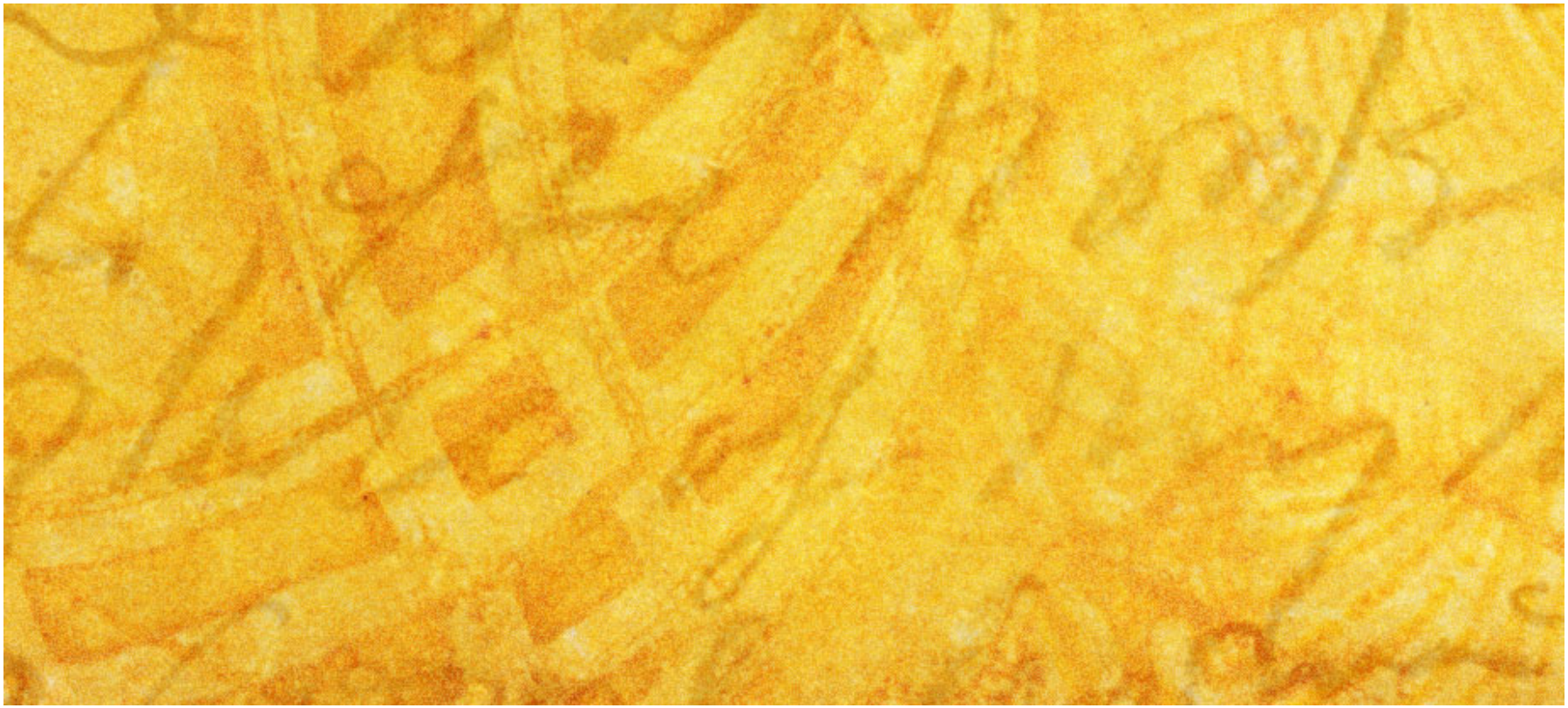
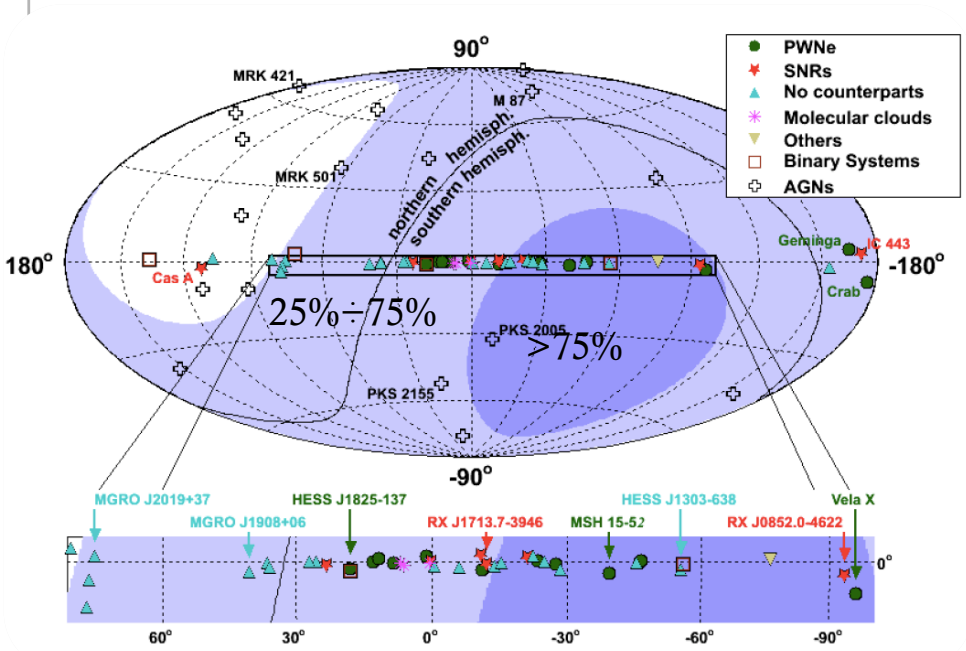
Status of the KM3NeT project

