

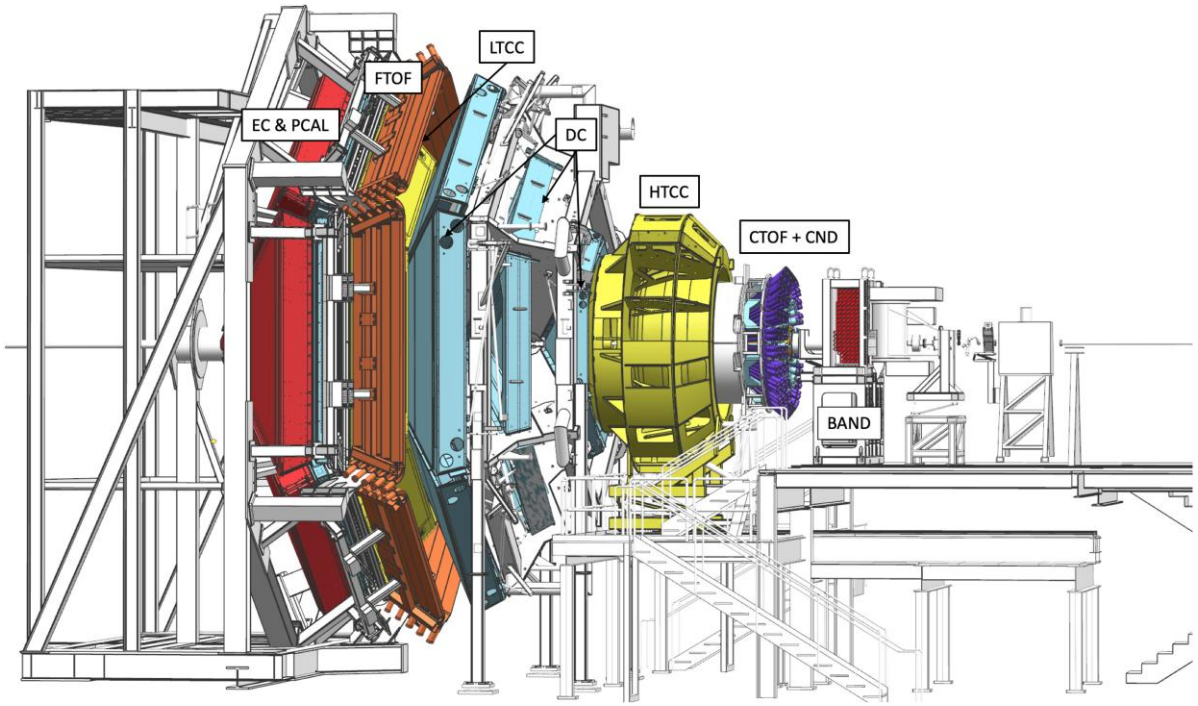
Pile-up Treatment in ALERT

Kathleen Ramage
Raphael Dupre, David Hamilton and Maxime Defurne
CLAS Collaboration Meeting November 2026

Jefferson Lab

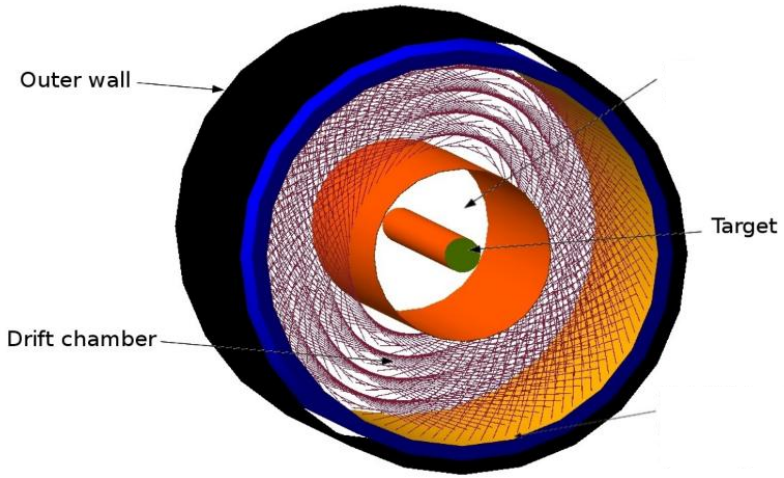
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Outline

