System Test Extraction Region Results

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LZ Collaboration Meeting
SLAC
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Purpose

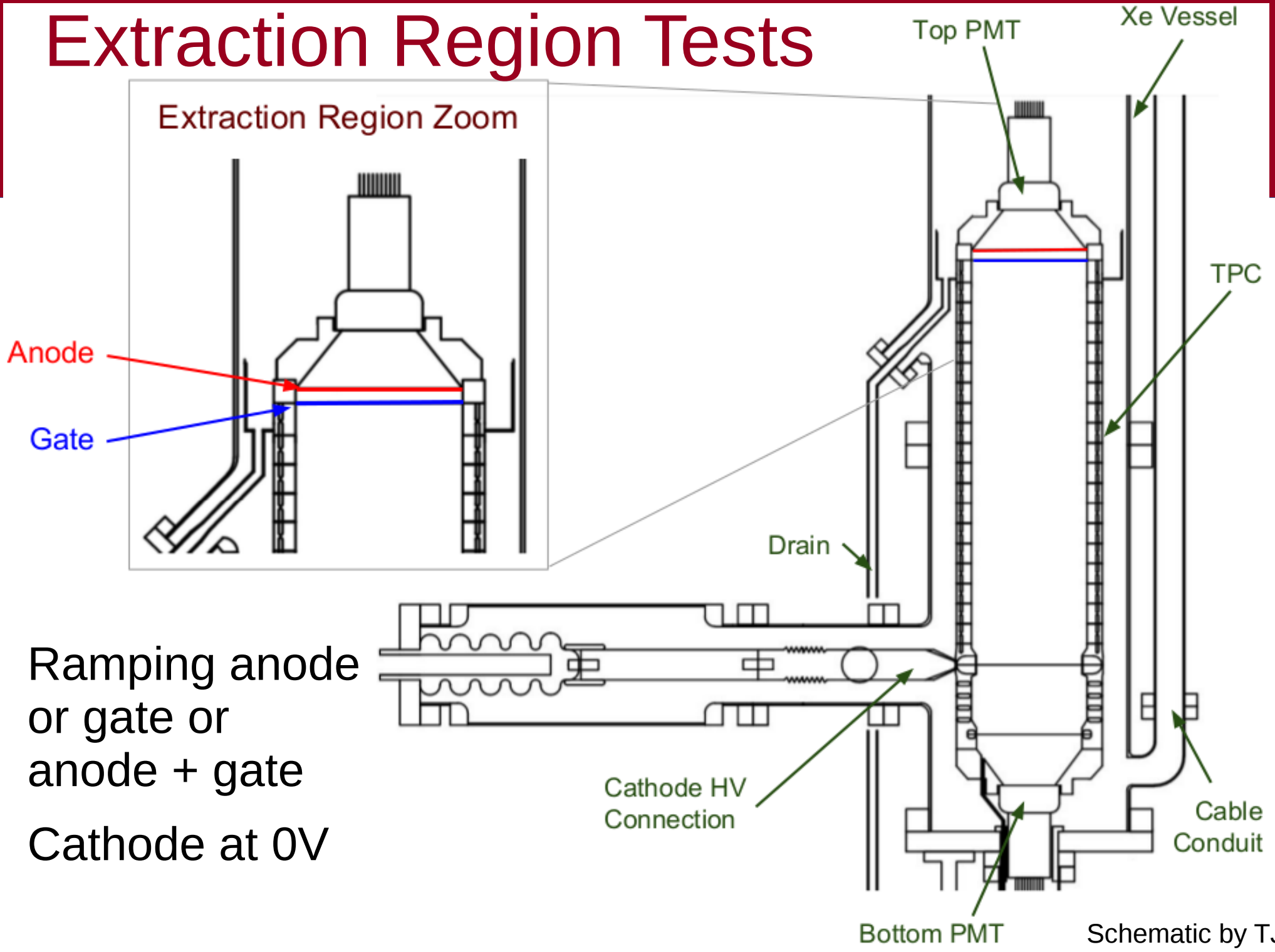
- Verify that the LZ extraction region design does not lead to excess photon or electron emission
  - Electron emission and photon emission from HV elements would increase false S1-S2 coincidence rate

    → Reduces the experiments sensitivity to low mass WIMPs
  - Translate our results into LZ expectations

Summary

- S1s: about 600Hz (double counting some S1s)
  - Expected ~3kHz → self shielding?
    - Ongoing simulation work
- S2s: about 100Hz
  - Expected ~30Hz from the liquid above the gate
- High rates
  - SPEs: up to ~100kHz
    - scales with extraction region voltage/which grid is biased
  - SE (-like) – actually multi-photon PODs: about 1kHz
    - Similar to SPEs - same population?
- Active Xe volume of order 1kg with cathode at 0V
  - low electron drift velocities – source of high rates?
- High rate during some liquid level oscillation

