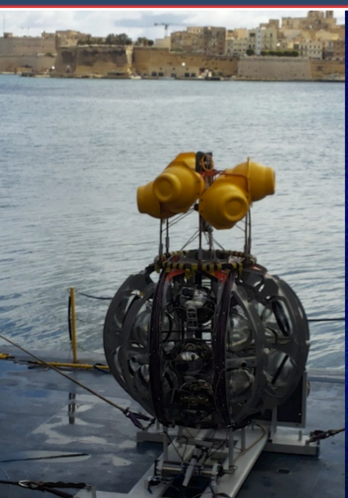
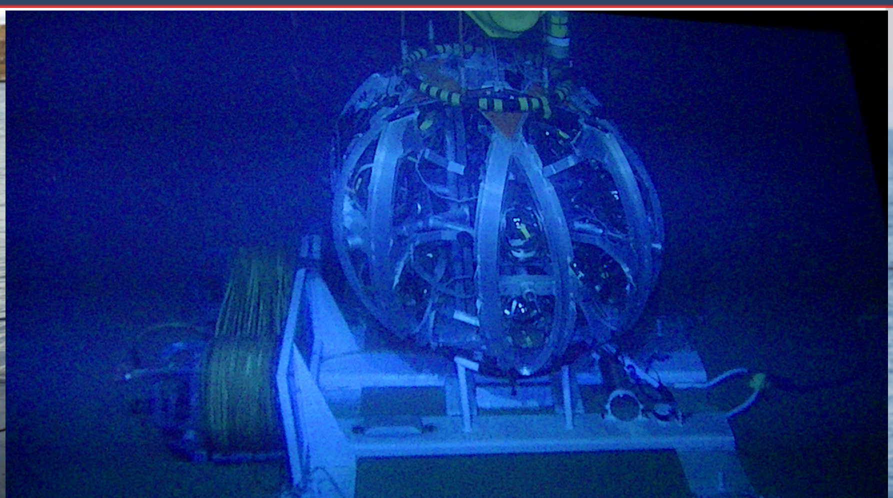
Status of KM3NeT


Outline

- The detector and its physics goals
- Research infrastructure
- Design and construction
- Demonstrators
- Production
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Physics Goal

- Measurement of HE neutrino flux and observation of high-energy neutrino sources in the Universe
  - Multi-messenger approach
  - Galactic Centre Region investigation

- Particle physics below 1 TeV: ORCA a denser detector
  - Neutrino mass hierarchy problem
  - Dark matter indirect search

- Synergy with Earth & Sea sciences →EMSO

The underwater choice

- Detection principle measure optical Cherenkov radiation produced by energetic charged particle interactions in water
- Faintness of atrophysical HE neutrino fluxes and small neutrino cross section oblige use of large natural target sea-water:

2000 m < depth < 4500 m

L_{abs} 50-70m, L_{scatt} > 100 m

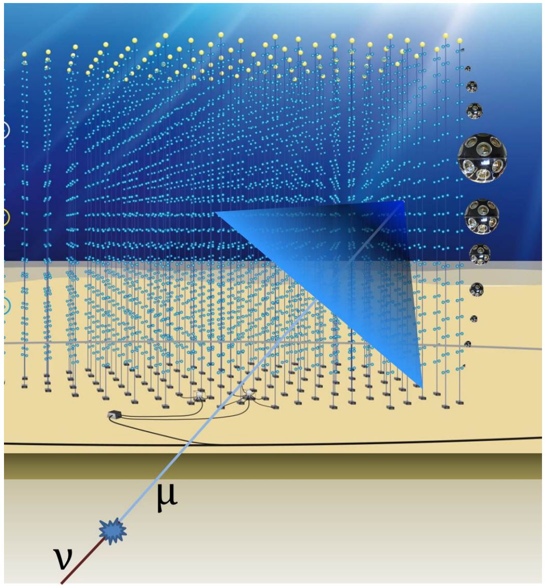
time resolution 1ns

position resolution 10cm

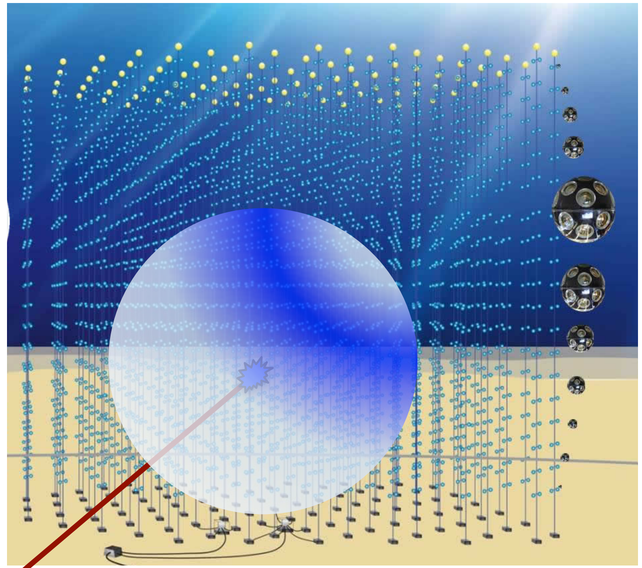
Very good angular resolution :

0.1° for tracks (E> 10TeV) - <2° cascades (E > 50 TeV)

