Status, recent results and prospects of KM3NeT/ARCA

KM^3 Neutrino **T**elescope

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on behalf of the KM3NeT Collaboration

Plan for today
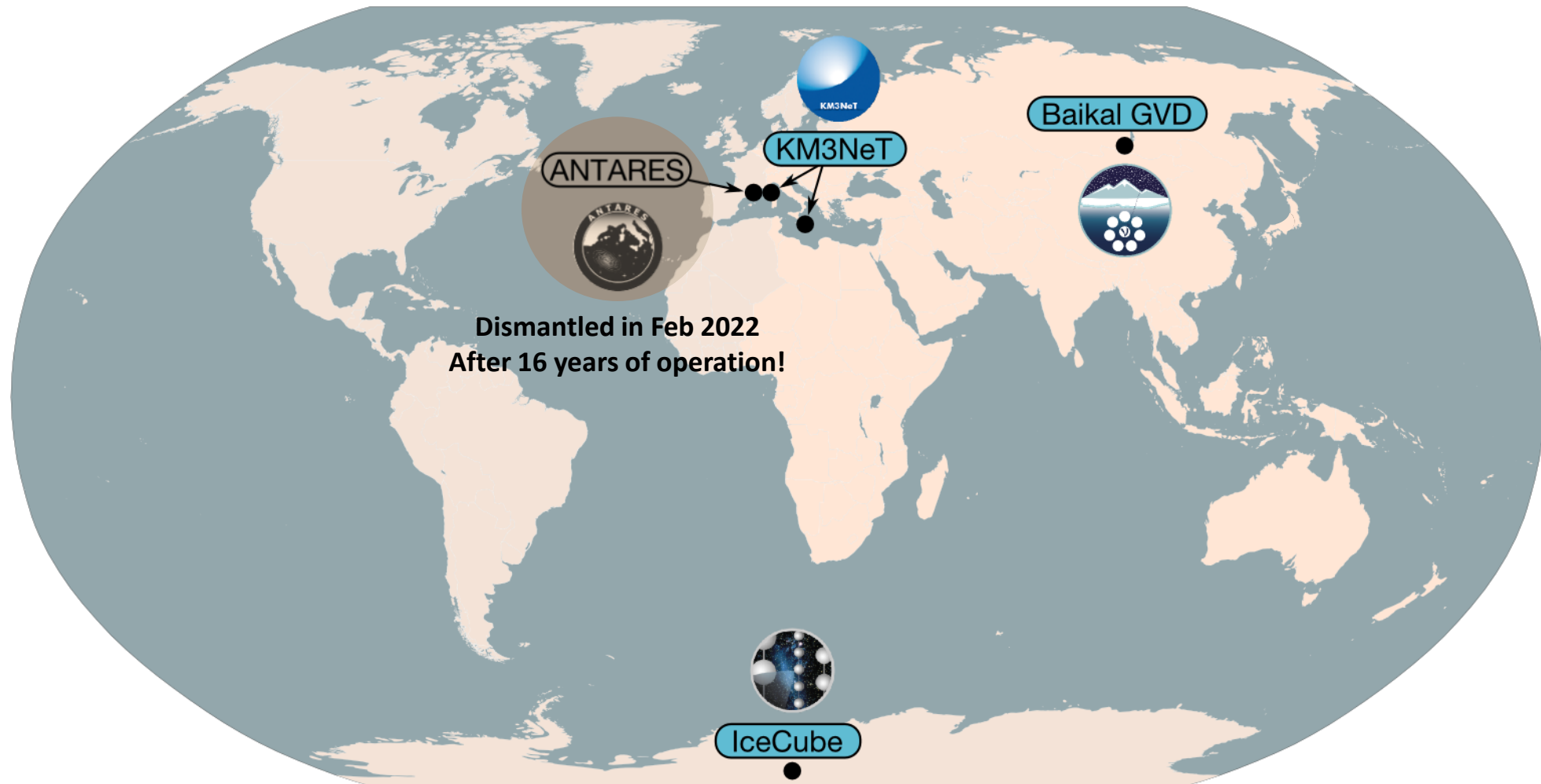
I.   KM3NeT detector

   I.   Design

   II.   Science and Prospects

   III. Deployments

II. Recent results and prospects

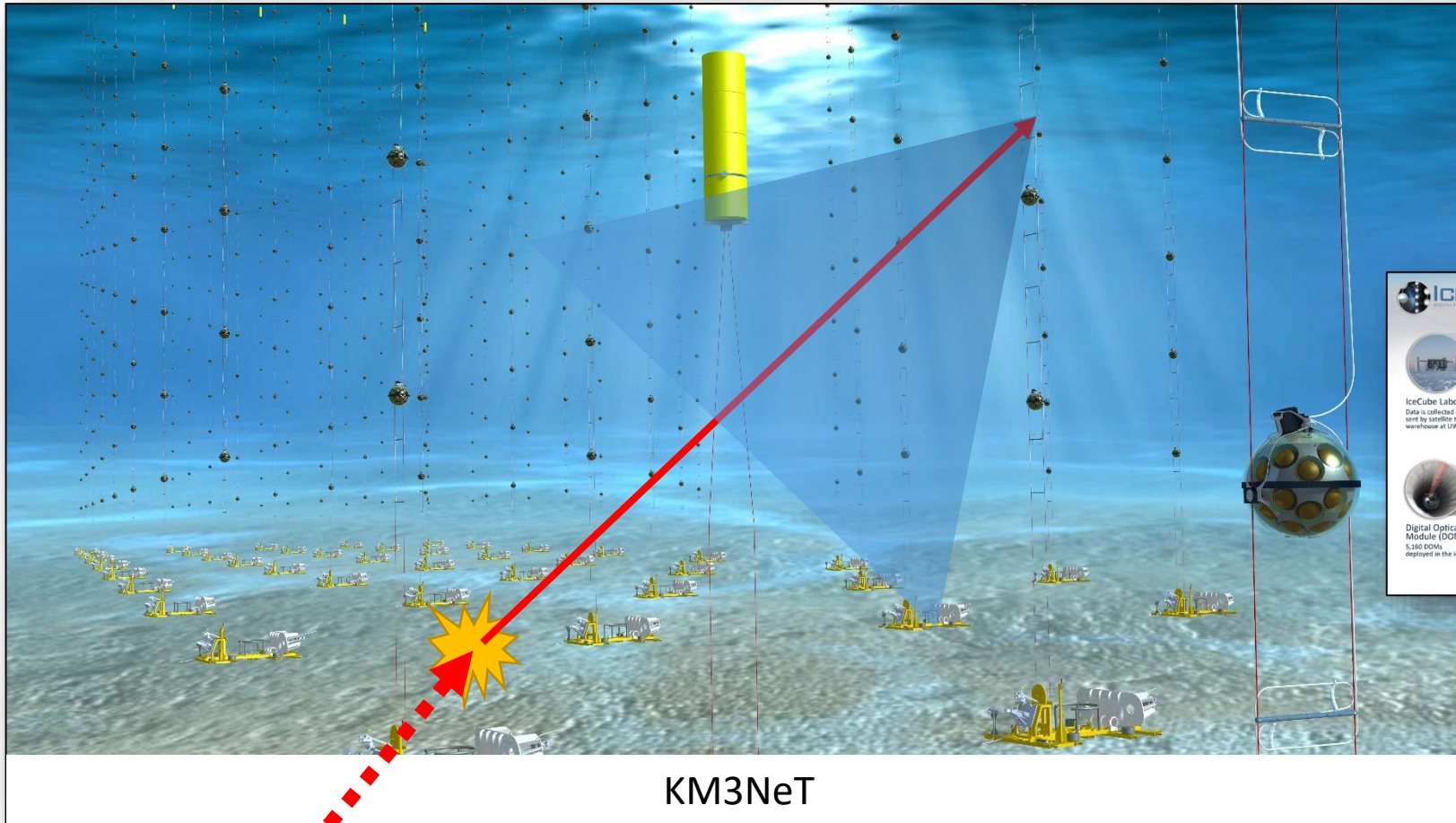   *I.   Predicted performance*

   II.   First muon data

   III. Atmospheric neutrino flux

   IV.   Diffuse analysis + Galactic ridge

   V. E^{-2} Point source study

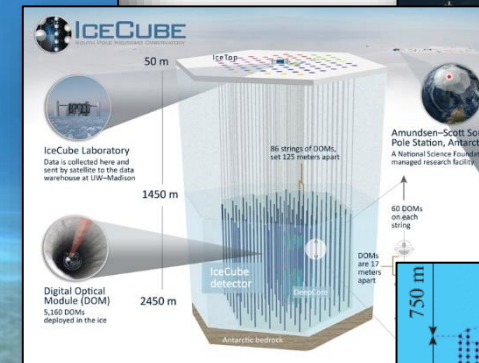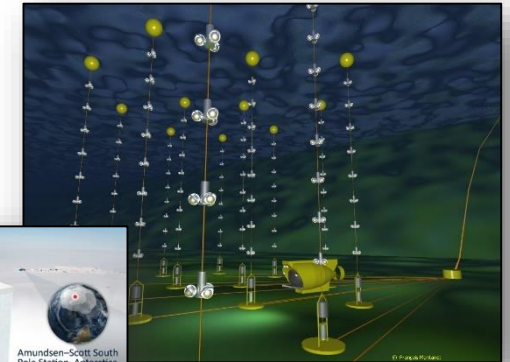   VI. Icecube alert follow-ups

Global Neutrino Network (GNN)

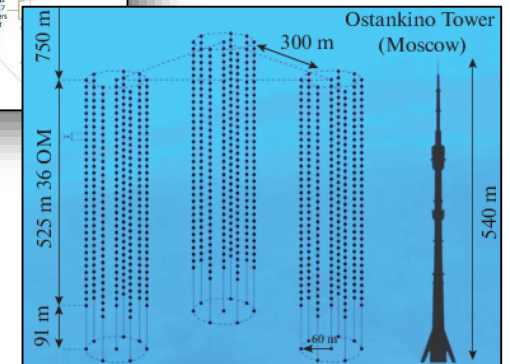Baikal GVD

KM3NeT

ANTARES

**Dismantled in Feb 2022
After 16 years of operation!**

IceCube

KM3NeT - concept

ANTARES

ICE CUBE

BAIKAL-GVD

KM3NeT

CC ν_μ
1. track like events
good pointing

CC ν_e+ all flavours NC
2. shower like events
good energy reconstruction

CC ν_τ
3. "double bang"

Atmospheric muon
BACKGROUND !!

