Production and high voltage testing of the LZ detector grids

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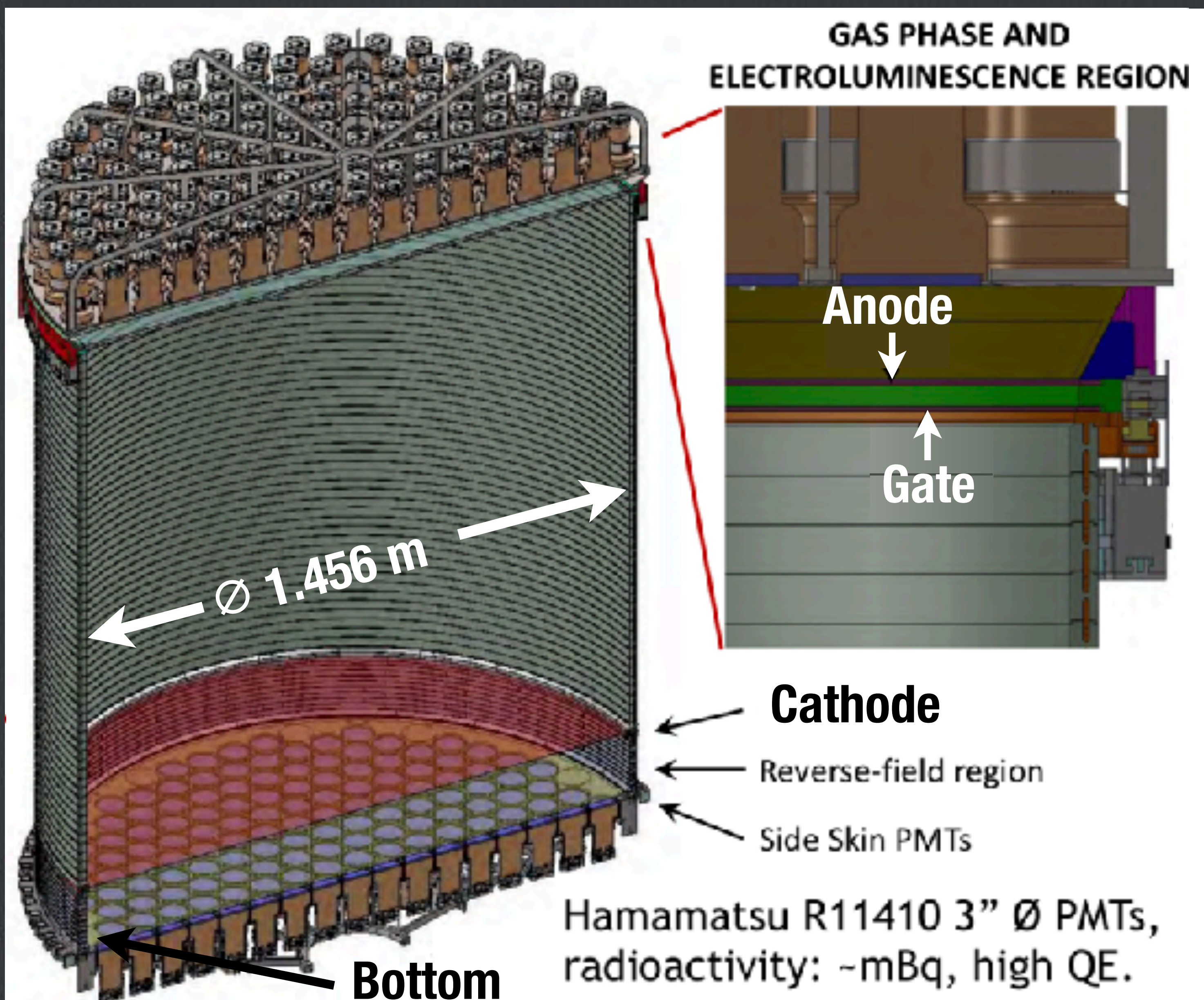
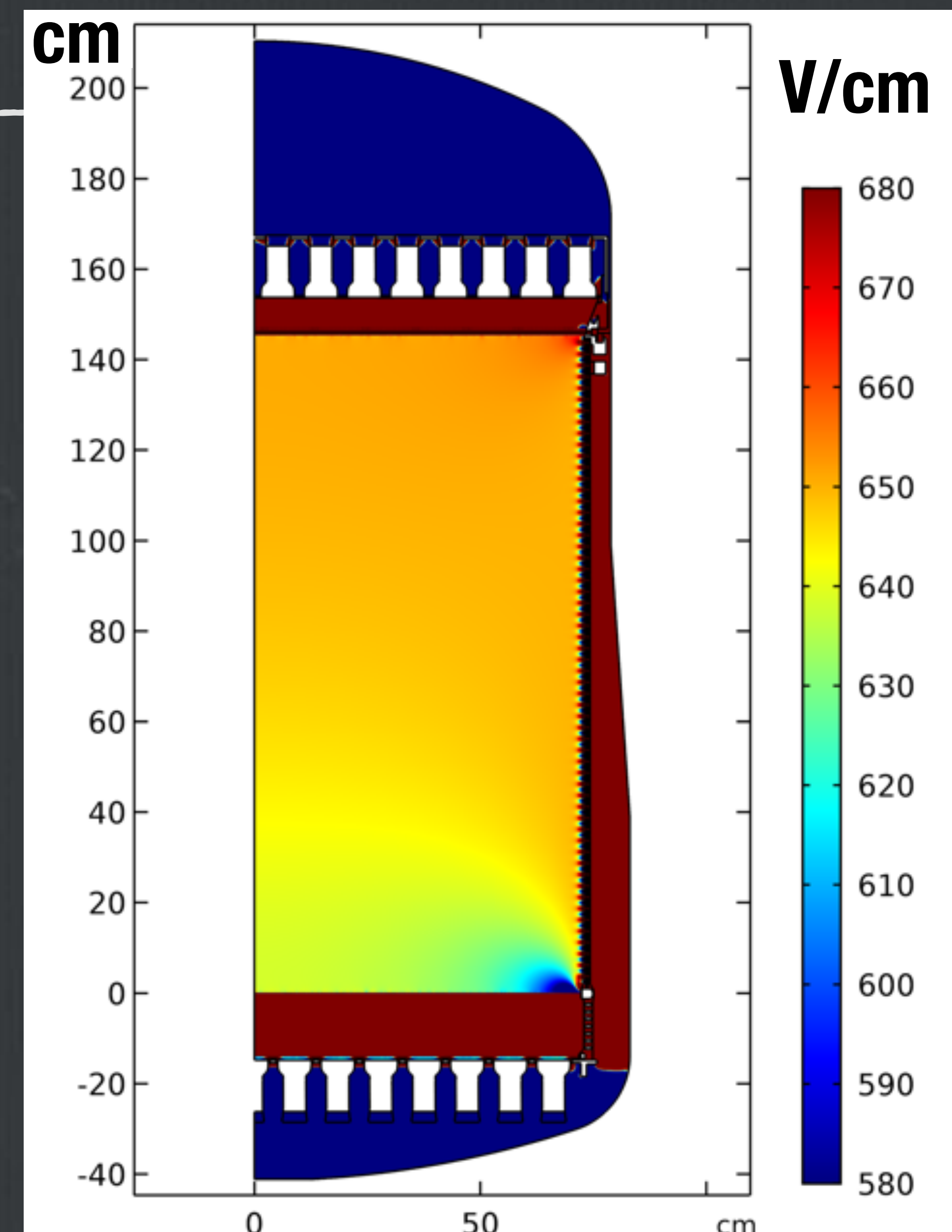
For the LZ collaboration

