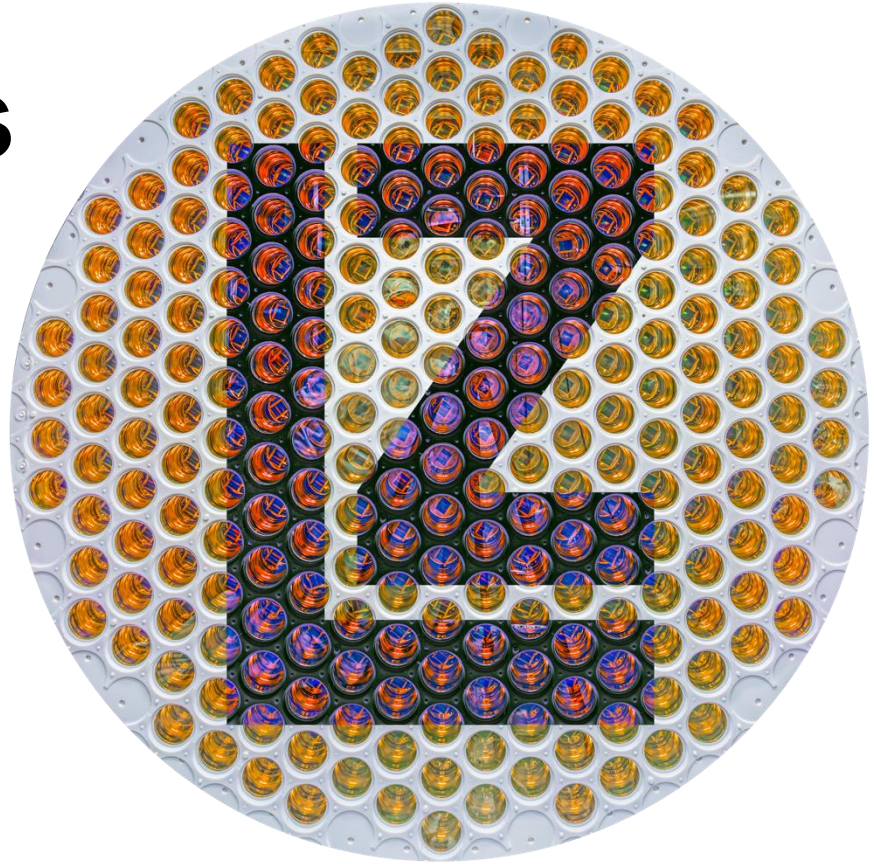
Modelling accidental coincidence backgrounds for the LUX-ZEPLIN experiment



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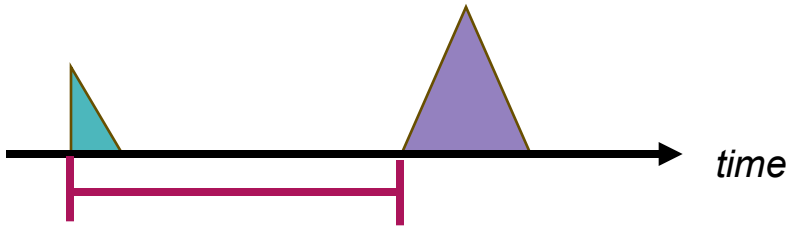
The LUX-ZEPLIN (LZ) experiment

