



MSCA

Marie Skłodowska-Curie Actions

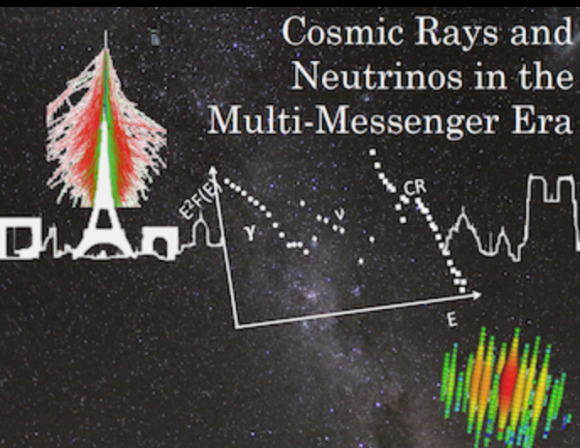


Astrophysics with large neutrino detectors



Gwenhaël de Wasseige





Cosmic Rays and Neutrinos in the Multi-Messenger Era

The 'Cosmic Rays and Neutrinos in the Multi-Messenger Era' conference aims to bring together the scientific communities working on high-energy cosmic rays and neutrinos, from an experimental point of view as well as from a theoretical and phenomenological sides.

Invited talks + Discussion sessions + Poster sessions for early-career scientists

7 – 11 December

ANTARES and KM3NeT in France



19 permanent researchers
32 engineers and technicians
5 postdocs
7 PhD students

Antoine Kouchner
ANTARES Spokesperson

Paschal Coyle
KM3NeT Physics coordinator
Chair of the Outreach Committee

Miles Lindsey Clark
KM3NeT Technical coordinator

Véronique van Elewyck
Chair of the Conference Committee

Jürgen Brunner
Neutrino osc. working group leader

Damien Dornic
MM working group leader

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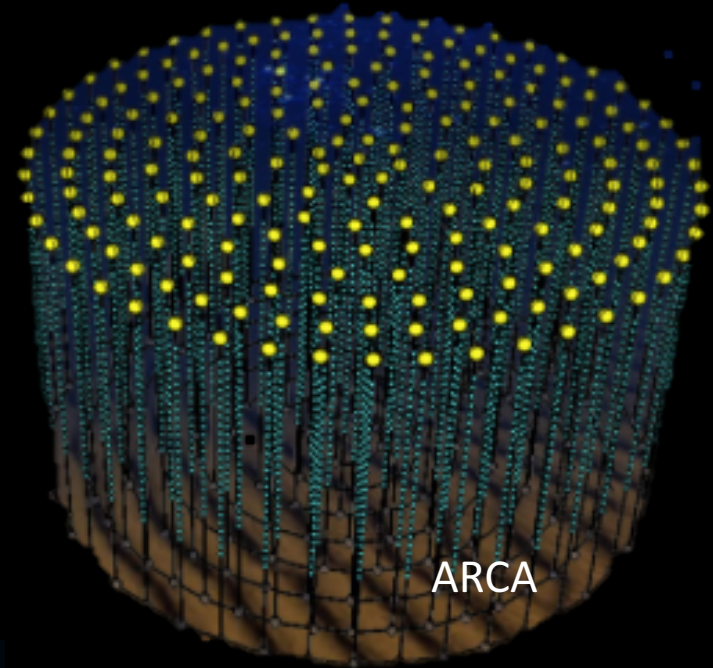
Damien Dornic
MM working group leader

ANTARES and KM3NeT: exciting times!



More than 15 years of data taking!

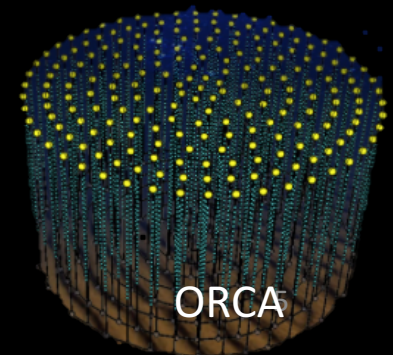
2020



Taking data for
more than 9
months!



1 ARCA Detection Unit
6 ORCA Detection Units



Detectors not to scale

ANTARES and KM3NeT: exciting times!



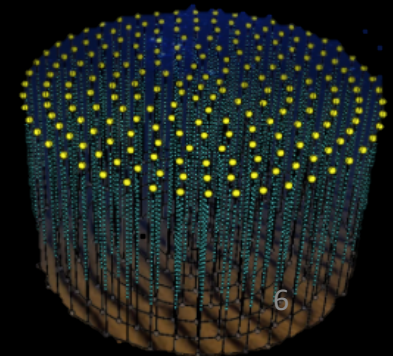
More than 15 years of data taking!

Expected for first semester in 2021:

- 6 more ORCA DUs
- ORCA Instrumentation Unit
- 5 more ARCA DUs

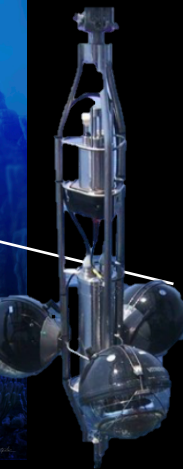
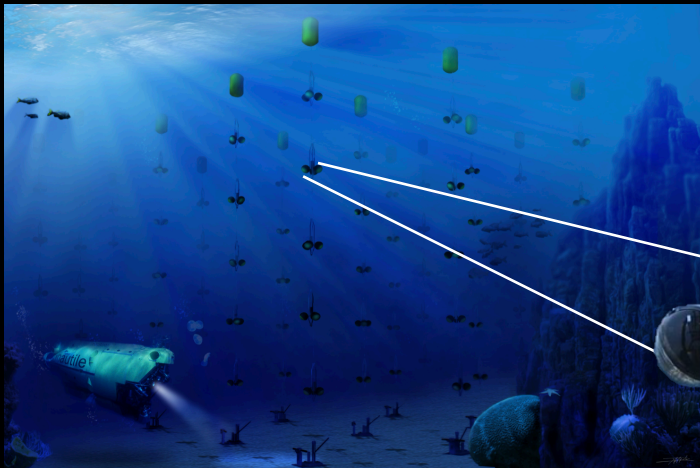
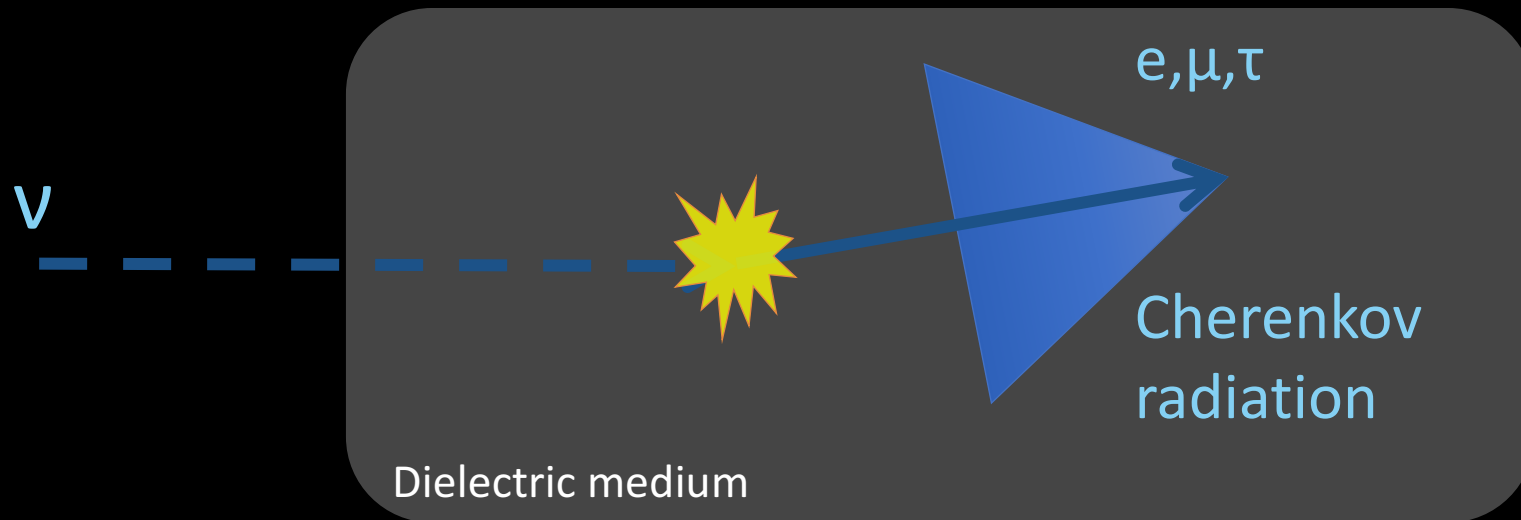
2020

1 ARCA Detection Unit
6 ORCA Detection Units



Detectors not to scale

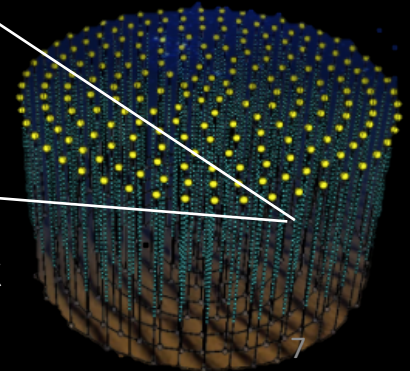
How to detect high-energy neutrinos?