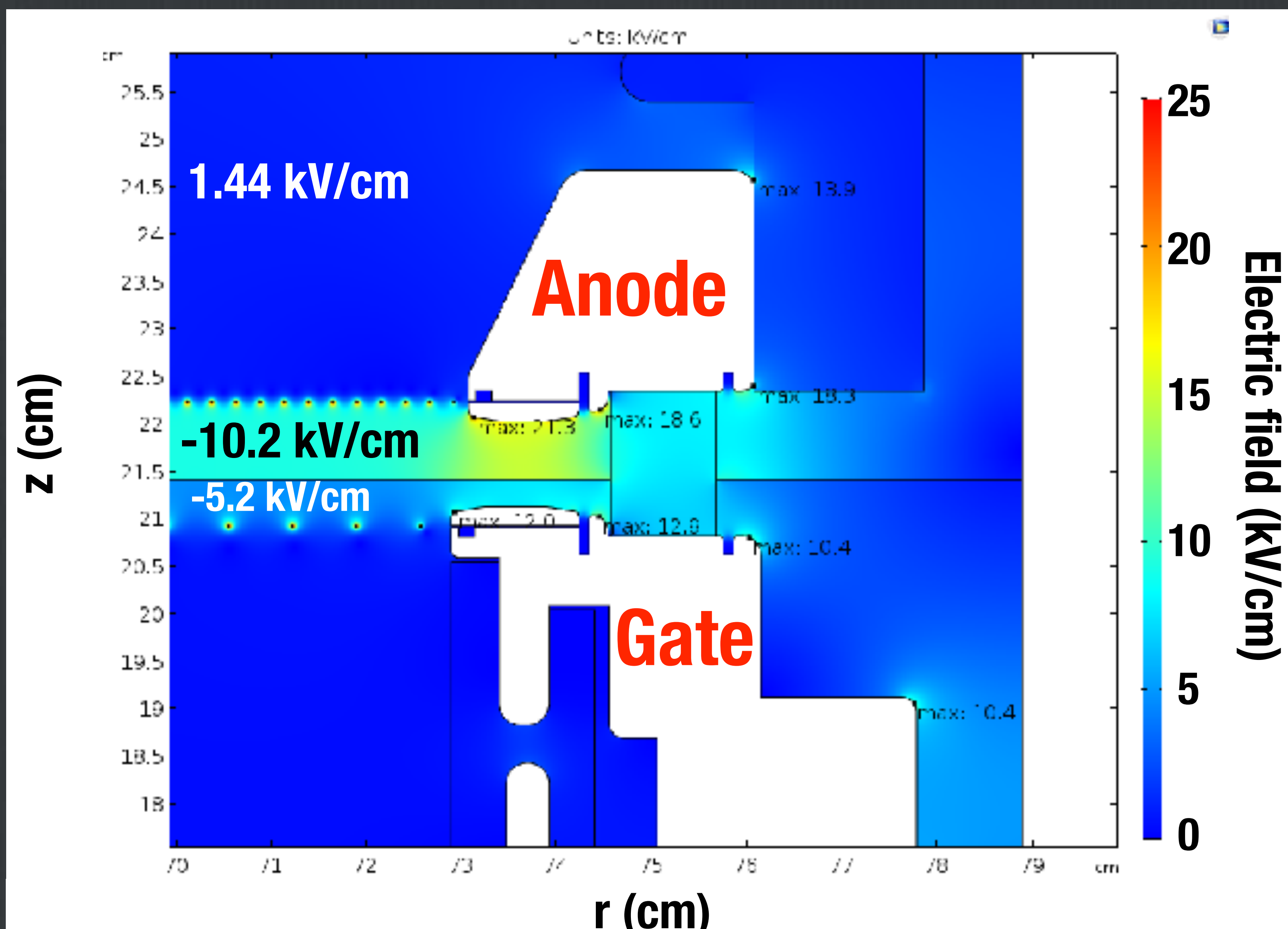
LZ detector





Electric fields in the LZ detector with the cathode at -100 kV

Extraction region



Grid	Voltage (kV)	Surface field (kV/cm)
Anode	5.75	46.2
Gate	-5.75	-51.8 -48.4

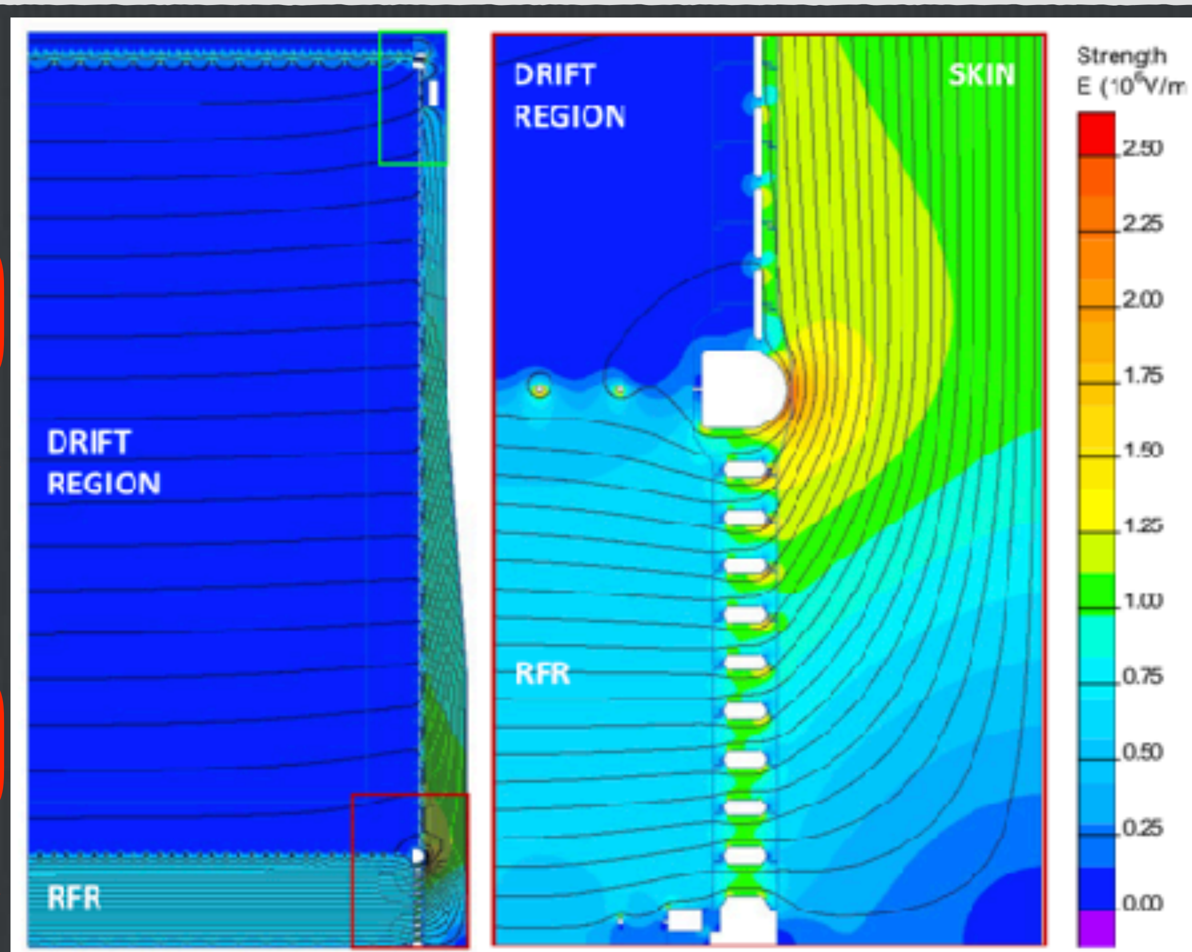
Cathode @ -50 kV
Cathode @ -100 kV

- Liquid-Anode gap = 8 mm
- Gate-liquid gap = 5 mm

Drift & reverse field region

-0.30 kV/cm
-0.65 kV/cm

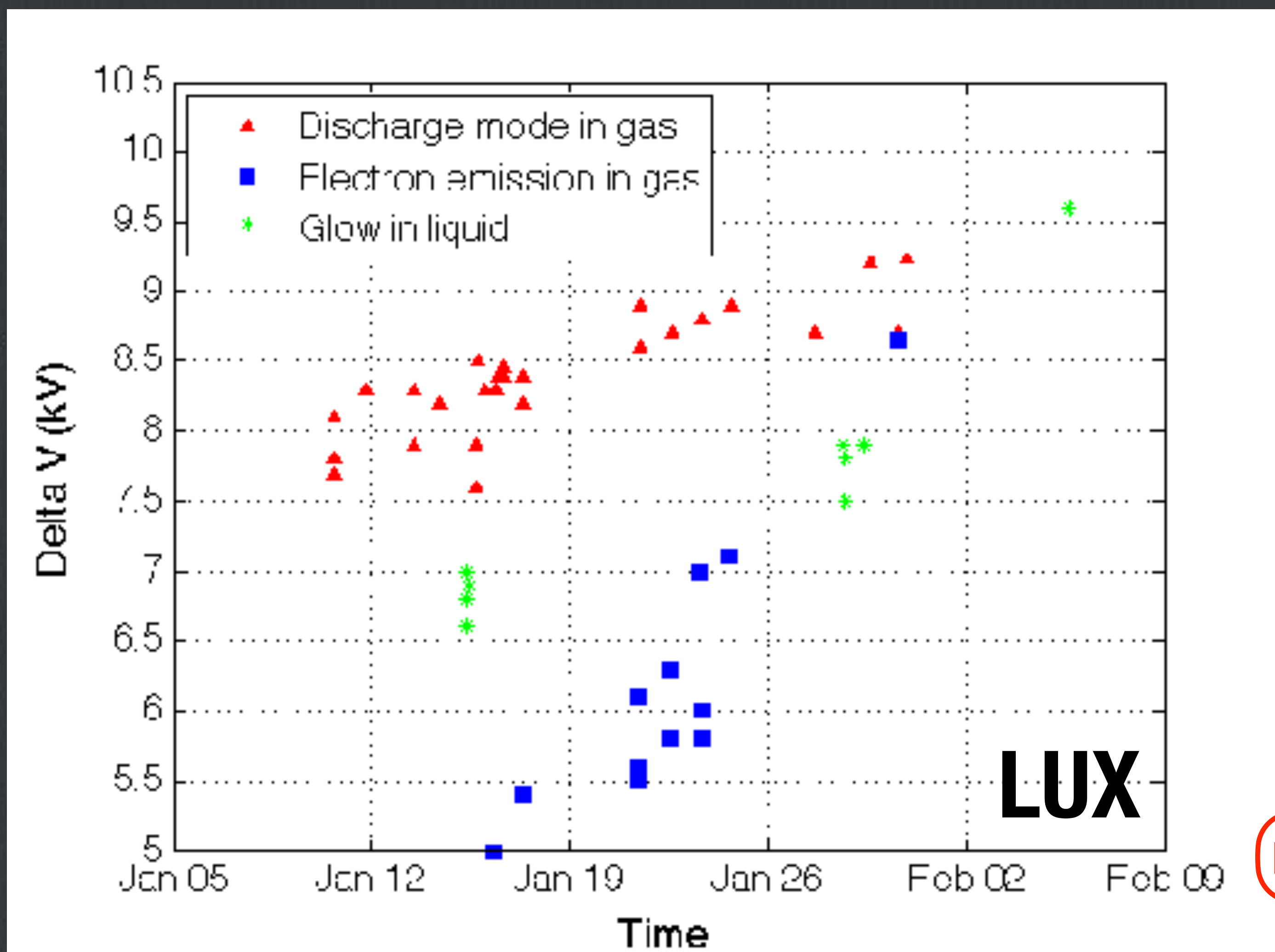
3.5 kV/cm
7.1 kV/cm

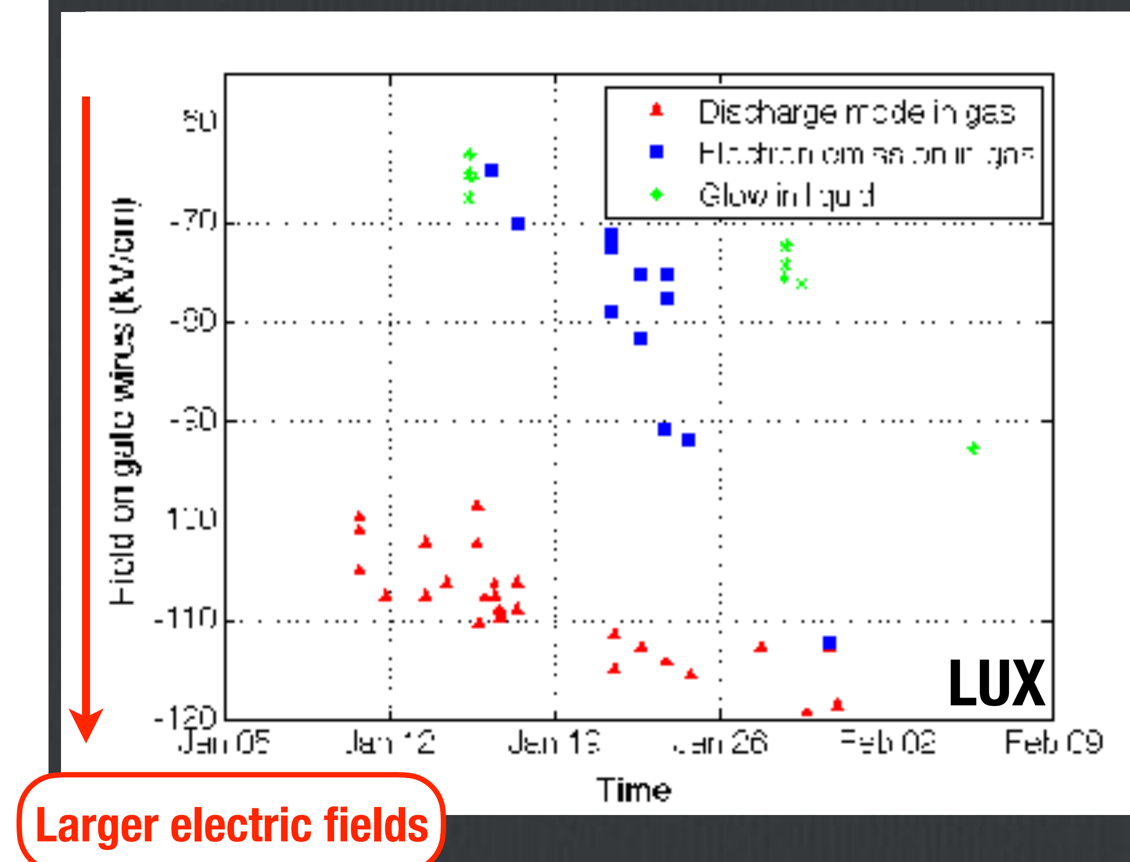


Grid	Voltage (kV)	Surface field (kV/cm)
Cathode	-50 -100	-30.1 -61.4
Bottom	-1.5	-33.8 -68.6

- High electric fields are required in the detector in order to:
  - Achieve high electron extraction & to drift electrons in a timely fashion without losing many to the wall, etc.

Problem: Emission from electrodes





- LUX conditioning campaign studied the onset of photon emission from the gate grid when in gas (green) and the onset of electron emission once the liquid was raised above the gate (blue).
- Study electron emission in gas as an approximation to a cathodic grid's performance in liquid xenon.

