# KM3NeT

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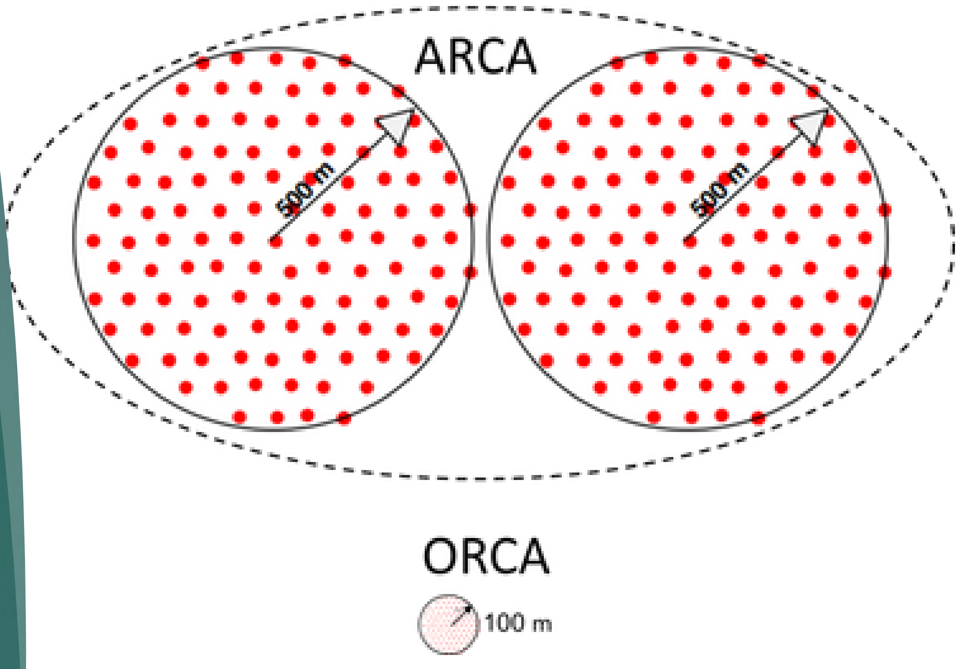
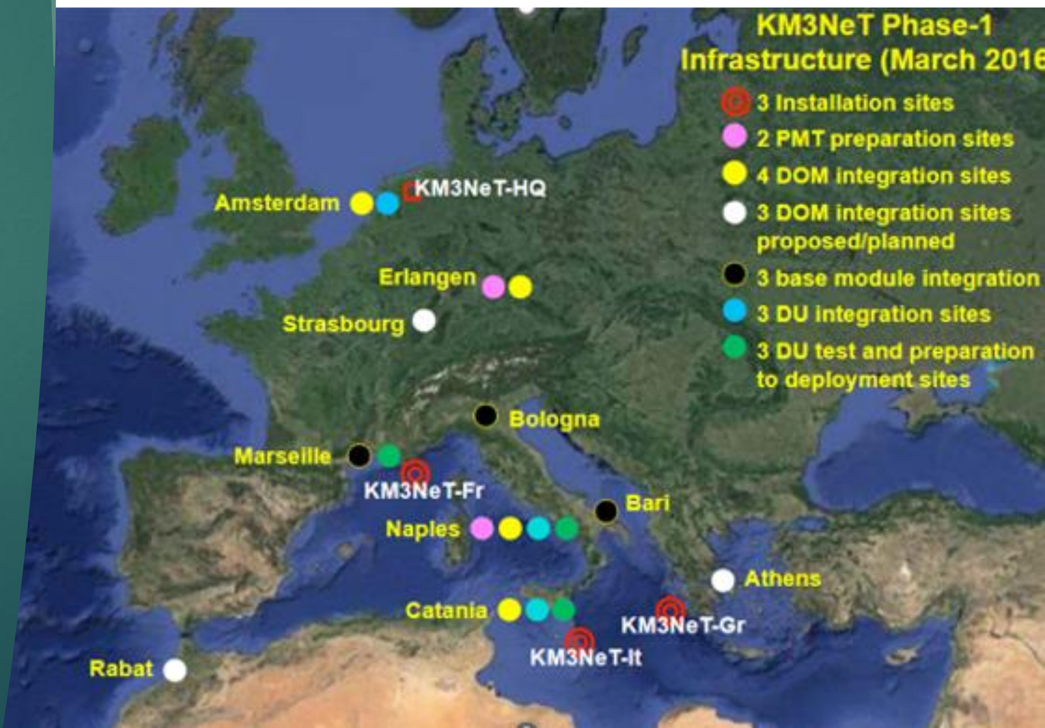
# Goals

