

Salting as a Bias Mitigation Technique in LZ

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LIDINE 2021



LZ (LUX-ZEPLIN) Collaboration

34 Institutions: 250 scientists, engineers, and technical staff

<https://lz.lbl.gov/>

- Black Hills State University
- Brandeis University
- Brookhaven National Laboratory
- Brown University
- Center for Underground Physics
- Edinburgh University
- Fermi National Accelerator Lab.
- Imperial College London
- Lawrence Berkeley National Lab.
- Lawrence Livermore National Lab.
- LIP Coimbra
- Northwestern University
- Pennsylvania State University
- Royal Holloway University of London
- SLAC National Accelerator Lab.
- South Dakota School of Mines & Tech
- South Dakota Science & Technology Authority
- STFC Rutherford Appleton Lab.
- Texas A&M University
- University of Albany, SUNY
- University of Alabama
- University of Bristol
- University College London
- University of California Berkeley
- University of California Davis
- University of California Santa Barbara
- University of Liverpool
- University of Maryland
- University of Massachusetts, Amherst
- University of Michigan
- University of Oxford
- University of Rochester
- University of Sheffield
- University of Wisconsin, Madison



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Outline

Part I: Why salt? (bias mitigation!)

Part II: How to salt?

Bias mitigation

- Overcome human biases in analysis (e.g. confirmation bias)
- Especially important when stakes are high

*“I’ve already written the paper;
that’s why it’s so hard to get
the right data!”*

Bias mitigation

- Overcome human biases in analysis (e.g. confirmation bias)
- Especially important when stakes are high
- Example: History of the elementary electric charge value
 - The Millikan-Fletcher oil drop experiment measured a value 0.6% smaller than currently accepted (at a 5σ discrepancy)
 - Following experiments were reluctant to deviate too much

It's a thing that scientists are ashamed of—this history—because it's apparent that people did things like this: When they got a number that was too high above Millikan's, they thought something must be wrong—and they would look for and find a reason why something might be wrong. When they got a number close to Millikan's value they didn't look so hard.

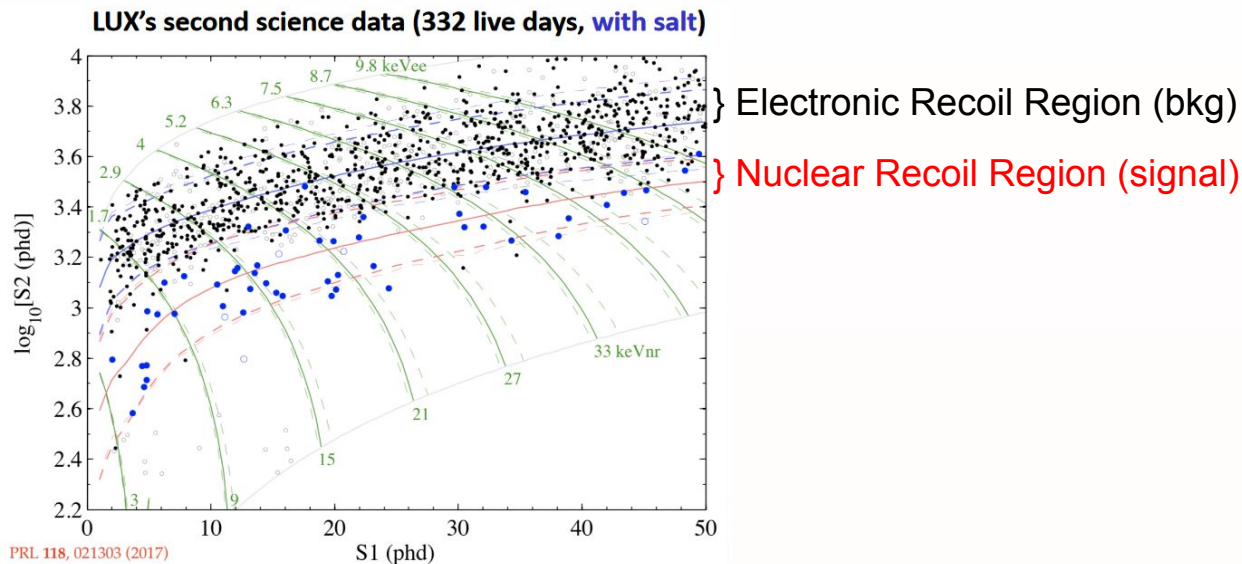
— Richard Feynman, 1974

Bias mitigation techniques

Techniques include blinding, data prescaling, hidden parameters, ...

