

RF breakdown in Magnetic Fields A Hypothesis



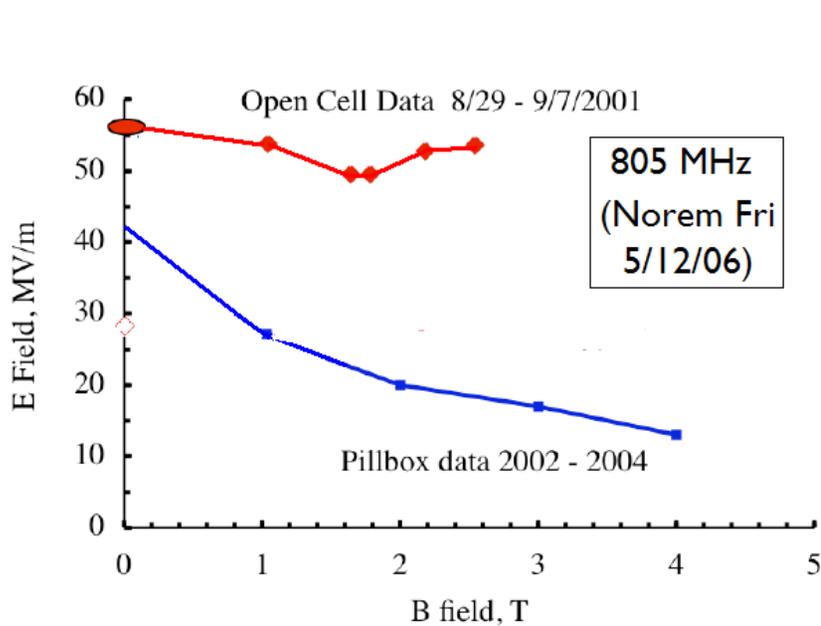
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D. Li (LBNL)

Friday NFMCC

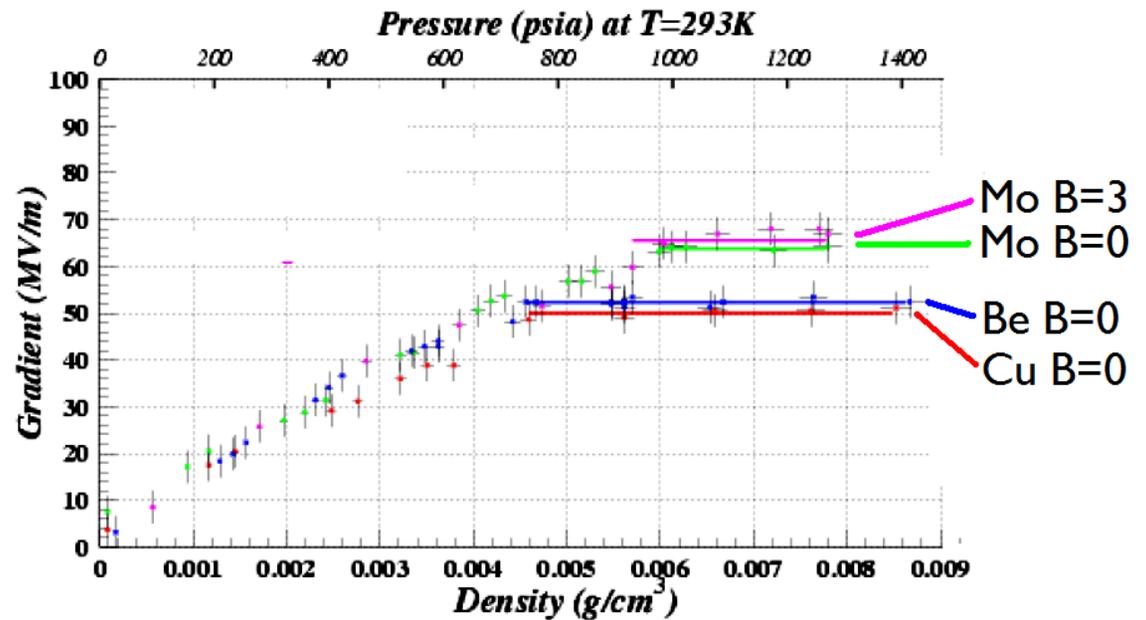
May 30, 2008

- "Conventional" damage and breakdown model
- Breakdown results reported by D Huang May 23
- Breakdown model that fits this data
- Proposed experiments and predicted behavior
- Implications
- Conclusion

”Conventional” Breakdown (no B)



Vacuum



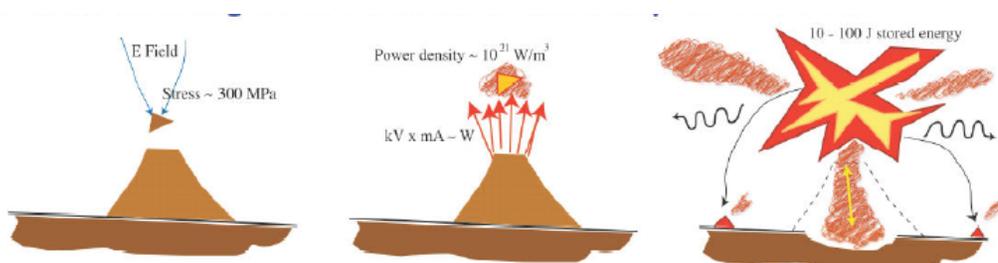
Gas

- Open Cavity driven to higher surface fields than pillbox
- Maximum gradients similar for Vacuum and gas

