RF BACKGROUND STUDIES AND PLANS

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Cast

People directly involved in measurements

Argonne: J. Norem

Berkeley: D. Li

CERN: P. Gruber

U. Cincinnati: V. Wu

Fermilab: A. Bross, A. Moretti, M. Popovic, Z. Qian

IIT: N. Solomey, Y. Torun

U. Illinois: L. Ducas

Imperial College: E. McKigney

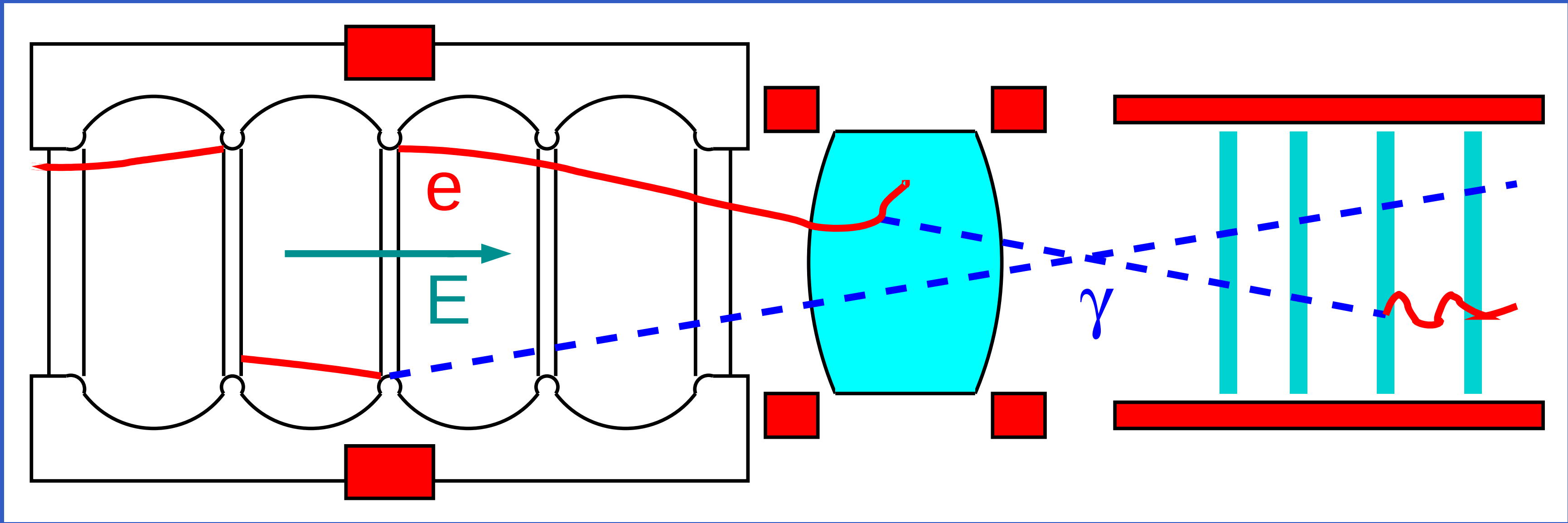
Many others have helped

Introduction

We need to characterize radiation field around RF cavities to

- identify relevant diagnostics for cavity operation
- test and select instrumentation for cooling channel
- understand background environment for detectors in a cooling experiment (MICE)

Problem



- Electrons stripped from metal surface
- accelerated by cavity field, generate x-rays
- dark current absorbed by liquid hydrogen
- x-rays flood downstream detectors

Issues

Initial concern due to results from 805MHz open-iris cavity at highest gradients

- Absorber heat load
  - saw $\sim 1\mu$A average dark current at 16MV/m
  - deposited energy per particle comparable to muons
  - Study II muon current $\sim 5\mu$A
- Window integrity
  - dark current focused around magnetic field lines
  - burned hole in vacuum window during operation
- MICE detector backgrounds

Field emission

Fowler-Nordheim current density j_{FN} from tunneling through potential barrier (work function ϕ) at metal surface

$$j_{FN}(E) = \frac{A}{\phi}(\beta E)^2 exp\left(-\frac{B\phi^{3/2}}{\beta E}\right)$$

$$n = \frac{E}{j}\frac{dj}{dE} \simeq 2 + \frac{67.4\text{GV/m}}{\beta E}$$

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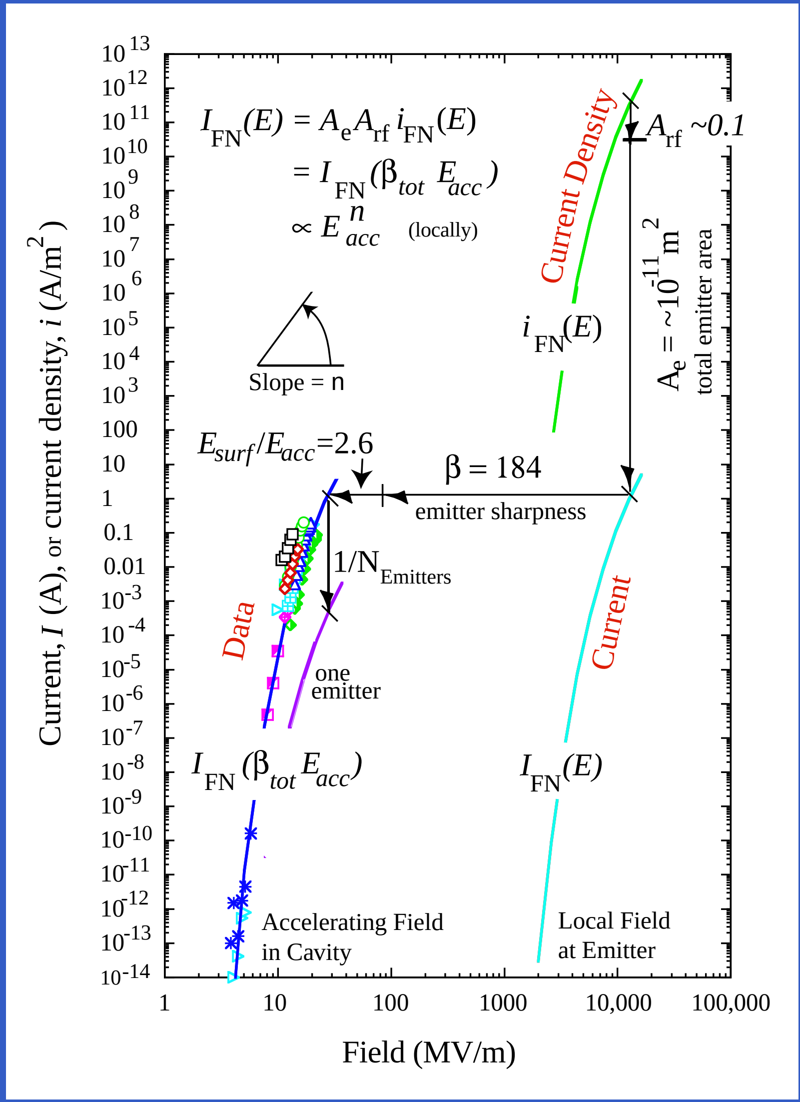


