Studies of the 'rf in magnetic field' problem

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NFMCC Friday

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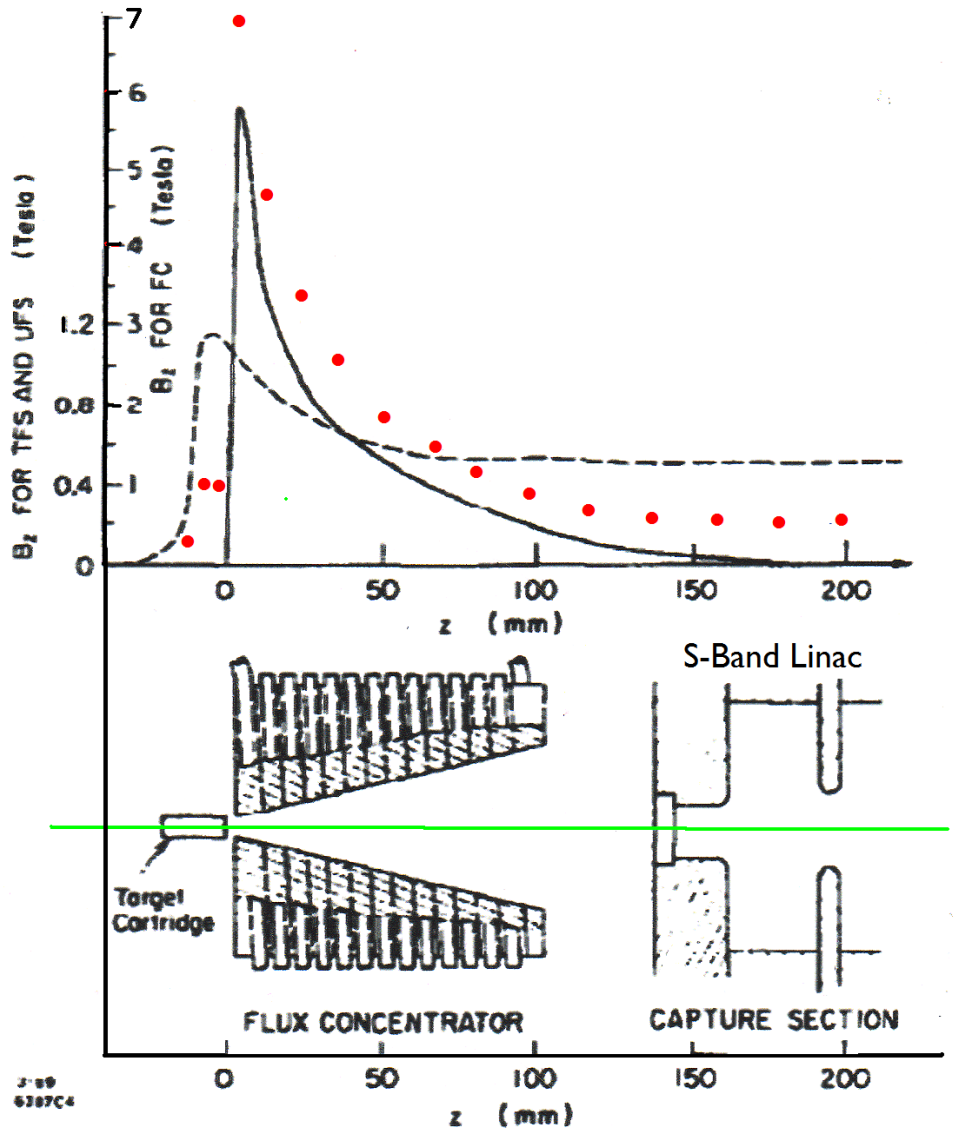
- Experimental Observations
- Can high pressure gas solve all problems?
- CAVEL Simulations
  - Normal open cavity with coils in irises
  - Special open cavities with 'Magnetically insulated rf'
  - Pillbox cavities with 'Magnetically insulated rf'
- Conclusion

Experience at SLAC

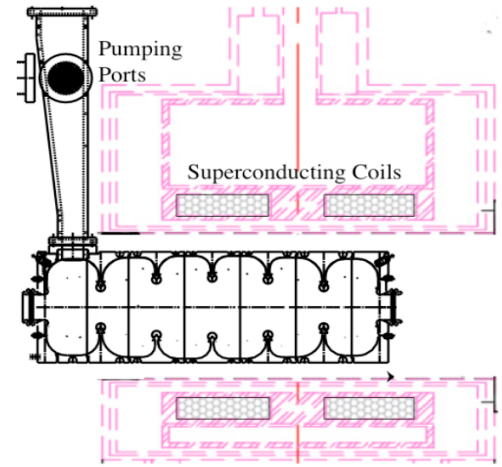
- SLAC positron source has 0.5 T fields on a 40 MV/m S-band Linac with no ill effects
- But, contrary to my impression, the high concentrator fields do NOT extend into the linac
- So this is only weak evidence that axial magnetic fields do not cause breakdown in cavities
- Mia Culpa: I had thought the 'Flux Concentrator' high fields extended into the cavities. I was wrong

