The NEMO Project

Neutrino Mediterranean Observatory

E. Migneco

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Sud

Amsterdam, 5-8 october 2003

Outline of the talk

NEMO - Towards the km3 neutrino telescope

- **R&D phase (1999-2002 …)**
  - ***Site selection and characterization***
    - *Several sites close to the italian coasts have been studied. A site close to Capo Passero (Sicily) at ~3500 m with optimal characteristics has been identified for the installation*
  - ***R&D activities***
    - *Development of specific ASICS for the underwater front end electronics*
    - *Large area hybrid photomultipliers*
    - *Development of deep sea instrumentation*
  - ***Feasibility study for the km3 detector***
    - *All the critical components and the deployment procedures have been examined*
    - *A preliminary project for a km3 detector has been developed*
- **Phase 1: Advanced R&D and prototyping (2002-2005)**
  - ***Realization of a detector subsystem including all critical components***
    - *The system will be installed off Catania at the Underwater Test Site of the LNS*
- **Towards the km3 neutrino telescope (EU Design Study)**

The NEMO Collaboration

INFN

Bari, Bologna, Cagliari, Catania, Genova, LNF, LNS, Messina, Roma

Universities:

Bari, Bologna, Cagliari, Catania, Genova, Messina, Roma *"La Sapienza"*

CNR

Istituto di Oceanografia Fisica, La Spezia
Istituto di Biologia del Mare, Venezia
Istituto Sperimentale Talassografico, Messina

Istituto Nazionale di Geofisica e Vulcanologia

Istituto Nazionale di Oceanografia e Geofisica Sperimentale

Site selection criteria

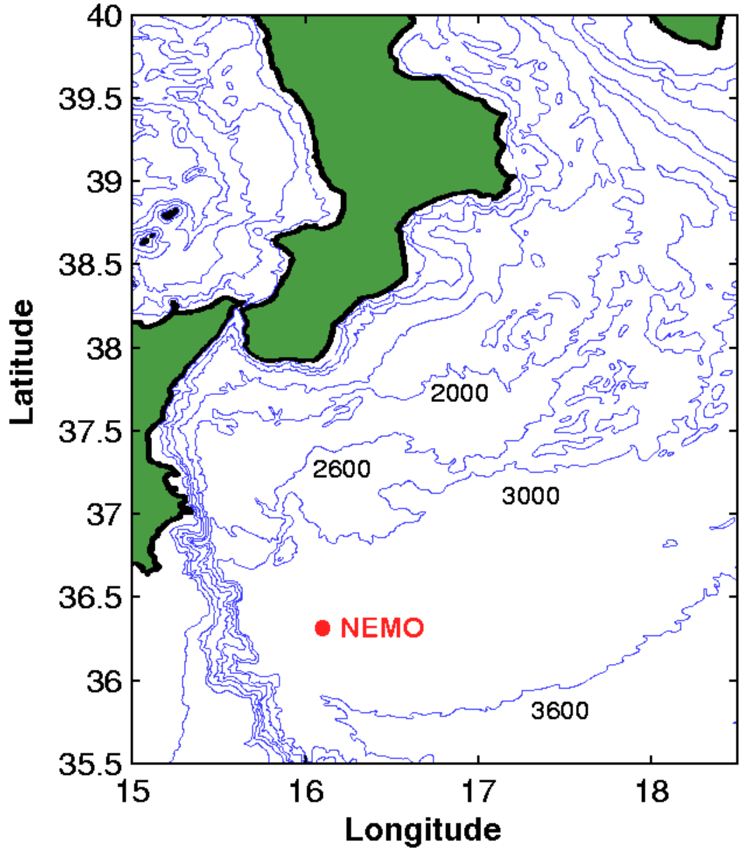
- **Depth**
  Reduction of atmospheric muon flux
- **Water optical transparency**
  Optimisation of detector performances (efficiency and angular resolution)
- **Low biological activity**
  Low optical background (bioluminescence) Þ detector performances
  Low biofouling and sedimentation on OM
- **Weak and stable deep sea currents**
  Reduce stresses on mechanical structures
- **Proximity to the coast and to existing infrastructures**
  Easy access for sea operations
  Reduction of costs for installation and maintenance
- **Distance from the shelf break and from canyons**
  Installation safety

Site exploration activities

- **Since 1998 continuous monitoring of a site close to the coast of Sicily**
- **More than 20 sea campaigns on the site to measure**
  - *water optical properties*
  - *optical background*
  - *deep sea currents*
  - *nature and quantity of sedimenting material*
- **Other sites explored for optical properties**
  - *Two sites in the Southern Thyrrenian Sea (Ustica and Alicudi)*
  - *Toulon (ANTARES site), in collaboration with Antares*
  - *Lake Baikal*

For more details on NEMO site exploration activities and results see talk by G. Riccobene

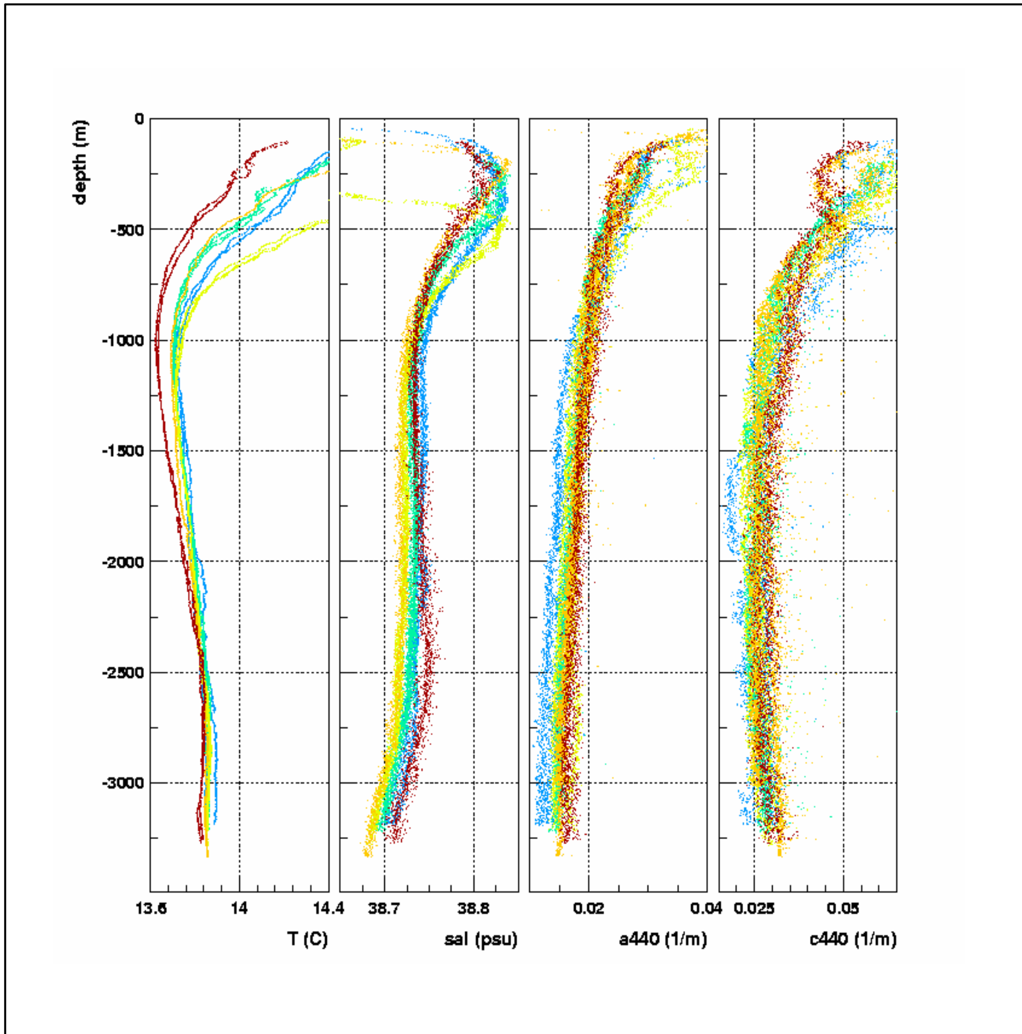
The Capo Passero Site



- Located in the South Ionian sea
- Selected after a screening of water optical properties in several sites close to the italian coasts
- About 50 NM from shore (Capo Passero, Sicily)
- Large and flat area at about 3400 m depth

Water optical properties

Seasonal dependence of optical parameters in Capo Passero



Seasonal dependence of oceanographical (Temperature and Salinity) and optical (absorption and attenuation) properties has been studied in capo Passero

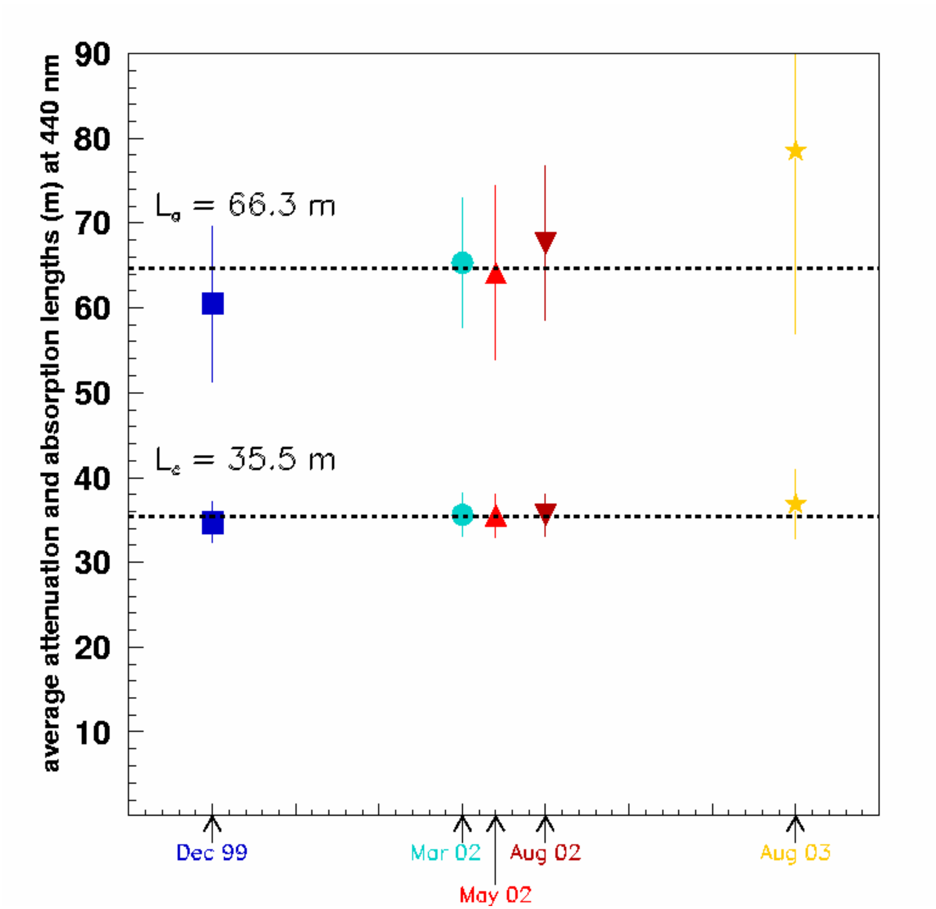
Variations are only observed in shallow water layers

