MuCool Test Area (MTA) vacuum RF studies

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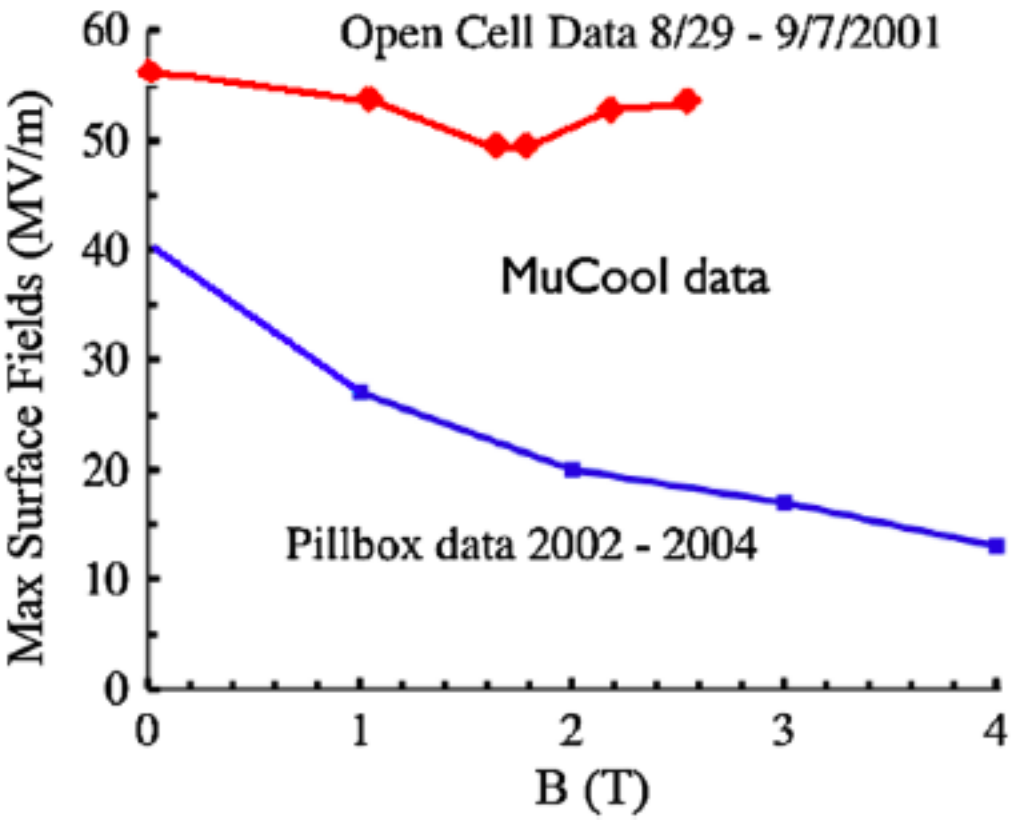
Outline

- **Introduction**
  - RF test program
  - B field effect
    - **Possible solutions**
    - **Model & Preliminary simulation results by OOPIC**
  - Cavity tests
- **805 MHz cavity test**
- **201 MHz cavity test: new results since MUTAC08**
- **MTA box cavity experiment**
- **Summary**

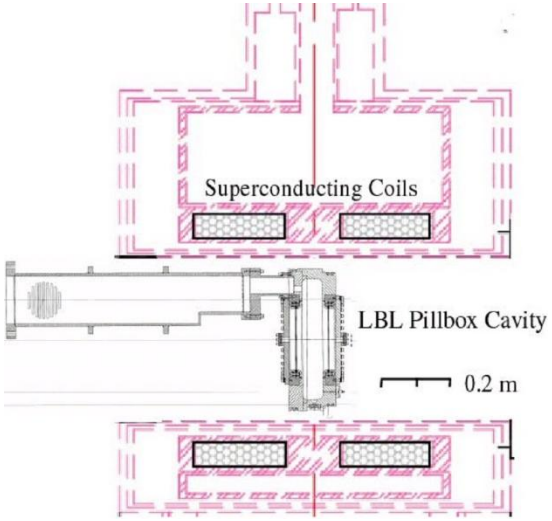
Introduction

- **Goal: Study Accelerating Gradient limit of NCRF cavities in magnetic field**
  - It has been proposed that the behavior of RF systems in magnetic field can be accurately described (predicted) by universal curves
  - Fundamental importance to both NF and MC
- **Achievements so far:**
  - 23 MV/m in 3.5 T with TiN_Cu button at 805 MHz
  - 14 MV/m in 0.37 T with curved Be windows at 201 MHz
- **Vacuum RF tests will continue after reconfiguration of MTA for the high pressure gas RF test with Linac beam**

