KM3NeT: Towards a km$^3$ Mediterranean Neutrino Telescope

- Some Physics Arguments
- Aiming at a km$^3$ Detector in the Mediterranean Sea
- The KM3NeT Design Study and Beyond
- Conclusions and Outlook
ANTARES + NEMO + NESTOR join their efforts to prepare a km³-scale neutrino telescope in the Mediterranean → KM3NeT Design Study
Neutrinos from Astrophysical Point Sources

- Association of neutrinos to specific astrophysical objects.
- Energy spectrum, time structure, multi-messenger observations provide insight into physical processes inside source.
- Searches profit from very good angular resolution of water Čerenkov telescopes.
- km³ detectors needed to exploit full potential of neutrino astronomy.
Sky Coverage of Neutrino Telescopes

We need $\nu$ telescopes in both hemispheres to see the whole sky.
High-energy sources in the Galactic Center

- 5 sources could be/are associated with SNR, e.g. RX J1713.7;
- 3 could be pulsar wind nebulae, typically displaced from the pulsar;
- Some coincide with EGRET, ASCA, … unidentified sources;
- 3 have no counterpart known to us.

W. Hofmann, ICRC 2005
Neutrinos from Supernova Remnants

Example: SNR RX J1713.7 (shell-type supernova remnant)

- Acceleration beyond 100 TeV.
- Power-law energy spectrum, index ~2.1–2.2.
- Spectrum points to hadron acceleration $\rightarrow$ $\nu$ flux $\sim$ $\gamma$ flux
- Detectable in current & future neutrino telescopes?!
- Typical $\nu$ energies: few TeV

W. Hofmann, ICRC 2005
Arguments for a $\text{km}^3$ Volume

Solid theoretical arguments indicate that a cubic kilometer is the right volume for detection of

- neutrinos from specific astrophysical accelerators (point sources);

- neutrinos from the cosmic distribution of all neutrino sources (diffuse flux);

- neutrinos produced in interactions of cosmic rays with the cosmic microwave background (cosmogenic neutrinos).
Aiming at a km$^3$-Detector in the Mediterranean

HENAP Report to PaNAGIC, July 2002:

- “The observation of cosmic neutrinos above 100 GeV is of great scientific importance. ...“

- “... a km$^3$-scale detector in the Northern hemisphere should be built to complement the IceCube detector being constructed at the South Pole.”

- “The detector should be of km$^3$-scale, the construction of which is considered technically feasible.”
How to Design a km³ Deep-Sea ν Telescope

Existing telescopes “times 30”?  
- Too expensive  
- Too complicated: production & deployment takes forever, maintenance impossible  
- Not scalable (readout bandwidth, power, ...)

R&D needed:
- Cost-effective solutions to reduce price/volume by factor 2-5  
- Stability goal: maintenance-free detector  
- Fast installation time for construction & deployment less than detector life time  
- Improved components

- Large volume with same number of PMs?  
  - PM distance: given by absorption length in water (~60 m) and PM properties  
  - Efficiency loss for larger spacing

• Too expensive  
• Too complicated: production & deployment takes forever, maintenance impossible  
• Not scalable (readout bandwidth, power, ...)

09.11.2005
U. Katz: KM3NeT
KM3NeT Design Study: Participants

- **Cyprus:** Univ. Cyprus
- **France:** CEA/Saclay, CNRS/IN2P3 (CPP Marseille, IreS Strasbourg, APC Paris-7), Univ. Mulhouse/GRPHE, IFREMER
- **Germany:** Univ. Erlangen, Univ. Kiel
- **Greece:** HCMR, Hellenic Open Univ., NCSR Demokritos, NOA/Nestor, Univ. Athens
- **Italy:** CNR/ISMAR, INFN (Univs. Bari, Bologna, Catania, Genova, Napoli, Pisa, Roma-1, LNS Catania, LNF Frascati), INGV, Tecnomare SpA
- **Netherlands:** NIKHEF/FOM (incl. Univ. Amsterdam, Univ. Utrecht, KVI Groningen)
- **Spain:** IFIC/CSIC Valencia, Univ. Valencia, UP Valencia
- **UK:** Univ. Aberdeen, Univ. Leeds, Univ. Liverpool, Univ. Sheffield

Particle/Astroparticle institutes (29) – Sea science/technology institutes (7) – Coordinator
KM3NeT Design Study: History . . .

