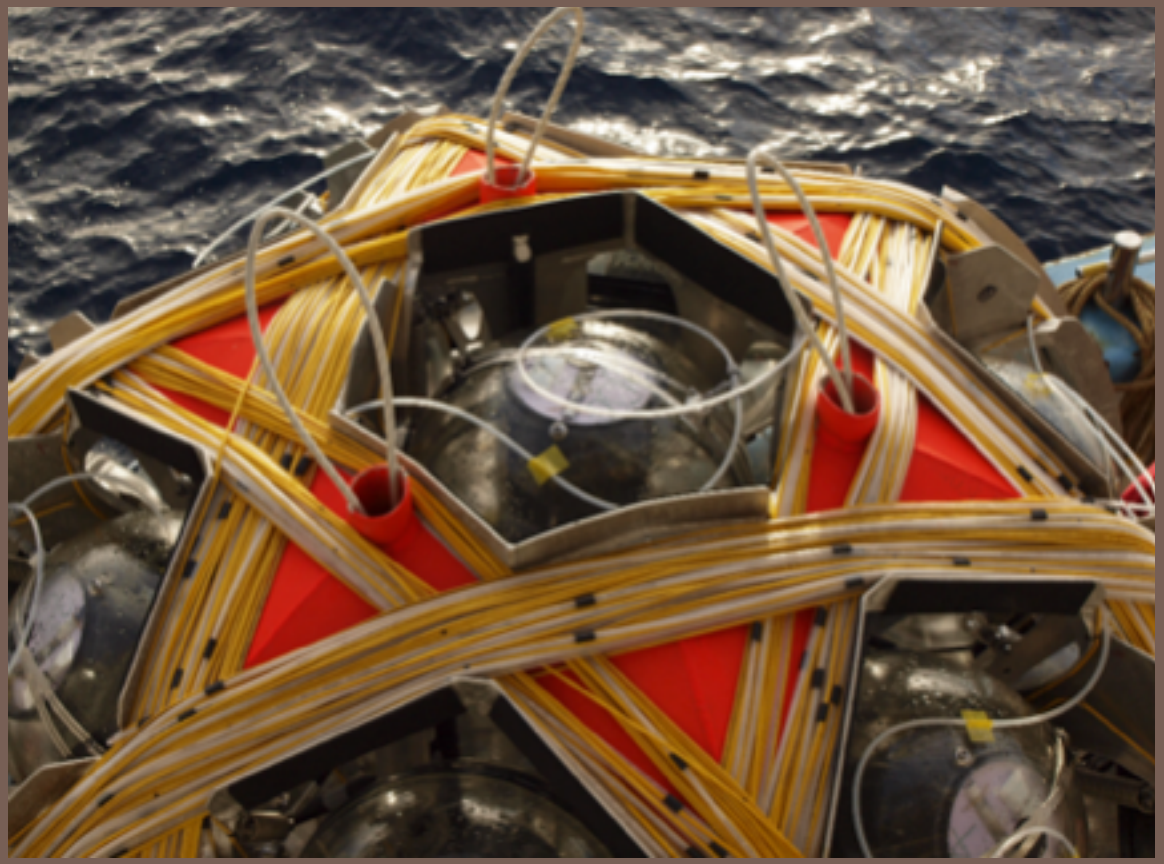
R. Coniglione for the KM3NeT collaboration

INFN-LNS - Catania (Italy)



# FIRST RESULTS AND PERSPECTIVES OF THE KM3NET/ARCA DETECTOR

*NOW 2018 - Ostuni 10 -15 September 2018*

# KM3NeT

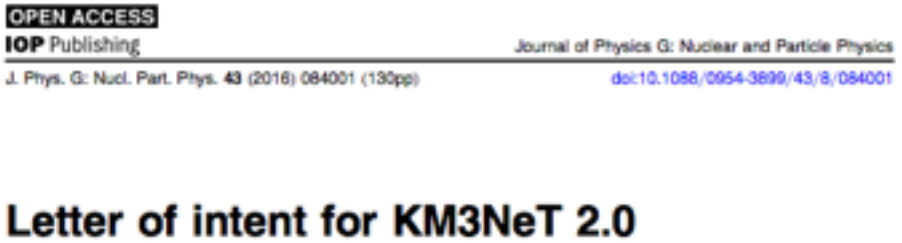


**KM3NeT is a research infrastructure in the Mediterranean Sea hosting neutrino detectors**

- KM3NeT/ARCA (Astroparticle Research with Cosmics in the Abyss ☛ this talk)
  - observation of high energy (GeV ÷ PeV) neutrino sources ☛ a telescope offshore Capo Passero (Sicily-Italy) is in construction at a depth of 3500m
- KM3NeT/ORCA (Oscillation Research with Cosmics in the Abyss ☛ talk of D. Samtleben)
  - determination of the neutrino mass hierarchy ☛ a detector offshore Toulon (France) able to detect neutrinos of tens of GeV is in construction at a depth of 2500m

**ORCA and ARCA same detector technology**

Details on the ARCA and ORCA physics performances and on the technical design in the published **Letter of Intent** ☛

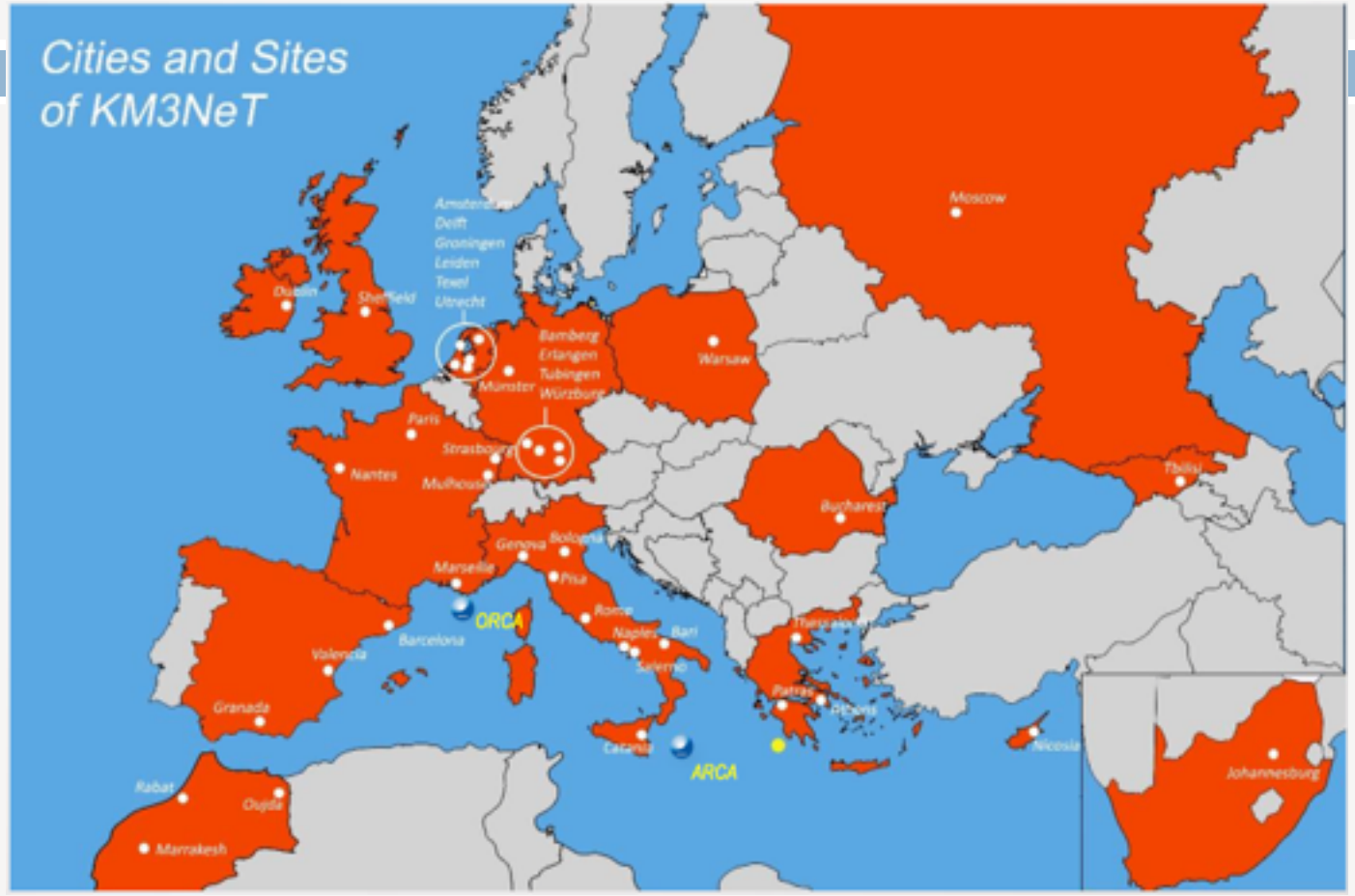

OPEN ACCESS
IOP Publishing
Journal of Physics G: Nuclear and Particle Physics
J. Phys. G: Nucl. Part. Phys. 43 (2016) 084001 (130pp)
doi:10.1088/0954-3899/43/8/084001