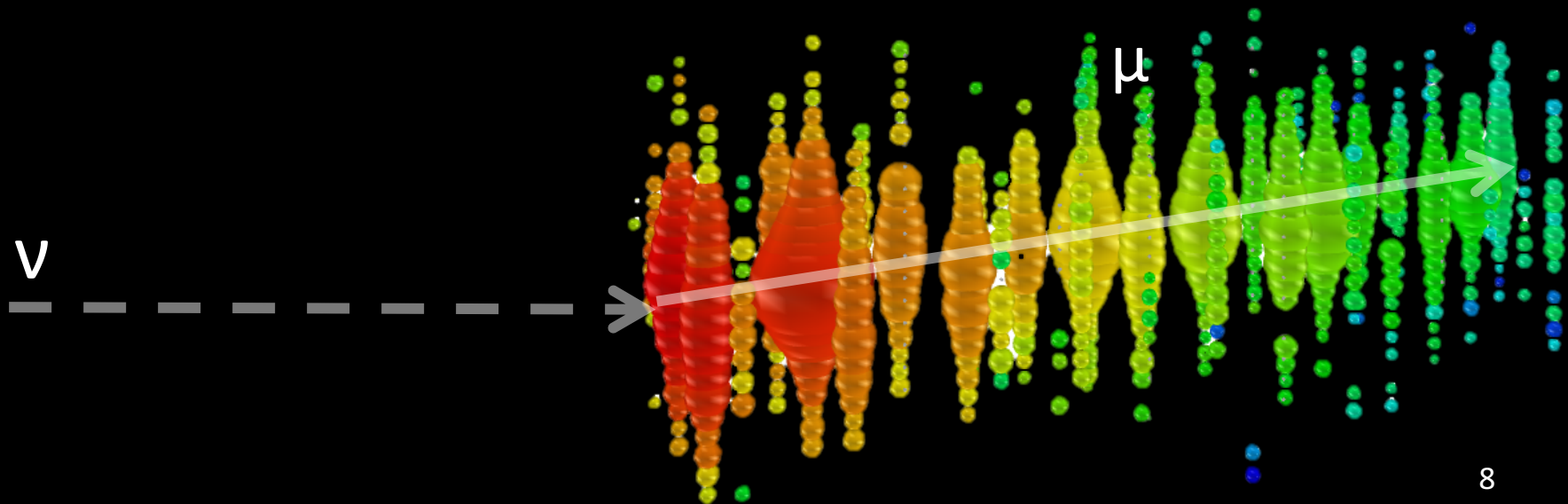
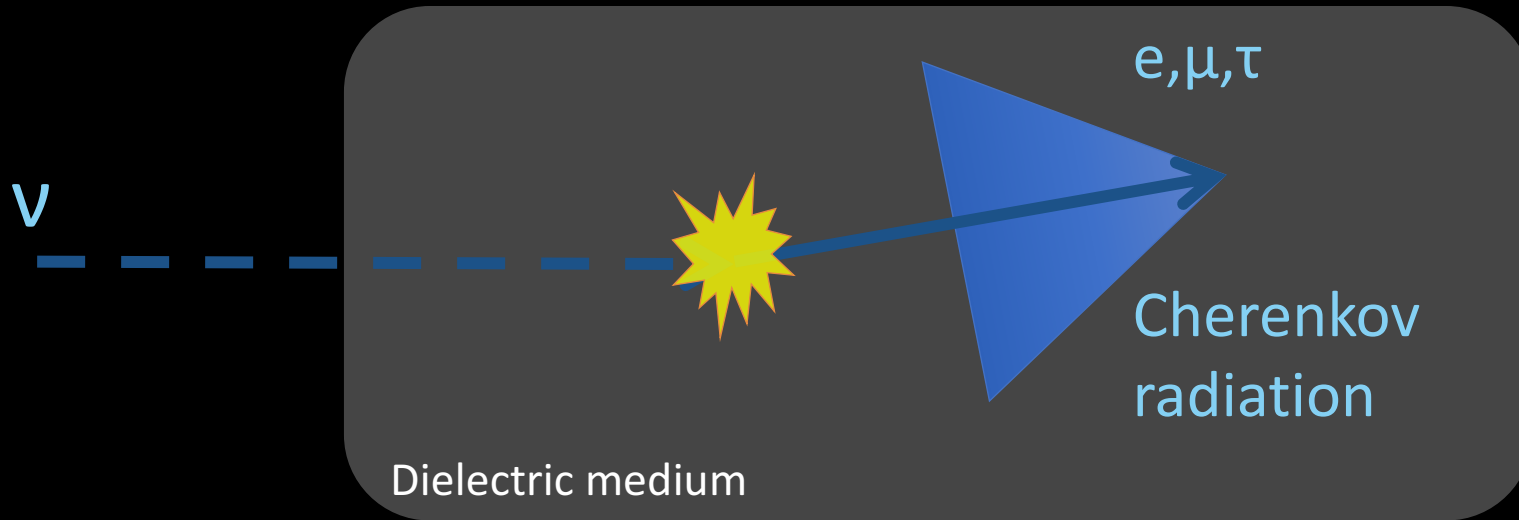
885 sensors



2070 sensors/block
1 block ORCA
+ 2 blocks ARCA

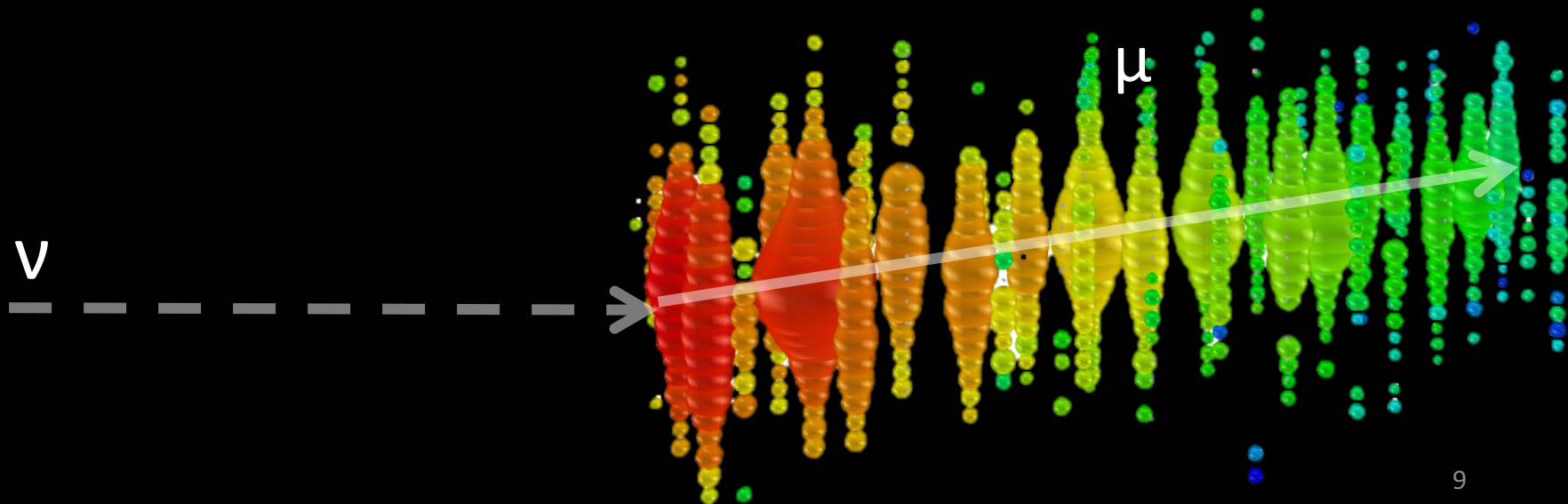
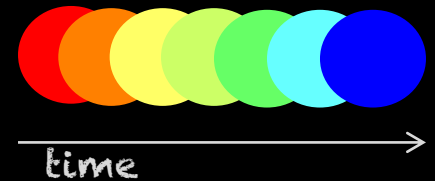


How to detect high-energy neutrinos?



Which information can we get?

- Amount of light \rightarrow Energy
- Timing \rightarrow Direction
- Topology (track/cascade) \rightarrow Flavour



1 - What have we learned with ANTARES?

2 - Which questions will we answer with KM3NeT?

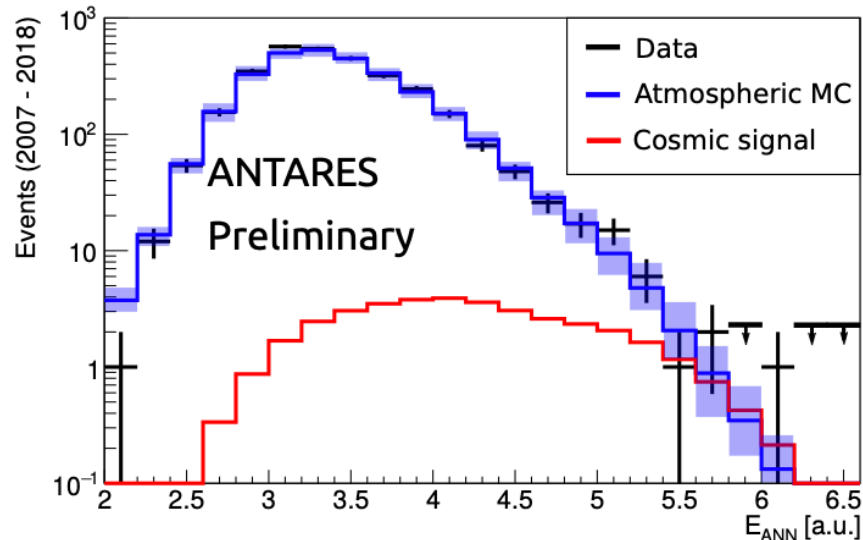
1 - What have we learned with ANTARES?

Preparing the legacy results of
ANTARES

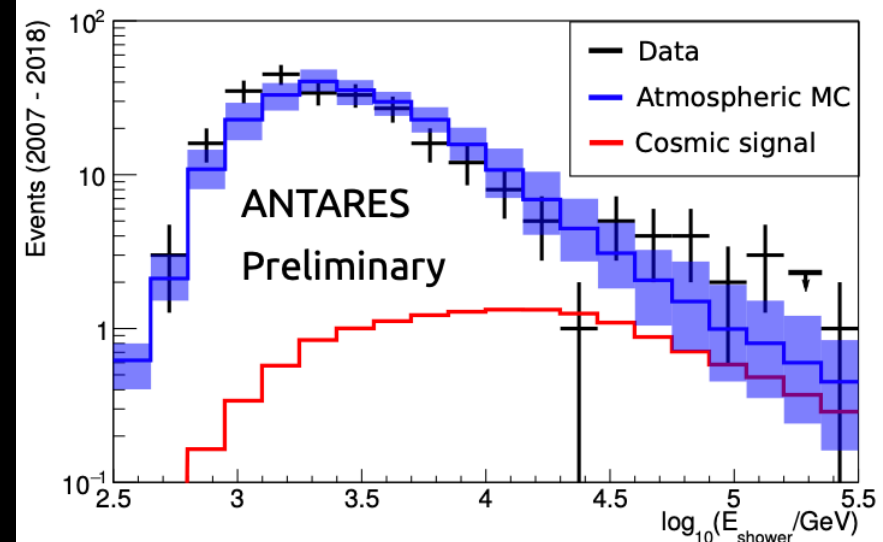
2 - Which questions will we answer with KM3NeT?

