

# Simulation and measurements of dark current in superconducting RF cavities

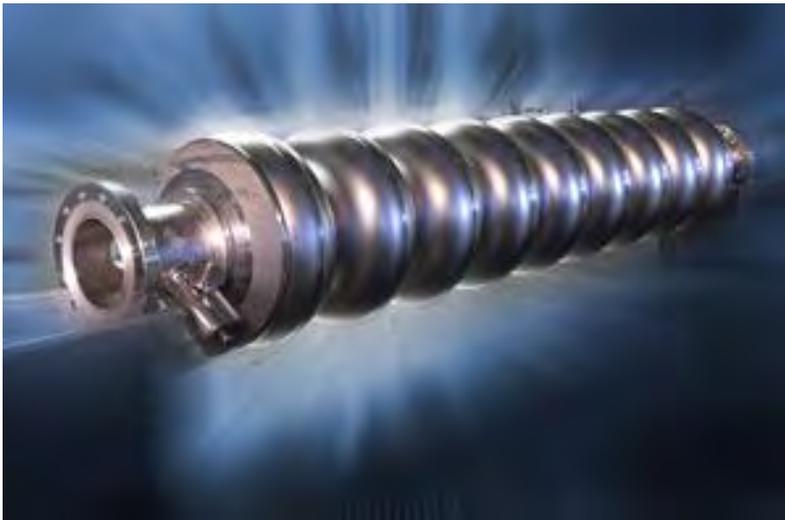


Anna Mukhortova

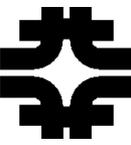
Moscow Institute of Physics and Technology

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Fermilab



PARTI Meeting  
8/31/2011



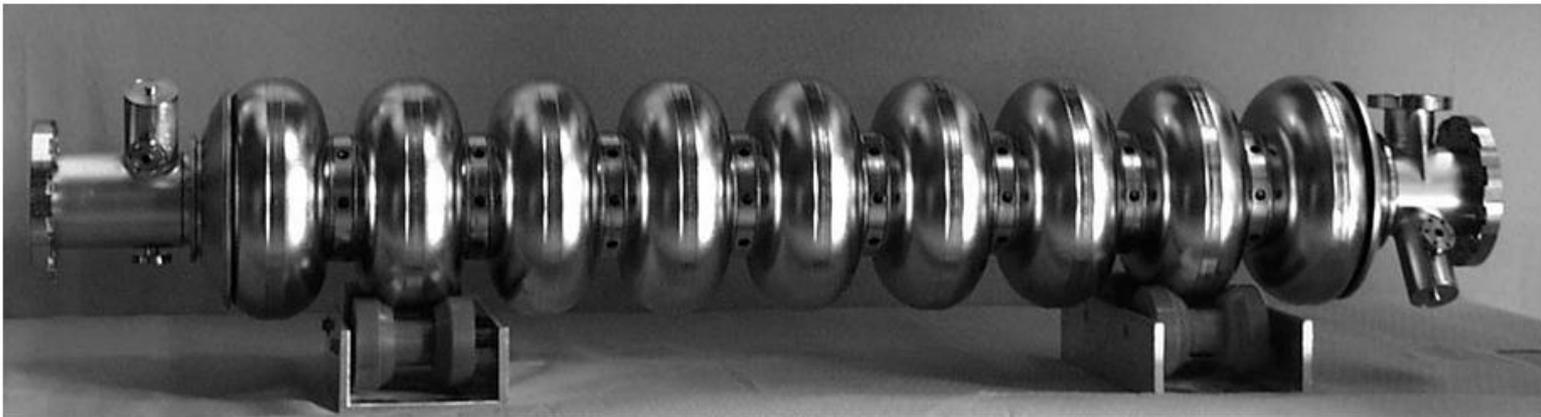
# SRF Cavities: Figures of Merit

- Quality Factor

$$Q_0 = 2\pi \frac{\text{energy stored in the cavity}}{\text{energy dissipated in one RF cycle}}$$

(easy to measure –  $Q_{nc} \approx 10^4$ ,  $Q_{sc} \approx 10^{10}$ )

