High Voltage Design in the LZ Detector

Ethan Bernard, Yale University (LZ Collaboration)

Fermilab - November 9th 2013

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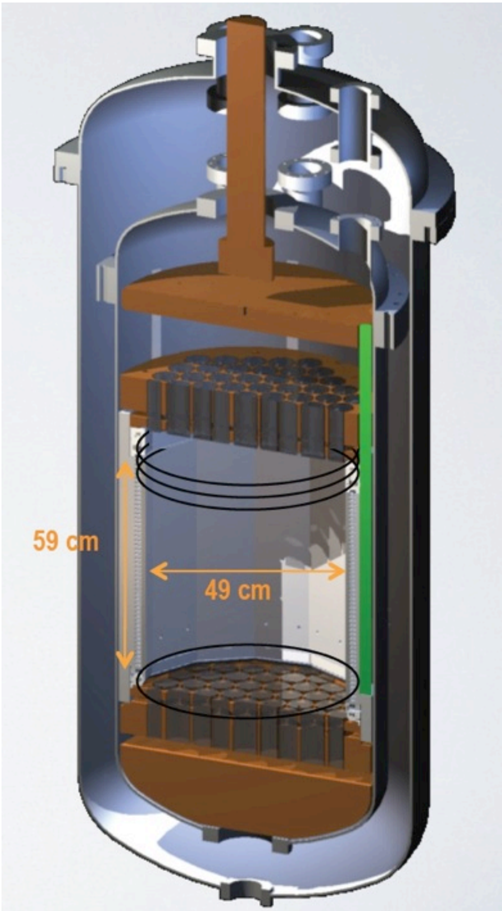
LUX cathode HV feedthrough design.

LZ electric field management design progress.

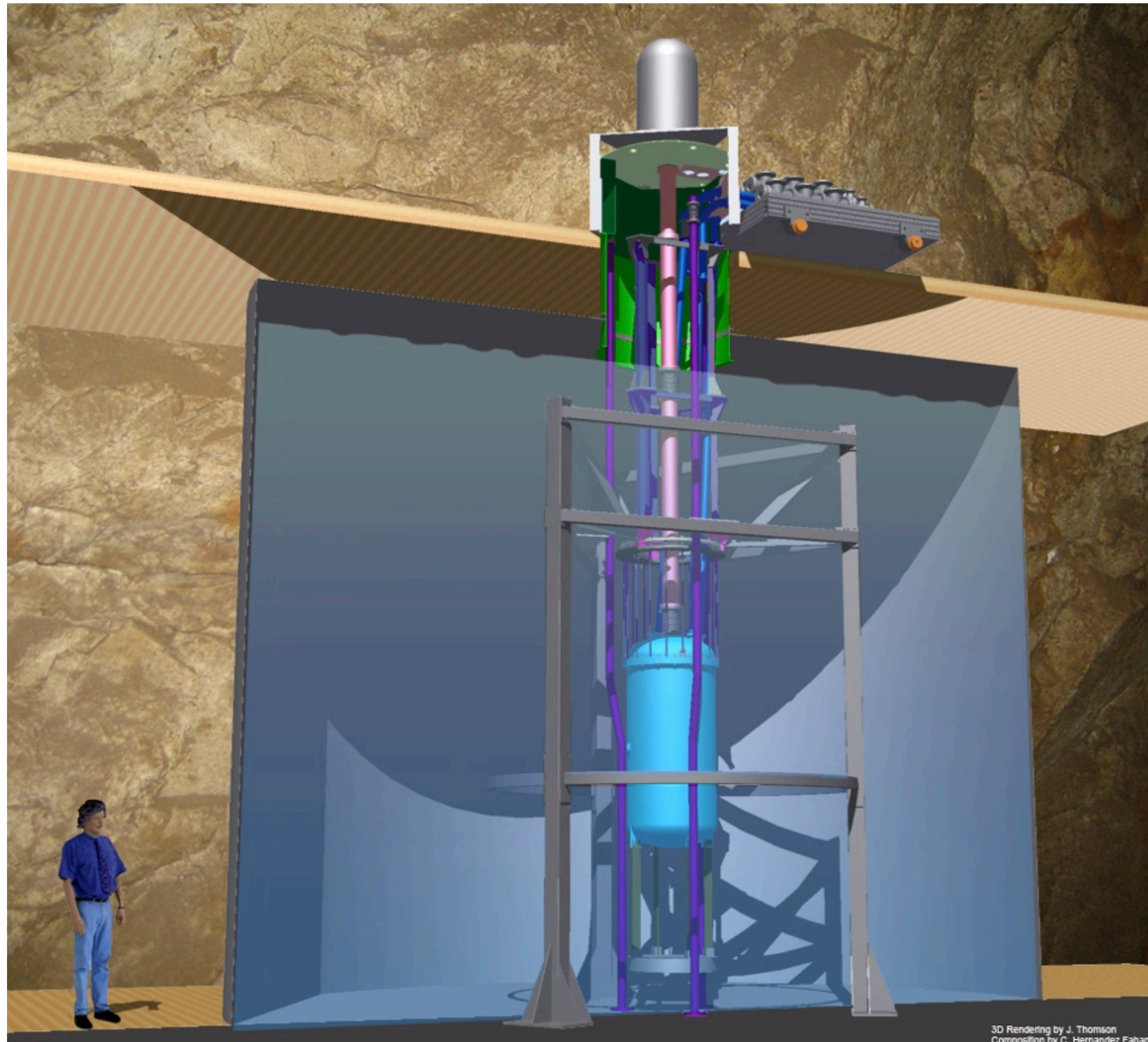
LZ cathode feedthrough design progress.

Yale feedthrough and liquid argon HV test system.

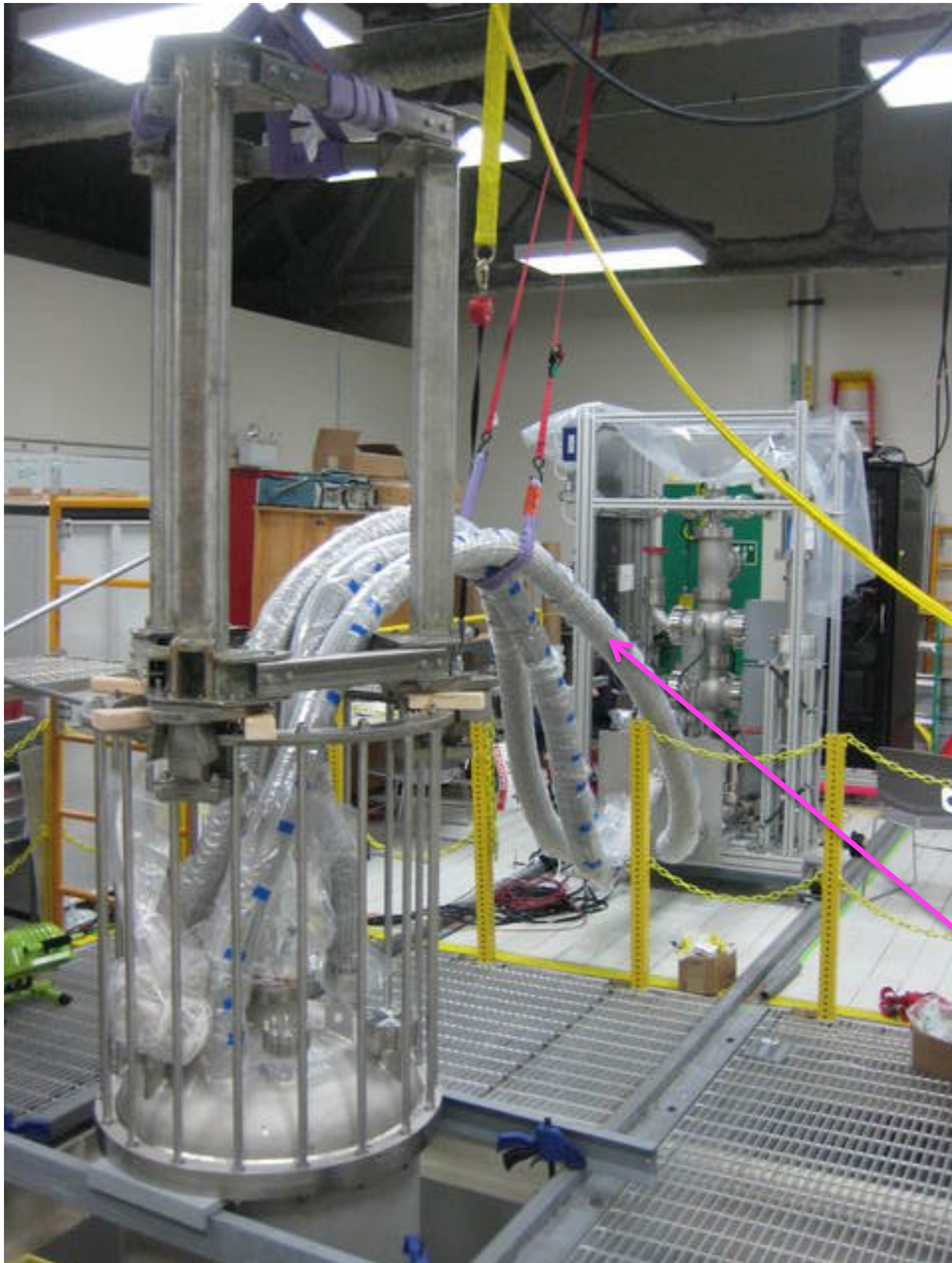
Once Upon a Time Some Physicists Designed a Detector Called LUX…



350 kg Liquid Xenon TPC
Dual Phase
Single photoelectron sensitive
Single drift electron sensitive
59 cm drift length
Designed for -100 kV cathode

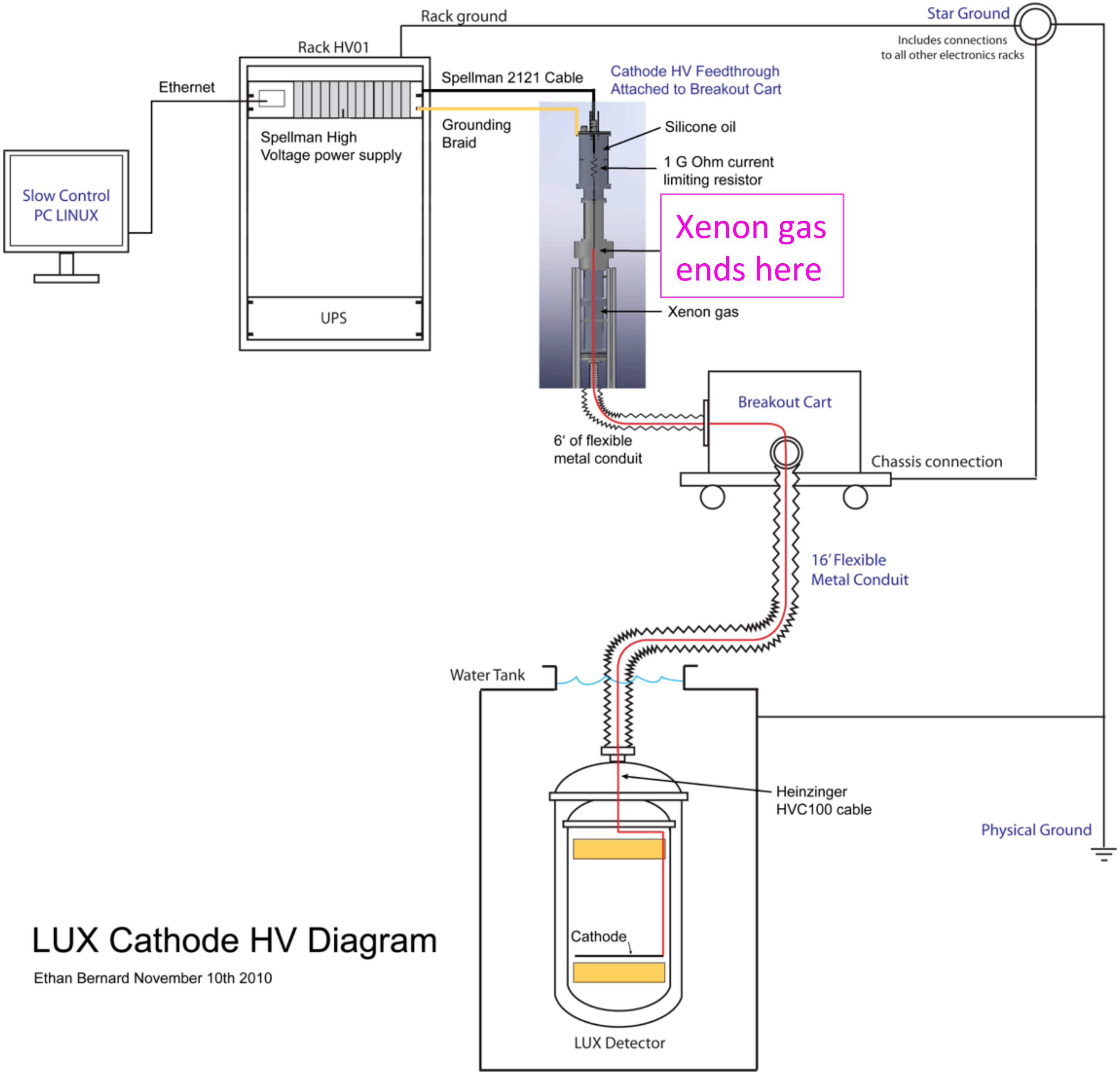


LUX Deployment Requires Flexibility



Assembled and sealed detector comes down the mine shaft as one package.

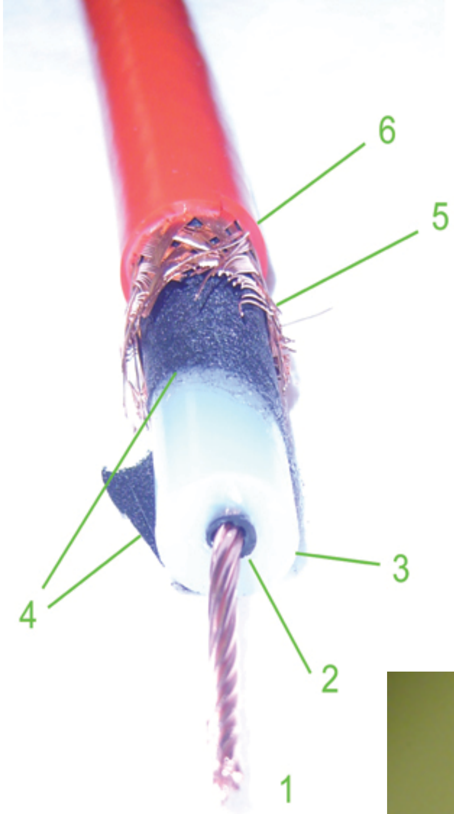
HV cable is in here



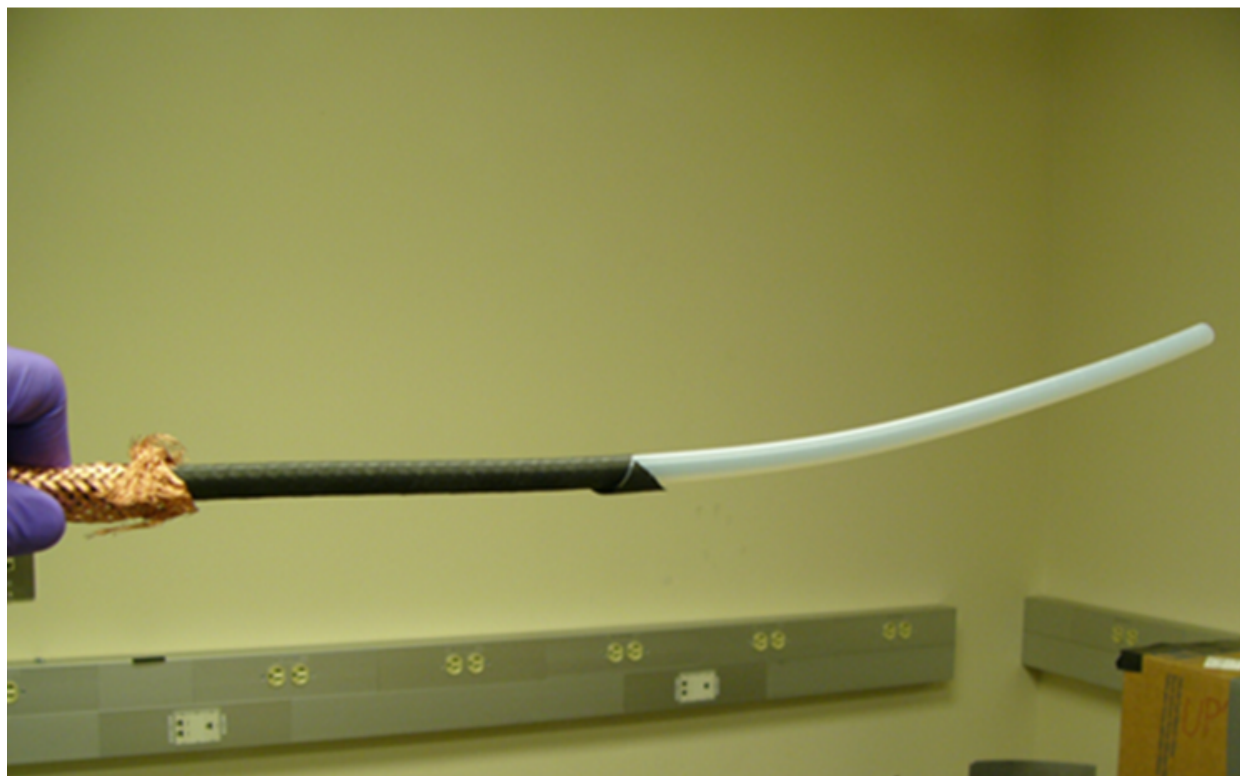
LUX Cathode HV Diagram

Ethan Bernard November 10th 2010

Heinzinger HVC100 Cable



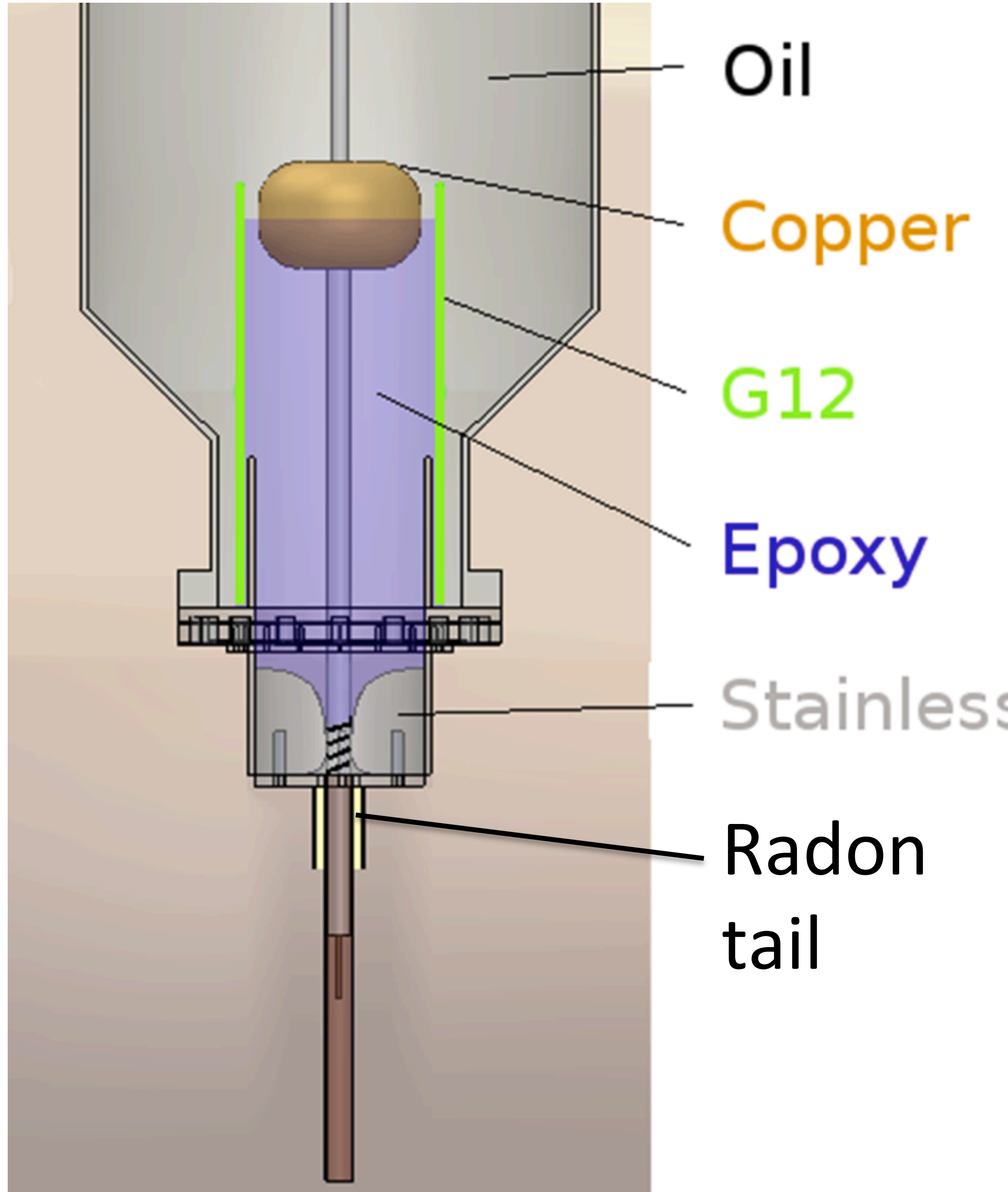
1) Copper conductor (2.2 mm = 0.087 in)
2) Black plastic
3) Polyethylene plastic (11 mm = 0.433 in)
4) Carbon paper
5) Copper shield (12 mm = 0.472 in)
6) PVC jacket (14 mm = 0.551 in)