$\mu^\pm$

$\nu / l^\pm$

τ

$\mu^\pm$

$\overset{(-)}{\nu_\mu}$

$\overset{(-)}{\nu_X}$

$\nu_\tau \underset{CC}{\rightarrow} \tau + \text{shower}$

Rasa Muller

Angular resolution full detector

KM3NeT

Tracks
(CC ν_μ ν_τ)

Better than 0.1° > 100 TeV
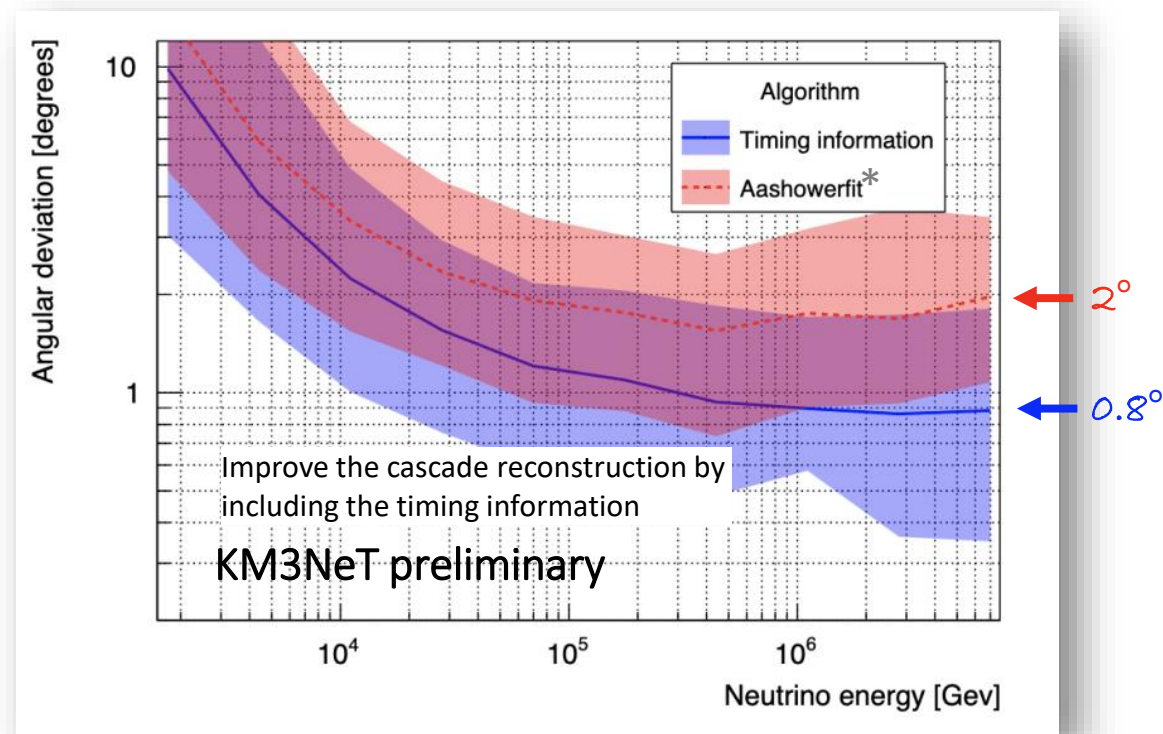
Cascades
(NC, CC νe ν_τ)

Better than 2° >100 TeV
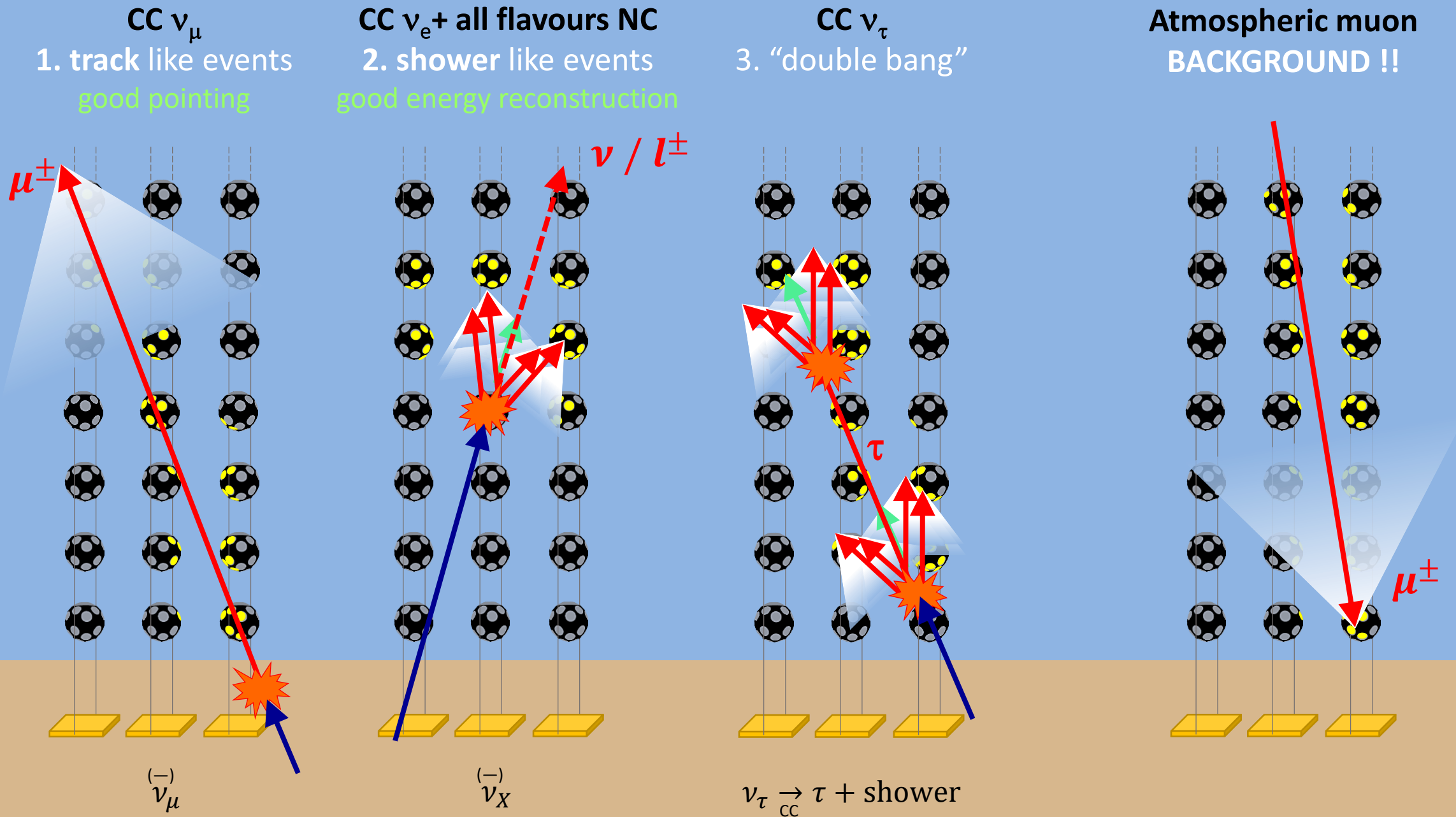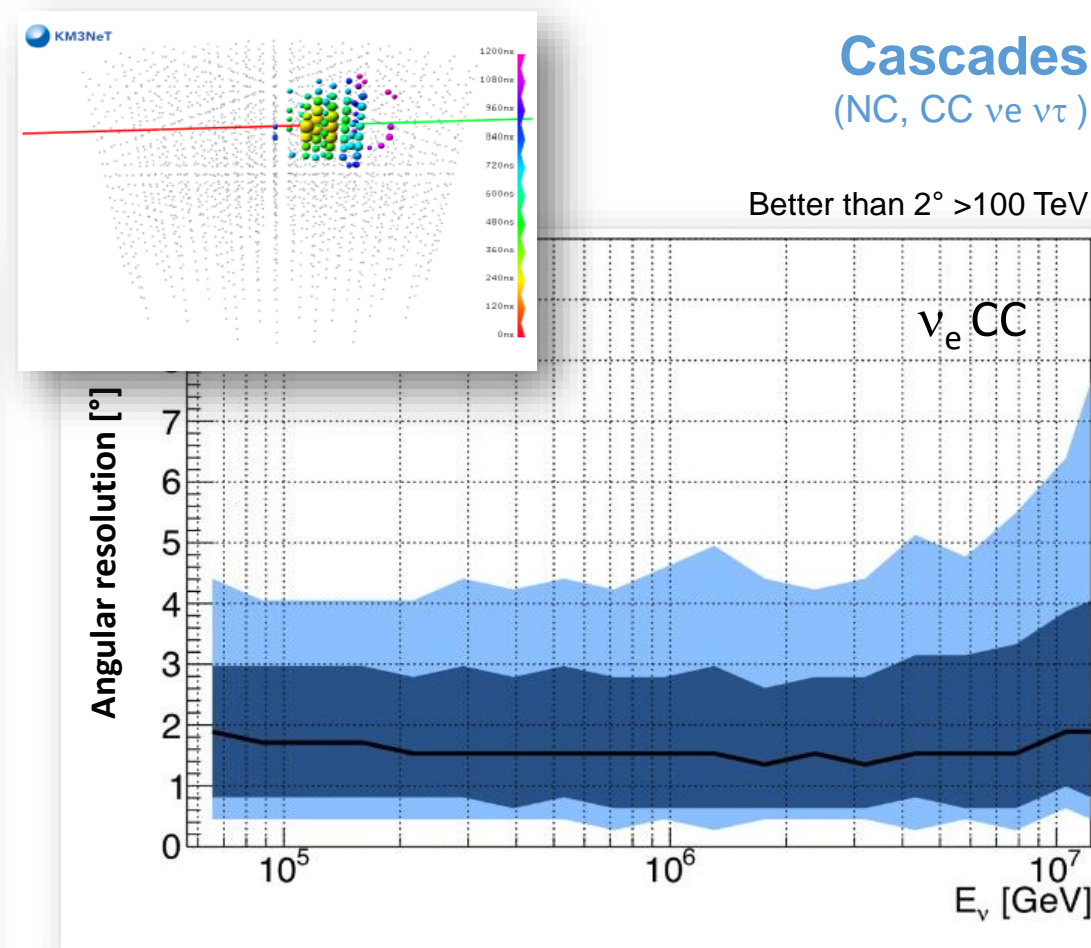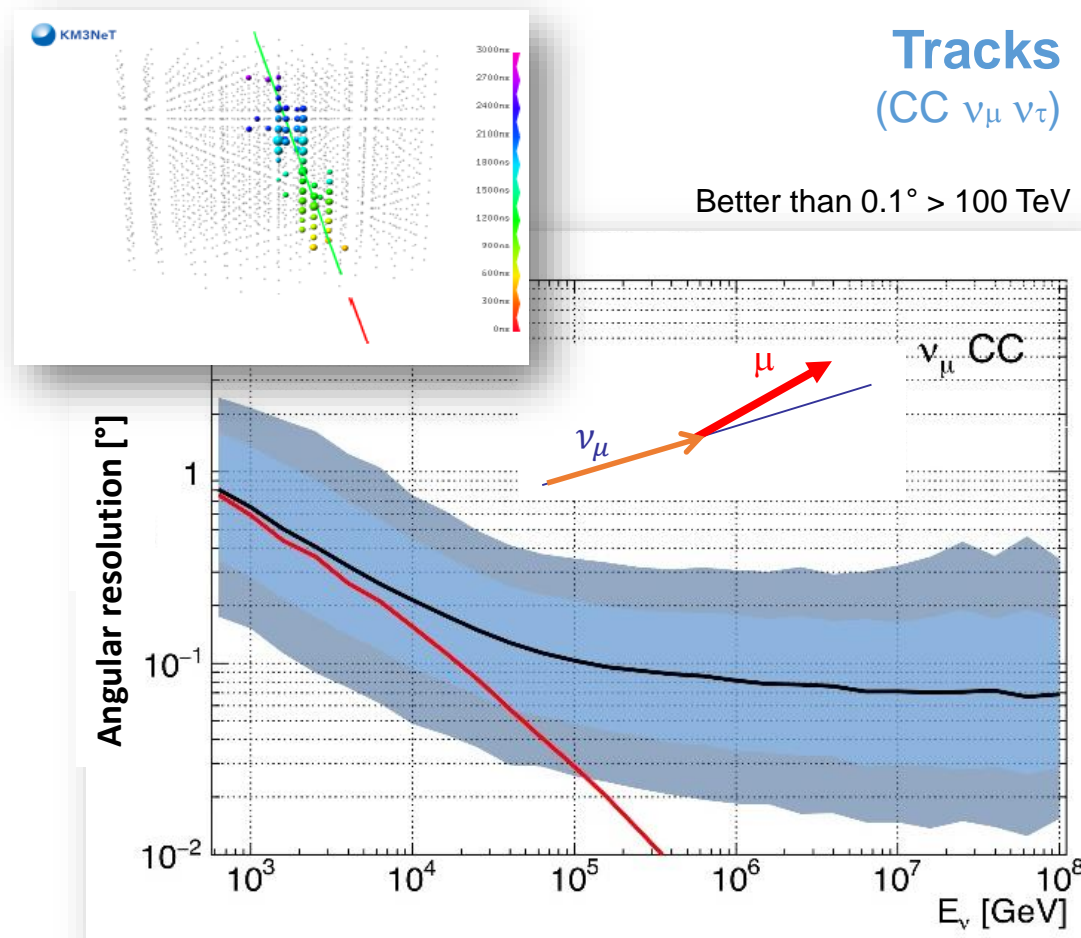
Angular resolution full detector

