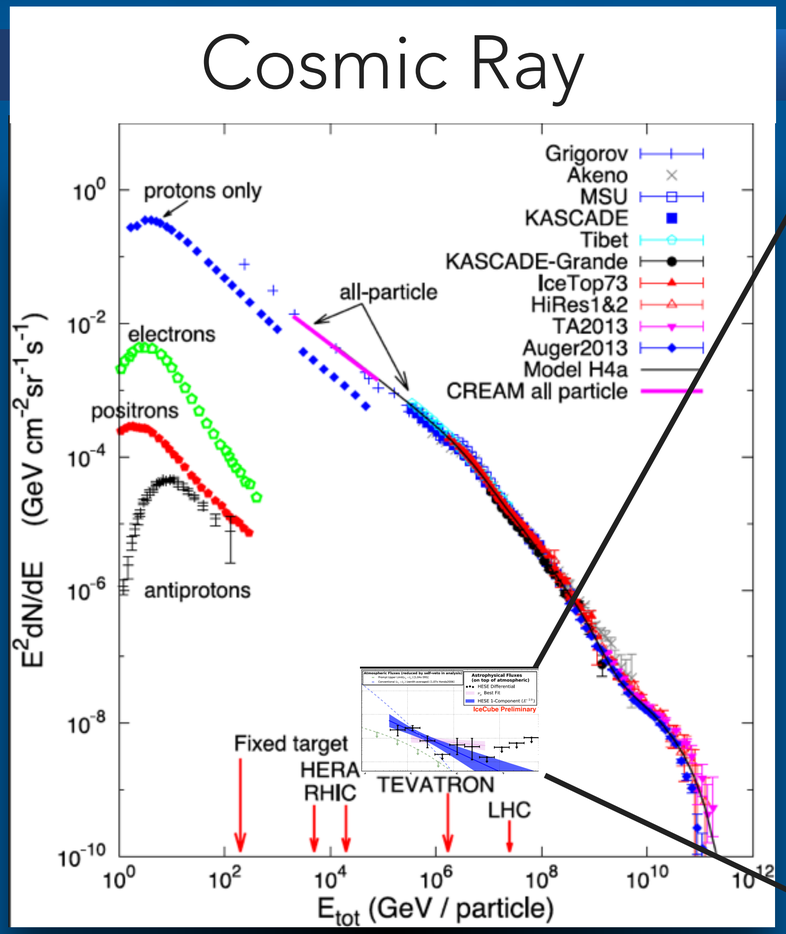
ICRC2019
36th International Cosmic Ray Conference - Madison, WI, USA
THE ASTROPARTICLE PHYSICS CONFERENCE

RESULTS FROM THE MEDITERRANEAN NEUTRINO DETECTORS

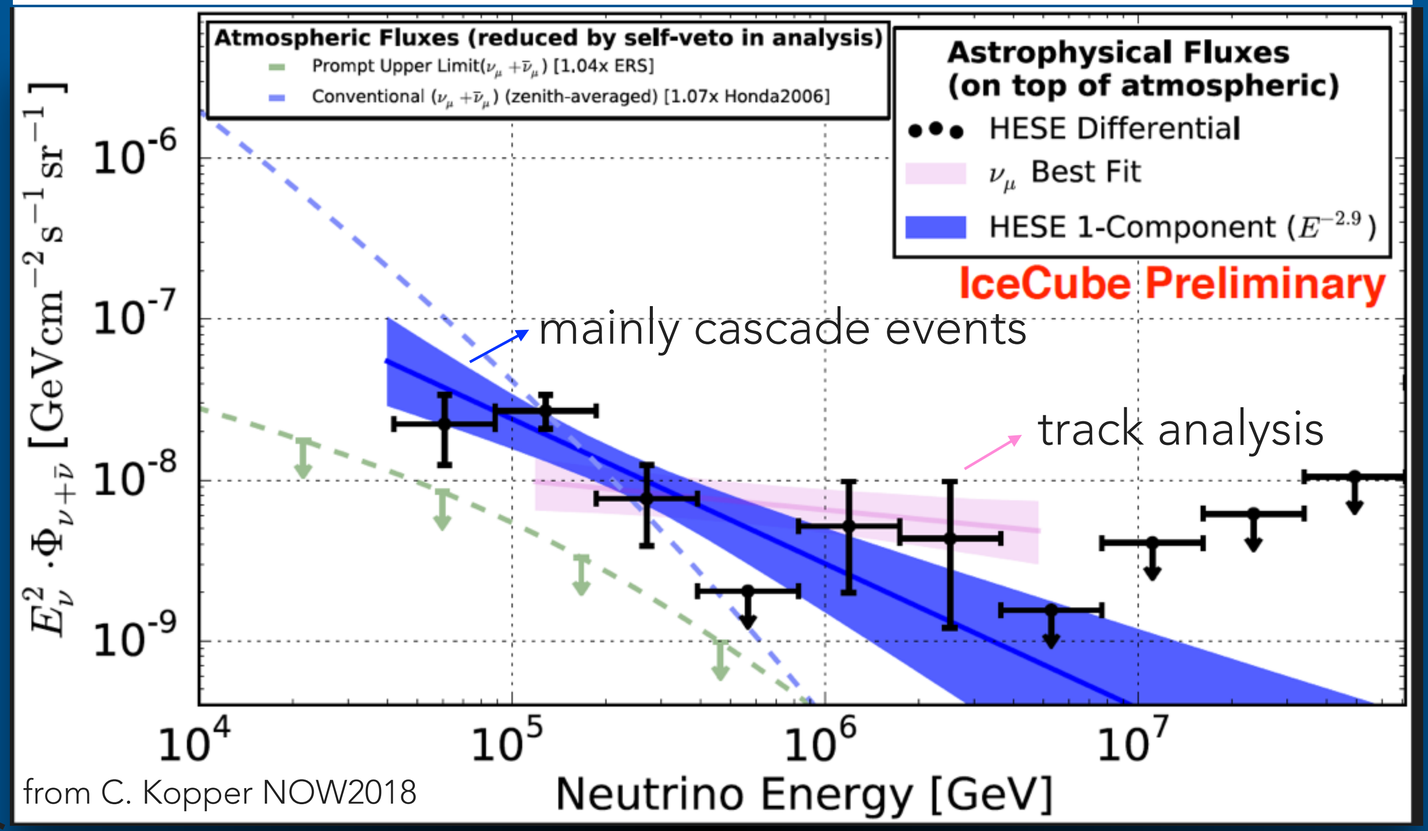
ROSA CONIGLIONE ON BEHALF OF THE ANTARES AND KM3NET COLLABORATIONS
INFN - LABORATORI NAZIONALI DEL SUD (ITALY)

INTRODUCTION: OPEN ISSUES

Cosmic Ray



Neutrino

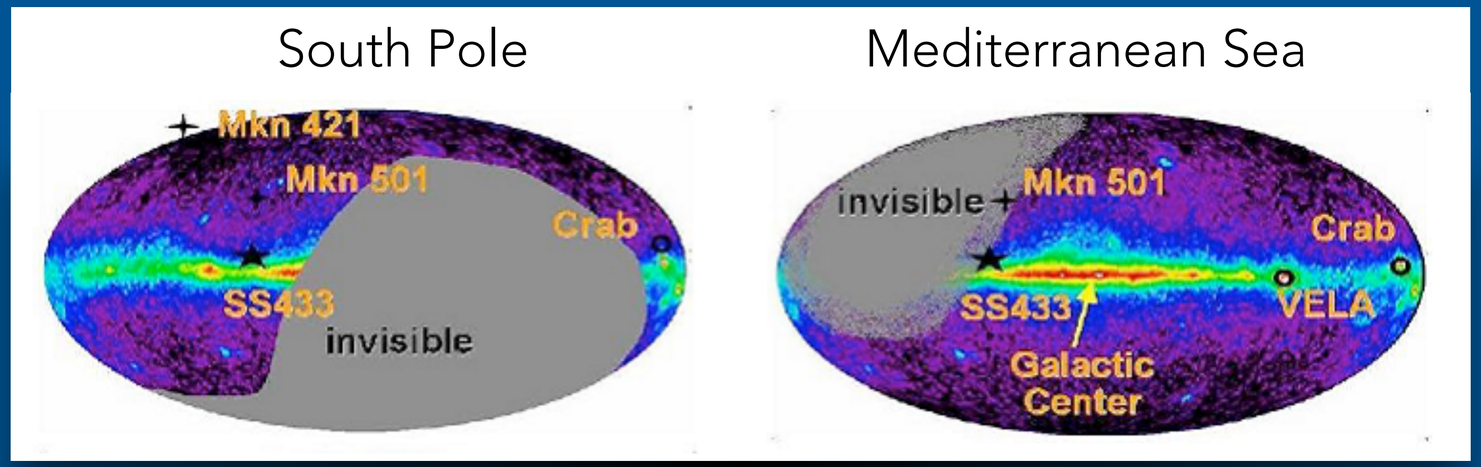


from C. Kopper NOW2018

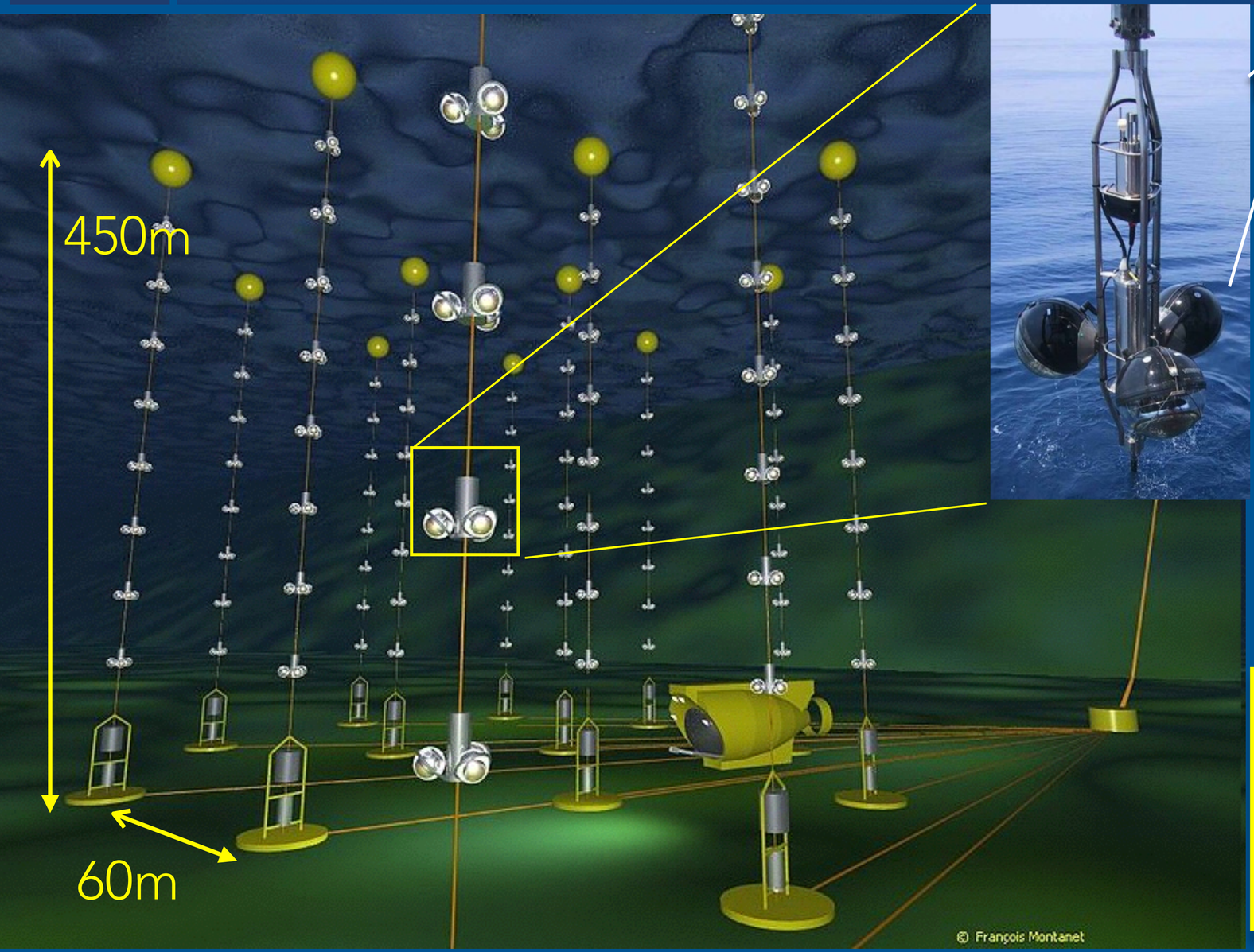
- CR measured up to ~10^{11} GeV but production sites of HE cosmic particles not yet known
- Measured neutrinos up to ~10^{8} GeV but origin of HE neutrinos not known

WHY NEUTRINO DETECTORS IN THE MEDITERRANEAN SEA

- **To confirm the measured cosmic flux from a different field of view**
- **Sky maps with a better angular resolution**
  - tracks @ 10TeV 👉 ~0.4° ANTARES ~0.1° KM3NeT/ARCA
  - cascades @ 10 TeV 👉 < 3° ANTARES < 2° KM3NeT/ARCA
- **High visibility of the Galactic region**
  - ~70% for the Galactic Center
- **Multi-messenger astronomy with neutrino detectors located in the Northern hemisphere**



