Saturation corrections in the LUX-ZEPLIN experiment

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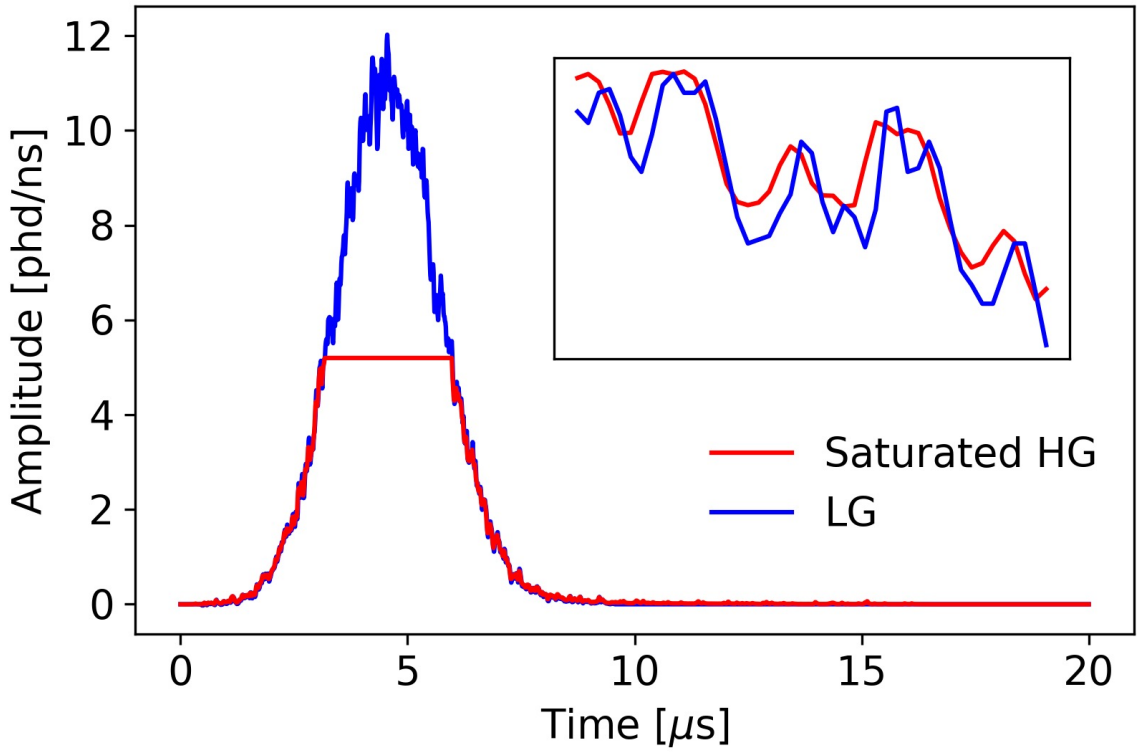
Illustration by Sandbox Studio, Chicago with Ana Kova

Introduction

- LZ designed for WIMPs, with nuclear recoil energies of $\mathcal{O}(10)$ keV_{nr}
- PMTs operated with **dual-gain** output:

