

P-ONE Demonstrator PMT Characterization

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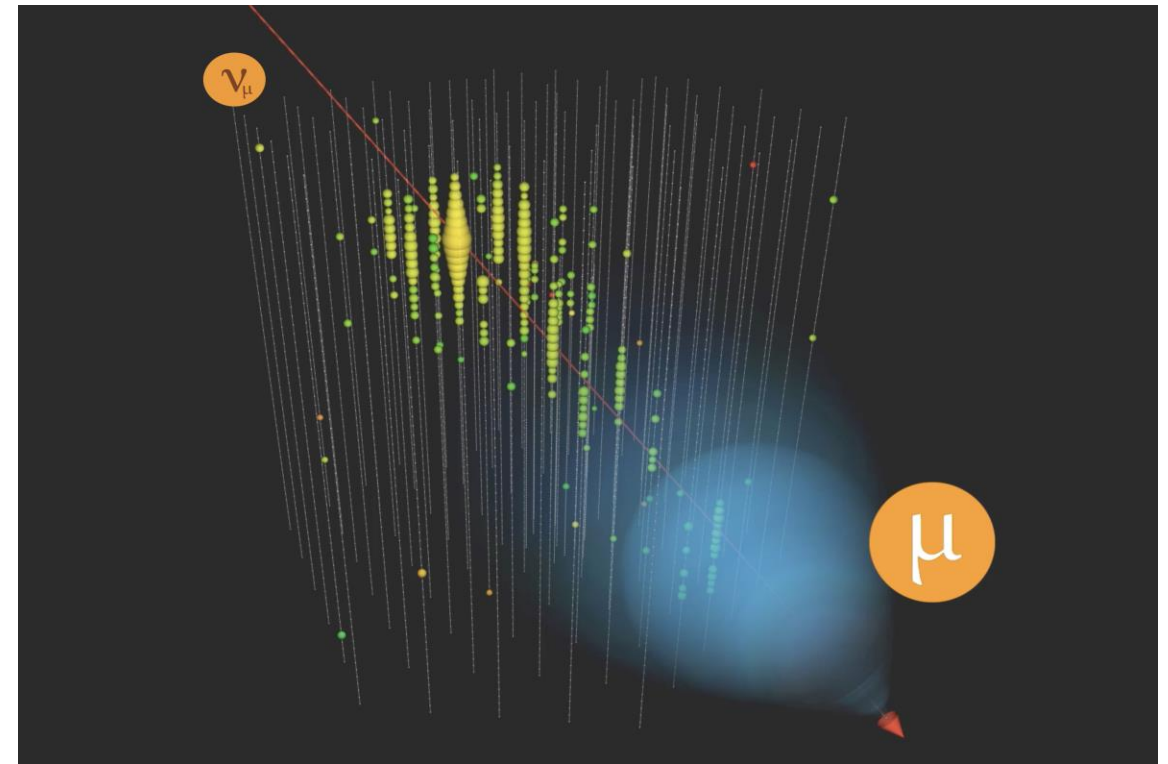