R. Coniglione on behalf of the KM3NeT collaboration
INFN - Laboratori Nazionali del Sud – Catania - Italy



KM3NeT: main facts

KM3NeT: a high energy neutrino telescope in the Northern hemisphere



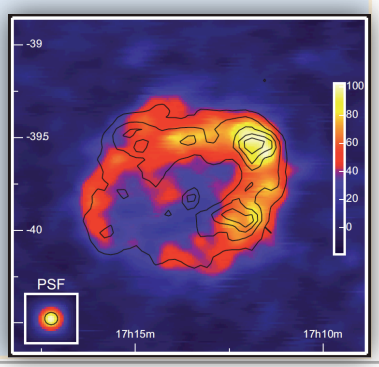
- KM3NeT will be located in the Mediterranean sea
  - large field of view
  - high visibility of the Galactic plane
  - complementary to IceCube
- Clean and homogeneous medium: the sea water
  - Very good angular resolution
- Large volume (~3 km^3)
  - Exceed the northern hemisphere telescope by a factor ~50 in sensitivity
  - Exceed IceCube sensitivity by substantial factor
- Important node for Earth and Sea sciences

High Energy neutrino astronomy

- The discovery of neutrinos from galactic sources is the primary physics objective for KM3NeT.
  - Detector optimization focused on discovery of Galactic sources
- Estimate of neutrino spectrum based on high-energy gamma observation

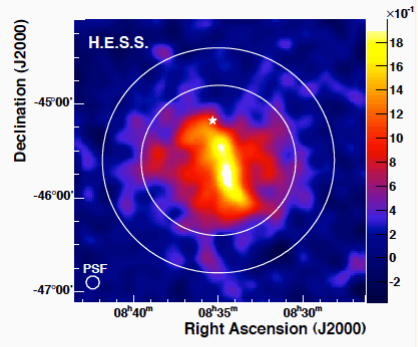
SNR RXJ1713 our reference source:

- Discovery (5σ 50%) at ~ 5 years of observation time
- Evidence (3σ 50%) at ~ 2 years of observation

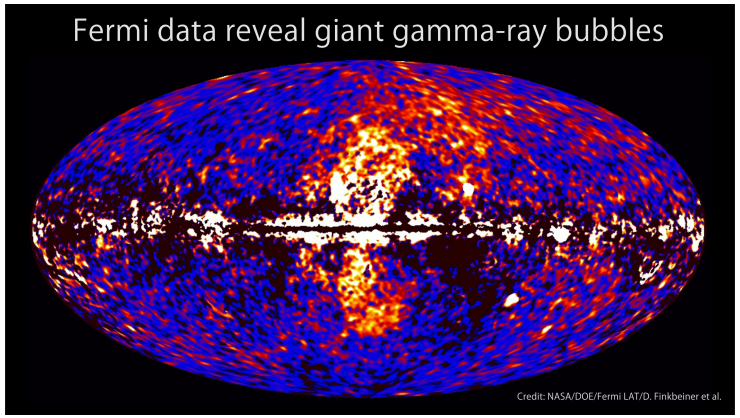


PWN VelaX:

- Discovery (5σ 50%) at ~ 3 years of observation time
- Evidence (3σ 50%) at ~ 1.2 years of observation

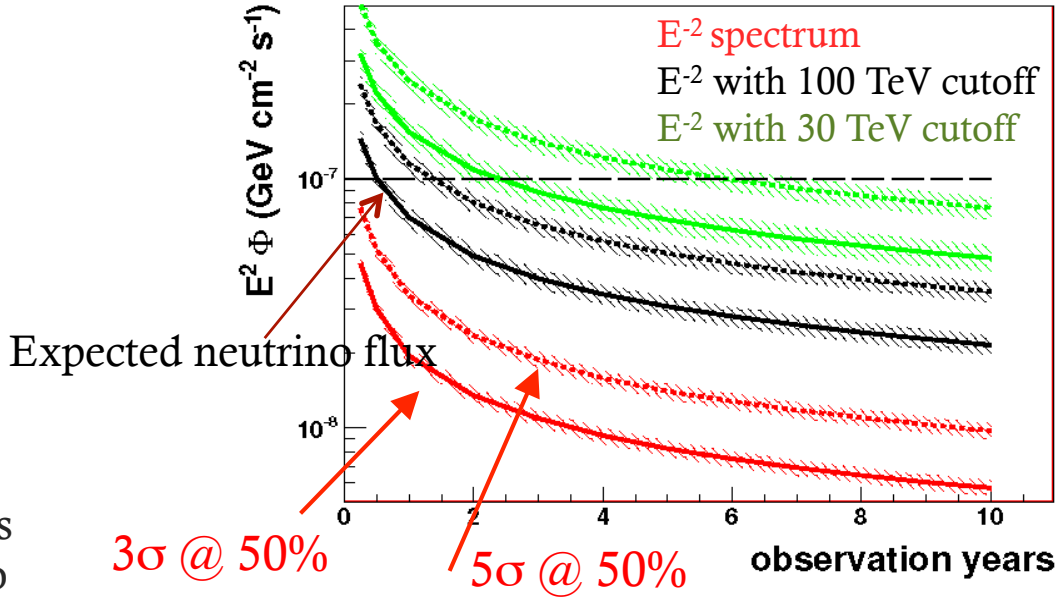


High Energy neutrino astronomy: the Fermi bubbles



- Two extended regions above/below centre of Galactic plane
- Origin and acceleration mechanisms under debate – if hadronic, neutrino source candidate

Discovery flux



Results published on Astrop. Physics 42 (2013) 7-14

Fermi bubbles:

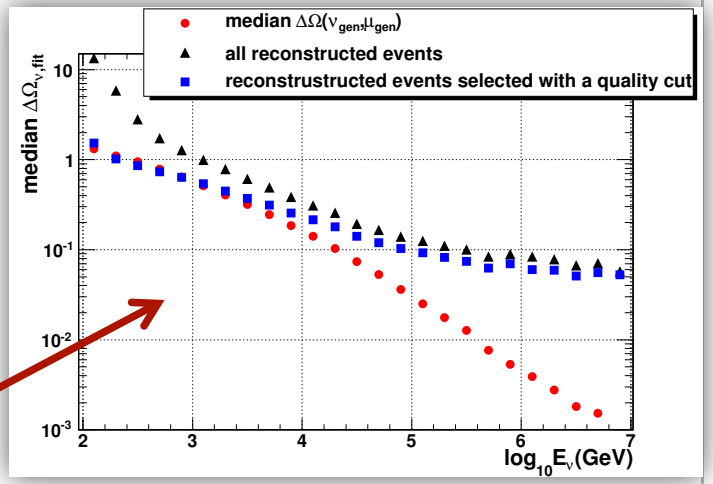
- Discovery (5σ 50%) at ~ 1.5 years of observation time (100 TeV cutoff)
- Evidence (3σ 50%)) at ~ few months of observation time (100 TeV cutoff)

KM3NeT and the new IceCube results

The detection of cosmic neutrinos in IceCube (@ 4.3σ) has triggered new enthusiasm in the high energy neutrino community.

Detected IceCube events

- Energy range from ~ 10 TeV to few PeV
- Isotropic flux (minor excess in southern sky compared to isotropic but not significant)
- E^{-2} spectrum with a cut off @ ~ 2PeV (?)
- Analysis based on contained events (vetoed events)



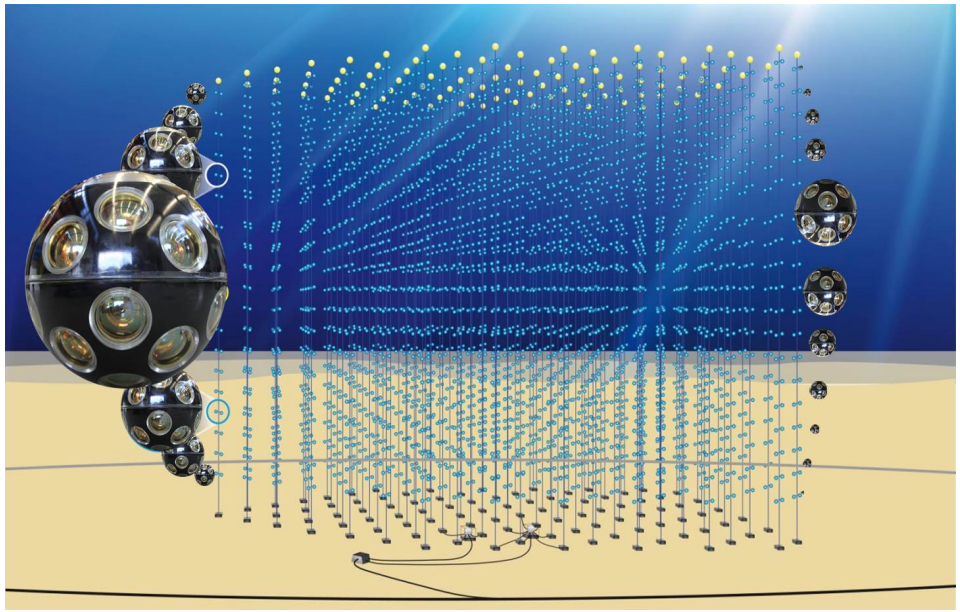
KM3NeT detector has a very good angular resolution ➔ design optimisation focused on Galactic point-like sources (μ channel, up-going events)

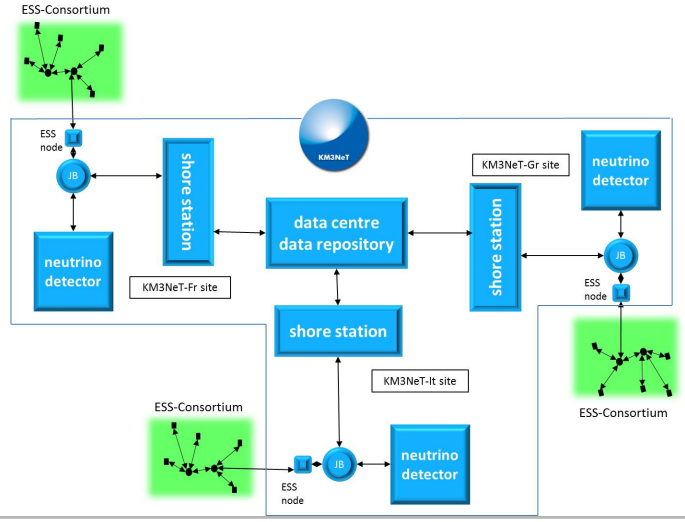
Big expectations for KM3NeT

✓ Cascade reconstruction and background rejection analysis not yet available.
✓ In depth-studies under way (high priority).
✓ No results ready

The detector

- Building block concept: the full detector is made of several blocks of Detection Units. Common hardware, software and data handling.
  - 6 blocks of 115 DUs 90 m distant.
  - Full volume ~ 3 km^3
  - DU vertical string equipped with 18 Optical Modules
  - Optical modules made of 31 3” PMTs
  - Candidate sites in France, Italy and Greece



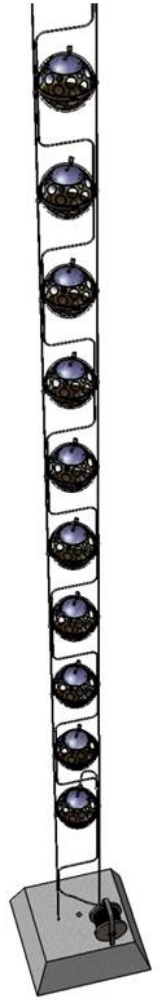


The Detection Unit

- The mooring line:
  - Buoy (probably syntactic foam)
  - 2 Dyneema© ropes (4 mm diameter)
  - 18 storeys (one OM each), 36 m vertical spacing, 100 m anchor-first storey
  - ~700 m total length

