KM3NeT INFRADEV – H2020 – 739560

Report on the participation of KM3NeT in a Technology Exhibition

KM3NeT INFRADEV GA DELIVERABLE: D9.7

Document identifier:	**KM3NeT-INFRADEV-WP9-D9.7**
Date:	**21/04/2020**
Work package:	**WP9**
Lead partner:	**NCSR-D**
Document status:	**Final Draft**
Dissemination level:	**Public**
Document link:	

Abstract

This document reports on the supporting material prepared for the participation of KM3NeT in a technology exhibition and the experience from participating in such an event.

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I. DELIVERY SLIP

	Name	Partner/WP	Date
Author(s)	E. Tzamariudaki	NCSR-D / WP9	23/03/2020
Reviewed by	C. Markou	NCSR-D	09/04/2020
Reviewed by	P. Coyle	CPPM	20/04/2020
Approved by	PMB		

II. DOCUMENT LOG

Issue	Date	Comment	Author/Partner
1	23/03/2019	1st version circulated to reviewer	NCSR-D
2	14/04/2020	2nd version including comments from G. Androulakis, C. Markou	NCSR-D
3	21/04/2020	3rd version including comments from reviewer	NCSR-D
4		Final version including comments from PMB	NCSR-D

III. APPLICATION AREA

This document is a formal deliverable for the GA of the project, applicable to all members of the KM3NeT INFRADEV project, beneficiaries and third parties, as well as its collaborating projects.

IV. TERMINOLOGY

A complete project glossary is provided:

ARCA: Astroparticle Research with Cosmics in the Abyss
ORCA: Oscillation Research with Cosmics in the Abyss
PMB: Project Management Board

V. LIST OF FIGURES

None

VI. LIST OF TABLES

None

VII. PROJECT SUMMARY

KM3NeT is a large Research Infrastructure that will consist of a network of deep-sea neutrino detectors in the Mediterranean Sea with user ports for Earth and Sea sciences. Following the appearance of KM3NeT 2.0 on the ESFRI roadmap 2016 and in line with the recommendations of the Assessment Expert Group in 2013, the KM3NeT-INFRADEV project addresses the Coordination and Support Actions (CSA) to prepare a legal entity and appropriate services for KM3NeT, thereby providing a sustainable solution for the operation of the research infrastructure during ten (or more) years. The KM3NeT-INFRADEV is funded by the European Commission's Horizon 2020 framework and its objectives comprise, amongst others, activities on technology transfer and innovation in the KM3NeT Collaboration (work package 9).

VIII. EXECUTIVE SUMMARY

The main goal of WP9 is twofold: 1. to establish methodologies for exposing to interested parties in the industrial sector the technological choices and innovative solutions that have been developed or adapted by KM3NeT and 2. to follow the technological advances in key areas of interest to KM3NeT. An important task of this WP has been the dissemination of the technological solutions that we have developed for complying with the specifications set to achieve the desired physics goals, to other stakeholders with potential interest. For this purpose, we planned on developing supporting dissemination material to be used for participating in technology transfer events and exhibitions. We have already used this material for the Workshop on Very Large Volume Neutrino Telescopes in Dubna, Russia in October 2018 and during the participation of KM3NeT Thessaloniki International Fair for technology and innovation in September 2019 and we plan to also use it to support the KM3NeT participation in future technology transfer events. Part of the dissemination material (posters and power point presentation) has been prepared and included in the D9.1. (Demonstrator on the material prepared for the participation of KM3NeT in technology exhibitions). The brochures discussed in this report are to be included in D9.6, as they have been prepared with input from the KM3NeT technology and innovation panel and comprise the outcome of work that has been achieved within task 9.1.
The material developed, is available to the KM3NeT Collaboration to be used as is and also provides a basis for presentations to technology experts and to technology oriented audience.

Table of Contents

1. Introduction

KM3NeT is a large Research Infrastructure (RI) currently under construction. When completed, it will consist of a network of deep-sea detectors with user ports for Earth and Sea sciences, deployed at the Mediterranean sea. The main science objectives, a description of the technology and a summary of the costs are presented in the KM3NeT 2.0 Letter of Intent (1).

KM3NeT/ARCA (Astroparticle Research with Cosmics in the Abyss), aims at the discovery and subsequent observation of high-energy neutrino sources in the Universe and is currently under construction at a depth of 3500 m, ~ 80 km off-shore Portopalo di Capo Passero in Sicily. KM3NeT/ORCA (Oscillation Research with Cosmics in the Abyss) at a depth of 2450 m, ~ 40 km off-shore from Toulon, will use atmospheric neutrinos at low energies to measure neutrino oscillations and determine the neutrino mass ordering, which is a fundamental property in neutrino physics.

The objective of this work package is to establish the procedures for exposing KM3NeT to the outside world, targeting relevant interested parties in the industrial sector. To achieve this, appropriate dissemination material needed to be developed for the participation of KM3NeT to technology and industrial exhibitions. For the purposes of the “Technology transfer and innovation” work package, a panel of members with expertise in the areas of technological interest to KM3NeT has been formed aiming to establish a sustainable methodology for the two-way flow of information and know-how between KM3NeT and the key technology areas. The members of this panel have been appointed to follow technological advancements and to identify cases at which KM3NeT needs have been the driving force behind industrial innovation or appropriate modifications to existing solutions in order to comply with the requirements set by the experiment. Several working groups provided input and dissemination material, which has been collected by the members of the panel and was used for the preparation of a presentation, informational brochures and posters. Material prepared for exhibitions has been included in D9.1. of WP9 on month 12 (M12) of the project and has been used for KM3NeT outreach events at different Universities. Since M12 and as the detector construction is ongoing, this material was updated and enriched by the Technology transfer and innovation panel.