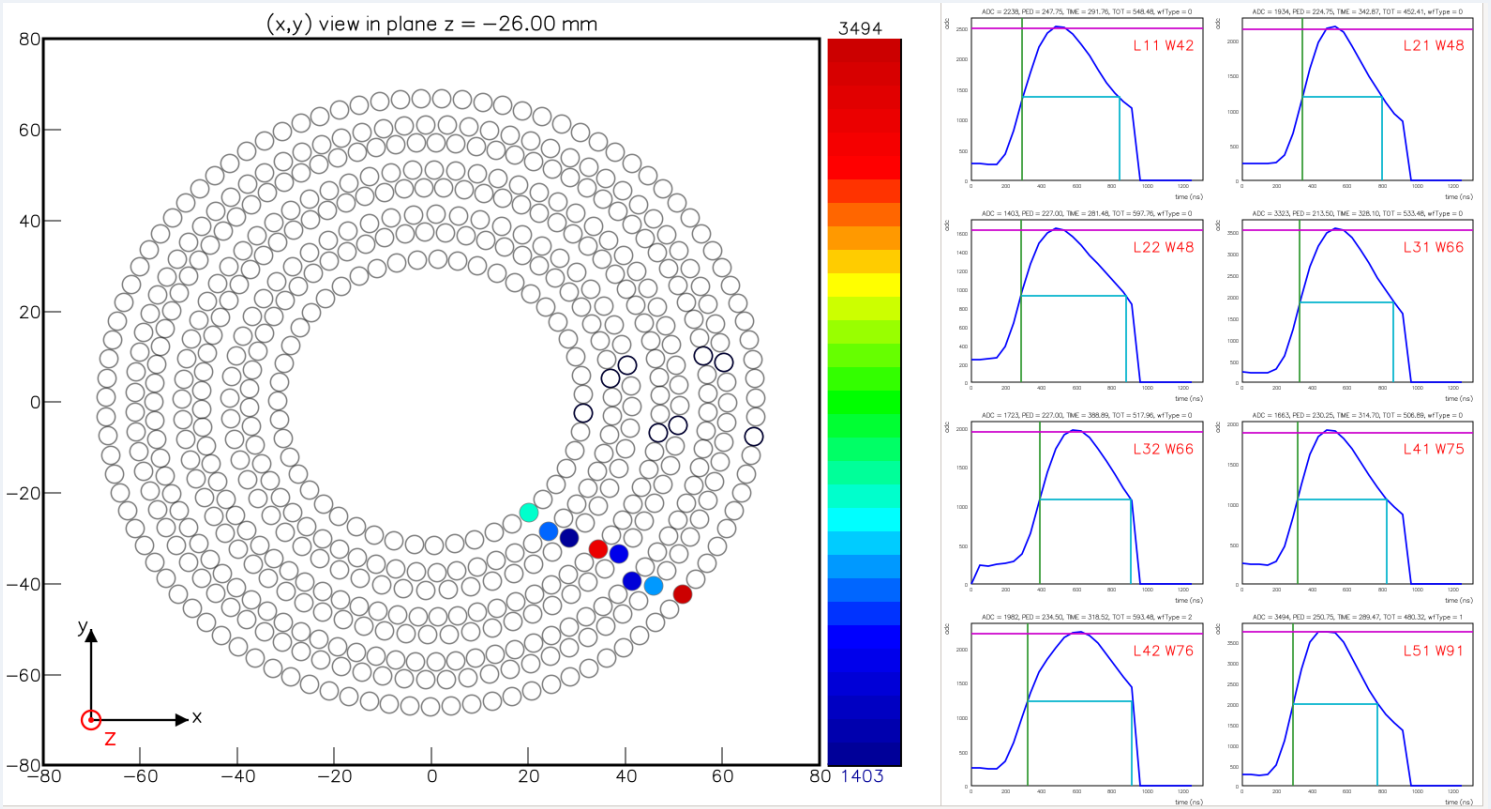


1. AHDC signals
2. Motivation for pile-up detection
3. Toy simulation
4. Detector features
5. Efficiency: definition and maps
6. Real-data checks
7. Summary and next steps

ALERT Hyperbolic Drift Chamber



- **He4/CO2** gas mixture (80/20)
- **2 mm** wire spacing
- **DREAM** chip read out
- Event level data



GUI tool kit for the AHDC https://github.com/ftouchte/amon-gui

Waveform types 0-6

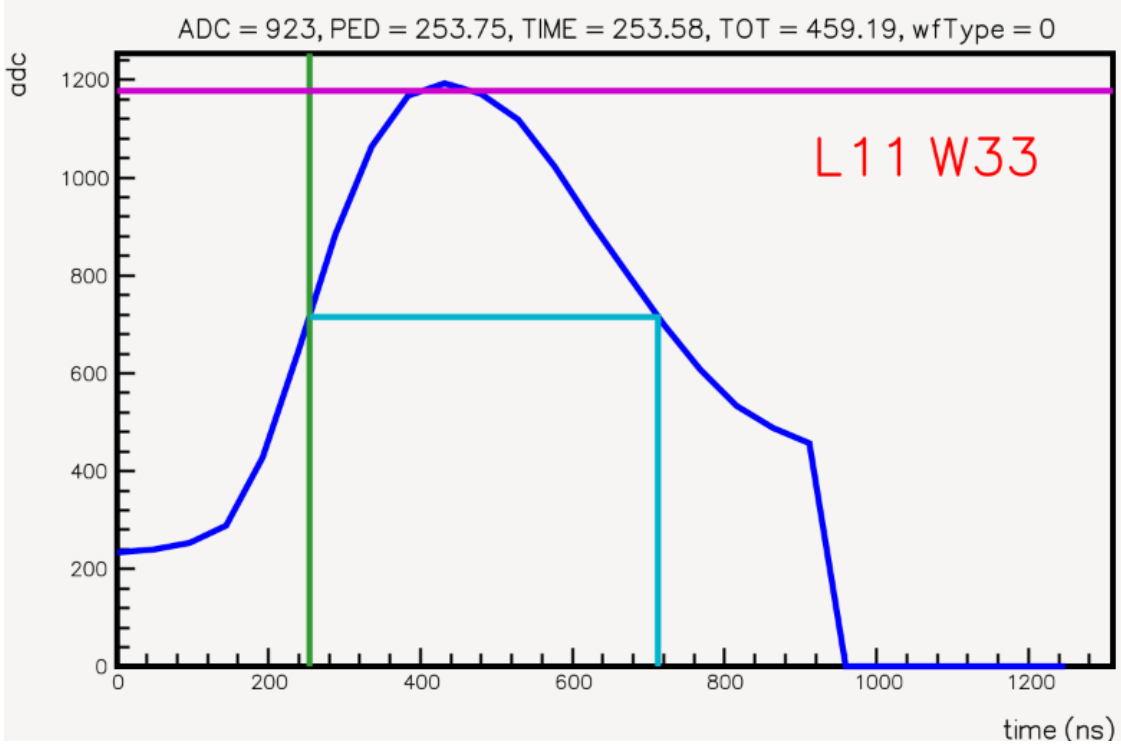
Waveform type 0 (good):

- Passes all quality checks
- **48 ns** per sample
- Up to **20 samples** analysed – 960 ns window

Type	Characteristic
1	Saturated (> 3500 ADC)
2	Bad trailing edge
3	**Pile-up**
4	Short ToT (< 300 ns)
5	No leading edge
6	Too few samples (< 10)

Types 4-6 are not used in reconstruction

Example type-0 waveform (layer 11, wire 33)