	Area gain	Shaping (FWTM)
High gain (HG)	40	60 ns
Low gain (LG)	4	30 ns



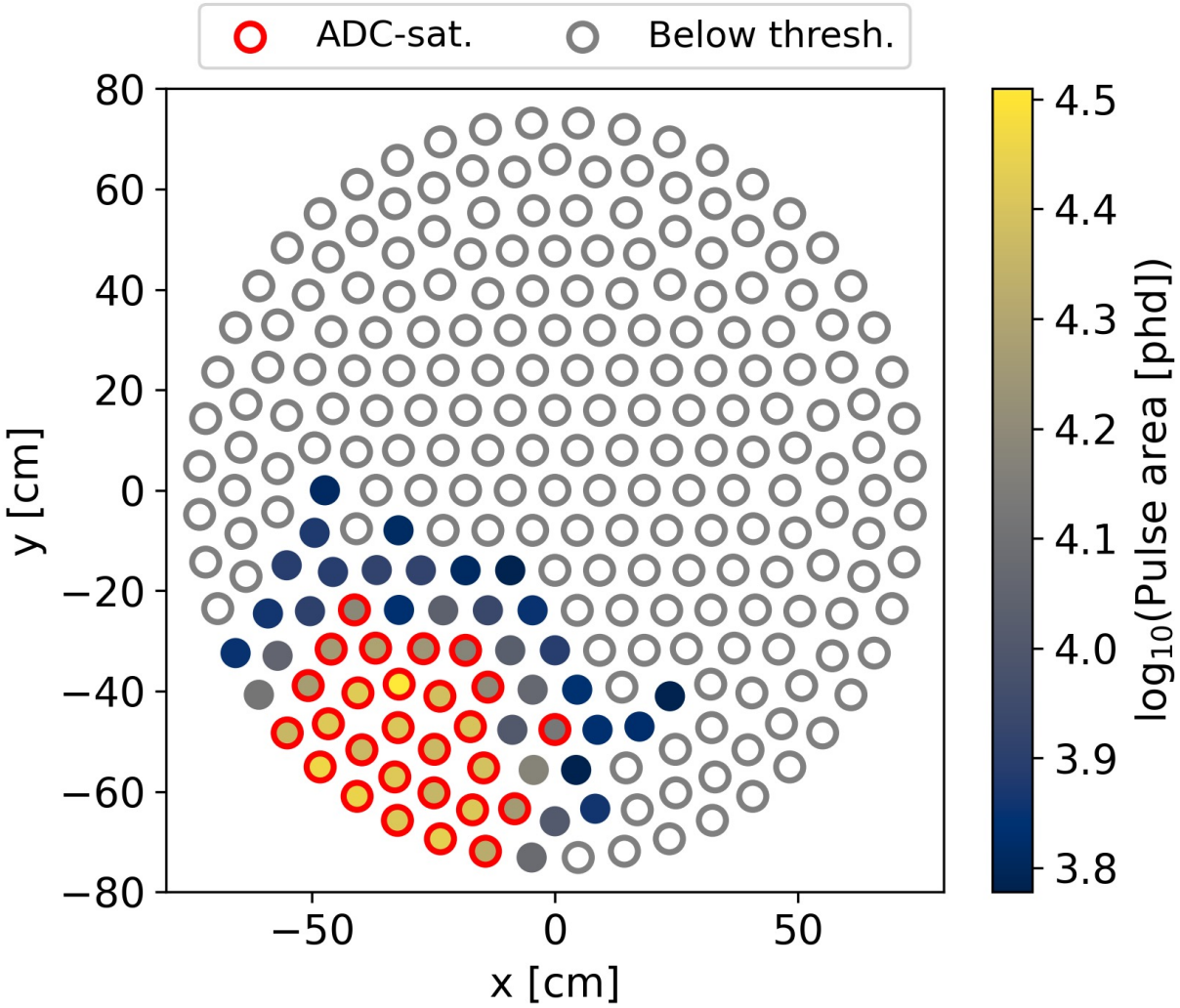
- Signals from ~200 keV_{ee} events can exceed 2 V dynamic range of DAQ
  ⇒ **ADC saturation**
- Impacts **reconstruction** and **resolution** of **position** and **energy**, relevant for high-energy searches and backgrounds, when **LG can saturate**

Proposed method (1)

- Various possible approaches for **saturation correction,** e.g. functional fits, machine learning
- This approach uses the **nearest non-saturated neighbour** as a template waveform

⇒ assumes neighbouring PMT signals have **comparable widths**

- PMTs addressed in order of **proximity to interaction vertex**, starting with the *furthest*



