# Status and Prospects of the TRIDENT Deep-sea Neutrino Telescope


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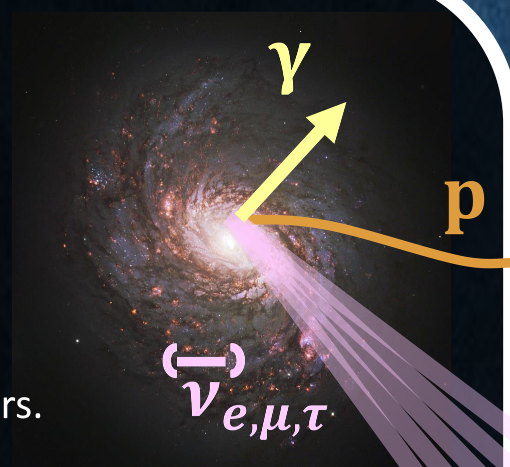
## Physics Goals

### What is the source of high energy cosmic rays?

Huge numbers of neutrinos are produced in the most violent processes in our universe.

**Weakly interacting** – neutrinos travel on **long, unperturbed** paths, allowing us to probe **deeply** into these cosmic accelerators.




*Example candidate cosmic ray source producing cosmic rays, gamma rays and neutrinos*

### Neutrino Astronomy

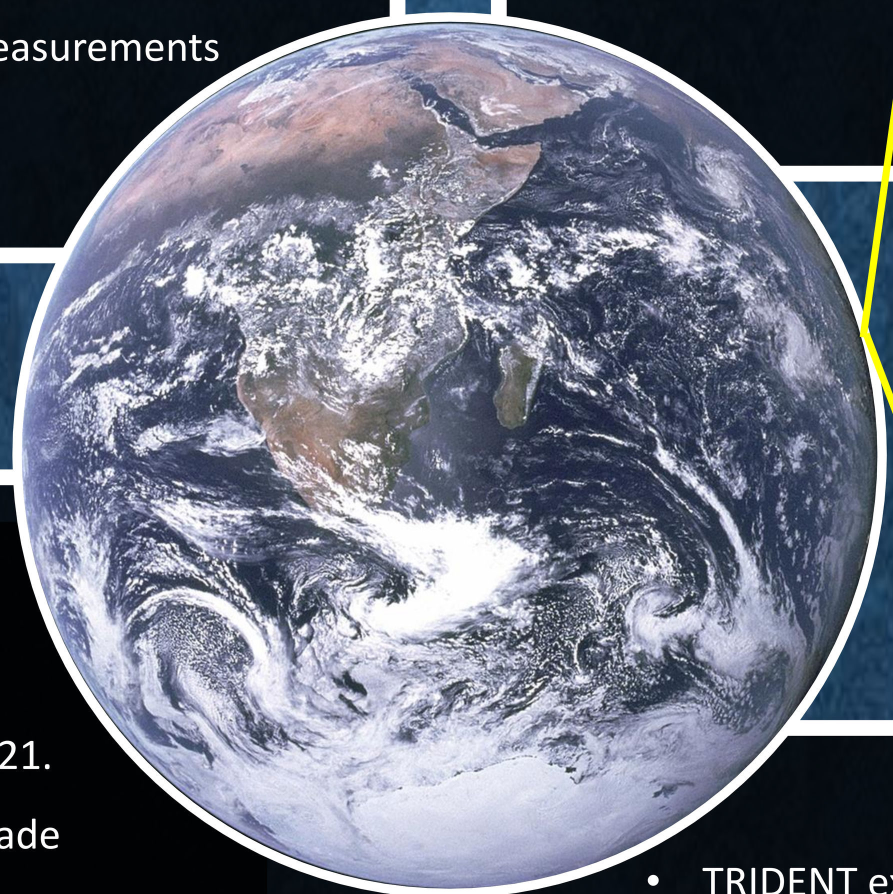
Aiming to answer this question **IceCube's** discovery of **high energy cosmic neutrinos** has driven the burgeoning field of high energy neutrino astronomy [1][2].

