KM3NeT – INFRADEV – H2020 – 739560

Report on implementation of sustainable cooperation with other science communities

KM3NeT – INFRADEV GA DELIVERABLE: D6.6

Document identifier:	**KM3NeT-INFRADEV-WP6-D6.6**
Date:	**13/01/2020**
Work package:	**WP6**
Lead partner:	**UVEG**
Document status:	**Final**
Dissemination level:	**Public**
Document link:	

Abstract

Cooperation with other science communities is important to fully profit from an infrastructure such as KM3NeT. Three main domains can be identified for this: particle physics, multi-messenger astronomy and sea-science. Two specific working packages are devoted to the two latter topics (WP7 and WP8), so in this report we will mainly focus on the activities regarding the connections with the particle physics community and other more general.

I. COPYRIGHT NOTICE

II. DELIVERY SLIP

	Name	Partner/WP	Date
Author(s)	J. Zornoza, T. Thakore, R. Gozzini	UVEG / WP6	21/11/2019
Reviewed by	V. Elewyck	IB	
Approved by	PMB and KM3NeT IB		

III. DOCUMENT LOG

Issue	Date	Comment	Author/Partner
1.1	15/11/2019	Initial draft	J.D. Zornoza/UVEG
1.2	13/01/2020	Version after V. van Elewyck's comments	V. van Elewyk/APC, J.D. Zornoza/UVEG

IV. APPLICATON 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.

V. TERMINOLOGY

ARCA	=	Astroparticle Research with Cosmics in the Abyss (KM3NeT neutrino particle physics detector)
DUNE	=	Deep Underground Neutrino Experiment
GNN	=	Global Neutrino Network
IIHE	=	Interuniversity Institute for High Energies
ORCA	=	Oscillation Research with Cosmics in the Abyss (KM3NeT neutrino particle physics detector)
Super-K	=	Super-Kamiokande
T2K	=	Tokai to Kamioka
WG	=	Working group

VI. LIST OF FIGURES

None

VII. LIST OF TABLES

VIII. PROJECT SUMMARY

KM3NeT-INFRADEV

KM3NeT is a large Research Infrastructure that will consist of a network of deep-sea neutrino telescopes 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 (CSAs) 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 project is funded by the European Commission's Horizon 2020 framework and its objectives comprise, amongst others, the Work Package “KM3NeT in the Global Science Context”, with the objective to establish a sustainable cooperation of KM3NeT with adjacent science communities.

IX. EXECUTIVE SUMMARY

The KM3NeT neutrino telescope is currently under construction in the Mediterranean Sea. It will make cutting edge observations in neutrino oscillation physics, high energy neutrinos, dark matter and sea sciences. The primary goal of this working package is to strengthen the KM3NeT collaboration by organizing workshops, starting new working groups, and make external collaborators. This report describes the activities being carried out to implement a sustainable cooperation with other science communities and to expand the reach of KM3NeT.

Table of Contents

1. Introduction

The KM3NeT neutrino telescope is a next-generation detector that will open new science opportunities in particle physics, astronomy and other topics. It means a big step forward from the current ANTARES neutrino telescope, also in the Mediterranean Sea. KM3NeT comes after the success of ANTARES in proving that undersea neutrino telescopes are technically feasible. The main player in the field at this moment is IceCube, in the South Pole. Its large size (one cubic kilometre) has allowed this experiment important achievements, like detection of a cosmic diffuse flux [1] and the first source of high energy neutrinos [2,3].

KM3NeT will consist of two detectors: one dense array close to France, called ORCA, and another, larger and sparser array close to Italy, called ARCA. The main goal of ORCA configuration, given its low energy threshold (a few GeV), is to determine the neutrino mass ordering with a high statistical significance within a few years of runtime with atmospheric neutrinos. For ARCA, the main goal is the detection and characterization of high-energy cosmic neutrino fluxes, based on its large size. Beyond these main goals, there are several other important topics that will be addressed by KM3NeT. This includes the search for dark matter, the search for non-standard neutrino physics like Non-Standard Interactions (NSIs), sterile neutrinos, supernova neutrinos, etc. More information about the technical details and the scientific goals of KM3NeT can be found in the Letter of Intent of this experiment [4]. The deployment of both ORCA and ARCA started in 2016.

