

# The Neutrino Telescope of the KM3NeT Deep-Sea Research Infrastructure



Robert Lahmann for the KM3NeT Consortium  
Erlangen Centre for Astroparticle Physics  
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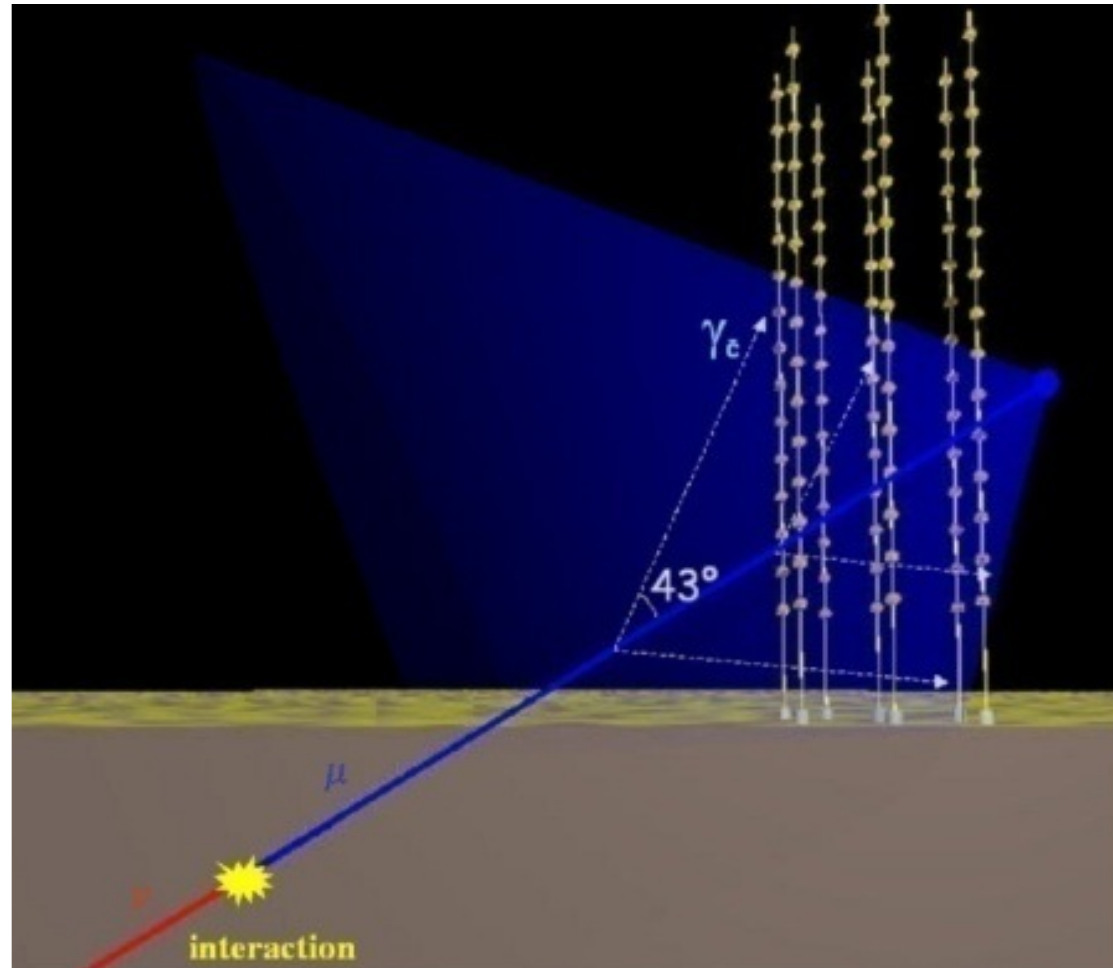
# Outline

- Objectives and Physics Case
- Technical Design and Implementation
- Optical Modules and Electronics

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# What is KM3NeT ?

- Future cubic-kilometre scale neutrino telescope in the Mediterranean Sea
- Exceeds Northern-hemisphere telescopes by factor  $\sim 100$  in sensitivity
- Exceeds IceCube sensitivity by substantial factor
- Provides node for earth and marine sciences (continuous deep-sea measurements)



# KM3NeT Organisation

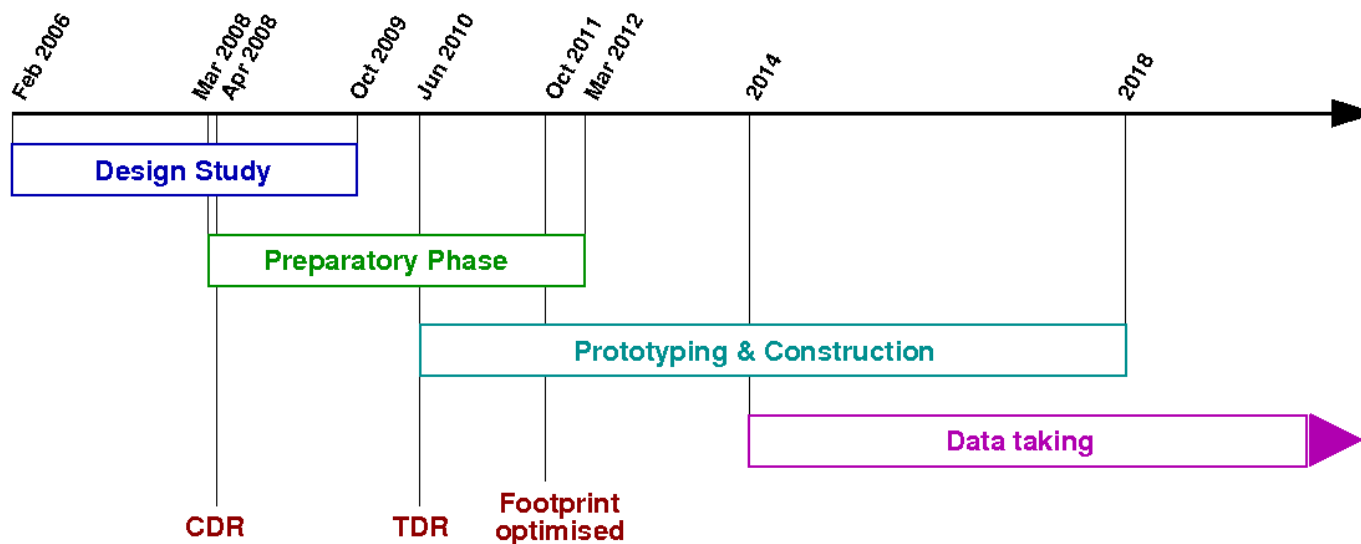
## The KM3NeT consortium:

