RF for MICE in the MTA

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MuCool Mtg.
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Muon Collaboration

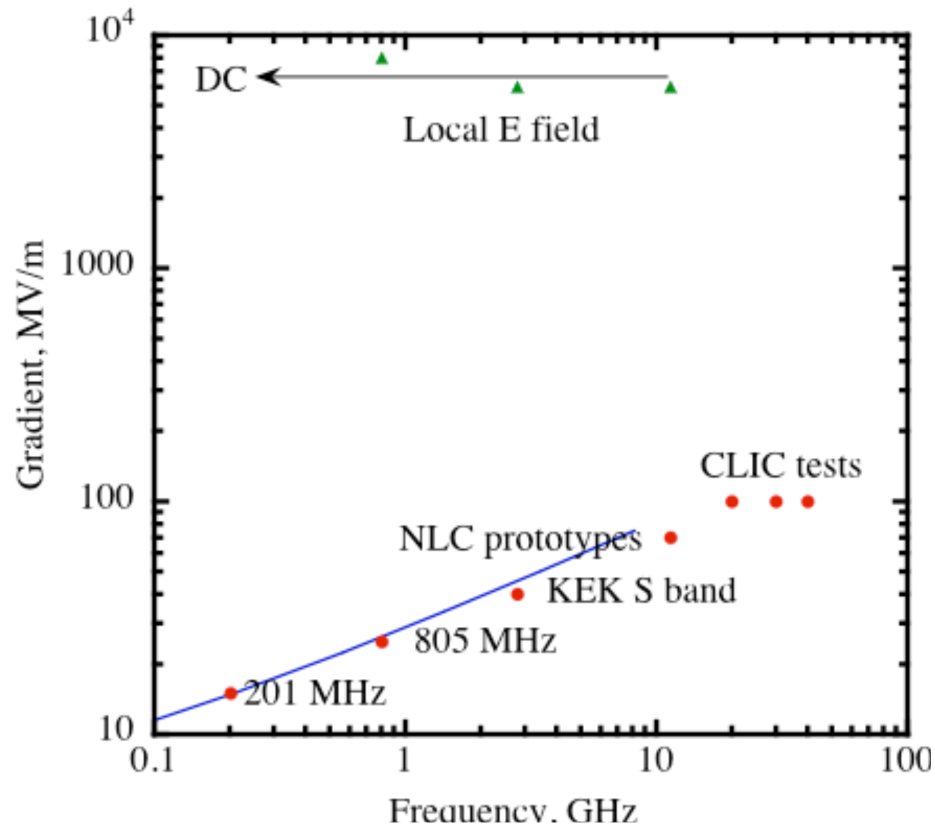
MICE and the MTA experimental program

There are things we should understand for MICE
for ν sources
generally.

- The stored energy of the 201 MHz cavity is higher than the 805 MHz cavity
    - more damage?
- "Parallel" faces of windows and fields not fully understood.
- Dark Current induced x ray backgrounds.
- Relation between magnetic fields and maximum operating gradient.
- Radiation levels produced during conditioning of the 200 MHz cavity.
- How can cavity performance be improved?

Stored Energy, Geometry issues

- The 201 MHz cavity stored energy is about equal that of the open cell cavity.
- Parallel electric and magnetic fields mean the discharge may not propagate very far in the radial direction, and energy deposition may be more localized.
- We had some experience with this in the open cell cavity, but do not understand the details.
- Be windows may be stronger.



Radiation levels during conditioning are important for MICE.

- Shielding requirements and the floor layout are determined to some extent by the operating conditions during the conditioning period.

