Magnetic Insulation of RF (MIR)

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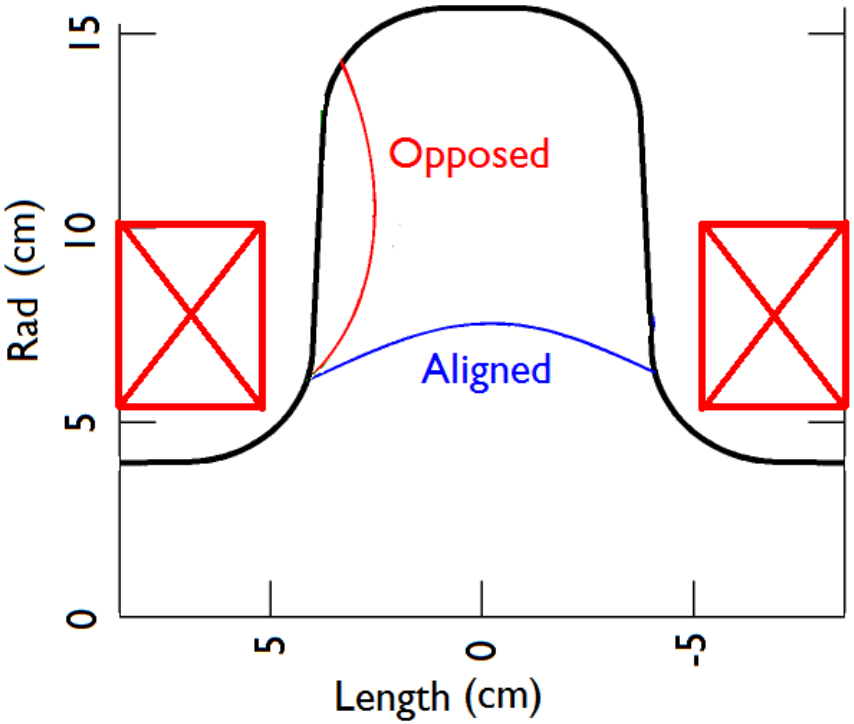
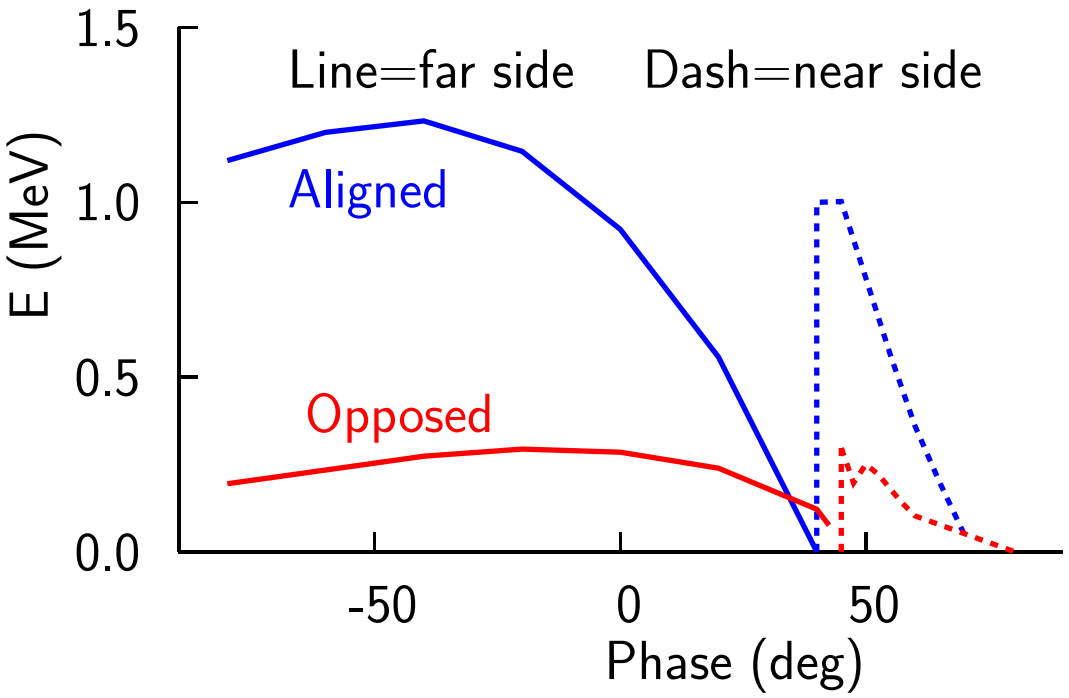
Friday Meeting

May 23, 2008

- Possible fix #1 with coils in irises
- Concept of magnetic Insulation of rf
- Simulations of simple pillbox with exact B direction
- Simulations with 1 degree miss direction of B
- Simulations of magnetically ionsulated cavity
- Experiments
- Conclusion

Fix # 1: Open 805 MHz cavity with coils in the irises



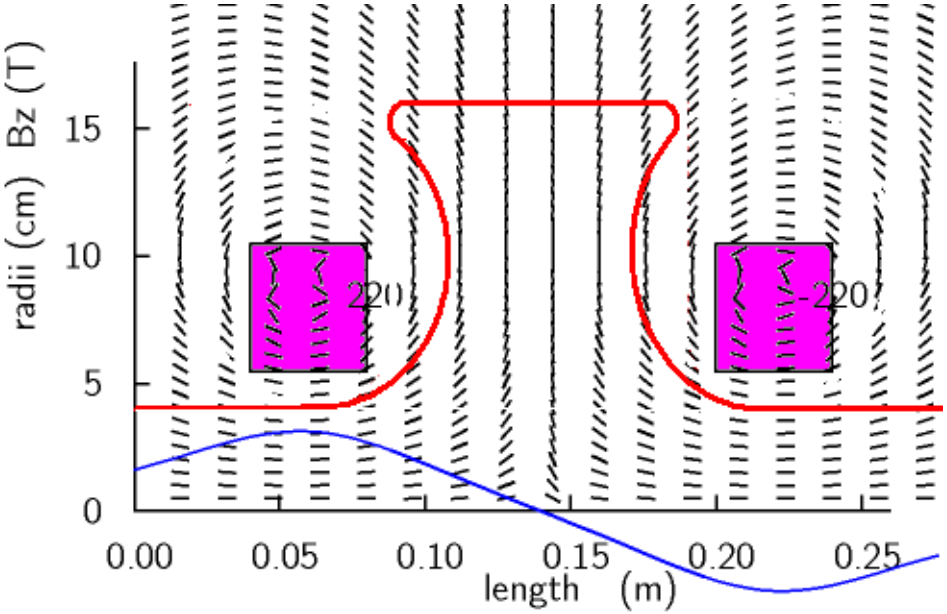


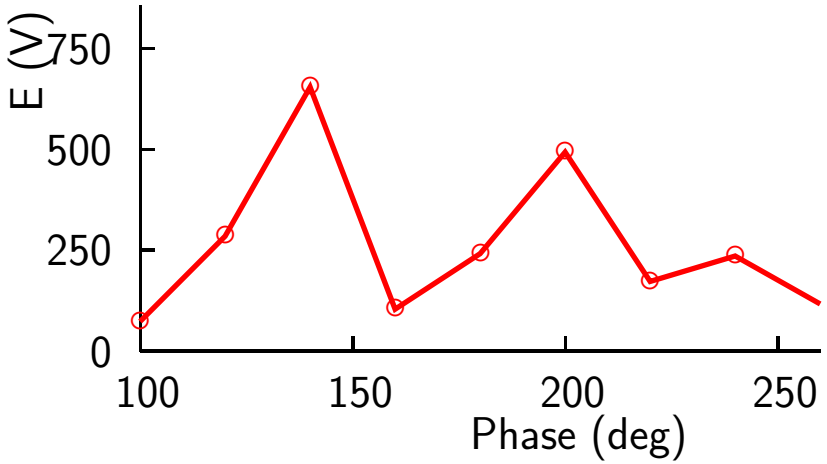
- For opposed coil currents
  - Electrons end in low field region, or
  - Return, but with low energy
  - This may, or may not, fix the problem
- Does not work for coils with same signs (see appendix 2 for fix)