THE ANTARES DETECTOR



Optical sensor
1 PMT of 10 inches

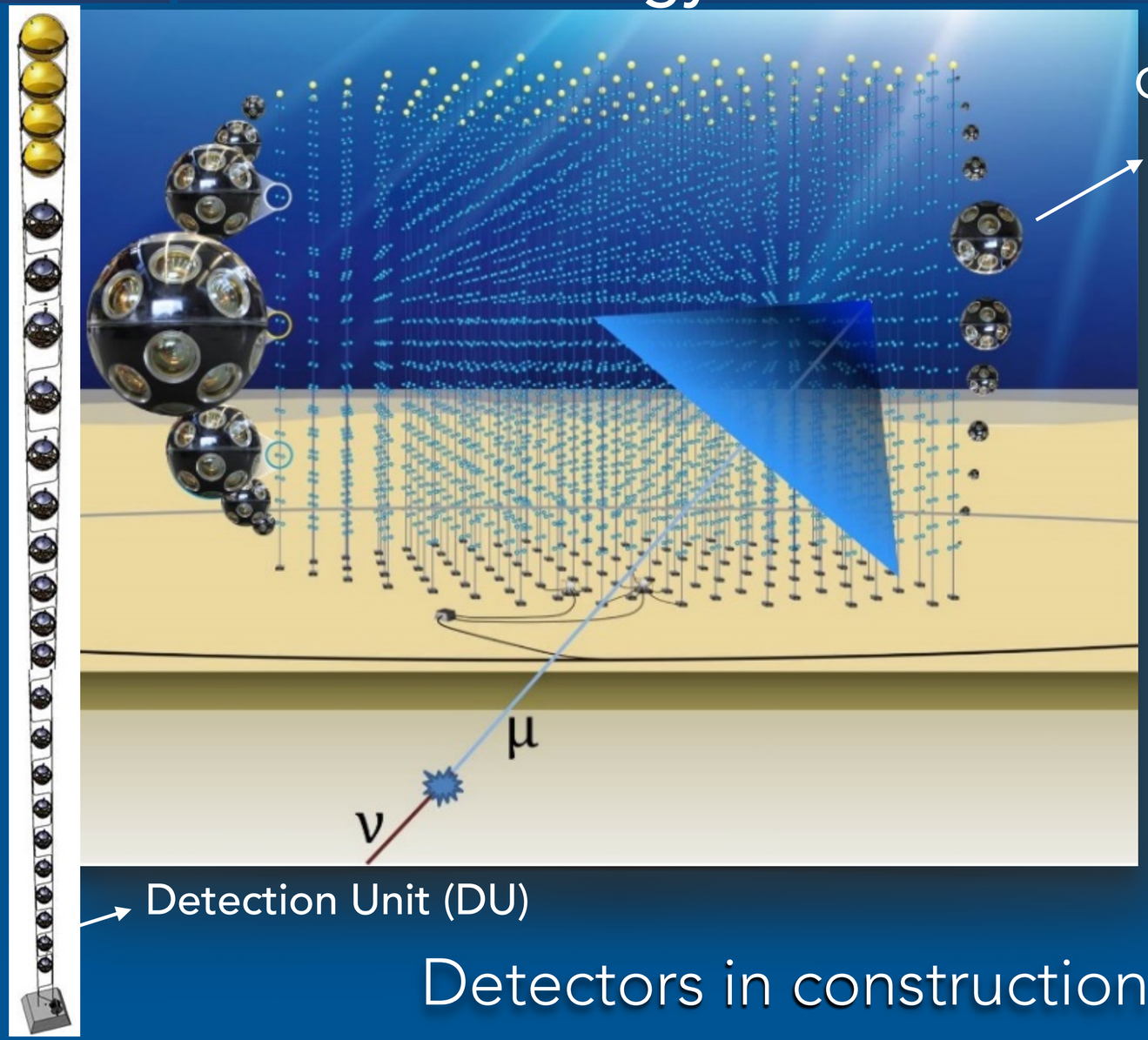
Depth 2475m

- 12 lines of 75 PMTs
- 1 line for Earth and Marine sciences
- 25 storeys / line
- 3 PMTs / storey
- 885 PMTs
- **Volume 0.01 km³**

Detector completed in 2008
Taking data since 11 years
with a duty cycle of ~95%

THE KM3NET DETECTORS

Same technology for the two detectors



Optical sensor (DOM)
31 PMTs of 3 inches

Detection Unit (DU)

ORCA

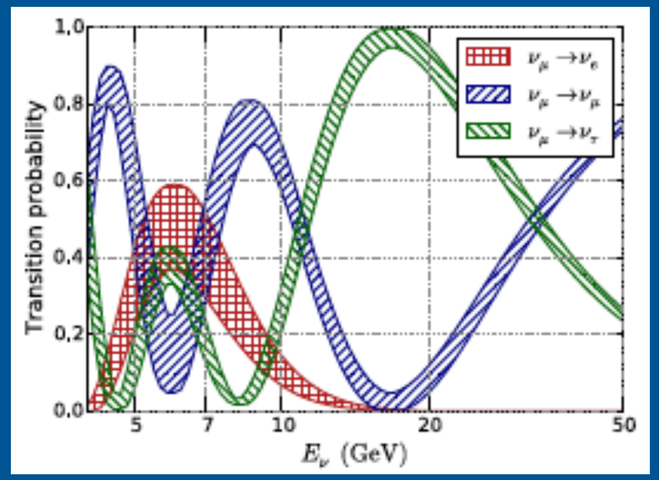
- Depth ~2500 m
- One block of 115 Detection Units
- Average distance between Detection Units ~20 m
- Average vertical distance between DOMs ~9 m
- **Volume ≈ 8 Mton**

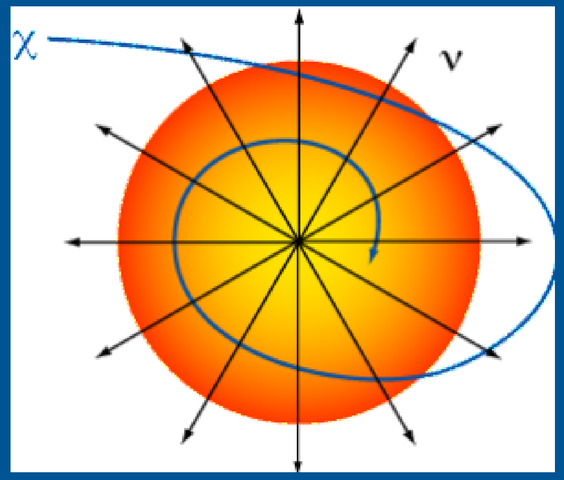
ARCA

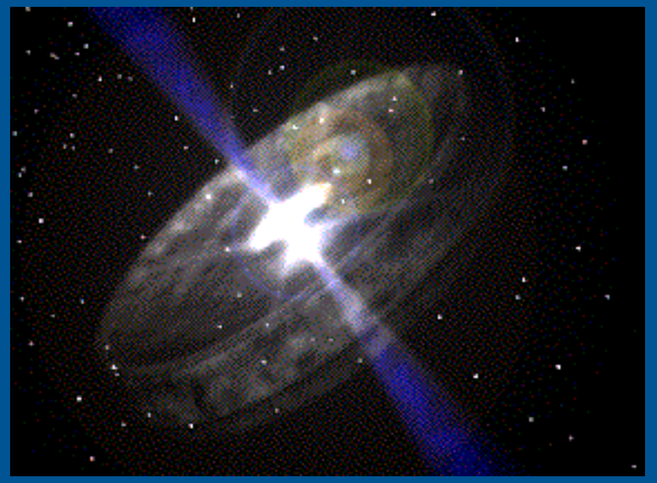
- Depth ~3500 m
- Two blocks of 115 Detection Units each
- Average distance between Detection Units ~90 m
- Vertical distance between DOMs ~36 m
- **Volume (0.5 × 2) km³ ≈1 Gton**

Detectors in construction

THE ENERGY RANGE







Low Energy	Medium Energy	High Energy
GeV < E < 50 GeV	10GeV < E < 1 TeV	E > 1 TeV
Oscillation studies	Dark Matter	Astrophysics

KM3NeT/ORCA

ANTARES & KM3NeT/ARCA

ANTARES & KM3NET @ ICRC2019

ANTARES and KM3NeT 35 contributions

results reported in this talk

- **Search from point-like sources**
  - G. Illuminati S. Navas - #920 Talk Saturday Nu6d
  - J. Aublin - #840 Talk Friday Nu3b
- **Search for neutrino diffuse flux**
  - L. Fusco - #891 Talk Friday Nu4g
- **Multimessenger**
  - D. Dornic - #871 Talk Tuesday Nu9e
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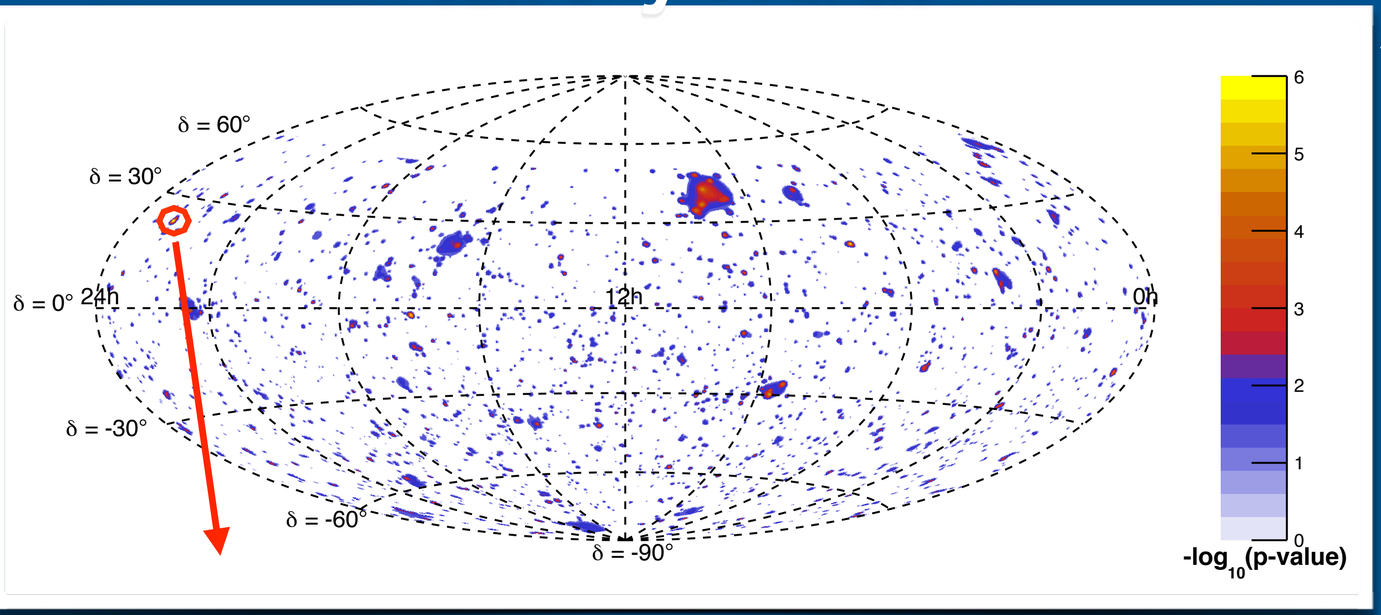
and many other results in 10 talks and many posters

POINT-LIKE

full sky search



ANTARES 11 years (3136 days of livetime)
track and cascade analysis

The most significant cluster

α=343.7° δ=+23.6°

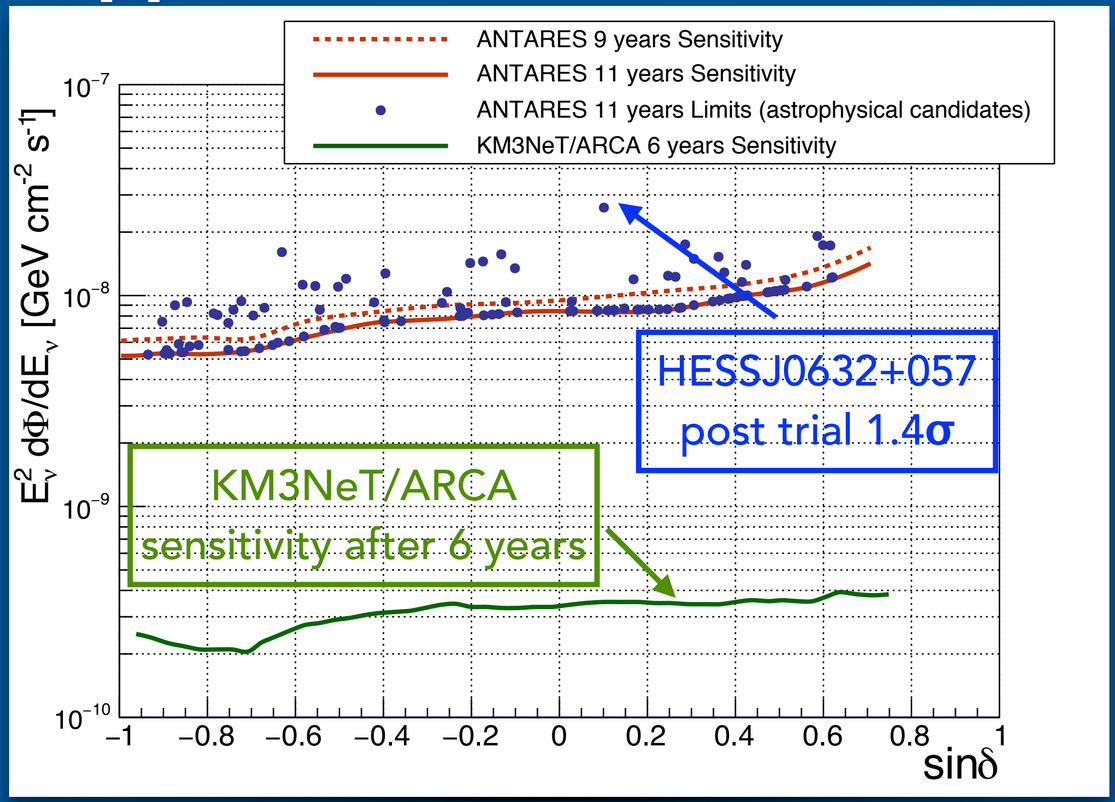
pre-trial 1.5 10^{-6} (4.8 σ)

post trial 0.23 (1.2 σ)

3 track events within 1°

15 tracks + 1 shower within 5°

upper limits and sensitivities



POINT-LIKE

Stacking analysis

11 years of track like events analyzed

CATALOG	PRE-TRIAL	POST-TRIAL	DOMINANT SOURCE
Fermi 3LAC All Blazars	0.19	0.83	
Fermi 3LAC FSRQ	0.57	0.97	
Fermi 3LAC BL Lacs	**0.088**	**0.64**	**MG3J225517+2409**
Radio-galaxies	**$4.8\ 10^{-3}$**	**0.10**	**3C403**
Star Forming Galaxies	0.37	0.93	
Obscured AGN	0.73	0.98	
IC HE tracks	0.05	0.49	