Better than 1° for tau track length >22m
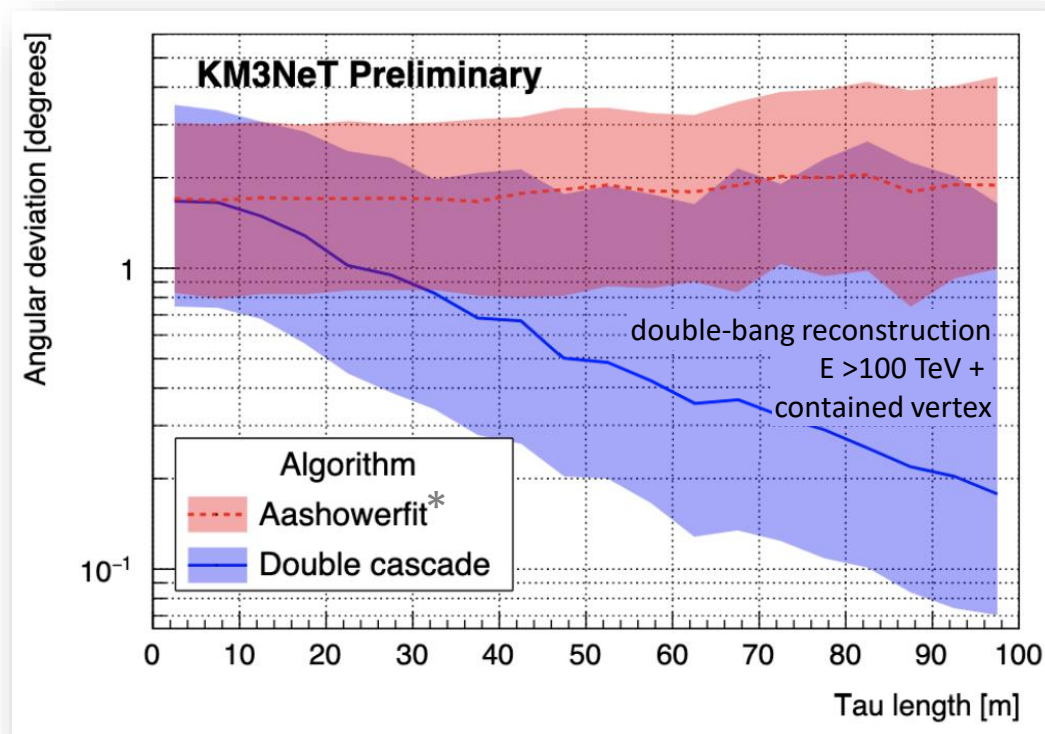
Better than 1° >30 TeV

*Aashowerfit is our standard shower reconstruction in use for KM3NeT/ARCA

Energy ranges

KM3NeT

KM3NeT/ORCA
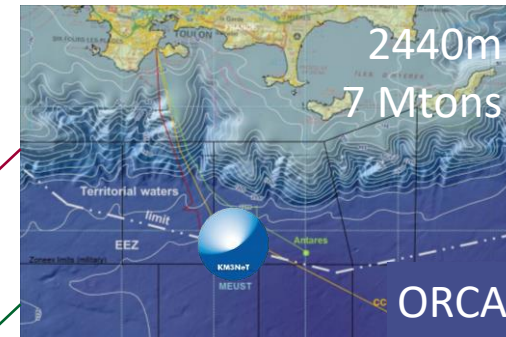*O*scillation *R*esearch
*with C*osmics In the *A*byss

