# Updated Results from the LZ System Test Platform At SLAC

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For the LZ Collaboration
09/22/2017

LIDINE 2017

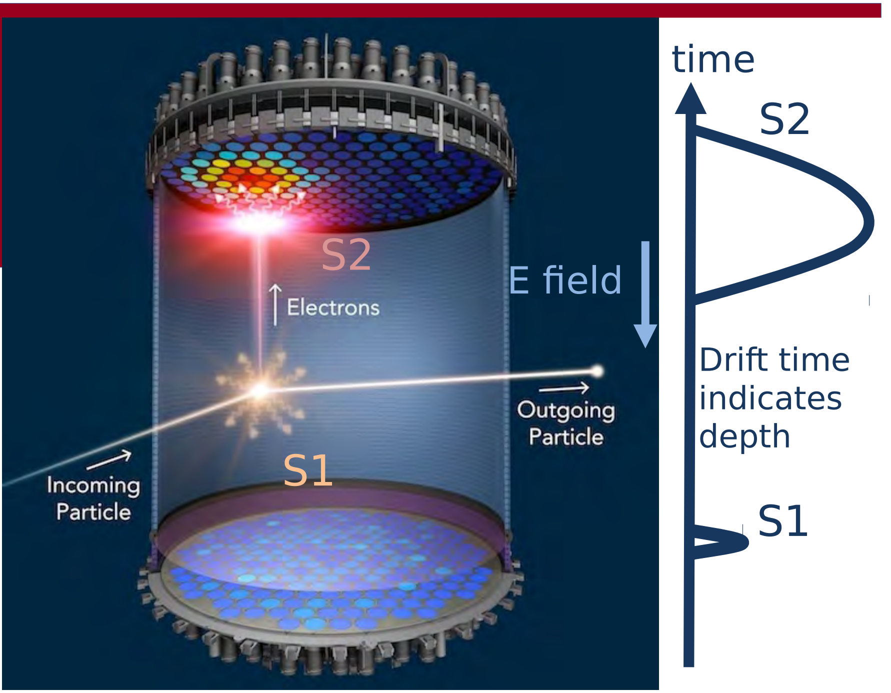
# LZ Collaboration


1. Center for Underground Physics (South Korea)
2. LIP Coimbra (Portugal)
3. MEPhI (Russia)
4. Imperial College London (UK)
5. Royal Holloway University of London (UK)
6. STFC Rutherford Appleton Lab (UK)
7. University College London (UK)
8. University of Bristol (UK)
9. University of Edinburgh (UK)
10. University of Liverpool (UK)
11. University of Oxford (UK)
12. University of Sheffield (UK)
13. Black Hill State University (US)
14. Brandeis University (US)
15. Brookhaven National Lab (US)
16. Brown University (US)
17. Fermi National Accelerator Lab (US)
18. Lawrence Berkeley National Lab (US)
19. Lawrence Livermore National Lab (US)
20. Northwestern University (US)
21. Pennsylvania State University (US)
22. SLAC National Accelerator Lab (US)
23. South Dakota School of Mines and Technology (US)
24. South Dakota Science and Technology Authority (US)
25. Texas A&M University (US)
26. University at Albany (US)
27. University of Alabama (US)
28. University of California, Berkeley (US)
29. University of California, Davis (US)
30. University of California, Santa Barbara (US)
31. University of Maryland (US)
32. University of Massachusetts (US)
33. University of Michigan (US)
34. University of Rochester (US)
35. University of South Dakota (US)
36. University of Wisconsin – Madison (US)
37. Washington University in St. Louis (US)
38. Yale University (US)

# Outline/Background

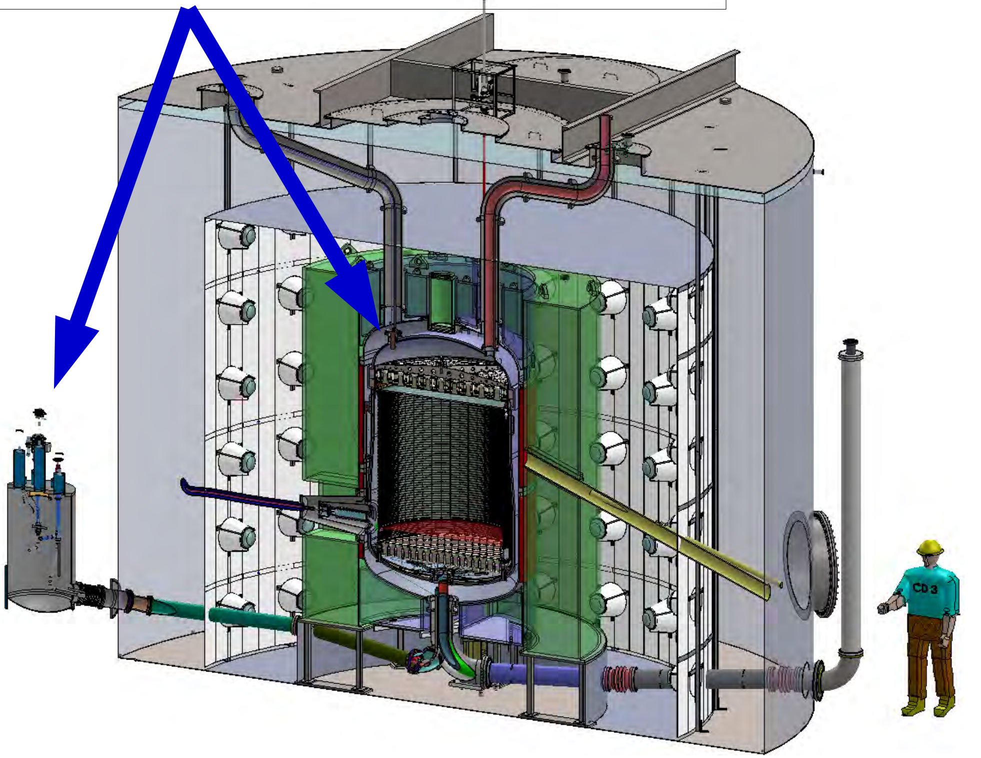
- Intro to LZ and the LZ System Test at SLAC;  Phase 1
- HV goals at SLAC LZ System Test
  - Confirm that the electron extraction region (non-grid) fields do not lead to excessive charge/light emission (needed to achieve low threshold)
  - Test small scale grid behavior in liquid to allow correlation to small grid gas tests and full size LZ grid validation in gas
  - Confirm that the reverse field region can sustain required fields
- Circulation goals at SLAC LZ System Test
  - Make sure that the LZ design of the circulation and purification system can handle flow rates of 500SLPM of Xe
  - Maintain stable liquid level in the detector to maintain constant electron extraction and electroluminescence for S2 light production
- Ancillary LZ tests

# LZ




- Dual phase Xe TPC
  - 7 tonnes of active Xe
  - 1.5 m diameter, 1.5 m height
  - 310 V/cm drift field (50kV Cathode)
  - 10.2 kV/cm electroluminescence field (11.5kV voltage difference)
- Located at SURF 4850 feet underground
- Operational in 2020

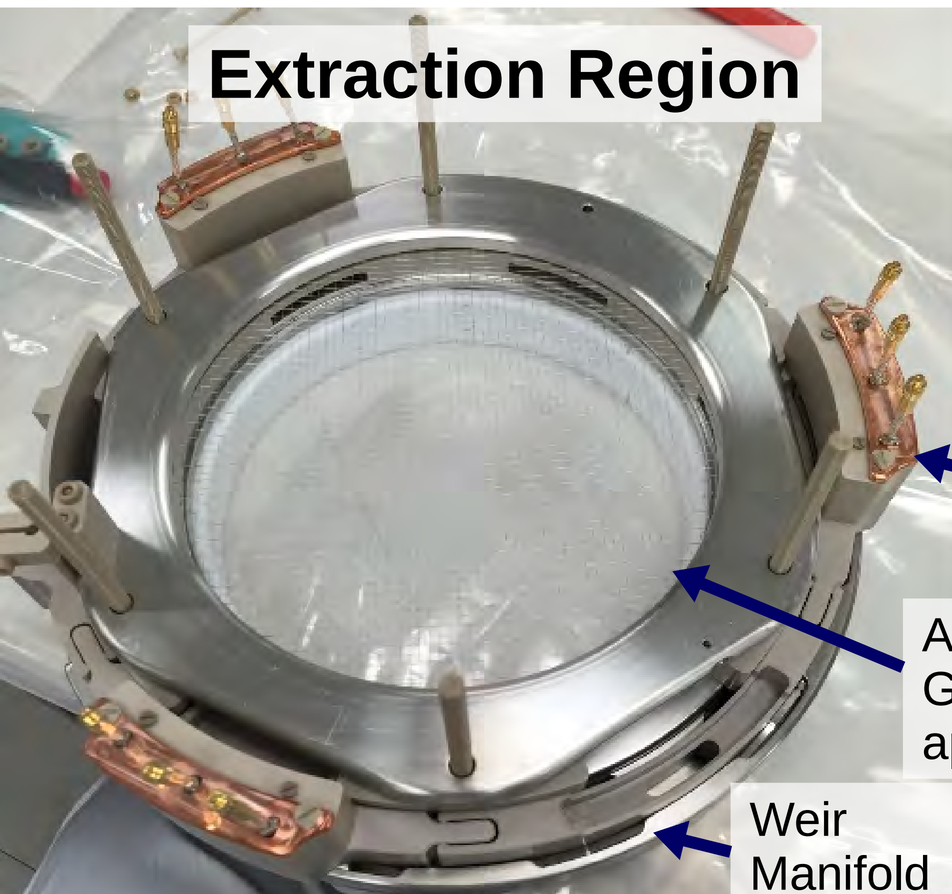
Xe-handling cryogenic tower and detector are prototyped at SLAC

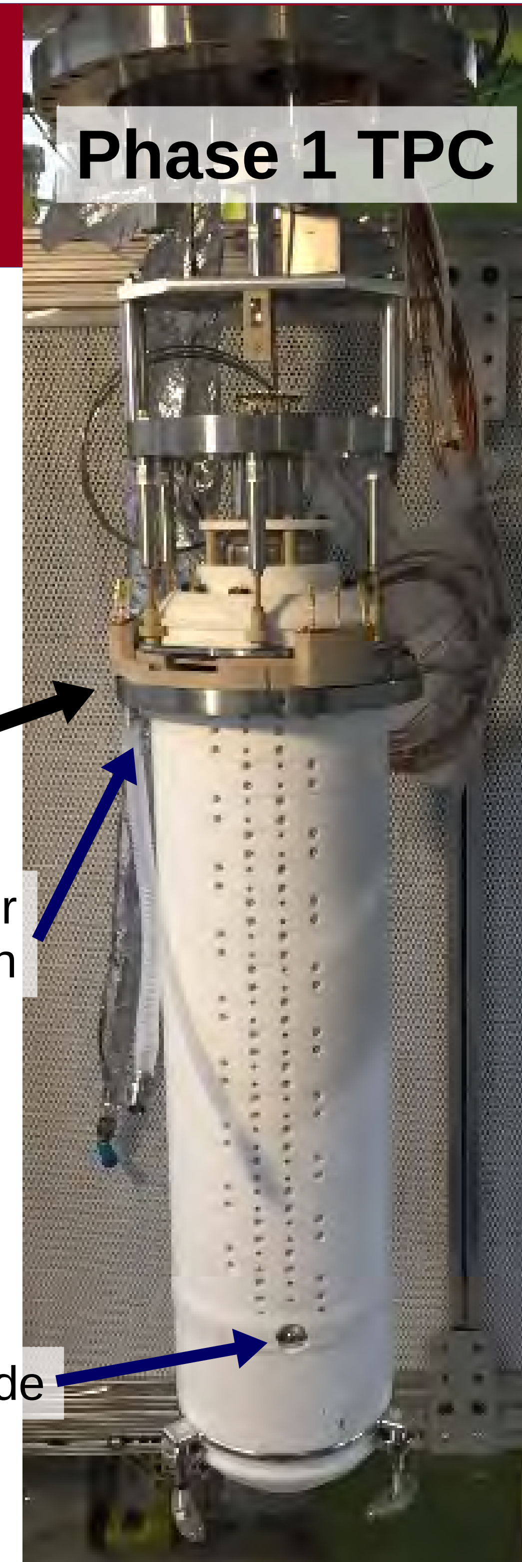


**Extensive test program underway at multiple institutions**

# SLAC System Test

- **Phase 1**
  - Minimize electron/photon emission to get low threshold
- Xe Gas Test – Compare to Phase 1 data
  - See Wei Ji's talk later today
- Phase 2
  - Actual LZ grid acceptance testing in Xe gas

