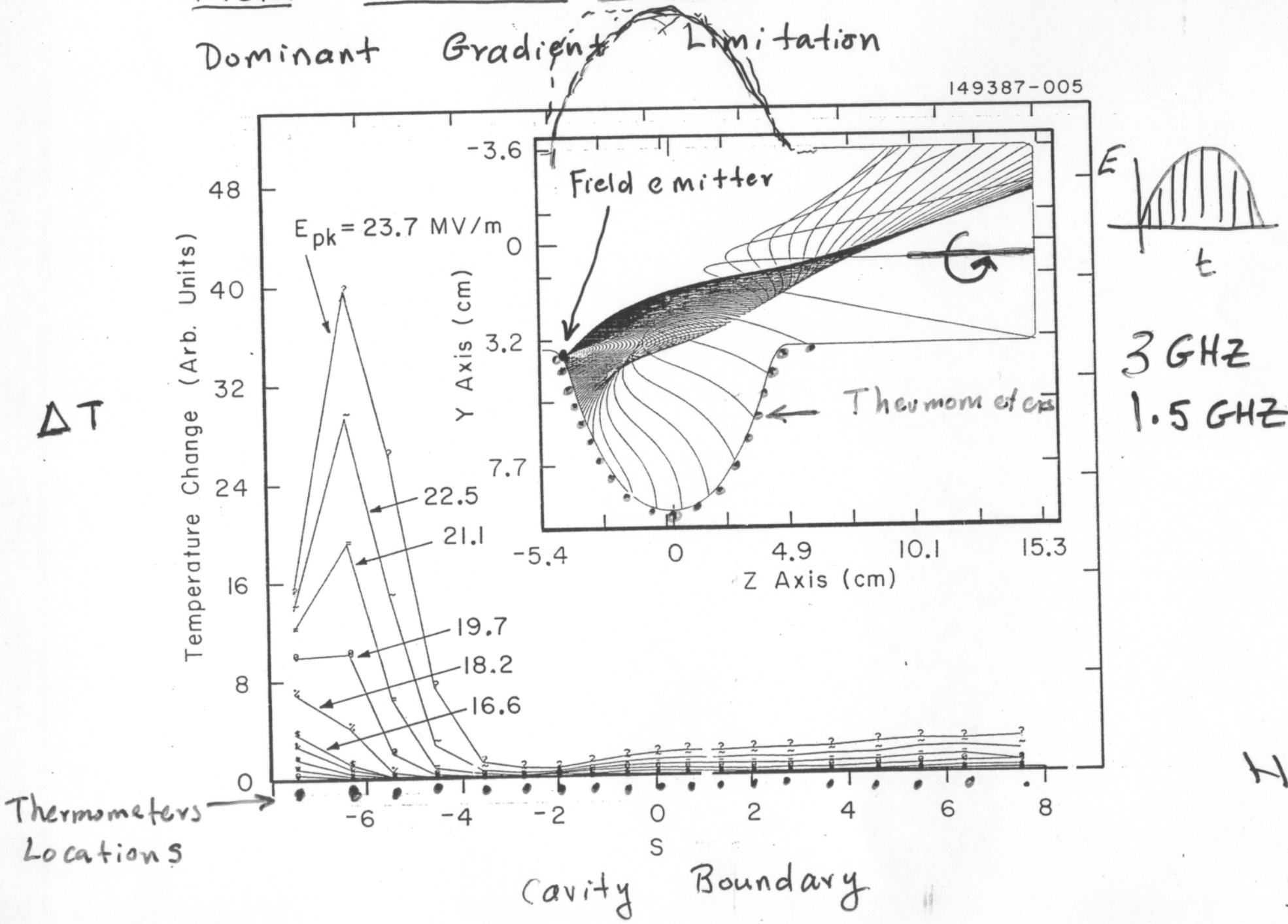




Occasionally it is even possible to detect the presence of the site due to higher rf loss

