Production and Installation of the LUX-ZEPLIN Cathode High Voltage Delivery System

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for the LZ Collaboration

UC Berkeley

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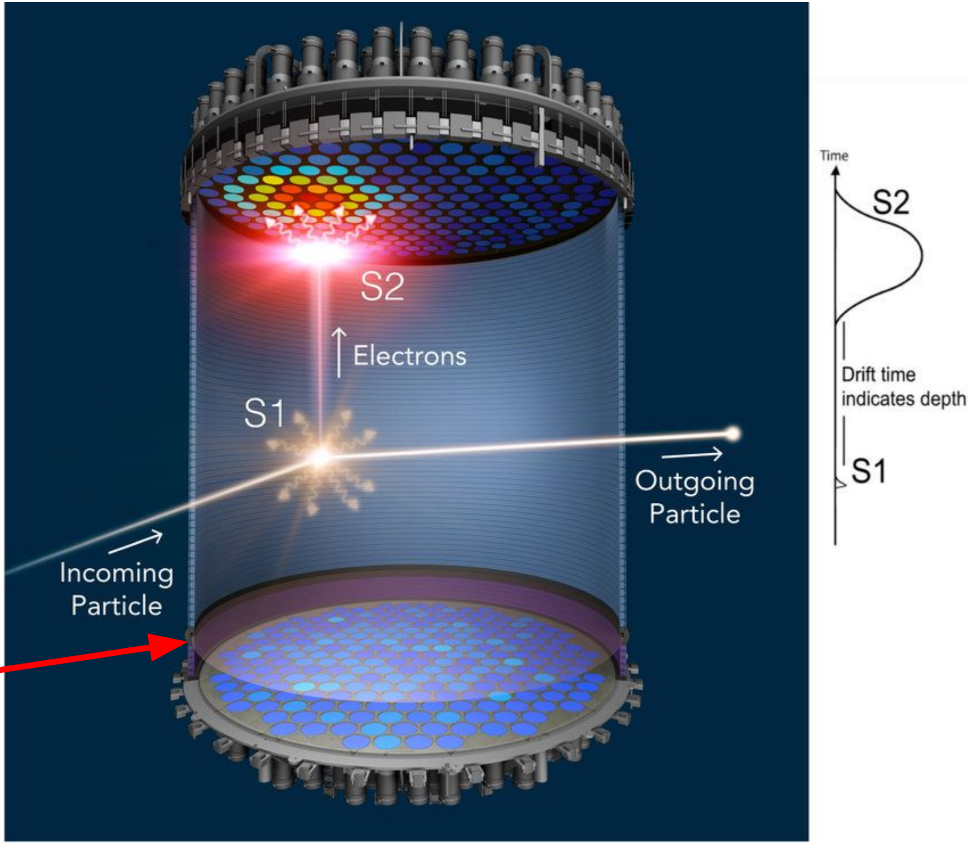
LUX-ZEPLIN

