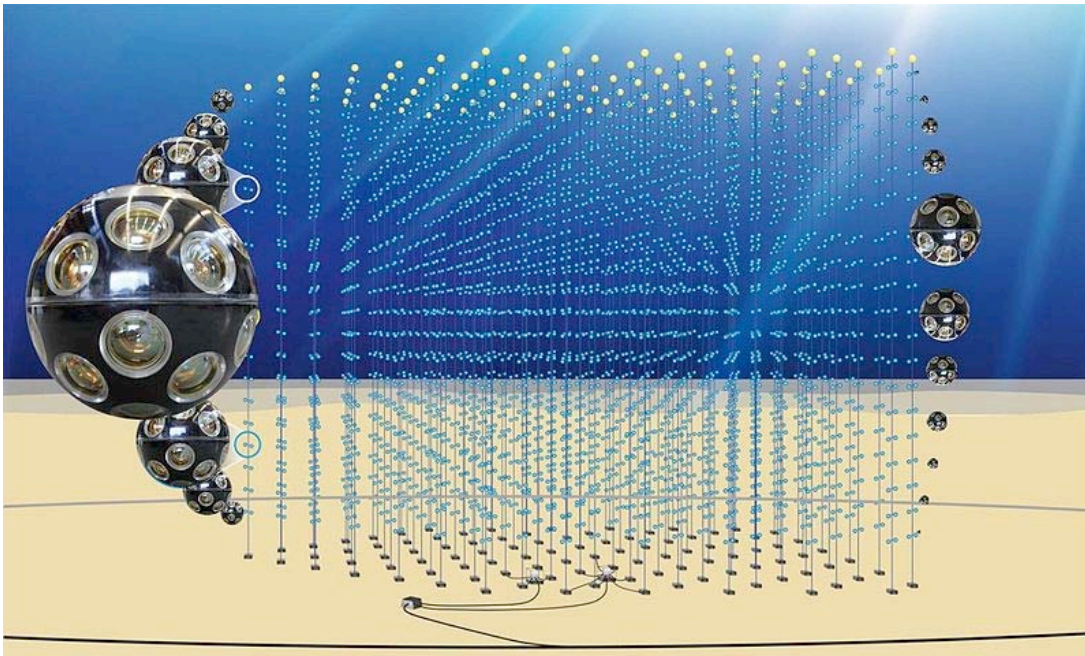# NEMO AND KM3NET

Carla Distefano – INFN, LNS

The giant-scale detector KM3NeT

Faintness of neutrino fluxes and small interaction probabilities oblige to use large natural target such as sea-water: a volume of 5 km^3 of seawater will be instrumented with optical detectors.

5 building blocks
115 Detection Units (DU)
750 m DU height
180m DU distance
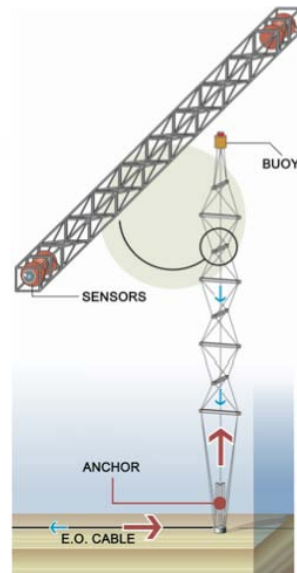5 km^3 volume
Budget 250 M€

KM3NeT-Italia is funded by INFN since 1999 (NEMO)
In 2010 the project was awarded with a
PON grant of 20.8 M€

KM3NeT is a EU funded ESFRI Infrastructure since 2006.
INFN leaded the Preparatory Phase

The Capo Passero Site infrastructure

3500 m

Capo Passero

BUOY
SENSORS
ANCHOR
E.O. CABLE

Shore Laboratory:
Electronics Labs
Data Acquisition Room
Control Room
Guest House 4 rooms
Power Feeding Equipment (UPS protected)
1Gb/s (upto 10) Optical-fibre link GARR-X

Submarine cable and infrastructure:
96 km
20 fibres ITU655-NZDSF
Single conductor with DC-sea return
Cable Termination Frame:
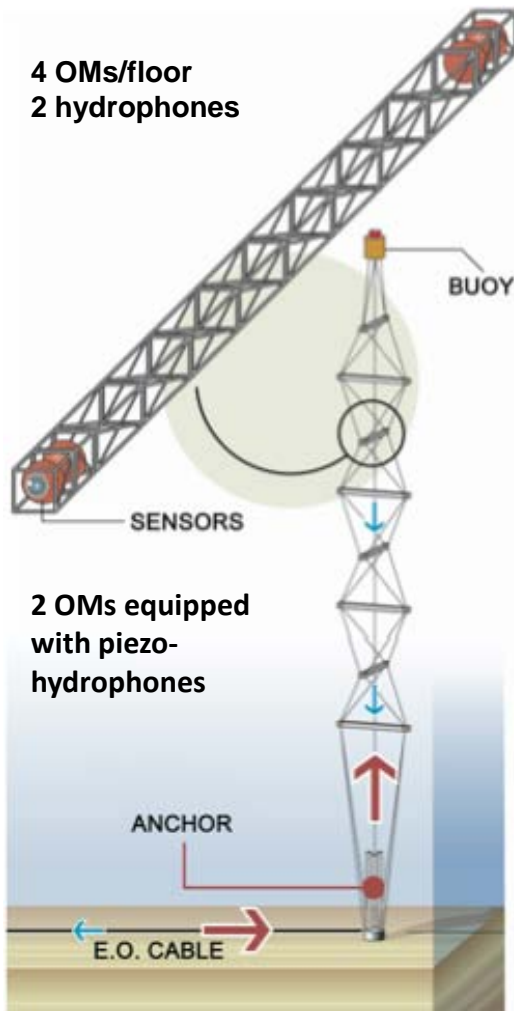**Medium Voltage Converter: 10kV to 375V**
3 ROV-mate e.o. output connectors

Off-shore Laboratory:
NEMO Phase-2 tower since 23 March 2013
Depth=3458 m

The NEMO Phase-2 tower: main components

**4 OMs/floor
2 hydrophones**

**2 OMs equipped
with piezo-
hydrophones**

- 8 floors
- 8 m bars, vertical dist. = 40 m, H_{tot} = 450 m
- 32 OM, 14 hydrophones
- oceanographic instrumentation

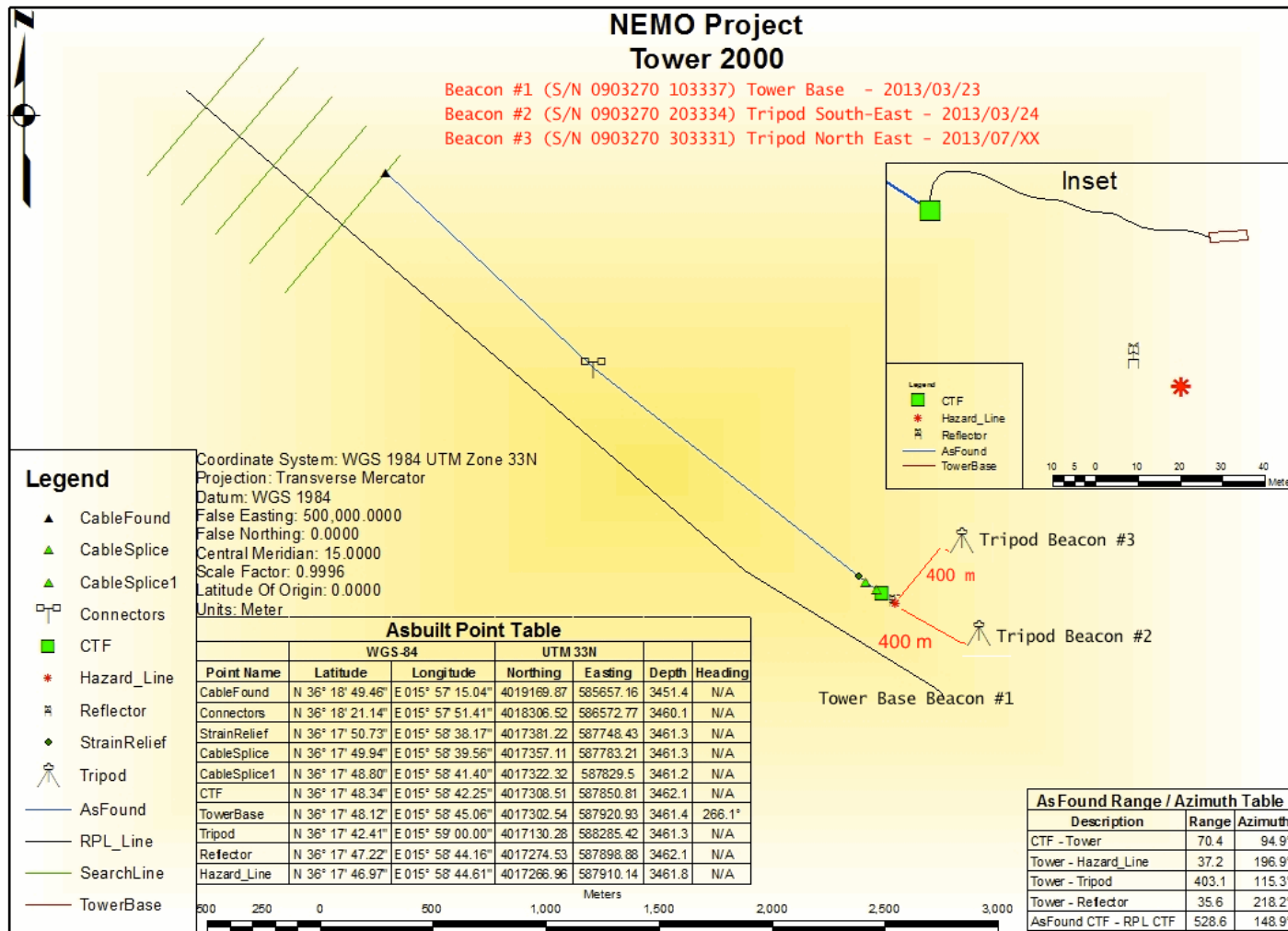The OM: 10" Hamamatsu R7081, Front End Module, Time Calibration, LED beacons