To **understand** potential neutrino sources, future neutrino telescopes need to:

1) Rapidly isolate neutrinos from astrophysical neutrino sources
2) Efficiently measure astrophysical neutrinos of all flavours

The next-generation Tropical Deep-sea Neutrino Telescope (TRIDENT) aims to have:

- Large effective area, a wide energy range and fine direction resolution for neutrinos of all flavours [3]
- Strong neutrino flavour discrimination for precise flavour ratio measurements made over astronomical distances – tests for new physics [4]



## The TRIDENT Detector

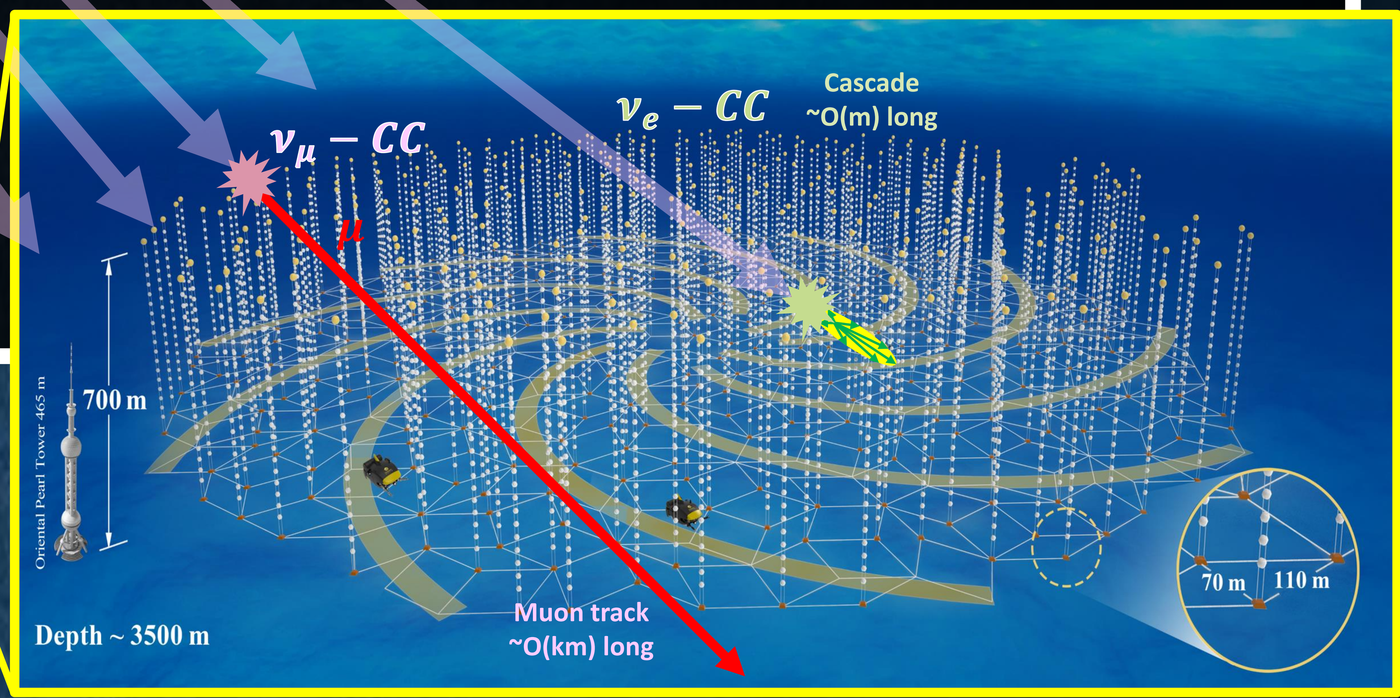
### Hybrid Digital Optical Modules (hDOM)

- Design includes multiple PMTs and SiPMs to maximize the photosensitive area and allow for precise photon timing measurement.
- Waveforms readout for added precision, useful for $\nu_\tau$ identification

