MuCool Test Area (MTA) RF program review

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Outline

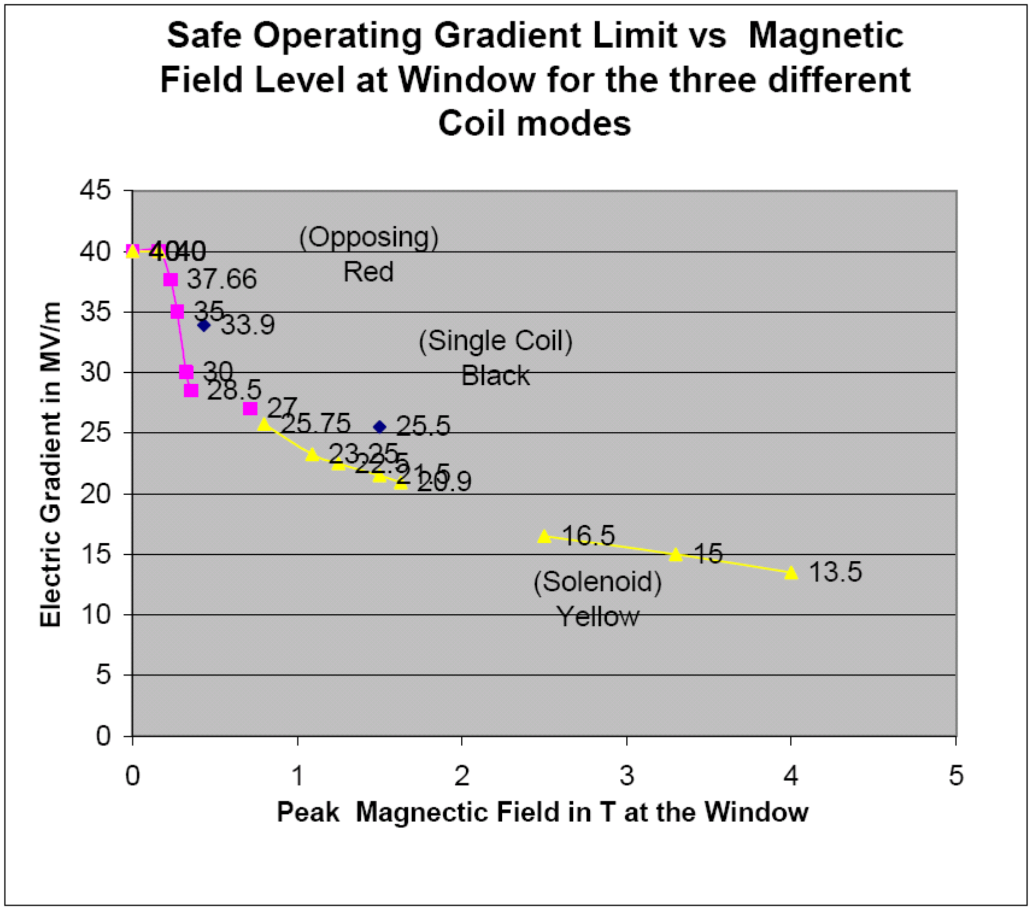
- **Introduction**
  - RF test program
  - B field effect
  - Tests done
- **805 MHz cavity test**
- **201 MHz cavity test**
- **Muons Inc. high pressure RF cavity test**
- **Summary**

Introduction: RF test program

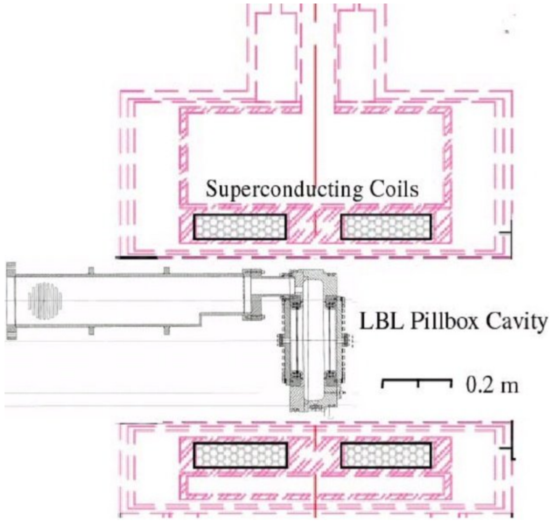
Fermilab has the primary responsibility to carry out the RF Test Program

- **Study the limits on Accelerating Gradient in NCRF cavities in magnetic field**
- **It has been proposed that the behavior of RF systems in general can be accurately described (predicted) by universal curves**
  - Electric Tensile Stresses are important in RF Breakdown events
- **This applies to all accelerating structures**
- **Fundamental Importance to both NF and MC**

Introduction: B field effect



- **Data seem to follow universal curve**
  - Max stable gradient degrades quickly with B field
- **Re-measured**
  - Same results