2440m
7 Mtons
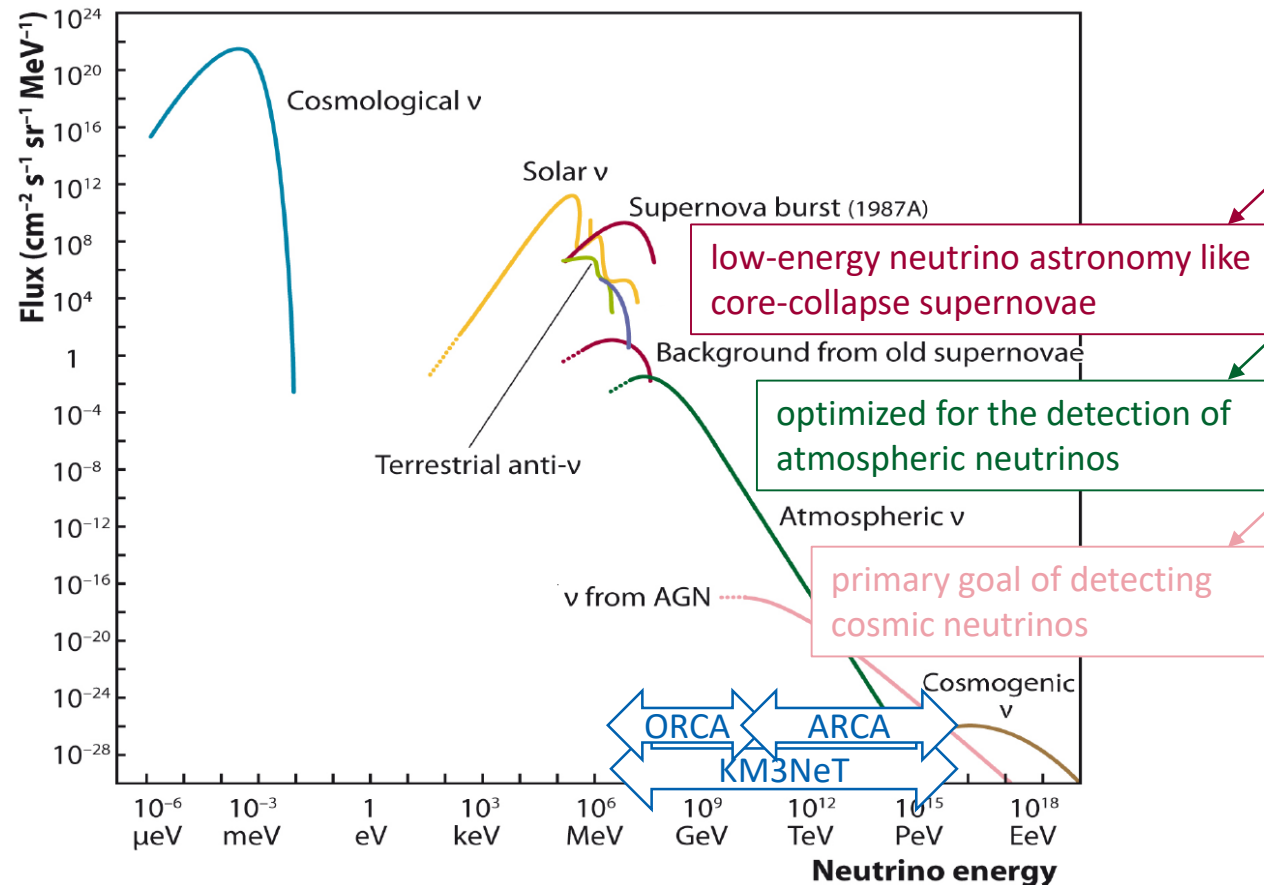
ORCA

low-energy neutrino astronomy like
core-collapse supernovae

optimized for the detection of
atmospheric neutrinos
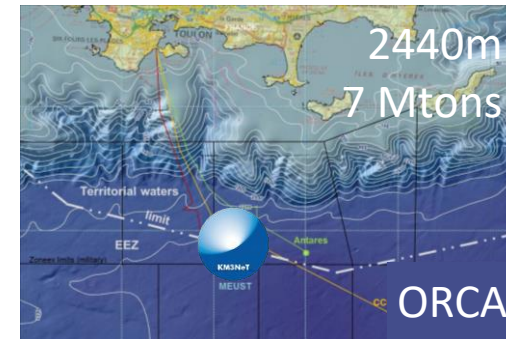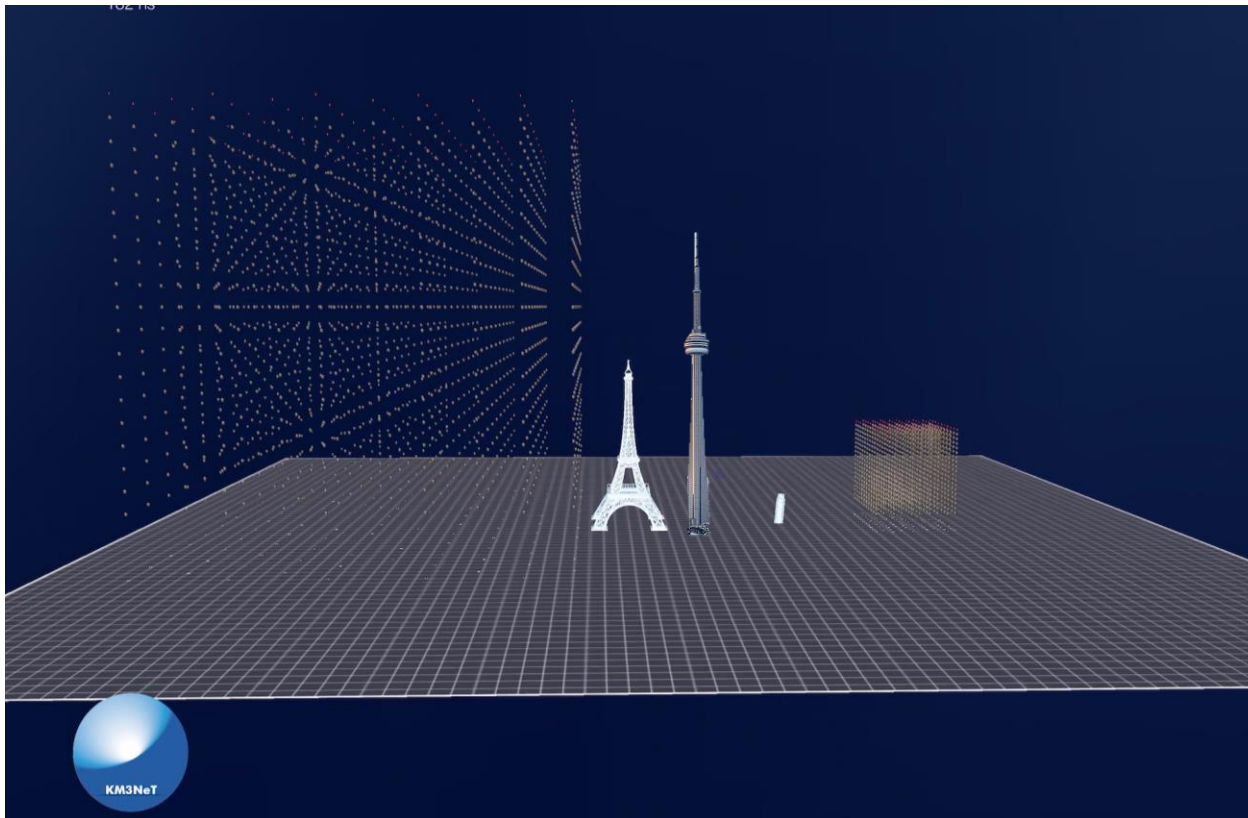
primary goal of detecting
cosmic neutrinos

KM3NeT/ARCA
*A*stroparticle *R*esearch
*with C*osmics In the *A*byss

3400m
1 Gton

ARCA

Position in the Northern Hemisphere:
optimal view of the Southern sky, including the Galactic Center

Two different sites

2440m
7 Mtons

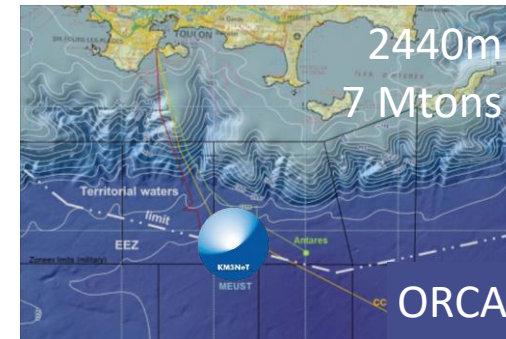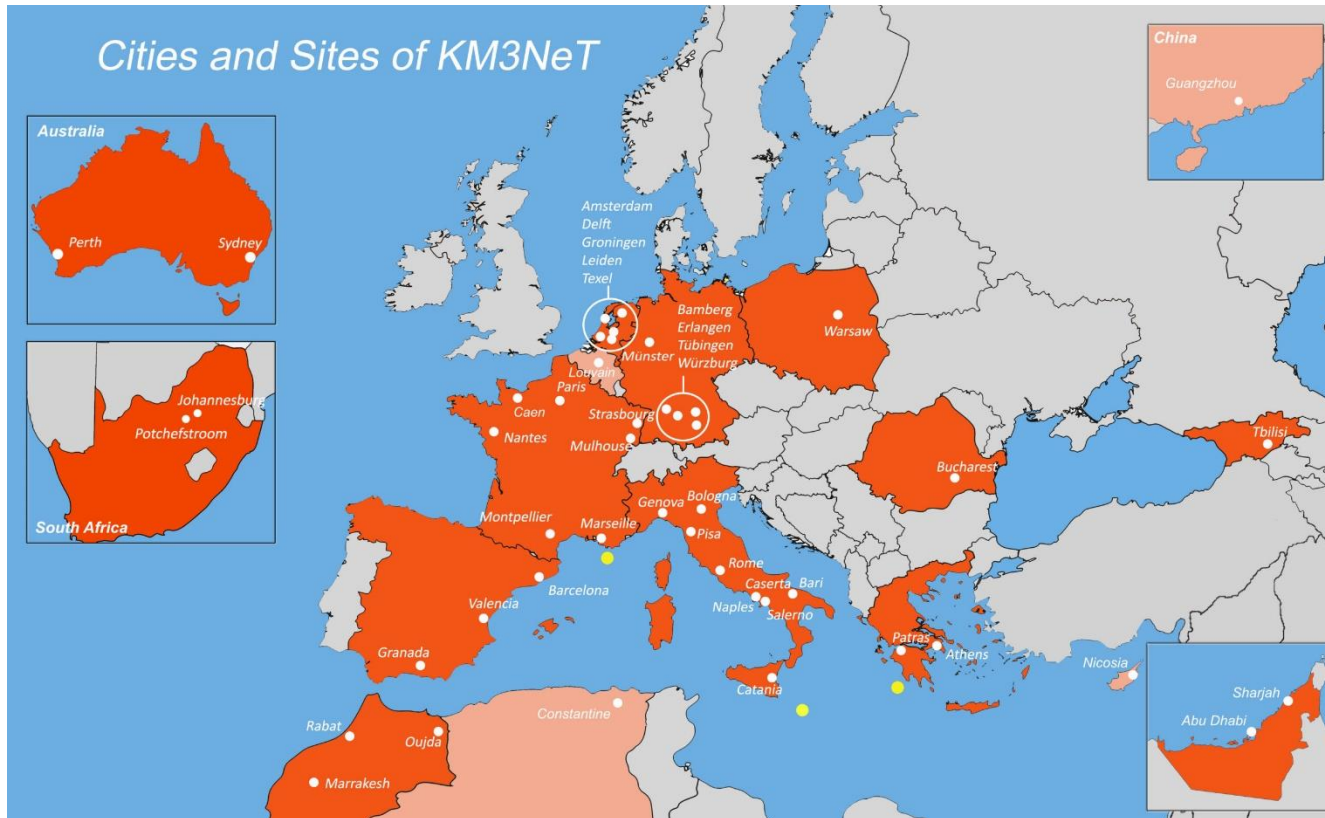ORCA

KM3NeT/ORCA
Oscillation Research with Cosmics In the Abyss

3400m
1 Gton

ARCA

KM3NeT/ARCA
Astroparticle Research with Cosmics In the Abyss

Collaboration

Cities and Sites of KM3NeT

KM3NeT/ORCA
*Oscillation Research
with Cosmics In the Abyss*

2440m
7 Mtons

ORCA

KM3NeT/ARCA
*Astroparticle Research
with Cosmics In the Abyss*

3400m
1 Gton

ARCA

Detector design
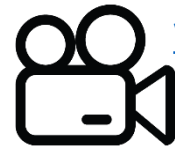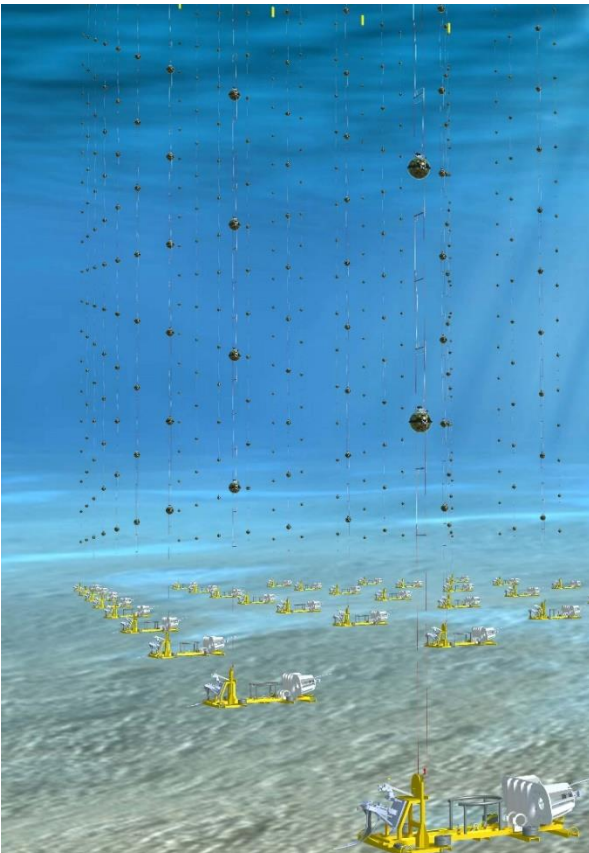
KM3NeT

1 building block =
115 lines
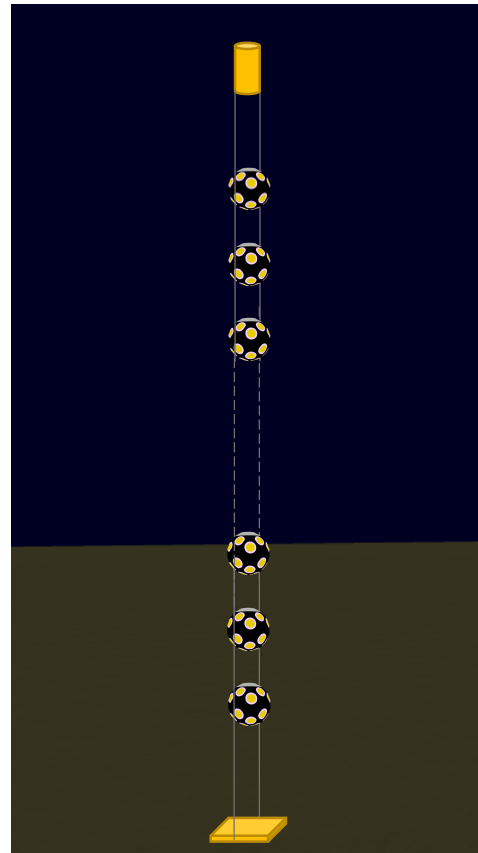
1 line =
18 optical modules

1 optical module =
31 photomultiplier tubes
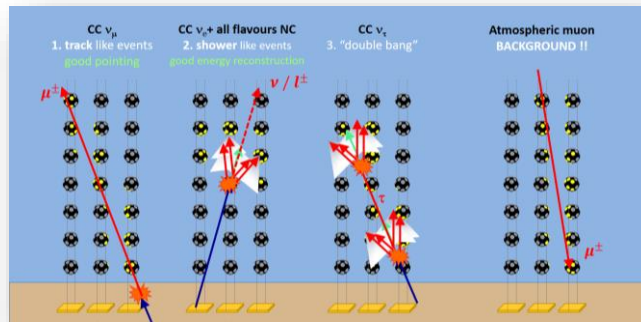
71 unique components
(in solid or liquid phase)

