

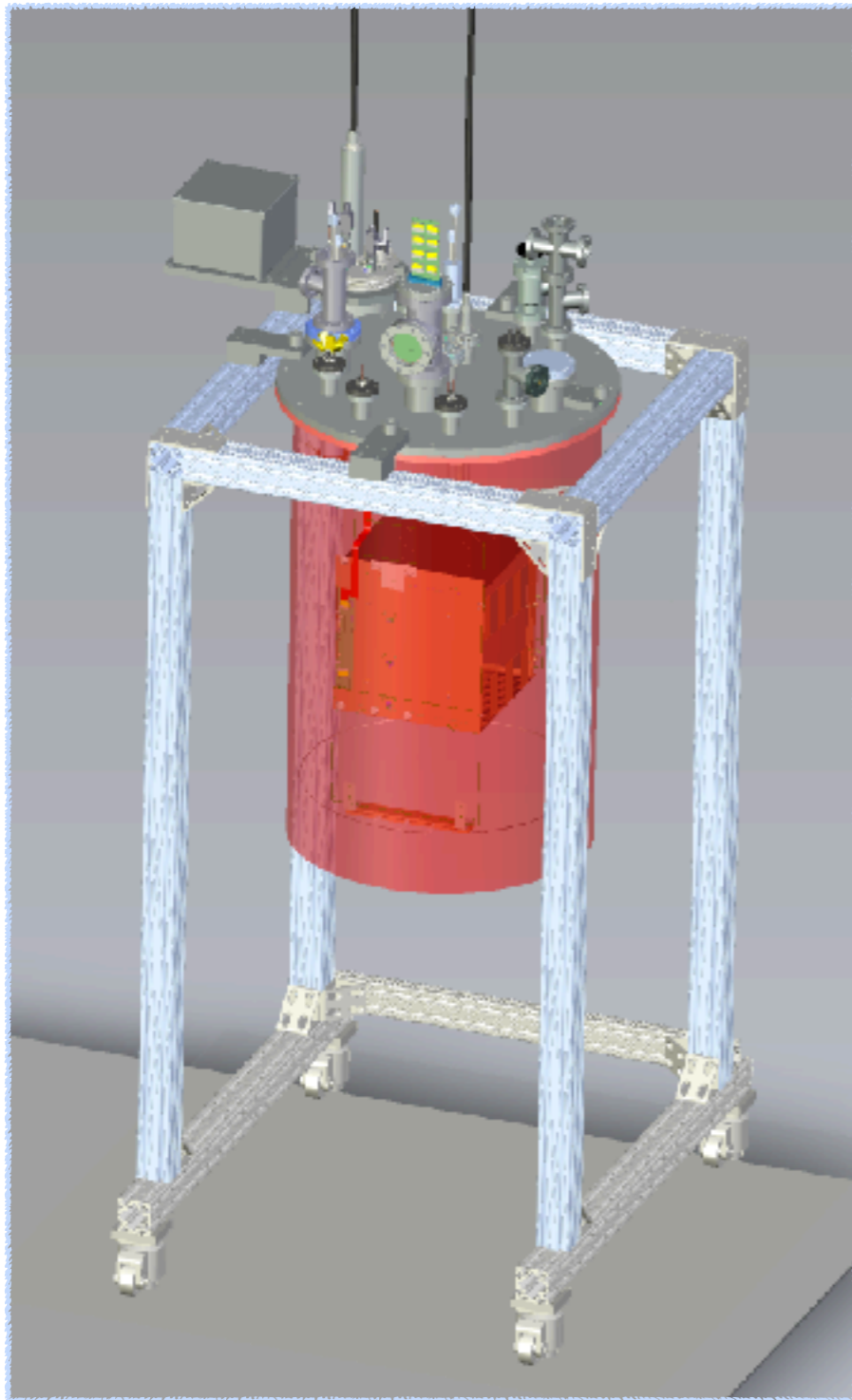


Liquid-Argon Time- Projection Chamber DIY



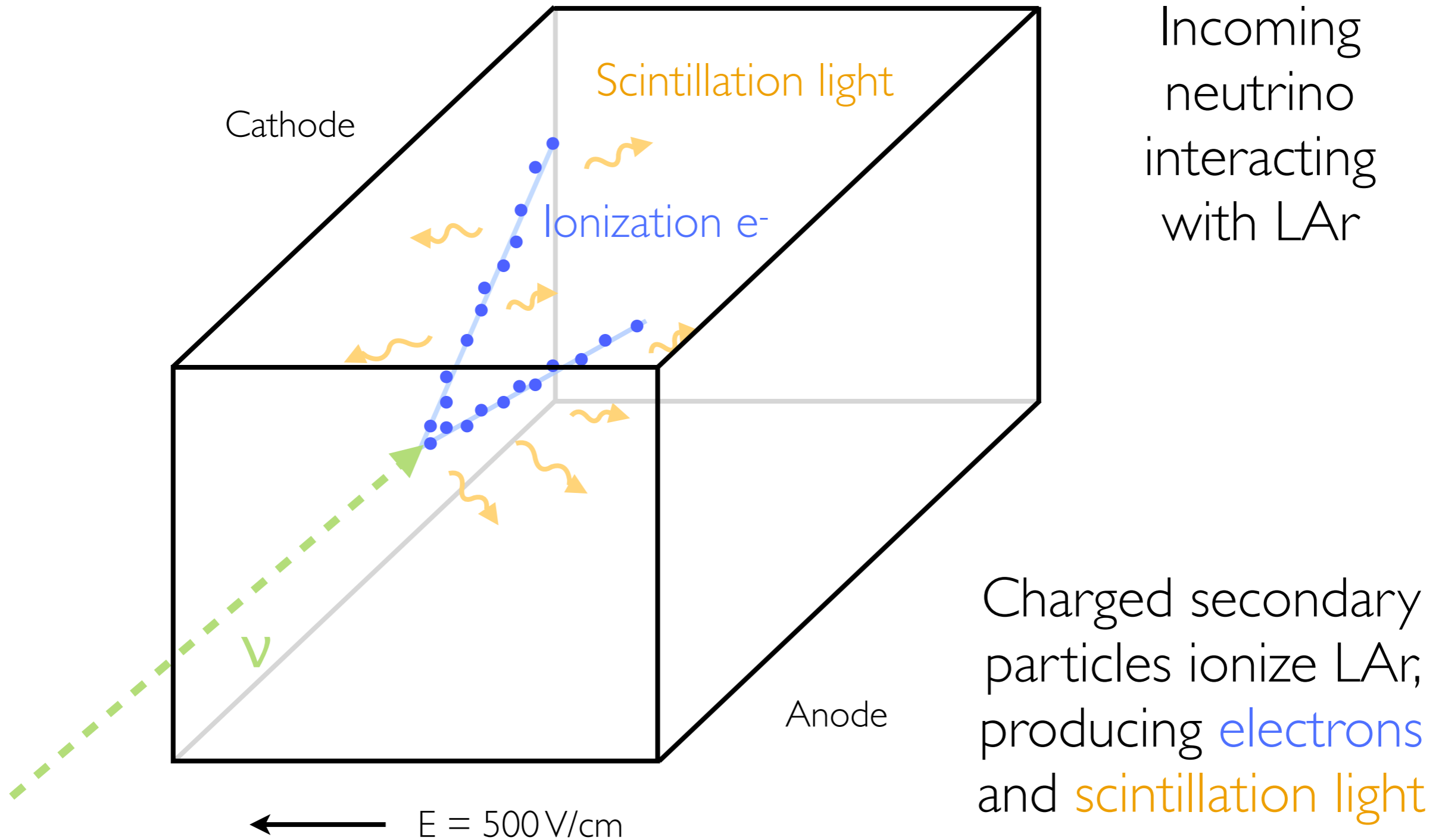
Yun-Tse Tsai (SLAC)
Mitchell Conference
May 26th 2022

Why LArTPC DIY?

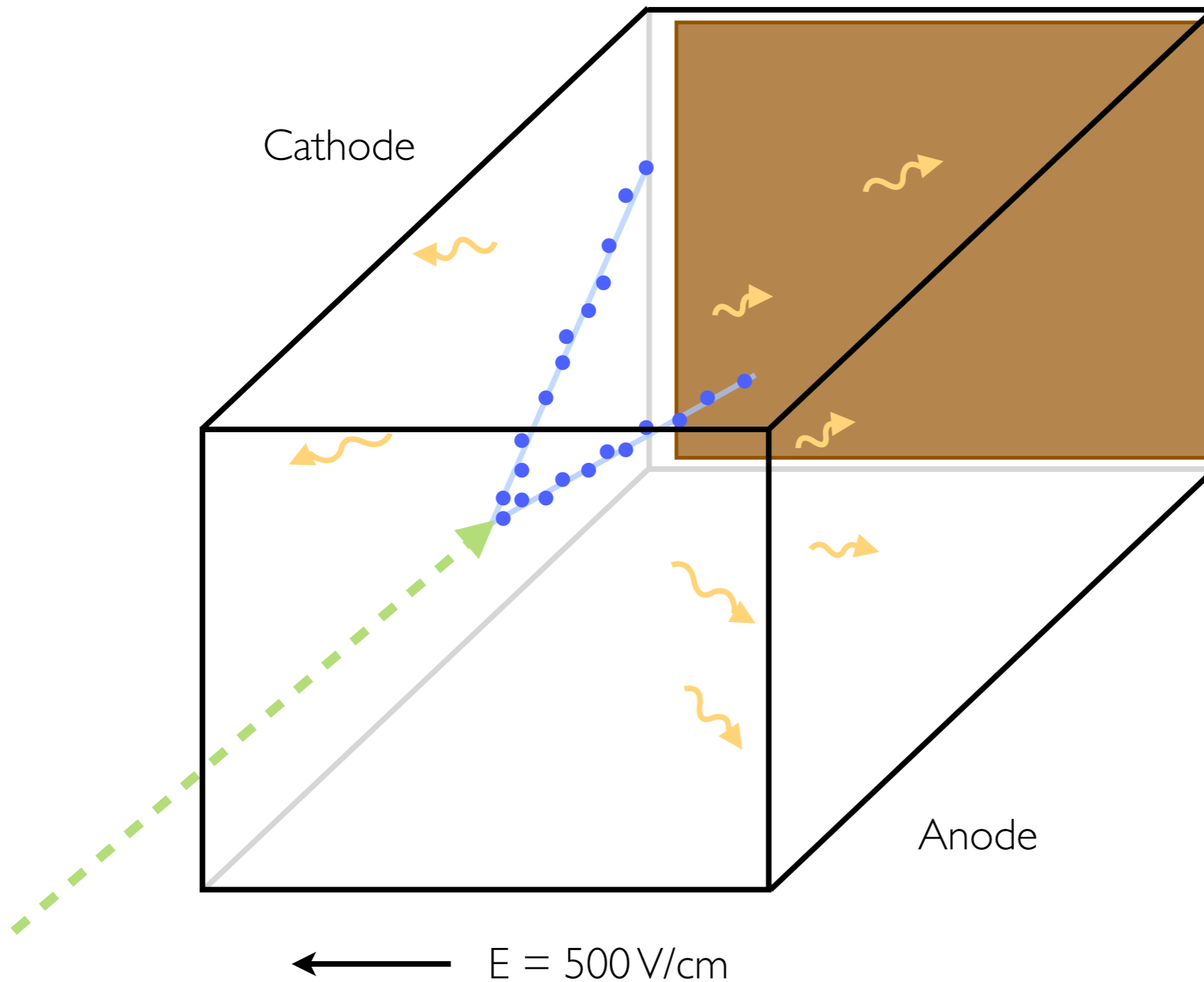


- LArTPC: widely used in neutrino and dark matter experiments
- Validate the **integrated performance** of the active detector elements
- Initiated for the **field shell R&D** at SLAC
 - Aim for DUNE LArTPC near detector (ND-LAr)
- Enable opportunities for more **LArTPC R&D**