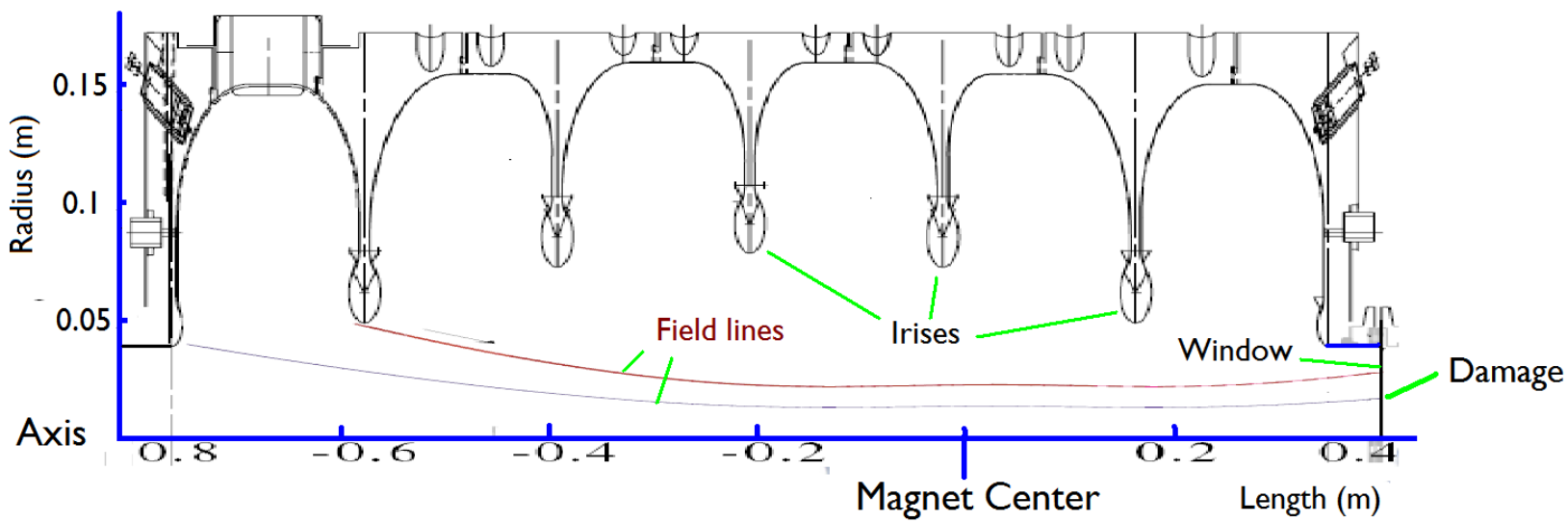


SLAC-PUB-5473 & 5049)

Lab G experience with Open Cavity

- Early tests of an 805 MHz multi cell open cavity attained good gradients but did have excessive dark currents that even made a hole in a window
  - Cavity was asymmetric in the magnet
  - Irises had differing radii
  - Field lines from irises did not join to other irises
  - Field lines from irises ended on window

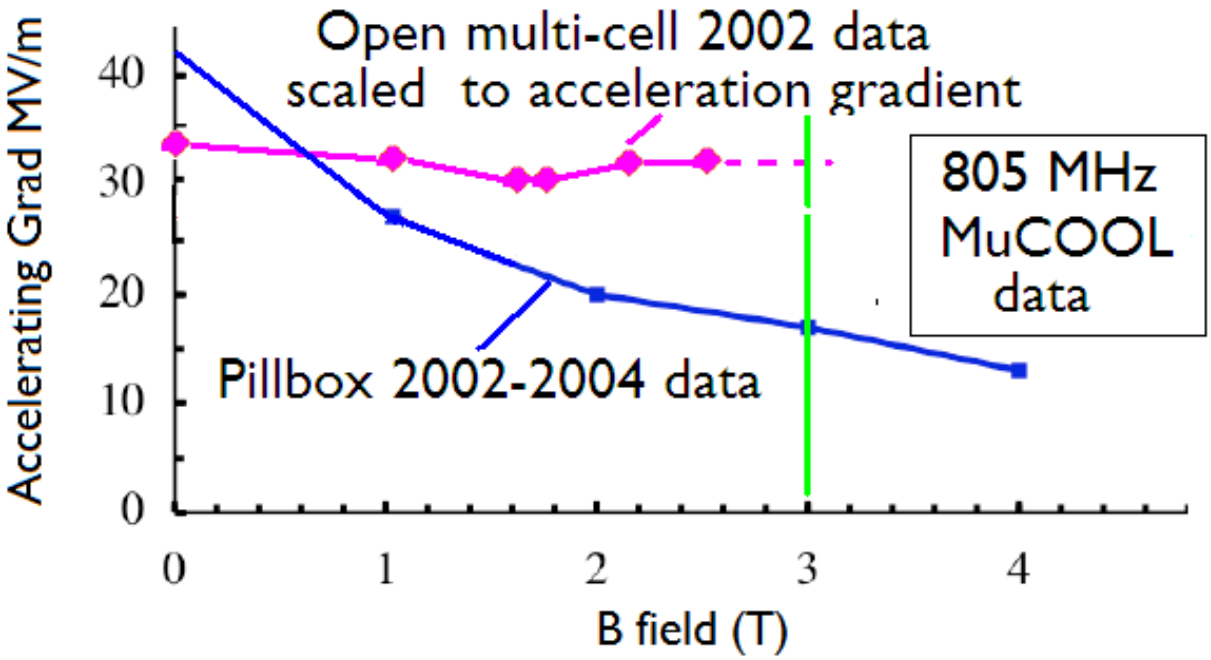


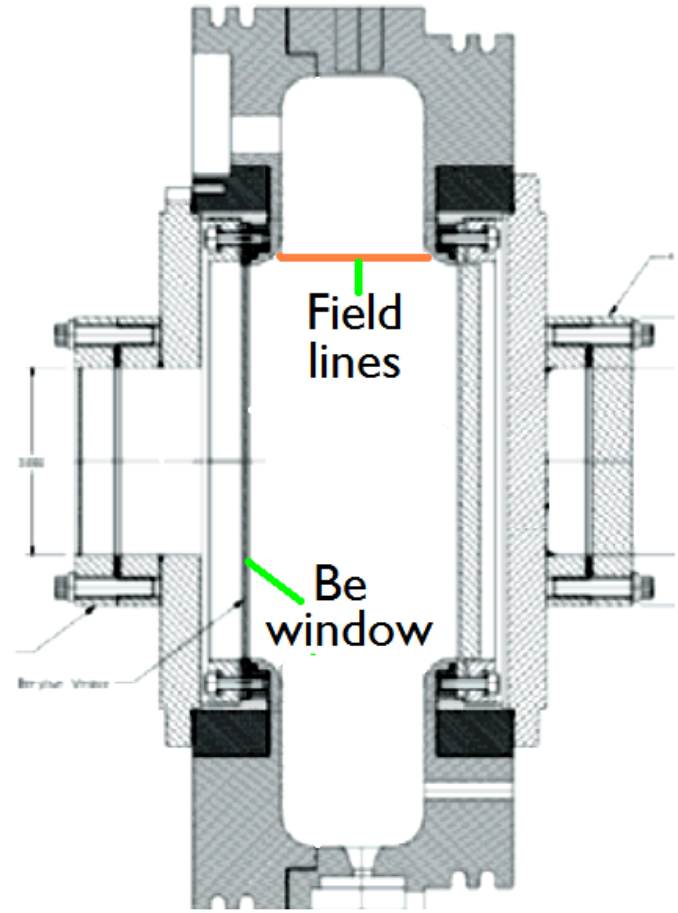


Norem et al, PRST Acc & Beams 6, 072001 (2003)

