# Magnetic Insulation

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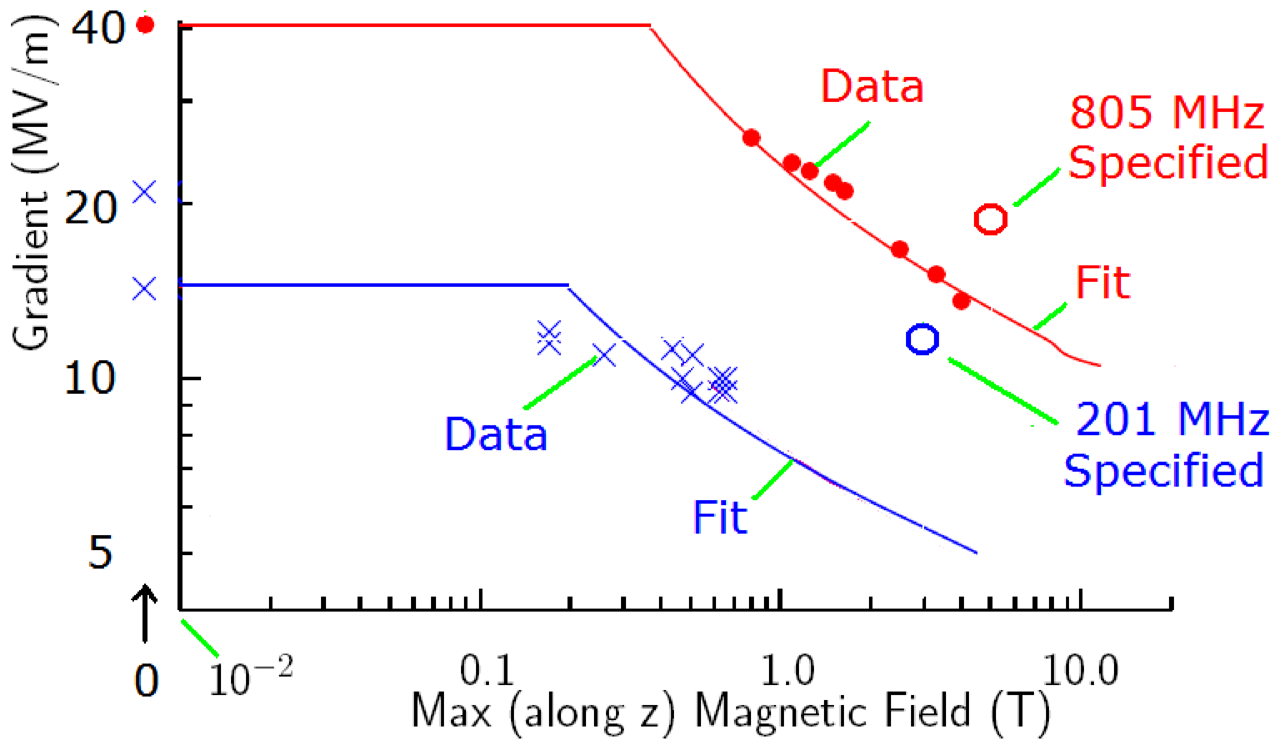
MCTF 1/15/09

- Cavel results on simple insulation experiment
- Superfish results on simple cavity efficiency
- Attempt to improve efficiency with bucking coils

