The Neutrino Telescope of the KM3NeT Deep-Sea Research Infrastructure

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TIPP 2011, Chicago
11-June-2011

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Outline

- Objectives and Physics Case
- Technical Design and Implementation
- Optical Modules and Electronics

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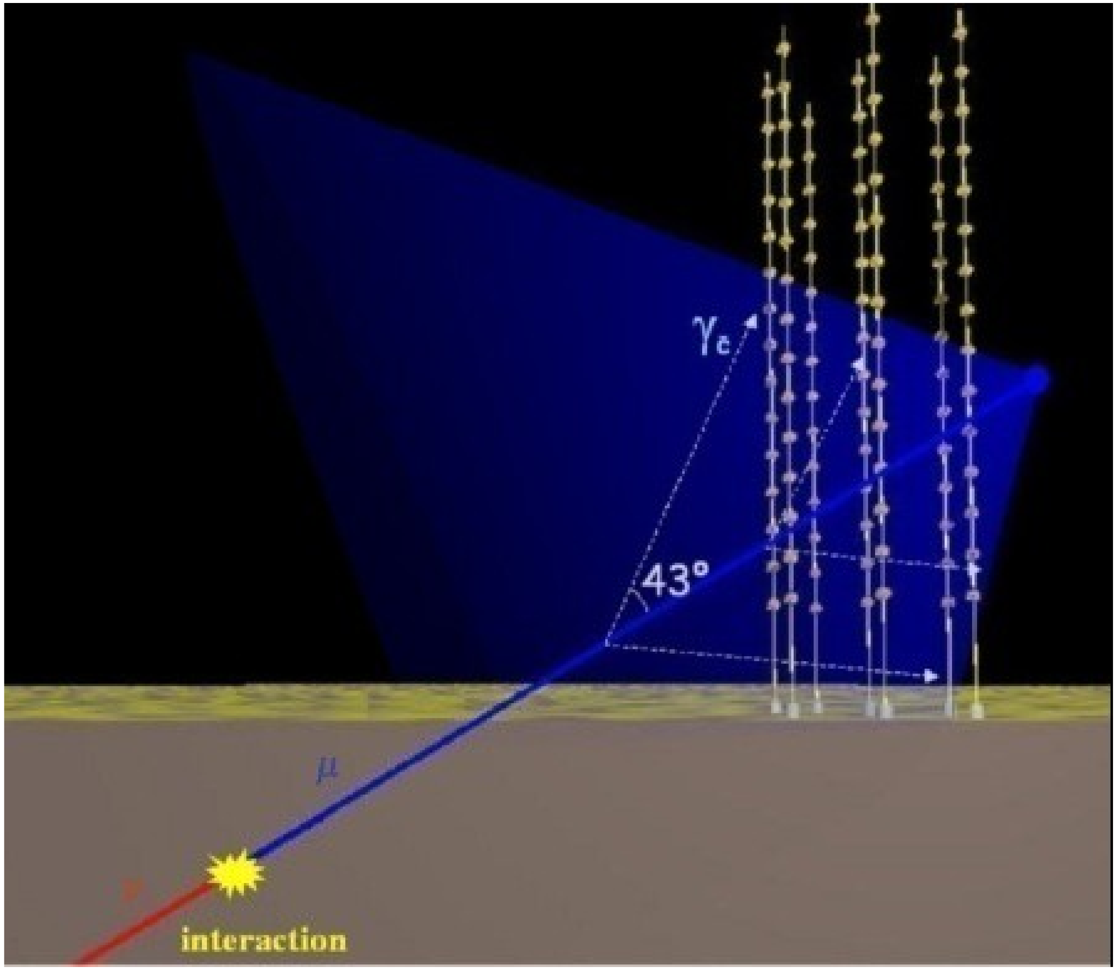
What is KM3NeT ?

- 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)