Design of electric field grids

- Wire grids to provide high optical transparency
- Wire mesh to provide mechanical strength, minimal grid deflection
- Wire diameter and pitch are tools to help minimize the electric fields on the wire surfaces

	Wire diameter (μm)	Wire pitch (mm)	Transparency (%)	Voltage (kV)
Anode	100	2.5	92.0	5.75
Gate	75	5	97.0	-5.75
Cathode	100	5	96.0	-50 / -100
Bottom	75	5	97.0	-1.5

Grid production: weave

- Commercial mesh does not come in the diameter needed for LZ
- Challenges: Maintain wire spacing, tension, even weave

LZ loom

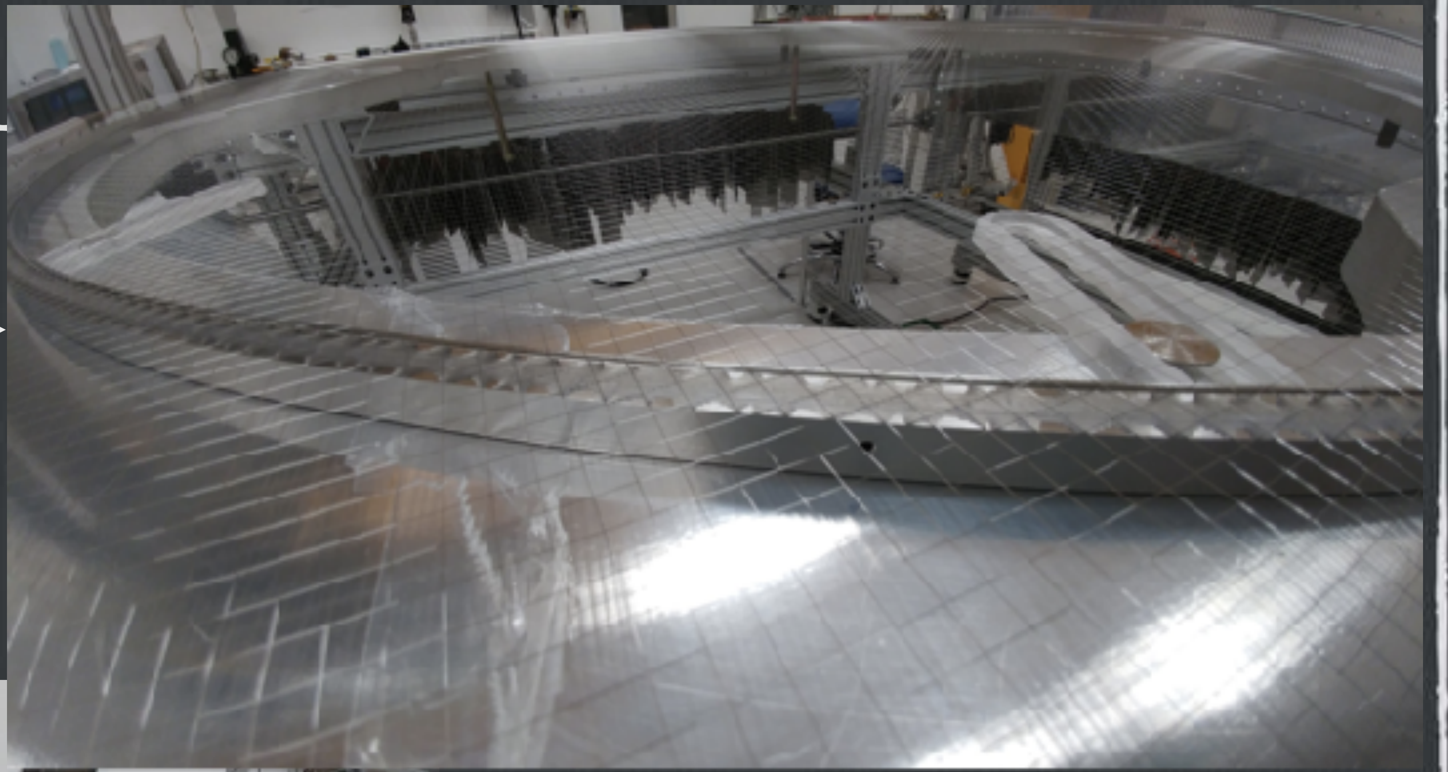
http://www.luitzphotography.com/

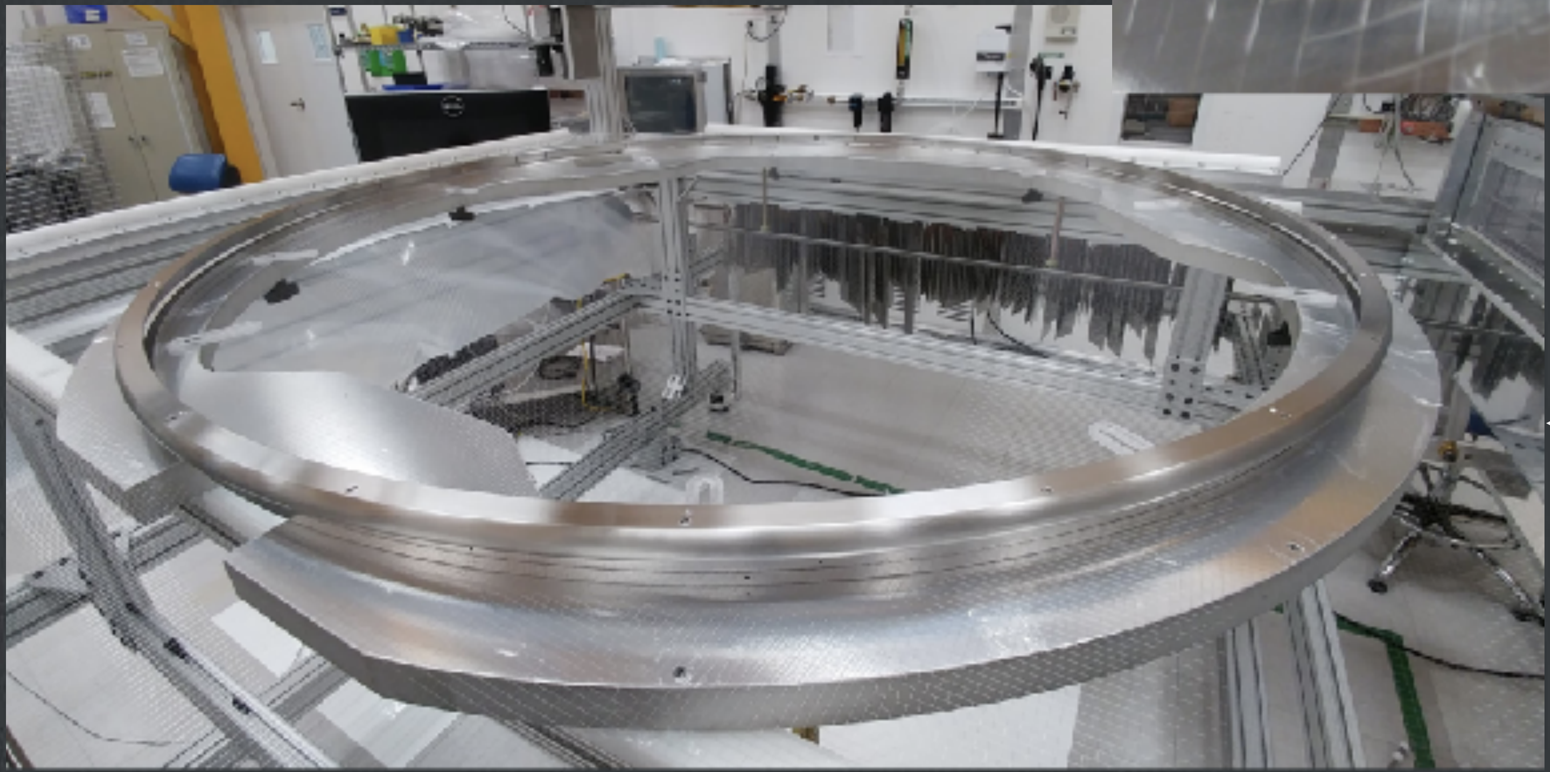
Grid production: glue

- Preparation includes engraving ring surface for better glue adhesion.
- Glue robot built to evenly distribute the glue bead over the grid ring.
  - Scan to find x, y positions of the ring ID and OD and engraved surface.
- Glue the grid wires to the grid ring
  - Epoxy is compatible with cryogenic cooling.

Completed grid

Engraved grid ring under wire mesh with 5 mm pitch





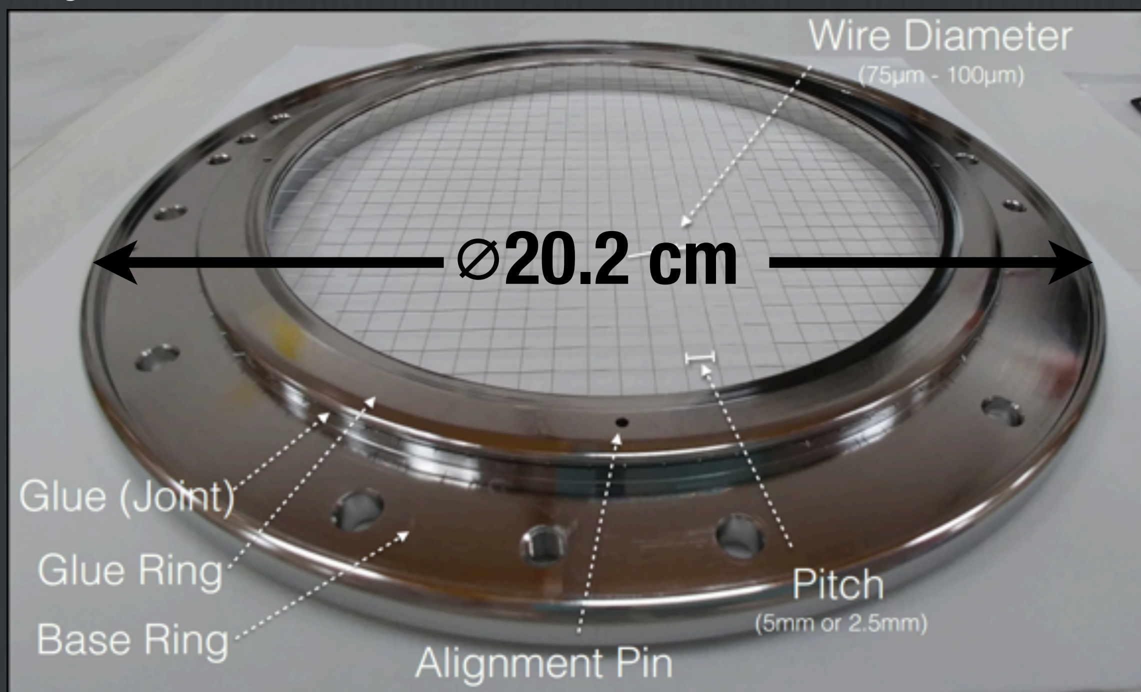
Glued and completed LZ grid

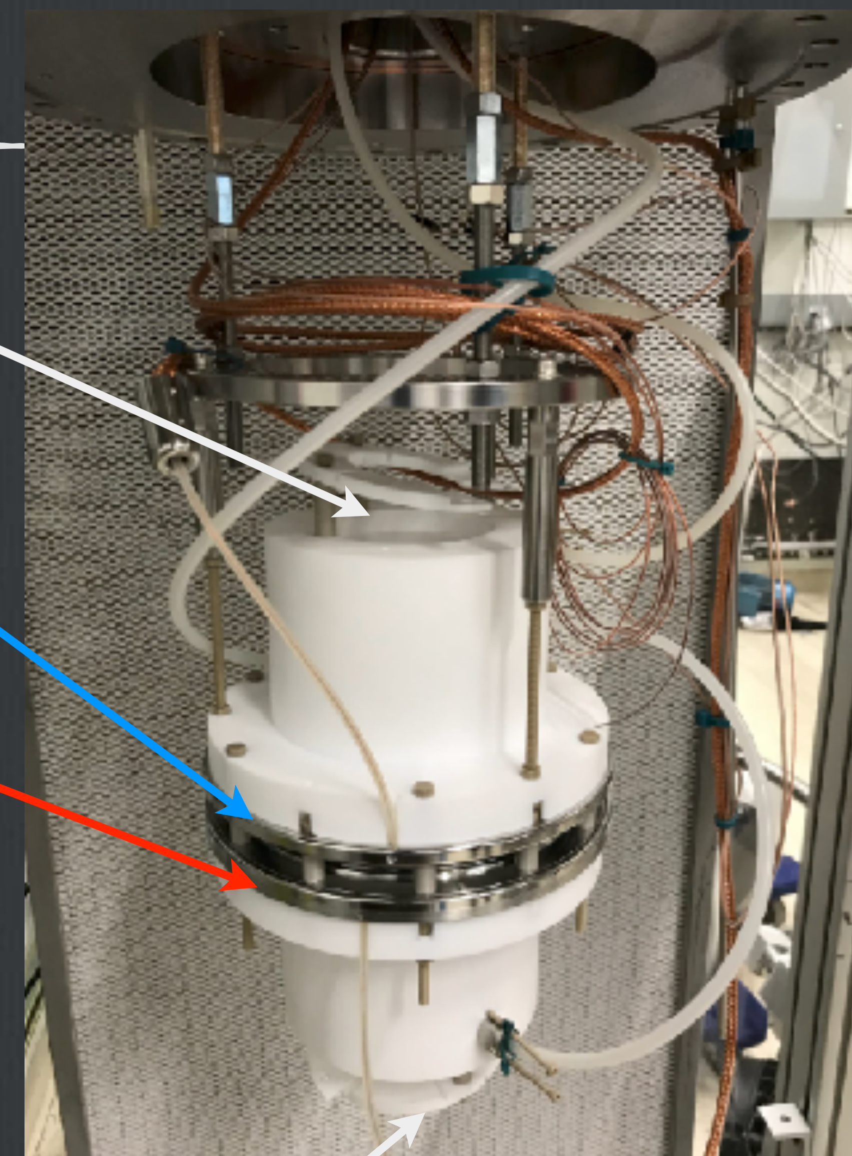
Testing program at SLAC

- Three detectors at SLAC to provide a comprehensive picture of grid performance and can be used to extrapolate the performance in LZ.
- Goal: Quiet background free of photoelectrons and other signals
- Focus on identification and quantification of electron emission from grids

