Identifying Astrophysical Tau Neutrinos with hDOM Waveforms in TRIDENT

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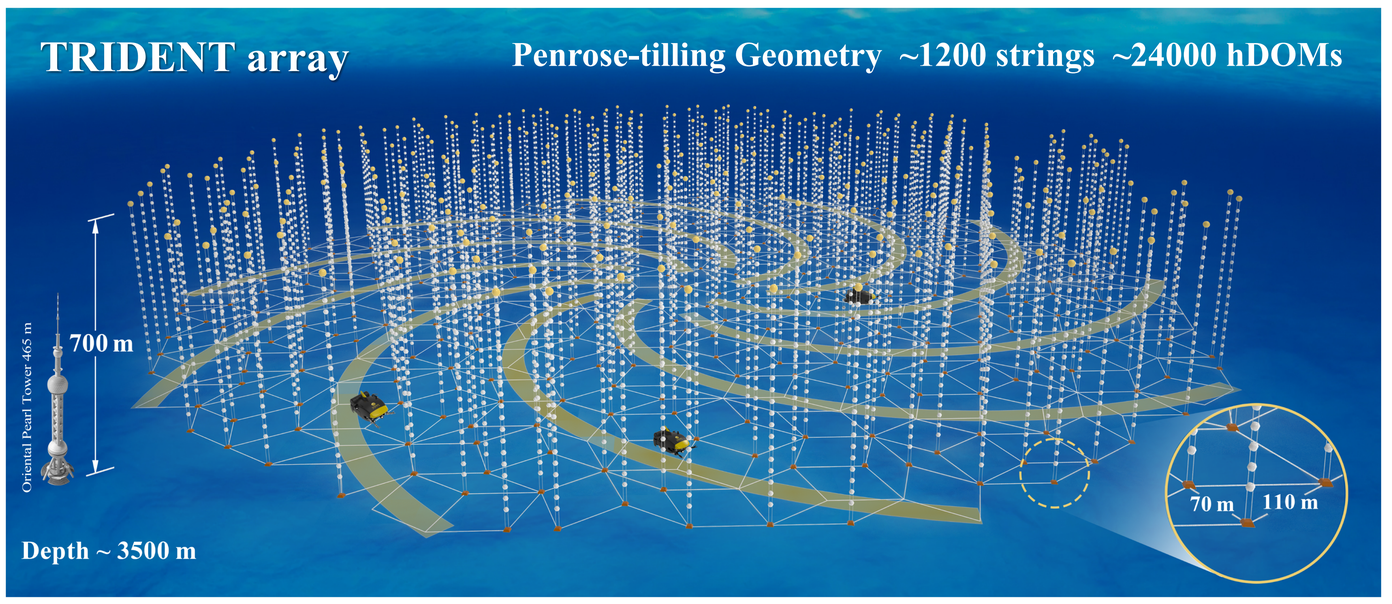
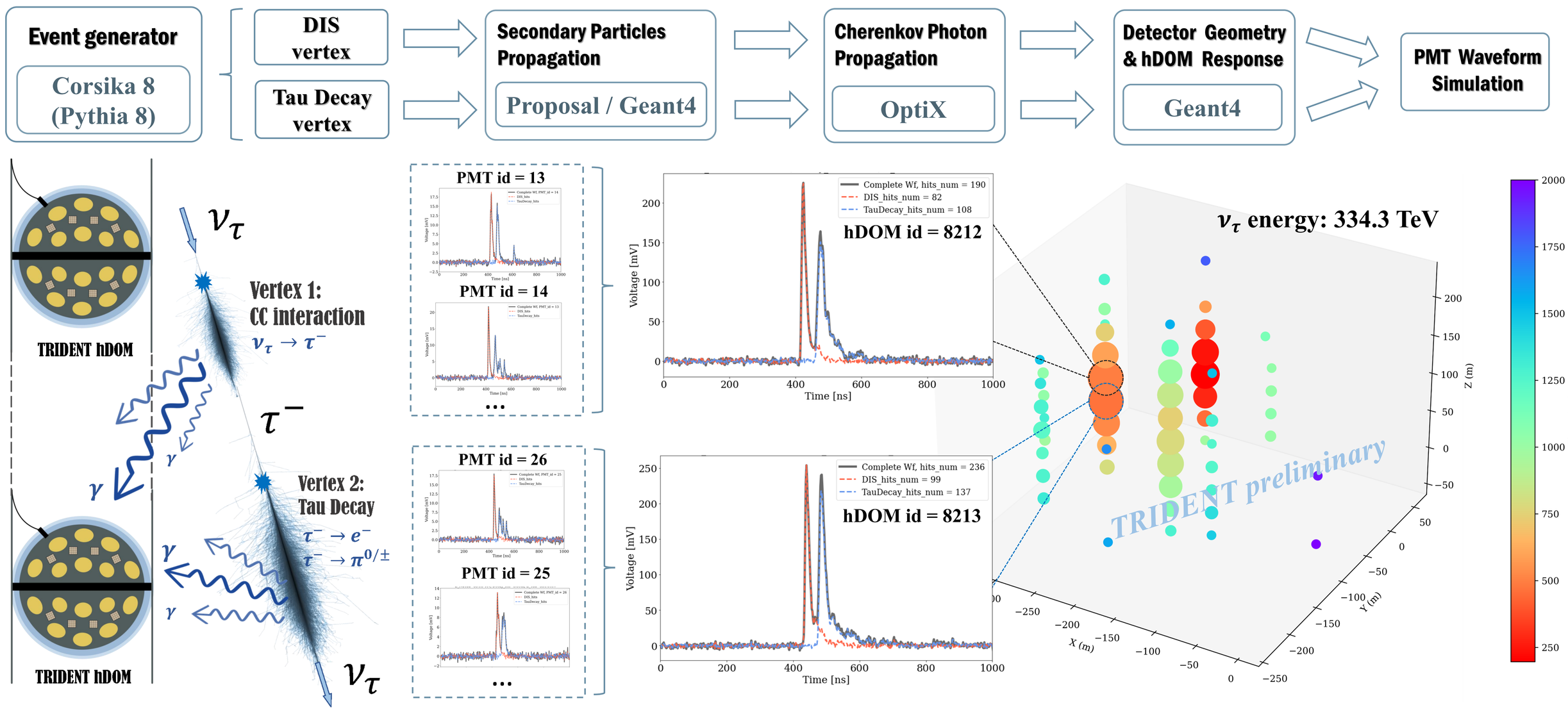
Abstract