Queen's
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Neutrino Detection



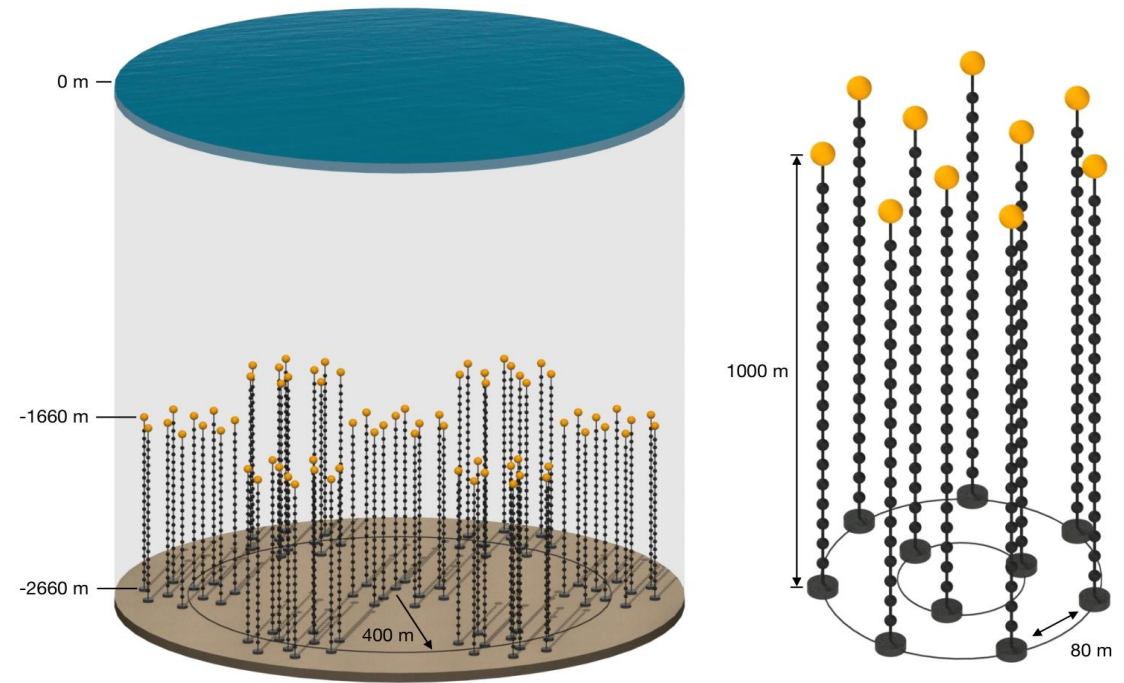
- Neutrino interacts within the detector producing charged particles
- High-energy particles travel faster than the speed of light in the medium, producing Cherenkov radiation that is measured by the PMTs in the P-OMs
- Event reconstructed using timing, charge, and position of modules



A muon neutrino interacting in the IceCube detector. Credit: IceCube Collaboration.

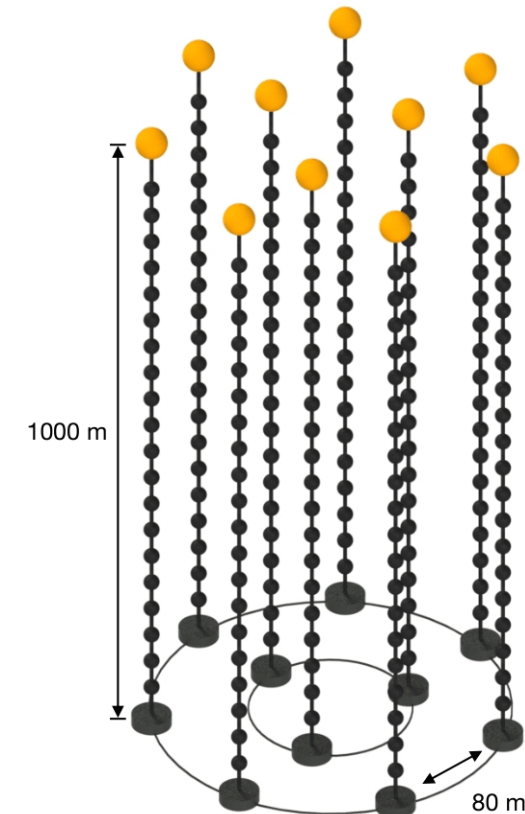
P-ONE Overview

- Proposed cubic-kilometer-scale ocean neutrino telescope
- Located in the Cascadia Basin off the coast of Vancouver Island
- Uses deep ocean water as the detection medium
- Instrumented with vertical detector lines holding optical modules
- Designed to detect Cherenkov light from neutrino-induced charged particles
- Aims to study high-energy astrophysical neutrinos from the Northern Hemisphere