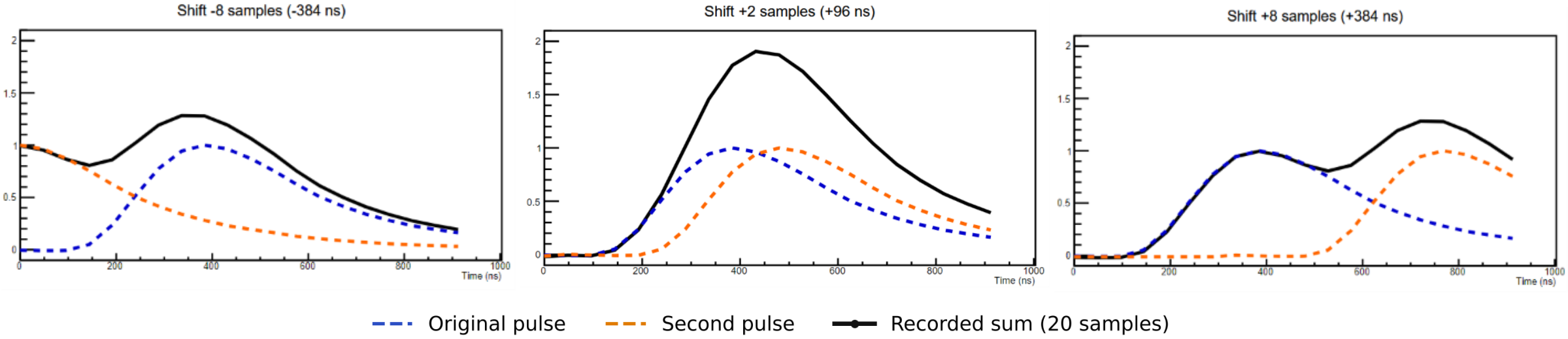
Leading-edge time, **time over threshold**, **amplitude**

Pile-up in the AHDC

Two hits on one wire within one 960 ns readout window

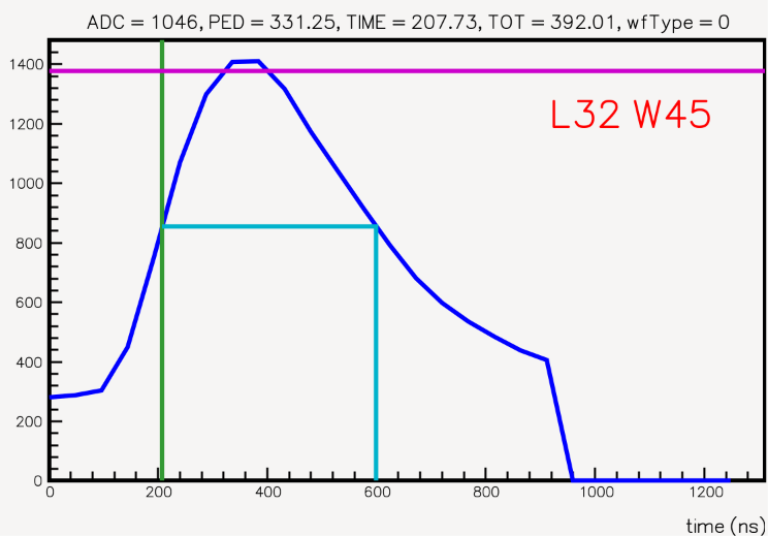
1. **Same event**: two particles hit the same wire
2. **Different events**: background hits recorded in the same window (more likely at **high rate**)

Pile-up distorts **timing** and **amplitude** – we want to identify the affected waveform

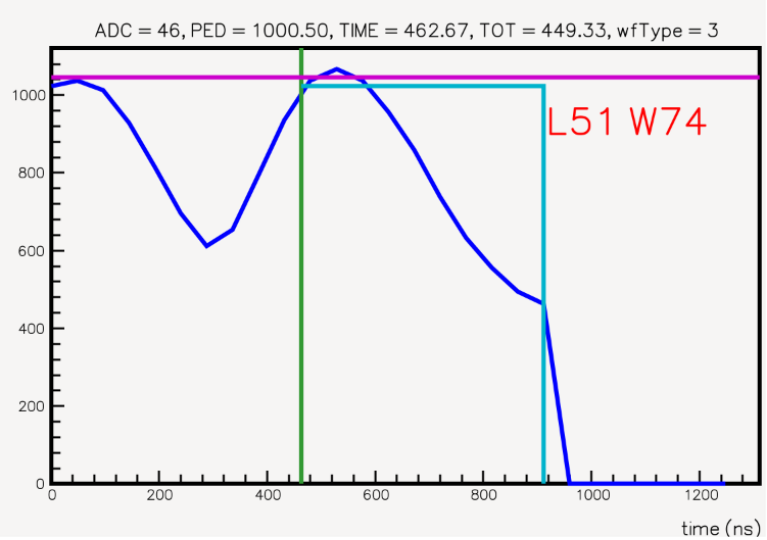


Pile-up effects

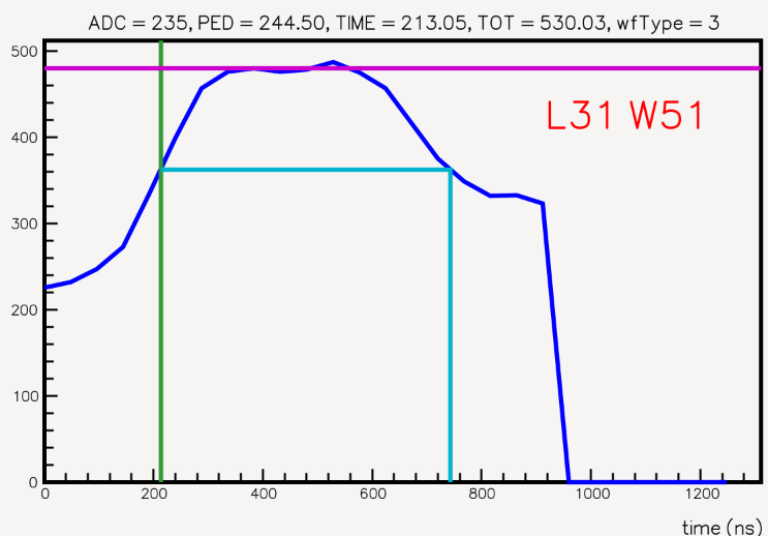
Track reconstruction relies on timing and amplitude – pile-up directly affects tracking efficiency



Good type-0 pulse



Amplitude 46 ADC



ToT 530 ns

Wrong time = wrong drift distance → Wrong amplitude = wrong 50% crossing → Fewer good hits on the track → **Track can be lost**