**Letter of intent for KM3NeT 2.0**

# The KM3NeT collaboration



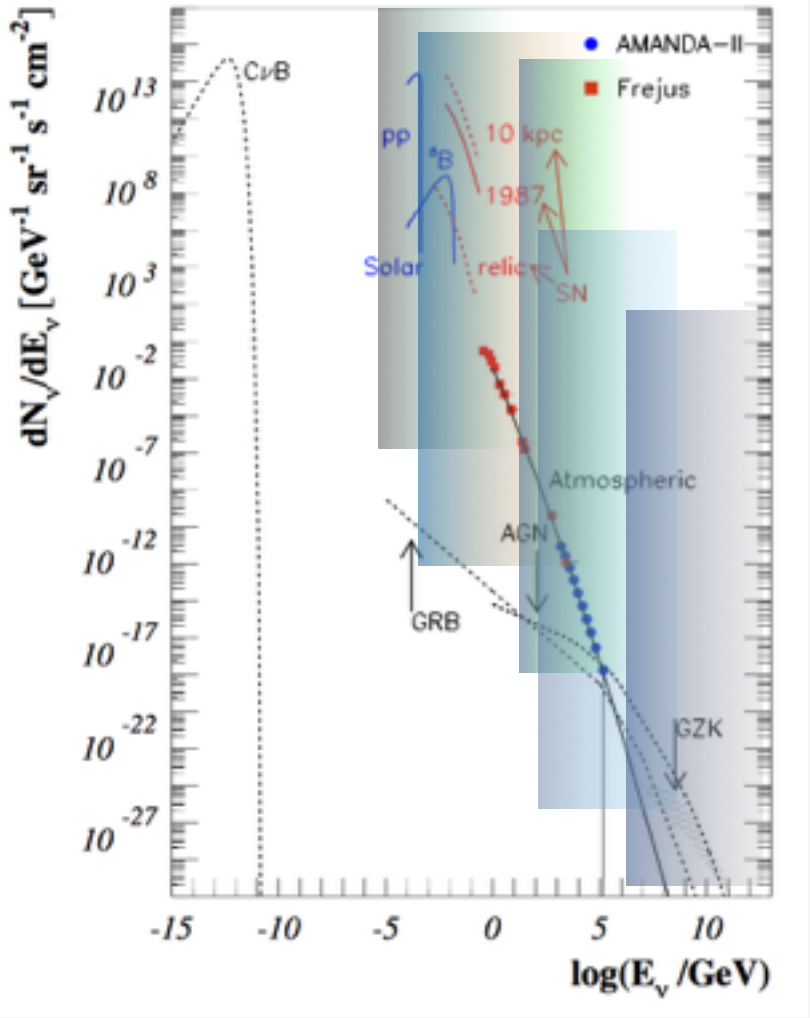
- *13 countries*
- *51 institutes*




*Number of Institutes and Scientists constantly increasing*
*New Entries: f.m. U.Johannesburg, U.Marrakech, U.Nantes; obs. LAM Marseille, U.Tbilisi*

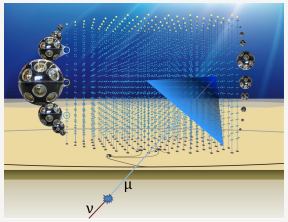
# Neutrino spectrum and water Cherenkov detectors



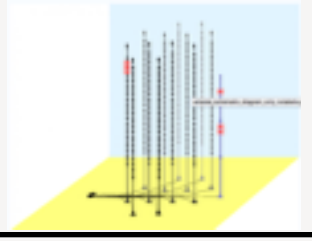



Superkamiokande 50 kton

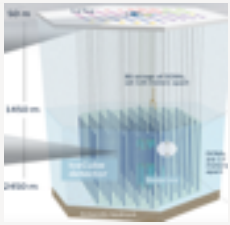
KM3NeT/ORCA - PINGU~ 5 Mton




ANTARES ~ 15 Mton



IceCube -KM3NeT/ ARCA - Baikal/GVD ~ 1 km$^3$ ->1 Gton

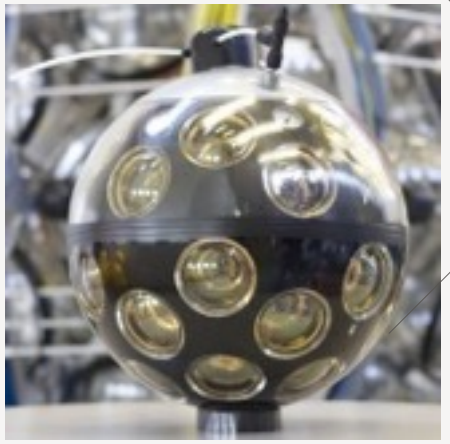


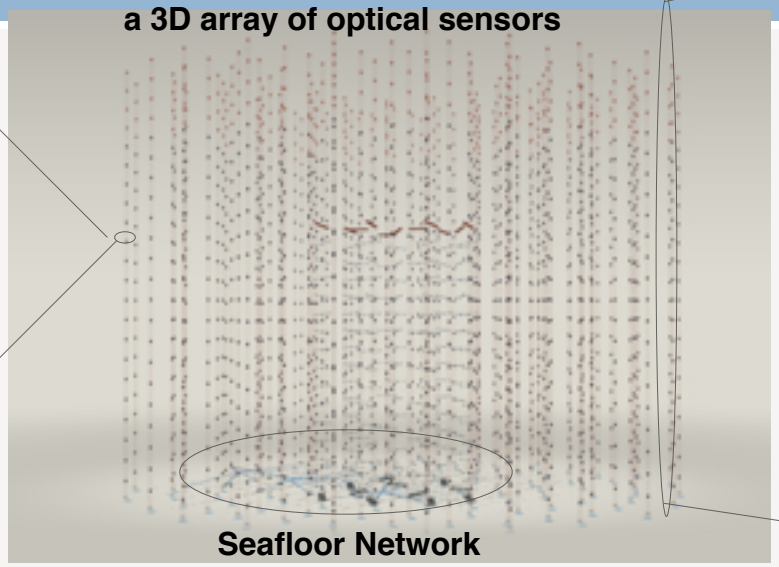
IceCube -Gen2 ~ 10km$^3$ -> 10 Gton

# The KM3NeT/ARCA design



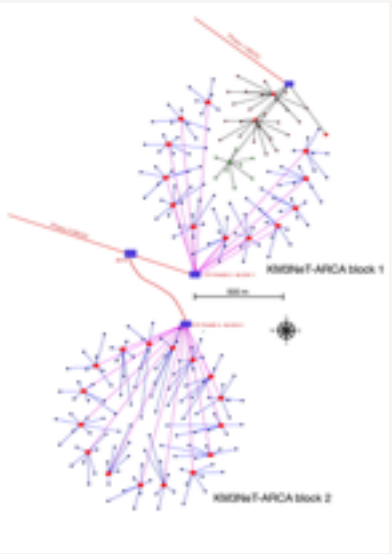
The optical sensor: the Digital Optical Module (DOM)





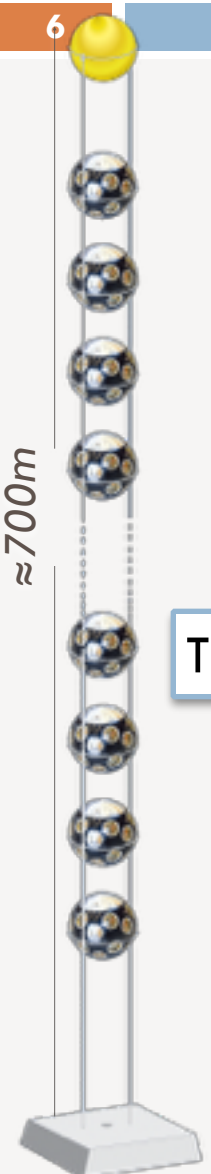

The Detection Unit (DU)

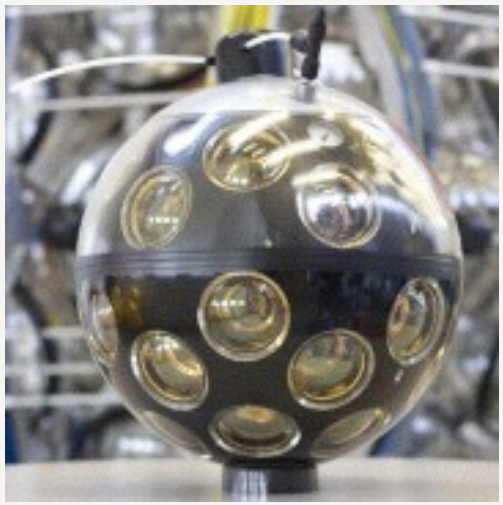
- **The ARCA detector is made of 2 building blocks of 115 Detection Units (DU)** each with 90 m DU interspacing (0.5 km3/block)
- The DU is a vertical slender string equipped with 18 Digital Optical Modules (DOM) 36 m distant. Each DOM consists of 31 3" PMTs.
- Power and data distributed by a single 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 Optical sensors and the Detection Unit





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 aerea ≃ 3 × 10" PMTs)
- LED and Piezo
- Front-end electronics -> FPGA

Hybrid white rabbit for time synchronization
DWDM for data transmission

Advantages:

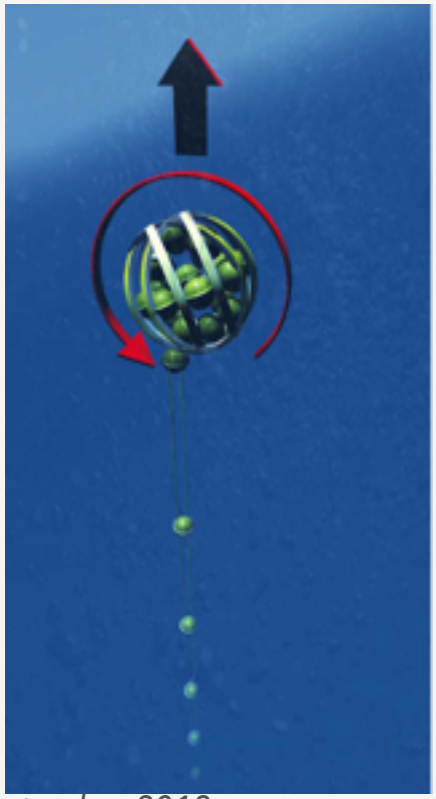
- increased photocathode area
- directionality
- single penetrator -> reduced risk
- Cost/photocathode area

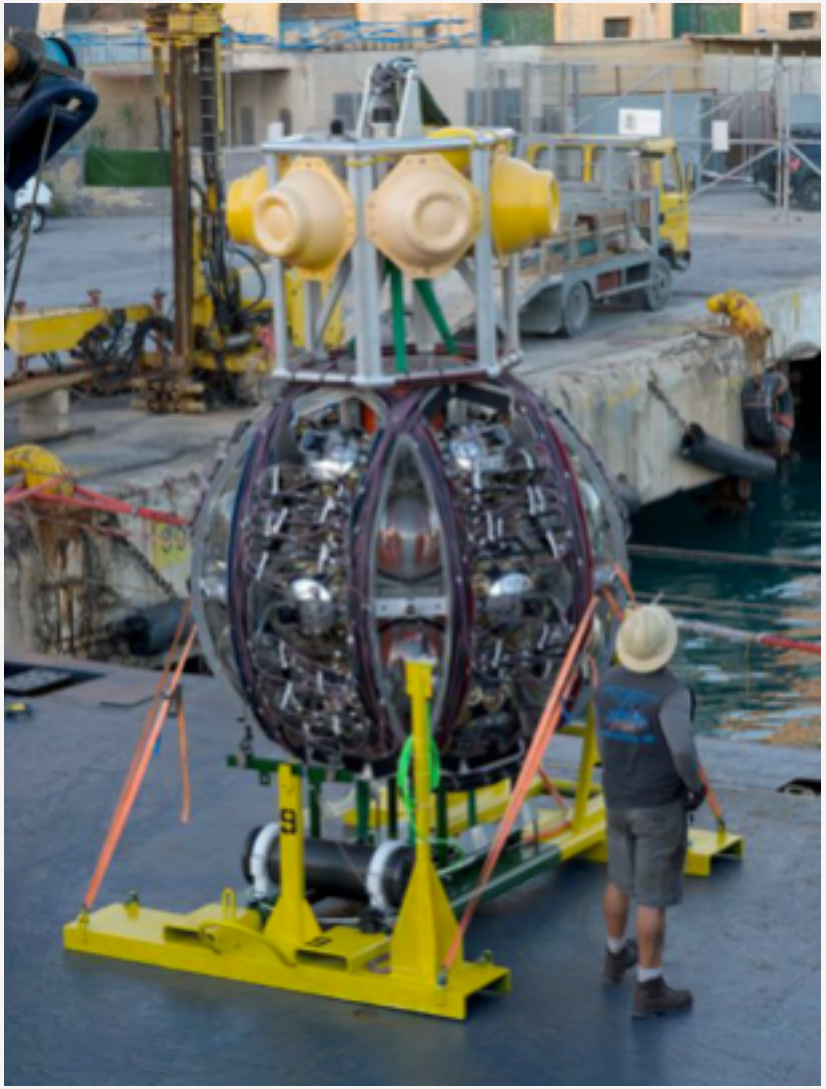
# The DU deployment




The Launcher vehicle (2m of diameter):

