KM3NeT science and multi-messenger synergies

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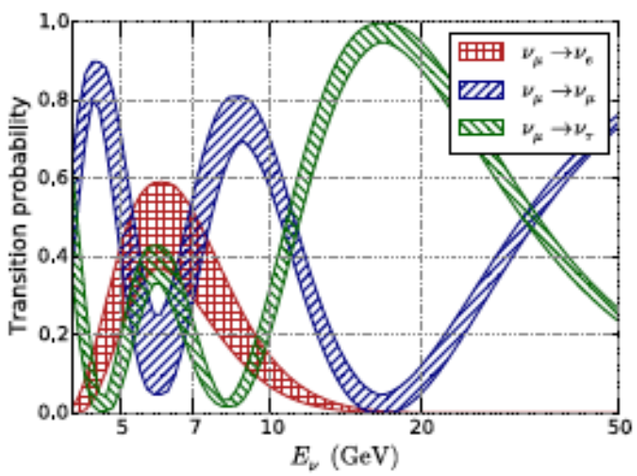
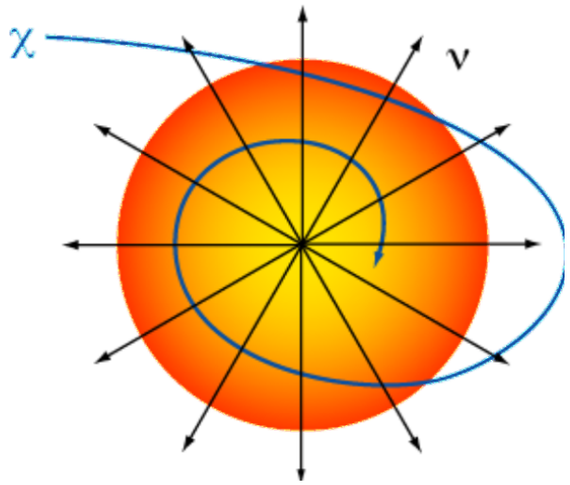
On behalf the KM3NeT Collaboration