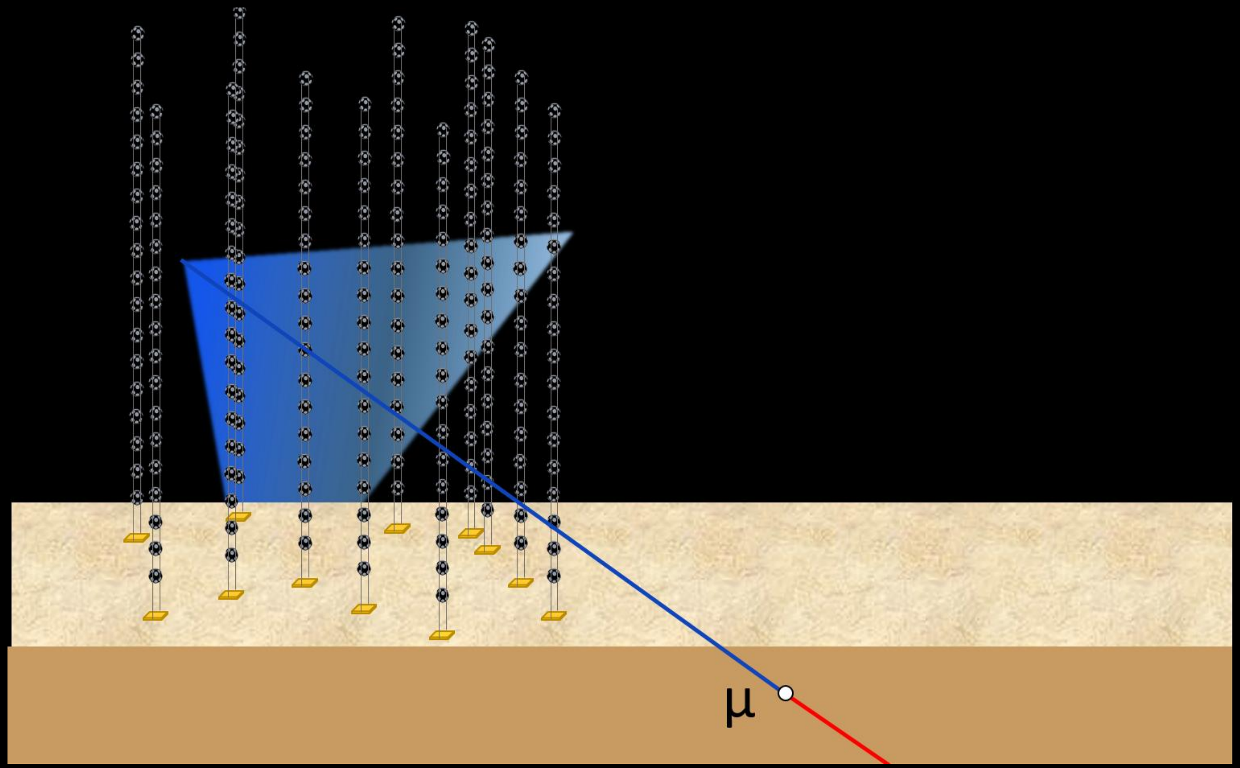
- the discovery and observation of high-energy neutrino sources (ARCA)
- the determination of the mass hierarchy of neutrinos (atmospheric neutrinos) (ORCA)
- marine biology, oceanography or environmental sciences applications

