LAPPDs for future neutrino detectors

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The University Of Sheffield.

Introduction

Photomultiplier tubes have been the workhorse photodetector in particle physics for decades... but they are not the only option.

There are many efforts underway to improve photodetector capabilities, this talk focuses on one particular technology, Large Area Picosecond PhotoDetectors (**LAPPD**s).

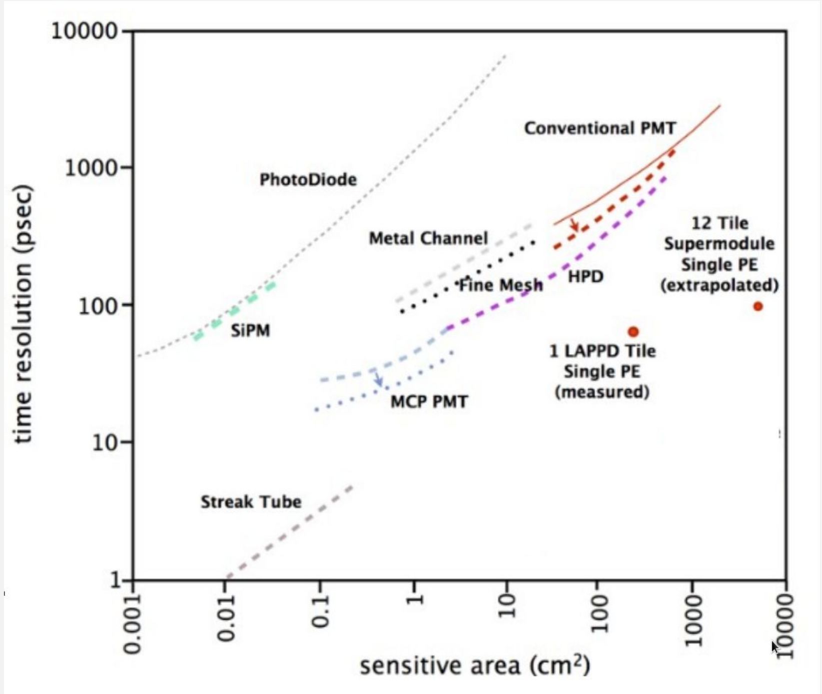


Image modified from https://doi.org/10.1016/S0168-9002(99)01203-6

Large Area Picosecond Photodetectors

LAPPDs are microchannel plate (MCP)-based photodetectors produced by Incom USA

Made up of 20x20 cm photocathode, two MCPs in a chevron pair and collection anode for readout

Excellent resolution in both space (***O*** few mm) and time (<80 ps single photon TTS) whilst offering more than 10^6 gain

Two readout options: Gen I stripline anode readout or Gen II capacitively coupled pixelated readout

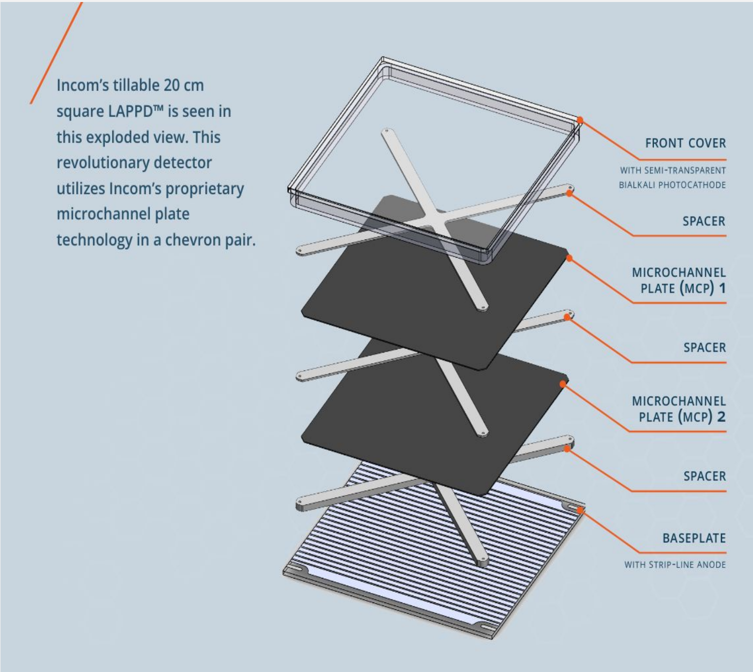


Image from Incom USA

Microchannel plates (MCPs)

As opposed to discrete dynodes in a PMT, MCPs use continuous dynodes. They contain many tiny capillaries (microchannels) that are each essentially a photomultiplier.