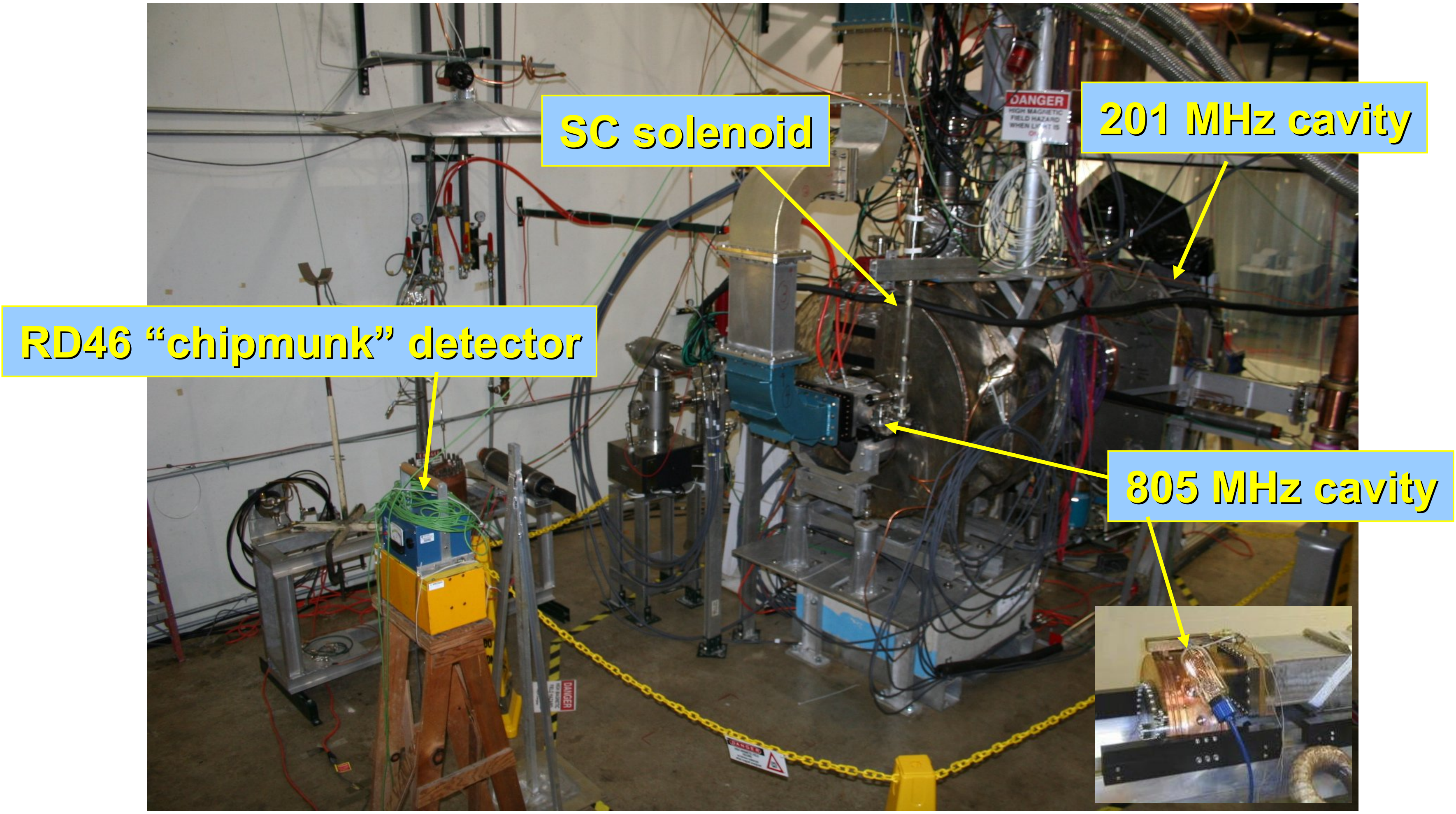
Introduction: possible solution

- **Three Approaches to a Solution**
  - Reduce/eliminate field emission
    - **Process cavities utilizing SCRF techniques**
    - **Material Studies**
  - RF cavities filled with High-Pressure gas (H_2)
    - **Utilize Paschen effect to stop breakdown**
  - Magnetic Insulation
    - **Eliminate magnetic focusing**
      - Not Yet Tested

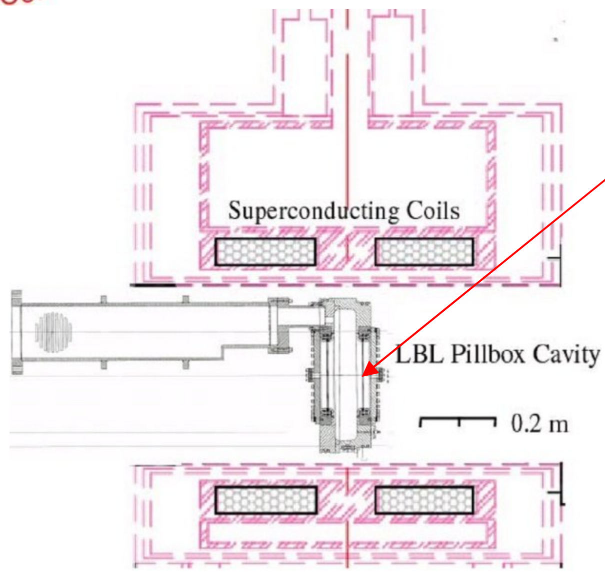
Introduction: tests done

- **805 MHz Cavity button material test:**
  - *Goal*: find materials and coatings that can withstand high peak surface field in strong magnetic field
  - *Approach*: use 805 MHz cavity to test buttons made of various materials
- **201 MHz cavity curved Be window test:**
  - *Goal:* Find the upper-limit that Be window is able to withstand w/, w/o magnetic field
- **High pressure RF cavity test with H_2 fill:**
  - *Goal*: Study breakdown properties of materials in H_2 gas w/ magnetic field

