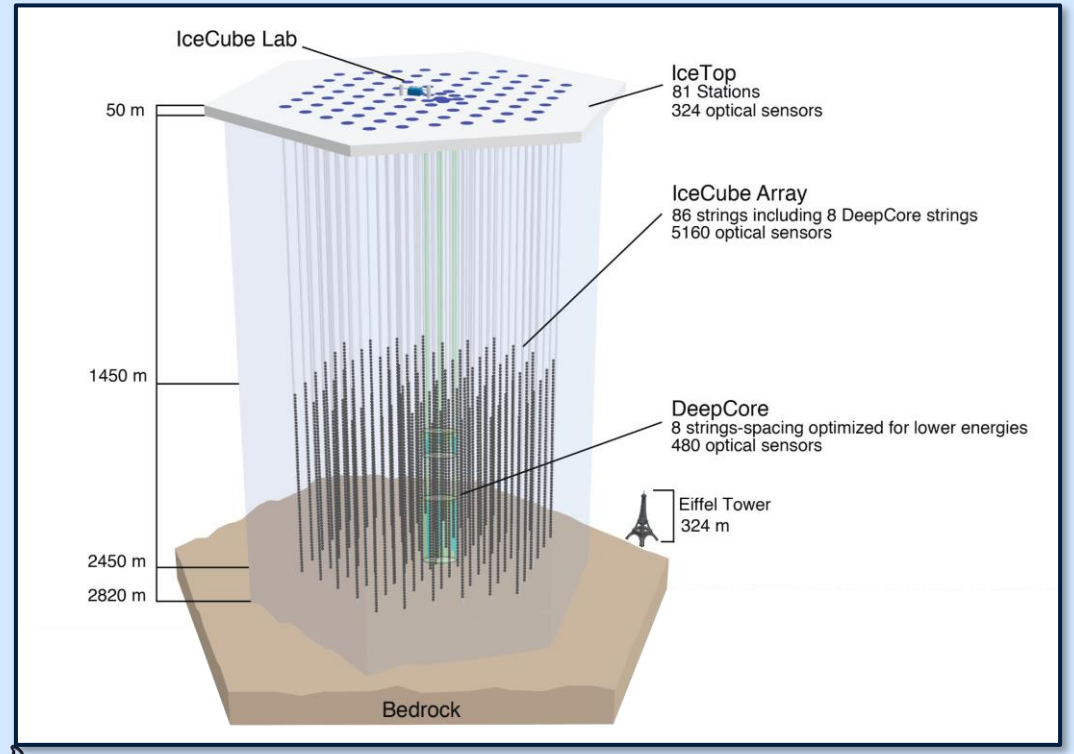
PROBING ASTROPHYSICAL GEV NEUTRINO EMISSIONS WITH ICECUBE AND KM3NeT