Field Emission in RF Cavities

Dominant Gradient Limitation



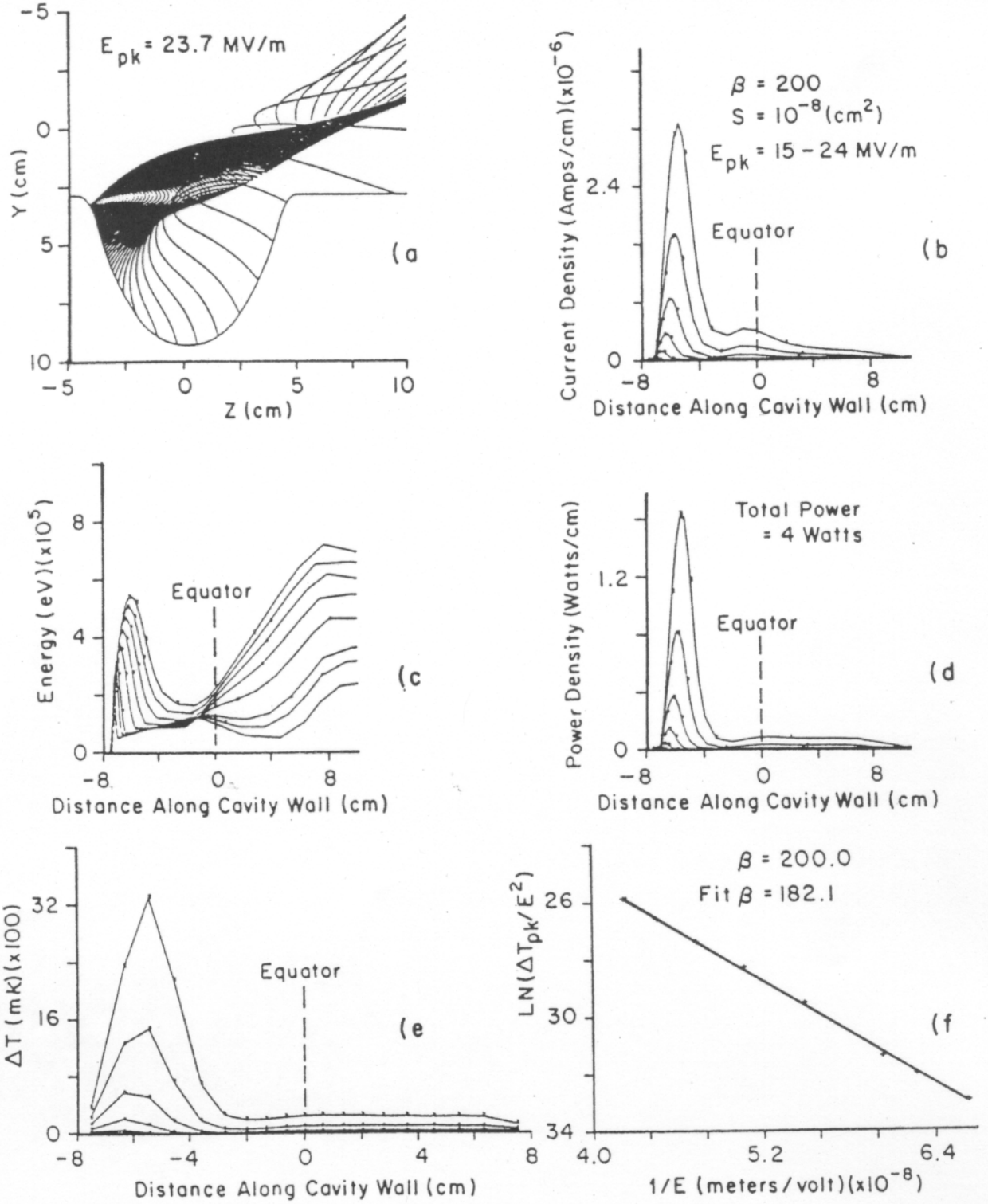
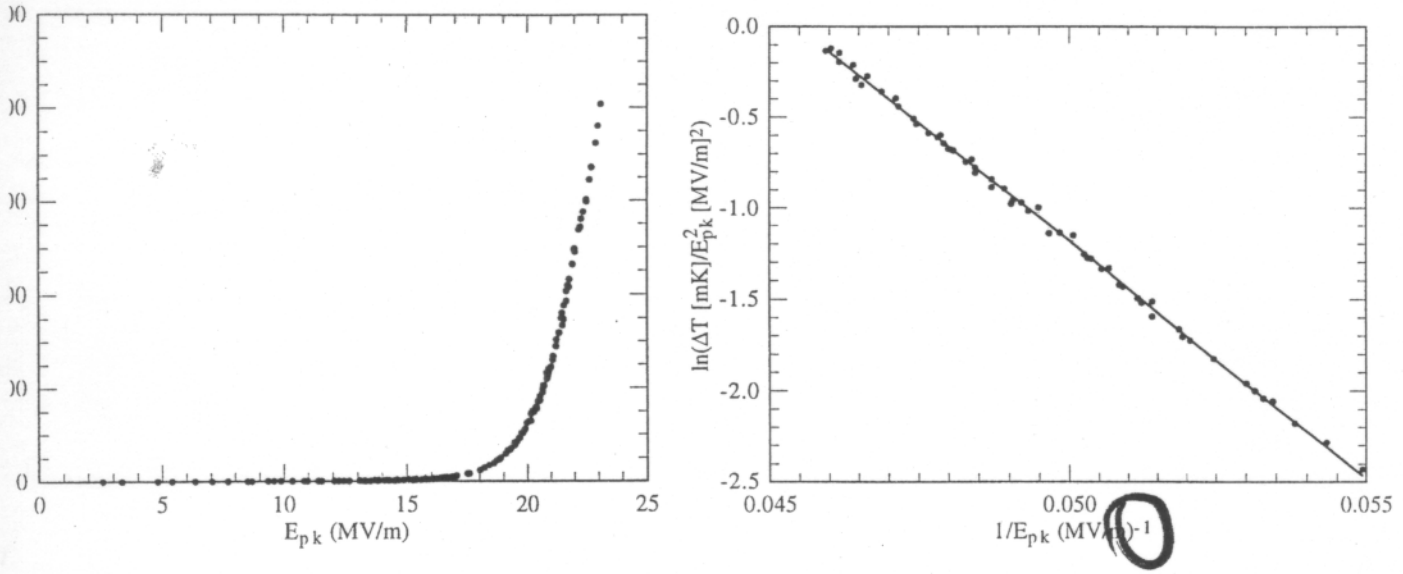
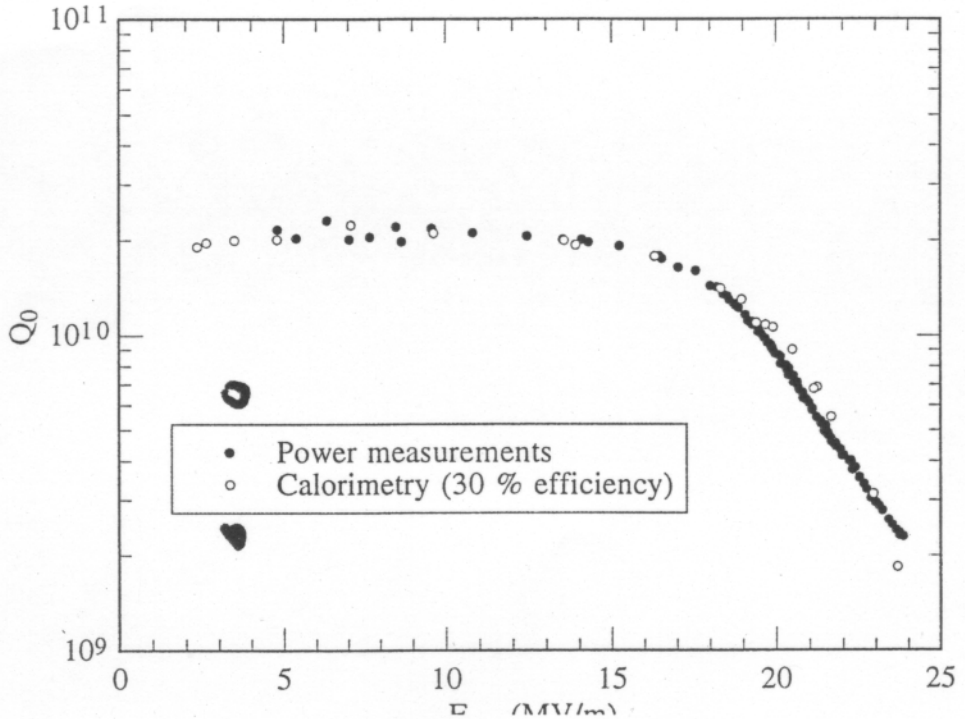


