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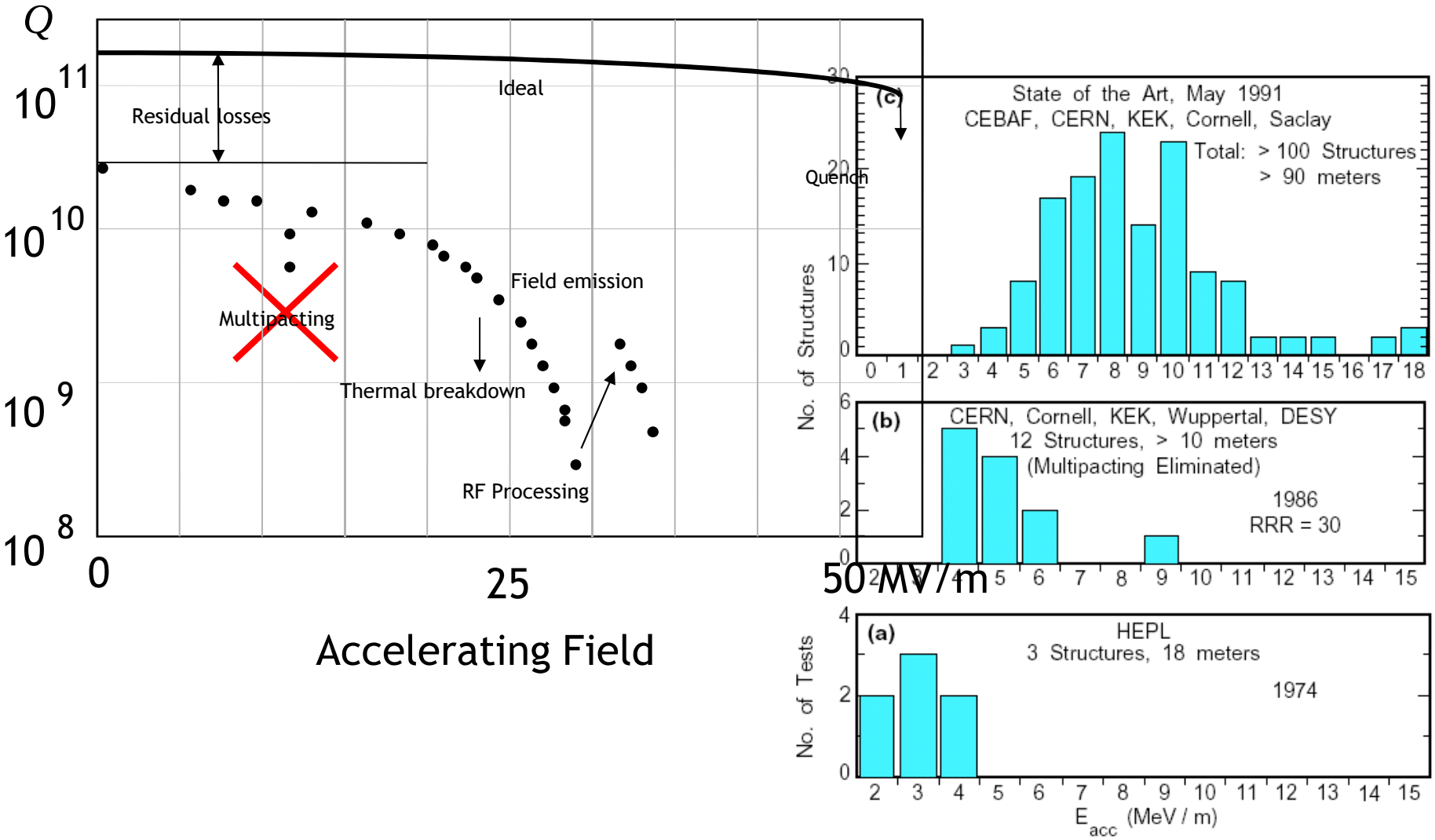
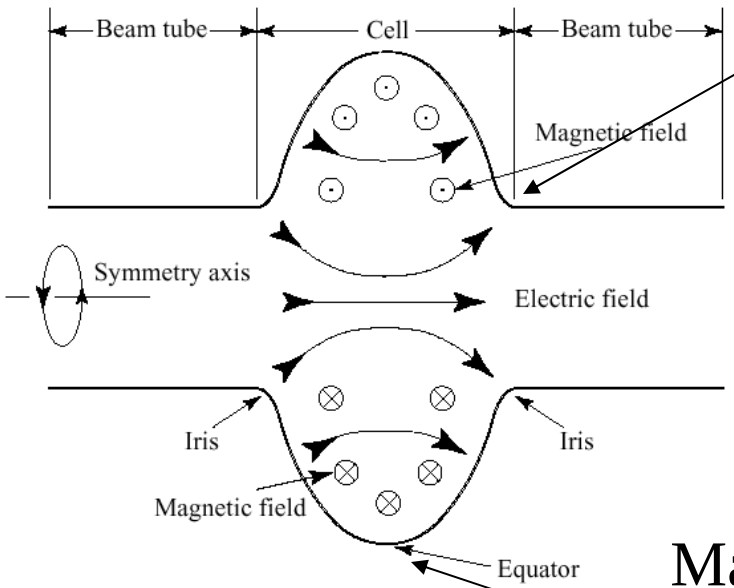
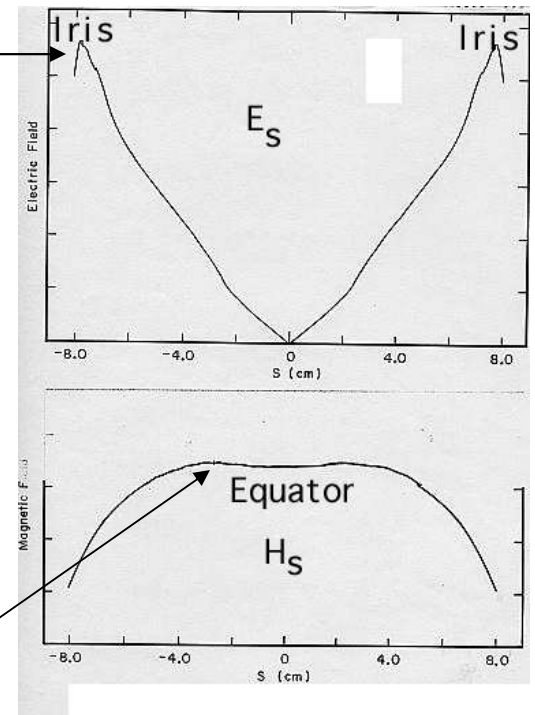
Field Emission