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KM3NeT Organisation

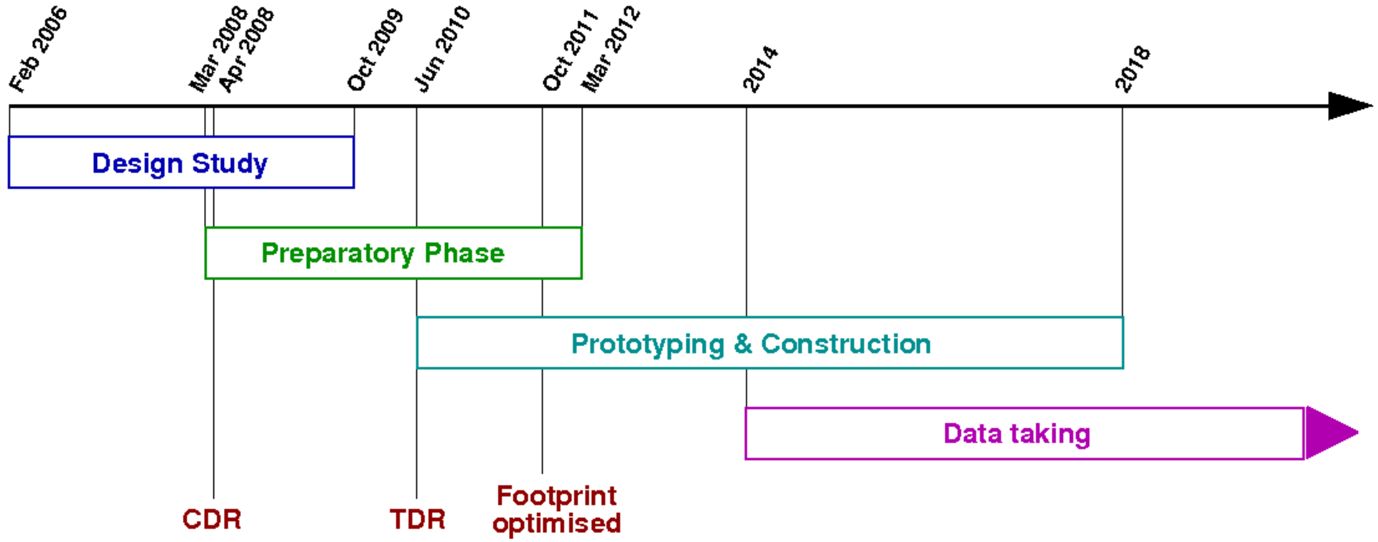
The KM3NeT consortium:

- 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)

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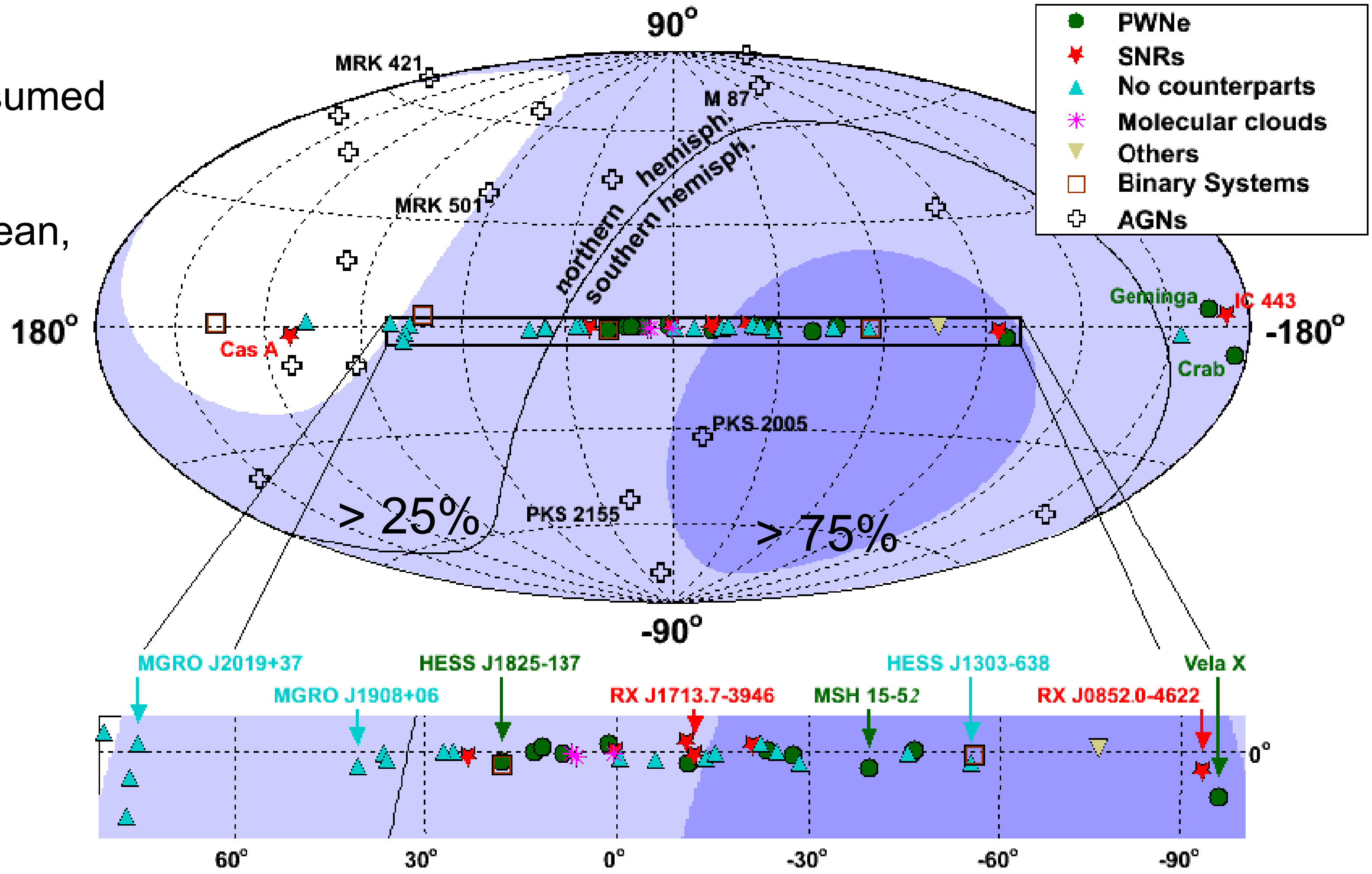
South Pole and Mediterranean Fields of View

