High energy neutrino astronomy with KM3NeT

piera sapienza for the km3net collaboration

TAUP2017 -Sudbury 25 june 2017

KM3NeT Physics case

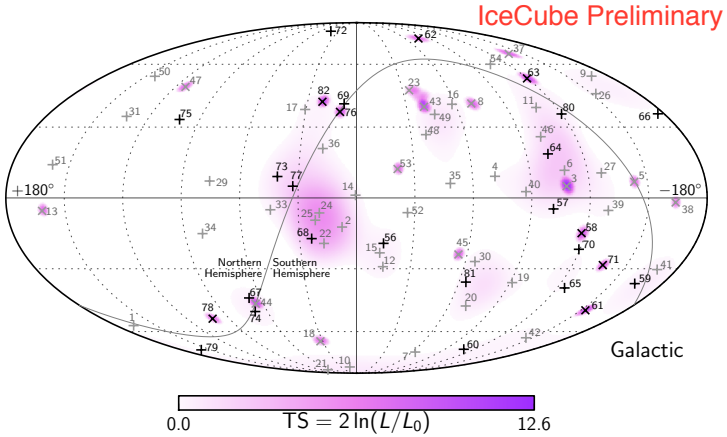
KM3NeT is neutrino research infrastructure in the deep Mediterranean Sea that hosts ν telscopes to:

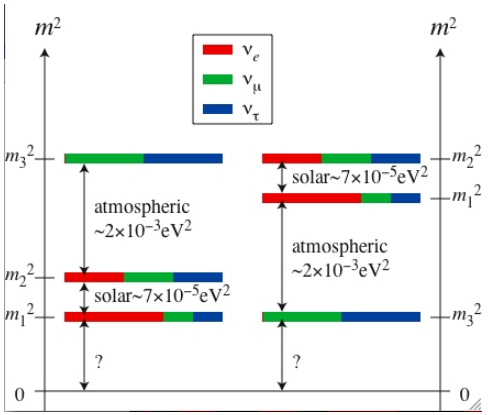
- observe high energy cosmic neutrinos and discover their sources

ARCA (off shore Capo Passero, It @ 3500 m depth) – *this talk*

- determine neutrino mass hierarchy

ORCA (off shore Toulon, Fr @2500 m depth) – *J. Hofestadt talk*





Same collaboration, same technology, two installation sites

Since 2016 KM3NeT is back in the ESFRI road map

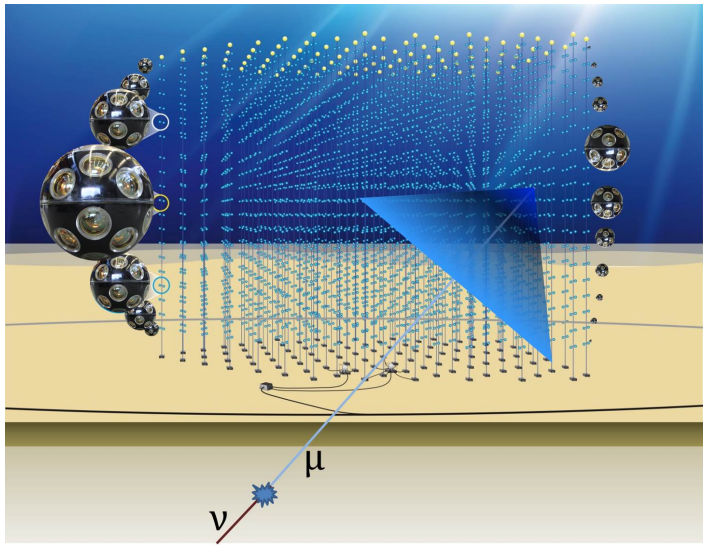
IceCube discovery of HE cosmic neutrinos enforce KM3NeT physics case

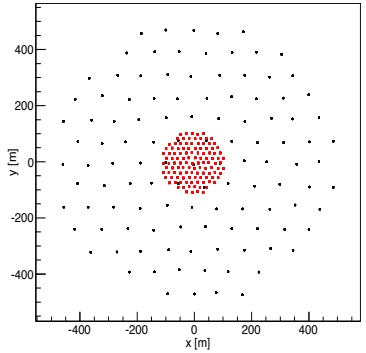
=> KM3NeT has almost full sky coverage for ν_μ and unprecedented angular resolution (about 0.1° tracks and 2° showers)

Letter of Intent for ARCA and *ORCA J. Phys. G Nucl. Part. Phys. 43 (2016) 084001*