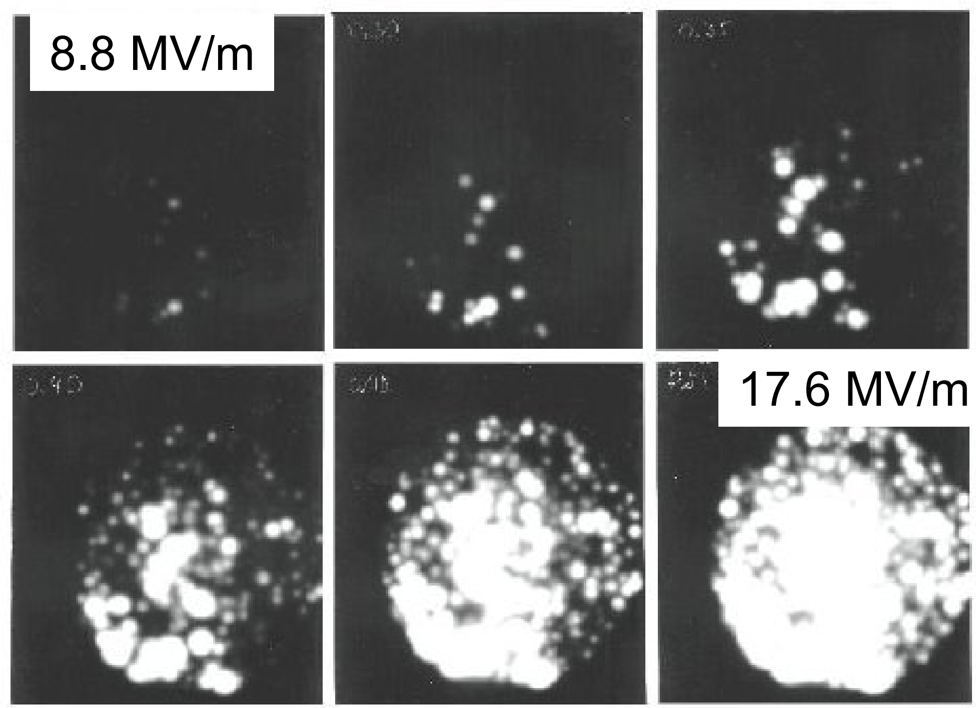
MTA Hall: before reconfiguration



805 MHz: imaging (2006)



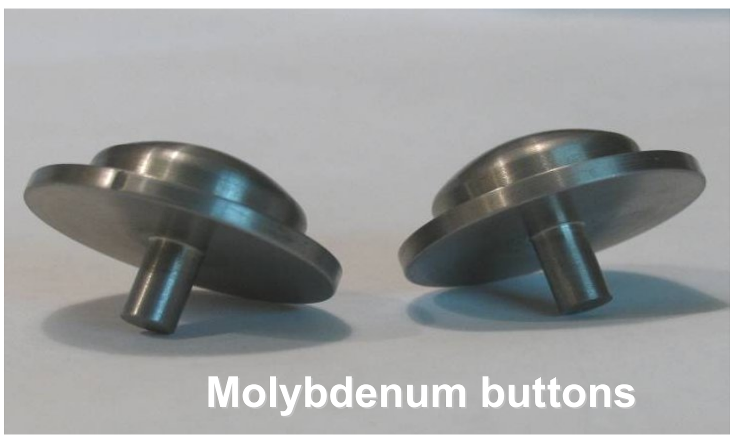
- **Insert Polaroid film near the Be window**



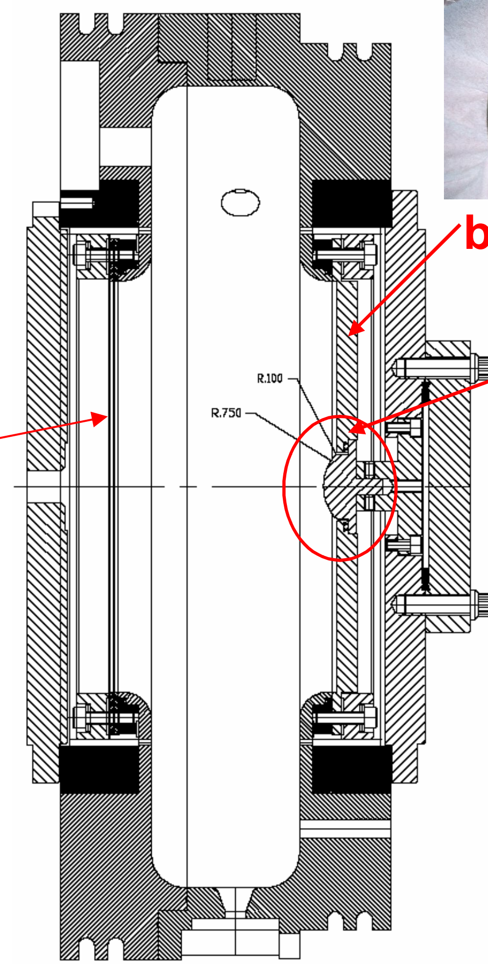
- **Direct pictures of how field emitters on the Be window change with RF field can be taken**

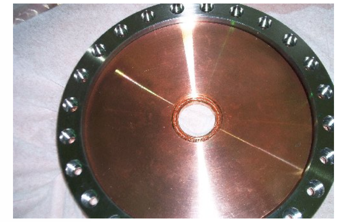
805 MHz: button test (2007 & 2008)

- "Button" system in pillbox cavity designed for easy replacement of test materials
- Tested so far: TiN-coated Cu & Mo, bare Mo and W
- To be tested: Cu (electro-polished & unpolished), Be
  - **More to come**



