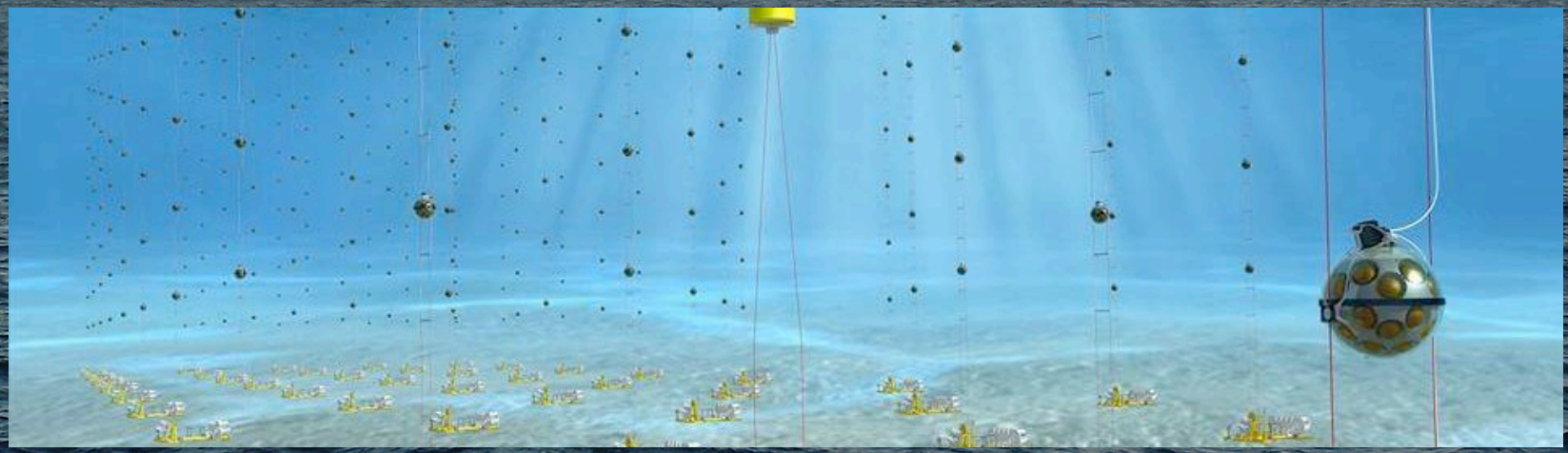
Status of the KM3NeT/ARCA telescope

C. Distefano
LNS-INFN



The KM3NeT project

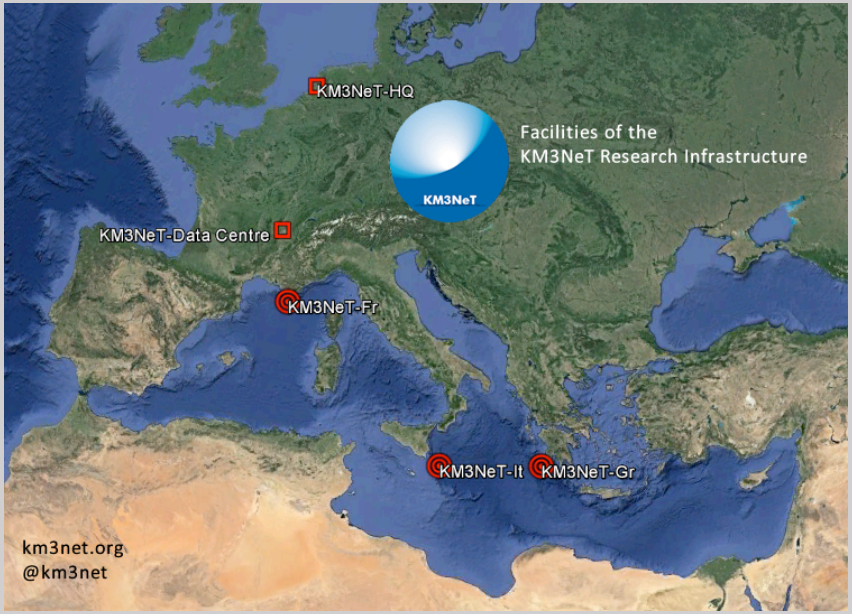
KM3NeT is a research infrastructure in the Mediterranean Sea hosting neutrino detectors

KM3NeT/ARCA (**A**stroparticle **R**esearch with **C**osmics in the **A**byss, this talk)

- discovery and observation of high energy (GeV ÷ PeV) neutrino sources of cosmic origin

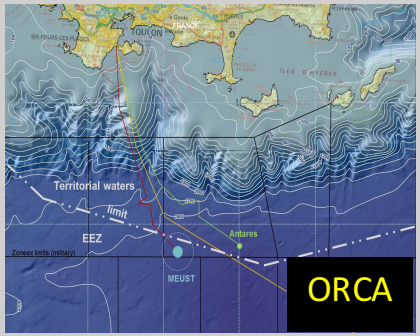
KM3NeT/ORCA (**O**scillation **R**esearch with **C**osmics in the **A**byss) (Liam Quinn's talk in this conference)

- determination of the neutrino mass hierarchy (neutrinos of tens of GeV)



Potential 3rd site: Pylos, Greece

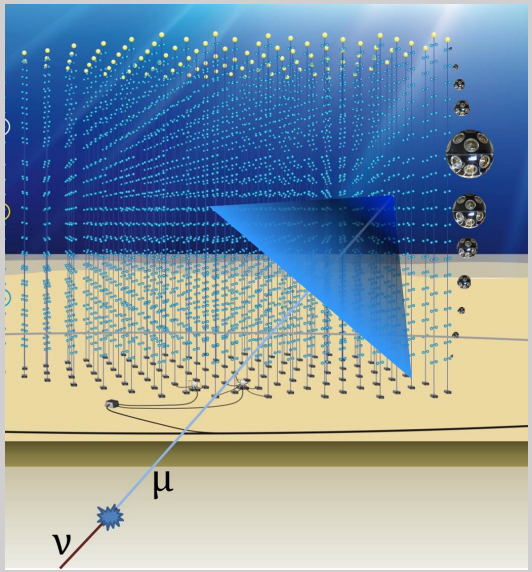
Capo Passero, Italy

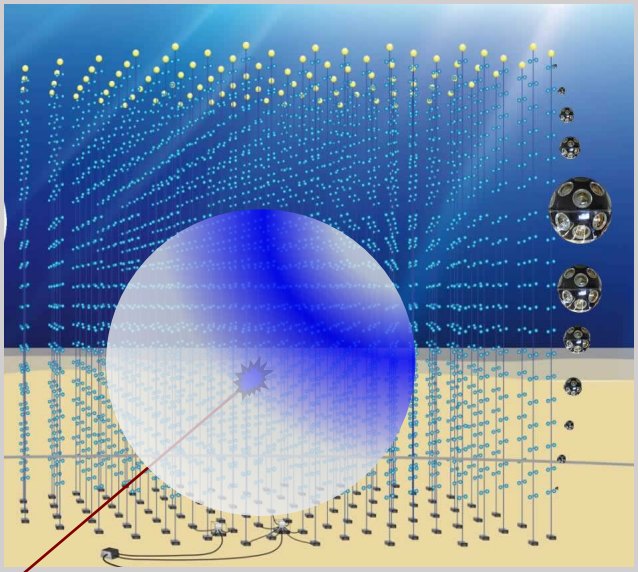


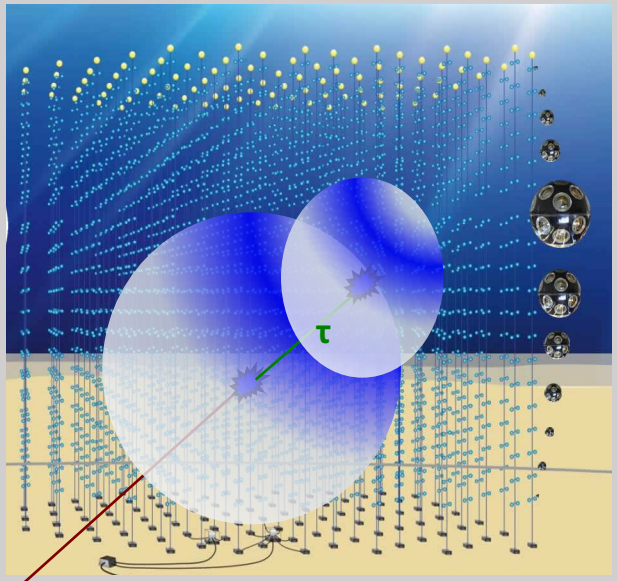
Toulone, France

ORCA and ARCA have same detector technology. Details on the ARCA and ORCA physics performances and on the technical design in our Letter of Intent 2016 J. Phys. G: Nucl. Part. Phys. 43 084001

