



# "Rocket" science in the deep sea

"I spy with my 'little' eye what nobody can see!"

*Marck Smit & Roel Bakker (NIOZ)*

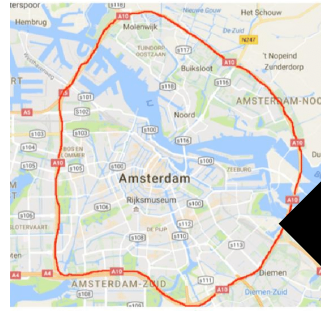
*&*

*Jan Visser (Nikhef) – slides courtesy of Rasa Muller*

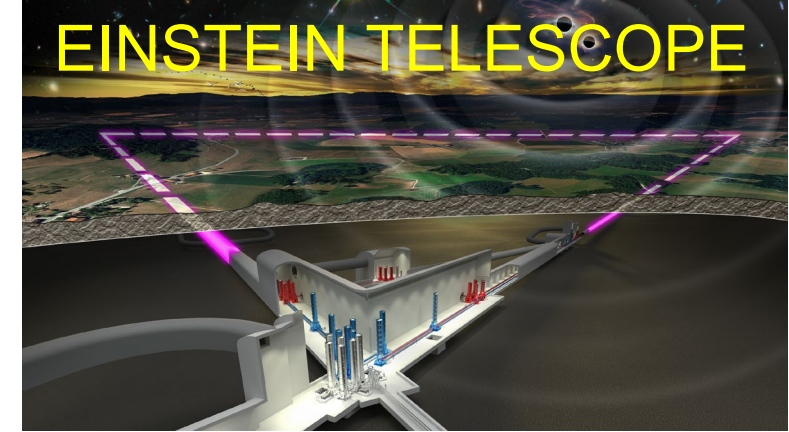
# CERN



# NIKHEF AT A GLANCE

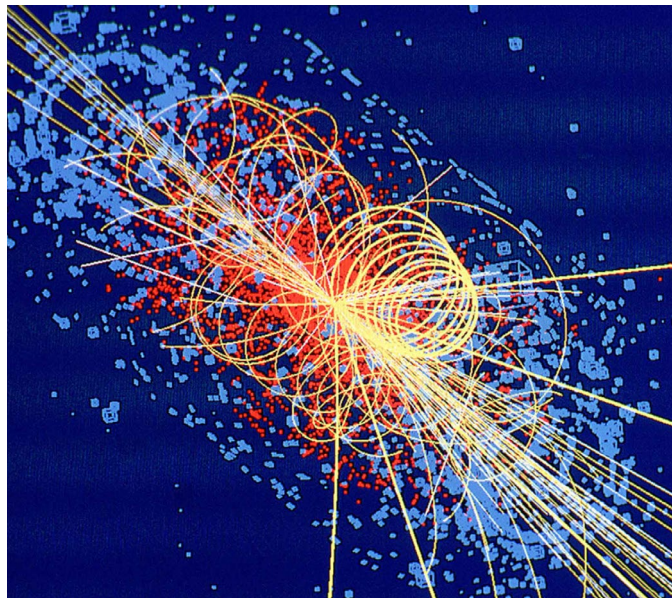
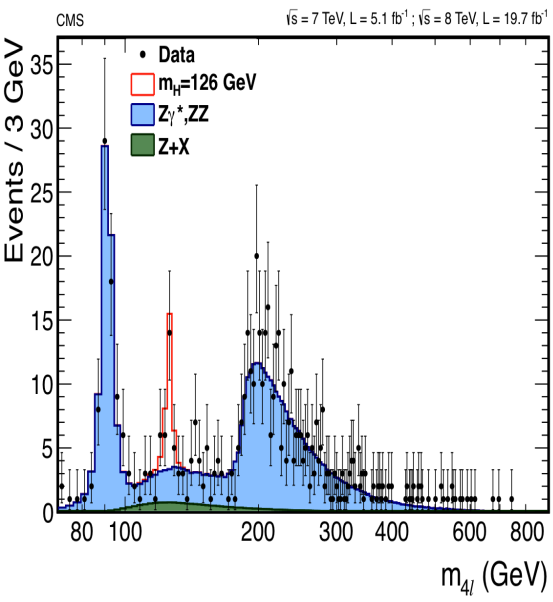


# EINSTEIN TELESCOPE

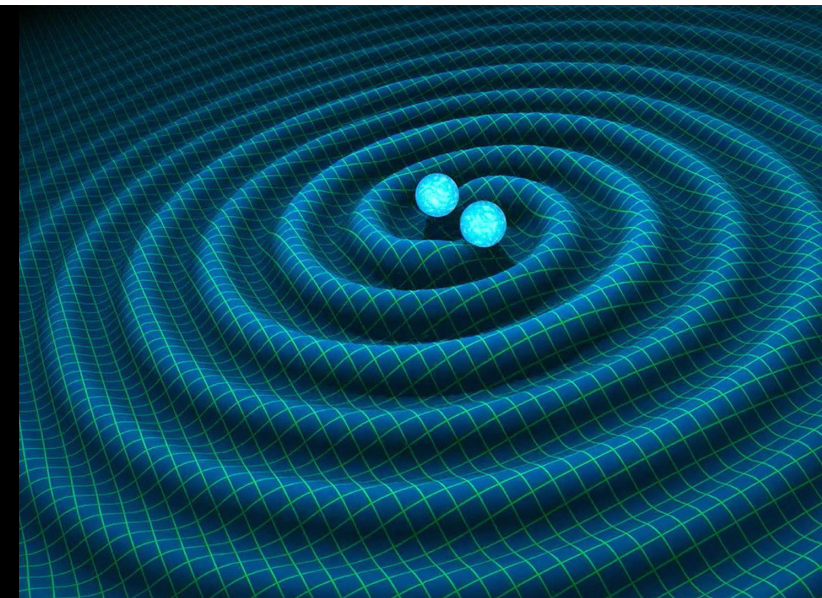
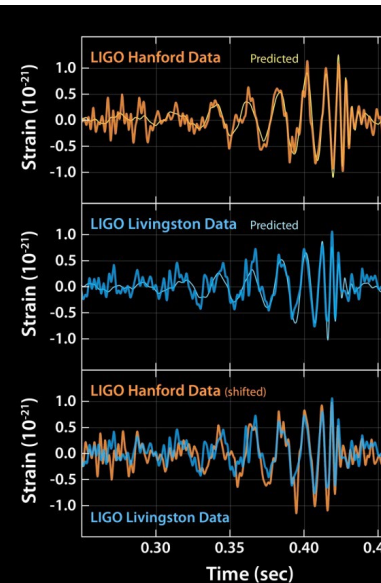


- Institute in Amsterdam & partnership with six universities
- Founded in 1946 and grown to nearly 400 staff