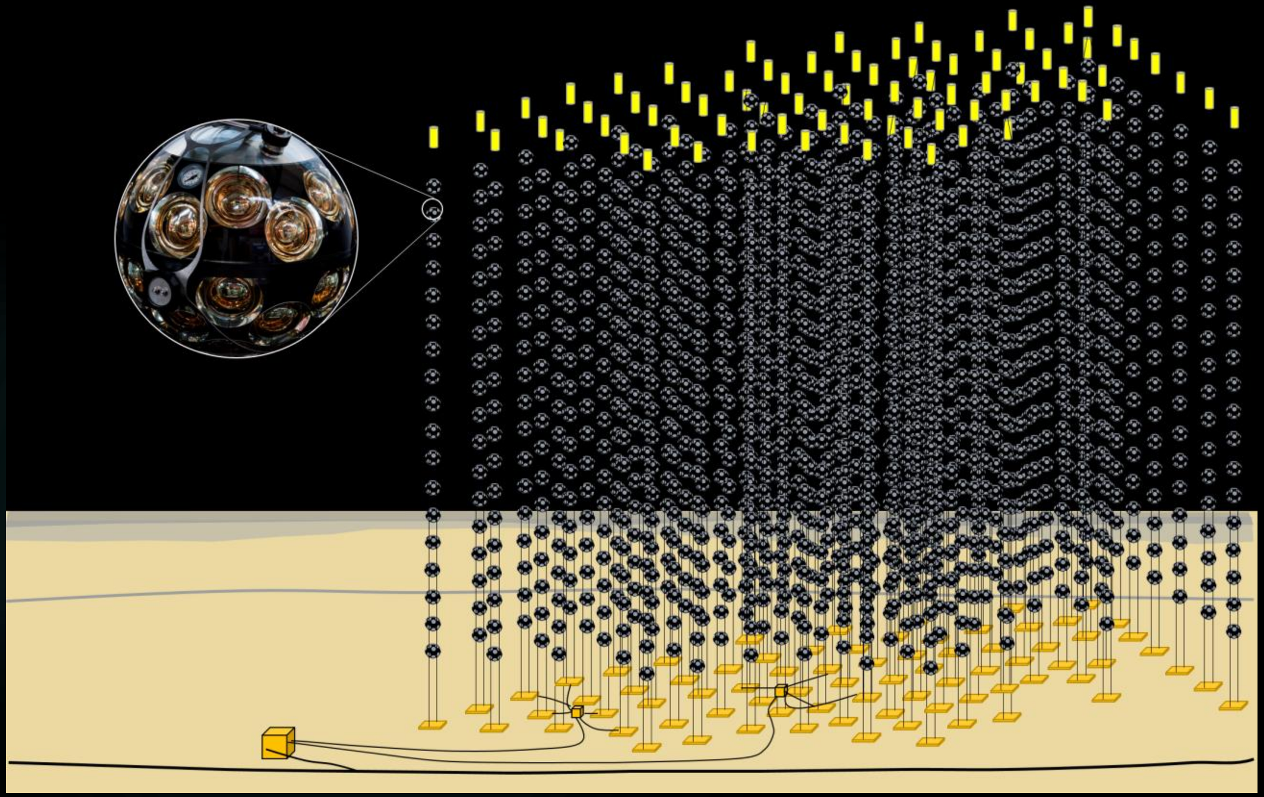


# What is being detected?

- Cherenkov radiation produced by the secondary particles of the neutrino-matter interaction (like muons and hadrons).
- Detected with photomultiplier tubes (PMT's)
- We measure: photon arrival time, time over threshold, position

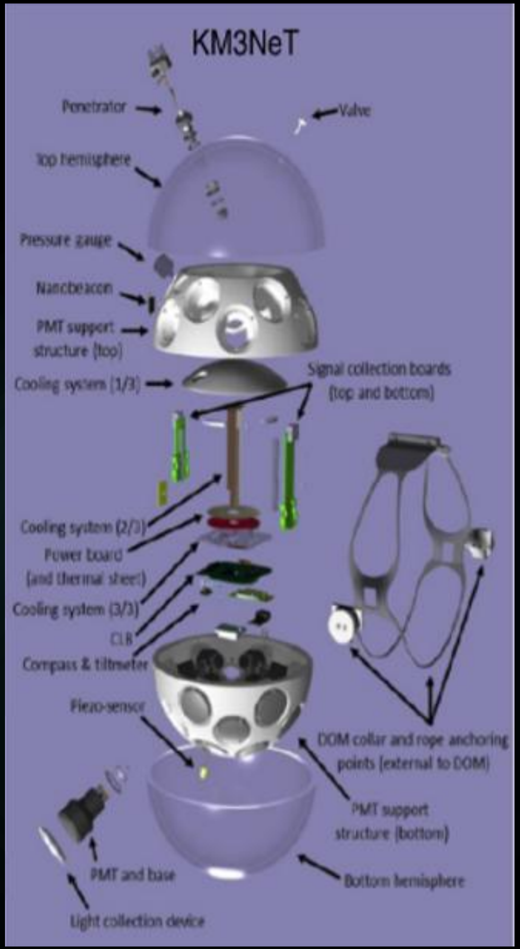




# Detector structure

- Each digital optical module (DOM) has 31 photo-multiplier tubes.
- Each string (Detection Unit or DU) comprises 18 optical modules.
- Each building block comprises 115 strings.