LArTPC

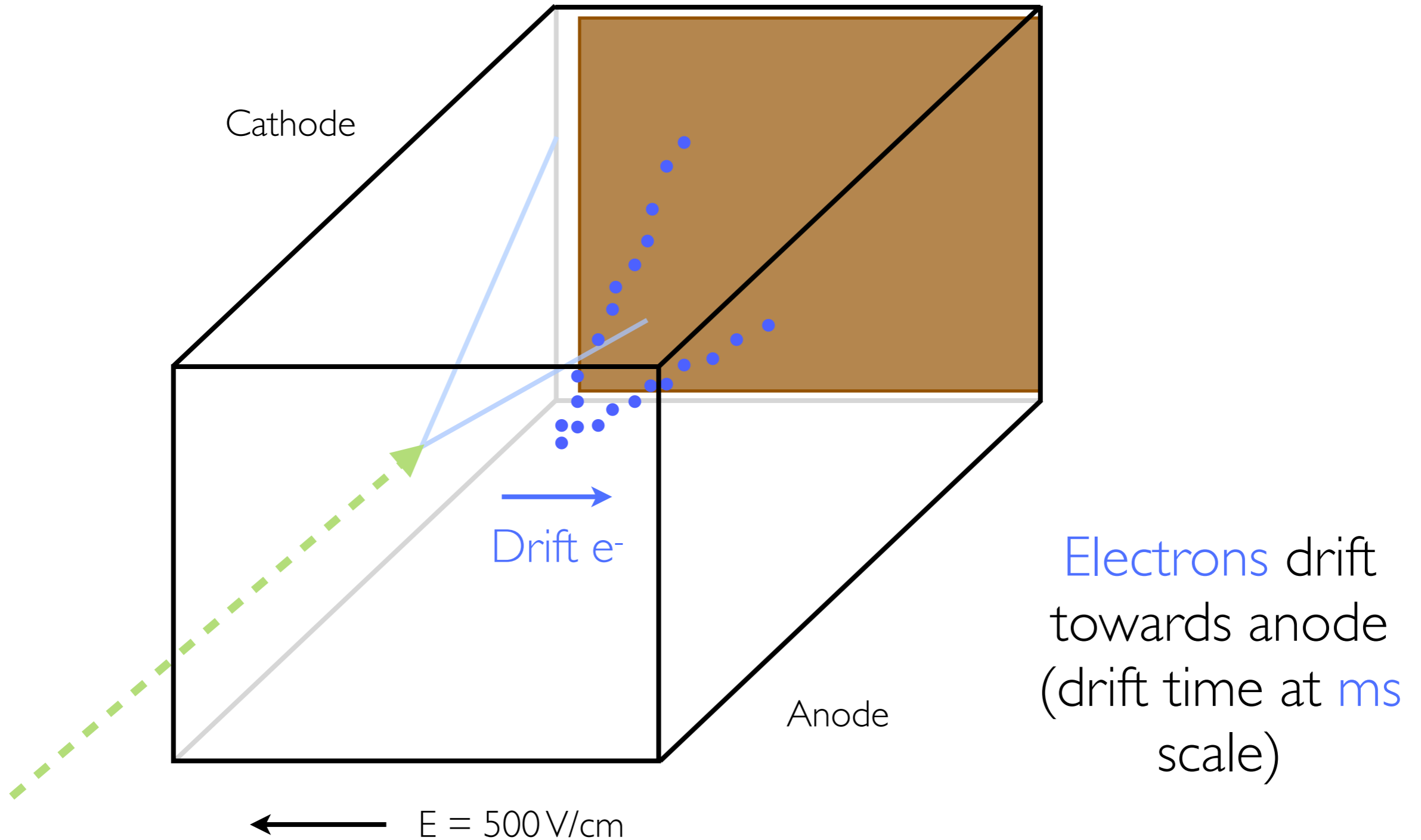


LArTPC

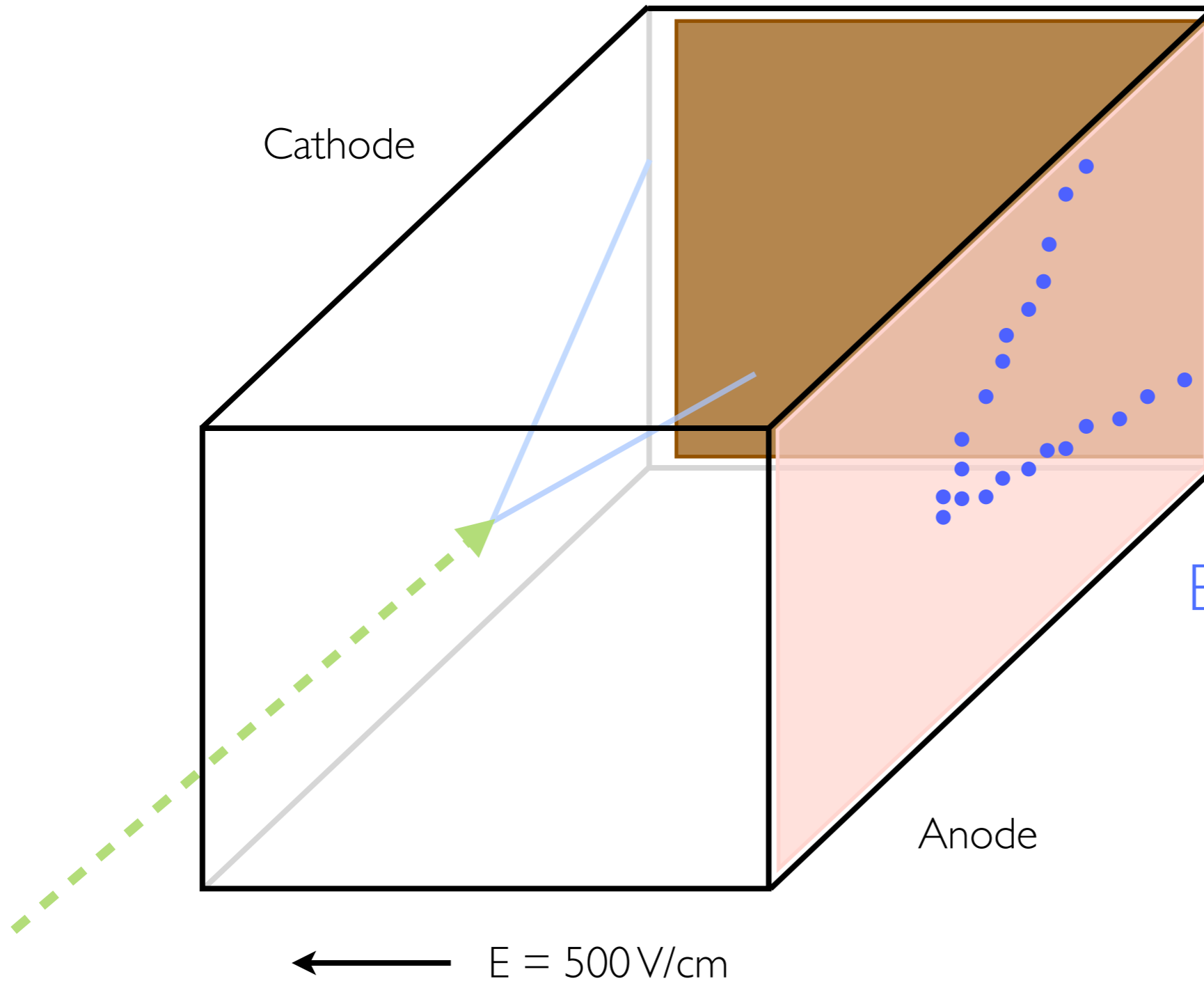


Light collected by
photon detectors
(10-100ns),
determining
event time t_0

LArTPC

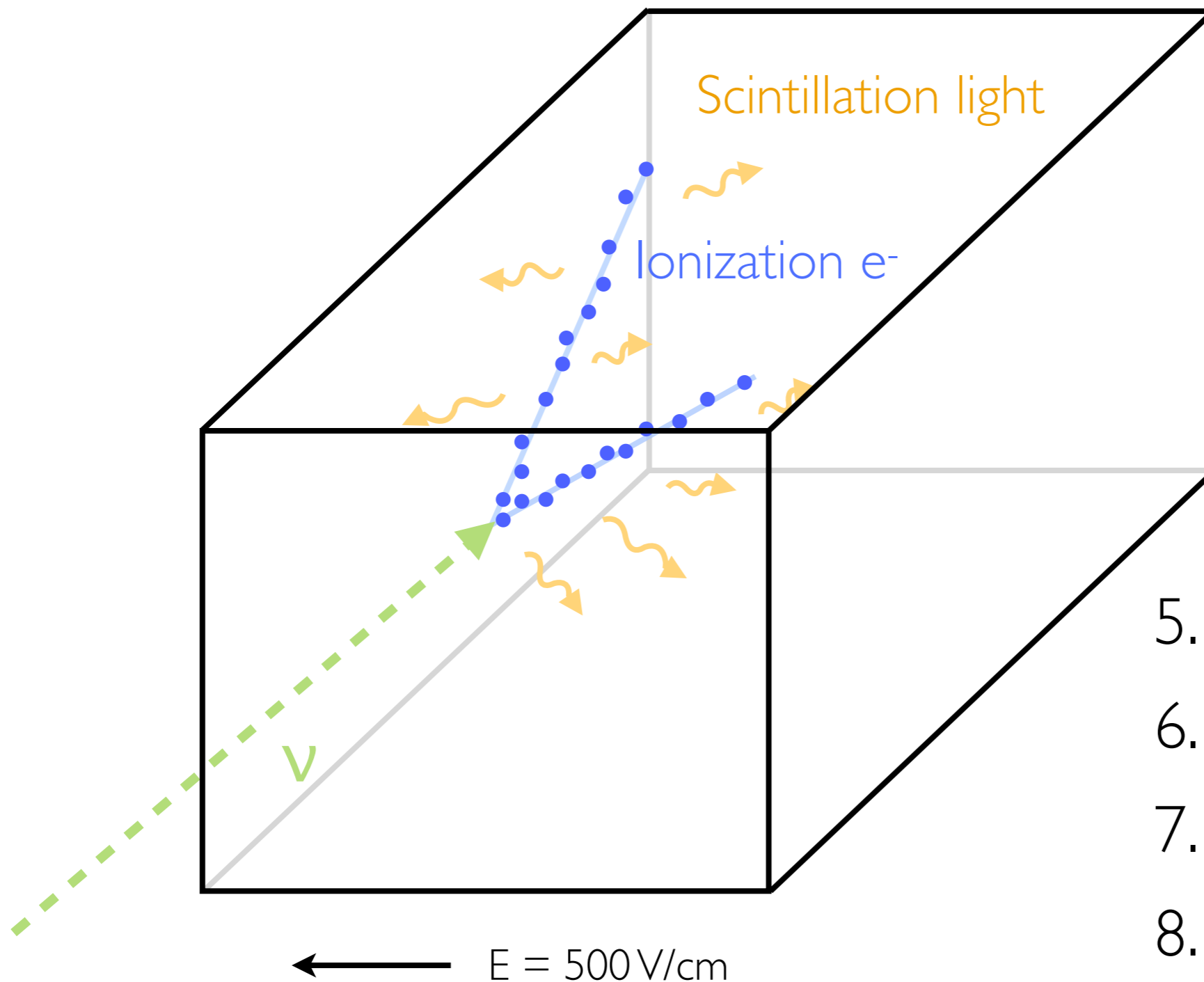


LArTPC

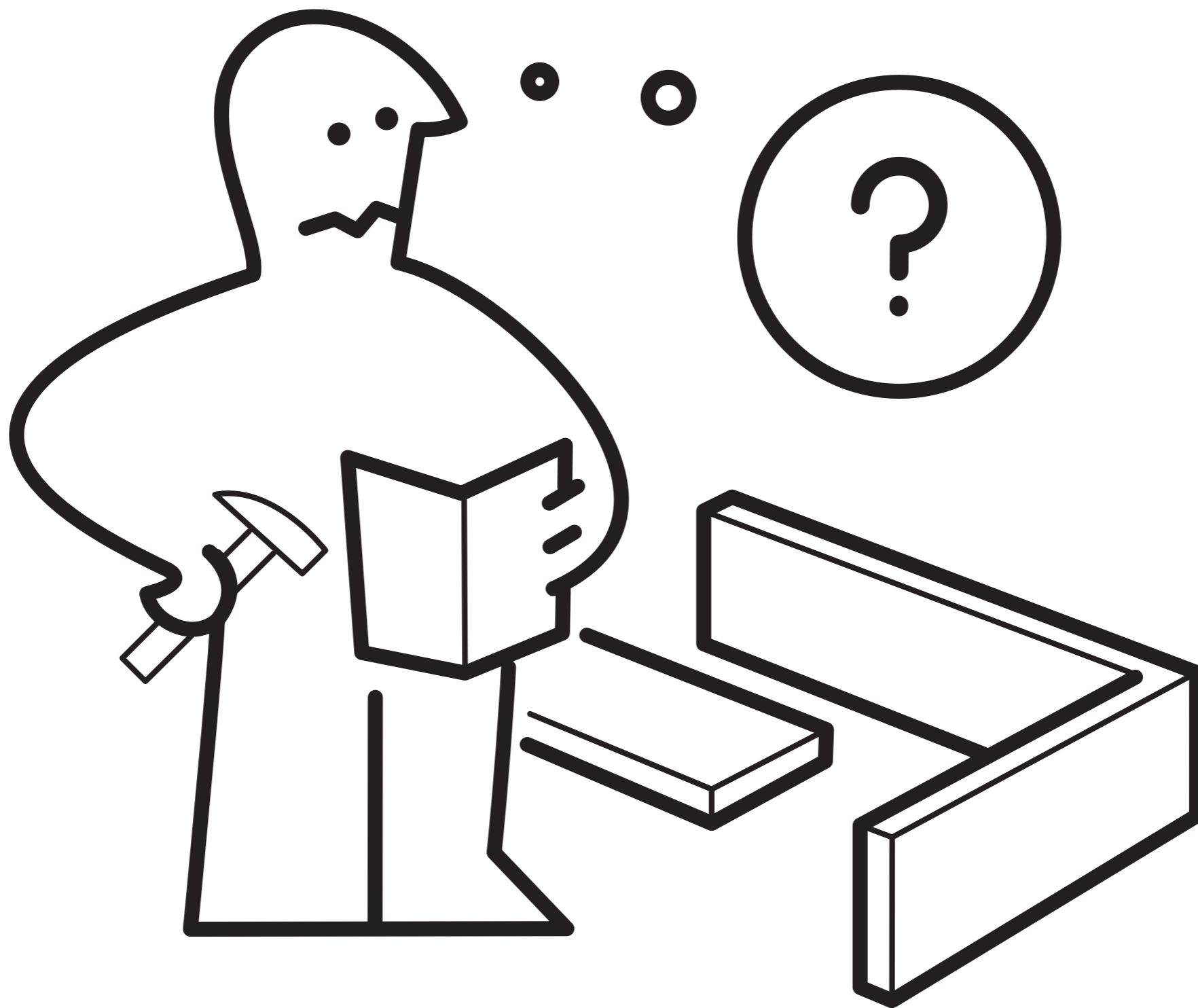


Electrons detected by the pixel plane at anode, providing the spatial, kinematic information.