Introduction: B field effect

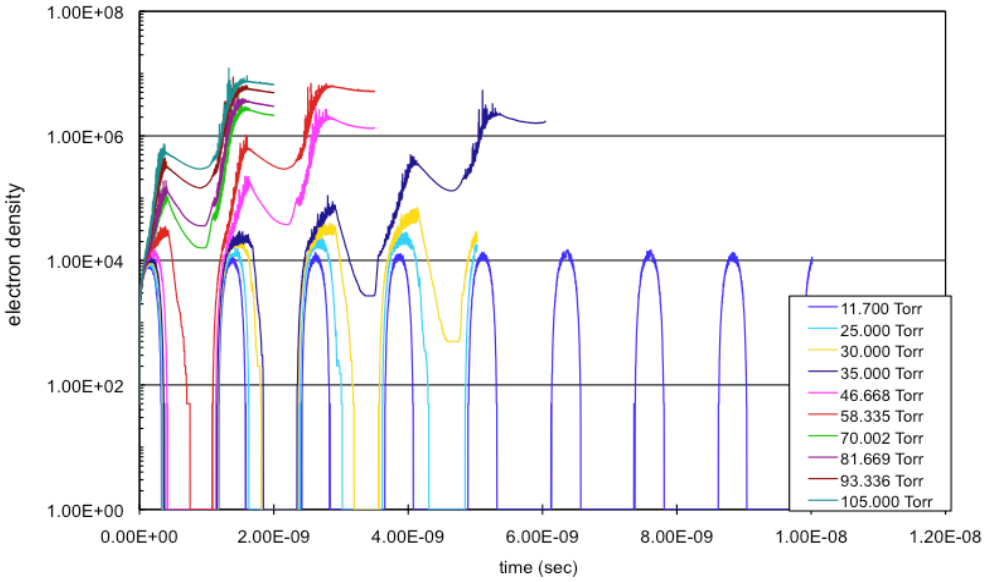


- **Pillbox cavity data seem to follow universal curve**
  - Max stable gradient degrades quickly with B field
- **Multiple tests: reproducible results**

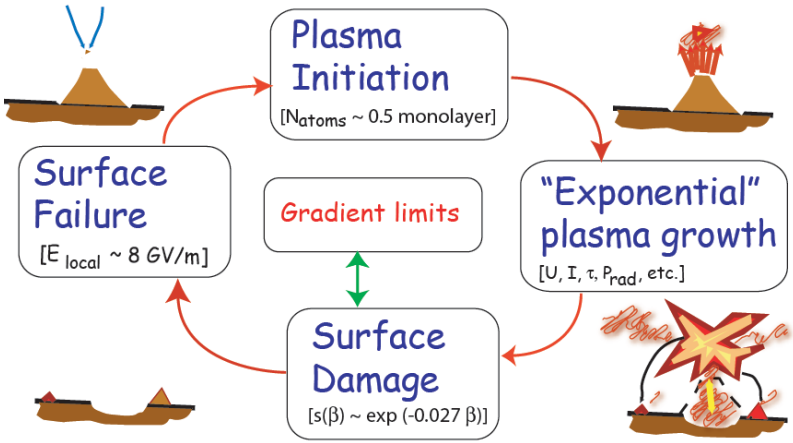


Introduction: model & simulation

- **field-emitted electron density at 3 T, 76 MV/m, 805 MHz**



- **One of the breakdown models**



- **Shows field-emitted electron density as a function of surface material plasma gas pressure, which is a trigger of breakdown**

