High energy neutrino detection with KM3NeT/ARCA

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What is KM3NeT?

KM3NeT aims to be the largest deep sea infrastructure in Mediterranean Sea consisting of a network of neutrino telescopes with user ports for earth and sea sciences. Its physics goals are:
- High energy neutrino astronomy (TeV-PeV energy range)
- Measurement of fundamental neutrino properties (GeV energy range)

ARCA- Astroparticle Research with Cosmics in the Abyss @KM3NeT-It
ORCA- Oscillation Research with Cosmics in the Abyss @KM3NeT-Fr

(see KM3NeT – ORCA: Measuring the neutrino mass hierarchy in the Mediterranean Antoine Kouchner this conference)
Physics with a Neutrino Telescope

Opening a new window on the universe
- Supernova neutrinos
- Cosmic rays
- Atmospheric neutrinos
- Diffuse astrophysical neutrino fluxes
- Extended neutrino sources
- Point sources
- Transient sources

Closing in on fundamental physics
- Charm production
- Neutrino oscillations
- Dark Matter
- Exotic particles (magnetic monopoles, Q balls)
- Lorentz invariance violation
- Quantum decoherence
## Phased implementation

<table>
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<th>Phase</th>
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<th>Primary deliverables</th>
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</table>
| 1     | 0.2    | Proof of feasibility and first science results  
(6 ORCA strings/24 ARCA strings by end 2016) |
| 2.0   | 2      | **Neutrino astronomy with ARCA**  
– focus on Galactic sources ("Raison d’être")  
– measurement of the IceCube signal with different methodology, improved resolution and complementary field of view  
– break-through capability of doing all-flavour neutrino astronomy |
|       | 1      | **Neutrino physics with ORCA**  
– first determination of neutrino mass hierarchy (faster, better and cheaper)  
– improve measurements of neutrino oscillation parameters  
– essential and timely input for CP-violation experiments |
KM3NeT Phase-1

KM3NeT Phase-1: Proof of feasibility of network of neutrino detectors

Started in January 2014
Funded with 31 million Euro
Detection Unit deployment in 2015-2016
Two sites
  KM3NeT-It (24 Strings + 8 towers)
  KM3NeT-Fr (7 DUs)

KM3NeT-It instrumented volume is 0.1 km$^3$, i.e. 10 times larger than Antares
KM3NeT building Block (115 DUs)
The Multi-PMT Digital Optical Module

- Digital photon counting
- Directional information
- Wide angle of view

17 inch
Each single PMTs is tested and calibrated. 120 PMTs are tested daily.
Detection Unit prototype (PPM-DU)

Prototype DU with three DOMs
Deployed at the KM3NeT-It site at 3500m depth
Followed successful operation of prototype DOM at the ANTARES site

Operational since May 2014
Proof of DU concept functionality
Test of readout, DAQ, connection, intra-DOM and inter-DOM synchronization
PPM-DU results

Photon counting

High level coincidences cleanly select muon events

Directional sensitivity

Muon events (coincidence level > 7)
PPM-DU: DOM intra&inter-calibration

DOM intra-calibration is performed by using $^{40}\text{K}$.

DOM inter-calibration is performed by using dedicated runs with the LED nanobeacon activated.

The distribution of the time differences between DOM1&DOM2 and DOM1&DOM3 when all 3 DOMs are in coincidence is shown.
First full DU already integrated and ready for deployment at the KM3NeT-Fr site
Integration of the second DU in progress. To be deployed at the KM3NeT-It site
Resolution for track reconstruction

Angular resolution
about 0.2° \((E_\nu > 10 \text{ TeV})\)

Energy resolution
0.26 in \(\log E_\mu\)
\((1 \text{ TeV} < E_\nu < 100 \text{ PeV})\)
Resolution for shower reconstruction

Angular and energy resolution for the event sample after the final cuts of the diffuse cascade analysis

Angular resolution vs $E_{\text{reco}}$

Energy resolution < 10%
KM3NeT/ARCA main physics goals

• Diffuse high-energy neutrino fluxes
  – We assume as benchmark the IceCube flux (isotropic and flavour symmetric)

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

M.G. Aartsen et al., Science 342 (2013) 1242856

• Neutrino point-like sources
  – We assume as benchmark the most intense galactic TeV gamma sources
Sensitivity to neutrino diffuse flux

Time needed to perform a $5\sigma$ significance discovery with a 50% probability
Diffuse flux from the galactic plane

ARCA performance to a flux from a region of the Galactic Plane near the Galactic Center Evaluation of the neutrino flux based on a radially-dependent cosmic-ray transport properties

D.Grasso this conference

Time needed to perform a 5σ significance discovery with a 50% probability
Galactic sources with ARCA

HE gamma emission observed by HESS in SNRs
Neutrino spectra predicted using gamma spectra


Hypotheses: 100% hadronic emission and transparent source

Vela X: $3\sigma$ in about 2 years
RXJ1713: $3\sigma$ in about 4 years
ARCA discovery potential for $E^{-2}$ sources

Better sensitivity (for equivalent exposure) and better sky coverage than IceCube
Conclusion

• First phase of Km3NeT is fully funded and under construction

• ARCA (about 1km$^3$) will be installed at the KM3NeT-It node of the KM3NeT infrastructure

• Very interesting and exciting physics
  – Investigate the neutrino sky with unprecedented resolution and sky coverage