Extraction Region Tests

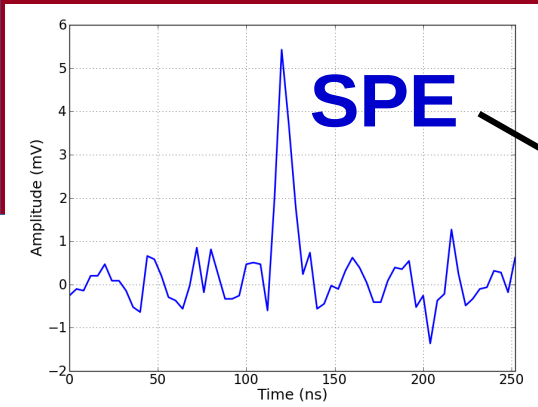


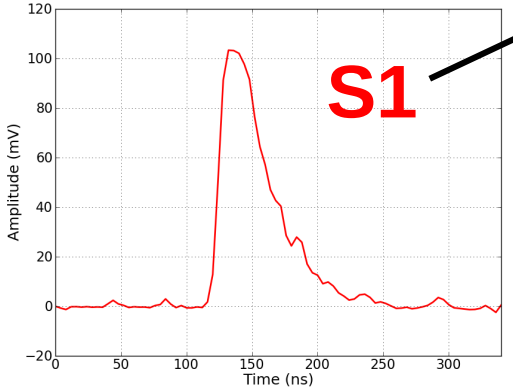
Ramping anode
or gate or
anode + gate

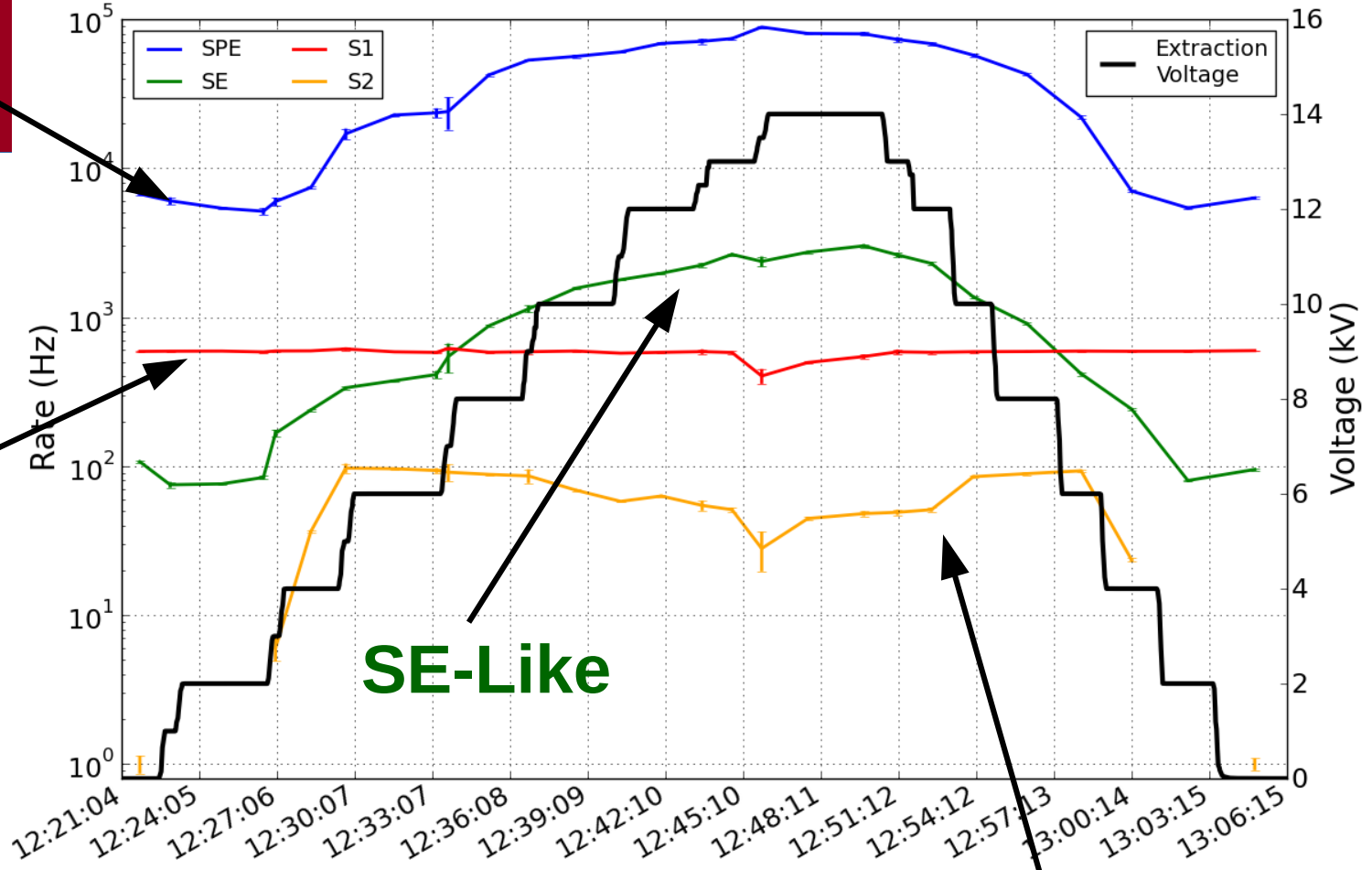
Cathode at 0V

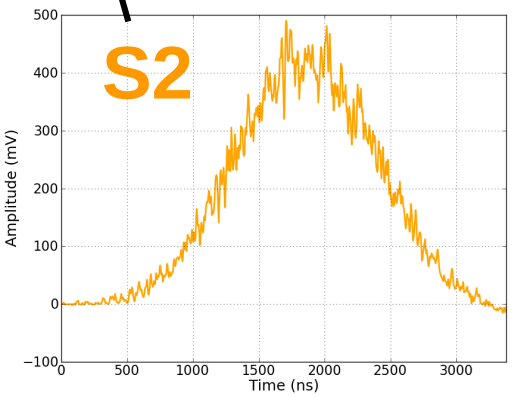
Schematic by TJ

Run 5: Pulses Seen



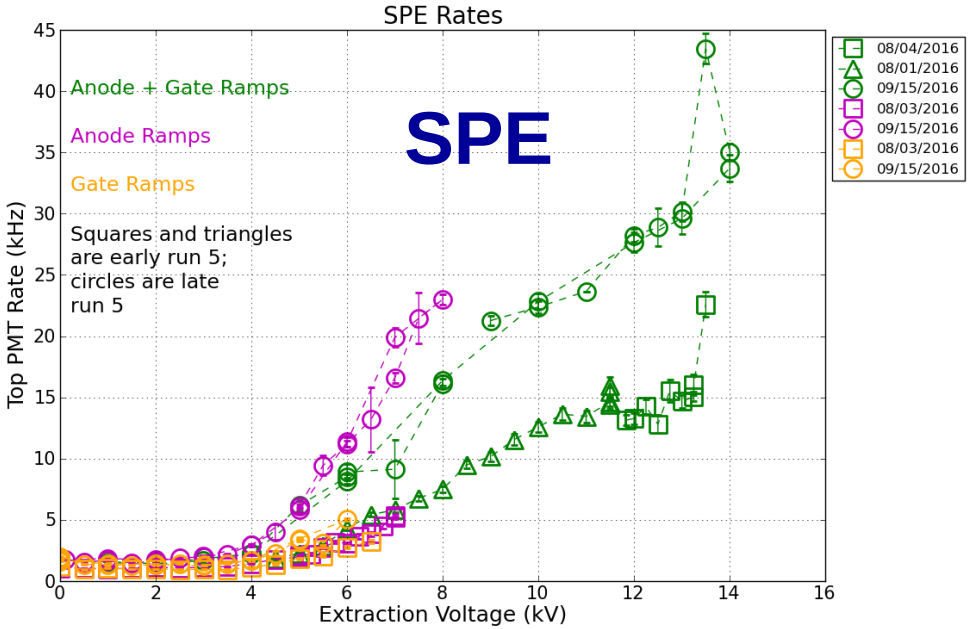


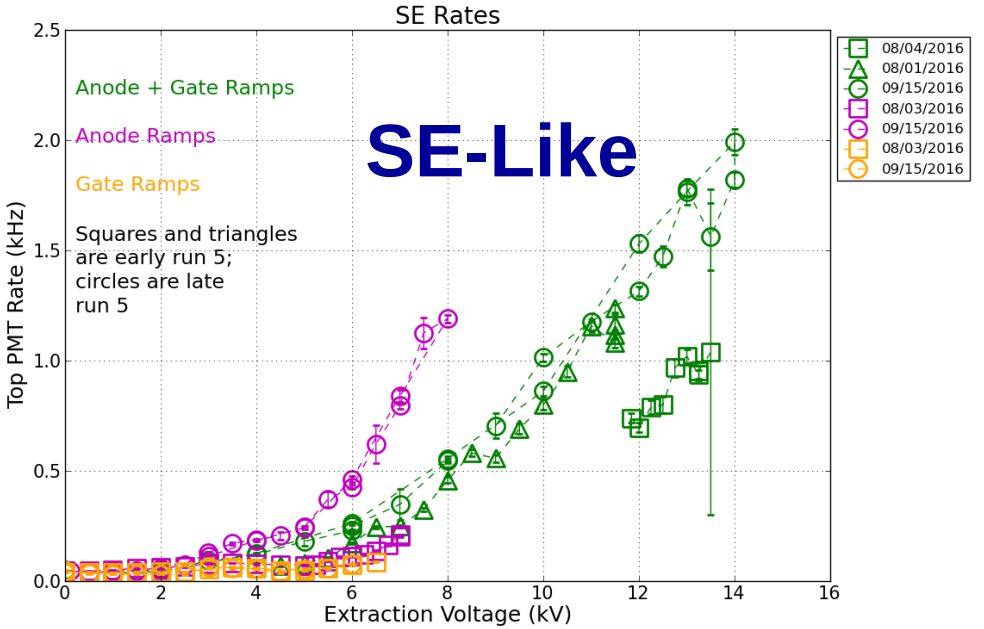




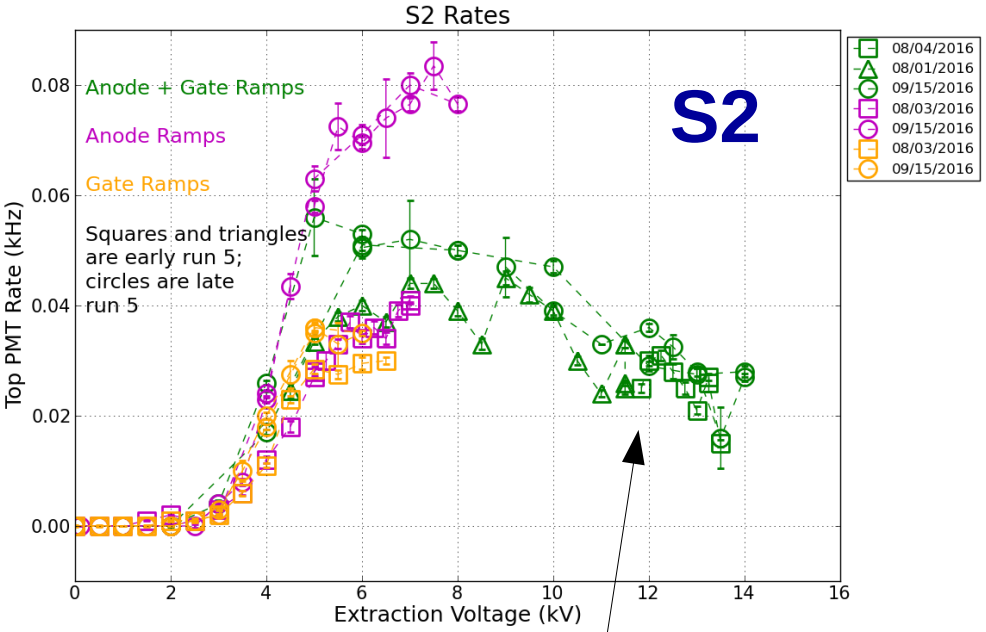
- Typical run 5 ramp
  - Anode to 8kV and gate to 6kV