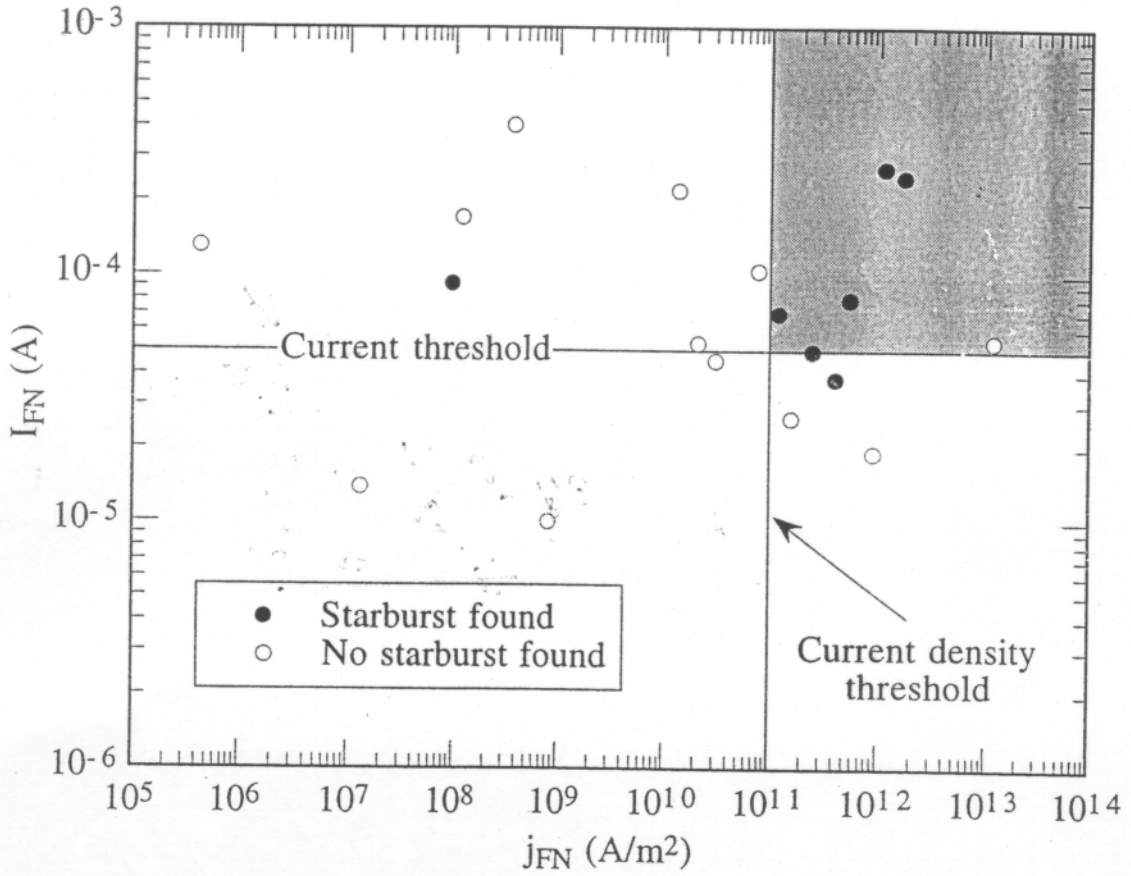
Fig. 41
Simulation of field emission in an rf cavity.
(a) Electron trajectories in one rf period from a hypothetical emitter.
(b) Corresponding impact current density profiles at the highest fields.
(c) Impact energy profiles.
(d) Power density profiles.
(e) Simulated temperature maps (at same azimuth as emitter location).
(f) Fowler Nordheim plot of peak temperature rise, showing β.