KM3NET TELESCOPE DESIGN

- Detection principle Optical Cherekov radiation
  - 6 order of magnitude in energy (GeV-PeV) covered
  - All flavor detection
- 3D array built with a modular design
- optical sensor: multi-PMT (DOM)
- Detection units (DU)
  - vertical slender strings host 18 DOMs
- Building blocks of 115 DUs each
- Power and data distributed by a backbone cable with breakouts at each DOM
- Sea network of submarine cables and Junction Boxes connected to shore via a main e/o cable
- All data to shore

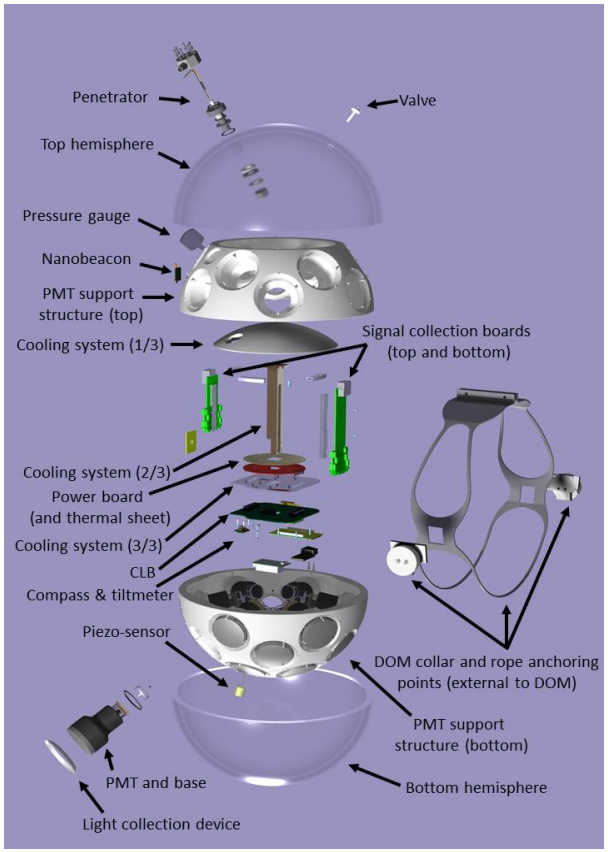




	ARCA	ORCA
Location	Italy	France
DU distance	90 m	20 m
DOM spacing	36 m	9 m
Intrumented mass	0.5 Gton	5.7 Mton

DOM - Digital Optical Module

- 31 x 3” PMTs
- LED & acoustic piezo inside
- Tiltmeter/compass
- Gbit/s fibre DWDM
- Hybrid white rabbit



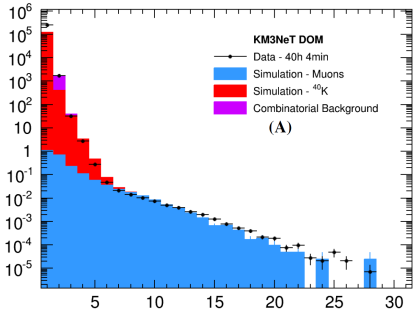
- Digital photon counting
- Directional information
- Wide acceptance angle
- Improved ^{40}K rejection capability

$\Rightarrow$ (500 Hz, for double coincidences, …)

- Compact and cost effective design: 1 DOM equivalent to 3 Antares OMs

From technology validation to construction

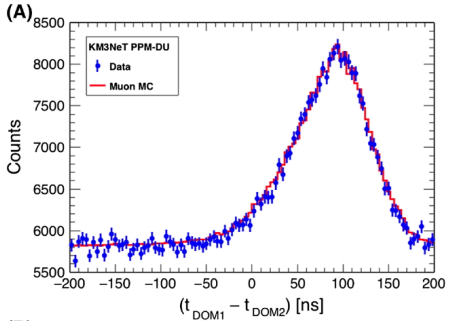
Prototype DOM deployed at Antares site April 2013



Test of photon counting capabilities and directional sensitivity of DOM
Eur. Phys. J. C (2014) 74:3056