	Vacuum	Gas
Maximum surface fields (MV/m)	56	53

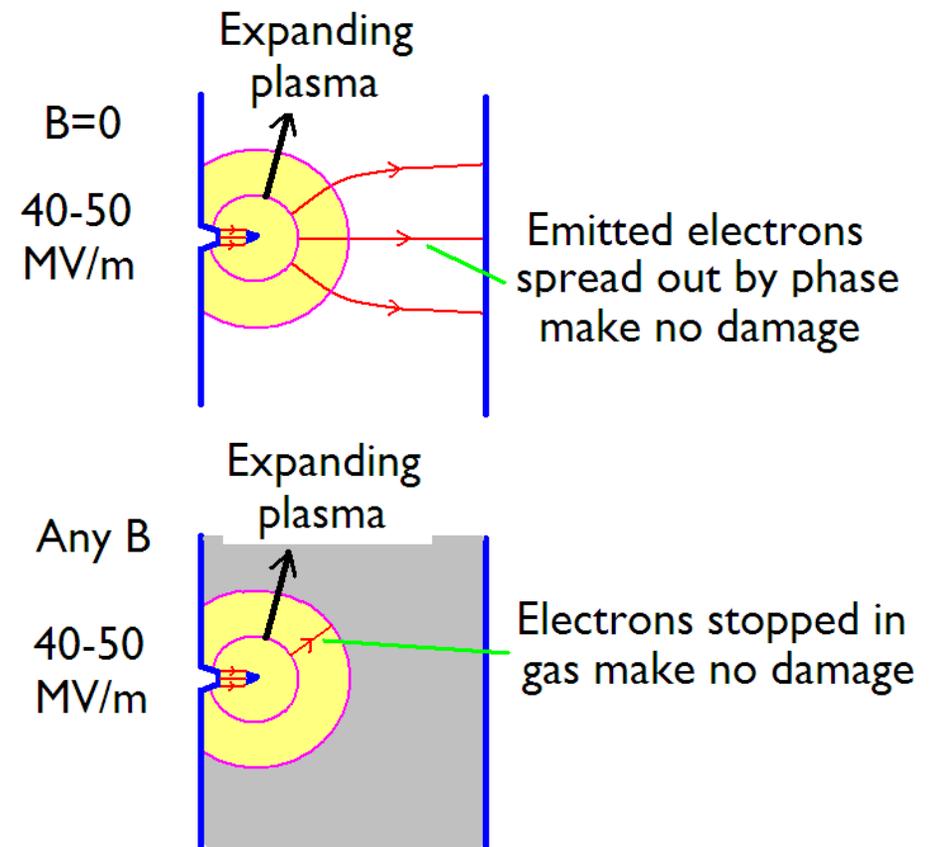
- Suggests the same mechanism of breakdown

”Conventional” Breakdown Mechanism



Norem Initiation

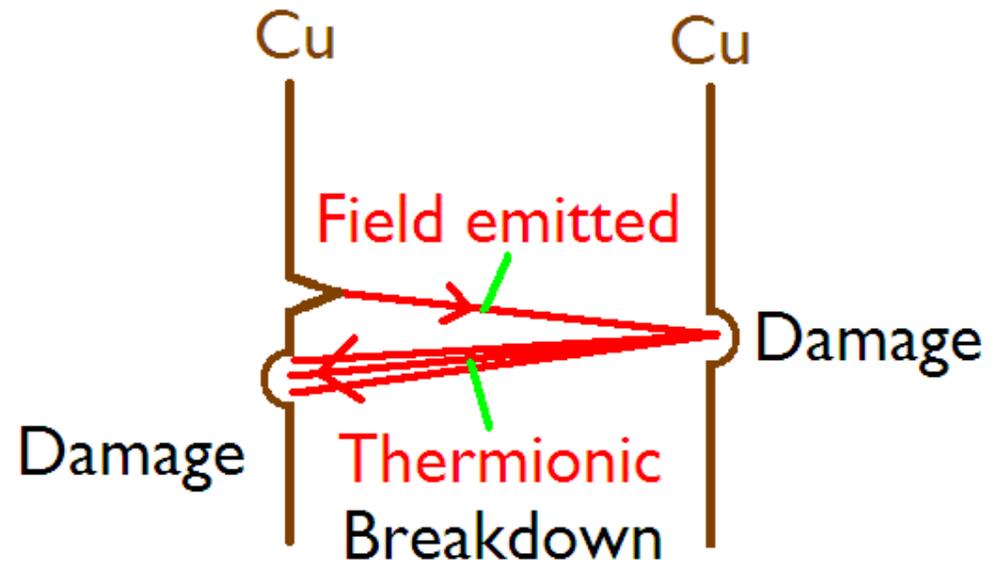
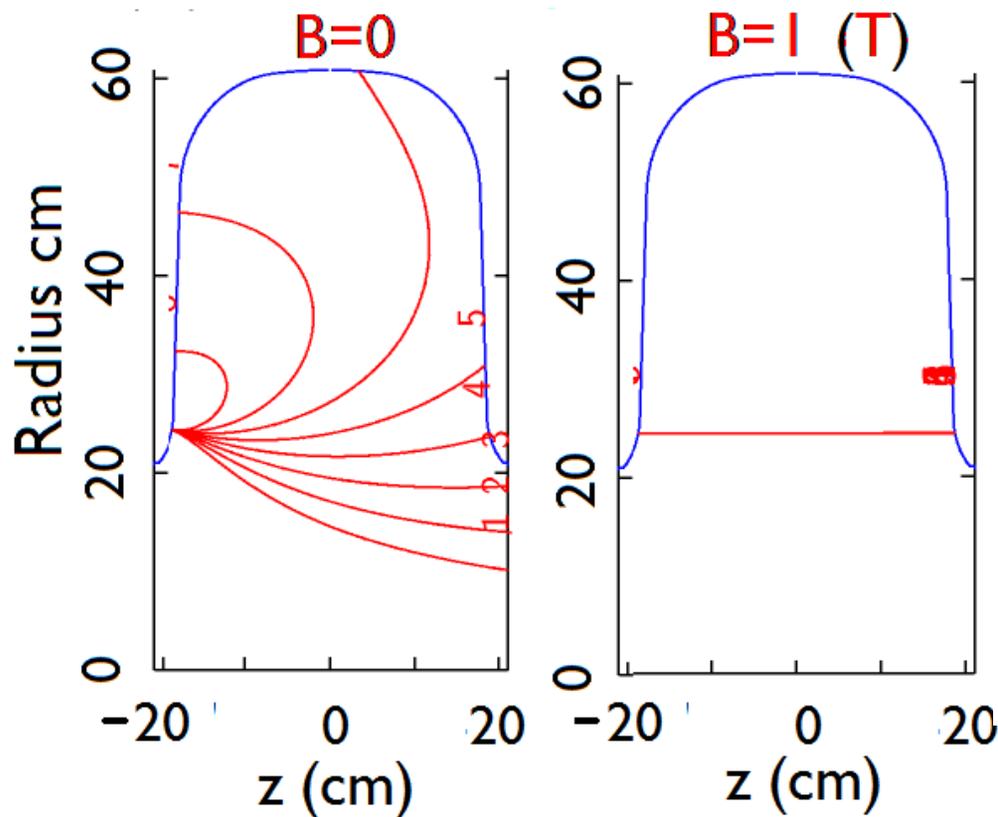
Spread and discharge →



