KM3NeT

Topics:

- **(Very brief) introduction to neutrino astronomy**
- **ANTARES, NEMO, KM3NeT**
- **KM3NeT: towers and strings**
- **Status (and recent news)**
- **Schedule & plans**

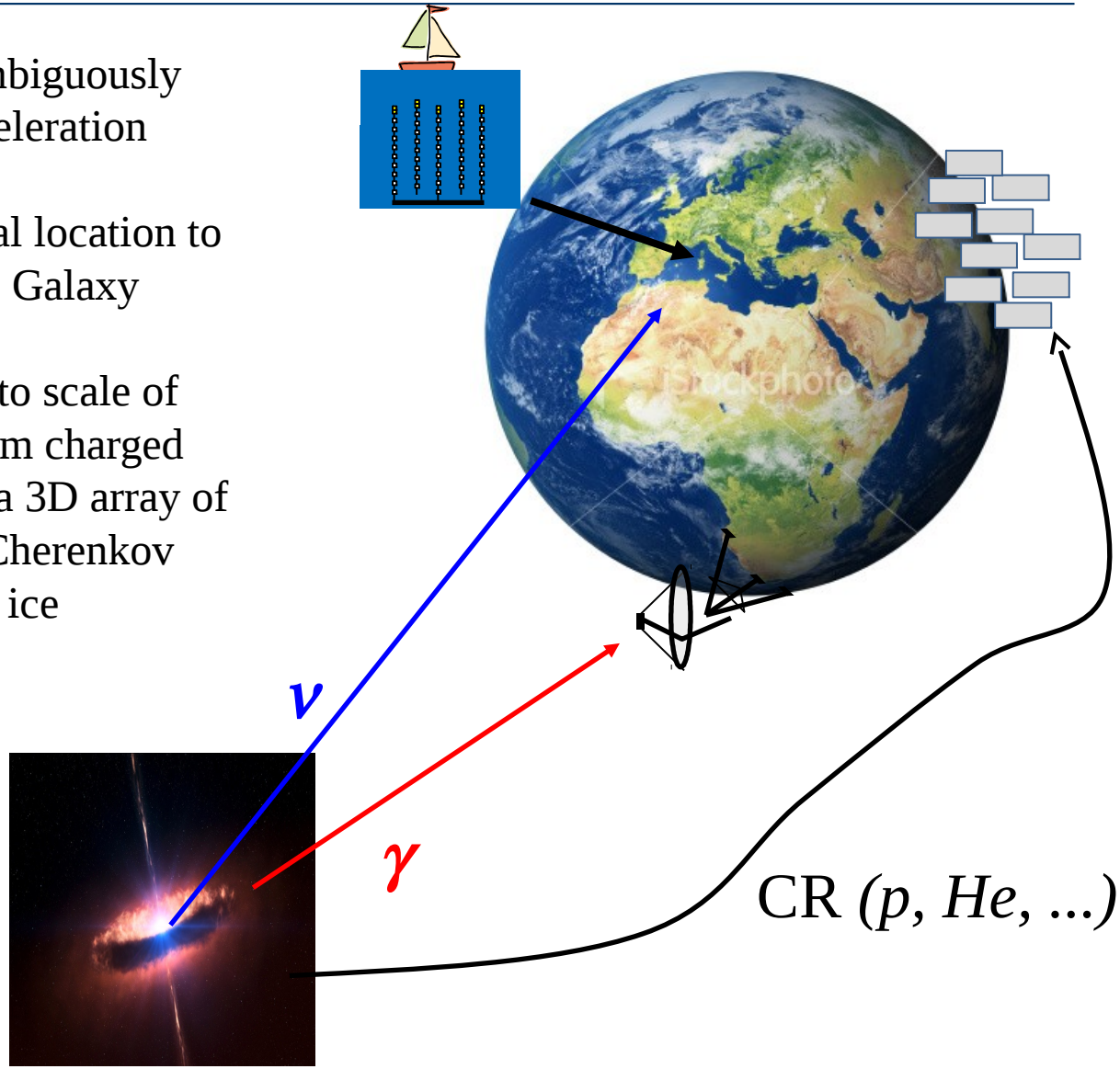
Neutrino astronomy

Neutrino telescopes for high-energy astrophysics

Concept: use neutrinos to unambiguously identify sites of hadronic acceleration

The Mediterranean Sea is the ideal location to look at the center of our own Galaxy

Need a very large detector (up to scale of various km3), well shielded from charged cosmic rays: solution is to equip a 3D array of photosensors for detection of Cherenkov radiation under water or ice



ANTARES, NEMO, KM3NeT: ν-astronomy in the Mediterranean

ANTARES
depth: 2500 m
40 km offshore Toulon

NEMO/KM3NeT
depth: 3500 m
80 km offshore Capo Passero

ANTARES – the first under-sea neutrino telescope:

- First string installed in 2006, apparatus completed in 2008, stable operation and data taking (including maintenance of offshore structures in 2009-2010)
- **Competitive limits published on flux of neutrinos from discrete or diffuse sources; several other studies published**
- Plan to take data until 2016 (and maybe more?)

