805 MHz Studies and Plans

(and more)

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RF Challenges for MUCOOL

- Low frequency cavities must operate at high E fields in magnetic fields.
  E = 16 MV/m during conditioning, B ~ >3 T, inhomogeneous magnetic fields
  There is no outside experience with cavities in this parameter range.

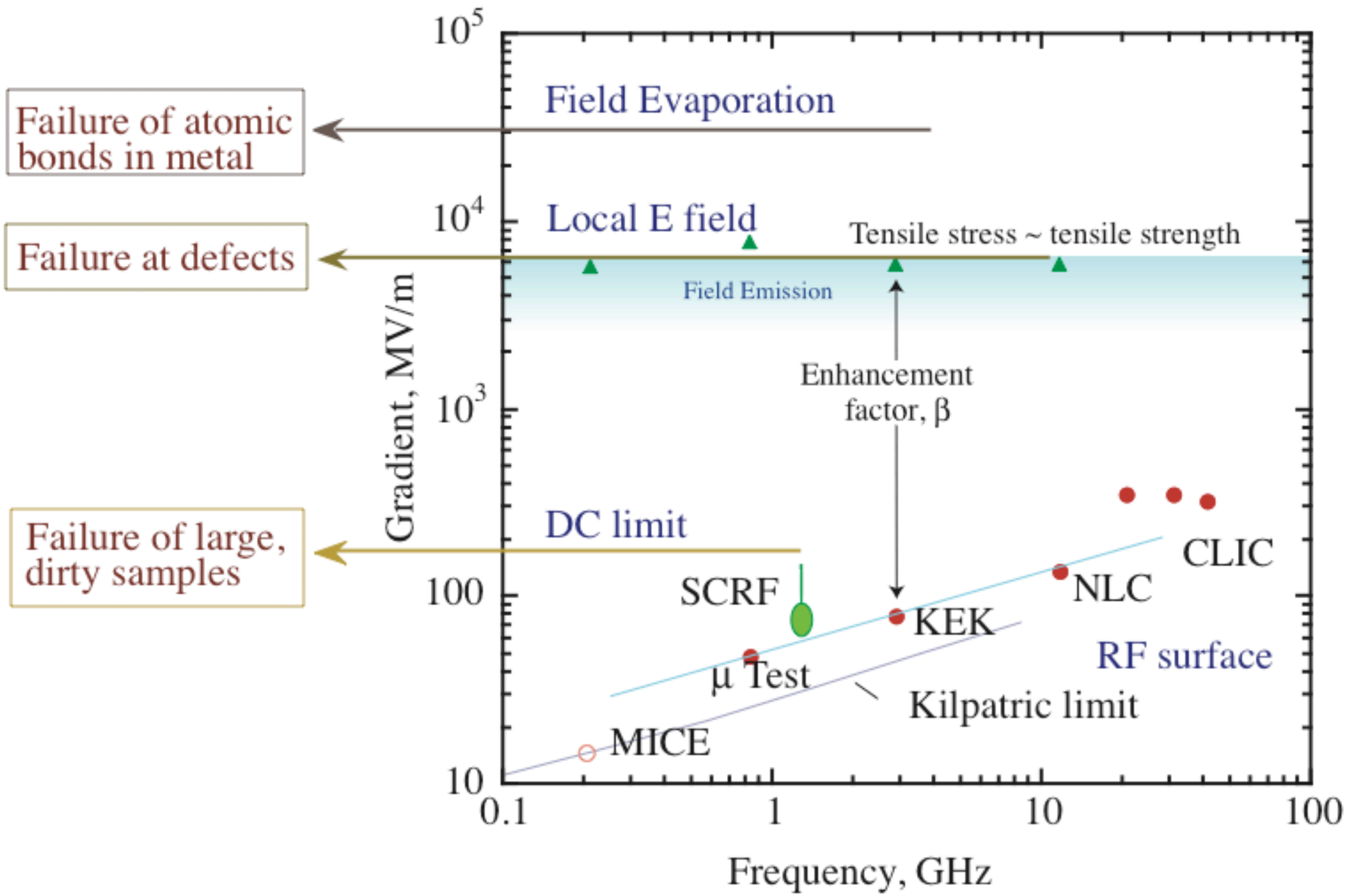
- The operating field must be lowered from the maximum conditioned field to minimize x ray backgrounds in the spectrometers.

- The design field for the MICE experiment is 8 MV/m.

- We have operated an 805 MHz open cell cavity with relevant stored energy at relevant solenoidal fields.

- The 805 pillbox cavity demonstrated great performance with Be windows.