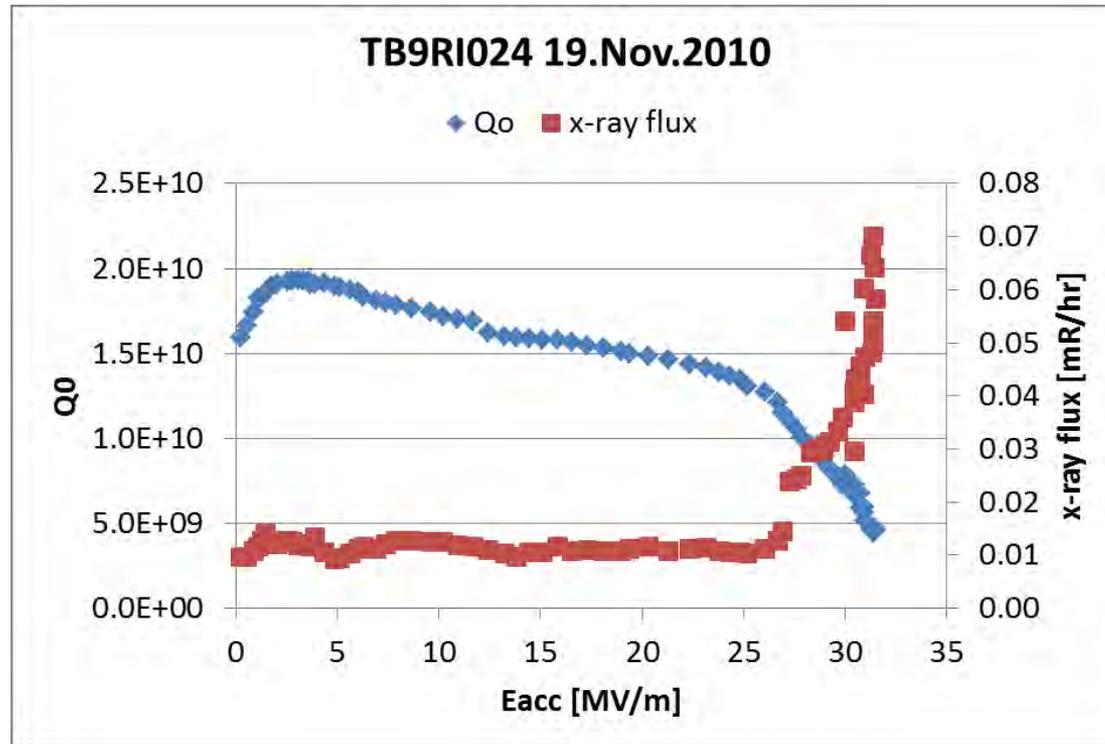
- Gradient of accelerating electric field  $E_{acc}$  (ILC goal is 35 MV/m)



# Field Emission (FE)



FE limits performance of a cavity



- High  $E_{acc}$   $\rightarrow$  FE  $\rightarrow$  Dark Current and X-ray  $\rightarrow$   $Q_0$  starts to fall steeply



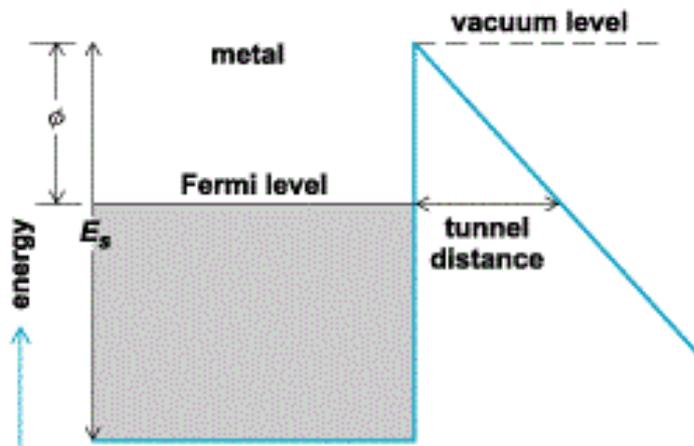
# Quantum Mechanical Nature of FE

There is a finite probability that some electrons will tunnel through the potential barrier

Fowler-Nordheim equation:

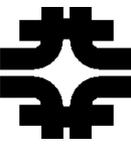
$$j = A1 \cdot E^2 \exp\left(-\frac{A2}{E}\right),$$

where  $A1$  and  $A2$  are some coefficients depending on work function  $\phi$  (in eV) of emitting metal.