Hydrophones: acoustic positioning and bioacustics

The deep-sea field

NEMO Project
Tower 2000

Beacon #1 (S/N 0903270 103337) Tower Base – 2013/03/23
Beacon #2 (S/N 0903270 203334) Tripod South-East – 2013/03/24
Beacon #3 (S/N 0903270 303331) Tripod North East – 2013/07/XX

Inset

Legend
- ■ CTF
- ✱ Hazard_Line
- ⌗ Reflector
- — AsFound
- — TowerBase

Coordinate System: WGS 1984 UTM Zone 33N
Projection: Transverse Mercator
Datum: WGS 1984
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 15.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter

Legend

- ▲ CableFound
- ▲ CableSplice
- ▲ CableSplice1
- ⌐⌐ Connectors
- ■ CTF
- ✱ Hazard_Line
- ⌗ Reflector
- ◆ StrainRelief
- ⚲ Tripod
- — AsFound
- — RPL_Line
- — SearchLine
- — TowerBase

Tripod Beacon #3
400 m

Tripod Beacon #2
400 m

Tower Base Beacon #1

Asbuilt Point Table

Point Name	WGS-84 Latitude	WGS-84 Longitude	UTM 33N Northing	UTM 33N Easting	Depth	Heading
CableFound	N 36° 18' 49.46"	E 015° 57' 15.04"	4019169.87	585657.16	3451.4	N/A
Connectors	N 36° 18' 21.14"	E 015° 57' 51.41"	4018306.52	586572.77	3460.1	N/A
StrainRelief	N 36° 17' 50.73"	E 015° 58' 38.17"	4017381.22	587748.43	3461.3	N/A
CableSplice	N 36° 17' 49.94"	E 015° 58' 39.56"	4017357.11	587783.21	3461.3	N/A
CableSplice1	N 36° 17' 48.80"	E 015° 58' 41.40"	4017322.32	587829.5	3461.2	N/A
CTF	N 36° 17' 48.34"	E 015° 58' 42.25"	4017308.51	587850.81	3462.1	N/A
TowerBase	N 36° 17' 48.12"	E 015° 58' 45.06"	4017302.54	587920.93	3461.4	266.1°
Tripod	N 36° 17' 42.41"	E 015° 59' 00.00"	4017130.28	588285.42	3461.3	N/A
Reflector	N 36° 17' 47.22"	E 015° 58' 44.16"	4017274.53	587898.88	3462.1	N/A
Hazard_Line	N 36° 17' 46.97"	E 015° 58' 44.61"	4017266.96	587910.14	3461.8	N/A

As Found Range / Azimuth Table

Description	Range	Azimuth
CTF - Tower	70.4	94.9°
Tower - Hazard_Line	37.2	196.9°
Tower - Tripod	403.1	115.3°
Tower - Reflector	35.6	218.2°
AsFound CTF - RPL CTF	528.6	148.9°

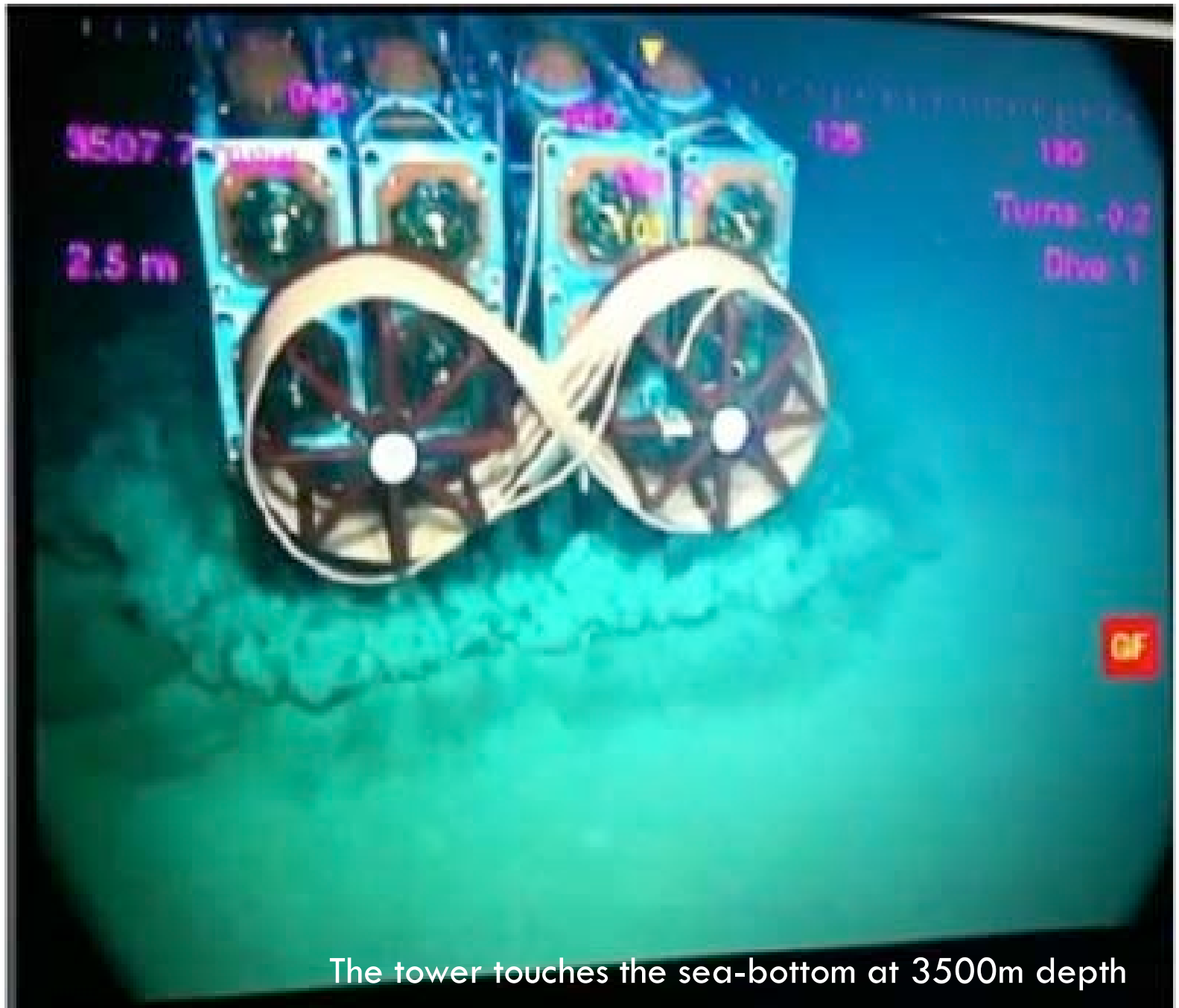NEMO-Phase2 under test in Malta before boarding on "Nautical Tide"