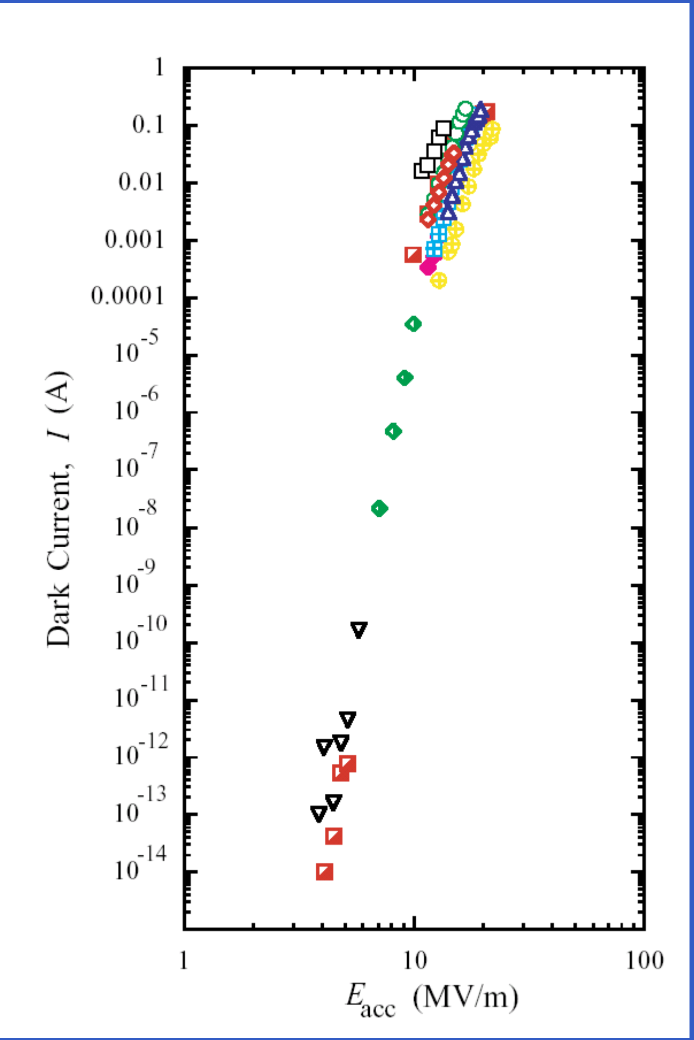
Instrumentation challenge

- Extremely steep dependence of I on E ($n \sim 10$ for 8GV/m surface field)
- No single detector/technology can cover (or survive!) entire dynamic range (over 10 orders of magnitude)
- Hard to control systematics and make repeatable measurements
- Had to try (and occasionally fry) many different detectors
- Need to crosscheck results often

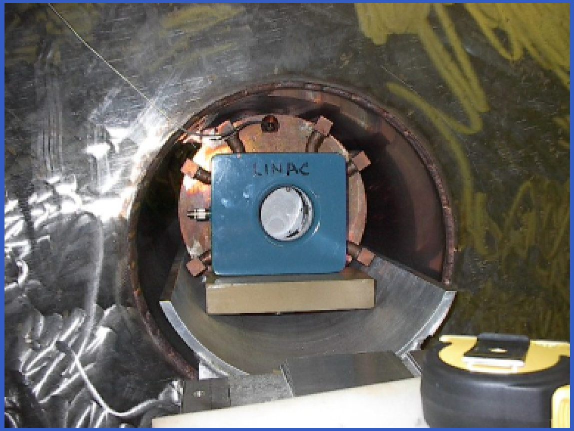
Facility: Lab-G

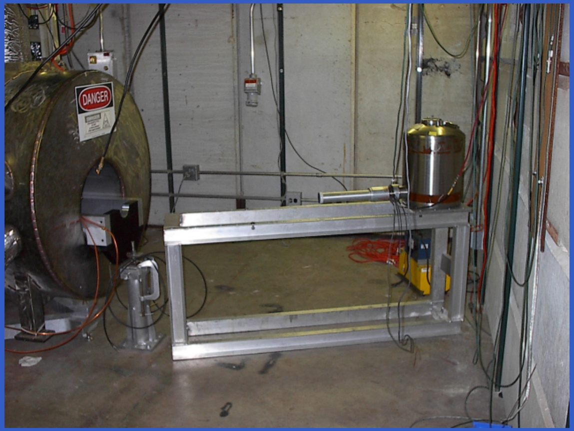
Detectors

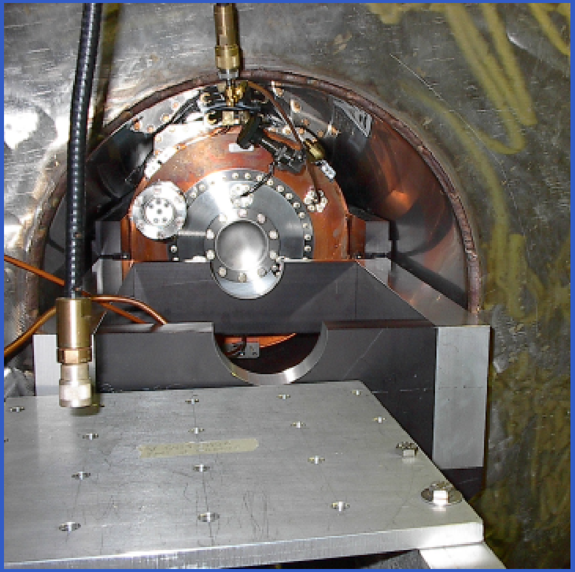
- Signals change scale during conditioning
- Dose monitors to track overall progress
- Glass, polaroid/standard film for spatial detail
- Current transformers for dark current
- Scintillators for rates and fast diagnostics
- Ge diode and rangestack for spec-trometry

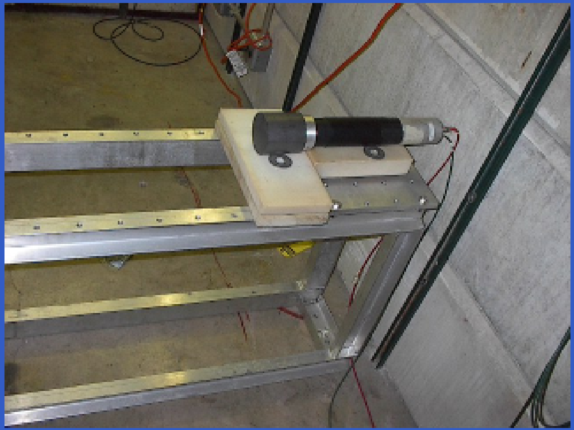


Results









Scintillator+PMT

Fast enough to follow cavity pulse by pulse

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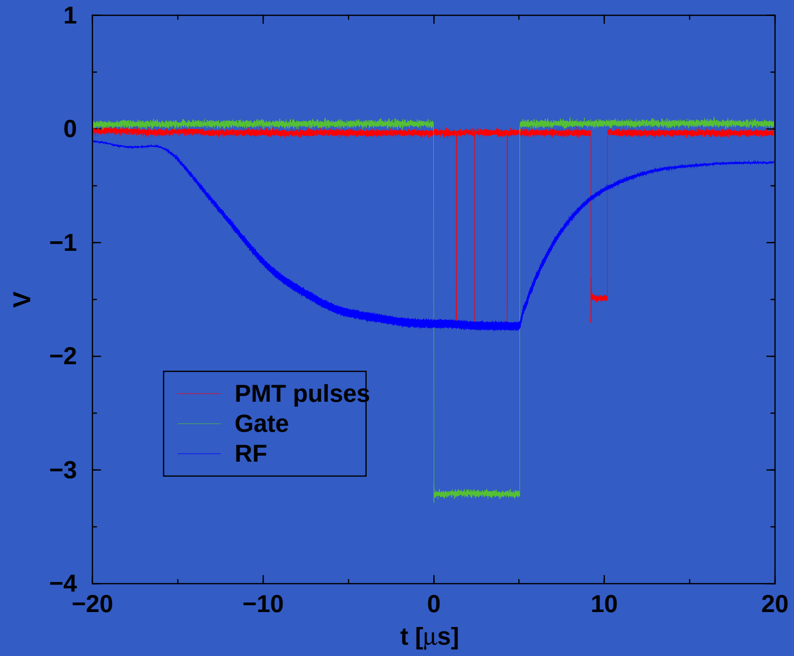

