The KM3NeT Neutrino Observatory:

opportunities for Latin American collaborators

Prof. Dr. Harold Yepes Ramirez ( )

KM3NeT Neutrino Observatory
(https://www.km3net.org/)
LASF4RI Preparatory Group, Neutrino Convener and Strategy Document Committee
(https://lasf4ri.org/)
LA-CoNGA Physics
(http://laconga.redclara.net/)

5th ComHEP: Colombian Meeting on High Energy Physics

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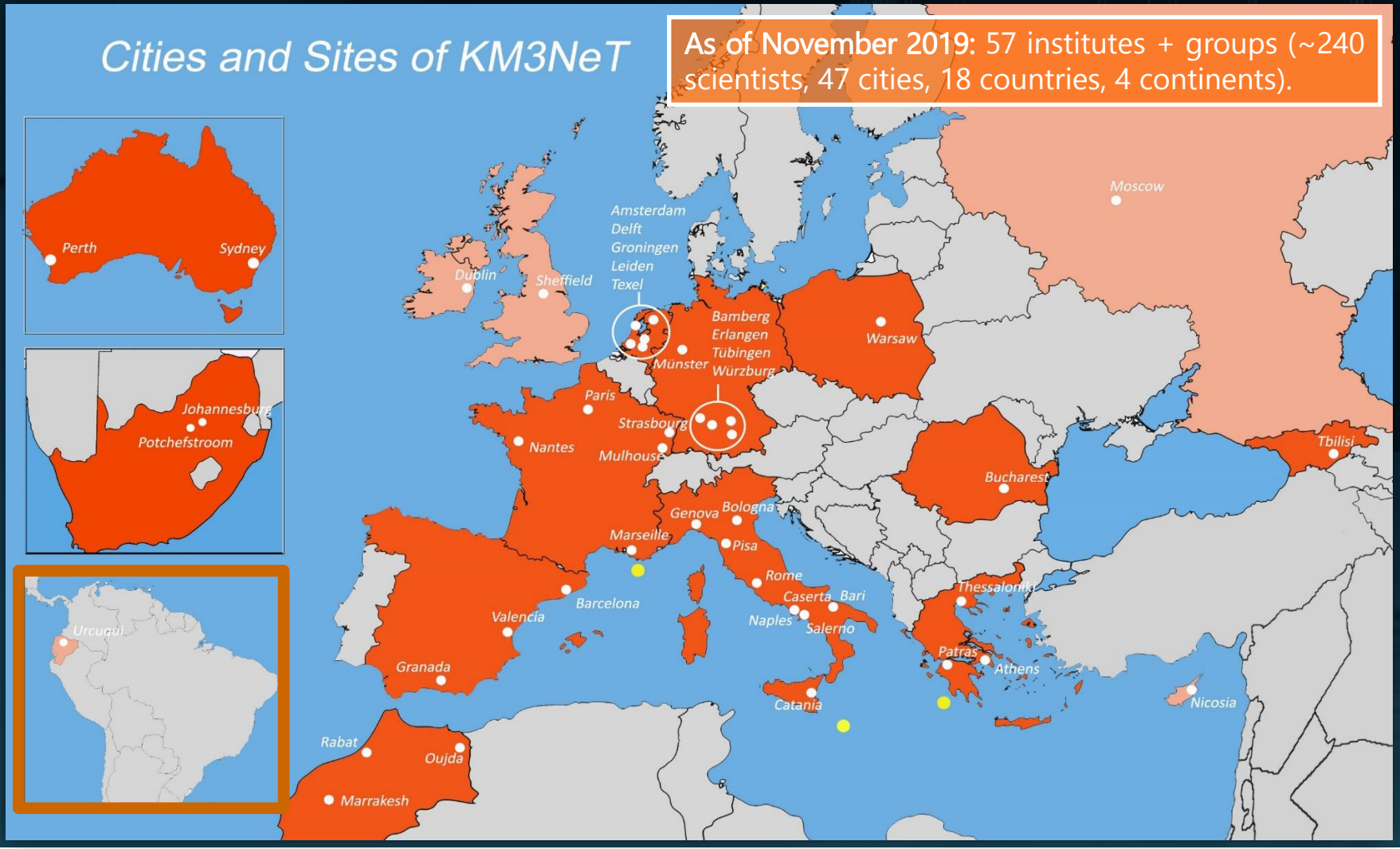
PART 4
LATINAMERICA IN KM3NET (STATUS)

PART 1
INTRODUCTION

INTRODUCTION



INTRODUCTION

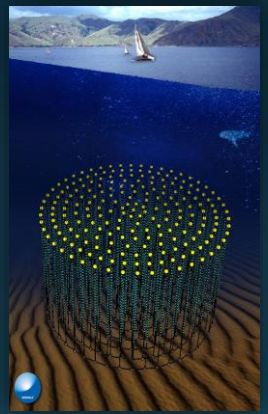
A multidisciplinary and multipurpose large-scale world-class cutting-edge facility

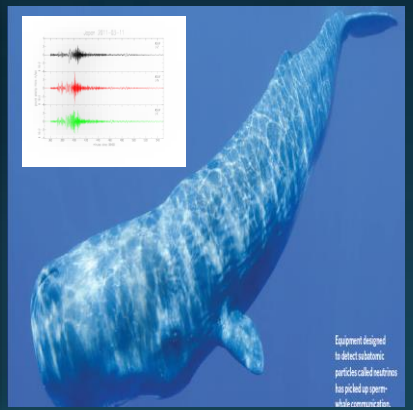
Multidisciplinary

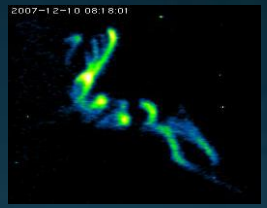
Space Sciences (particle astrophysics).
Earth and Sea Sciences.

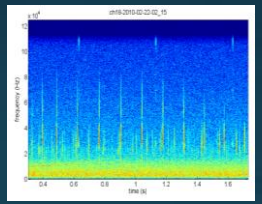
Multipurpose

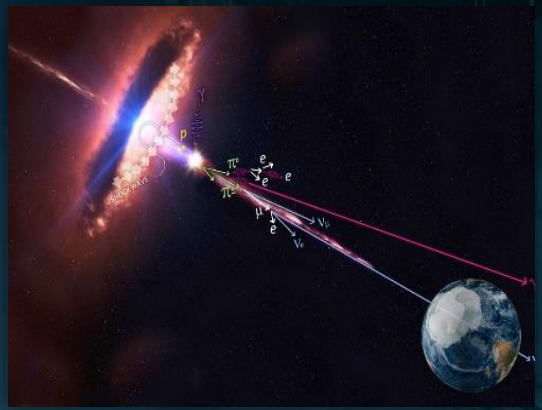
From particle astrophysics:
Astrophysical and Atmospheric Neutrinos.

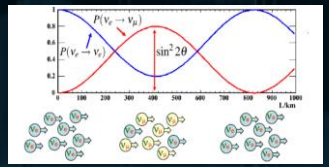


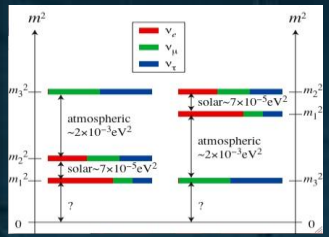












Operational experience of undersea Neutrino Observatories.
Mediterranean Sea as sanctuary for research and long-term monitoring of geohazards, marine life and ocean dynamics.

