6th Workshop on Very Large Volume Neutrino Telescopes (VLVnT 13)
Stockholm, 5-7 August 2013

News from KM3NeT

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07.08.2013

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FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

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The plan for the next 30 minutes:

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

KM3NeT

Not included: ORCA case study (see talk by A. Tsirigotis)

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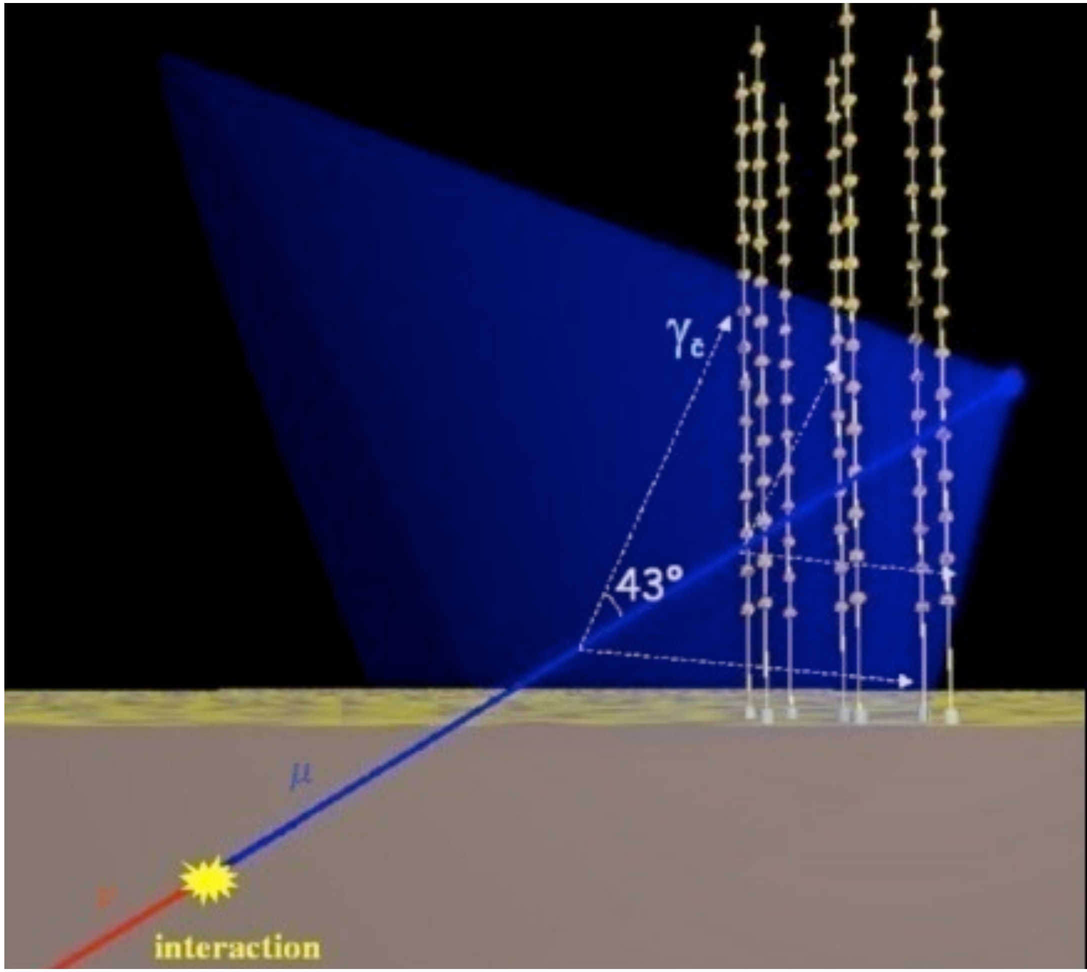
Why KM3NeT

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



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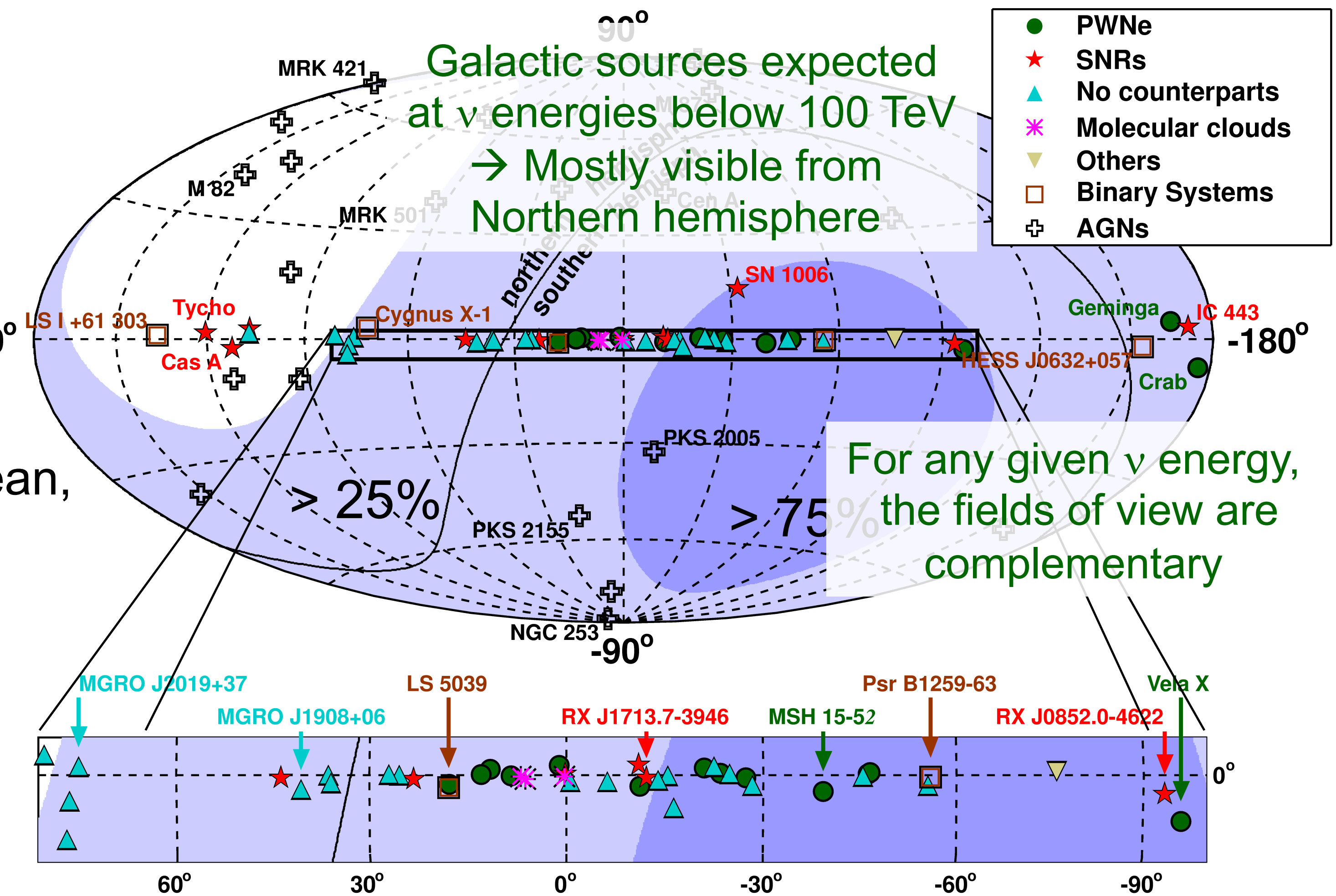
South Pole and Mediterranean fields of view

Galactic coordinates

2π 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 ν energies below 100 TeV → Mostly visible from Northern hemisphere