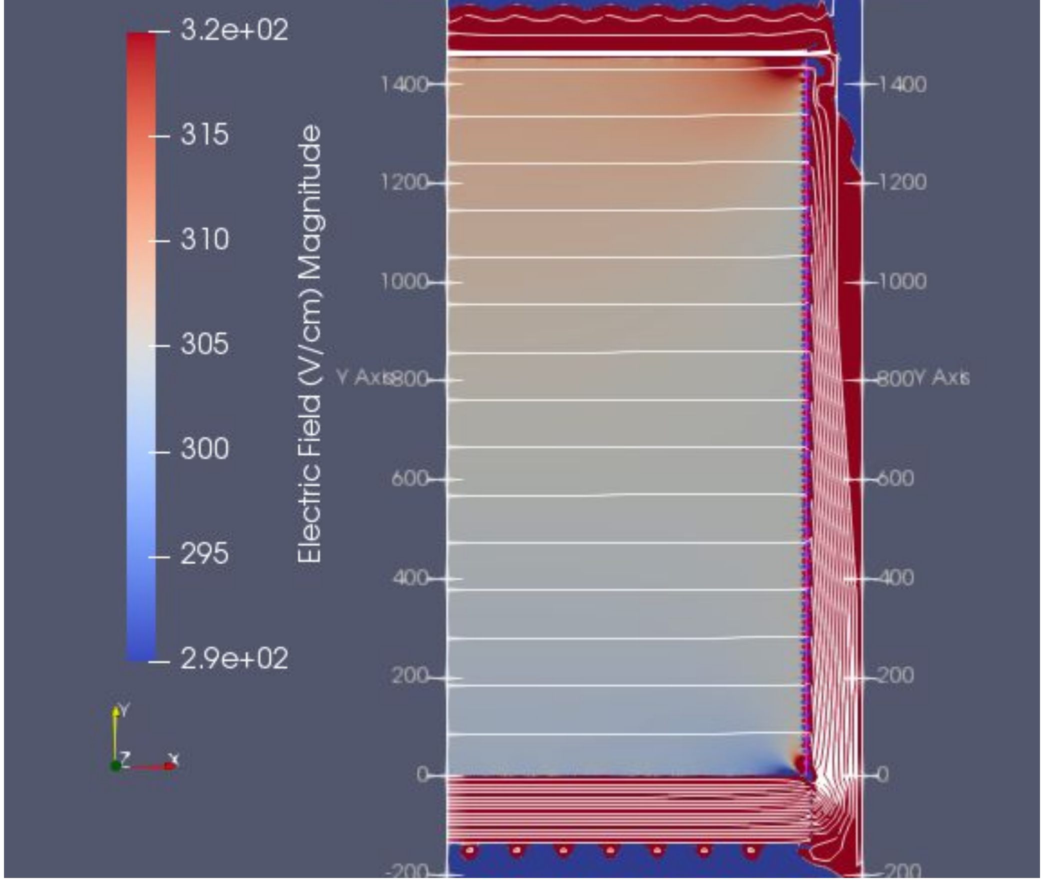
- **LZ** is a 7-ton active mass dual-phase Xenon Time Projection Chamber (**TPC**).
  - Located at the 4850ft level of the Sanford Underground Research Facility (**SURF**) in Lead, SD.
- Physics searches include **Dark Matter Direct Detection** and Neutrinoless Double Beta Decay
- 1.46 m electron drift length Cathode-Liquid Level
- 300 V/cm drift field (requirement)
  - -50kV on cathode
- Carmen Carmona-Benitez gave a status talk for LZ in session C13.



LZ's operation

Electric Fields

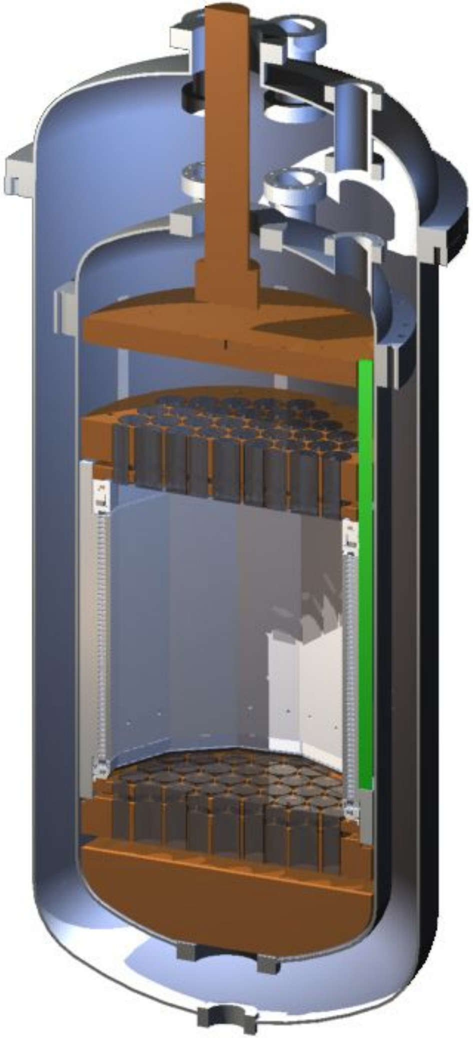
- Uniformity matters:
  - Position reconstruction (fiducialization)
  - Electron-ion recombination
  - Field uniformity increases with cathode voltage
- Field magnitude matters because of electron-recoil / nuclear recoil discrimination.
  - See Vetri Velan's talk in session R13 (4/20 2:42pm)
  - ~250 V/cm is ideal for discrimination



Electric field simulation in LZ (goal cathode voltage)

