KM3NeT

Status and performance

R. Coniglione for KM3NeT collaboration
INFN- Laboratori Nazionali del Sud Catania - Italy

The KM3NeT consortium aims at developing a deep-sea research infrastructure in the Mediterranean Sea. The construction of a multi-cubic-kilometre Cherenkov telescope for neutrinos with energies above 100 GeV is the principal KM3NeT goal

- Physics case & main objectives
- KM3NeT design
- Performance

The KM3NeT consortium

- KM3NeT consortium consists of 40 European institutes, including those in Antares, Nemo and Nestor, from 10 countries (Cyprus, France, Germany, Greece, Ireland, Italy, The Netherlands, Rumania, Spain, U.K)
- KM3NeT is included in the ESFRI and ASPERA road maps
- KM3NeT Design Study (2006-2009) defined telescope design and outlined main technological options
  - Approved and funded under the 6th EU Framework Programme
  - Conceptual Design Report published in 2008
  - Technical Design Report (TDR) completed => outline technology options for the construction, deployment and maintenance of a deep sea neutrino telescope http://www.km3net.org/KM3NeT-TDR.pdf
- KM3NeT Preparatory Phase (2008-2012) defines final design, production plans for the detector elements and infrastructure features. Prototype validation is underway. Legal, governance and funding aspects are also under study.
  - Approved and funded by EU under the 7th EU Framework Programme

KM3NeT and the international context

High energy neutrino telescope world map

Antares

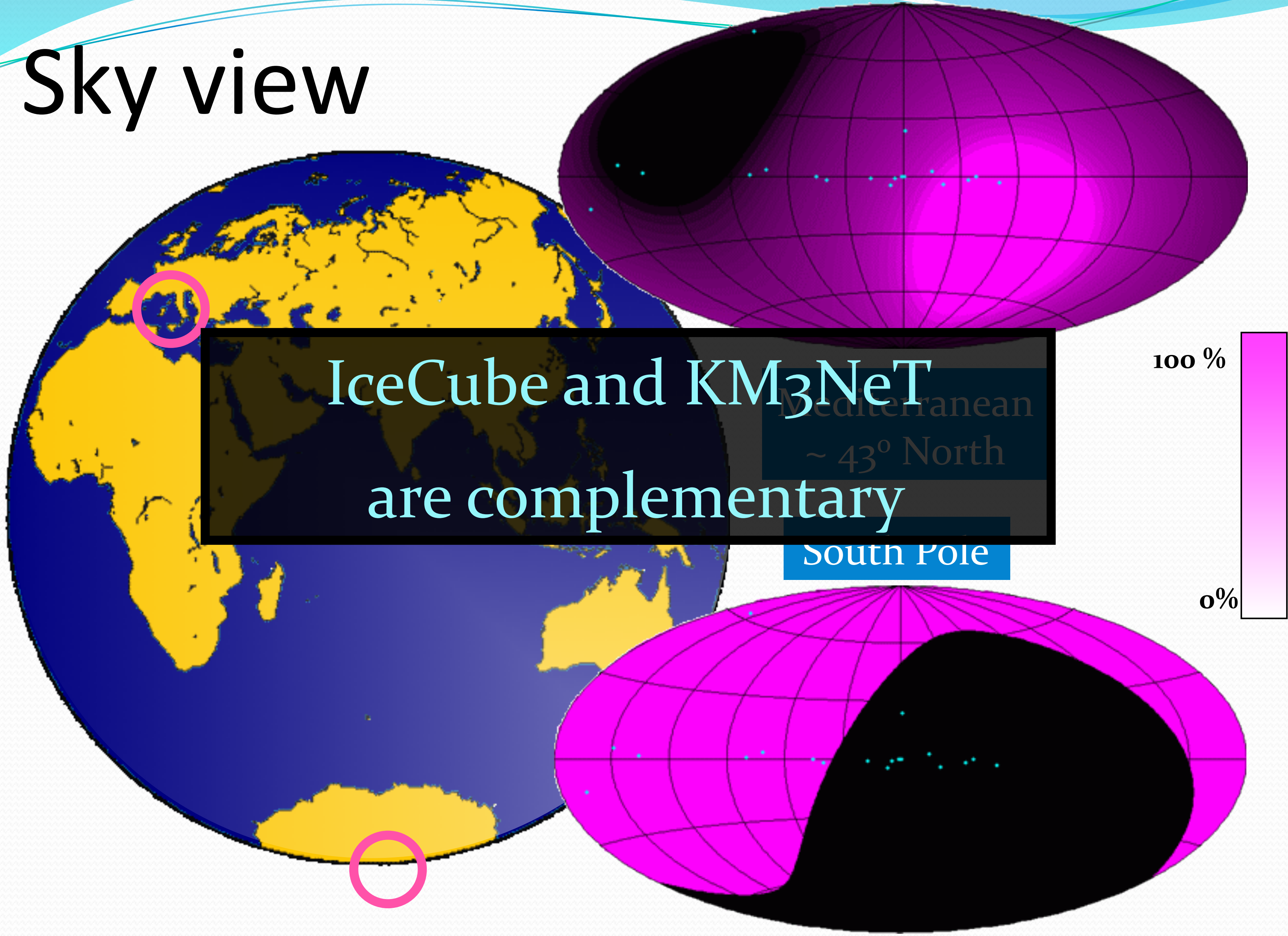
In its final configuration (12 lines) since may 2008.

ANTARES, NEMO, NESTOR joined efforts to prepare a km3-size neutrino telescope in the Mediterranean Sea: KM3NeT

