IDM 2016: Sheffield *July 21, 2016*

The LZ System Test Program

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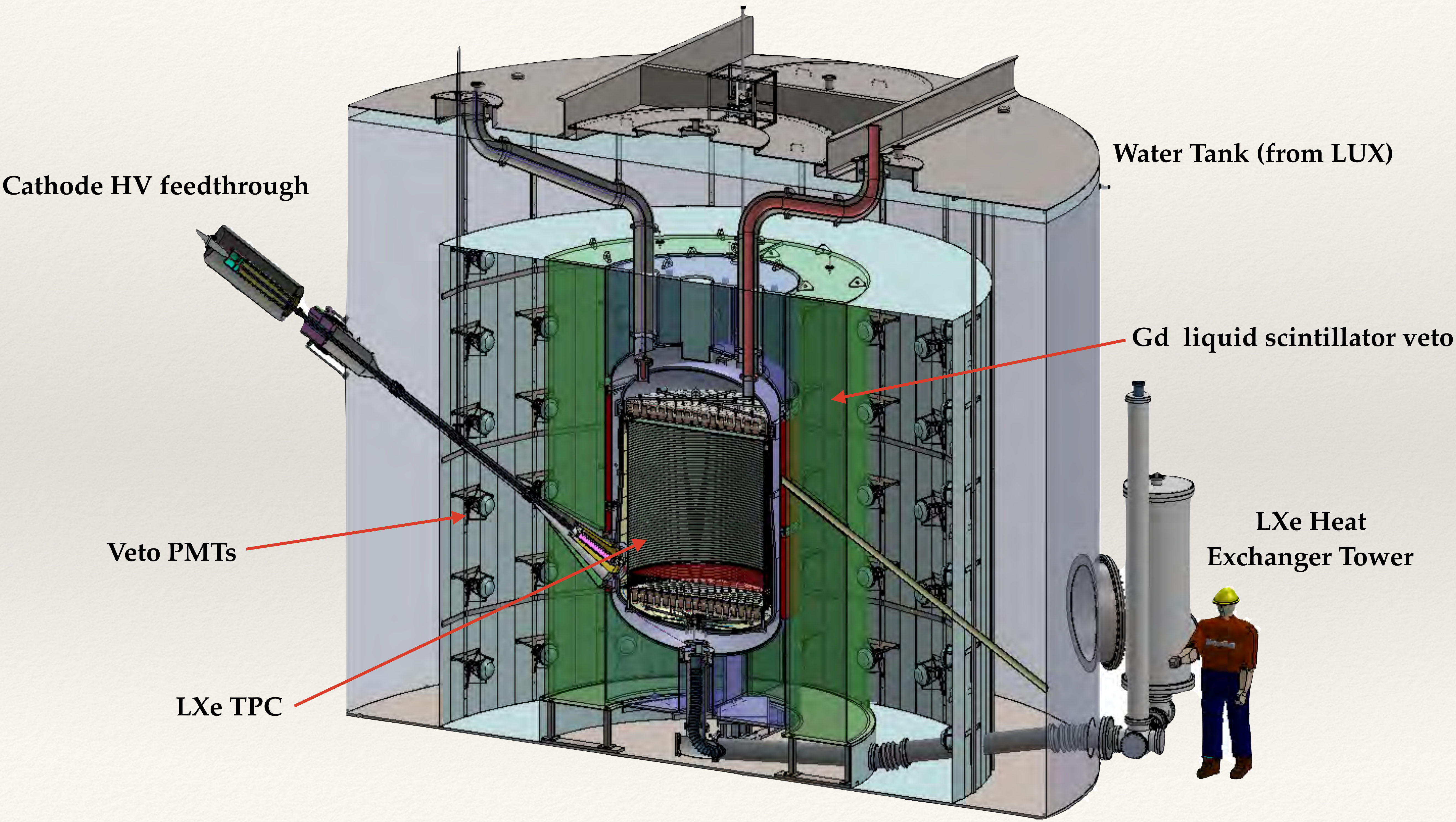
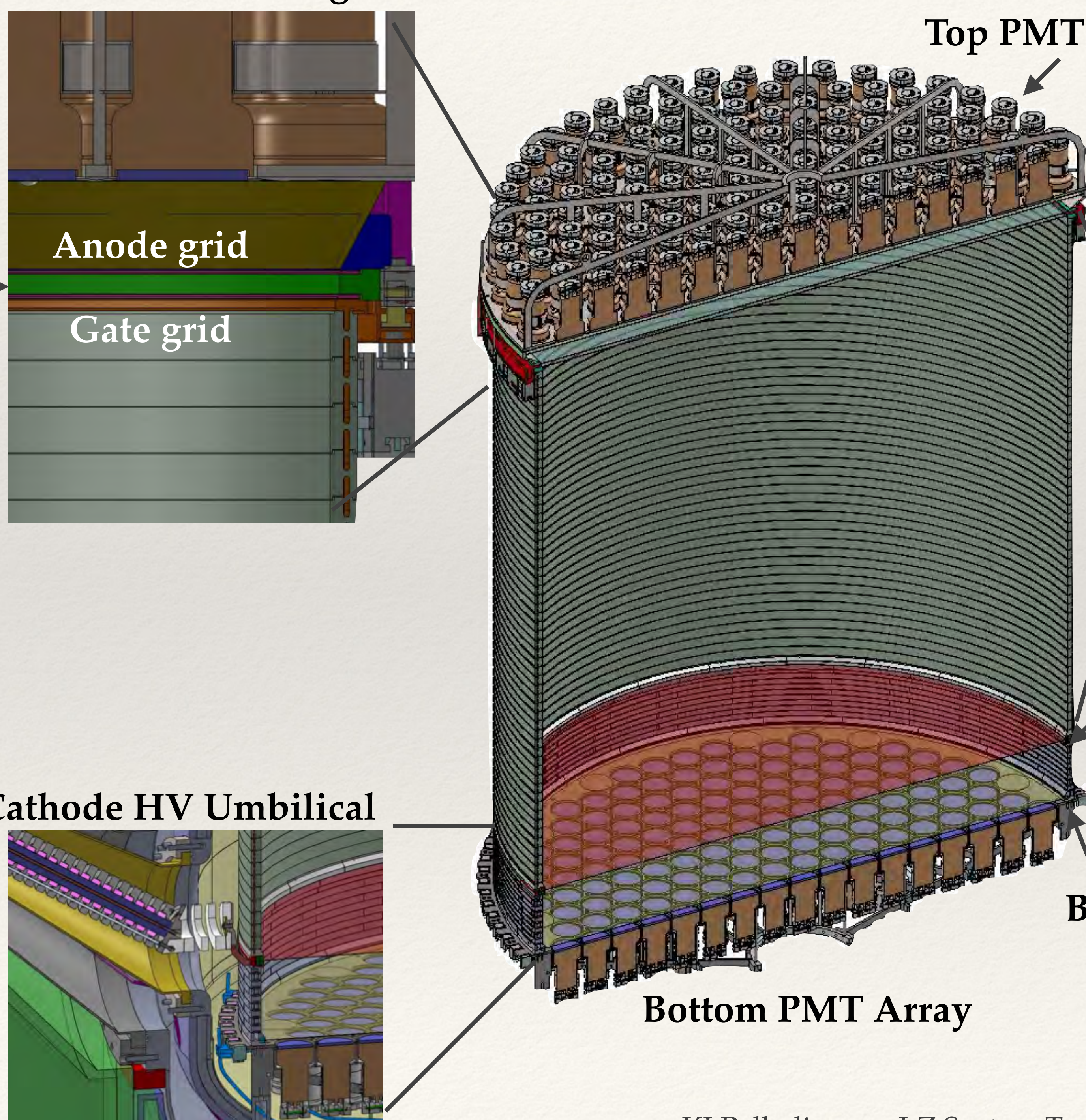
UW-Madison
for the LZ collaboration

LZ Detector



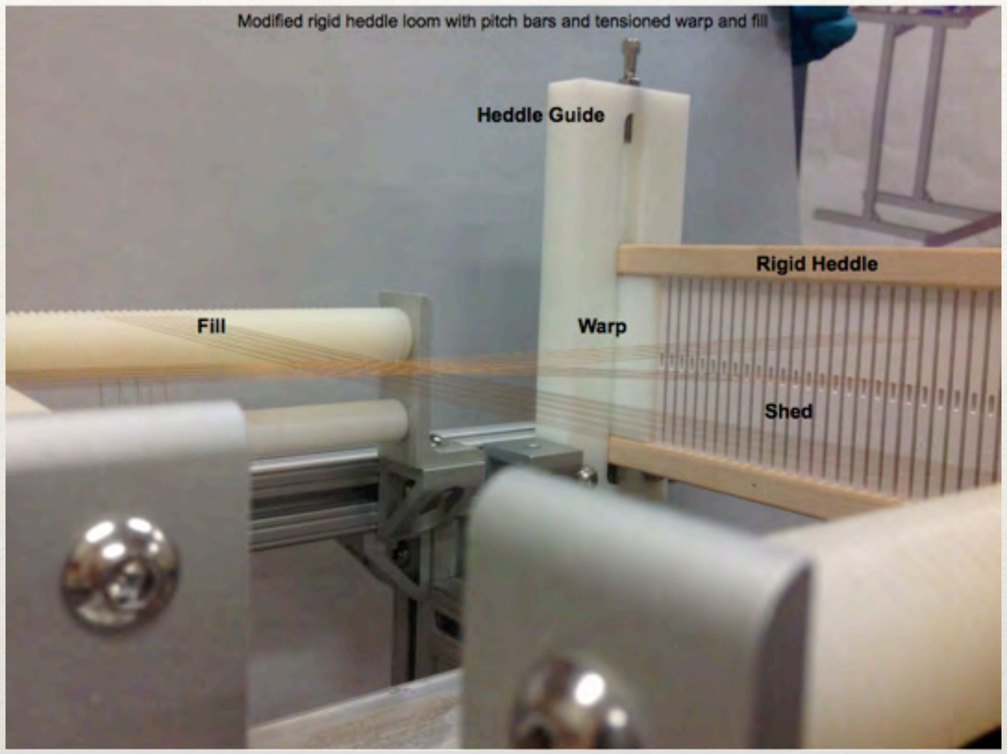
Cathode HV feedthrough
Water Tank (from LUX)
Gd liquid scintillator veto
Veto PMTs
LXe Heat Exchanger Tower
LXe TPC