NEMO – Long-term R&D program of INFN, including:

- **Search and characterization of a deep-sea optimal site**
- **Test site (2000 m depth) equipped offshore Catania, connected to shore station in the port of Catania**
- **Deep-sea site equipped and connected to shore station in Capo Passero**
- **Various prototyping campaigns performed (including tower of NEMO Fase 2, installed in spring 2013 and operated until recently)**

KM3NeT – Second-generation detector aiming at a detection volume of several km3:

- Supported by EU during Design Study (2006-2008) and Preparatory Phase (2009-2012)
- **PON Project (20.8 M€) gave boost to new international collaboration!**
- 8 towers and 24 strings to be installed in Capo Passero starting in 2014 (so-called Phase-1)
- In addition: a few strings will be installed in new infrastructure under construction in France
- Plans for future include Phase-1.5, ORCA, Phase-2 (see later)

KM3NeT: towers and strings

Technical solutions for KM3NeT

Large PMTs on tower structure (NEMO concept)

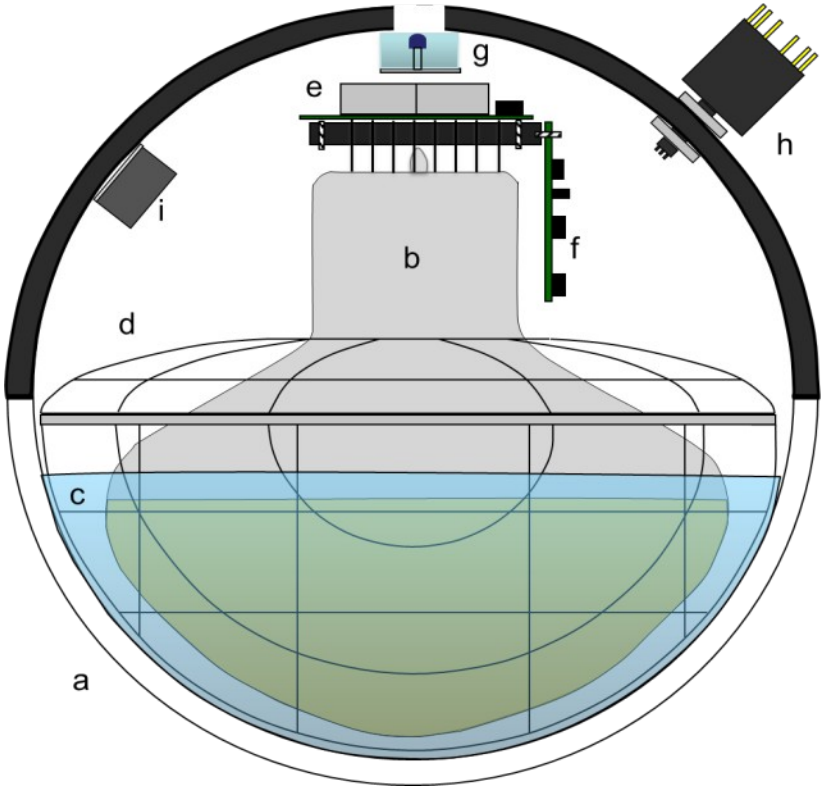
- 10” PMT in 13” sphere
- Front-end electronics in Optical Module
- Waveform digitization (5 ns sampling)
- Very low power consumption
- 6 optical modules on each bar (8 m length)
- Data collected and sent to shore by electronics on each floor (DWDM 50 GHz)
- 14 bars (mutually perpendicular), 20 m spacing
- Folded structure during deployment

Multi-PMT DOMs (*) on string structure

- 31 3” PMT in 17” sphere
- Front-end and data communication electronics (DWDM 50 GHz) in Optical Module
- Digitization of time-over-threshold of individual channels
- Very low power consumption
- 18 DOMs on each string, 36 m spacing
- Folded structure during deployment

(*) DOM = Digital Optical Module

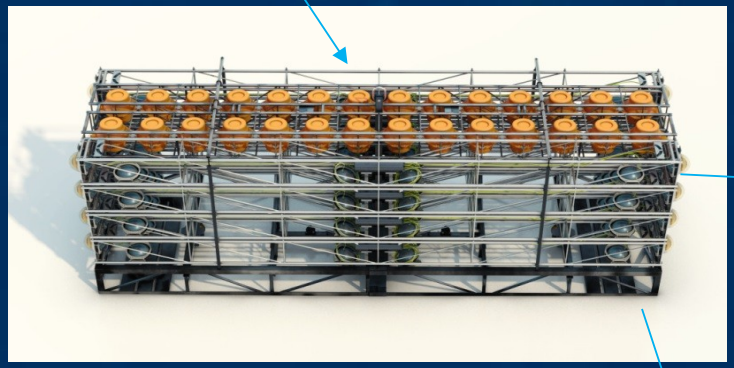
Large-PMT optical module (for towers)



a. 13” glass sphere by BENTHOS
b. PMT 10” R7081 by Hamamatsu
c. Wacker silicon optical gel 612
bi-component A / B
d. Mu-metal cage
e. HV base voltage supply by ISEG
f. FEM (Front-End Module) board
g. LED beacon
h. 8-pin connector
i. Manometer