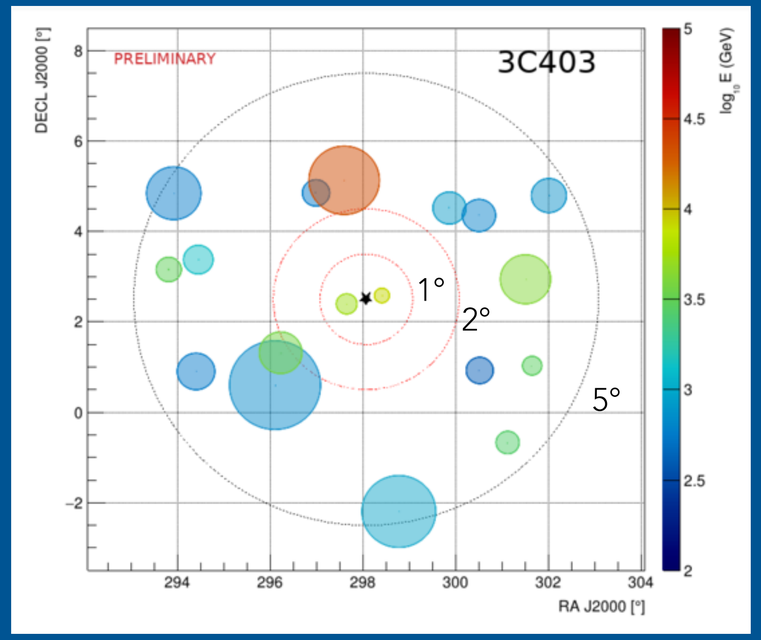
1.6 σ

The most significant population is the Radio-galaxies

POINT-LIKE

Radio-Galaxy 3C403

α=298.06° δ=+2.5°



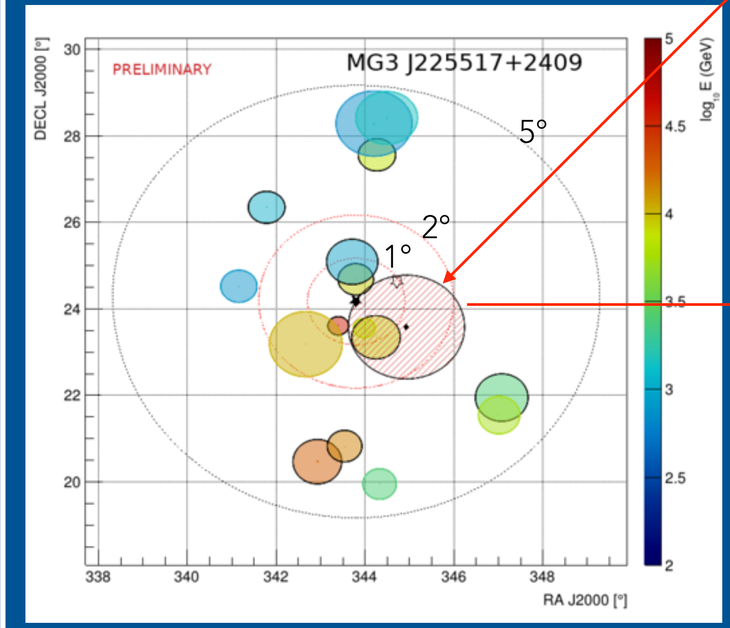
pre-trial value 2.3 10^{-4} (3.7**σ**)
2 tracks within 0.5°

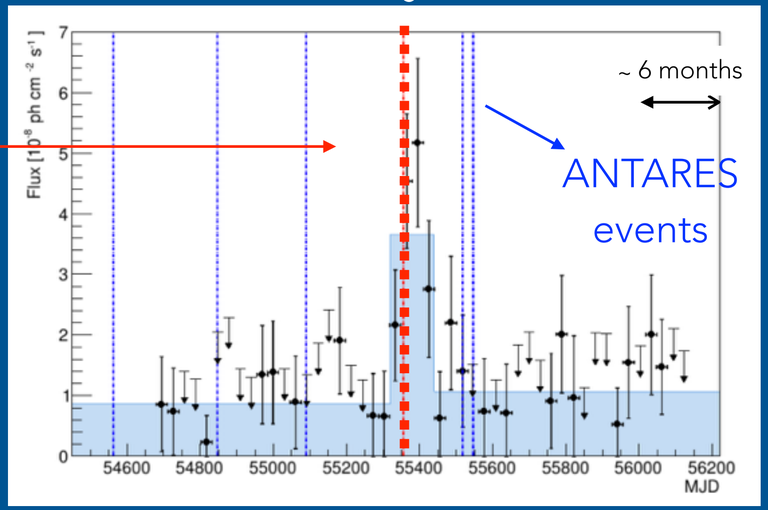
Blazar MG3J225517+2409

α=343.78° δ=+24.19°

same location found in the full-sky search

EHE IC#3 event
pre-trial value 3.8 σ
5 tracks within 1°
July 2010





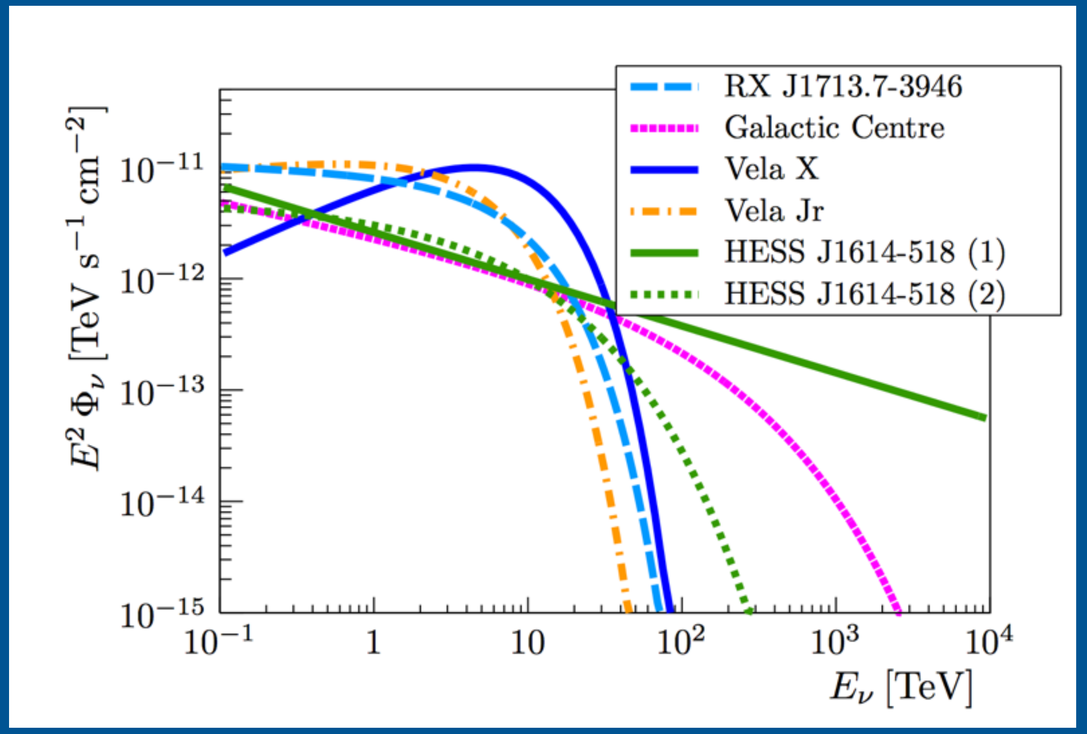
Time analysis & combining the IceCube - ANTARES events

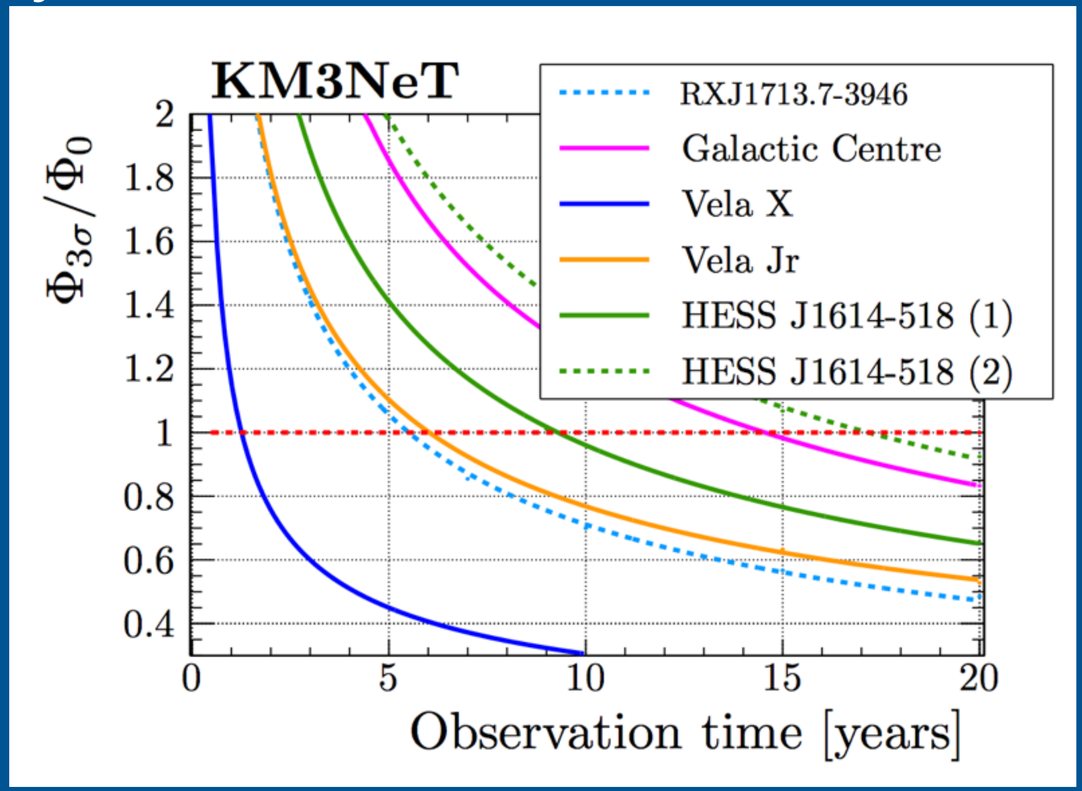
- continuous emission pre-trial value ~ 2 10^{-7} (5.2 **σ**)
- transient emission pre-trial value ~ 5 10^{-4} (3.5 **σ**)

KM3NET/ARCA GALACTIC SOURCES

Selected Galactic intense γ-ray emitter sources (HESS)

Neutrino spectra predicted from γ-ray spectra
Hypotheses: 100% hadronic emission and transparent source





3σ discovery in ~5 years for the SNR RXJ1713
3σ discovery in ~3 years stacking RXJ1713 & Vela Jr

KM3NeT Collaboration Astropart.Phys. 111 (2019) 100-110

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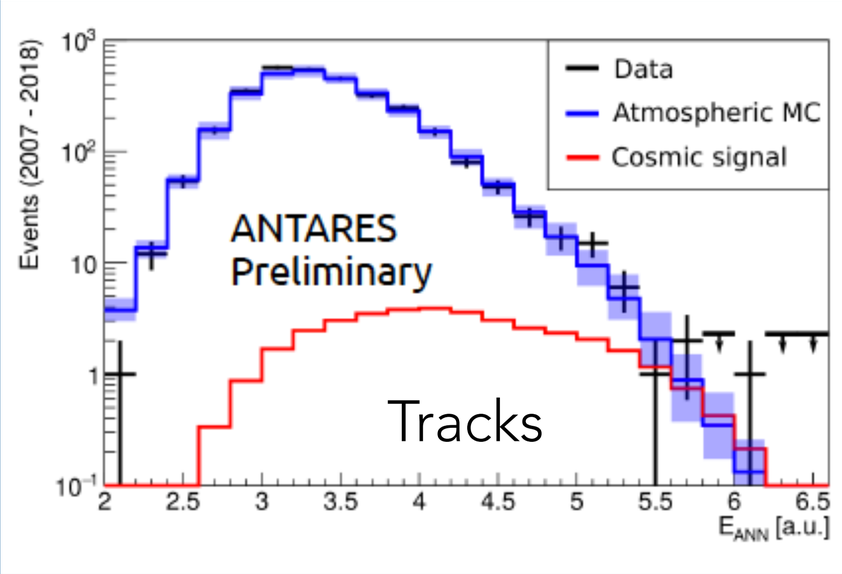
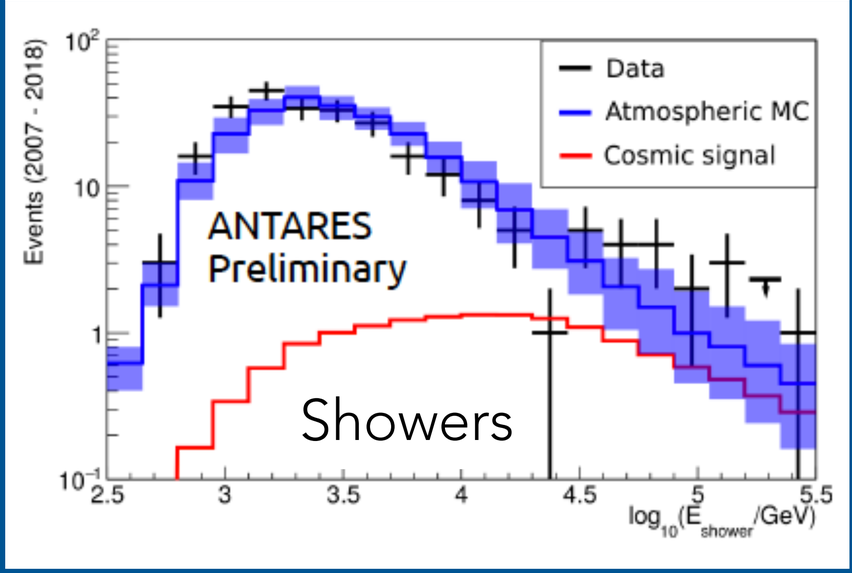
DIFFUSE FLUXES