- 40 European institutes

including those from Antares, Nemo and Nestor neutrino telescope projects

- 10 countries

(Cyprus, France, Germany, Greece, Ireland, Italy, The Netherlands, Rumania, Spain, U.K)

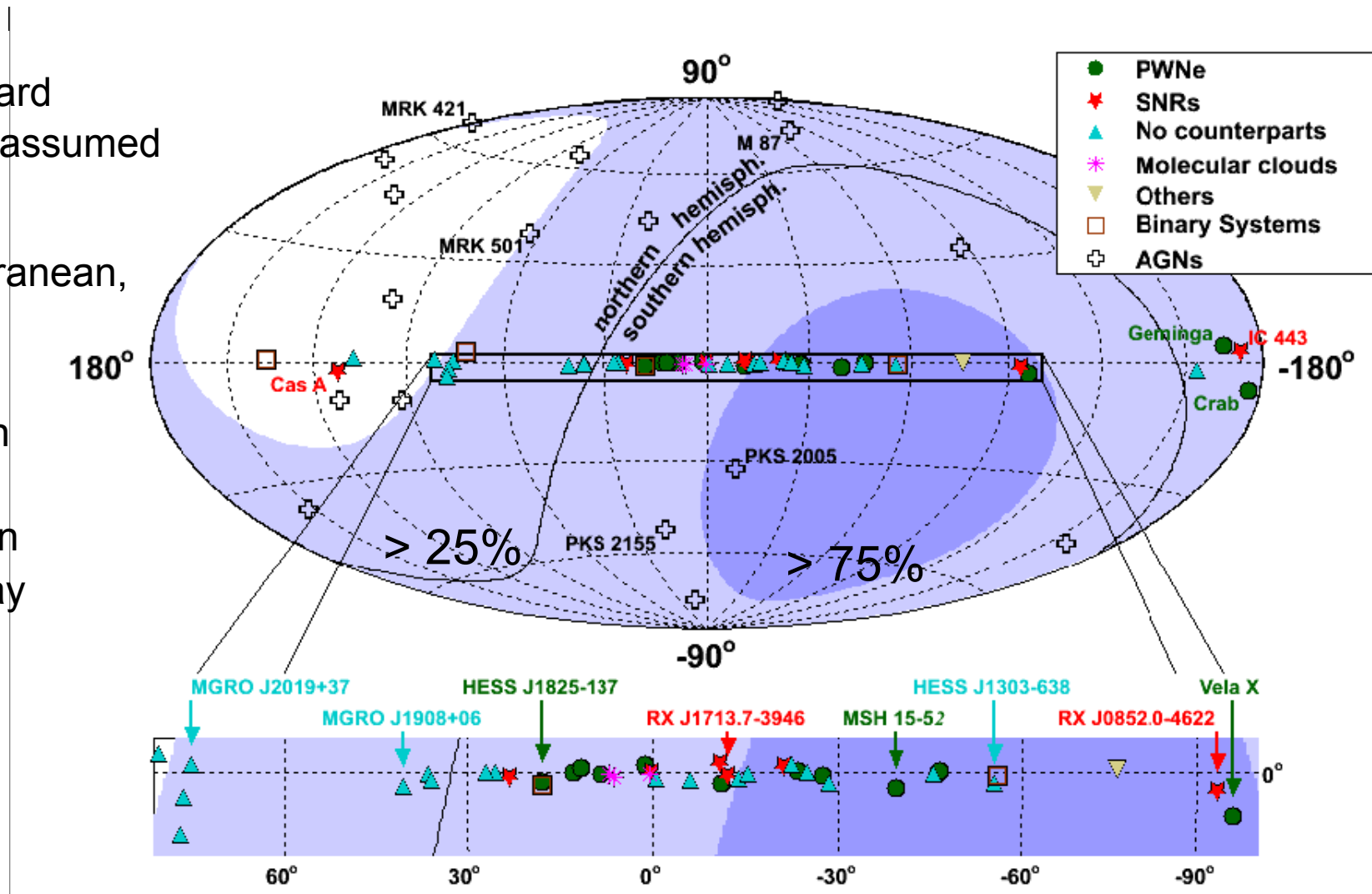


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# South Pole and Mediterranean Fields of View

$2\pi$  downward  
sensitivity assumed

In Mediterranean,  
visibility  
of given  
source can  
be limited  
to less than  
24h per day



