RF BACKGROUND STUDIES AND PLANS

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Introduction

We need to characterize radiation field around RF cavities to

- identify relevant diagnostics for cavity operation
- look for hints to improve performance
- help select instrumentation for cooling channel
- understand background environment for detectors in a cooling experiment

Problem

- Electrons are stripped from metal surface at imperfections where electric field is locally enhanced
- get accelerated by the cavity field
- strike metal surfaces and generate x-rays
- Energetic electrons and x-rays escape the cavity through the thin windows
- Electron dark current absorbed by liquid hydrogen depositing heat
- X-rays penetrate absorber and flood detectors

Dark currents

- limit accelerating gradient by absorbing input power
- trigger destructive cavity breakdown
- can damage cavity surface and windows
- are focused/deflected by magnetic field in cooling channel
- can be efficiently accelerated in channel
- contribute to absorber heat load and can cause local bubbling
- limit detector placement options for cooling experiment

Field emission

Fowler-Nordheim approximation for current density j due to tunneling through the potential barrier (work function) at a metal surface

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

- E = nominal electric field at surface
- β = local field enhancement factor
- ϕ = work function ($\simeq 4.6$ eV)
- $A = 1.54$MeV A/MV^2, $B = 6830$V/m/eV$^{3/2}$
- A_{rf} = rf duty factor ($\simeq 0.1$)

Field emission

- Total dark current off interior surface dominated by the worst emitter sites

$$I = \int j(E(\vec{r}))\, d^2r \simeq \sum_i A_i j(E_i; \beta_i)$$

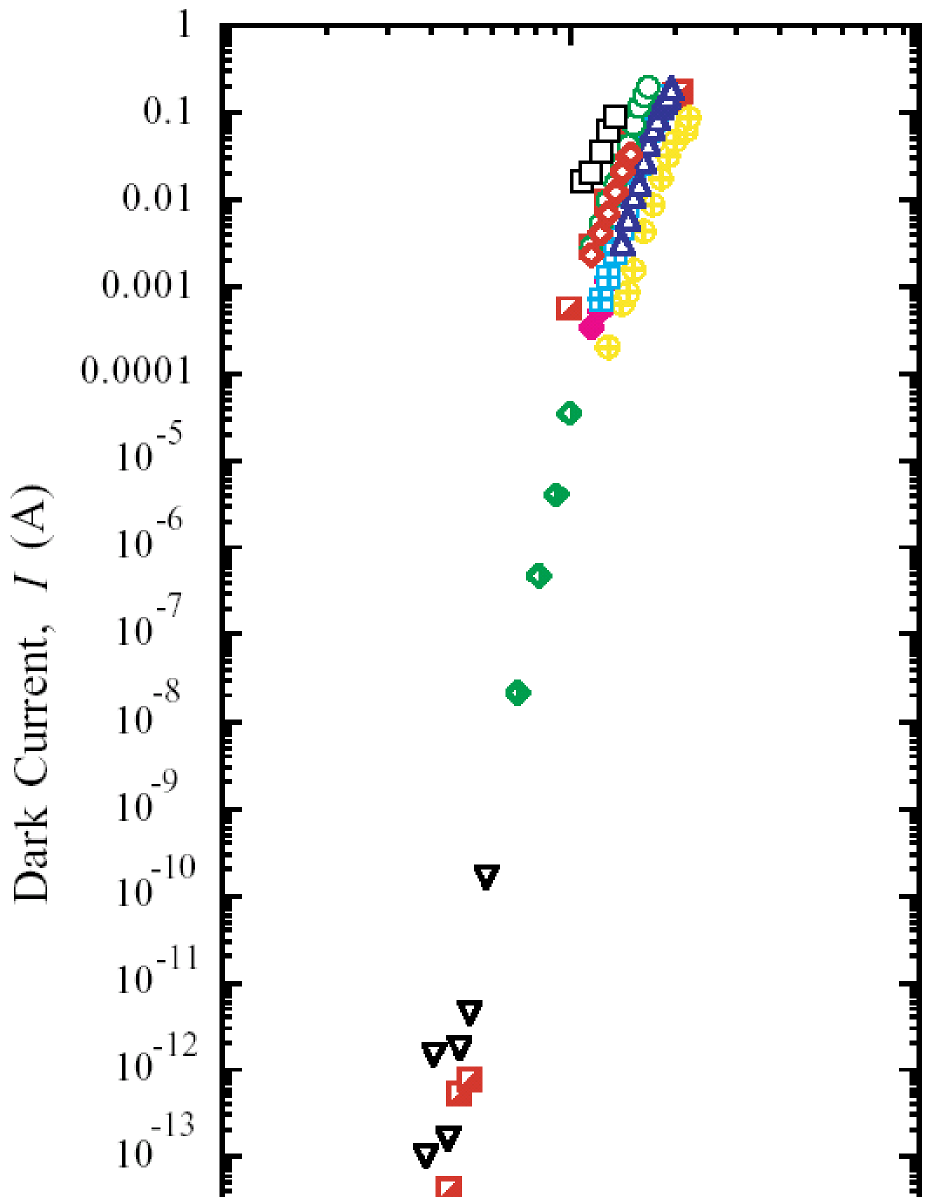
- Emitter distribution determined by surface treatment and conditioning history
- Electric field highest at irises/windows
- Measured current depends on geometry and electron transport