2. Dissemination material for the participation of KM3NeT in technology transfer exhibitions

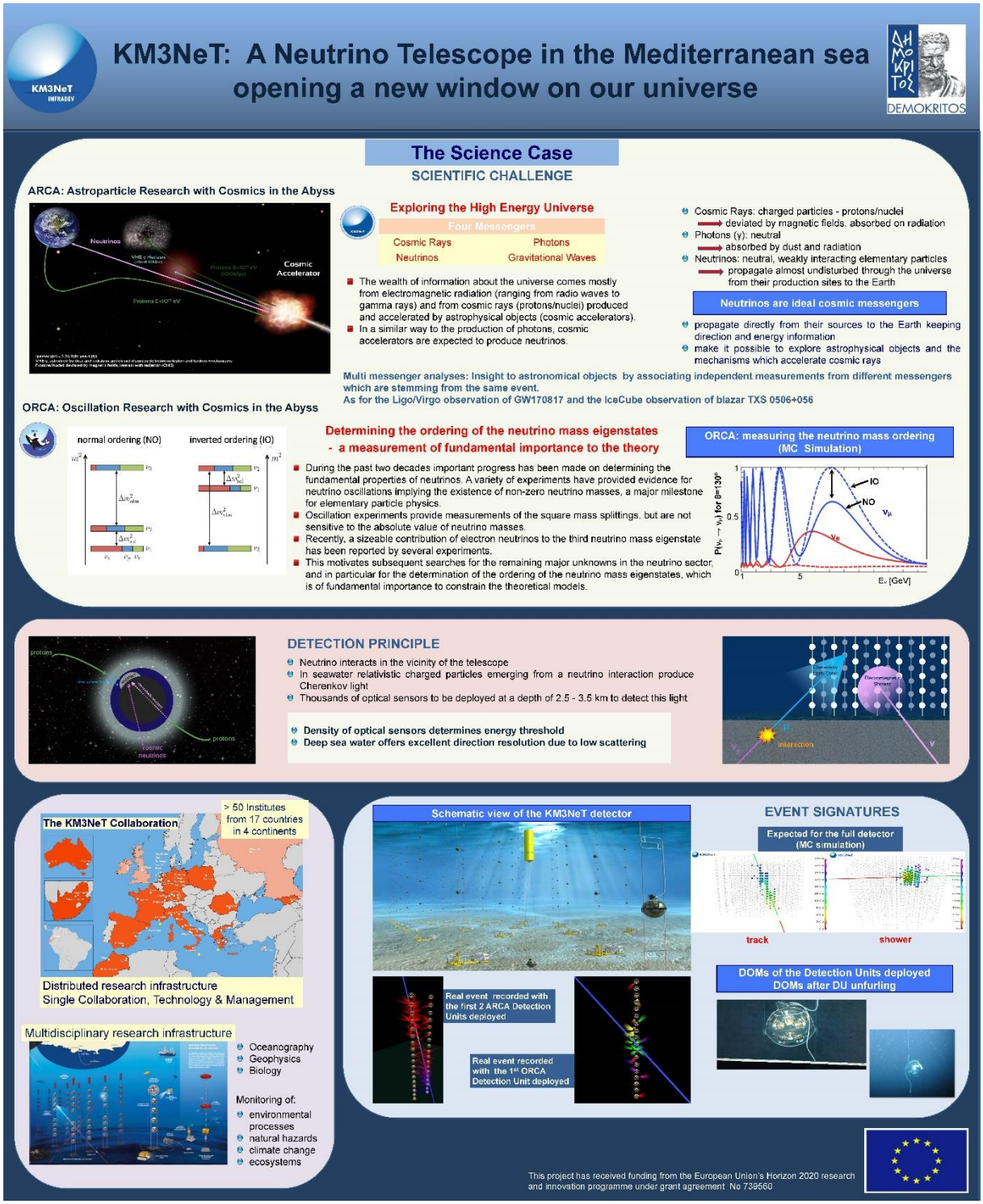
Our plan was to prepare posters and a power-point presentation in an early stage to be used in technology related events (during the length of time of the WP) and then to use all collected input from the panel (Task 9.1.) to prepare brochures with information on specific technological challenges and solutions. We decided to have 2 posters: one poster to introduce the audience of the technology exhibitions to the scientific goals of KM3NeT, the size and multi-national character of the collaboration, and one poster to address the technological challenges and the solutions developed or adapted by KM3NeT. In parallel, a power point presentation with slightly more details has been prepared, to be loaded on a laptop during events or exhibitions, aiming to be self-explanatory and at the same time

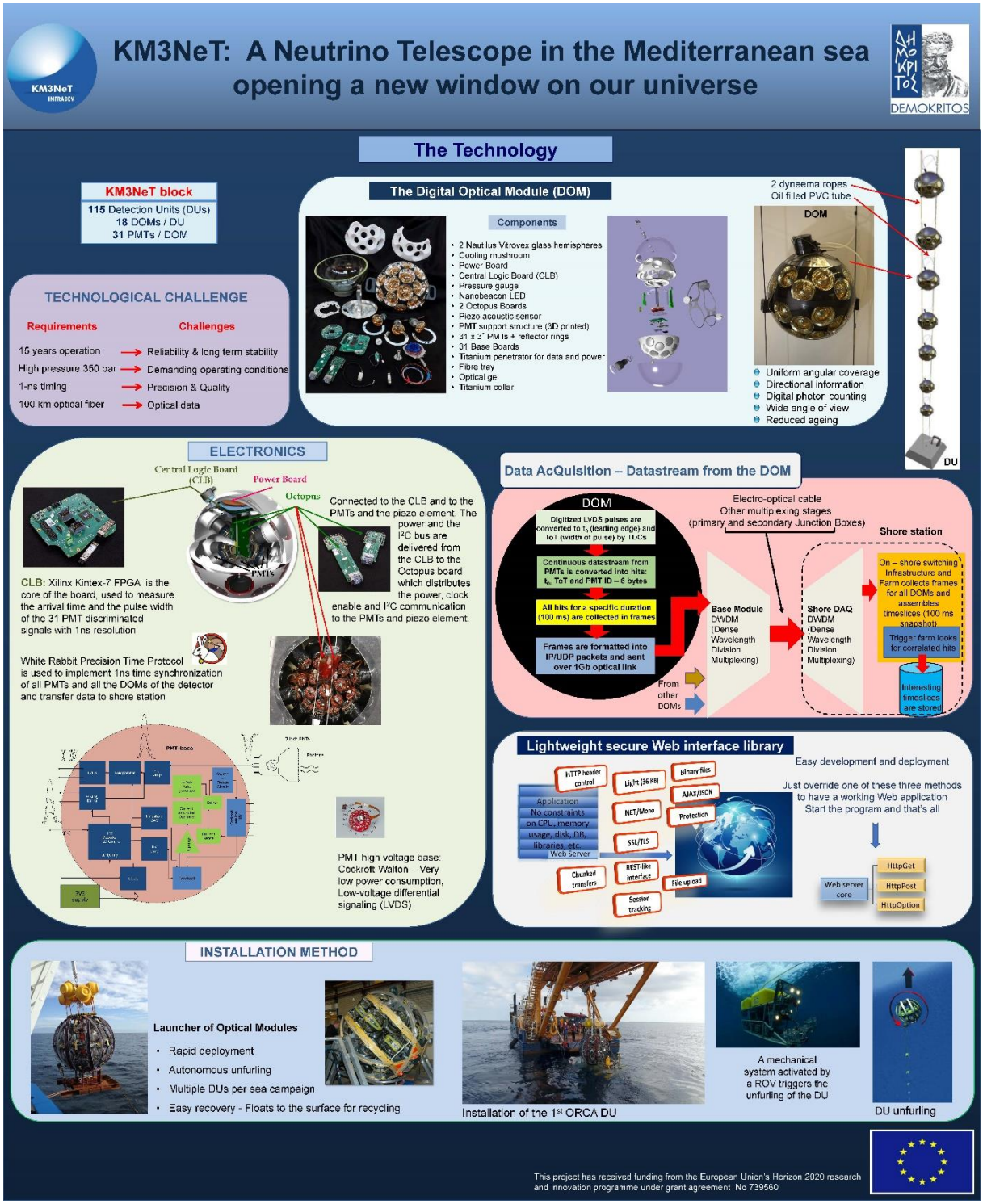
provide additional material for the technology experts. Both for the posters and for the presentation it was intended to avoid including detailed descriptions since the technological solutions presented cover several areas and experts on one technological item are not necessarily interested in other specializations. In addition, our intention was to make a video by selecting parts from existing videos, shot during the sea campaigns for the deployment of KM3NeT detection units, showing the most impressive snapshots from the deployment procedure. The integration of a dummy DOM to be used for exhibition purposes had been set as an objective since the beginning of the project. Significant effort has been put to both collecting relevant information and material (from Task 9.1) and to developing the brochures (the development of the brochures was made possible through funding provided by the project). Initially we developed double-sided leaflets in A5 format which, during the timeline of the project, we evolved into the brochures which were handed to technology experts during the exhibition. Both leaflets and brochures are available to the KM3NeT Collaboration to support future KM3NeT participations in technology transfer events. We have achieved all the goals we had set.

