Design Concepts for Magnetic Insulation

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NFMCC Meeting – LBL

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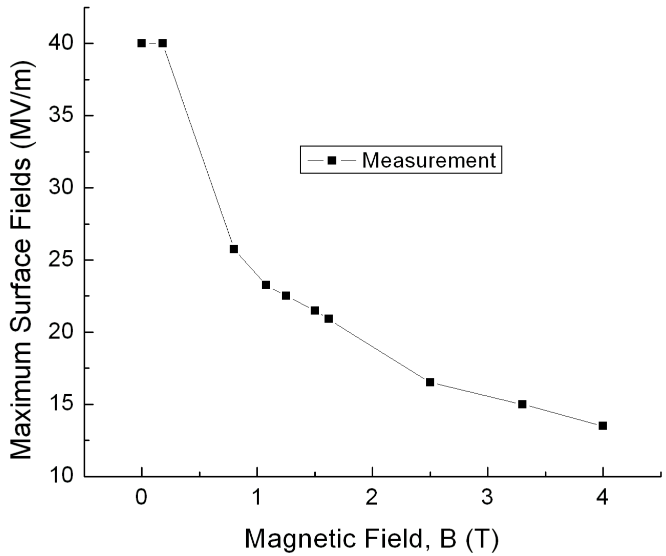
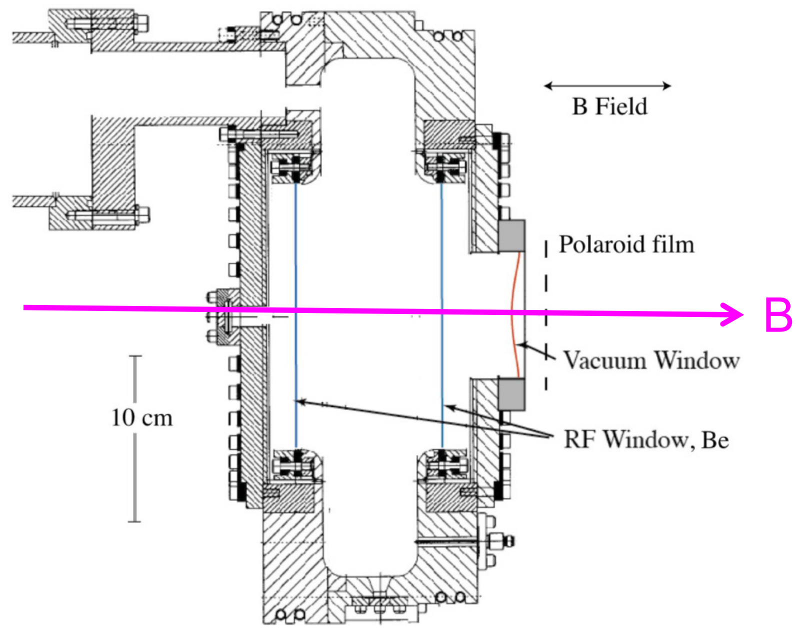
Outline

- Motivation
- Discussion I: Why magnetic insulation is needed
- Discussion II: Some things we need to know before start designing.
- Discussion III: Illustrate a design of a magnetically insulated cavity. Show simulation results regarding the efficiency of such cavity
- Show a proof-of-principle experiment to demonstrate magnetic insulation
- Summary

Motivation



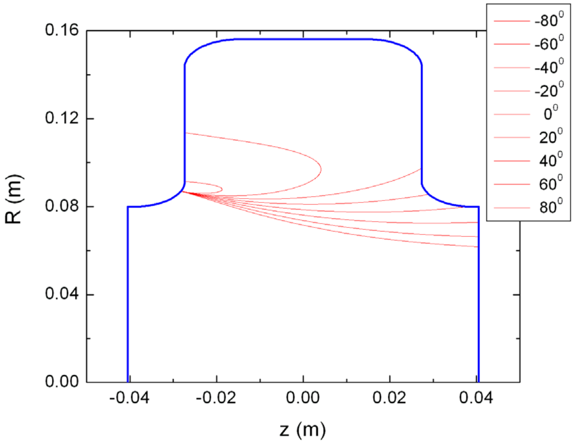
Moretti et al. PRST - AB (2005)



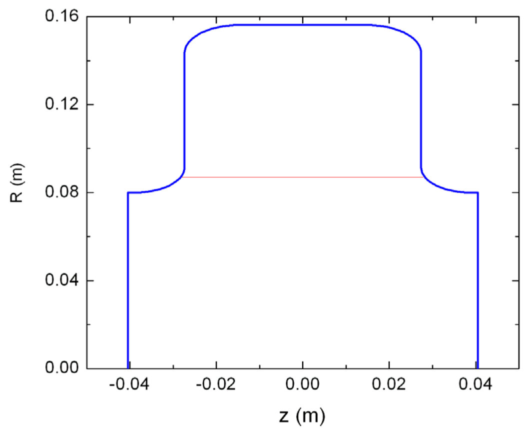
805 MHz

- Maximum gradients were found to depend strongly on the external magnetic field
- Consequently the efficiency of the RF cavity is reduced
- A cavity design is needed that prevents effects of magnetic fields. Most importantly, a proof-of-principle is needed to verify its efficiency!