e 6.20: (a) Temperature signal of the circled site in Figure 6.19 as a function of E_{pk}. No ɔt changes ~~in ΔT~~ were observed. (b) Fowler-Nordheim plot of the same temperature data ʳe $E_{pk} = 18$ MV/m).



What kind of emitters are likely to process?

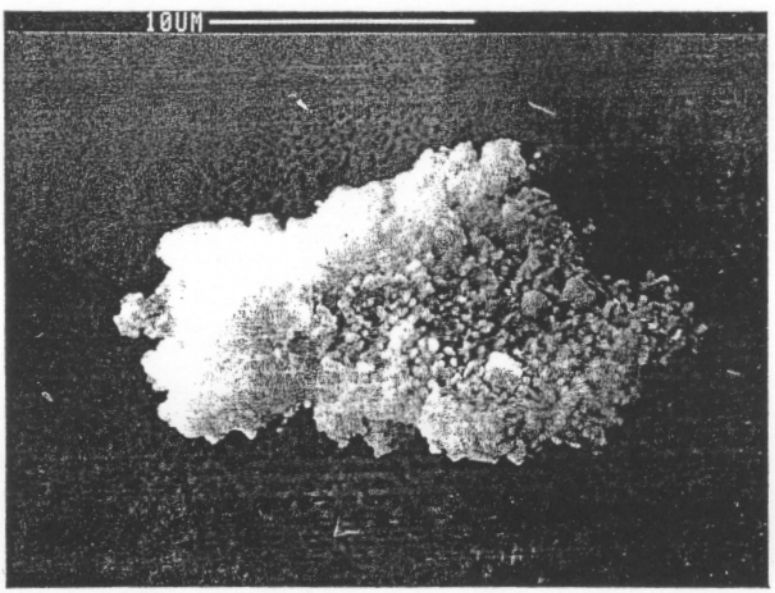


Critical Current Density ~ 10^{11} A/m^2

Critical Current ~ 50-100 μA

10μm
FIELD EMITTER

Ti, C, O,



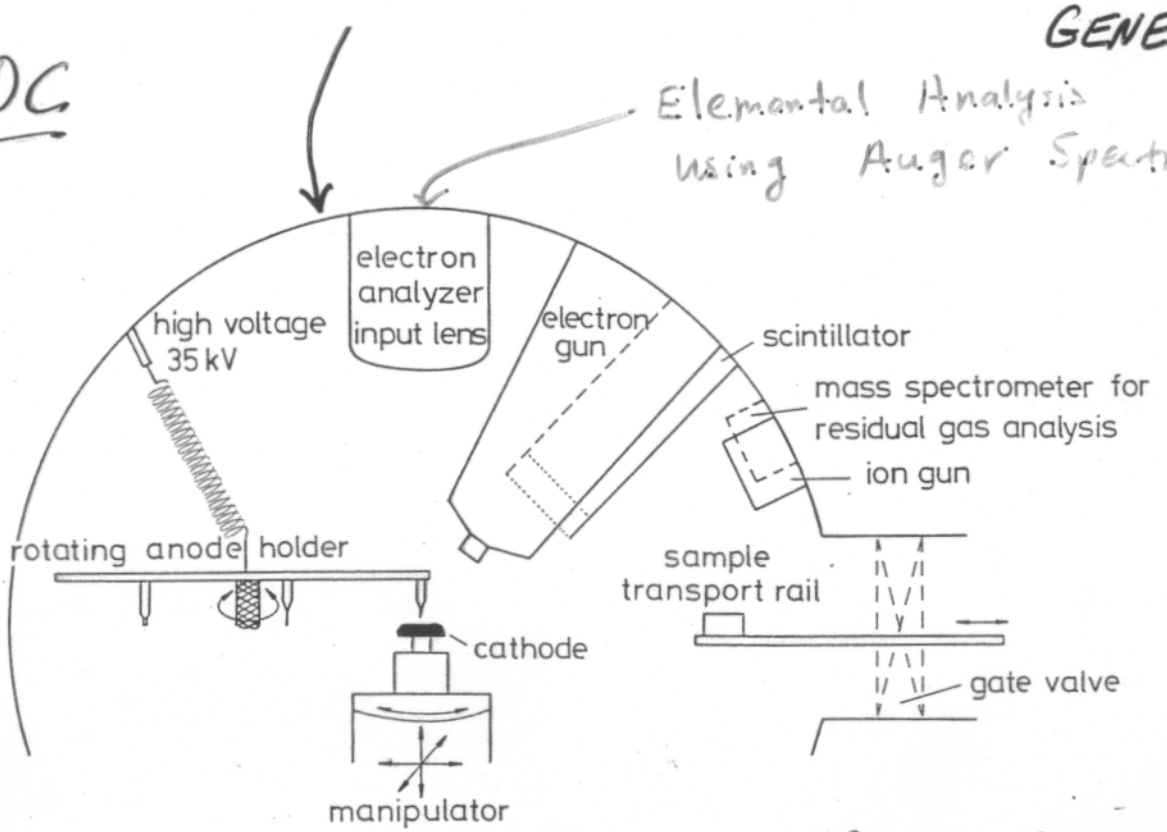
(b) SEM photograph of the site associated with the temperature signals shown in part (a).