The tower on the "Nautical Tide"

Deployment of the NEMO-Phase2 Tower from the "Nautical Tide"

The "Nautical Tide" ROV and its launching system

The tower touches the sea-bottom at 3500m depth

Inspecting the tower with the ROV

C. Distefano, INFN-LNS Users committee 2013-12-06

Brief summary of the status

- In operation since the deployment date (23 March 2013)
- All Optical transmission parameters OK
- Optical Modules
  - 31 out of 32 OMs are sending data (1 OM internal electrical malfunction)
- Acoustics (in coll. with France: CPPM, Spain: UPV, Germany: ECAP)
  - No hydrophones on floor 5
  - 2 Piezo on floor 8
  - All hydrophones are sending data
  - LBL: 2 external beacons (autonomous) and 1 tower base beacon (autonomous clock) working, 1 tower base beacon (triggered) under commissioning
- Time calibration (in coll. with Spain: IFIC)
  - Led-beacon on floors 1-4, working
  - Tower base laser-beacon under commissioning
- Environmental instrumentation
  - 2 CTD probes working and sending data
  - 1 Current metre working and sending data
  - 8 Compasses working and sending data
- DAQ and TRIGGER system working
- Slow Control working

PMT Rate Monitoring

- ☐ The rate is sampled once per second by the PMT Front-End electronics;
- ☐ Rate is measured in a time window $\Delta t = 10ms$;
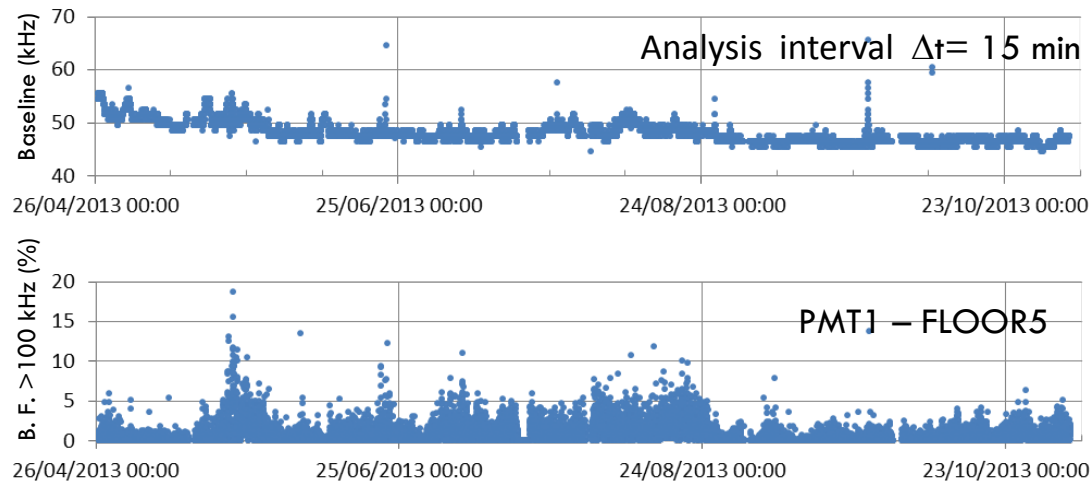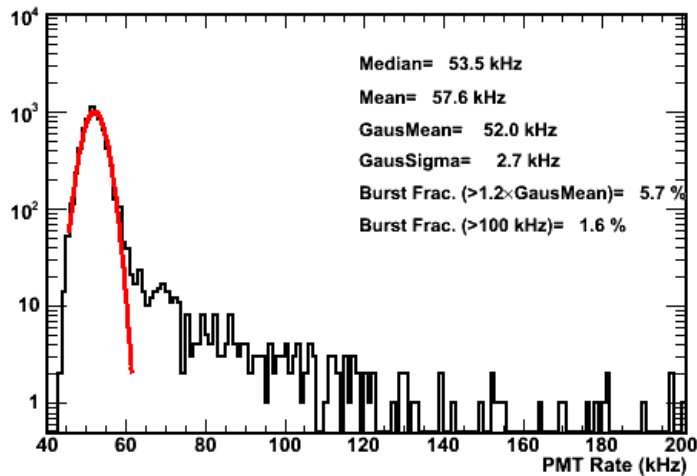
- ☐ Baseline values are quite constant for over 8 months;
- ☐ There is a small burst percentage.

CTD probes

- ☐ Two CTD probes: Conductivity, Temperature, Pressure and Depth, Density, Salinity, Sound Velocity;

- ☐ Both working;

- ☐ Sampling every 10 min;

- ☐ Depths and sound velocity used as input for positioning algorithm.
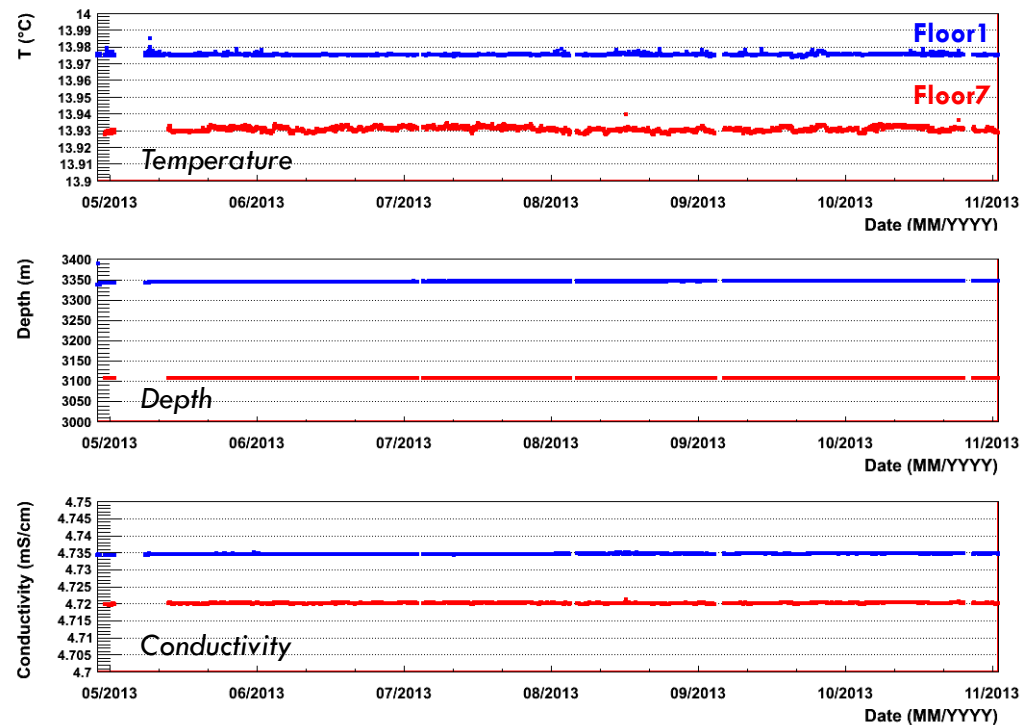
DCS probe and Compasses
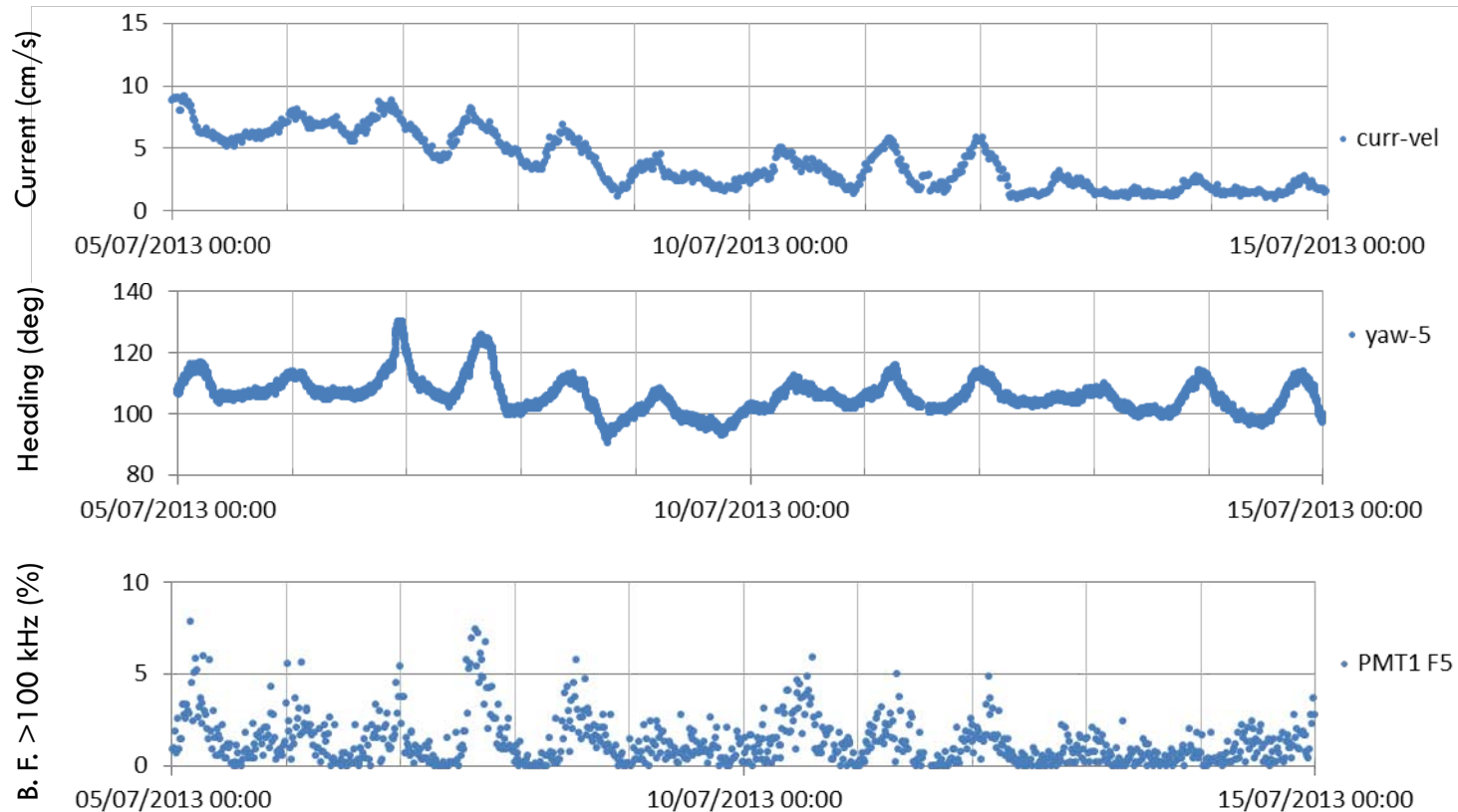
Inertial currents are evident at the same time in b.f., current intensity and heading variations