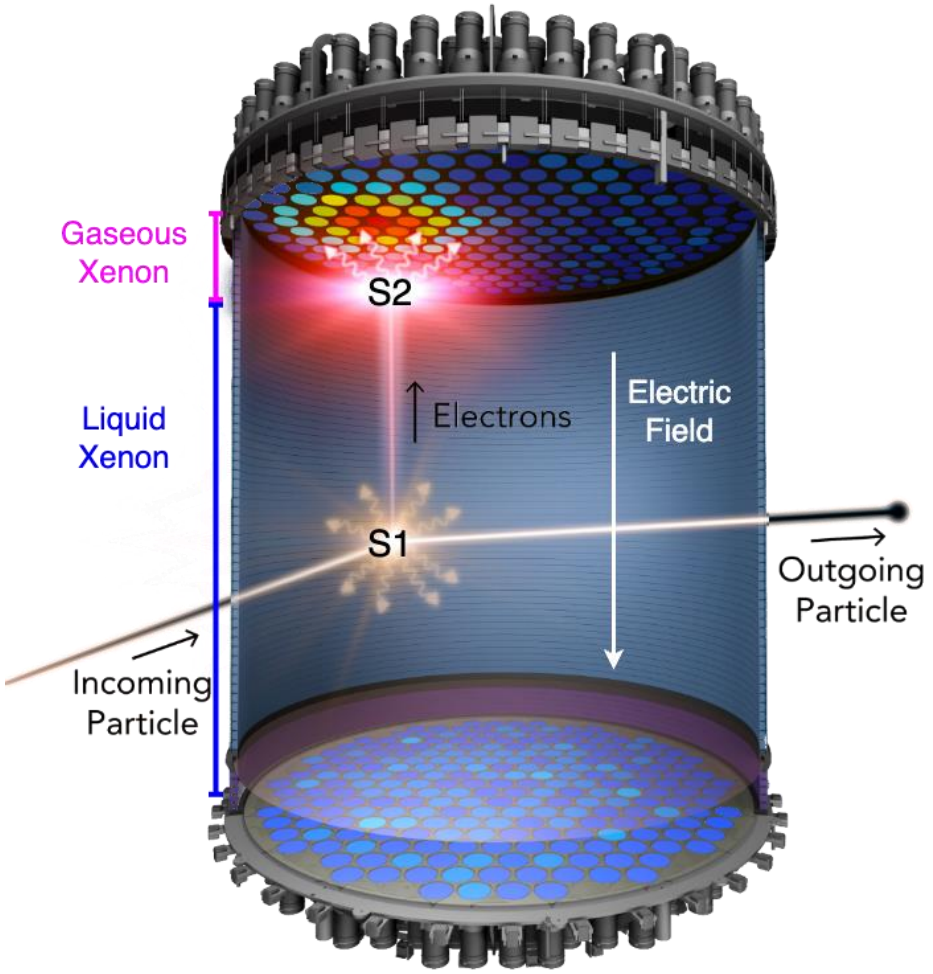
- Dual-phase time projection chamber (TPC)
- 7t of active liquid xenon
- 2 PMT arrays

