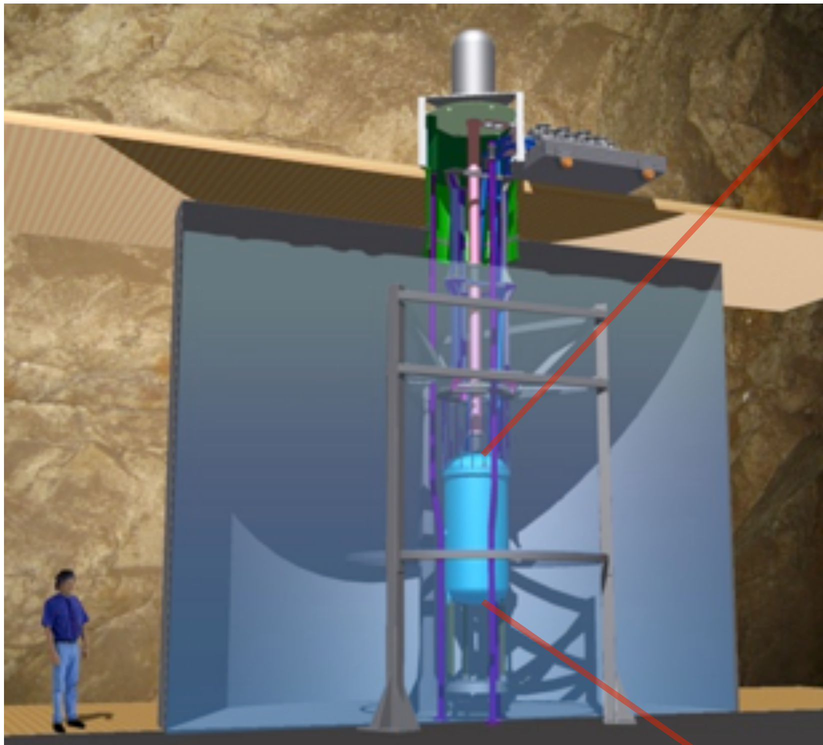
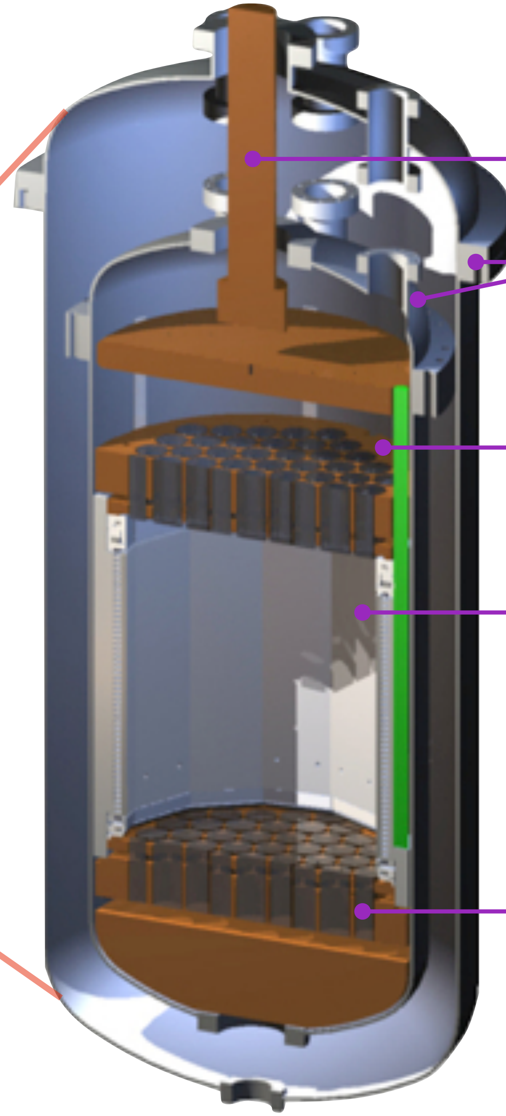
LUX Grid High Voltage

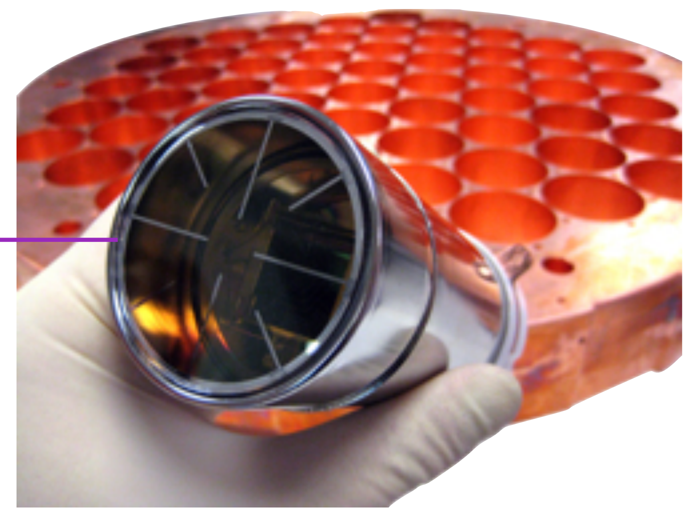
Carlos Faham
LBNL

HVNL, November 9, 2013

The Large Underground Xenon (LUX) Detector

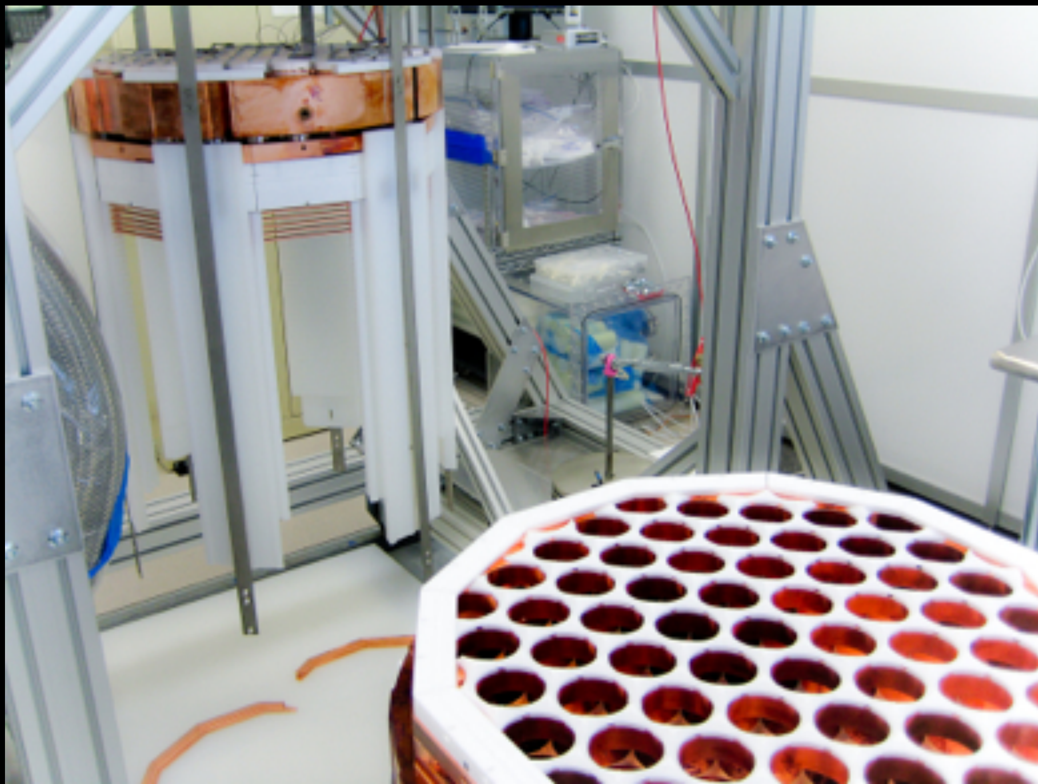


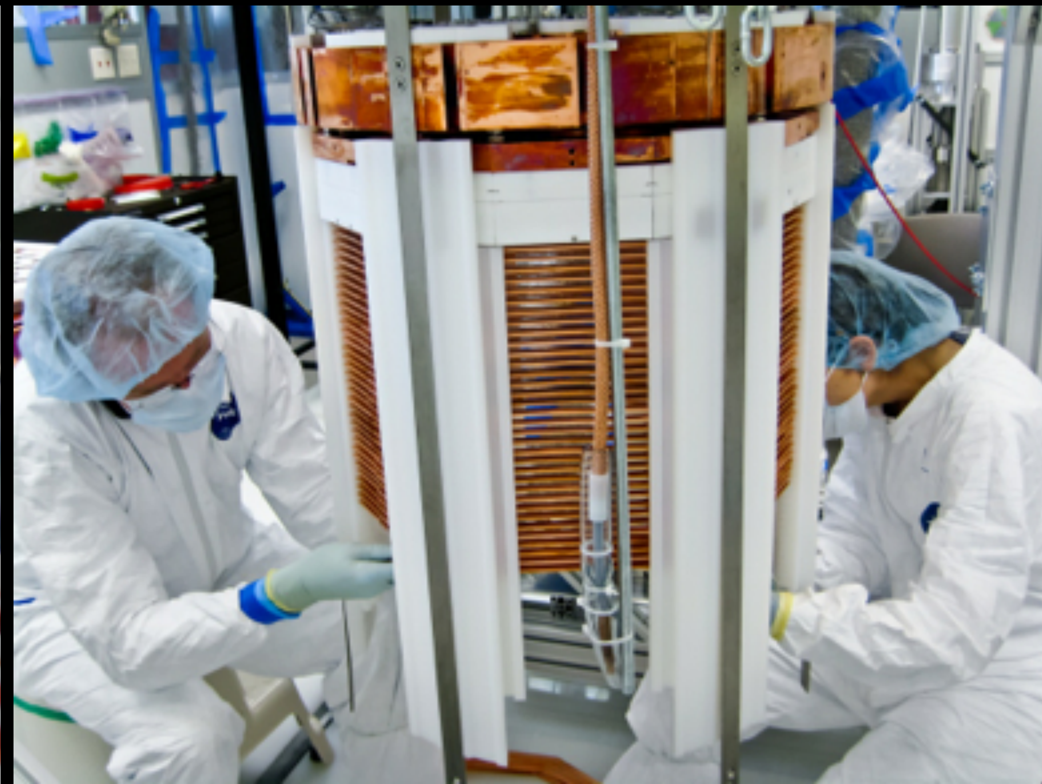


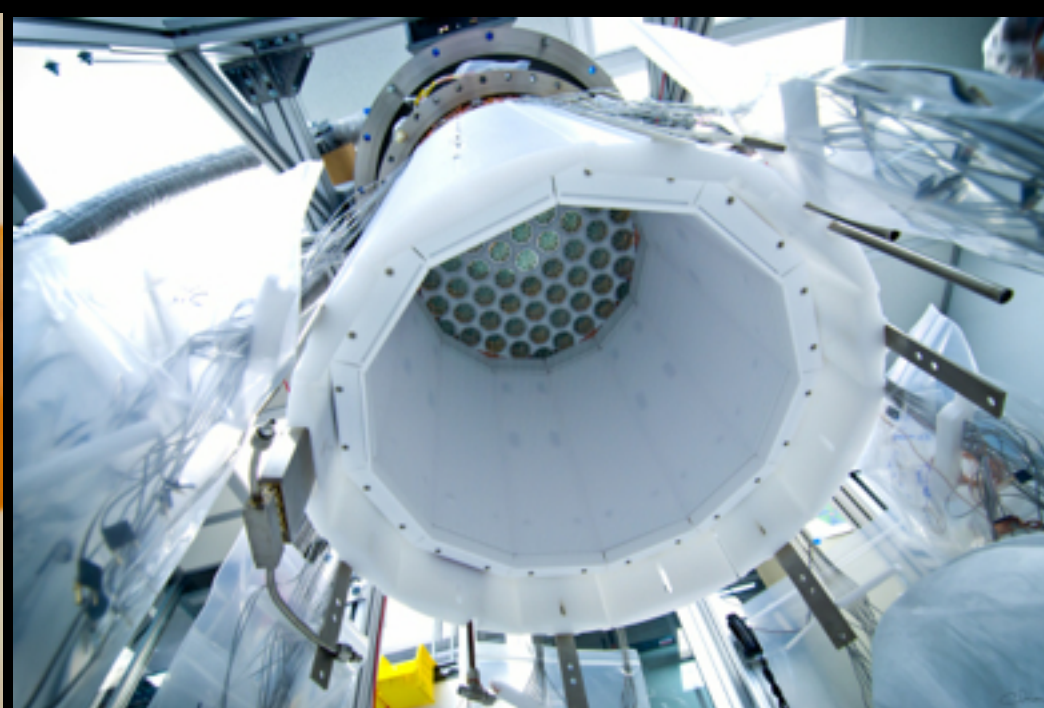


2” Hamamatsu R8778
Photomultiplier Tubes (PMTs)

- 370 kg (250 kg active) LXe
- 122 PMTs (2” round)
- Low-background Ti cryostat
- PTFE reflector cage
- Thermosyphon used for cooling (>1 kW)