# DOMs





- 31 PMT's and readout electronics.
- Calibration sensors (LED nano-beacon, compass and tilt-meter, acoustic piezo sensor)
- glass sphere (17 inch diameter) two separate hemispheres, designed to resist pressure
- Reflector ring around each PMT increases photon collection efficiency by 20–40%
- Optical gel between support and glass
- The support and the gel are sufficiently flexible
- power consumption: 7 W

# PMT's specifications

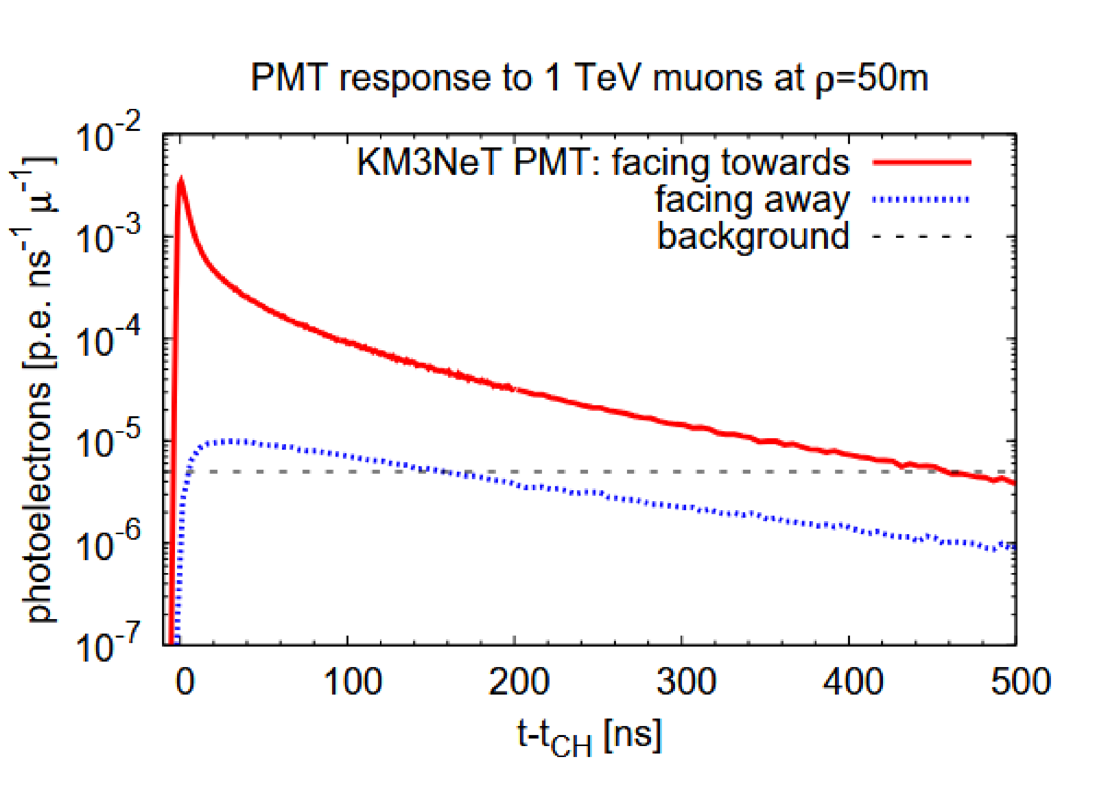
| | |
|---|---|
| Radiant blue sensitivity at 404 nm | 130 mA/W |
| Quantum efficiency (QE) | 20% @ 470 nm and 28% @ 404 nm |
| Inhomogeneity of cathode response | 10% |
| Supply voltage for a gain of $3 \times 10^6$ | 900–1300 V |
| Dark count at 15°C and 0.3 photo-electron threshold | 1.5 kHz |
| Transit time spread (TTS) | 4.5 ns (FWHM) |
| Peak to valley ratio | 2.5 |

Table 2: Specification of the PMTs.