The electron cascade then induces a signal in the stripline anode.

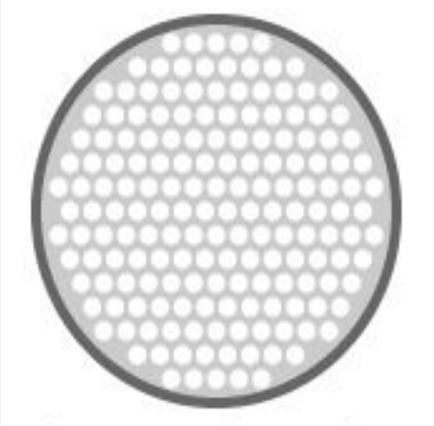


Image from https://www.rp-photonics.com/microchannel_plates.html

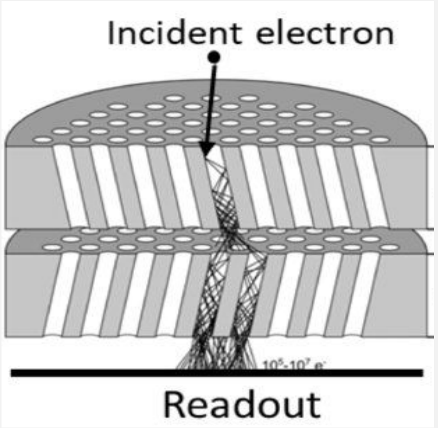


Image from https://doi.org/10.1117/12.2530037

MCPs are not a new technology but are not in widespread use in particle physics experiments

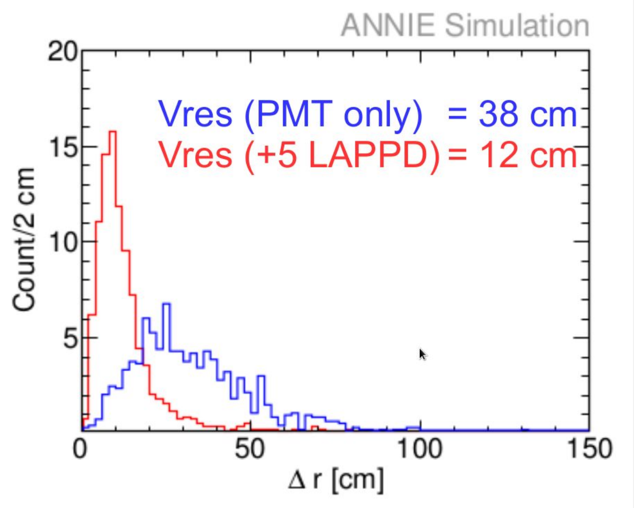
The LAPPD project (UChicago, Argonne National Lab, Incom et al) was created to resolve this. *(arXiv:1603.01843. A Brief Technical History of the Large-Area Picosecond Photodetector (LAPPD) Collaboration)*

Potential applications

The fast timing, spatial resolution and large area of the LAPPD offers significant opportunities for future water cherenkov neutrino detectors

- Improved vertex reconstruction
- Cherenkov ring imaging
- Cherenkov-scintillation separation in novel detection media like water-based liquid scintillator

The ANNIE experiment at Fermilab will deploy LAPPDs imminently, and many small-scale testbeds are planning to study LAPPD applications (see Andrew Scarff's talk on the BOLEYN testbed)