The exhibition material comprises two posters, a presentation and four brochures to be used for the participation of KM3NeT to technology exhibitions. The posters and the presentation have been prepared and included in the D9.1. (Demonstrator on the material prepared for the participation of KM3NeT in technology exhibitions) and expose the scientific goals of KM3NeT as well as the technological challenges and the adopted solutions. The latest version is shown below for completeness. Four brochures (also in the form of leaflets with A5 format – double sided, as mentioned above) have been prepared by E. Tzamariudaki and G. Androulakis with the help of the members of the panel, for the exposure and promotion of the technological achievements and solutions provided by KM3NeT. The brochures are included in D9.6., the final report on the activities of the technology transfer and innovation panel. Using components rejected from production, a dummy digital optical module (DOM) has been integrated to be used for exhibition purposes.

Posters

The updated posters (few aesthetic changes and an updated KM3NeT Collaboration map compared to D9.1) are included in this report for completeness.

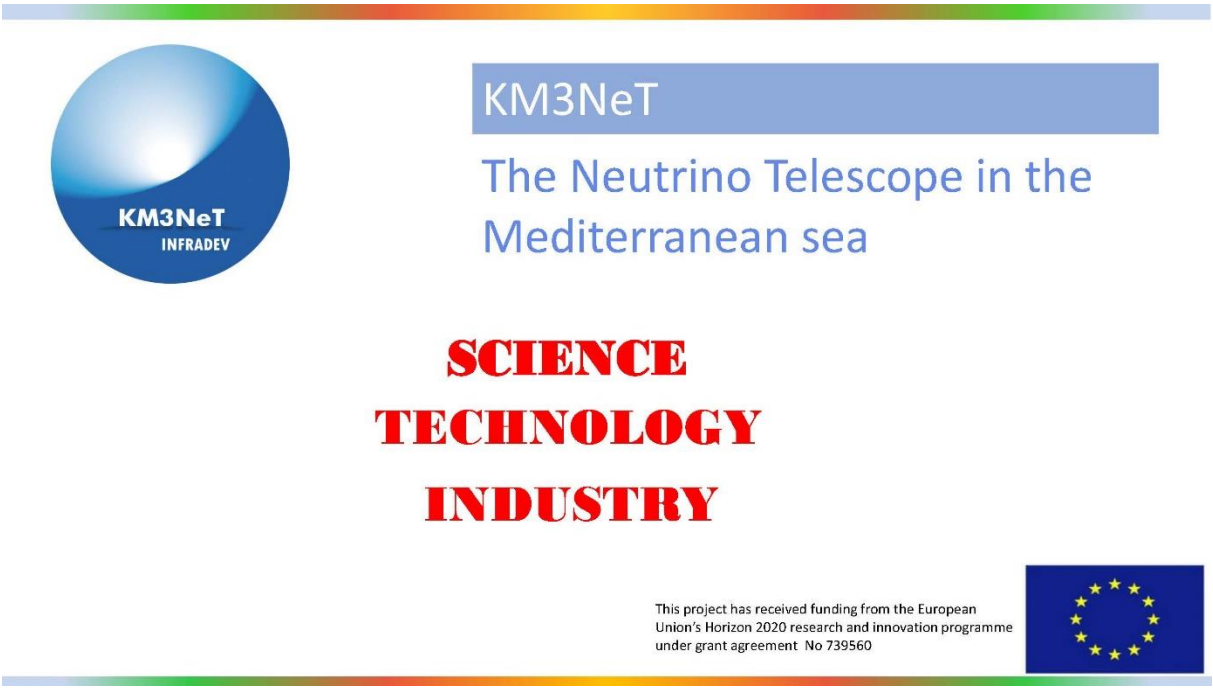




The aim of the posters is to introduce KM3NeT presenting the scientific goals as well as the technological challenges and the adopted solutions to a technical oriented audience. As they do not include the status of physics analyses and studies no major updates are necessary. The posters can be used for future technology events and exhibitions, as well as in University open days.

2. Presentation

A power-point presentation was prepared and included in the D9.1 (Demonstrator on the material prepared for the participation of KM3NeT in technology exhibitions). Minor updates have been made aiming to stress the KM3NeT requirements, the peculiarity of the environment (the deep sea) and the technological challenges. The purpose of this presentation is to be, up to a large extent, self explanatory and to guide the audience through the physics goals, the challenges and the technology of KM3NeT. At the same time, it can be used (and we have used it during the exhibition) to introduce KM3NeT to the audience and, as it covers several areas of KM3NeT technology, to answer questions and provide more information for experts in particular fields. Experts in different technology areas can use this as basis and expand the contents, if deemed necessary, emphasizing achievements and providing details in their field of expertise. The presentation is included in this report for completeness.