Analyzed 2007 -2018 data



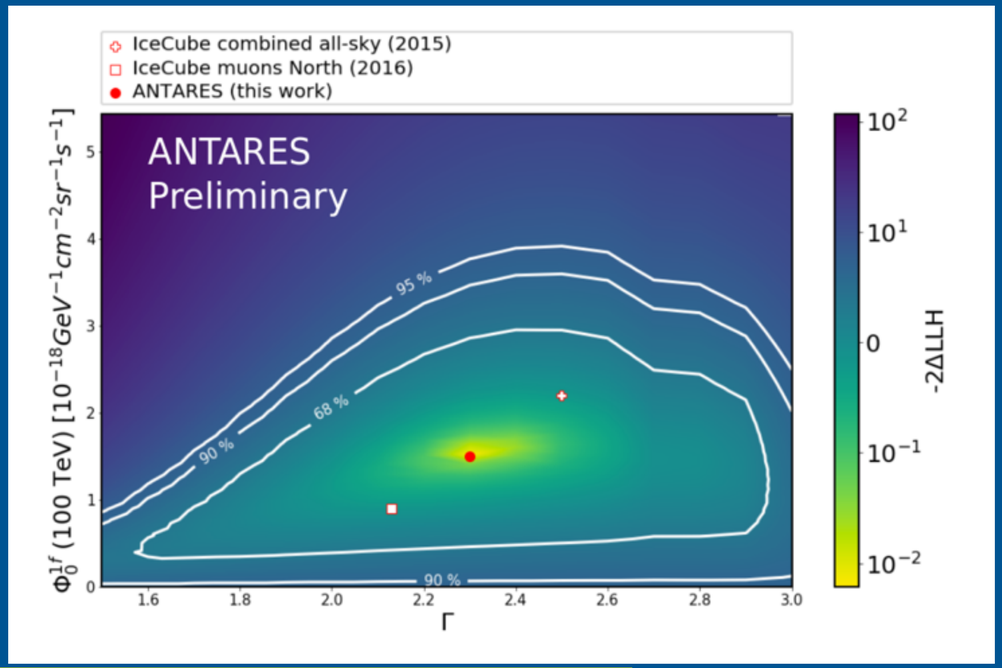


data: 50 events (27 tracks + 23 showers)
bkg MC: 36.1 ± 8.7 (19.9 tracks and 16.2 showers)

$\Phi = 1.5 \pm 1\ 10^{-8}\ GeV^{-1} cm^{-2} sr^{-1} s^{-1}$

$\Gamma = 2.3 \pm 0.4$

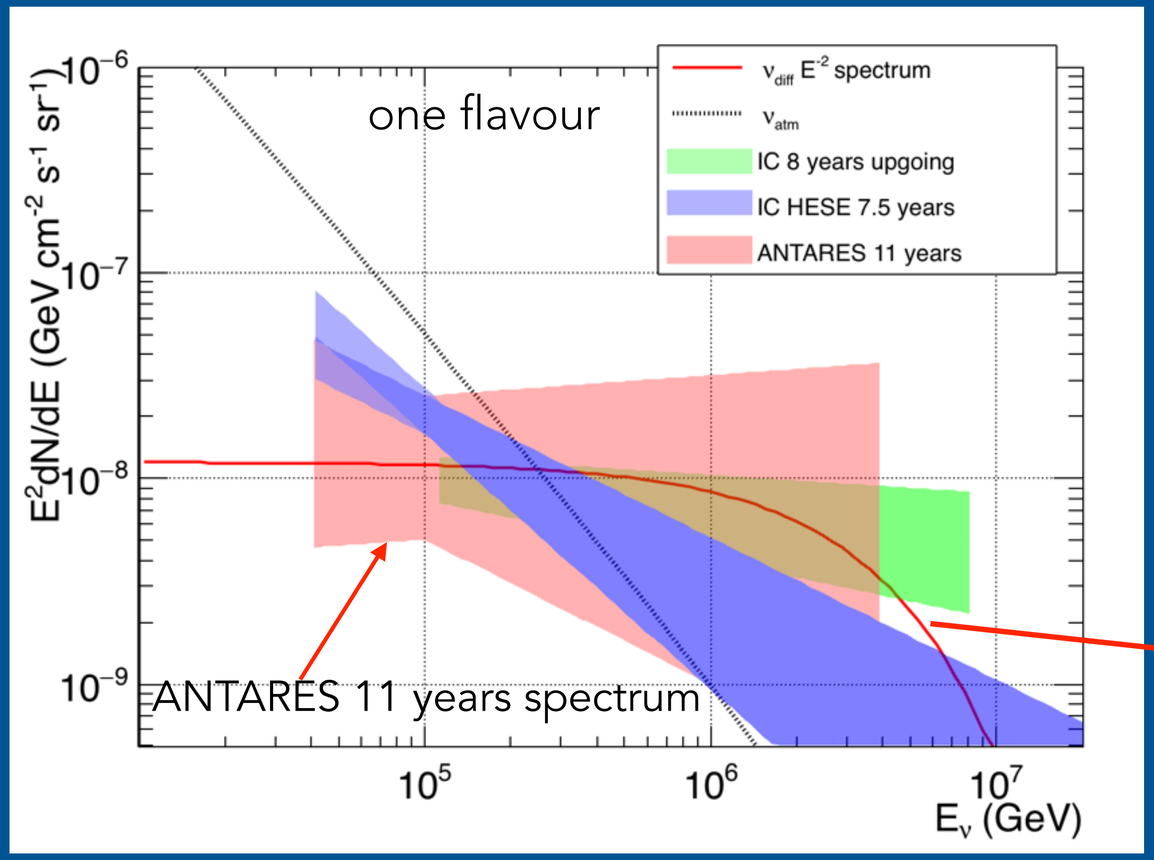
Atmospheric flux
1.25 x (Honda + Enberg)

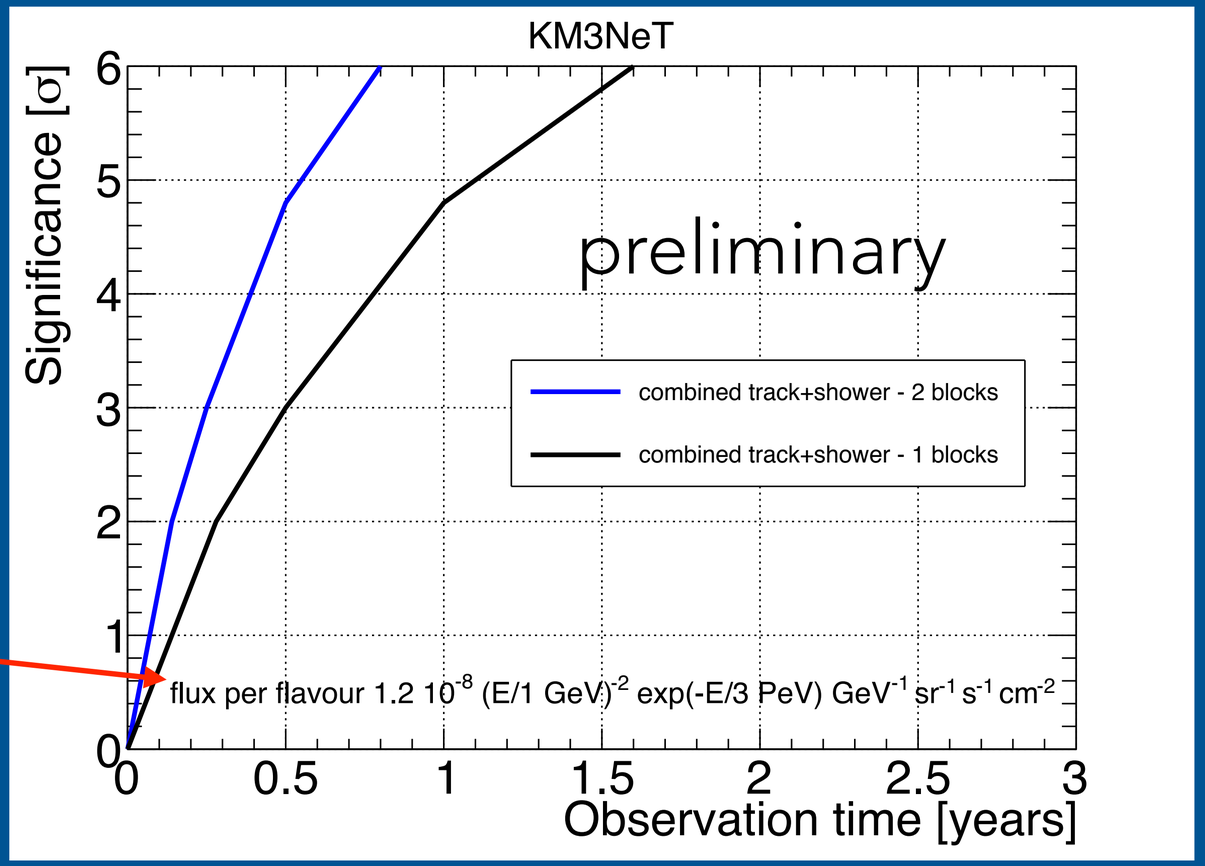


1.8σ excess
increased w.r.t. the 9 years analysis*

* ANTARES coll. The Astrophysical Journal Letters, 853, Number 7 (2018)

DIFFUSE FLUXES: KM3NET/ARCA





5σ in ~ 0.5 year for the full detector (230 DUs)

5σ ~ 1 year for one block detector (115 DUs)

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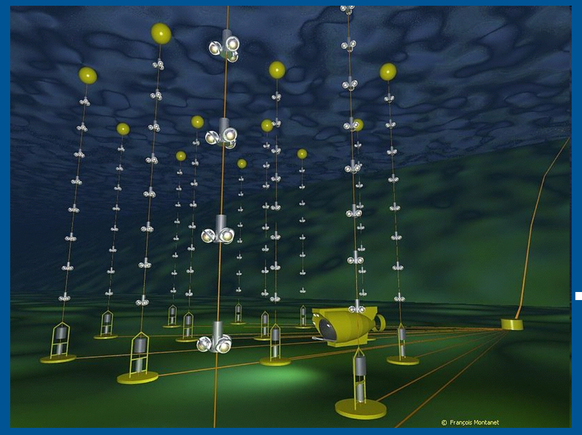
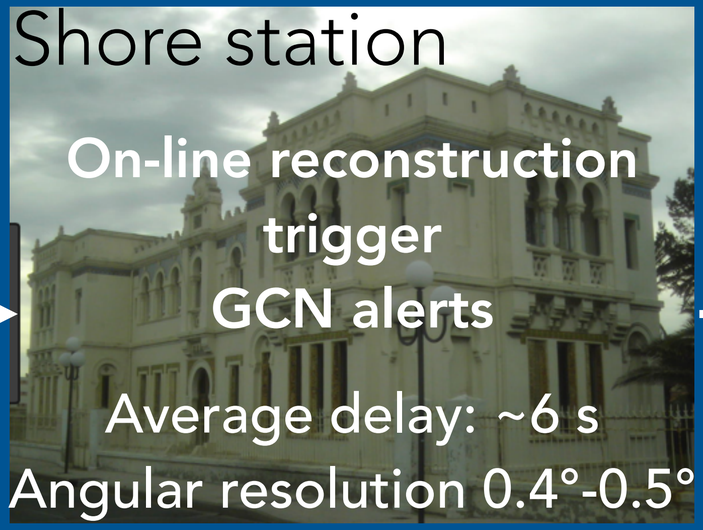
MULTIMESSENGER

ANTARES sends alerts





in 10 years

311 alerts sent to robotic telescopes

18/25 followed by Swift

4 followed by Integral

4 followed by MWA

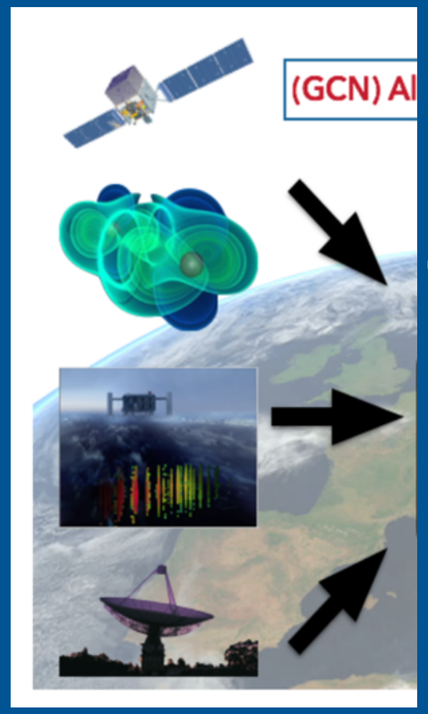
2 followed by HESS

NO transient source associated to ANTARES alerts so far

MULTIMESSENGER

D. Dornic Poster # 872

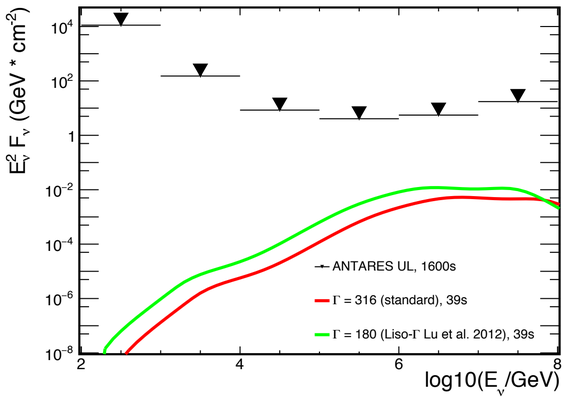
ANTARES receives alerts



GCN alerts

Follow-up of GW - runs O2 and O3
Follow-up of 11 high energy IC alerts
Follow-up of GRB triggers (226 Swift and 536 Fermi GRBs.)