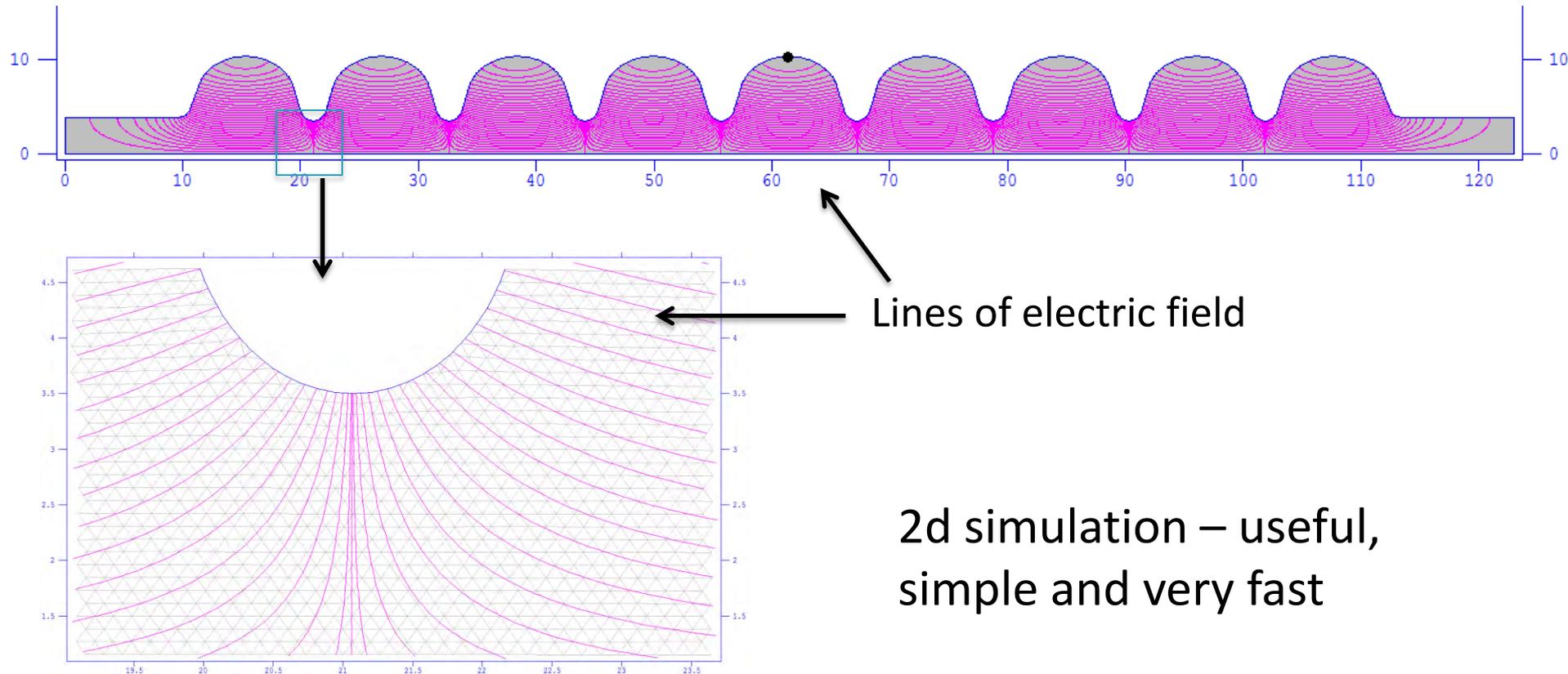


Current is a strong function of field

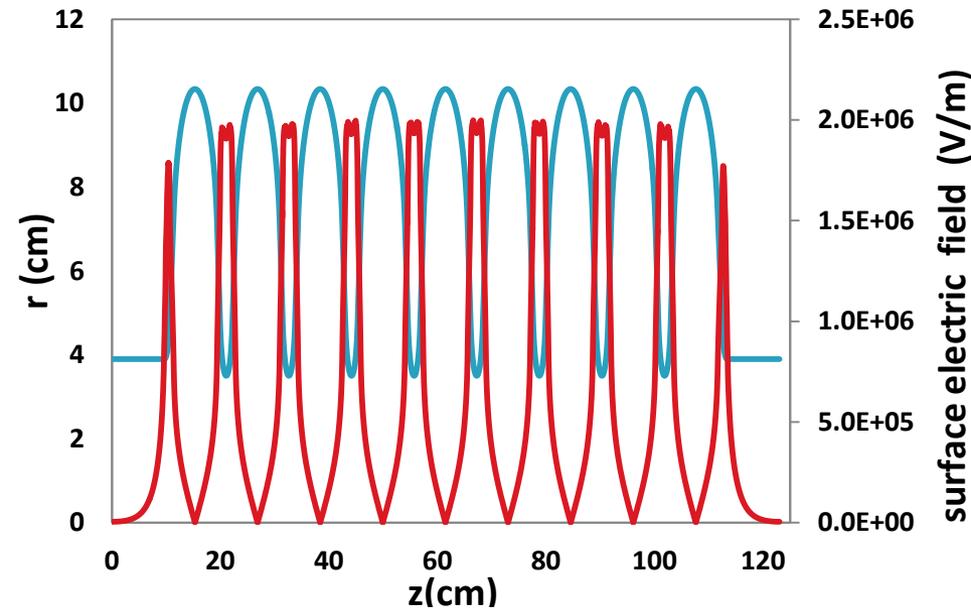
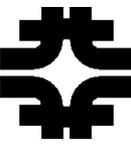
# SUPERFISH simulations