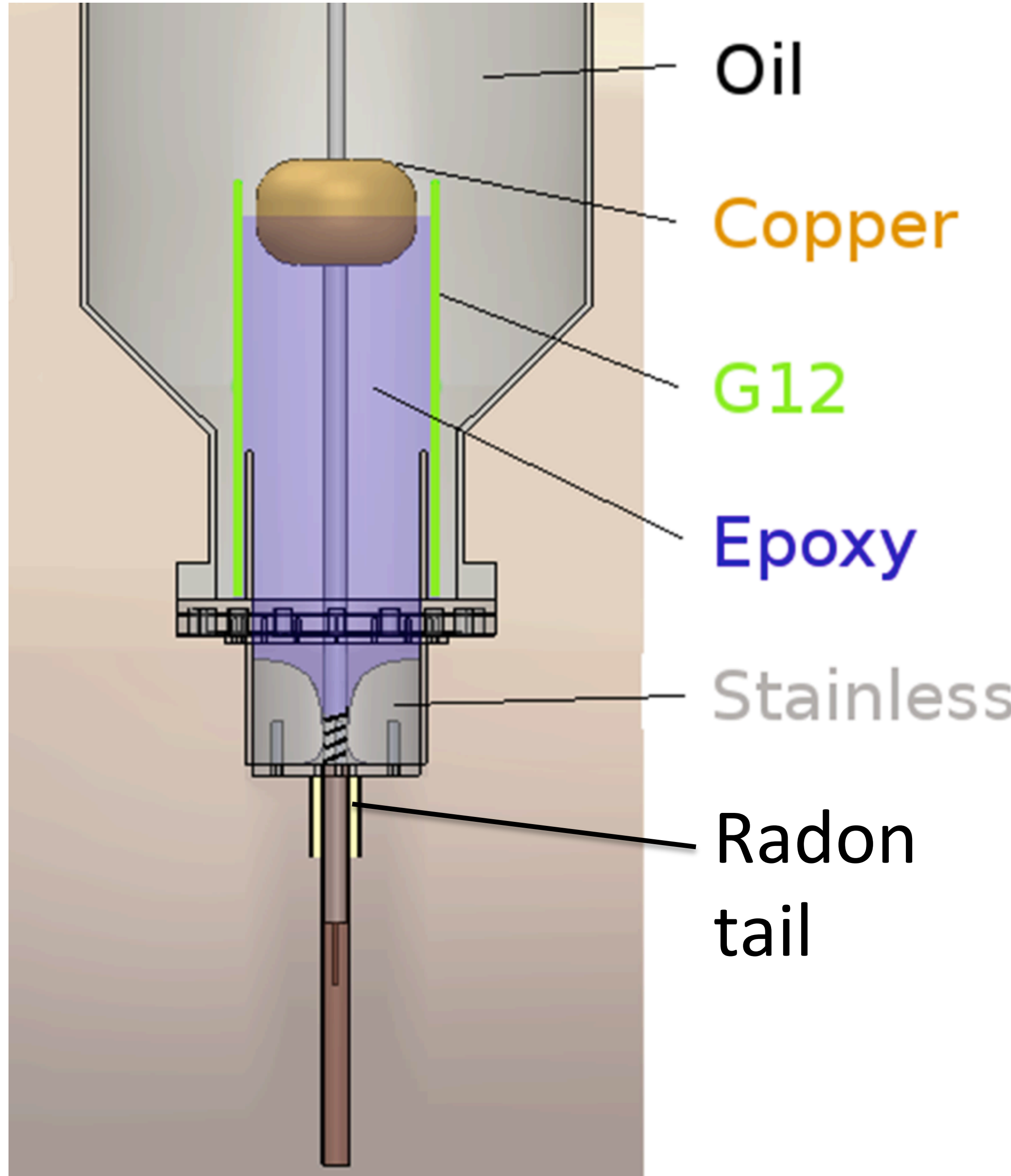
LUX Cathode HV Feedthrough

Complete Feedthrough on 6-inch Conflat.

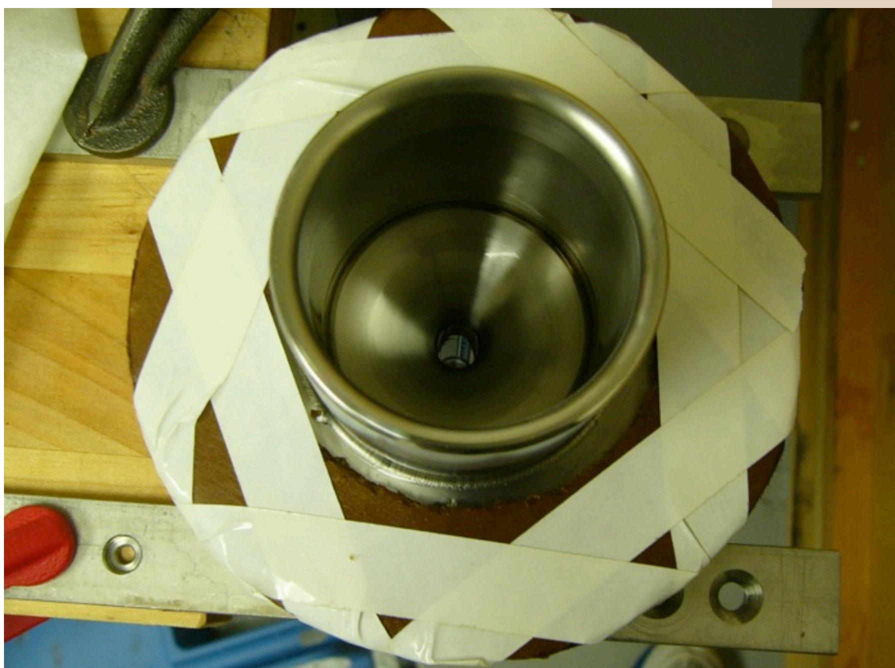
Epoxy is Stycast 2850FT Blue
Alumina filled; 15 kV / mm rating