Neutrino detection channels

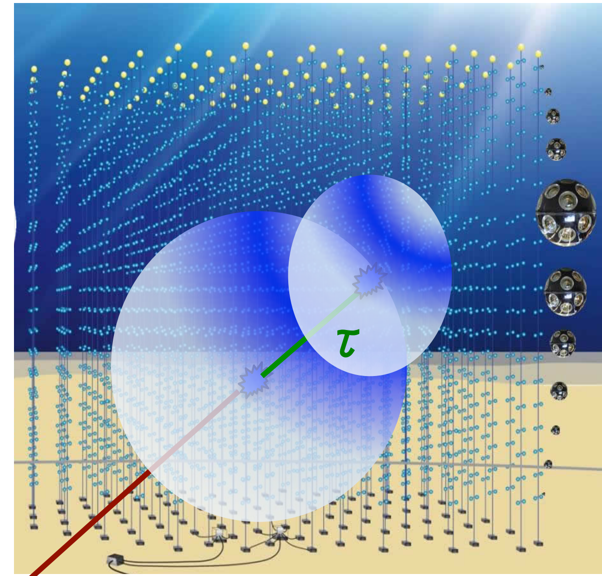


$$\nu_\mu \xrightarrow[CC]{} \mu + \text{shower}$$



$$\nu_\ell \xrightarrow[NC]{} \nu'_\ell + \text{shower}$$

$$\nu_e \xrightarrow[CC]{} \text{shower}$$



$$\nu_\tau \xrightarrow[CC]{} \tau + \text{shower}$$

$$\tau \xrightarrow[\sim 83\%]{} \nu_\tau + \text{shower}$$

$$\tau \xrightarrow[\sim 17\%]{} \nu_\tau + \mu + \bar{\nu}_\mu$$

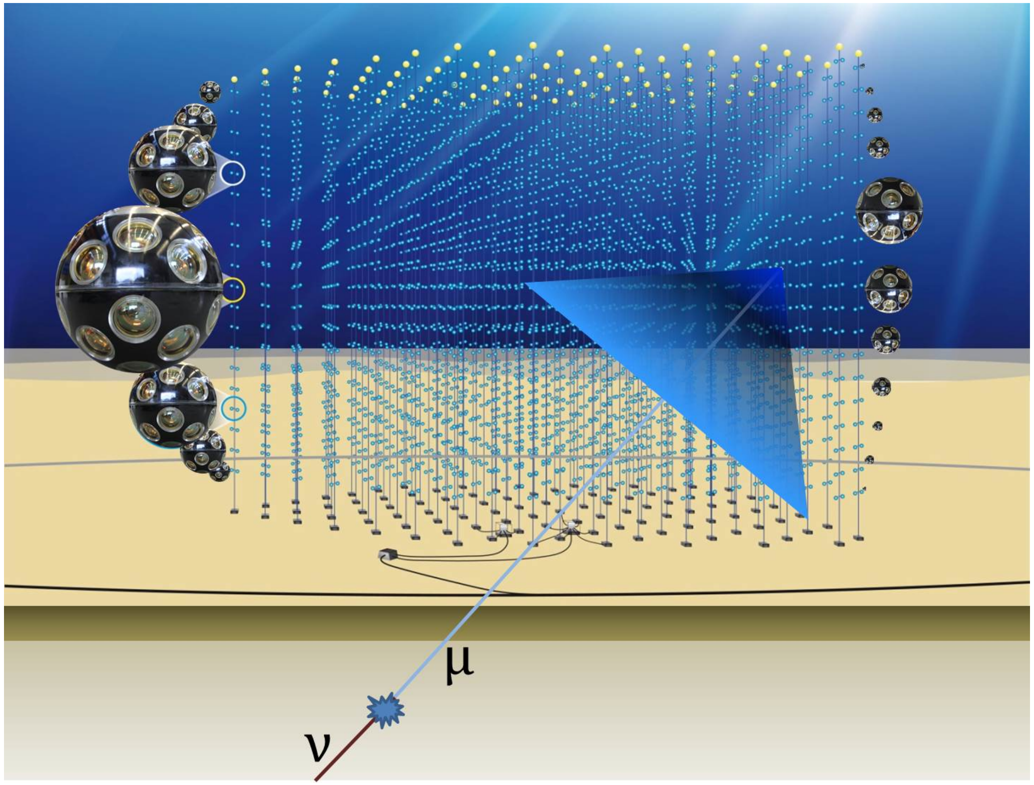
Muons:
highest effective area, good angular resolution (~0.1°)
High atmospheric muon background: look at events from below only

Showers:
Remove atmospheric muon background: studies over 4π.
'Good' energy resolution, worse directional resolution: diffuse flux!

Taus:
Unambiguous topology

The giant-scale detector KM3NeT

KM3NeT is a EU funded ESFRI project since 2006.



6 building blocks
115 Detection Units(DU)/Bblock
90-120 m inter-DU distance

700 m DU height
0.5-0.8 km^3 Bblock volume

3.5 x IceCube
photocathode area

DU:vertical slender string with multi-PMT digital optical modules (DOM)

Seafloor network provide data and power distribution

Phased implementation

Phase	Total costs [M€]	Primary deliverable	Status
1	31	Proof of feasibility of network of distributed neutrino telescope ***24 strings in Capo Passero*** ***7 strings in Toulon***	***Funded***
1.5	+(50:60)	Measurement of neutrino signal reported by IceCube ***2 building blocks (> IceCube)***	***Letter of Intent***
2	+(130:160)	Neutrino astronomy ***6 building blocks***	ESFRI road map

Outline

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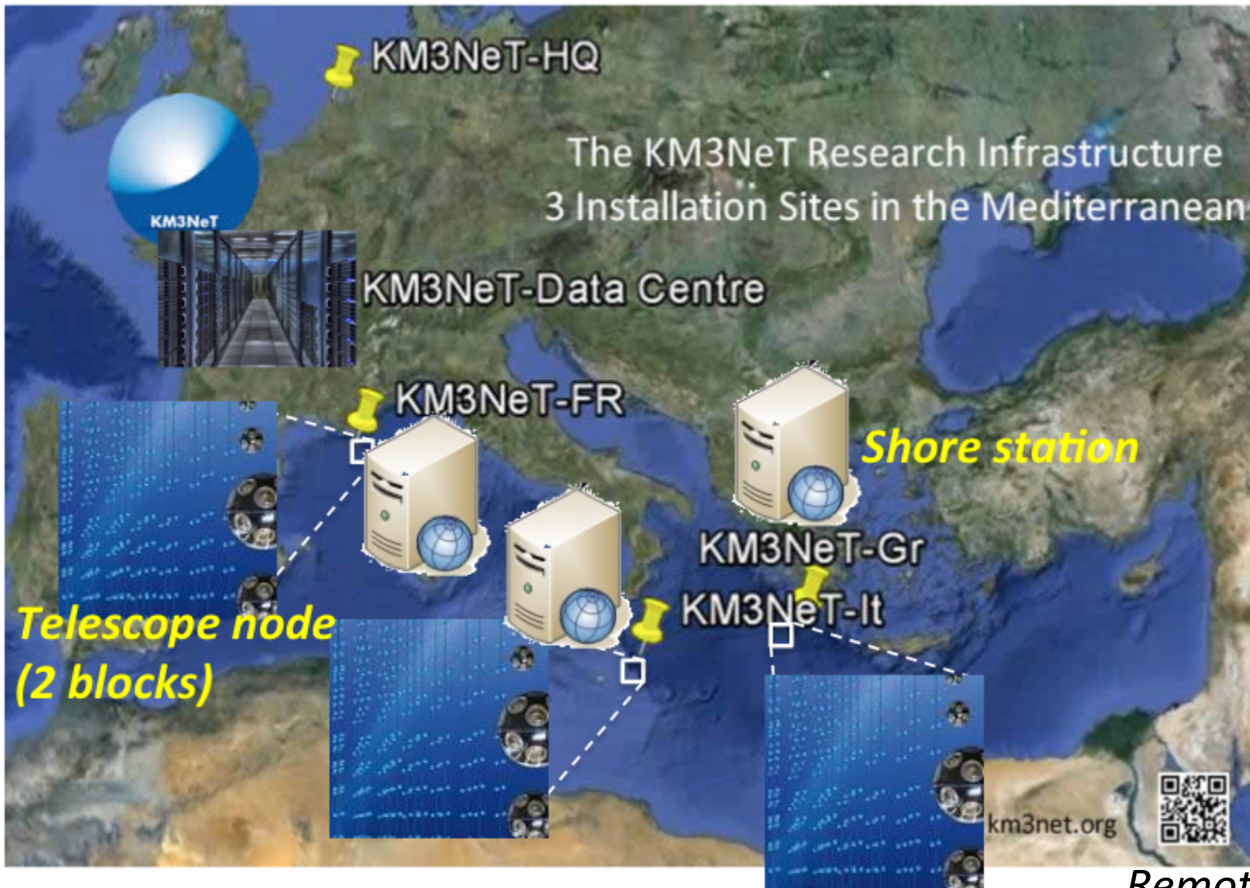
Distributed Research Infrastructure

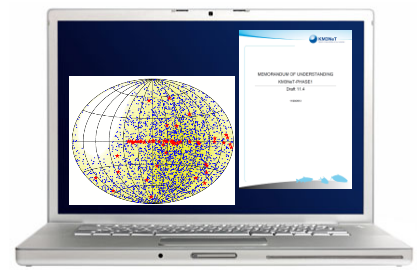
Network of cabled observatories located in deep waters of the Mediterranean Sea.