IceCube

80 lines in December 2010

Sky view

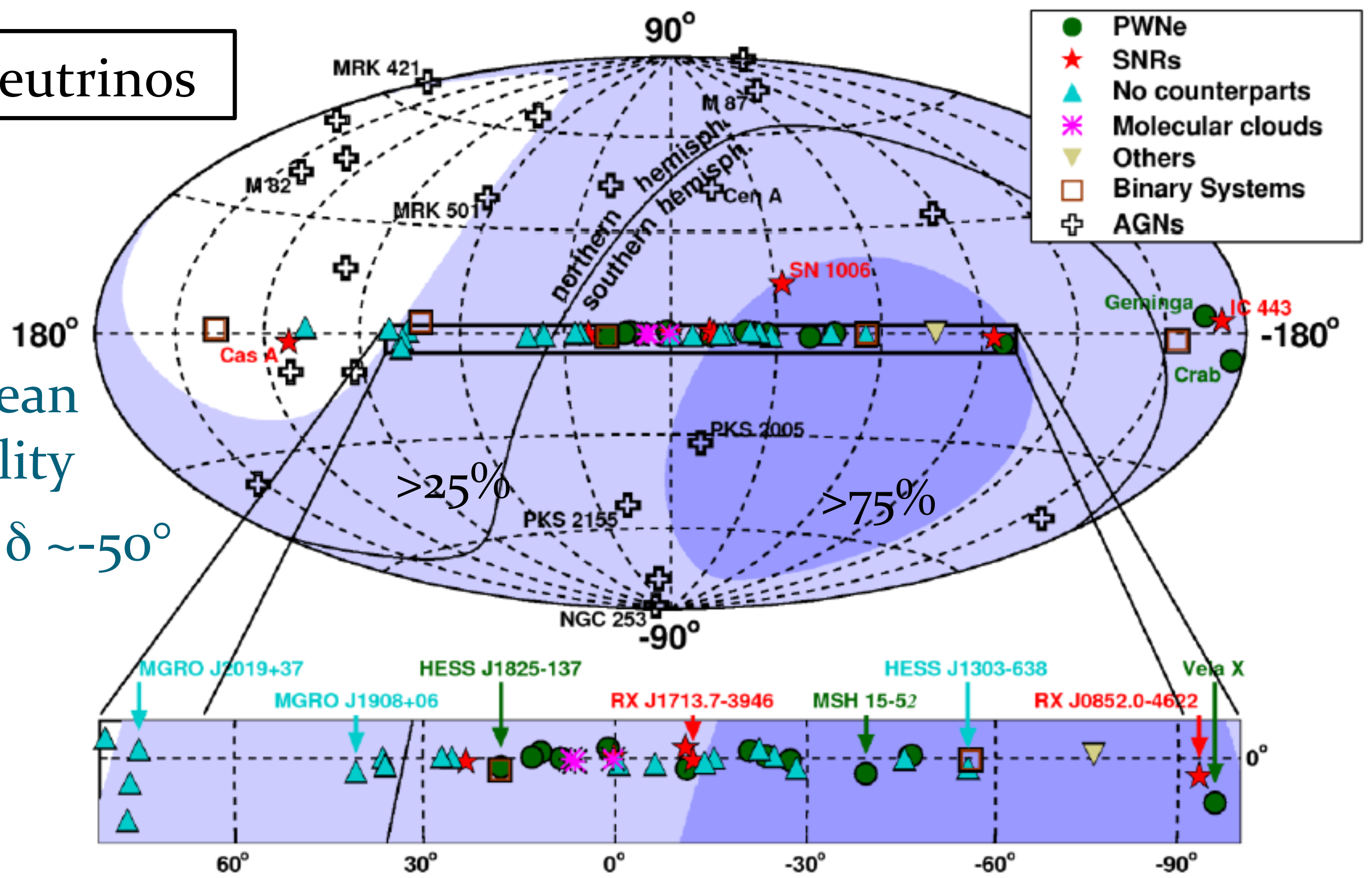


IceCube and KM3NeT are complementary

Sky view of a Mediterranean Sea telescope

FOV for up-going neutrinos

From Mediterranean
24h per day visibility
up to declination δ ~-50°



- KM3NeT coverage of most of the sky (87%) including the Galactic Centre

Physics Case and Main objectives

- Main physics goals

  Origin of Cosmic Rays and Astrophysical ν sources

  - Galactic Candidate ν Sources (SNRs, Fermi Bubbles, microquasar,…)
  - Extragalactic Candidate ν Sources (AGN, GRB, …)
  - Telescope optimisation→ “point sources” energy range 1 TeV-1 PeV

- Implementation requirements
  - Construction time ≤5 years
  - Operation over at least 10 years without “major maintenance”

- Cabled platform for deep-sea research (marine sciences)

Technical Challenges and Telescope Design

- Technical design
  Objective: Build, deploy and operate a km3-scale 3D-array of photosensors connected to shore (power, slow control, data)

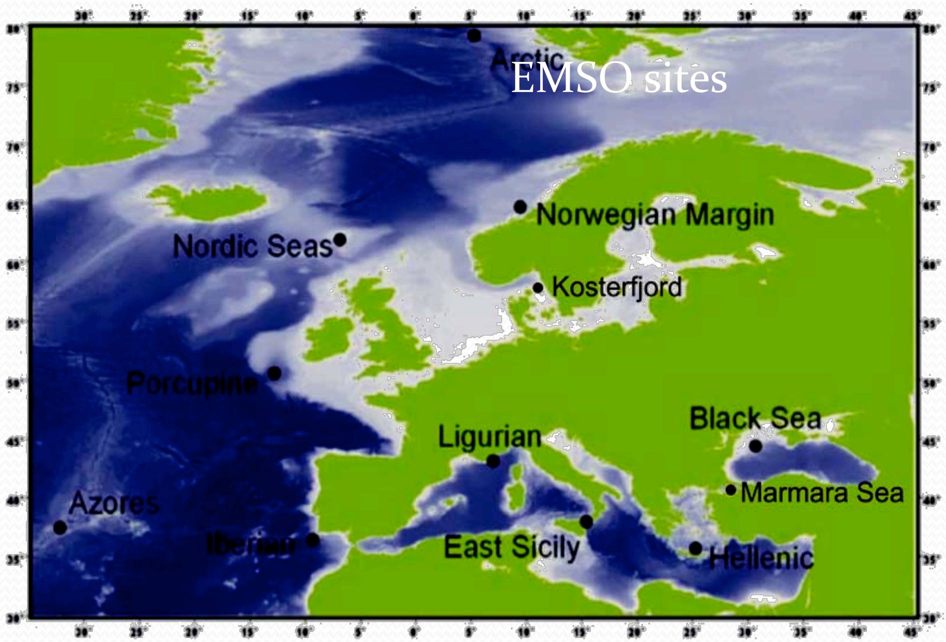
  @ 2500 – 5200 m depth undersea
  - Optical modules (OM)
  - Front-end electronics & read-out
  - Mechanical structures & deployment
  - Data transmission, information technology and electronics
  - Deep-sea infrastructure: cables and Junction-boxes
  - Calibration
  - Risk analysis and quality control

Builds on the experience gained with ANTARES, NEMO and NESTOR

Described in the KM3NeT Technical Design Report http://www.km3net.org/KM3NeT-TDR.pdf

Other issues addressed in KM3NeT

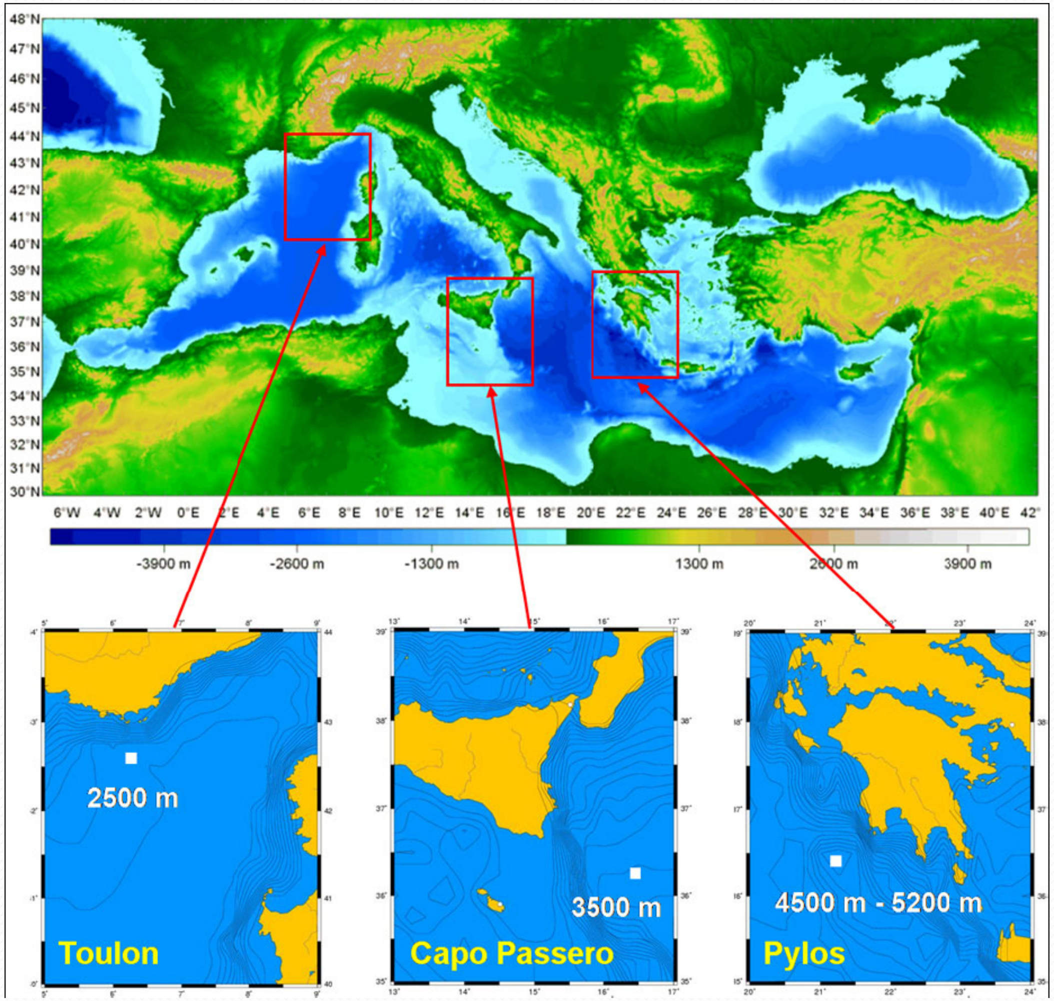
- Characterization of the candidate sites and single vs multi-site option
  - Measurements of optical properties and optical background, currents, sedimentation
  - Simulation of telescope performance
- Earth and Sea science requirements
  - Define the infrastructure needed to implement multidisciplinary science nodes