J. Mauro*
G. de Wasseige

on behalf of
KM3NeT Collaboration
IceCube Collaboration

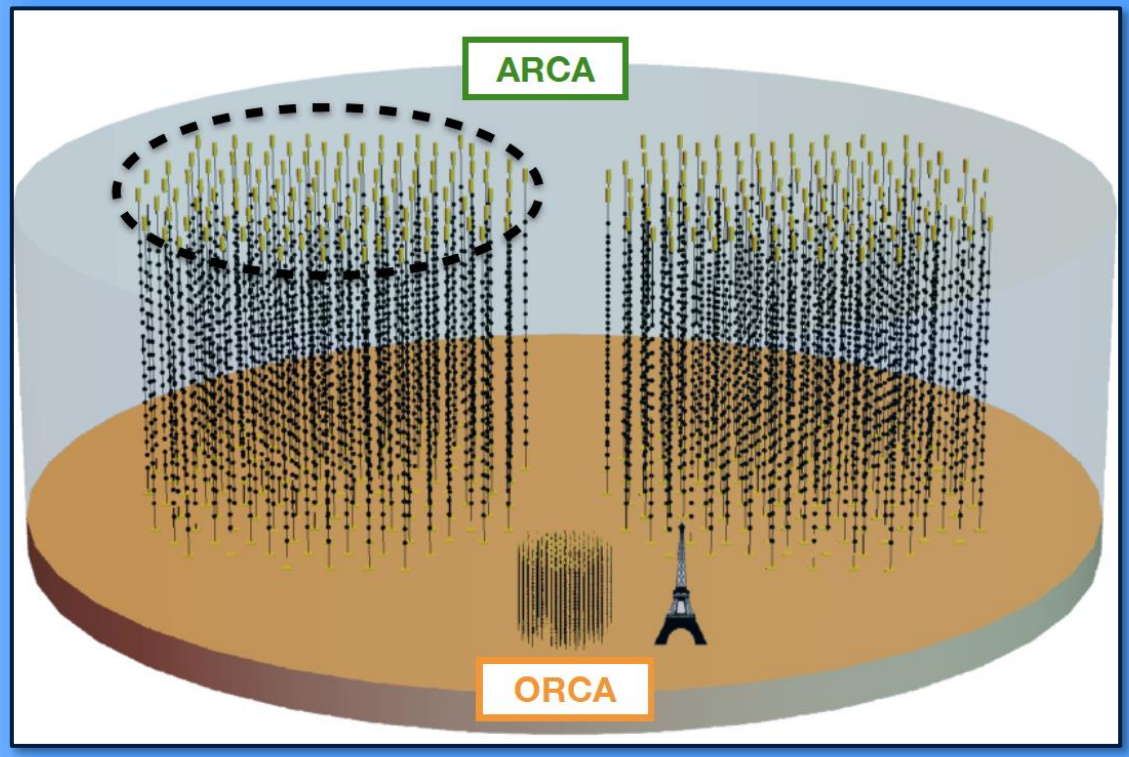
Location: South Pole

Size: 1 km^3
86 strings (8 DeepCore)
5160 optical modules

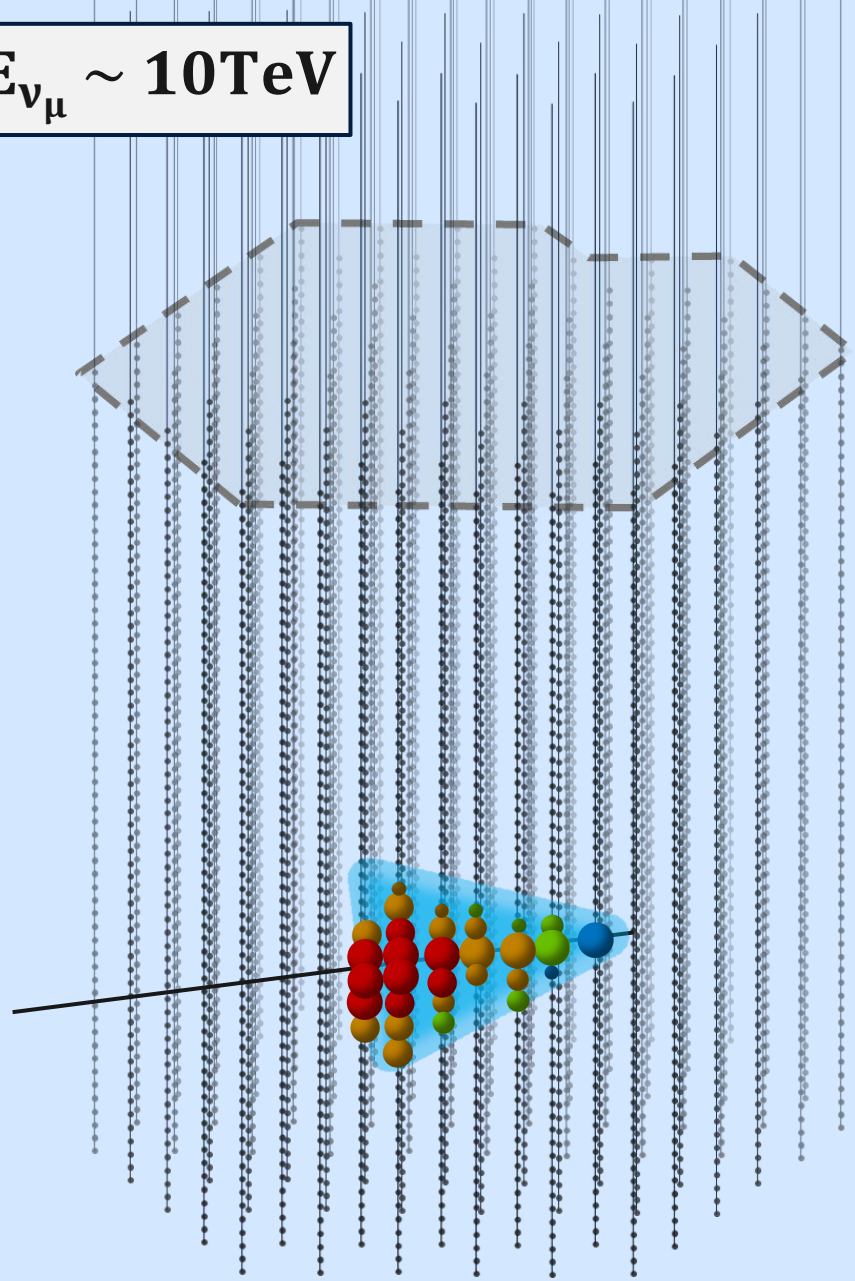