Rates Vs. Voltage



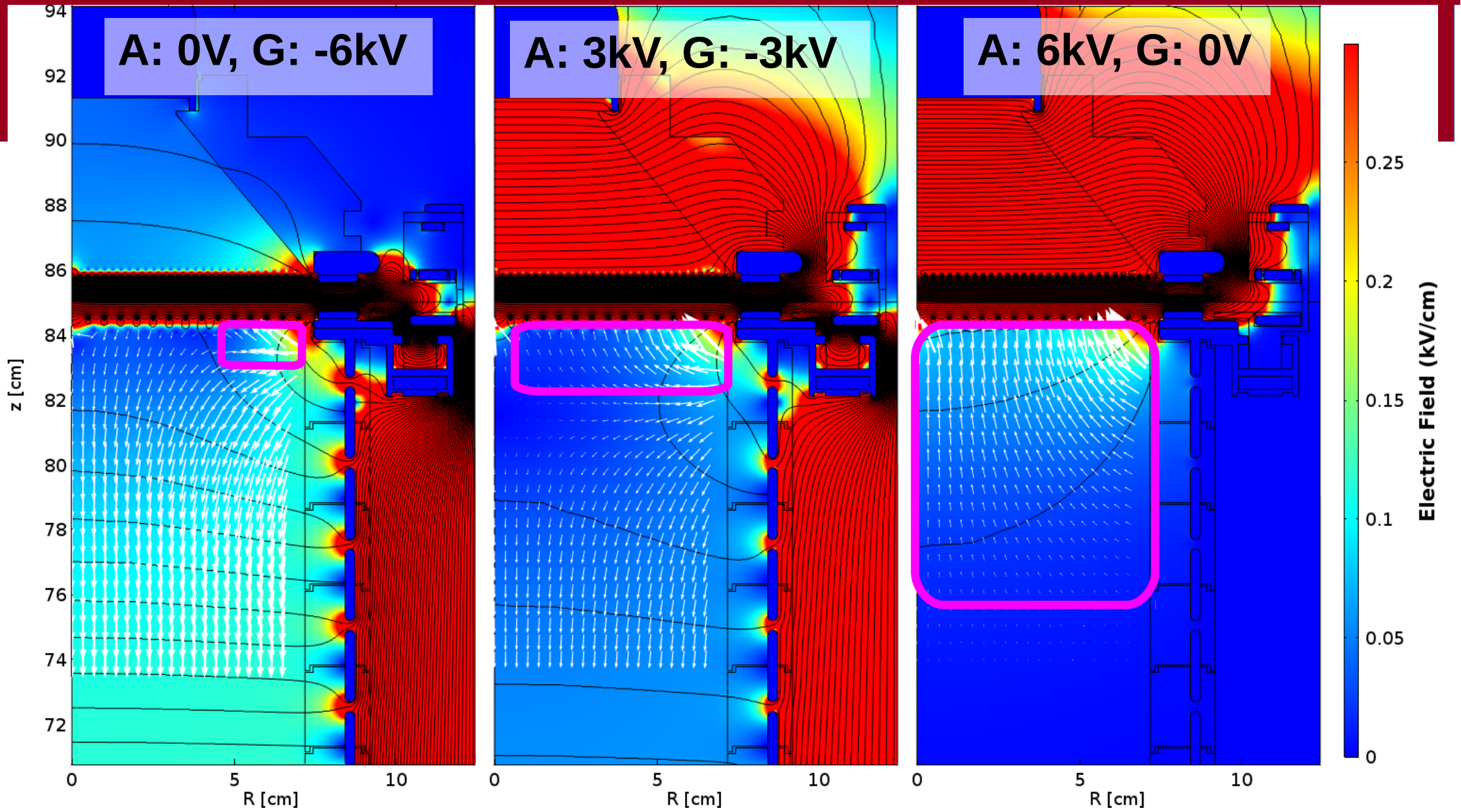


- Emission depends on grid type
  - anode > anode+gate > gate
  - not an empirically expected runaway emission
- Rate (anode especially) probably affected by purity



Rate falls due to digitizer saturation

Why Differences Between Grids?



E-field by Alden

- Field leakage into the FFR significant
  - Active area in pink

Fields And Purity

Anode: 6kV, Gate: 0V, Rate in kHz

	Run 5 (early)	Run 5 (late)	Run 6
SPE (-BG)	5.0	22.7	38.9
SE (-BG)	0.12	0.61	0.92
S1	0.66	0.6	0.65
S2	0.072	0.125	0.15

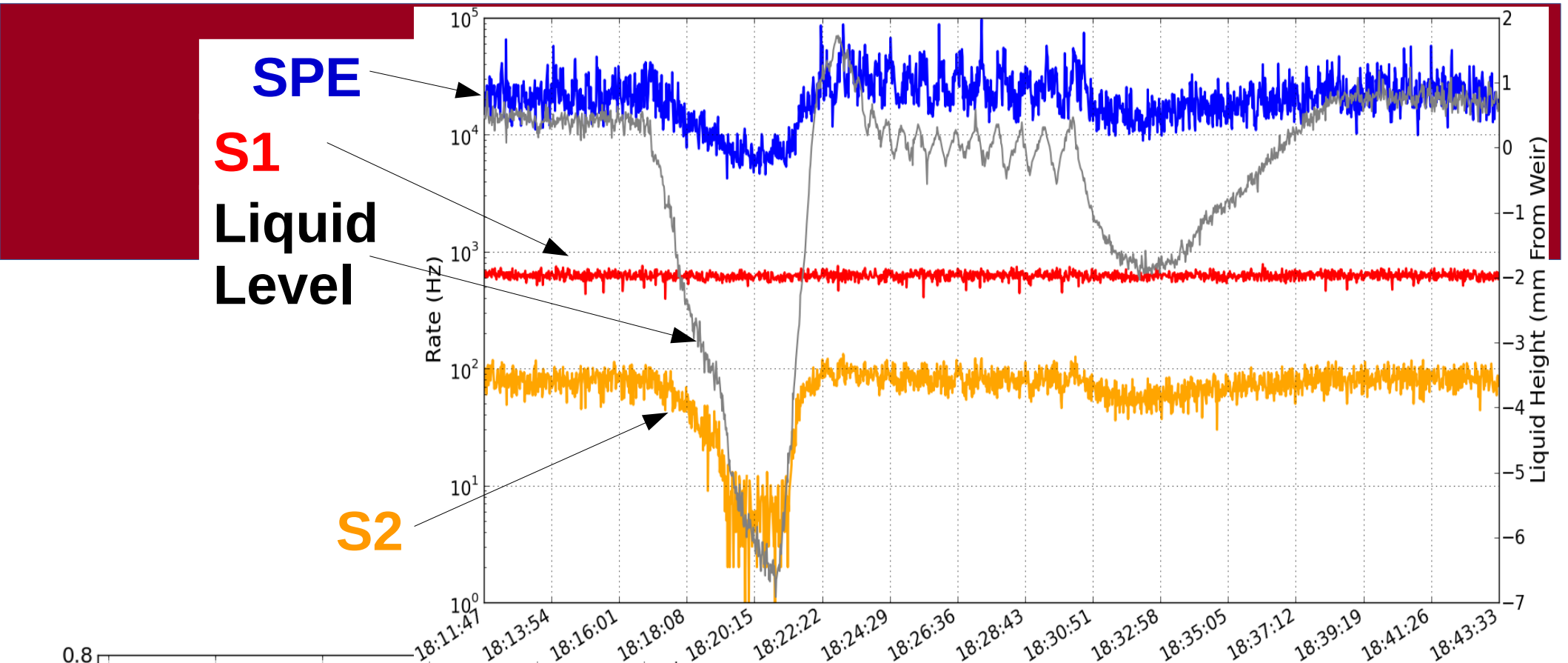
Anode: 0V, Gate: 6kV, Rate in kHz

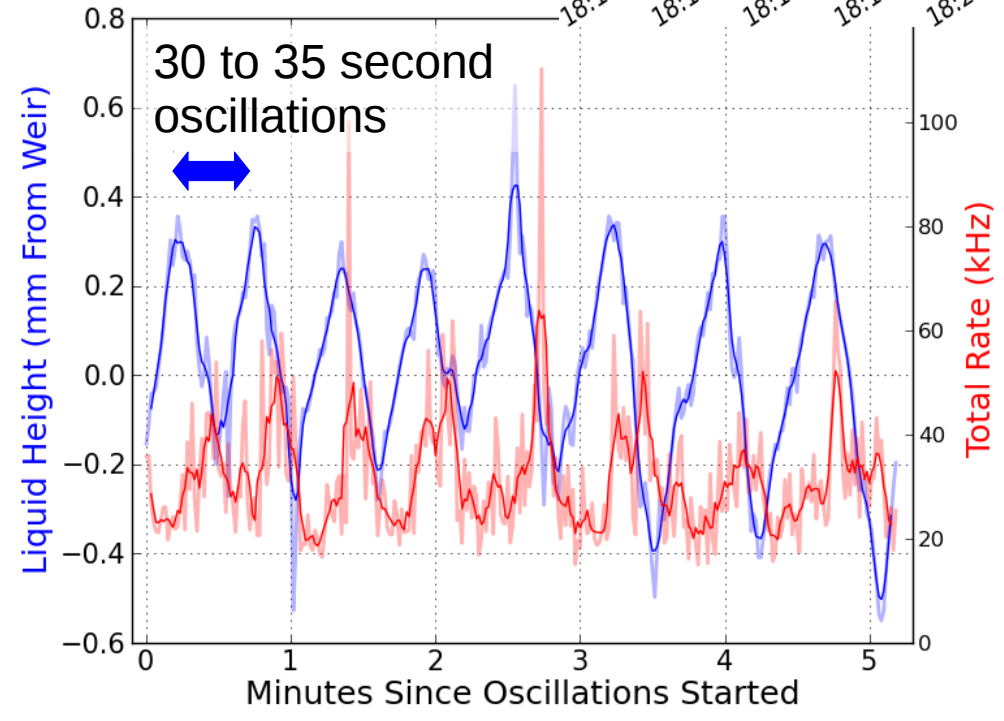
	Run 5 (early)	Run 5 (late)	Run 6
SPE (-BG)	4.1	8.9	10
SE (-BG)	0.05	0.08	0.07
S1	0.67	0.6	0.62
S2	0.053	0.067	0.075

- Purification
  - Early run 5: no purification
  - Late run 5: purification several days prior
  - Run 6: purifying
- Purer Xe → higher rate
- Anode affected more
  - Larger active Xe volume
- Increase in SPE and SE rate due to purity → emission source in Xe? Is it Xe itself?