# rf Breakdown problem

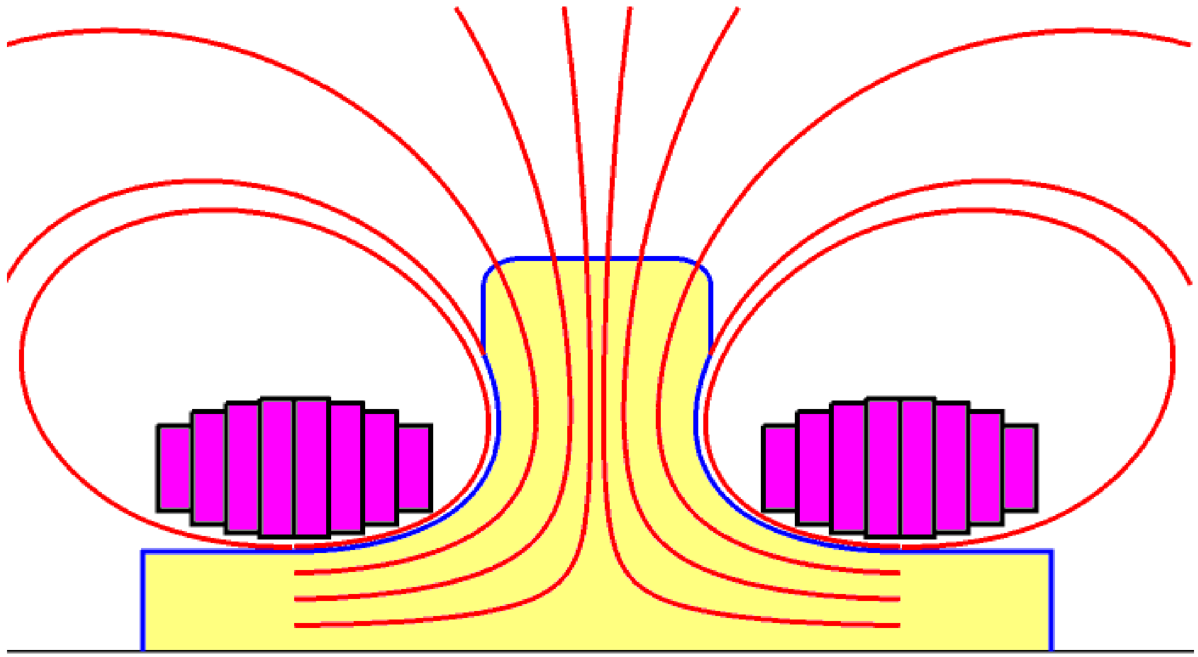
- Current design will not work
- High pressure gas HCC may work
  - Effect of beam unknown
  - Integration of rf still a problem




- Bucking the field at rf should work
  - But losses appear to be a problem (see talk at JLab)
- Magnetic insulation should work
  - Losses do not seem to be a problem (see talk at JLab)

# Magnetic Insulation   Simple Demonstration Cavity

Form cavity surface to follow magnetic field lines



- All tracks return to the surface
- Energies are very low
- No dark current, No X-Rays !
- No danger of melting surfaces
- But secondary emission → problems ?  Grateful to SLAC for help
- Need to study Cavity 'efficiency'

# Criteria for magnetic insulation

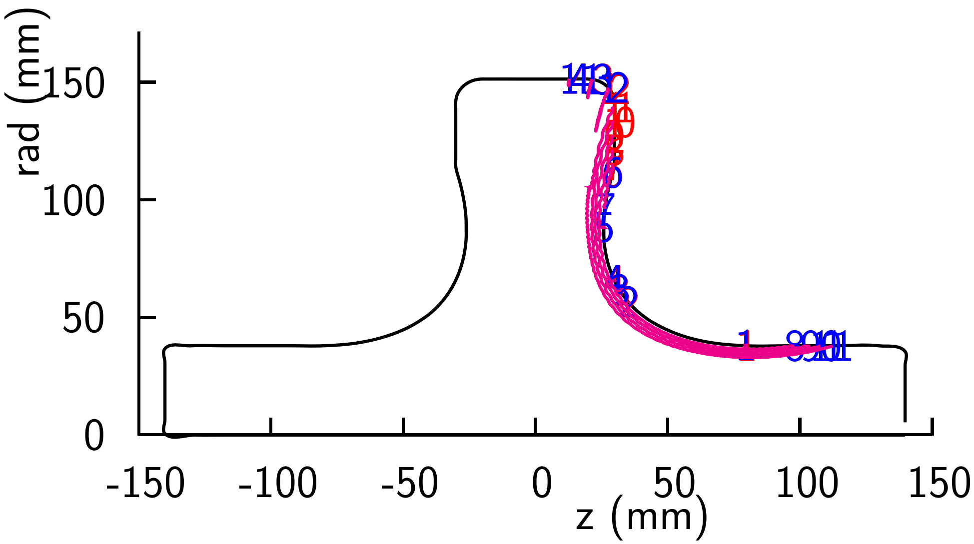
There should be no electron trajectory that