THE KM3NeT ROADMAP:

KM3NeT is a recognized experiment by CERN

European+LatinAmerican Strategy Forum for Research Infrastructures (ESFRI+LASF4RI):

KM3NeT selected for the 2016 ESFRI Roadmap

10 March 2016 – Today, at its launch event at the Royal Netherlands Academy of Arts and Sciences in Amsterdam, the European Strategy Forum for Research Infrastructures (ESFRI) announced that KM3NeT 2.0 is selected for the 2016 ESFRI Roadmap for Research Infrastructures. The ESFRI Roadmap identifies new Research Infrastructures of pan-European interest corresponding to the long-term needs of the European research communities. Its mission is to ensure that scientists in

LASF4RI

Latin American Strategy Forum for Research Infrastructure

For High Energy, Cosmology and AstroParticles

Developing a strategy to strengthen Latin American Scientific Collaborations and their impact.

Latin American Strategy Forum for Research Infrastructures for High Energy, Cosmology, Astroparticle Physics LASF4RI for HECAP

Latin American Strategy for HECAP

Proposal endorsed by the High Level Strategy Group

Strategy Document Committee

Alfredo Aranda, Diana López Nacir, Marta Losada, Rogerio Rosenfeld, Arturo Sánchez, Federico Sánchez, Harold Yepes Ramirez

Preparatory Group

ARGENTINA: Diana López Nacir, Hernán Wahlberg, Federico Sánchez
ASIA-JAPAN: Hiroaki Aihara
BOLIVIA: Martin Subieta
BRAZIL: Thiago Goncalves, Rogerio Rosenfeld
CHILE: Mauro Cambiaso, Alfonso Zerwekh
COLOMBIA: Marta Losada (Chair), Diego Restrepo
ECUADOR: Edgar Carrera, Harold Yepes Ramirez
EUROPE-CERN: Martijn Mulders
MEXICO: Alfredo Aranda, Juan Carlos D'Olivo, Gerardo Herrera
PERU: Alberto Gago
PARAGUAY: Jorge Molina
USA: Marcela Carena, Marcelle Soares-Santos
VENEZUELA: Reina Camacho Toro, Arturo Sánchez

Date: November 16, 2020

DECLARACIÓN

IV REUNIÓN DE MINISTRAS, MINISTROS Y ALTAS AUTORIDADES DE CIENCIA, TECNOLOGIA E INNOVACIÓN

"INNOVACIÓN PARA EL DESARROLLO SOSTENIBLE – OBJETIVO 2030. IBEROAMÉRICA FRENTE AL RETO DEL CORONAVIRUS"

Formato virtual, Andorra, 27 de octubre de 2020

Las Ministras, los Ministros y las Altas Autoridades de Ciencia, Tecnología e Innovación de los países iberoamericanos, reunidos por medios telemáticos el día 27 de octubre de 2020, en el marco de la XXVII Cumbre Iberoamericana de Jefes de Estado y de Gobierno,

Considerando que,

La XXVII Cumbre Iberoamericana de Jefes de Estado y de Gobierno, que se celebrará en Andorra, bajo el lema "Innovación para el Desarrollo Sostenible – Objetivo 2030. Iberoamérica frente el reto del Coronavirus", se vincula con la voluntad de impulsar la innovación en Iberoamérica y ponerla al servicio del cumplimiento de los Objetivos de Desarrollo Sostenible.

El conocimiento constituye un motor esencial para el desarrollo sostenible y la innovación contribuye a promover los cambios necesarios, no solamente tecnológicos, para generar una reacción, tanto en el sector público como en el conjunto de nuestras sociedades, y un efecto acelerador en la consecución de los 17 Objetivos de Desarrollo Sostenible (ODS) y las 169 metas establecidos por la Agenda 2030 de las Naciones Unidas.

El concepto de innovación es transversalmente aplicable a la Agenda 2030, tal como quedó recogido en el II Plan de Acción Cuatrienal de la Cooperación Iberoamericana (PACCI), y los Objetivos del Desarrollo Sostenible están relacionados entre ellos, siendo el ODS 9, que se refiere a la industria, innovación e infraestructura, la mención más clara al concepto de innovación en la Agenda 2030.

Es especialmente importante destacar también el ODS 7, sobre energía asequible y no contaminante, por la preocupación que manifiesta por facilitar el acceso a la investigación y a la tecnología; el ODS 8, que promueve el incentivo y la adaptación del trabajo decente y el desarrollo económico; y también los ODS 11 y ODS 17, como objetivos estratégicos, ya que promueven no sólo la cooperación entre administraciones locales y nacionales para lograr ciudades y comunidades sostenibles, sino también la revitalización de las alianzas mundiales para el desarrollo sostenible entre los diferentes sectores: público, privado, académico, asociativo y solidario.

In particular, the **1st time** a strategy process is conducted in Latin-America !!!

PART 2

THE KM3NET NEUTRINO OBSERVATORY

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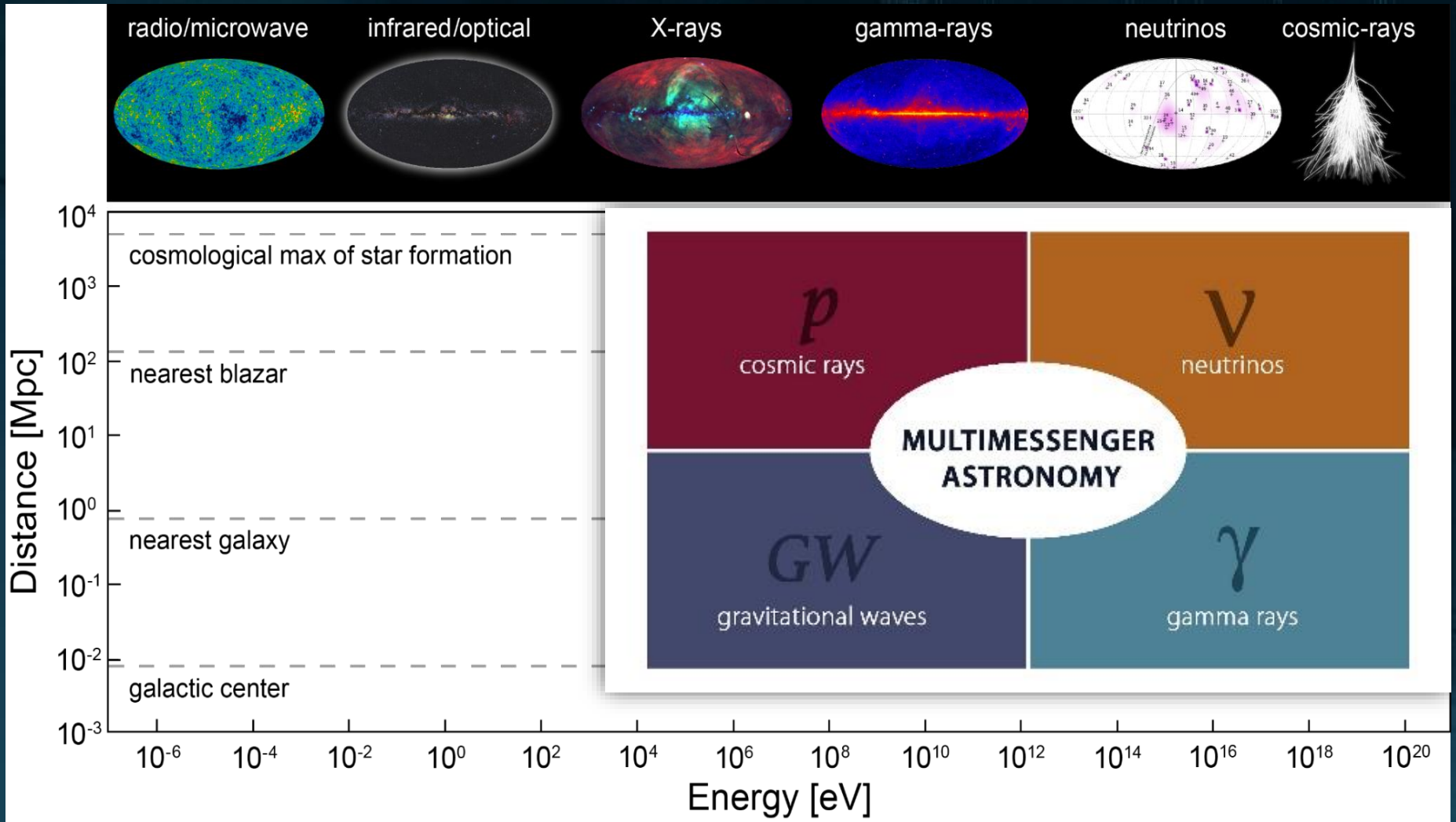
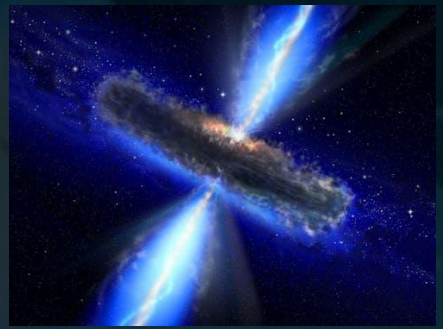