- Similar maximum gradients imply same mechanism: electrons (stopped by gas) cannot play a big role
- Electrons from plasma are spread out with phase would explain why they play little role
- No B dependence in gas → No B dependence of this mechanism in vacuum

What is cause of magnetic field dependence?

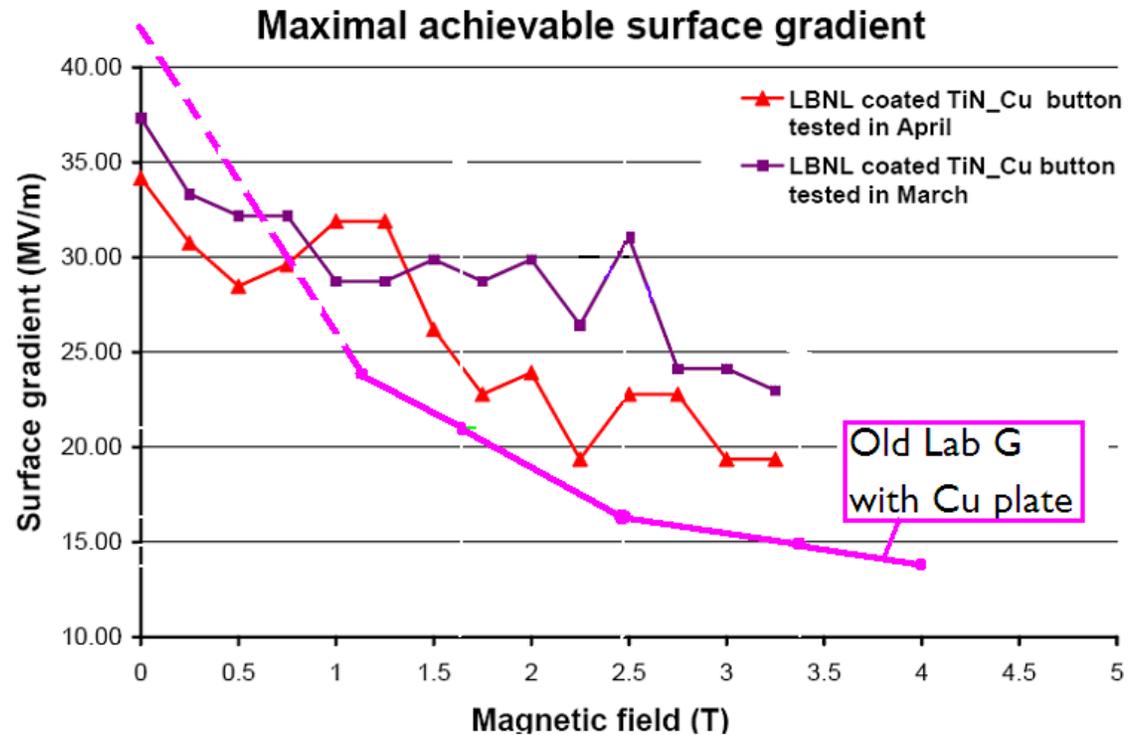
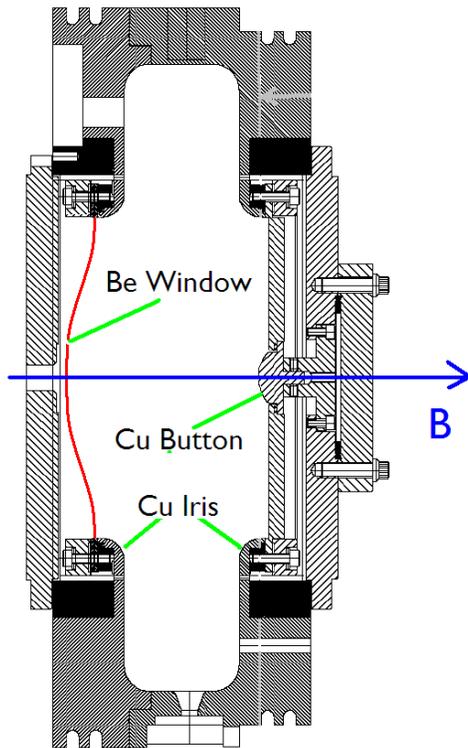
- At 4 T breakdown at 13 MV/m (c.f. 40-50 MV/m with $B=0$)
- Implausible that Norem mechanism ($F \propto \mathcal{E}^2$) works at 13 MV/m
- But B focuses the field emission electrons \rightarrow melt crater in other side
- Thermionic emission from molten Cu will now short out the cavity