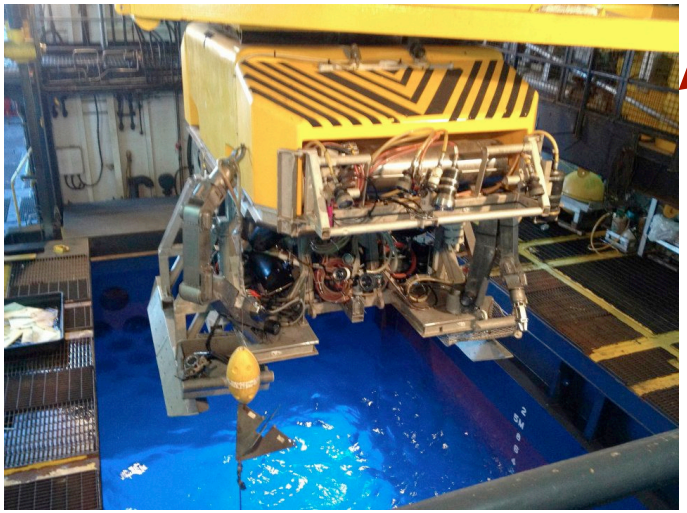
- Electro-optical backbone (VEOC):
  - Flexible hose ~ 6mm diameter
  - Oil-filled
  - Fibres and copper wires
  - At each storey: connection to 1 fibre+2 wires
  - Break out box with fuses at each storey: One single pressure transition

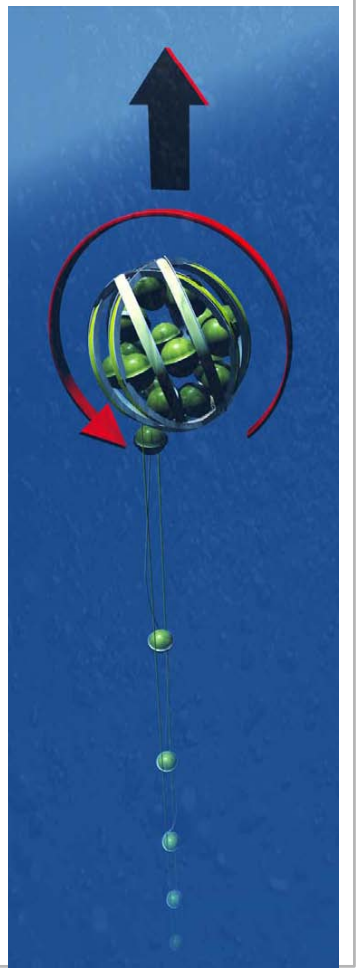
- The hydrodynamic stability
  - Dynamics studied for currents up to 30 cm/s (2 times the max. observed)
  - Deviation from vertical at top about 150 m at 30 cm/s (can be reduced by extra buoyancy)
  - Critical current ~45 cm/s (anchor starts to move)



The string deployment

- 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
  - Recovery of launcher vehicle
- Connection to seabed network by ROV





First tests on mechanics of string and deployment

- In situ qualification campaigns
  - Dec 2009 and Feb 2011
  - April 2013 @ Motril (Spain) 10 days and five deployments

- Successful demonstration of deployment concept
- DOMs are horizontal
- VEOC cable ➔ no leaks
- Some issues with penetrators (understood)

The Digital Optical Module

- 17-inch glass sphere
- 31 3-inch PMTs (cathode area ~ 3x10" PMTs) suspended by plastic structure with a light collection ring (20−40% gain in effective photocathode area)
- 31 PMT bases (total ~140 mW)
- Front-end electronics (FPGA readout for each individual PMT with sub-ns time stamping and time over threshold concept)
- Al cooling shield and stem
- Single penetrator
- 2mm optical gel

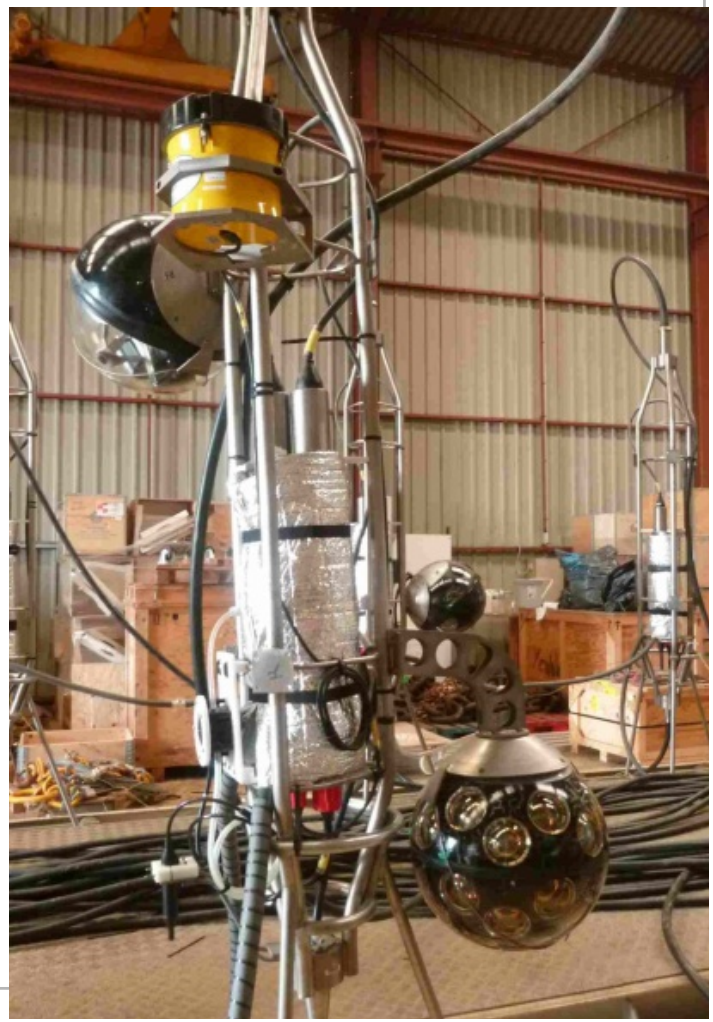
- ✓ Low power consumption <10 W / DOM
- ✓ Calibration: LED & acoustic piezo
- ✓ Optical fiber data transmission: DWDM with 80 wavelengths