Electron Tracking under External Fields (1)



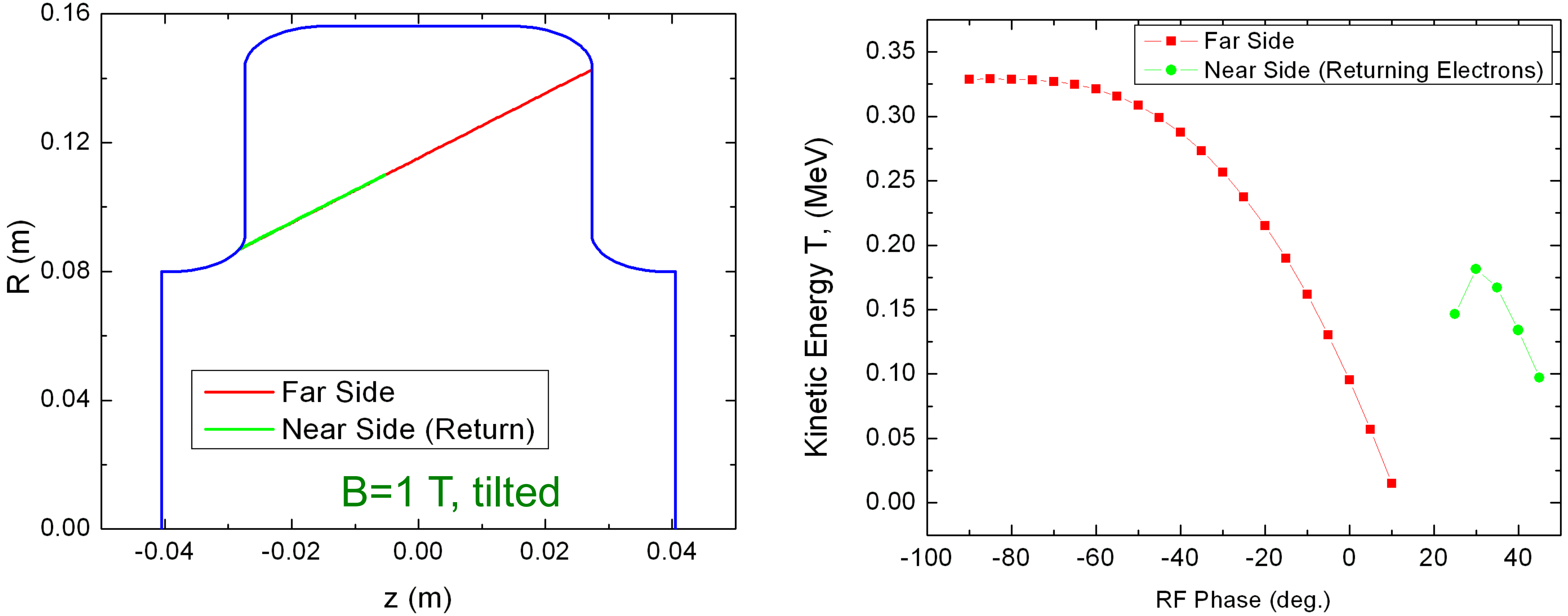
B=0 T



B=1 T

- Electron is emitted from the location of maximum field enhancement (the cavity iris) and tracked at various RF phases.
- In the presence of magnetic fields they get focused to a particular point
- Impact the cavity wall with large energies. Can create damage that may lead to breakdown.

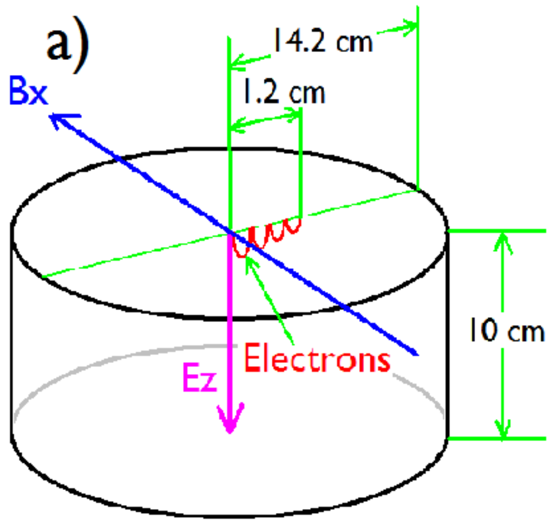
Electron Tracking under External Fields (2)



- Note the second peak in energy (green color)
- Returning electrons can also damage the material
- Having MeV range electrons "hitting" both sides is not good - A solution is needed. New cavity design?

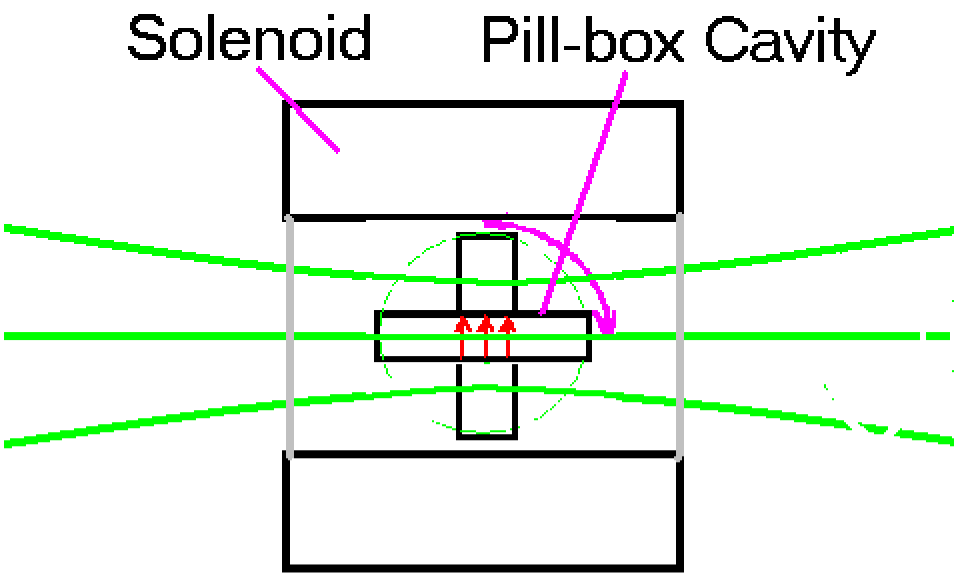
Concept of Magnetic Insulation

- Simulations suggest that when the magnetic field is parallel to the surface that is exposed to RF gradients, emitted electrons do not move far from surface but instead come back with low energies.