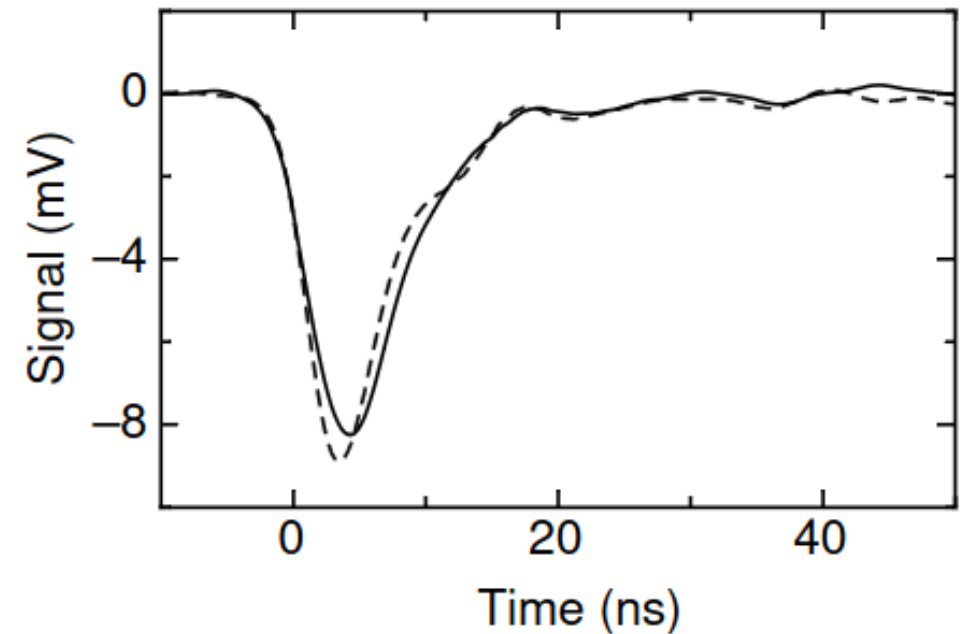
P-ONE Demonstrator

- First cluster for P-ONE detector
- Designed to validate detector technologies in the ocean environment
- Builds on the first P-ONE deployment phase
- The Demonstrator will add three additional detector strings, each string containing 20 optical modules
 - Totaling over 900 PMTs
- Tests deployment, operation, calibration, and long-term stability



PMT Characterization

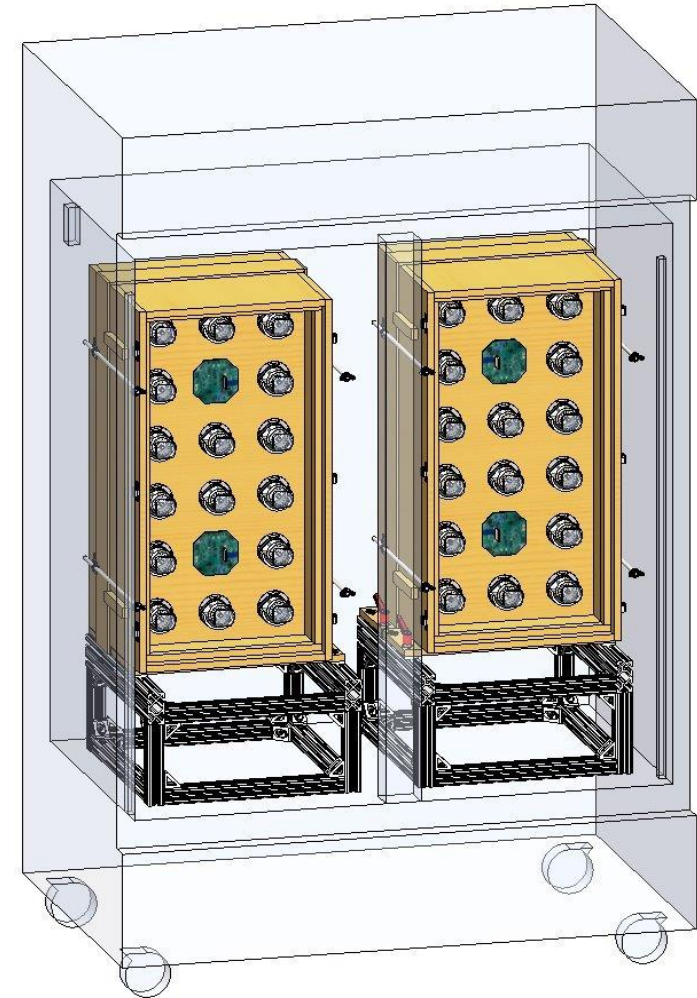
- Goal: qualify PMTs before deployment in the P-ONE Demonstrator
- Each PMT must satisfy performance requirements for noise, gain, charge response, and timing
- Key qualification measurements include:
 - Dark rate: below 3000 Hz
 - Gain: target operating gain of 5×10^6
 - SPE response: peak-to-valley ratio greater than 2
 - Timing uncertainty: below 2 ns
- PMTs outside the required performance range can be flagged before deployment



Abbasi et al Nucl.Instrum.Meth.A618:139-152,2010.