Typical TPC High Voltage

- Top-down coaxial cable or rod
- Outside the field cage
- Standoff distance

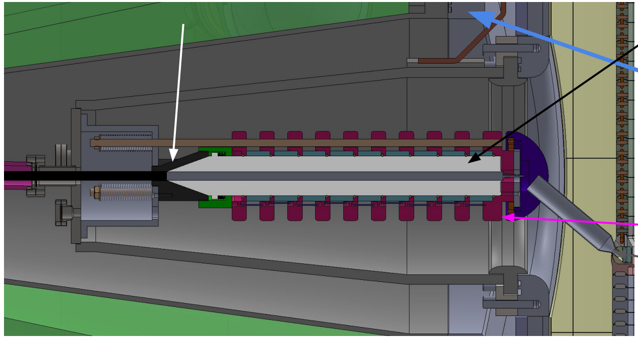


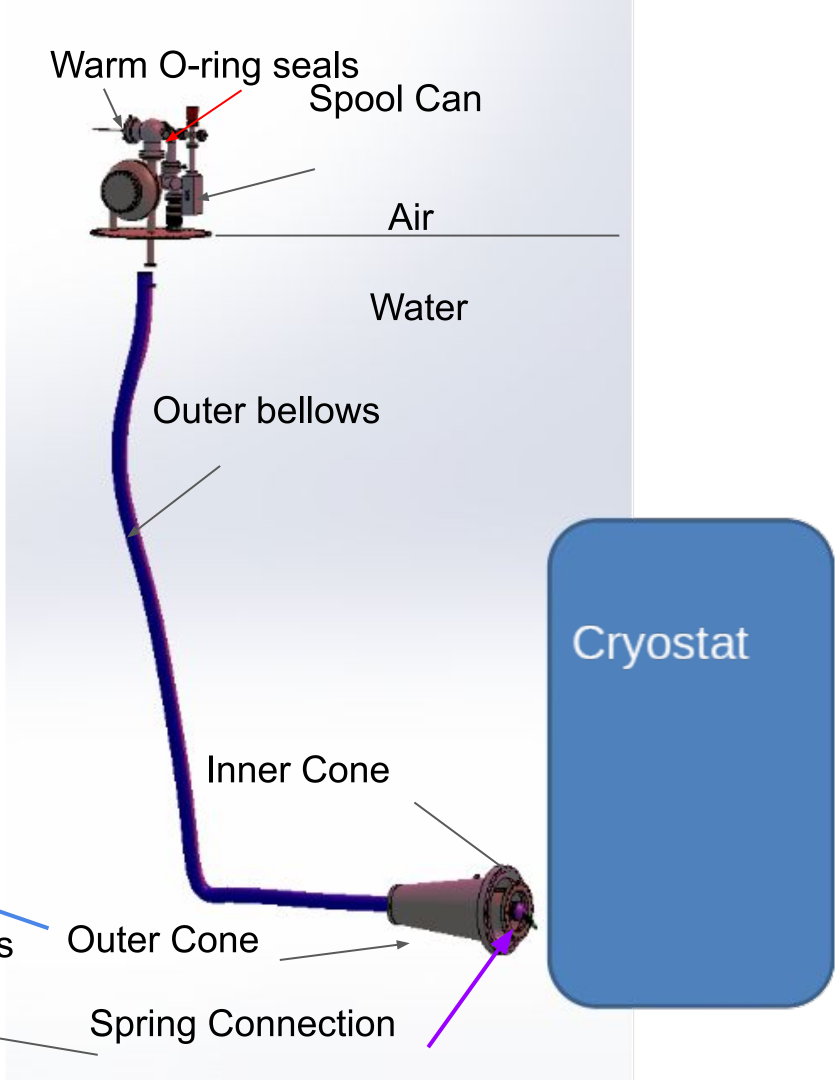
Figures from B. Rebel et al. "High Voltage in Noble Liquids for High Energy Physics." *JINST* 9 (2014) T08004

LZ’s High voltage design

- Goes in from **the side**
- Continuous connection from power supply almost to cathode itself
- **Grading structure** in standoff distance keeps field uniform
- Cable has a warm vacuum seal to air.
  - Two o-ring seals, GXe-Vacuum and Vacuum-Air
  - Thermal stress mitigated with extra loop in the **spool can**
- Trades **electrostatic** difficulty for **mechanical** difficulty.