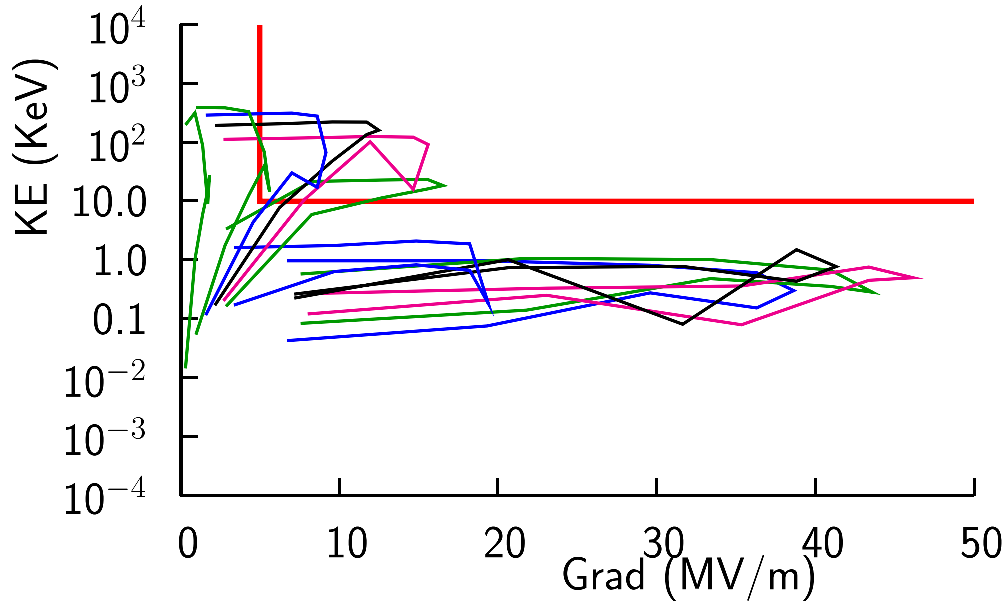
1. starts with a surface field $> 5$ MV/m
   - At lower gradients there will be little emission
2. ends on a surface with kinetic energy $> 10$ keV
   - at lower energies they can do little damage

Search over different start locations and starting phases (-80→80 deg)