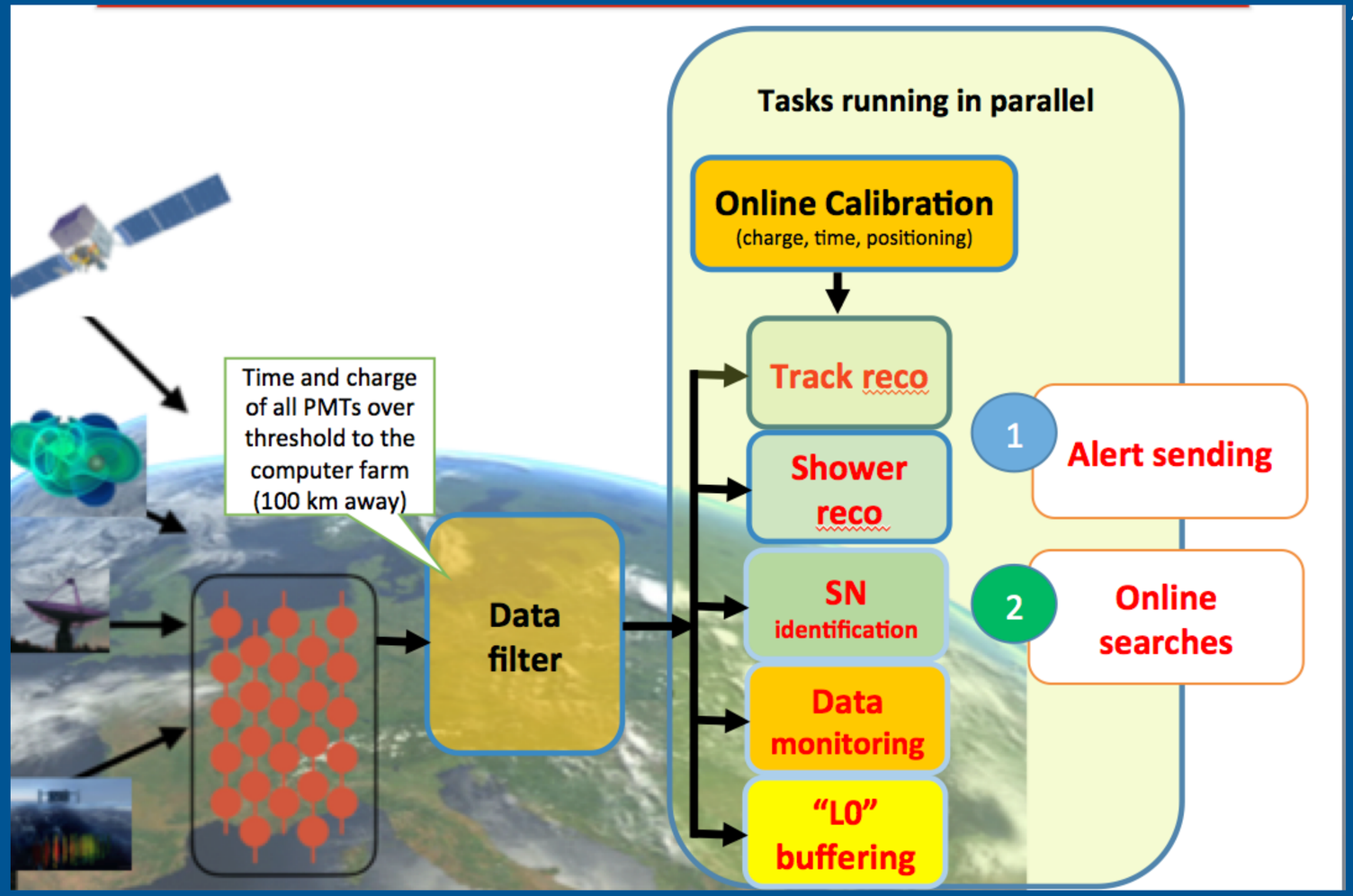
upper limits for GRB 190114c



NO neutrino associated to external alerts so far

search for counterparts GW O2 - M. Colomer Molla Talk Tuesday #856
search for counterparts HAWC Mrk 421/501 - M. Organokov Talk Saturday #972
search for counterparts AUGER - A. M. Barbano (IceCube), Talk Saturday

KM3NET MULTIMESSENGER PROGRAM



Already implemented:

- on-line track reconstruction
- trigger for CCSN

Open Public Alert Program is being implemented for both ORCA and ARCA detectors

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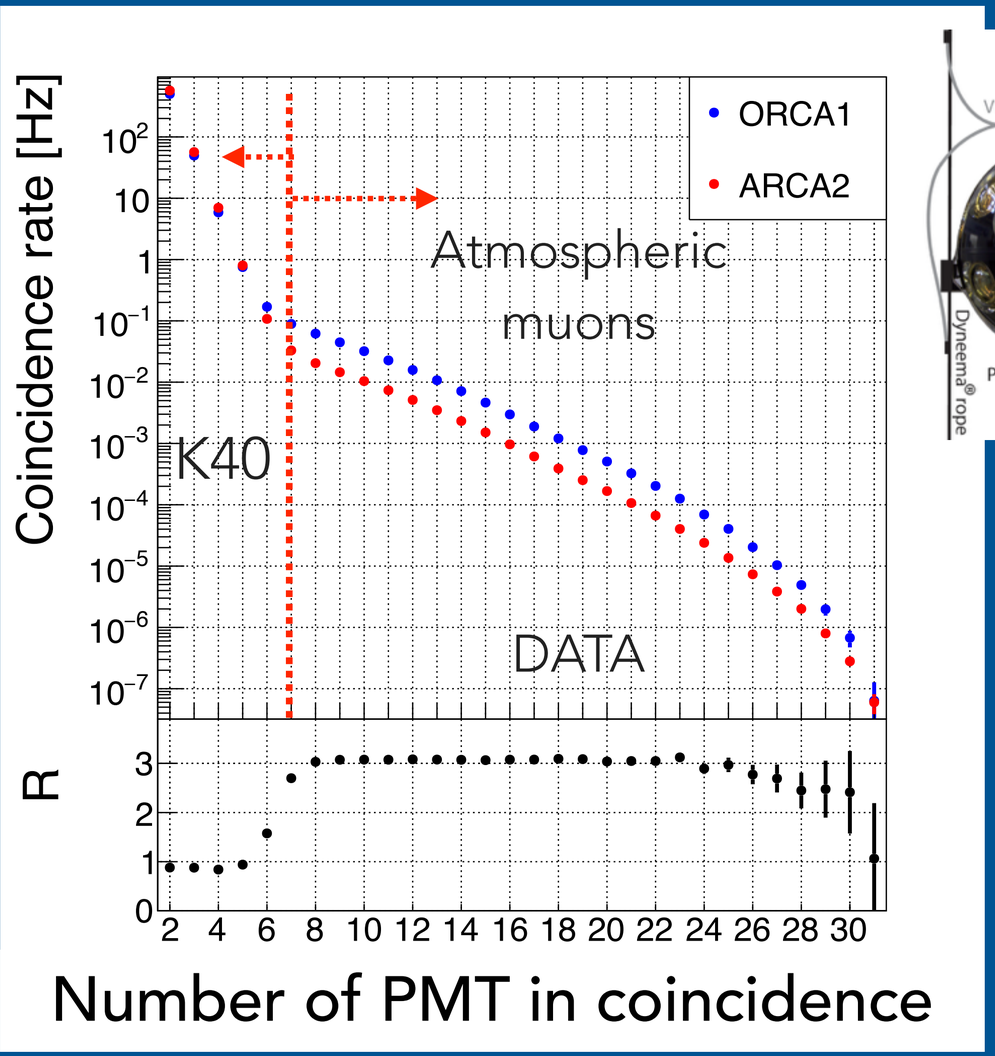
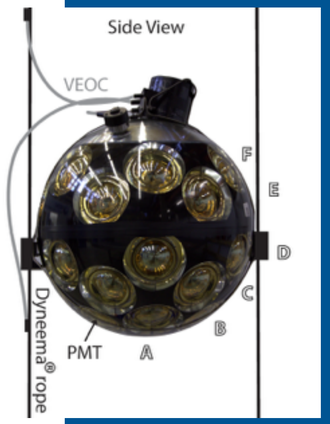
CORE COLLAPSE SUPERNOVAE (CCSN)

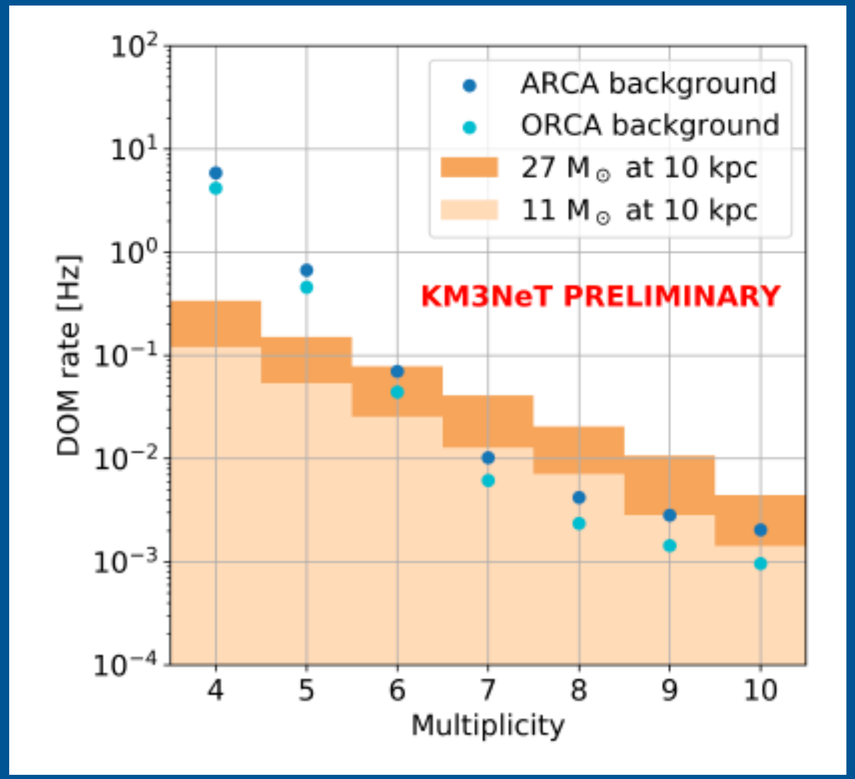
M. Colomer - PoS #857

From MC and first KM3NeT data developed a method to observe CCSN





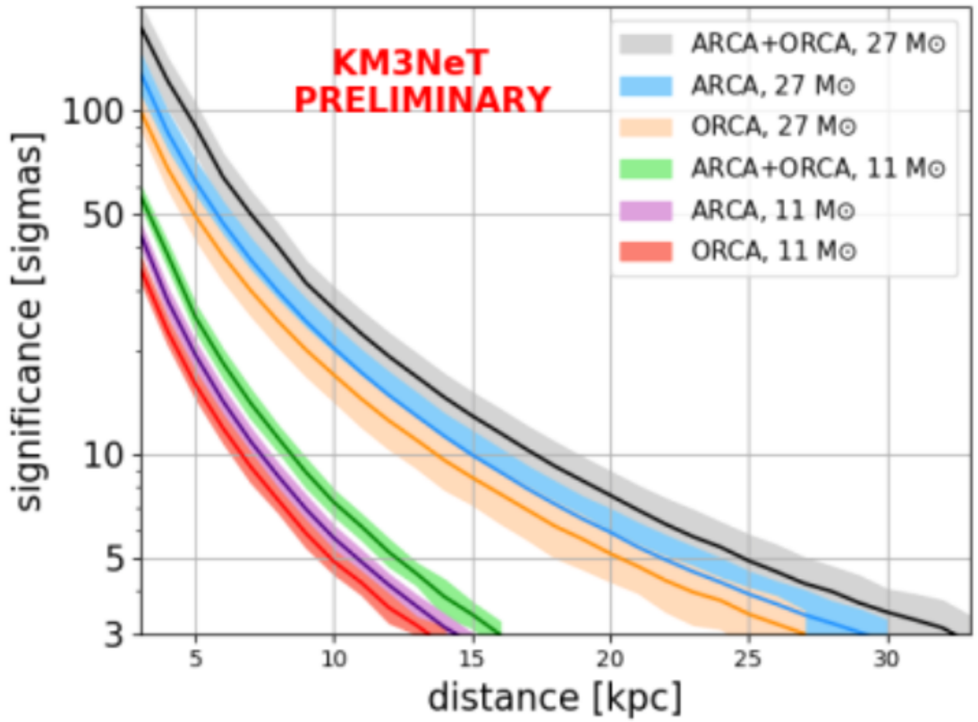
Many MeV neutrino expected and observed as a collective increasing of DOM rates



Muon rejection applied

A single DOM can act as a detector

CORE COLLAPSE SUPERNOVAE (CCSN)



>5σ for ARCA+ORCA for 27M $_\odot$ at a distance <25kpc

SNEWS requires no more than 1 false alert per week

ARCA 230 DU + ORCA 115 DU		
Threshold	11 $M_\odot$	27 $M_\odot$
1 / 14 days	12.5 kpc	23 kpc

