Update on Cathode High Voltage Research and Development for LUX-ZEPLIN

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Project

- The LZ Collaboration
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- Will Waldron
- Lucie Tvrznikova
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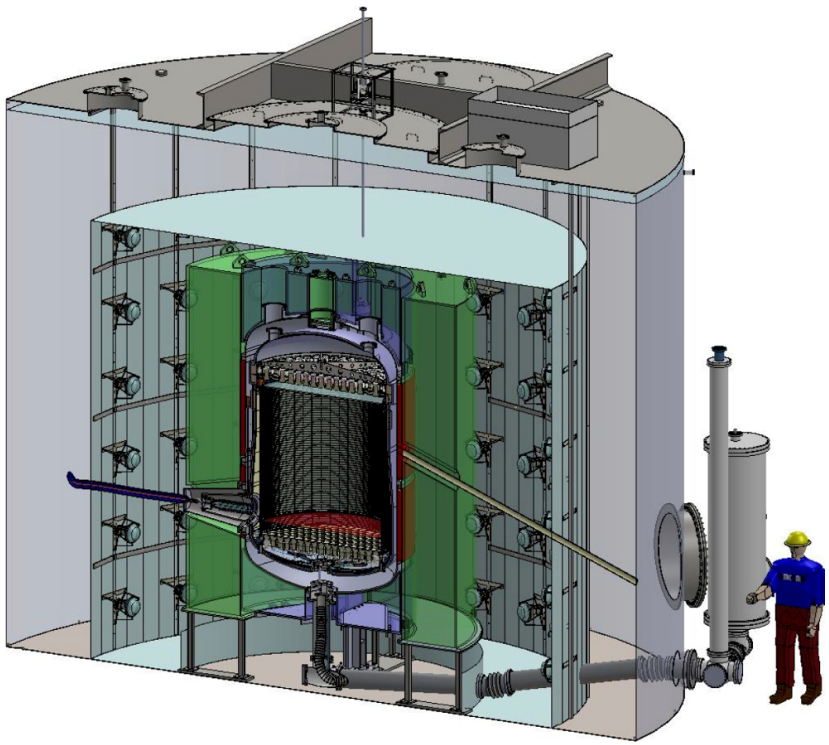

Figure 1: A schematic of LZ

LUX-ZEPLIN

- LZ in a 7-ton active Xe dual-phase Time Projection Chamber (TPC)

- DM WIMP hits Xe atom, which produces prompt scintillation (S1) and ionization, which later creates electroluminescence(S2).

- **All signal comes in the form of light detected**, so anything that produces light will be relevant for the experiment.

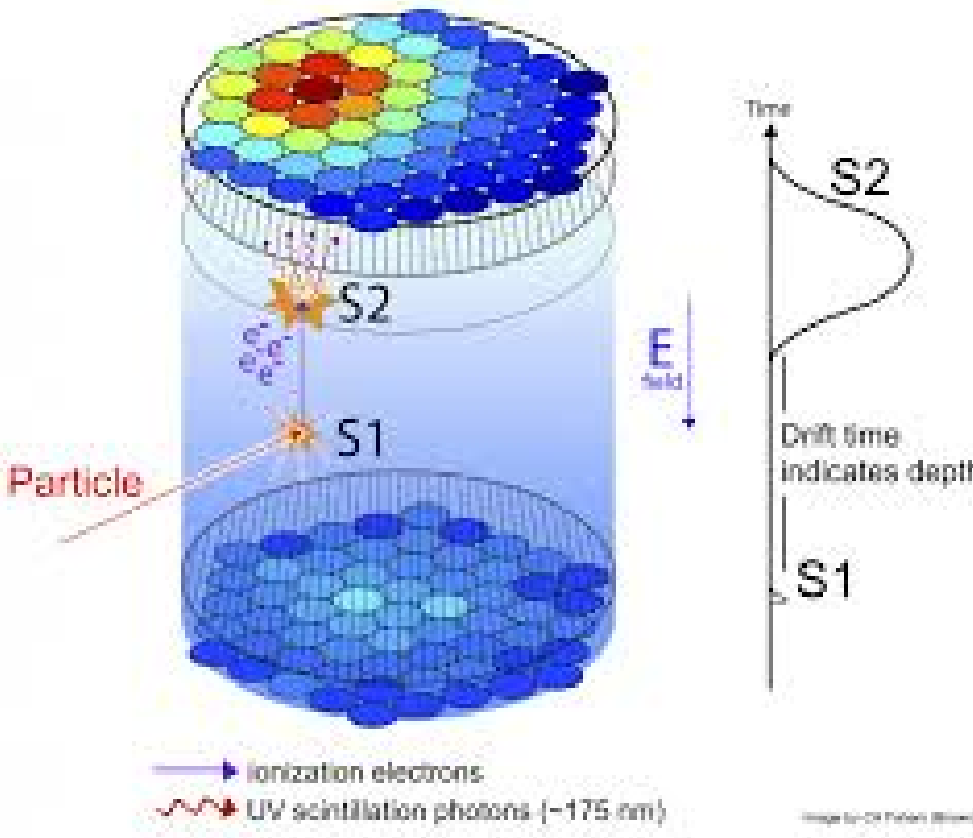

Figure 2: The functionality of the LZ TPC.