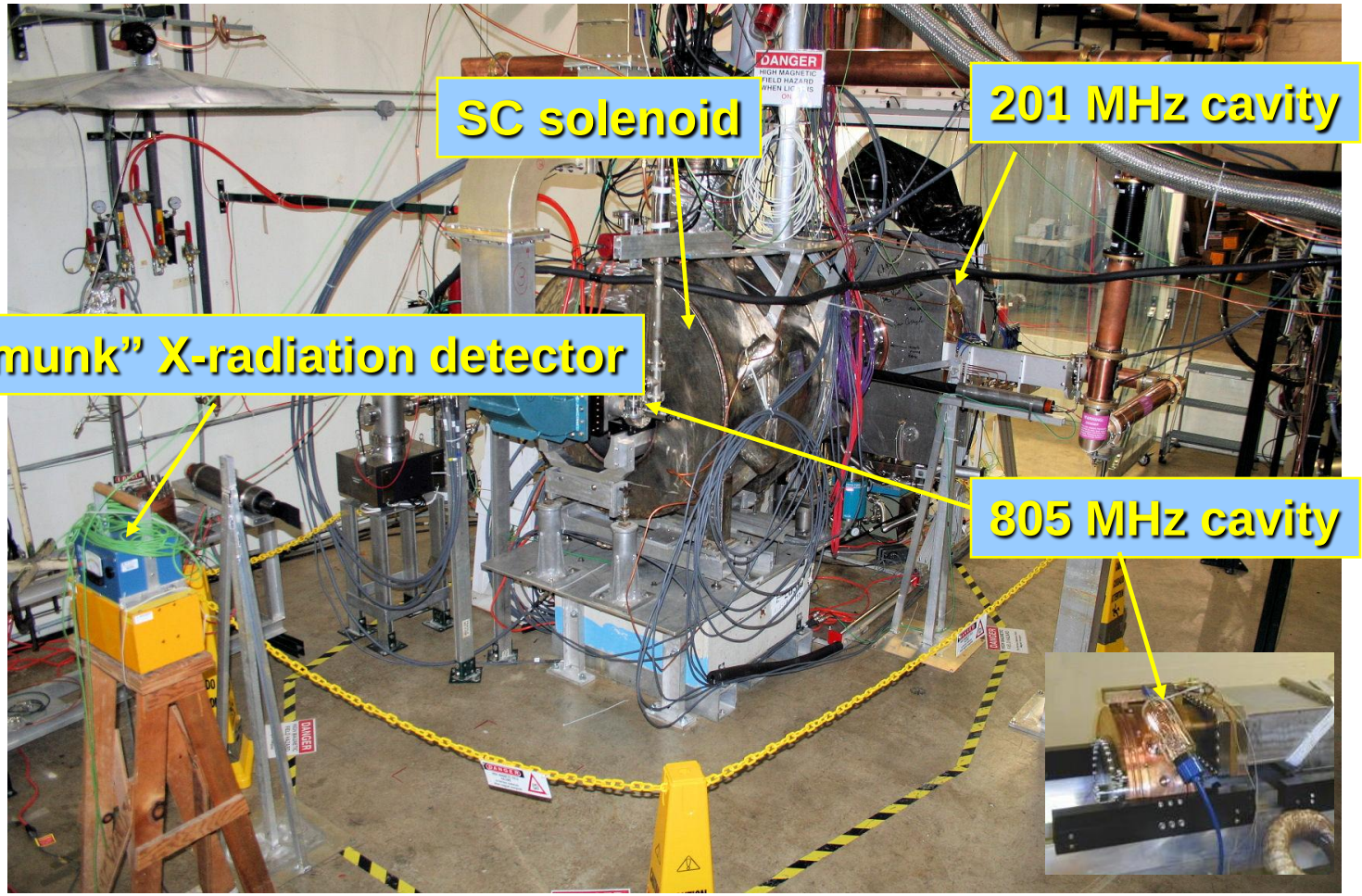
Introduction: possible solutions

- **Three Approaches to a solution**
  - Choice of materials to reduce surface strain damage (*BNL*)
  - Using atomic layer deposition (ALD) to synthesize and analyze cavity surfaces in addition to SCRF processing techniques (*Argonne*)
  - RF cavities filled with High-Pressure gas (*Muons Inc. & Fermilab*)
    - **Use high pressure gas (H2) as the insulator**

Introduction: cavity tests

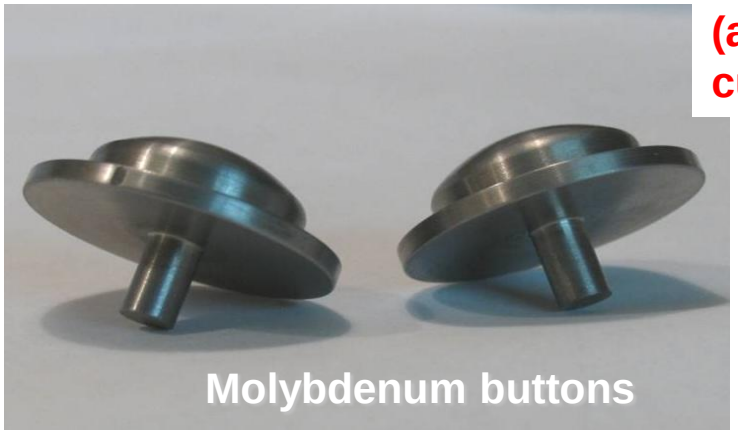
- **805 MHz Cavity button material test:**
  - *Goal*: find materials and coatings that can withstand high peak surface field in strong magnetic field
  - *Approach*: use 805 MHz cavity to test buttons made of various materials
- **201 MHz cavity curved Be window test:**
  - *Goal:* Find the upper-limit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