  Ill-defined (so far) mechanism has to be invoked to make that happen

Effect Of Liquid Level
And
Fast Liquid Level Oscillations





- Measured rates vs liquid level
  - liquid level affects rates in interesting ways
- Noticed an increase in rates during “fast” oscillations
- Rates highest during falling edge of level oscillation

What's Next

- More analysis ongoing
  - Investigating correlation of SPEs to see if they are due to particle interactions in Xe
    - Can “broken apart” S2s in low drift field be the source of high rate seen?
  - Investigating shapes of pulses under various conditions
  - More E-field simulations to understand the active volume
  - Simulations of backgrounds
- Run 7 coming soon
  - Improved, LZ-like extraction region
  - multi-PMT array for better diagnostics of active volume light
  - skin PMTs to see if emission present outside of the TPC
  - Tests designed to explore field leakage using cathode bias

Acknowledgements

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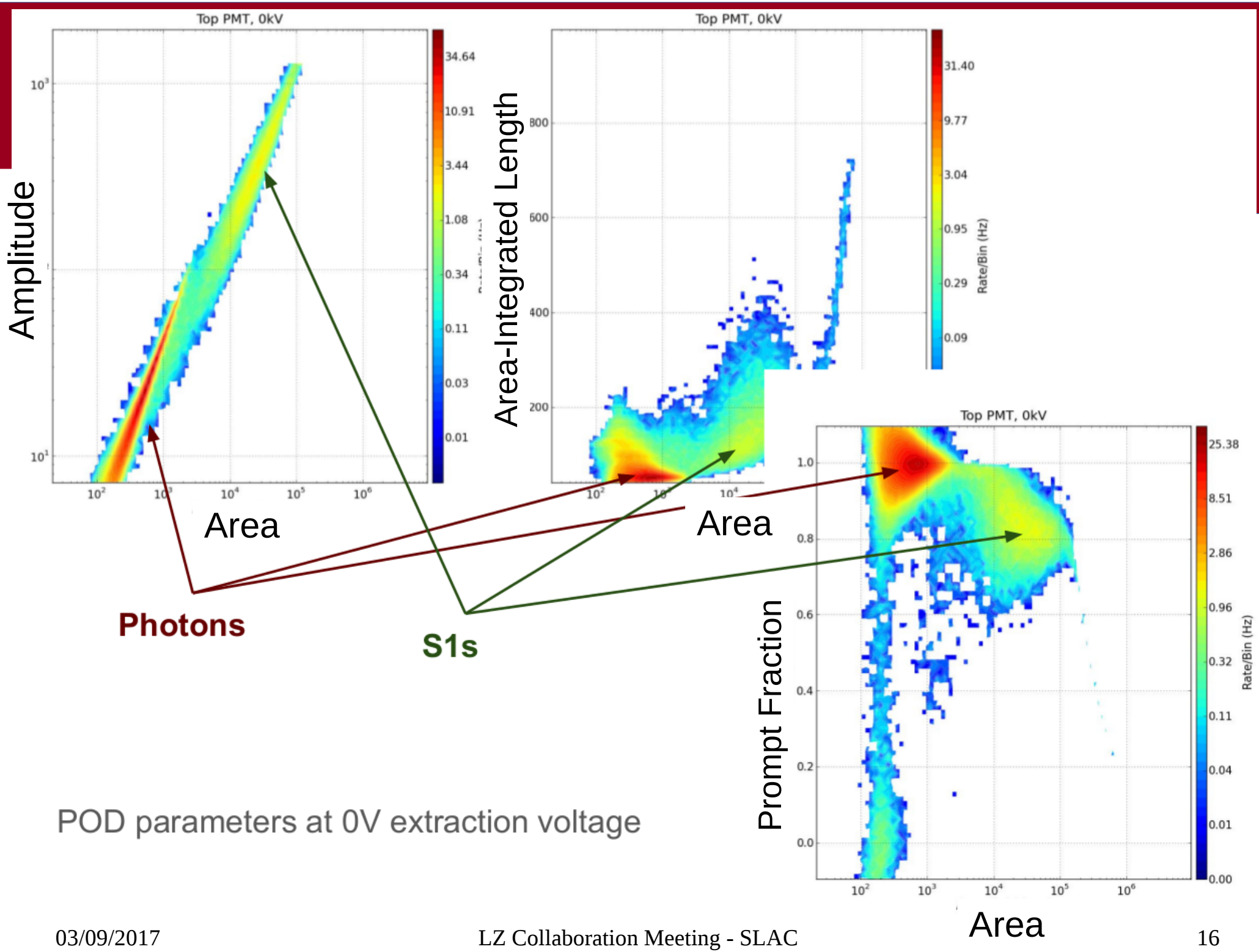
And many others through their Project tasks in 1.4 and 1.5, and summer help

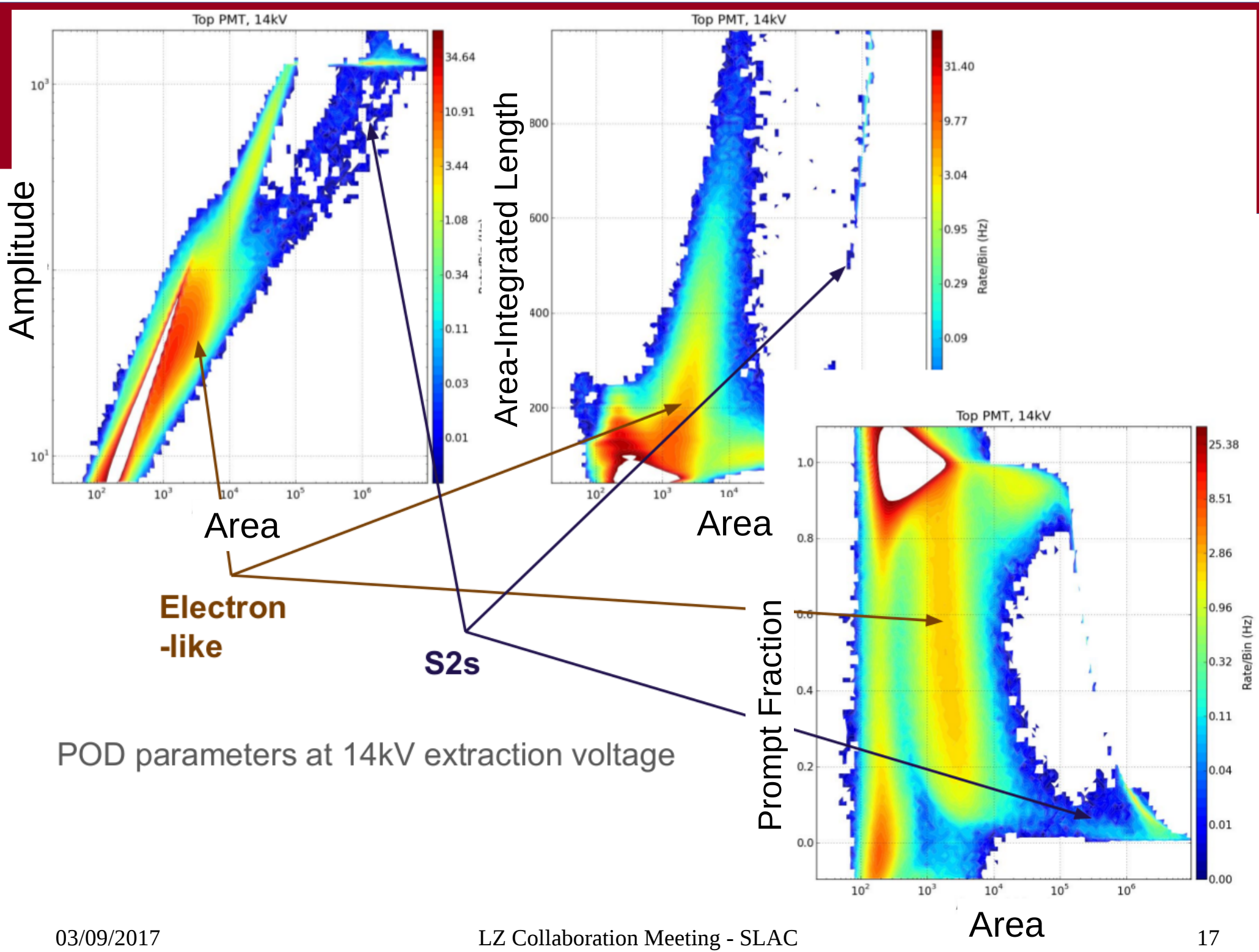
Backup

Pulse Classification Using PODs

- No pulse finder → Assuming POD == Pulse
- Using prompt fraction, area-integrated length, amplitudes, areas, negative area fraction noise cut
- Tuned by eye