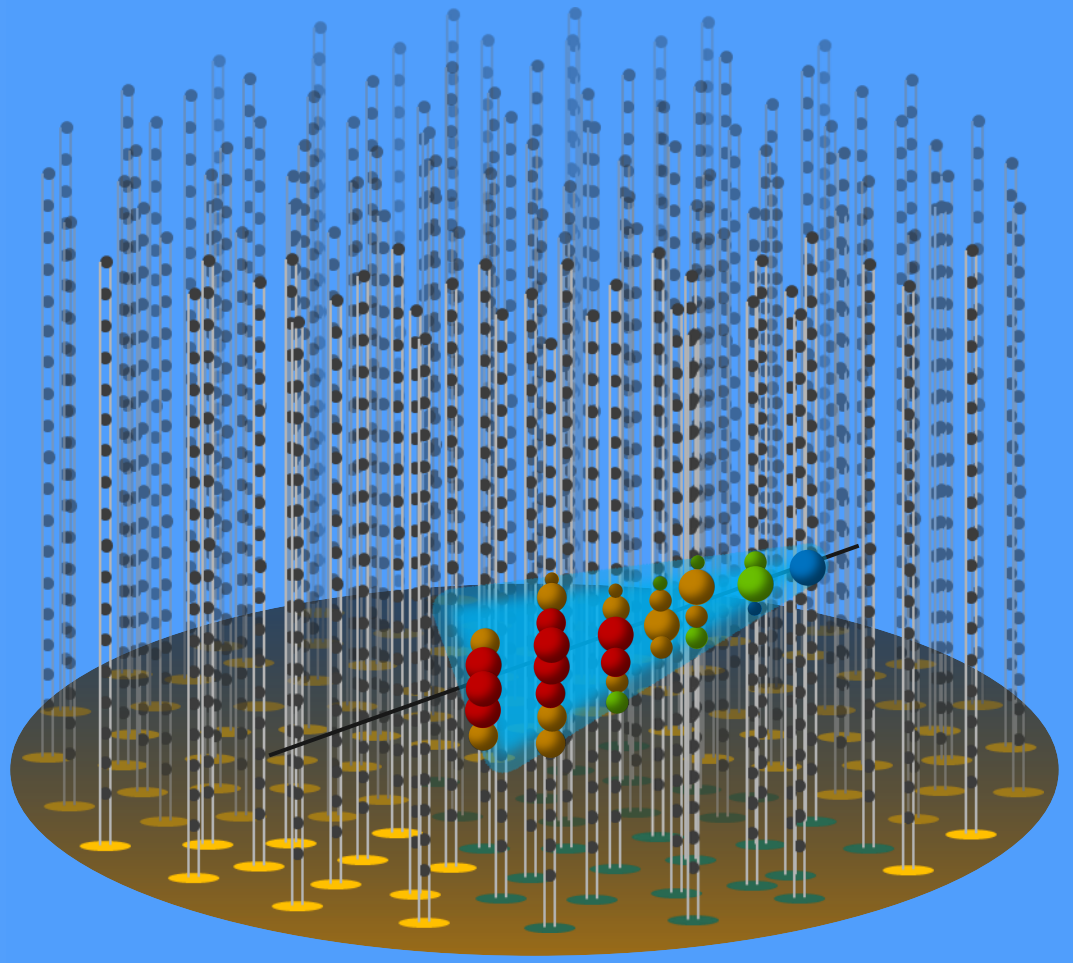
Location: Mediterranean Sea

Size: 1 km^3 (planned)
230 lines (ARCA) + 115 lines (ORCA)
6210 optical modules

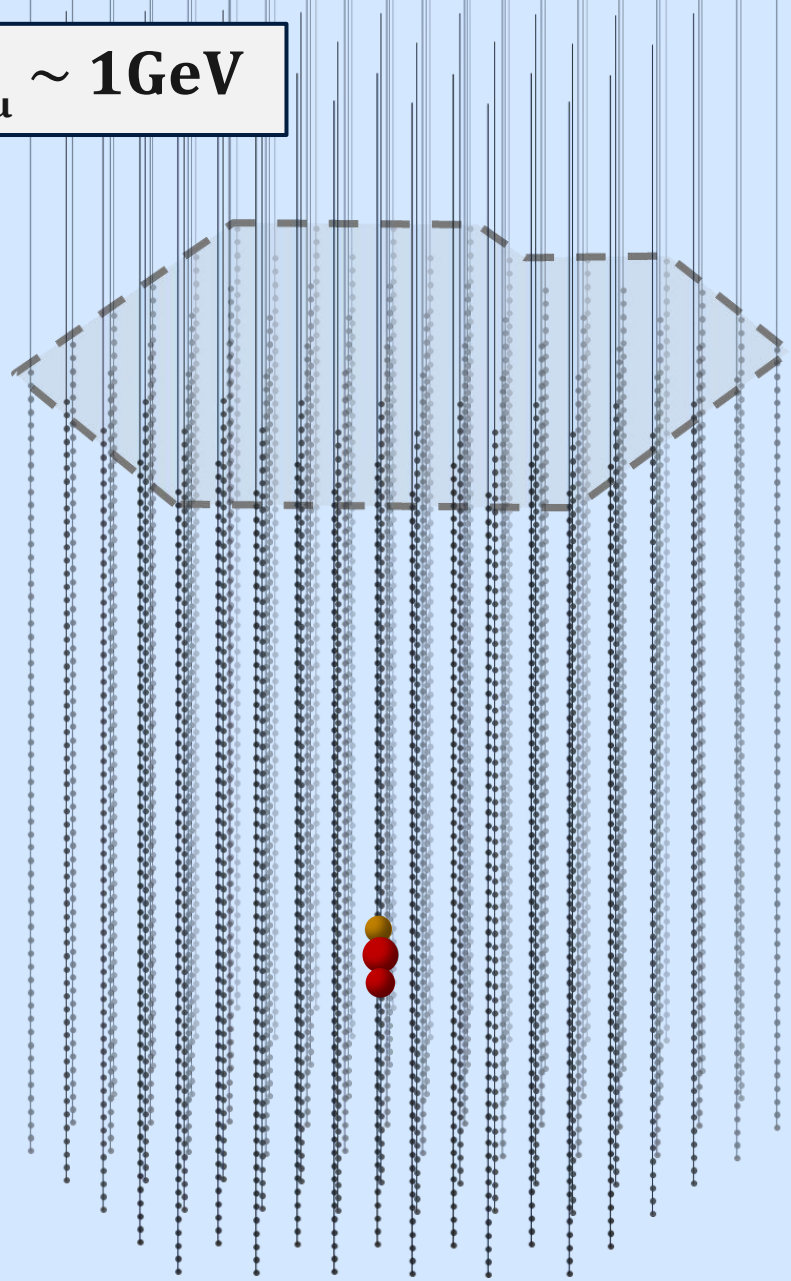


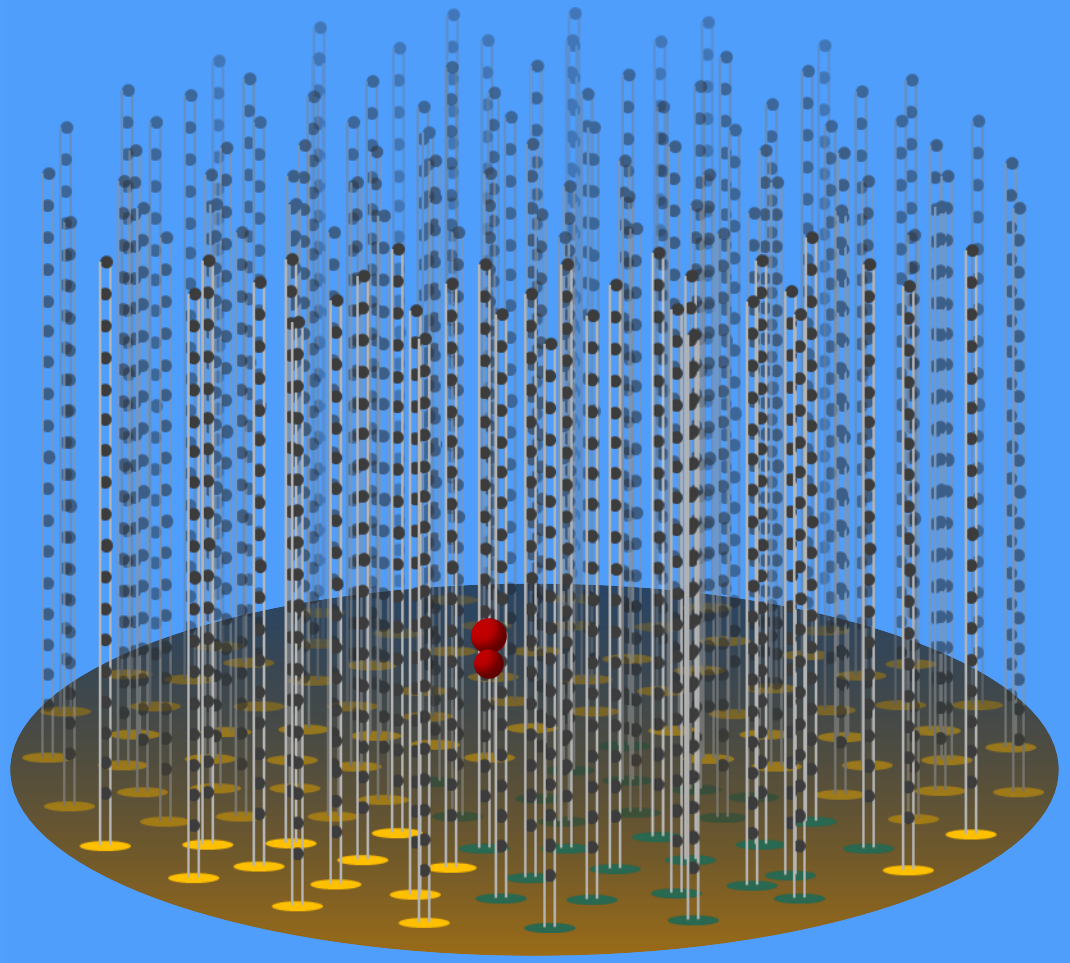
$E_{\nu_\mu} \sim 10\text{TeV}$