Tests of Pill-Box Cavity

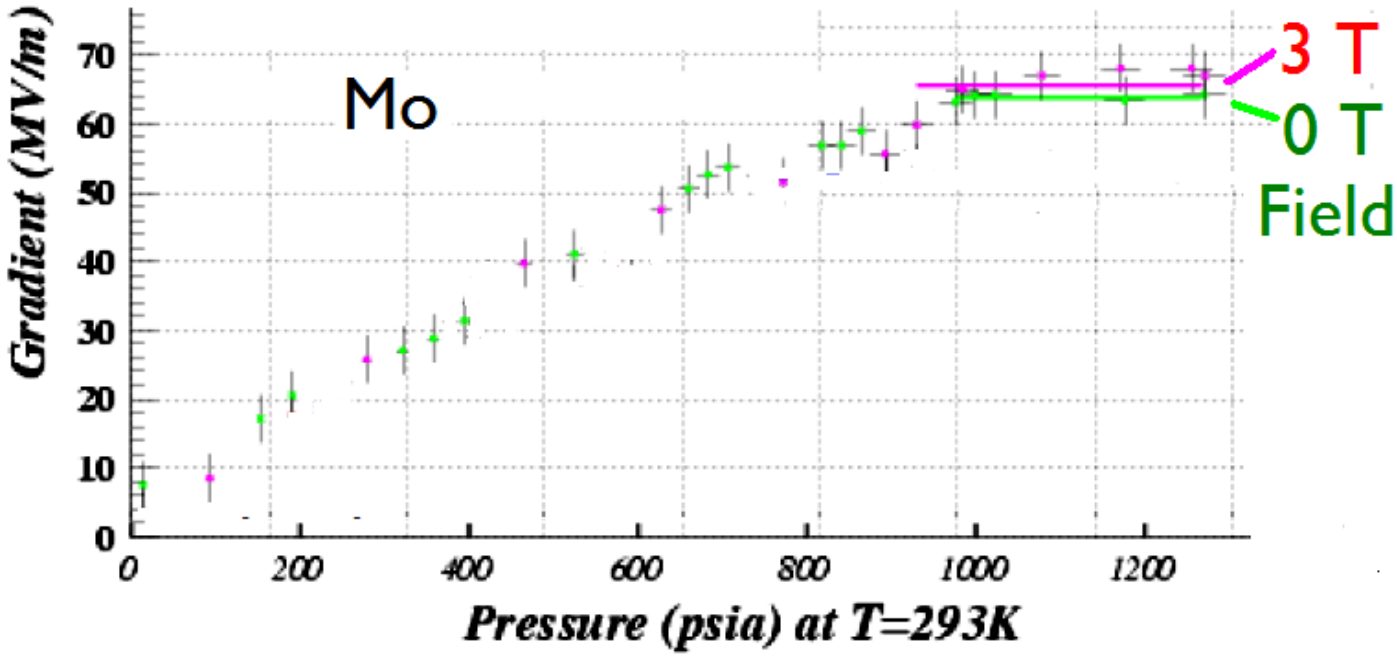
- But more recent tests with a 'pillbox' cavity similar to those used in simulations achieved gradients that fell rapidly with field
  - Cavity is short compared with magnet dimensions so:
  - Lines cross from iris to iris





- Results suggest focusing of electrons is causing trouble

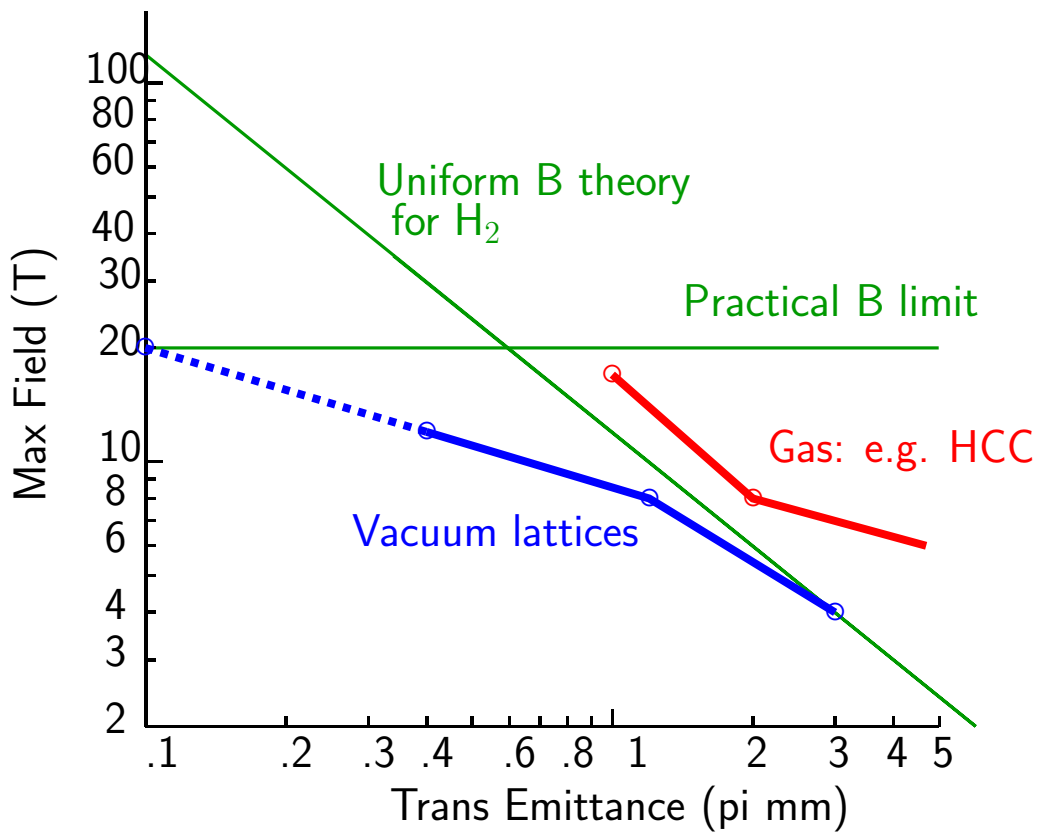
Gas filled cavities show no such effect



- Gas would stop electrons, so this is consistent
- So can we use high pressure gas?
  - Helical Cooling Channel uses high pressure gas
    These simulate well with 'ideal' fields, but have yet to be simulated with realistic integration of rf
  - 'Guggenheim' lattices have been simulated with gas and LiH wedges
    These work reasonably well in early, high emittance, stages
- But can high pressure gas be used for all 6D cooling?