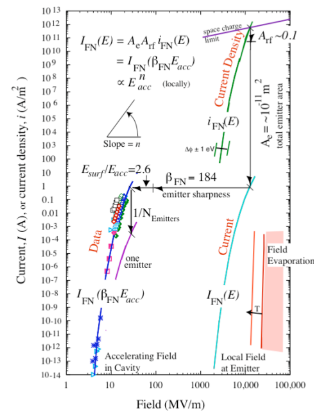
- At 10 MV/m, the cavity has a stored energy of about 60 J, with a capacity to produce 3 MeV gammas. A 1 Hz breakdown rate gives the following radiation levels, if all energy goes into x rays.

Stored energy =	60	J
Discharge rate =	1	Hz
1 disch / sec =	0.06	kW max into radiation

	inline	perpendicular	
conv fact =	1.00E+06	1.00E+04	(rem/hr) / (kW m^2)
Rad level =	6.00E+04	6.00E+02	rem/hr
Working dist =	3	3	m
unshielded =	6667	67	rem hr
1 m concrete =	1.00E-04	1.00E-04	
Rad level =	670	7	mr/hr

- Each breakdown event should produce ~16 Rads at the surface of the cavity.

Magnetic Field Effects



- The current densities that are produced by emitters are enormous.

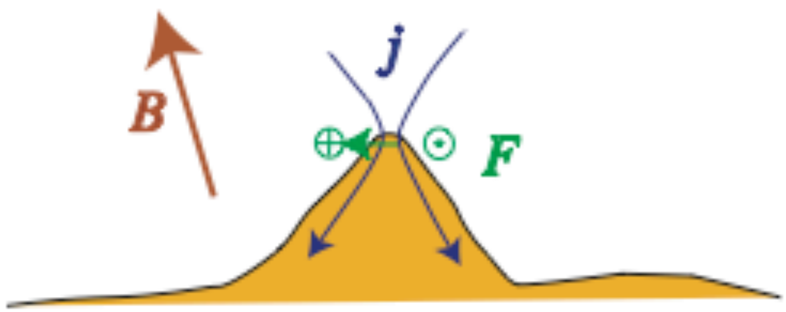
  Lab G data showed that emitters produce:

  0.1 mA currents

  $10^{10} - 10^{11}$ A/m^2 current densities

  These are produced in sharp impacts a few 100 ps long.

- Geometry requires that currents flow in a variety of different directions.



- Pressures $\boldsymbol{P} = \boldsymbol{J} \times \boldsymbol{B} =$ (~10^{10} A/m^2)(~3 T) (~ sin 45^{O}) = ~20000 MPa.

  = ~50 times tensile strength

However:

- We are already within a factor of ~two of where we want to run, and we should be able to reduce the field emission currents by a large factor.

Can the stresses be so high?

- The tensile strength seems to be much higher for microscopic samples.

- Field ion microscopes operate at fields much higher than the macroscopic tensile stress limit, with samples that are on the order of 100 nm in diameter . They frequently break, however.

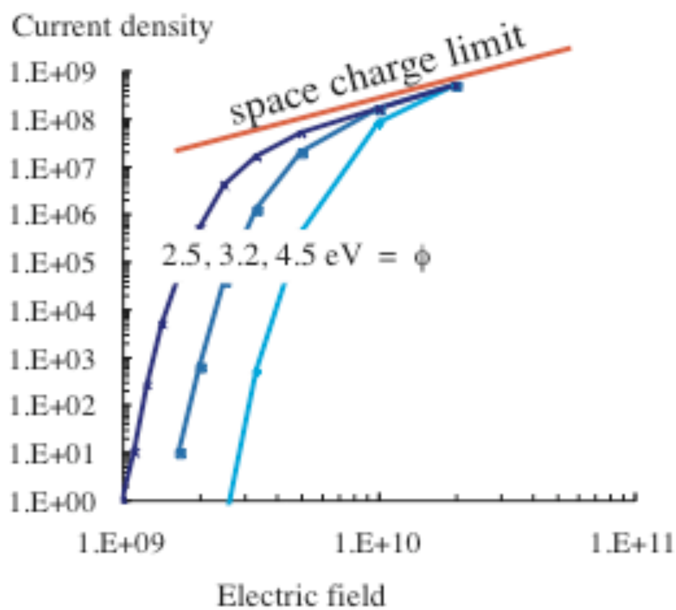
	Tensile strength	FIM Operating stress	Ratio
Be	310 MPa	18000 MPa	30
Cu	350	4000	10
W	600	45000	76