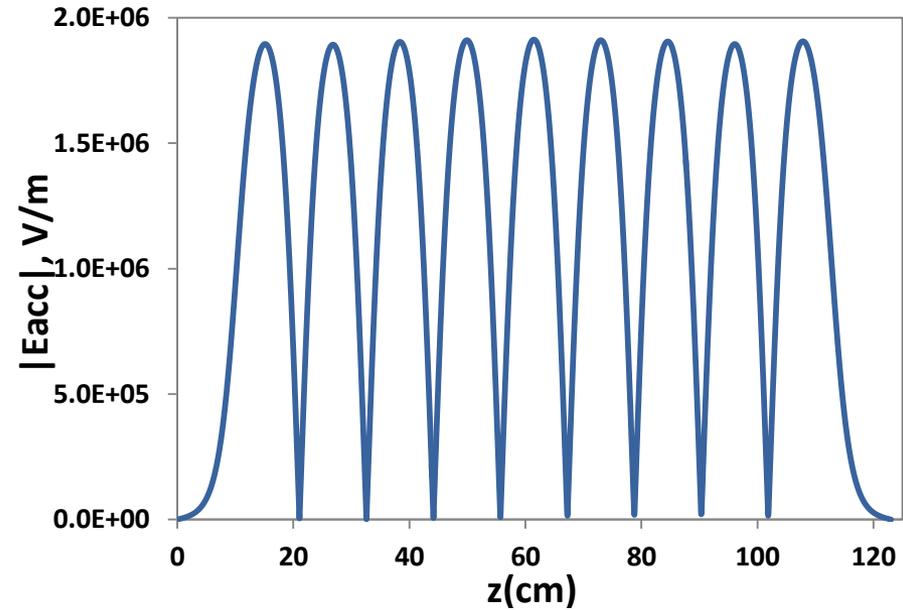
Superfish is a simulation package used to calculate RF electromagnetic fields.



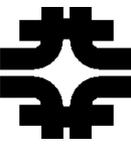
# SUPERFISH simulations



Cavity cell structure and simulated surface electric field as a function of cavity Z axes