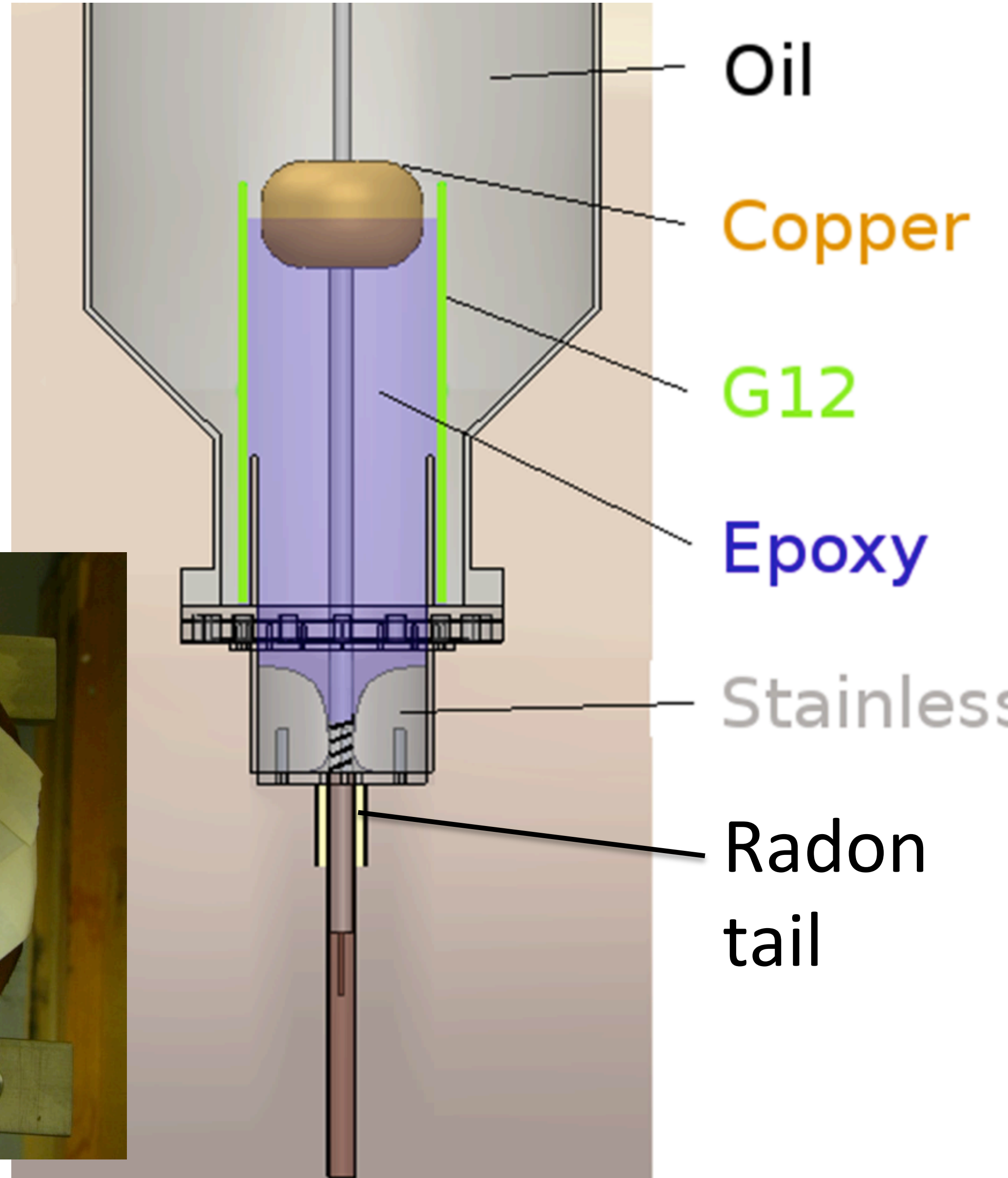


LUX Cathode HV Feedthrough

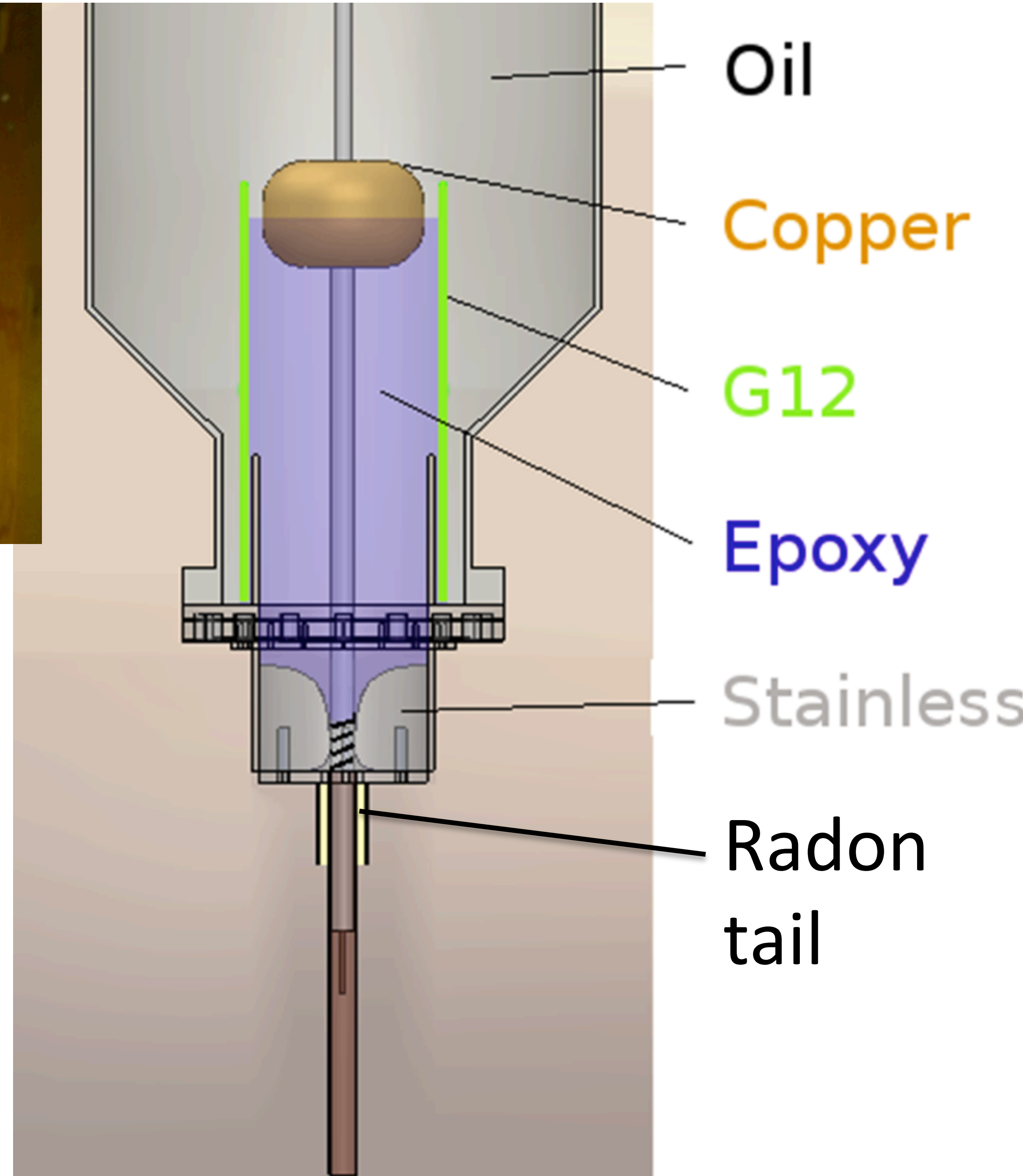


LUX Cathode HV Feedthrough

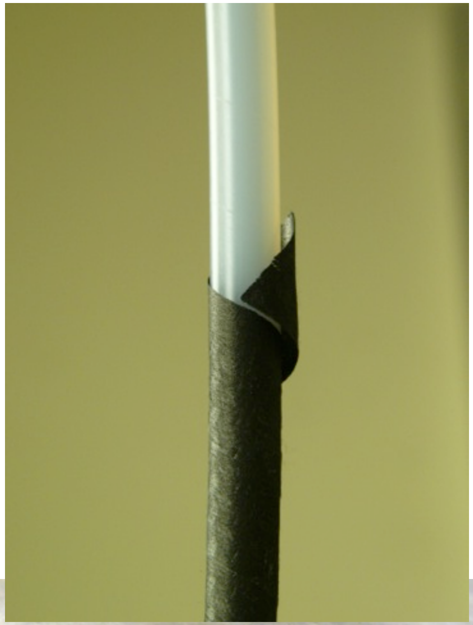


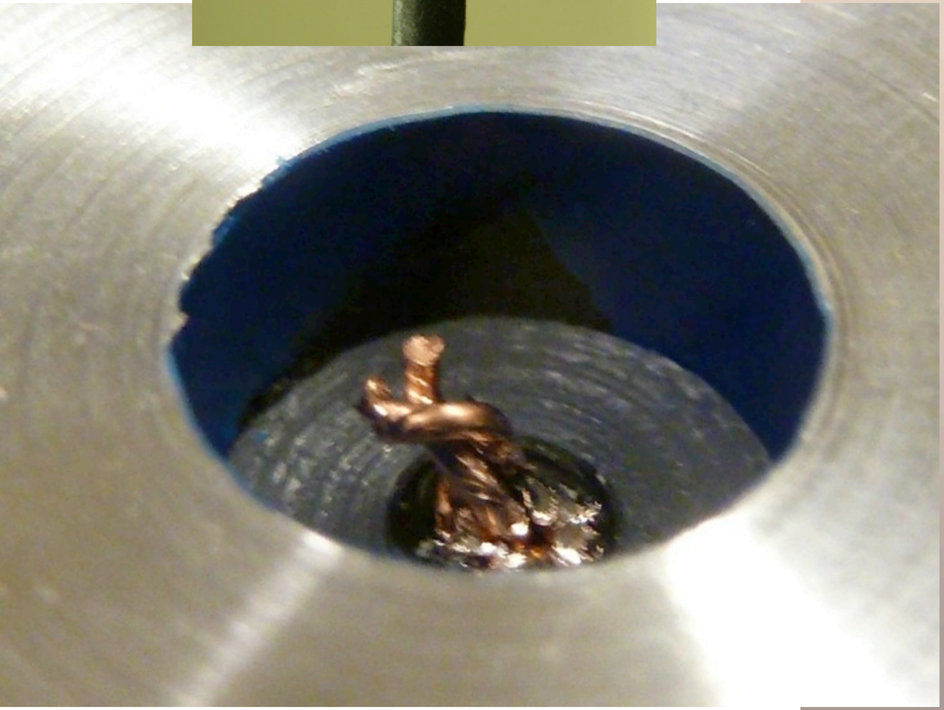


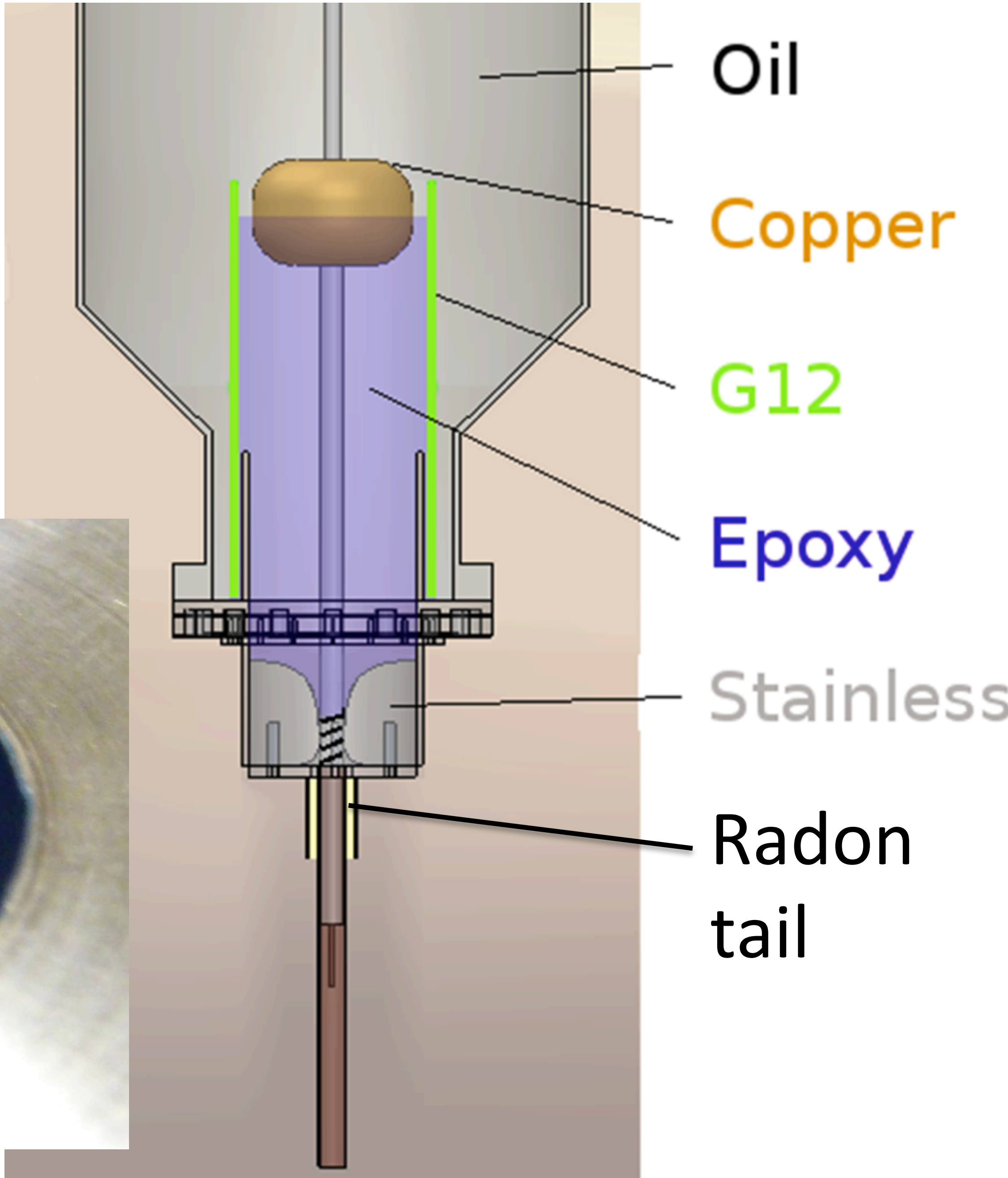
LUX Cathode HV Feedthrough



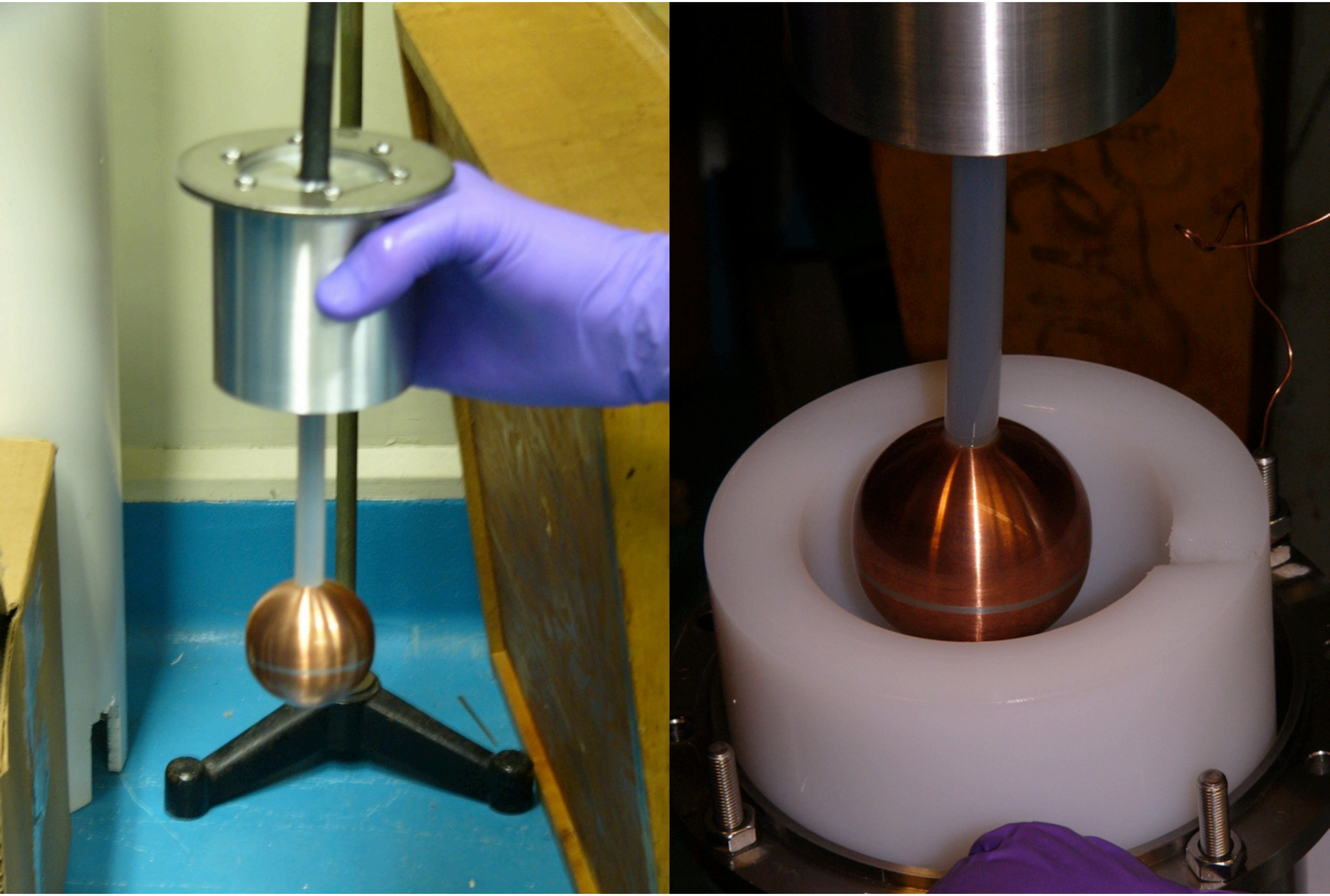
LUX Cathode HV Feedthrough



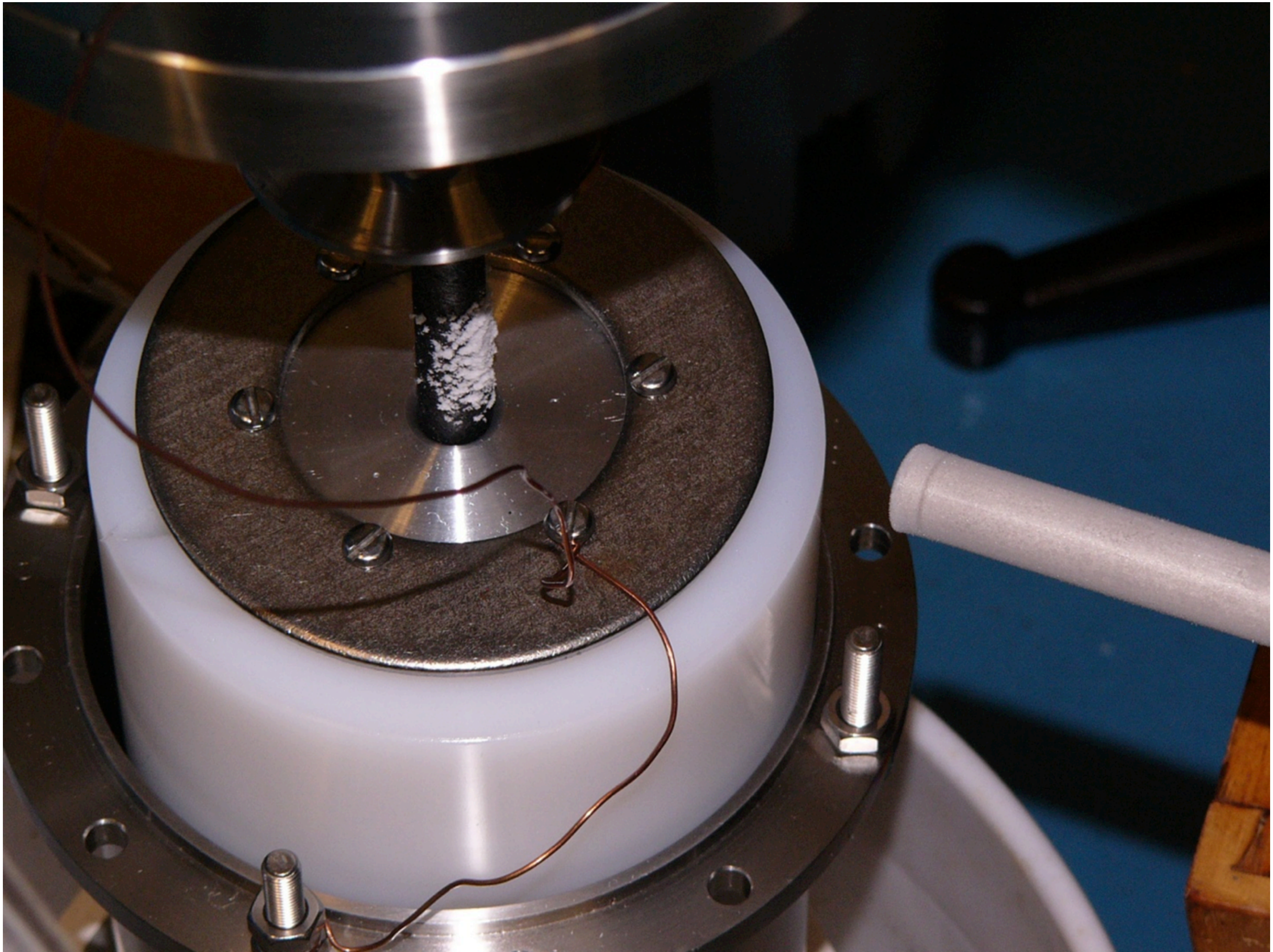




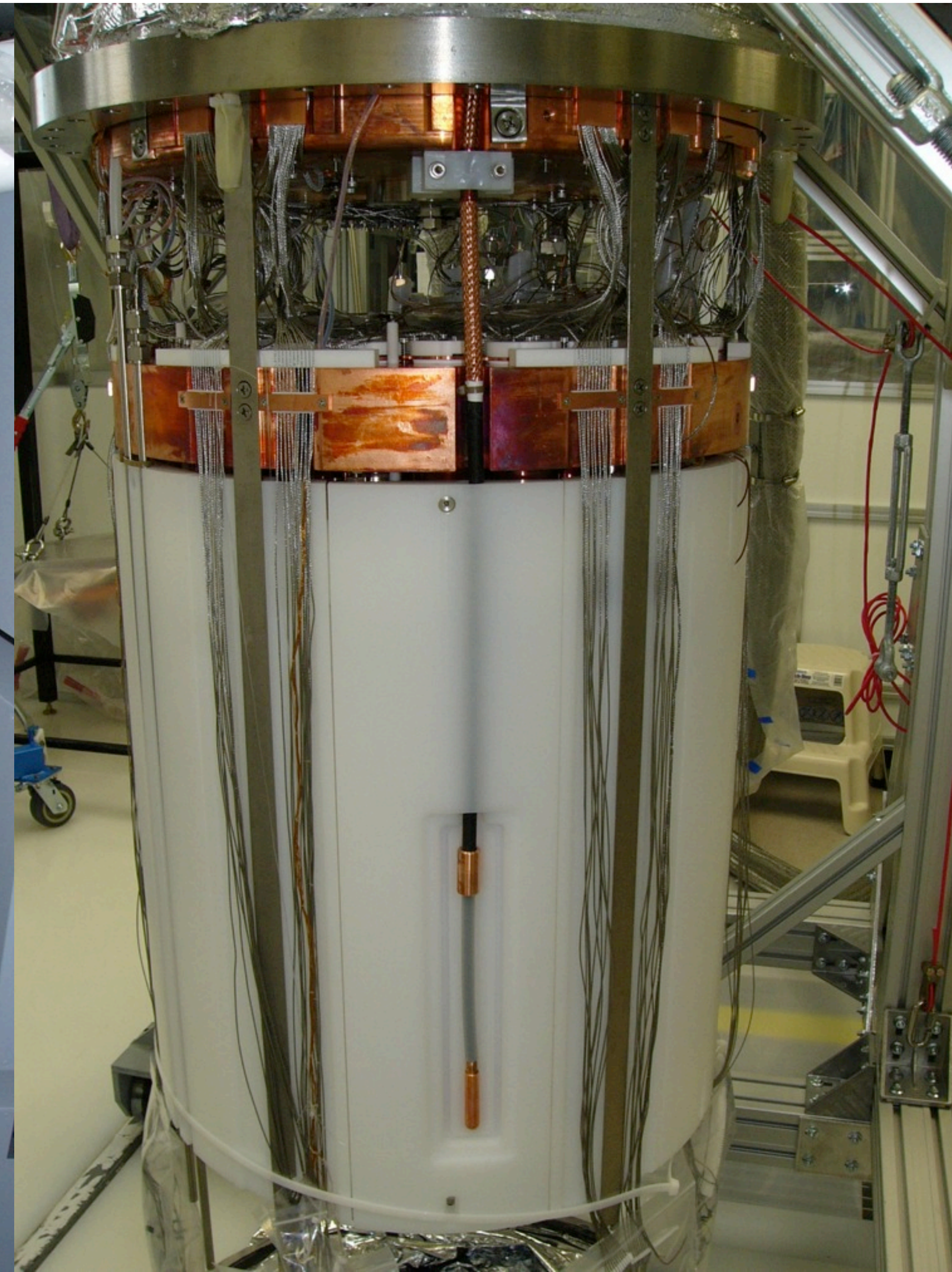
Testing in Silicone Oil



Cold Testing at Full Voltage



LUX Cathode HV Feedthrough Installed



LUX Feedthrough Summary

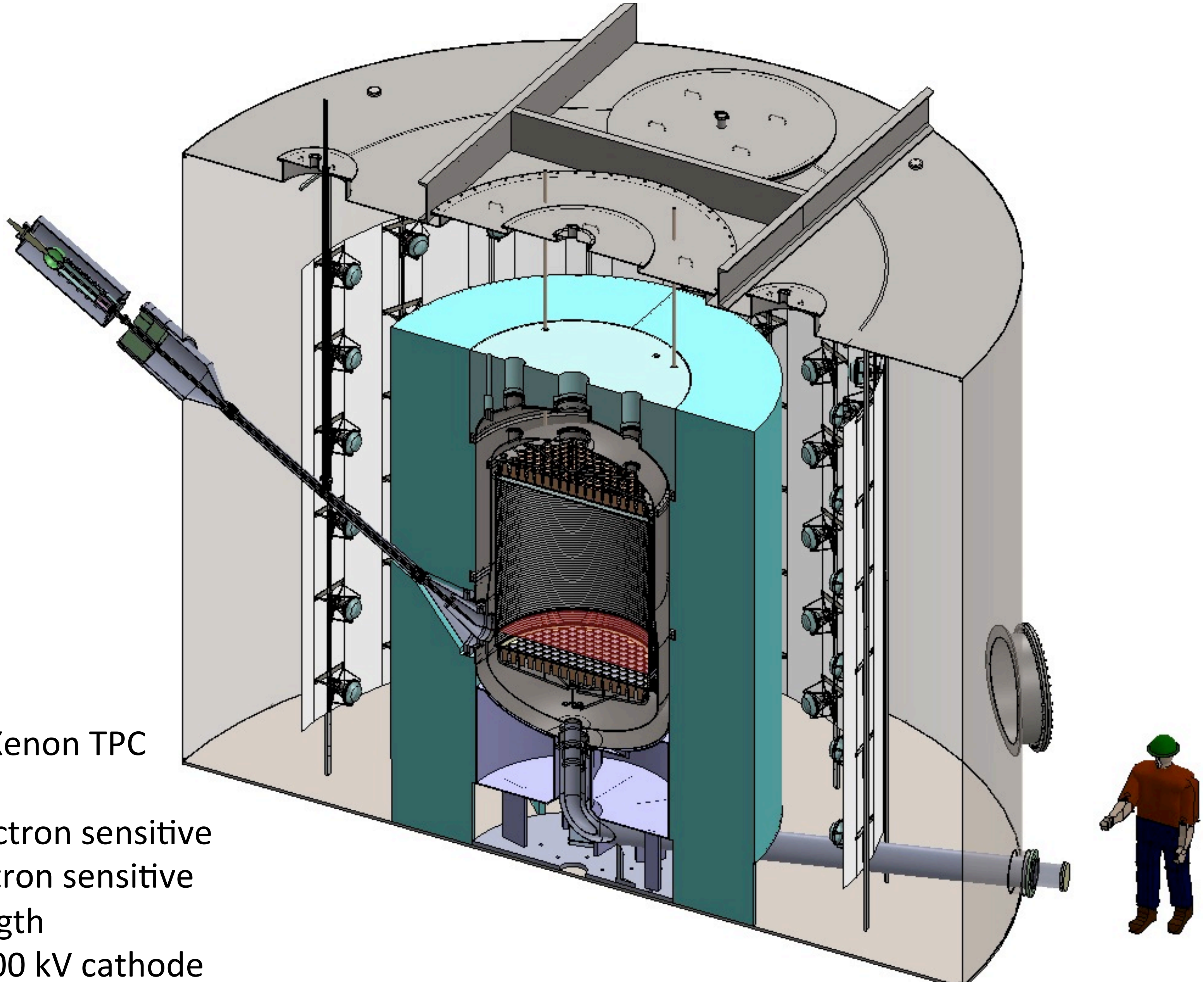
Three epoxy feedthroughs made.

Two tested to 100 kV, one untested. No signs of aging.

One tested feedthrough is installed in LUX now.

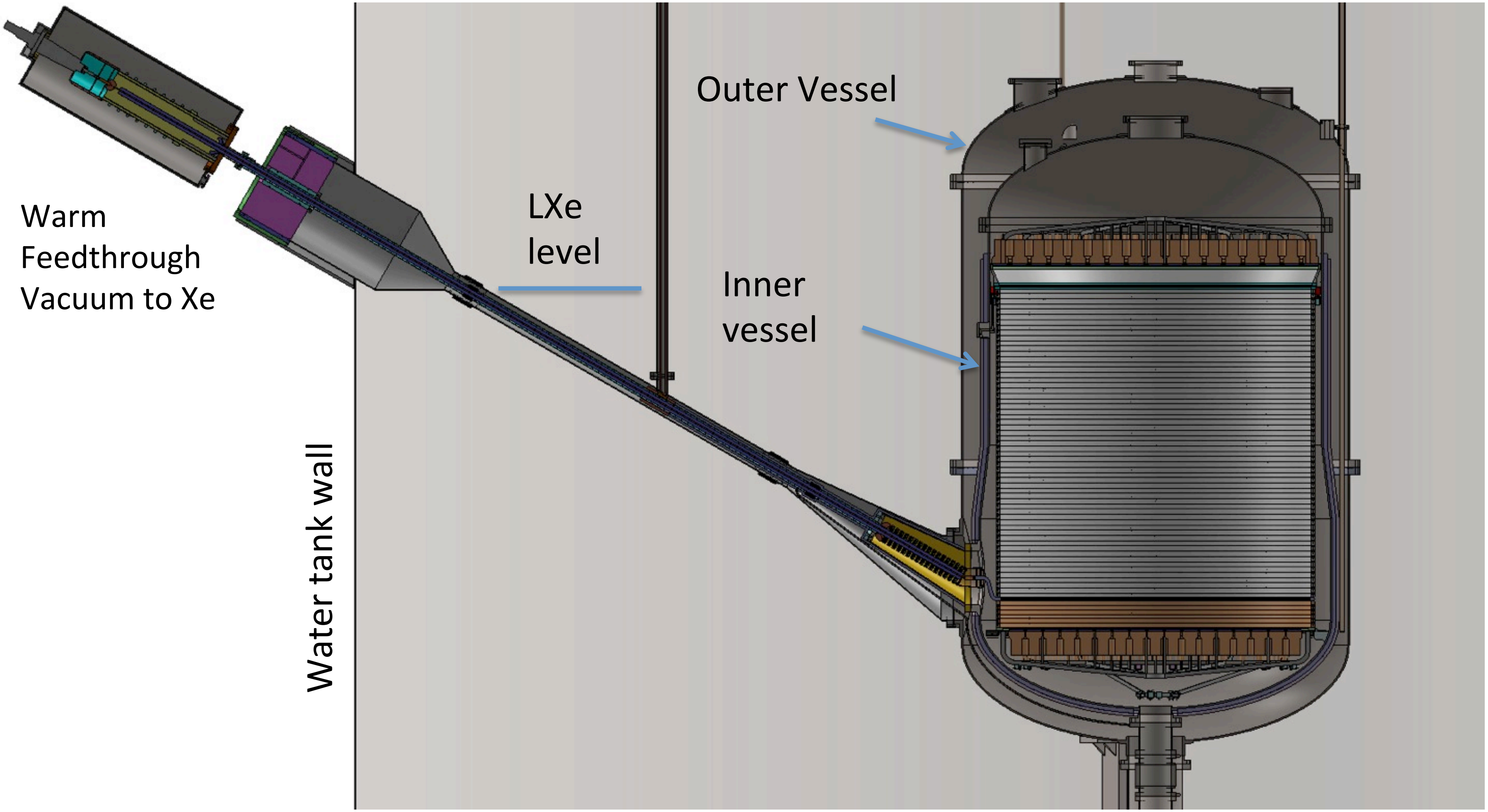
This feedthrough and cable combination solves the problem of bringing -100 kV into liquid xenon through a flexible channel.