For any given ν energy, the fields of view are complementary

Figure courtesy A. Kappes

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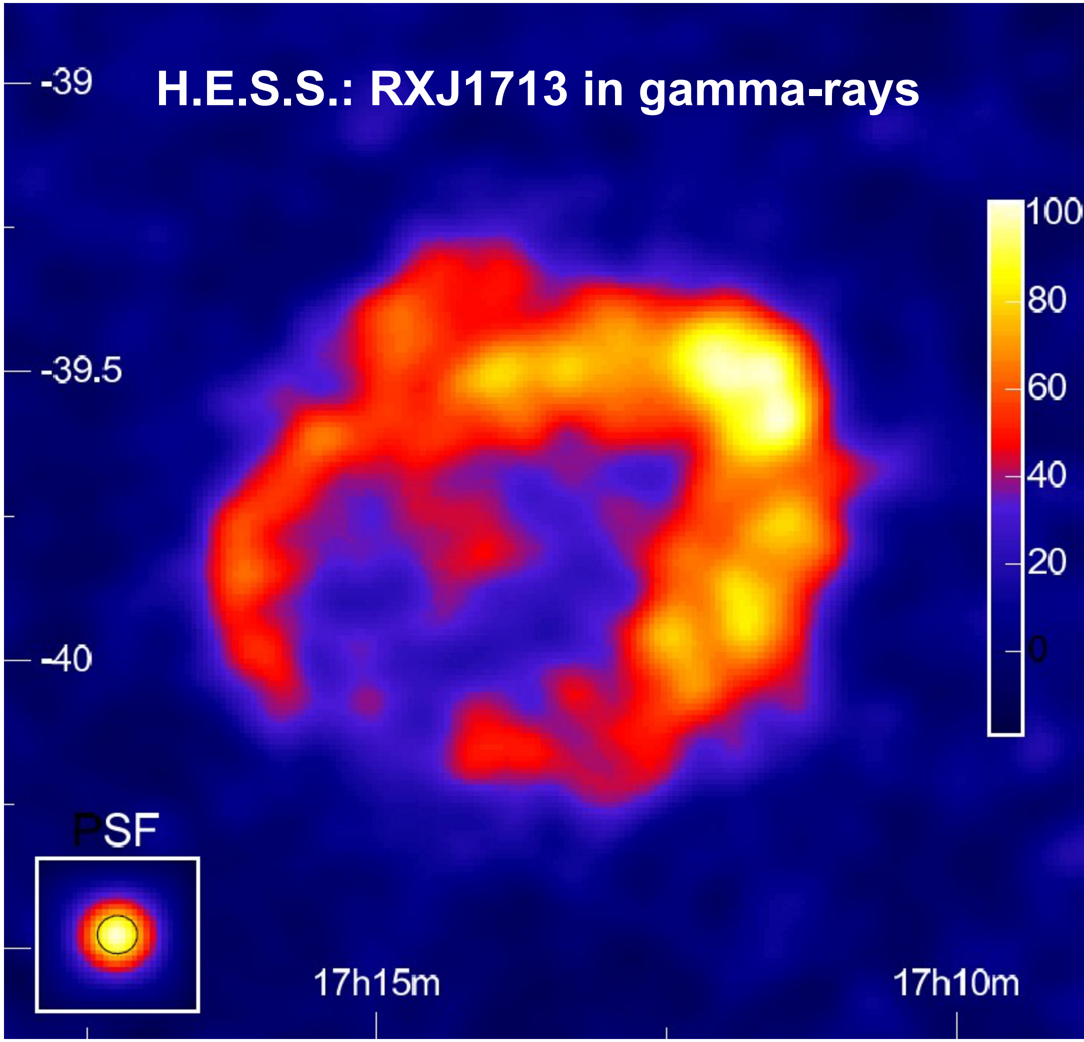
Sensitivity to Galactic sources

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

  Priority physics objective of KM3NeT

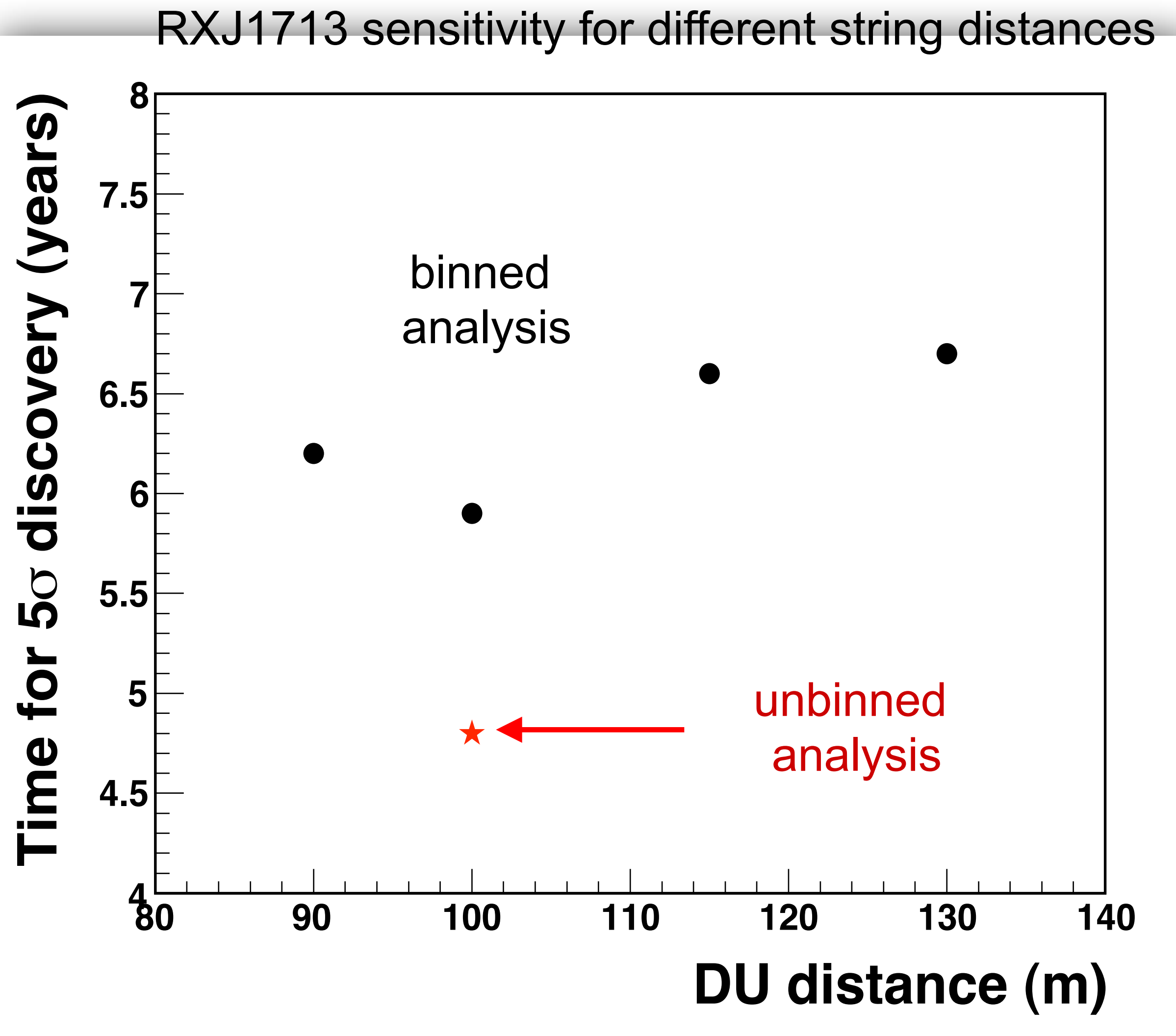
  → Talk Paul Kooijman
- Fermi Bubbles

  → Talk Paolo Piattelli



Discovery potential for Supernova remnants

- Simulation results for 2 x 310 strings
- 5σ 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



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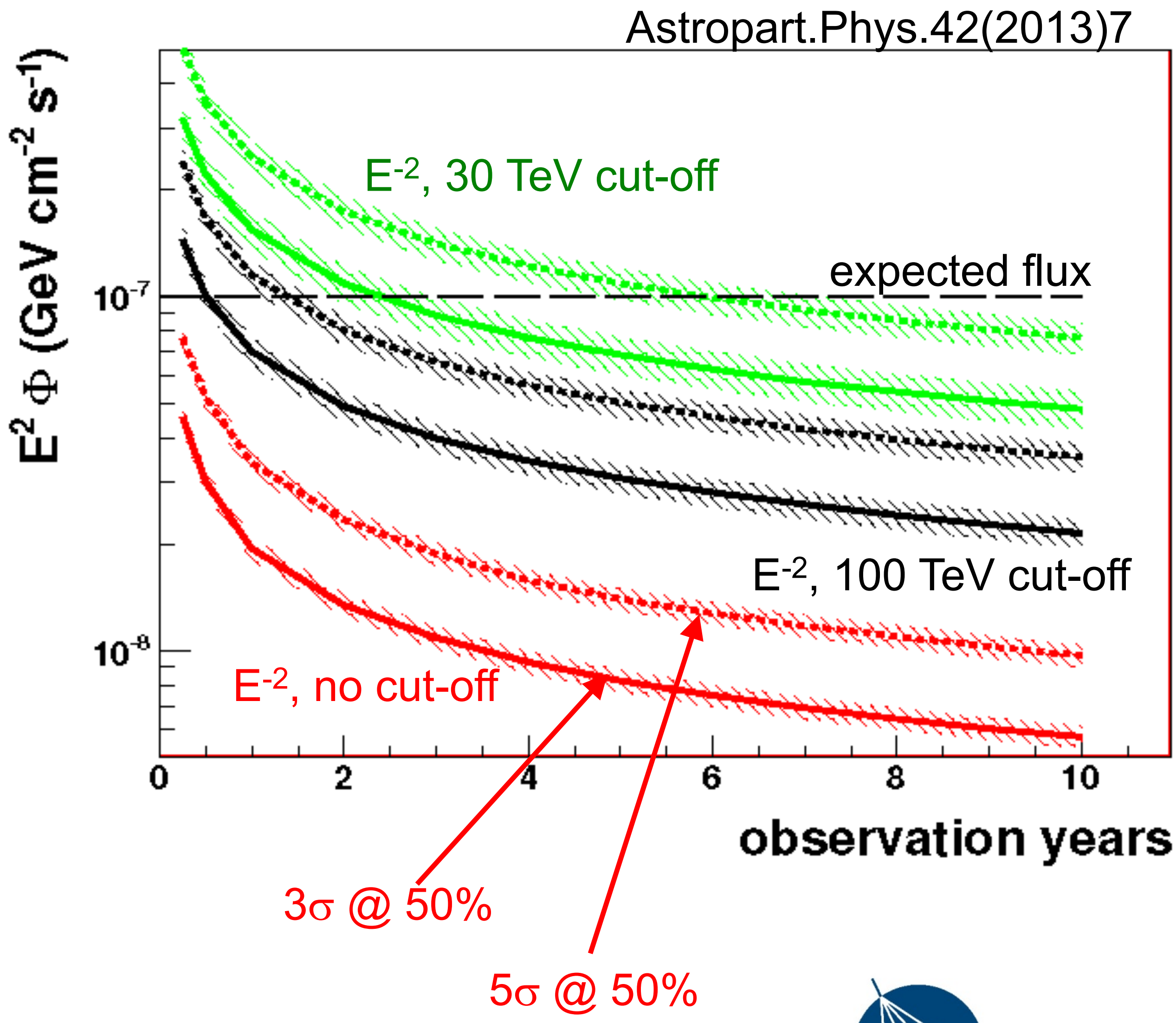
The Fermi bubbles

- Two extended regions above/below centre of Galactic plane
- Fermi detected hard γ 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



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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 desig

- Design of photo-detection un
  (large vs. several small PM ectionality, ...)