In order to accomplish the stated goals for KM3NeT physics program, several new challenges have to be addressed in areas such as: marine engineering, electronics, detector simulations, computing, physics sensitivity studies and statistical analyses. Many challenges in the aforementioned areas are shared by other experiments around the world. Accomplishment of many goals for KM3NeT depends on the outcome of other research programs in the particle and astroparticle physics communities. To this end, it is necessary for the KM3NeT scientists to have a strong presence in the discussions of these topics (conferences, workshops, etc.) and to collaborate with researchers from the global scientific community.

The actions undertaken in this respect can be classified in several categories: organization of conferences and workshops, organization of working groups, collaboration with researchers from other experiments and with theoreticians, attendance to conferences to show the potential of KM3NeT and inclusion of new institutes to KM3NeT.

2. Organization of conferences and workshops

In order to encourage and enhance the interactions of KM3NeT collaboration members with other scientists, several workshops have been organized in the framework of this work package.

Earth and Sea Science with KM3NeT (Athens, 4-6 December 2017)

https://indico.cern.ch/event/676718/

In this workshop, with more than 50 attendants, the KM3NeT project was presented to experts of the Earth and Sea Science community. The agenda included both scientific topics related to these fields and discussions about the technological needs and solutions for enabling KM3NeT as a multidisciplinary platform for these studies (cf. to Working Package 8 for more details).

Dark Ghosts 2018 (Brussels, 13-14 November 2018)

https://indico.iihe.ac.be/event/1199/

It gathered about 50 researchers working on projects related to the search for dark matter, including theoreticians and experimentalists from different collaborations. There were reviews of the status and potential of ANTARES and KM3NeT, among other items. The combined analysis of ANTARES and IceCube (and the potential for KM3NeT) was also discussed. Contacts to include ANTARES and future KM3NeT results in the nulike project [5] were started. Nulike is a software to include full event-level information in the likelihood calculations used by neutrino telescopes searching for dark matter.

H2020 Oscillation Workshop (HOW) (Valencia, 28-29 November 2018)

https://indico.ific.uv.es/event/3395/

This workshop gathered representatives of the neutrino oscillation community (60 participants), including experimentalists (T2K, DUNE, Super-K…) and theoreticians. The potential of KM3NeT was discussed in depth, together with the main challenges for measurements like the neutrino mass ordering. One of the outputs of this meeting, beyond the promotion of the KM3NeT project and the useful discussions, was to initiate contacts with the experts of the GENIE neutrino Monte Carlo generator, in order to invite them to IFIC within the pilot exchange program (see Section 3).

Town Hall KM3NeT Meeting (Marseilles, 17-19 December 2019)

https://indico.cern.ch/event/848390/overview

This meeting was organized mainly by the Working Package 7 on Multi-messenger Astronomy, with participation of the WP leader and several other members of the collaboration in the Scientific

Committee. It gathered the main players of the multi-messenger astronomy community, including experts on cosmic neutrinos, gamma rays, optical telescopes, radio-astronomers, etc.

These meetings have been good opportunities for announcing and describing the Pilot Ex-change Program described in Task 6.2 of this proposal (see the corresponding report, deliverable D6.5).

Very Large Volume Neutrino Telescope Workshop (VLVnT) (Valencia, 15-17 September 2020)

Finally, the IFIC group is organizing the next Very Large Volume Neutrino Telescope (VLVnT) workshop, which will take place in September 2020. This is one the largest meeting of the neutrino telescope community which is organized under the umbrella of the Global Neutrino Network, with an expected attendance of about one hundred people. Reviews of other related experiments will also be part of the program. Coupled to this workshop, there will be the Mediterranean and Antarctic Neutrino Telescope Symposium (MANTS), a closed meeting where members of IceCube, ANTARES and KM3NeT will discuss about the details of their analyses and common challenges.