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Electric fields

- Cathode produces 3 field regions: extraction region forward/drift field region (FFR), reverse field region (RFR), above which the cathode resides.

- 2.5 times the size of LUX, goal voltage is 10.75 times the voltage the LUX data taking voltage, **many** times the effort.

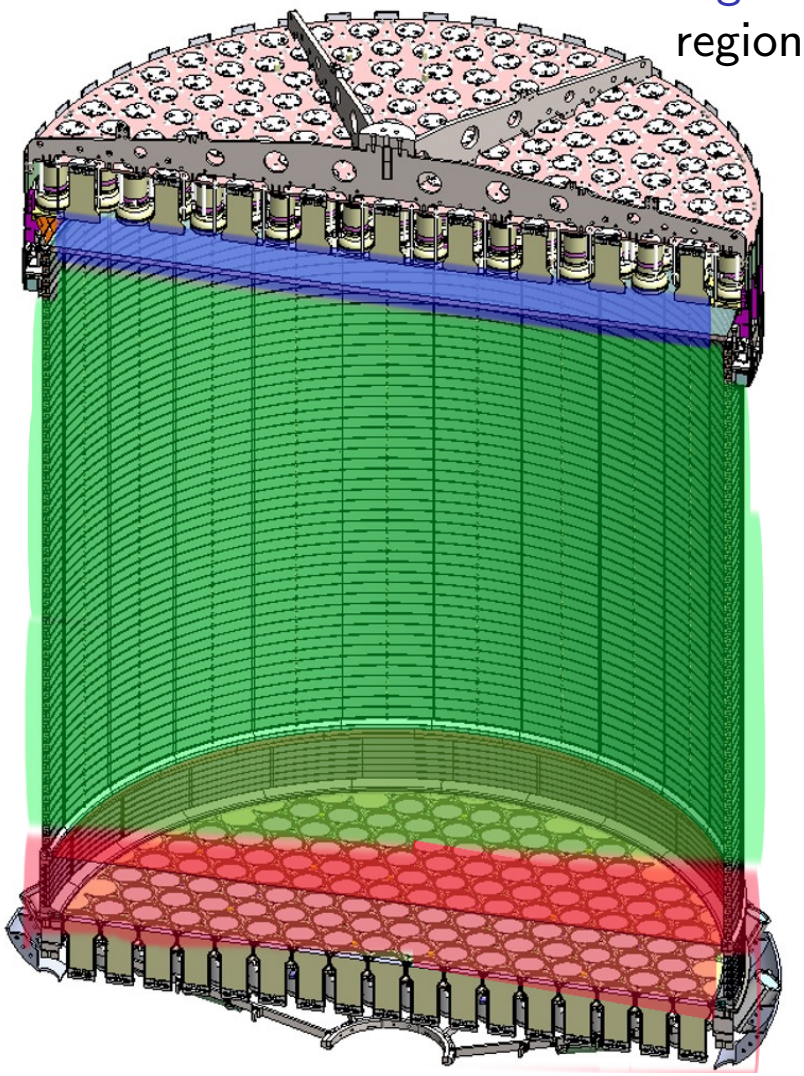


Figure 3: The electric field regions of LZ.

High Voltage

- LZ needs to be sensitive to weak signals, so any additional light could harm the experiment.
- Sources of light: radioactivity (materials and leaks), electroluminescence, breakdown, which scale with volume.
- Additionally, leaks will spoil purity.