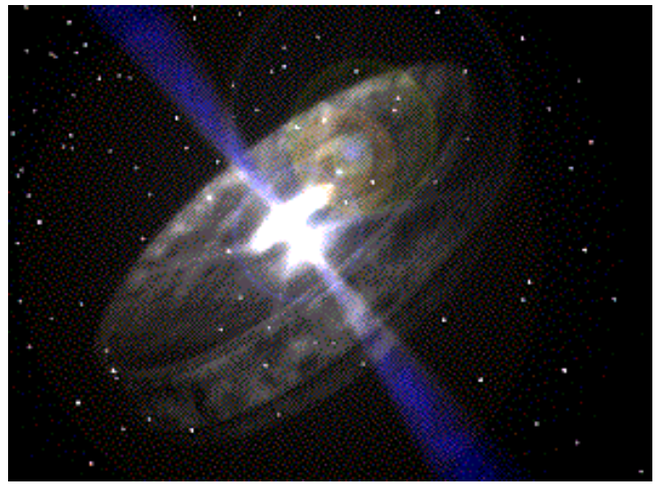
Groningen — 2019/03/27

KM3NeT Science cases

- **A vast multi-disciplinary program**







Low Energy
MeV < E_ν < 20 GeV

Oscillations, supernova

Medium Energy
20 GeV < E_ν < 10 TeV

Dark matter, exotic particles

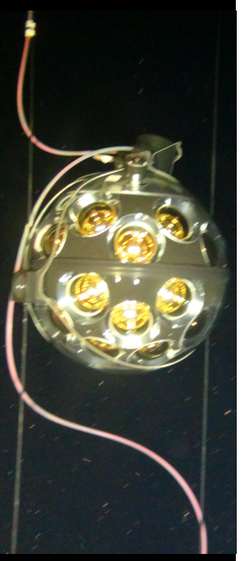
High Energy
E_ν > 10 TeV

Sources of ν, diffuse flux, link to CR

KM3NeT- ORCA — KM3NeT- ARCA

ANTARES

+ Oceanography, marine biology, seismology

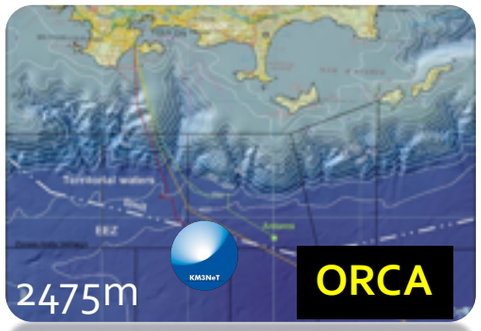


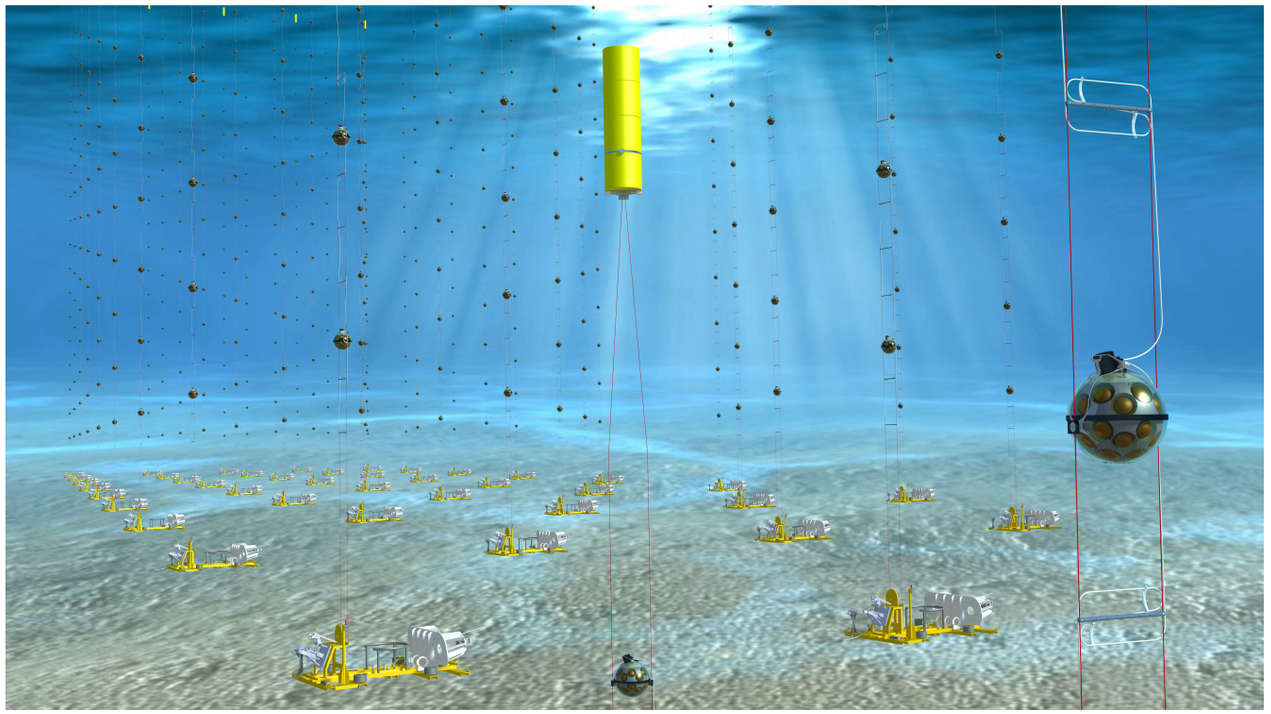
KM3NeT detectors

KM3NeT is the neutrino research infrastructure in the deep Mediterranean Sea

Oscillation **R**esearch with **C**osmics In the **A**byss

ORCA: off shore Toulon, France





Astroparticle **R**esearch with **C**osmics In the **A**byss

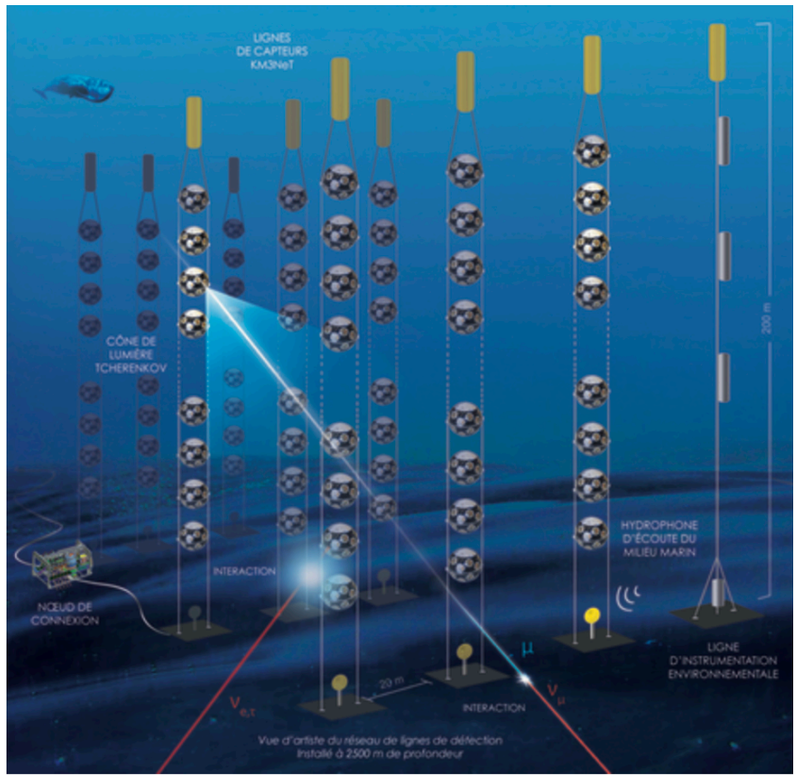
ARCA: off shore Capo Passero, Italy

Same collaboration, same technology, two installation sites

- **31** 3-inch PMTs = 1 Digital Optical Module (DOM)
- **18** DOMs = 1 Detection Unit (DU)
- **115** DUs = 1 Building Block (BB)
- **6 DUs ORCA + 24 DUs ARCA = KM3NeT Phase 1**
- **1 BB ORCA + 2 BB ARCA = KM3NeT Phase 2**

	ARCA	ORCA
DU distance	90 m	20 m
DOM spacing	36 m	9 m
Instrumented mass	2*500 Mton	5.7 Mton

KM3NeT in number for astronomy



Main characteristics:

- Extended energy range: ~ 3 GeV → > 10 PeV
- Full sky coverage with the best sensitivity for the galactic sources
- High duty cycle (> 90-95%)
- All flavour neutrino detection
- Good angular resolution

⟹ Construction on-going: at present 1 DU working in ARCA and in ORCA + 5 DUs ready for deployment in ORCA (>300 DOMs builded)

⟹ Mid 2020, better sensitivities than ANTARES in the whole energy range.