THE KM3NET NEUTRINO OBSERVATORY

ARCA (KM3NeT-It)

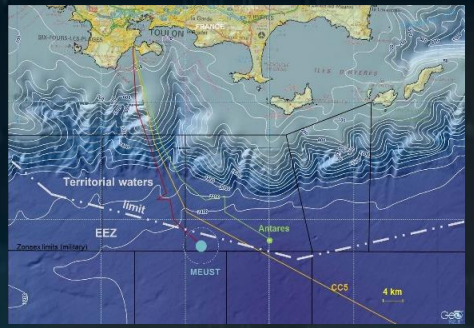
(Astroparticle Research with Cosmics in the Abyss)

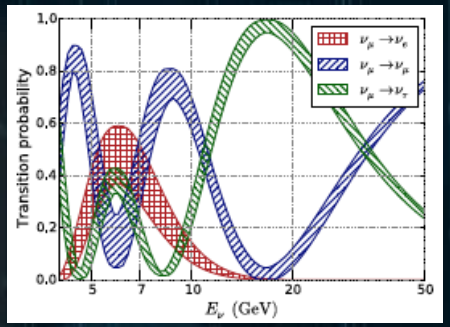


100 km off-shore Capo Passero, Depth ~ 3.4 km

ORCA (KM3NeT-Fr)

(Oscillation Research with Cosmics in the Abyss)





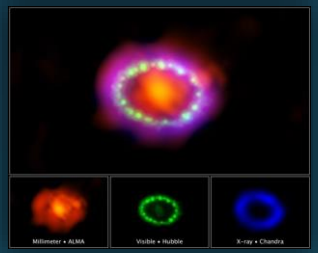
40 km off-shore Toulon, Depth ~ 2.5 km

High Energy (E_ν [TeV] > 1)

MM astronomy, HE astrophysics (Blazars, GRBs), ν-tomography (by absorption)

Low Energy (1 < E_ν [GeV] < 100)

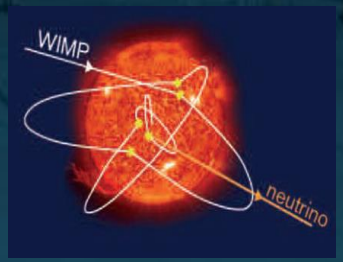
NMH, oscillation parameters, tau appearance, sterile-ν, NSI, ν-tomography (by oscillation)



SuperNova, SuperNova Remnants, Kilonova (~MeV)

Medium Energy [10 GeV < E_ν < 1 TeV]

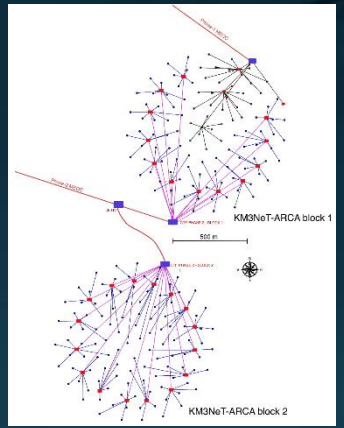
Dark Matter, exotics (monopoles, nuclearites, etc.)

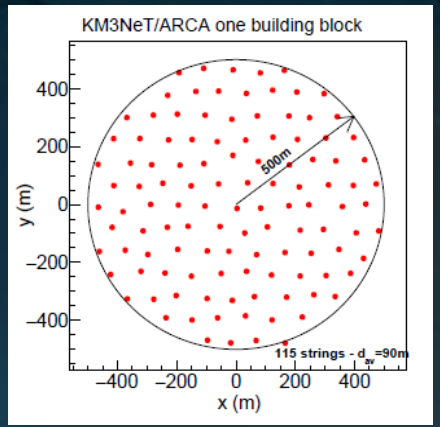


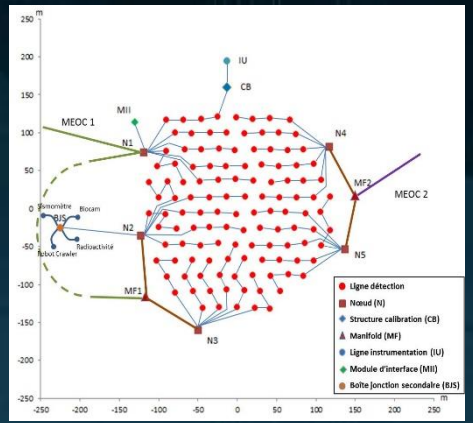
THE KM3NET NEUTRINO OBSERVATORY

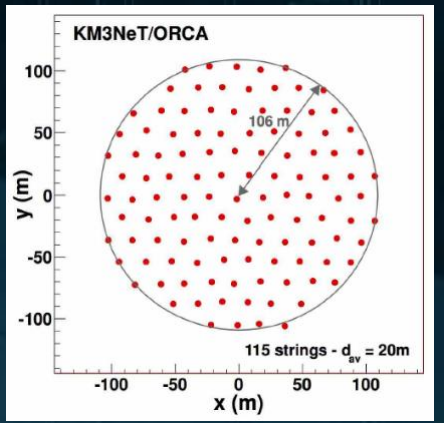
ARCA (Sparser Detector)
Large volume, low fluxes optimization, large effective area
[astrophysical neutrinos]

ORCA (Denser Detector)
High density, low threshold optimization, sensitivity to changes of flavour
[atmospheric neutrinos]