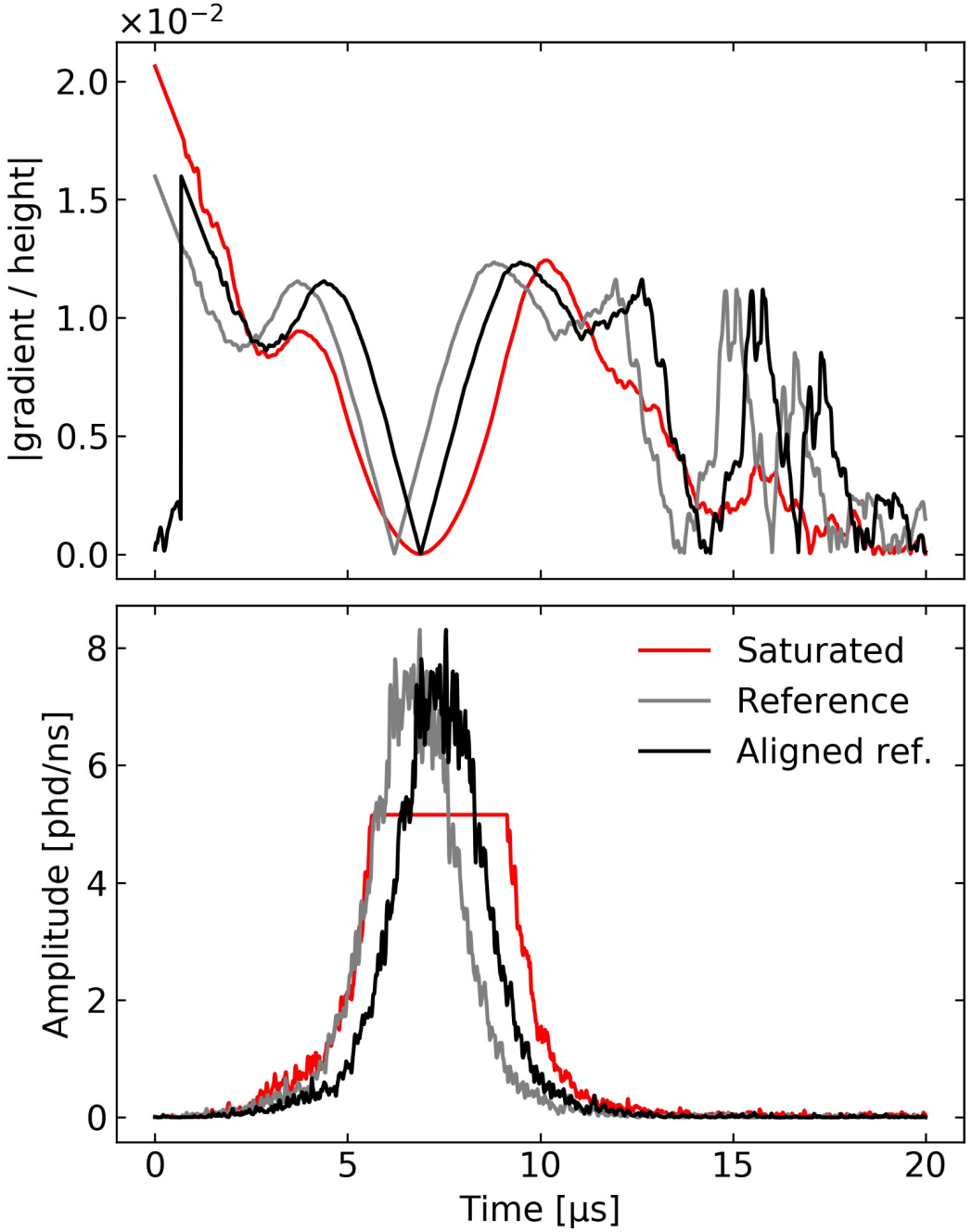
Proposed method (2)

- For a given saturated signal, the reference must first be **aligned**

Utilise **smoothed gradient/height space**, with match point at **absolute minimum**

⇒ assumes peaks are **approximately Gaussian**

- Possible complications expected for:
  - **asymmetric** waveform shapes
  - **double-peaked** waveforms