Neutrino detection channels







$$\nu_\mu \xrightarrow[CC]{} \mu + \text{shower}$$

$$\nu_\ell \xrightarrow[NC]{} \nu'_\ell + \text{shower}$$

$$\nu_e \xrightarrow[CC]{} \text{shower}$$

$$\nu_\tau \xrightarrow[CC]{} \tau + \text{shower}$$

$$\tau \xrightarrow[\sim 83\%]{} \nu_\tau + \text{shower}$$

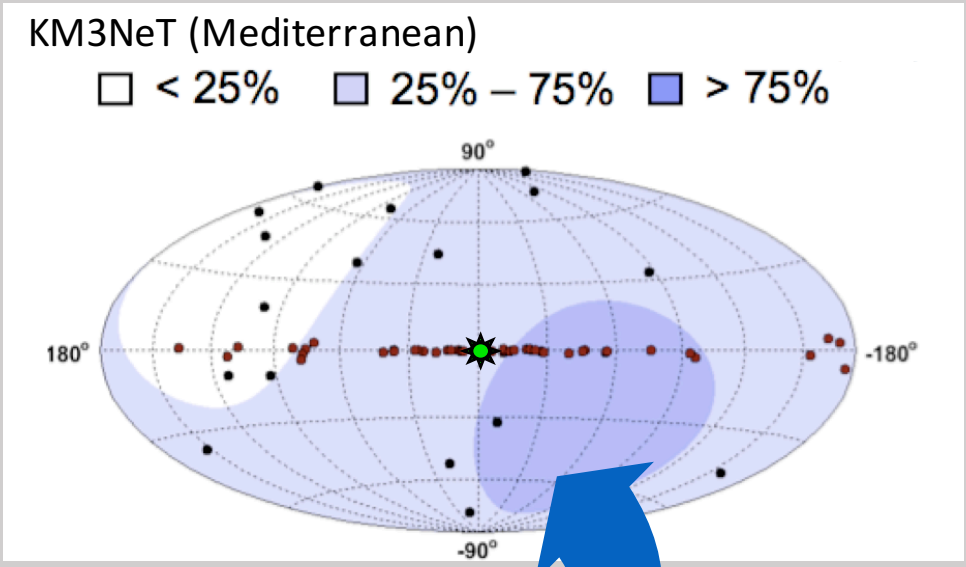
$$\tau \xrightarrow[\sim 17\%]{} \nu_\tau + \mu + \bar{\nu}_\mu$$

Muons:
highest effective area, good angular resolution (~0.1°)
High atmospheric muon background: look at events from below only

Showers:
Remove atmospheric muon background: studies over 4π.
'Good' energy resolution, worse directional resolution: diffuse flux!

Taus:
Unambiguous topology

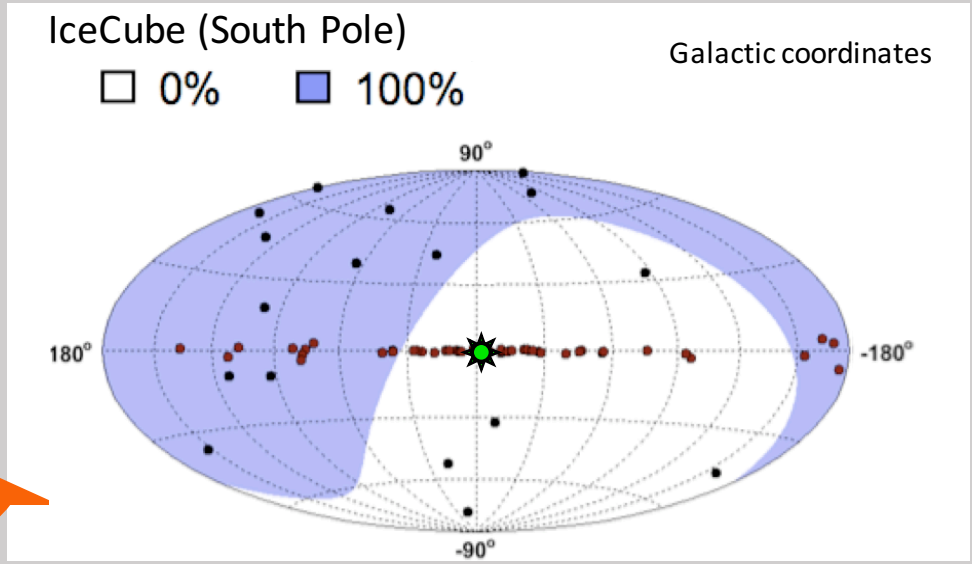
A second km³ neutrino telescope



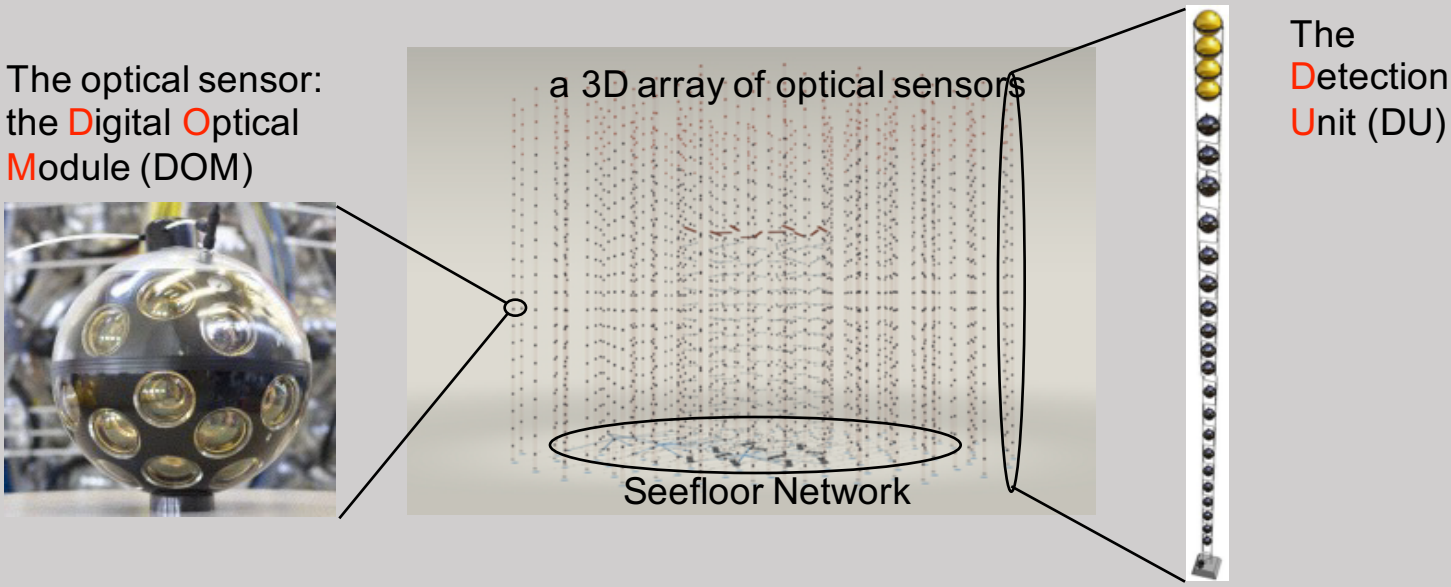
Full sky coverage

- Extragalactic
- Galactic
- Galactic centre

1.5 π sr common view per day



The KM3NeT/ARCA design



- The ARCA detector is made of 2 building blocks of 115 Detection Units (DU) each with 90 m DU interspacing (0.5 km^3/block)
- The DU is a vertical slender string equipped with 18 Digital Optical Modules (DOM) 36 m distant. Each DOM consists of 31 3'' PMTs.
- Power and data distributed by a single backbone cable with breakouts at DOMs
- Sea network of submarine cables and Junction Boxes connected to shore via a main e/o cable
- All data to shore