The above suggests 'Magnetitic ally Insulated rf'

Concept discussed for DC or slowly changing electric fields. e.g. RV Lovelace and E Ott Physics of Fluids 17, (1974)

Form cavity surface to follow magnetic field lines

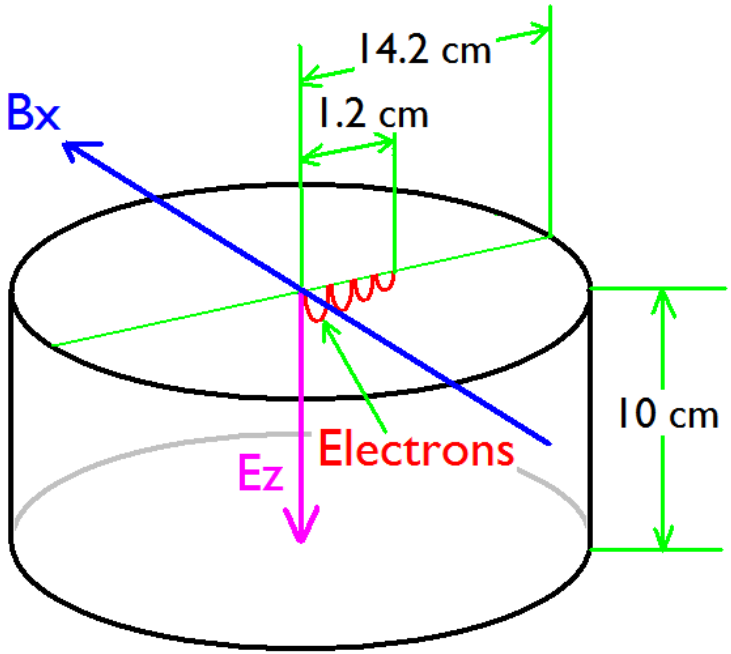




- All tracks return to the surface, but
- Energies are very low
- No dark current, No X-Rays, no danger of melting surfaces
- Again does not work for same sign coils (see appendix 3 for fix)

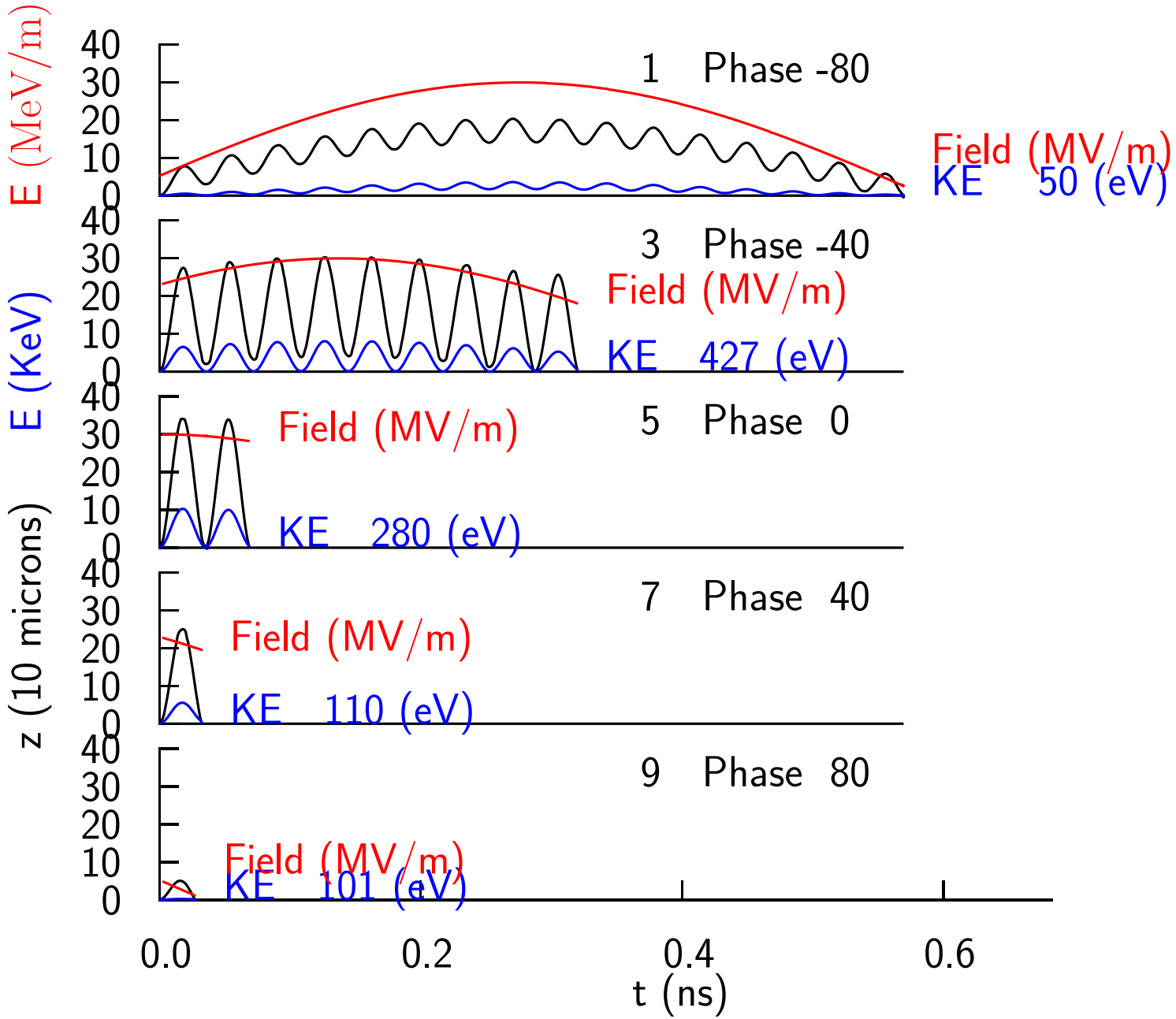
Simulation of simple pillbox

CAVEL Simulation of 10 cm long simple 805 MHz cavity with 1 T magnetic field $\perp$ axis