Searching for a diffuse flux

Tracks



Cascades



Data:

50 events

(27 tracks + 23 showers)

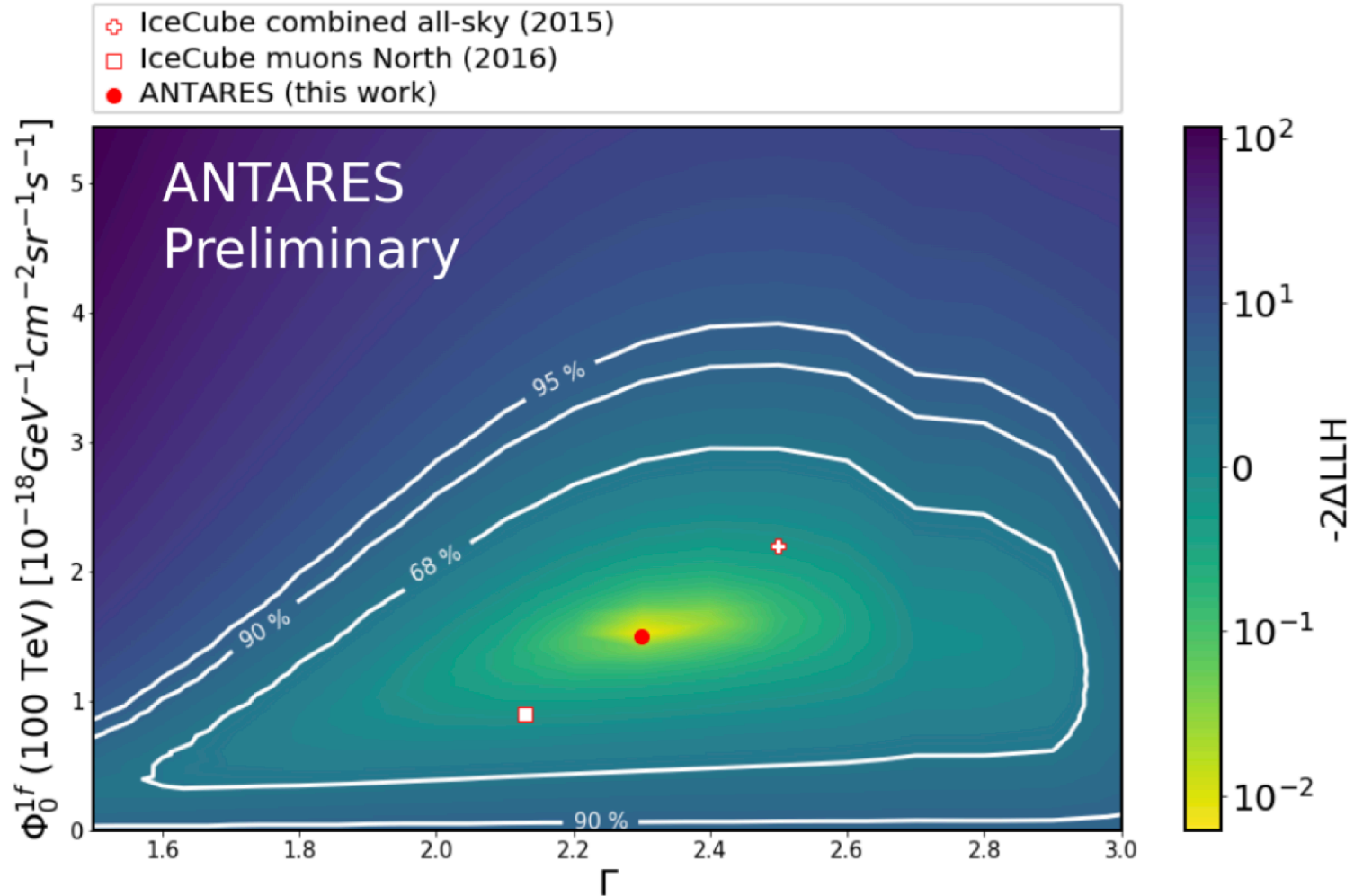
1.8 σ excess

Background (estimated from simulation)

36.1 ± 8.7 events

(19.9 tracks and 16.2 showers)

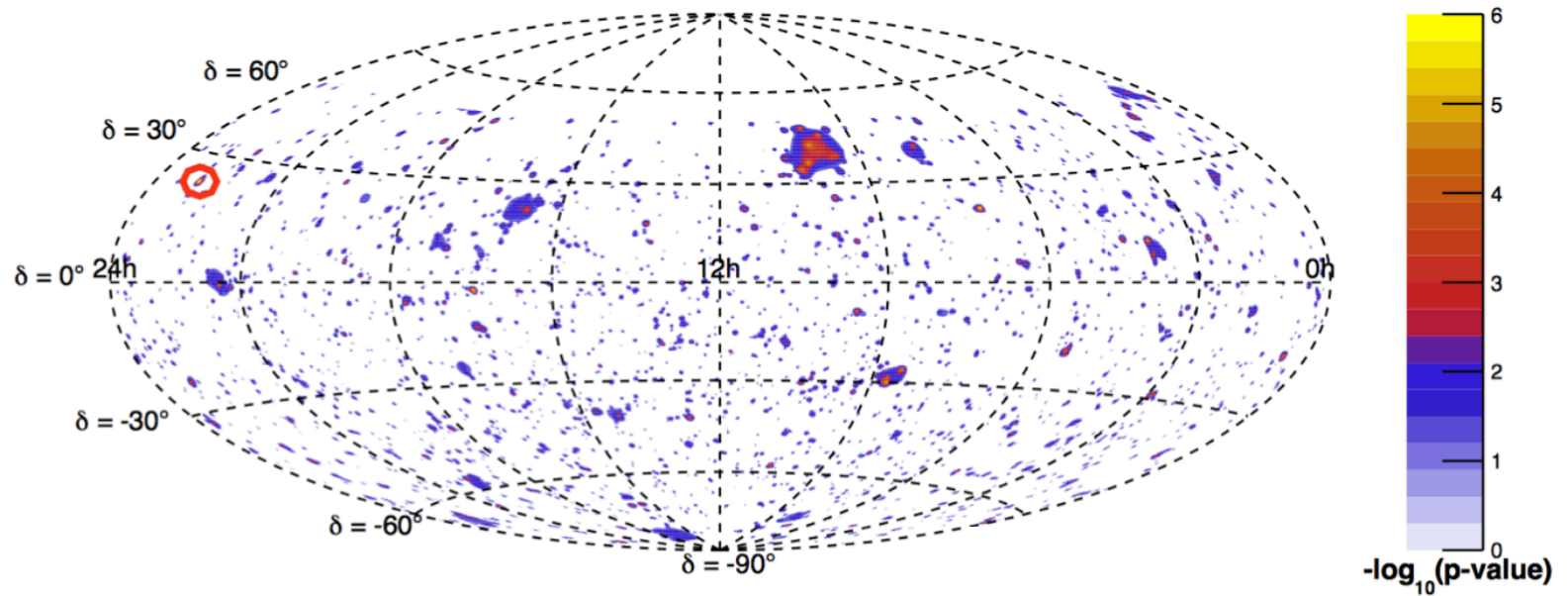
Searching for a diffuse flux



Hunting for point-like sources

ANTARES 2007-2017

8754 tracks, 195 cascades

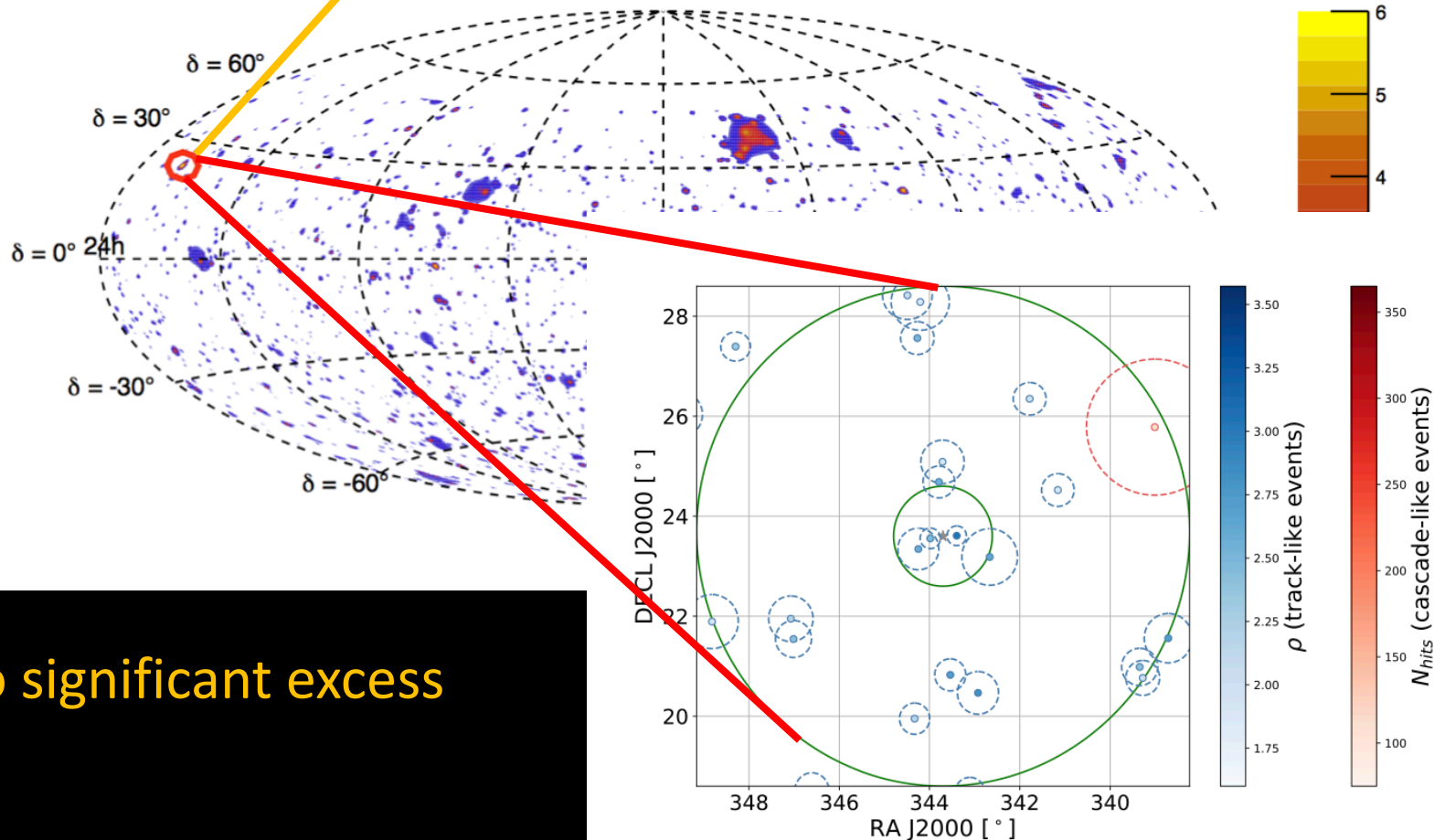


- Looking at prominent known sources
- Searching in the direction of High Energy tracks seen by IceCube

