First Results From the LZ system Test Platform @ SLAC

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For the LZ Collaboration
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UCLA Dark Matter 2016

LZ = LUX + ZEPLIN

32 Institutions
About 200 people

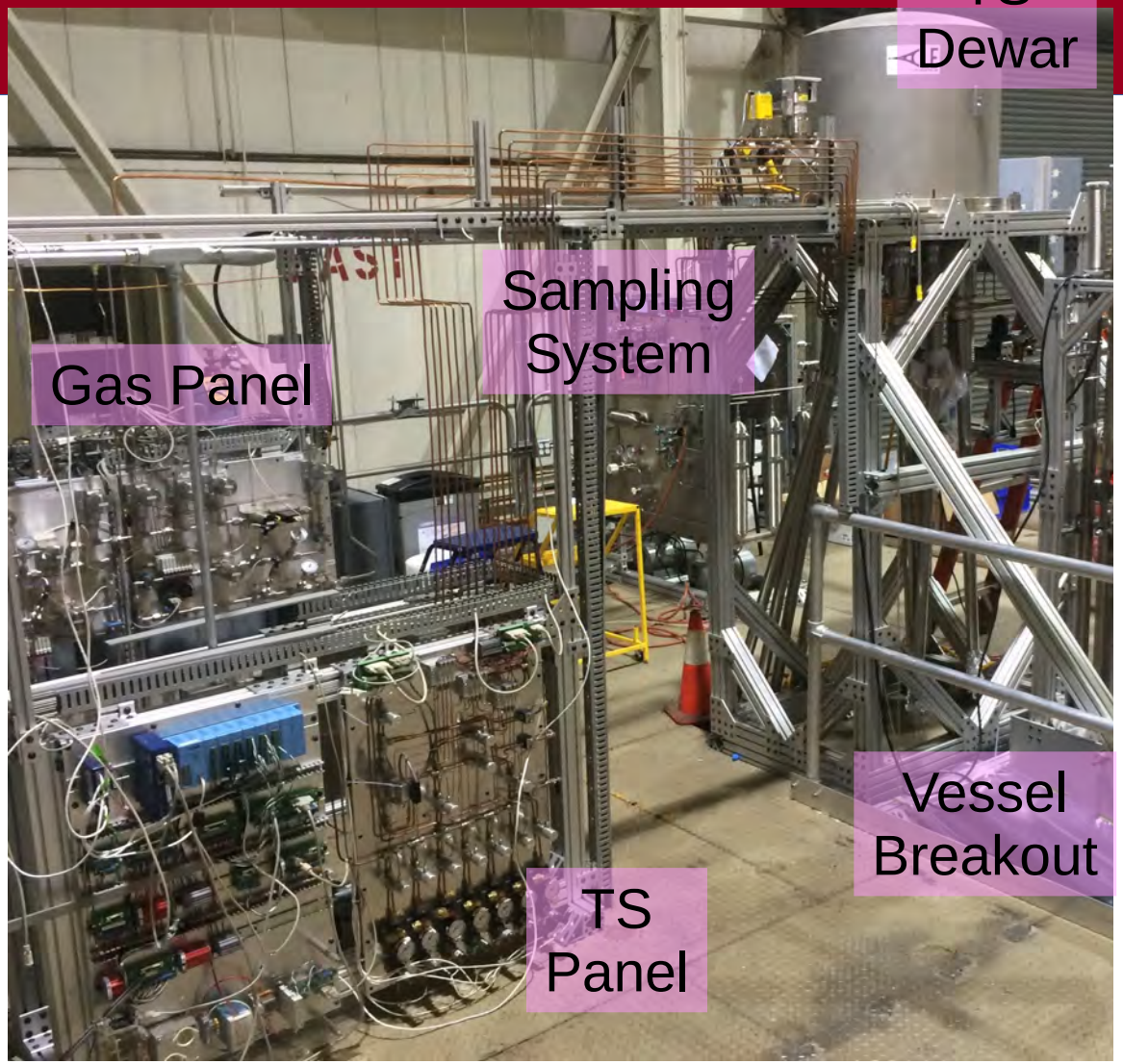
Center for Underground Physics (Korea)
LIP Coimbra (Portugal)
MEPhI (Russia)
Edinburgh University (UK)
University of Liverpool (UK)
Imperial College London (UK)
University College London (UK)
University of Oxford (UK)
STFC Rutherford Appleton Laboratories (UK)
University of Sheffield (UK)

