KM3NeT

Performance

Town Hall Meeting Catania

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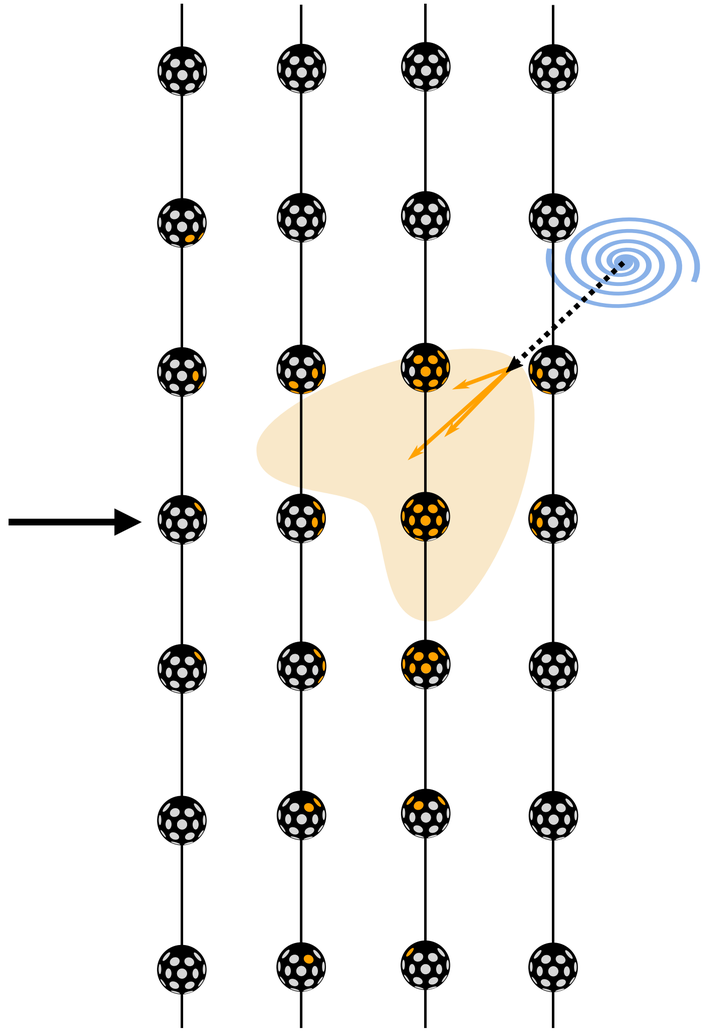
Overview

- Technology
- Calibration
- Reconstruction
- Performances
  - KM3NeT/ORCA
  - KM3NeT/ARCA
- Outlook & Summary

Technology

- Digital Optical Module (DOM)
  - 31 Photomultiplier tubes (PMTs)
- KM3NeT/ARCA: 2x115 lines of 18 DOMs
  - *Currently 21 lines*
- KM3NeT/ORCA: 115 lines of 18 DOMs
  - *Currently 11 lines*



Precision and Calibration

Multi PMT design: arXiv:2203.10048

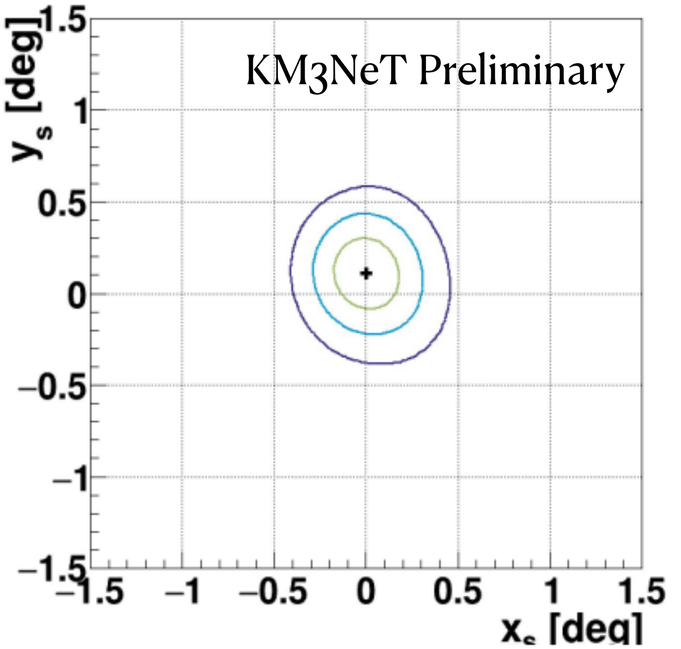
- Good handle on light intensity
- O(1 ns) hit time accuracy
- Long γ scattering length

—> Promising reconstruction performance

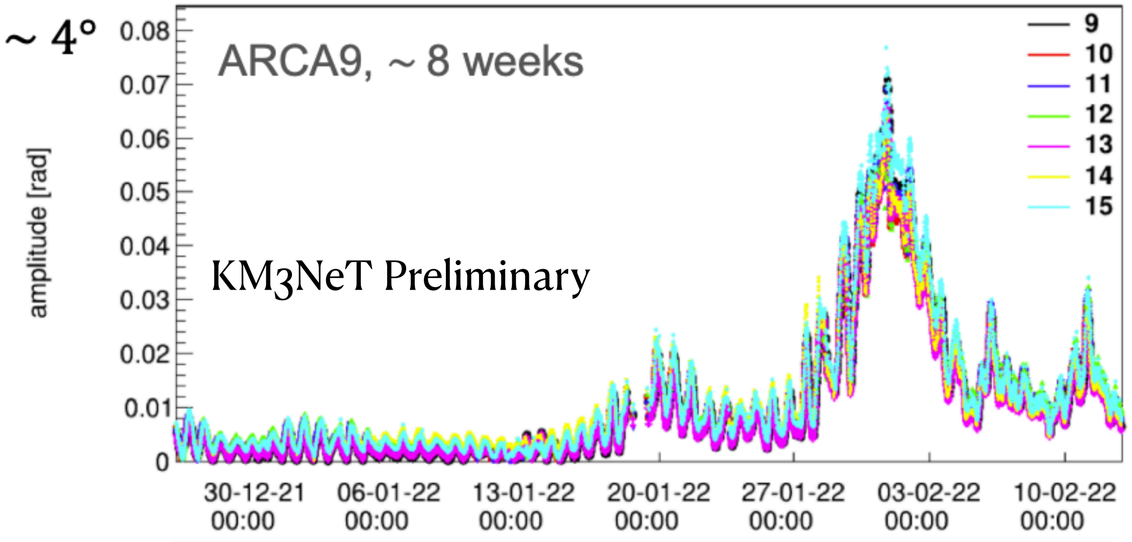
Calibration

- Acoustic positioning system
- Sun/moon cosmic ray shadow

Sun shadow (6σ)



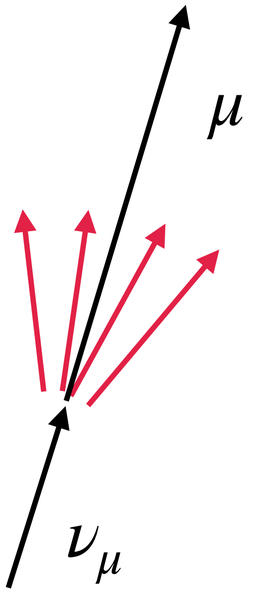
Tilt over time



Reconstruction

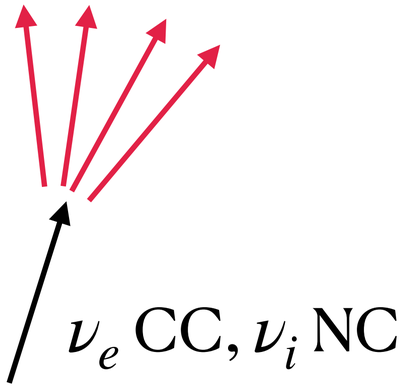
Tracks

- Fit Cherenkov cone hypothesis of propagating μ to data
- Lever arm effect



Showers

- Assume point-like emission
- Vertex fit using hit time information
- Direction fit using spatial distribution of light yield (Cherenkov cone)



KM3NeT/ORCA

Expected event rates for 115 lines after preselection (upgoing, quality & containment):

- Atmospheric ν: 2 mHz (66.000 [1/year])
- Atmospheric μ: 0.1 Hz
- Noise events: 0.4 Hz
- Cosmic ν!

