High-energy reconstruction of single and double cascades using the KM3NeT detector

Thijs Juan van Eeden*, Jordan Seneca*, Aart Heijboer, on the behalf of the KM3NeT collaboration
tjuanve@nikhef.nl jseneca@nikhef.nl aart.heijboer@nikhef.nl

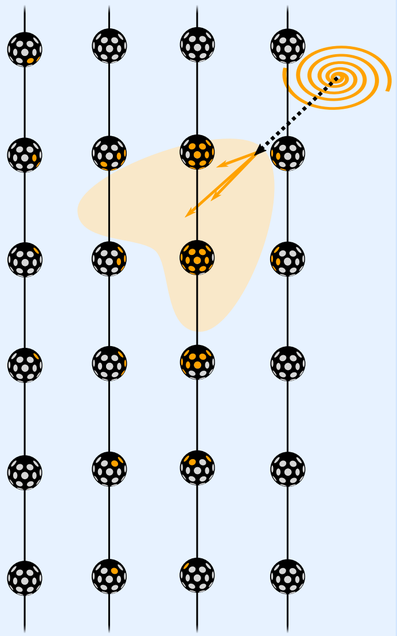
KM3NeT
Two neutrino detectors

under construction on the bottom of the Mediterranean sea. [1]

ORCA: 1-100 GeV atmospheric ν-oscillations studies.

ARCA
>1 TeV cosmic-ν telescope

Two *building blocks*, 1 km^3 grids of 4000 optical modules, which observe light from neutrino interactions.



Digital Optical Module (DOM)

Thirty-one 3" photomultiplier tubes (PMT).

Hit - PMT recording a photon time.

White Rabbit infrastructure
→ O(1 ns) hit time accuracy.

Acoustic calibration
→ 50 cm PMT position accuracy. [2]

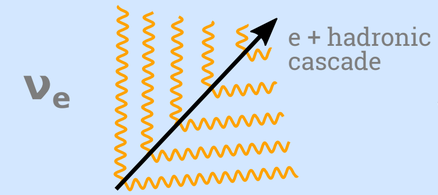
High granularity

→ good handle on light intensity and arrival time.

Long γ-scattering length in water
→ little smear in γ-arrival position and time.

New reconstruction with time of PMT hits and cascade elongation modelling

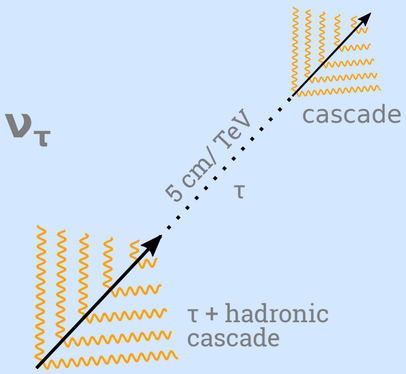
ν_e-CC and neutral current interactions → particle cascade.



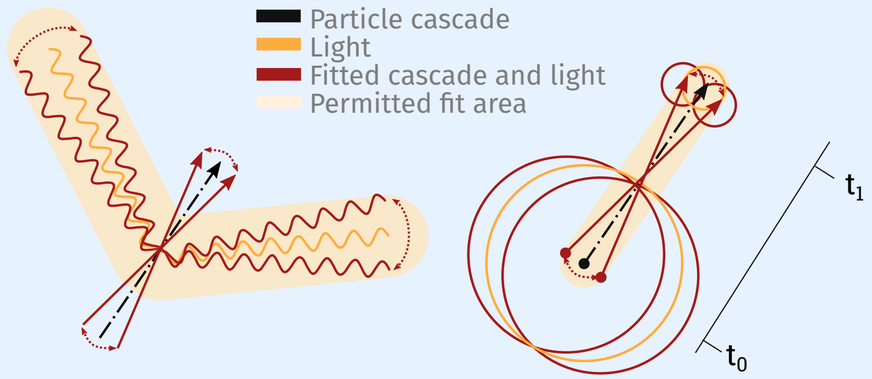
Single cascades are elongated at high energies → spread in time of light emission.

Single cascade model
electromagnetic (EM) cascade Cherenkov light model sampled along energy deposition profile.

83% of ν_τ-CC events → two particle cascades. [3]



Double cascade model
2 colinear elongated EM cascade models.

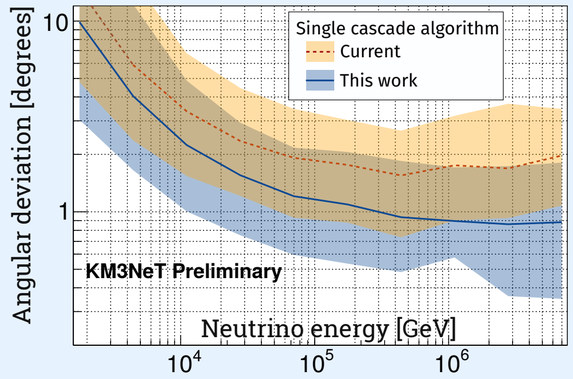


Previous reconstruction fits Cherenkov light cone geometry using hit positions [1]

New reconstruction *also* fits light-emitting structure of event using hit times

Improvement in direction resolution

Study on E^{-2} neutrino flux simulations



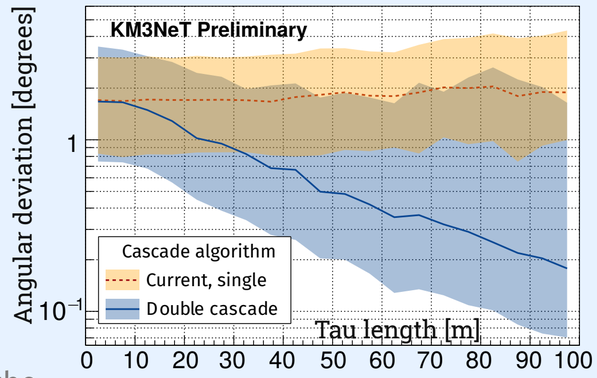
ν_e-CC
<1 deg median above 300 TeV

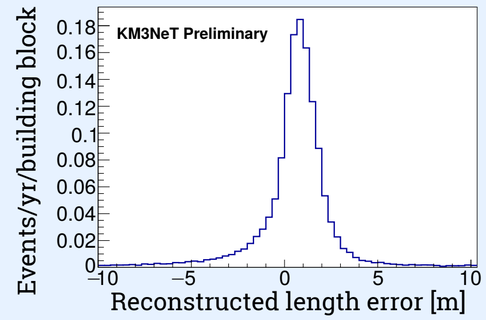
Bands show 68% of distribution

ν_τ-CC
<1 deg median above 25 m tau decay length

τ-decay length accrues the angular resolution!

3.17 m τ-decay length resolution





Can we improve the direction resolution of the current cascade reconstruction?

New reconstruction exploits more of the data received by the DOMs, yielding excellent angular resolution for both single and double cascades.

1. S. Adrián-Martínez et al. (KM3NeT Collaboration), Journal of Physics G43(8) (2016).DOI 10.1088/0954-3899/43/8/084001
2. Aiello, S. et al. (2021). Architecture and performance of the KM3NeT front-end firmware. Journal of Astronomical Telescopes, Instruments, and Systems, 7(1), 016001.
3. Bormuth, R. (2017). Chasing cosmic tau neutrinos in the abyss (Doctoral dissertation, Leiden University).