The Neutrino Telescope of the KM3NeT Deep-Sea Research Infrastructure

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Outline

• Objectives and Physics Case
• Technical Design and Implementation
• Optical Modules and Electronics
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What is KM3NeT?

- Future cubic-kilometre scale neutrino telescope in the Mediterranean Sea
- Exceeds Northern-hemisphere telescopes by factor ~100 in sensitivity
- Exceeds IceCube sensitivity by substantial factor
- Provides node for earth and marine sciences (continuous deep-sea measurements)
KM3NeT Organisation

The KM3NeT consortium:

- 40 European institutes
  including those from Antares, Nemo and Nestor neutrino telescope projects
- 10 countries
  (Cyprus, France, Germany, Greece, Ireland, Italy, The Netherlands, Rumania, Spain, U.K)

TDR published: http://www.km3net.org/TDR/KM3NeT-TDR.pdf (ISBN 978-90-6488-033-9)
South Pole and Mediterranean Fields of View

2π downward sensitivity assumed

In Mediterranean, visibility of given source can be limited to less than 24h per day
The Objectives

• **Central physics goals:**
  – Investigate neutrino “point sources” in energy regime 1-100 TeV
  – Complement IceCube field of view
  – Substantially exceed IceCube sensitivity
  – Topics not used for optimisation:
    - Dark Matter
    - Neutrino particle physics aspects
    - Exotics (Magnetic Monopoles, Lorentz invariance violation, …)

• **Implementation requirements:**
  – Construction time ≤5 years
  – Operation over at least 10 years without “major maintenance”
• Objectives and Physics Case
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• Optical Modules and Electronics
KM3NeT in the Mediterranean Sea

- Long-term site characterisation measurements performed during the Design Study at three different locations: Toulon (ANTARES), Capo Passero (NEMO), Pylos area (NESTOR)

- Infrastructure of networked KM3NeT nodes foreseen
Technical Design

Objective: Support 3D-array of photodetectors and connect them to shore (data, power, slow control)

- Optical Modules
- Front-end electronics
- Readout, data acquisition, data transport
- Mechanical structures, backbone cable
- General deployment strategy
- Sea-bed network: cables, junction boxes
- Calibration devices
- Shore infrastructure
- Assembly, transport, logistics
- Risk analysis and quality control

Design rationale:
Cost-effective
Reliable
Producible
Easy to deploy

Unique or preferred solutions
The Deep Sea environment

One of the most adverse places for a technical installation:

- High pressure (~200bar at 2km)
- Salt water: highly corrosive environment
- Long distance from shore for communication
- Forces on structure due to sea currents
- Wet-mateable connectors required

Acoustic position calibration:

Optical calibration:
See poster #13 by U. Emanuele
**KM3Net Detection Unit**

Detection unit (DU): 20 storeys / 40 m distance (DU height ~ 900 m)

storey: bar of 6 m with 2 DOMs

DOM: digital optical module with 31 3” PMT
Surface area = \( \pi R^2 = 4.2 \text{ km}^2 \)

\( R = 1160 \text{ m} \)

Instrumented volume = \( \pi R^2 h \)
\( h = 760 \text{ m (19x40)} \)
\( V_{\text{inst}} \approx 3 \text{ km}^3 \)

2 Building Blocks will make up KM3NeT

Budget \approx 220 \text{ M€}
Data Network and Data Transmission

- All data to shore concept (no trigger undersea)
- Data transport on optical fibers (data, slow control)
  - Optical point-to-point connection DOM-shore ⇒ large number of channels
  - DWDM (Dense Wavelength Division Multiplexing) technique: signals carried by different frequencies (colors) over the same fibre ⇒ minimize number of fibers

Alternative option:

- Ring geometry

Star geometry of power and fibre distribution

EOC  = electro-optical cable
MVC  = main voltage converter
PJB   = primary junction box
SJB   = secondary junction box
Optical Network

Dense Wavelength Division Multiplexing:
Following ITU Grid Specification:
C (1530-1570 nm) or L band (1570-1610 nm)
with 25GHz separation

Up to ~80 λ / fibre
< 10 Gbps P2P
Up to ~70 fibres in main cable

Time delay measurements possible
• Objectives and Physics Case
• Technical Design and Implementation
• Optical Modules and Electronics
DOM (Digital Optical Module)

Multi-PMT Design:
- Large photocathode area per OM
- Single vs. multi-photon hit separation

- Sphere Ø17"
- PMTs (19+12) Ø3"
- Base
  - Adjust. HV (800-1400V)
  - Comparator for time-over-threshold
- Power board, electronics
- Calibration devices
- Single penetrator
Photo Multiplier Tubes

Requirements:
Quantum efficiency (QE) at 404nm >32% (>20% @ 470nm)
Transit time spread (TTS) <2ns (sigma)
Gain $5 \times 10^6$

Requirements adapted to in-situ conditions:
- Cherenkov photon spectrum in Mediterranean Sea most intense between ~400nm and ~500nm
- Chromatic dispersion sets lower level of required TTS

Prototype tubes from company ETEL:
DOMs: Recent Technical Progress

Concentrator ring

Increases effective photocathode area by 20-40%

Ring simplifies PMT fixture
Front End Electronics

Time-over-threshold (TOT):

Two options for readout

Analog signal → Comparator
(levels set through I²C control) → LVDS signal → "Scott chip" (ASIC) → TDC → FPGA
(system on chip)

Time stamped "hits"

TOT count (time stamp in FPGA)

Timing resolution of ~1ns required

Scott = Sampler of Comparator Outputs with Time Tagging

TDC = Time to Digital Converter

Scott chip

FPGA

31x
Summary and Conclusions

• Major technical design decisions taken, minor points optimised for mass production
• In-situ operation of prototype Detection Unit planned for first half of 2012
• Footprint being optimised for detection of Galactic sources
• Infrastructure of networked KM3NeT nodes most likely scenario
• Data taking could start 2014

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