Possible Experiments: Square Pill-box Cavity

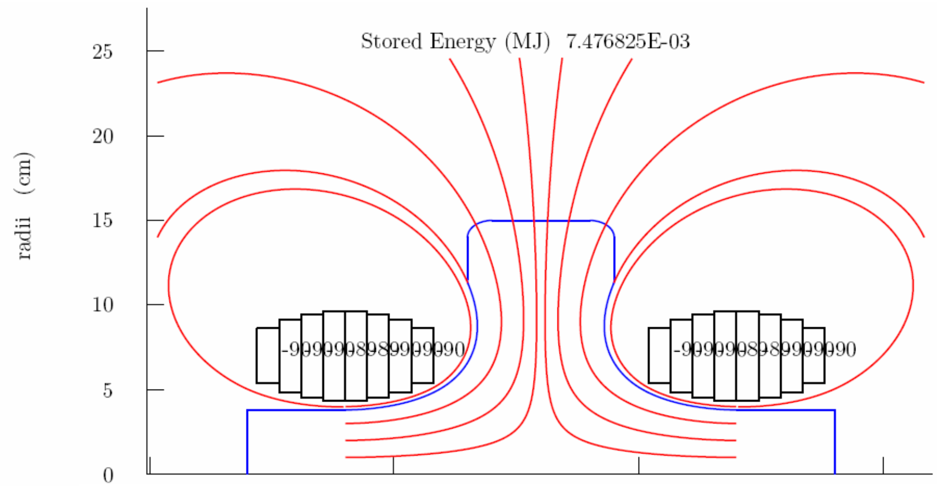
- Simple Square Pill box cavity



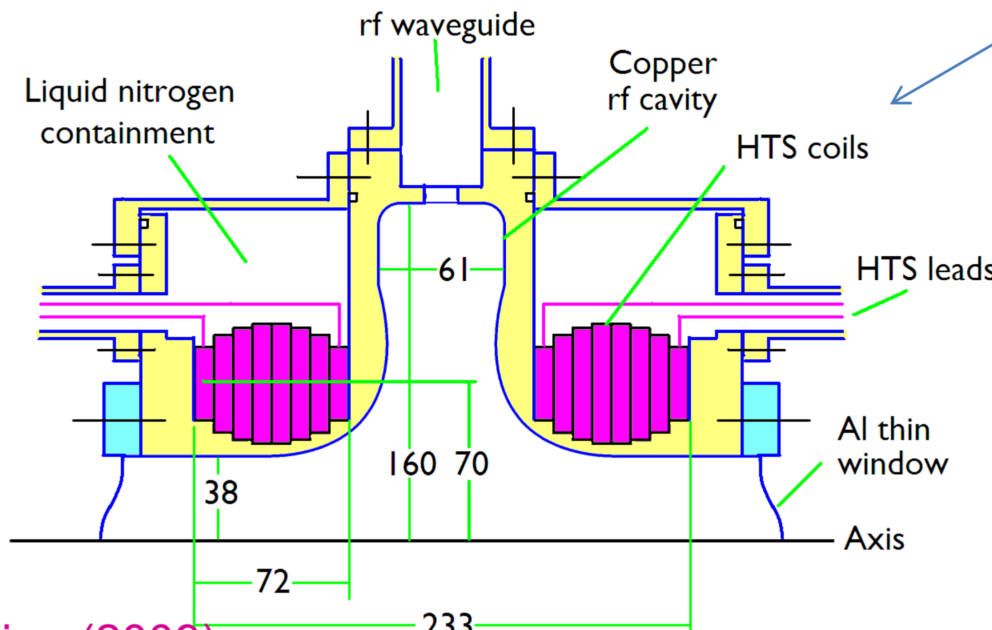
Moretti, MCTF Meeting (2008)
Morretti, NFMCC Meeting (2009)