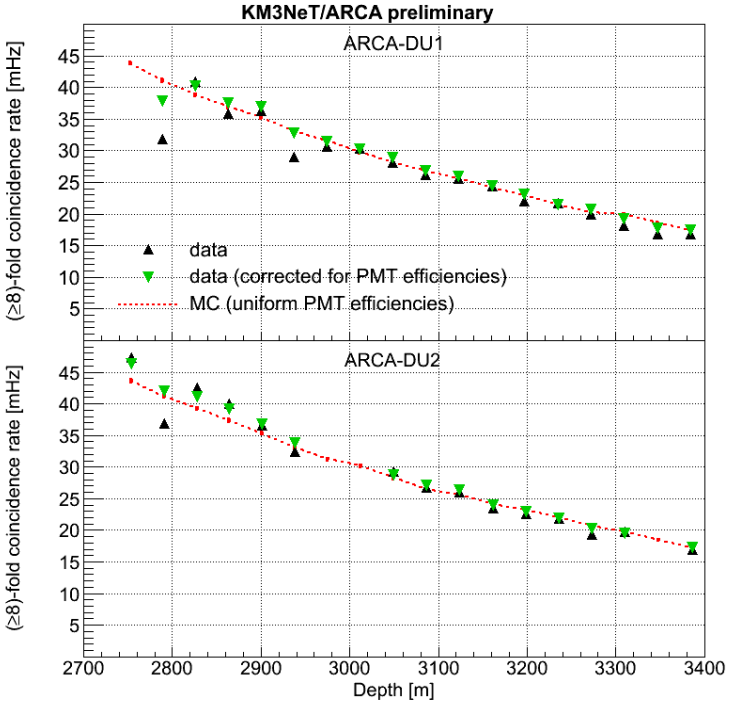
Prototype DU (three DOMs) deployed in Capo Passero May 2014

Test of DU structure functionality intra-DOM and inter-DOM calibration - *Eur. Phys. J. C (2016) 76:54*



ARCA DUs in Capo Passero since December 2015

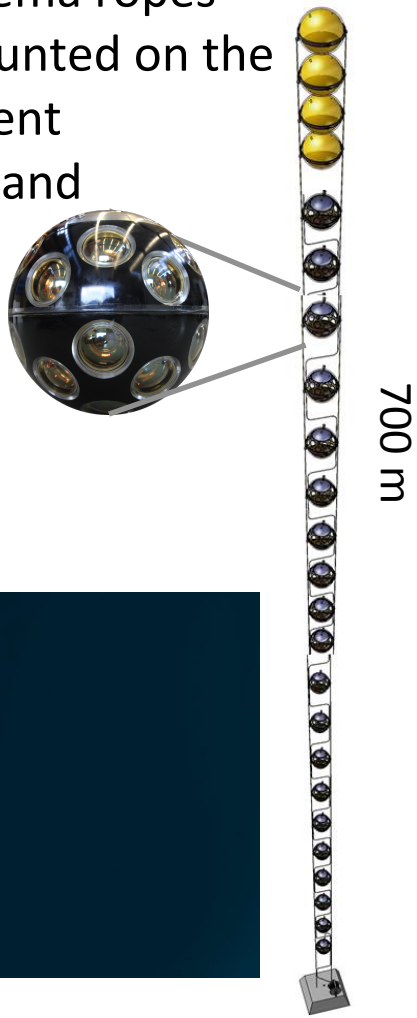
Muon flux dependence on depth
DU calibration
Trigger implementation
PMT efficiency correction
MC comparison
6-7 kHz ^{40}K, < 1% bioluminiscence



ARCA DETECTION UNIT

- 18 DOMs integrated on vertical e/o cable supported by two parallel Dynema ropes
- DUs arranged on the LOM mounted on the anchor and ready for deployment
- DU unfurled after deployment and connection to seabed network
- Unfurling triggered by ROV