Queen's Setup

- Need to qualify ~1400 PMTs for P-ONE-D
- Planned testing rate: 32 PMTs per set, with an automated 24-hour test cycle
- PMTs are tested in a temperature-controlled fridge at 5°C
 - Fridge minimum tolerance of 0.1°C
- Custom rack system holds PMTs in fixed, repeatable positions during testing
- Fixed fibre tray delivers light consistently to each PMT
- Dark material and enclosed rack design reduce light leaks



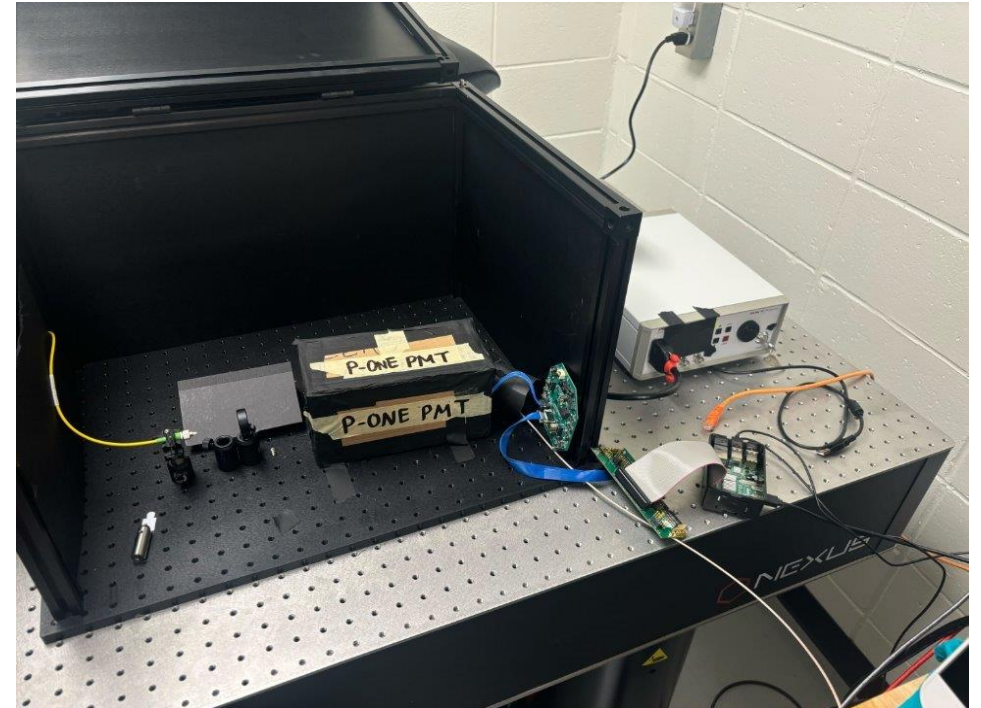
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Single-PMT table-top setup

- Provides controlled test channel to validate the measurement procedure before scaling to 32 PMTs
- We have one 3-in PMT + uBase in the lab to use to test the setup and fADC
- Develop scripts for each test and incorporate into one automated test script for the fridge
 - Includes monitoring as the tests are running to check progress
 - Immediate alerts if there are any issues during a run