Bias mitigation techniques

Techniques include blinding, data prescaling, hidden parameters, ...
LZ will use **salting** (injection of fake signal events), as used in LUX:

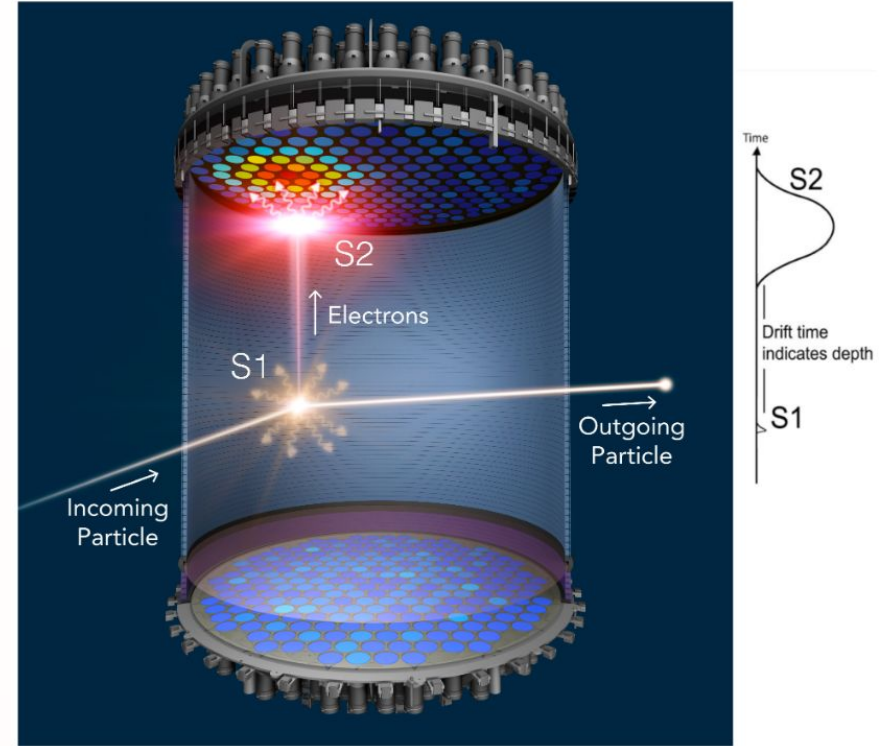


Remove salt only after developing your analysis and background cuts

The TPC

Each scatter in the TPC creates photons and electrons

- S1 is proportional to the number of photons created
- S2 is proportional to the number of electrons created



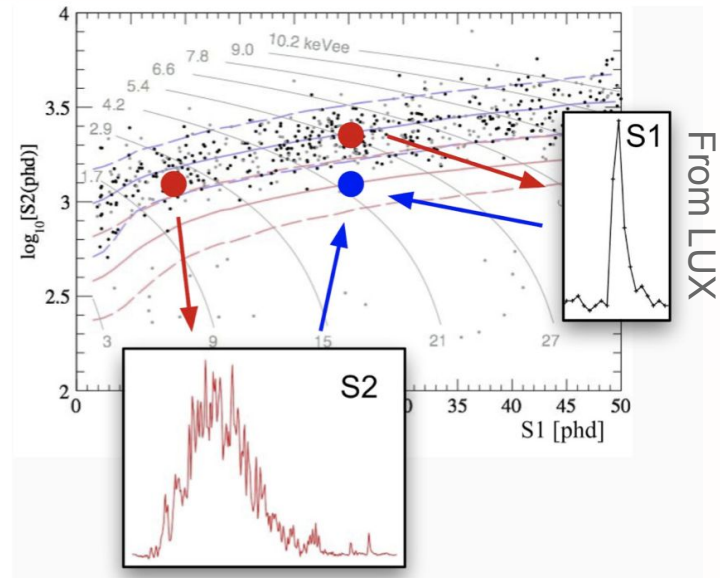
Part II: How to salt?

It's not every day you're allowed to secretly inject a dark matter signal into your collaborations data!