Once Upon a Time Some Physicists Designed a Detector Called LZ

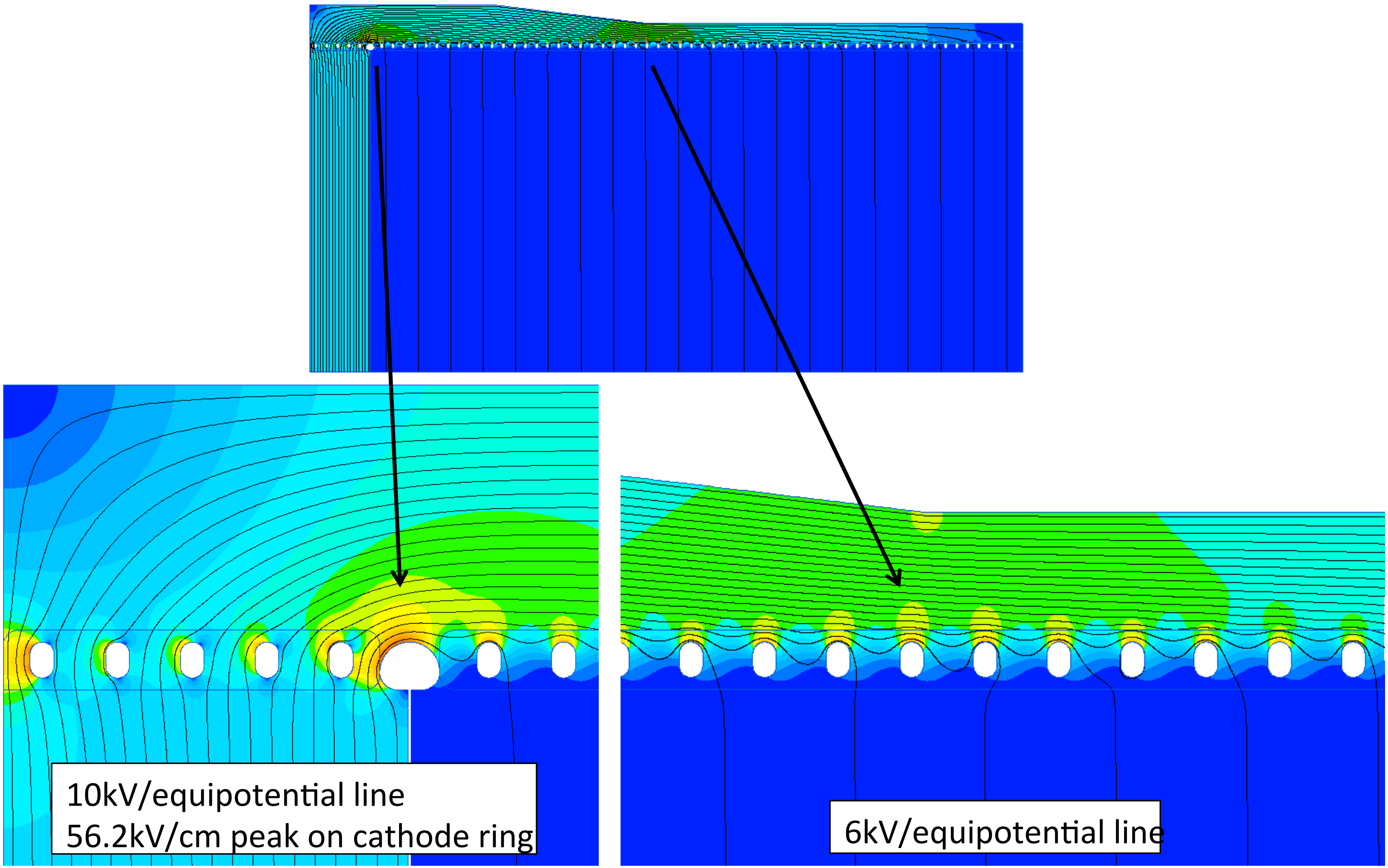


7000 kg Liquid Xenon TPC
Dual Phase
Single photoelectron sensitive
Single drift electron sensitive
140 cm drift length
Designed for -200 kV cathode

Cathode HV Comes in From the Side

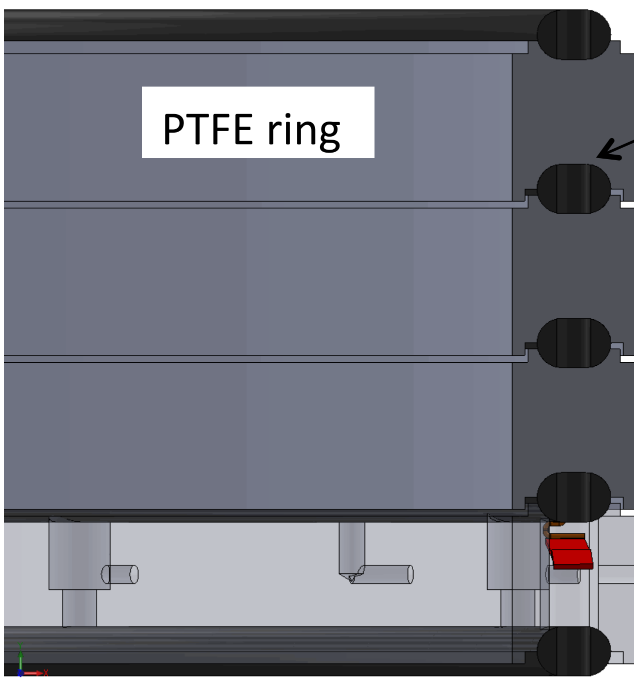


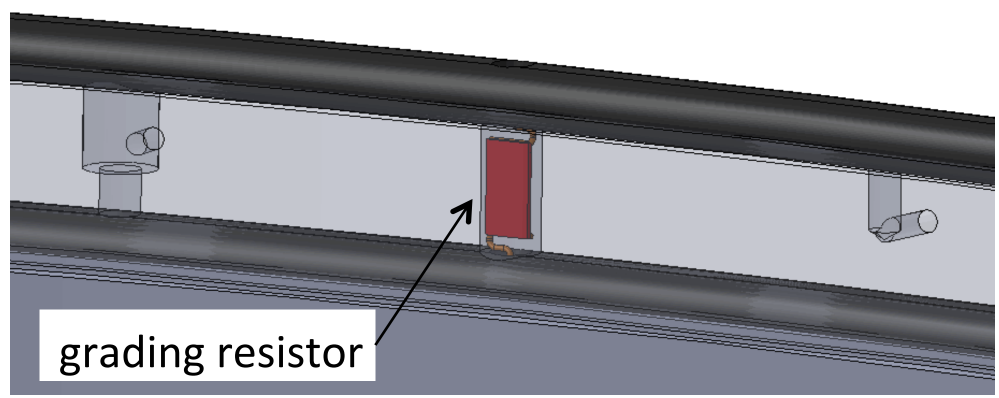
Electrostatic modeling of a generic geometry with embedded grading rings (200kV cathode voltage)



Forward Field Region Above Cathode (TPC) – 1.4 kV/cm

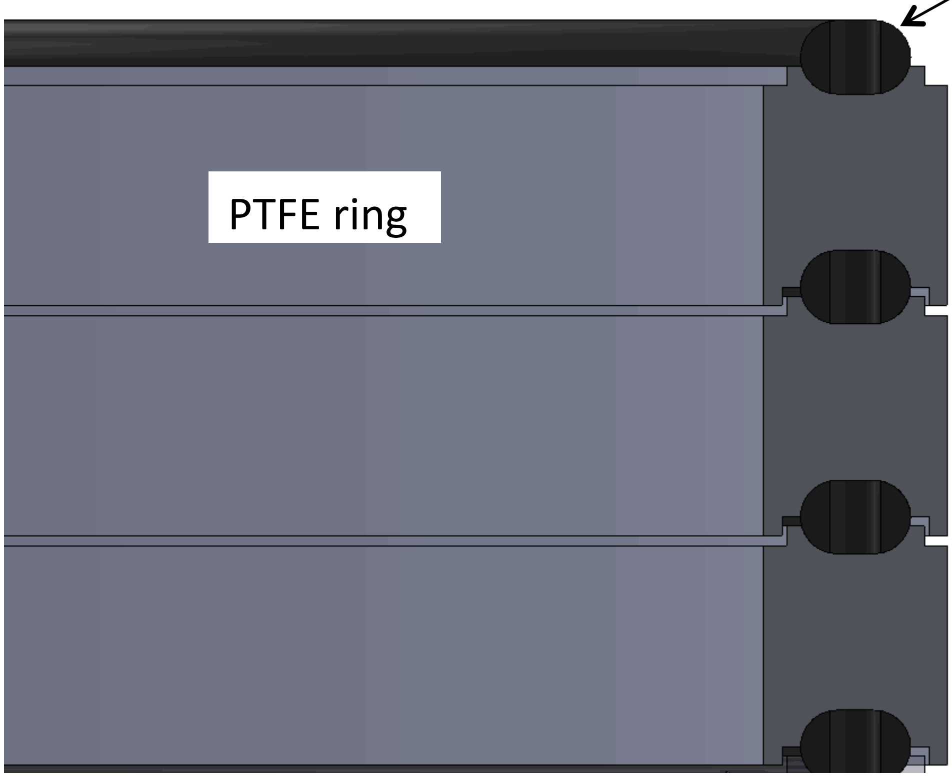
- Embedded conductive plastic grading rings to maintain reflectivity and to avoid different thermal expansion coefficients
- Gaps in Teflon to break up the surface with fixed potential grading rings (fix potentials, stop avalanche, provide bleed path, etc.)
- Grading resistors are within Teflon rings to avoid field enhancements between the resistors and the vessel wall
- Decrease in reflectivity?..to be simulated/measured

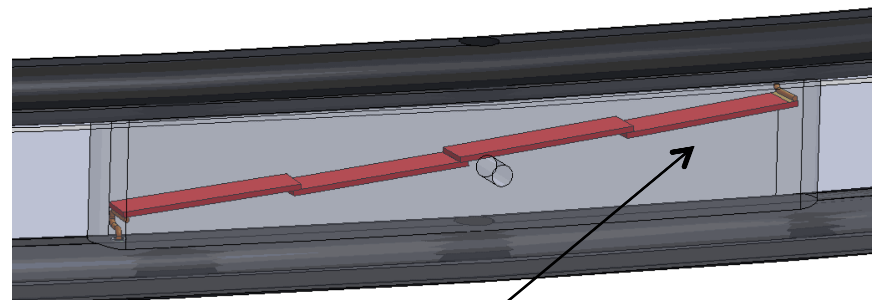




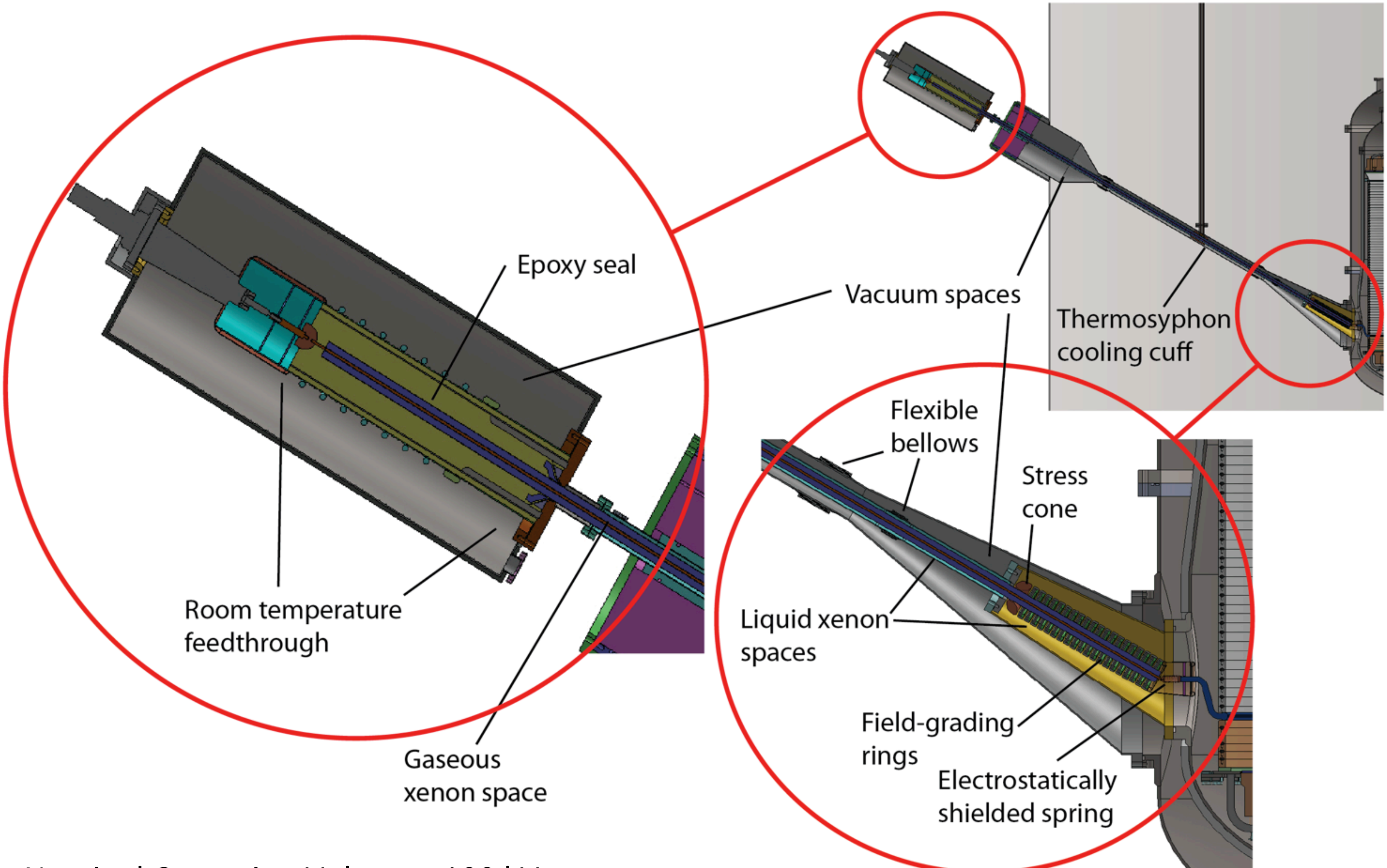
Reverse Field Region Below Cathode – 14 kV/cm

Same idea as forward field region, but 10x higher gradient, so the packaging of the grading resistor is different (4 series resistors per section)



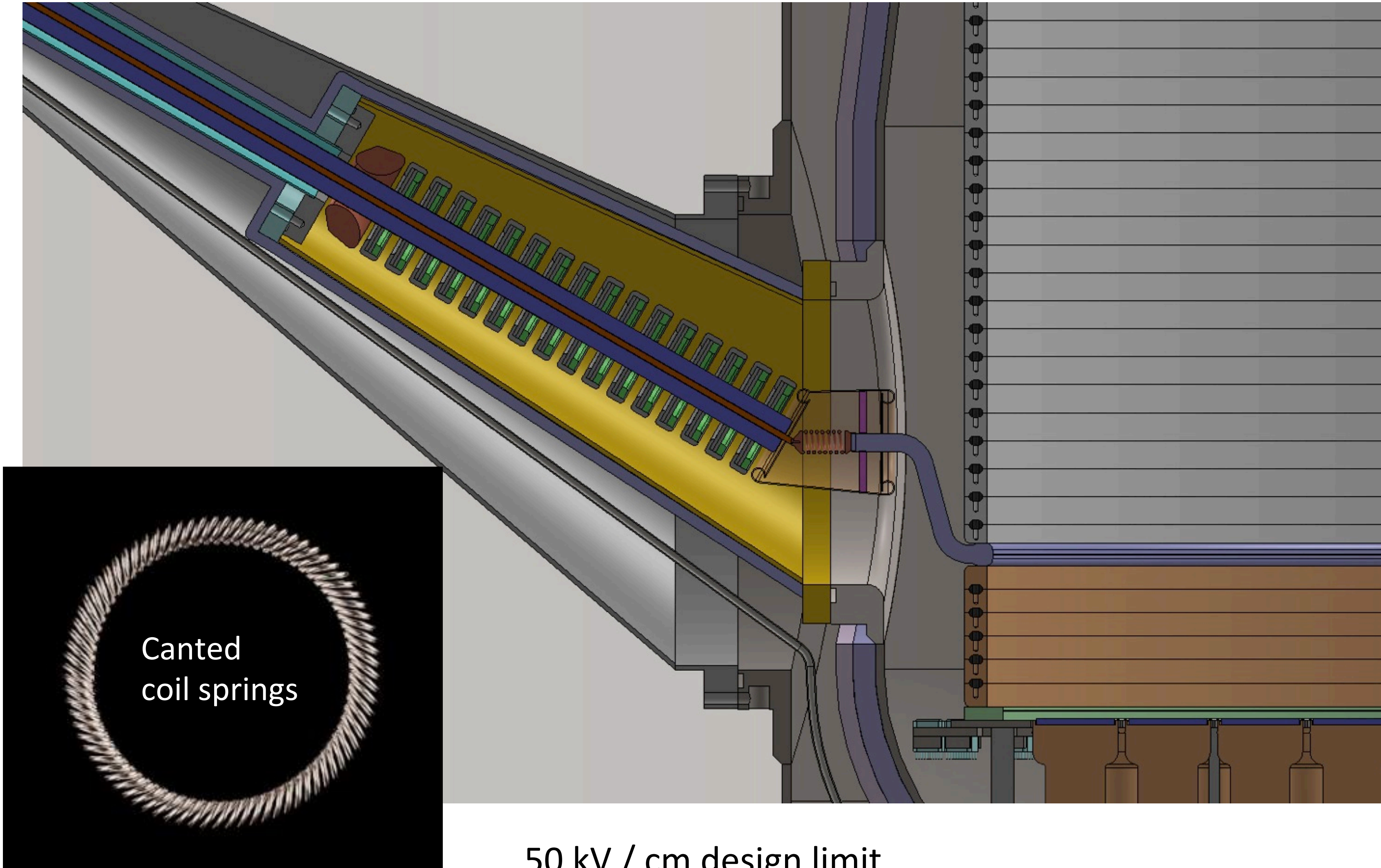


Cathode High Voltage Arm



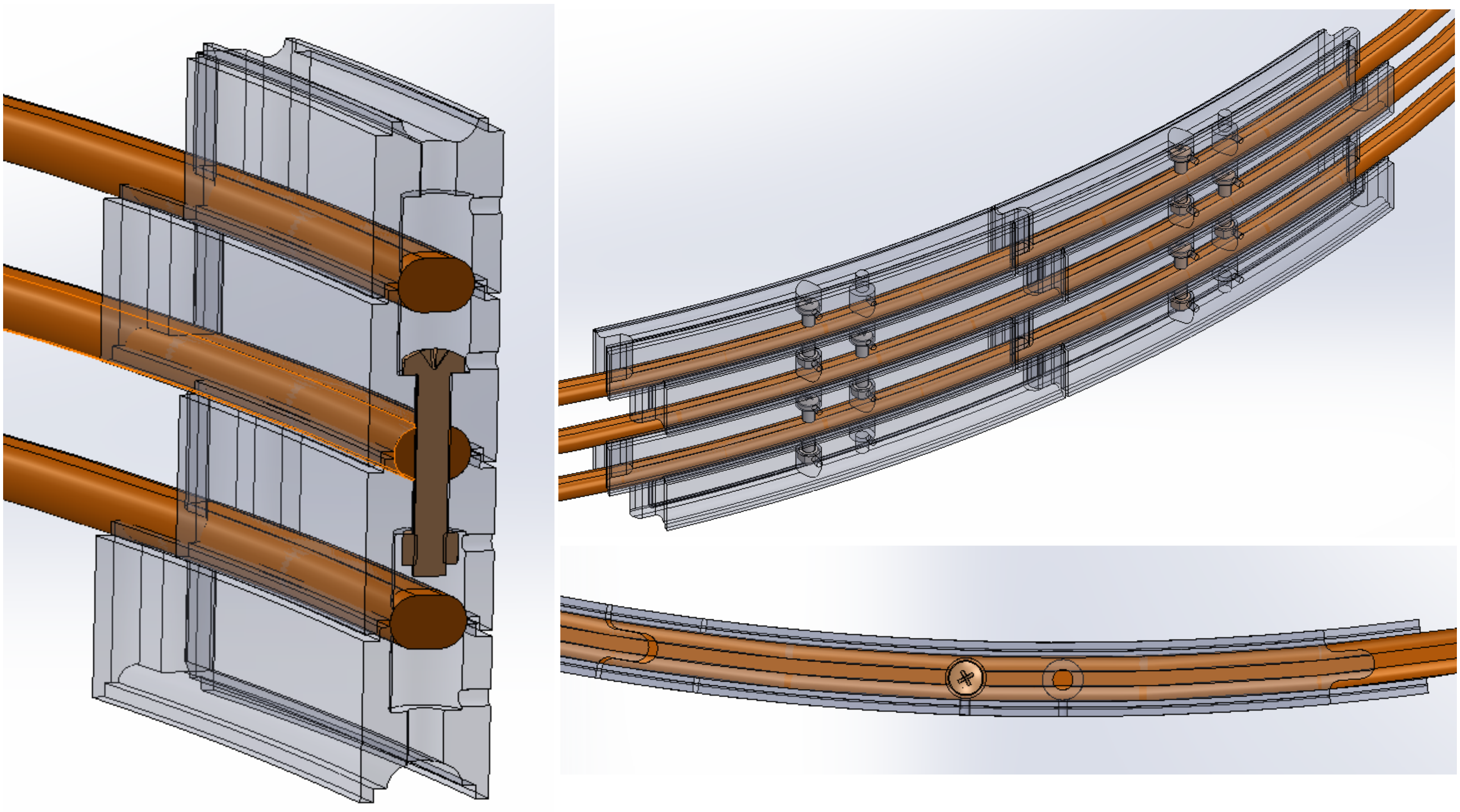
Nominal Operation Voltage: -100 kV
Designed for -200 kV