Data taken in

Aug 02 (3)
March 02 (4)
May 02 (2)
December 99 (2)
August 2003 (2)

Water optical properties

Seasonal dependence of absorption and attenuation lenghts



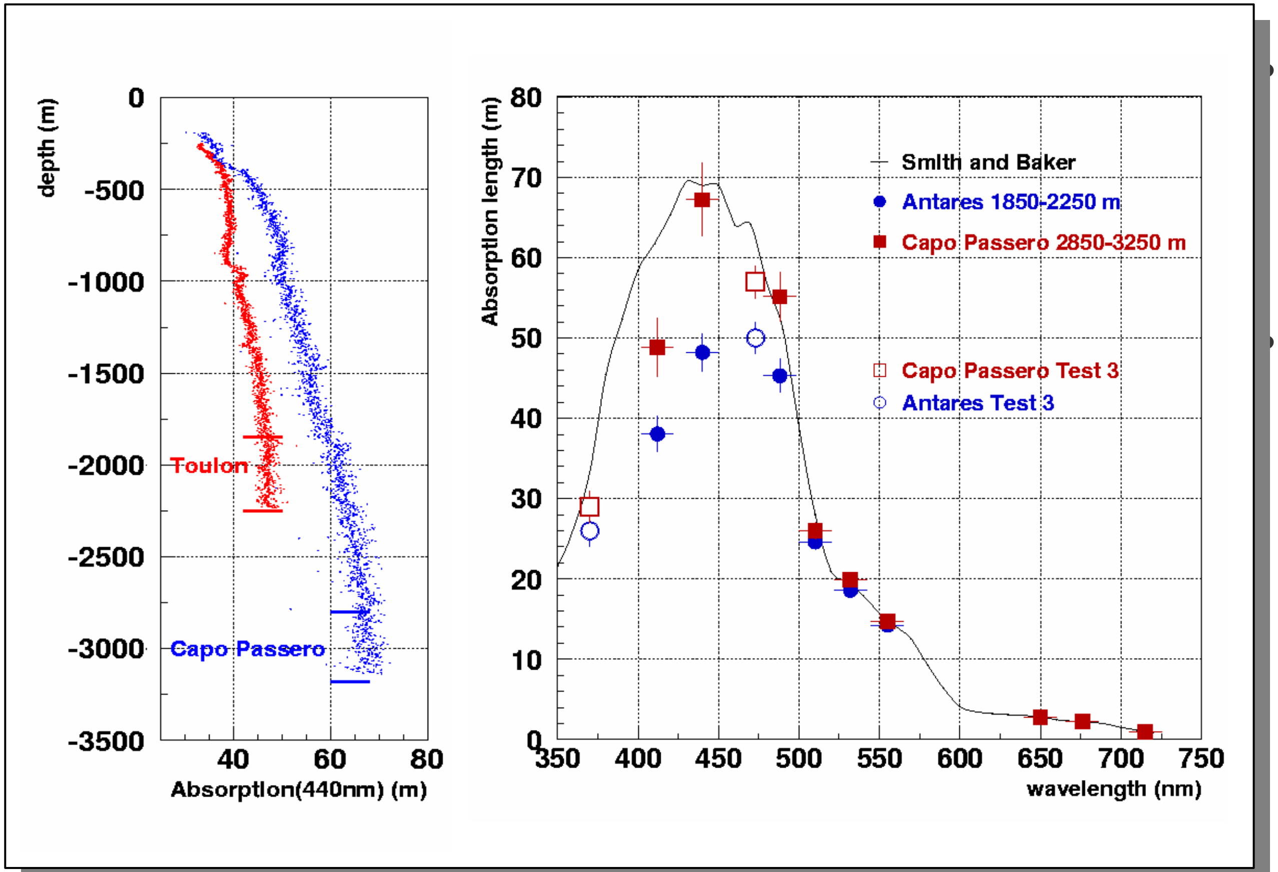
Values averaged in the depth region 2850÷3250 m and over several profiles

No seasonal variations of absorption and attenuation lengths are observed in deep waters in the blue region (λ = 440 nm)

Water optical properties

Comparison of NEMO and Antares data

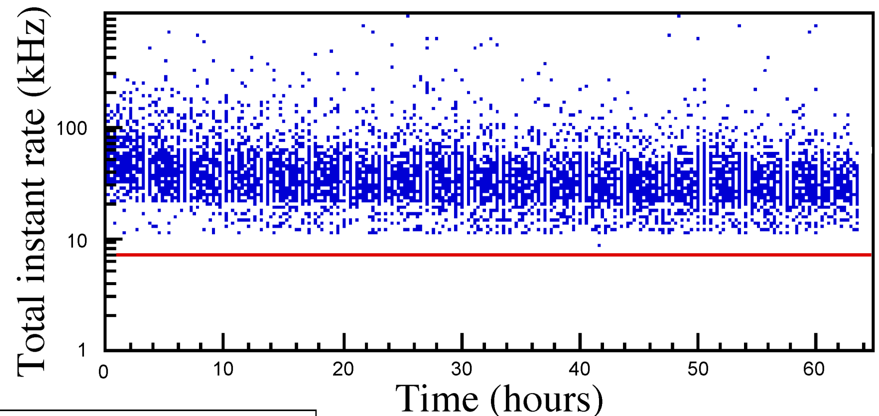
Optical water properties have been mesured in the summer 2002 in Capo Passero and Toulon in two joint NEMO-ANTARES campaigns

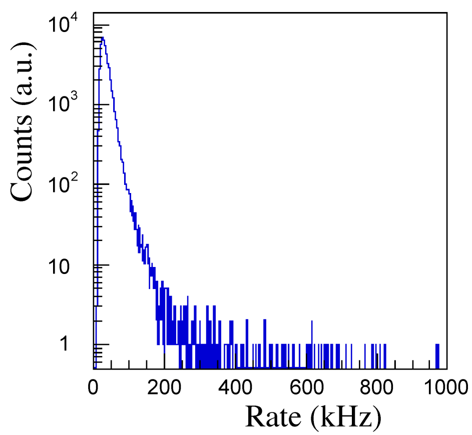


- **Absorption lengths measured in Capo Passero are compatible with optically pure sea water data**
- **Differences between Toulon and Capo Passero are observed in the blue region**

Optical background

- Decay of radioactive elements (mainly ^{40}K) ® stable frequency noise (˜30 kHz on a 8” PMT at 0.3 p.e. threshold)
- Light produced by biological entities (bioluminescence) ® random bursts with very high counting rate

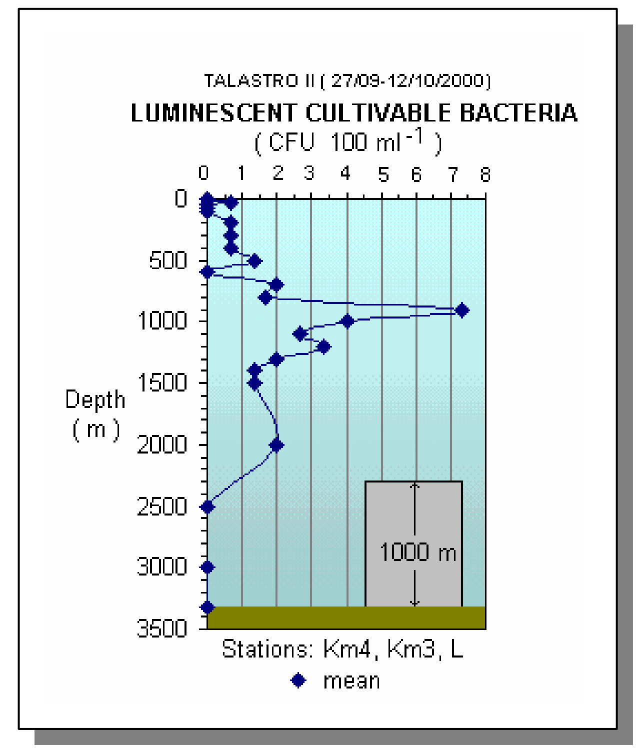




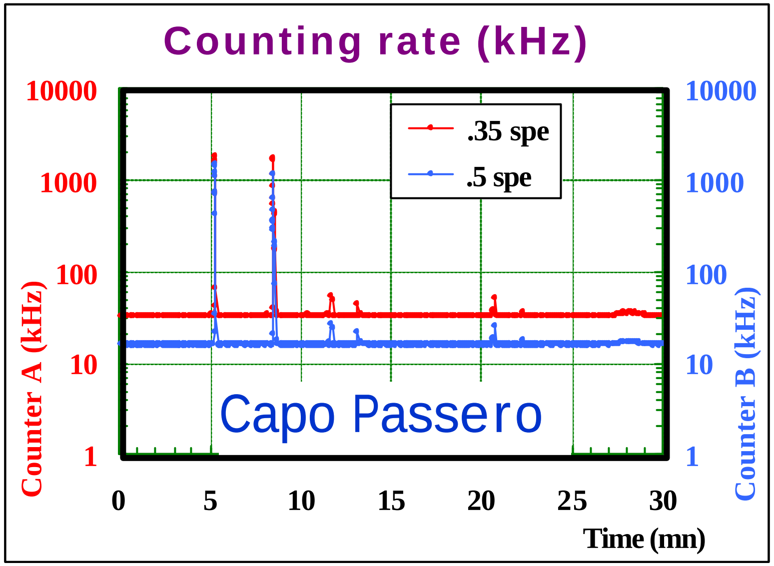
Capo Passero

Noise on a 8” PMT

28.5 ± 2.5 kHz



Optical background

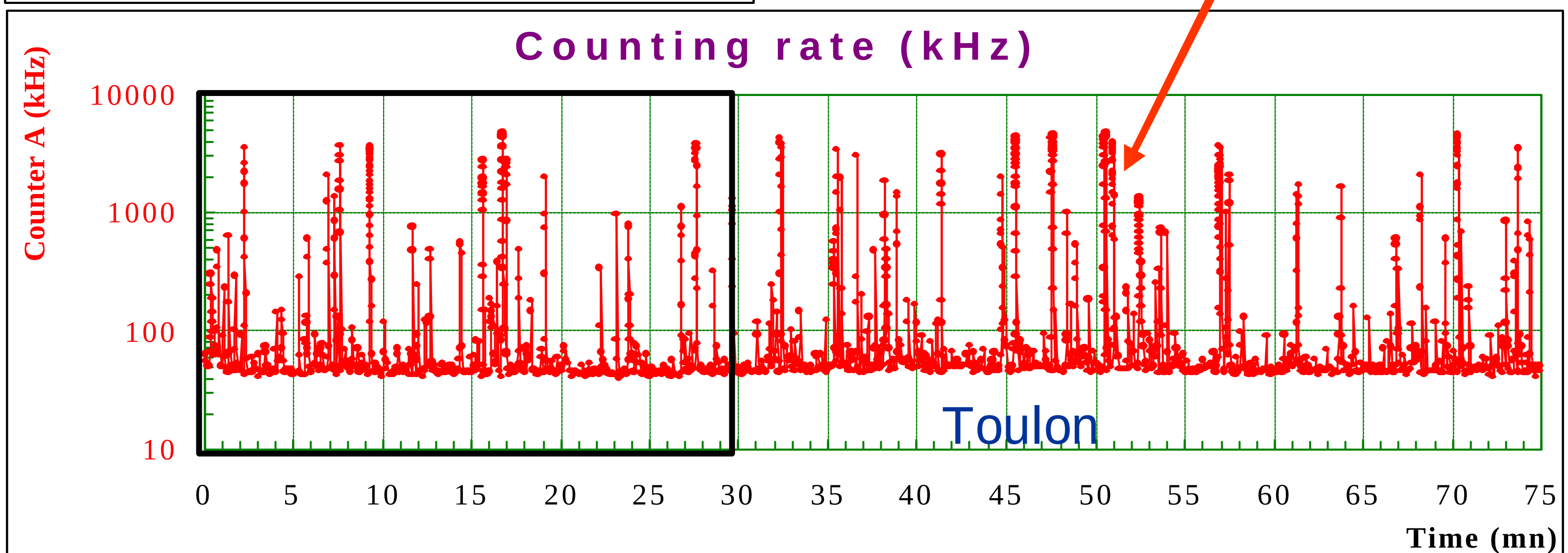


Test 1 data

Courtesy of J.P. Schuller

ANTARES device (10'' PMT at 0.5 spe)