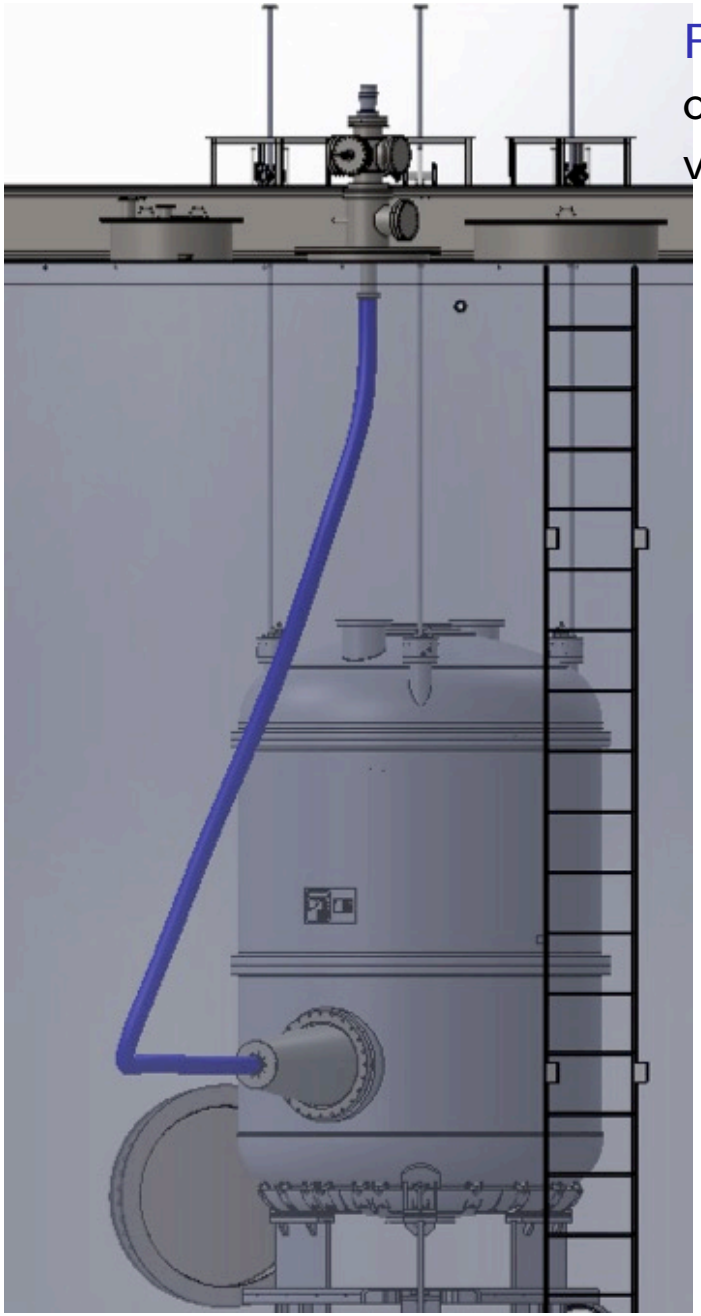


Figure 4: The view of the outer cryostat and high voltage feedthroughs.

Cable

- Cable layers from inside: conductive plastic(HV), separated by an insulating layer, conductive plastic (ground), braided wire (ground), and plastic sheath.

- Cable can an seal to an o-ring, rated for 150kV (50% higher than goal voltage), and thermally matched.

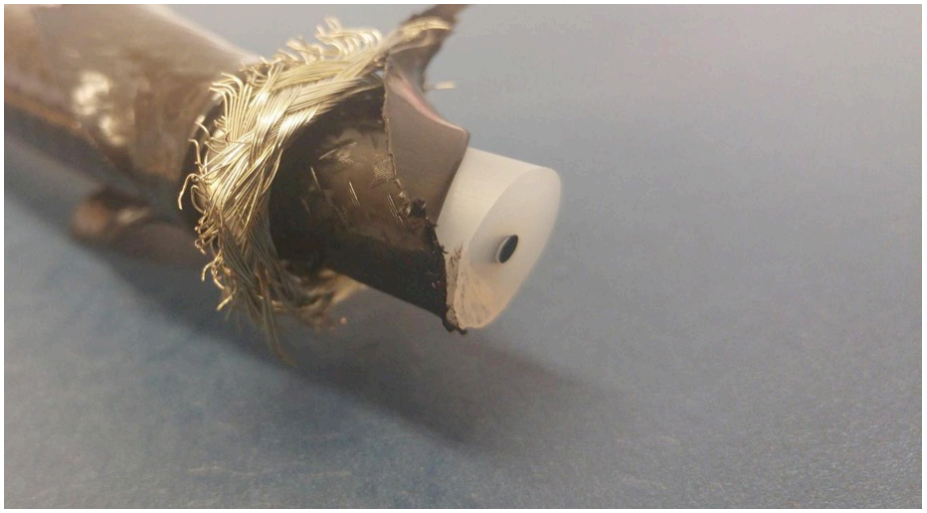


Figure 5: The layers of the high voltage cable.

Feedthrough - hot end

- Hot feedthrough takes the CHV cable from air to the Xe filled bellows in the water tank.
- O-rings seal the cable to the vacuum chamber, ensuring robustness against small leaks.