Acoustic detection: status

Distance differences derived from TOA differences using sound velocity measured by CTDs.
Distances between hydrophones on the same floor are known.

FLOOR 6 SMID HYDRO #0

Spectrogram 1024pts, overlap 70 %

Beacon signal

~500 m

Beacon signal
Amplitude: 180 dB re 1 μPa @1 m
Frequency : 32 kHz
Pulse length: 5 ms

~400 m

4 m

C. Distefano, INFN-LNS Users committee 2013-12-06
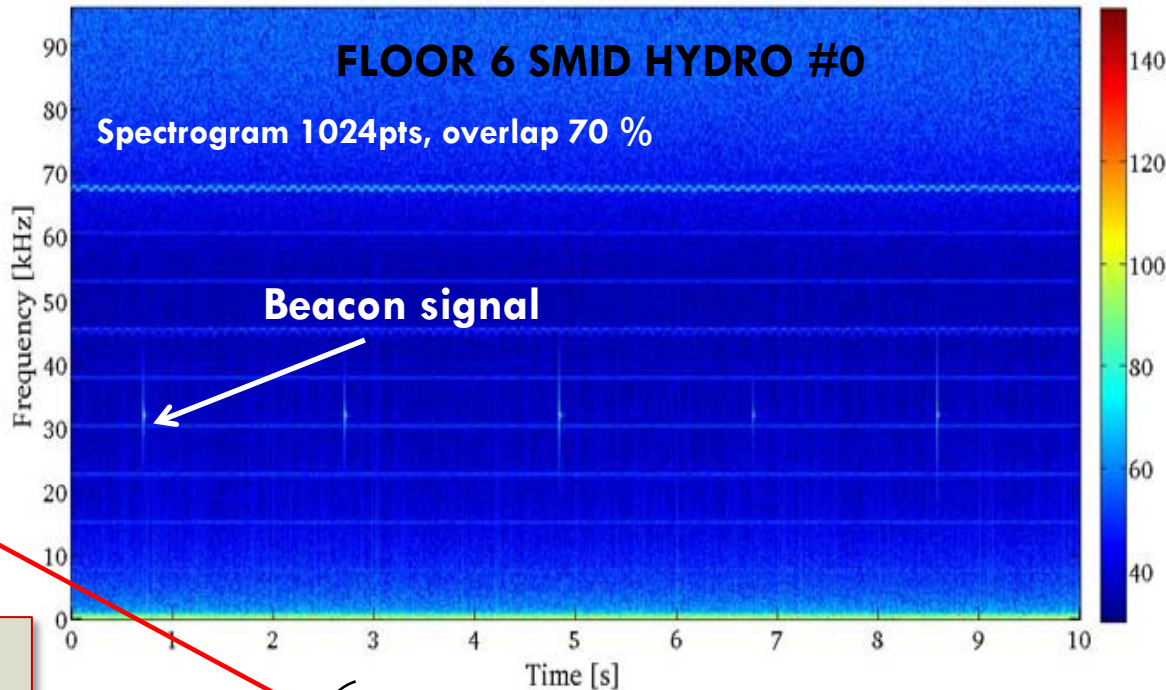
Reconstruction with acoustics pos.

Floor 8 not in
the plot

Not longer bar! Just different
hydrophone position (piezo).
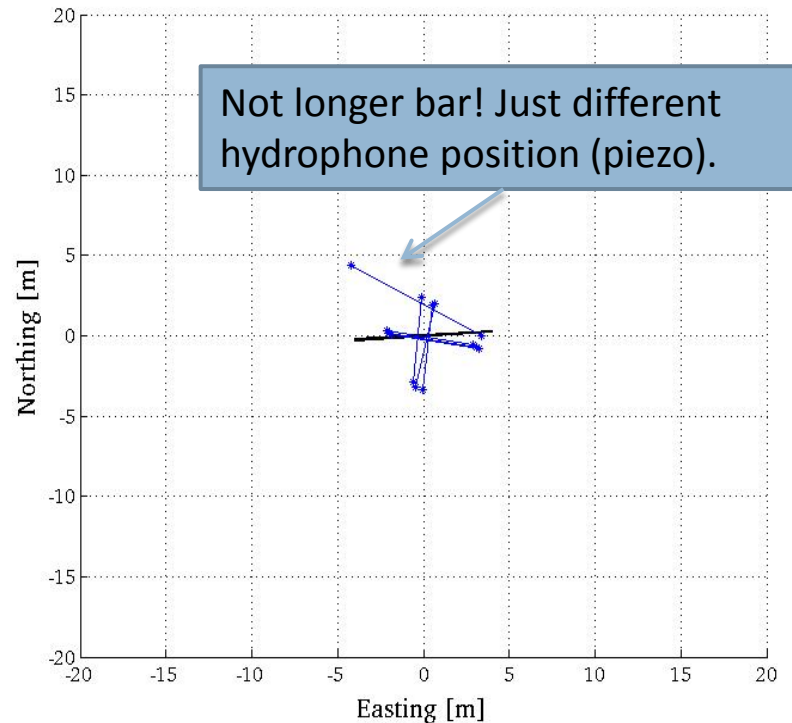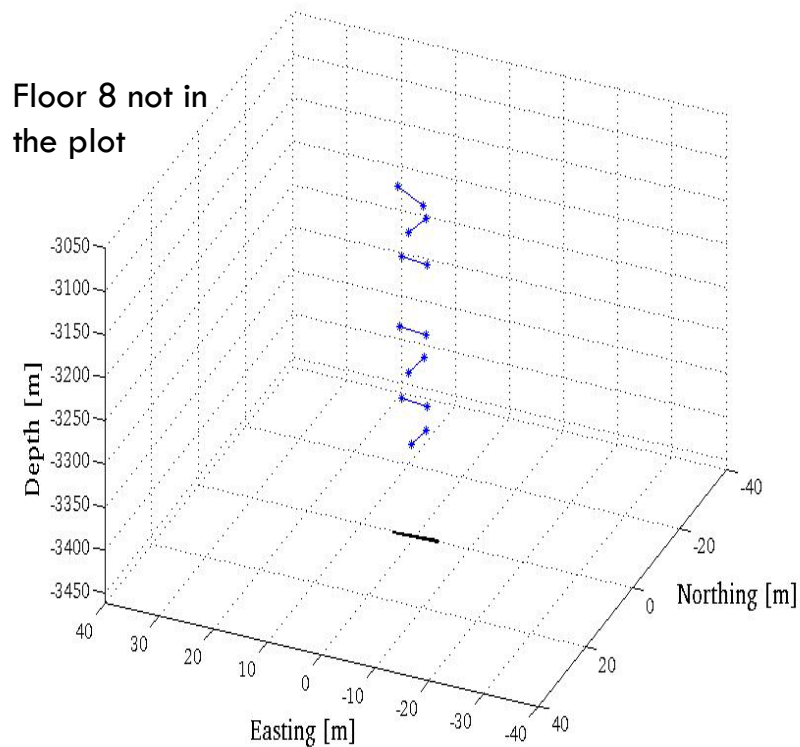
**07/05/2013
00:00 UTC**