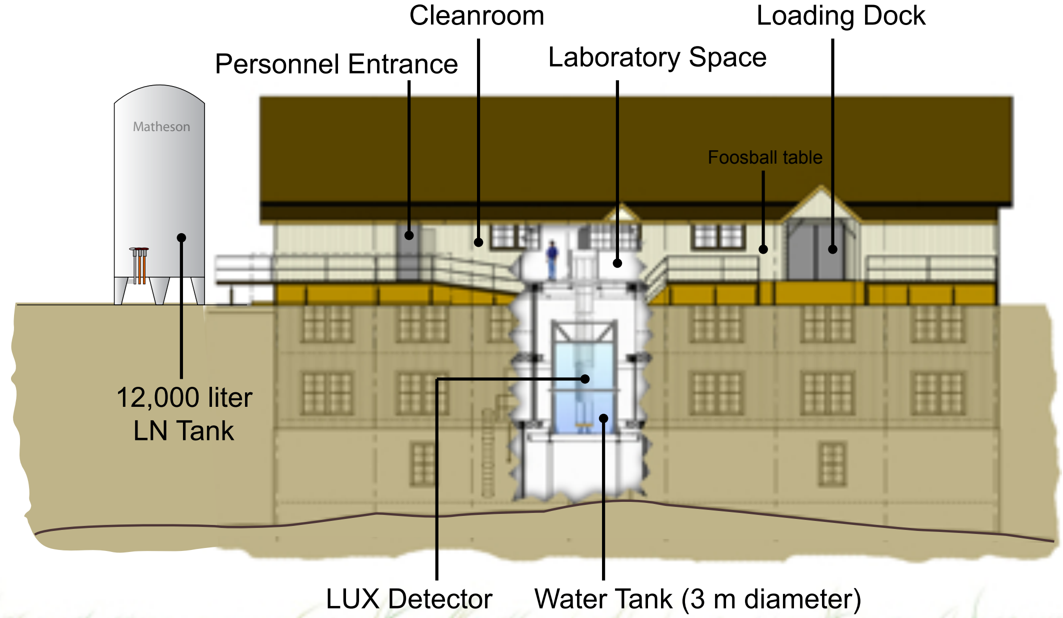






Run02

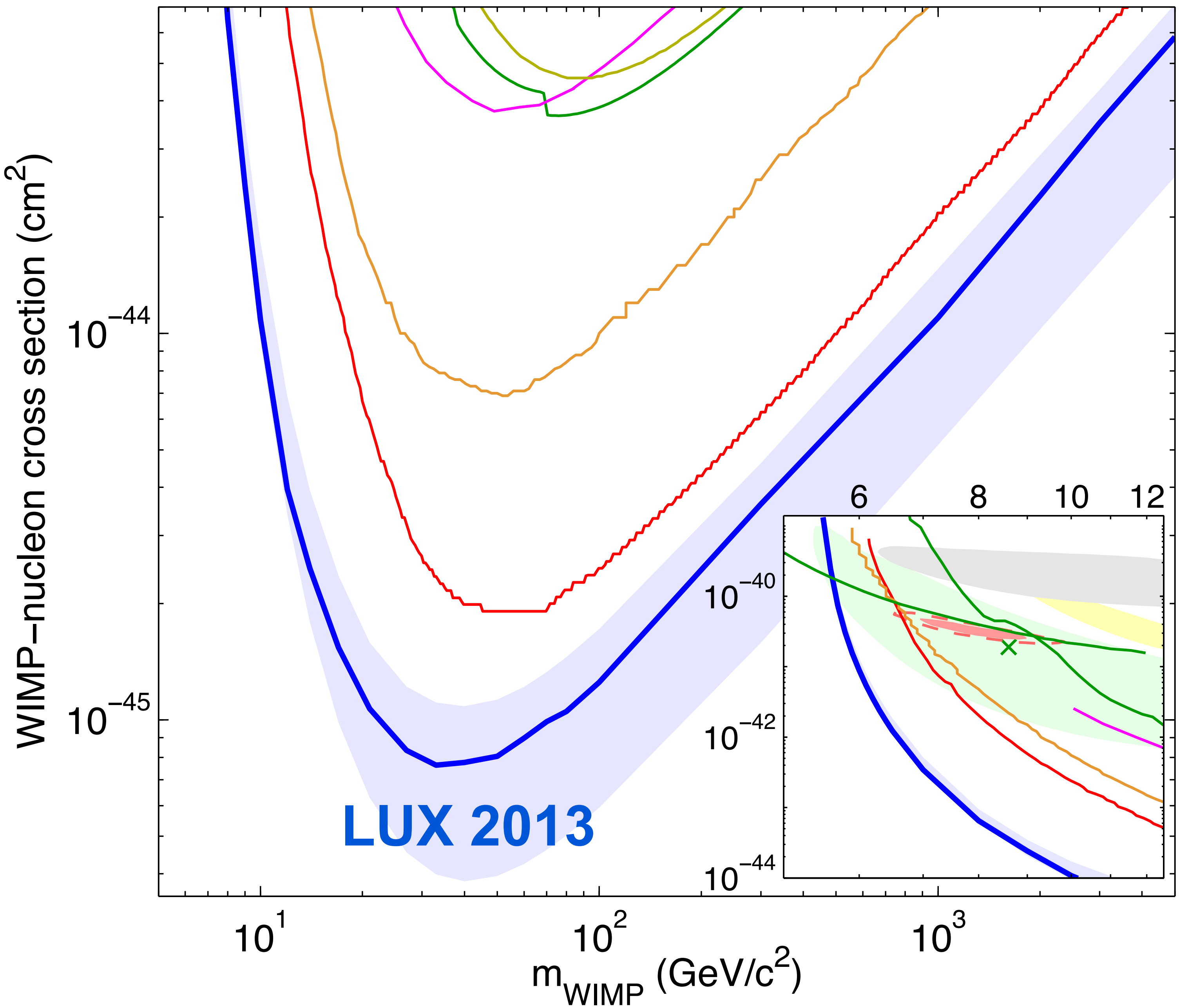
Above Ground Commissioning Run



Run03

Underground First Science Run

First Results from LUX



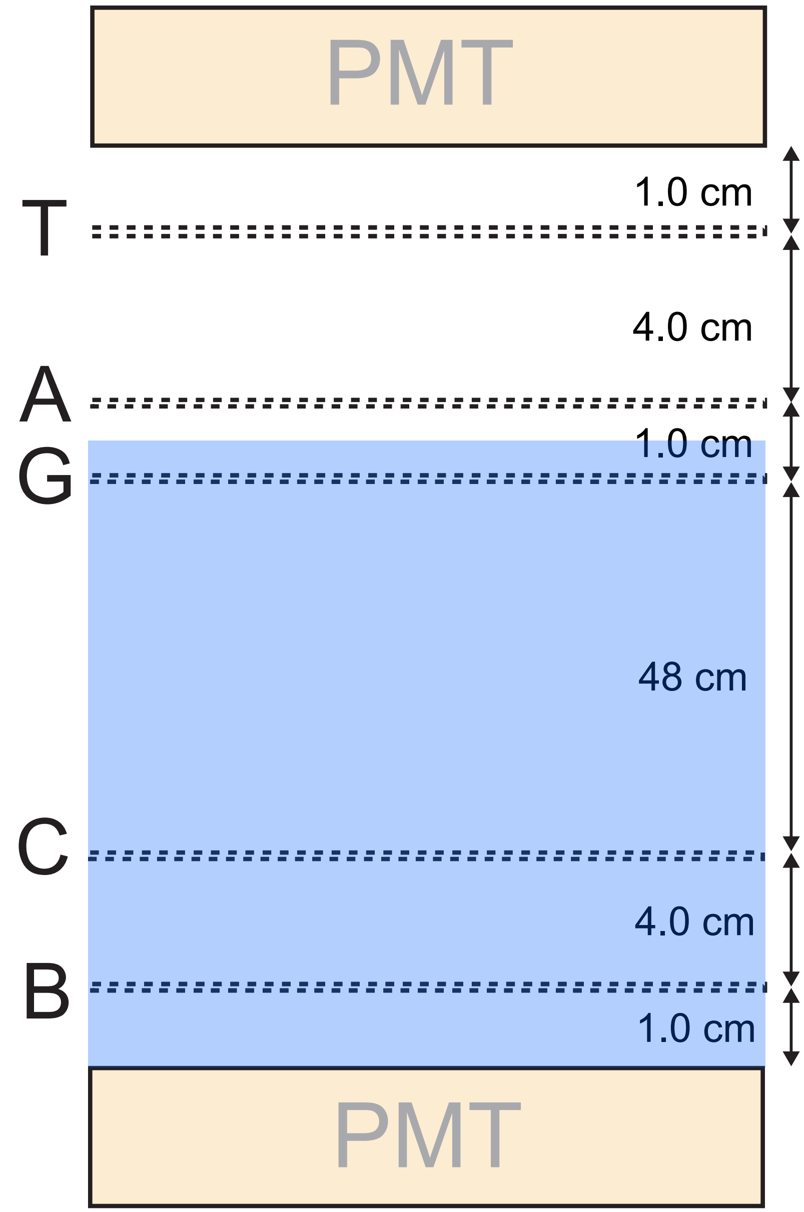
Results from 85 live days

[arXiv:1310.8214]

Submitted to PRL

LUX Grid Configuration

	Type	Wire diameter	Pitch
Wire strung		50 µm	5 mm
Mesh		30 µm	250 µm
Wire strung		100 µm	5 mm
Wire strung		206 µm (100 µm)	5 mm (1 cm)
Wire strung		206 µm (100 µm)	1 cm (5 mm)



Summary of HV Breakdown in LUX

Run03 (UG)

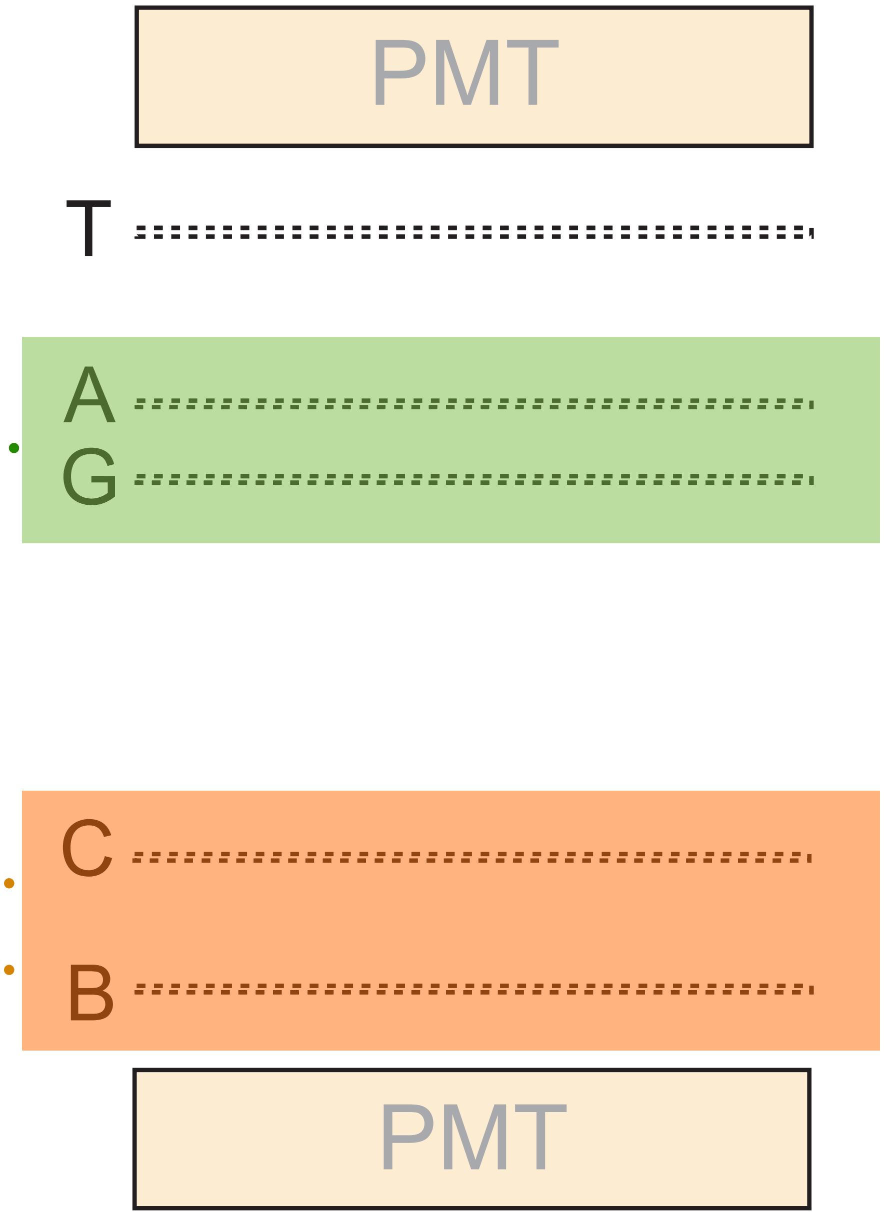
- Limited to 6 kV/cm gas (e^- extraction eff. 65%)
- Light generation above this value

Run02 (surface)

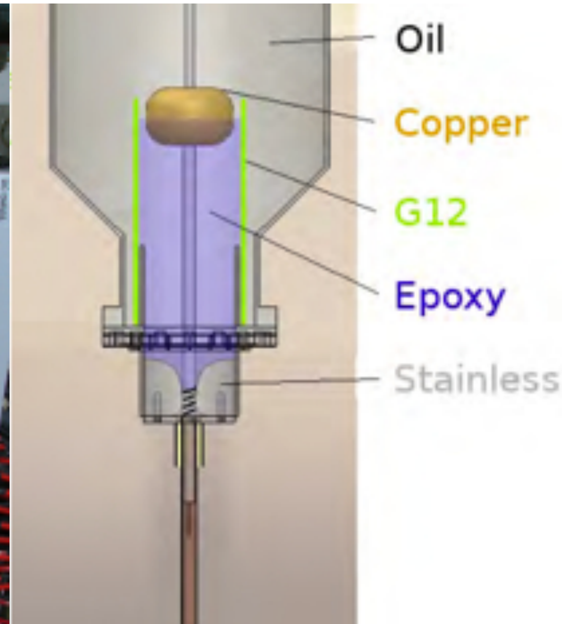
- Onset of glow at -7 kV in cathode (-60 kV/cm at wire surface)
- Glow localized

Run03 (UG)

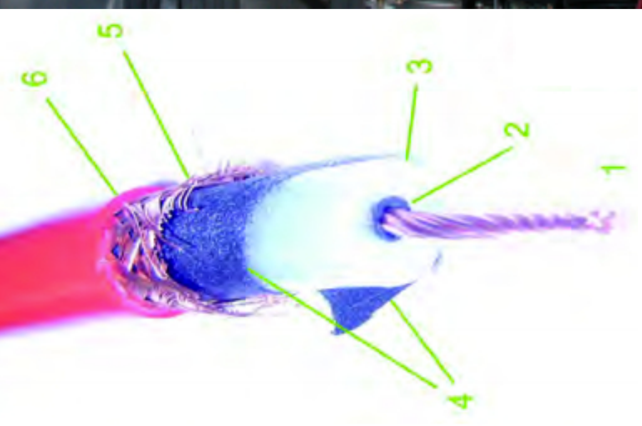
- New C, B grids: 1/2 pitch, x2 radius
- Onset of glow at about -10 kV in cathode (-17 kV/cm at wire surface)
- Glow localized

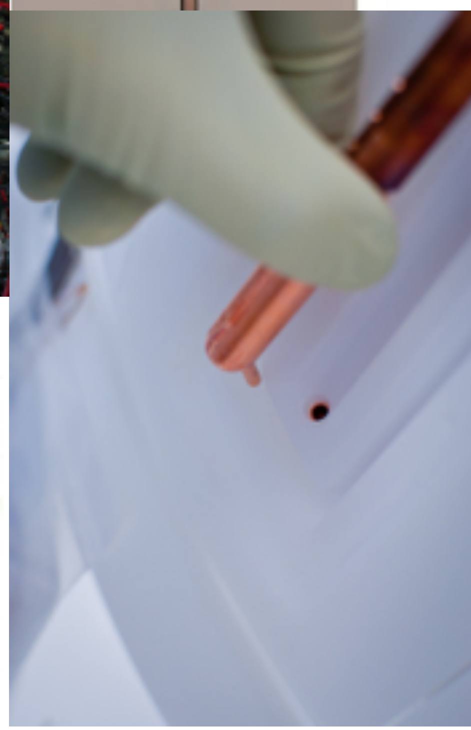


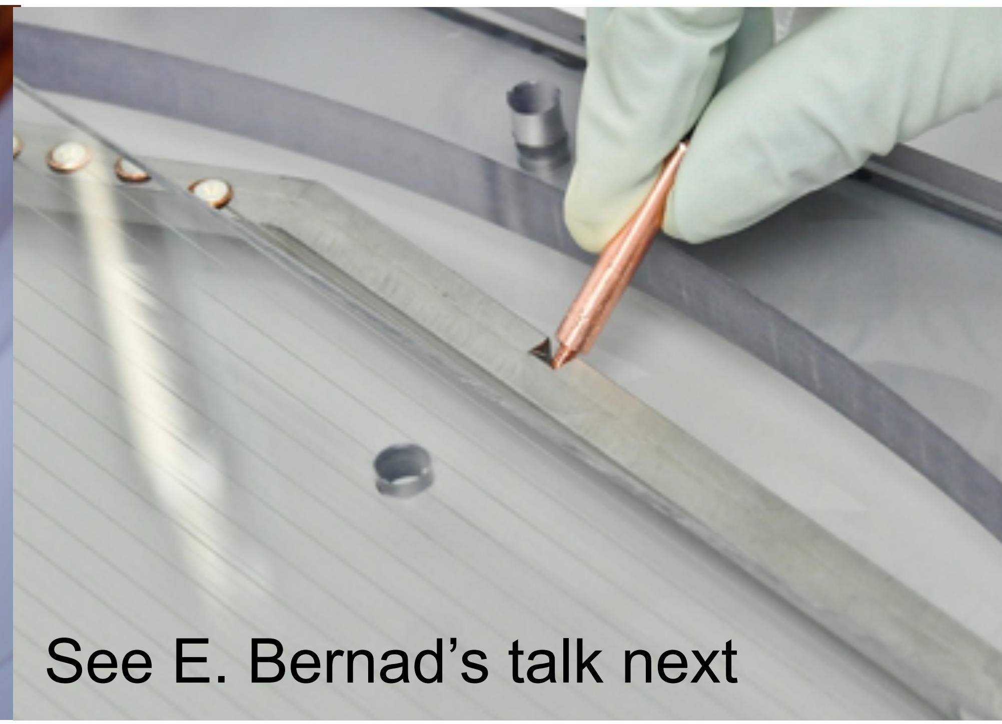
LUX Cathode HV Feedthrough



- 60 kV cathode feedthrough (tested to 100 kV) designed by Yale.
- No evidence of trouble with feedthrough or cathode connection.

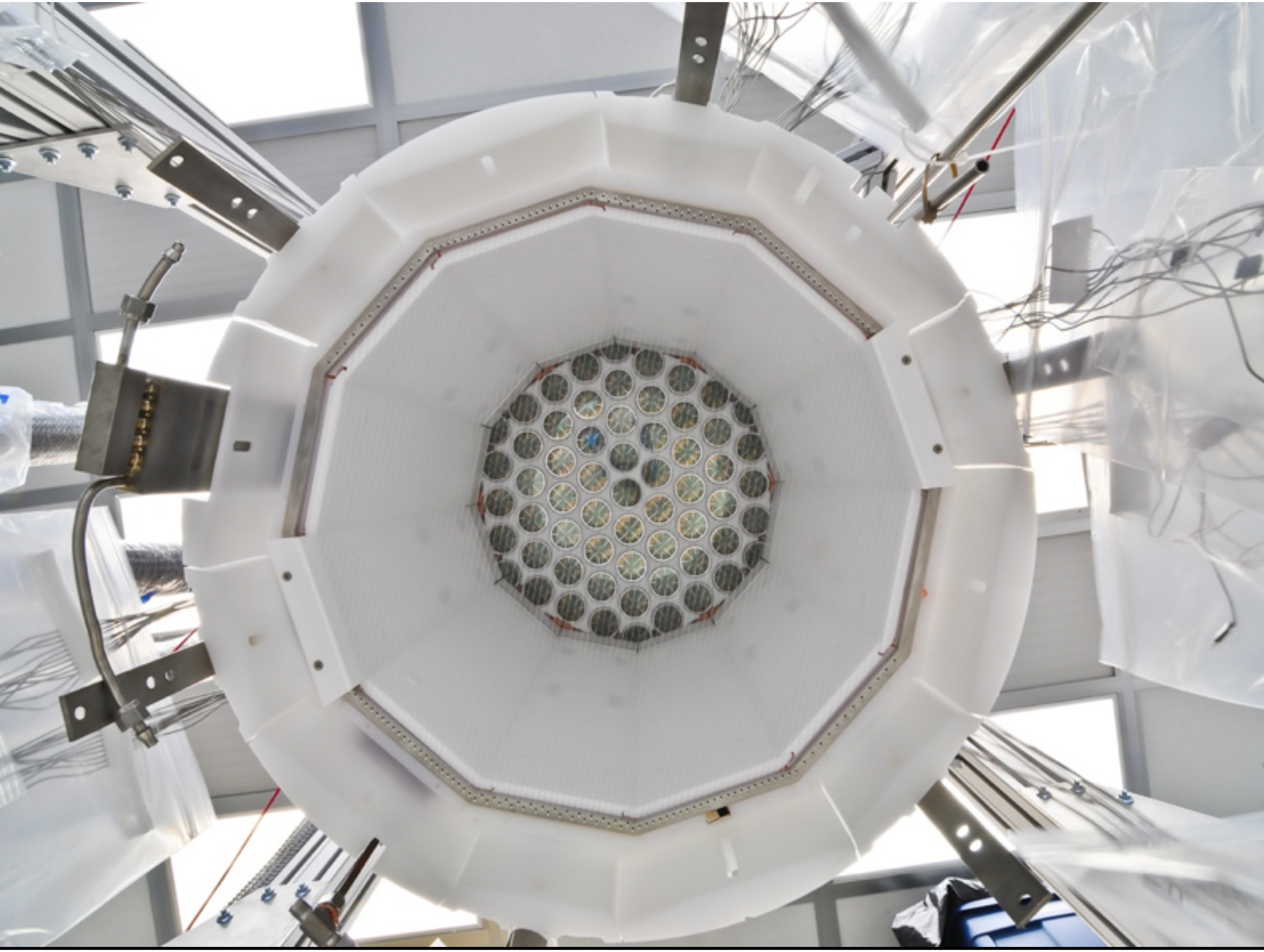






See E. Bernad's talk next

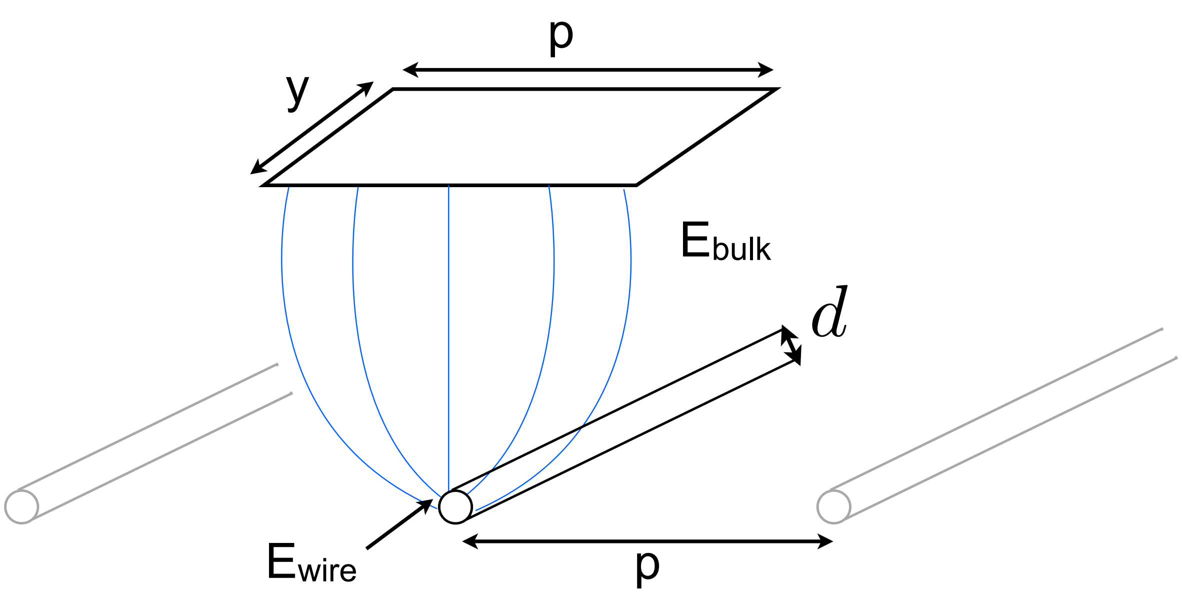

www.sanfordlab.org



A Note on Electric Field Calculation

Electric Field at the Surface of a Wire (K. McDonald)