Molybdenum buttons



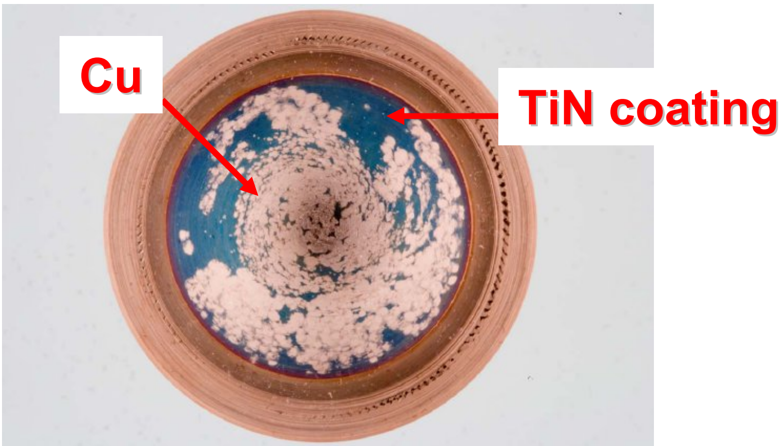


(*1.7x* field enhancement factor on button surface)

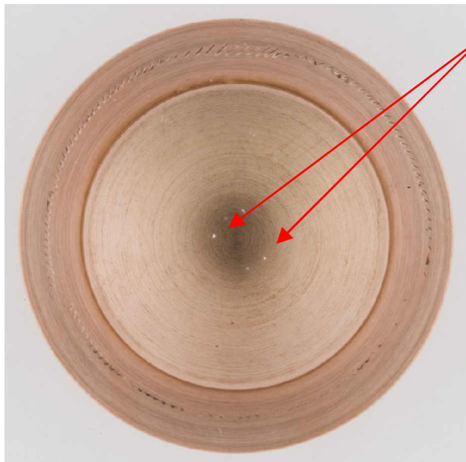
Button test: coating issue (Pictures by Fermilab media service)

- After 1st (Fermilab-coated) TiN_Cu button test, observed ≈80% of TiN coating lost
- LBNL then coated 2 new TiN_Cu buttons via 2 different techniques
  - LBNL coating gold, unlike Fermilab's (color determined by thickness)
- After test of LBNL TiN_Cu button #2, observed smooth surface w/ no coating loss

