Demonstrator on the material prepared for the participation of KM3NeT in technology exhibitions. This material comprises two posters and a power point presentation to be used for the participation of KM3NeT to one or more technology exhibitions.
1. Posters

**KM3NeT: A Neutrino Telescope in the Mediterranean sea opening a new window on our universe**

**The Science case**

**SCIENTIFIC CHALLENGE**

**ARCA: Astroparticle Research with Cosmics in the Abyss**

**Exploring the High Energy Universe**

- Cosmic Rays
- Neutrinos
- Photons
- Gravitational Waves

- The wealth of information about the universe comes mostly from electromagnetic radiation (ranging from radio waves to gamma rays) and from cosmic rays (protons and nuclei) produced and accelerated by astrophysical objects (cosmic accelerators).
- In a similar way to the production of photons, cosmic accelerators are expected to produce neutrinos.

- Cosmic Rays: charged particles - protons/nuclei
- Photons (q.v. neutrals and photons) absorbed on dust and radiation
- Neutrinos: neutral, weakly interacting elementary particles - propagate almost undisturbed through the universe from their production sites to the Earth.

- Neutrinos are ideal cosmic messengers:
  - propagate directly from their sources to the Earth.
  - carrying information on the energy distribution of their producing astrophysical objects.
  - the mechanisms which accelerate cosmic rays.

**ORCA: Oscillation Research with Cosmics in the Abyss**

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

- During the past two decades, important progress has been made on determining the fundamental properties of neutrinos. A variety of experiments have provided evidence for neutrino oscillations implying the existence of non-zero neutrino masses, a major milestone for elementary particle physics.
- Oscillation experiments provide measurements of the square mass splittings, but are not sensitive to the absolute values of neutrino masses.
- Recently, a sizeable contribution of electron-neutrinos to the third neutrino mass eigenstate has been reported by several experiments.
- This motivates 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.

**DETECTION PRINCIPLE**

- Neutrino interacts in the vicinity of the telescope.
- In water, relativistic charged 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.

- Density of optical sensors determines energy threshold.
- Deep sea water offers excellent discriminator due to low scattering.

**The KM3NeT Collaboration**

- > 50 institutes from 12 countries
- Distributed research infrastructure
- Single Collaboration, Technology & Management
- Multi-disciplinary research infrastructure

- Oceangraphy
- Geophysics
- Biology
- Monitoring of environmental processes
- Natural hazards
- Climate change
- Ecosystems

**Schematic view of the KM3NeT detector**

**EVENT SIGNATURES**

- Expected for the full detector (MC simulation)

**DOMs of the Detection Units deployed DOMs after DU unbinding**

- Event recorded with the first 2 ARCA Detection Units deployed.
- Event recorded with the 1st ORCA Detection Unit removed.

- Track
- Shower
KM3NeT: A Neutrino Telescope in the Mediterranean sea opening a new window on our universe

**TECHNOLOGICAL CHALLENGE**

**Requirements**
- 15 years operation
- High pressure 300 bar
- 1 ms timing
- 120 km optical fiber

**Challenges**
- Reliability & long term stability
- Demanding operating conditions
- Precision & Quality
- Optical data

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**ELECTRONICS**

- CLB: Xilinx Virtex-7 FPGA is the core of the board, used to measure the arrival time and the pulse width of the 31 PMT discriminated signals with time resolution.
- OmegaNet: Precision Time Protocol is used to implement the line synchronization of all PMTs and all the DOMs of the detector and transfer data to shore station.

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**THE DIGITAL OPTICAL MODULE (DOM)**

**Components**
- 2 Neutrons 76mm glass hemisphere
- Cooling mechanism
- Power Board
- Custom Logic Board (CLB)
- Pressure gauge
- Temperature LED
- 3 Octopus boards
- Prisma optics sensor
- PMT support structure (20 printed)
- 2 x 7 PMTs + reflector rings
- Fibre tray
- Optic gel
- Titanium changer for data and power

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**Data Acquisition – Datastream from the DOM**

Electrical cable driver/multiplexing stages (primary and secondary excitation boxes)

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**INSTALLATION METHOD**

**Launcher of Optical Modules**
- Rapid deployment
- Autonomous unfurling
- Multiple DUs per sea campaign
- Easy recovery - Floats to the surface for recycling

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Installation of the 1st ORCA DU

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A mechanical system activated by a ROV triggers the unfurling of the DU
2. Presentation

**KM3NeT**
The Neutrino Telescope in the Mediterranean sea

**SCIENCE TECHNOLOGY INDUSTRY**

**SCIENTIFIC CHALLENGE**
ARCA: Astroparticle Research with Cosmics in the Abyss

Exploring the High Energy Universe

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 Cosmic in the Abyss

- 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.

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**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

> 40 Institutes from 12 countries

Oscillation Research with Cosmics in the Abyss
Low-energy studies of atmospheric neutrinos

Astroparticle Research with Cosmics in the Abyss
High-energy neutrino astrophysics

TECHNOLOGICAL CHALLENGE

Requirements
15 years operation
High pressure 350 bar
1-ns timing
100 km optical fiber

Challenges
Reliability, long term stability
Demanding operating conditions
Precision and Quality
Optical data
The Digital Optical Module

- Glass sphere
- Cooling system
- Power Board + CIB
- Pressure gauge
- Naphthenate
- Octopus Boards
- Acoustic screen
- PMT support structure (3D printed)
- PMTs + reflector rings

High Statistic 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 5 input 70 outputs

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 (< $100C) 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: ~500mW

Sensor with digital readout:
- Internal or external clock signal
- Output formats flexible through integrated FPGA
- Existing firmware ALS/ERU readout for “plug and play” with standard digital audio devices
- Low power: ~500mW

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

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

Data Acquisition - Datastream from the DOM

DOM
Optical DEM pulses are converted to IP (transmit stage) and 10Gbps packets to fiber

Continuous data stream from PMTs is converted into 8 Giga bits and PMT1 (or -N) pulses
All data for a specific detector (N) may be collected by four stations

Signals are transferred into DAQ modules and processed in local stations

Electro-optical cable
Other multiplexing stages (primary and secondary Junction Boxes)

Same modules exist (Photo-Wavelength Selection/Multiplexing)

Share DMQ (Photo-Wavelength Selection Multiplexing)

DMQ  (Photo-Wavelength Selection Multiplexing)
Share data across DMQs (primary and secondary stages)

Share stations

On – share switching infrastructure and data, all stations

Share data across DMQs (primary and secondary stages)

Trigger form basis for correlated hits

From other DOMs

From other DOMs

From other DOMs
KM3NeT: The Neutrino Telescope in the Mediterranean Sea

EVENT SIGNATURES

Expected for the full detector (MC simulation)

- track
- shower

Two characteristic event topologies:
- tracks: muons emitting light as they travel
- linear
- cascades: point-like light emission from electromagnetic and hadronic particle showers
- spherical

From the first detection unit deployed (real event)
The KM3 Underwater Neutrino Telescope

**SCIENCE**

- Neutrinos
  - as messengers to explore the High Energy Universe
  - Cosmic rays
  - Photons
  - Gravitational Waves

**TECHNOLOGY & INNOVATION**

**INDUSTRY**