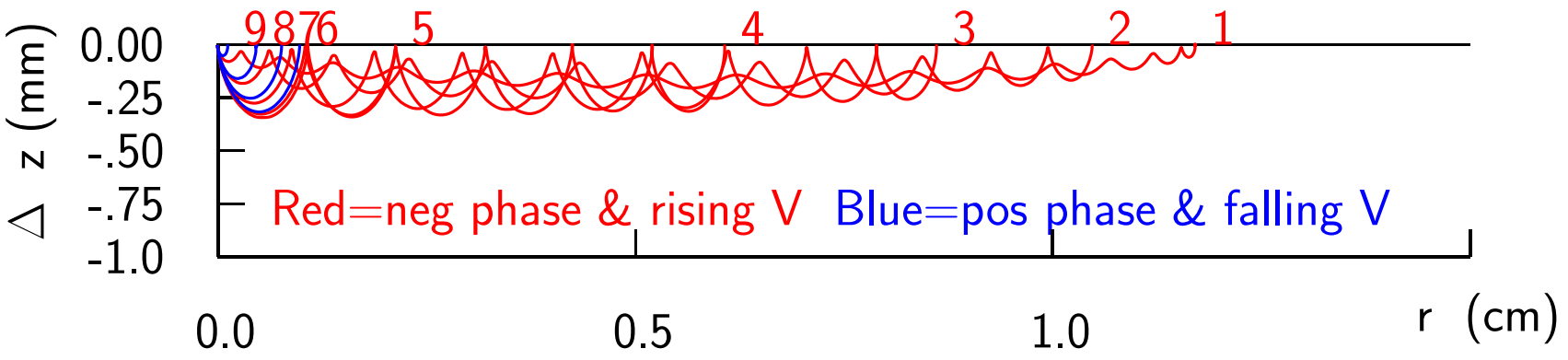


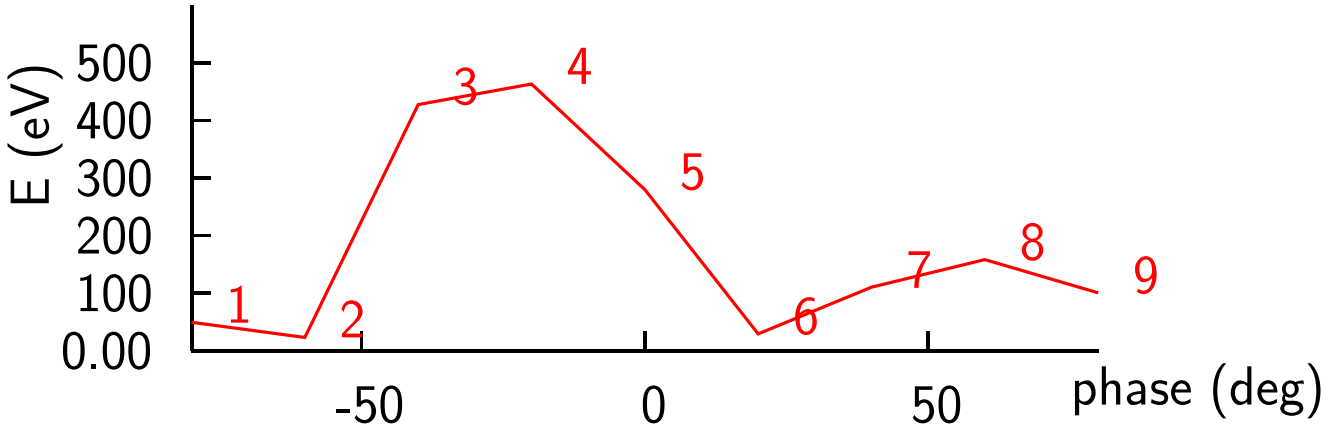
- Electrons move perpendicularly to field
- remaining close to surface
- Distance traveled depend on initial rf phase

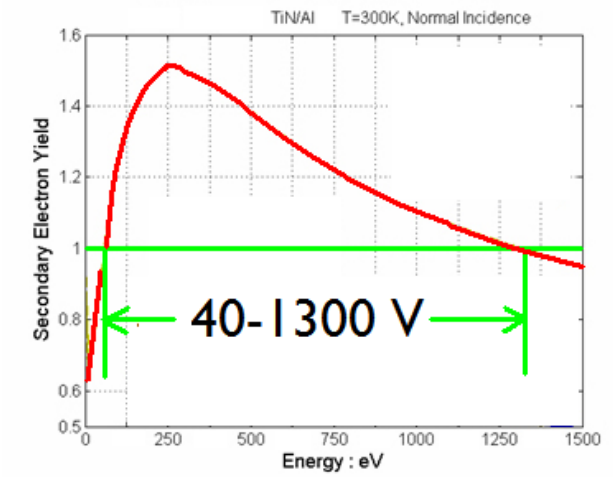
Parameters versus time



Side view and Final Energies

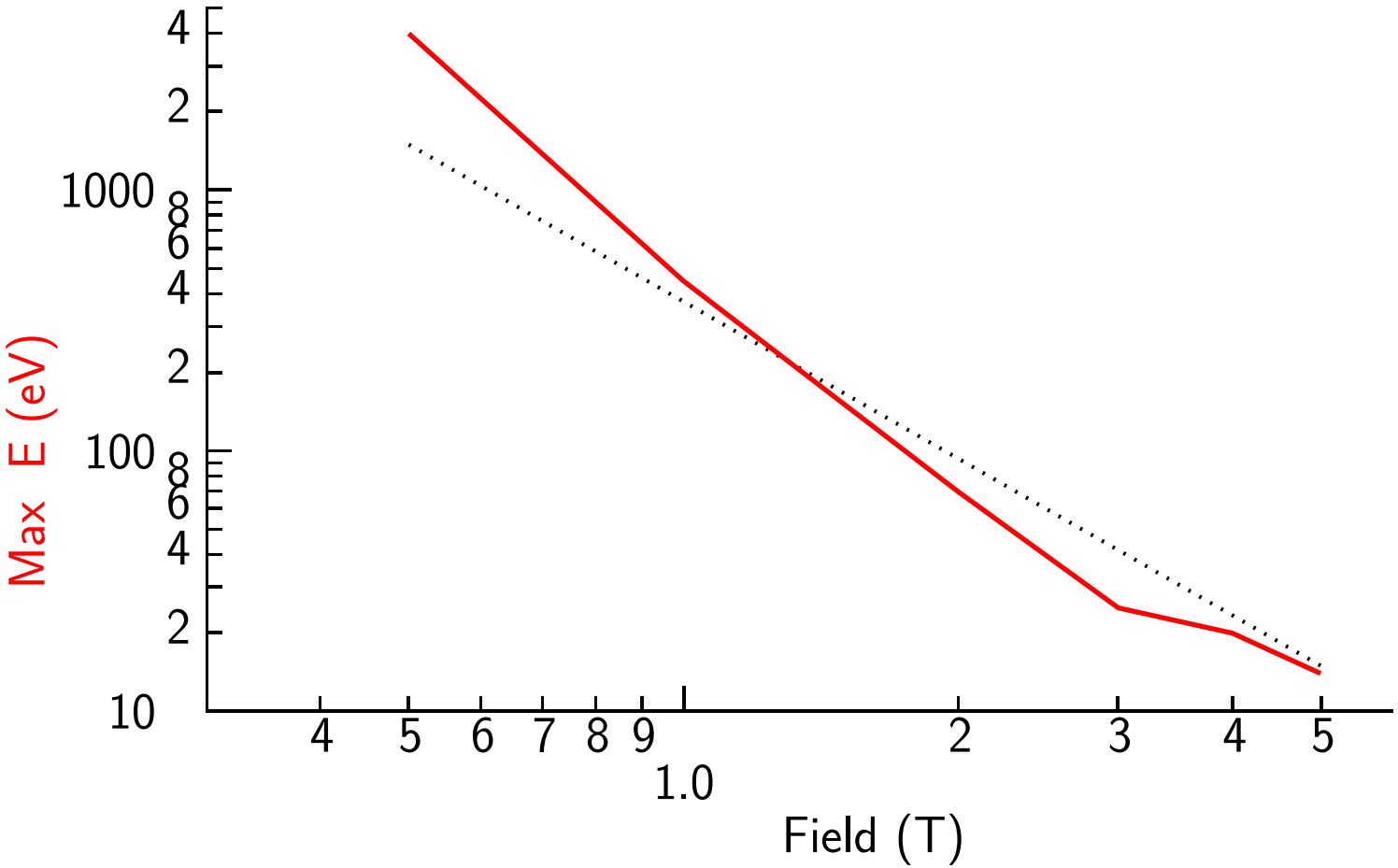






- Energies (for 1T) are near maximum of secondary emission
- But no electron returns in following rf cycle
- So no build up of electrons (multipactering)

