LAPPD activities at Sheffield

Multiphoton reconstruction on stripline LAPPDs

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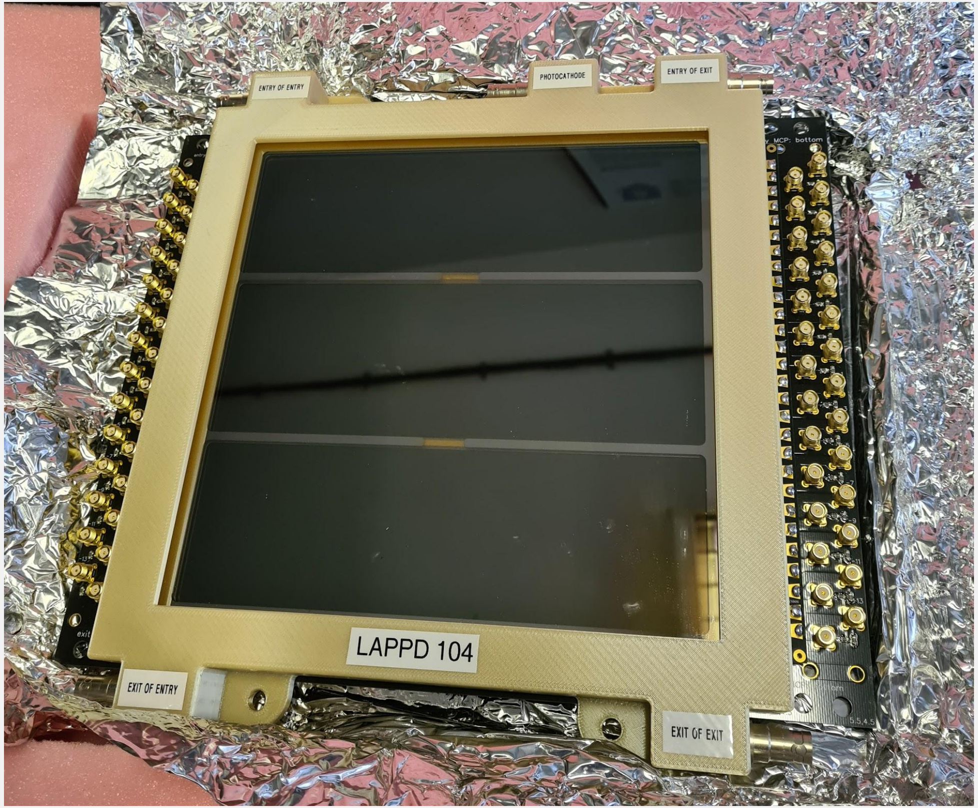
3rd LAPPD Workshop
April 20th 2023

LAPPDs in the UK

The University Of Sheffield.

- Sheffield
  - 2x Gen I (stripline anode readout)
- Edinburgh
  - 1x Gen II (pixelated readout)
  - Purchased for LHCb
- Glasgow
  - 1x Gen II

Initial UK studies will focus on characterisation. QE, dark rate, time and position resolution etc