A trigger for CCSN already implemented

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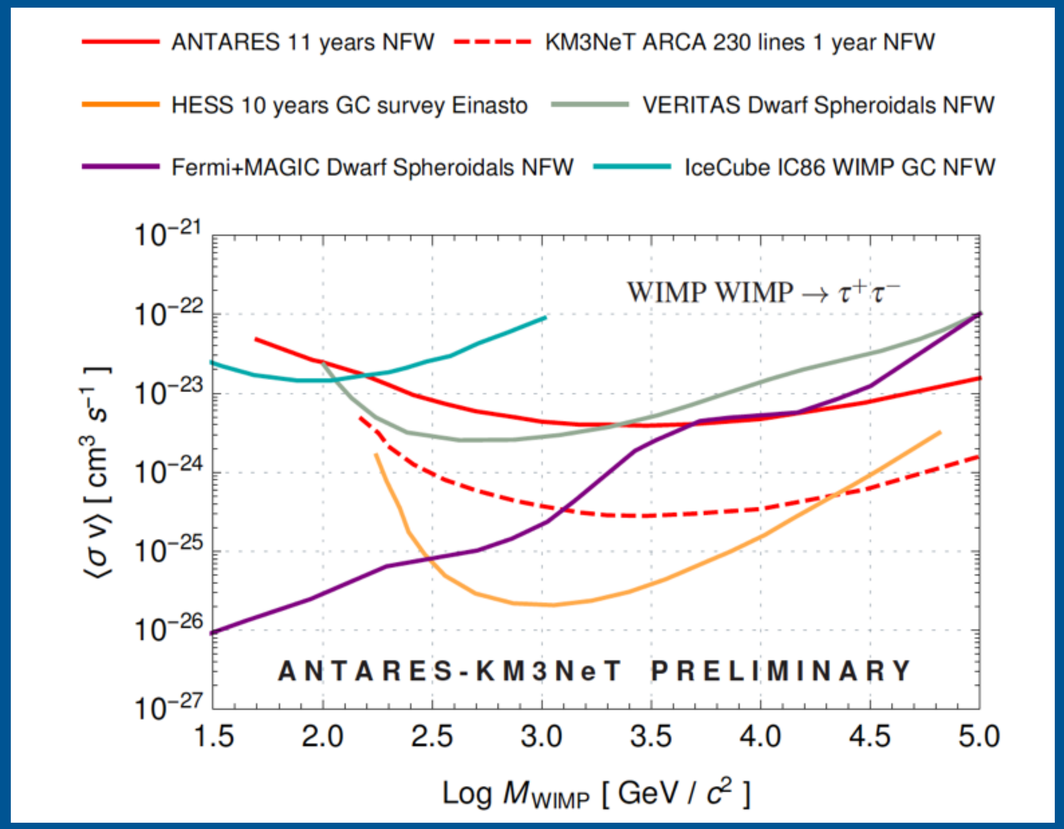
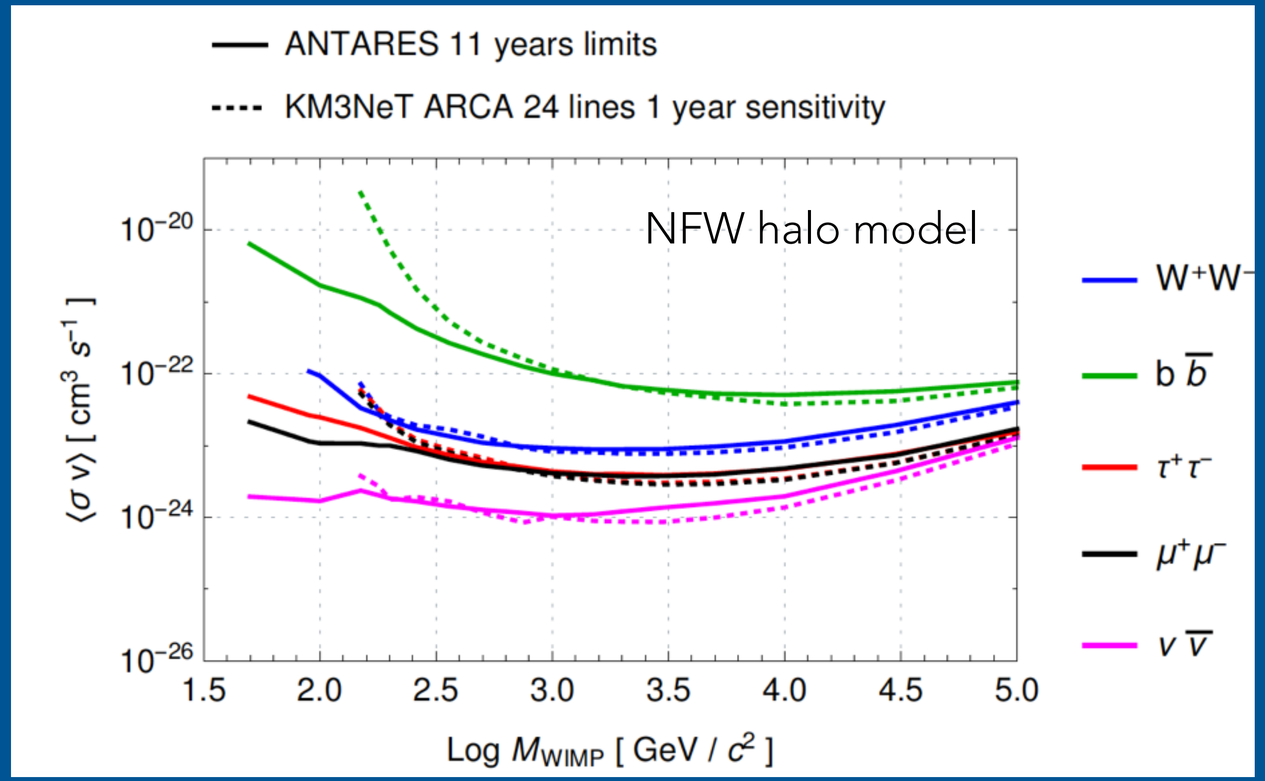
DARK MATTER SEARCHES

#522 R. Gozzini Talk Monday DM1c

Dark Matter from the Galactic Center





11 years of ANTARES data compatible with background

Sensitivity for KM3NeT/ARCA-24 DUs, 1 year comparable with 11 years of ANTARES

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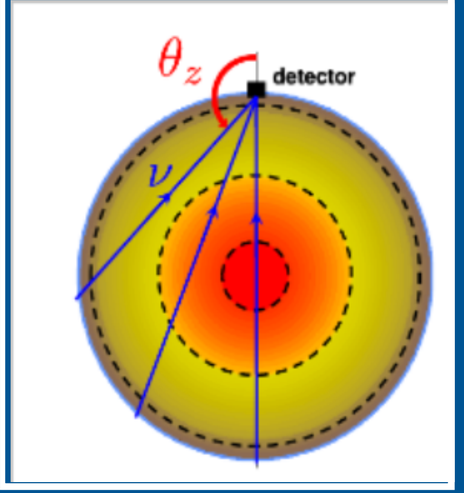
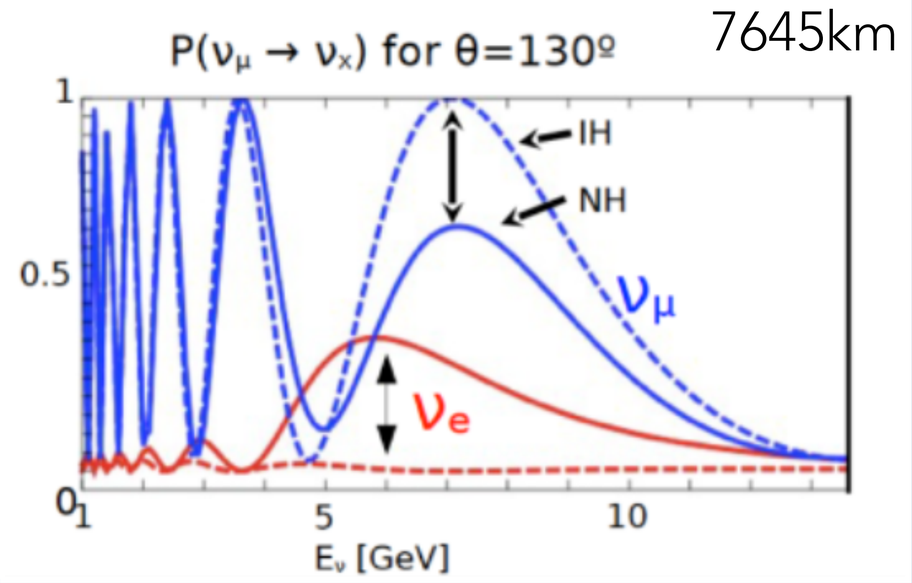
NEUTRINO OSCILLATION WITH KM3NET/ORCA

