Measurements of electron emission reduction from grid electrodes in the R&D test platform for the LZ experiment

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CPAD 2019

On Behalf of the LZ Experiment

WISCONSIN
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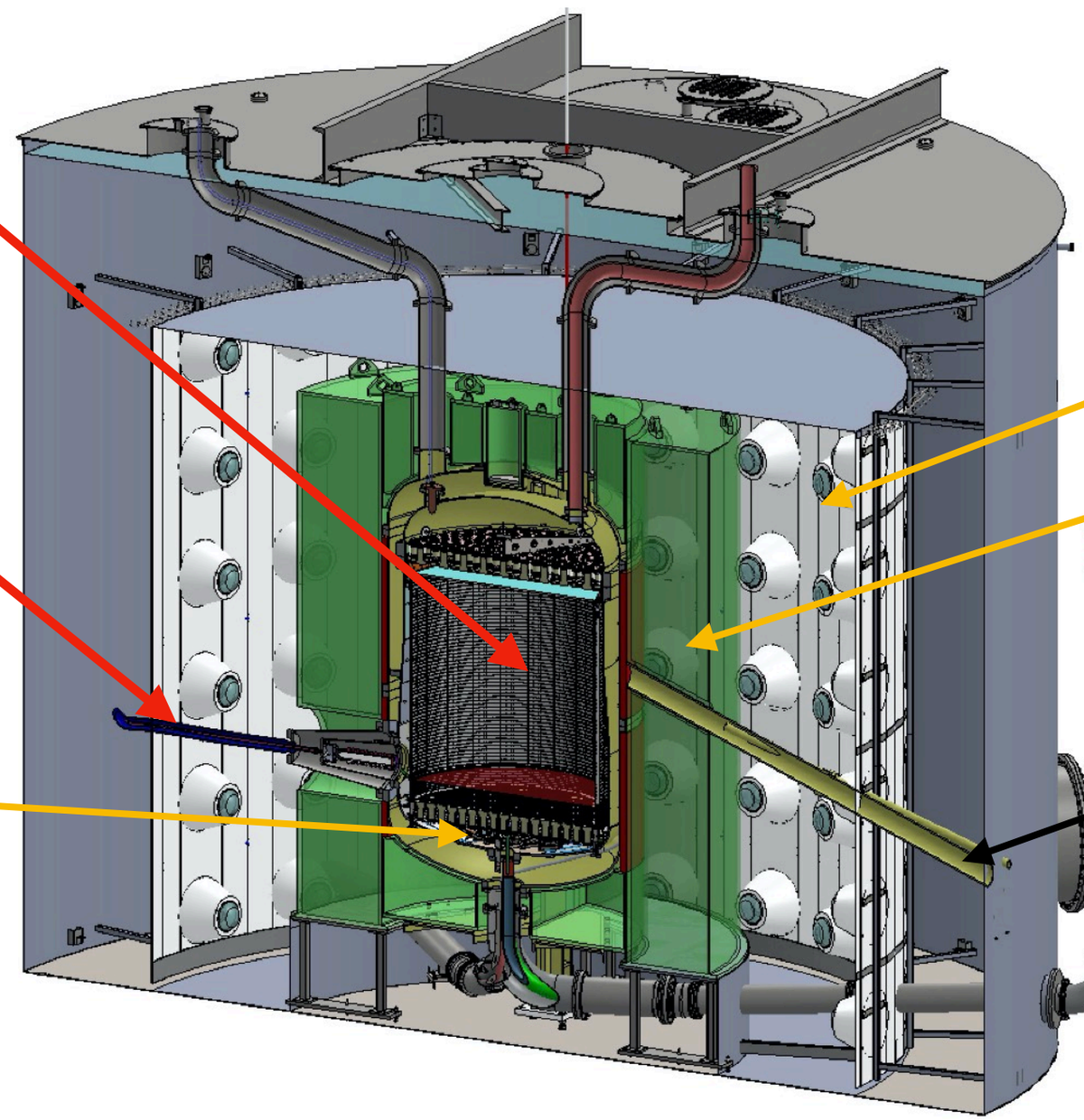
LZ detector

- Search for WIMP dark matter candidate
- 4850-ft underground at Sanford Lab



TPC with 7 tonne LXe active volume

Cathode HV feedthrough

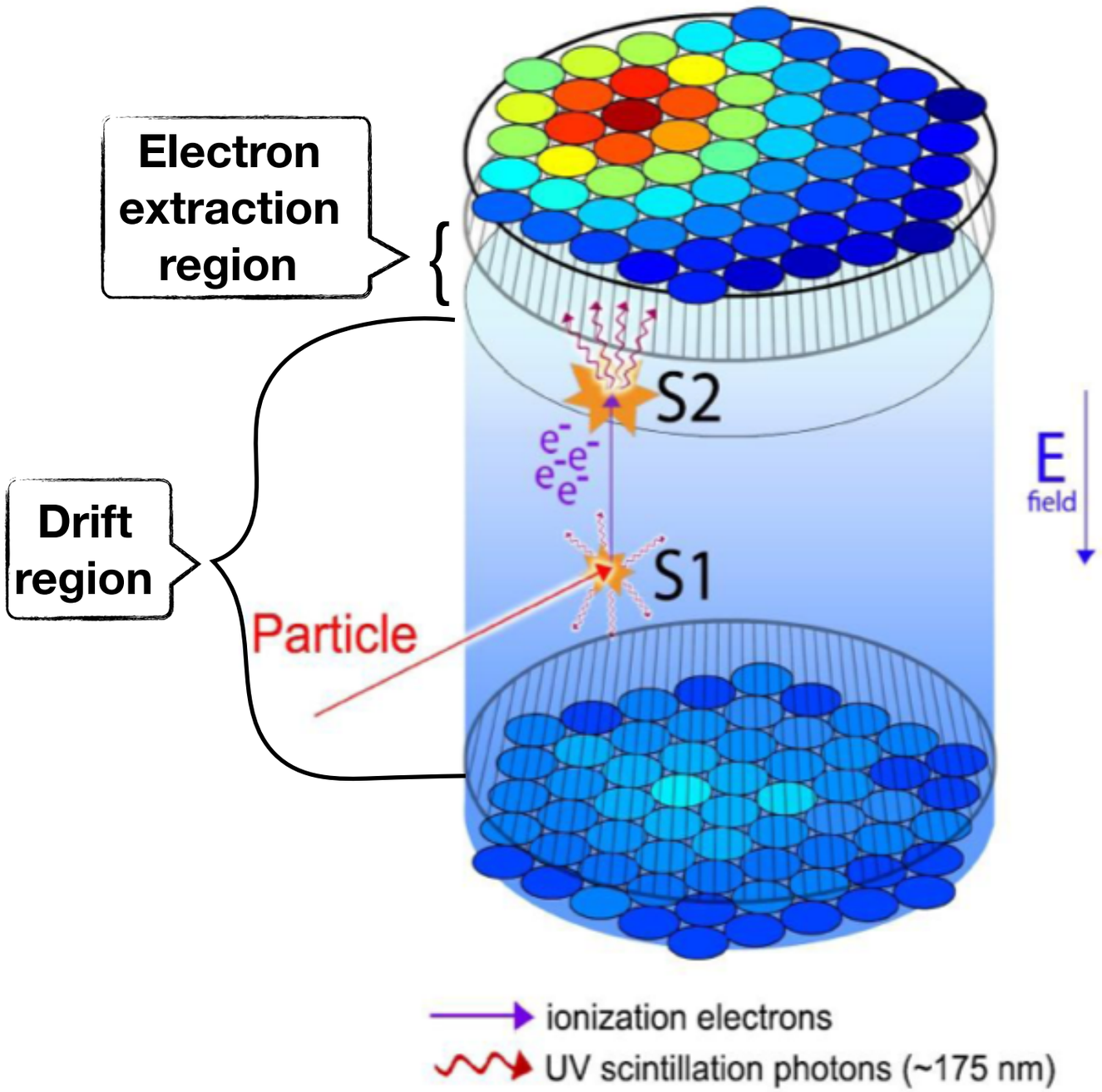
Instrumented Xe skin

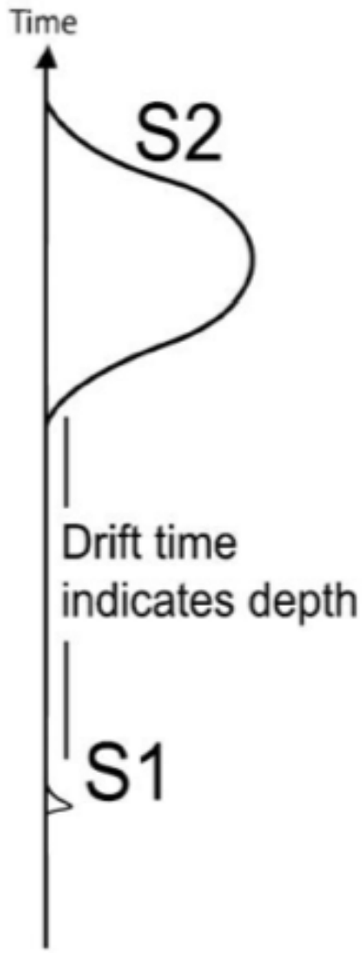
Water tank

Gadolinium loaded liquid scintillator

DD (NR) calibration conduit

LZ TPC

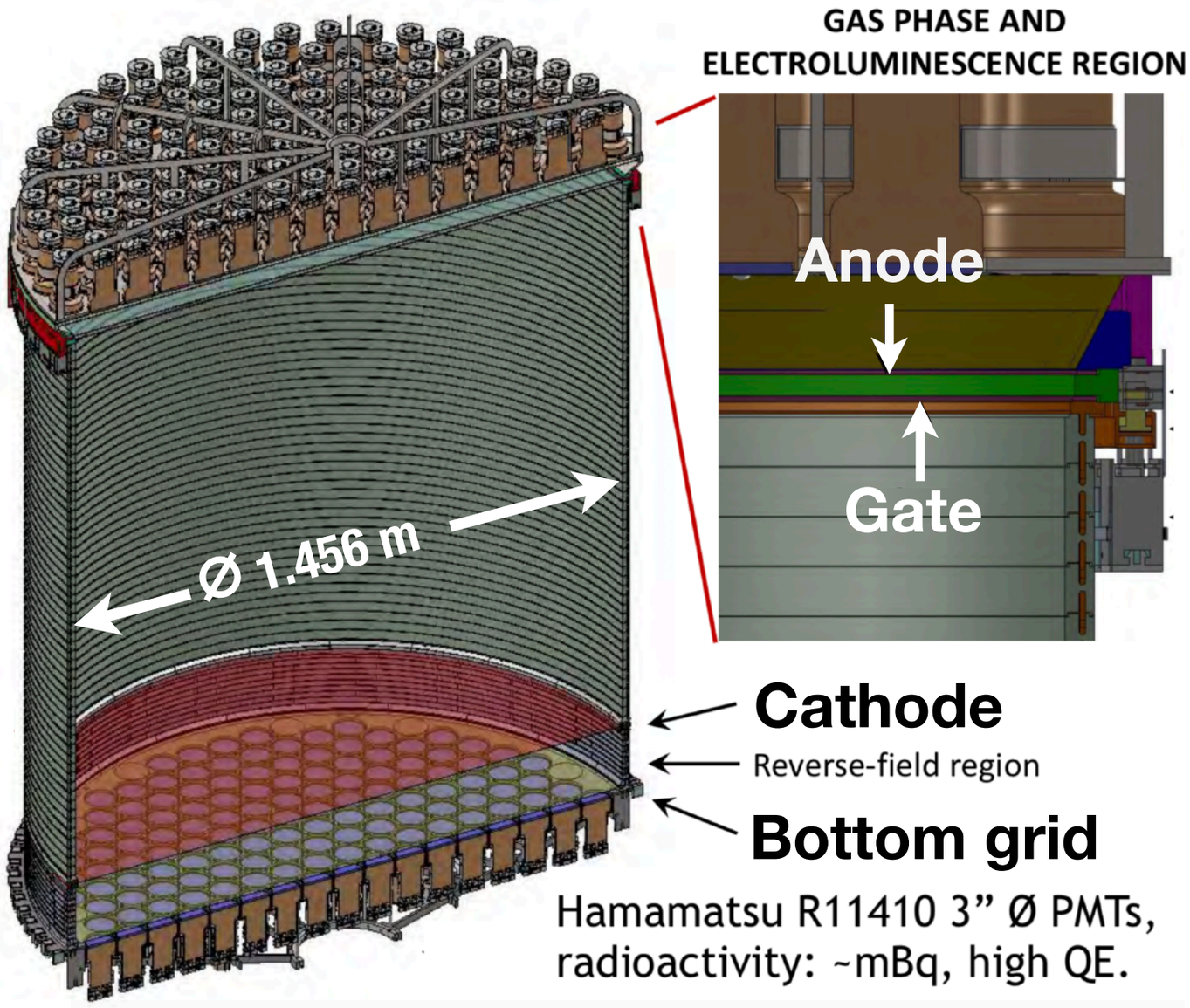




TPC = **T**ime **P**rojection **C**hamber

Image by CH Faham (Brown)

