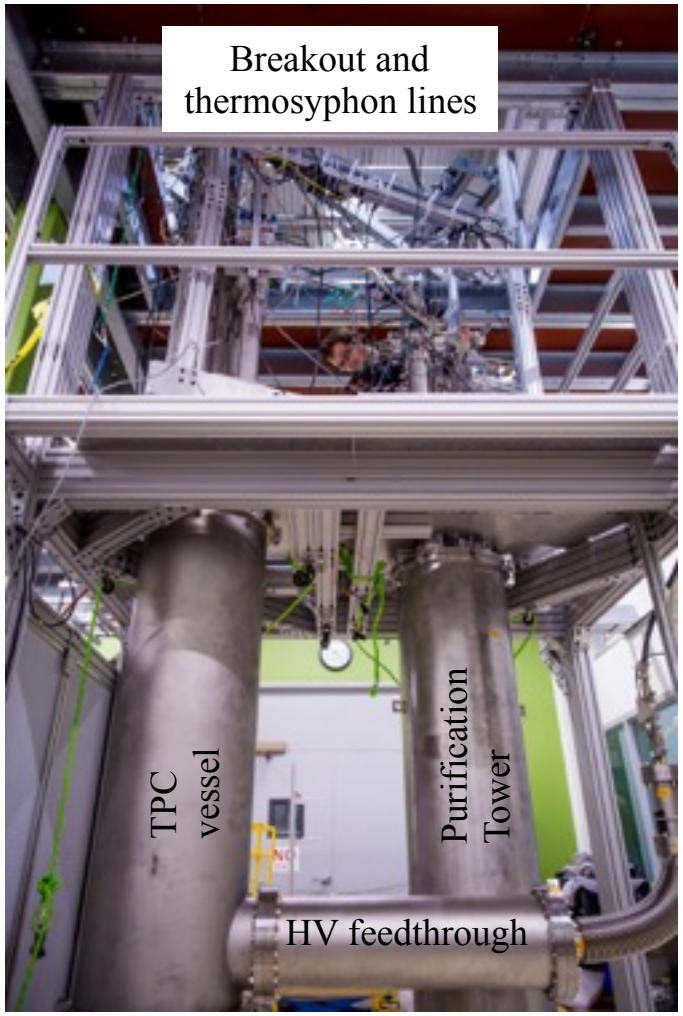
System Test Update, Review and Summary

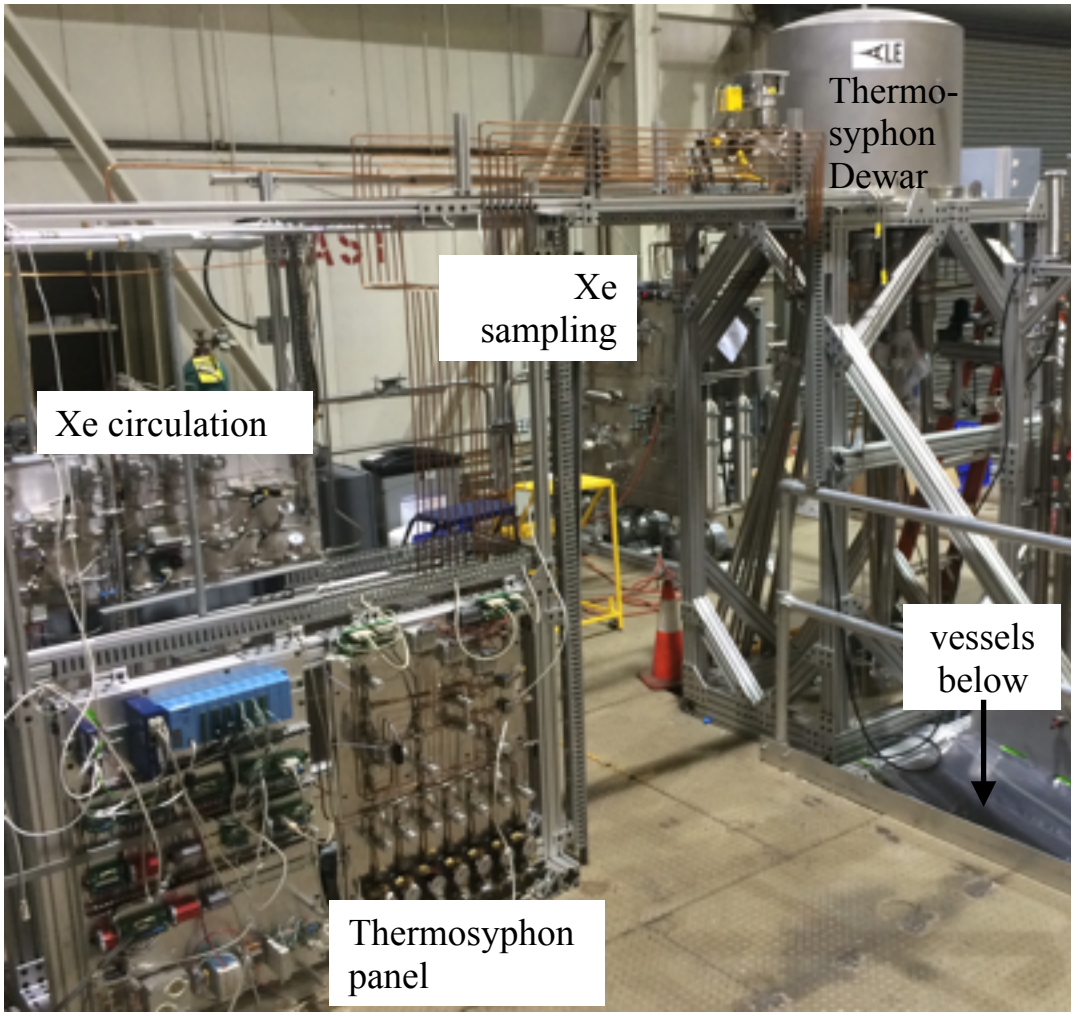
Kimberly Palladino

January 16, 2016

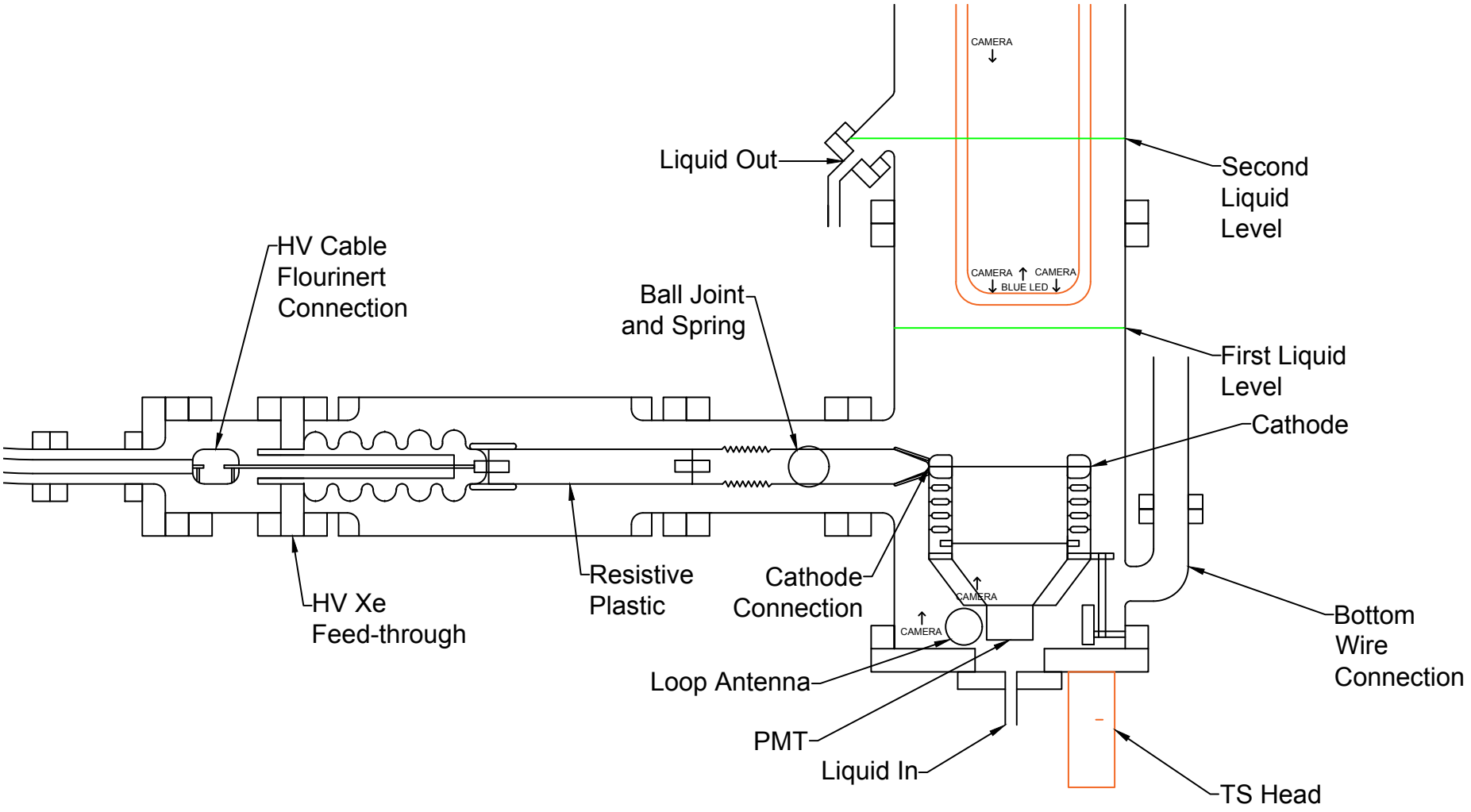
Since we last spoke

- Finished Run 2 of the system test
- HV review at SLAC
  - Went well, big push of plan for tests before CD-2/3b which will have to go to the tech board
- Interviewed Postdoc candidate
- 2 weeks in SD for LUX: all going smoothly
- Meetings at LBNL/ LLNL for LZ
  - Starting process with project office to get collaborator travel to SLAC covered