Old (FNAL-coated) button

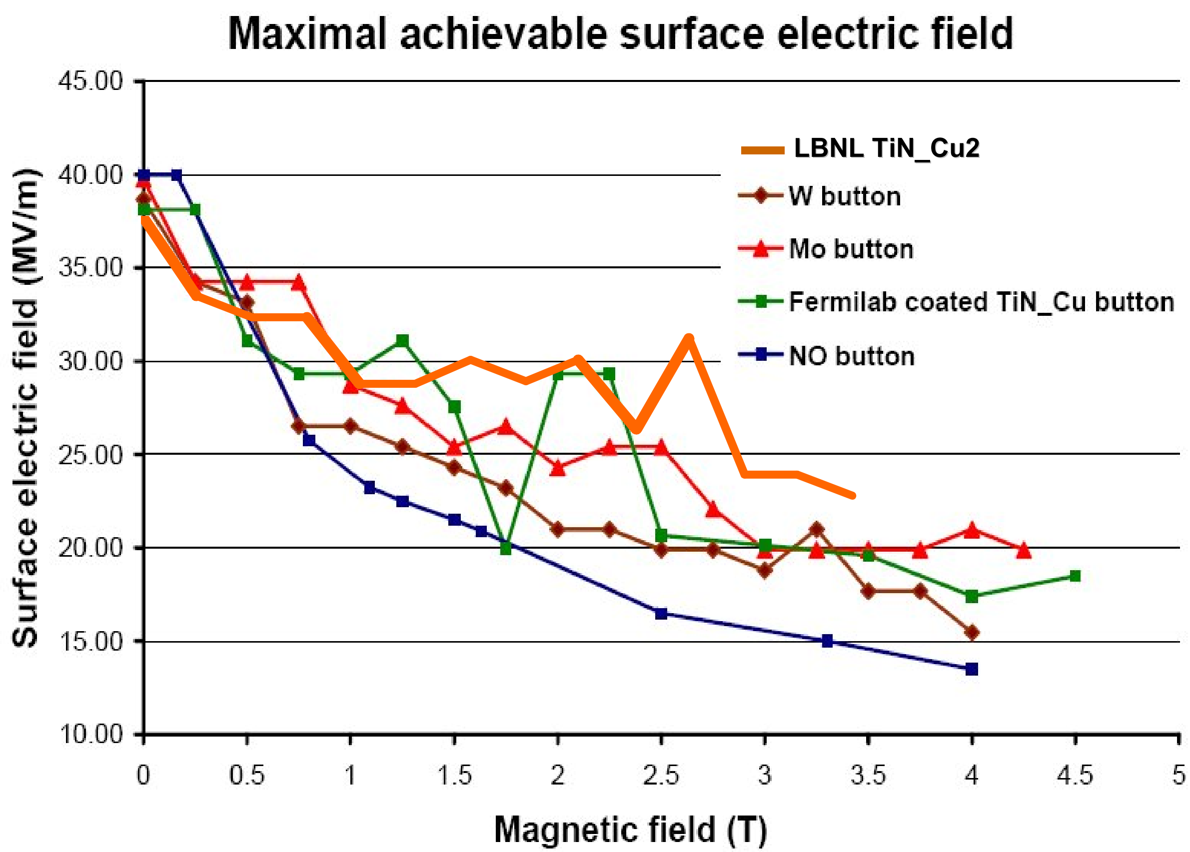


New LBNL button #2



- A few pits

Button test results: 2007 & 2008

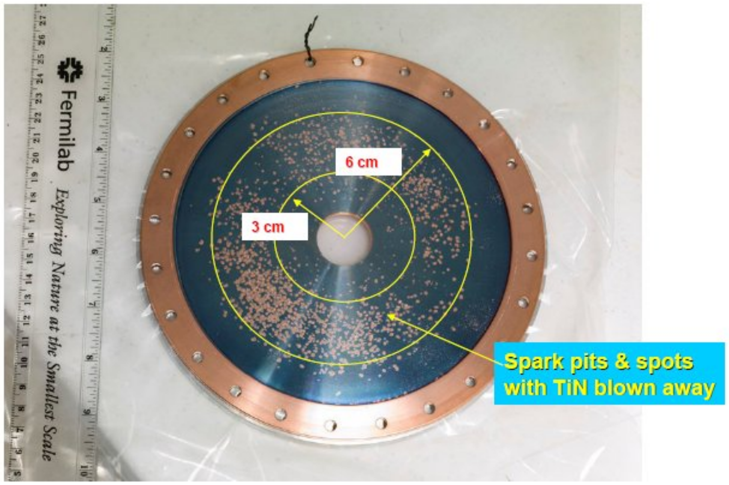


- TiN_Cu data:
  - less stable than rest, maybe due to loss of TiN coating
- Mo data:
  - generally above W data
  - Mo appears to withstand higher surface field than W

- **2008: New LBNL coated TiN_Cu button:**
  - data appear more stable than FNAL-coated **TiN_Cu**
  - better performance at high magnetic field

Button test: cavity damage

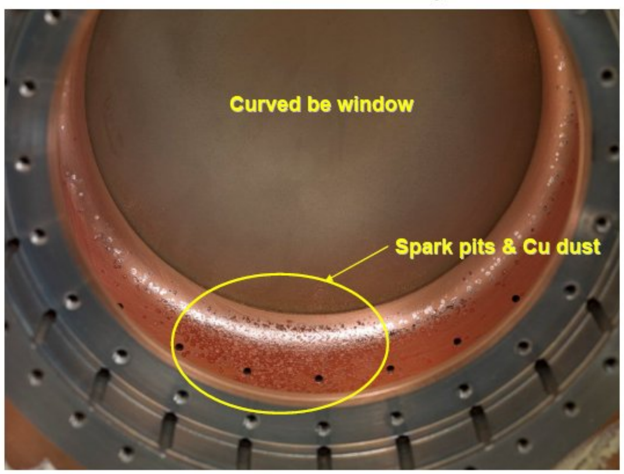
Button holder



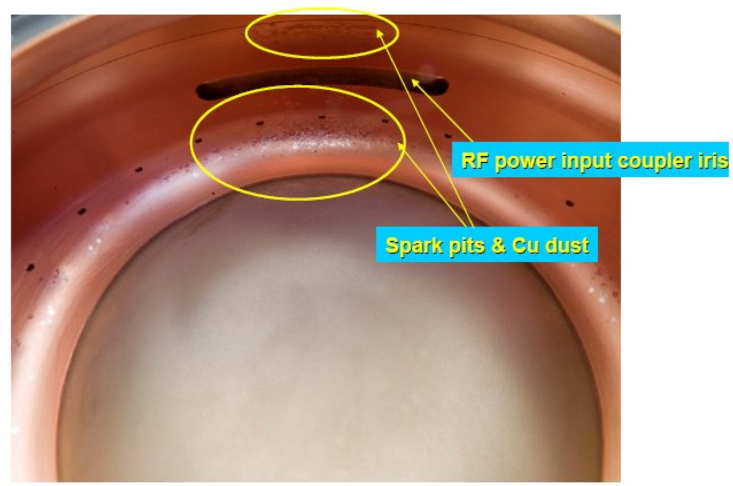
- After opening up the cavity, we observed the button holder and the inner surface of cavity were damaged by sparks, thus the test results may not be accurate