## Discovery of the Higgs boson (2012)

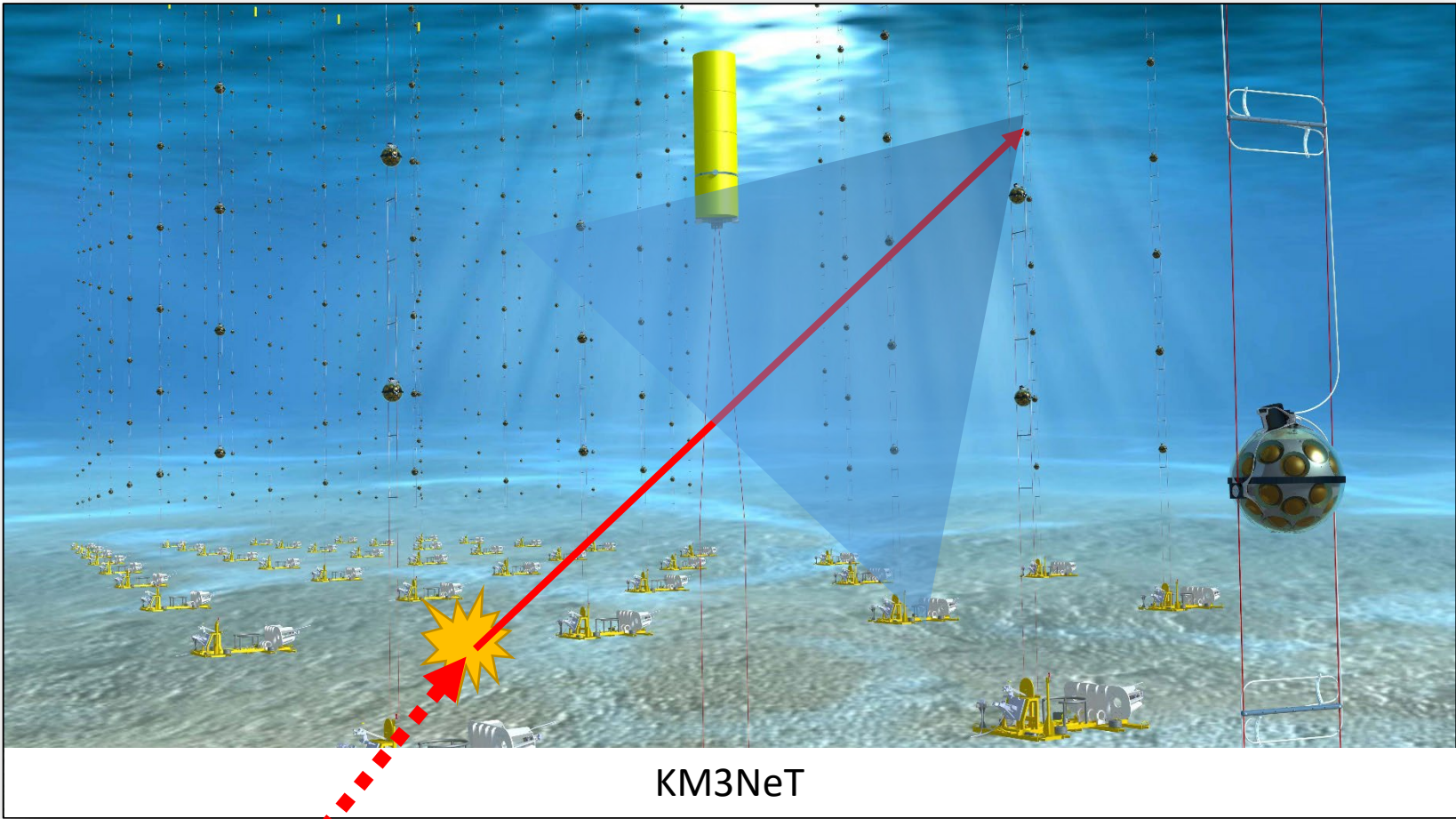


## Discovery of gravitational waves (2015)



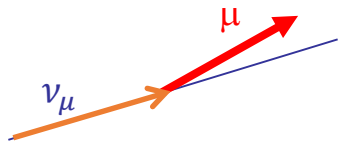


# KM3NeT - concept

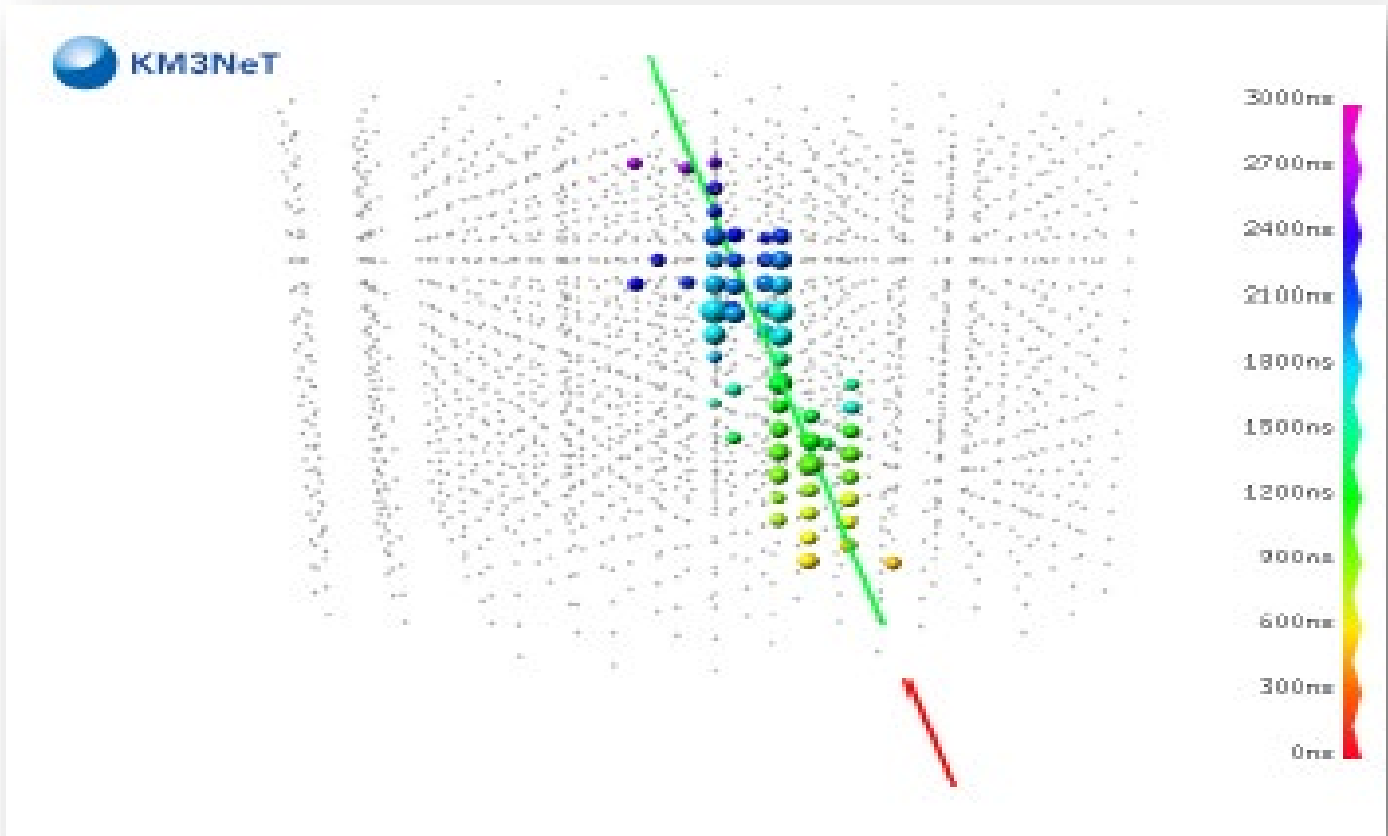


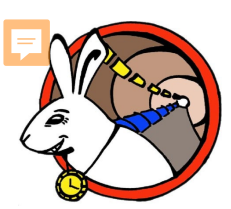


# Angular resolution



Angular resolution is better than  $0.1^\circ$  for neutrino energies above 20 TeV