Neutrino Mass Ordering measuring atmospheric neutrinos crossing the Earth

Baseline from 50 to 12800 km



Energy range of interest 5-15 MeV

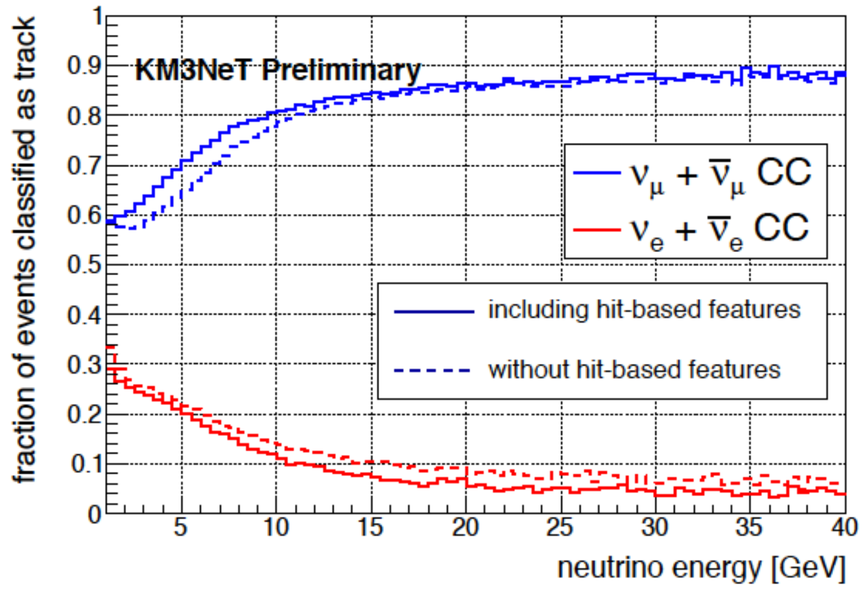


Energy resolution ~25% @ 10GeV

Zenith angular resolution ~ 5° @ 10GeV

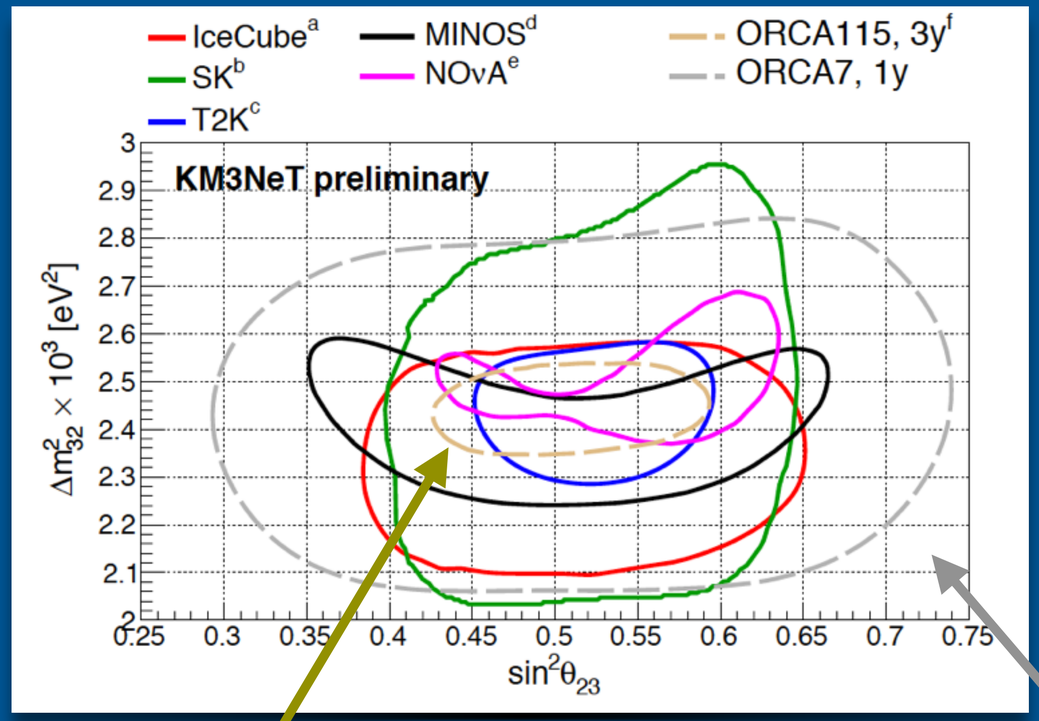
Good track-cascade discrimination

track-cascade discrimination with Random Decision Forest



NEUTRINO OSCILLATION WITH KM3NET/ORCA

Measurement of the ν_μ disappearance



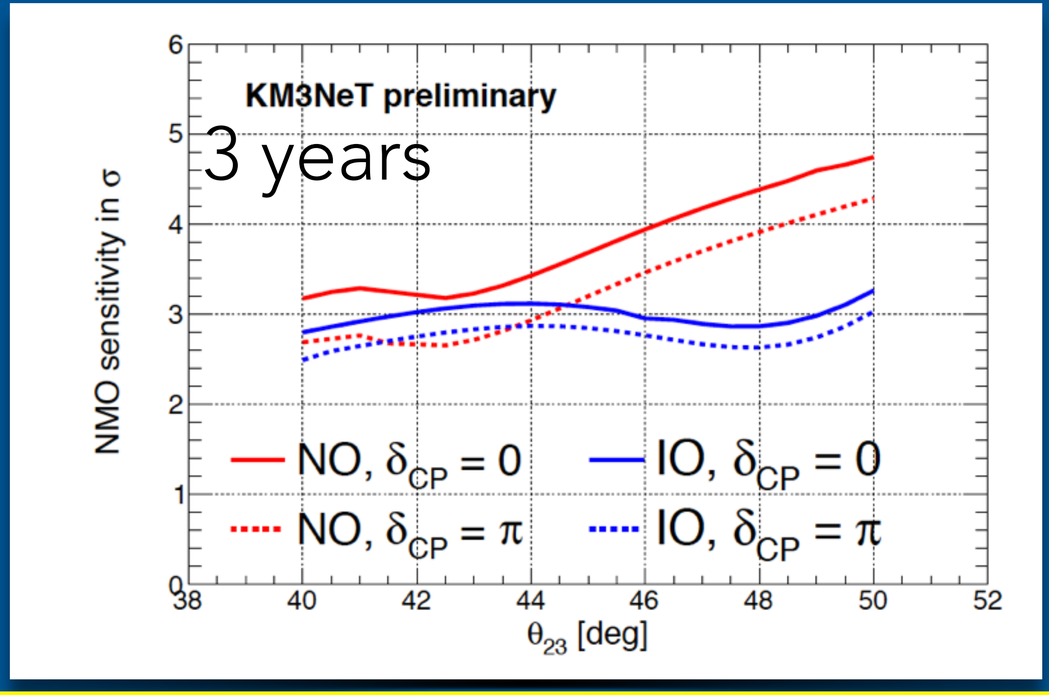
ORCA115 DUs 3y

ORCA 7 DUs 1y

KM3NeT/ORCA competitive

Systematics

- Neutrino oscillation parameters
- Atmospheric neutrino flux parameters



≳ 3σ in 3 years

> 4σ in 3 years for NO and large θ_{23}

ANTARES & KM3NET @ ICRC2019

ANTARES and KM3NeT 35 contributions

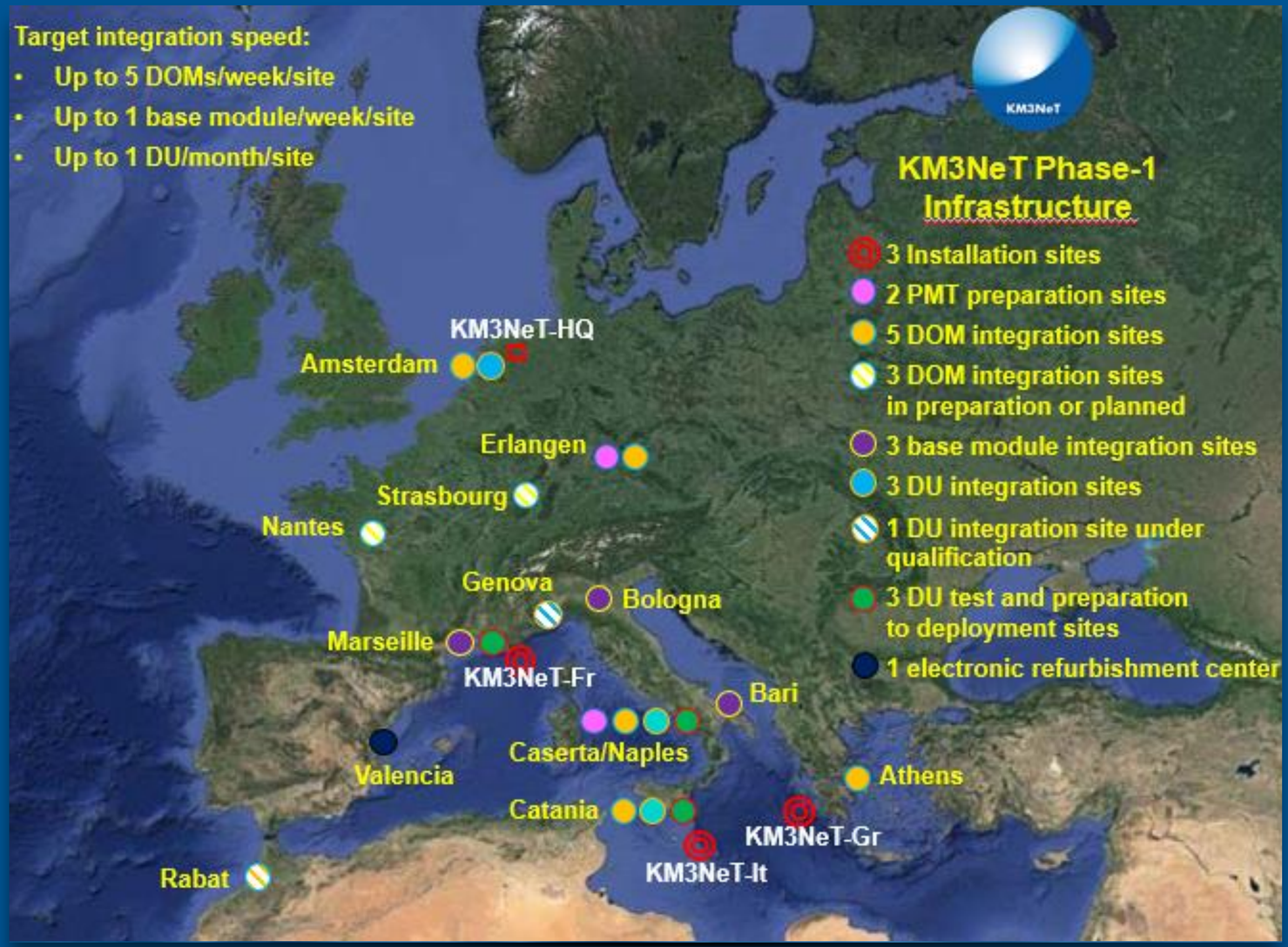
results reported in this talk

- **Search from point-like sources**
  - G. Illuminati S. Navas - #920 Talk Saturday Nu6d
  - J. Aublin - #840 Talk Friday Nu3b
- **Search for neutrino diffuse flux**
  - L. Fusco - #891 Talk Friday Nu4g
- **Multimessenger**
  - D. Dornic - #871 Talk Tuesday Nu9e
  - Poster #872
- **CCSN**
  - M. Colomer Molla - Poster #857
- **Dark Matter**
  - R. Gozzini - #522 Talk Monday DM1c
- **Oscillation studies**
  - B. Strandberg - #1019 Talk Monday Nu7b
- **KM3NeT first results**
  - J. Hofestadt - #910 Talk Friday Nu4c

and many other results in 10 talks and many posters

KM3NET: STATUS

Detector in the construction phase



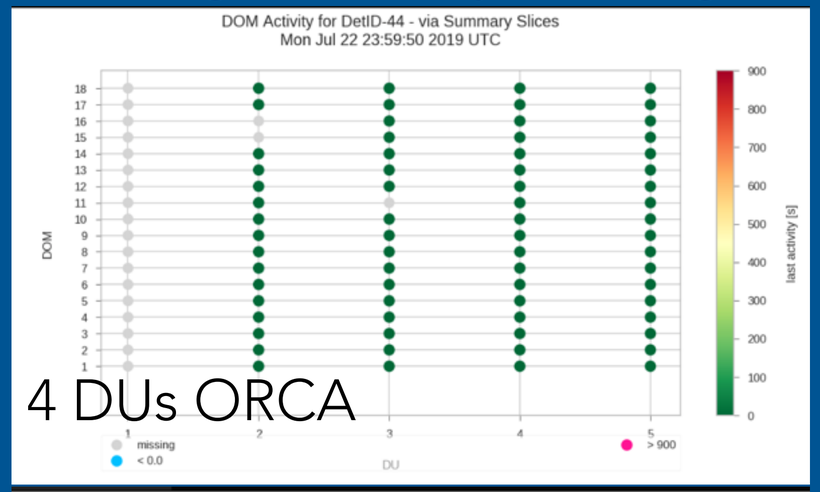
Integration sites

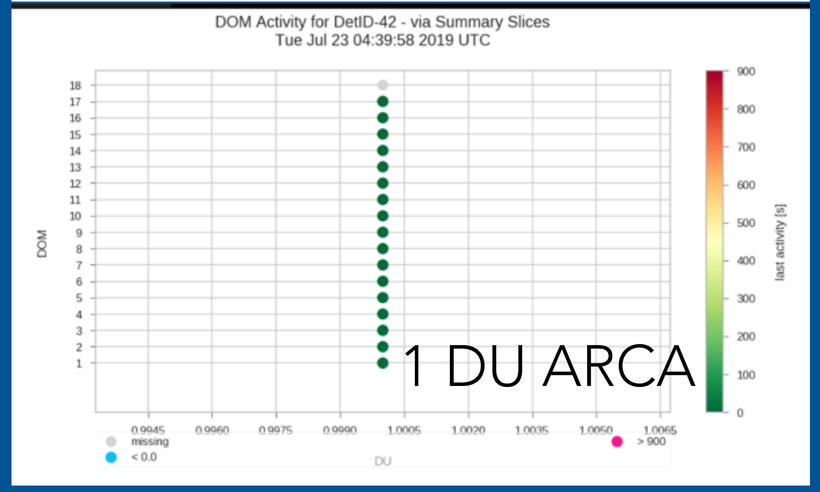
- 3 DU integration sites
- 8 DOM integration sites
- 3 base module integration sites