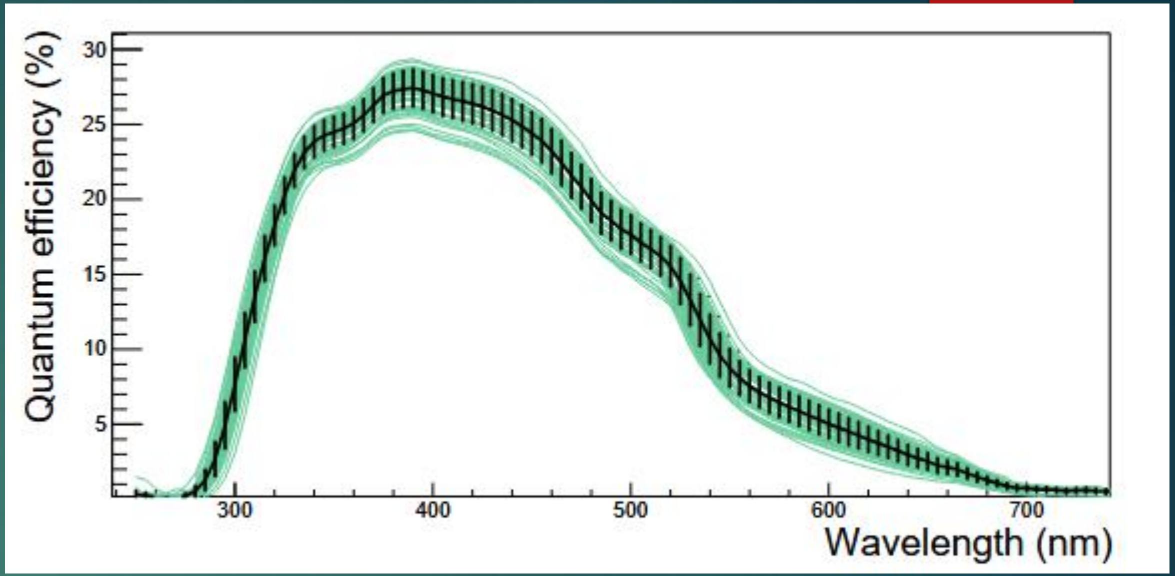
- photo-cathode diameter of at least 72 mm
- length of less than 122 mm

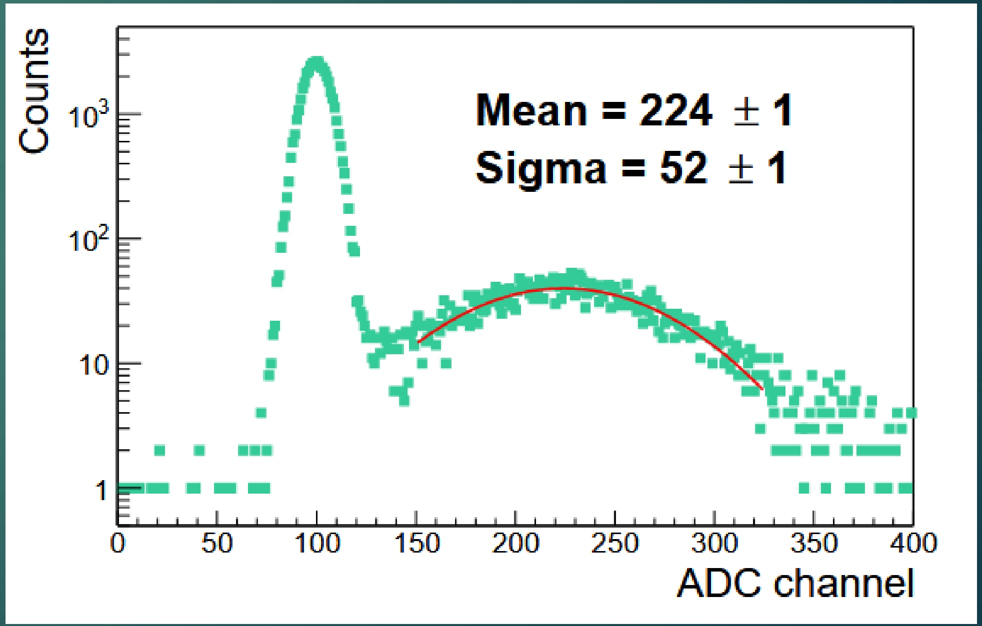
- ten stage dynode structure with a minimum gain of $10^6$
- Prototype PMTs from Hamamatsu and ETEL satisfy the requirements