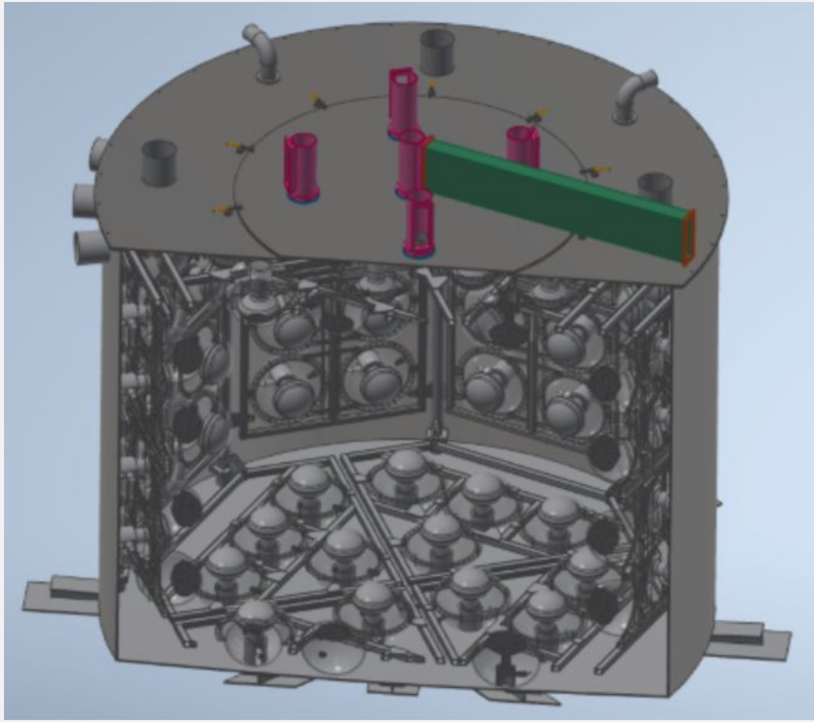


Motivation

In a water Cherenkov detector, we want to precisely reconstruct every photon, but this becomes more challenging as more photons strike the LAPPD

Ideally, would like to have an algorithm to reconstruct photon hits on the LAPPD across a range photon occupancies

This will become more important with detection media with higher light yields such as WbLS



BUTTON - 30 tonne water Cherenkov detector

Sheffield LAPPD setup

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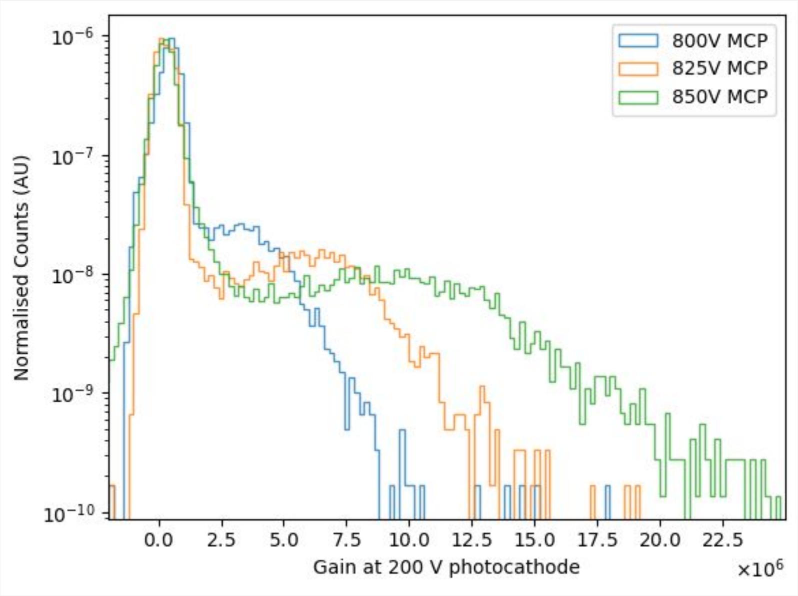
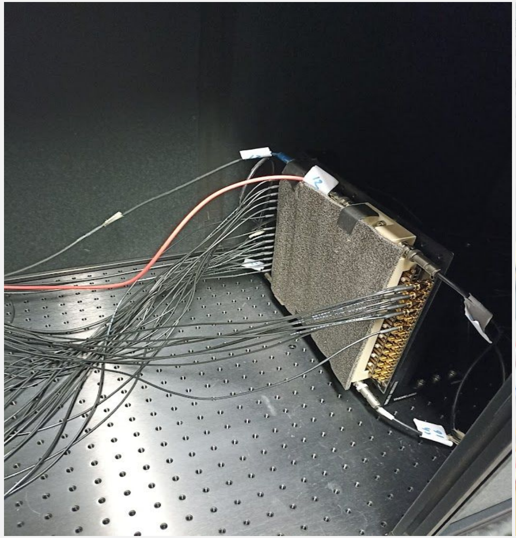
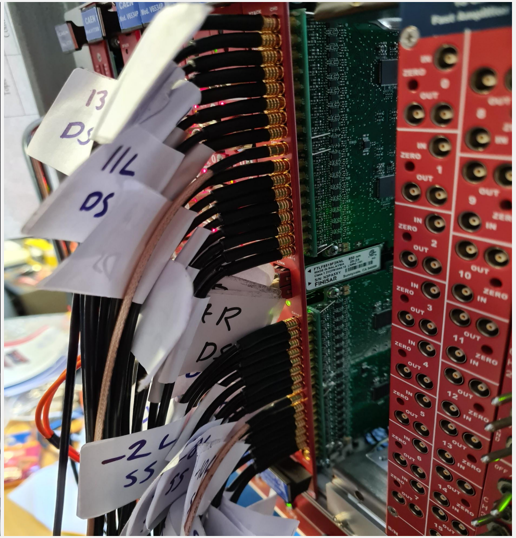
Currently using CAEN DRS4-based readout (5 GS/s, 32 channel). Reading out half the LAPPD with double-ended readout. Currently using this setup to inform simulations