Recent Pillbox Results

In the talk given by D Huang at the May 23 08 NFMCC Friday meeting

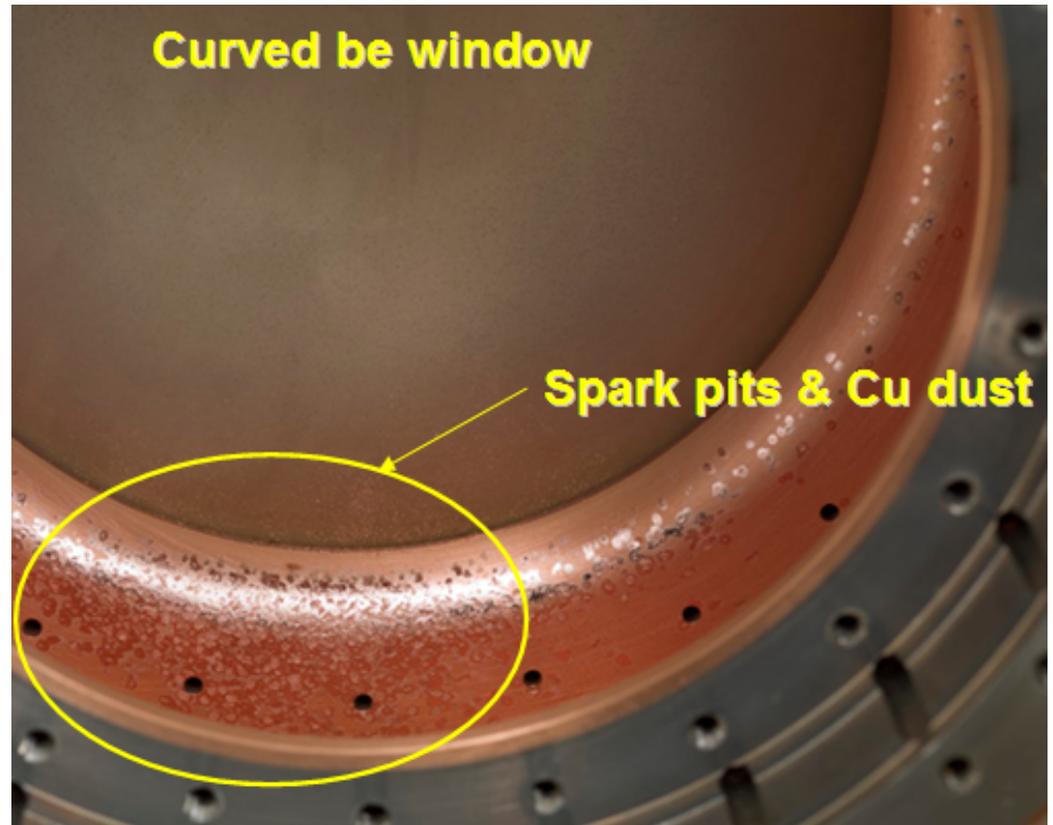
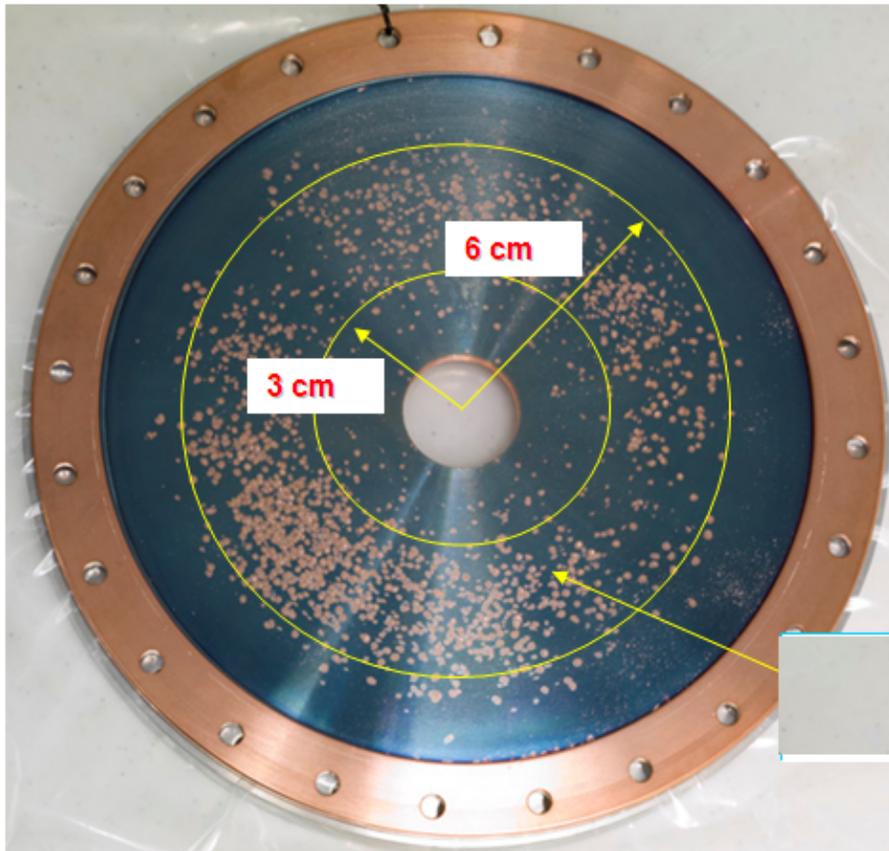
http://www.fnal.gov/projects/muon_collider/FridayMeetings/23-MAY-2008/Huang.ppt



- With magnetic fields, breakdown is observed at rf gradients on the button that are higher than those seen earlier with a copper window and no button.
- However, since the button gave a local field enhancement of around 1.7, breakdown elsewhere in the cavity was occurring at gradients that were equal of lower than those observed earlier with a copper window and no button.