Possible Experiments: Mag. Insulated Cavity

Simplified Configuration



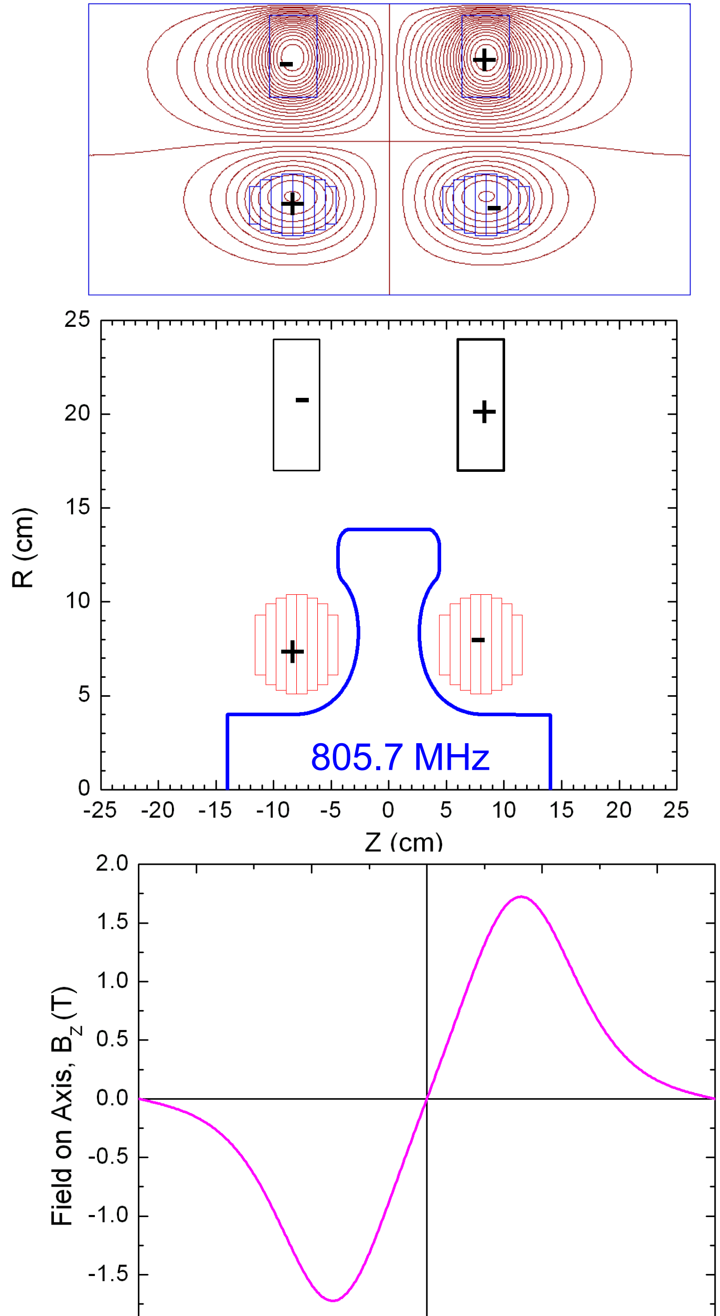
Experimental Configuration



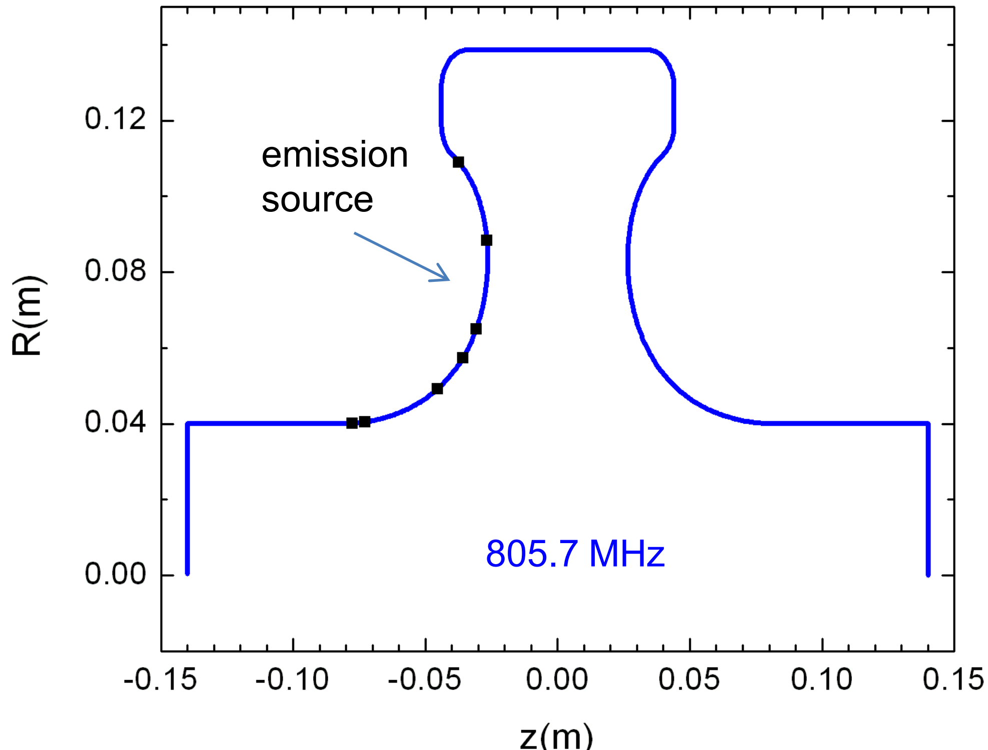
2-3 T

Palmer, NFMCC Meeting (2009)

Magnetic Insulation for 805MHz Cavity

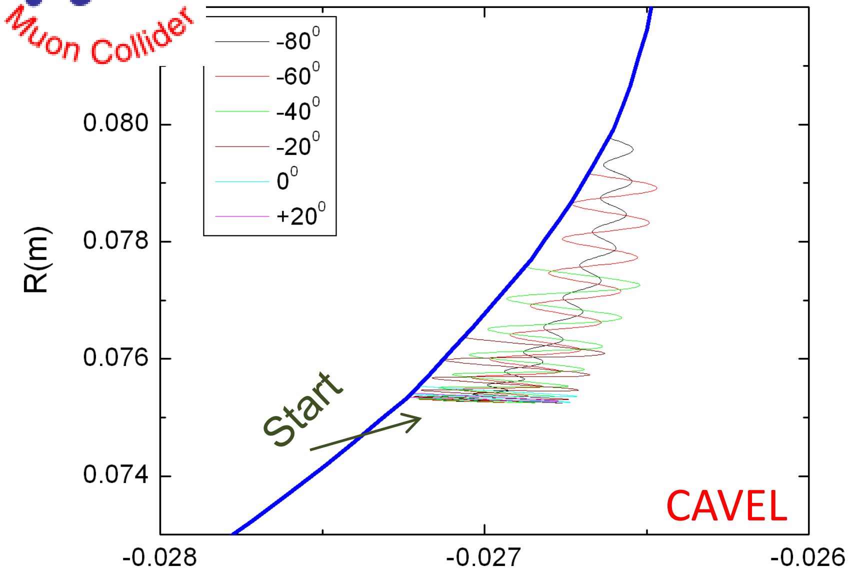


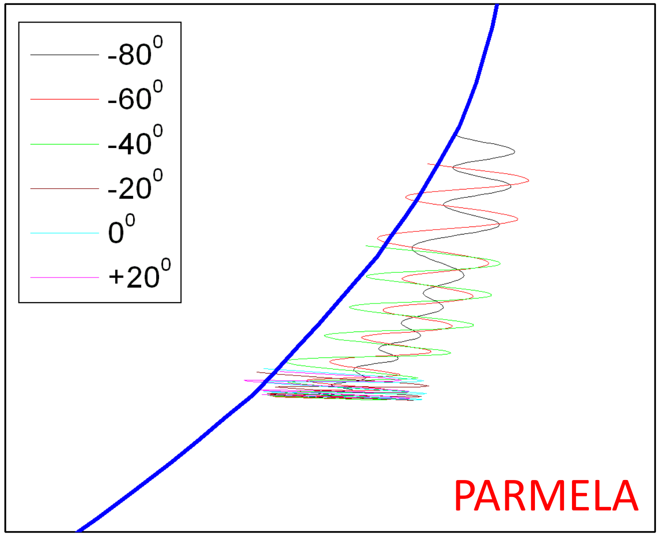
Tracking of field emitted electrons (1)