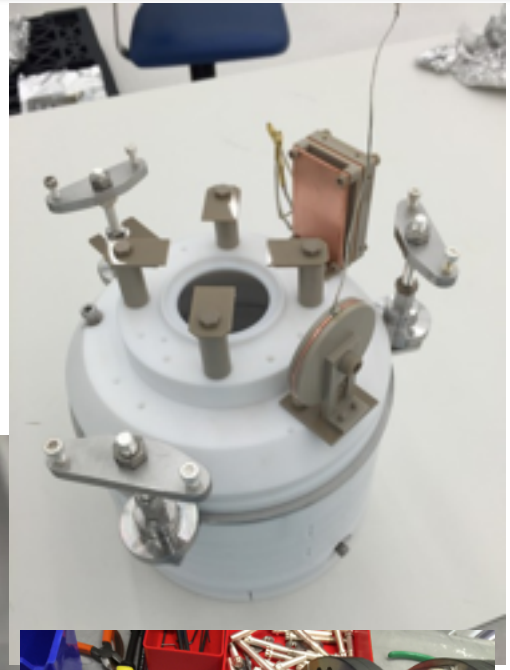

Breakout and thermosyphon lines
TPC vessel
Purification Tower
HV feedthrough

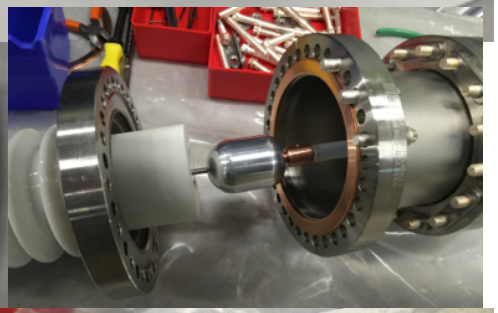

Thermo-syphon Dewar
Xe sampling
Xe circulation
vessels below
Thermosyphon panel

Reverse Field Region



Phase I Reverse Field Region





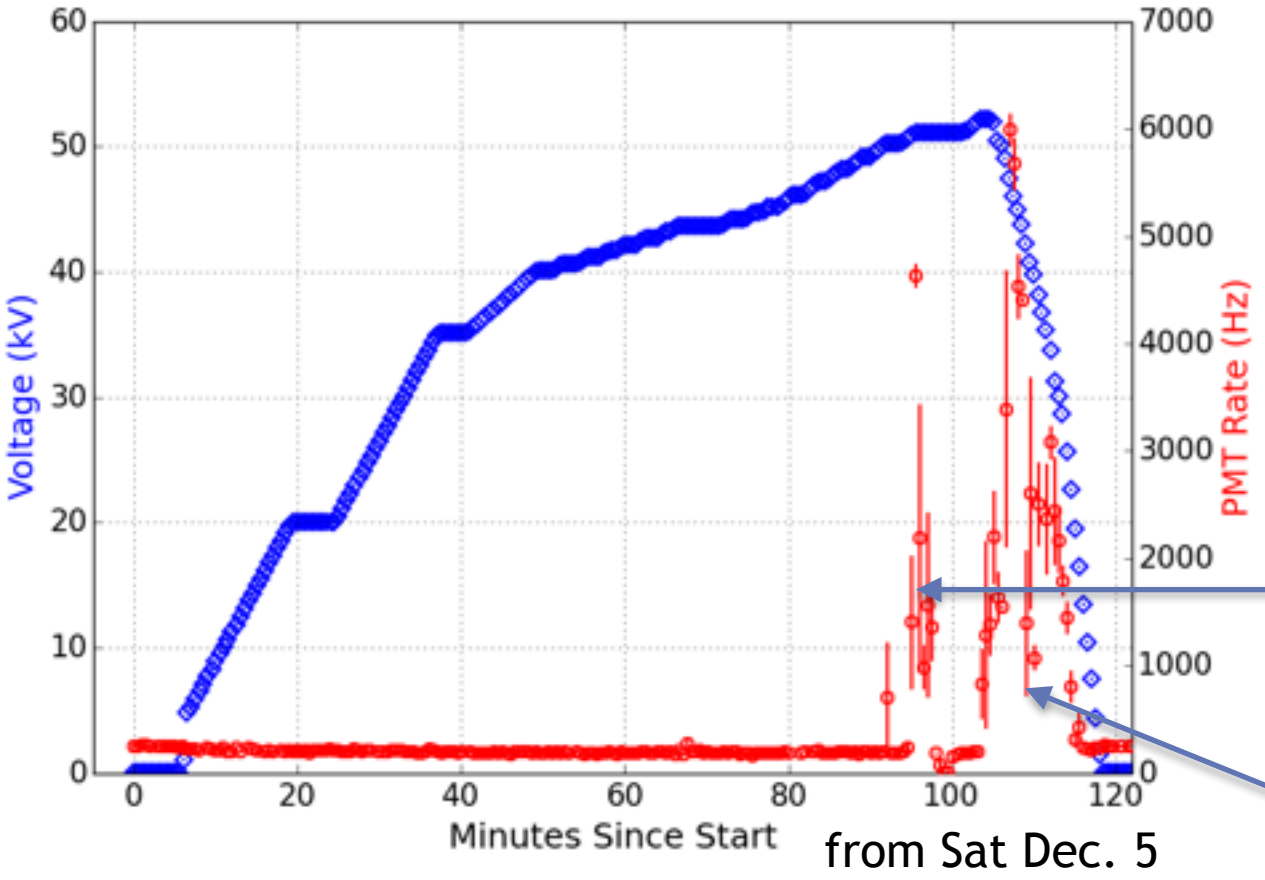
- RFR has 5 resistor stages down to ground, with two parallel resistor chains, 12.5 GOhm total resistance
- Instrumented with 1 PMT, loop antenna, 7 camera fibers, level sensor and temperature sensors
- Cathode HV feedthrough diverges from LZ design

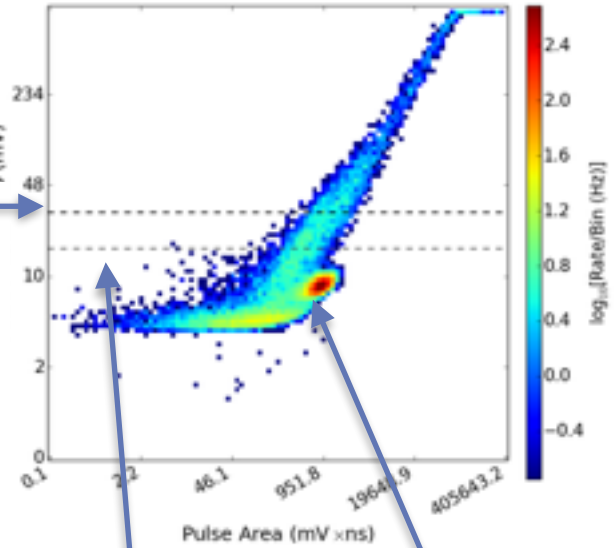
Run 2: RFR HV Tests summary

- HV testing started Dec 4 (Friday)
  - ramped up to ~42kV with 75 kg LXe2 over course of hour
  - some light seen in PMT that went away <1 min, when light persisted, we ramped down cathode voltage
  - Saw continued light after HV ramped down and power cycled the PMT
- Dec 5th: (Saturday)
  - Changed PMT bias voltage and ramped to 52 kV
- Dec 7th: (Monday)
  - very noisy environment
  - high PMT rates at 15-20 kV
- Dec 9th: (Wednesday)
  - now 100 kg LXe to weir level
  - again very noisy, even worse with Kr removal system operating
  - high rates at 15-20 kV
- Dec 11th: (Friday)
  - not quite as noisy, but also simplified the monitoring to just PMT to digitizers
  - ramped up to 72 kV and saw sparking/Cathode HV supply trips
  - **Camera light and Resistance measurements points to HV feedthrough/connection hardware**
- Dec 14th: (Monday)
  - checking after sparking of Dec 11
  - noisy again to raised thresholds
  - ramped up to 50 kV and stayed there for ~5 hours

Dec 5 ramp

Discriminator threshold for scalar:30 mV
~30% trigger efficiency on single PE at 900V PMT bias