2 Building Blocks (BBs)
[2 x 115 Detection Units (DUs)]
(~ 1 Gton instrumented)

1 Building Block (BB)
[1 x 115 Detection Units (DUs)]
(~ 6 Mton instrumented)

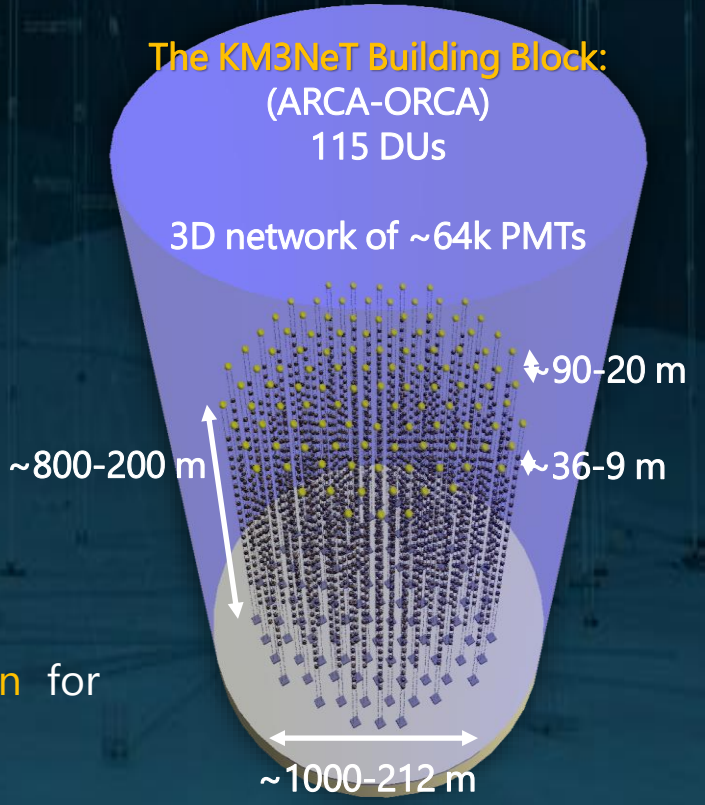
SAME TECHNOLOGY AND LAYOUT (DIMENSIONS SCALED)

THE KM3NET NEUTRINO OBSERVATORY

- ✓ 18 DOM on vertical slender strings. 31x3" PMTs / DOM:
  - Less overheads: improved and integrated readout and calibration devices.
  - Directional Sensitivity. Improved Background Rejection.
  - Improved Photon Counting.

- ✓ Backbone: 2 copper conductors, 18 fibers (+spares). Breakout of cable at each DOM.
- ✓ Optical fiber transmission (Gbit/s) by base module with DWDM at string anchor.
- ✓ White Rabbit (WR) time synchronization protocol.
- ✓ All-data-to-shore concept: filtering / trigger on-shore in computer farm.

+ Nodes for long-term high-bandwidth connection for Earth and Sea Sciences.



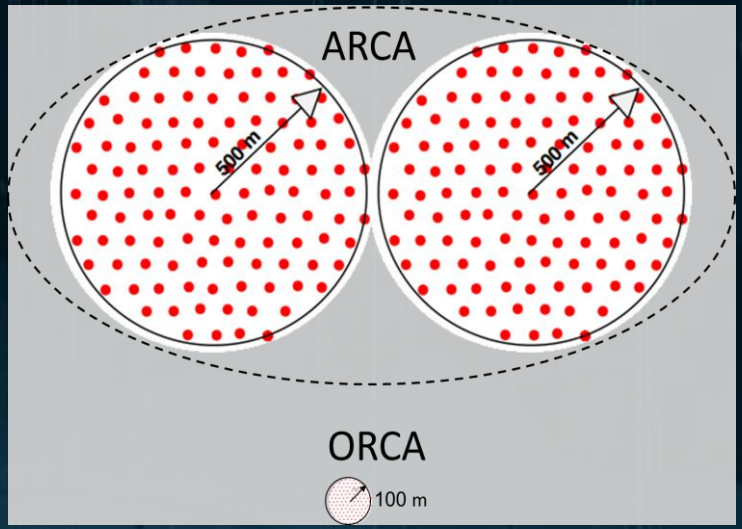
KM3NET PHASES AND CONSTRUCTION:

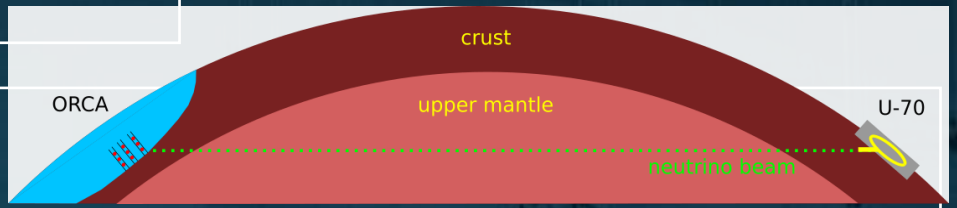
PHASE-I: (on-going)

- ✓ Fully funded.
- ✓ 30 DU's: 24 ARCA + 6 ORCA (finished): ~0.3BB.
- ✓ Proof of feasibility and first science results.

PHASE-II: (letter of intent)

- ✓ Funding in progress.
- ✓ 345 DU's: 2x115 (≡2BB) ARCA + 1x115 (≡1BB) ORCA.
- ✓ All flavor neutrino physics and astronomy.





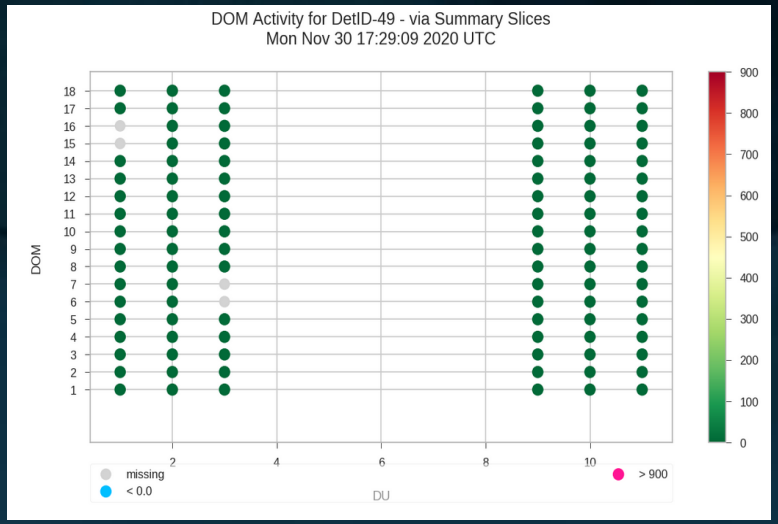
PHASE-III: (the horizon...)

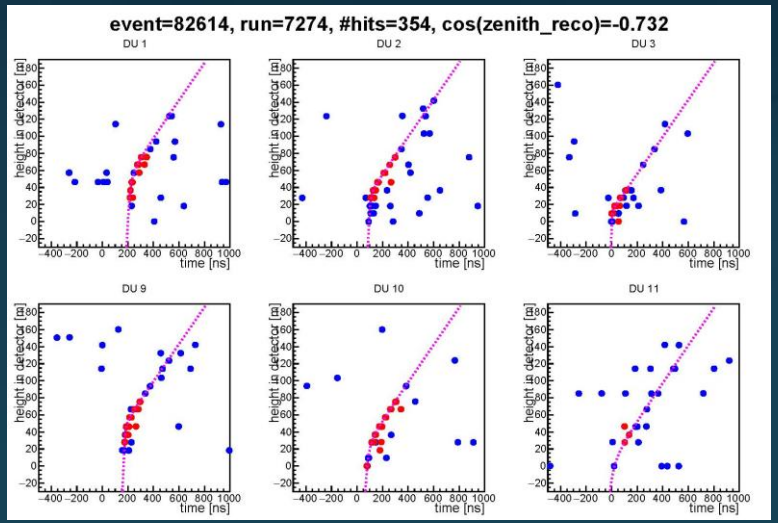
- ✓ Next Step.
- ✓ 690 DU's: 6x115 (≡6BB) ARCA + Super-ORCA in total.
- ✓ Neutrino astronomy including Galactic sources. P2O Long Base Line Protvino-ORCA.