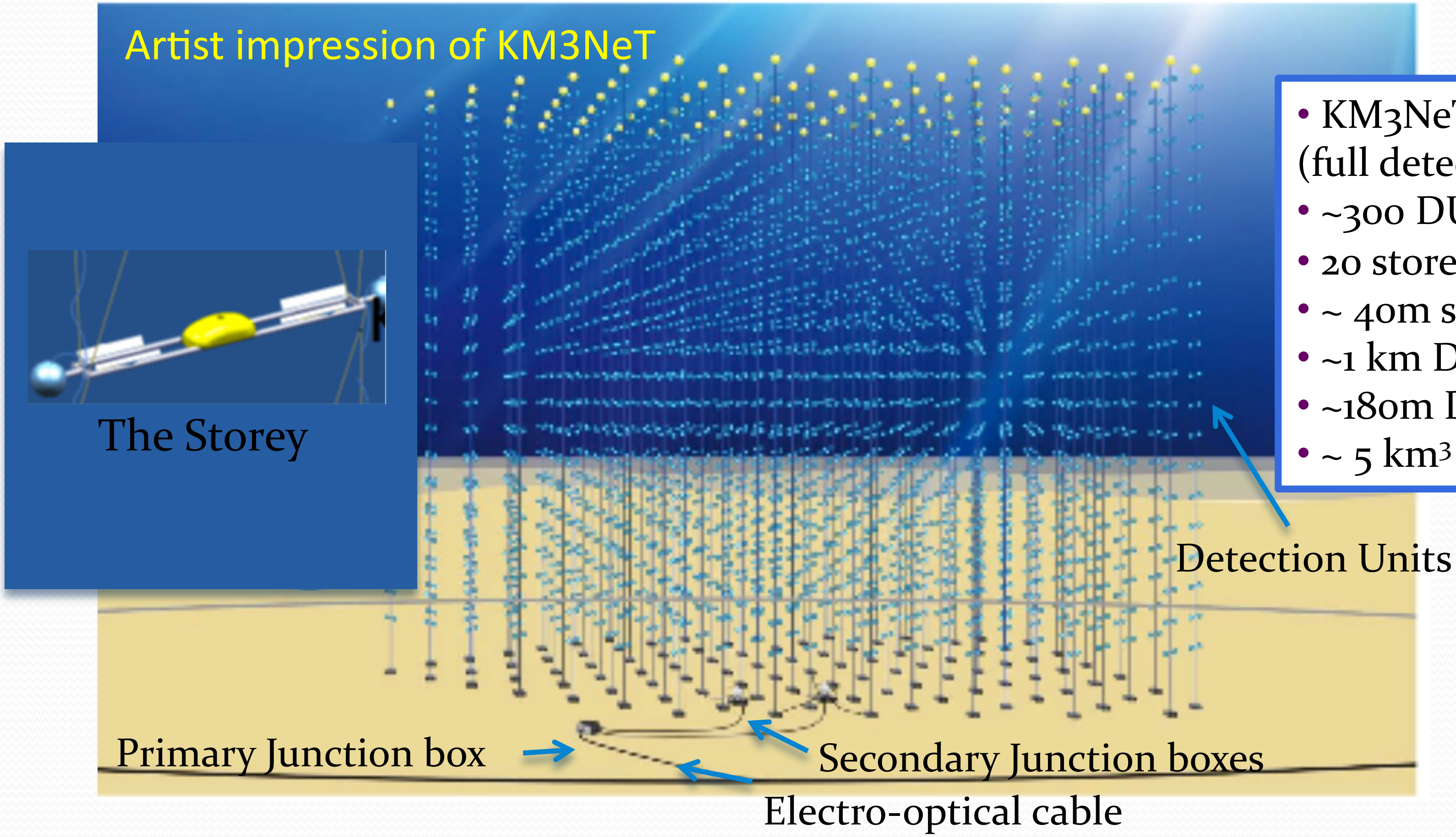
- EMSO is a ESFRI-PP project aiming at the construction of a European network of seafloor multidisciplinary observatories
- Mediterranean Sea sites and infrastructure technologies are of common interest

Candidate sites

- Three candidate sites
  - Toulon (France), 2500 m
  - Capo Passero (Italy), 3500 m
  - Pylos (Greece), 4500-5200 m
- Long-term site characterization measurements performed
- Connection with funding opportunities



KM3NeT scheme



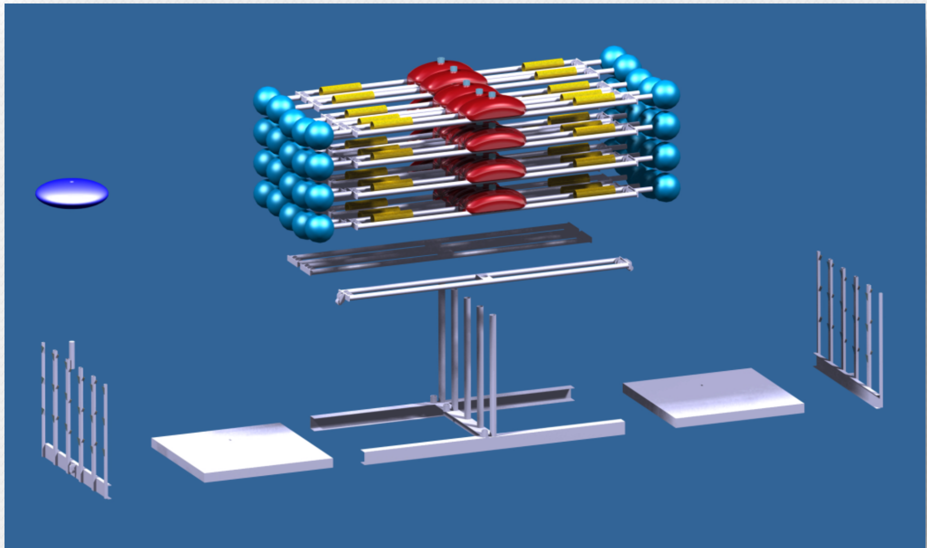
- KM3NeT in numbers (full detector)
- ~300 DU
- 20 storey/DU
- ~ 40m storey spacing
- ~1 km DU height
- ~180m DU distance
- ~ 5 km^3 volume