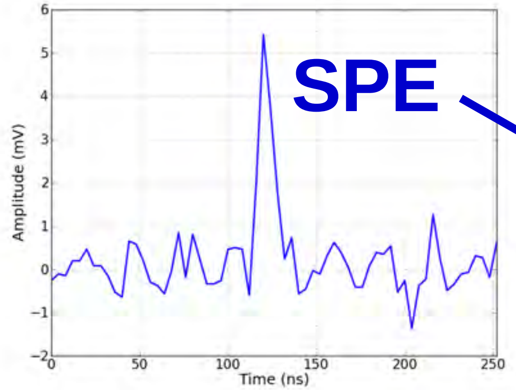


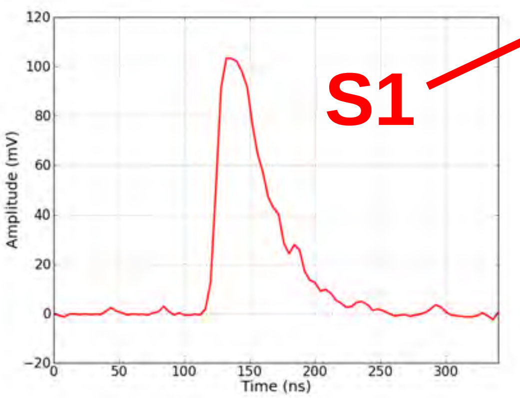



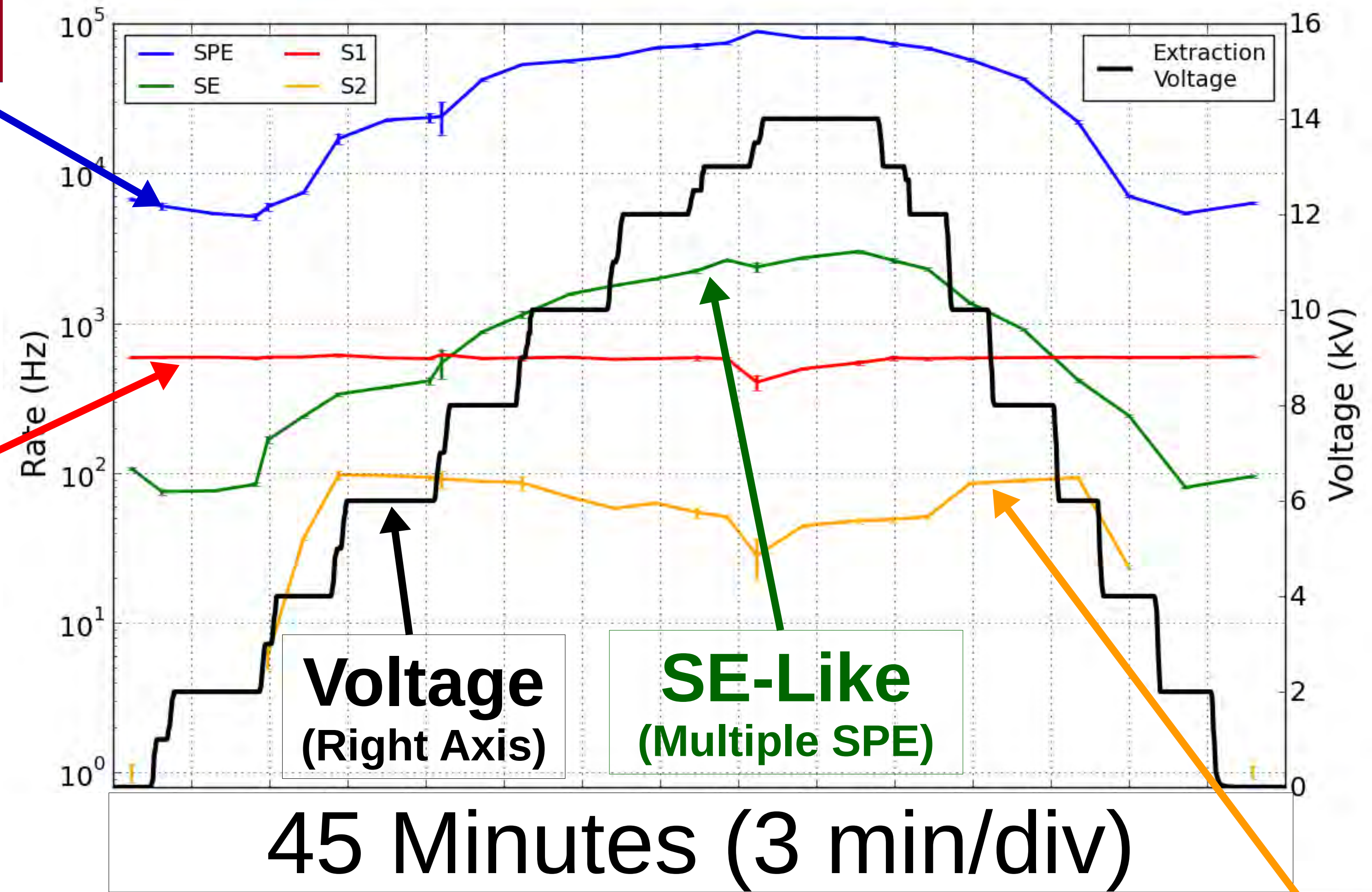
## Study of Rates Due To Extraction Region HV

Or not due to HV,
It's complicated...

# Rates During Extraction Region Ramp Up

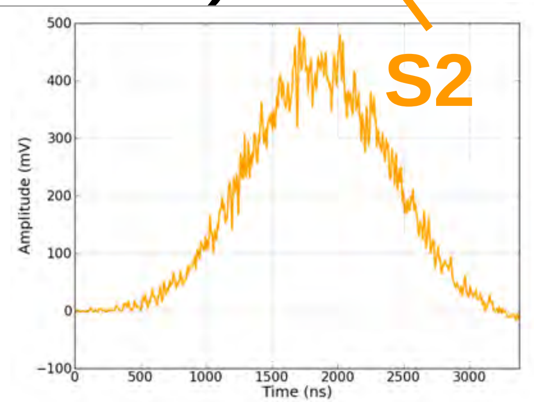



Rates Are High...

Single photo electrons dominate What is their source?