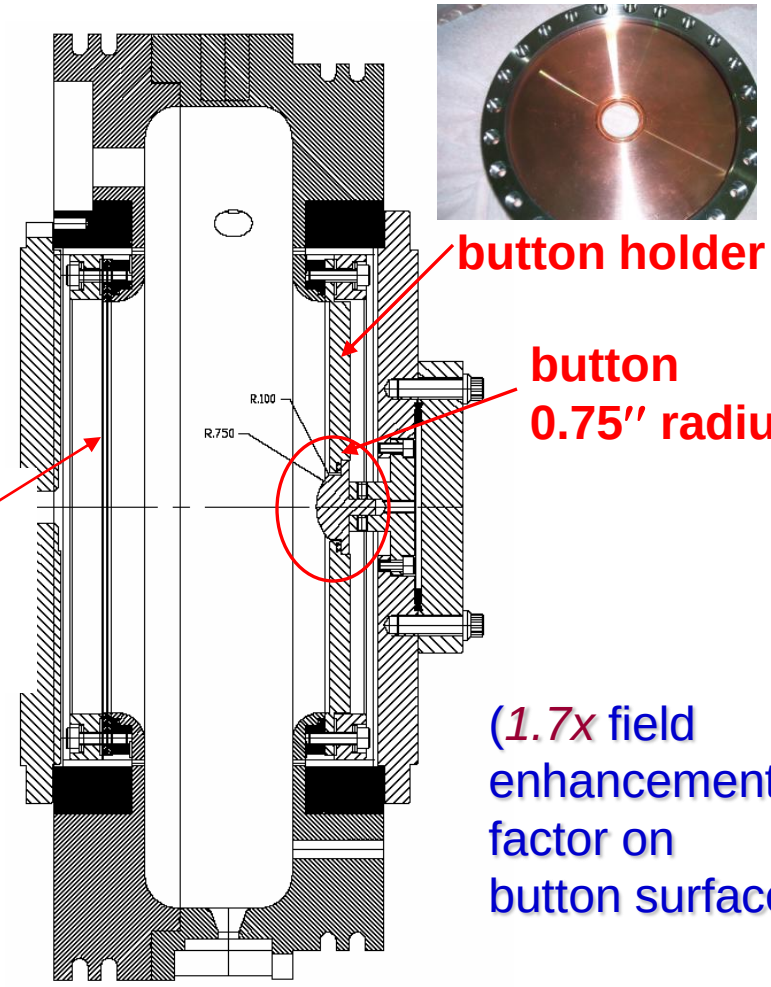
MTA Hall: before reconfiguration



805 MHz: button test (2007 & 2008)

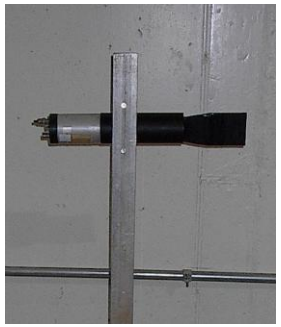
- "Button" system in pillbox cavity designed for easy replacement of test materials
- Tested so far: TiN-coated Cu & Mo, bare Mo and W
- To be tested: Cu (w/, w/o e.p.), Be
  - More to come

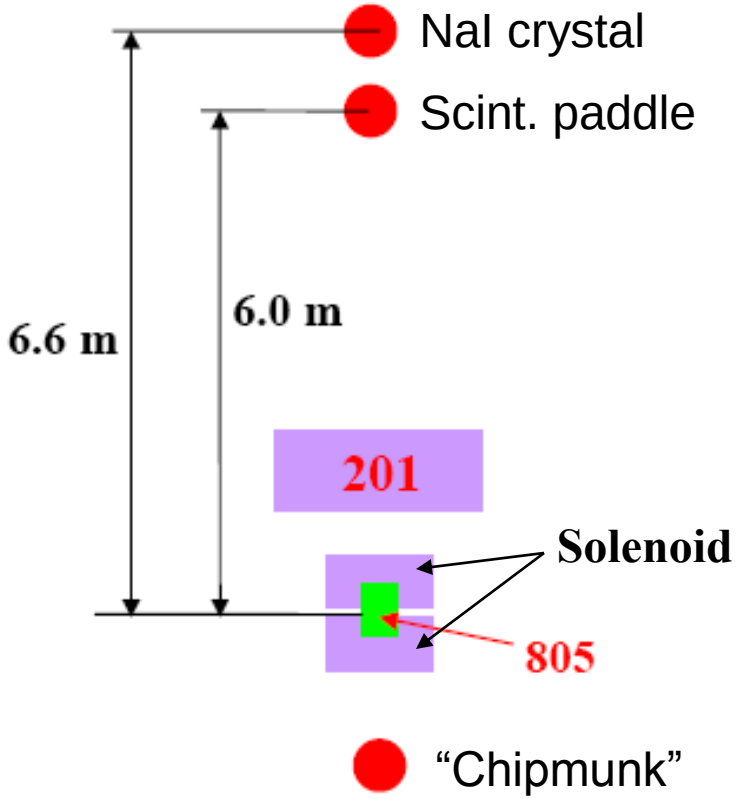




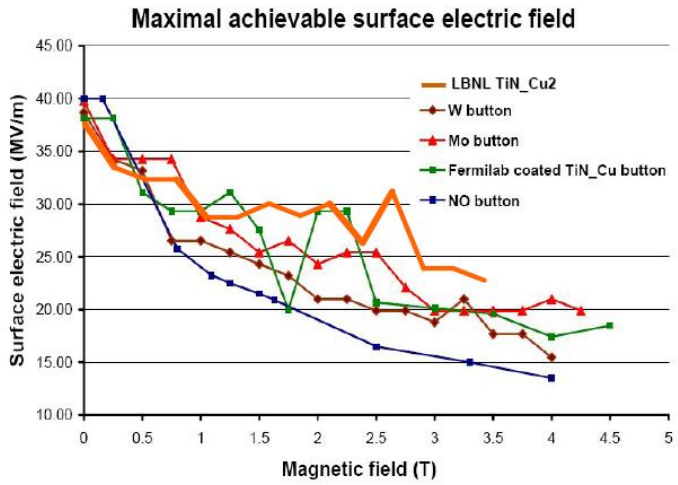
Button test: x-ray detectors

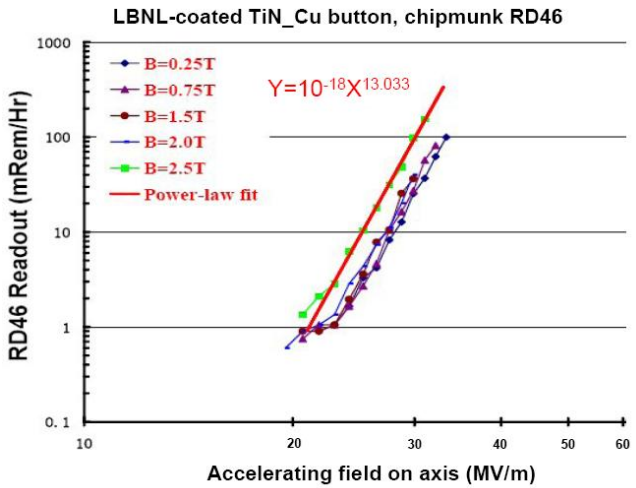
- 10 x-ray detectors in MTA hall
  - 9 fast scintillation counters, counting rate limit: ~ 10 MHz
  - 1 NaI-crystal energy measurement, counting rate limit: ~ 1 MHz
- Detectors frequently used in button tests:
  - Scint. paddle
  - NaI crystal
  - "Chipmunk" X-radiation detector (measuring integrated x-ray dose in 20 sec.)