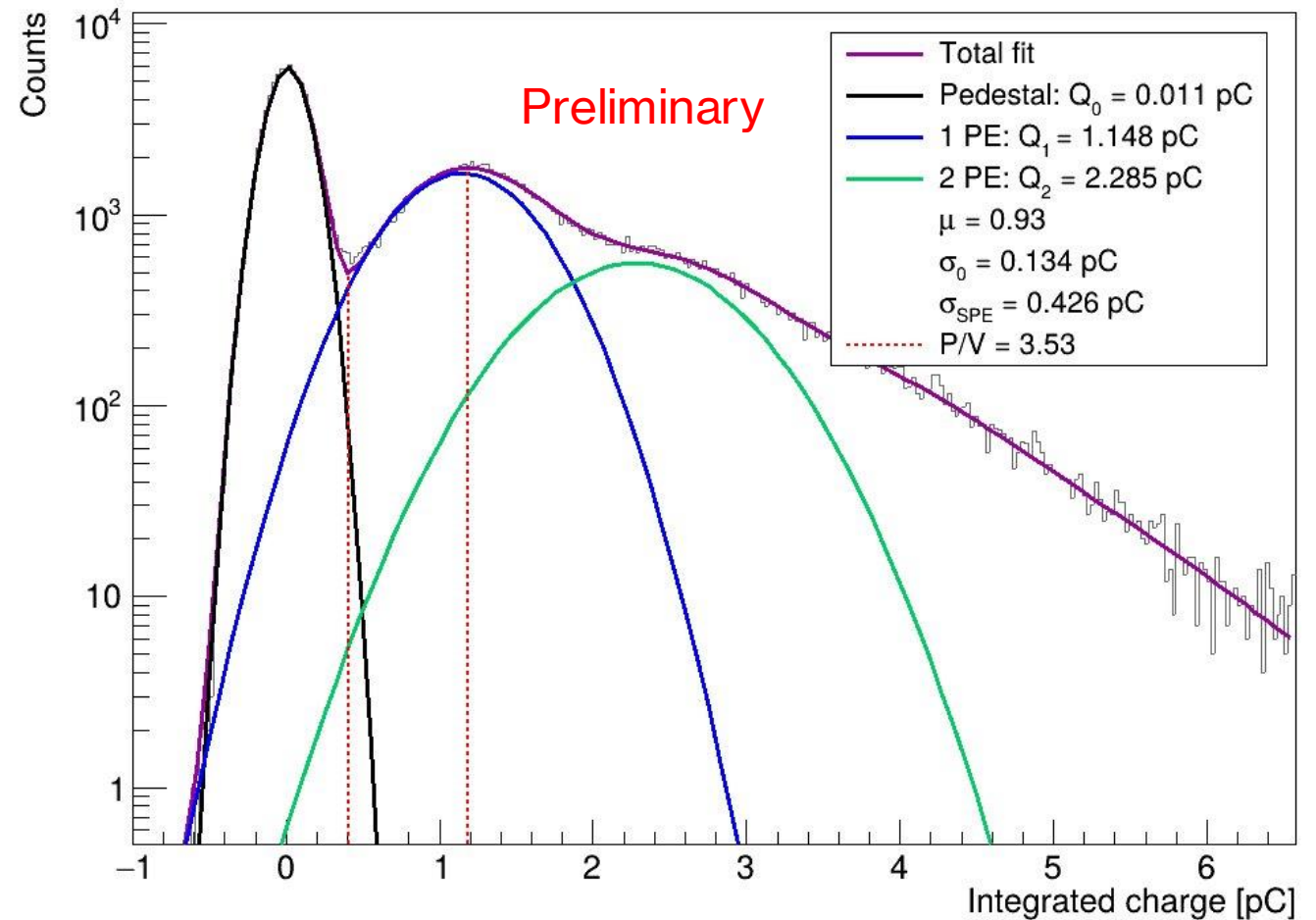


Measurements

- Measurements performed:
 - Dark rate
 - Single-photoelectron response
 - Gain calibration
 - Transit time spread
- Used to validate the table-top procedure before scaling to the 16-PMT verification set
- Results satisfy the key PMT requirements for P-ONE-D characterization