Reconstruction possible with accuracy O(1m)

Muon Triggers

L1 triggers

SC (20 ns)	FC (100 ns)	$Q_{threshold}$ && SC	Random
1:100 or all if #≥2	(SC in 20 ns + PMT)	($Q_{first10\ samples}$ > 500 adc)	(1 ms @ 1 Hz)

Trigger rates

connessioni
- L1RTrate
- L1SCrate
- L1FCrate
- L1Qrate
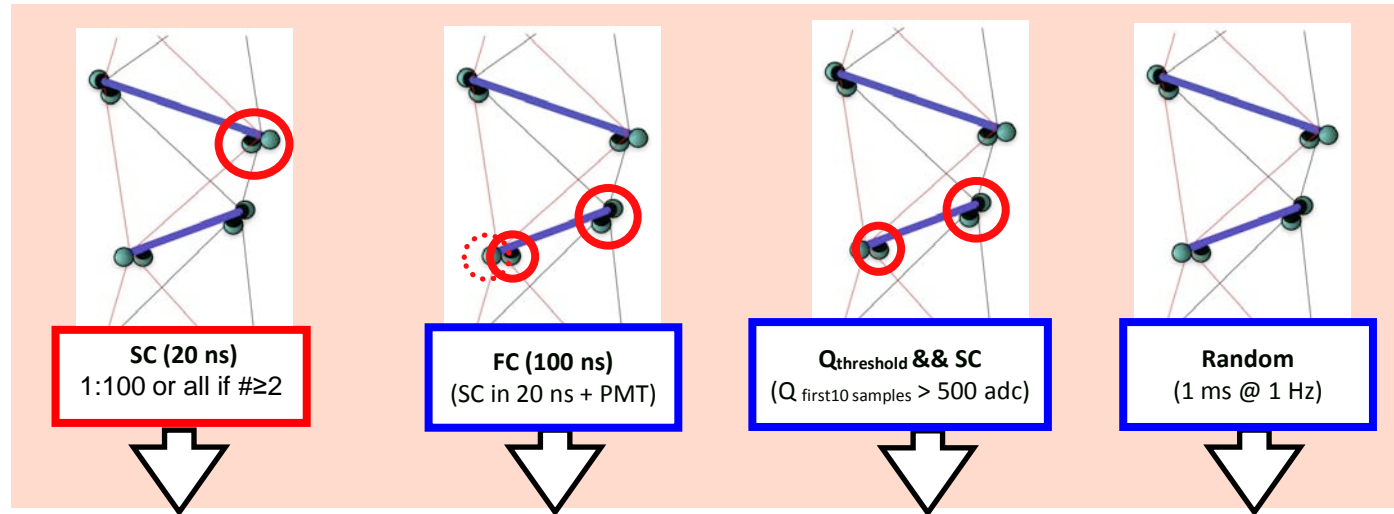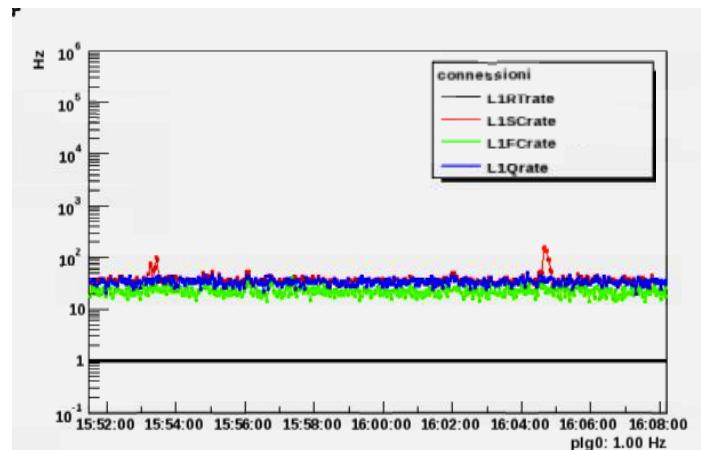
- Event trigger rate: ~100 Hz
- Muon purity: ~10^{-3}
- More selective trigger strategies under study

Data taking and Shifts

- The tower takes data continuously (h24). It's controlled by automatic systems and monitored by a shift crew during the daytime.

- The shift crew is composed of two persons, responsible of the operation, calibration and monitoring of the detector for a period of 1 week.

- All INFN sections participating to the experiment (Bari, Bologna, Catania, Genova, LNF, LNS, Napoli, Pisa, Roma, Salerno) contribute to the shifts.

- Up to August: only local shifts. Since September: 50% of shifts in remote.

Live time and accumulated events

DAQ reconfiguration

≈100% live time

Change in trigger conditions
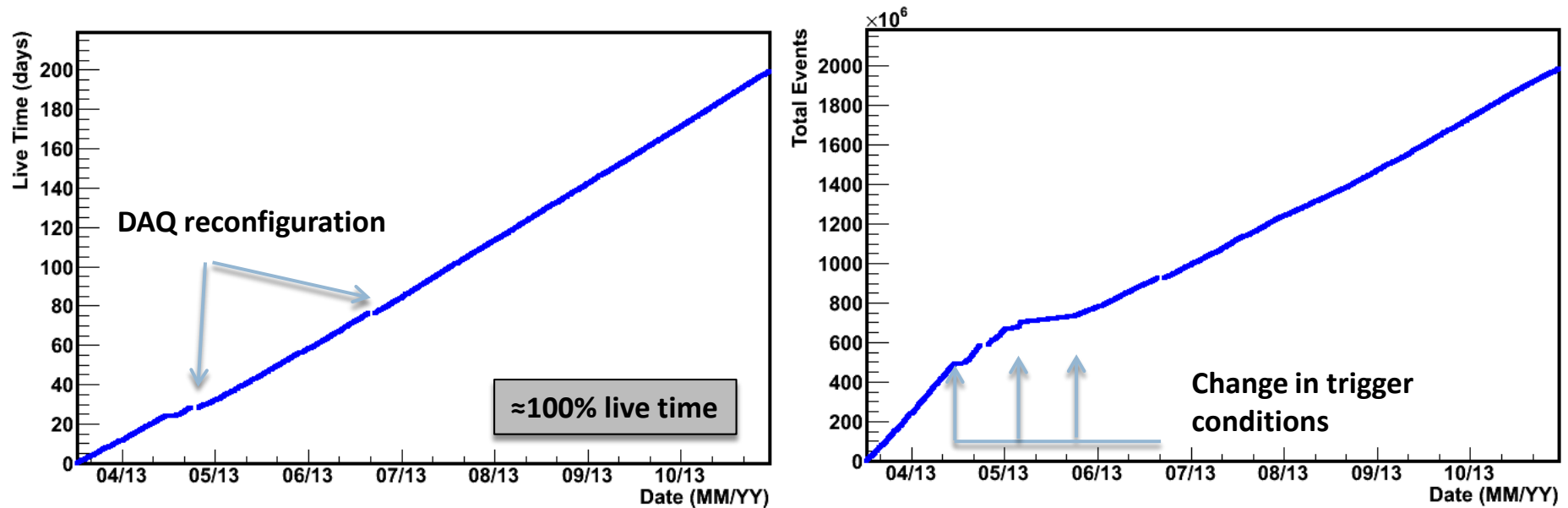
Live time and total number of events accumulated since April 16 2013