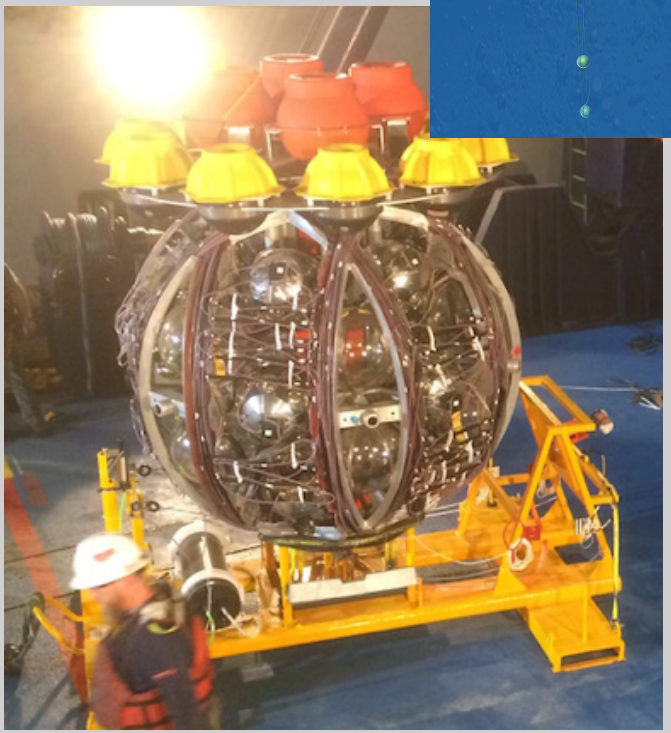
The detection unit and the optical sensors

The Launcher vehicle (2m diameter)
- rapid deployment
- autonomous unfurling
- recoverable

The DOM is a new design for optical sensors developed in the collaboration. It is a 17" glass sphere with inside:

- 31 3" PMTs (photocathode area ≃ 3 x 10" PMTs)
- LED beacon and acoustic piezoelectric
- FPGA readout

White rabbit technology for time synchronization
DWDM for data transmission

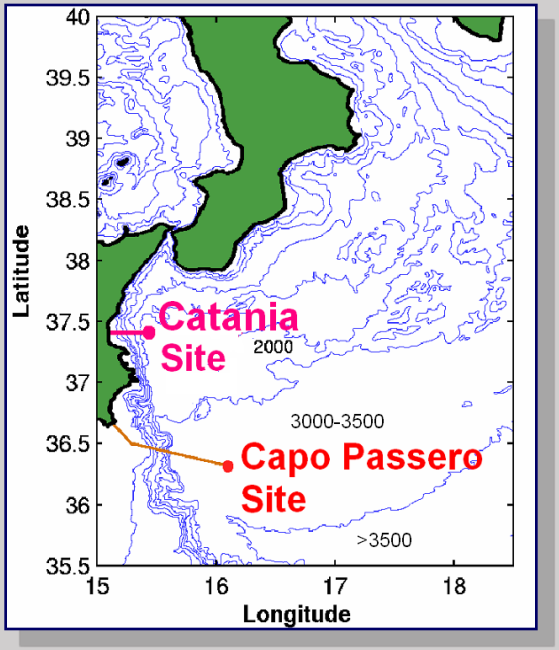


The KM3NeT phased implementation

from our Letter of Intent

Phase	Building blocks		Number of DUs		Physics goal		Status
	ARCA	ORCA	ARCA	ORCA	ARCA	ORCA	
1	0.2	0.06	23	7	Proof of feasibility and first science results. Joined analysis with ANTARES data		Fully funded. First 2 DUs installed and functioning at Capo Passero
2.0	2	1	230	115	All flavor astronomy. Study of the neutrino signal reported by IceCube.	Determination of the neutrino mass hierarchy	~~Not yet funded~~ Now partially funded
3	6	-	690	-	Neutrino astronomy including Galactic sources.		Not yet funded

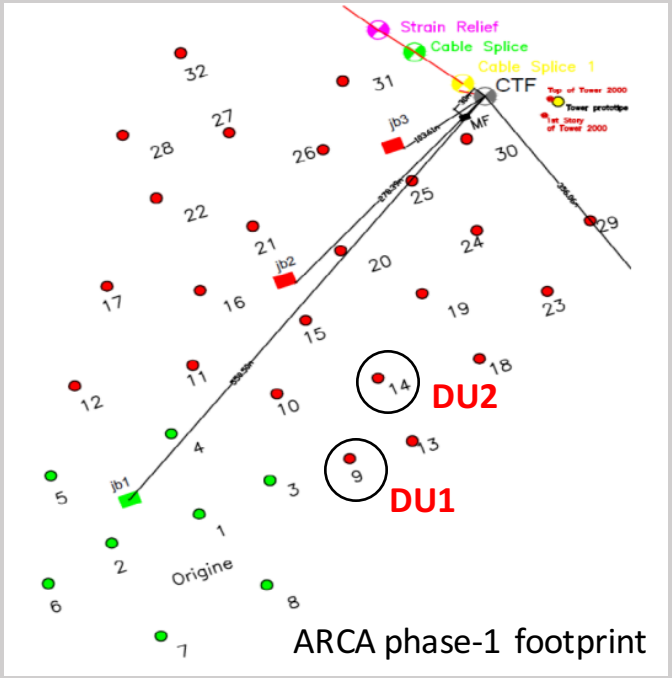
KM3NeT/ARCA Phase 1



Two strings deployed at Capo Passero site: the first one deployed in December 2015, the second one in May 2016.