	Large	Small
TPC	LZ	Phase I
Gas only	Phase II	Gas test

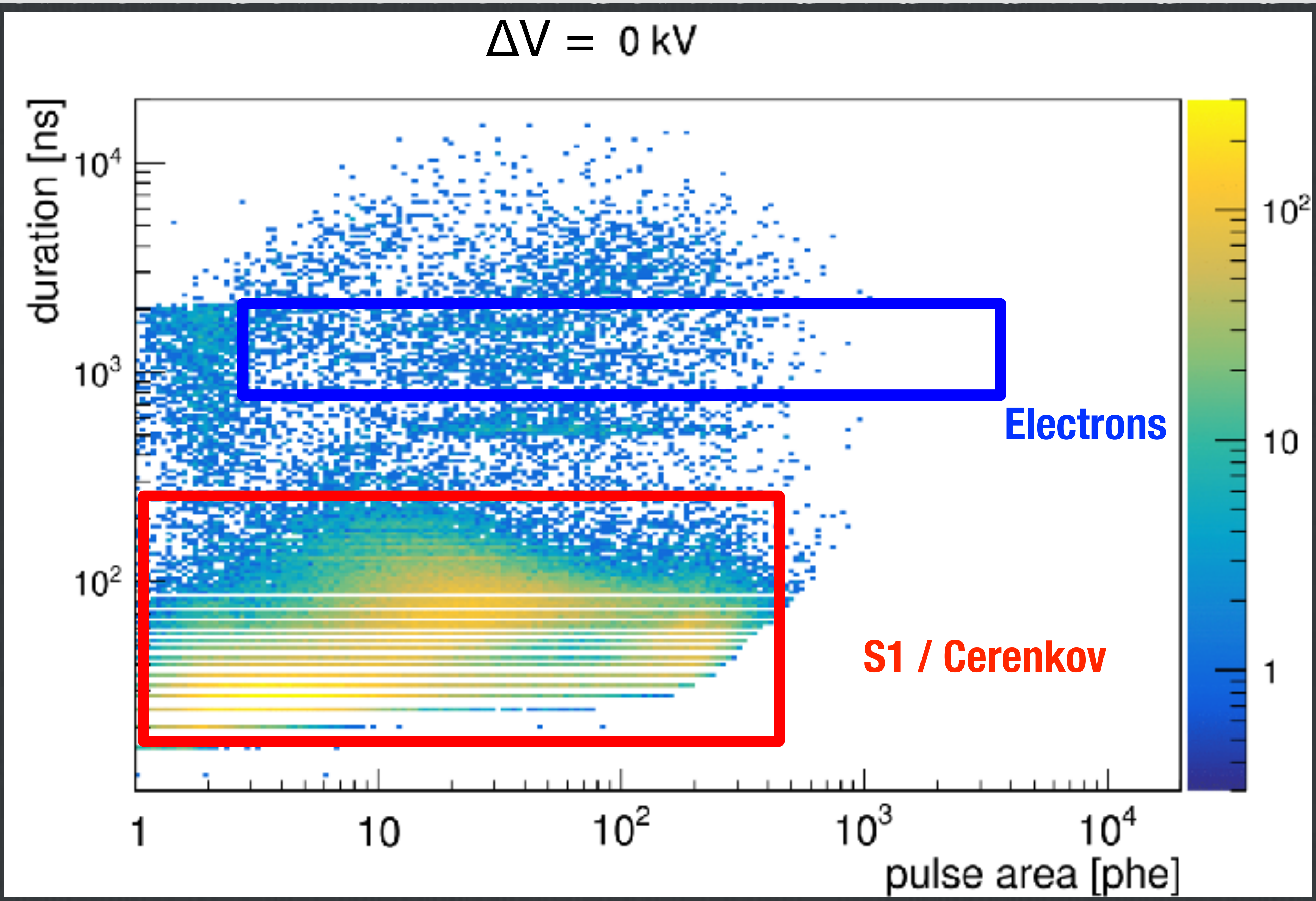
Gas test





- Test only the extraction region (anode and gate)
- High pressure Xe gas
- Quick turnaround to test different grids