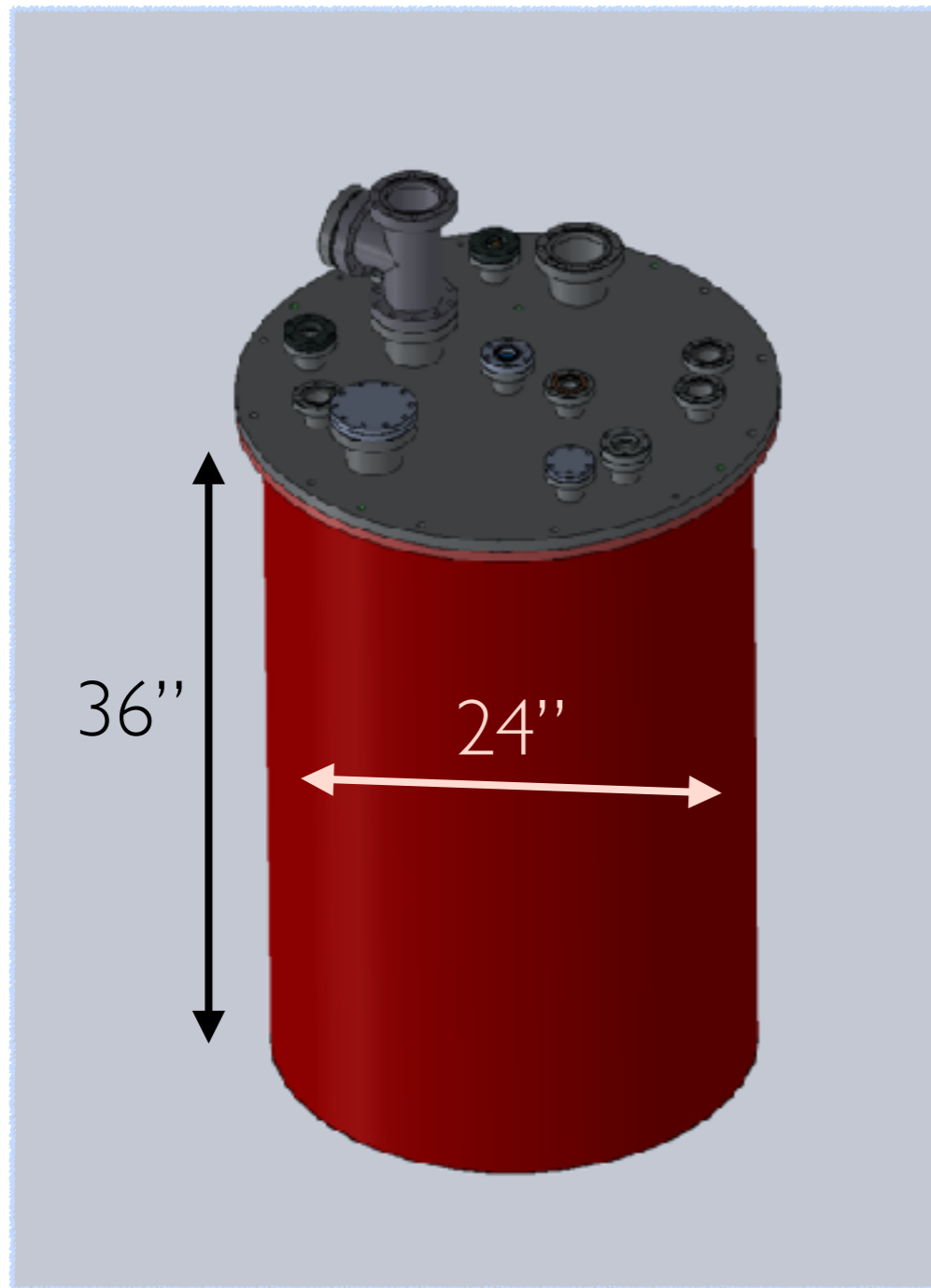
LArTPC



1. Cryogenic system
2. Detector control
3. High voltage
4. Field shell
5. Charge detector
6. Light detector
7. Pure LAr
8. Calibration



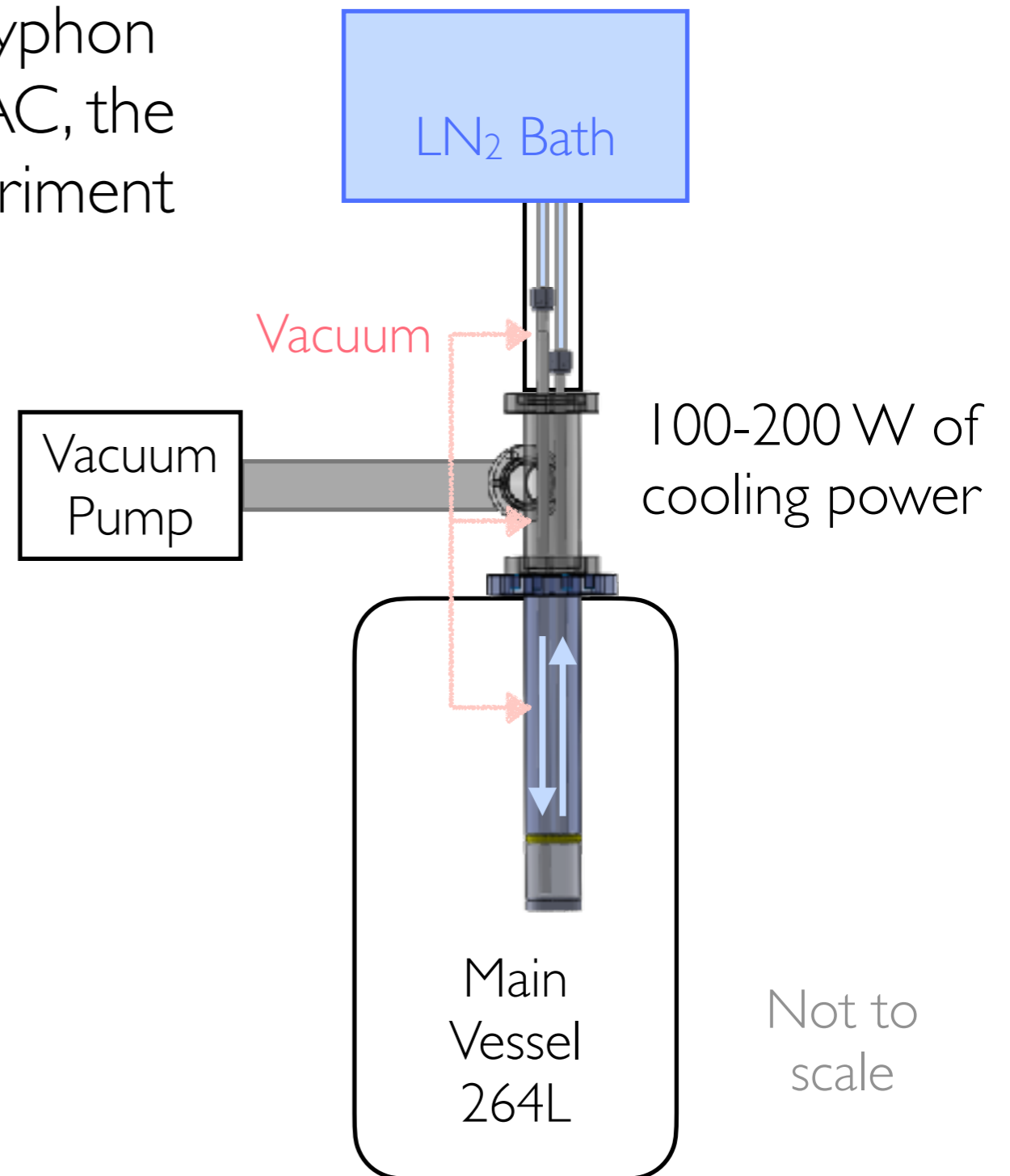
Cryogenic System



- Standard Cryofab dewar for LAr
 - Inner diameter: 24", height: 36"
 - Gross capacity: 264 L
 - Maximal allowable working pressure: 10 psig
- Customized top lid
 - Feedthroughs for power, data and detector sensors
 - LAr filling and venting
 - Cooling power
 - Pressure relief devices

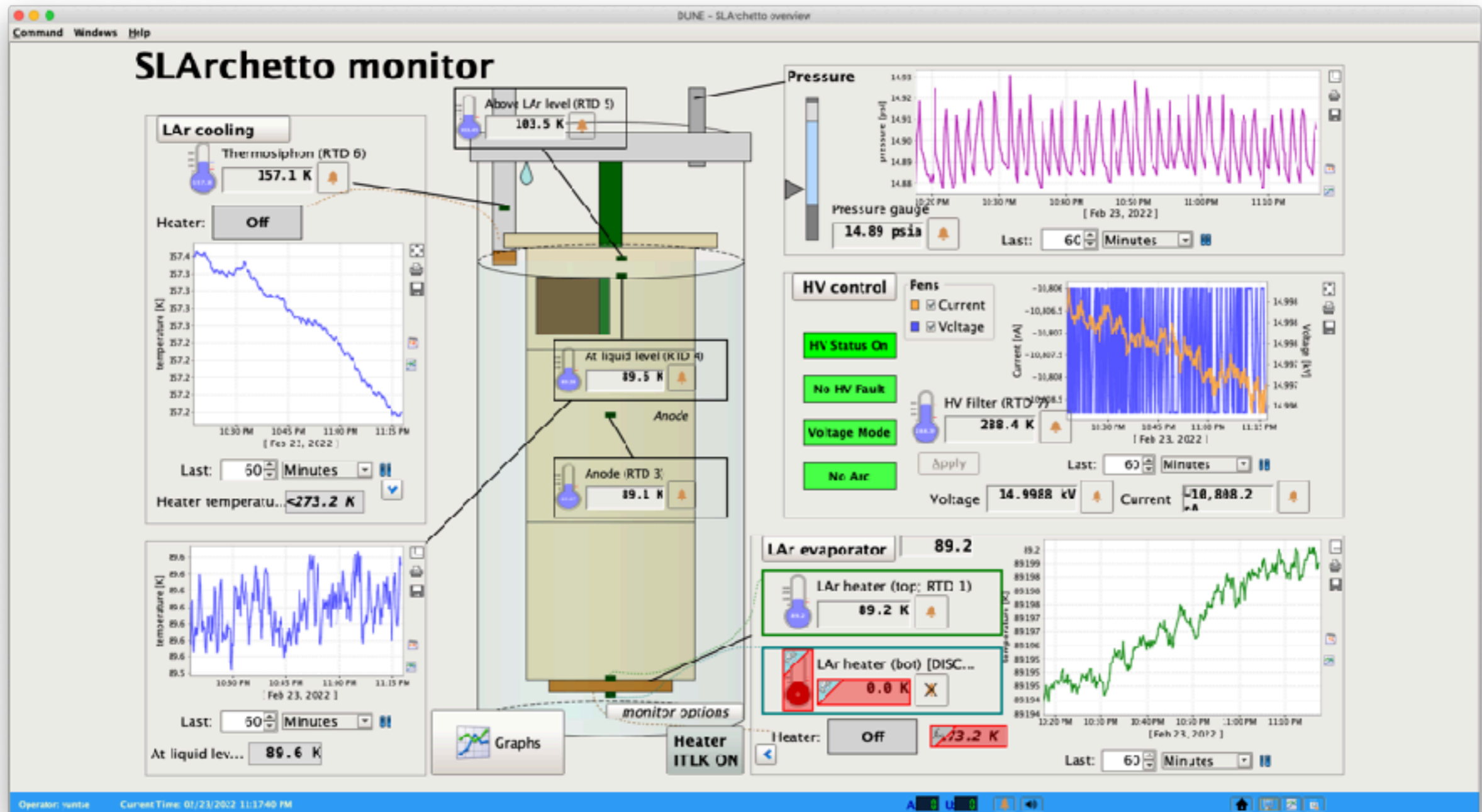
Cooling Power

Cooling power from the thermosyphon at Liquid Noble Test Facility at SLAC, the same technology used in LZ experiment