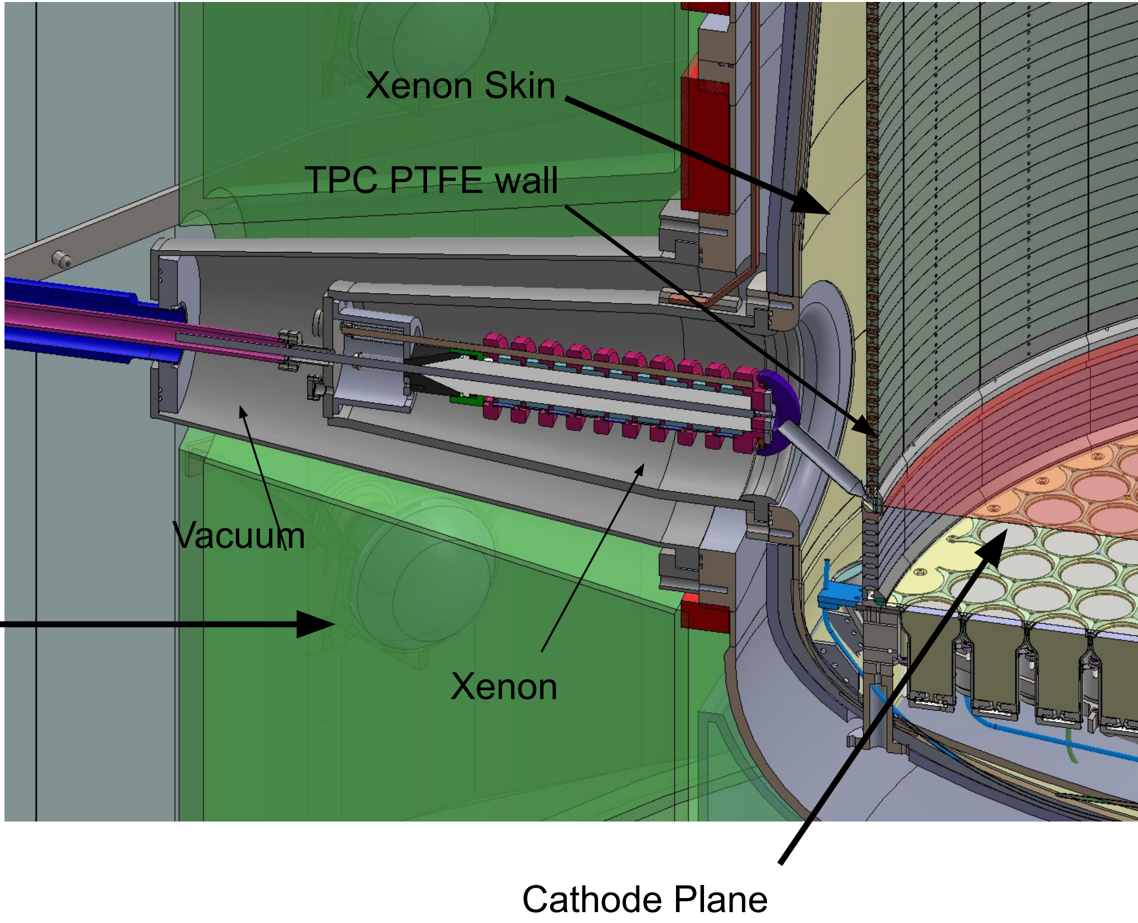
HV Stress cone



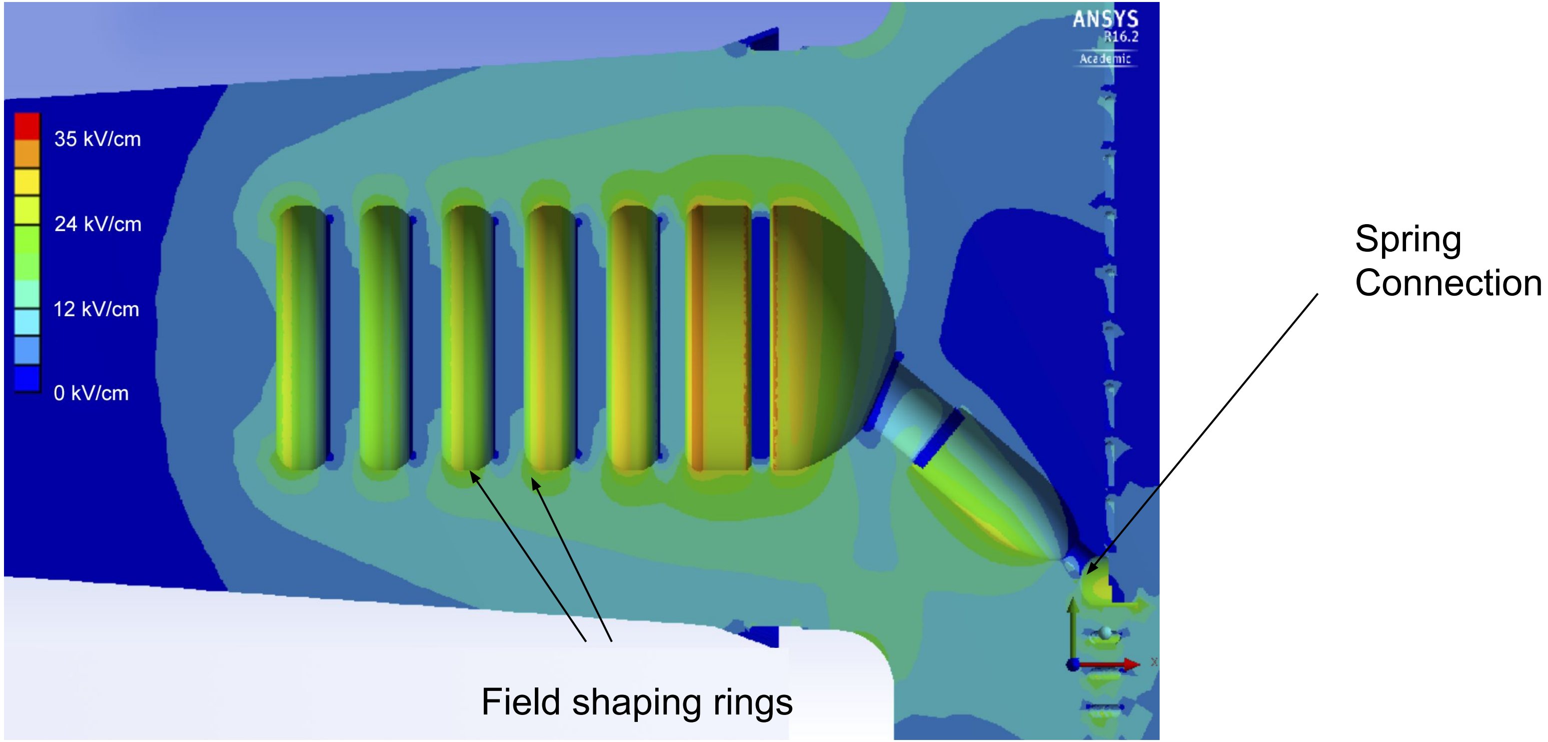


Skin Veto

- Between the ICV wall and the TPC
- Veto of events from outside detector/detector components.
- Going in from the side keeps the field low& uniform in the skin region.
- Also seen: Outer Detector (**OD**). Gadolinium-Loaded Liquid Scintillator for neutron veto.



Grading Structure Electric Field



Prototype testing

- Full-scale prototype was built, tested in LAr.
    - LAr and LXe have similar breakdown fields*.
- High voltage was ramped up to 120 kV.
- Excess light production examined with a PMT and fiber optic cameras
- Transient current monitored with a pair of charge-sensitive amplifiers.
- Period of 1 hour without light -> Pass when correcting for area, purity.

