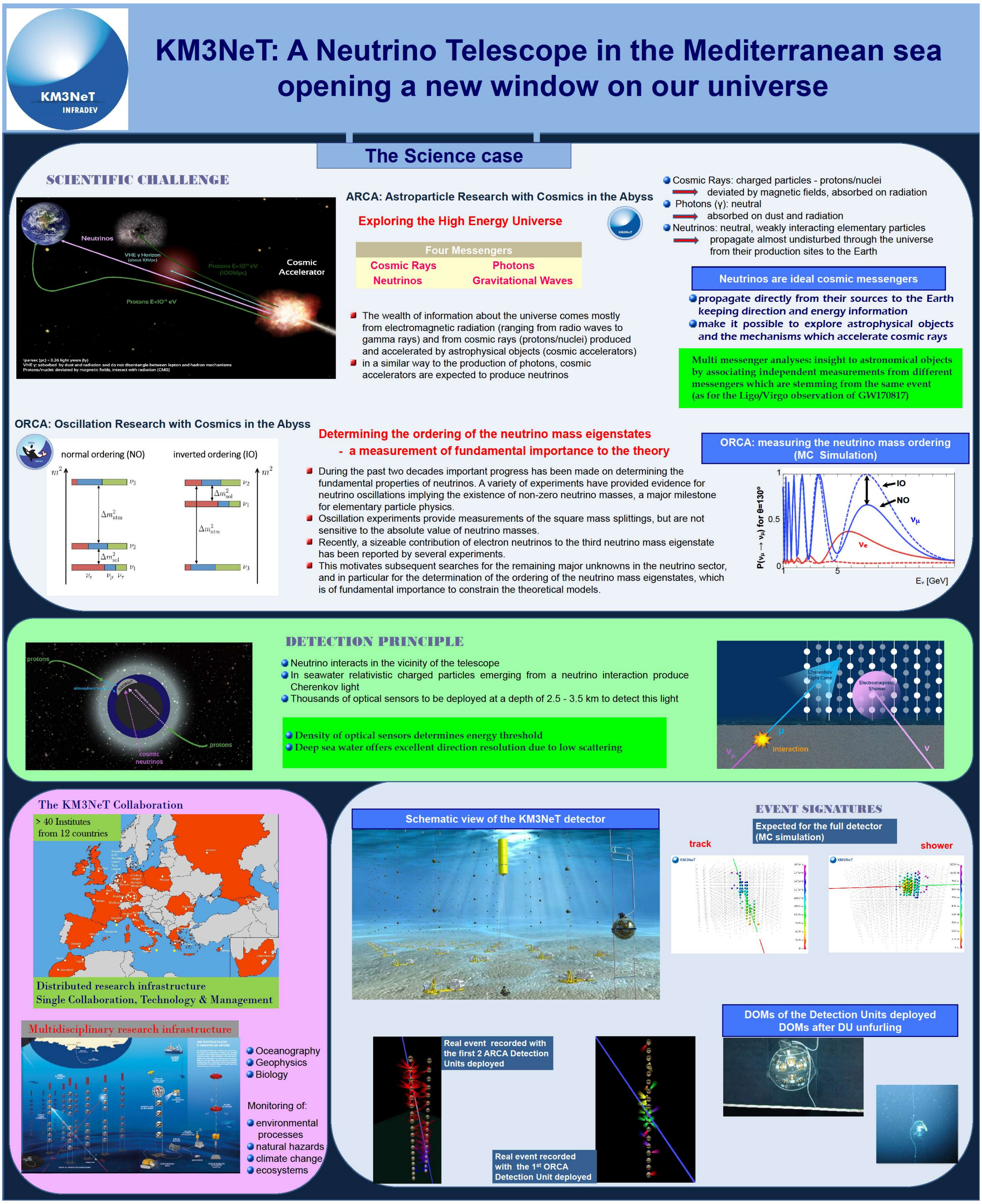
KM3NeT INFRADEV – H2020 – 739560

KM3NeT INFRADEV GA DELIVERABLE: D9.1

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 INFRADEV
KM3NeT: A Neutrino Telescope in the Mediterranean sea opening a new window on our universe
The Science case
SCIENTIFIC CHALLENGE
Neutrinos
VHE γ Horizon (about 10Mpc)
Cosmic Accelerator
Protons E<10^19 eV
ARCA: Astroparticle Research with Cosmics in the Abyss
Exploring the High Energy Universe
Four Messengers
Cosmic Rays
Photons
Neutrinos
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/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
deviated by magnetic fields, absorbed on radiation
Photons (γ): neutral
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 keeping direction and energy information
make it possible to explore astrophysical objects and the mechanisms which accelerate cosmic rays
Multi messenger analyses: insight to astronomical objects by associating independent measurements from different messengers which are stemming from the same event (as for the Ligo/Virgo observation of GW170817)
ORCA: Oscillation Research with Cosmics in the Abyss
normal ordering (NO)
inverted ordering (IO)
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 value 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.
ORCA: measuring the neutrino mass ordering (MC Simulation)
IO
NO
P(νμ → νμ) for θ=130°
Eν [GeV]
DETECTION PRINCIPLE
protons
cosmic neutrinos
Neutrino interacts in the vicinity of the telescope
In seawater 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 direction resolution due to low scattering
Electromagnetic Shower
interaction
The KM3NeT Collaboration
> 40 Institutes from 12 countries
Distributed research infrastructure
Single Collaboration, Technology & Management