- rapid deployment
- autonomous unfurling
- recoverable

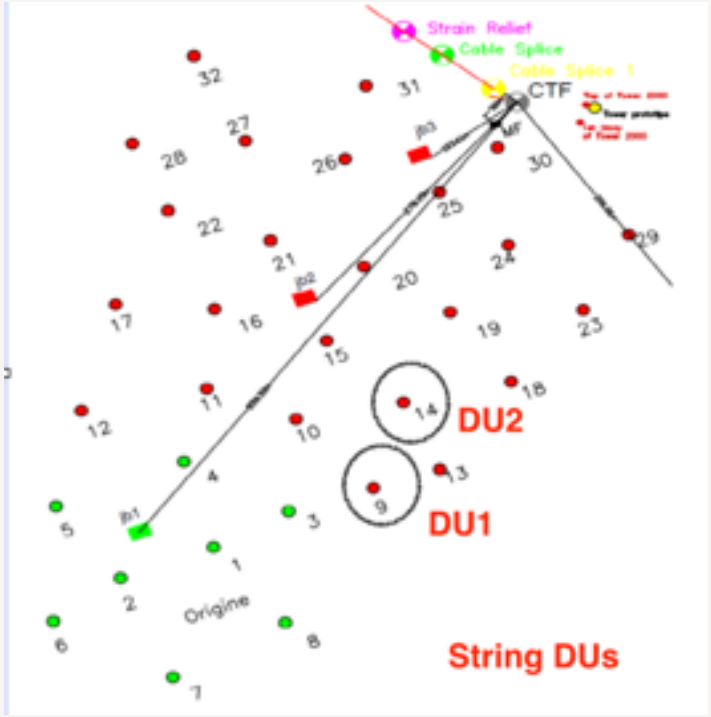




# KM3NeT-phase1

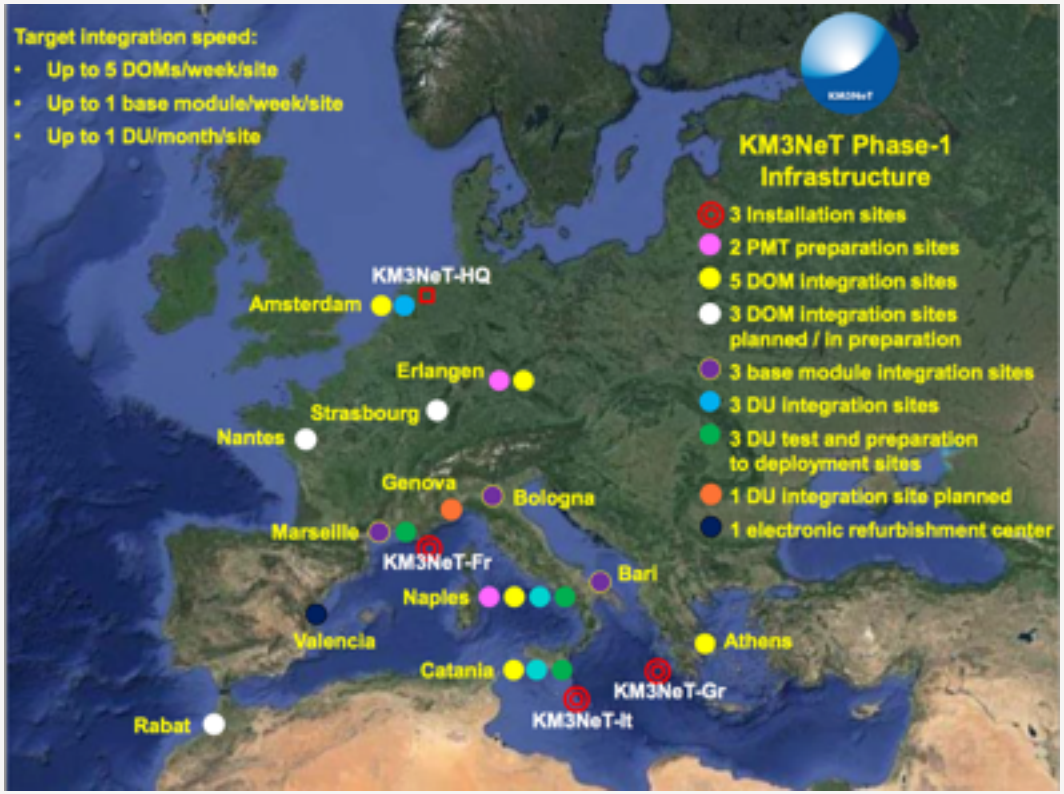


First construction phase fully funded
- ARCA 24 DUs
- ORCA 6 DUs




*Integration of DOMs and DUs on going*

Integration site map



# KM3NeT-phase1: the first DUs installed



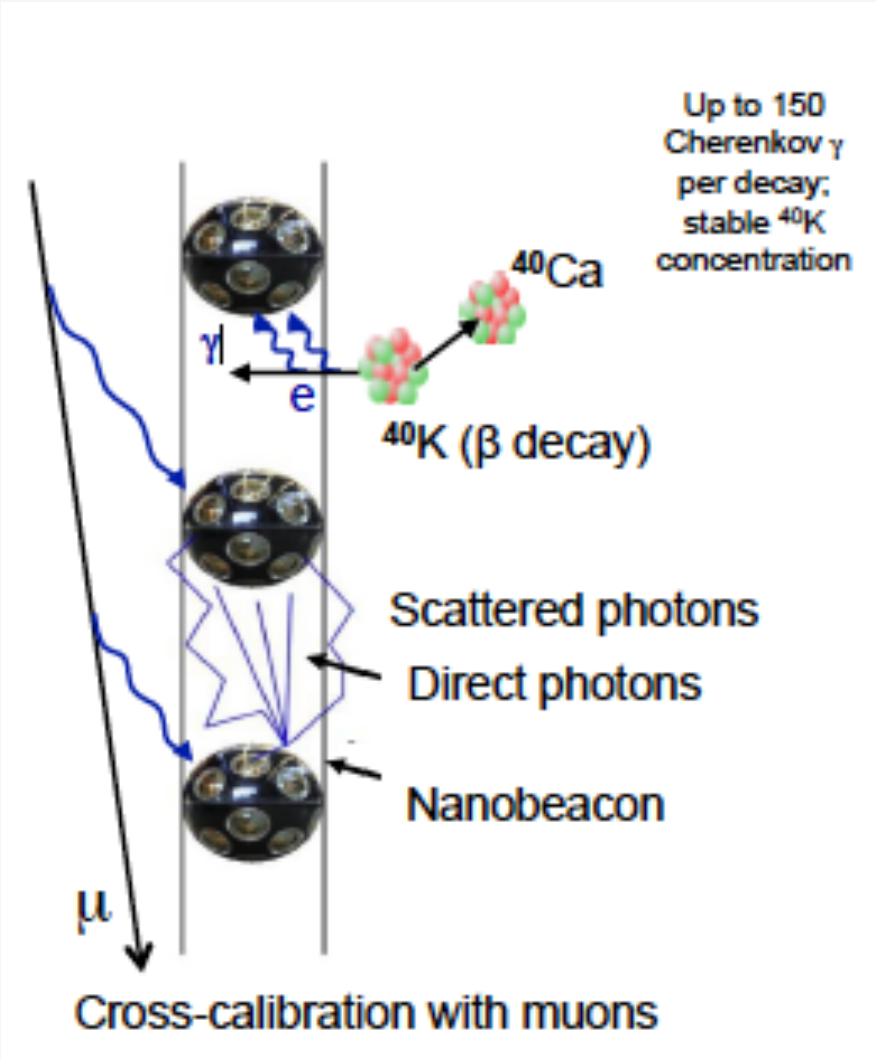
- *Three lines deployed at Capo Passero site: one in December 2015, two in May 2016*
  - *2 out of three operated until March 2017.*
  - *Recovery of the DUs foreseen by fall 2018*
  - *Full restoration of the sea bed infrastructure end 2019*

**Capo Passero shore station**

**ARCA DU1 at the sea bottom**

# Calibration methods






Stored for each hit:
- arrival time of photons
- Time Over Threshold (ToT)

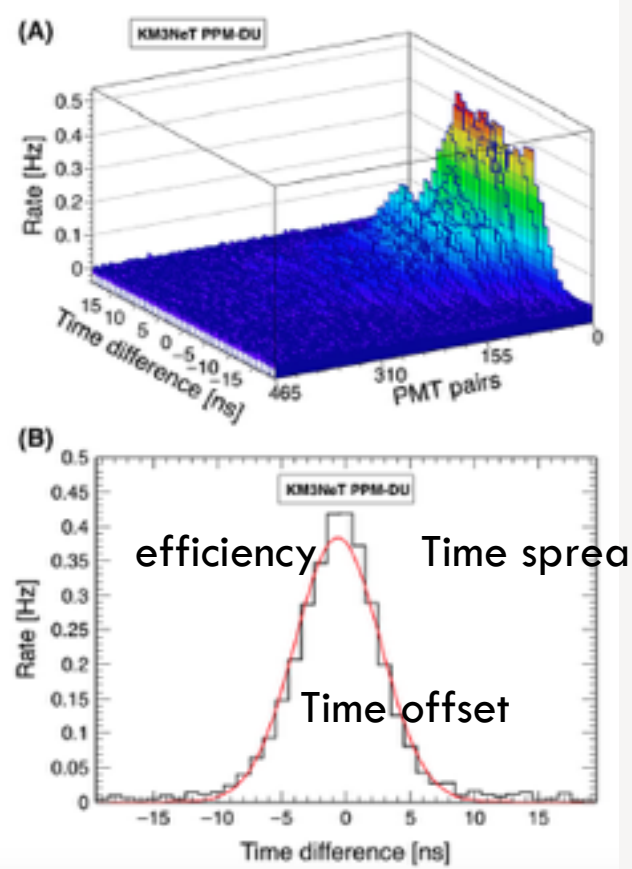
- Calibration of the PMTs inside the DOM with $^{40}$K
- Calibration of time offset between DOMs with nano beacon and atmospheric muons

# Calibration

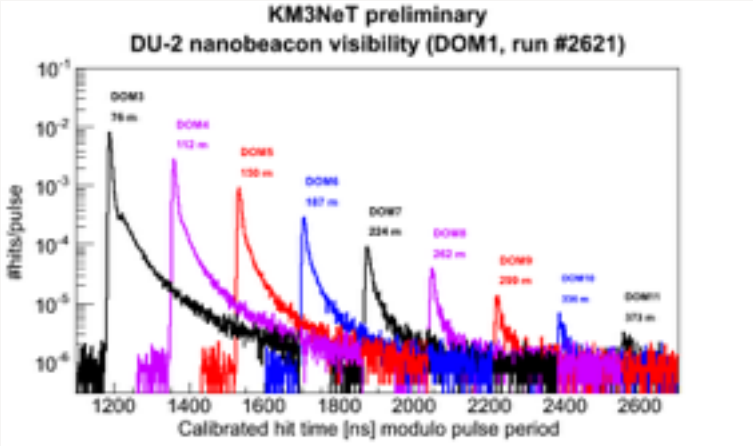


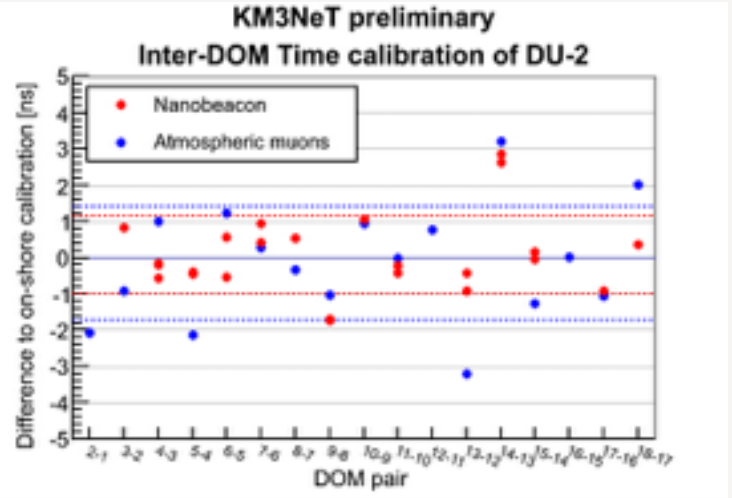
## Calibration of the PMTs inside the DOM with $^{40}K$