But gas does not work for lower emittances

- To cool to lower emittances we need the absorber to be at foci (low betas)
- And must NOT have absorber between foci (where beta is high)
- This in NOT possible with gas

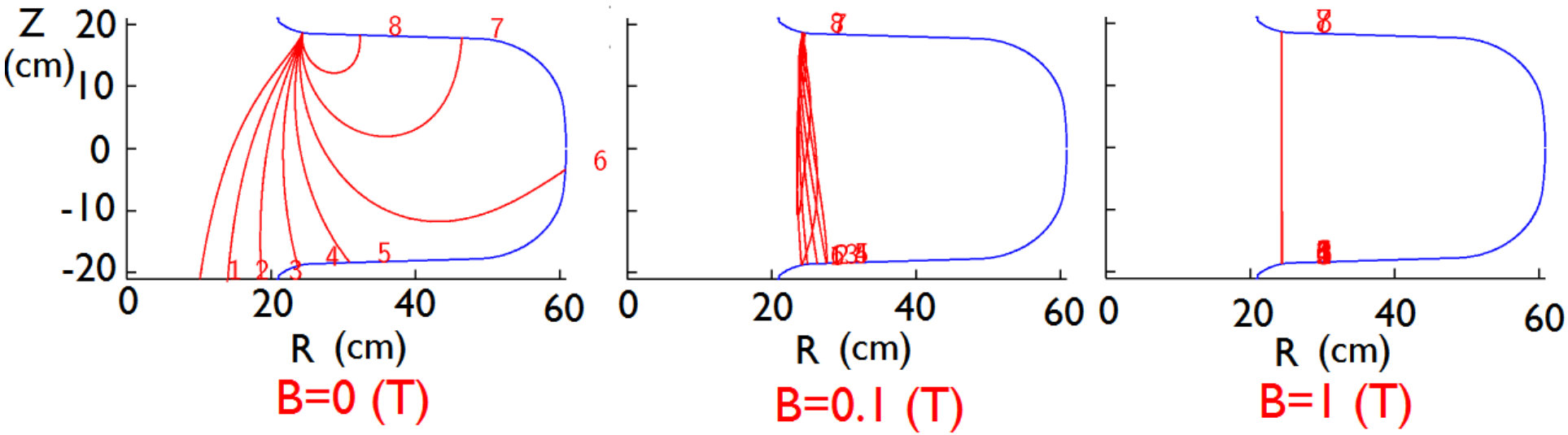


- Is there some other way to 'fix' the electron motion ?

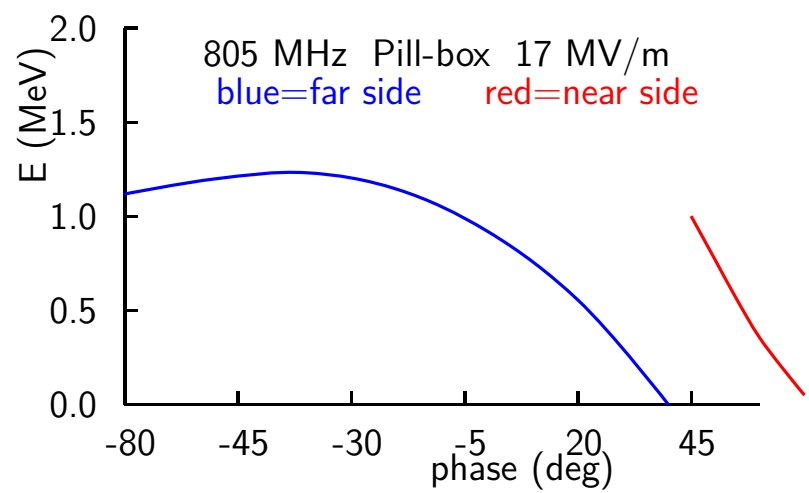
Dark Current Electron Motion with/without Fields

Tracking, with Fernow's new program CAVEL, electrons from highest field location shows strong focus along field lines for B $\geq$ 1 (T).

e.g. 201 MHz with 17 MV/m

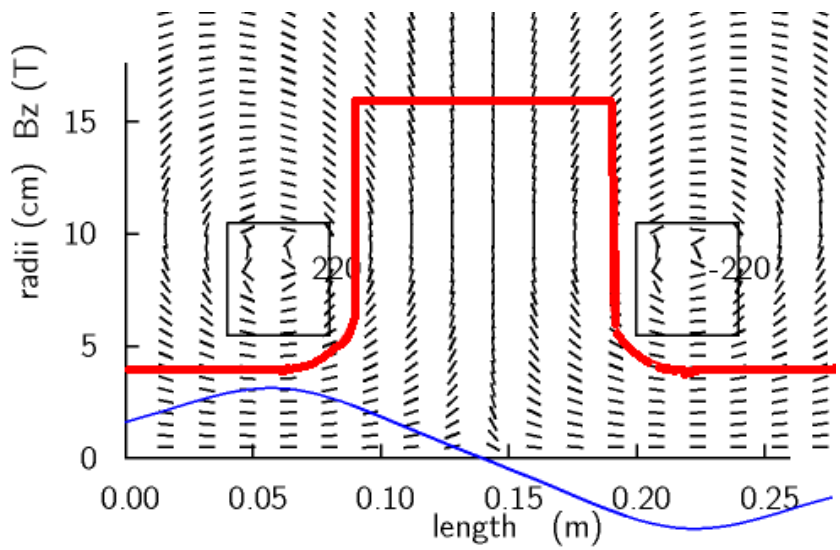


- Some electrons come back to source
- Energies of order 1 MeV for 805 MHz
  Moderate currents will melt copper
- Energies of order 4 MeV for 201 MHZ
  Less bad than 805 because deeper