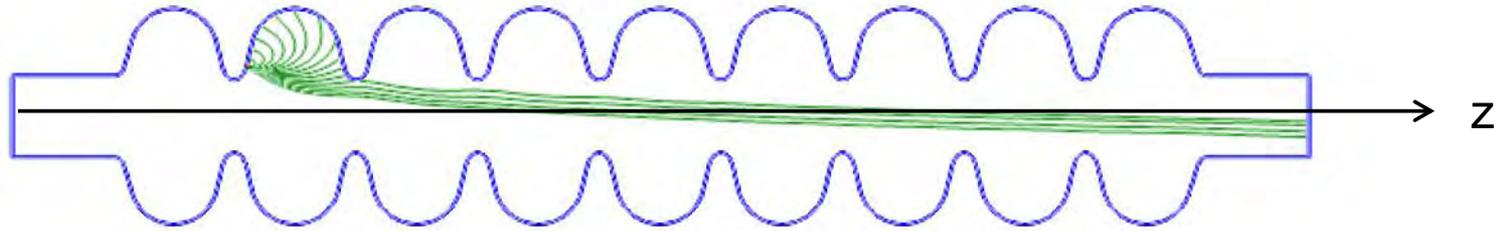


Simulated accelerating electric field as a function of cavity Z axes

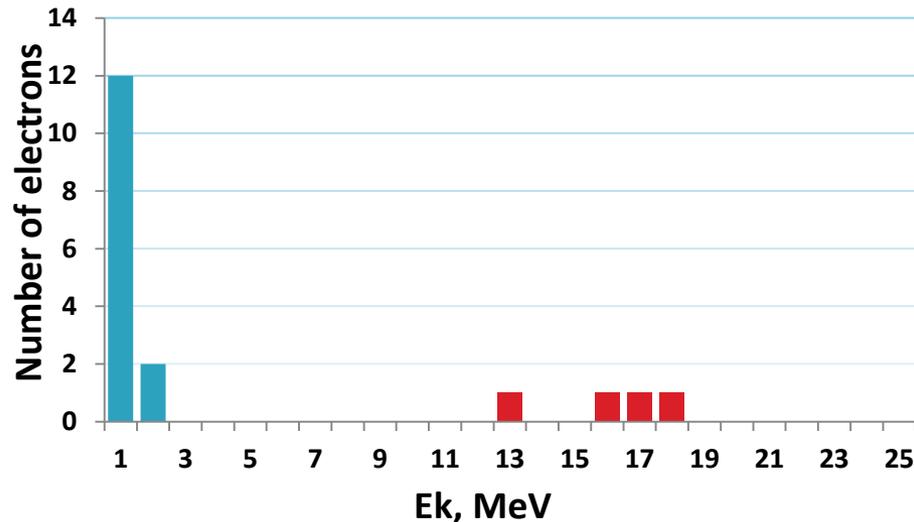


# FISHPACT simulations

Fishpact is a software used to simulate trajectories of emitted electrons



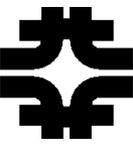
Simulated electron trajectories with  $E_{\text{acc}}=25$  MV/m for one preset emitter location



Most of electrons don't get enough energy to contribute to dark current

The simulation was carried out for 1.3 GHz TESLA cavity @ 15, 20, 25 and 35 MV/m gradient of accelerating field

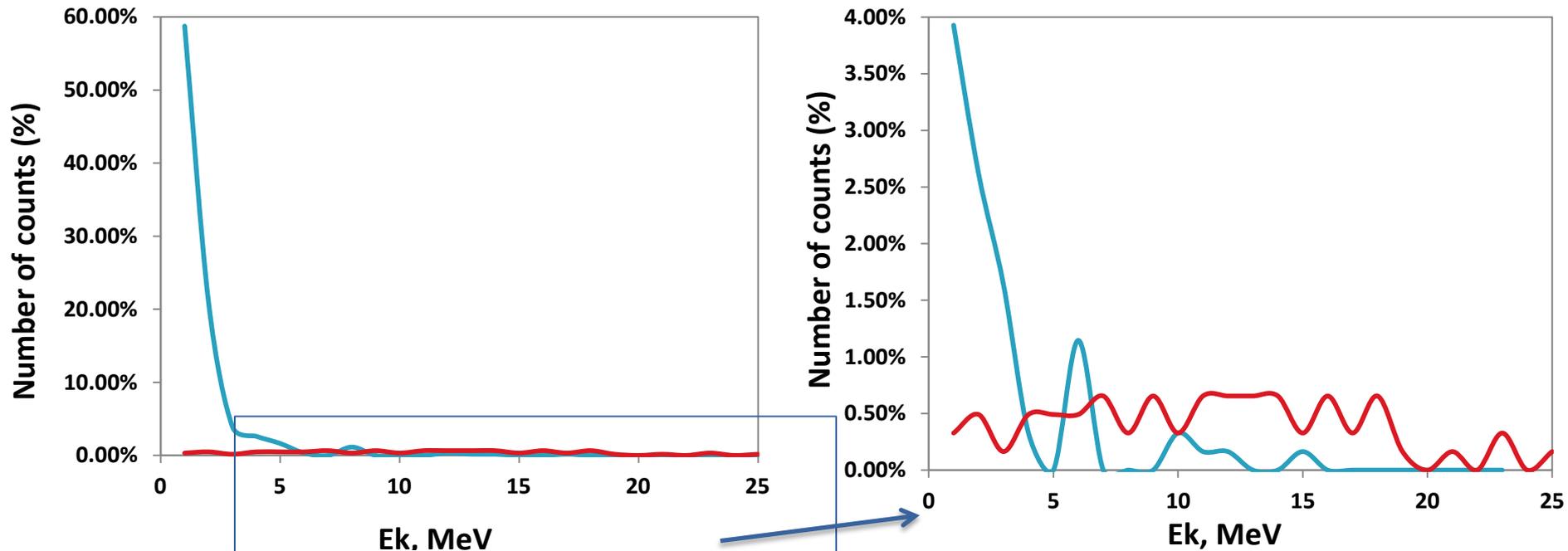
# FISHPACT results (for $E_{\text{acc}}=25$ MV/m simulation)



If to take into account all emission sites...