Designed for oscillation studies

- Also possibilities for multi-messenger astronomy

KM3NeT/ORCA

Effective volume

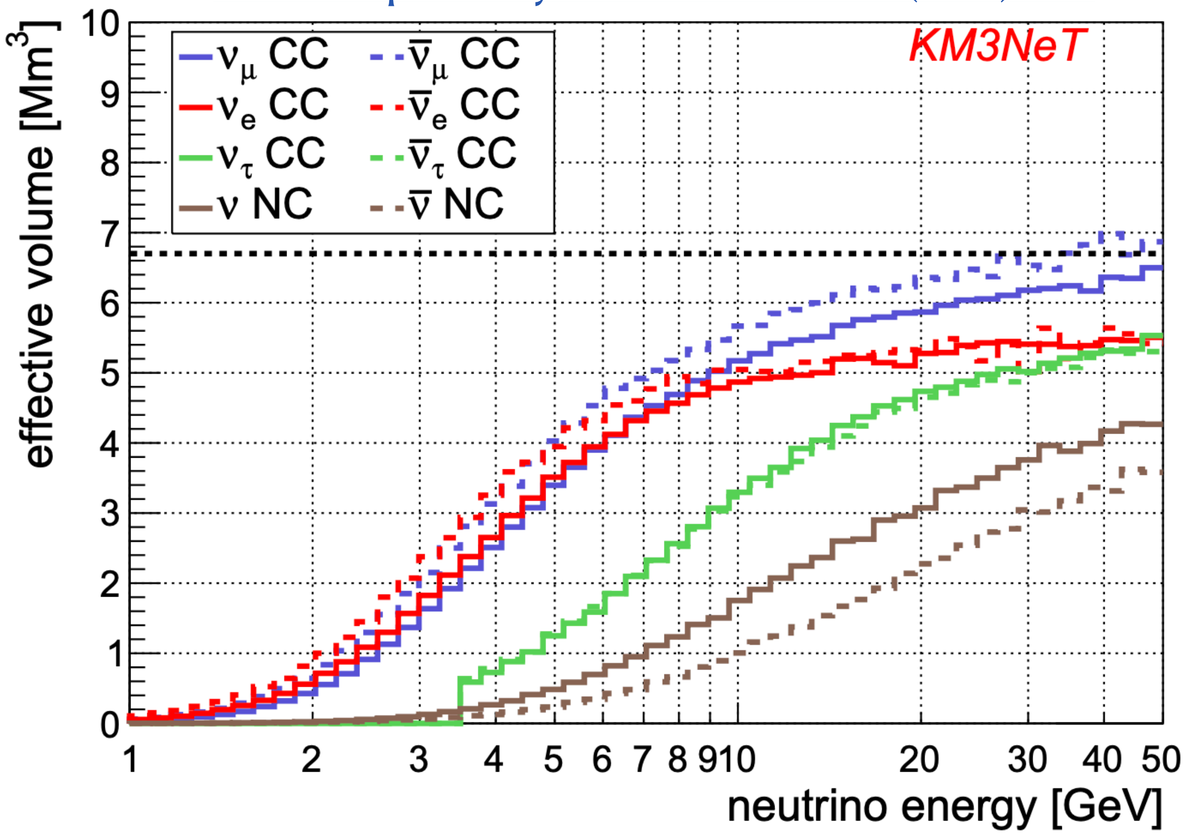
Event preselection based on reconstructed direction (upgoing) and quality

Weighted using Honda atmospheric ν flux model

Instrumented volume: $6.7 \cdot 10^6$ m^3

- ~ 7.0 Mt of sea water

The European Physical Journal C 82.1 (2022): 1-16



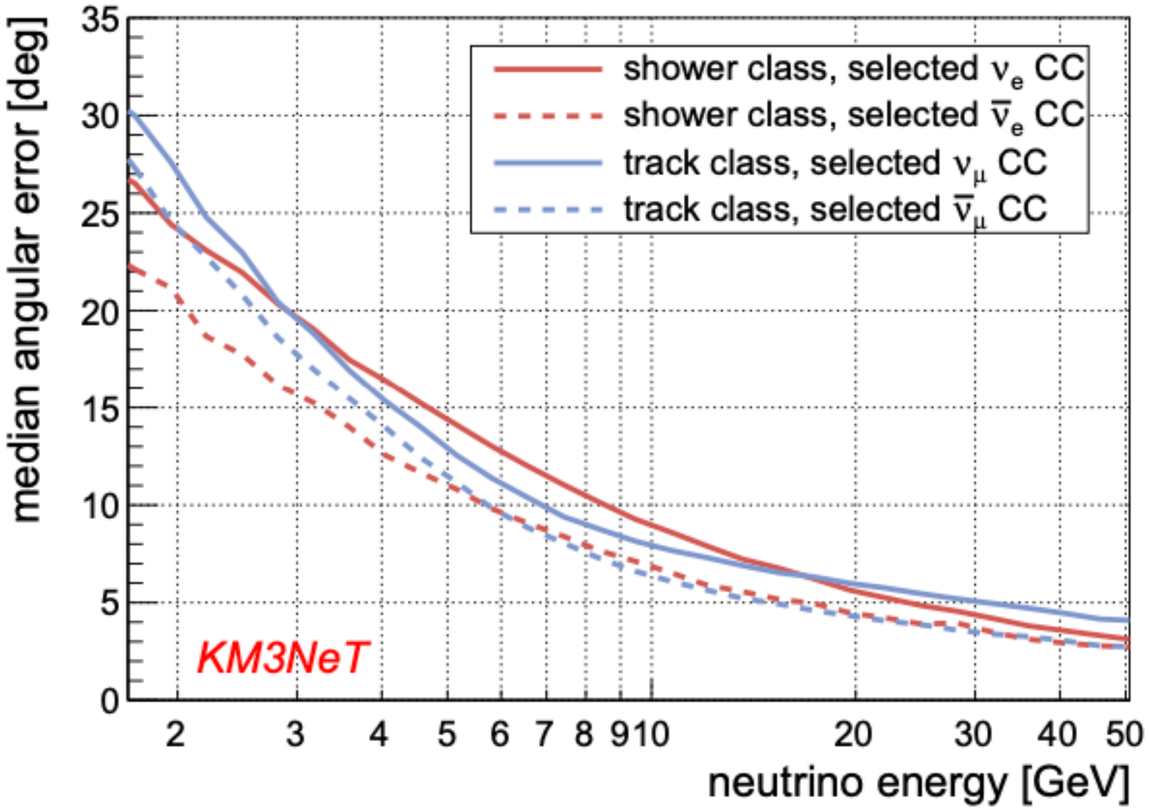
KM3NeT/ORCA

Angular resolution

- Direction resolution dominated by lepton-ν scattering kinematics

- Median angular resolution ($E_\nu = 10$ GeV)
- $\nu_e/\bar{\nu}_e$ CC $= 9.3°/7.0°$
- $\nu_\mu/\bar{\nu}_\mu$ CC $= 8.3°/6.5°$