# First Exp Design

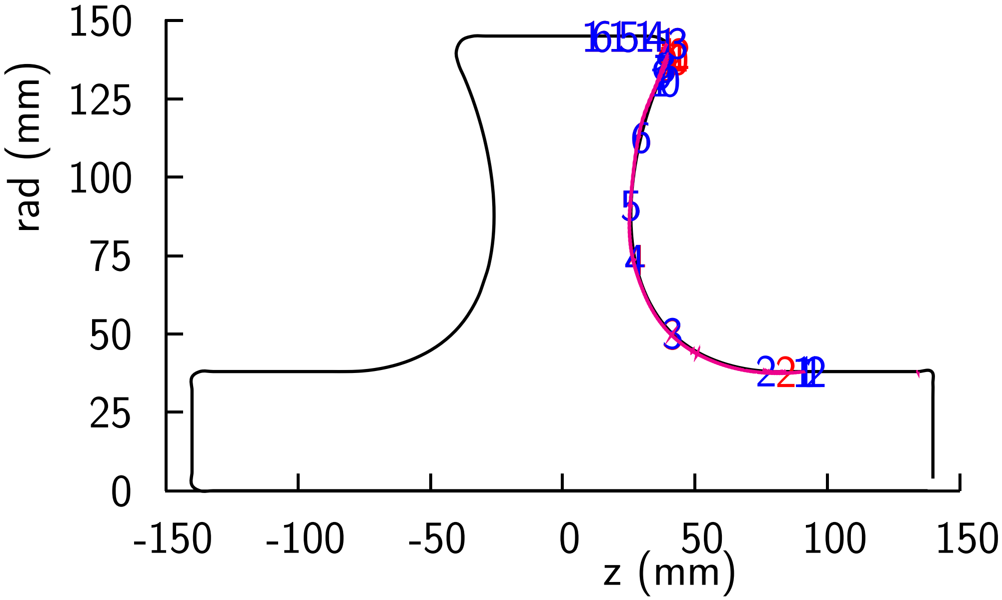
Plot final Energy vs initial gradient

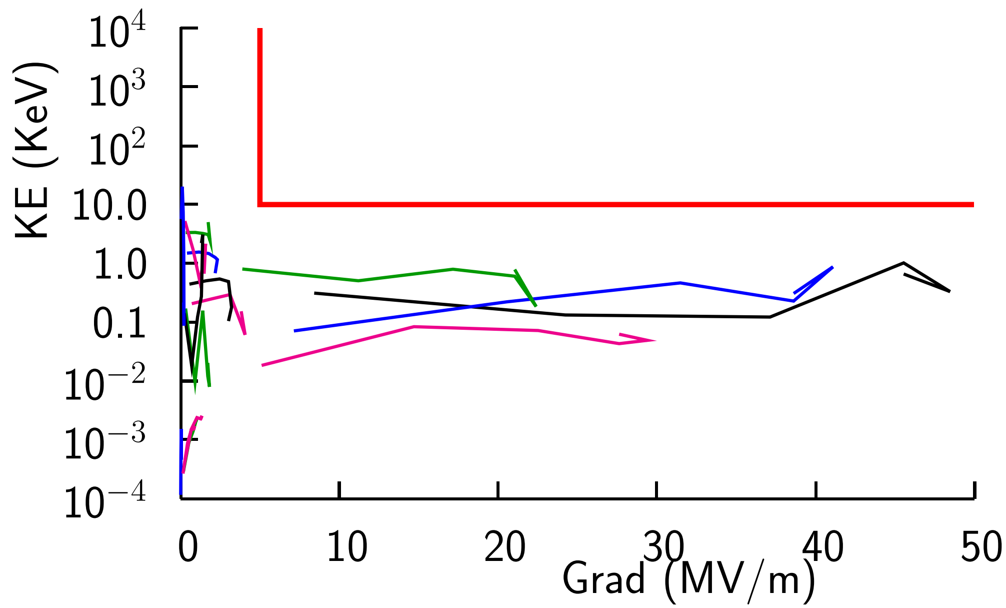



- Electrons emitted from the flat regions at large r
- Have too high a surface field ($\approx$ 16 MV/m >> 5 MV/m)
- And gain significant energies ($\approx$ 300 keV = worst possible)