SCIENTIFIC CHALLENGE

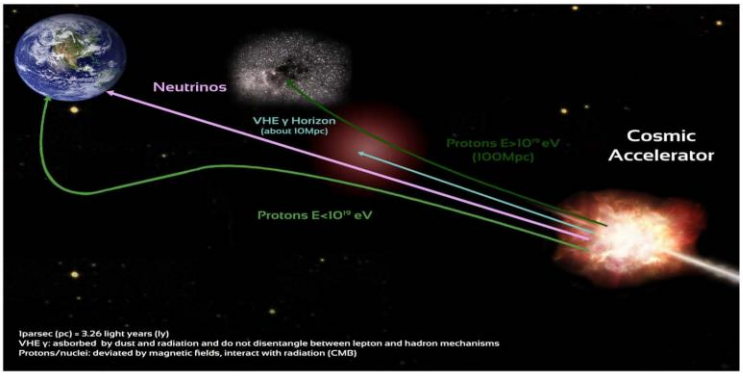
ARCA: Astroparticle Research with Cosmics in the Abyss

Exploring the High Energy Universe

Four Messengers	
Cosmic rays	Photons
Neutrinos	Gravitational Waves

neutrinos

- elementary particles that propagate directly from their sources to the Earth
- ideal cosmic messengers
- make it possible to explore astrophysical objects and the mechanisms which accelerate cosmic rays

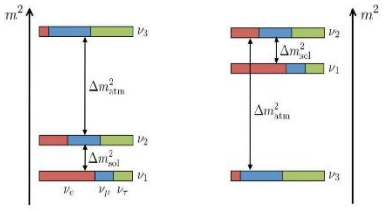


SCIENTIFIC CHALLENGE

Determining the ordering of the neutrino mass eigenstates
- a measurement of fundamental importance to the theory

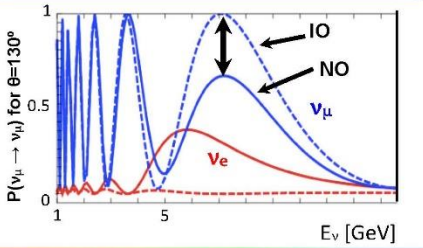
ORCA : Oscillation Research with Cosmics in the Abyss

normal ordering (NO) inverted ordering (IO)



- During the past two decades important progress has been made on determining the fundamental properties of neutrinos with the evidence for neutrino oscillations implying the existence of non-zero neutrino masses, a major milestone for elementary particle physics.
- The observed sizeable contribution of electron neutrinos to the third neutrino mass eigenstate has motivated subsequent searches for the remaining major unknowns in the neutrino sector, and in particular for the determination of the ordering of the neutrino mass eigenstates, which is of fundamental importance to constrain the theoretical models.

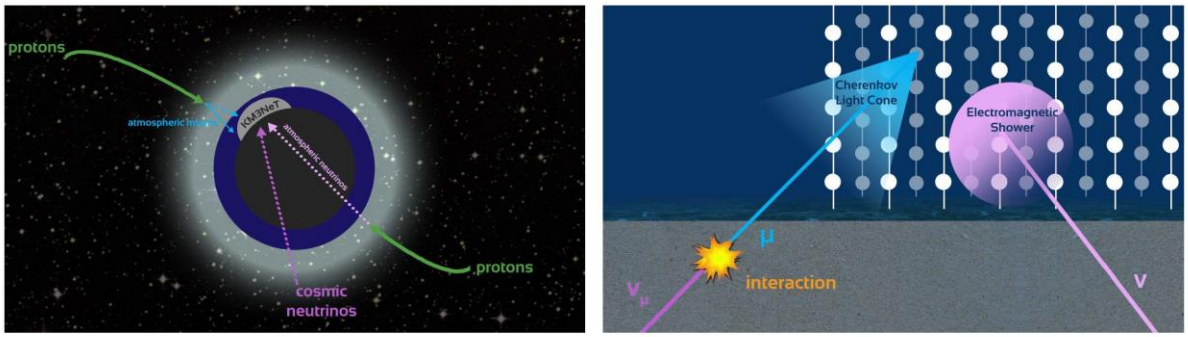
ORCA: measuring the neutrino mass ordering (MC Simulation)



KM3NeT: THE NEXT GENERATION NEUTRINO TELESCOPE

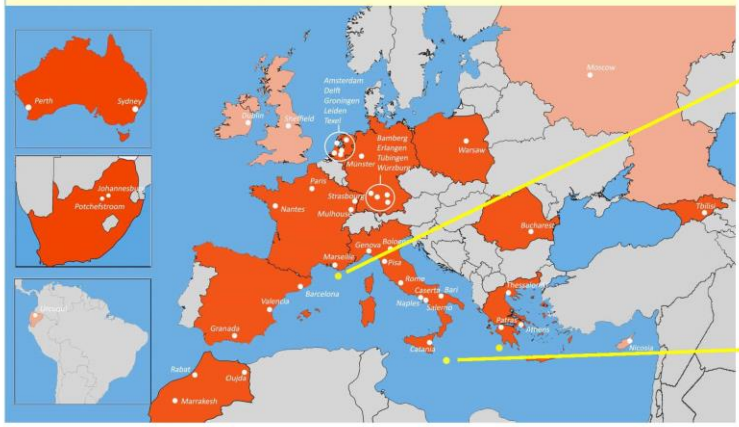
DETECTION PRINCIPLE

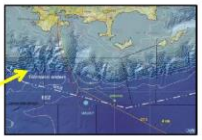
- In seawater relativistic particles emerging from a neutrino interaction produce Cherenkov light
- Thousands of optical sensors to be deployed at a depth of 2.5 - 3.5 km to detect this light



KM3NeT: A Distributed Research Infrastructure

> 50 Institutes from 17 countries in 4 continents



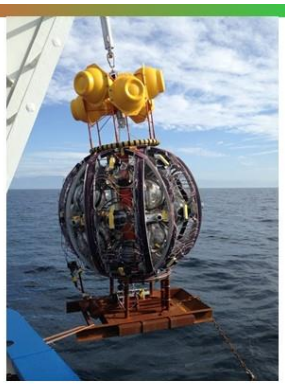


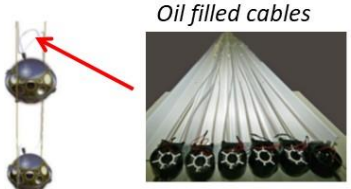
Oscillation **R**esearch with **C**osmics In the **A**byss
Low-energy studies of atmospheric neutrinos

Astroparticle **R**esearch with **C**osmics In the **A**byss
High-energy neutrino astrophysics

Same collaboration, same technology
Distributed infrastructure, phased implementation