Observed Damage

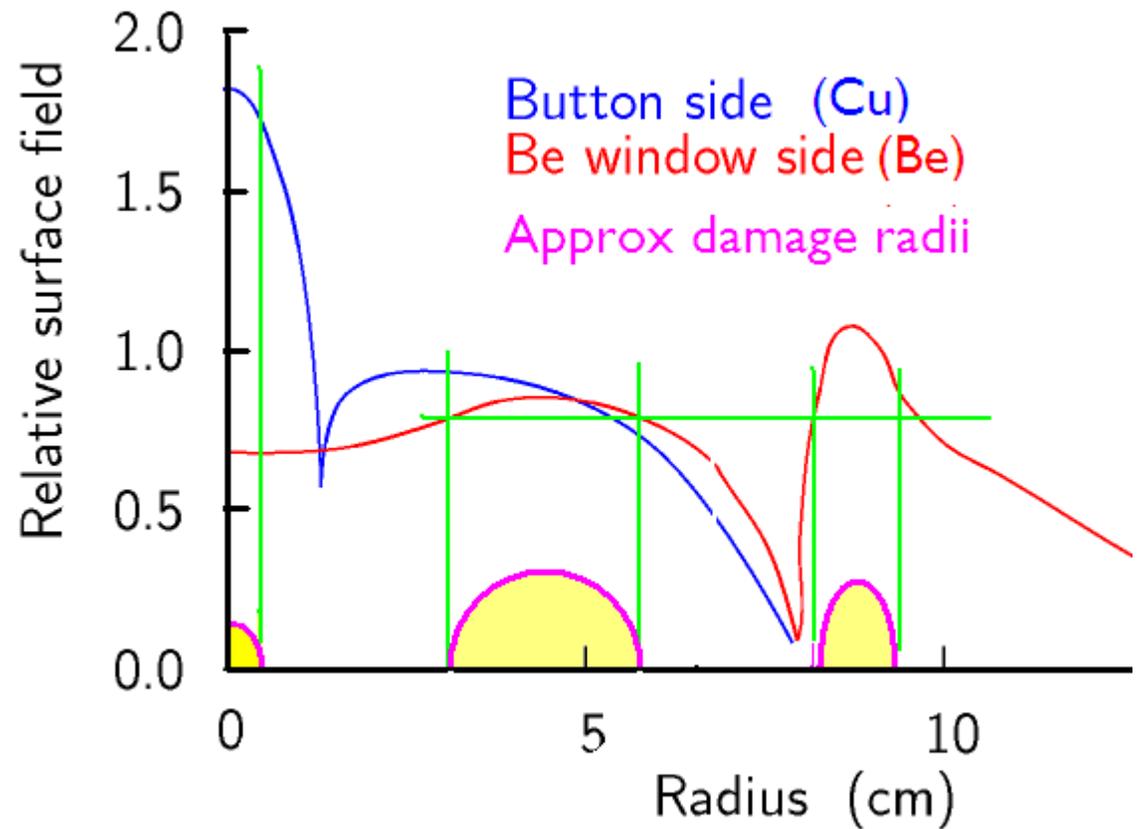
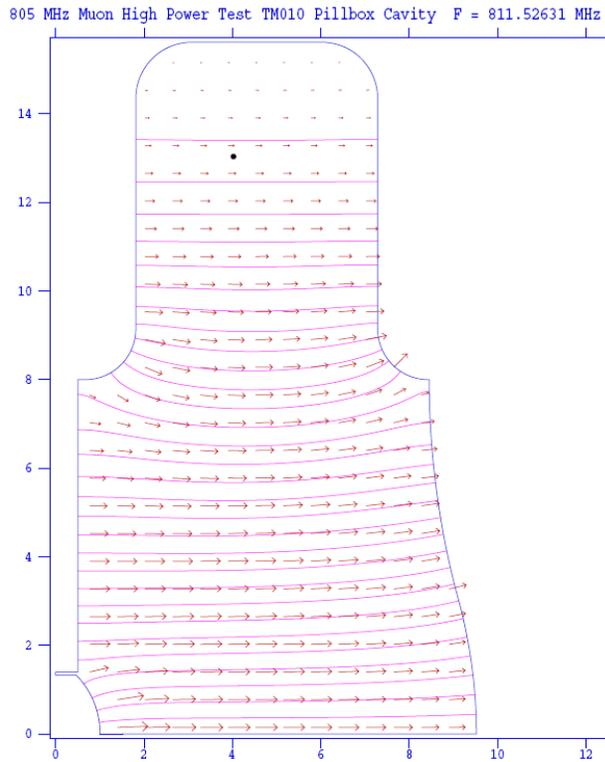
The following pictures of damage on the inside were shown



- Most damage is seen concentrated between 3 and 6 cm, and on the iris at approximately 8 cm
- There was a little damage (5 craters) on the button
- There was no observed damage on the Be window