*Time difference between PMTs in the same DOM (2-fold from $^{40}K$)*




## Calibration of time offset between DOMs



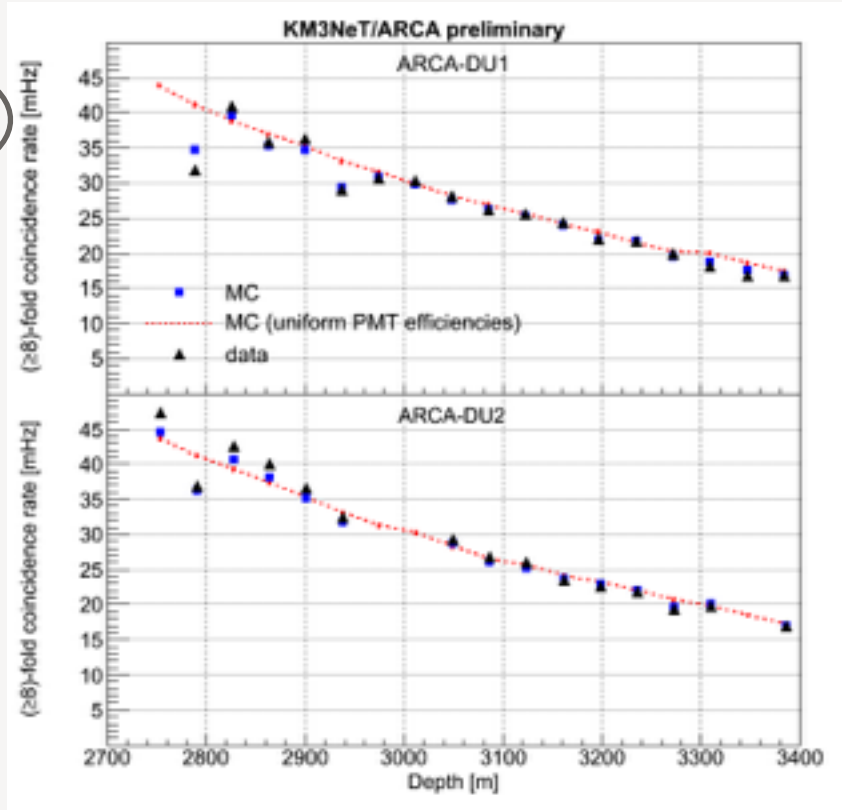



# First results from the first DUs installed



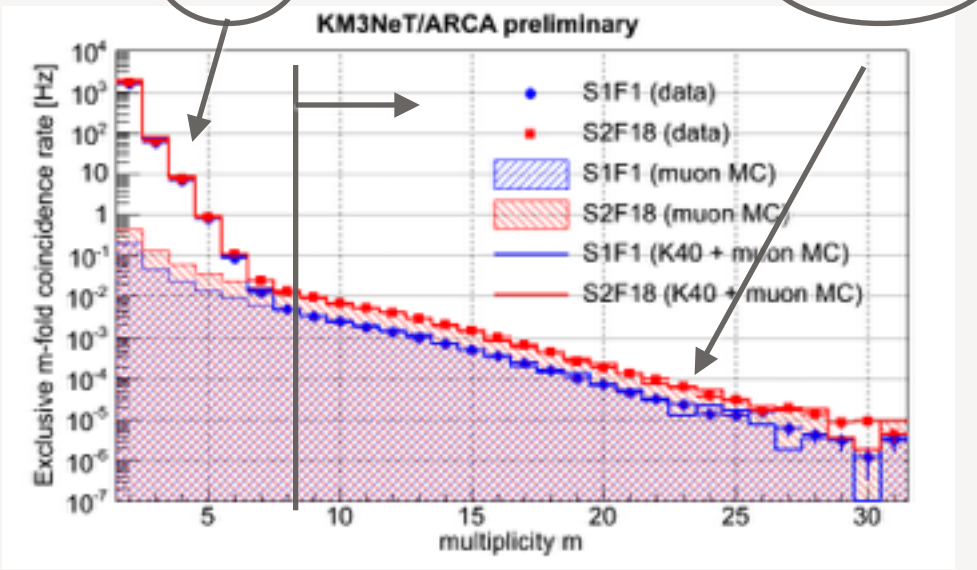
No reconstructions applied

*integral of m>8 for each DOM in the line*




40K

muons

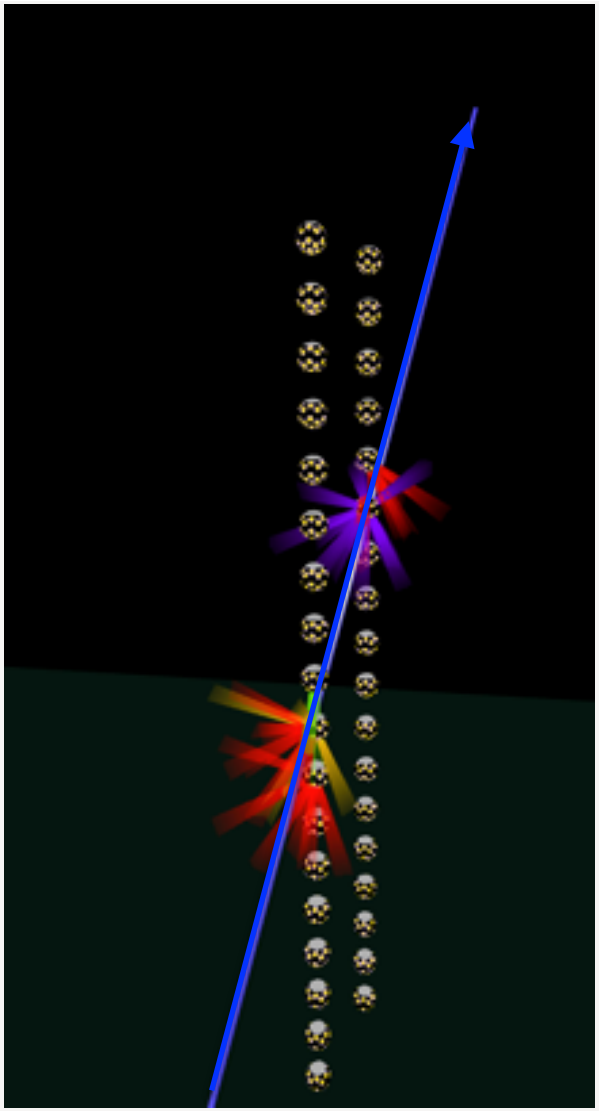



*number of PMTs in coincidence*

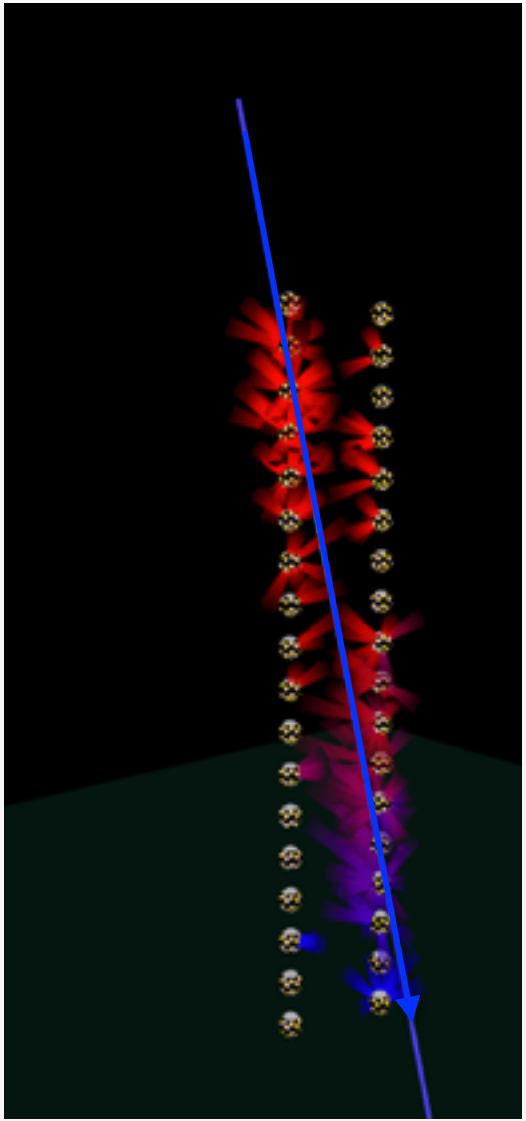
# First reconstructed tracks



*reconstructed tracks*



Run 5012 Event 1591
L1 hits 36
L1 DOMs 5
θrec 148.4°



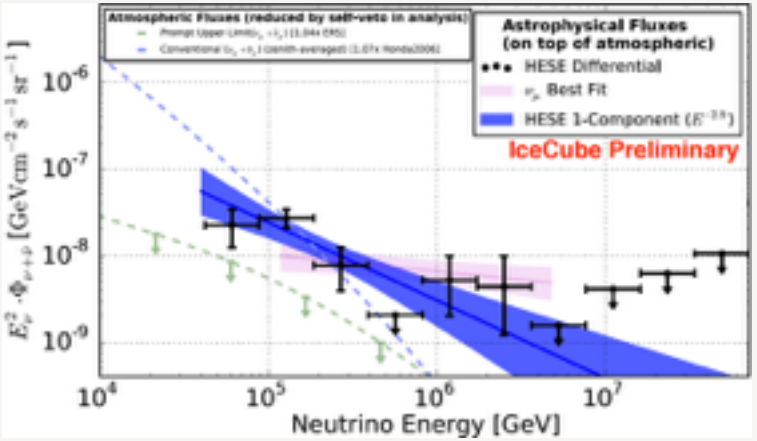
Run 5009 Event 9448
L1 hits 244
L1 DOMs 24
θrec 12.1°

# The KM3NeT/ARCA peculiarities



**Current knowledge:**

- Tension in the energy slope of the measured high energy muon neutrinos from Northern Hemisphere and the full sky all flavour data.
- Thanks to a multi-messenger observation high energy neutrinos from an extragalactic source have been recently observed by IceCube




From C. Kopper this morning

**Multi-messenger observation more and more important**

KM3NeT-ARCA can probe the Universe from a different field of view with a better angular resolution

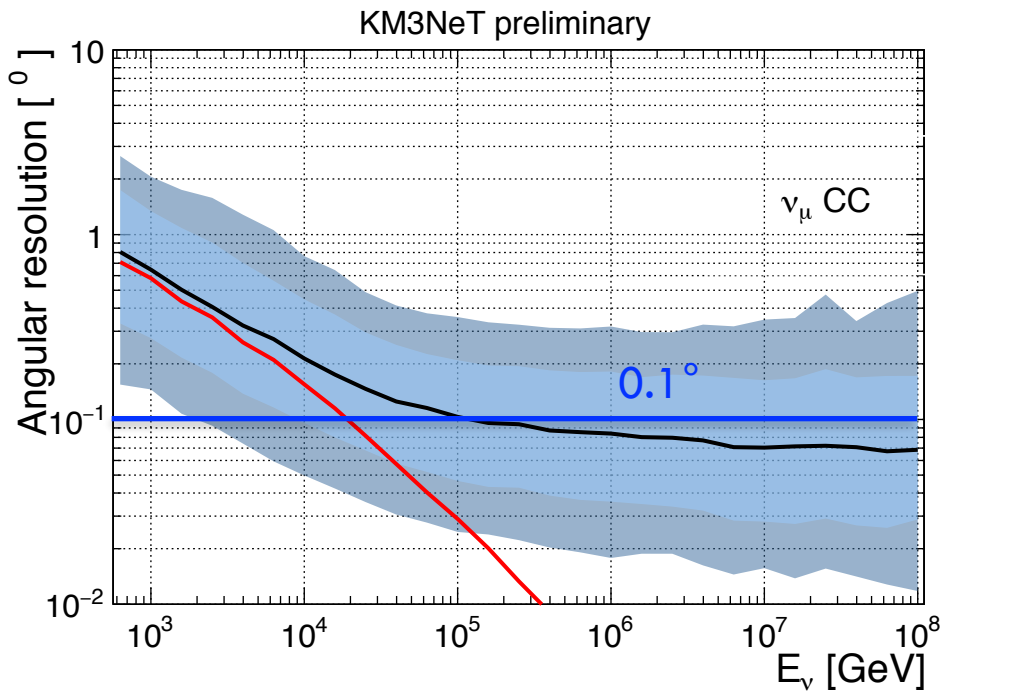
Located in the Northern hemisphere 👉 very good visibility of the Galactic Plane