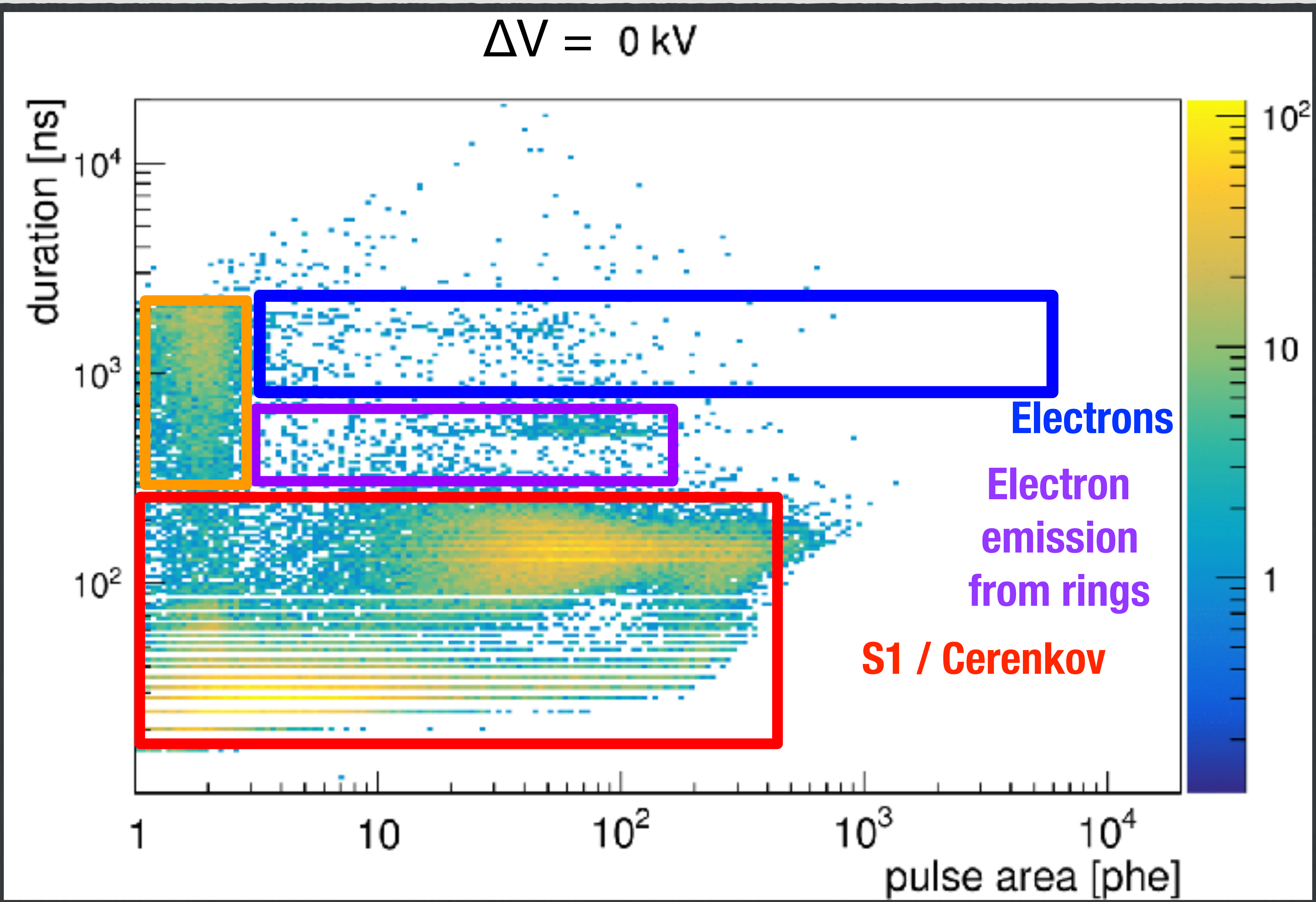
Gas test results: untreated grid



Gas test results: passivated grid

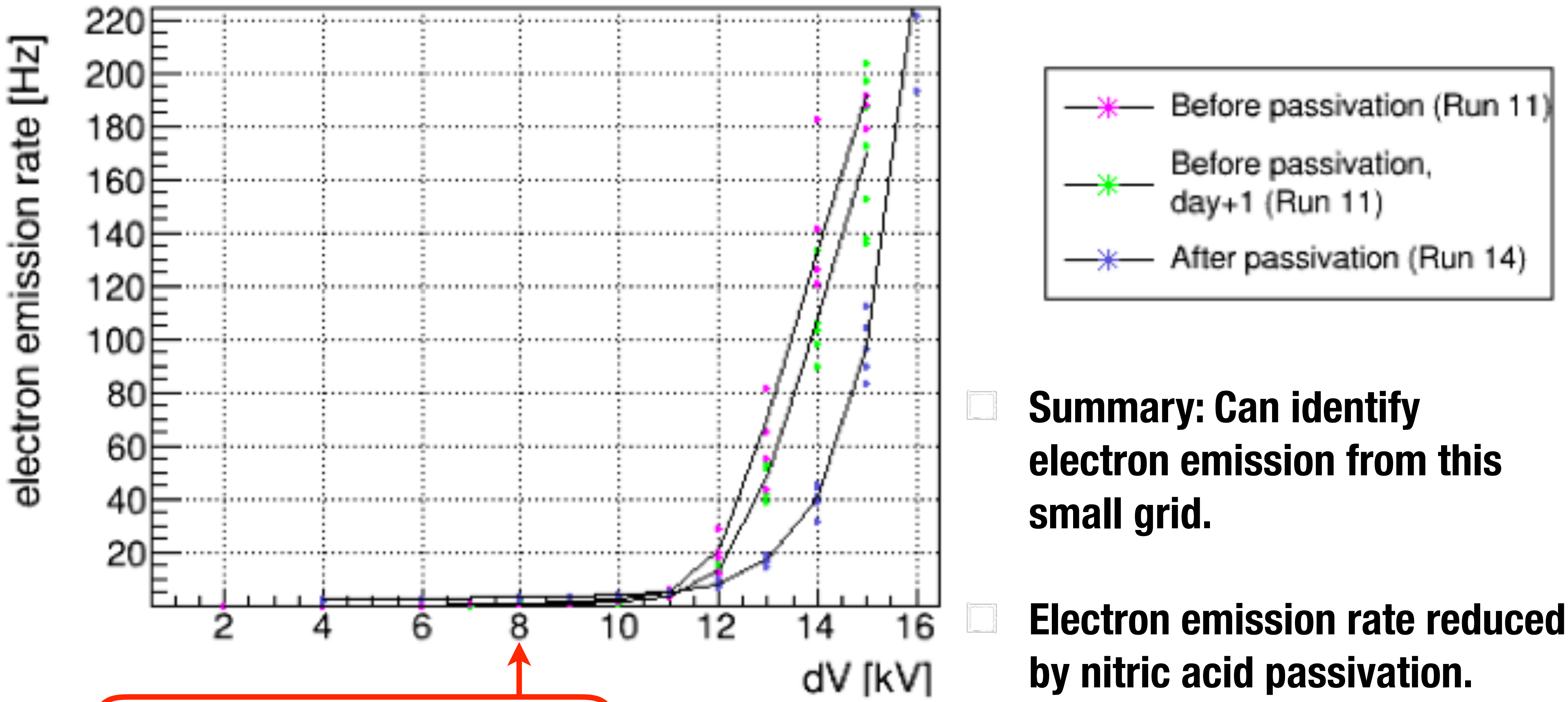
Acid-cleaned with nitric acid

False coincidence after a big pulse



A. Tomas, et al., https://arxiv.org/abs/1801.07231

Gas test results: electron emission

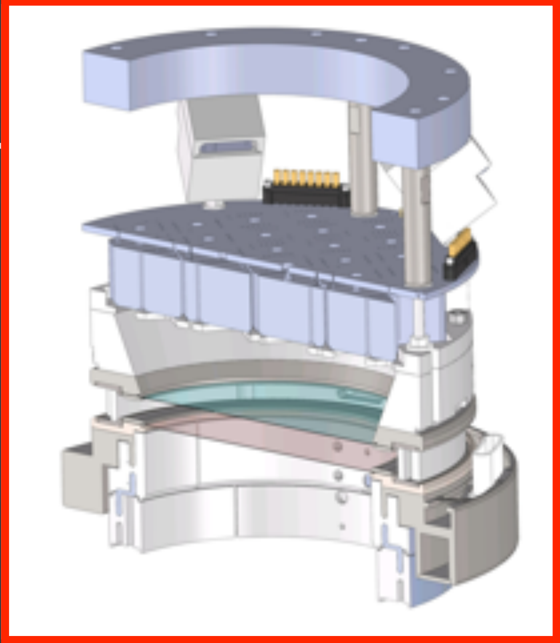


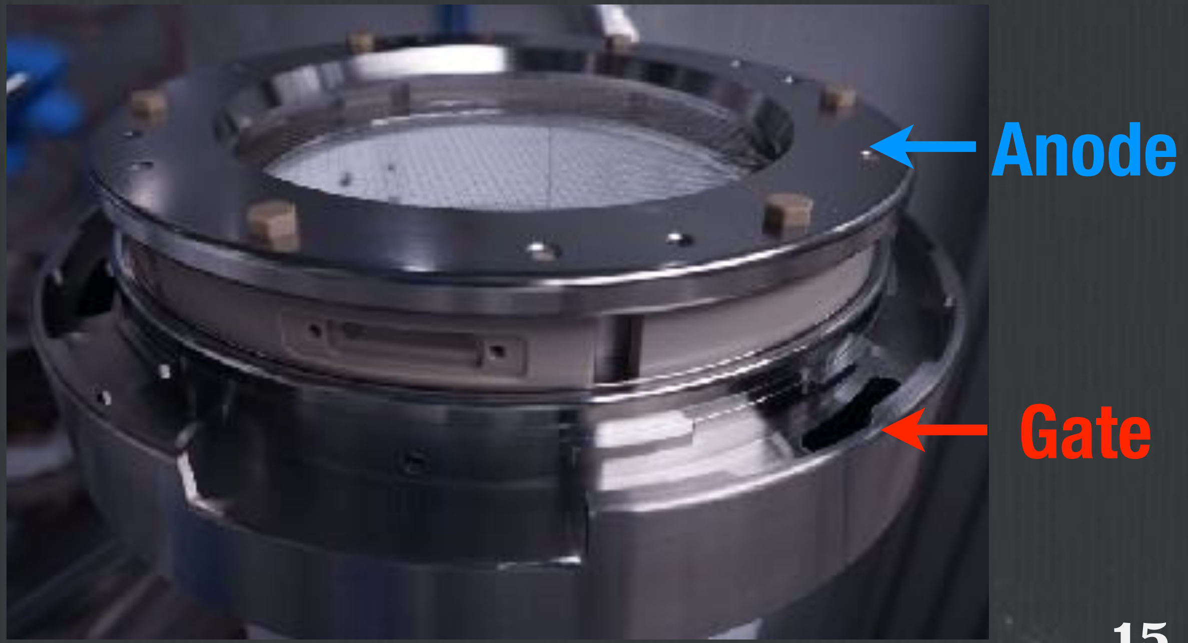
- Summary: Can identify electron emission from this small grid.
- Electron emission rate reduced by nitric acid passivation.

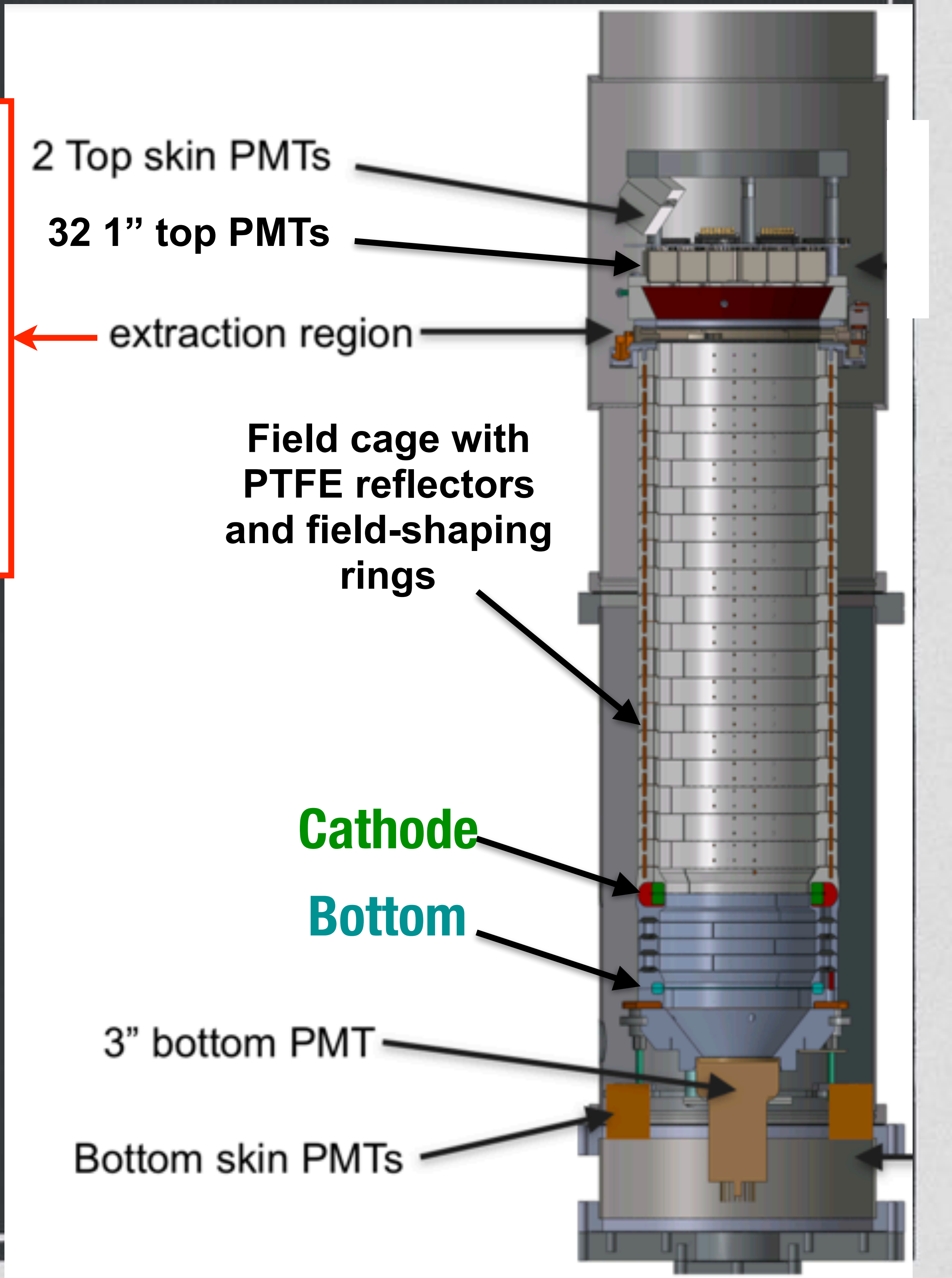
Equivalent to LZ's extraction region ΔV, given different gas pressures

Liquid xenon small detector

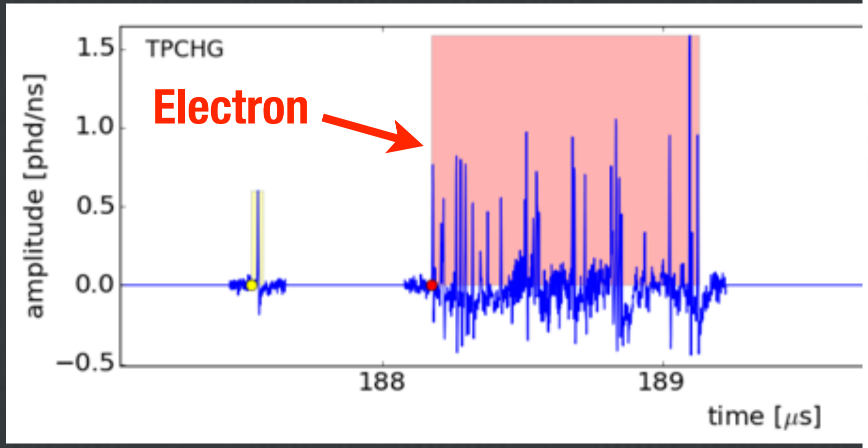
- Scaled-down version of LZ of ~120 kg Xe with 30 kg active region.
- Extraction region is a clone of LZ with the same weir structure and support pieces.
- TPC with array of 32 PMTs for x-y localization