Centrally managed: common hardware, software, data handling and control

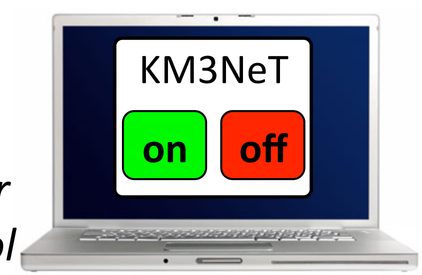


Node → Shore Station
1 Tbps

Shore Station → Data Centres
> 100 Mbps



Remote access to data



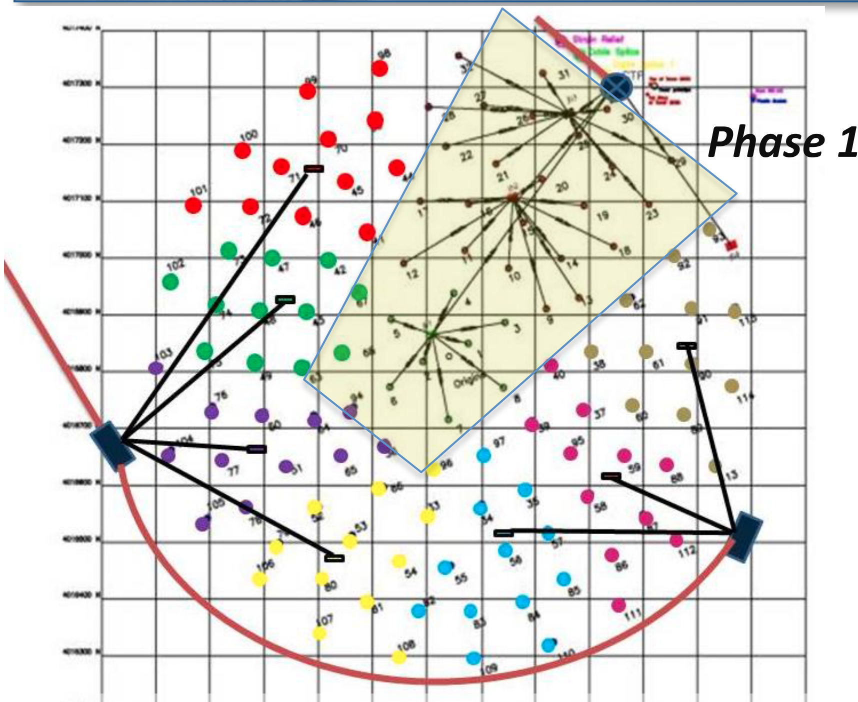
Remote detector operation control

KM3NeT-IT Capo Passero

Shore Laboratory in Capo Passero harbour

Shore Laboratory:
Electronics Labs
Data Acquisition Room, Control Room
Guest House
Power Feeding Equipment (UPS protected)
Upto 10 Gbps direct Optical-fibre link GARR-X

Submarine cable and infrastructure (now):
96 km - 20 fibres ITU655-NZDSF
Single conductor with DC-sea return
Phase 1: Cable Termination Frame
Medium Voltage Converter: 10kV to 375V