For a wire-strung grid: $$E_{\text{wire}} = (E_{\uparrow} - E_{\downarrow}) \cdot \frac{p}{\pi d}$$



Run02 example:

$$p = 10 \text{ mm}$$
$$d = 0.1 \text{ mm}$$
$$E_{\uparrow} = -0.15 \text{ kV/cm}$$
$$E_{\downarrow} = -1.75 \text{ kV/cm}$$

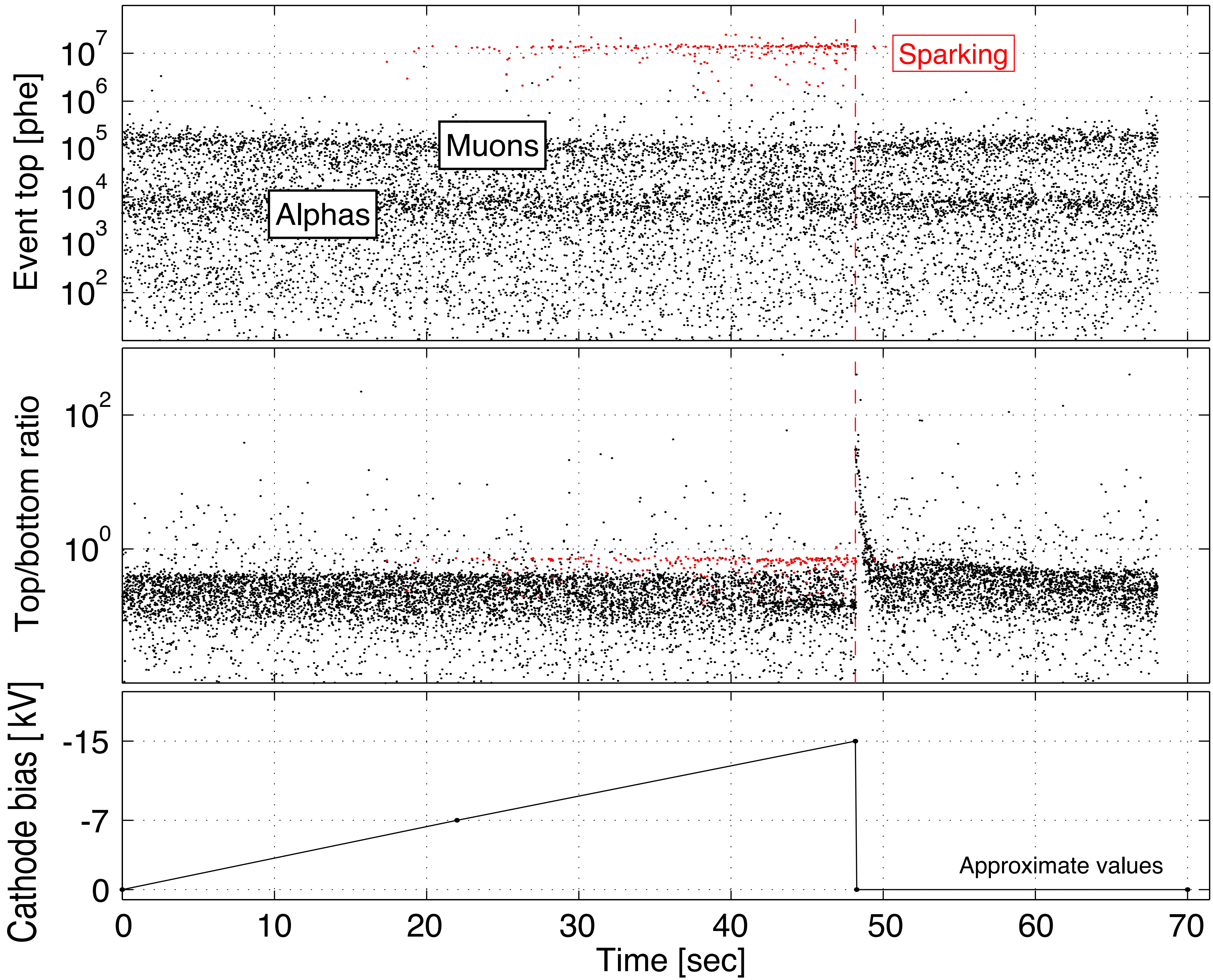
$$E_{\text{wire}} = -60 \text{ kV/cm}$$

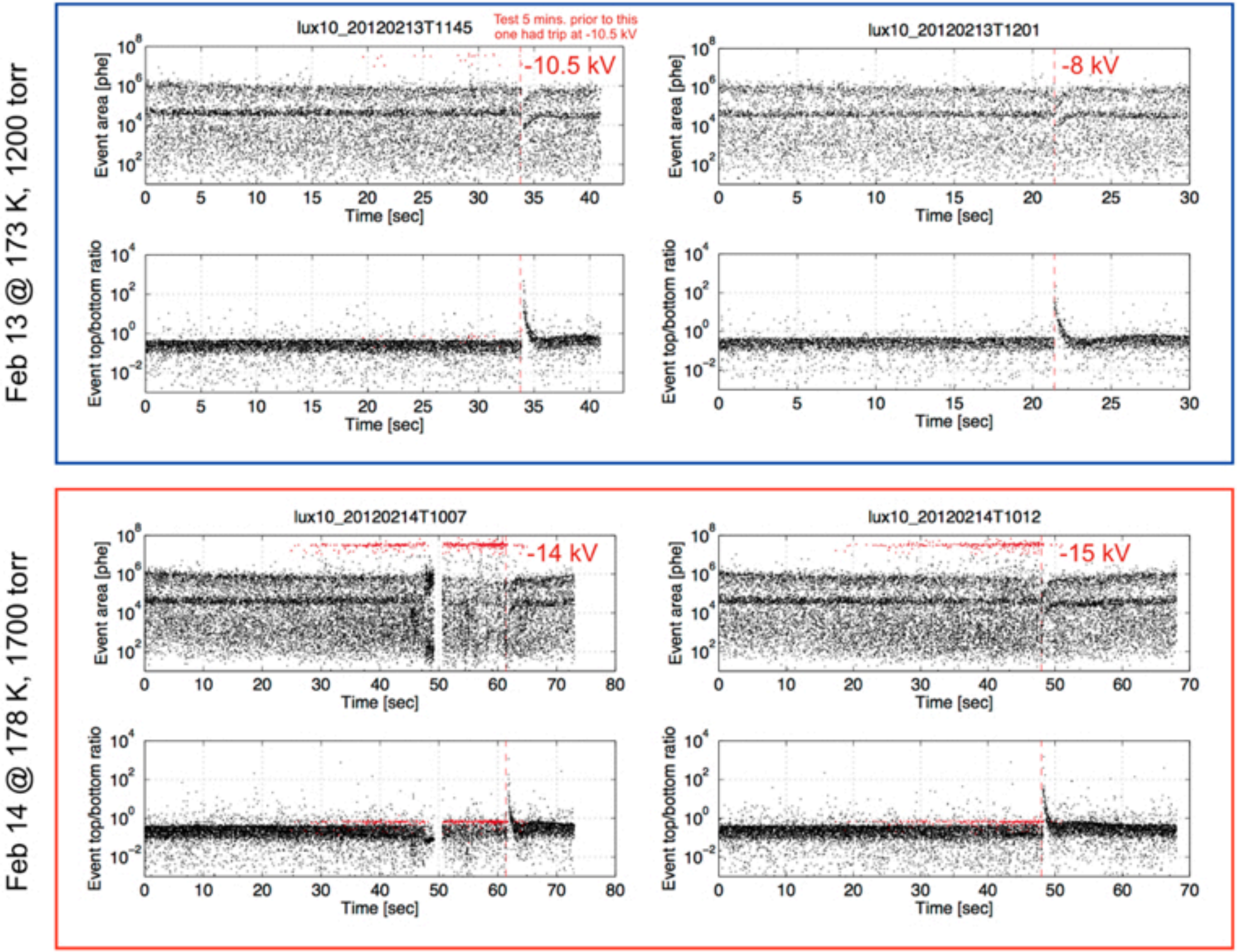
at the cathode wire surface
for C = -7 kV, B at ground

Run02 - LUX Surface

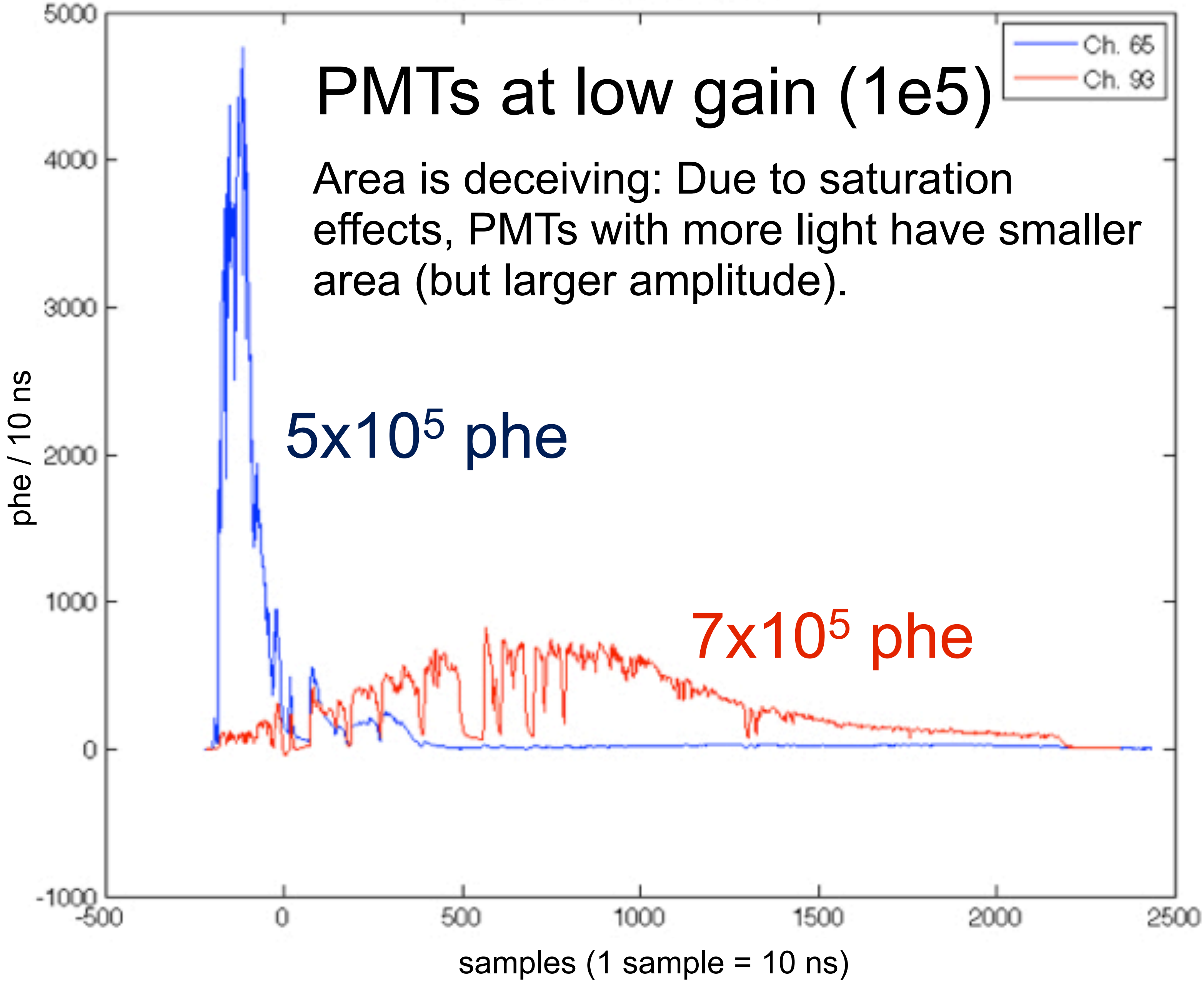
Cathode Surface Operation Summary

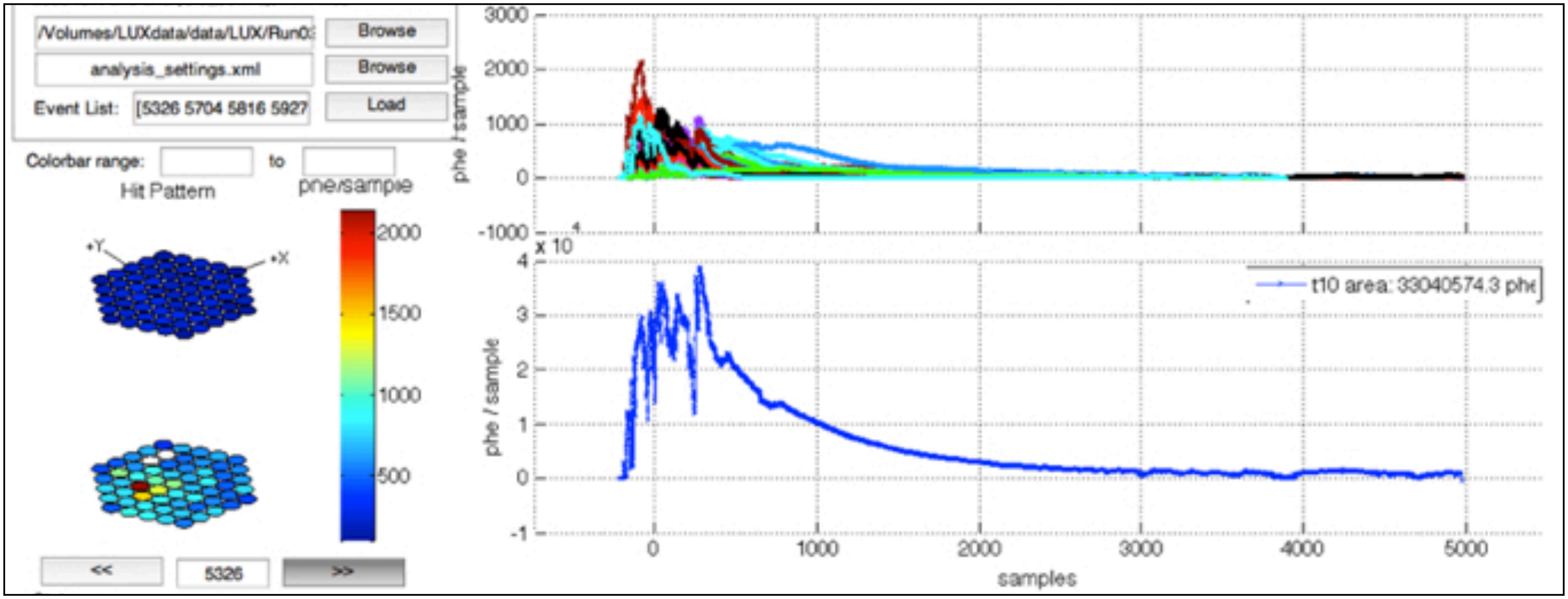
- Light generated close to the bottom array at about -7 kV applied to the cathode (C) grid, bottom (B) grounded.
  - This is about -60 kV/cm at the surface of the C wires.
- Breakdown (power supply over-current) between -8 kV and -15 kV. Temperature (pressure) dependence observed.
  - This is between -70 kV/cm and -130 kV/cm at the surface of the C wires.
- PMTs were set to low gain for surface operation. Only large pulses could be observed.
- Location of light generation could be located in x-y (~z) with the bottom PMT array (hot spot).