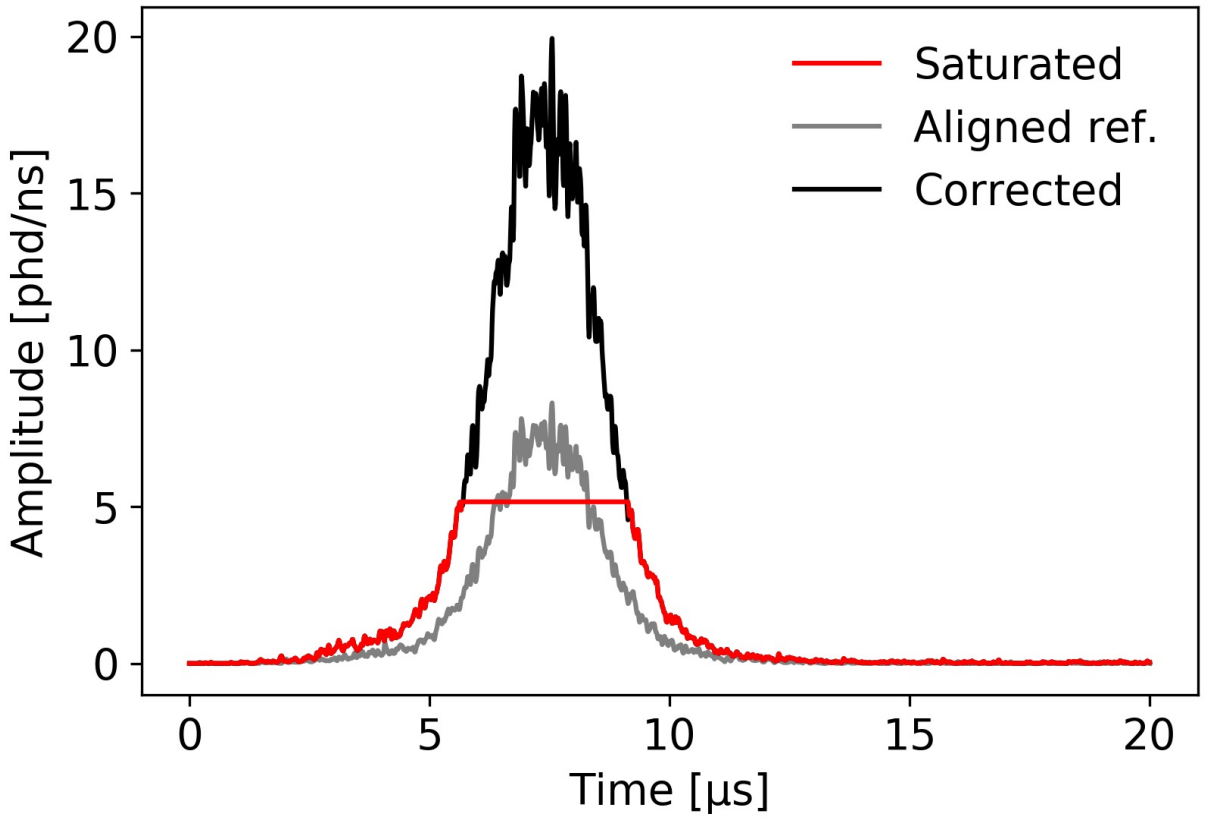


Proposed method (3)

Aligned waveform is **scaled up** such that rises **intersect** at start of **saturated interval**