Salting LZ: The Process

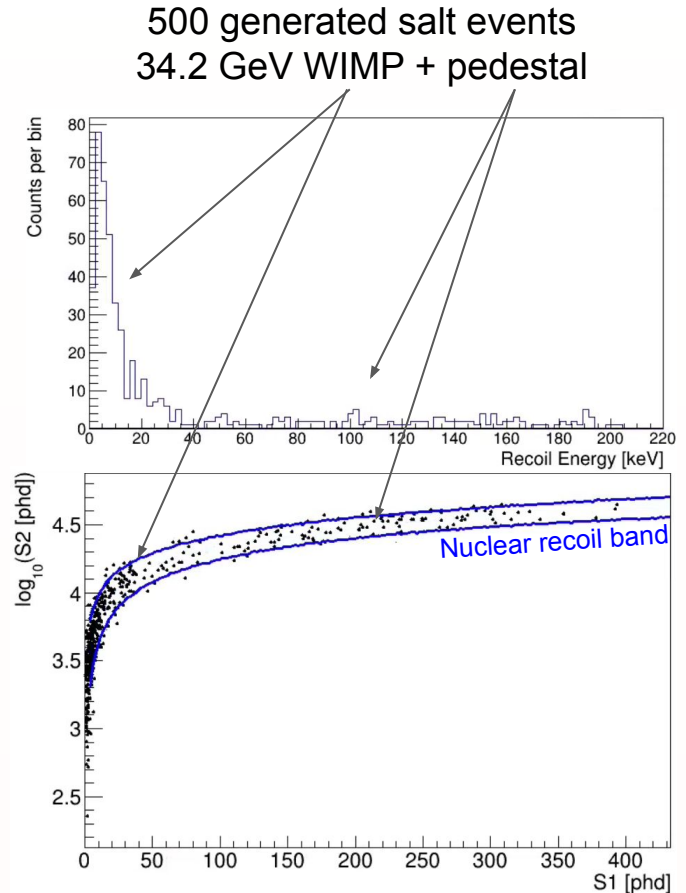
Strategy: Use two calibration events to create one salt event

1. Generate properties of desired salt
2. Combine calibration event waveforms into salt event waveforms
3. Secretly inject the salt events into data
4. Unsalt after completing analysis



1. Plan salt events

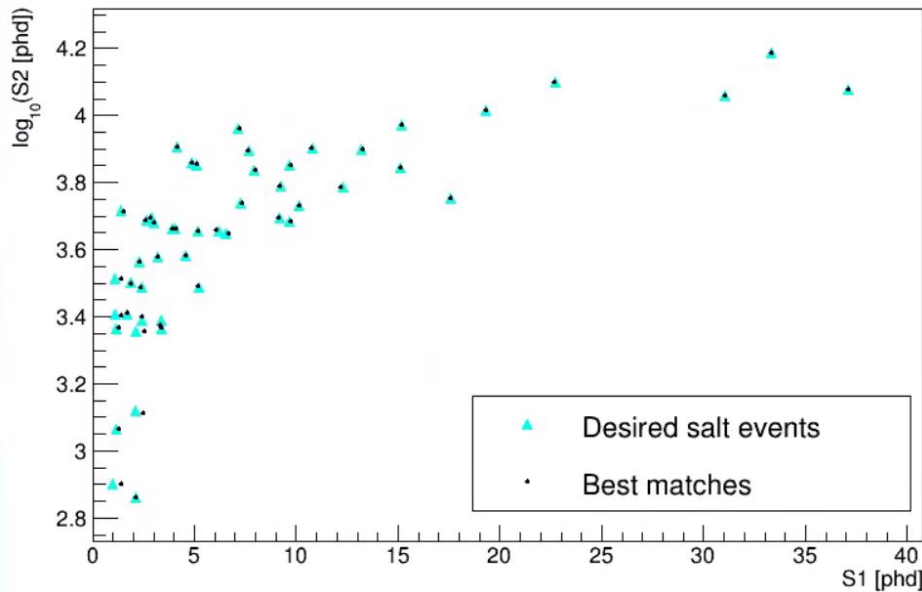
- Semi-randomly pick WIMP characteristics to model the salt
 - Mass, cross section, ...
- Sample a semi-random number of desired salt events from that WIMP spectrum or a flat pedestal
 - S1, S2, timestamps, ...