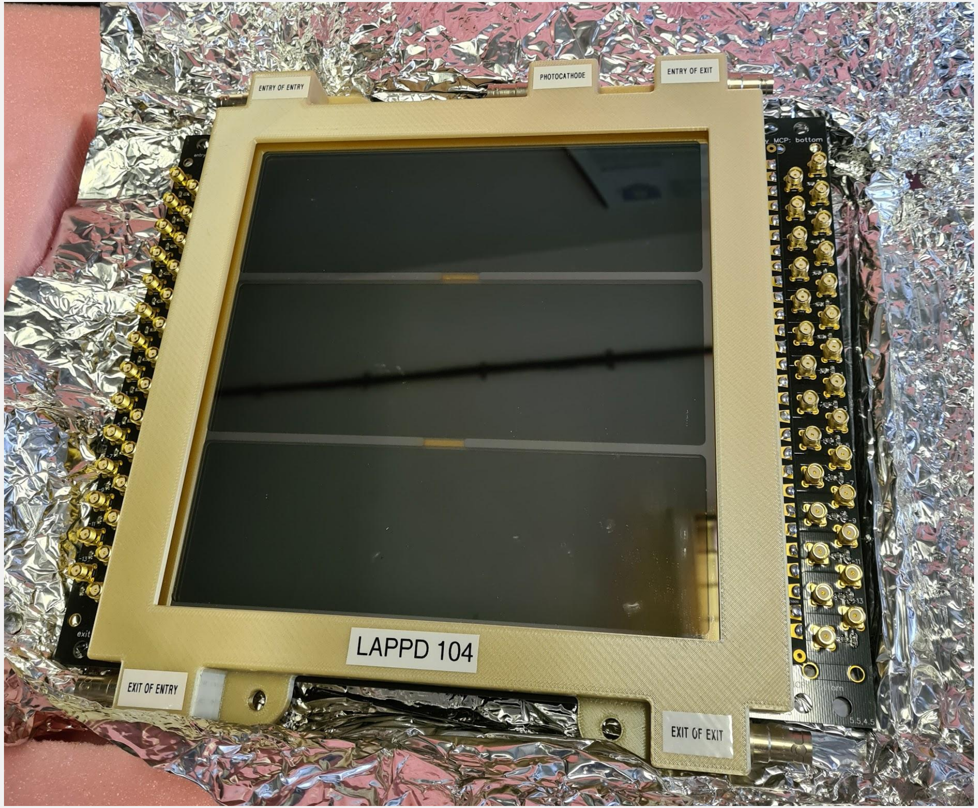


Vertex resolution in ANNIE with (red) and without (blue) LAPPDs

LAPPDs in the UK

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

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



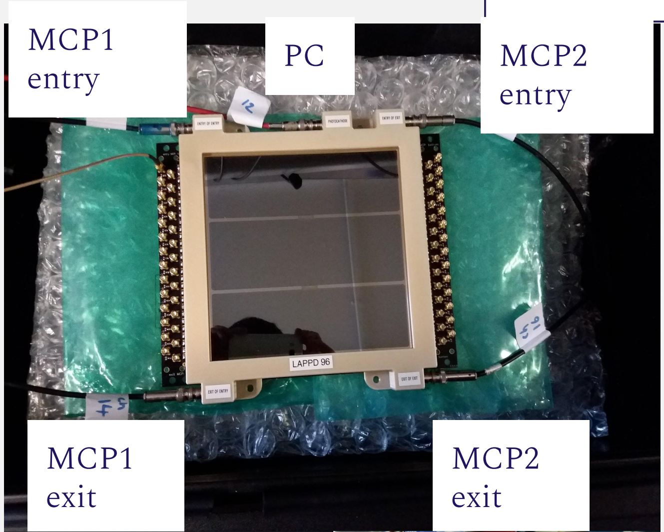
LAPPD setup

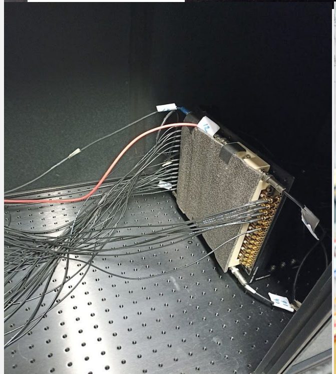
LAPPDs are not as plug and play as PMTs…

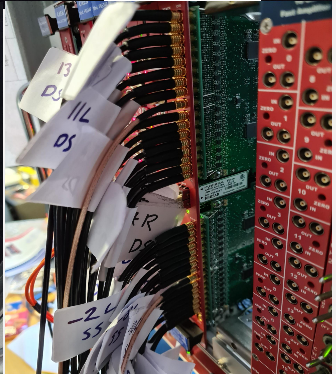
Requires 5 HV connections: Top and bottom of each MCP + photocathode

56 signal connections on Gen I (28 strips, reading out both left and right ends)