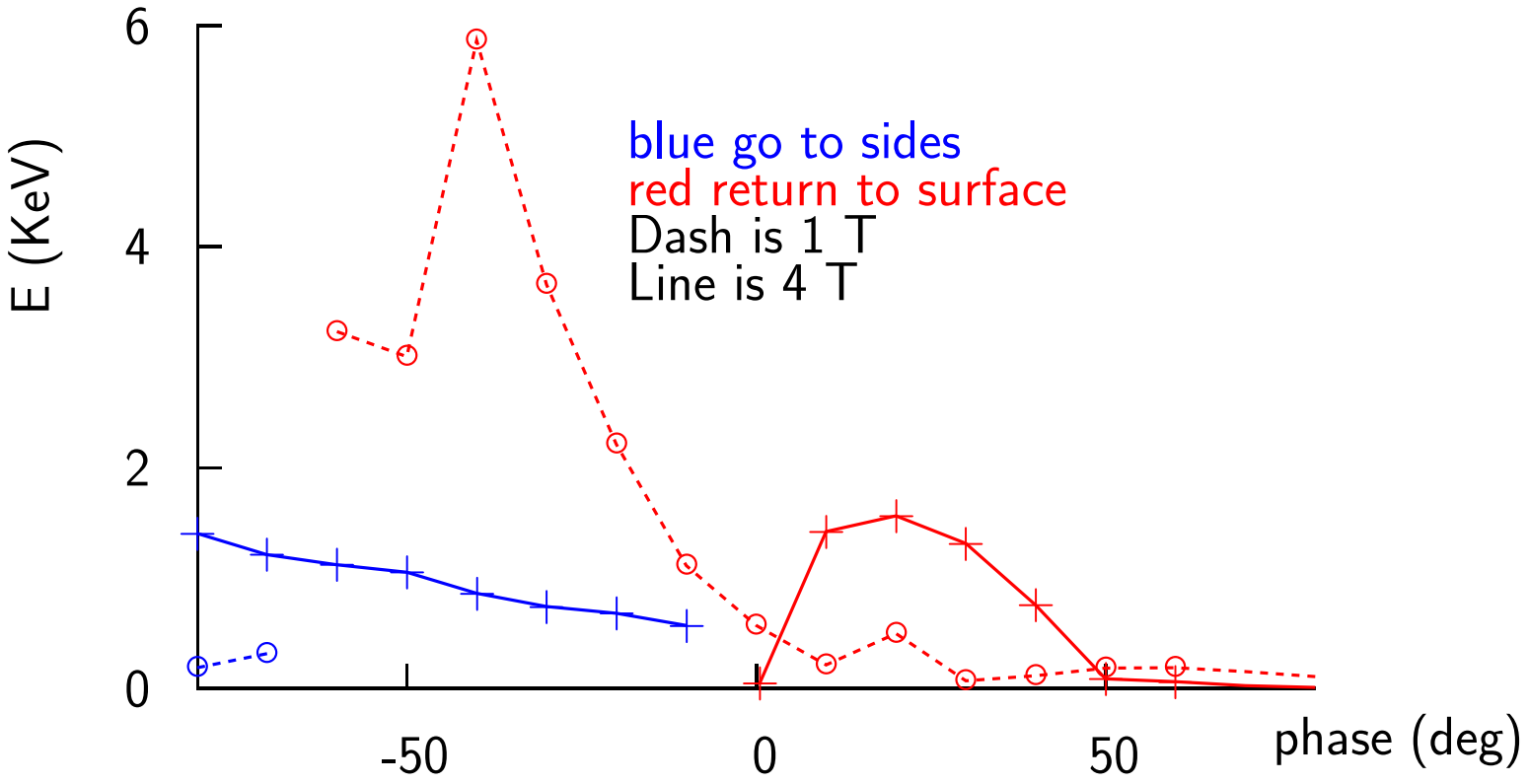
Dependences on Field strength



- Energies and distances from surface $\propto 1/B^2$
- At B=1 T secondary emission could be a problem
- But at B$\geq$4 T the energies are too low ($\leq$ 20 eV)