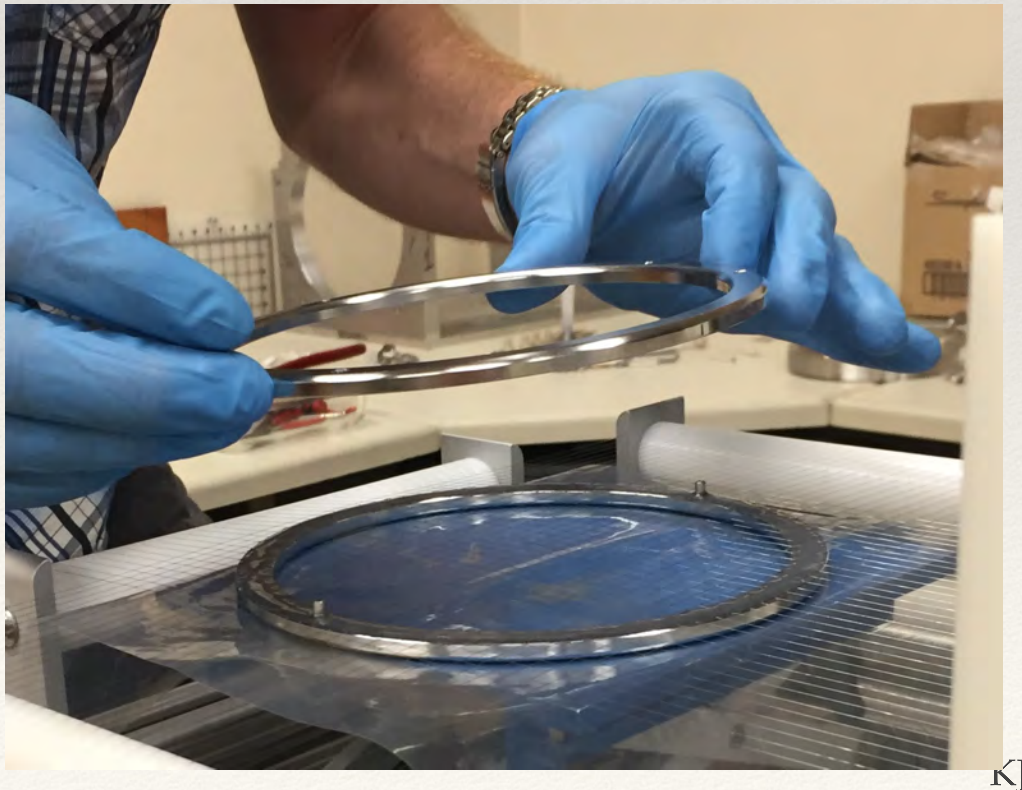
LZ High Voltage



- Designed to meet our requirements:
  - 300 V / cm drift field
  - 10 kV / cm electroluminescence field
  - 50 kV / cm maximum surface fields
  - Cathode HV feedthrough tested to -200 kV

LZ Grids





- Grids made of stainless steel wire
  - Current prototypes are California Fine Wire SS304
- Woven mesh
- Bonded to grid ring with Masterbond cryogenic epoxy
- Electropolished and passivated after bonding

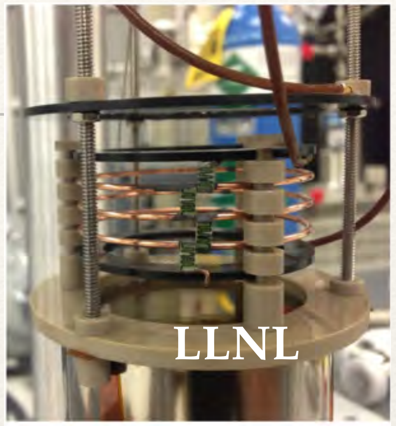
Grid Parameters

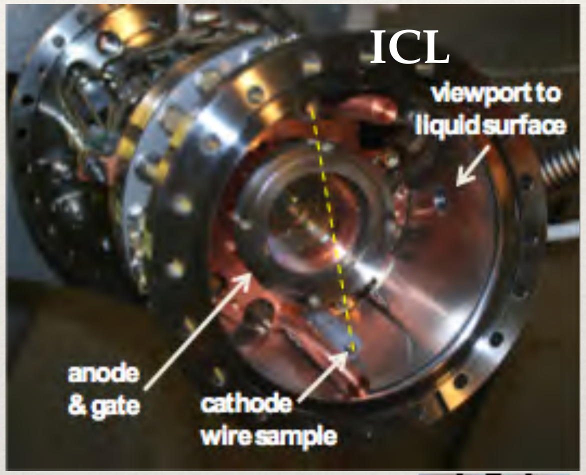
	Req. V	Goal V	Pitch	Diam.
Anode	+5.75 kV	+7 kV	2.5 mm	100 um
Gate	-5.75 kV	-7 kV	5 mm	75 um
Cathode	-50 kV	-100 kV	5 mm	100 um
Bottom	-1.5 kV		5 mm	100 um

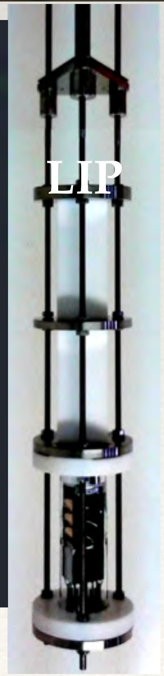
LZ Testing Program

- **SLAC System Test Program**
  - Located in IR-2 hall at SLAC (former home of BaBar)
  - Focus upon HV operations of TPC to minimize low levels of electron and photon emission
  - Requires a full experiment -> up to 500 kg of LXe (cryogenics, circulation and purification, recovery, slow controls, data acquisition, calibrations)
  - **Phase I: full TPC, 120 kg LXe**
  - Phase II: full LZ grids, 500 kg LXe

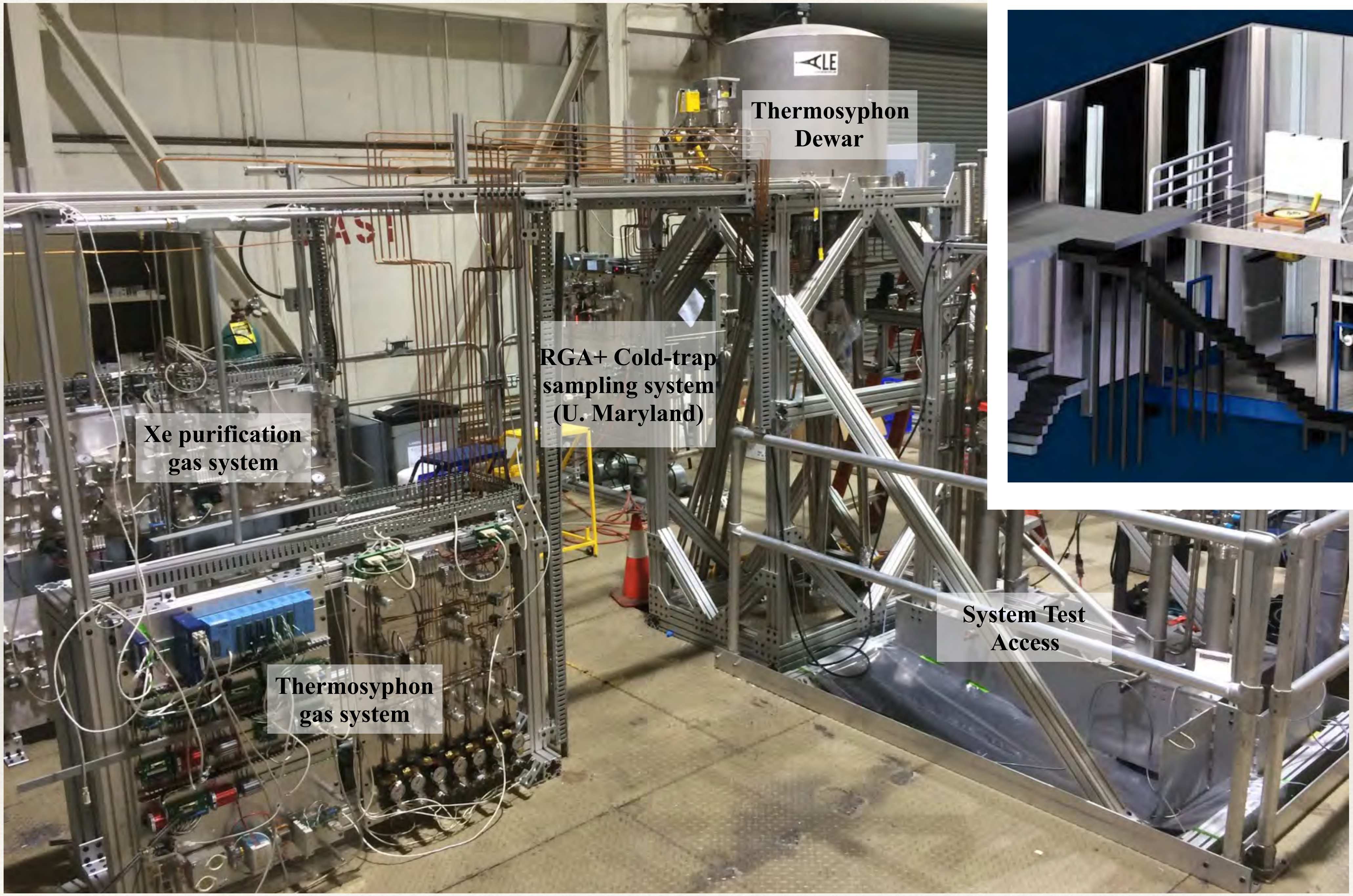
- Testing in many small test chambers at a variety of institutions
  - Imperial, LBNL, LLNL, LIP Coimbra, U. Michigan, UC Berkeley, UC Davis, MEPHI
  - See F. Neves Tuesday 14:40 talk on PTFE reflectivity
- PMT testing at Brown and Imperial
- Cathode HV feedthrough testing at LBNL
- Electronics testing at U. Rochester