- Readout and data acq n?
  (how to implement? n-built ASIC vs. FPGA, …)

- Deployment tech y?
  (2 types of “Co ify and unfurl” vs. traditional)

- And finally: to) site decision.

2013: All solved and decided!

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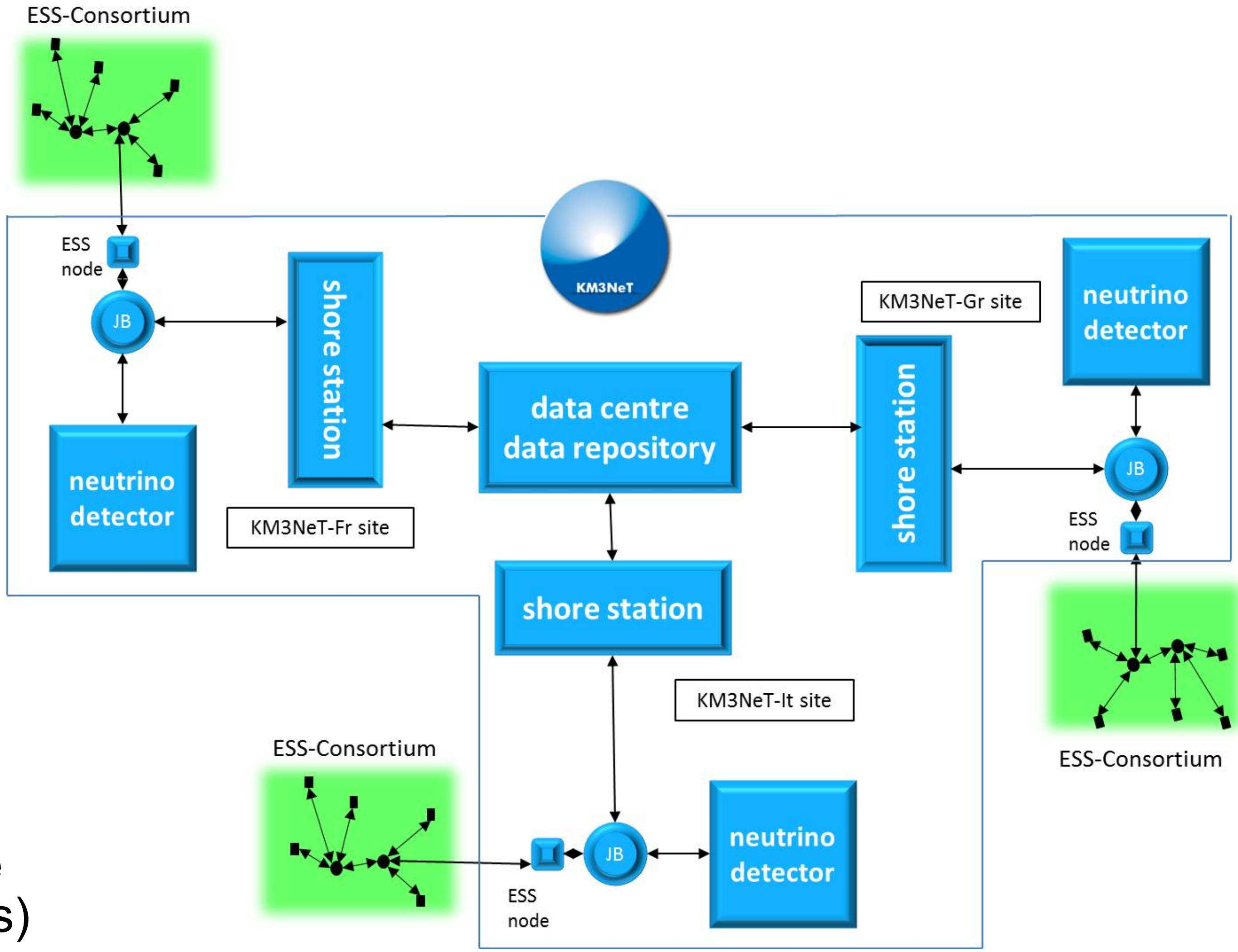
KM3NeT: a distributed Research Infrastructure