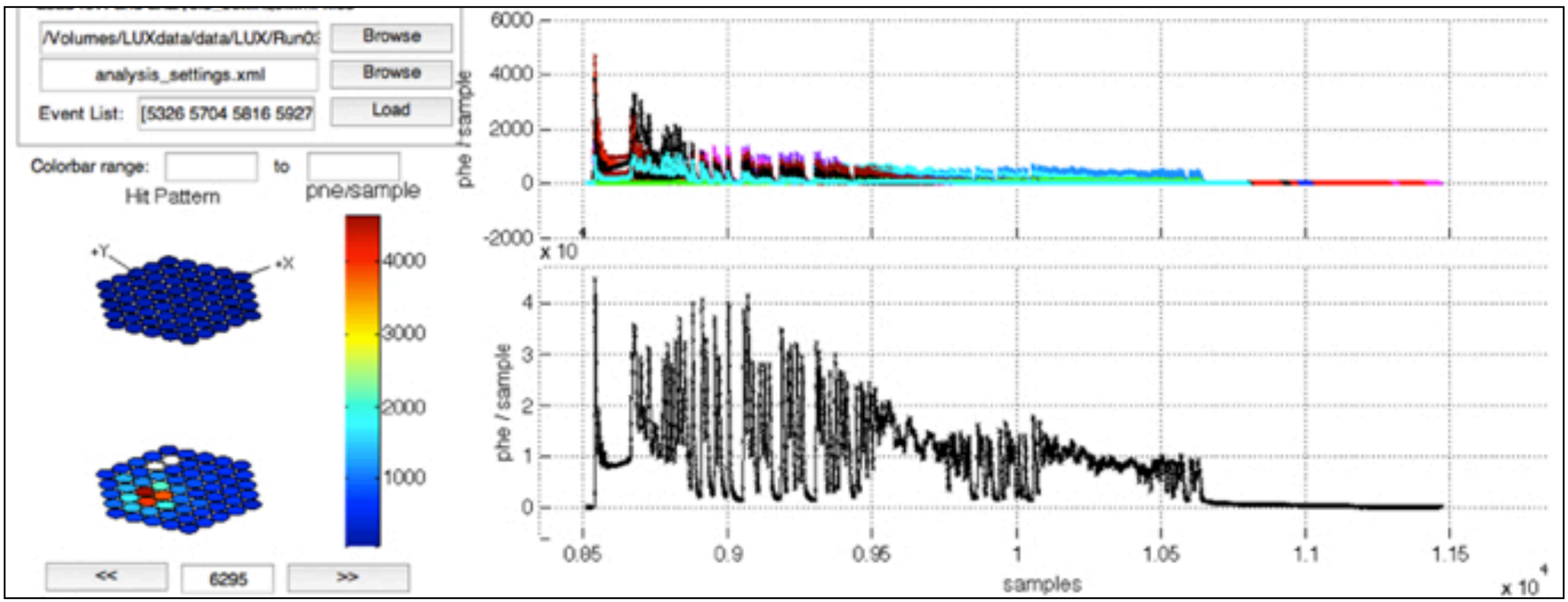

Event top [phe]
10^7
10^6
10^5
10^4
10^3
10^2
Sparking
Muons
Alphas
Top/bottom ratio
10^2
10^0
Cathode bias [kV]
-15
-7
0
Approximate values
0
10
20
30
40
50
60
70
Time [sec]

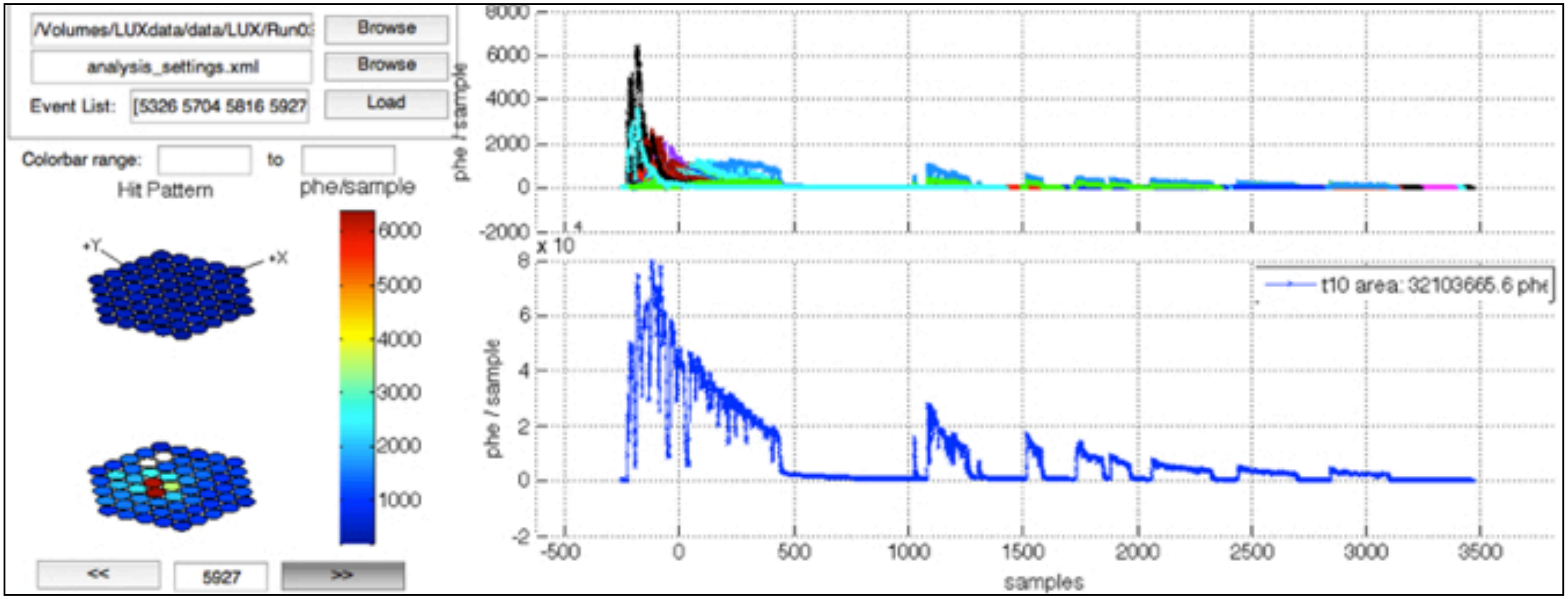

Feb 13 @ 173 K, 1200 torr
lux10_20120213T1145
Test 5 mins. prior to this one had trip at -10.5 kV
-10.5 kV
lux10_20120213T1201
-8 kV
Event area [phe]
Event top/bottom ratio
Time [sec]
Feb 14 @ 178 K, 1700 torr
lux10_20120214T1007
-14 kV
lux10_20120214T1012
-15 kV

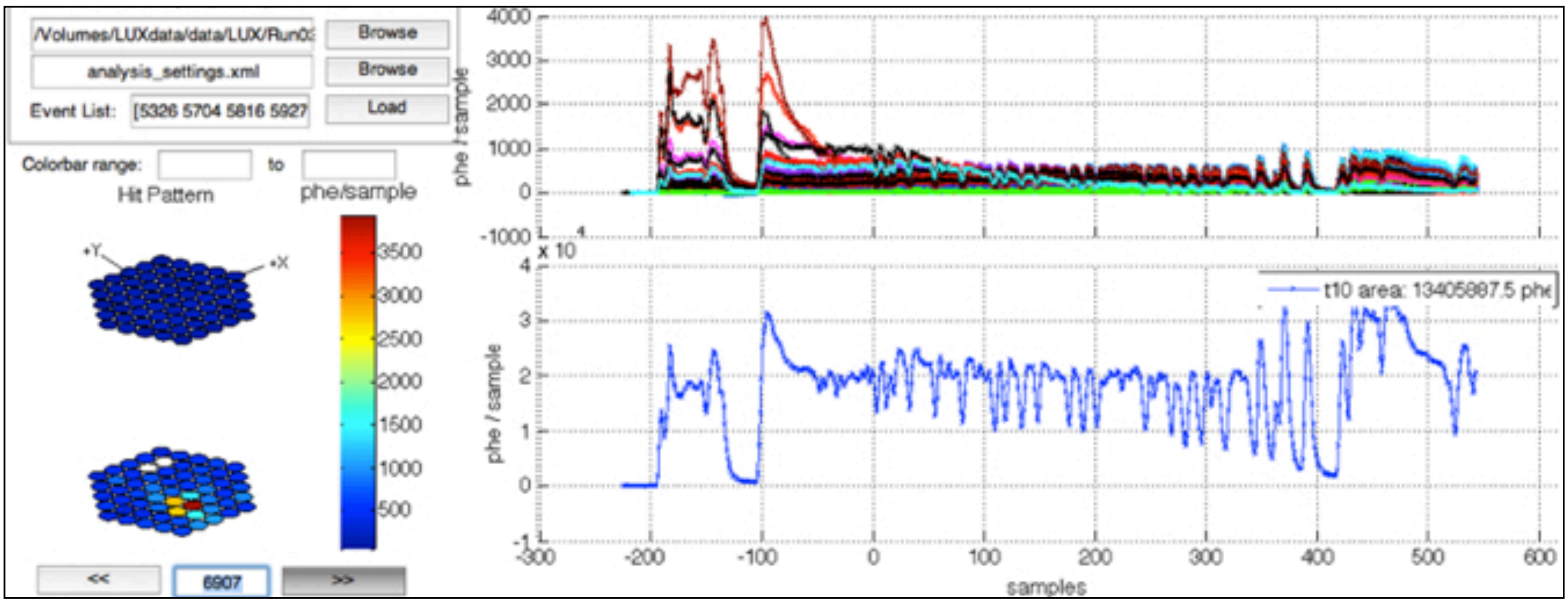
Using pulse height as a proxy for area



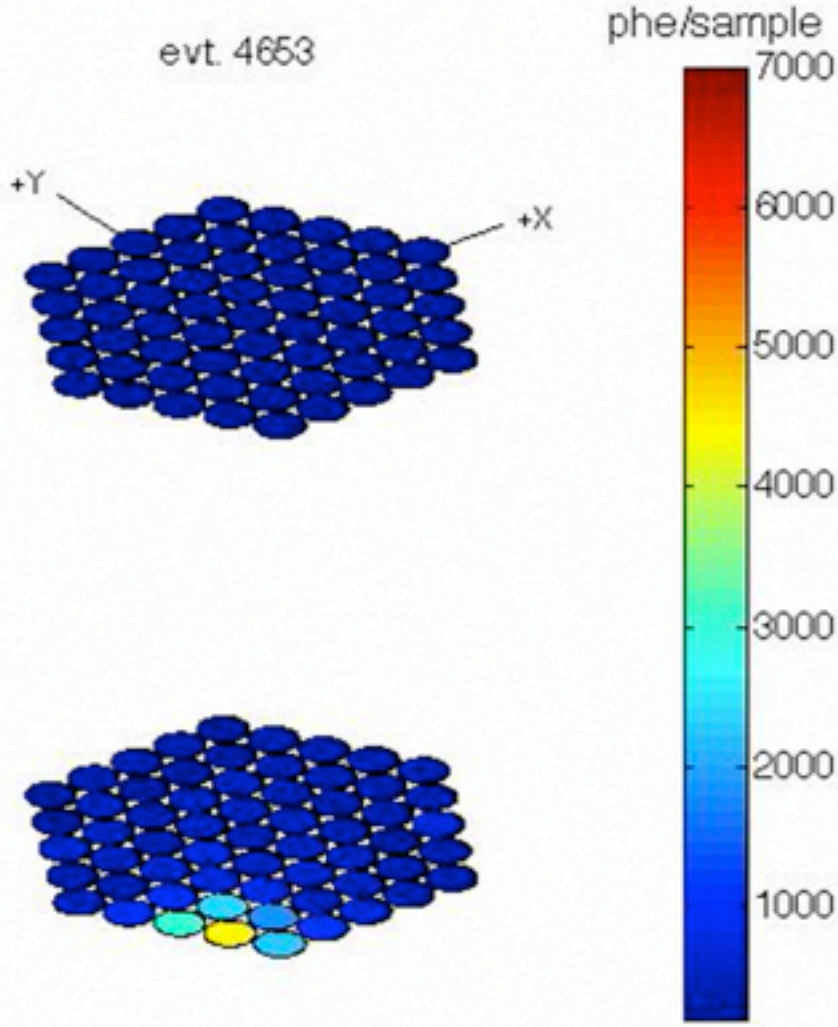

/Volumes/LUXdata/data/LUX/Run0
Browse
analysis_settings.xml
Browse
Event List:
[5326 5704 5816 5927
Load
Colorbar range:
to
Hit Pattern
phe/sample
+Y
+X
<<
5326
>>
phe / sample
t10 area: 33040574.3 phe
samples

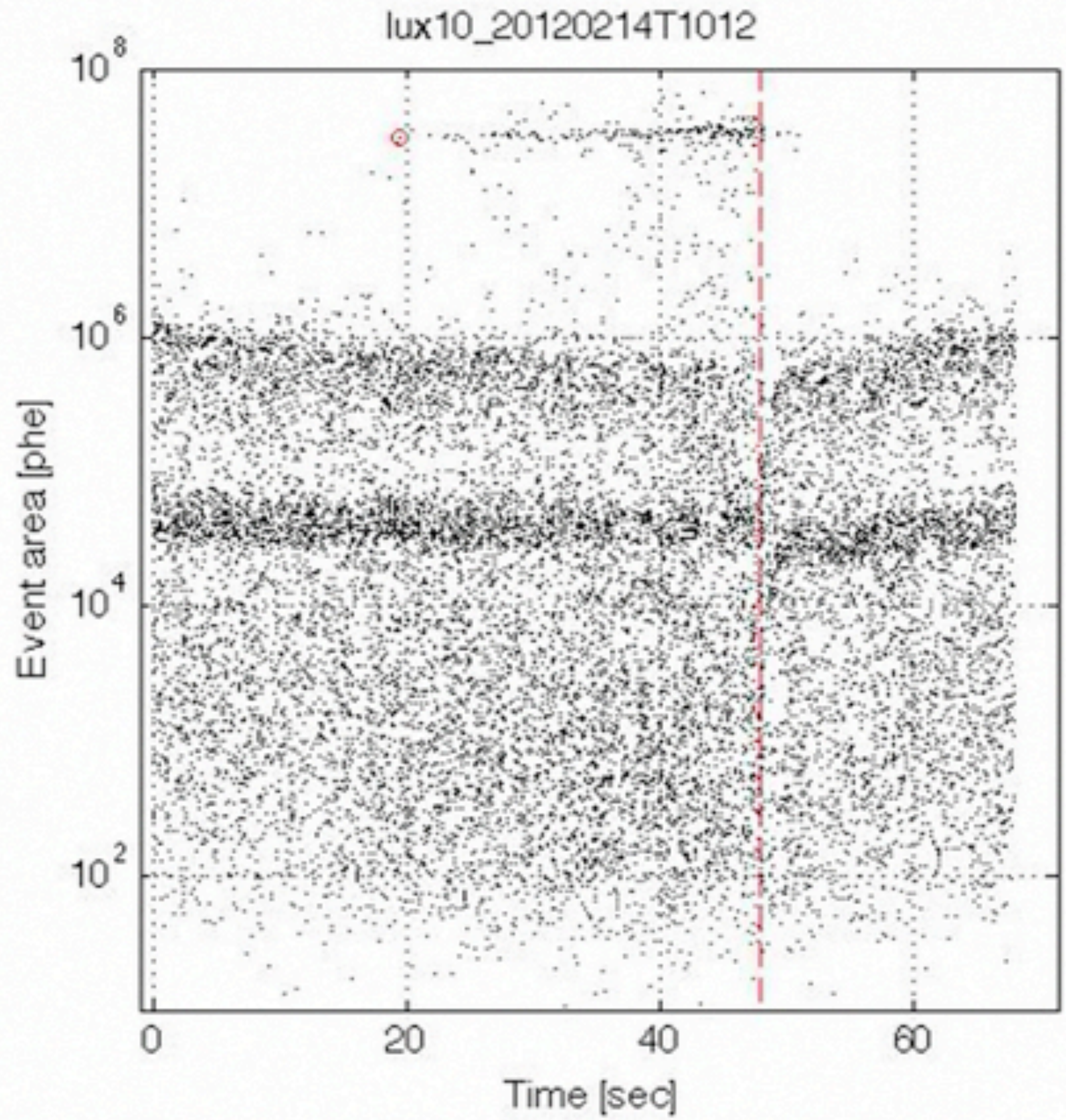

/Volumes/LUXdata/data/LUX/Run0
Browse
analysis_settings.xml
Browse
Event List:
[5326 5704 5816 5927
Load
Colorbar range:
to
Hit Pattern
phe/sample
+Y
+X
<<
6295
>>
phe / sample
samples


/Volumes/LUXdata/data/LUX/Run0
Browse
analysis_settings.xml
Browse
Event List: [5326 5704 5816 5927
Load
Colorbar range: to
Hit Pattern
phe/sample
+Y
+X
<<
5927
>>
phe / sample
t10 area: 32103665.6 phe
samples

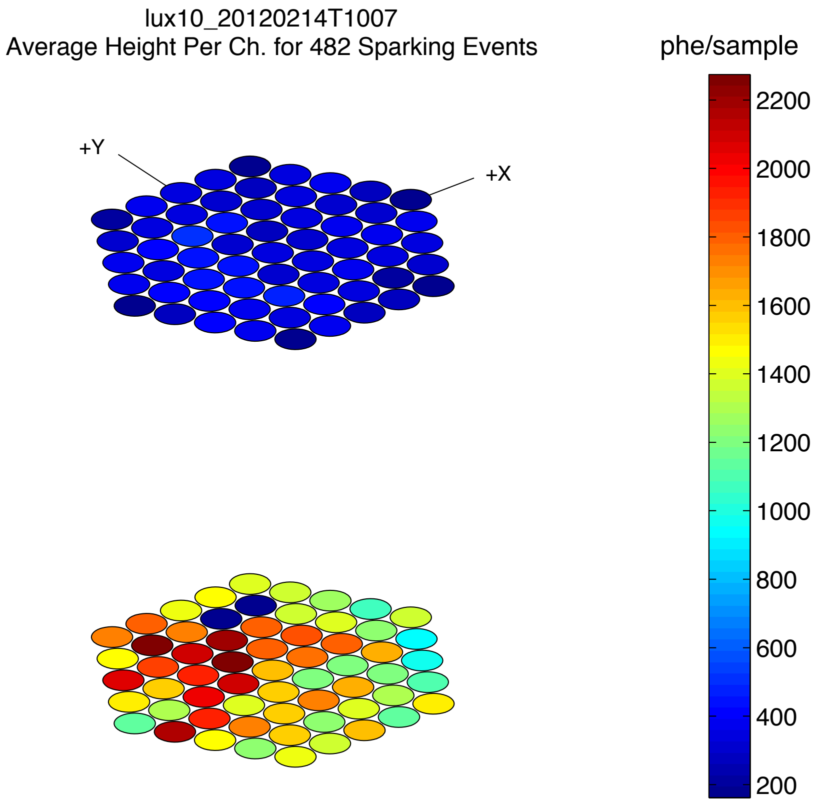

/Volumes/LUXdata/data/LUX/Run0
Browse
analysis_settings.xml
Browse
Event List: [5326 5704 5816 5927
Load
Colorbar range: to
Hit Pattern
phe/sample
+Y
+X
<<
6907
>>
phe / sample
t10 area: 13405887.5 phe
samples