# White Rabbit: an extension of Ethernet

- Two separate tasks

## 1. Synchronisation: Fundamental for track reconstruction

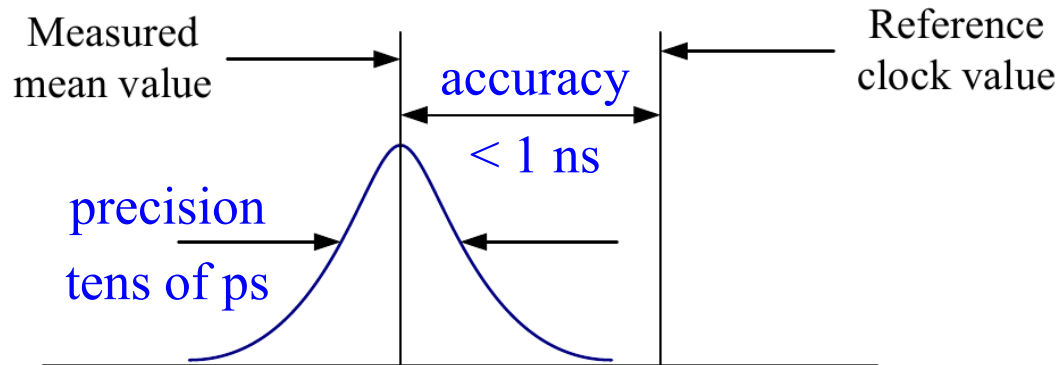
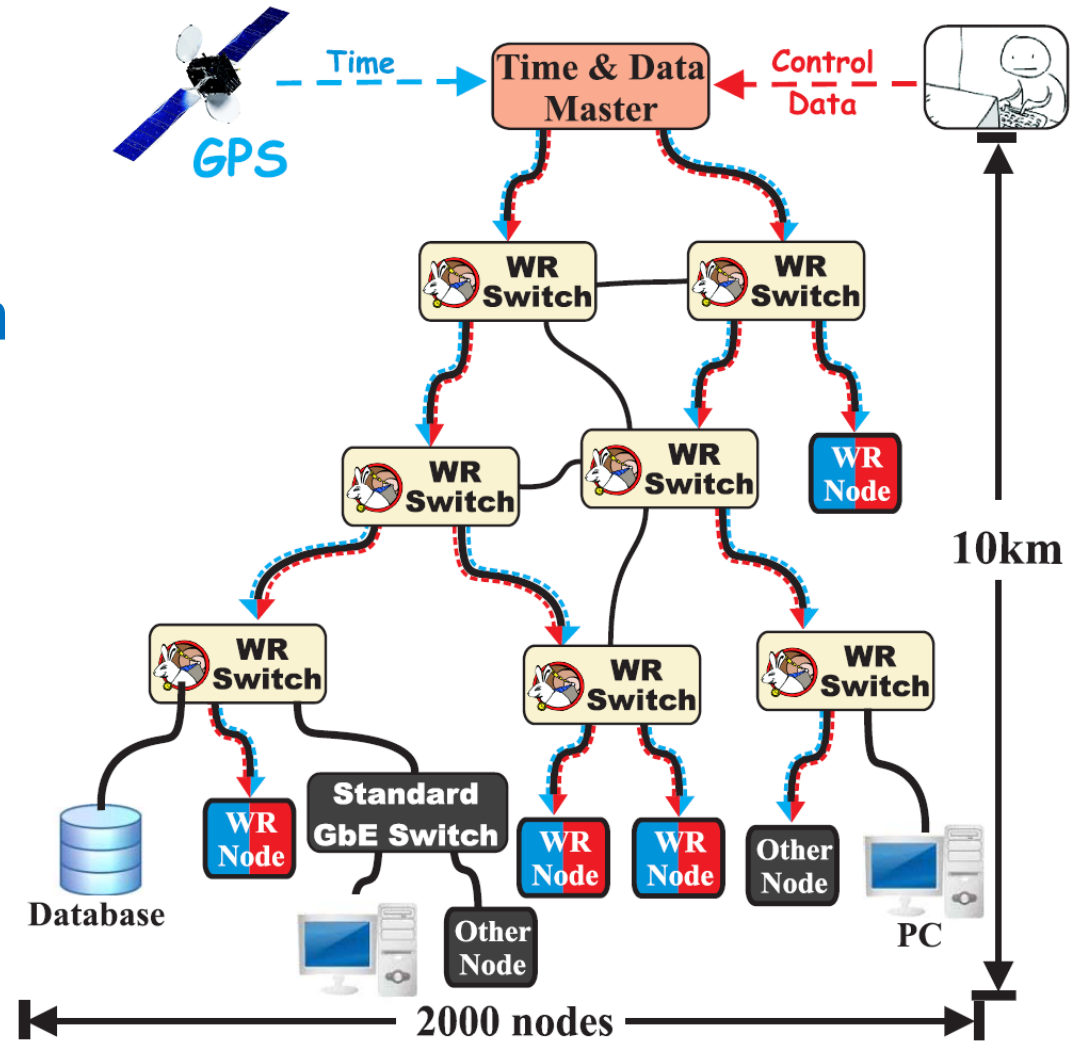


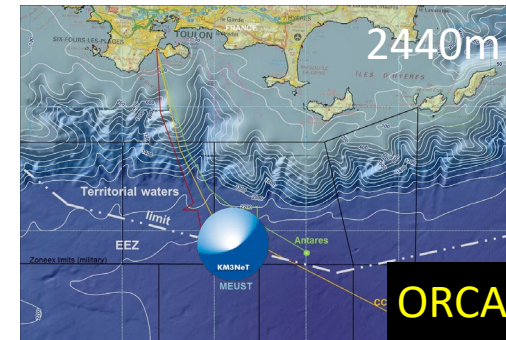
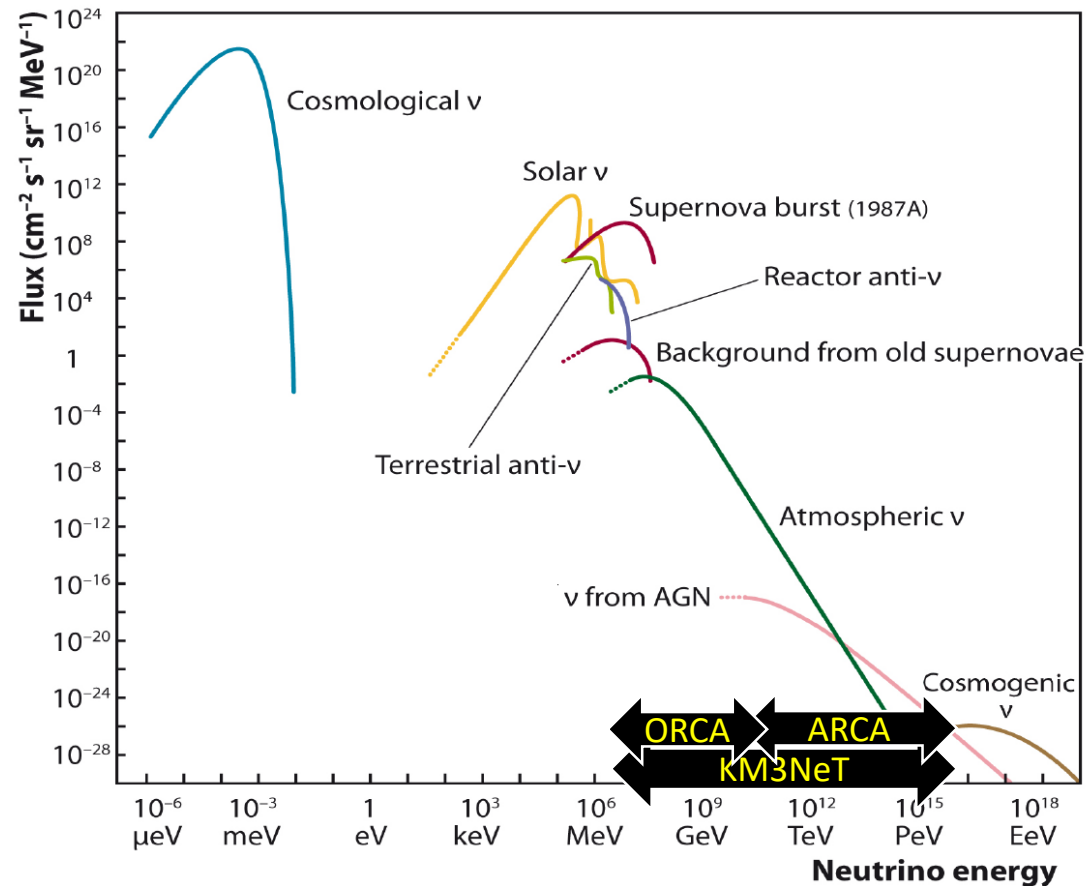
Figure 1—Histogram of an ensemble of measurements<sup>[1]</sup>

## 2. Deterministic, reliable and low-latency Control Data delivery



[1] <https://standards.ieee.org/ieee/1588/6825/>

# Energy ranges



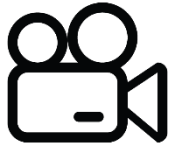
**KM3NeT/ORCA**  
Oscillation Research  
with Cosmics In the Abyss



