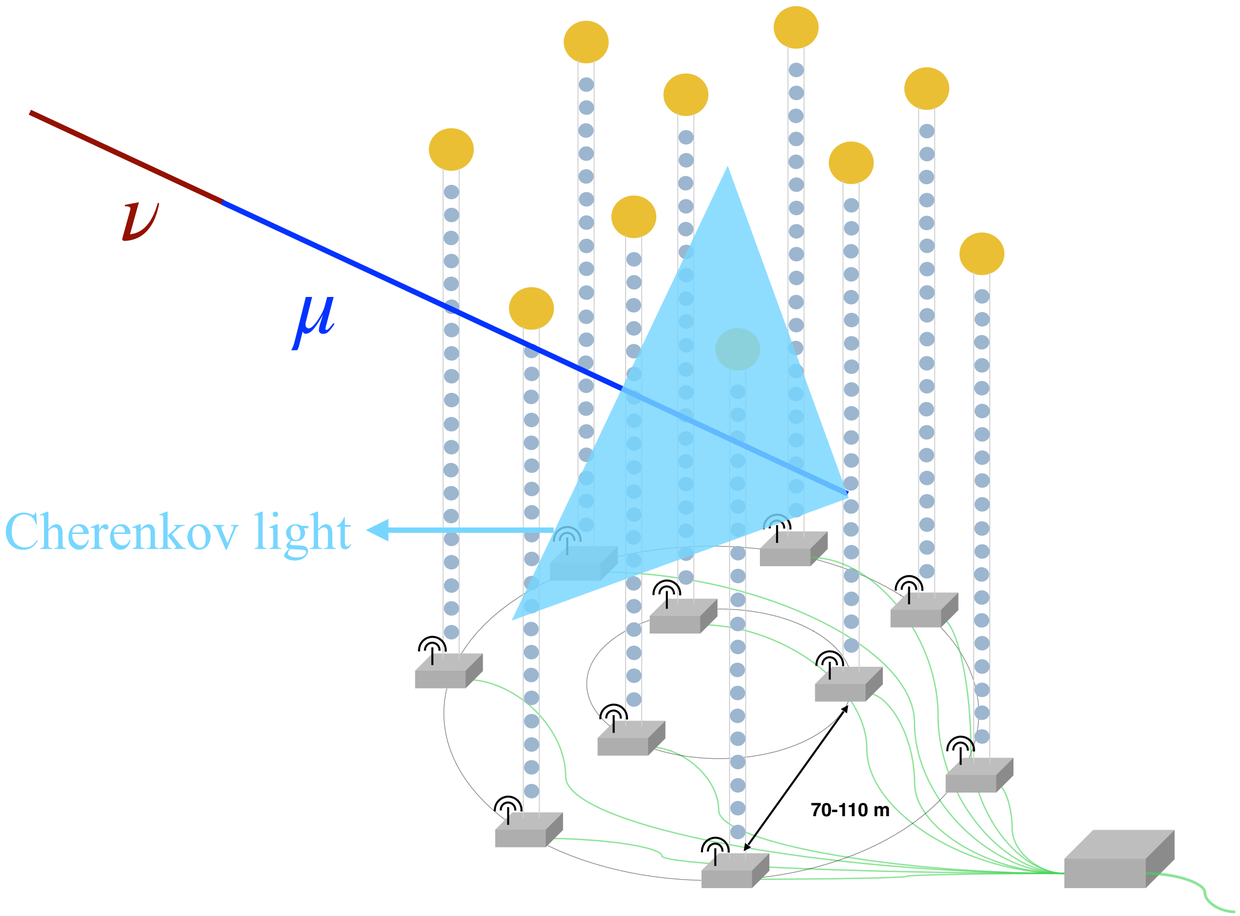
A cost-Effective Optimization of the hybrid-DOM Design for TRIDENT

Hengbin Shao, on behalf of the TRIDENT collaboration

Tsung-Dao Lee Institute / Shanghai Jiao Tong University. China

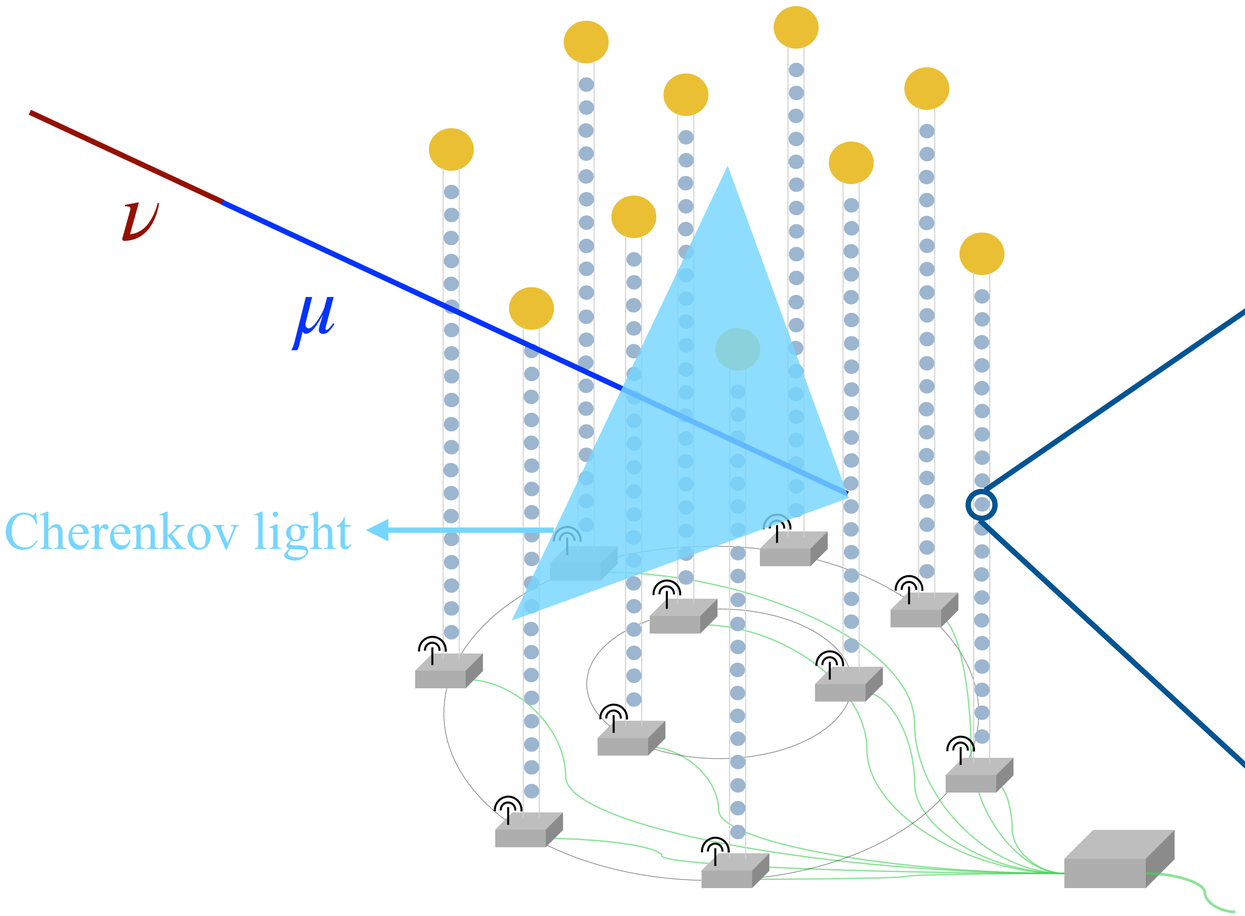
Based on arXiv:2507.10256

Introduction



Neutrino telescope

Introduction



Neutrino telescope

IceCube

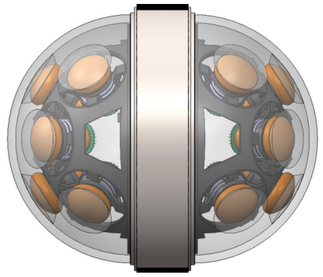
NIM A 876 (2017)

Baikal GVD

JINR, 16 Feb(2023)