Noise

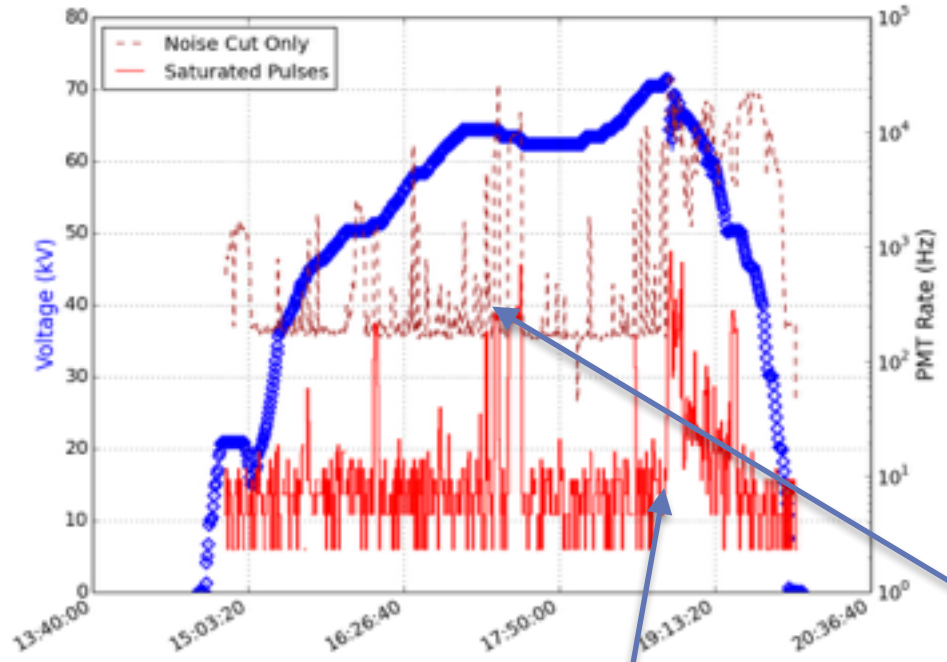
Threshold for DAQ above noise

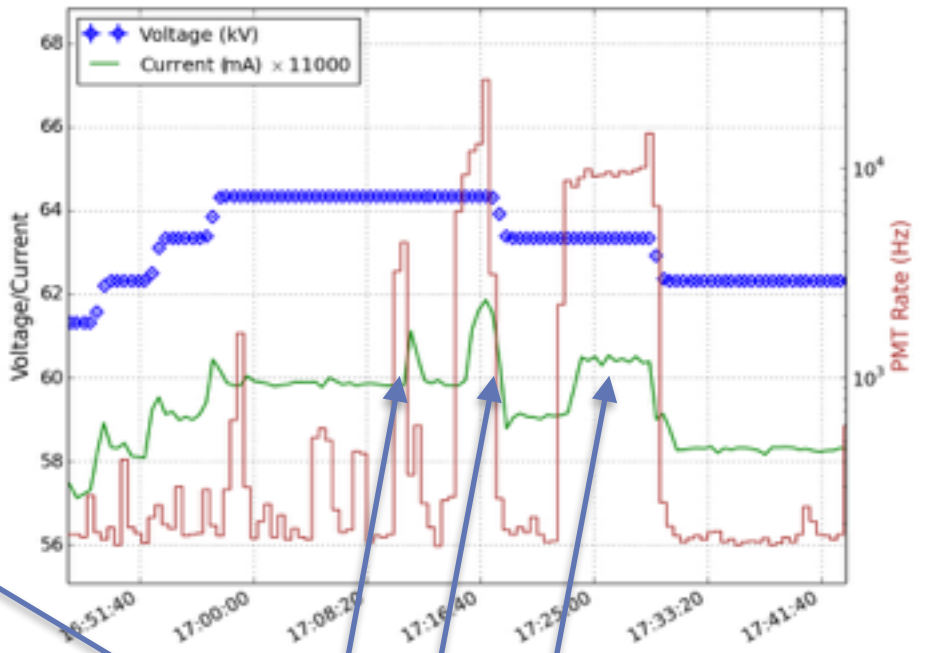
Power cycled PMT and burst did not return, so continued ramping