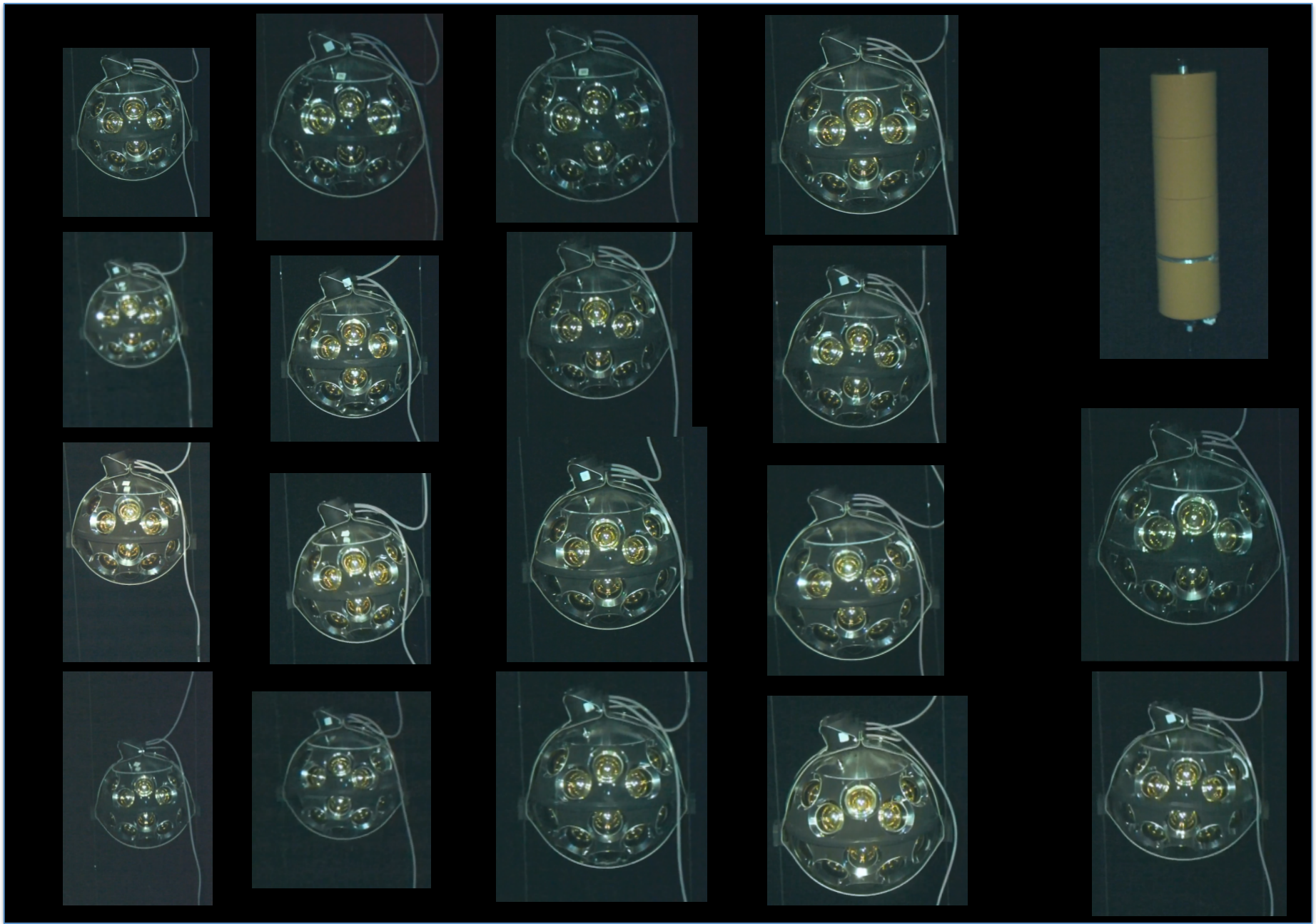
then proceed under buoy pull



LAUNCHER VEHICLE

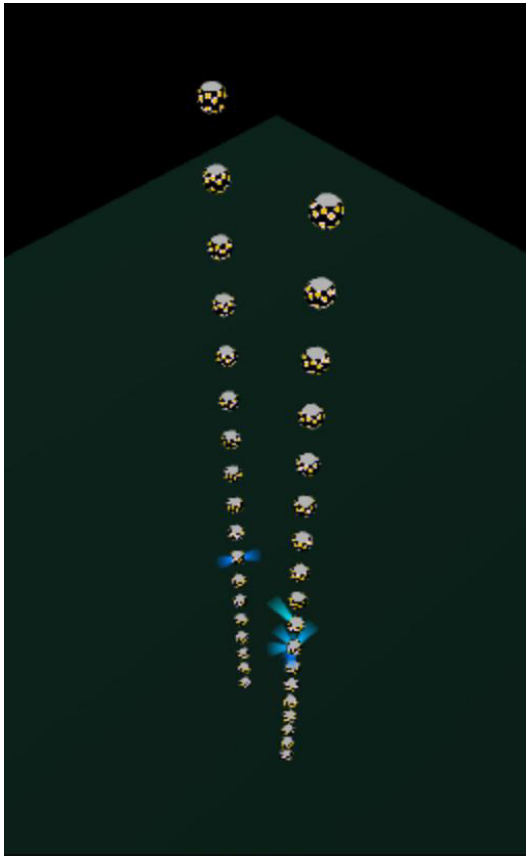
Compact structure
Rapid deployment
Autonomous unfurling
Recoverable