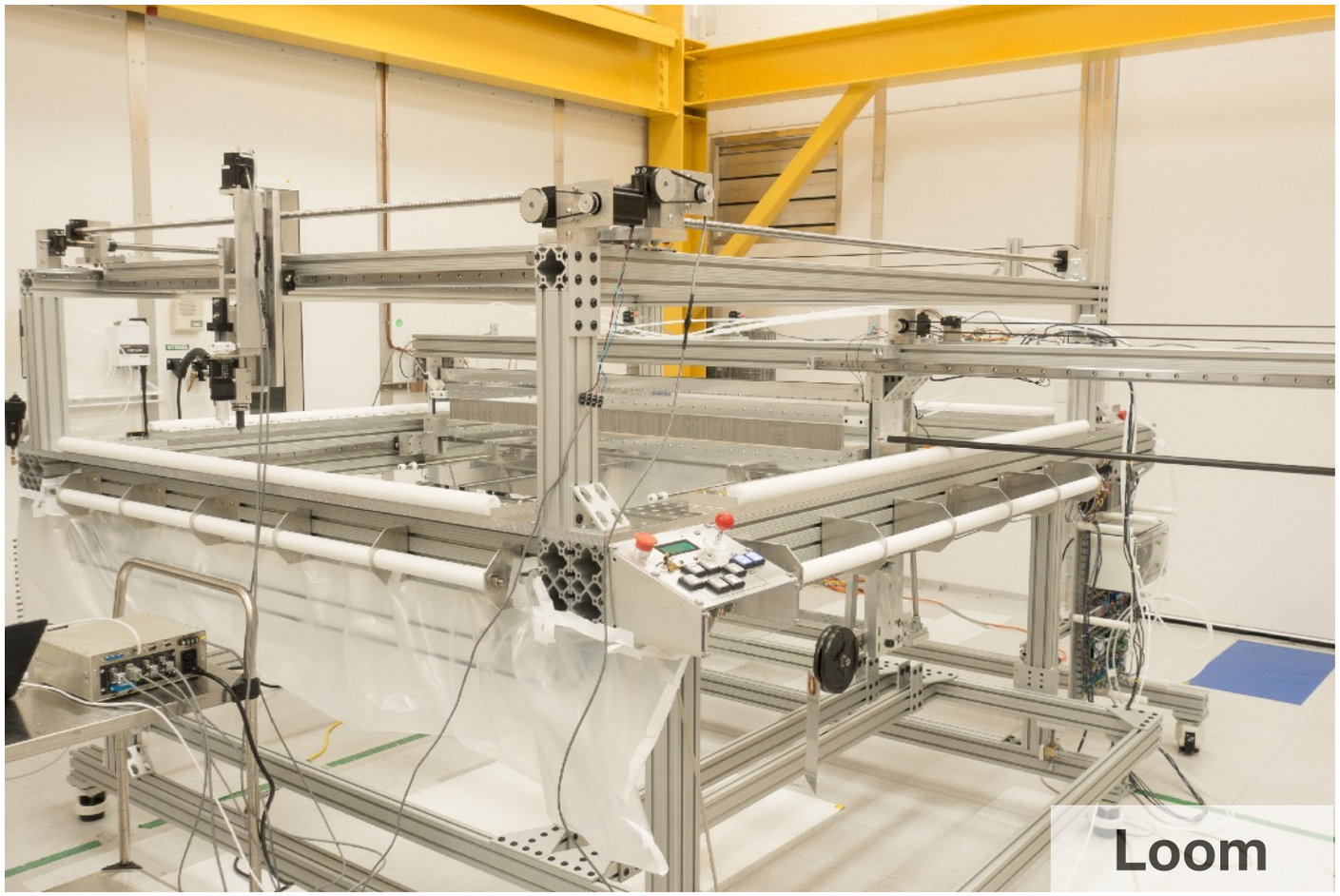
LZ grids



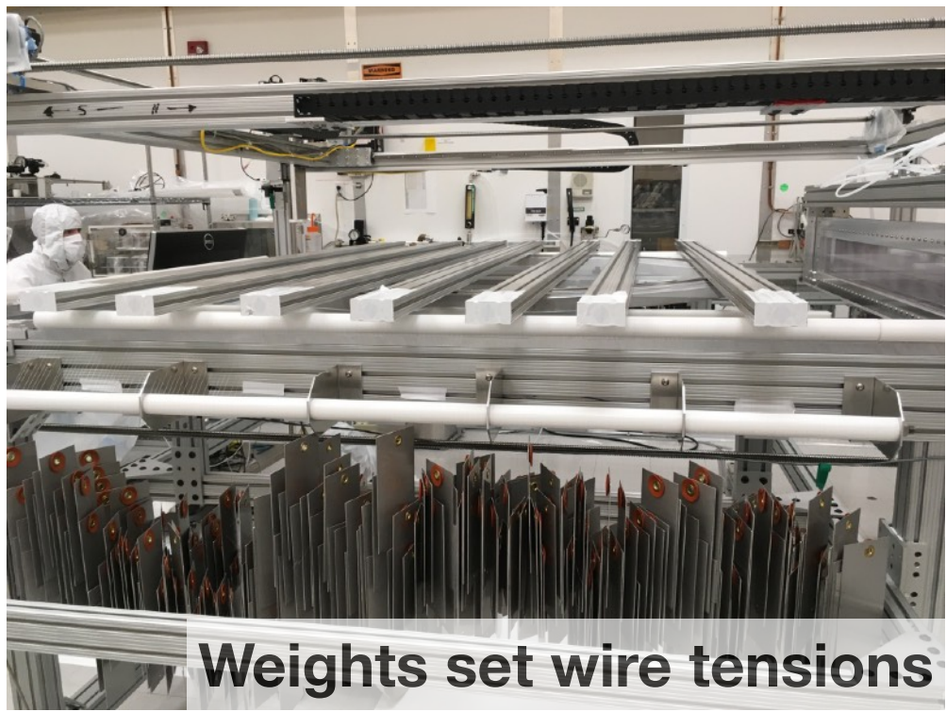
Electric fields established by 4 woven SS mesh grids

	Wire pitch (mm)	Wire diameter (μm)	Trans-parency (%)	Voltage (kV)
Anode	2.5	100	92	5.75
Gate	5	75	97	-5.75
Cathode	5	100	96	-50 / -100
Bottom	5	75	97	-1.5

Grid production: weave

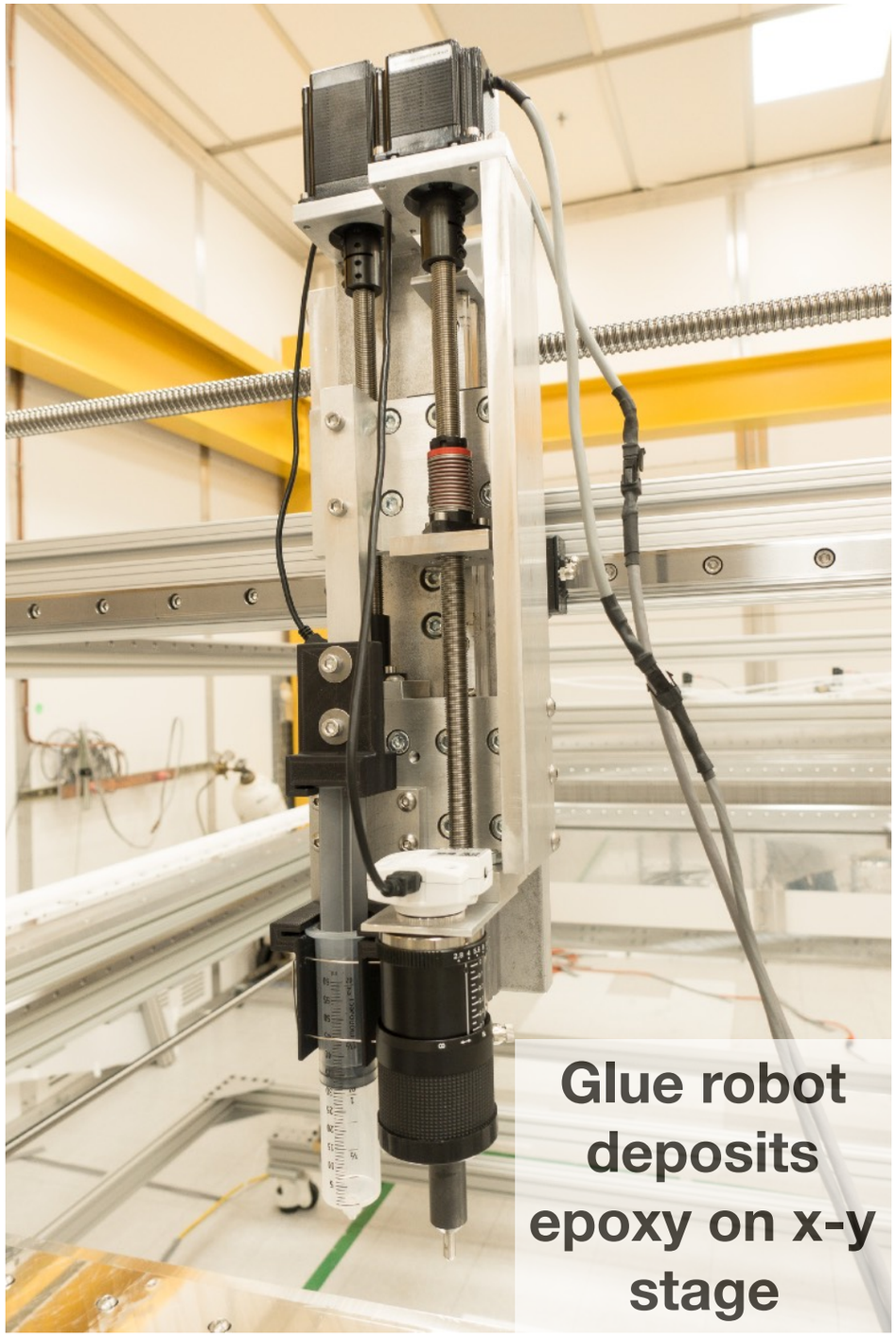

Loom


Installing warp wire through the heddles

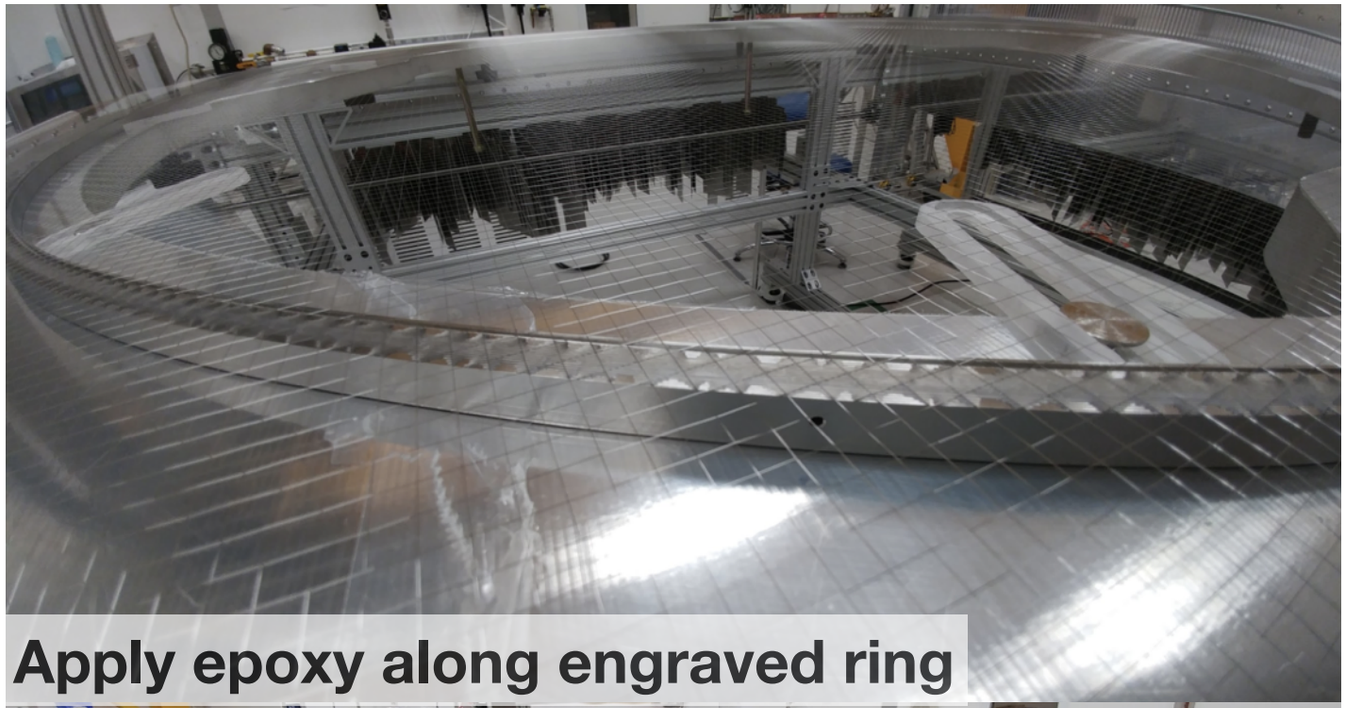

Weights set wire tensions

- Commercially available wire mesh does not come in the LZ grid diameter
- Challenges: Maintain wire spacing & tension
- Video of weaving process