# PMT's




Simulated time distribution (relative to the nominal time of the Cherenkov shock front) of photoelectrons detected by a KM3NeT PMT from a 1 TeV muon track




Charge distribution of single photoelectrons

# Data acquisition and transmission

- "All-data-to-shore": Data above threshold digitized, send to shore and analyzed in real time.
- Arrival time and the time-over-threshold (ToT) recorded by time-to-digital converter implemented in an FPGA (Field Programmable Gate Array).
- Threshold level:  0.3 of the mean single photon pulse height.
- Each hit corresponds to 6 bytes (1 B for PMT address, 4 B for time and 1 B for time over threshold)
- Relative time offsets between any pair of DOMs within 1 ns

# Data acquisition and transmission

- FPGA is mounted on the central logic board
- logic board transfers data to shore via optical fibres
- each DOM in a string has a dedicated wavelength, all wavelegths transferred together via fiber
- bandwidth per DOM: 1 Gb/s, observed singles rate: 9–12 Mb/s per DOM (mostly $^{40}K$)
- total data rate for a single building block: 25 Gb/s
- reduction of the data rate by $10^5$ to store the filtered data on disk!
- data from the acoustics positioning system also processed

# Triggers

- L0: threshold for analogue pulses, applied off-shore
- L1: coincidence of 2 or more L0 hits in the same DOM (within 10ns)
- L2: coincidence of 2 or more L0 hits in the same DOM, within some relative angle between the PMT's (max $90^o$)
- For muons: we need to assume the muon direction. We consider hits within the intersection of a cylinder and the detector array. S/N ration reduced by $10^4$.
- For hadrons: we consider hits within a maximum distance.

# Performance

- Depends on effective volume (different for ARCA and ORCA), event purity and data processing time
- Processing time : All data for the same time period processed in the same CPU core