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



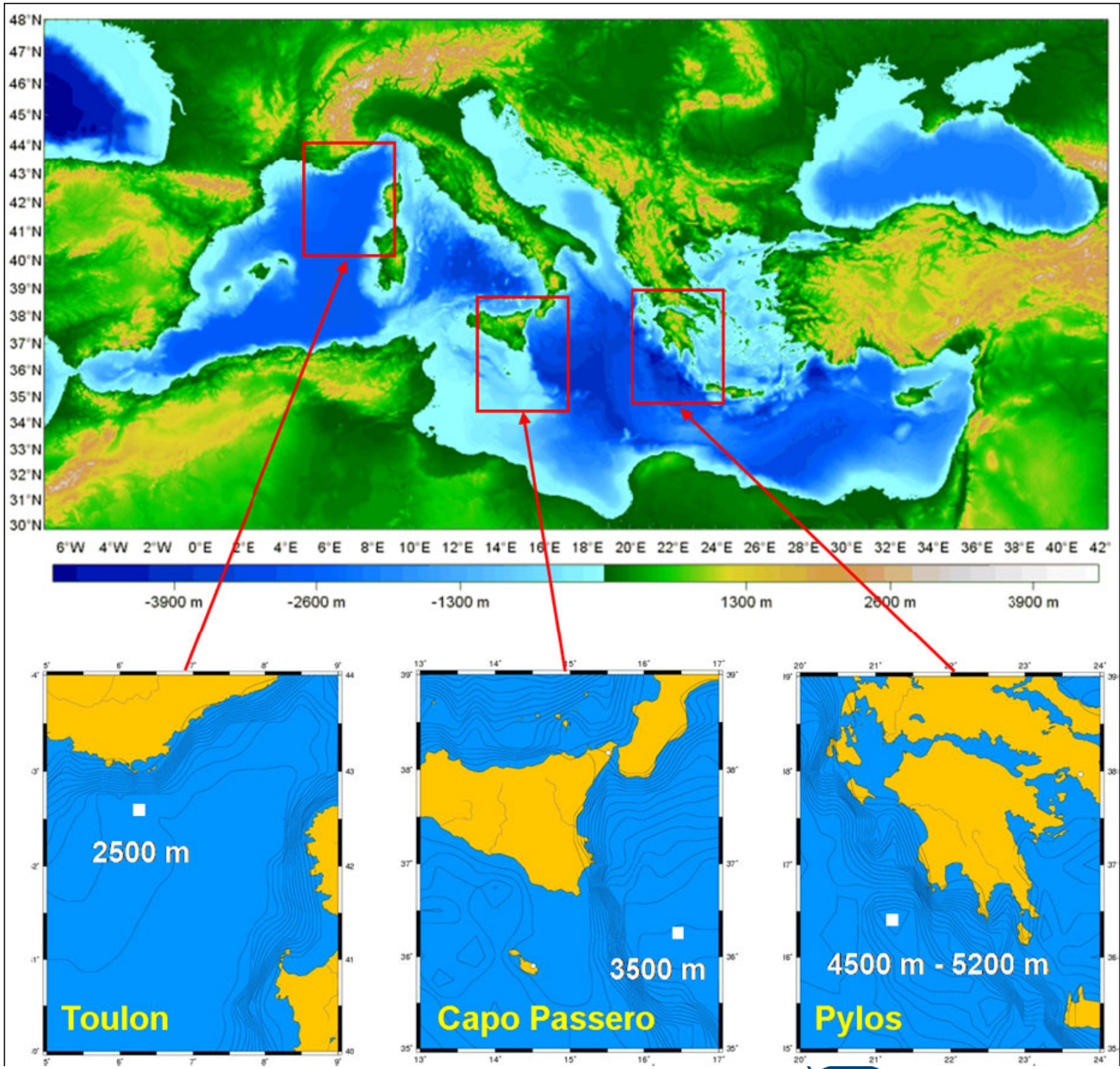
KM3NeT Sites

- KM3NeT-France: Toulon

  KM3NeT-Italy: Capo Passero

  KM3NeT-Greece: Pylos

- Long-term site characterisation measurements performed



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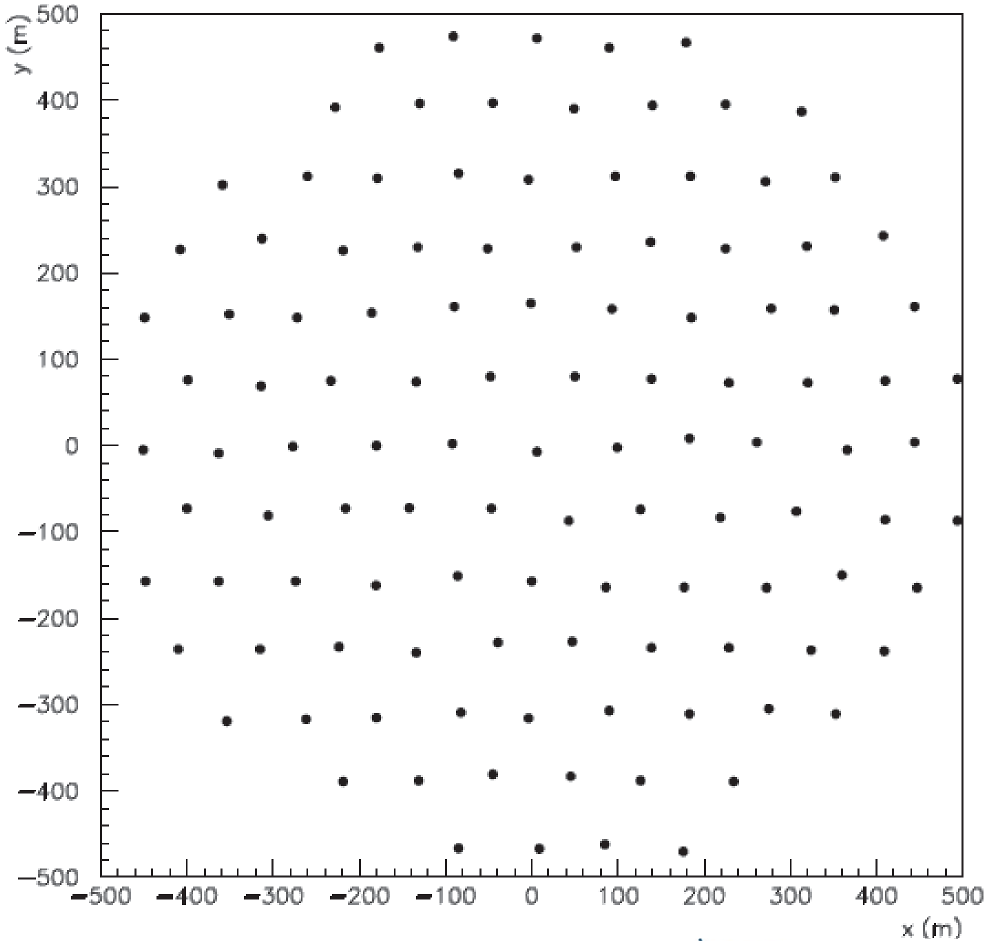
The building block concept

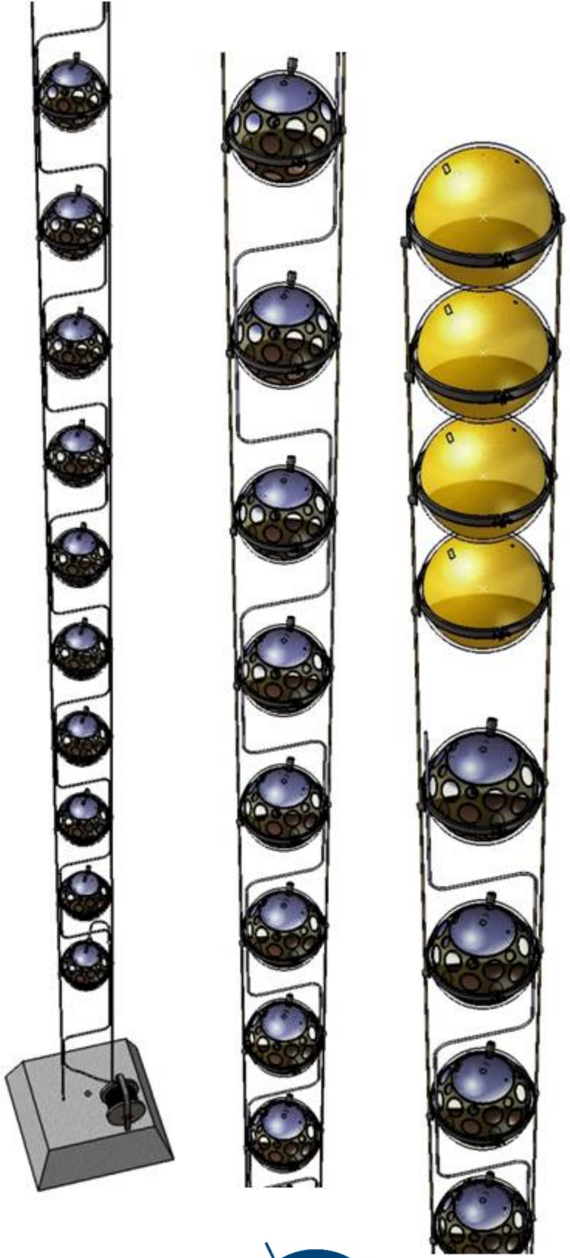
- Building block:
  - 115 detection units
  - Segmentation enforced by technical reasons
  - Sensitivity for muons independent of block size above ~75 strings
  - One block ~ half IceCube
- Geometry parameters optimised for galactic sources (E cut-off)
- Technical feasibility verified
- KM3NeT includes 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



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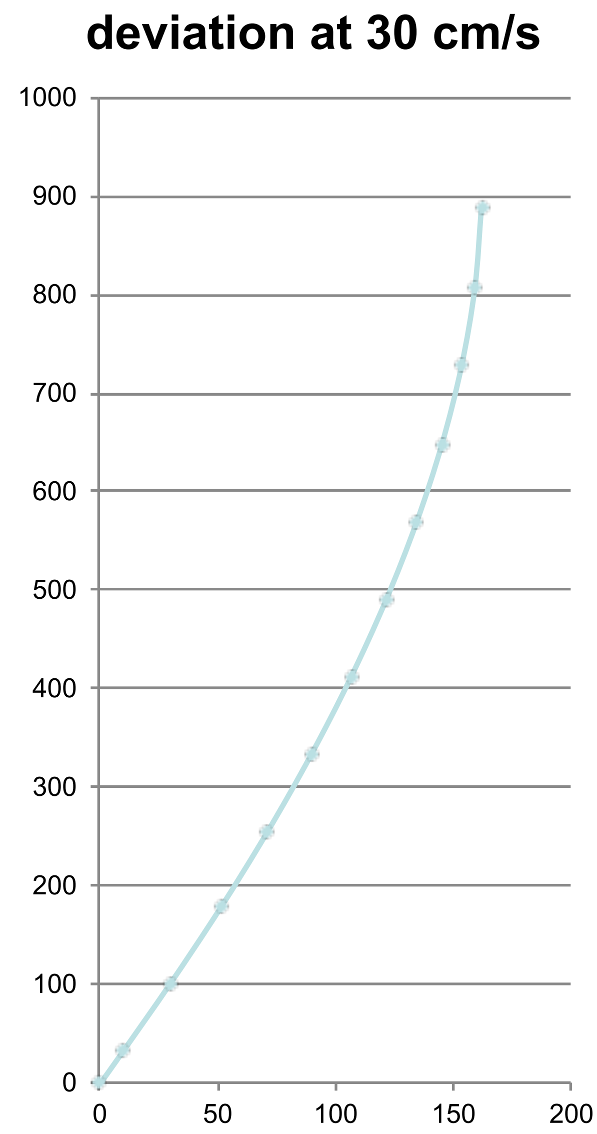
Hydrodynamic stability

- 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)