Electric Field Dominated Effect

Electric field high at iris

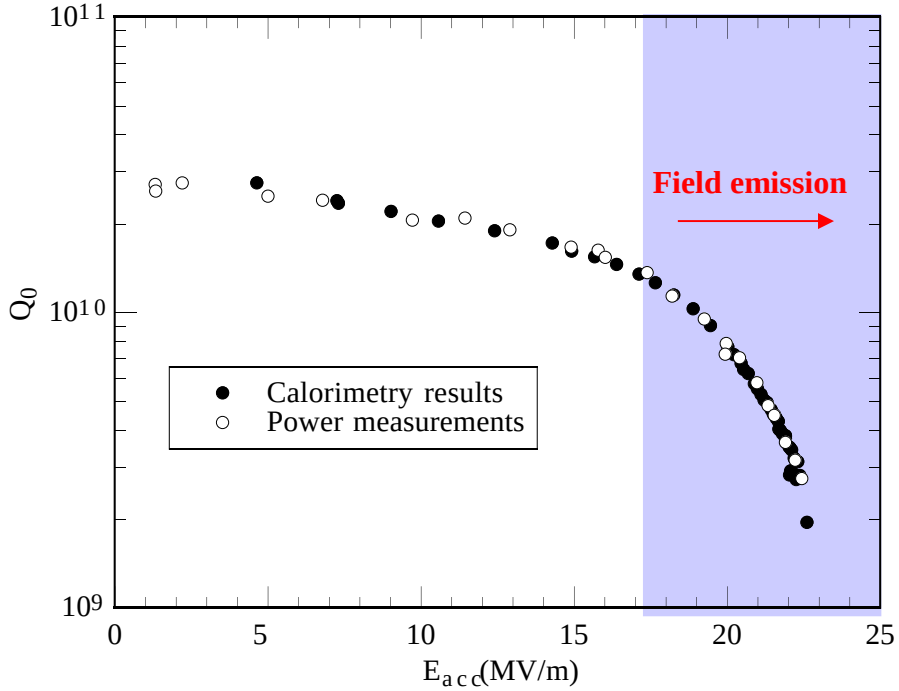




Magnetic field high at equator

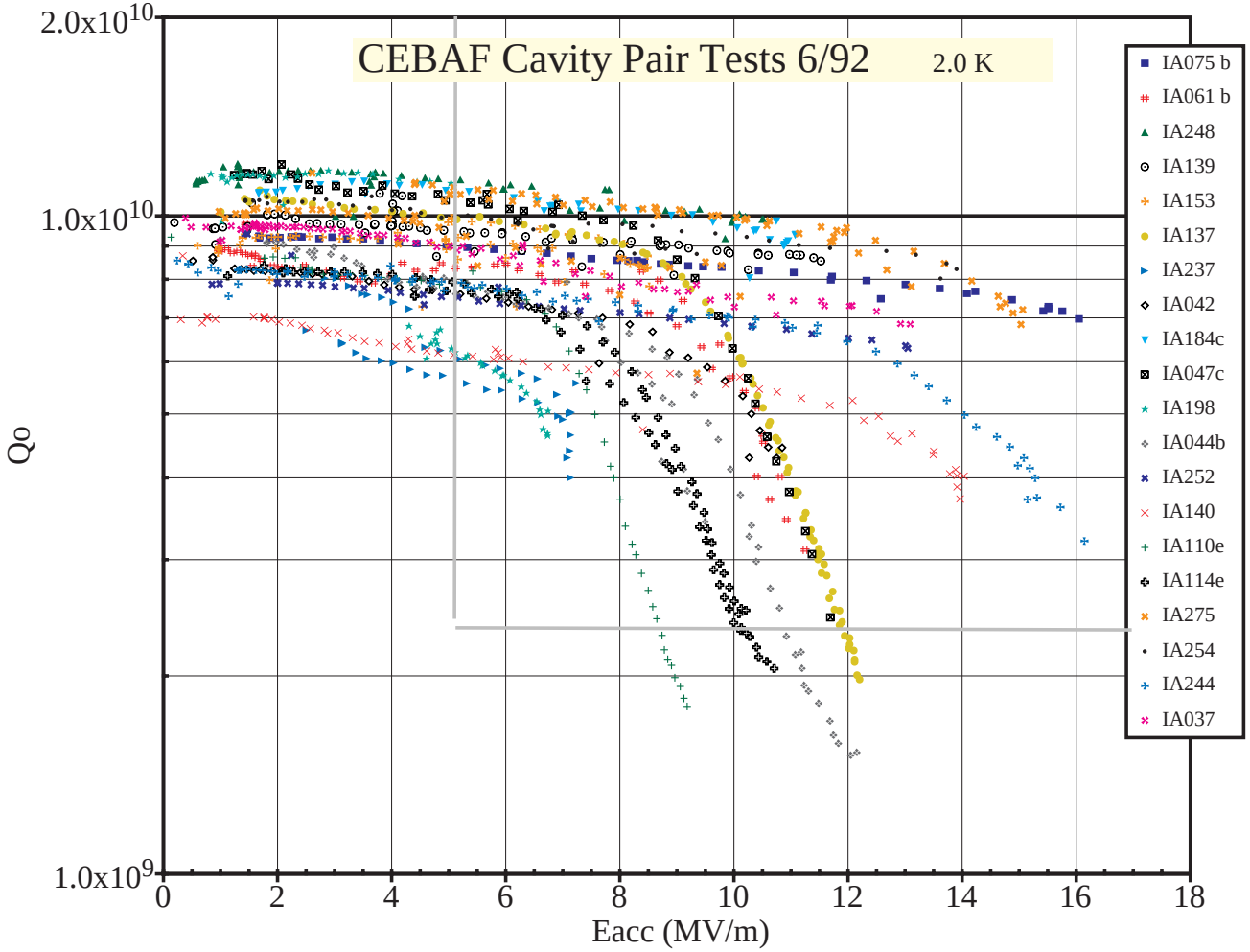
Electron field emission

- Responsible for an exponential drop of the cavity quality (Q) at high field.