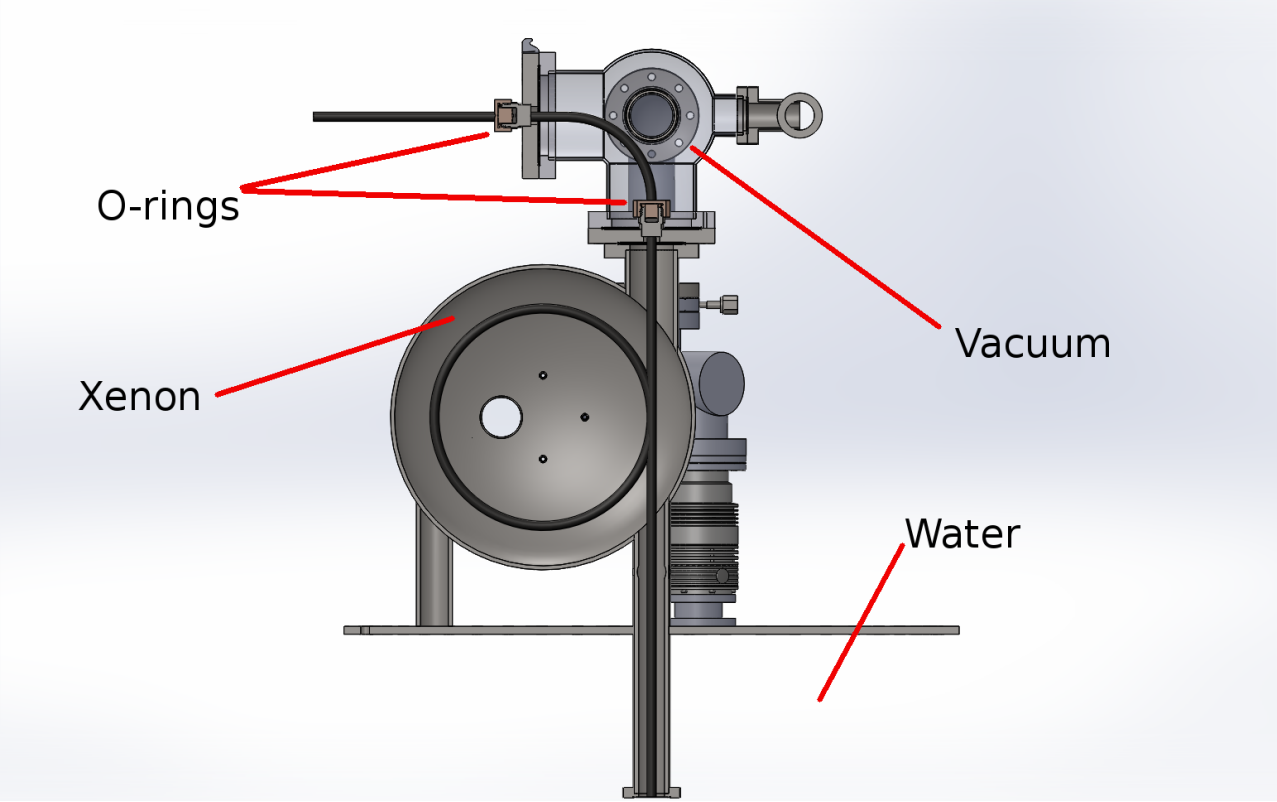


Figure 6: The warm end feedthrough.

CHV connection

- Cable grounding stops, connects to polypropelene stress cone and Xe displacer (cryofit).
- Insulator stops, center wire connects to grading cap, which connects to a spring connection to cathode.
- Ringed resistor-divider bridges HV to ground.