KM3NeT full detector in summary

KM3NeT

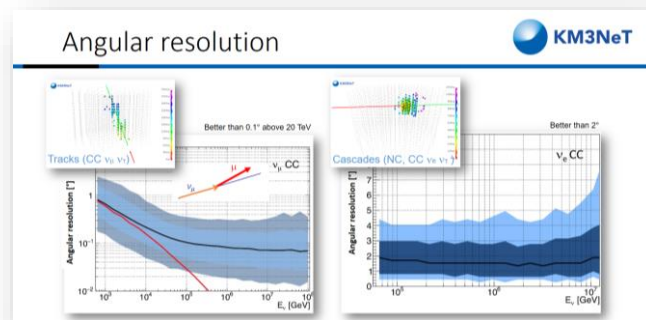Multi-flavour astronomy (ν_e, ν_μ, ν_τ)
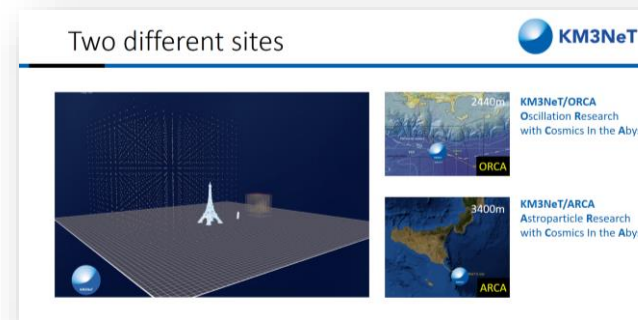

Large energy range [MeV - PeV]
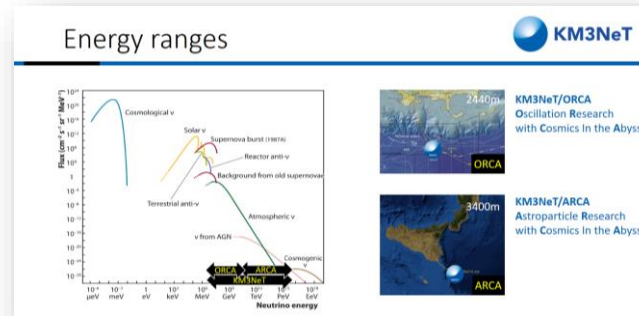
Detector design
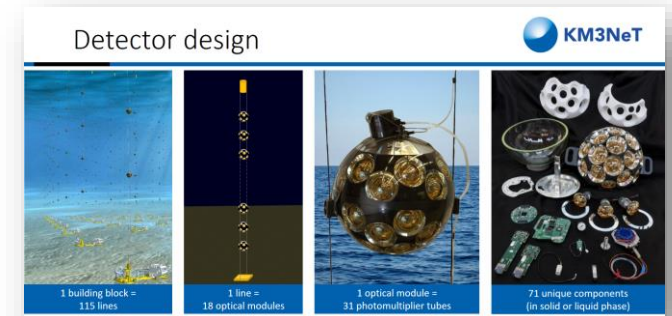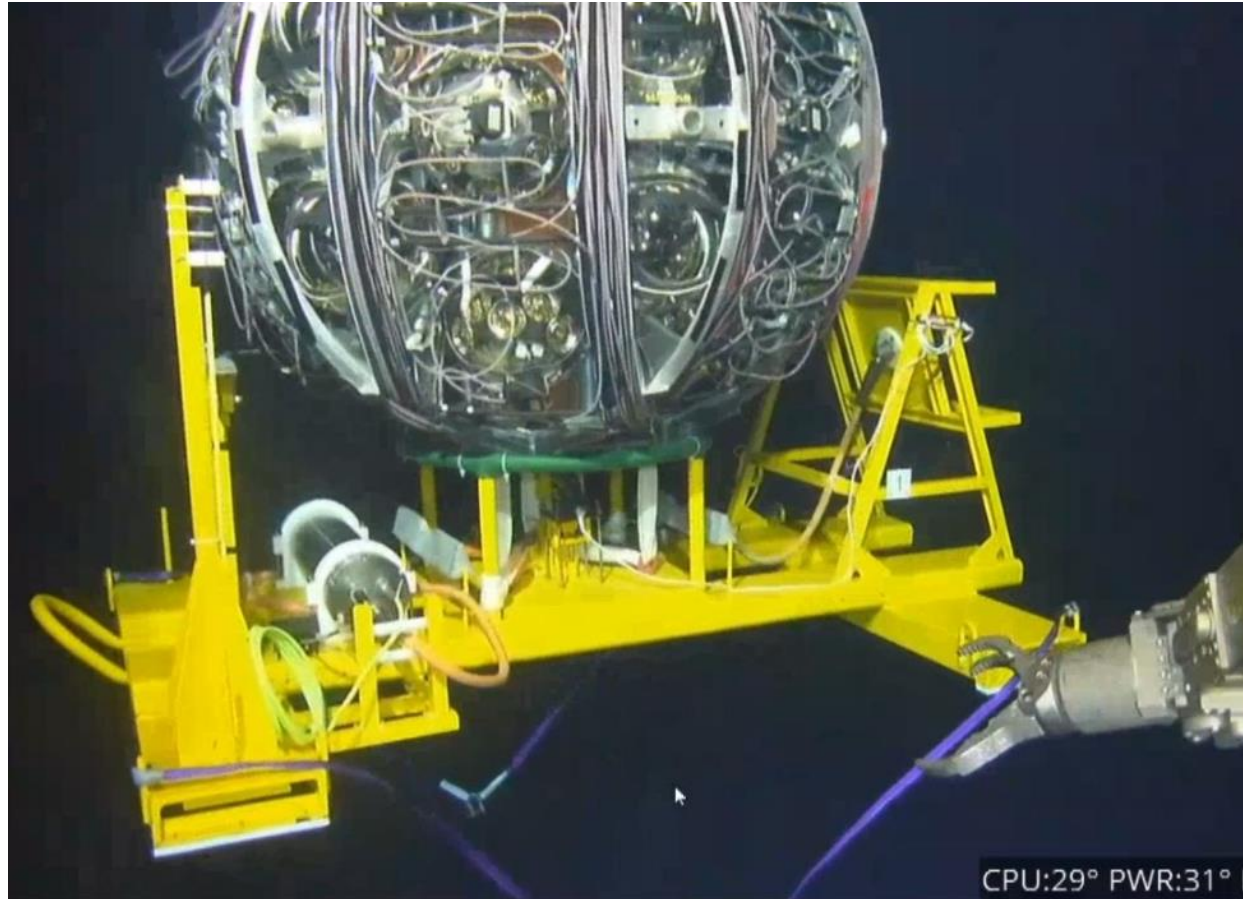

Sub-degree angular resolution

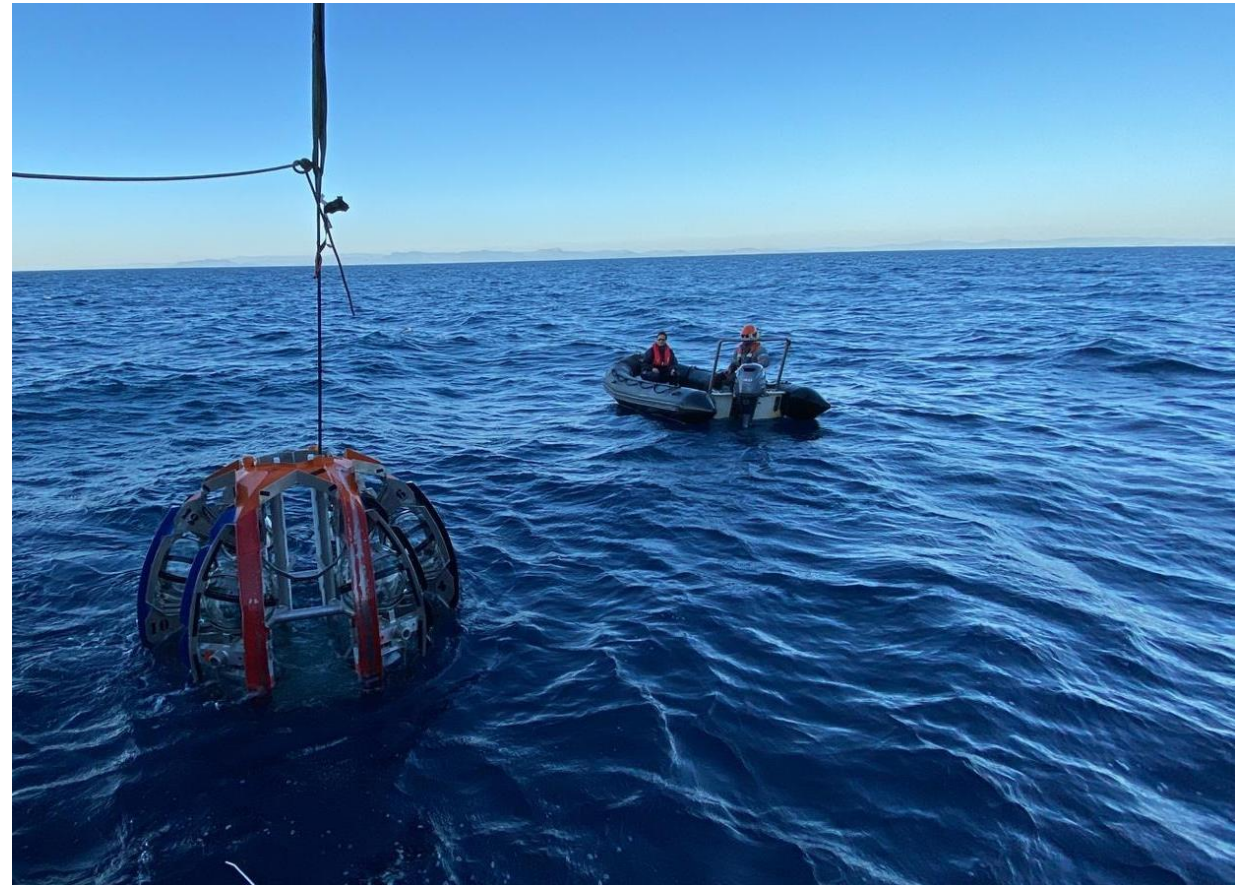Large effective volume &
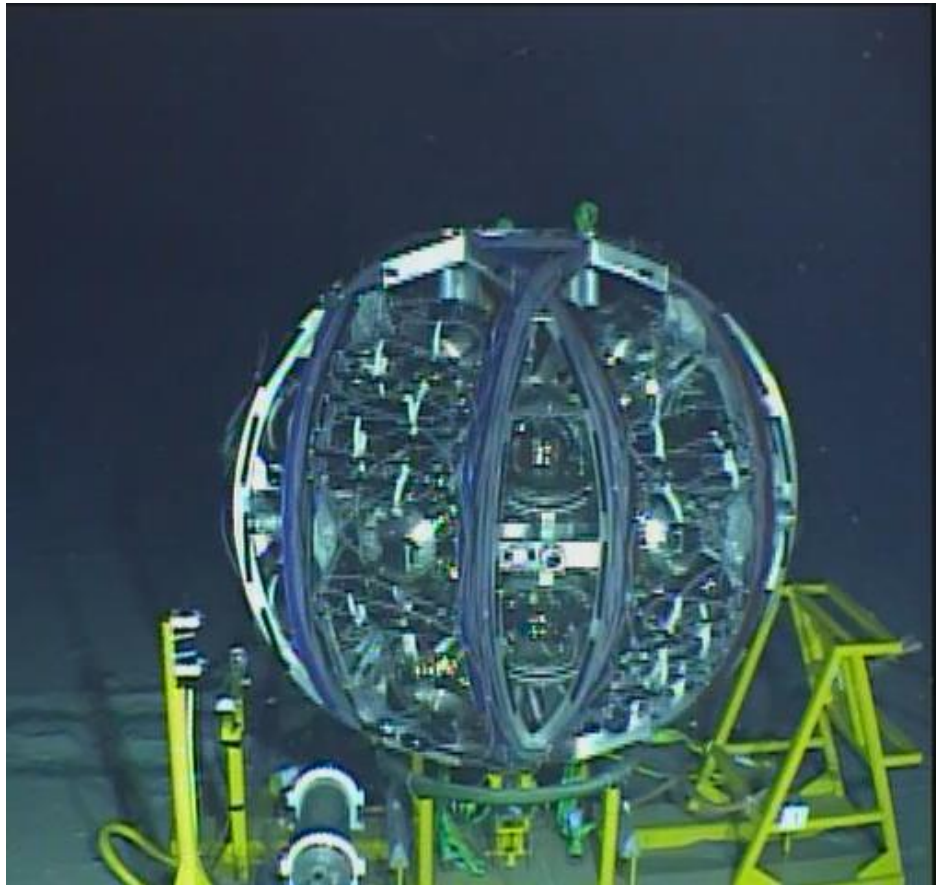Location: good view of Galactic Centre