Instrumentation challenge

- Extremely steep dependence of I on E ($n \sim 10$ for 8GV/m surface field)

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

- No single detector/technology can cover (or survive!) entire dynamic range (over 10 orders of magnitude)
- Very hard to control systematics and make repeatable measurements
- Had to try (and occasionally fry) many different detectors
- Need to crosscheck results often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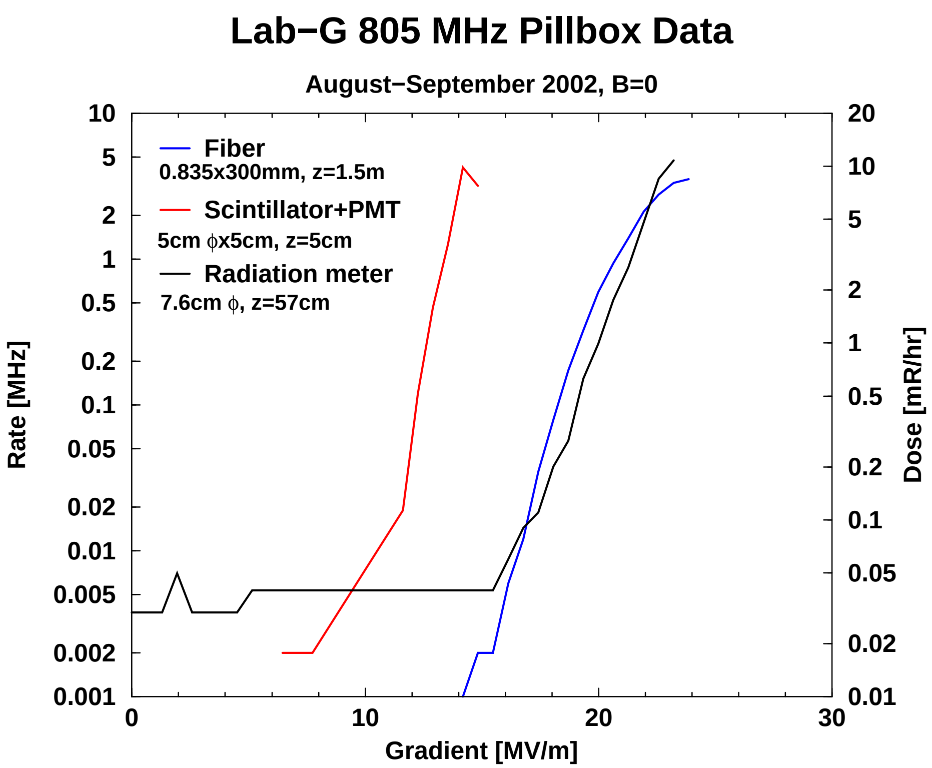
Dark Current, I (A)