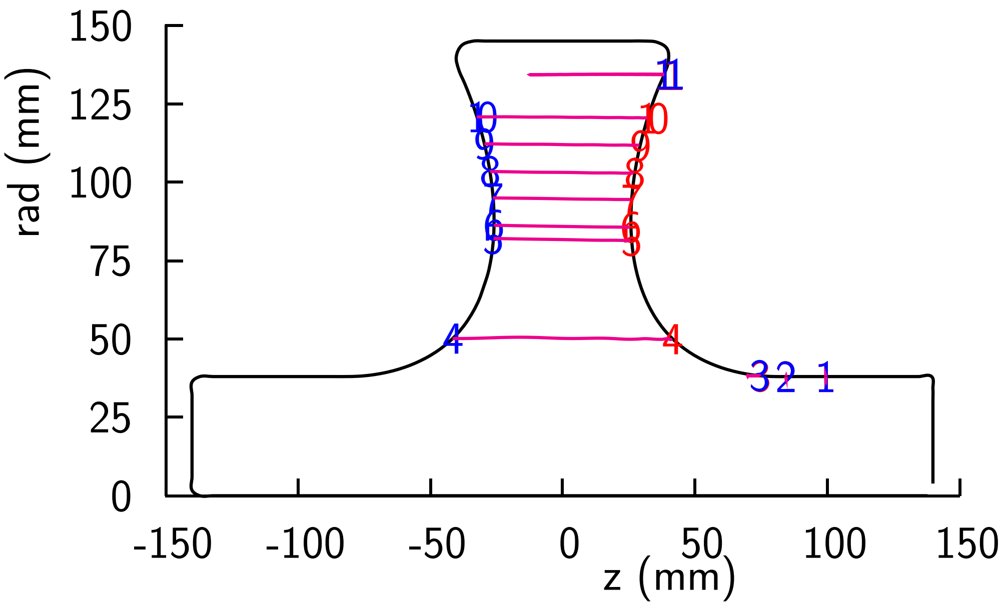
# New design with no flat region

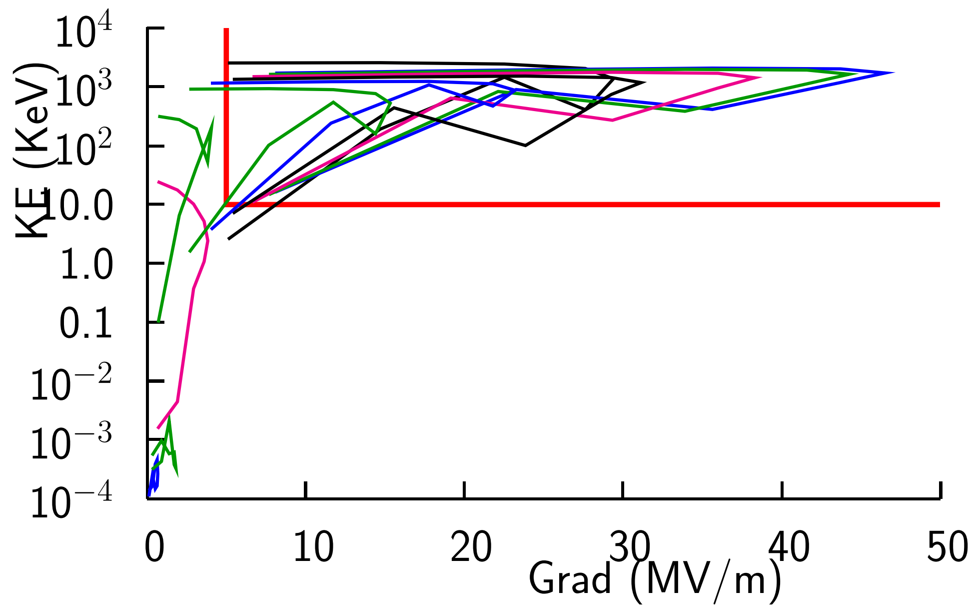



- Tracks now closer to surfaces
- No track with $\mathcal{E} > 5$ MV/m has final energy $>$ 10 keV with plenty to spare
- Meets our requirements