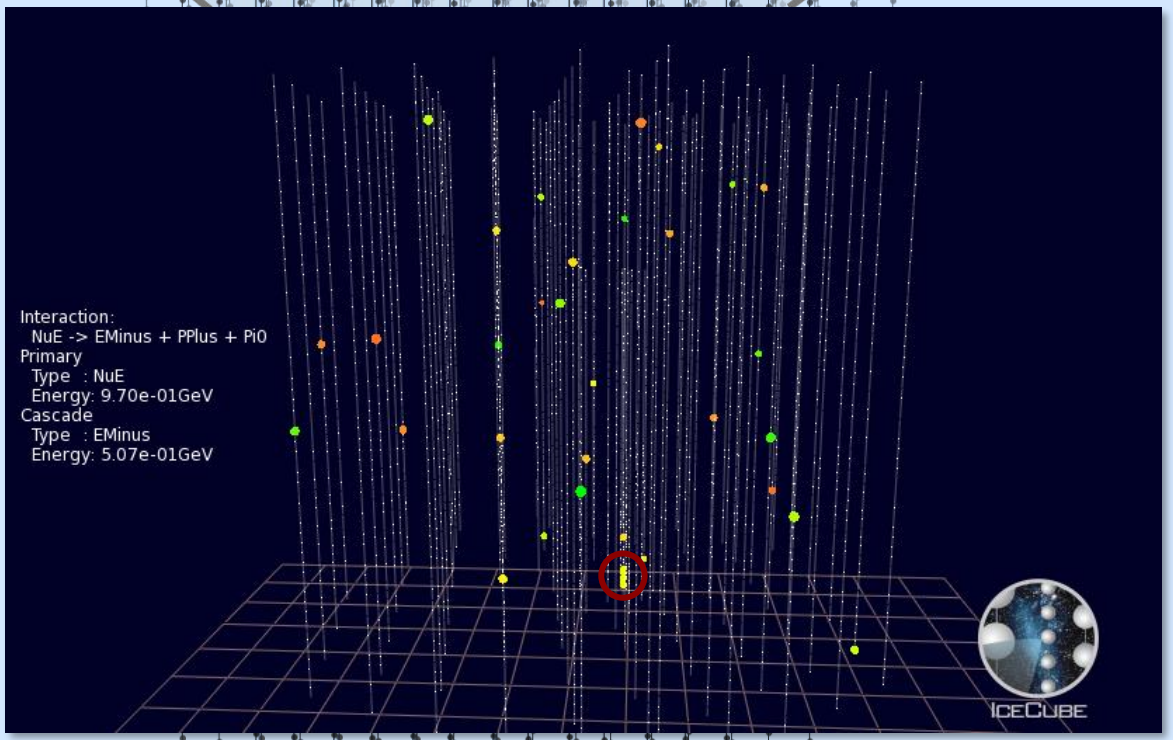


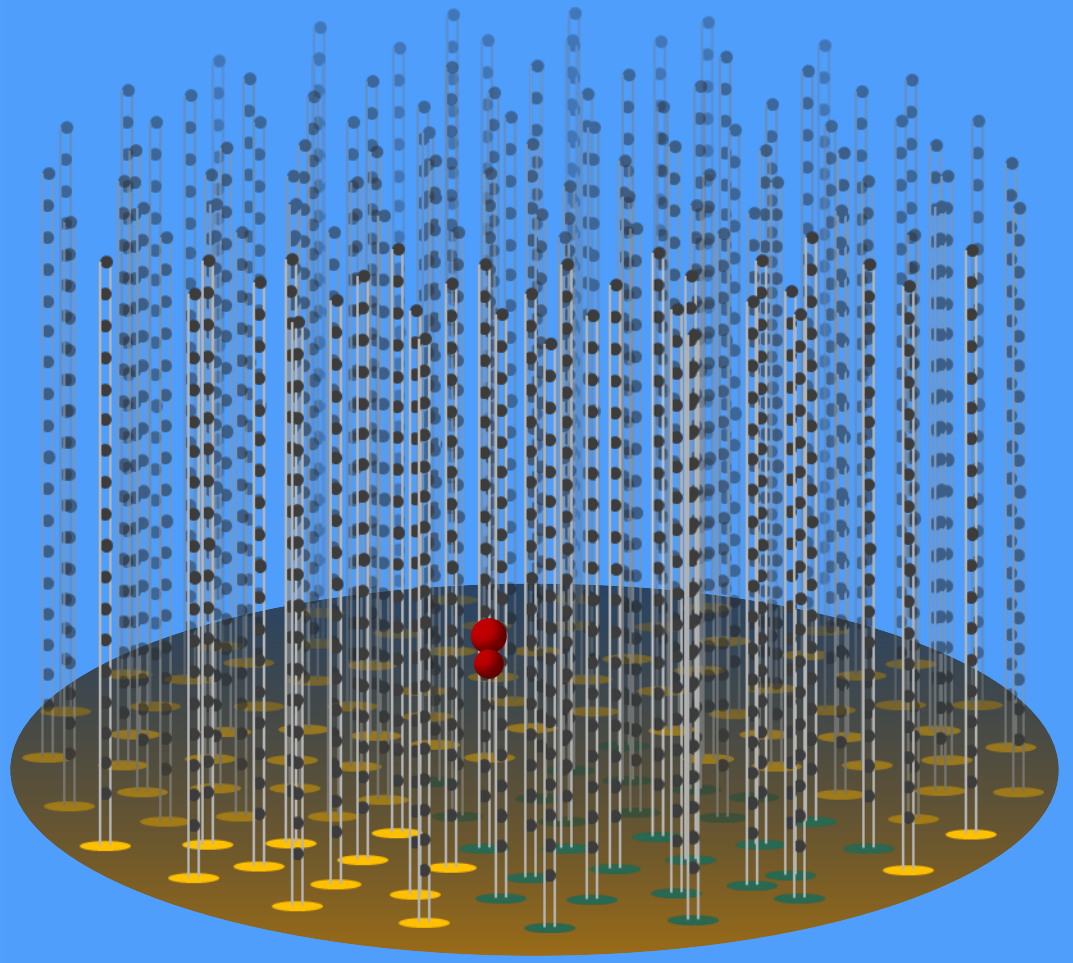
$E_{\nu_\mu} \sim 1\text{GeV}$





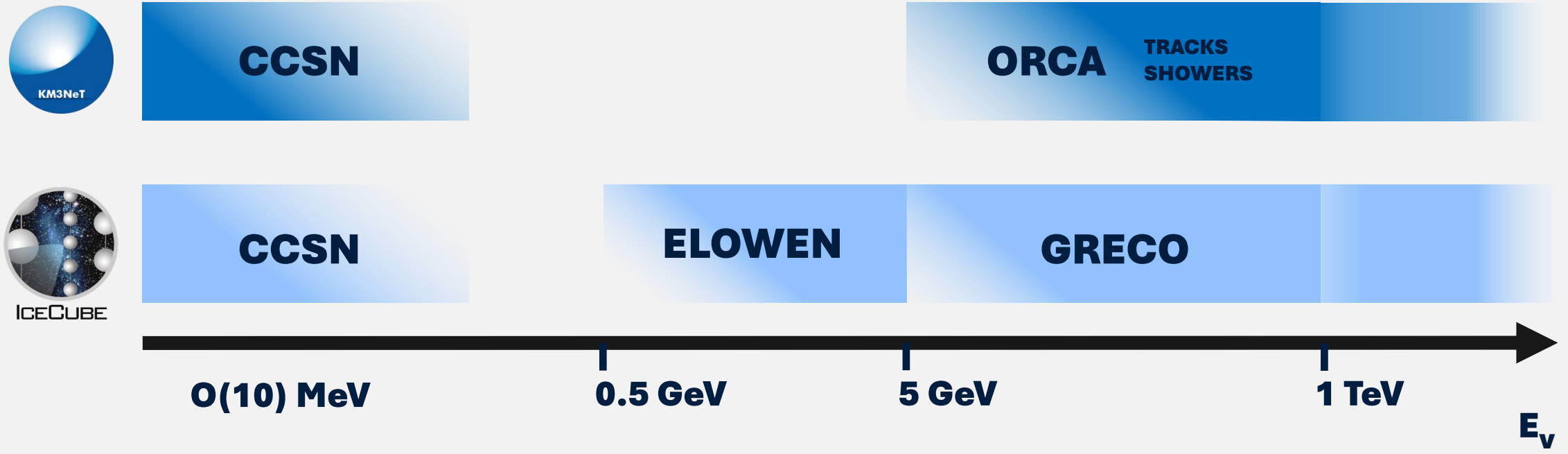
$E_{\nu_\mu} \sim 1\text{GeV}$





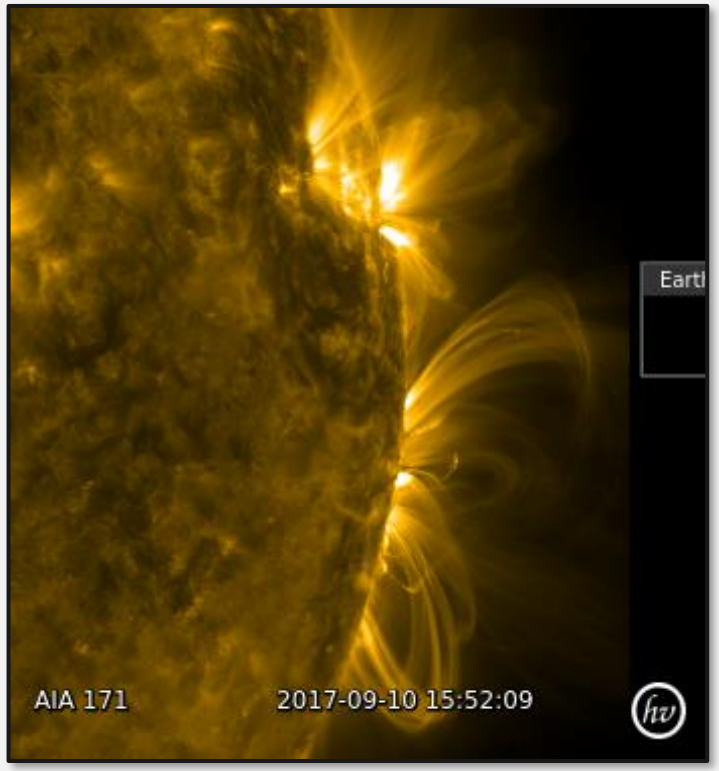
MeV-GeV neutrino selections