Design Study for a Deep-Sea Facility in the Mediterranean for Neutrino Astronomy and Associated Sciences

- Proposal submitted to EU 04.03.2004.
- Evaluation report received June 2004 (overall mark: 88%).
- Confirmation that Design Study will be funded (Sept. 2004).
- Invitation to negotiations with EU Commission (July 2005).
- Submission of “negotiation documents” 30.09.2005
- 2nd VLVνT Workshop, Catania, 08-11.11.2005
... and Presence

Message received from Brussels yesterday noon:

“The KM3NeT contract will be produced now and should be sent to you within 2 weeks for signature”

- Negotiations are successfully concluded.
- The EU will fund the KM3NeT Design Study with 9 million €.
- Total volume ~20 million €, ~370 person-years.
- Start date: February 1, 2006.
- Major objectives:
  - Conceptual Design Report by summer 2007;
Objectives and Scope of the Design Study

Establish path from current projects to KM3NeT:

- Critical review of current technical solutions;
- New developments, thorough tests;
- Comparative study of candidate sites (figure of merit: physics sensitivity / €);
- Assessment of quality control and assurance;
- Exploration of links to industry;
- Investigation of funding and governance models.

Envisaged time scale of design, construction and operation poses stringent conditions.
Some Key Questions

- Which architecture to use? (strings vs. towers vs. new design)
- How to get the data to shore? (optical vs. electric, electronics off-shore or on-shore)
- How to calibrate the detector? (separate calibration and detection units?)
- Design of photo-detection units? (large vs. several small PMs, directionality, ...)
- Deployment technology? (dry vs. wet by ROV/AUV vs. wet from surface)

And finally: path to site decision

All these questions are highly interconnected!
The KM3NeT Design Study Work Packages

- **WP1**: Management of the Design Study
- **WP2**: Physics analysis and simulation
- **WP3**: System and product engineering
- **WP4**: Information technology
- **WP5**: Shore and deep-sea infrastructure
- **WP6**: Sea surface infrastructure
- **WP7**: Risk assessment and quality assurance
- **WP8**: Resource exploration
- **WP9**: Associated sciences
Detector Architecture

(D. Zaborov at VLVνT)

50 floors
20 m step
6 floors,
PMs each
0 m step
homogeneous lattice of 20 x 20 x 20 downward-looking 10-inch photomultiplier tubes

25 towers, each consists of 7 strings of PMs
50 x 20 m = 1000 m
250 m
20 m
200 m
40 m
200 m

20 x 60 m = 1200 m
20 x 60 m = 1200 m
20 x 60 m = 1200 m

Top view

56 x 20 m = 1120 m
200 m
20 m
200 m

200 m
200 m
Sea Operations

- Rigid towers or flexible strings?
- Connection in air (no ROVs) or wet mateable connectors?
- Deployment from platform or boat?
Photo Detection: Options

- Large photocathode area with arrays of small PMs packed into pressure housings - low cost!
- Determination of photon direction, e.g. via multi-anodic PMs plus a matrix of Winston cones.
- But: phase space for developments from scratch is too tight.
Photo Detection: Requirements

Example of a device discussed: Hamamatsu HY0010 HPD
Excellent p.e. resolution

Glass pressure vessel ≤ 17 inch

Requirements for ν telescopes:
- High quantum efficiency
- Large photocathode areas
- Wide angular coverage
- Good single-photon resolution
- High dynamic range
Associated Sciences Node

Cable to shore

1. Array Data
2. Observatory Data
3. Test Data

Fixed Cable
ROV Moveable tether

M. Priede, Sept. 2005
KM3NeT: Political Environment

- **ESFRI** (European Strategy Forum on Research Infrastructures)
  - Charge: Assess future research infrastructures in Europe.
  - KM3NeT is on the *List of Opportunities* (first step).
  - Now: Evaluation of projects by expert groups;
    KM3NeT belongs to *Astrophysics and Astroparticles*  
    (presentation on Nov. 24, 2005).
  - Further steps: *Road Map* and *List of Priorities*.

- **EU**
  - Views KM3NeT as a long-term project; the Design Study is only the first step towards preparation, construction and exploitation.
  - The necessary political steps are to be initiated by the proponents in the Design Study phase.

- **National** support reinforced in several countries.
KM3NeT: Towards a Site Decision

- Final site decision involves scientific and political arguments (funding, host country support, ...).

- Objective of Design Study: Provide scientific input and stimulate political discussion.

- Possible scenario: Similar to Pierre Auger Observatory (two candidate sites, decision based on commitment of host country).

- Relation of funding options to site choice will be explored in Design Study.
KM3NeT: Path to Completion

Time scale given by "community lifetime" and the objective to take data concurrently with IceCube

**Time schedule (partly speculative & optimistic):**

- 01.02.2006: Start of Design Study
- Mid-2007: Conceptual Design Report
- February 2009: Technical Design Report
- 2009-2010: Preparation Phase (possibly in FP7)
- 2010-2012: Construction
- 2011-20xx: Data taking
Conclusions and Outlook

- Compelling **scientific arguments** for complementing IceCube with a km³-scale detector in the Northern Hemisphere.

- The Mediterranean-Sea neutrino telescope groups NESTOR, ANTARES and NEMO comprise the leading expertise in this field. They have **united their efforts** to prepare together the future, km³-scale deep-sea detector.

- An EU-funded **Design Study (KM3NeT)** will provide substantial resources for an intense 3-year R&D phase; start on February 1, 2006.