Cable Grading Structure



50 kV / cm design limit

Alternative Grading Ring Design – Titanium Grading Rings with segmented PTFE sections (tongue and groove)

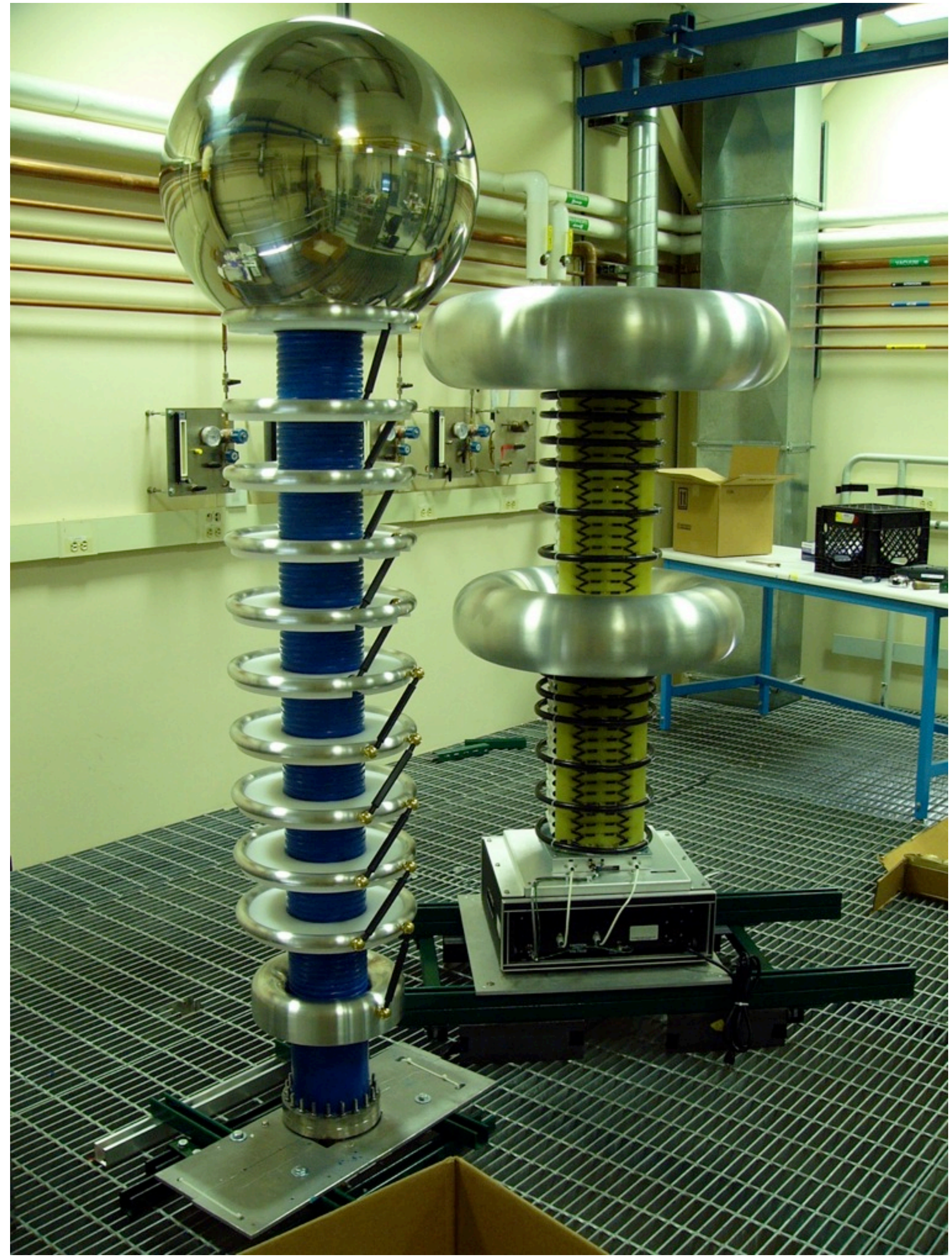


Scaling up the LUX Feedthrough – 300 kV Air - Insulated Design

"If some blue epoxy is good, more blue epoxy is better."

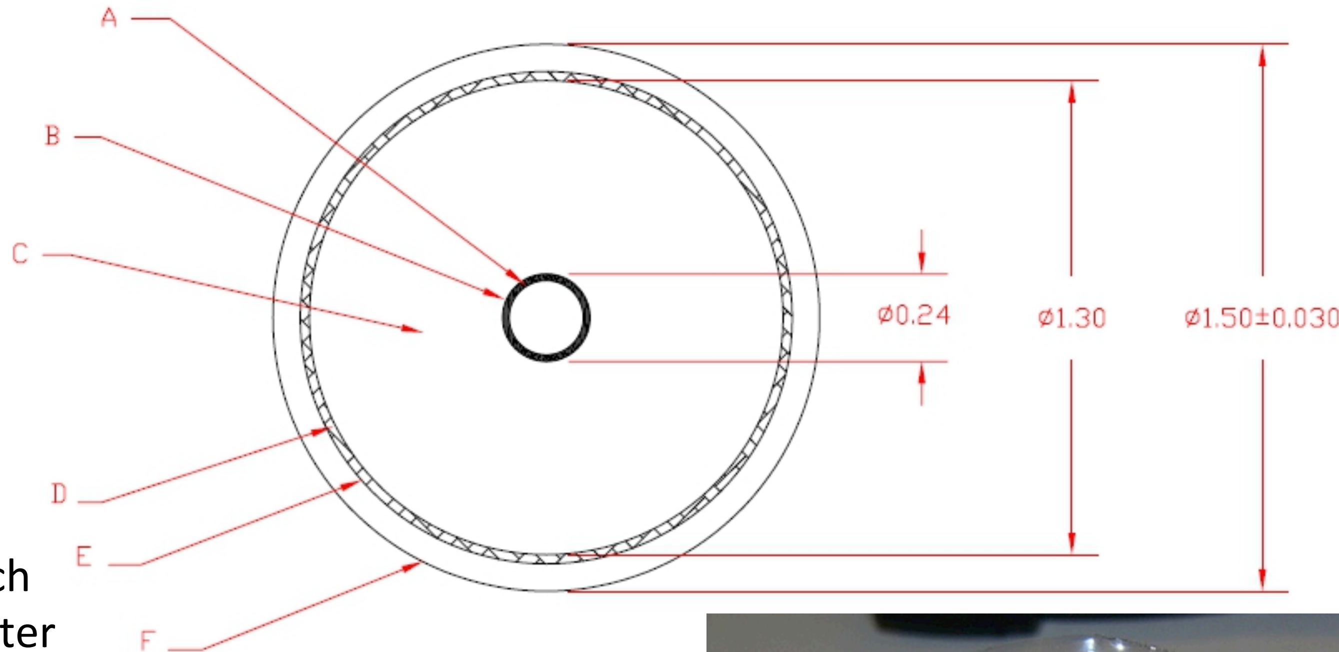
10 in tall

6 feet tall



Scaling up the Feedthrough – Scale the cable

DWG NO 2077 REV



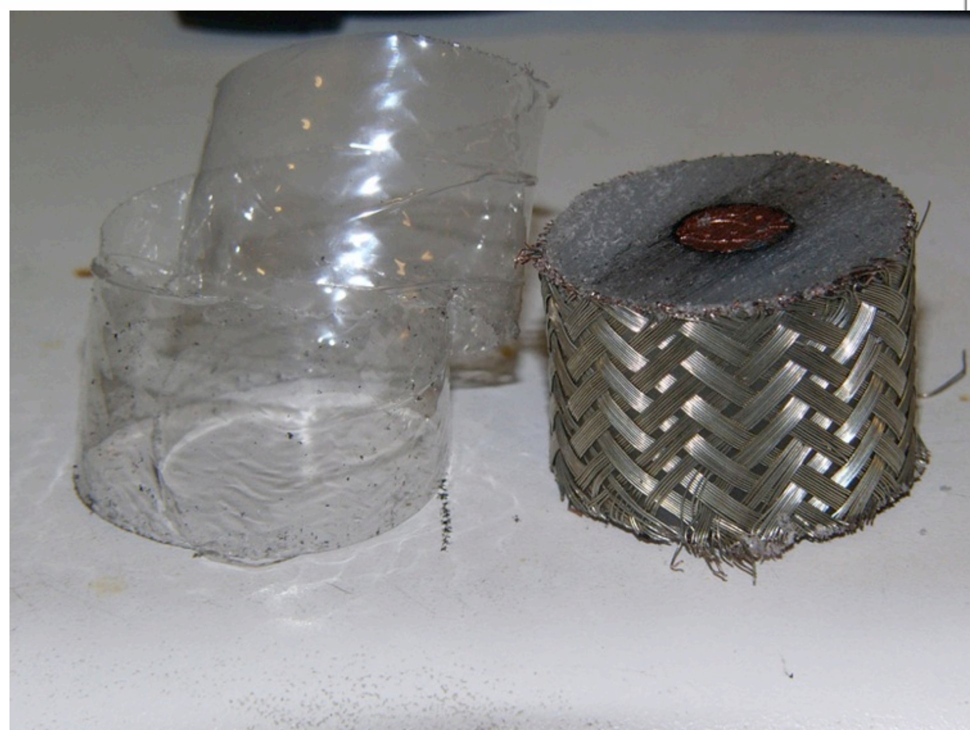
1.3 inch diameter

CAPACITANCE @ 1KHZ=25 pfd/ft

TOLERANCE= ±2%, ANY DIAMETER.

NO PRINTING ON JACKET.

TEST VOLTAGE: 400 KVDC, 10 MIN.