Light production persistent

from Sat Dec. 5

Dec 11th ramp

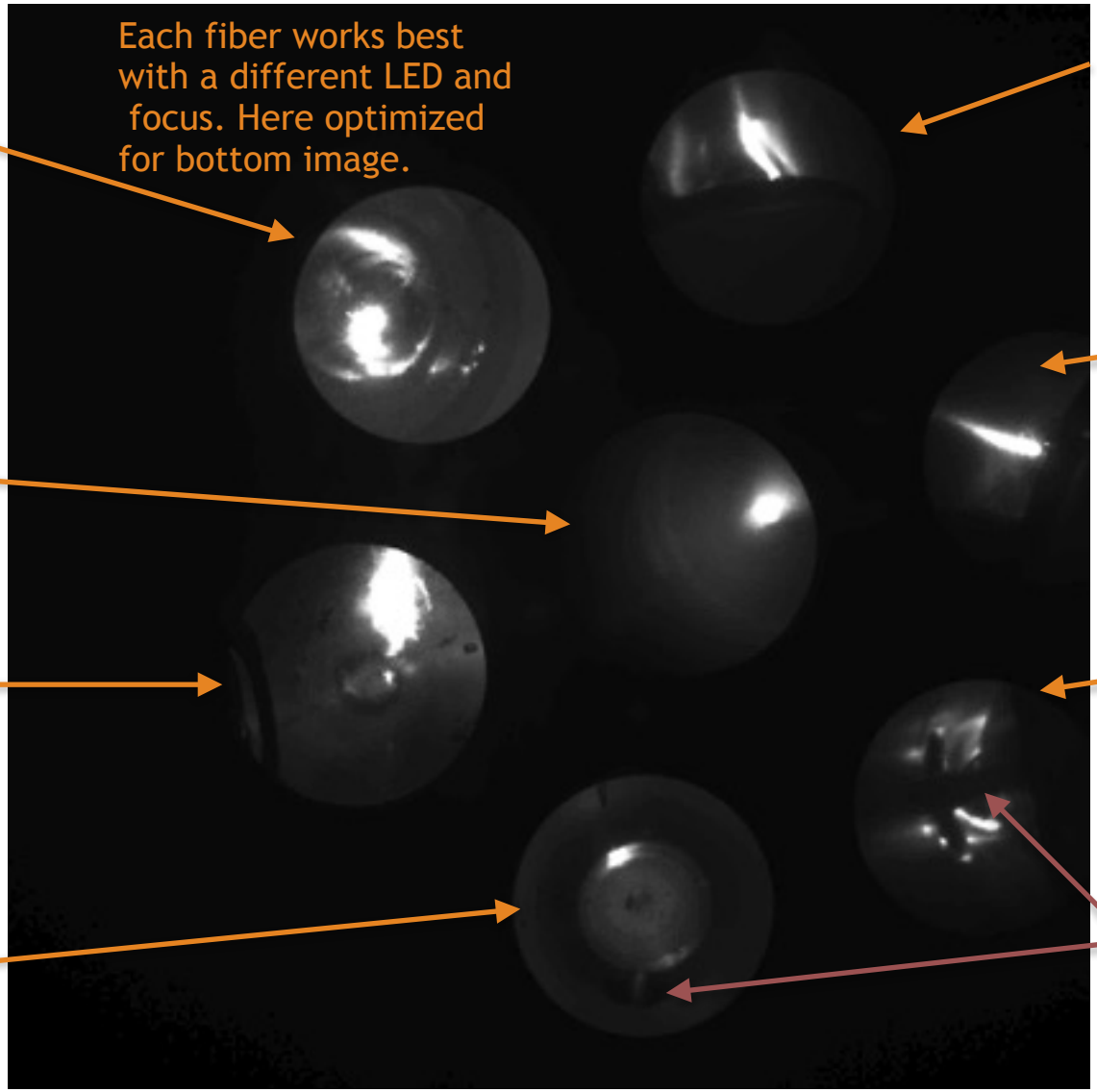




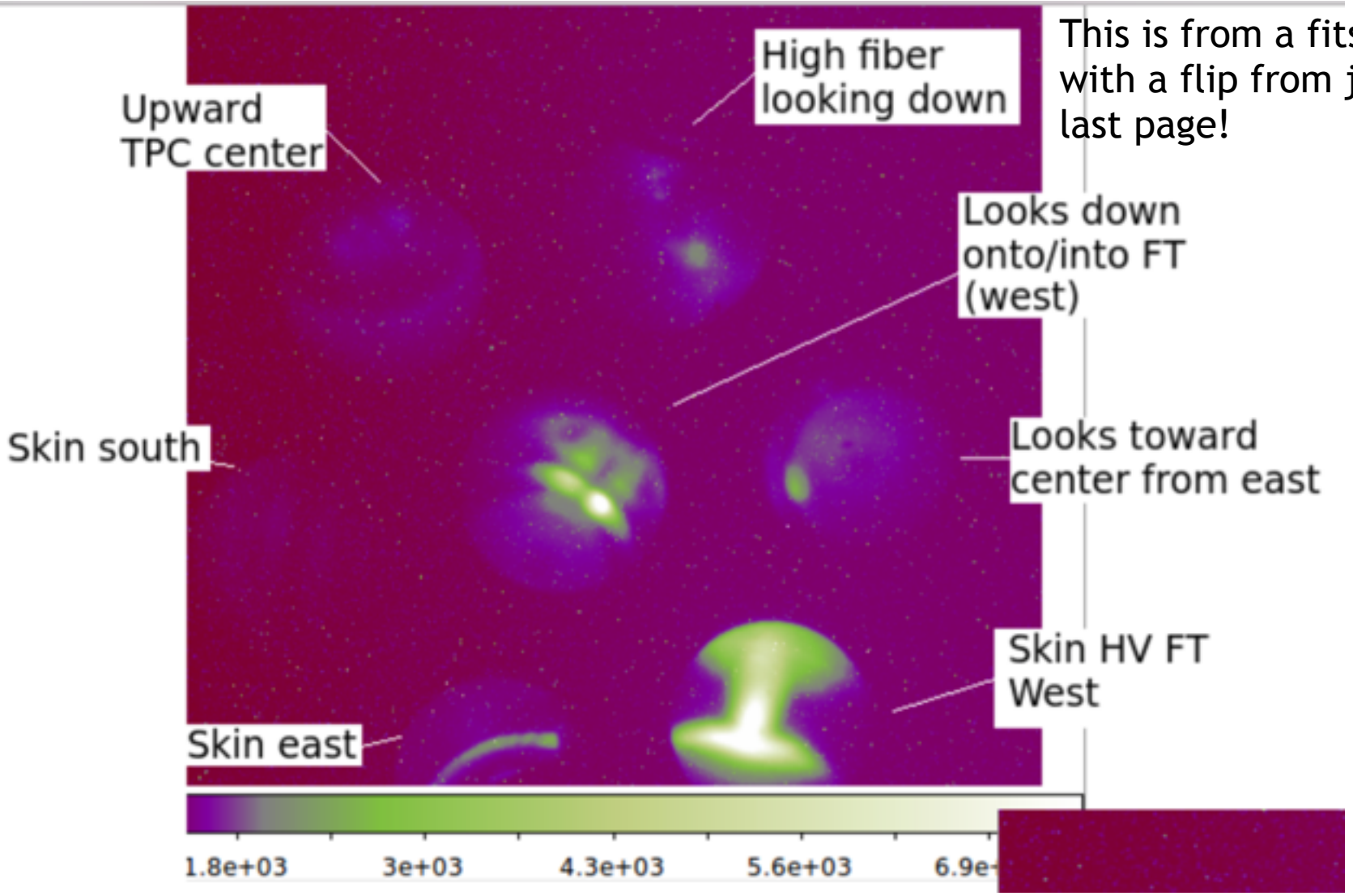
Non-ohmic cathode behavior, ramped down

- Cathode PS trips at 71 kV: no interlock, so ramped cathode HV down

Camera images: w/ LED, in gas

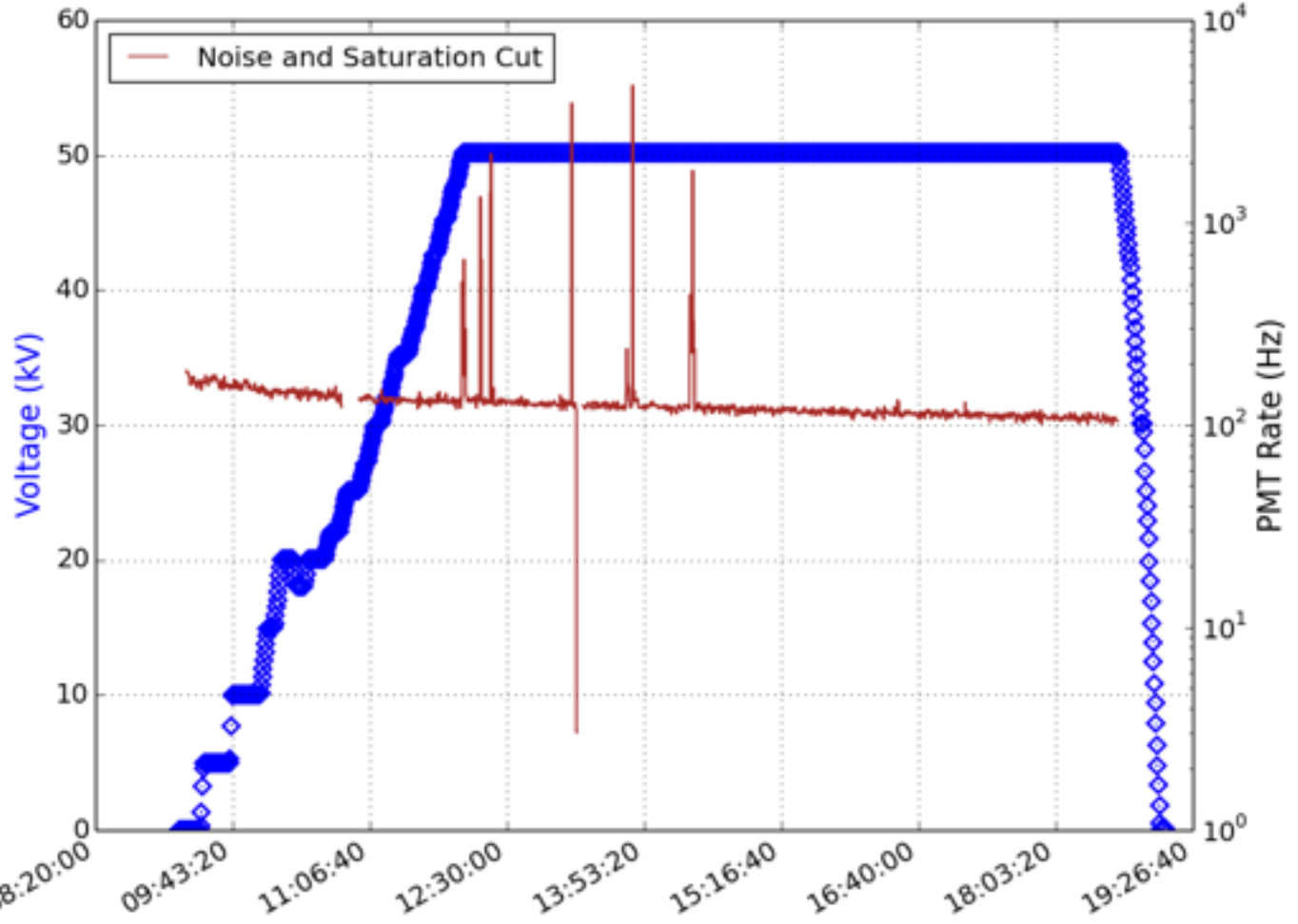


Dec 11:Camera sees Light



This is from a fits file with a flip from jpg on last page!

Dec 14th Ramp



Phase I Future Plans

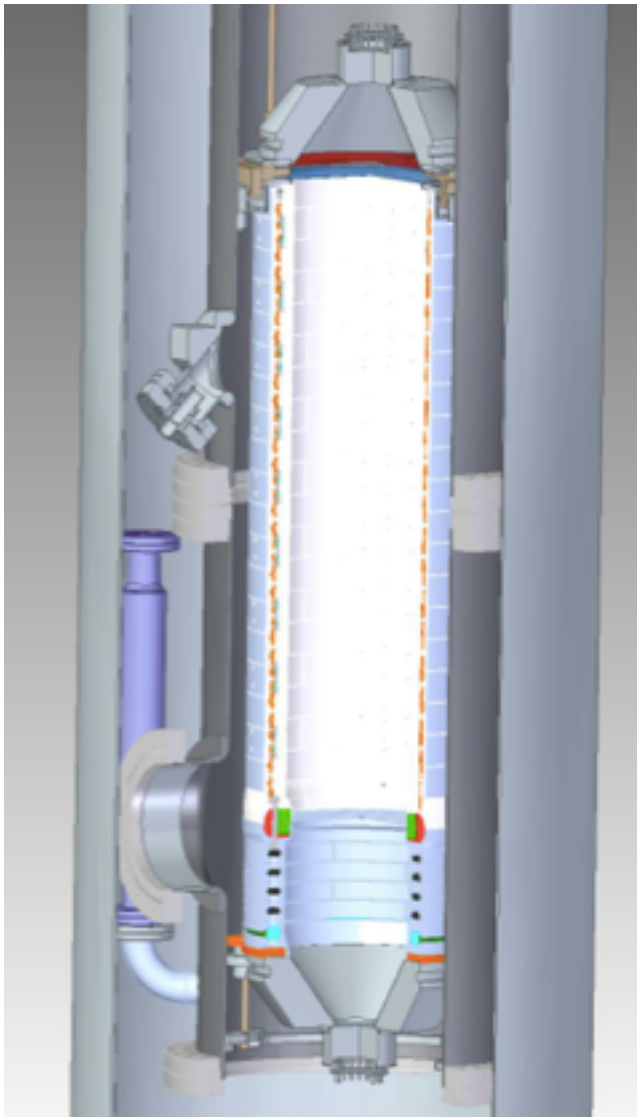
- Preparation for Run 3: Before CD-2/3b
  - Construct full Phase I TPC (2 PMTs)
  - Mitigate noise environment
  - Improve cryo/instrumentation for circulation
  - long task list at https://docs.google.com/document/d/13tydhXwbfyRZX_ZfE0gN3GCy9QMqT5FCzYp2POGsFQg
- Run 3: HV data taking in March
  - Performance goals for CD-2/3b: Cathode at 25 kV for a week
  - Test plan iterating from https://docs.google.com/document/d/14lMOmHyigCqcH0PKvE8RsGA2XYR7yqvd8qKAzWFgerc
- Future runs
  - Calibration sources
  - Skin tests
  - Different grids (wires, treatments)
  - Purity monitoring
  - Iterations in HV feedthrough, cryogenics and gas handling (cryo valves, 2 phase heat exchanger mods)
  - Array of top PMTs for position dependent studies

Backup slides

SLAC System Test

- Primary focus is high voltage
  - Discrimination has field dependence
  - Optimize grids: light collection (opacity) vs surface fields
  - **Minimize low-level electron and light emission**: primary concern for LZ
- Previous experience
  - All Xe experiments, LUX included, have fallen short of goals
  - Prior to XENON1T, no serious HV testing programs
- Goals
  - Risk retirement
  - Quality Assurance
  - Performance improvement
- Comprehensive, progressive program at multiple institutions
  - See separate slides in backup material for Small Chamber test information
- A comprehensive detector is needed
  - Testing many LZ subsystems! (Slow control, circulation, etc.)