- **ARCA dedicated to neutrino astronomy:**

⟹ Tracks (100 TeV - 10 PeV) with the excellent angular resolution (<0.2º)

⟹ Cascades (100 TeV - 10 PeV) thanks to the good angular resolution (1-2º) and taking advantages of the low atmospheric background contribution

- **ORCA can do also astronomy:**

⟹ Tracks & cascades at low energy (few GeV - 10 TeV), looking for time/space clusters

⟹ Example sources: winds of binaries, chocked GRBs, hidden jets in core-collapse SN

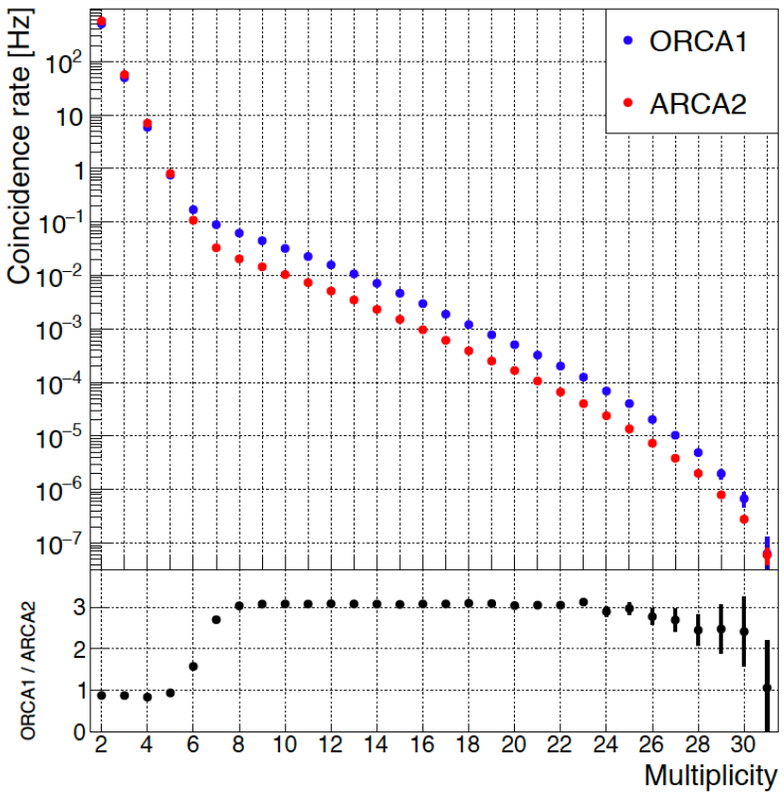
- ORCA & ARCA: detection of MeV neutrinos from ccSN

KM3NeT first data

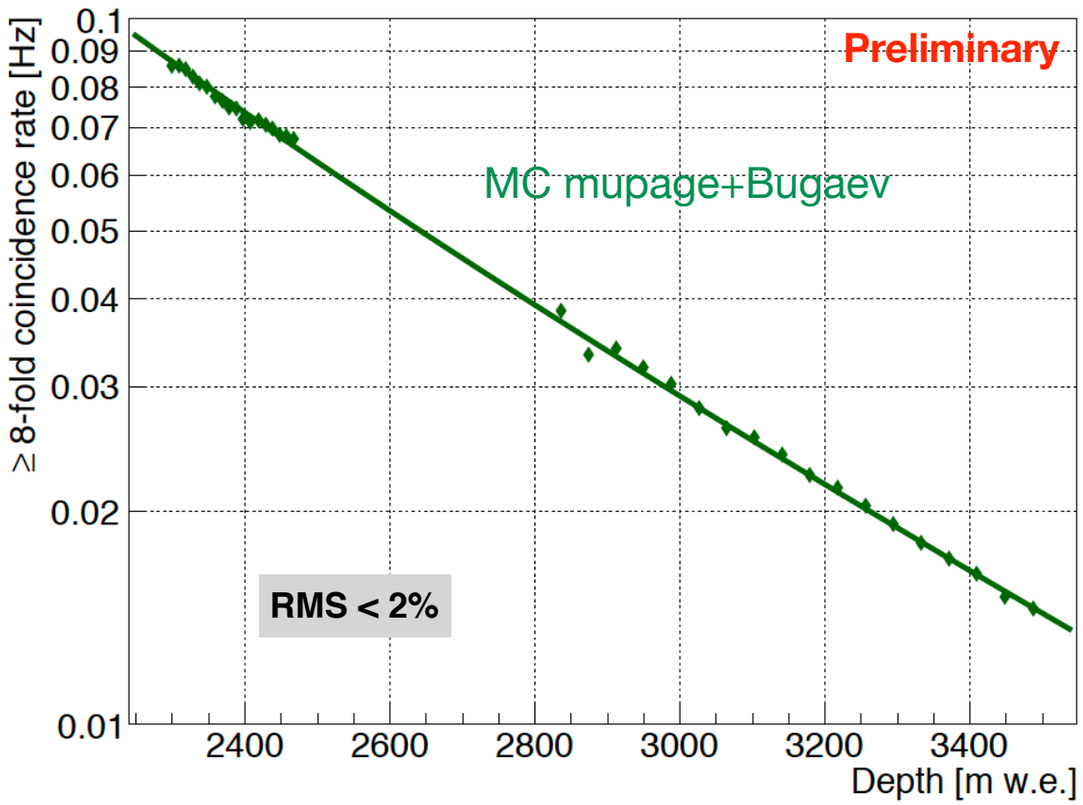
ARCA2 and ORCA1 data analysed to estimate the detector stabilities, the performances of the calibration methods (PMT detection efficiencies, time offsets) with detailed run-by-run simulations: good understanding of the PMTs / DOMs and the environment properties.

$\Longrightarrow$ Neutrino events already detected in each site.

Average coincidence rates



Muon coincidence rates vs depth



(SN search: M. Lincetto talk tomorrow)

KM3NeT performances

Tracks:

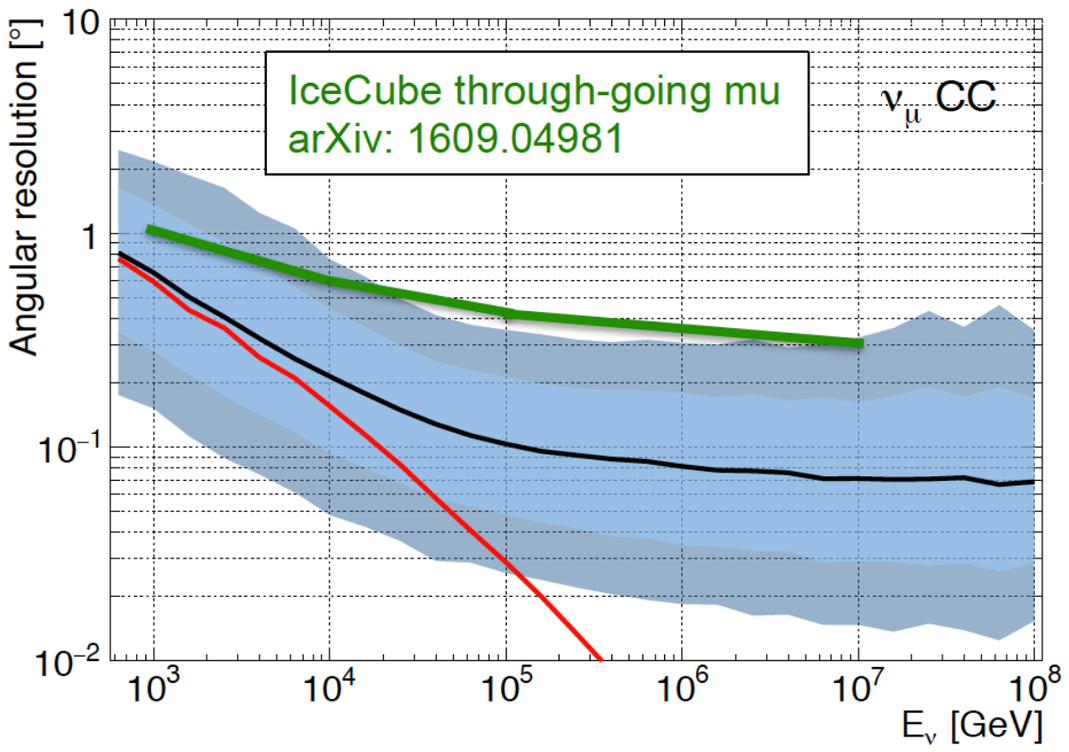
- Direction:

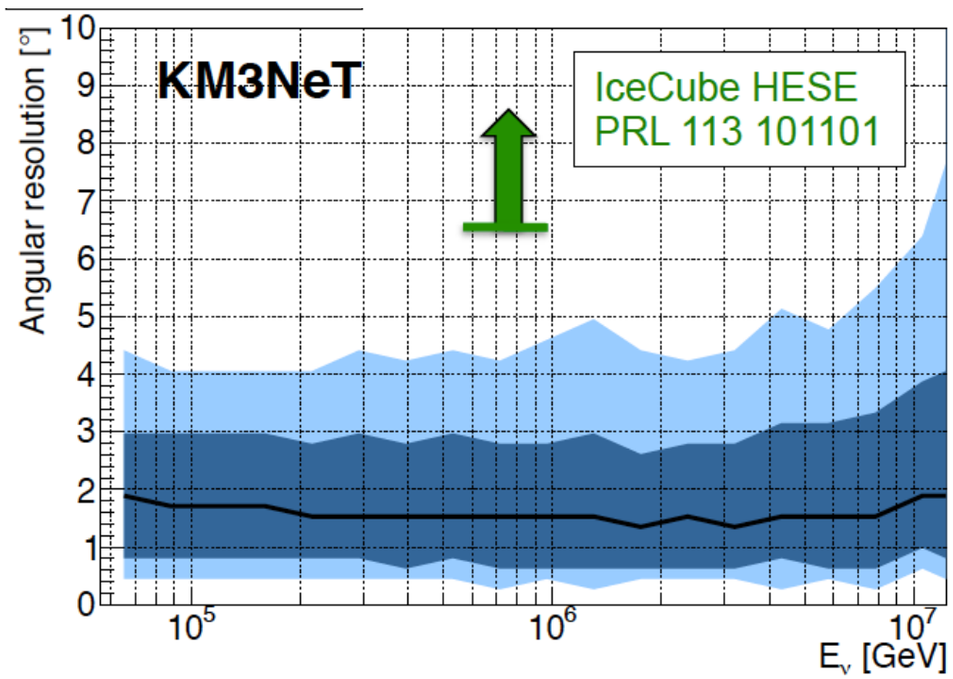
➡ Gal. sources: 0.2º at 10 TeV

➡ Extra-gal. sources: 0.1º at 100 TeV

- Energy: 0.27 in Log10(E)

For ORCA, 2º at 100 GeV, 1º at 1 TeV



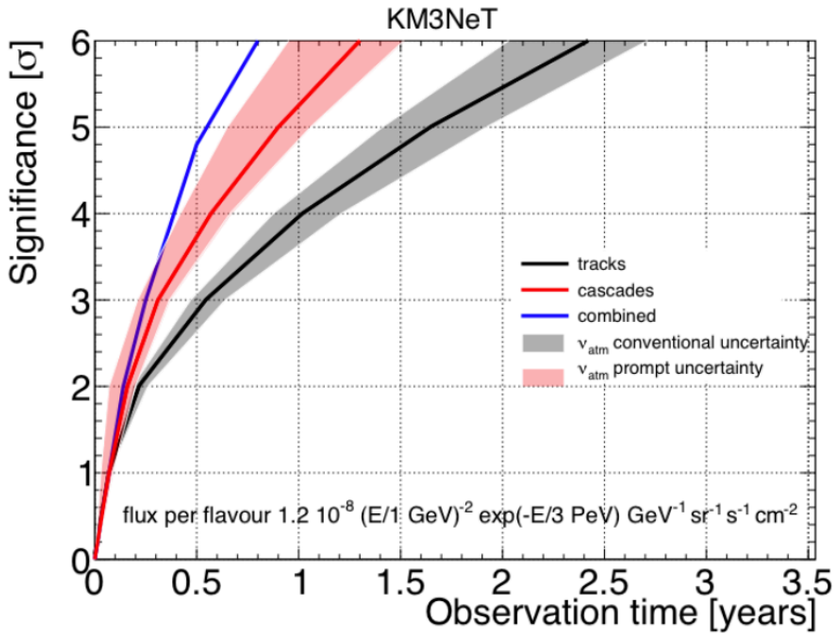


Cascades:

- Vertex: 6-8m (long), 0.5m (perp)
- Direction: ~1.5º
- Energy: 5%

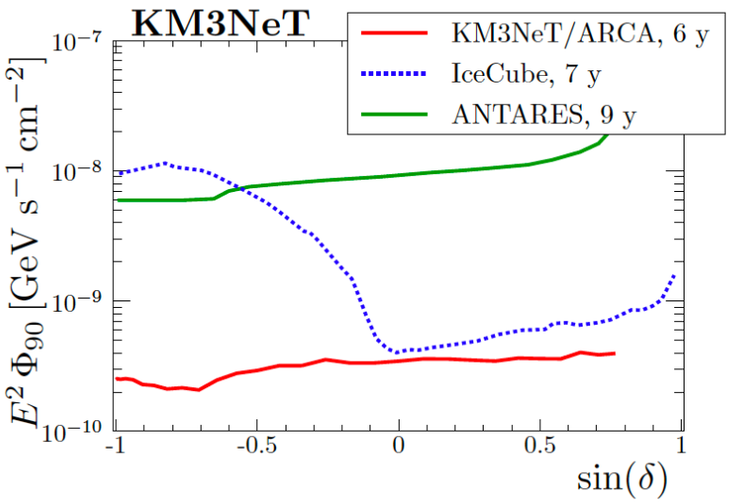
For ORCA, 3-4º at 100 GeV

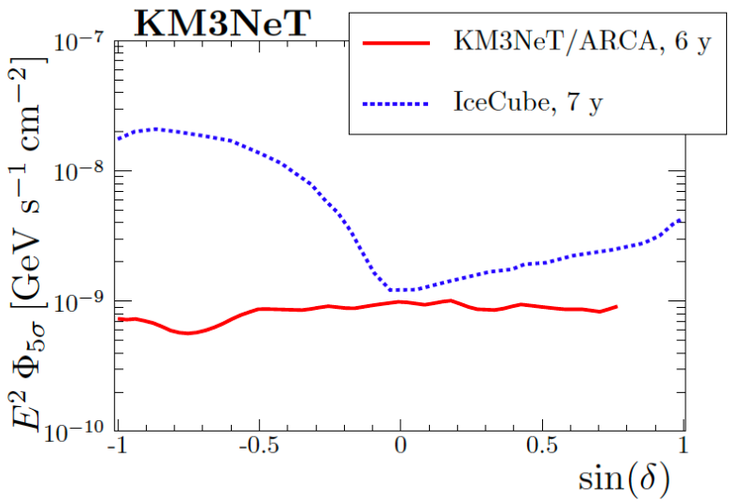
KM3NeT expected performances

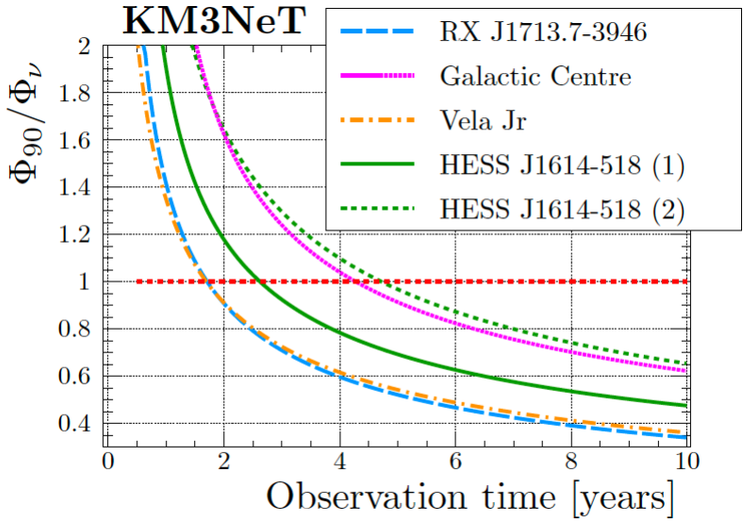


Full ARCA will be able to detect the IceCube cosmic diffuse flux in less than 1 year.
$\Longrightarrow$ Investigate isotropy, spectral shape, flavor composition.

Point-like steady search sensitivities: 1st targets are the galactic sources (thanks to the detector localisation)





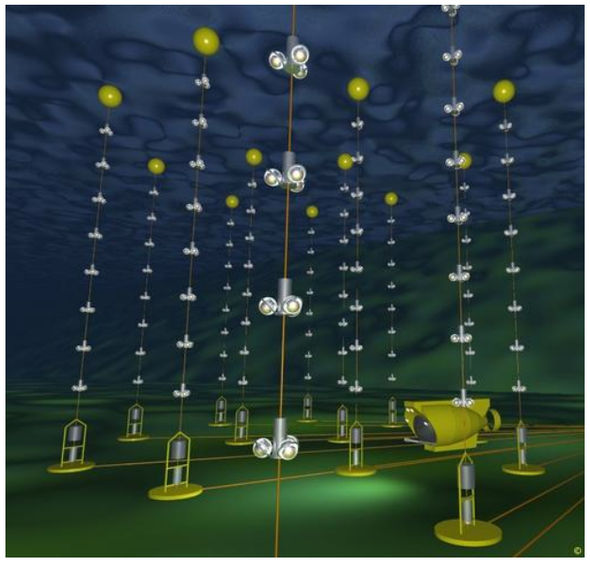


(KM3NeT Coll., arXiv:1810.08499)