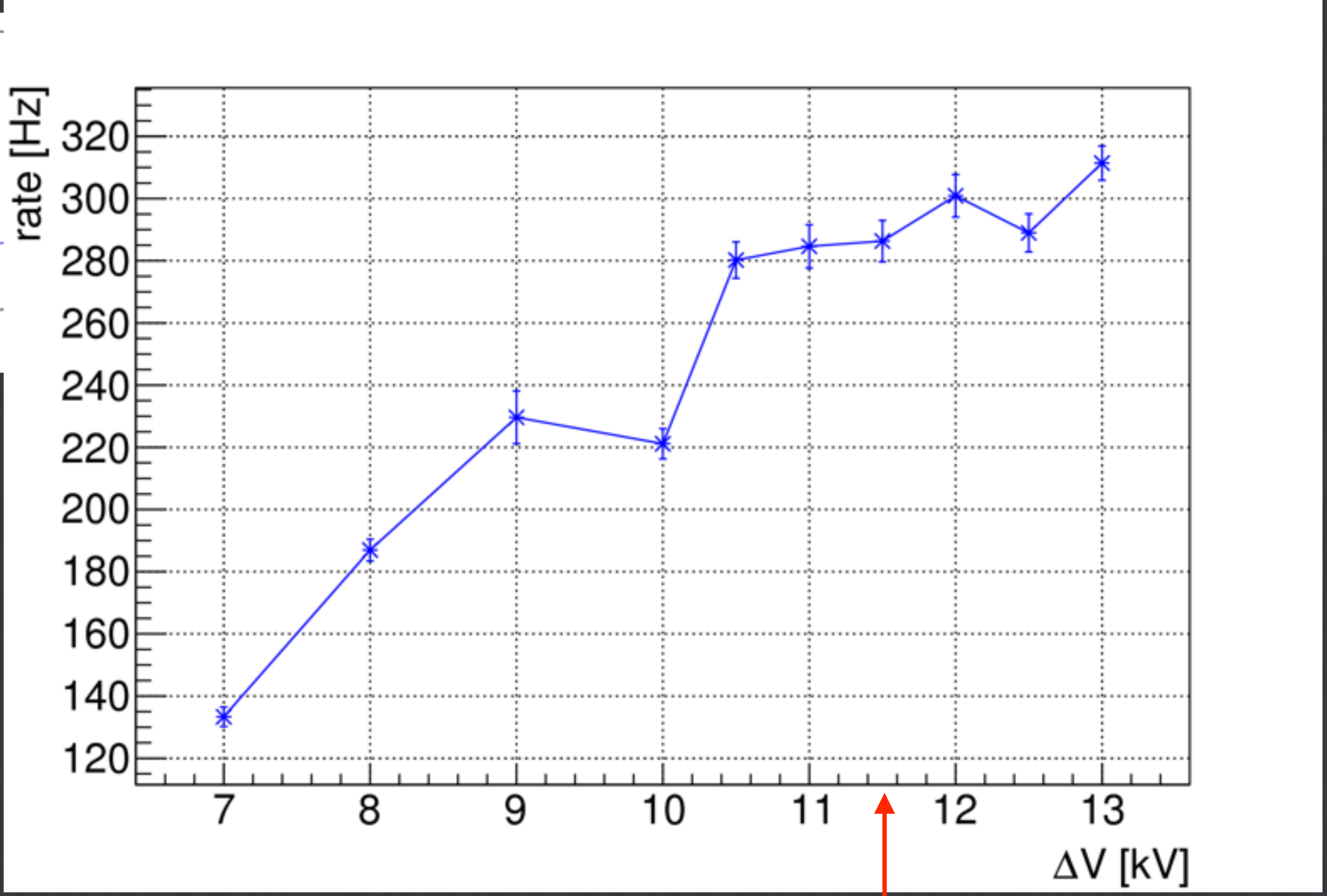






LXe small detector results



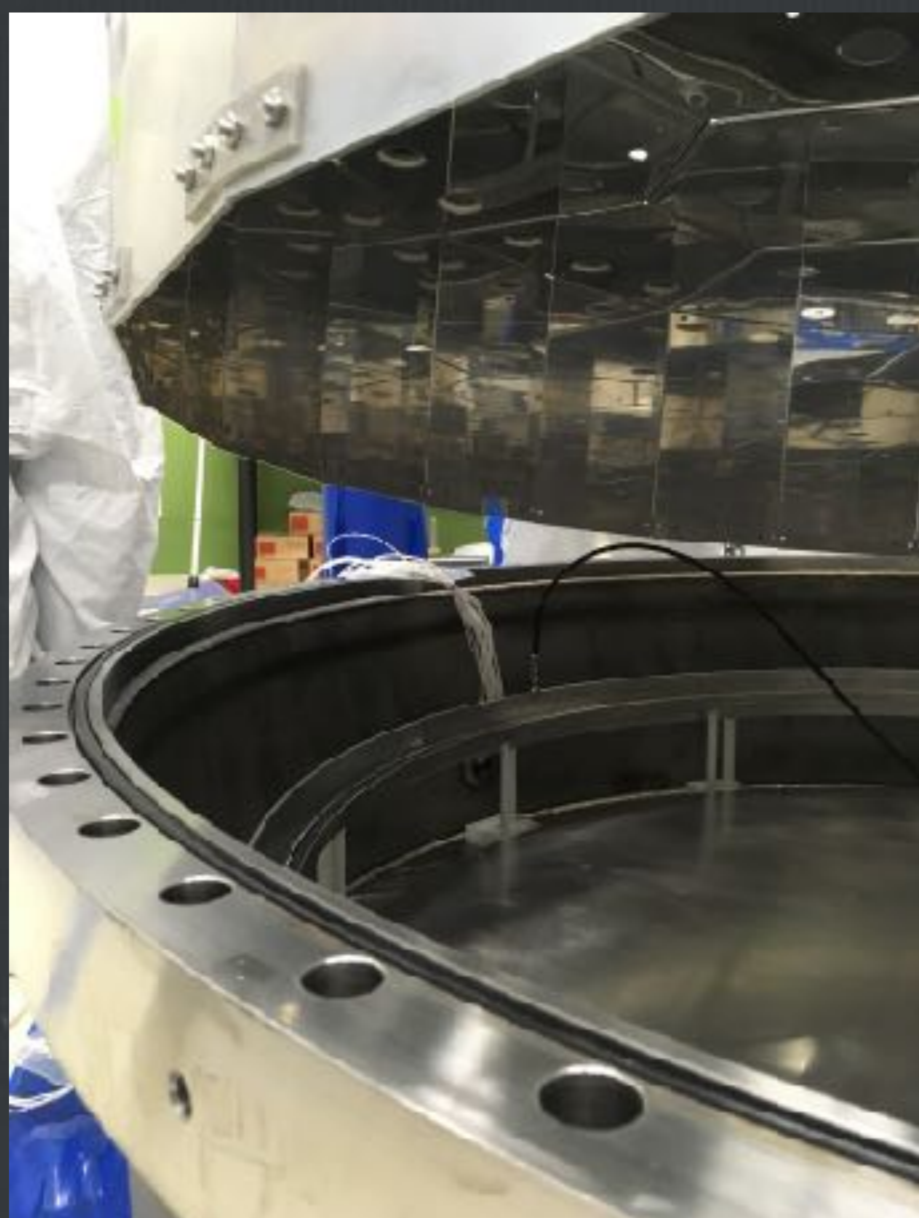


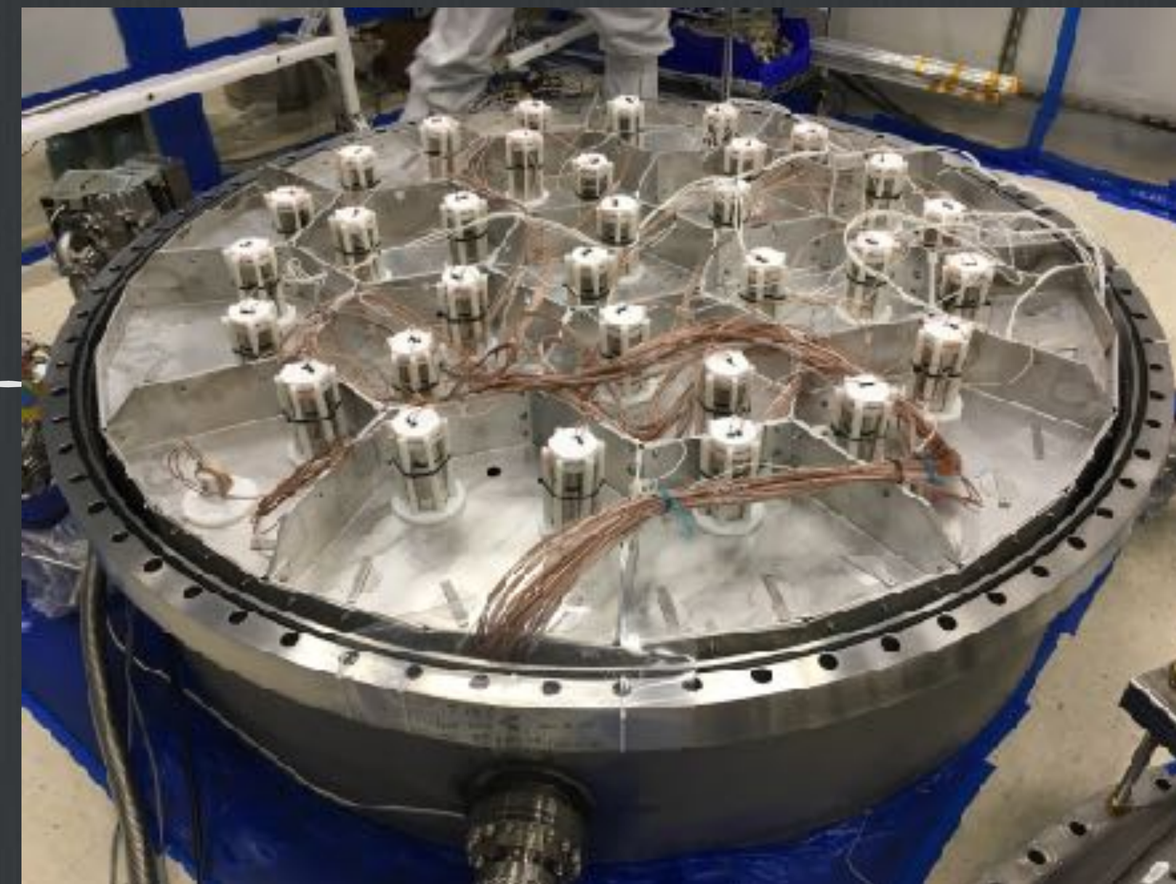
- ☐ Identify single electrons in the data.
- ☐ Calculate the rate of electrons in the data.