PART 3

DETECTORS PERFORMANCE AND FIRST PHYSICS RESULTS (SELECTION)

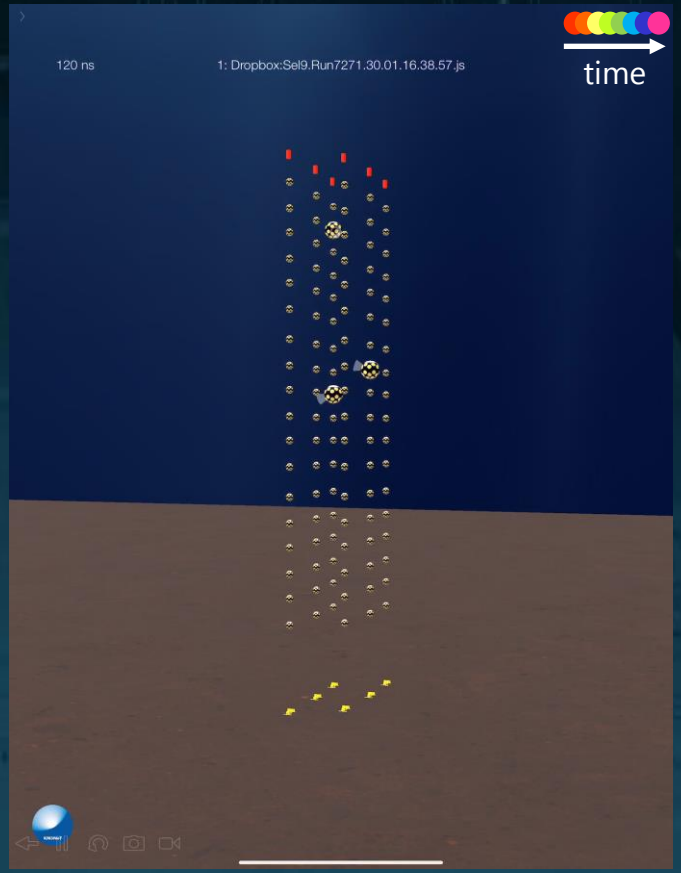
DETECTORS PERFORMANCE AND FIRST PHYSICS RESULTS (SELECTION)





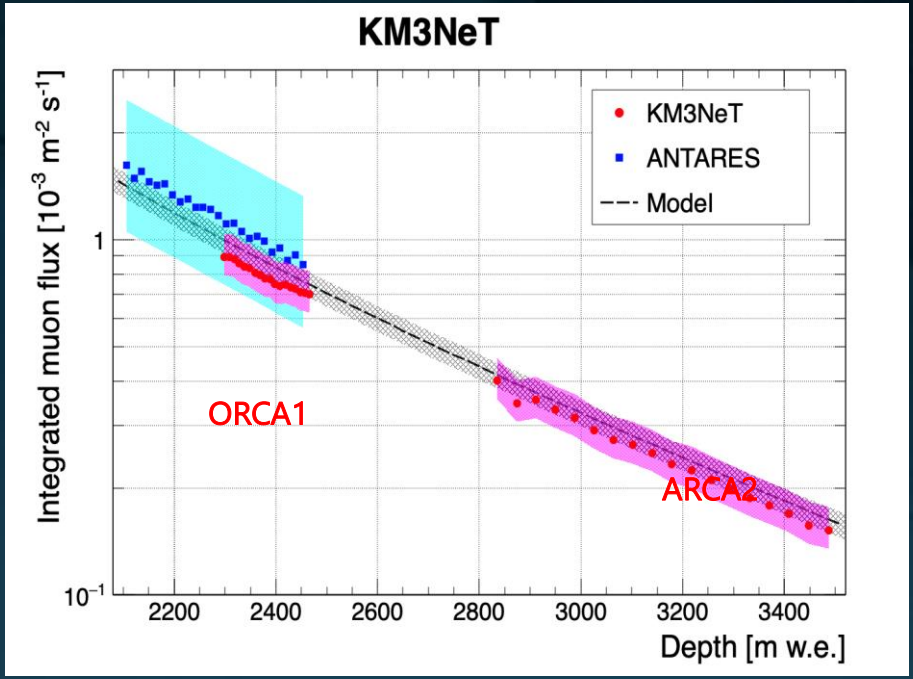
TRACKS RECONSTRUCTION CAPABILITIES:

Reconstruction of arrival direction and energy of neutrinos: position + timing + amplitude of the hits



MUON DEPTH DEPENDENCE:

https://arxiv.org/pdf/1906.02704.pdf



DATA SAMPLE:

ORCA1: 320 hours. **ARCA2:** 1269 hours.

Muon flux as function of depth compared to Bugaev model *(Bugaev et al, Phys. Rev. D 58 1998 054001).*

- RMS < 2%.
- Proved calibration and PMT detection efficiency.
- Coincidence rate ∝ muon flux × normalization factor.

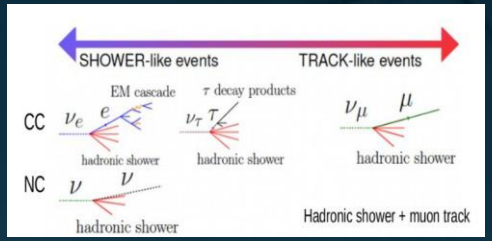
Energy losses in seawater ➔ Lower rate of atmospheric muons ➔ Effect on coincidence rates.

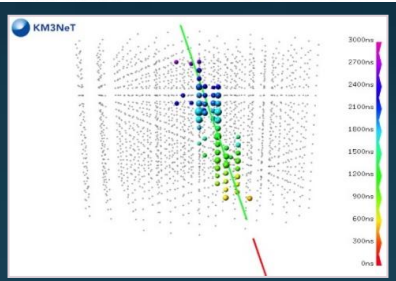
Muon flux attenuation over more than 1 km of depth

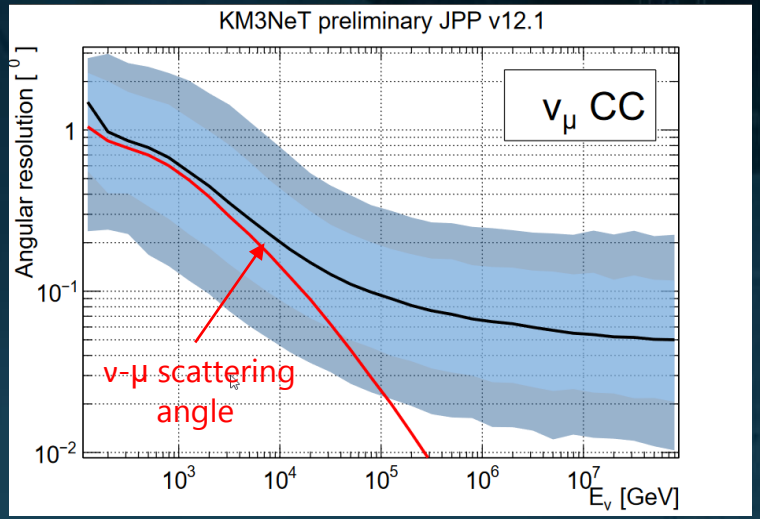
DETECTOR RESPONSE (ARCA) – ANGULAR RESOLUTION: TRACKS