Button test results (2007 & 2008)

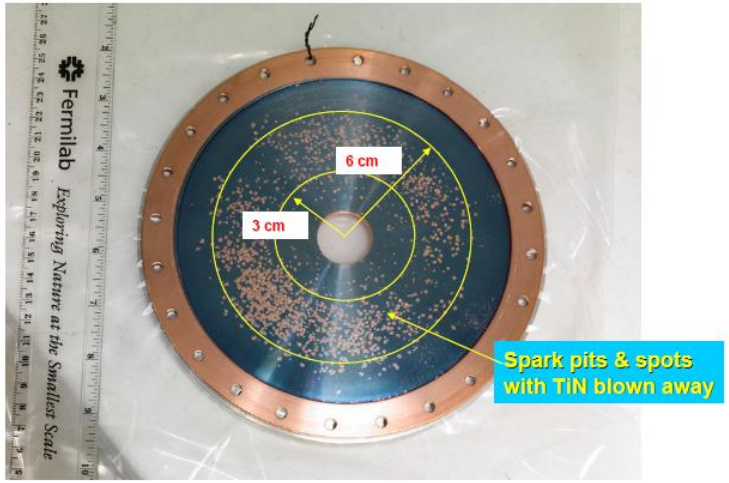




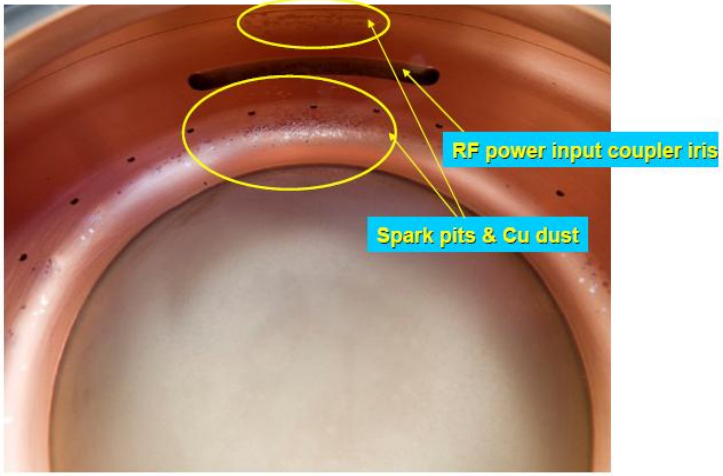
- **TiN_Cu** data:
  - less stable than rest, maybe due to loss of TiN coating
- **Mo** data:
  - generally above W data
  - Mo appears to withstand higher surface field than W
- **2008: New LBNL coated TiN_Cu button:**
  - data appear more stable than FNAL-coated **TiN_Cu**
  - better performance at high magnetic field
- **All radiation curves display power-law growth, ~E^{13}, consistent w/ Fowler-Nordheim field-emission law**