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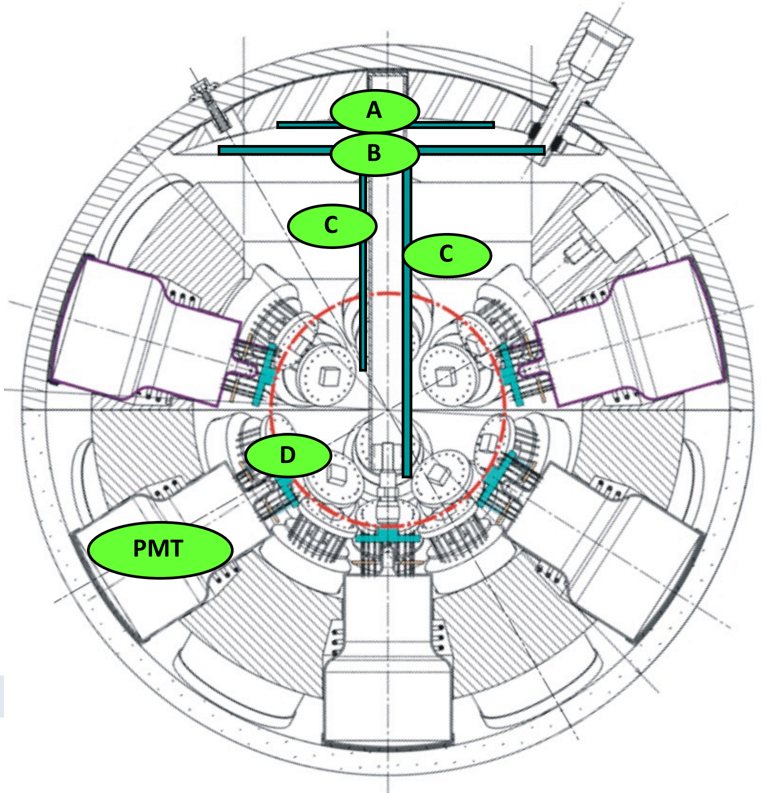
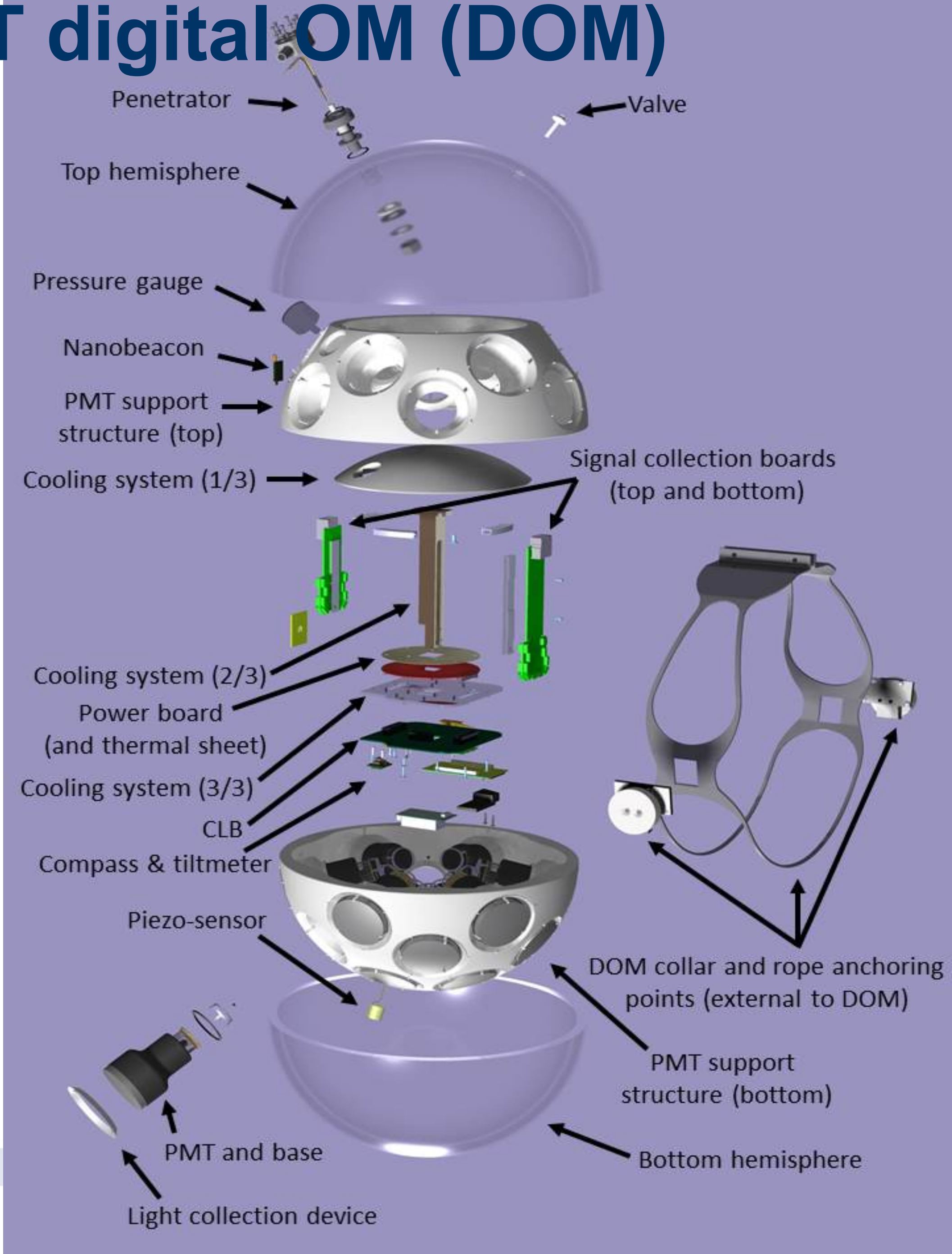
OM with many small PMTs

- 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)

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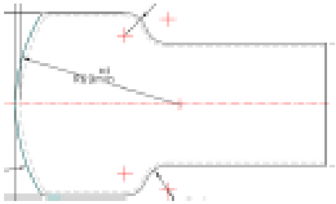
PMT availability

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



Talk by O. Kalekin:

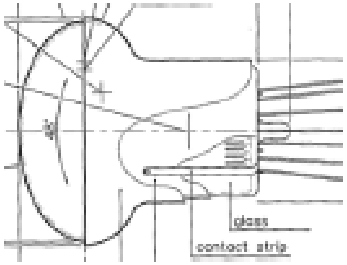
ET Enterprises Ltd (ETEL, UK)

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

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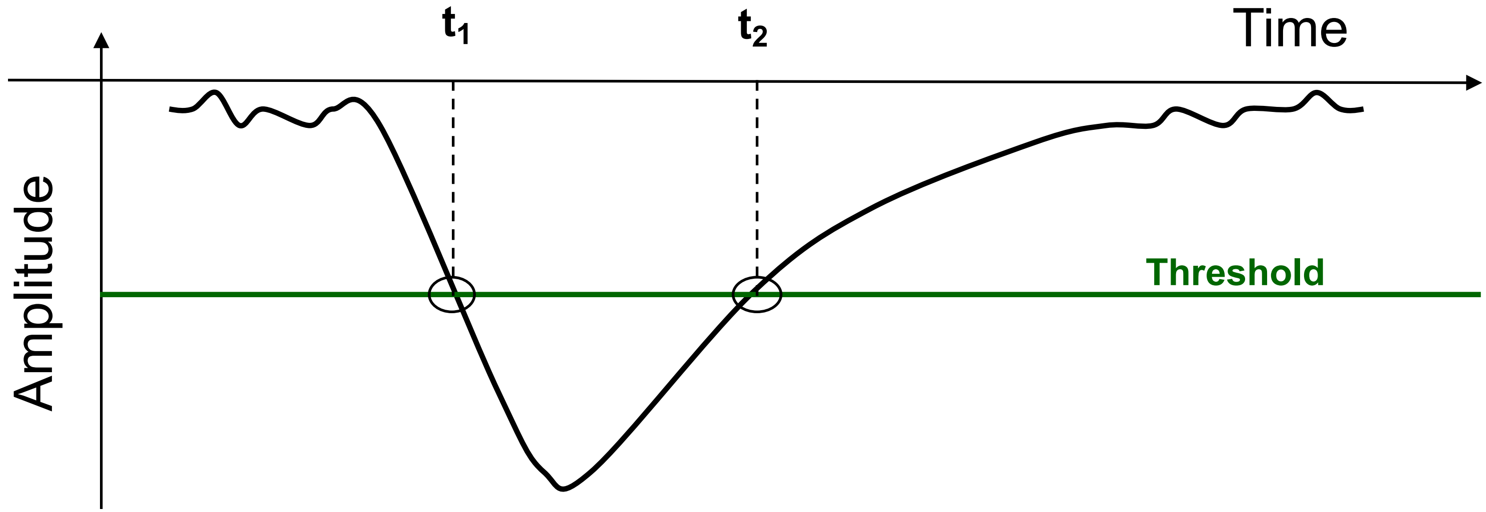
Readout: time-over-threshold

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

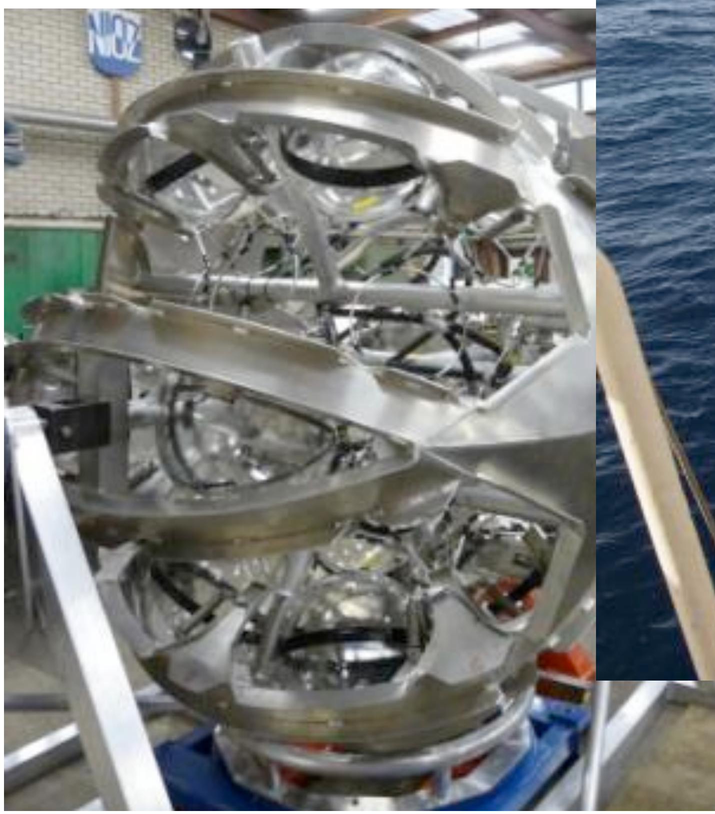
→ see presentations by D. Real and G. Kieft