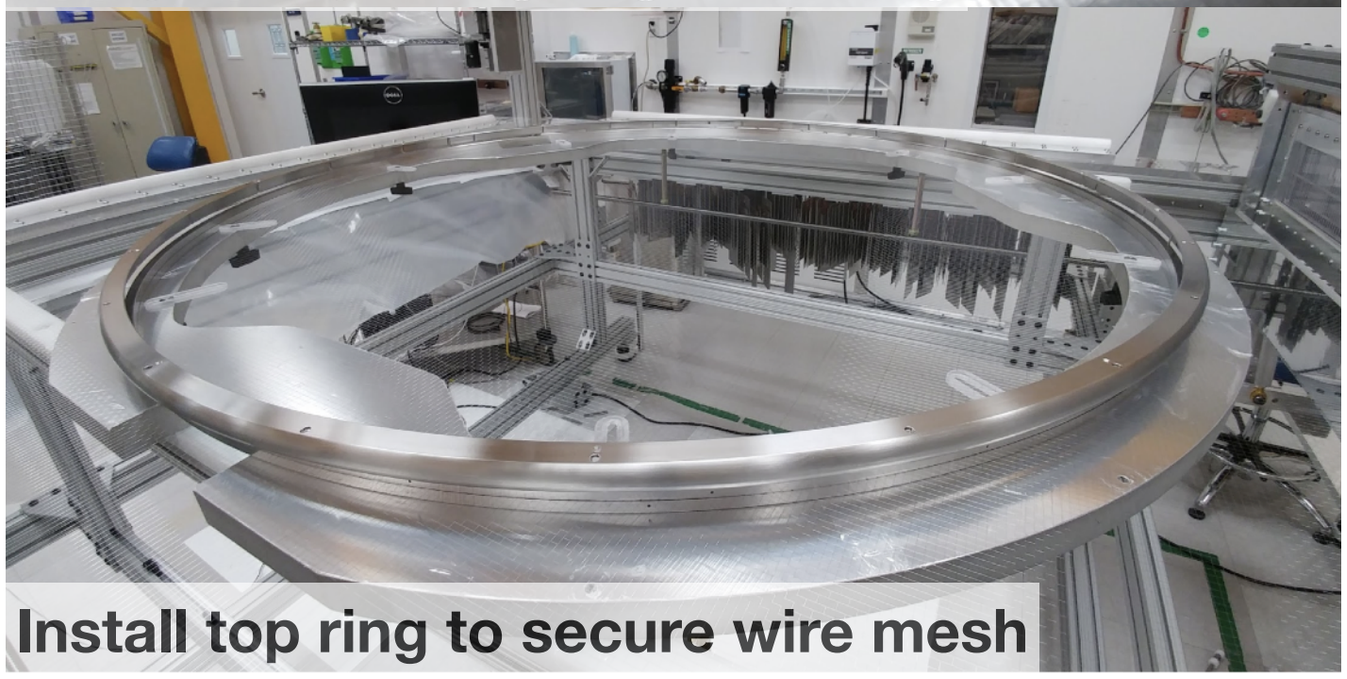
Grid production: glue



Glue robot deposits epoxy on x-y stage

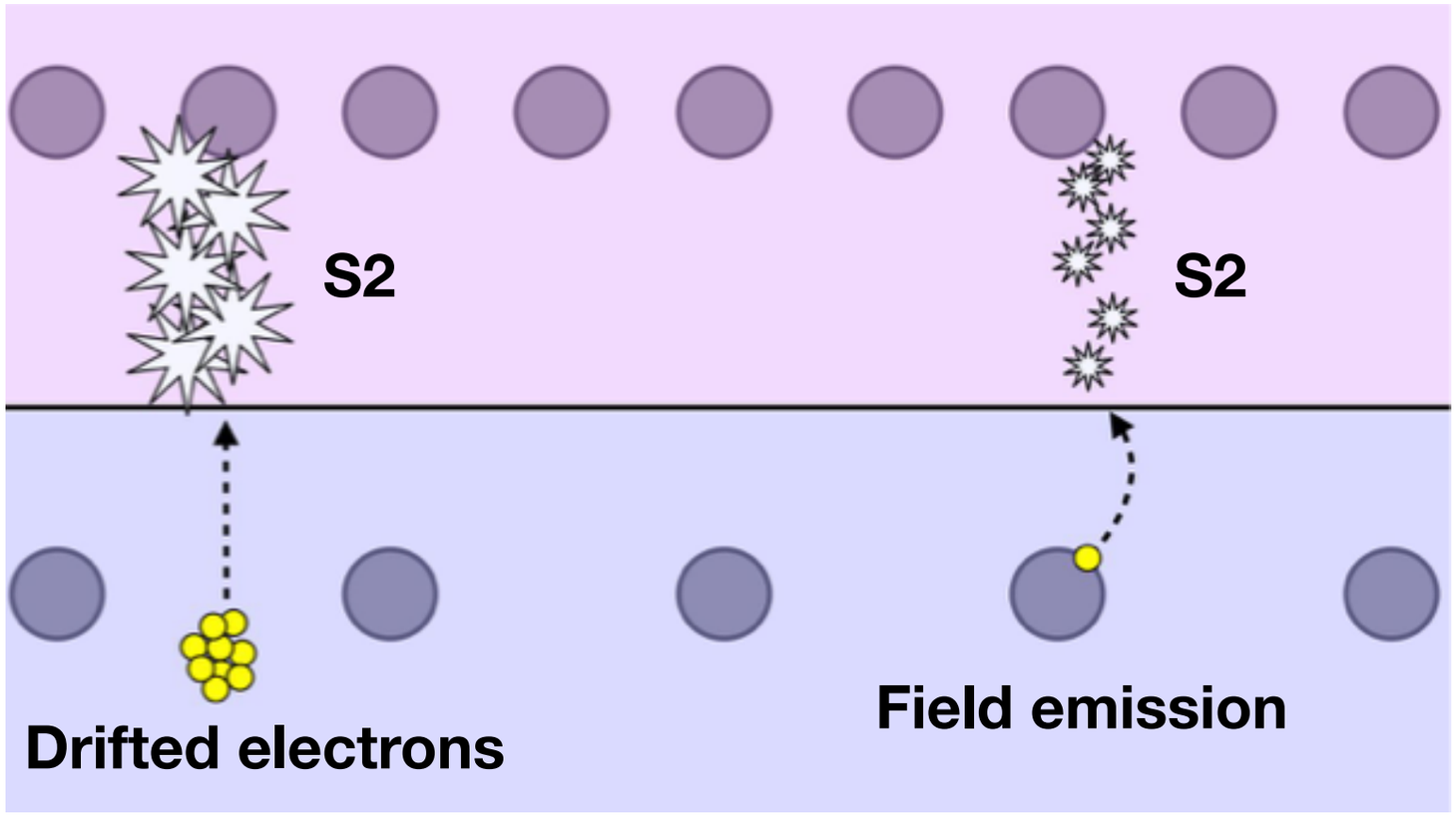


Apply epoxy along engraved ring

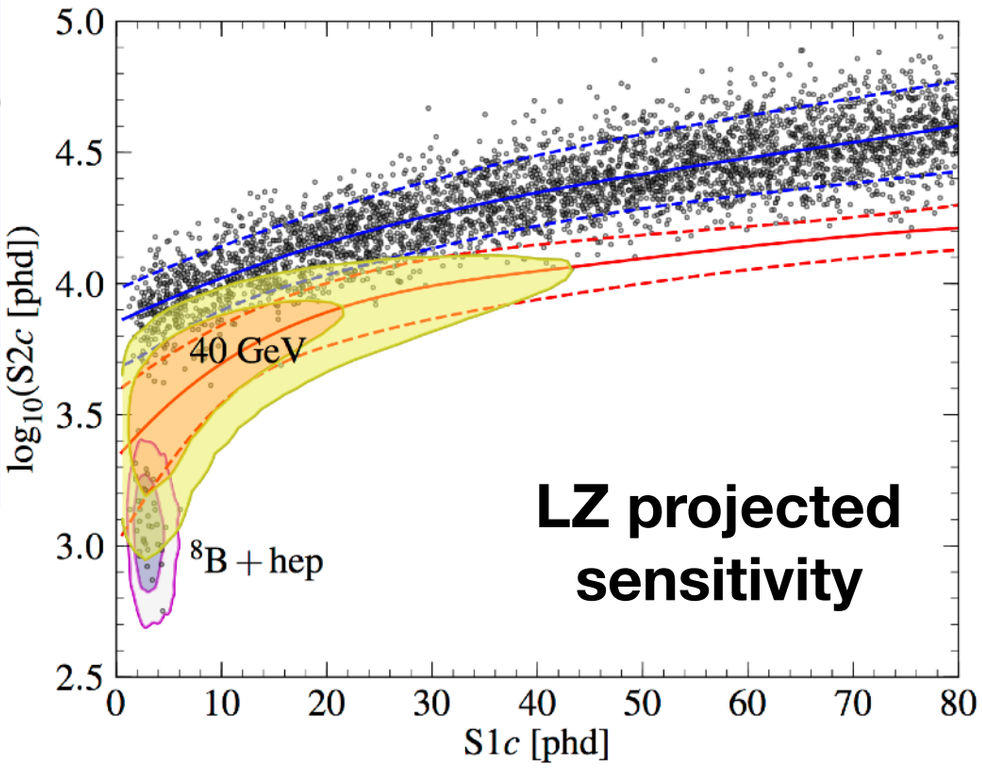


Install top ring to secure wire mesh

Electron emission



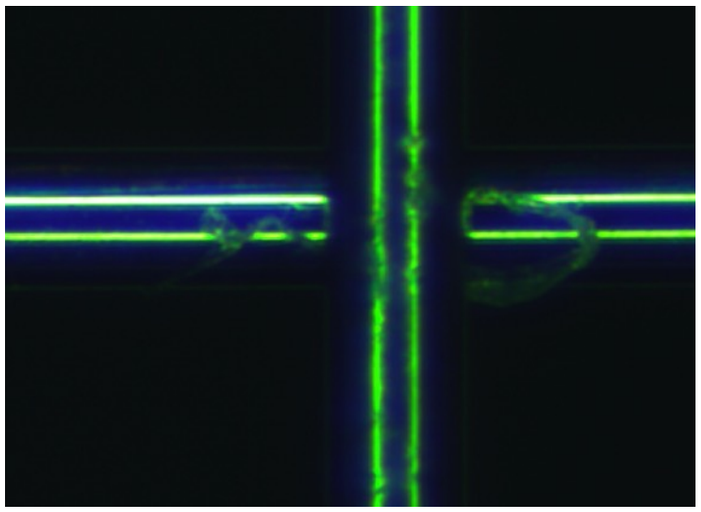
Events with an “S2” from electron emission can mimic NR event (red).



LZ simulated data set for a background-only 1000~live day run and a 5.6 tonne fiducial mass. ER and NR bands are indicated in blue and red, respectively (solid: mean; dashed: 10% and 90%). The 1σ and 2σ contours for the low-energy ^{8}B and hep NR backgrounds, and a 40 GeV/c^2 WIMP are shown as shaded regions.

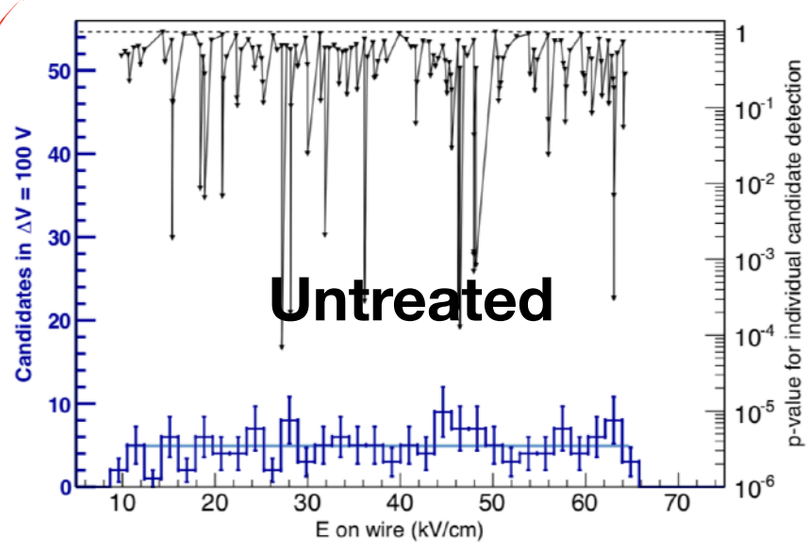
- Electron emission from wires is problematic:
  - Impacts low energy dark matter search → Accidental coincidence can mimic low energy events & limit S2-only search
  - Affects detector operability → high DAQ rate from electron trains can increase dead time

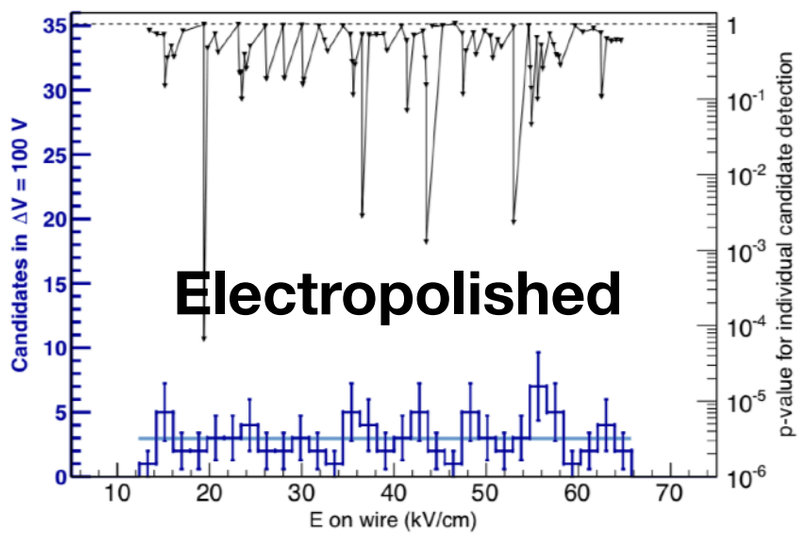
Electron emission mitigation

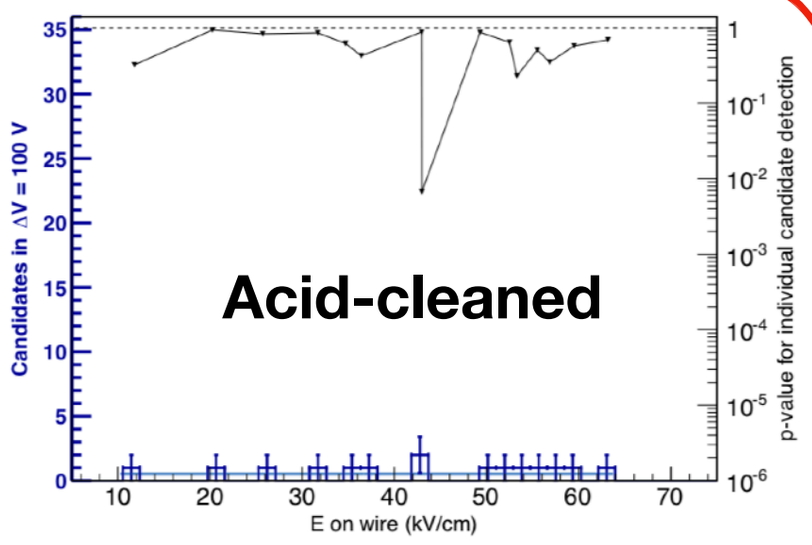


1. **Dust removal:** Construct grids in a cleanroom & remove dust

2. **Passivation:** Changes chemical composition of the oxide layer & increases the Cr:Fe ratio.