# The Objectives

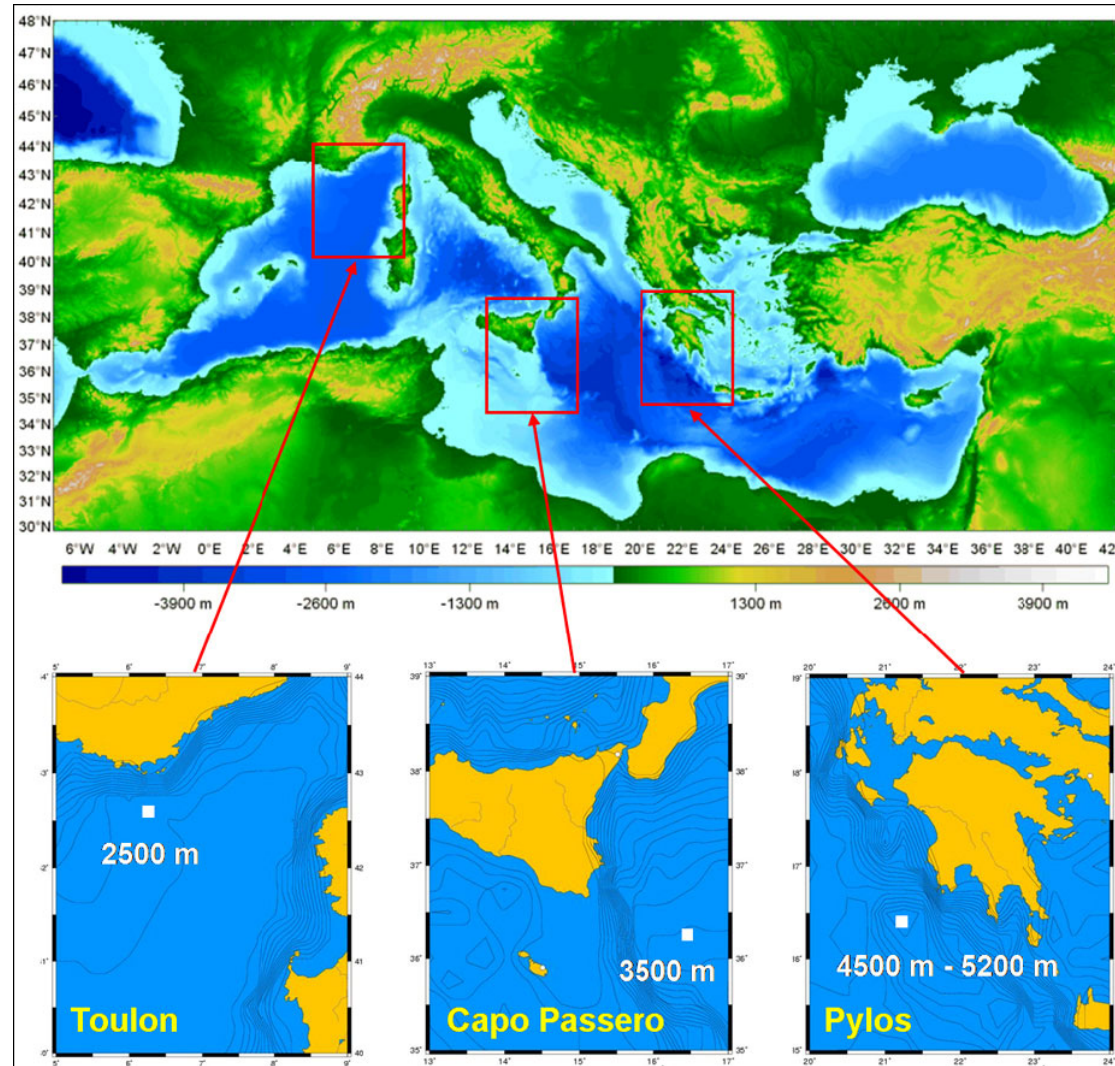
- Central physics goals:
  - Investigate neutrino “point sources” in energy regime 1-100 TeV
  - Complement IceCube field of view
  - Substantially exceed IceCube sensitivity
  - Topics not used for optimisation:
    - Dark Matter
    - Neutrino particle physics aspects
    - Exotics (Magnetic Monopoles, Lorentz invariance violation, ...)
- Implementation requirements:
  - Construction time  $\leq 5$  years
  - Operation over at least 10 years without “major maintenance”

- Objectives and Physics Case
- **Technical Design and Implementation**
- Optical Modules and Electronics



# KM3NeT in the Mediterranean Sea

- Long-term site characterisation measurements performed during the Design Study at three different locations:  
Toulon (ANTARES),  
Capo Passero (NEMO)  
Pylos area (NESTOR)
- Infrastructure of networked KM3NeT nodes foreseen



# Technical Design

Objective: Support 3D-array of photodetectors and connect them to shore (data, power, slow control)

- – Optical Modules
- – Front-end electronics
- – Readout, data acquisition, data transport
- – Mechanical structures, backbone cable
- – General deployment strategy
- – Sea-bed network: cables, junction boxes
- – Calibration devices
- Shore infrastructure
- Assembly, transport, logistics
- Risk analysis and quality control

Unique or  
preferred  
solutions

Design rationale:

Cost-effective  
Reliable  
Producible  
Easy to deploy

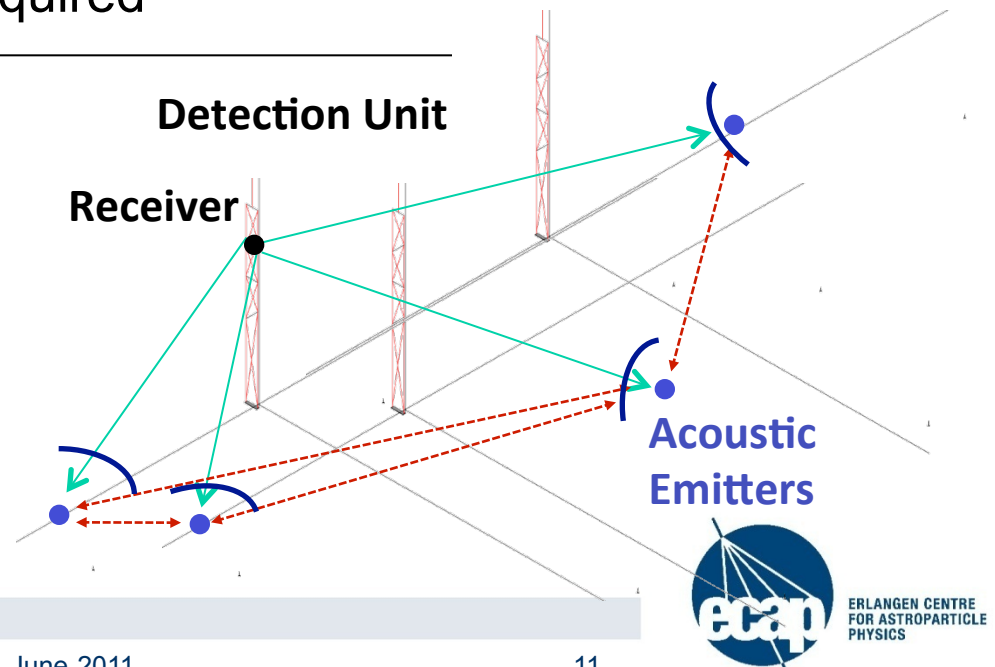
# The Deep Sea environment

One of the most adverse places for a technical installation:

- High pressure (~200bar at 2km)
- Salt water: highly corrosive environment
- Long distance from shore for communication
- Forces on structure due to sea currents
- Wet-mateable connectors required

Acoustic position calibration:

Optical calibration:  
See poster #13 by U. Emanuele

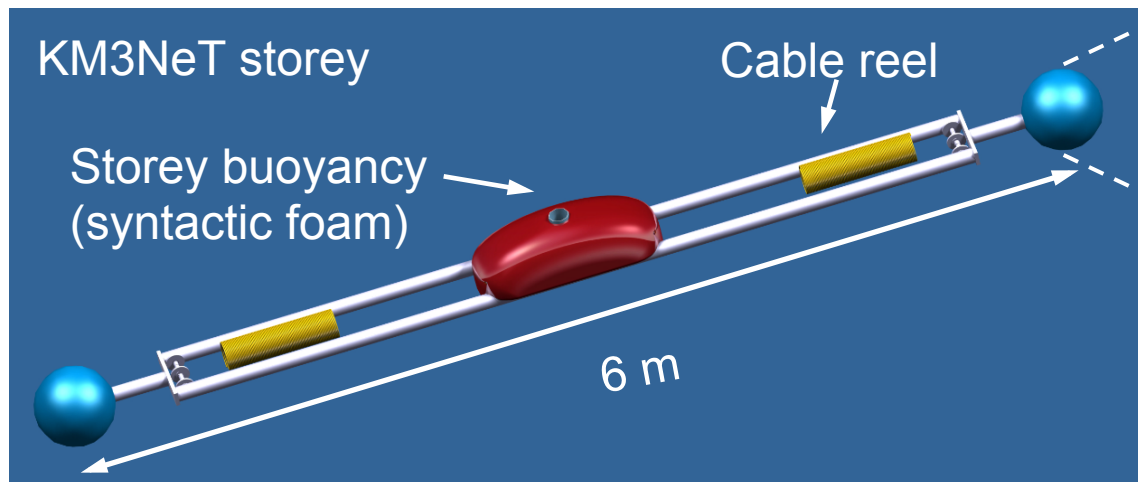


# KM3Net Detection Unit

Detection unit (DU): 20 storeys / 40 m distance (DU height  $\sim 900$  m)