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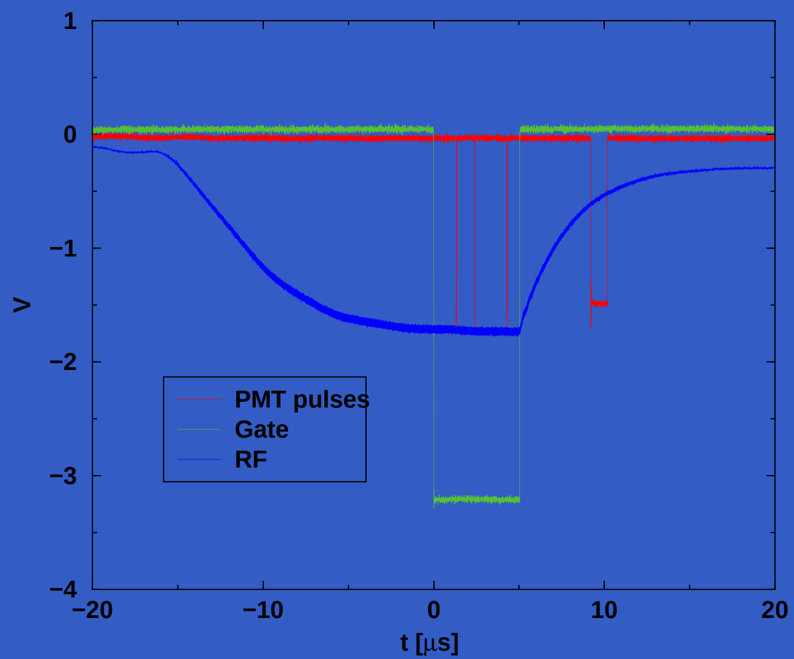

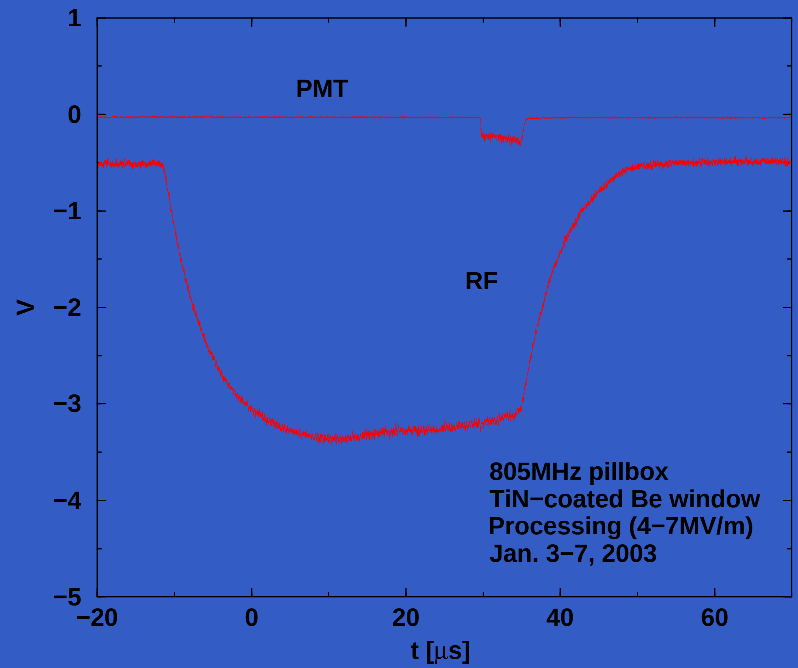

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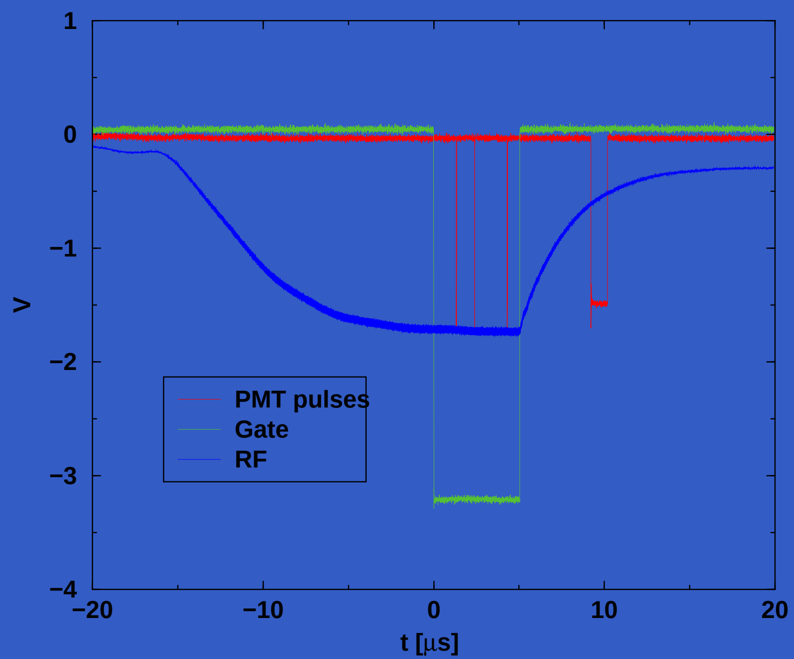