S1: prompt scintillation signal

S2: delayed electroluminescence

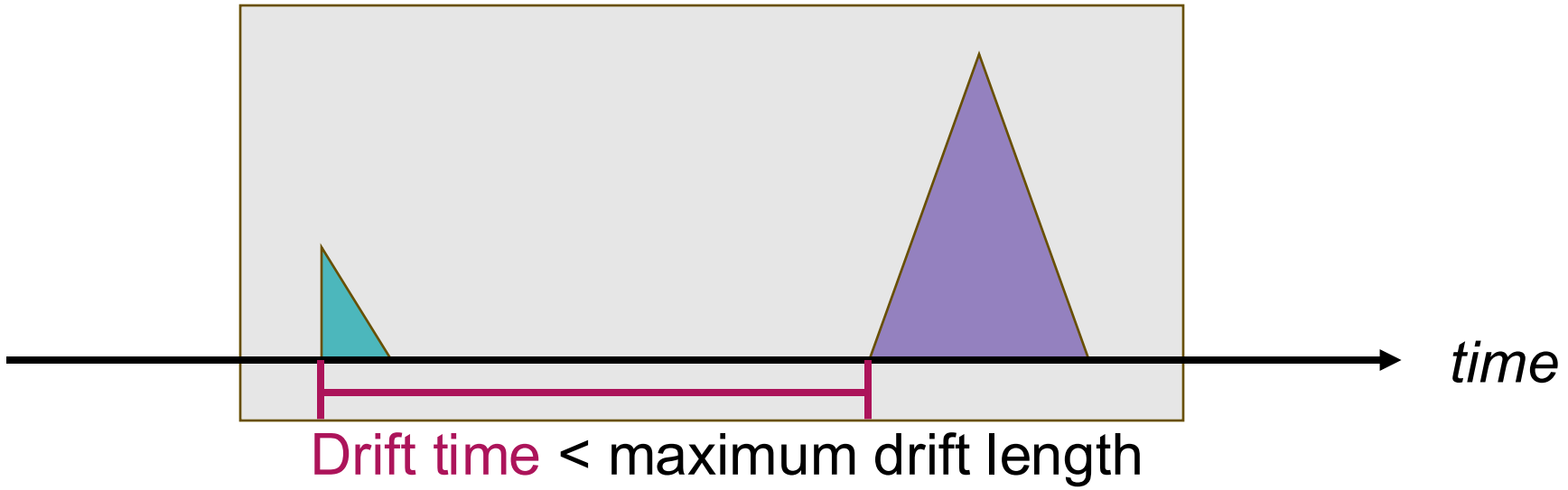


Drift time → Z position
PMT hit map → XY reconstruction



Accidental Coincidence Backgrounds

A dominant source of background for low mass WIMP searches arises from the accidental pairing of an **isolated S1 pulse (iS1)** with an **isolated S2 pulse (iS2)**

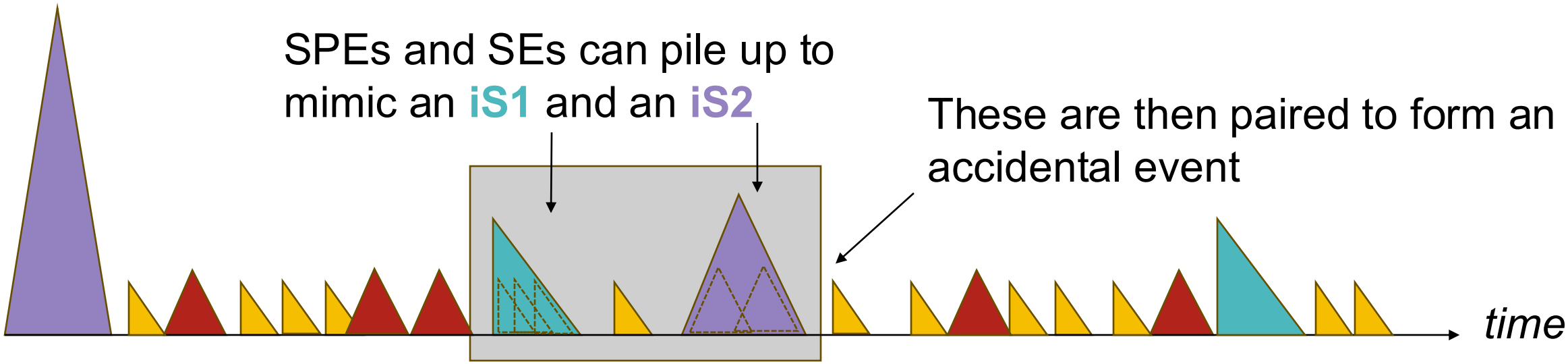


We model these events in LZ with a data-driven approach, pairing real isolated pulses in the detector together to create accidental events at the waveform level.

Detector Environment

The type of isolated pulse is dependent on the local detector environment

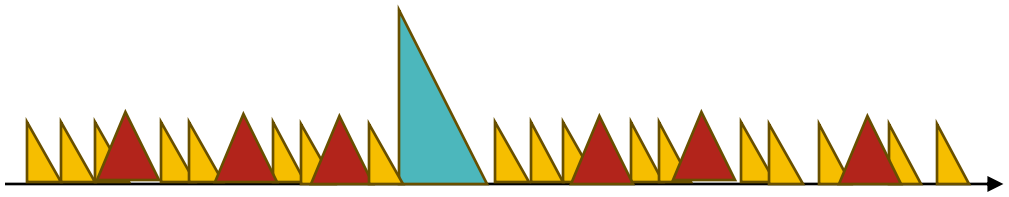
Following large events in the detector there is an elevated rate of **single photoelectrons (SPEs)** and **single electrons (SEs)**



Need to pair iS1s and iS2s according to their SPE-SE environment

Procedure

1. Look at events not containing physical scatters
2. Determine the SPE and SE rate in the first ms each event
3. Create a 2D “lookup table” in SPE-SE rate where each point corresponds to the chance to select an event containing an iS1 at a given rate