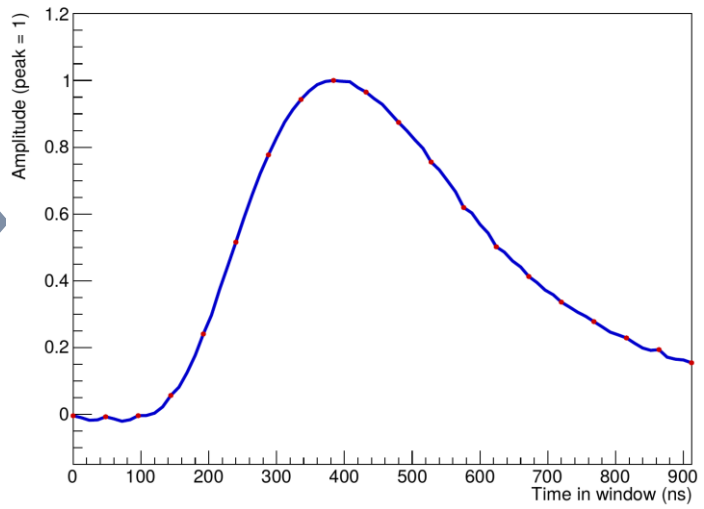
Building a toy simulation

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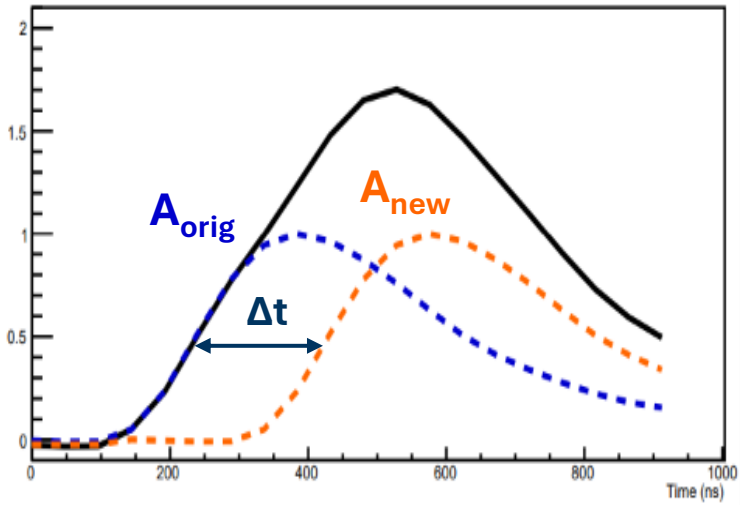
1 Select type-0 pulses

- Peak above pedestal ≥ 400 ADC
- Pulse inside 200 - 700 ns
- 10% of pedestal baseline
- Valid 50% leading-edge crossing
- Retains number of samples
- **Template – 20 samples**

2 Align and average



3 Shift, scale, combine



Average-template pairs

Choose cuts

- Template + shifted, scaled copy
- **Δt = ±1-15 samples, R = A_{orig}/A_{new} = 0.1-3**
- Isolates the effect of timing and amplitude

Mixed real-waveform pairs

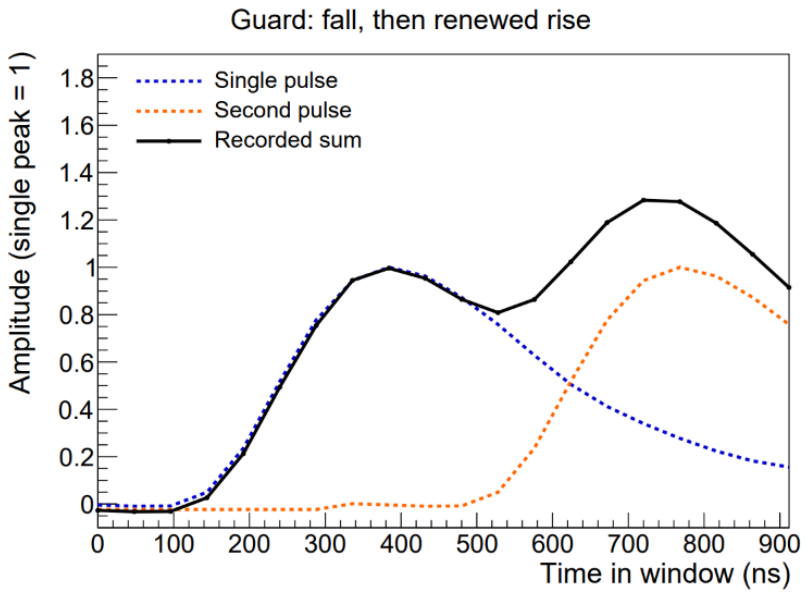
Validation

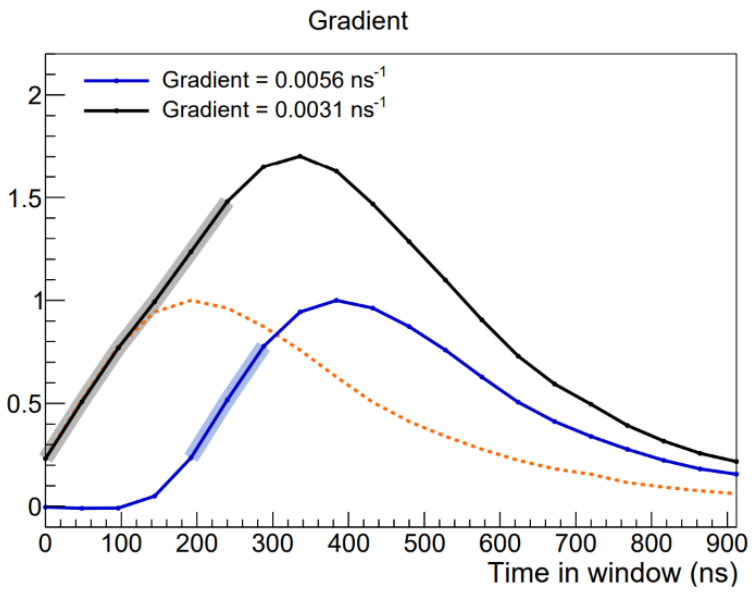
- Two **different** recorded type-0 **pulses**
- Each keeps its own shape, noise and length
- New pulses used, every 1 ns shift