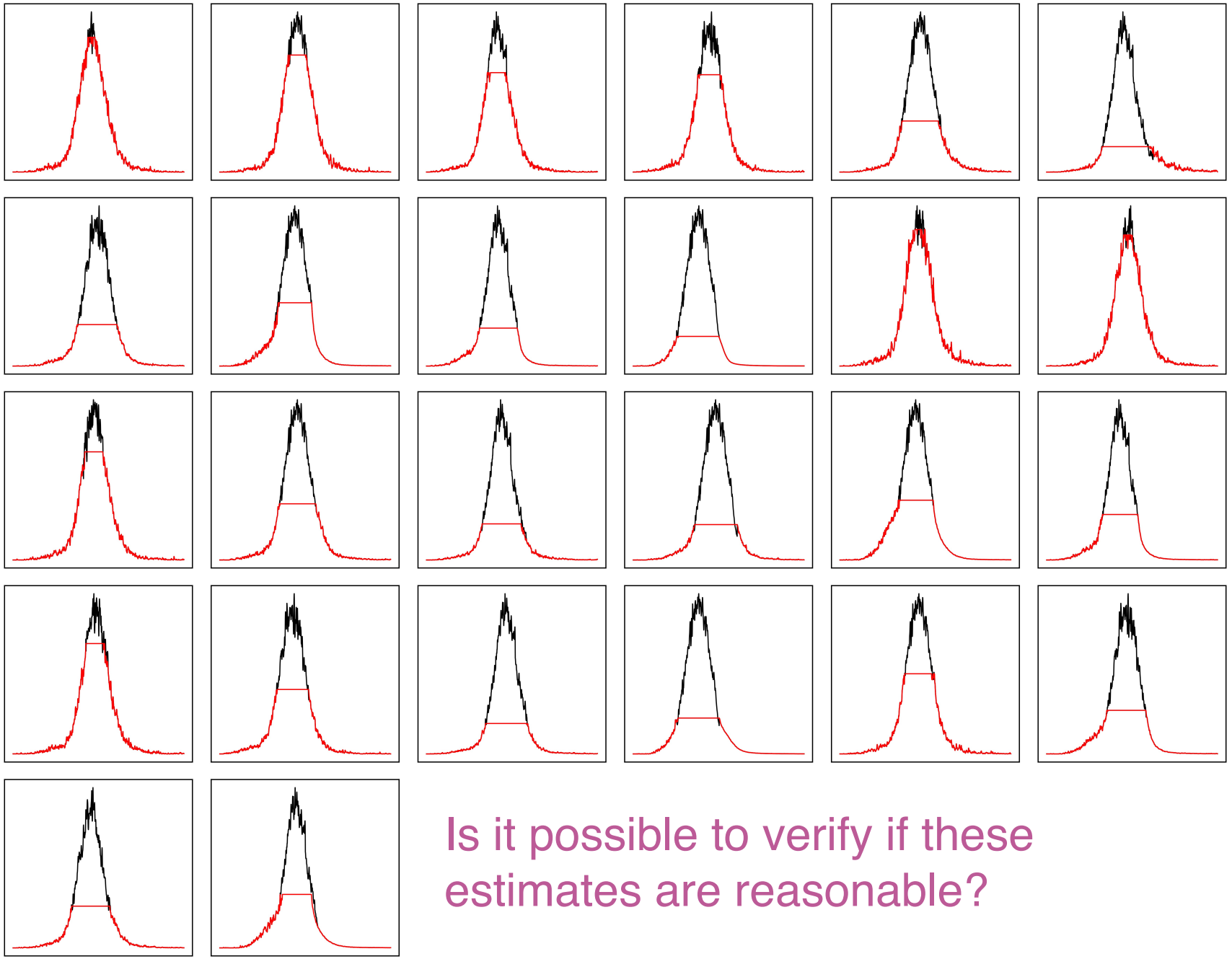
Original rise and tail are **stitched** at **intersection points** (where possible*)

*otherwise defaults to discontinuous cut-off



- PMT **updated with result**; may be used for subsequent corrections
  ⇒ *could lead to systematic error*

What does this look like for the **entire cluster**?



Single-event example

- Total of 27 saturated waveforms considered

Negligible saturation if
<10 saturated samples

- Outcomes appear qualitatively good, but…

Is it possible to verify if these estimates are reasonable?