Digital Optical Module (DOM) = pressure resistant/tight sphere cointaining photo-multipliers and associated electronics

Detection Unit (DU) = mechanical structure holding DOMs, enviromental sensors

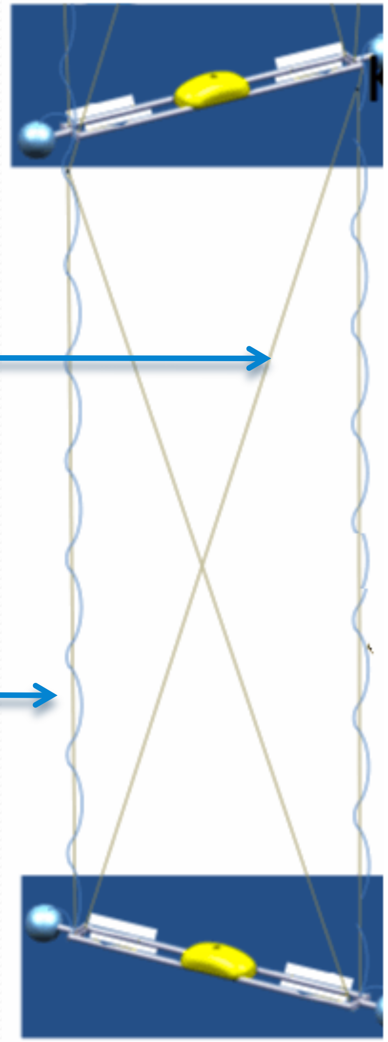
The DU packing concept

- 3D structure in a single DU (remove azimutal ambiguities => advantage at “low energy”)
- Very compact packaging ➔ integration in several production sites and transport on trucks, “easy” to be deployed

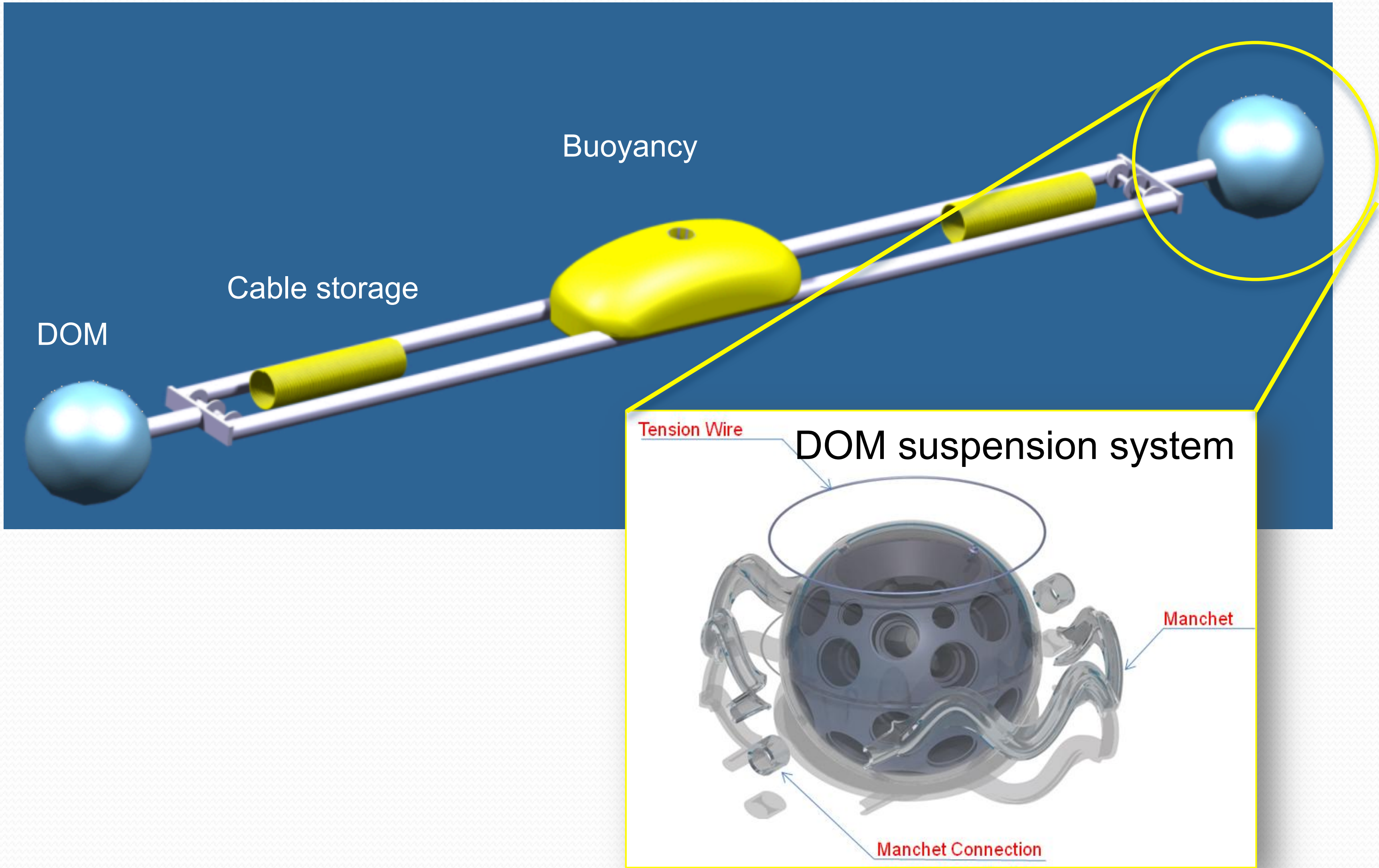


4 “crossing” tensioning ropes allow 3D structure

e/o backbone cable spirals around tensioning rope



The Storey concept

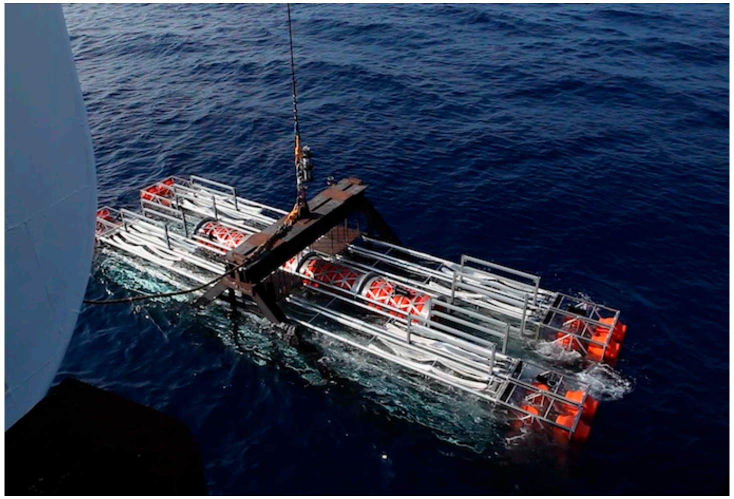


Detection Unit - Flexible Tower

Prototype & validation

Not the most recent DU lay-out

- Compact package (transportation) & Self unfurling from sea bed => easy logistics that speeds up and eases deployment
- Connection to seabed network by Remotely Operated Vehicle