- from: *Stress, Strain and Strength*, R. Juvinall, McGraw-Hill, (1967)

  "The stress required for fracture ranges from about one-fifth to as little as one-thousandth of the theoretical cohesive strength of the lattice structure because of submicroscopic flaws or dislocations. The only exceptions are short lengths of fine wire that have been "grown" in the laboratory as single dislocation-free crystals. With these so-called *whiskers*, it has been possible to approximate the theoretical strengths."

Limits on field emission.

- Magnetic field effects are sensitive to high current densities. At the highest fields one would expect to see the space charge limit determine the current density.



- If $F = J \times B$, and $J \sim E^n$, then for a maximum force, $F_{max} \sim E^n B$, we have $E \sim B^{-1/n}$.

The trend of the E_{max}(B) data is consistent with *J* x *B* effects.

- ***j*** x ***B*** forces are sensitive to current density. The emitters, and the total currents they produce, may not be large.

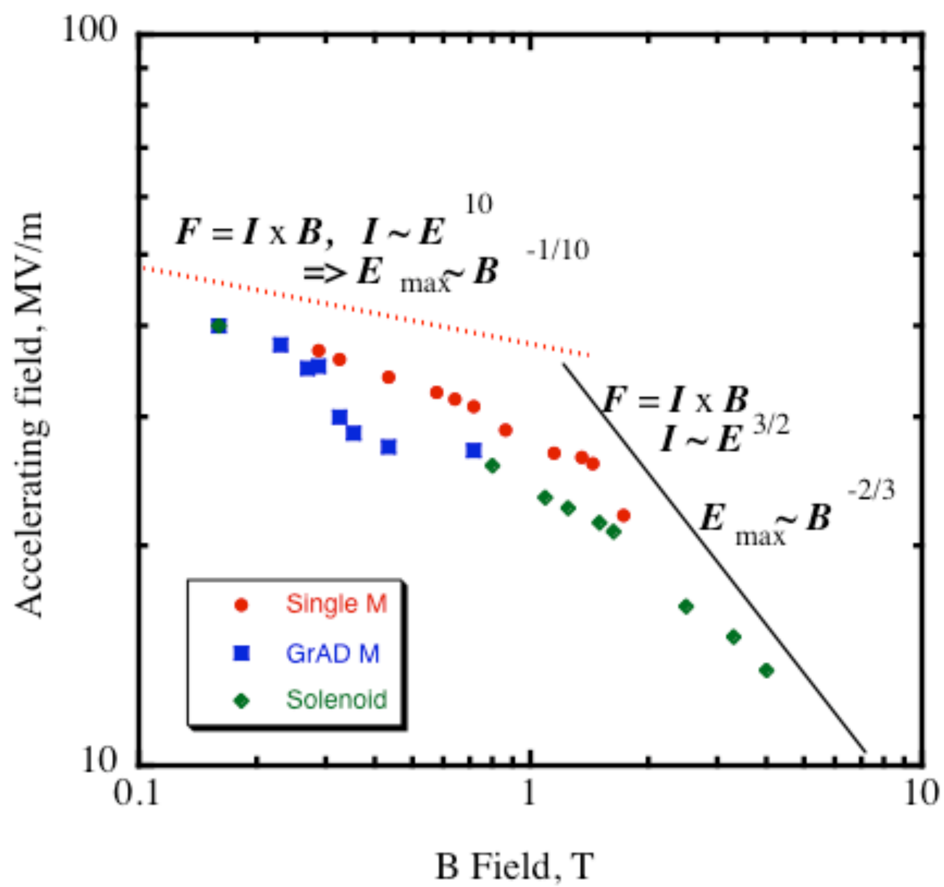
- Assume:
  $F = I \times B$
  with $I \sim E^n$
  and $(3/2 < n < 10)$
  normal max field: $n \sim 10$
  space charge limit: $n \sim 3/2$

