First neutrinos with KM3NeT/ORCA

Valentin Pestel

On behalf of the KM3NeT Nikhef group

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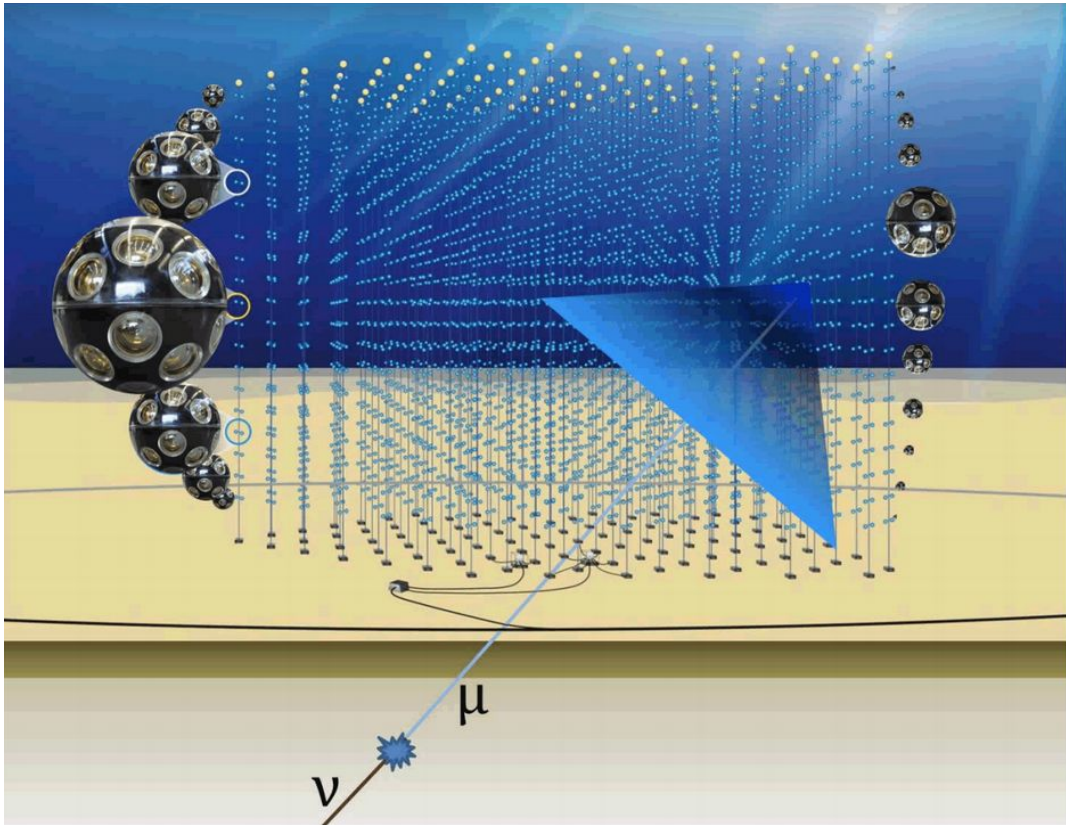
KM3NeT principle

Use large sea water volume as detection volume

- Neutrino interaction produce charged secondary(ies), inducing cherenkov radiation

Need for a (very) large array of photosensors

- Story started with ANTARES



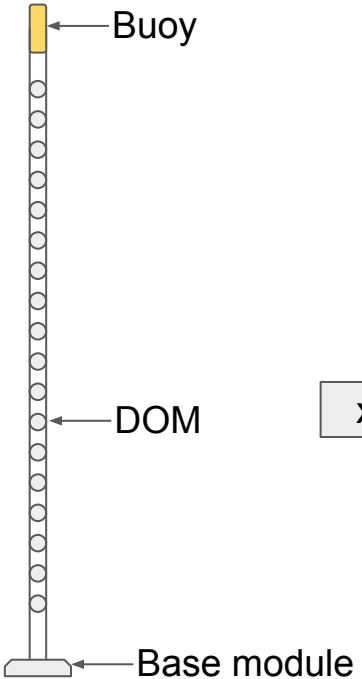
KM3NeT technology

Digital Optical Module (DOM)