KM3NeT DOM advantages

- Increased photocathode area
  - 1 KM3NeT DOM ≈ 3 10-inch 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 down-going events (PMTs are also looking upwards)
  - Reduction of random background (K40, bioluminescence)

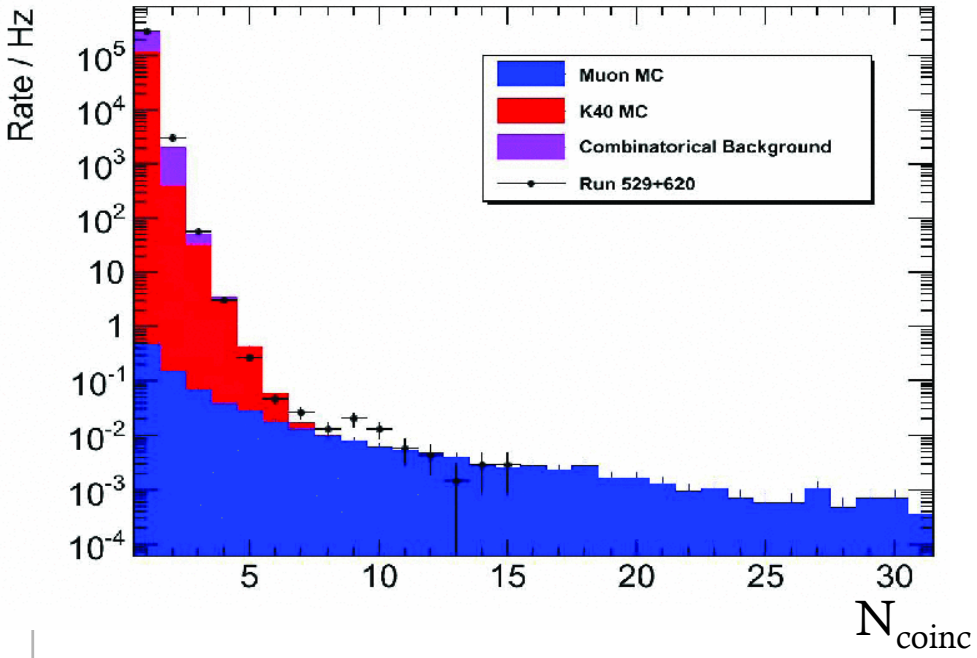
Tests of the DOM

- Fully equipped DOM - 31 PMTs + acoustic positioning sensors + time calibration LED beacon mounted on the Instrumentation Line of ANTARES (2475 m deep)
- Deployed and connected with ROV on 16 April 2013
- PPM-DOM fully operational and working well