Phase 1 in KM3NeT Italia: 24 strings + 8 towers

See C. Distefano's Talk

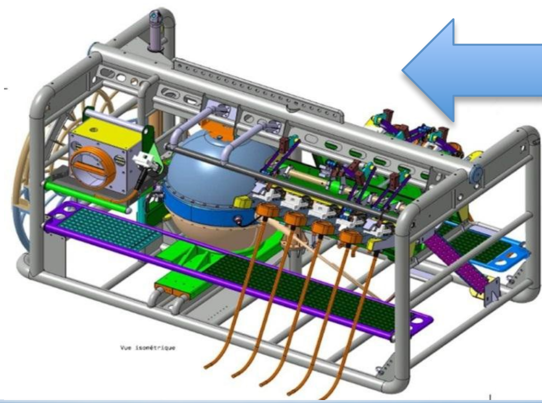
KM3NeT-FR MEUST

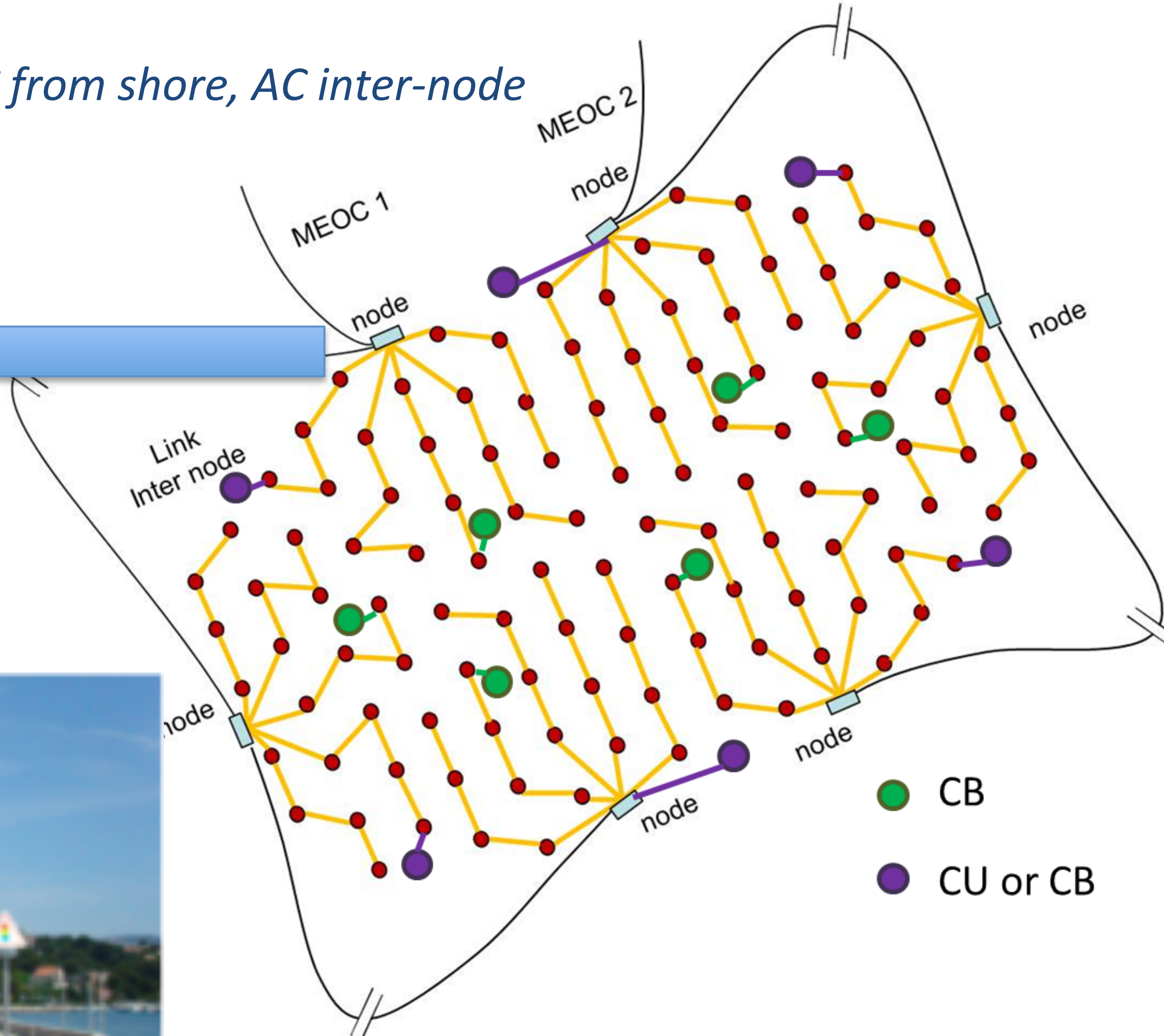
3 nodes per MEOC

24-36 Optical fibres in MEOC. DC from shore, AC inter-node

20 strings per node

sets of 4 strings in series





Outline

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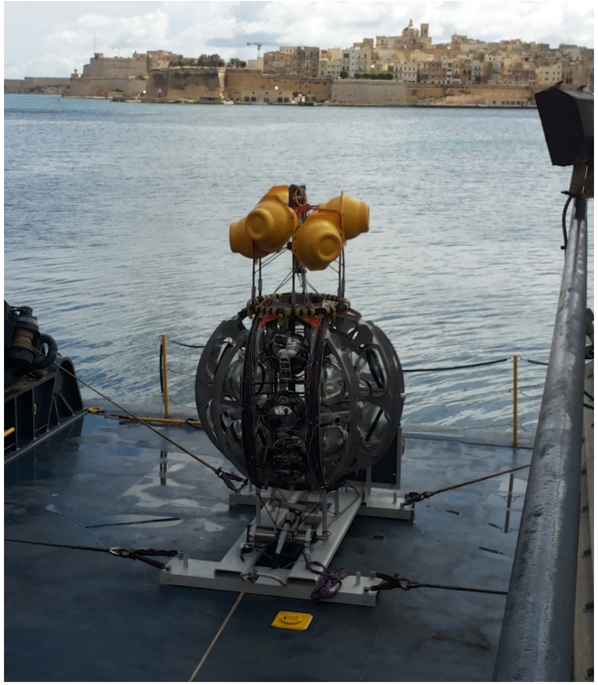
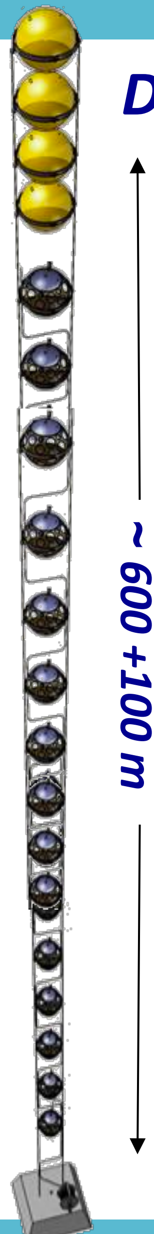
Design

Launcher vehicle



- rapid deployment
- small space on the boat
- autonomous unfurling
- recoverable



Detection Unit

–Buoy
–2 Dyneema ropes
–18 storeys (one OM each)
– 36m distance
– 100m anchor-first storey

Electro-optical backbone:
–Flexible hose ~ 6mm
–Oil-filled
–fibres and copper wires

DOM

The Digital Optical Module

31 x 3" PMTs
active base & digital signal readout (ToT)
light collection cone

1AHRS (tilt, compass)
1 digital piezo receiver
1 LED emitter (time calibration)

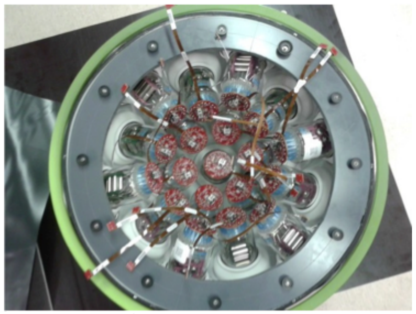
Central logic board (CLB)

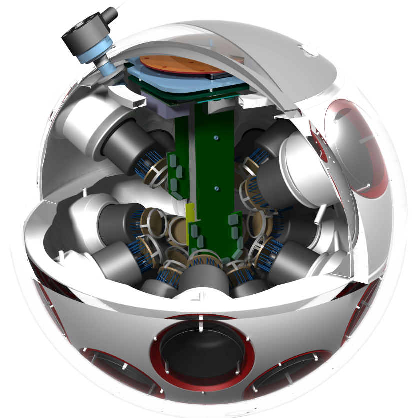
FPGA-based, white rabbit (T_{GPS})

DWDM optical comm(1 color/DOM)

power board

3d printed support structure
cooling structure (mushroom)
penetrator

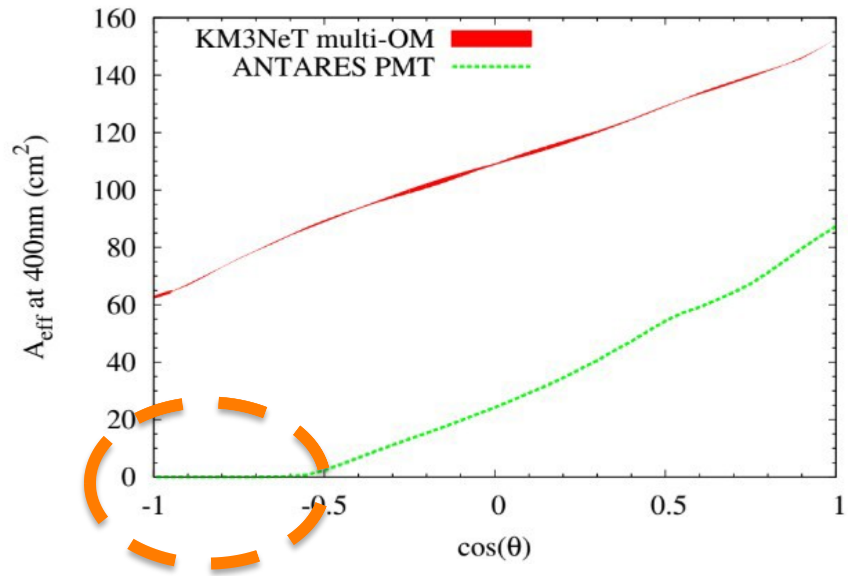




DOM performances

1 DOM = 1 ANTARES Storey

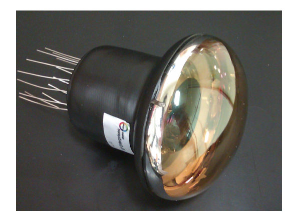
Allows photon counting: very powerful
Allows direct track direction reconstruction



Key features of 3'' PMTs:

– Timing	≤ 4.5 ns (FWHM)
– QE	≥ 25-30%
– collection efficiency	≥ 90%
– price/cm^2	≤ 10'' PMT

Hamamatsu R12199



ETEL D792

See V. Giordano's Talk

HZC XP53B20

The Central Logic Board

SFP connector: LASER for optical communication

Octopus connectors: 31 PMTs signals

Tunable oscillators: White Rabbit compliant

External Instrumentation:
Nanobeacon LED
Acoustic (Piezo)