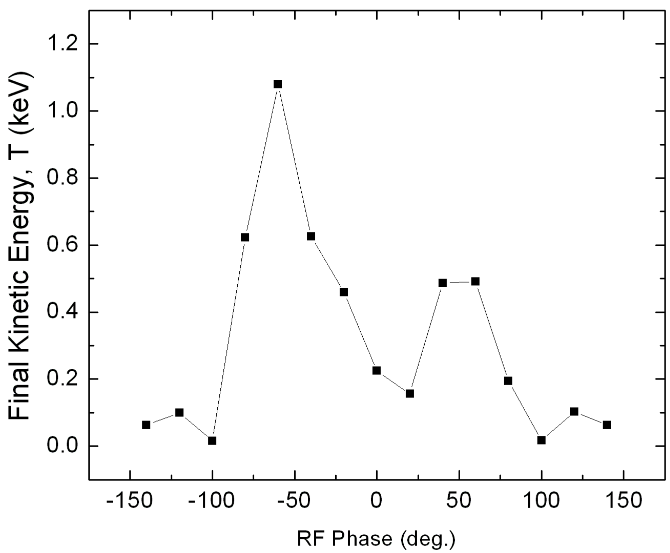


- Electrons are emitted normal to the surface at various locations and different RF phases
- Initial electron energy is 1 eV
- Maximum axial Field is 17 MV/m

Tracking of field emitted electrons (2)

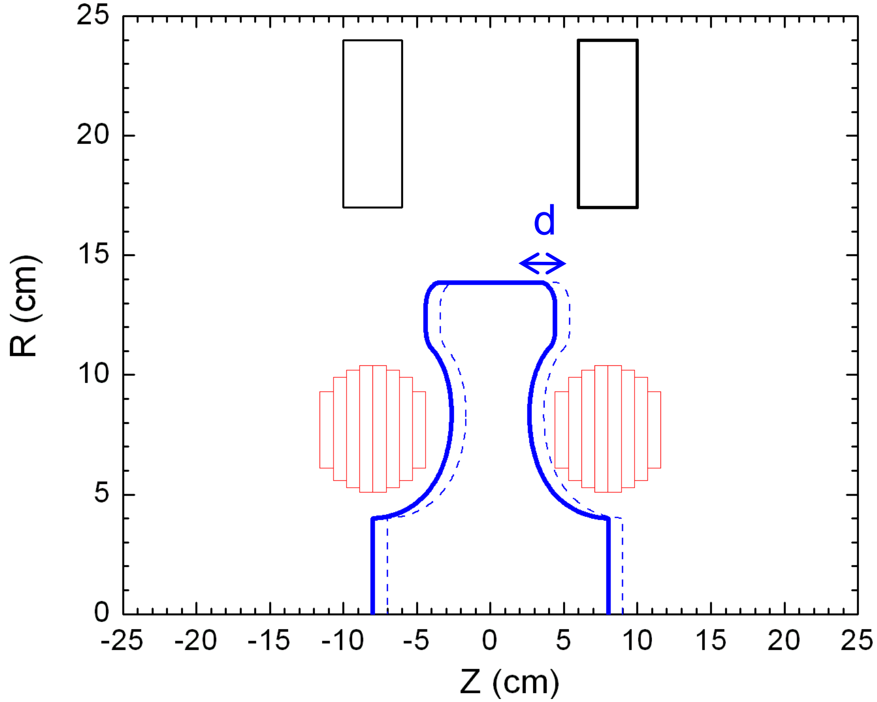


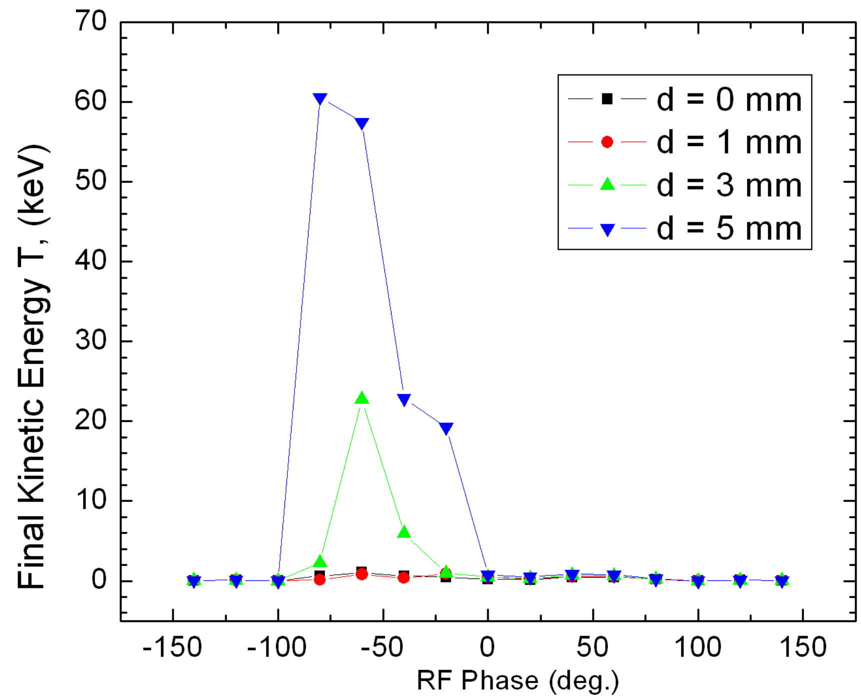




- All particles return to surface
- The final energies are very low
- Secondary electrons were not tracked (to be done)