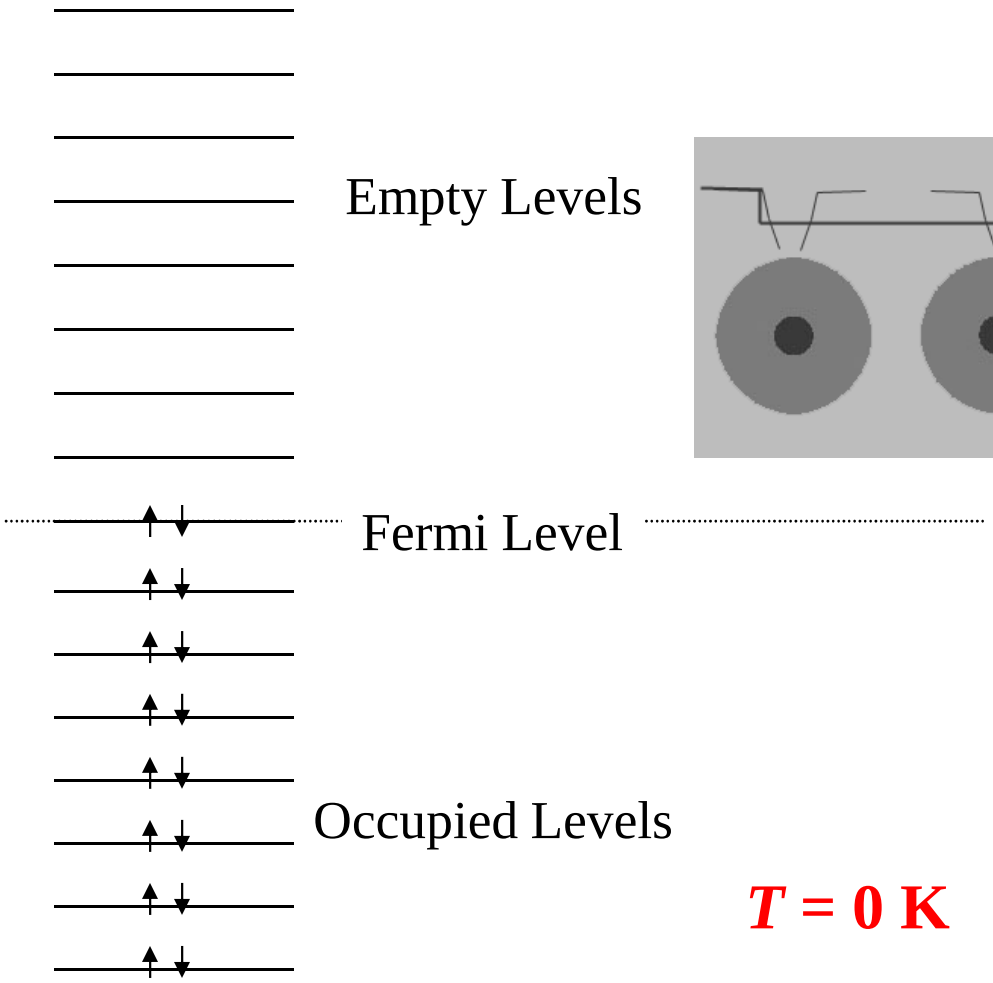


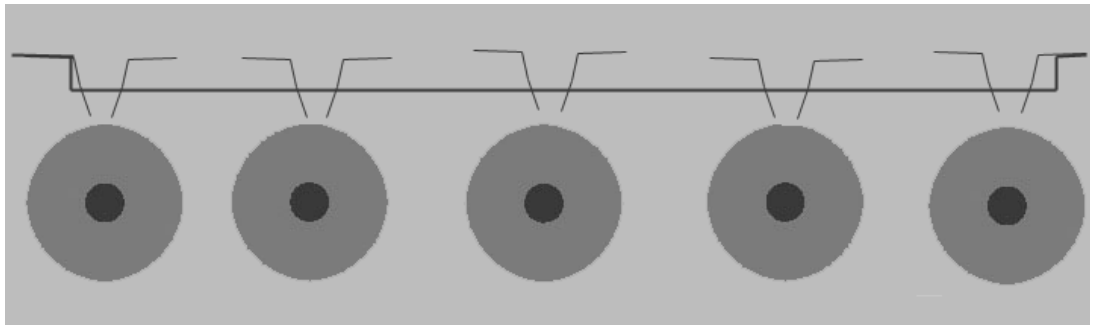
- Large scatter in cavity performance
- X rays detected
- Current detected
- *X rays and current may strike peripheral devices!*

Scatter in Performance Due to FE



Field Emission Theory

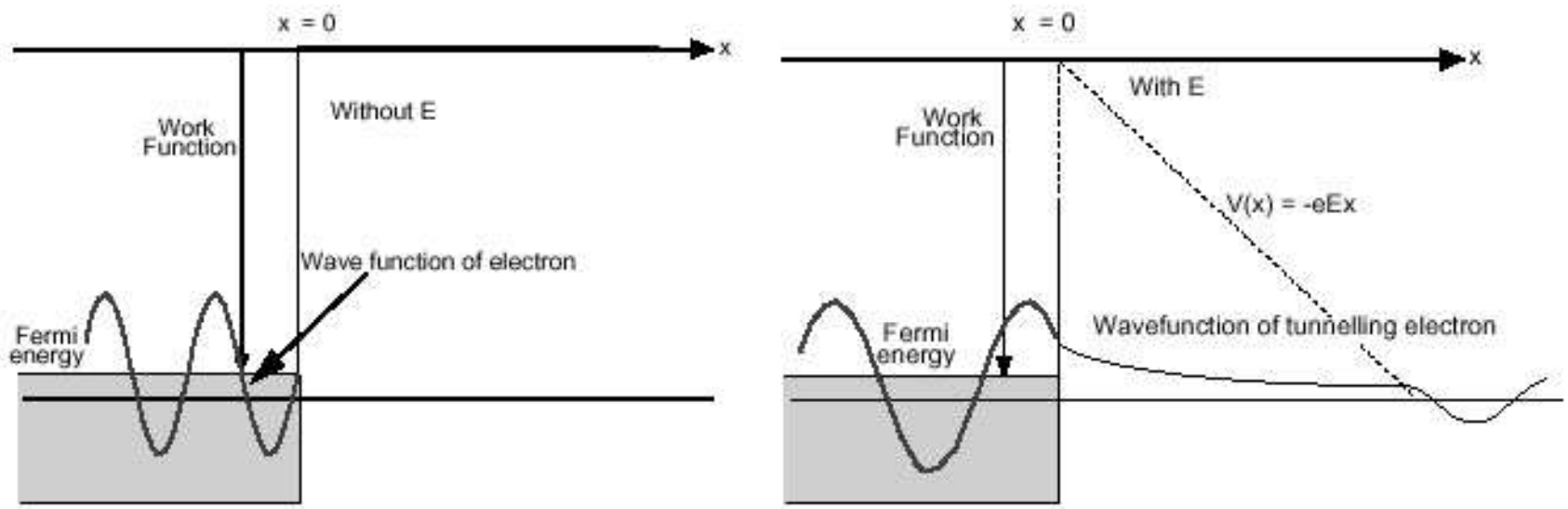




T = 0 K

Normal conductor

Field Emission Theory



- QM tunneling theory predicts exponential *Fowler–Nordheim* emission current density.