Multidisciplinary research infrastructure
Oceanography
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)
track
shower
DOMs of the Detection Units deployed
DOMs after DU unfurling
Real event recorded with the first 2 ARCA Detection Units deployed
Real event recorded with the 1st ORCA Detection Unit deployed

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

The Technology

TECHNOLOGICAL CHALLENGE

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

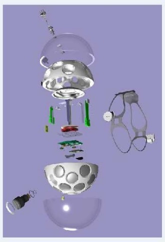
KM3NeT block

115 Detection Units (DUs)
18 DOMs / DU
31 PMTs / DOM

The Digital Optical Module (DOM)

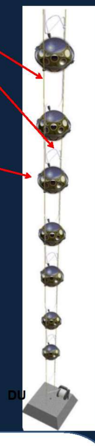
Components

- 2 Nautilus Vitrovex glass hemispheres
- Cooling mushroom
- Power Board
- Central Logic Board (CLB)
- Pressure gauge
- Nanobeacon LED
- 2 Octopus Boards
- Piezo acoustic sensor
- PMT support structure (3D printed)
- 31 x 3" PMTs + reflector rings
- 31 Base Boards
- Titanium penetrator for data and power
- Fibre tray
- Optical gel
- Titanium collar

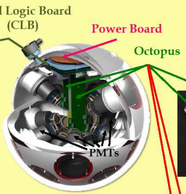


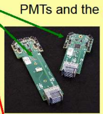
- Uniform angular coverage
- Directional information
- Digital photon counting
- Wide angle of view
- Reduced ageing

2 dyneema ropes
Oil filled PVC tube



ELECTRONICS

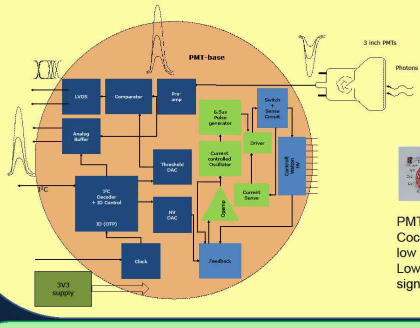




Connected to the CLB and to the PMTs and the piezo element. The power and the I^2C bus are delivered from the CLB to the Octopus board which distributes the power, clock enable and I^2C communication to the PMTs and piezo element.

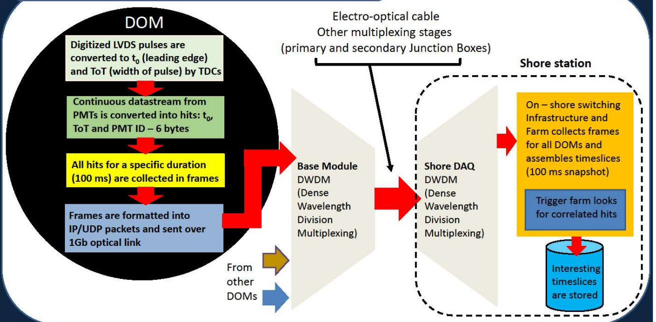
CLB: Xilinx Kintex-7 FPGA is the core of the board, used to measure the arrival time and the pulse width of the 31 PMT discriminated signals with 1ns resolution