Superfish Field calculations

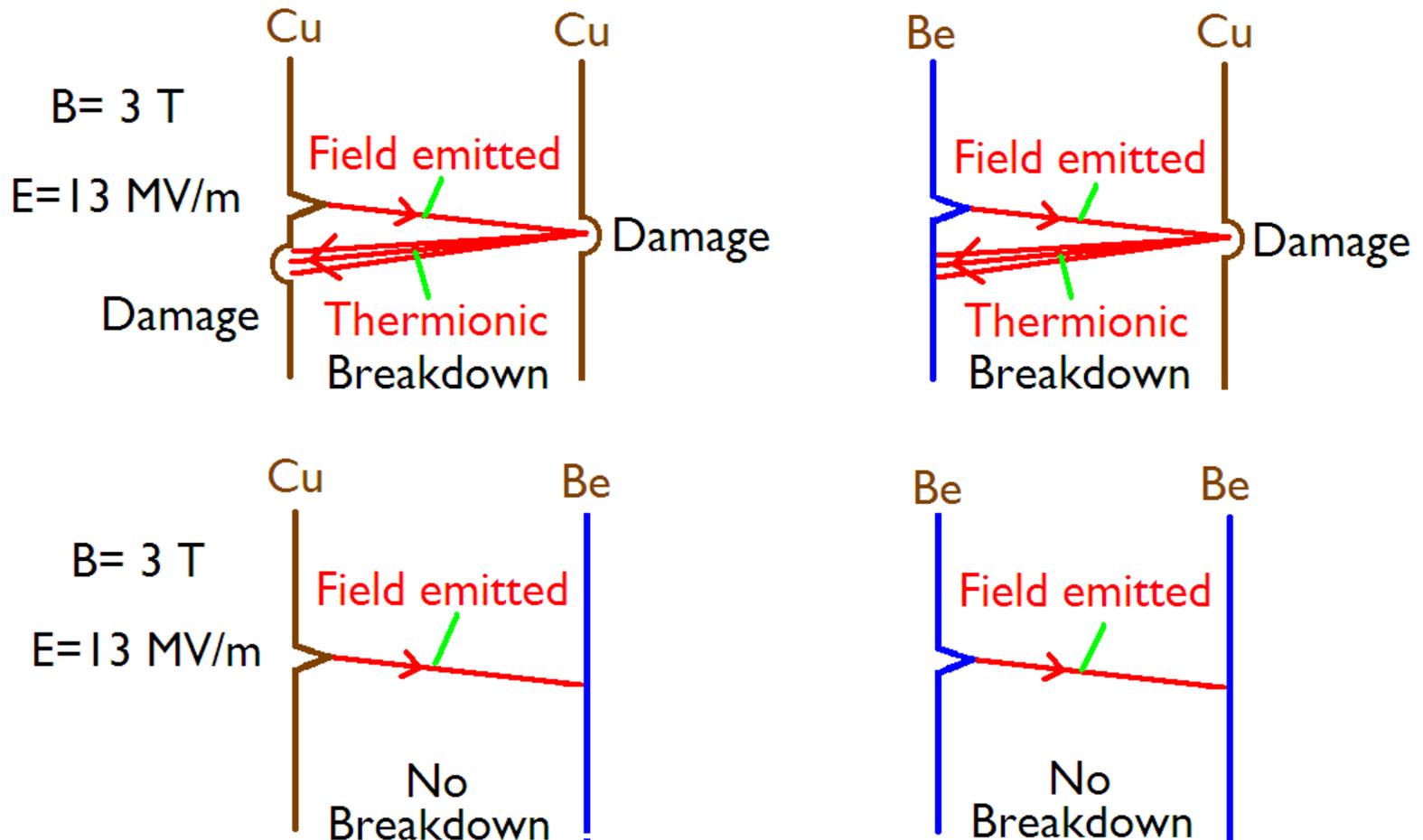
Derun Li's Superfish calculations give:



- At the maximum surface field on the copper button there is only minor damage
- Most of the damage (3-6 cm and at 8 cm) does NOT occur where the fields on the copper are maximal
- But does correspond to maxima in the surface field on the Be window opposite.

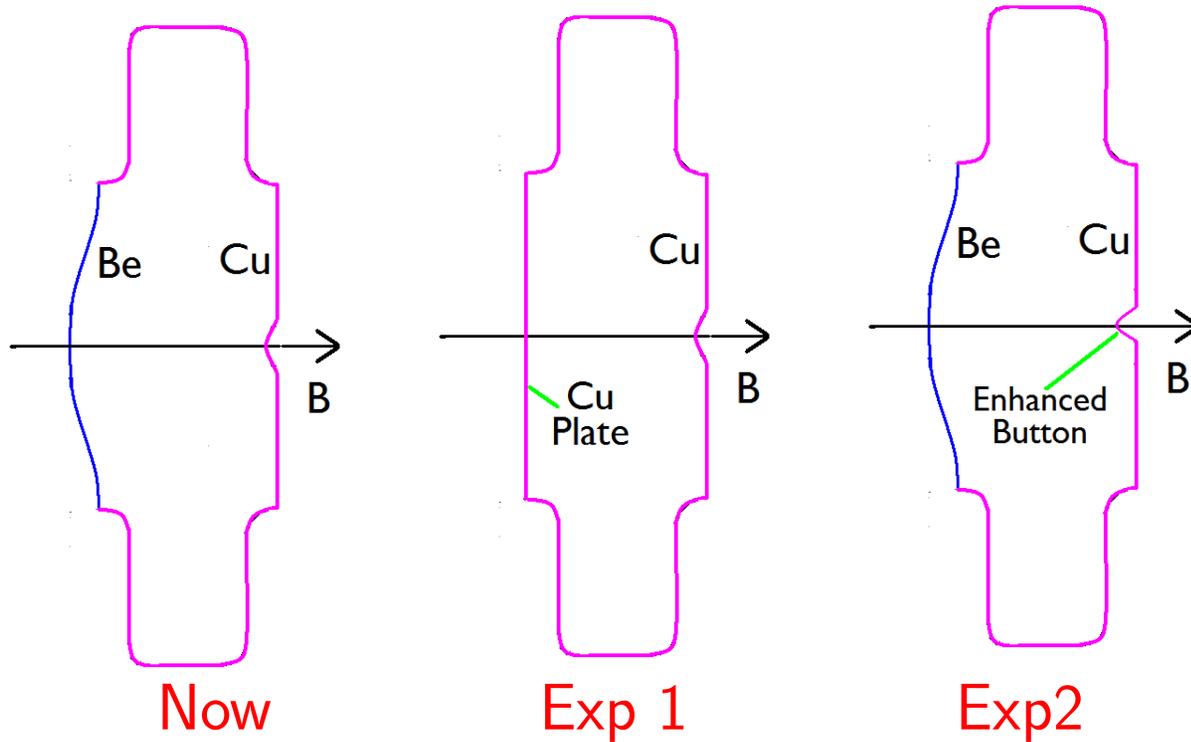
Why?