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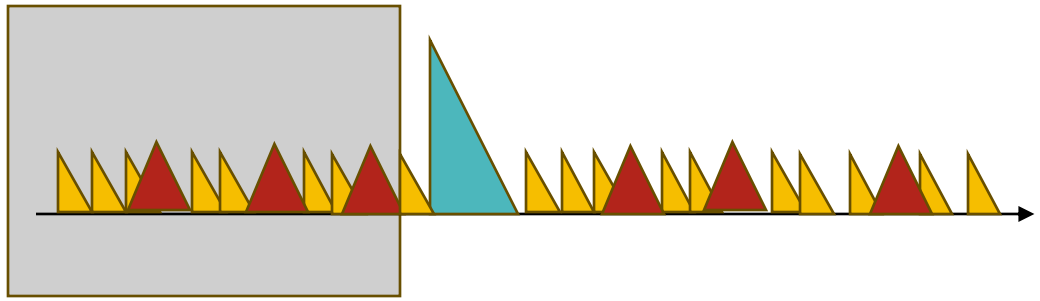
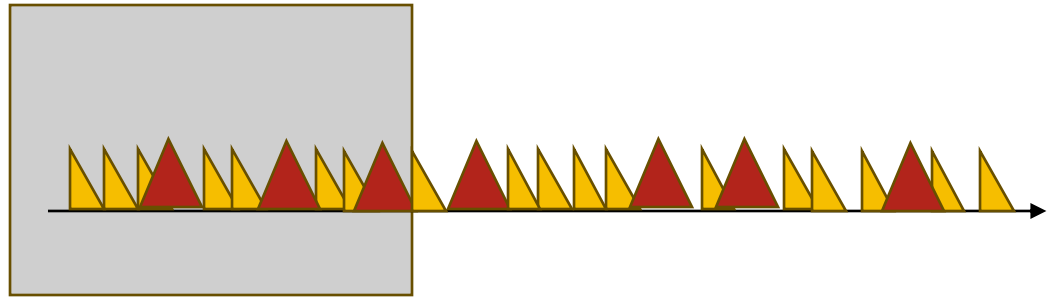


7 SPEs and 3 SEs



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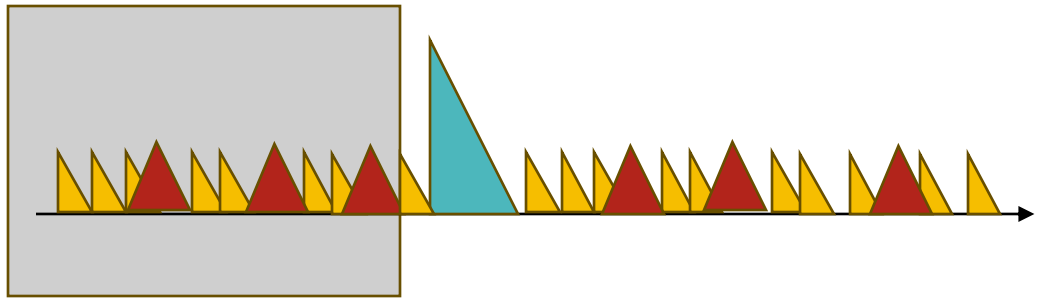

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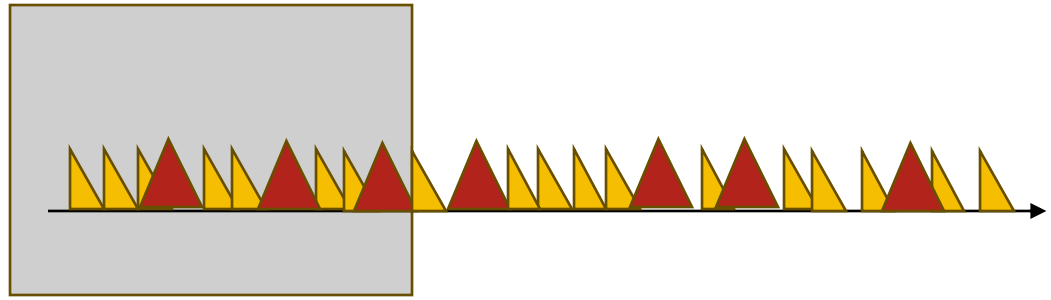