see G. Vannoye's talk



MeV-GeV neutrino sources

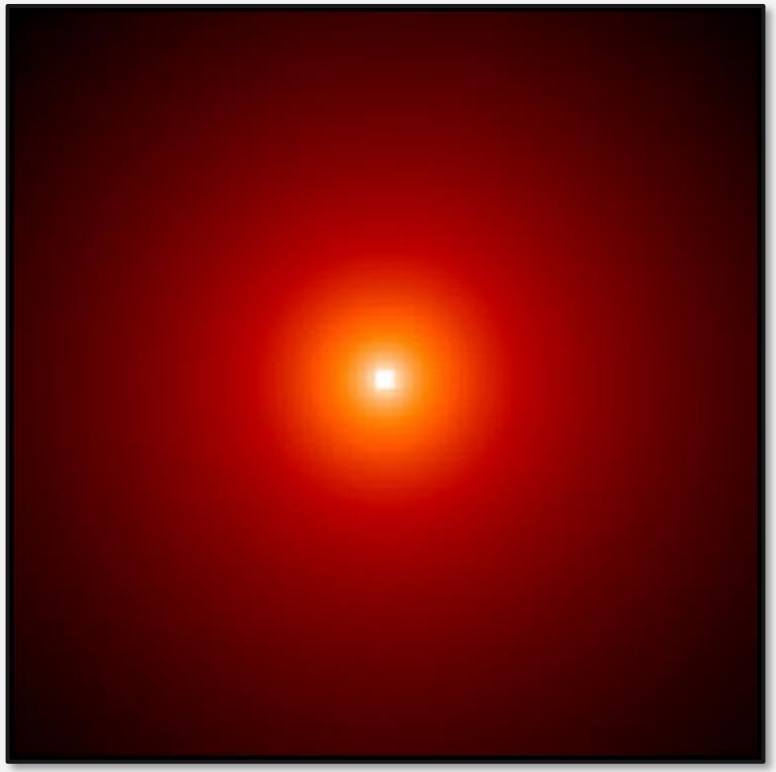
Solar Flares



Credit: NASA/SDO

G. de Wasseige, *"Solar Flare Neutrinos in the Multi-Messenger Era: Flux Calculations and a Search with the IceCube Neutrino observatory", PhD