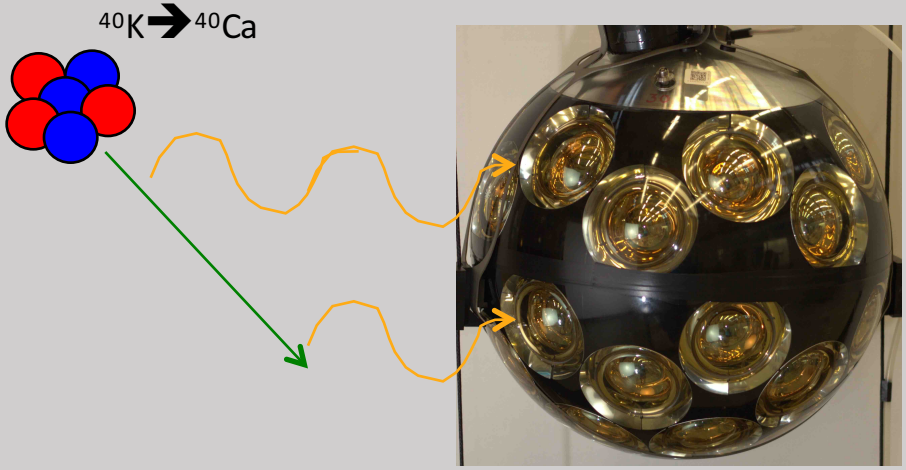
Capo Passero shore station

ARCA phase-1 will be ≈ 0.1 km^3

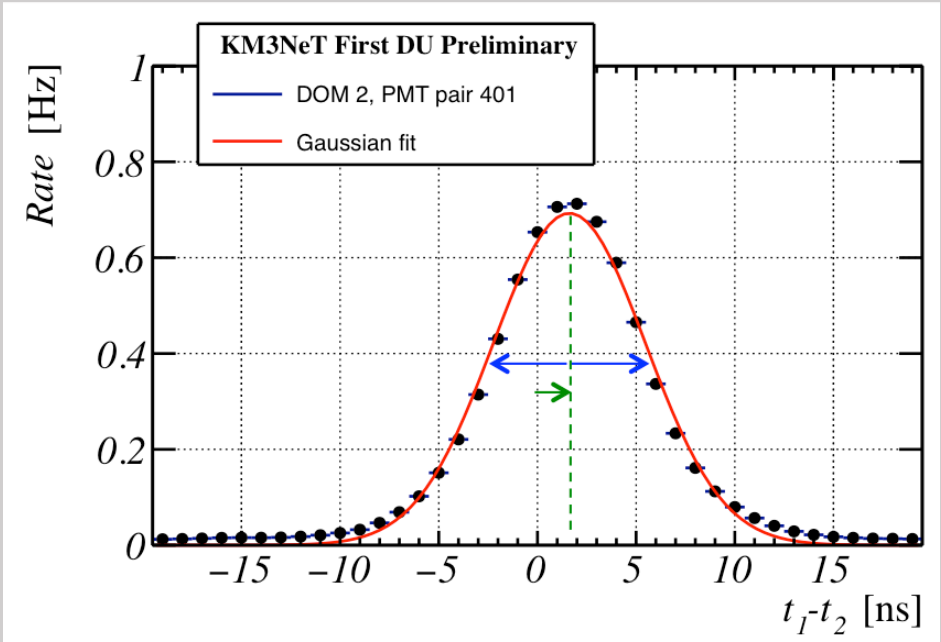


Intra-DOM calibration

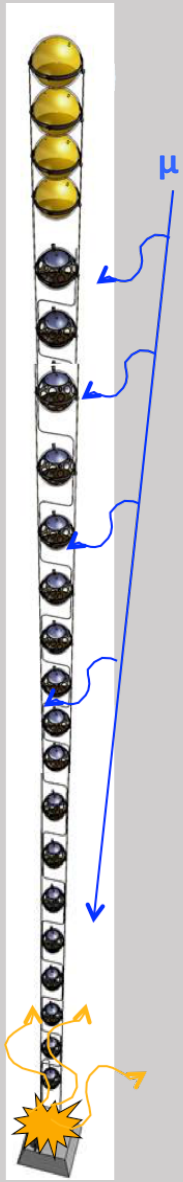
Self-calibration: ^{40}K



- Natural radioactive decays from ^{40}K
  - Cherenkov light
  - ~5 kHz rate in PMTs
  - Filtered by CPUs at on-shore DAQ
  - Self-calibration mechanism!
- Calibration tells us:
  - Time offset (centre)
  - Relative efficiency (area)
  - Single-photon spread (width)
- Long-term stability observed