- The cavity is being remanufactured by JLab now

Inner surface of cavity

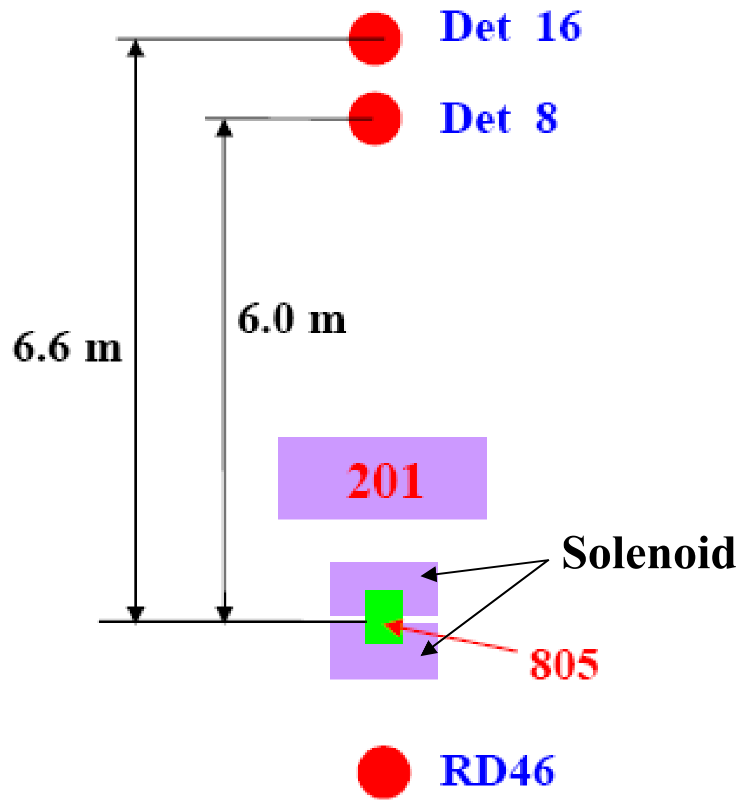


Inner surface of cavity

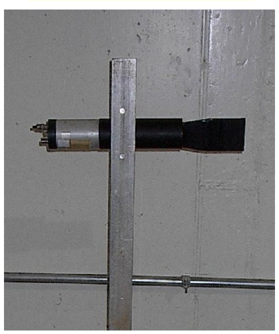


Button test: x-ray detectors

- 10 x-ray detectors in MTA hall
  - 9 fast scintillation counters, counting rate limit: ~ 10 MHz
  - 1 NaI-crystal energy measurement, counting rate limit: ~ 1 MHz
- Detectors frequently used in button tests:
  - #8 (small scint. paddle)
  - #16 (NaI crystal)
  - RD46 “chipmunk” (measuring integrated x-ray dose in 20 sec.)