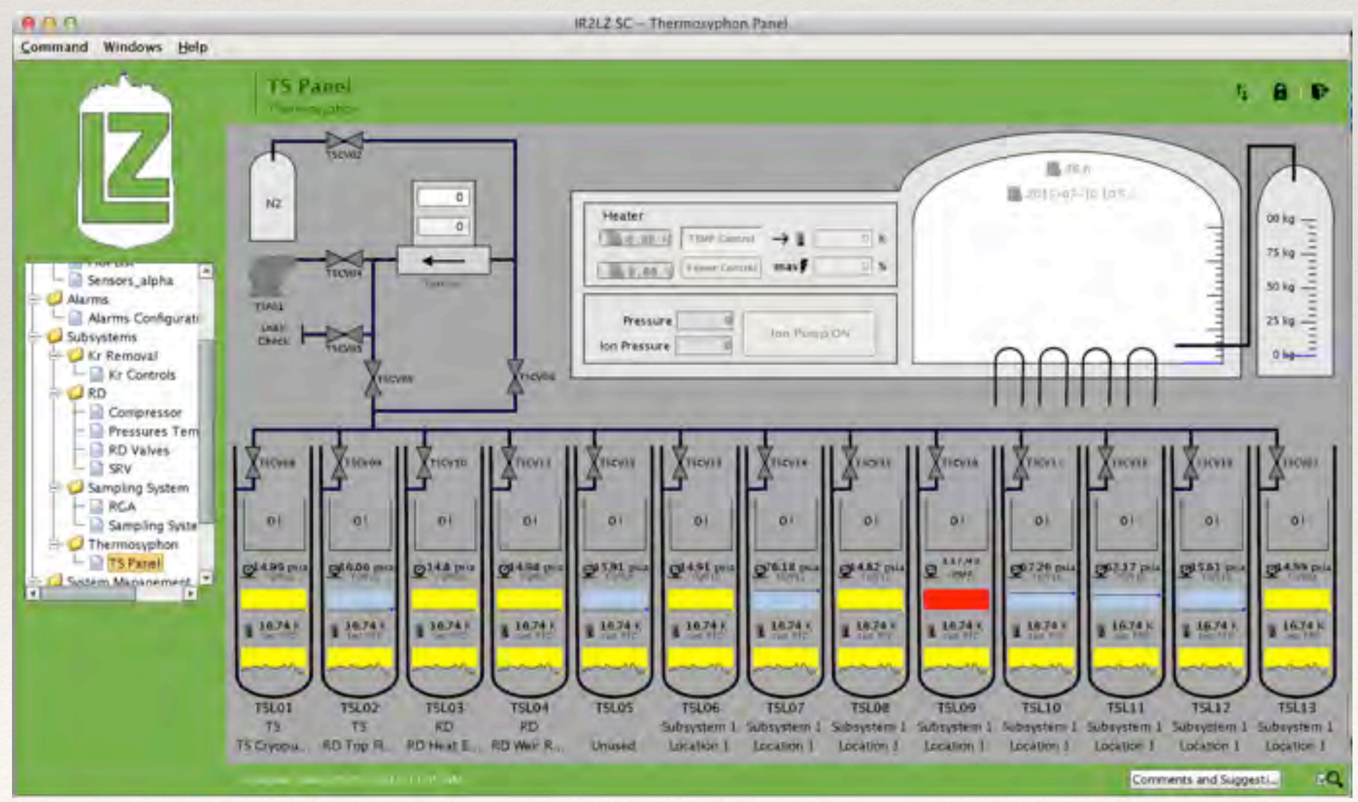


System Test Platform at SLAC

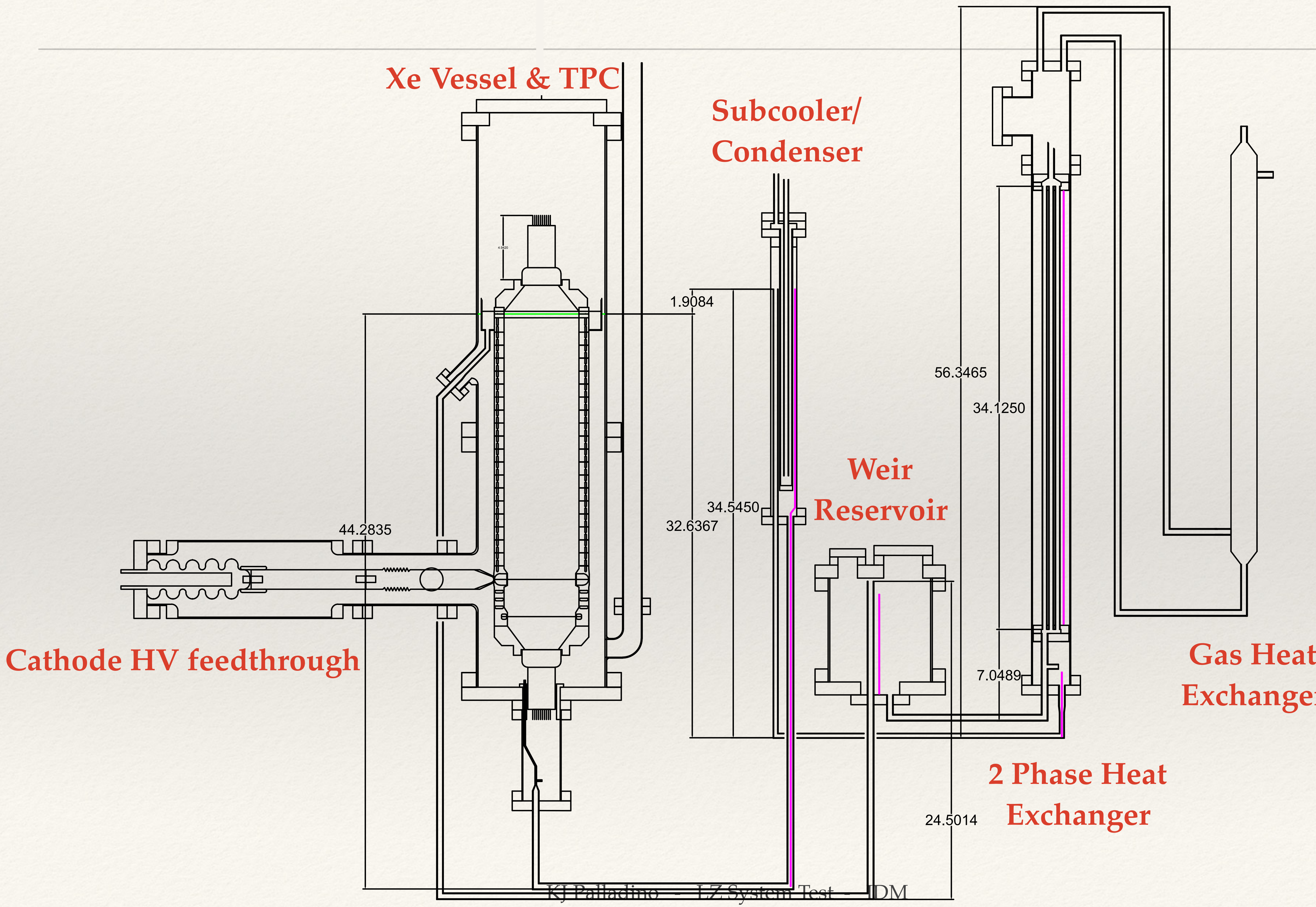


Gas Handling and Slow Controls

- Circulation with noise and vibration isolated Fluitron compressor up to 100 slpm
- Purification with SAES MegaTorr getter
- PLC managed slow controls with Ignition software front end