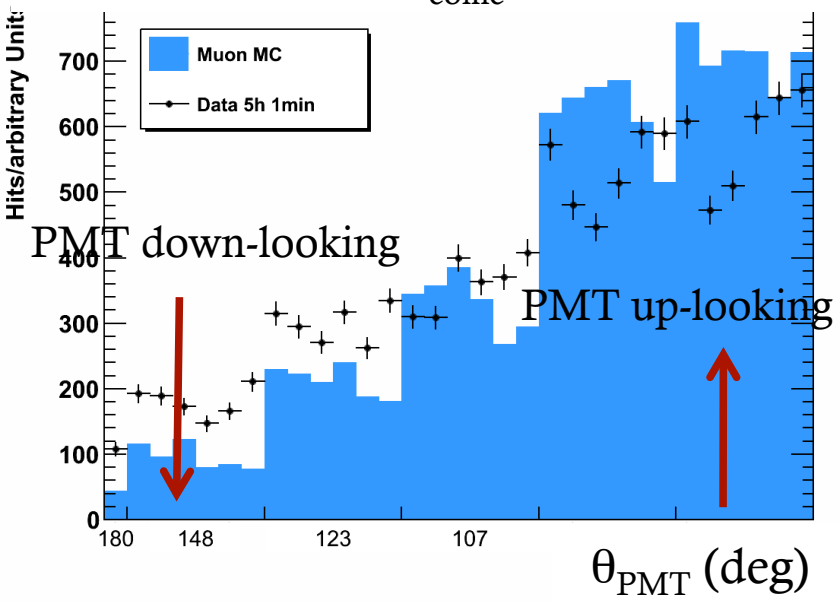


Results from DOM

Coincidence in a DOM ⇒ hits in different PMTs in a time window of 20ns



Events with N_{coinc}>6 selected

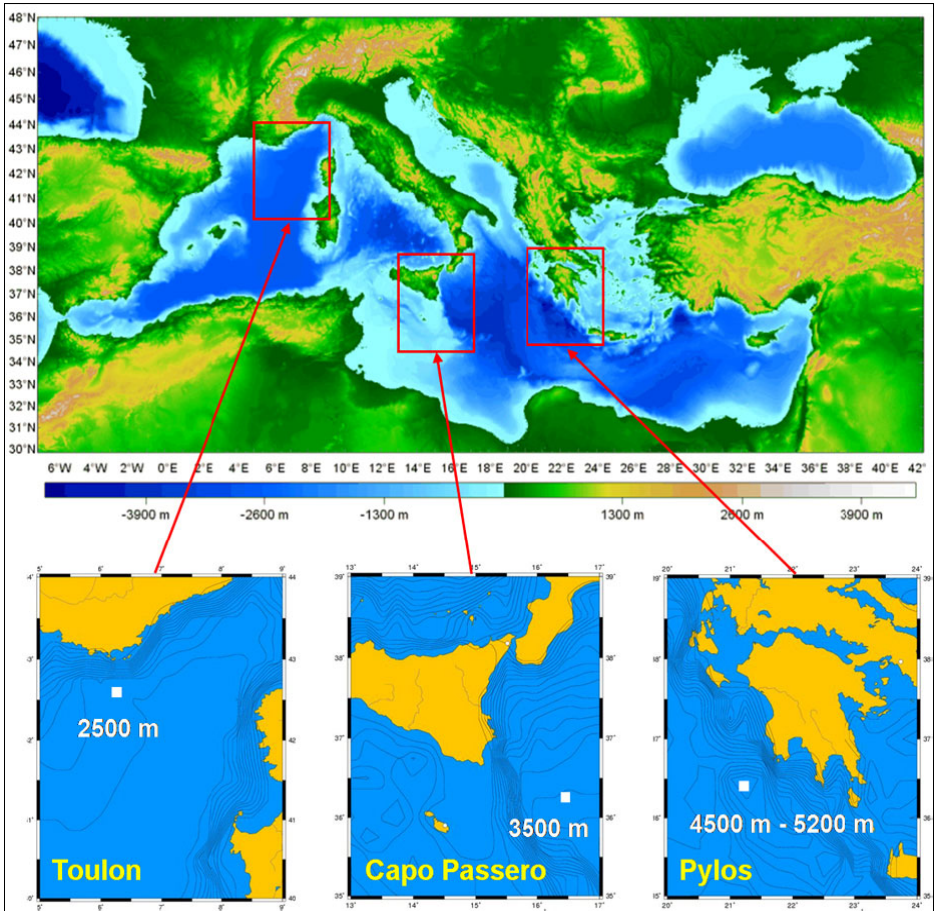


- N_{coinc}>6 reduces ^{40}K contribution
- Single ^{40}K rate ⇒ 5kHz as expected

Upper PMTs more events ⇒ directional information from single storey

KM3NeT Sites

- KM3NeT-France: Toulon (~2500m)
  KM3NeT-Italy: Capo Passero (~3400m)
  KM3NeT-Greece: Pylos (~4500m)
- Long-term site characterisation measurements performed
- Shore distances: 15km-100km
- Exact design site-dependent
- Power via Main Electro-Optical cable MEOC
- Short distances (AC), Long distances (DC)
- Transmission on optical fibers (24-36 Optical fibers)



KM3NeT Phase-1

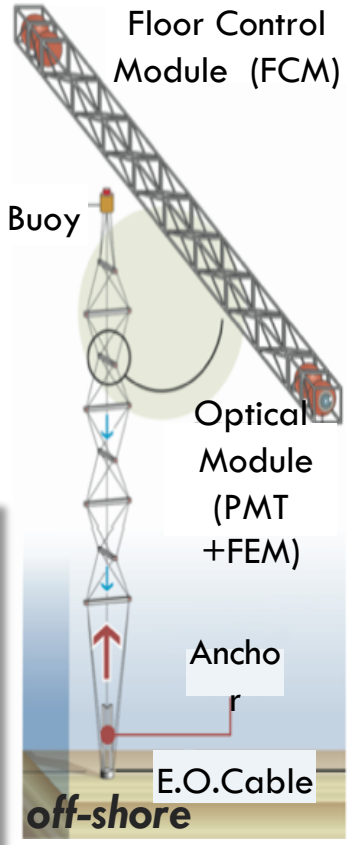
- The organization:
  - transformation of consortium in a collaboration in early 2013
  - management established
  - MoU in advanced state of preparation
- The funds
  - 40 M€ available (out of ~220 M€ estimated for full KM3NeT), mostly from regional funds
- The decisions
  - construction starting at Toulon and Capo Passero sites
  - common technology, software, data handling, operation, governance
- In the next year
  - KM3NeT-Italy: rigid time constraint for regional funds ➔ a first batch of DU will be constructed with the technologies already developed and available (8 towers with 10" PMTs). Following DUs will be built with the string design (about 24 strings)
  - KM3NeT-France: MEOC deployment, node deployment ➔sea-floor infrastructure ready for connection of DUs

KM3NeT-Italy

Already installed and working:

- Shore laboratory in Capo Passero
- Optical fibre 1 Gbit link between Capo Passero shore station and LNS
- Main Electro-Optical Cable (MEOC): 96 km, 20 optical fibers, single conductor,
- Medium Voltage Converter: 10 kV to 375 V and 3 ROV mateable electro-optical connectors
- A tower with 8 floors (40 m spacing) with 32 10" PMT, 16 acoustic sensors and oceanographic instrumentation. Working since March 2013