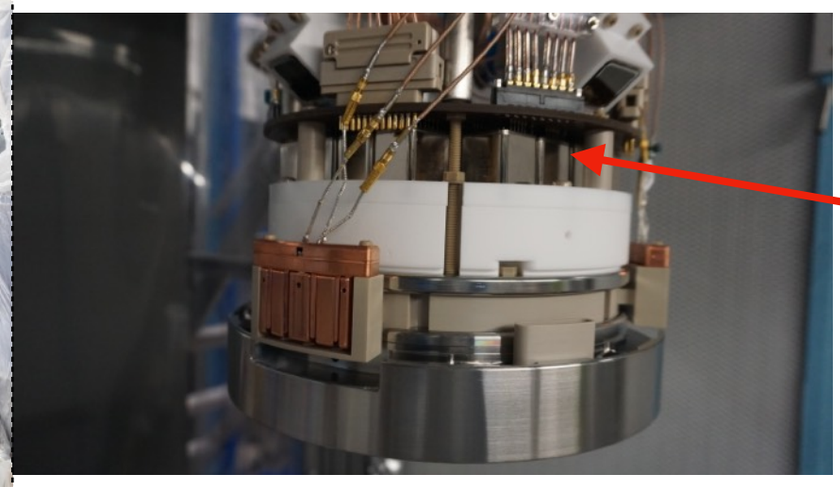
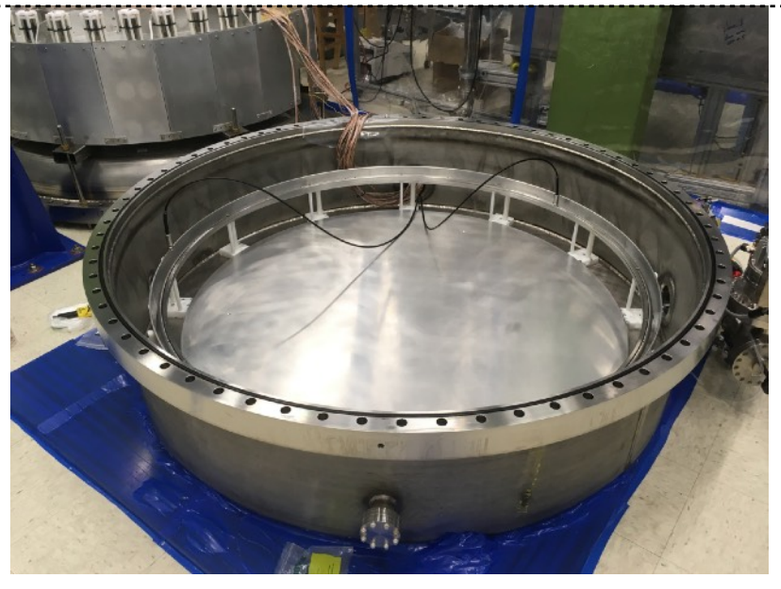
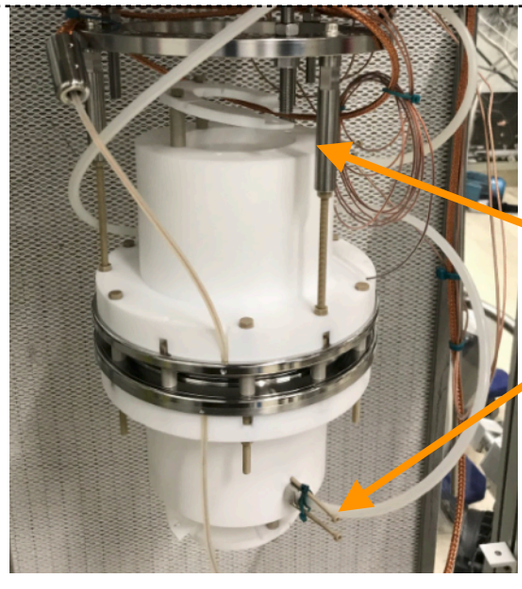




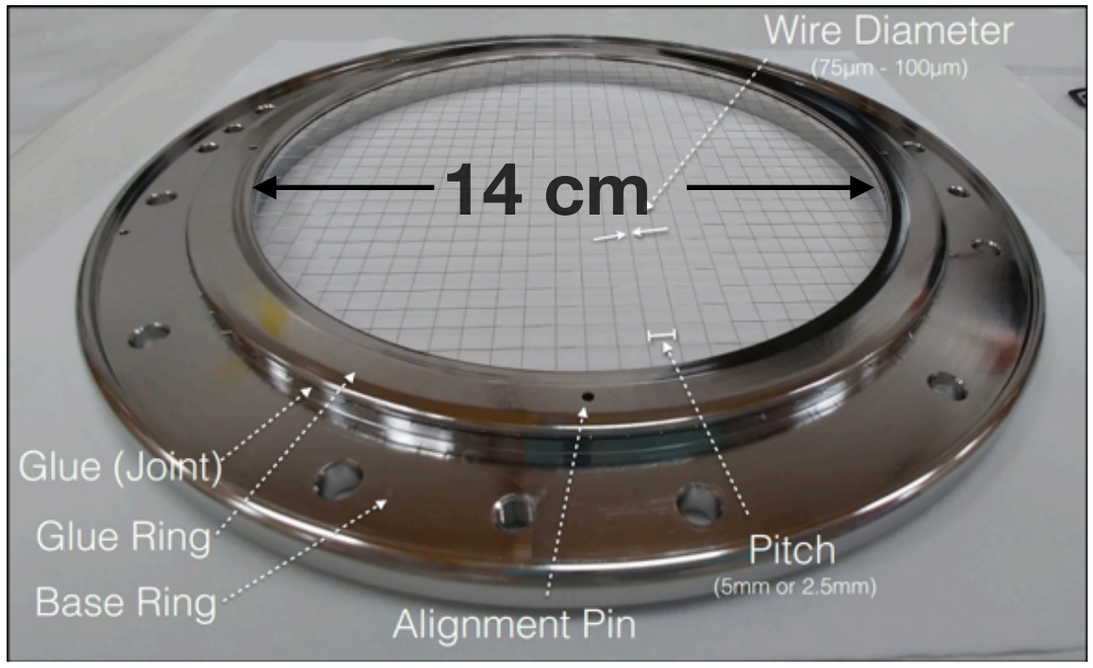
Collaborators at ICL measured reduction of electron emission from passivation

Tomás, A., et al. "Study and mitigation of spurious electron emission from cathodic wires in noble liquid time projection chambers." Astroparticle Physics 103 (2018): 49-61.