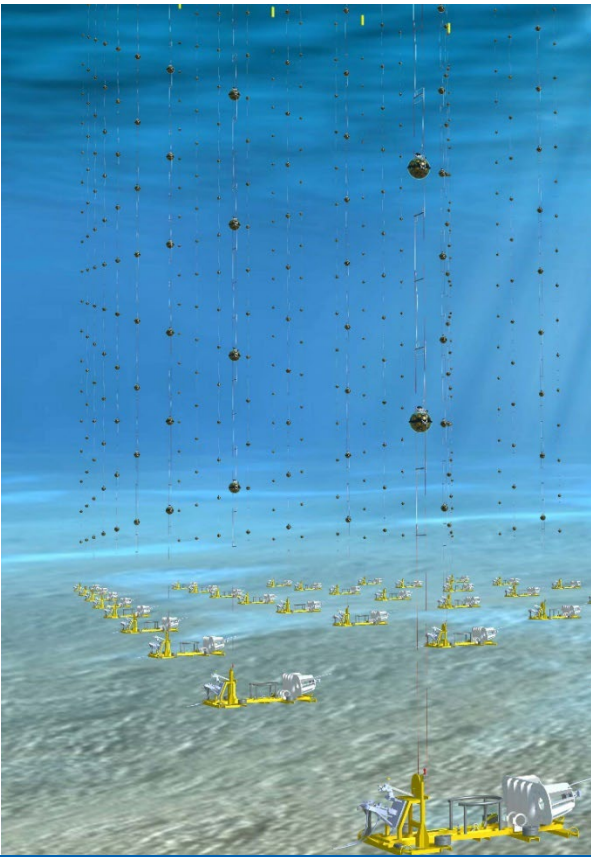
**KM3NeT/ARCA**  
Astroparticle Research  
with Cosmics In the Abyss



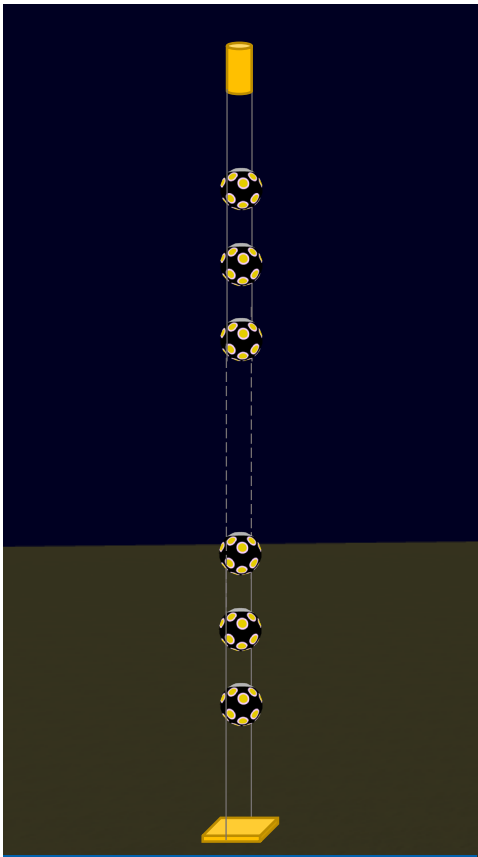
# Detector design



[Video of the production at Nikhef](#)



1 building block =  
115 lines



1 line =  
18 optical modules



1 optical module =  
31 photomultiplier tubes



71 unique components  
(in solid or liquid phase)