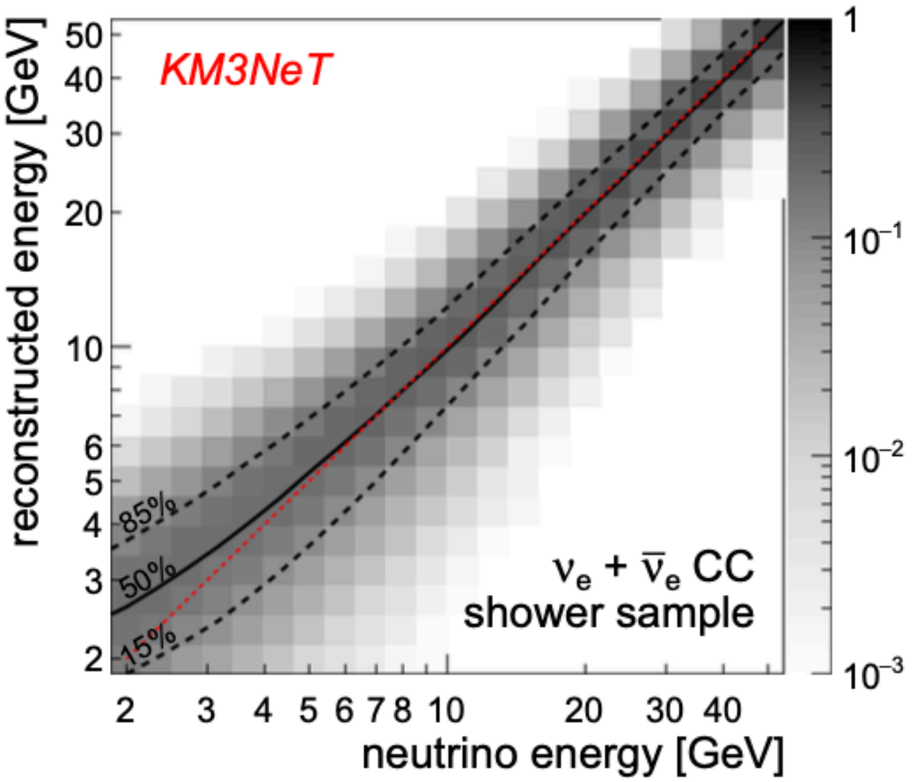
The European Physical Journal C 82.1 (2022): 1-16

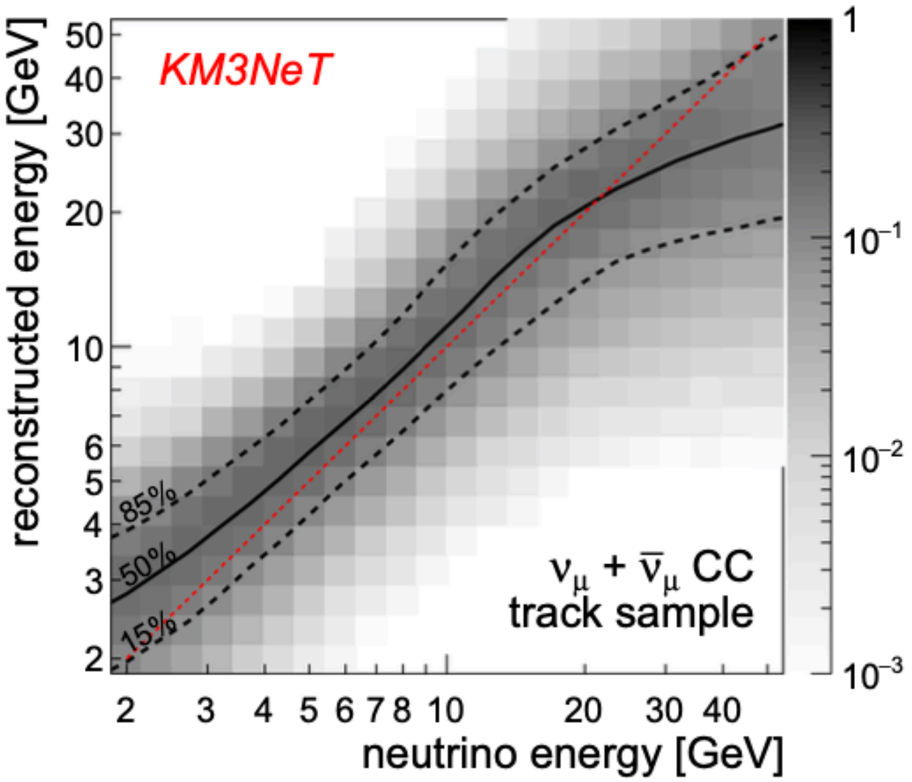


KM3NeT/ORCA

Energy resolution

The European Physical Journal C 82.1 (2022): 1-16





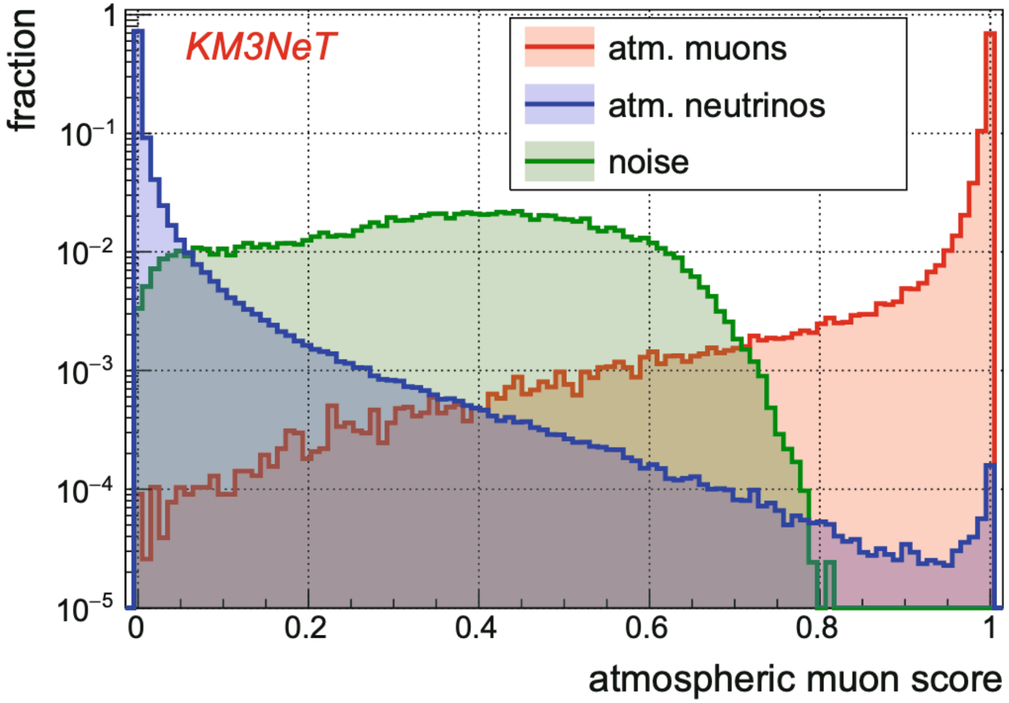
$$\Delta E/E \text{ at } E_\nu = 10 \text{ GeV}$$