# Causes of High Rates

1) Field leakage

   S2s &

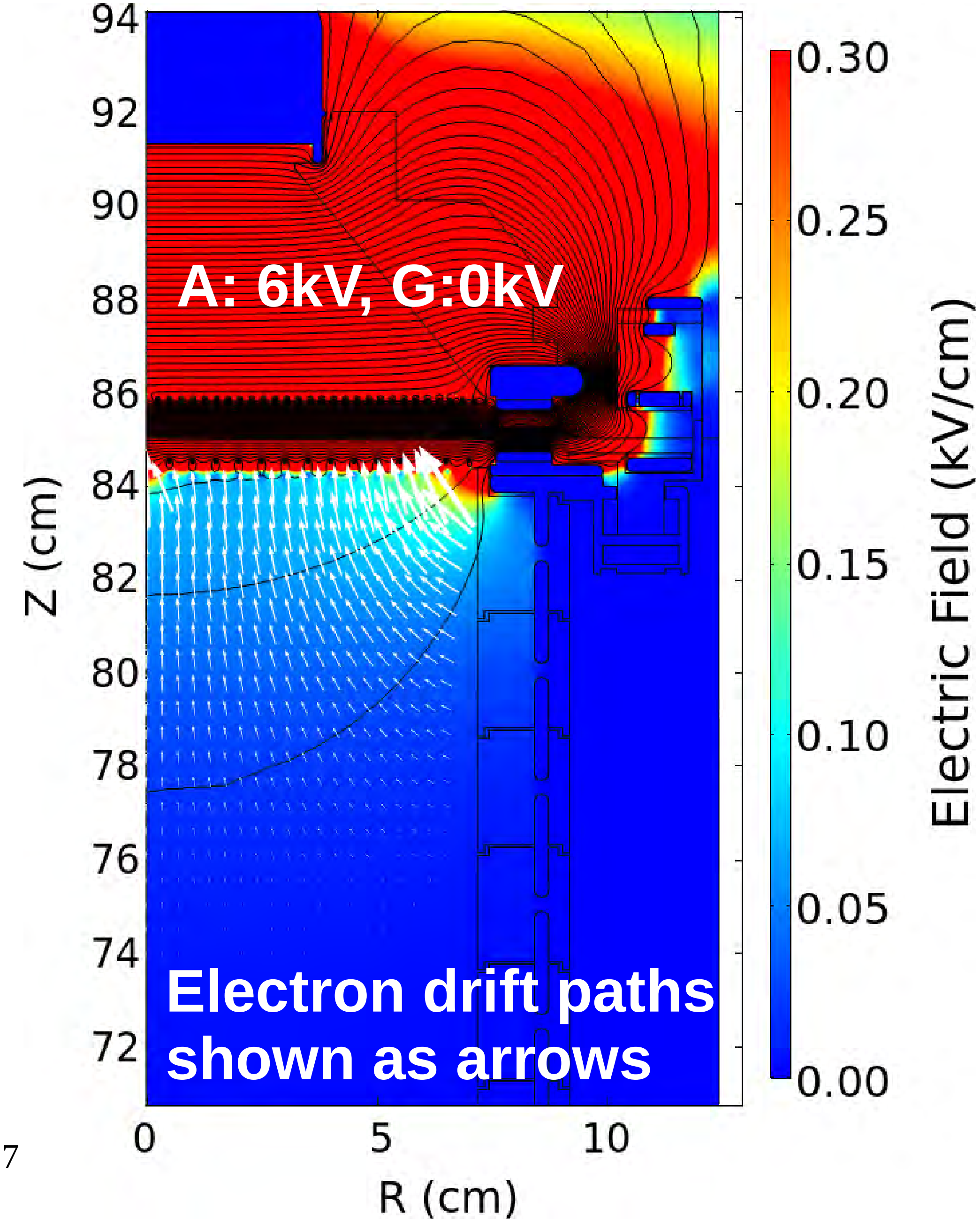
   splitting &

   low light collection

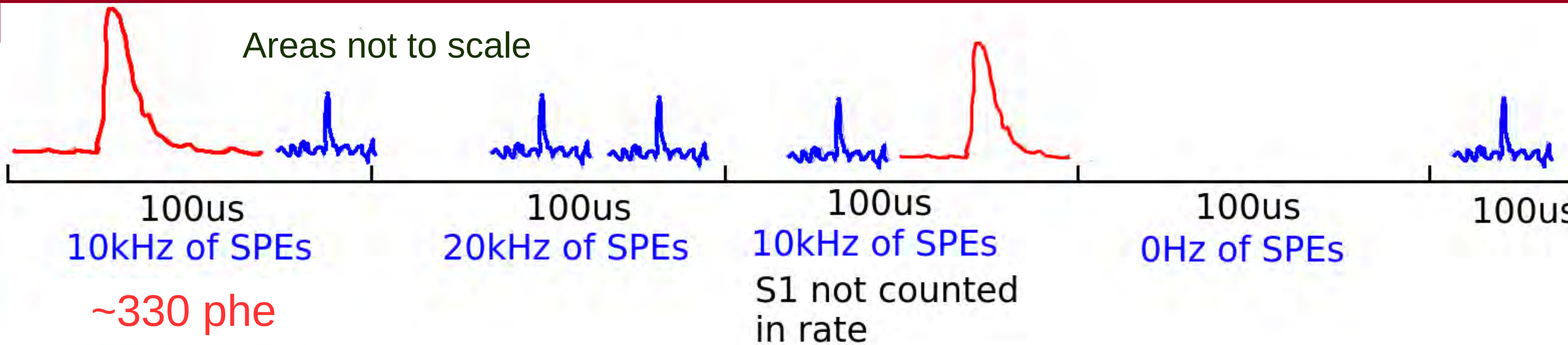
2) Photon production mechanism

   PTFE fluorescence?

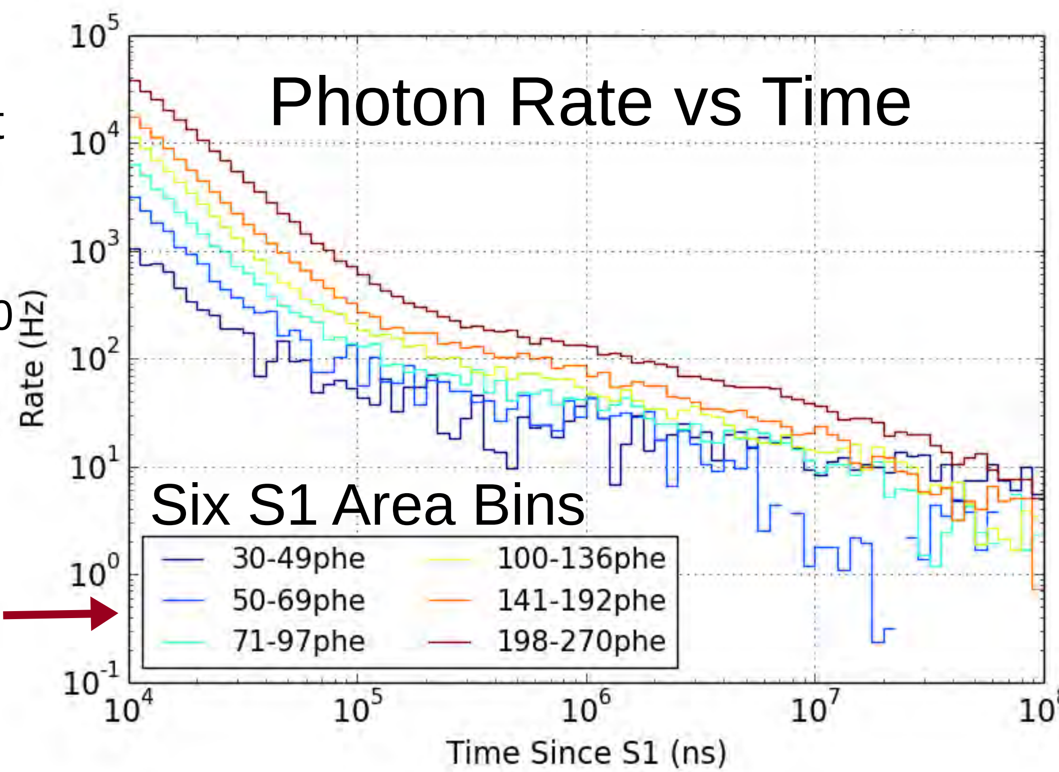
   Study correlations of photons to events → Do they cause the high rates?



# Photon Production: Measurement

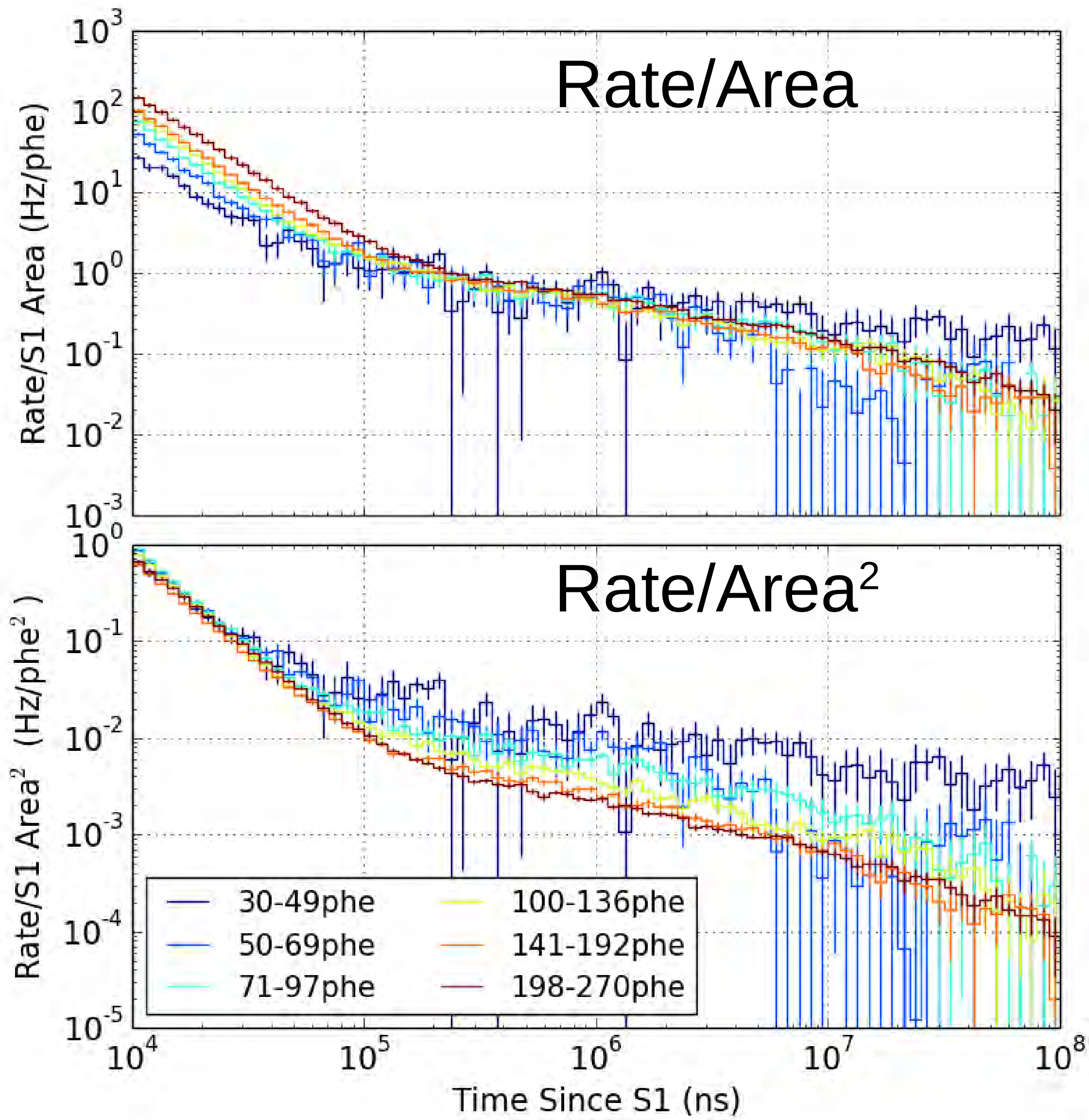



- Single photon rate high even with no fields
  - Could real events cause this?
- Measure the excess of SPE rate after event S1s (see cartoon above)
  - Take an S1 of a given area
  - Bin SPE counts in time to get the local rate (100 us bins shown above)
  - Get the SPE rate as a function of time since an S1
  - Average such rates in bins of S1 area
- Result: **photons correlated** with preceding large S1s
- What process causes these photons?



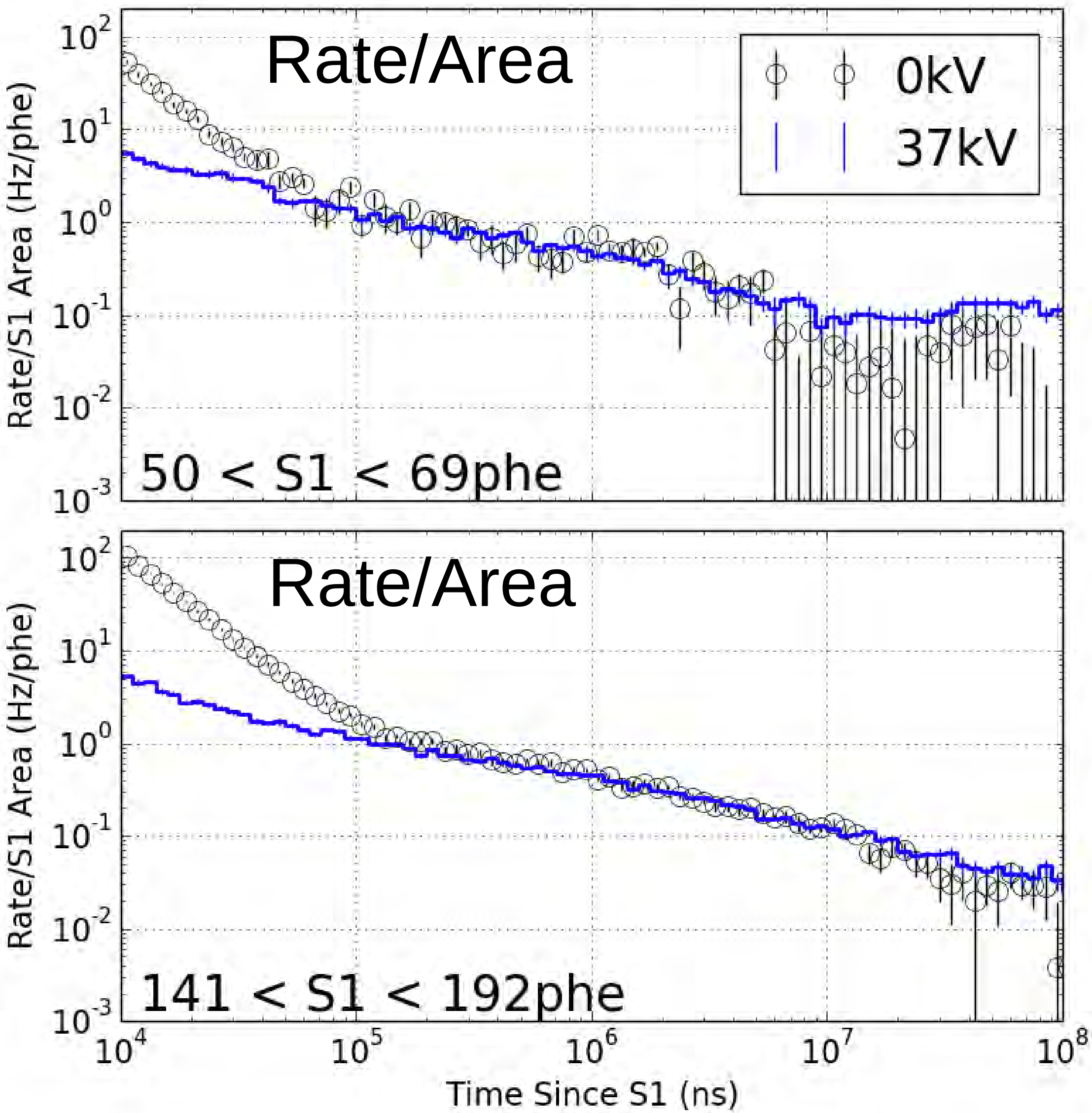
# Photon Production: How?