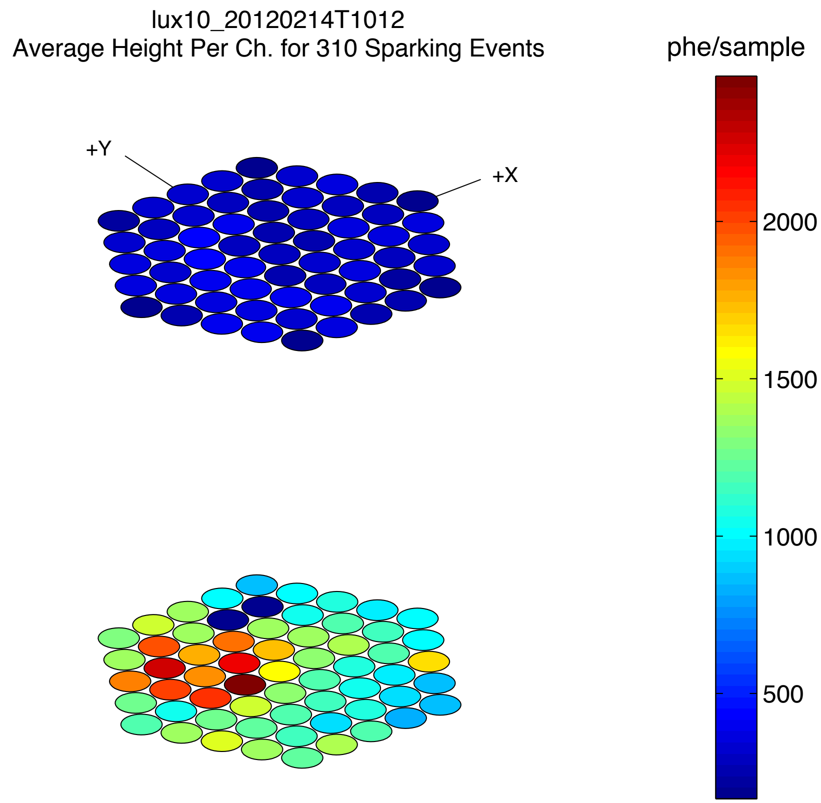
HV Breakdown Sequence

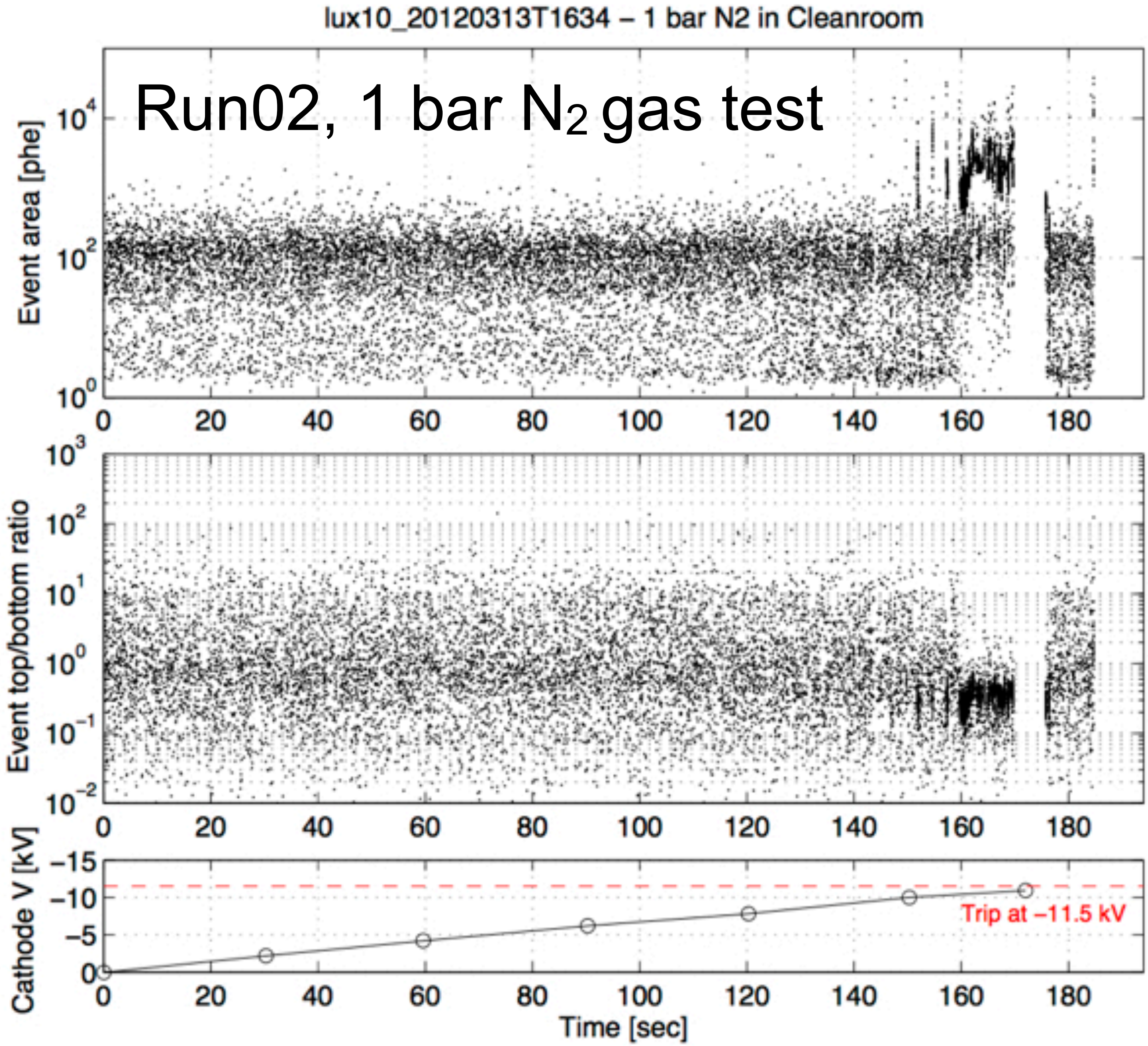




Average Hit Pattern

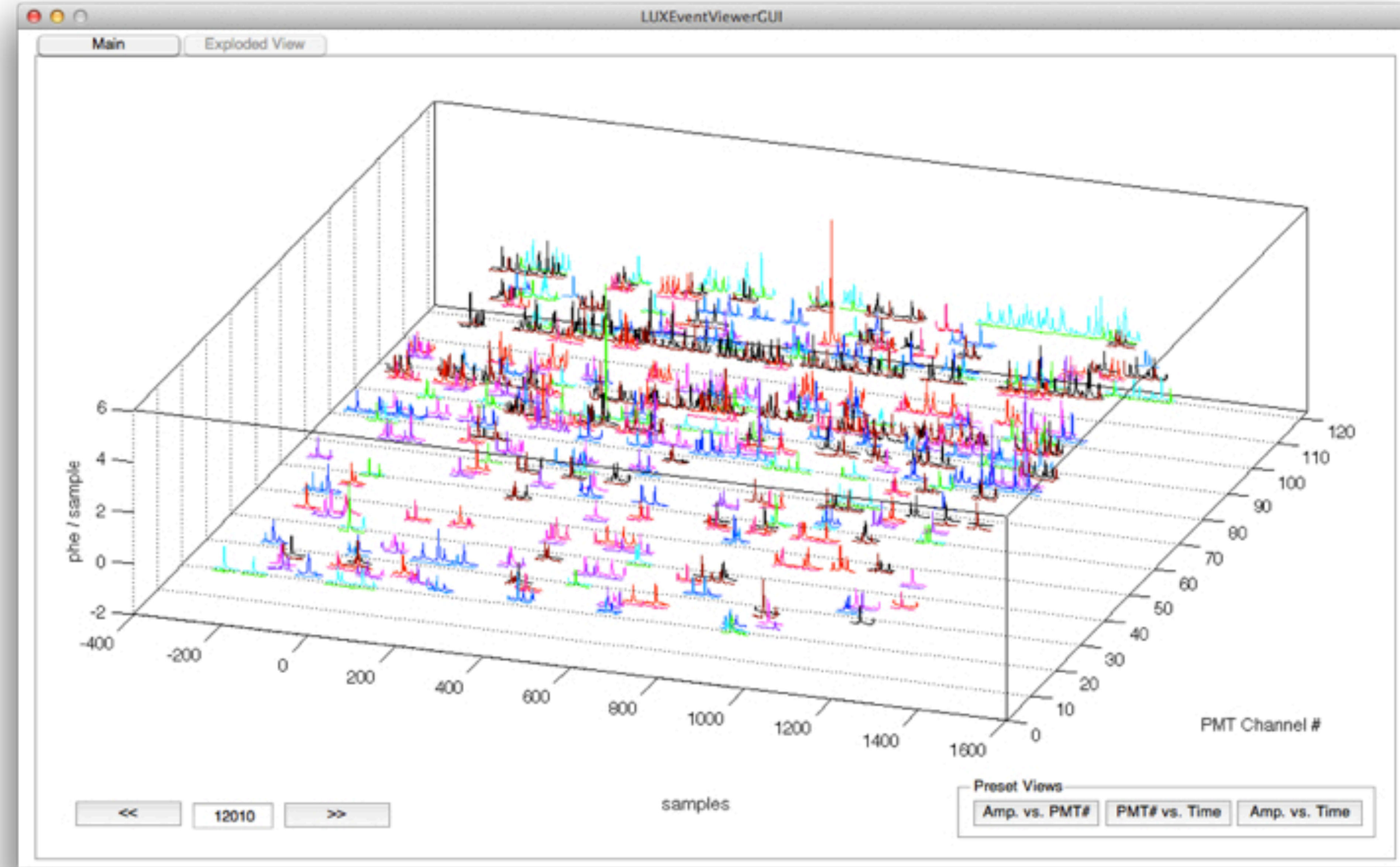




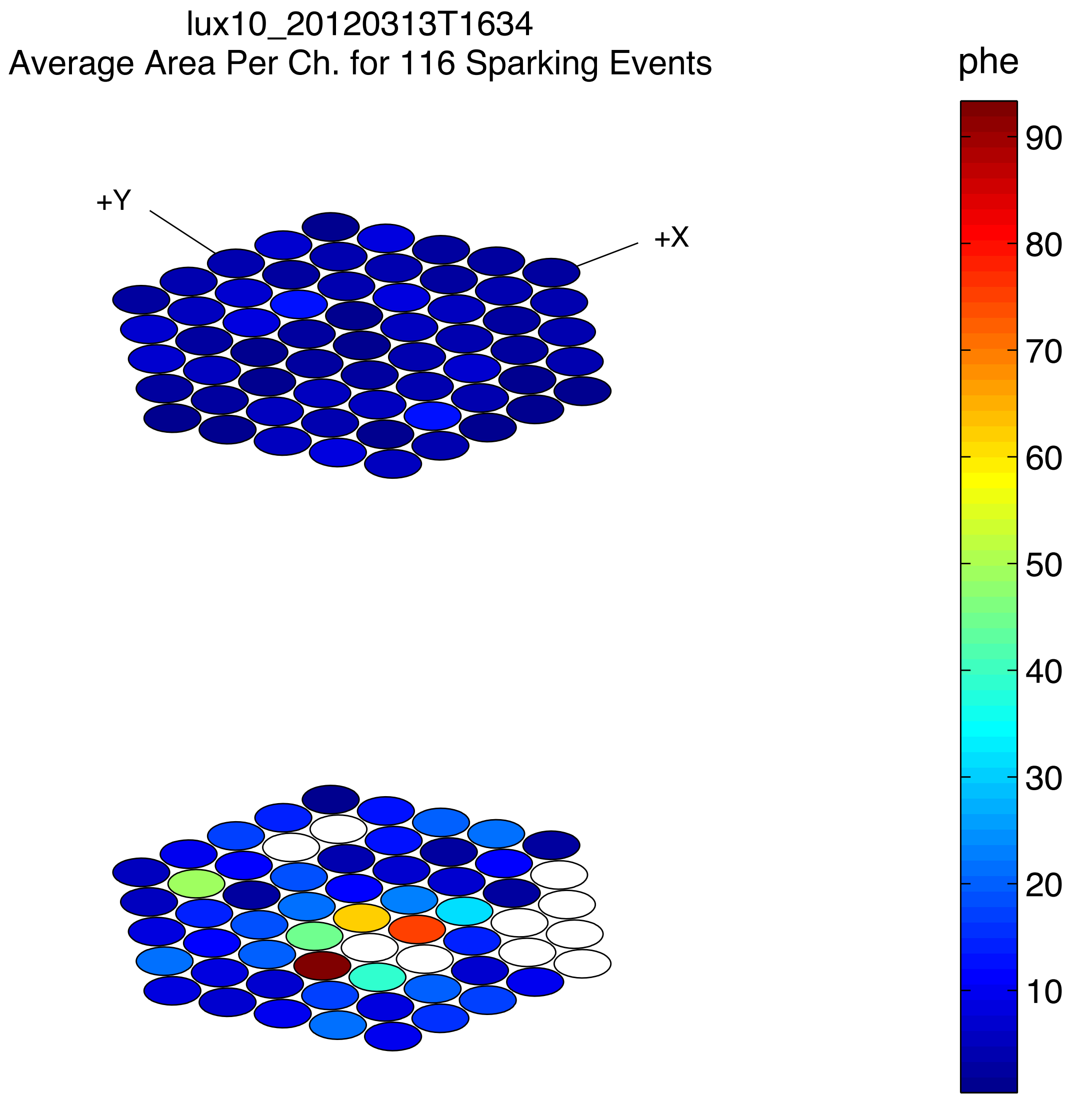


lux10_20120313T1634 – 1 bar N2 in Cleanroom
Run02, 1 bar N_2 gas test
Event area [phe]
Event top/bottom ratio
Cathode V [kV]
Trip at −11.5 kV
Time [sec]

Run02 1 bar N_2 gas test



Run02 1 bar N_2 gas test



Run03 - LUX Underground

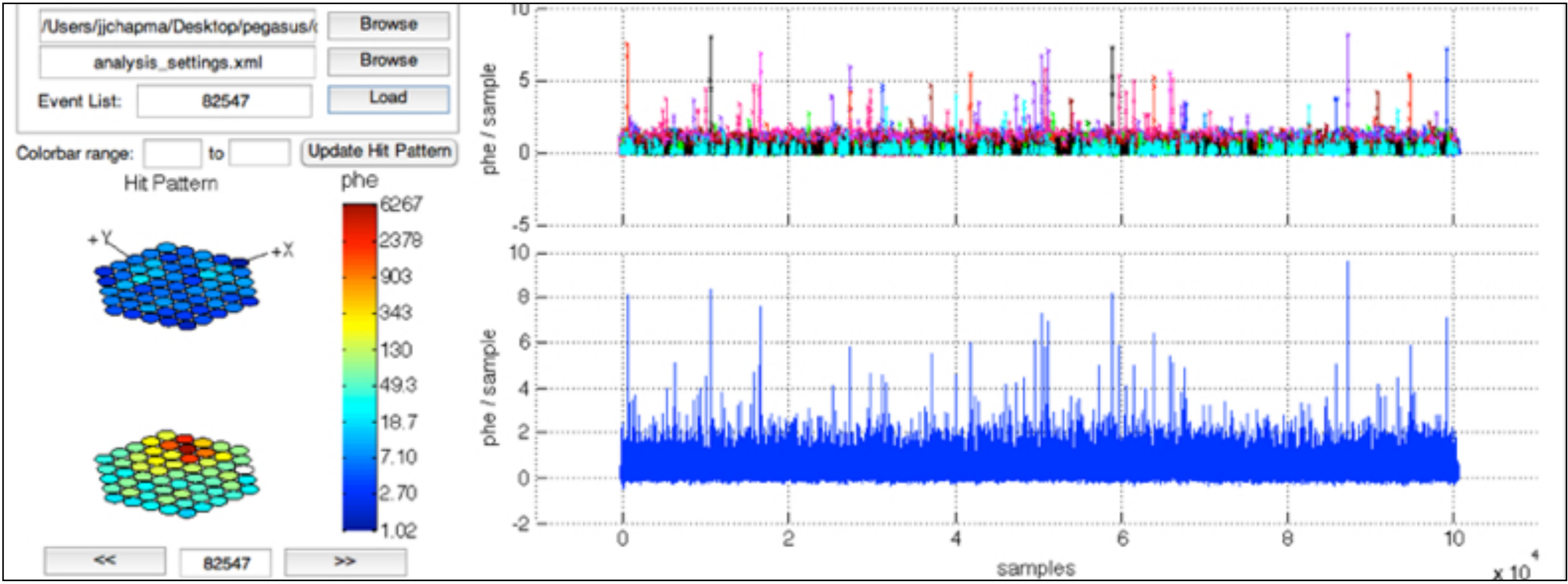
Cathode Underground Operation Summary

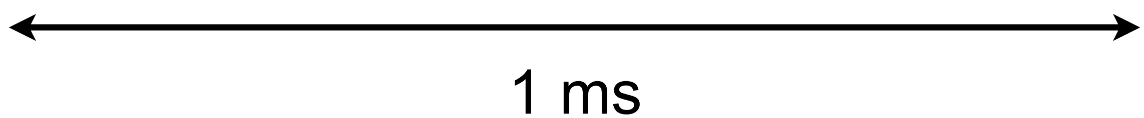
- Cathode and Bottom grids replaced with 206 μm wire (x2 diameter increase). Cathode pitch changed by x1/2.
- Grids not burned-in as previously done, but each wire was inspected.