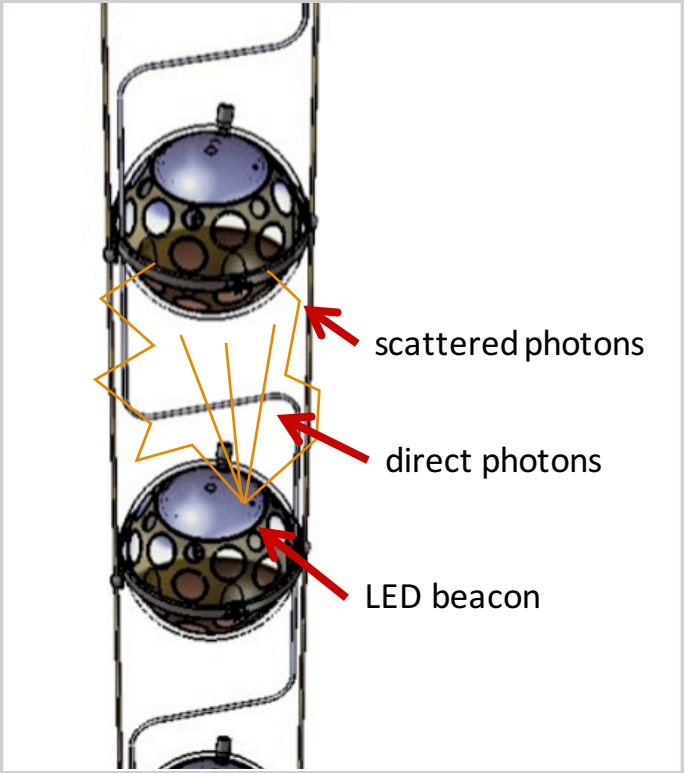


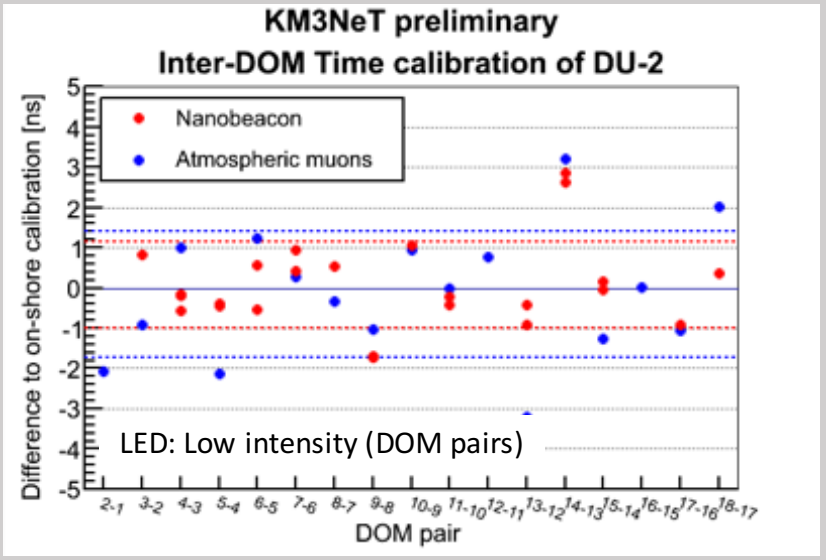
Inter-DOM calibration

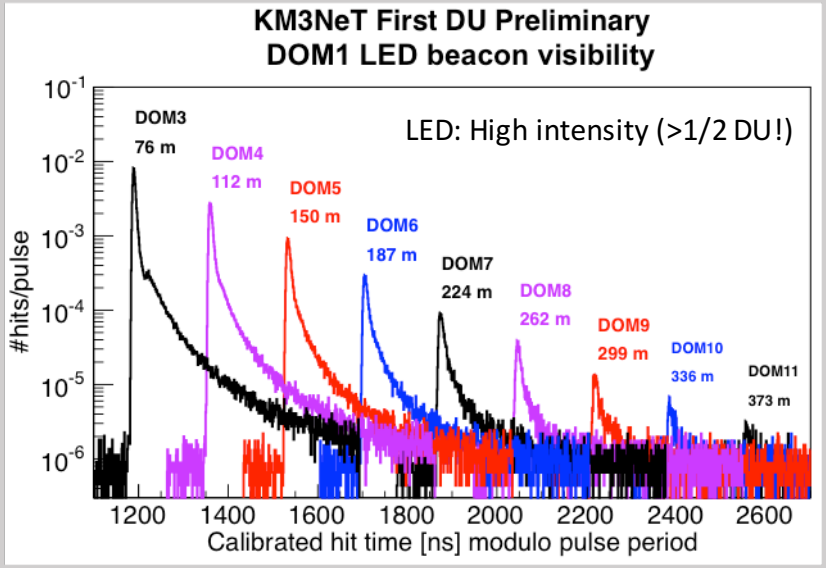


Time calibration check with LED beacons and atmospherics muons

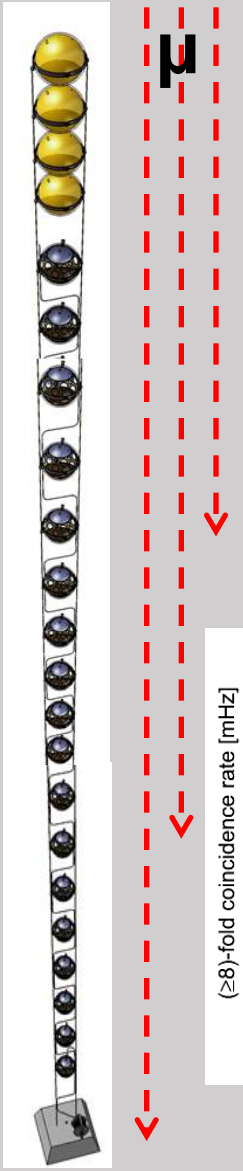
- LED beacon
- Atmospheric Muons

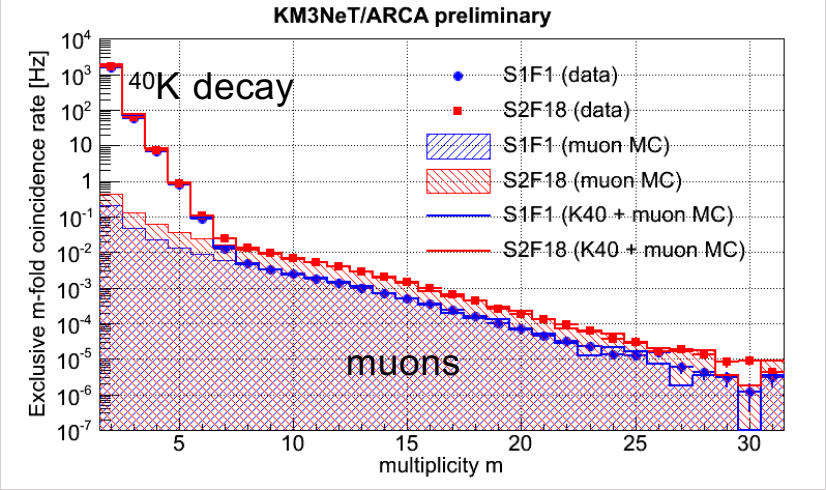


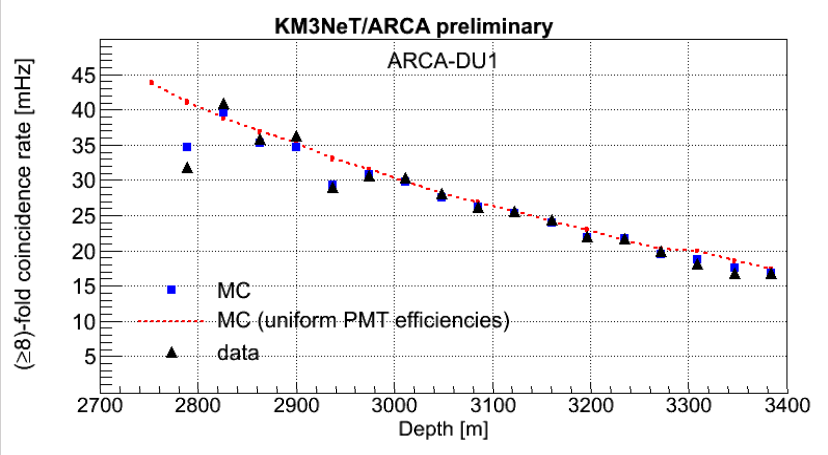


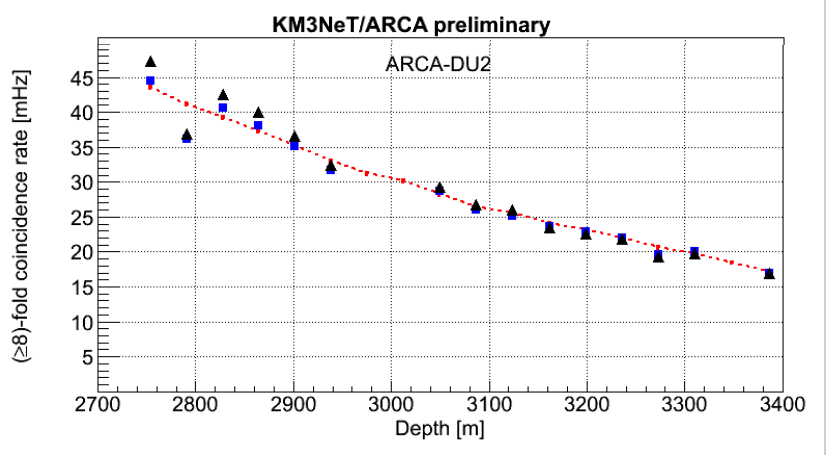


Muon Depth Dependence