- **Toulon 44 kHz**
- **Capo P. 15 kHz**

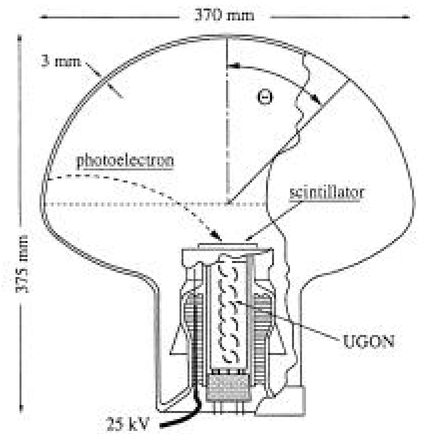


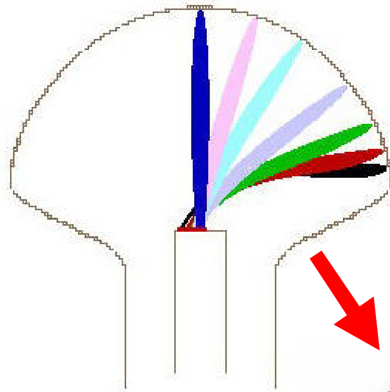
The Capo Passero site

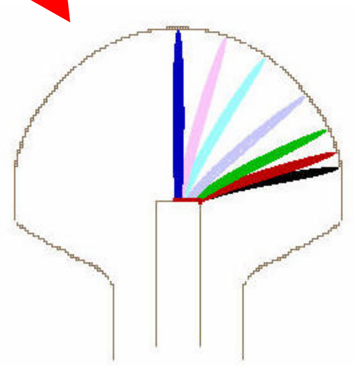
Site optical and oceanographical characteristics

- **Absorption lengths (~70 m @440 nm) are compatible with optically pure sea water values**
- **Measured values are stable troughout the years *(important: variations on La and Lc will directly reflect in changes of the detector effective area)***
- **Optical background is low (consistent with ^{40}K background with only rare occurrences of bioluminescence bursts)**
- **The site location is optimal (close to the coast, flat seabed, far from the shelf break and from canyons, far from important rivers)**
- **Measured currents are low and regular (2-3 cm/s average; 12 cm/s peak)**
- **Sedimentation rate is low**
- **No evidence of recent turbidity events**

Development of a large area hybrid PMT

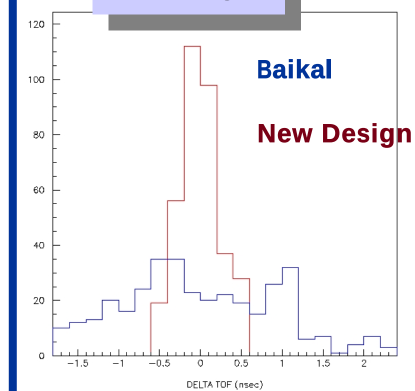




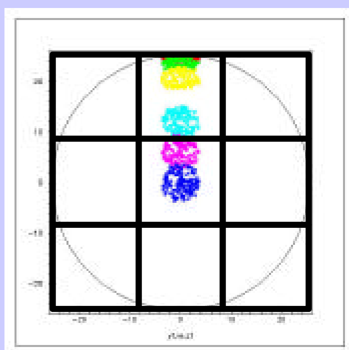


I. SIMION simulations show that shape of exisiting BAIKAL PMT can be improved to provide one-one correspondence and timing improvement

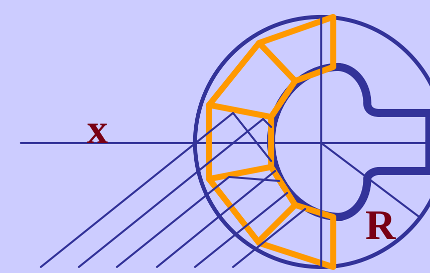
Timing



II. Coupling to a position sensitive detector provides information on the photoelectron emission point



III. Coupling to a light guide system also provides information on the detected light direction

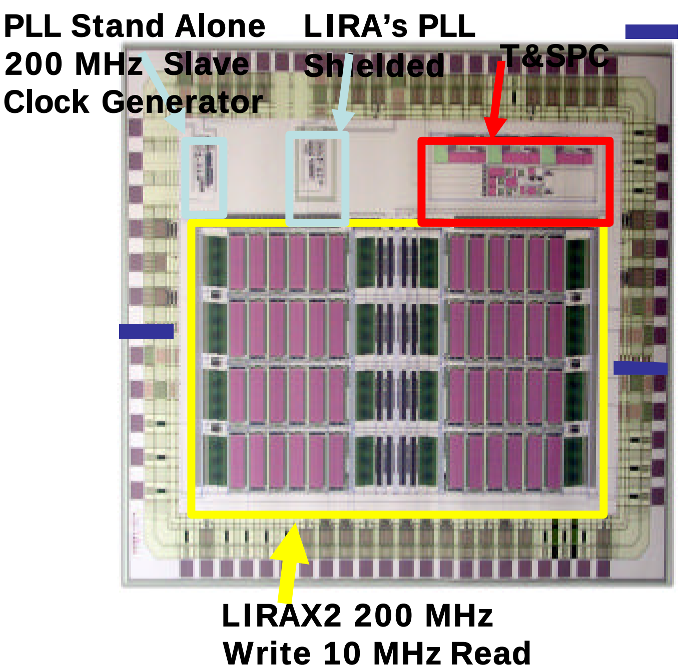


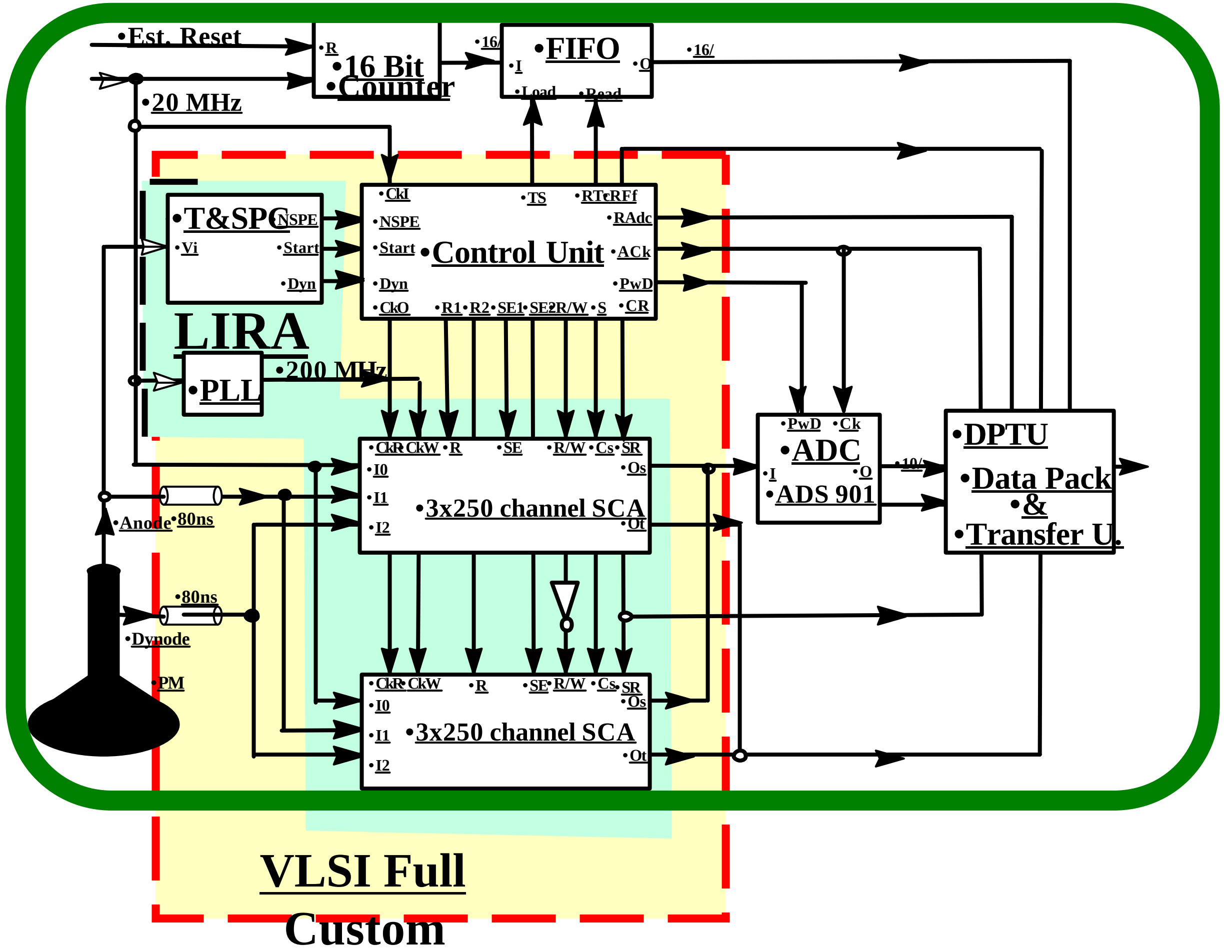
See talk by A. Bersani

Development of low power electronics

Front-end Optical Module Electronics

- Sampl .Freq.: 200MHz
- Trigger level remote controlled;
- Max Power dissipation less than 200 mW
- Input dynamic range 10 bit
- Dead time < 0.1%.
- Time resolution < 1 ns





See talk by D. Lo Presti

Feasibility study for the km3 detector

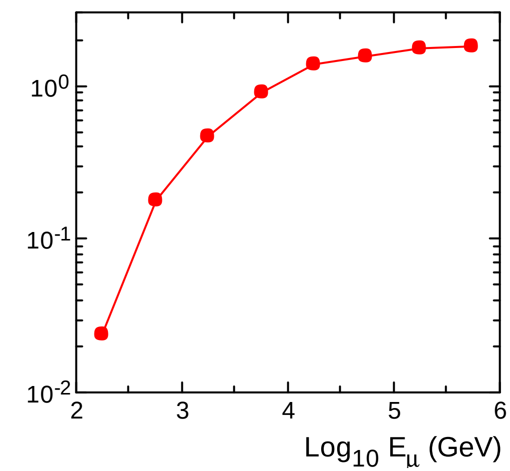
Aim: *demonstrate that an underwater Cherenkov detector with effective area of more than 1 km² is technically feasible and can be constructed with a "reasonable" budget*