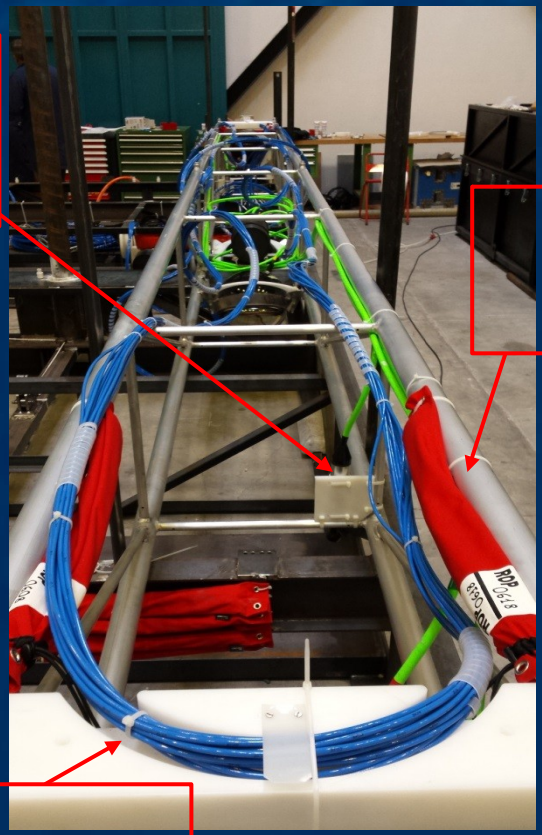
The tower

The buoy structure comprises a battery of 17” floatation spheres



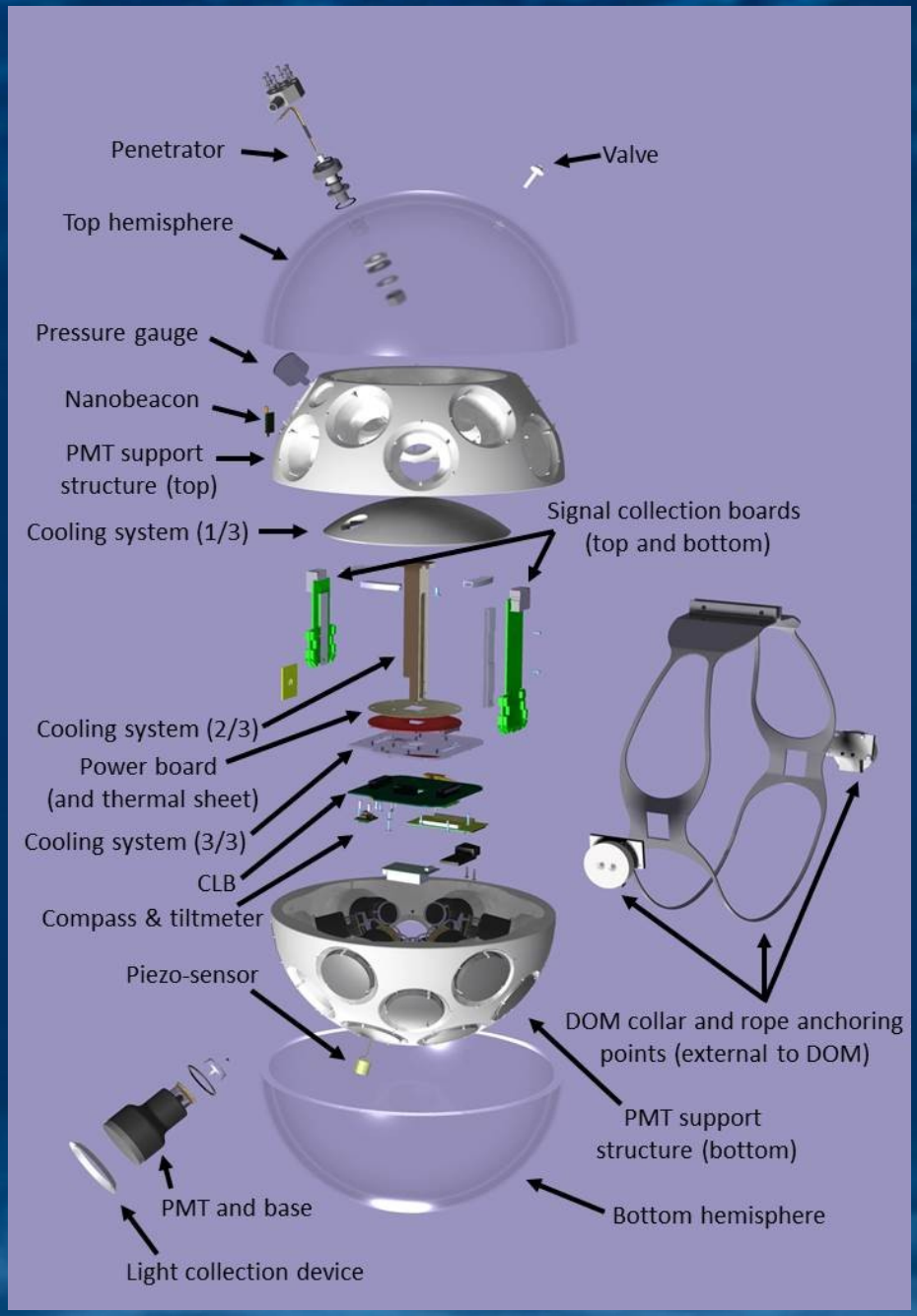
Folded tower for deployment

Each of the 14 storeys is equipped with 6 optical modules, one electronics container and two hydrophones



The anchor is equipped with a base container, an acoustic transponder and a hydrophone, an ROV-operatable mechanism for unfurling and a panel for ROV wet-mateable connection

Exploded view of the DOM (for the strings)



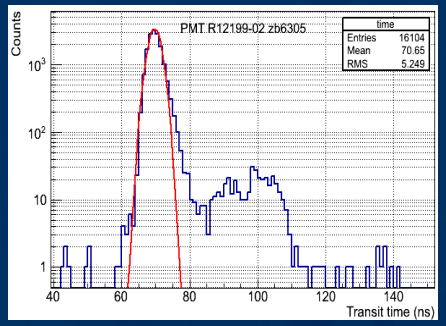
3" PMTs

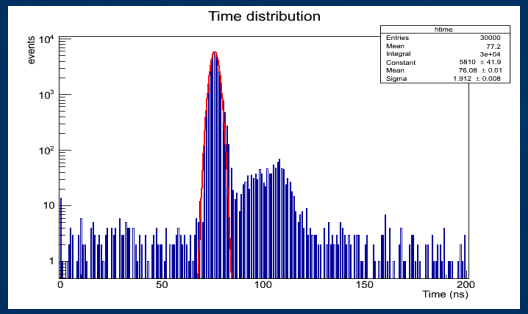
- Long-term tests performed on various prototypes (by ETL, Hamamatsu, HZC) performed at various laboratories (NIKHEF, Erlangen, INFN Catania) with comparable results
- Comparable performance of ETL and Hamamatsu