*Hemisphere of hDOM prototype with PMTs and SiPM back-end locations*

### Deep-sea String Array

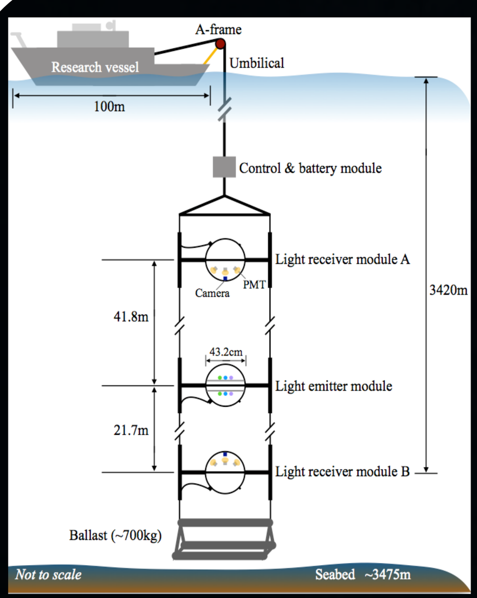
- Favourable site for the detector located in the South China Sea.
- Positioned near the equator – telescope can scan the entire sky as the Earth rotates.
- Site is 3.5km below sea level – large depths expect to reduce atmospheric backgrounds, have milder sea currents and lower bioactivity.
- ~1200 strings arranged over ~8km³ in an uneven Penrose tiling layout.
- String arrangement aims to balance a wide energy range for a variety of potential neutrinos sources, along with boosted sensitivity to all neutrino flavours.




## Status

### Pathfinder T-REX Mission:

- Deployed a pathfinder experiment 3.5km deep at the detector site, at the end of 2021.
- Independent PMT and camera systems made measurements of light scattering and absorption.
- Measured sea current speeds, $^{40}K$ decay rates.
- At 3.5km, measured, $\lambda_{abs} \approx 27$m and $\lambda_{scat} \approx 63$m for Cherenkov light, and sea current speeds < 10 cm $s^{-1}$.




*T-REX PMT + Camera "Fishing" system*

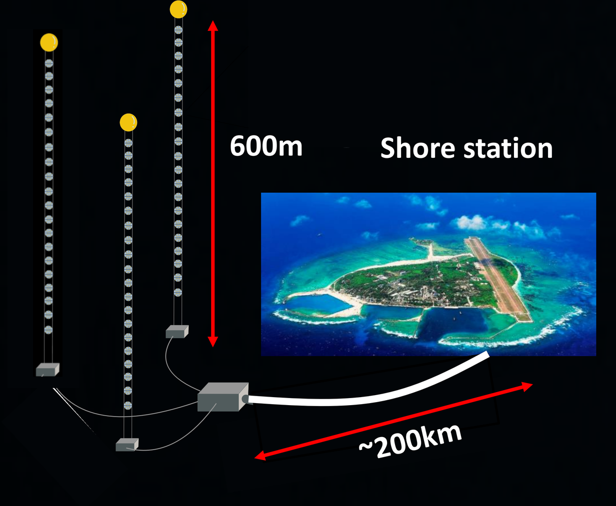
### R&D for Electronics, Calibration and hDOM

- Undersea power and data network under development.
- PMT and SiPM testing ongoing.
- hDOM optical calibration testing in water tank.
- hDOM acoustic positioning testing.
- hDOM production line initiation at shore station.
- hDOM design performance testing in simulation.
- String integration underway.
- DAQ and Trigger design progress. See poster #

*View of LED at the end of the 10m long hDOM and calibration water tank*

### Ahead

- Aim to deploy power distribution & data transmission cable along with the first 10 strings – TRIDENT Phase 1 in 2026, to serve as:
  - Technology demonstration
  - Measure atmospheric neutrinos
  - Environment characterization and monitoring