Atmospheric muon analysis: first results

Single PT files reconstruction rates

Track reconstruction level

DATA: 7741
MC: 9504
Ratio: 1.23

Live time: 13.4 days
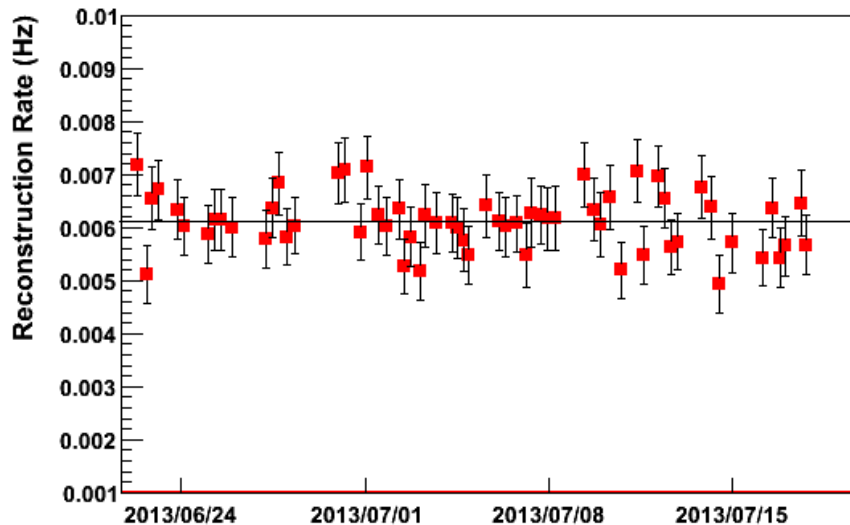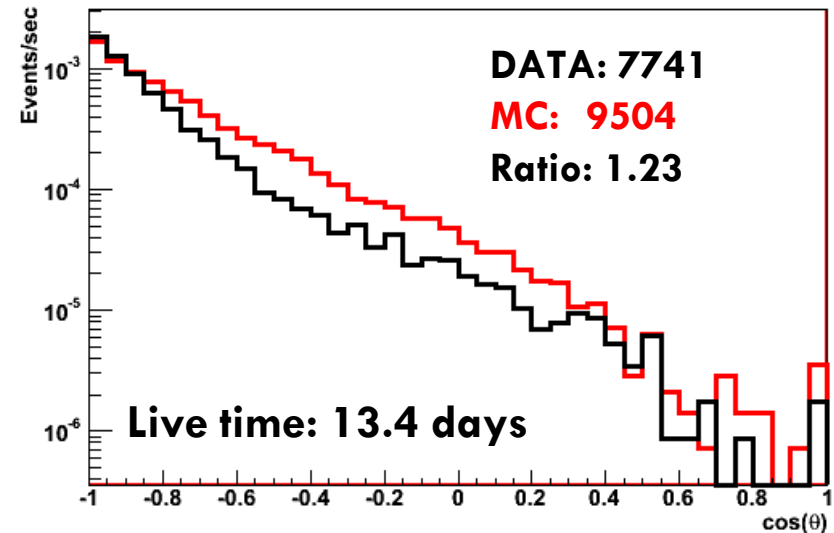
- Post Trigger files selected between 2013-06-22 and 2013-07-17.
- Reconstruction rate stable in time. Mean value of 0.0065 Hz (consistent with Depth=3500m).
- Agreement with MC but excess in simulations: under investigation.
- In progress: analysis of the whole data set

The future
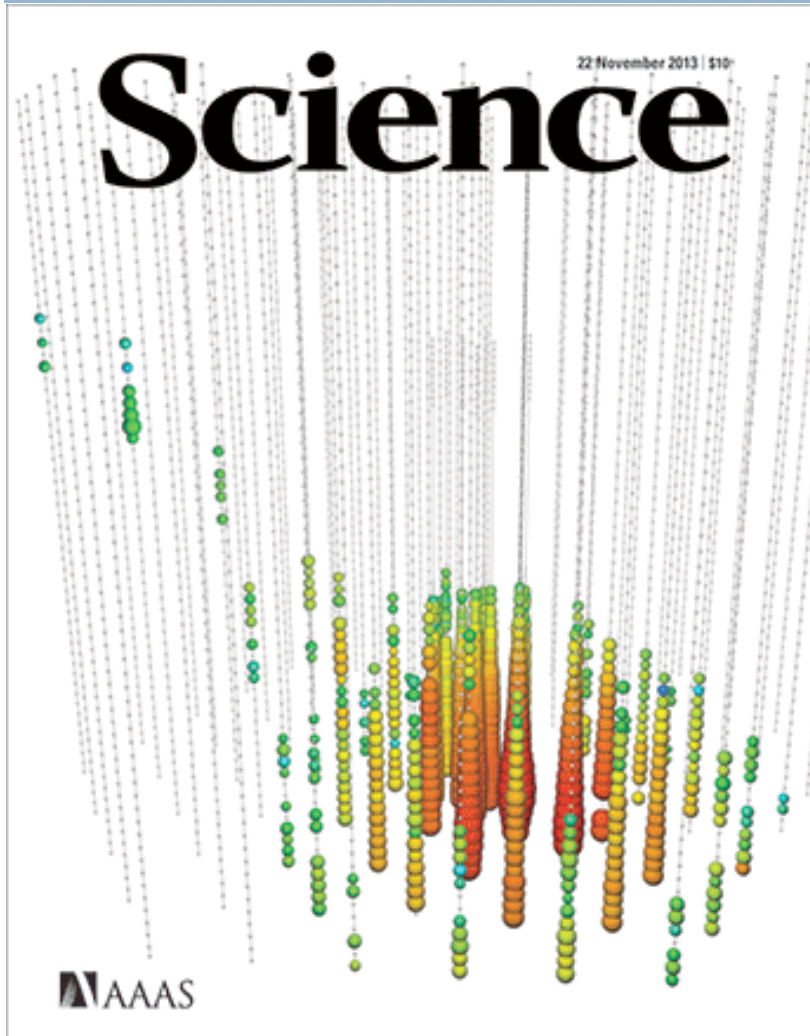
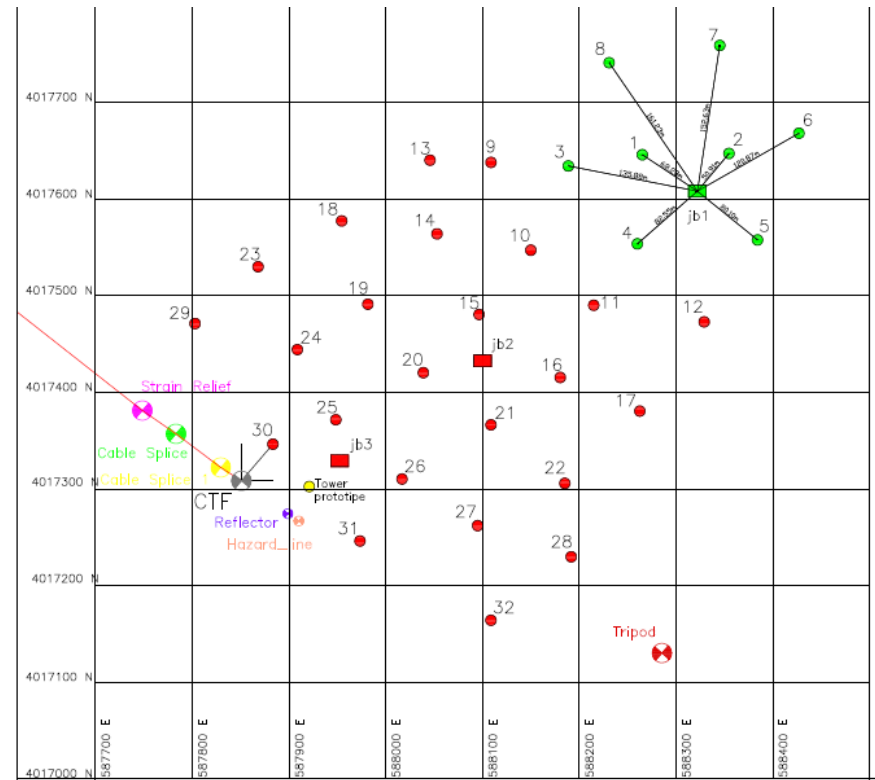IceCube Neutrino Observatory reports first evidence for extraterrestrial high-energy neutrinos.