Equivalent to LZ's extraction region ΔV

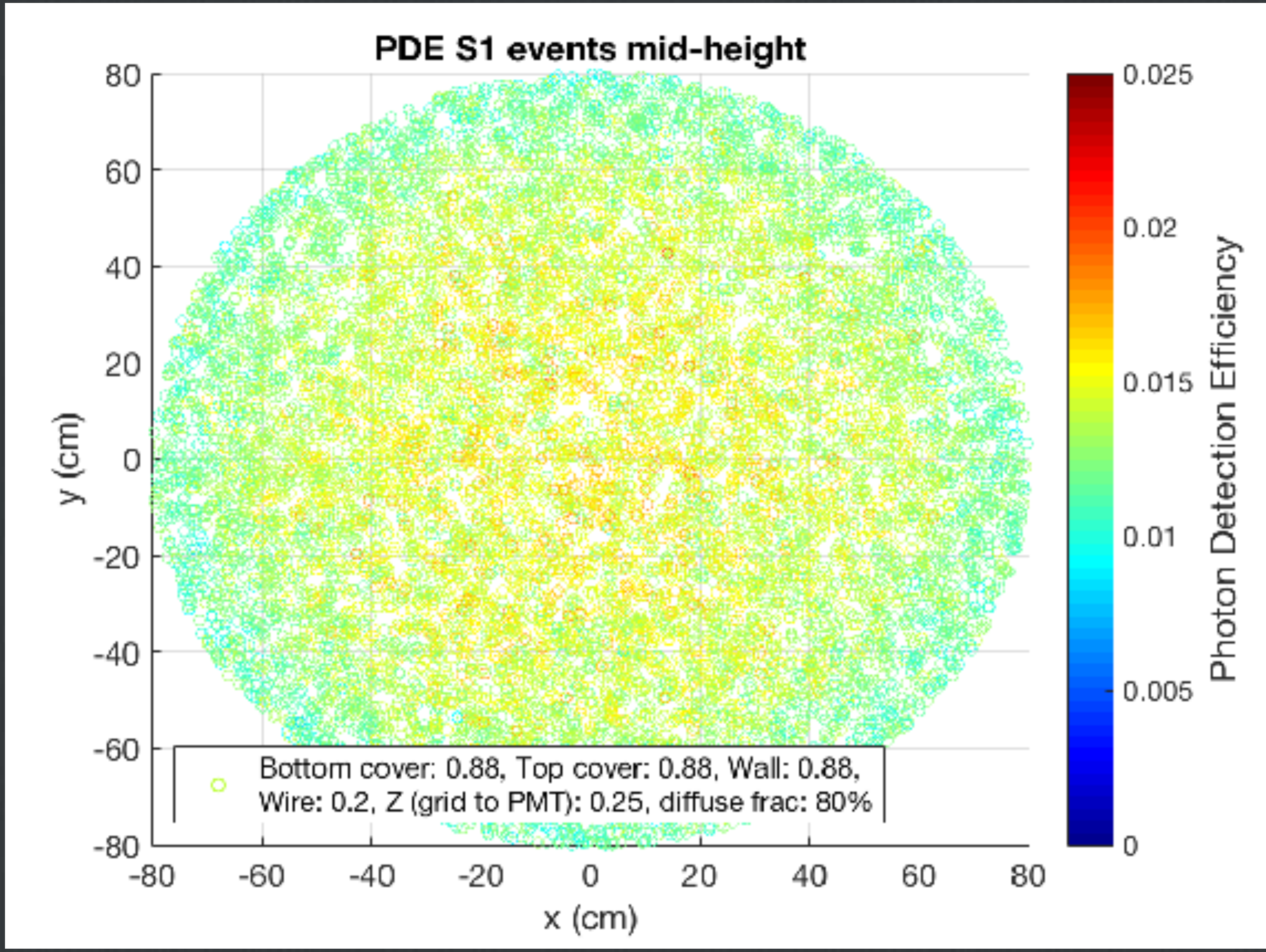
Full-scale gas test

3.5 bar Xe gas = equivalent density to LZ



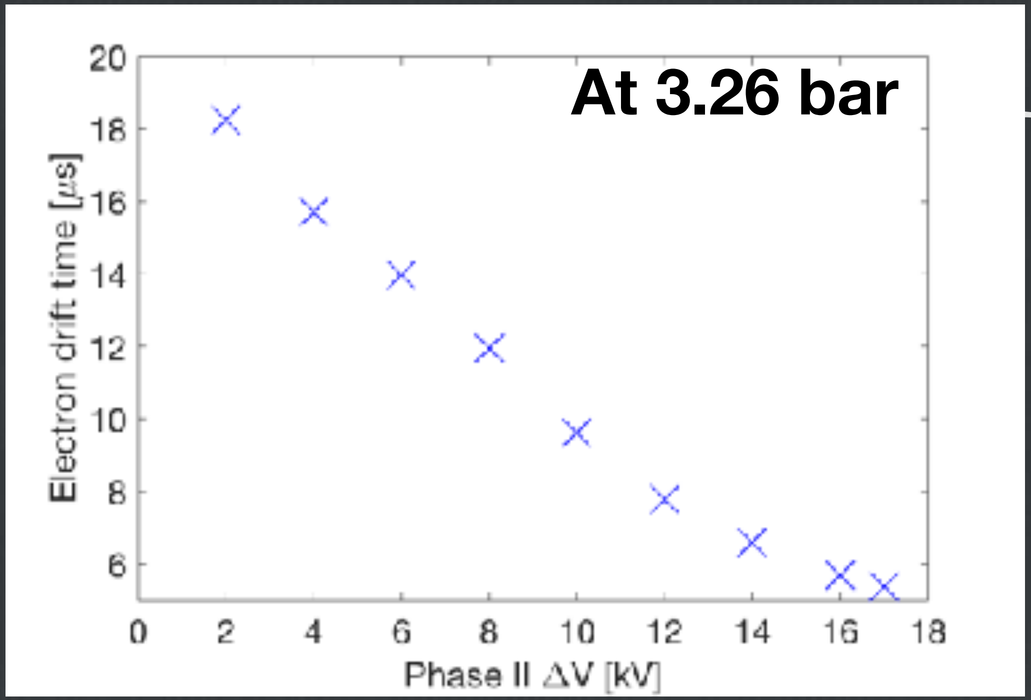


Full-scale gas test: optical simulations

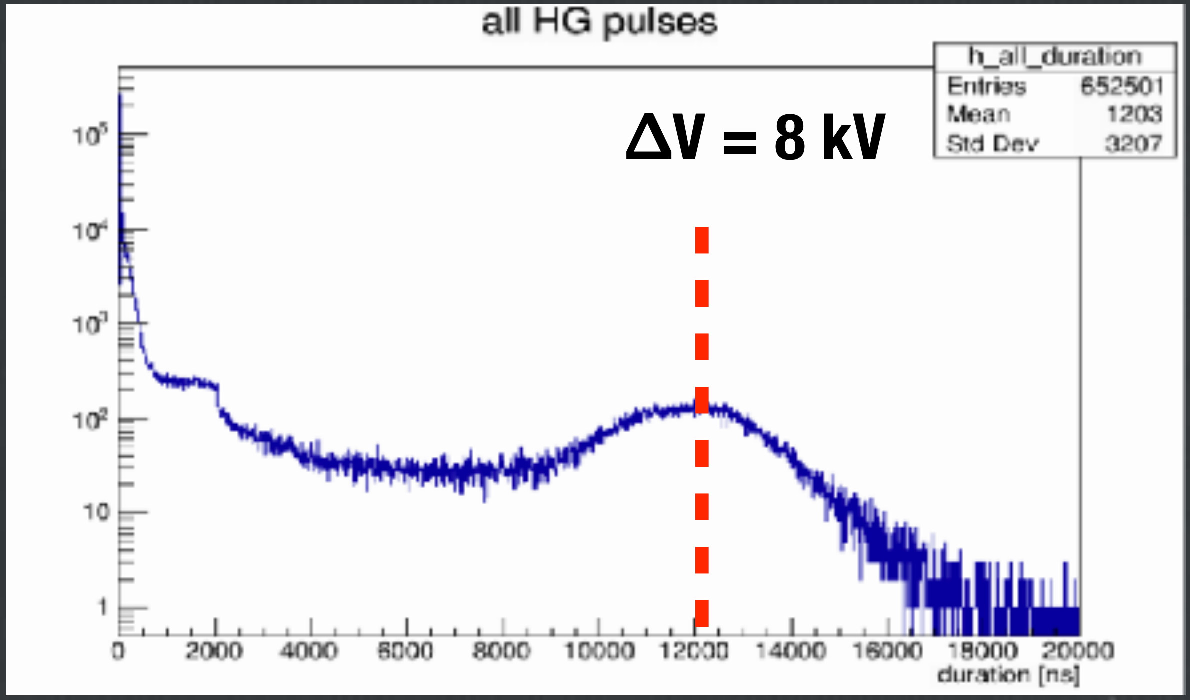


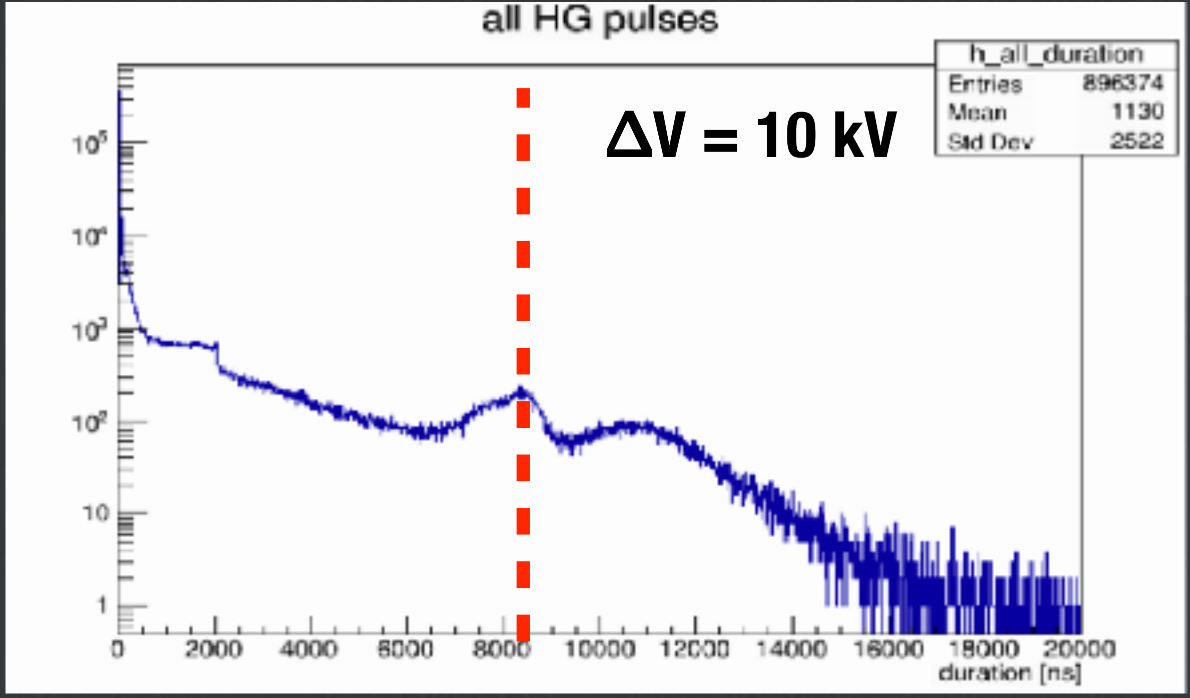
- Optical simulations of Phase II with reflective surfaces sees ~1-1.5% photon detection efficiency.
- Fields are high enough to detect electrons.
- MgF_2 coated Al surfaces enable high reflectivity (~88% reflective compared to PTFE's 40-70% values in gaseous Xe)
- Have single electron sensitivity in this detector with only 32 PMTs

Full-scale gas test: results

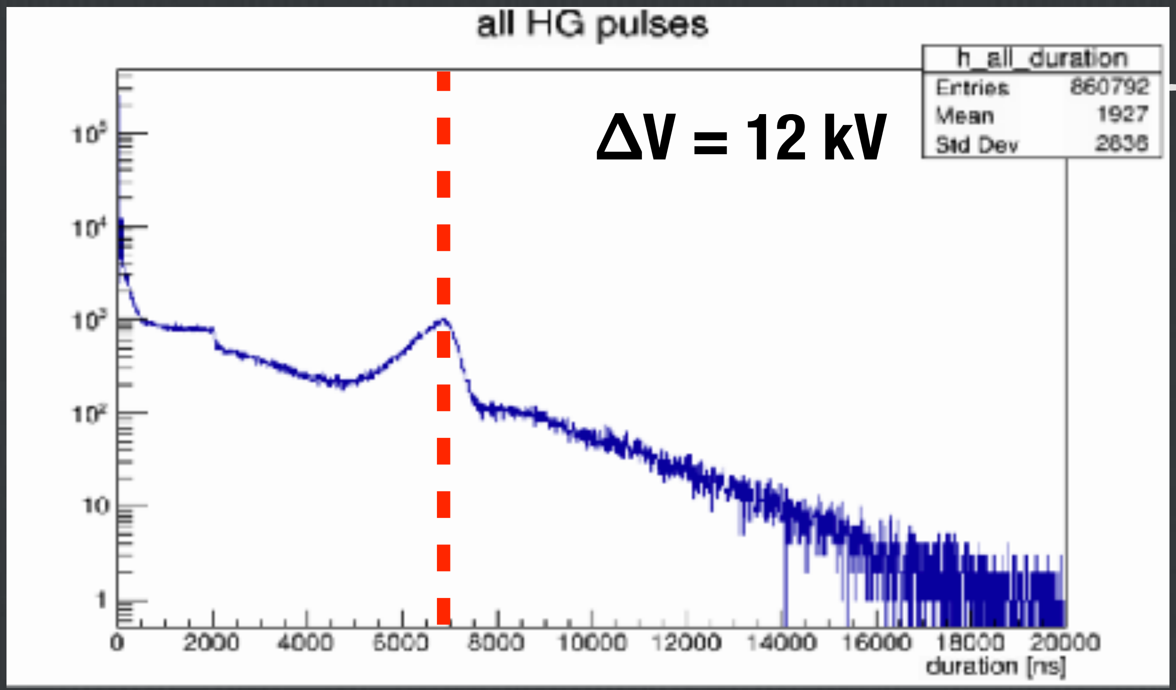


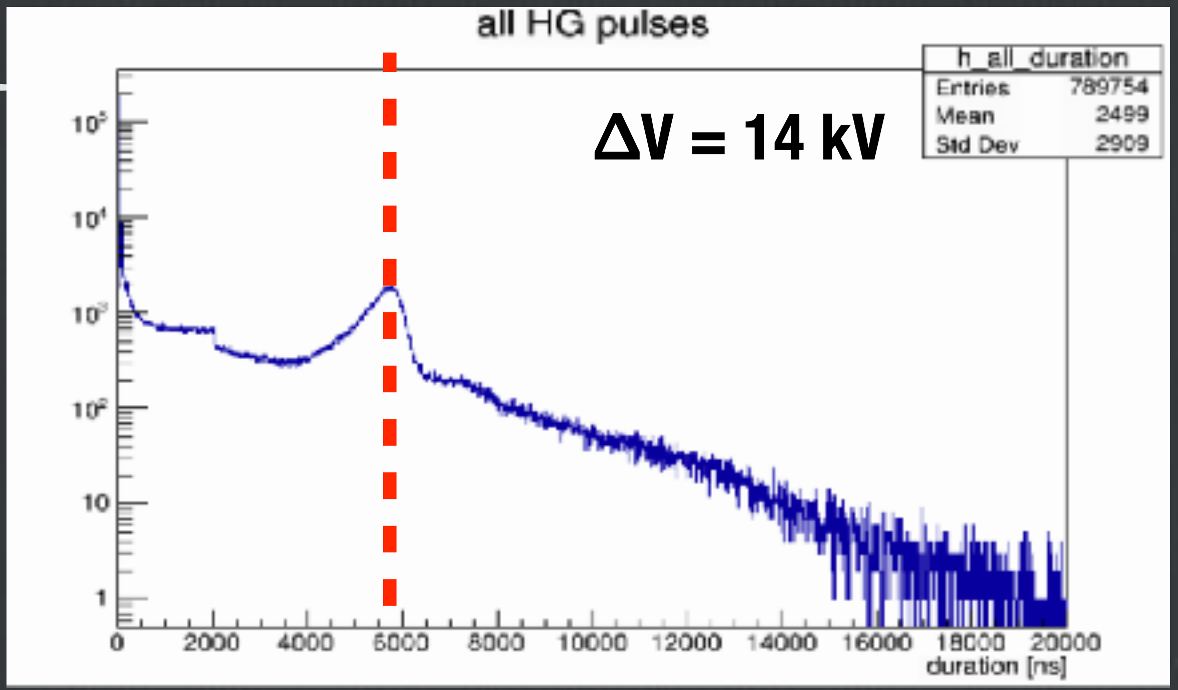
- (left) Calculated electron drift times given for the range of ΔV in the full-scale gas test at the operating pressure.
- (below) Pulse durations (widths) of any pulse type observed in data.
- Single electron sensitivity!