TRIDENT [1] is a next-generation water-based neutrino telescope, incorporating Hybrid Digital Optical Modules (hDOM) [2] with **multi-channel PMTs** and SiPMs. This system expects to enhance the sensitivity to **Tau Neutrinos** by providing larger photon coverage and independent waveform readout, fully leveraging the low optical scattering in seawater. Here, we present the latest progress of tau classification in TRIDENT using **Waveform Techniques**.



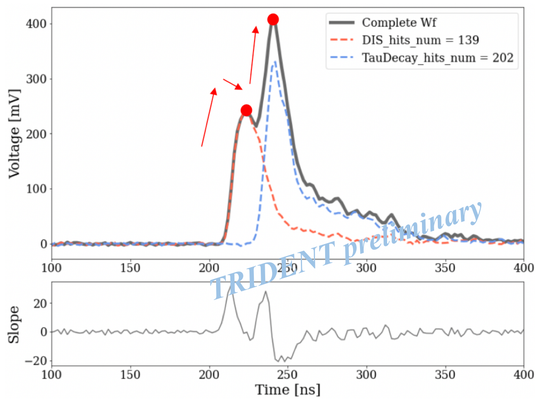
Tau neutrino Charge Current interaction & Simulation pipeline in TRIDENT



Double Pulse Algorithm (DPA) in TRIDENT

Key Parameters:

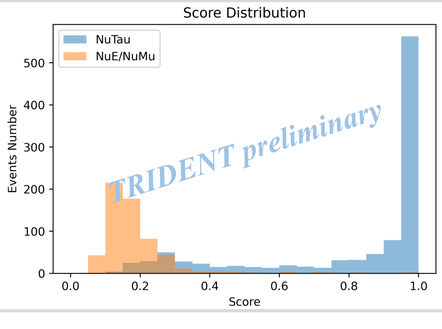
- **Peak Charge threshold** >= 16 P.E.
- **Peak Width threshold** >= 20ns
- **Width of Peak Rising Edges** >= 12ns
- **Peak number** >= 2
- **Distance of first two peaks** > 20ns
- **Voltage ratio of first two peaks** < 3



Future: combining with Graph Neural Networks

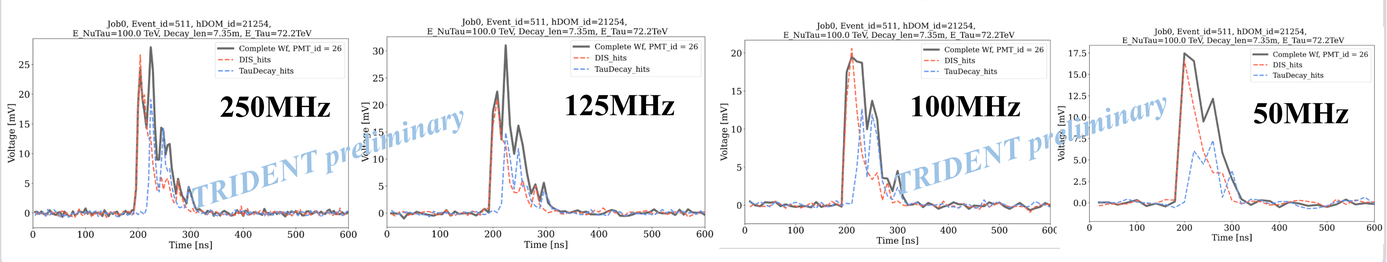
Point Cloud in Trident-Net [3] :

- **GNN node:** each hDOM
- **Connection:** 10-15 brightest hDOMs
- **Feature:** hDOM[x, y, z] + [waveform]
- **Label:** ν_τ as 1, ν_μ/ν_e as 0

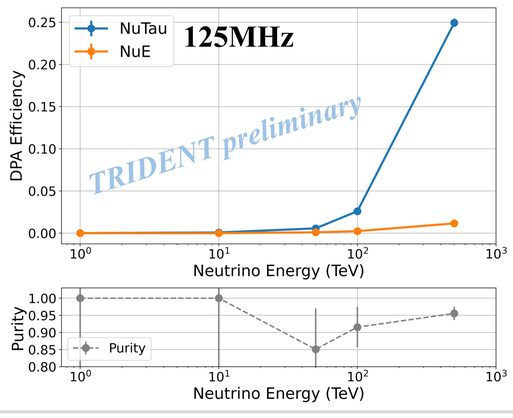


Exploration on different waveform sampling rates

MC examples from waveform sim: potential merge of the two pulses



DPA selection efficiency & Expected event rate in TRIDENT



Assumed an isotropic diffused flux [4] :

$$\Phi_{Astro}^{per-flavor} = 1.68\times\left(\frac{E_\nu}{100TeV}\right)^{-2.58}\times 3\times 10^{-18} GeV^{-1}s^{-1}cm^{-2}sr^{-1}$$

Double pulse event rate per year in TRIDENT :

	1-100TeV	100TeV-1PeV
NuTau CC	0.60 ± 0.51	3.98 ± 0.15
NuE CC	0.27 ± 0.21	0.12 ± 0.03

[1] *Ye, Z.P., Hu, F., Tian, W. et al. A multi-cubic-kilometre neutrino telescope in the western Pacific Ocean. Nat Astron 7, 1497–1505 (2023).*
[2] *Fan Hu , Zhuo Li , Donglian Xu , Exploring a PMT+SiPM hybrid optical module for next generation neutrino telescopes, PoS ICRC2021 (2021), 1043*
[3] *Wei Tian. et al. Searching for astrophysical tau neutrinos with hDOM waveforms in TRIDENT, PoS ICRC2023 (2023), 1092*
[4] *Abbasi, R. et al, Characterization of the Astrophysical Diffuse Neutrino Flux using Starting Track Events in IceCube, Arxiv 2402.18026*

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