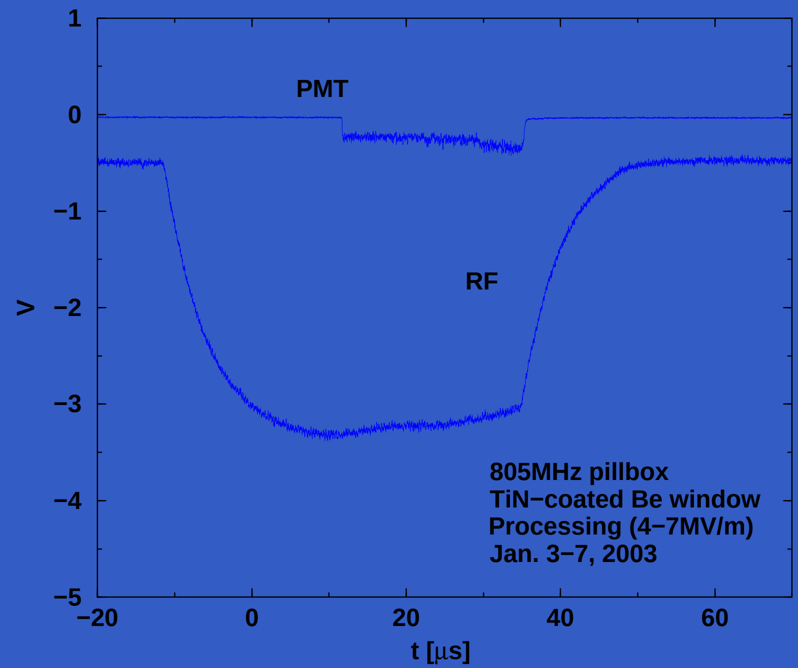

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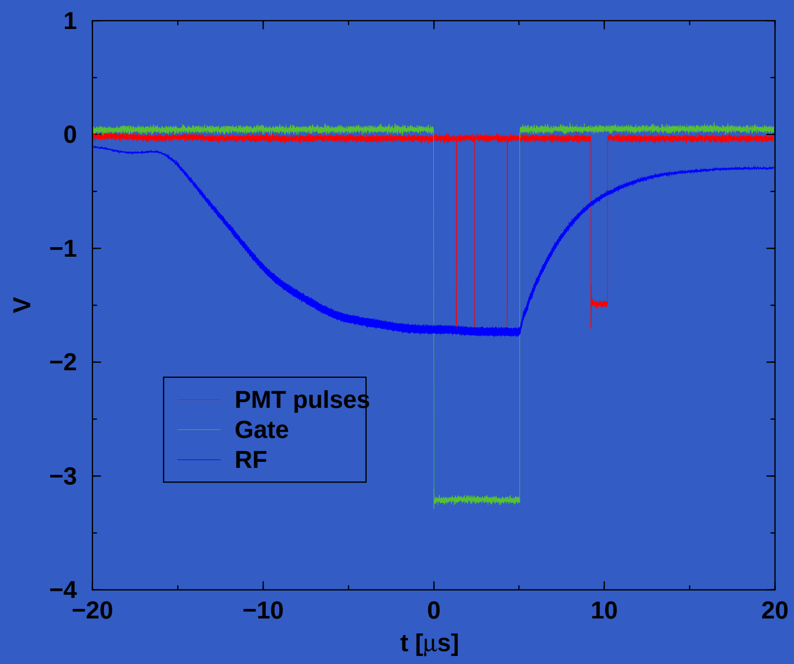

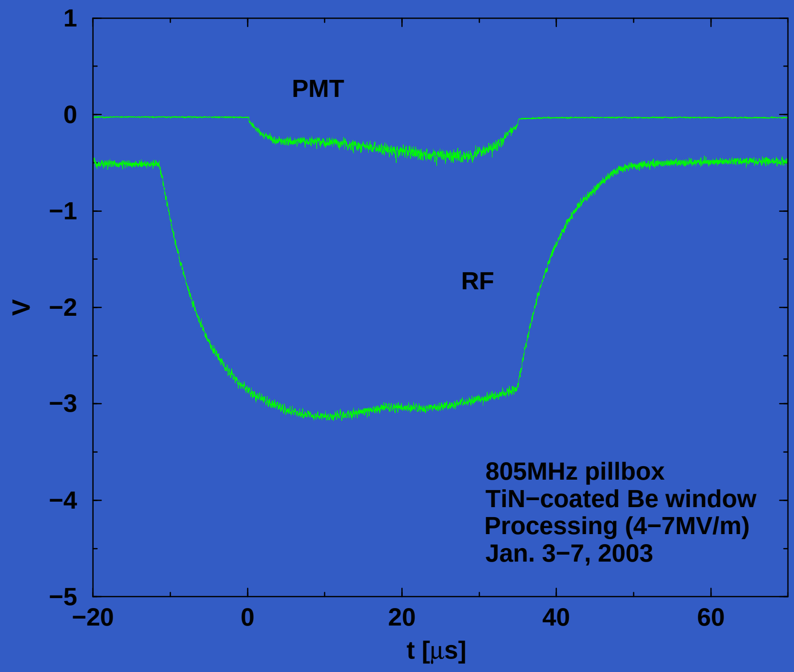

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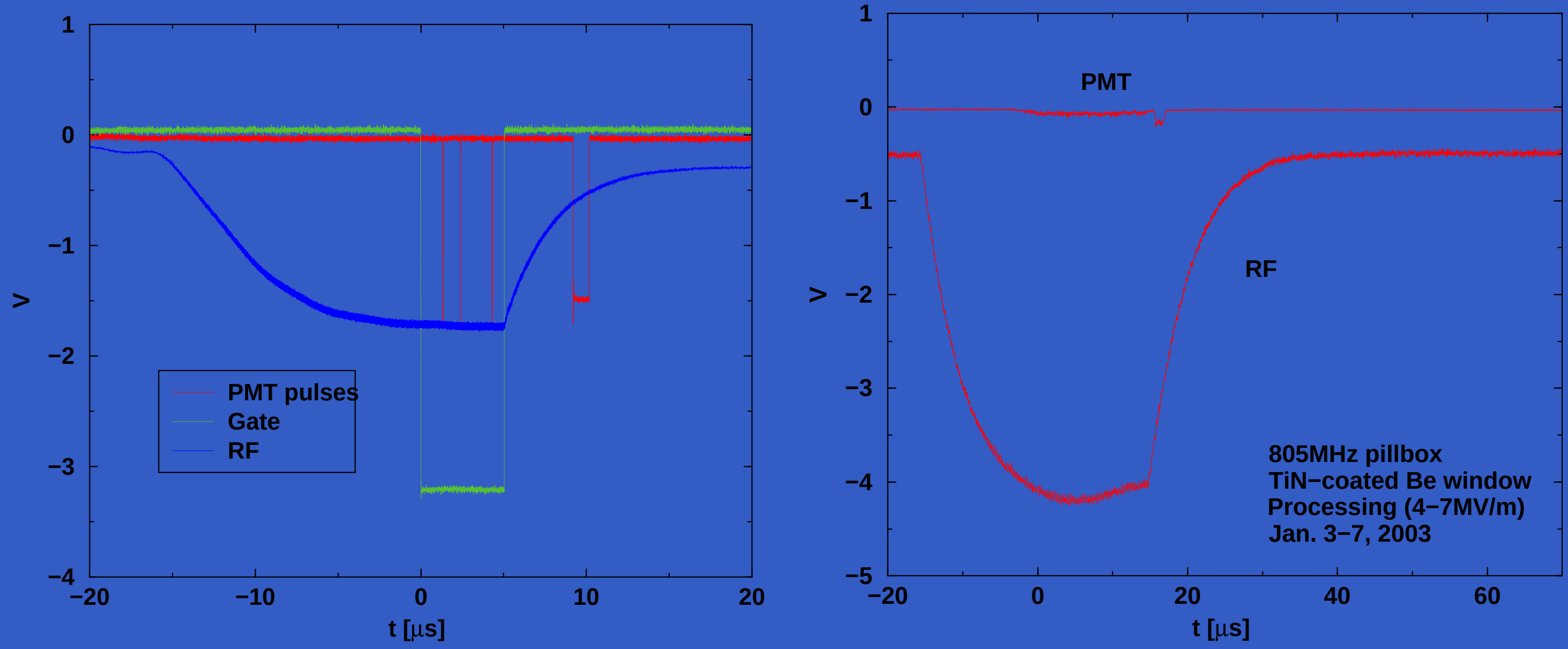