Waveform simulator

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Using simulated LAPPD waveform model to test reconstruction method

RAT-PAC is used to simulate liquid scintillator (LAB) and the LAPPD geometry

Waveforms are produced post-simulation using the MC photon position, timing (TTS ~60 ps) and charge information output by RAT-PAC

Simple model of charge sharing is included (crosstalk is not)

Total waveform is produced by stacking together the contributions from each individual photon

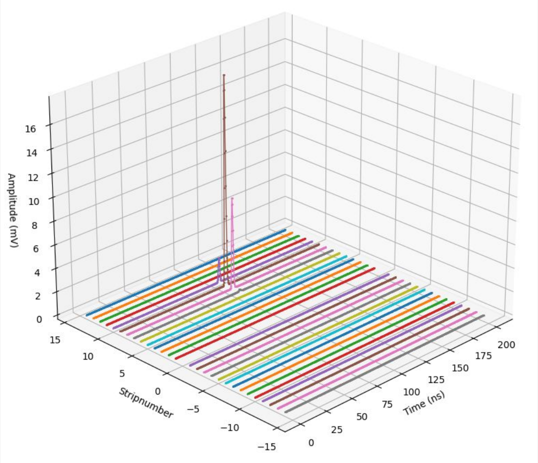
Noise is added to every event

Waveform simulator

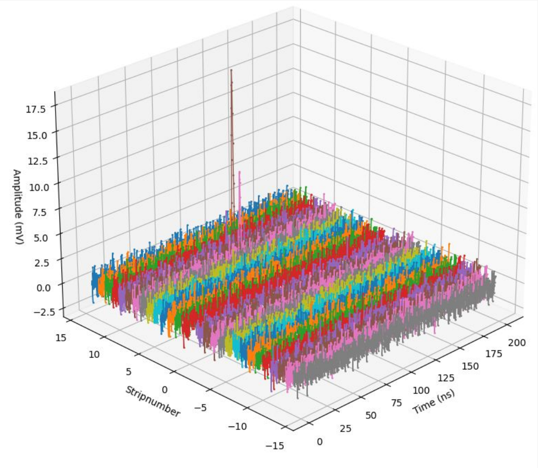
The University Of Sheffield.