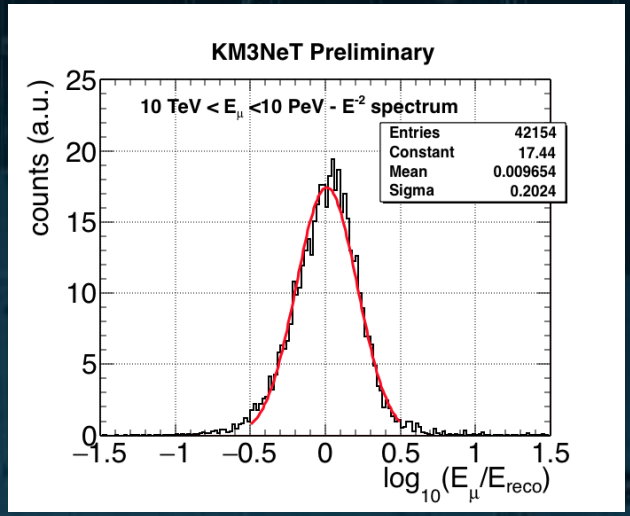
Preliminary Results

- Track and shower topologies: all flavour (indirect) neutrino observation, 6 orders of magnitude in E [GeV-PeV].
- Golden channel for ν-astronomy: **μ-track from Charged Current ν_μ.**







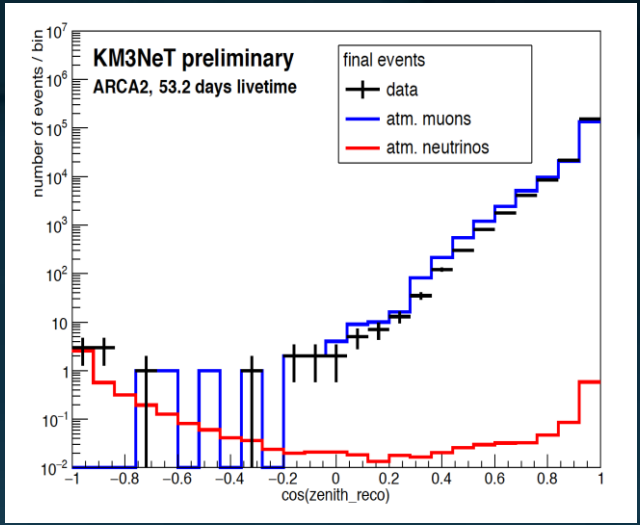


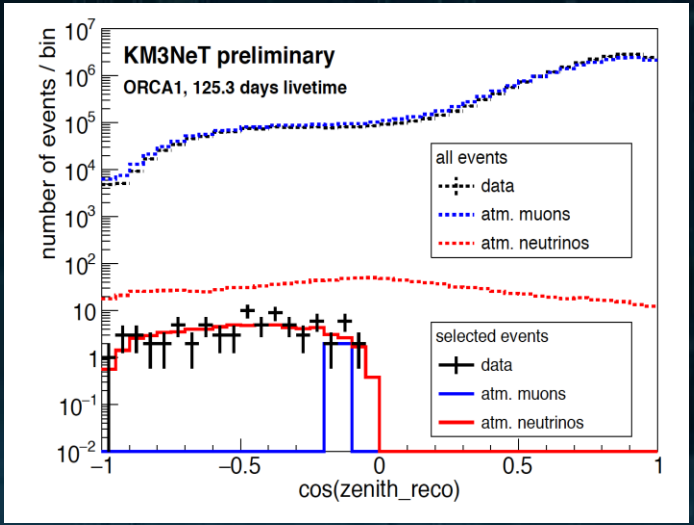
Excellent resolution due to good water properties
Physics limited < 10 TeV
0.1° at 100 TeV, 0.05° at 100 PeV

Energy measured from the total amount of light (*dE/dx* resolution factor 2-3)

TRACKS RECONSTRUCTION: up-going atmospheric neutrino selection

Preliminary Results





ARCA:

Data: 6 up-going neutrino candidates [$\cos\theta_{reco} < -0.8$]

Monte Carlo: 0 μ_{atm} + 3.3 ν_{atm}

$E_{th} \sim 100$ GeV

Trigger rate $\mu_{atm} \sim 0.2$ Hz, $\nu_{atm} \sim 1$ / day

ORCA:

Data: 77 up-going neutrino candidates [$\cos\theta_{reco} < 0$]

Monte Carlo: 4 μ_{atm} + 67.5 ν_{atm}

$E_{th} \sim$ few GeV

Trigger rate $\mu_{atm} \sim 2$ Hz, $\nu_{atm} \sim 10$ / day

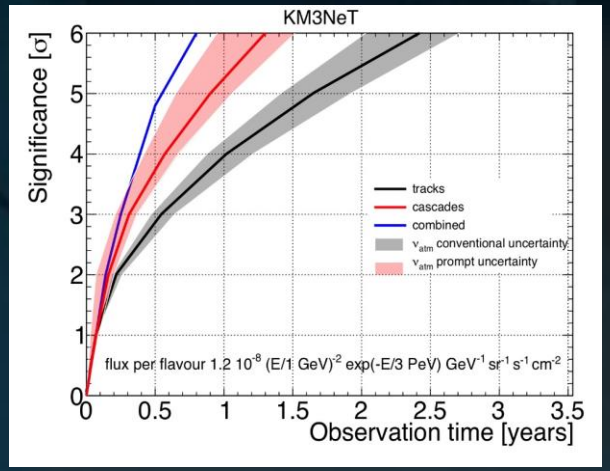
KM3NeT can performs an outstanding reconstruction with only a few lines and short lifetime !!!

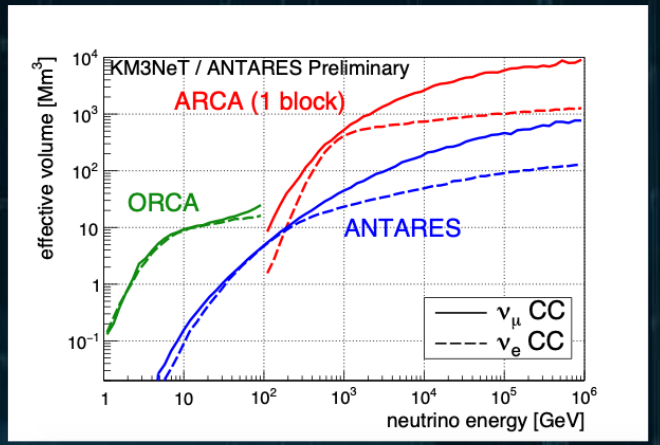
DETECTORS PERFORMANCE AND FIRST PHYSICS RESULTS (SELECTION)

SENSITIVITY TO COSMIC DIFFUSE FLUX (ALL SKY):

Preliminary Results

J. Phys. G: Nucl. Part. Phys. 43 (2016) 084001

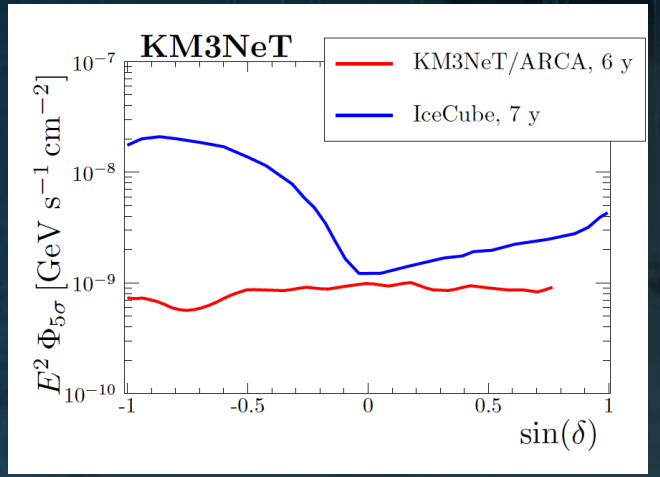




- Discovery at 5σ significance in 0.5 years for full detector (2 Building Blocks).
- 5σ in 1 year for half the detector (1 Building Block).

