News from KM3NeT

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The plan for the next 30 minutes:

- Why KM3NeT?
- Decisions taken: Technology and sites
- Tests and prototypes
- Next steps
- Summary

Not included: ORCA case study (see talk by A. Tsirigotis)
Why KM3NeT
What is KM3NeT?

- Future research infrastructure in the Mediterranean Sea
- Includes cubic-kilometre scale neutrino telescope
- Exceeds Northern-hemisphere telescopes by factor ~50 in sensitivity
- Exceeds IceCube sensitivity by substantial factor
- Provides node for earth and marine sciences
South Pole and Mediterranean fields of view

Galactic coordinates

$2\pi$ downward sensitivity assumed (true below some 10 TeV)

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

Galactic sources expected at $\nu$ energies below 100 TeV → Mostly visible from Northern hemisphere

For any given $\nu$ energy, the fields of view are complementary

Figure courtesy A. Kappes
Sensitivity to Galactic sources

- Supernova Remnants
  - RXJ1713.7-3946 (prime example)
  - Vela X (exciting option after update of H.E.S. data)

Priority physics objective of KM3NeT

→ Talk Paul Kooijman

- Fermi Bubbles
  → Talk Paolo Piattelli
Discovery potential for Supernova remnants

- Simulation results for 2 x 310 strings
- $5\sigma$ discovery in less than 5 years for RXJ1713.7-3946 (unbinned analysis)
- Even higher sensitivity for Vela X
- SNR neutrino fluxes ($E^{-2}$ spectrum with cutoff) used for detector optimisation

![Graph showing RXJ1713 sensitivity for different string distances]

- Time for $5\sigma$ discovery for different string distances
- DU distance (m)
  - Unbinned analysis
  - Binned analysis

U. Katz: KM3NeT, VLVnT13, 05.08.2013
The Fermi bubbles

- Two extended regions above/below centre of Galactic plane
- Fermi detected hard $\gamma$ emission ($E^{-2}$) up to 100 GeV
- Origin and acceleration mechanisms under debate – if hadronic, hot neutrino source candidate
- Could be first source detected by KM3NeT

![Graph showing expected flux and cut-offs](image)

$E^2 \phi$ (GeV cm$^{-2}$ s$^{-1}$)

- $E^{-2}$, 30 TeV cut-off
- $E^{-2}$, 100 TeV cut-off
- $E^{-2}$, no cut-off

3σ @ 50%
5σ @ 50%
KM3NeT and the new IceCube results

• For Technical Design Report and design optimisation we focused on Galactic sources (µ channel, up-going)
  ➢ Cascade reconstruction and starting track analysis not yet available.
  ➢ In depth-studies under way (high priority).
  ➢ No results ready for this workshop.

• Required: Assumption on the nature of the signal
  ➢ Isotropic (?)
  ➢ Flavour-symmetric
  ➢ \( E^{-2} \) flux with cutoff around 2 PeV (?)

• Detector re-optimisation possible for phase-2, not for phase-1
Decisions taken
Flashback end-2009 (after Design Study):

- Which architecture to use?
  (strings vs. towers vs. new design)

- Design of photo-detection units?
  (large vs. several small PMs, directionality, ...)

- Readout and data acquisition?
  (how to implement? custom-built ASIC vs. FPGA, ...)

- Deployment technology?
  (2 types of “Compactify and unfurl” vs. traditional)

- And finally: (path to) site decision.

2013: All solved and decided!
KM3NeT: a distributed Research Infrastructure

- Centrally managed
- Common hardware
- Common software, data handling and operation control
- Sites in France, Greece, Italy
- Consistent with funding structure (regional sources)
**KM3NeT Sites**

- **KM3NeT-France**: Toulon

- **KM3NeT-Italy**: Capo Passero

- **KM3NeT-Greece**: Pylos

- Long-term site characterisation measurements performed
The building block concept

- Building block:
  - 115 detection units
  - Segmentation enforced by technical reasons
  - Sensitivity for muons independent of block size above ~75 strings
  - One block ~ half IceCube

- Geometry parameters optimised for galactic sources (E cut-off)
- Technical feasibility verified
- KM3NeT includes 6 building blocks

Simulated configuration: 115 DUs, 90m distance on average
Detection units: Strings

- **Mooring line:**
  - Buoy (probably syntactic foam)
  - 2 Dyneema® ropes (4 mm diameter)
  - 18 storeys (one OM each), 36m distance, 100m anchor-first storey

- **Electro-optical backbone (VEOC):**
  - Flexible hose ~ 6mm diameter
  - Oil-filled
  - fibres and copper wires
  - At each storey: connection to 1 fibre+2 wires
  - Break out box with fuses at each storey: One single pressure transition
Hydrodynamic stability

- DUs move under drag of sea current
  - Currents of up to 30cm/s observed
  - Mostly homogeneous over detector volume
  - Deviation from vertical at top about 150m at 30cm/s (can be reduced by extra buoyancy)
  - Critical current ~45cm/s (anchor starts to move)
OM with many small PMTs

- 31 3-inch PMTs in 17-inch glass sphere (cathode area~ 3x10” PMTs)
  - 19 in lower, 12 in upper hemisphere
  - Suspended by plastic structure
- 31 PMT bases (total ~140 mW) (D)
- Front-end electronics (B,C)
- Al cooling shield and stem (A)
- Single penetrator
- 2mm optical gel
More on the KM3NeT digital OM (DOM)

- Light collection device
  - 20–40% gain in effective photocathode area

- Low power
  - <10 W / DOM

- FPGA readout
  - for each individual PMT
  - sub-ns time stamping
  - time over threshold