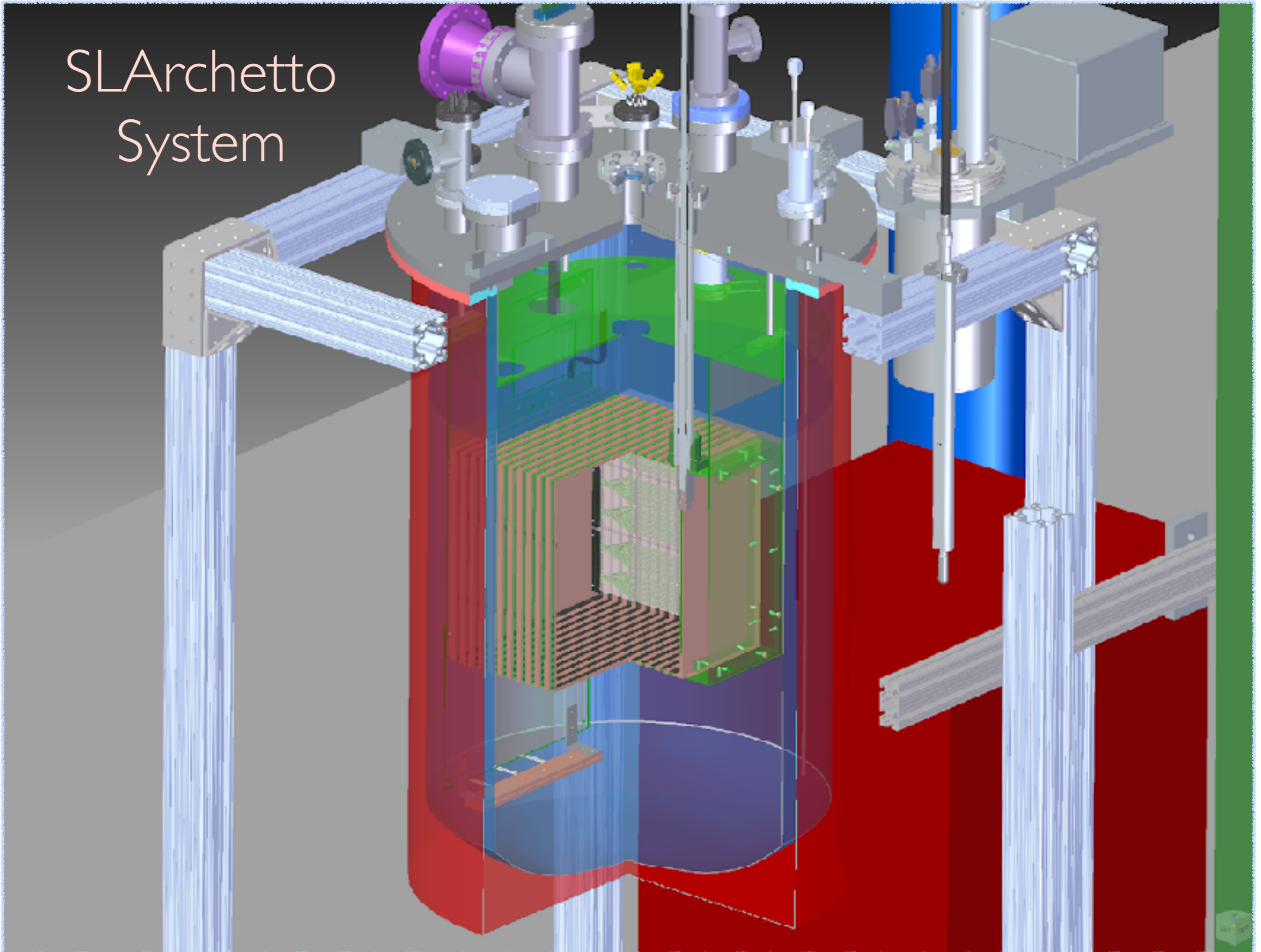


Detector Control

Based on Ignition: industrial detector control & monitoring,
programmable in python



SLArchetto System

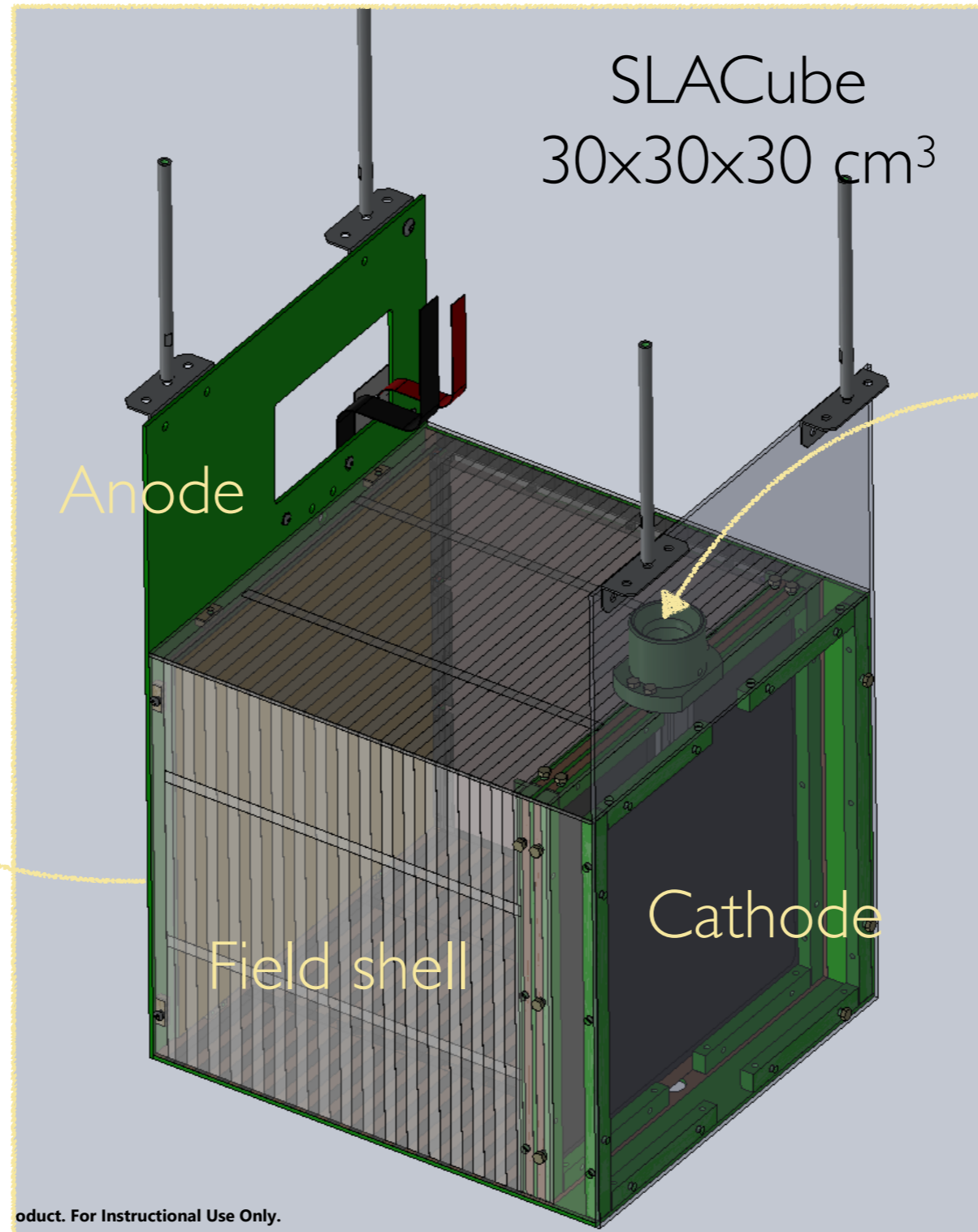


Time-Projection Chamber

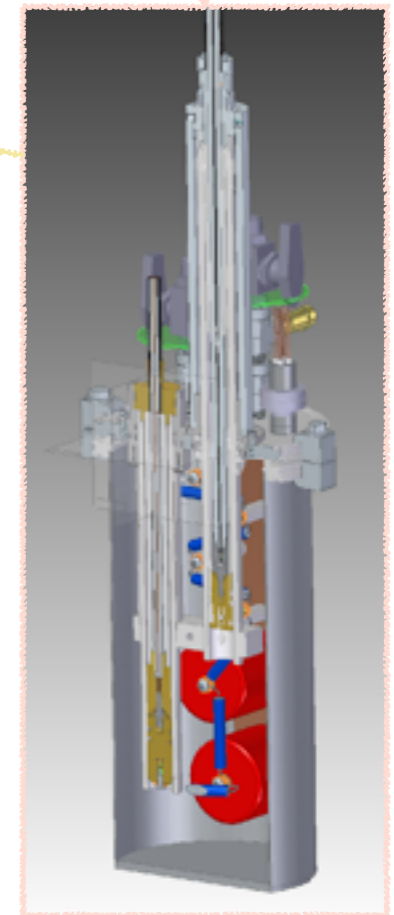
High voltage (HV) power supply ground = building ground

PicoAmmeter (Current measurement)

Nominal field: 500 V/cm (15 kV total)



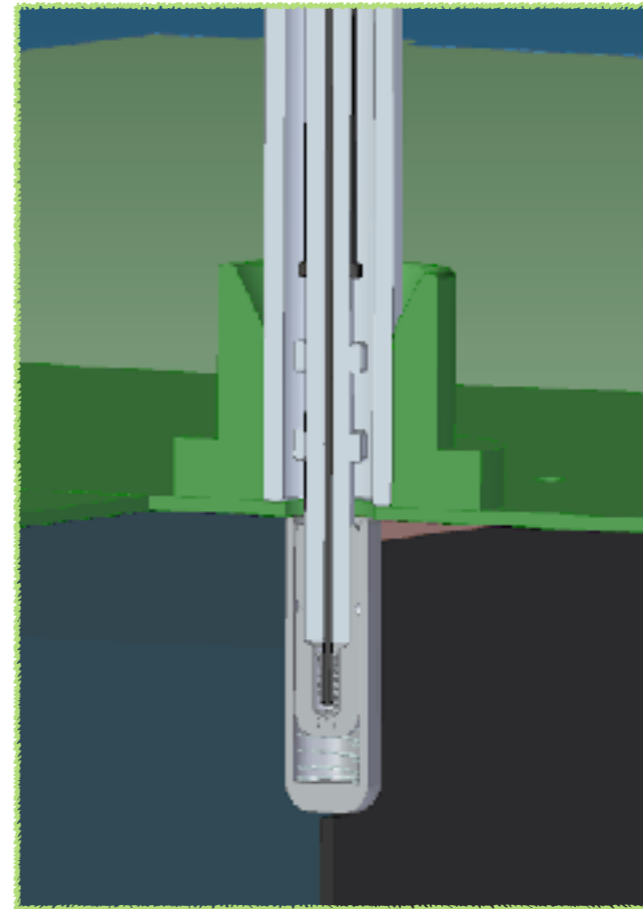
HV power supply



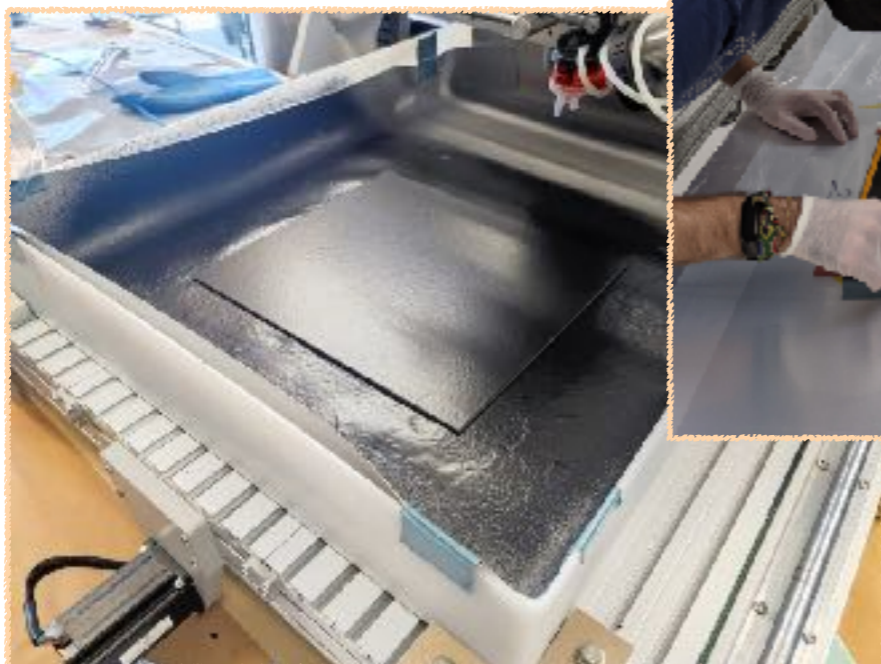
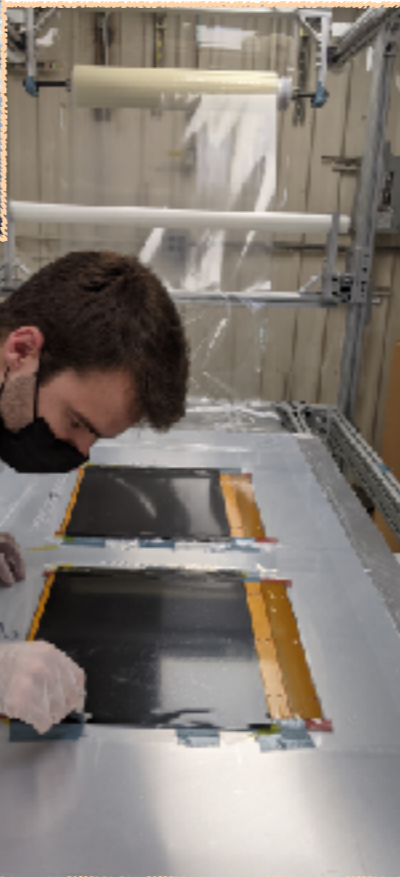
HV filter (low pass)

High Voltage

- Designed by Knut Skarpaas (SLAC engineer)
- HV cable originally designed for nEXO, and similar to the final DUNE ND-LAr design
 - Consideration for sealing, grounding, thermal contraction, buckling, etc.
- RC-circuits to filter high-frequency noise
 - Placed in a pot with electrical insulation oil