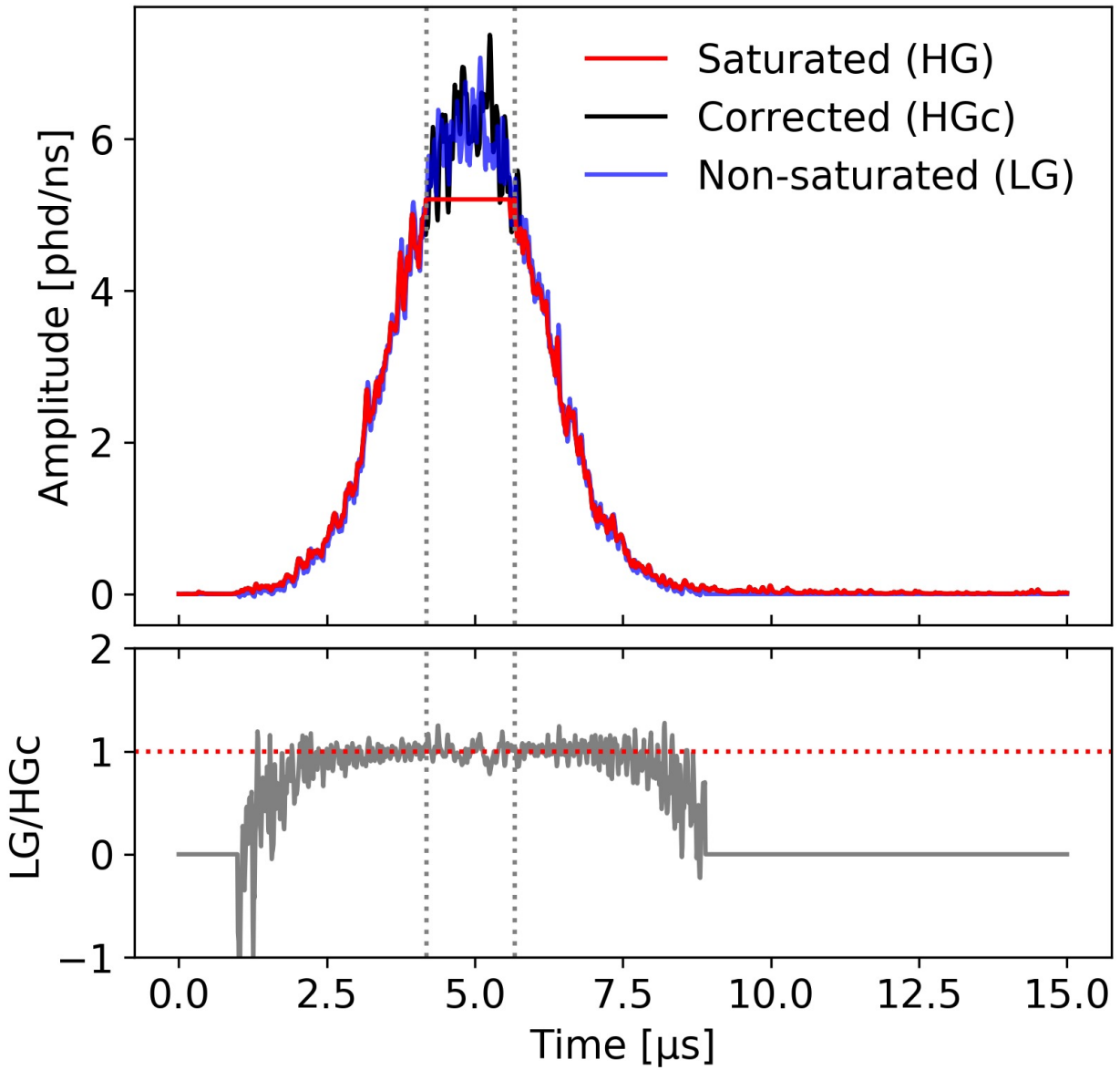
Validation with LG

- Consider events with **saturated HG** and **non-saturated LG**

Use **LG waveform** as proxy for **true shape** to validate method

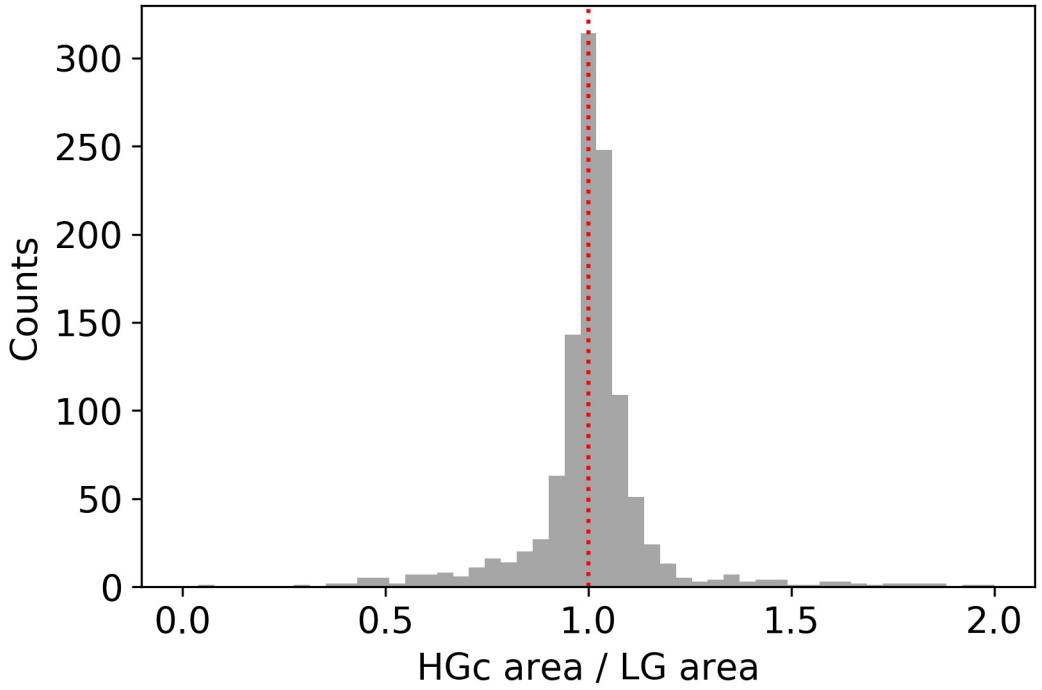
- Accuracy of method mainly depends on **energy** (maximum amplitude) and **depth** (pulse width)

Along with pulse **area**, use peak **height/width ratio** as a metric