storey: bar of 6 m with 2 DOMs

DOM: digital optical module with 31  $3''$  PMT



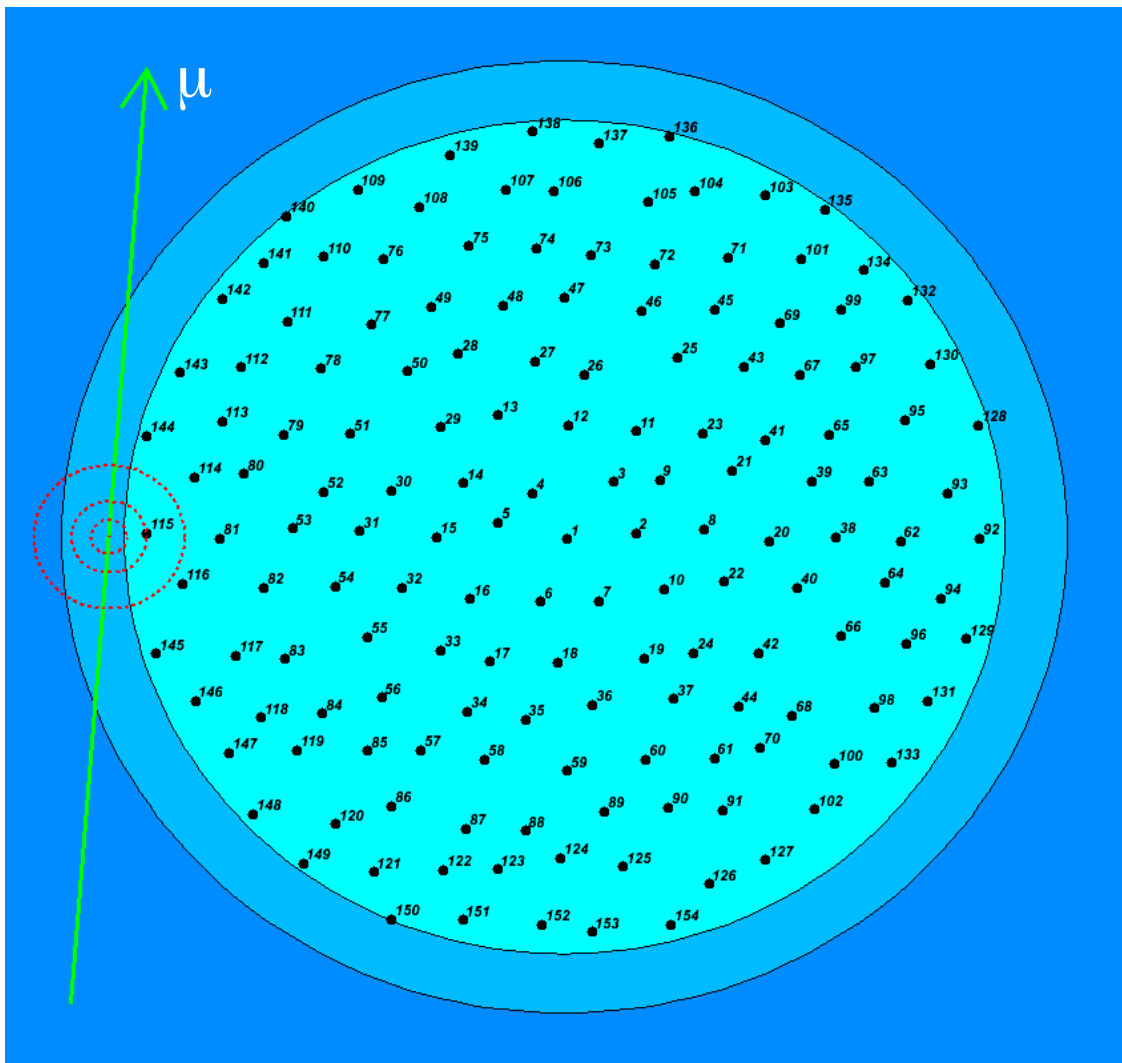
KM3Net DOM

KM3Net “Building Block” configuration

| DU  | St/DU | DOM/St. | PMT/DOM | PMT     |
|-----|-------|---------|---------|---------|
| 154 | 20    | 2       | 31      | 190 960 |

KM3Net DU

# Detector Geometry



Building Block:  
Currently considered option:  
Randomised hexagonal grid

$$\text{Surface area} = \pi R^2 = 4.2 \text{ km}^2$$

$$R = 1160 \text{ m}$$

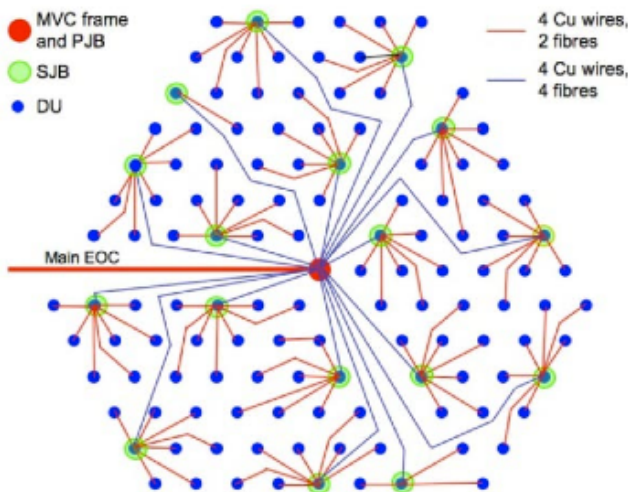
$$\begin{aligned} \text{Instrumented volume} &= \pi R^2 h \\ h &= 760 \text{ m (19x40)} \\ V_{\text{inst}} &\approx 3 \text{ km}^3 \end{aligned}$$

2 Building Blocks will make  
up KM3NeT

Budget ~220 M€

# Data Network and Data Transmission

- All data to shore concept (no trigger undersea)
- Data transport on optical fibers (data, slow control)
  - Optical point-to-point connection DOM-shore  $\Rightarrow$  large number of channels
  - DWDM (Dense Wavelength Division Multiplexing) technique: signals carried by different frequencies (colors) over the same fibre  $\Rightarrow$  minimize number of fibers



EOC = electro-optical cable  
MVC = main voltage converter  
PJB = primary junction box  
SJB = secondary junction box