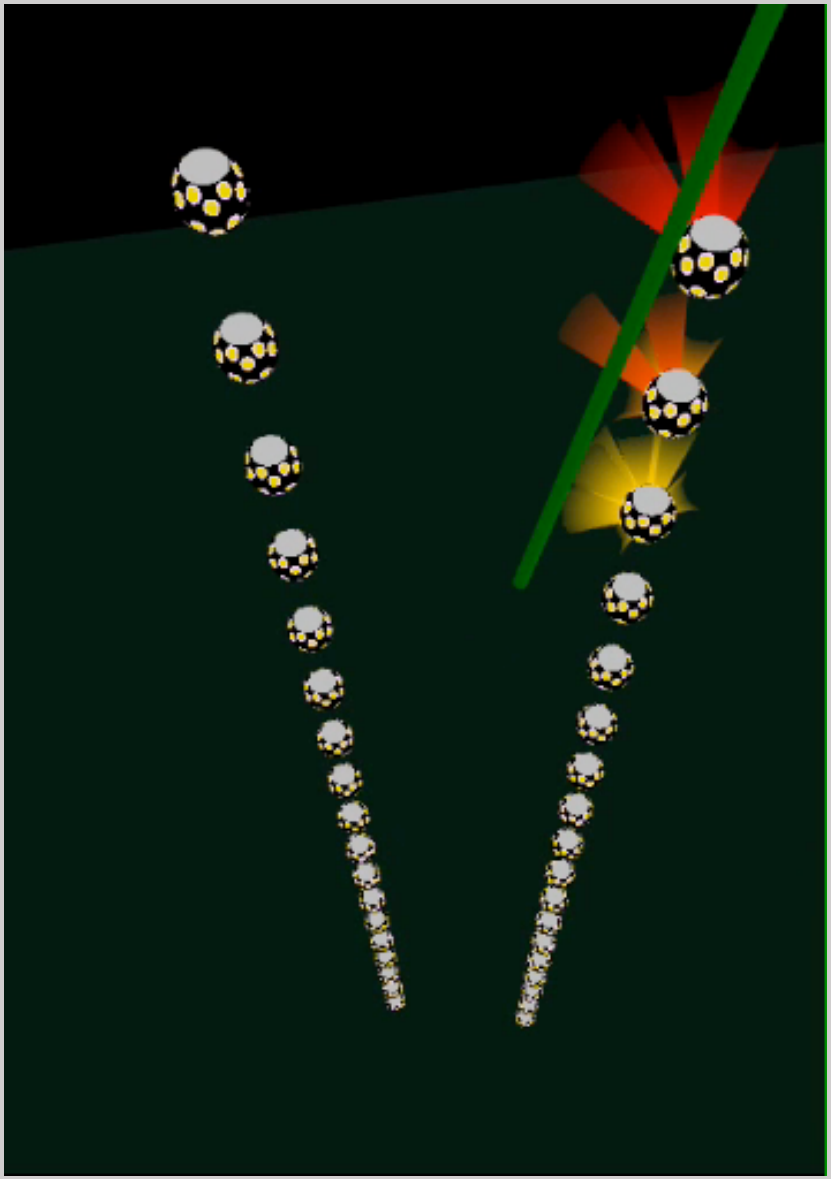


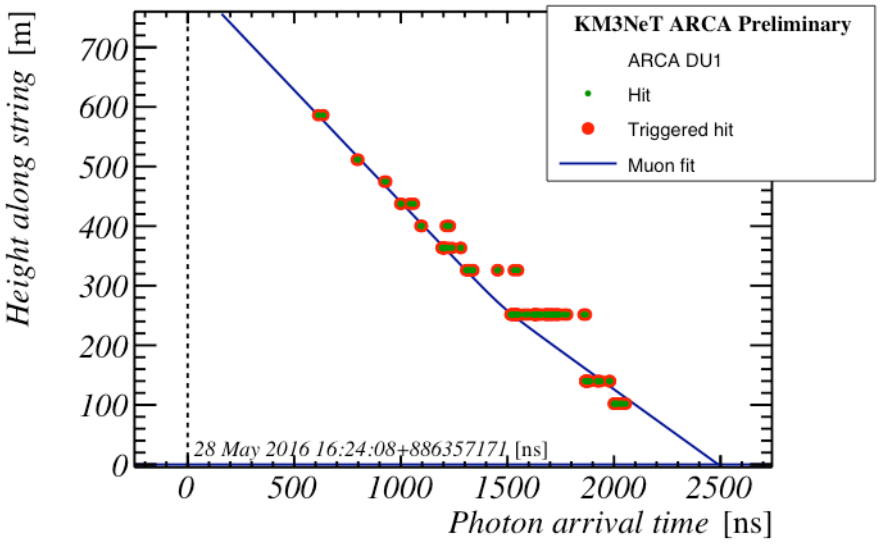


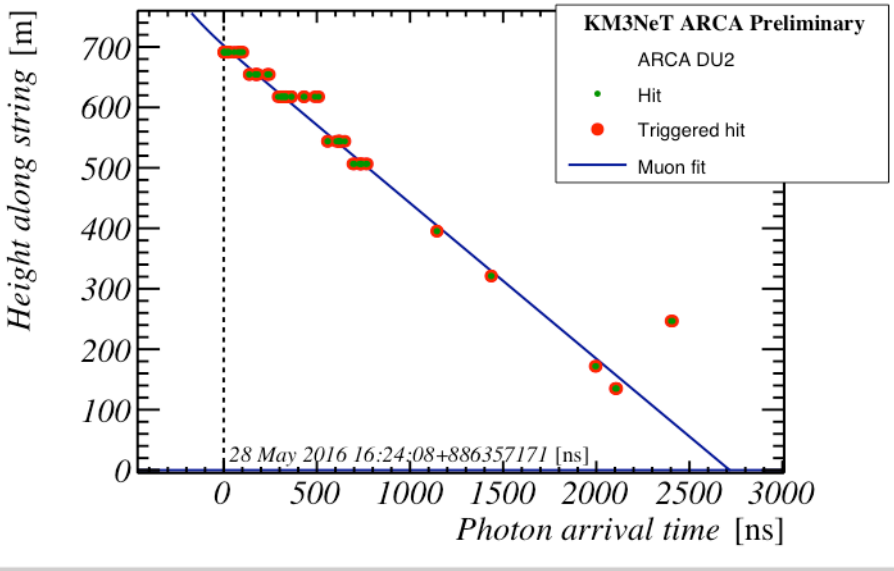




Two String Event

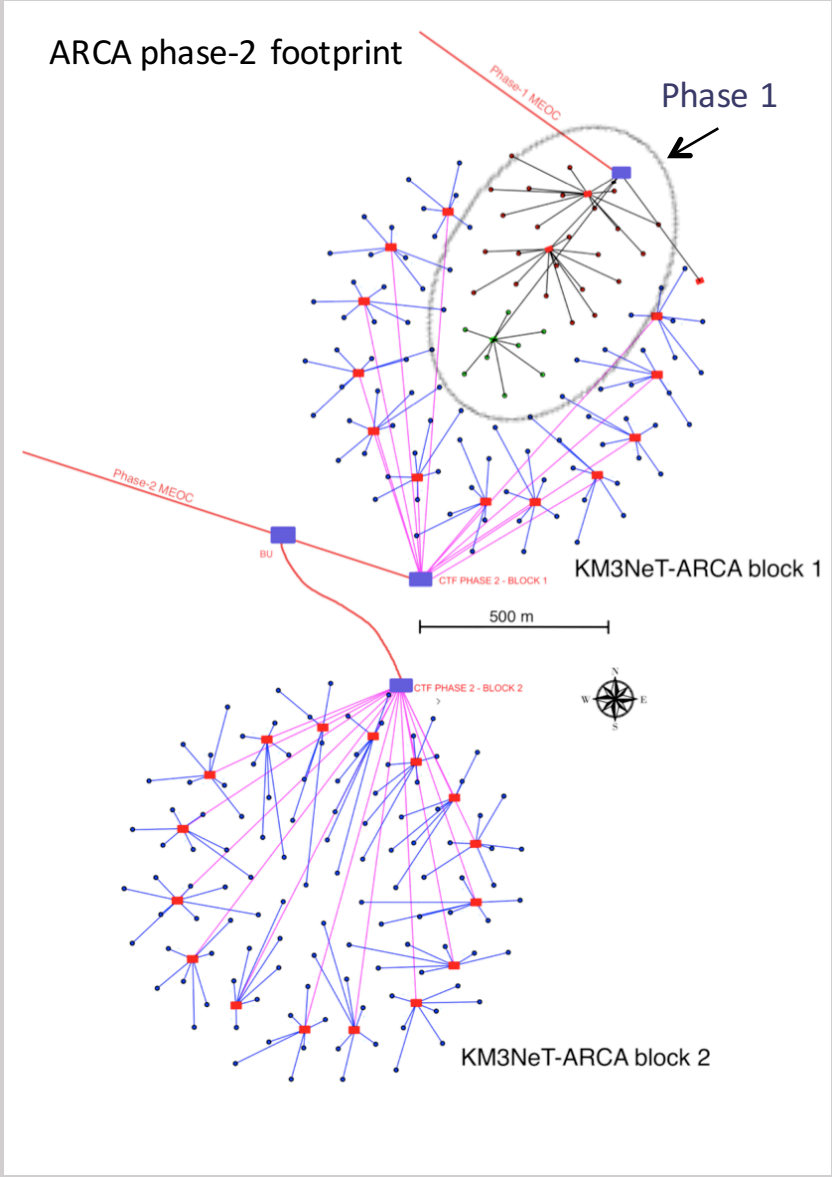






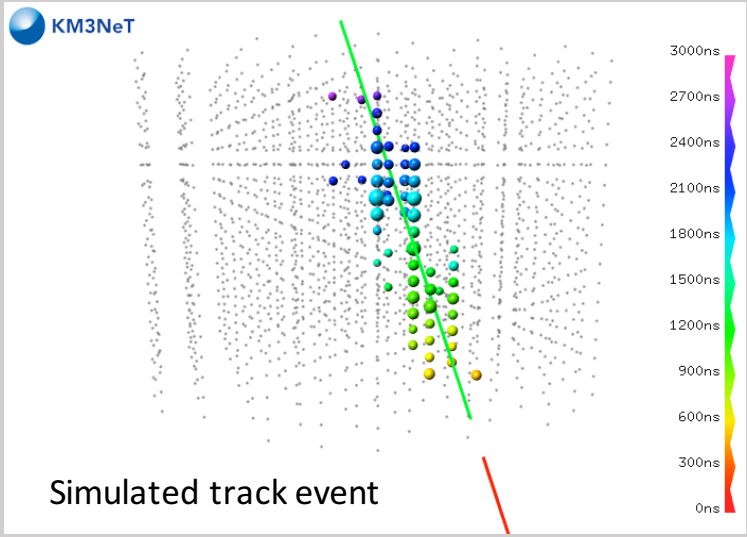
KM3NeT/ARCA Phase 2

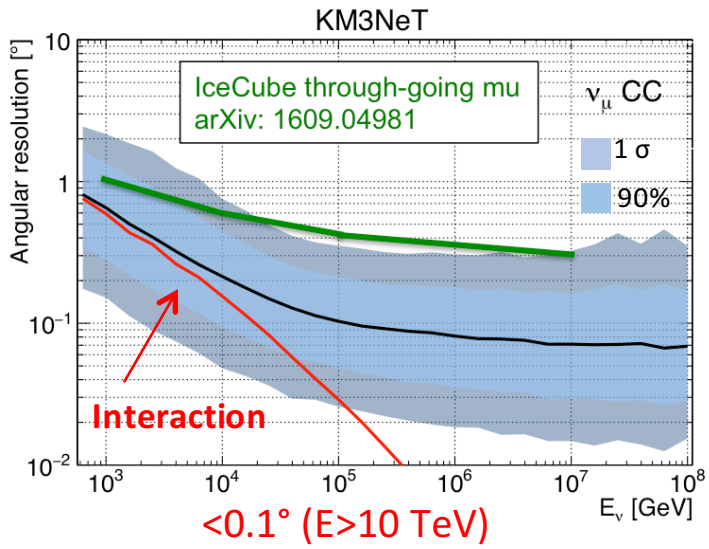
- ARCA: 2 blocks:
  - 115 'detection units' per block
  - 90m horizontal spacing
- Detection unit:
  - Line anchored to the sea floor