thesis Vrije Universiteit Brussel (2018)*

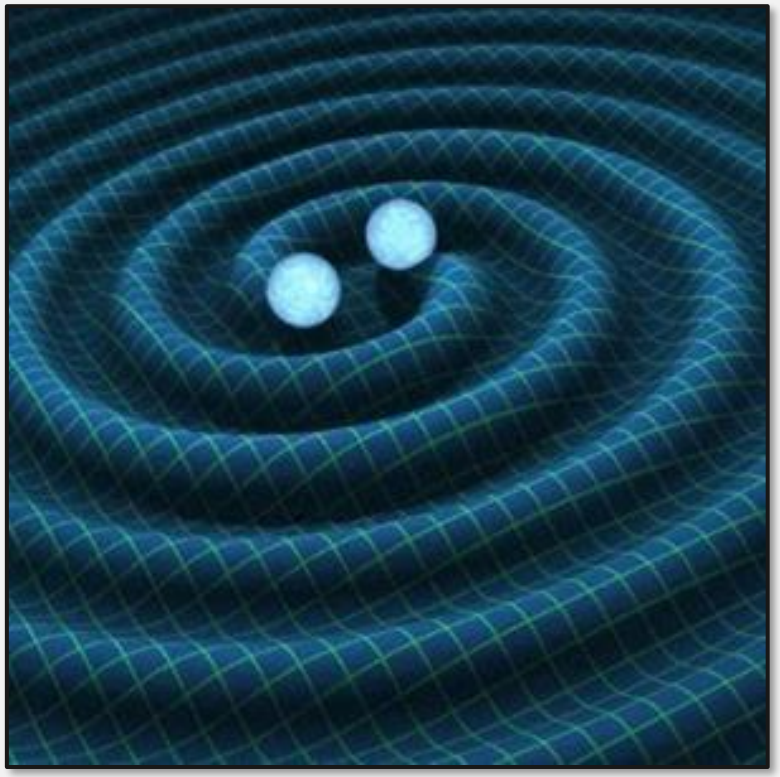
GRBs



Credit: NASA/DOE/Fermi LAT Collaboration

K.Murase, et al., "Subphotospheric Neutrinos from Gamma-Ray Bursts: The Role of Neutrons", *Phys. Rev. Lett.* ***111*** *(2013)*