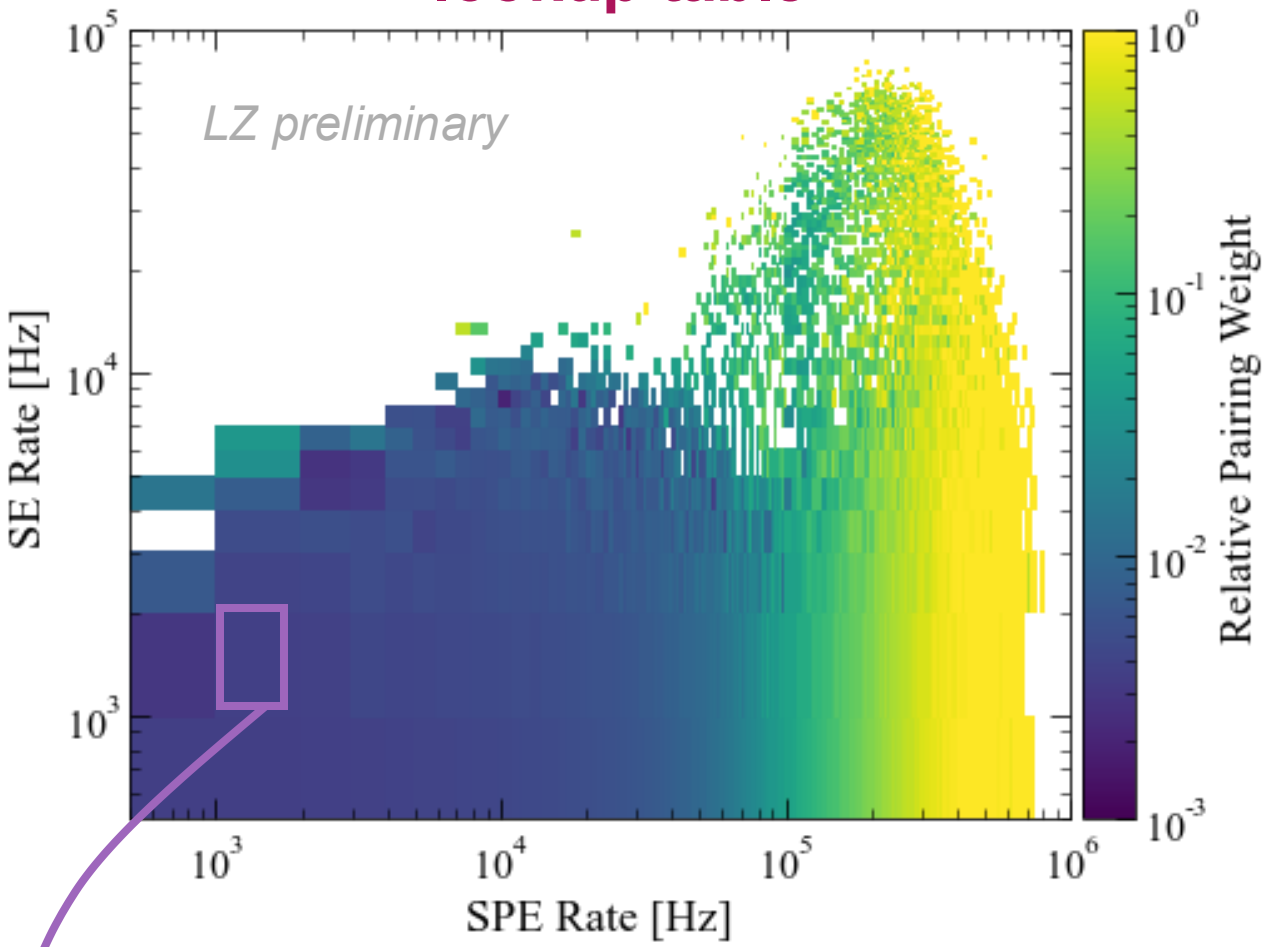
7 SPEs and 3 SEs

In a random event at a local SPE and SE rate of 7 and 3 kHz respectively we expect to see an **iS1 half of the time**

Procedure

1. Look at events not containing physical scatters
2. Determine the SPE and SE rate in the first ms of each event
3. Create a 2D “lookup table” in SPE-SE rate where each point corresponds to the chance to select an event containing an iS1 at a given rate
4. Multiply this by a 2D histogram of iS2 SPE-SE rates to get the number of events we want to make in each SPE-SE rate bin.