Button test: cavity damage

Button holder

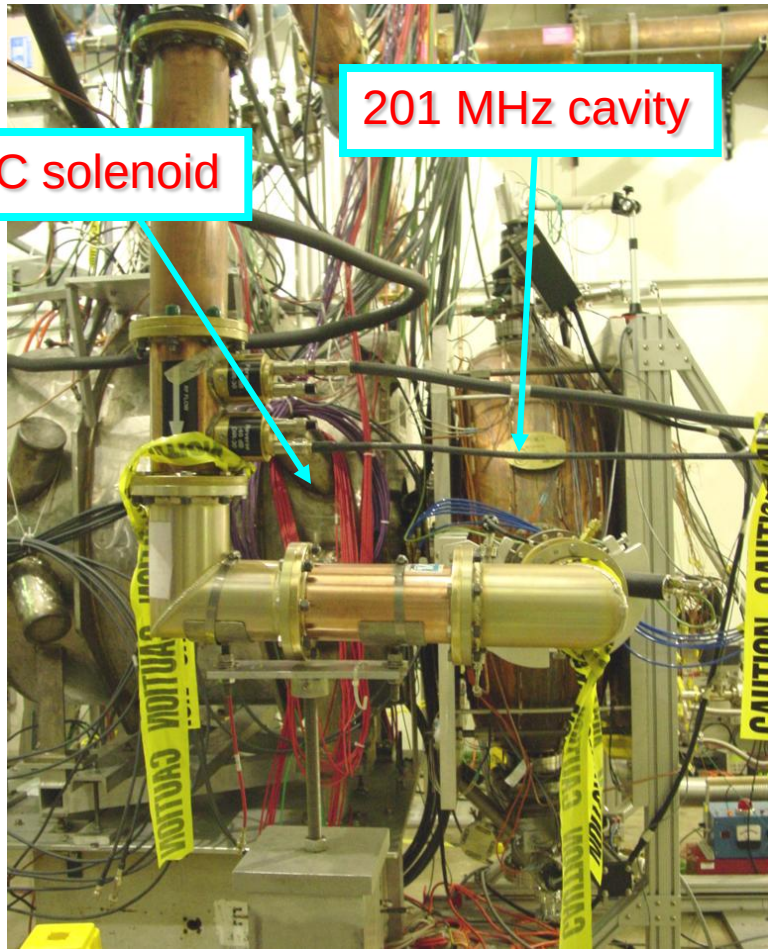


Inner surface of cavity



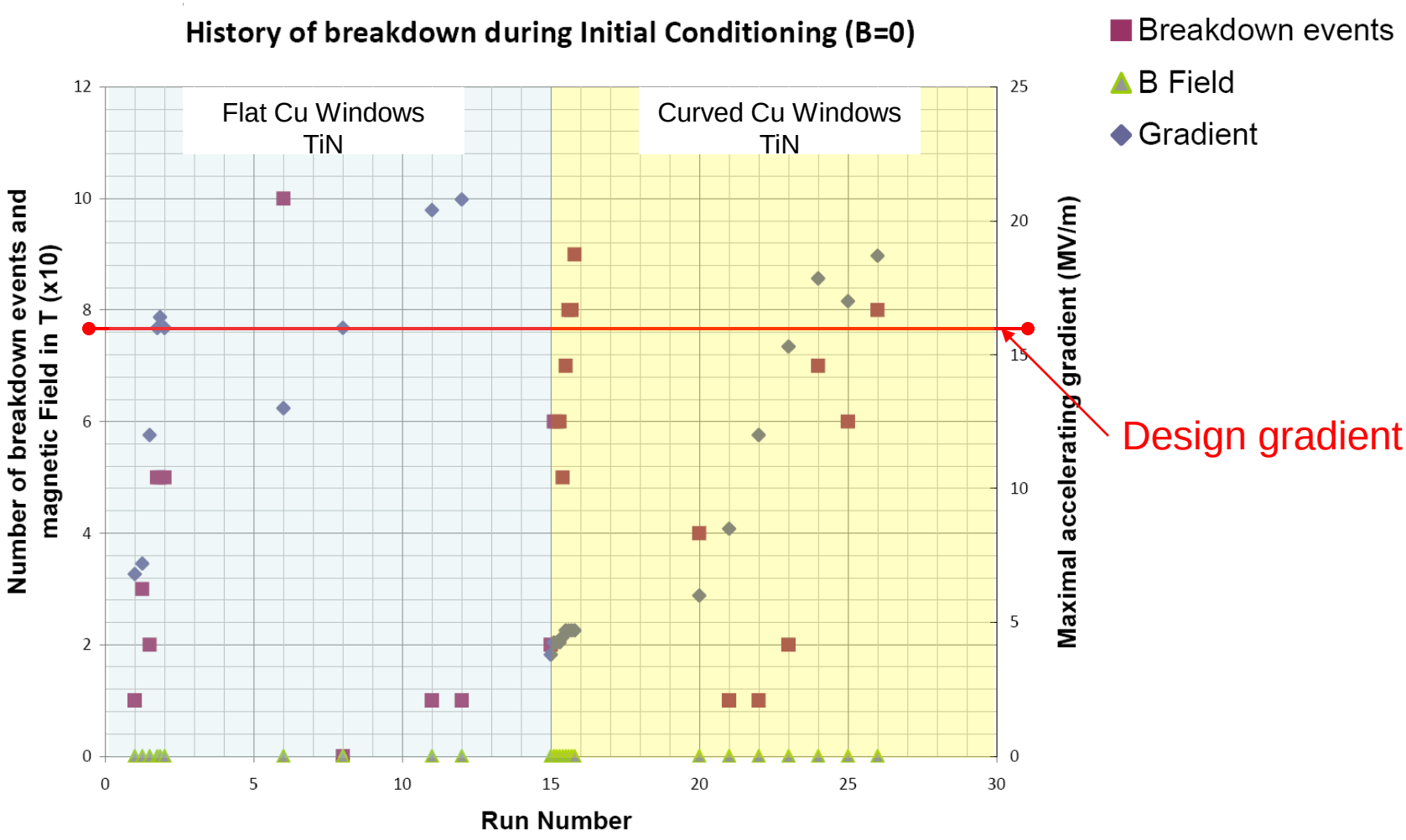
- Opened up the button cavity for inspection
- We observed the button holder and the inner surface of cavity were damaged by sparks, the damage may have influence on the test data
- The cavity is being remanufactured by JLab now
  - some new pits were discovered. Must be cleaned off before re-coating, hopefully be done this week