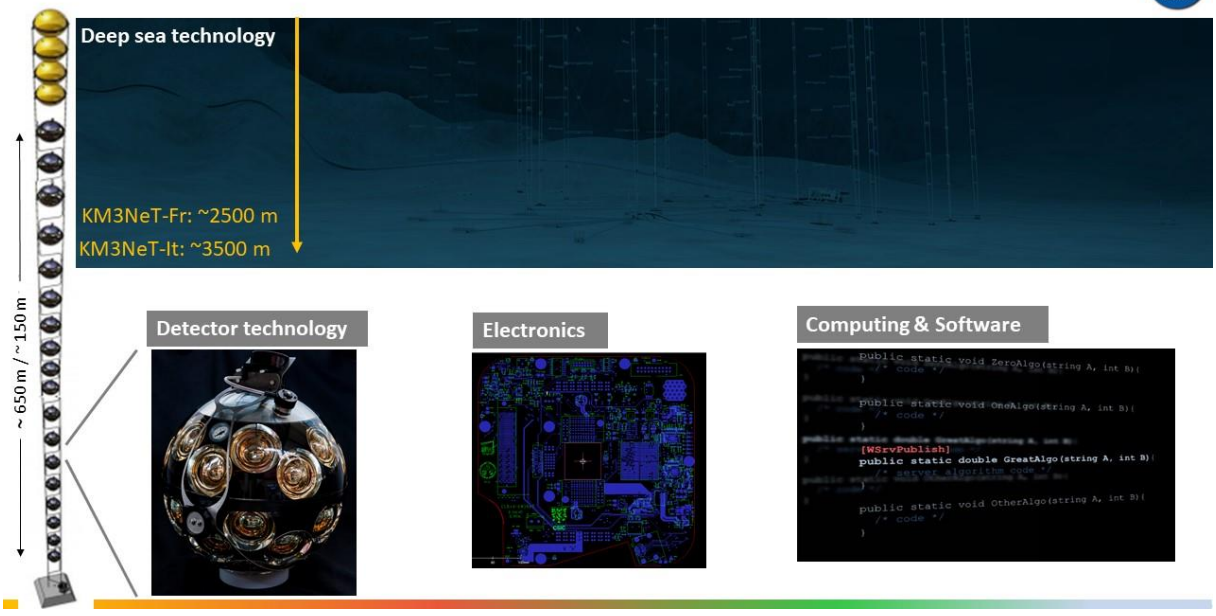
TECHNOLOGICAL CHALLENGE





Requirements		Challenges
15 years operation	→	Reliability, long term stability
high pressure 350 bar	→	Demanding operating conditions
1-ns timing	→	Precision and Quality
100 km optical fiber	→	Optical data

TECHNOLOGY



Deep Sea Technology

Deployment and precise underwater positioning

KM3NeT-Fr: ~2500 m
KM3NeT-It: ~3500 m

The LOM (Launcher of Optical Modules)



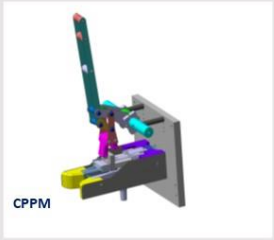
NIOZ (Royal Netherlands Institute for Sea Research)

Deep Sea Technology

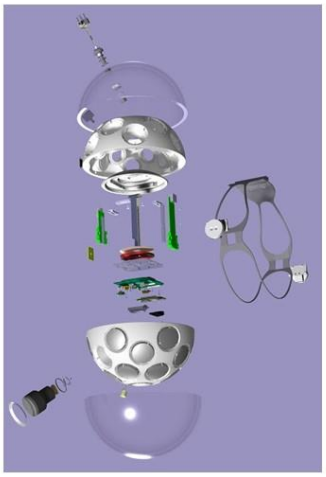
Deployment and precise underwater positioning

KM3NeT-Fr: ~2500 m
KM3NeT-It: ~3500 m

Tool for (dis)connecting wet-mateable connectors with lightweight ROVs



The Digital Optical Module



- Glass sphere
- Cooling system
- Power Board + CLB
- Pressure gauge
- Nanobeacon
- Octopus Boards
- Acoustic sensor
- PMT support structure (3D printed)
- PMTs + reflector rings
- Base Boards
- Penetrator
- SFP
- Fibre tray

Detector Technology

Detector: 3-D array of optical modules

tens of thousands of optical sensors to be tested

KM3NeT-Fr: ~2500 m
KM3NeT-It: ~3500 m

Multiple photomultiplier testing facility

- easy, fast and safe loading and unloading of PMTs
- simultaneous multiple PMT characterization

INFN Napoli (Instituto Nationale di Fisica Nucleare)

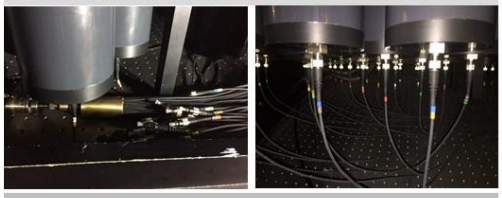
High Statistics PMT Testing Facility

PMT parameters: dark counts, transit time, transit time spread, spurious pulses

Dark Box
- Black wooden box: 120 cm 88 cm 58 cm
- 2 removable trays with 31 PMT holders each
- Two complete KM3NeT DOM electronics
- Allow simultaneous characterization of 62 3'' PMTs

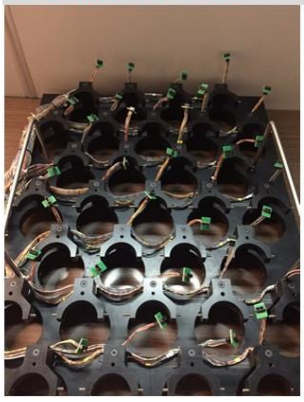
Dark box

Optical splitter 1 input → 70 outputs



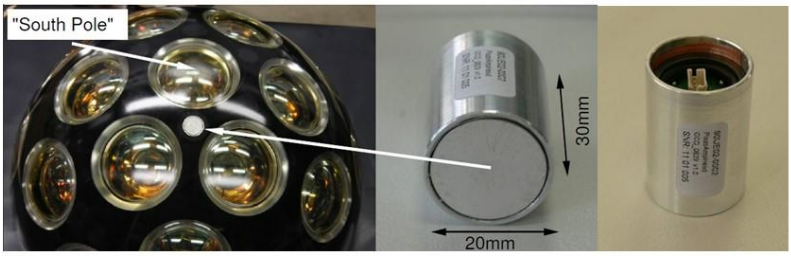
INFN Napoli (Instituto Nationale di Fisica Nucleare)

PMT tray equipped with cable extensions and removable connectors



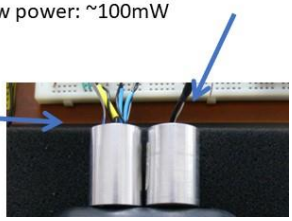
Internal Acoustic sensors for position calibration