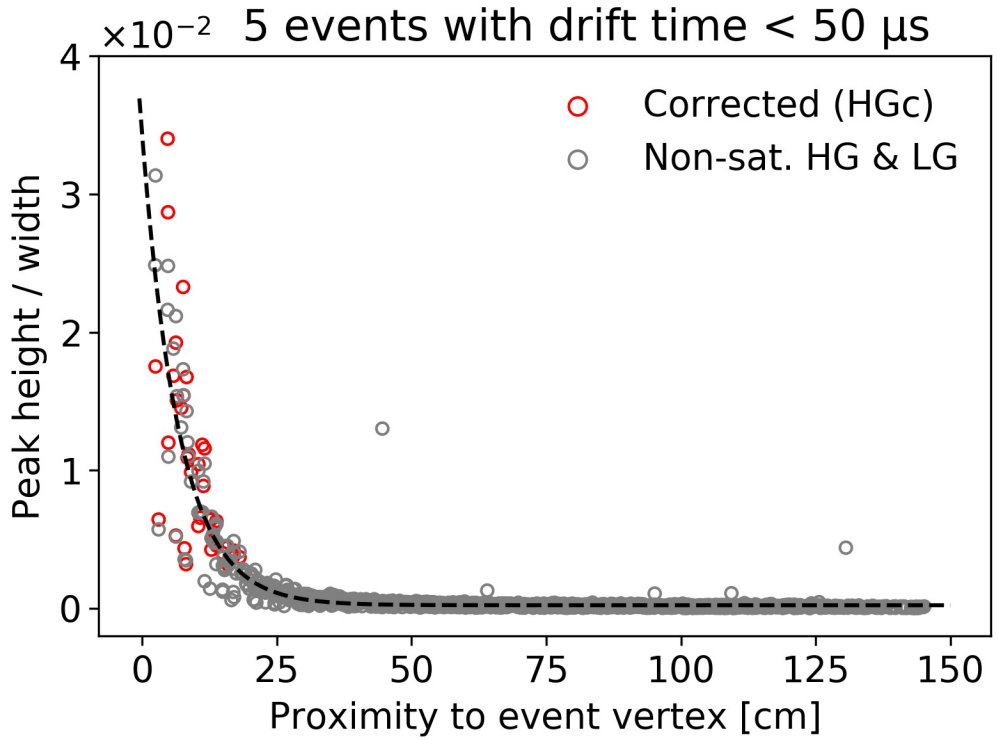


Validation with LG

Corrected area is fairly consistent with expectation – ratio at:
(1.008 ± 0.005)



Peak height/width behaviour is **similar** between corrected and non-saturated cases



Summary

- Demonstrated a simple method to correct for ADC saturation
- Enhances high energy searches and background characterisation

What's next?