Deployment of new lines

Deployment of new lines

Deployment of new lines

Deployment of new lines @ social media

KM3NeT

KM3NeT Neutrino @km3net · Jun 14
‼️ KM3NeT/ARCA19 is a fact ‼️

The campaign was a complete success, everything was accomplished as foreseen. In only two weeks we more than doubled our #detector!

We now have
2 new junction boxes perfectly working
11 new lines + the 8 we already had
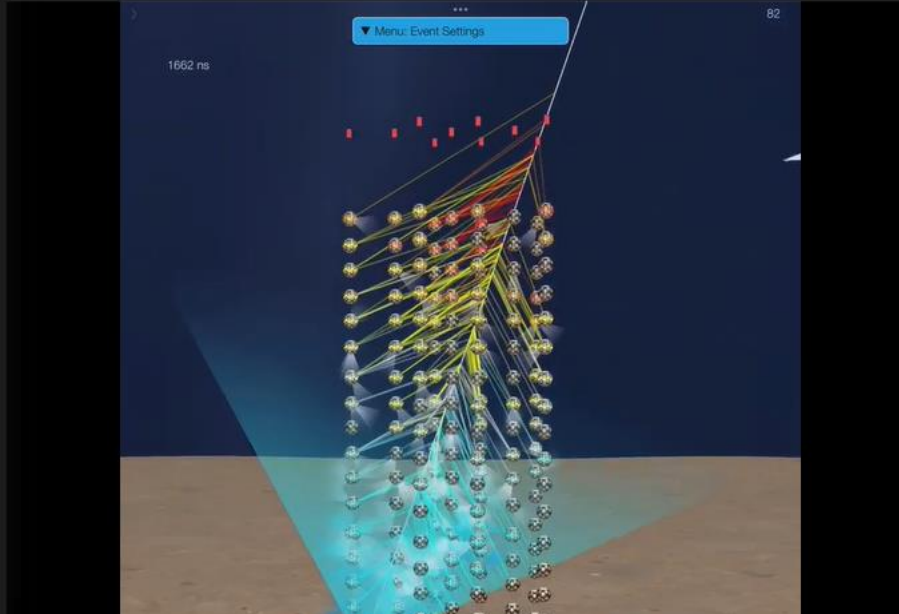
Let's catch some #neutrinos!

KM3NeT
3 december 2021 · 🌐

First KM3NeT/ORCA10 data is streaming in!

Anyone dare to guess which of these data events is a N E U T R I N O?!

Let's 'catch' many more of them, and improve our statistics and physics results.

#neutrino #oscillation #masshierarchy #particle #physics #detector

▼ Menu: Event Settings

82

1662 ns

Next deployments scheduled in autumn

For the production of new lines, we're affected by component shortage as everyone is…

67 M€ budget approved in Italy! Complete first block of ARCA and start second one + upgrade/realization new laboratories for DOM /DU/BM integration

For more follow us at:
https://www.km3net.org

Calibration is performed dynamically!

- Every 10 min:
  - Dynamic **detector positioning**: From the time-of-arrival and waveform of acoustic emitters-receivers
  - Dynamic **DOM orientation**: From compass accelerometer and magnetic field sensor

Path top DOM of 1 ARCA line in ~5 days   ✖ Line anchor

Path of 1 ARCA line in ~7 hours

✖ Line anchor
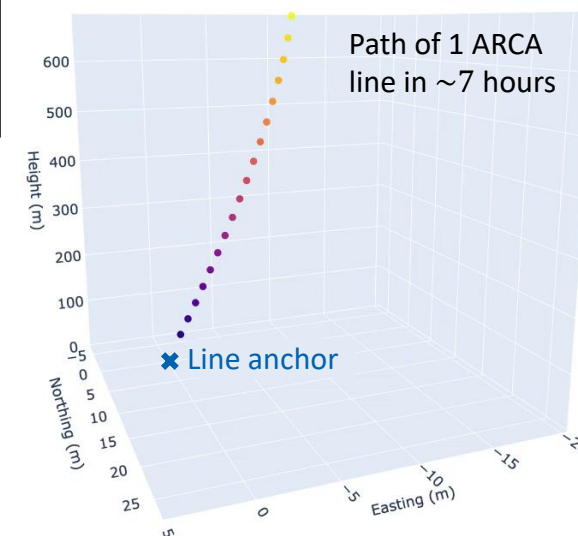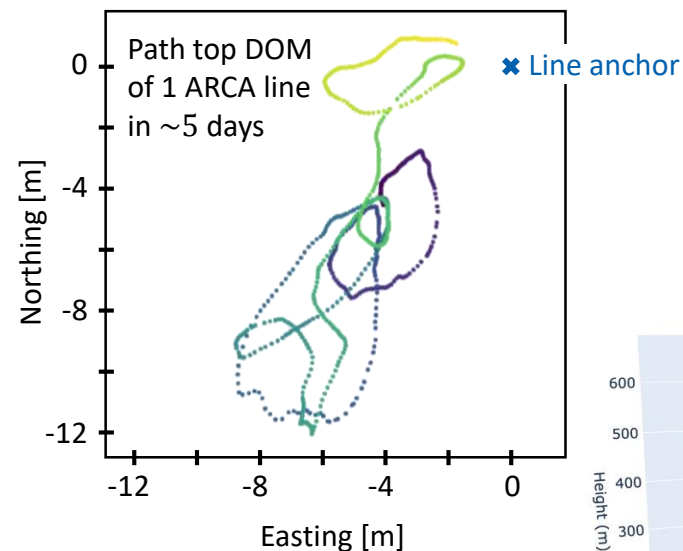
Predicted performance

$$N = A_{eff} \cdot \Phi$$
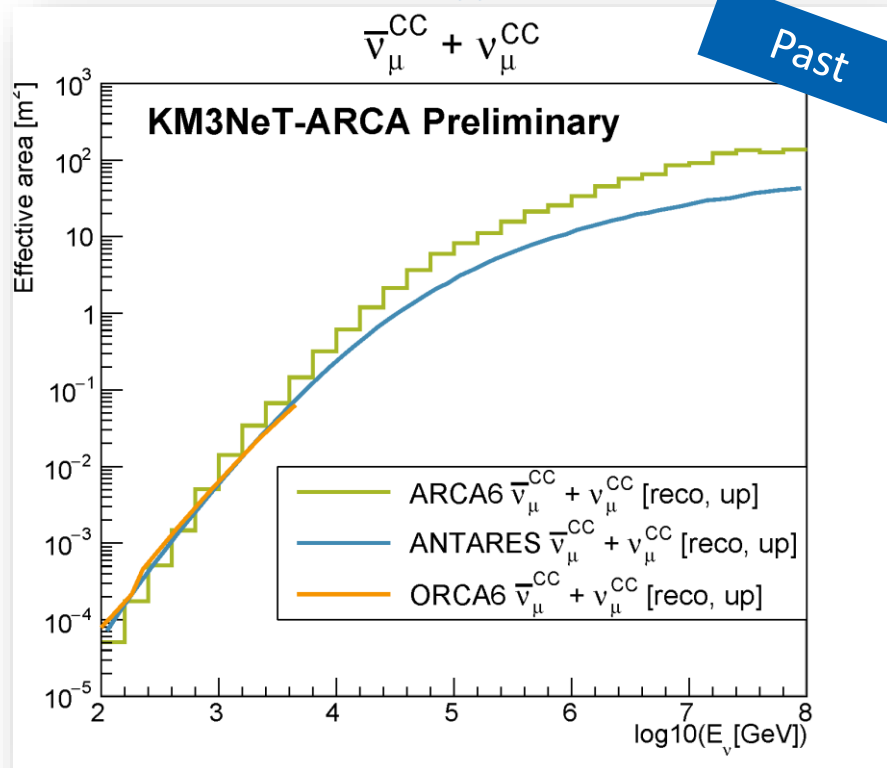
$$N = V_{eff} \cdot \Phi \cdot \sigma \cdot \rho \cdot N_A$$