System Test Program Hardware



- Testing TPC to operational fields/ voltages at SLAC
- Phase I
  - 10" Ø test vessel, 120 kg Xe
  - Fields same as LZ for half the applied cathode voltage
  - Full TPC prototype
- Phase II
  - 166 cm Ø test vessel, 500 kg Xe
  - Upper corner tested at full voltage, Cathode tested to LZ field
  - Full scale grid prototyping and QA

Where we were at Coimbra

- Work remaining to first liquid run in high detail

- Finish vacuum leak test
- Remove vacuum vessels, lift needed to remove the purification tower vac vessel
- Finishing the cleanroom (Gabe and Shaun have most of this information- sticky mat for floor in in flat white box under wooden tables in 621)
- Putting burst disks in place (Mike finishing on some related welding, torque wrenches to be used, leak check after installation)
- Vacuum space pressure relief: benchtop with leak detector needed, SRV and TS dewar workaround, leave big flange open, have to figure out vacuum space of our research vessels (Gabe and/or Shaun can play with leak detector)
- New TS top section vacuum jacket should be tested and then get more from Mike (I believe the one finished is the length that is different from the other 2)
- PLC external cabling Tomasz and Shaun should be following up on most of this)
- Put on Xe vessel flange (Gabe and Shaun have info, pictures on Twiki, Wei for final 0-length reducer orientation)
- Minor counterweight system improvements (TJ gave info to Shaun)
- Camera system testing, (Wei, Steffen, Christina)
- Internal cabling for purification tower ready (Tomasz finished the cables- teflon and wire wrap advised for 5 RTDs on copper tube)
- 2PHX installation (Wei getting from Mike/plating&cleaning shop)
- purification tower part assembly
- HV assembly (Wei, epoxy cable, and assembly other parts, Tomasz has additional infro from Will's visit Thursday for Wei on this)
- Level sensor boards cabling and communication(Shaun) (Kim is giving info to Dan for ordering more)
- Build out parts of Xe system (TJ gave info to Gabe: put Xe vessel in place on floor to allow it to be raised without a crane lift)
- Install Xe vessel (alignment from Wei)
- Vacuum space sensors: Will wait for shipment, keep checking Donna's office for them)
- TS lines to vessel TS heads
- vacuum space cabling

Science and User support building currently under construction at SLAC. Will the system test turn on before it opens?

No, they were a week ahead!

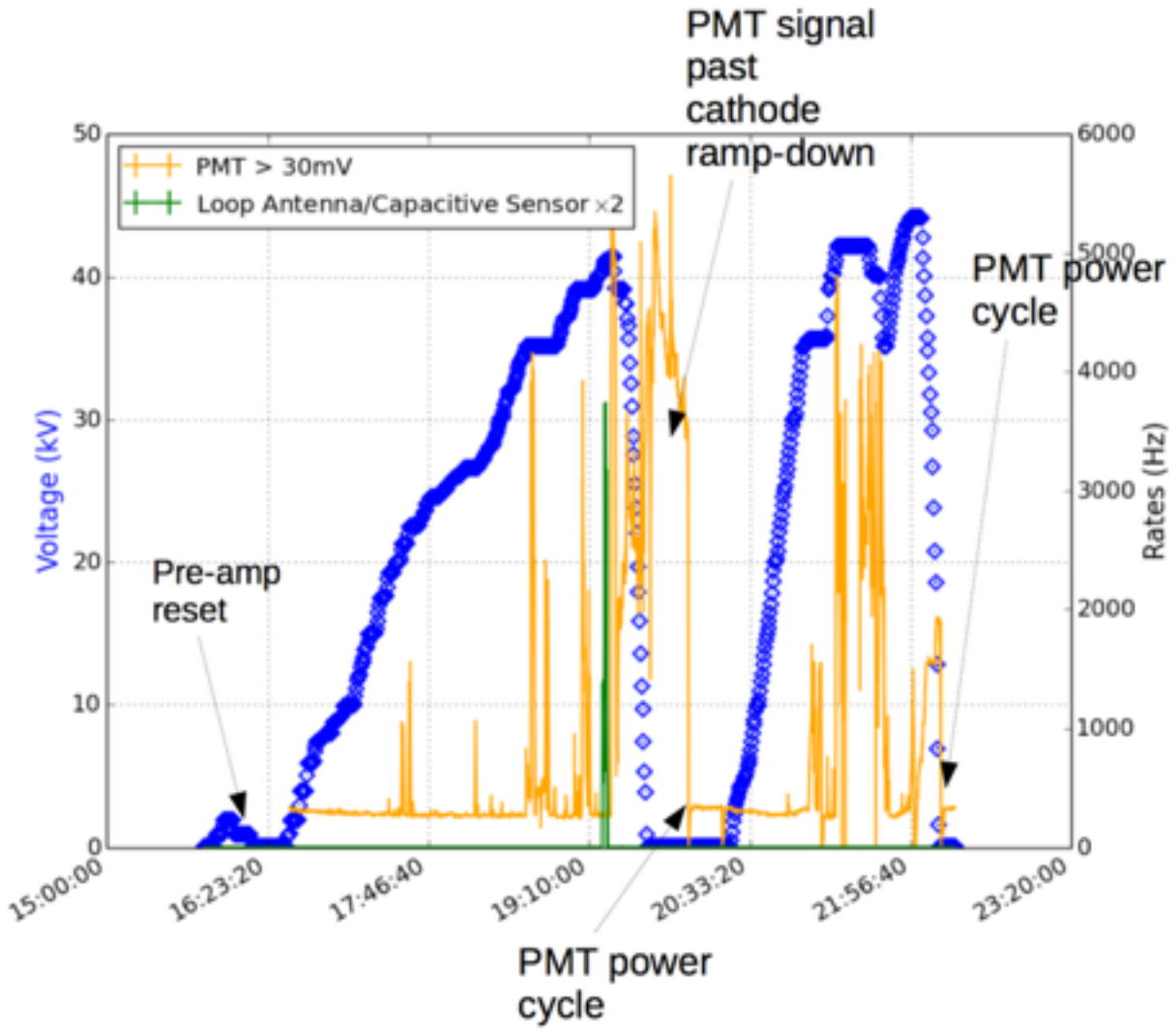
- superinsulation
- vacuum vessels on
- U-tube on
- start pump down
- TS Vent line (Mike)
- ODH (Kim will be working on it remotely)
- Buffer space for compressor (Andy not needed next week)
- [illegible] commissioning knowledge and tool share (Christina and Emma)
- test devices as hood and [illegible] (Rods and gears)
- talk to power supplies in rack (Tomasz and Christina)
- Level sensor communication
- UPS power to rack (Steffen)
- Power strip to top of box

Just one task list of many this fall!

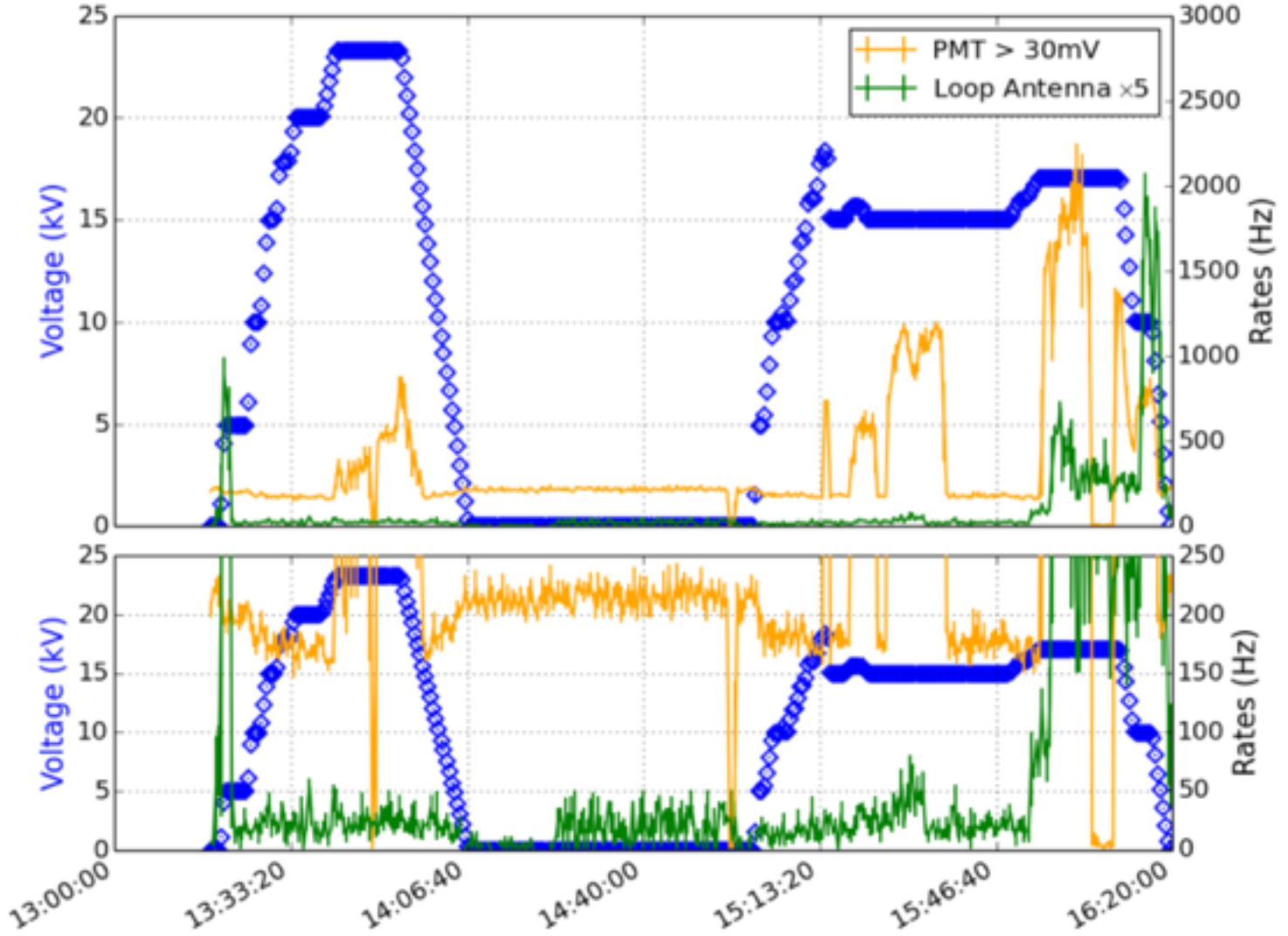
Since September

- Run 1:
  - Commissioning run with no TPC: Oct. and Early Nov 2015
  - HV connection disconnected in fluorinert: indeterminate results on feedthrough performance
  - Areas of improvement for cryogenics (purification tower, SRV)
  - Circulation not tested with detector
  - But 75 kg cold for ~2 weeks, successful monitoring
- Run 2
  - HV testing run with Phase I RFR of TPC (1 PMT)
  - Circulation tests with detector: fixing instrumentation necessary for fully testing in future