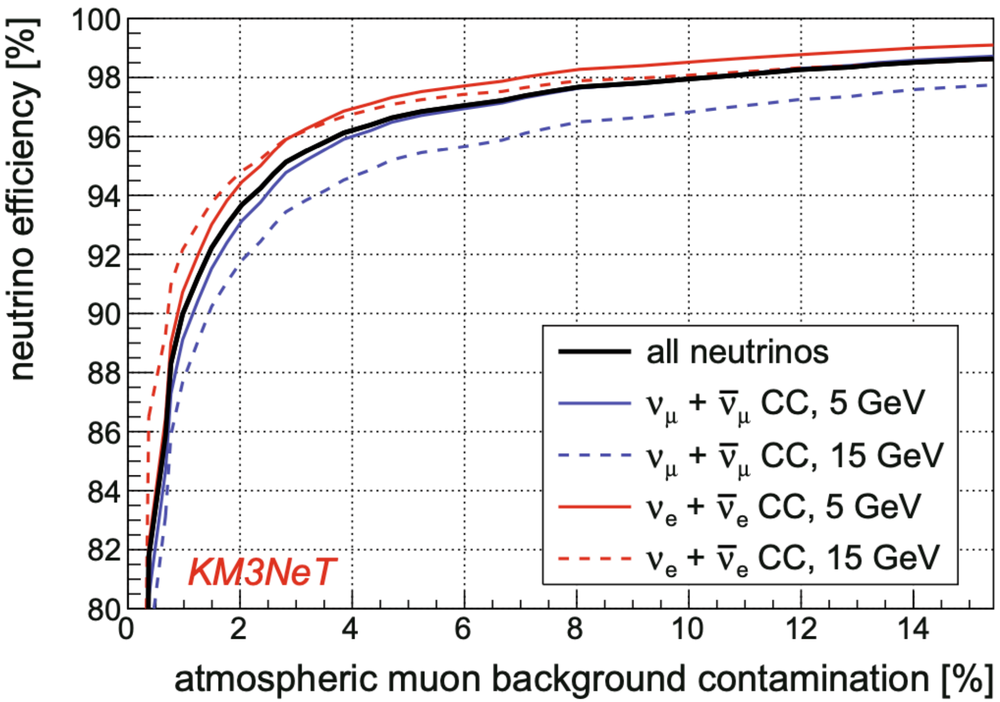
$$\nu_e/\bar{\nu}_e \text{ CC} = 25\,\%\,,\ \nu_\mu/\bar{\nu}_\mu \text{ CC} = 35\,\%$$

KM3NeT/ORCA

Selection performance

The European Physical Journal C 82.1 (2022): 1-16



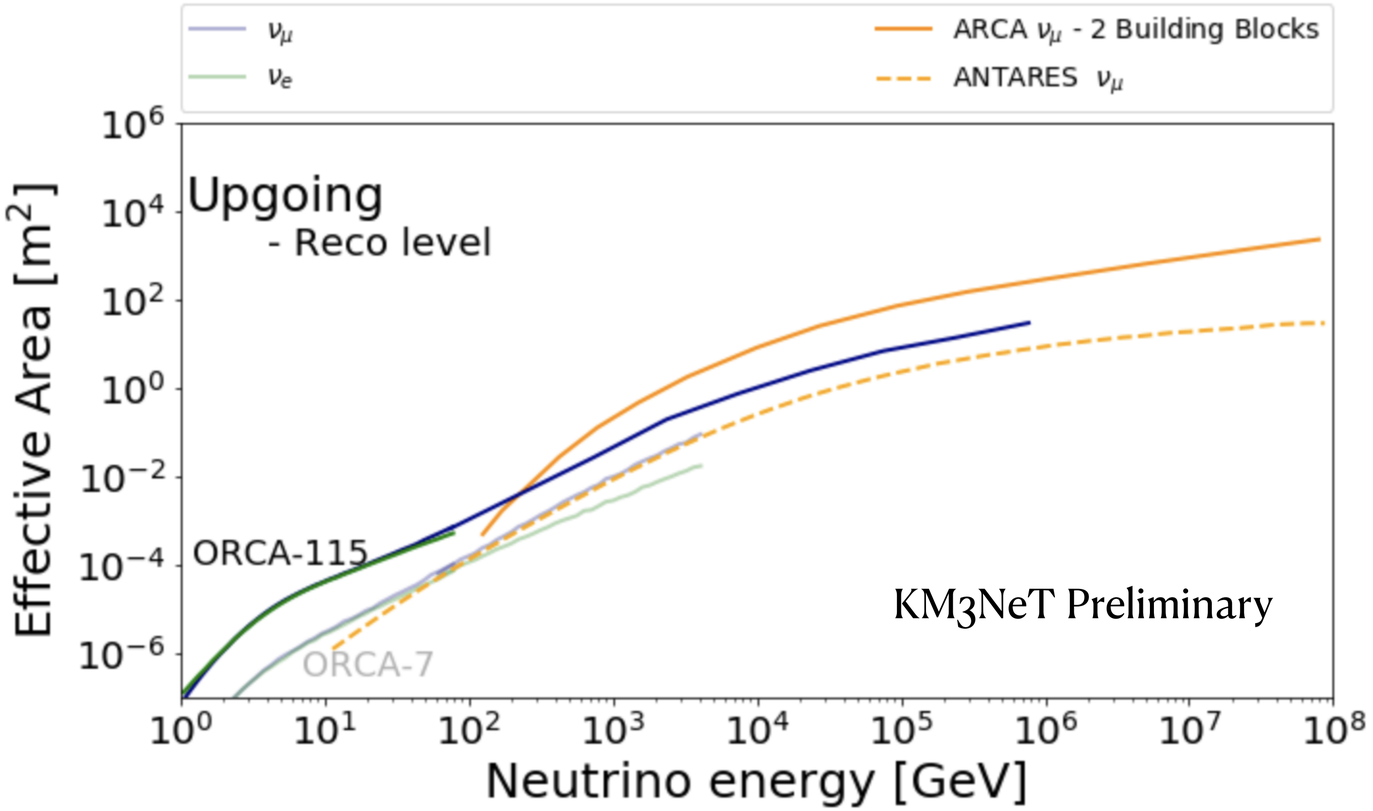


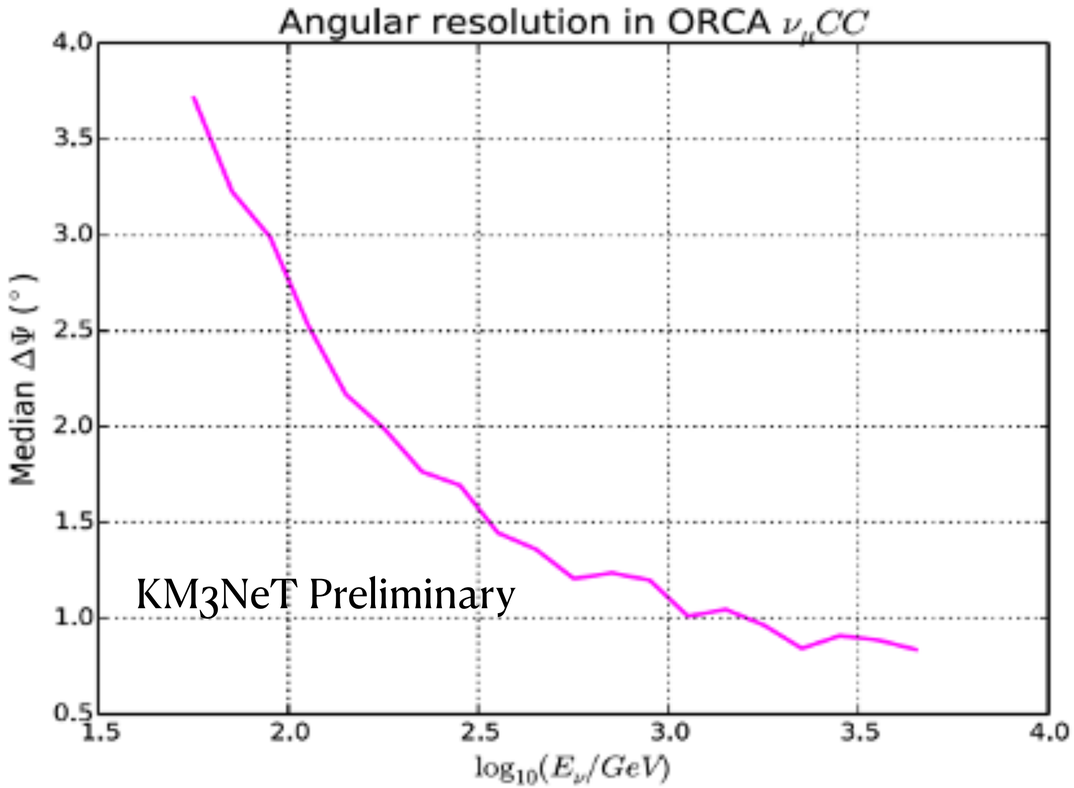
Random Decision Forest to discriminate ν from μ

Other RDFs to reduce noise, discriminate track/cascade

KM3NeT/ORCA

Performance at high-energy





Current ORCA detector (11 lines) and 115 lines also sensitive at higher energies: follow ups!