White Rabbit Precision Time Protocol is used to implement 1ns time synchronization of all PMTs and all the DOMs of the detector and transfer data to shore station



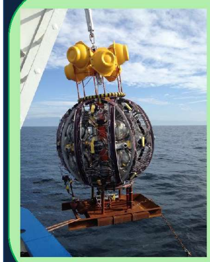
PMT high voltage base: Cockroft-Walton – Very low power consumption, Low-voltage differential signaling (LVDS)

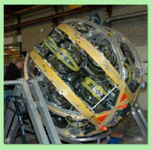
Data AcQuisition – Datastream from the DOM



Lightweight secure Web interface library

INSTALLATION METHOD





Launcher of Optical Modules

- Rapid deployment
- Autonomous unfurling
- Multiple DUs per sea campaign
- Easy recovery - Floats to the surface for recycling

Installation of the 1st ORCA DU

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

DU unfurling

2. Presentation

KM3NeT
INFRADEV

KM3NeT

The Neutrino Telescope in the Mediterranean sea

SCIENCE

TECHNOLOGY

INDUSTRY

SCIENTIFIC CHALLENGE

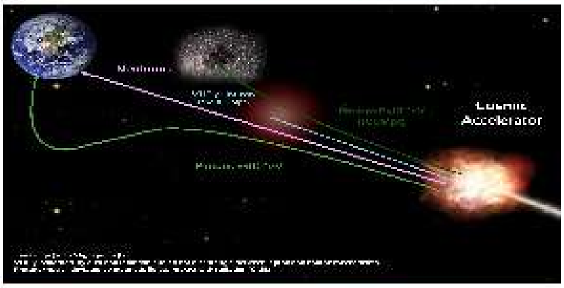
ARCA: Astroparticle Research with Cosmics in the Abyss

Exploring the High Energy Universe

Four Messengers	
Cosmic rays	Photons
Neutrinos	Gravitational Waves

neutrinos

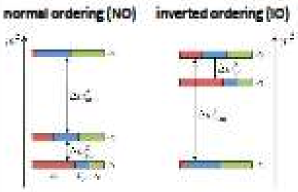
- elementary particles that propagate directly from their sources to the Earth
- ideal cosmic messengers
- make it possible to explore astrophysical objects and the mechanisms which accelerate cosmic rays



SCIENTIFIC CHALLENGE

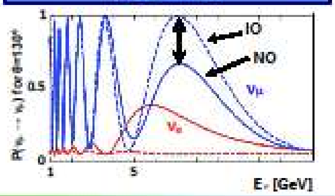
Determining the ordering of the neutrino mass eigenstates
- a measurement of fundamental importance to the theory

ORCA : Oscillation Research with Cosmics in the Abyss



- 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.

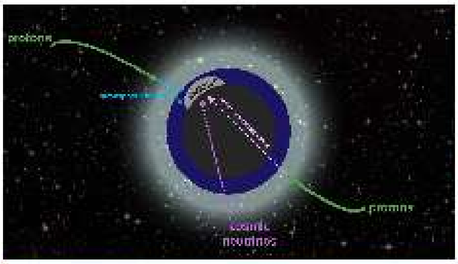
ORCA: measuring the neutrino mass ordering (MC Simulation)