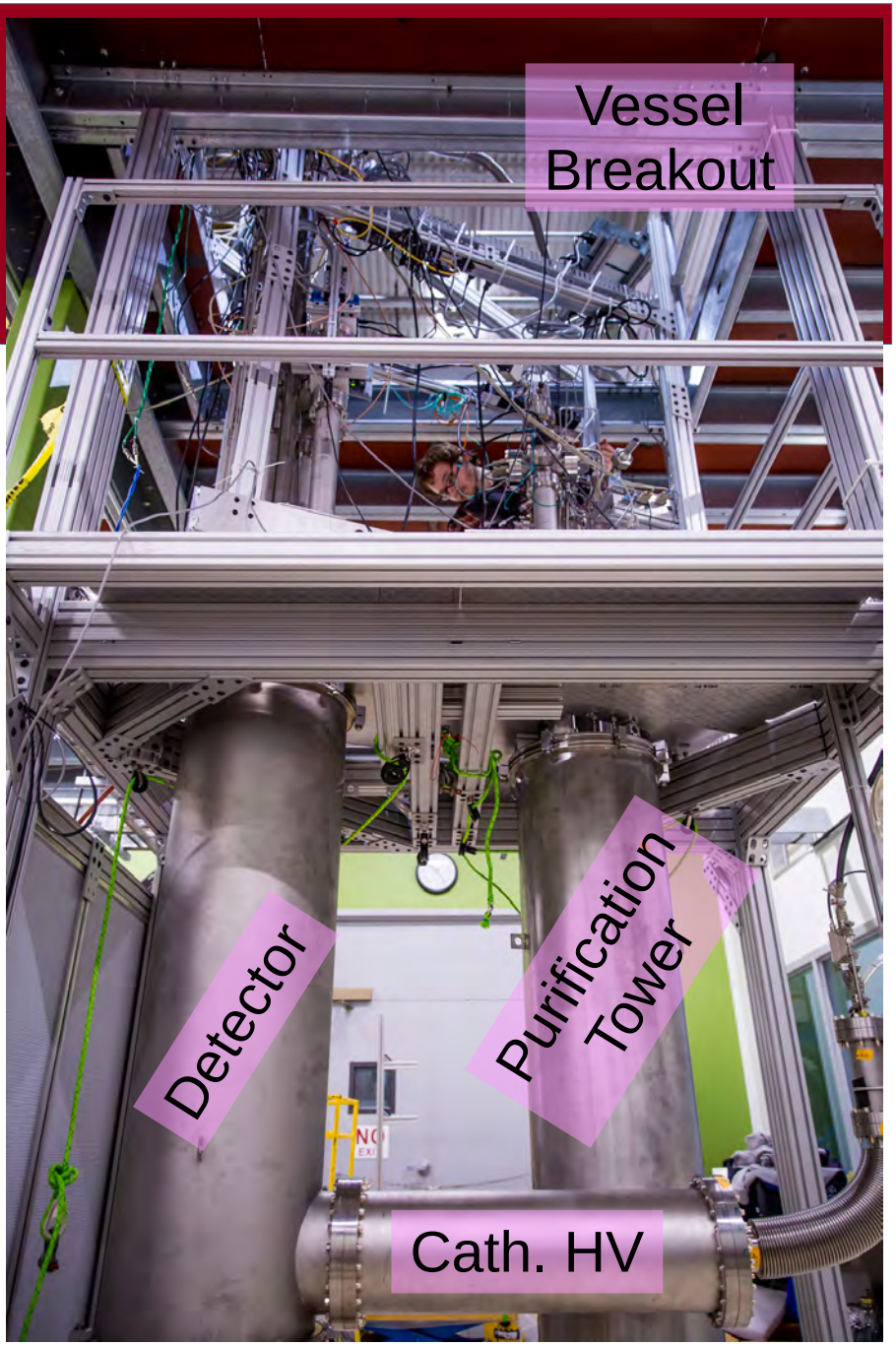
University of Alabama
University at Albany SUNY
Berkeley Lab (LBNL)
University of California, Berkeley
Brookhaven National Laboratory
Brown University
University of California, Davis
Fermi National Accelerator Laboratory
Lawrence Livermore National Laboratory
University of Maryland
University of Michigan
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
Yale University

LZ Testing Program...

- … is very extensive
- LZ systems and components development and Xe TPC research at many institutions
  - Small chamber Xe tests at Imperial, LBNL, LLNL, LIP Coimbra, U. Of Michigan, UC Berkeley, UC Davis, MEPHI
    - Testing of electrical characteristics of wires and small grids, PTFE and wire reflectivity, purity monitoring,
    - Research into S2 generation, energy resolution, yields and more!
  - PMT testing (Brown)
  - Cathode HV feedthrough performance in liquid Ar (LBNL)
  - Many more!
- SLAC system test platform