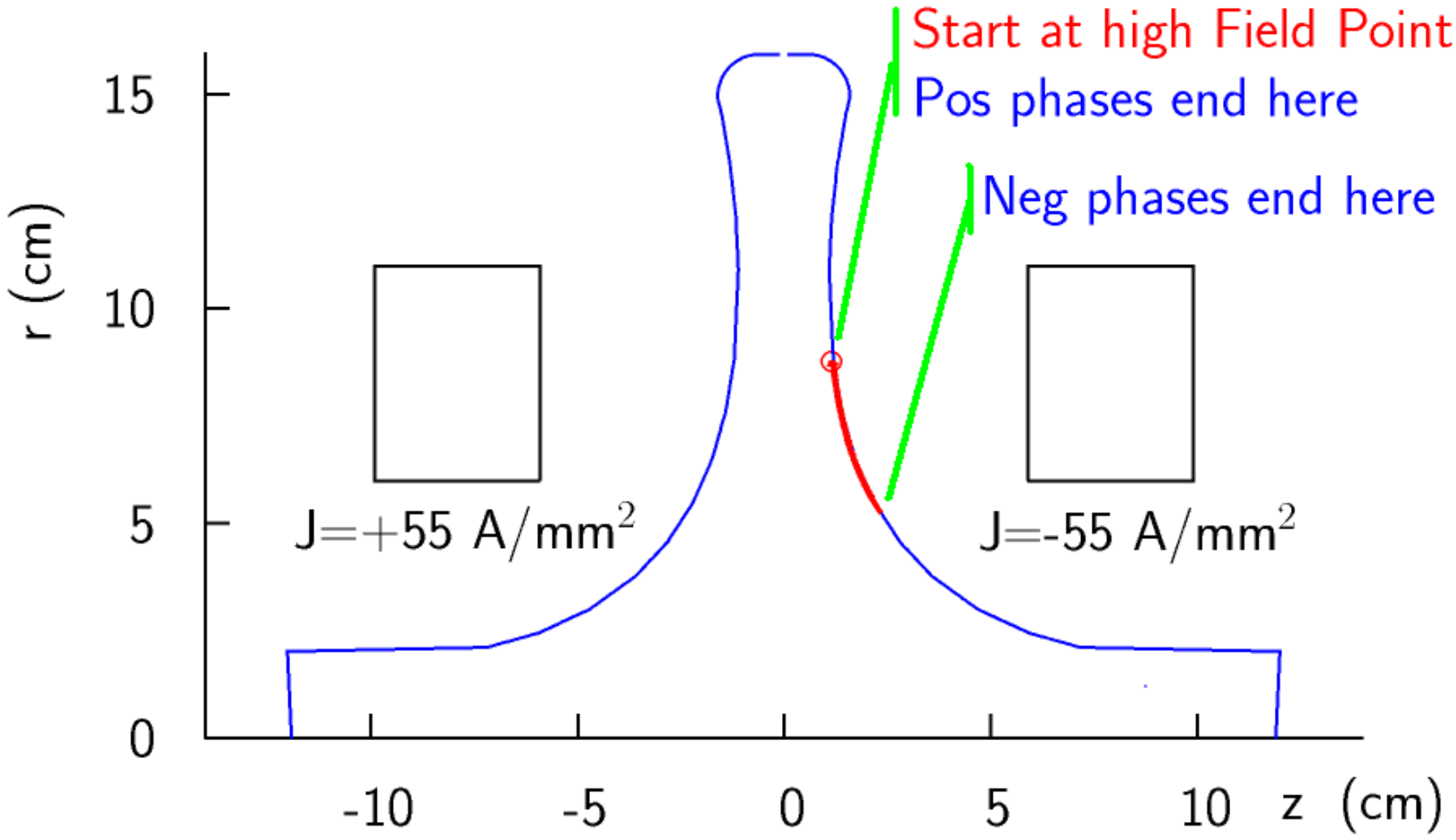
Sensitivity to angle of field

Simulate case with B at 91 degrees from cavity axis



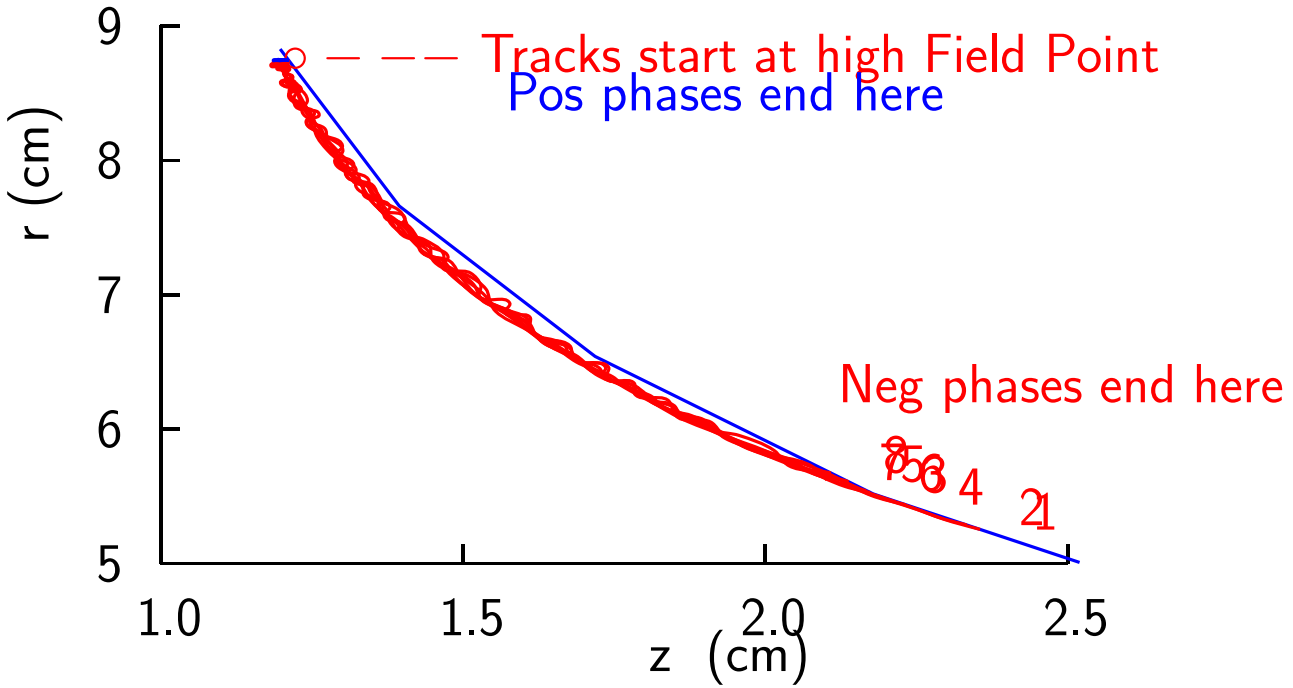
- Situation is more complicated
- many tracks go to side walls
- But some return to surface with V enough for secondary emission
  More studies needed to check multipactering

Magnetically insulated acceleration cavity

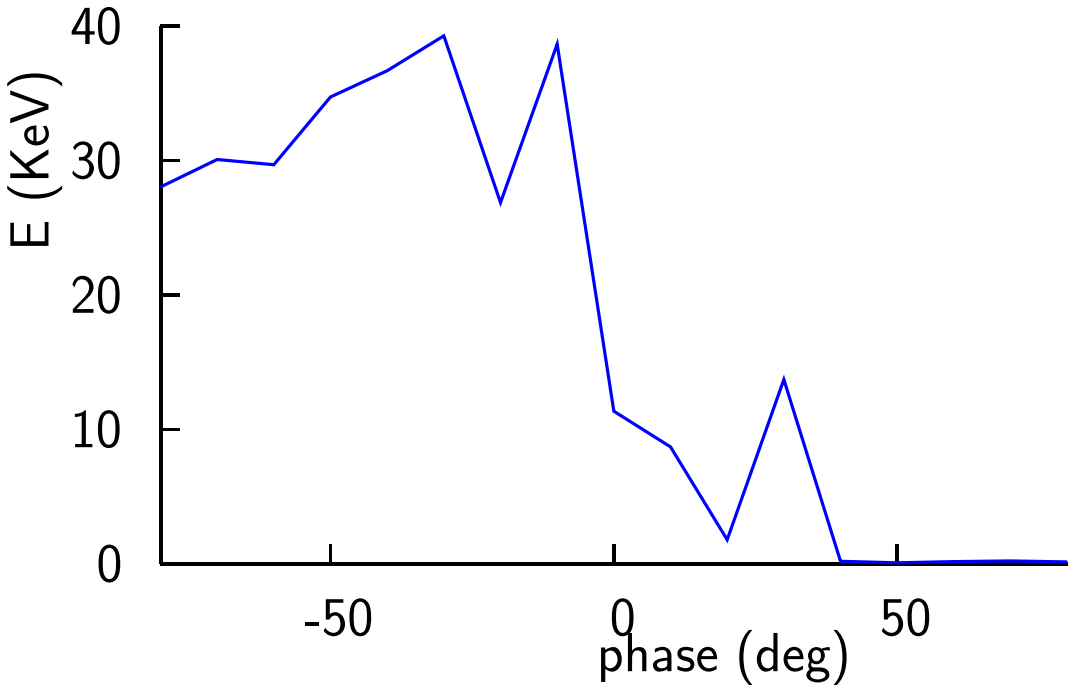


- This is NOT a good cavity
  Emax = 3 × Eacc
- But IS shaped to follow field lines