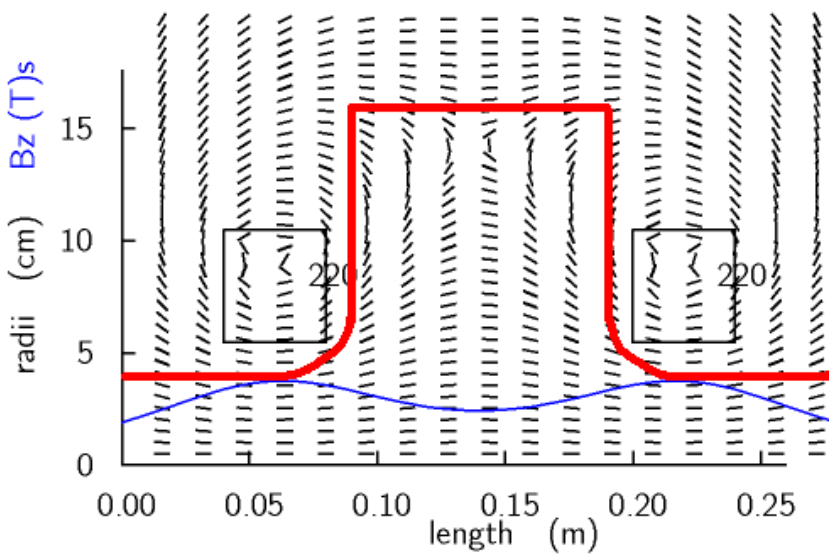


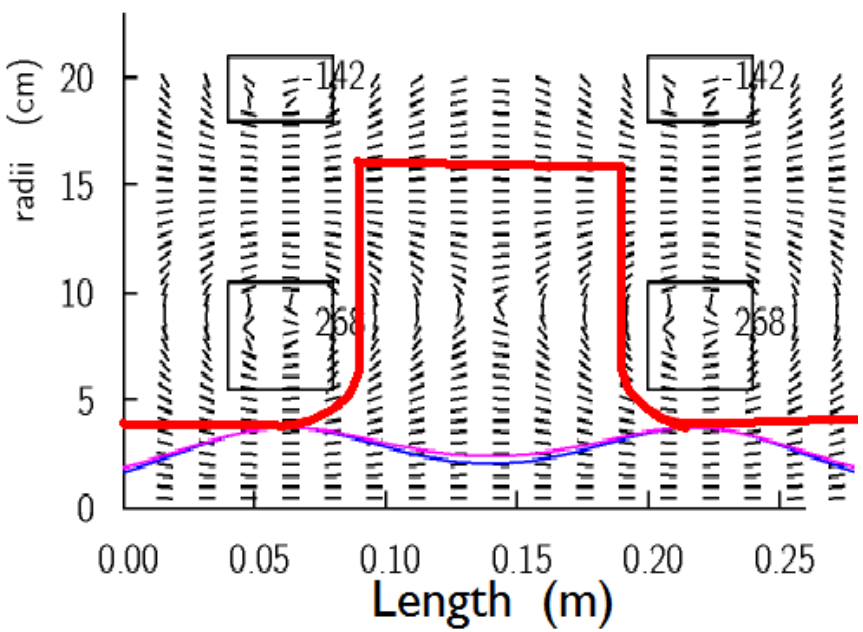
Open Cavities with Iris Coils

- Use Open cavities
- Place coils in irises
- field lines now more perpendicular to electric fields