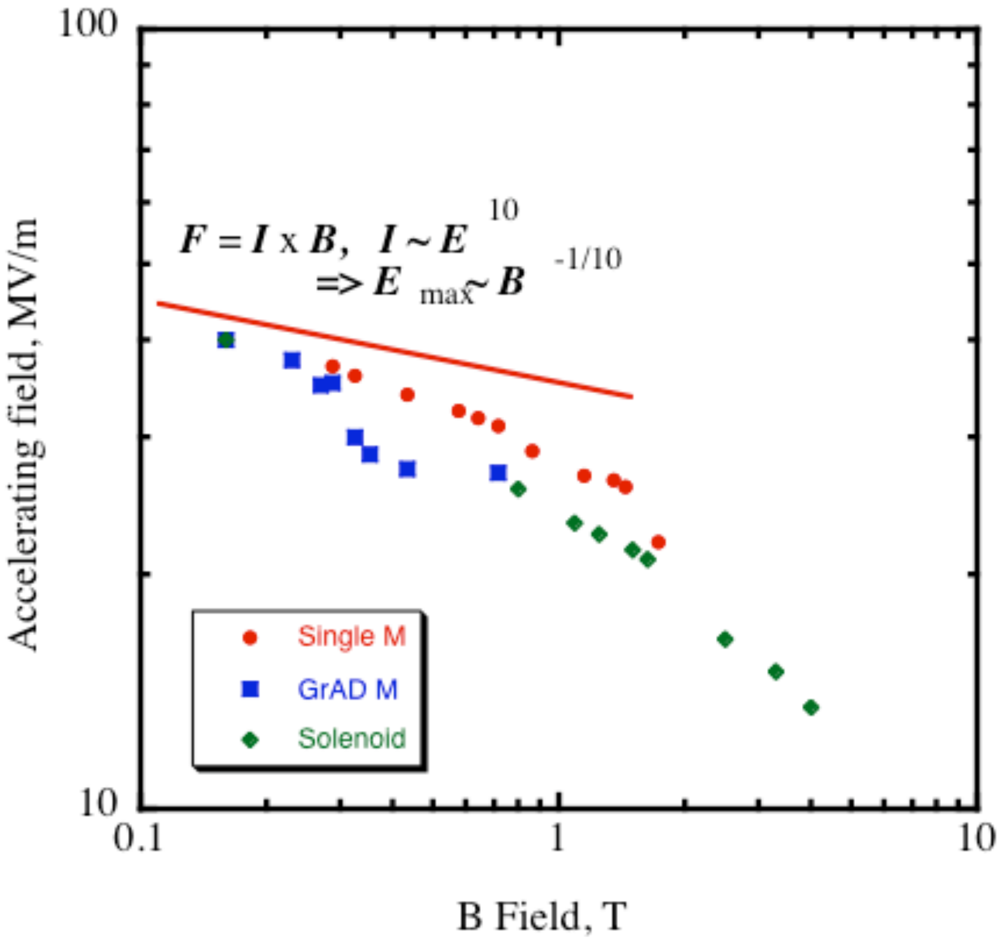
We claim to understand breakdown in cavities



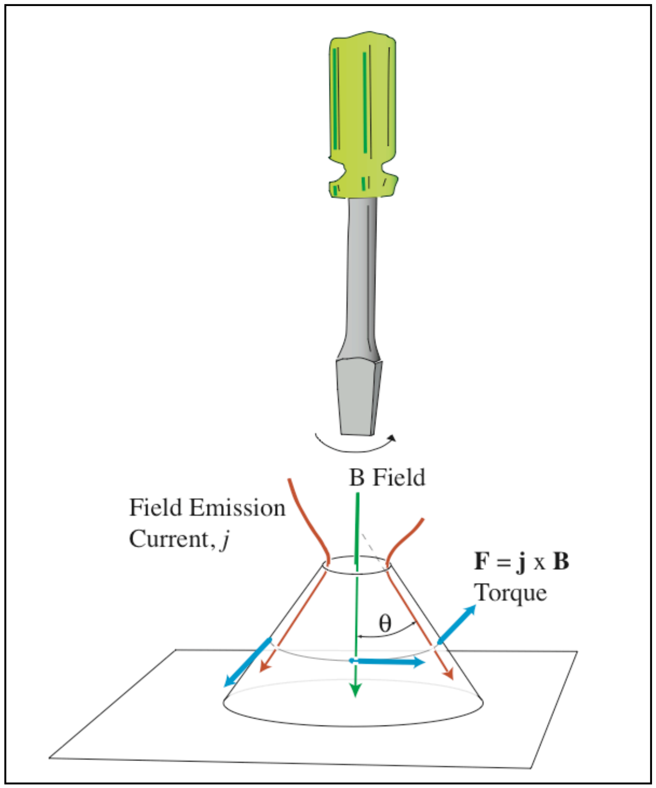
Recent magnetic field data is consistent with *J* x *B* effects.

- ***j*** x ***B*** forces are driven by field emission currents <u>in</u> the emitter.

The data



The model



- We want to <u>cure</u> this by suppressing dark currents (and forces) with coatings.