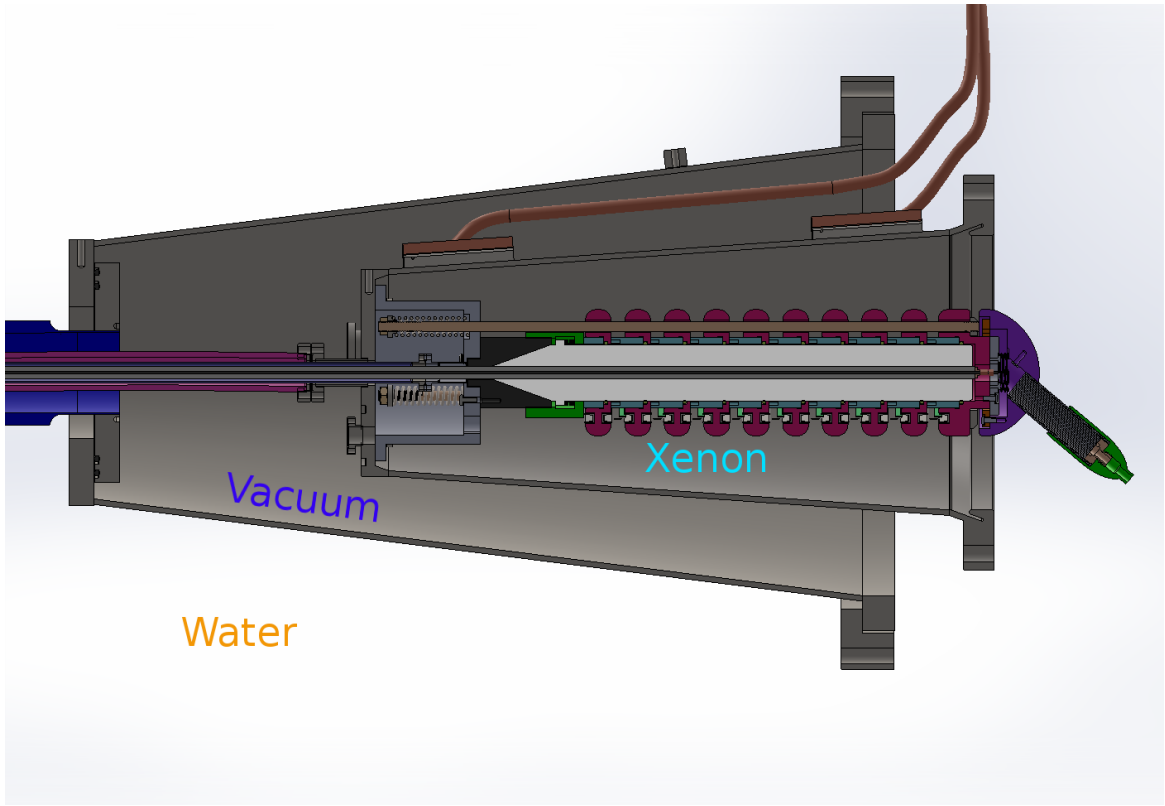
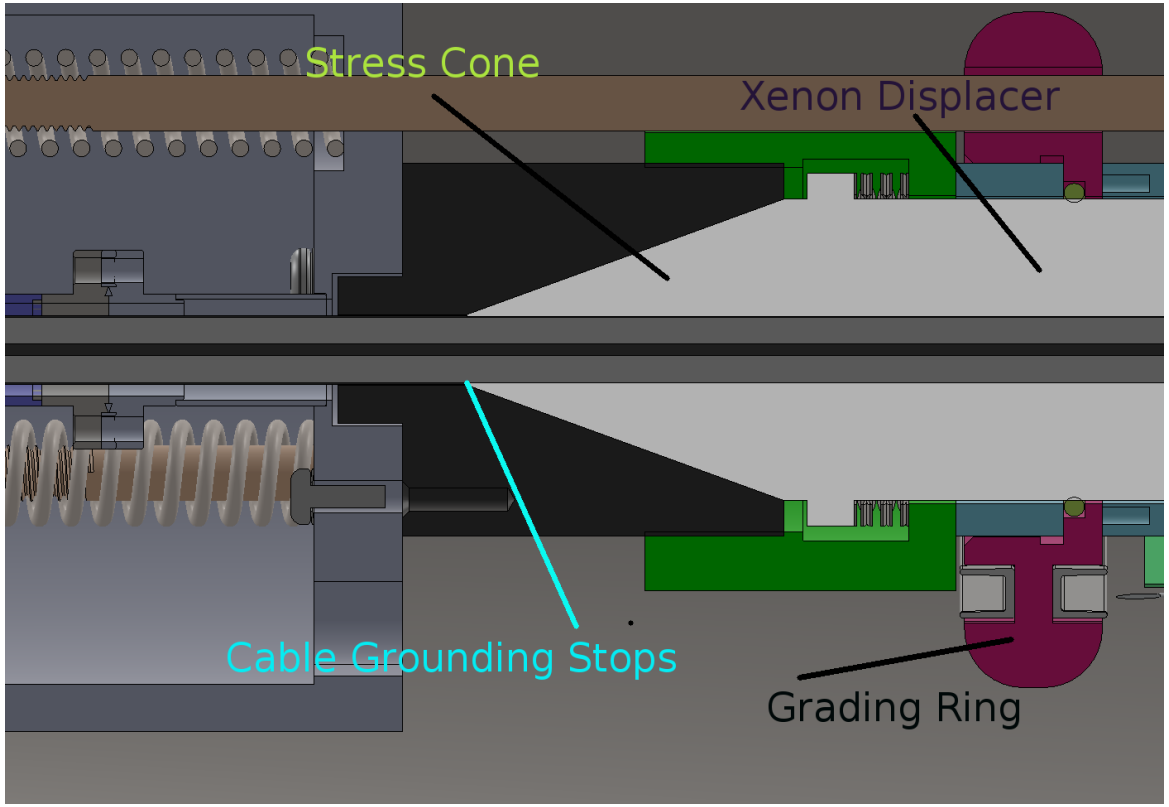
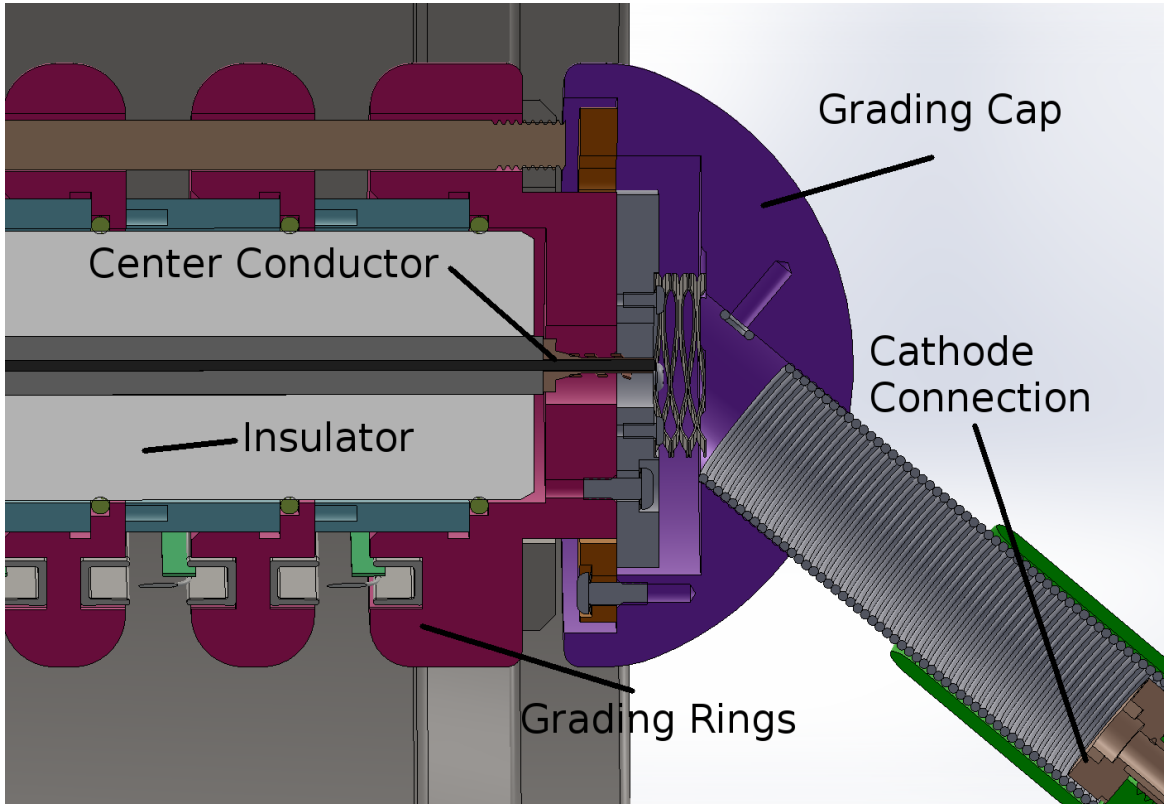