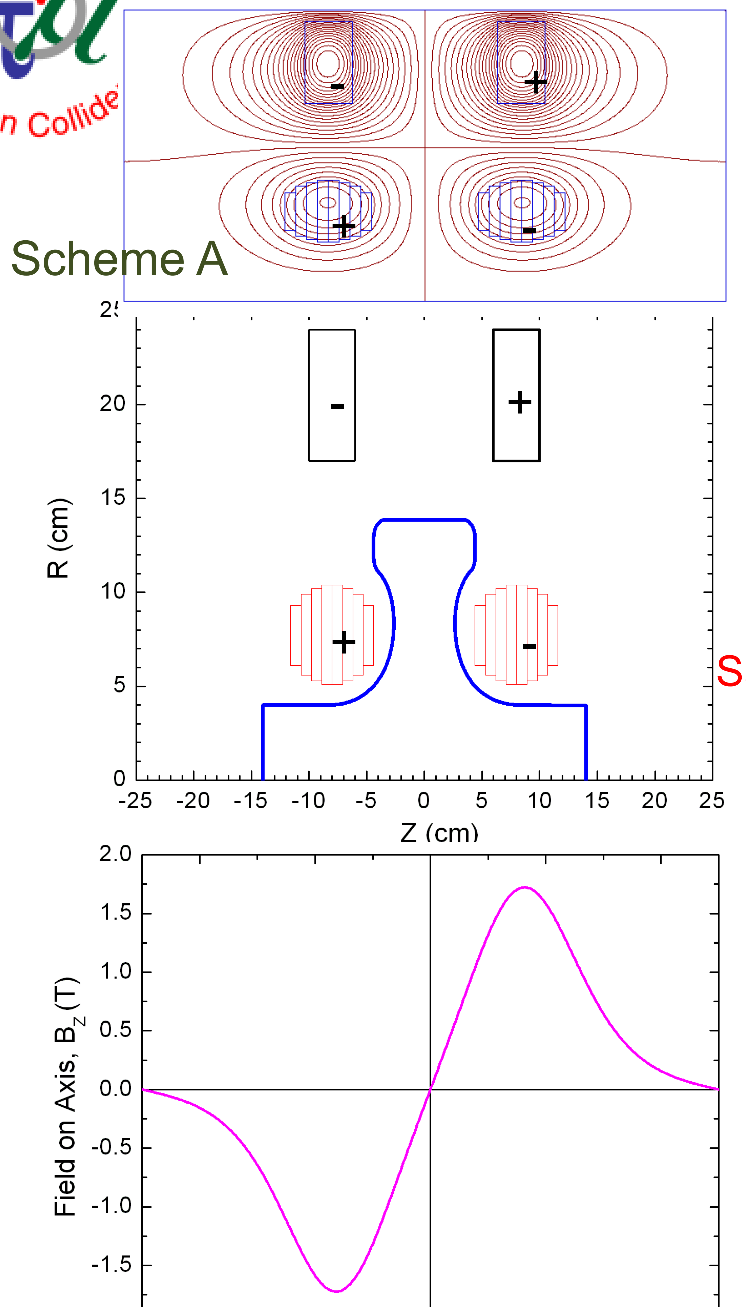
Test of Cavity Tolerances



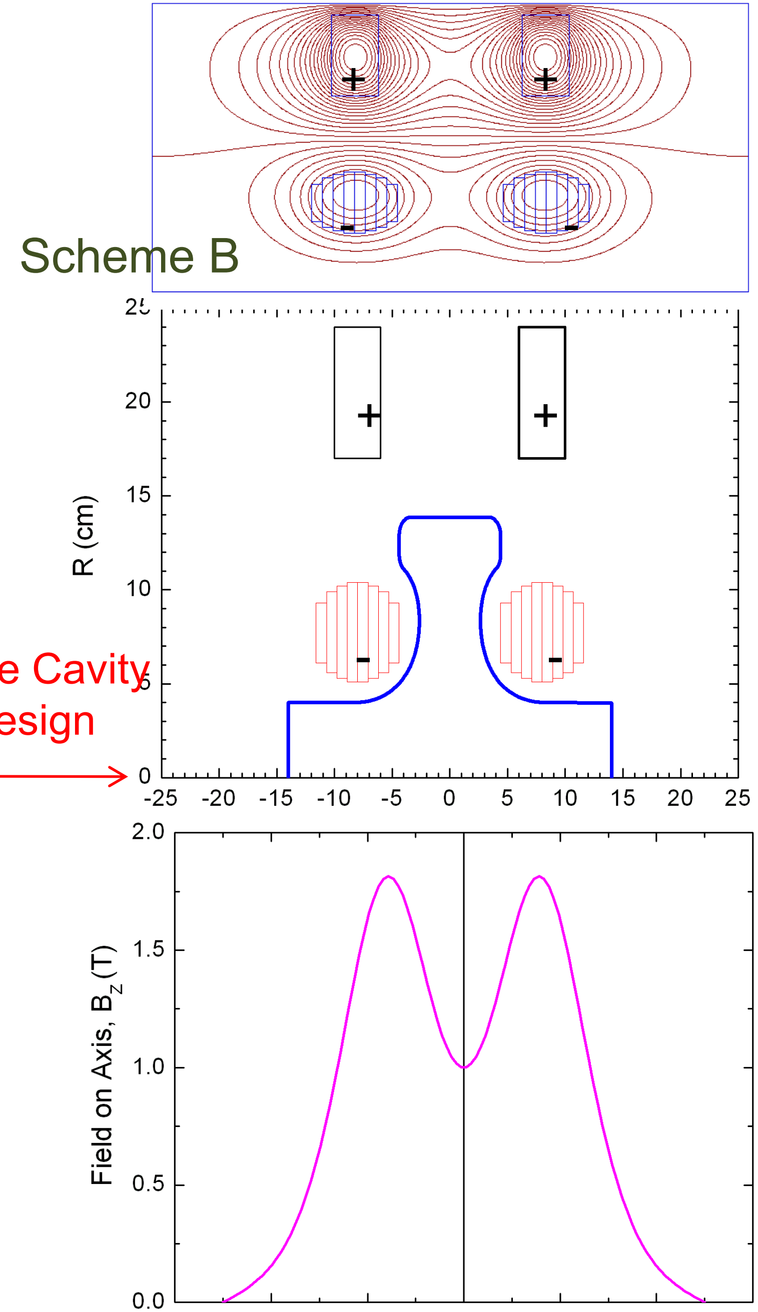


- A cavity displacement greater than 3 mm reduces the efficiency of insulation

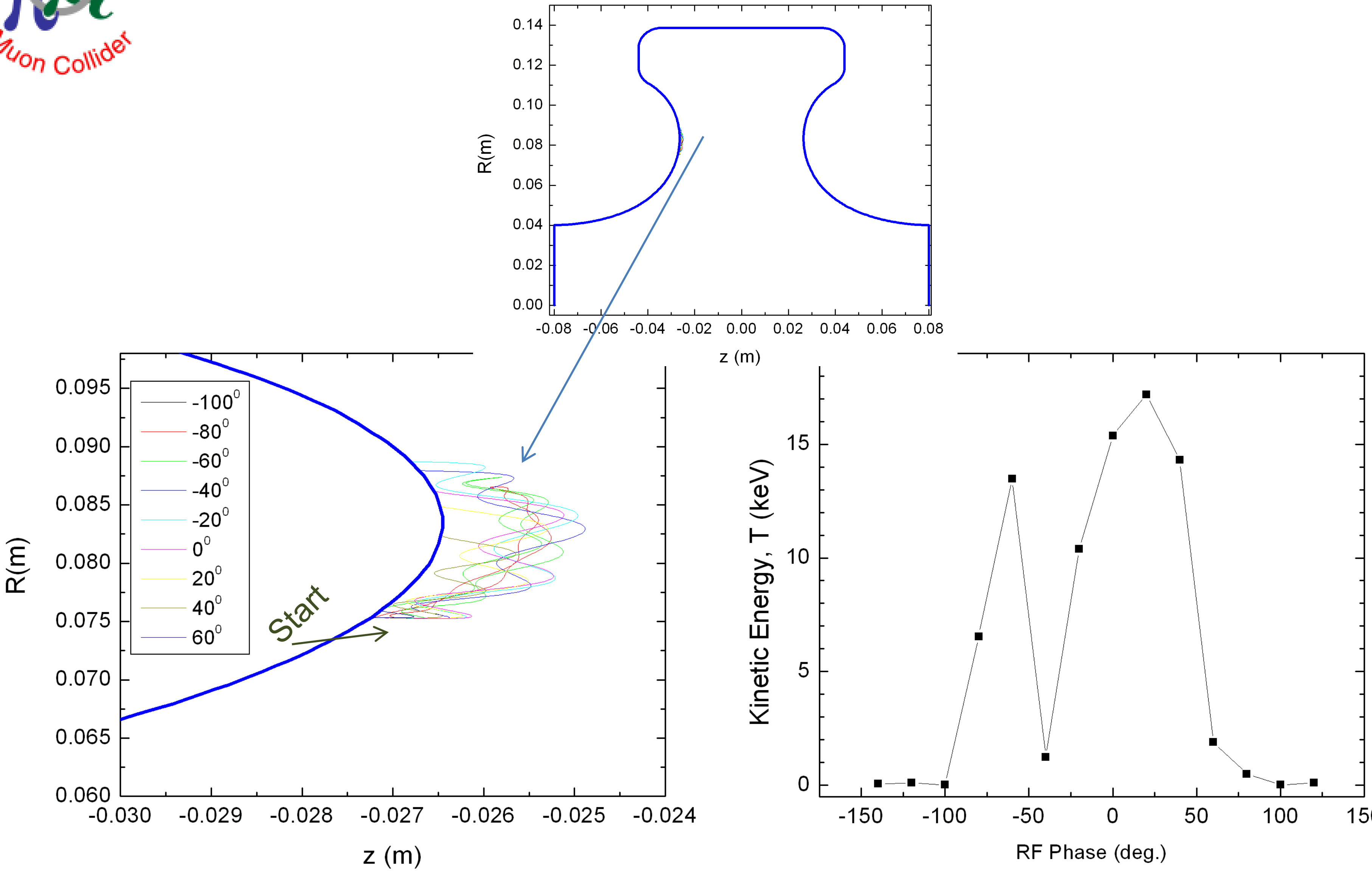
Magnetic Insulation for 805MHz Cavity



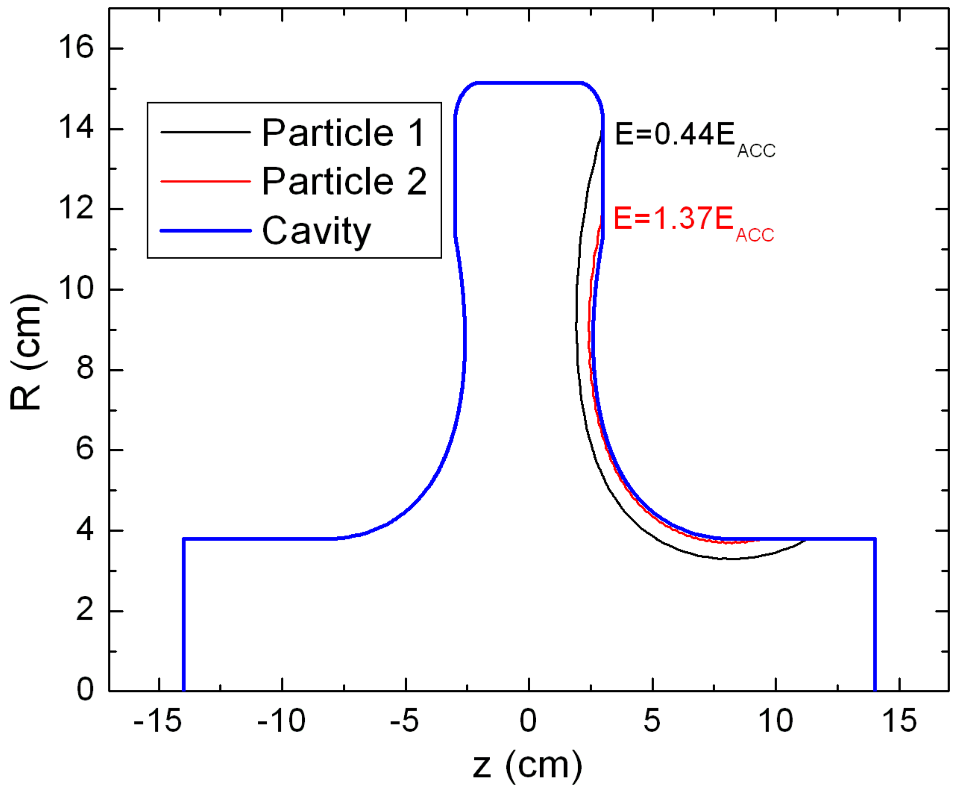
Same Cavity Design



Electron Tracking for Scheme B



Problems with Flat Cavity Regions

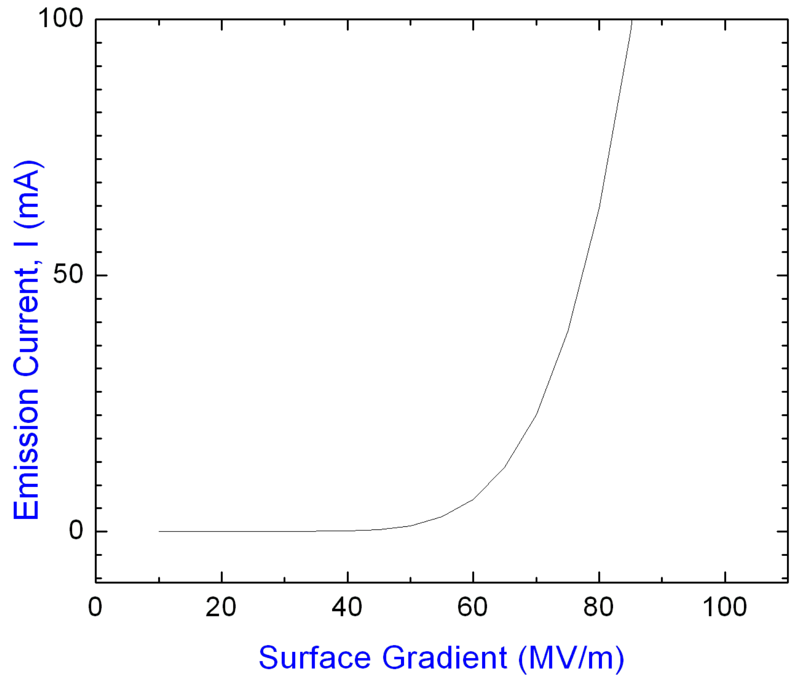


Final energies:
Particle 1: 570keV
Particle 2: 125 kev

- A typical 17 MV/m acceleration gradient provides large surface fields even at the flat regions ($E_{Surf} \geq 10\text{MV/m}$)