  - 18 optical modules, 36m spacing
- Total volume: 1 km^3
- Site: 3.5 km depth, Capo Passero (Sicily)

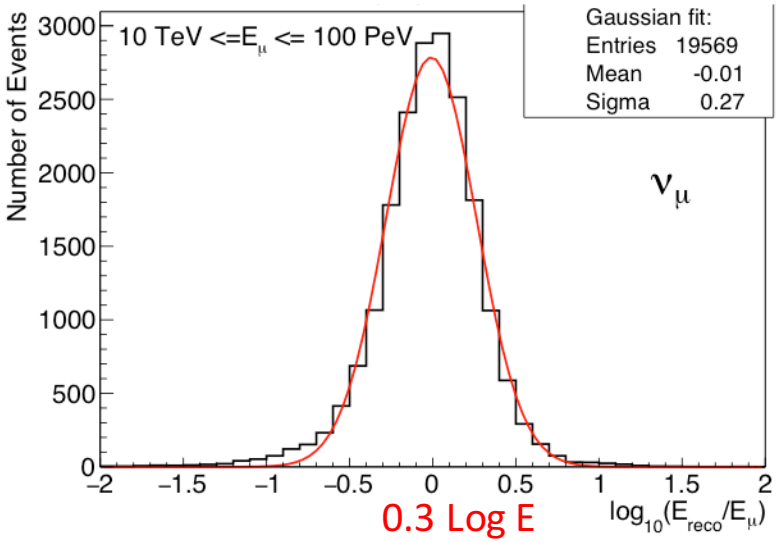


Angular and energy resolution

"Track-like" events mainly from ν_μ CC interactions

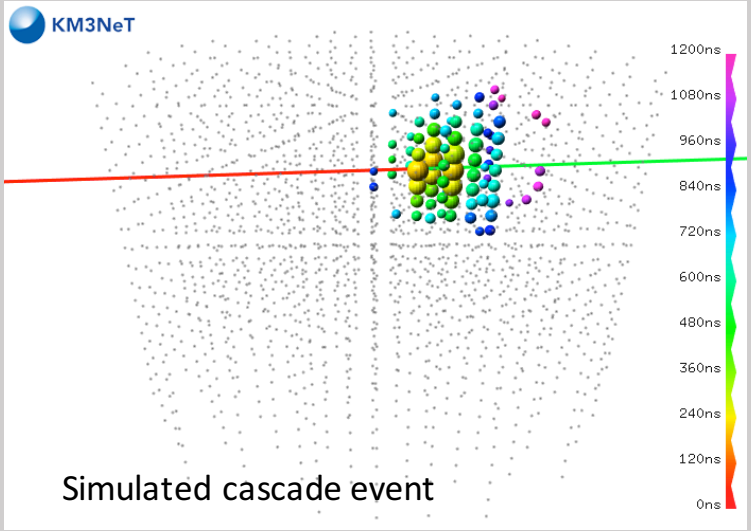




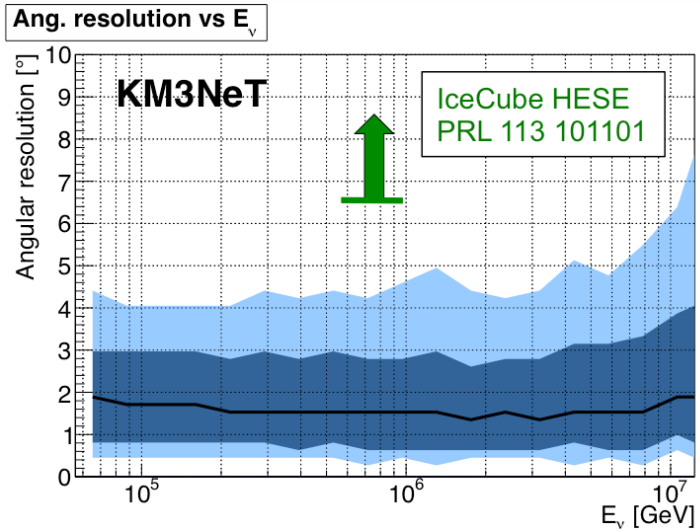


Angular and energy resolution

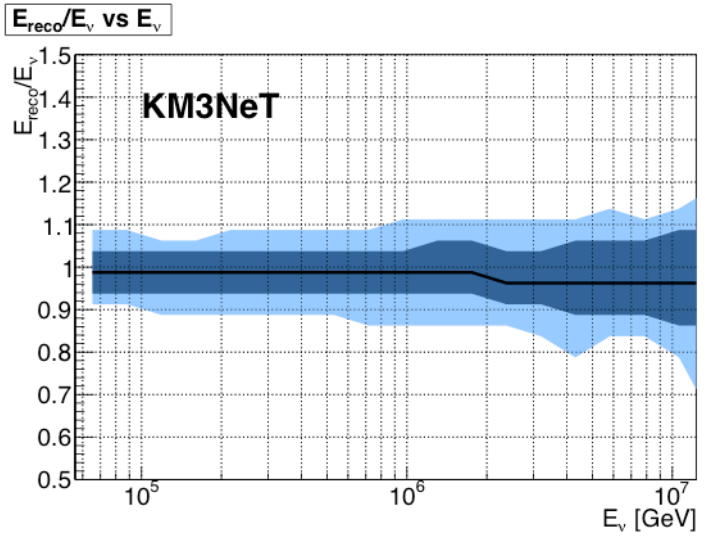
"Cascade-like" events mainly from ν_e CC and NC interactions