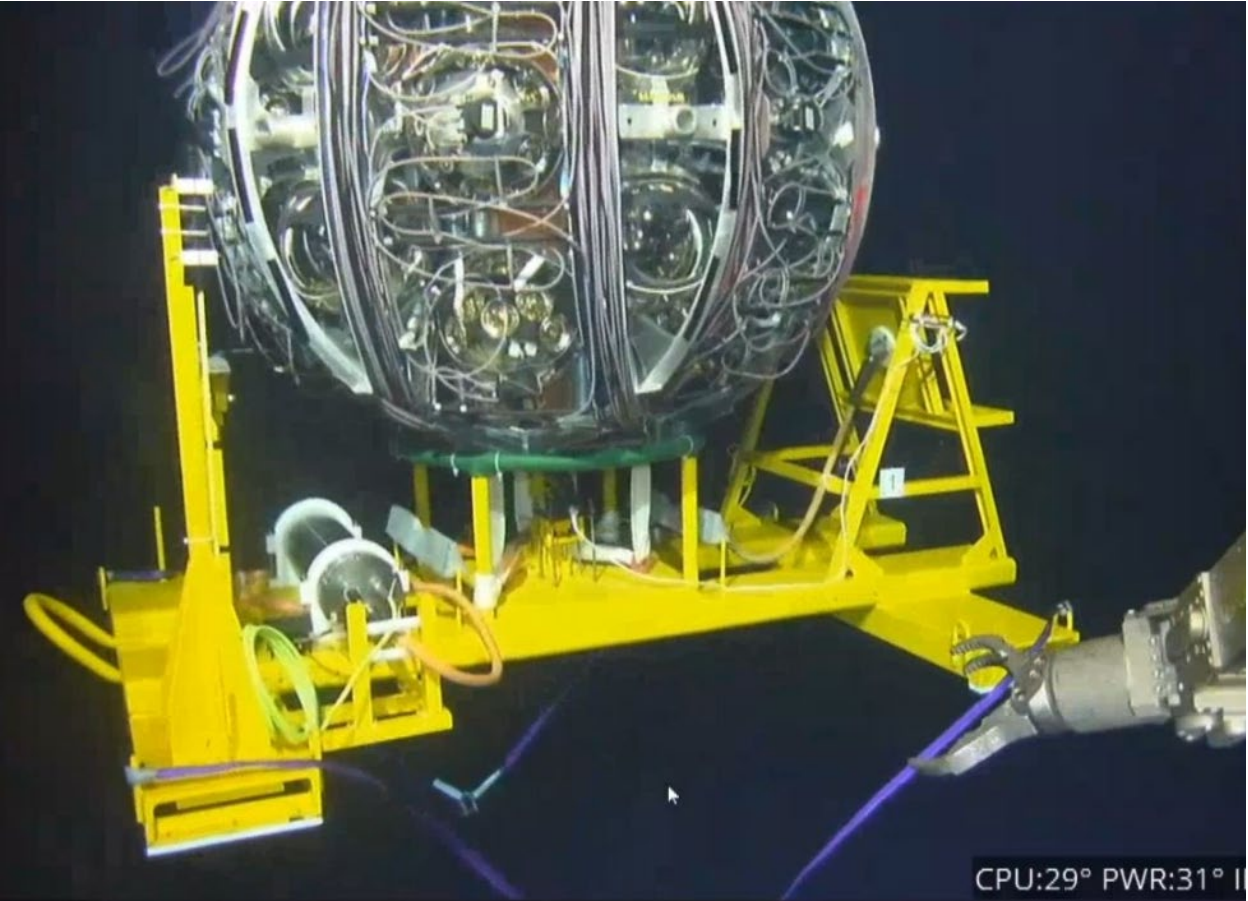
# Deployment of new lines





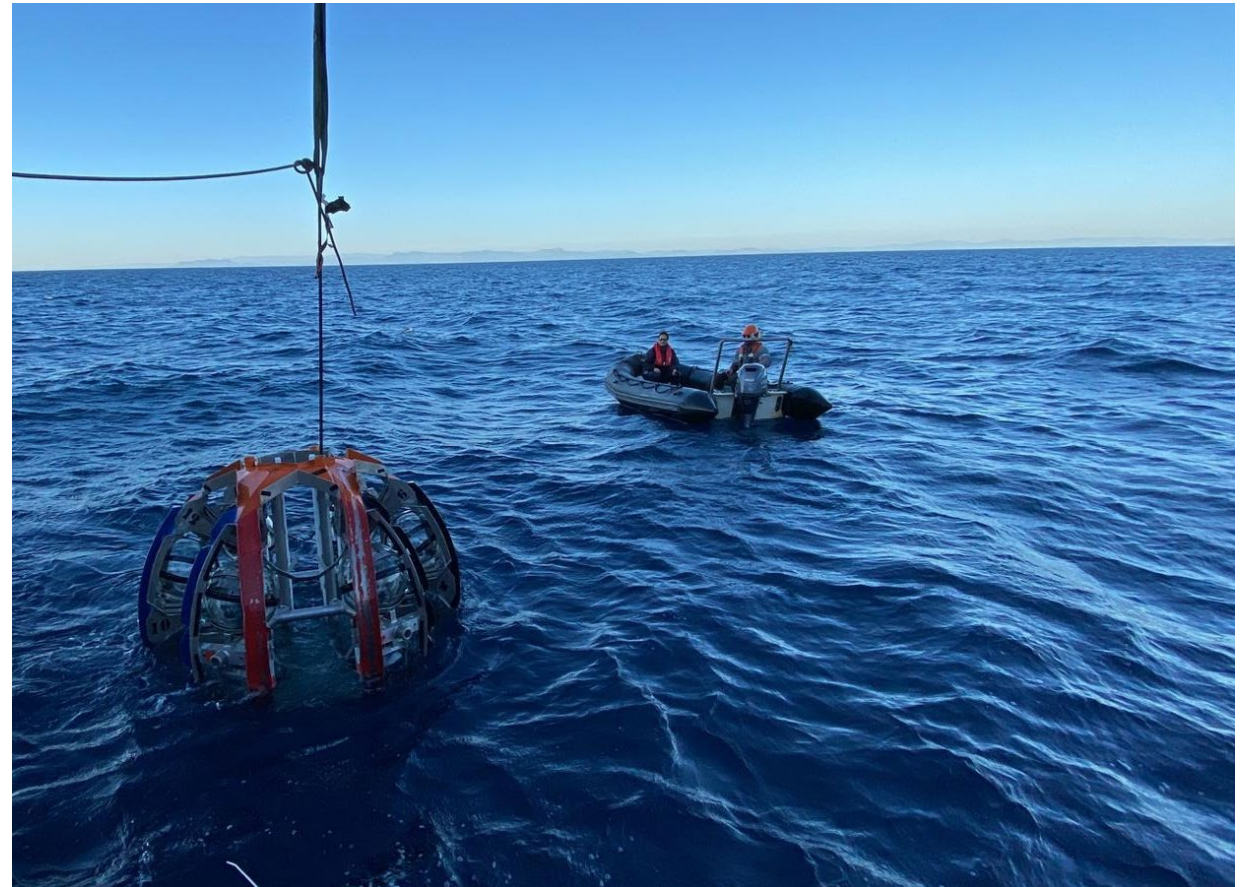


# Deployment of new lines





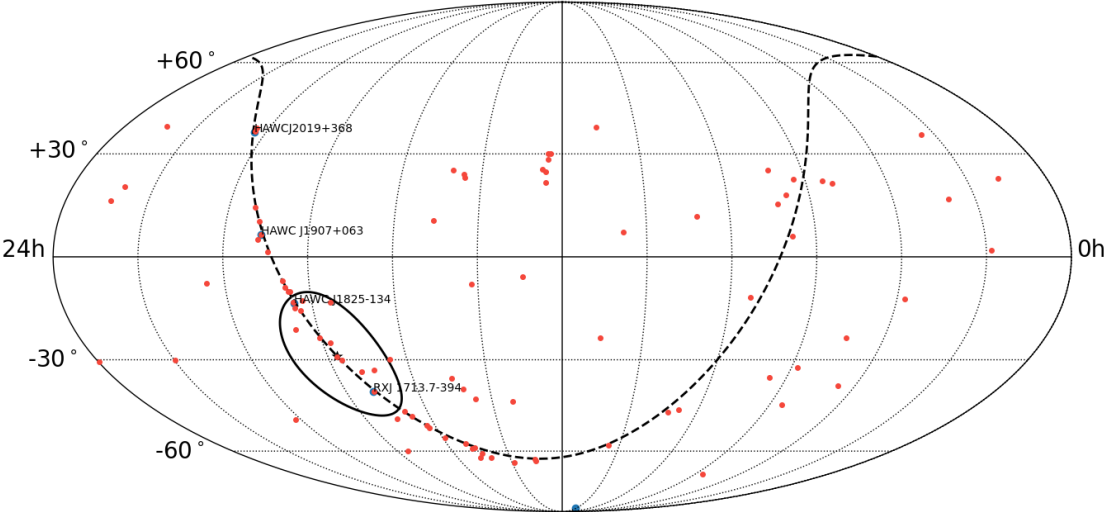
# Deployment of new lines



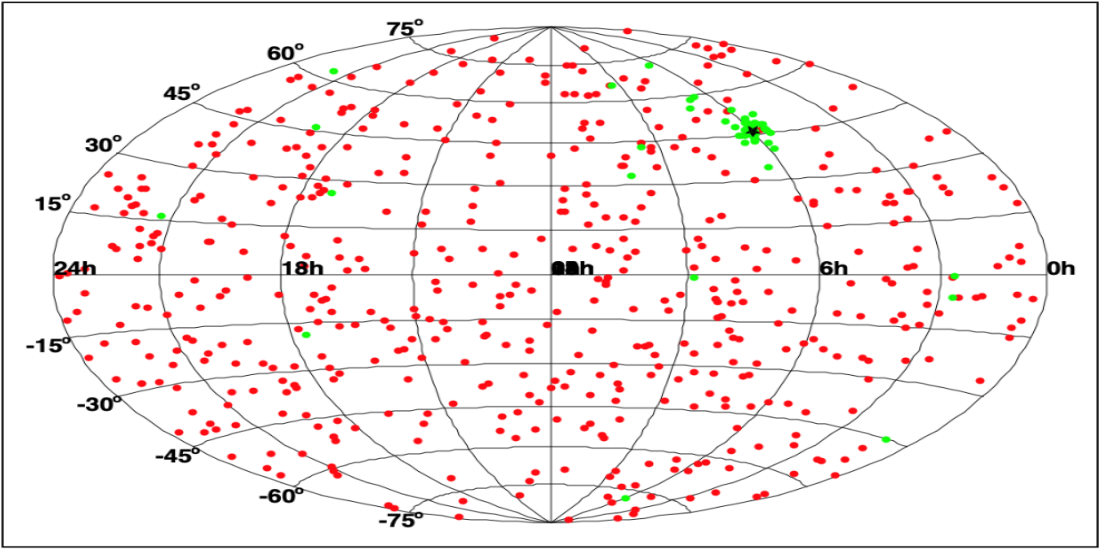


# Sources under observation

Selected sources under observation



Simulation example of background distribution (red) and possible signal clusters (green)





Sea Research



KM3NeT



"Rocket" science in the deep sea

"I spy with my 'little' eye what nobody can see!"

part 2 ... and now something completely different!