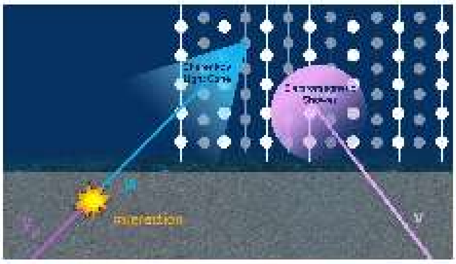


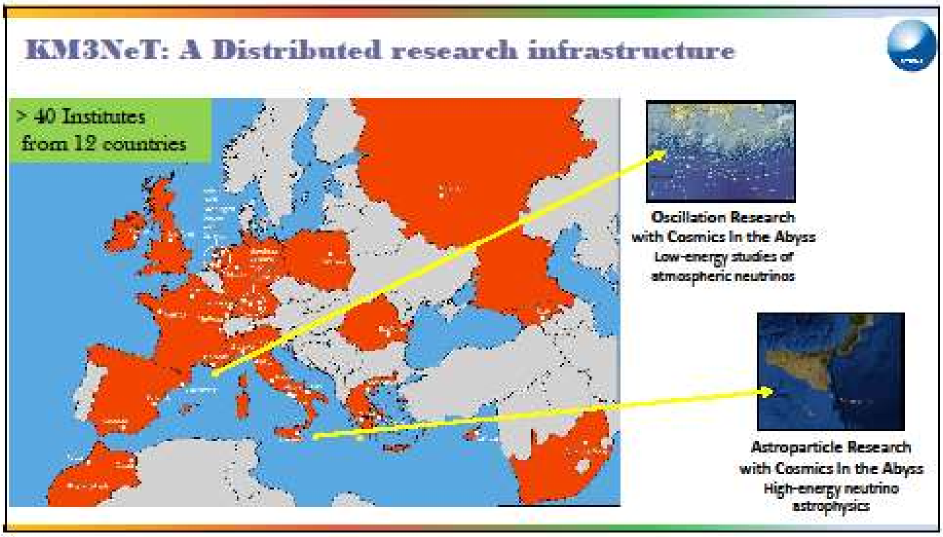
KM3NeT: the next generation neutrino telescope

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



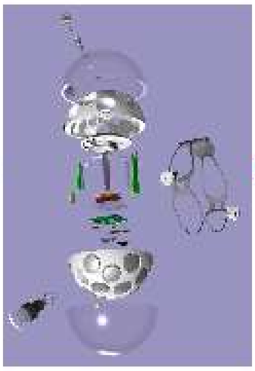



KM3NeT: A Distributed research infrastructure
> 40 Institutes
from 12 countries
Oscillation Research
with Cosmics In the Abyss
Low-energy studies of
atmospheric neutrinos
Astroparticle Research
with Cosmics In the Abyss
High-energy neutrino
astrophysics


TECHNOLOGICAL
CHALLENGE
Requirements
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
Oil filled cables
Digital Optical Module

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



High Statistic PMT Testing Facility

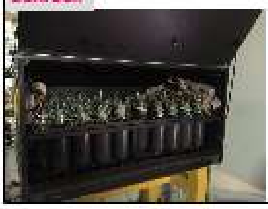
PMT parameters: dark counts, transit time, transit time spread, spurious pulses

Dark Box

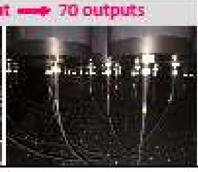
- Black wooden box: 120 cm 88 cm 58 cm
- 2 removable trays with 31 PMT holders each
- Two complete KM3NeT DOM electronics
- Allow simultaneous characterization of 62 3'' PMTs