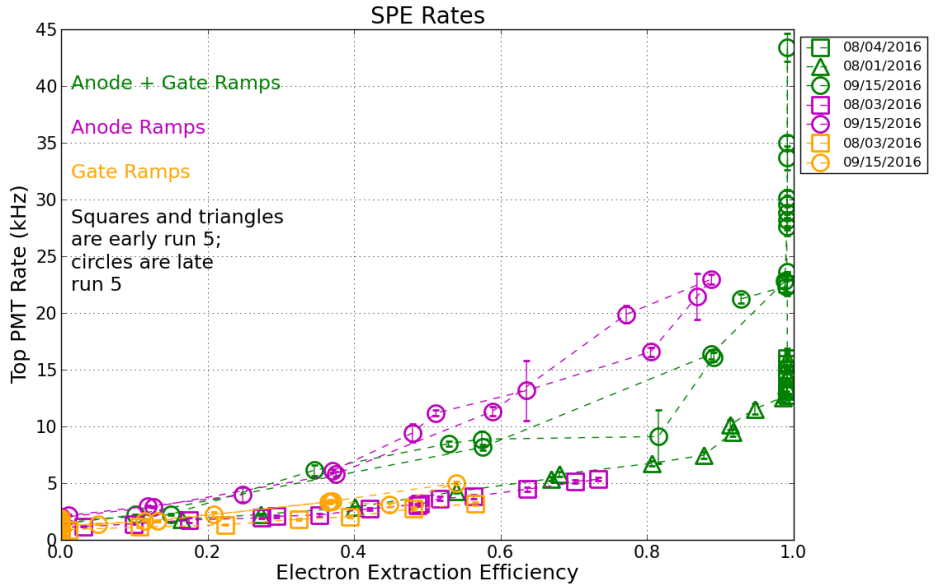


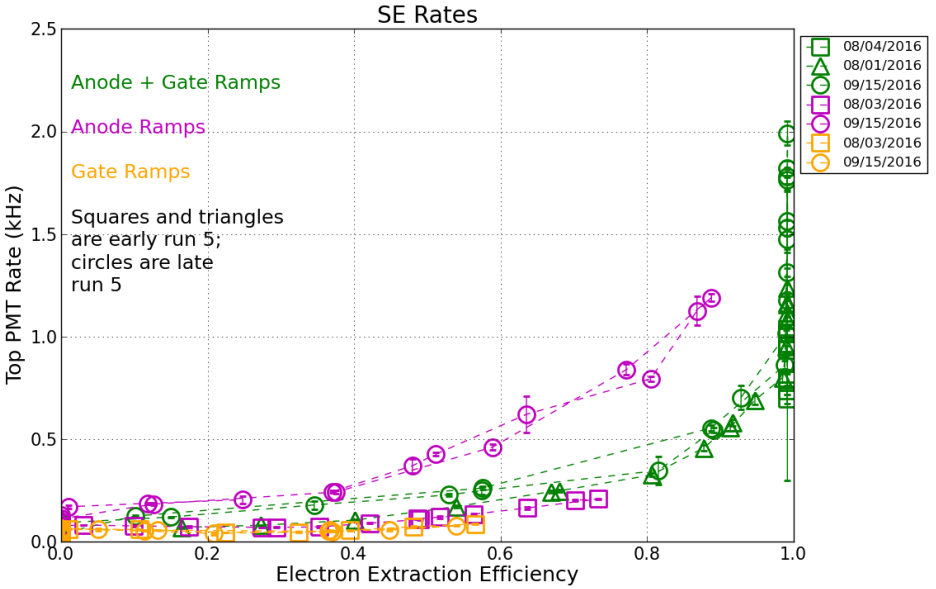
POD parameters at 0V extraction voltage



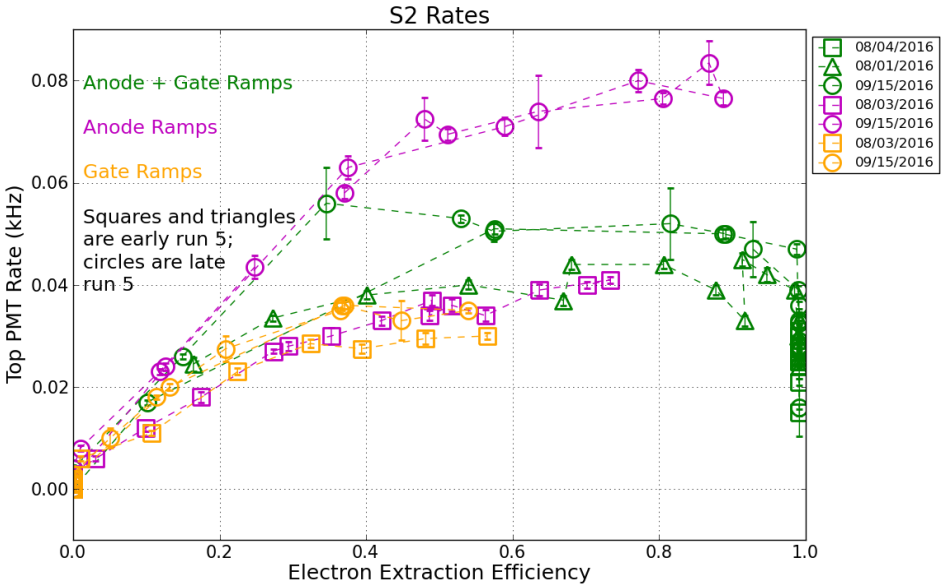
POD parameters at 14kV extraction voltage

Run5: Emission vs EEE Estimate

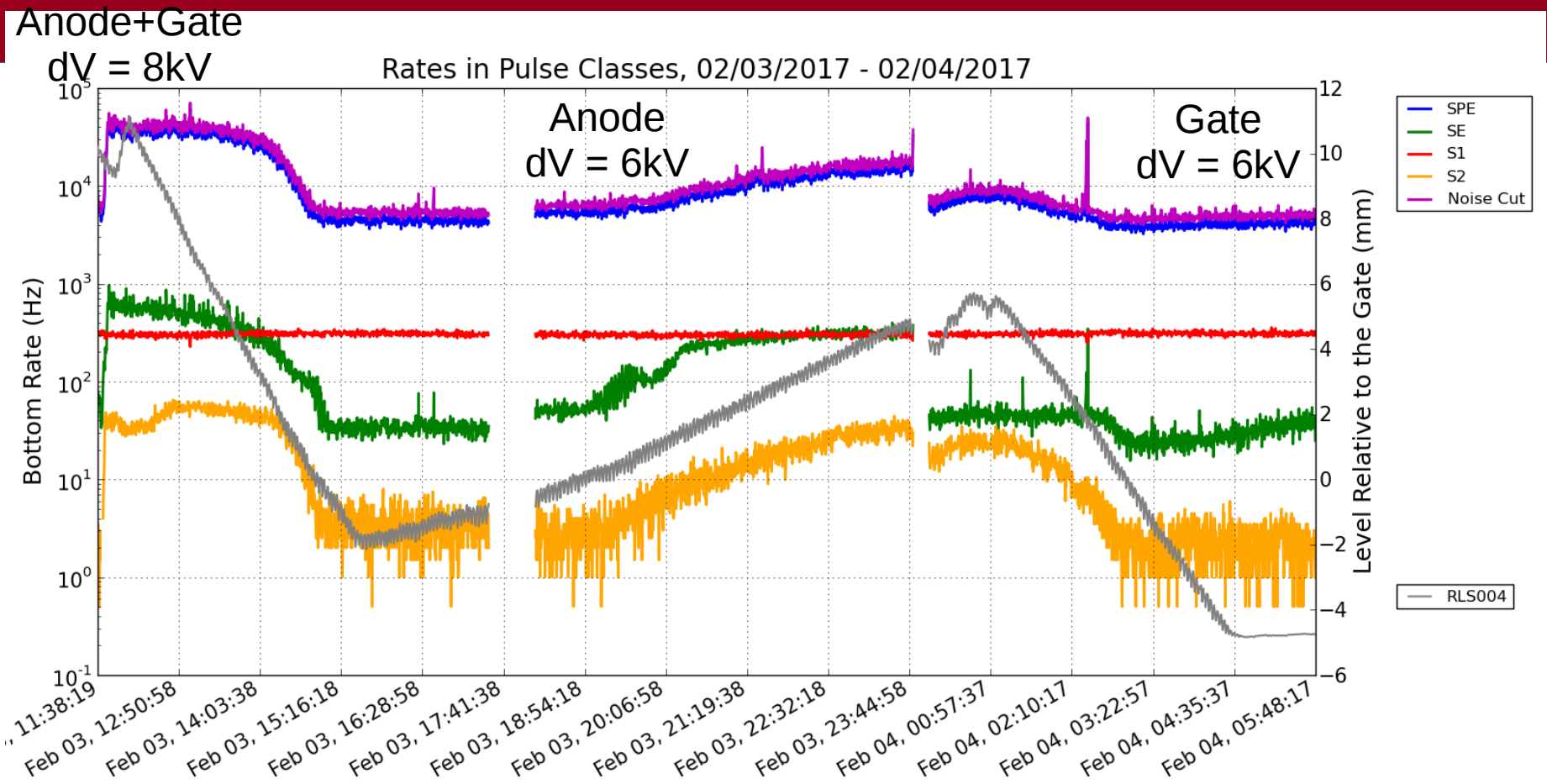




- A lot of variability at 100% EEE
  - Explained (possibly) by accessing larger and larger volumes of Xe leading to higher rates
  - EEE isn't computed very well