GWs

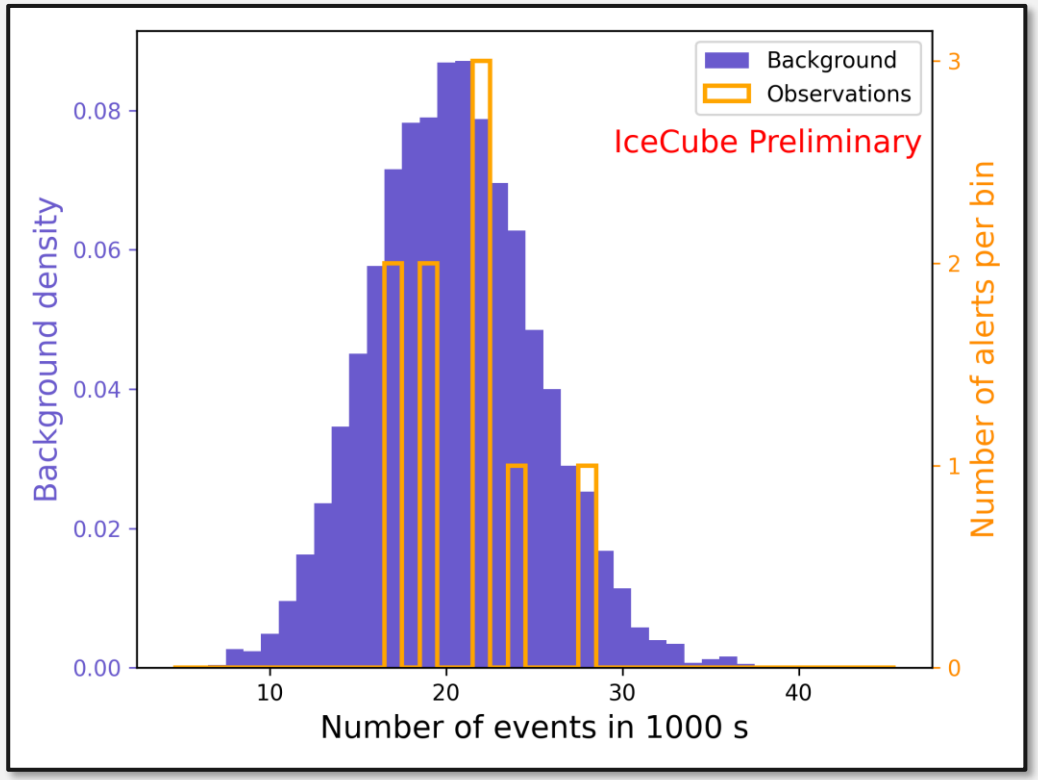


Credit: R. Hurt/Caltech-JPL

K. Asano, K. Murase "Gamma-Ray Bursts as Multienergy Neutrino Sources", *Adv. in Astro., 568516 (2015)*

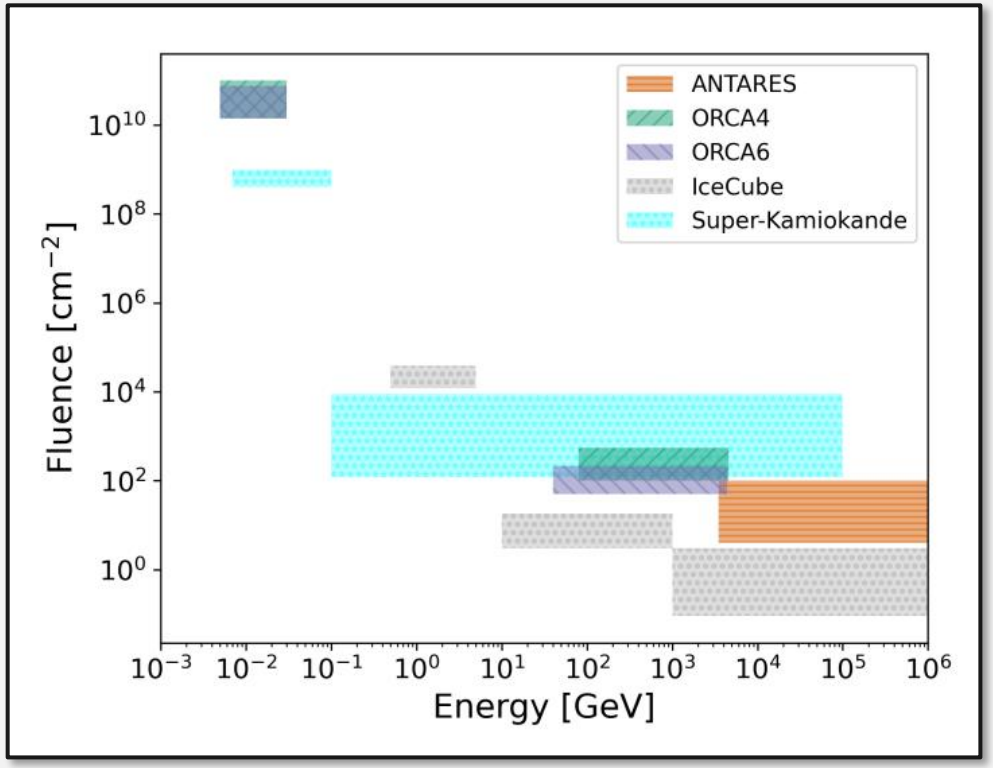
Gravitational waves follow-up

O4



K.Kruiswijk, M. Lamomoureux, G. de Wasseige, on behalf of the **IceCube** Collaboration, "First results of low-energy neutrino follow-ups of Run O4 compact binary mergers with the IceCube Neutrino Observatory", *PoS(ICRC2023)* **444** (2023)

O3



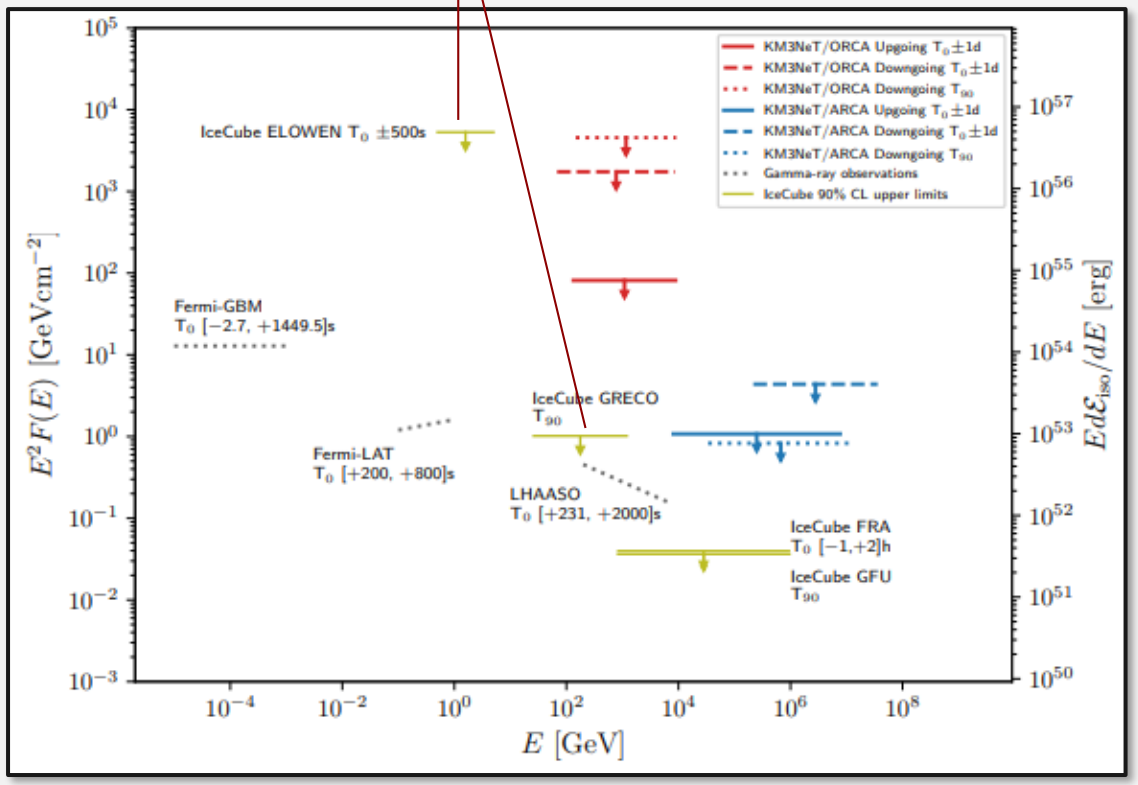
KM3NeT Collaboration, "Searches for neutrino counterparts of gravitational waves from the LIGO/Virgo third observing run with KM3NeT", *JCAP* **04** (2024)