201 MHz: curved Be window test : work done since MUTAC08

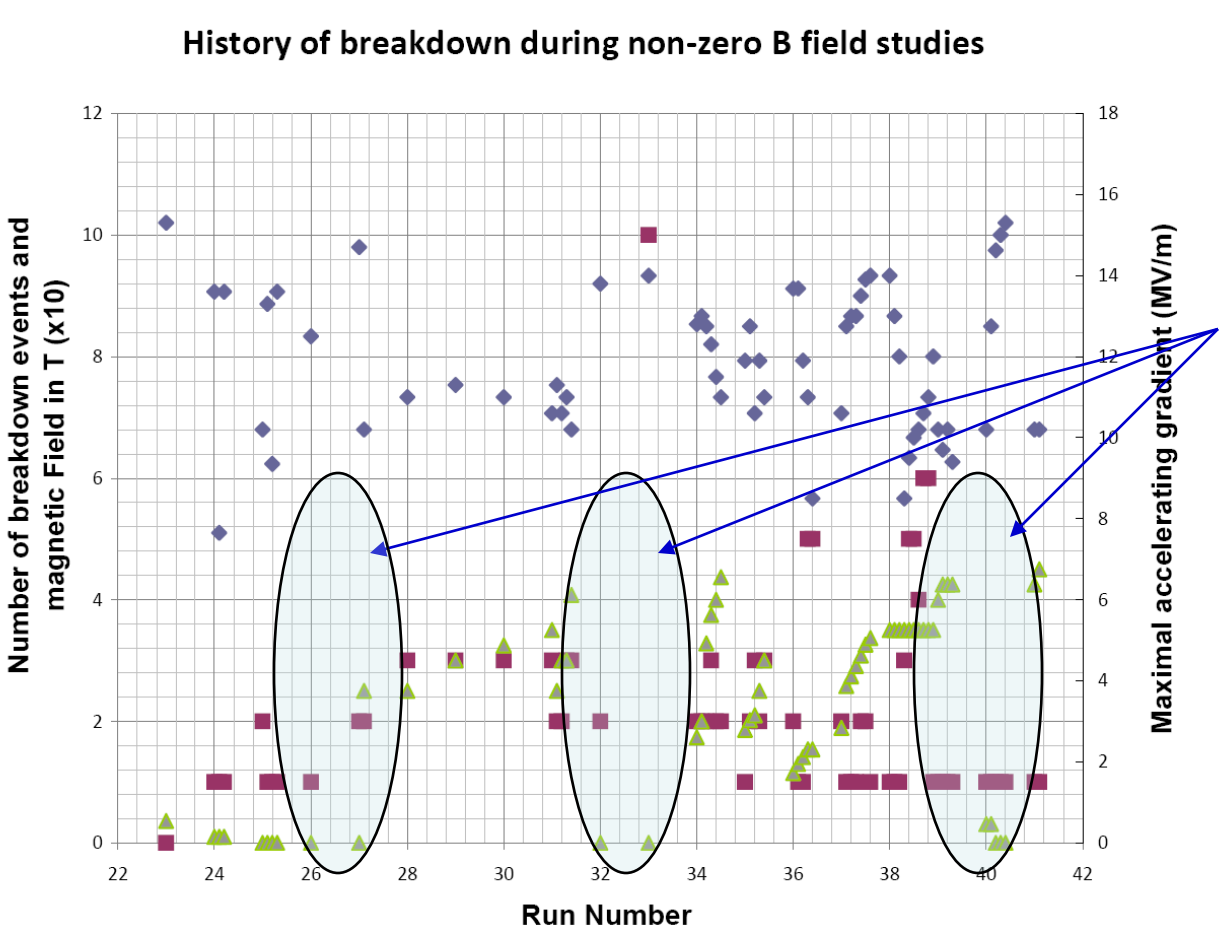


- **At Zero magnetic field:**
  - Stable operating gradient:19 MV/m
  - Maximal gradient: 21 MV/m
  - Design operating gradient: *16 MV/m !!*
- **Tests in magnetic field**
  - Achieved ~ 14 MV/m at 0.37 T in center
  - Magnetic field limited by quench problem B_{max}=0.42 T in center