Detail

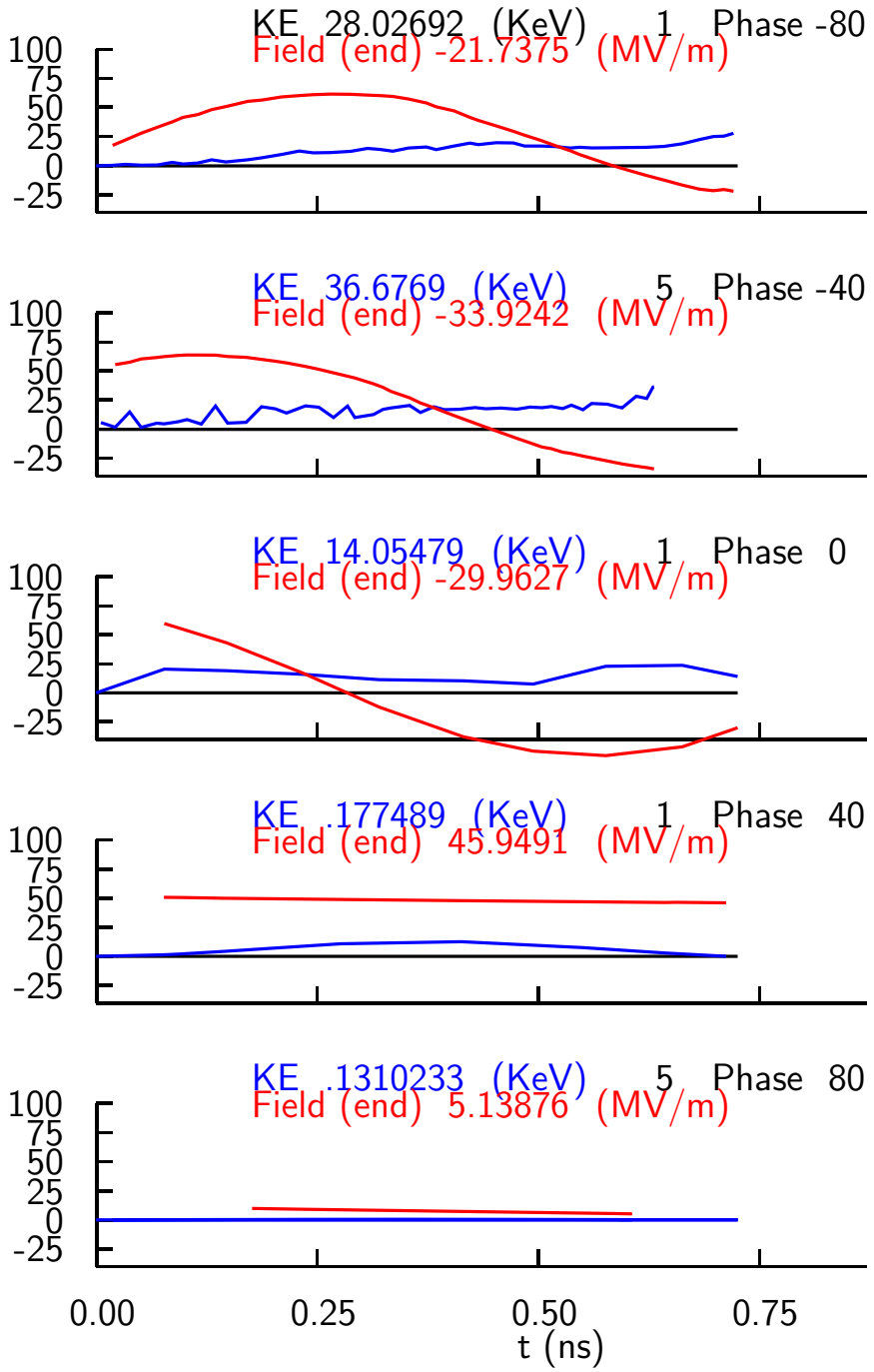


- Negative phases end with too high an energy for secondary emission
- But too low for damage
- Multipactering is less of a problem



Vs time

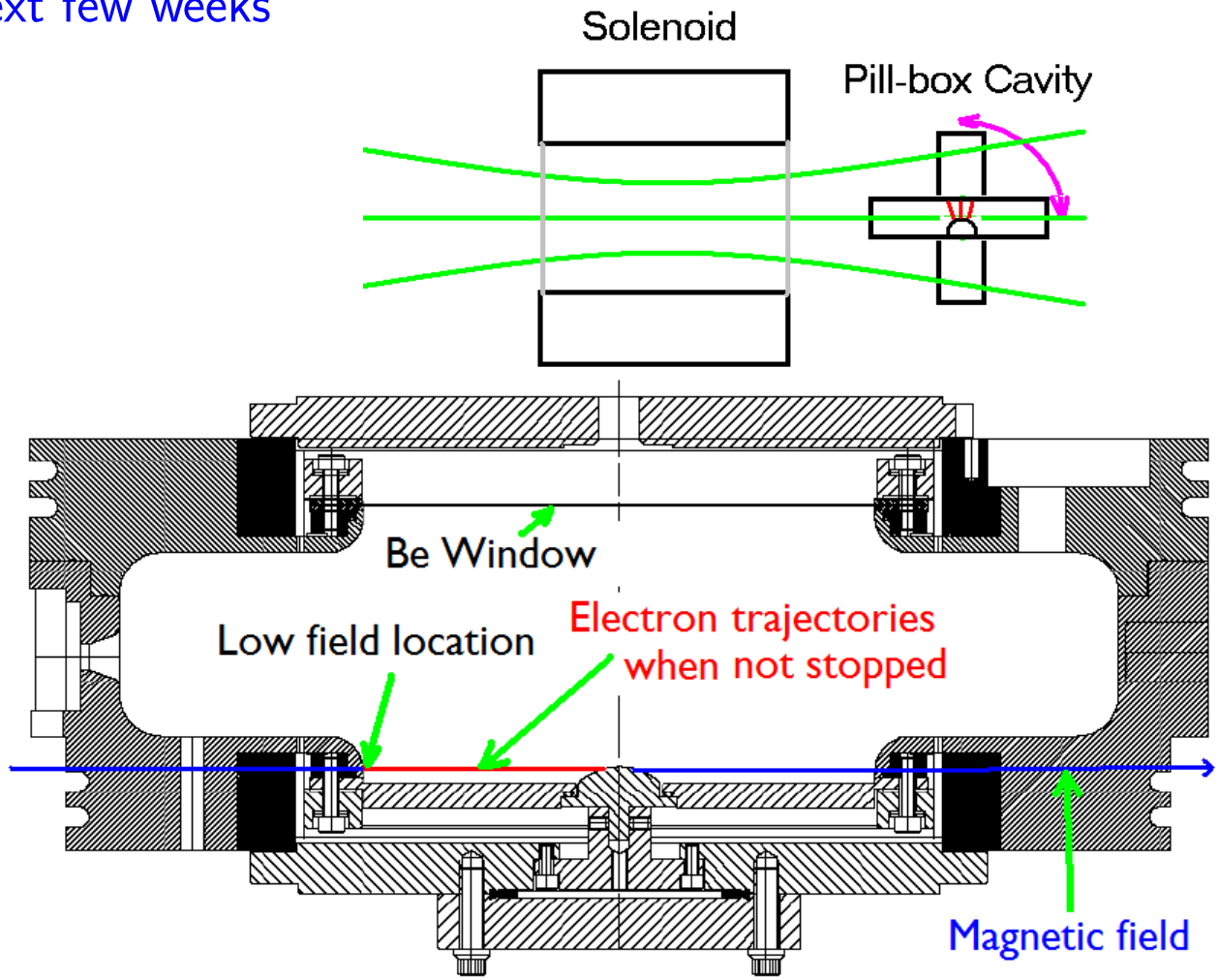
- Again muons end either at negative phases, or advance towards negative phases
- There will be no multipactoring



First Experiment in MTA

Using lab G Magnet and existing cavity at two angles

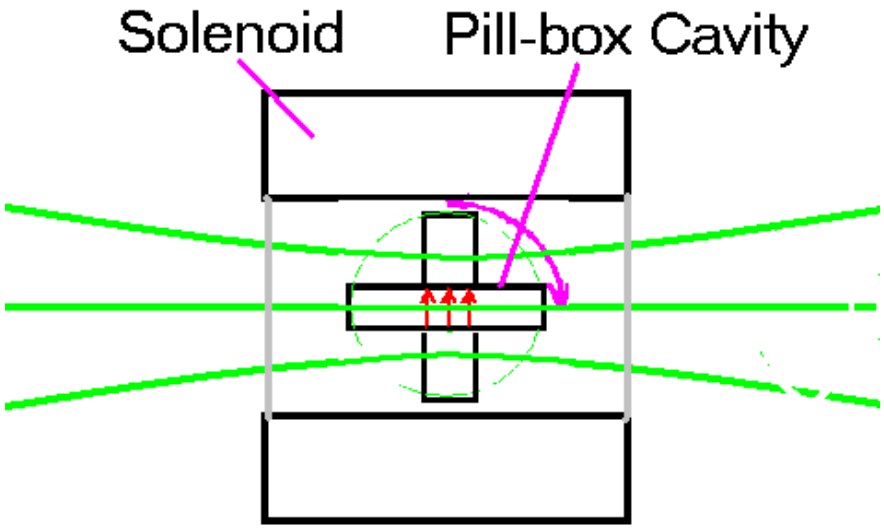
In next few weeks



- This is a test of "Fix #1" but not of "magnetically insulated rf"
- Note sensitivity to angle: if field lines focus to an iris, breakdown will not be supressed