Example of single photon event

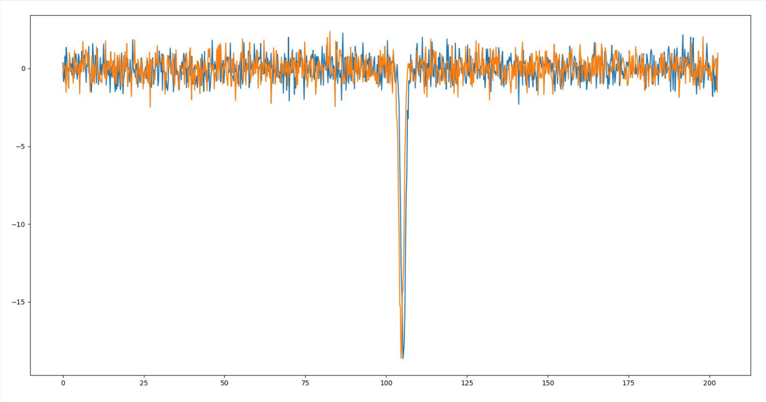
No noise



Noise added



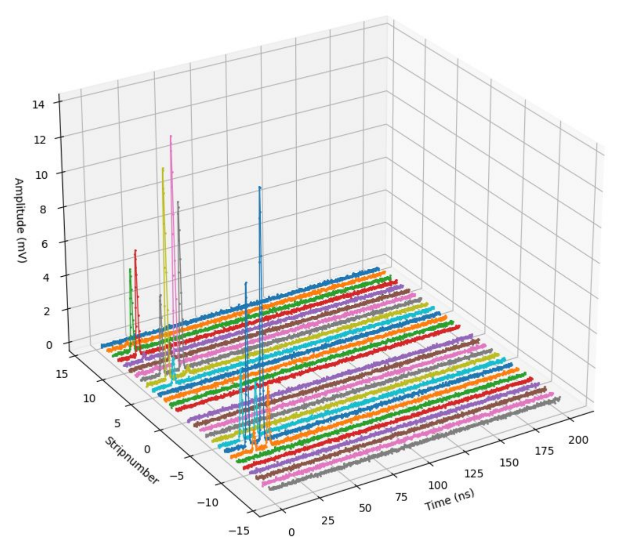
Individual stripline (L&R)