- Scaling with S1 size?
  - Rates divided by S1 area (top right)
    - Long term rates → production, fluorescence?
  - Rates divided by S1 area$^2$ (bottom right)
    - Short term rates →delayed recombination
- Recombination? Turn on drift field...



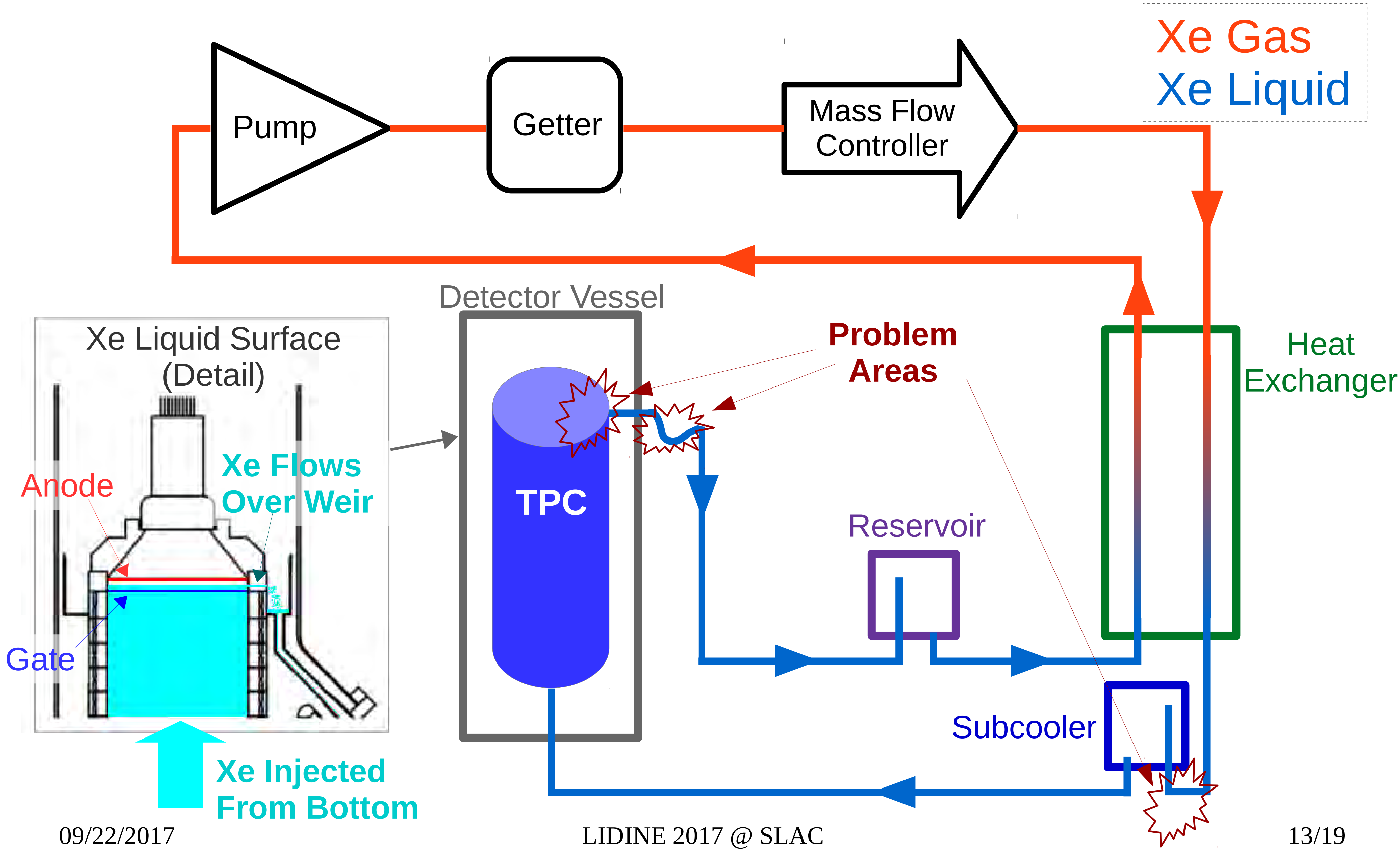
# Photon Production vs Drift Field

- Rate/Area for two S1 area bins (top vs bottom) with (blue) and without (black) drift field
  - Drift field reduces short term rates
    - consistent with delayed recombination
  - Long term rates not affected by drift field

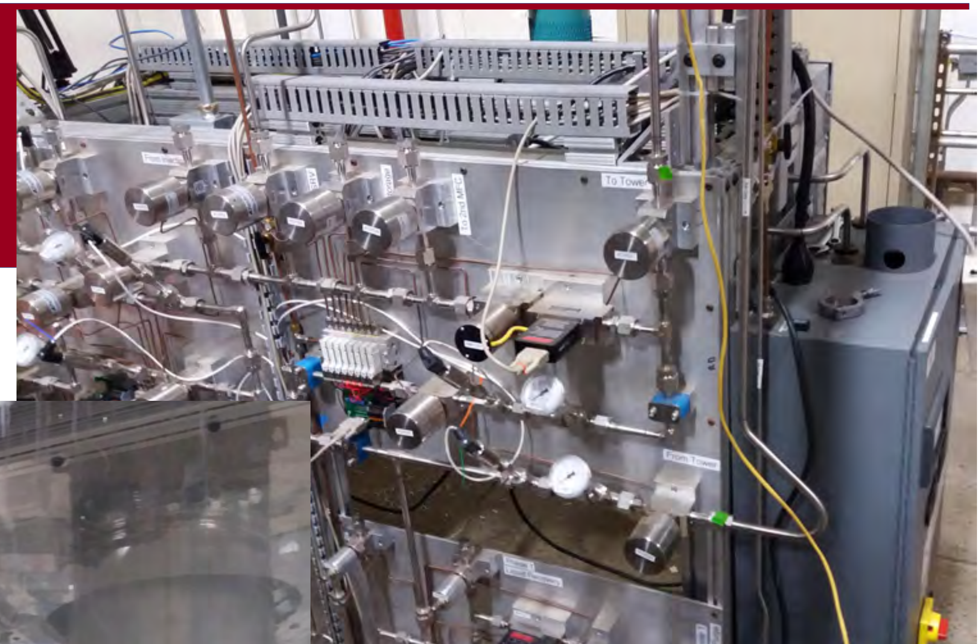


## Study of Circulation:
## Xe Purification and Stable Liquid Surface

# Circulation: Simplified Diagram



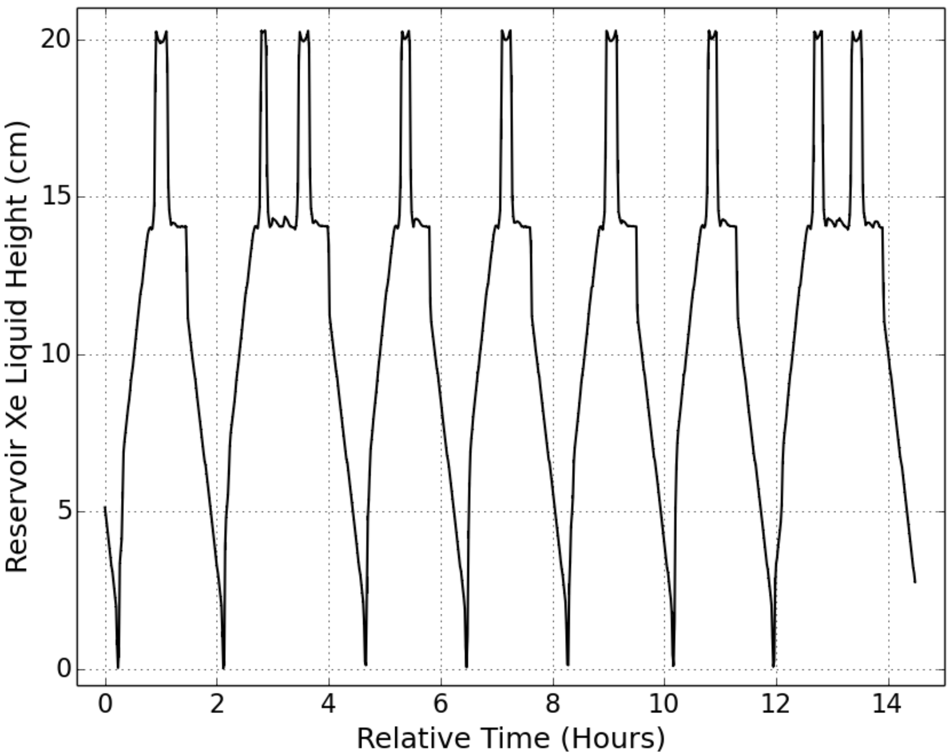

120 VOLTS

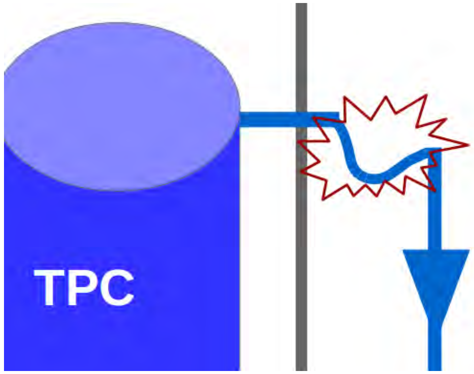


# Circulation: Smooth Flow Problems

- First run did not achieve stable circulation
  - About 19kg of Xe would collect and drain in cycles (see right plot)
- Gas trap in drain line
  - Thermal load generates gas
- Implemented solution:
  - Bypass line drains gas
  - Sub-cool the exiting liquid Xe