- Hamamatsu PMTs will be used in KM3NeT-IT (15,000 produced for INFN)

ETL D792KFL

Hamamatsu R12199-02





Measurements of PMT time response (example plots)

DOM internal mechanics

- PMT support structure to be produced with 3-D printing – design optimized for large production

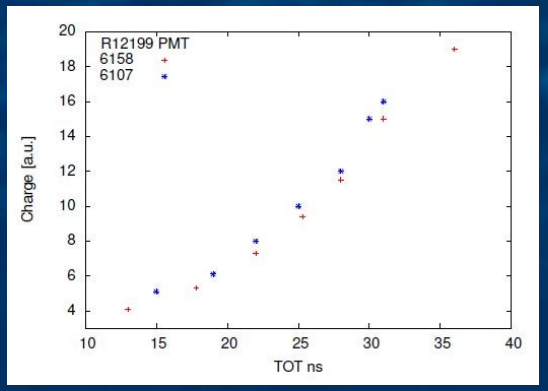
- Cooling system to provide mechanical support and to efficiently transfer heat from the electronics to the glass sphere – sliding bar allows connection between the two hemispheres before closure

Arrangement of PMTs inside DOM

DOM electronics

- **Custom-made bases to produce HV for the PMTs and to extract the time-over-threshold (TOT) from the analogue signals**

- **Two signal collection boards ('octopusses') connect the PMTs to the Central Logic Board (CLB)**



Transfer function of charge vs. TOT

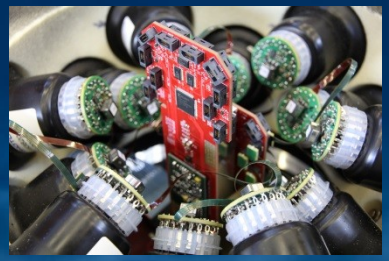
Main tasks of CLB:

- **Control of PMTs and instrumentation (piezo-sensor, nanobeacon, monitoring devices)**
- **Hit digitization with sub-nanosecond time-stamping from the 31 PMTs**
- **Long-range communication with shore (with fixed latency): White Rabbit**

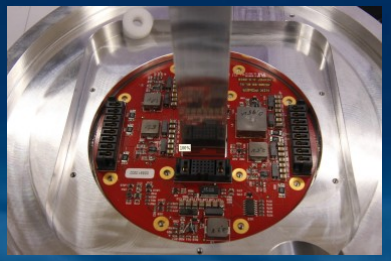
- **A power-board regulates all needed voltages from the input +12V**

⇒Various rounds of prototyping implemented this year for each board (mass productions ongoing)

Octopus connected to a set of PMT bases



Internal view of DOM



CLB (left) and power-board (right) in 'mushroom' structure

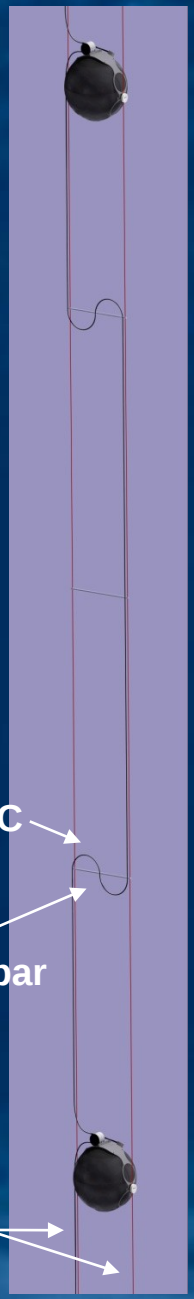
String mechanics

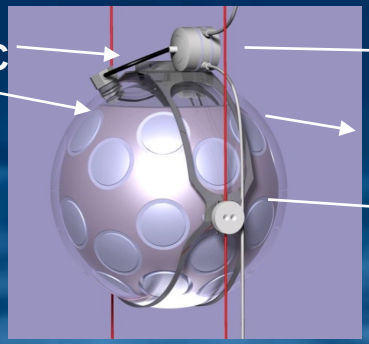
- Mechanical structure of the string based on two dyneema ropes, anchored on sea floor and kept taught by commercial top buoys (plus DOM buoyancy)
  - Robust and stiff arrangement
  - DOMs keep the correct attitude
  - String dynamics under control

- the VEOC (Vertical Electrical-Optical Cable) connects all DOMs to the DU base – the VEOC is an oil-filled pressure-balanced hose equipped with 18 optical fibres (one for each DOM)

- DOM collars keep the DOMs in their positions

- A Break-out-box (BOB) is the interface between a DOM and the VEOC
  - Very simple structure hosting fibre splices and a DC/DC converter
  - A short cable (BEOC – BOB Electrical-Optical Cable) connects the BOB to the DOM penetrator





DOM and ropes

String installation

- DU is packed on launcher vehicle (LOM) and installed on an anchor

- After deployment on sea bed, unfurling is done by operating an acoustic release (to be changed into ROV-friendly mechanism for Capo Passero)