2π downward sensitivity assumed

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



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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"

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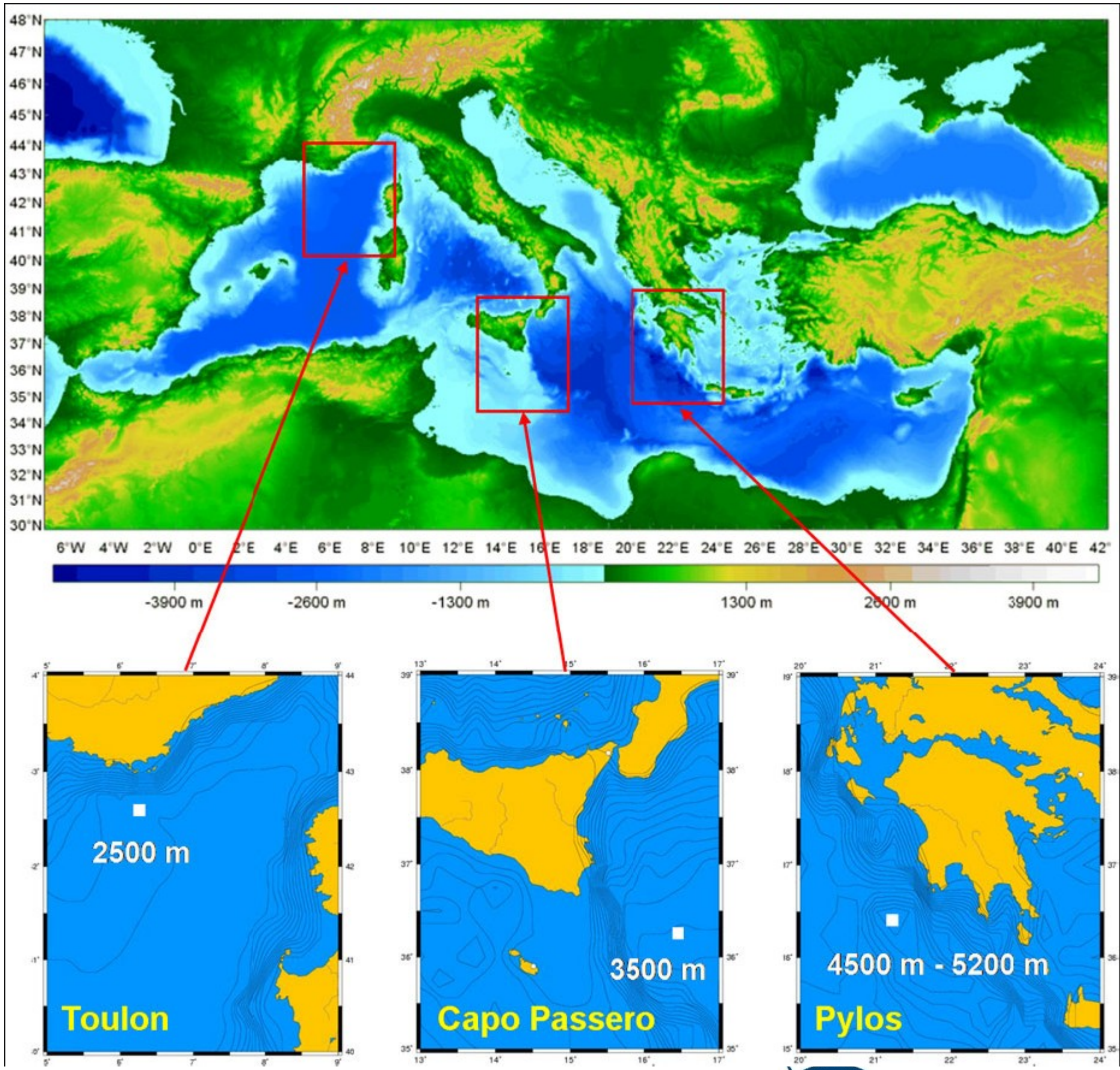
KM3NeT in the Mediterranean Sea

- 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

Unique or preferred solutions

Design rationale:

Cost-effective
Reliable
Producible
Easy to deploy

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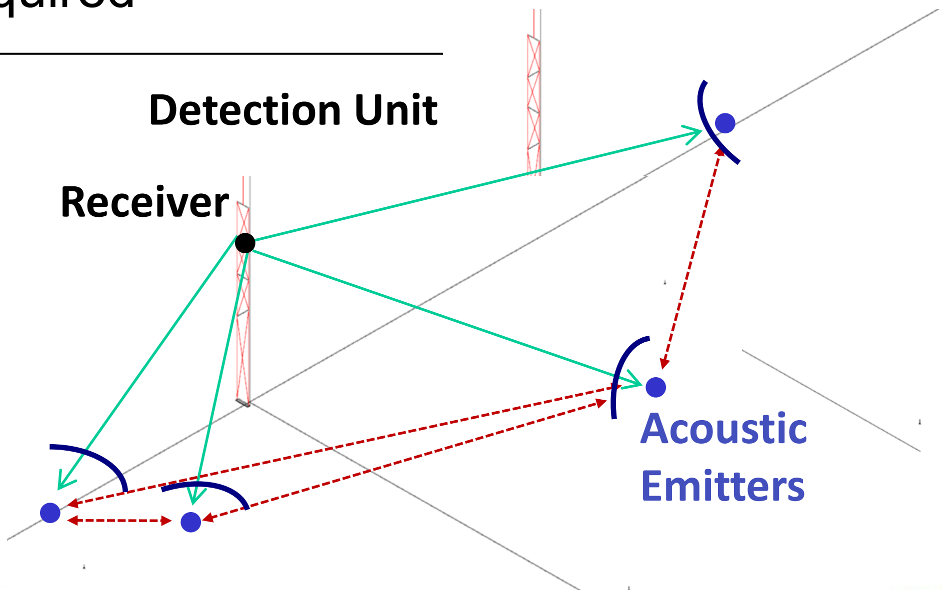
The Deep Sea environment

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

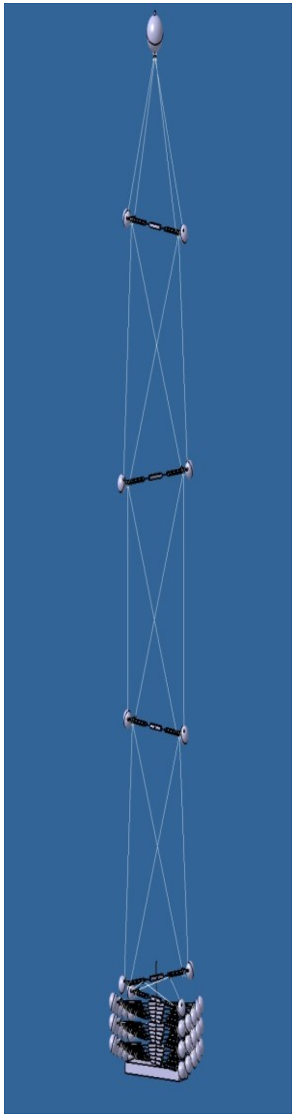
Acoustic position calibration:



Optical calibration:

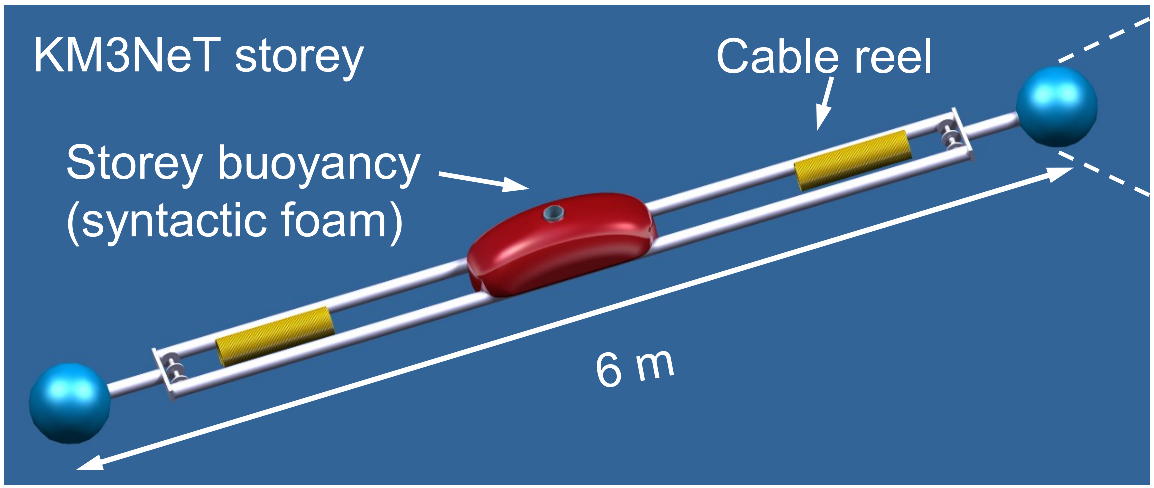
See poster #13 by U. Emanuele

KM3Net Detection Unit



KM3NeT DU

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



KM3NeT DOM

KM3NeT “Building Block” configuration

DU	St/DU	DOM/St.	PMT/DOM	PMT
154	20	2	31	190 960

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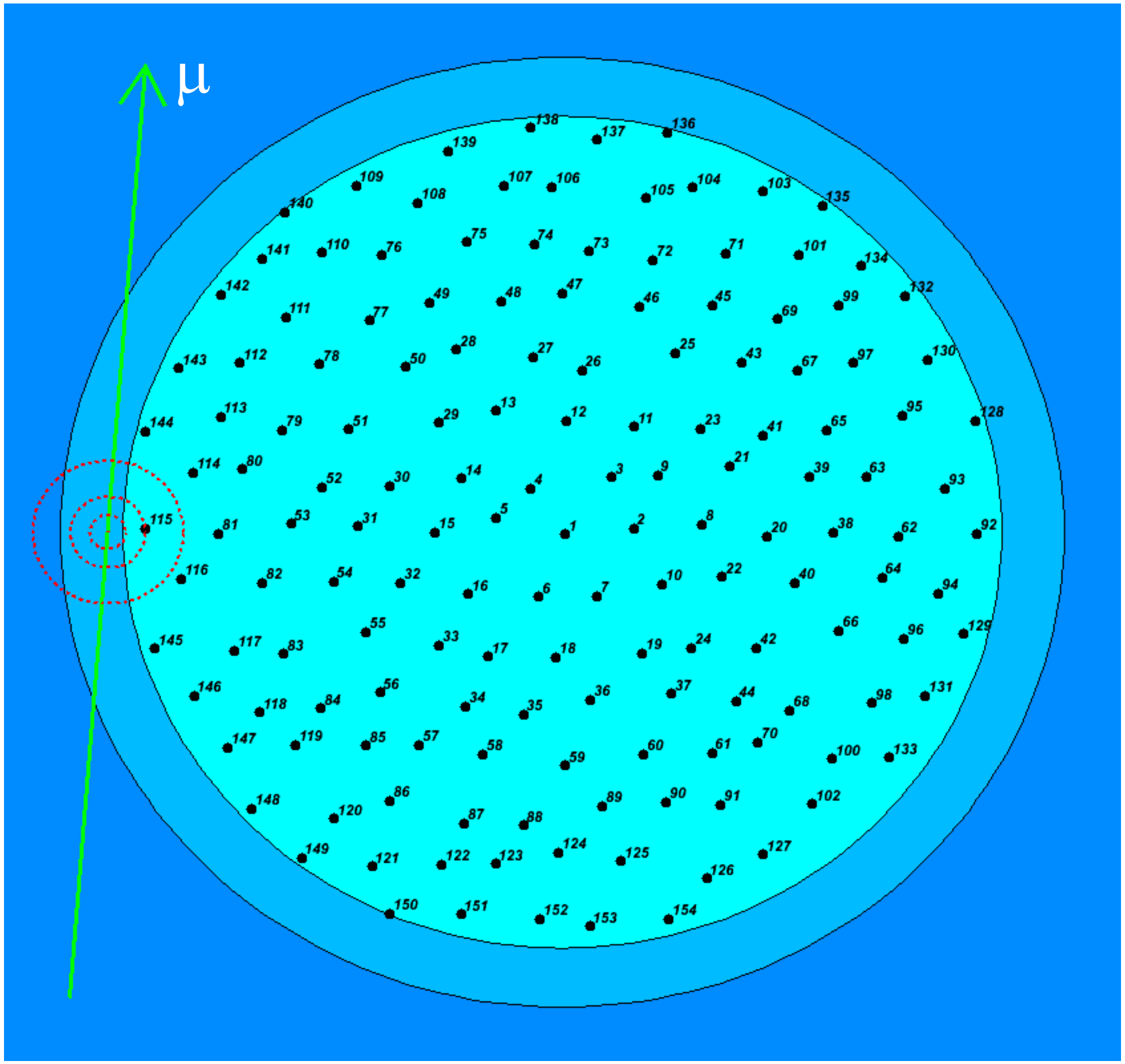
Detector Geometry



Building Block:
Currently considered option:
Randomised hexagonial grid

Surface area = $\pi R^2 = 4.2\ km^2$

R = 1160 m

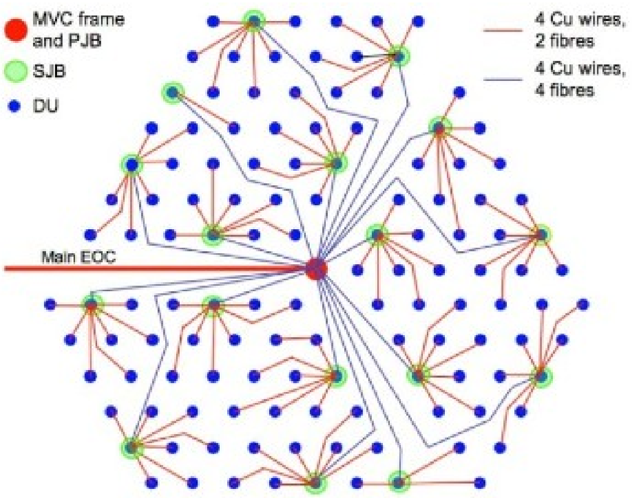
Instrumented volume = $\pi R^2 h$
h = 760m (19x40)
$V_{inst} \approx 3\ km^3$