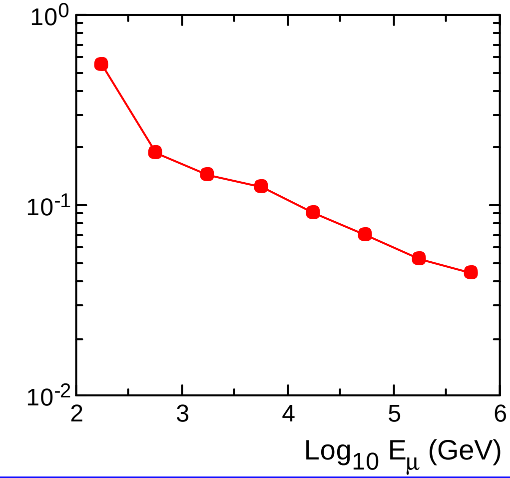
Needs first to define the detector architecture

First approximation: Cubic lattice of equally spaced (horizontally and vertically) downward looking OMs

Spacing 60 m (~ L_a)

Gives an effective area of ~ 1 km² with ~ 5000 OM





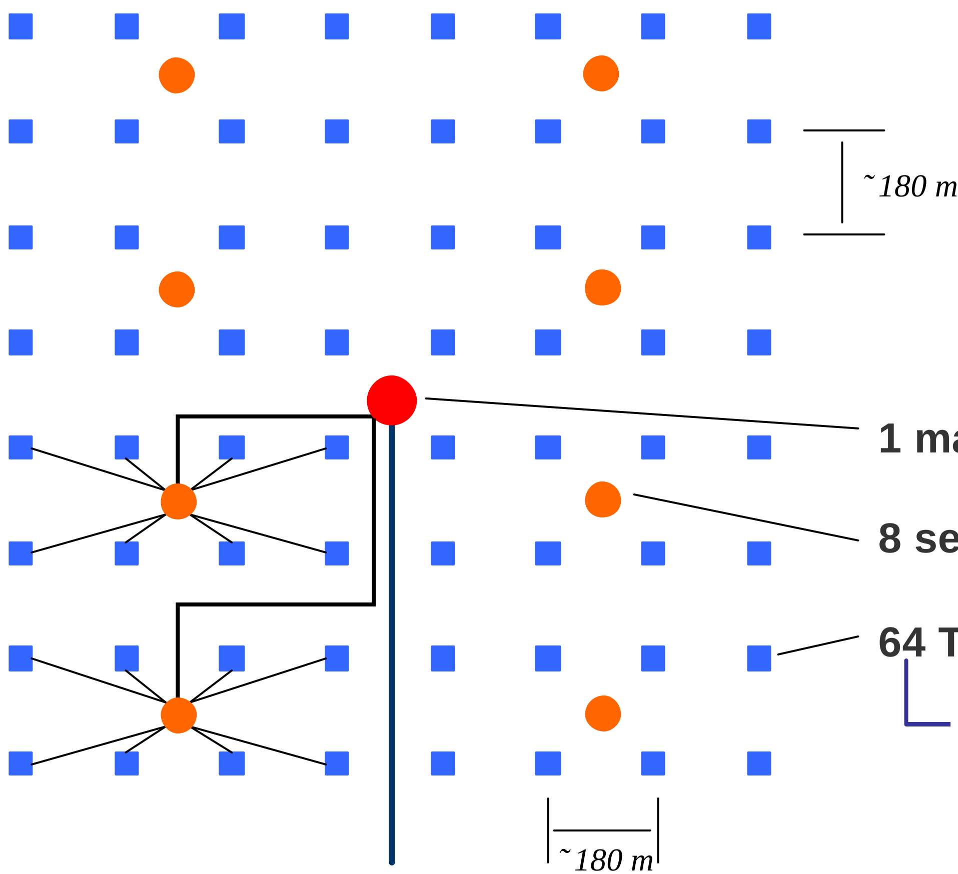
Hardly feasible and very expensive
needs 400 strings spaced of 60 m

Number of structures must be reduced

Preliminary project for a km^3 detector

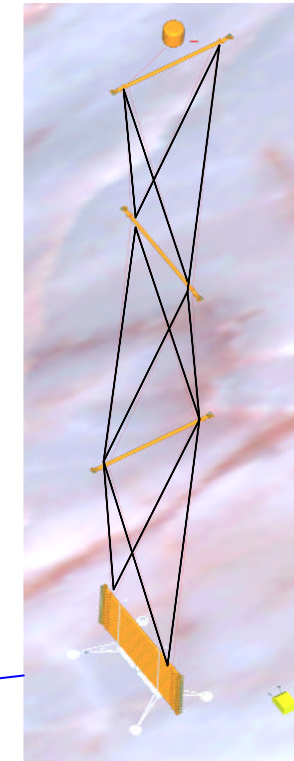
Schematic detector layout

Reference layout used for the feasibility study



Detector architecture

- *Reduce number of structures to reduce connections and allow underwater operations with a ROV Þ non homogeneous sensor distribution*
- *Modularity*



1 main Junction Box

8 secondary Junction Boxes

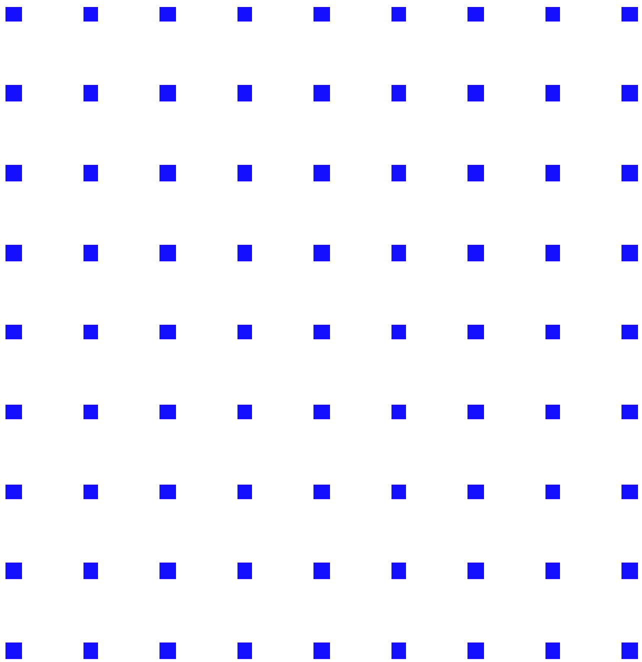
64 Towers

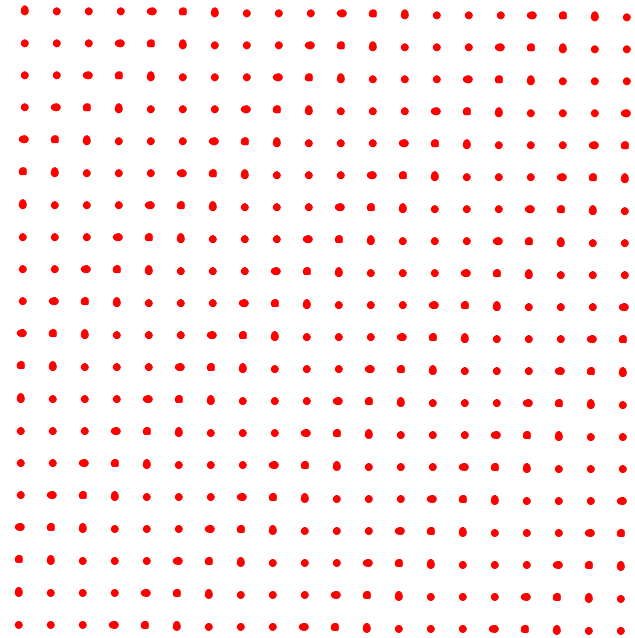
16 storeys with 4 OM (active height 600 m)

4096 OM

Total instrumented volume ~1 km^3

Comparison of different km3 architectures





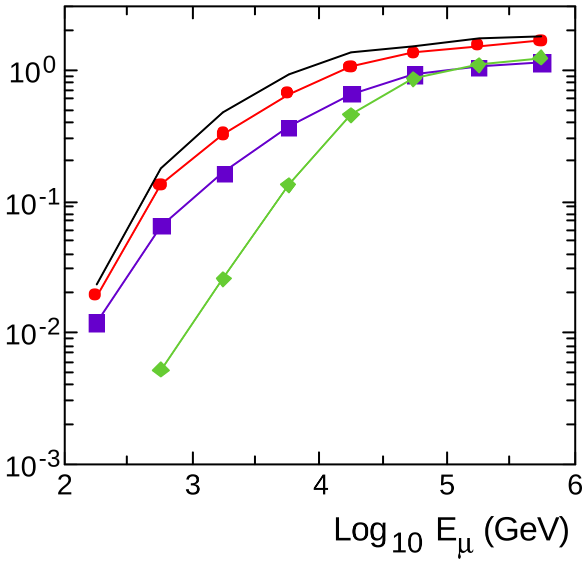
Tower architecture (5832 OM)

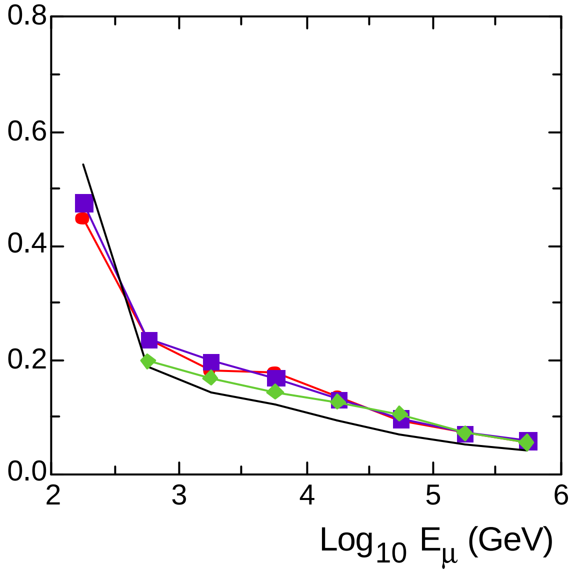
18 storey towers with 4 OM per storey
20 m storey length
40 m spacing between storeys
81 towers arranged in a 9x9 square lattice
140 m spacing between towers

Homogeneous lattice architecture (5600 OM)

Strings with 16 OM spaced by 60 m
400 strings arranged in a 20x20 lattice
60 m spacing between strings

Comparison of different detector architectures





—	**Homogeneous lattice detector**	**5600 PMTs**	**20 kHz**
●	**NEMO Tower detector**	**5832 PMTs**	**20 kHz**
■	**NEMO Tower detector**	**5832 PMTs**	**60 kHz**
◆	**NEMO Tower detector**	**5832 PMTs**	**120 kHz**

Effective areas and median angles for two different detector architectures and different optical background rates