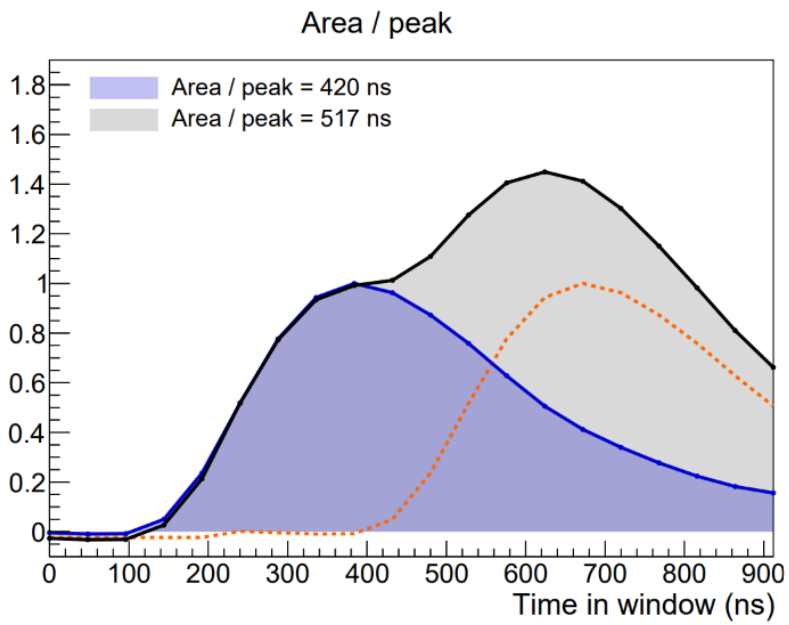
Detection features

- Resolved two peak pile-up is straight forward to detect for shifts $\Delta t \geq 8$ samples
  - Requires a **fall followed by a renewed rise**

- For pile-up with shifts $\Delta t \leq 8$ samples, shape distortions become more useful
  - **Gradient** of leading-edge **decreases** with pile-up
  - **Area** under the pulse **increases** with pile-up

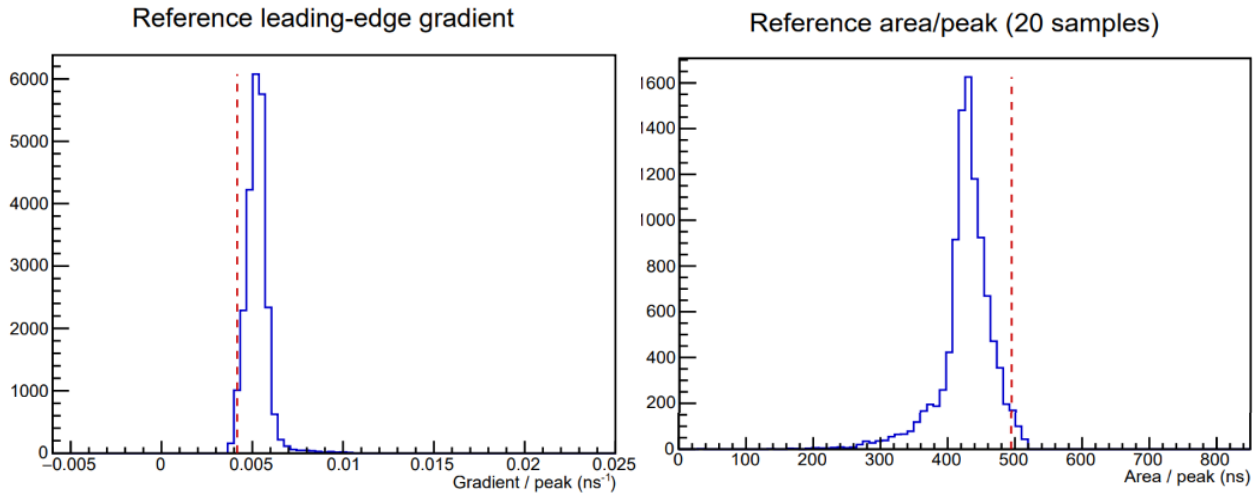


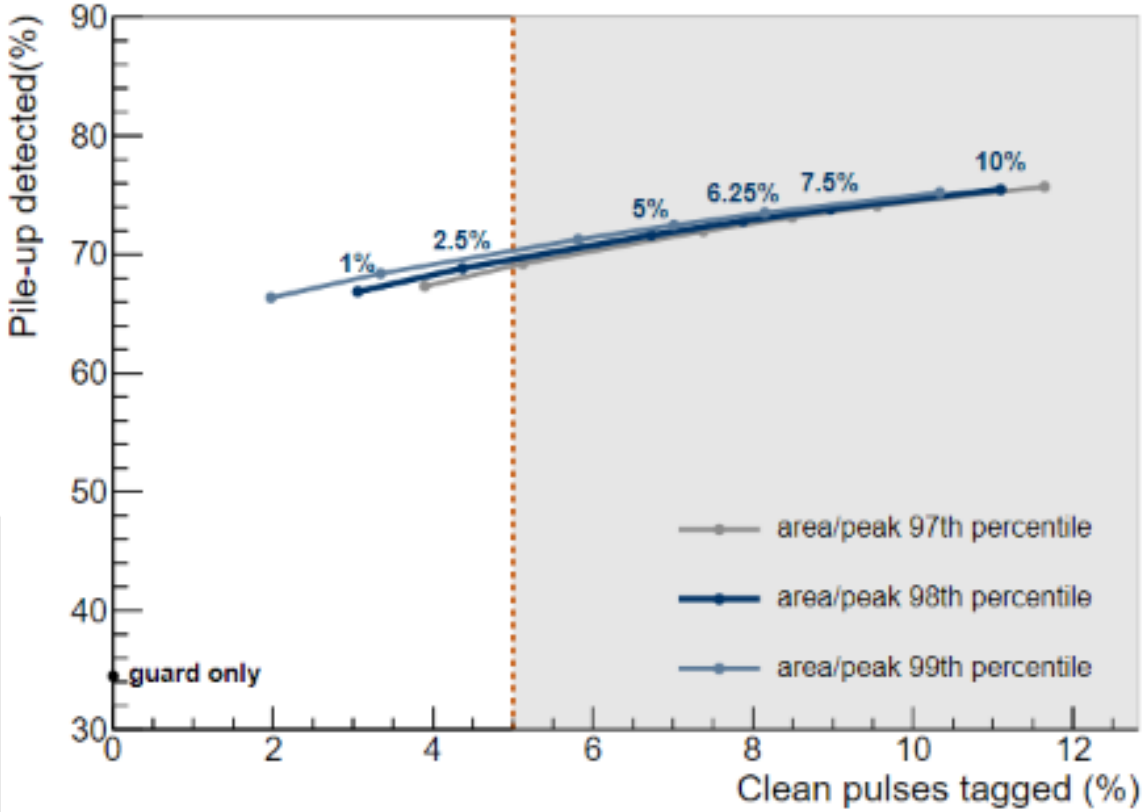




Selecting feature cuts

- **Cut = a percentile of clean pulses.**
- Limit: **≤ 5%** of clean pulses tagged
- Cuts: Gradient 2.5% + area 98%