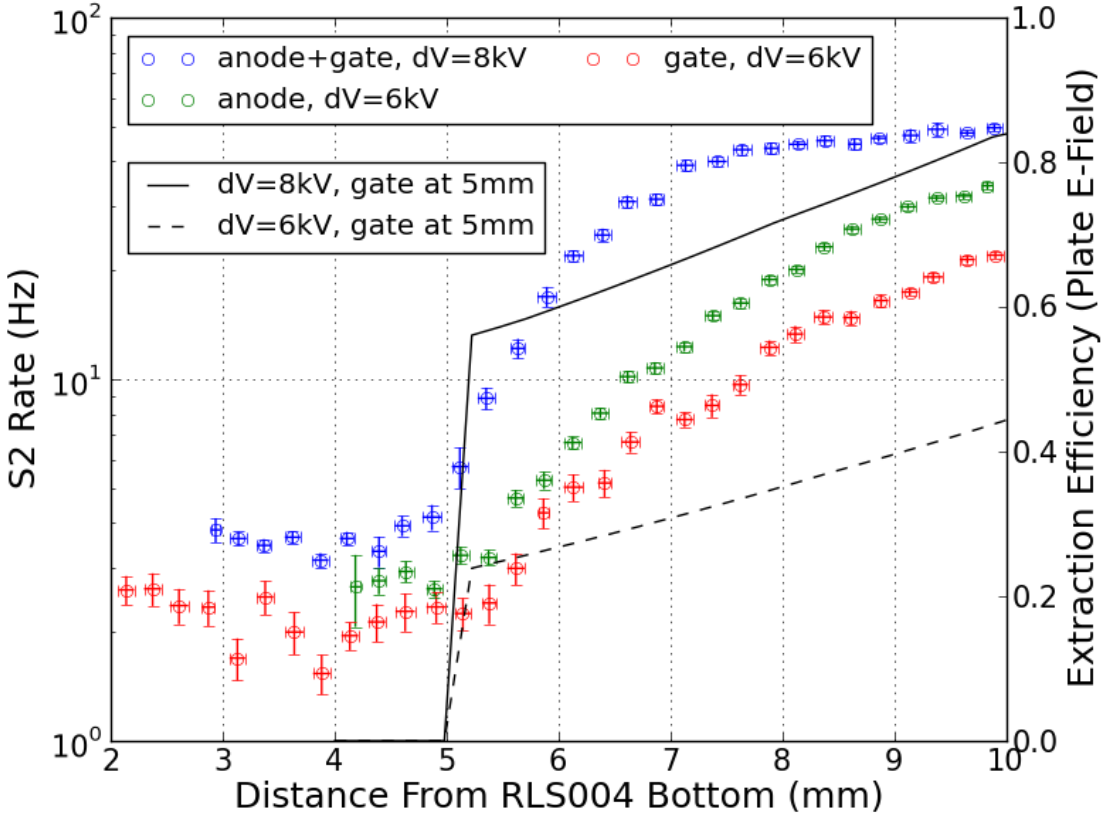


Slow Liquid Level Changes: Finding the Gate



- Onset of SPE and SE rate increases is consistent with the onset of S2s

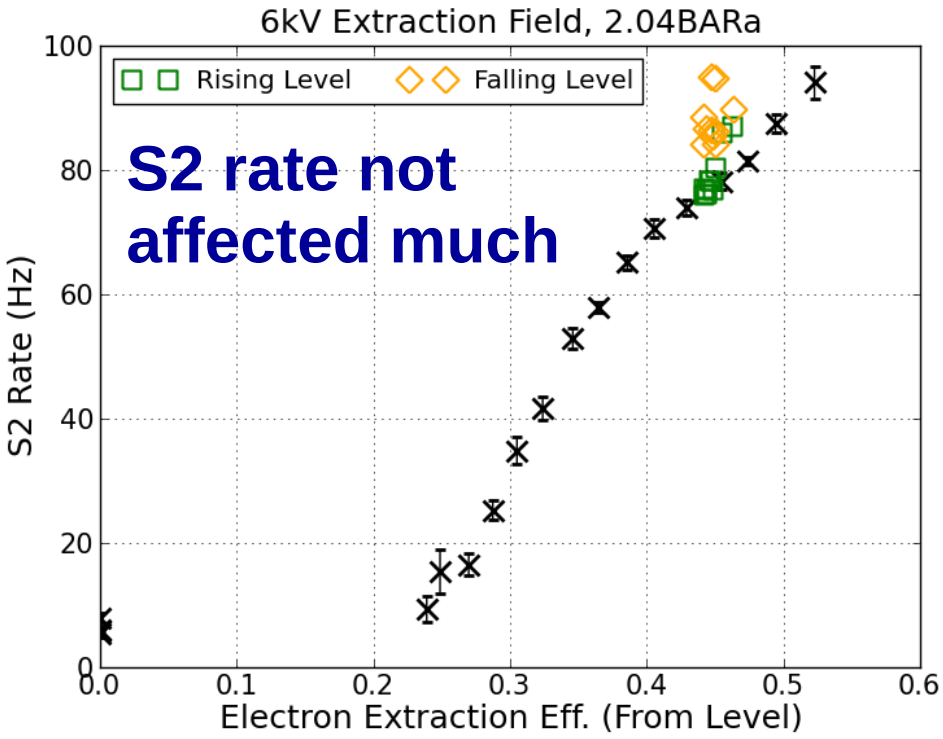
Slow Liquid Level Changes: Finding the Gate