P-ONE

PoS (ICRC2025) 1202



KM3NeT

JINST 17 (2022) P07038

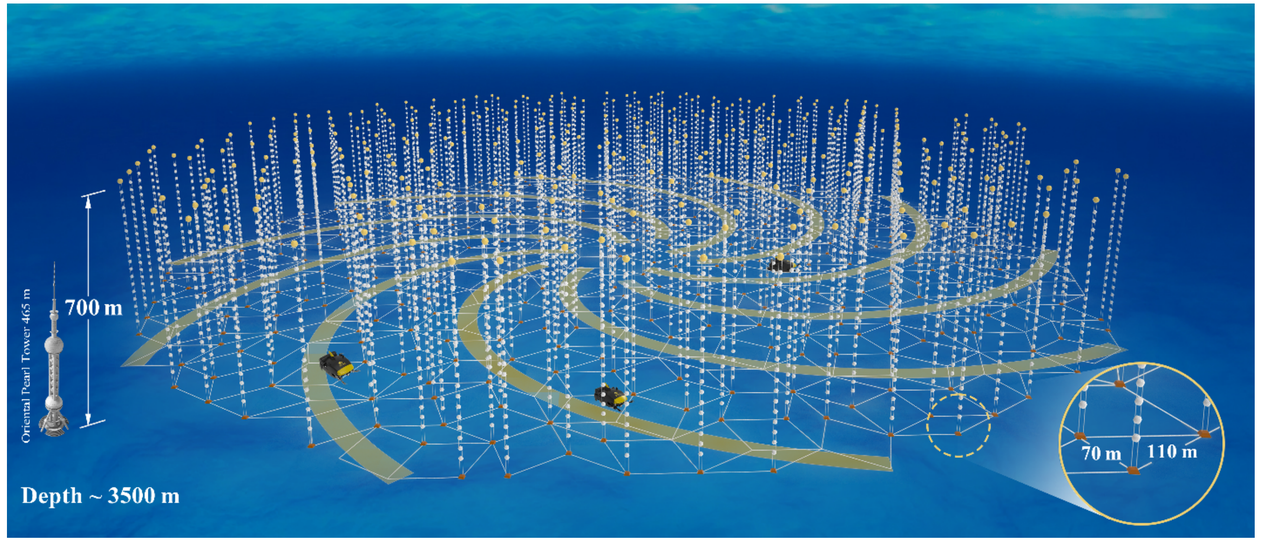
IceCube Upgrade

PoS(ICRC2023)967

Directional information · Local coincidence

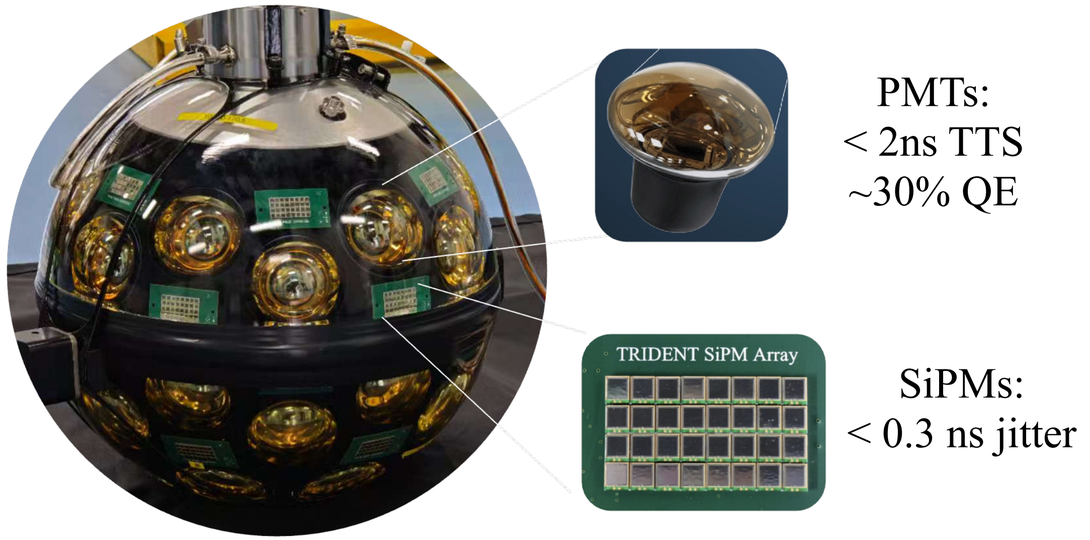
Introduction

TRopIcal DEep-sea Neutrino Telescope (TRIDENT)



- ~1000 strings × ~20 hDOMs
- Depth:~3.5 km
- Volume: ~8 km^3

hybrid Digital Optical Module (hDOM)



Preliminary Mechanical Design of the hDOM, PoS (ICRC2023)

PMTs

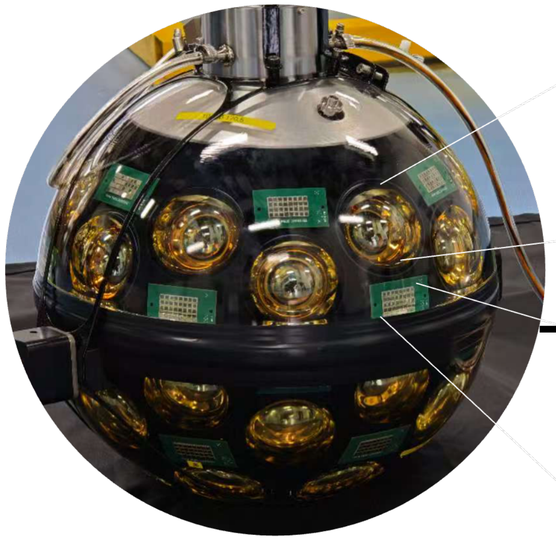
- waveform readout

SiPMs

- fast timing

Introduction

Detector design = Trade-off between physics performance and engineering



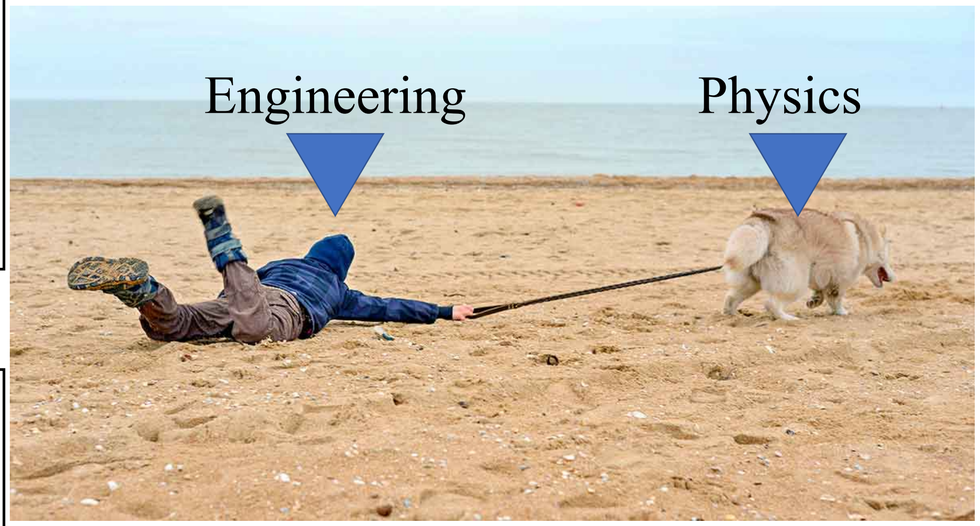
hDOM prototype

Physics:

- Photocathode coverage
- Timing resolution
- Detection efficiency

Engineering:

- Power
- Cost
- Complexity



Introduction

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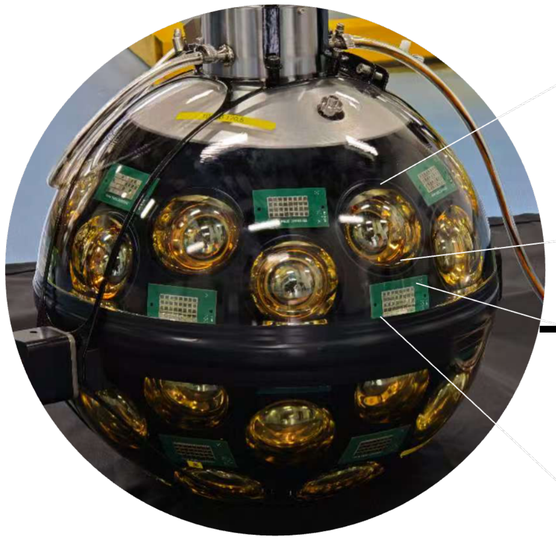

hDOM prototype

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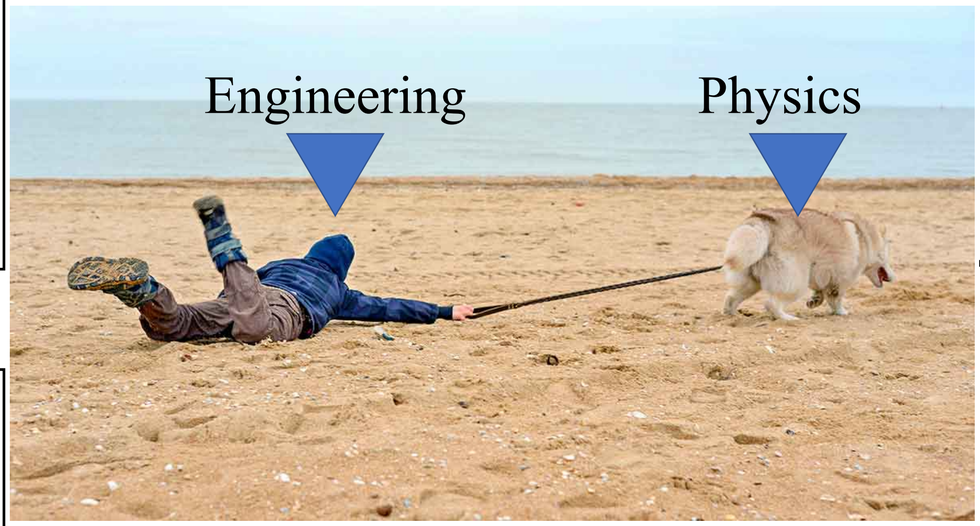