KM3NeT/ARCA

Expected event rates without cuts (year^{-1} 115 lines^{-1})

- Atmospheric μ: O(10^7)
- Diffuse cosmic ν: O(10^2)

Selections using boosted decision trees (BDTs)

- Upgoing and horizontal tracks
- Contained showers

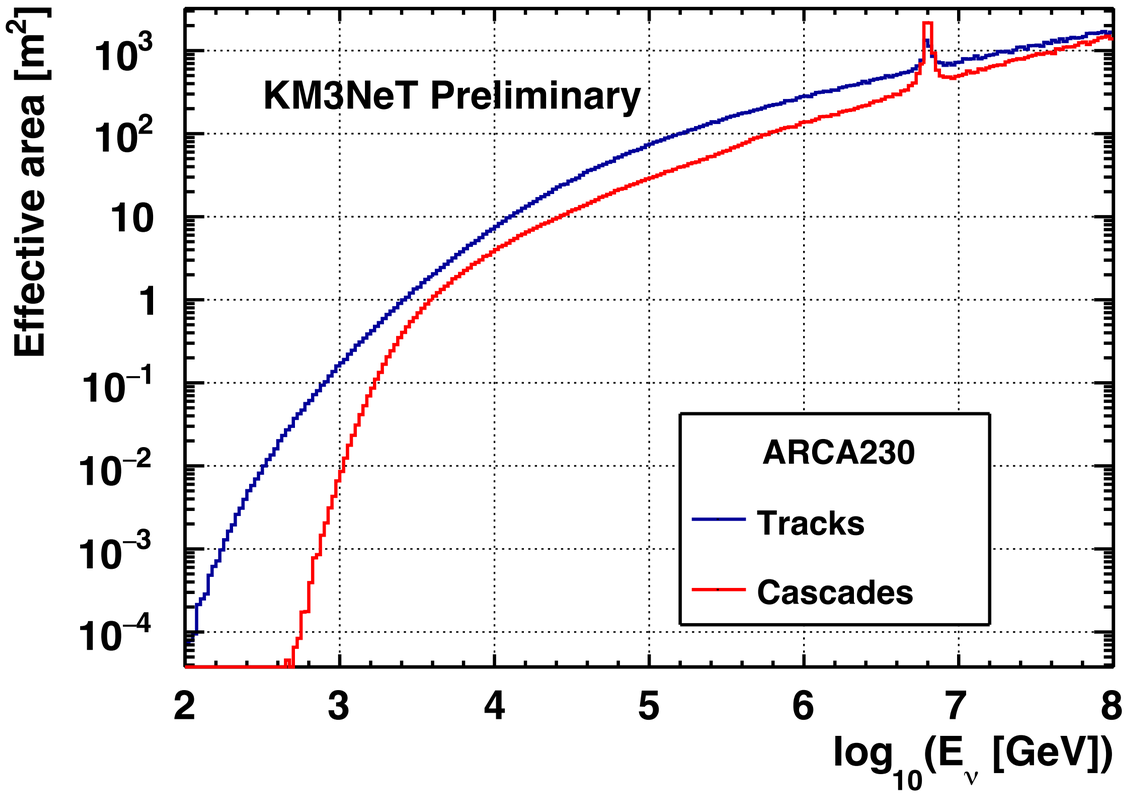
KM3NeT/ARCA

Effective area

- Convolute with $\Phi_{\nu_i+\bar{\nu}_i}$ to obtain total track/cascade event rate

- Glashow resonance visible in both channels
  - Tracks: BR($W \rightarrow \mu\bar{\nu}_\mu$) = 0.105
  - Cascades: other leptonic decays to e, τ or hadronic