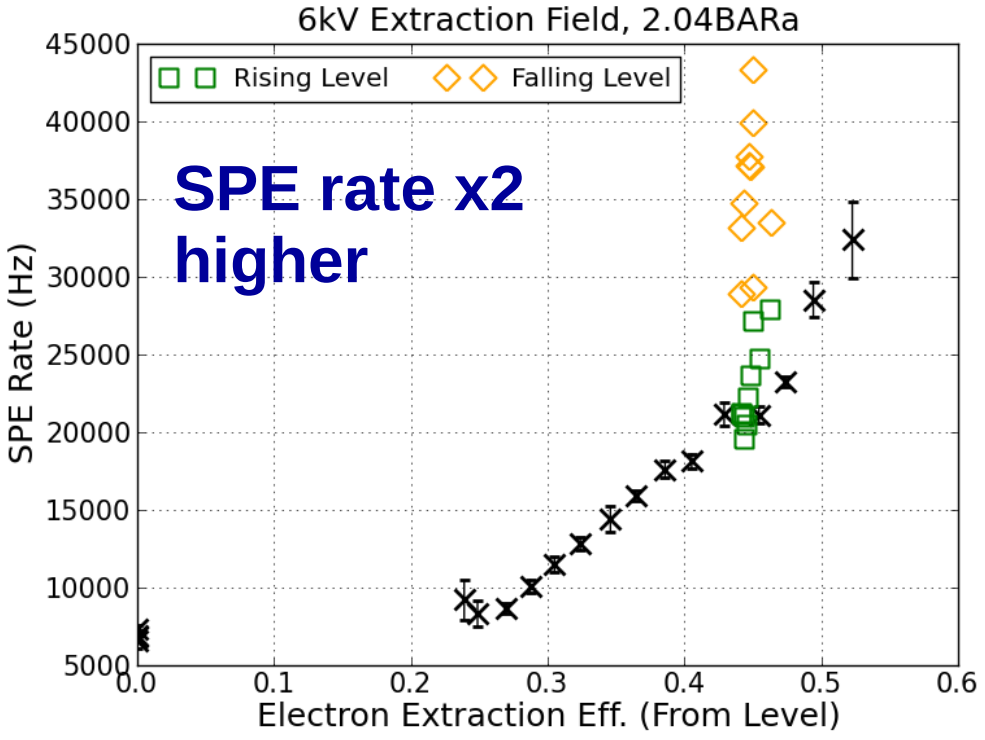


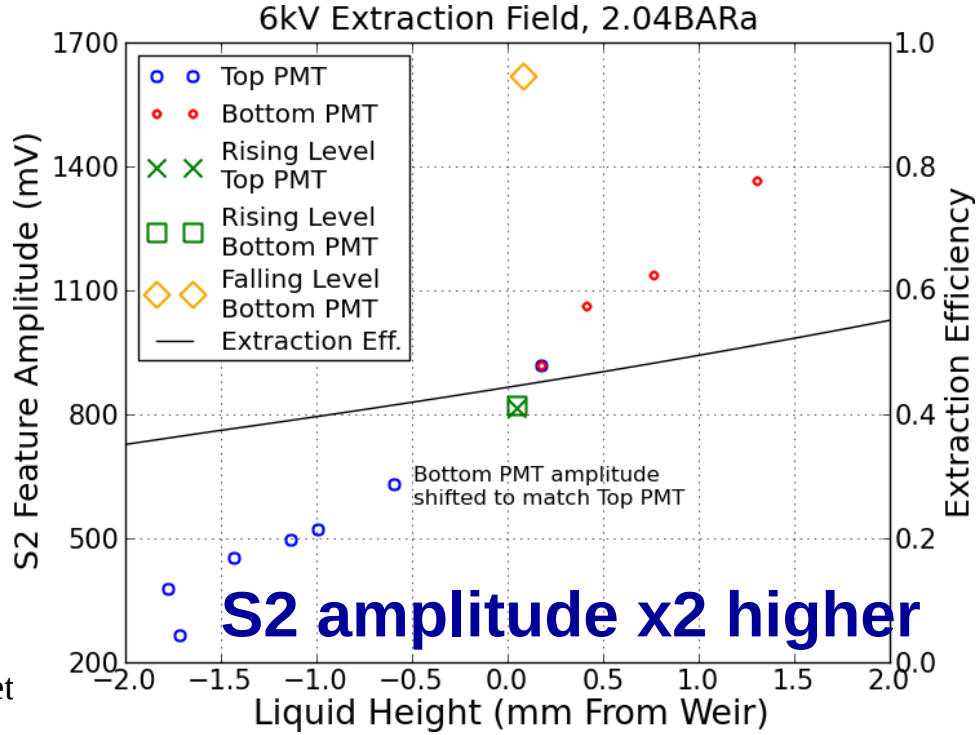
- Anode+gate bias data → gate 5mm above bottom of level sensor
- S2s onset later during the other sets
  - Likely due to lower field in the liquid

EEE or Increased Scintillation (or Neither)

- EEE based on measured level varied only between ~43% and 47%
  - Too little to account for extra rate
- But, don't see larger-area SE population
- Is EEE enhanced locally?
- Or is source changing?