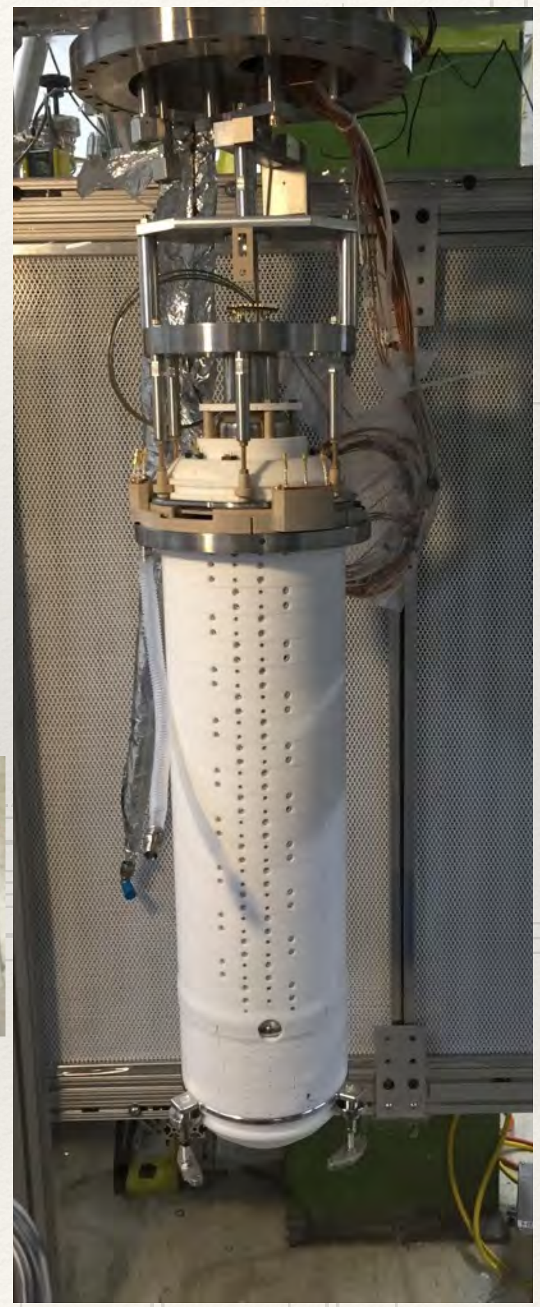


Phase I Overview

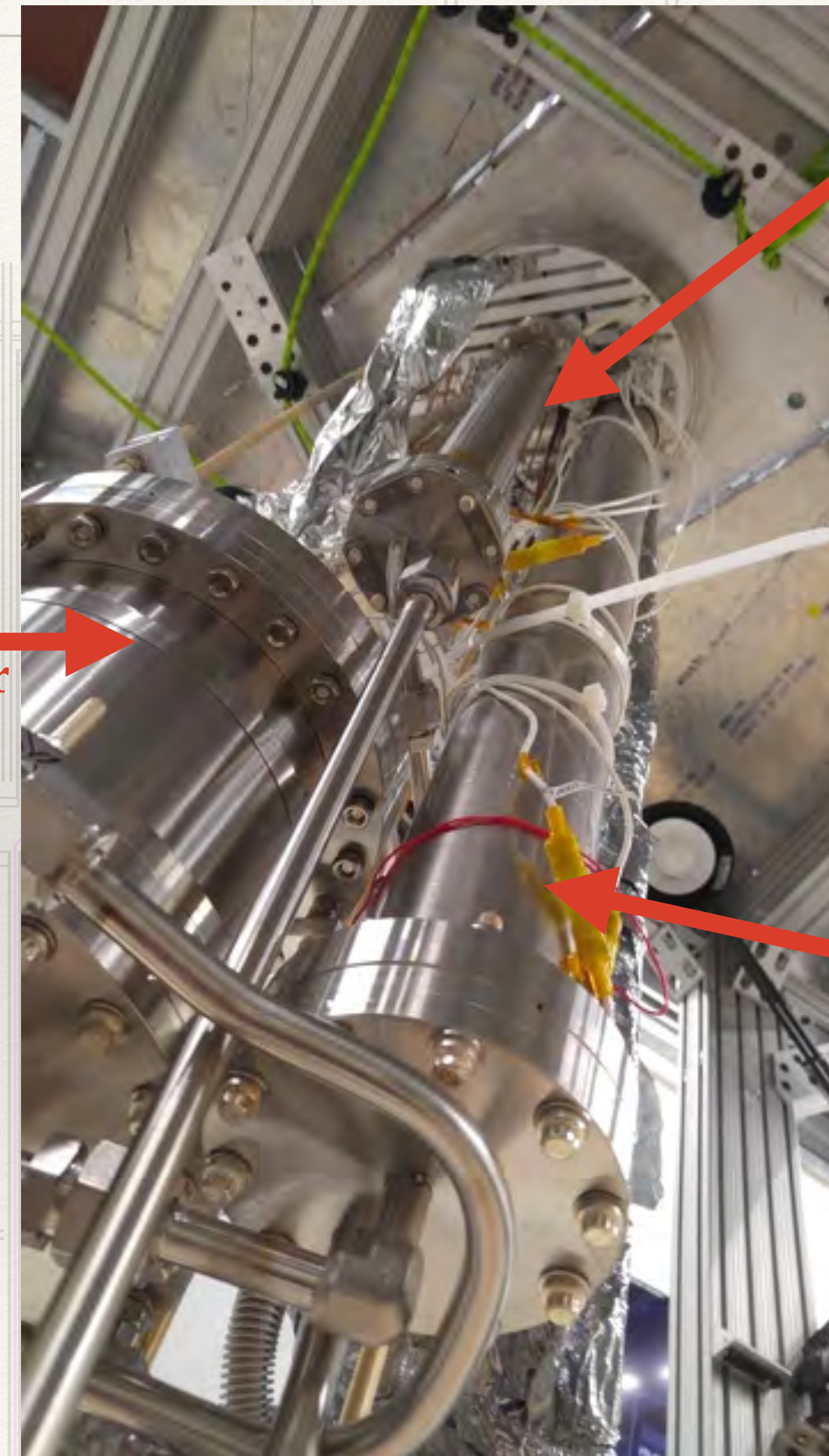


Phase I Overview

TPC



Weir Reservoir



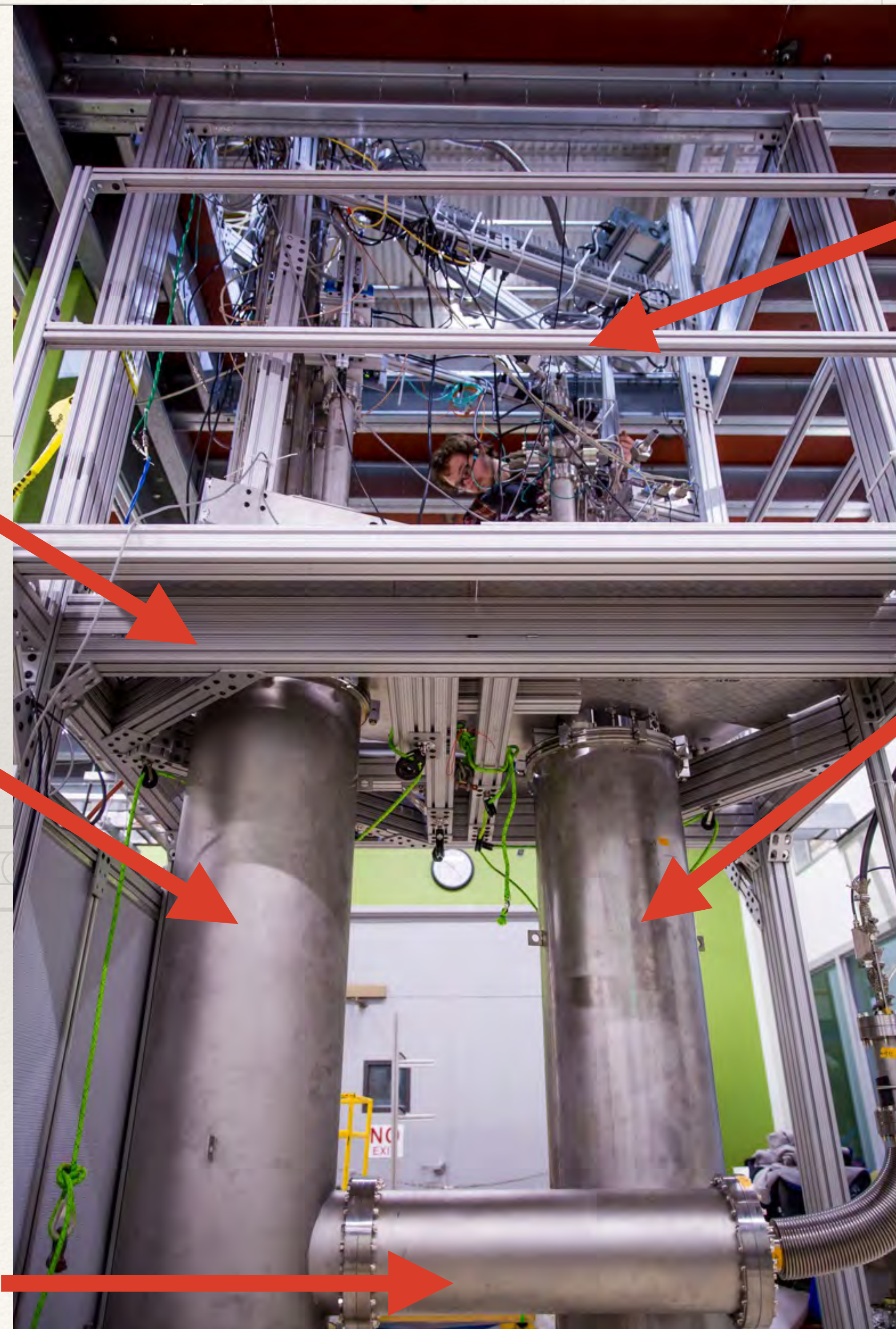
Subcooler/ Condenser

2 Phase Heat Exchanger

Gas Heat Exchanger (hidden from view)

Cathode HV feedthrough

Phase I Overview



Gas and Instrumentation Breakout

Clean Tent area

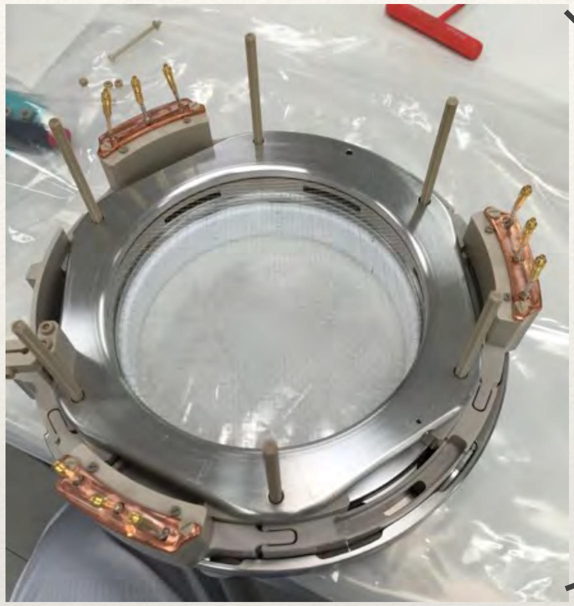
Purification Tower (heat exchangers etc)

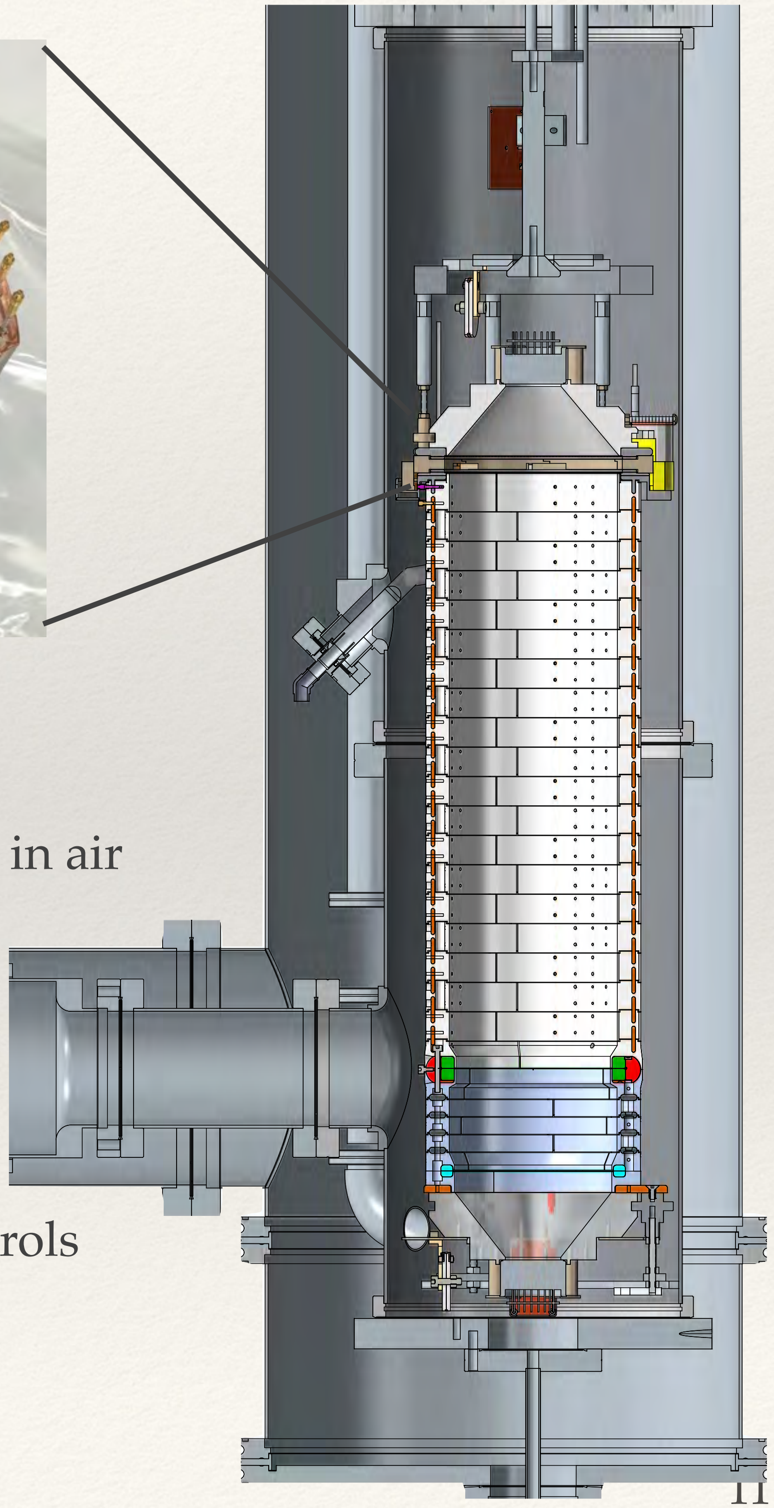
Xe Vessel &TPC

Cathode HV feedthrough

TPC Design Overview

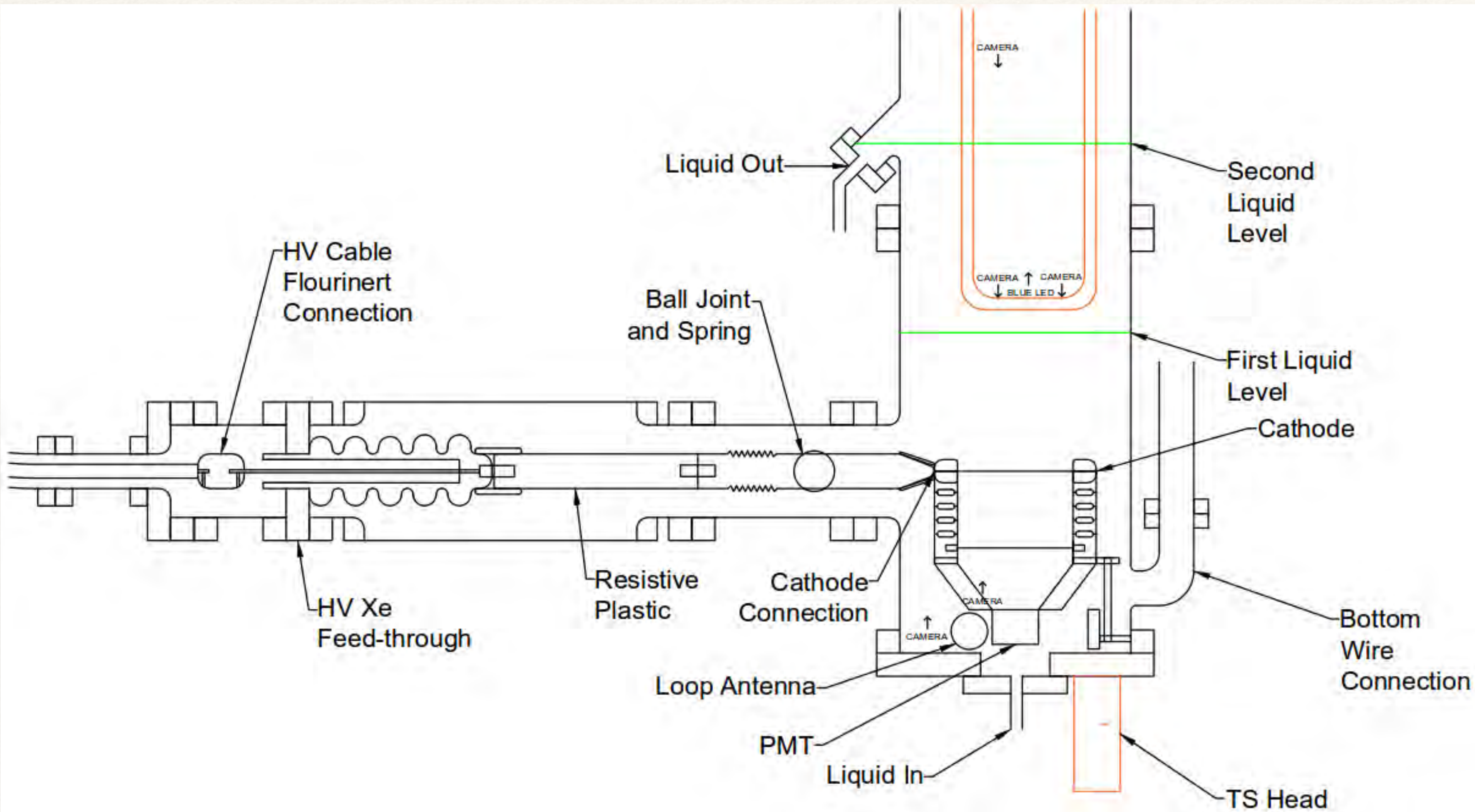
- 10” diameter vessel, 6” inner diameter TPC
- >120 kg LXe total, nearly 100 kg LXe cathode to gate
- Scaling to LZ
    - TPC to vessel wall is 1/2 of LZ design
    - Cathode to bottom grid is 5/8 of LZ
    - Cathode to gate is 1/3 of LZ
    - Gate to anode same as LZ
- 4 woven grids, gate and anode in integrated “upper corner” including liquid weir and precision level sensors
    - See K. Boast, Tuesday 15:40 and posters