SLAC Test Platform Infrastructure

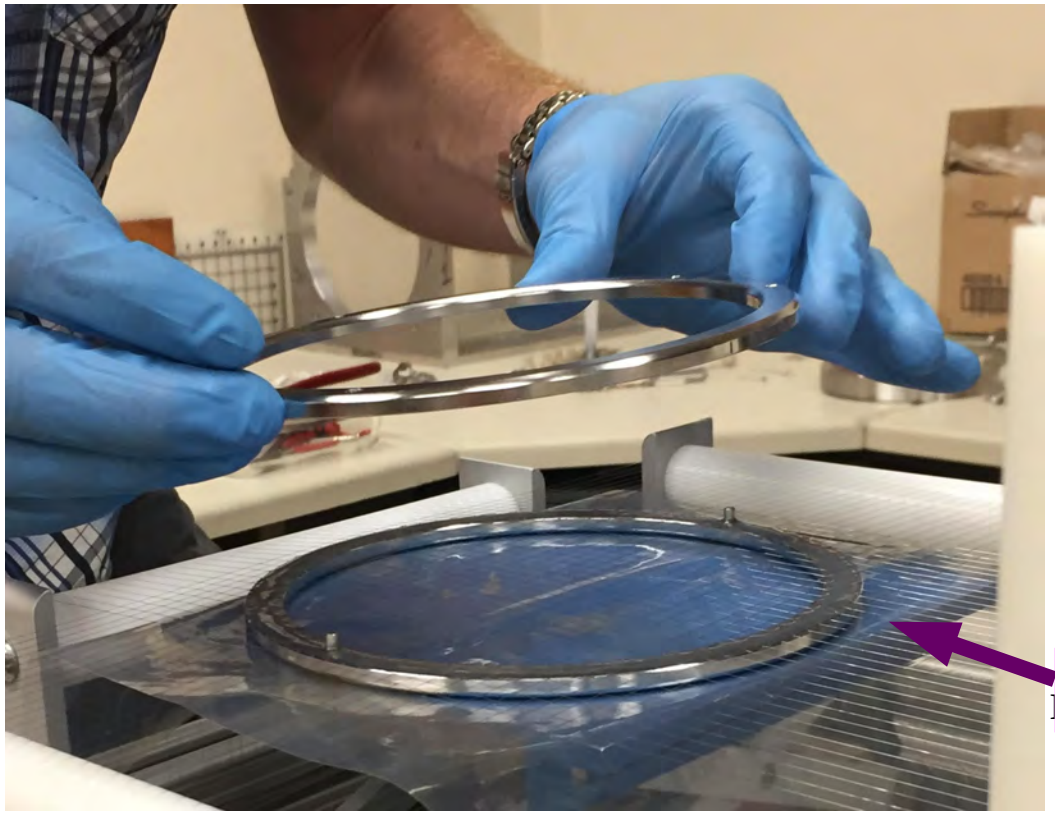


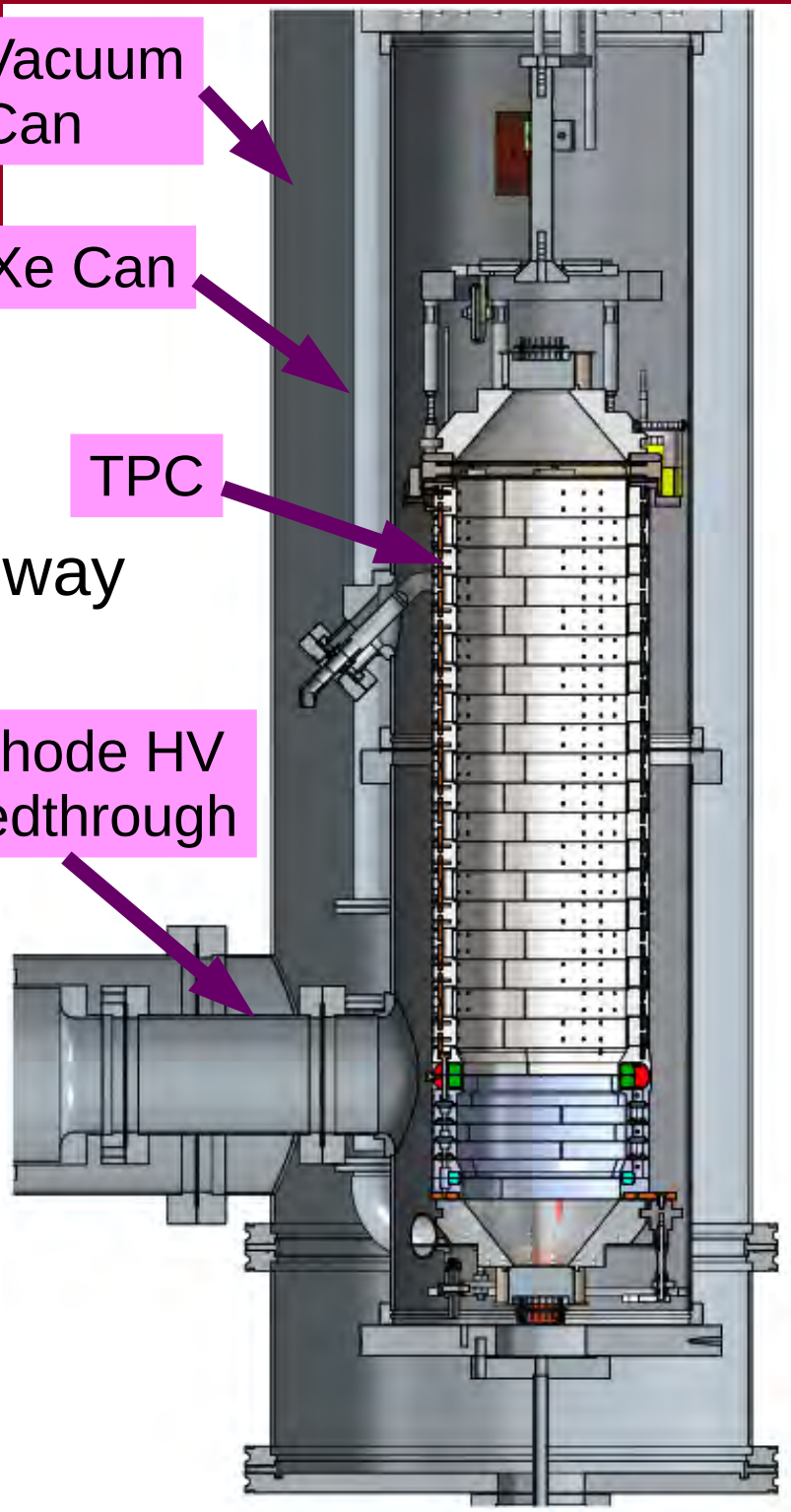


- 2 floors (the “hut”) within the former BaBar hall
- Circulation pump housed in a separate building

Phase 1

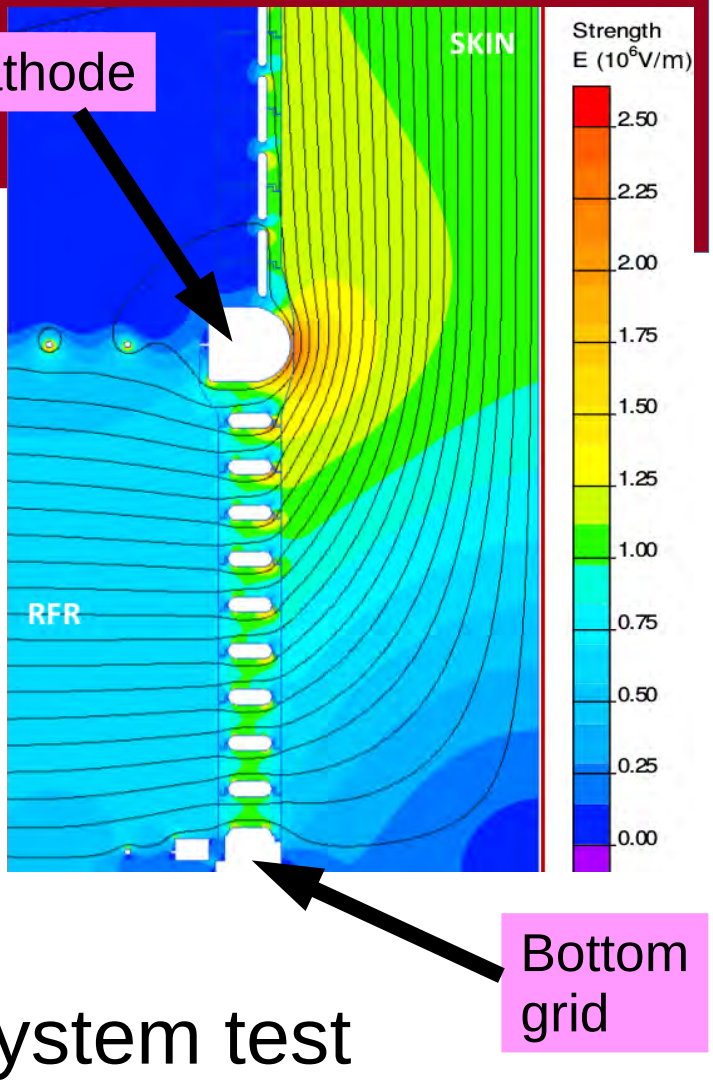
- Main goals:
  - High voltage tests of components
  - Purification system tests
- Ancillary LZ systems tested along the way
  - Sensors, slow control + PLC