Figure 4.25. An example of an SEM located surface site associated with a field emission site which was not processable through HPP.

GENEVA

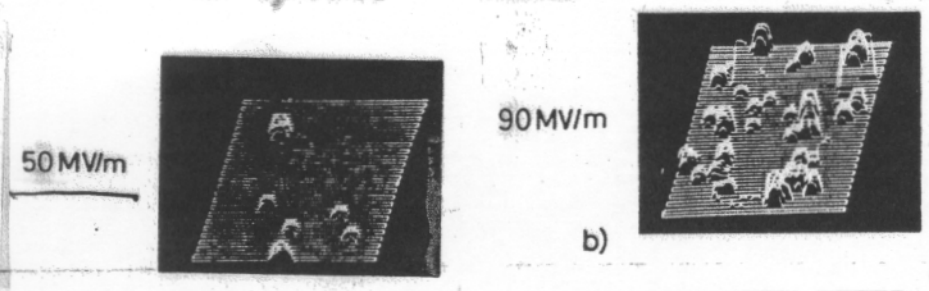
DC

Elemantal Analysis
using Auger Spectroscopy.



non-annealed

1 cm² sample



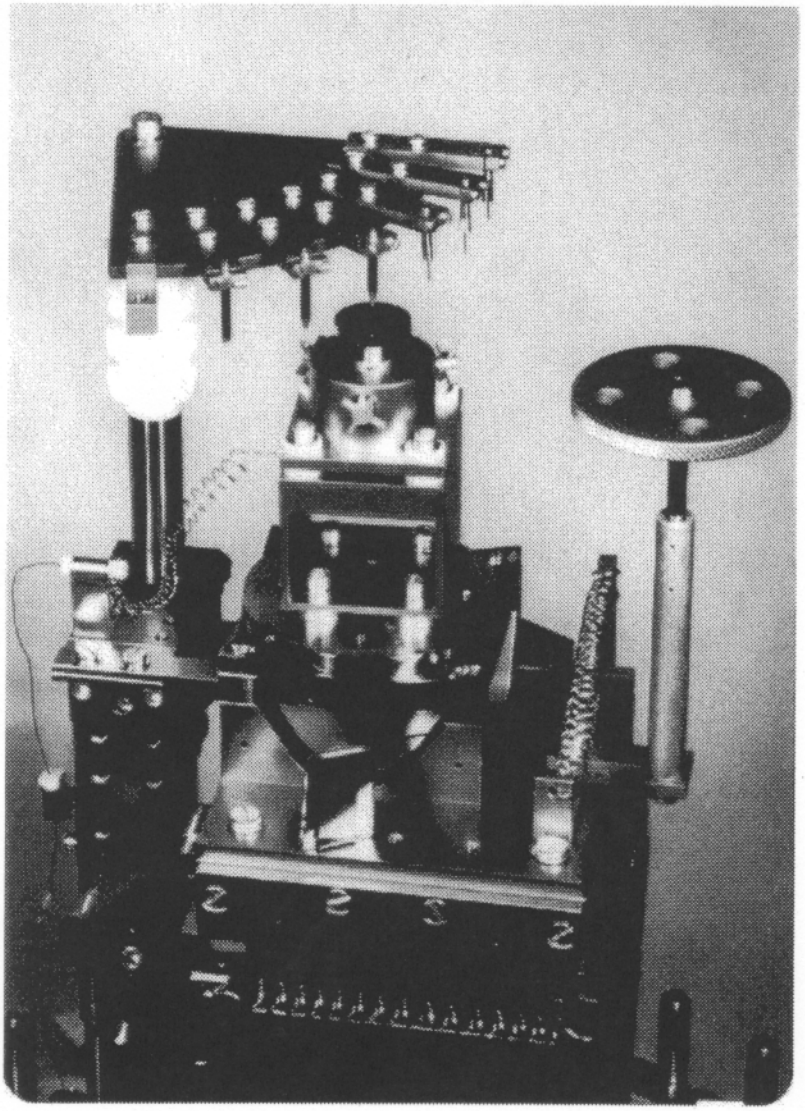
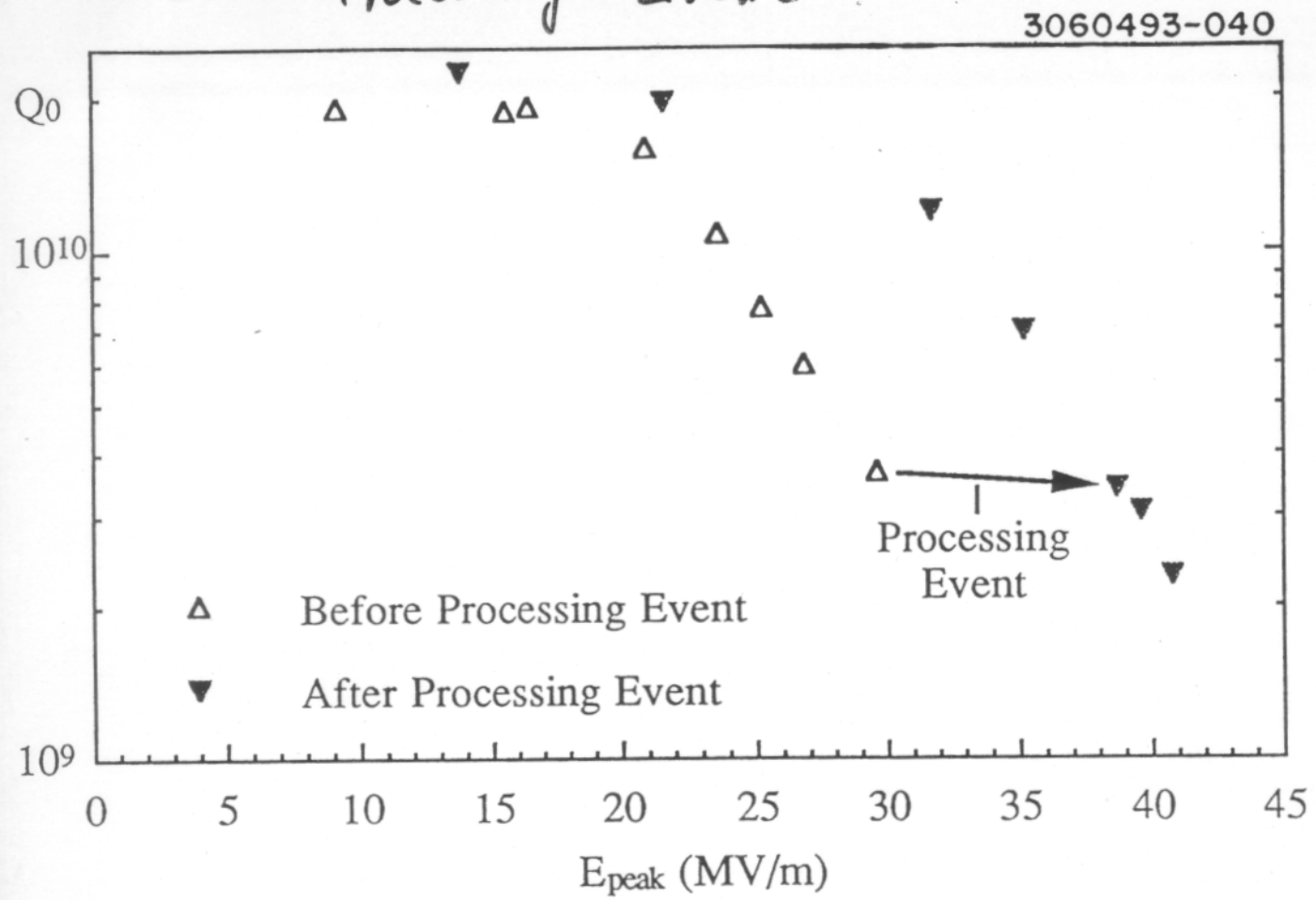


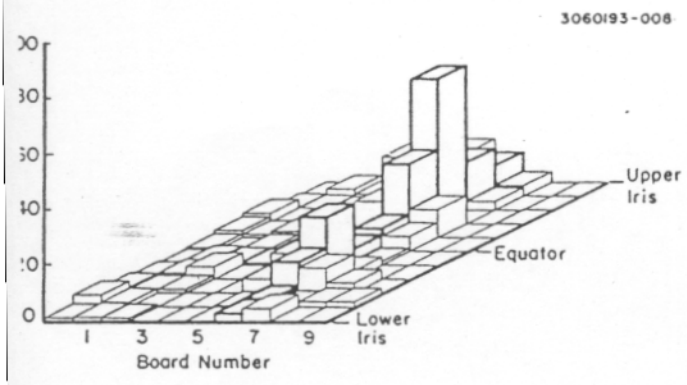
Figure 20. Scanning apparatus to explore field emission on metallic surfaces. A DC voltage is applied between the sample and a sharp needle, thus localizing the electric high-field region. The vacuum apparatus allows *in situ* heating, sputtering and surface imaging [28].