Detectors

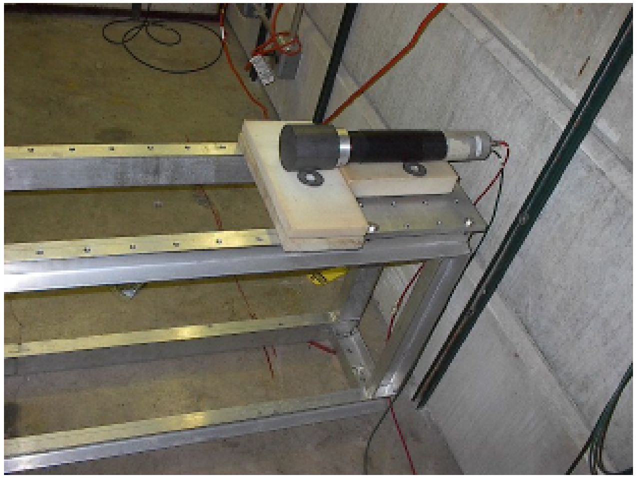
- Area radiation monitors, dose meter
- Dose monitoring film
- Glass plates
- Polaroid and standard photographic film
- Current transformers
- Scintillator with photomultiplier tube
- Scintillating fibers with photomultiplier tube
- Scintillating fibers with hybrid photodetector
- Scintillator with hybrid photodetector
- Ge diode spectrometer