Taken from Neutrino 2022

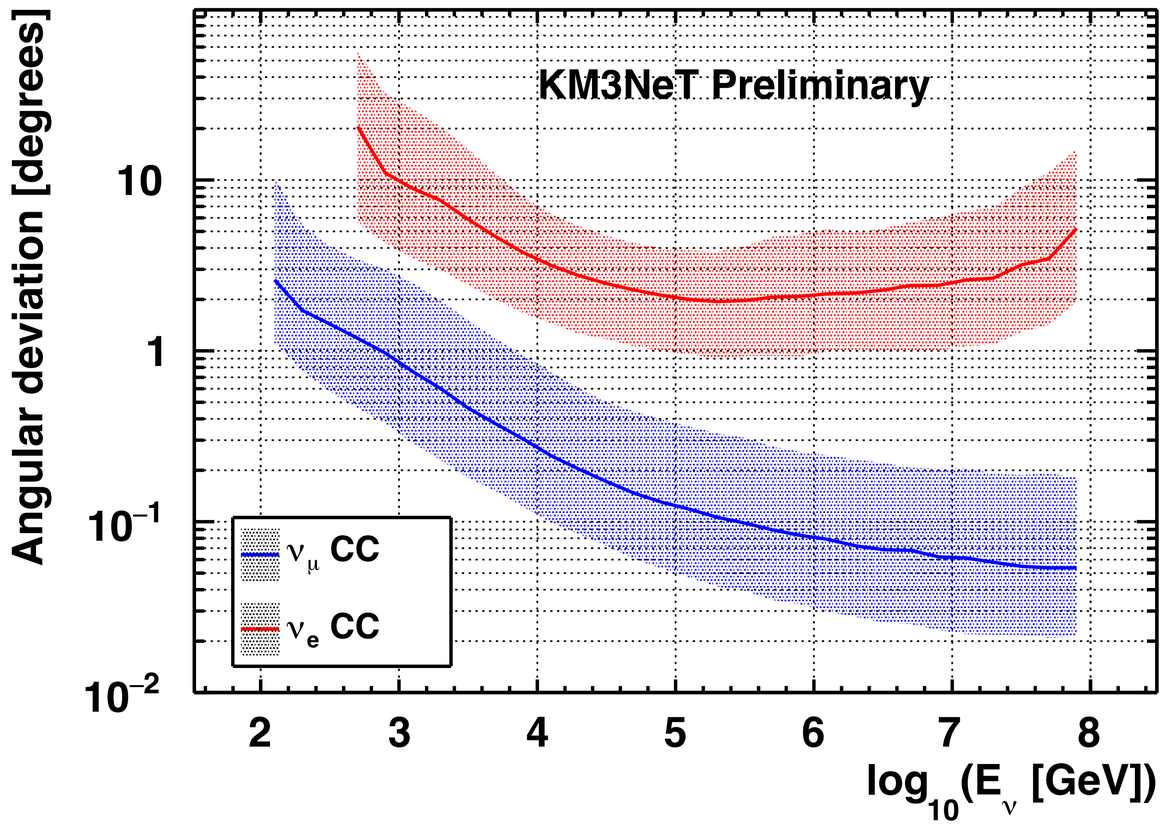


KM3NeT/ARCA

Angular Resolution

- Median angular resolution reaches
  - 0.06° for tracks
  - 2° for cascades

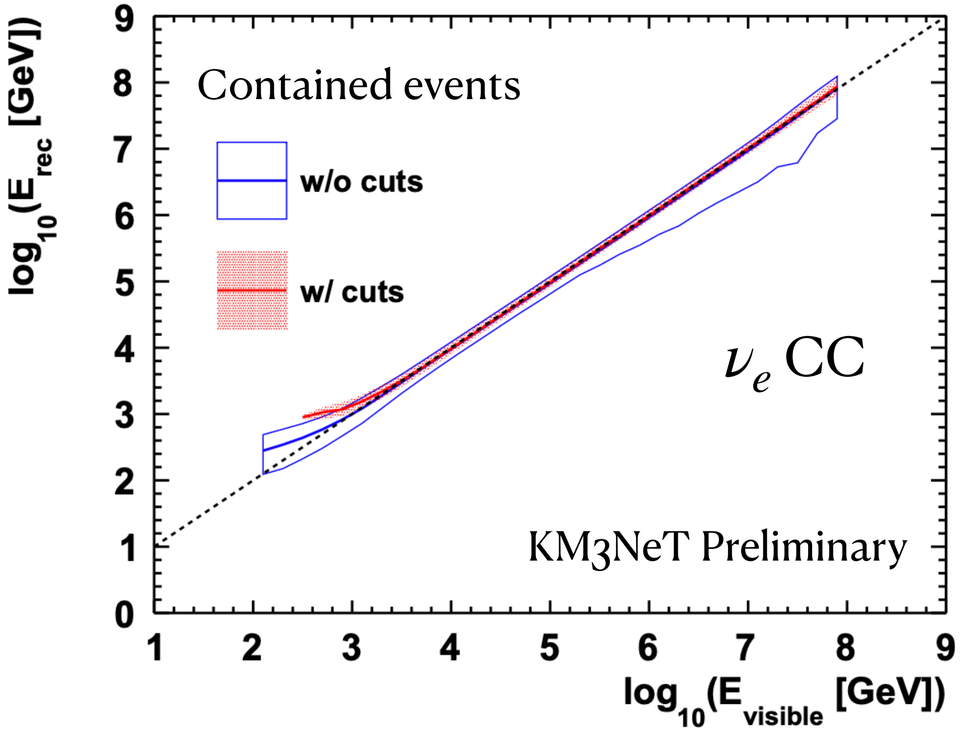
Taken from Neutrino 2022

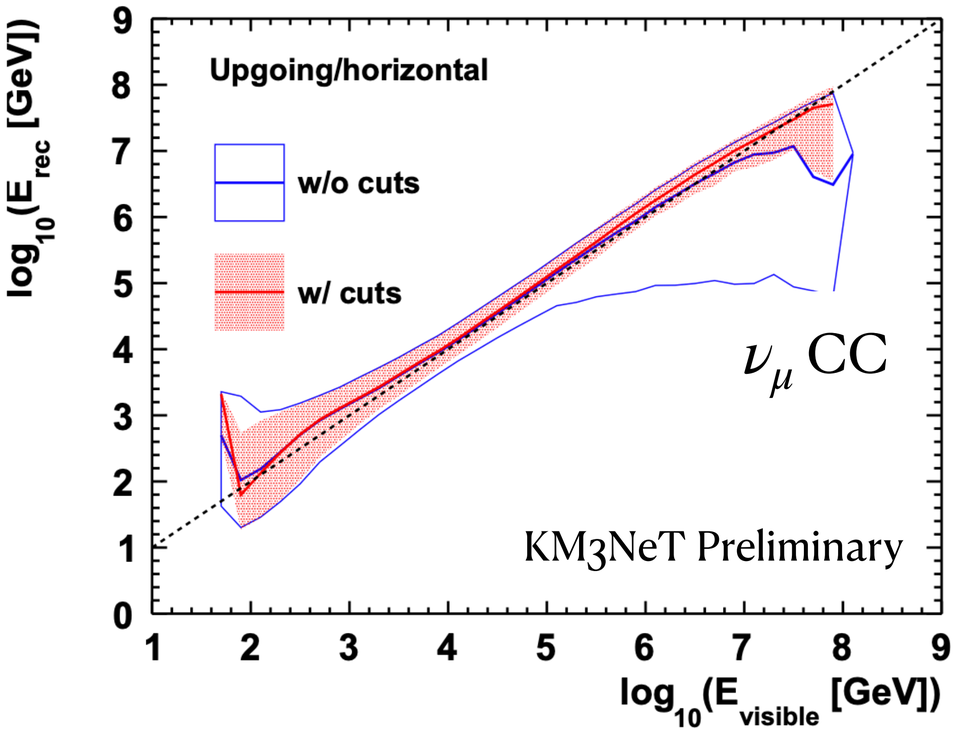


KM3NeT/ARCA

Energy resolution

Taken from Neutrino 2022



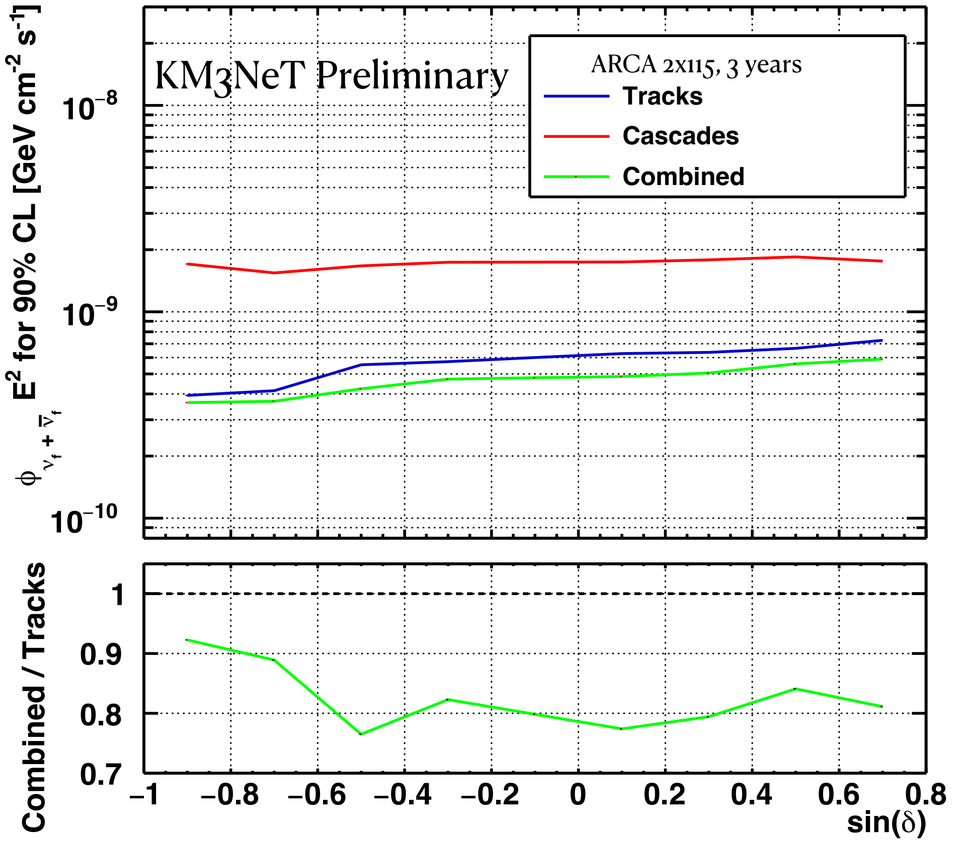


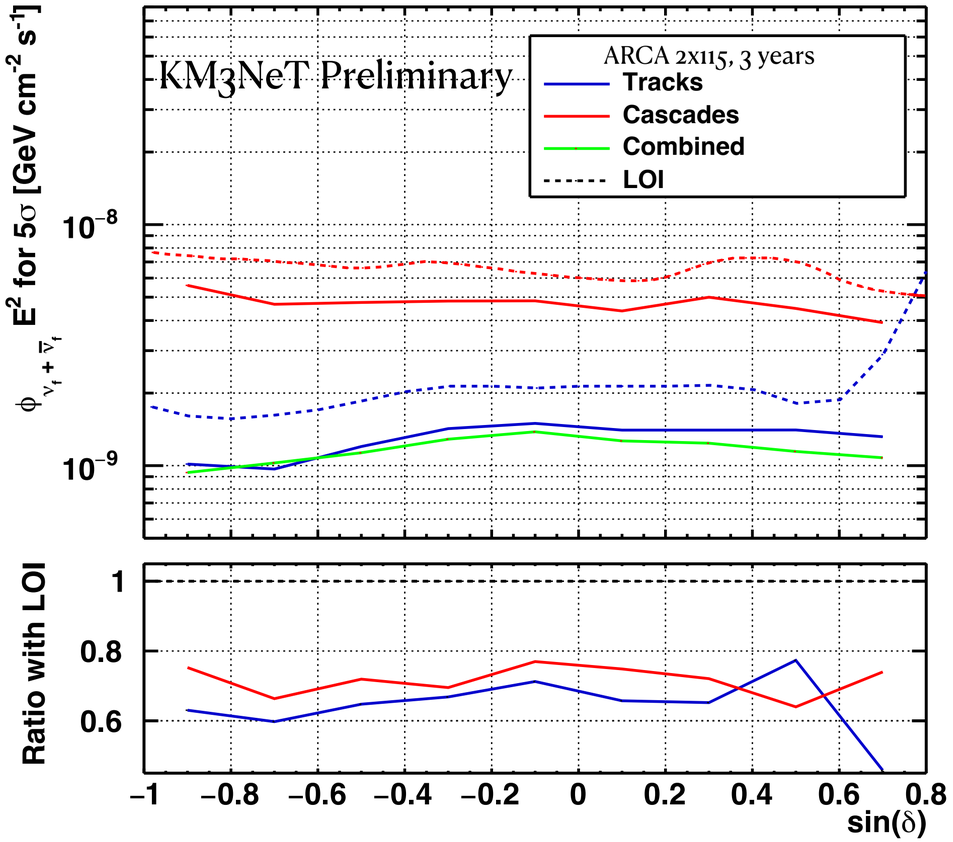