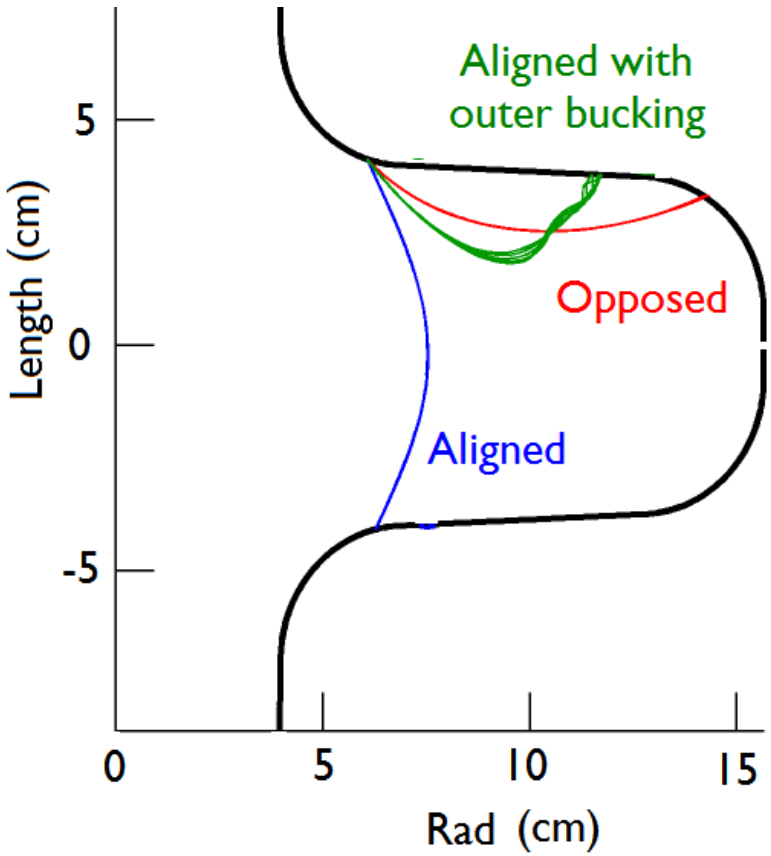


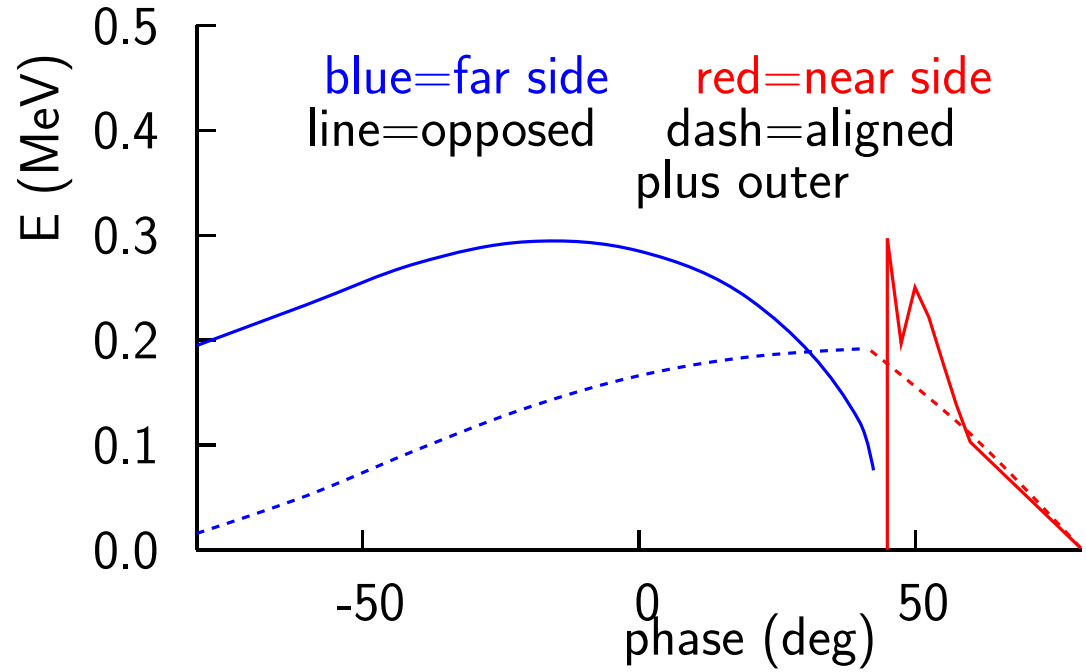
- For opposed currents ok
- for aligned Currents need outer bucked coil





CAVEL Simulations



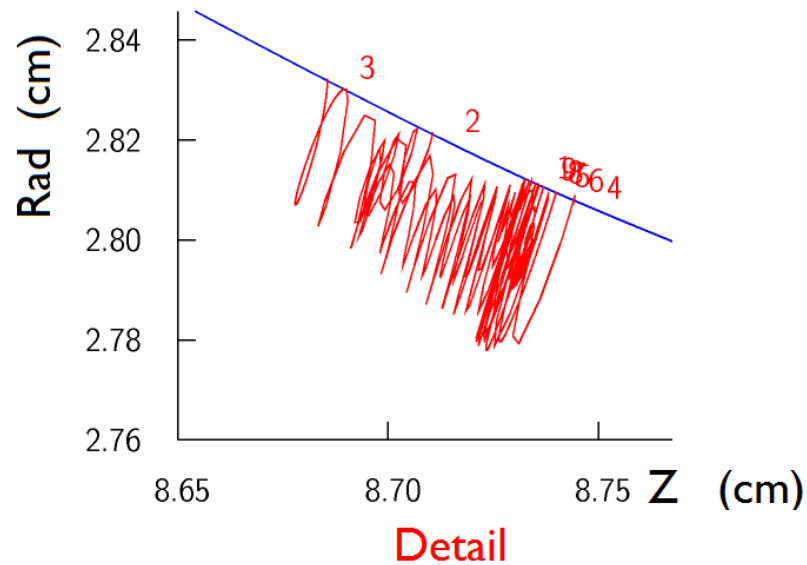


- Aligned case without outer coils is no better than uniform field
- Opposed, & with outer coils put most of energy where electric fields are low
- Energies are less, but are closer to worst energy from range considerations
- And some tracks come back to source

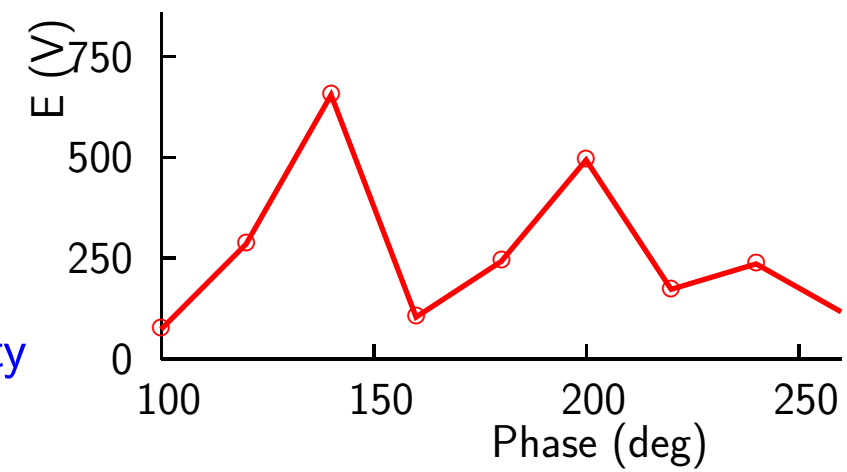
- Only an experiment would tell if this is a significant improvement

If B Parallel to Surface: (Magnetic Insulation)