- 31x3” PMTs
- Timing at ns
- Positioning
- Gbit/s optical fiber

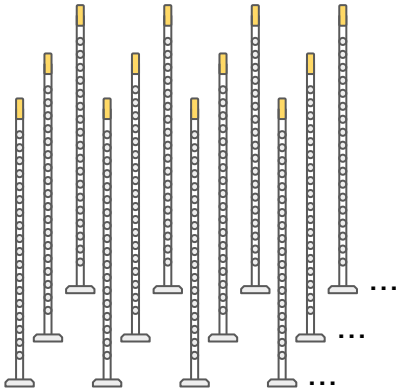
x18

Detection Unit (DU)



x115

Building Block (BB)



KM3NeT detectors

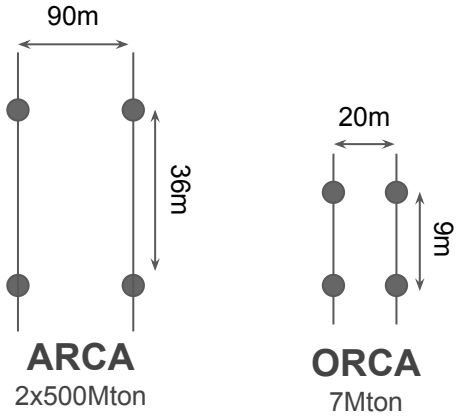
1 collaboration, 1 technology , 2 detectors

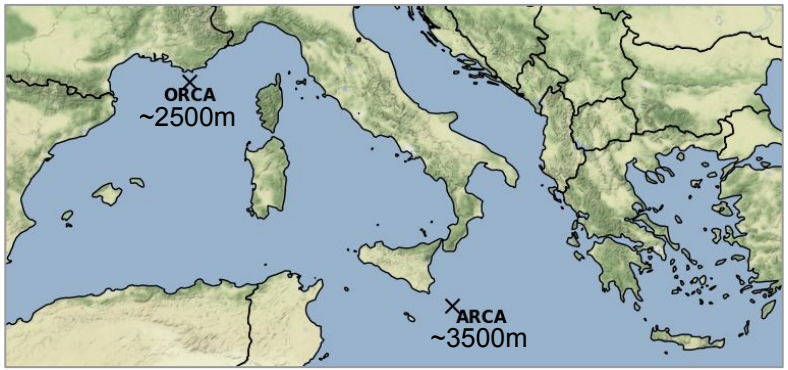
ARCA (2xBB)**:**

- Large array, optimized for [1TeV:10PeV]
- Neutrino astronomy
  - ➢ Point source observation, diffuse flux
- 1 DU already deployed

ORCA (1xBB)**:**

- Dense array optimized for [1GeV:100GeV]
- Atmospheric neutrino oscillation
  - ➢ Neutrino mass hierarchy, Oscillation parameter
- 6 DU already deployed