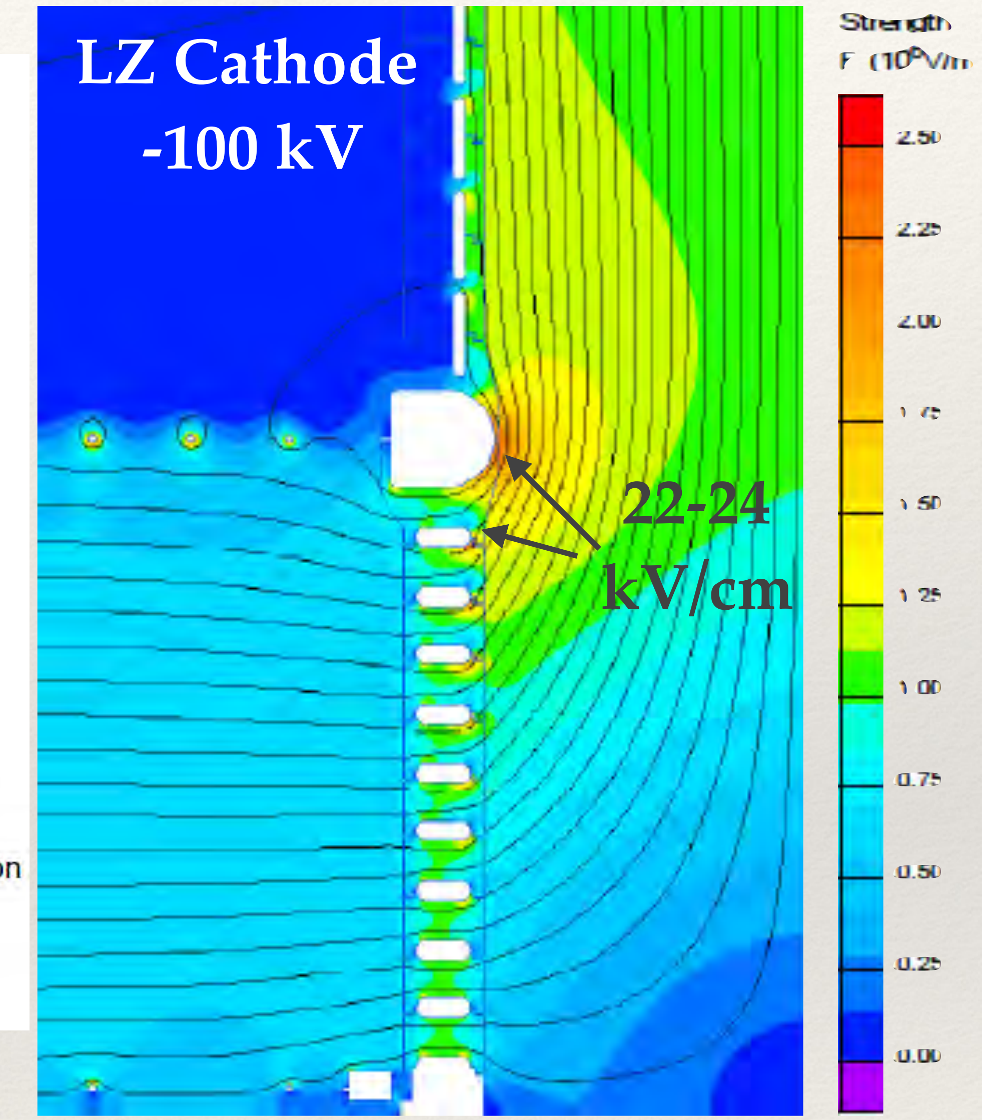




- Data from:
    - 2 PMTs
    - 7 optical camera fibers to camera in air
    - 2 loop antennas
    - Acoustic sensors
    - Power supply slow controls
    - Temperature/pressure slow controls
    - Purity monitoring with external sampling system for volatiles

Reverse Field Region Test: Design



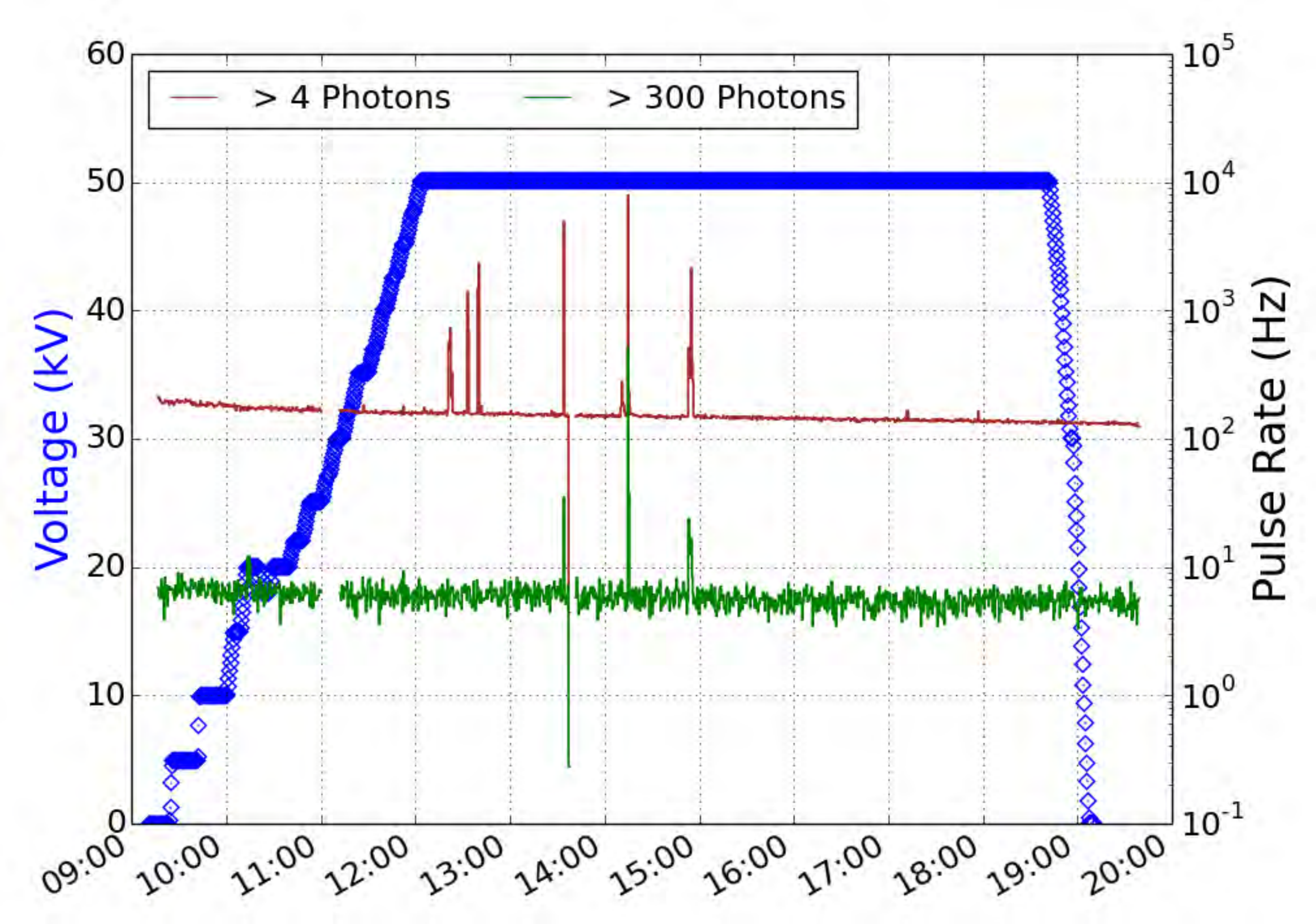


- Commissioning run in late fall 2015
- Testing high surface field regions, and highest voltage
- S1 light collection only; single phase, 75 kgs LXe
- Reach LZ cathode surface fields at ~1/2 applied voltage in System Test

Reverse Field Region Test: Photos

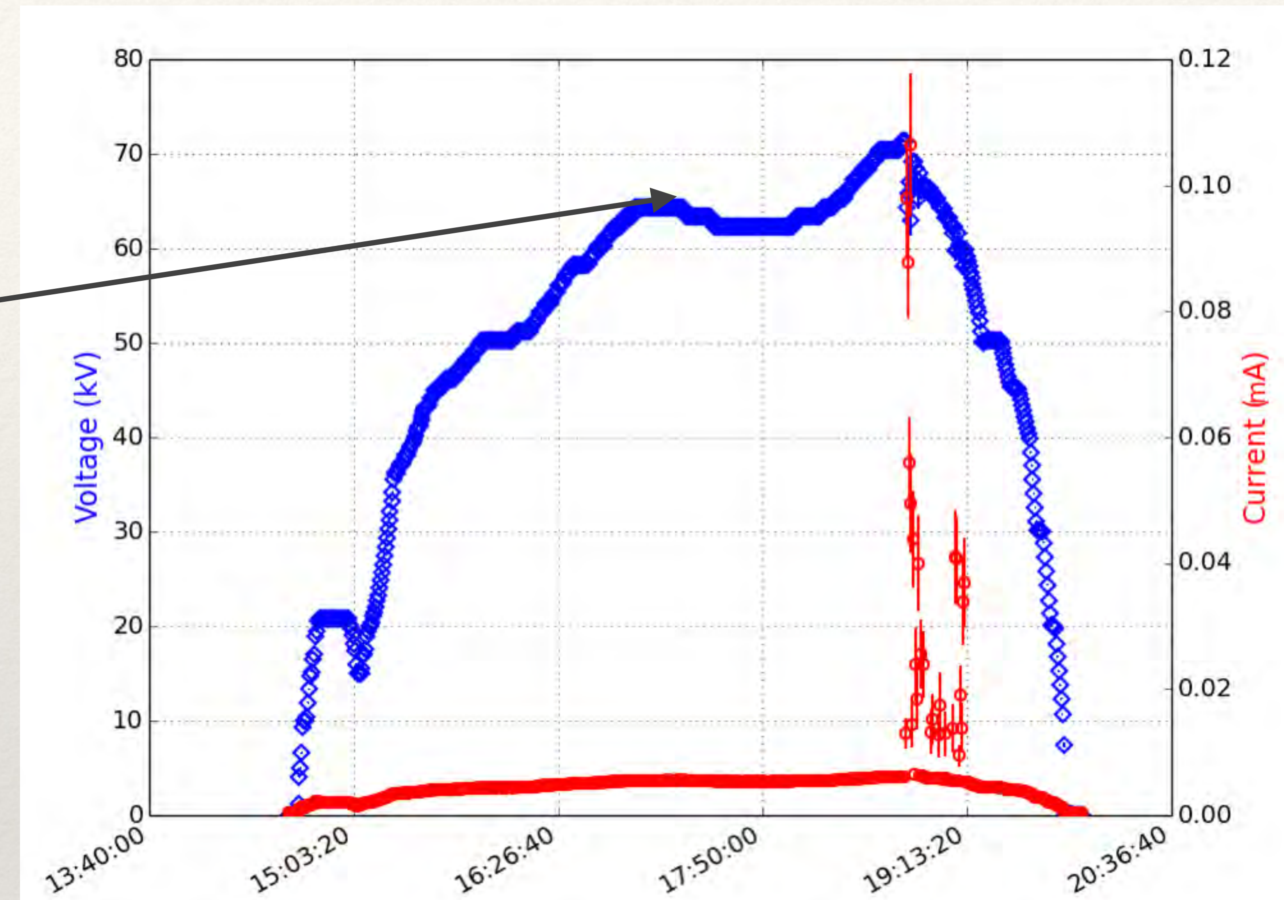
- Cathode and bottom grids
  - 5 stages of parallel resistors totaling 12.5 GOhm
- 1 PMT, loop antenna, 7 optical camera fibers, for data collection
- Low purity (circulation not running)