$$j_{FN} = C_1 E^2 \exp\left(-\frac{C_2}{E}\right)$$

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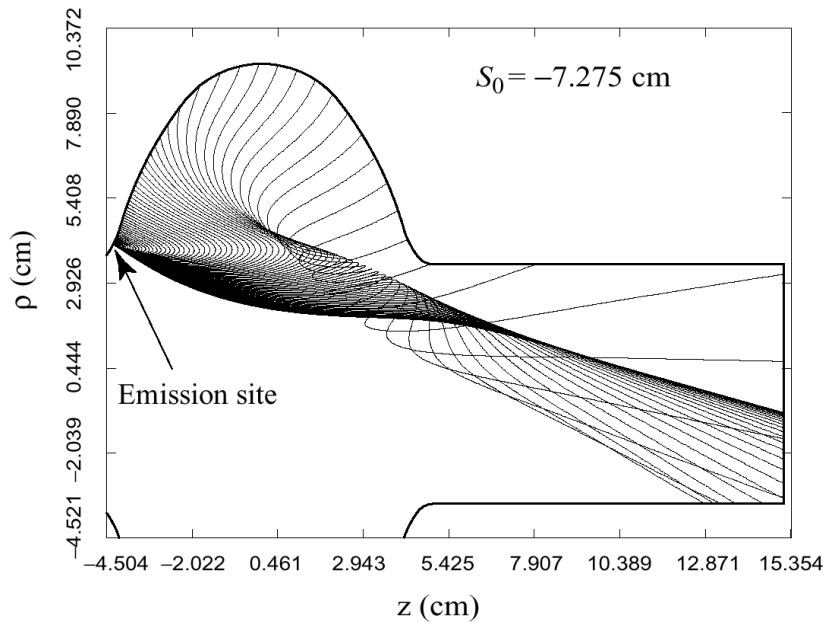
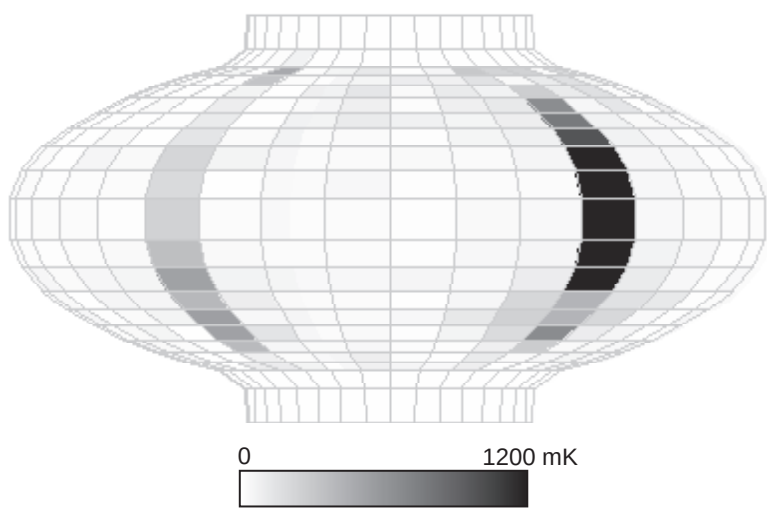
Field Emission

- Acceleration of electrons drains cavity energy
- Impacting electrons produce line heating detected by thermometry.

Impact also produces bremsstrahlung x rays.





Temperature Map Movie Showing Field Emission Induced Heating and Defect Induced Heating

Problem With Theory

- FE in cavities occurs at fields that are up to 1000 times lower than predicted → need β_{FN}.

$$j_{FN} = C_1(\beta_{FN}E)^2 \exp\left(-\frac{C_2}{\beta_{FN}E}\right)$$

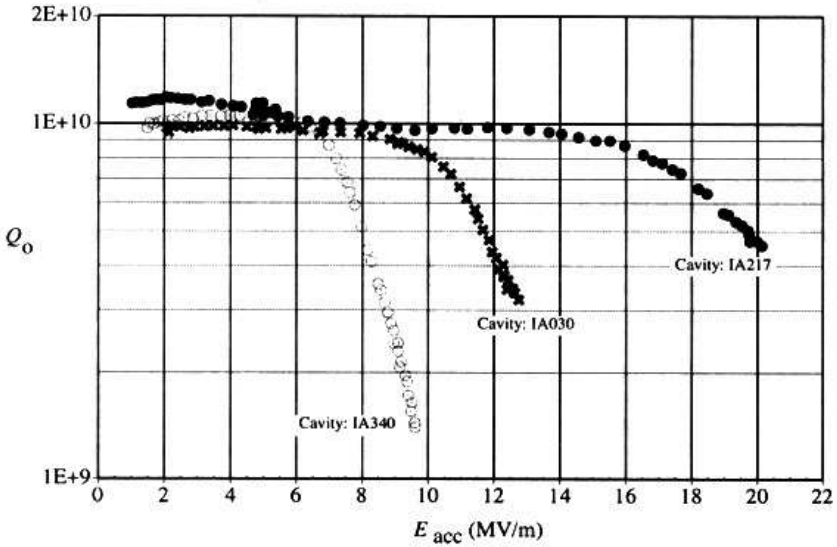
- $50 < \beta_{FN} < 1000$

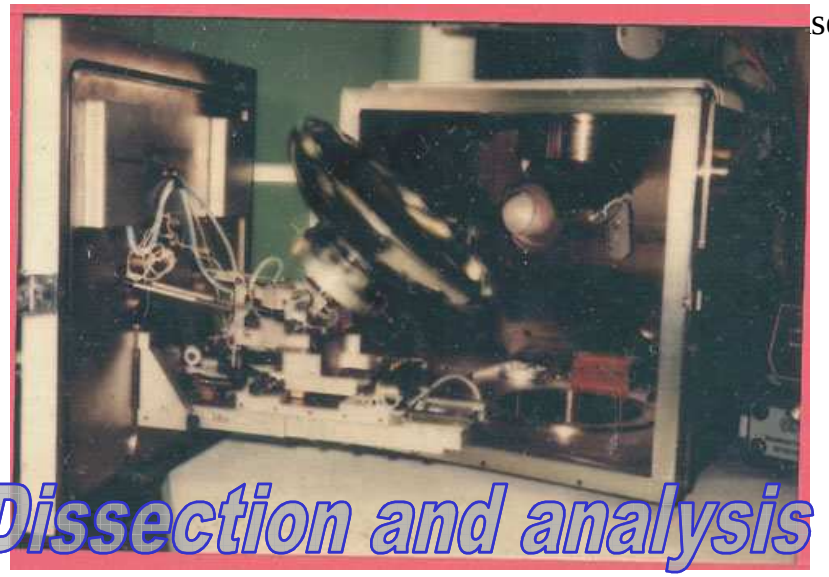
Field emission

- Classical explanation for FE: Whiskers.
- ***Whiskers with 50 < ß < 1000 have not been found in cavities.***
- All emission is associated with (conducting) <u>microscopic</u> foreign particles (smaller than thermal breakdown particles)