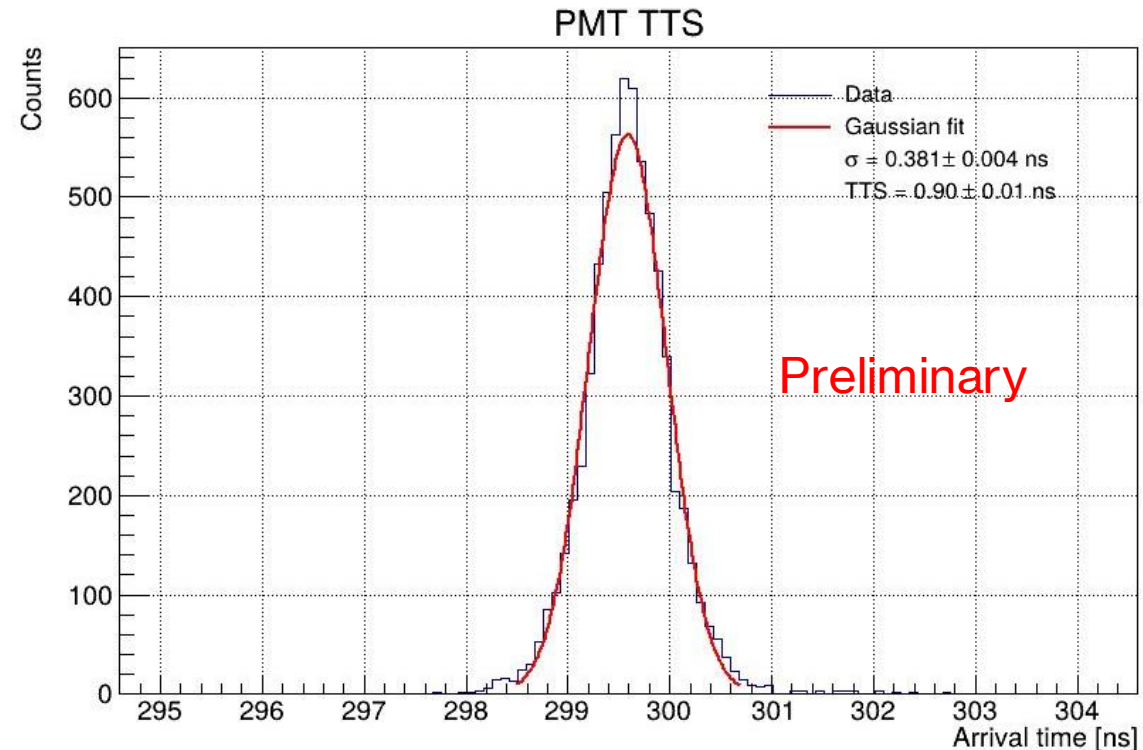
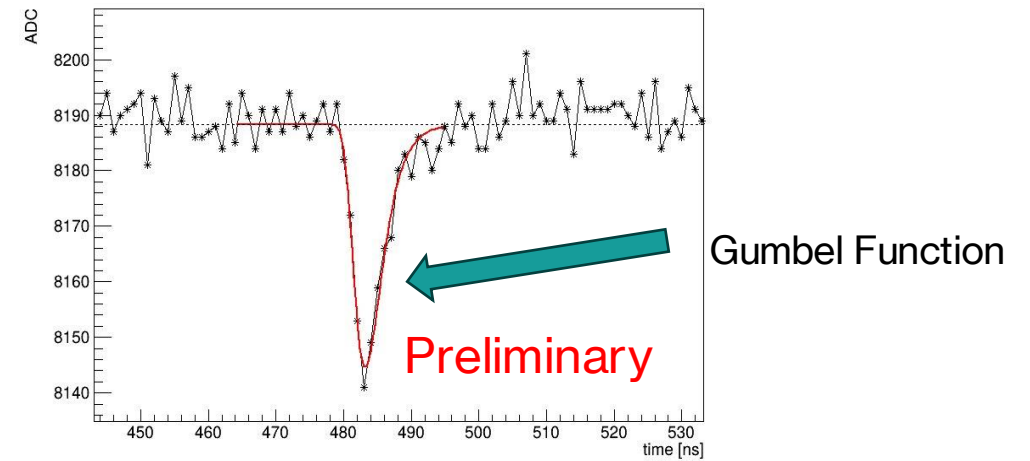