Simulations performed with the ANTARES simulation package

See talk by P. Sapienza

Feasibility study for the km3 detector

Aspects that have been analysed in detail

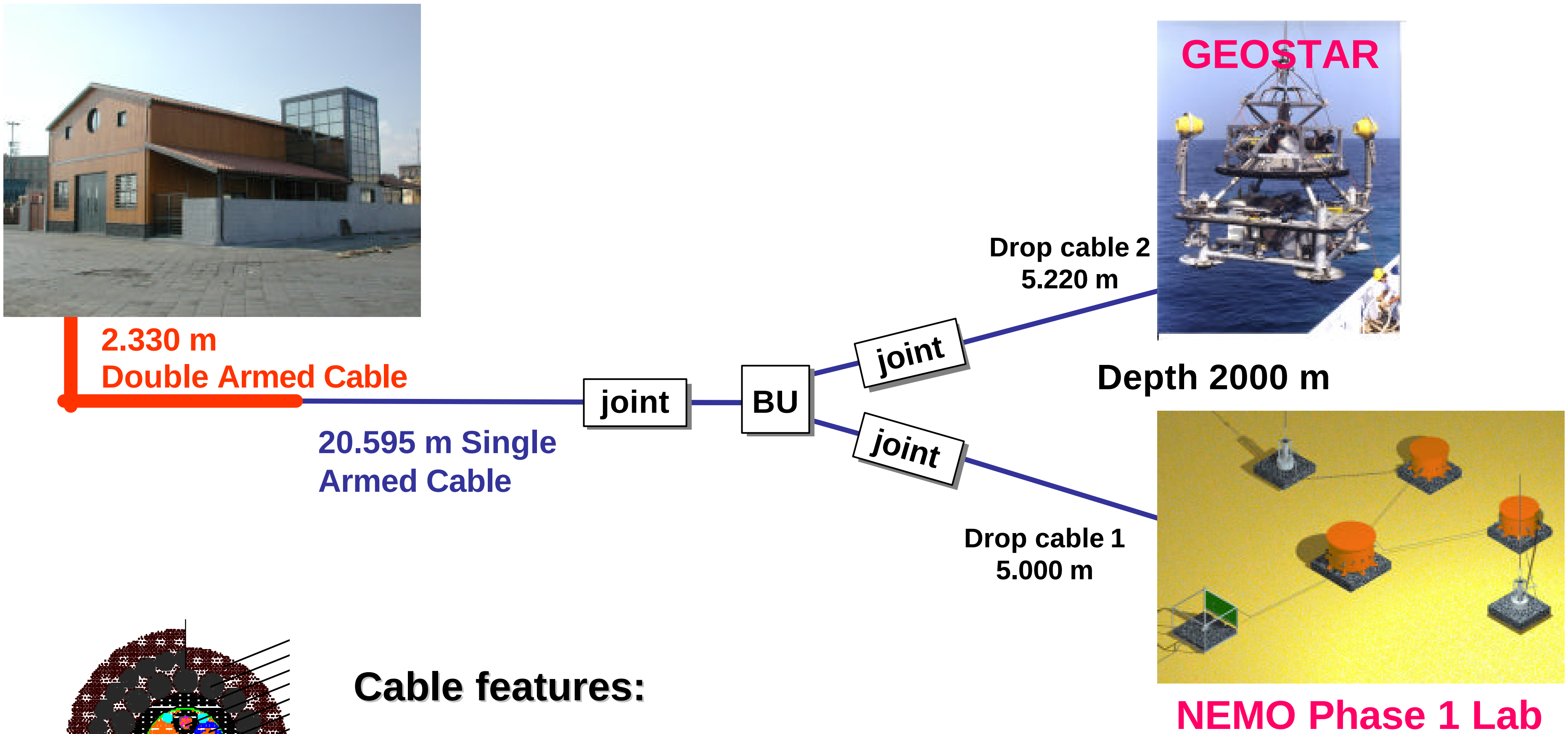
- Mechanical structures
- Power distribution
- Front end electronics
- Data transmission to shore
- Cable network (submarine cables and connectors)
- Deployment of the structures and cables

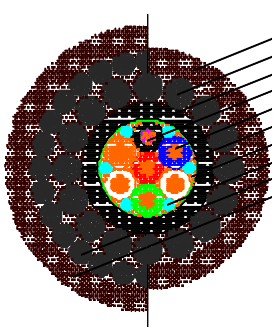
The study indicates that technologies exist to realize a km3 detector feasible at an affordable cost

Some aspects may require further R&D for technical and cost effectiveness optimization

The NEMO Phase 1 project

Layout of the LNS Underwater Test Site installation





Cable features:

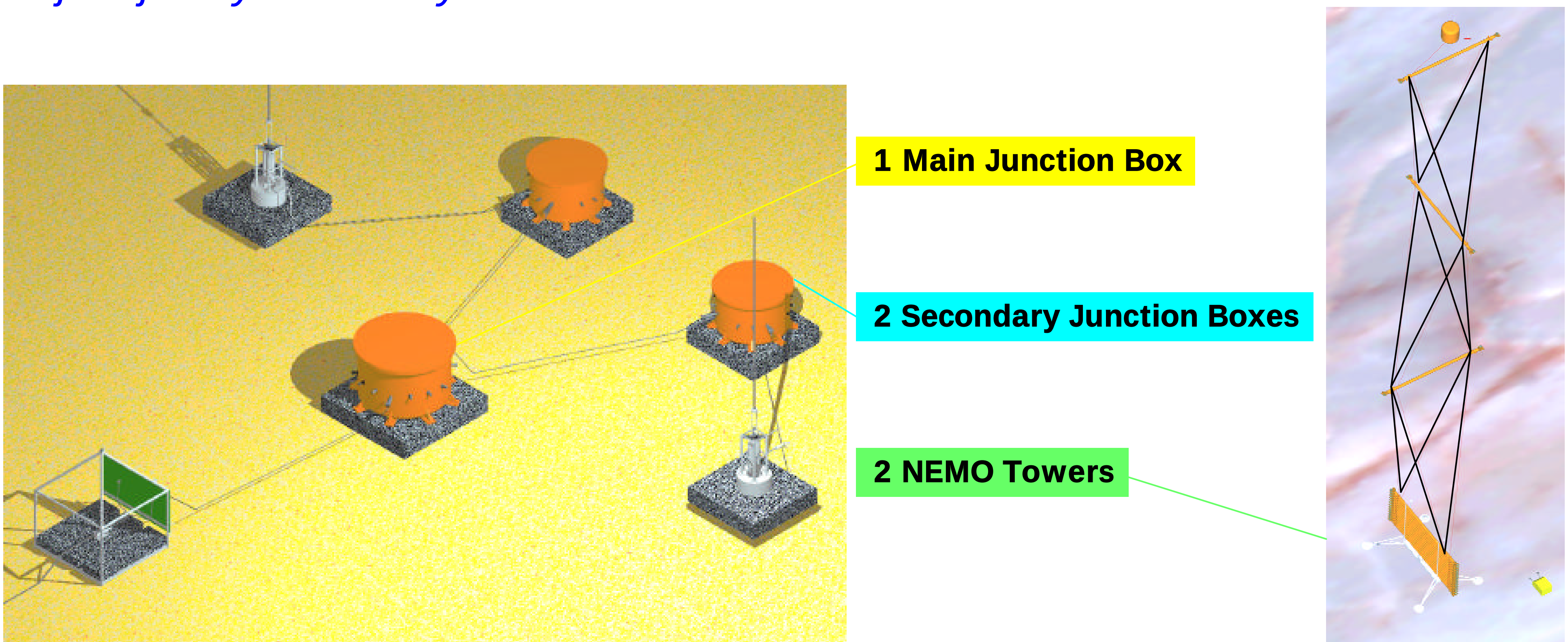
- 10 Optical Fibres standard ITU-TG-652
- 6 Electrical Conductors F 4 mm^2

The NEMO Phase 1 project

A step towards the km3 detector

Realization of a detector subsystem including all critical components

Project jointly funded by INFN and MIUR



The NEMO Phase 1 project

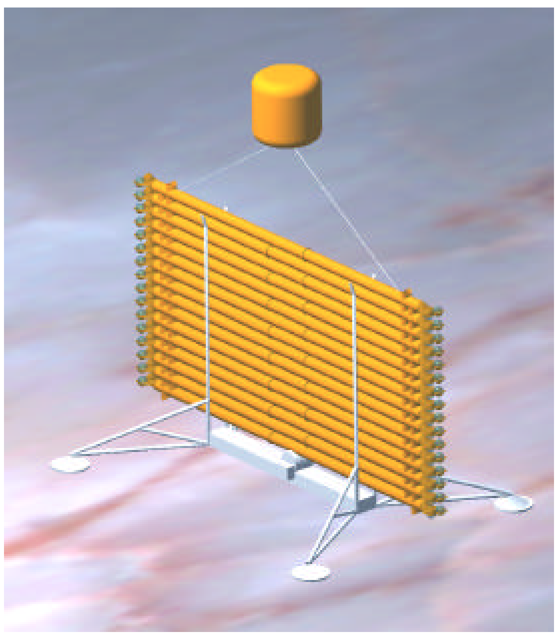
More details will be given in other talks of this conference

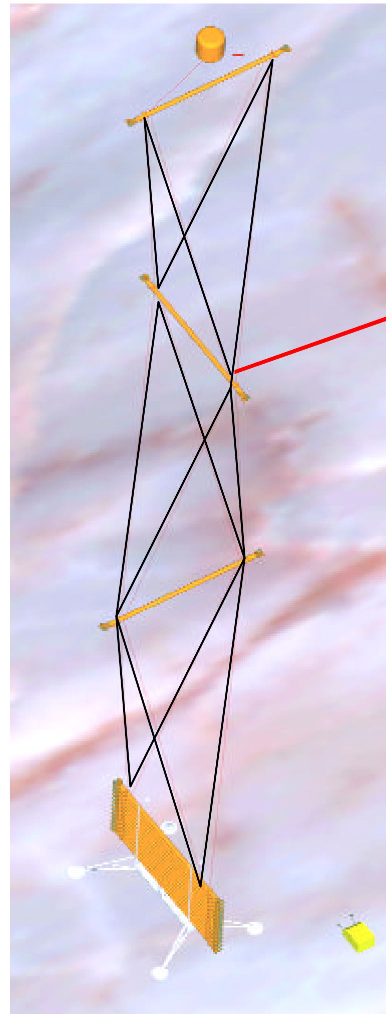
- Mechanical structures *(M. Musumeci & R. Occhipinti)*
- Power distribution system *(R. Cocimano)*
- Optical Modules *(S. Reito)*
- Front end electronics *(D. Lo Presti, C.Nicolau)*
- Data transmission to shore *(F. Ameli)*
- Timing calibration *(M. Circella)*
- Deployment techniques *(M. Musumeci, R. Brandi - Sonsub)*

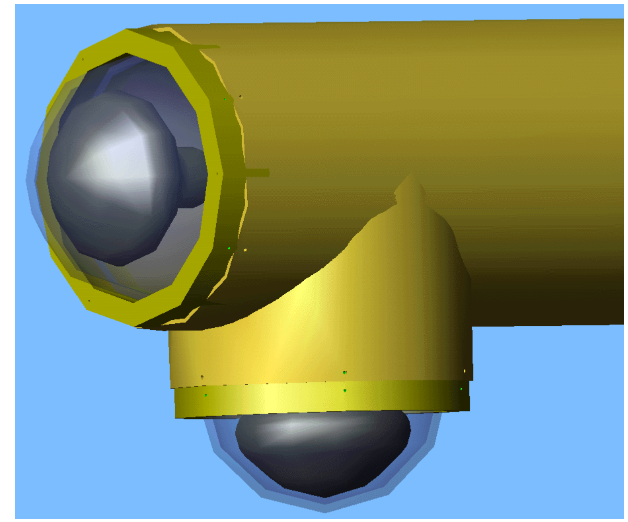
The NEMO tower

“Tower” structure

Semi rigid structure
Tensioning and electro-optical cables are kept separated
The structure can be packed for transportation and deployment