# Compare with axial magnetic field

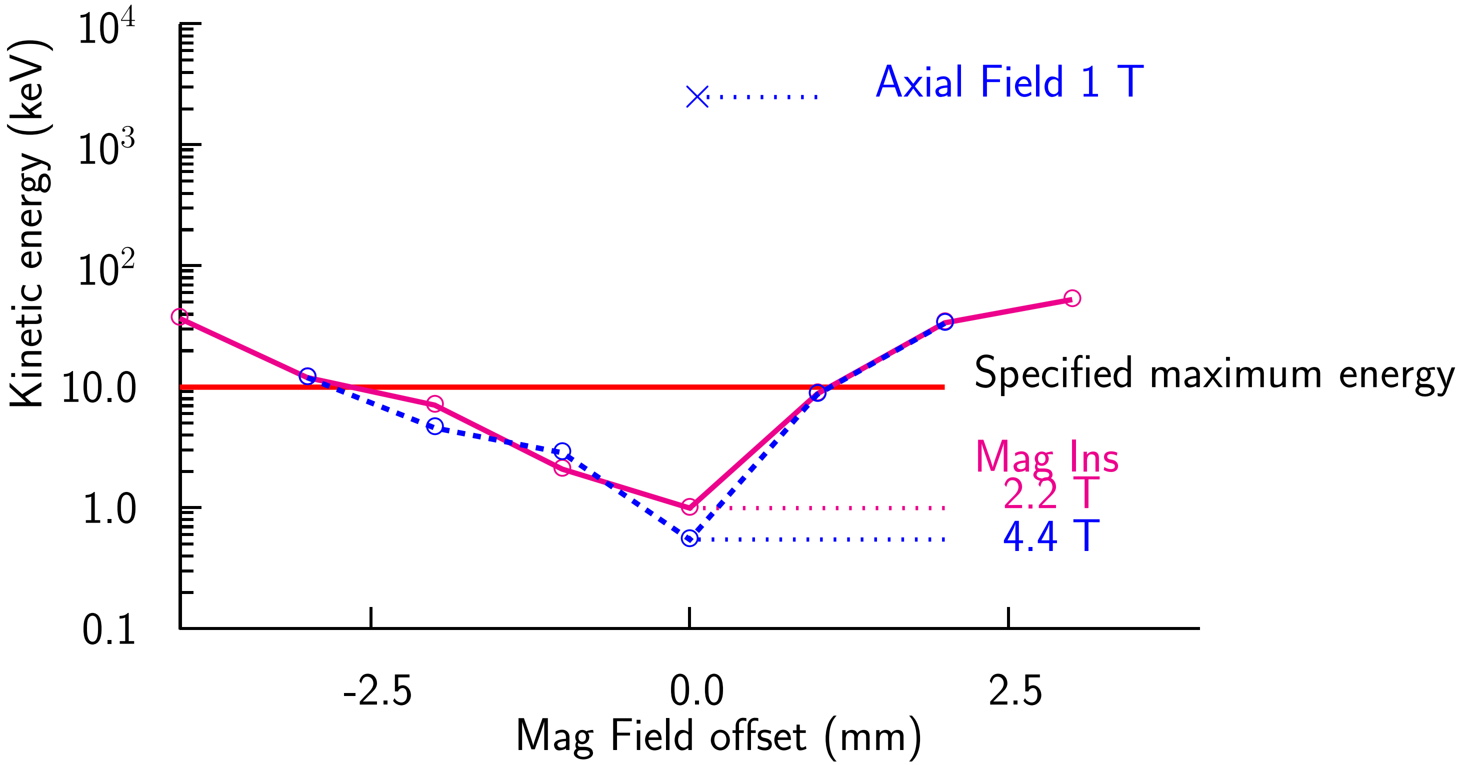



- Tracks go straight across
- Most tracks with $\mathcal{E} > 5$ MV/m have final energy $>$ 10 keV & maximum energy of 2.5 MeV
- Not good

# Sensitivity to errors

For tracks starting with $\mathcal{E} > 5$ MV/m :
plot maximum final energies vs. z displacement of magnetic fields

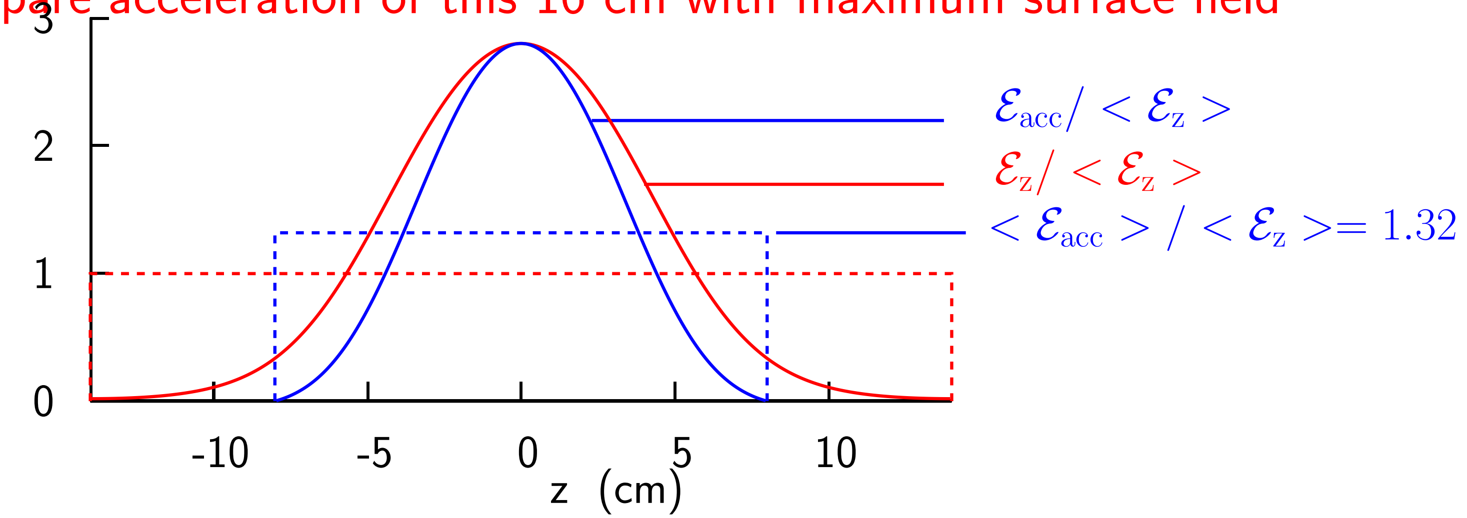



- Meets requirements for axial displacements up to $\pm$ 1 mm
- Little effect of doubling the strength of the magnetic fields
- Energies down by $>$ 2 orders of magnitude from axial field case