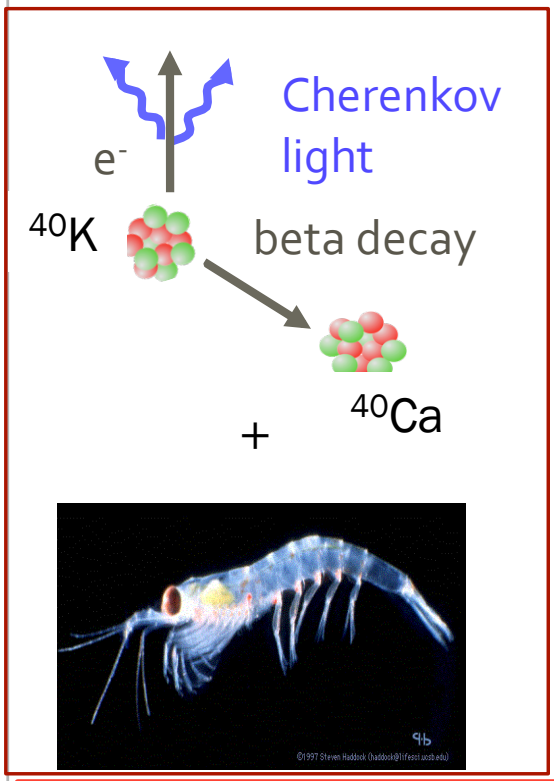
Tower scheme

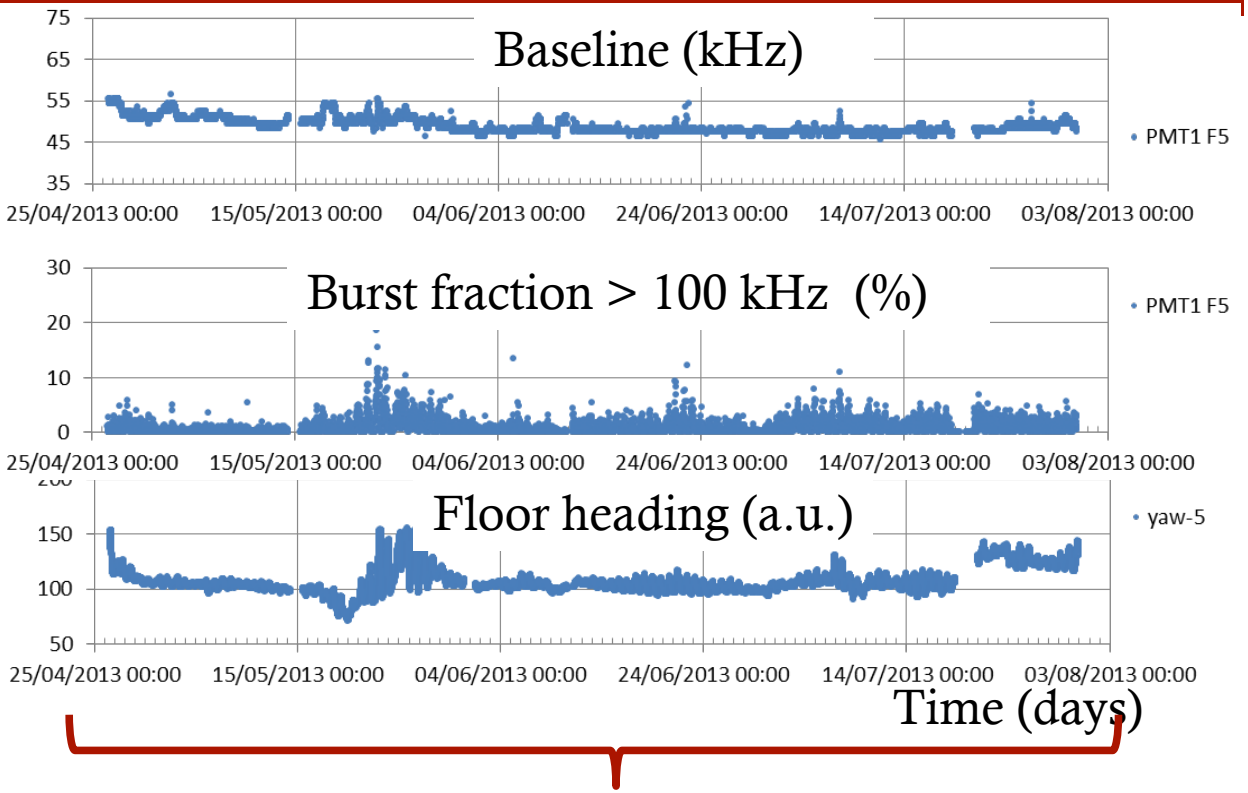


Deployment of the 8 floor tower

KM3NeT-Italy: long term measurement

Optical background



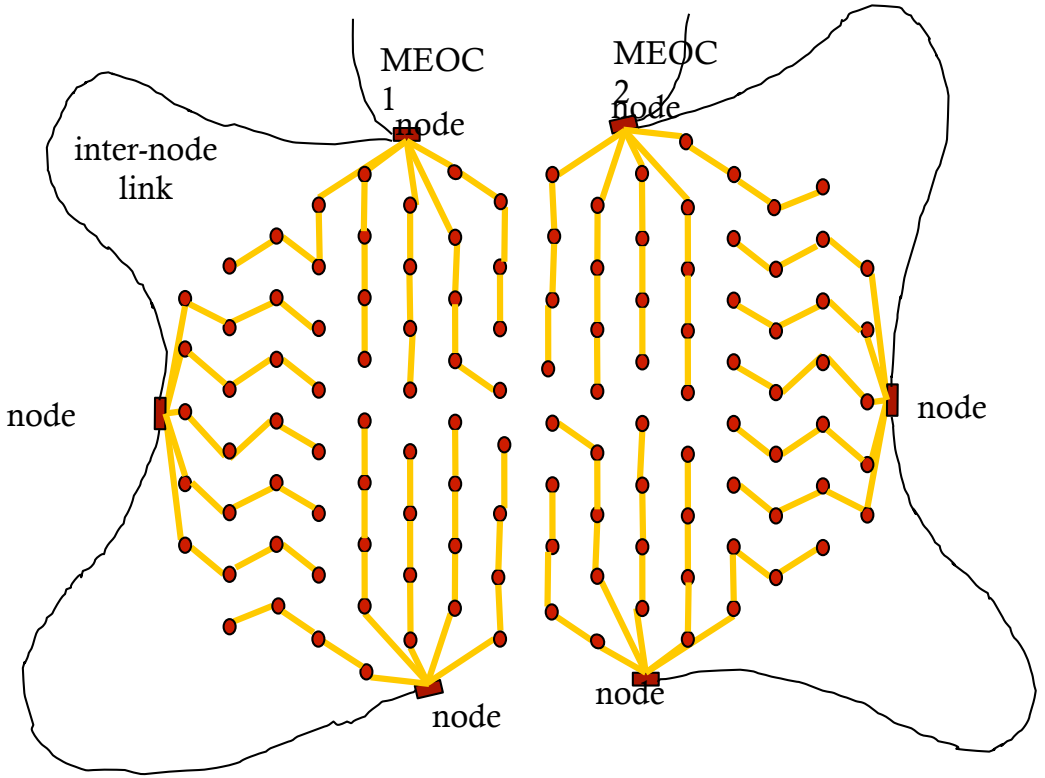


Very low background rates (50 – 60 kHz) compatible with a ^{40}K background with few bioluminescence bursts

KM3NeT- France

Sea floor infrastructure: a scheme for a block of 115 strings

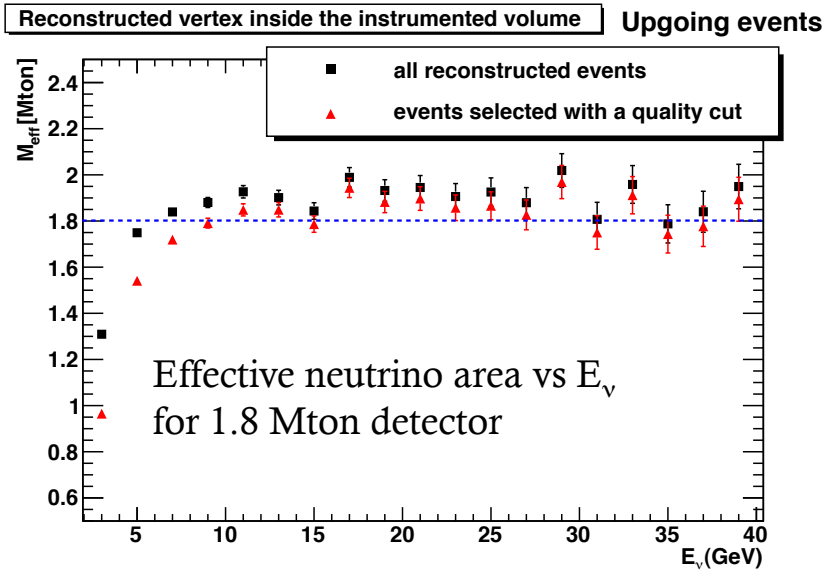
- 3 nodes per MEOC
- 20 strings per node
- sets of 4 strings in series



Low energy studies: ORCA

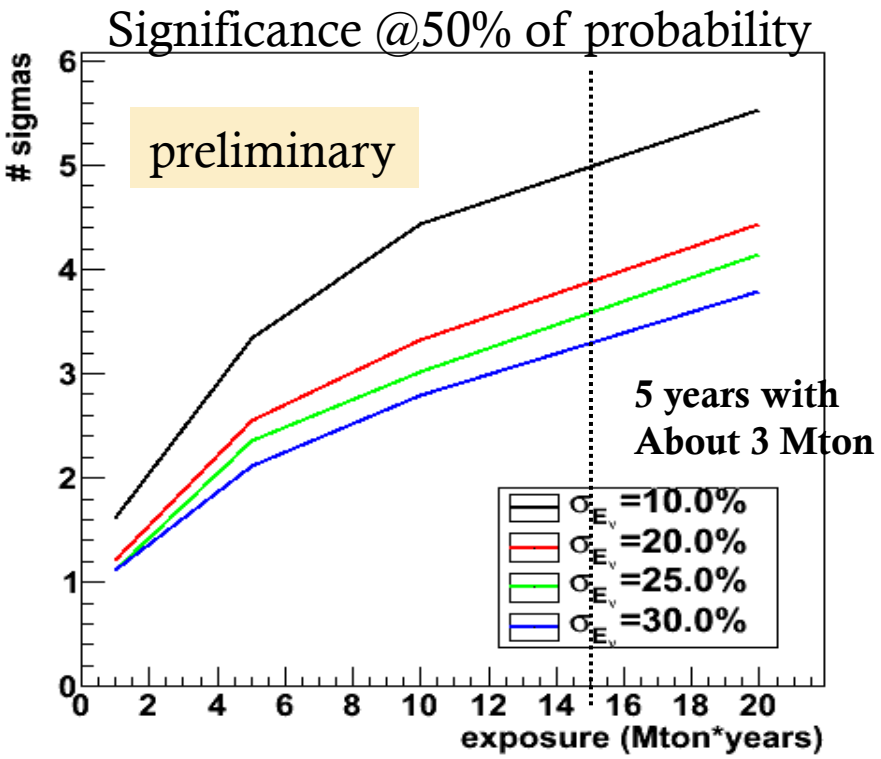
Feasibility studies ongoing for mass hierarchy measurement with atmospheric neutrinos: energy range of interest 6 - 20 GeV.

Main issues under studies:
- Flavour separation
- Low energy reconstruction
- Atmospheric muon rejection
- Detector size and density optimization



Effective neutrino area vs E_ν for 1.8 Mton detector

Significance @50% of probability



Summary

- KM3NeT will be a powerful instruments for neutrino astronomy, it will complement IceCube exceeding ~50 times the ANTARES and 3-4 times IceCube sensitivities
- KM3NeT will be a distributed detector and infrastructure (more effective for Sea and Earth sciences)
- Technical design is fixed and decided.
- Intense prototyping and test program ongoing
- First construction phase will start 2014 (KM3NeT phase-1).
- Path towards full implementation to be defined during phase-1.
- KM3NeT part of a Global Neutrino Observatory network