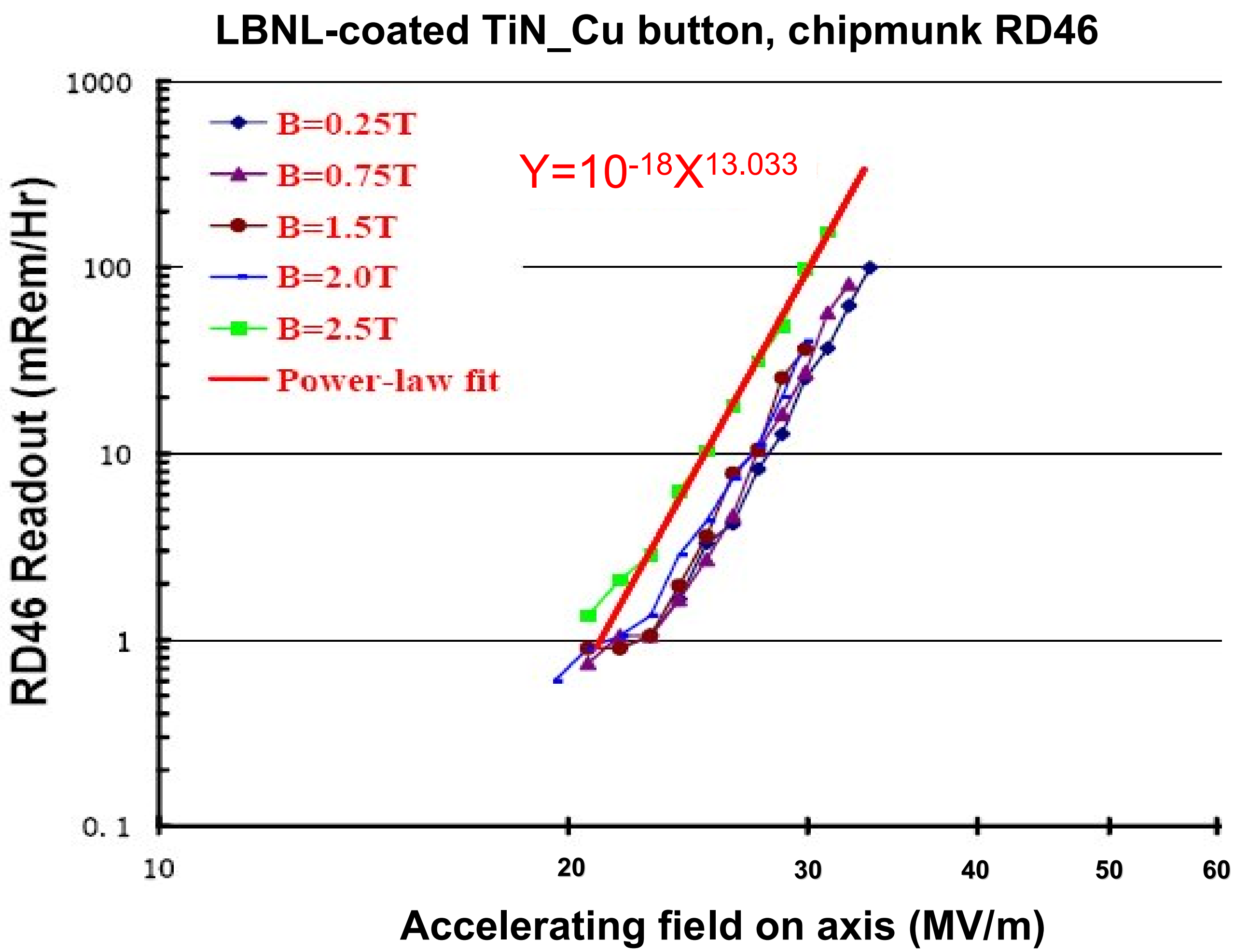


Det. 8



Det. 16

Button test: x-ray background

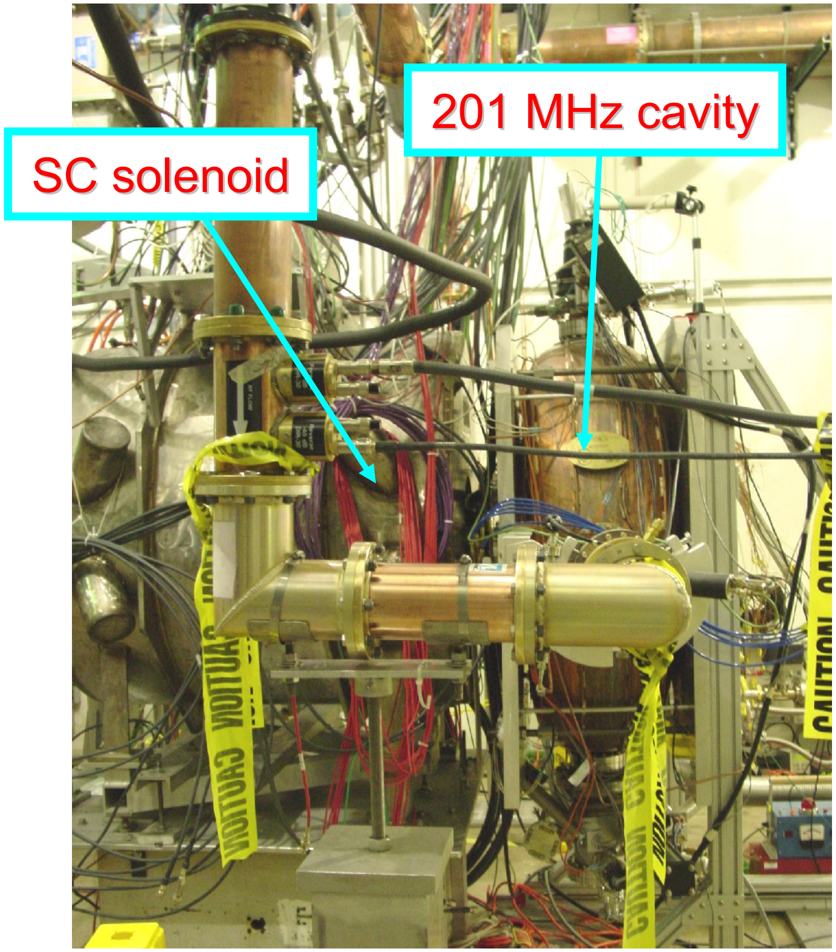


- **LOG-LOG** plot
- All curves display power-law growth, ~E^{13}, consistent w/ Fowler-Nordheim field-emission law which can be **approximated** by:

  $I \sim E^n$,

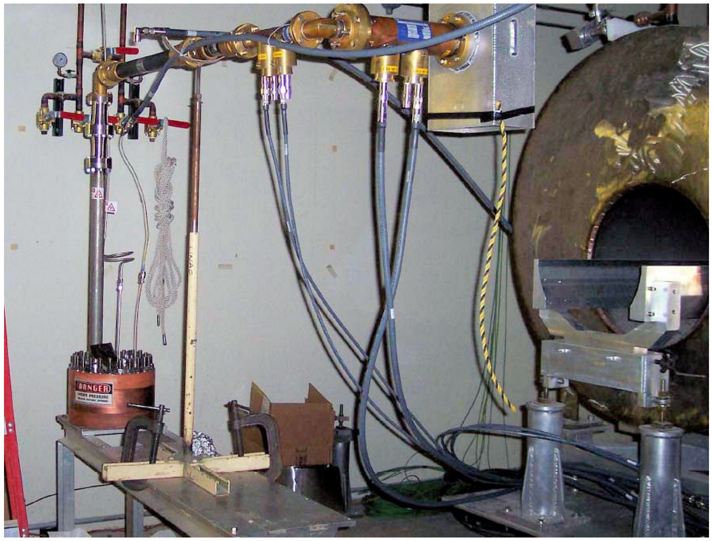
  where I is field-emission current, n depends on work function and local field

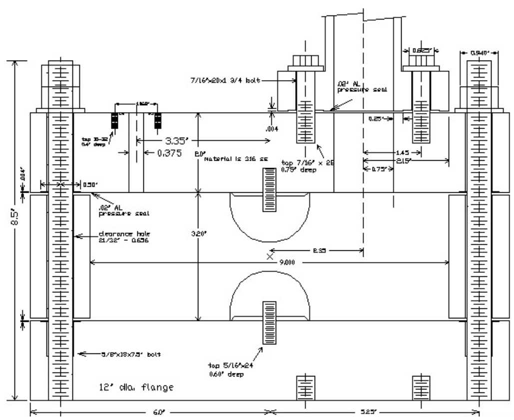
201 MHz: curved Be window test (2008)