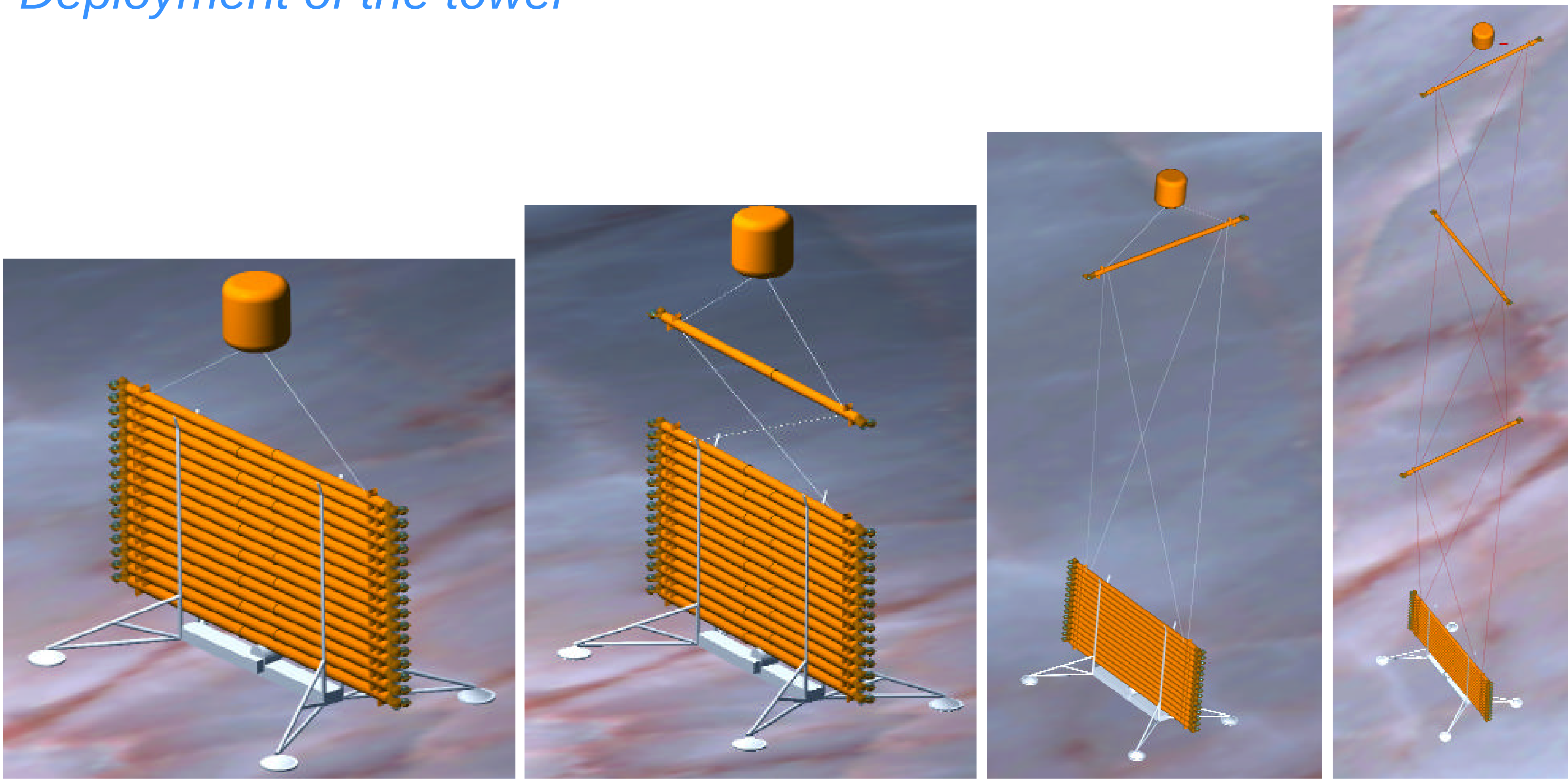
Packable structure realized with 20 m long glass fibre tubes

16 storeys spaced by 40 m
4 OM per storey
64 OM per tower
600 m active length

For the NEMO tower structure see talk by M. Musumeci

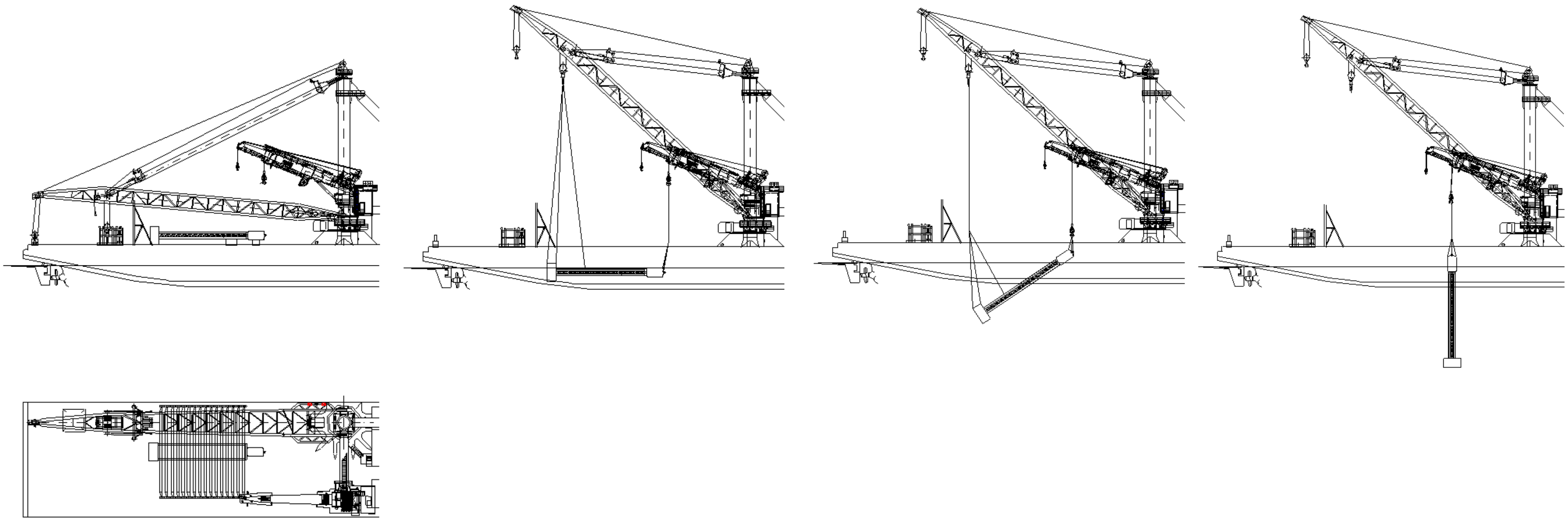
The NEMO tower

Deployment of the tower



The NEMO tower

Deployment of the tower

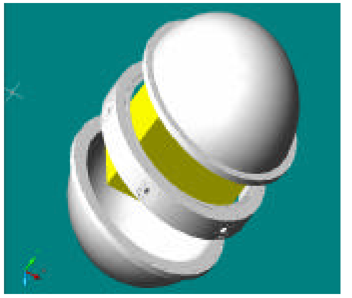


Study by Sonsub S.p.A.

Junction Boxes

Preliminary design of the JB container pressure-compensated with oil

Pressure vessel for electronics devices

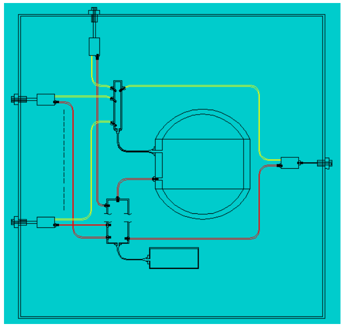


Alternative design to the Titanium container (Antares-like)

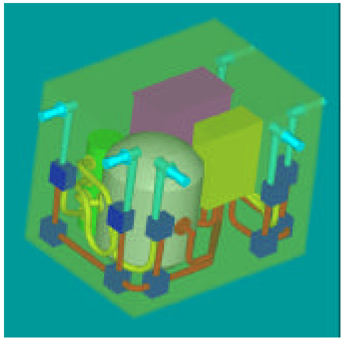
Aim

Decouple the two problems of pressure and corrosion resistance

Internal cable layout



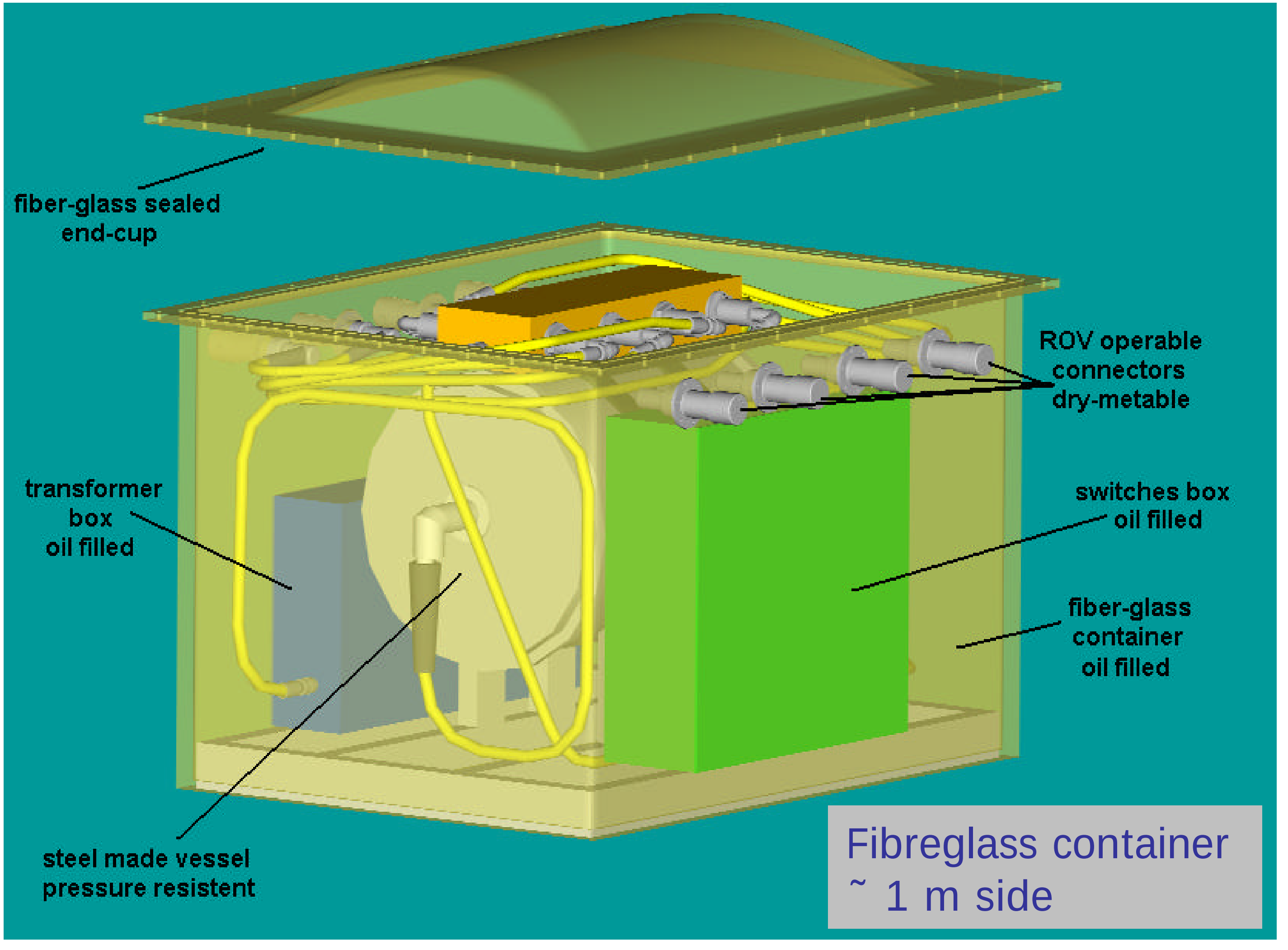
Fiberglass container and it's components