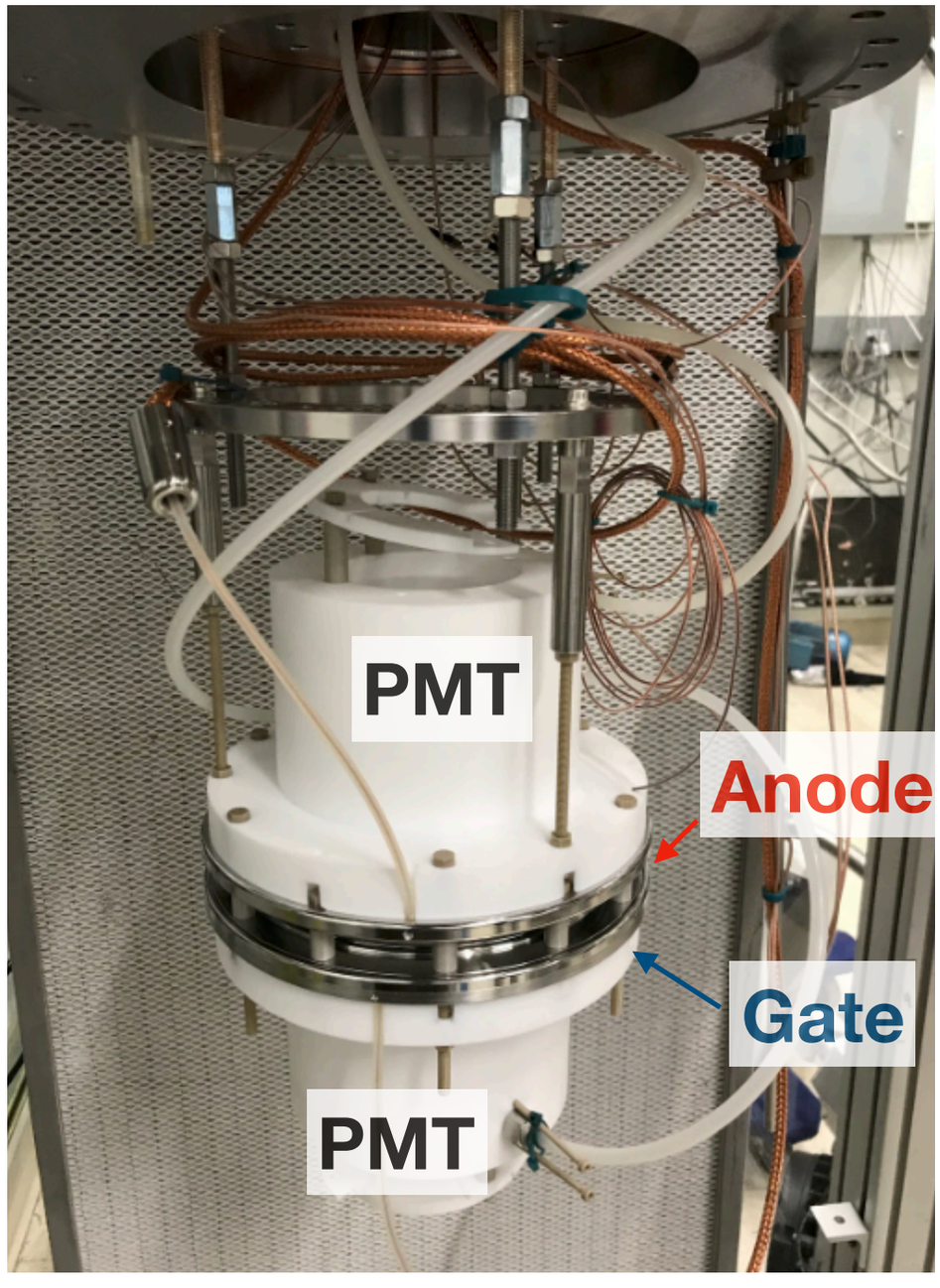
System test platform at SLAC

	Large (1.5-m ⌀ grids)	Small (14-cm ⌀ grids)
TPC		
Gas only		

Small 2-PMT gas-only detector



- Scaled-down extraction region
- Quick turnaround
- Xenon gas, 3.3 bar



Gas test nitric passivation

35% Nitric acid at room temperature for 30 min

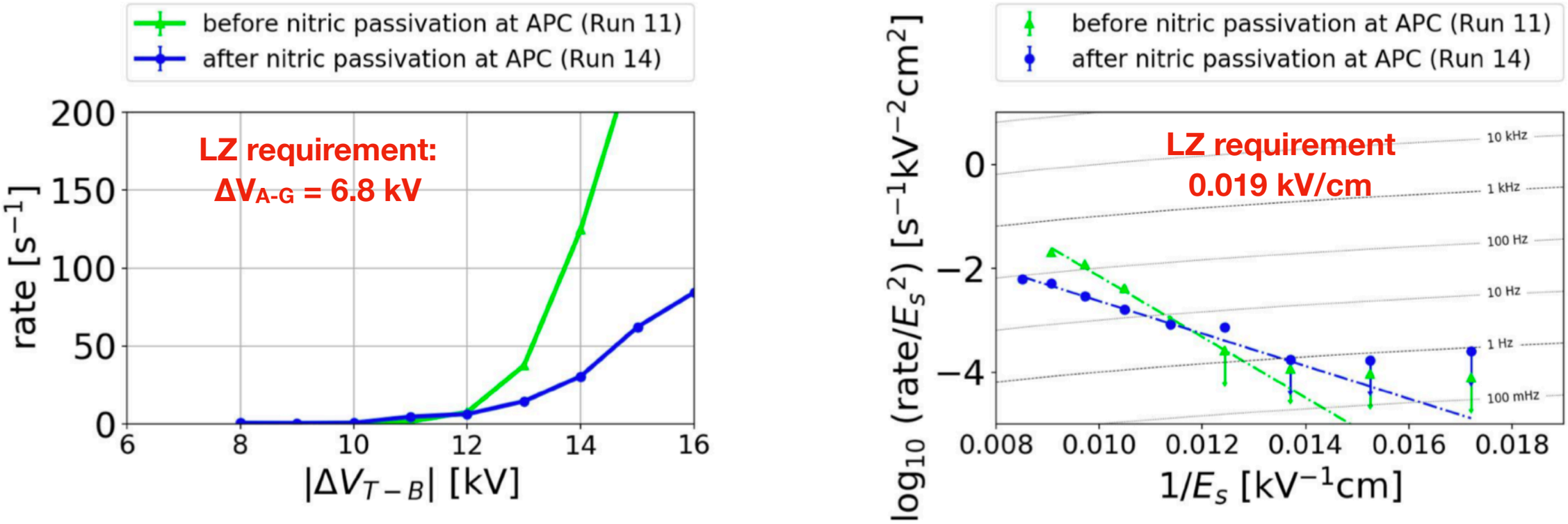
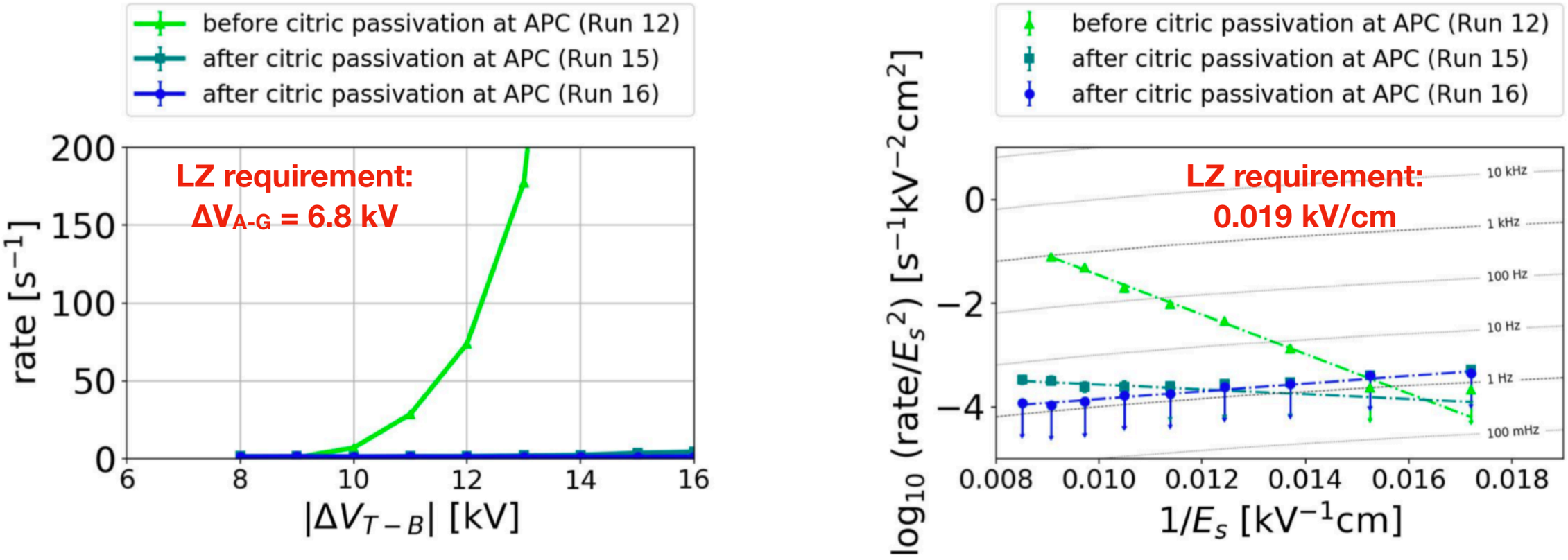


Figure 4.7: Electron emission rate before and after nitric passivation at APC: (a) rate vs. $\Delta V_{\text{T-B}}$; (b) Fowler-Nordheim plot.

W. Ji PhD, Stanford, 2019.

Gas test citric passivation

3-5% Citric acid at 175°F for 2 hr



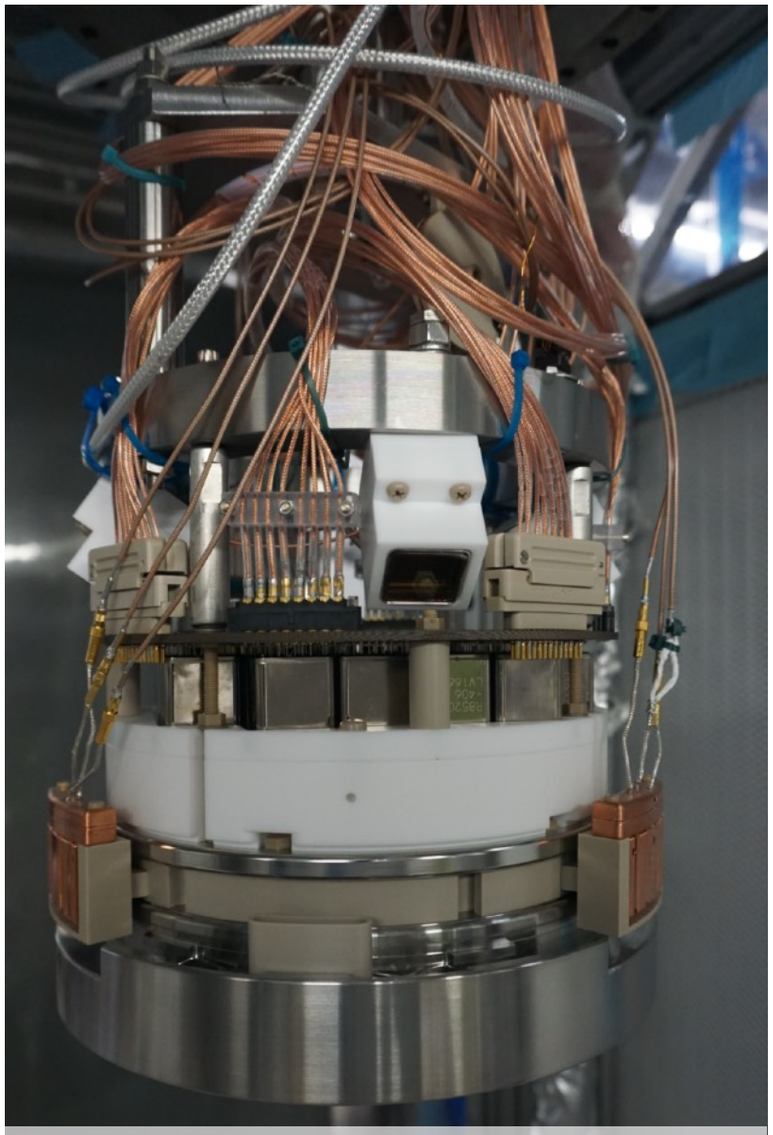
(a) (b)

Figure 4.8: Electron emission rate before and after citric passivation at APC: (a) rate vs. $\Delta V_{\text{T-B}}$; (b) Fowler-Nordheim plot. The blue (or green) dashed line fit to the F-N equation gives the before (or after) entry for APC treatment in Table 4.1.

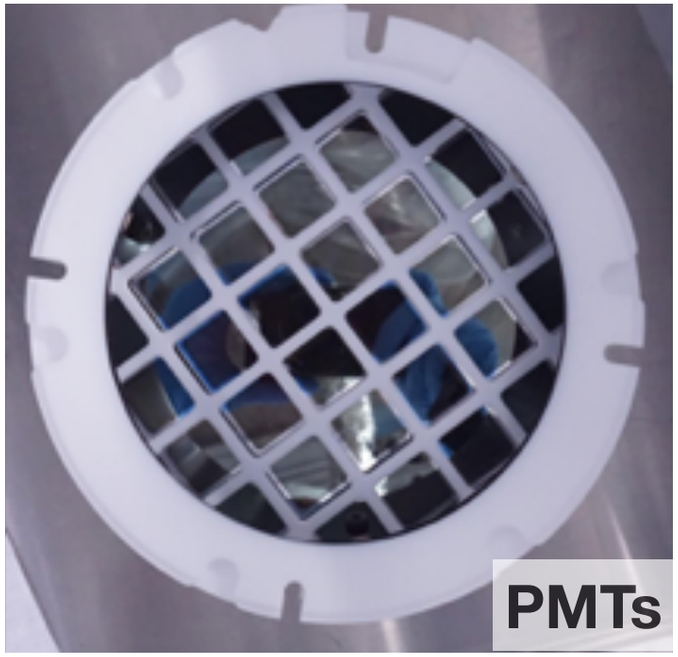
W. Ji PhD, Stanford, 2019.

Small 32-PMT detector

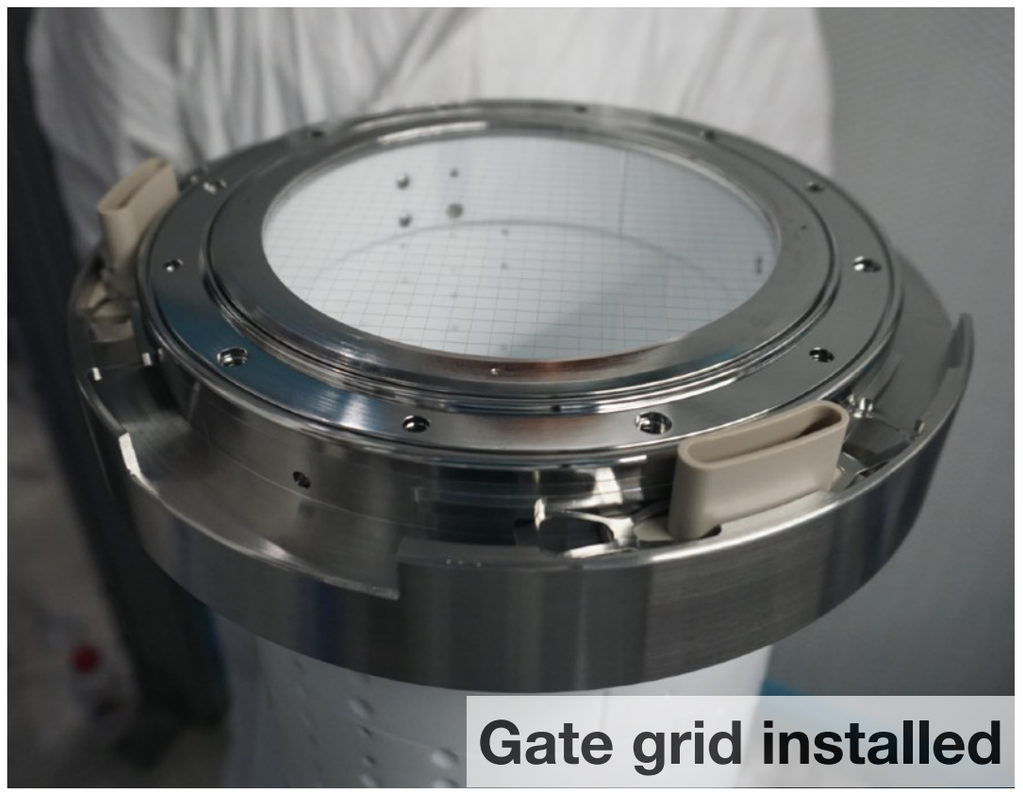
Designed as TPC to test cryogenics, circulation, HV