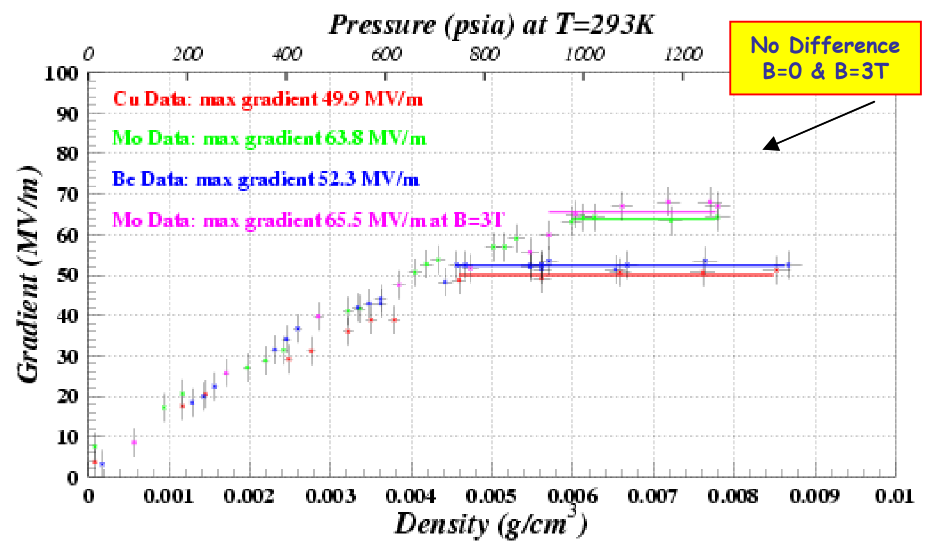
- At Zero magnetic field: cavity can be stably operated at 19 MV/m; also achieved 21 MV/m gradient for short spells (note: the design operating gradient is *16 MV/m*)
- Tests in magnetic field by moving cavity closer to SC solenoid
  - Achieved ~ 14 MV/m as B = 0.38 T at the near curved Be window
  - Multipactoring observed at all magnetic field up to 3.75 T in the center of 2 solenoid coils (limited by quench problem), which corresponds to 0.50 T at the near Be window

High Pressure H_2 Filled Cavity test (with Muons Inc.)

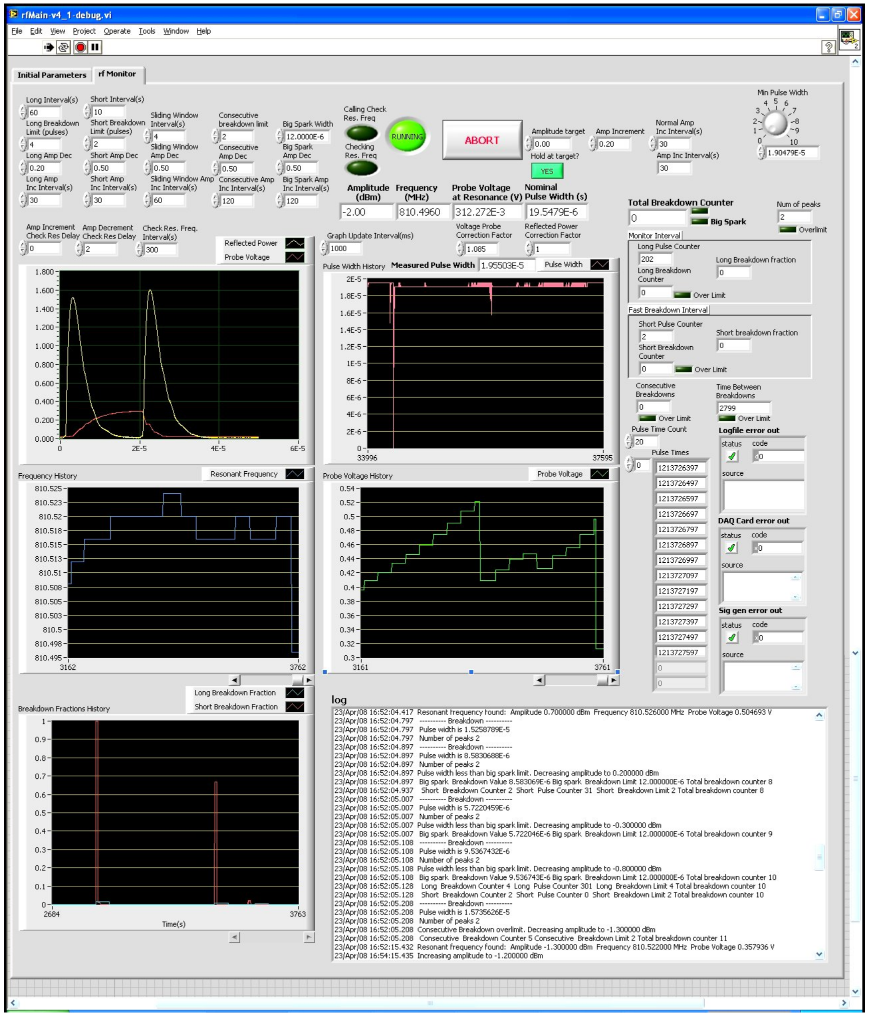




- **High Pressure Test Cell**
- **Study breakdown properties of materials in H_2 gas**
- **Operation in B field**
  - No degradation in M.S.O.G. up to ≈ 3.5T
- Next Test – Repeat with beam



New RF automatic control/diagnostic screen



- **Developed by *Ajit Kurup* (Imperial College, UK.) w/ Labview**
- **Precise control in RF commissioning**
  - RF forward/reflection signal
  - Pulse width history (tells breakdown or not)
  - Resonant freq. history
  - Probe voltage history (tells RF gradient)
  - Breakdown fraction history
- **Has been tested, works well**

Summary

- **Experimental studies of various button materials in 805-MHz cavity have been carried out at MTA.**
  - Coating loss on Fermilab-coated TiN_Cu button. LBNL-coated button #2 shows better behavior without visible loss
  - Mo seems to withstand higher accelerating field than W
  - X-ray radiation follows Fowler-Nordheim law
  - 805 cavity automatic control program has been tested
    - **Improved uniformity of test procedures**
    - **Reproducibility improved**

- **201 MHz cavity tests with curved Be windows at zero magnetic field is successful; preliminary tests with non-zero magnetic field have been carried out and more work is going to be done after the coupling coil is in position**

- **Initial high pressure cavity test with H_2 fill was carried out, more tests are scheduled with proton beam**