- LOM and acoustic release are recovered after operation

- The string is connected to deep-sea infrastructure by a ROV

String unfurling

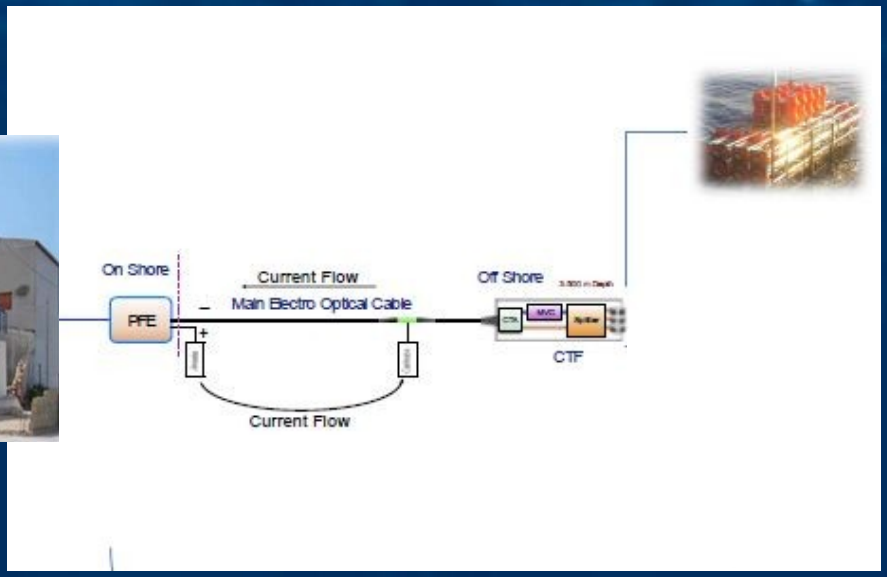
Arrangement on LOM (detail)

String deployment

ROV inspection of an unfurled string (Motril tests, April 2013)

Status (and recent news)

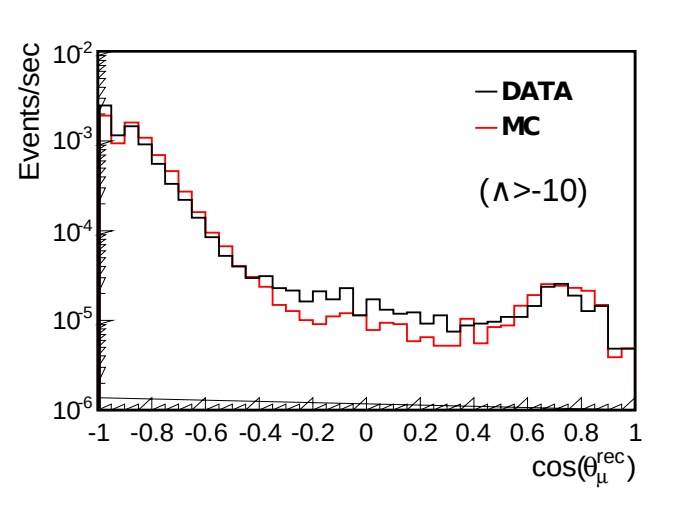
Status of KM3NeT-IT infrastructure at Dec. 2013



- Shore station
- Main electro-optical cable terminated with preliminary CTF (Cable Termination Frame): 3 ROV-operatable connectors
- Prototype tower of NEMO Fase 2 connected in March 2013

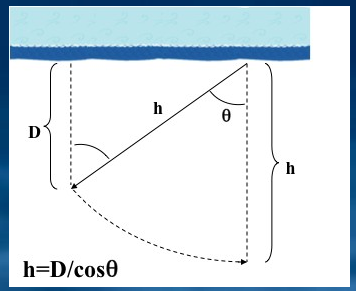
Tower of NEMO Fase 2

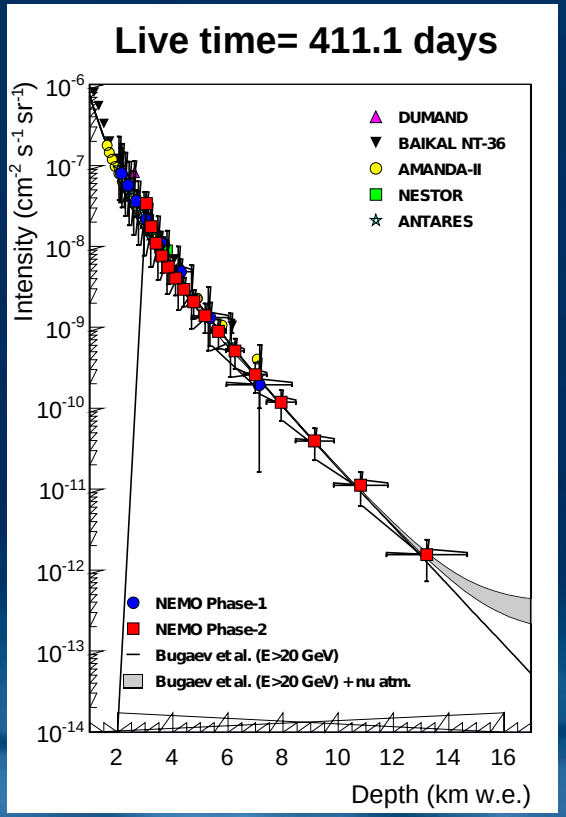
- 8-storeys, 32 optical modules in total, 450 m height
- Installed in March 2013, disconnected recently
- Operated for more than 1 year, ~100% live-time
- Long-term monitoring of (excellent) water properties – paper in preparation
- Proof of installation technique, stable data taking, calibration, positioning, …
- Good understanding of data and simulations
- Paper submitted on depth-intensity relation for muons (extended to a largely unexplored region)