Field Shell

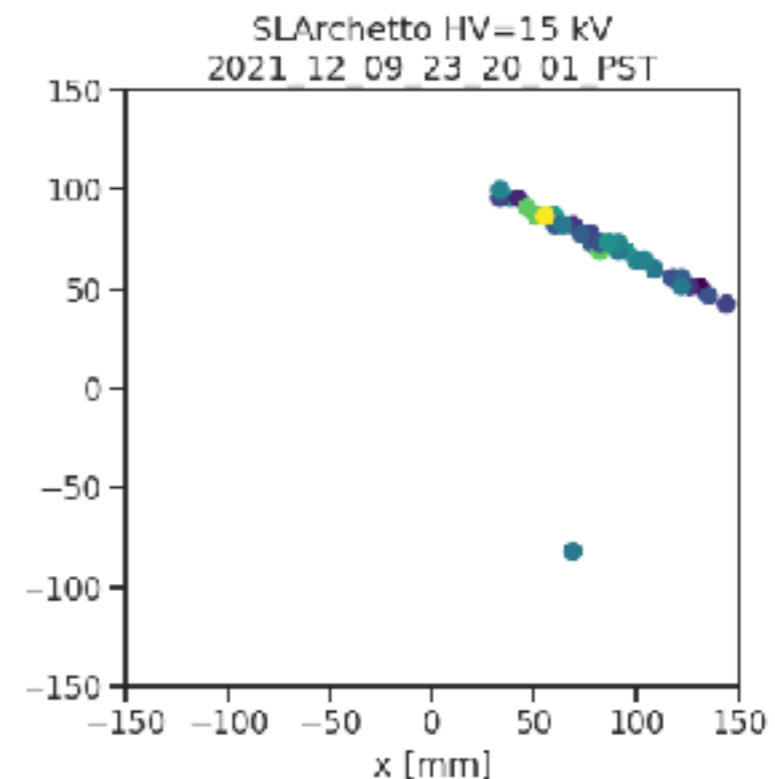
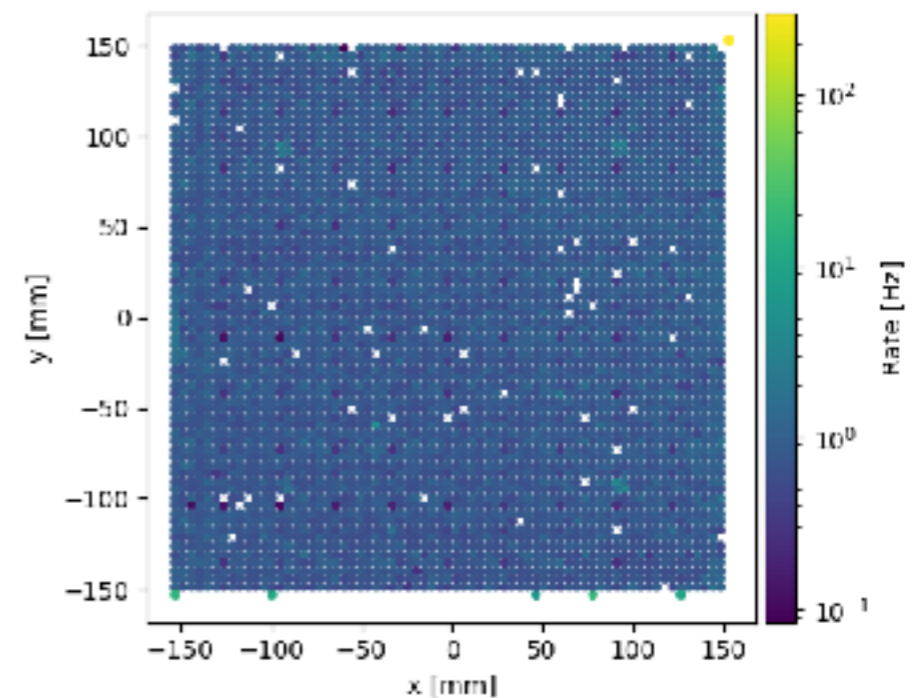


- Time projection requires **uniform electric field**
- Maximize the active volume in a modular TPC
→ thin panels
- Keep the electric potential linear and smooth
→ resistive materials
- Operate at 500V/cm
- Heat local density $< 100 \text{ mW/cm}^2$
- ➔ Dupont Kapton sheets or carbon coated panels

Charge Collection System

- LArPix: Pixelated charge collection system developed by LBNL for DUNE ND-LAr
- 4 mm pixel, 4900 channels in a 30x30 cm² tile
- 2.5 μ s time-binning
- ~ 62 μ W/channel
- Self-triggering channel by channel
- First tracks observed in December 2021
- DAQ implemented and maintained by P.Tsang

Self-triggering rate

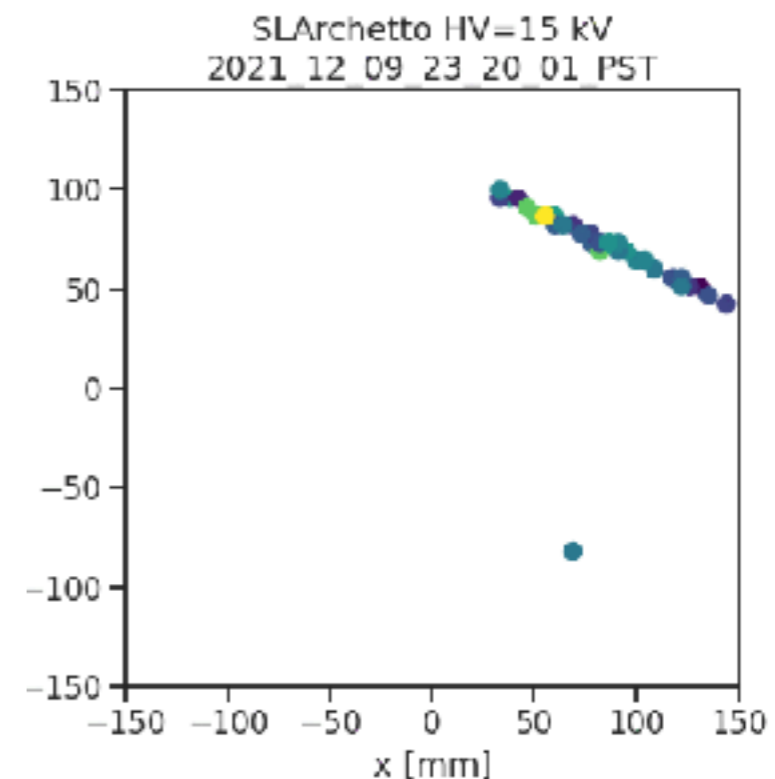
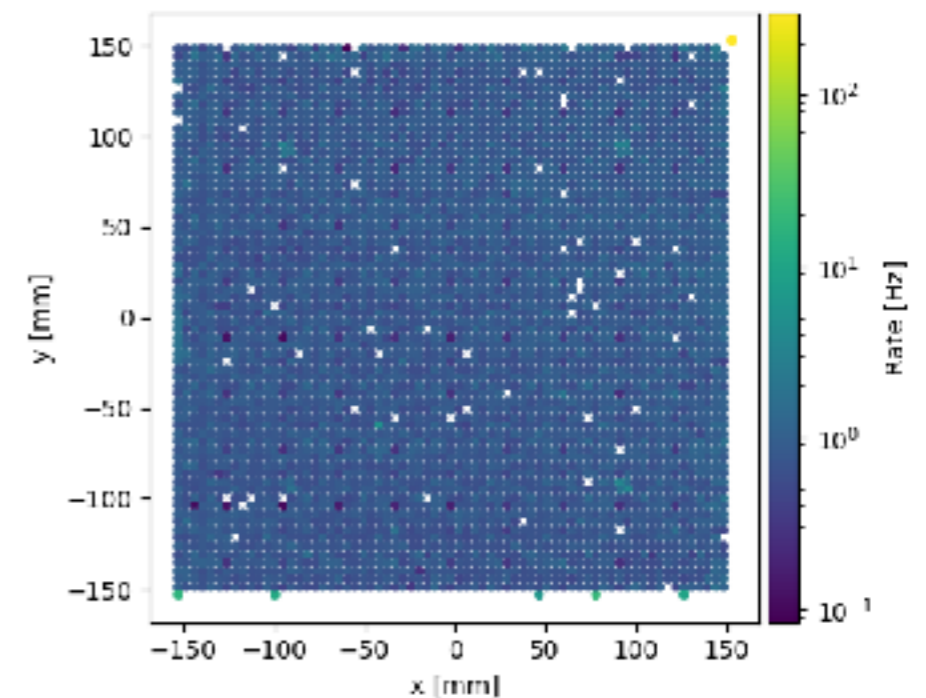


Plots made
by P.Tsang

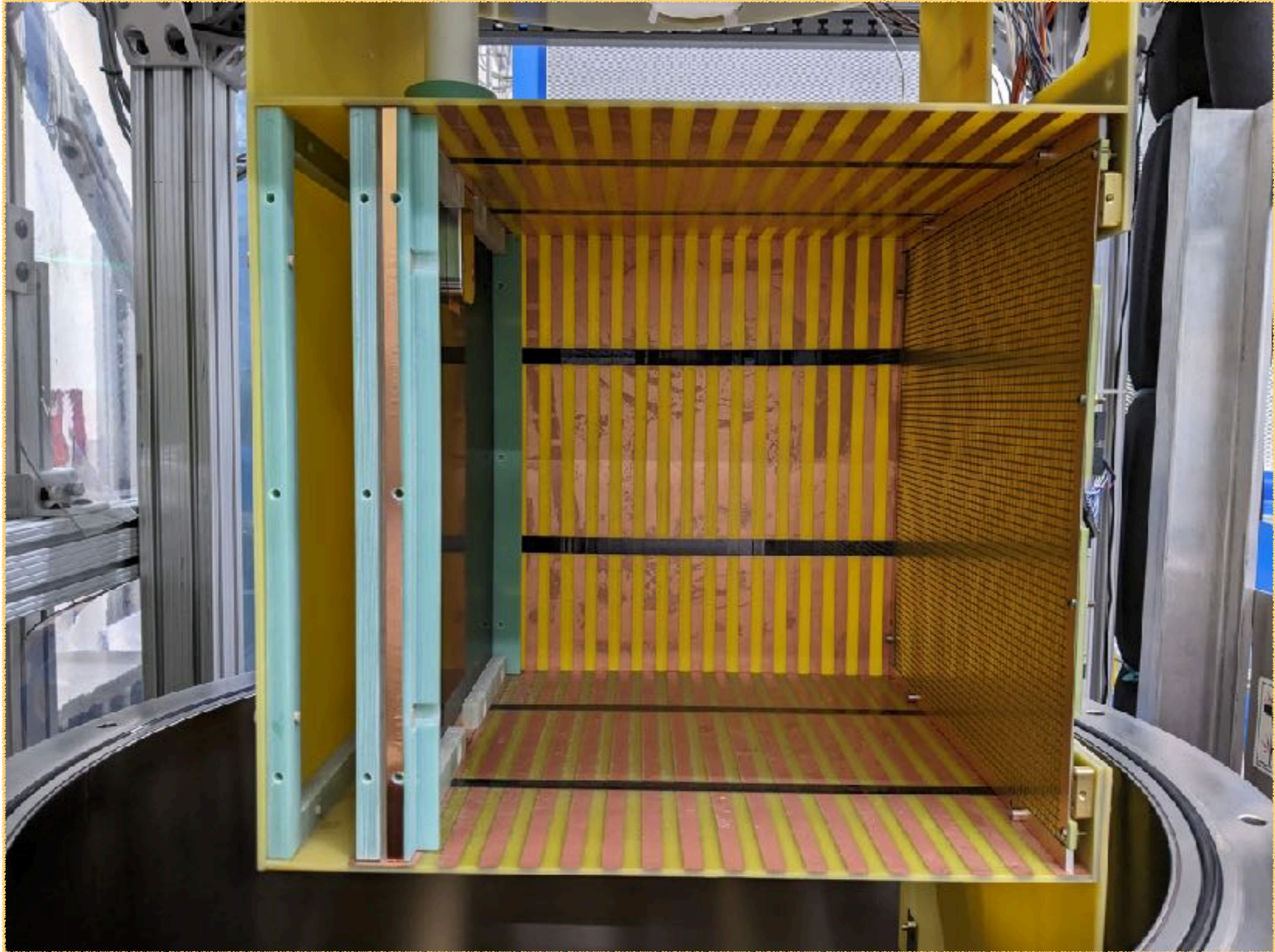
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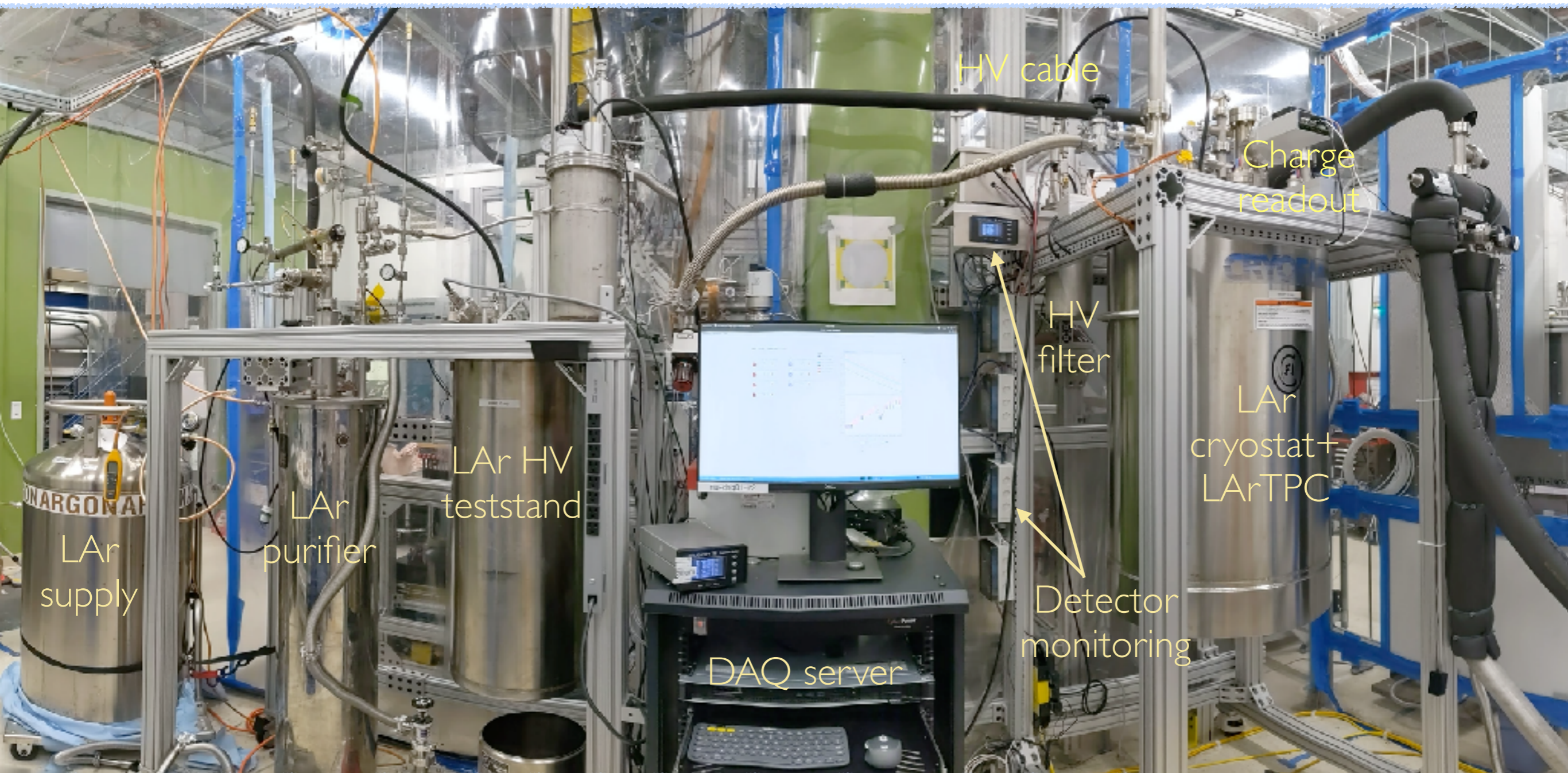
Self-triggering rate