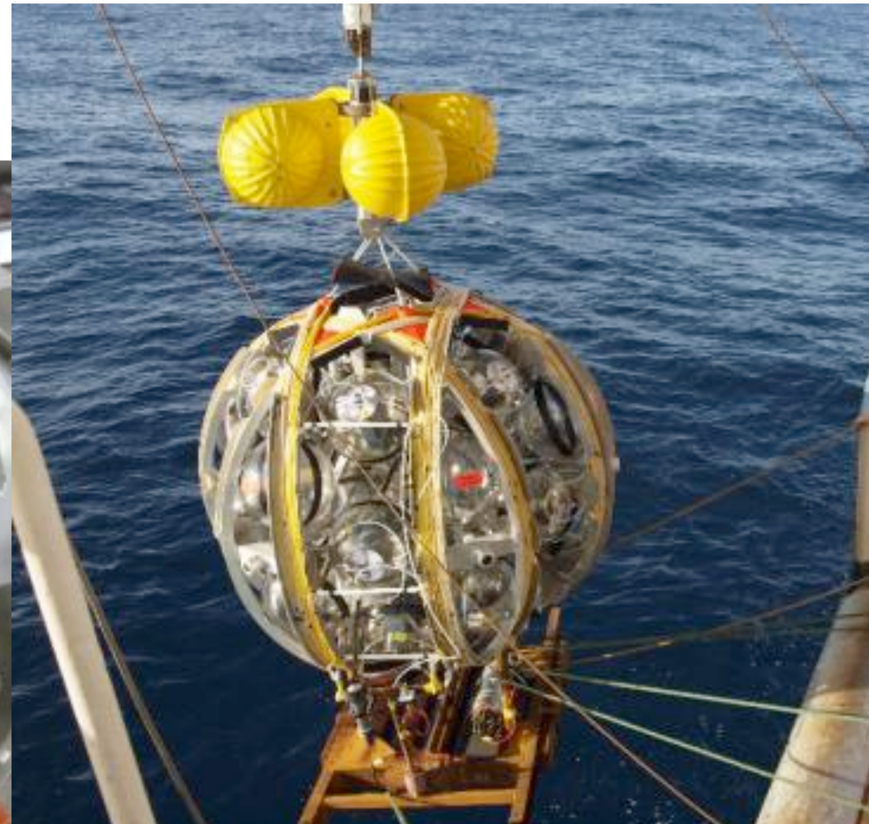
Deployment strategy

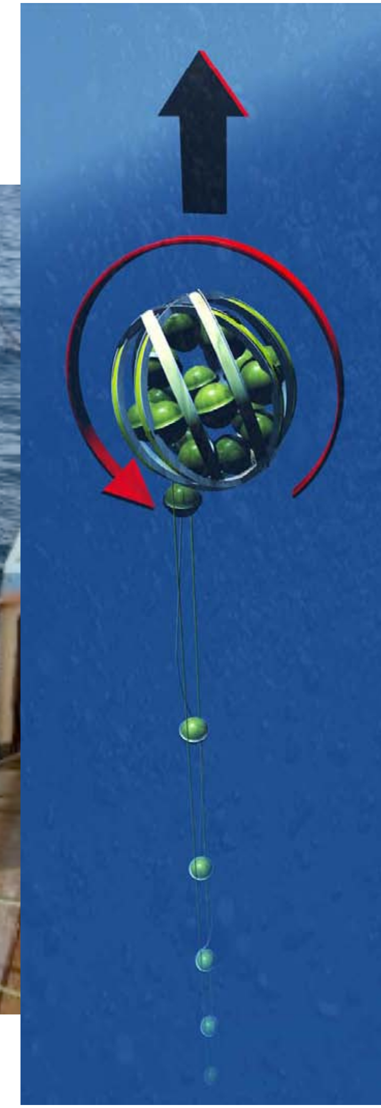
- Compact package – deployment – self-unfurling
  - Eases logistics
    (in particular in case of several assembly lines)
  - Speeds up and eases deployment;
    several units can be deployed in one operation
  - Self-unfurling concept being thoroughly tested and verified
- Connection to seabed network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

In detail: deploying strings

string rolled
up for self-unfurling:







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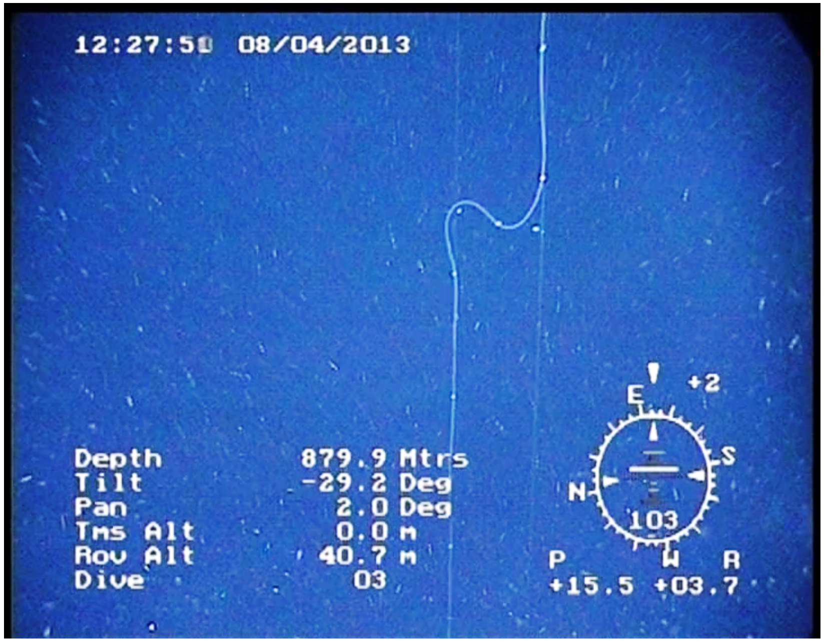
Tests and prototypes

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

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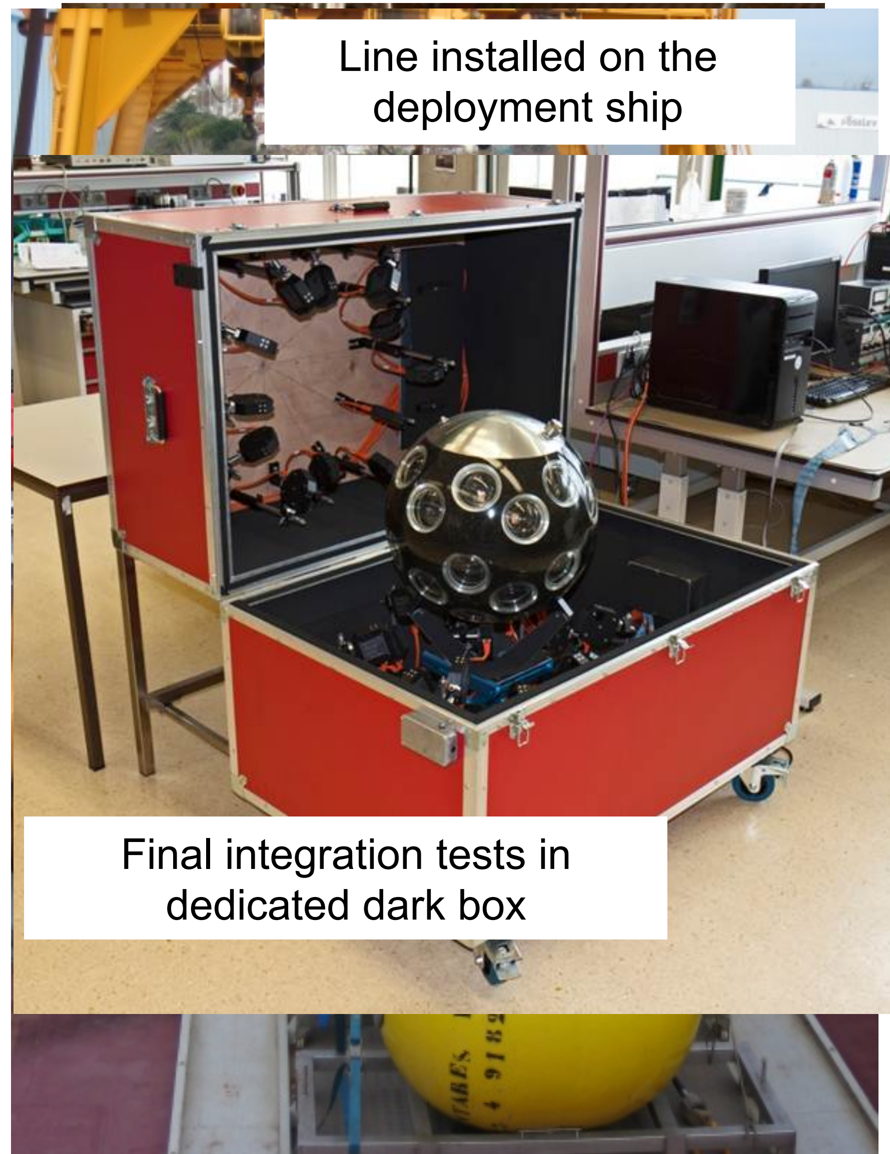
The Pre-production Optical Module