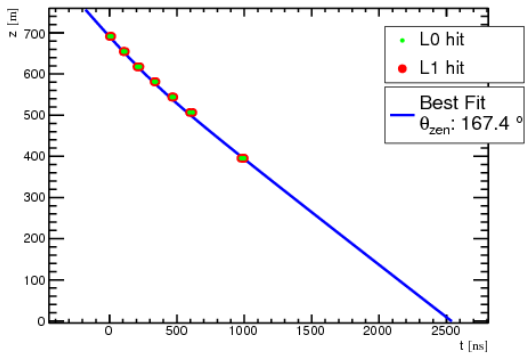
The First DU installed in situ 3500 m

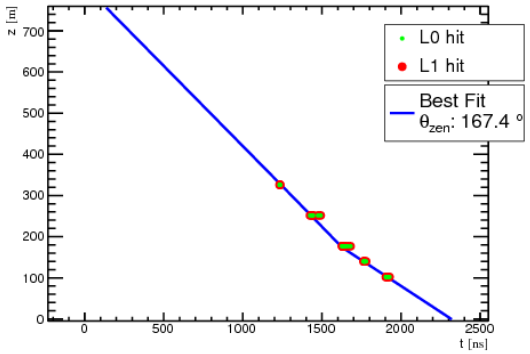


Track reconstruction on data sample

A muon event seen and reconstructed in two DUs



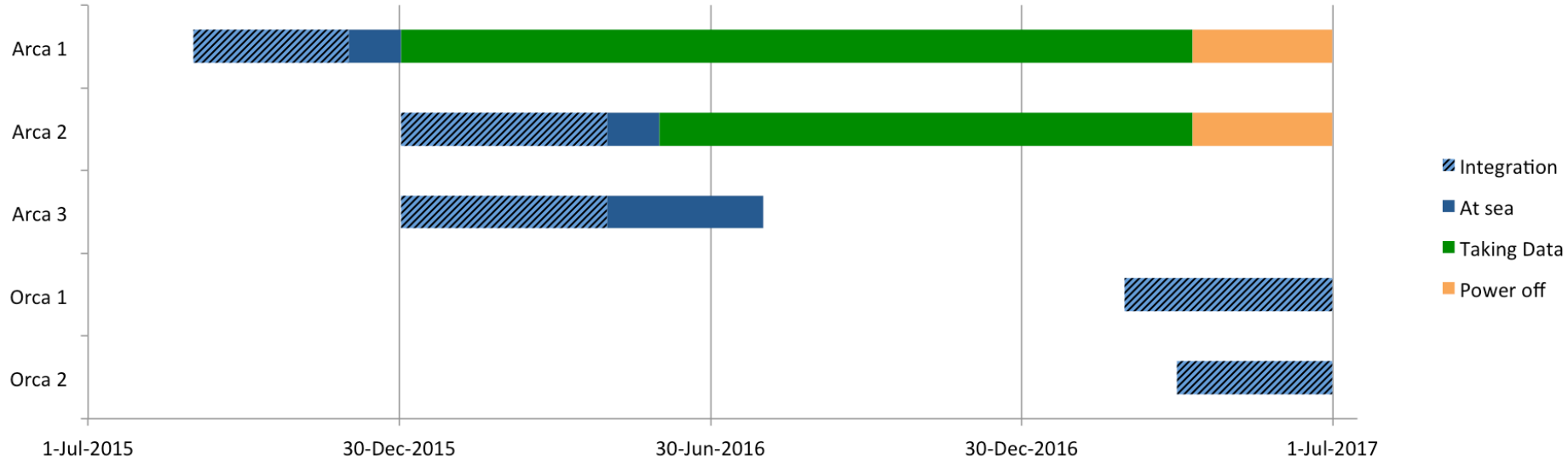




A PHASED APPROACH TOWARDS 1km^3

PHASE	BLOCKS	PRIMARY DELIVERABLES	FUNDS
1 0.1 km3 10xANTARES	0.2	Proof of feasibility and first science results 24 ARCA strings	fully funded
ARCA 2 1 Gton	2	Study of neutrino signal reported by IceCube All flavor neutrino astronomy	partially funded

