# KM3NeT INFRADEV – H2020 – 739560

# KM3NeT report on expert groups established, meetings held and agreements in preparation

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Abstract

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 starting new working groups, organizing workshops and make external collaborators. This report describes the activities performed to accomplished this goal and plans for the following year.

# I. Copyright notice



# II. Delivery slip

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# IV. Application area

This document is a deliverable for the grant agreement 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)
ORCA = Oscillation Research with Cosmics in the Abyss (KM3NeT neutrino particle physics detector)
WG = Working group
DUNE = Deep Underground Neutrino Experiment
Super-K = Super-Kamiokande
Hyper-K = Hyper-Kamiokande
T2K = Tokai to Kamioka
NOνA = NuMI Off-Axis $\nu_e$ Appearance
JUNO = Jiangmen Underground Neutrino Observatory
IIHE = Interuniversity Institute for High Energies
GNN = Global Neutrino Network

# VI. List of figures

none

# VII. List of tables

none

# 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 starting new working groups, organizing workshops and make external collaborators. This report describes the activities performed to accomplish this goal and plans for the following year.

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# 1 Introduction

The Kilometer Cube Neutrino Telescope (KM3NeT) is a next generation neutrino telescope built on the proven technologies of the ANTARES telescope. It will be deployed at two sites in the Mediterranean Sea. The first site is located off the coast of France, will house the low energy detector configuration, called ORCA. The second site is located off the coast of Italy and will house the high energy detector configuration, called ARCA.

The ORCA configuration aims to determine the neutrino mass hierarchy with a 3σ statistical significance with 3 years of runtime with atmospheric neutrinos. It will also make precision measurements of the atmospheric oscillation parameters and search for non-standard physics scenarios, such as Non-Standard Interactions (NSIs), sterile neutrinos, Lorentz Invariance Violation and quantum decoherence. ORCA will be a complementary neutrino experiment to the forthcoming accelerator experiments DUNE, Hyper-K as well as the reactor experiment JUNO. ARCA will observe very high-energy neutrinos from astrophysical sources such as supernovae, gamma ray bursts and blazars. It will also perform indirect searches for dark matter. It will be complementary to other neutrino telescopes IceCube and Baikal. The technical details of the detector and main physics goal can be found in the KM3NeT 2.0 Letter of Intent [1]. The deployment of both ORCA and ARCA has begun in 2018, and the Phase-2 is expected to be completed by 2021.

Since KM3NeT-ORCA is a new oscillation experiment, the collaboration needs to develop expertise on several new frontiers. As the detectors are already under construction, it is necessary to expand the KM3NeT collaboration and engage into discussions with broad neutrino oscillation and astro-particle physics communities.

Towards the ORCA oscillation physics program, cooperation between detector simulation experts, oscillation phenomenologists, neutrino-nucleon theoretical model developers, neutrino event generator community is foreseen. Under the current working package, a working group on neutrino cross section modelling is proposed. To promote KM3NeT as an upcoming neutrino telescope and to initiate cooperation with a broader community, two workshops were organized in 2018. Several possibilities for external collaborations have been identified.

For ARCA physics program, coordination with model builders of astrophysical point neutrino sources, dark matter model builders, combined analysis with other experiments has started. One of the major aims of ARCA is the detection of astrophysical neutrino sources. To this extent a collaboration between the KM3NeT group in Genova and the INAF group in Milan has

been established. INAF is a national Italian Institute dedicated to astrophysics. The group of Milan includes researchers who have relevant experience on modelling the emission mechanism from AGN, in particular on the evaluation of high-energy neutrino fluxes. Starting from these evaluations and from the ARCA configuration it is possible to estimate the expected significance of the most promising sources in a given time interval in KM3NeT. For the moment, various face to face and skype meetings have allowed to define the tasks to be developed. In particular the INAF group has provided the neutrino spectra from Flat Spectra Radio Quasars (FSRQ), a promising candidate for intense neutrino emission, while the KM3NeT group is going to reconstruct how these neutrino events are seen in the detector.

# 2 Proposed Working Group

Until now, uncertainties in neutrino-nucleon cross-section modelling have not been taken into account in the sensitivity analyses for ORCA. The neutrino mass hierarchy sensitivity in ORCA arises primarily in the true neutrino energy range [4,10] GeV, where Quasi-Elastic (QE), Resonance (RES) interactions contribute 30-40% events in addition to the Deep-Inelastic (DIS) interaction. The theoretical modelling of neutrino interactions in this range is challenging. Also, until now there are only a few experimental measurements available to guide theoretical developments. The interaction uncertainties are all the more important for extensions proposed for ORCA, such as SuperORCA [3] and Protvino-to-ORCA (P2O) [4], which intend to measure the CP violating phase in the PMNS matrix. Uncertainties of hadronization model parameters are also crucial to establish a robust analysis for ORCA.