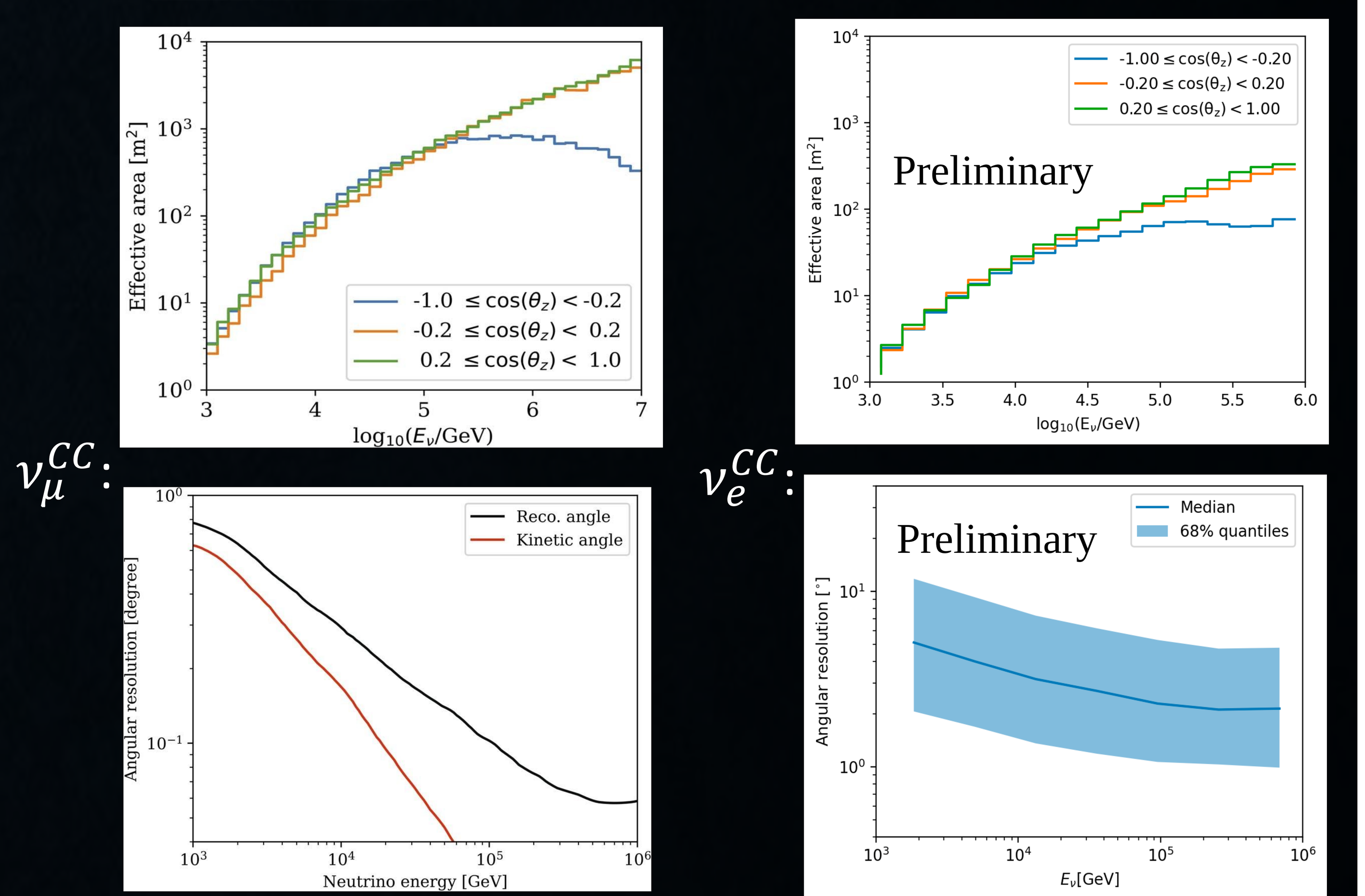

Build Phase 1 and power/data communication with island

## Prospects

### Track and Cascade Reconstruction

- TRIDENT expects **large** effective areas ($A_{eff}$)* for **both** tracks and cascades, while balancing good angular resolution (AR) for each interaction type.
- Improve $\nu_e$ and $\nu_\tau$ flavour separation with quality hDOM light collection along with PMT waveforms. See poster #285.