— electrons striking cavity walls

— electrons striking cavity flanges

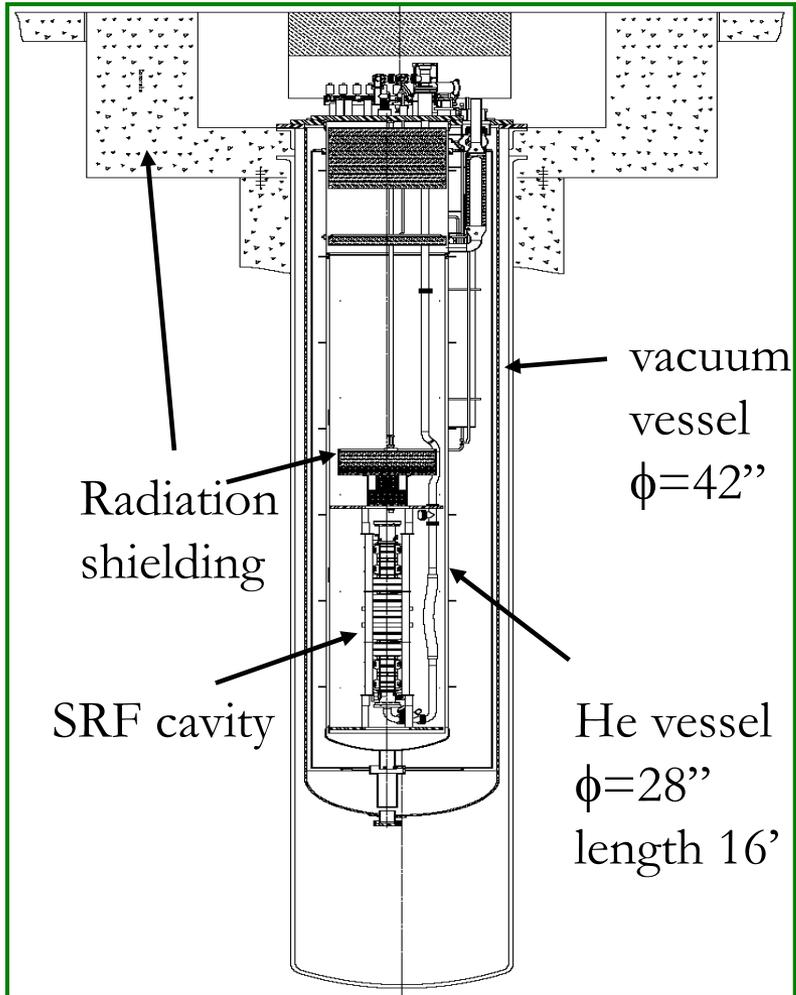


About 80% of all electrons have energies less than 2 MeV

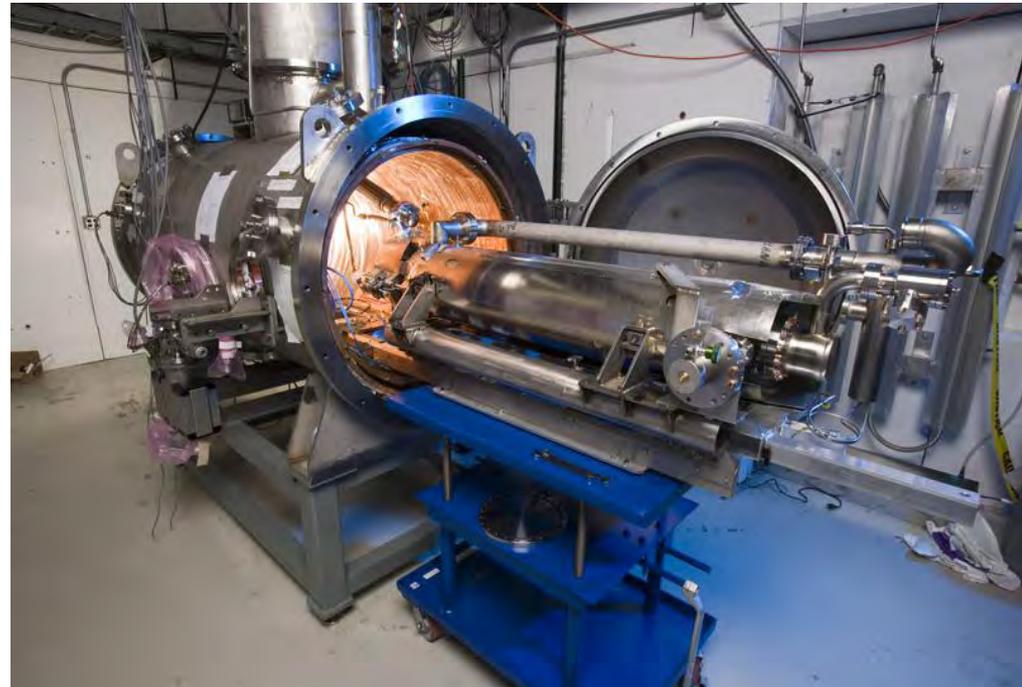