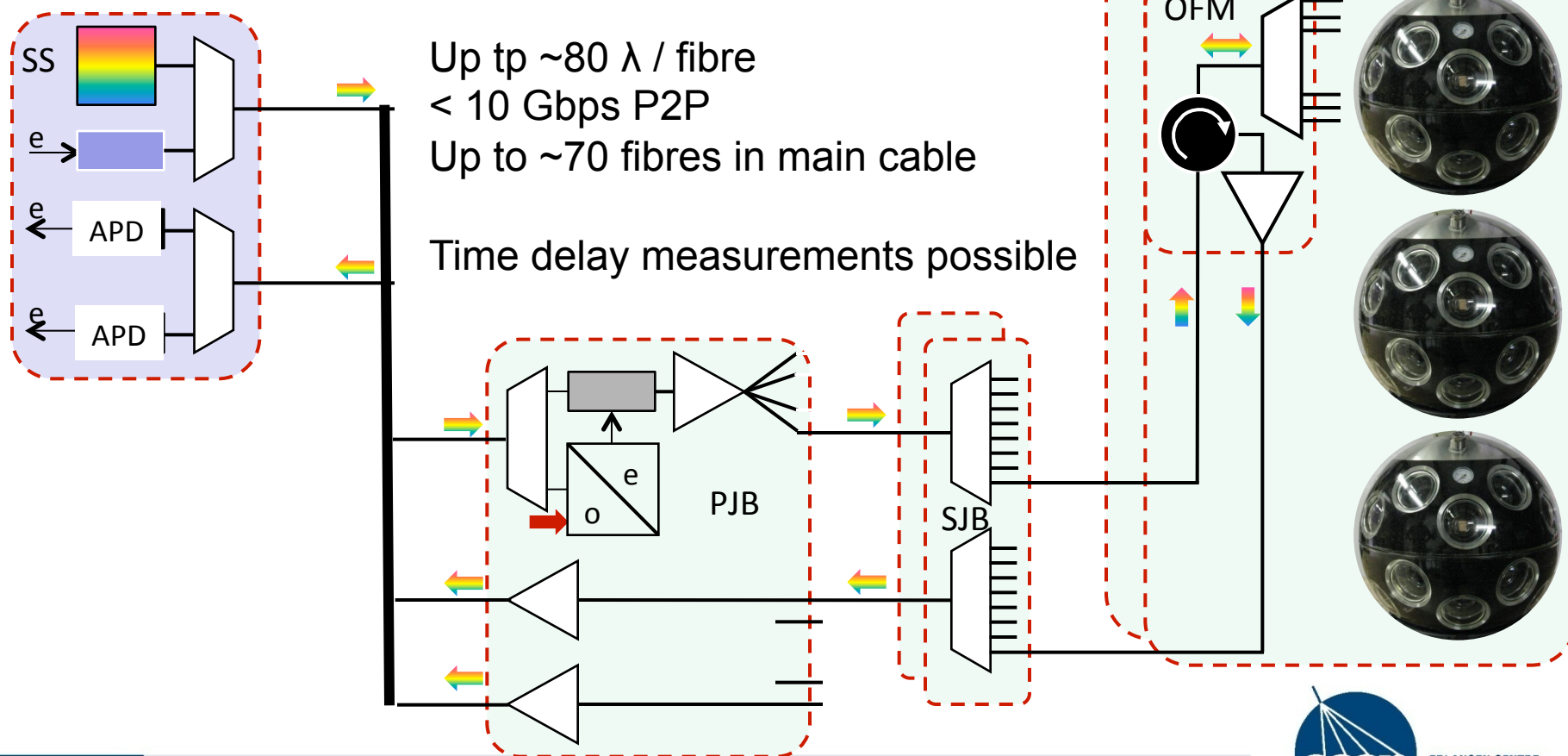
Alternative option:  
Ring geometry

Star geometry of power and fibre distribution



# Optical Network

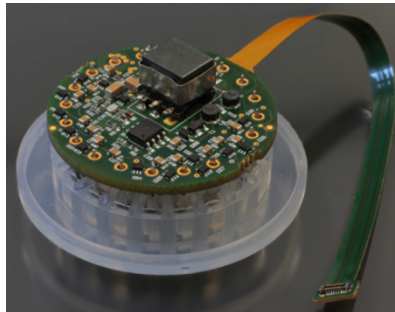
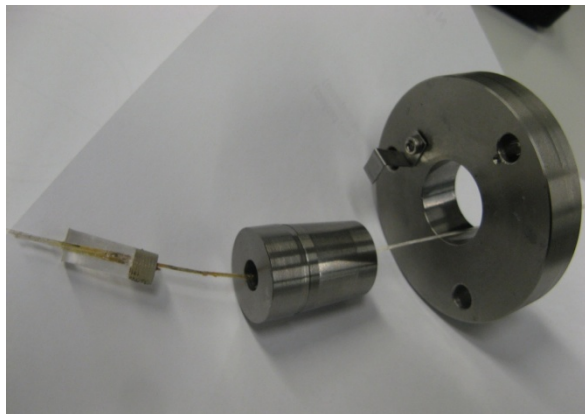
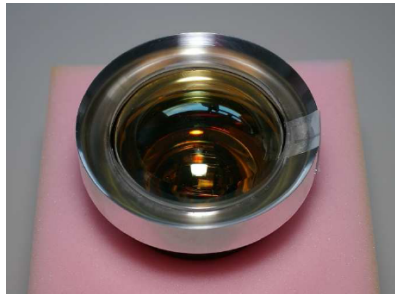
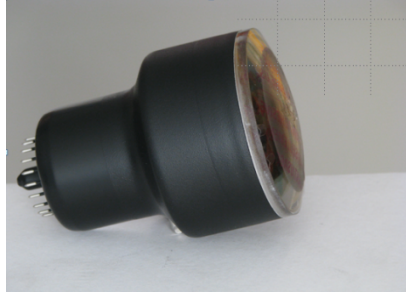
Dense Wavelength Division Multiplexing:  
Following ITU Grid Specification:  
C (1530-1570 nm) or L band (1570-1610 nm)  
with 25GHz separation