- Contains one piezo ceramics
- Compact design, pressure couples in through glass sphere
- Inexpensive (< 100€) and versatile device
- Designs with Analog and Digital Output



Sensor with analog readout
- Single ended signal easily routed to further amplification or processing (e.g. oscilloscope)
- Low power: ~100mW

Sensor with digital readout
- Internal or external clock signal
- Output format flexible through integrated FPGA
- Existing firmware AES/EBU readout for "plug and play" with standard digital audio devices
- Low power: ~450mW



Detector Technology

Detector: 3-D array of optical modules

Synchronization of the optical modules

KM3NeT-Fr: ~2500 m
KM3NeT-It: ~3500 m

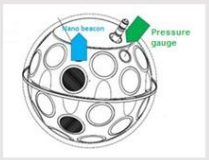
Central Logic Board (CLB)

CLBv3

CLBv4

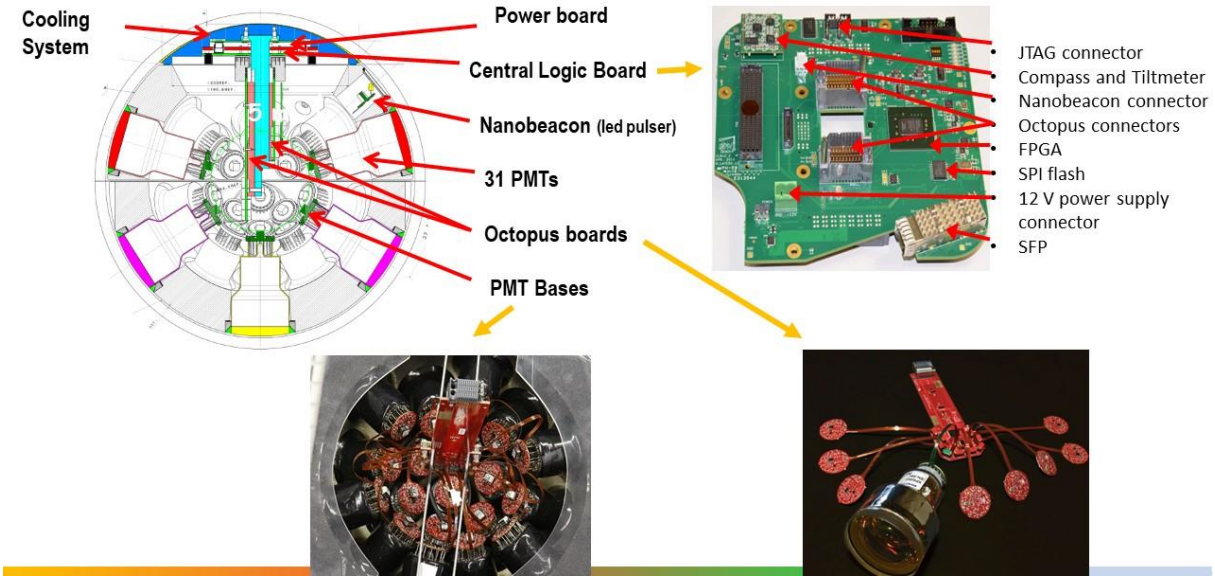
Nanobeacon board

Relative time calibration between the optical sensors



IFIC (Instituto de Fisica Corpuscular)

Electronics Boards in the KM3NeT-DOM



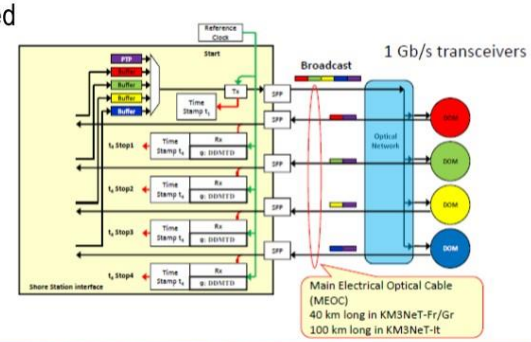
Time Synchronization and Data Transfer

White Rabbit optical network:

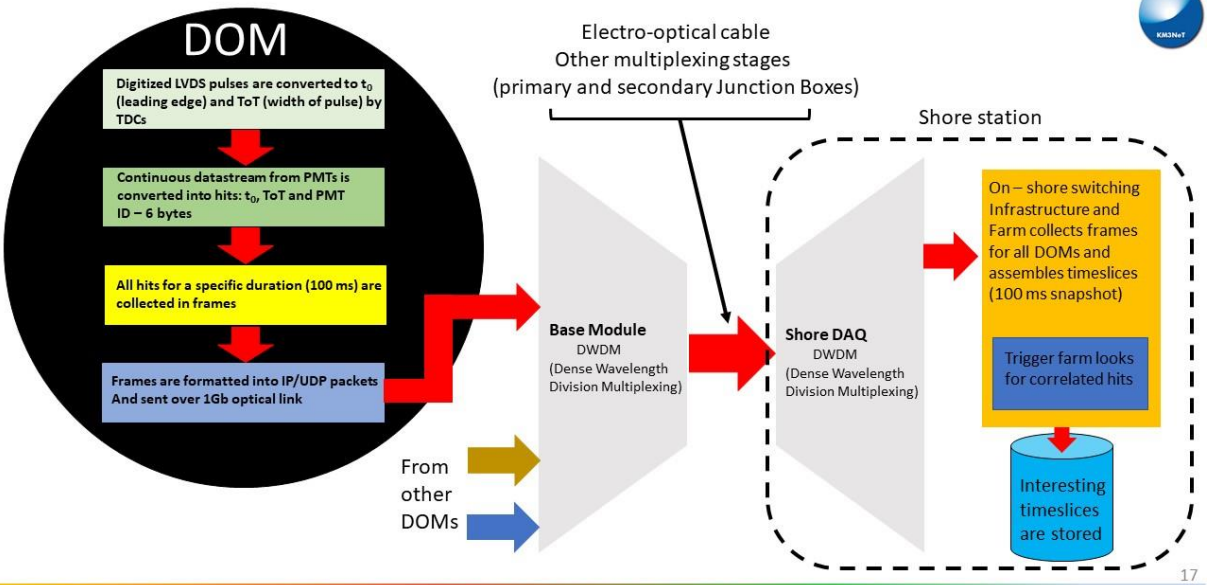
- Ethernet
- + Determinism & Reliability
- + High-Accuracy Synchronization

Data transfer, Control and Time Synchronization combined
International collaboration
Based on well-known technologies (CERN)
Open Hardware and Open Software