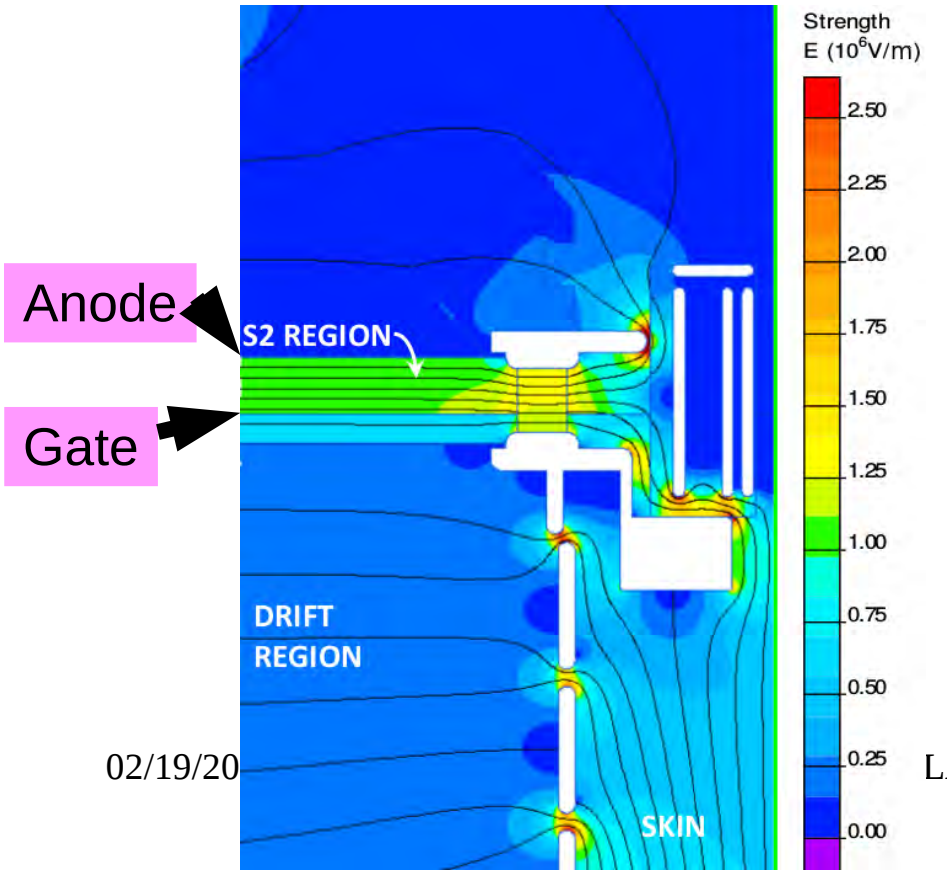




High Voltage Tests

- Cathode Voltage
  - Previous LXe experiments reached only ~10kV on cathode
- Anode-gate extraction field
  - validation of the design S2 region
- Avoid single photon and electron generation
  - Ex: E. Aprile, et al., Astroparticle Physics, 35, (2012), 573





- SLAC LZ system test
  - Surface fields match LZ
  - Measure light/charge vs voltage, purity, wire treatment, etc

Purification

- Vaporize → purify → re-condense
- Circulation
  - Testing LZ design: circulation compressor (Wisconsin + others) + gas system
- Purification at high flow rates
  - LZ – like purification tower
    - dual and single phase heat exchanges, weir reservoir, condenser/sub-cooler, liquid valves (coming soon)
  - SAES Getter – should handle over 100L/min
  - Purity measurement
    - TPC with half meter drift length (LBNL + SLAC)
    - ppt (volatiles) sampling system (Maryland)
    - source injection coming soon (LBNL + SLAC)
    - Purity monitor coming soon (UC Davis)

First (Simplified) Run Of Phase 1

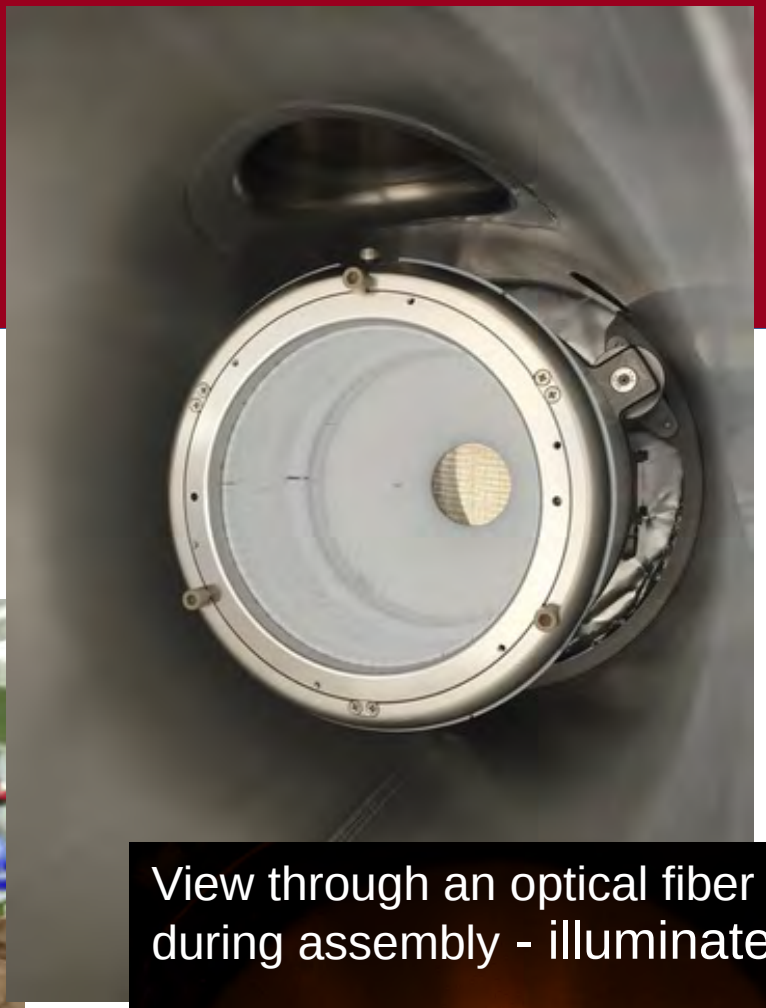
Testing the region where highest voltage is applied