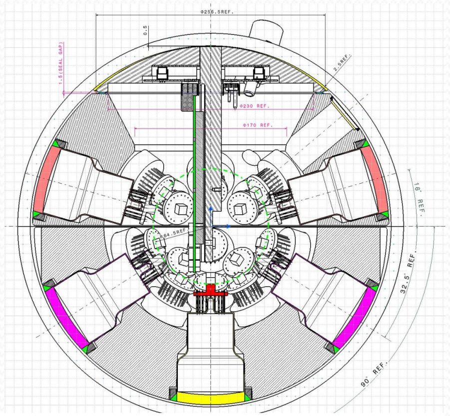
A packed flexible tower

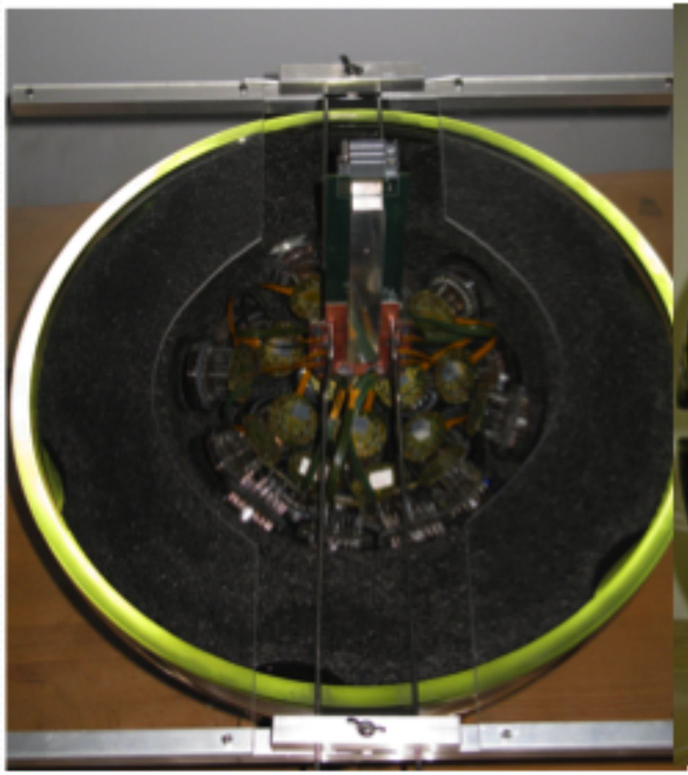
Successful deployment test in February 2010

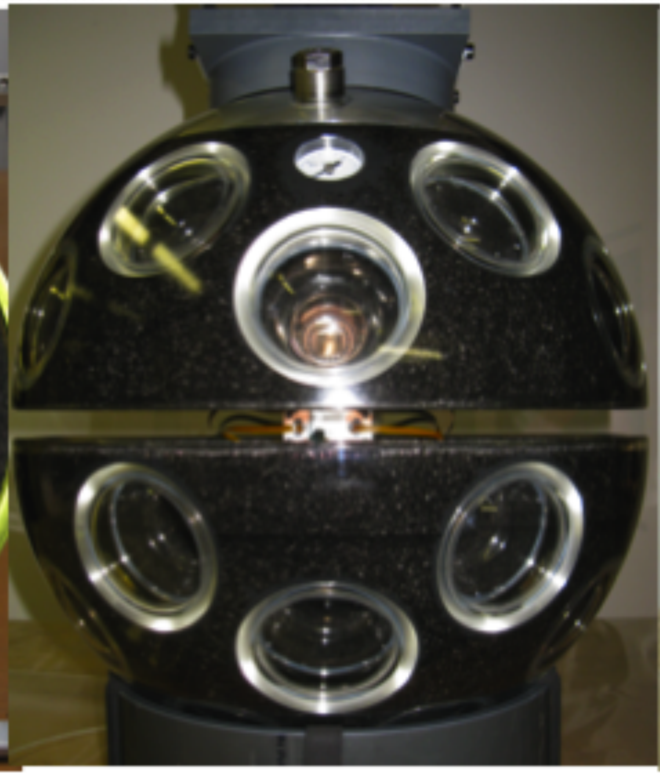
Digital Optical Module

- 31 3" PMTs inside a 17" glass sphere with 31 bases (total ~140 mW)
- Cooling shield and stem
- First full prototype under test

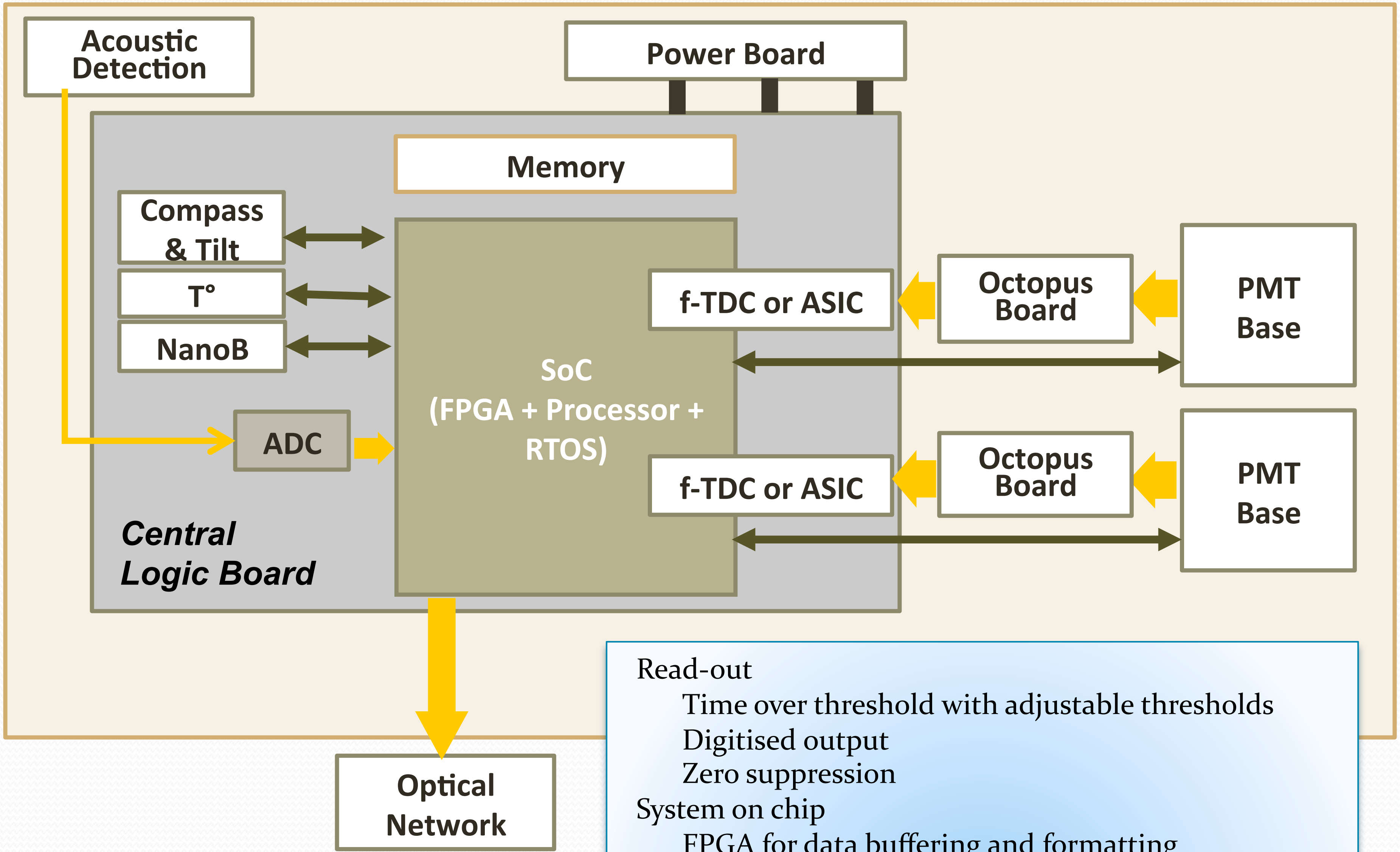
- Single vs multi-photon hit separation
- Larger photocade area per OM