The MUCOOL Collaboration rf program

Experimental

- MUCOOL Test Area at Fermilab
  Tests of cavities at 805 and 201 MHz with magnetic field

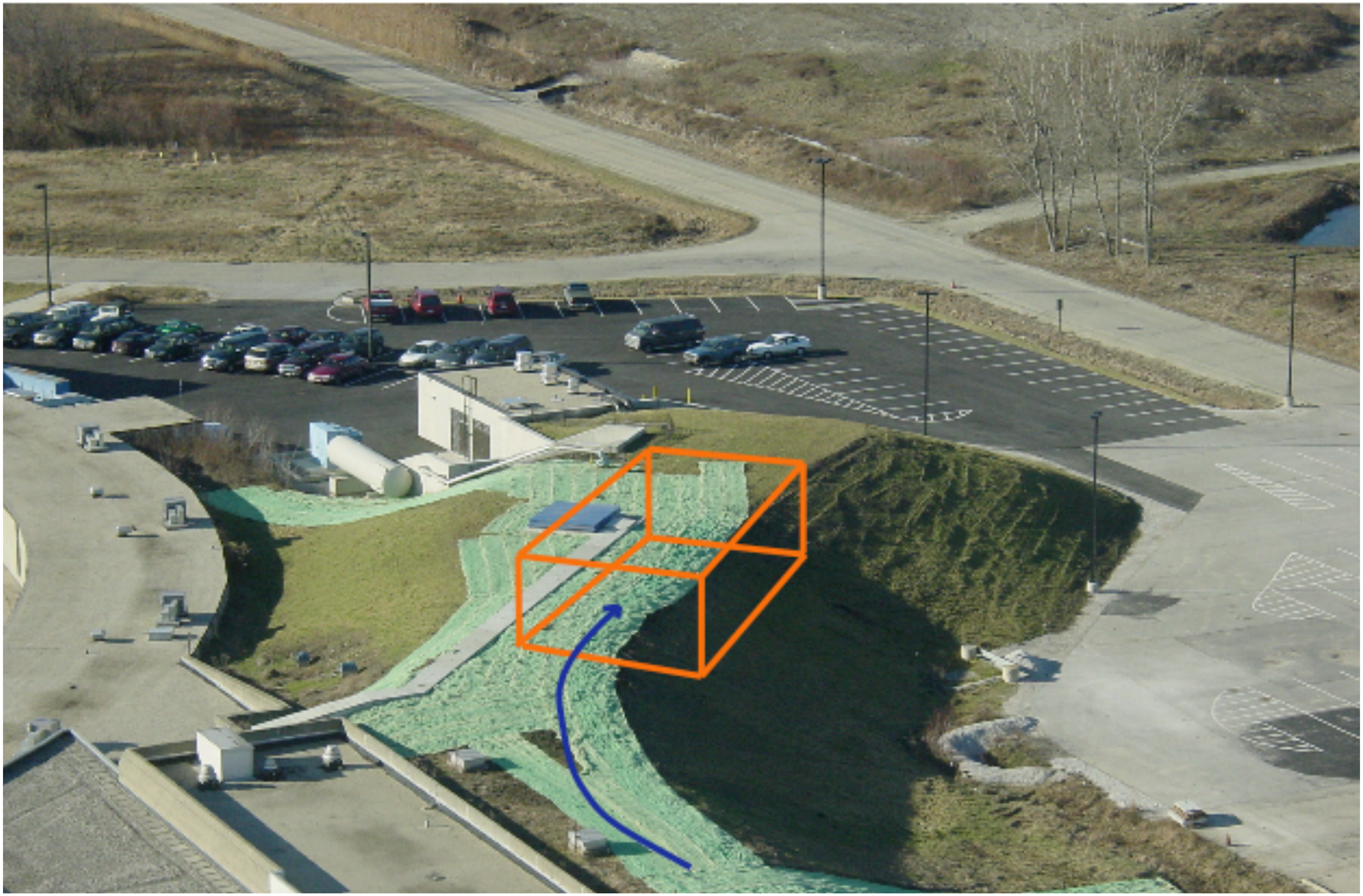
- Atom probe experiments at Northwestern
  Materials studies relevant to Muon cooling, breakdown and SCRF
  Funded from ANL funds so far.
  Done with Prof. David Seidman and Jason Sebastian
    Northwestern University Center for Atom Probe Tomography

Modeling

- Model breakdown process, at Argonne
  Argonne funding
  Done with Zeke Insepov and Ahmed Hassanein

We have a new experimental area at Fermilab

The MUCOOL Test Area (MTA)



The MTA is almost ready.

- Cabling is complete.
- Tests of 805 and 201 MHz
  - windows
  - magnetic field effects
  - coatings, high pressure
- Components are being moved in.

The MTA Experimental Program

- 805 MHz cavity

  Curved Be windows

  The flat ones were unstable when operated in the 805 MHz cavity. The operating frequency depended slightly on the field, and at high fields it was hard to achieve stable operation at any frequency. Curved ones should be better.

  Button tests of different materials

  We have tested Cu and TiN coated Be, but it is not clear what the limits of Be are, or whether coatings or other materials offer advantages. We need experience with damage with different materials, and more systematic data with real rf.

  Magnetic field studies

  We need to understand the mechanism behind the limits on accelerating field set by solenoidal B fields.

  High pressure cavities

  High pressure gasses may be useful. Covered by R. Johnson (MUONS Inc).

- 201 MHz cavity

Conditioning and breakdown studies of the MICE prototype cavity

This cavity will operate at high stored energy with curved Be windows. We need to understand the level of damage produced in the Cu and Be surfaces, how fast the cavity conditions, what are the radiation levels produced, what shielding will be required, whether mechanical deformation in the windows introduce instabilities in the operation and how the x ray backgrounds depend on electric field with a fully conditioned cavity.

The sequence of tests will be:

Conditioning with Copper Windows

Radiation levels, etc

Be Windows

Stability and damage measurements.