Expansion: FMC connector

Embedded Instrumentation:
Temperature & Humidity
Tilt & Compass

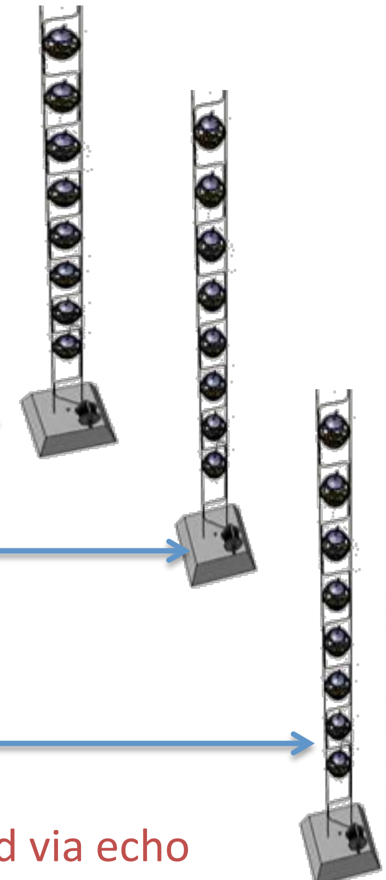
Reset & Configuration:
Quad-SPI Flash Reset circuit

Test & Debug:
GPIO Header
Dip-Switch
USB-UART

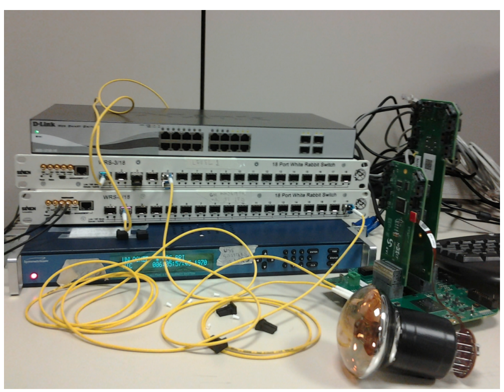
Synchronous Data Transport

GPS

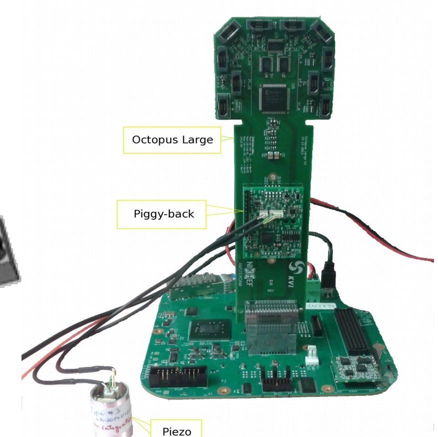
Master clock broadcast



White Rabbit Switch Fabric
Nano-sec precision-time-protocol
on Ethernet (synchronicity, phase reconstruction)



Optical path measured via echo
Optical fiber properties measured

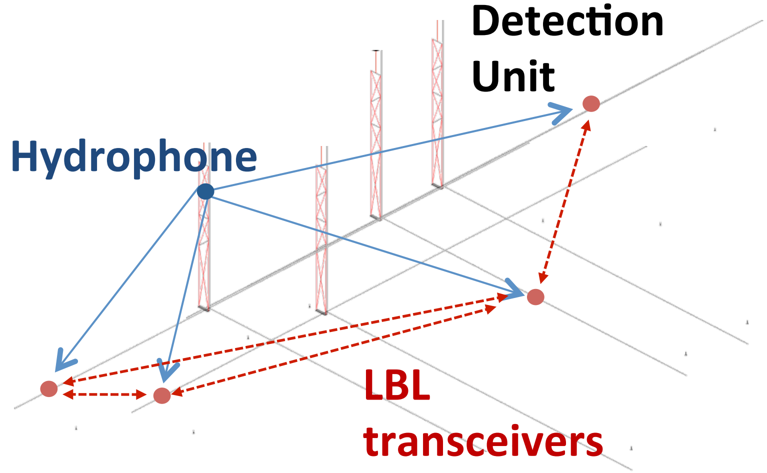


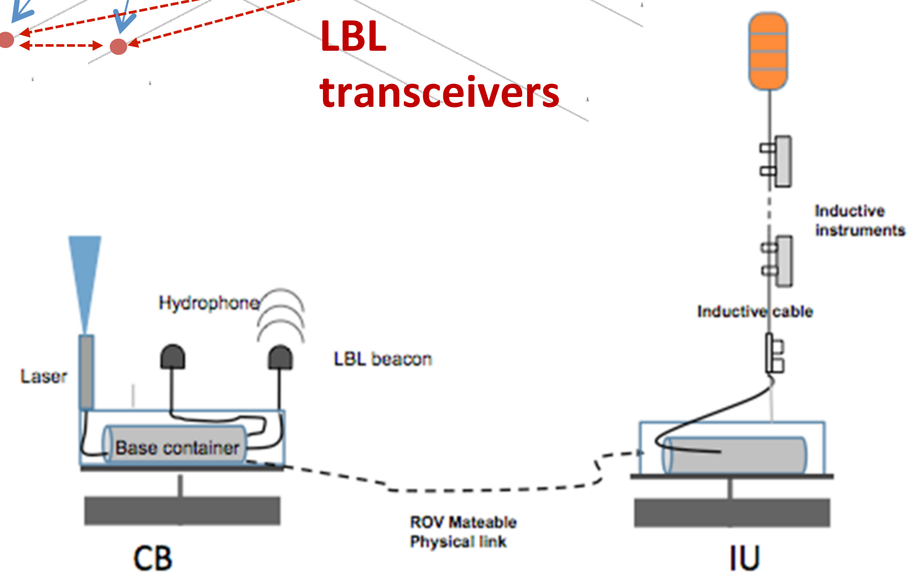
CLB running White Rabbit synchronisation kernel
PMT and piezo data time stamped by the CLB

Detector Positioning

DU base

Hydrophone





Calibration Base

Acoustic Long Base-Line

Laser Beacon (time calib)