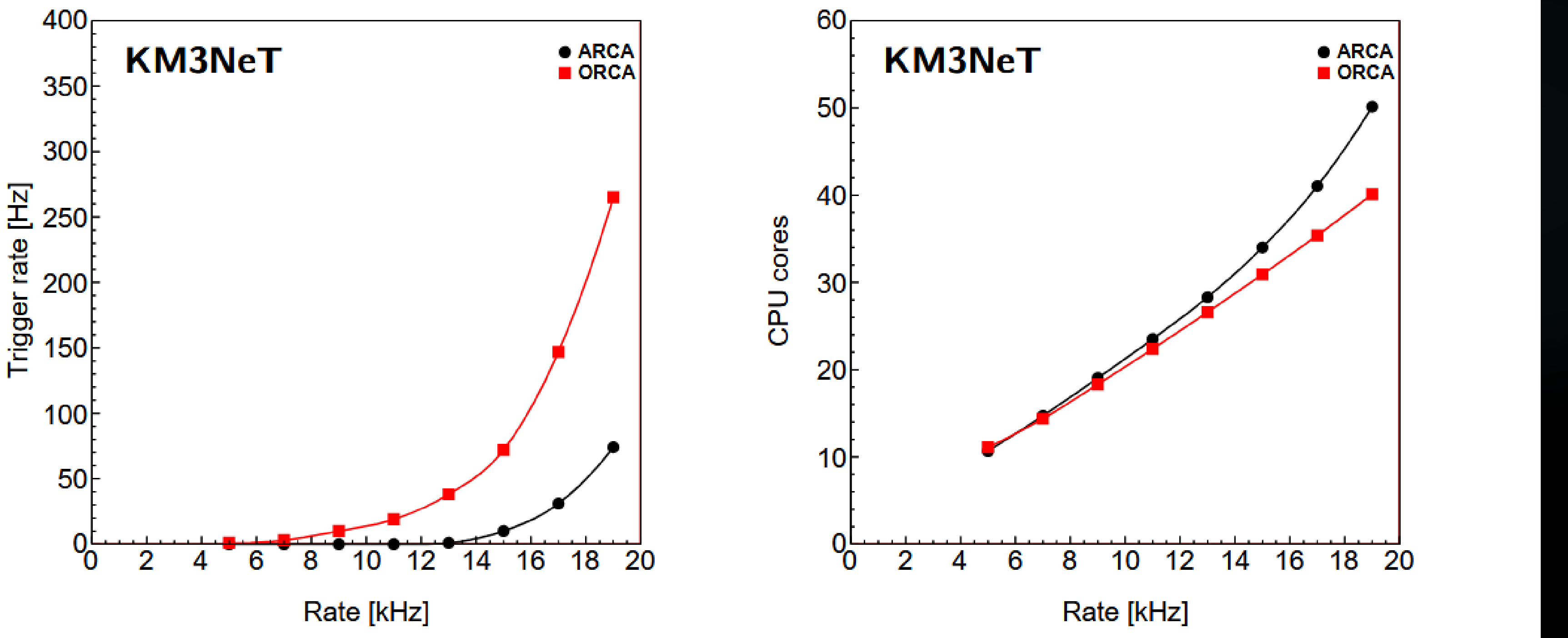
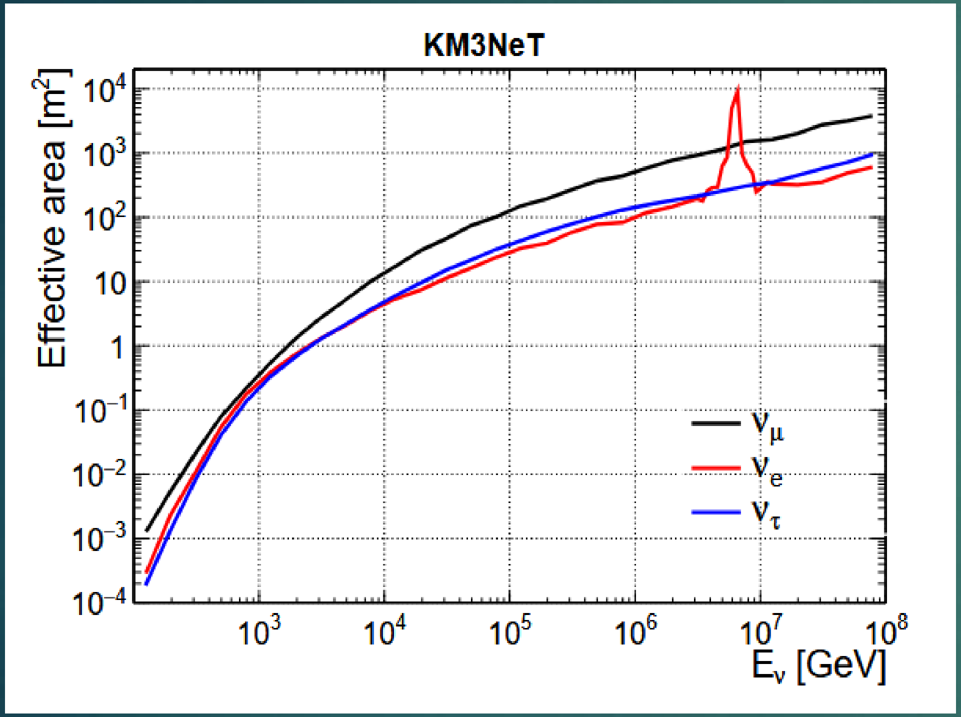