Central Logic Board inside DOM



- Read-out
  - Time over threshold with adjustable thresholds
  - Digitised output
  - Zero suppression
- System on chip
  - FPGA for data buffering and formatting

Data Network and data transmission

- All data to shore concept (no trigger undersea)
- Data transport on optical fibers (data, clock, slow control)
  - Optical point-to-point connection to shore
  - Continuous wave laser on shore with reflective modulator inside the DOM

Star-like geometry

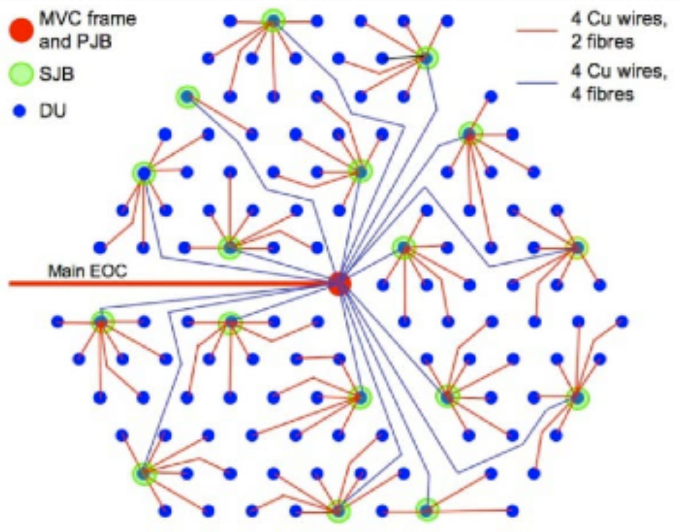


Figure 3-47: *Star* scheme of power and fibre optic distribution.

•Requirements
- Power distribution from shore toDUs
- Support data network
- Slow control and communication

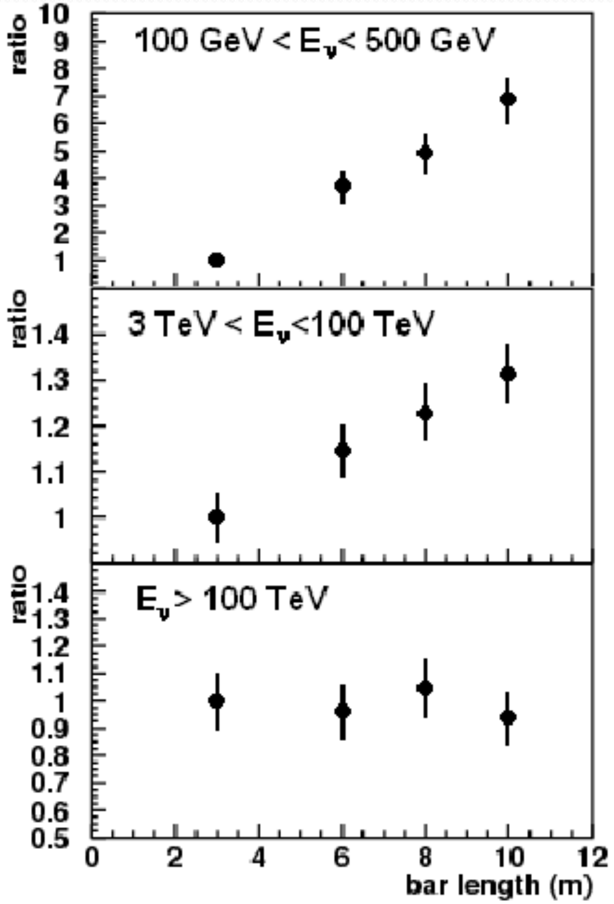
•Structure
- Hierarchical topology Primary and Secondary Junction Boxes
- Commercial electro-optical data cables and connectors
- Intallation with ROV

Simulations: optimization studies

Results from the KM3NeT TDR, optimization not for the final floor configuration.

Bar length optimization

ratio of the effective area relative to 3m



Low energy region

100GeV<E_ν<500 GeV

Quality cuts applied

$\Delta\Omega_{\mu-\mu rec}$~ 2° (close to the $\Delta\Omega_{\nu-\mu}$)

Point like sources

3TeV<E_ν<100 TeV

Quality cuts applied

$\Delta\Omega_{\mu-\mu rec}$~ 0.4°

(close to the search cone radius)

Diffuse flux studies & GRB

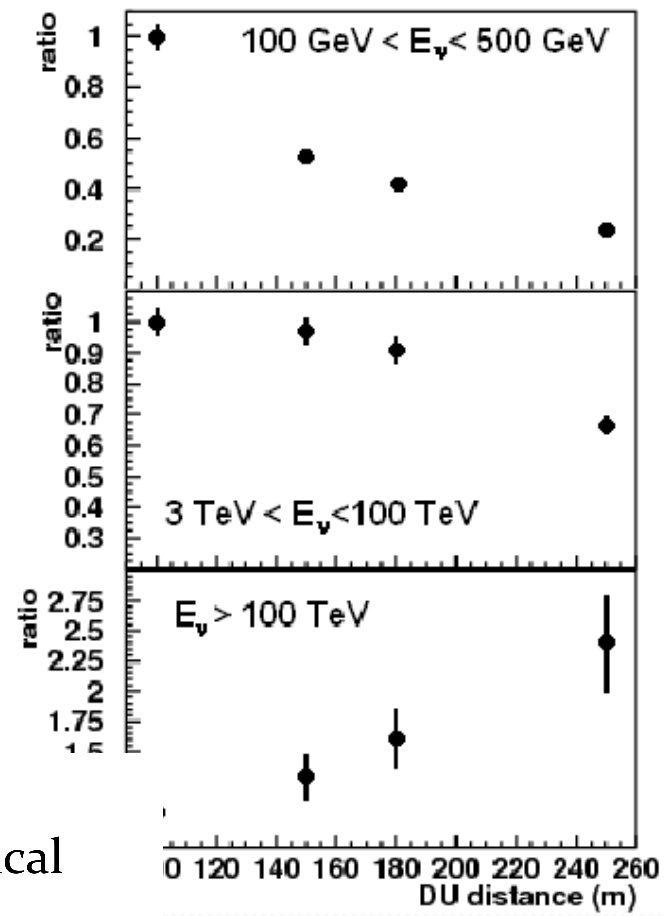
E_ν>100 TeV

No quality cuts applied

Final bar length choice is a compromise between physical performance and technical constraints