Liquid Xe Level Oscillations in the Reservoir Volume



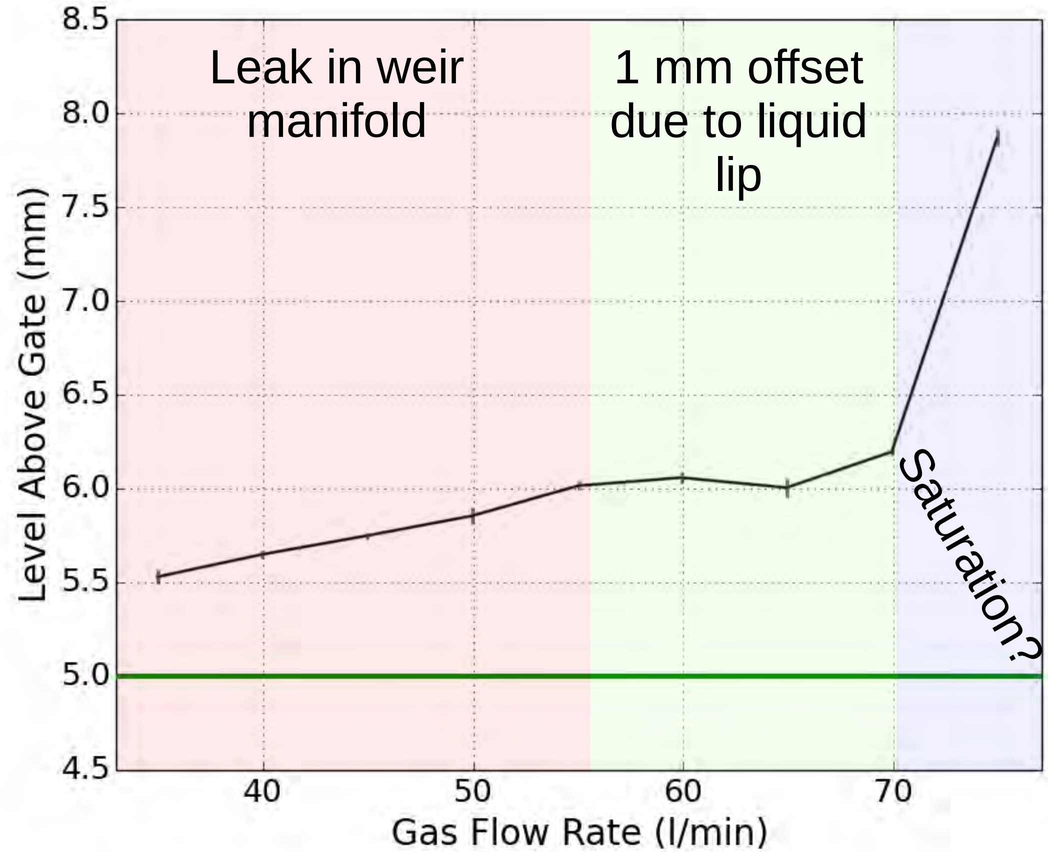



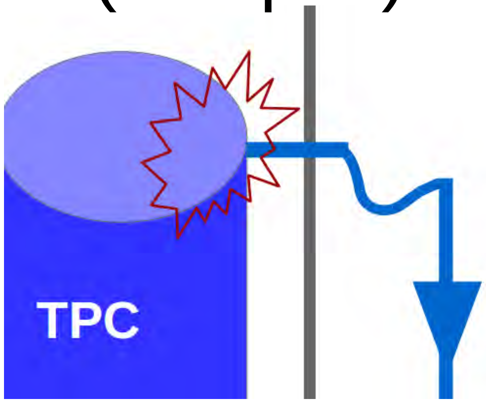

**Lessons learned** for LZ:

- Avoid trapped spaces in drain line
- Add cooling to drain line – it is much longer in LZ

# Liquid Level Height in the Electroluminescence Region

- Liquid level maintained by spill over the weir
  - How large to handle 500SLPM?
  - Too large → instability in liquid surface
- Weir & weir manifold tested in phase 1 appear to have been insufficient (see plot)




**Lessons will be learned** for LZ:

- New weir design and weir manifold (with no leak) being tested now

# Ancillary LZ Tests

- In addition to main system test goals...
- Technology and parts developed for LZ by collaborators from many institutions and integrated into phase 1
  - PTFE parts, field rings, and resistor assembly
  - Getter/purification
  - Circulation pump (compressor) and gas handling
  - PMT HV and signal cabling, connections
  - level sensors
  - position sensors
  - acoustic sensors
  - loop antennas
  - Slow control and PLC

# Ongoing and Near Term Work

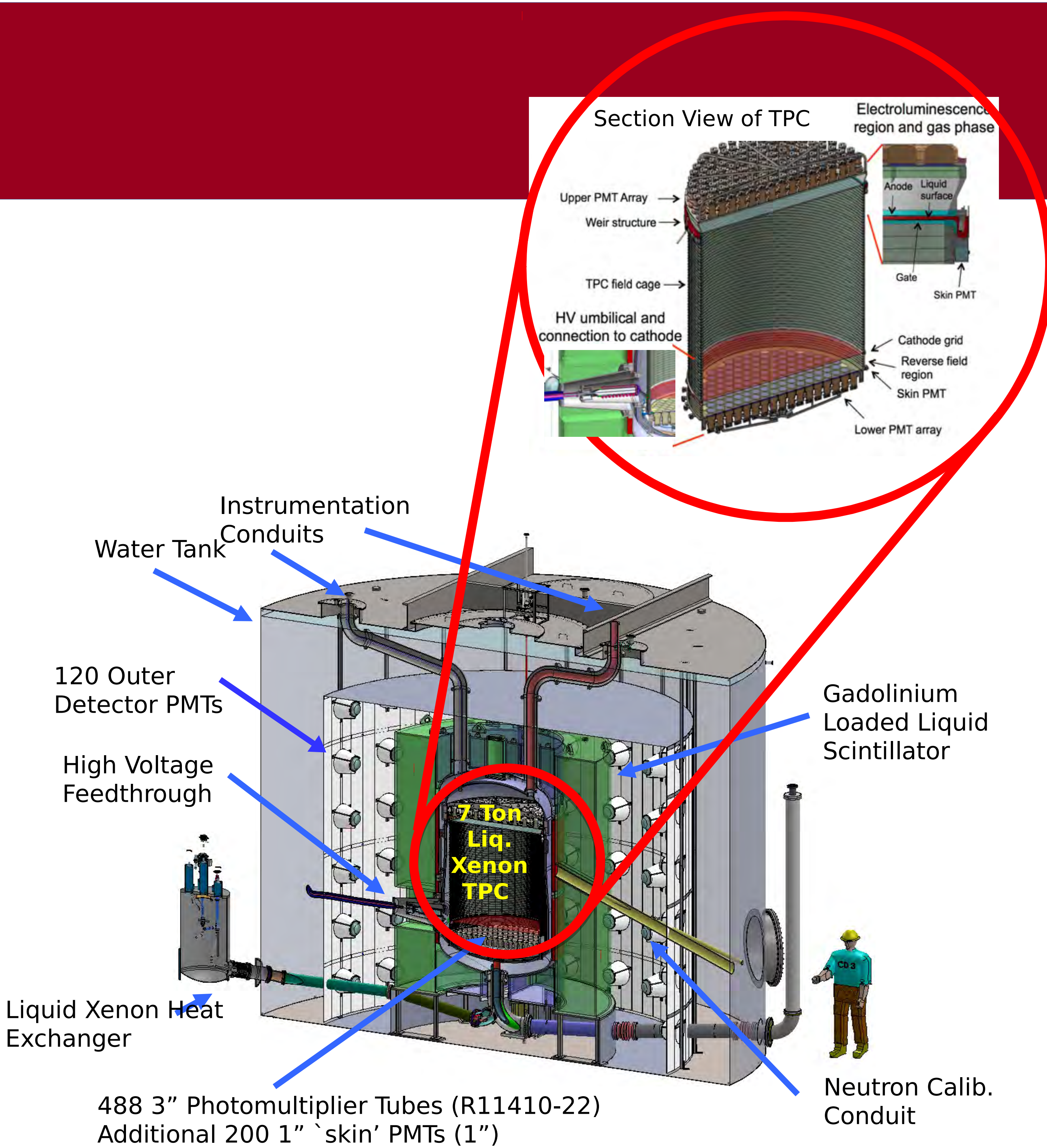
- Phase 1: Run 7 begins shortly
  - Testing solutions to circulation problems
  - New, LZ-like extraction region
  - PMT array increases light collection efficiency and allows for position reconstruction
  - Control of field leakage by biasing cathode positive
  - Ancillary tests mentioned before
- Small scale gas test
  - Correlation with liquid behavior and more (see talk by Wei Ji)
- Phase 2 under construction now
  - Test of production LZ grids