- Calibration
  - LED & acoustic piezo

- Optical fibre data transmission
  - DWDM with 80 wavelengths
  - Gb/s readout
Advantages of the KM3NeT DOM

- Increased photocathode area
  - 1 KM3NeT DOM = 3 ANTARES OMs
  - Reduces numbers of penetrations/connectors (expensive & risky)
  - Reduces number of optical modules and their infrastructure (expensive)
- 1-vs.-2 photo-electron separation
  - Better sensitivity to coincidences / background suppression
  - Information at online data filter level
- Directionality
  - Additional input to reconstruction and veto algorithms
  - Identification of downgoing events (PMTs are also looking upwards)
  - Reduction of random background (K40, bioluminescence)
PMT availability

Hamamatsu R12199-02 (see talks by E. Leonora and G. Bourlis)

Talk by O. Kalekin:

ET Enterprises Ltd (ETEL, UK)
D783KFLA, D793KFLA – 78 mm
  104 pc  10 pc
D792KFLA – 90 mm
  12 pc

HZC (China) XP53
  7 pc  76 mm

Test sites:
Hellenic University, Nikhef, LNS INFN Catania and ECAP
Readout: time-over-threshold

From the analogue signal to time stamped digital data:

• Implemented for each PMT through FPGA on central logic board (CLB) contained in optical module
• All data to shore via optical fibres
• Time synchronisation and slow control
→ see presentations by D. Real and G. Kieft
Deployment strategy

- Compact package – deployment – self-unfurling
  - Eases logistics (in particular in case of several assembly lines)
  - Speeds up and eases deployment; several units can be deployed in one operation
  - Self-unfurling concept being thoroughly tested and verified
- Connection to seabed network by ROV
In detail: deploying strings

string rolled up for self-unfurling:
Tests and prototypes
String mechanical deployment tests

9 deployments 2-12 April at a depth of 1000m (NIOZ boat)  
20 miles off the coast of Motril, Spain

• Successful demonstration of deployment concept  
• DOMs are horizontal  
• VEOC cable → no leaks  
• Some issues with penetrators (understood)  
• Second test towards end of year
The Pre-production Optical Module

- Fully equipped DOM (31 PMTs + acoustic positioning sensors + time calibration LED beacon)
- Mounted on the Instrumentation Line of ANTARES (2475m deep)
- Internal reference: “PPM-DOM”
- Deployed and connected with ROV on 16 April 2013
- PPM-DOM fully operational and working well

→ see talk by T. Michel
PPM-DOM: K40 Coincidences

Concentration of $^{40}\text{K}$ is stable (coincidence rate ~5 Hz on adjacent PMTs)

Up to 150 Cherenkov photons per decay

$^{40}\text{Ca}$

$^{40}\text{K}$

$\gamma$

$\gamma$

$e^-$ ($\beta$ decay)

Coincidence rate on 2 adjacent PMTs

K$^{40}$ coincidence rate $\rightarrow$ PMT efficiencies

Peak position $\rightarrow$ time offsets

PRELIMINARY
PPM-DOM: Atmospheric Muons

Number of coincident hits in a DOM

>5 coincidences within 20ns ⇒ reduced K40 contribution, dominated by atmospheric muons

Zenith angle of hit PMTs in events with more than 6 coincident hits

More upper PMTs in multi-hit events ⇒ directional information from single storey
KM3NeT-Italy: site qualification

Connected by ROV
March 23, 2013

First continuous rate measurements

Long term monitoring of site characteristics
Next steps
KM3NeT Phase-1

• 40 M€ available (out of ~220 M€ estimated for full KM3NeT)
• Substantial part: European Regional Development Funds
  Must be spent by March 2015 → Use or lose!
• KM3NeT decided to embark on first construction phase
  • Transformation consortium → collaboration early 2013,
    management established, MoU in advanced state of preparation
  • Construction will start at Toulon and Capo Passero sites,
    very tight time schedule
  • Common technology, software, data handling, operation, governance
• Goals:
  • Provide Northern-hemisphere NT with unprecedented sensitivity
  • Demonstrate feasibility, operability, stability, resolutions, sensitivity
  • Provide infrastructural environment for phase-2
Seabed infrastructure

- Shore distances: 15km-100km → exact design site-dependent
- Power via main electro-optical cable (MEOC)
  - short distances (intra-detector): AC; long distances (shore-detector): DC
  - 24-36 Optical fibres
- Example: KM3NeT-France
  - 3 nodes per MEOC
  - 20 strings per node
  - sets of 4 strings in series
• Start with 8 towers (necessary to match spending profile and to demonstrate construction activity)
• Add 24 strings until 2015
• Level of common tower-string data under discussion
Towards KM3NeT phase-2

- KM3NeT-Greece (phase-1.5?)
  - Application pending (~15 M€)
  - If successful: Site development and first detector construction
  - Time scale for decision and implementation unclear

- Full installation (phase-2)
  - No firm commitments yet
  - Financial construction part of phase-1 program
  - ERIC planned (headquarter in Amsterdam)

- Future of neutrino astronomy will have global dimension
Summary
Summary

• KM3NeT will be a distributed, networked research infrastructure.
• Technical design is fixed and decided.
• Intense prototyping and test program ongoing; very encouraging results so far.
• First construction phase will start 2014 (KM3NeT phase-1).
• Path towards full implementation to be defined during phase-1.
• Considering global dimension for future planning will be crucial for neutrino astronomy.