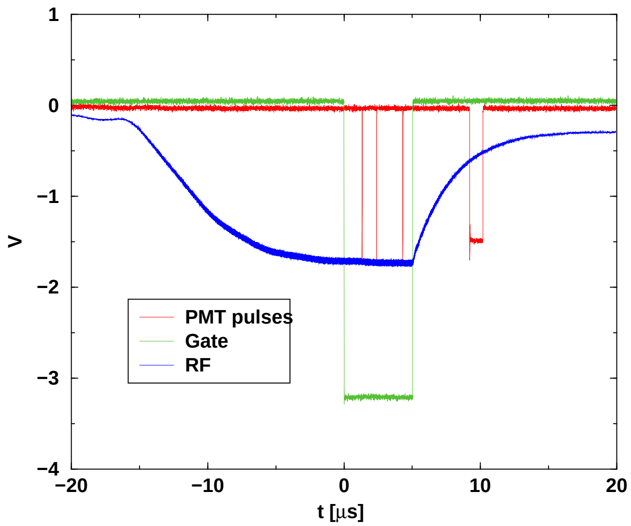
Radiation monitors



- Robust
- Limited range
- Slow

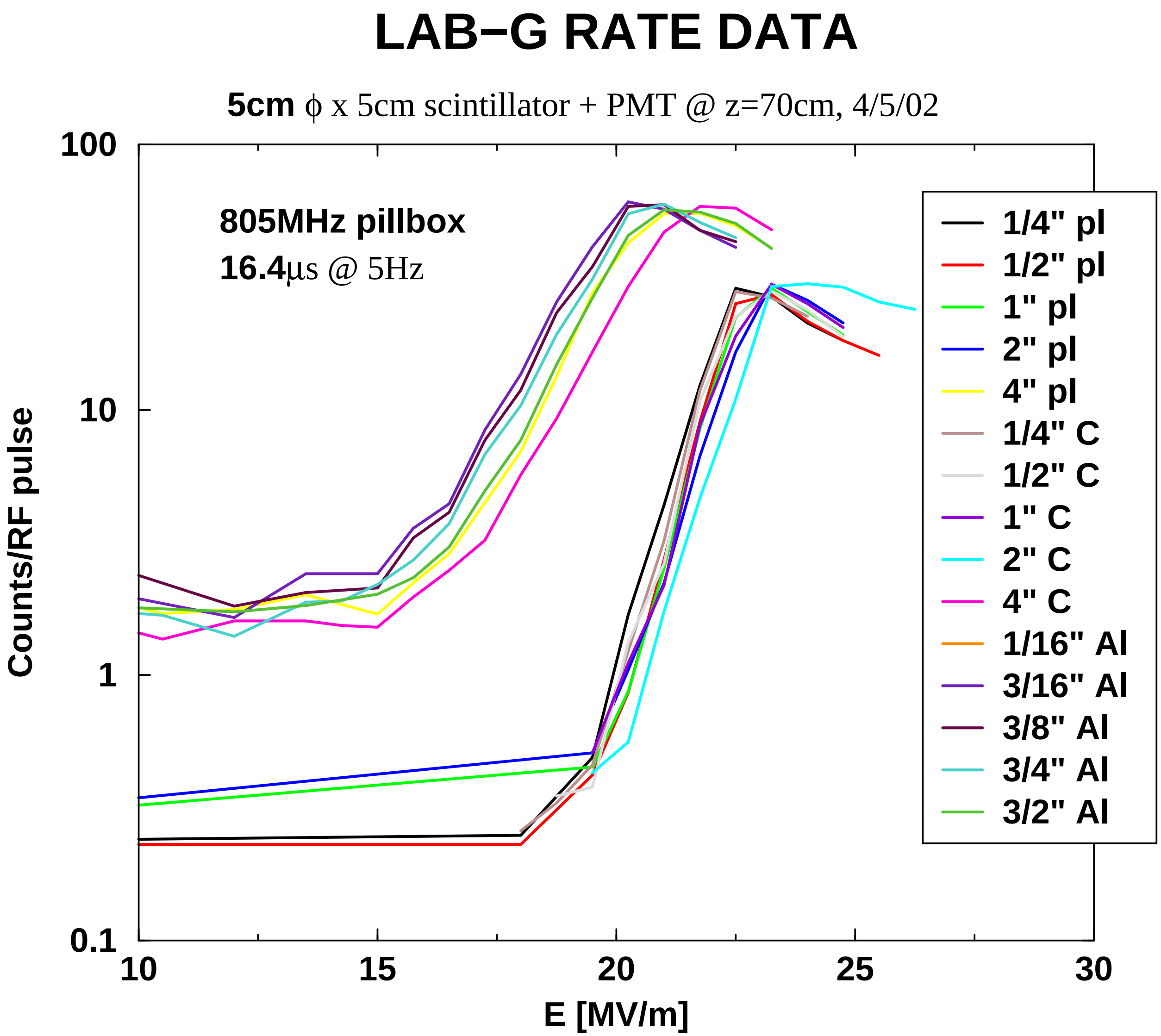
Scintillator+PMT