Mass production phase

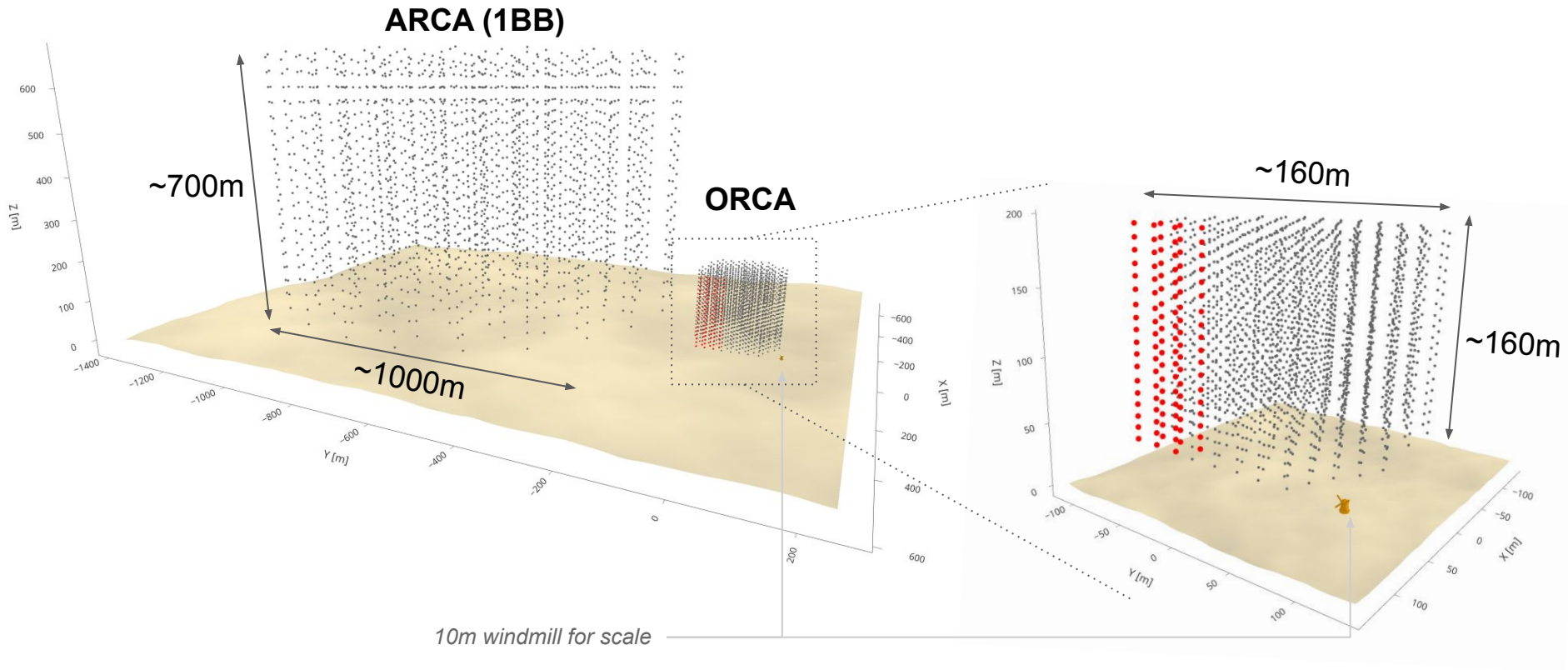
ARCA and ORCA require 6210 DOMs

- More than 10 construction sites
  - In Netherlands, France, Italy, Germany, Greece, Morocco ...
- DU deployment to become more and more regular

Nikhef heavily involved in the process

- DOM & DU integration
- More than 5 DU integrated since last July
- More details in this nice video

ARCA/ORCA Detector size



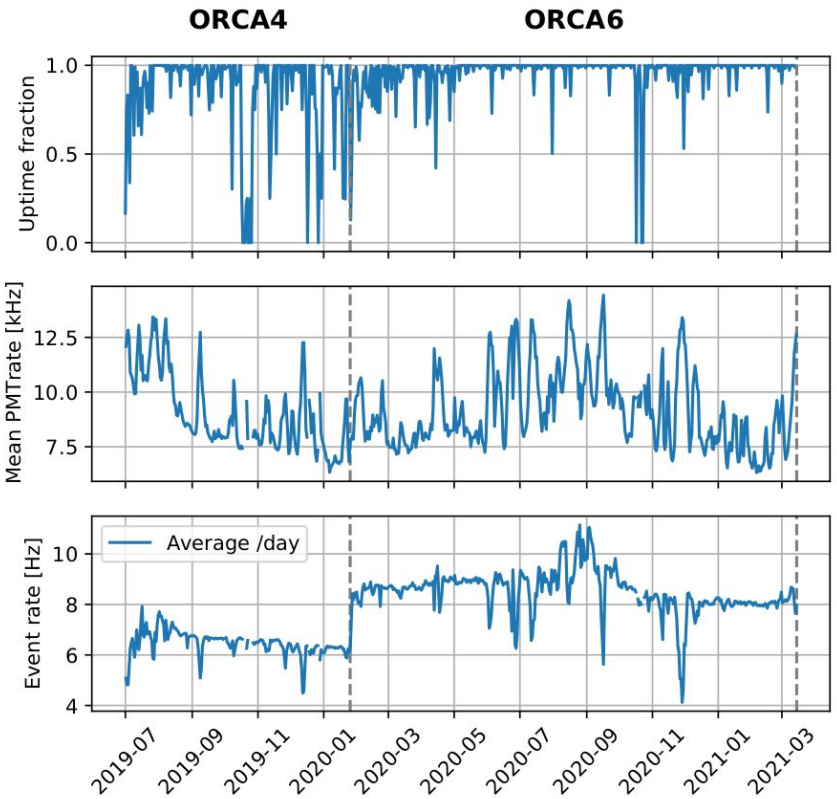
Current ORCA detector

Stable data-taking since mid 2019

- 4 DUs, then 6DUs in January 2020
- Very good uptime
  - ~94% in 2020, > 98% in 2021