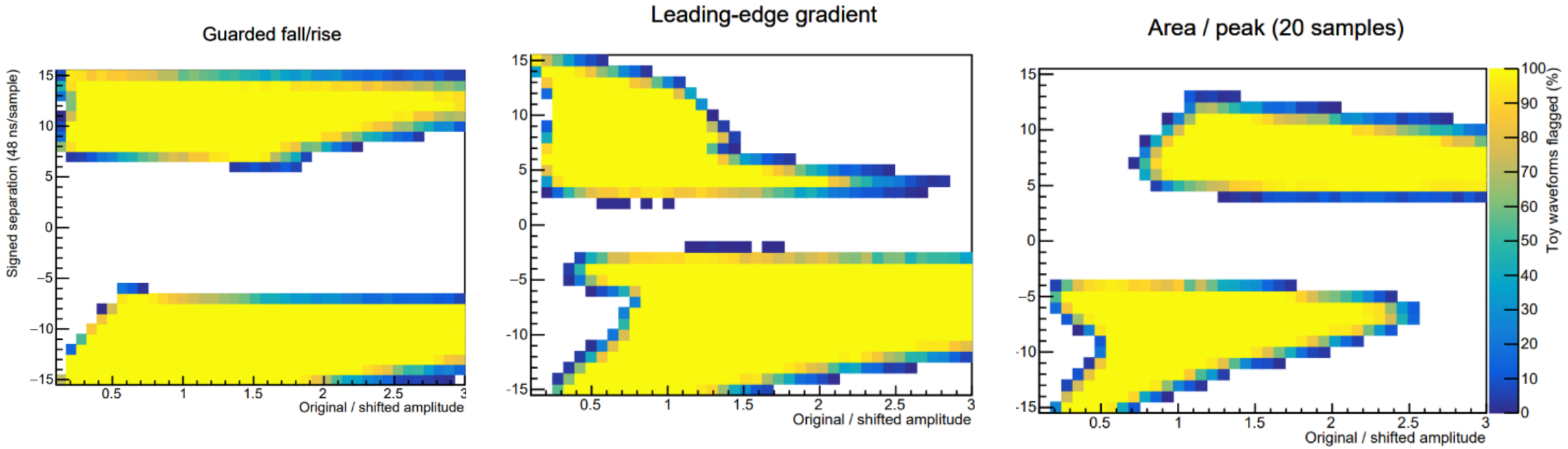
Pile-up detection efficiency versus clean-pulse tag rate

Efficiency of each cut

- Efficiency defined by

$$\varepsilon(\Delta t, R) = \frac{N_{flagged}(\Delta t, R)}{N_{pairs}(\Delta t, R)}$$

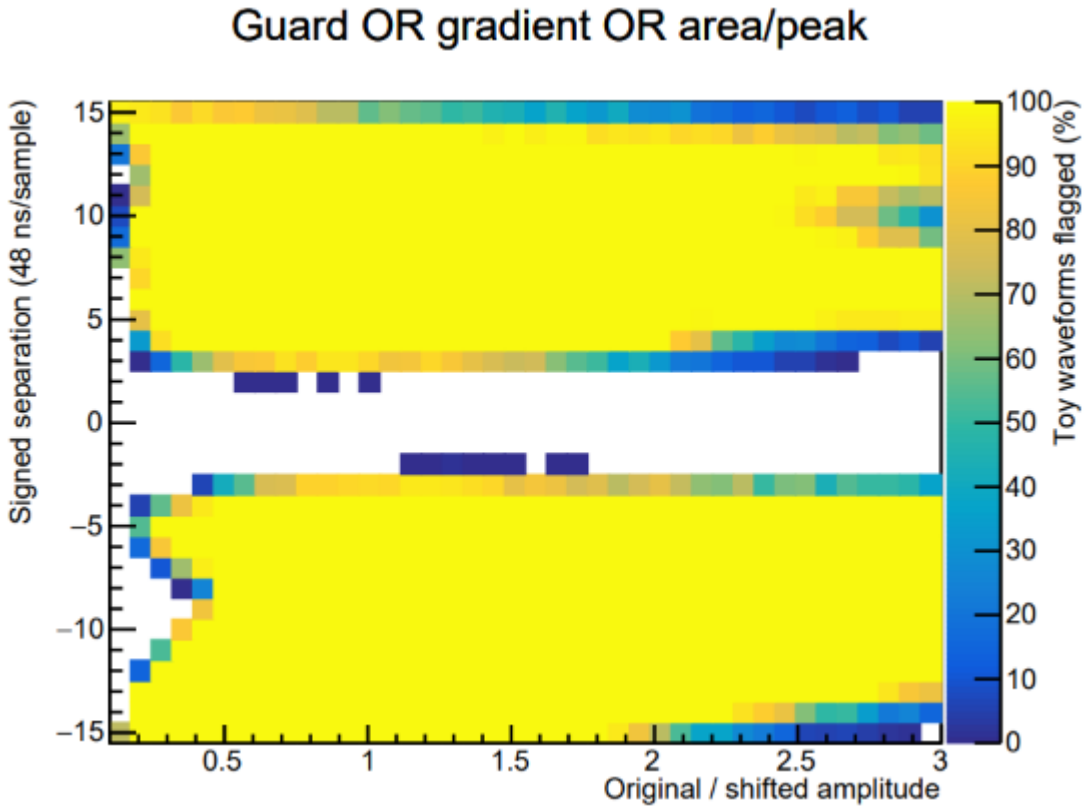
- The guard catches clearly separated pulses, the gradient catches pulses on the rising edge, and area/peak catches extra width.