Assess for a **large set** of high-energy events; measure impact on **energy resolution**

Investigate **variations in performance** with energy, position, etc.

Thanks for listening!

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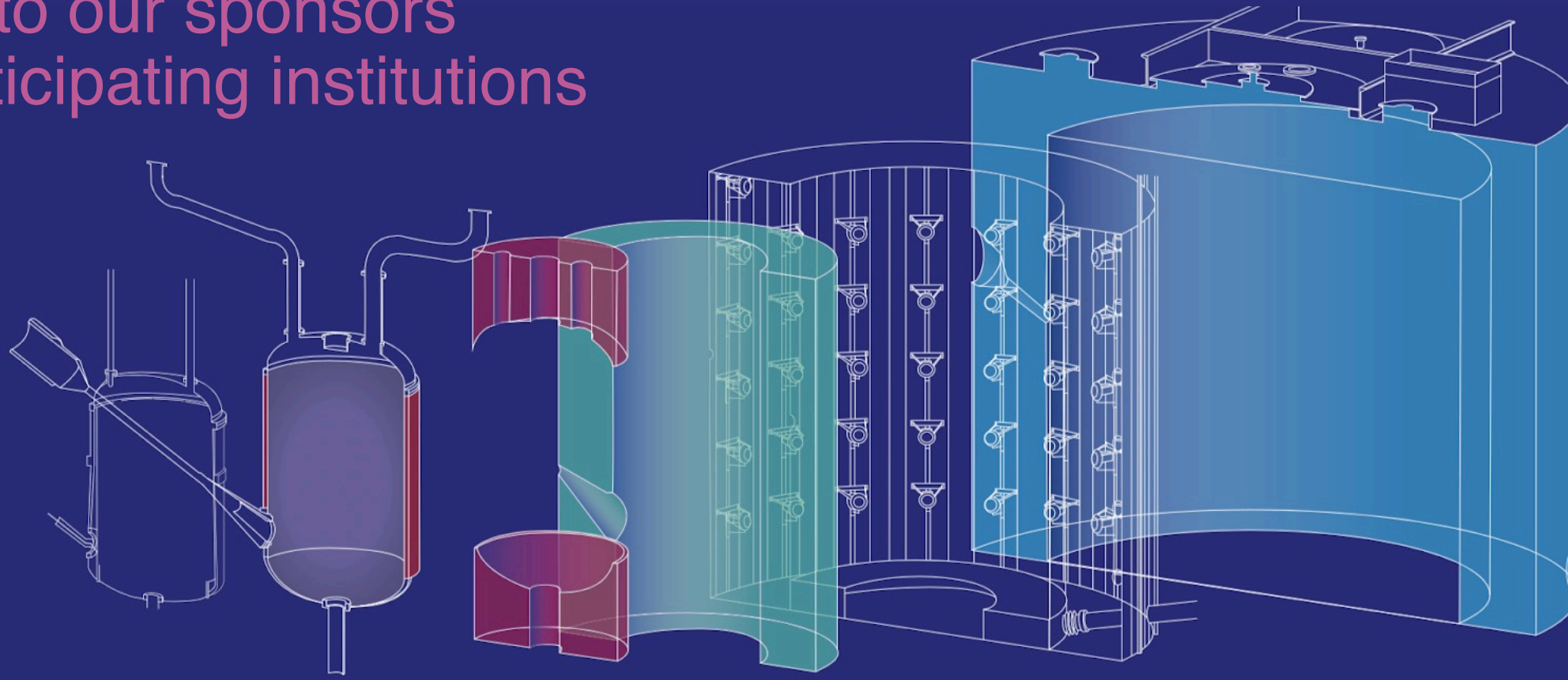

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