Status of the KM3NeT/ARCA telescope
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The KM3NeT project

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

KM3NeT/ARCA (Astroparticle Research with Cosmics in the Abyss, this talk)

• discovery and observation of high energy (GeV ÷ PeV) neutrino sources of cosmic origin

KM3NeT/ORCA (Oscillation Research with Cosmics in the Abyss) (Liam Quinn’s talk in this conference)

• determination of the neutrino mass hierarchy (neutrinos of tens of GeV)

ORCA and ARCA have same detector technology. Details on the ARCA and ORCA physics performances and on the technical design in our Letter of Intent 2016 J. Phys. G: Nucl. Part. Phys. 43 084001
Neutrino detection channels

\[\nu_\mu \xrightarrow{CC} \mu + \text{shower}\]
\[\nu_\ell \xrightarrow{NC} \nu'_\ell + \text{shower}\]
\[\nu_e \xrightarrow{CC} \text{shower}\]
\[\nu_\tau \xrightarrow{CC} \tau + \text{shower}\]
\[\tau \xrightarrow{\approx83\%} \nu_\tau + \text{shower}\]
\[\tau \xrightarrow{\approx17\%} \nu_\tau + \mu + \bar{\nu}_\mu\]

Muons:
highest effective area, good angular resolution (~0.1°)
High atmospheric muon background: look at events from below only

Showers:
Remove atmospheric muon background: studies over 4\pi.
‘Good’ energy resolution, worse directional resolution: diffuse flux!

Taus:
Unambiguous topology

EPS-HEP 2017
Venice, 5-12 July 2017
A second km³ neutrino telescope

Full sky coverage

- Extragalactic
- Galactic
- Galactic centre

1.5 π sr common view per day

IceCube (South Pole)

KM3NeT (Mediterranean)

Galactic coordinates
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 detection unit and the optical sensors

The Launcher vehicle (2m diameter)
- rapid deployment
- autonomous unfurling
- recoverable

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 area ≃ 3 x 10” PMTs)
- LED beacon and acoustic piezoelectric
- FPGA readout

White rabbit technology for time synchronization
DWDM for data transmission
The KM3NeT phased implementation

<table>
<thead>
<tr>
<th>Phase</th>
<th>Building blocks</th>
<th>Number of DUs</th>
<th>Physics goal</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>ARCA</td>
<td>ORCA</td>
<td>ARCA</td>
<td>ORCA</td>
</tr>
<tr>
<td>1</td>
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<tr>
<td>3</td>
<td>6</td>
<td>-</td>
<td>690</td>
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Two strings deployed at Capo Passero site: the first one deployed in December 2015, the second one in May 2016.

ARCA phase-1 footprint

ARCA phase-1 will be ≈ 0.1 km³
Self-calibration: $^{40}\text{K}$

- Natural radioactive decays from $^{40}\text{K}$
  - Cherenkov light
  - $\sim5$ kHz rate in PMTs
  - Filtered by CPUs at on-shore DAQ
  - Self-calibration mechanism!

- Calibration tells us:
  - Time offset (centre)
  - Relative efficiency (area)
  - Single-photon spread (width)

- Long-term stability observed
Inter-DOM calibration

Time calibration check with LED beacons and atmospherics muons

- LED beacon
- Atmospheric Muons

LED: Low intensity (DOM pairs)

LED: High intensity (>1/2 DU!)
Muon Depth Dependence

KM3NeT/ARCA preliminary

40K decay

μ
depth

EPS-HEP 2017 Venice, 5-12 July 2017
KM3NeT/ARCA Phase 2

- ARCA: 2 blocks:
  - 115 ‘detection units’ per block
  - 90m horizontal spacing

- Detection unit:
  - Line anchored to the sea floor
  - 18 optical modules, 36m spacing

- Total volume: 1 km³

- Site: 3.5 km depth, Capo Passero (Sicily)
Angular and energy resolution

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

Simulated track event

<table>
<thead>
<tr>
<th>KM3NeT</th>
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<tbody>
<tr>
<td>IceCube through-going muon CC</td>
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<tr>
<td>1 $\sigma$</td>
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</table>

Angular resolution [°]

$<0.1^\circ$ (E$>10$ TeV)

Number of Events

10 TeV $\leq E_\mu \leq$ 100 PeV

0.3 Log E

Gaussian fit:
- Entries: 19569
- Mean: -0.01
- Sigma: 0.27
Angular and energy resolution

“Cascade-like” events mainly from $v_e$ CC and NC interactions

Simulated cascade event

Angular resolution vs $E_\nu$

**KM3NeT**

IceCube HESE
PRL 113 101101

Angular resolution better than 2°

Energy resolution better $\approx 5\%$ at 1σ
Sensitivity to diffuse fluxes

Benchmark flux: IceCube flux (isotropic and flavour symmetric)

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

Goal: don’t just re-discover the IceCube flux, investigate it!

- Track channel
  Analysis for up-going events based on maximum likelihood of preselected events. Pre-cuts on $\theta_{\text{zen}} > 80^\circ$, reconstruction quality parameter and Nhit (proxy for muon energy)

- Cascade channel
  Containment cut on reconstructed vertex to remove atmospheric muons (excludes upper 100m layer)
  All sky analysis based on BDT and maximum likelihood.
Source identification

Visibility of Galactic Plane + Galactic Center
Better angular resolution in water will help the source identification

Point-like sources

Galactic (SNRs) sources

Up-going muon neutrinos analysis
Better sensitivity (for equivalent exposure) and better sky coverage than IceCube

For ANTARES see Annarita Margiotta’s talks

Spectra cutoffs of the order of few tens of TeV
Source extension taken into account (0.6° for RXJ1713 and 0.8° for Vela X)

Conclusions

KM3NeT/ARCA will soon take over as the biggest neutrino telescope in the Northern Hemisphere (KM3NeT phase-1 will be \( \approx 0.1 \text{ km}^3 \))

KM3NeT phase-1: 2 DUs of ARCA already installed at the Italian site

Data under analysis: time calibration, check of Monte Carlo simulations, atmospheric muons...

Following phase KM3NeT 2.0

KM3NeT/ARCA (\( \approx 1 \text{ km}^3 \)) will be installed at the Italian node of the KM3NeT distributed infrastructure

Exciting physics prospects:

- Excellent angular resolution: perform neutrino astronomy
- Study IceCube flux from a different hemisphere
- Discover galactic plane emission, and galactic sources