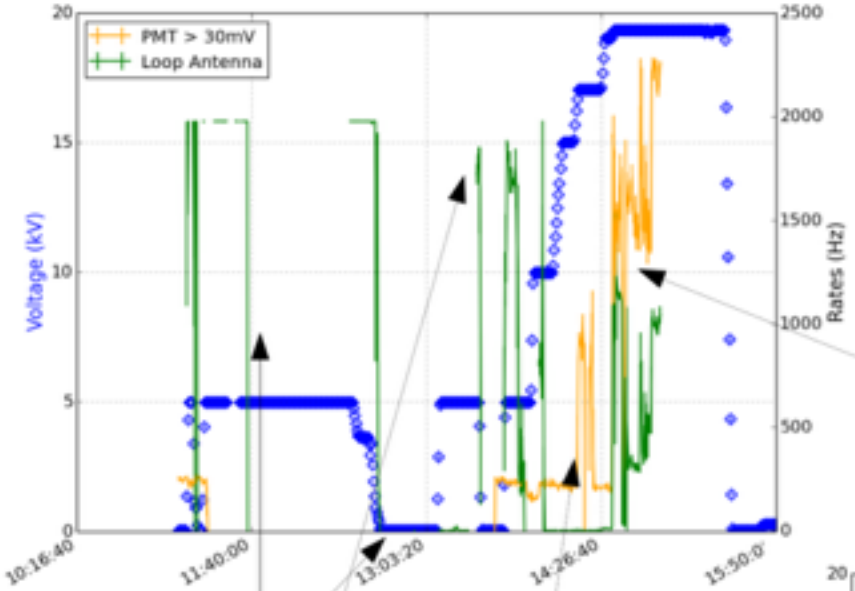
Dec 4 Ramps


PMT signal past cathode ramp-down
PMT power cycle
PMT > 30mV
Loop Antenna/Capacitive Sensor ×2
Voltage (kV)
Rates (Hz)
Pre-amp reset
PMT power cycle
15:00:00
16:23:20
17:46:40
19:10:00
20:33:20
21:56:40
23:20:00
0
10
20
30
40
50
0
1000
2000
3000
4000
5000
6000

Dec 7 Ramps


PMT > 30mV
Loop Antenna ×5
Voltage (kV)
Rates (Hz)
25
20
15
10
5
0
3000
2500
2000
1500
1000
500
250
200
150
100
50
13:00:00
13:33:20
14:06:40
14:40:00
15:13:20
15:46:40
16:20:00

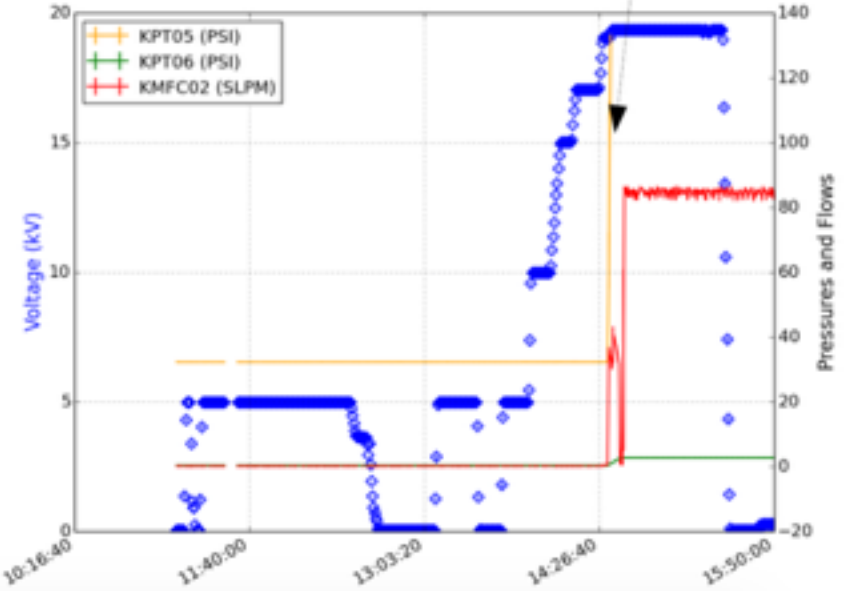
Dec 9 Ramps



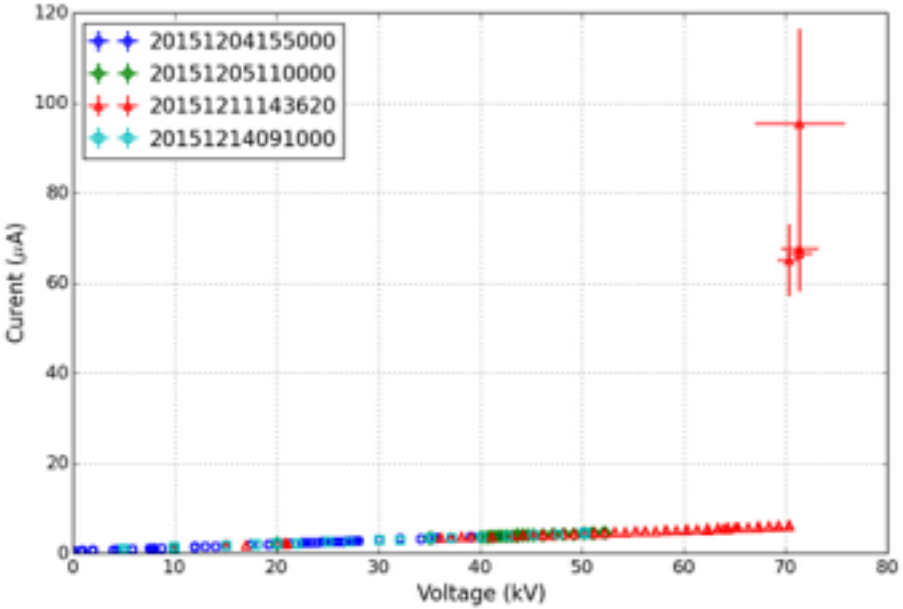
Noise, same shape on loop antenna and PMT lines. Coincides with Kr operations

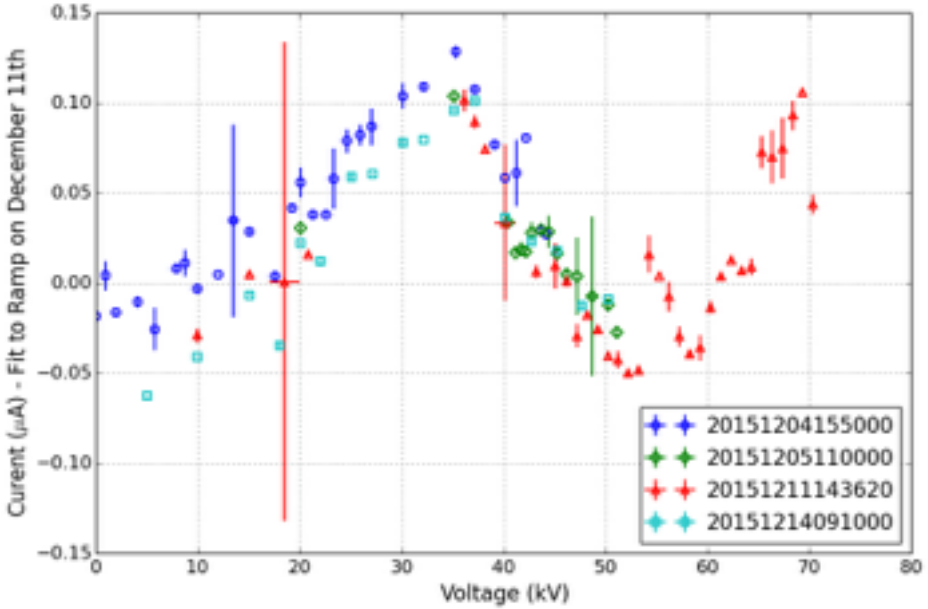
Loop antenna active when cathode biased up

Real photons according to Maria Elena. Power cycled the PMT with no effect. Rate did come down on its own

