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annie

First results from the LAPPDs in ANNIE

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About ANNIE

The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a 26-ton gadolinium doped water Cherenkov detector on-axis of the Booster Neutrino Beam (BNB) at Fermilab.

ANNIE detector setup (from left to right):

- Front muon veto to tag muons created upstream of the tank
- Cylindrical tank (4 m high and 3 m in diameter) with 132 PMTs and 5 LAPPDs and high purity water loaded with gadolinium sulfate ($Gd_2O_{12}S_3$)
- Muon-Range-Detector (MRD) to detect muons leaving the tank

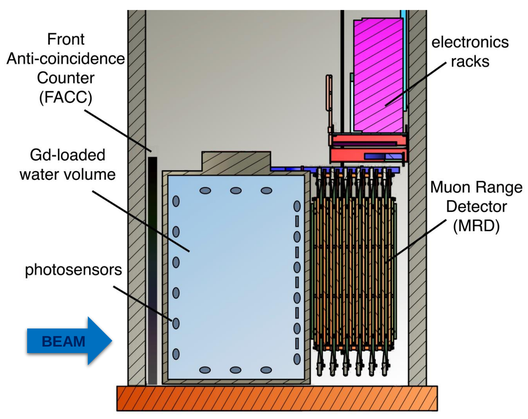

Fig 1: ANNIE detector setup

ANNIE physics goals:

- ANNIE aims to measure the neutrino cross-section in water which will improve the systematic uncertainties of next-generation long-baseline neutrino experiments
- To do so, ANNIE uses the final state neutron multiplicity of neutrino-nucleus interactions in water
- It will also improve backgrounds of Diffuse Supernova Neutrino Background (DSNB) and atmospheric proton decay searches

Large Area Picosecond Photodetectors

What are LAPPDs?

The Large Area Picosecond Photodetector (LAPPD) is a micro-channel based (MCP) photosensor. It offers a timing resolution of about 60 ps and a sub-centimeter spatial resolution while having an active photosensitive area of 20x20 cm.

How do LAPPDs work?

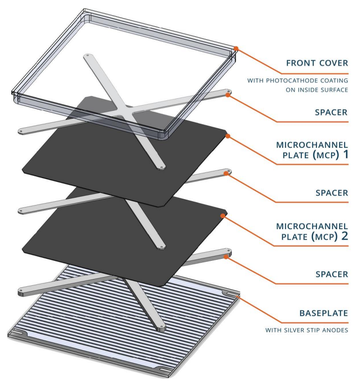

Fig 3: LAPPD schematic setup

- A photoelectron is multiplied by two layers of MCPs
- The created electron cascades hit one or more of the strip-anodes
- By reading out the signal at both ends of a strip a Δt can be used to determine the position in one dimension
- Information in the second dimension is given by the position of the strip itself

Why are LAPPDs important for ANNIE?

Due to the high time and spatial resolution the LAPPDs have a large impact on the reconstruction capabilities of ANNIE.
By adding 5 LAPPDs to the already existing PMTs the accuracy of the vertex reconstruction can be vastly improved, which in turn allows for a more precise reconstruction of the muon and thus neutrino energy.

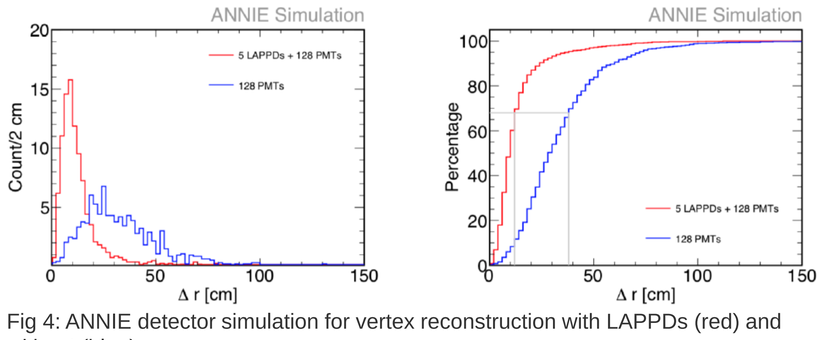

Fig 4: ANNIE detector simulation for vertex reconstruction with LAPPDs (red) and without (blue)

Funding Acknowledgements

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First LAPPD deployed in ANNIE

What does the LAPPD 'Package' look like:

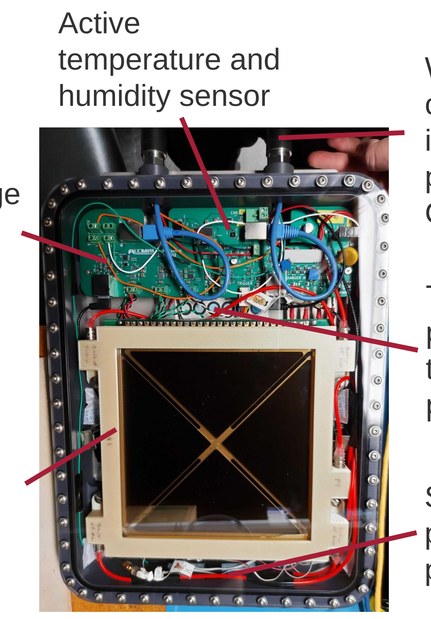

Fig 6: Complete LAPPD package

Since the 29th of March 2022 LAPPD 40 has been deployed in a large-scale neutrino experiment for the first time.