Test extraction region in gas-only mode by removing field cage

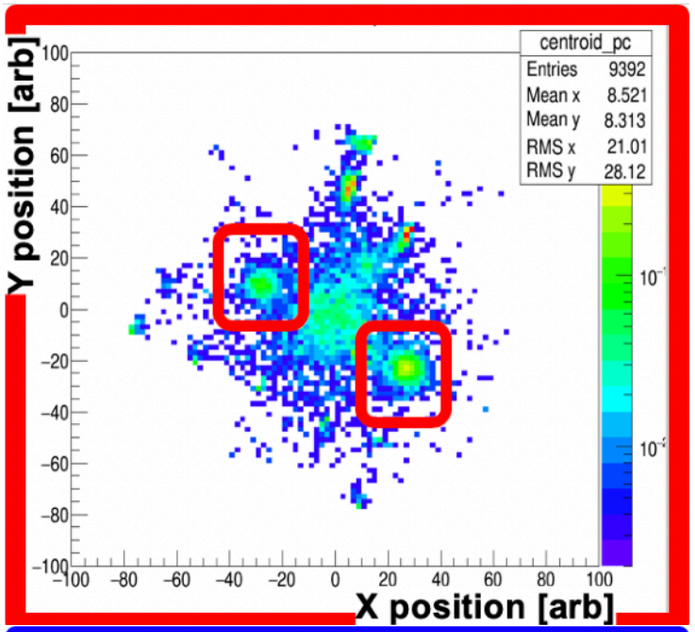


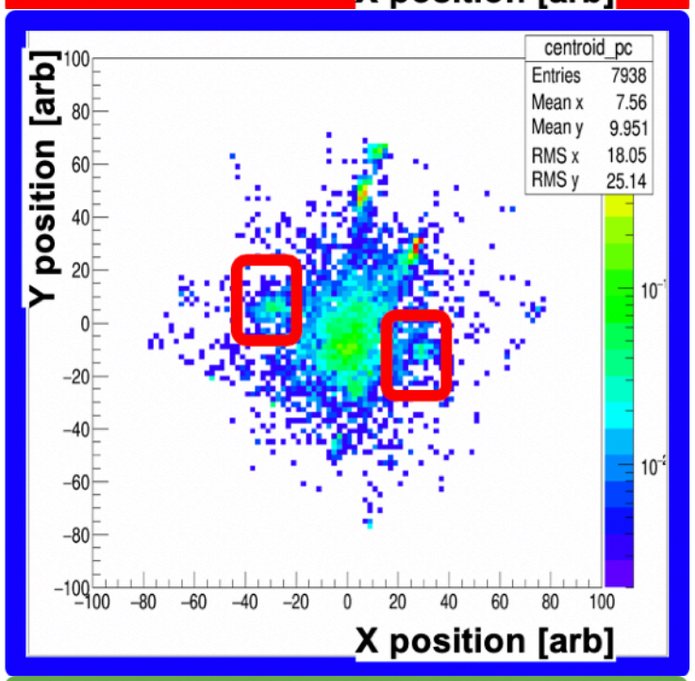
PMTs

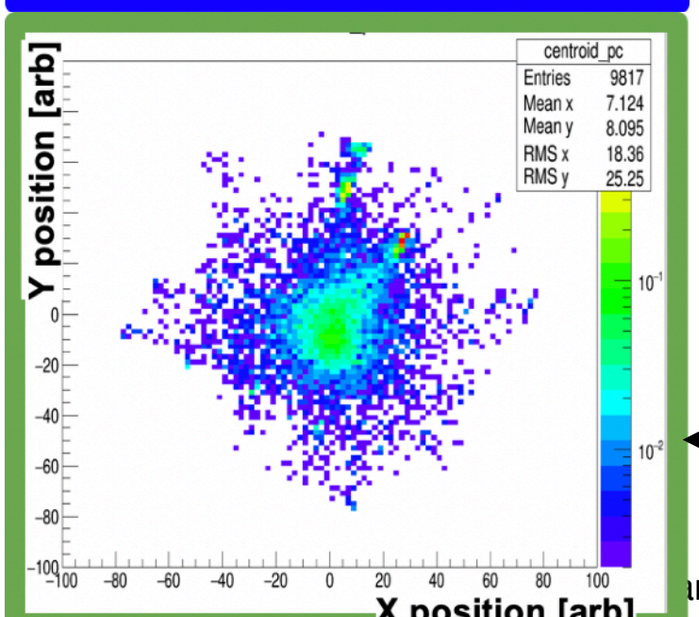


Gate grid installed

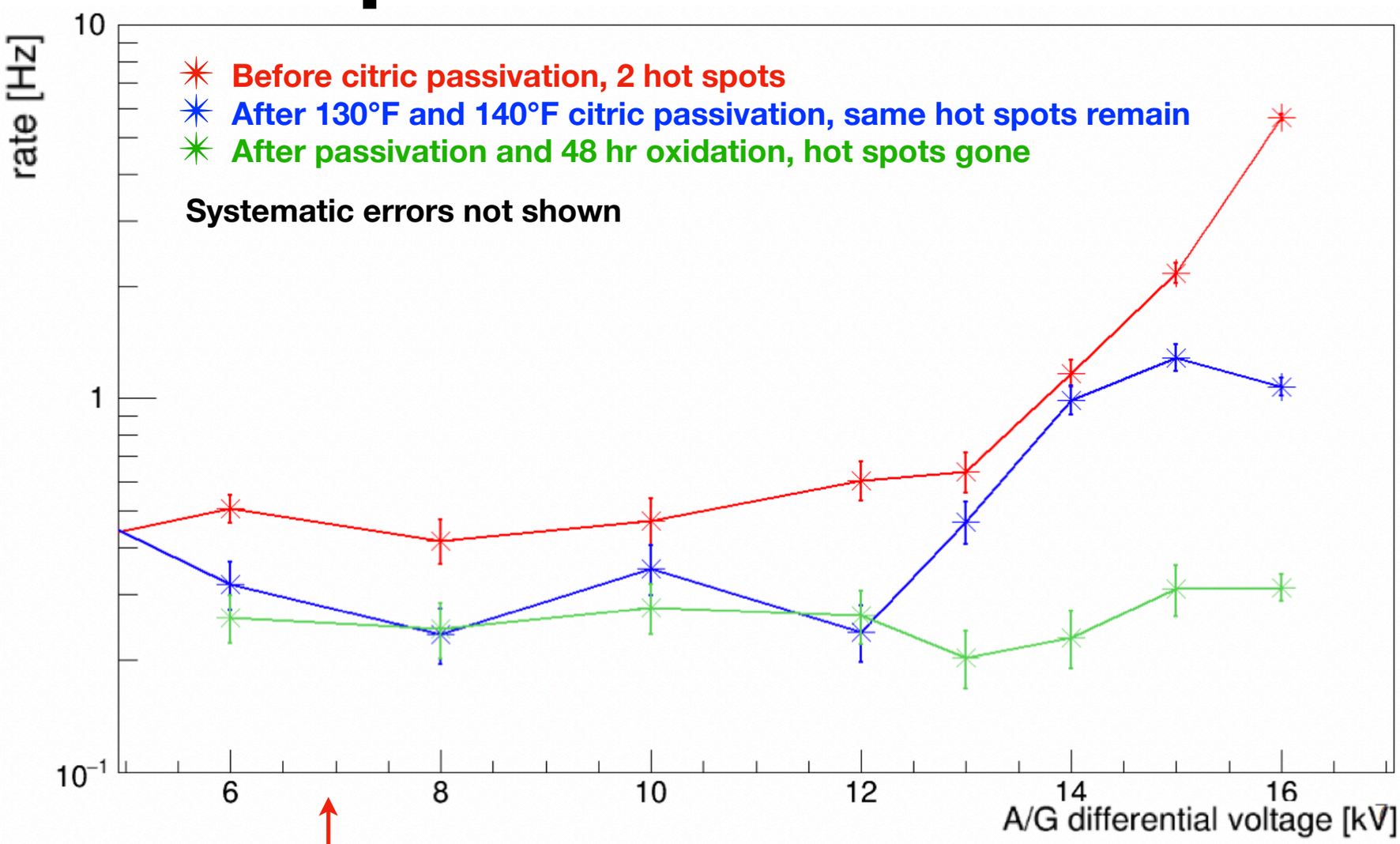
32-PMT gas detector: citric passivation results