Magnetic field studies

With magnetic field on a part of the cavity, we want to know how the maximum operating electric field is degraded.

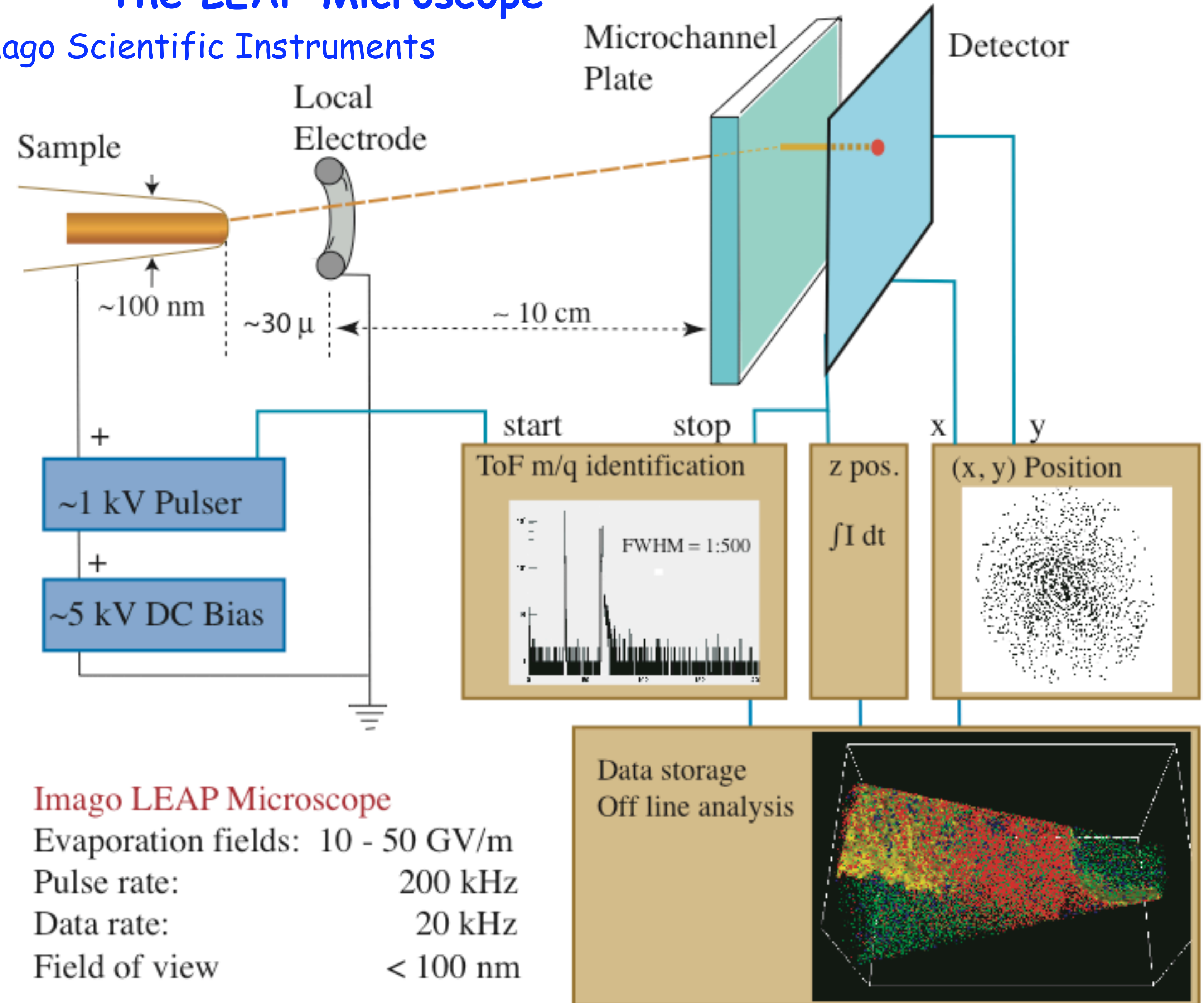
- Surface modification and control

  What limits our control of the surface?

  The development of a real neutrino source requires optimizing cost and performance. We need a method for changing the surface and determining the behavior in a cavity. This will be done with the atom probe microscope, which offers fast turnaround, amazing resolution, sensitivity and statistics.