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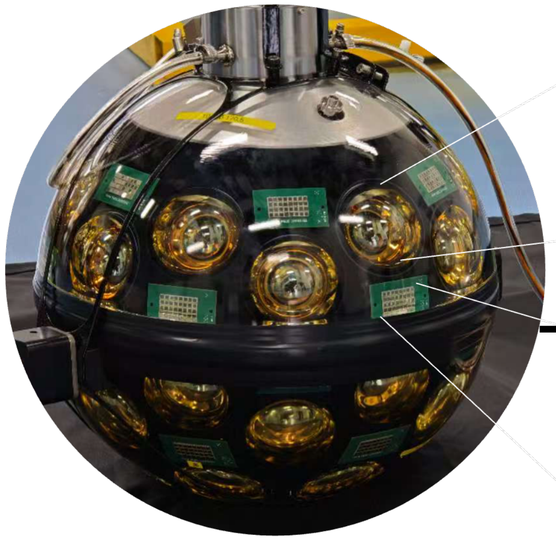
Explore alternative hDOM designs

Introduction

Detector design = Trade-off between physics performance and engineering



hDOM prototype

Physics:

- Photocathode coverage
- Timing resolution
- Detection efficiency

Engineering:

- Power
- Cost
- Complexity

3” PMT : R14374 4” PMT : N2042

Design Configurations

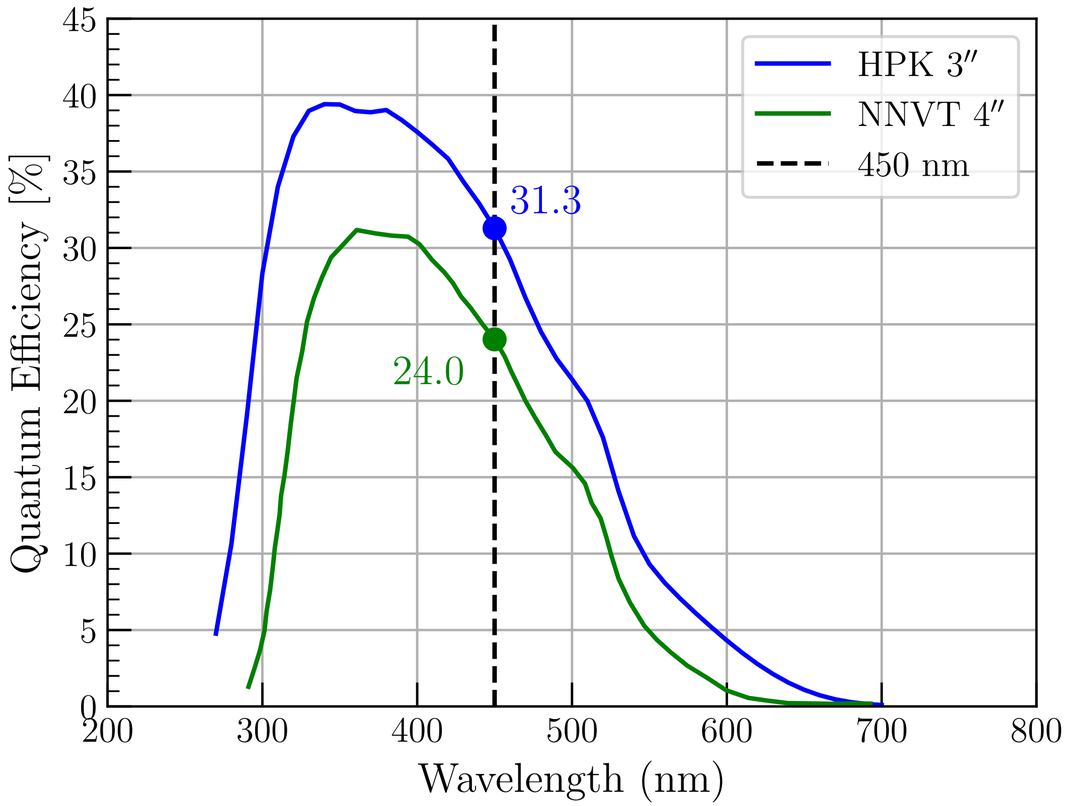
3” PMT hDOM design
•3” PMTs × 31

4” PMT hDOM design
•4” PMTs × 19

	Key Configuration Parameters	
Parameters	**Hamamatsu R14374（3”）**	**NNVT N2042（4”）**
Photon cathode diameter [cm]	7.2	9.8
QE@450nm [%]	31.30	23.39
TTS [ns]	1.4	2.0
Number per DOM	**31**	**19**
Total photon-sensitive area [cm^2]	**1455**	**1704**

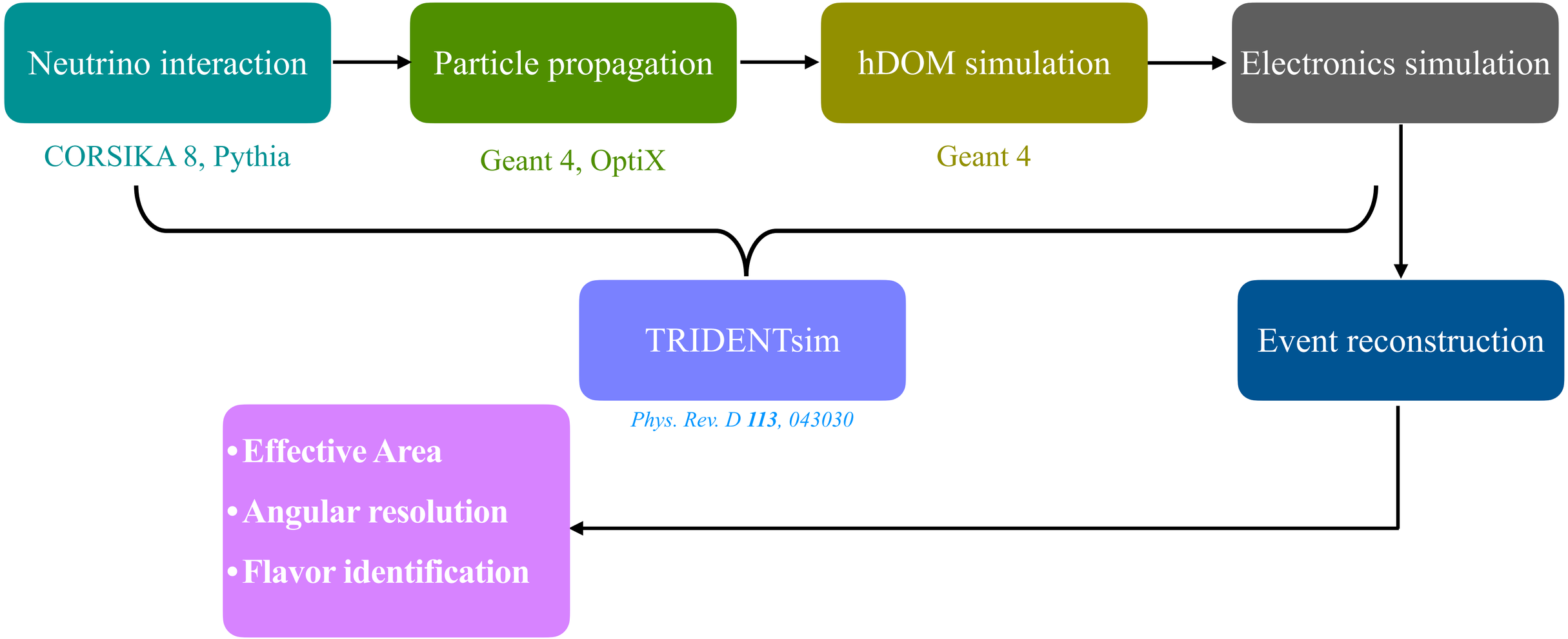
QE setup

QE configuration



Configuration	QE curve used	QE data source
3″ baseline	🔵 Hamamatsu 3″	Hamamatsu
4″ high-QE	🔵 Hamamatsu 3″	
4″ low-QE	🟢 NNVT 4″	Icecube-Gen2 *PoS ICRC2023 (2023)985*