“lookup table”



x number of iS2s at this rate

Procedure

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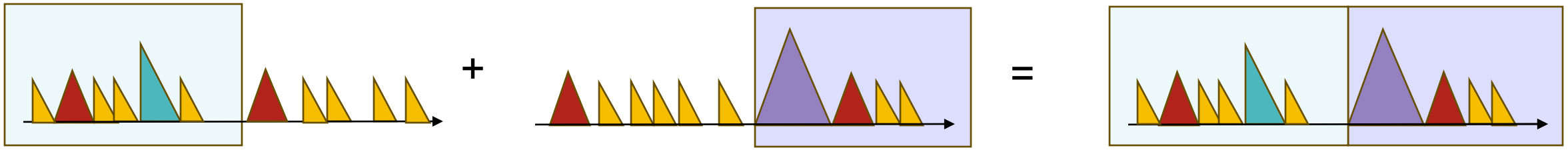
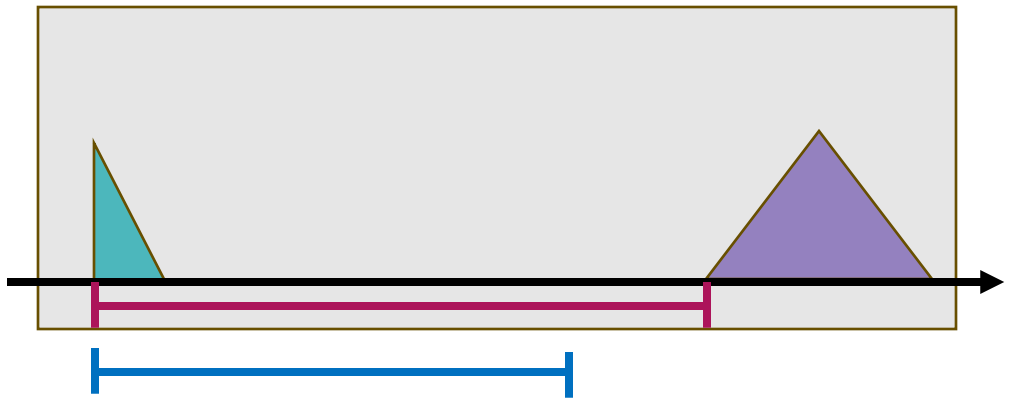
2. Determine the SPE and SE rate in the first ms of each event
3. Create a 2D “lookup table” in SPE-SE rate where each point corresponds to the chance to select an event containing an iS1 at a given rate
4. Multiply this by a 2D histogram of iS2 SPE-SE rates to get the number of events we want to make in each SPE-SE rate bin.
5. “Stitch” together iS2 events with iS1 events from the same SPE-SE rate bin



Comparing to data

- Need a sideband of accidental events
- Look at events which are classified as single scatters but have a drift time longer than is physical for the detector



Drift time > maximum drift length

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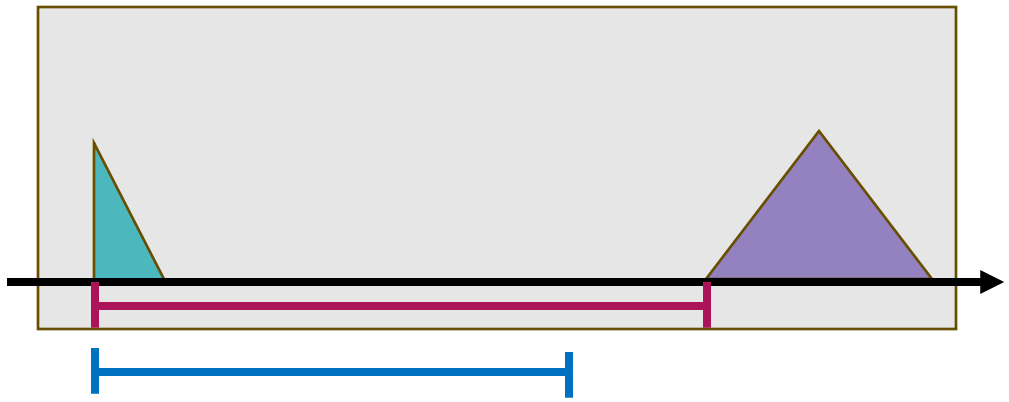