Instrumentation Unit

Currents

Sound Velocity

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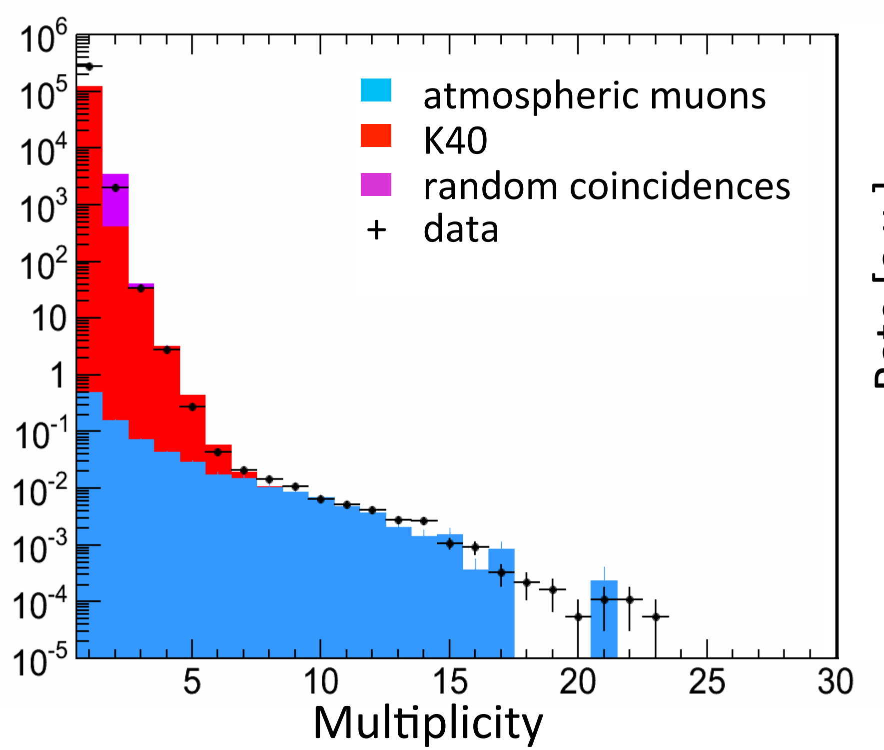
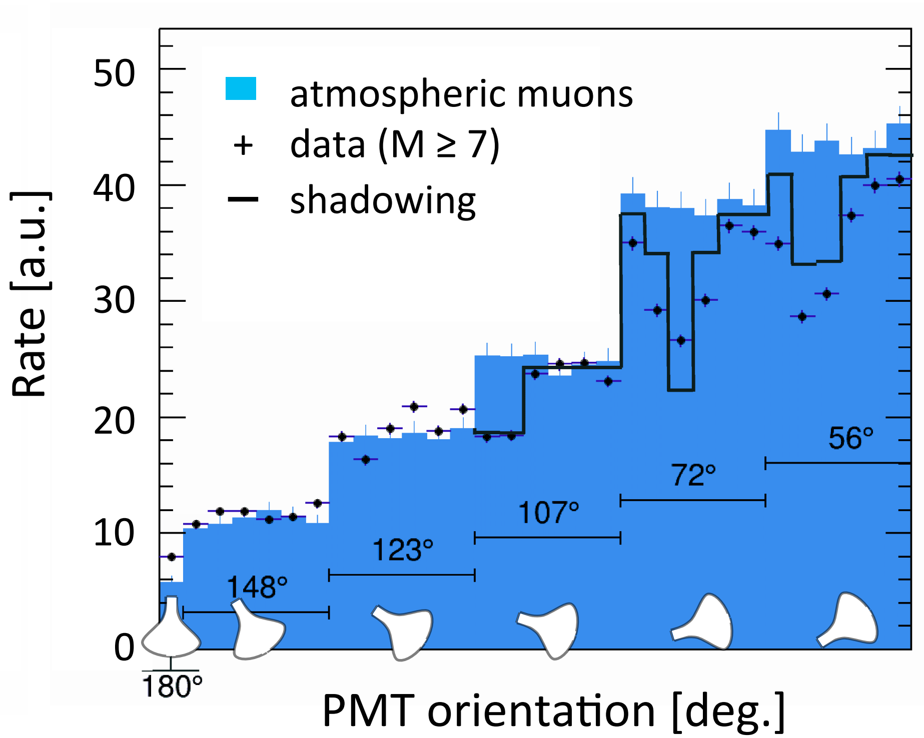
The demonstrators

The PPM DOM: deployed March 2013 at Toulon in the ANTARES facility



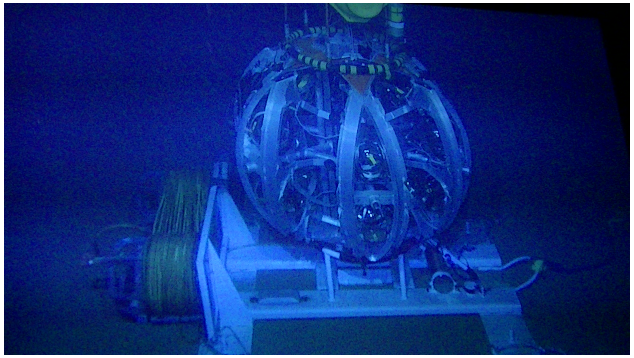
>6 coincidences within 20ns ⇒ reduced K40, dominated by atmospheric muons

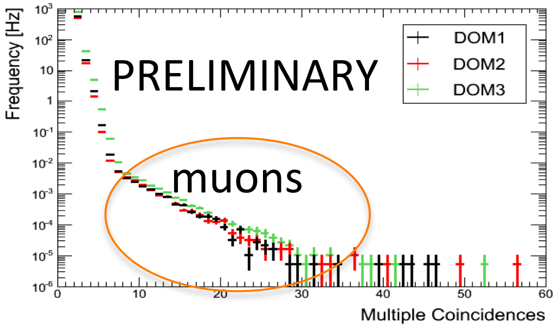


More upper PMTs in multi-hit events ⇒ directional information from single storey

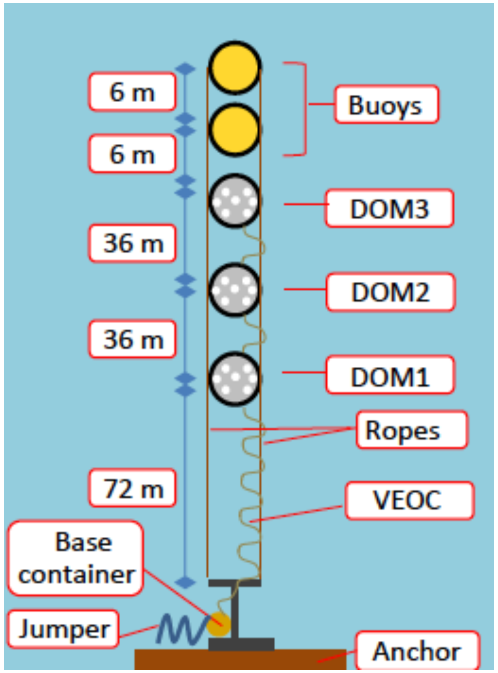
The demonstrators

The PPM DU:
deployed May 2014
at Capo Passero Site

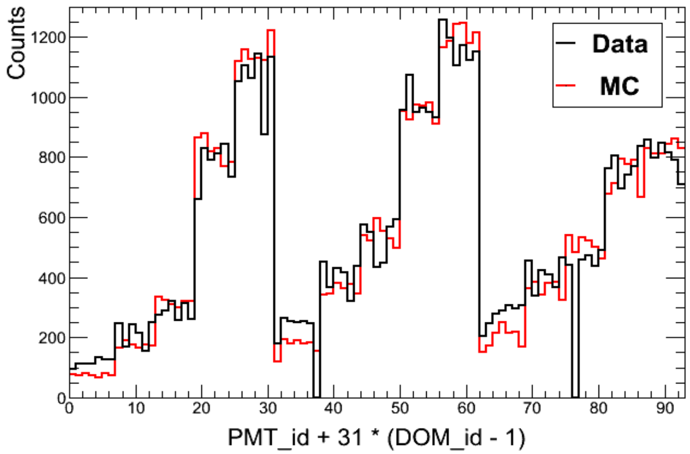




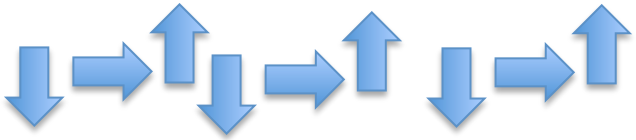
Same as per PPM-DOM



See S. Biagi's Talk



PMT Orientation



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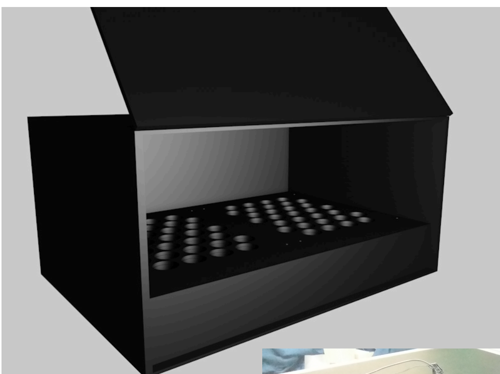
Mass Production (phase 1)