Presently, there is a lack of expertise of interaction modelling and relevant systematics in the ORCA working group. However, several members have expressed interest towards incorporation of cross-section systematics in oscillation analyses. The purpose of the proposed working group on cross-section is to create a dedicated space for such studies and make focussed efforts. Similar working groups in other oscillation experiments such as T2K and NO$\nu$A play a crucial role in their oscillation analyses. This involves understanding the available literature, and identifying dominant sources of systematics; implementation of interaction models in neutrino generators such as GENIE [5] and NuWro [6], validity of modelling, fine tuning of model parameters for ORCA will be addressed by this WG; analysis algorithms to propagate the uncertainties from the event generator. To guide all of these activities, it is desirable to have a theoretical model developer be included in this WG. Such a member may come through an exchange program under consideration in the Task 6.2. In the long term, this group will have an in-house expertise on interaction systematics.

# 3 Workshops Organized

Two workshops were planned in 2018. The first meeting was held at IIHE, Brussels on November 13-14, focussed on dark matter. The second meeting was held at IFIC, Valencia on November 28-29, 2018, focussed on neutrino oscillations. Both workshops had a total participation of more than 50 people each. Both workshops were planned jointly by IFIC and GNN.

Both of the workshops were announced in the KM3NeT/ANTARES mailing lists as well as in the collaboration meeting held at Caserta in October 2018. The workshops were also widely advertised in scientific communities of relevance.

1. Dark Ghosts 2018
   Web page : http://indico.iihe.ac.be/indico/conferenceDisplay.py?confId=1199

   This workshop was the second edition of a Dark Ghosts Workshop held in Valencia in 2014. It was planned in coordination with the group of IceCube in IIHE, Brussels. The workshop covered topics on dark matter theory/phenomenology, indirect searches by neutrino telescopes (IceCube, ANTARES/KM3NeT, Baikal), gamma ray observations, impact of particle and astrophysics uncertainties on dark matter searches. There were rich discussions among the experts, which set the basis for further collaborations in topics like the combined analyses by different neutrino telescopes, the inclusion of the experimental data in global analyses or improvements in software tools.

2. H2020 - Oscillation Physics Workshop 2018
   Web page : https://indico.ific.uv.es/event/3395/

   This workshop covered three broad topics, (i) neutrino theory/phenomenology and global data fits, (ii) neutrino-nucleon cross-section modelling and uncertainties, (iii) neutrino oscillation experiments. There was a good participation from all of the above diverse community. An effort was made by the ORCA members to promote it as a next major oscillation experiment in complementarity to other major upcoming oscillation experiments such as DUNE, Hyper-K and JUNO. The need to push cross section systematics study in atmospheric oscillation experiments was recognized. An internal Face-to-Face ORCA oscillation working group meeting was planned in the same week at IFIC, in order to facilitate easy participation by ORCA working group members.

In addition to discussions of the scientific topics of interest, another major goal was to promote the H2020 science exchange program and identify people who may be interested to participate

in it. In each of the workshops, a session was devoted to explain the KM3NeT-InfraDev project and to promote the scientist exchange program.

The overall impression of the output of these workshops was very positive and several of the attendants explicitly encouraged us to organize new editions on these topics.

There are plans to organize two more workshops in the year 2019. They may be focussed on sea sciences and multi-messenger astronomy, in coordination with the corresponding working packages in this project (WP8 and WP7, respectively).

# 4 Other Scientific Exchanges

The neutrino phenomenology group at IFIC has expressed a strong interest in ORCA oscillation sensitivity studies. In collaboration with an ORCA WG member (T. Thakore, a postdoc hired by the KM3NeT-InfraDev project), they have performed a sensitivity analysis to neutrino decay with ORCA. This work is available as a preprint [7] and is currently under publication review. The IFIC phenomenology group is continuing to help with other ORCA analyses such as Non-Standard Interactions and sterile neutrinos.

Discussion has also started with members of neutrino interaction modelling community to start a study on cross-section systematics for ORCA analyses.

# 5 Proposed Collaborations

1. As mentioned earlier, there is a strong motivation to start a cross-section systematics study for ORCA. Towards this, a collaboration between theoreticians as IFIC, GENIE neutrino generator and ORCA WG member is proposed. Due to a shortage of human resources, the neutrino event generator community encourages the experiments to get involved in interaction model developments in the generator codes. An MoU has already been established between the Super-K and KM3NeT collaborations to share the NEUT event generator code.
2. The developer of the atmospheric neutrino flux systematics package MCEq has expressed interest to be affiliated with KM3NeT and help incorporate flux systematics in KM3NeT analyses.

3. The main analyser of the group at IIHE working together with the IFIC group in the combined analysis of dark matter with IceCube/ANTARS/KM3NeT could visit the IFIC group to advance in this work.

The above proposed collaborations may be realized via the pilot exchange program described in Task D6.2.

# 6 References


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