- One PMT (R9288) with 4 ns digitizer resolution, high and low gain channels
- Single phase, no precision level or position sensor

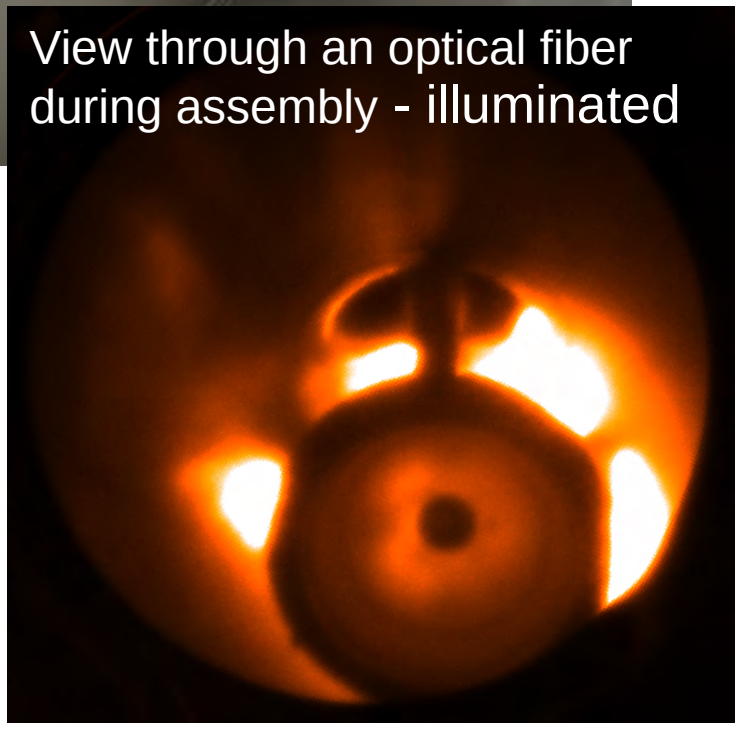
Cathode-Bottom Grid Region

Thanks to: Jeremy Mock

02/19/2016

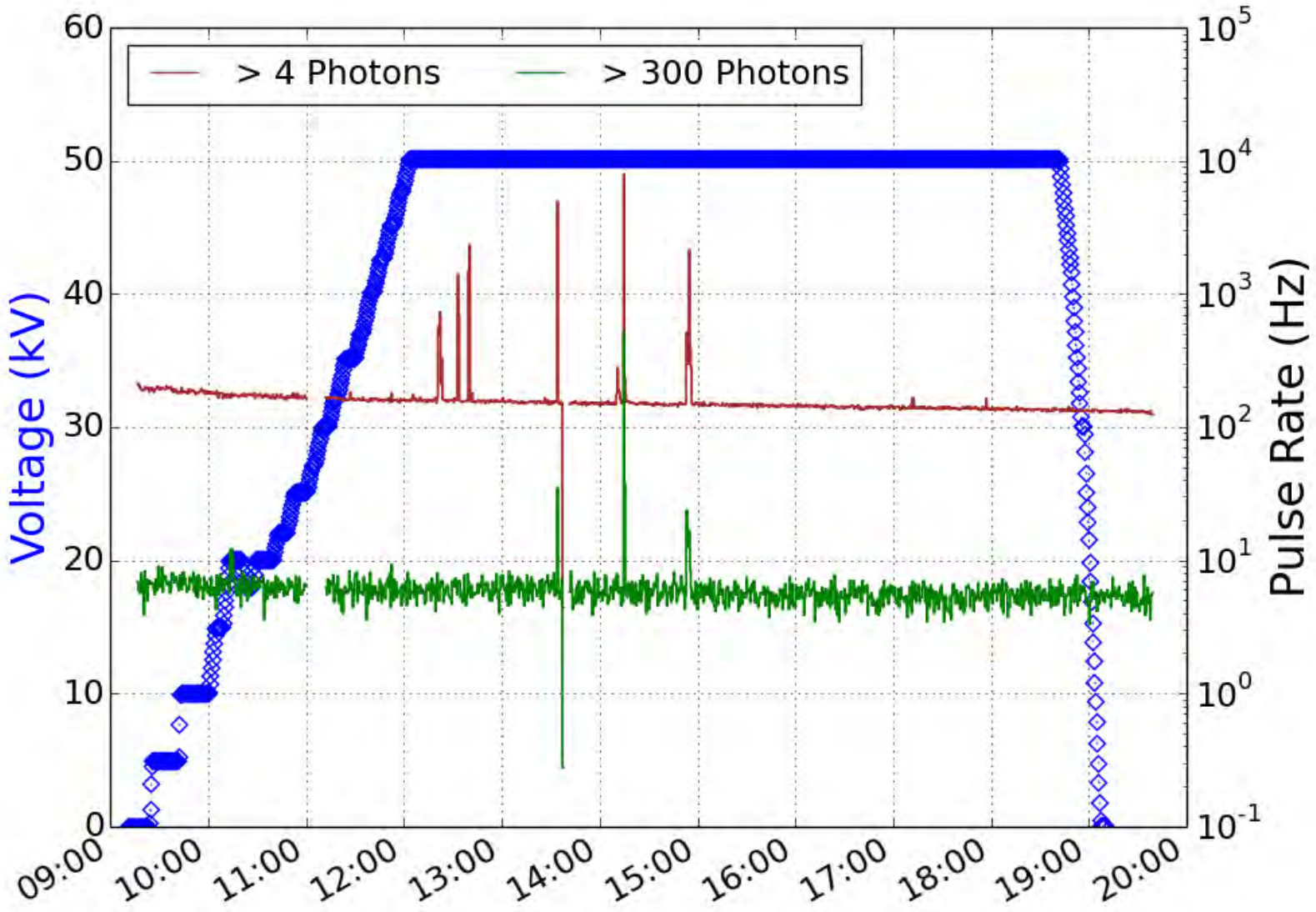


View through an optical fiber during assembly - illuminated



Cathode Grid HV Performance

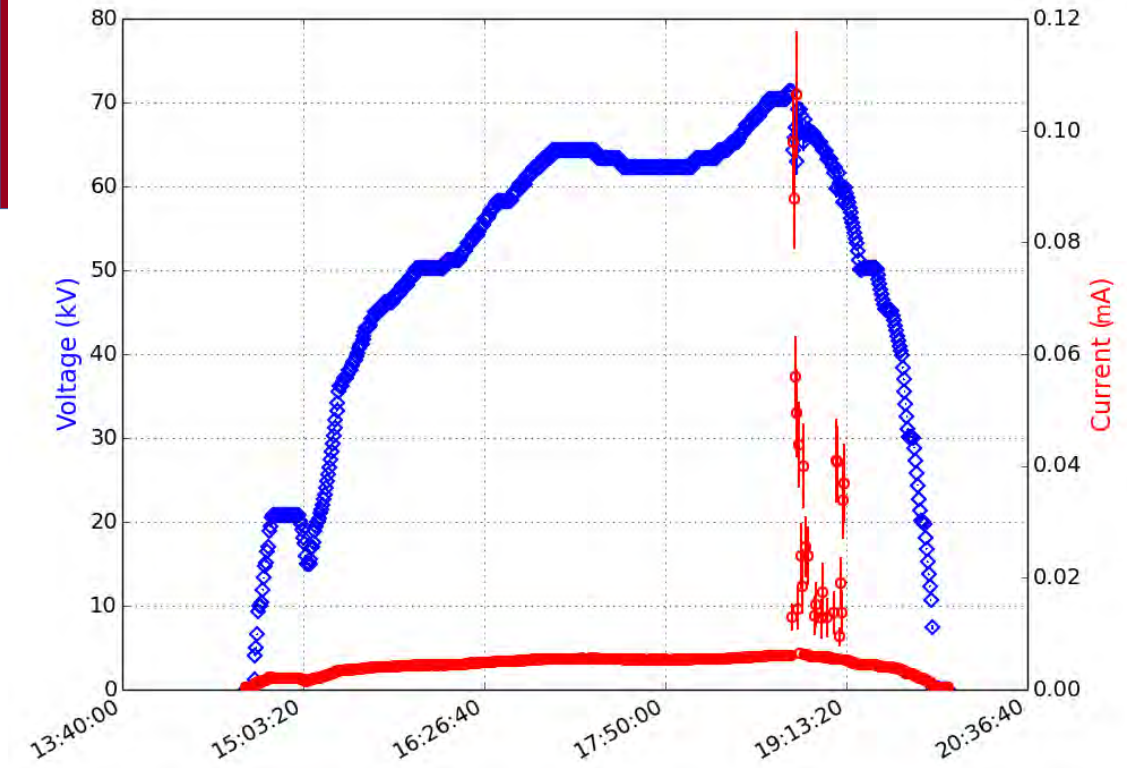
- 50kV requirement and 100kV goal for LZ
  - Same fields achieved at half voltage in the test platform
- Tested with multiple ramp ups