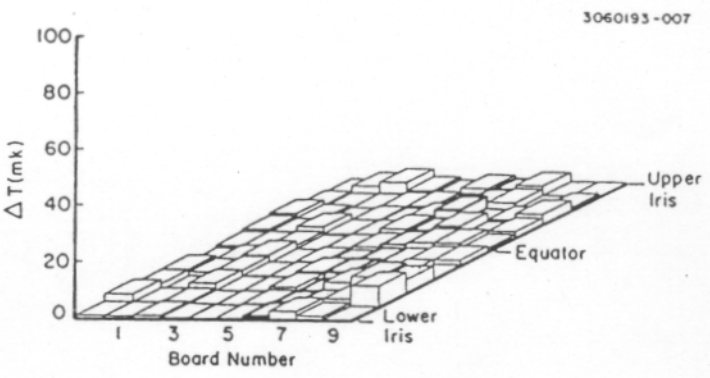
The experience with DC field emission suggests that small particles are the main origin of field emitted current and that geometric effects determine the field enhancement factor. It seems plausible that the same parameters are also important for radiofrequency field emission, but it cannot be excluded that other parameters might be relevant, too. Therefore, field emission studies under radiofrequency conditions are necessary. At Cornell many field emitters in cavities have been localized by temperature mapping. After dismounting (or

- Evidence that breakdown sites arise from contaminants
    - RF and DC
    - Apparatus used to find/analyze breakdown sites

CW Processing Event:







. Before low power event;
E_{peak} = 29.6 MV/m.

(b). Following low power event;
E_{peak} = 31.7 MV/m.