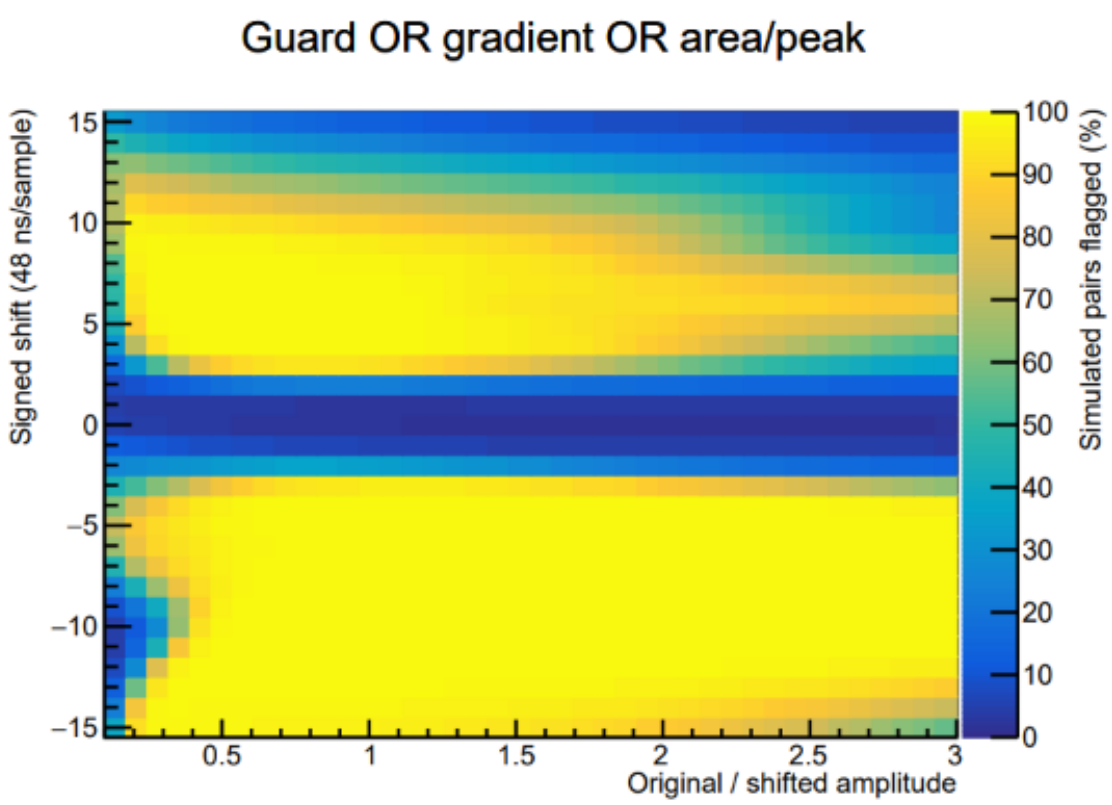
Detection efficiency maps

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Average-pulse toys



Real-pulse pairs



- At large positive Δt the second pulse falls outside the recorded window. Real windows vary in length (13–20 samples) and pulse position, accounting for the difference in averaged vs real pulses.

Performance on real pulses

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Final configuration

Guard fall ≥ 2%, trough ≥ 10%, rise ≥ max(5%, 50 ADC)

Gradient < 2.5th %ile (0.00418 ns^{-1})

Area/peak > 98th %ile per length (396–496 ns)

70%

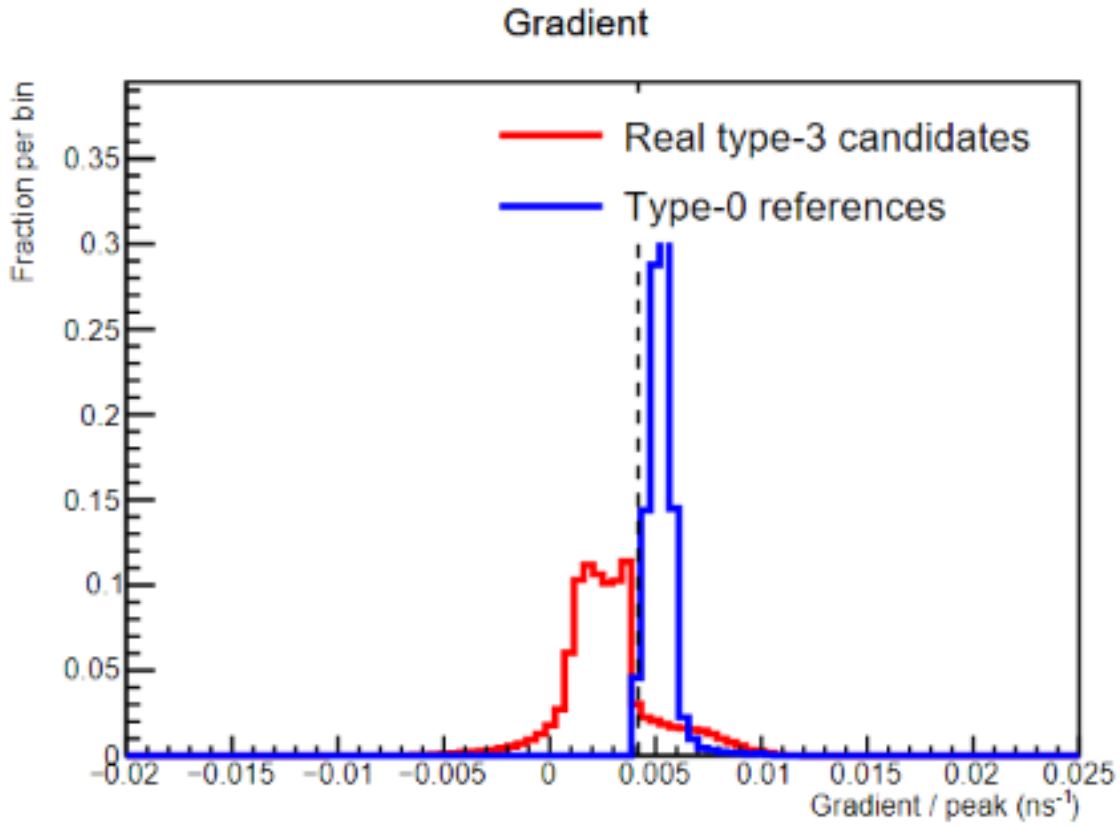
Pile-up flagged for Δt = ±1-15 samples, R = 0.1-3