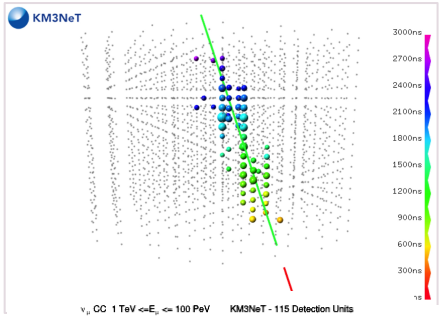
DETECTOR STATUS



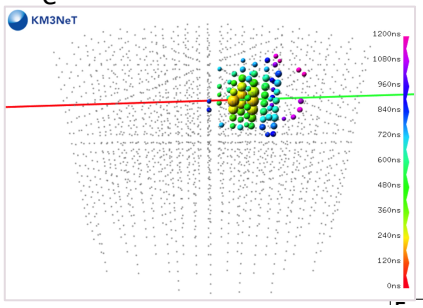
Three ARCA DUs have been deployed. ARCA DU3 failed soon after unfurling.
It was recovered within a dedicated campaign and failures analysed.
Post mortem analysis lead to review project and procedures

EVENT TOPOLOGIES AND DETECTOR RESPONSE

Upgoing track like ν_μ CC event

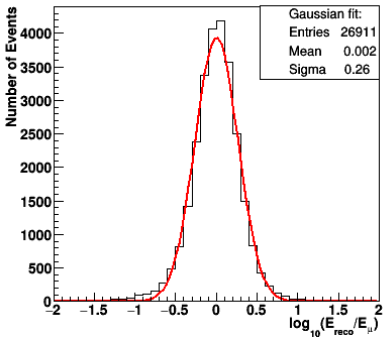


Contained shower ν_e and NC event

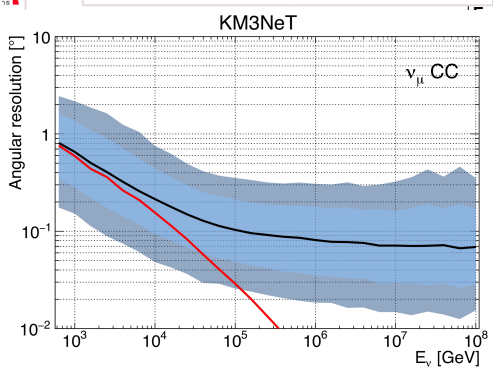


ν_μ are the golden channel for neutrino astronomy

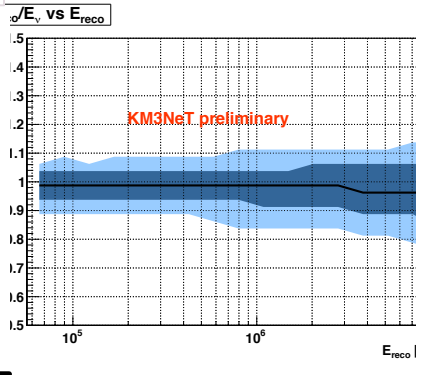
Deep sea water properties, i.e. long scattering length allow to achieve very good angular resolution



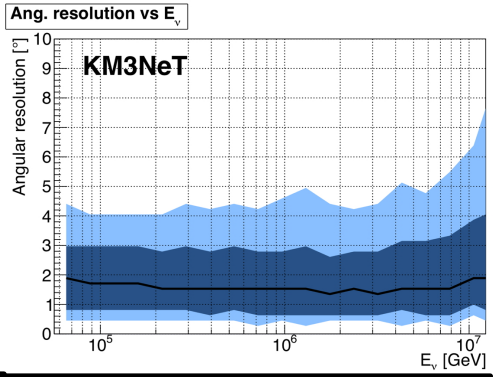
Energy resolution about 0.3 in logEμ



Angular resolution about 0.1° (E_ν>10 TeV)



Energy resolution about 10%

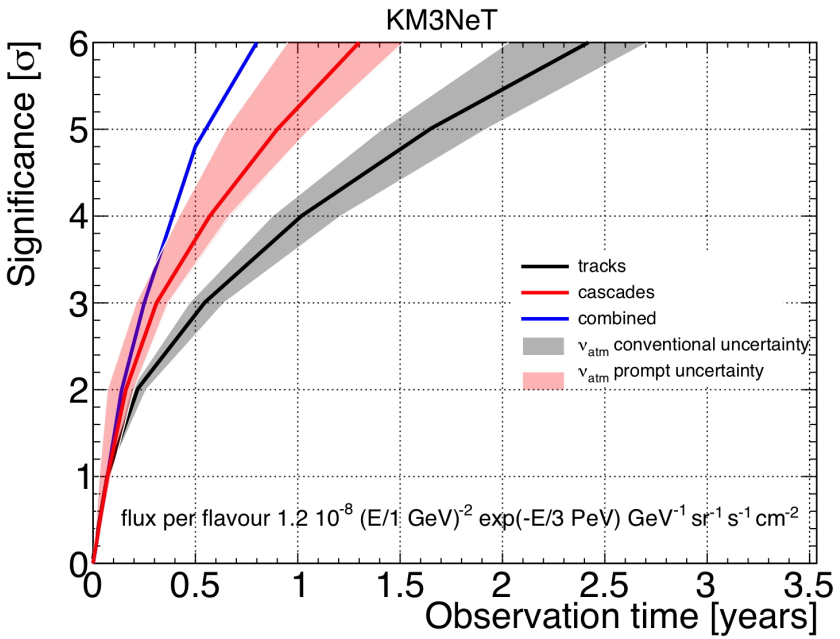


Angular resolution about 2° (E_ν>10 TeV)