*Marck Smit & Roel Bakker (NIOZ)*



# Rocket science in the deep sea 2

Visualizing underwater waves using  
temperature & underwater robotics



sea and oceans,  
academic,  
fundamental and  
applied research

**Roel Bakker**  
**Marck Smit**

**June 2023**



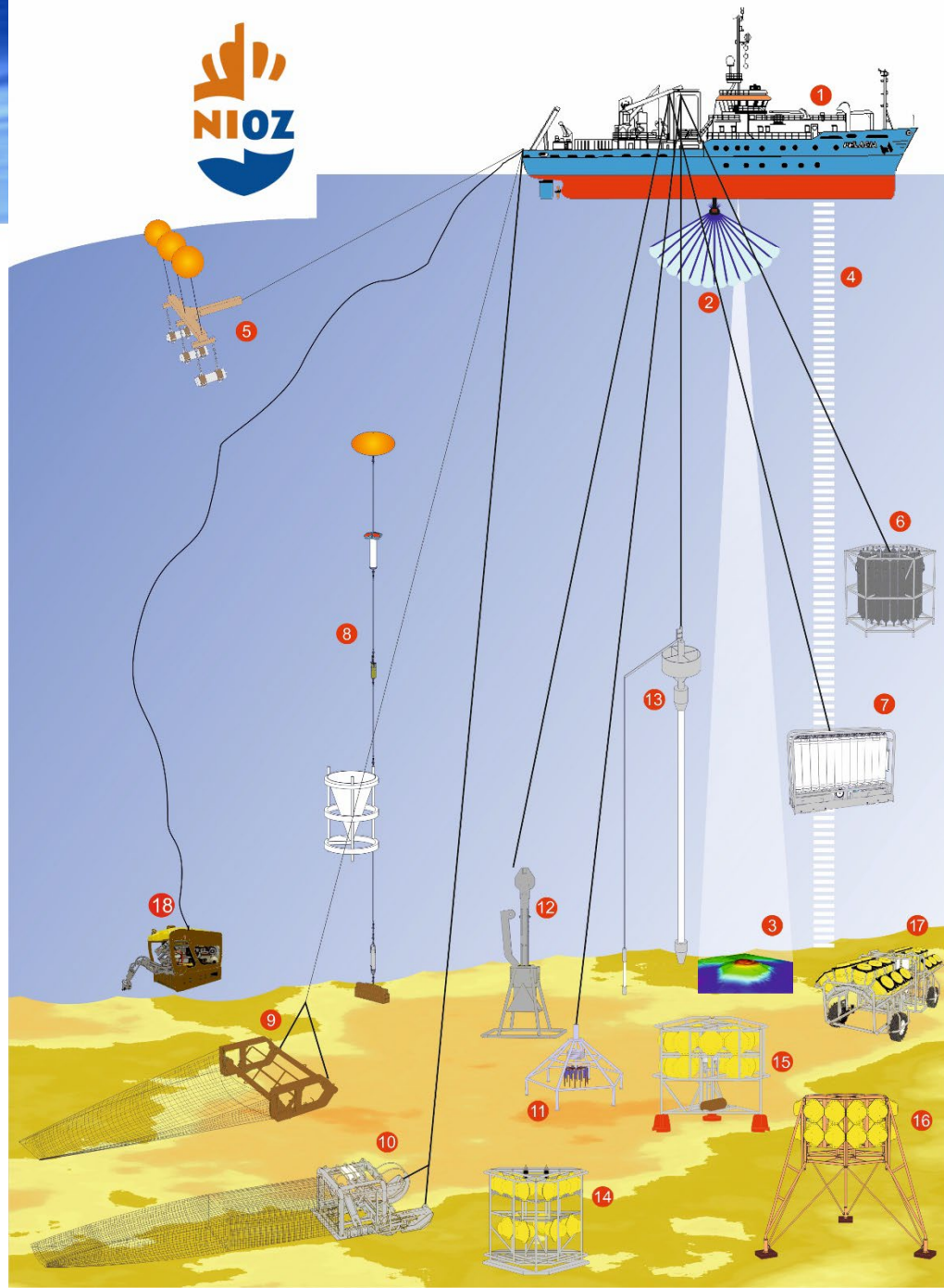
## Royal NIOZ at a glance:

- On the island of Texel and Yerseke
- Major working areas: North/Mid Atlantic, North Sea, Mediterranean, etc!
- Staff: 200 people + 200 flex
- Founded in 1876



RV Pelagia



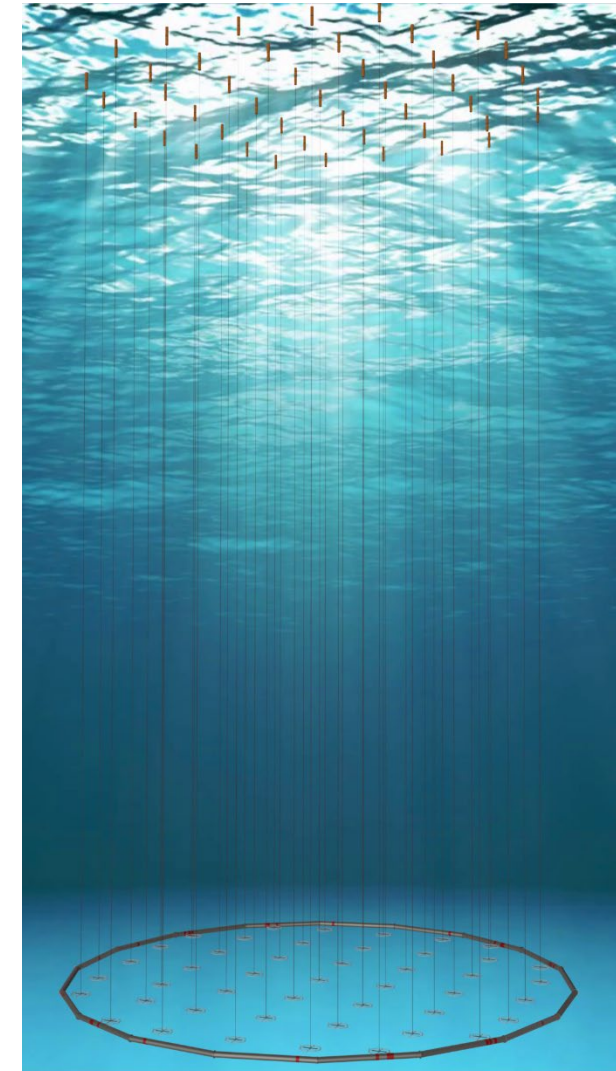
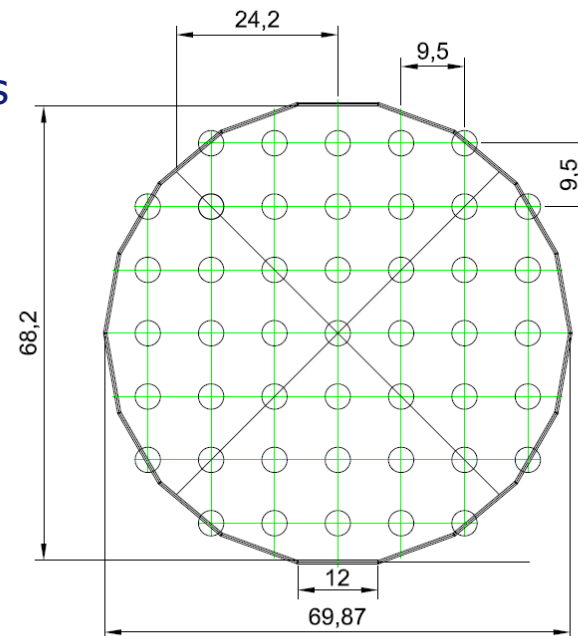


# RV Pelagia: tools & capabilities

- 1 RV Pelagia
- 2 Hipap 100 USBL acoustic direction finder
- 3 Kongsberg EM-302 Multibeam Echosounder
- 4 Bottom penetrating echosounder
- 5 Seismic Array (Sleeve Guns)
- 6 CTD Rosetta frame with water samplers
- 7 Ultra-clean-CTD Frame 'Titanium' with Pristine® water samplers
- 8 Deep Sea Mooring with ADCP, current meter and Sediment Trap
- 9 Agassiz Trawl for quantitative deep-sea bottom trawling
- 10 Deep Digging Dredge (Triple-D) for sampling benthic macrofauna
- 11 Multi-Corer for multiple small samples of surface sediments
- 12 Box Corer for large samples of surface sediments
- 13 Piston Corer for sampling long (10-20 m) sediment cores
- 14 Altrap Bottom Lander with larvae collector
- 15 Albex multi-purpose Bottom Lander for measurements and experiments at the sea floor
- 16 BoBo Bottom Lander with downward-looking ADCP current meter
17. Mobile underwater vehicle (MOVE)
18. Remotely operated vehicle (ROV)

## Key points

- Measuring internal underwater waves
- Spatial and temporal resolution
- Based on ideas of KM3Net (cubic km neutrino telescope)  
the concept of 3D-Thermistor array was born
- Sensor volume: 500,000 m<sup>3</sup>
- 45 lines, 125 m long, 9.5 m apart, 3,000 sensors
- 3 years sampling
- Water depth 2,500 m
- French Mediterranean
- Close to KM3Net neutrino detector