SENSITIVITY TO POINT-LIKE SOURCES:

- Almost the whole sky at 5σ (about one order of magnitude better than IceCube for equivalent exposure time).
- Excellent sensitivity ($\Phi_{\nu\mu} \propto E^{-2}$) at southern hemisphere.

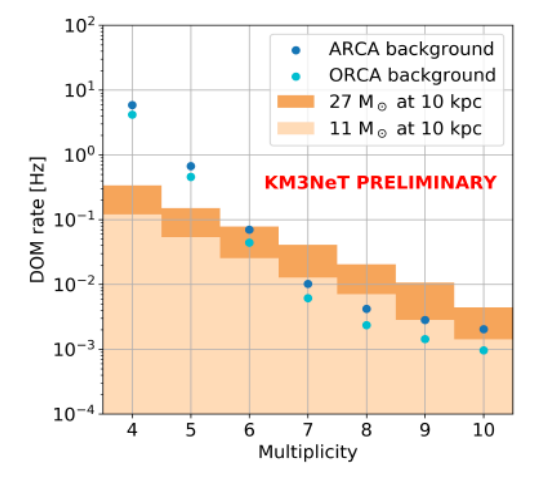


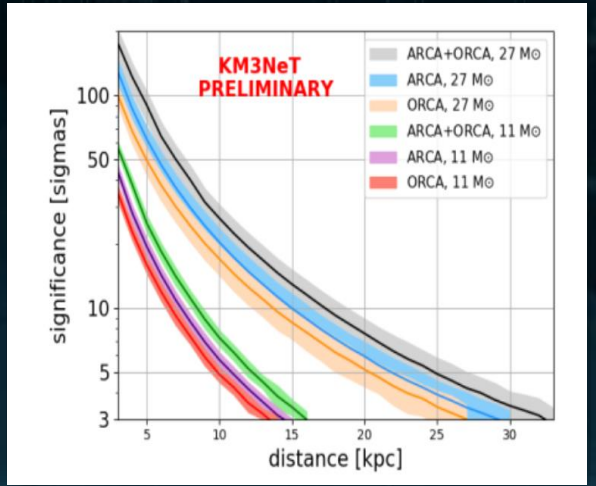
Astroparticle Physics 111 (2019) 100

CORE COLLAPSE SUPERNOVA NEUTRINOS (CCSN):

Preliminary Results

MC and first data used: MC for accretion phase of CCSN with stellar progenitors of 27 and 11 $M_{\odot}$. Simulations show LE (MeV) CCSN neutrinos are mostly detected on a single DOM.



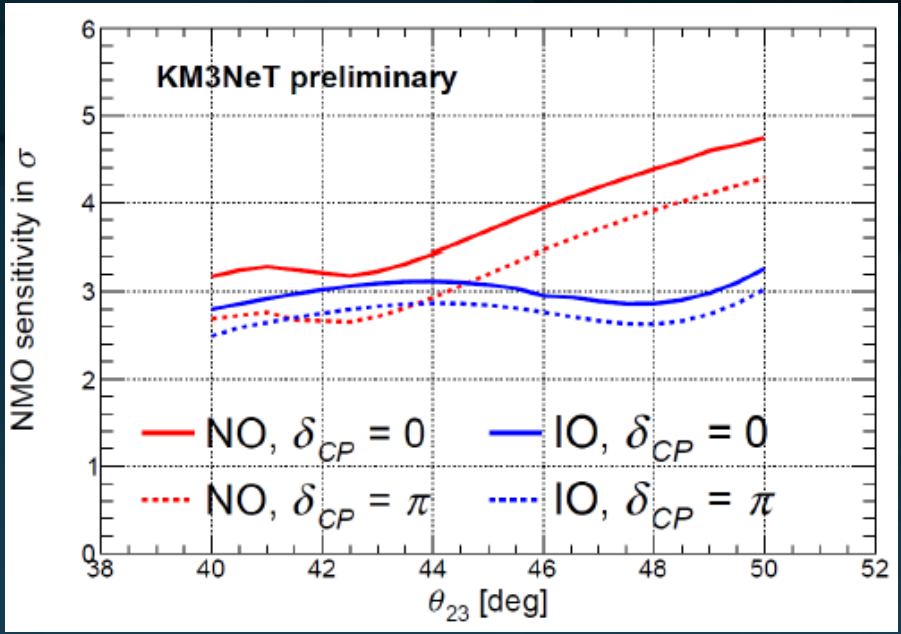


Individual MeV neutrinos seen on single DOMs (as Supernova neutrino detectors) as multiple hits. Best sensitivity for PMT coincidence level: 6 < M (multiplicity) < 10.

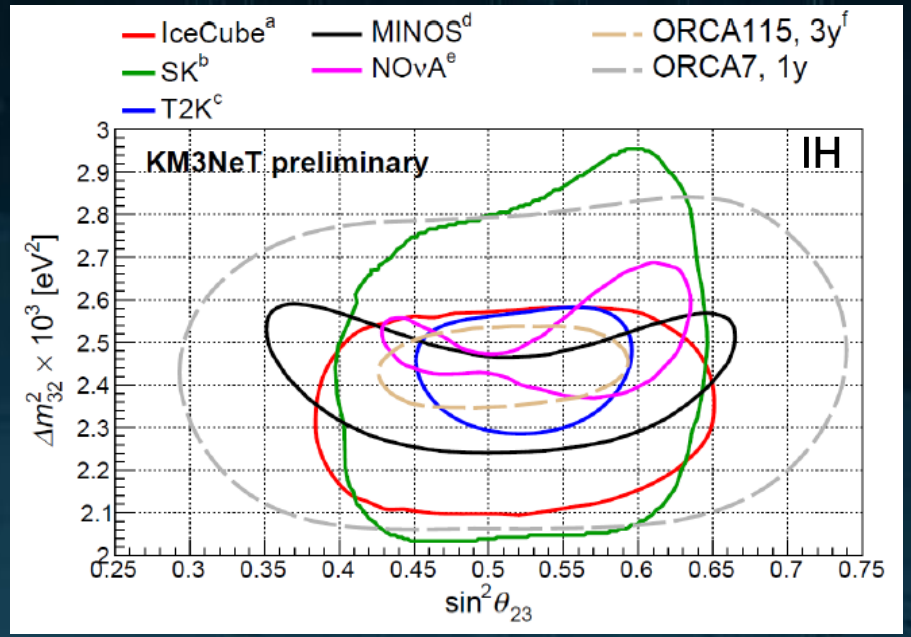
5σ combined sensitivity (ARCA+ORCA) for 27 $M_{\odot}$ (550 ms window) at 25 kpc.
5σ combined sensitivity for 11 $M_{\odot}$ (350 ms window) at 12 kpc.