Angular distribution of events reconstructed from data and from simulated muon tracks

Vertical Muon Intensity as a function of Depth

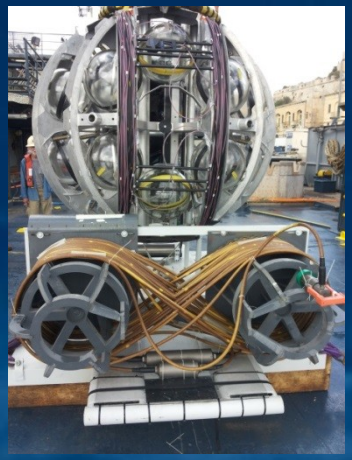




PPM-DU (Pre-production Model of Detection Unit)

- Installed on May 7, 2014 with Nautical Tide, sailing from Malta
- Deployment assisted by ROV
- Line positioned and oriented thanks to ROV
- Line position: 60 m from tower, 84 m from CTF (1 m off nominal)
- Connection performed nicely at first attempt
- Inspection of unfurled structure: everything in good order
- Acoustic release frame and LOM recovered directly from the ship

PPM-DU onboard the Nautical Tide



Jumper arranged on anchor

ROV orienting the anchor of the PPM-DU

Connections on CTF

Development plan for DOMs

PPM-DOM

- Single, complete DOM with long-distance communication with shore
- Installed on instrumentation line of ANTARES at 2500 m depth in April 2013, operated smoothly since then
- Paper recently published

PPM-DOM during deployment

PPM-DU

- Reduced-size DU equipped with 3 DOMs
- Equipped with VEOC, deployed with LOM
- Installed at Capo Passero (3500 m depth) on 7 May 2014
- In smooth operation since then
- Paper in preparation

Installation tests

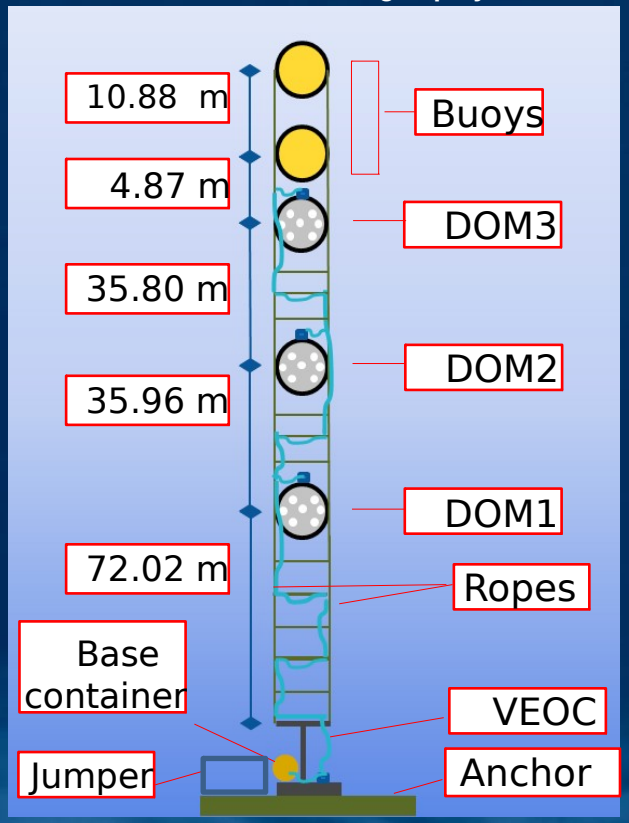
- Various tests performed in sea and laboratory
- New deployment campaign performed in June 2014

Onshore qualification

- Electronics and optical system to be qualified onshore
- Environmental and pressure tests on critical components

DU-1

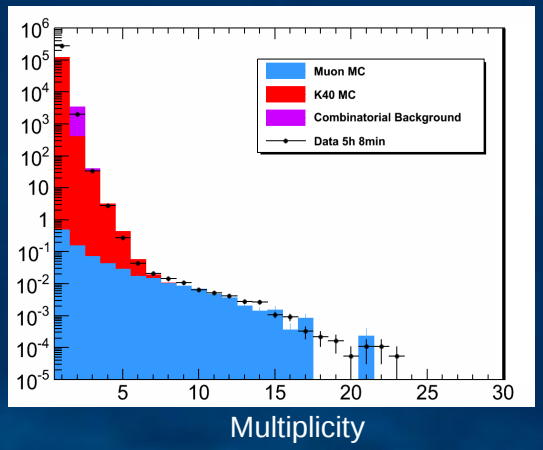
- Final validation of all technical solutions will come with operation of first line