Hunting for point-like sources

The most significant cluster ($\alpha=343.7^\circ$ $\delta=+23.6^\circ$)
pre-trial 4.8σ
post trial 1.2σ

ANTARES 2007-2017
8754 tracks, 195 cascades

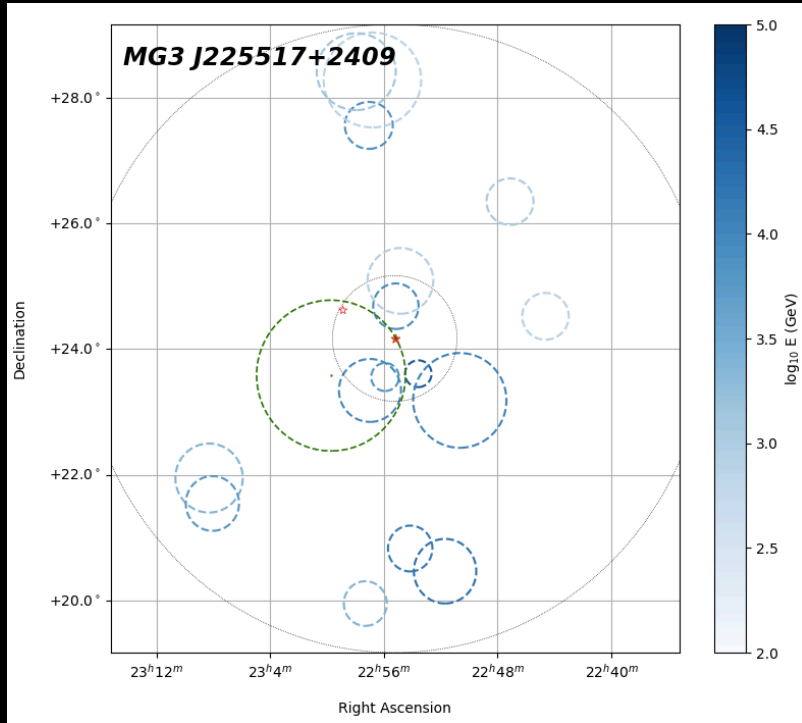


No significant excess

Hunting for point-like sources

Blazar MG3 J225517+2409 ($\alpha=343.78^\circ$ $\delta=+24.19^\circ$)

with **ANTARES** tracks & **IceCube** track

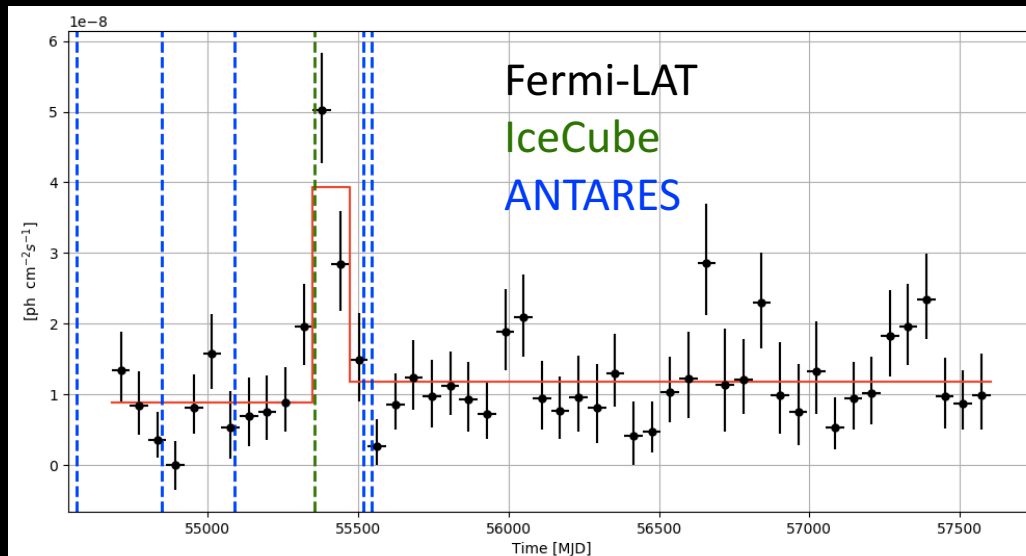


Blazar coincident with all-sky hotspot
and IceCube high energy track

Space-time association:

ANTARES $\rightarrow 2.3 \sigma$

+ IceCube $\rightarrow 2.6 \sigma$



Exploring the transient sky

Offline analyses

EM/Neutrino/CR/GW partners

We have detected a potential signal from **these sources**

We look at **archival data** in the most optimal way.

Maybe we will do a stacking analysis.

ANTARES

Real-time searches

EM/Neutrino/CR/GW partners

We issue an alert from **this direction** a few minutes ago

We look what our detector has seen **right now**

ANTARES

Exploring the transient sky

Offline analyses

- Allow to probe source populations
- Better constraints on physical parameters of the sources

Studied sources:

GRBs, FRBs, TDEs, Blazars, microquasars, binaries, GW subthreshold candidate sources,...

Real-time searches

- Help constraining the localization in case of a detection
- Give an almost instantaneous summary of the transient source and motivate multi-messenger follow-up searches

Current partners:

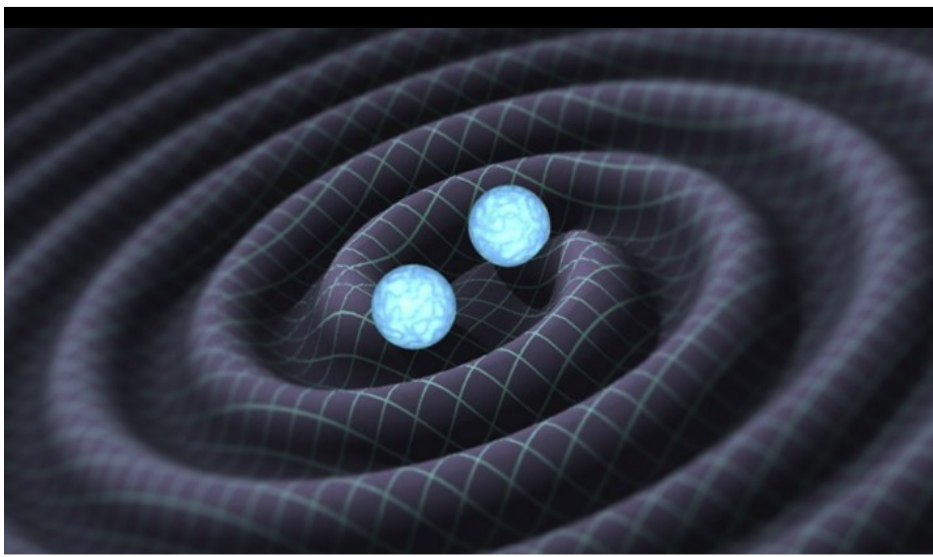
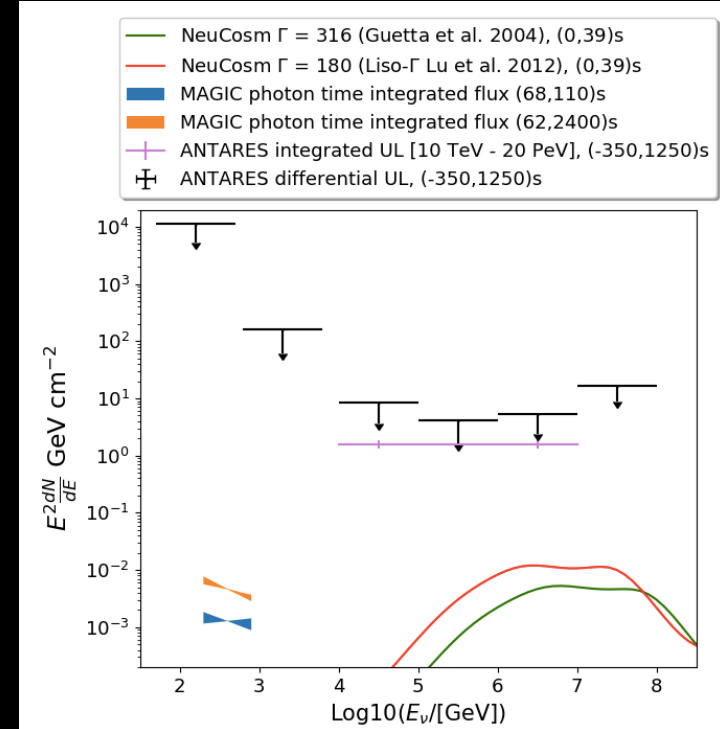
IceCube, GVD, Fermi, H.E.S.S., HAWC, MWA, TAROT, MASTER, Swift, INTEGRAL, Pierre Auger, Telescope Array, LIGO, Virgo

Exploring the transient sky

First GRBs detected with VHE gamma rays
GRB180720A, GRB190829B (H.E.S.S.)
GRB190114C (MAGIC)

Searching for tracks and cascades

No events found
in time & space coincidence



62 follow-ups for O1, O2, and O3

No evidence of associated
neutrino emission

Program

1 - What have we learned with ANTARES?

2 - Which questions will we answer with KM3NeT?