For the NEMO hybrid junction box design see talk by R. Occhipinti

Junction Boxes

JB internal layout



Fibreglass container
~ 1 m side

Data transmission

Objective

- Transmit the full data rate with minimum threshold
- Only signal digitization should be performed underwater
- All triggering should be performed on shore
- Reduce active components underwater

Assuming

- An average rate of 50 kHz (40K background) on each OM
- Signal sampling (8 bits) at 200 MHz
- Signal length of 50 ns (true for 40K signals) ☑ 10 samples/signal

5 Mbits/s rate from each OM ☑ **25 Gbits/s** for the whole telescope (5000 OM)

Rate affordable with development and integration of available devices for telecommunication systems

Data transmission system

Proposed architecture for the km3 detector

Based on DWDM and Interleaver techniques

First Multiplation Stage (Tower base):

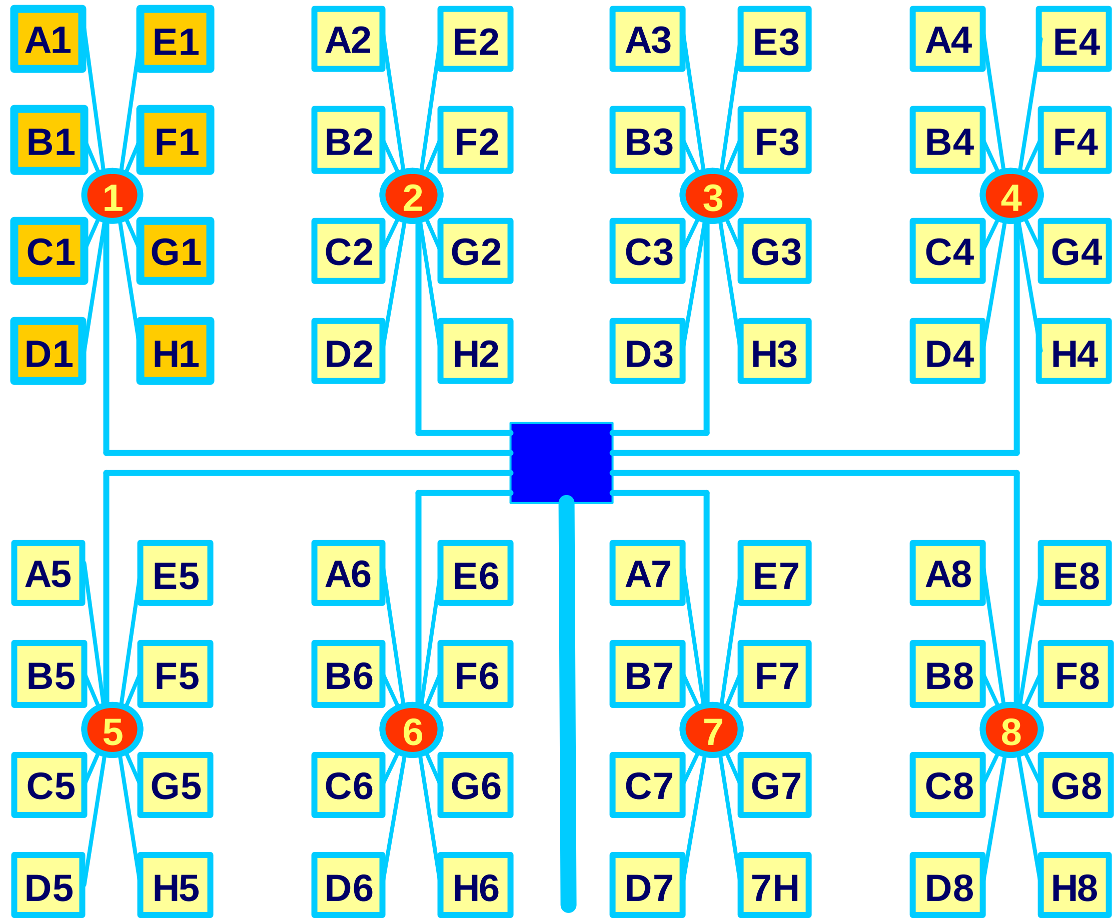
– 16 Channels coming from the 16 tower floors. The channels are multiplexed in one fibre at the base of each tower.

Second multiplation stage (secondary JB):

– 32 channels coming from a couple of tower are multiplexed with an interleaver;

– The output is a single fibre for each of the four couples of towers.

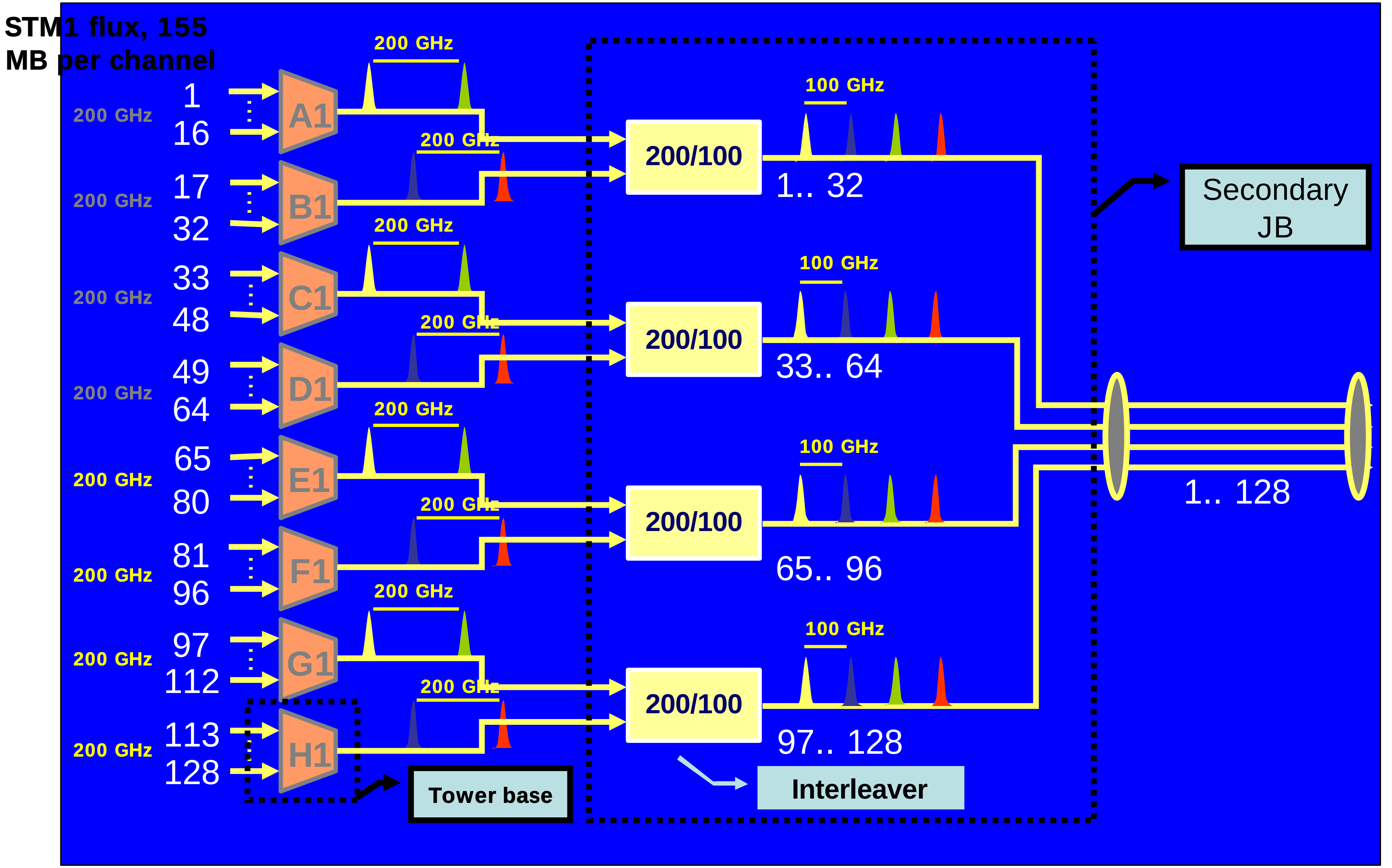
All the fibres coming from the secondary JB go directly to shore (connection to the main electro-optical cable inside the main JB)