- 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

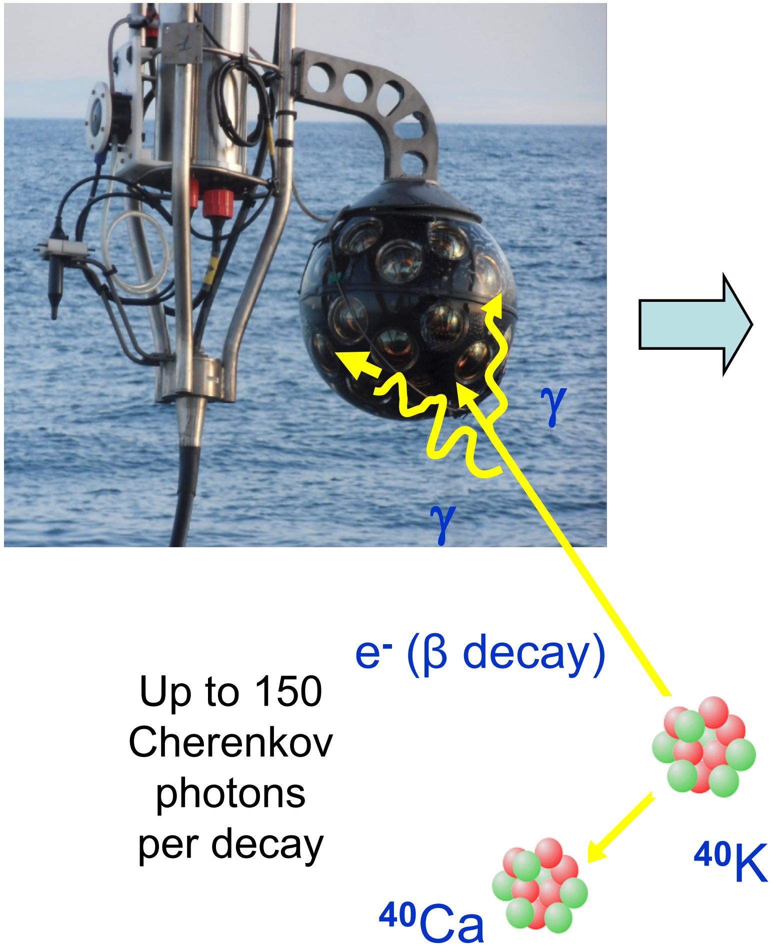
→ see talk by T. Michel



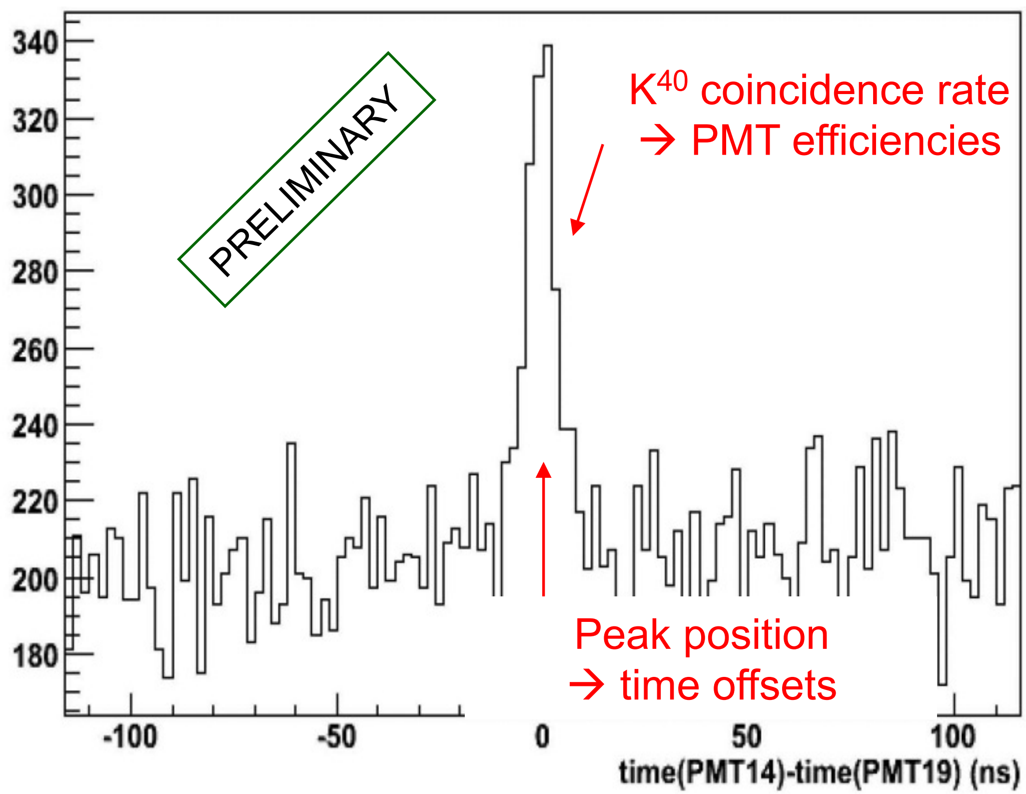
Line installed on the deployment ship

Final integration tests in dedicated dark box

PPM-DOM: K40 Coincidences



Coincidence rate on 2 adjacent PMTs



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

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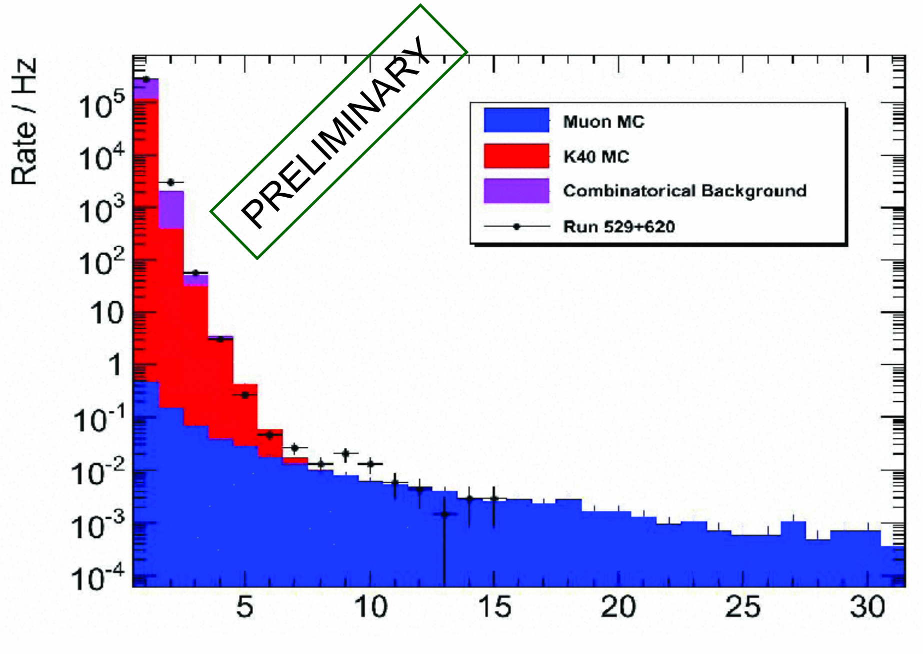
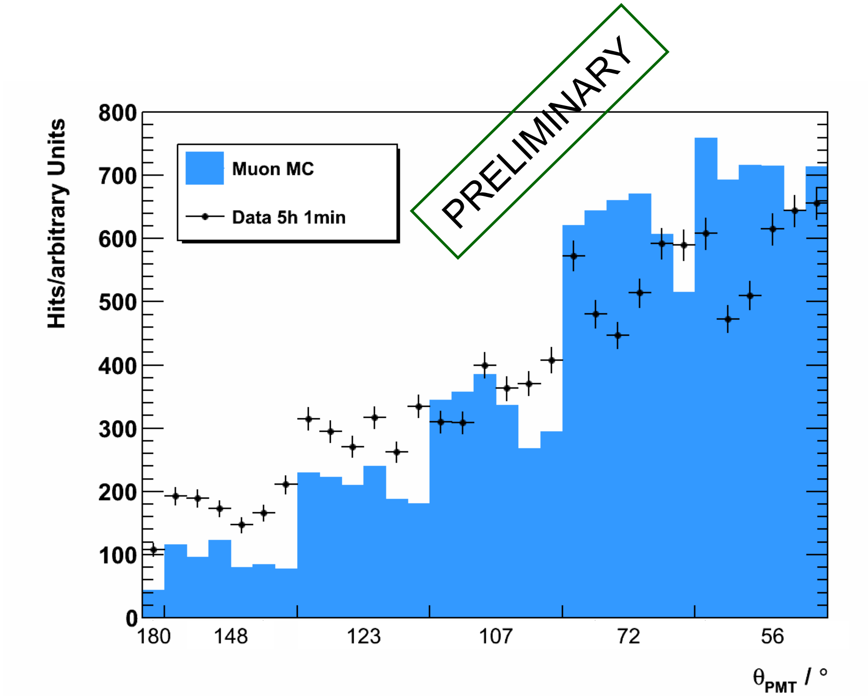
PPM-DOM: Atmospheric Muons