Thank You

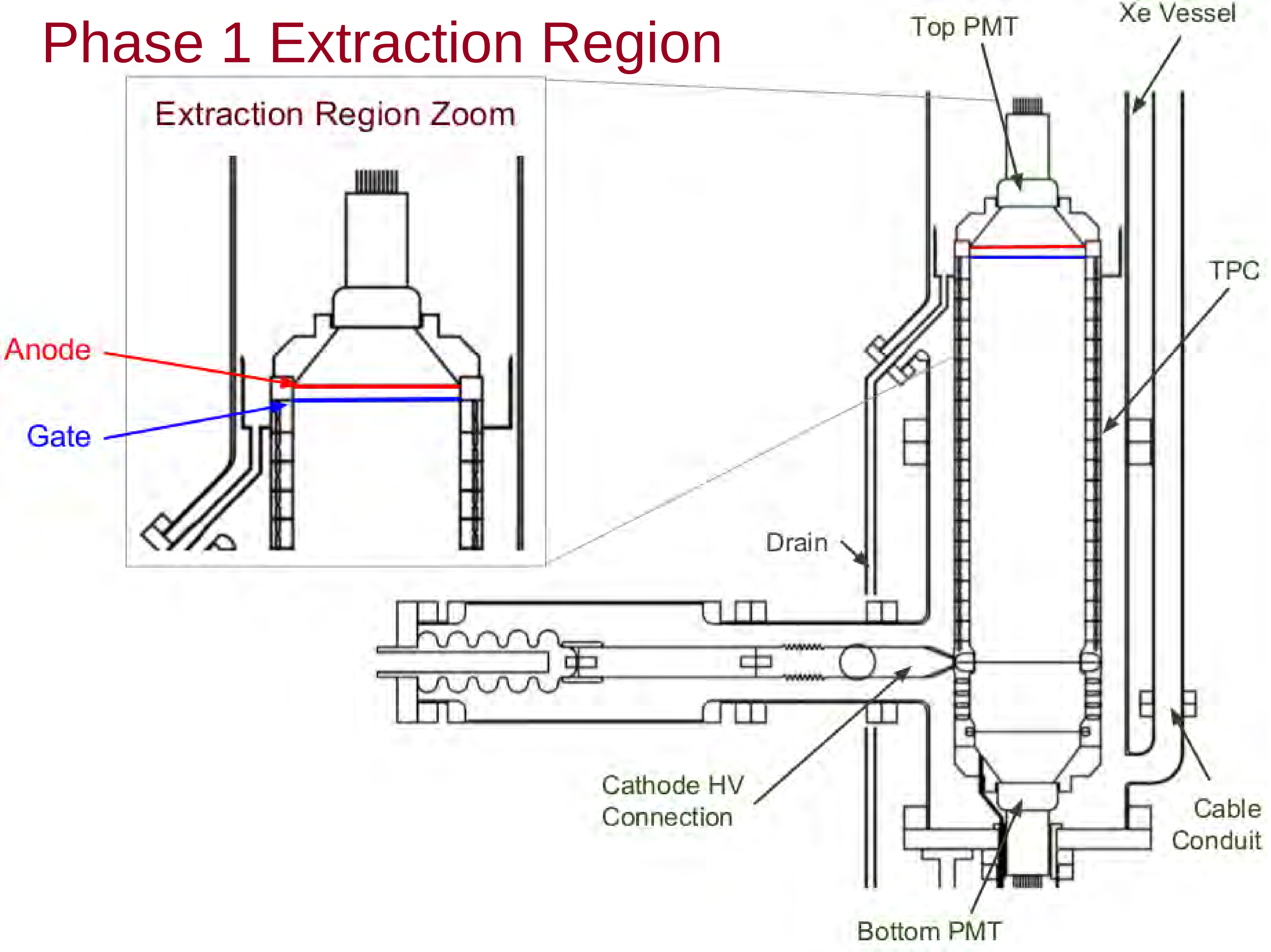
And please come see us during the tours

Backup

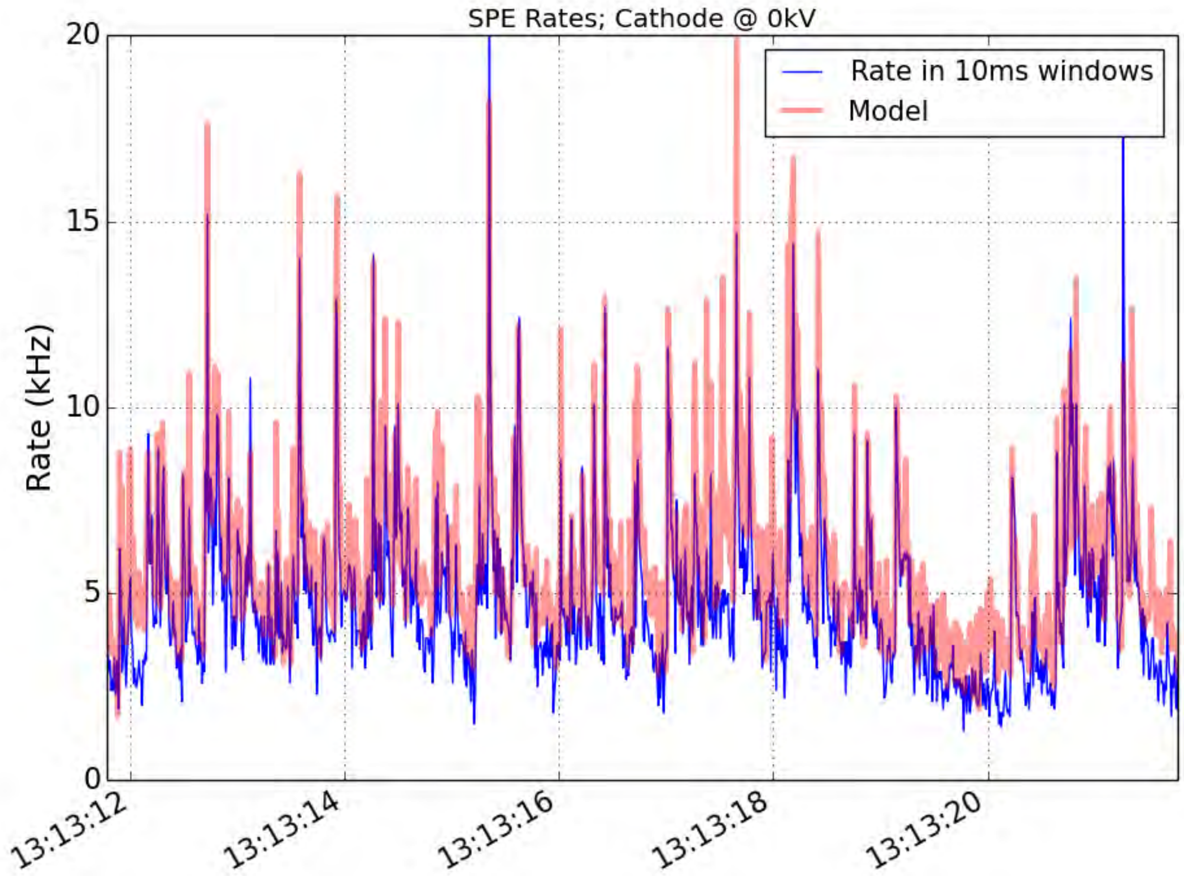
# LZ


Section View of TPC
Electroluminescence region and gas phase
Upper PMT Array
Weir structure
TPC field cage
HV umbilical and connection to cathode
Anode
Liquid surface
Gate
Skin PMT
Cathode grid
Reverse field region
Skin PMT
Lower PMT array
Instrumentation Conduits
Water Tank
120 Outer Detector PMTs
High Voltage Feedthrough
Liquid Xenon Heat Exchanger
7 Ton Liq. Xenon TPC
Gadolinium Loaded Liquid Scintillator
Neutron Calib. Conduit
488 3” Photomultiplier Tubes (R11410-22)
Additional 200 1” `skin’ PMTs (1”)

# Phase 1 Extraction Region

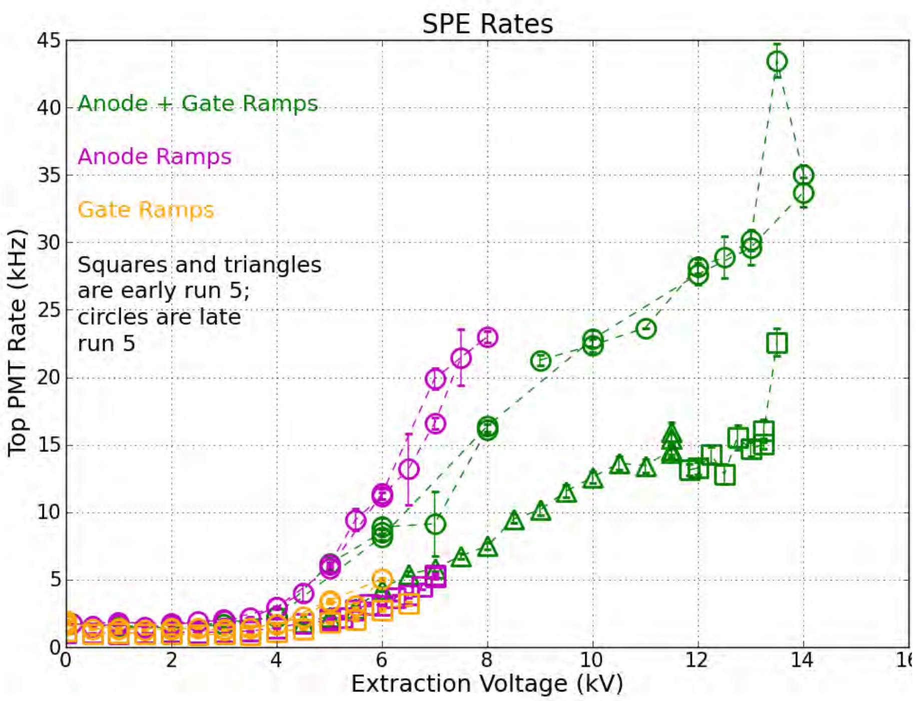


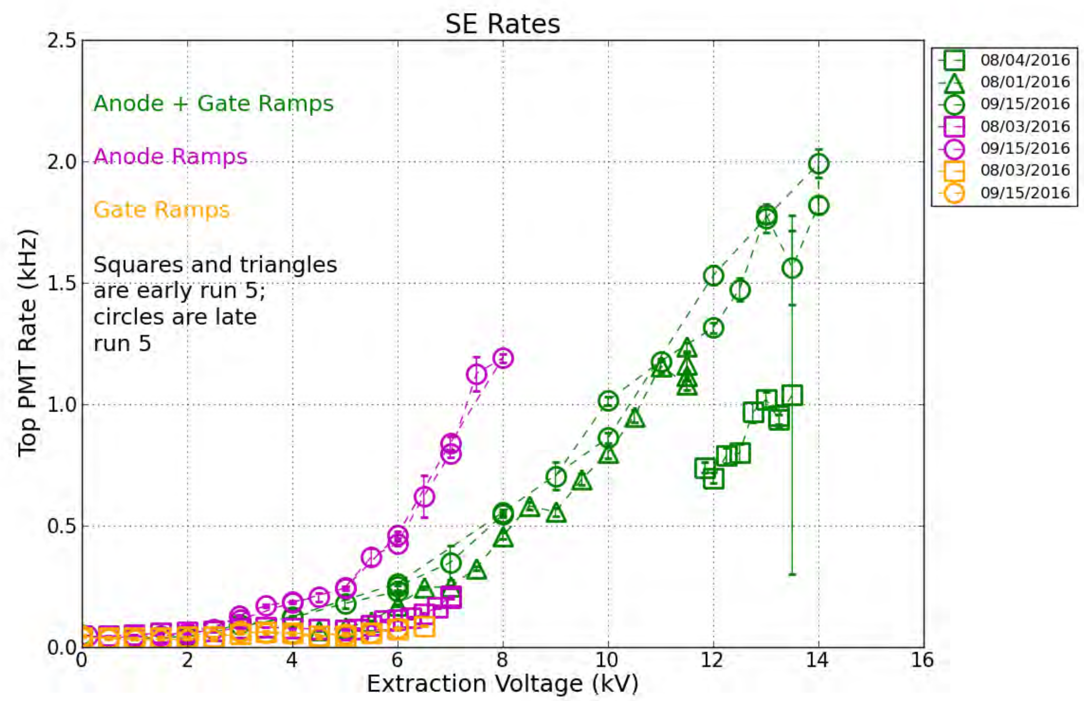
# Long Term Photon Production




- Plot modeling the rates
  - Computed average photon rate as a function of time since and area of S1s
  - Applied model to a data set (blue histogram shows photon rate) to obtain the prediction of photon rate (red histogram)