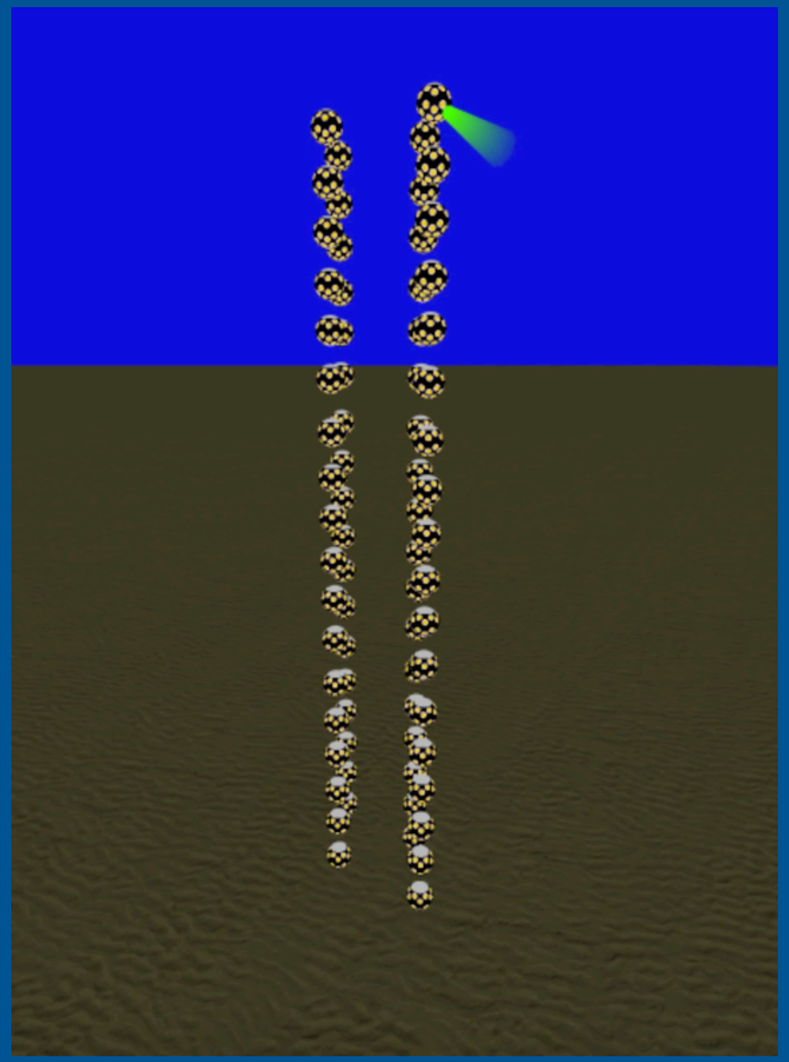
KM3NET: STATUS

DUs working

Strings currently working



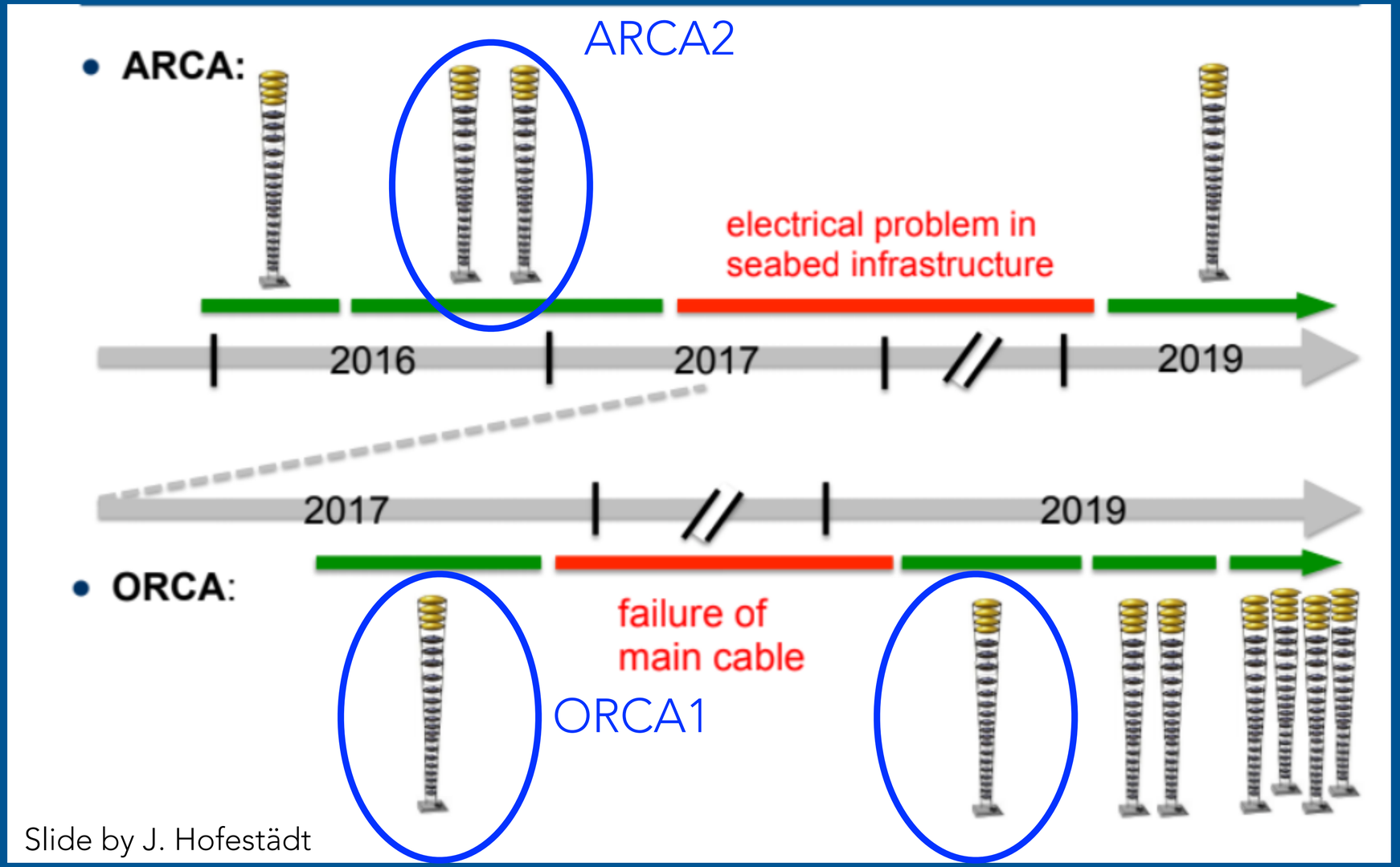




event detected
the 18th of July
cos(θ)=-0.95

KM3NET: STATUS

History of detector construction

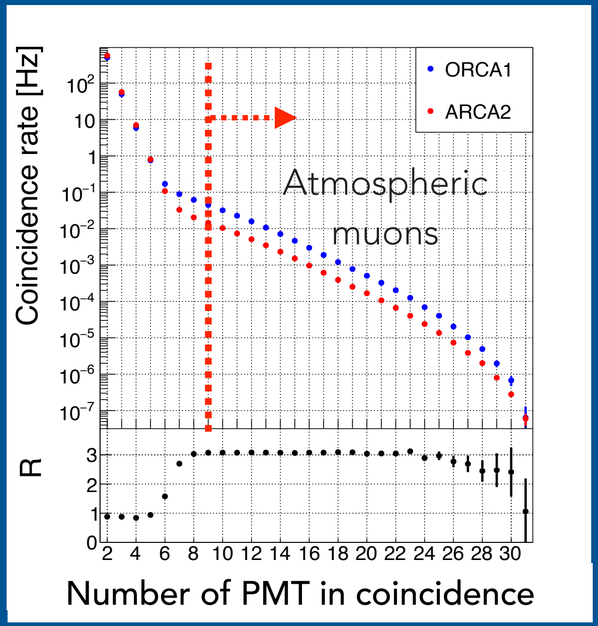


Slide by J. Hofestädt

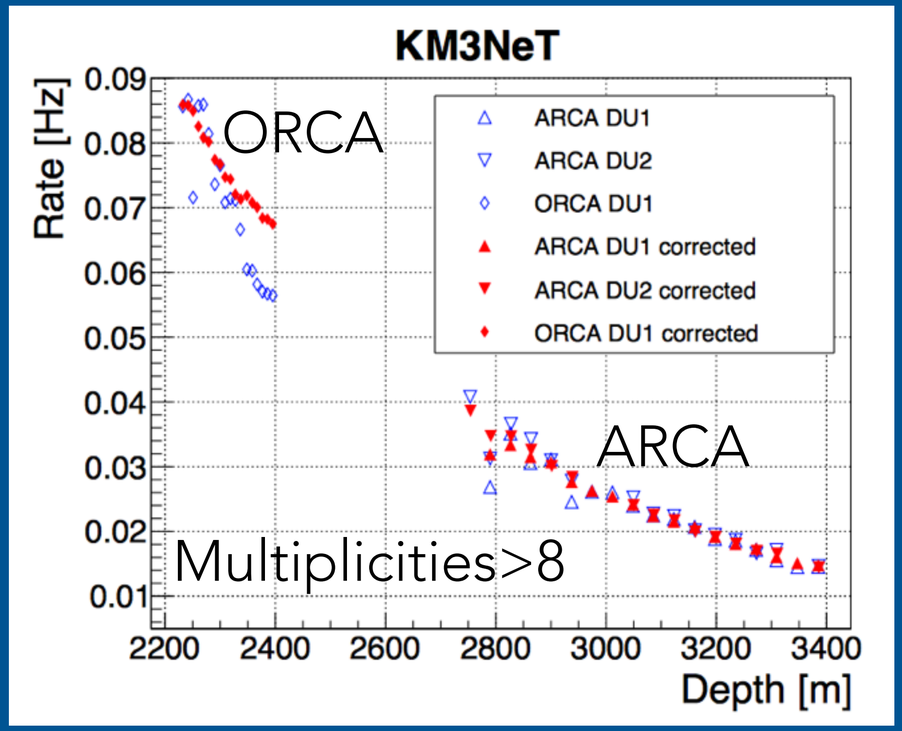
KM3NET FIRST RESULTS

M. Lincetto PoS #943

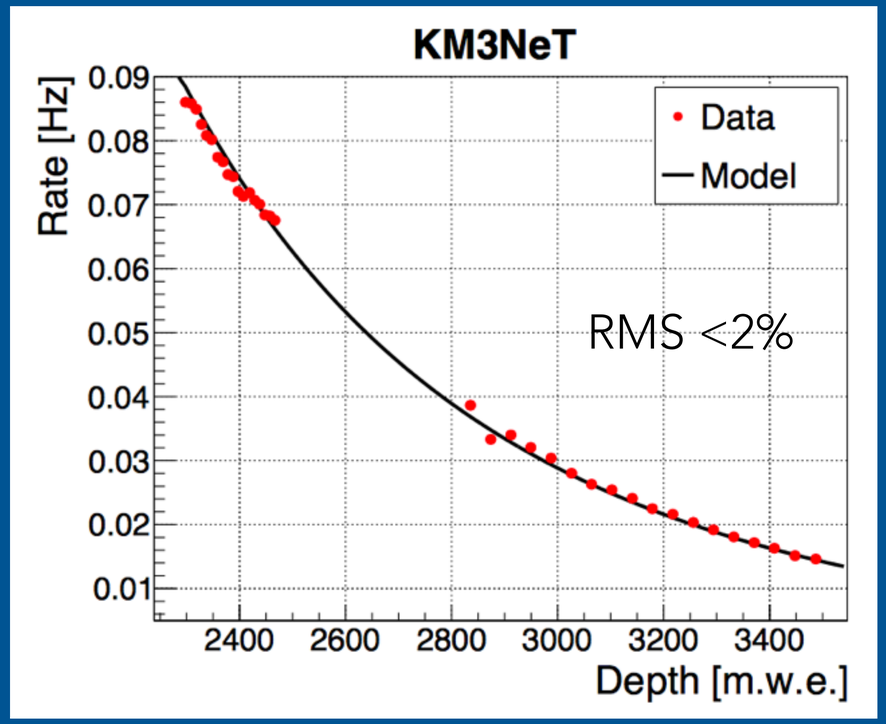
From the data collected with 2 DUs of ARCA and 1 DU of ORCA



DATA corrected for the PMT detection efficiency measured from K40 (run-by-run)



DATA compared with a muon depth dependence model (Bugaev et al, Phys. Rev. D 58 1998 054001)



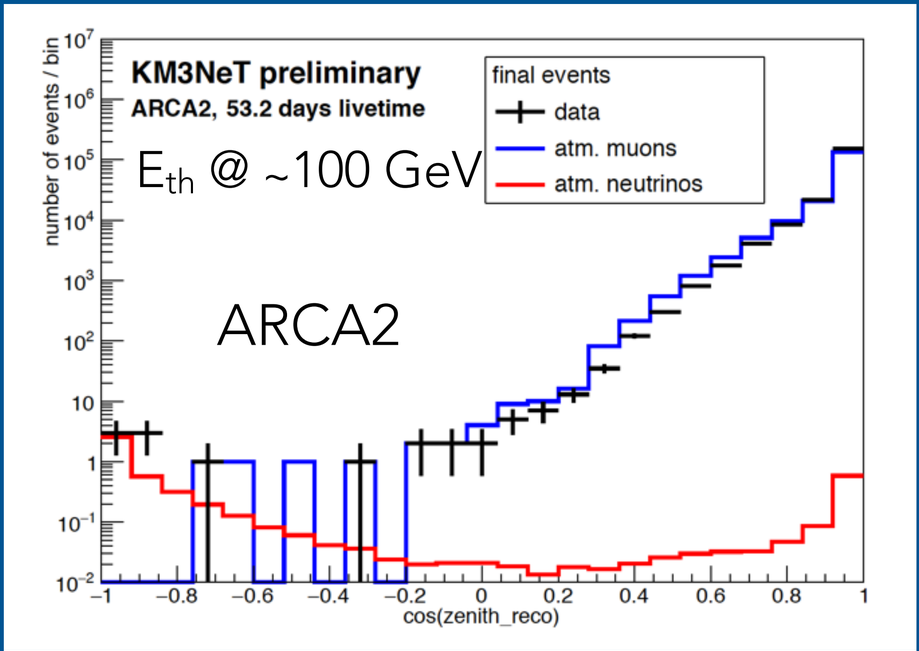
https://arxiv.org/pdf/1906.02704.pdf

Proved calibration and PMT detection efficiency measurement

KM3NET: FIRST RESULTS

Up-going atmospheric neutrino selection

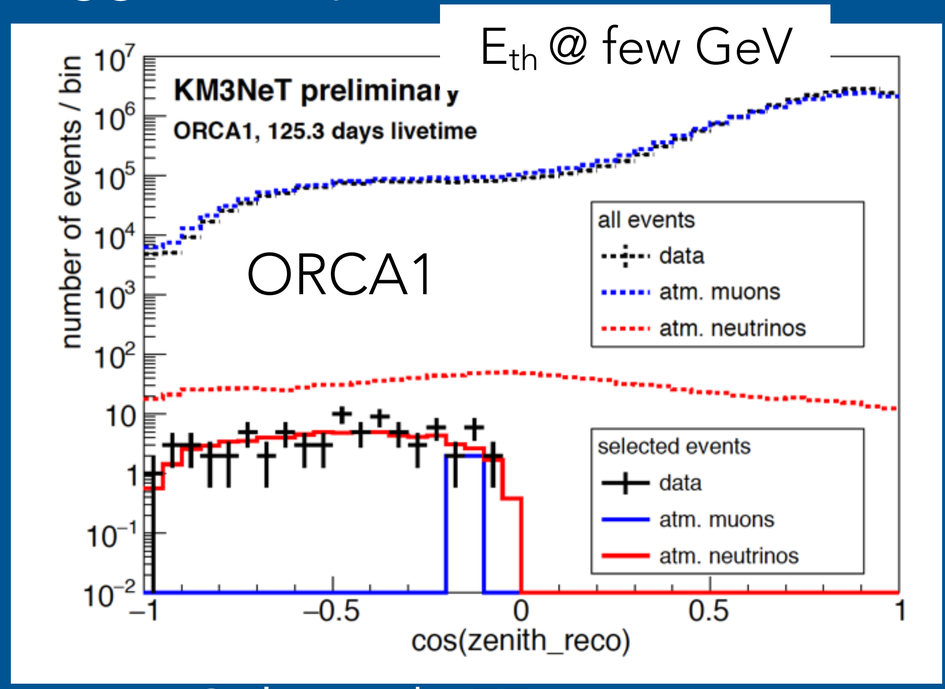
trigger rate μ_{atm} ~0.2 Hz - ν_{atm} ~1/day



Selected ~6 neutrinos with $\cos(\theta_{rec})<-0.8$

MC: μ_{atm} 0 - ν_{atm} 3.3

trigger rate μ_{atm} ~2 Hz - ν_{atm} ~10/day



Selected ~77 neutrinos

MC: μ_{atm} 4 - ν_{atm} 67.5

Good Data-MC agreement

Proved the possibility to detect neutrinos also with 1-2 DUs

CONCLUSIONS

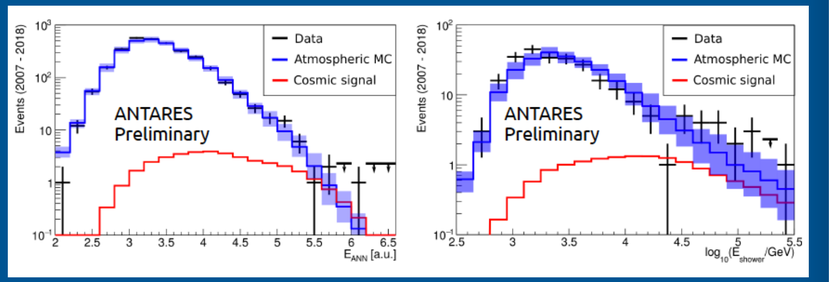
Results from 11 years of ANTARES data

Results from about 15 different analyses presented @ICRC and many others ongoing

- **Search for a diffuse flux**

  Mild excess of neutrinos in the search for a diffuse flux (1.8**σ**)

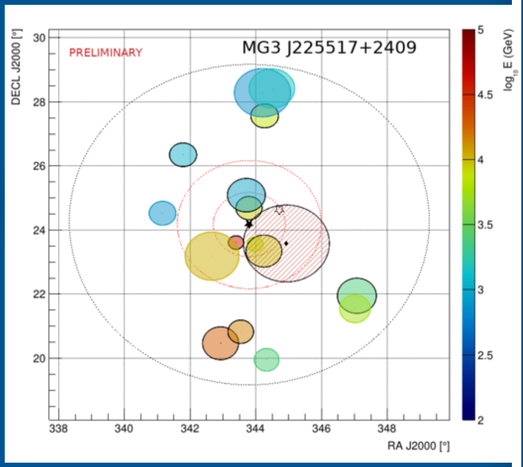
  Flux measurement compatible with IceCube observation



- **Point-like searches**

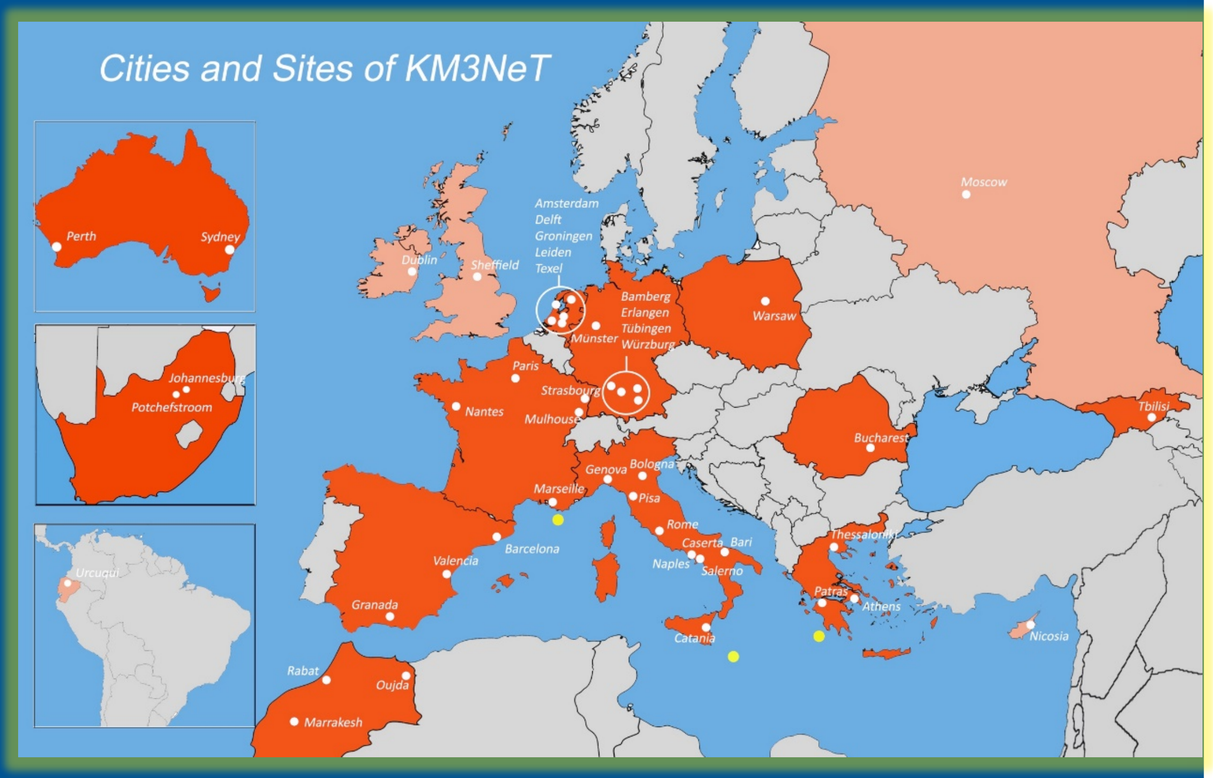
Interesting region identified (**α**=343.78° **δ**=+24.19°) in coincidence with the Blazar MG3J225517+2409

If combined with the IC ID3 pre-trial probability of about 2.2 10^{-7}(5.2**σ**)



CONCLUSIONS

KM3NeT



- Collaboration is growing
- Detectors under construction
- First 5 DUs deployed and working
- Results from first data
  - Reliability of MC simulations
  - Good calibration
  - SN alert system operational
  - Ability to select neutrinos also with few DUs