Possible next Experiment in MTA

- Using lab G Magnet and new simple pillbox cavity at multiple angles

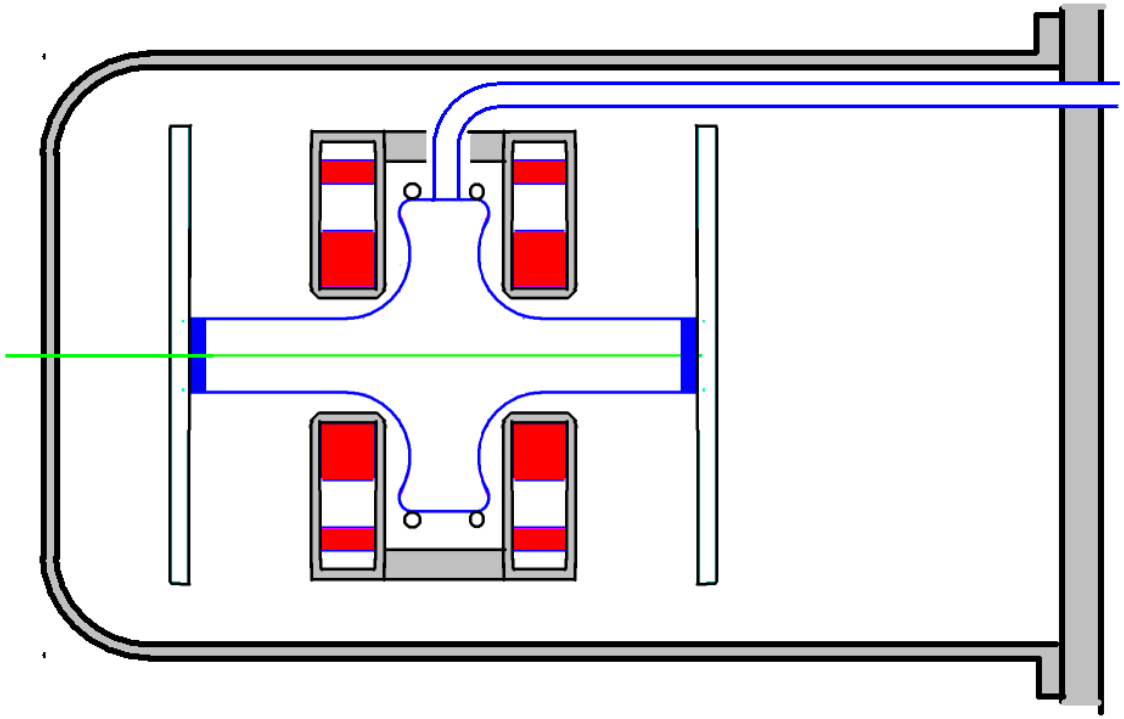


This will be a better test of 'magnetic insulated rf

But angles should be good to a fraction of a degree, or adjustable over such a range, to see the sensetive angle dependence

Later test of Magnetically Insulated Cavity

Under discussion



- Use of double coil geometry allows condition to be tuned

Conclusion

- Ionization cooling for muon colliders require rf in magnetic fields
- But damage & gradient degradation seen with cavities in axial magnetic fields
- Coils in standard open cell irises offer possible solution # 1
  - Electrons end in low field regions
  - or return to source
  - but at lower energies
- By shaping cavity walls we can obtain solution "Magnetic Insulation"
  - Electrons are constrained to be near their sources
  - Dark current and X-Rays should be suppressed
  - Only possible problem is secondary emission
- Simulations of simple pill-box
  - If B exactly parallel to surface then no secondary emission problems because no carry-over to next cycle
  - But if error of 1 degree, situation more complicated
- Help from SLAC promised to study this

Appendix 1: Estimate of worst electron energy

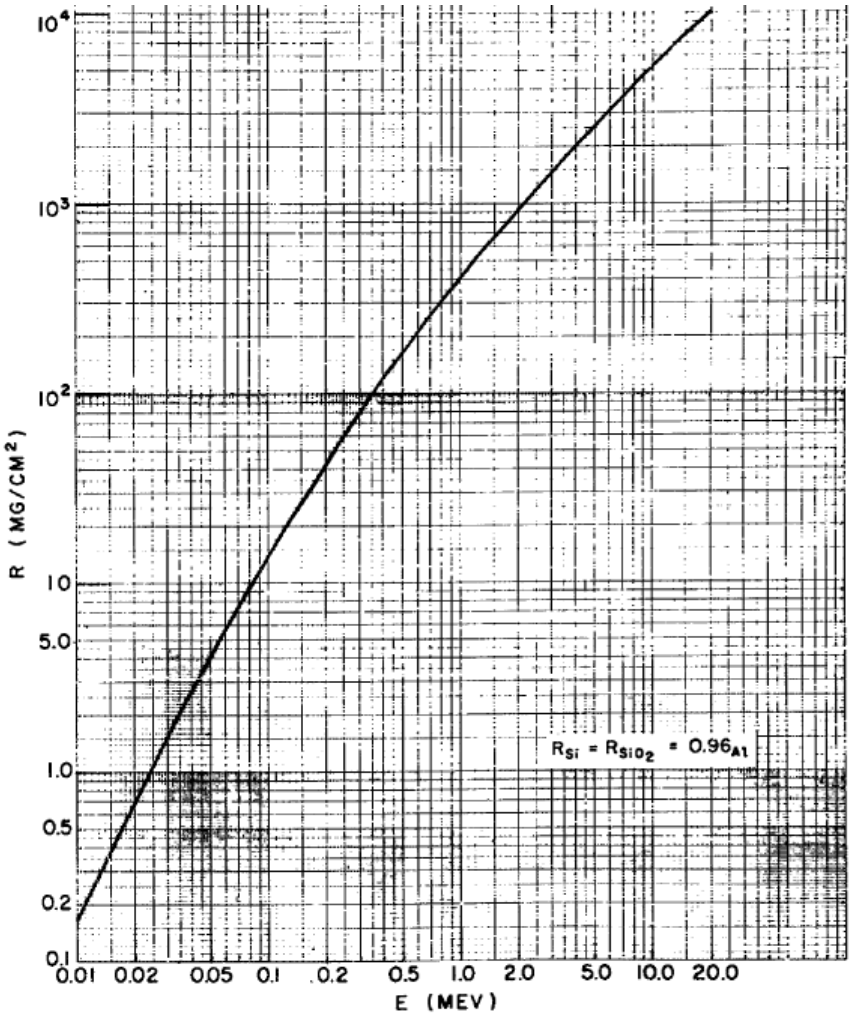


Fig. 5 - Range-energy relationship for electrons in aluminum (from Ref. 9)

Energy MeV	Cu range mm	Be range mm
.13	.02	.07
0.25	0.05	.2
.5	0.19	.76
1	0.44	1.76
4	2.2	8.8