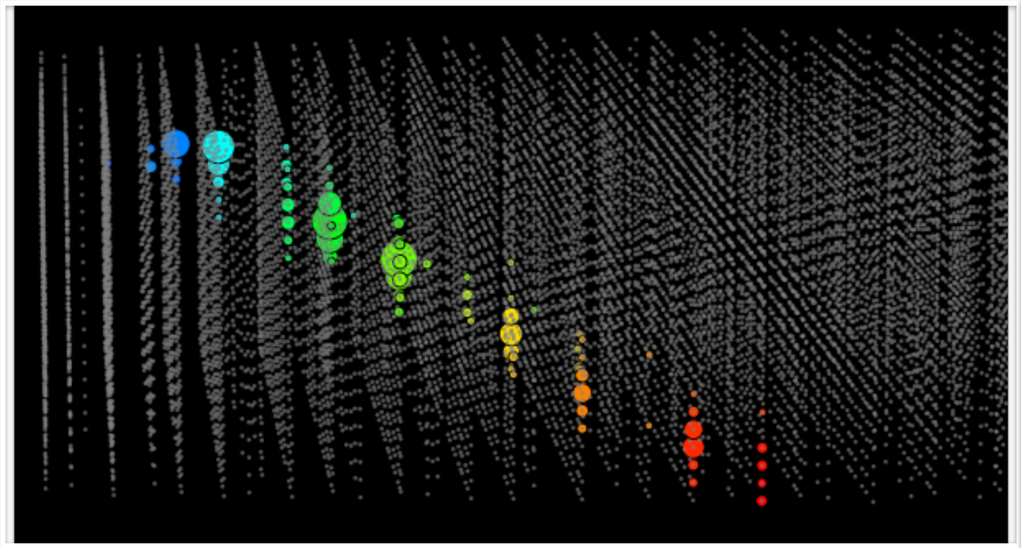
TRIDENT simulation



Neutrino event

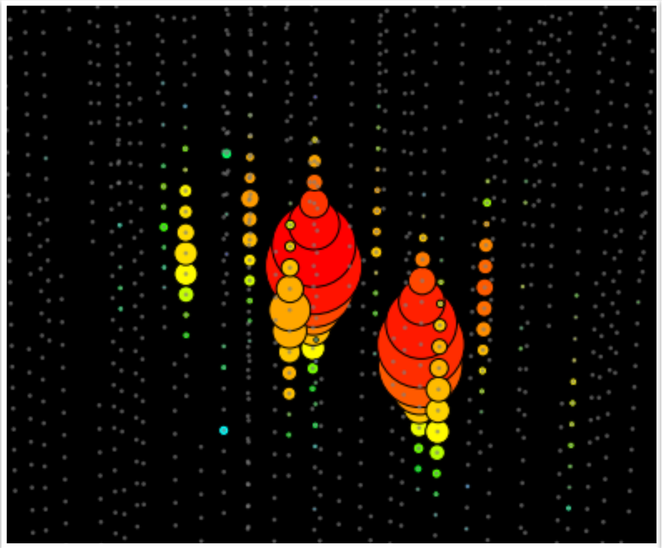
- TRIDENT Simulation

Track like event



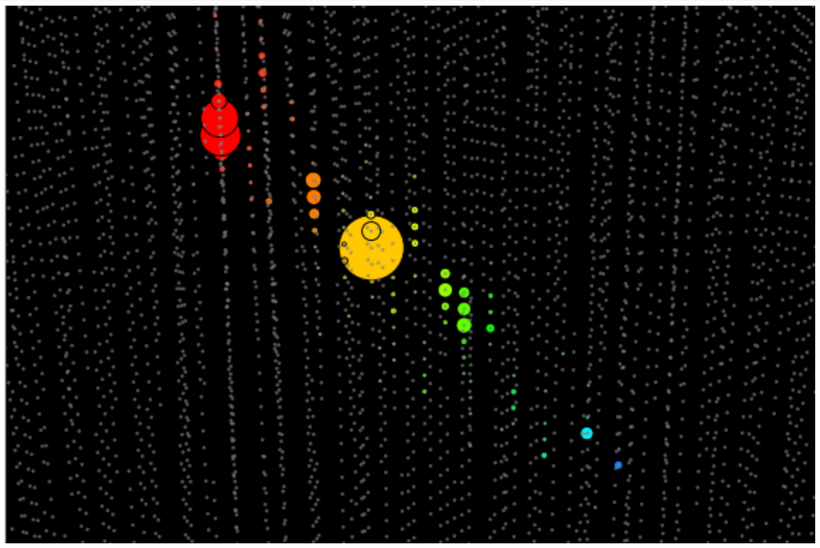
ν_μ

Cascade like event



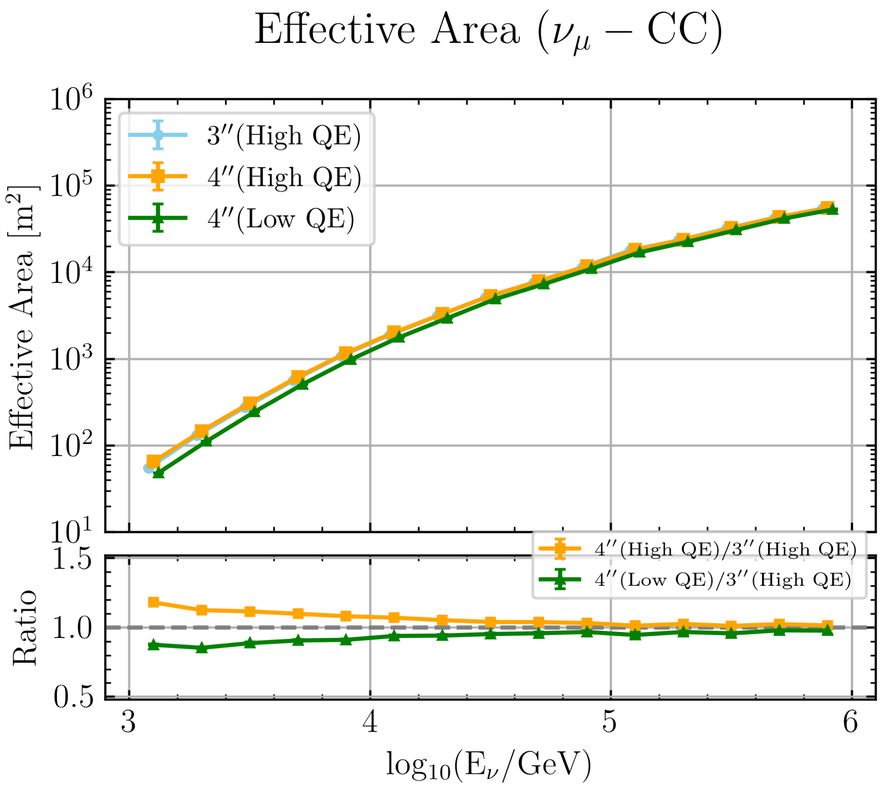
ν_e

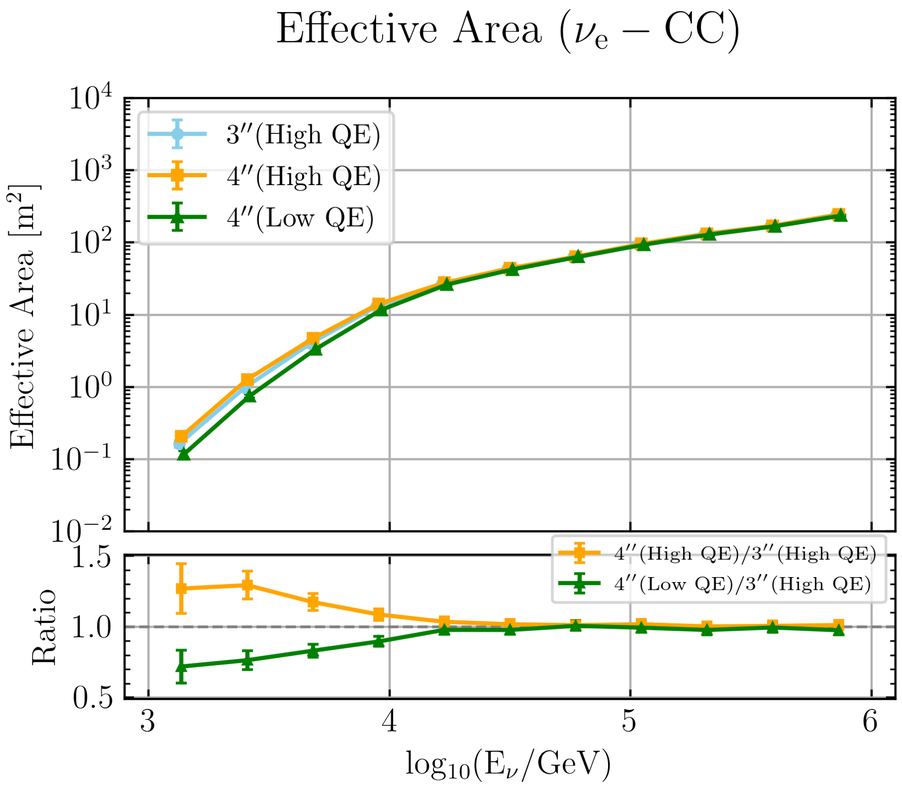
Double cascade like event