3. Cooperation with researchers of other groups and theoreticians

3.1. Collaborations with experimental communities

The collaboration with other experimental teams is a great tool to: 1) improve scientific results, 2) harmonize analysis and results presentation, 3) increase the visibility of KM3NeT. A good example of this has been the analysis of combined data for the search of dark matter with IceCube, KM3NeT and ANTARES. As explained in deliverable 6.5, the pilot exchange program, and in particular the visit of Nadège Iovine (from the IceCube group at the IIHE in Brussels) has been instrumental in order to achieve these goals. This collaboration has allowed for the development of a common framework for combined searches, and it will be pursued, now that the machinery is readily available, for future update studies [6]. It has to be mentioned that other physics cases beyond the scope of this work package can also benefit from these combined searches. Neutrino point-like searches is also a good example of common studies to be continued, as a continuation of the already existing joint work by the ANTARES and IceCube collaborations.

Another example has been the joint studies with researchers of the Protvino accelerator facility, near Moscow, to explore the possibility of setting up a neutrino beam towards the ORCA detector (or its potential upgrade, called SuperORCA), which could allow testing the violation of CP in the neutrino sector. A Letter of Interest has been published together by the KM3NeT Collaboration and Protvino researchers [7].

3.2. Collaborations with theoretical groups

The stay of Prof. Costas Andreopoulos, Dr. Marco Roda and the PhD student Júlia Vidal-Tena at IFIC thanks to the pilot exchange program has set a working line related to the adaptation of the GENIE Monte Carlo generator to KM3NeT which will continue in the future. This is a very important output, since it will allow to incorporate the latest advances in the cross section systematics, which is critical for this kind of experiments. GENIE [8] is the most used Monte Carlo generator in neutrino experiments studying mass ordering, CP violation, etc.

Another collaboration has been set up with one of the main groups devoted to global neutrino fits. In these analyses, results of different experiments worldwide measuring neutrino oscillation parameters are combined in order to produce “global” constraints. We have collaborated with the group of Dr. P. Fernández de Salas (Stockholm University/IFIC) to include ANTARES results in such global fits [9]. Work

is ongoing to include an updated version of the ANTARES results in the next global fit of this group and once KM3NeT starts to provide data, its results will be also included in this global fit.

A fourth cooperation line that has been established concerns the work with experts on machine learning from several institutes: Roberto Ruiz de Austri (IFIC-CSIC/UV), Sydney Otten (Univ. of Amsterdam and Univ. of Nijmegen), Gianfranco Bertone (University of Amsterdam), Sasha Caron (Univ. of Nijmegen and Nikhef). A Memorandum of Understanding has been signed by the KM3NeT Collaboration and these experts in order to incorporate state-of-the-art techniques of the field of machine learning to the collaboration. The software produced under this agreement will be part of the software of KM3NeT. Work has started to improve the speed of simulation generation using auto-encoders. Future works will include the search for rare events and event classification issues.

3.3. Creation of working groups

One of the outputs of the discussions in the workshops mentioned above has been the creation of a working subgroup of KM3NeT, with contributions of external experts, for exploring the status and needs related to KM3NeT concerning the effect of systematic uncertainties in neutrino-nucleon interaction cross-sections.
A collaboration with geophysicists of the Institut de Physique du Globe de Paris (IPGP), specialists in the structure and dynamics of the inner Earth, has also been initiated by the IN2P3 APC group. A PhD student coadvised by V. Van Elewyck (APC) and E. Kaminski performed the first study of the potential of ORCA for Earth tomography using atmospheric neutrino oscillations; and the collaboration is expected to develop as a new student has just started his PhD on further developments of neutrino tomography (also with ARCA).

4. KM3NeT in Conferences

In order to gather interest of researchers of related fields (both experimentalists and theoreticians) and potential new members, it is important to present status of KM3NeT and its scientific potential. In these forums, there is also the opportunity of informal discussions to support this aim. As a part of this effort, we can mention, as examples, the attendance funded by this H2020 project of members of our group to the following conferences: Neutrino 2018 (London), SUSY 2018 (Barcelona), Gemma 2018 (Lecce), CPAN Days 2016 (Salamanca), Magic DM Meeting (Barcelona), WIN 2019 (Bari), ICRC 2019 (Madison), AstroMatera 2019 (Matera), Baikal Conference 2019 (Dubna), PPNT 2019 (Uppsala). Regarding the KM3NeT the collaboration as a whole, a total of 200 contributions to international conferences have been made.