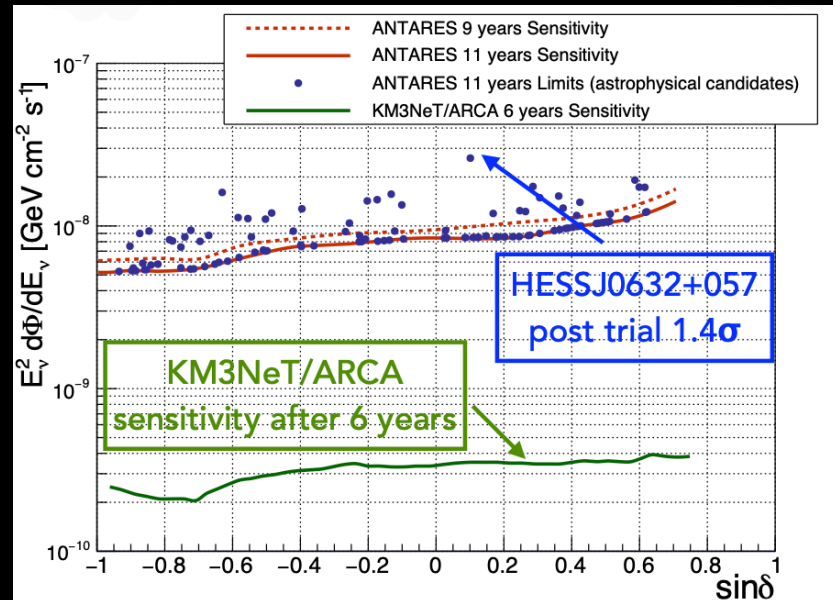
Same science cases than for ANTARES
but with better resolution
+ some more!

ANTARES/KM3NeT Comparison

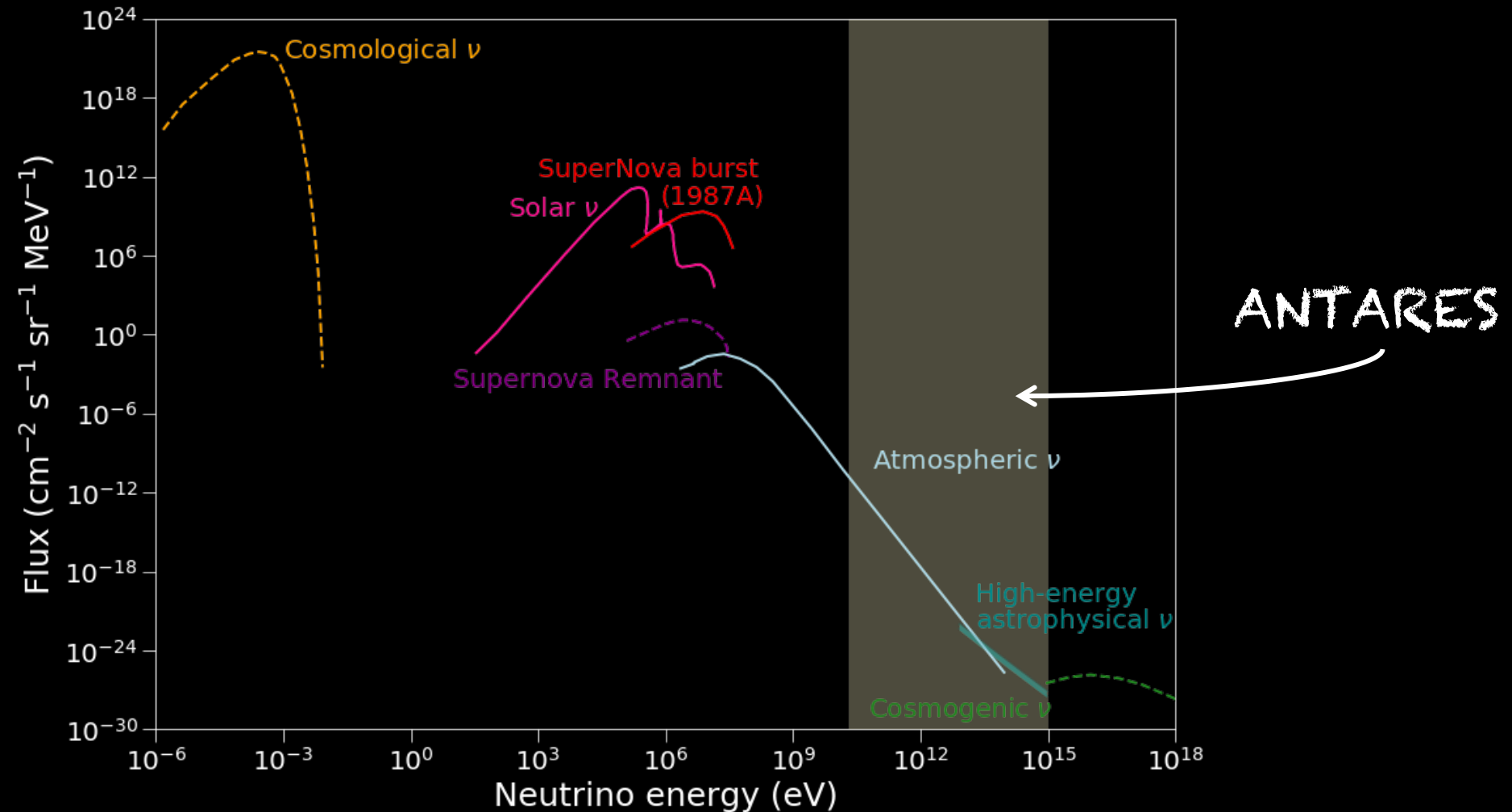
Angular resolution

	ANTARES	ARCA
Tracks at 10 TeV	0.4 degrees	0.2 degrees 0.05 degrees at 10 PeV
Cascades at 10 TeV	4 degrees	2 degrees