With cuts: reconstruction quality and BDT selection

KM3NeT/ARCA

Point source sensitivity (E-2)

LOI: Letter of intent
arXiv:1601.07459





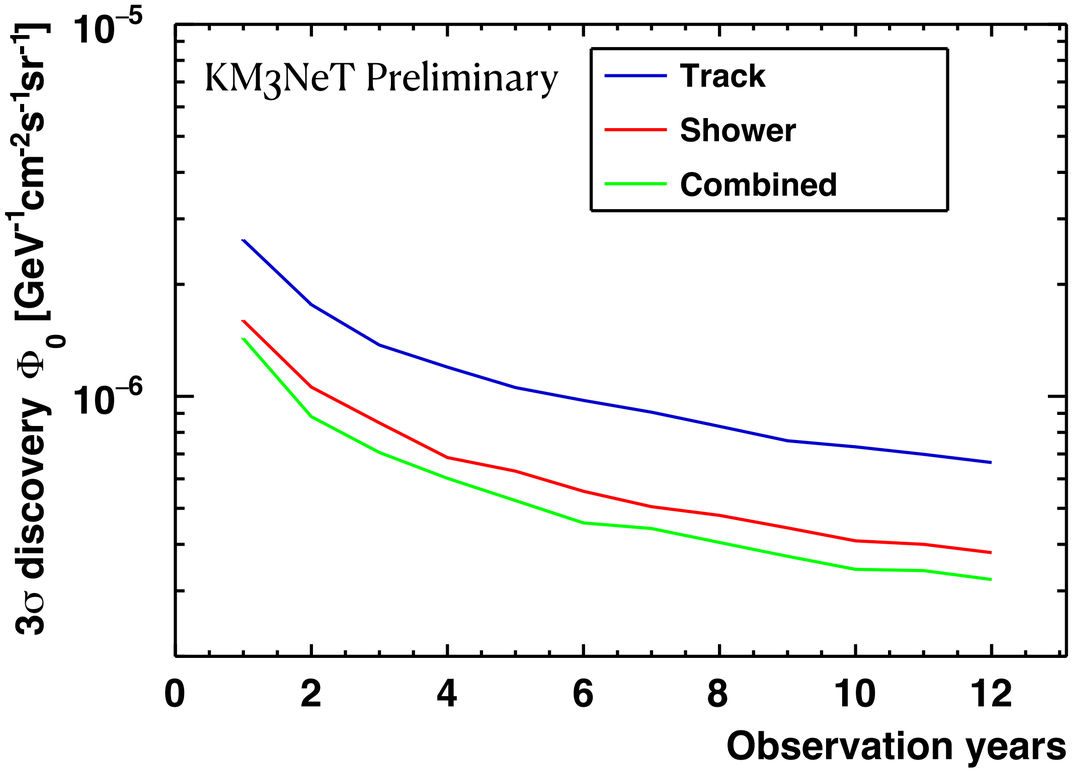
Main improvements due to better reconstruction performance

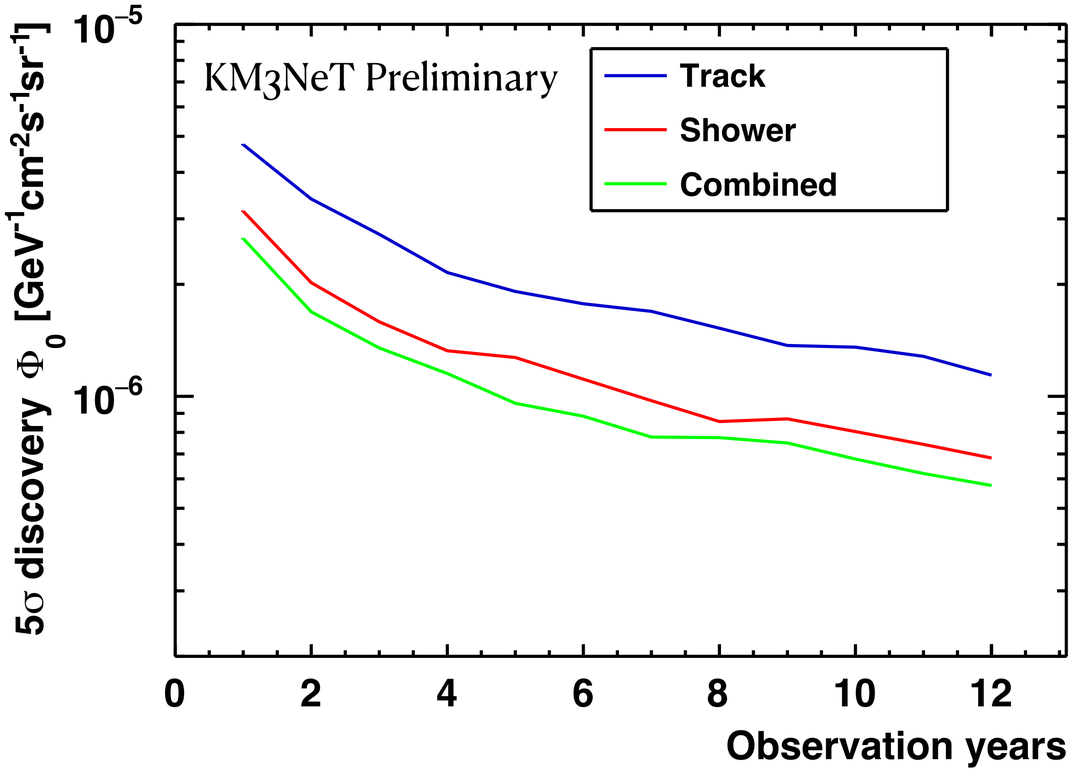
KM3NeT/ARCA

Diffuse flux sensitivity

Single power law flux (arXiv:2107.13050, ICC)

$$0.963 \cdot 10^{-6} E^{-2.37} \ [\mathrm{GeV}^{-1}\mathrm{cm}^{-1}\mathrm{s}^{-1}\mathrm{sr}^{-1}]$$