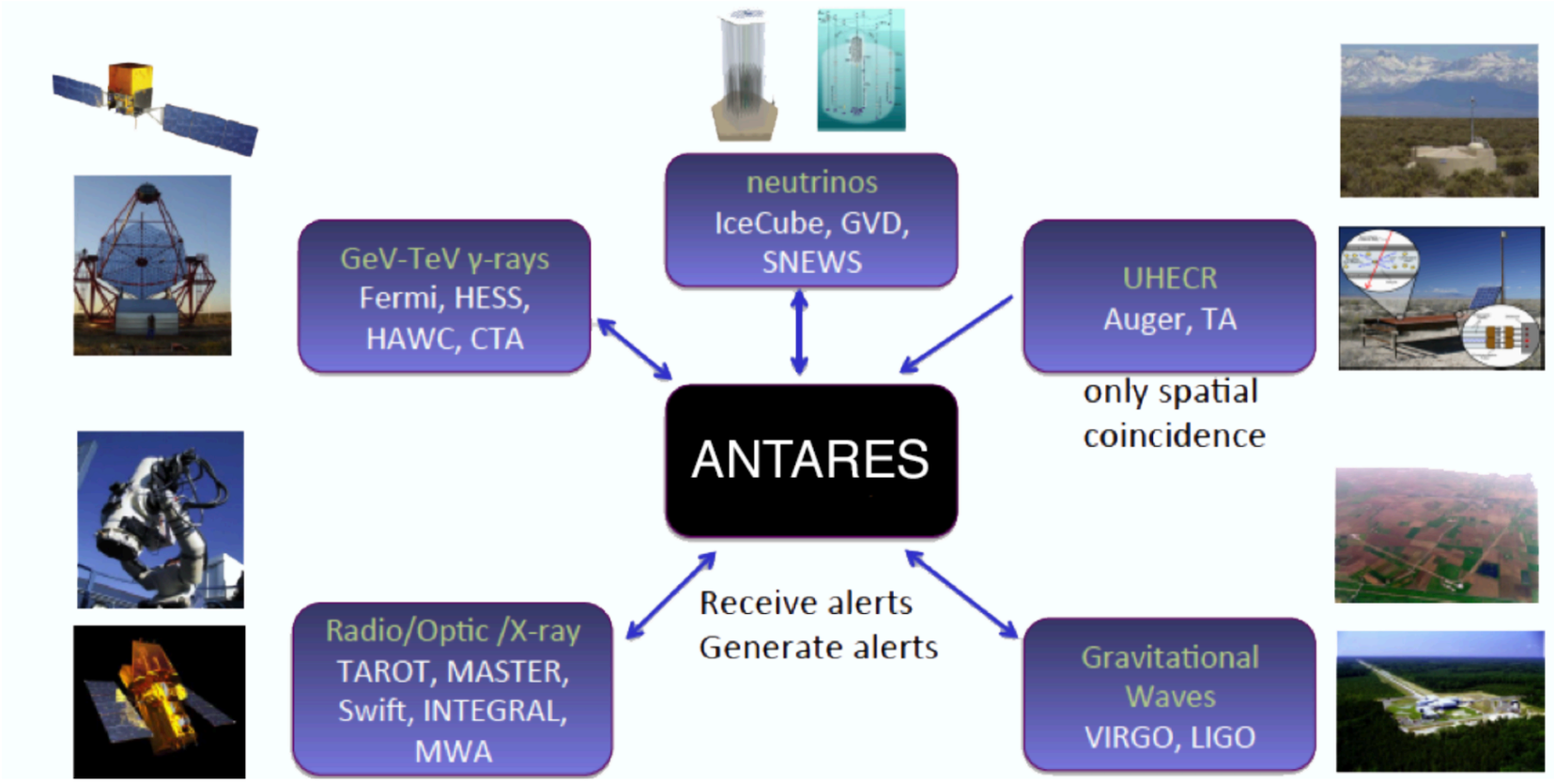
ANTARES multi-messenger program

ANTARES in numbers:

- Stable data taking since 2007 with high duty cycle (>95% efficiency)
- Large field of view (2π instantaneously)
- Quite good angular resolution: 0.3-0.4° (median)
- But it is also small: A_{eff} ≈1m² @ 30 TeV (o(12000) detected neutrinos)
- Real-time data processing



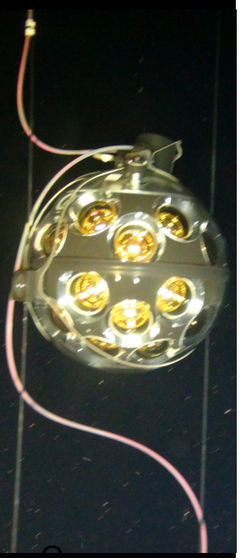
Very large multi-messenger program:



+ AMON Astrophysical Multimessenger Observatory Network

(See M. Colomer's talk)