PMT tray equipped with cable extensions and removable connectors

Dark box



Optical splitter   1 input ⟶ 70 outputs



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

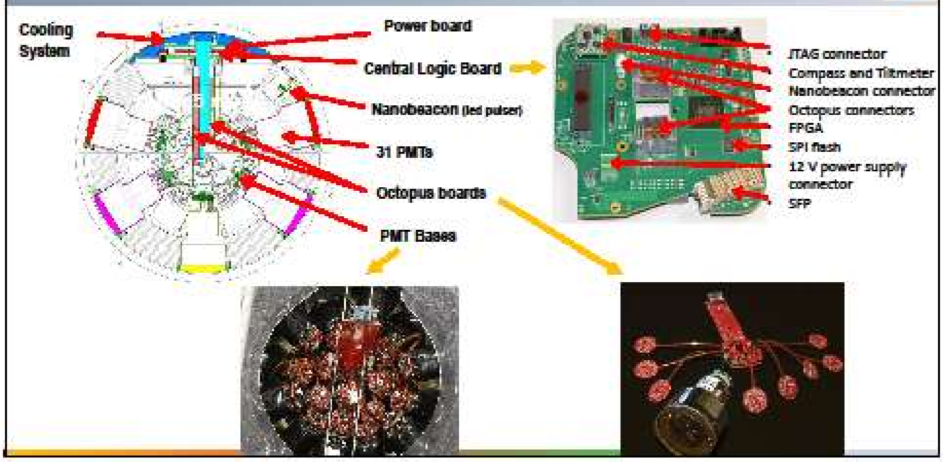
Sensor with analog readout

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

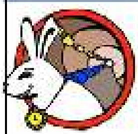
Sensor with digital readout

- 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

Electronics Boards in the KM3NeT-DOM



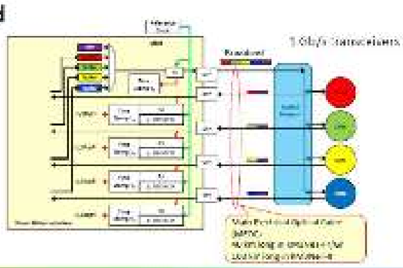
Time Synchronization and Data Transfer



White Rabbit optical network:

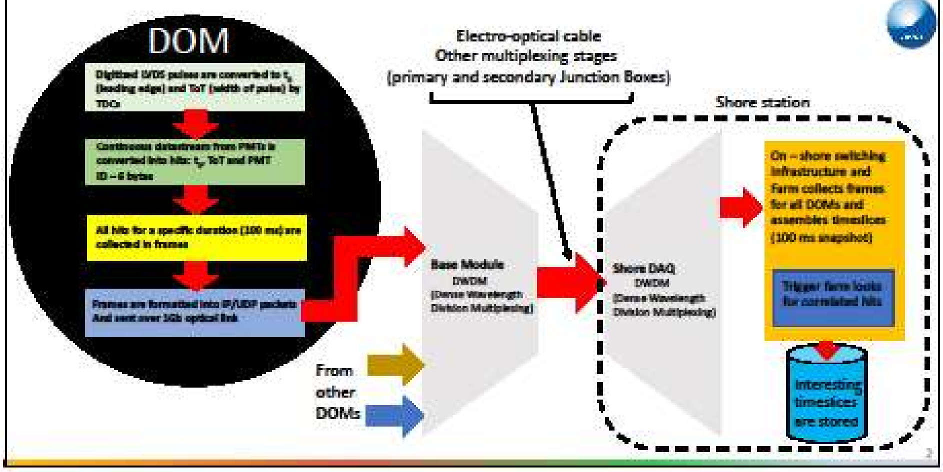
- Ethernet
- + Determinism & Reliability
- + High-Accuracy Synchronization