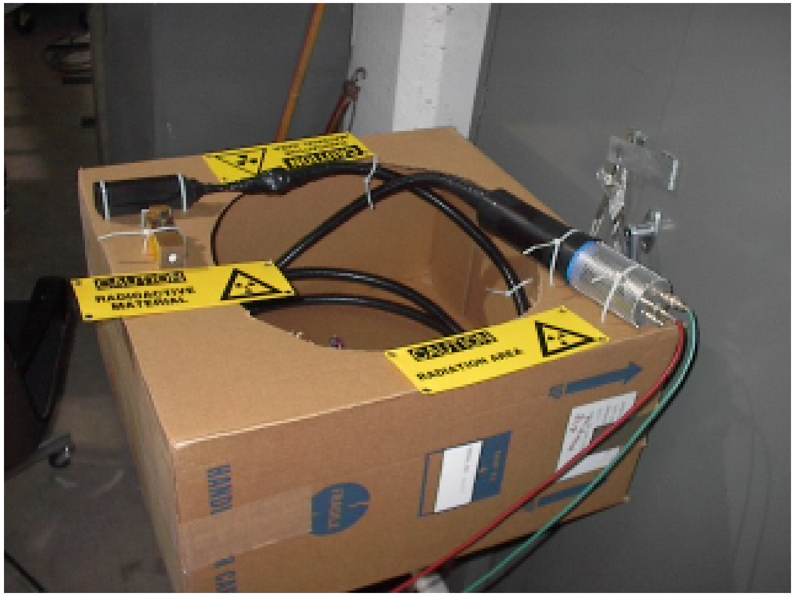
- Robust, fast
- Limited rate

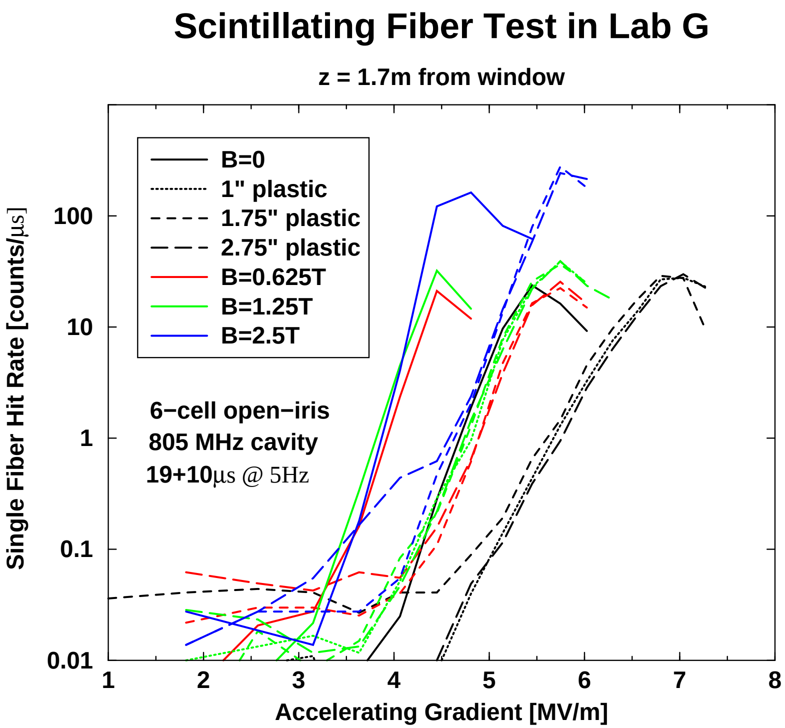
Scintillator+PMT



Scintillating Fiber

MUSCAT prototype (E. McKigney, P. Gruber)