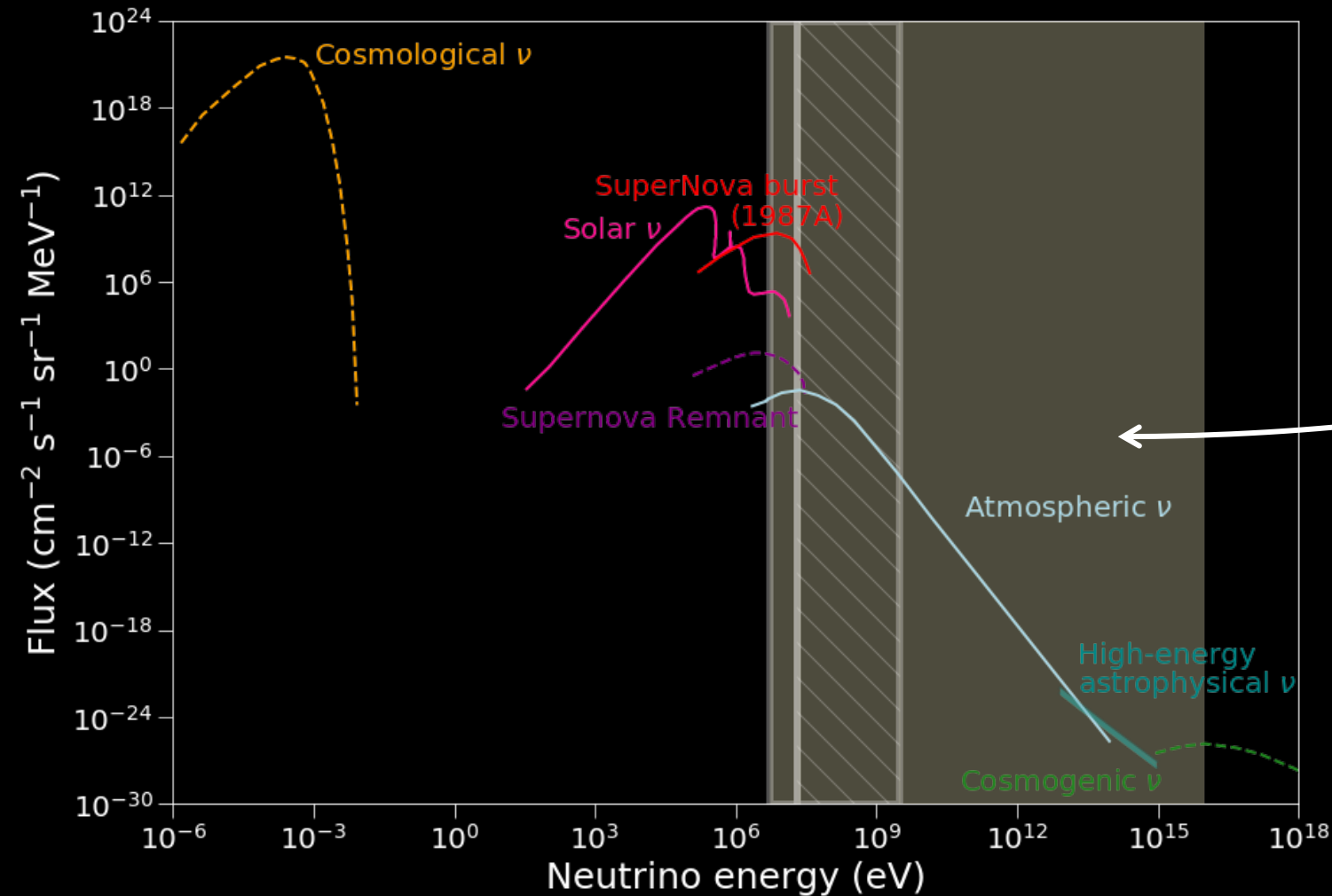
Sensitivity



ANTARES/KM3NeT Comparison



ANTARES/KM3NeT Comparison



KM3NeT

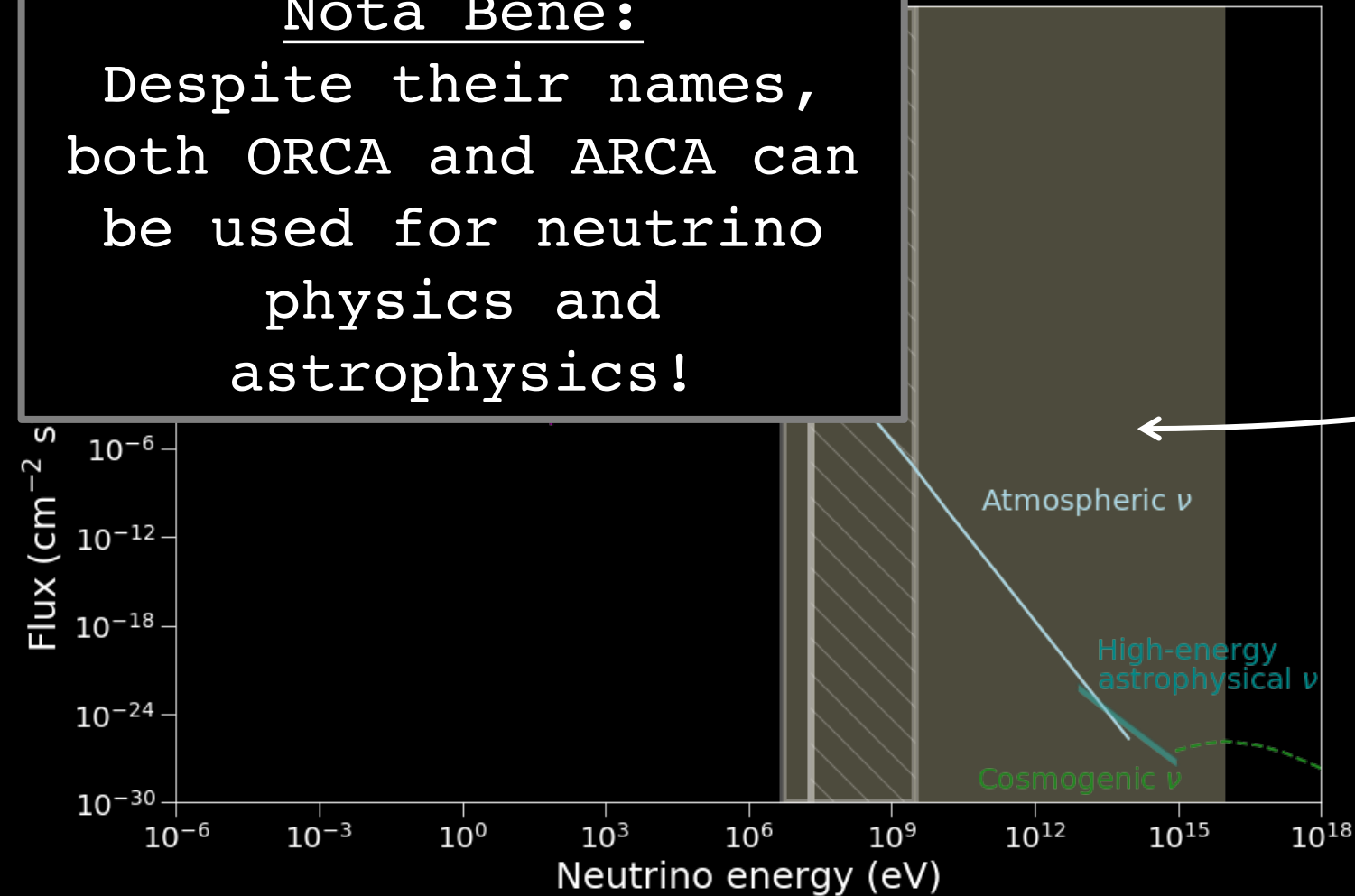


KM3NeT = High sensor density + Large volume

ANTARES/KM3NeT Comparison

Nota Bene:

Despite their names,
both ORCA and ARCA can
be used for neutrino
physics and
astrophysics!