The LEAP Microscope

Imago Scientific Instruments



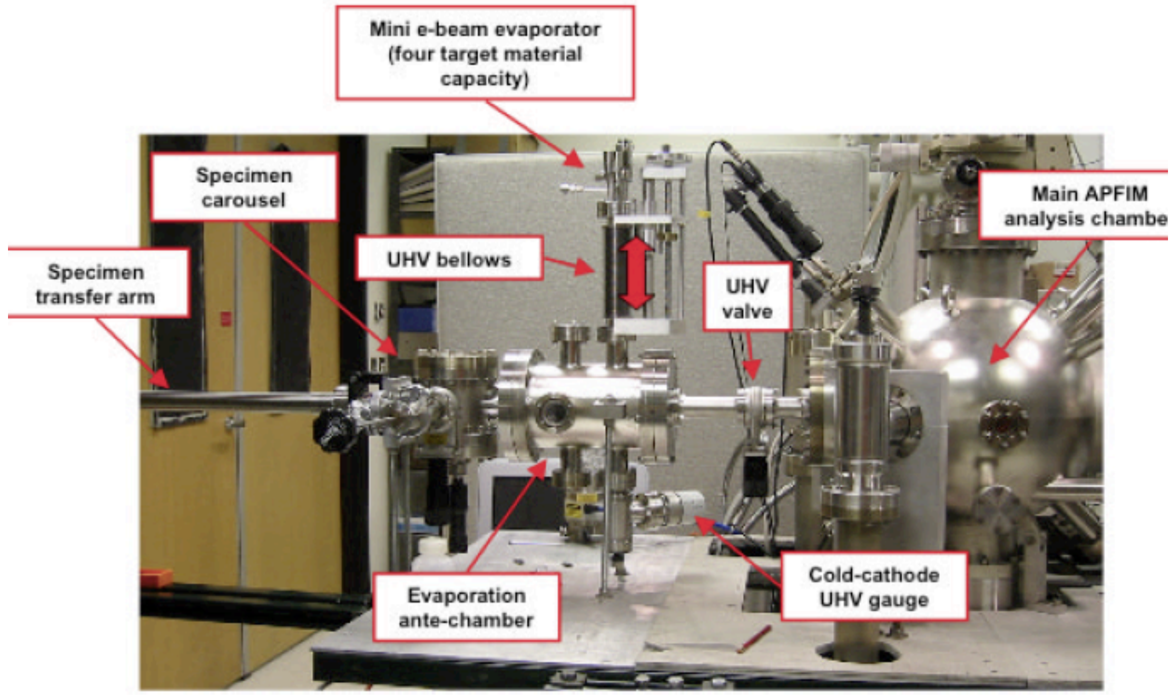
Imago LEAP Microscope

Evaporation fields:	10 - 50 GV/m
Pulse rate:	200 kHz
Data rate:	20 kHz
Field of view	< 100 nm

Atom Probe Coating Tests

Typical experimental sequence (simplified)

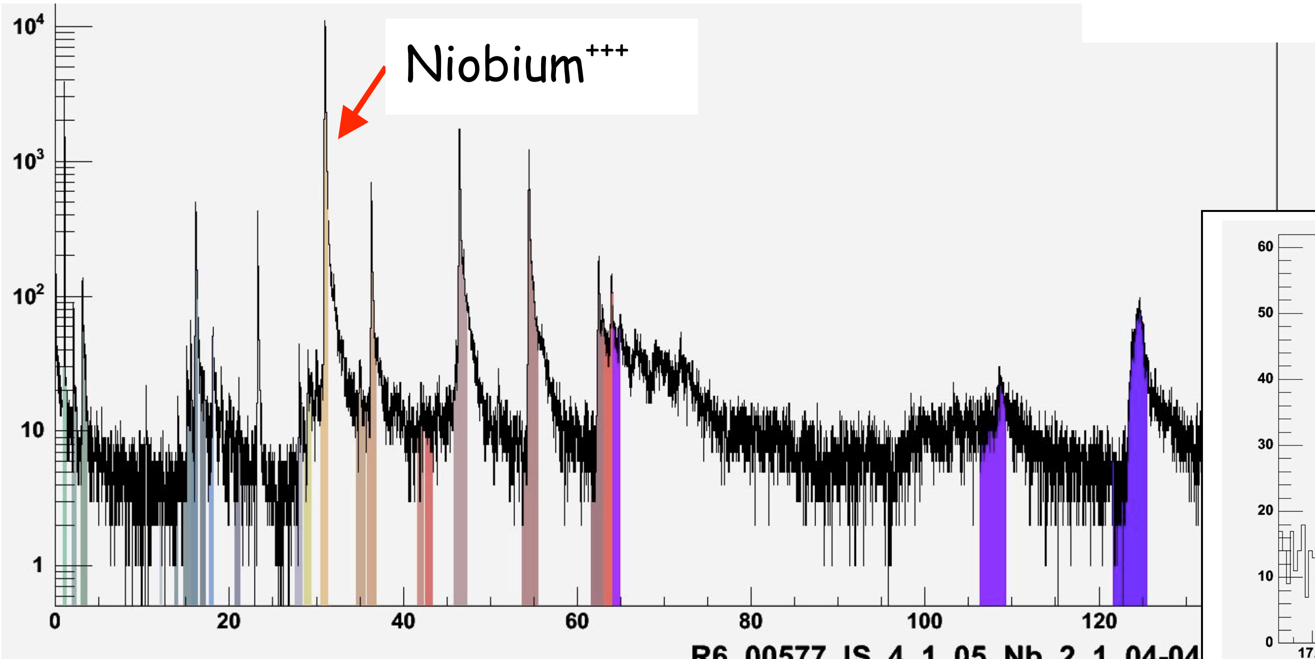
1. Move tip into main chamber
2. Develop tip to smooth end-form via field-evaporation
    - Positive high voltage
3. Measure I-E response (field-emission; Fowler-Nordheim plot)
    - Negative high voltage
4. Move tip into evaporation ante-chamber
5. Evaporate onto developed tip surface
    - Other tip treatments
6. Move tip back into main chamber
7. Re-measure I-E response (field-emission; Fowler-Nordheim plot)
    - Negative high voltage
8. Remove coating via field evaporation
    - Positive high voltage
    - Information about coating adhesion, bonding, interdiffusion, etc.