PMT and active base Test and calibration: 2 sites → PMTs (40 DOMs) / week

Pre-qualified DOM components → DOM assembly, test, calibration: 4 sites → 20 DOMs / week

DU Integration, test and calibration: 2 sites → 2-4 DUs/week

DU Deployment: > 4 DU deplyoyed in a single sea operation



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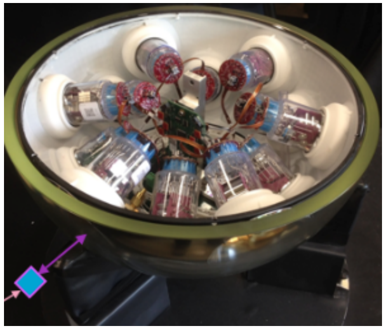
Timeline

- first DU: now integrating the first DOM



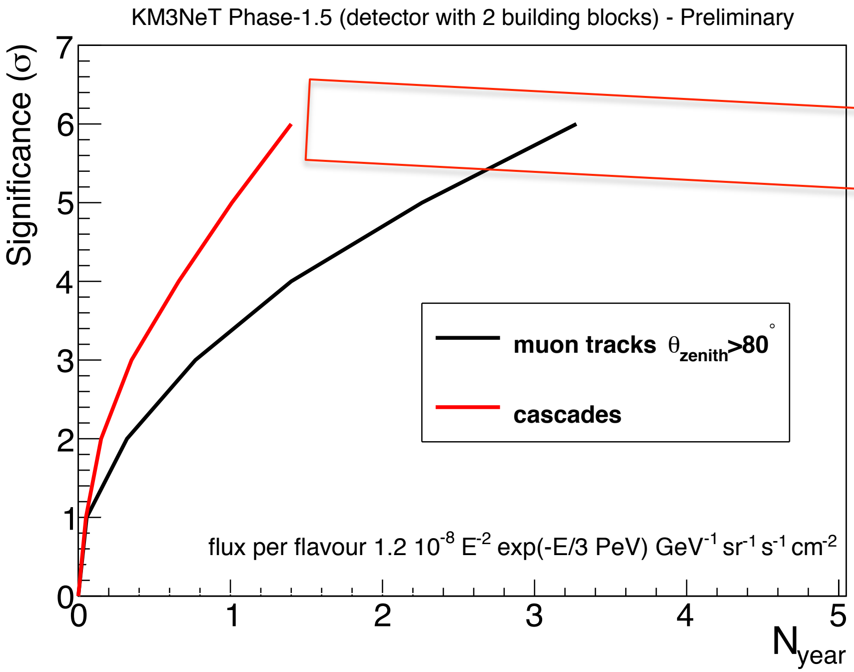
Set-up of mass production tools and procedures

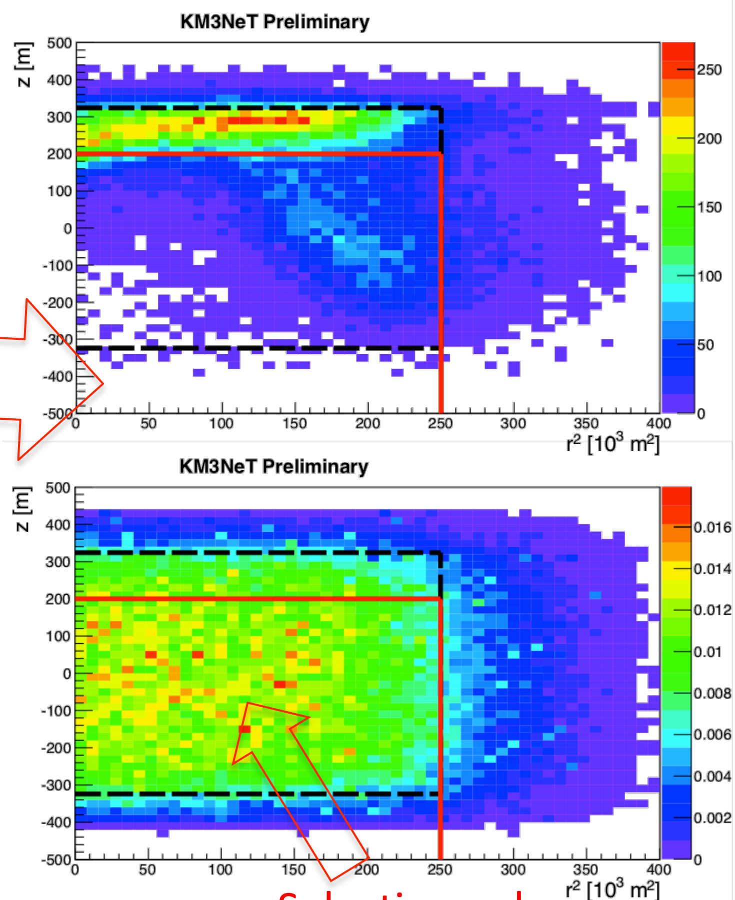
- Phase 1 Technology & Commissioning
- Phase 1.5 IceCube Neutrino Signal Measurement
- Phase 2 Astronomy

Search for an all-sky excess of high-energy events

Cascade-Background: Cascades from atmospheric neutrinos, Mis-reconstructed muon bundles

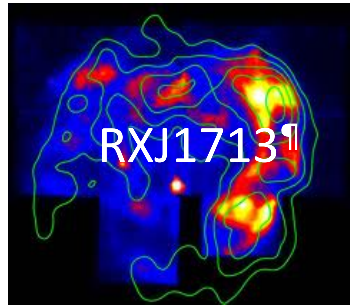
Expected measurement of IceCube signal in 1 year (tracks + cascades)