- **Glow seen at about -11 kV in the C, or -3 kV in B.**
- Need to reduce voltage by ~0.8 - 0.85 to get rid of glow once it begins.

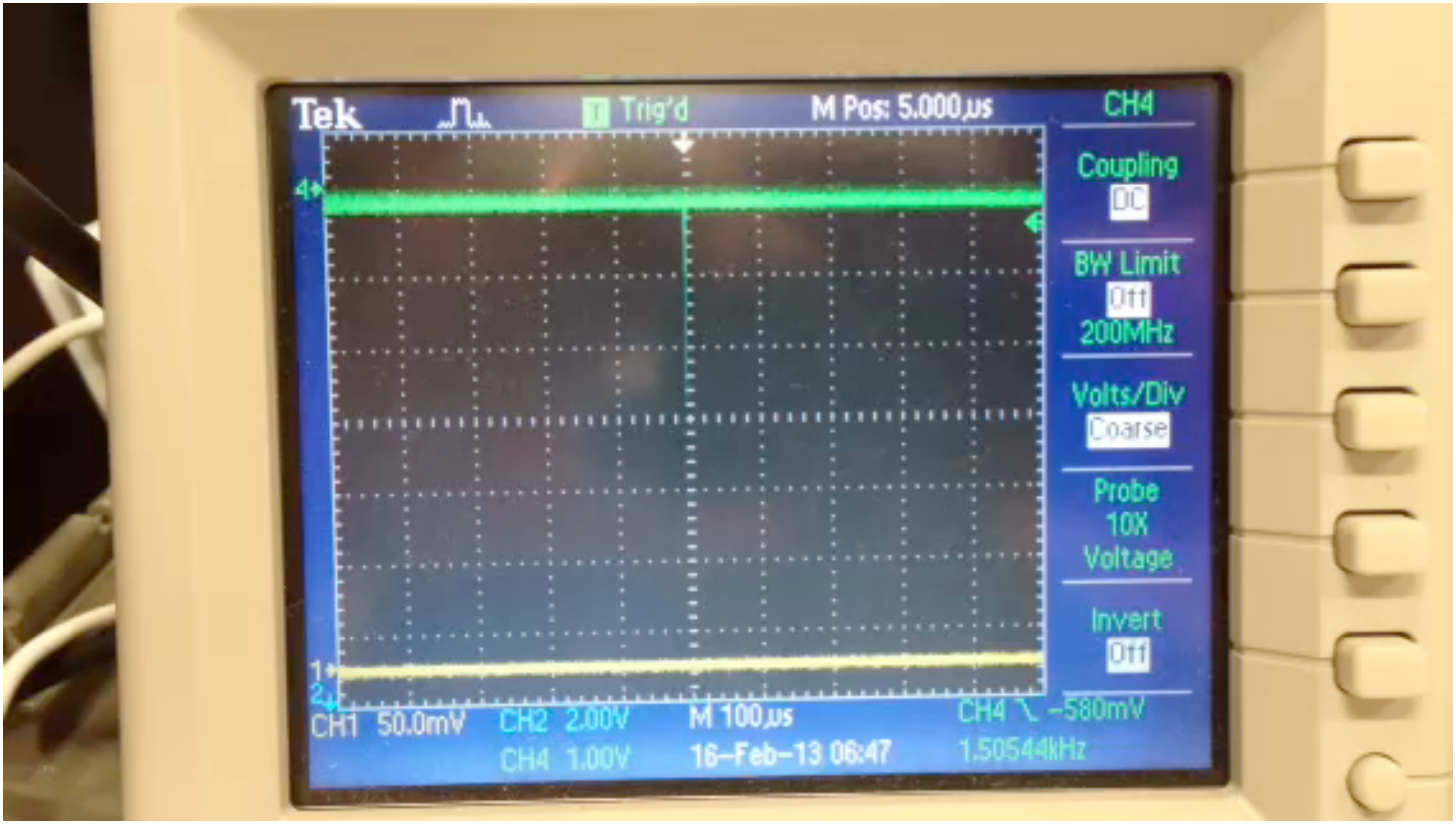
- Able to run at -10 kV cathode bias (181 V/cm drift field) with no HV glow. Average NR, ER discrimination in 2-30 phe S1 was 99.6%.

Characteristic "Photon Grass"



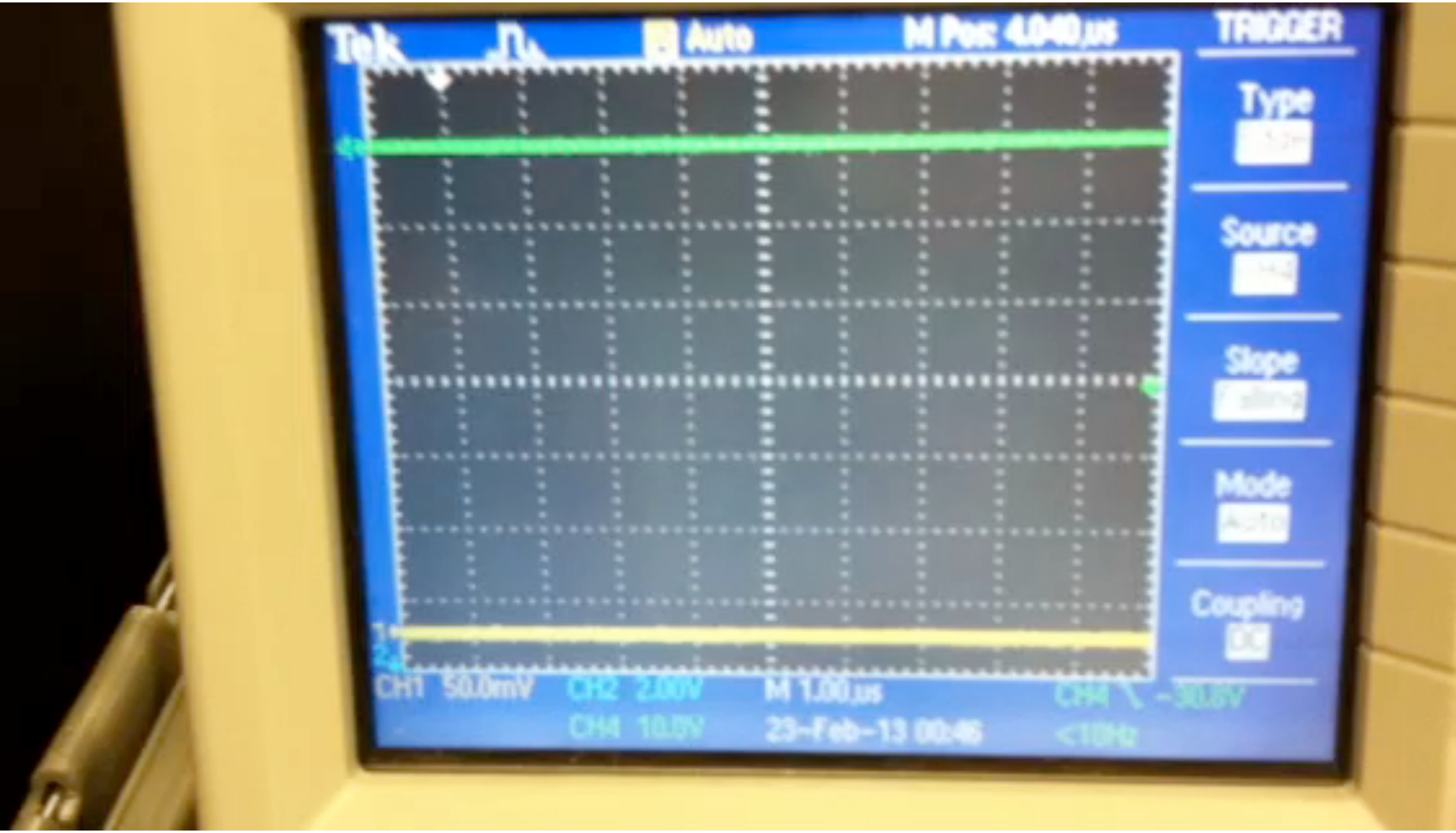


Characteristic "Photon Grass"

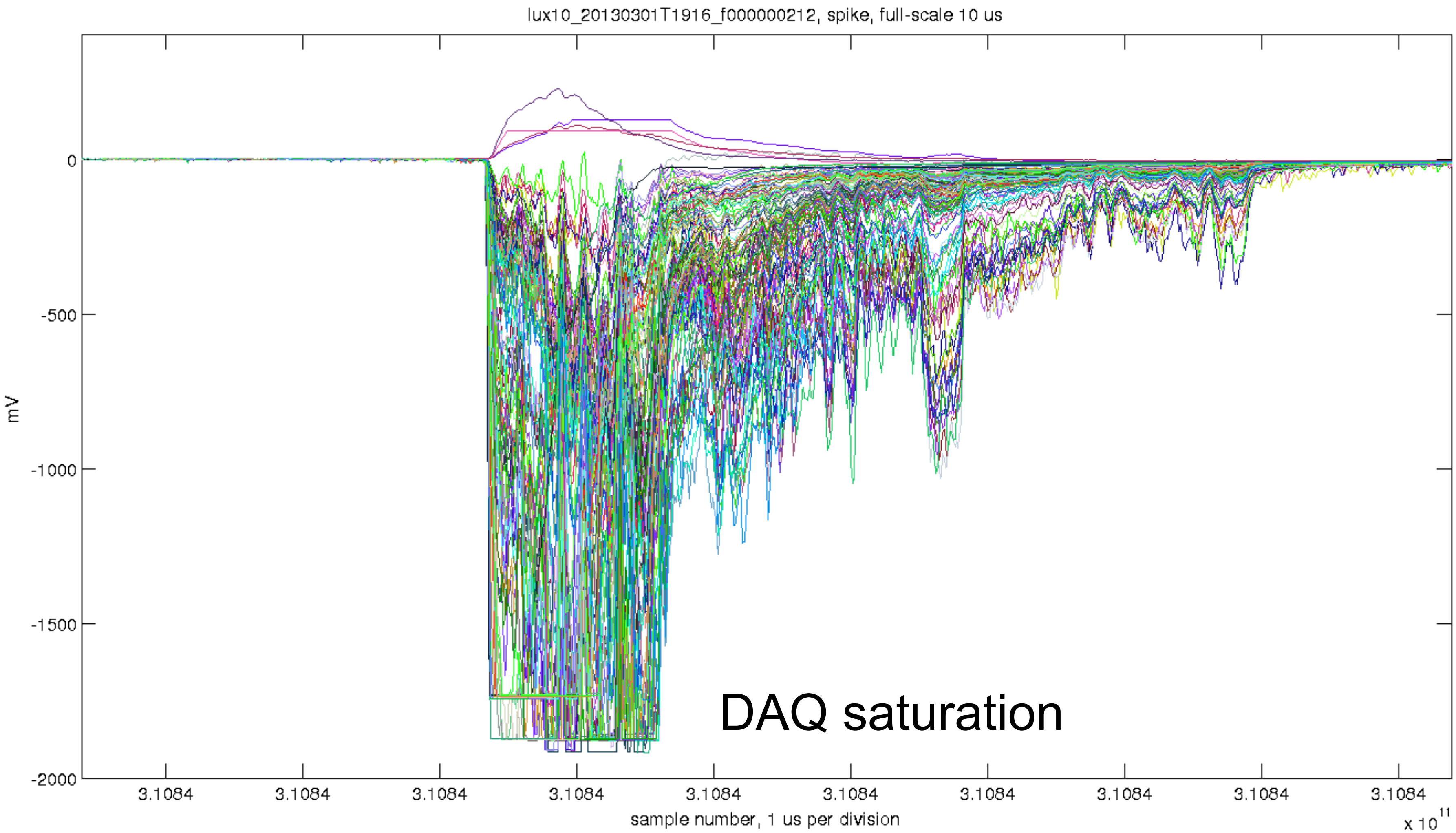


C = -11 kV, B = -3 kV

Saturated Pulses



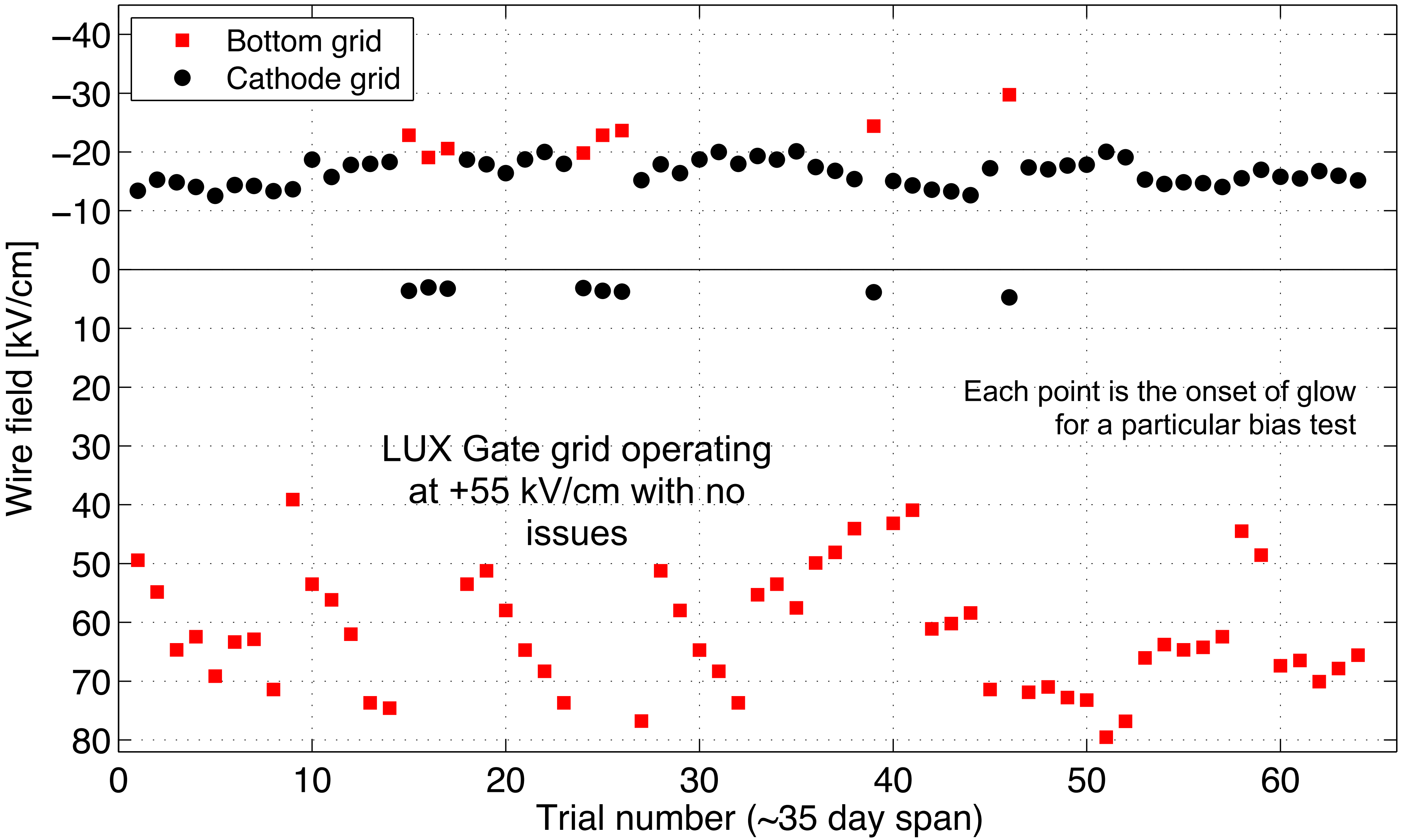
Saturated Pulses



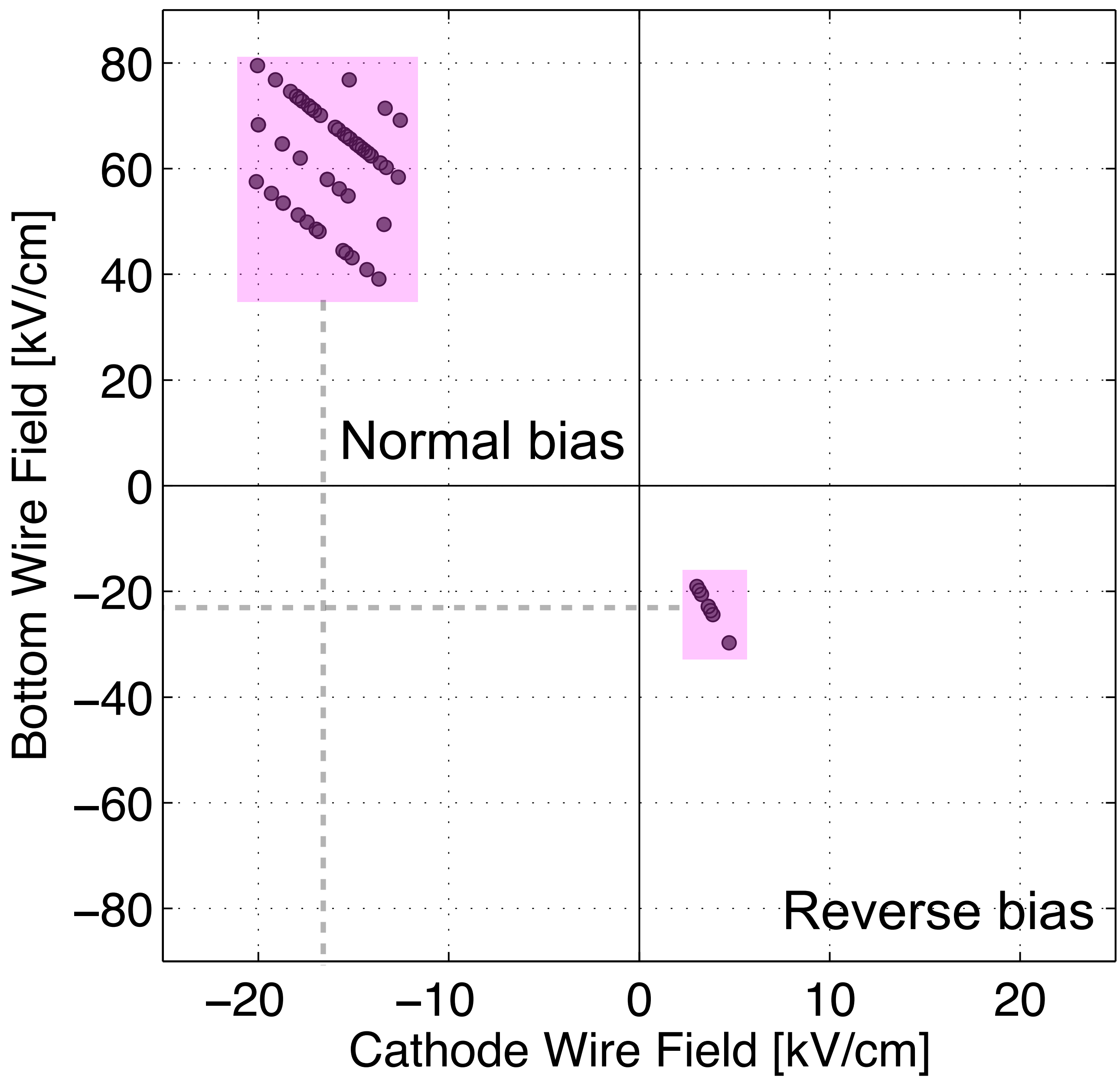
Soak-in & Liquid Conditioning

- Soak-in
  - Cathode and Bottom grids were biased below onset of glow and left there for ~2 weeks.
  - Experience in ZEPLIN III to yield progressively higher voltages.
  - **No long-term improvement observed.**
- Liquid conditioning
  - Cathode and Bottom grids were biased at/above onset of glow and left there for up to 100 mins.
  - **No long-term improvement observed.**