Plots made
by P.Tsang







LAr supply

LAr purifier

LAr HV teststand

DAQ server

HV cable

HV filter

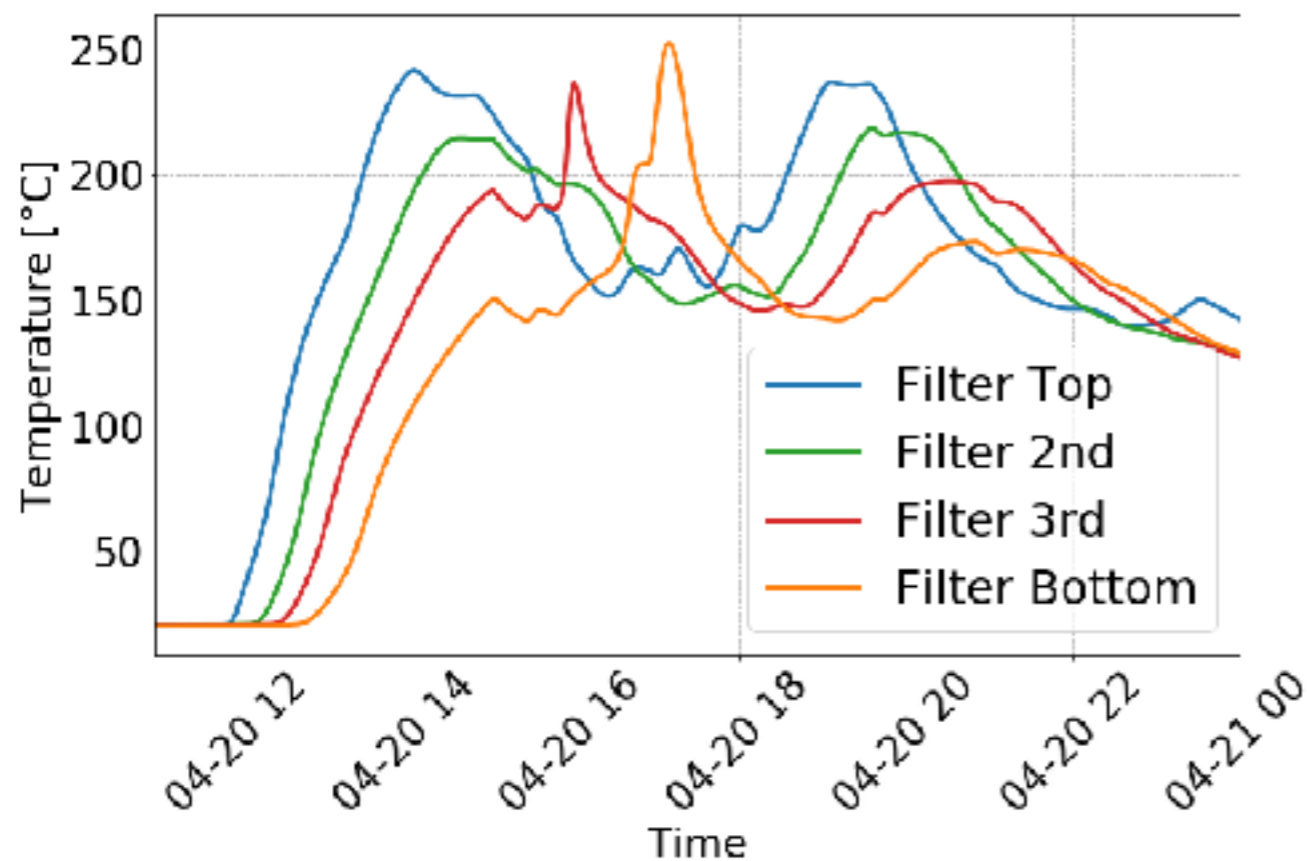
Detector monitoring

Charge readout

LAr cryostat+ LArTPC

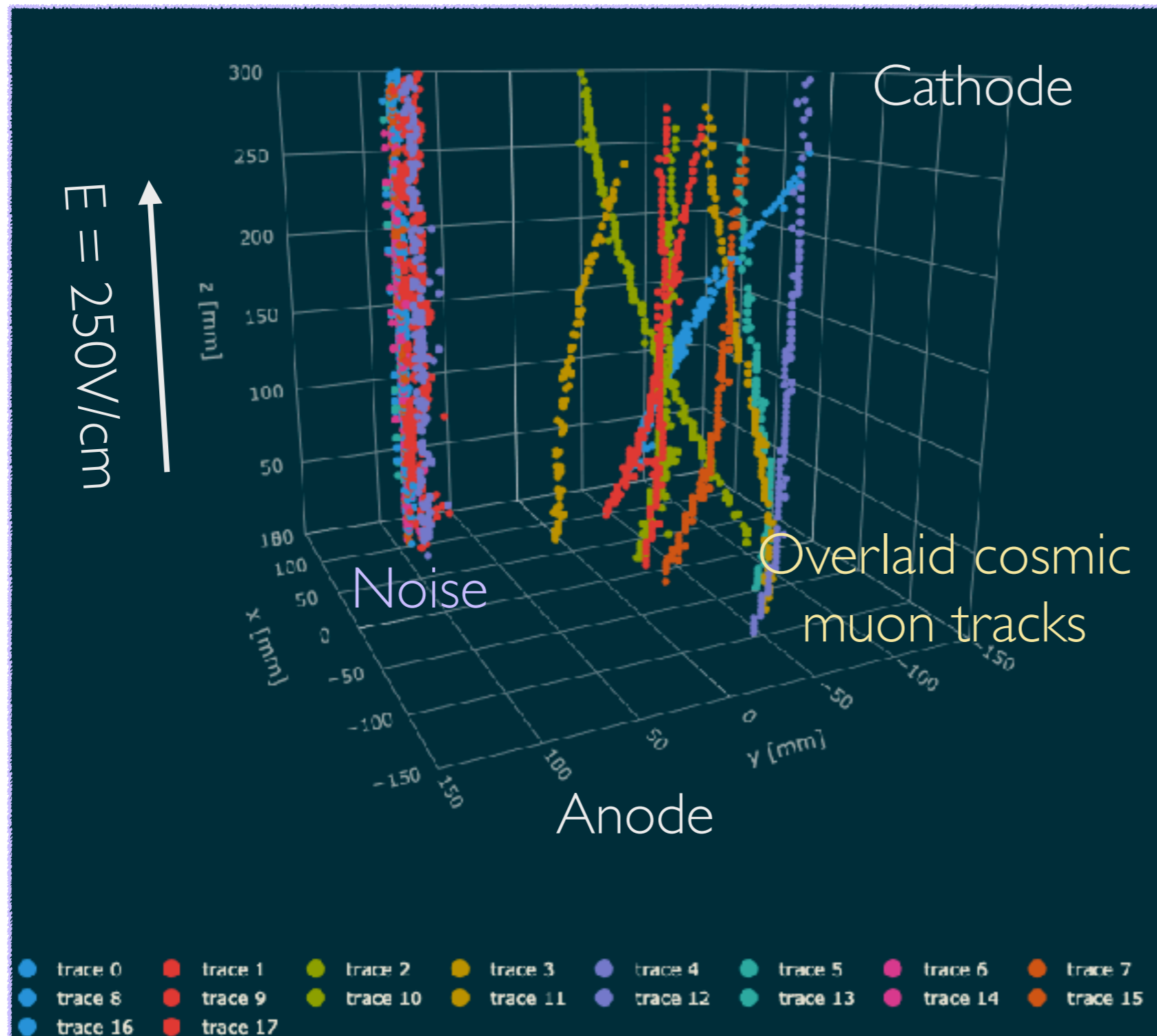
LAr Purifier

- Single pass purifier
- Top: 4.6 kg molecular sieves (water)
- Bottom: 5.2 kg copper sieves (oxygen)
- Ar and 2% H₂+Ar gas to regenerate the molecular and copper sieves



- 15 L/min gas flow/kg
- ~200°C
- $\text{H} + \text{O} \rightarrow \text{H}_2\text{O}$
exothermic reaction

Cosmic Muon Track



$E = 250 \text{ V/cm}$

Electron lifetime
(LAr purity)
 $\sim 128 \mu\text{s}$

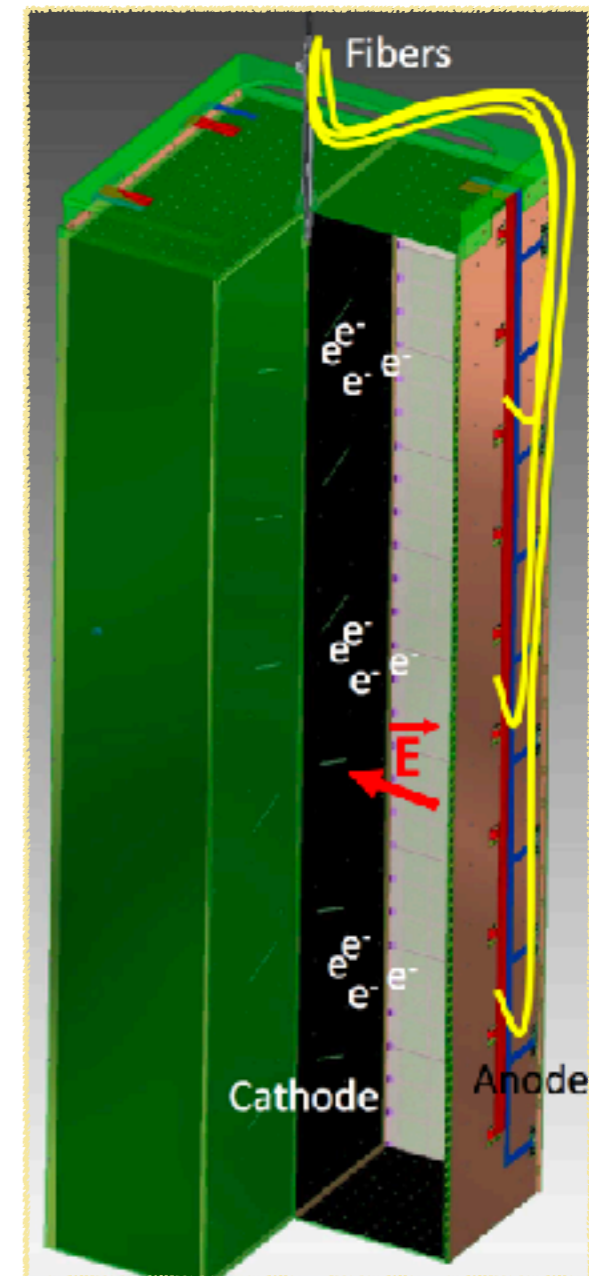
First time seeing
the entire
detector (May
15th 2022)

Plots, analyses
by P.Tsang

Status and Plan

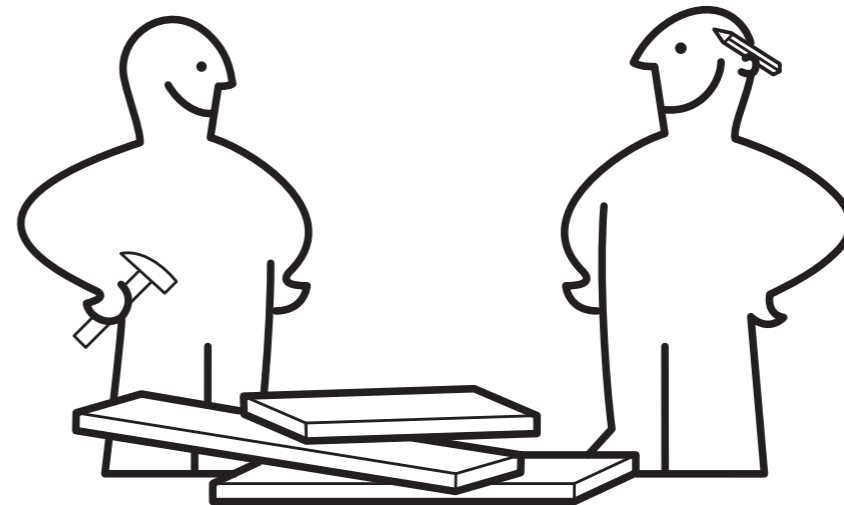
- Upgrade plans
 - Plumbing system to further improve the LAr purity
 - Light detector and synchronization
 - More sensors and controls
 - LAr recirculation
- R&D plans (performance validation)
 - R&D field shells (continuing)
 - Calibration system using laser (UHawaii & MSU)
 - Charge and light detection systems R&D targeting MeV-scale particles