$$A^{eff} = \frac{N_{detected}}{\int \Phi \, dE \, d\Omega \, dt}$$
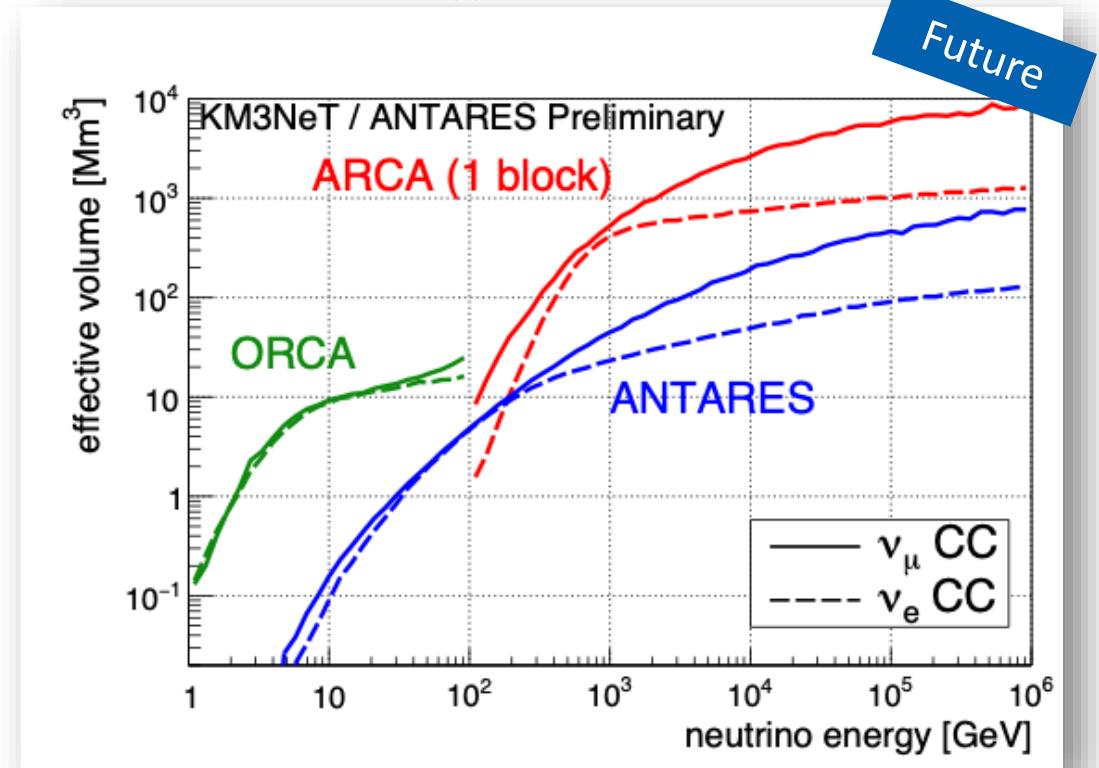
$$V_{eff}(E) = V_{gen}(E) \cdot \frac{N_{det}(E)}{N_{gen}(E)}$$

Let's look at DATA

First data (ORCA1 + ARCA2)
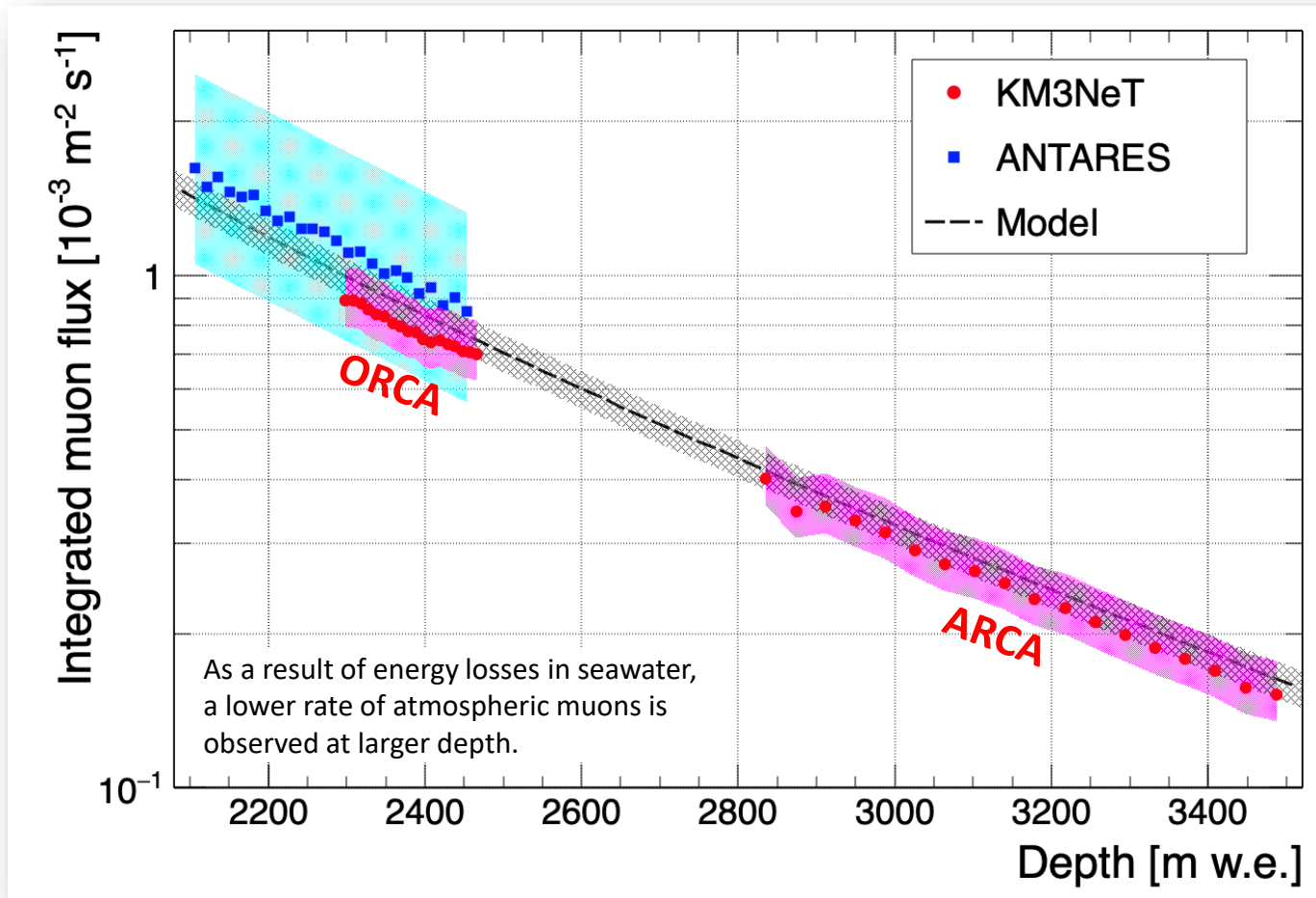
KM3NeT

Independently of the physical site and of the depth of the detector, the measurements of the **atmospheric muon flux** of KM3NeT ORCA1 and ARCA2 are **in agreement with the expected Bugaev** atmospheric muon flux over a range of more than one kilometre

Bugaev model
(Bugaev et al, Phys. Rev. D 58 1998 054001)

springer.com/10.1140/

Atmospheric ν flux (ARCA6)

KM3NeT

With only 6 lines and **20 (!) days** of data taking a powerful rejection of atmospheric muons mis-reconstructed as up-going events is achieved

We find **reasonable agreement** between Data and Monte Carlo

A total number of **15 up-going events** is observed with an up-going track direction while 7 events are expected from the atmospheric muon and **4 events from the atmospheric neutrino simulation**.

ICRC 2021 contribution: https://pos.sissa.it/395/1134

Up-going   Down-going
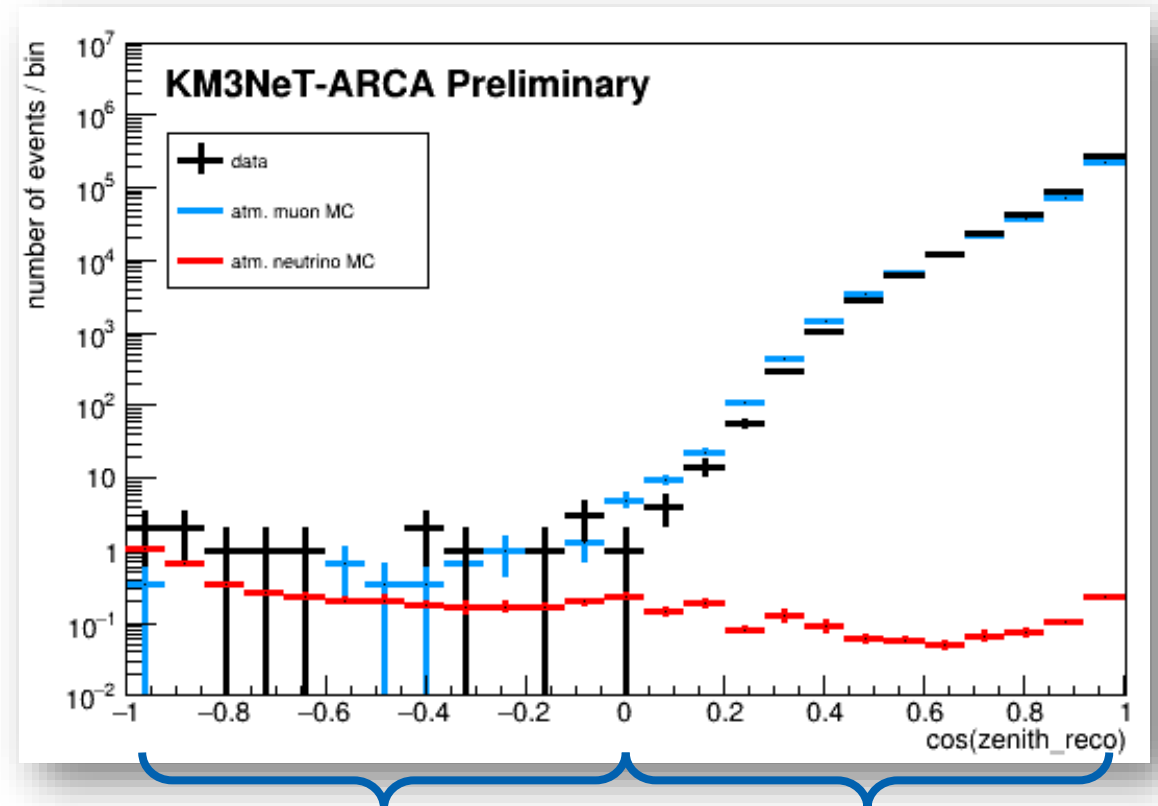
Galactic ridge analysis (ARCA6)
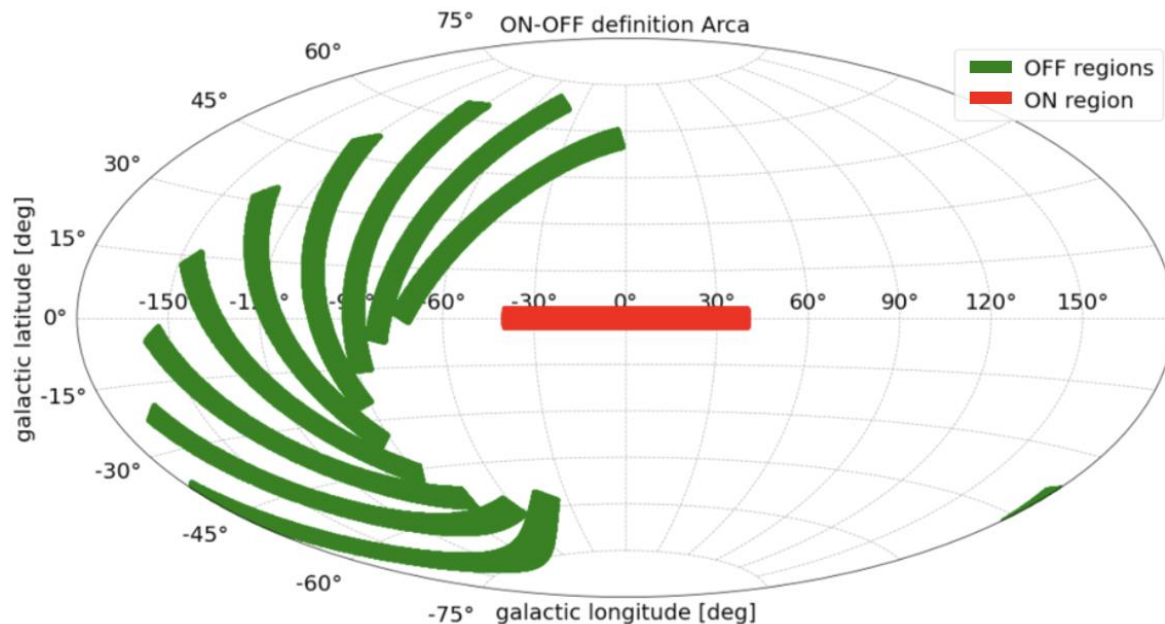
Sources in galactic centre produce HE Cosmic Rays.
Interaction with interstellar medium produces ν's

With ~**100 days** of ARCA6 an ON/OFF analysis is performed where: **ON region: galactic ridge** (|Lgal | < 40° , |Bgal | < 3°), 9 OFF regions: obtained by time-shifting the ON region (avoiding the Fermi Bubbles), assuming an **E$^{-2.4}$ spectrum**

Excess was observed, but not significant yet.
The **upper limit** = $6.2 \cdot 10^{-4}$ [GeV^{-1} cm^{-2} s^{-1} sr^{-1}].