Currently using off-the-shelf readout electronics (32 ch CAEN 5 GS/s digitiser), aiming to move to custom PSEC4-based ASIC later







Reading out a Gen I LAPPD

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The position of the incident photon is determined by analysing the signals on either side of the striplines

- Position along a stripline (x)
  - Determined from the time difference between pulses on the left and right side of a stripline
- Position across striplines (y)
  - Determined by the centroid of pulse heights across neighbouring striplines

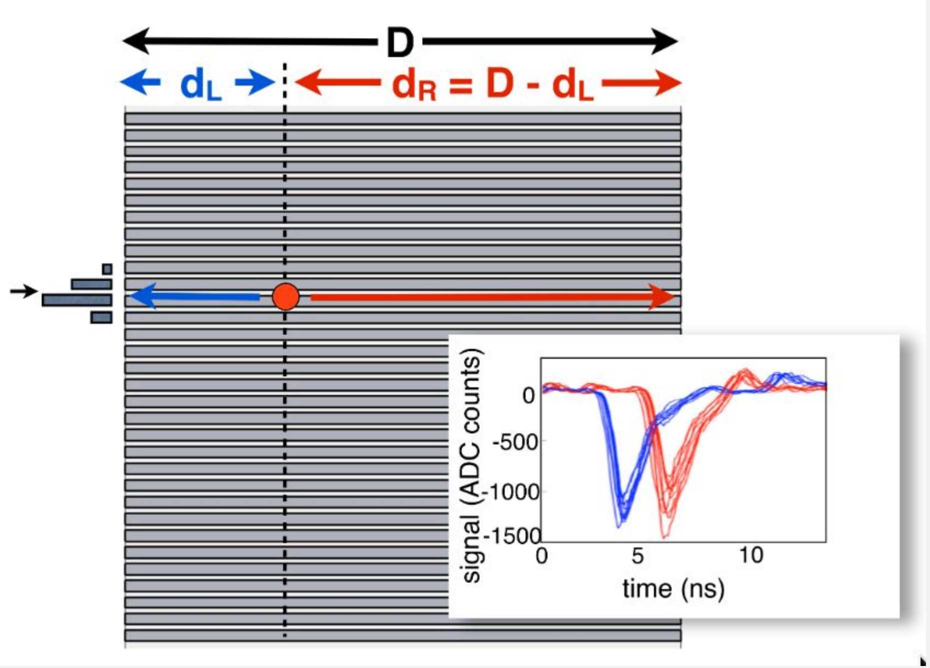


Image from arXiv:1805.01077v1. *Multiple-Photon Disambiguation on Stripline-Anode Micro-Channel Plates*