28 neutrino candidate events, substantially more than the expected from atmospheric backgrounds (4σ level).
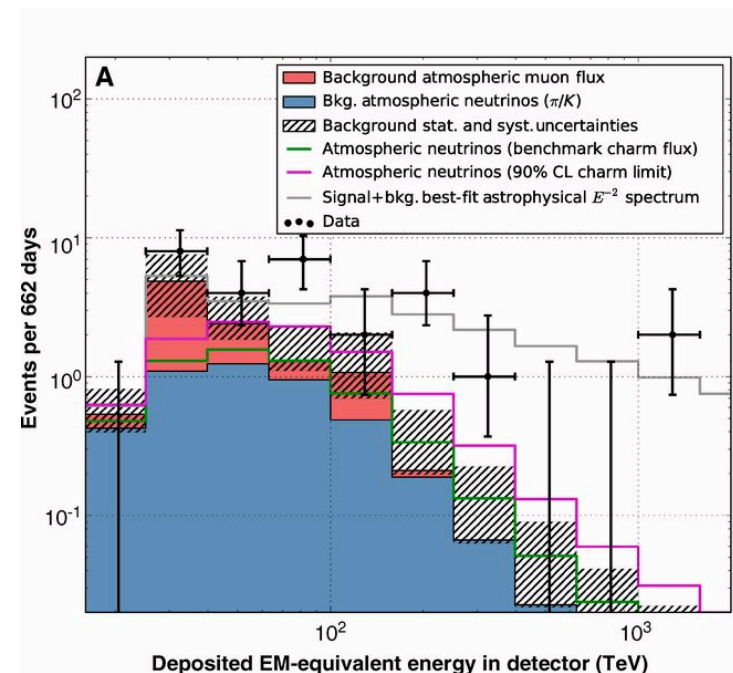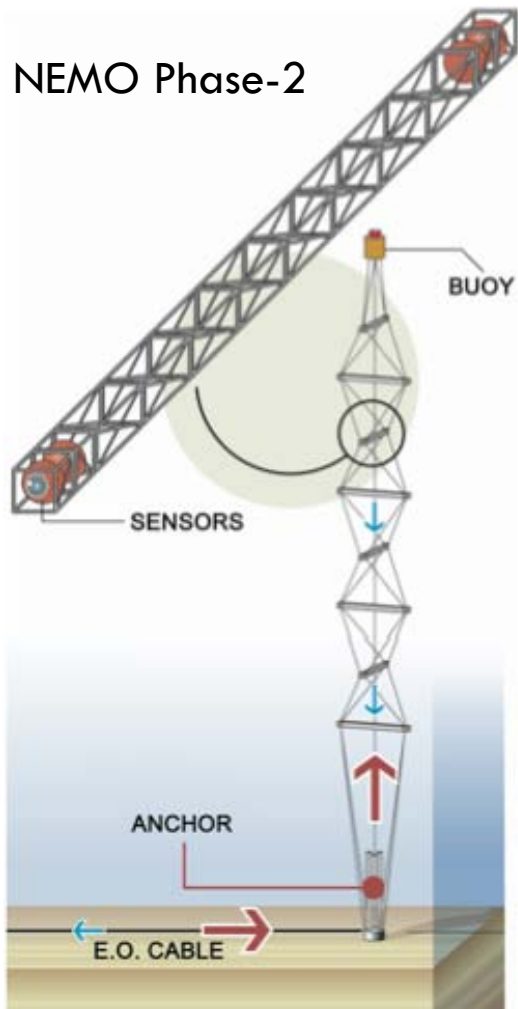
KM3NeT Phase-1 at Capo Passero Site

- 8 Towers + 24 Strings

- New CTF with 5 outputs (4 fo, 2 e)

- Up to 5 Secondary JB
  - 1 SJB x 8 towers
  - 2 SJBs x 12+12 strings
  - 1 SJB for EMSO

The NEMO Phase-3

NEMO Phase-2

- 8 towers
- 14 floors/tower
- 8 m bars, vert. dist. = 20 m, H_{tot} ~ 450 m
- 6 OMs + 2 hydrophones/floor
- oceanographic instrumentation
- towers at ~ 100 m horiz. dist.

BUOY

SENSORS

ANCHOR

E.O. CABLE

NEMO Phase-3

Shorter vertical distance and larger number of PMT/floor → lower energy threshold

C. Distefano, INFN-LNS Users committee 2013-12-06
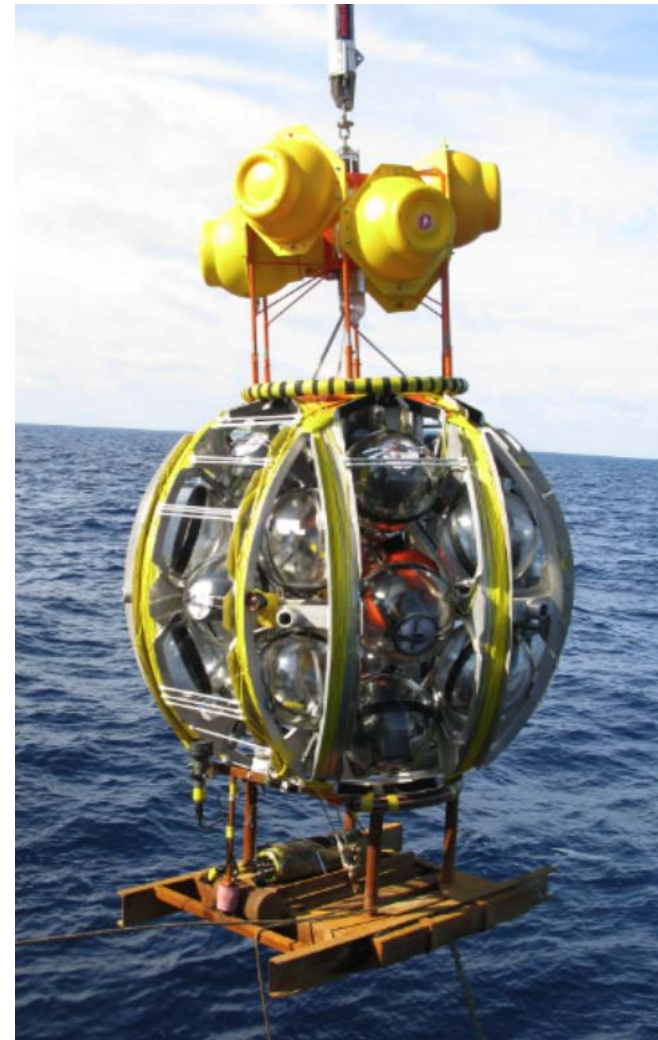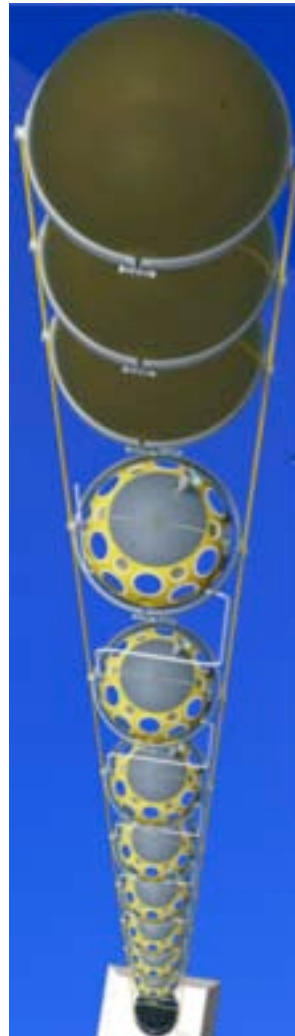
Multi-PMT DOM Strings