KM3NeT: Development of specific software to implement the Broadcast White Rabbit



Data AcQuisition – Datastream from the DOM



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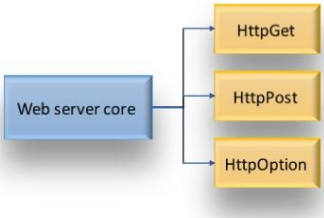
Lightweight secure Web interface library

Easy development and deployment

Just override one of these three methods to have a working Web application
Start the program and that's all



University of Salerno

SAWI: Server Application with Web Interface

Publish a method for Remote Procedure Call
by just setting an attribute on existing code

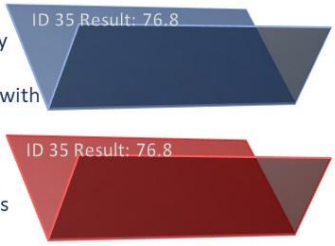
```
public static void ZeroAlgo(string A, int B){
  /* code */
}

public static void OneAlgo(string A, int B){
  /* code */
}

[WSrvPublish]
public static double GreatAlgo(string A, int B){
  /* server algorithm code */
}

public static void OtherAlgo(string A, int B){
  /* code */
}
```

Web-accessible call stub
Debug service using a browser

Short calls:
return immediately

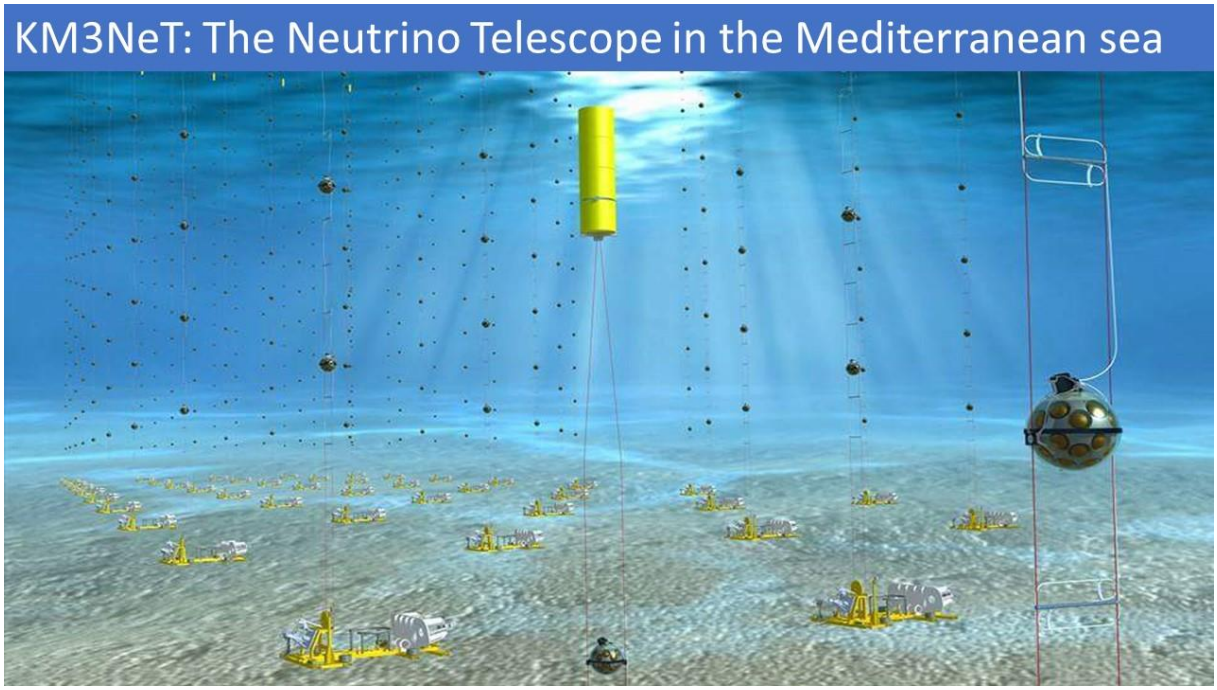
Long calls are jobs with
result persistence

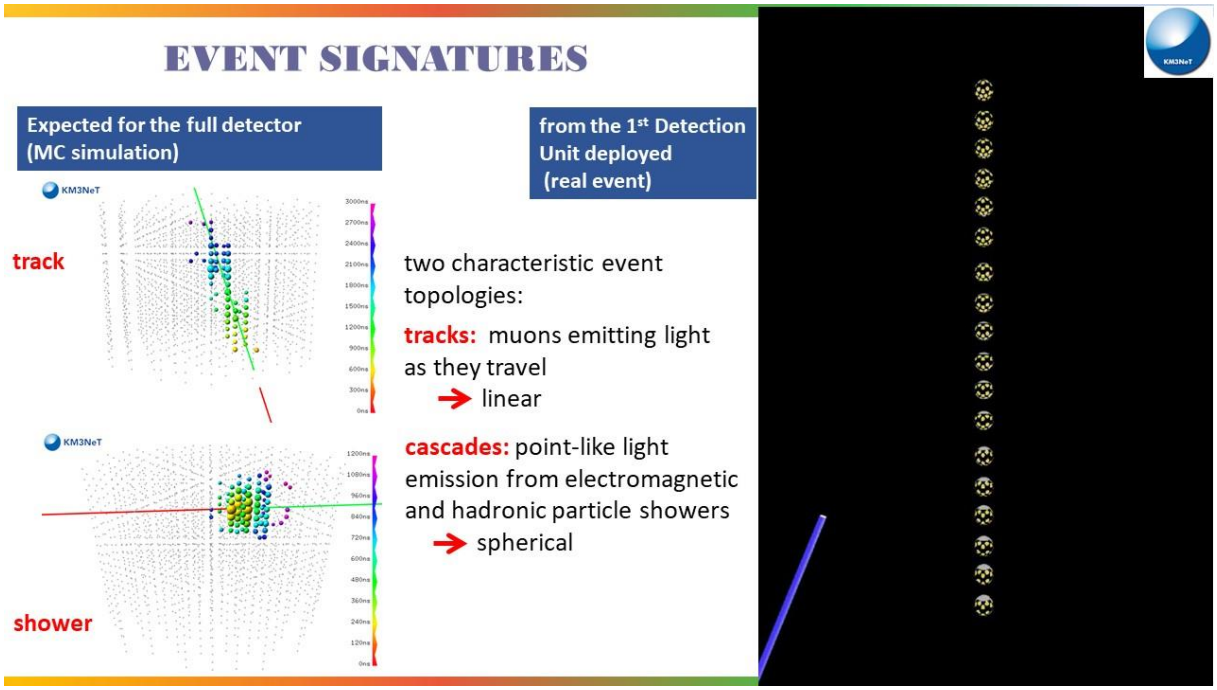
Server exceptions
Protocol exceptions



RPC client
over HTTP
Same library!