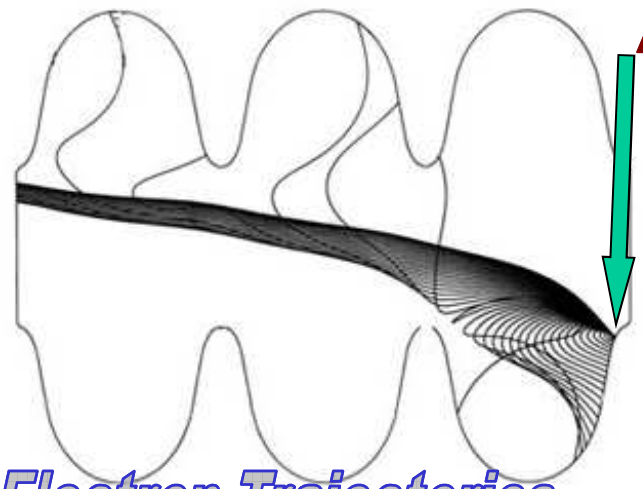
Micron size particles cause FE

Field Emission in SC Cavities



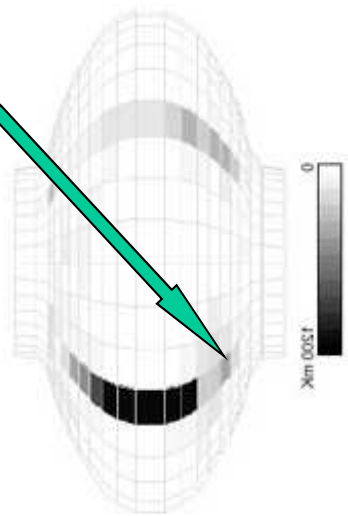


Dissection and analysis

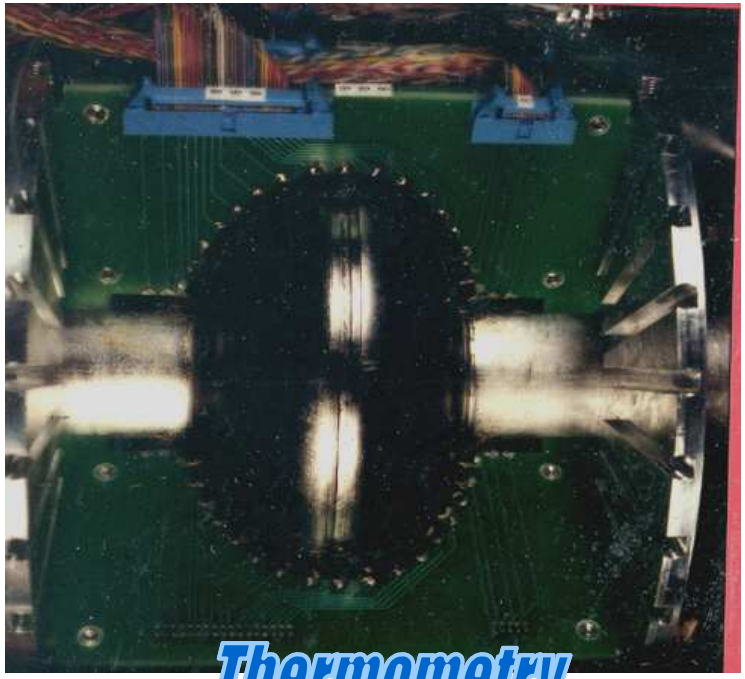


Electron Trajectories

Emitter

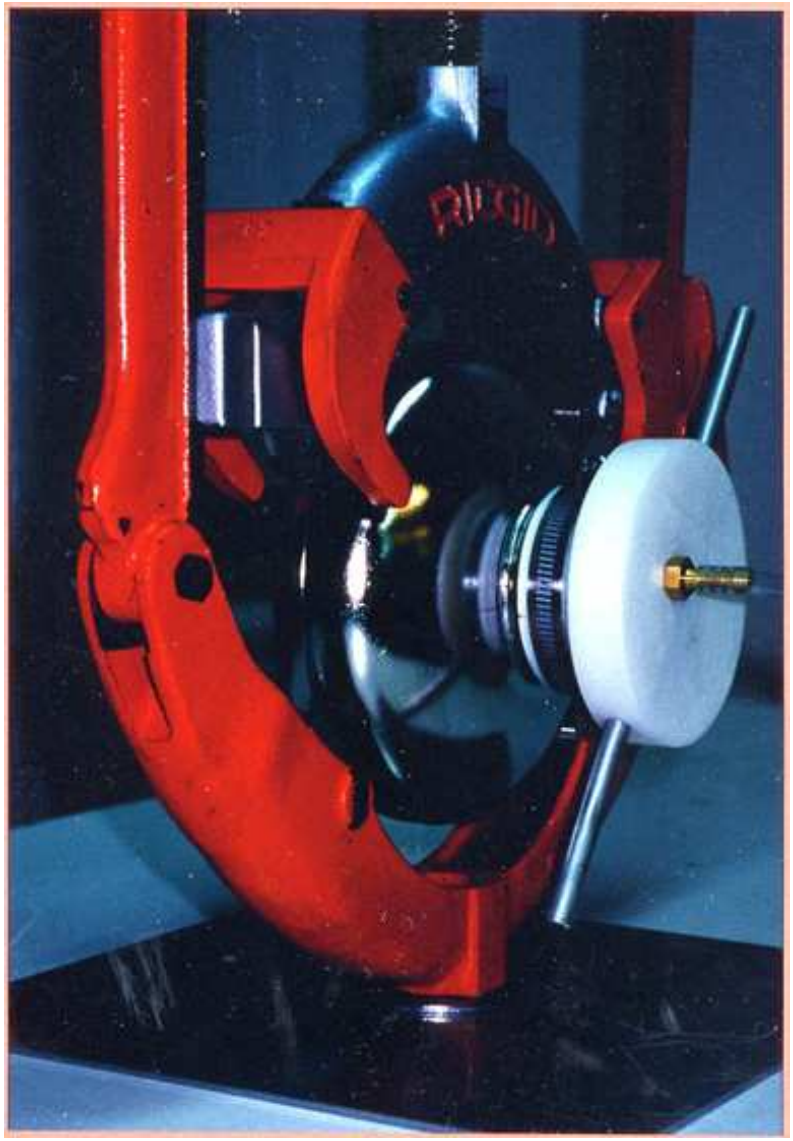