* [Direct comparison of high voltage breakdown measurements in liquid argon and liquid xenon]() - Tvrznikova, L. *et al.* JINST 14 (2019) no.12, P12018 arXiv:1908.06888 [physics.ins-det]

Construction (actual grading structure)

All construction took place at LBL's clean room prior to shipping to SURF.

The grading structure, with wave spring, which is captured by the cap of the spring connection.

Ethan Bernard (left), Reed Watson (right)

Construction (Routing)

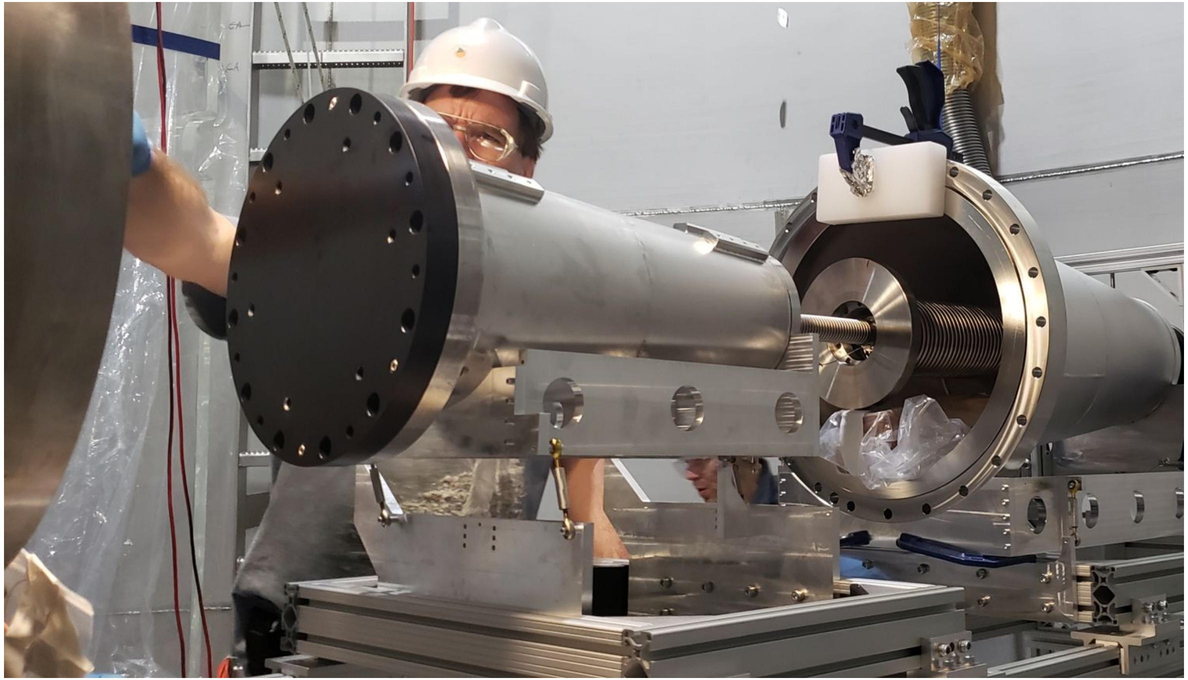
- Cable emerges from **Inner Cone**
- **Radon Guard** covers the cable in LXe
- Vacuum-Jacketed (**VJ**) hose routes the cable in Xenon Space.
- **Outer Bellows** routes the vacuum space from the **outer cone** to the top of the water tank.
- **Spool Can** attaches to the top of the water tank