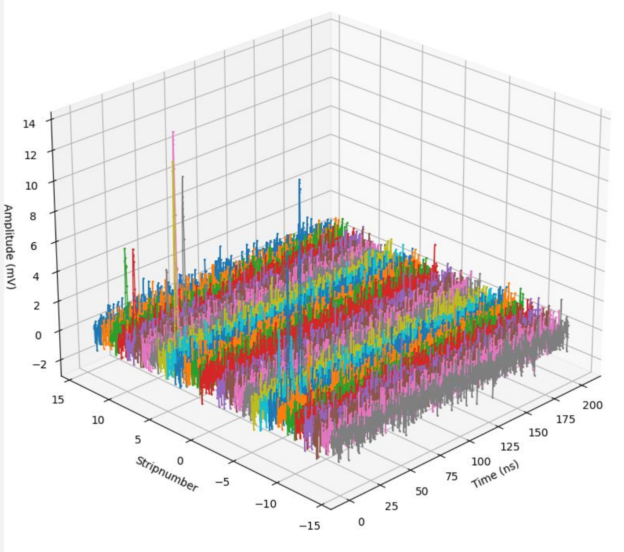
Waveform simulator

Example of multiphoton event

No noise



Noise added

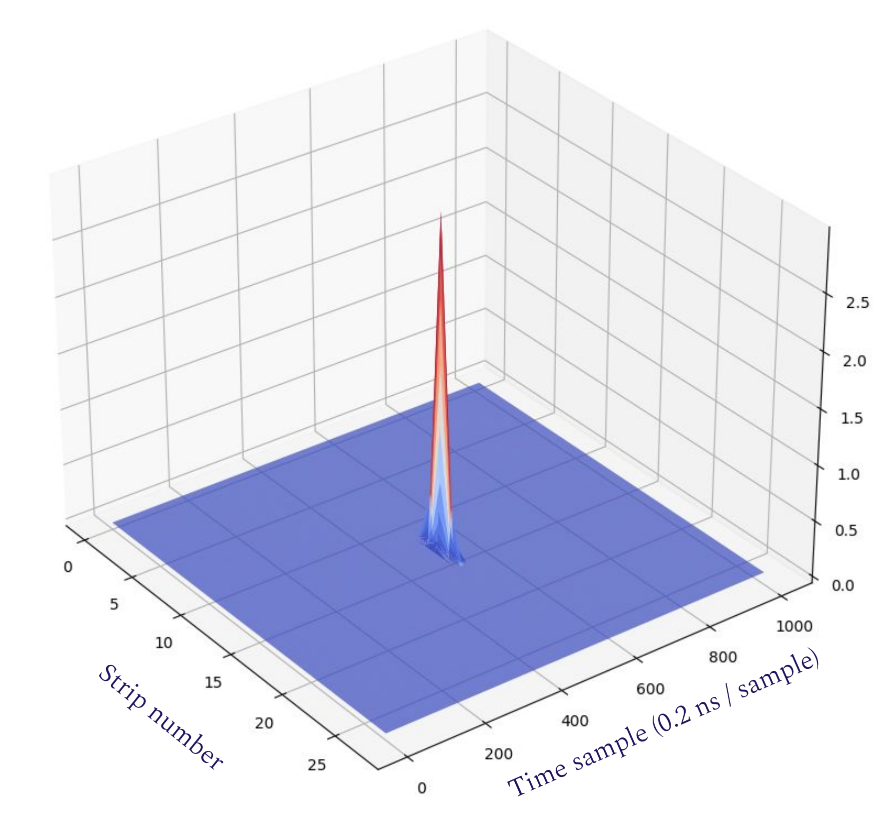


Finding MCP-shaped pulses

Use Wiener-Hunt deconvolution - applying Wiener filtering to a deconvolution problem.

Provide a Point Spread Function (PSF), essentially a template waveform, to deconvolve the image with.

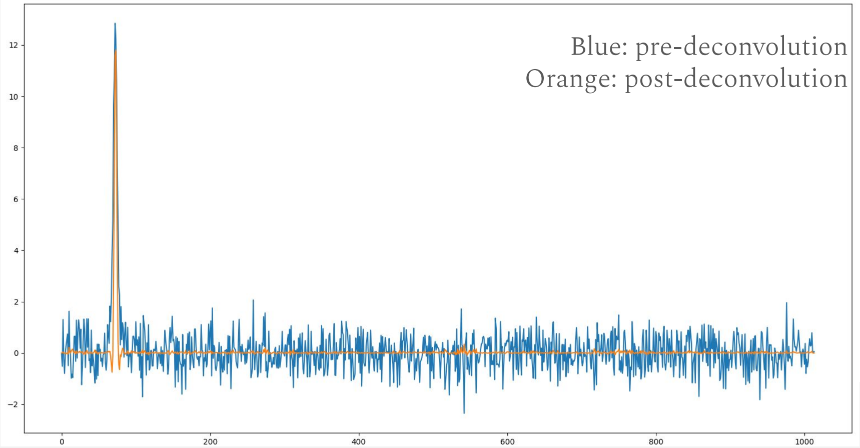
For real data, the PSF is the average of many LAPPD pulses. For simulated data, the PSF is the log-normal function used to generate the waveforms