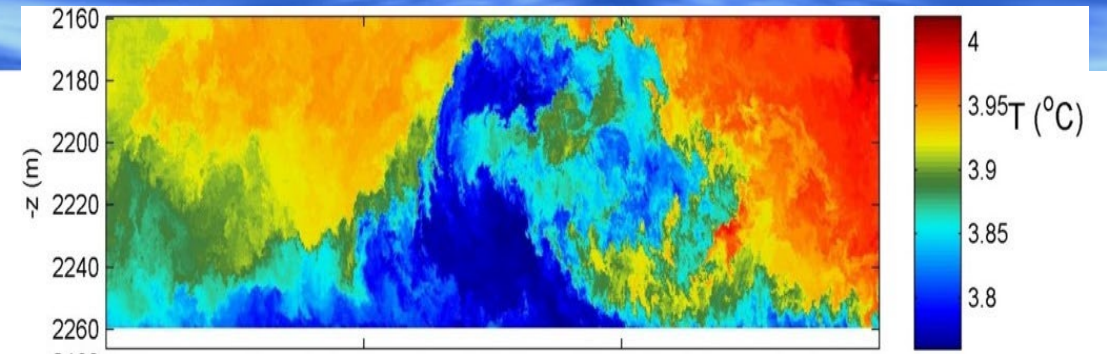
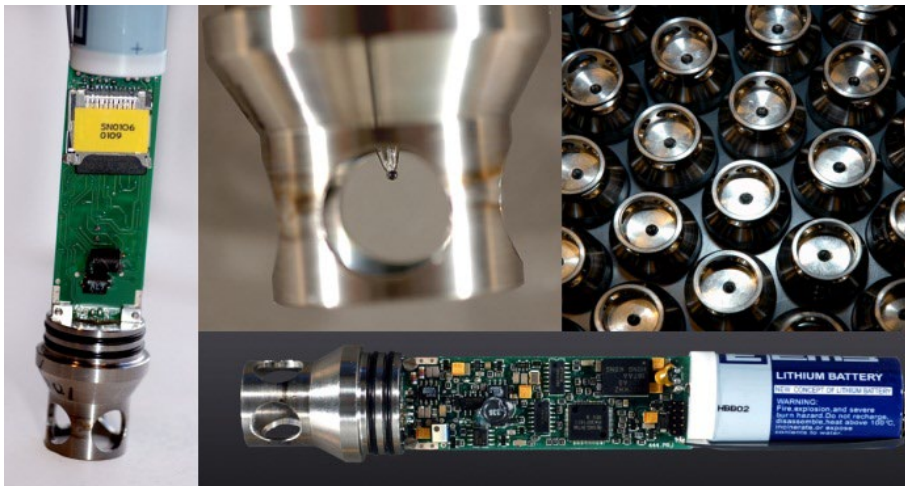




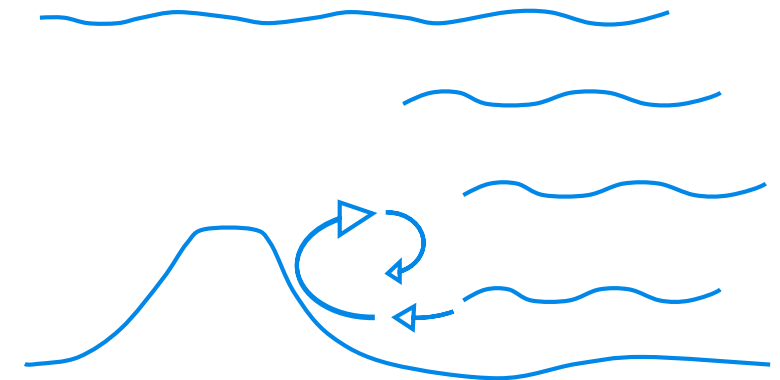
# Thermistor sensor

## High-res temp sensor

- Precision < 0.5 mK
- Response time 0.25 s (in water)
- Sensors are 'wireless':
  - any number (100 or more)
  - at any position on moorings
  - no connecting cables
- All clocks are **synchronized inductively**



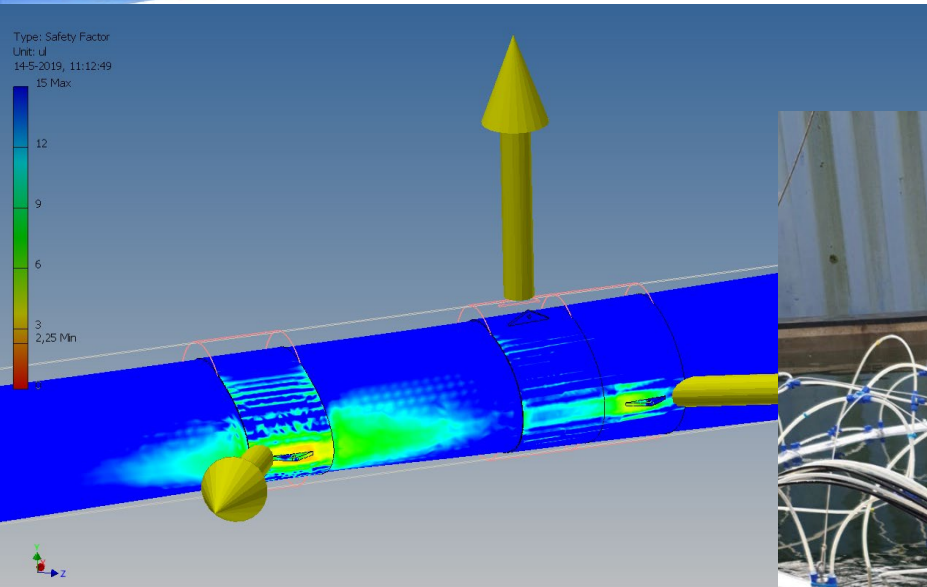
## Internal waves



- \* transport of matter → marine geology
- \* without turbulence no life → marine biology
- \* large-scale ocean stratification → marine chemistry
- \* Impact on underwater structures



# Designing, modelling, engineering, and ...testing, testing, testing



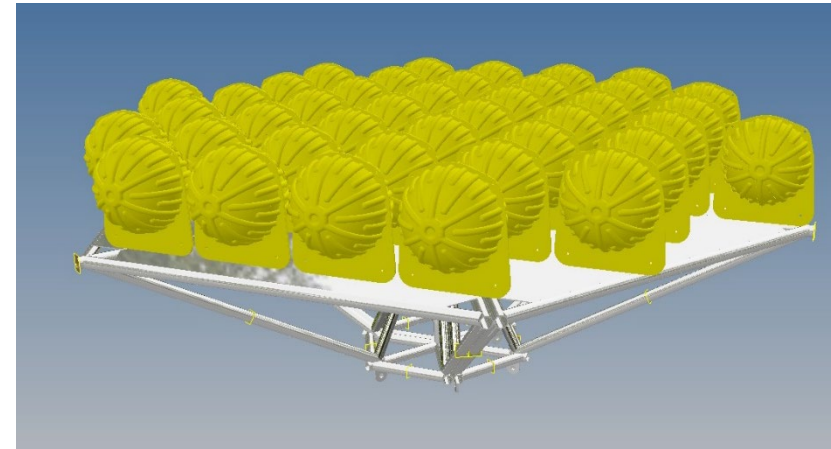
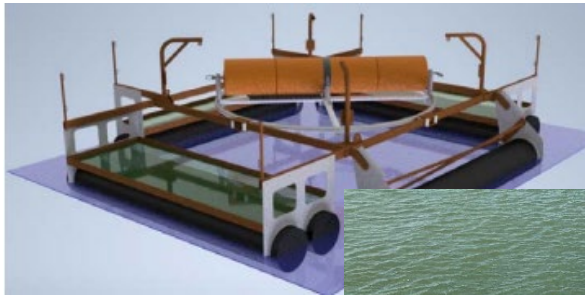
## Testing

- Controlled floating and sinking tests
- Scale model of the Steel ring
- Free fall? Air release valves?  
or controlled by parachute??



## ■ Testing 3

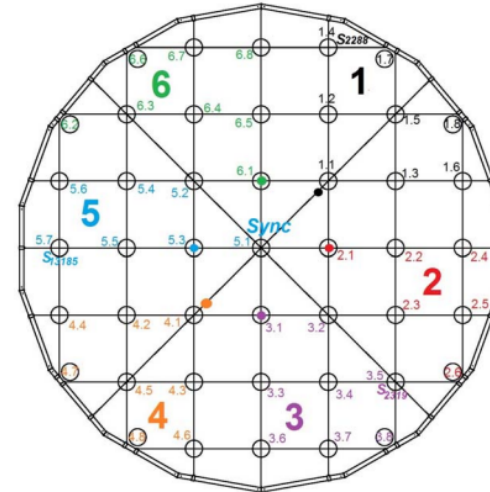
- Controlled sinking parachute
- Sensor package placing, with custom build assembly raft