201 MHz: curved Be window test (B=0)

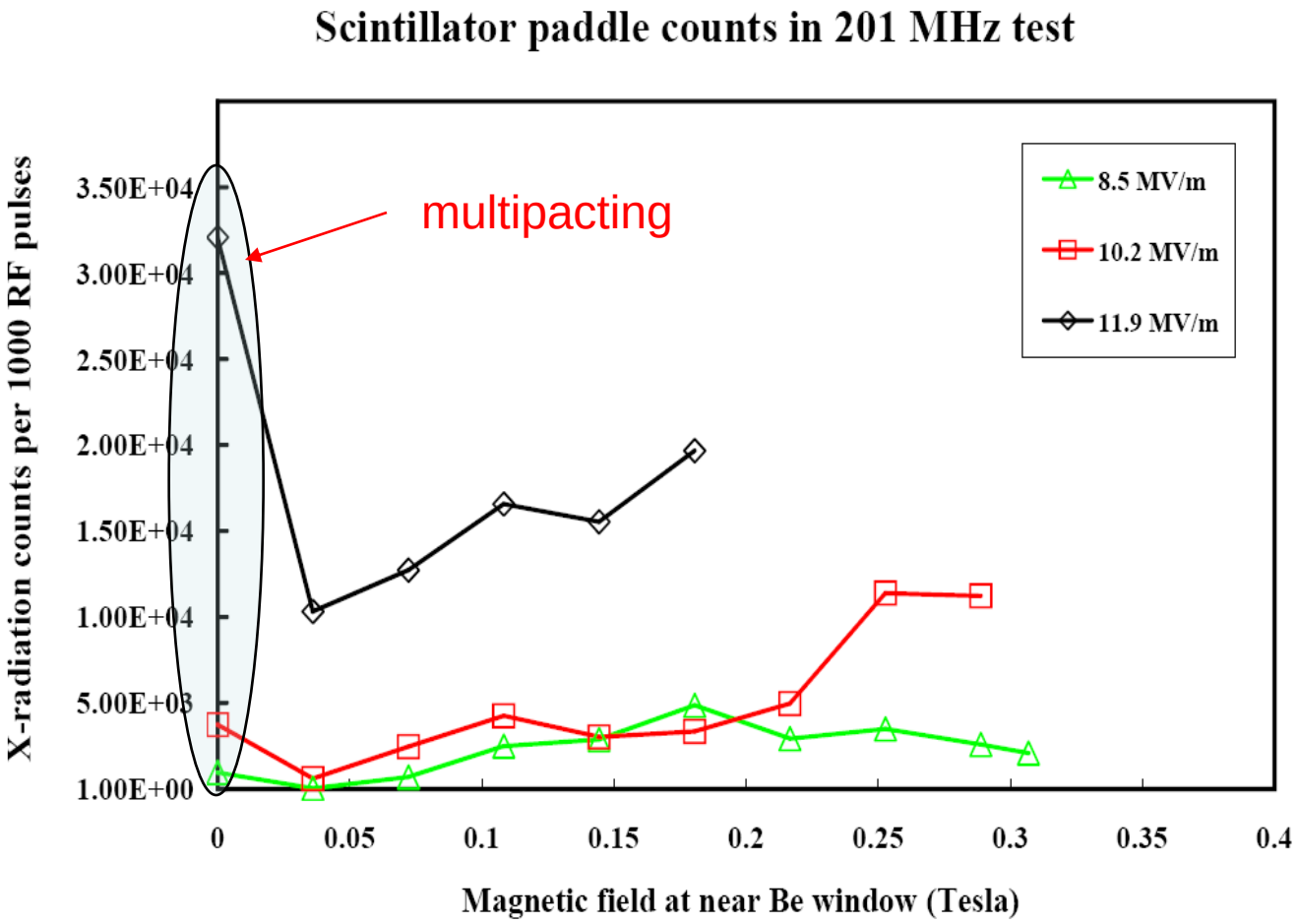


201 MHz: curved Be window test (B≠0)



- Conditioning: a breakdown event may generate more field emitters and radiation level goes high. Thus we reduce magnetic field back to zero, and recondition the cavity to remove those field emitters in order to measure the accurate M.S.O.G. in magnetic field later on.

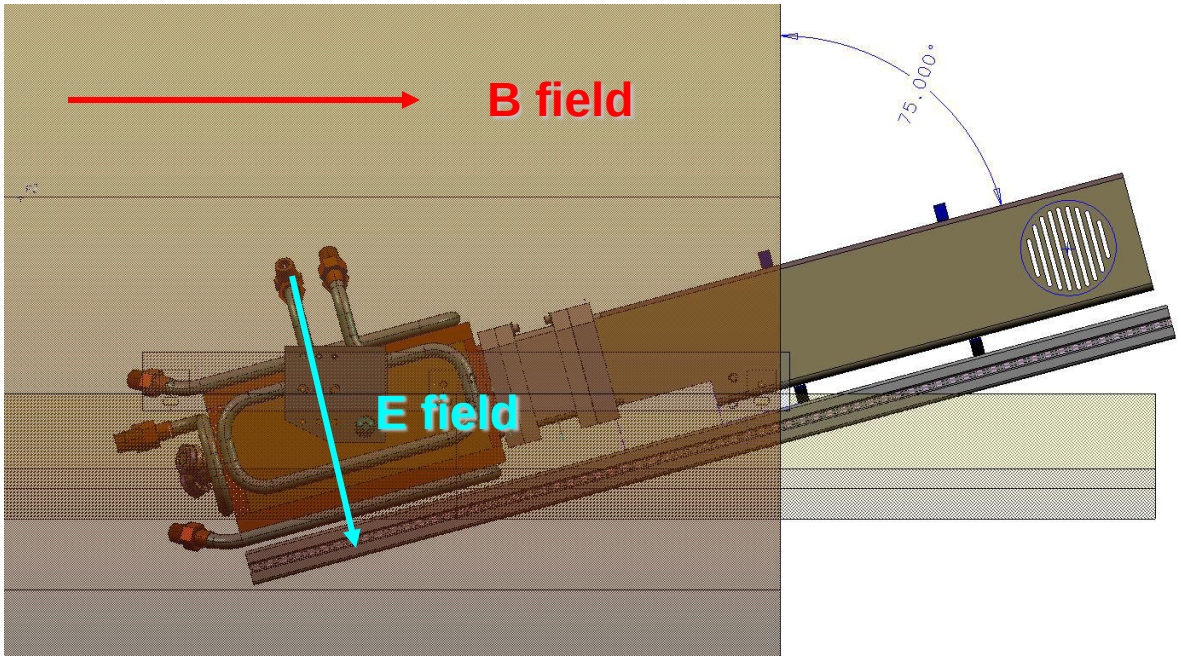
201 MHz: curved Be window test: X-background

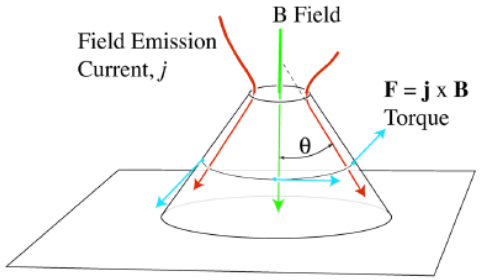


- It can be used to estimate MICE background

MTA box cavity experiment

- **Goal: study the relationship between S.M.O.G. and the cross-angle between accelerating and external magnetic field (E⊗B)**
- **Method: use rotatable box cavity and waveguide system**
  - Rotation angle: 90±15 degrees





Summary

- **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 since MUTAC08 and more work is going to be done after the coupling coil is in position**

- **Experimental studies of various button materials in 805-MHz cavity have been carried out at MTA, although being postponed by MTA reconfiguration**
  - 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

- **MTA box cavity experiment is under way**
  - Initial design: done
  - Schedule & cost estimation: done
  - Parts out for fabrication