Simulated cascade event



angular resolution better than 2°



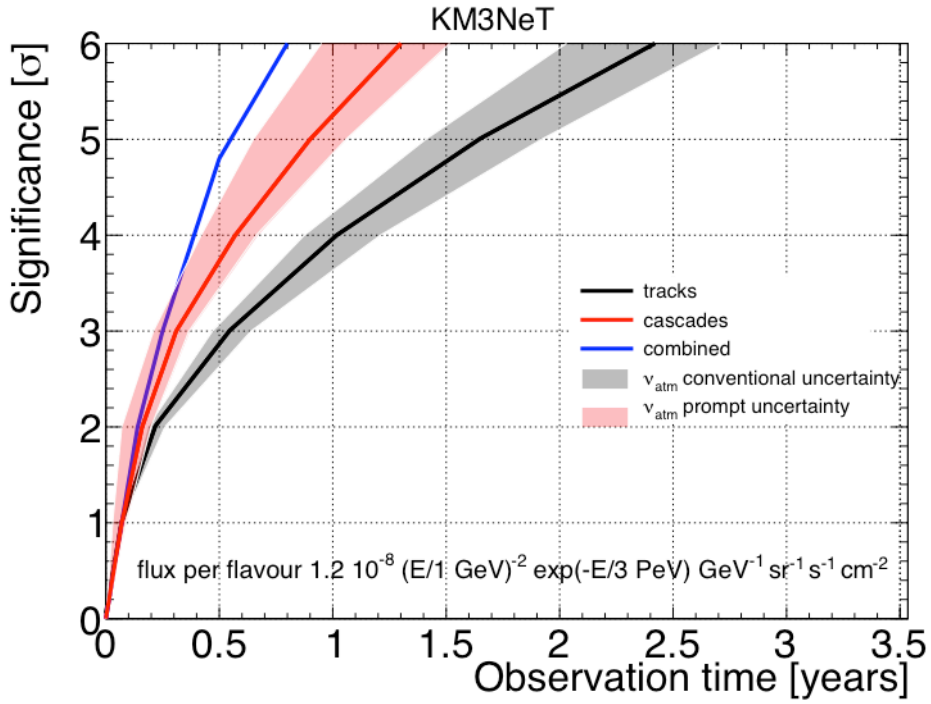
energy resolution better ≈ 5% at 1σ

Sensitivity to diffuse fluxes

Benchmark flux : IceCube flux (isotropic and flavour symmetric)

$$\Phi(E) = 1.2 \cdot 10^{-8} (E/1\ \mathrm{GeV})^{-2} \exp(-E/3\ \mathrm{PeV})\ \mathrm{GeV}^{-1}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}\ \mathrm{sr}^{-1}$$

Goal: don't just re-discover the IceCube flux, investigate it!



Discovery at 5σ (50% probability) in 6 months of ARCA

- Track channel

Analysis for up-going events based on maximum likelihood of preselected events. Pre-cuts on θ_{zen} >80°, reconstruction quality parameter and Nhit (proxy for muon energy)

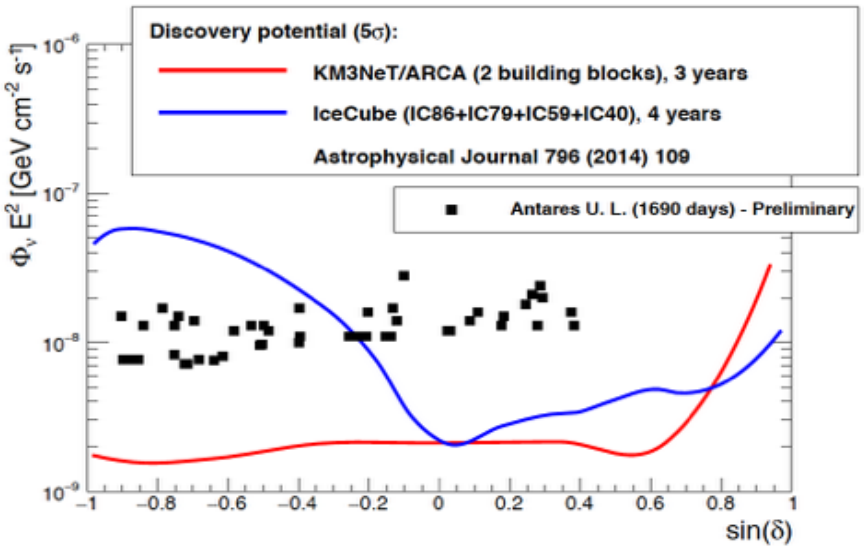
- Cascade channel

Containment cut on reconstructed vertex to remove atmospheric muons (excludes upper 100m layer)
All sky analysis based on BDT and maximum likelihood.

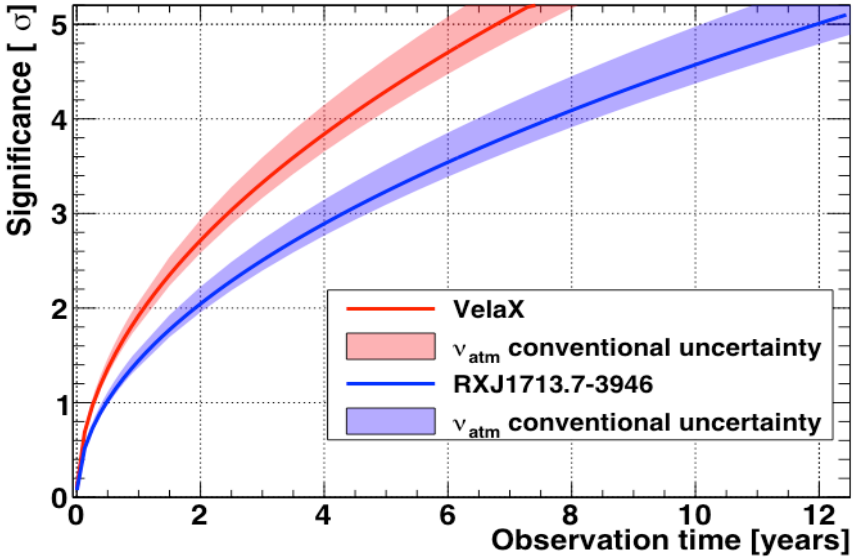
Source identification

Visibility of Galactic Plane + Galactic Center
Better angular resolution in water will help the source identification

Point-like sources



Galactic (SNRs) sources



Up-going muon neutrinos analysis
Better sensitivity (for equivalent exposure) and better sky coverage than IceCube

For ANTARES see Annarita Margiotta's talks

Spectra cutoffs of the order of few tens of TeV
Source extension taken into account (0.6° for RXJ1713 and 0.8° for Vela X)

Neutrino spectra: RXJ1713 from S. R. Kelner et al., Phys. Rev. D74 , 034018 (2006), Vela X from F. L. Villante and F. Vissani, Phys. Rev. D78 , 103007 (2008).

Conclusions

KM3NeT/ARCA will soon take over as the biggest neutrino telescope in the Northern Hemisphere (KM3NeT phase-1 will be ≈ 0.1 km^3)

KM3NeT phase-1: 2 DUs of ARCA already installed at the Italian site

Data under analysis: time calibration, check of Monte Carlo simulations, atmospheric muons…

Following phase KM3NeT 2.0

KM3NeT/ARCA (≈ 1 km^3) will be installed at the Italian node of the KM3NeT distributed infrastructure

Exciting physics prospects:

- Excellent angular resolution: perform neutrino astronomy
- Study IceCube flux from a different hemisphere
- Discover galactic plane emission, and galactic sources