Mostly passive components

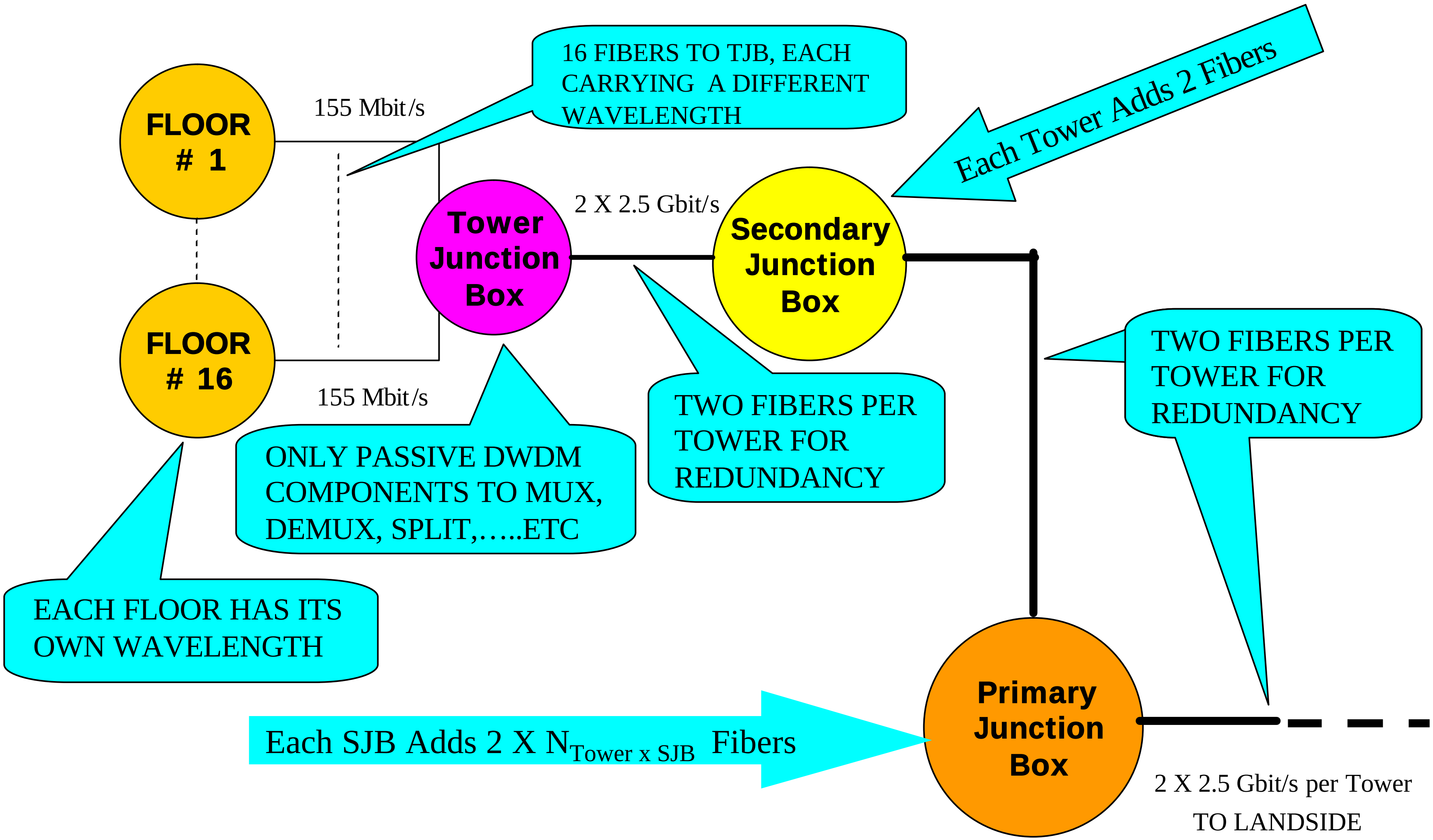
Very low power consumption

Data transmission system



Data transmission system

NEMO Phase 1 solution



Data transmission system

NEMO Phase 1 solution

- Totally passive network (except Transceivers)
- Use of SDH standard
- High bandwidth
- Architecture based on DWDM systems and Interleavers reduces dimensions and power load
- Uses only commercially available components
- No data filtering underwater

Power budget

Storey power load (4 OM + storey electronics + additional sensors) 20 W

x 16 storeys 320 W

+ additional power load at the tower base (electronics, sensors, ...) 100 W

Total power load per tower 420 W

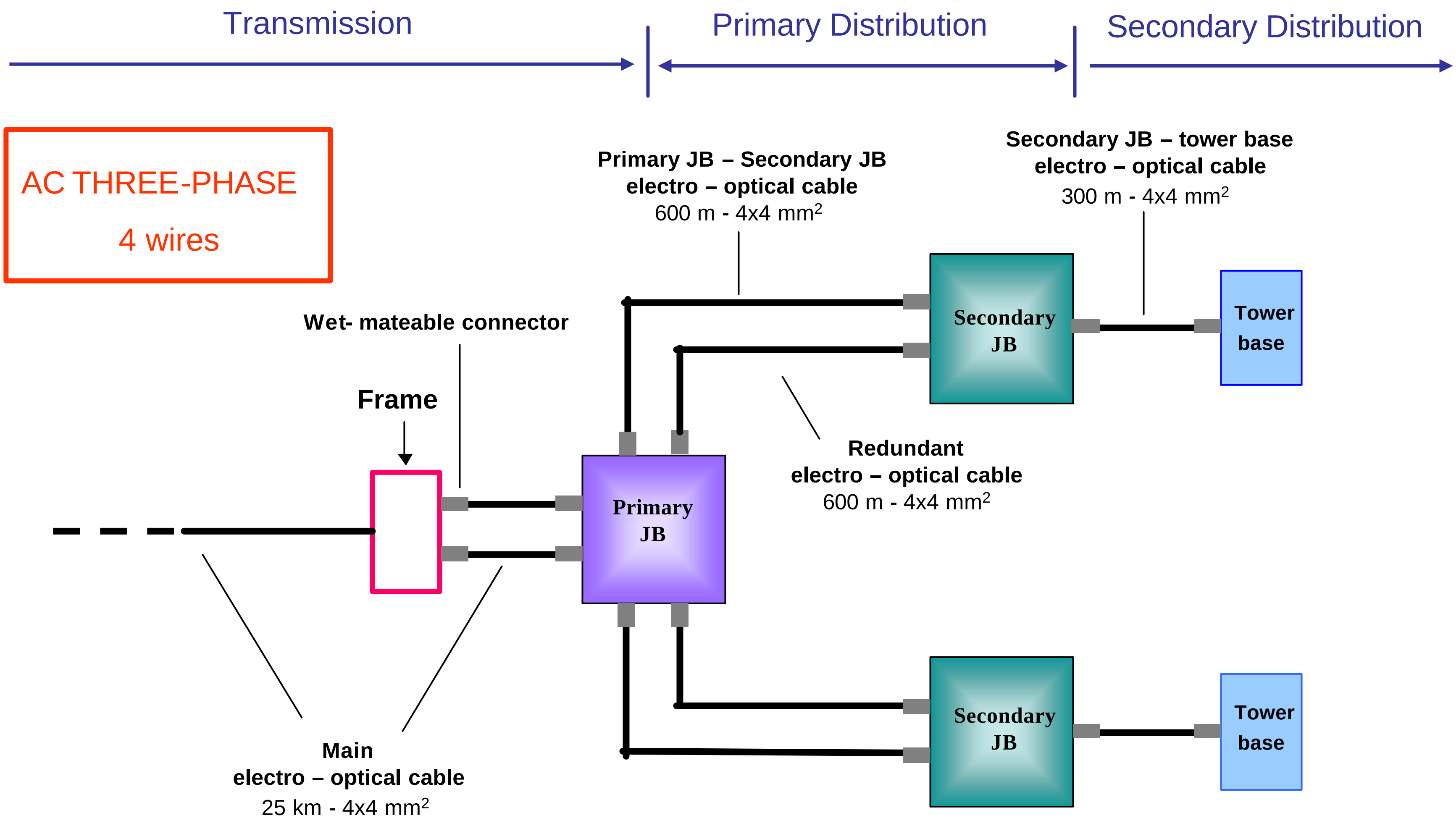
x 64 towers (4096 OM) **27 kW**

+ JB power load (electronics, sensors, ...), 300 W per JB 3 kW

Total power load 30 kW

Power distribution system

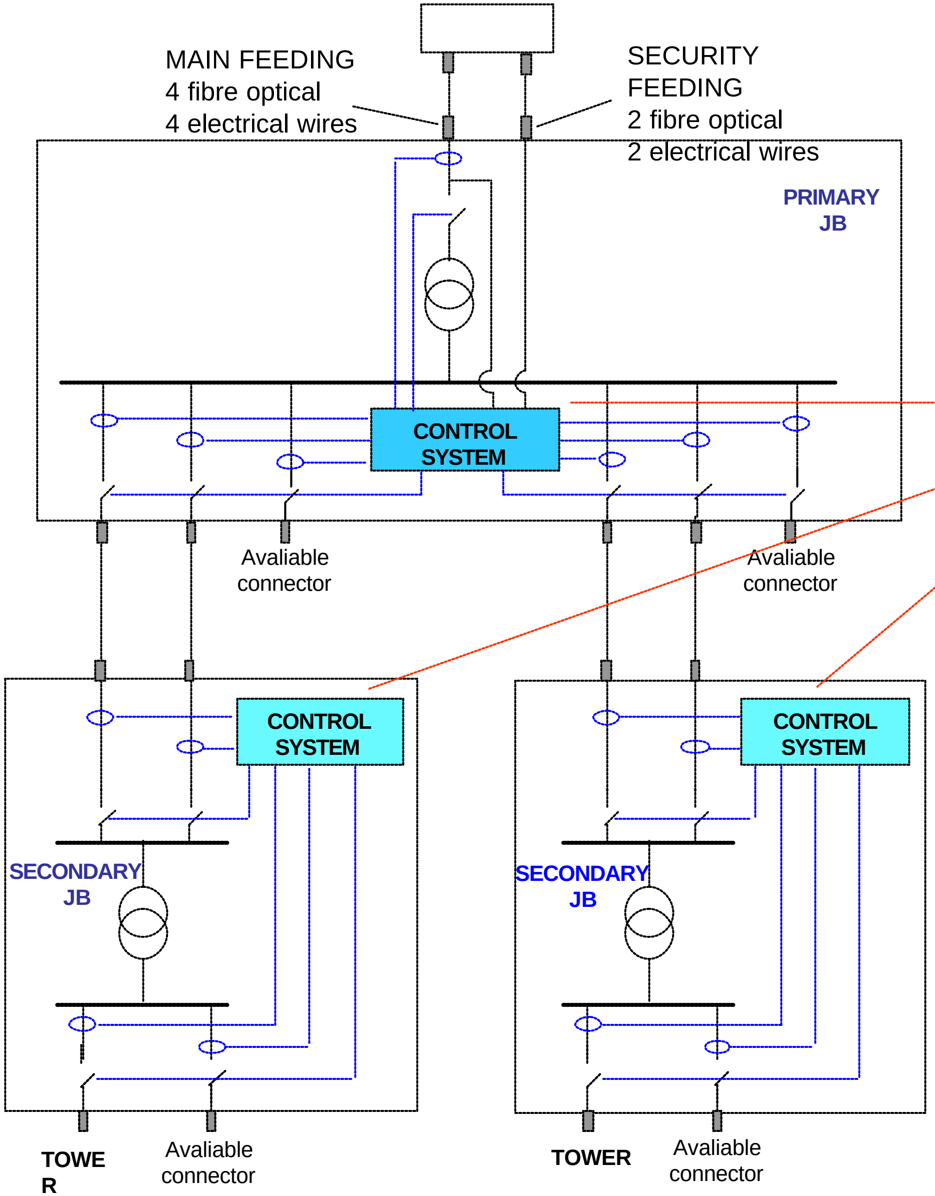
NEMO PHASE 1 POWER SYSTEM



See talk by R. Cocimano

Power distribution system

Control system



The power control system should be able to:

- monitor physics parameters (temperature, humidity, current, voltage, etc.) inside the boxes,
- switch the power on and off, individually, to the feeding lines both under ordinary and fault conditions,
- reveal the electric fault and remotely control the breakers in order to continue feeding the JB interested by the fault.

The communication among the field control levels will be realized using electrical wires (there aren't optical fibers available), while, the communication between field control systems and shore will be realized with optical fibres.

Summary and outlook

- **Site selection**
  - *The Capo Passero site close to the coast of Sicily has been deeply studied*
  - *The results show that it is an excellent location for the km3 telescope*
- **Feasibility study**
  - *All the critical detector components and their installation has been analysed in detail*
  - *Technologies and costs affordable by a* ***large international collaboration***
- **Present activity**
  - *Phase 1 project to realize a subset of the detector including the critical components, to be completed by the end of 2006*
- **Future plans**
  - *Construction of the km3 within a large international collaboration*