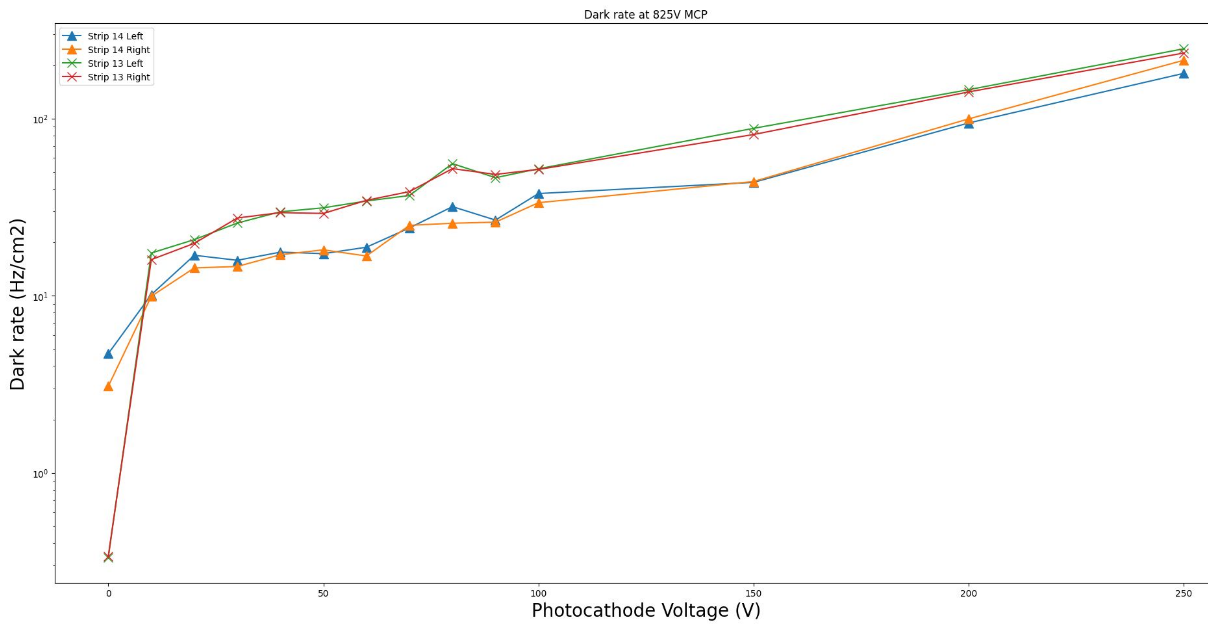
Detector characterisation measurements

Dark rate

Understanding the dark rate is critical

Leave LAPPD in dark for 1 hour before acquiring data and counting the number of SPE pulses in 15 min run

Dark rates of the order **100 Hz/cm^2** at expected operating voltage (photocathode 200 V above MCP1 for *this* LAPPD)



Detector characterisation measurements

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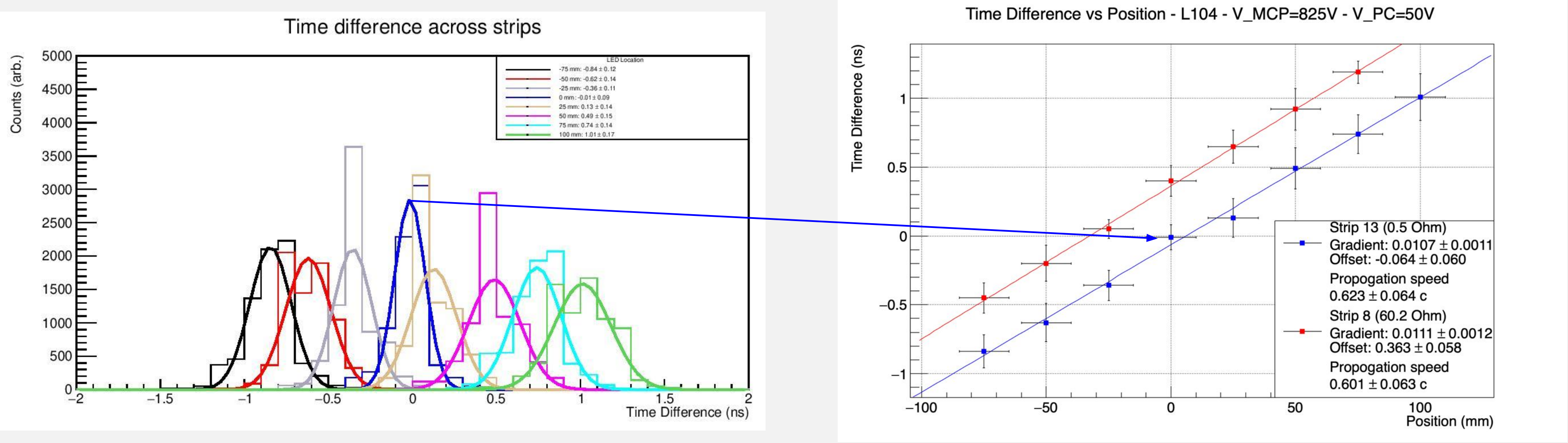
Position Resolution

Scanning along a strip with an LED and measuring the difference in time between left and right signals. Position resolution of ~1 cm along strips although this would likely be improved by replacing LED with laser.