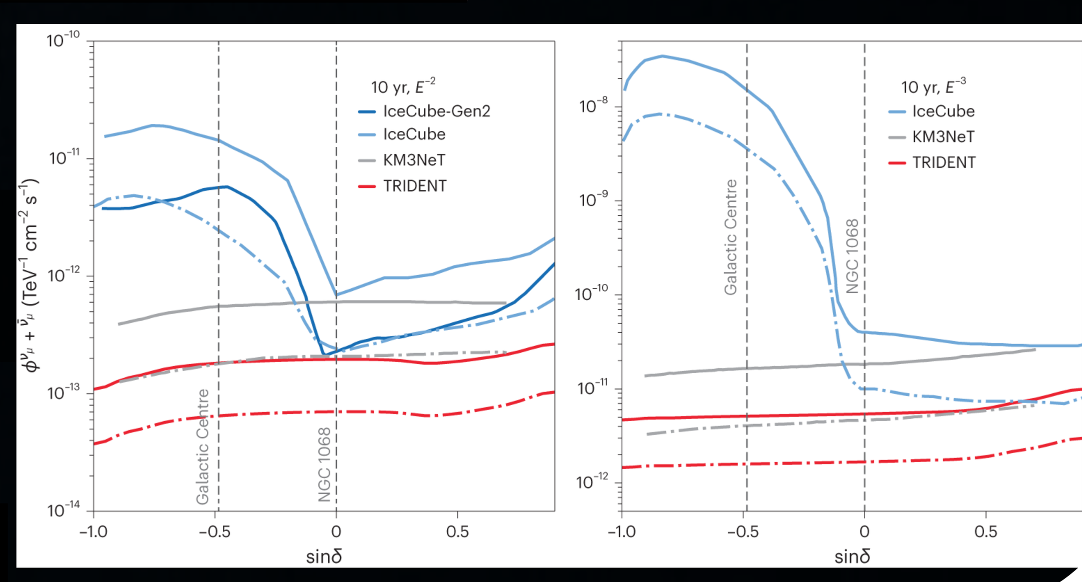
*Effective area and angular resolution for $\nu_\mu^{CC}$ and $\nu_e^{CC}$ interactions simulated in the TRIDENT detector [3]*




| String separation | $\nu_e - CC$ | | $\nu_\mu - CC$ | | |
|---|---|---|---|---|---|
| $E_\nu$ = 5 TeV | Angular resolution | $A_{eff}$ | Angular resolution | $A_{eff}$ (vert.) | $A_{eff}$ (hor) |
| + 30% | -15% | -20% | -25% | -20% | +20% |
| - 30% | +30% | 0% | +15% | -20% | -40% |
| $E_\nu$ = 100 TeV | AR | Aeff | AR | Aeff (vert) | Aeff (hor) |
| + 30% | -30% | +60% | -35% | +20% | +40% |
| - 30% | +20% | -50% | +25% | -40% | -40% |

Preliminary

*Example varying TRIDENT string separation, and calculating the impact to the effective area and angular resolution for tracks and cascades, impacting sensitivity*




*Projected point source sensitivities and discovery potentials of TRIDENT [3]*

* ($A_{eff}$ * Flux = Event Rate)

## References


[1] Aartsen, M. G. et al. Evidence for high-energy extraterrestrial neutrinos at the IceCube detector. Science 342, 1242856 (2013).

[2] IceCube Collaboration et al. Neutrino emission from the direction of the blazar TXS 0506+056 prior to the IceCube-170922A alert. Science 361, 147–151 (2018).

[3] The TRIDENT Collaboration, "A multi-cubic-kilometre neutrino telescope in the western Pacific Ocean", Nature Astronomy volume 7, pages1497–1505 (2023)

[4] Abbasi, R. et al. Search for quantum gravity using astrophysical neutrino flavour with IceCube. Nat. Phys. 18, 1287–1292 (2022).