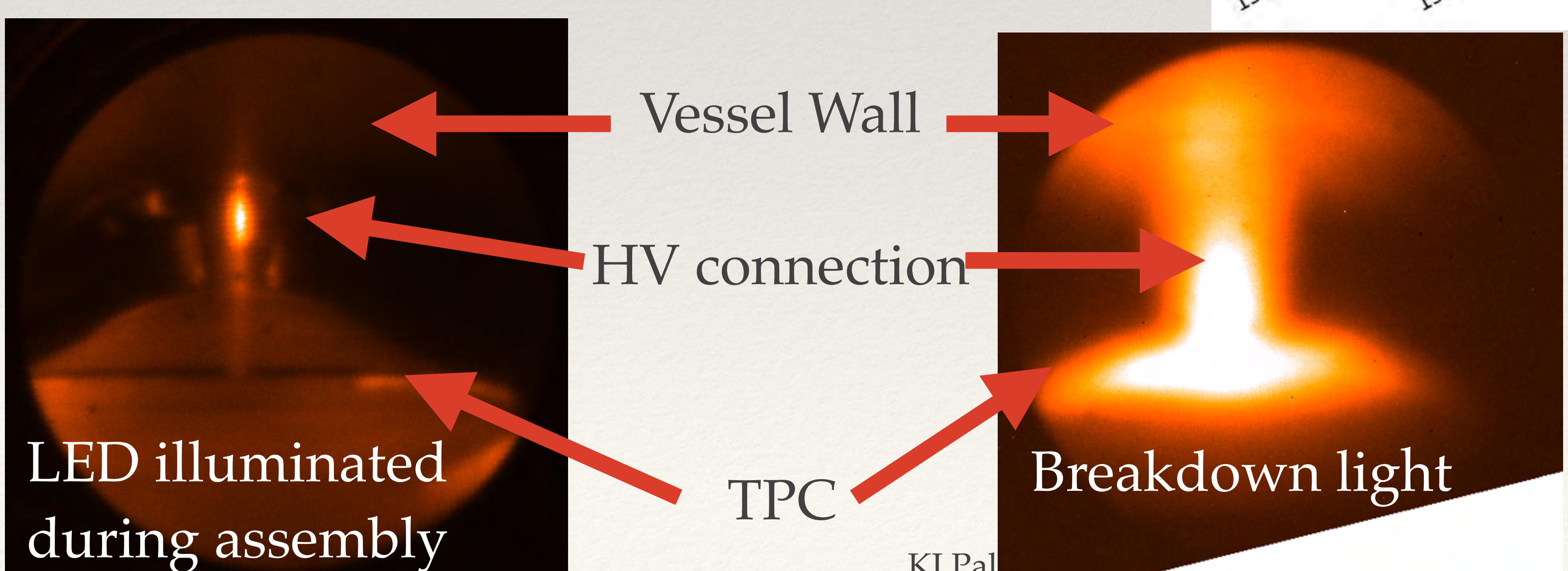
Reverse Field Region: -50 kV Test



Reverse Field Region: Breakdown

- Tripped Cathode PS at -72 kV
- Non-Ohmic behavior seen ramping to -64 kV
    - Not seen just before breakdown as had been expected
- Suspect problem is at feedthrough (which is not LZ style)

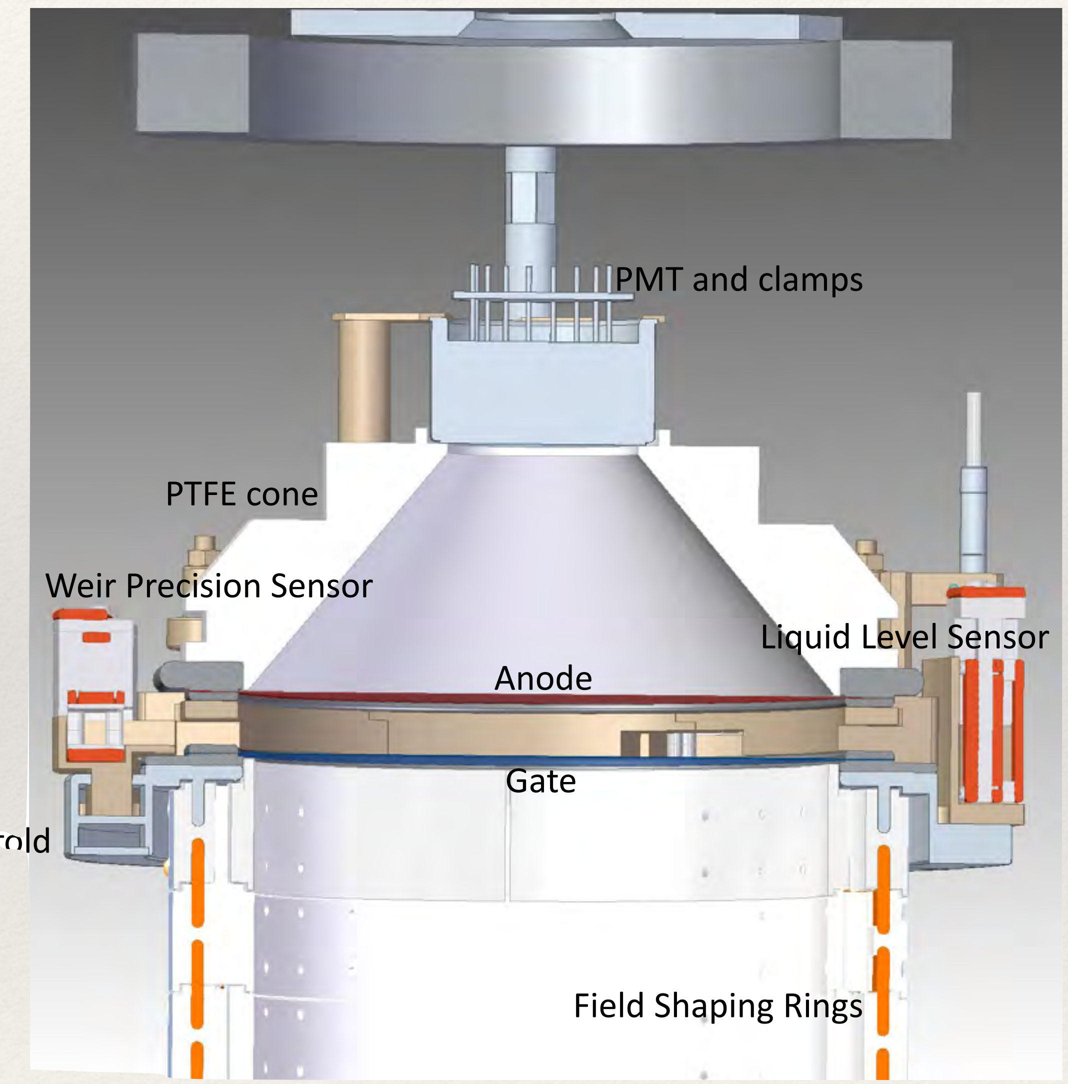




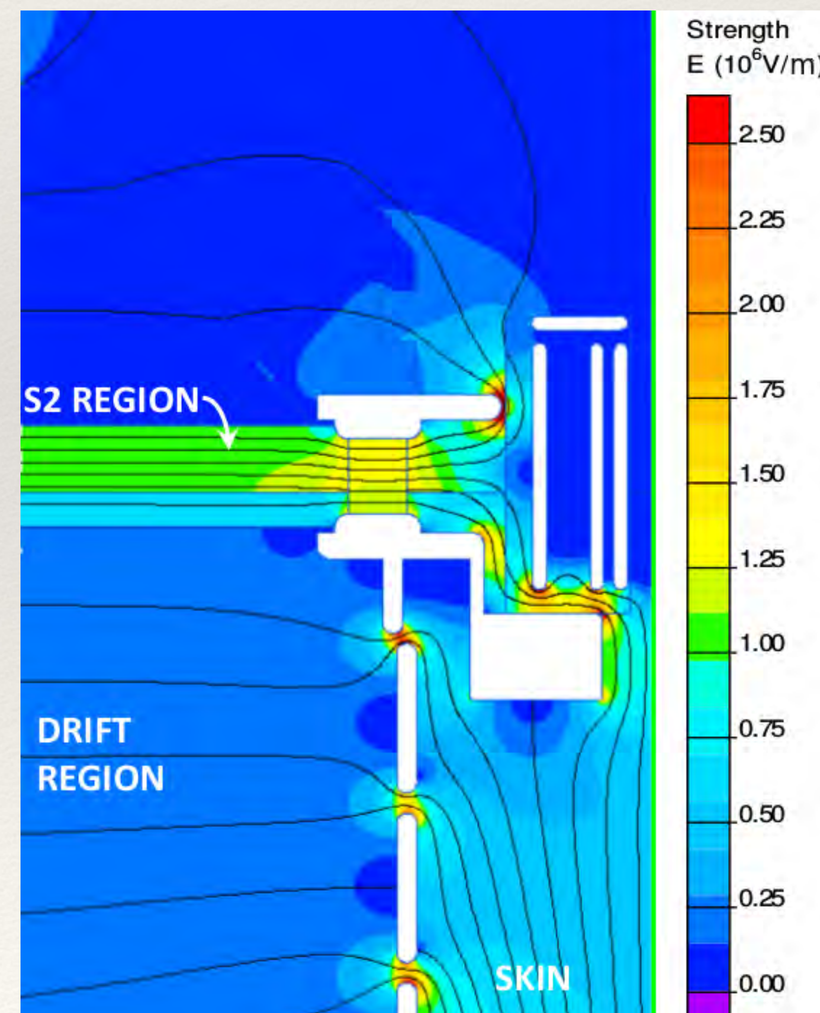
Resistance of conducting plastic in feedthrough:
before run: 16.5 kOhms
after run: 9 kOhms