Calibration system by J. Maricic (Hawaii) & K. Mahn (MSU)



Summary

- First LArTPC operating at SLAC
- Aim to validate the performance of the ongoing TPC field shell R&D at SLAC for DUNE ND-LAr
- Enable opportunities for LArTPC R&D
- New collaborators welcome! Contact Yun-Tse Tsai <yuntse@slac.stanford.edu>



SLAC (former members included):

Haufai Auyeung, Dan Carber, Yifan Chen, Bob Conley, Laura Domine, Francois Drielsma, Zach Hulcher, Patin Inkaew, Ran Itay, Dae Heun Koh, Nadine Kurita, Gianluca Petrillo, Norm Picker, Brian Qiu, Gabe Shutt, James Sinclair, Knut Skarpaas, Hiro Tanaka, Yun-Tse Tsai, Patrick Tsang

Michigan State University (MSU):

Dan Douglas, Kendall Mahn, DeMario Ross, Liz Triller

University of Hawaii:

Ranjan Dharmapalan, Alex Dvornikov, Jelena Maricic

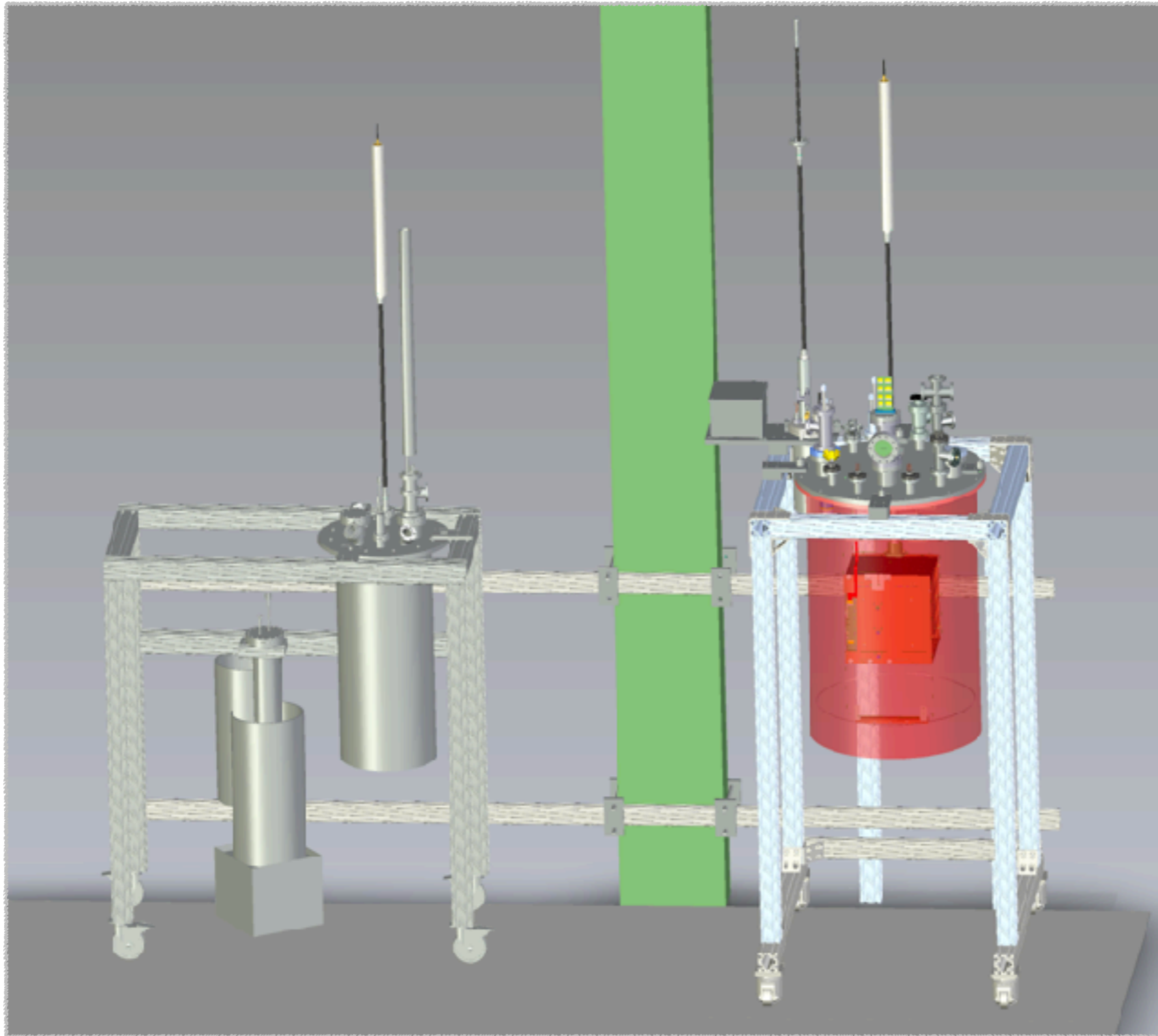
Special thanks to SLAC LZ and nEXO groups