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

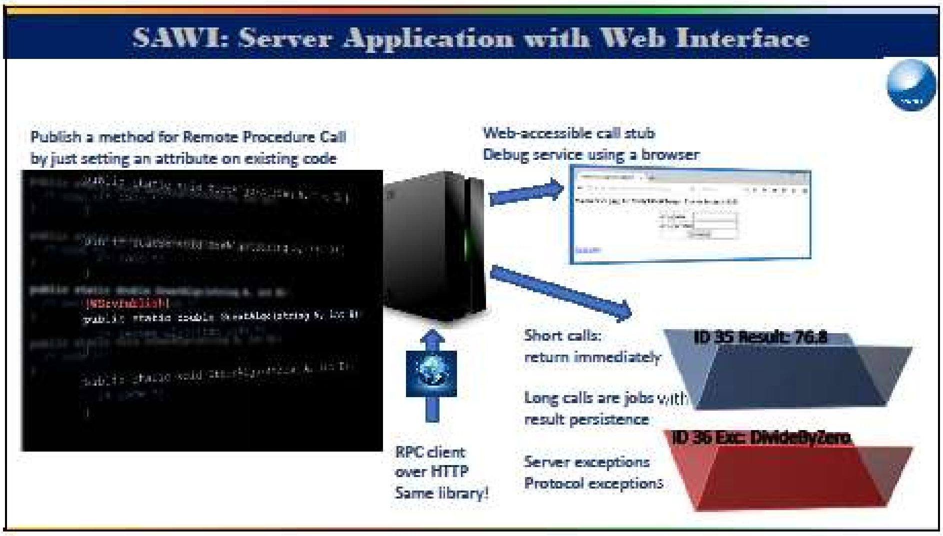


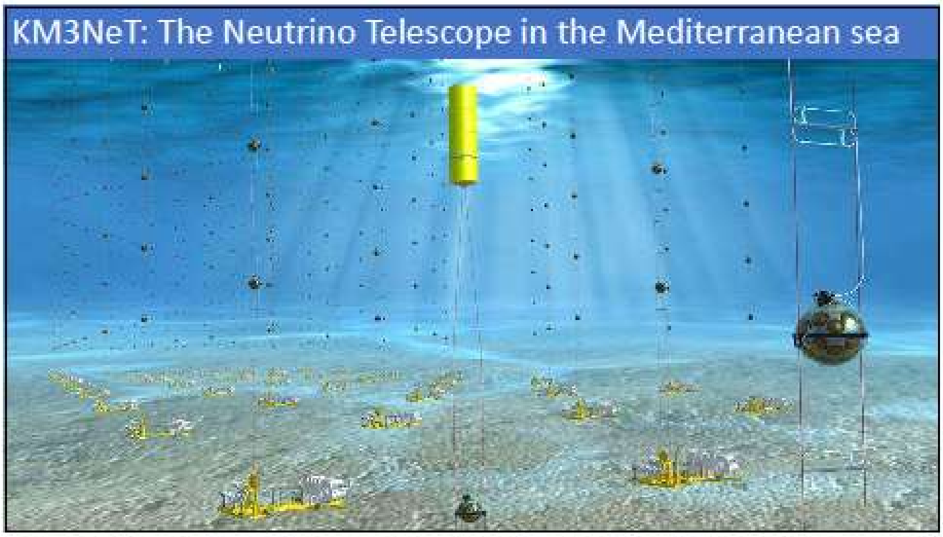
KM3NeT: Development of specific software to implement the Broadcast White Rabbit

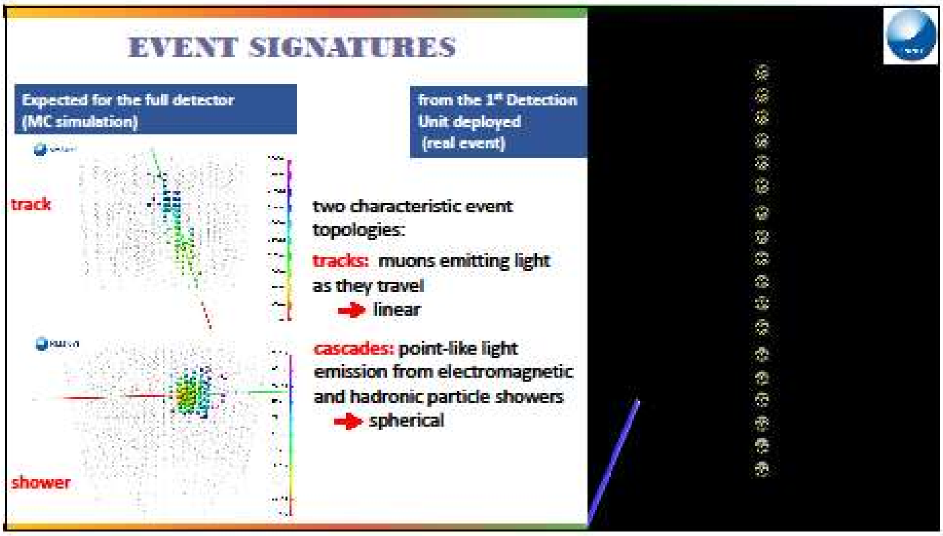
Data AcQuisition – Datastream from the DOM




Lightweight secure Web interface library
HTTP header control
Light (36 KB)
Binary files
AJAX/JSON
.NET/Mono
Protection
SSL/TLS
No constraints
on CPU, memory
usage, disk, DB,
libraries, etc.
Web server
Chunked transfers
REST-like interface
Session tracking
File upload
Easy development and deployment
Just override one of these three methods
to have a working Web application
Start the program and that's all
Web server core


SAWI: Server Application with Web Interface
Publish a method for Remote Procedure Call
by just setting an attribute on existing 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
ID 35 Result: 76.8
ID 36 Exc: DivideByZero
RPC client
over HTTP
Same library!


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)
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

The KM3 Underwater Neutrino Telescope
SCIENCE
TECHNOLOGY &
INNOVATION
Neutrinos
as messengers to explore
the High Energy Universe
associate with
Cosmic rays
Photons
Gravitational
Waves
INDUSTRY