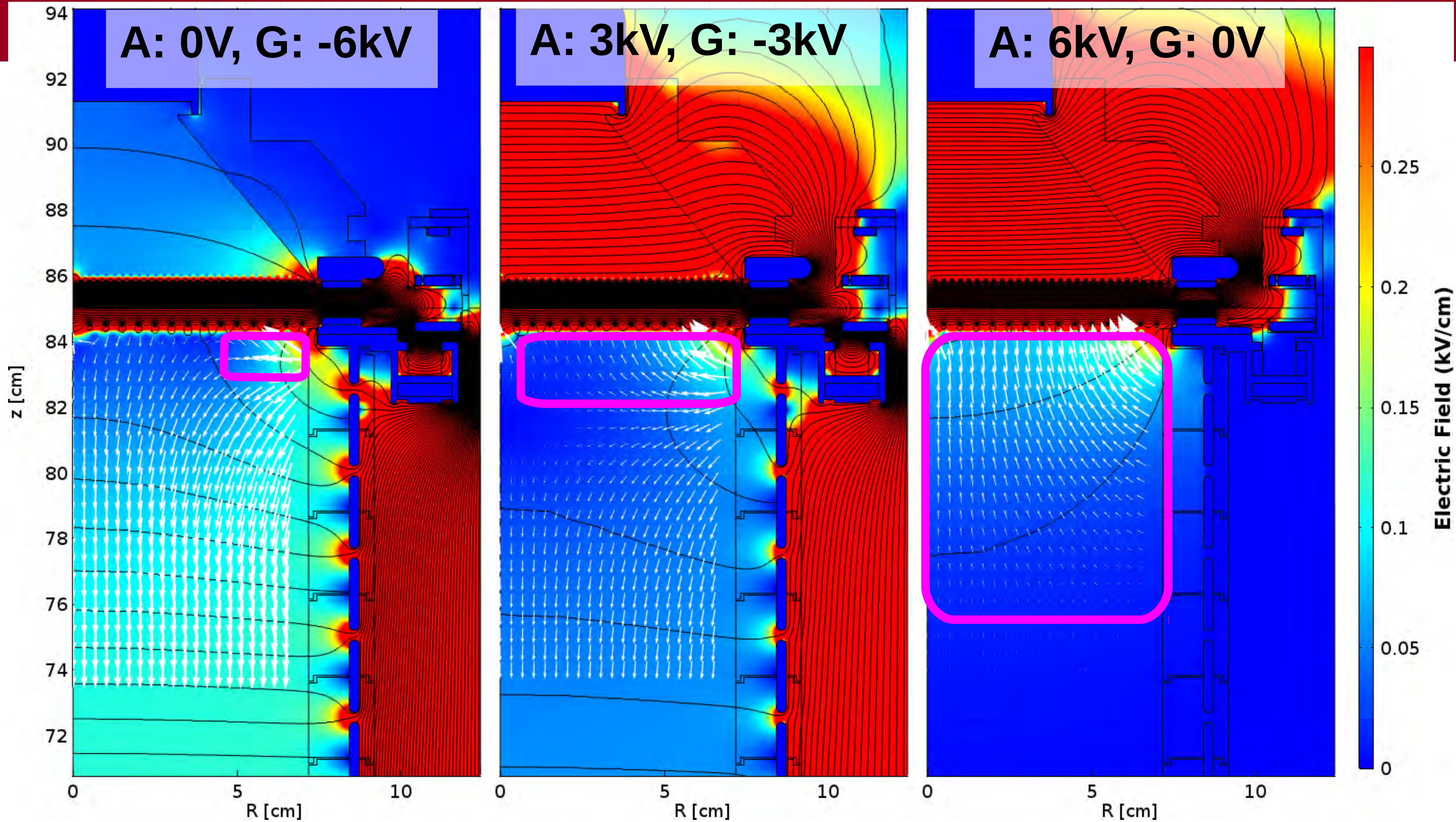
# Rate Dependence On Voltage and Ramp Type




- Emission depends on grid type
  - anode > anode+gate > gate
- Rate (anode especially) probably affected by purity in the bulk Xe (see next slide)

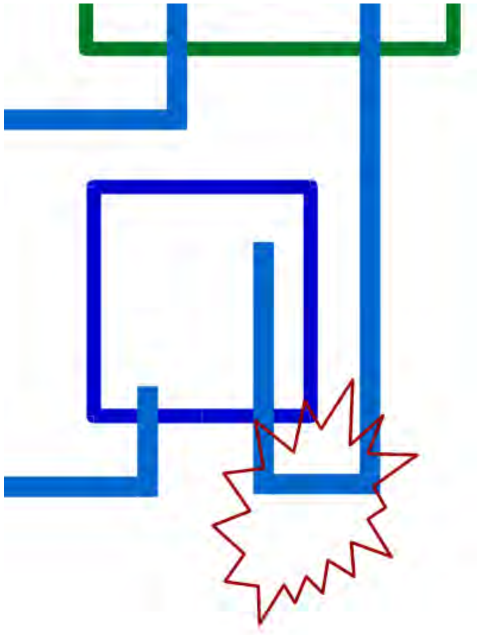
# Differences Between Grids



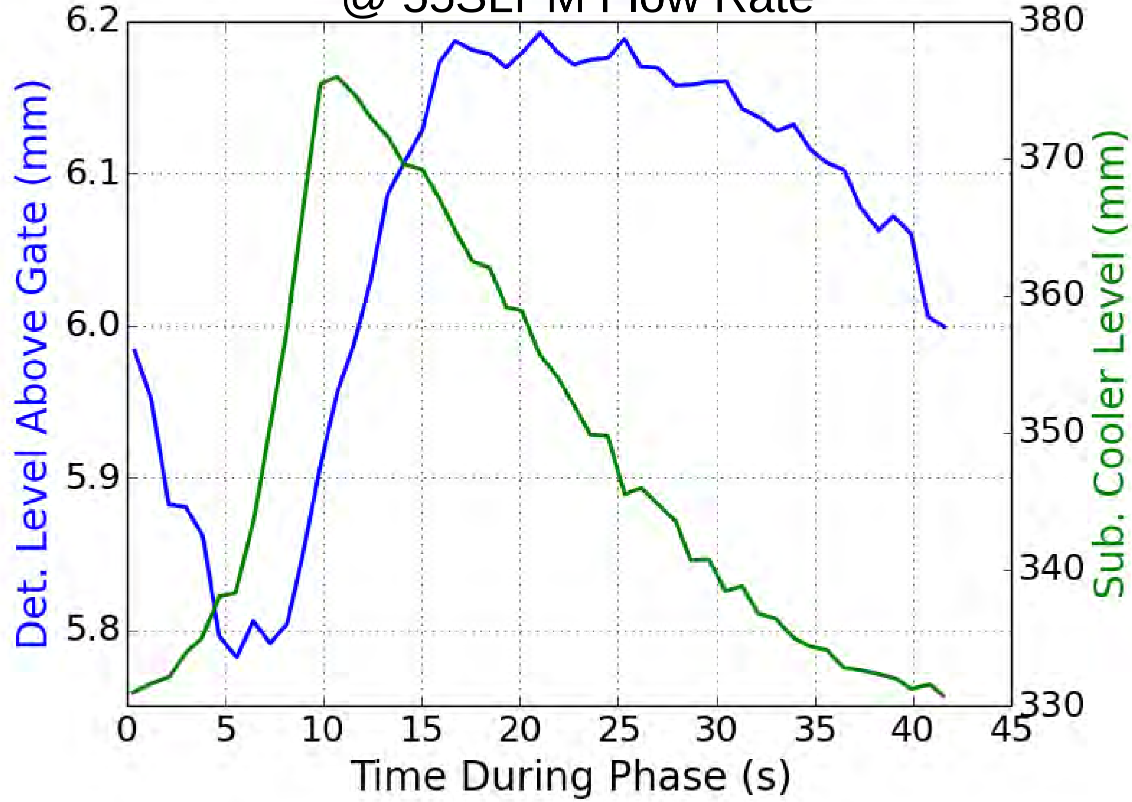

- Field leakage when extraction field is achieved biasing different grids
- Lower purity will reduce active volume

# Liquid Level Oscillations

- Stable flow over the weir → oscillations in the detector liquid level
  - Also in other liquid levels, pressures and temperatures
  - Flow into the detector slows down/stops and resumes
  - 0.4 mm peak to peak in detector level → 5% of electroluminescence distance, ~60g of Xe
- Suspected liquid trap in the heat exchanger – subcooler line



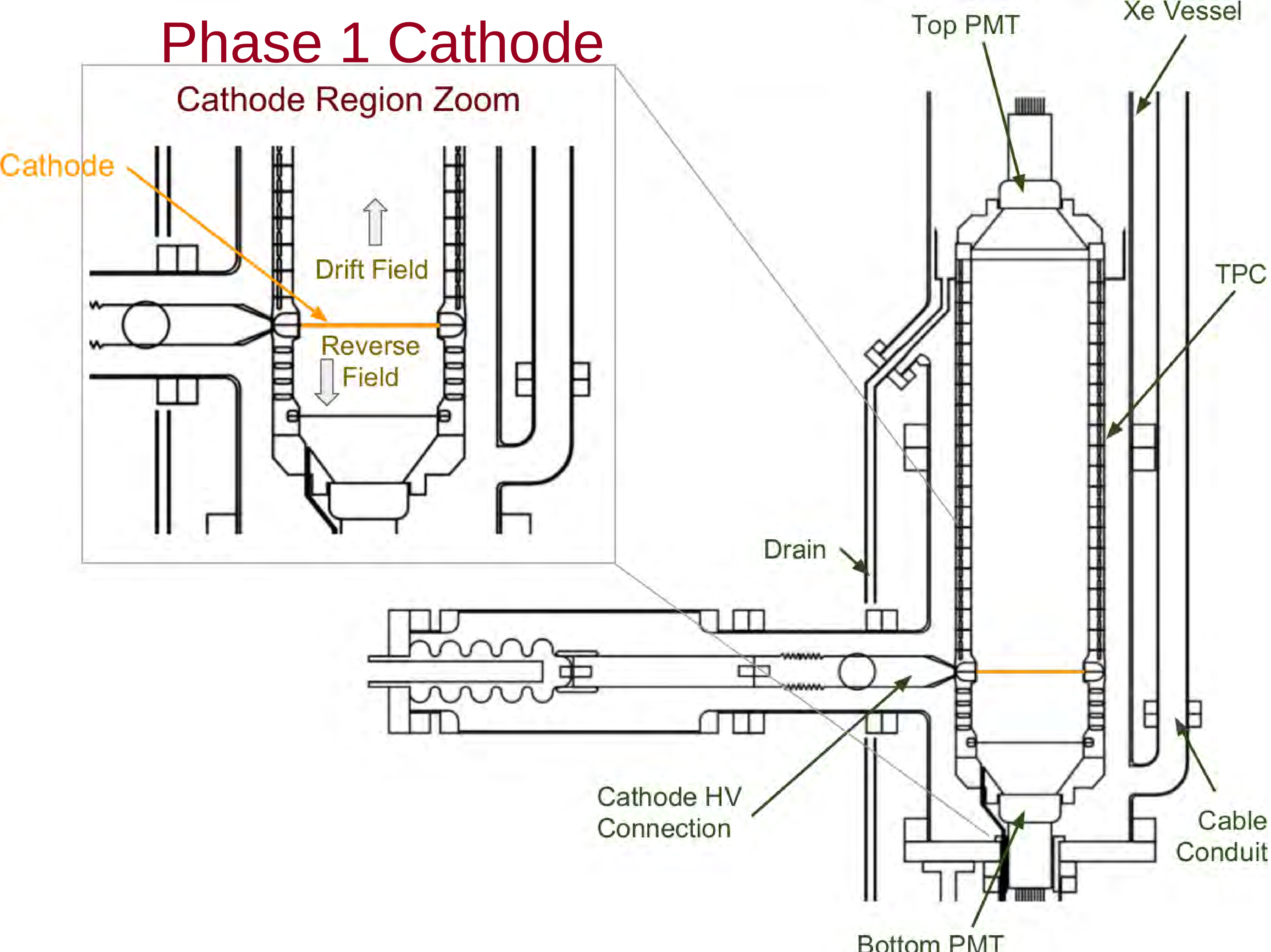
Oscillations In the Detector and Subcooler Levels @ 55SLPM Flow Rate