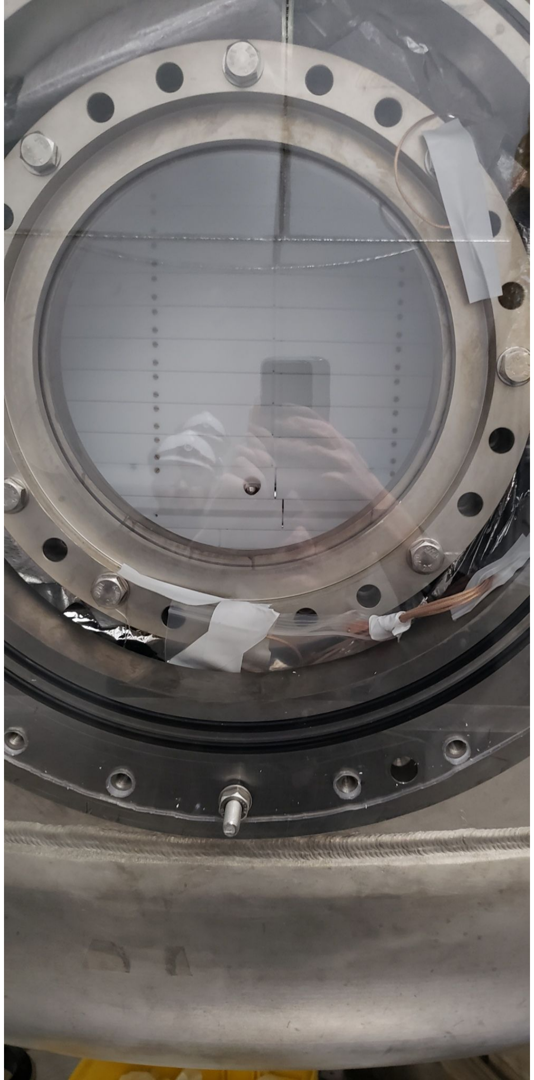
Shipping

Installation into the water tank

- Entire structure had to be lowered from the top into the water tank.
- Captured by the HV cart, then rotated sideways

Inner Cone Extraction / HV Cart





Above: the high voltage cart, made to quickly slide the cones in place horizontally
Right: the cathode connection

Installation (attachment to electrode)

The spring connection made between the grading structure and the cathode

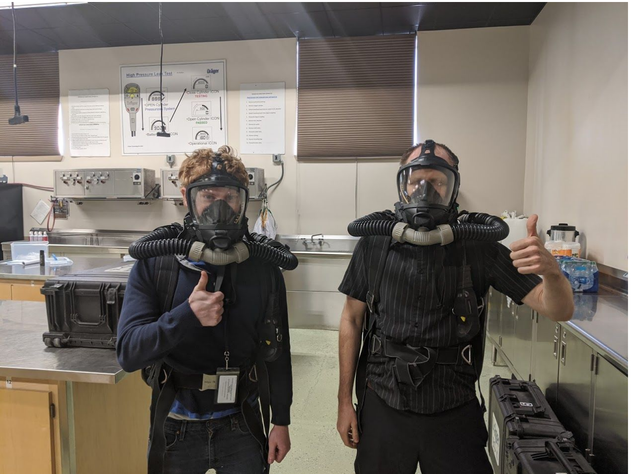
Derek Lucero (front) and I sealing the inner cone to the ICV.