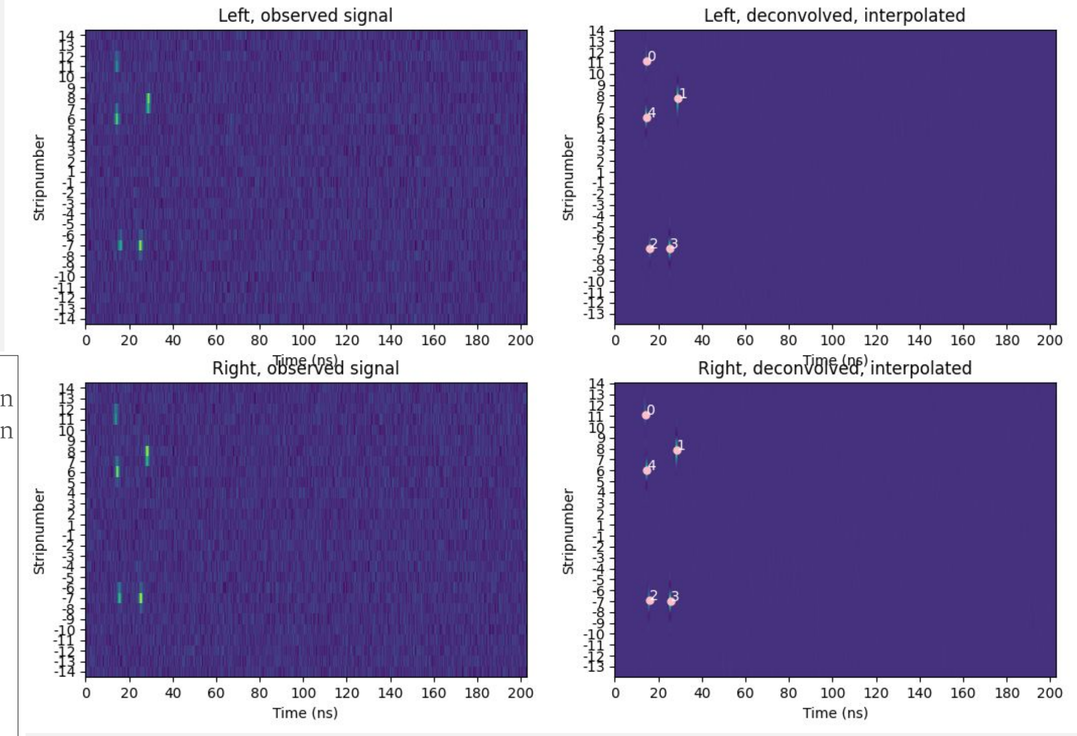


This method follows very closely from Jocher, Wetstein et al work on simulated LAPPD waveforms (https://arxiv.org/pdf/1805.01077.pdf)

Deconvolution and peak finding

Deconvolve image with PSF and peak find using local maxima filter (performance of filter dependent on fine tuning of the deconvolution)



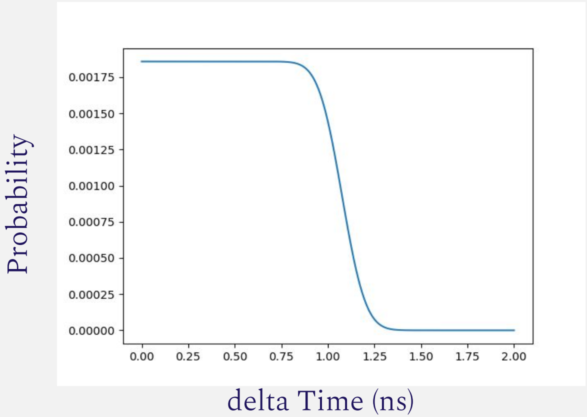


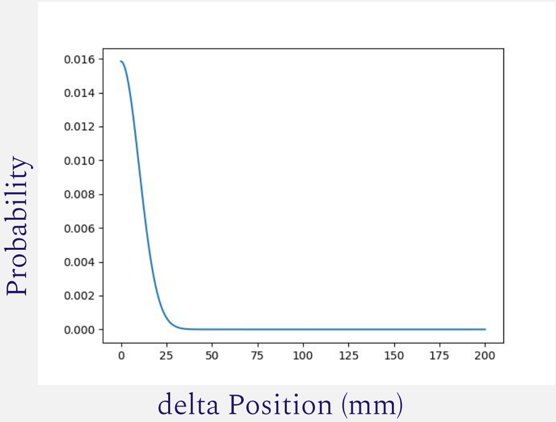
Peak correlation

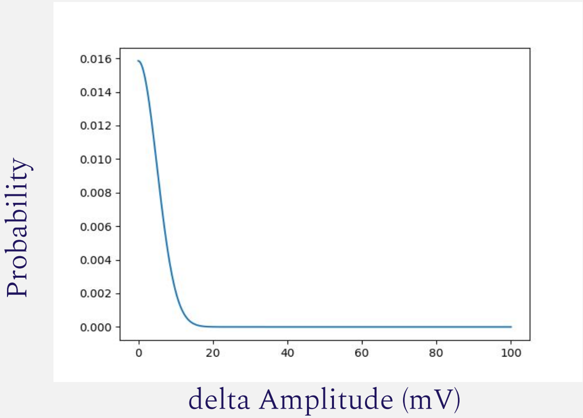
Peaks are correlated based on their relative time (x), position (y) and voltage amplitude (z).

A likelihood is calculated for each possible pair of peaks using PDFs for each of these variables.

These PDFs are just guesses at the moment.