Figure 7: The cross section of the CHV connection.

Stress cone and Xe displacer



Center conductor connection



CHV connection testing at LBNL-Design

- Goal: test the CHV connection and **see if any new light is produced** and that all the parts survive cold cycling.

- Test at goal voltage, then to failure in LAr.

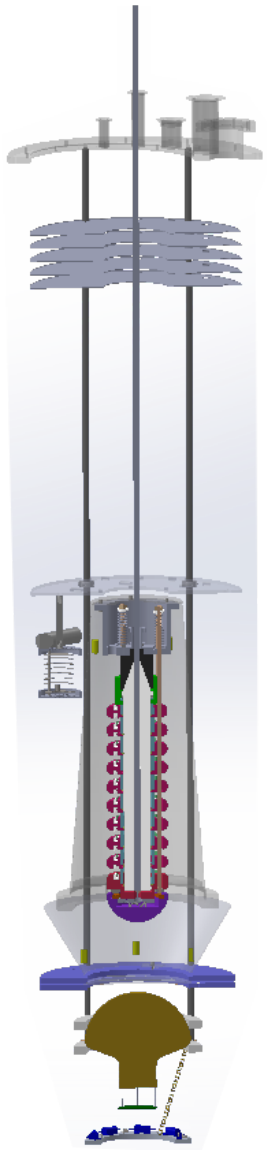


Figure 8: CHV test stand model.