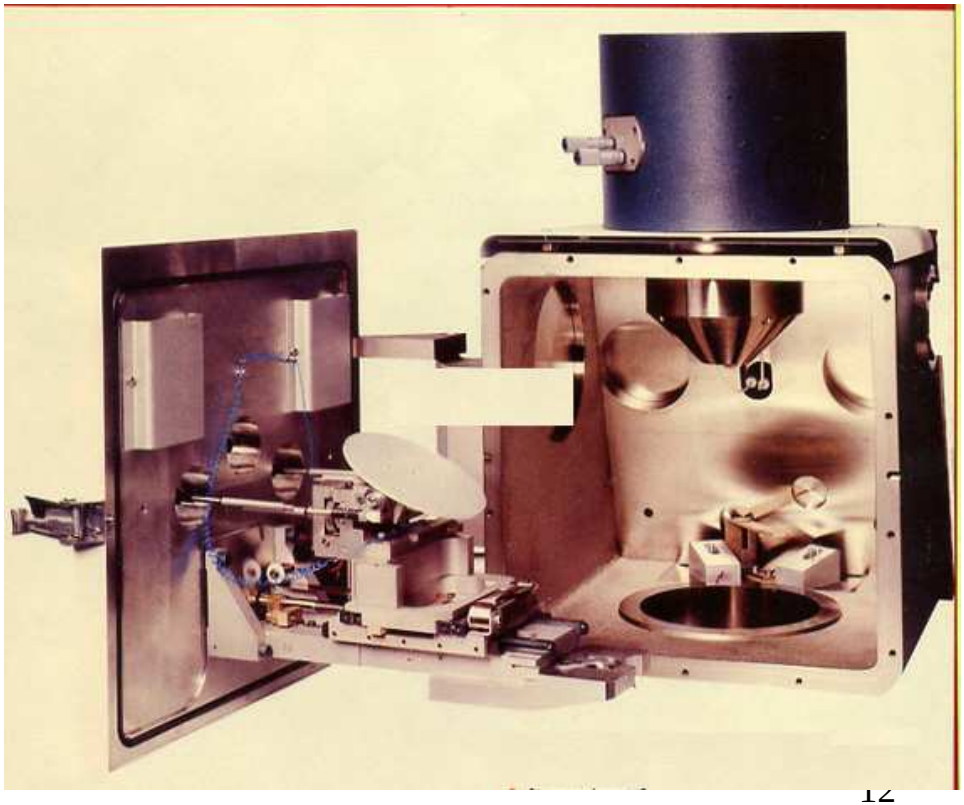
Temperature Map

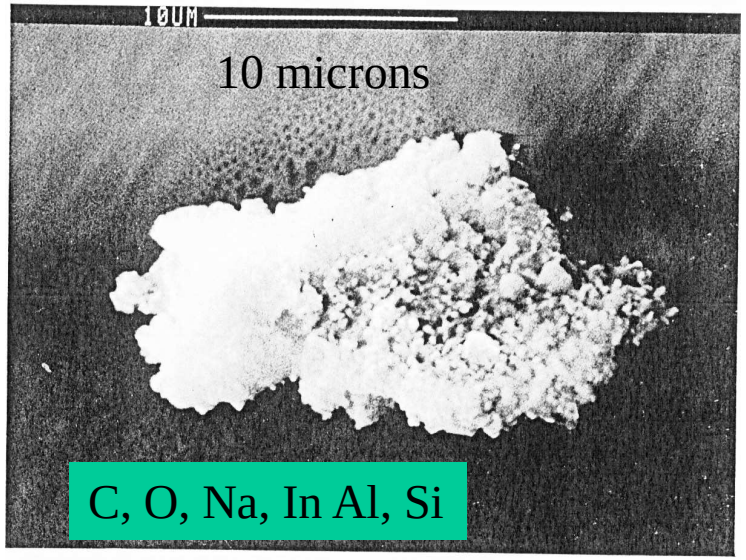


Thermometry

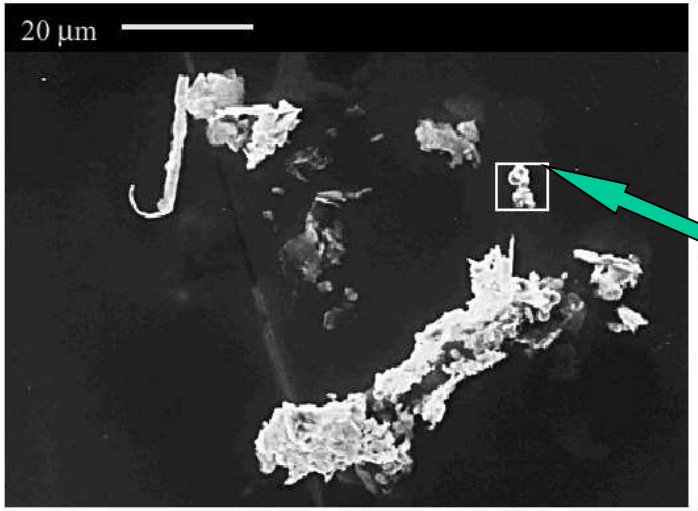
Dissection and SEM



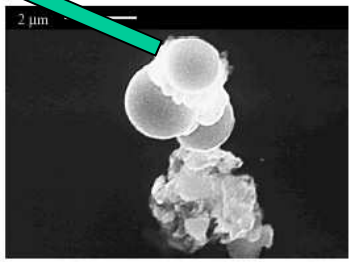


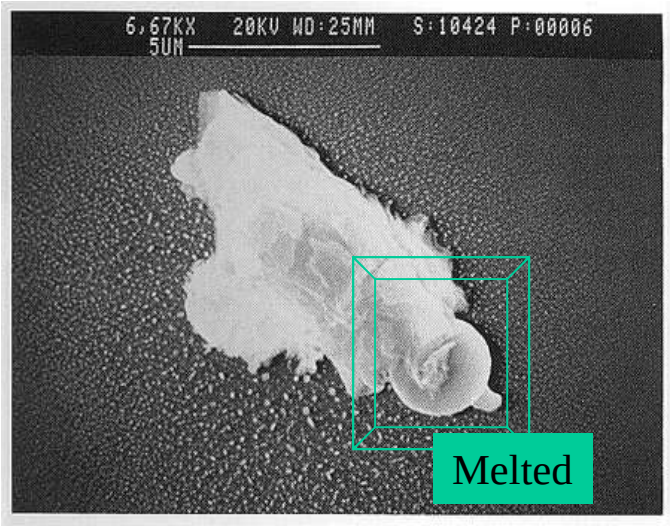


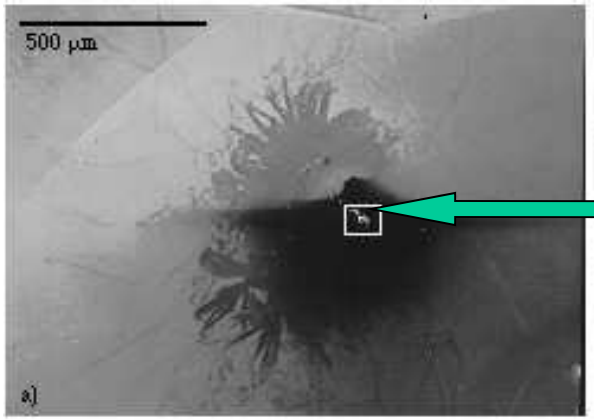