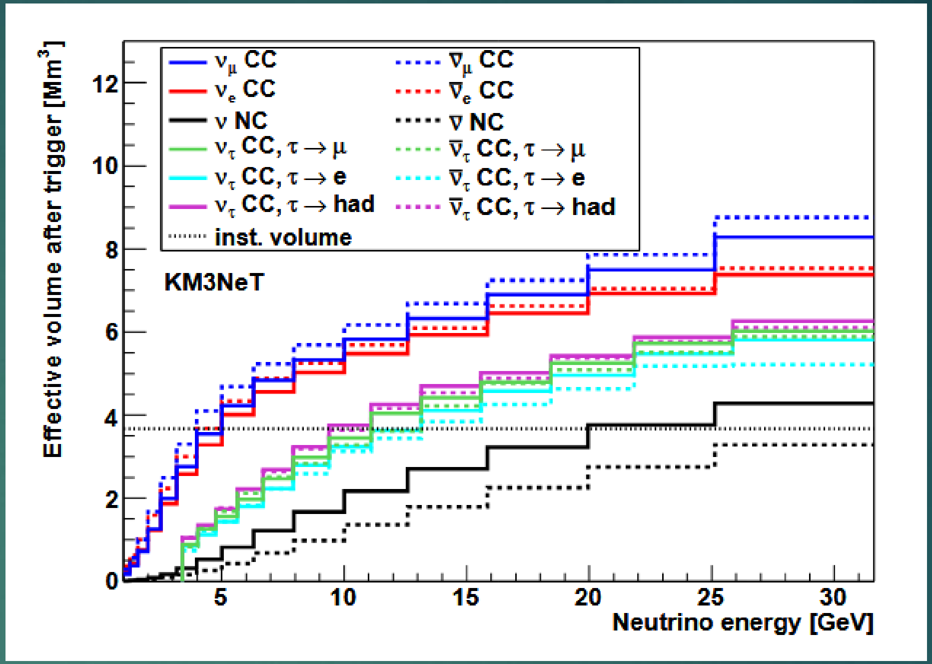

Figure 14: Trigger rate due to random coincidences (left) and required number of CPU cores (right) as a function of the singles rate for one building block of ARCA (black circles) and ORCA (red squares).

# Performance

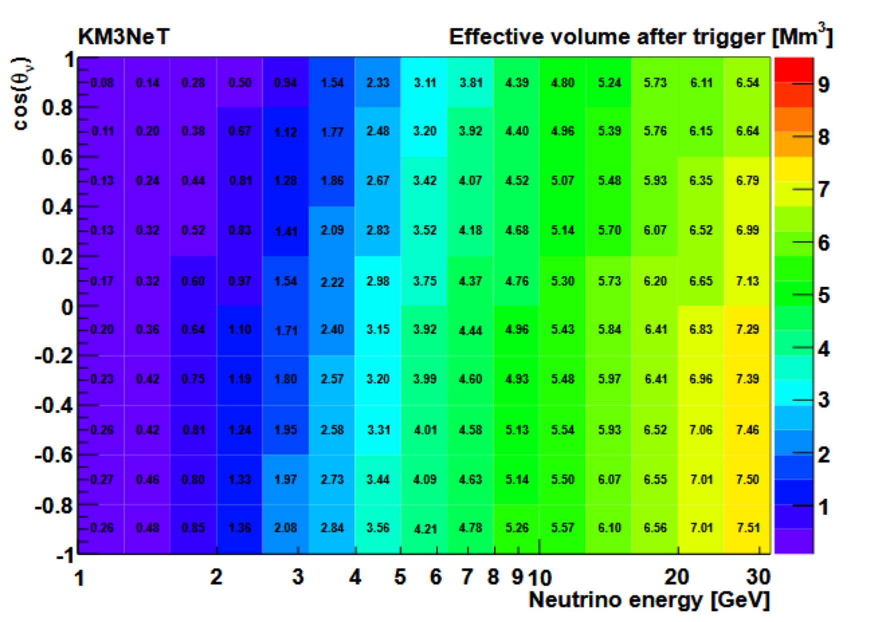
- Effective area




ARCA effective area. The peak at 6.3 PeV is due to the Glashow resonance of anti $\nu_e$




ORCA: Effective volume or 6 m vertical spacing for up-going events only




ORCA: Effective volume for $\nu_e$ CC events as a function of neutrino energy and cosine of the neutrino zenith angle

# Performance

- Event purity: the fraction of events that contain a neutrino interaction or atmospheric muon bund
- For ORCA, event purity estimated at 65-73%

| detector configuration | trigger configuration | | trigger rates [Hz] | | |
|---|---|---|---|---|---|
| vertical spacing [m] | *R* [m] | *D* [m] | pure noise | atm. muons | event purity |
| 6 | 35 | 40 | 19 | 36 | 0.65 |
| 9 | 39 | 43 | 18 | 41 | 0.69 |
| 12 | 42 | 46 | 19 | 47 | 0.71 |
| 15 | 44 | 50 | 20 | 55 | 0.73 |

# Bibliography


- S. Aiello et al (2018). Characterisation of the Hamamatsu photomultipliers for the KM3NeT Neutrino Telescope. *Journal of Instrumentation*, *13*(05), P05035. https://doi.org/10.1088/1748-0221/13/05/p05035
- Adrián-Martínez et all (2016). Letter of intent for KM3NeT 2.0. *Journal of Physics G Nuclear and Particle Physics*, *43*(8), 084001. https://doi.org/10.1088/0954-3899/43/8/084001