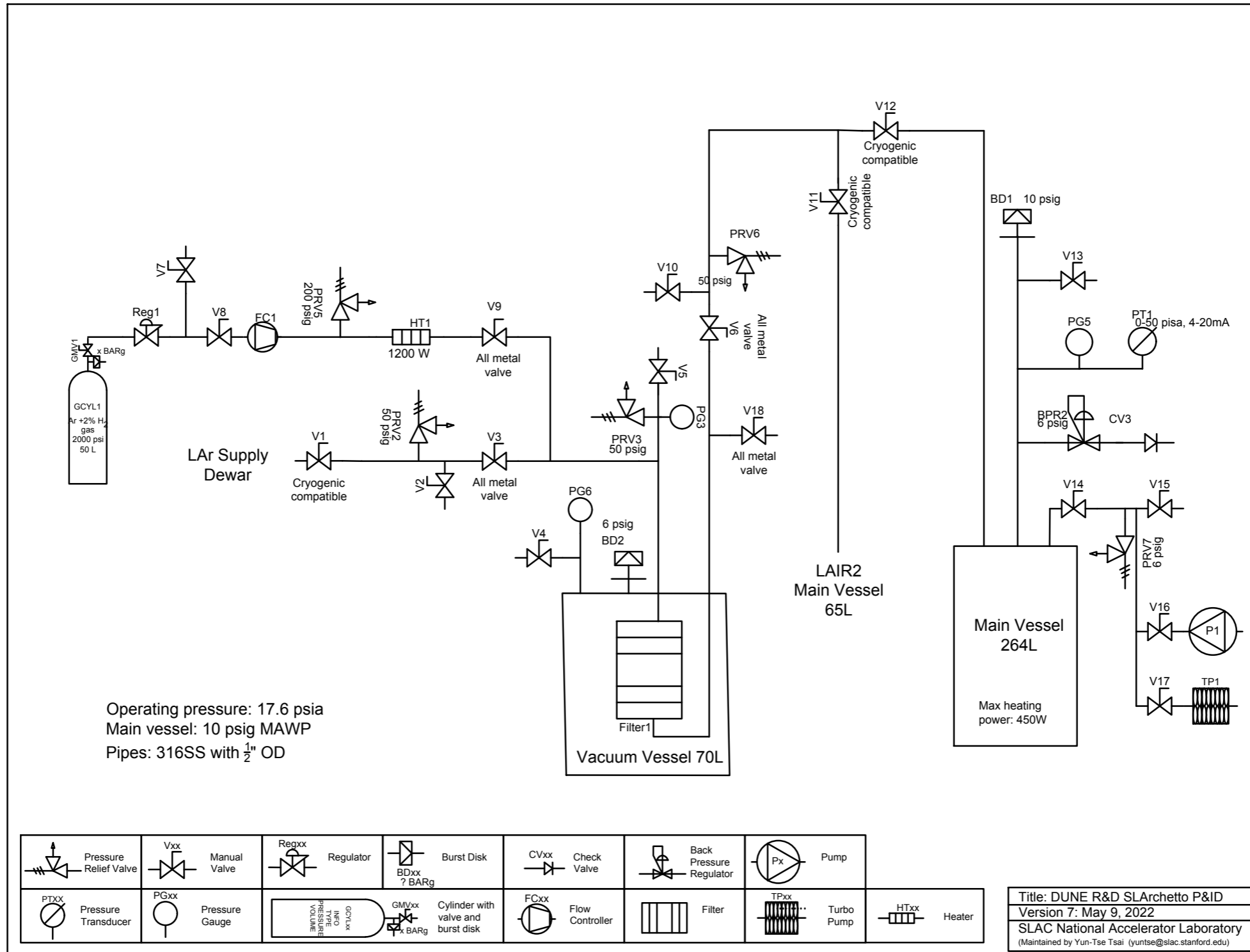
Backup

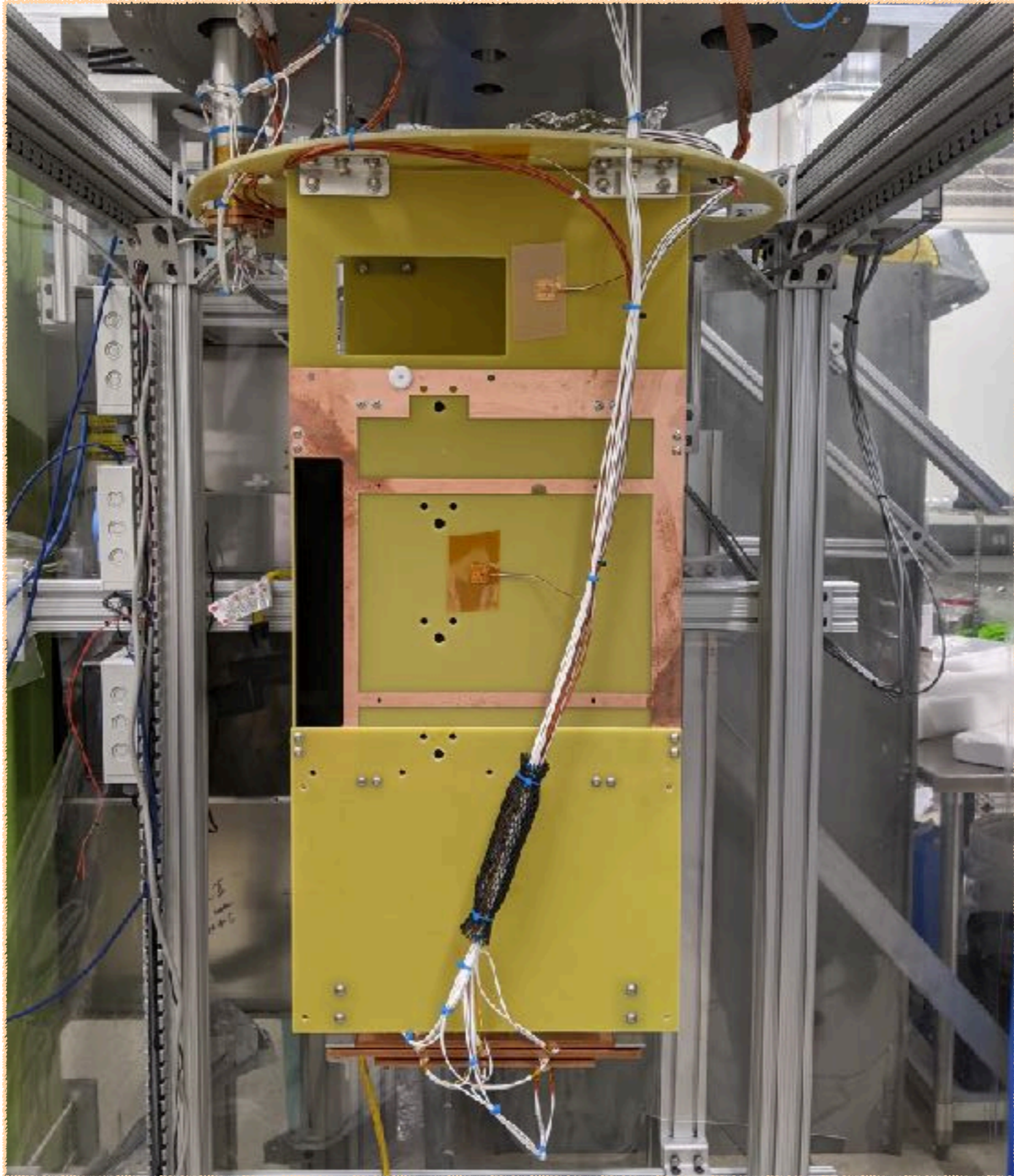


LAr Setup at LNTF

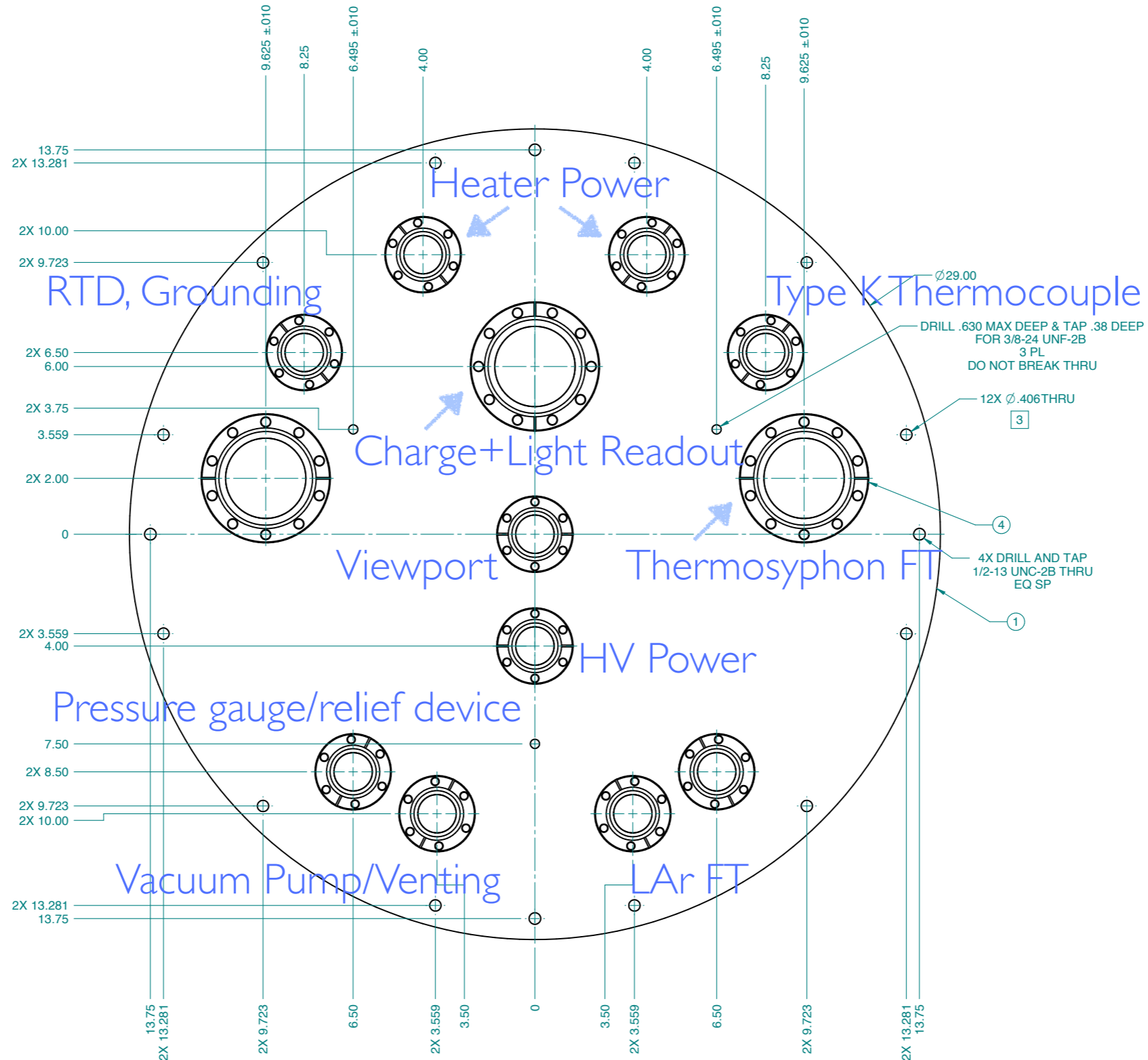


P&ID



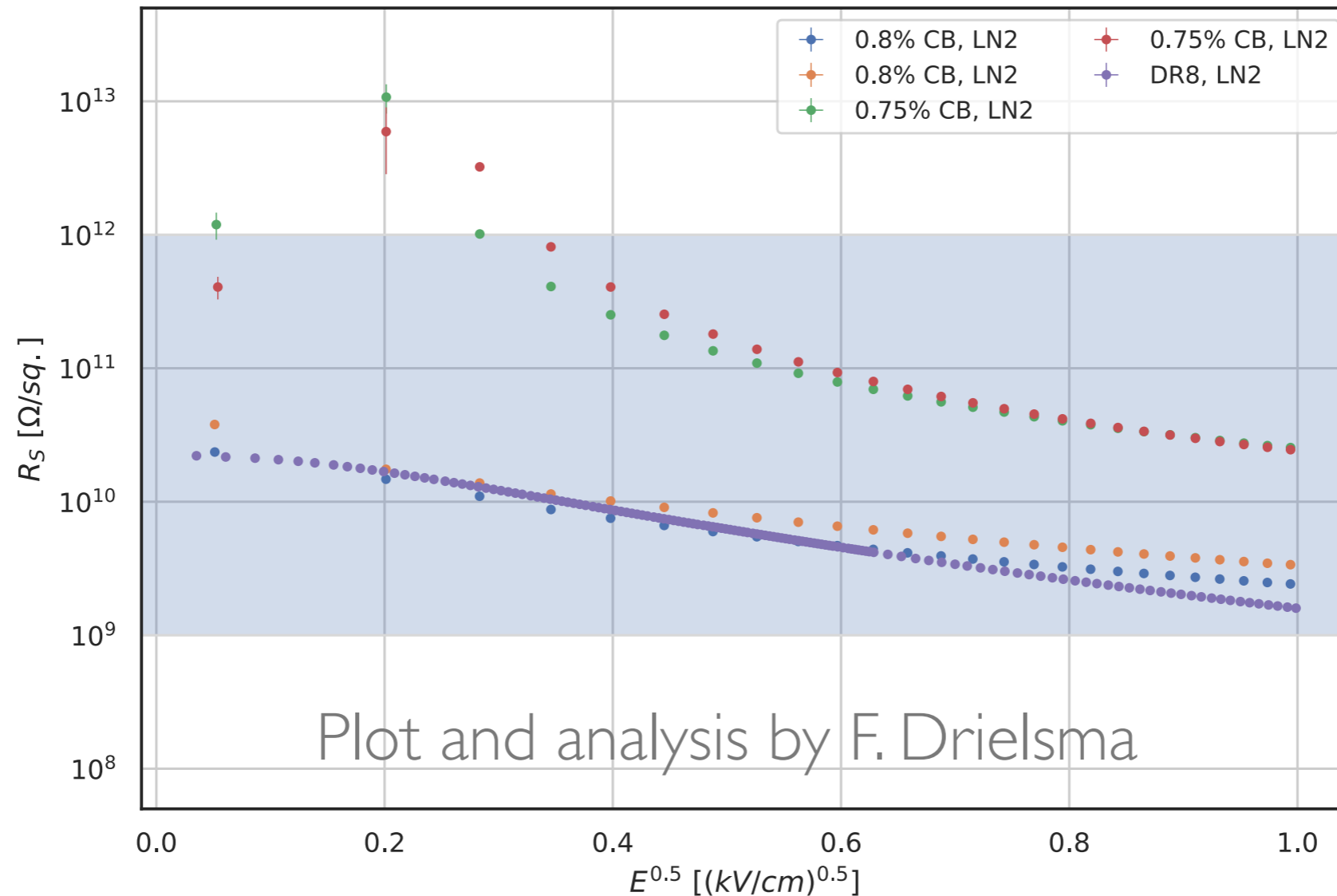


Top Lid

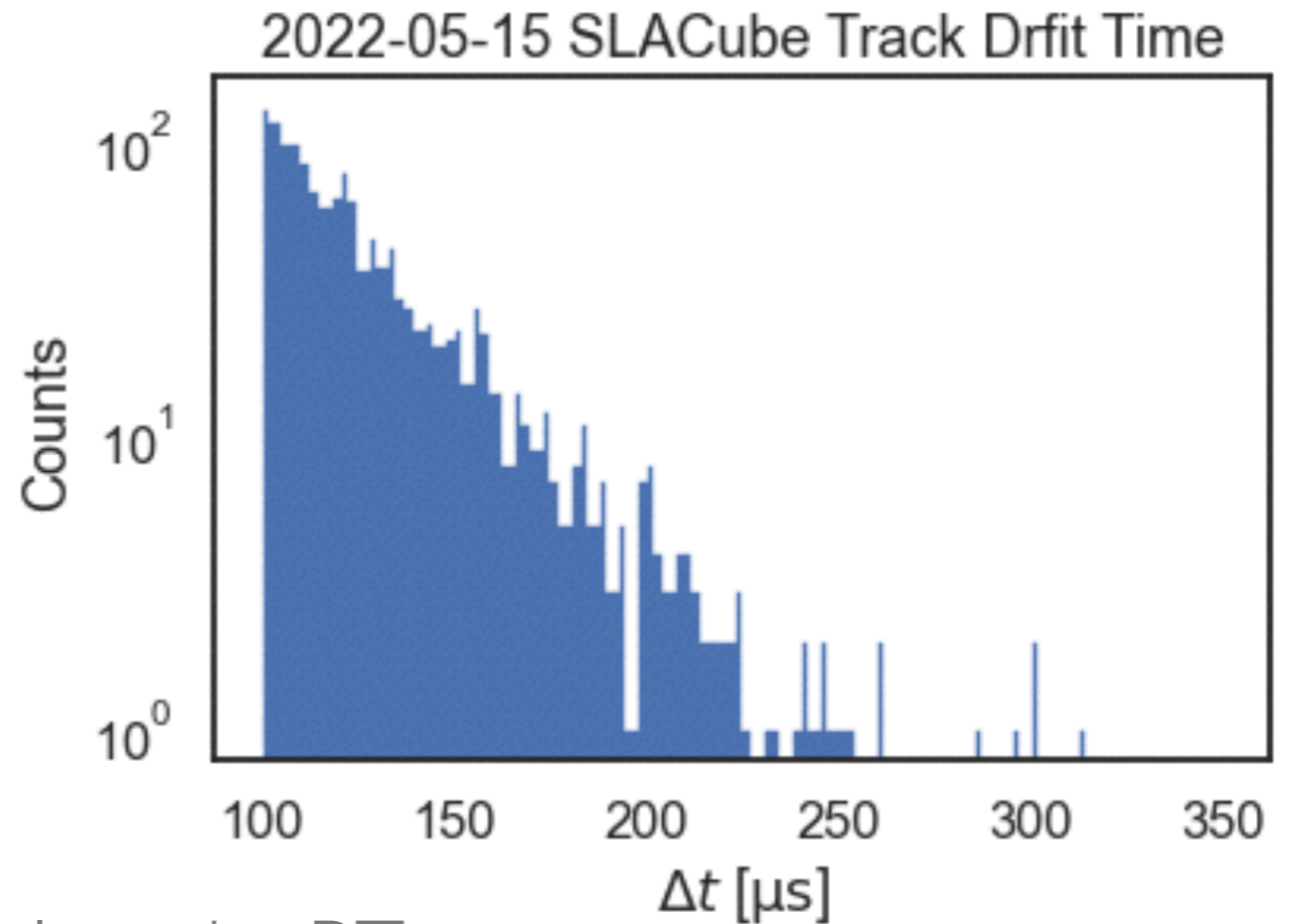
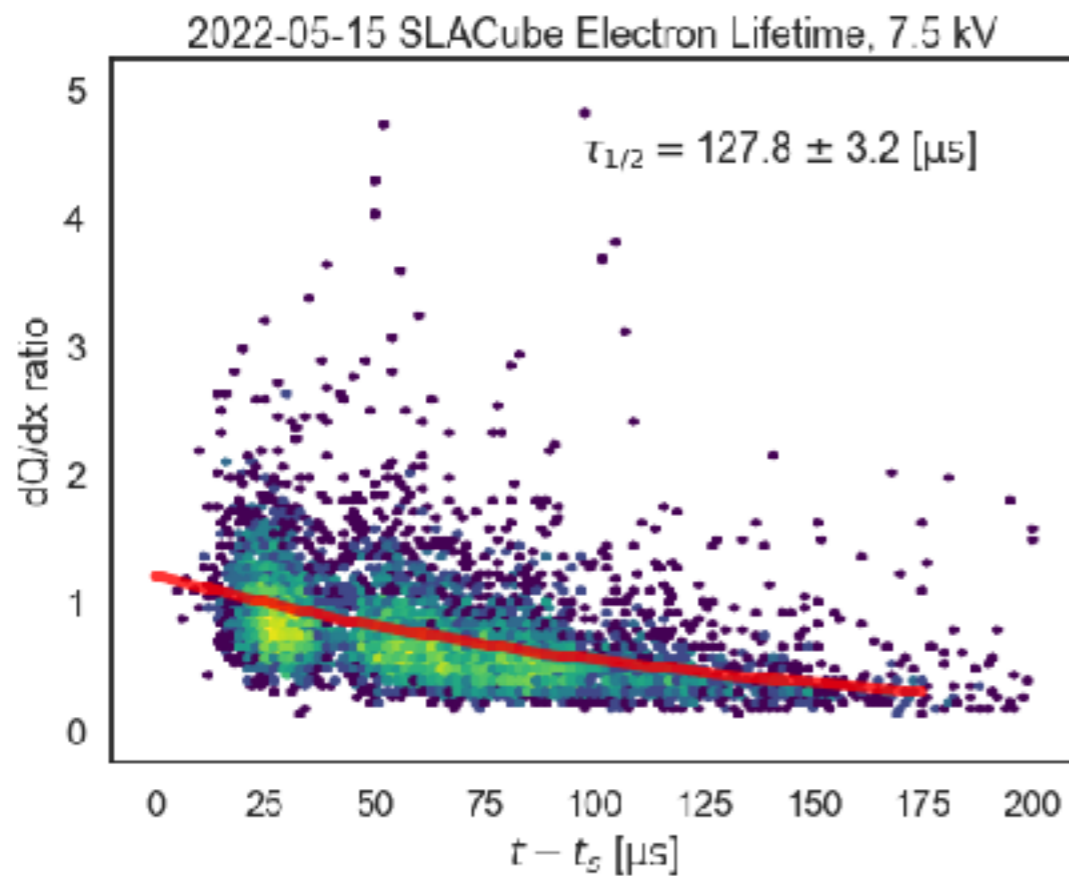


Field Cage Demonstration

- Carbon coating design comparable to DR8-based designs in liquid nitrogen cold box
- To be further demonstrated in SLArchetto/SLACube



May 15th Run



Plots and analyses by P.Tsang