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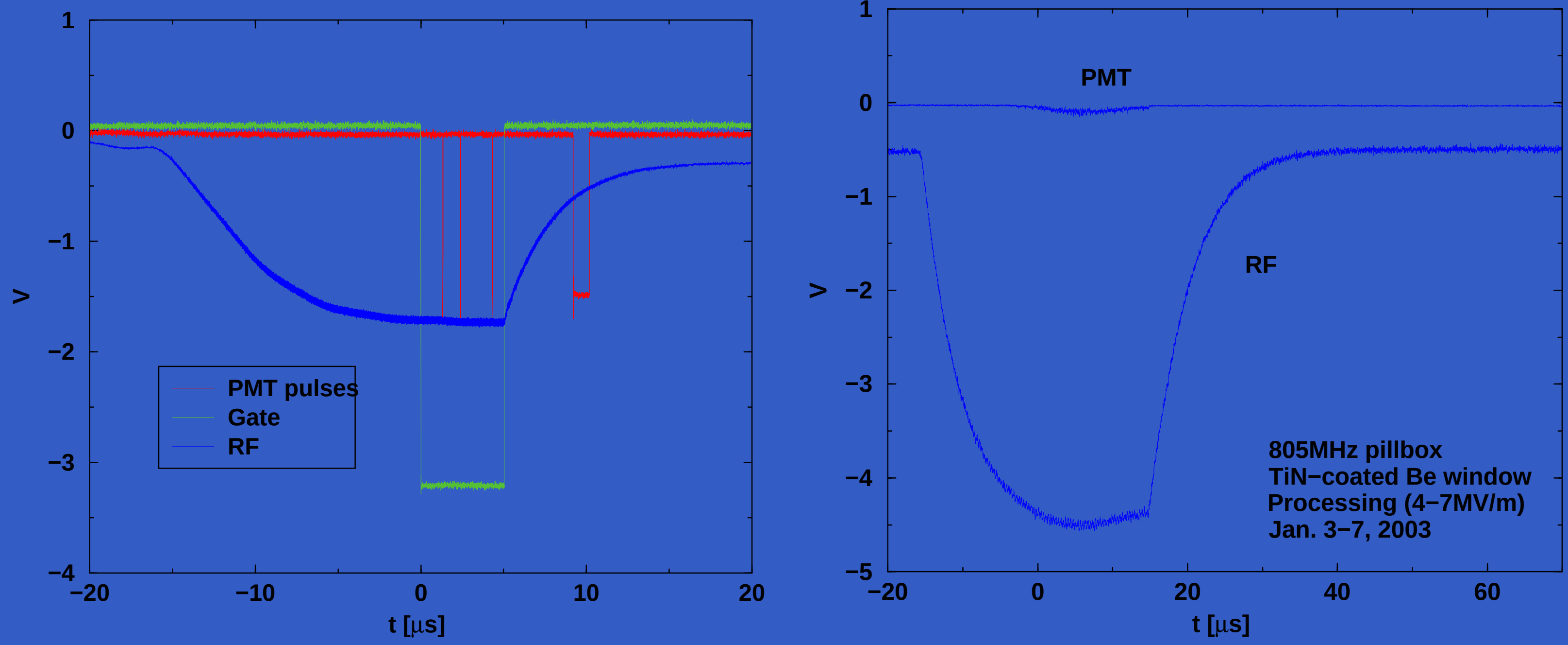

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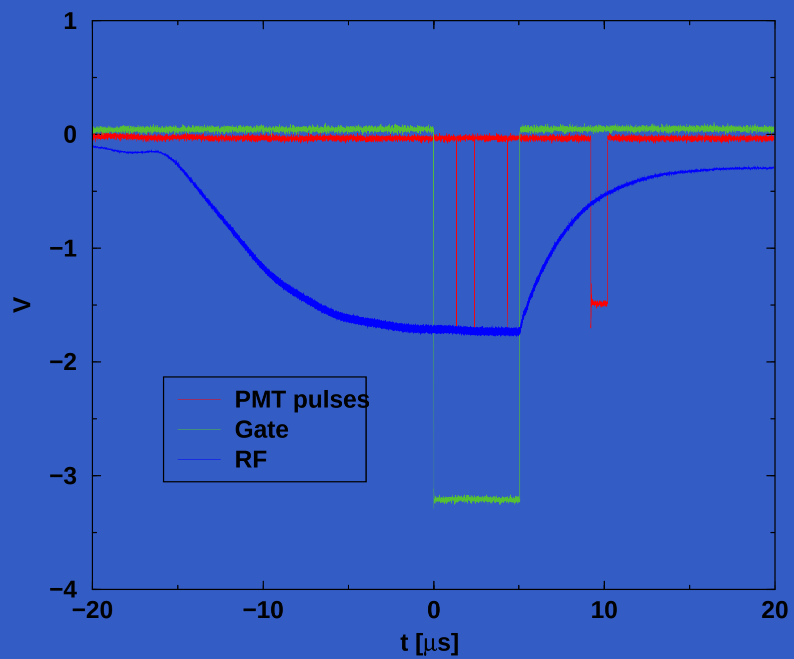