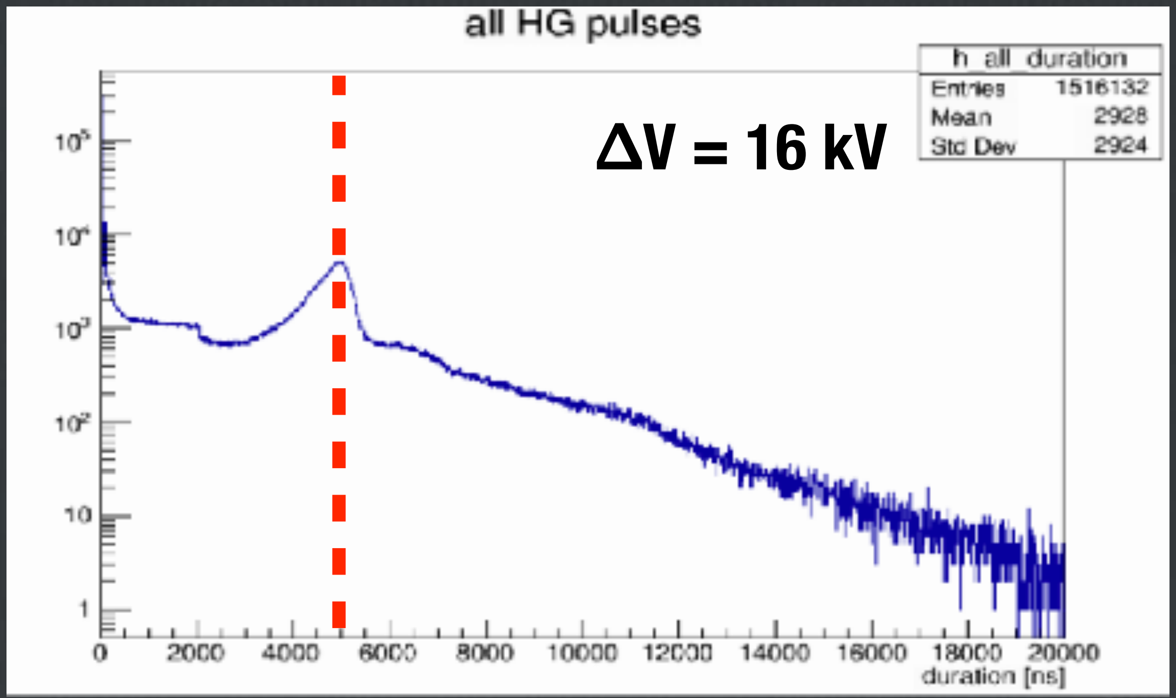


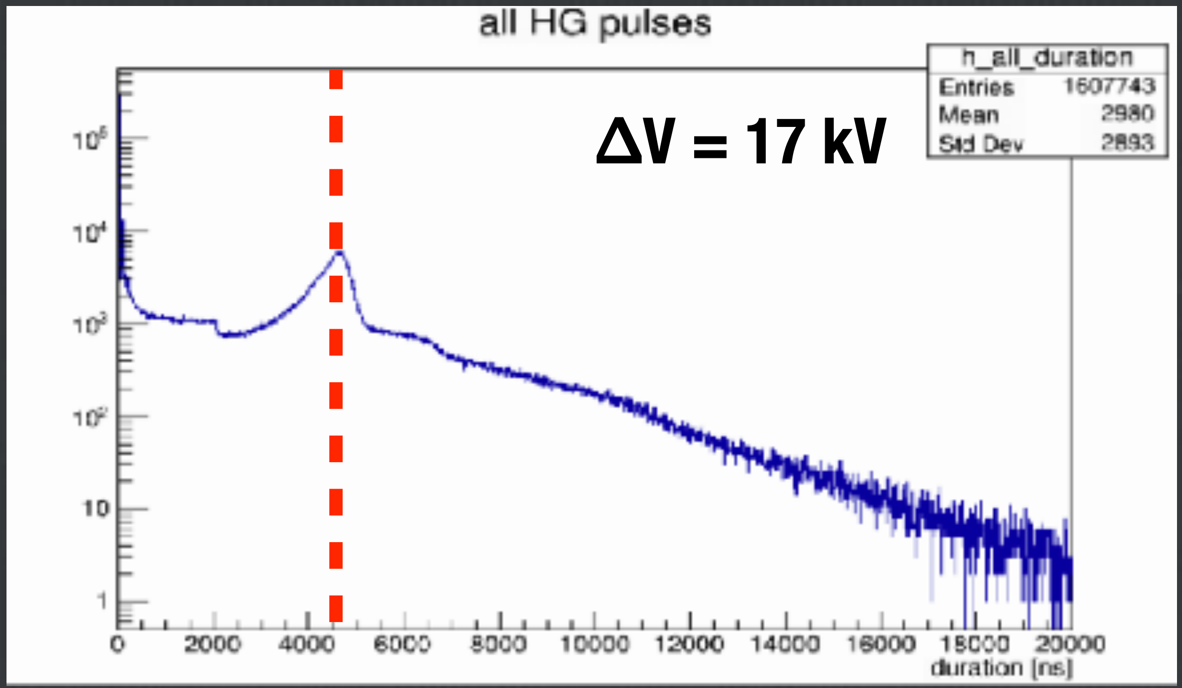


Phase II: results









Summary

- LZ has built and tested prototypes of its electric field grids.
- This fall: Weaving & testing the LZ production grids

Thank you

1)Center for Underground Physics (South Korea)
2)LIP Coimbra (Portugal)
3)MEPhI (Russia)
4)Imperial College London (UK)
5)Royal Holloway University of London (UK)
6)STFC Rutherford Appleton Lab (UK)
7)University College London (UK)
8)University of Bristol (UK)
9)University of Edinburgh (UK)
10)University of Liverpool (UK)
11)University of Oxford (UK)
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16)Brown University (US)
17)Fermi National Accelerator Lab (US)
18)Lawrence Berkeley National Lab (US)
19)Lawrence Livermore National Lab (US)
20)Northwestern University (US)
21)Pennsylvania State University (US)
22)SLAC National Accelerator Lab (US)
23)South Dakota School of Mines and Technology (US)
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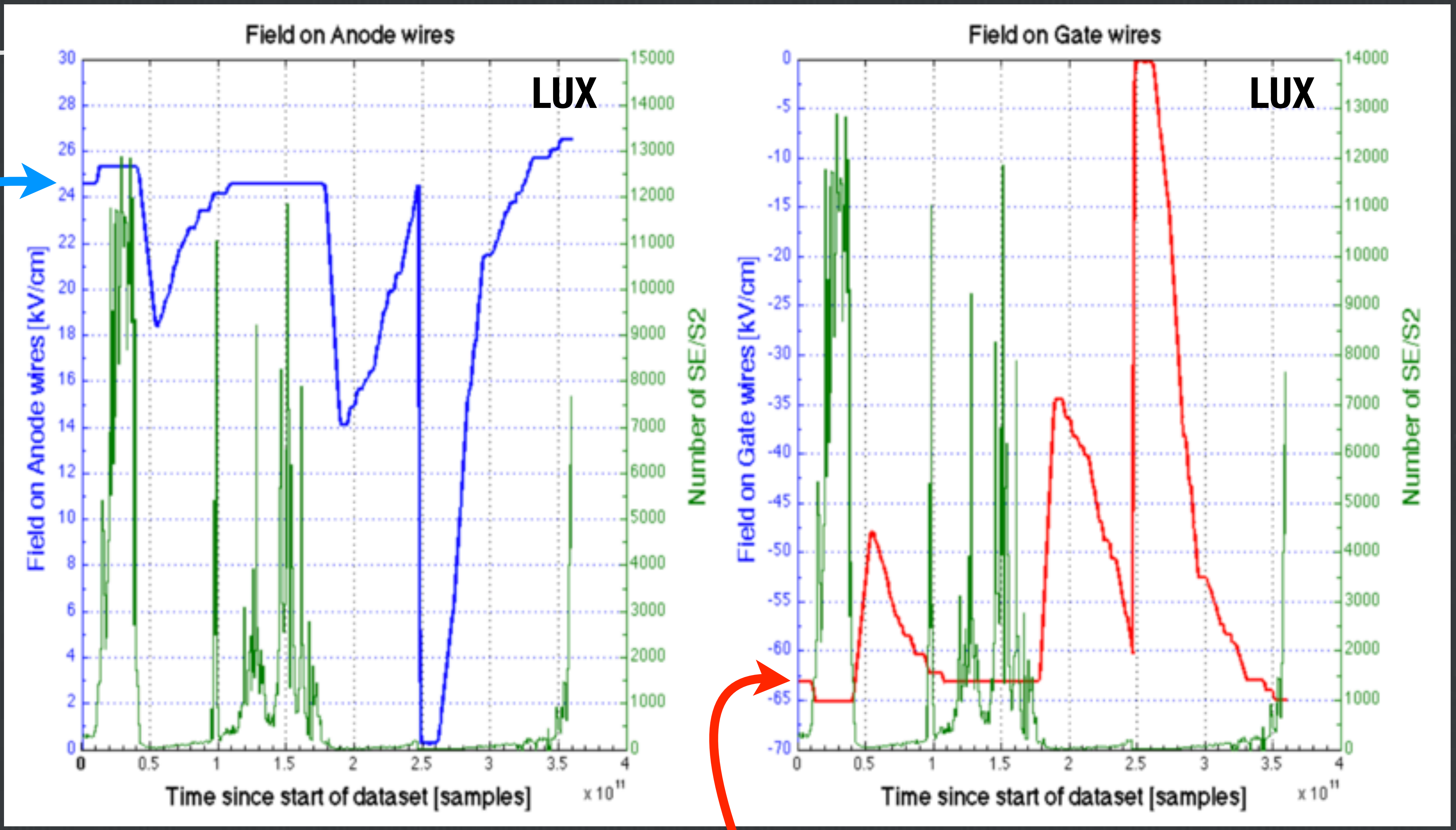
35)University of South Dakota (US)
36)University of Wisconsin – Madison (US)
37)Washington University in St. Louis (US)
38)Yale University (US)

Extra slides

Electron emission concerns

LUX anode grid wires' fields are ~24 kV/cm



LUX gate grid wires see electron emission near -62 kV/cm

Plots are from the LUX conditioning campaign in January 2014 with electron emission in green.