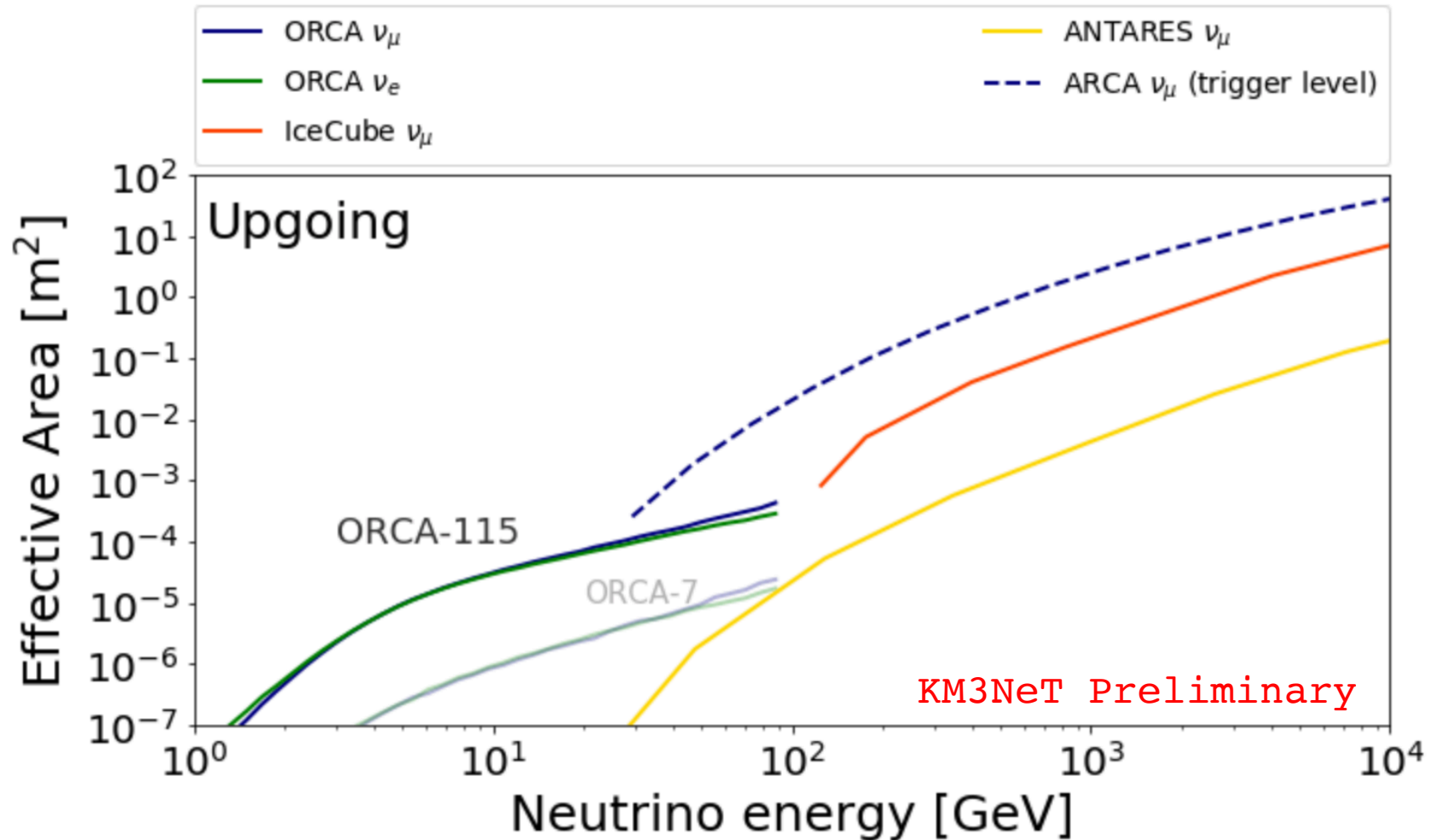


KM3NeT

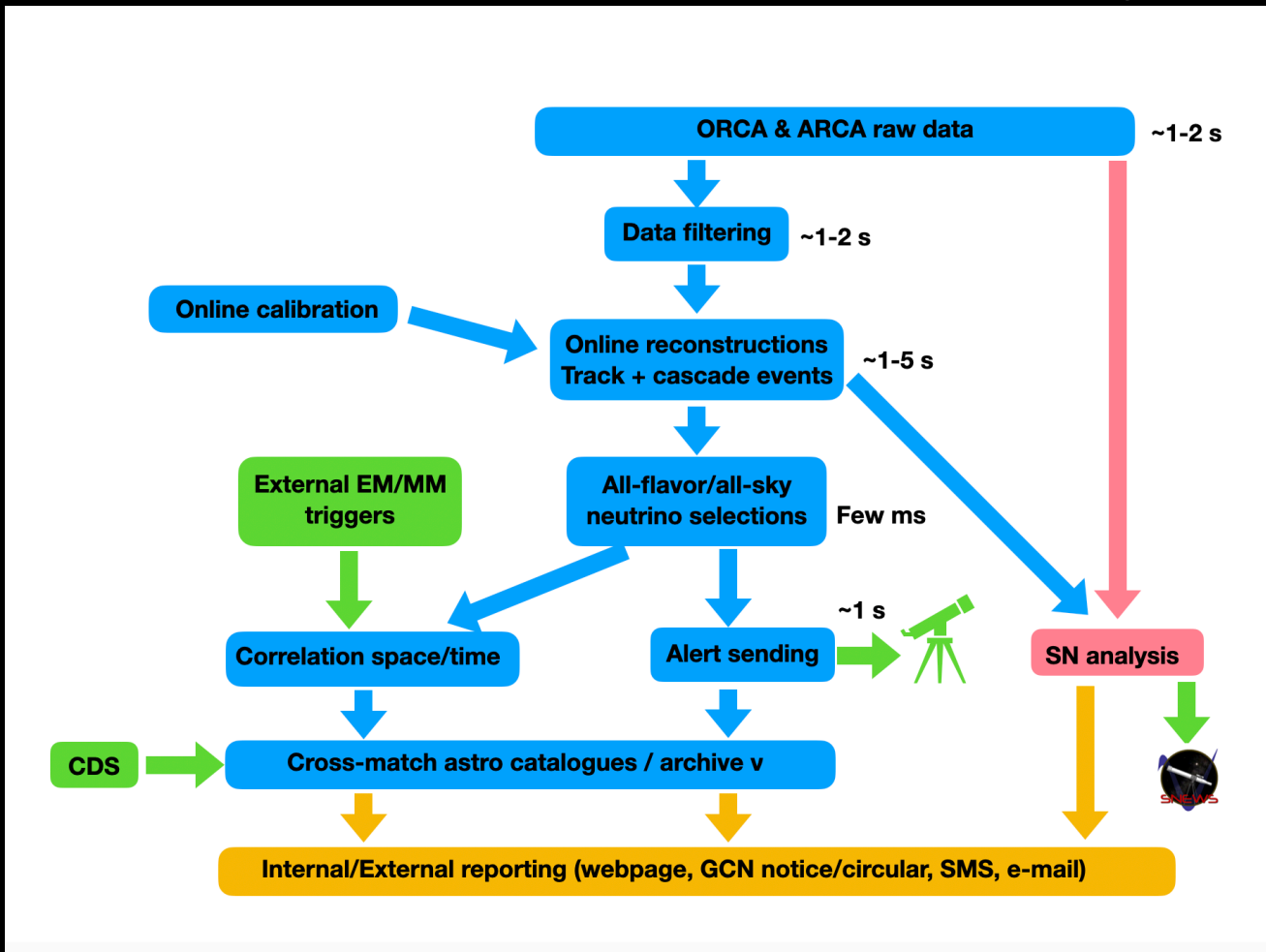


KM3NeT = High sensor density + Large volume

ANTARES/KM3NeT Comparison

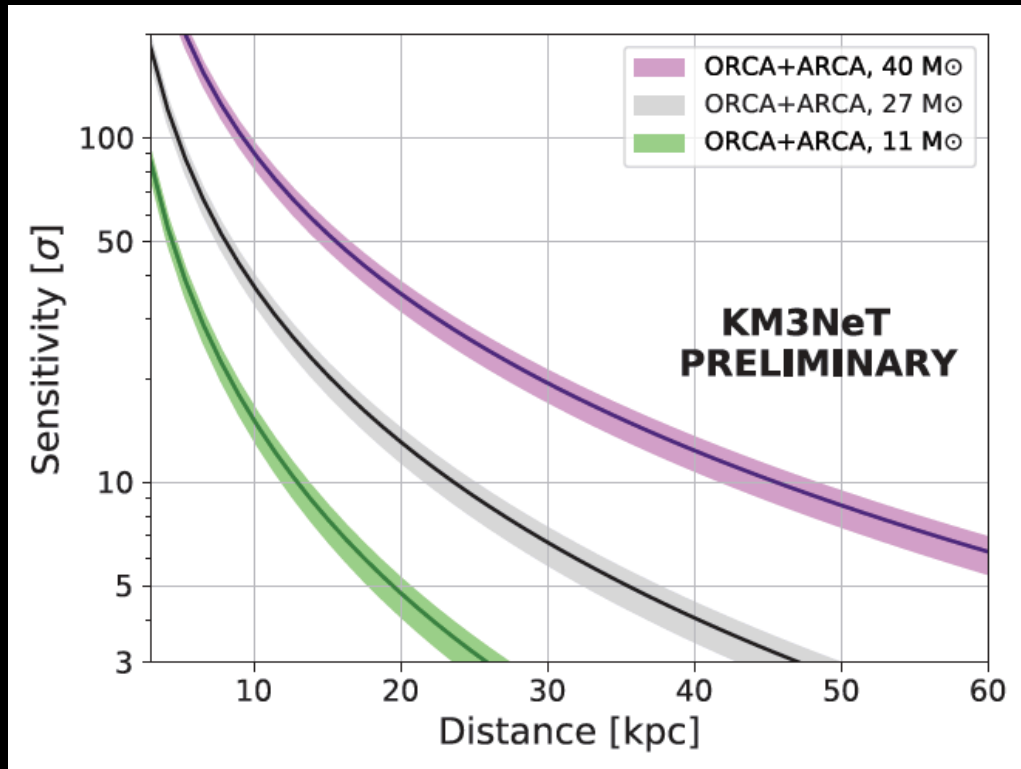


Real-time astronomy with KM3NeT



- Fast online selection of a high-purity neutrino sample ($> 95\%$)
- On average **< 10 seconds** from filtering raw PMT data to neutrino classification (for tracks)

Core Collapse Supernovae



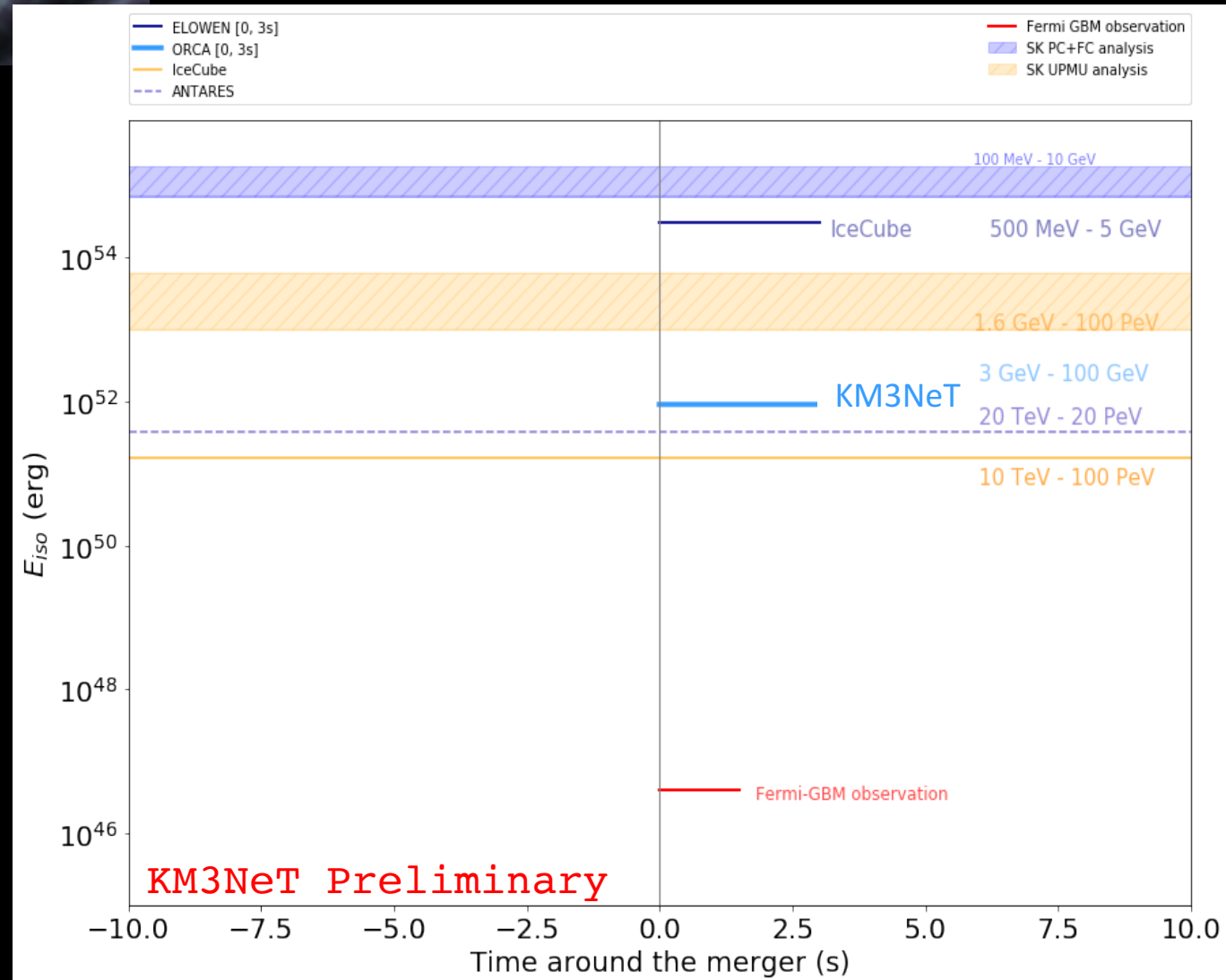
The first two
follow-ups with
KM3NeT!



- 1 (+1) follow-up for O3
- S200114f (+ S191110af)
- No evidence of associated neutrino emission
- Lower limit on the distance for 2 progenitor masses
- $E_{\nu} < 2.9 \times 10^{53}$ erg at 10 kpc

Sub-TeV neutrino searches

Example for
GW170817



Take-home message

- Legacy results of ANTARES in preparation with 15 years of data
- Need for more statistics to resolve the neutrino sky
- KM3NeT will help with larger volume and increased resolution capabilities
- Expansion of the energy spectrum that can be probed
- Exciting times for Neutrino Astronomy!

Thanks!

Draw me a Neutrino in numbers

More than 500 drawings
sent from 16 different countries!

More than 150 participants connected for the result
announcement.

3 categories

Electron neutrino : infant and primary school

Muon neutrino : middle and high school

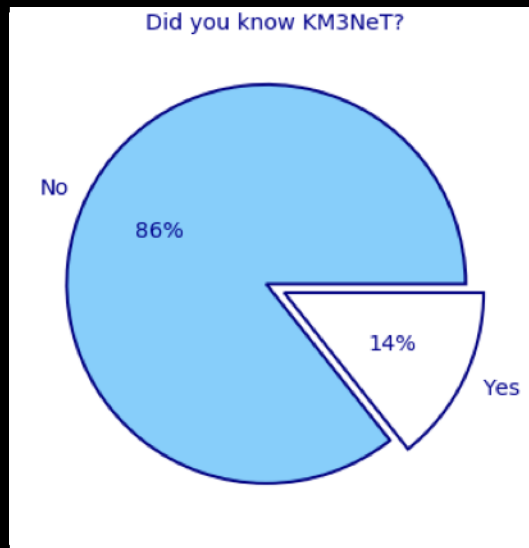
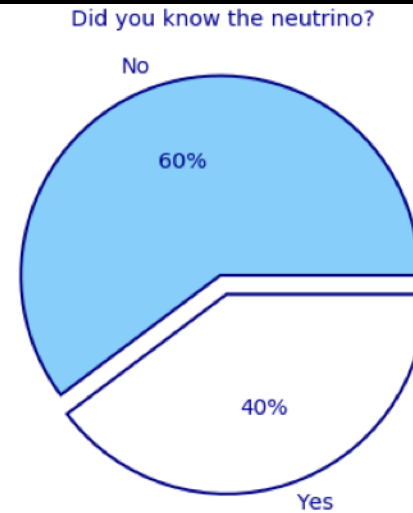
Tau neutrino : adults