- Objectives and Physics Case
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# DOM (Digital Optical Module)



## Multi-PMT Design:

- Large photocathode area per OM
- Single vs. multi-photon hit separation

- Sphere  $\varnothing 17''$
- PMTs (19+12)  $\varnothing 3''$
- Base
  - Adjust. HV (800-1400V)
  - Comparator for time-over-threshold
- Power board, electronics
- Calibration devices
- Single penetrator

# Photo Multiplier Tubes

Requirements:

Quantum efficiency (QE) at 404nm

Transit time spread (TTS)

Gain

>32% (>20% @ 470nm)

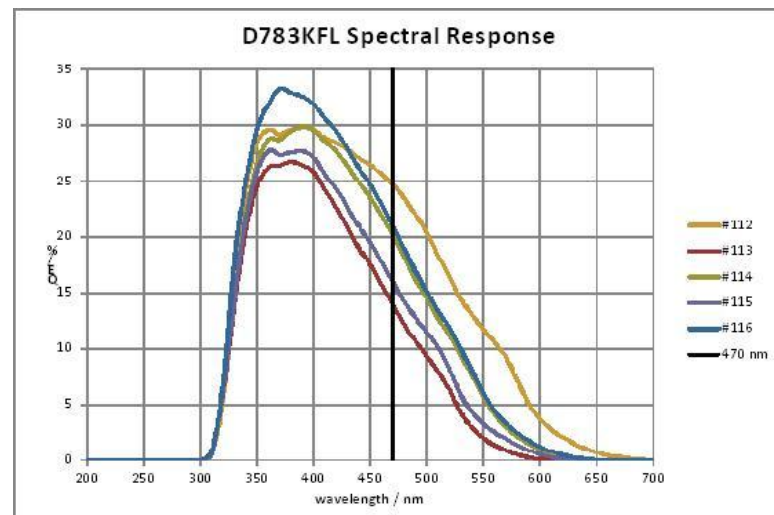
<2ns (sigma)

$5 \times 10^6$

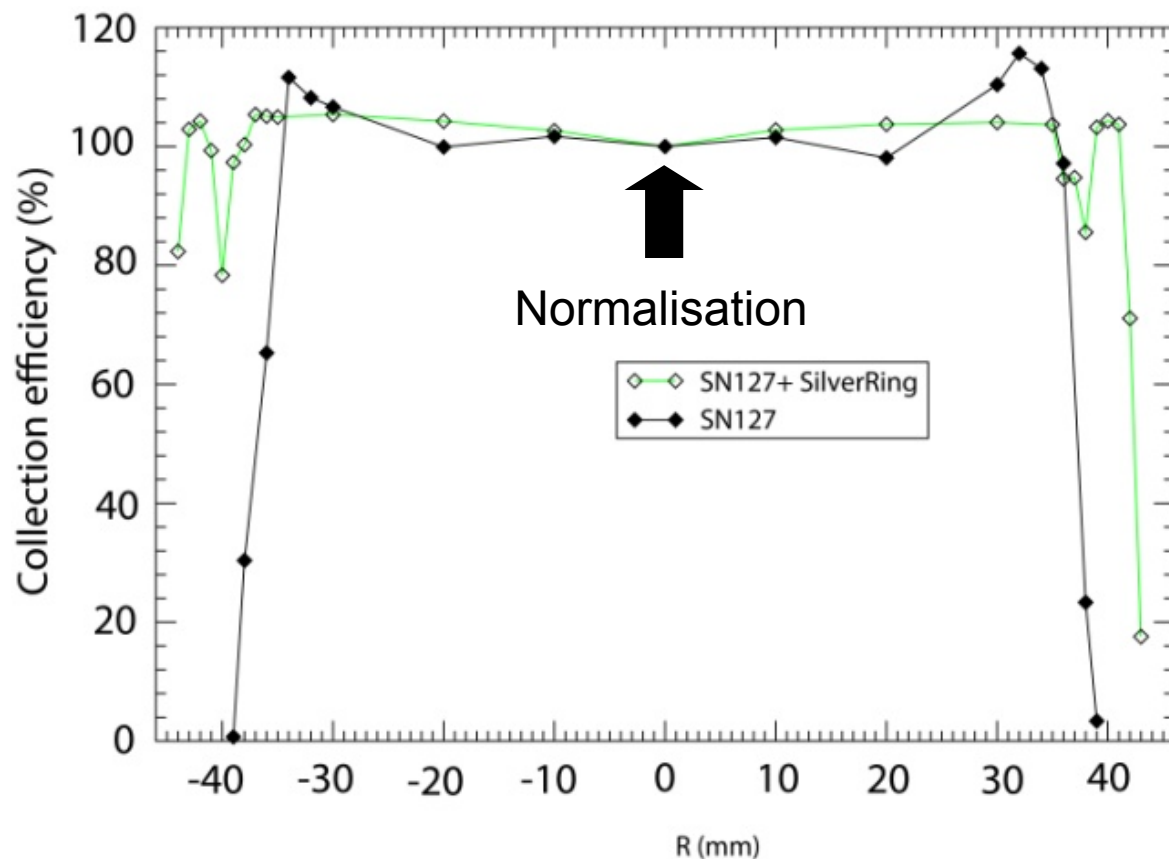
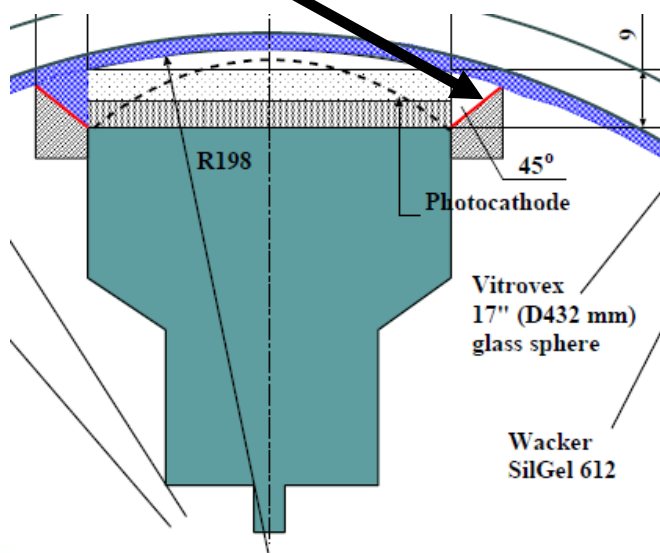
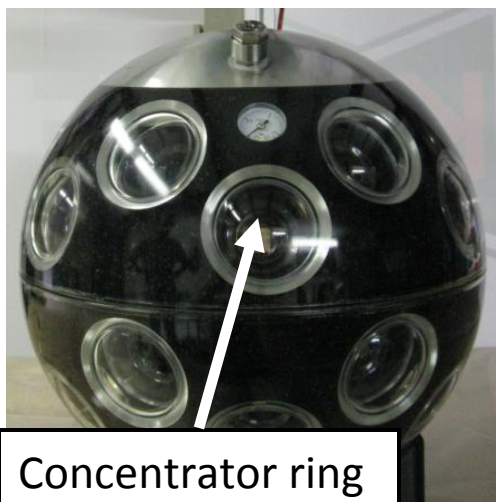
Requirements adapted to in-situ conditions:

- Cherenkov photon spectrum in Mediterranean Sea most intense between ~400nm and ~500nm
- Chromatic dispersion sets lower level of required TTS

Prototype tubes from company ETEL:



# DOMs: Recent Technical Progress

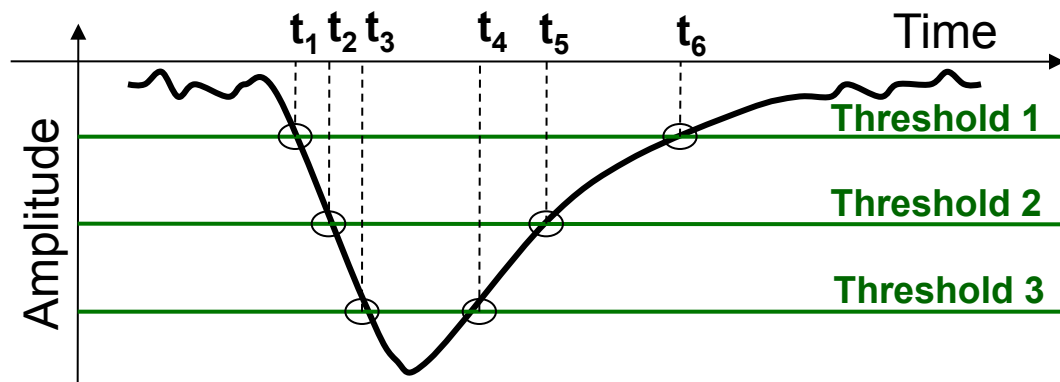


Increases effective photocathode area by 20-40%

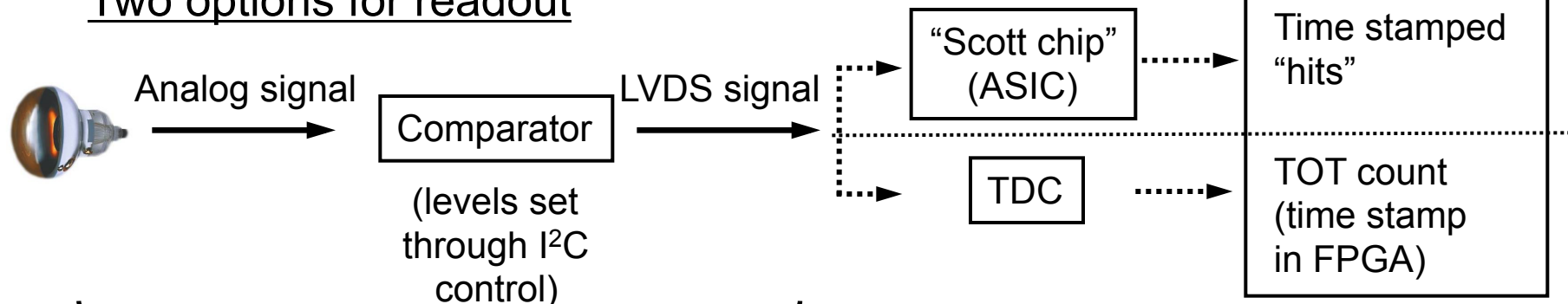
Ring simplifies PMT fixture

# Front End Electronics

Time-over-threshold (TOT):



Two options for readout



Timing resolution of ~1ns required

31x

Scott = Sampler of Comparator Outputs with Time Tagging  
TDC = Time to Digital Converter

# Summary and Conclusions

- Major technical design decisions taken, minor points optimised for mass production
- In-situ operation of prototype Detection Unit planned for first half of 2012
- Footprint being optimised for detection of Galactic sources
- Infrastructure of networked KM3NeT nodes most likely scenario
- Data taking could start 2014

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