SENSITIVITY TO ICEBUBE NEUTRINO FLUX

ALL FLAVOR ANALYSIS

- **Track channel:** analysis for up-going events based on Max. likelihood
  - Pre-Cuts on θ_{zen} >80°, Λ (reconstruction quality parameter), N_{hit} (number of hits -> parameter related to the muon energy)
- **Cascade channel**: contained events
  - **Vertex cut**: cut on position of reconstructed vertex (z<200m AND r<500m)
  - **Energy cut**: cut on the total ToT of the event (ToT>12 μs)

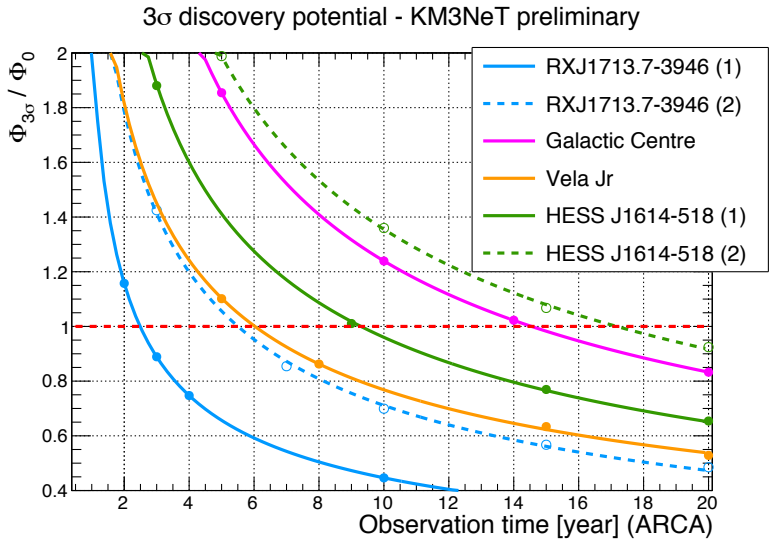


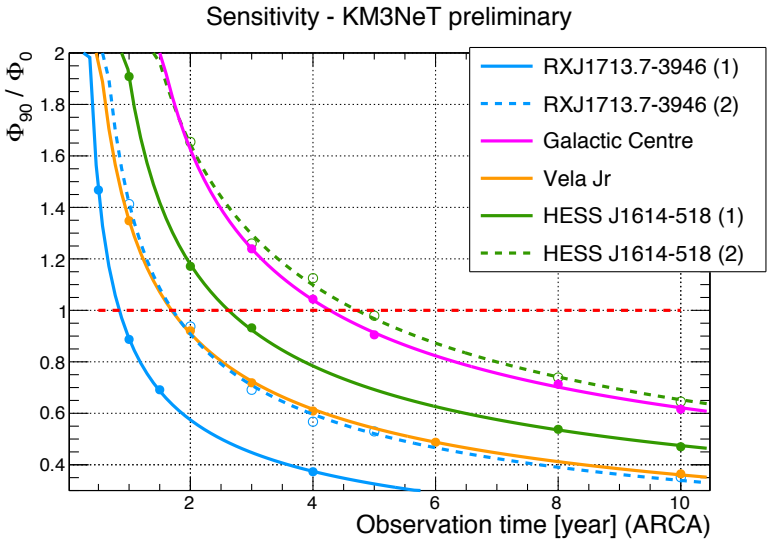
LoI => Combined discovery at 5σ significance (50% probability) in less than one year

Updated results on track anlalysis (R. Coniglione ICRC2017) => 5σ in one year!!!