Digital Optical
Module
31 small, 3" PMTs in
one glass sphere
Photon counting

Detection Unit with 18 storeys
36 m inter-storey distance
Compact deployment

Prototype DOM tested successfully
on ANTARES instrumentation line

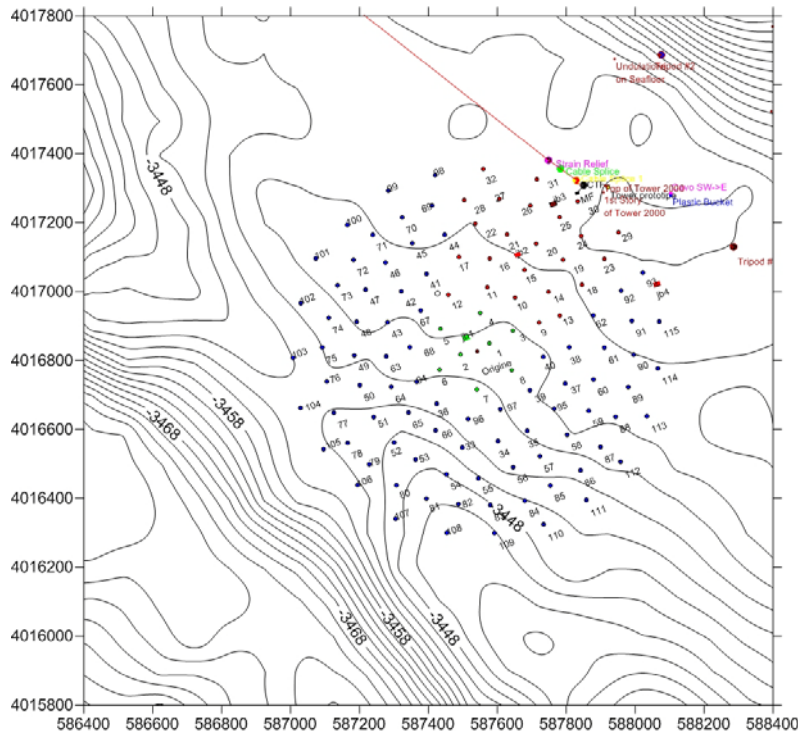Prototype DU with 3 DOMs to be
deployed in Capo Passero in March
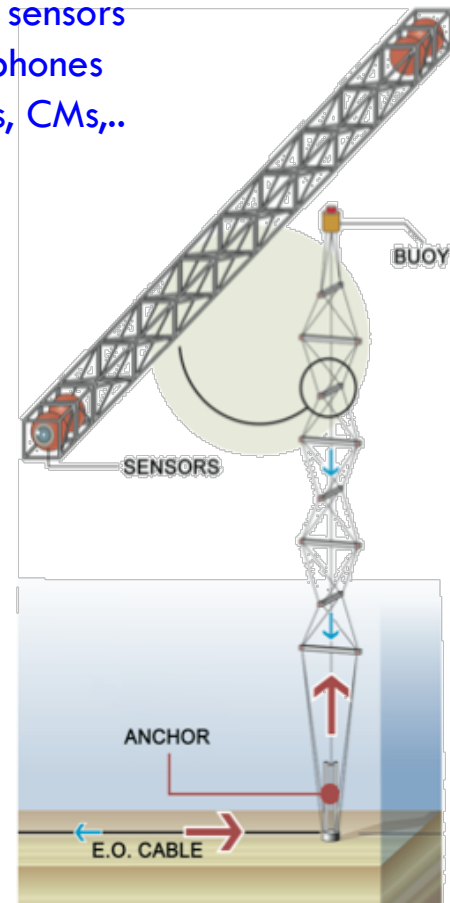2014

Capo Passero Site Future Layout

→ 8 Detection Units in 2014 (towers)
→ PPM Detection Unit in March 2014 (string)
→ 24 Detection Units in 2015 (strings)
→ A full Building Block before 2020 (≈1.5 IceCube)

10.000 light sensors
1000 hydrophones
 tens of CTDs, CMs,..

The largest deep-sea
observatory in the world

C. Distefano, INFN-LNS Users committee 2013-12-06

KM3NeT and EMSO

Common efforts with the Earth and Sea Science Community

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 acoustics, Biofouling, Bioluminescence, Water samples analysis,...
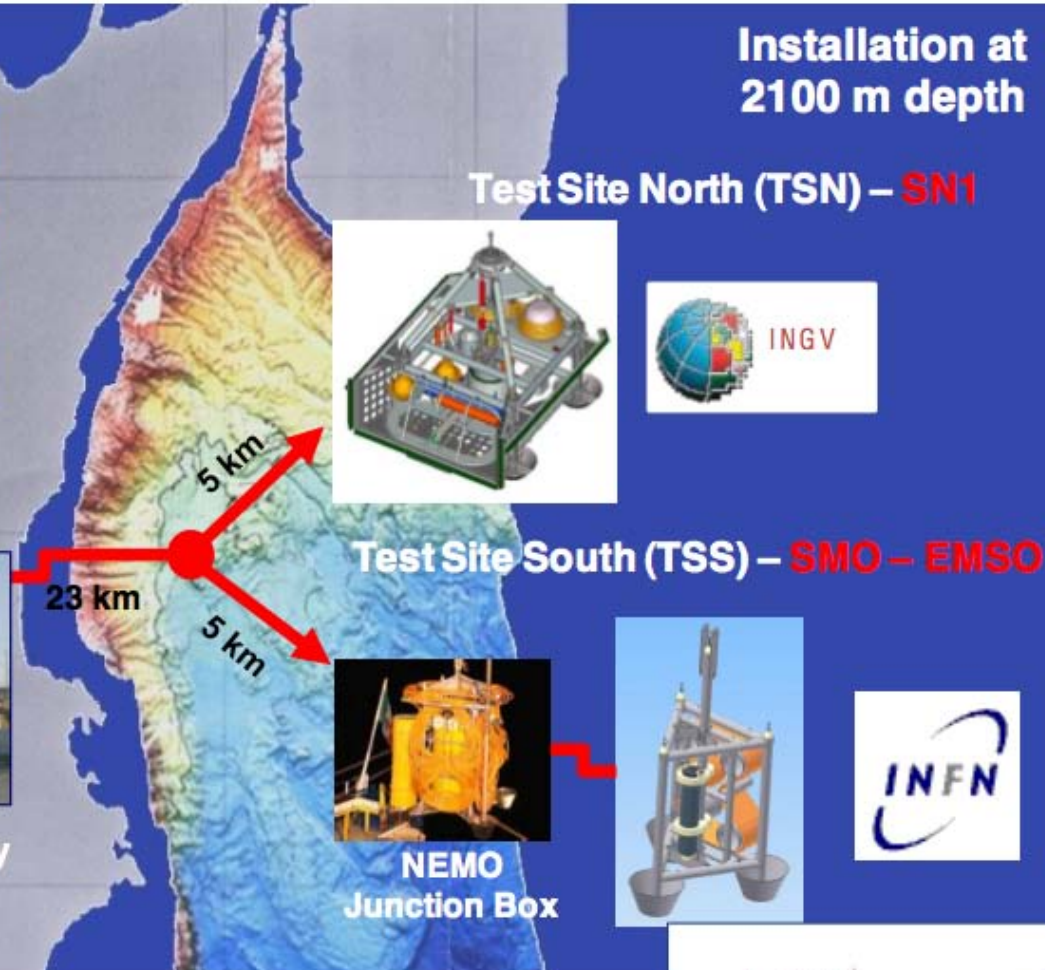
The Catania Test Site:
a multidisciplinary deep sea-lab

LNS-INFN Catania

Installation at 2100 m depth

Test Site North (TSN) – SN1

LNS Test Site – Laboratory at Catania's harbour

23 km

5 km

5 km

Test Site South (TSS) – SMO – EMSO

NEMO Junction Box

INGV

INFN

North:
4 LBW hydrophones
2 LF hydrophones
CTD, ADCP,
Seismometers
magnetometers
pressure gauges
GPS time stamping

South:
4 LBW hydrophones
Underwater GPS time stamping

european
multidisciplinary
seafloor
observatory
emso

Summary

- 8 storey tower deployed on March 23 2013

- Operational since then

- First results and in particular

  - Very low background rates (compatible with 40K background with few bioluminescence bursts)

  - Acoustic positioning: still in progress but accuracy O(1m) reachable

  - First results from muon track reconstruction analysis

- Toward KM3NeT telescope

  - Nemo Phase-3: an 8 tower detector (2014)

  - PPM Detection Unit (March 2014)

  - KM3NeT Phase-1: 8 towers plus 24 strings equipped with Multi-PMTs (2015)

  - km^3-scale detector before 2020