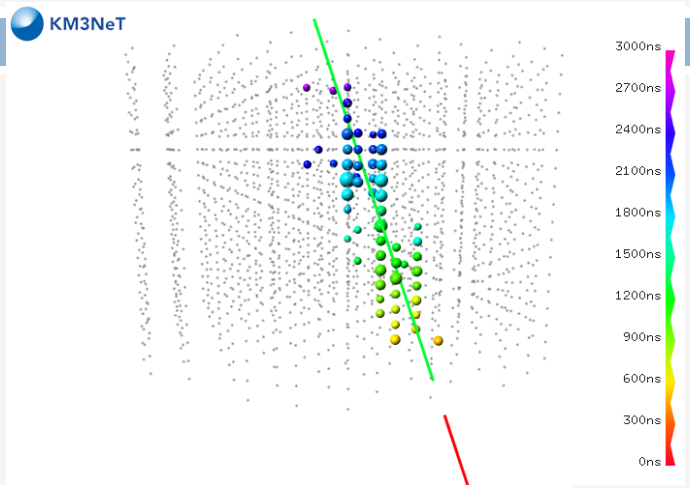
sea water is a clean and homogeneous medium 👉 good angular resolution

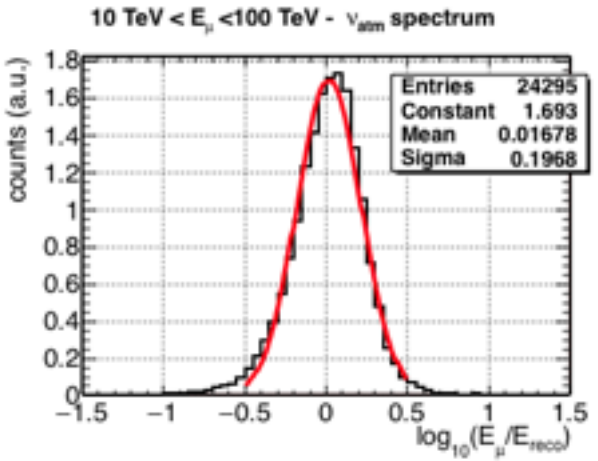
# The KM3NeT/ARCA resolution for "track-like" events



"Track-like" events mainly from $\nu_\mu$ CC interactions



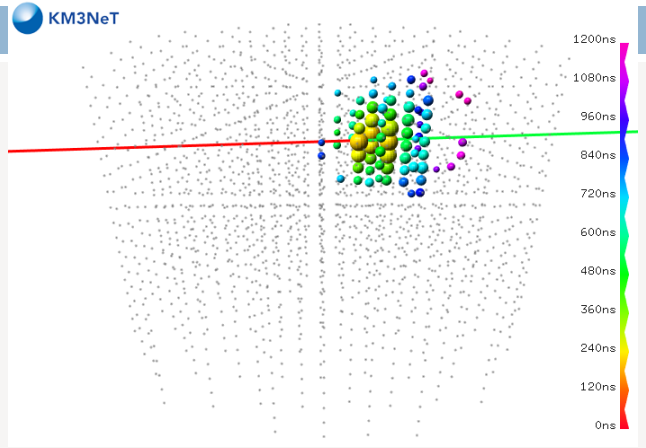

angular resolution better than 0.2° for $E_\nu$>10 TeV and 0.1° for $E_\nu$>100 TeV

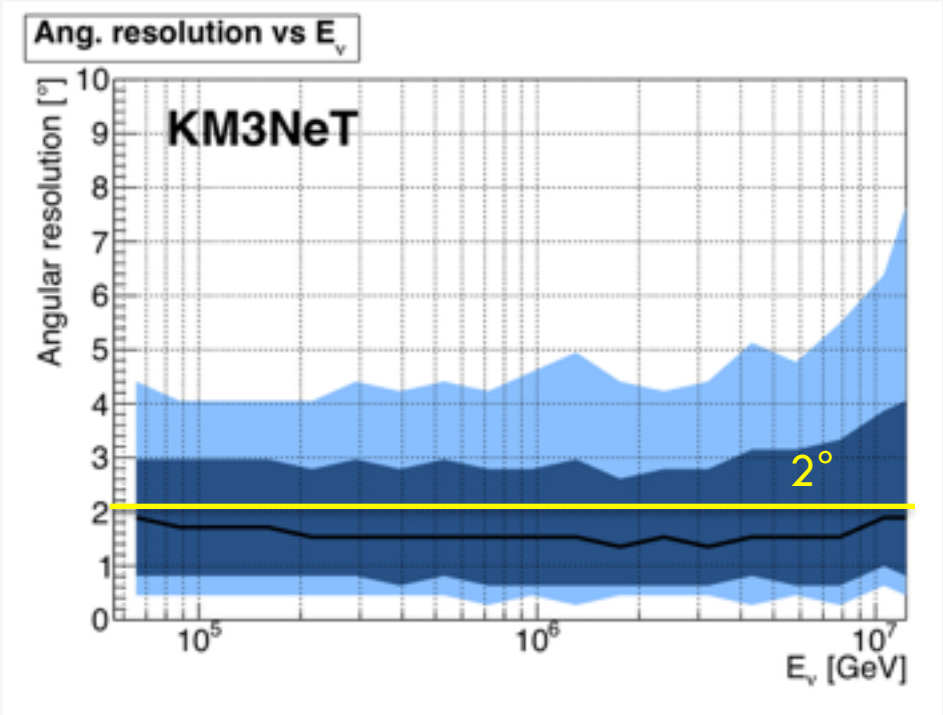
energy resolution better ≈ 20% of the $\log_{10}E_\mu$ for $E_\mu$>10 TeV

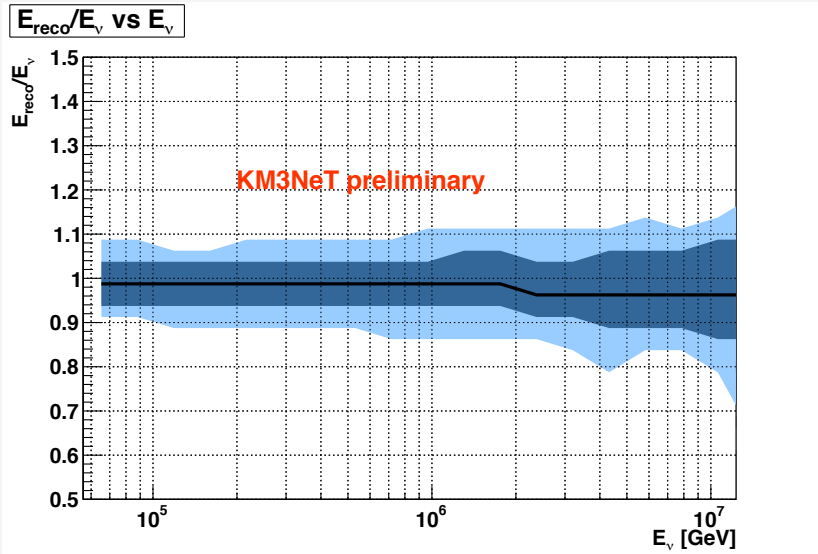
# The KM3NeT/ARCA resolution for "cascade" events



"Cascade-like" events mainly from $\nu_e$ CC and NC interactions




angular resolution better than 2°

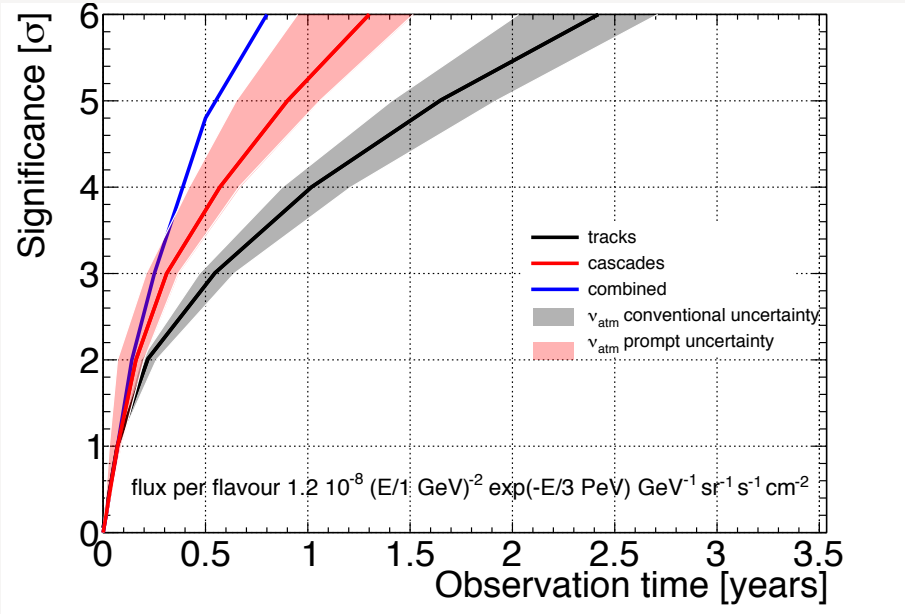
energy resolution better ≈ 5% at 1σ

# Diffuse flux



*Benchmark flux : IceCube flux (isotropic and flavour symmetric)*

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




**Discovery at 5σ (50% probability) in less than one year**

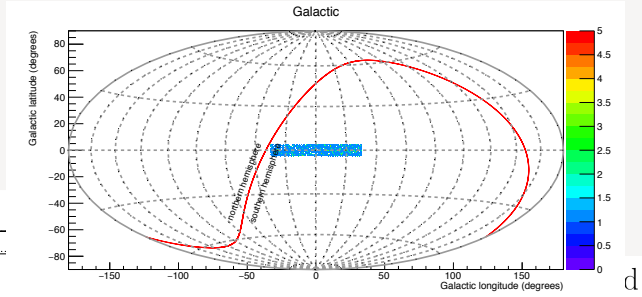
*Predictions recently confirmed by starting-event analysis*