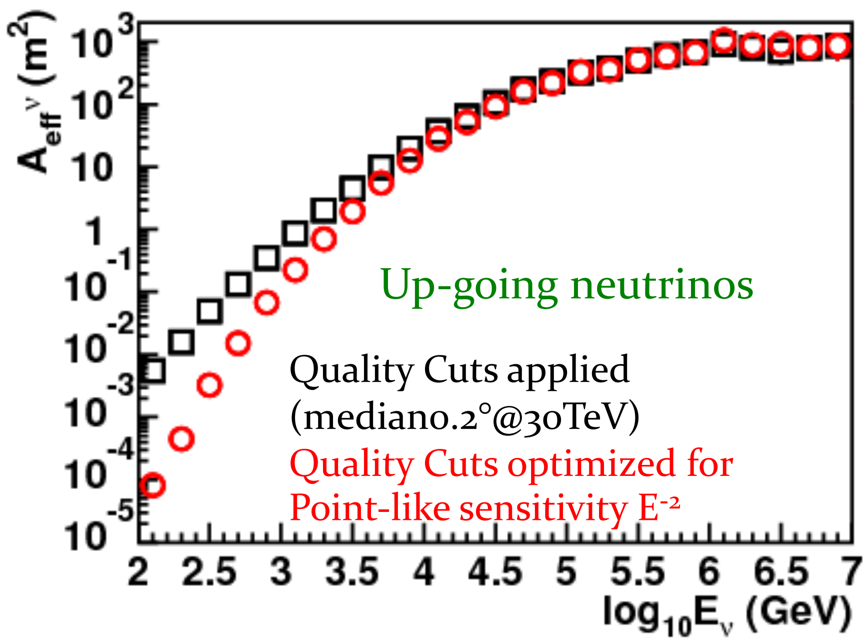
Optimization of Detection Unit separation

ratio of the effective area relative to 100m

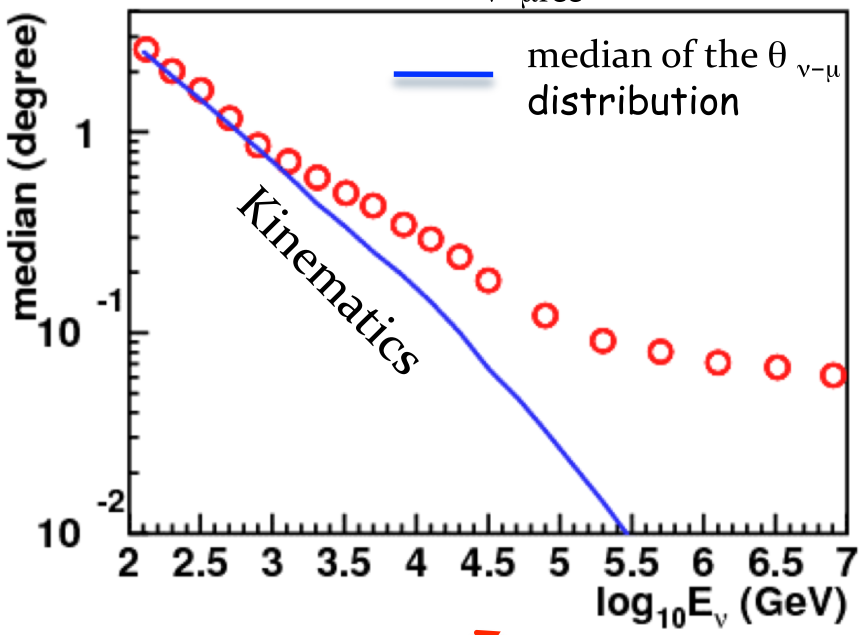


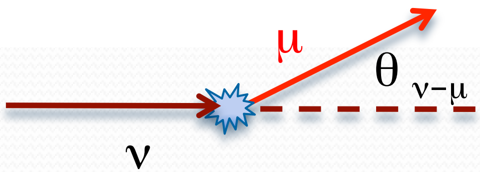
KM3NeT performance

- Results for 310 DU KM3NeT detector, each DU with 20 storeys
  http://www.km3net.org/KM3NeT-TDR.pdf



Detector resolution
Median of $\Delta\Omega_{\nu-\mu rec}$

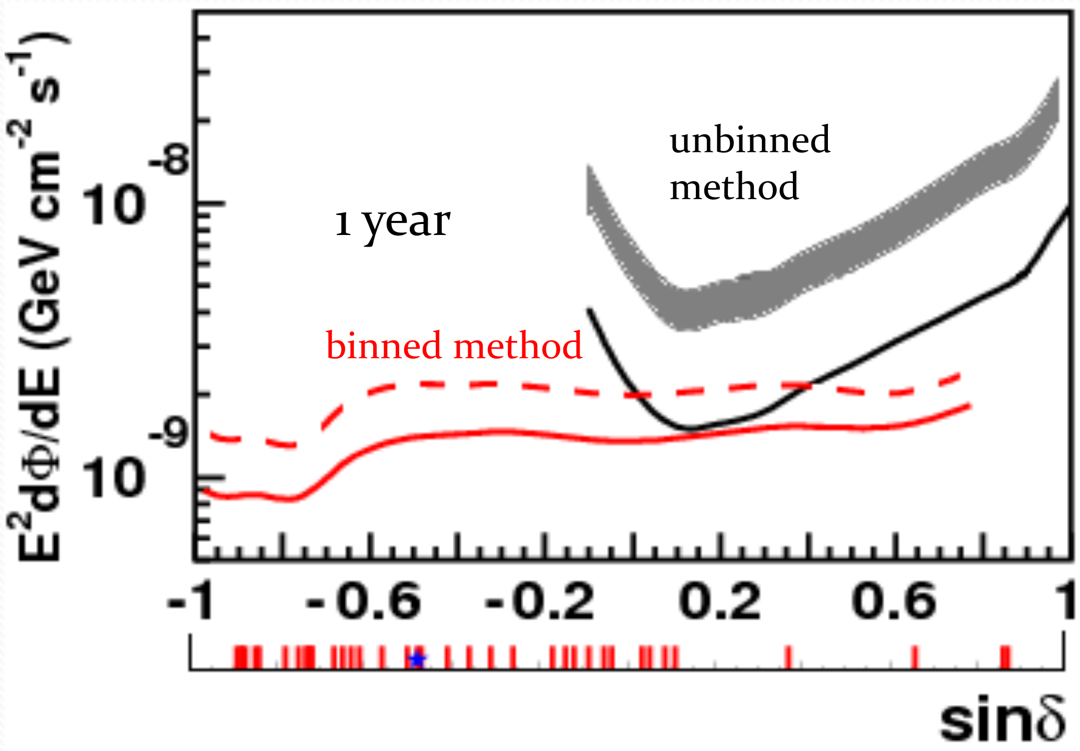




Sensitivity & Discovery potential

Sensitivity and discovery fluxes for point like sources with E^{-2} spectrum

Full detector (310 DUs)



KM3NeT sensitivity 90%CL

KM3NeT discovery 5σ 50%

IceCube sensitivity 90%CL

IceCube discovery 5σ 50% 2.5÷3.5 above sensitivity flux. (extrapolation from IceCube 40 string configuration)

| Observed Galactic TeV-γ sources (SNR, unidentified, microquazars) F. Aharonian et al. Rep. Prog. Phys. (2008) Abdo et al., MILAGRO, Astrophys. J. 658 L33-L36 (2007)