Stainless steel

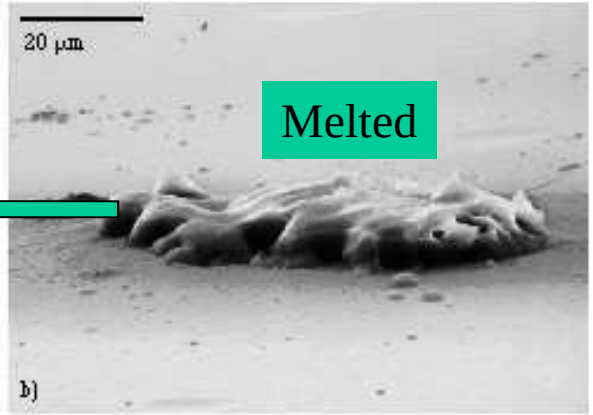


Melted









Emitters Found in Niobium SC Cavities

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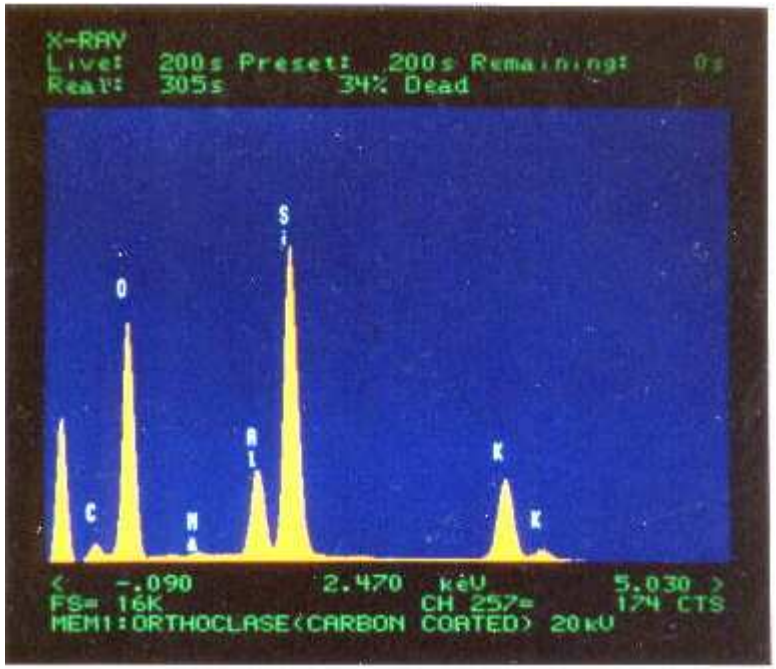
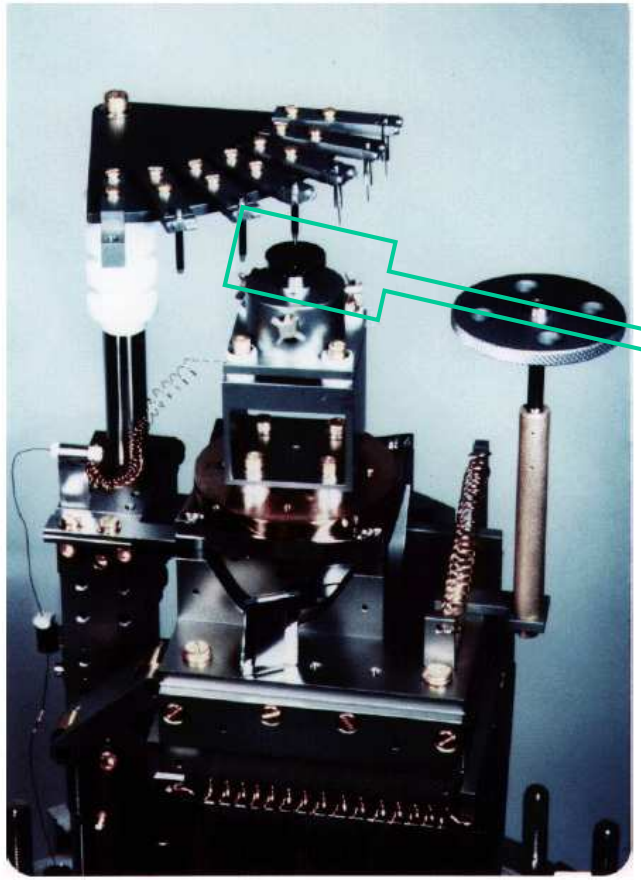
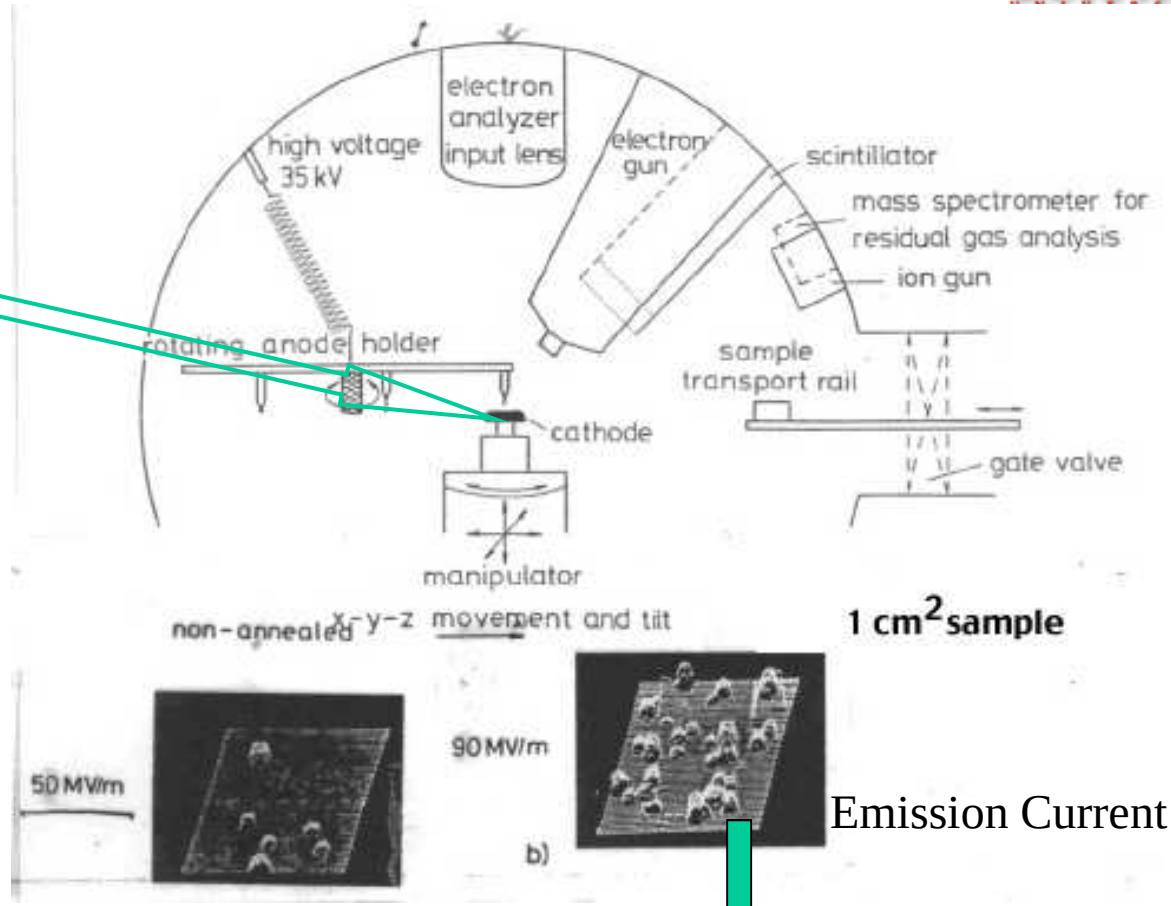
EDX System