- This suggests that the flat regions have to be removed

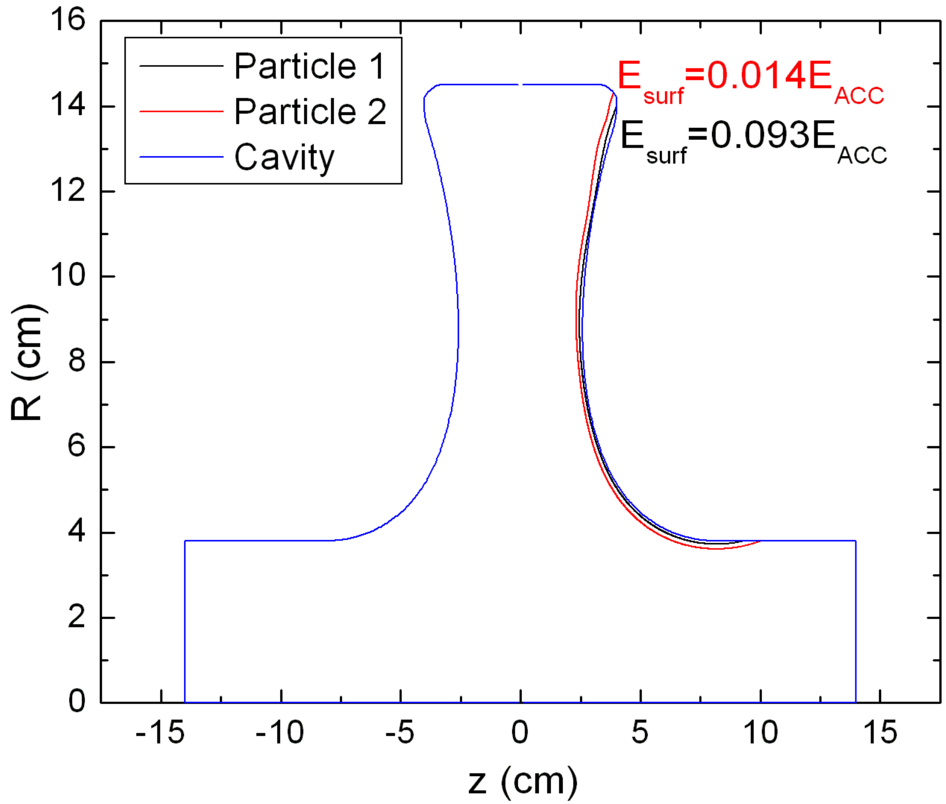
Electron Emission

- Norem's experiment (PRST-AB 2003):
  - Average asperities have enhanced local fields: $E_{Local} = 184 \times E_{Surf}$
  - Then, current scale as: $I = \left(184 \times E_{Surf}\right)^n$



- If $E_{Surf} \leq 10\ MV/m$ then: $I \leq 10^{-15}\,\mathrm{mA}$
- Reasonable to assume that gradients below 10 MV/m are not enough to create potential damage

A Better Cavity Without Flat Ends



- Even though still particles can move far from the surface the surface gradient are low.
- Even for a 100 MV/m the surface field is not enough to supply sufficient emission current

Conclusions

- External magnetic fields affect the operation of the “traditional” pill-box 805 MHz cavities.
- A design for magnetic insulation for the 805 MHz cavity was illustrated. All points with surface fields > 10 MV/m were “insulated” . No fear of large emitting currents.
- Emitted electrons return to surface with very low energies.
- An experiment for demonstrating the principle was discussed
- Further investigation for reducing the cost and increasing the efficiency of this cavity will be pursued.