Cathode High Voltage Testing at LBNL - Channels

- PMT signal indicates photon production.
- CCD camera locates the sight of large signals.
- Purity monitor measures electron lifetime.
- Charge sensitive amplifiers measure the size and general location of any breakdowns.
- Ratemeter measures pulse rate and feeds into the slow control.

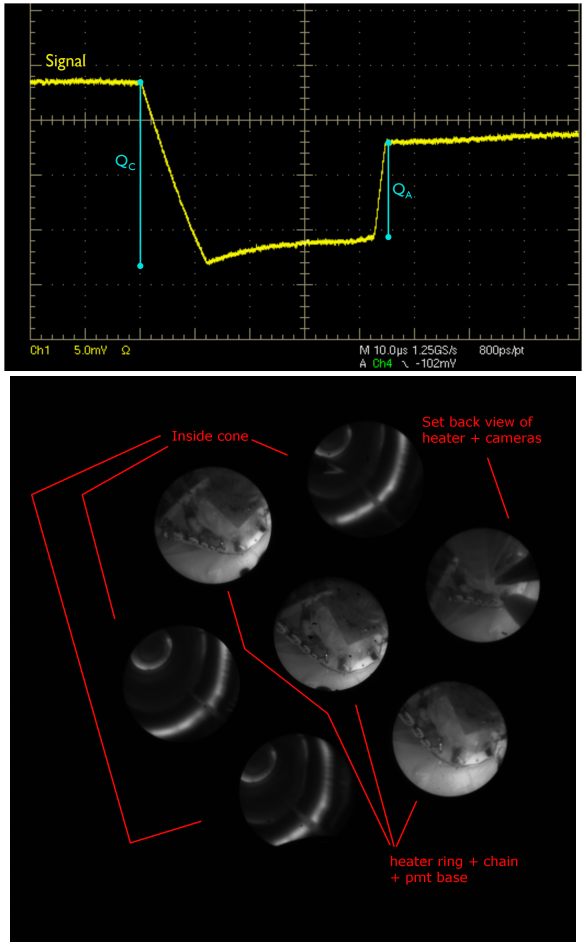


Figure 9: Readouts from some of the channels used in the test stand.

Cathode High Voltage Testing at LBNL- Status

- HV cable and power supply - tested at -120 kV in oil for 1 month, -200 kV for 1 hour.

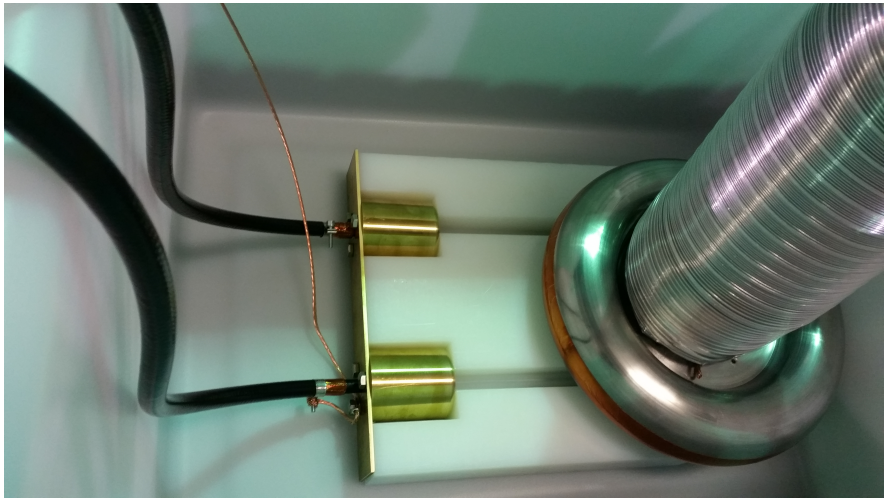


Figure 10: The setup for the cable in oil test.

- Test stand largely assembled, close to first test, warm end feedthrough to be assembled.

Figure 11: Cable test, test stand, and Ar filter in clean room tent.

Status of other components

- Radioactivity counting underway.
- Grading structure: assembled.
- Plastic pieces cold cycled.
- O-ring seal: confirmed leak tight.