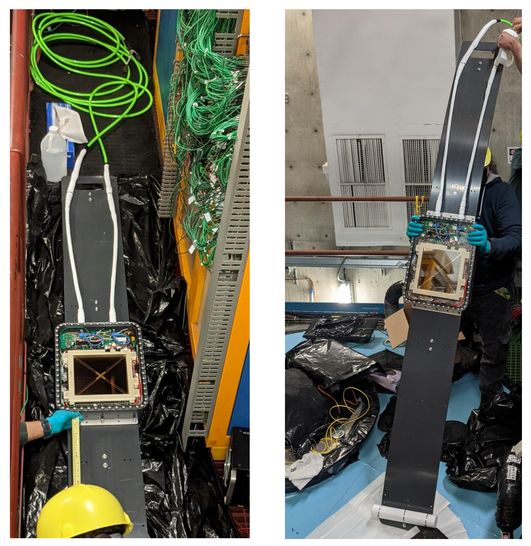

Fig 7: LAPPD installed on its mount and the underwater cables wrapped in Teflon

First LAPPD Beam Data

The first ever data recorded by an LAPPD induced by a neutrino beam is shown below:

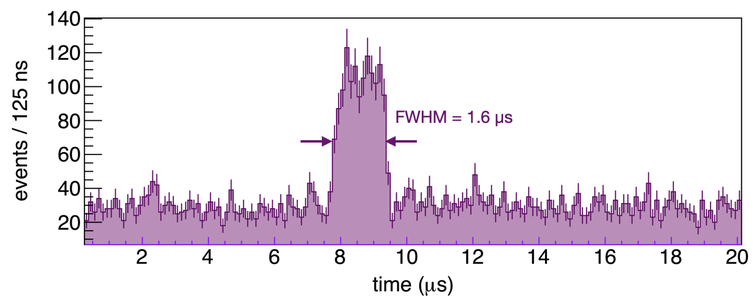

Fig 8: Beam event time distribution for the LAPPD with the time from the beam acquisition window vs events per 125 ns

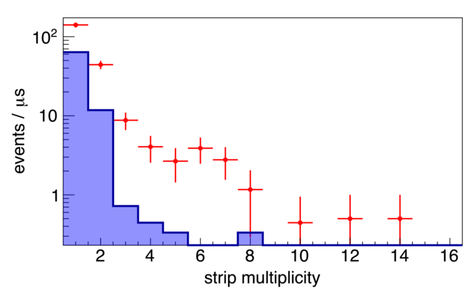

Fig 9: Strip multiplicity normalized to 1 μs for on-beam data (red) and off-beam data (blue)

Figure 8 shows the time evolution of events per 125 ns as a function of time passed since the beam acquisition window was active. A clear excess of events can be seen with a FWHM of 1.6 μs which coincides with the BNB beam window.

⟶The LAPPD sees the neutrino beam.

Strip multiplicity (see figure 9) is defined as the number of LAPPD strips with signal over threshold, normalized to 1 μs. The blue bars show strip multiplicity for off-beam time, the red data points show on-beam data. In comparison, higher multiplicities are more frequent during beam-on time.

First Deployment of Multiple LAPPDs

Since February of this year two more additional LAPPDs (LAPPD 63 and LAPPD 64) have been deployed in ANNIE. With this, a total of three LAPPDs have been deployed for the first time in a neutrino experiment.

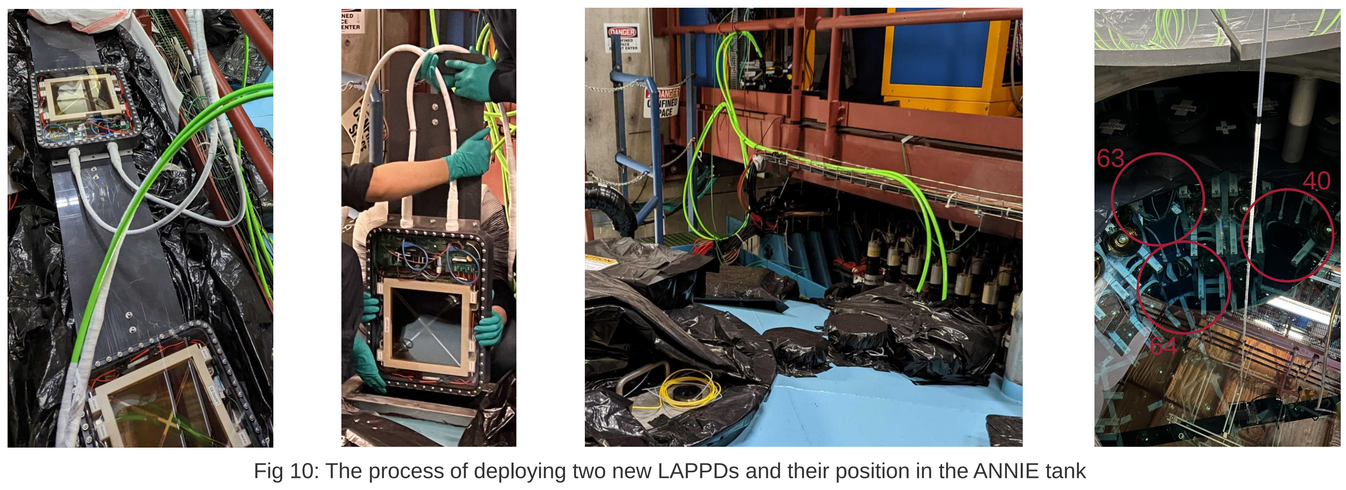

Fig 10: The process of deploying two new LAPPDs and their position in the ANNIE tank

From left to right the process of the deployment is shown in figure 10:

- The first picture shows them installed on their mount, to a sub-centimeter precision, where they are thoroughly cleaned
- Then they are inserted into a slot on the top of the ANNIE tank and carefully lowered into the water
- The slot is then sealed again to prevent outside light from entering and the cables are routed to the electronics rack
- The last picture shows their final position in the ANNIE tank

⟶ Stay tuned for multi LAPPD neutrino data soon!