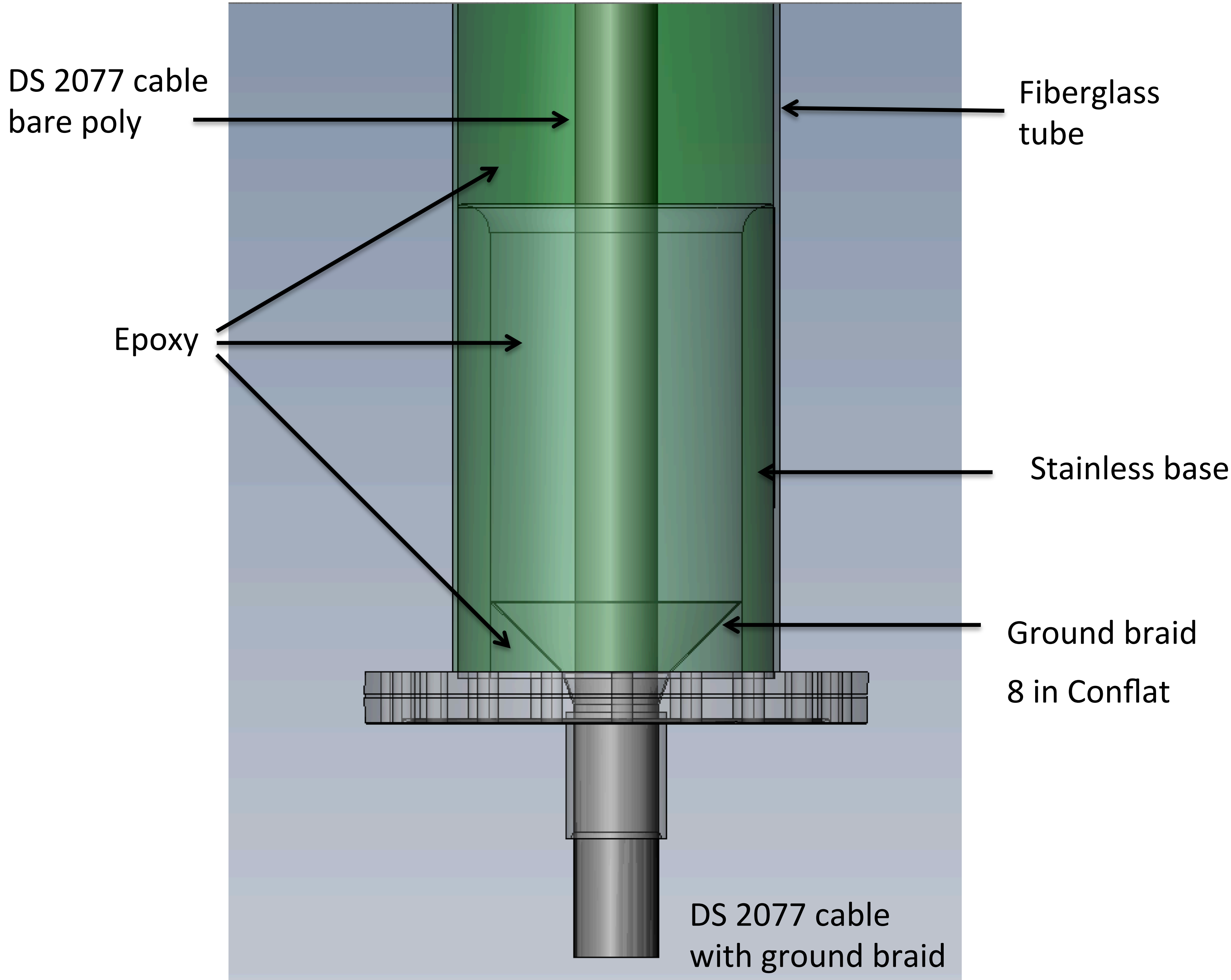


Scaling up the Feedthrough – Straightening the cable

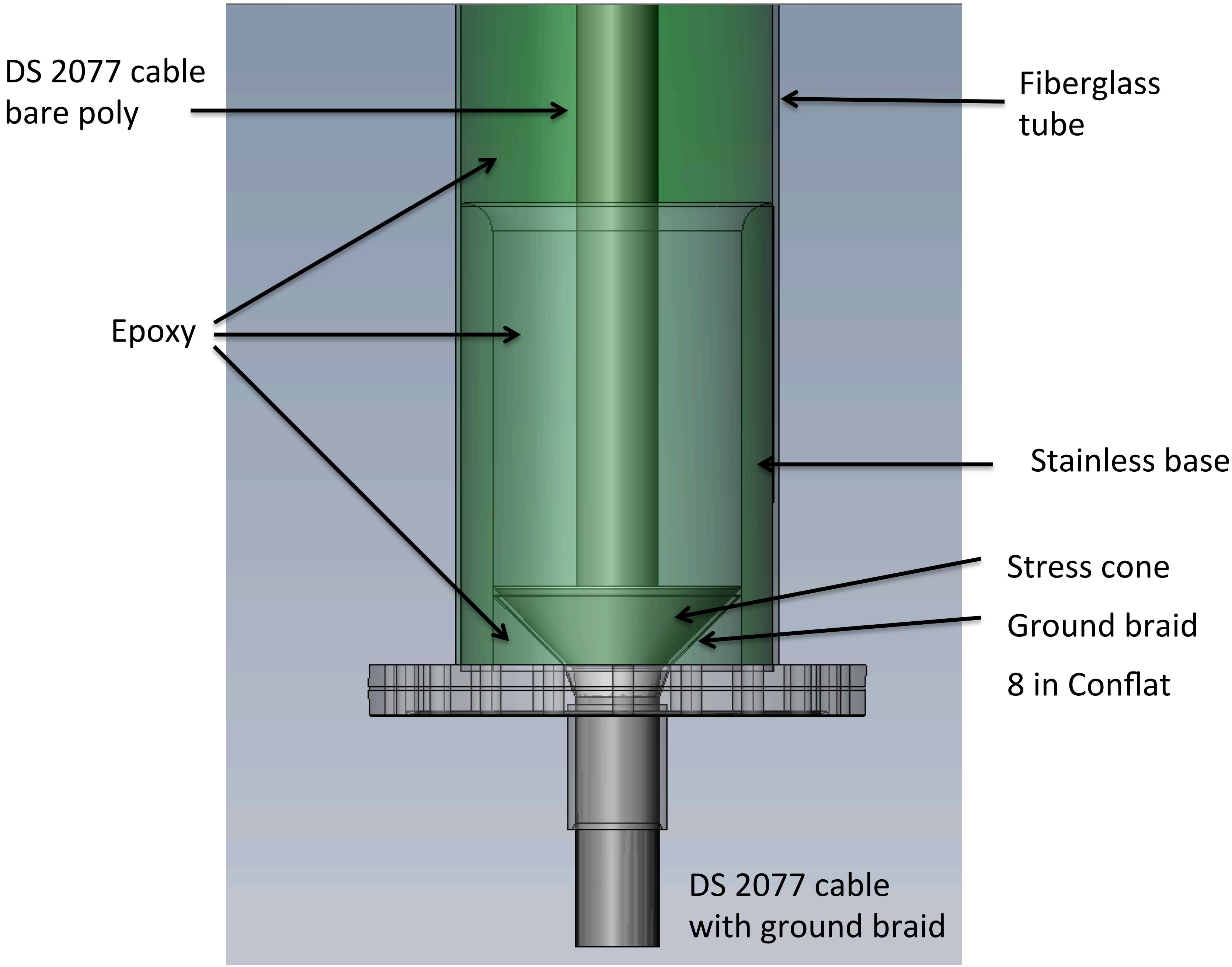
US Patent
5213750A

Anneal overnight with heater tape around pipe at ~ 90 C

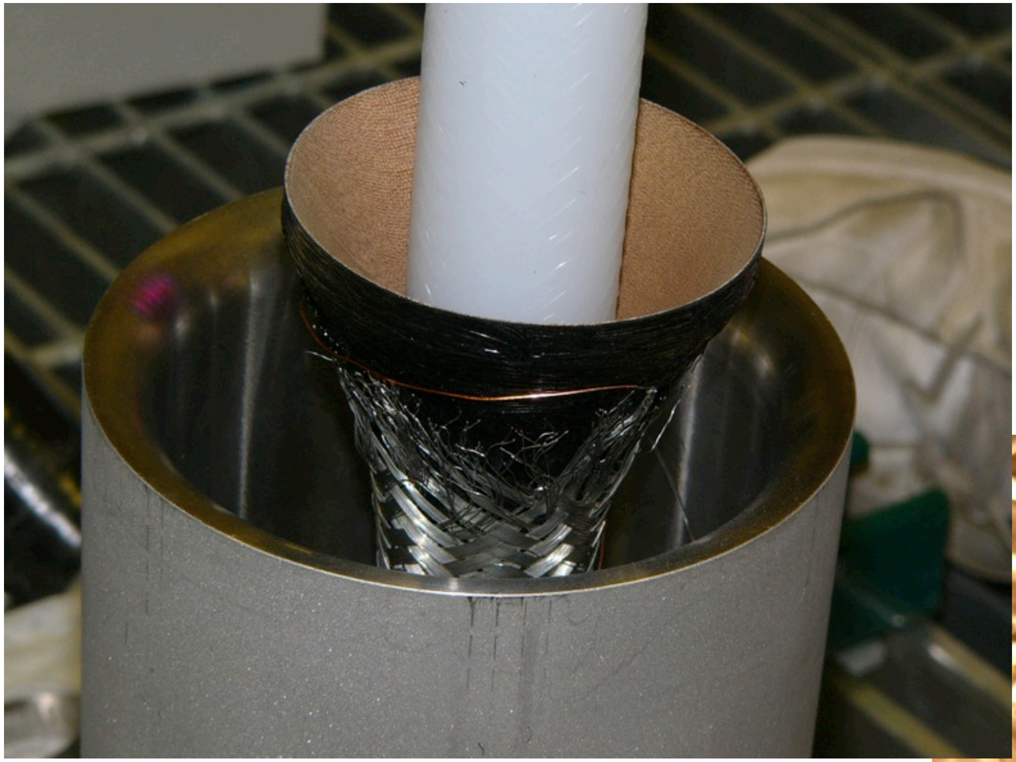
8 inch Conflat Design

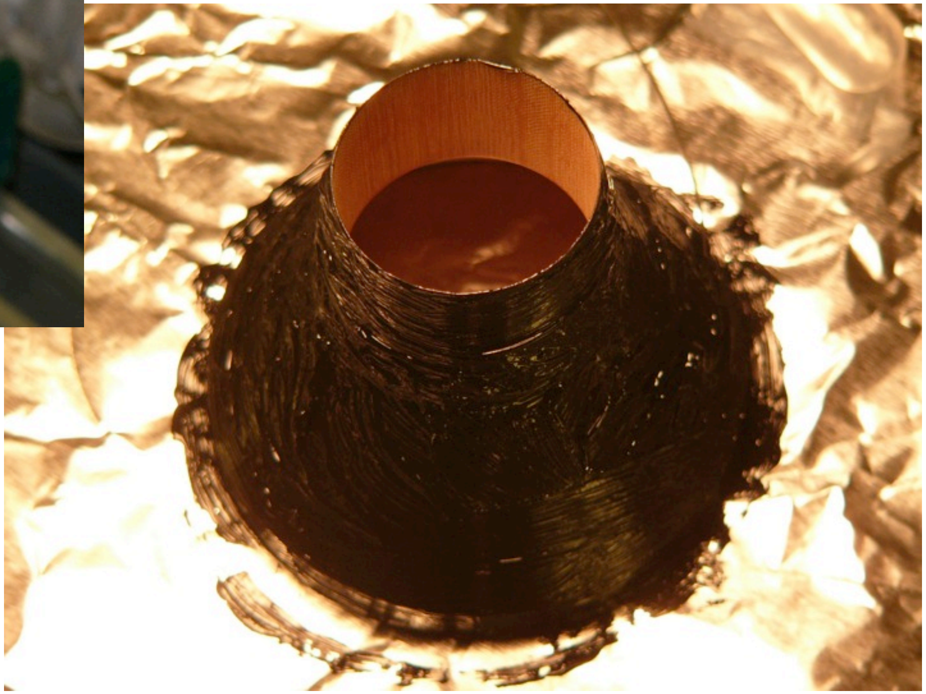


8 inch Conflat Design



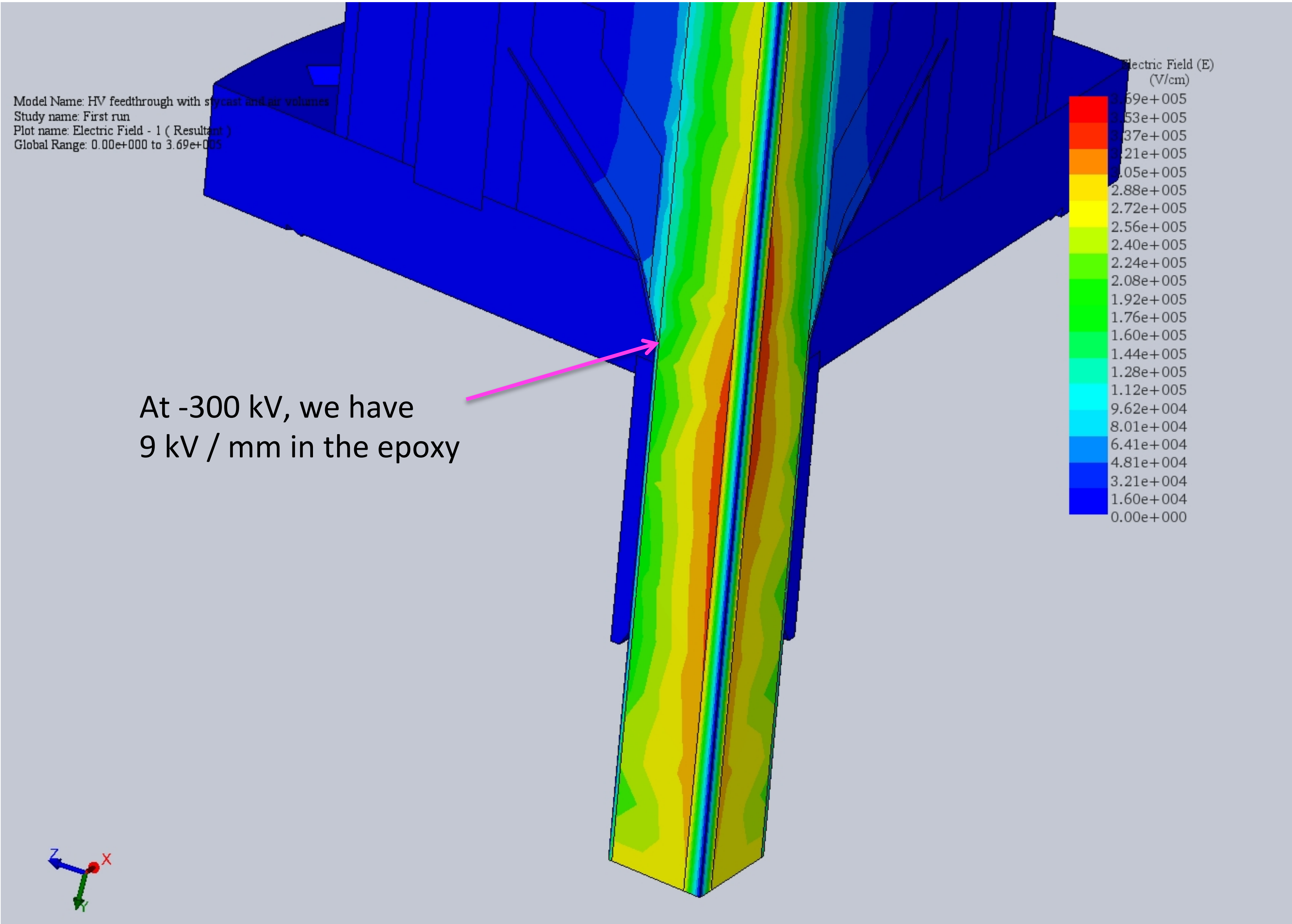
Stress Cone





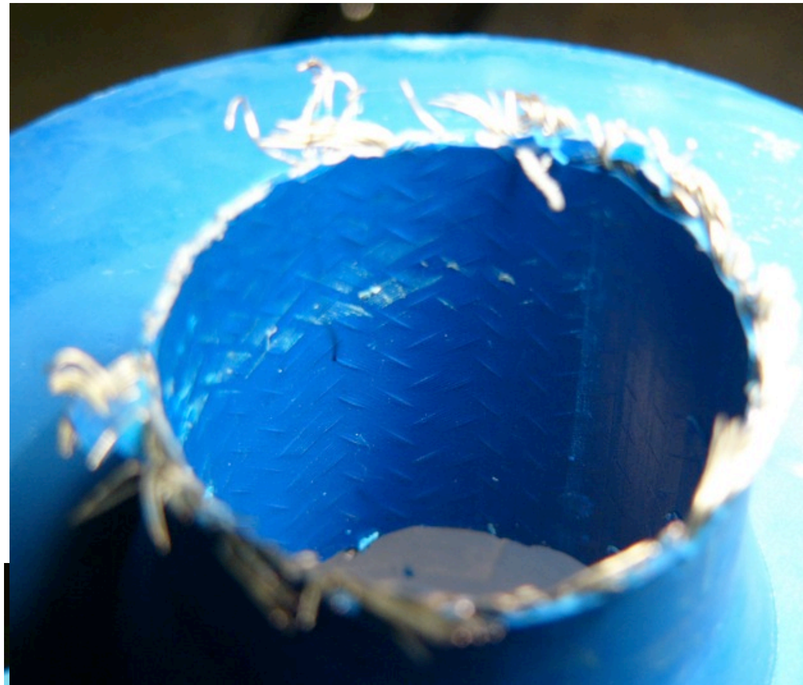
Carbon loaded epoxy (stycast 1266)
painted on paper phenolic

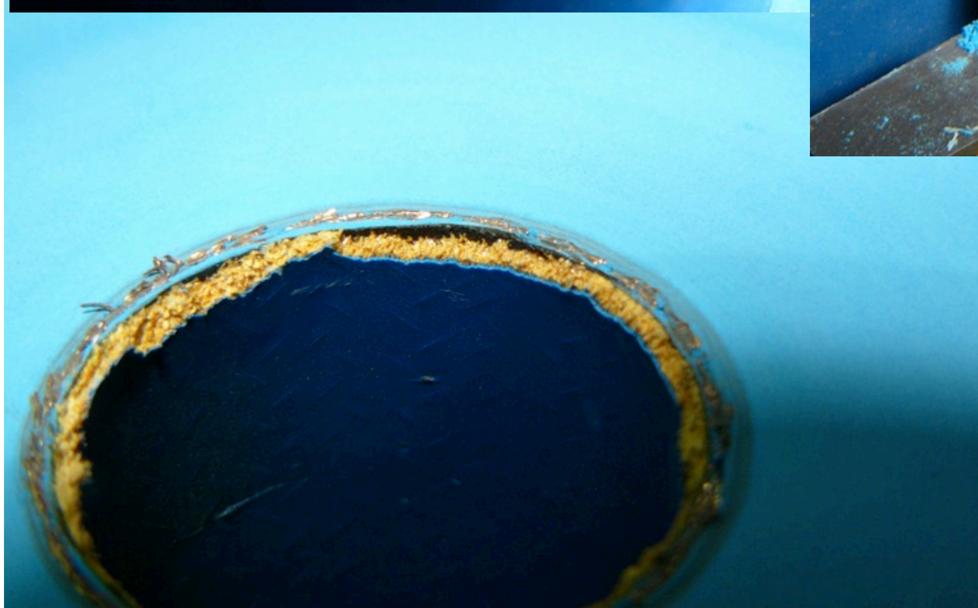
Field Simulation – 8 inch Conflat Design



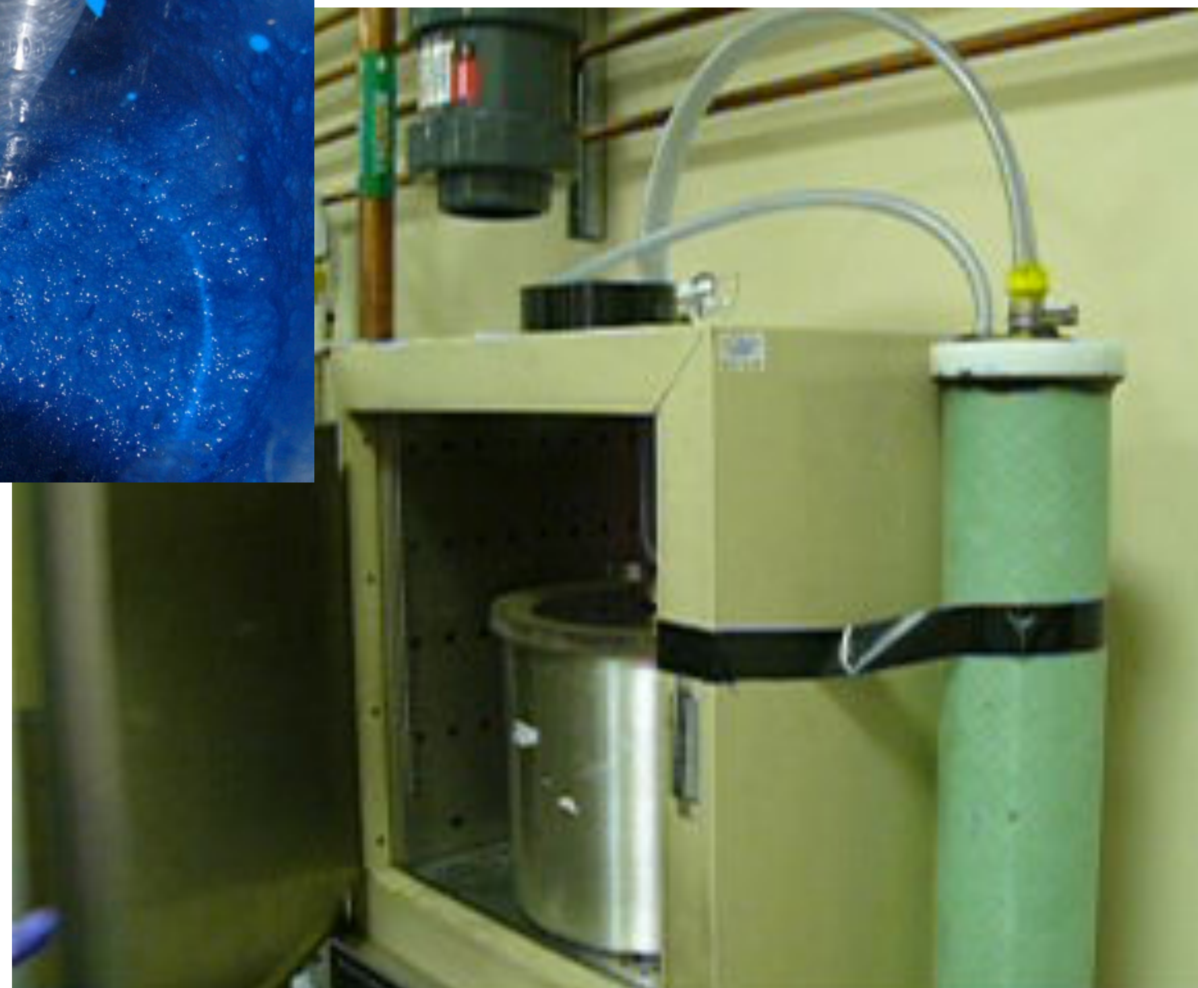
At -300 kV, we have
9 kV / mm in the epoxy

Dissecting Test Encapsulations

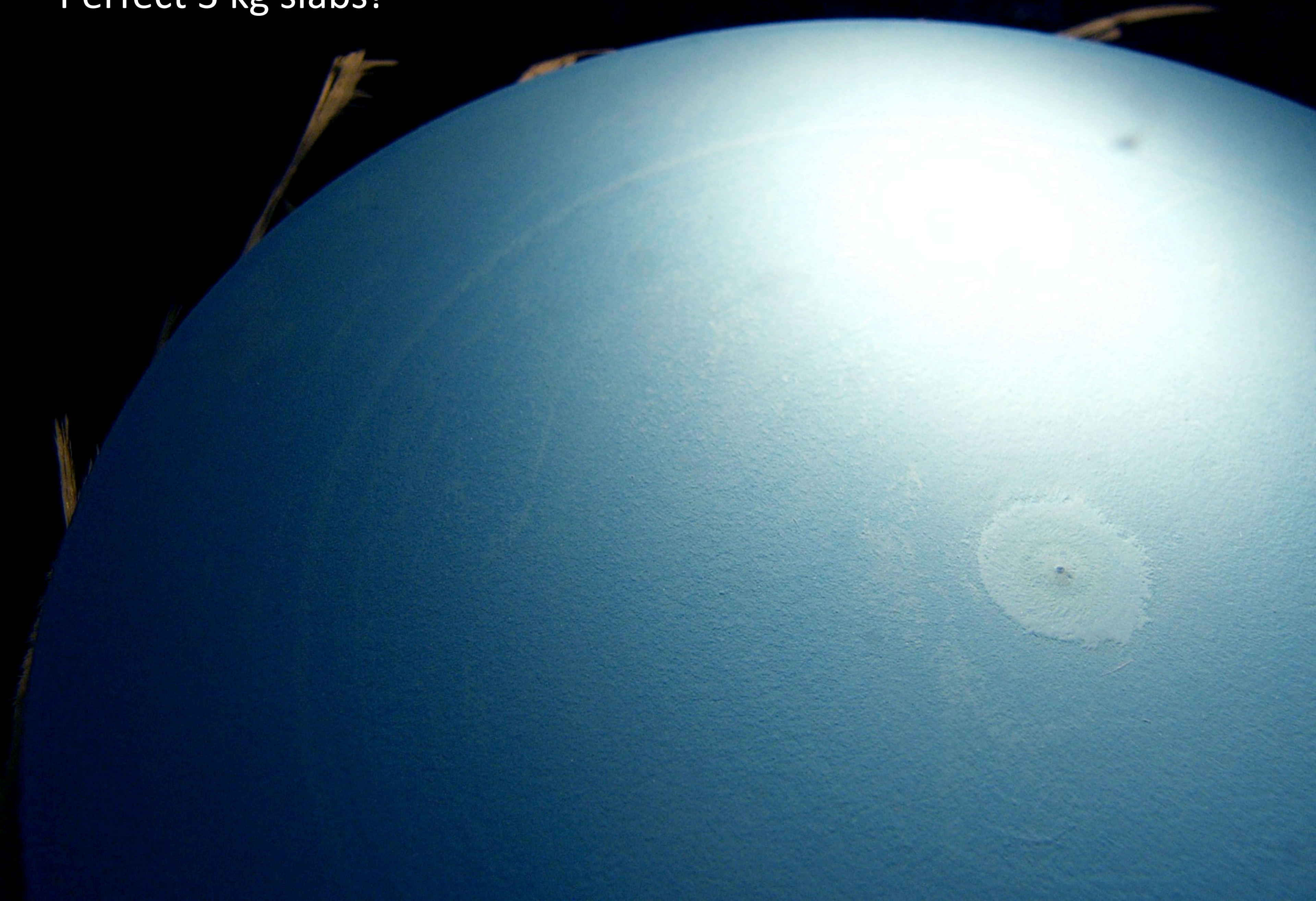




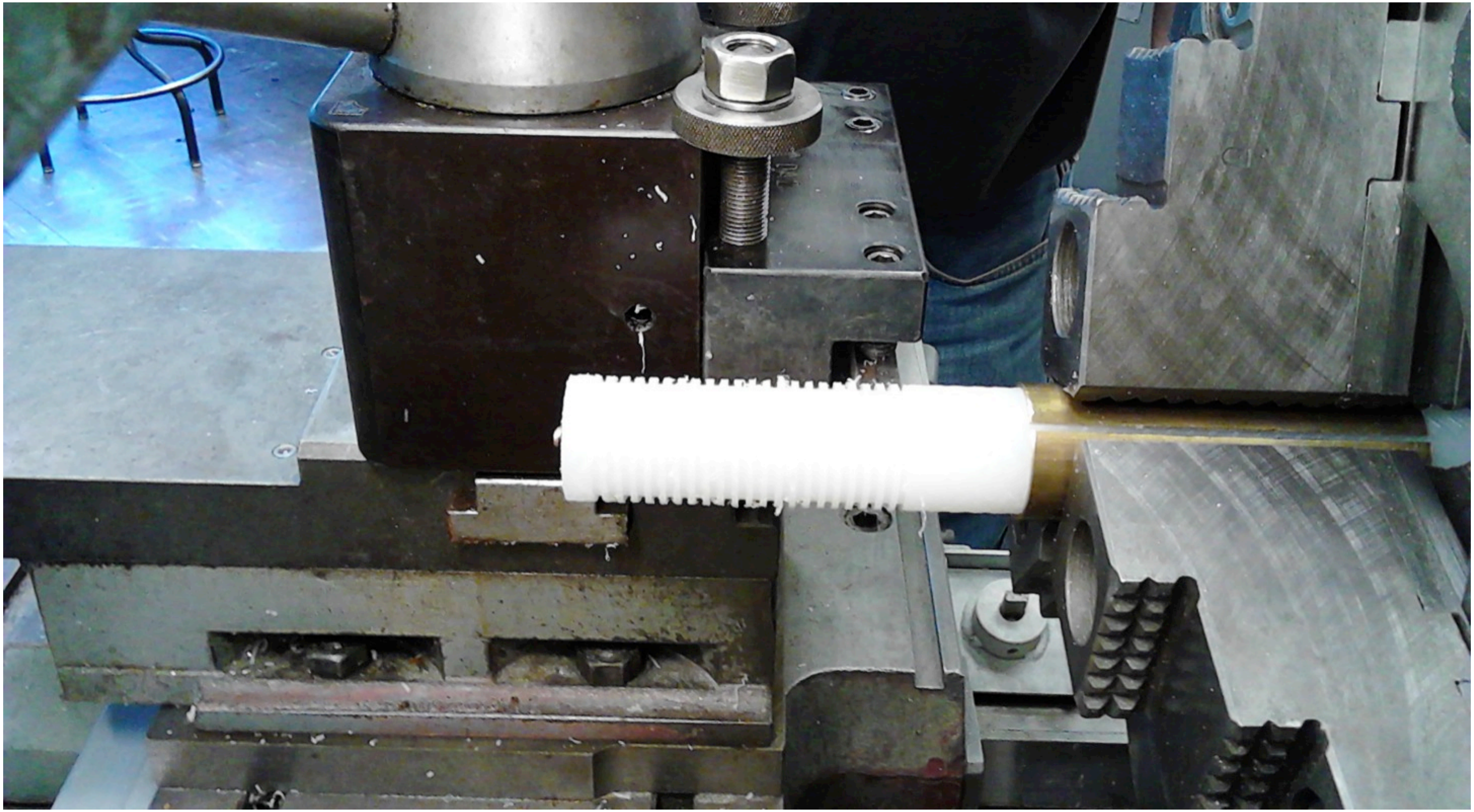
Degassing and Transferring Epoxy in Bulk



Perfect 3 kg slabs!