Field at the Wire - Time Series

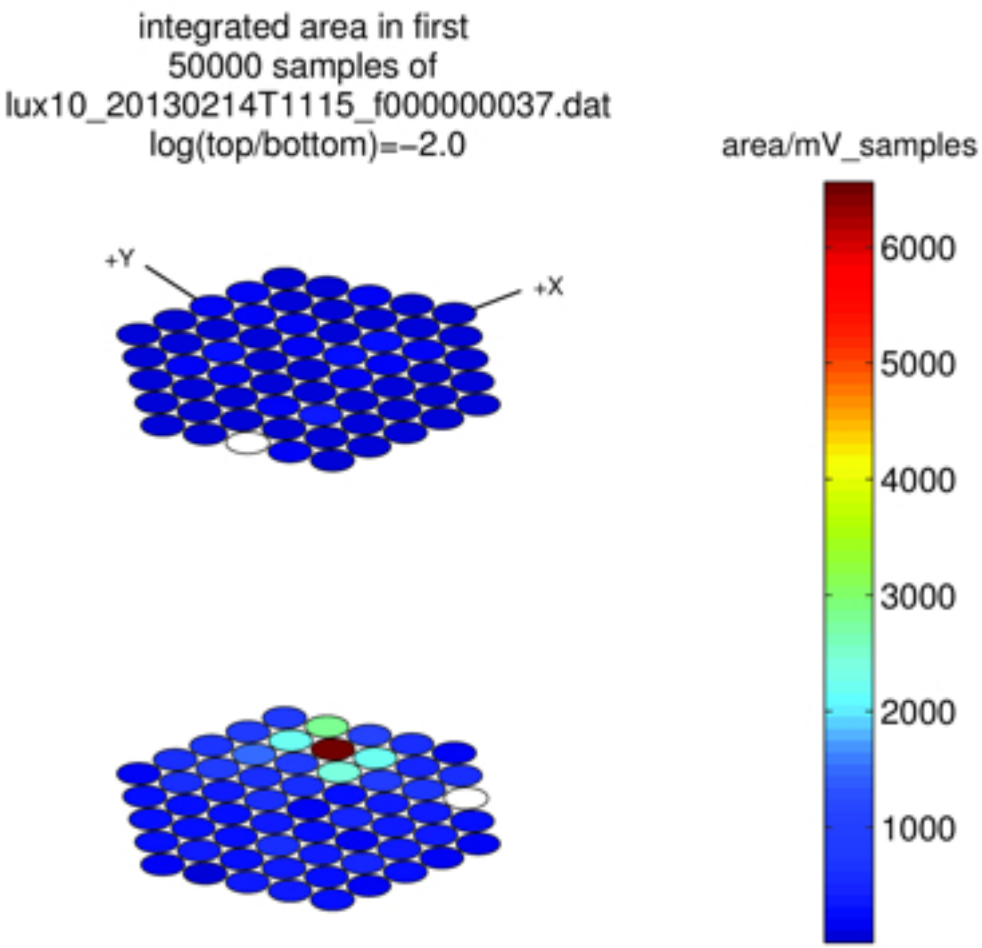


Electric Fields at the Wire Surfaces

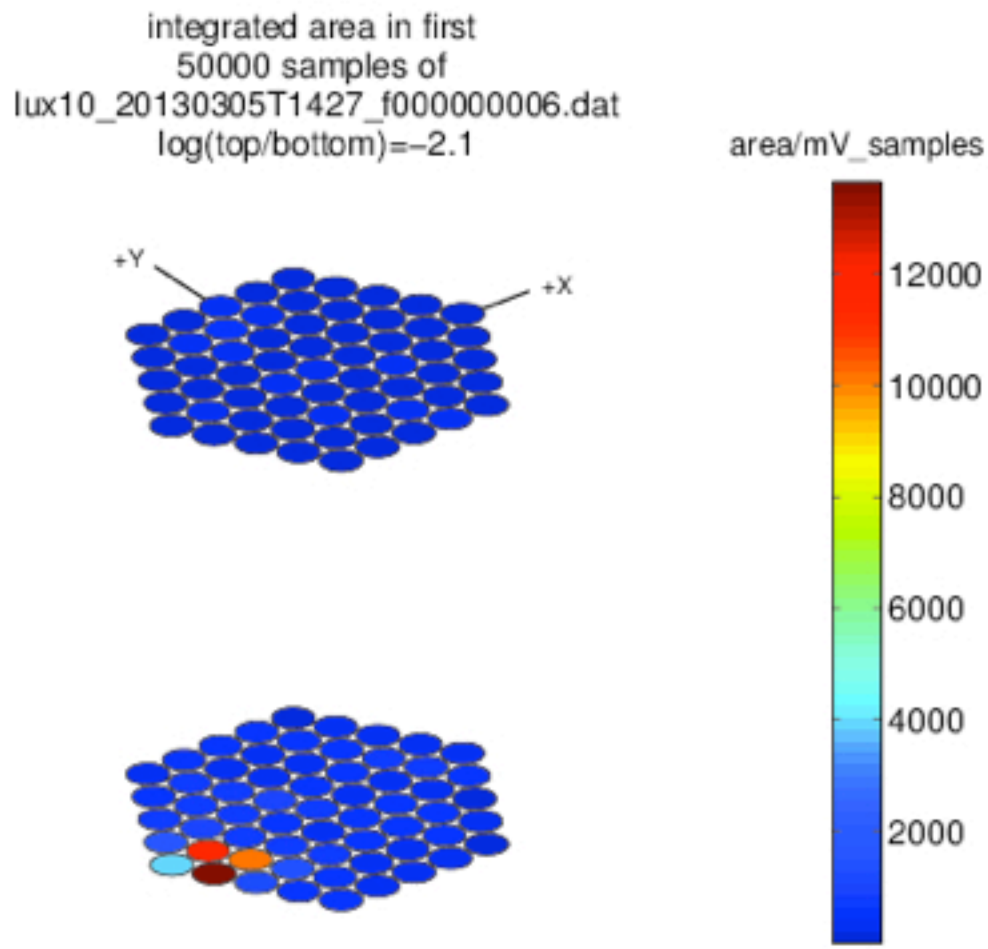


Each point is the onset of glow for a particular bias test

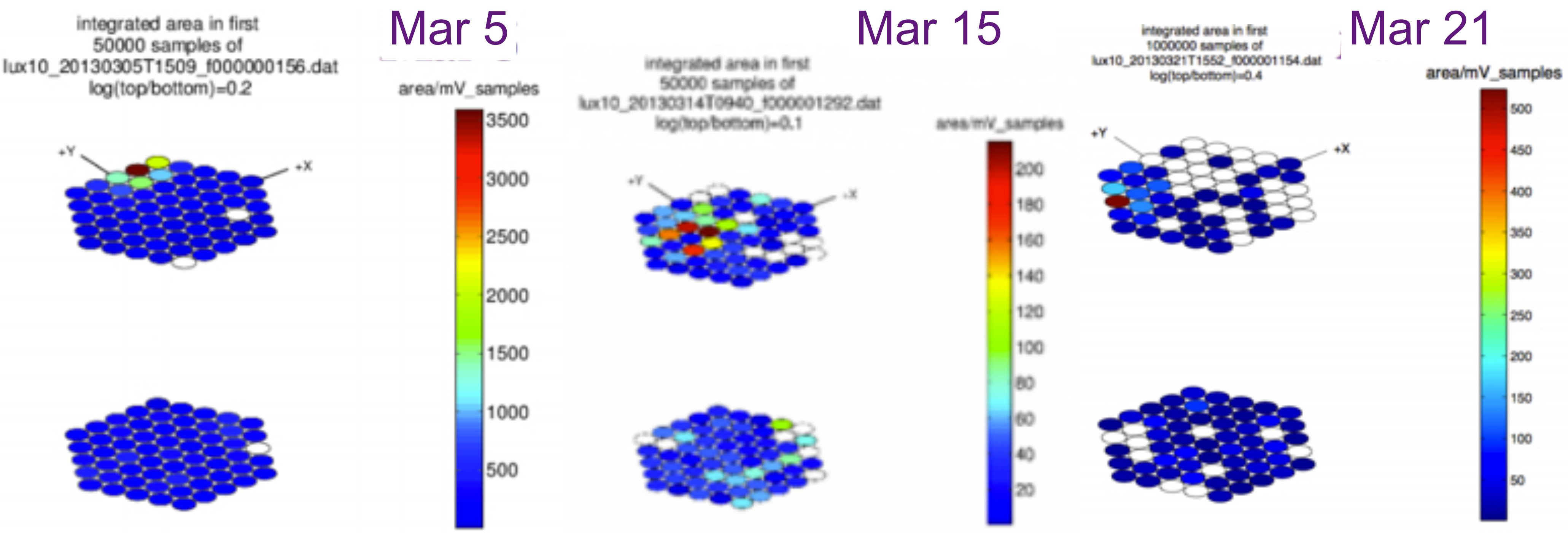
Normal bias (C more negative)



Reverse bias (B more negative)



Anode-Gate



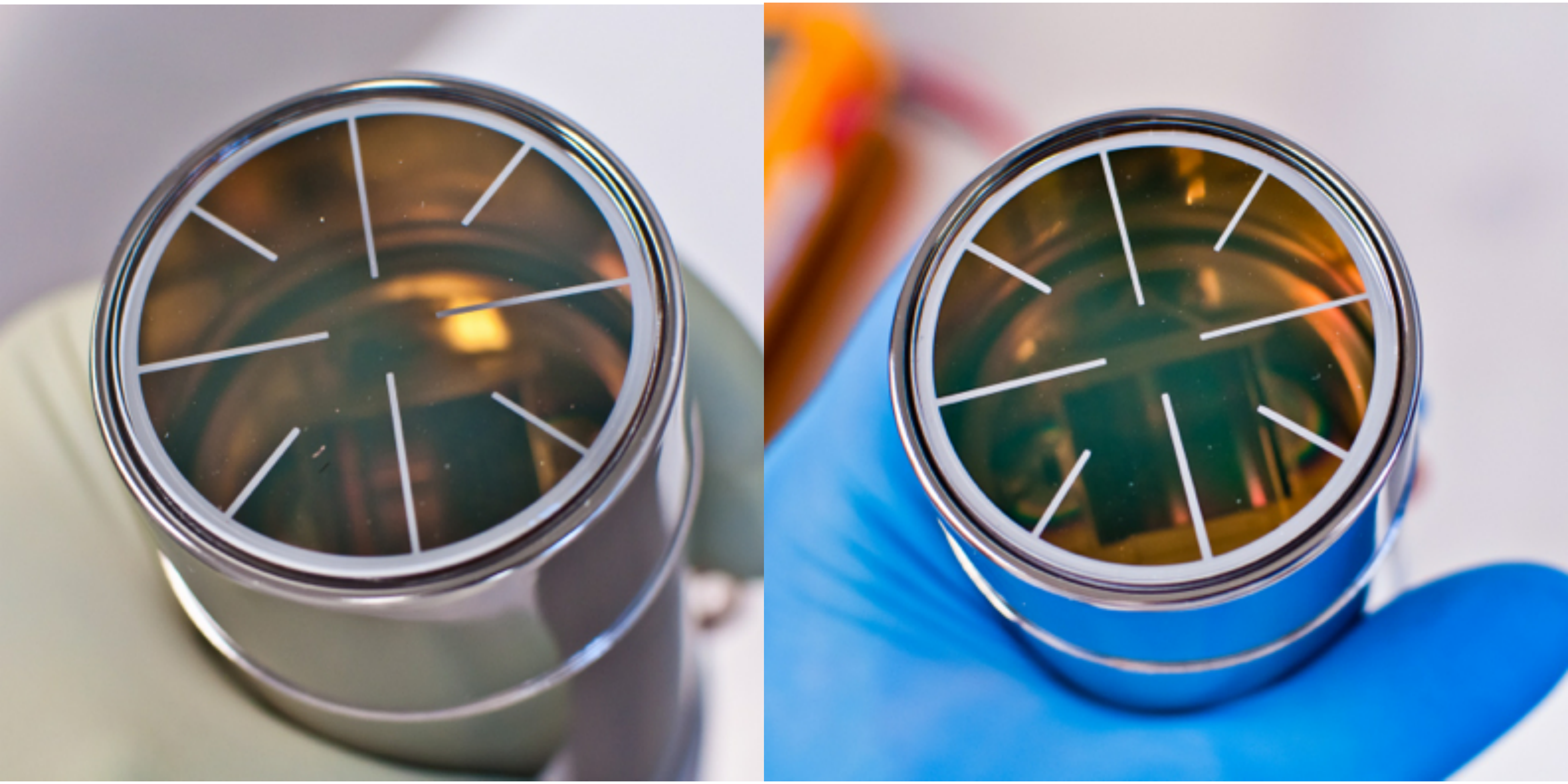
- Glow seen with a top-array hit pattern when A-G voltage difference is ~5.5-6 kV.
- Location of hit pattern has not been constant over time.

Other Experiments

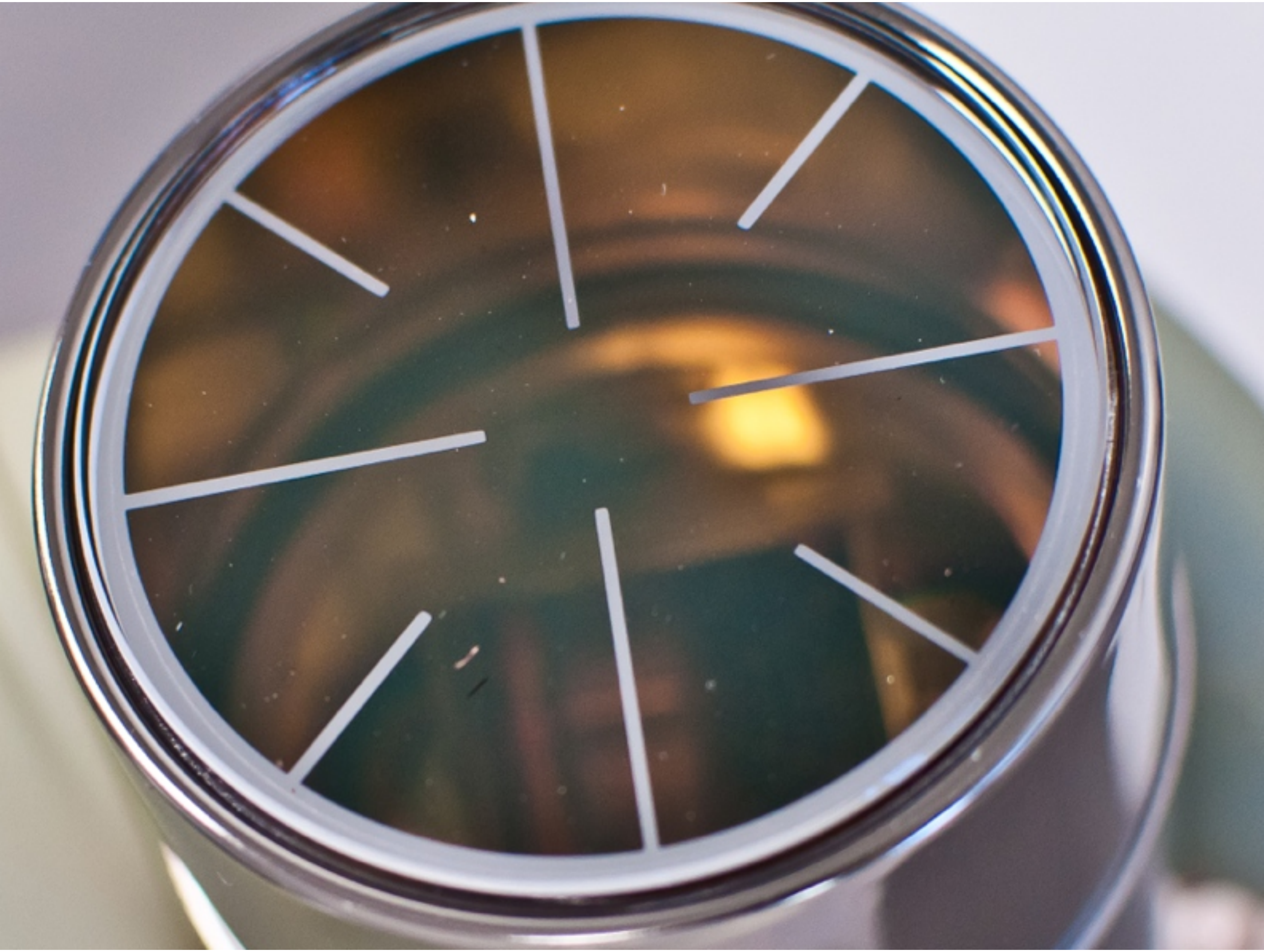
Experiment	Wire material	Type	Pitch, diameter	Max. cathode field at wire
ZEPLIN III	SS	Wire-strung	100 μm, 1 mm	-62 kV/cm -40 kV/cm
ITEP Prototype #1	SS	Wire-strung	100 μm, 1 mm	-39 kV/cm
ITEP Prototype #2	SS	Wire-strung	?	-61 kV/cm
Imperial ZEP3 Prototype	SS	Wire-strung	100 μm, 1 mm	-65 kV/cm
LUX Run02	SS	Wire-strung	100 μm, 10 mm	-60 kV/cm
XED @ CWRU	BeCu	Wire-strung	40 μm, 2 mm	**-220 kV/cm**
XENON10	SS	Mesh (rectangular)	203 μm, 2 mm	(-12 kV bias)
XENON100	SS	Mesh (hexagonal)	75 μm, 5 mm	(-16 kV bias)