# Cavity Tests

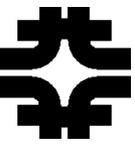


## Vertical Test Stand (VTS)

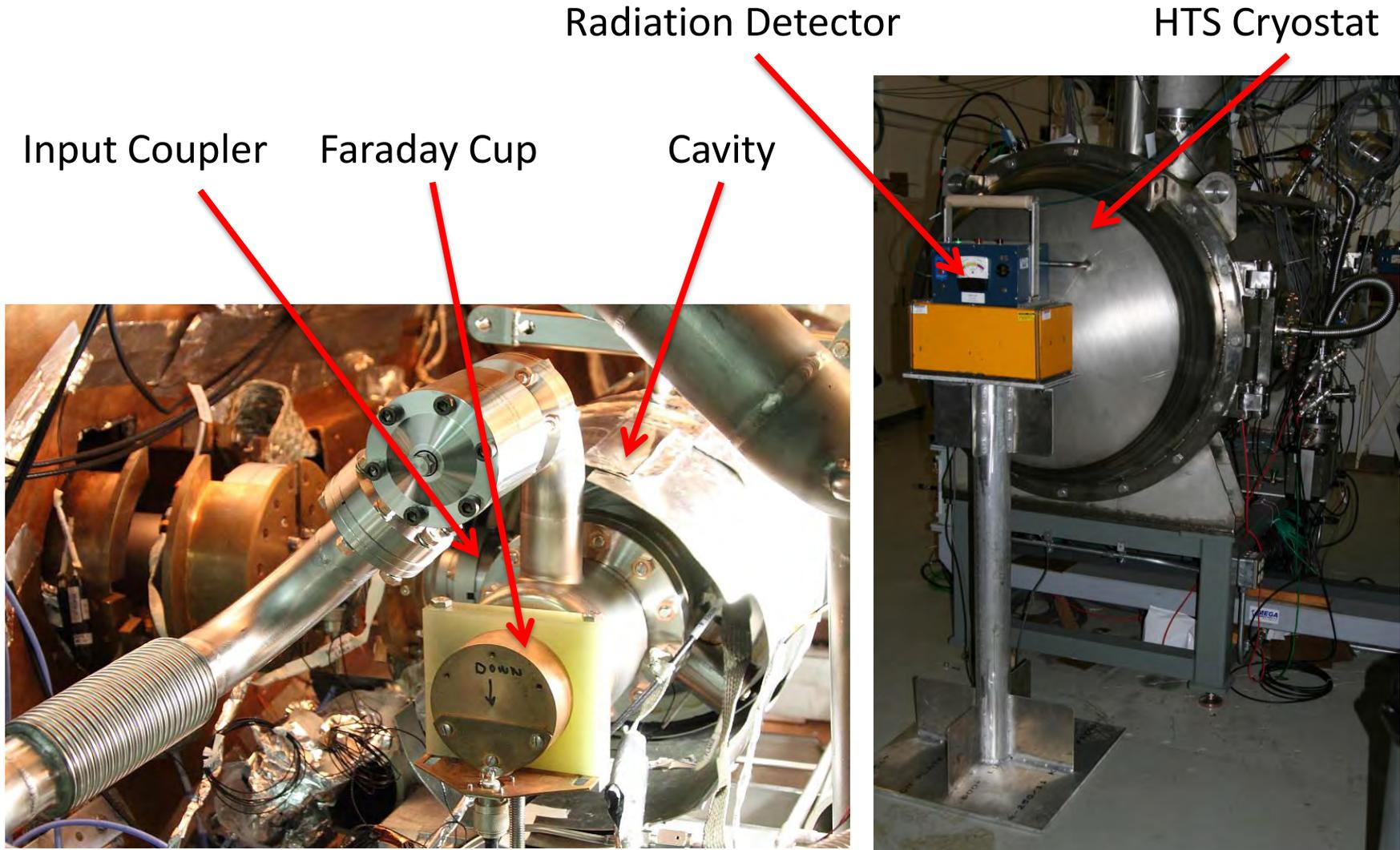


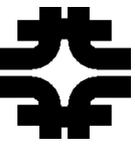
## Horizontal Test Stand (HTS)