Thermal diffusion depth

$\tau_{201} = 200\mu\ sec \quad \tau_{805} = 25\ \mu\ sec$

$$\delta = \sqrt{\frac{2k\tau}{C_v}} = \sqrt{\frac{2\ 4.01\ \tau}{3.45}}$$

$= 0.2\ \ (mm)$ for 201 MHz

$= 0.07\ \ (mm)$ for 805 MHz

So $\approx$ .5 (.2) MeV bad at 201 MHz for Cu (Be)

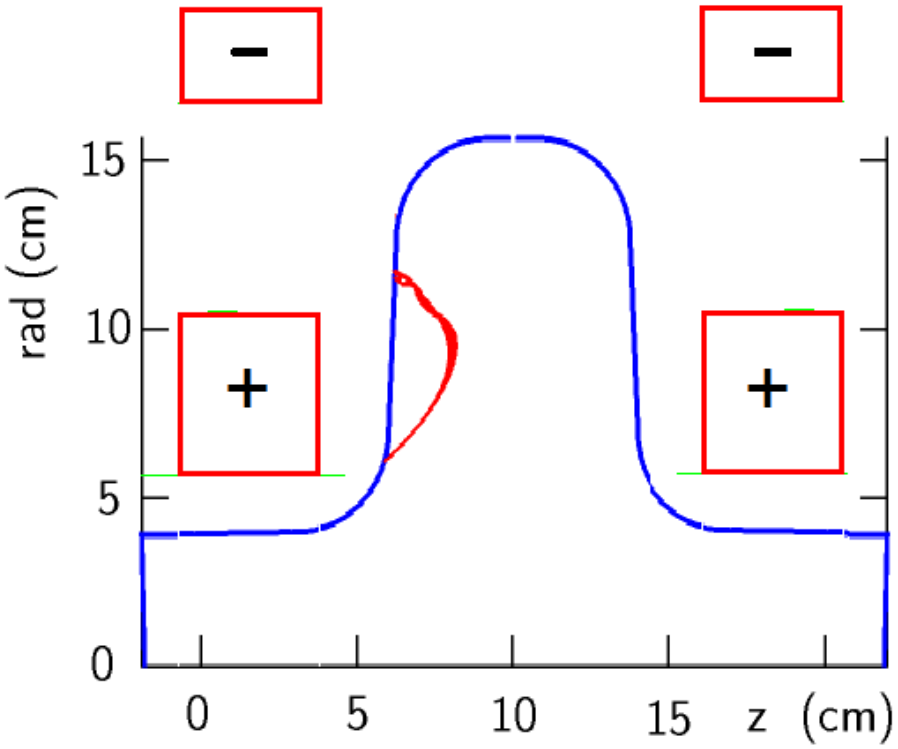
So $\approx$ .3 (.13) MeV bad at 805 MHz for Cu (Be)

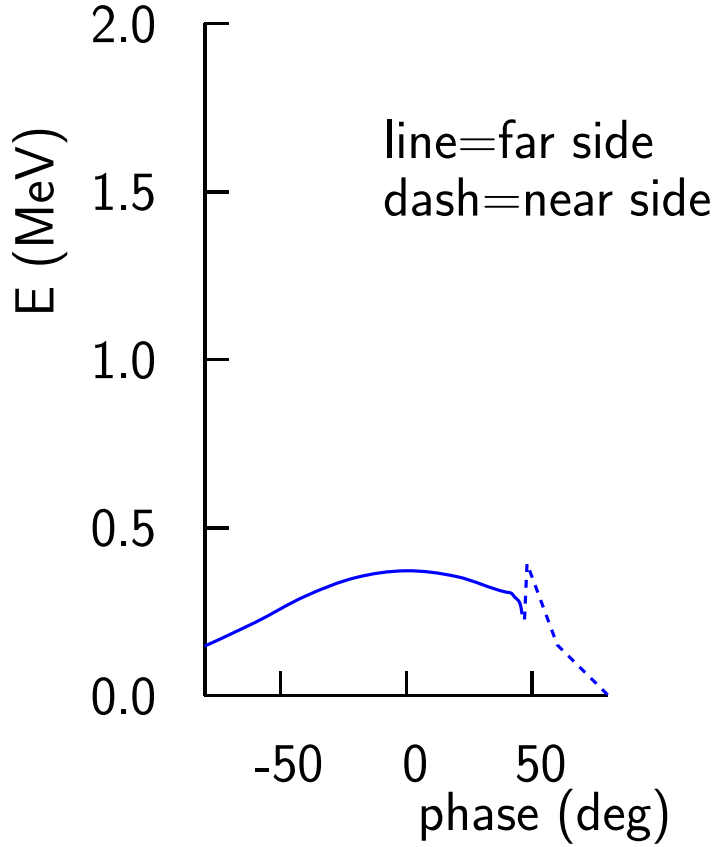
Be is better than Cu because the electrons go deep & dE/dx is less

This needs a real simulation, the above is only a qualitative argument

Appendix 2: Coil in iris solution for same sign currents

- Add outer coils with opposite currents
- Increase, somewhat main coils to regain field
- Fields on axis are not much different





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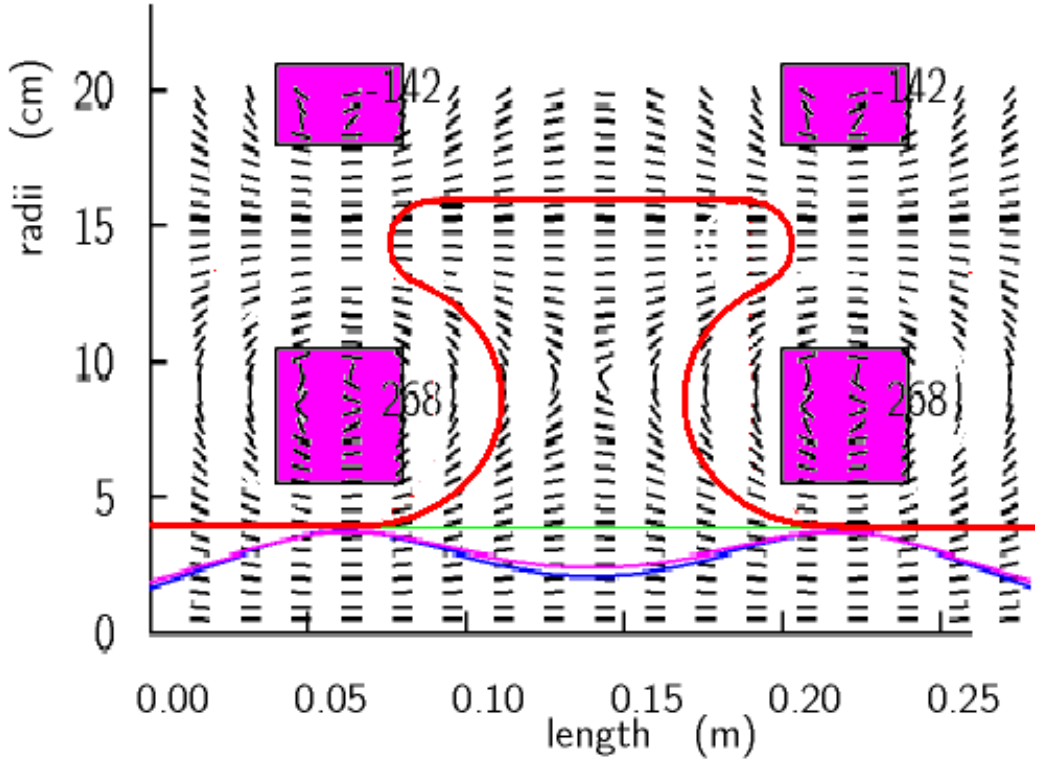
Appendix 3: fix with non-alternating fields



- Note fields on the axis is little effected by outer coils
- Need experiments