# Accelerating gradient

Superfish defines fields relative to the average axial field along z (over the 28 cm length). Continuous acceleration would employ multiple cavities whose length (16 cm) would equal the distance corresponding to a $\pi$ phase advance for a muon with $\beta_v = 0.85$

We will compare acceleration of this 16 cm with maximum surface field

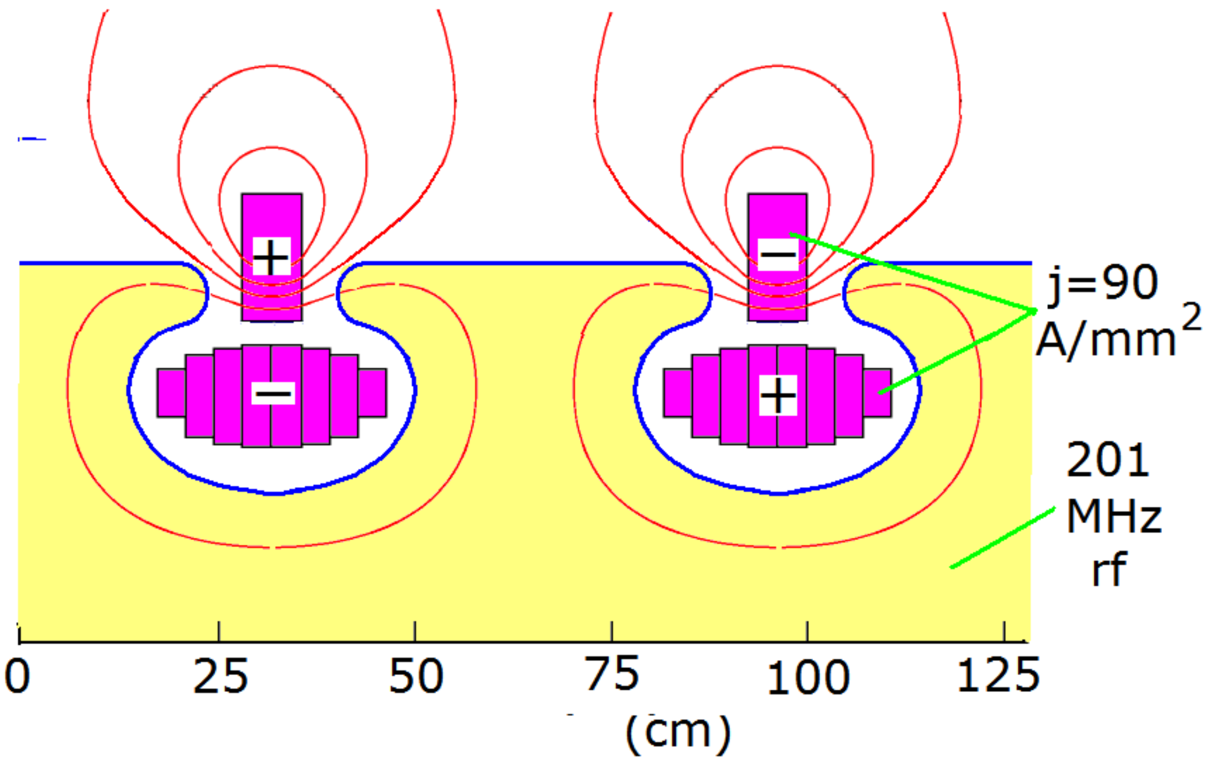



| | | | cf pill |
|---|---|---|---|
| max surface field / max axial field | $\hat{\mathcal{E}}_{surface} / \hat{\mathcal{E}}_z$ | 4.0/2.8= 1.42 | ($\approx$ 1.0) |
| max surface field /ave acc in 16 cm | $\hat{\mathcal{E}}_{surface} / < \mathcal{E}_{\rm acc} >$ | 4.0/1.32= 3.0 | ($\approx$ 1.3) |