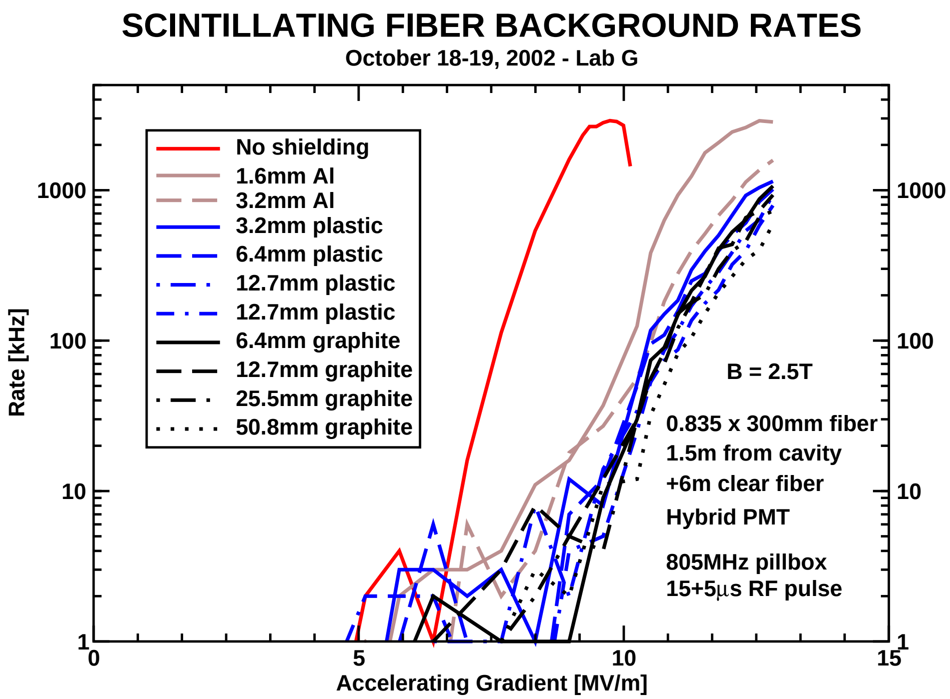




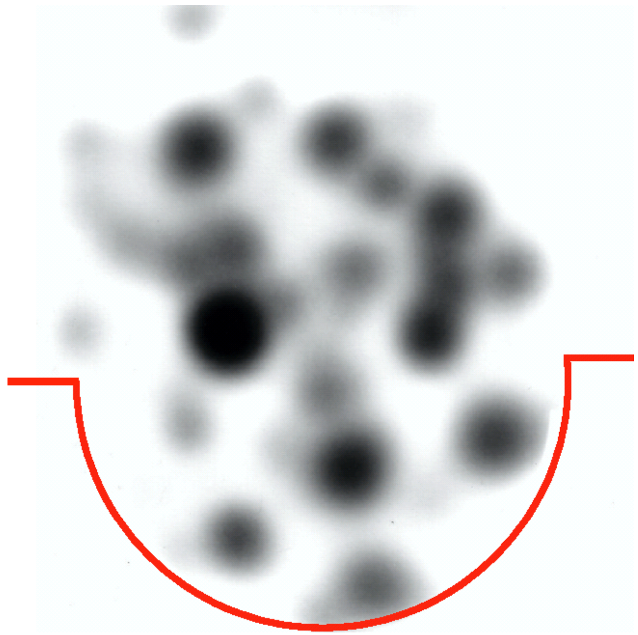
Scintillating Fiber

New fiber detector with low loss clear fiber light guide and hybrid phototube readout

Scintillating Fiber



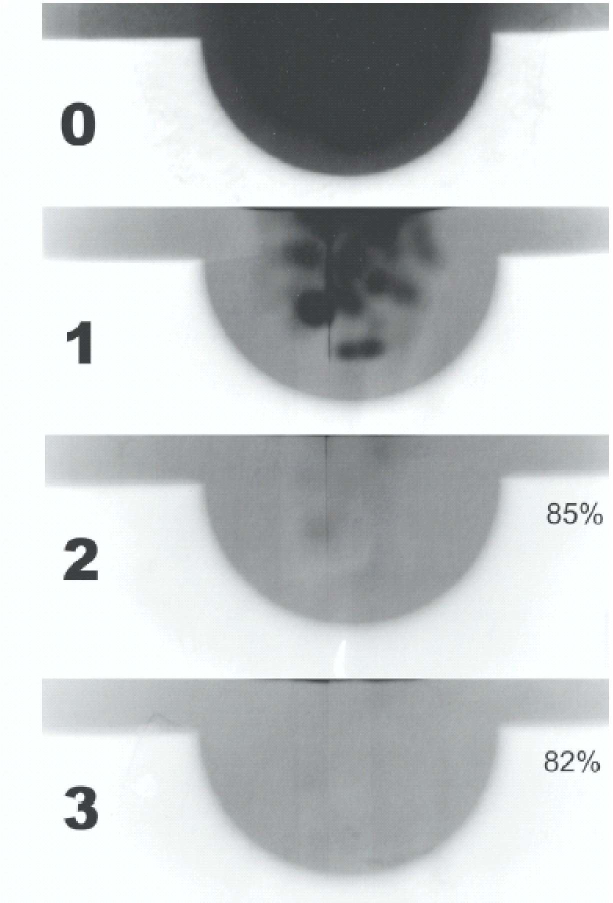
Photographic paper (P. Gruber)