2 Building Blocks will make up KM3NeT

Budget ~220 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



Star geometry of power and fibre distribution

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

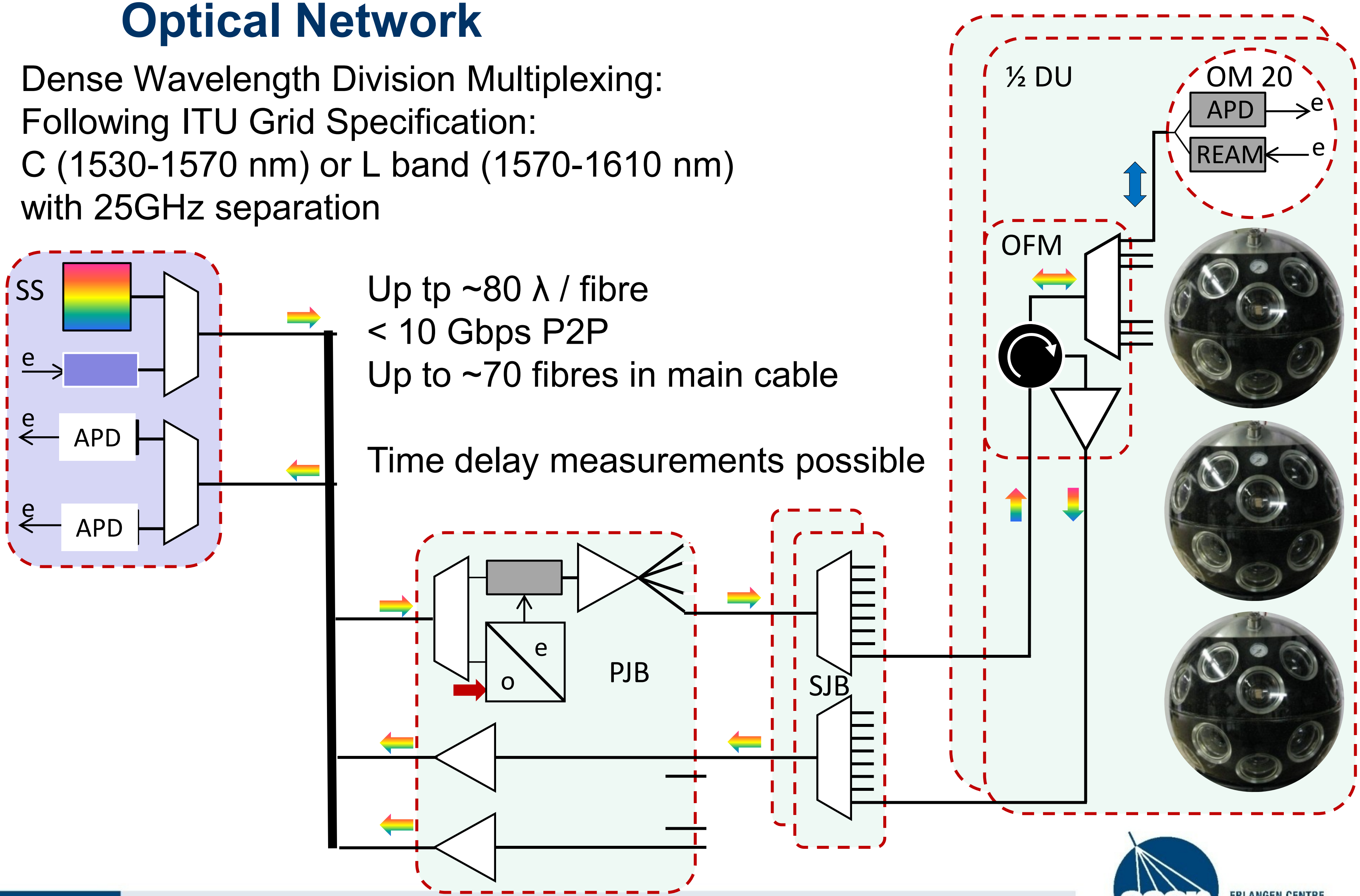
Alternative option: Ring geometry

Optical Network

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

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

Time delay measurements possible



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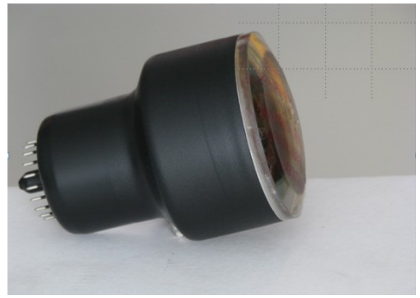
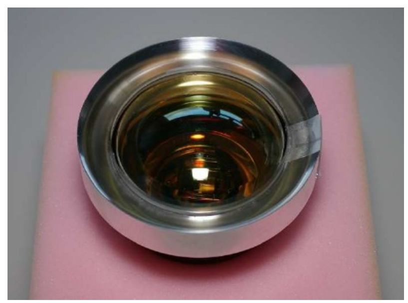
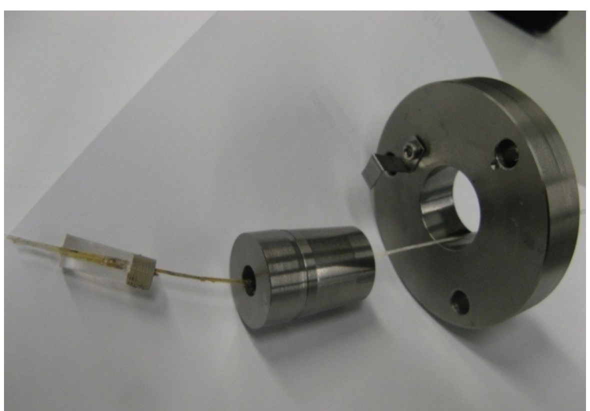
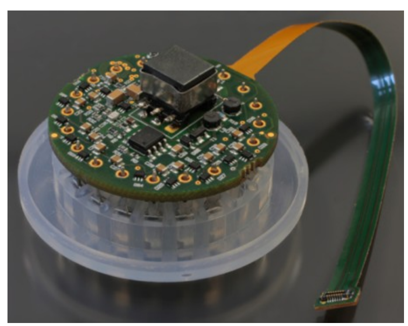
DOM (Digital Optical Module)