- This gives:

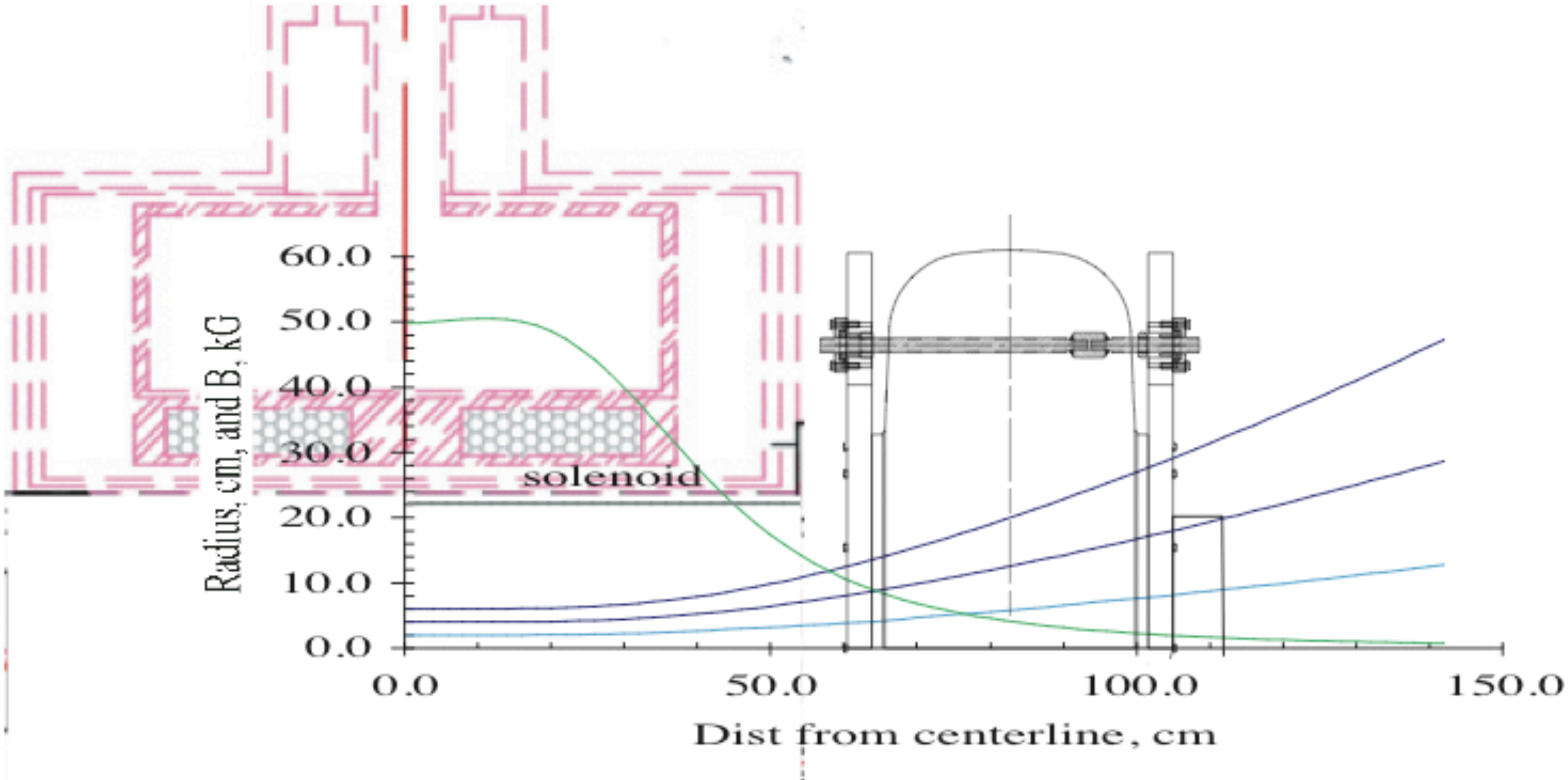
  $E_{max} \sim B^{-2/3}$ and/or $B^{-1/10}$