★ Galactic Centre

Sensitivity and discovery will improve with the unbinned analysis

Fermi Bubbles Discovery potential

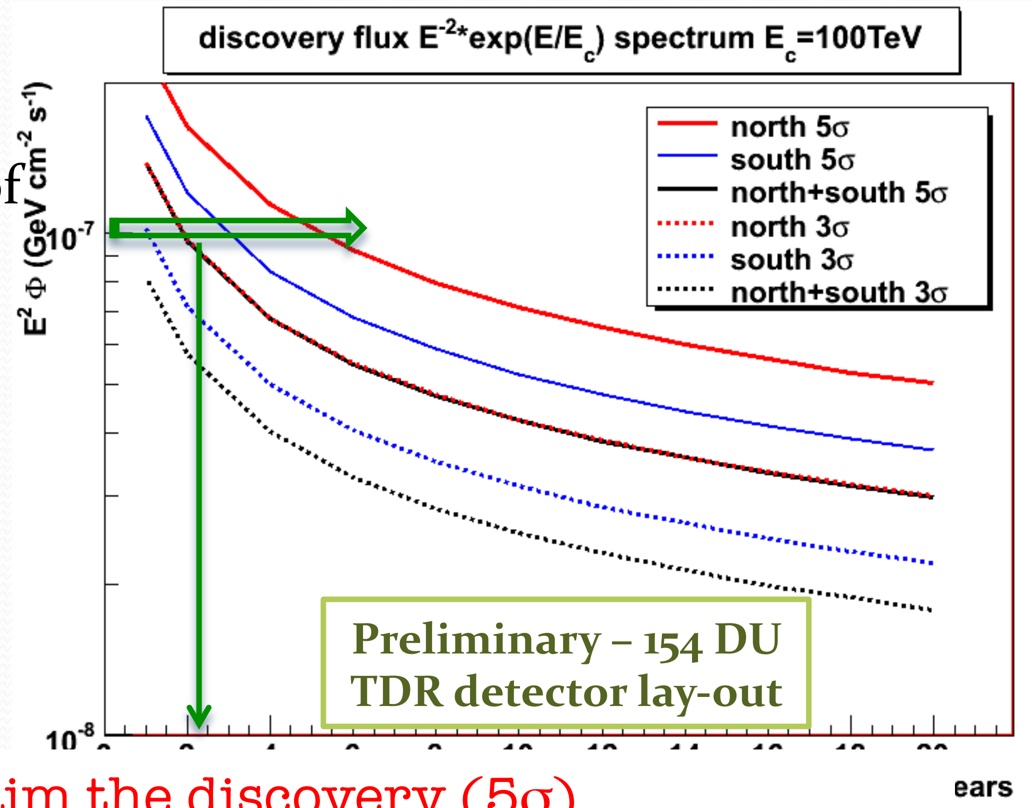
Uses : M. Crocker and F. Aharonian Phys. Rev. Lett. 106 (2011) 11102
"We show below that a cosmic ray population can explain these structures"

....

"...Finally, we predict that there should be a region of extended, TeV γ radiation surrounding the Galactic nucleus on similar size scales to the GeV bubbles with an intensity up to $E^{-2} F_\gamma(\text{TeV}) \sim 10^{-9}$ TeV cm^{-1} s^{-1} sr^{-1} which should make an interesting target for future γ-ray studies. Likewise, the region is a promising source for future, Northern Hemiphere, km3-volume neutrino telescope: we estimate (assuming a γ=2.0 proton spectrum cut-off 1 PeV)...."

"back of the envelope" estimate of ν flux

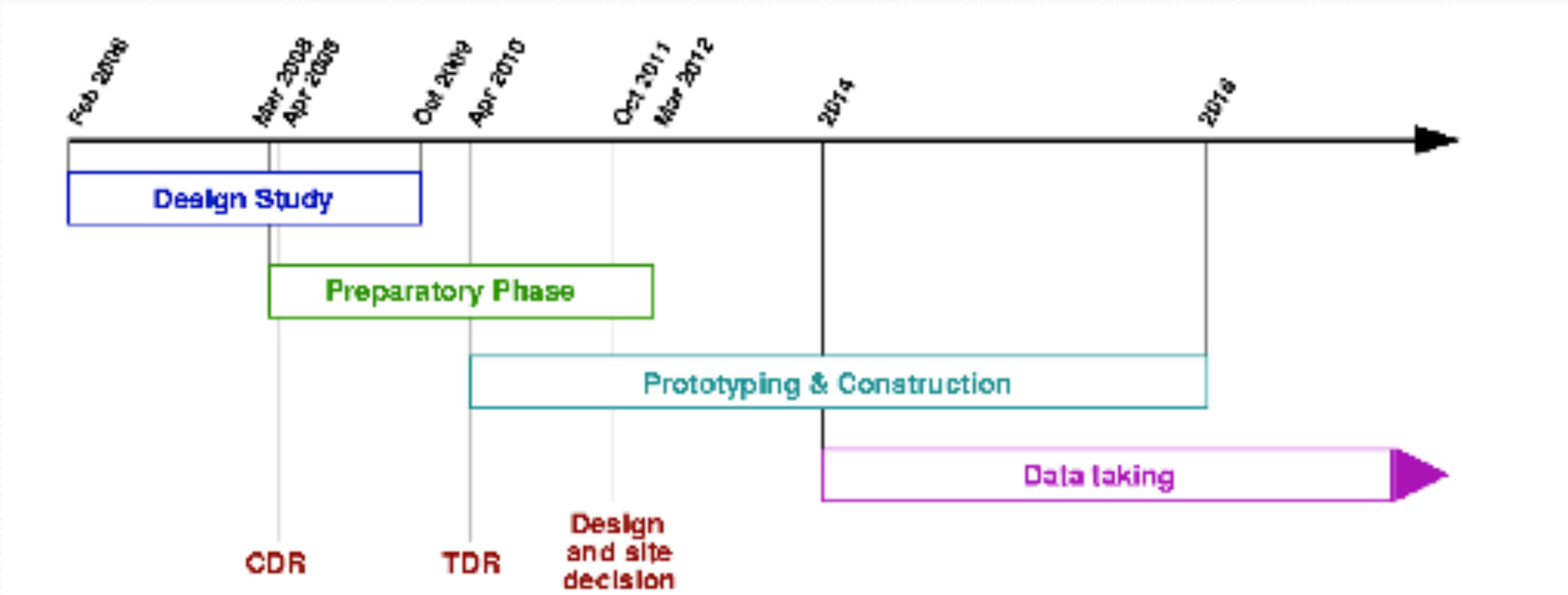
~ 1 10^{-7} GeV cm^{-1} s^{-1}



Predicition not for the most recent detector lay-out

- ~ 2 years to claim the discovery (5σ)

Project Timeline



Construction Phase can start in 2012
depending on funding…

Concluding remarks

- KM3NeT will cover most of ν sky with unprecedent sensitivity
- KM3NeT-Preparatory Phase ongoing
  - Final design in preparation
  - Construction of a pre-production model of the DU in progress
- Major impact also on the deep-sea sciences
  - Technological solutions developed by KM3NeT provide a unique opportunity for deep-sea sciences allowing long-term, real time data taking => Strong synergies with the EMSO project
  - Collaboration with INGV, IFREMER and HCMR already active at the Catania, Toulon and Pylos sites respectively
- MOU after KM3NeT-Preparatory Phase in preparation