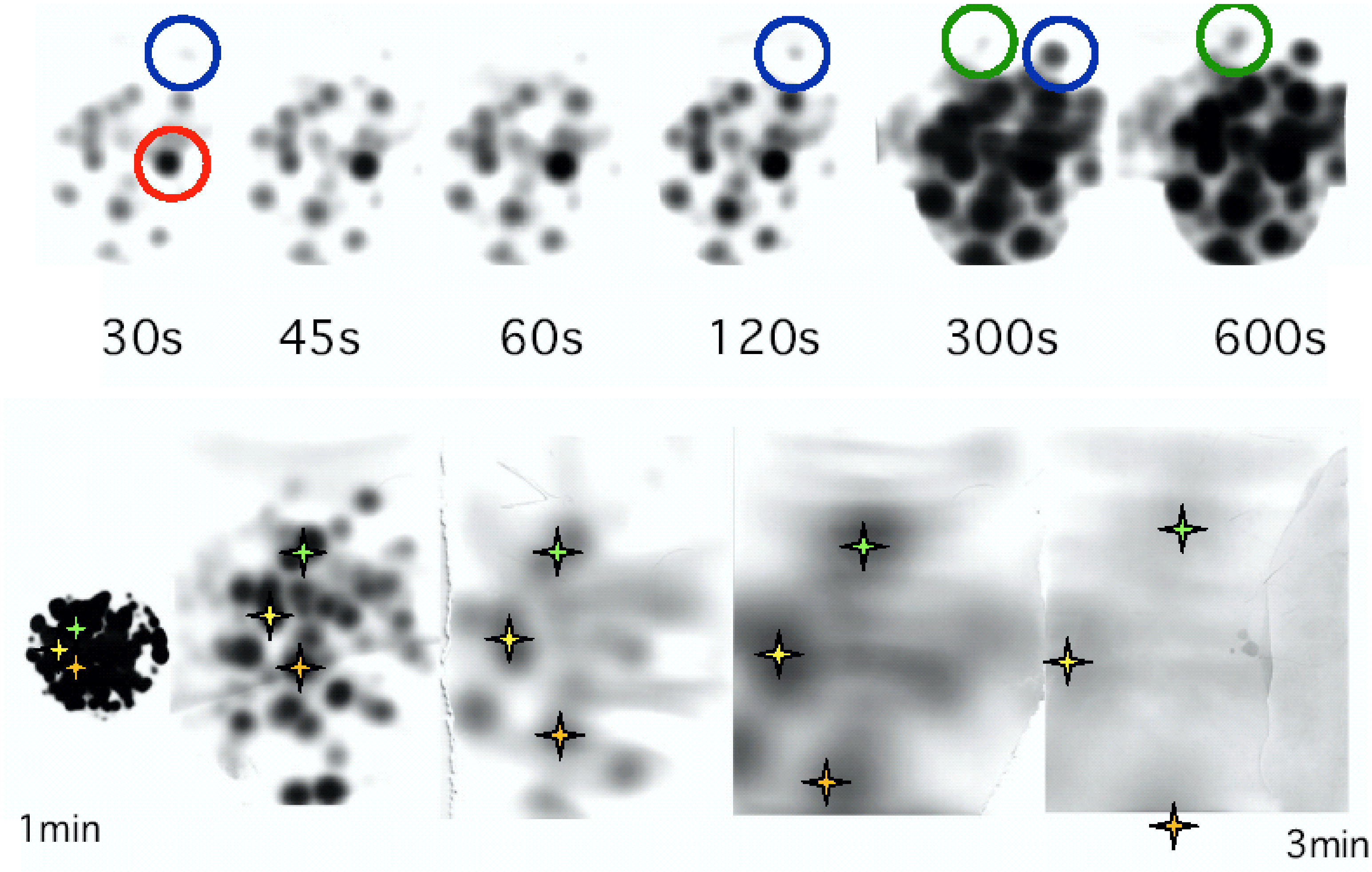
- Expose bw photographic paper, develop, scan
- Can give intensity pattern over large area
- Individual emitters visible
- Can follow transport in fringe field

Photographic paper

Range stack with 1.6mm Al plates



Photographic paper



Away from cavity →

Current Status

- Identified useful detectors and measurement
- Scary open-cell cavity data at high gradients, results submitted to Phys Rev STAB
- Successful pilbox cavity run with Cu windows, more detailed results
- Pillbox cavity being conditioned with Be window, studies will continue
- We have gained valuable experience at 805MHz (the first systematic study of high gradient Cu rf in magnetic field)
- We have educated guesses for 201MHz based on the results
- We are refining measurements
- MICE can probably live with the estimated rates but at