Cable Scalloping

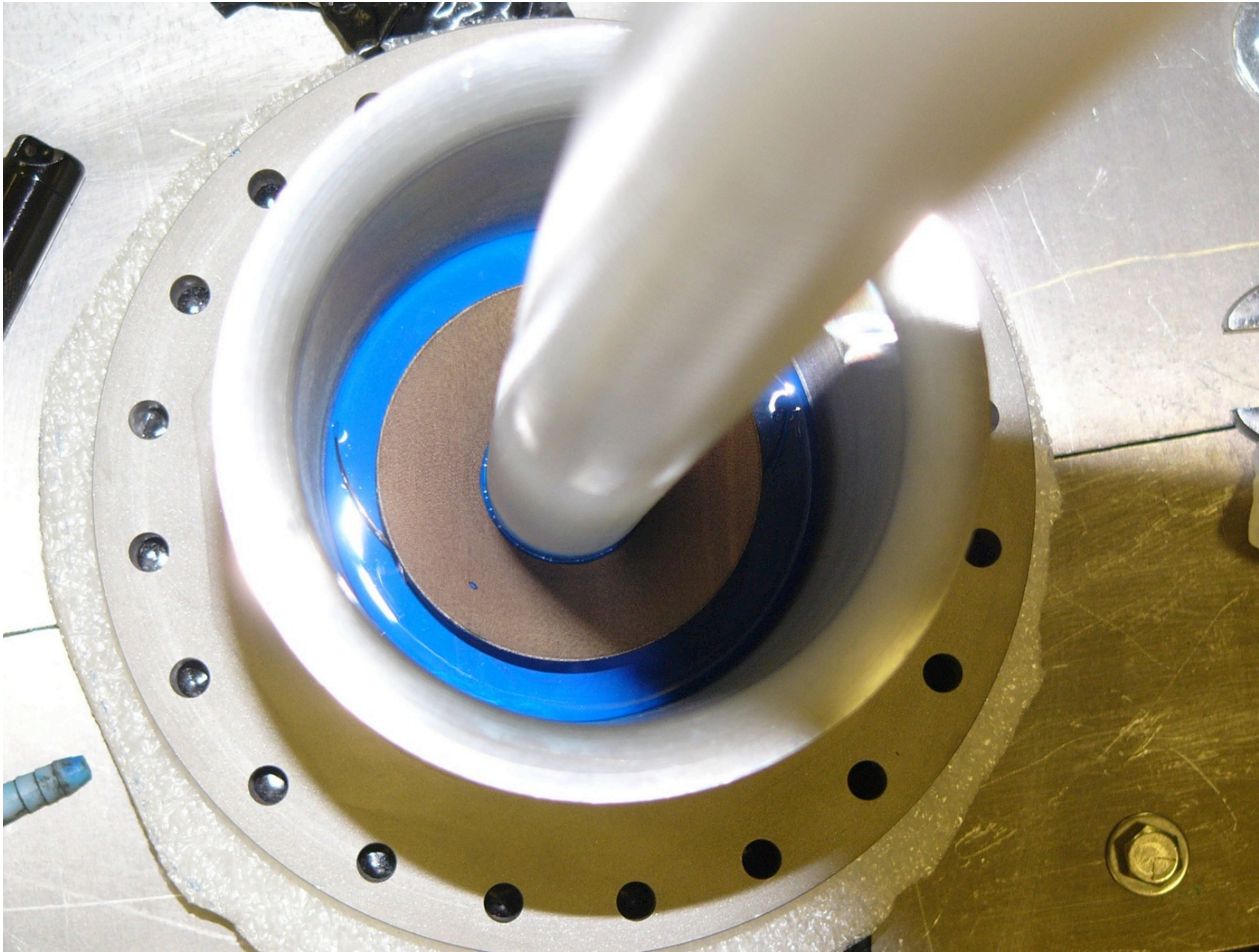


The Whole Cable Turns!