Full TPC Tests: Design

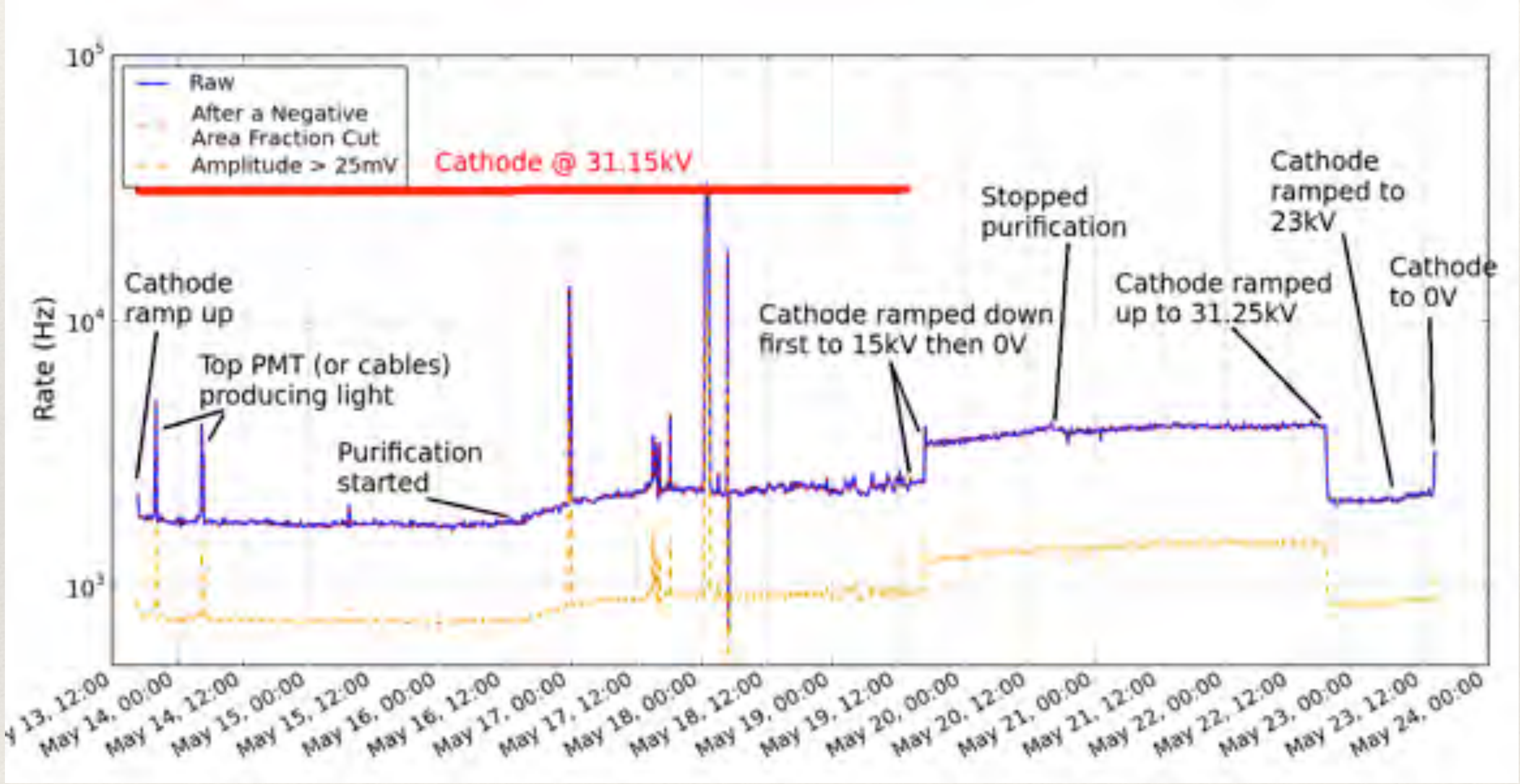
- Added forward field and extraction regions
- Gate and anode grids
- Level sensors
- 2nd PMT & loop antenna added
- Full TPC runs began spring 2016



System test field simulation gate/anode at +/- 7 kV

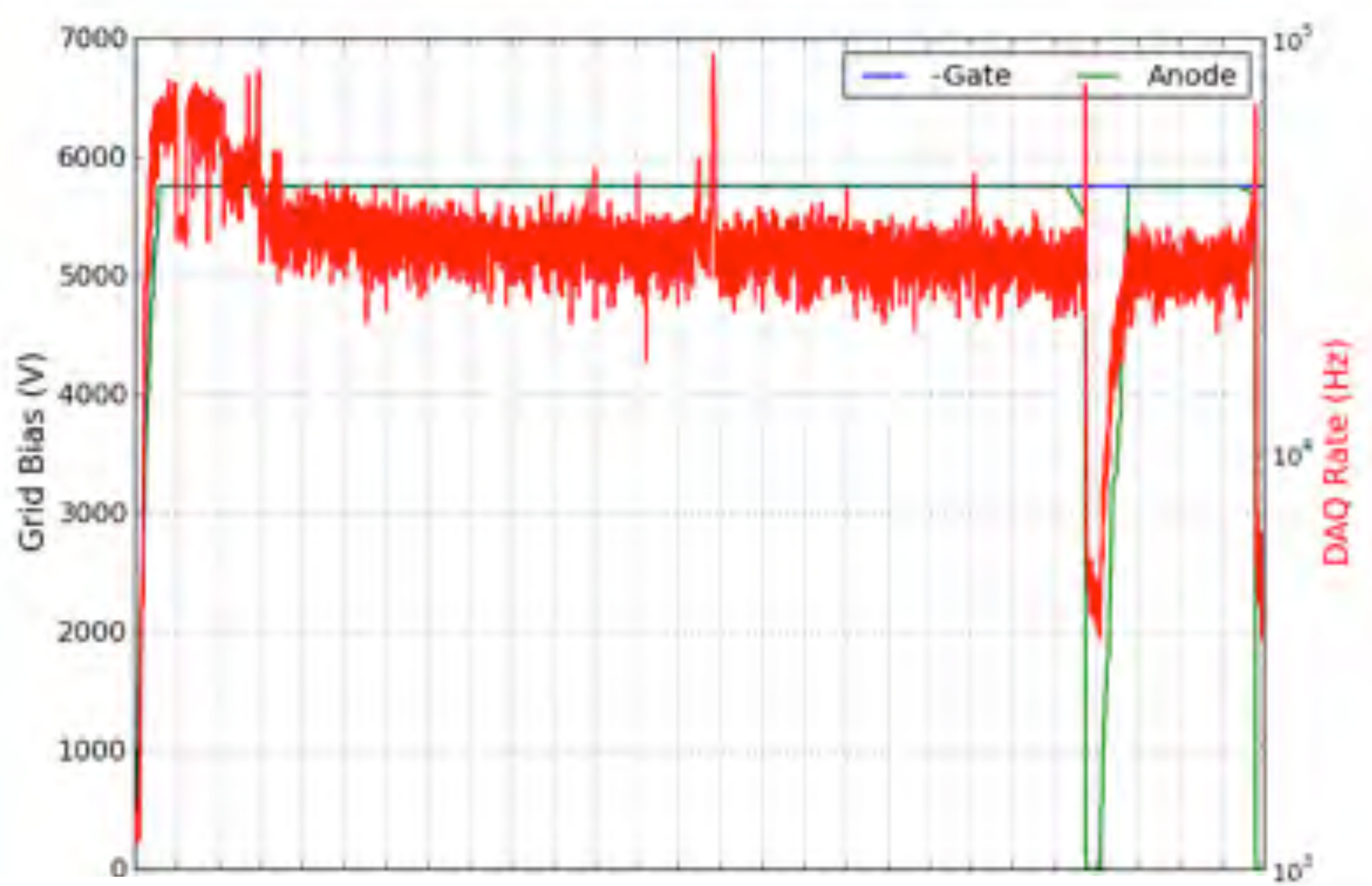


Full TPC: Tests



- Non-HV effects impacted system operations (circulation & liquid level, PMT cable issues in gas)
- Multiple HV Tests:
  - **Cathode at -31.25 kV = LZ -50 kV for 1 week**
  - Cathode ramped up to -50 kV and light is seen
  - Cathode at -44 kV for 3 days
  - Cathode ramped up to -63 kV and light is seen
  - Cathode at -51 kV for 12 hours
  - Cathode at -31.25 kV, Gate at -5.75 kV, Anode at +5.75 kV for 12 hours
  - Individual ramping gate and anode to PS trips

Full TPC: Tests



Time: 7 pm to 7 am

- Non-HV effects impacted system operations (circulation & liquid level, PMT cable issues in gas)
- Multiple HV Tests:
  - Cathode at -31.25 kV = LZ -50 kV for 1 week
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  - Cathode ramped up to -63 kV and light is seen
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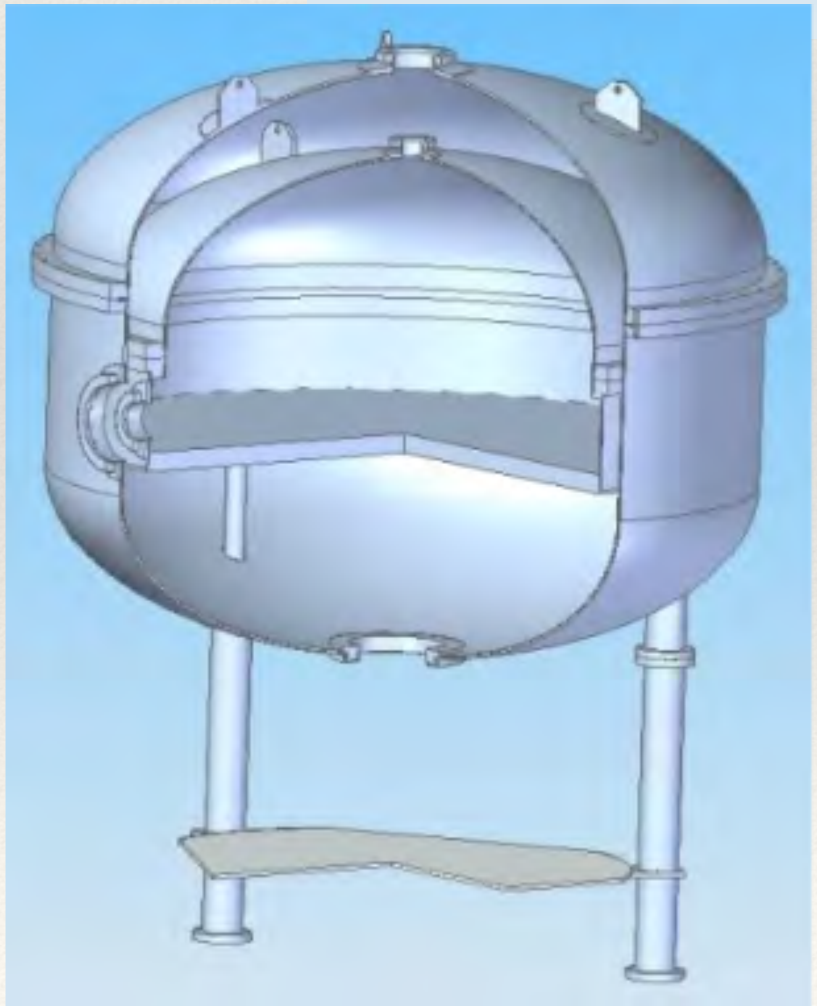
  - Individual ramping gate and anode to PS trips

Future Phase I Tests

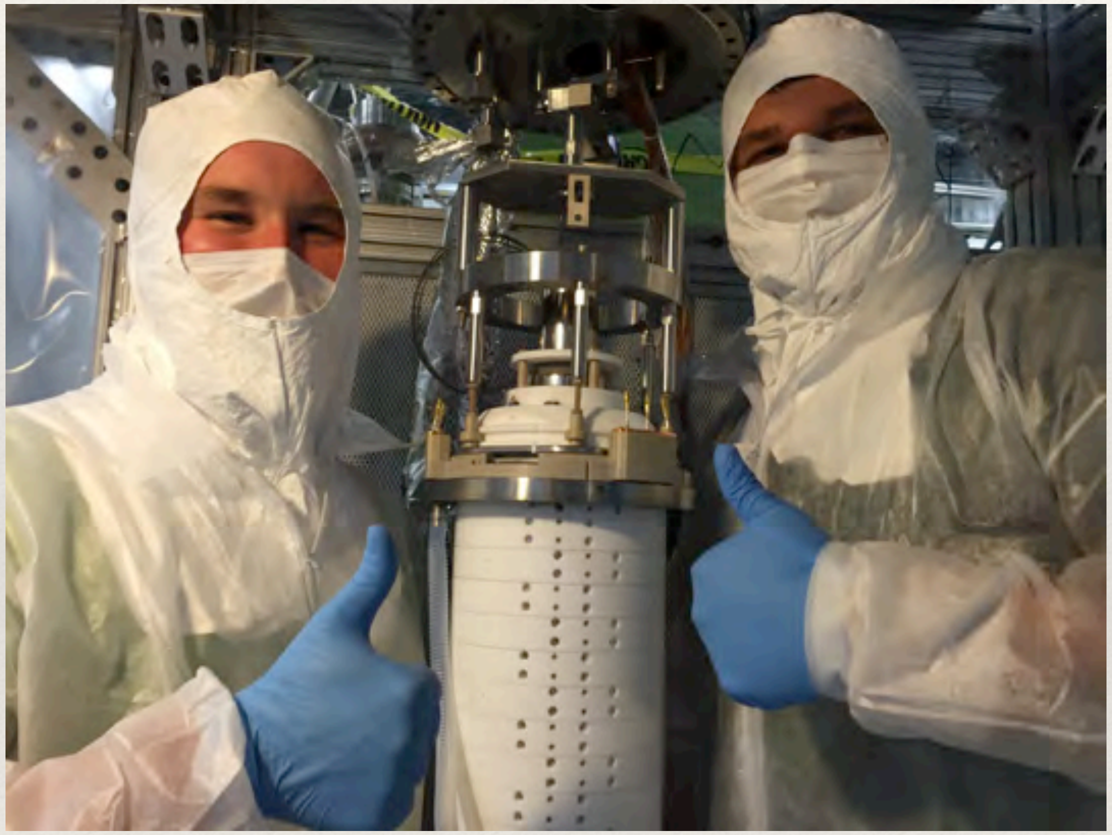
- Improved basic operations and longevity tests
- Adding gas calibration source injection
- New grids, different wires/surface treatments
- Upgraded sensors
- PMT array to localize election emission
- Mechanical tests for skin and upper corner