1. Plan salt events

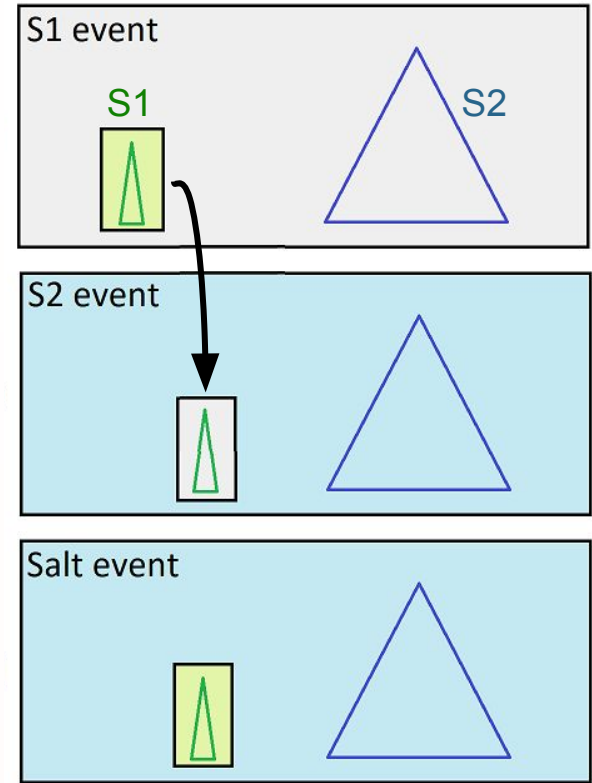
- Semi-randomly pick WIMP characteristics to model the salt
 - Mass, cross section, ...
- Generate a list of desired salt events corresponding to that WIMP or a flat spectrum
 - S1, S2, timestamps, ...
- Locate calibration events to create the salt

50 generated salt events and their nearest S1+S2 pairs in a simulated calibration



2. Create salt waveforms

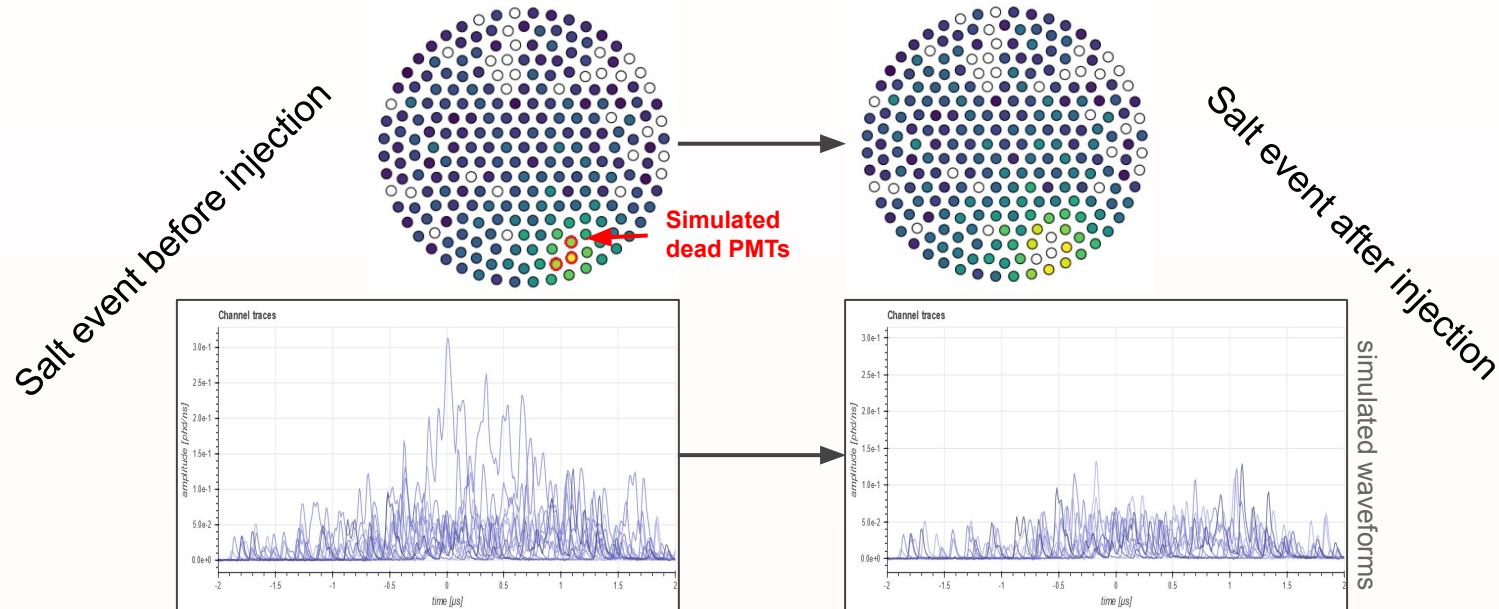
1. Pick out the S1 waveform from the S1's event
2. Remove the S1 waveform from the S2's event
3. Move the S1 in (1) to the gap left in (2)