Very efficient trigger algorithm

- Good event rate stability
- Resilient against background fluctuations
  - Utilize coincidences between PMTs and DOMs



Look into the data : ORCA4

Everything reconstructed as a track

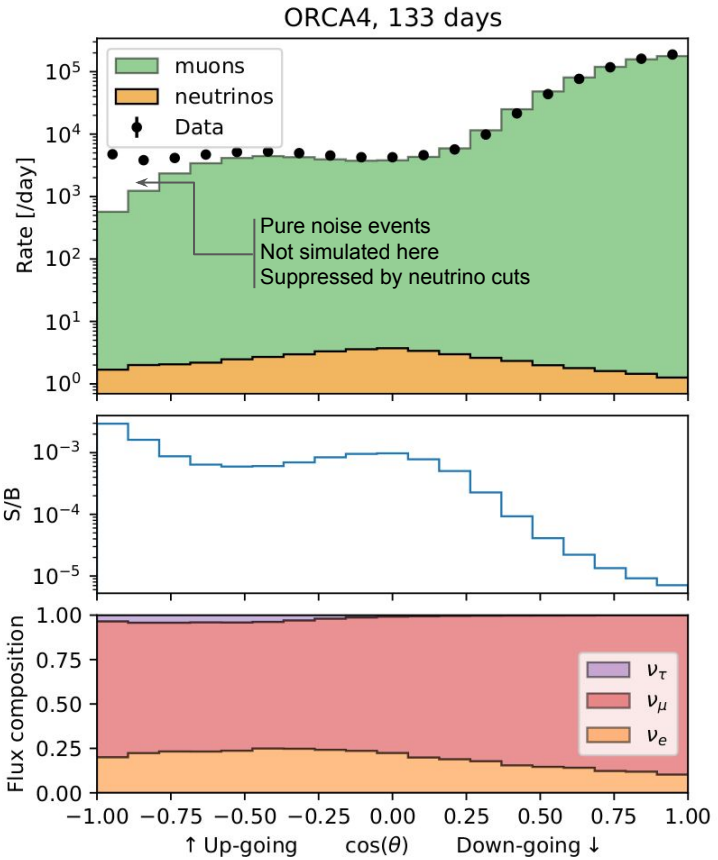
- (Atm)muons MC produced with MUPAGE
  - Flux verified against HEMAS full CR-shower simulation
- Neutrino MC produced with gSeaGen
  - KM3NeT-GENIE code

Mostly atmospheric muons

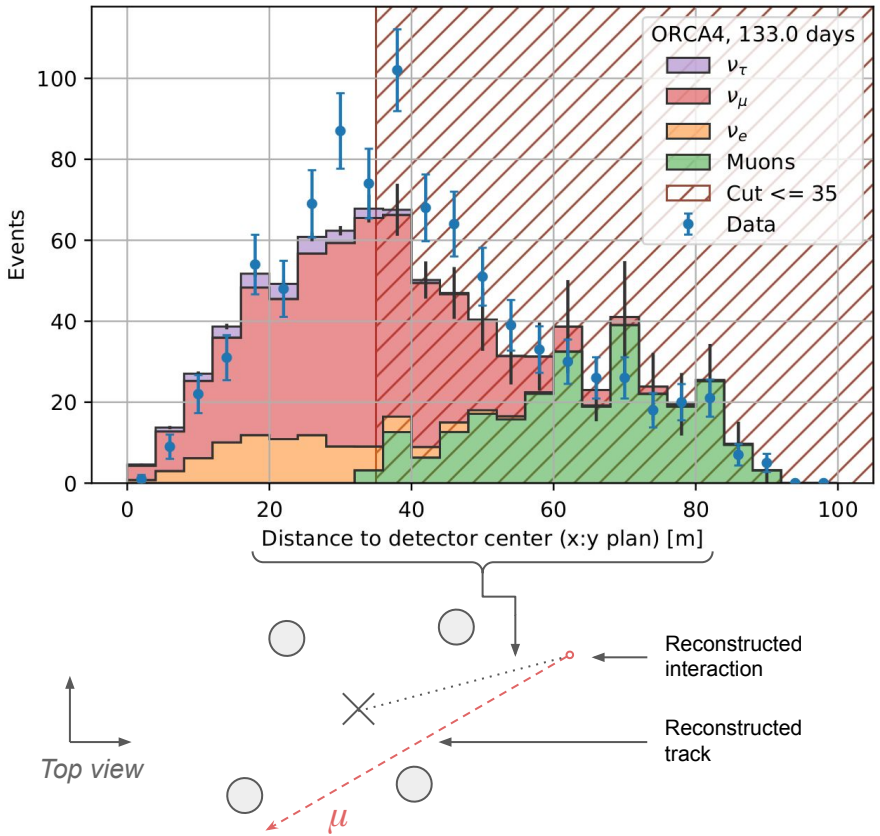
- About 600 000 muons per days
  - “Only” ~40 neutrinos