  - Test platform exceeded 50kV goal
  - Intermittent light generation observed
  - HV taken to breakdown



Hold Test @ 50kV

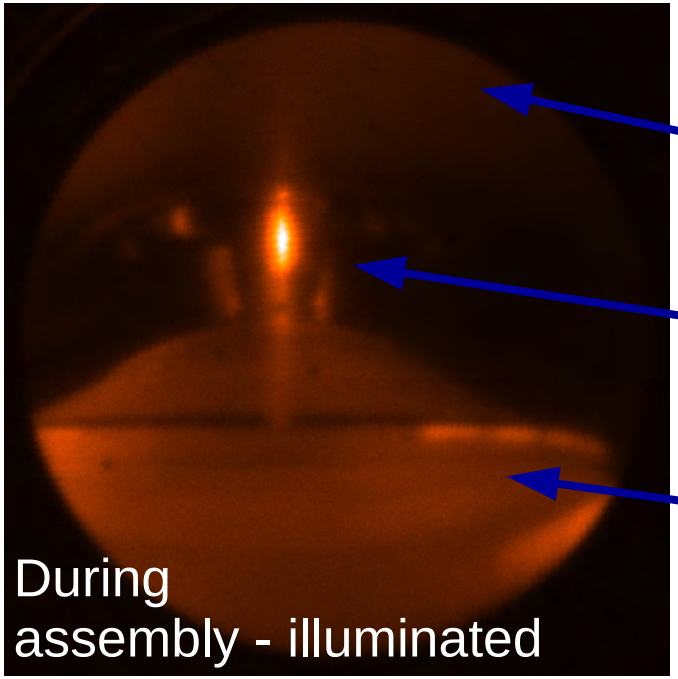
- Voltage held for over 6 hours + successfully monitored light emission
  - Single photon threshold varied between ramp ups – will improve during next run
- Long term light/charge emission will be tested soon

Breakdown @72kV



- Breakdown believed to originate in the (non-LZ) HV feedthrough
- Non-ohmic behavior @64kV
  - disappeared after ramping down to 62kV and not seen during following ramp up