3. Inject salt events

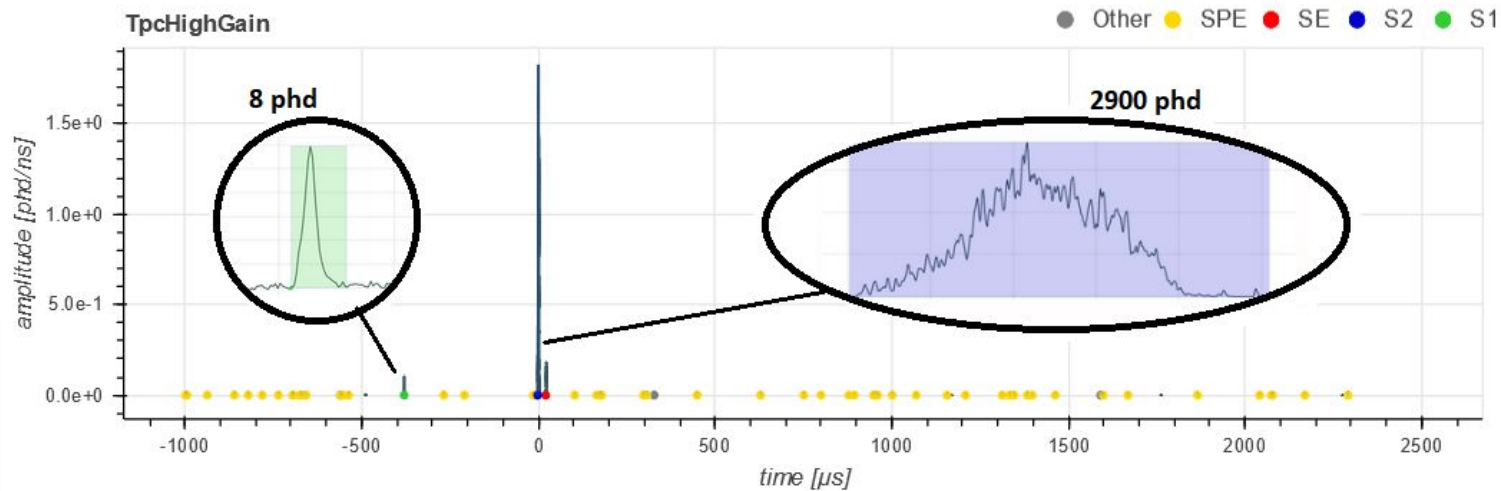
As data is taken, inject the salt events into data by replacing random triggers which occur at an adjustable average rate

Add some final touches: modify metadata and remove signals from dead PMTs



3. Inject salt events

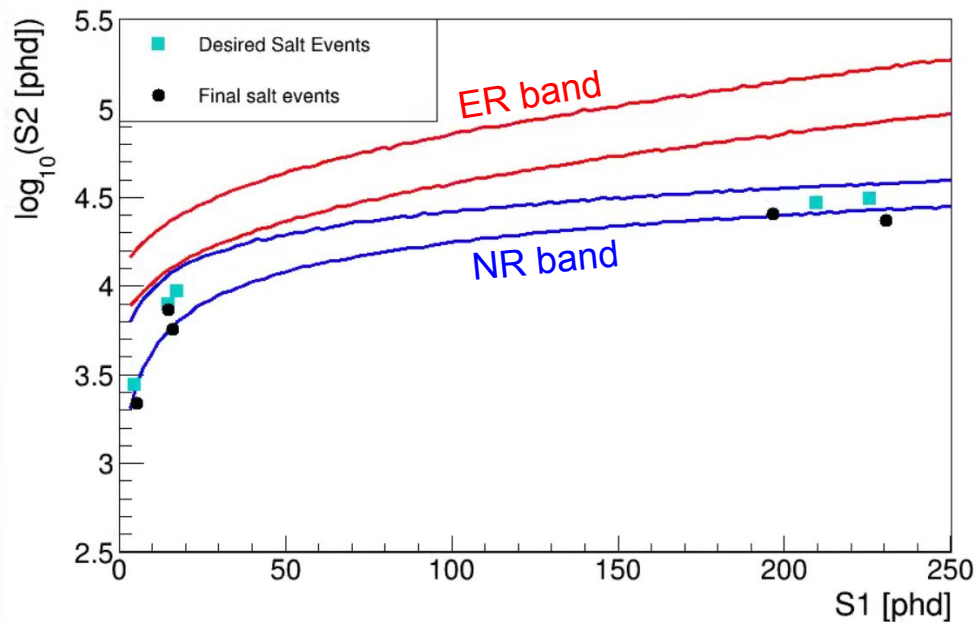
Final result: an event that looks like a WIMP