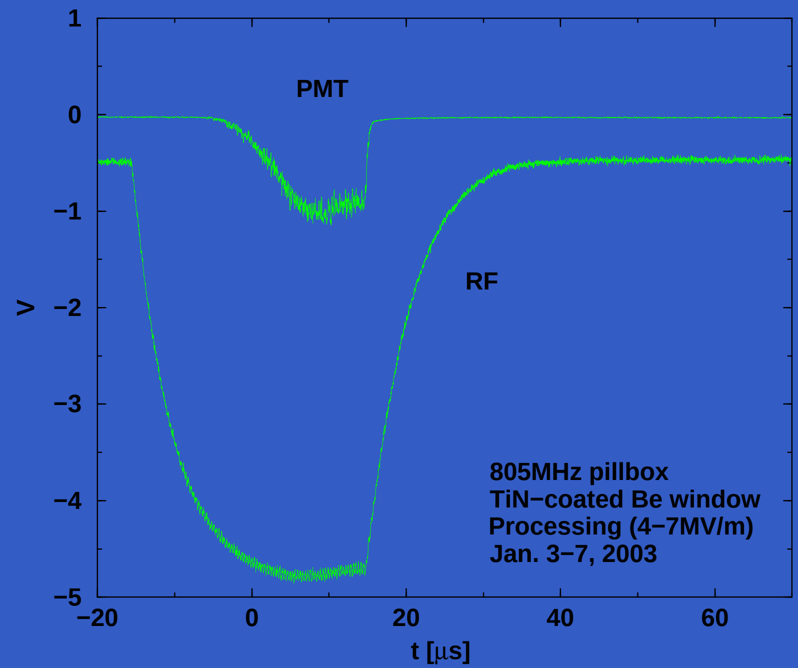

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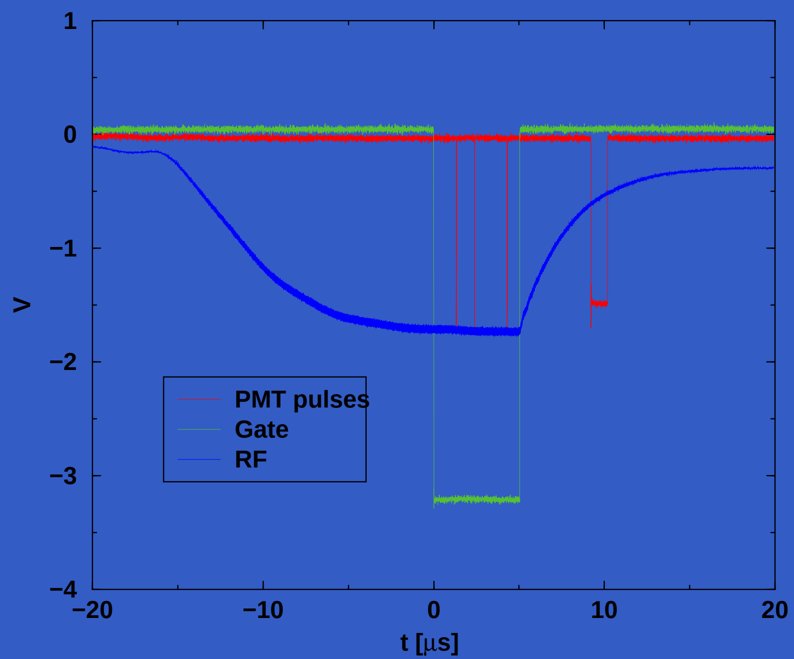
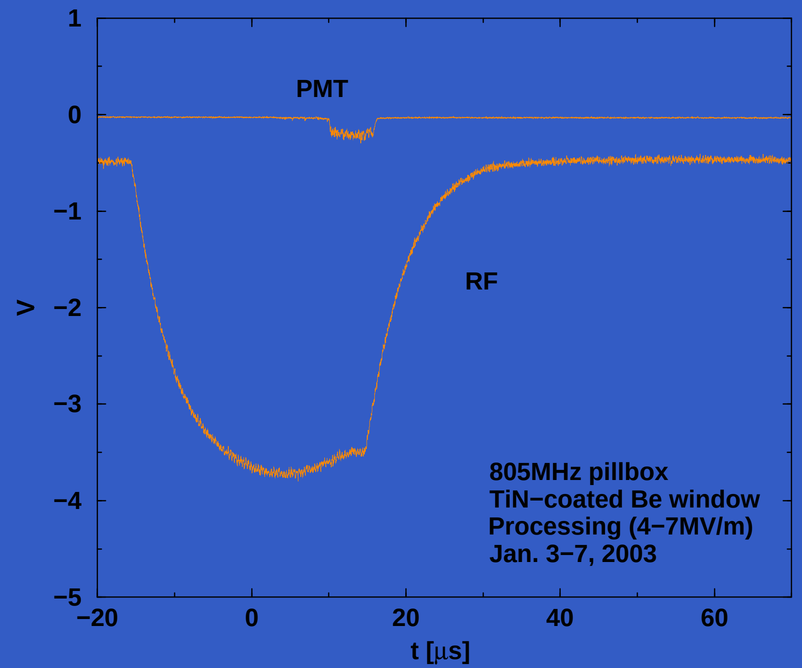
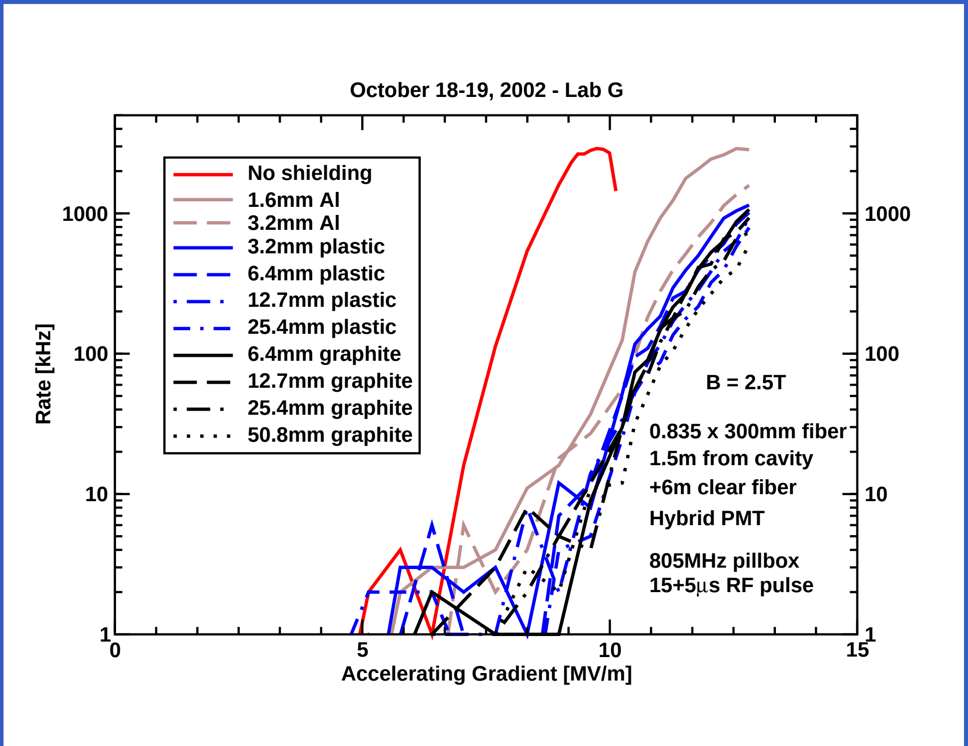


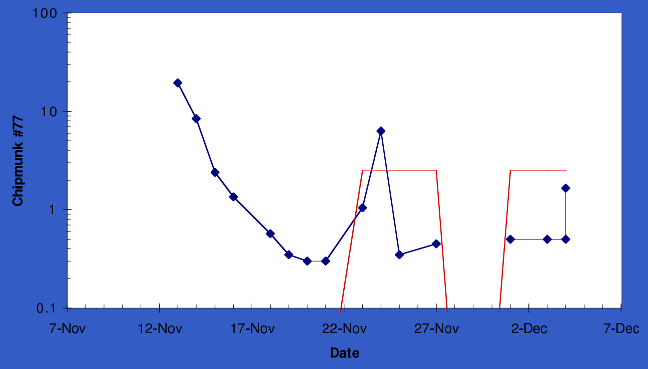


Scintillating fibers

MUSCAT prototype tested Nov 01 (E. McKigney, P. Gruber). New detector (A. Bross) used for MICE background estimates

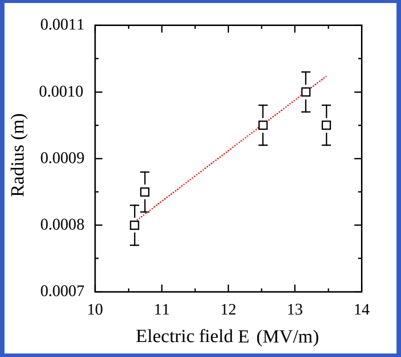
- Would overwhelm MICE fiber tracker without shielding
- OK with absorber
  $\sim$ 1kHz/fiber at 8MV/m $\Rightarrow$
  <10MHz at 200MHz
- Improved with conditioning

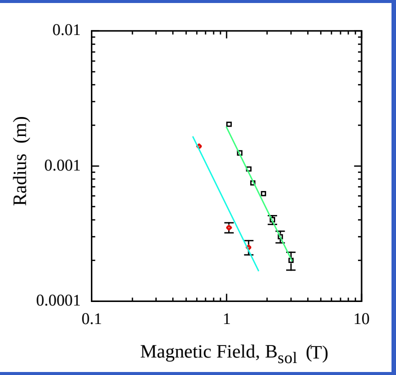


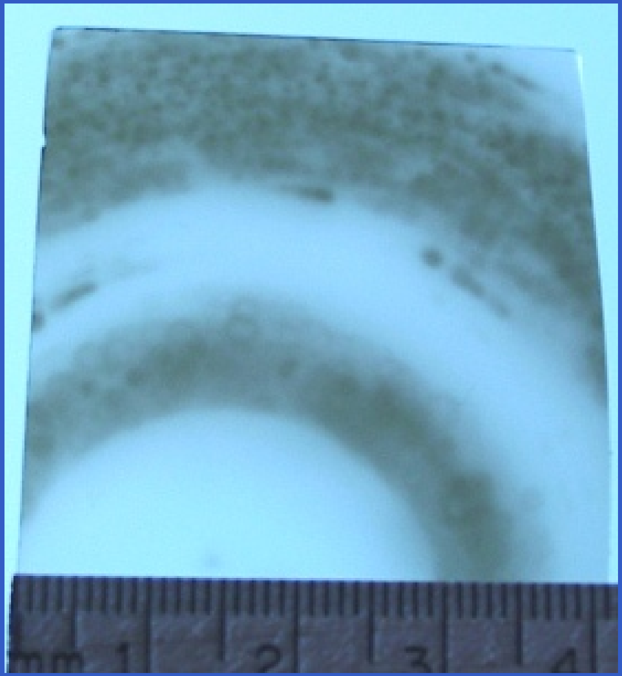


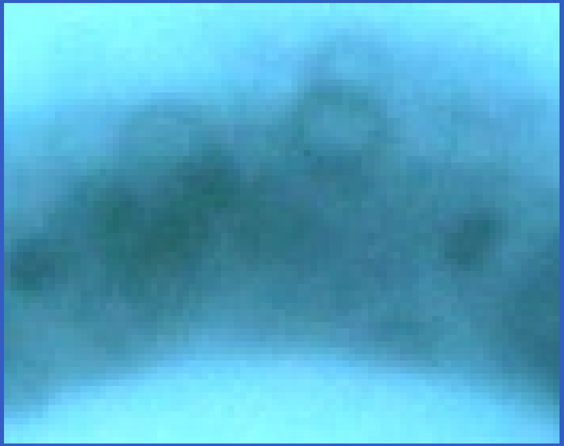
Glass plate photography

- Put thin plates flush against window (J. Norem)
- Beamlets from single emitters in magnetic field
- Turned into rings at low field
- Radius consistent with ExB drift $r \sim E/B^2$