University of Salerno


KM3NeT: The Neutrino Telescope in the Mediterranean sea


EVENT SIGNATURES
Expected for the full detector (MC simulation)
from the 1st Detection Unit deployed (real event)
KM3NeT
track
two characteristic event topologies:
tracks: muons emitting light as they travel
linear
KM3NeT
cascades: point-like light emission from electromagnetic and hadronic particle showers
spherical
shower
KM3NeT

The presentation can be used in future technology events and exhibitions, and in University open days and science events with only minor updates displaying science results.

3. Integration of a dummy DOM for exhibition purposes

The availability of DOMs to be used for outreach purposes has been a long-standing request from the various member institutes of KM3NeT. The digital optical module is really the core concept of the project as, leaving aside important but too technical aspects of KM3NeT such as electro-optical network, time and position calibration, underwater power distribution etc., our detectors essentially comprise three dimensional grids of DOMs. Given that the full scale of the detectors can only be visualised and experienced through VR, the DOM, which is the detection element of KM3NeT, is the best representation of the detector modules. In particular, exhibiting a DOM suffices for demonstrating key aspects of the project such as the innovative multi PMT concept, technological innovations that have been developed by KM3NeT, the detection principle e.t.c., thus justifying why exhibition DOMs are so much in demand within KM3NeT.

Using real functional DOMs for exhibitions poses unacceptable risks as they are expensive, heavy, sensitive to vibrations and of course, vulnerable under sun-light. However, there are several -rejected from production- defective DOM components in production sites around Europe, which if not recycled somehow, they would have been thrown away. We have therefore collected enough of these components to integrate a "dummy" exhibition DOM at our local DOM integration site in Athens. Being

able to inspect the internals of the DOM is really important for demonstrating its technology; accordingly, the object that we integrated is actually a half DOM, consisting of a fully integrated upper half, which contains DOM's most critical components (electronics, power circuity, penetrator) and the lower half is just a transparent glass hemisphere, thus allowing observing the internals of the DOM. This DOM was first exhibited in TIF 2019 and certainly drew the attention of a large number of visitors.

It goes without saying that this DOM is really a KM3NeT property and accordingly, it is available to anyone in the collaboration who wishes to exhibit it. We would like to acknowledge our colleagues in IFIC/Valencia, INFN/Napoli and Nikhef/Amsterdam for readily responding positively to our request for defective DOM components.

Integration of the dummy DOM in the DOM integration site in Athens

4. Participation in a technology exhibition

In the framework of this WP, we participated to two major technology exhibition events:

1. The Very Large Volume Neutrino Telescopes Workshop (VLVnT 2018) which was held in Dubna, Russia, in October 2018 with an invited talk on KM3NeT Knowledge and Technology Transfer (2). Apart from the oral presentation on the subject, a dedicated desk with leaflets on the technological achievements and solutions developed by KM3NeT was present where interested participants of this Workshop could receive further information. These leaflets (in A5 format) formed the basis for the final layout of our brochures.

2. We participated in the Thessaloniki International Fair (TIF) for technology and innovation in September 2019. TIF is an annual international exhibition event officially opened by the country's prime minister. TIF is the most important exhibition in Greece focusing on promoting new technologies, innovative ideas and ambitious entrepreneurial ventures. It is housed in a centre with indoor exhibition areas of a total of 62000 m^2, distributed into a complex of 17 pavilions corresponding to different thematic entities.

The development of exhibition material (to support also the KM3NeT participation in future technology and innovation events) and the KM3NeT participation in TIF (KM3NeT booth, presentation material and infrastructure as well as the promotional material) were made possible through the funding provided by this project. In TIF, the KM3NeT kiosk was equipped with 2 large TV screens on which videos were launched showing the most impressive snapshots from the deployment of KM3NeT Detection Units (including also the short video discussed in Section 2 which was made particularly for this purpose); the posters providing information both on the physics goals and the current status of KM3NeT, as well as on the technical aspects (technical solutions and achievements) of the experiment; a Virtual Reality experience allowing visitors to "dive" to the abyssal depth of the Mediterranean sea and "observe" sea life as well as detection elements of the experiment (VR video developed by the University of Napoli, INFN) ; a projector and a laptop on which the slide show presentation of KM3NeT science and technology was launched; and the dummy digital optical module prepared for exhibition purposes. We have also used banners (courtesy of the Nikhef group) and brochures which have been prepared within the outreach working group (WP3) of the INFRADEV project aiming to introduce KM3NeT to the general public. KM3NeT souvenir pencils and wristbands were given to the visitors.

The event announcement in the NCSR Demokritos Institute website

KM3NeT souvenir pencils and wristbands

The exhibition lasted for a week. More than 500 visitors among which University students, academics and technology experts were introduced by our team to the KM3NeT physics objectives and technology. Representatives from the Greek General Secretariat for Research and Technology (GSRT) have also visited the KM3NeT kiosk. A video shooting was organized by the GSRT aiming to highlight the advancement of research and technology in Greece as well as European projects in which Greek research teams are participating. We took part in this video shooting presenting a short introduction to KM3NeT.

A view of the dummy digital optical module exhibited in the KM3NeT kiosk. On either side of the DOM, our technology leaflets and the outreach brochures.

A penetrator (used for powering the DOM and for data transfer) and a breakout box (used for branching out the power conductors and the fibre) are displayed next to the dummy digital optical module.

A lot of visitors tried the Virtual Reality experience. One can distinguish the KM3NeT detection elements (Digital Optical Modules – DOMs) floating in the sea (on the computer screen).

Visitors have shown great interest in KM3NeT science and technology.

Members of our team are discussing with University students.

Members of our team are discussing with University students.

Members of our team introducing KM3NeT to the public.

The material prepared to support our participation to the TIF is available and can be used to support future participations of KM3NeT in research and technology exhibitions as well as open days at all Universities members of the KM3NeT Collaboration. In particular, in terms of cost for future participations of KM3NeT in technology transfer events, posters and brochures would need to be re-printed using the existing source files since re-printing is fast and more cost effective than sending by mail. However, the dummy DOM prepared for exhibition purposes would need to be transported to the destination of the event.

5. References

1. *Letter of Intent for KM3NeT 2.0.* **Adrián-Martínez, S., et al.** 2016, Journal of Physics G: Nuclear and Particle Physics, Vol. 43 (8), p. 084001. arXiv:1601.07459 [astro-ph.IM]. DOI: 10.1088/0954-3899/43/8/084001.

2. *Knowledge and technology transfer in KM3NeT* **E. Tzamariudaki et al.** 2019, EPJ Web Conf. 207 (2019) 06001.