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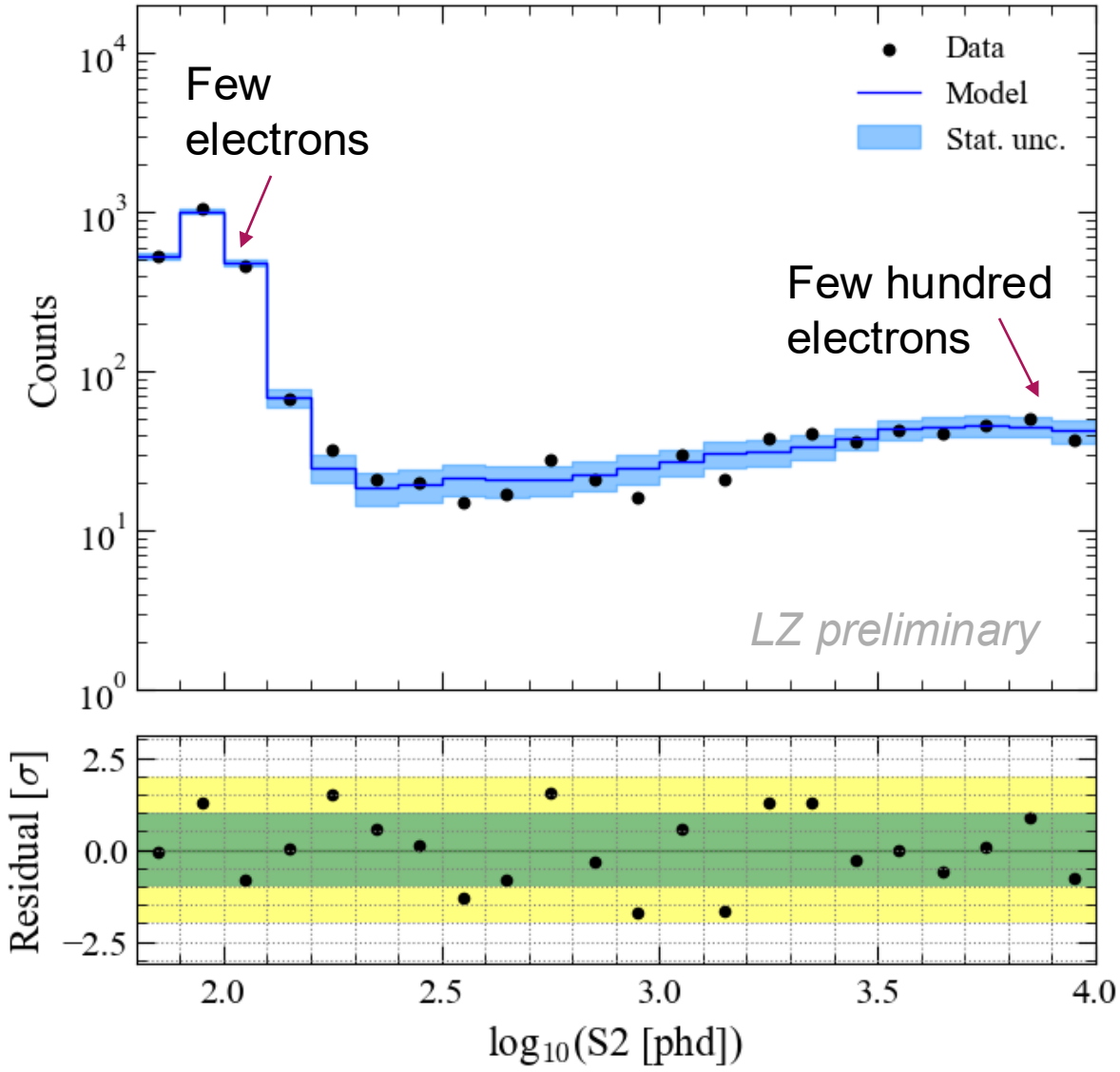