ν_τ

Detection Efficiency

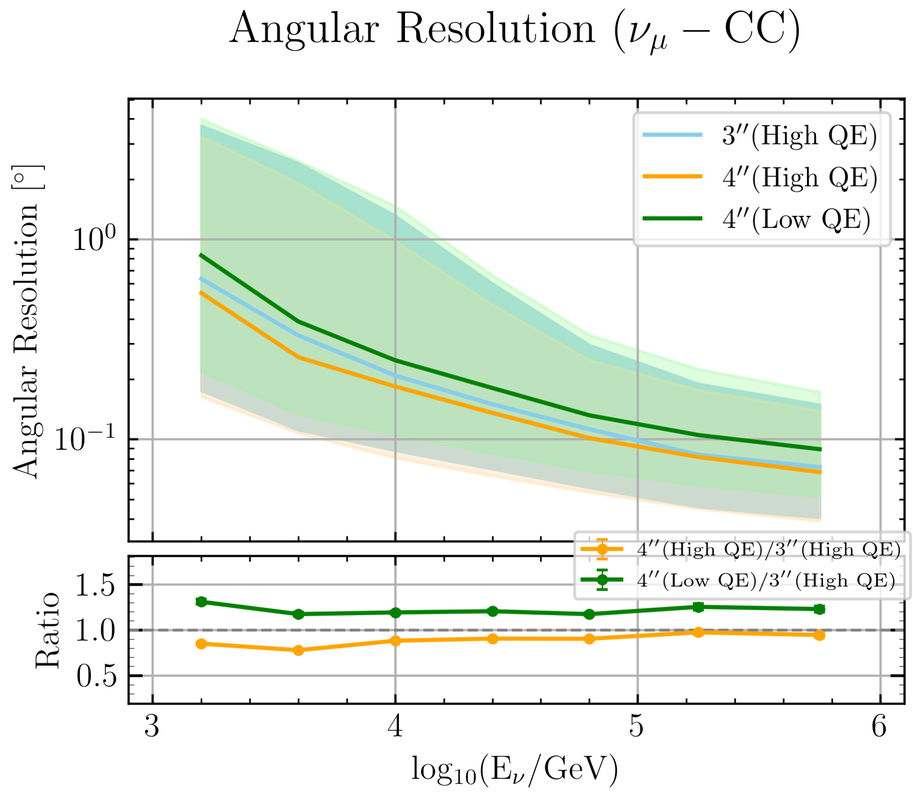


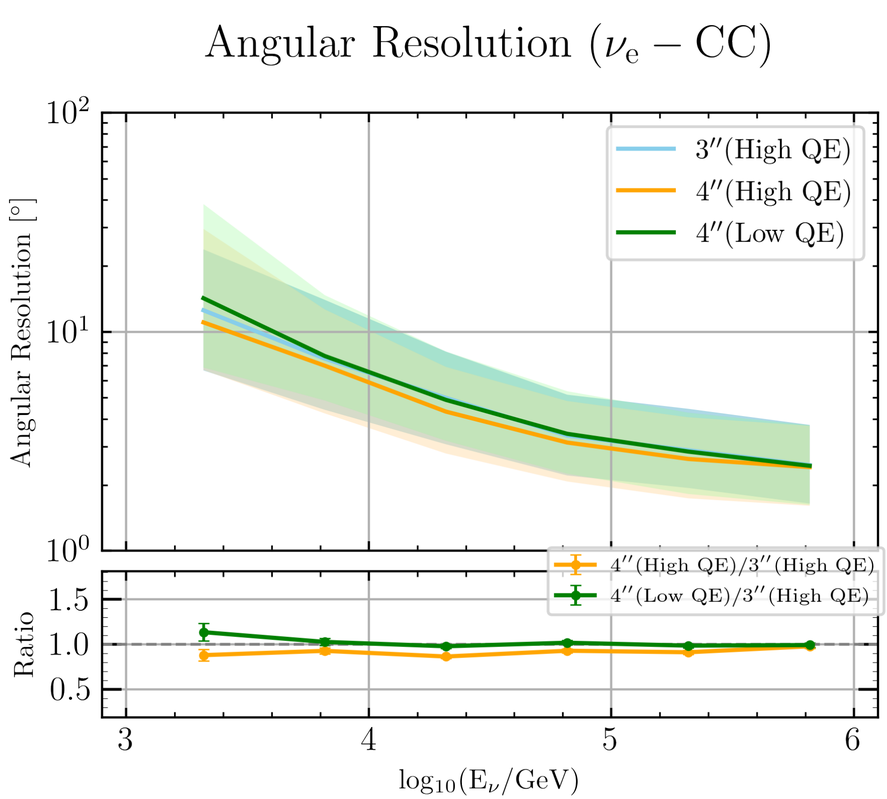


< 10 TeV: Larger effective area with high-QE 4”

> 10 TeV: Comparable performance across designs

Angular resolution





νμ CC:

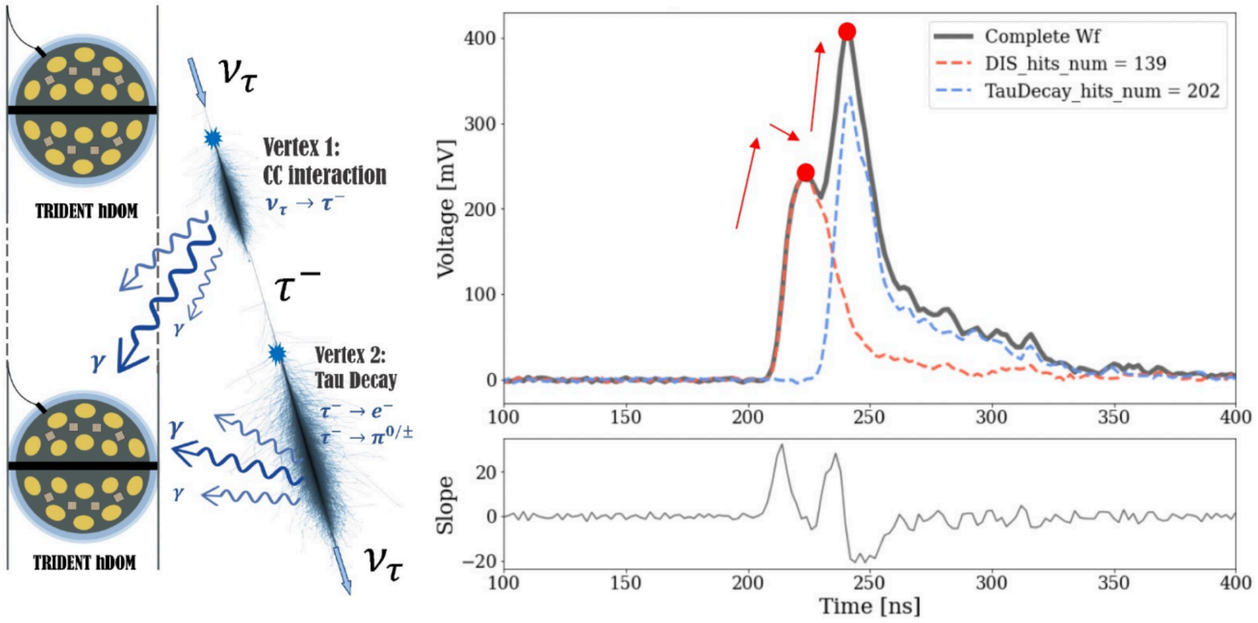
- TeV-PeV: Better performance with high-QE 4″

νe CC:

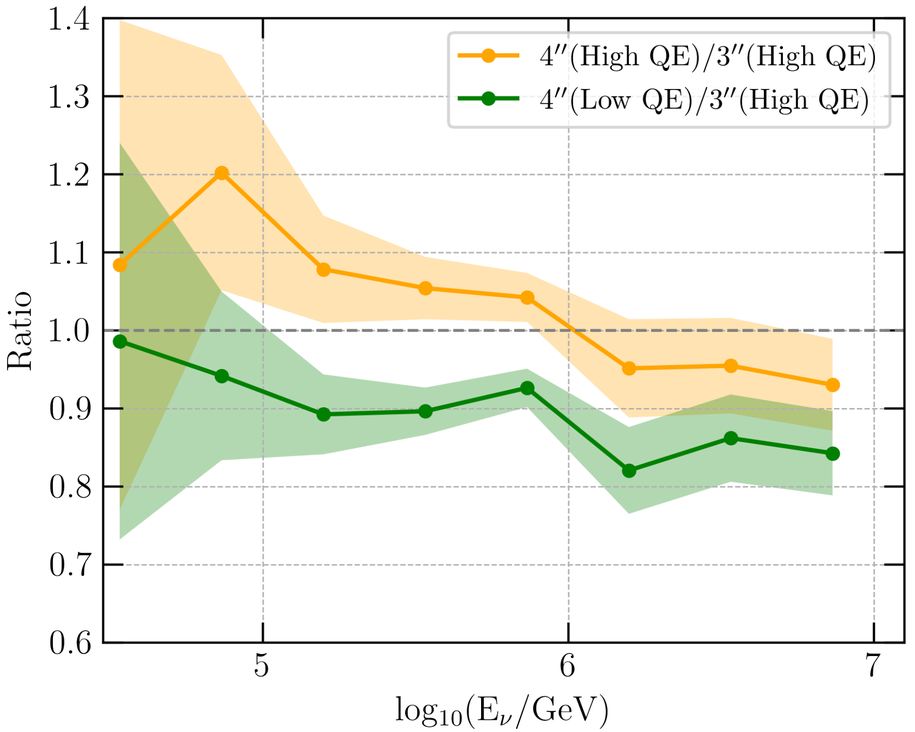
- <100 TeV: Better performance with high-QE 4″
- >100 TeV: All designs converge

Tau identification

Waveform-based search for ν_τ double-pulse events



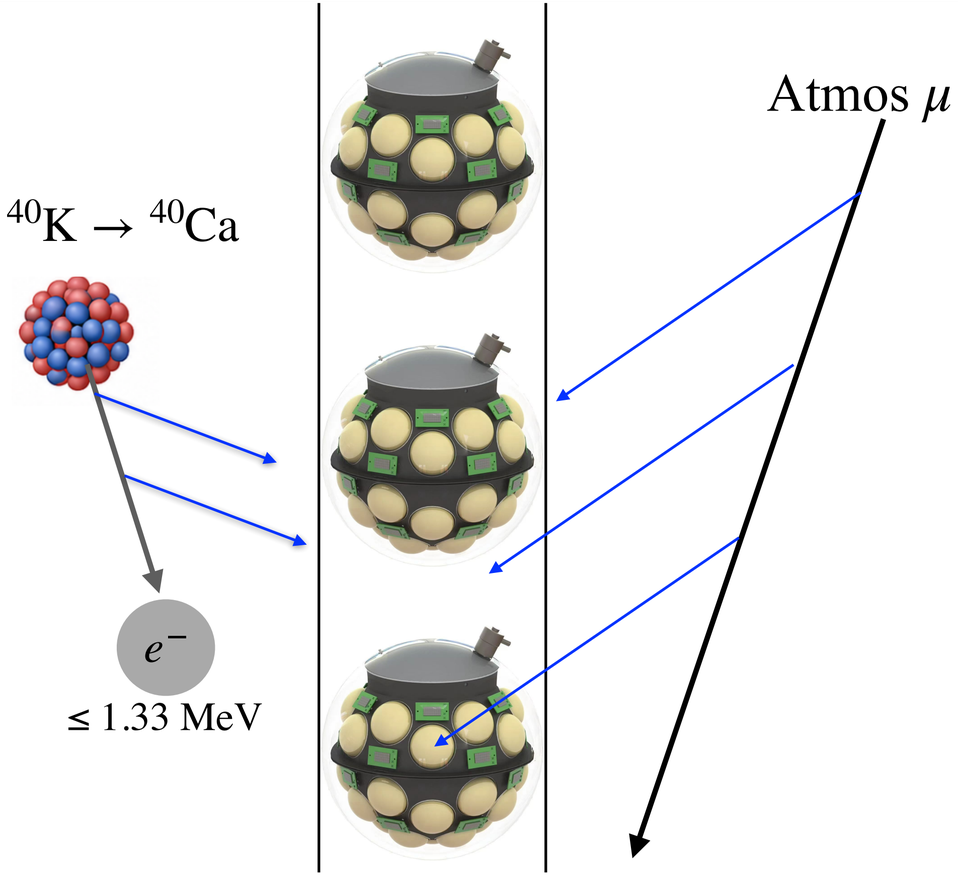
ν_τ Double Pulse Identification



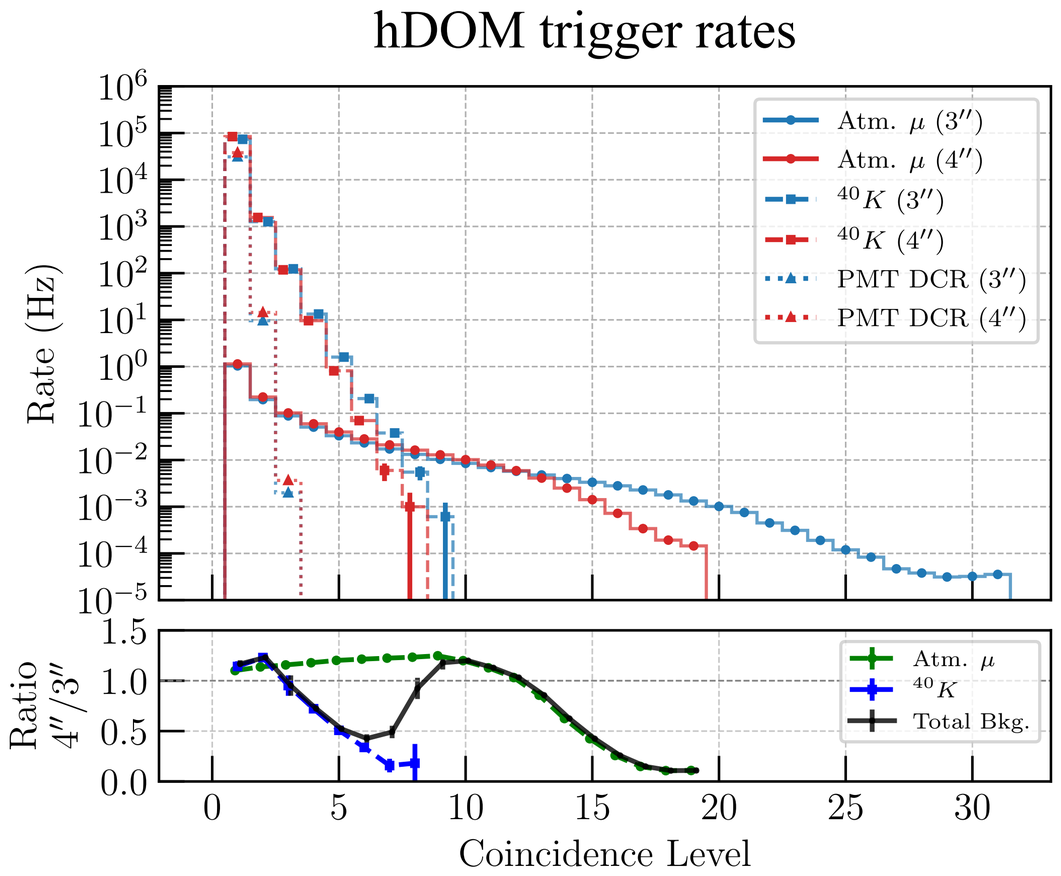
Searching for astrophysical τ neutrinos with hDOM waveforms in TRIDENT, PoS (ICRC2023)

High-QE 4”: ~10% difference from 3” in tau identification

Background Trigger Rates



Main background signal



High-QE 4″ matches 3″ background-trigger performance with fewer channels.