The electrons are trapped close to the surface



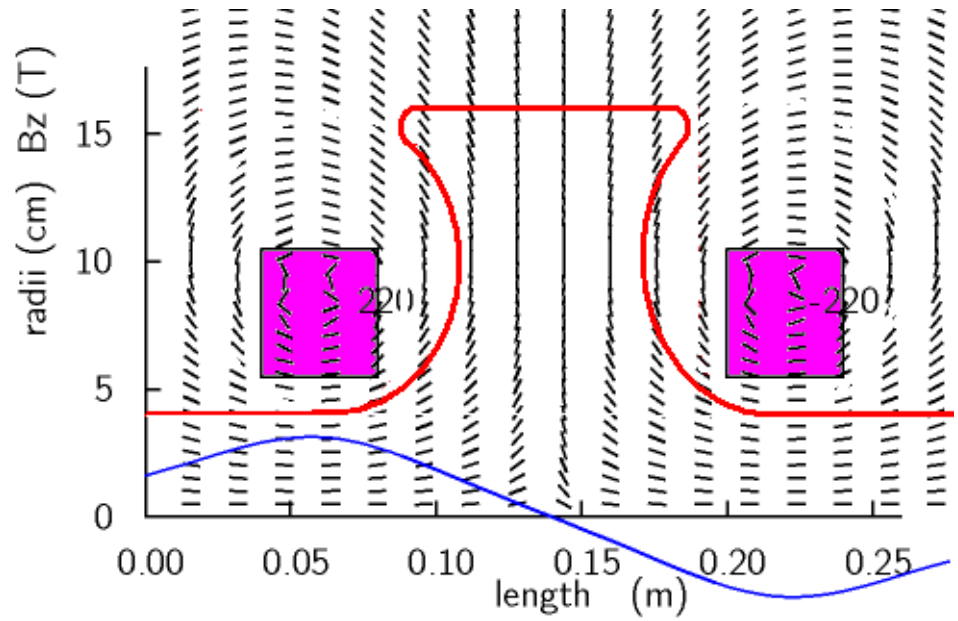
- All tracks return to the surface
- Energies are very low
- No danger of melting surfaces
- But secondary emission now possible
- Could lead to space charge instability
  $\longrightarrow$ Magnetron



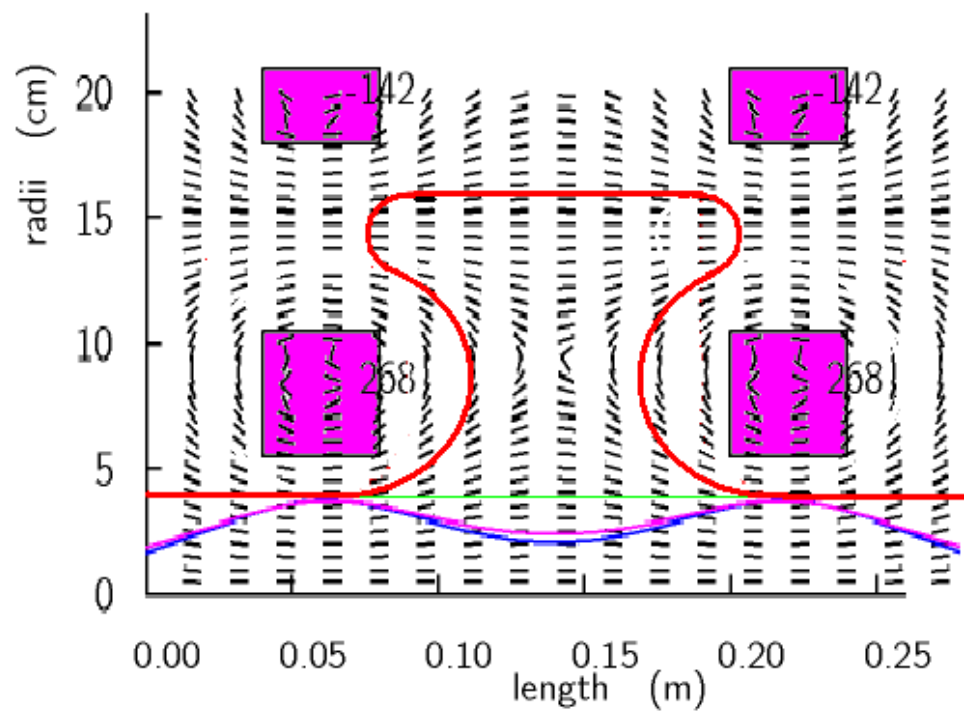
Open cavities with all high field surfaces $\parallel$ B