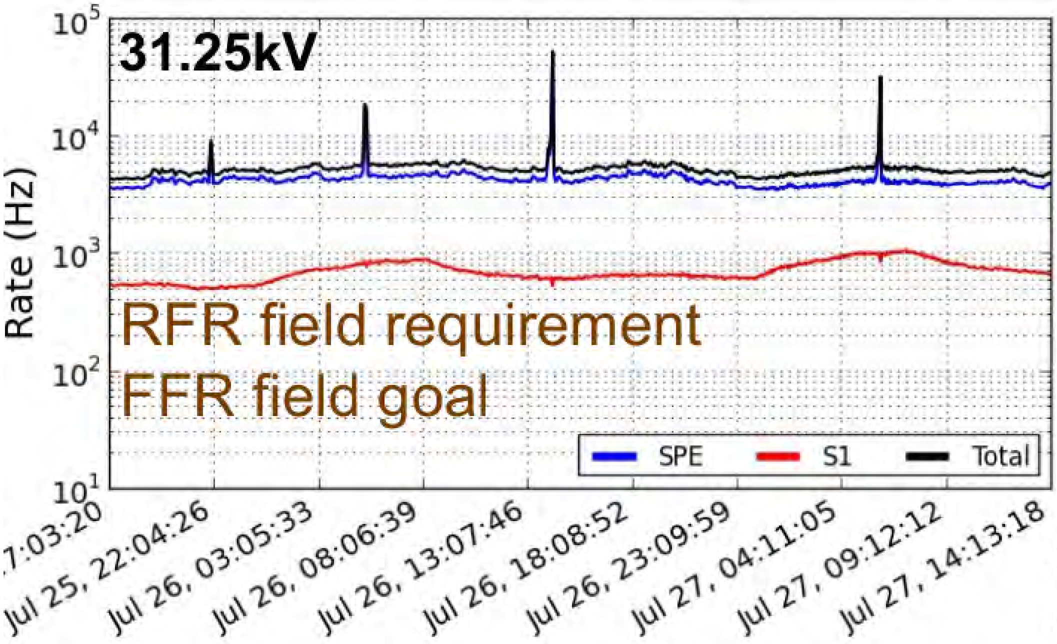

**Lessons being learned** for LZ:

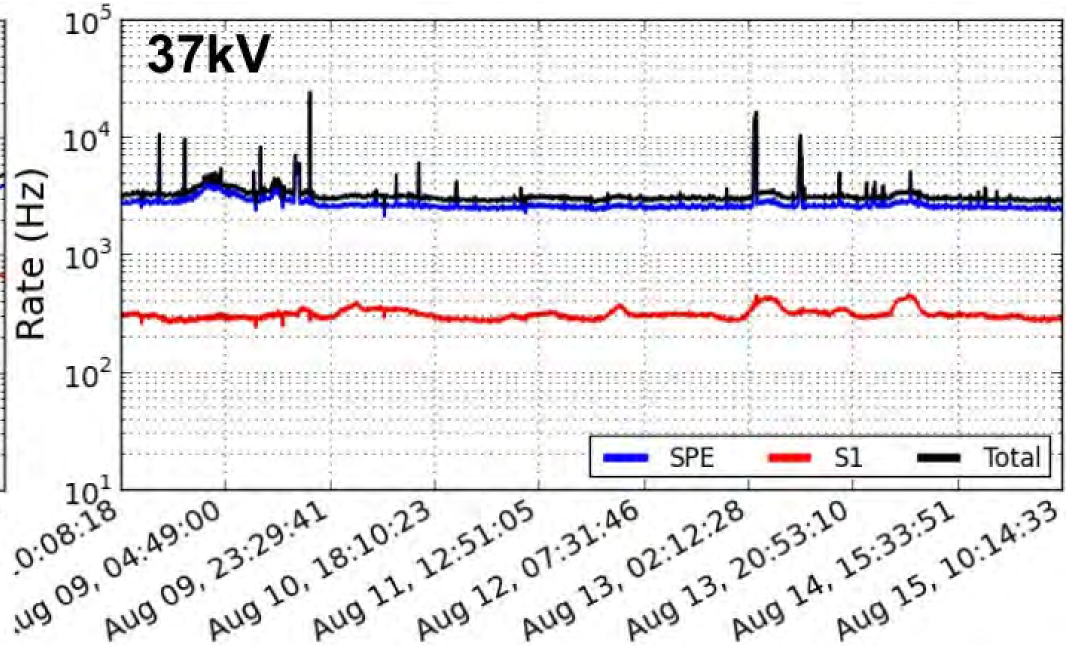
- Stack heat exchanger and subcooler vertically (to avoid trapped spaces)
  - liquid inlet into subcooler at the top
- Testing gas bypass and active subcooler pressure feedback

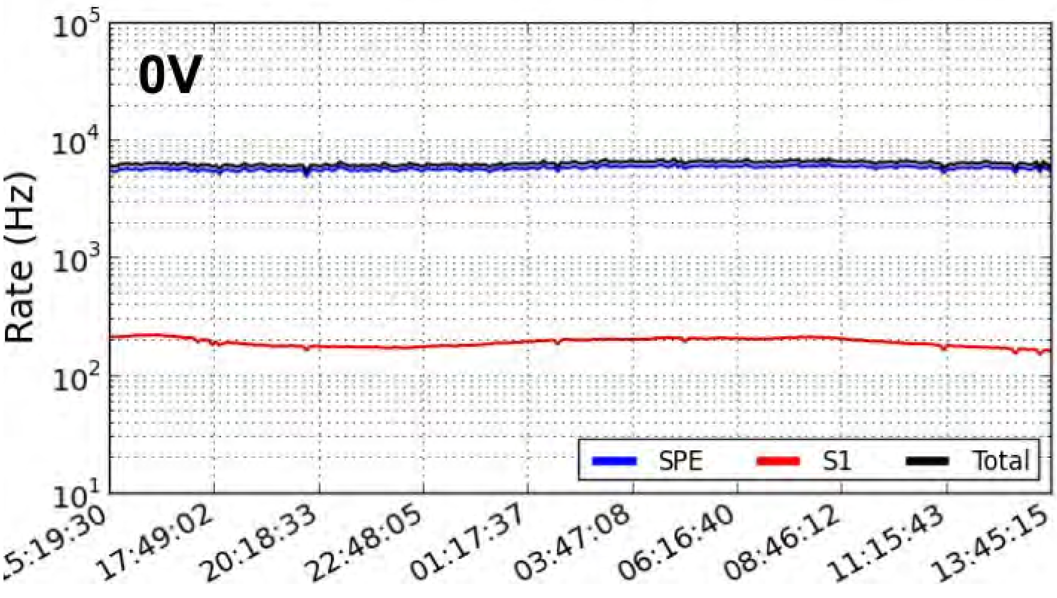
# Phase 1 Cathode



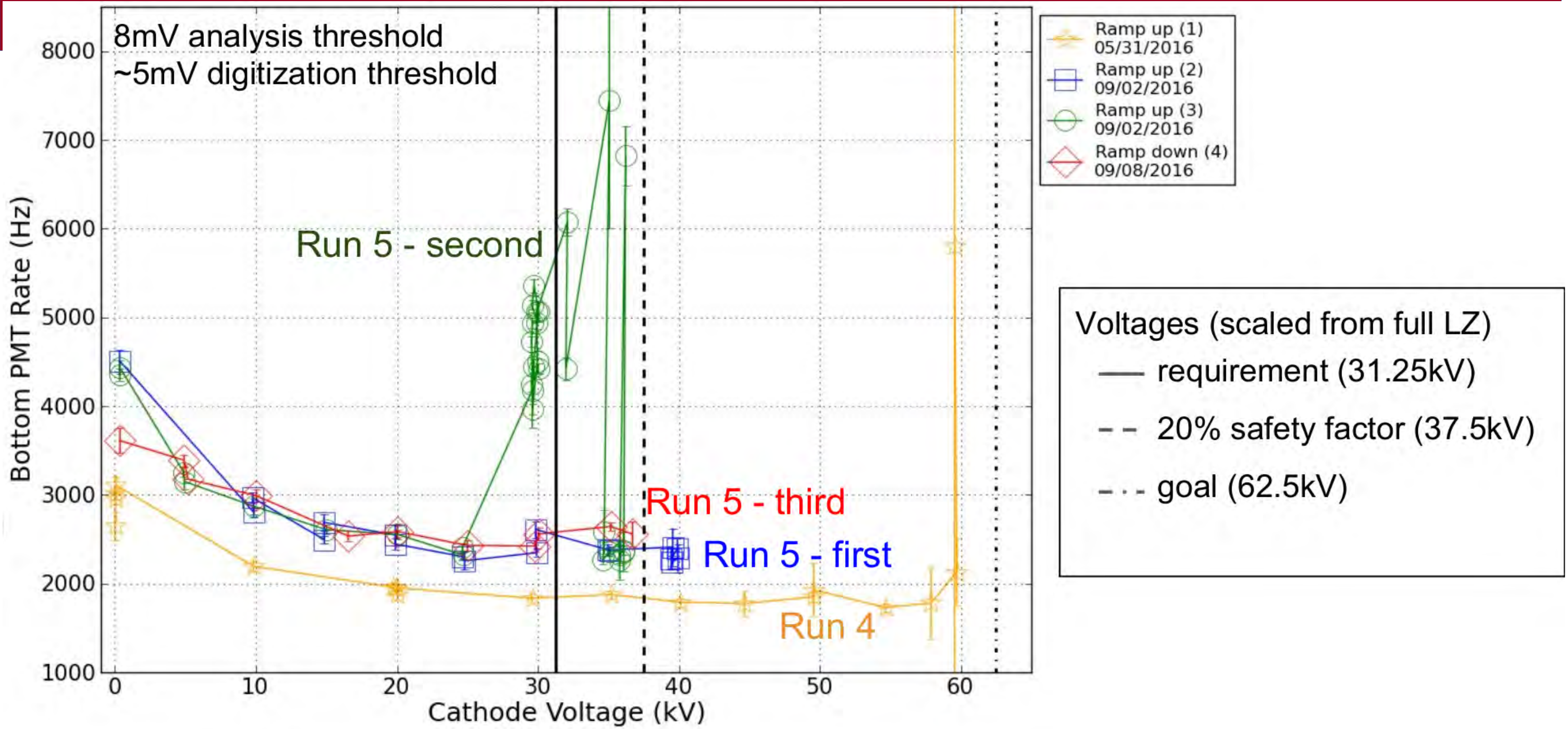
# Cathode Long Term Stability



# Cathode Ramp Reproducibility




- Late run 5 ramp up (green circles) shows light production at lower voltage than previous ramps
  - Rate fell and stabilized prior to the long run (ramp down shown as red diamonds with no light production)
- The rate during a run 4 ramp up (orange stars) showed light production at 60kV. Following ramps on the same day showed light production at lower voltages