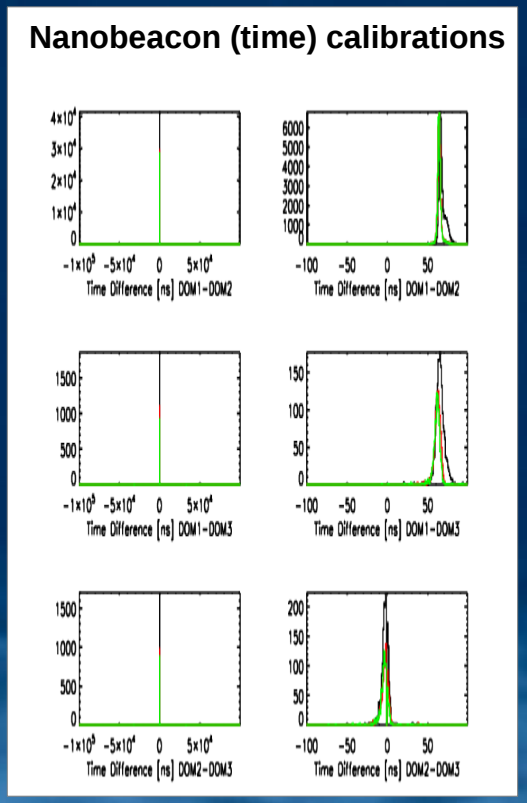
PPM-DU configuration

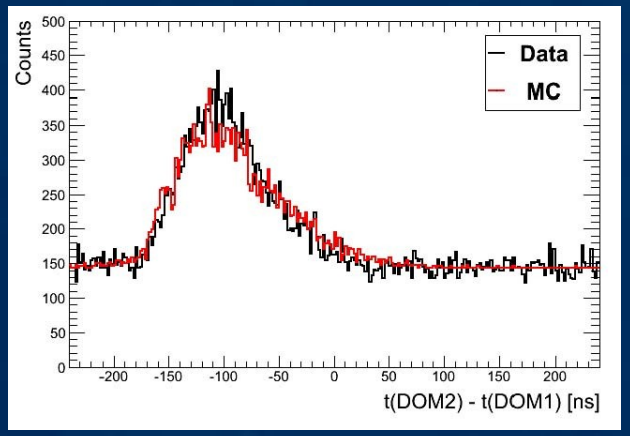
Status of PPM-DU

- Communications ok, stable data taking
- All PMTs active, except channel 14 of DOM2 (damaged during DOM integration)
- All calibration devices operational
- Good understanding of the data (and simulations)



Coincidence plot





Time difference of signals induced by muons on different DOMs

Installation of first Junction box and tower of KM3NeT Phase-1

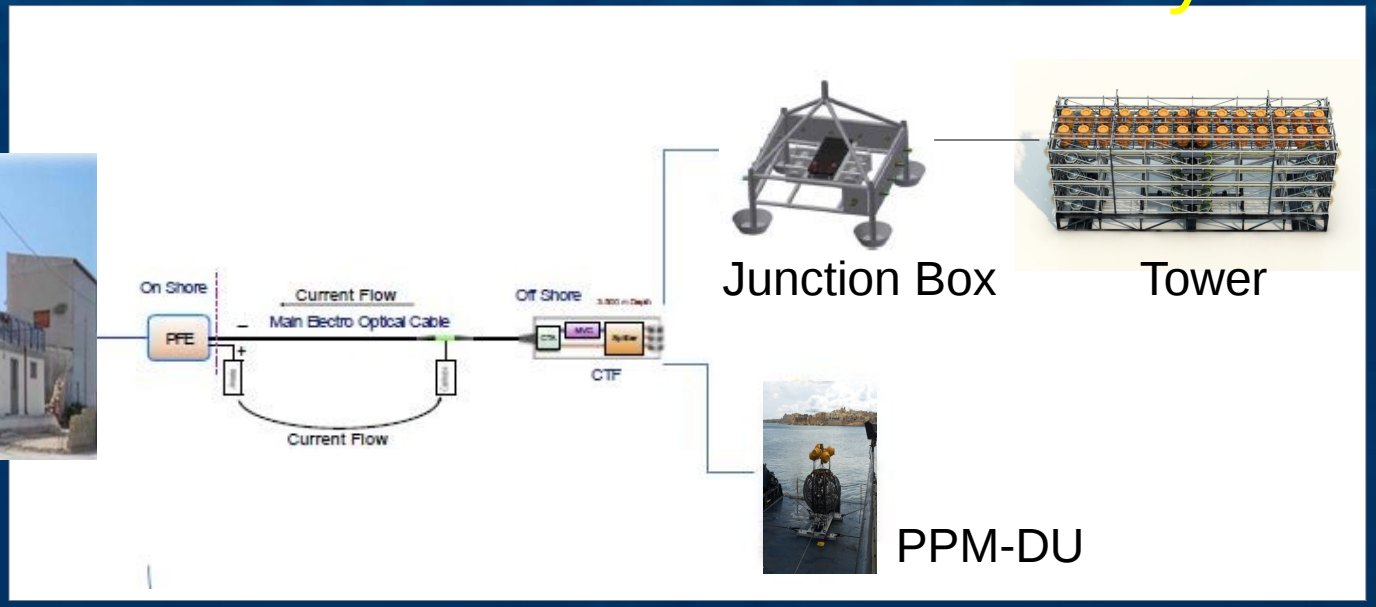
- Performed with Ambrosious Tide in mid-November
- First phase dedicated to recovery of instrumentation from the Catania test site

- Second phase (3 days) devoted to:
  - site survey and marker deployment for junction box and tower
  - deployment of the cable tray with the interlink cable CTF-JB
  - unfurling of the long cable (600 m!)
  - deployment of the JB
  - connection of the JB to the cable termination frame
  - switch on JB - check JB - switch off JB
  - deployment of the cable tray with the interlink cable JB-Tower
  - unfurling of the cable (200 m)
  - connection of the cable to JB
  - deployment of the tower
  - connection with the tower
  - JB and tower switched on and tested
  - unfurling of the tower (with instrumentation on for monitoring the process)
  - ROV inspection of the unfurled structure

Outcome:

- All structures installed within 1 m from target positions
- Good functionality at first test, commissioning ongoing

Status of KM3NeT-IT infrastructure today



Available:

- Shore station (with air conditioning and power system improved, ready for Phase-1)
- Main electro-optical cable terminated with preliminary CTF (Cable Termination Frame): 3 ROV-operatable connectors
- PPM-DU in operation since May
- Junction Box (JB) and first tower installed in November

What remains to be done:

- New CTF to be installed on cable for full connection of 20 fibres over 5 connectors for JBs
- 2 JBs to be installed for strings
- 7 towers and 24 strings to be produced and installed

Schedule and plans

Milestones ahead

Towers

- **First tower installed!**
- **Full set of PMTs tested, integration of optical modules ongoing at LNS (250 optical modules already built)**
- **Integration of next towers can proceed at a rate of 1 tower/month/site at LNS and LNF**

Strings

- **Integration of DOMs launched at NIKHEF, being launched in Catania and Naples**
- **Integration of DU-1 starting, aiming at deployment (KM3NeT-FR) in early 2015**
- **First batch of strings for Capo Passero to be installed in spring together with first junction box for strings**

On KM3NeT Strategy

See document recently released:
http://www.km3net.org/publications/2014/KM3NeT-Strategy.pdf

Funded

Proposed

Phase	Additional costs [M€]	Blocks	Primary deliverables
1	0	0.2	Proof of feasibility and first science results.
1.5	50-60	2	Measurement of the neutrino signal reported by IceCube.
ORCA	40	1	Determination of the neutrino mass hierarchy.
2	130-170	6	Neutrino astronomy including Galactic sources.

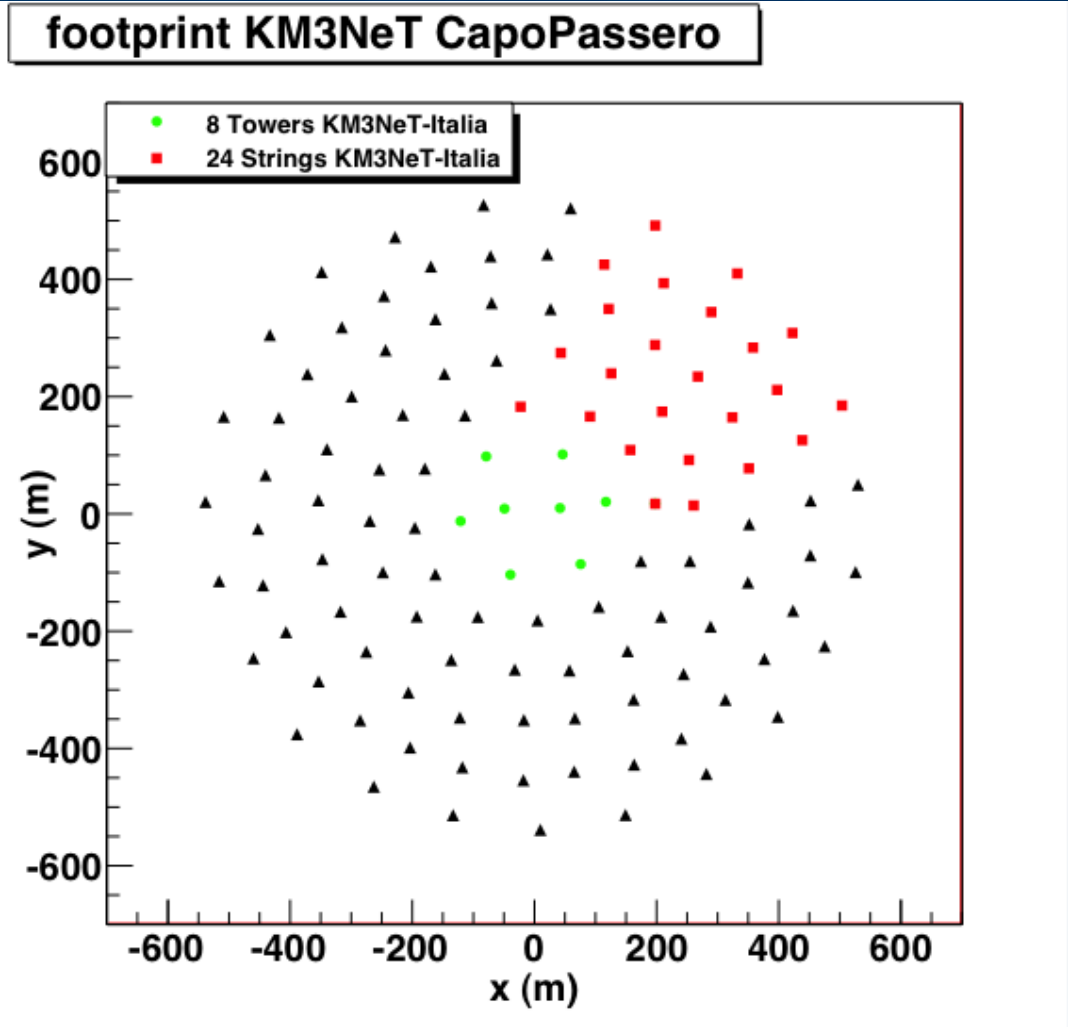
Table 1: Summary of the phased implementation of the KM3NeT research infrastructure. The costs for Phase-1 are fully covered. When both Phase-1.5 and ORCA are pursued, about 10 M€ additional costs are needed to accommodate both detectors.

Remarks:

- **One block comprises 115 detection units**
- **Medium-term possibility: ORCA in KM3NeT-FR, Phase 1.5 in KM3NeT-IT**
- **Preparing to re-apply for ESFRI roadmap**

From Phase-1 to Phase-1.5

Phase-1.5: 8 towers and 107 strings



Conclusions

- **A (very) challenging project, but deemed feasible!**
- **Big step made recently: from qualification to construction (first tower installed!)**
- **Working hard on construction of towers and strings and on completion of undersea infrastructure (to be done in 2015-2016)**
- **Ambitious plans for longer term in preparation...**