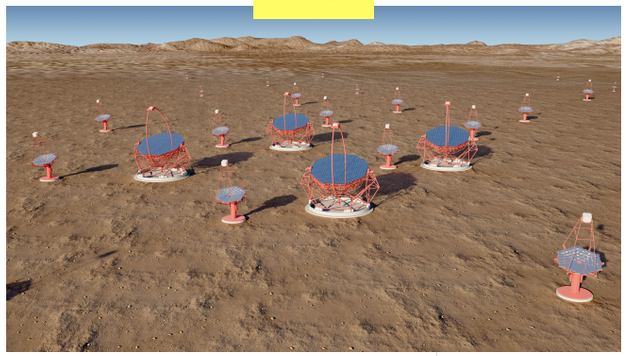
KM3NeT multi-messenger programs



- Follow-up of neutrino alerts
- Joint sub-threshold analysis

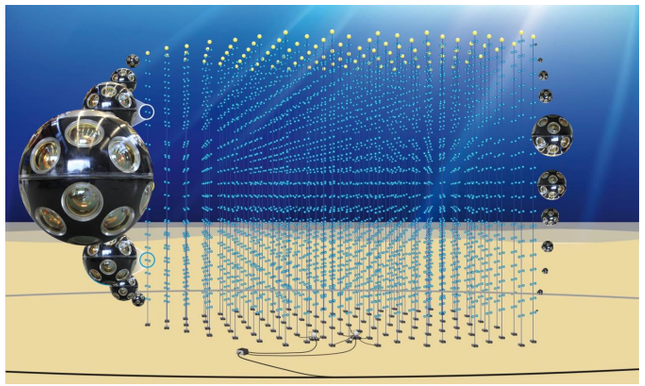
MASTER/TAROT

CTA

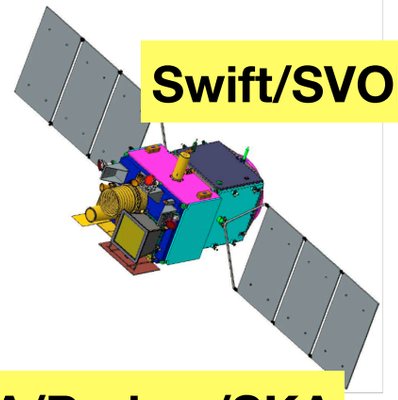


LSST

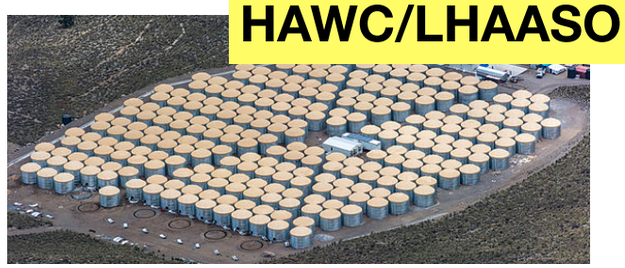
KM3NeT



Swift/SVOM



HAWC/LHAASO



LIGO/VIRGO

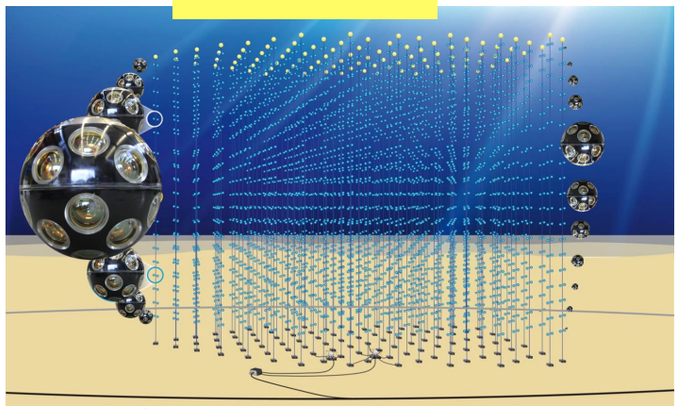
MWA/Parkes/SKA

ELT

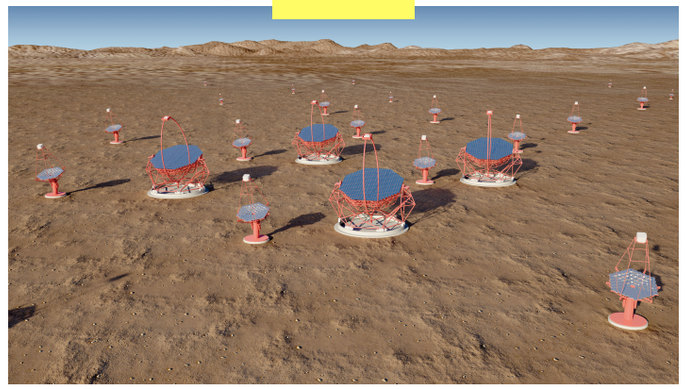
- Follow-up of EM/GW alerts
- Offline time/space correlation search with catalogues (GRB, AGN, XRB, SN, FRB…)

Synergies ESFRI facilities

KM3NeT



CTA



Send HE ν alerts in real-time

Receive HE γ triggers in real-time

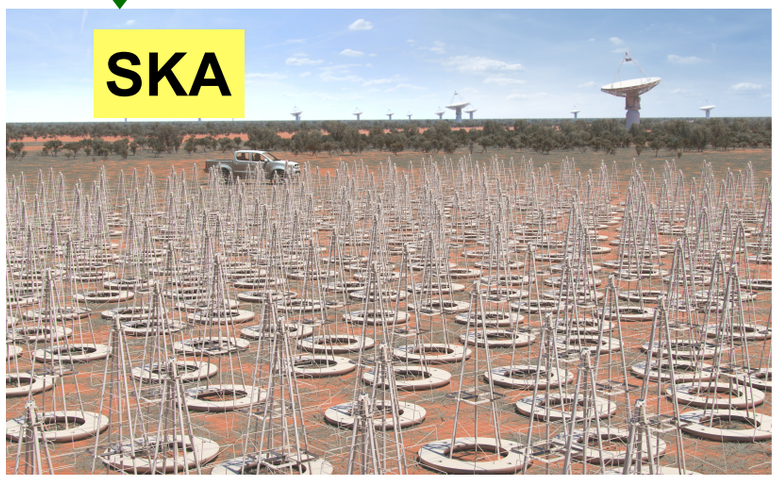
Get updated source catalogues (SNR, PeVatrons, AGN…)

Send HE ν alerts in real-time

Receive radio triggers in real-time (FRB…)

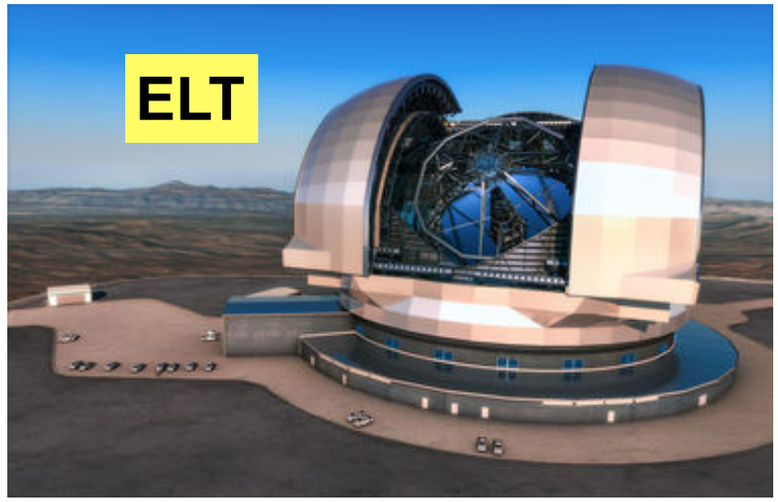
Get updated source catalogues

SKA



Send HE ν alerts via ToO for redshift, host galaxy studies

ELT



https://indico.astron.nl/materialDisplay.py?materialId=3&confId=99

Summary

- Detection of gravitational waves (LIGO/Virgo), cosmic HE neutrinos (IceCube) and the first Galactic PeVatron (H.E.S.S.) $\Longrightarrow$ **new era of multi-messenger astronomy**.