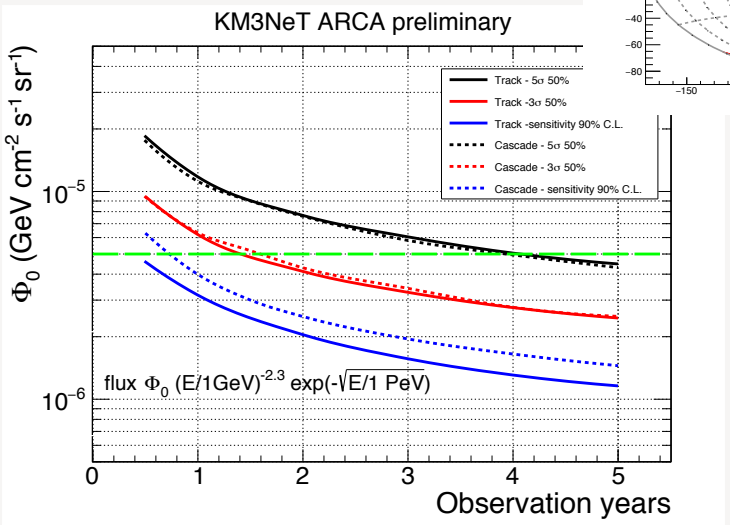
*(K. Pikounis Neutrino 2018 https://indico.desy.de/indico/event/18342/session/35/contribution/291/material/poster/0.pdf)*

# Diffuse flux from Galactic plane |l| <30° |b|<4°

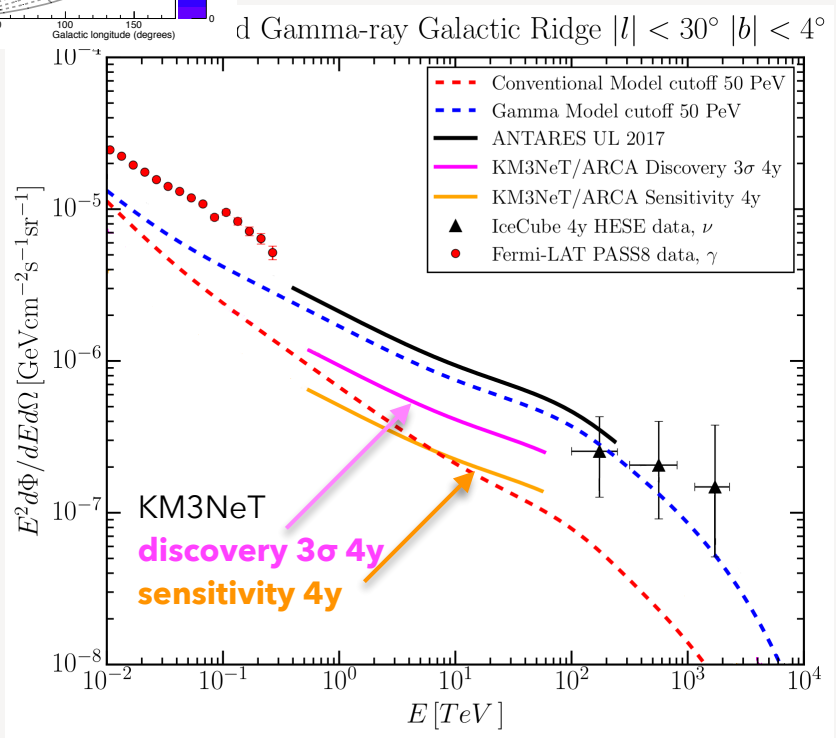


*Benchmark flux from D. Gaggero et al., (D. Gaggero et al., Astrophys. Journ. Letters 815 : L25 (2015)).*
*Evaluation of the neutrino flux based on a radially-dependent cosmic-ray transport*




## Comparisons




**Discovery at 5σ (50% probability) in about 4 years**

*Details of the analysis in R. Coniglione ICRC 2017*

# Galactic sources



| Source | $\delta$ | radius |
|---|---|---|
| RX J1713.7-3946 | -39.77° | 0.6° |
| Vela X | -45.6° | 0.8° |
| Vela Jr | -46.36° | 1° |
| HESSJ1614-518 (1) | -51.82° | 0.42° |
| HESSJ1614-518 (2) | -51.82° | 0.42° |
| Galactic Centre | -28.87° | 0.45° |

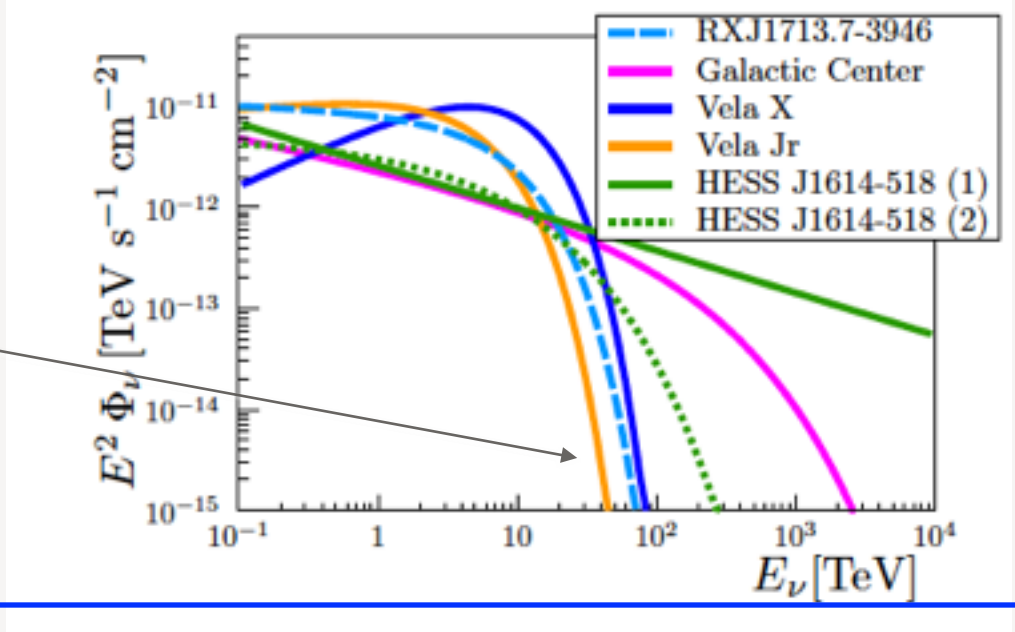
## *Source list*

*Extension of the sources taken into account*

*Neutrino spectra evaluated from recent measured gamma-ray spectra*

*(F. Vissani and F. L. Villante Nucl. Inst. Meth. A588 , )*

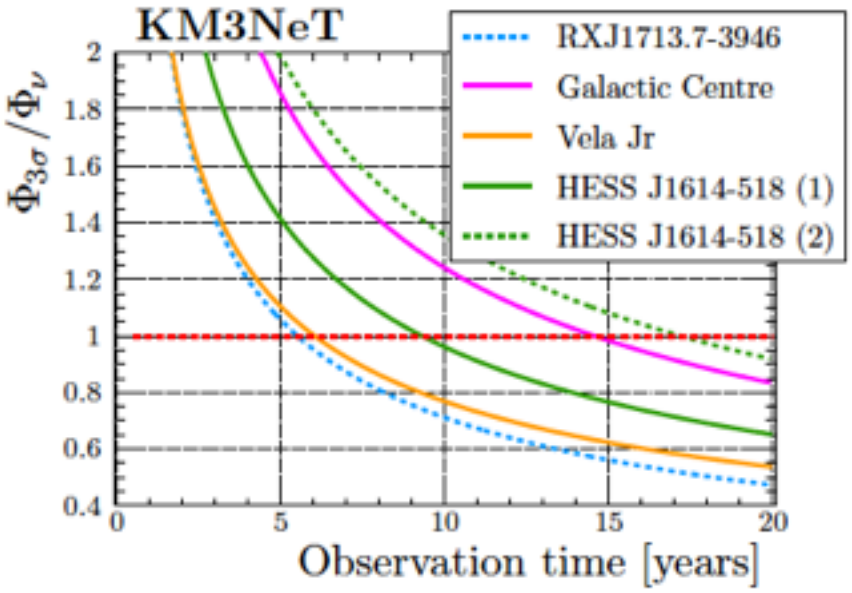
*Spectra cutoffs of the order of few tens of TeV*