Up-going muons

- Ambiguous track reconstruction
- Main background for neutrino analysis



Neutrino selection



Selection based on multiple criteria

- Upgoing tracks
- Track quality
- Interaction point position

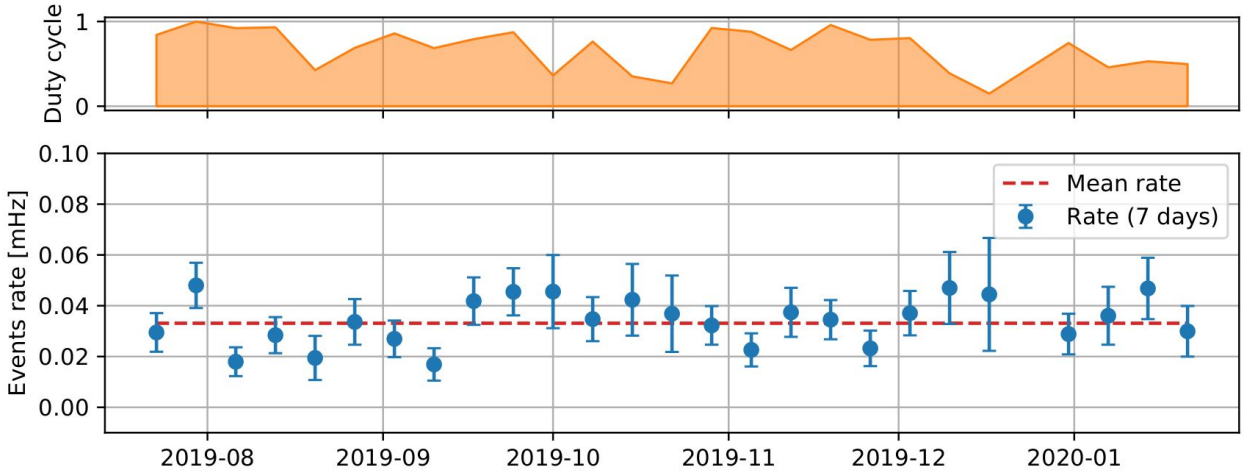
Result in a high-purity neutrino sample

- Data 2.86 ± 0.15 events/day
- MC($\nu + \mu_{atm}$)2.68+0.02 ± 0.08 events/day

Good data/MC shape agreement

- Light generation/propagation/detection well reproduced in Monte-Carlo

Selection rate and time stability



Good Data/MC agreement in rate

- Proper efficiency, flux, cross sections

Candidate rate stable over time

- Calibration inline with physic goals
- Selection resilient against external variation
  - Single rates, gain etc ...