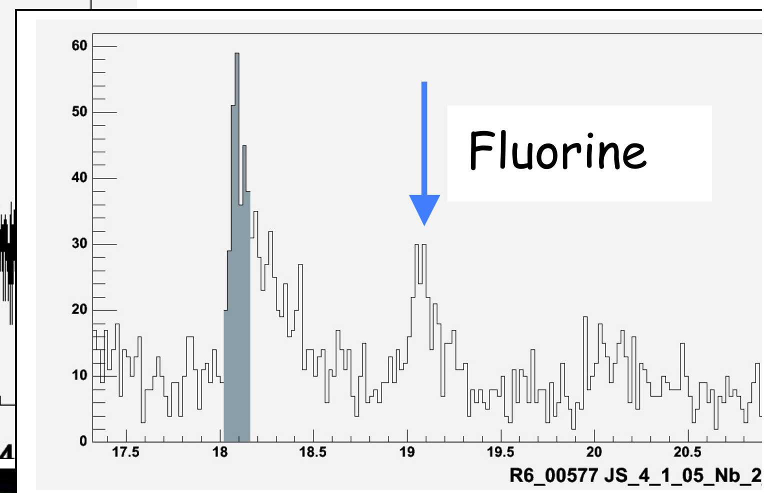


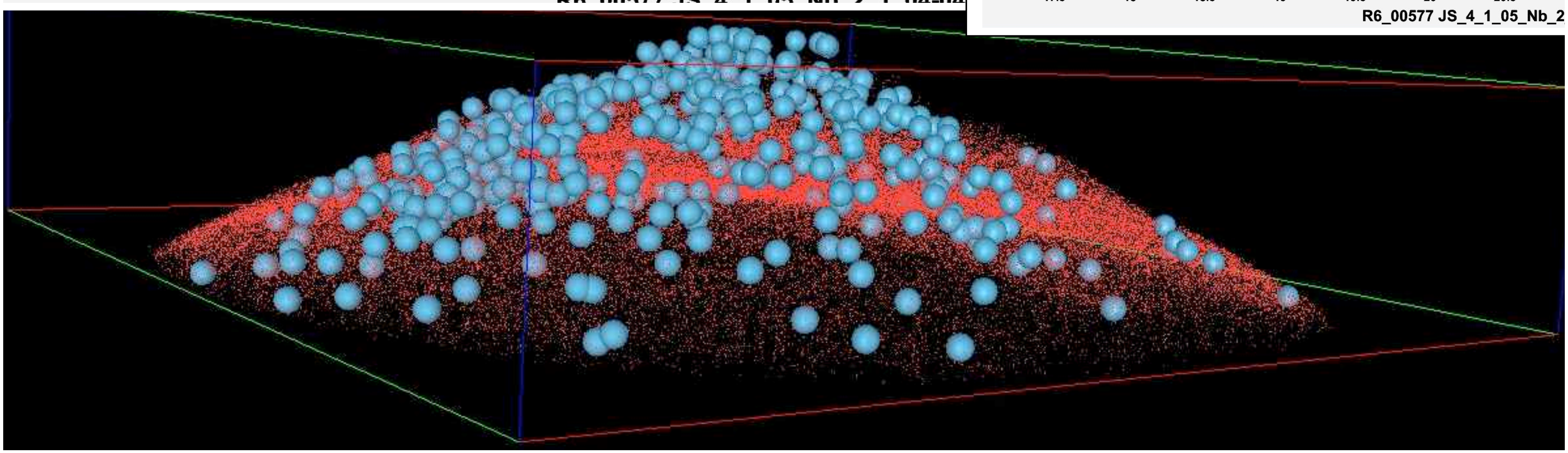
Atom Probe Data: Fluorine Contamination on Niobium

- Ions are identified by time of flight (over ~10 cm).