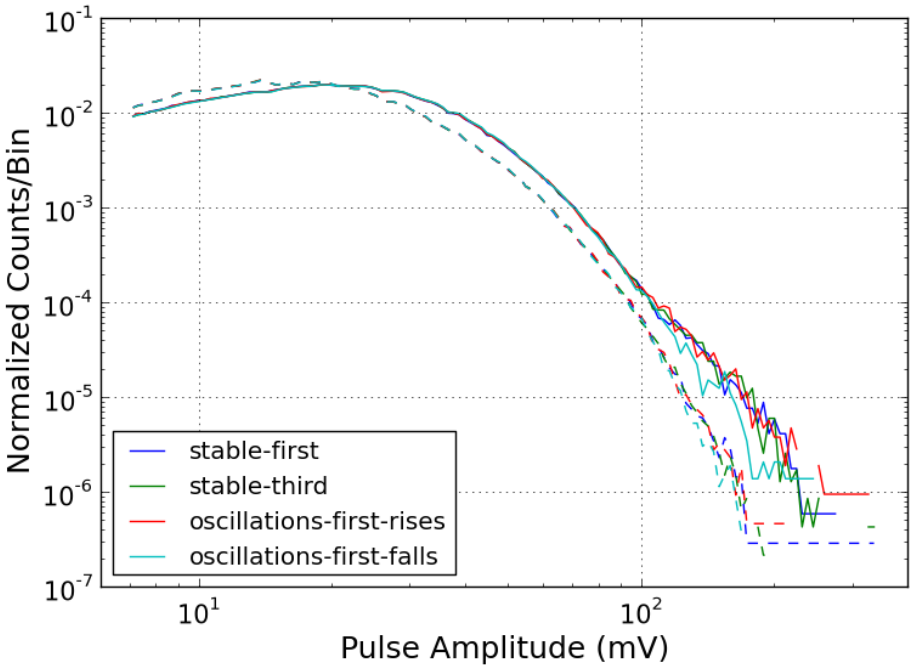


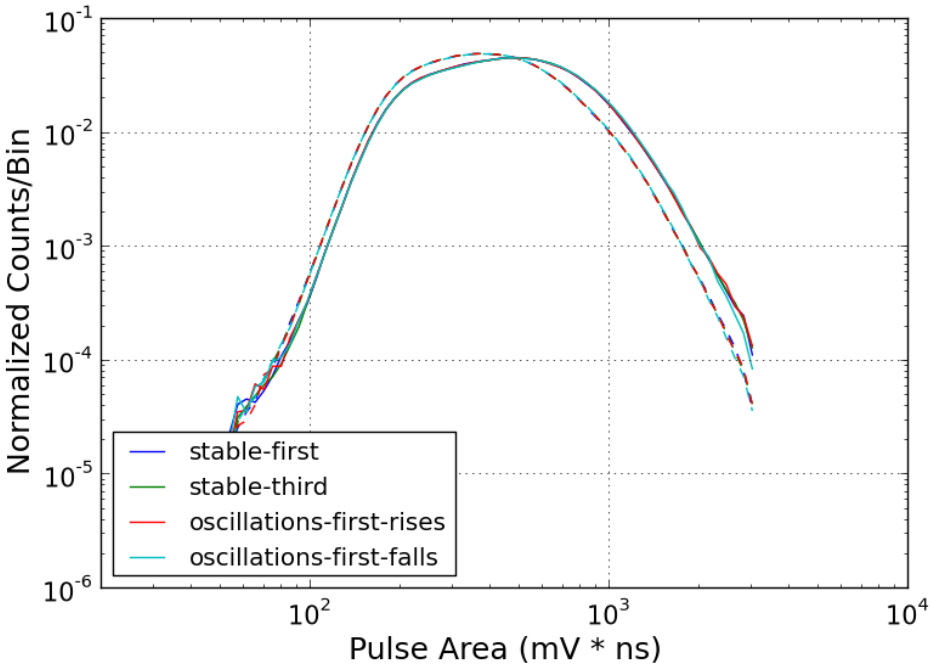


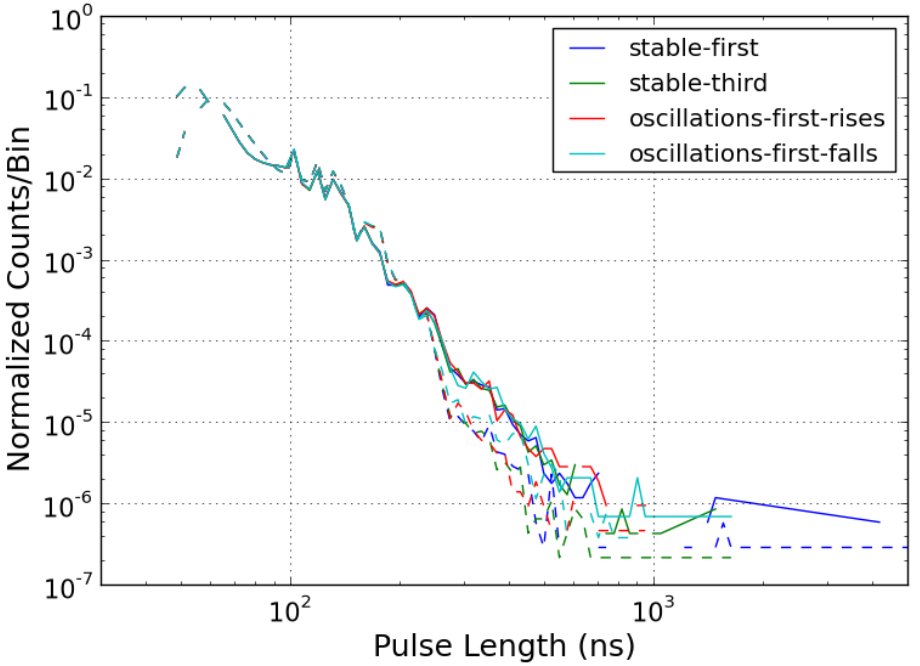


Meet

Fast Oscillations: SPE Distributions

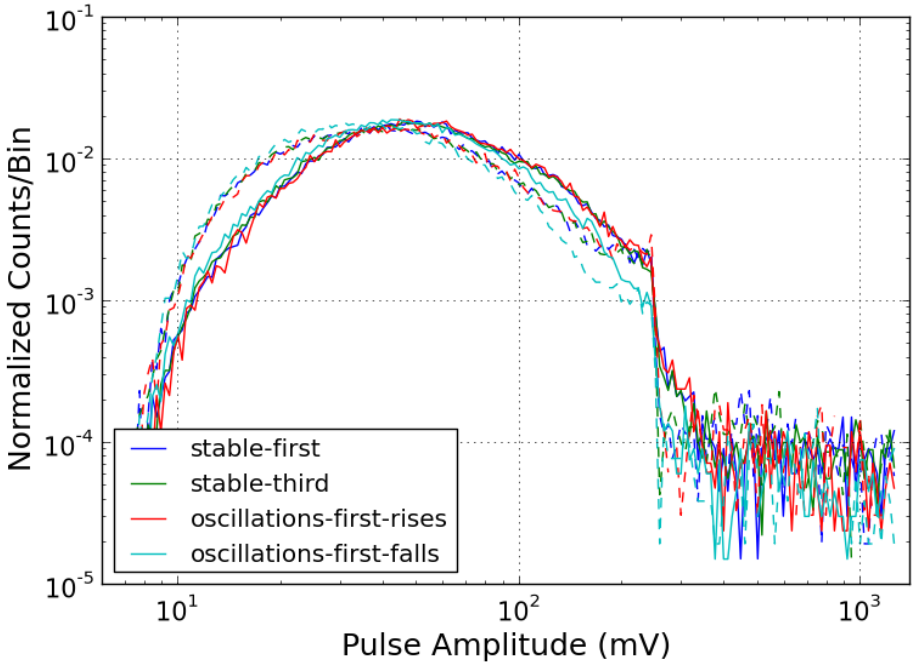


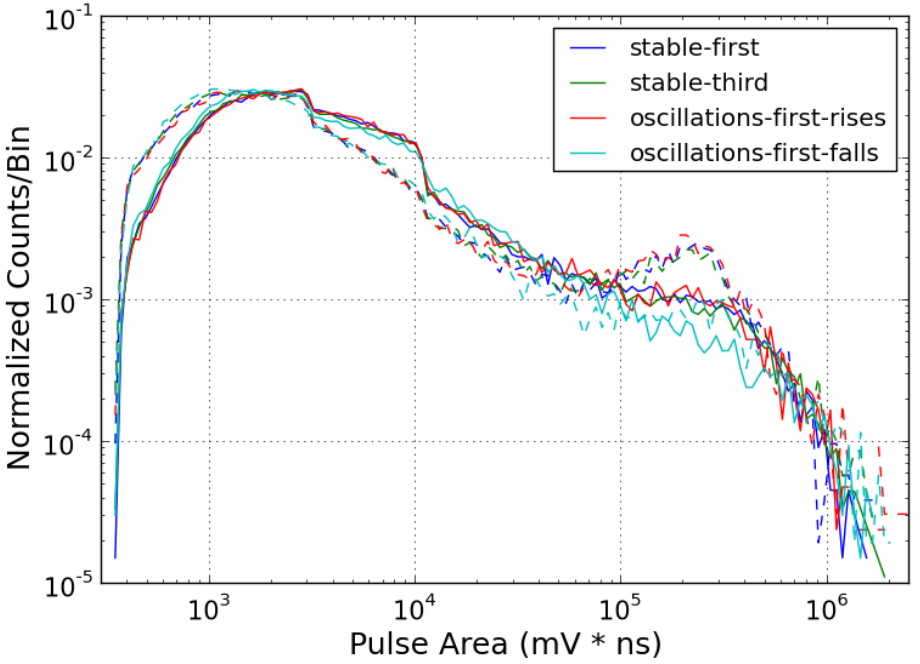


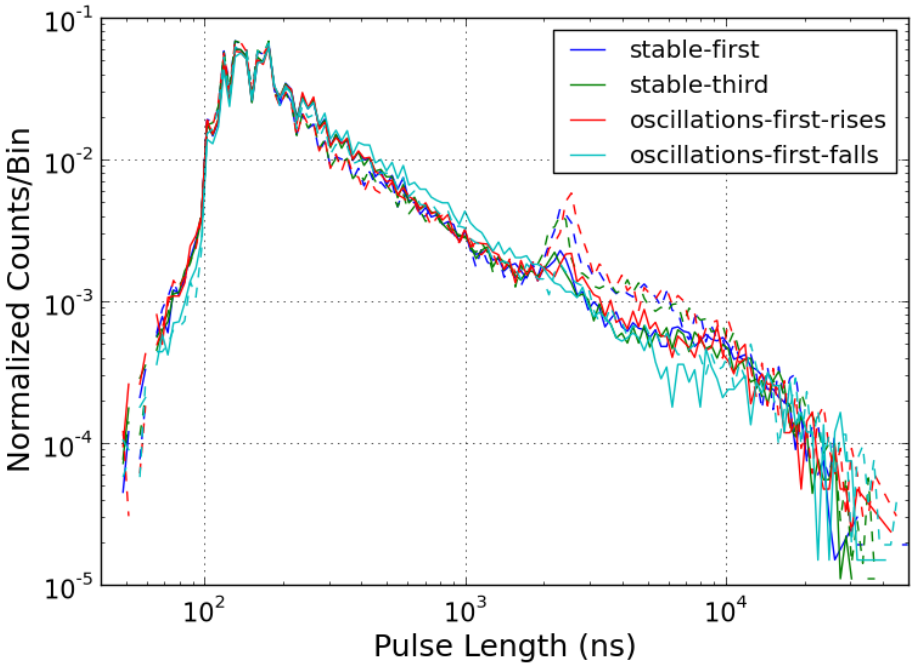


- Solid curves are from top PMT, dashed from bottom PMT
- Stable-first and stable-third are stable liquid levels at the start and end, respectively.
- While the rate at the fall during oscillations is larger, the shapes of distributions are not altered

Fast Oscillations: SE Distributions



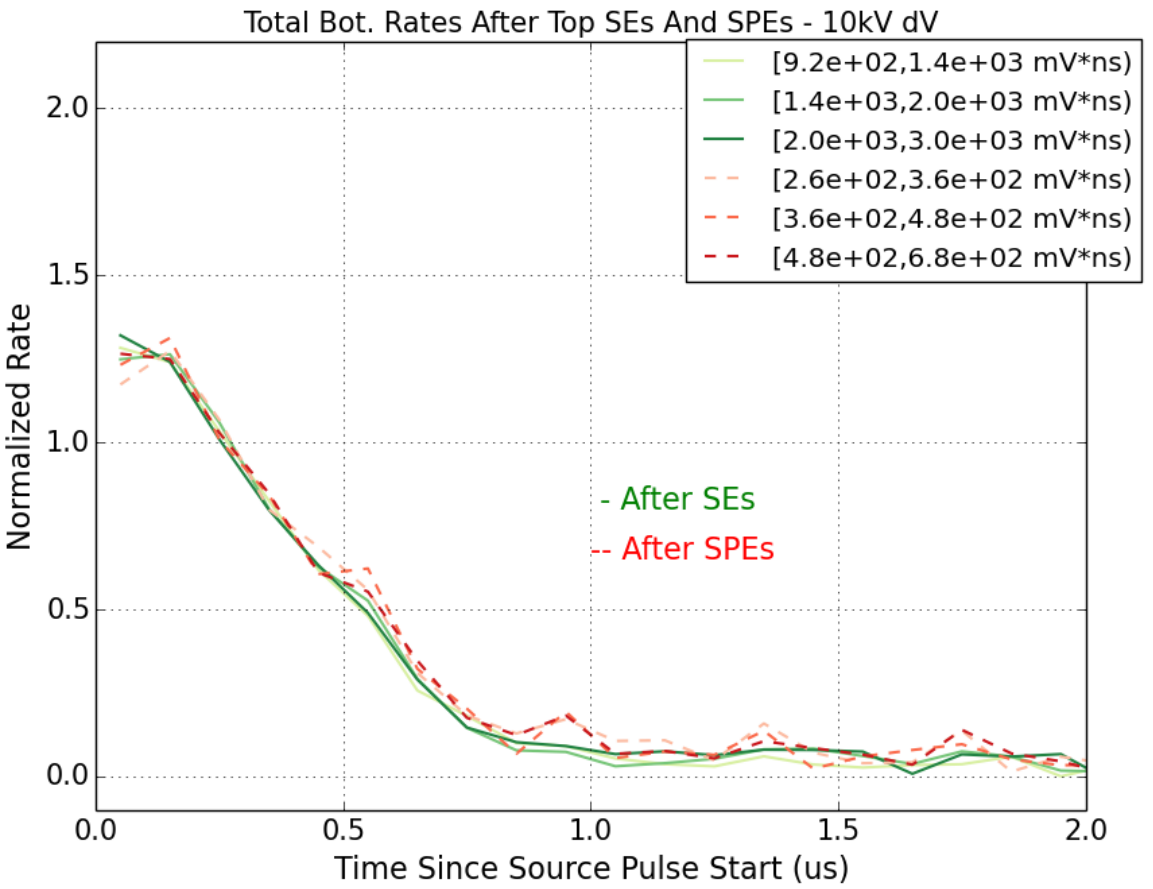




- Solid curves are from top PMT, dashed from bottom PMT
- Stable-first and stable-third are stable liquid levels at the start and end, respectively.
- Small change at area of ~1.5e^5, possibly due to S2 leakage and at low amplitudes possibly due to SPE leakage

Correlation of pulses after SEs and SPEs

- The shape of the correlation of PODs after SPEs and SEs (at 10kV) is the same → SPEs come from the same population as SEs
  - Few photon pulses get split into individual PODs and appear as SPEs



Correlation of pulses after SEs: Grids and Fields

- The “shape” of SEs appears to be the same for anode, gate and anode+gate ramps
  - Further suggests that ramp types don't alter extraction characteristics
- Shapes do change as a function of field
  - They are shorter than (naively) expected; ~1.5us @ 10kV