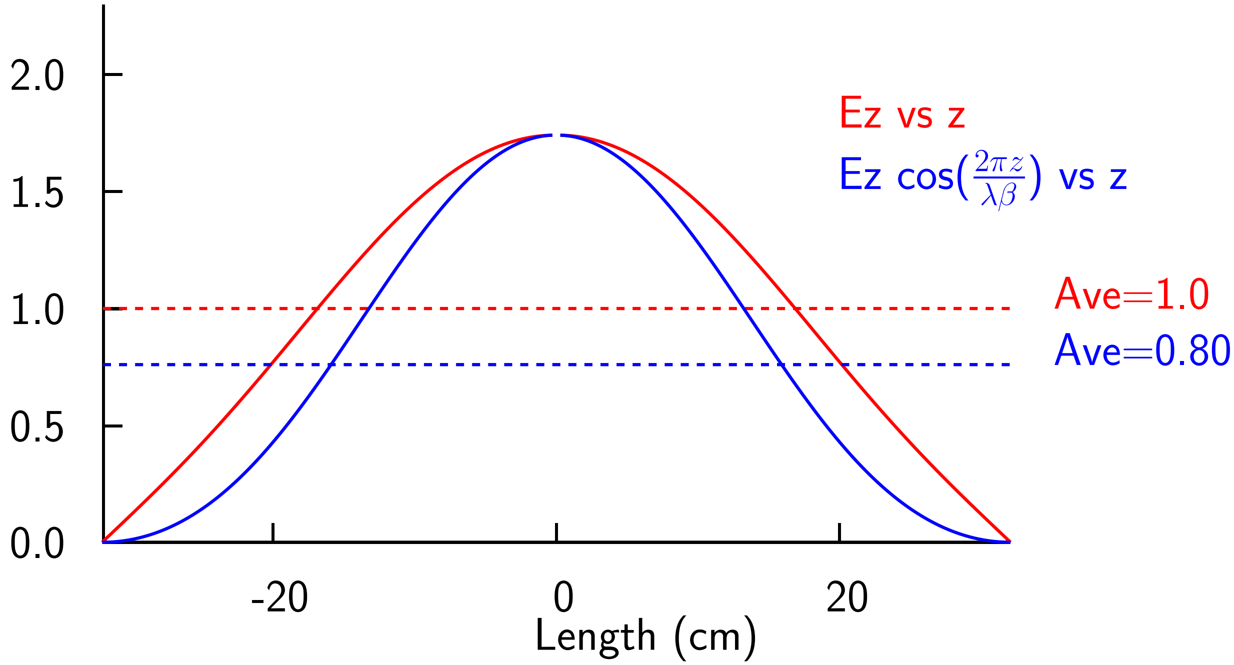
This last ratio ($< \mathcal{E}_{\rm acc} > / < \mathcal{E}_{\rm z} >= 3.0$) is worse than normal cavities for which the value is typically near 2.0. This is not an "efficient" cavity

# Improved Cavity ?

- In above design, maximum surface field is at large radius
- Assume this is the problem
- Add outer bucking coil to bend field lines more strongly
- Lowers radius of maximum field



# Maximum $\mathcal{E}_{\text{surface}}$ / Acceleration




| | | | |
|---|---|---|---|
| | | | no buck |
| max surface field / max axial field | $\hat{\mathcal{E}}_{surface}/\hat{\mathcal{E}}_z$ | 2.73/1.74= 1.57 | (1.42) |
| max surface field /ave acc in 16 cm | $\hat{\mathcal{E}}_{surface}/ < \mathcal{E}_{\text{acc}} >$ | 2.73/0.80= 3.4 | (3.0) |

- This procedure made it worse
- We need to understand what would improve it

# Likely effective gradient without improvement

- If Magnetic insulation works, maximum surface field at 201 MHz ≈ 25 MV/m
- Average acceleration now 25/3= 8 MV/m

- Specified pillbox gradient = 12 MV/m
- Giving, with transit and gaps, ≈ 9.2 MV/m
- Mag ins solution is below specified, but close
- Improving ratio of acceleration to peak surface fields remains important

- At 805 MHz: surface gradient ≈ 50 MV/m
- giving average acceleration ≈ 16 MV/m
- Compared with specified 20/1.3= 15 MV/m
- meets specification

# Conclusion

- Study of simple experiment suggests magnetic insulation will suppress all problem field emitted electron
  - Emitted at surface fields $> 5$ MV/m
  - Arriving with energies $> 10$ KeV
- They remain suppressed with field displacements of up to 1 mm
- But the ratio of maximum surface field to average acceleration ($\approx 3$) is disappointing