Number of coincident hits in a DOM



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

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

More upper PMTs in multi-hit events ⇒ directional information from single storey

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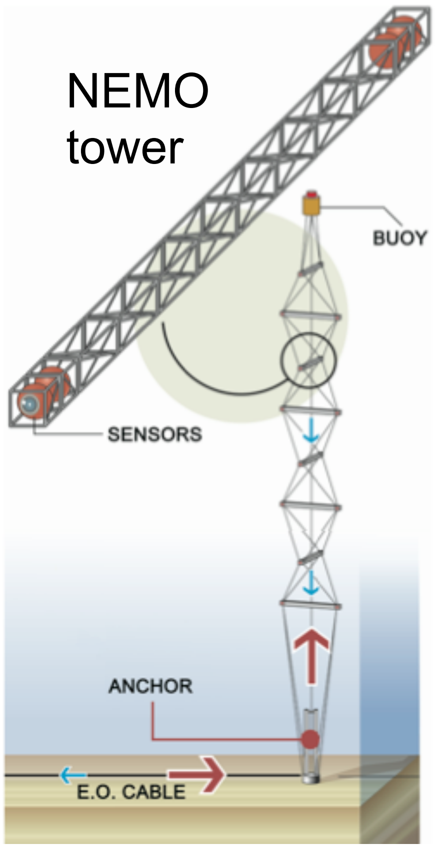
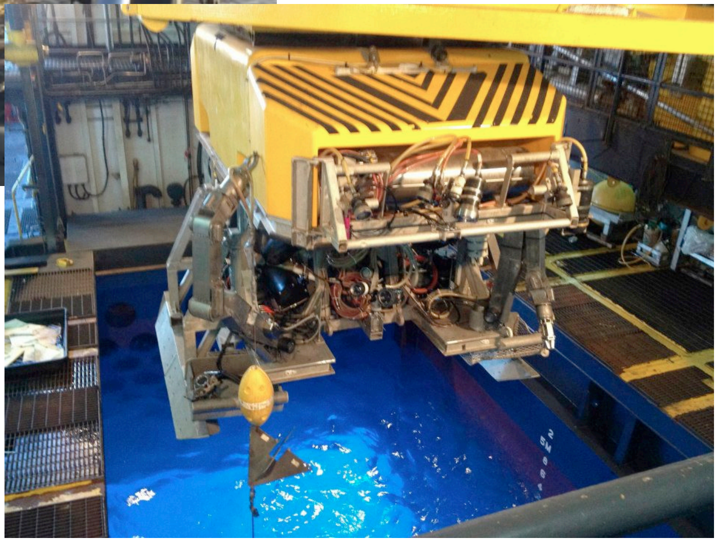
KM3NeT-Italy: site qualification

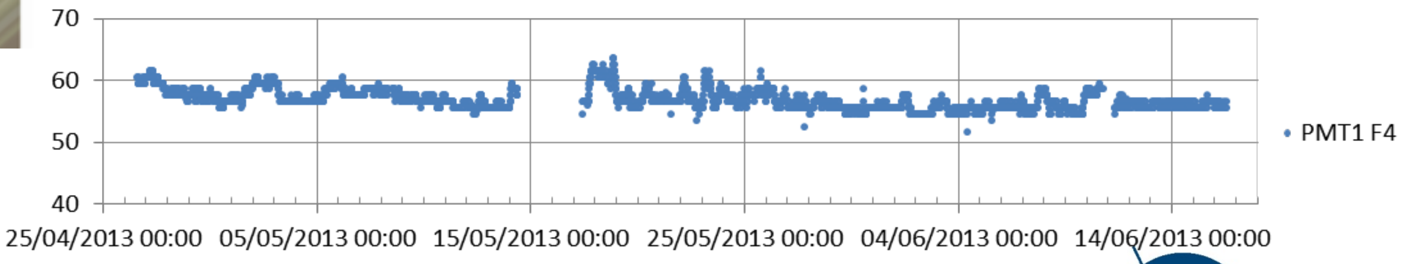


NEMO tower



Connected by ROV
March 23, 2013

First continuous rate measurements



Long term monitoring of site characteristics

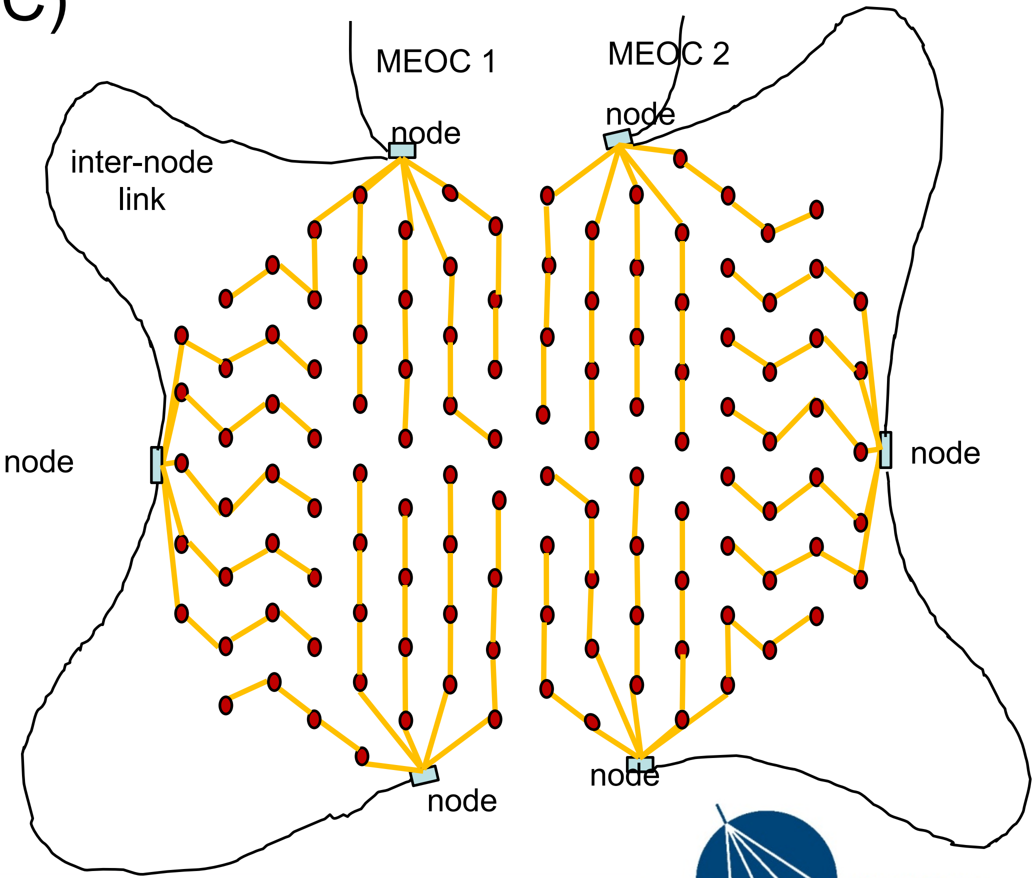
Next steps

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



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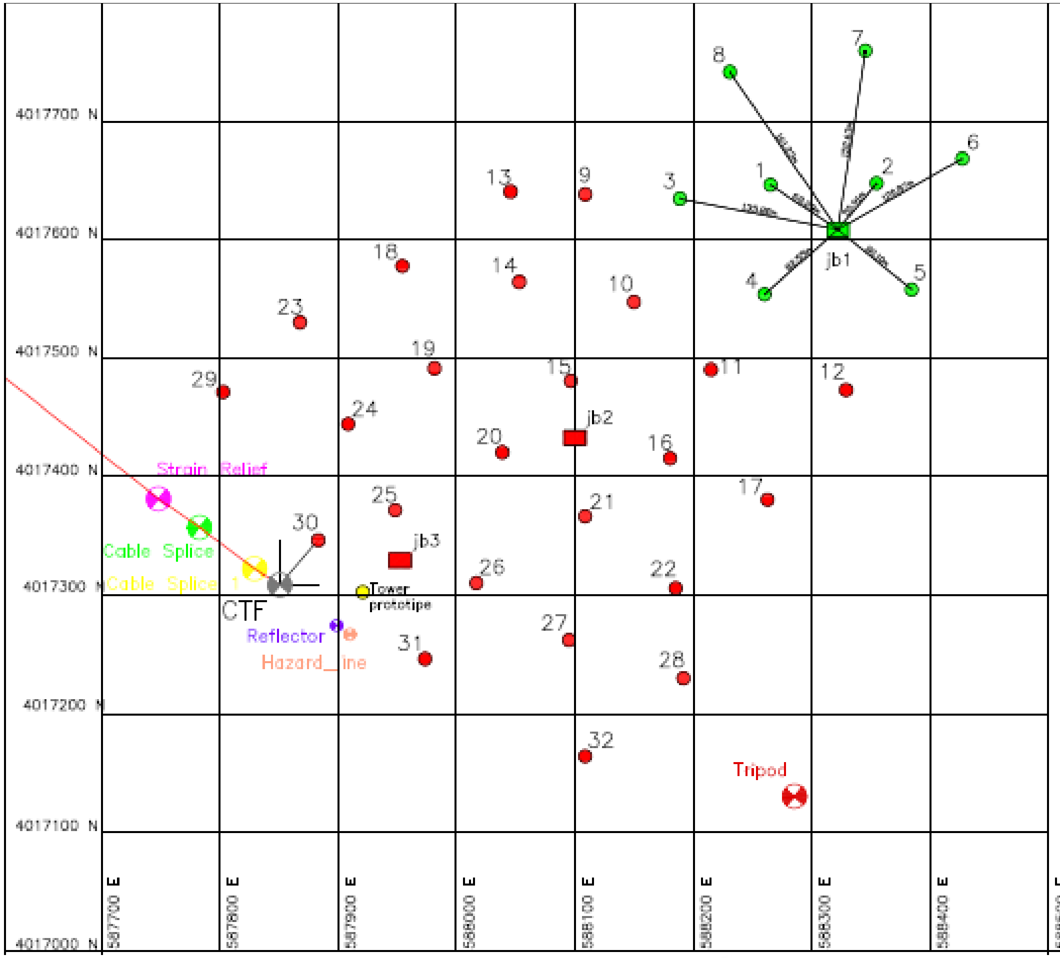
KM3NeT-Italy installation plans (phase-1)

- 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



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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

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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.