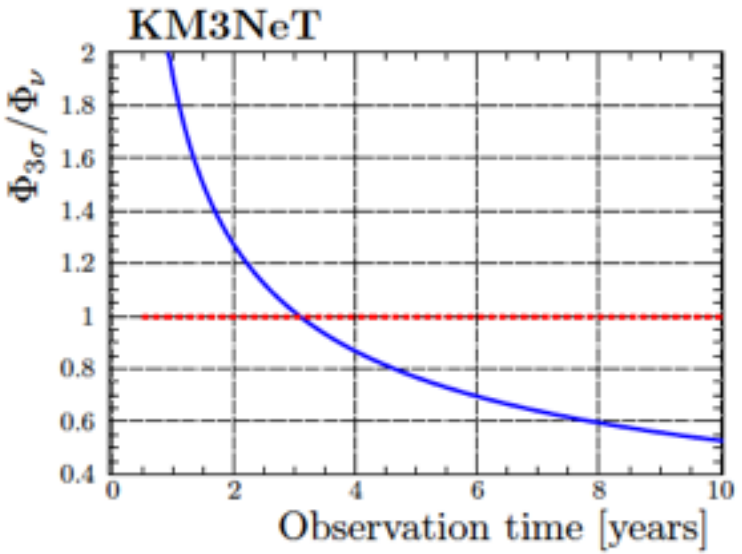
# Galactic sources

*preliminary*






Discovery at 3σ at around 5 years for the most intense SNRs




Stacking the SNRs RXJ1713 and Vela Junior discovery at 3σ after around 3 years of observation

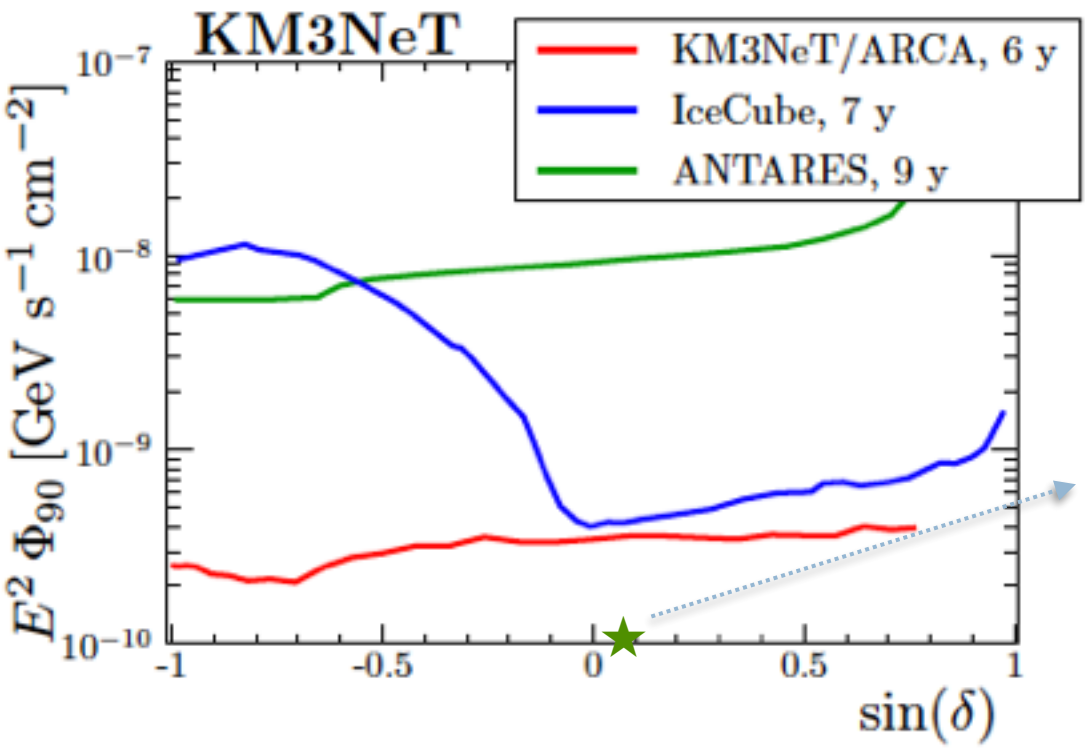
# Point-like sources

*preliminary*



*Benchmark flux proportional to $E^{-2}$ flux*

*Sensitivity for up-going muon neutrinos analysis*




Note:
IceCube will have ~10 years of data when KM3NeT will start operation

TXS 0506+056 blazar discovered by IC as neutrino source
$\delta$=+5.6°
$\Gamma \approx$ 2.0 - 2.1

**larger sky coverage than IceCube**

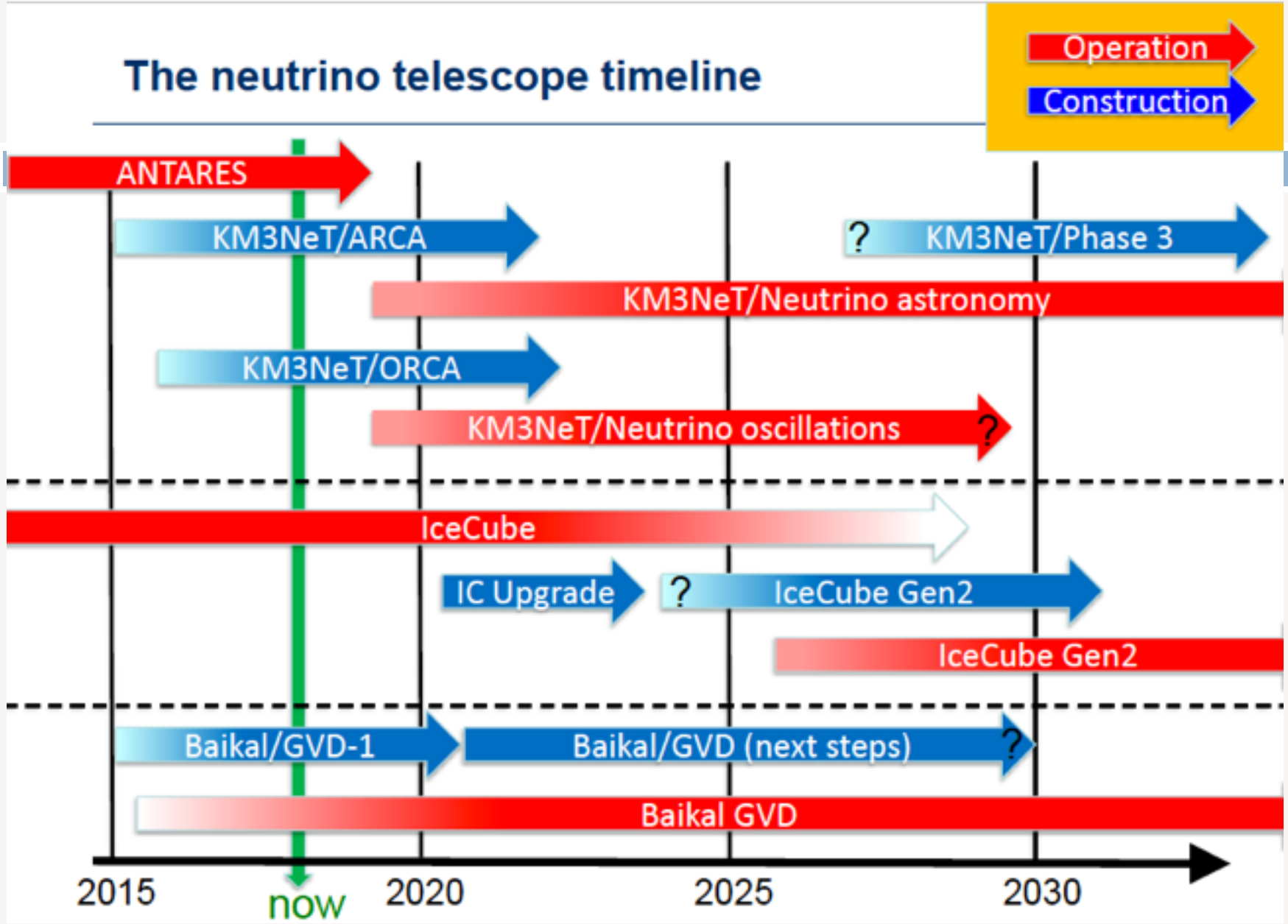
# Conclusion



**KM3NeT will soon take over from ANTARES as the biggest detector in the Northern Hemisphere (KM3NeT phase-1 will be ≈ 0.1 km$^3$)**

- ★ KM3NeT/ARCA (≈ 1 km$^3$) will be installed at the Italian node of the KM3NeT distributed infrastructure
- ★ KM3NeT phase-1 (fully funded): 2 DUs of ARCA already and first results shown
- ★ Following phase KM3NeT 2.0 (partially funded)
- ★ Exciting physics prospects
  - ★ Neutrinos detected from a different field of view and unprecedented resolution and sky coverage can effectively contribute to the multi-messenger astronomy

# Back up slides




*slide from U. Katz Neutrino 2018*