- A higher radial mode unlikely because the operating frequency was almost exactly as predicted by Superfish
- But the above mechanism with magnetic fields predicts what is observed



- With Be facing Cu: Damage only with high grad on Be side as observed

Experimental test of this hypothesis



Exp 1

1. Replace the button plate
2. Replace the Be window with Cu plate
3. Use similar button
4. Do not change anything else
5. Test with magnetic fields as before

Exp 2

1. Replace the button plate
2. Leave the Be window
3. Make sharper button
4. Do not change anything else
5. Test with magnetic fields as before

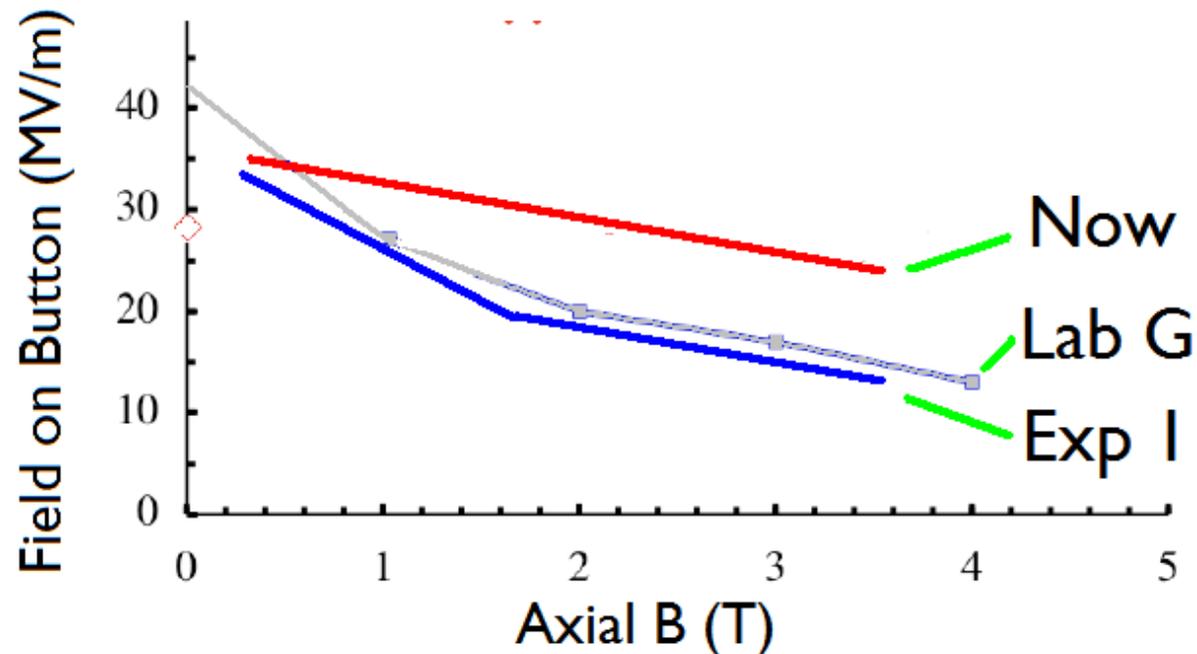
Experiment 1 with Cu plate

This hypothesis would predict that:

1. Breakdown button electric field gradients approximately 1.7 times lower than now, and similar to the G experiments.

Because the damaging electrons now coming from the button ($\times 1.7$ higher)