Oxygen masks had to be worn because of the N_2 purge.

Summary

- The Cathode High Voltage feedthrough allows for an instrumented skin veto in LZ, along with more efficient use of the cryostat volume.
- The feedthrough was **assembled** and **tested** at LBL before transport to SURF.
- At SURF, the feedthrough was **connected** to the LZ TPC.
- With this, LZ's two cryostat vessels are **sealed.**

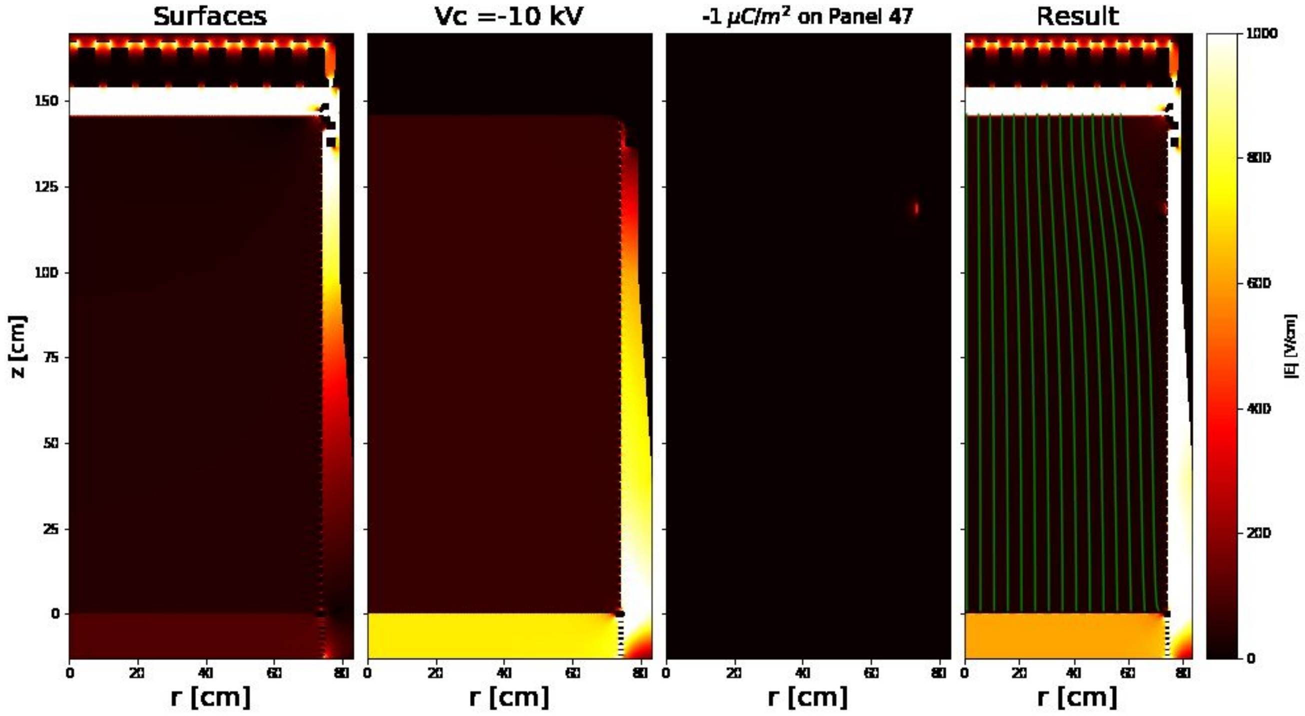
Shortly after attaching the outer cone to the OCV, it was wrapped in plastic.