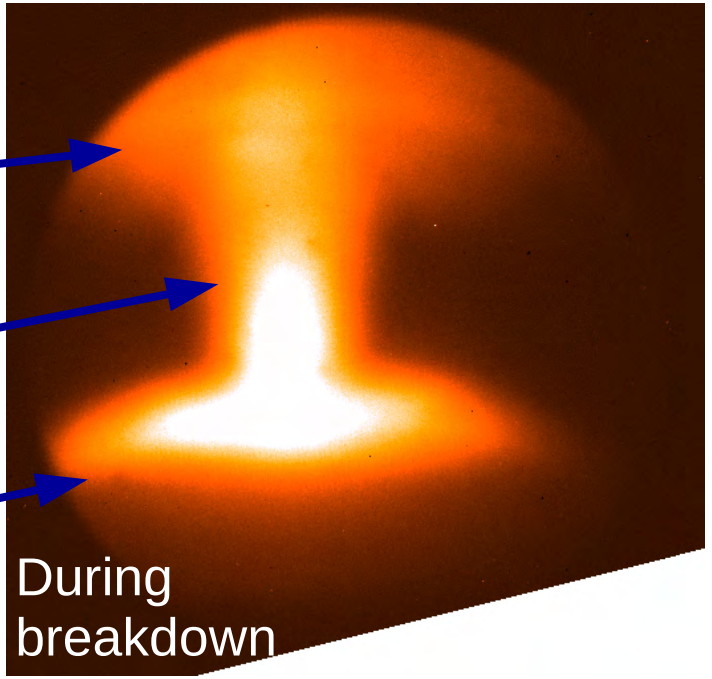
Optical fiber view of cathode HV connection. Looking from the bottom