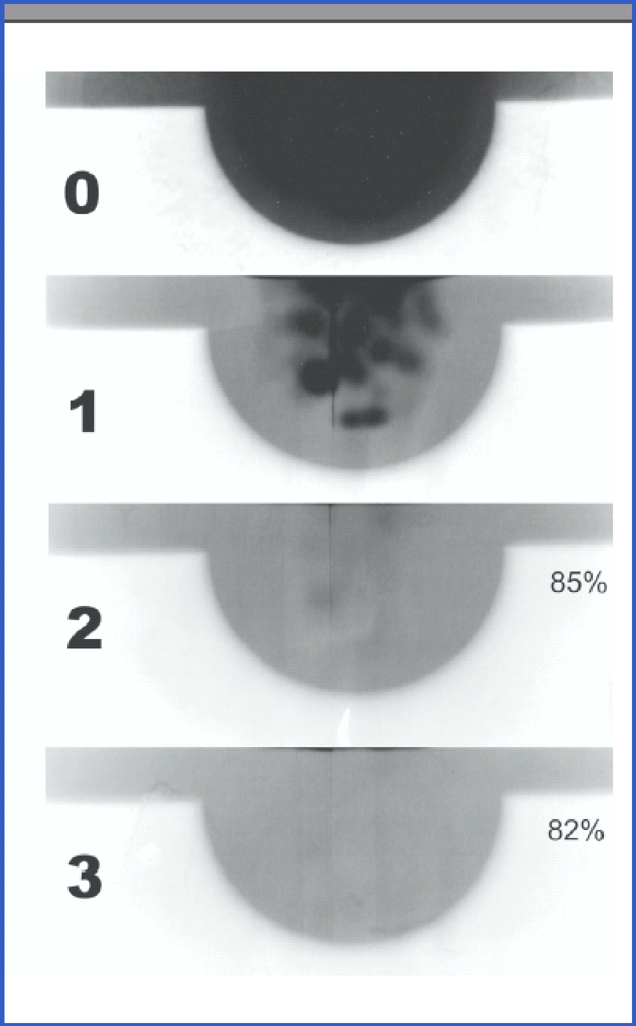






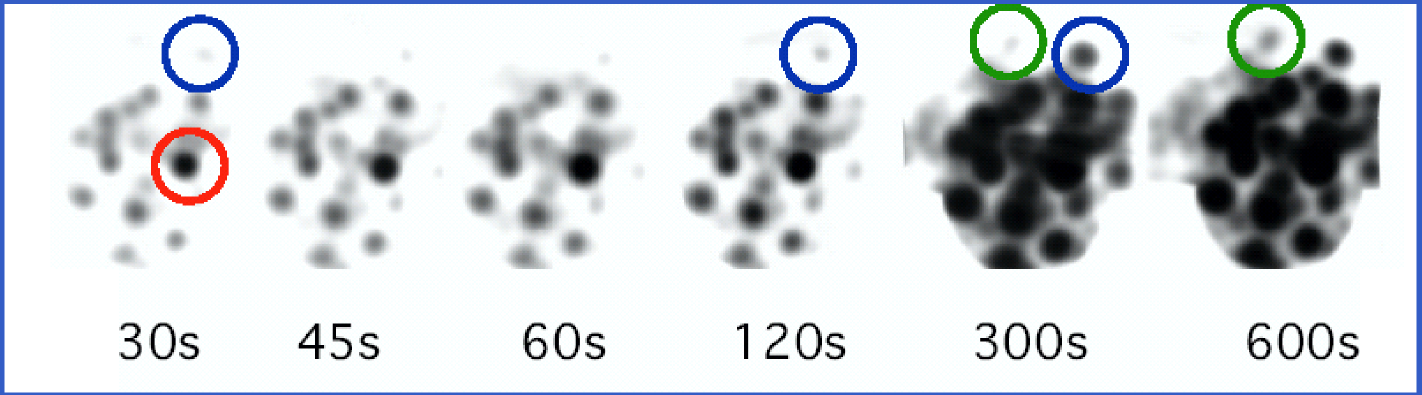
Photographic paper

- Use Polaroid for short exposures to follow progress in cavity conditioning
- Exposed standard b&w paper, develop, scan (P. Gruber)
- Intensity pattern over large area
- Rangestack with 1.6mm Al plates at 10MV/m →
  - Front layer saturated
  - Can see emitters after 1 plate
  - 2 plates stop dark current
  - uniform x-ray image