NMH AND OSCILLATION PARAMETERS (Δm^2_{32}, $\sin^2\theta_{23}$): Atmospheric Neutrinos

PoS, Volume 358, 36th International Cosmic Ray Conference 2019



Sensitivity to distinguish between NH<-> IH:
≥3σ in 3 years (median sensitivity)
>4σ in 3 years for NH(NO) and large θ_{23}



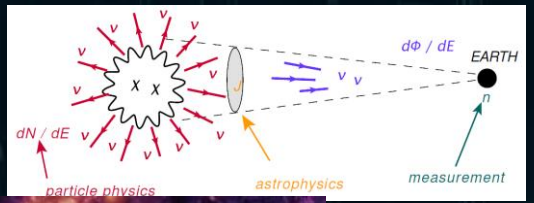
90% CL contours for oscillation parameters:
Competitive measurements of Δm^2_{32} (2-3% precision) and $\sin^2\theta_{23}$ (4-10% precision)

NMH and δ_{CP} : Accelerator Neutrinos

(P2O LBL Protvino–ORCA) → *D. Zaborov et al., Eur. Phys. J. C (2019) 79:758*

INDIRECT DARK MATTER SEARCHES: The Sun and Galactic Center

Preliminary Results



Relic WIMPs acc

re.

WIMP annihila
yield significan
(10 GeV < E_ν <
to halo models.

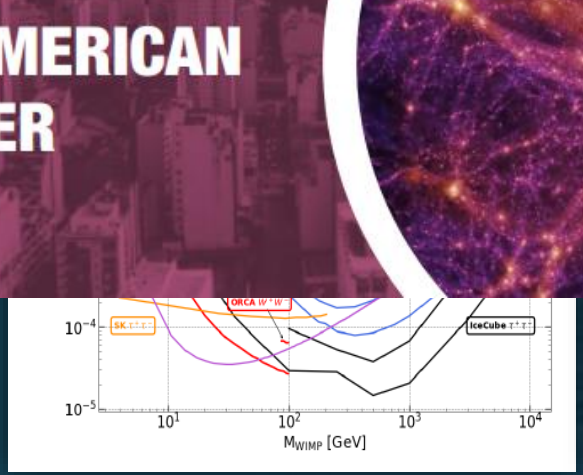
$$\chi\bar{\chi} \to b\bar{b}/W^+W^-$$

Talk by C. Poiré: "Dark Matter searches with ANTARES and KM3NeT", December 4.

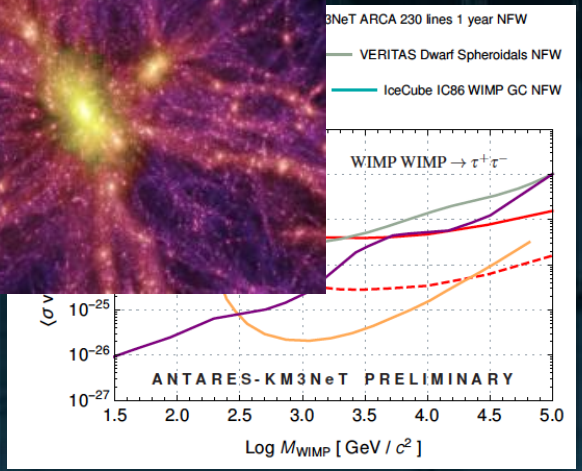
ICTP SAIFR | International Centre for Theoretical Physics South American Institute for Fundamental Research

3rd SOUTH AMERICAN DARK MATTER WORKSHOP

Search for cluster of events with dark-matter spectral features.
Limits (90% CL) on cross section for WIMP pair annihilation.



Sun: ORCA (1BB) (spin-dependent)



Galactic Centre: ARCA (2BB's)

PART 4

LATINAMERICA IN KM3NeT (STATUS)

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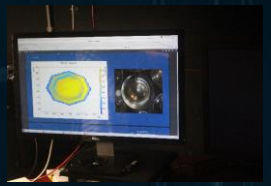
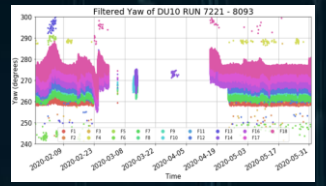
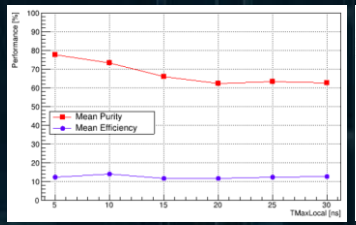
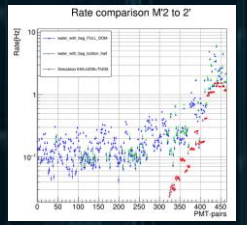
WORK IN PROGRESS IN ECUADOR (02/2019 – Current):

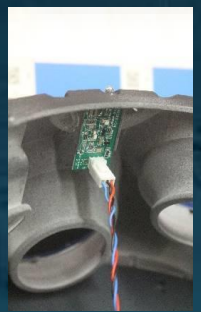
- Angular acceptance of the KM3NeT DOM: light detection efficiency, absolute quantum efficiency.
- Calibration and monitoring of positioning subsystems: digital compasses and acoustic beacons.
- High-Voltage tuning of KM3NeT light sources: nano-beacons.
- Radioactivity influence by ^{40}K in the KM3NeT DOM.

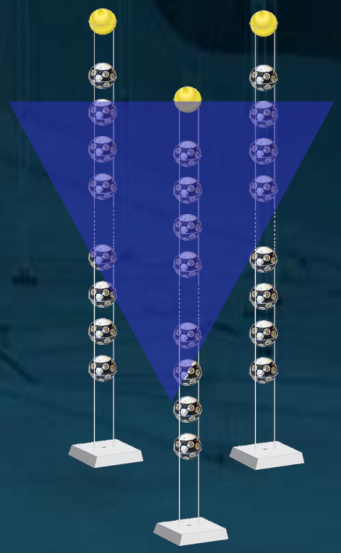












ADDITIONAL PLANNED ACTIVITIES:

- ✓ Construction of an Optical Calibration System (OCS) based on dimmable Multi-Wavelength NanoBeacons (MwNb) for KM3NeT Phase-II (device might be also used for Life Sciences).
- ✓ Blazar and Supernova neutrinos.
- ✓ Implement R&D drivers in agreement to the LASF4RI.

CONCLUSIONS

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TECHNICAL ASPECTS:

1. Operational experience, technical and scientific outcomes of previous Mediterranean Neutrino Telescopes have been fundamental for KM3NeT.
2. Mass production phase has started, integration and deployment of DUs will be pursued at a continuous pace, at the highest priority level.

SCIENCE PROGRAMS:

1. Discovery of astrophysical neutrino sources at 5σ significance in less than one year.
2. Sensitivity to NMH $\sim 3\sigma$ in 3 years. Competitive measurements of Δm^2_{32} and $\sin^2\theta_{23}$.
3. P2O will allow (~ 3 yrs. at 90 kW) to reach ≥ 3σ sensitivity, for any value of θ_{23} and δ_{CP}.

Opportunities within KM3NeT? Get in contact! (*hyepesr@km3net.de*)
Towards a KM3NeT LatinAmerican Node endorsed by the LASF4RI strategy!