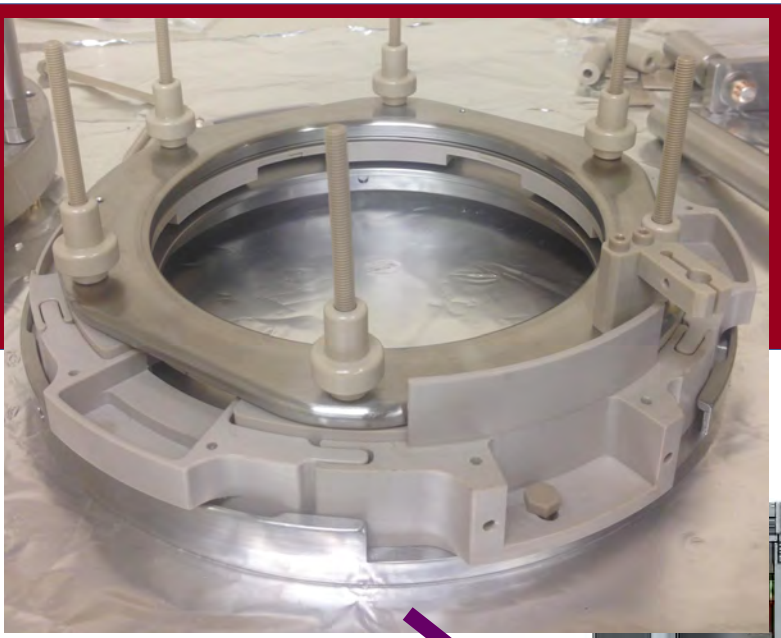
Vessel wall

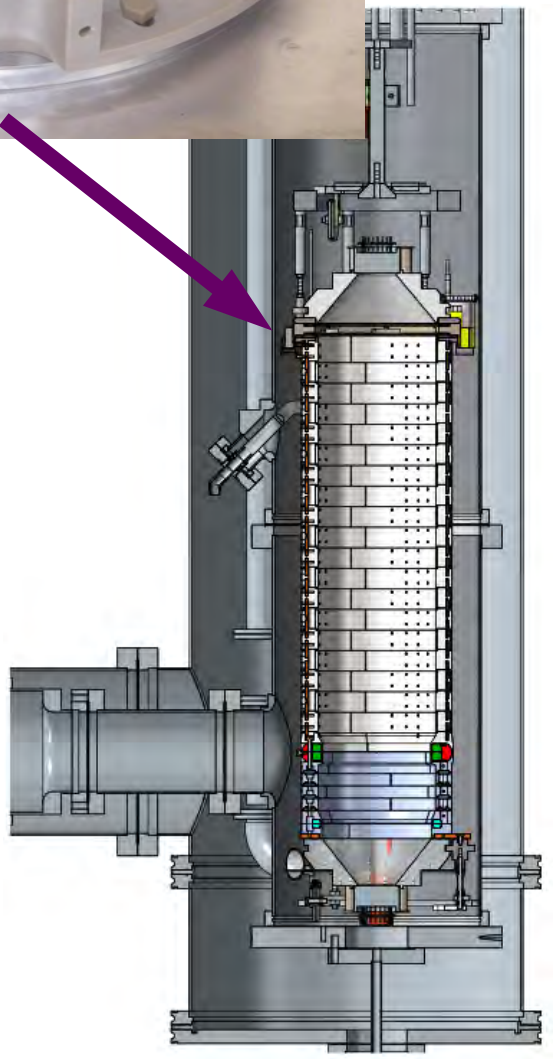
HV Connection

TPC



Phase 1 in Near Future

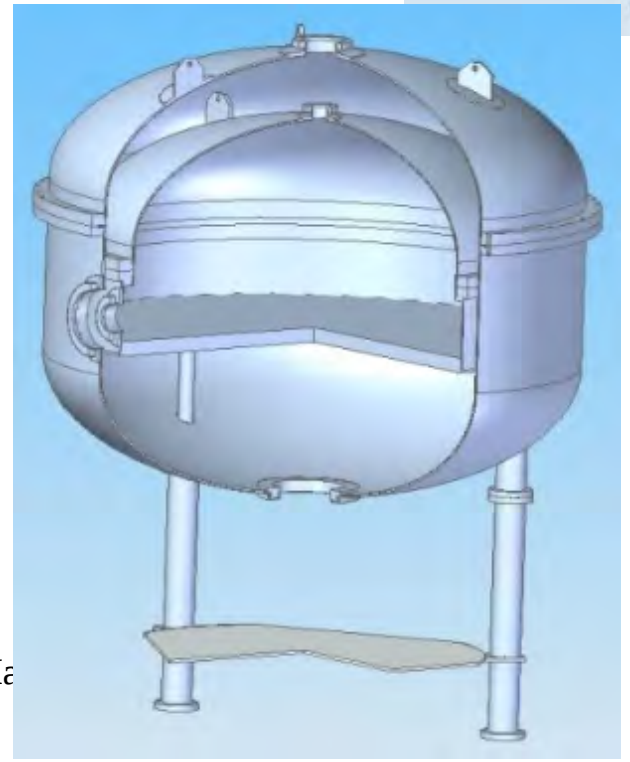




- Full TPC installed
  - Two LZ prototype PMTs R11410-20
  - Ability to upgrade to a multi-PMT array
- New and/or improved instrumentation
  - Precision level sensors, precision position sensors, acoustic sensors, loop antenna (TAMU), RTDs
- Improvements to slow control stability and performance
- Condenser/sub-cooler added to the circulation path
- Source injection to be added in near future

Phase 2

- Wide and short
  - 166 cm diameter, 25cm height available
- Will hold the cathode or anode-gate pair
  - Full scale grid prototyping
- Quality testing of final LZ grids
  - Upper corner of the TPC tested at full LZ voltage
  - Cathode tested to LZ field
- About 500kg of Xe needed



Conclusion

- Extensive testing of LZ design underway
- Phase 1 system test platform provides a unique opportunity to test various components and their integration
- Phase 2 will make sure that actual LZ grids meet their goals

Thank You

Backup

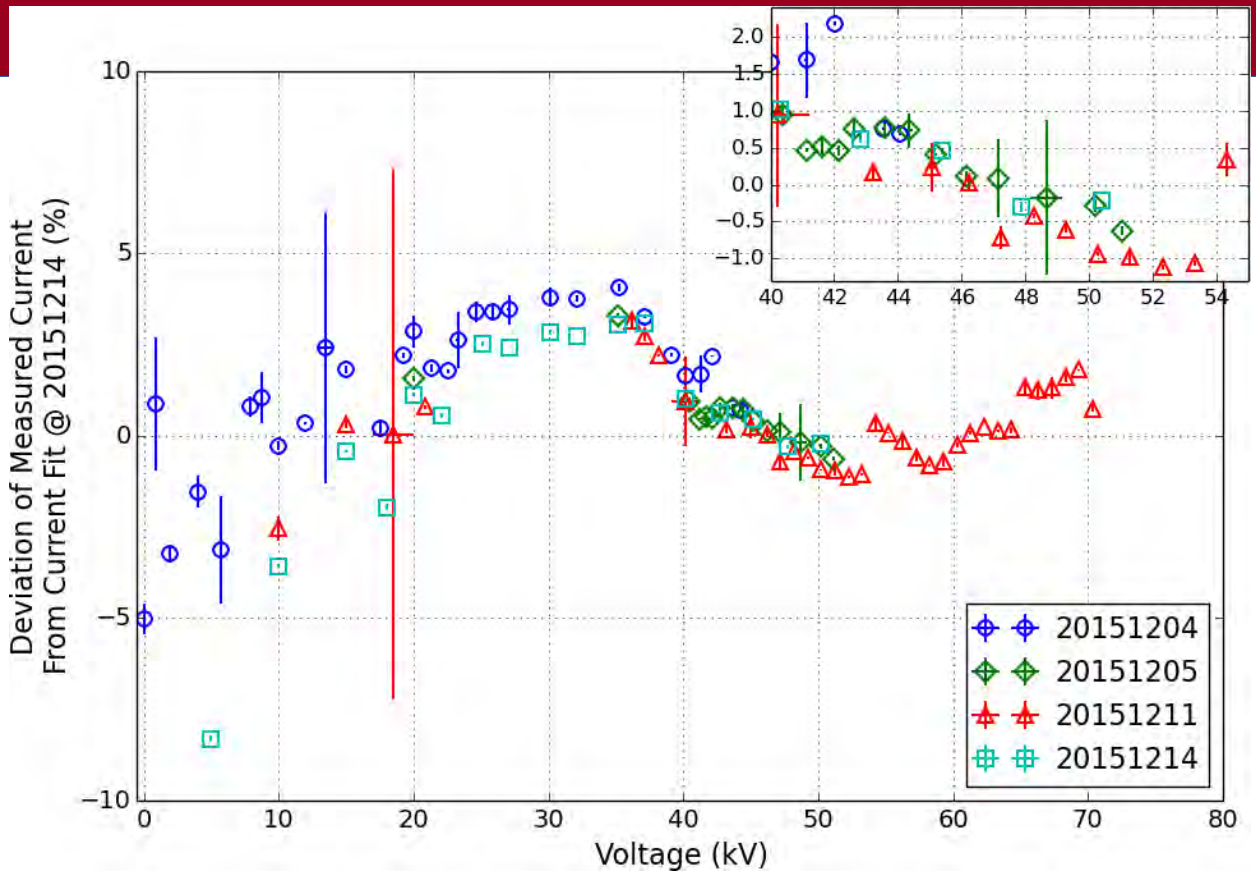
Grids and Wires

- California fine wire SS304
- Anode:
  - 100 µm, 2.5 mm spacing
- Gate:
  - 75 µm, 5 mm spacing
- Cathode:
  - 100 µm (150 µm during past run), 5 mm spacing
- Bottom:
  - 100 µm (slightly larger than LZ plan), 5 mm spacing

Lessons From First Phase 1 Run: Successes and “Successful Failures”

- Detector
  - Circulation at 50L/min through detector
  - Low condensation rate, ~16 L/min of gas
  - Problems with some sensors due to wiring, handling and readout
- Slow control software and PLC successfully controlled the system
  - Allows for quick creation of custom “process” pages
  - Some stability issues
- HV!

Consequences of Breakdown



- Comparison of RFR chain resistance across multiple voltage ramp-ups
  - Before (circles, diamonds, triangles) and after (squares) breakdown
- No change observed after breakdown → early sign that performance was not altered
  - RFR since inspected and no damage observed

Understanding Light

10 Random Waveforms Plotted