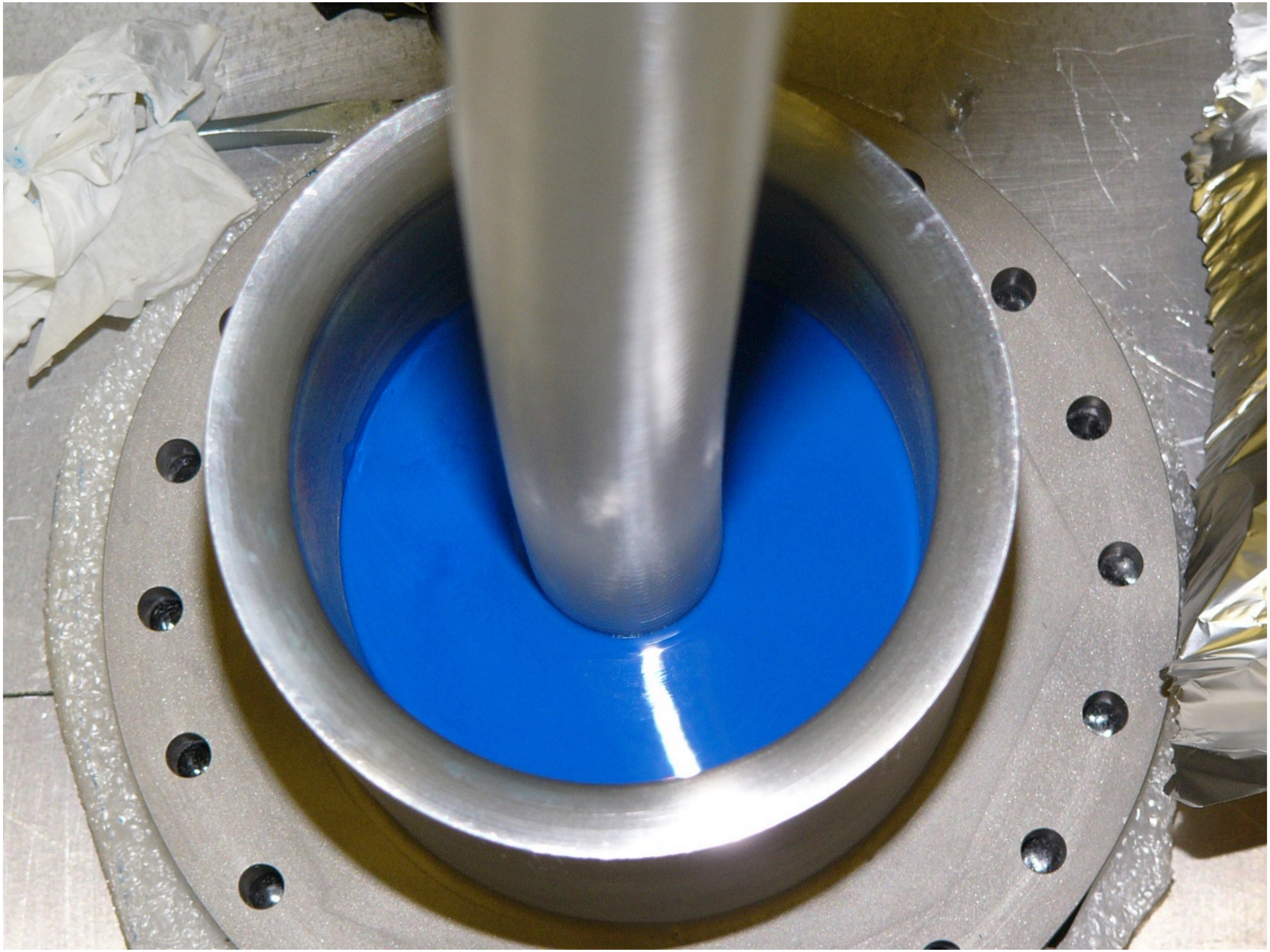
Feedthrough Stalk

Stress Cone

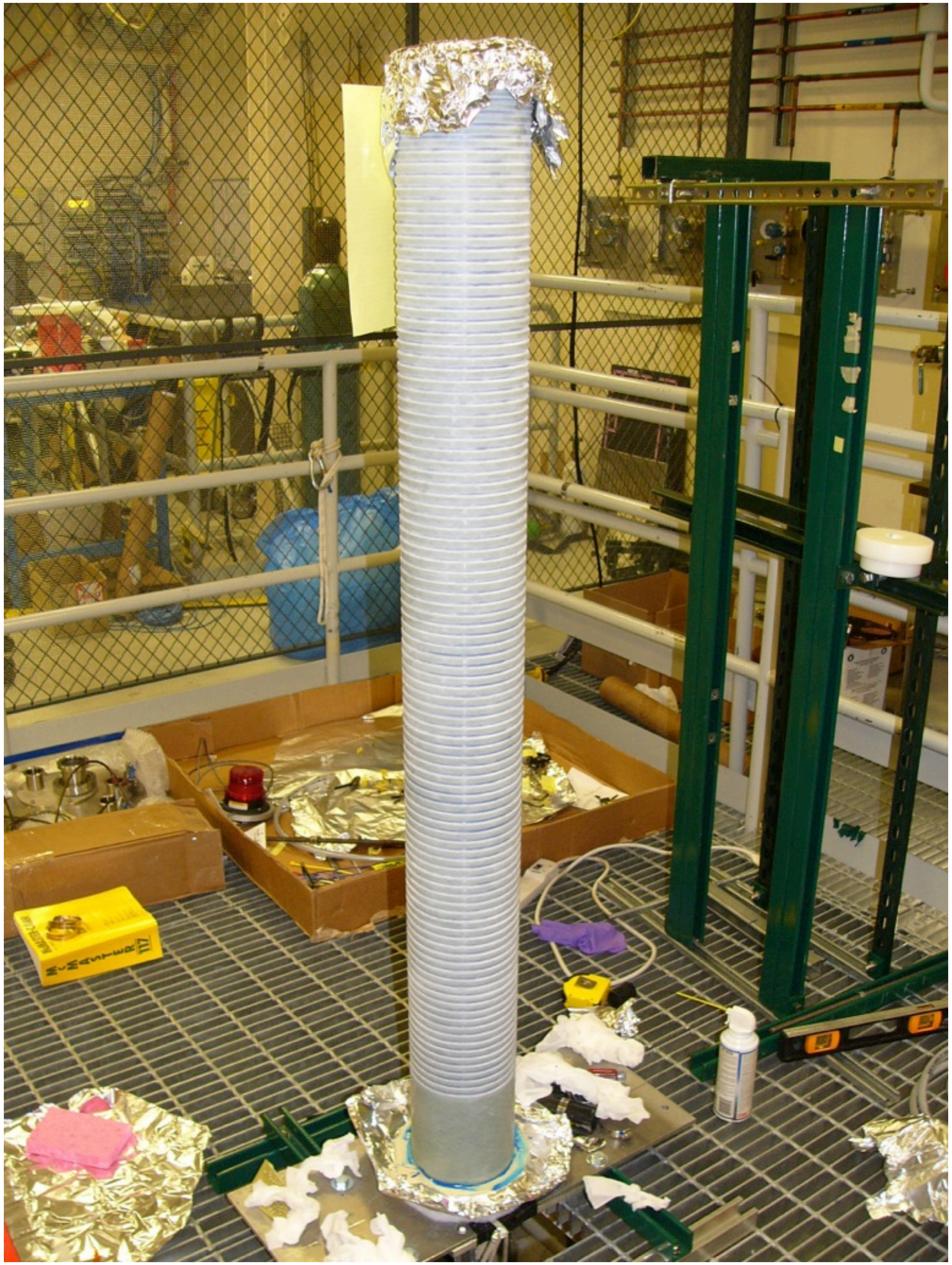
Pour with Stress Cone in Place



Second Epoxy Pour



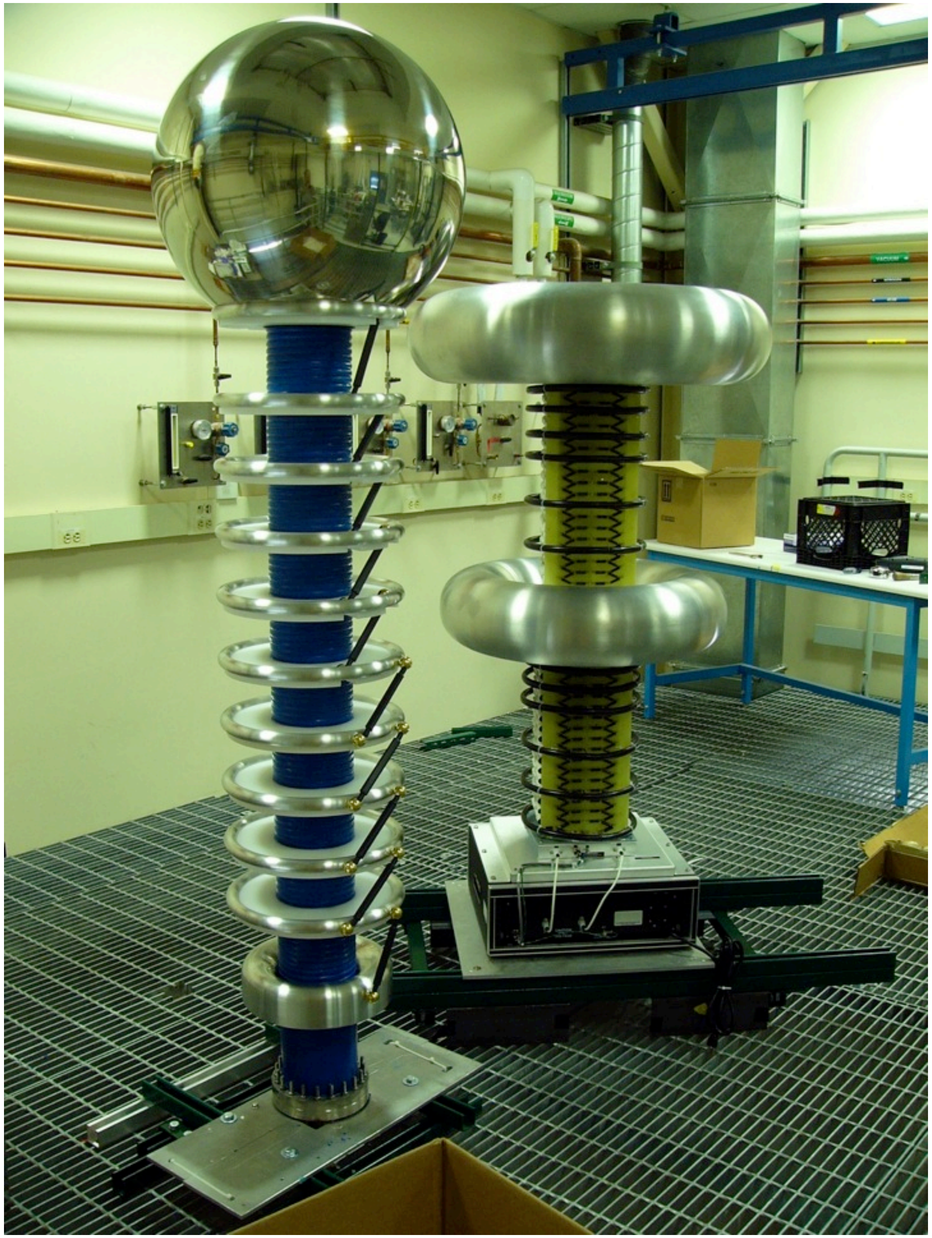
Glue on the Stalk

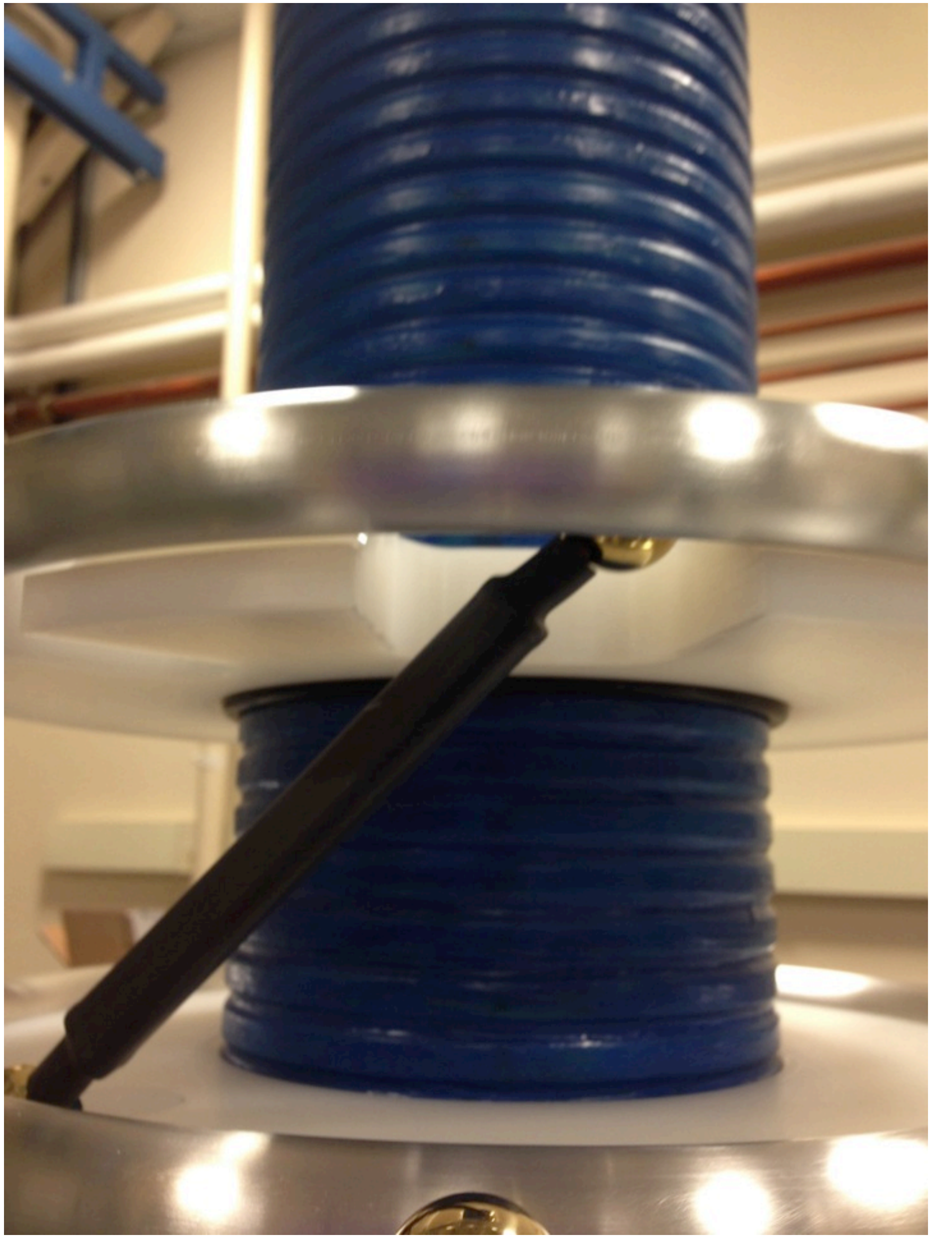


Filling the Stalk

Cap and Paint

Add Corona Rings and Resistors



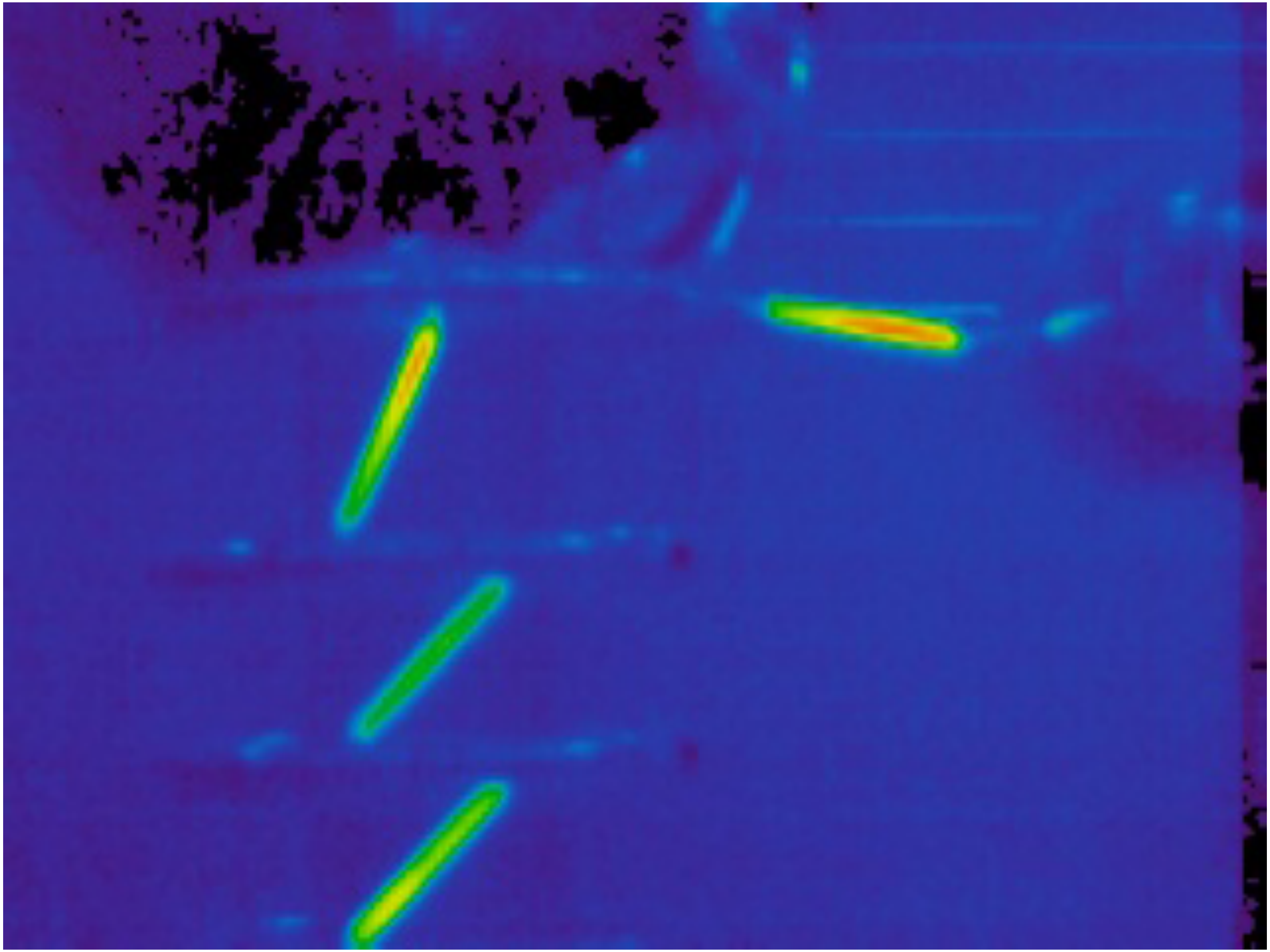


Enclose in Cage

Oil Terminate Free End

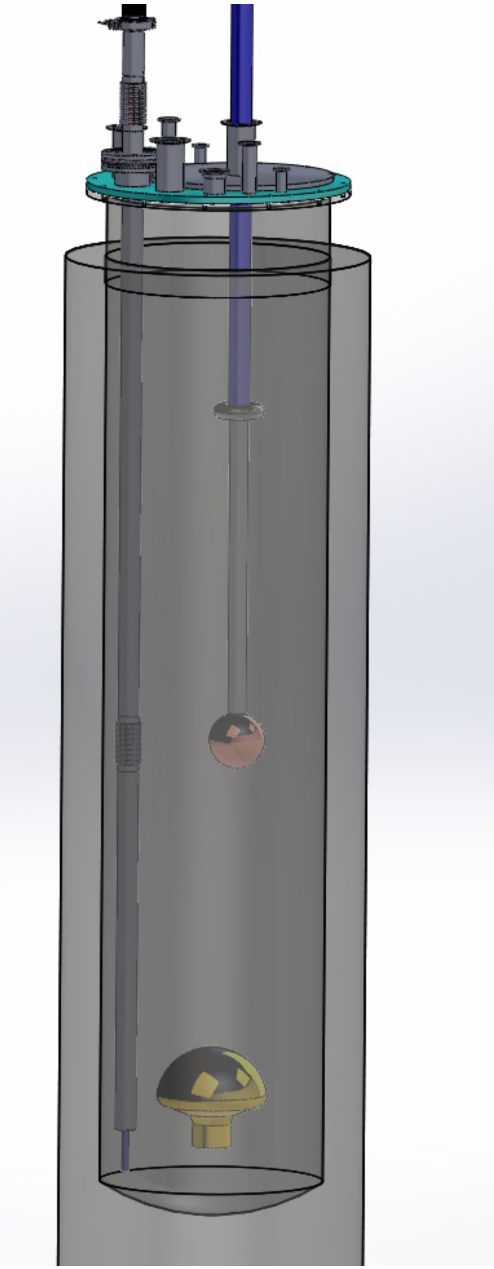
Turn it On!

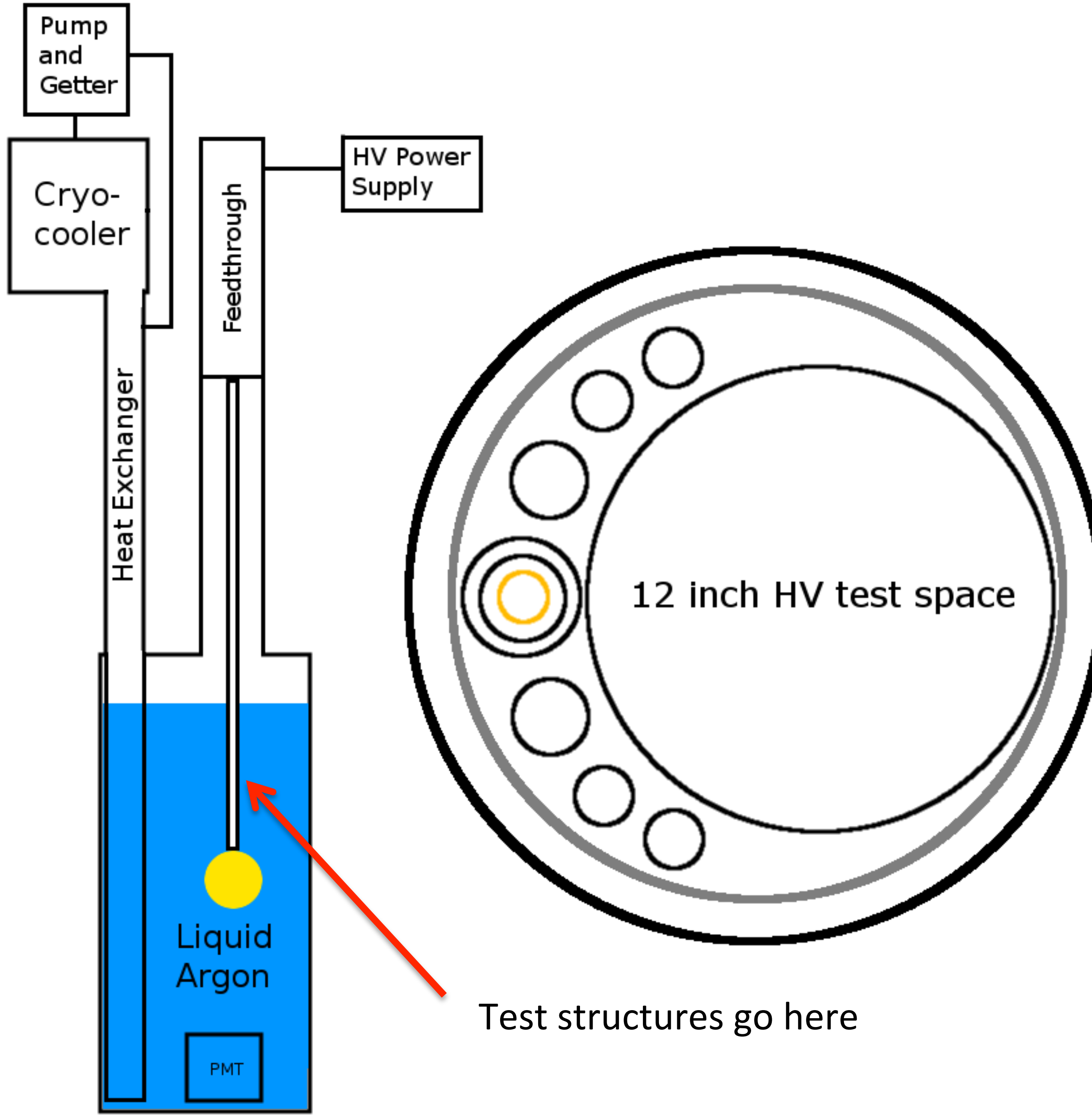
Turn it On!



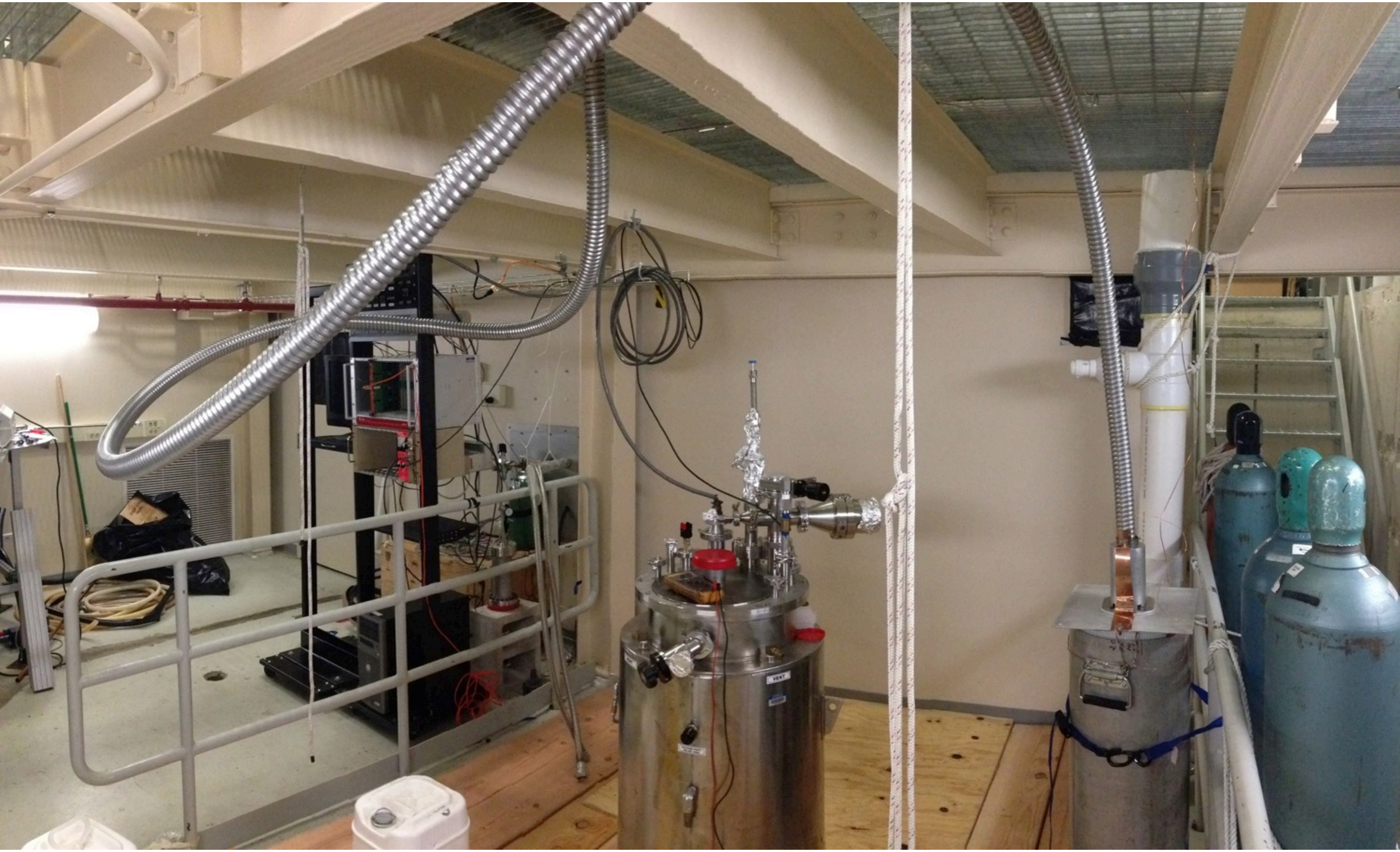
We now have 2 weeks of operation at -200 kV with no sign of aging.

Liquid Argon Test System





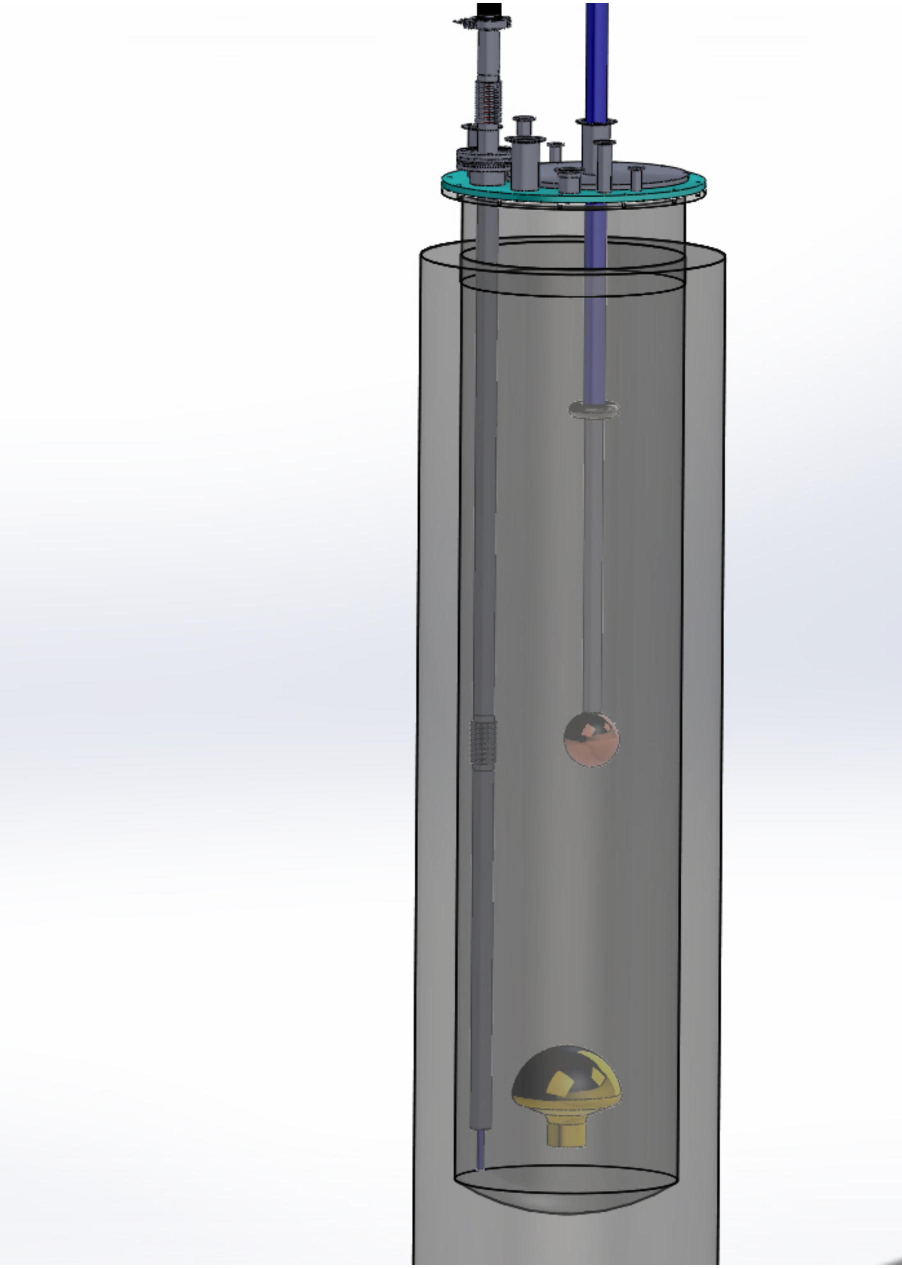
Liquid Argon Test System

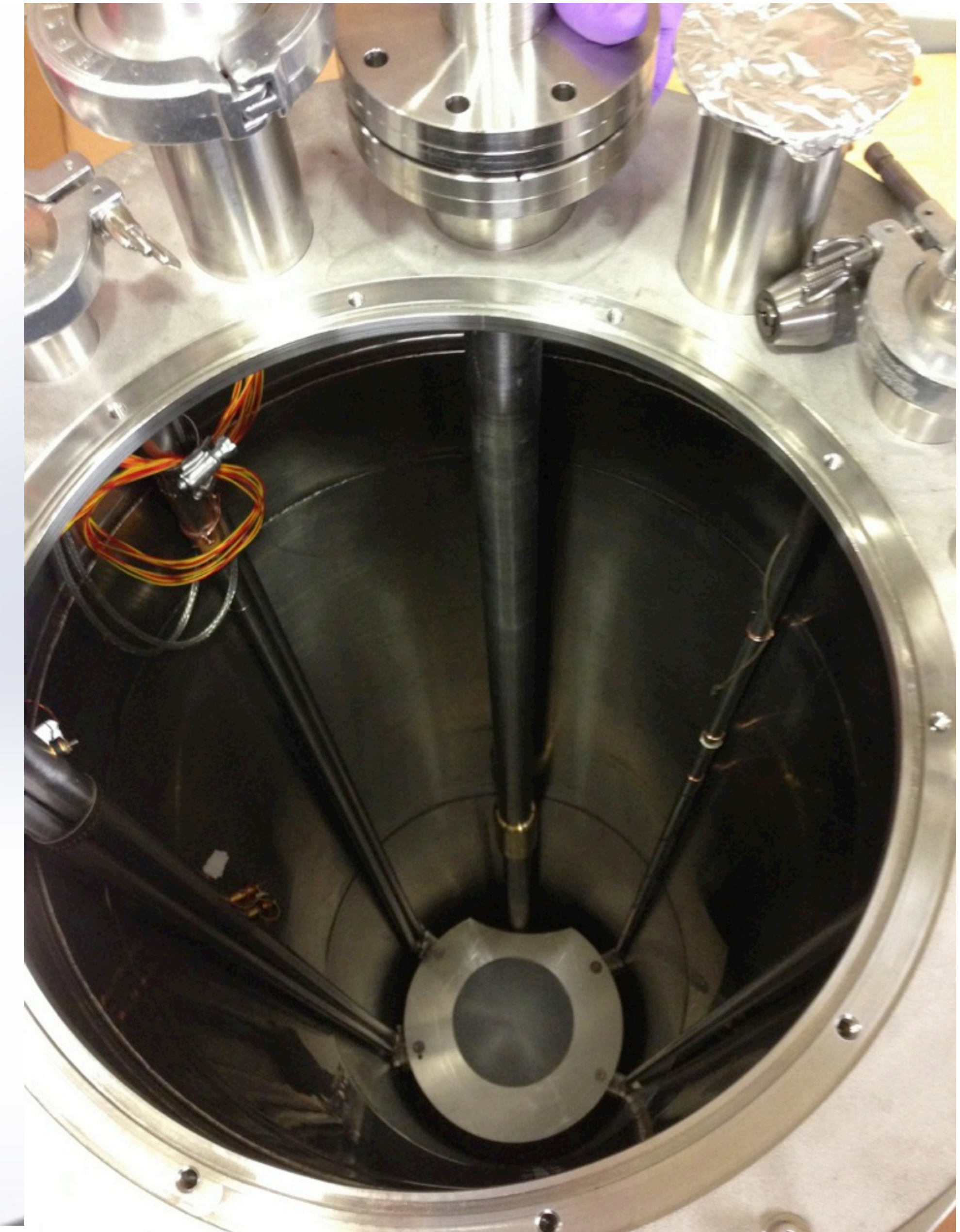


Argon Dewar

Oil Terminator

Liquid Argon Test Dewar





LZ Feedthrough Summary

One epoxy feedthrough made, tested to -200 kV for two weeks.

Liquid argon system for testing grading structures is nearly complete.

Much design of feedthrough and TPC grading structures remains.

Thanks to Evan Pease, Kevin O'Sullivan, LBNL staff