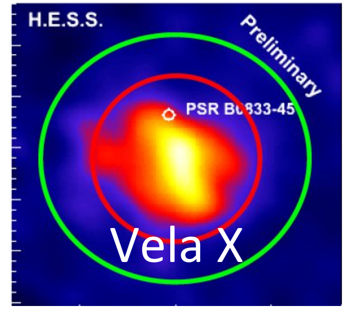




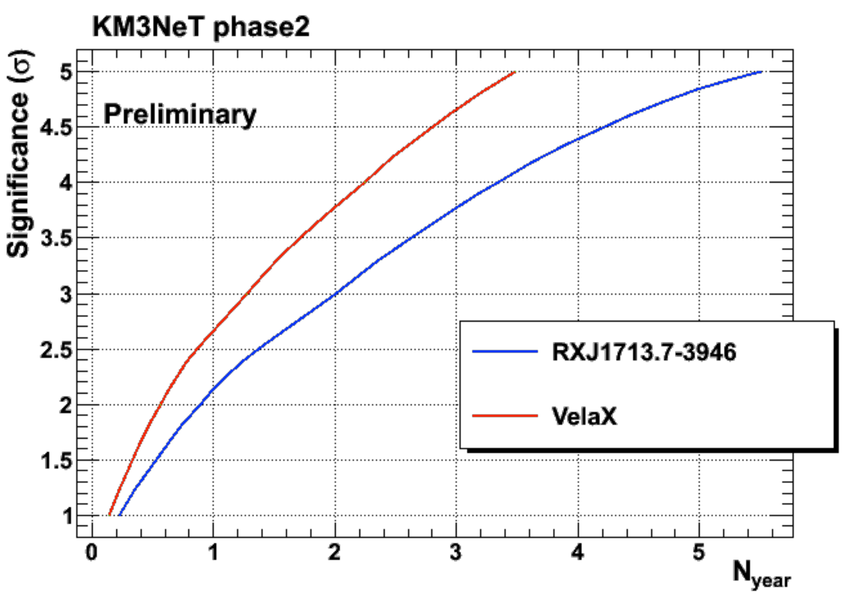
See L. Fusco's Poster

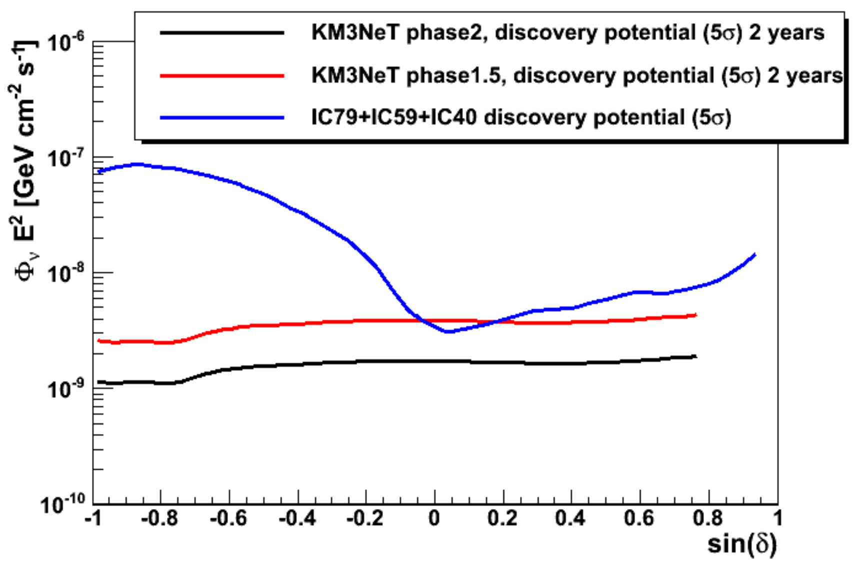
Phase 2





Other promising sources , stacking analisys…
Room for improvement (include morphology, energy dependence)





See A. Trovato's Talk

KM3NeT and EMSO

Common effort with the Earth and Sea Science Community

KM3NeT

european multidisciplinary seafloor observatory emso

Real Time Environmental Monitoring

Toulon, Sicily and Hellenic: sites of common interest for KM3NeT and EMSO

Oceanography (water circulation, climate change):
Current intensity and direction, Water temperature, Water salinity ,...
Geophysics (geohazard):
Seismic phenomena, low frequency passive acoustics, magnetic field variations,...
Biology (micro-biology, cetaceans,...):
Passive acoustic monitoring, Biofouling, Bioluminescence, Water samples analysis,...

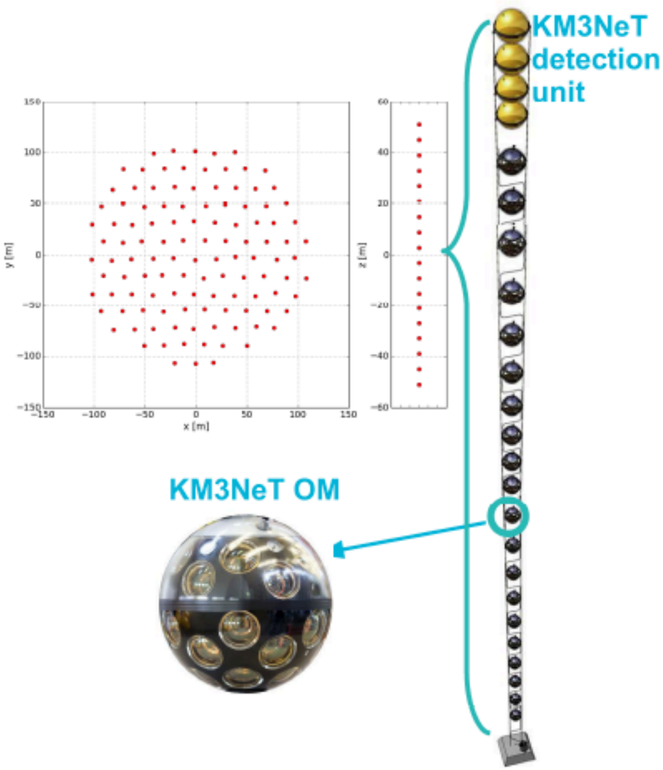
Summary

- KM3NeT will be a distributed, networked research infrastructure.
- Technical design is fixed and decided, infrastructures (IT and FR) are close to be ready.
- Construction of Phase 1 started.
- Path to Phase 1.5 (IceCube size) paved.
- Astronomy era with KM3NeT-Phase 2.

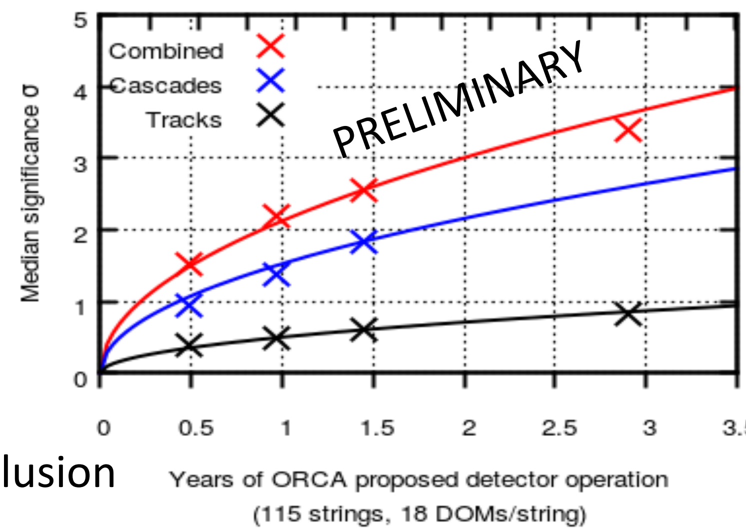
ORCA

ORCA is part of the KM3NeT research infrastructure. Different detector, same technology

- Few GeV signal => more compact detector (75 times denser!)
- Angular and energy resolution are very challenging



- 115 detection units, 20m spacing
- 18 Optical Modules (DOMs) per detection unit
- 6m vertical distance between DOMs
- 31 3" PMTs/DOM
- Instrumented volume about 3.75 Mtons
- Estimated cost 40 M€ (conservative)
- Geometry optimisation study ongoing



Inverted mass hierarchy exclusion