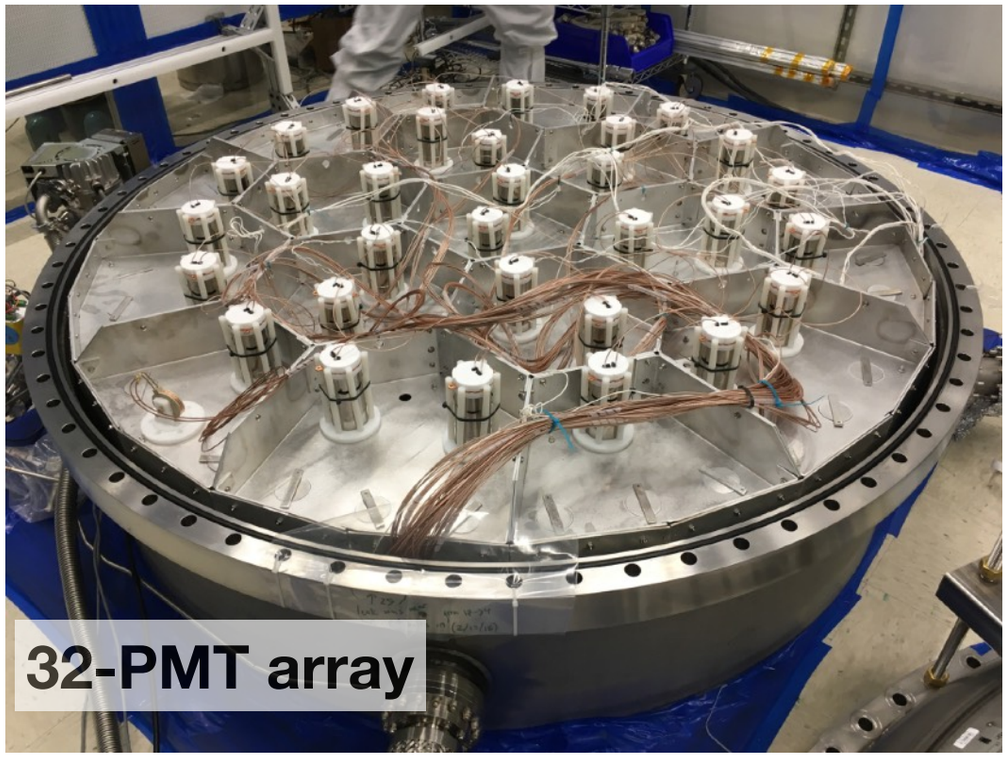


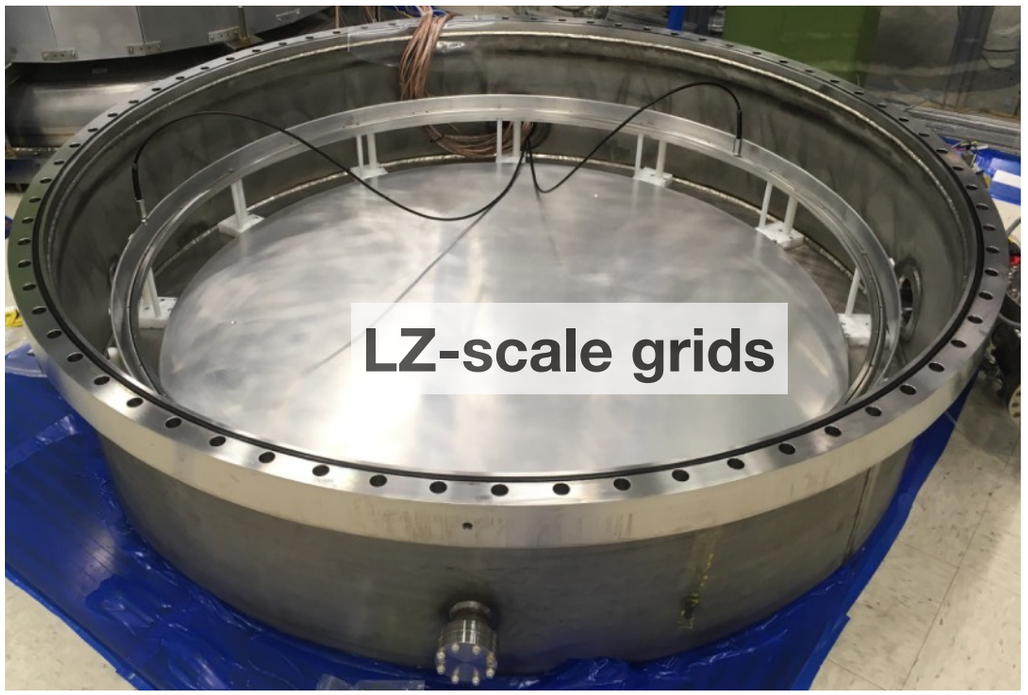


Plots at $\Delta V_{A\text{-}G}$ =16 kV

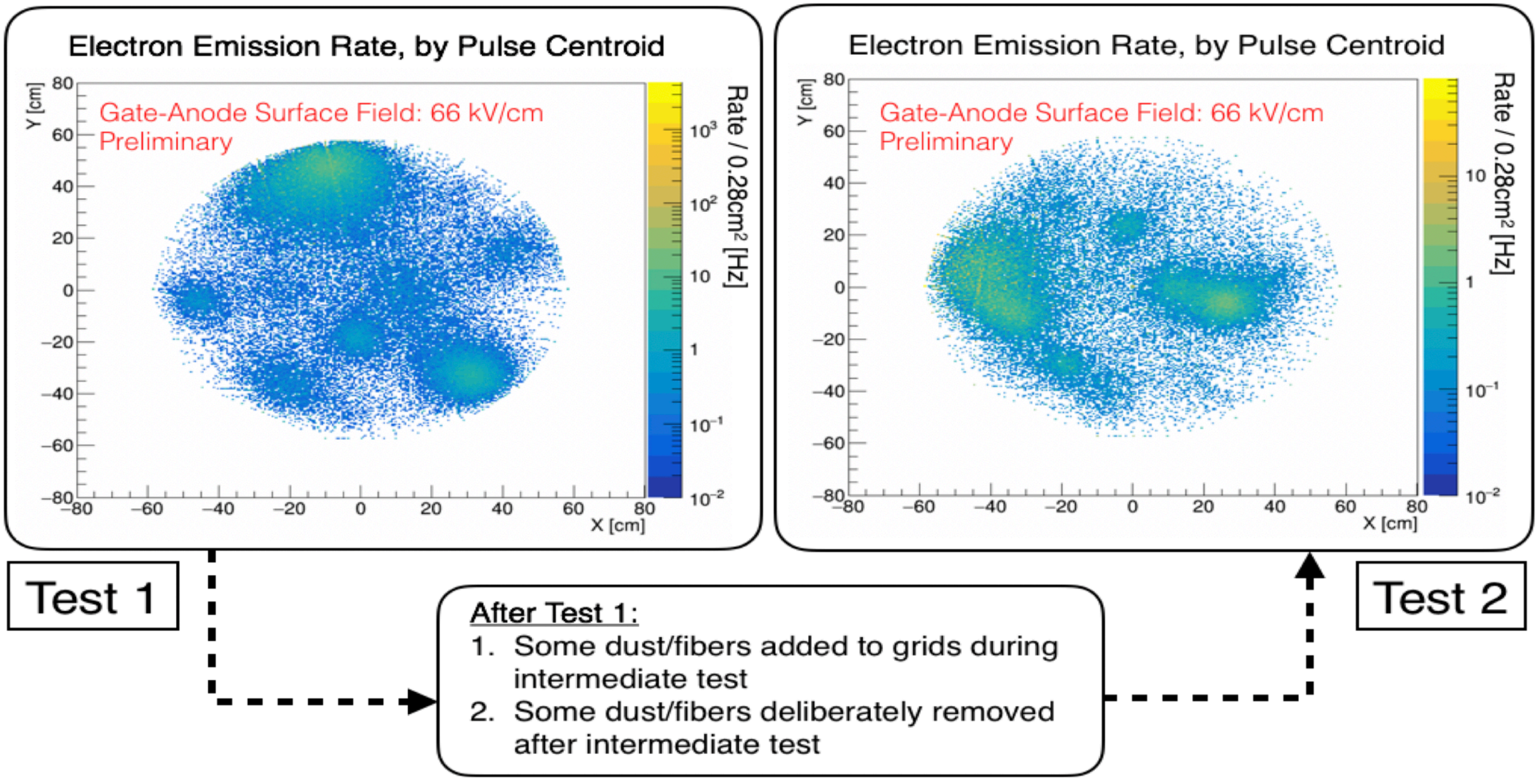


System test: Large gas-only detector



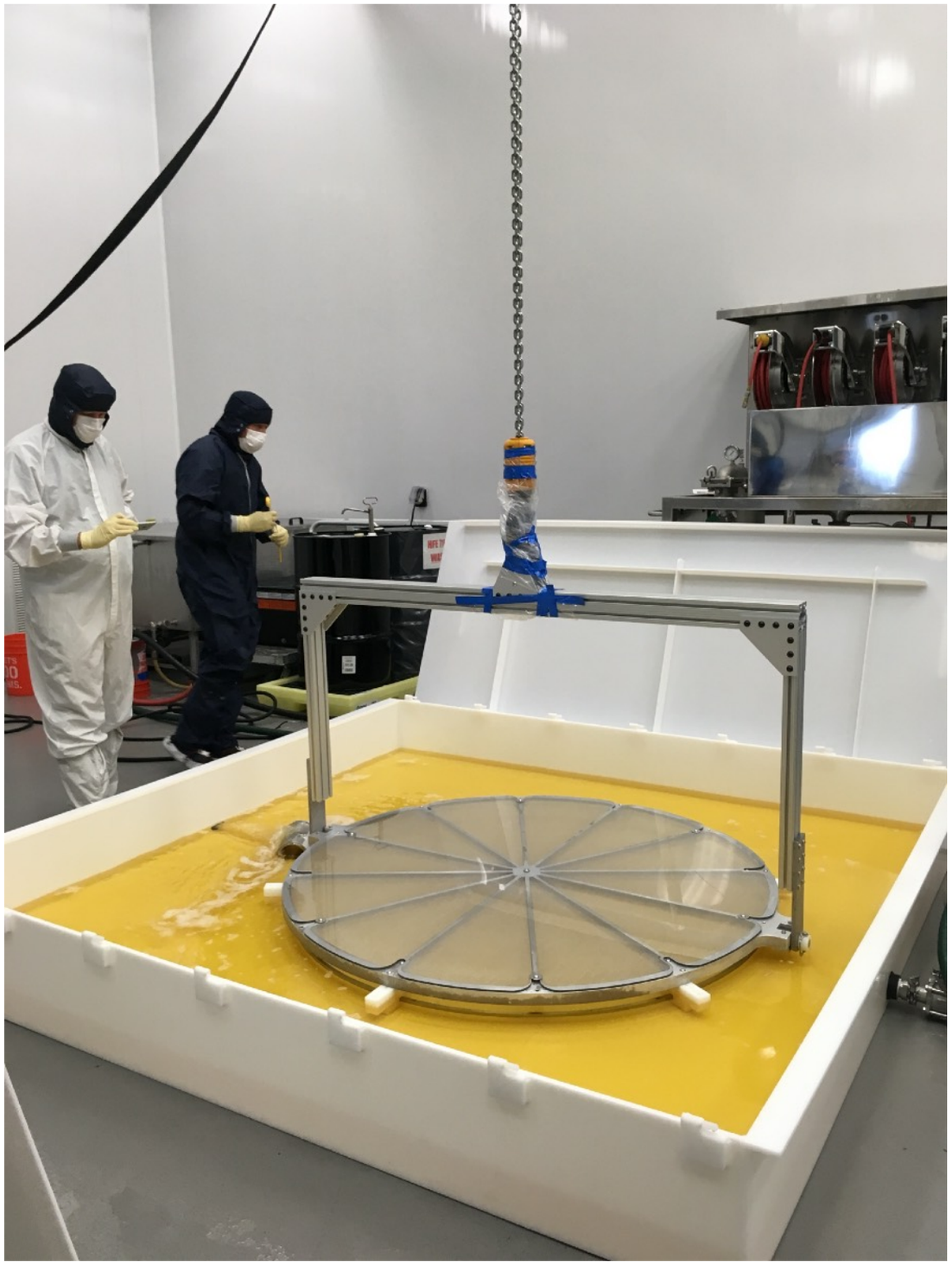


Emission from dust



Results from passivation of a prototype grid are being analyzed.

LZ passivation & grid cleaning



- Gate grid passivated in 3-5% citric acid.
  - Cathodic and in the electron extraction region
- Each grid was spray washed with DI water and UV-inspected for dust before assembly.

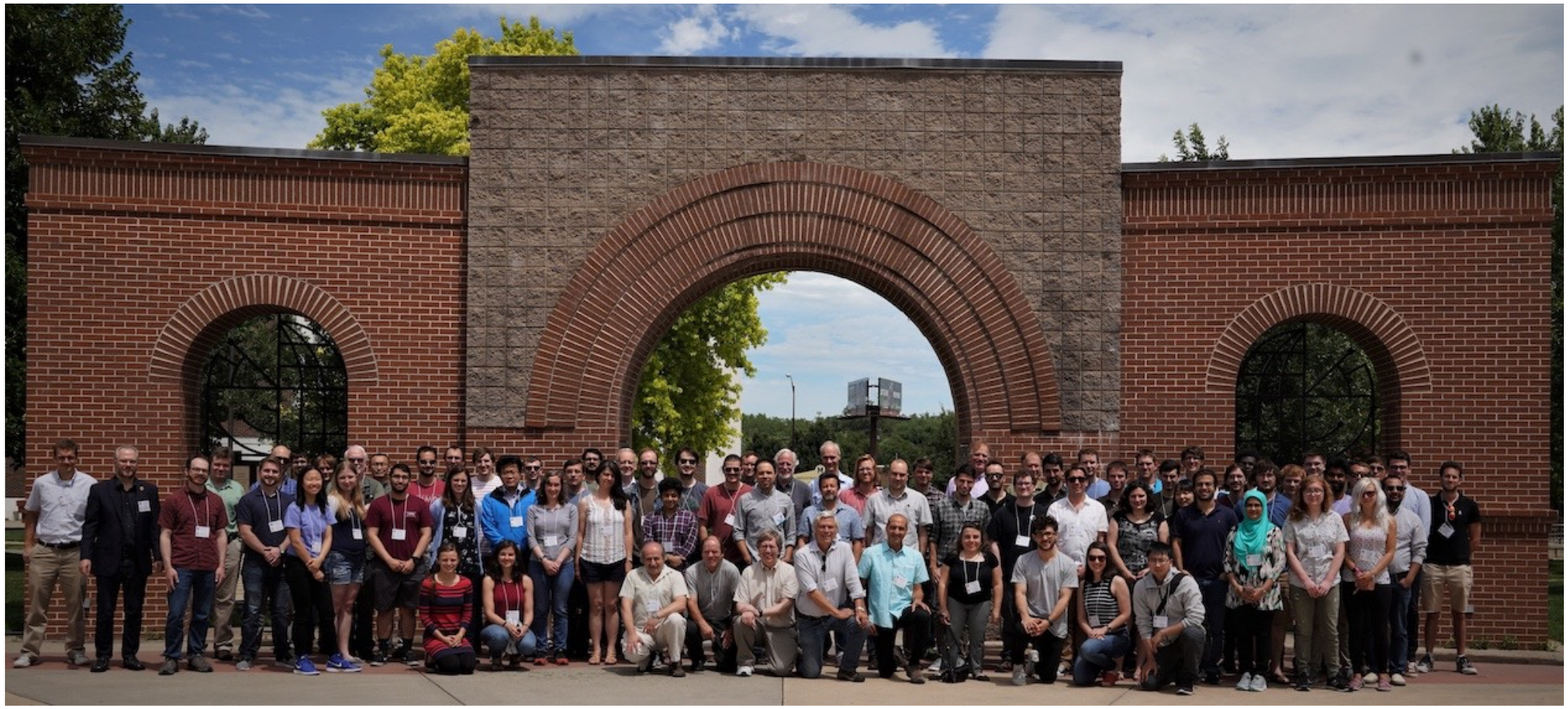
HV in future experiments

- HV issues affect many noble liquid detectors.
  - Fermilab's 2013 HV in Noble Liquids workshop
- Future larger-scale detectors affected by HV issues.
  - Scaling up can increase likelihood of dust or surface defects on electrodes.
- Techniques to mitigate electron emission may become increasingly important.

Conclusions

- SLAC R&D System Test studied passivation as a treatment for electron emission reduction.
- Promising results observed in many prototype grids
- Paper in preparation now.

Thank you



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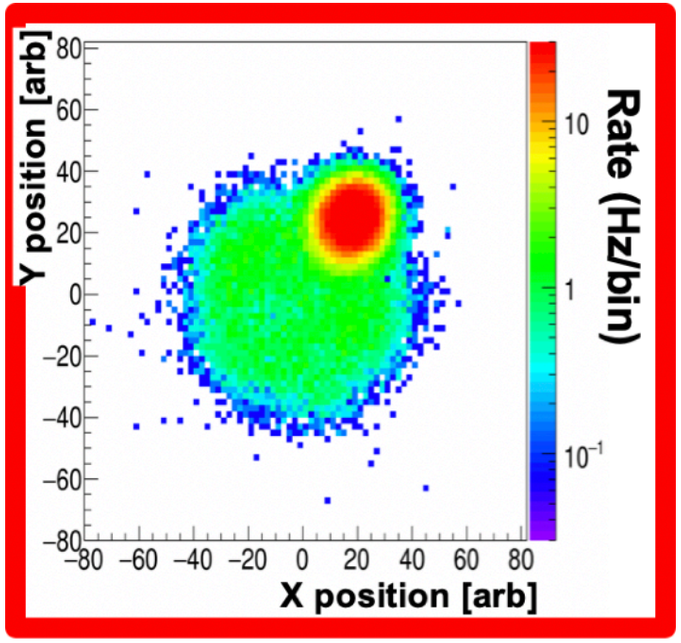
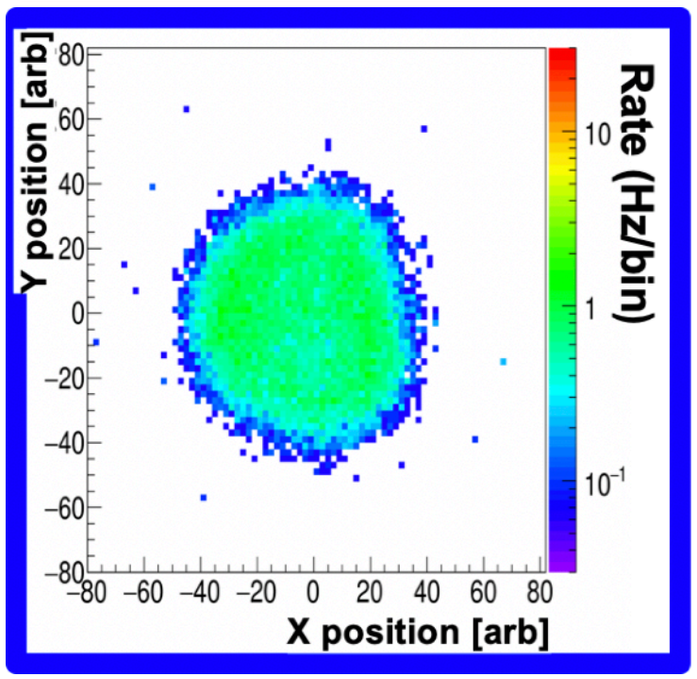
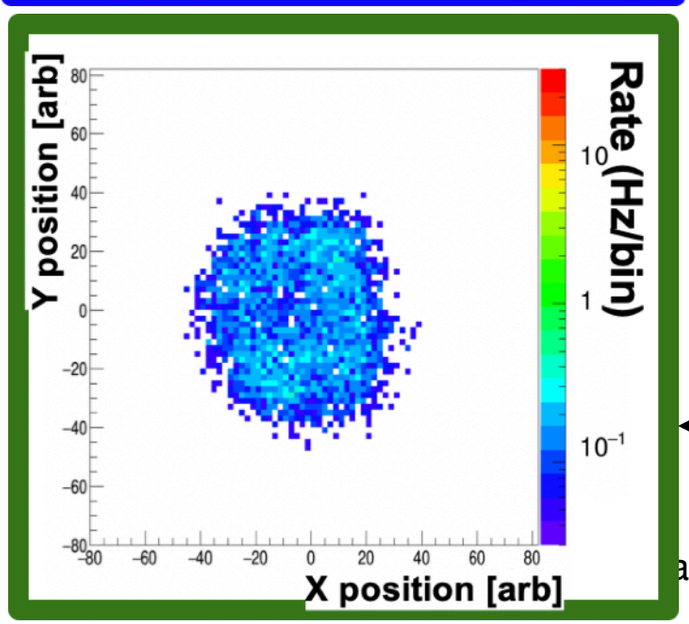
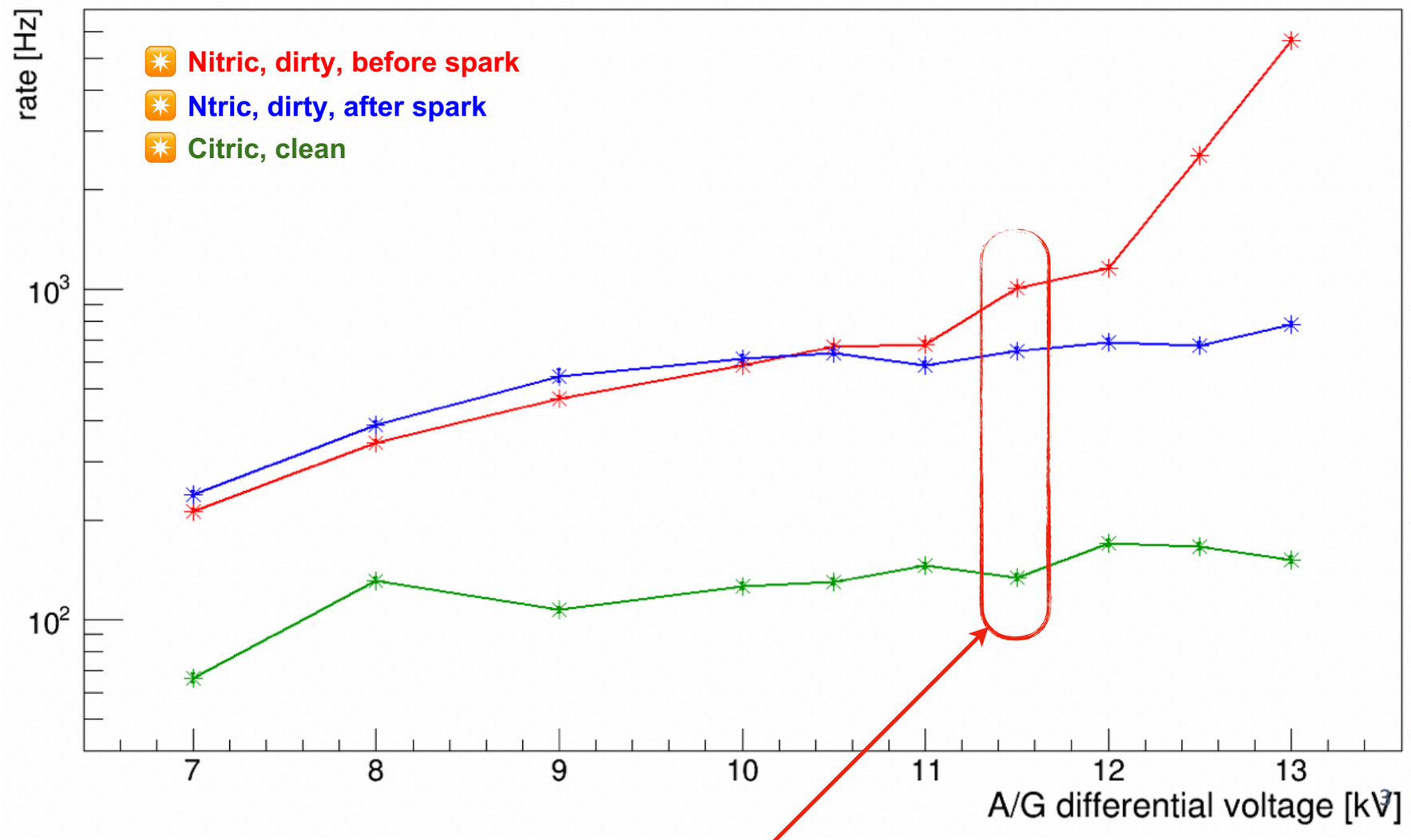
Extra slides