simulated waveform

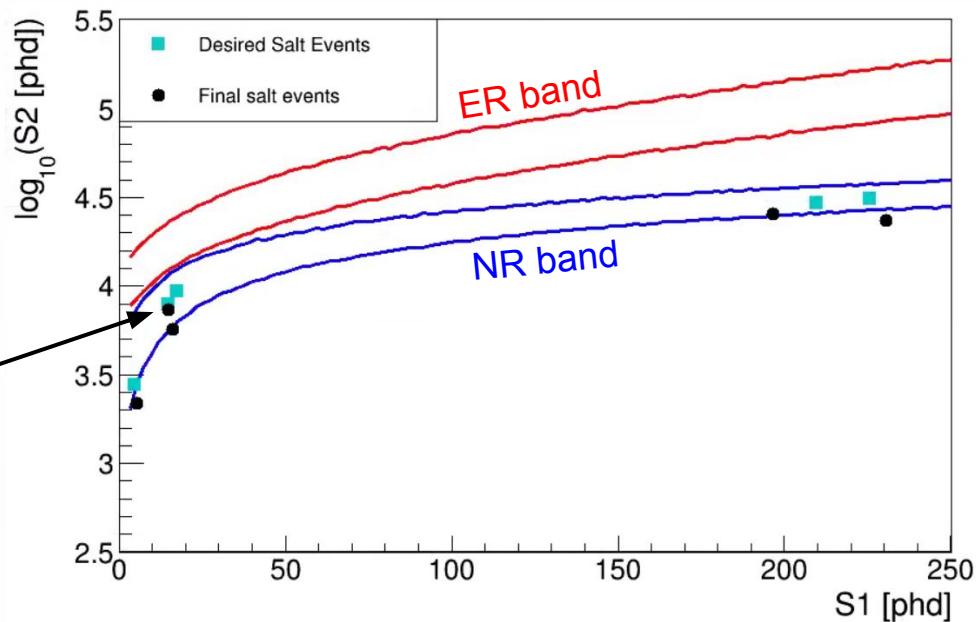
Success in LZ's Mock Data Challenge 3

- MDC3 was a test of LZ's production and analysis chains on simulated data
- 5 salt events were injected