Results on Processed Emitters From Mushroom Cavity

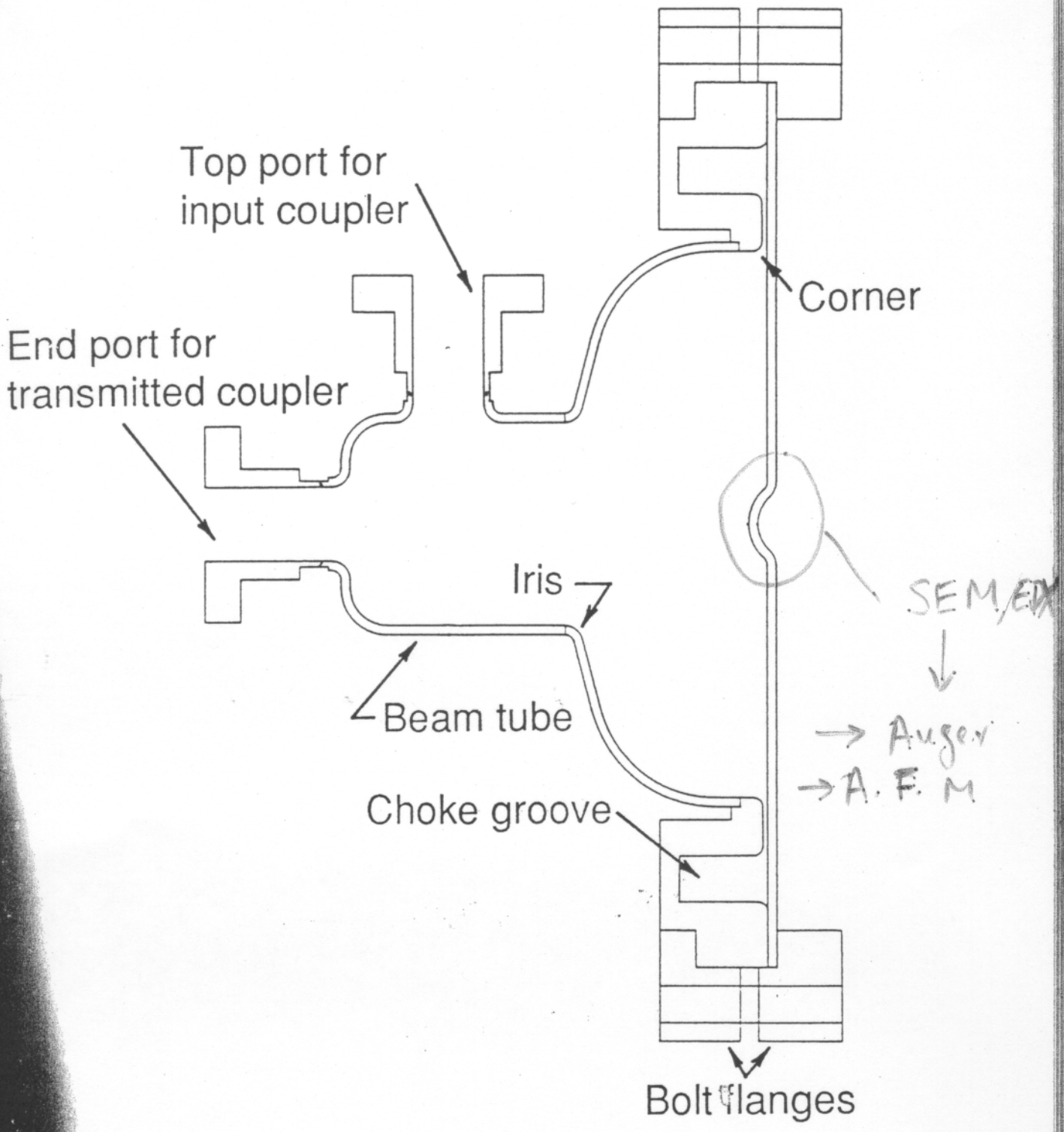
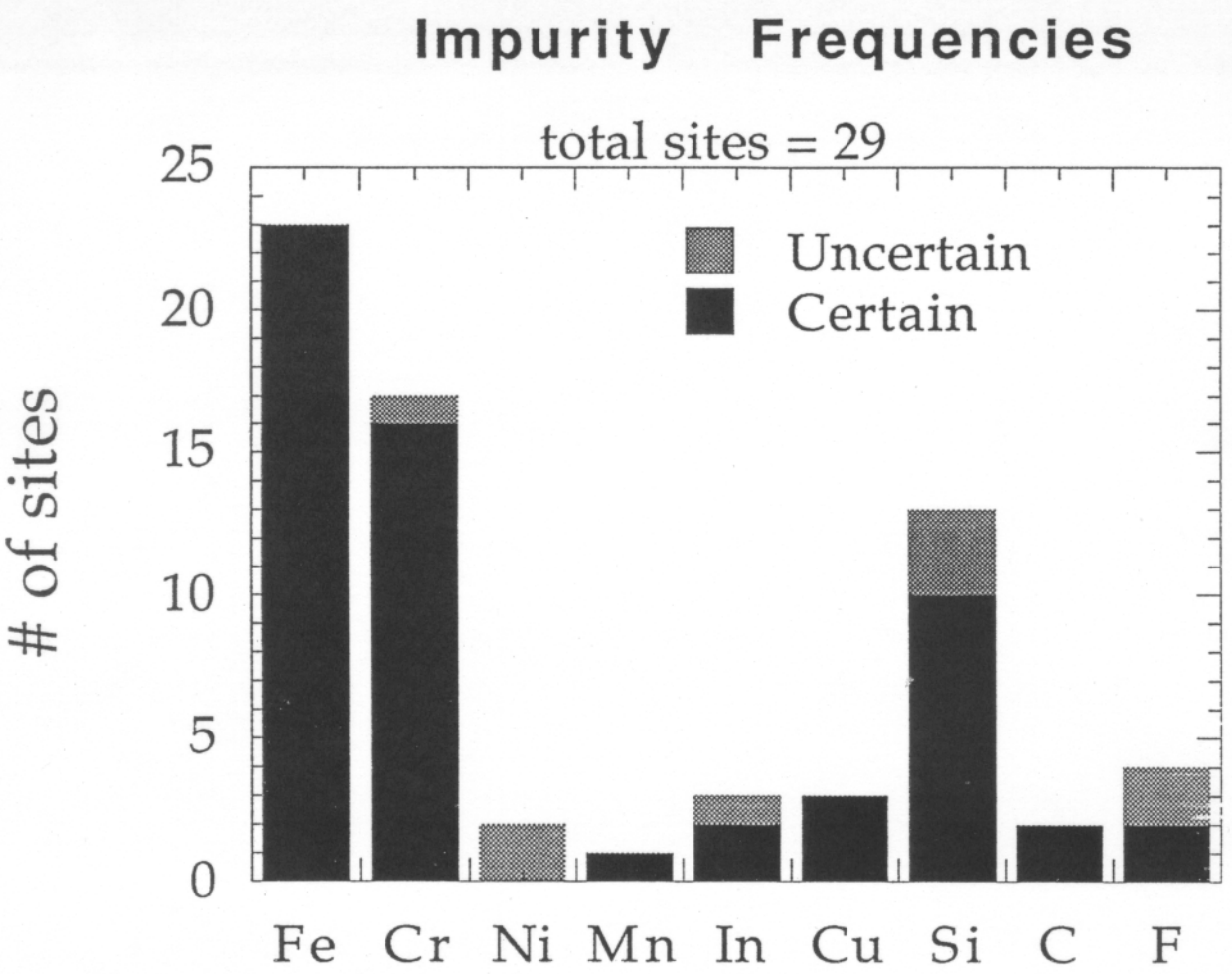


FIGURE 10 The Mark II cavity design. The baseplate is joined to the cavity using an indium -ring.



Impurities were found in every site examined.

From the mushroom cavity using Auger

- The smoking gun
  Intentionally introduced particles that cause breakdown
  RF and DC

DC Field Emission