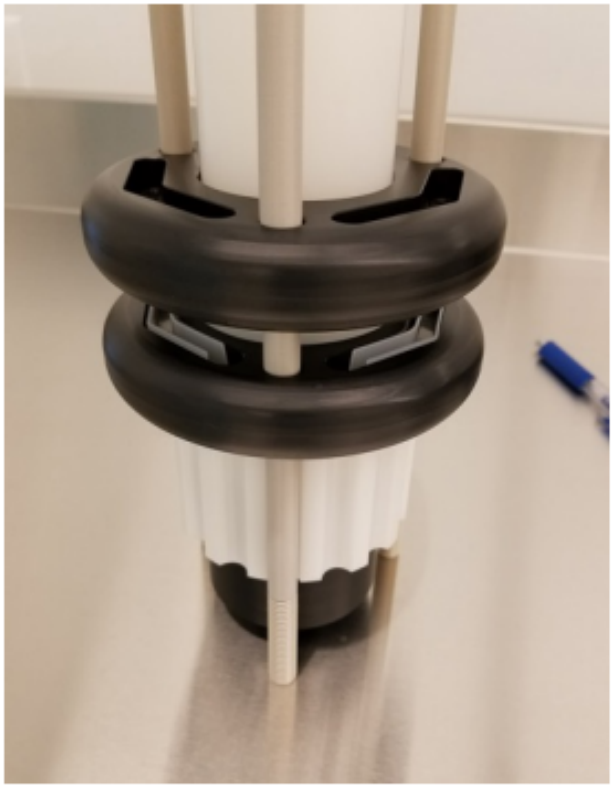


Figure 12: The cold end grading structure.

Figure 13: The Ar filter used for filling the dewar

Analysis of PMT signals.

- Dark box signals: pernicious ringing demands nontrivial pulsefinder to resolve pileup.
- Operating voltage is 1700V from power supply, translates to 1380V from power supply. Gain is consistent with Hamamatsu specs.
- Spotfinder written for enhancing appearance of spots in camera images.

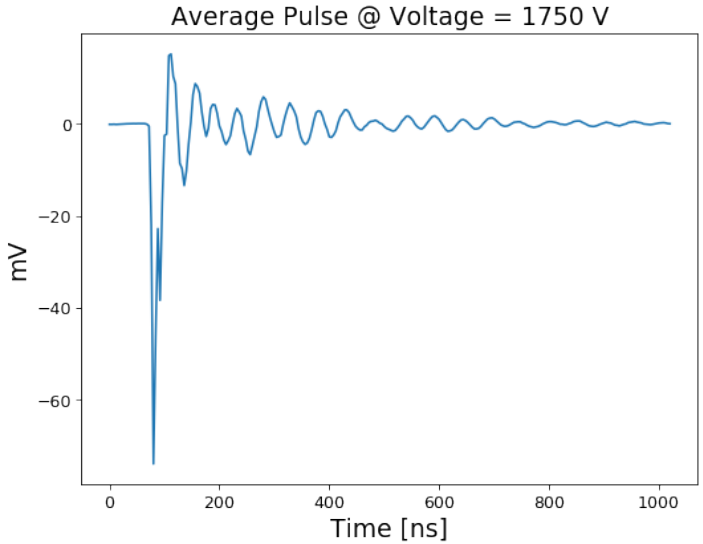


Figure 14: Average response of PMT/ SPE shape

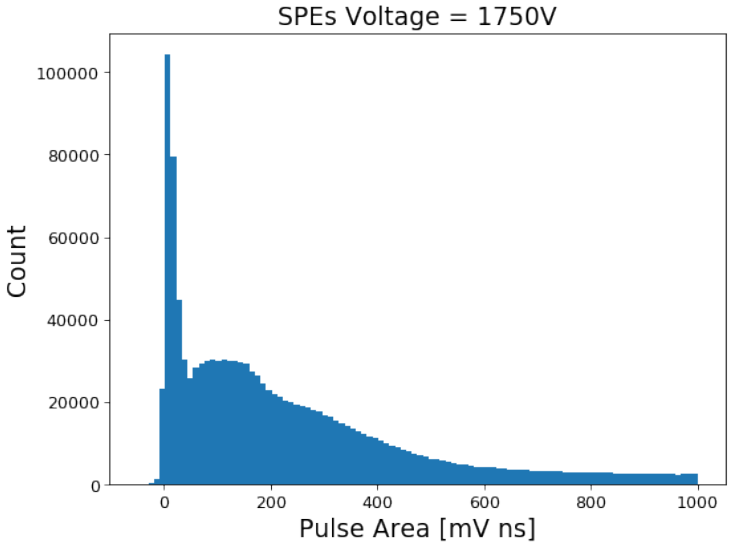


Figure 15: SPE gain vs. applied voltage

Summary and next steps

- The design of cathode high voltage delivery has large impacts on the LZ experiment.
- The updated feedthrough design is being tested at LBNL.
- The test stand will undergo a commisioning test soon, followed by a full operations test.
- Also to be designed/tested: Radon blocking tube.