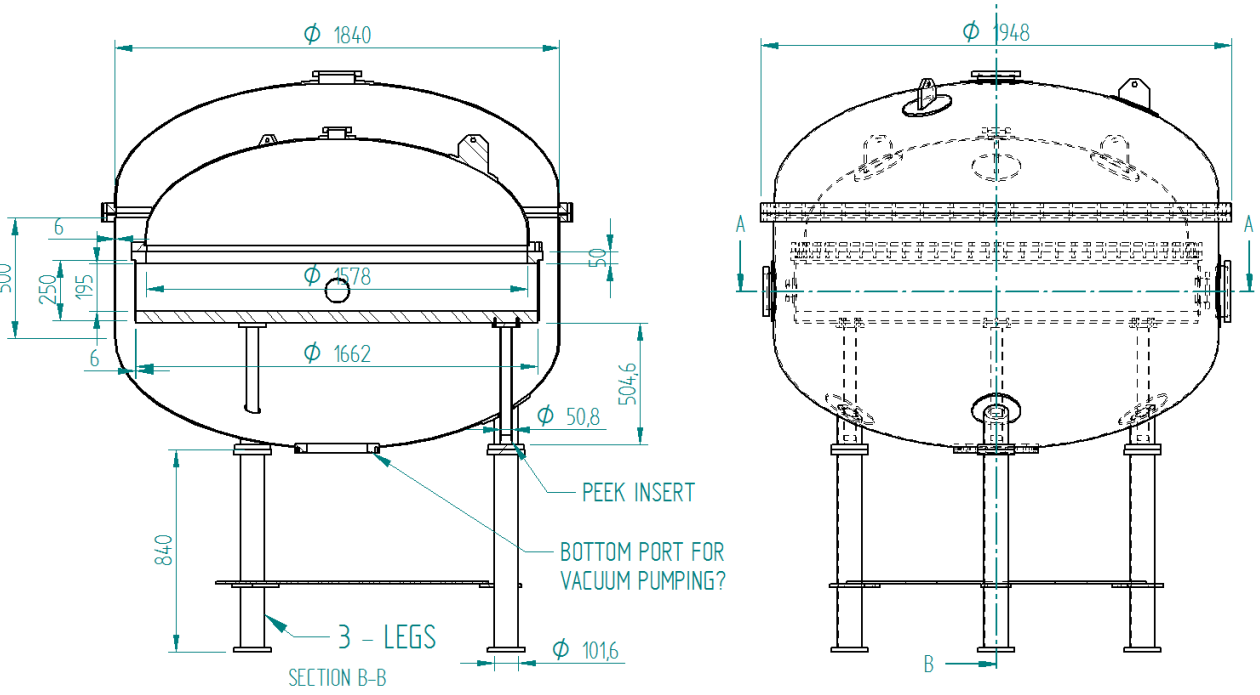


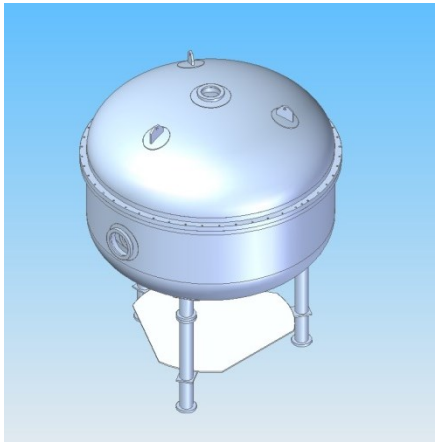
Ohms law

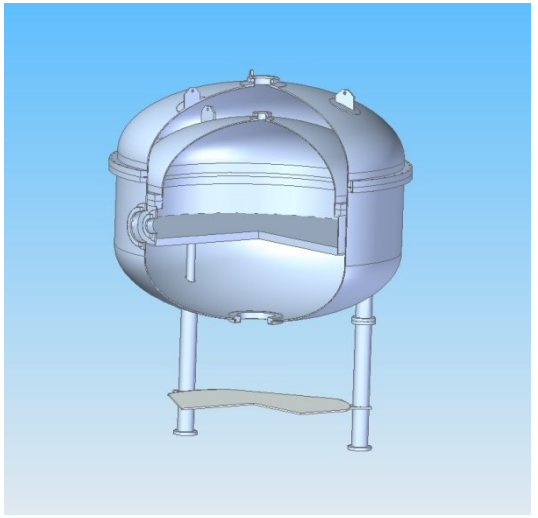

20151204155000
20151205110000
20151211143620
20151214091000
Curent (μA)
Voltage (kV)


Curent (μA) - Fit to Ramp on December 11th
Voltage (kV)
20151204155000
20151205110000
20151211143620
20151214091000

Phase II is coming!







- Test full scale grids (prototype and final) in LXe
- Upper corner tested as assembly at full voltages
- Cathode and bottom grid tested together, to LZ surface fields
- 60 kg per cm of LXe height: ~6 cm liquid level anticipated
- Fall 2016-Fall 2017

Lots of things to do!

- Come join us at SLAC!
  - Talk to me (Kim) or Tom about trips to SLAC
- Hardware work: TPC, sensors, gas system and cryo
  - Lots of hands on work, already working with LBNL, Oxford, FNAL/ Northwestern, Maryland, PSL but every run needs hands on work
- Slow controls: Ignition front end
  - Exercising needs for LZ
  - Looking at the data taken to understand and improve gas systems and cryogenics
- DAQ
  - Exercising early modules for LZAP
  - Looking at the data to understand light/charge production as parts of primary HV studies

Staying in touch

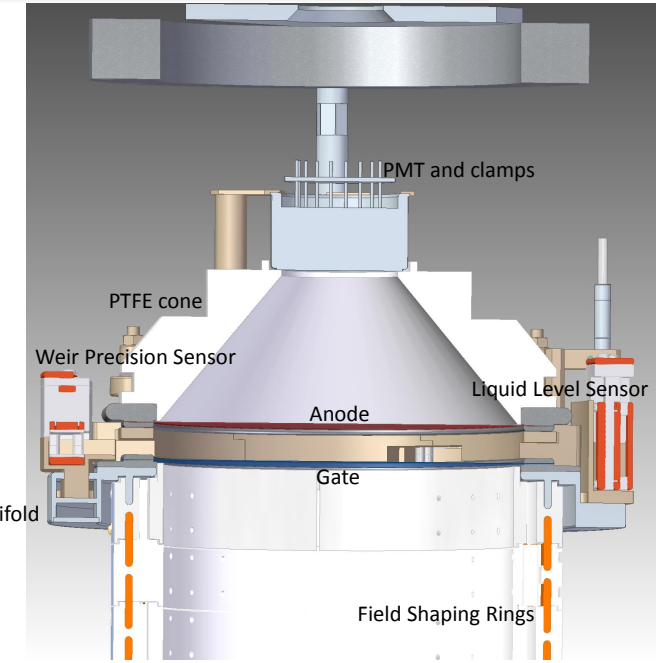
- slack!
  - #slac_ops
  - #slacsystemtesthv
  - for more specific work
    - #slacsystemtestplc
    - #systemtestslowcontrol
    - #systestinstrumentation
- Fortnightly 1.5.11 Calls: Thursday 11:30 am MT
- TWiki
  - Main page: http://teacher.pas.rochester.edu:8080/wiki/bin/view/Lz/SystemTest
  - Results page: http://teacher.pas.rochester.edu:8080/wiki/bin/view/Lz/SystemTestRunDocumentation

System Test Schedule

Test	Duration	Risk Addressed
Wires in LXe at Imperial, Phase 1	Fall 2014- Spring 2015	Grids maintain HV
Reverse Field region in LAr, Camera system at Yale	Fall 2014- Spring 2015	Cathode and reverse field region maintain HV
Wires in LXe at Imperial, Phase 2	Spring 2015- Fall 2016	Grids maintain HV
SLAC Phase 1: TPC in LXe + sensors, slow controls	Fall 2015- Spring 2017 concurrent with some of Phase II	For ability to maintain goal HV: materials of grids and field shaping components, cleanliness protocols, operating procedures, single electron and single p.e. sensitivity
SLAC Phase 2: Full scale grid prototypes in LXe	Fall 2016- Spring 2017	Full Scale grid iterations to maintain HV with materials and cleanliness protocols
SLAC Phase 2: Final grid QA	Summer 2017- Fall 2017	Testing of production grids: Ability to hold HV at full voltage for gate and anode, full field for RFR