Data compiled by H. Araujo and P. Sorensen

Detector Debris



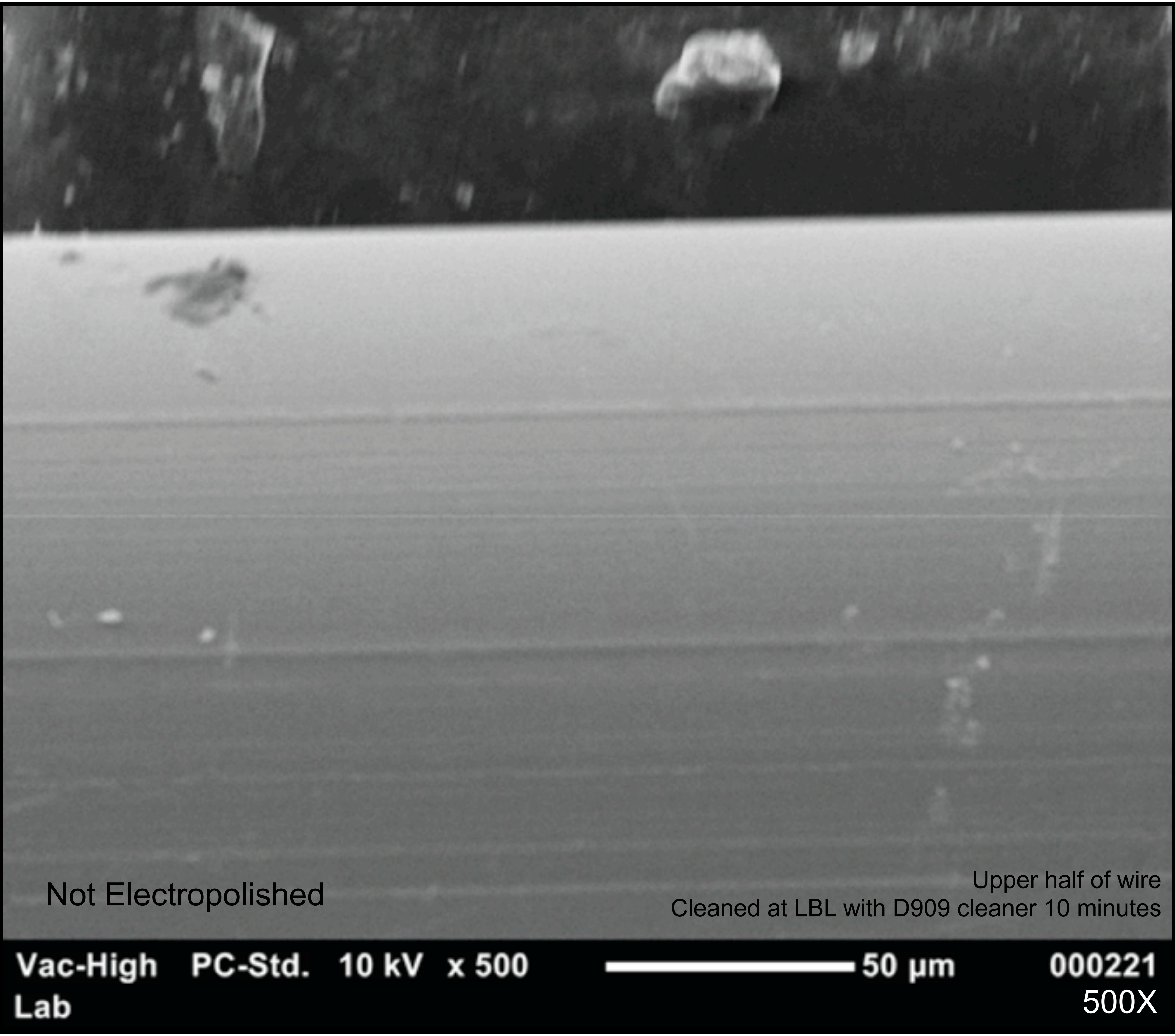
PTFE and small Cu pieces seen in bottom PMTs after Run02.

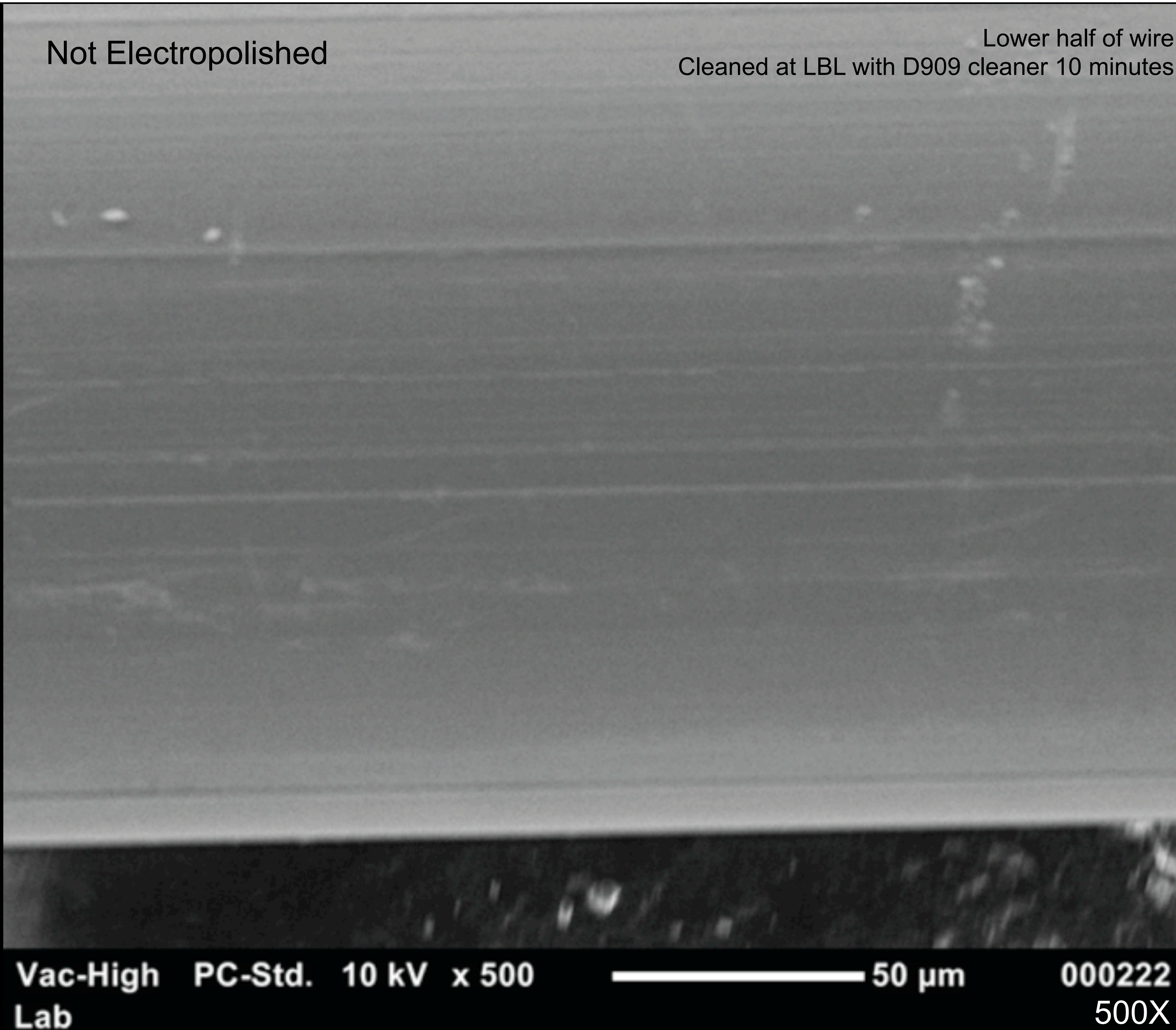


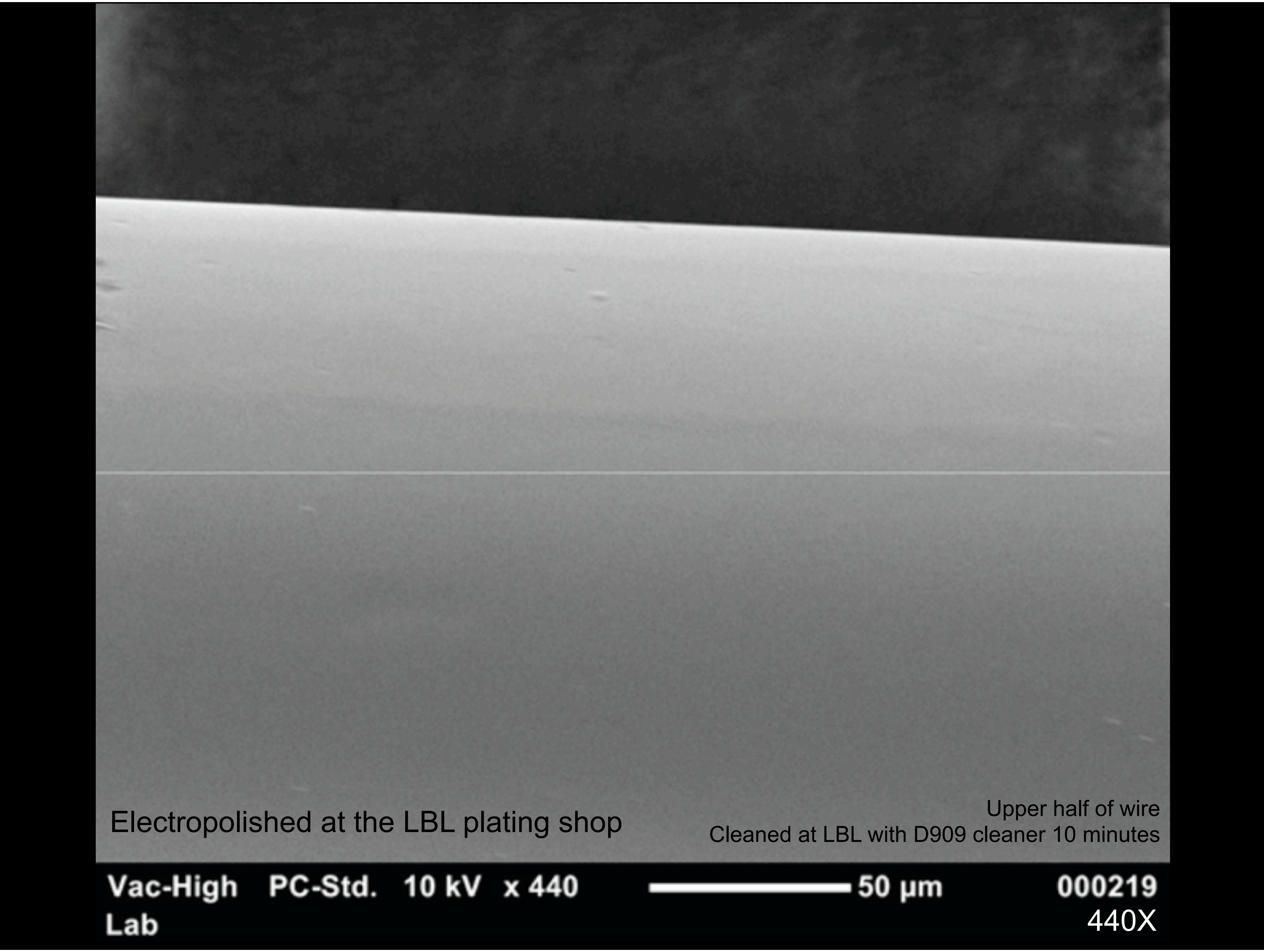
Ideas and Tests: The Usual Suspects (It Seems)

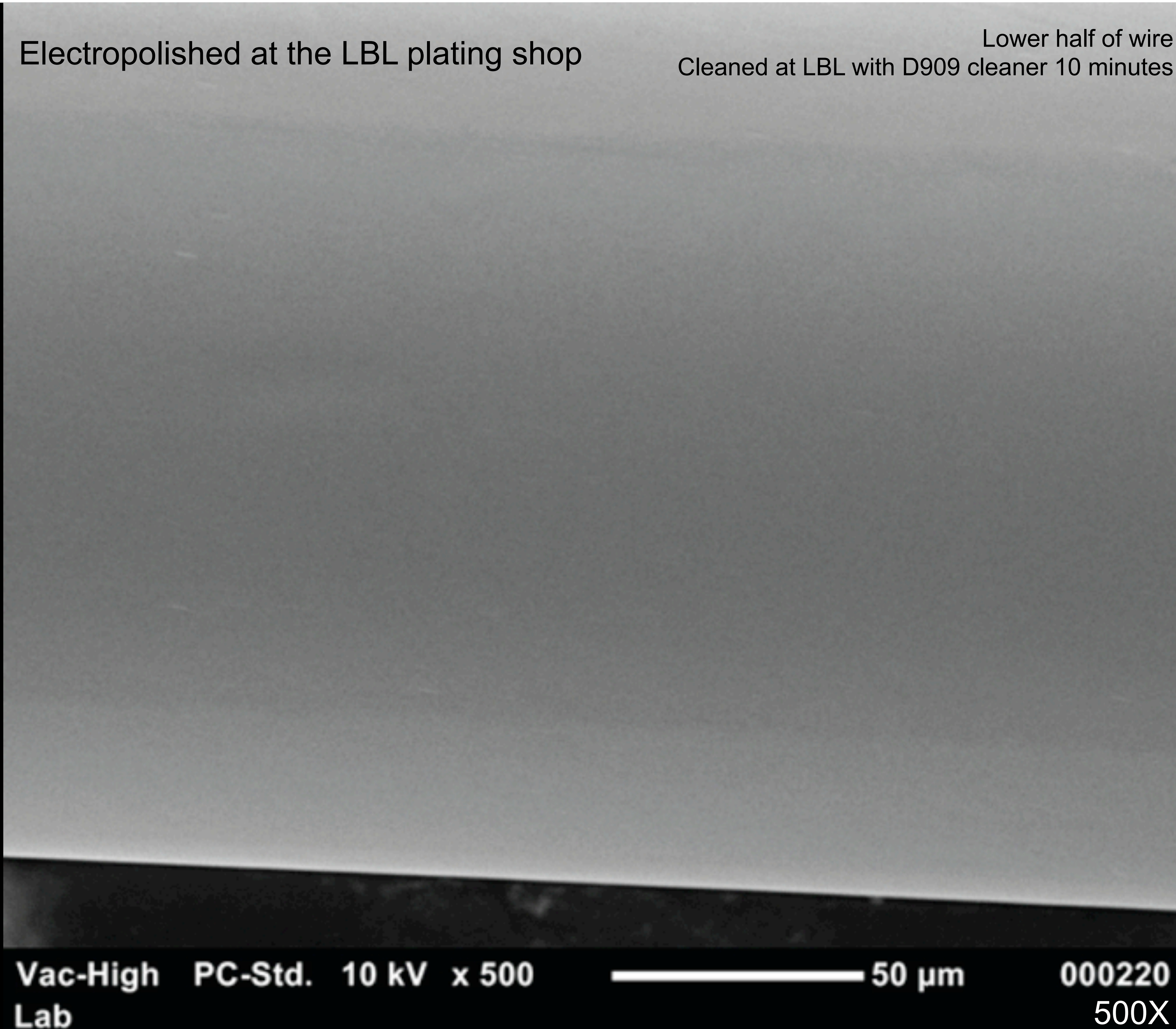
- Bubble formation: lowers voltage for glow onset.
  - Performed a bubble-quenching test by introducing a 5 K temperature gradient in detector, no difference in glow.
- **Debris: Most likely scenario.**
  - Evidence of conductor debris during detector filling (temporary PMT shorts to ground).
  - Conductor pieces were seen in NEXT prototype to cause continuous discharge (photon “grass”).
  - Can also explain G-A discharge.
- Wire surface: asperities, Malter effect, etc.
  - Wire is ultra-finish and seen to be reasonably smooth.
  - Liquid conditioning at onset of light has given no steady improvement.
  - Gas-phase conditioning will be performed next.

Supplemental Material


Not Electropolished
Upper half of wire
Cleaned at LBL with D909 cleaner 10 minutes
Vac-High PC-Std. 10 kV x 500
50 µm
000221
Lab
500X


Not Electropolished
Lower half of wire
Cleaned at LBL with D909 cleaner 10 minutes
Vac-High PC-Std. 10 kV x 500
50 µm
000222
Lab
500X


Electropolished at the LBL plating shop
Upper half of wire
Cleaned at LBL with D909 cleaner 10 minutes
Vac-High PC-Std. 10 kV x 440
50 µm
000219
Lab
440X


Electropolished at the LBL plating shop
Lower half of wire
Cleaned at LBL with D909 cleaner 10 minutes
Vac-High PC-Std. 10 kV x 500
50 µm
000220
Lab
500X