5. Memoranda of Understanding

As mentioned in Section 3, a Memorandum of Understanding (MoU) was signed in the context of the collaboration with the external experts on machine learning. There are also discussions on-going related to the Working Package 7 on multi-messenger astronomy, since they are typically needed for sharing alerts or combining data (see also Deliverable 7.1 of this project).

6. Expansion of KM3NeT

The KM3NeT collaboration has expanded during the years of the project. There are two kinds of membership in the project: as a “Full Member” or as a “Observer”, the latter with less rights/obligations, but often a first step towards being full member. Several of these new groups are of fields like radio-astronomy, optical astronomy or sea sciences. Table 1 shows the list of new member in KM3NeT during 2017-2019.

Date	Institute	Status
2/2017	SUBATECH-Nantes, France	Full member
2/2017	Uni. of Marrakesh, Morocco	Full member
2/2017	Univ. of Johannesburg, South Africa	Observer
2/2017	Univ. of Tbilisi, Georgia	Observer
10/2017	Univ. of Johannesburg, South Africa	Full member
10/2017	Laboratoire d' Astrophysique de Marseille, France	Observer
2/2018	Uni. of Tbilisi, Georgia	Full member
5/2018	Western Sydney University, Australia	Full member
10/2018	Curtin University, Parth, Australia	Full member
2/2019	North western University, Australia	Observer
2/2019	ITEP, Russia	Observer
2/2019	Yachay Tech, Equador	Observer
6/2019	Univ. of Witswaterand, South Africa	Full member
6/2019	Univ. of Montpellier	Full member
10/2019	Sun Yat-Sen University, China	Observer
10/2019	North Western University, South Africa	Full member
10/2019	Instituto Español de Oceanografía, Valencia, Spain	Full member

Table 1: List of new institutes in the KM3NeT collaboration during 2017-2019

X. REFERENCES

[1] Evidence for High-Energy Extraterrestrial Neutrinos at the IceCube Detector
IceCube Collaboration: M. G. Aartsen et al., Science 342 (2013) 1242856, 22 November 2013; DOI: 10.1126/science.1242856

[2] Multimessenger observations of a flaring blazar coincident with high-energy neutrino IceCube-170922A, The IceCube, Fermi-LAT, MAGIC, AGILE, ASAS-SN, HAWC, H.E.S.S, INTEGRAL, Kanata, Kiso, Kapteyn, Liverpool telescope, Subaru, Swift/NuSTAR, VERITAS, and VLA/17B-403 teams, Science 361, eaat1378 (2018). DOI:10.1126/science.aat1378.

[3] Neutrino emission from the direction of the blazar TXS 0506+056 prior to the IceCube-170922A alert," IceCube Collaboration: M.G. Aartsen et al. Science 361, 147-151 (2018). DOI:10.1126/science.aat2890.

[4] 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.

[5] Use of event-level neutrino telescope data in global fits for theories of new physics, Scott, Savage, Edsjö & IceCube Collaboration 2012, JCAP 11:057

[6] Searches for dark matter with the ANTARES and KM3NeT neutrino telescopes, S.R. Gozzini and J.D. Zornoza Gómez, PoS(ICRC2019)552

[7] Letter of Interest for a Neutrino Beam from Protvino to KM3NeT/ORCA, A.V. Akindinov et al. Eur.Phys.J. C79 (2019) no.9, 758

[8] The GENIE Neutrino Monte Carlo Generator, C. Andreopoulos et. al., Nucl.Instrum.Meth. A614 (2010) 87-104

[9] Status of neutrino oscillations 2018: 3σ hint for normal mass ordering and improved CP sensitivity, Physics Letters B, Volume 782, 10 July 2018,