Describe the neutrino and KM3NeT in one word



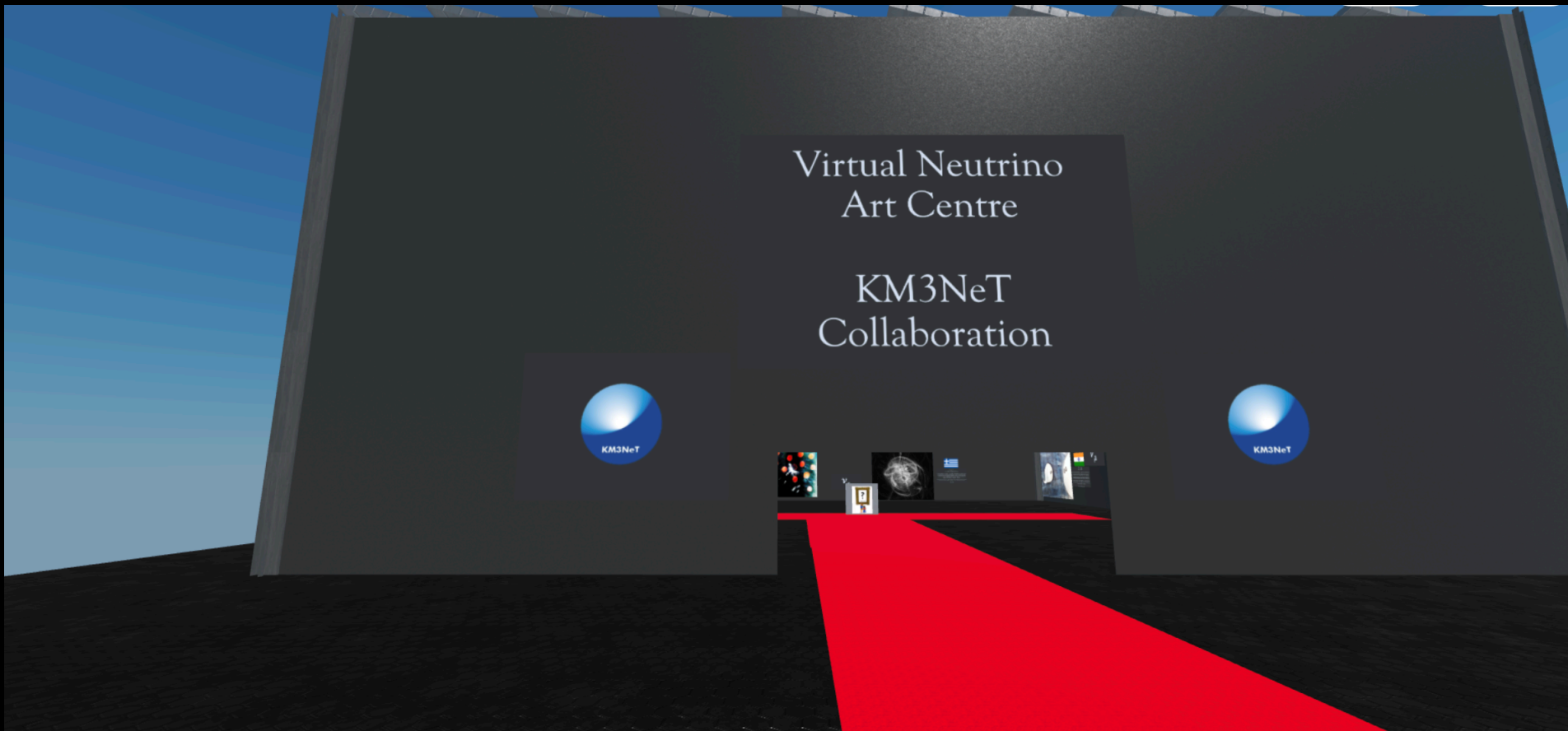
Word cloud for neutrino



Word cloud for KM3NeT

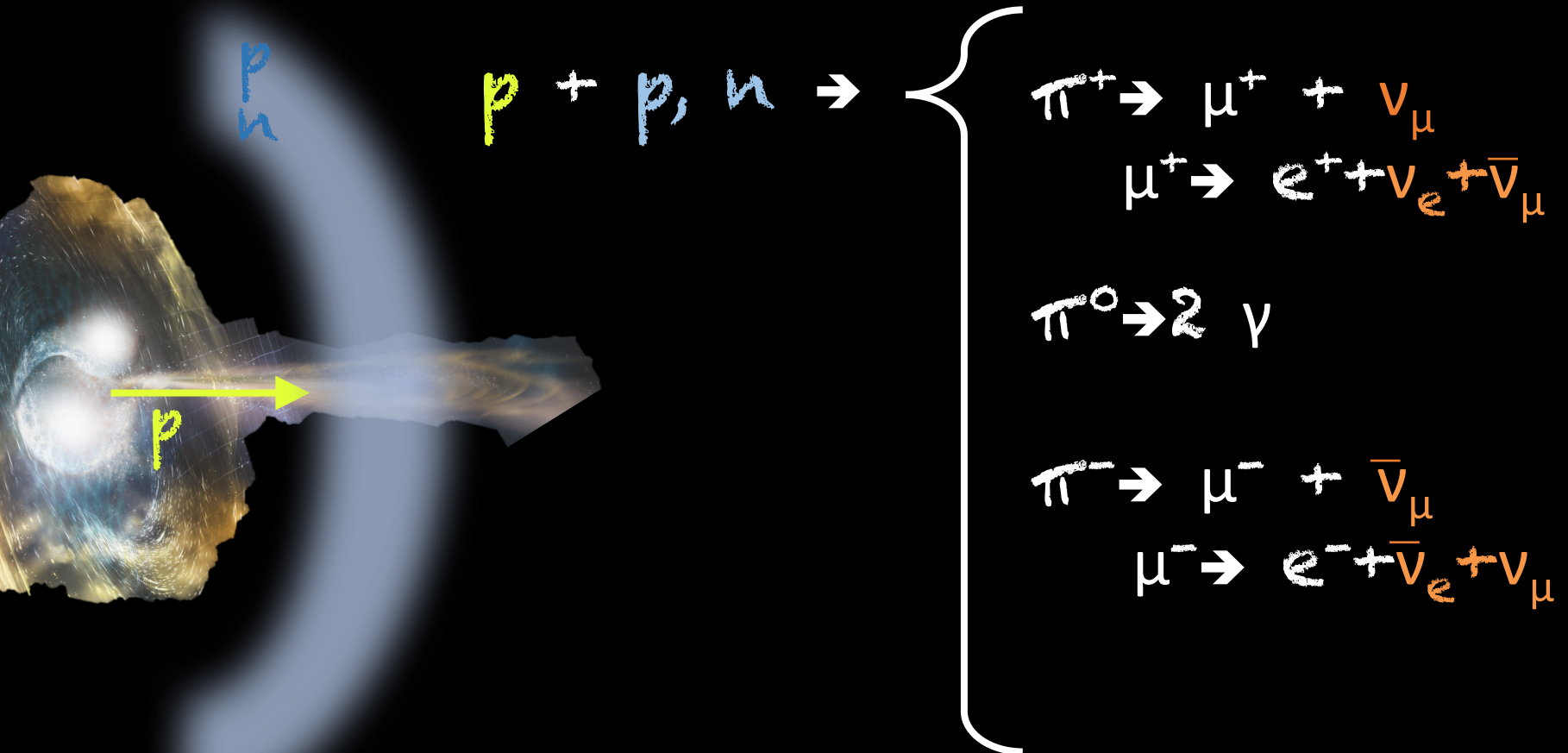


Virtual Neutrino Art Centre



To access the Art Centre, click on the link below
hub.link/ZZwzhf7

Why exploring the sub-TeV sky

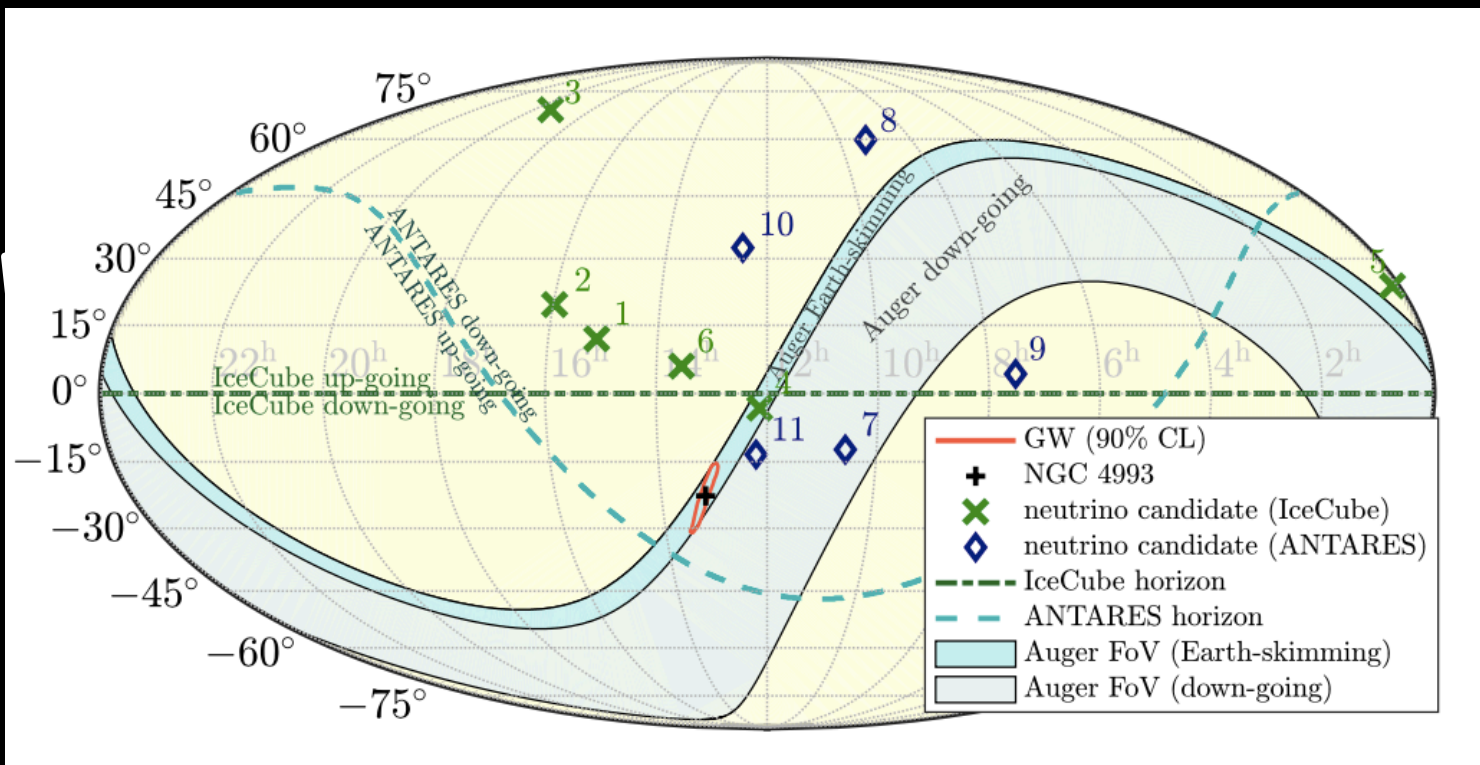


Give extra information on source environment

Murase *et al.*, Phys.Rev.Lett. 111 (2013) 131102

Bartos *et al.*, Phys.Rev.Lett. 110 (2013) 241101

Maouloud, GDW, Ahlers, Bustamante, van Elewyck, PoS(ICRC2019)1023



GW170817
[-500s ,
+500s]