32-PMT TPC nitric & citric passivation





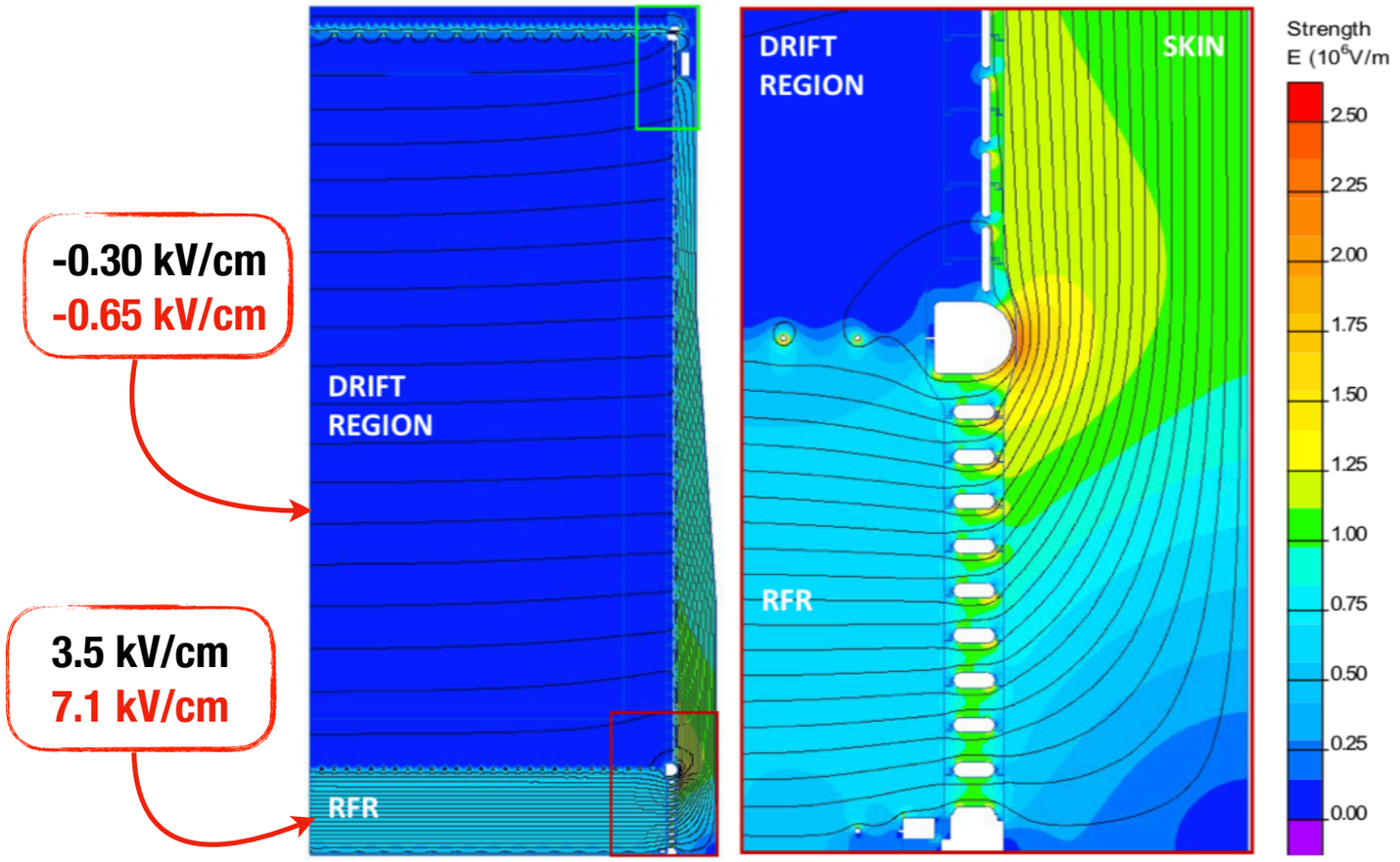


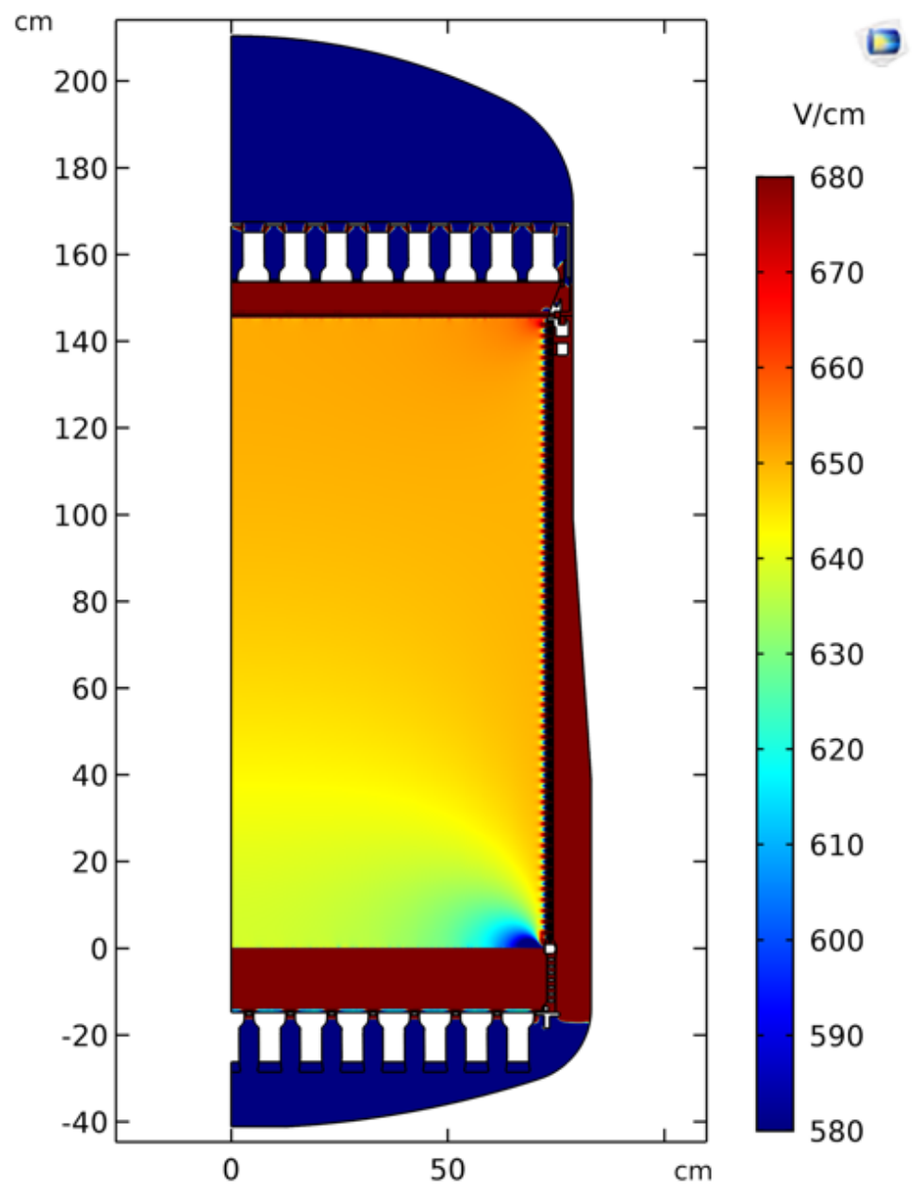


LZ equivalent field at 11.5 kV

← Plots at dV = 12.5 kV

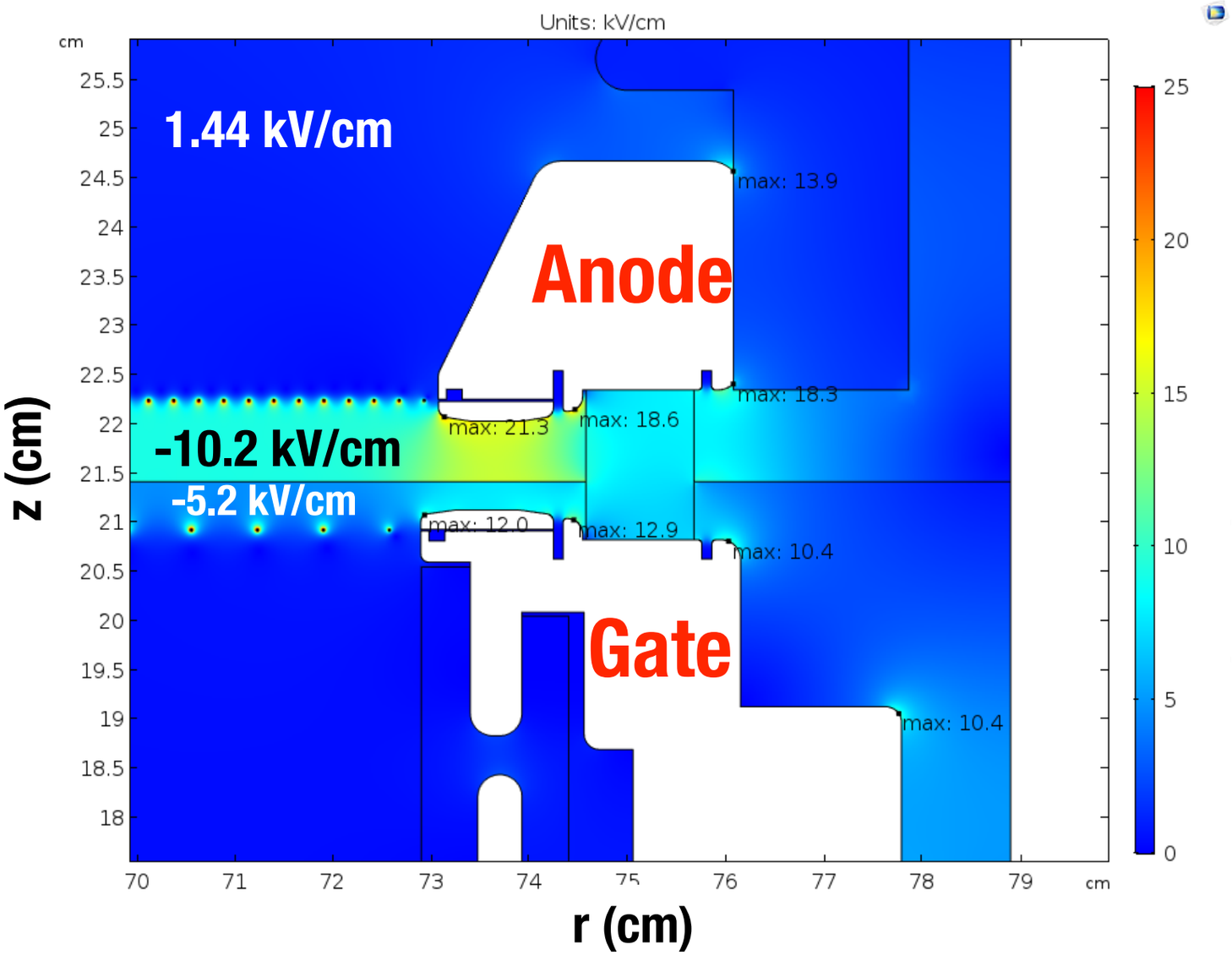
Drift and reverse field region





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

Electron 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