Phase II Plans

- Test full scale 1.5m diameter grids
    - Wide and short vessels with ~500 kg LXe
- Extraction region grids tested to full voltage
    - Gate and anode with full weir structure
- Cathode tested to final LZ surface fields
    - < Goal voltage due to feedthrough/ LXE constraints
- Operations begin Spring 2017



Conclusion



- LZ has extensive ongoing testing
- The System Test platform at SLAC is comprehensive with a 120 kg LXe TPC, and a ~500 kg LXe full scale grid test chamber
- When testing concludes in the summer of 2018 we should have much to share on HV operations!

Backup Slides

LZ Collaboration

LIP Coimbra (Portugal)
Center for Underground Physics (Korea)
MEPhI (Russia)
Edinburgh University (UK)
University of Liverpool (UK)
Imperial College London (UK)
University College London (UK)
University of Oxford (UK)
STFC Rutherford Appleton Laboratories (UK)
University of Sheffield (UK)

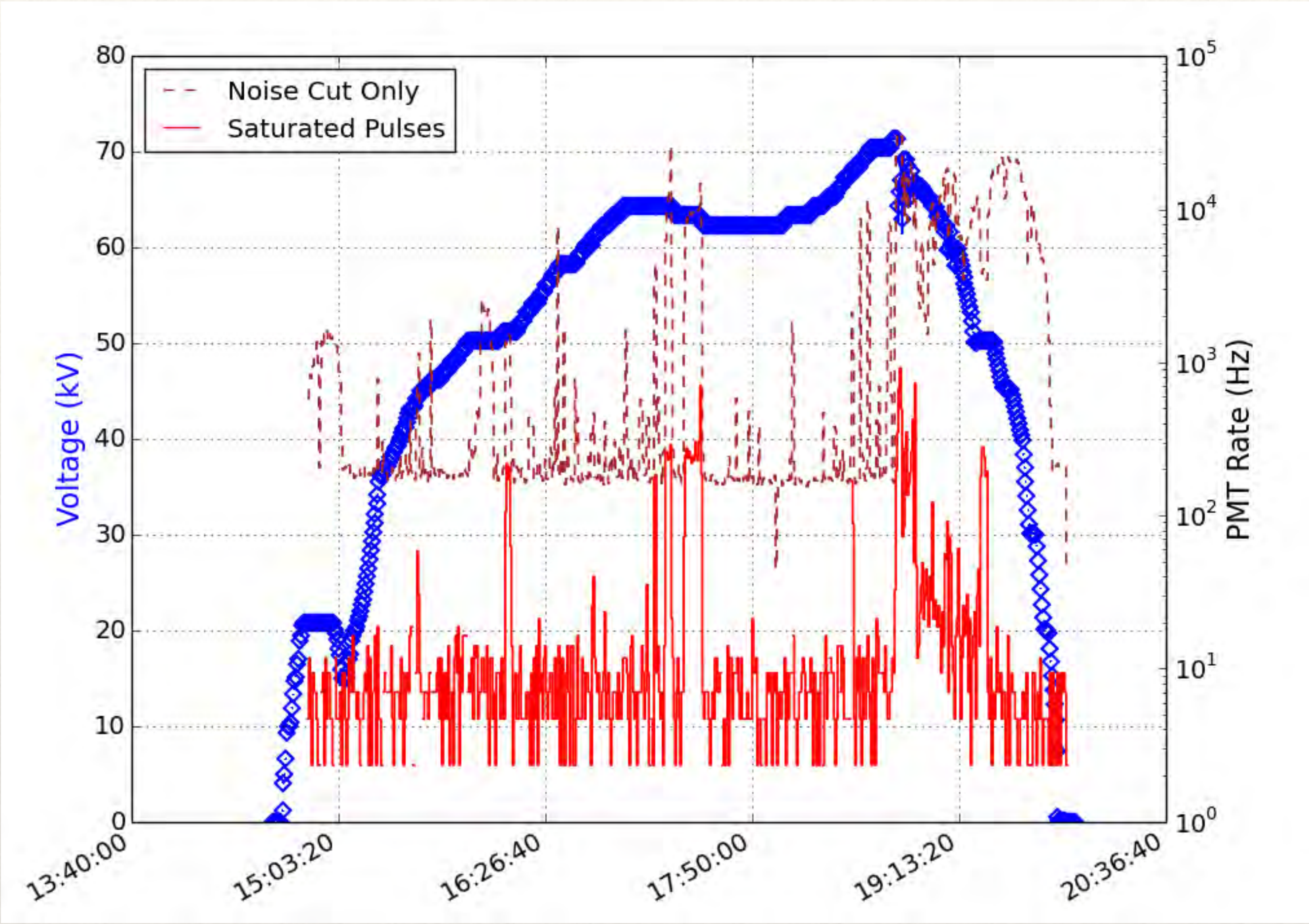
University of Alabama
University at Albany SUNY
Berkeley Lab (LBNL)
University of California, Berkeley
Brookhaven National Laboratory
Brown University
University of California, Davis
Fermi National Accelerator Laboratory
Lawrence Livermore National Laboratory
University of Maryland
University of Michigan
Northwestern University
University of Rochester
University of California, Santa Barbara
University of South Dakota
South Dakota School of Mines & Technology
South Dakota Science and Technology Authority
SLAC National Accelerator Laboratory
Texas A&M
Washington University
University of Wisconsin

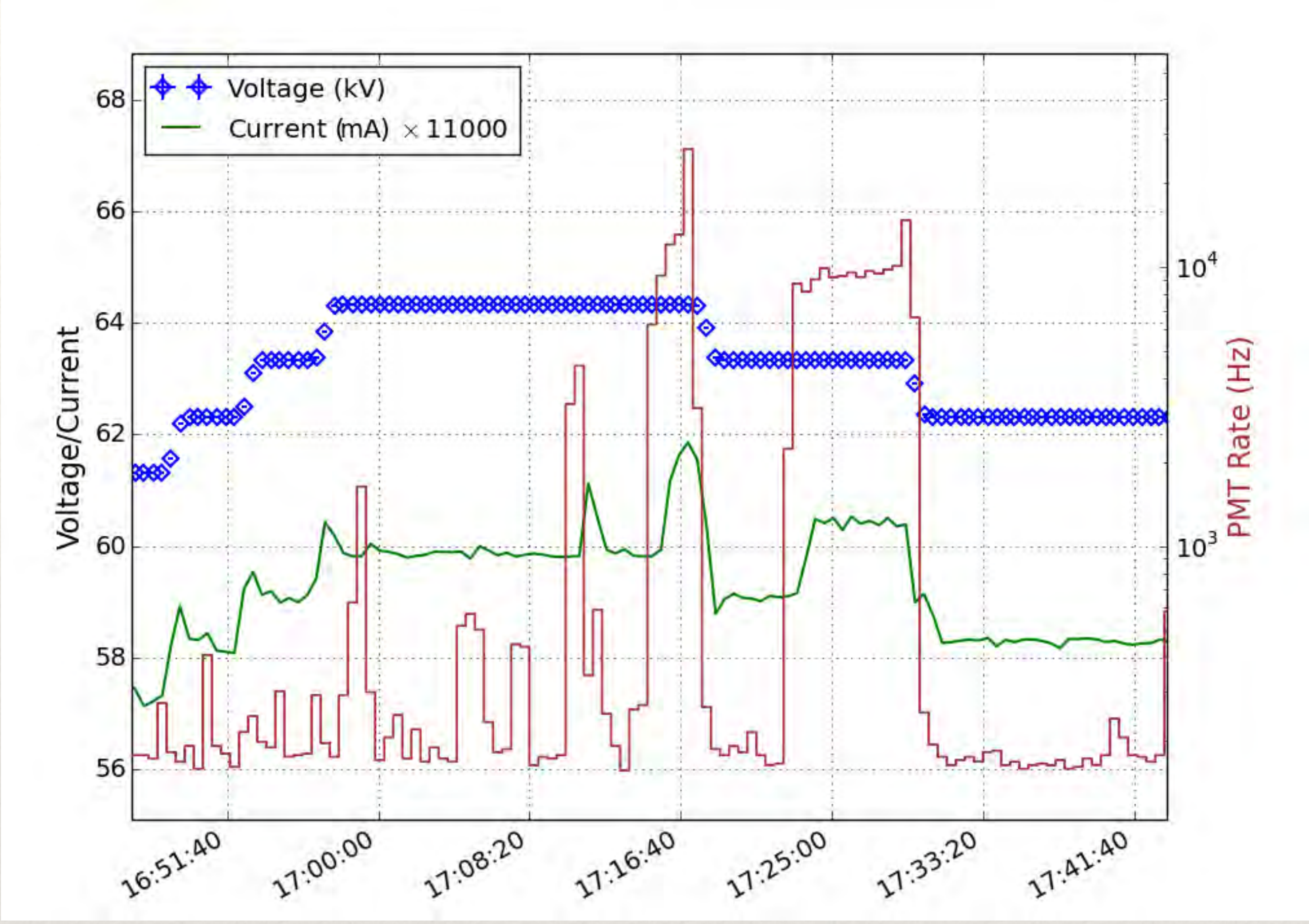
LZ Collaboration @SLAC System Test

LIP Coimbra (Portugal)
Center for Underground Physics (Korea)
MEPhI (Russia)
Edinburgh University (UK)
University of Liverpool (UK)
Imperial College London (UK)
University College London (UK)
University of Oxford (UK)
STFC Rutherford Appleton Laboratories (UK)
University of Sheffield (UK)

University of Alabama
University at Albany SUNY
Berkeley Lab (LBNL)
University of California, Berkeley
Brookhaven National Laboratory
Brown University
University of California, Davis
Fermi National Accelerator Laboratory
Lawrence Livermore National Laboratory
University of Maryland
University of Michigan
Northwestern University
University of Rochester
University of California, Santa Barbara
University of South Dakota
South Dakota School of Mines & Technology
South Dakota Science and Technology Authority
SLAC National Accelerator Laboratory
Texas A&M
Washington University
University of Wisconsin

Reverse field region breakdown cont'd





- Voltage in blue diamonds, Red: PMT pulses (with various cuts), green is cathode PS current
- Right plot: at constant voltage, non-Ohmic spikes in current draw at -64 kV, which disappear after decreasing to -62 kV; not seen again until full tripping at -72 kV