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

- Sphere ∅17”
- PMTs (19+12) ∅3”
- Base
  - Adjust. HV (800-1400V)
  - Comparator for time-over-threshold
- Power board, electronics
- Calibration devices
- Single penetrator

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Photo Multiplier Tubes

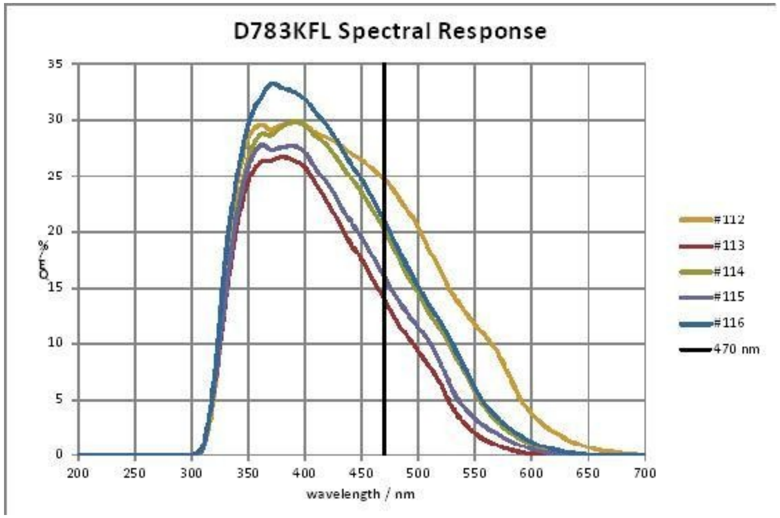
Requirements:

Quantum efficiency (QE) at 404nm	>32% (>20% @ 470nm)
Transit time spread (TTS)	<2ns (sigma)
Gain	$5x10^6$

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:



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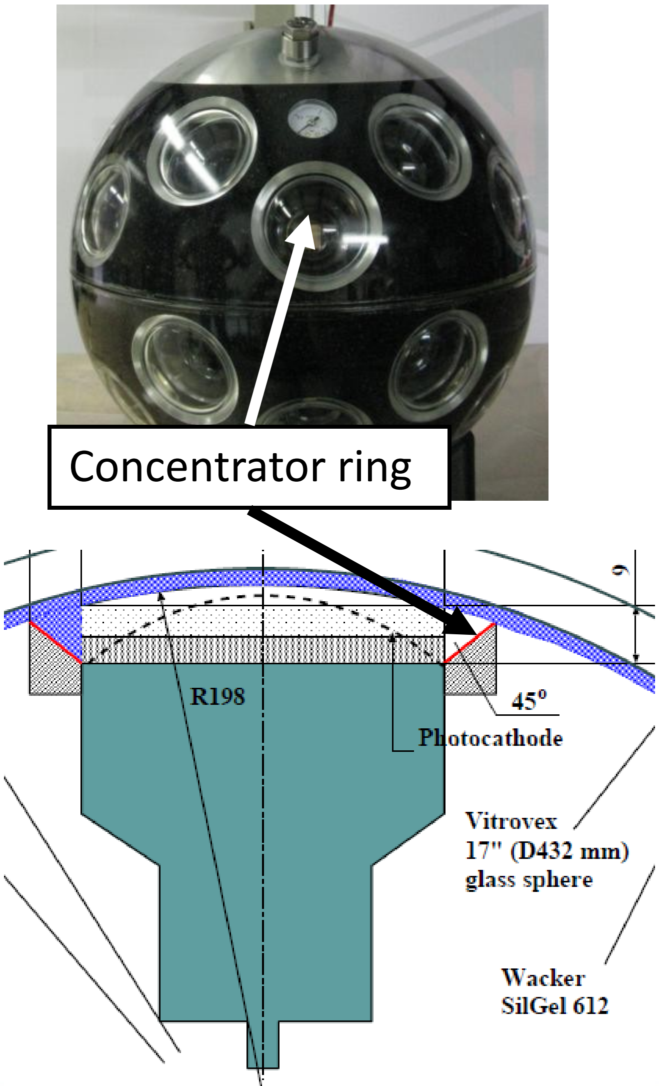
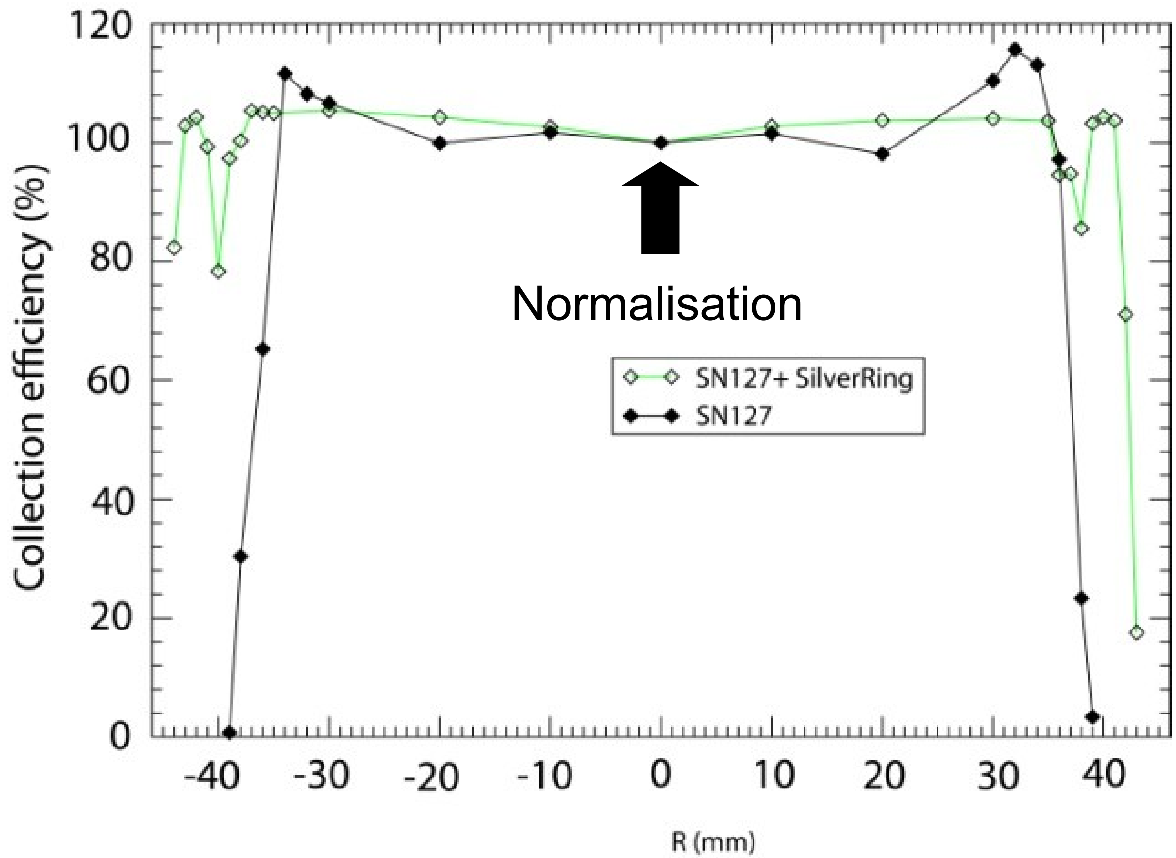
DOMs: Recent Technical Progress



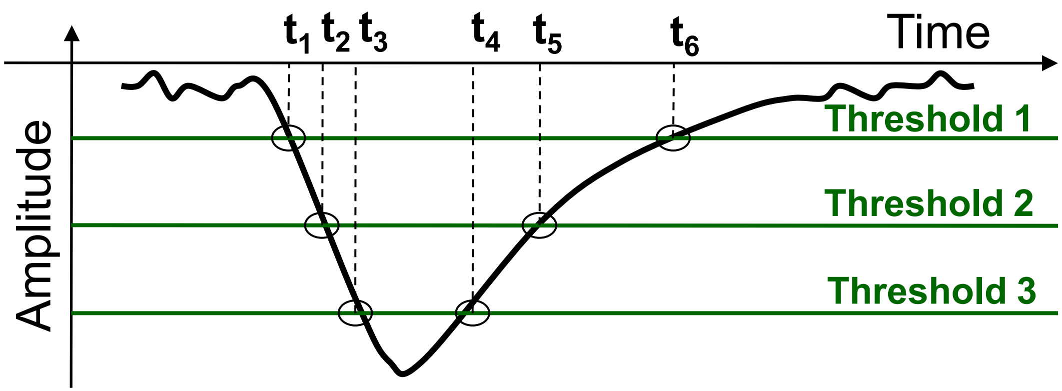


Increases effective photocathode area by 20-40%

Ring simplifies PMT fixture

Front End Electronics

Time-over-threshold (TOT):



Two options for readout

Analog signal → Comparator → LVDS signal

(levels set through I^2C control)

31x

→ "Scott chip" (ASIC) → Time stamped "hits"

→ TDC → TOT count (time stamp in FPGA)

FPGA (system on chip)

Timing resolution of ~1ns required

Scott = Sampler of Comparator Outputs with Time Tagging

TDC = Time to Digital Converter

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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

Funding provided by EU through
FP6 contract no. 011937 and FP7 grant agreement no. 212252