Neutrino oscillations analysis

Extraction of oscillations parameters

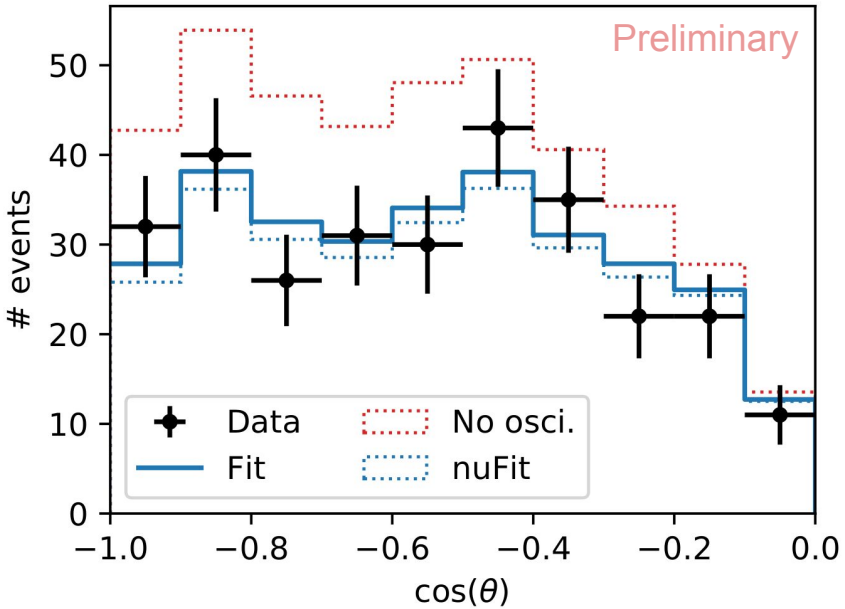
- Fit perform in Energy vs cos(theta) plane
  - Only on θ_{23} and Δm^2_{31} as free parameters

$$\theta_{23} = 34.3^{+8.1}_{-4.9}\ (\text{stat.})\ [\text{deg}]$$
$$\Delta m^2_{31} = 2.1^{+0.9}_{-0.4}\ (\text{stat.})\ [10^{-3}\text{eV}^2]$$

- No systematic uncertainties
  - E.g. 15% on flux normalisation

ORCA4 still at the limit for probing oscillations

- ~5% of complete detector volume
- Will improve quickly
  - ORCA6 under analysis



Result friendly provided by Lodewijk Nauta

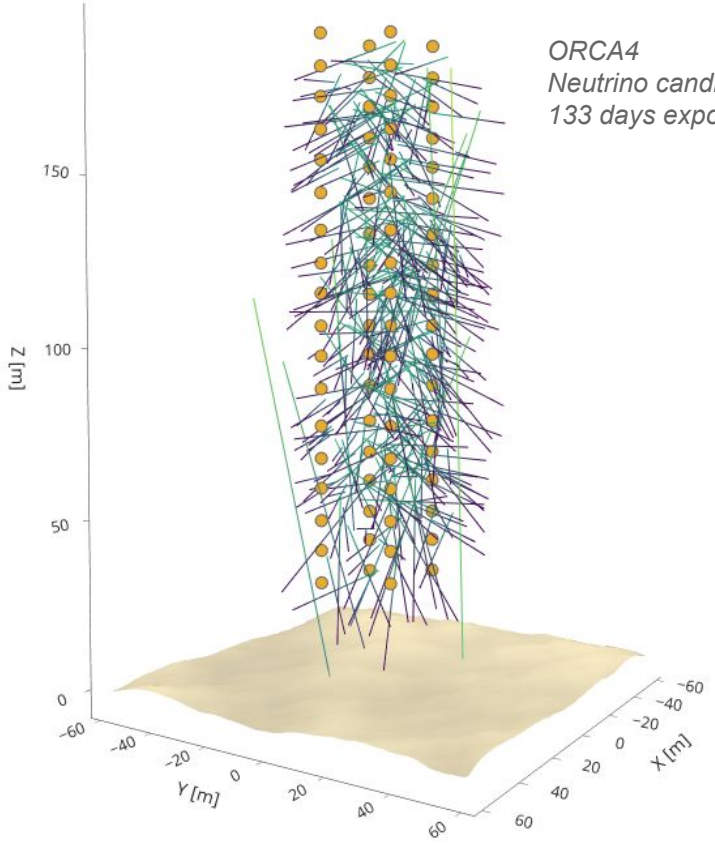
Summary

KM3NeT ORCA and ARCA mass production started

- Deployment of new DUs to restart in 2021
- High involvement of Nikhef teams (physicists and technicians)
- Detectors will grow faster and faster

ORCA4 already able to extract neutrino signal

- Shows detector good performances
- Still limited for oscillation analysis
  - Larger volume -> larger efficiency, better resolution
- ORCA6 data under analysis, stay tuned !



ORCA4
Neutrino candidates
133 days exposure

Thank you !

3 of the 5 DUs currently on their way to Malta for deployment (few days ago)

DUs installed on the Launching vehicle of Optical Module (LOM) before deployment (Yesterday, Malta)