Conclusion

- Model accidental coincidence events in LZ using a data-driven approach
- Isolated S1 and S2 events are stitched together to form accidental coincidence events at the waveform level
- The SPE-SE environment of the iS1 and iS2 is matched
- Model matches what we see in data across a large energy range
- Accidental coincidence events are the dominant background for low mass WIMP searches, understanding and modelling them is crucial for LZ and future experiments

LZ (LUX-ZEPLIN) Collaboration, 38 Institutions

@lzdarkmatter

250 scientists, engineers, and technical staff

https://lz.lbl.gov/

- Black Hills State University
- Brookhaven National Laboratory
- Brown University
- Center for Underground Physics
- Edinburgh University
- Fermi National Accelerator Lab.
- Imperial College London
- King's 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
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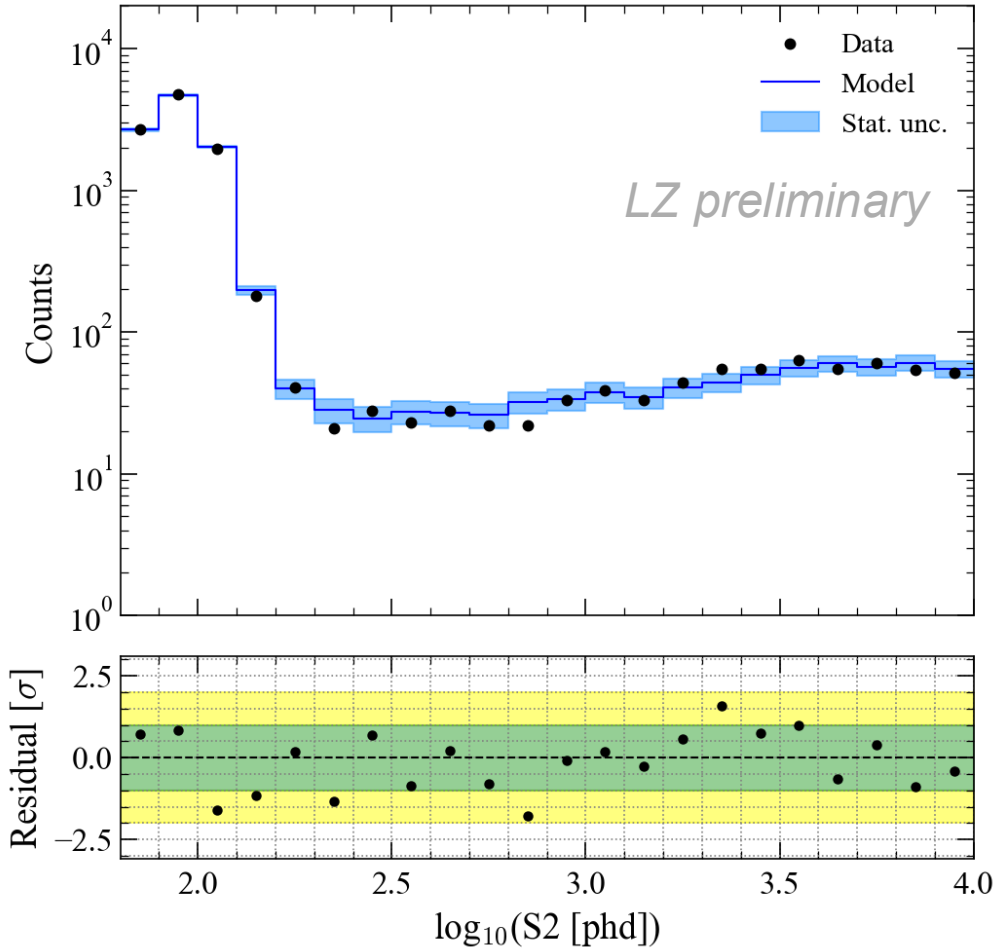
Backup

Further validations

High SPE-SE rate dataset



AmLi Calibration dataset