- The two limits can result from:
  different mechanisms
  different populations of emitters
  different conditioning techniques.
  trouble conditioning (probable).

- Lots of loose ends.



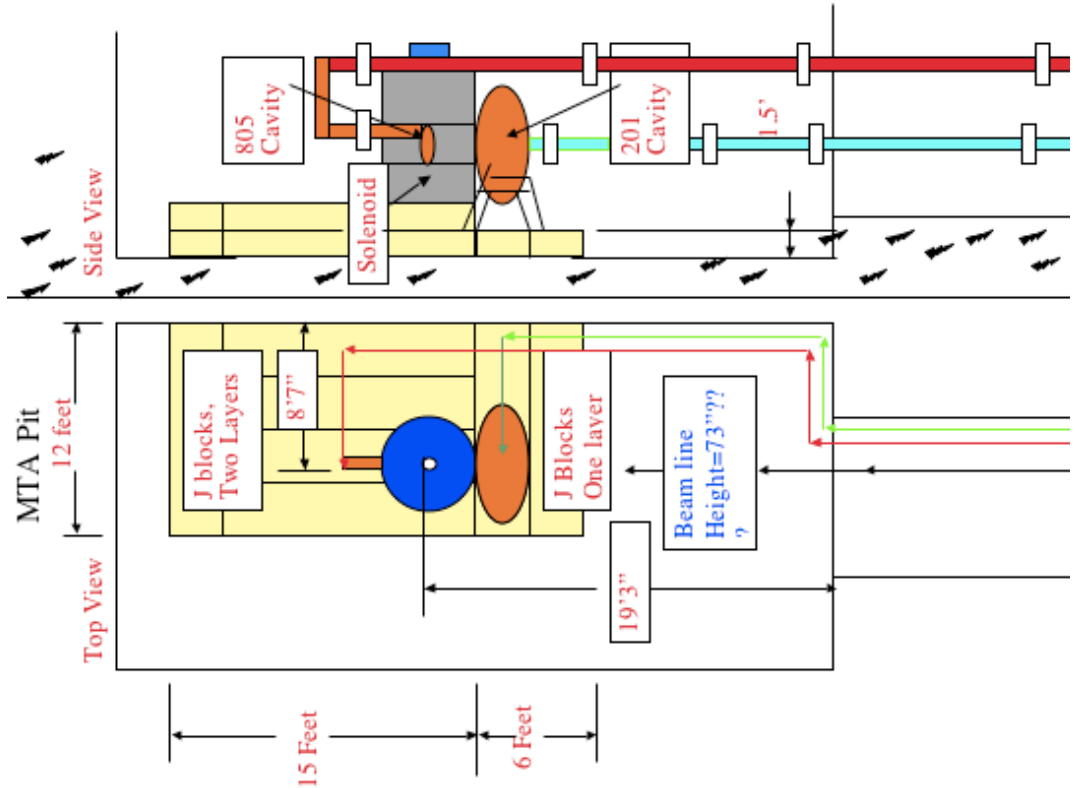
The solenoidal fringe field: weak and inhomogeneous