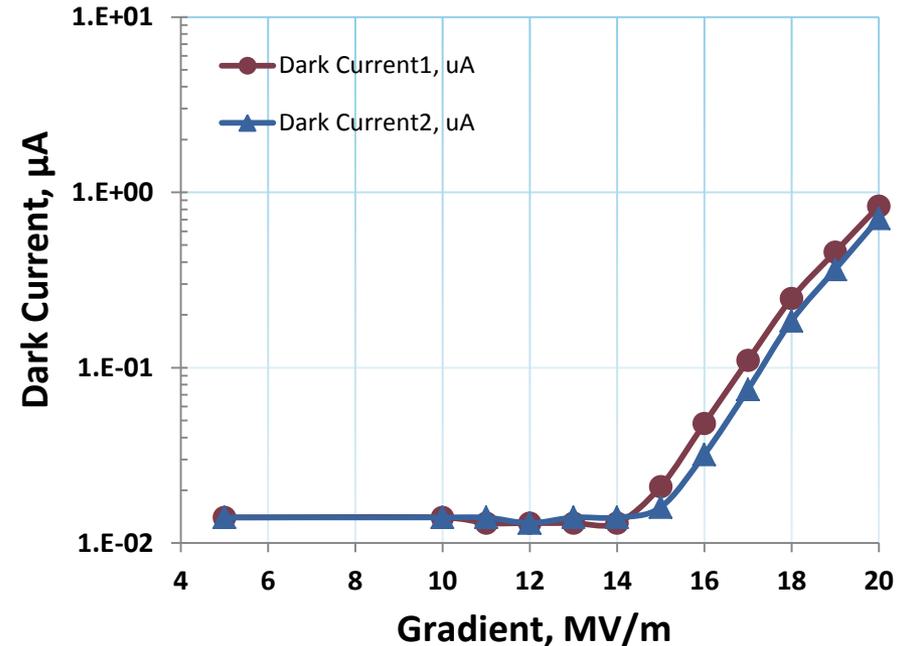
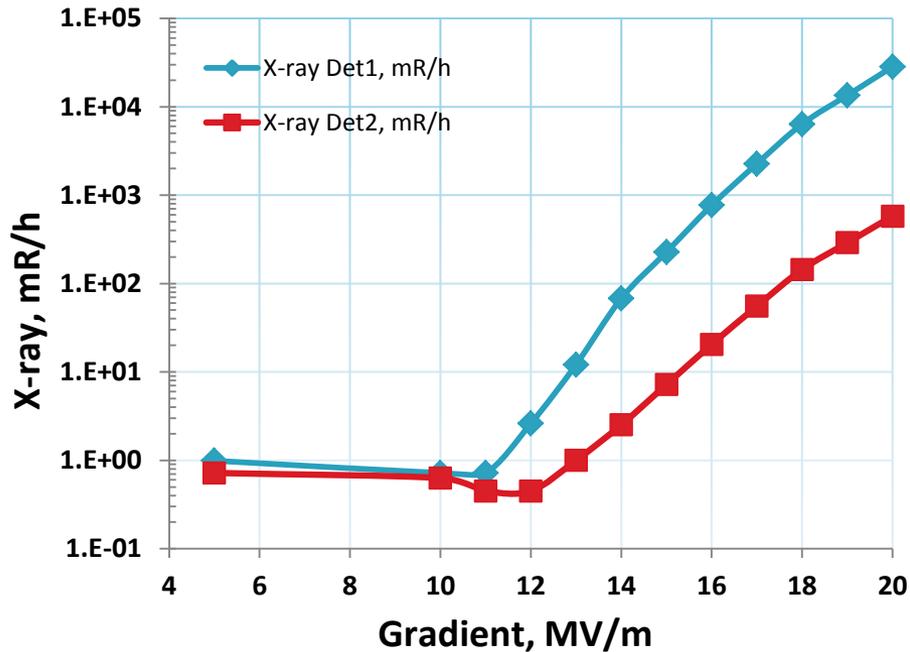


# Location Of Faraday Cups And Radiation Detectors At HTS





# HTS Measurements of TB9RI024 cavity at 20 MV/m gradient



Very high field emission, emitter locations are not symmetrical



## Summary:

- The simulation of electron trajectories was carried out at different gradients of electric field
  - That would allow to determine where to place X-ray detectors
  - That would allow to analyze results from cavity test stands
- Cavity was tested at VTS and HTS and showed a lot of field emission
- The impact of field emission on cavity performance was investigated

## Future Work:

Continue to participate in measurements and evaluation of cavity performance at HTS focusing on FE effects (X-ray and dark current measured by Faraday cups)

## Acknowledgements:

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