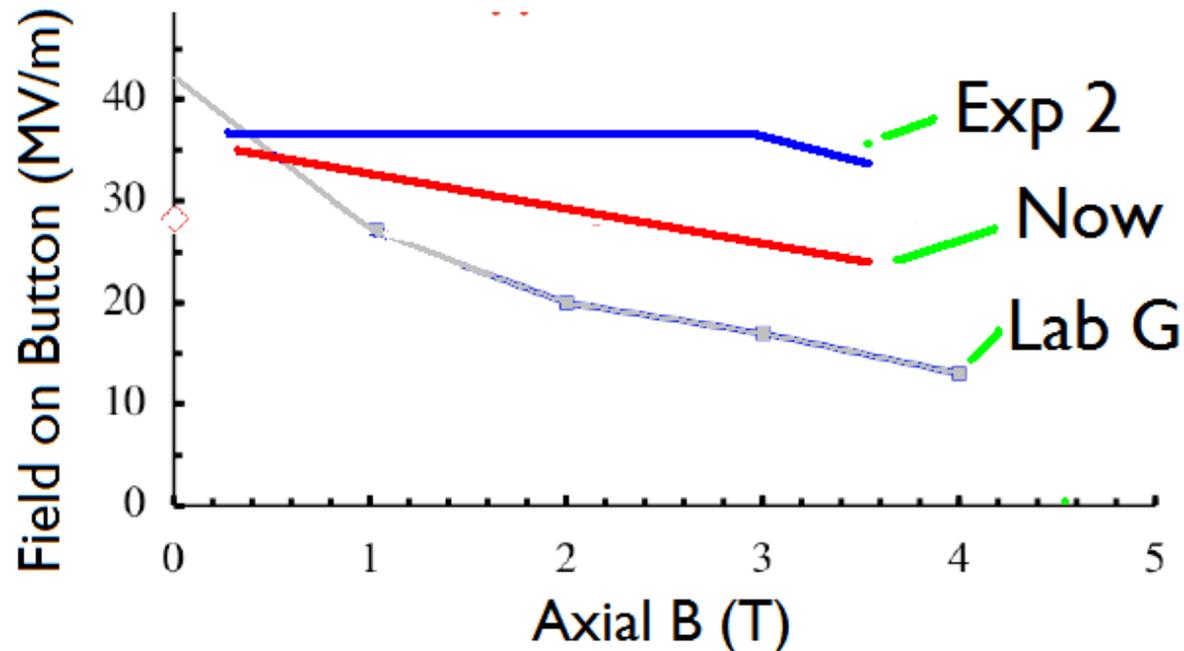
2. Breakdown fields sensitive to the button work function
3. Damage on the flat Cu window opposite to the button, and on the button, but nowhere else.



Prediction for enhanced button profile

This hypothesis would predict that:

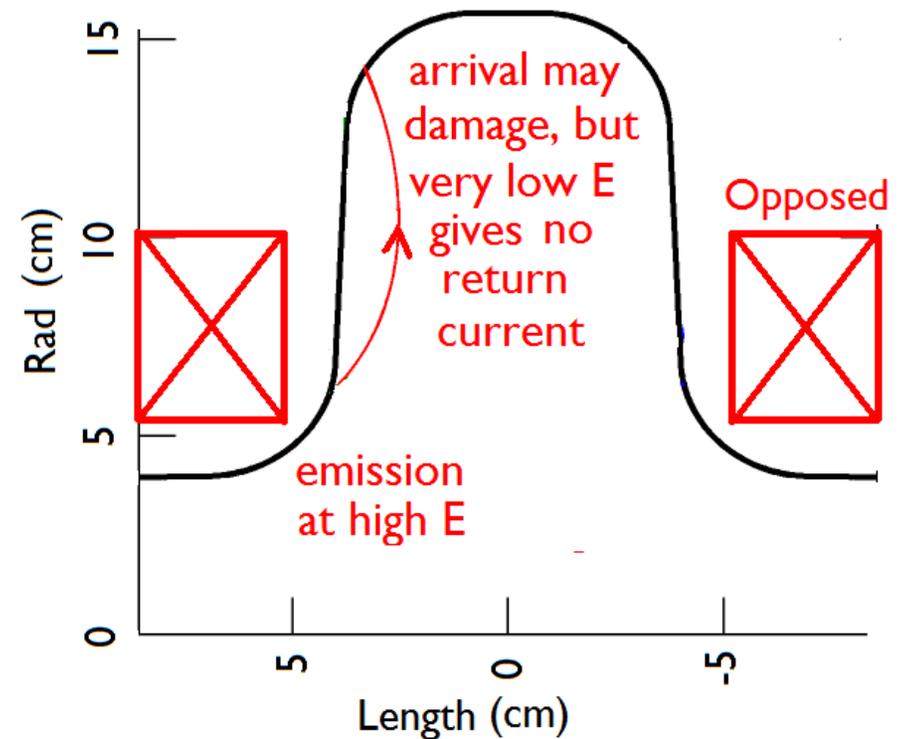
1. Little Field dependence to 3 T
Be breakdown gradient as now ($\mathcal{E}_{\text{Be}} \approx 12 \text{ MV/m}$ at 3 T),
Button grad $\mathcal{E}_{\text{button}} = 3.4 \times 12 = 44 \text{ MV/m} \approx$ button breakdown for B=0
2. Breakdown sensitive to Tensile strength of button material
3. Damage on the button plus a little on the button support plate



Implications

- An all Be Cavity should show no \mathcal{E} drop with B
Be does not suffer damage from focused field emission electrons
- Magnetic insulation should also show no \mathcal{E} drop with B
Stops acceleration of field emitted electrons
- But neither should raise \mathcal{E} for B=0
They do not stop the Norem mechanism

- The simple "Coil in Iris" Fix might work
Field emitted electron have less energy
and fall on parts with little \mathcal{E}
Even if some damage,
cavity will not be shorted out



Conclusion

- Results presented by Huang are easily understood given the proposed model
 - Field emitted electrons from the Be are focused and damage Cu surfaces
 - Return electrons from the damaged surface short the cavity fields
 - Damage with B only opposite high Be gradient ($r=3-6$ cm)
 - Little breakdown induced by the Cu button at $B \geq 1T$
- Model predicts very different behaviors in two proposed experiments
 1. New button support plate, and copper plate instead of the Be window
 - Breakdown with magnetic fields at lower gradients
 - Dependence on work function of button materials
 - Damage only on the button and plate opposite the button
 2. Button with higher field enhancement but same Be window
 - Little dependence of breakdown on magnetic field
 - Dependence on strength of button materials
- Implications
 - All Be or Magnetic Insulation should remove B effect
 - Simple coil in iris may also work