Reconstruction

Along a stripline (x) - time difference between left and right using constant fraction discriminator

Across striplines (y) - centroid of neighbouring striplines

Time in acquisition window (t) - average of left and right time using constant fraction discriminator

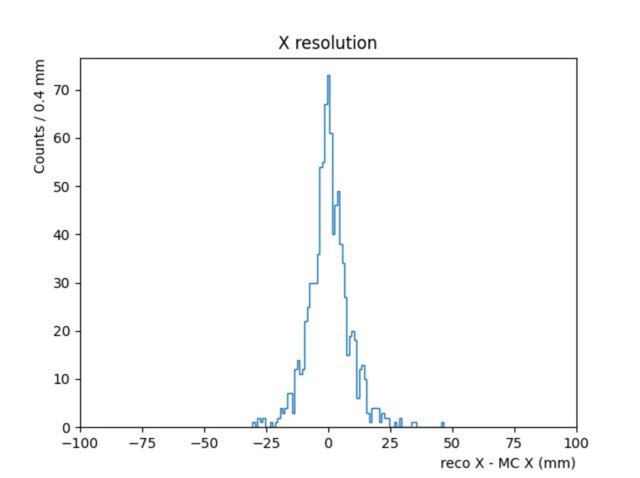
Single photon reconstruction

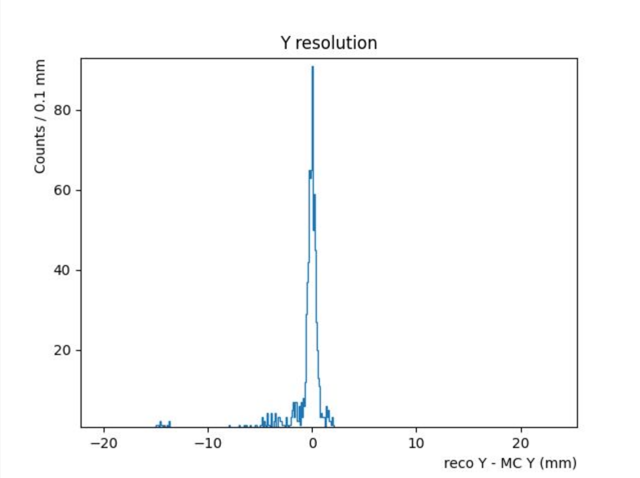
X resolution: 6.67 mm

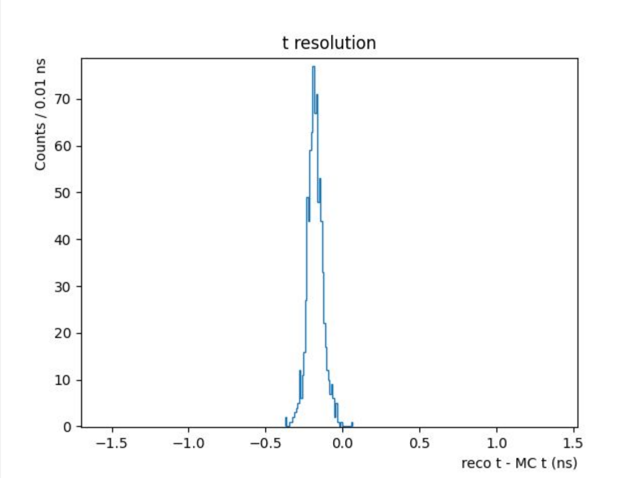
Y resolution: 0.381 mm

Timestamp resolution : 80.4 ps (MC photon time of arrival vs waveform timestamp)

Efficiency: 0.993 (hits reconstructed / total photons)