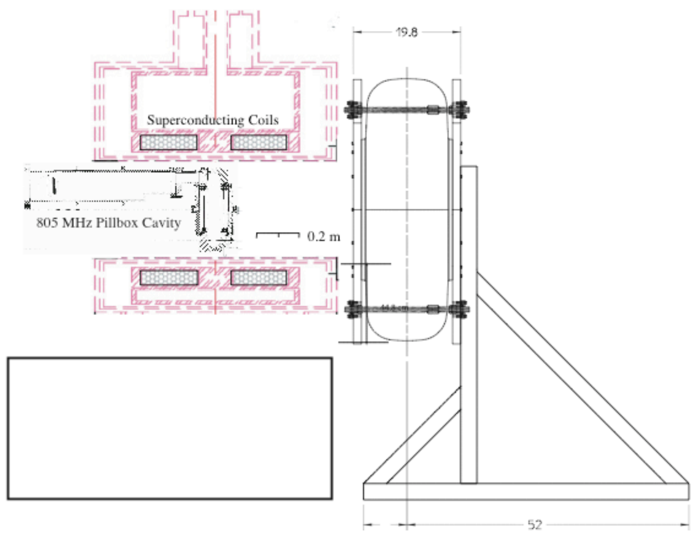


- Solenoidal field effects on gradients will be hard to study.
- We can track electrons back to see where they come from.
- Study of $\boldsymbol{E}_{\max}$ vs. $\boldsymbol{B}$ will have to be done in the pillbox cavity for now.

Layout in the MTA

- No final designs



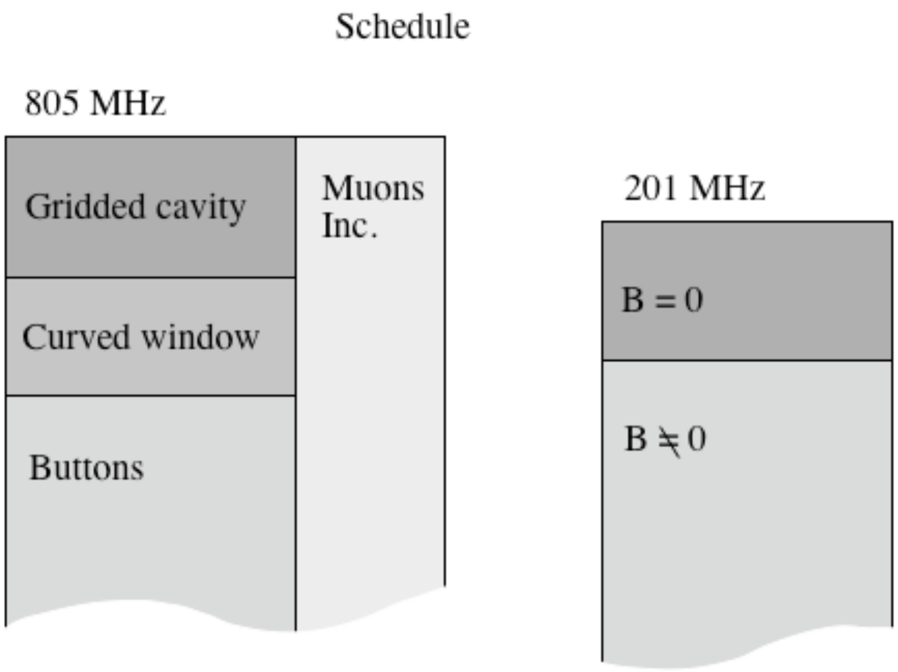


Experiments and schedule

- Experiments
  - Measure background rates during conditioning with B field
  - Quantify damage
  - Measure Production distribution of dark current
  - Study Different materials

- Geometries
  - 805 MHz pillbox
    - Aluminum grid
    - Be windows
    - Sample insertion
  - 201 MHz pillbox
  - High pressure cavity
  - Open Cell cavity (?)

- Schedule at right.
  - Starts around Jan 1
  - Moves at a deliberate pace.



Summary

- We have important work to do in the MTA.
- We don't understand everything we have seen in Lab G, but things may be falling into place.
- In principle, coatings can reduce x ray backgrounds, and raise the maximum E fields with a solenoidal field.
- The basic physics is not well understood.