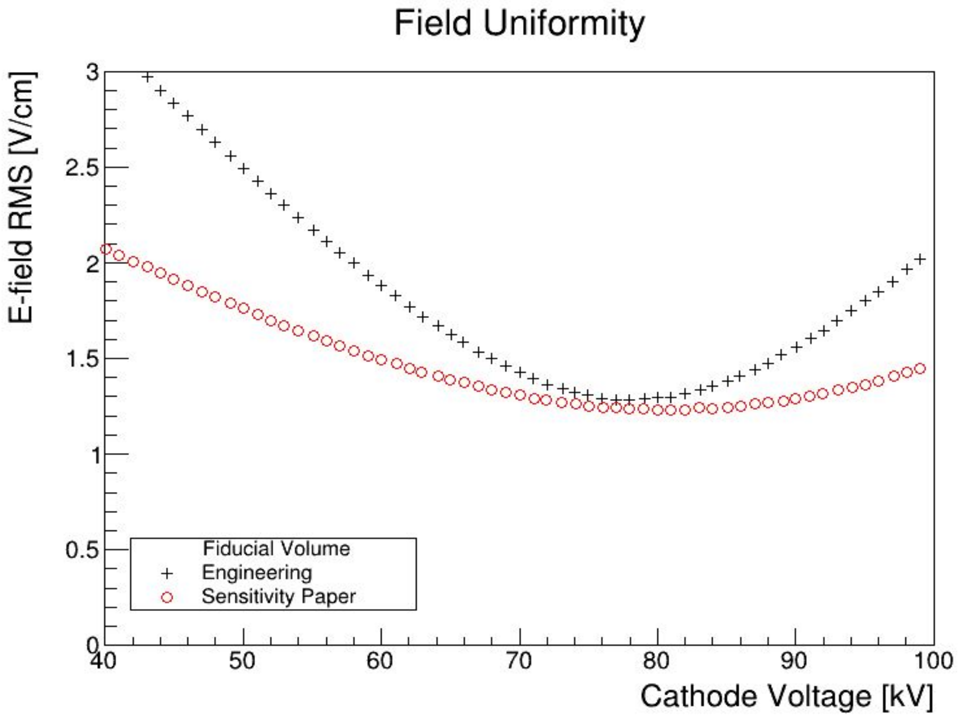
Thanks for listening!

Backup Slides

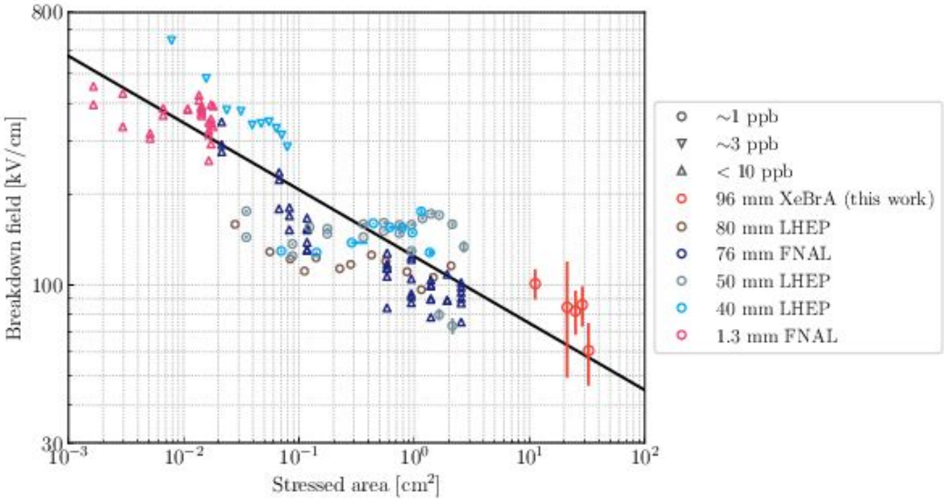
Field Uniformity



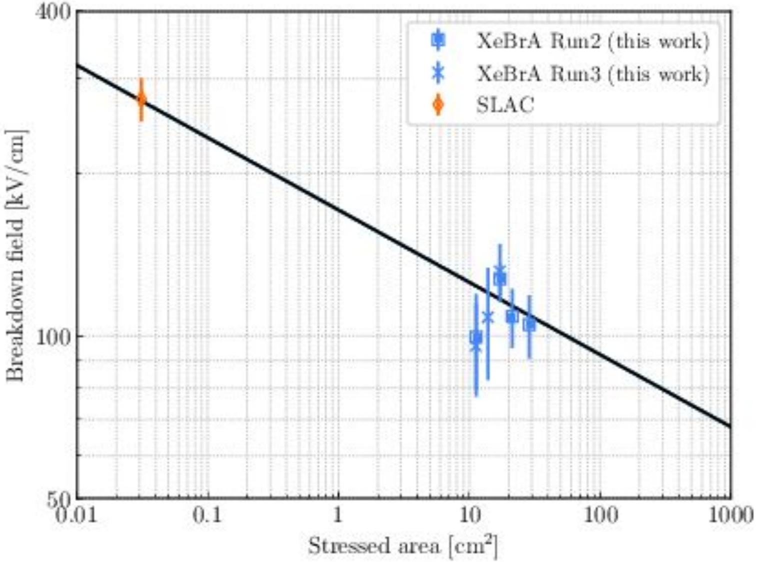
Field Uniformity



Liquid Argon / Liquid Xenon



LAr dielectric breakdown



LXe dielectric breakdown

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