Multi photon reconstruction

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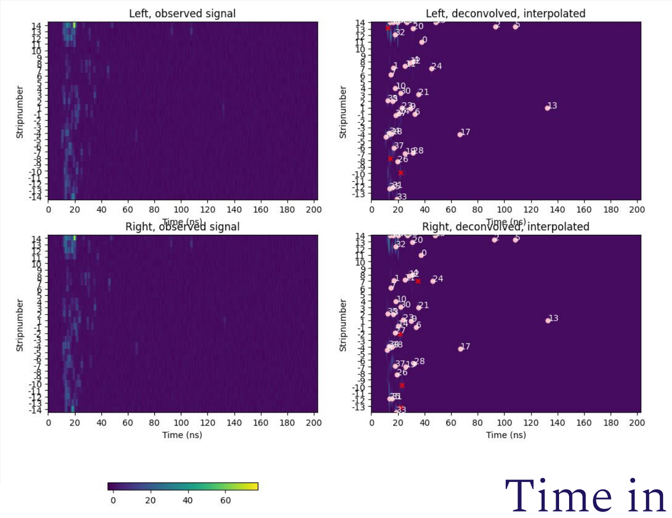
Randomly sample N photons from the total number of scintillation photons in the event to study how reconstruction performances degrades with number of photons

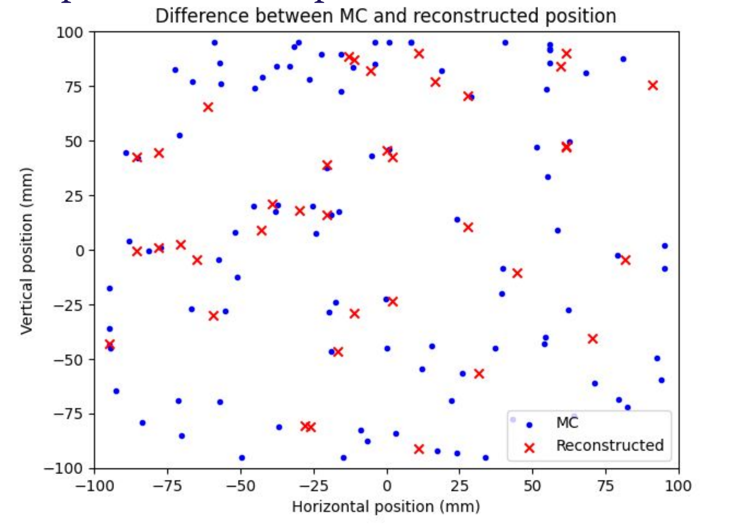
N photons	X res (mm)	Y res (mm)	t res (ps)	Efficiency
1	6.67	0.381	80.4	0.993
5	7.01	0.408	81.5	0.874
25	8.27	1.56	89.5	0.619
100	13.3	3.38	243	0.297

(preliminary)

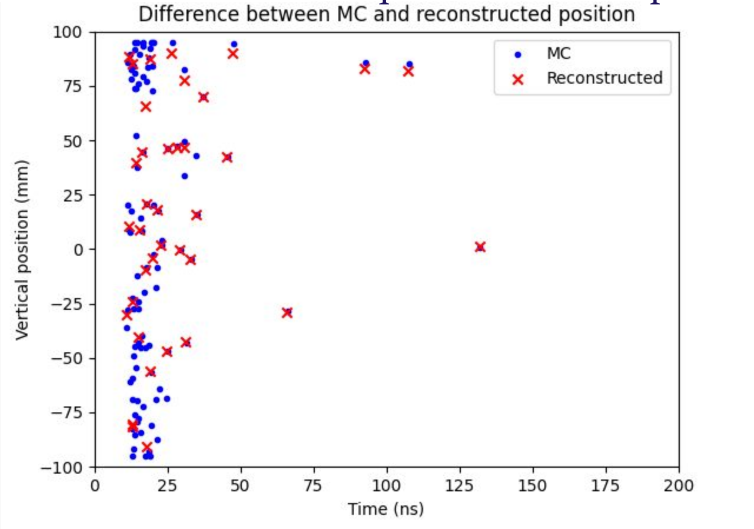
100 photon event



X position : Y position



Time in acq window : Y position



Summary

Decent reconstruction for multiphoton events in most scenarios

Decreased efficiency for detecting individual hits at higher number of photons, going to look at total reconstructed charge rather than hits

Currently simulating 5 GS/s sampling rate, will investigate other potential sample rates (PSEC4 operates at ~ 10 GS/s)

I would also be very interested to see the response of a pixellated LAPPD in these scenarios