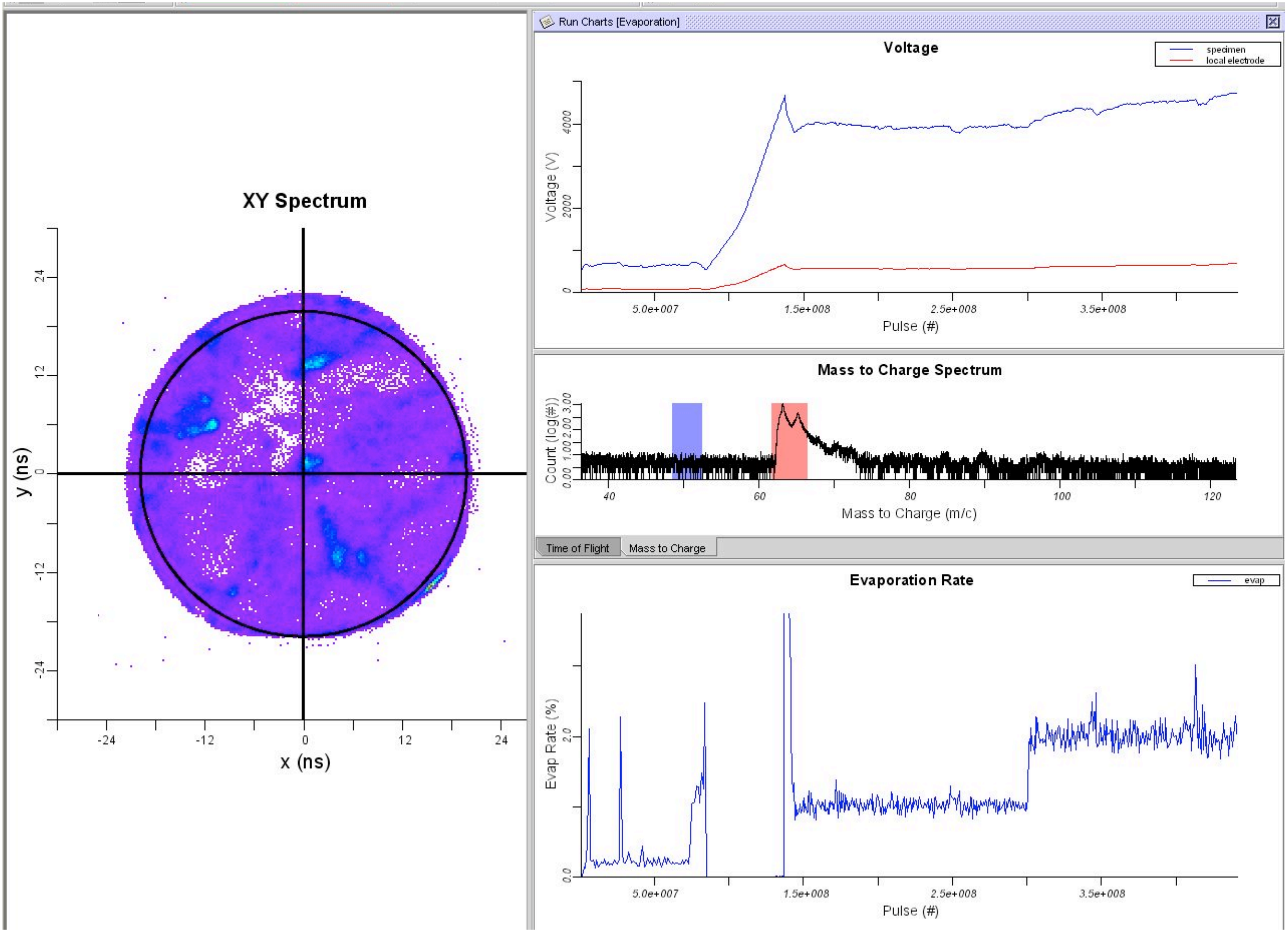
w/ P. Bauer, C. Boffo, FNAL



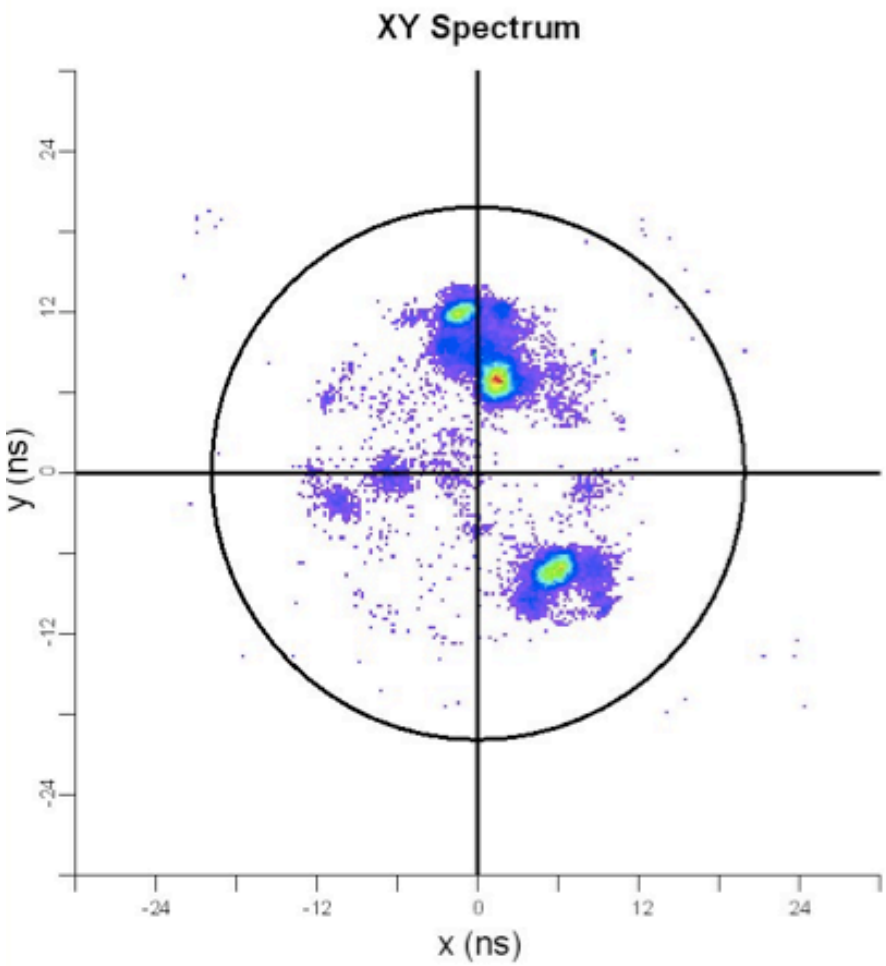


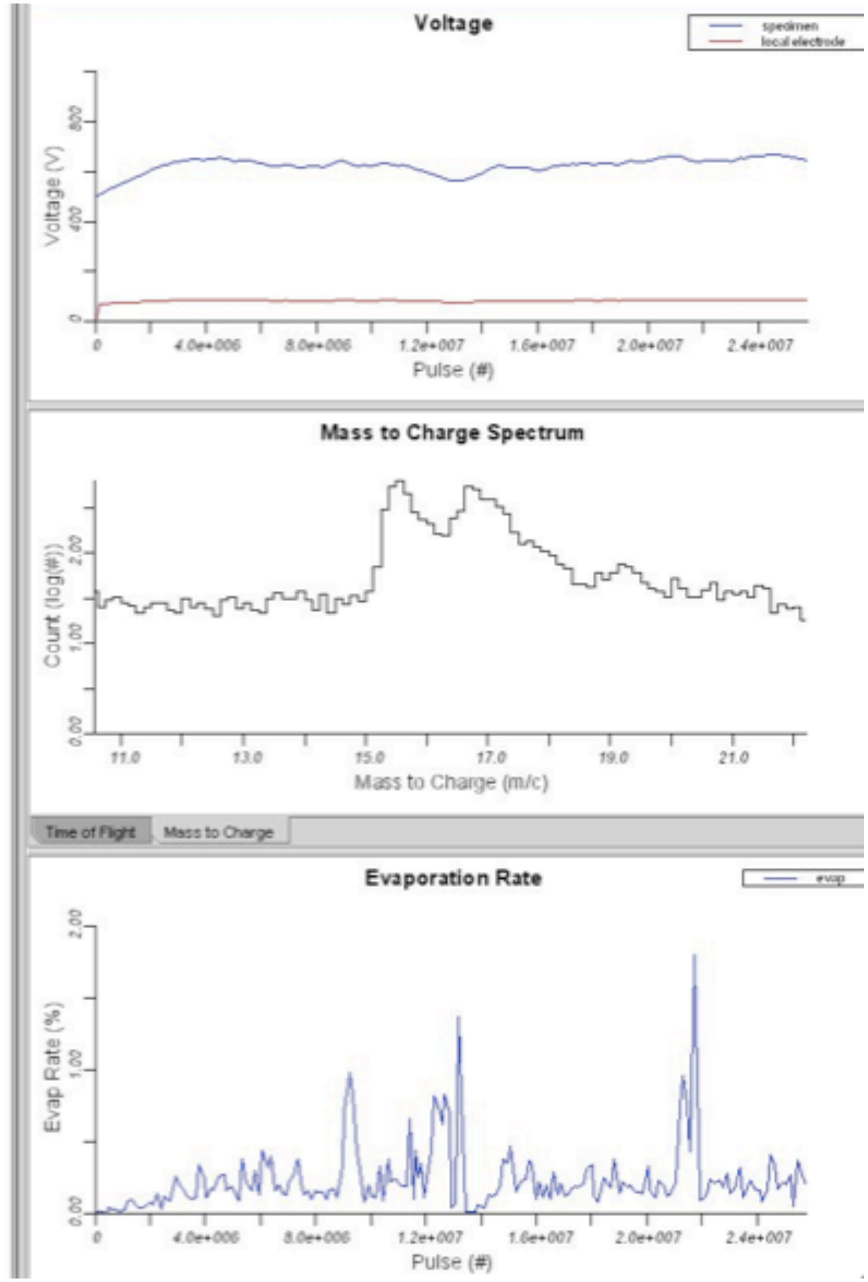


Atom Probe Data: Room Temp. Cu (Very preliminary)



More Data: Are these Breakdown Triggers?





Field Emitters and Atom Probe samples: Similar environments.

- Surface field
  RF field emitter: 4 – 8 GV/m
  Atom Probe sample: 4 – 40 GV/m

- Temperature
  RF field emitter: ~300 ^{O}K
  Atom Probe sample: 20 – 300 ^{O}K

- Pulsing
  RF field emitter: 200 – 12,000 MHz
  Atom Probe sample: 0.2 – 0.5 MHz

- We can produce breakdown triggers in a controlled way.

Summary

- The MTA is coming on, we expect more data in a month.

- We need to understand magnetic field effects and reduce x-ray backgrounds.
  Coatings should suppress field emission
    - improving backgrounds
    - improving operation with high B fields
    - Will they stay on?

- Atom probe techniques are fantastic ! !
  21st century technology
  surface analysis with this machine is uncommon (and tricky).
  We expect breakthroughs

- We see "flashes" that look like they could trigger rf breakdown events.
  We can do relevant coating tests with unprecedented precision and speed.

- This work will be useful to many accelerator projects.
  ILC, SMTF, RIA, CLIC etc.
  (We are looking for other funding for this work, from DOE, NSF and ANL)