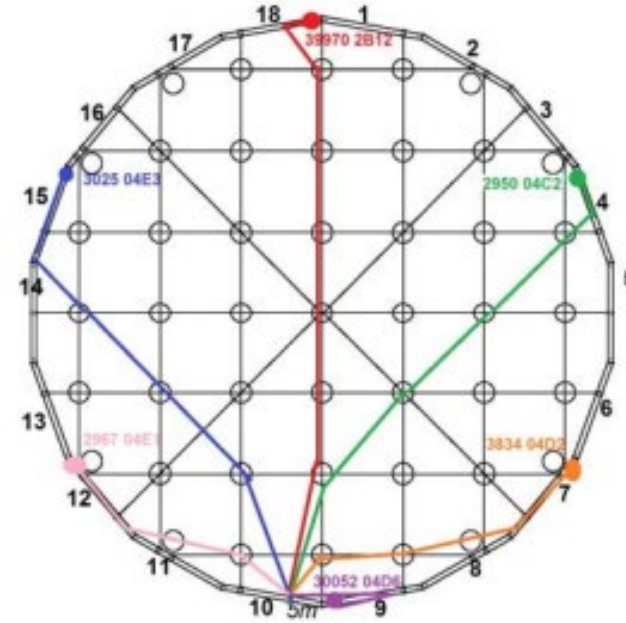
- Complete ring in the water



- Making electrical connections for the synchronizer
- Tensioning steel cable grid



- Placing releases with lines to parachute
- Prepare for towing





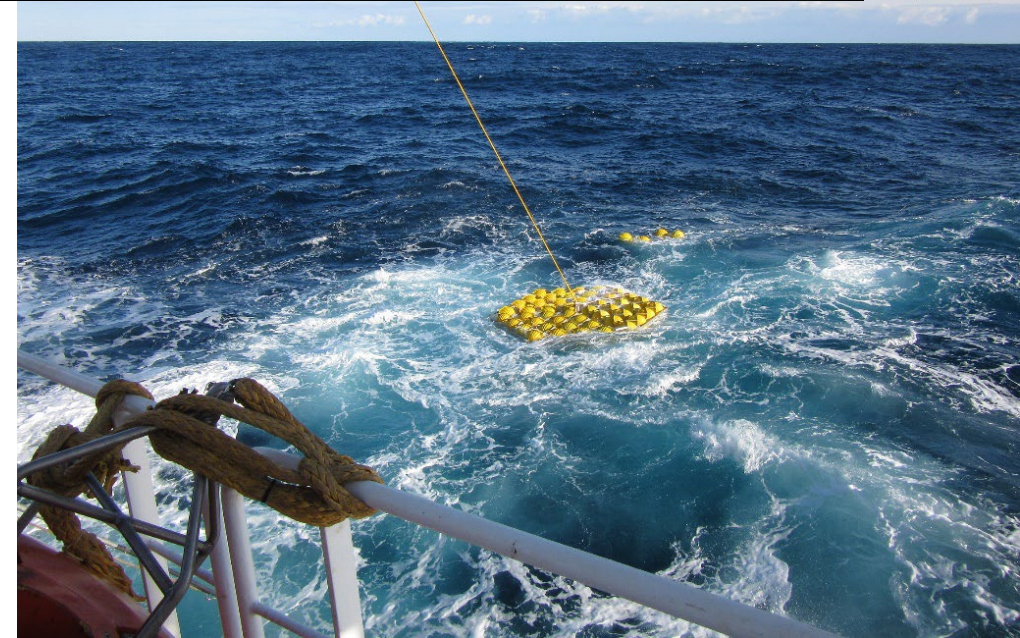
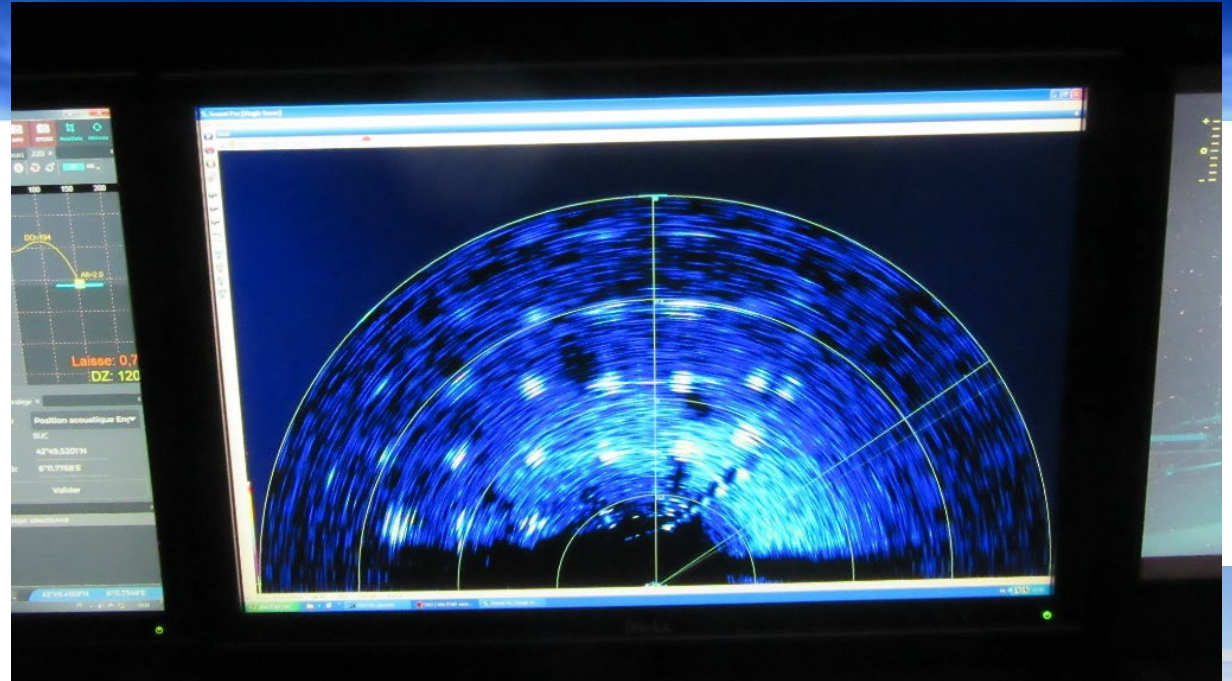
# And finally, sinking to the bottom!

- Disconnection from the Pelagia
- Removing air vent flaps at the bottom
- Releasing air by manually opening valves
- Timed release per steel section





# ROV inspection, 2 months later





# New Underwater Robotics for NL science community



Info GWI  
project

6,000 m  
Remotely Operated Vehicle, ROV



Underwater glider, 3 x



2,000 m Autonomous Underwater Vehicle, AUV

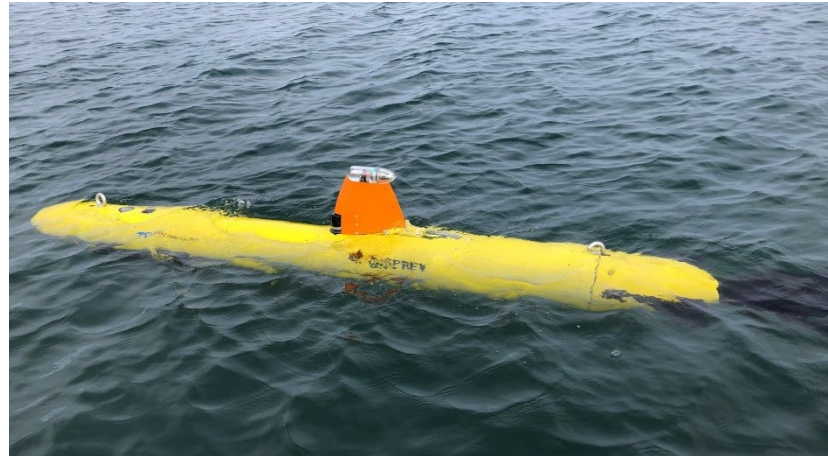


# Information on the sub projects



## Long range gliders

- Data almost real time via satellite telemetry
- Remote control
- Long range en long endurance
- Wide array of sensors
- Diving depth down to 1,000 m



## Autonomous Underwater Vehicle (AUV)

- subsea scanning at a close distance
- high resolution measurements
- depth rating 2,000 m
- endurance up to 24 hours
- wide array of sensors



## Remotely Operated Vehicle (ROV)

- experiments, measurements and interventions at depth
- depth rating 6,000 m
- robust, stable and precise
- Opto/electric tether
  - o wide band fibre optic connection
  - o unlimited endurance
- Live data availability
- Wide array of sensors and tools