Photocathode response of PMT

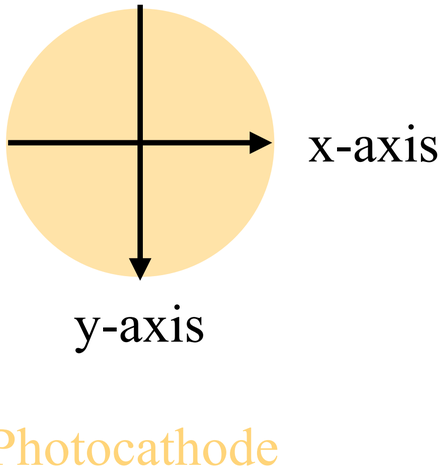
4” PMT hDOM design

Comparable physics performance with fewer channels

Photocathode response of PMT

4” PMT hDOM design

3” PMT: R14374

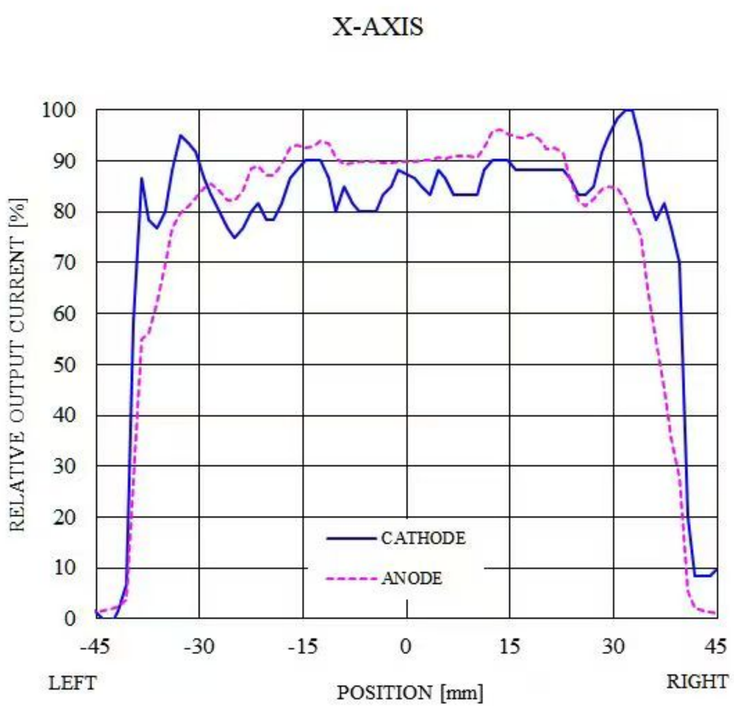


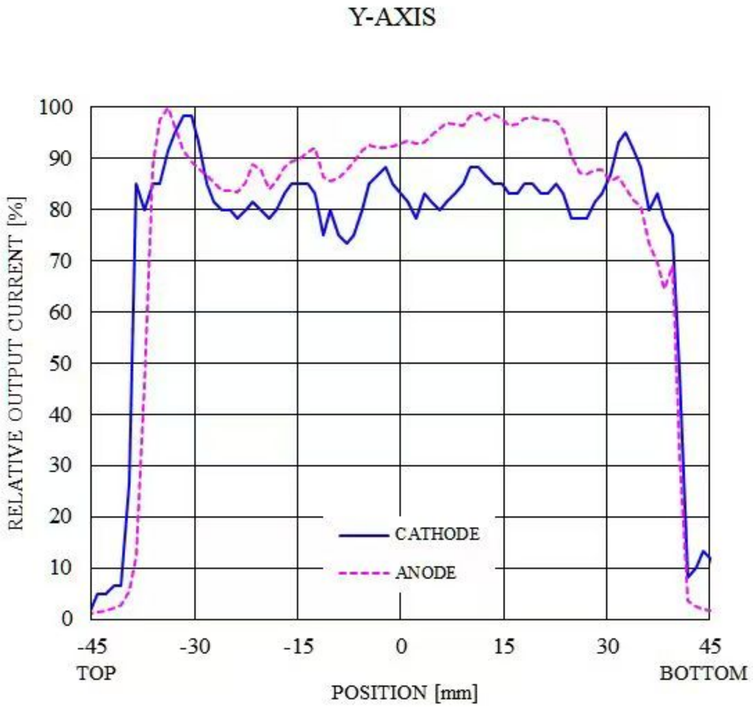
Photocathode

Comparable physics performance with fewer channels

Photocathode response of PMT

4” PMT hDOM design



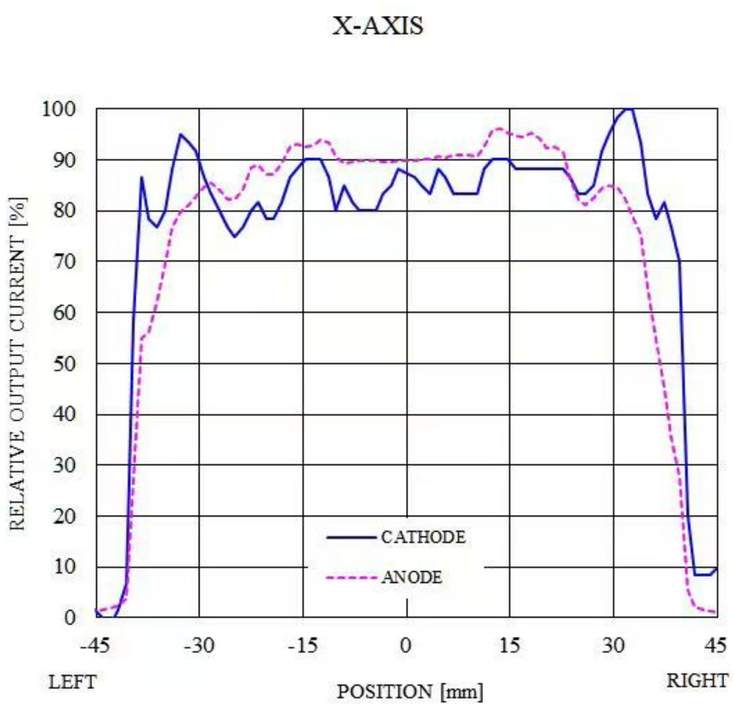


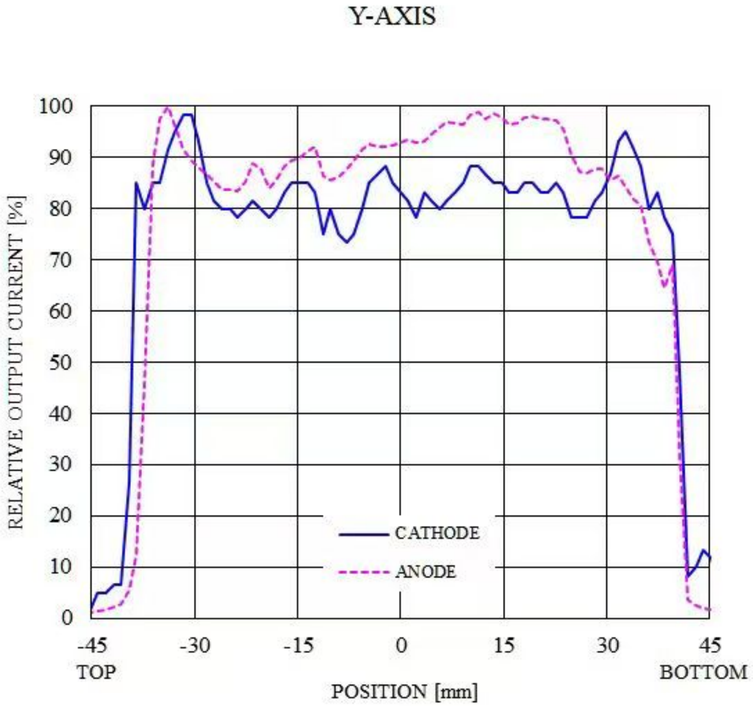
3” PMT response provided by Hamamatsu

Comparable physics performance with fewer channels

Photocathode response of PMT

4” PMT hDOM design





3” PMT response provided by Hamamatsu

Comparable physics performance with fewer channels

How about 4”?