Elemental Analysis
on the micron scale



see

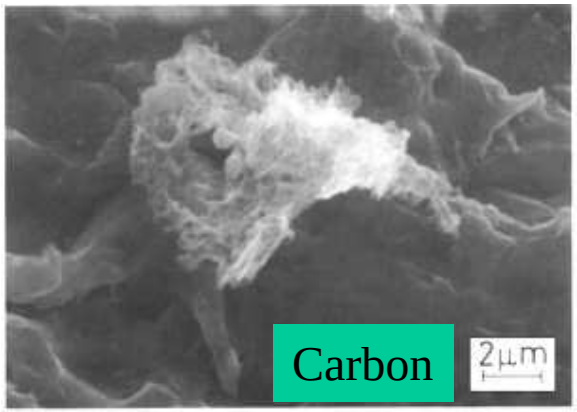


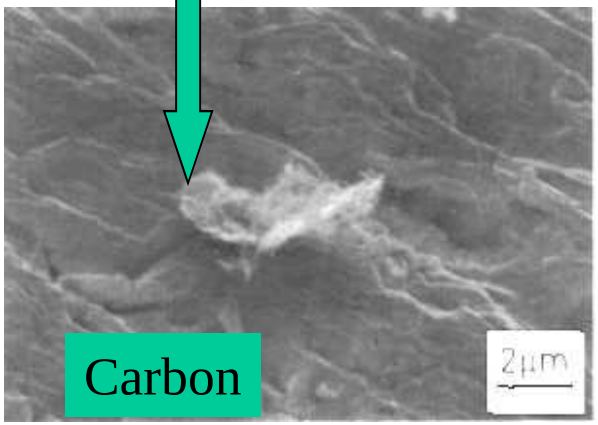


Emission Current

DC Field Emission

U. Geneva and Wuppertal





Particle Counts - KEK

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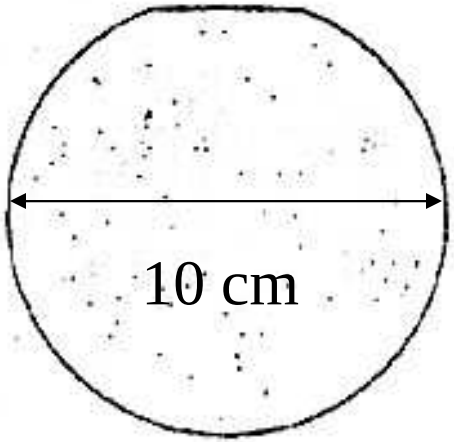
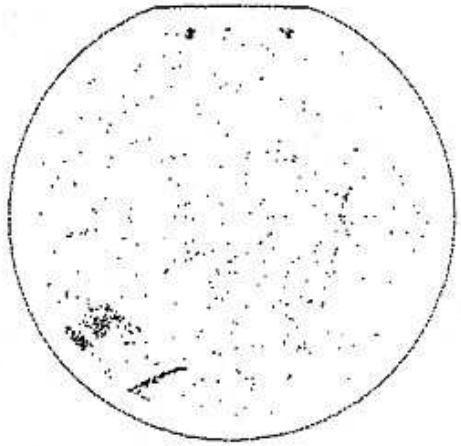
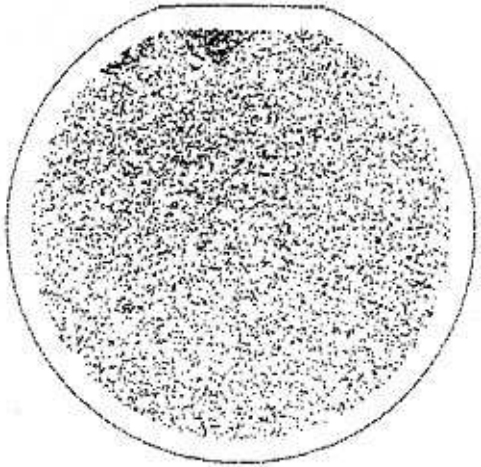


New Wafer

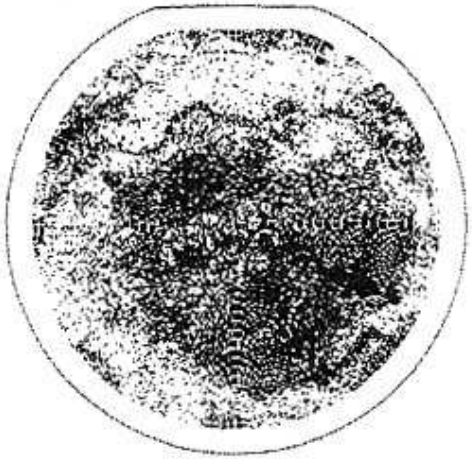


Class 100 Clean Room
5 hrs



No Clean Room
10 min

Only 5 - 10% Particles Are Emitters at < 100 MV/m



Rinsed with ethanol
No clean room, 10 min