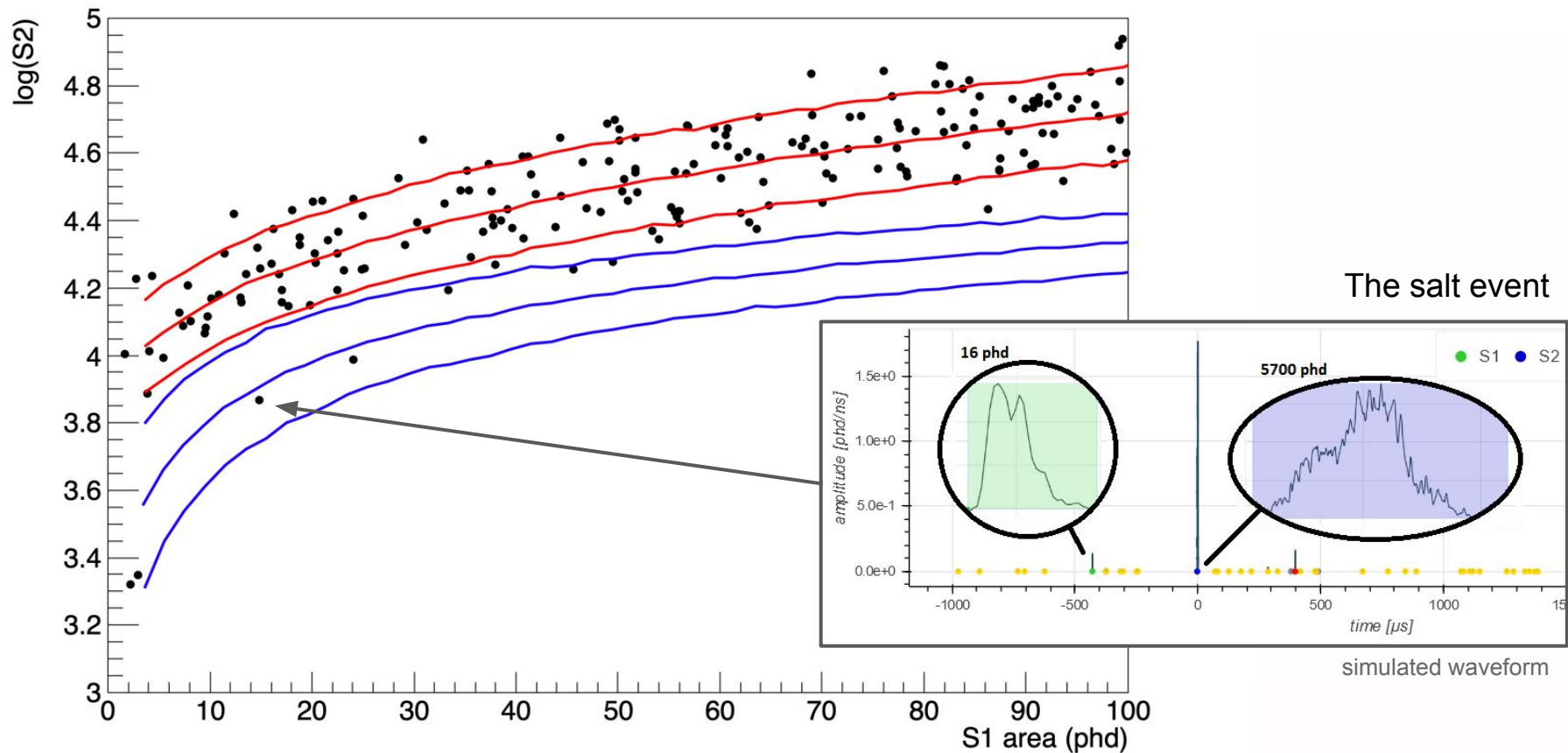


Success in LZ's Mock Data Challenge 3

- MDC3 was a test of LZ's production and analysis chains on simulated data
- 5 salt events were injected
 - 2 outside our ROI
 - 2 cut by a fiducial cut
 - 1 survived all background cuts



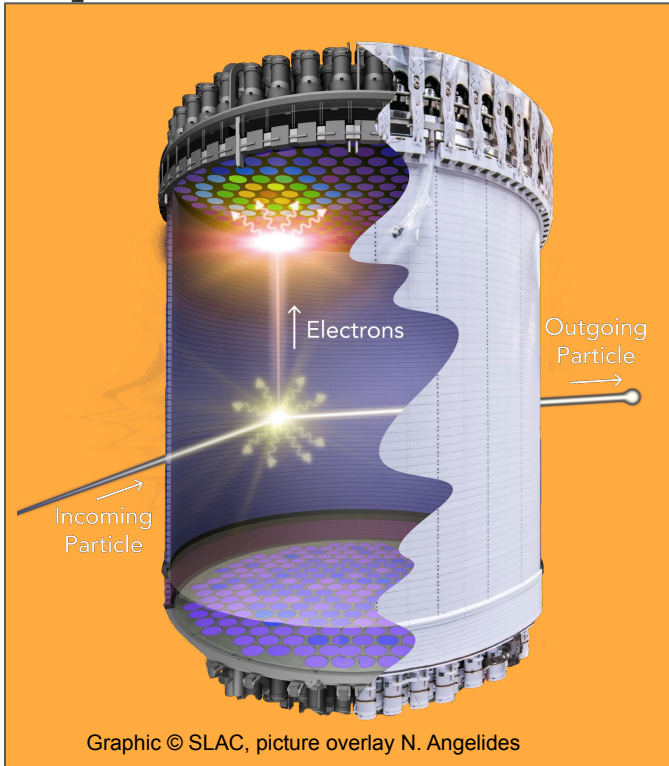
The final MDC3 WIMP search before unsalting





Thank you!

Thanks to our sponsors and 34 participating institutions!



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