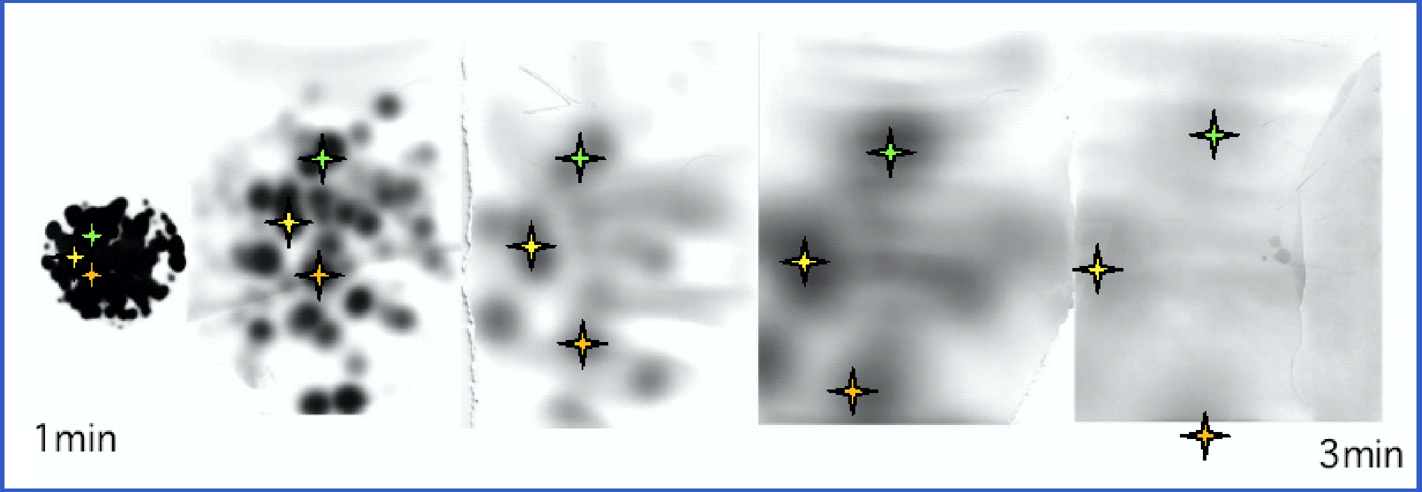


Photographic paper

Individual emitters visible



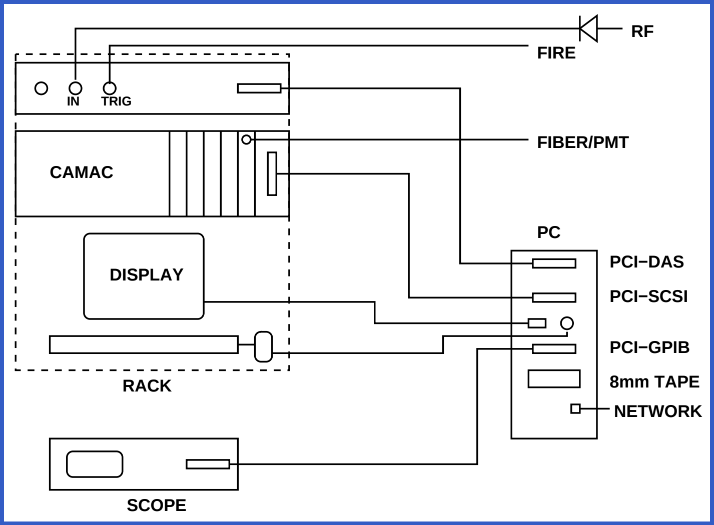
Can follow transport in fringe field

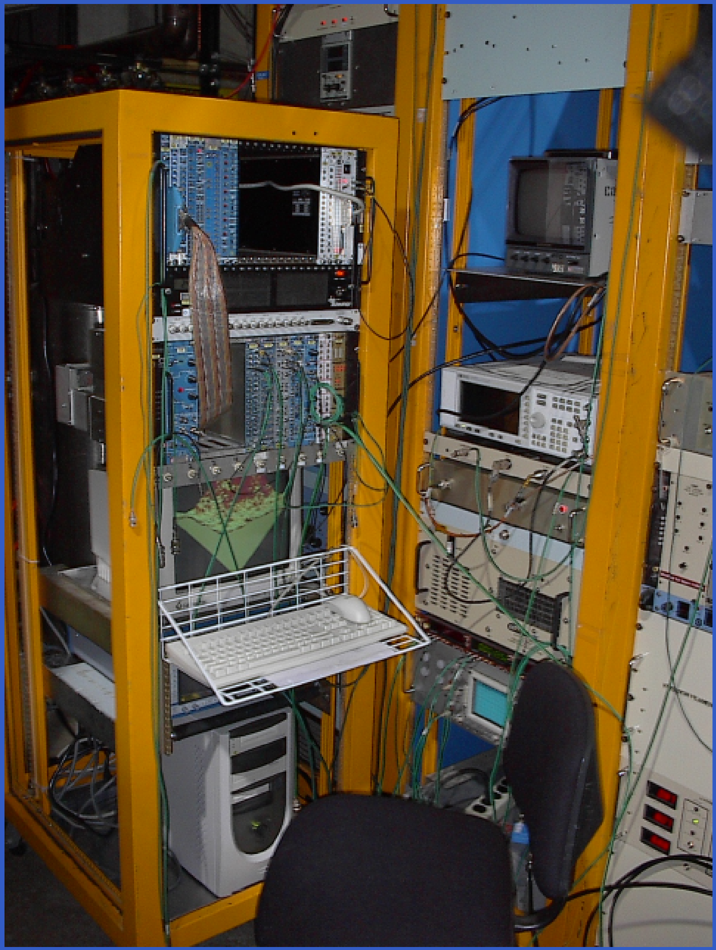


Away from cavity $\longrightarrow$

Data acquisition

- Existing DAQ system saves slow signals
- Built auxiliary DAQ to make it easier to set up and automate new measurements
- System in use but not integrated yet



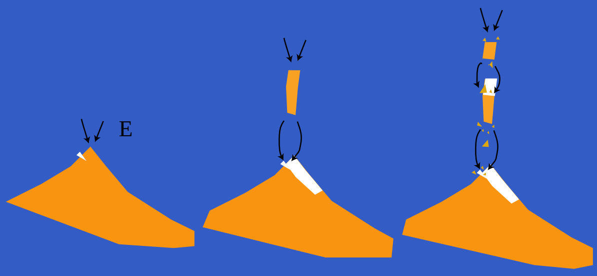


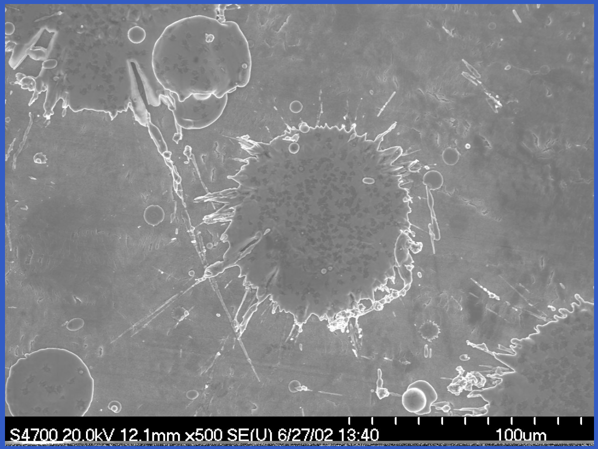
Open-iris vs pillbox data

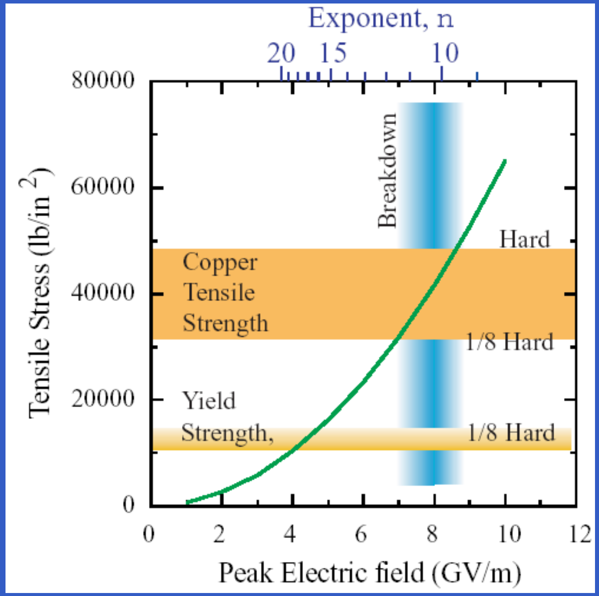
	Open-cell	Pillbox
Dark current	25 mA at 16 MV/m, 600 mA at 24 MV/m	Not measurable (<0.1mA)
Fiber saturation at B = 2.5T	1.5MV/m	>13MV/m
Window interior	covered with Cu	no deposits
Window failures	two during magnetic field operation	none
Cavity interior	heavy pitting on irises	some pitting on endplates

All-copper breakdown model

- Observation (J. Norem): stress ($T = 0.5\epsilon_0 E^2$) can exceed Cu tensile strength at emitter tips
- deforming surface into sharper features, removing chunks
- triggering breakdown
- Molten Cu splashes form more emitters







Conclusions

- Pillbox cavity operation shows
  - Absorber heat load not significant
  - Windows can survive dark current
  - MICE detectors can live with projected rates if placed behind hydrogen (at high channel count/cost)
- Surface treatment important for cooling channel
- Need 201MHz prototype for reliable results

Current status

- Identified useful detectors and measurements
- Physical picture consistent with existing data, refining measurements
- Open-cell cavity results submitted to Phys Rev STAB (first systematic study of high-gradient Cu rf in B)
- Successful pilbox cavity run with Cu windows, encouraging results
- Pillbox being conditioned with Be window, studies in progress

Future plans

- 805 MHz testing with Be windows and grids
- Analysis of windows removed from pillbox
- DAQ integration/commissioning
- Improved understanding of emission phenomena, surface treatment tests
- Simulation of electron transport in channel
- Study effect of field configuration (gradient mode)
- More rate measurements for MICE
- Test 201MHz prototype when available