GALACTIC SOURCES

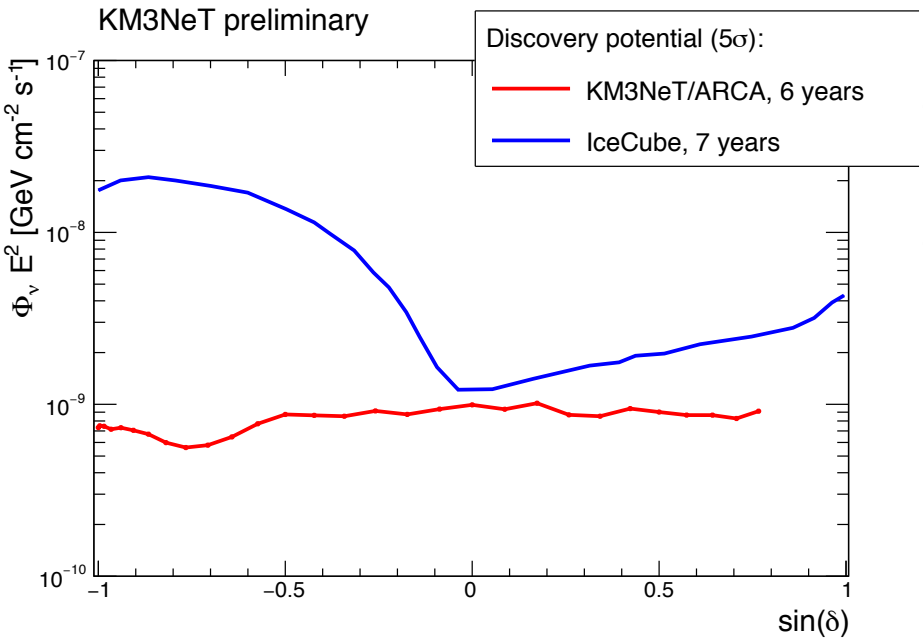
Sensitivity to Galactic sources calculated with ν fluxes estimated from HE γ observed fluxes in the hypothesis of fully hadronic emission and 100% transparent sources

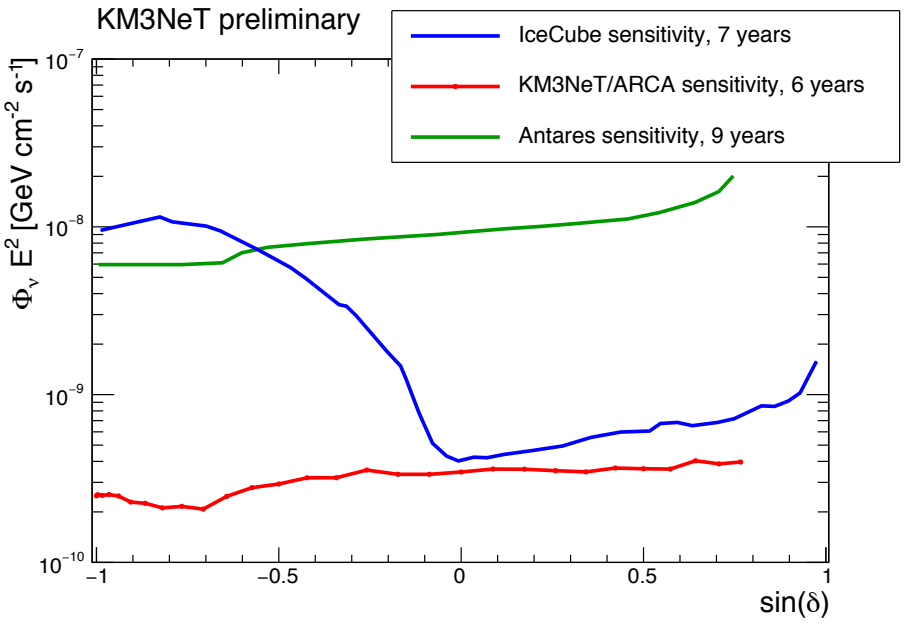




Good perspectives for ν detection and/or model constraints for galactic sources (also Fermi Bubbles, Galactic, Plane, …)

Sensitivity to point-like sources for ν_μ





- ARCA can survey almost the whole sky with a discovery potential @ 5σ about one order of magnitude better than IceCube in the Southern hemisphere for equivalent exposure

- ARCA will have a sensitivity better by more than a factor 20 w.r.t. ANTARES

CONCLUSIONS

- KM3NeT entered the construction phase
  - first two strings in the Capo Passero site operated for 1 year
  - data in agreementewith MC
- IceCube data expected to be confirmed in less than 1 year of full exposure
- Good perspectives for Galactic source detection (point-like, Galactic halo, …) due to km3net location

KM3NeT Collaboration

- 12 Countries
- >40 Institutes
- >220 Scientists

South Africa recently joint the Collaboration