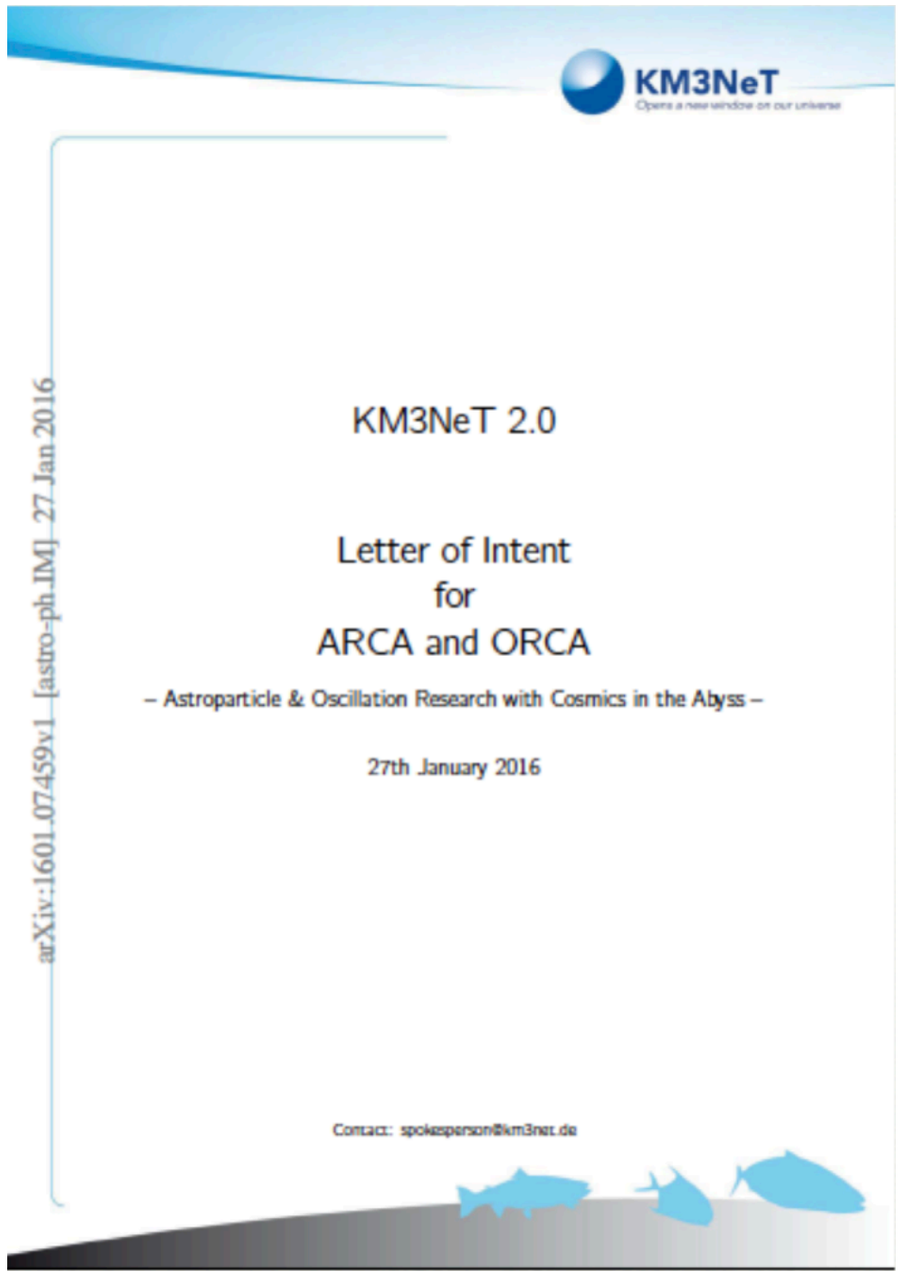
- **With ANTARES, we have performed plenty multi-messenger analyses with 12 years of data** (See Talk of M. Colomer tomorrow)

$\Longrightarrow$ ANTARES will be probably decommissioned next year and pass the baton to KM3NeT.

- By observing astrophysical neutrinos with **good angular resolution, an extended energy range and a full sky coverage with a high duty-cycle**, KM3NeT will play a key role.

- **Important synergies with others facilities** such as CTA, SKA, LVC, ELT, SVOM, etc: mutual real-time follow-ups, exchanges of data (flares, spectral/angular shapes…)

KM3NeT 2.0: Letter of Intent



More details on KM3NeT technologies and science cases in the Letter of Intent: arXiv/1601.07459 J. Phys. G: Nucl. Part. Phys. 43 (2016) 084001

⇒ Since then, large improvement in the event reconstructions and analysis method. + Analysis of 1st ORCA/ARCA data. Updates planned end of this year

KM3NeT data policies

➡ **KM3NeT neutrino data are proprietary but become public after a latency of 2 years after the data taking.**

➡ However, **significant events might trigger alerts** that will be distributed **publicly** to the astro community using standard **VO event** format within **~10s** after the neutrino detection

➡ **Sub-threshold alerts** and **multiplets** will be distributed through **private channel** to observing teams upon **MoU agreements.**