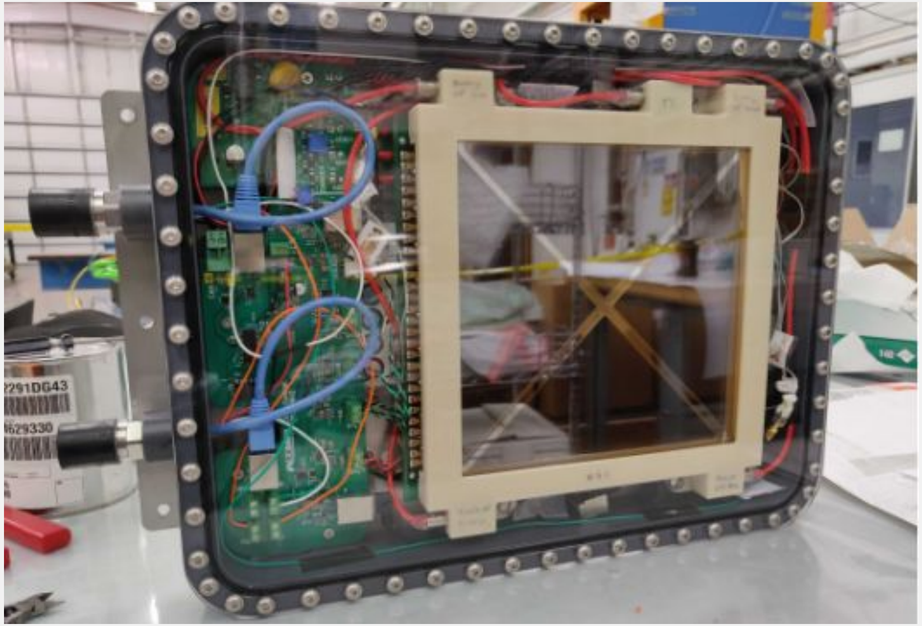


Challenges ahead

Deployment

Challenges in going from tabletop to a real water detector. The ANNIE experiment has spent many years preparing for their first detector deployment of LAPPDs.

- Waterproofing
- Custom electronics
  - HV supply
  - Signal readout
  - Environmental monitoring
- DAQ integration



ANNIE LAPPD in waterproof housing with encapsulated electronics

Challenges ahead

Event building

Still lots of work needed to fully understand how to interpret pulses from stripline-based LAPPDs, especially when it comes to multi-photon hits (i.e. in Cherenkov or scintillation detectors)

Need to deconvolve and correlate all pulses to find which correspond to each photon event, whilst also dealing with crosstalk between strips

Very challenging, but great possibilities

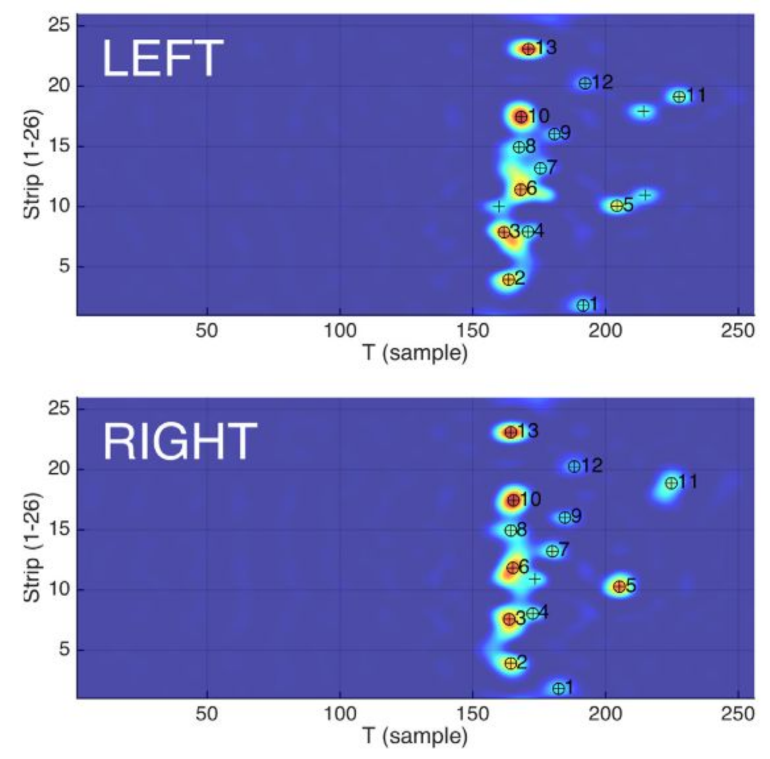


Image taken from arXiv:1805.01077v1. *Multiple-Photon Disambiguation on Stripline-Anode Micro-Channel Plates*

Summary

LAPPDs are an exciting development in photosensor technology and offer good temporal and spatial resolution for single photons

First deployment is happening now in ANNIE at Fermilab

LAPPDs are being tested on benchtop in the UK right now, with plans to deploy in small-scale testbeds soon after