Planned scope of tests

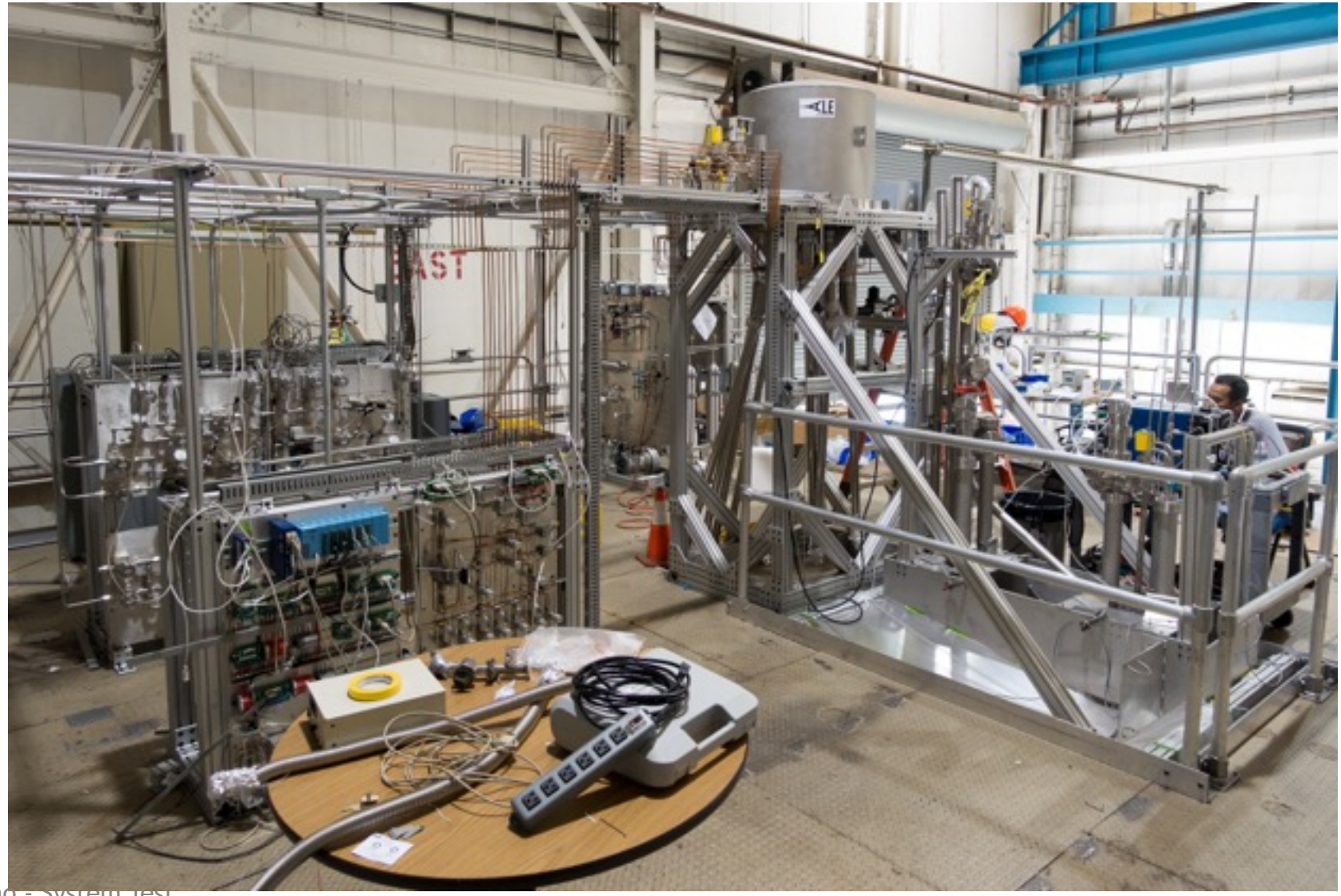
- Phase I:
  - Low light and charge emission studied with TPC PMTs: single pe sensitivity
    - As a function of purity, circulation rate, temperature gradient, aging and longevity, reproducibility
  - HV operation up to breakdown studied with current monitors, cameras, loop antennas & PMTs
    - Fields to vessel at Cathode
    - Extraction region fields, with LZ style instrumentation
  - Materials choices & handling following work at Imperial, LBNL, Yale
    - TPC design: options for teflon rings
    - Field shaping rings and resistors
    - Grid design: bonded woven grids, 1% of LZ grid area
    - Electropolishing through dust removal
    - Non-Cathode HV feedthroughs and delivery to grids
  - Subsystem tests
    - Sensors: capacitive level and position sensors, loop antennas, acoustic sensors
    - Skin operation
    - Design of upper corner: avoid undesired S2 light



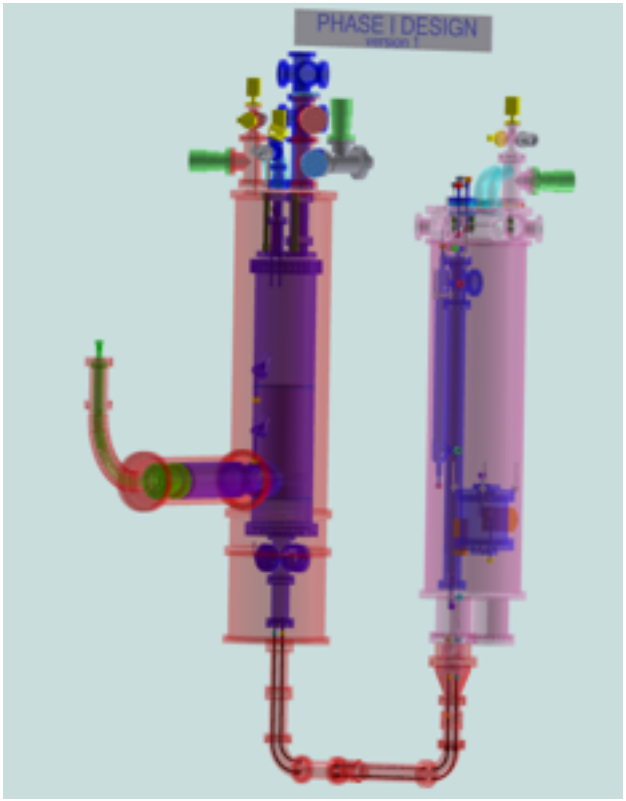
- Phase II:
  - Full scale Grids
    - Mechanical design: tensioning, bonding, cooling at full scale
    - Extraction region performance with camera and limited number of PMTs, full LZ voltage +/- 7 kV
    - Cathode and bottom grid to surface fields, 70 kV/cm goal

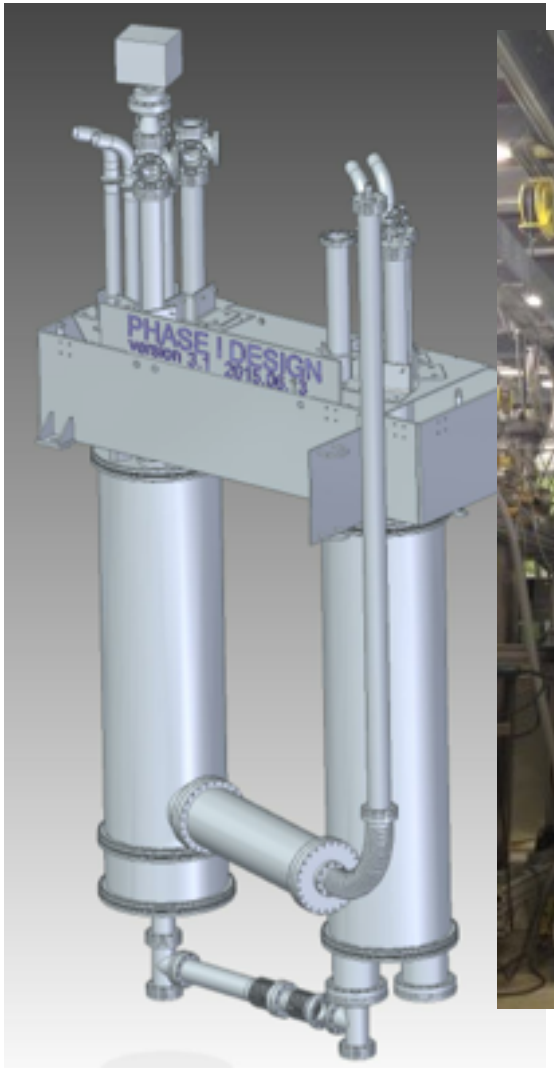
Platform design

Top of the Hut

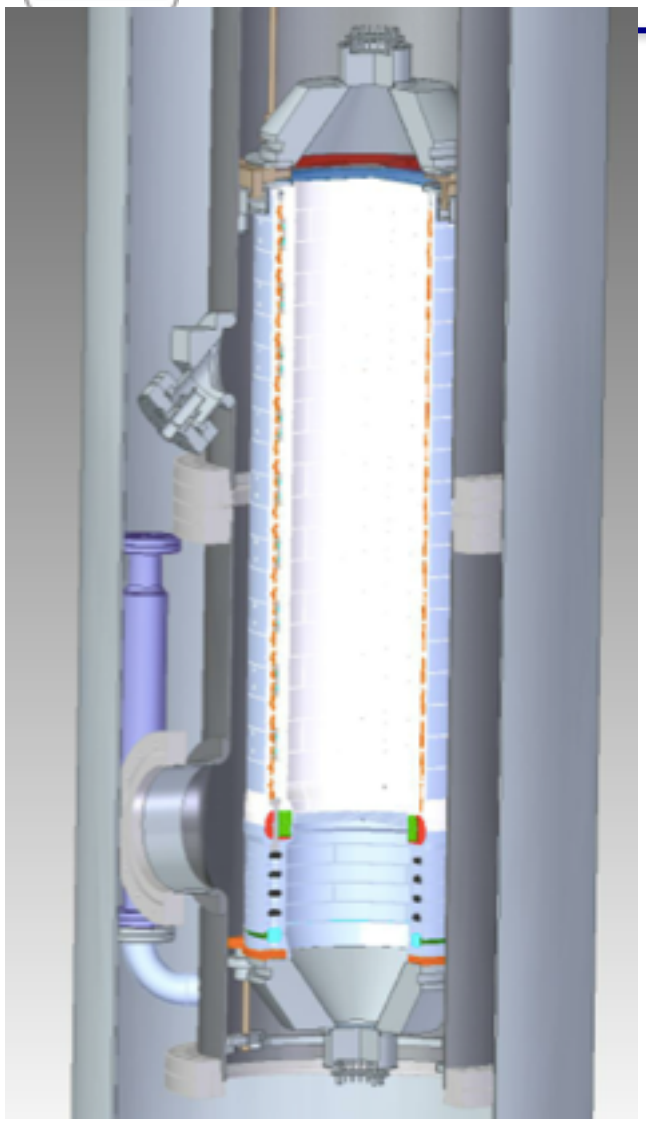


Phase I System Test Vessels





Phase I TPC Design



- Full 2 phase TPC with 4 grids
  - Cathode grid (-50 kV, hope -100 kV)
  - Bottom grid (-1.5kV)
  - Gate grid (-7 kV)
  - Anode grid (+7 kV)
- 2 2” PMTs, 1 each top and bottom
- Cathode to bottom grid ~3”
- Cathode to gate ~20”
- ~6” diameter grids
- Weir trough and surface level sensors
- Purity monitoring

Cathode connection