Observation years using 115 lines

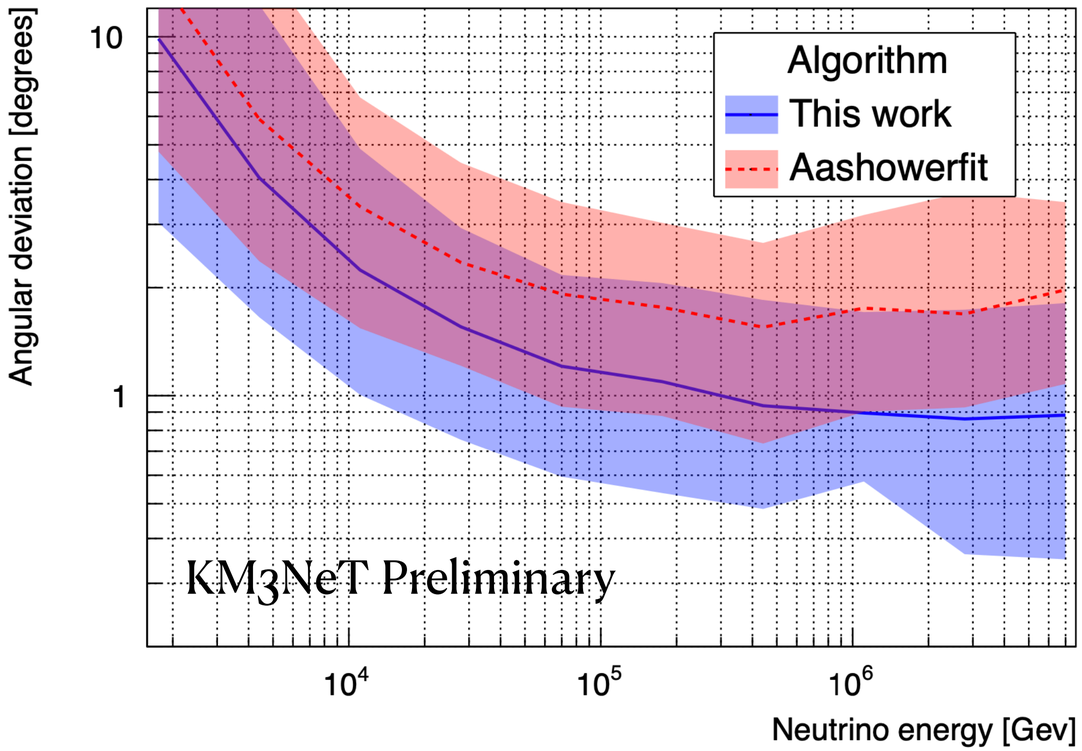
KM3NeT/ARCA

Improved cascade reconstruction

Aashowerfit: standard cascade reconstruction

- Elongated cascade model
  - Includes hit time information in direction reconstruction
  - Lever-arm effect
- Sub-degree resolution expected for the full detector

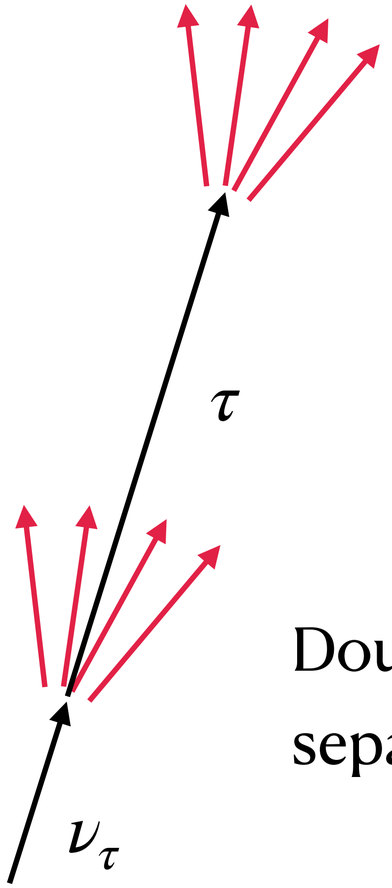
Taken from arXiv:2205.02641



KM3NeT/ARCA

Double cascade reconstruction

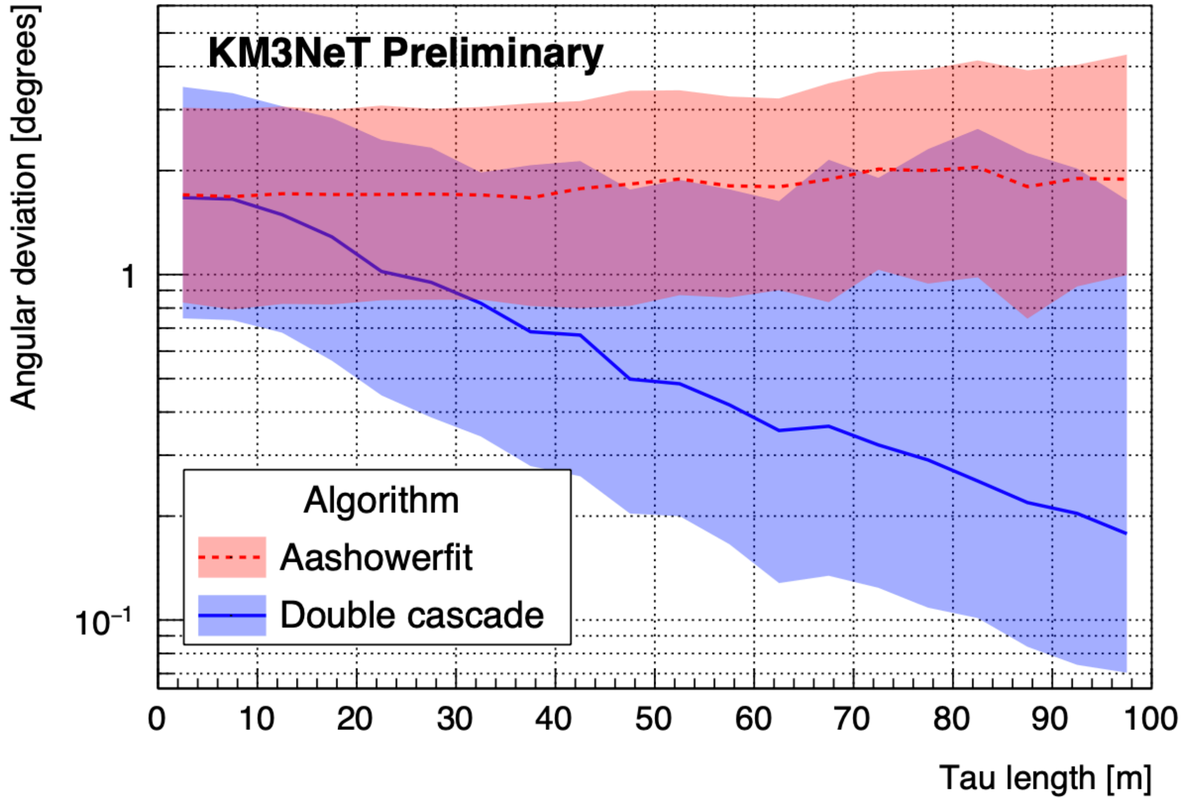
Aashowerfit: standard cascade reconstruction



Double cascade model separated by τ flight distance

Separation between cascades provides extra lever arm effect

Taken from arXiv:2205.02641



Summary

- KM3NeT/ORCA
  - Angular resolution < 10° for E > 10 GeV, below 1° for high-energy tracks: follow ups!
  - Energy resolution $\nu_e/\bar{\nu}_e$ CC = 25 % , $\nu_\mu/\bar{\nu}_\mu$ CC = 35 %

- KM3NeT/ARCA
  - Angular resolution reaches 0.06° for tracks, below 2 for showers
  - Single/double cascade reconstruction improvements: < 1°