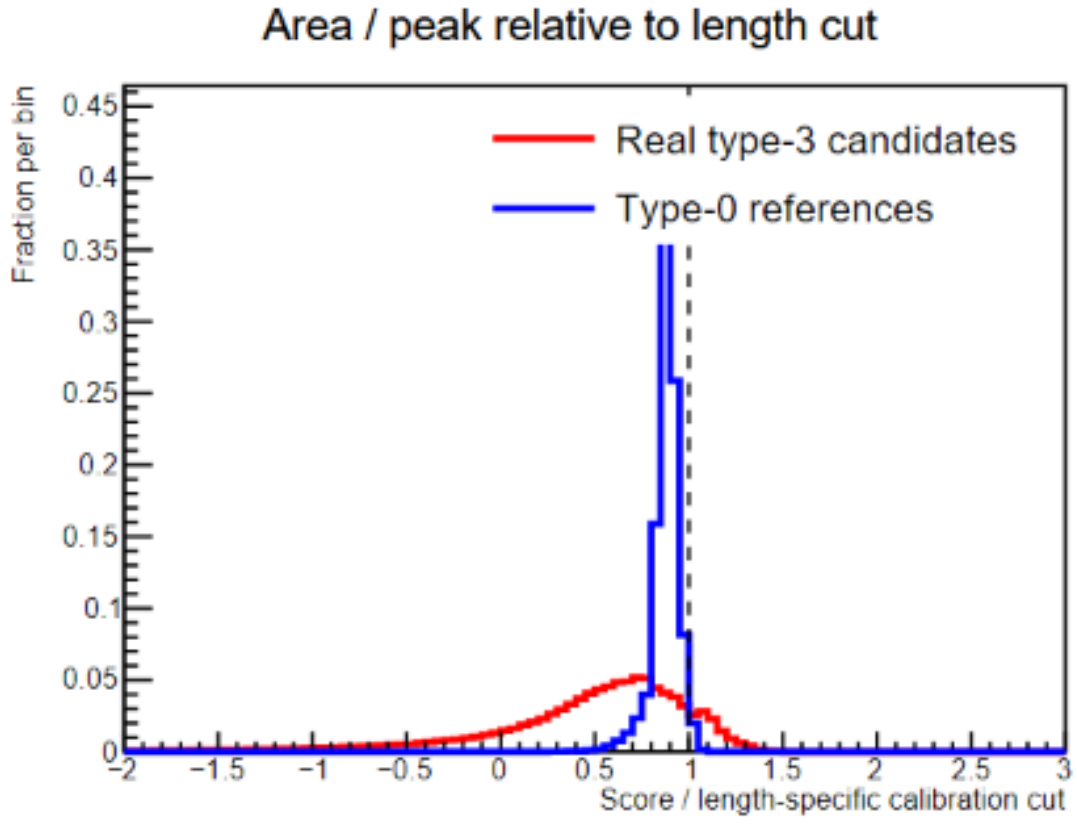
4.5%

Clean pulses flagged (false positive proxy)

Blind spot at $|\Delta t| = 1 - 2$ samples where two pulses merge

Type-3 consistency check



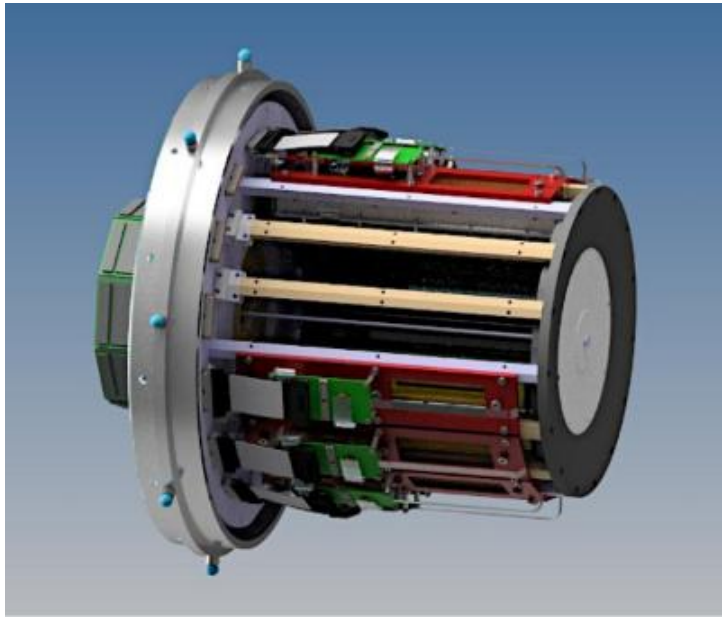


- **Type-3 waveforms re-checked:** guard **53%**, gradient **77%**, area **10%**
- **Gradient clearly adds information:** type-3 gradients extend far below clean pulses

Summary and next steps

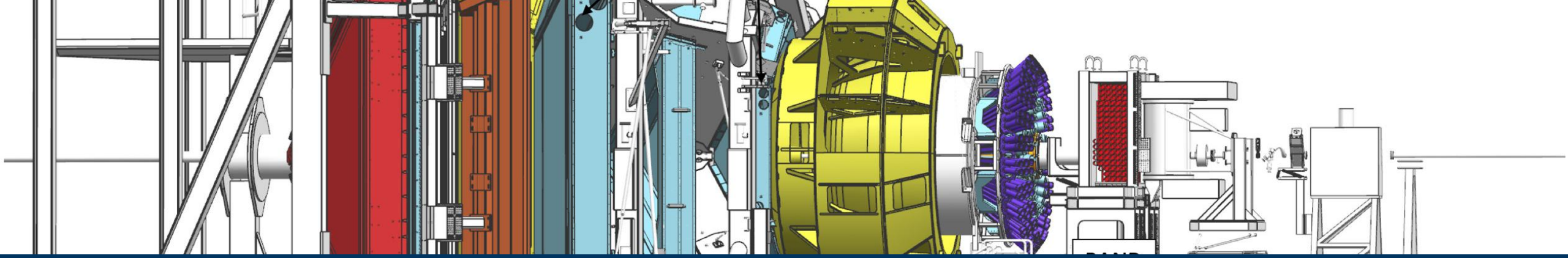
Summary

- Three feature algorithm: guard, gradient, area/peak
  - Cuts are percentiles of clean pulses: gradient 2.5%, area/peak 98%
  - Set on one half of the data, tested on the other - both studies agree
- Performance on real pulse pairs
  - 70% of all simulated pile-up flagged
  - 4.5% of clean pulses tagged
  - Blind spot: merged pulses, $|\Delta t| \lesssim 2$ samples



Next steps

- Weight toys by the measured amplitude spectrum
- Reconstruct true pulse timing and amplitudes from pile-up contamination with fitting
- Quantify the effect on tracking efficiency



Thank you for listening

Kathleen Ramage

CLAS Collaboration Meeting November 2026

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