Charge Distribution



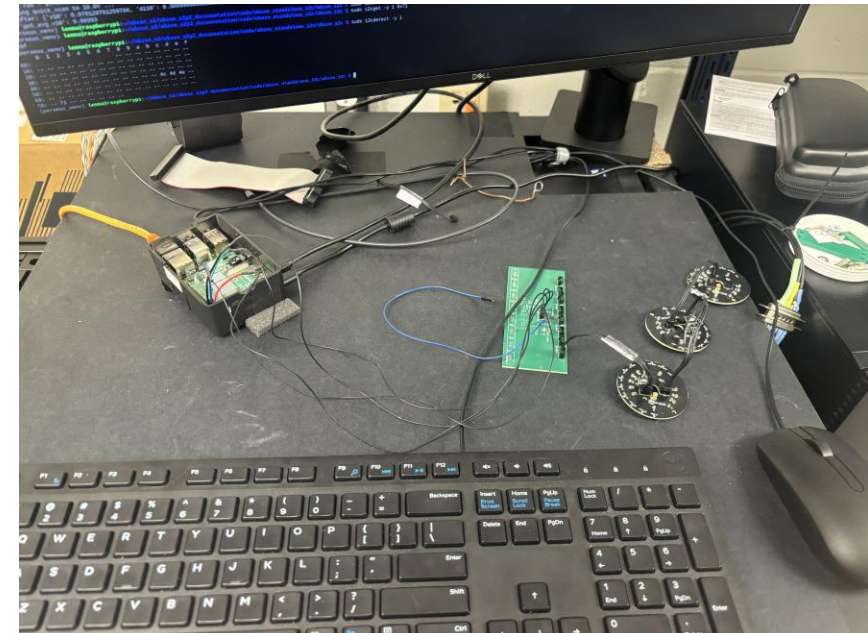
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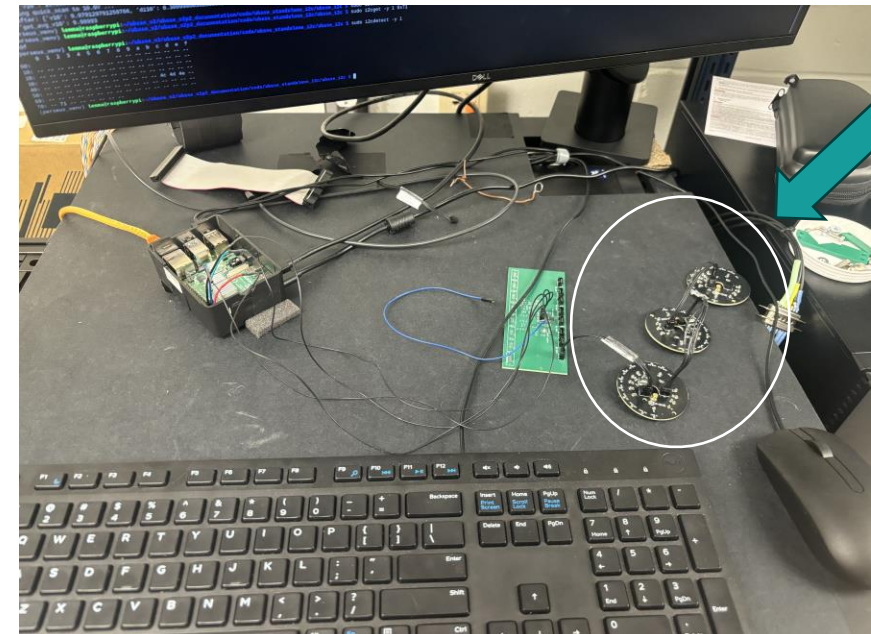
Scaling to 16 PMTs

- Initial 16-PMT verification set has arrived at Queen's
- First opportunity to test multiple updated P-ONE Demonstrator PMTs together
- Used to validate updated uBases, interposer boards, cabling, and readout connections
- Checks that the mechanical loading procedure works with real PMTs installed
- Test the single-PMT measurement workflow scaling to multi-PMT operation
- Next step toward a fully automated batch-testing cycle



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Summary

- P-ONE is a newly proposed cubic-kilometer-scale high-energy neutrino telescope near Vancouver Island
- P-ONE-D requires qualified PMTs, with performance checks for noise, gain, single-photon response, and timing
- Queen's is developing a scalable characterization workflow, from single-PMT testing to automated multi-PMT measurements



P-ONE-1 PMT integration