Put coils in the irises

- If the currents can be alternated

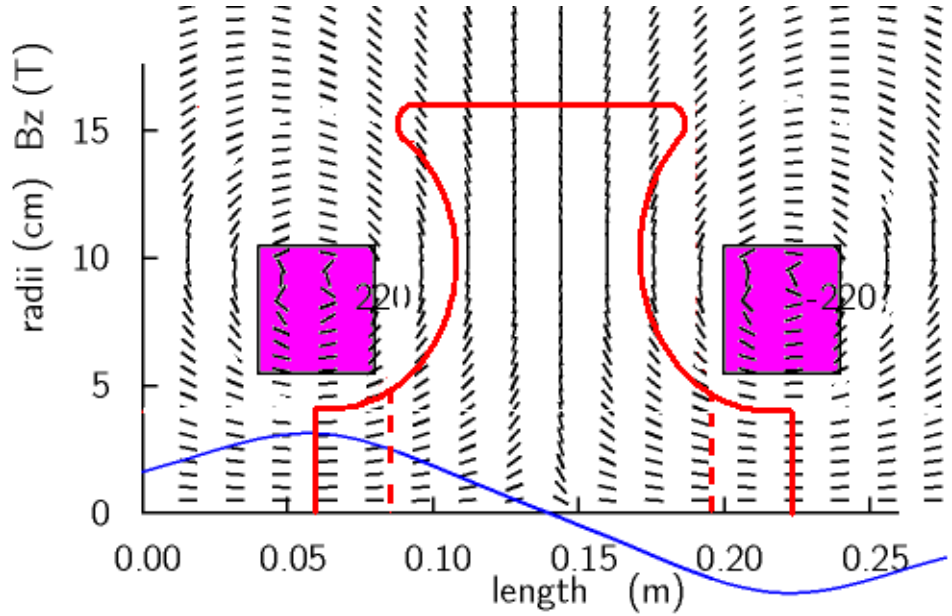


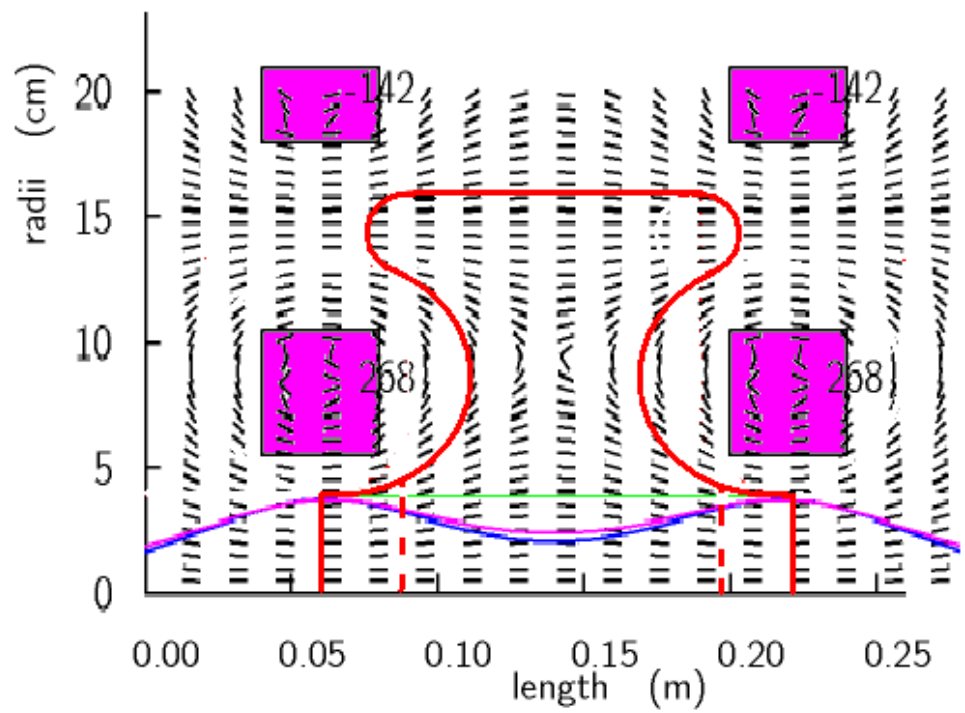
- For same polarity, requires reverse outer coils



Pillbox cavities with most high field surfaces $\parallel$ B

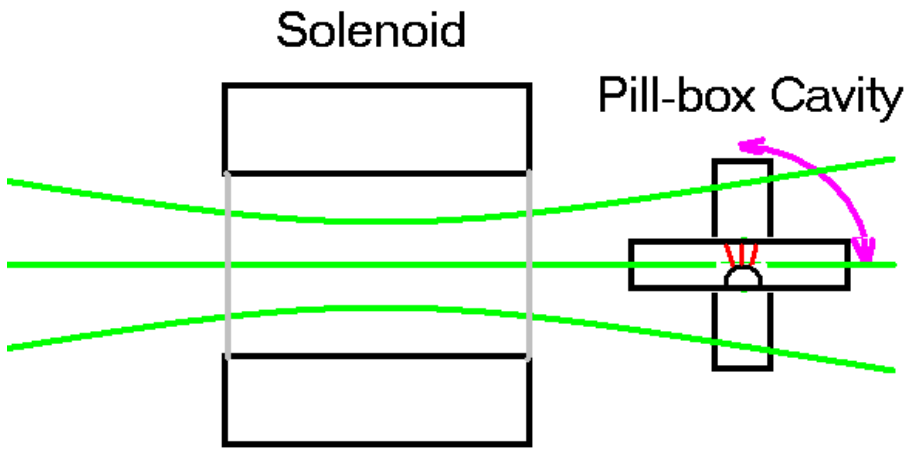
- Steve Geer proposed adding Be Windows to make them 'Pillbox Cavities'
- The Fields on the windows are low in line case shown
- And Be is far more resistant to electron bombardment because the electrons go so deep
- This would remove the cell length constraint of open cavities
- To raise the shunt impedance much, the ends have to move in (dotted lines)
- But now electrons emitted from the windows could damage outer surfaces



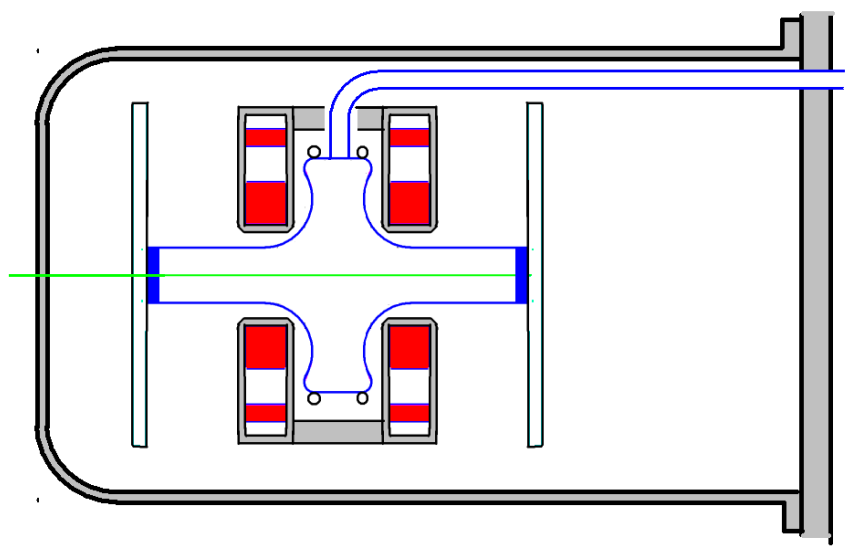


Needed Experiments

First using lab G Magnet and existing cavity at two angles



Then test new Mag Insulated Cavity with coils



Conclusion

- Experimental Observations:
  1. SLAC Positron Source 3 GHz rf operated at 40 MV/m in 0.5 T field
  2. Lab G open cavity operated at good field
     But had excessive dark currents and drilled a hole in a window
  3. Pillbox cavity had falling gradients with field
- These are consistent with simulation expectations
- Placing coils in the irises of standard open cavities probably helps
  - Lowers the electron energies & directs them to a low field location
  - But some tracks return to the sources
- But specially shaped cavities (Magnetically Insulated rf) would trap electrons fixing the field problem and improving performance
  1. Stop all dark current & eliminate possibility of damage
  2. Raise attainable gradients (much as high pressure gas does)
  3. But TiN coatings needed to stop electron cloud formation
- Windows could be introduced to make 'pillbox' cavities
  - But there could be problems if the windows are brought in to raise R (shunt)
- Need experiments