Poster P0173 @Neutrino2022
+ Diffuse cosmic neutrino analysis

E^{-2} point sources study (ARCA6)

KM3NeT

With **92 days** of ARCA6 we performed a **time-integrated point source search** for a neutrino excess at the location of **46** known candidate **sources**.

No strong neutrino emitters were observed. The lowest p-value (0.0202) was found for the radio galaxy Centaurus A, but this is in line with the background expectation.
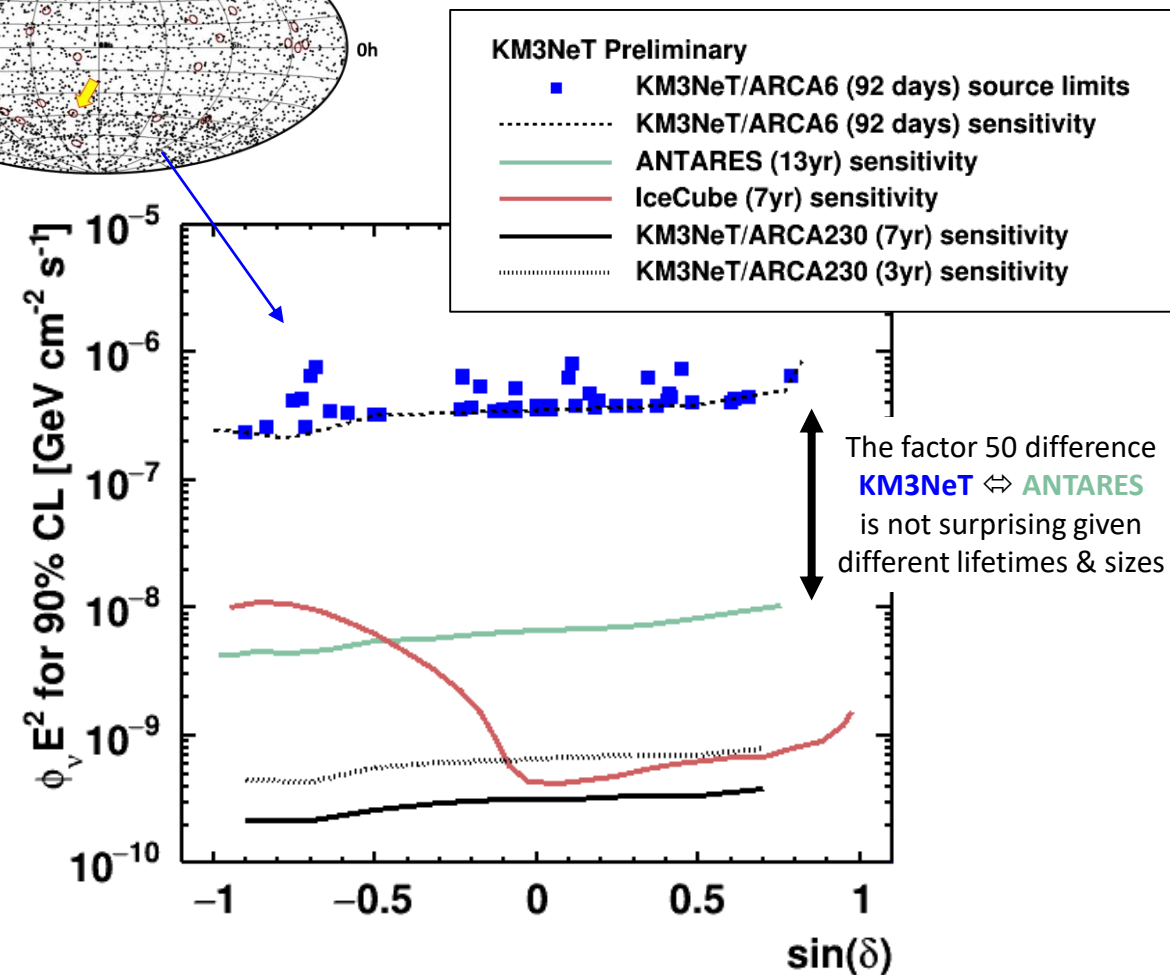
Nevertheless this study shows that our **analysis framework is in place, and working**.

Poster P0745 @Neutrino2022

KM3NeT-ARCA Preliminary

KM3NeT Preliminary
- KM3NeT/ARCA6 (92 days) source limits
- KM3NeT/ARCA6 (92 days) sensitivity
- ANTARES (13yr) sensitivity
- IceCube (7yr) sensitivity
- KM3NeT/ARCA230 (7yr) sensitivity
- KM3NeT/ARCA230 (3yr) sensitivity

The factor 50 difference **KM3NeT** ⇔ ANTARES is not surprising given different lifetimes & sizes
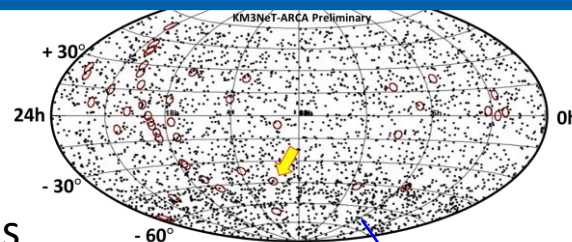
Icecube alert follow-ups (ARCA8)

KM3NeT

Legend:
- Fermi PKS 0735+17 position
- IceCube-211208A alert, 90% containment
- Baikal shower event, 50% containmnet
- 1.4° cone, ON Zone
- KM3NeT/Arca data
  Atm muon contamination 99%
  Median E^{-2} cosmic neutrino angular resolution = 1.7°
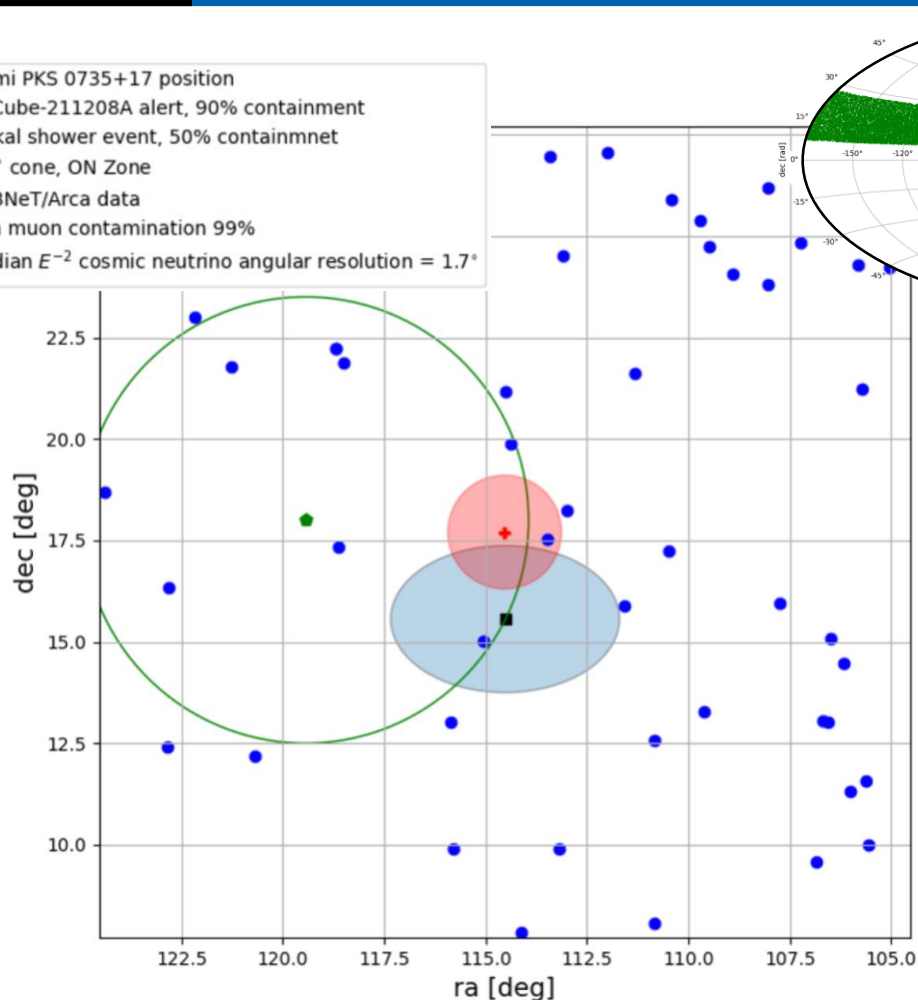
Follow-ups are done +-1day
with ORCA & ARCA.
(For PKS0735+17 also 1 month.)

ON/OFF technique, where ON region: cone centred on the source position & OFF region: declination band centred at the source's position (ON region subtracted).

E^{-2} spectrum assumed.
Selection: **up-going track-like** events.

No significant discovery for ORCA & ARCA.
Only 1 ν_μ candidate in ARCA for PKS0735+17
with ~18TeV (**p = 0.14**)

Poster P0739 @Neutrino2022

More work ongoing…

- Diffuse cosmic neutrino analysis
- Starburst diffuse analysis
- Combined γ-ray – ν analysis
- Gamma Ray Burst (GRB) analysis
- Periodic source (pulsar) analysis
- GW follow-ups
- Online direct follow-ups

- GeV neutrino analysis
- CCSN analysis

- Include cascades in analysis
- Double bang ν_τ reconstruction
- Improving shower reconstruction

Thank you
for your attention!

For remaining questions,
don't hesitate to e-mail me:
rmuller@km3net.de