Test setup

Laser

Optical fiber

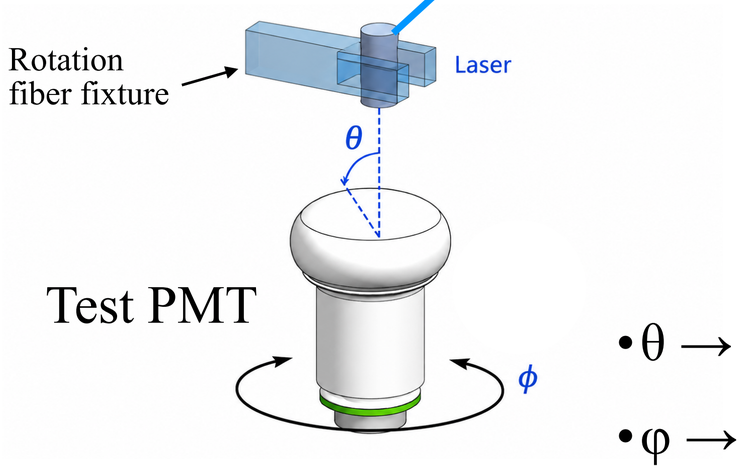
Fiber splitter

Optical fiber

Reference PMT

Normalize light intensity fluctuation

Optical fiber



Rotation stage

- θ → incident angle
- φ → azimuthal angle

Test setup

Laser

Optical fiber

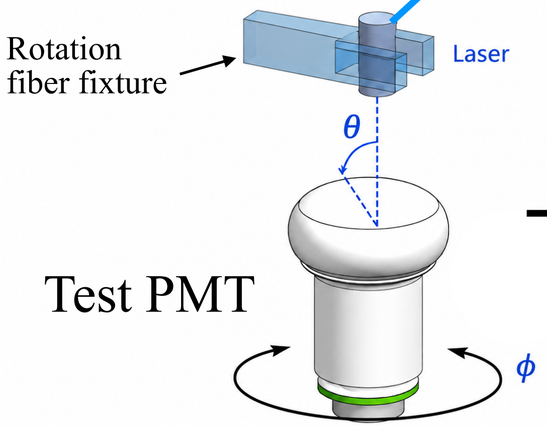
Fiber splitter

Optical fiber

Reference PMT

Normalize light intensity fluctuation

Optical fiber



Rotation stage

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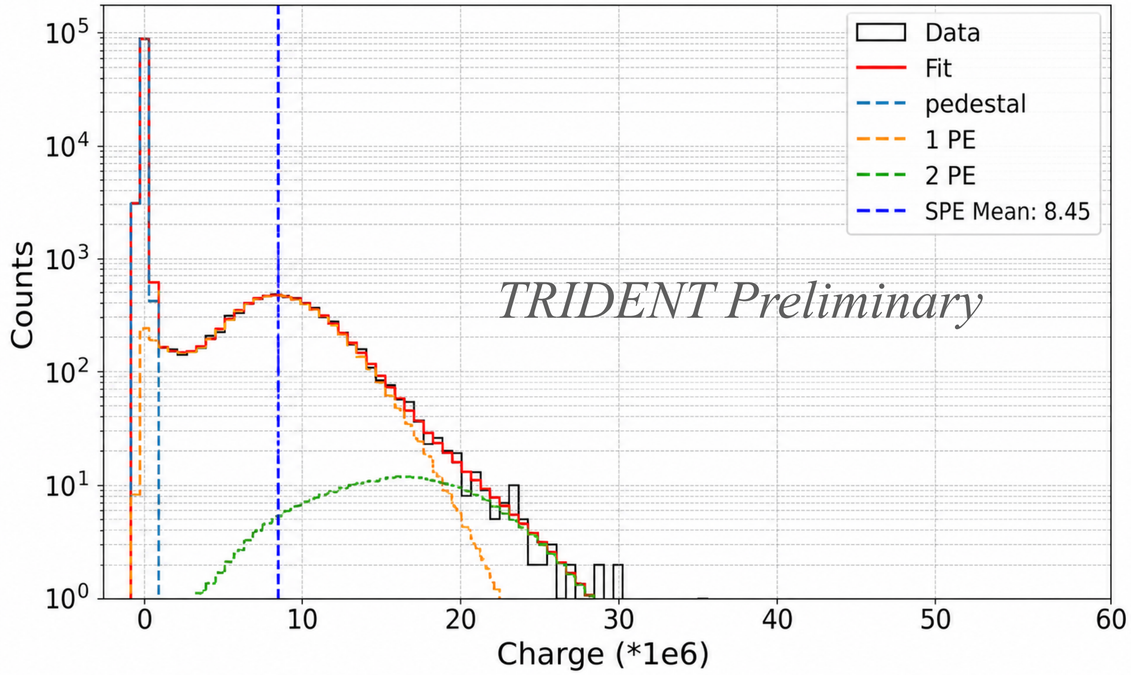
- φ → azimuthal angle

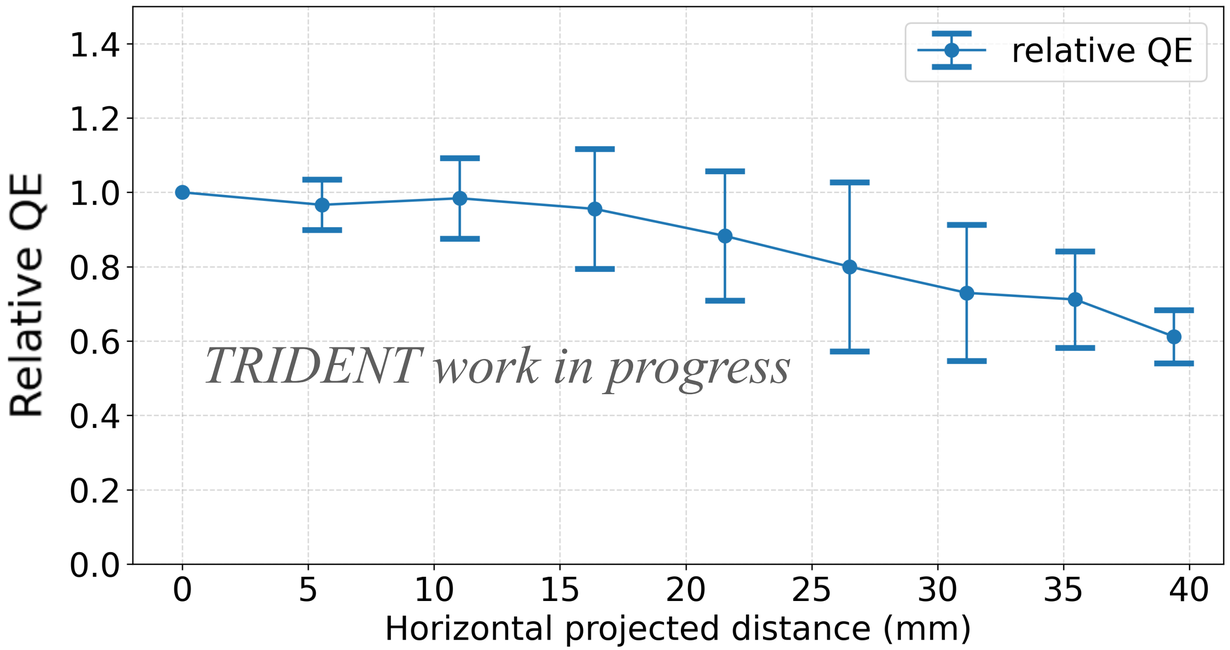


Charge spectrum: get the mean photons of the PMT recieved

Angular dependence of 3” PMT

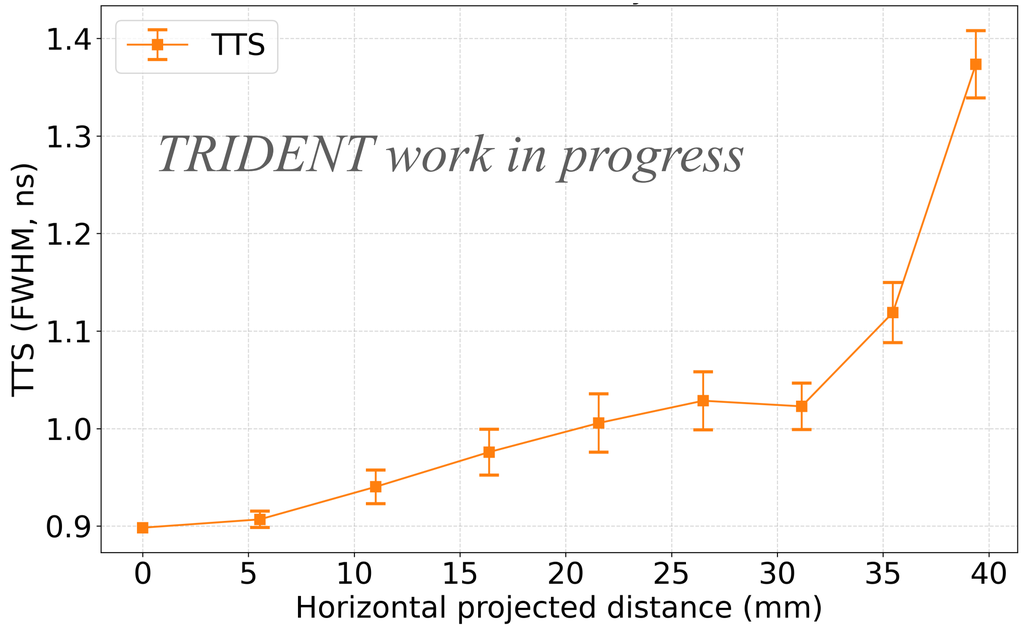
PMT model:Hamamatsu R14374

Detection efficiency



Relative Detection Efficiency

Transit Time Spread



Transit Time Spread (TTS)

4″ PMT characterization is ongoing

Conclusion

1. **4″ hDOM configurations**
   - Compared with the 3″ PMT hDOM: +17% photosensitive area and ~40% fewer channels

2. **Physics performance with high QE**
   - Low-energy gains in effective area and angular resolution
   - Within ~10% difference in τ identification; comparable background-trigger performance

3. **Looking Ahead**
   - Finalize the characterization of collection efficiency, angular response, and timing

Thanks