GRB 221009A

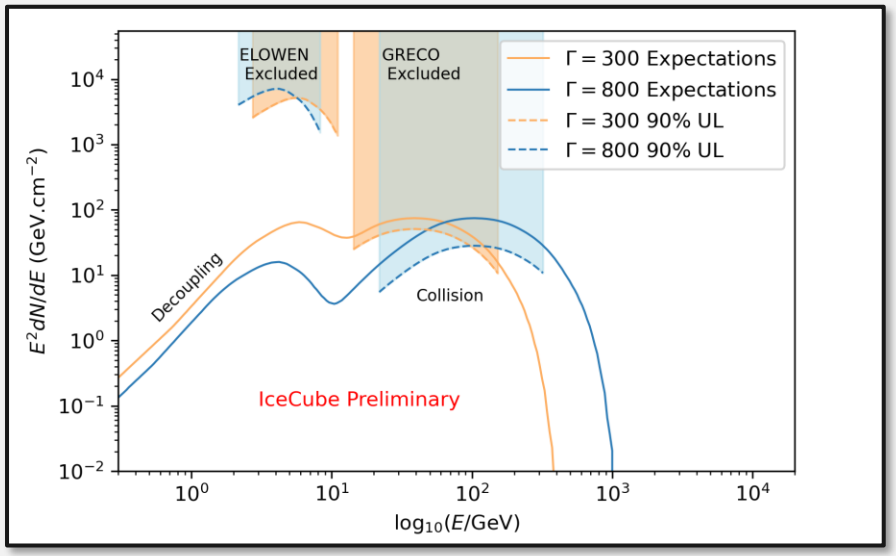
K.Kruiswijk, B.Brinson, R. Procter-Murphy, J. Thwaites, N. Valtonen-Mattila on behalf of the **IceCube** Collaboration, "IceCube search for neutrinos from GRB 221009A", *PoS(ICRC2023)* **444** (2023)

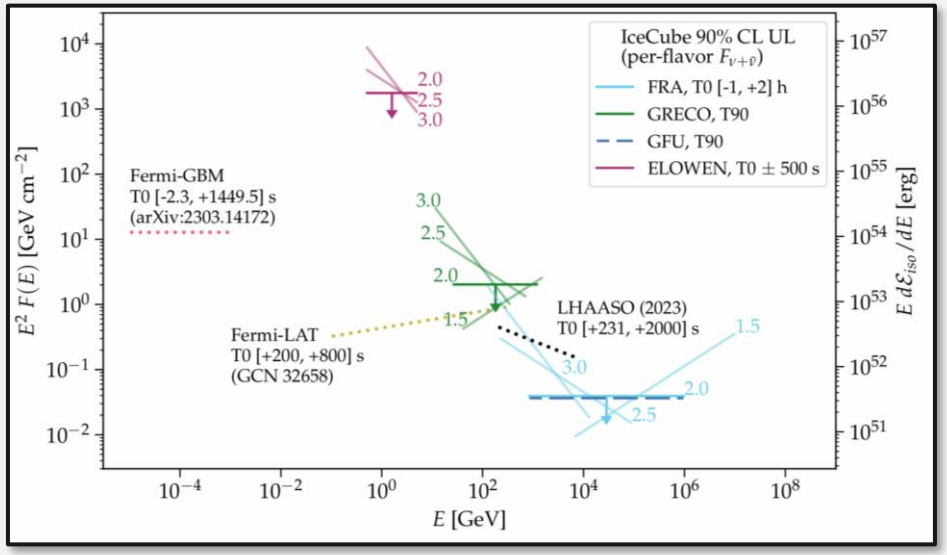
see **IceCube** Collaboration, Erratum:"Limits on Neutrino Emission from GRB 221009A from MeV to PeV Using the IceCube Neutrino Observatory", *ApJL* **970** (2023)

see J. Palacios González's talk



KM3NeT Collaboration, "Search for Neutrino Emission from GRB 221009A using the KM3NeT ARCA and ORCA detectors", *JCAP* **08** (2024)





IceCube Collaboration, "Limits on Neutrino Emission from GRB 221009A from MeV to PeV Using the IceCube Neutrino Observatory", *ApJL* **946** (2023)

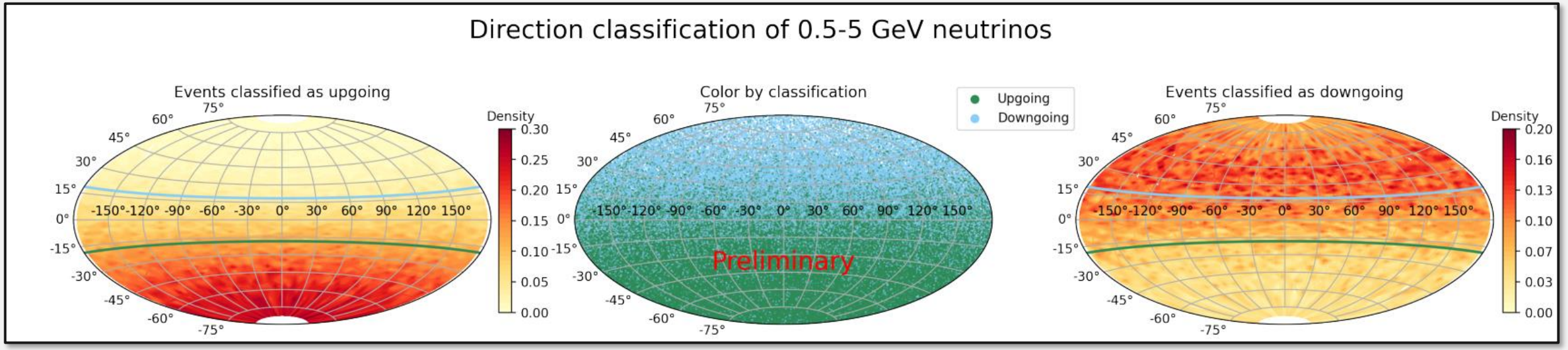
PROSPECTS

Improvements of IceCube GeV selection

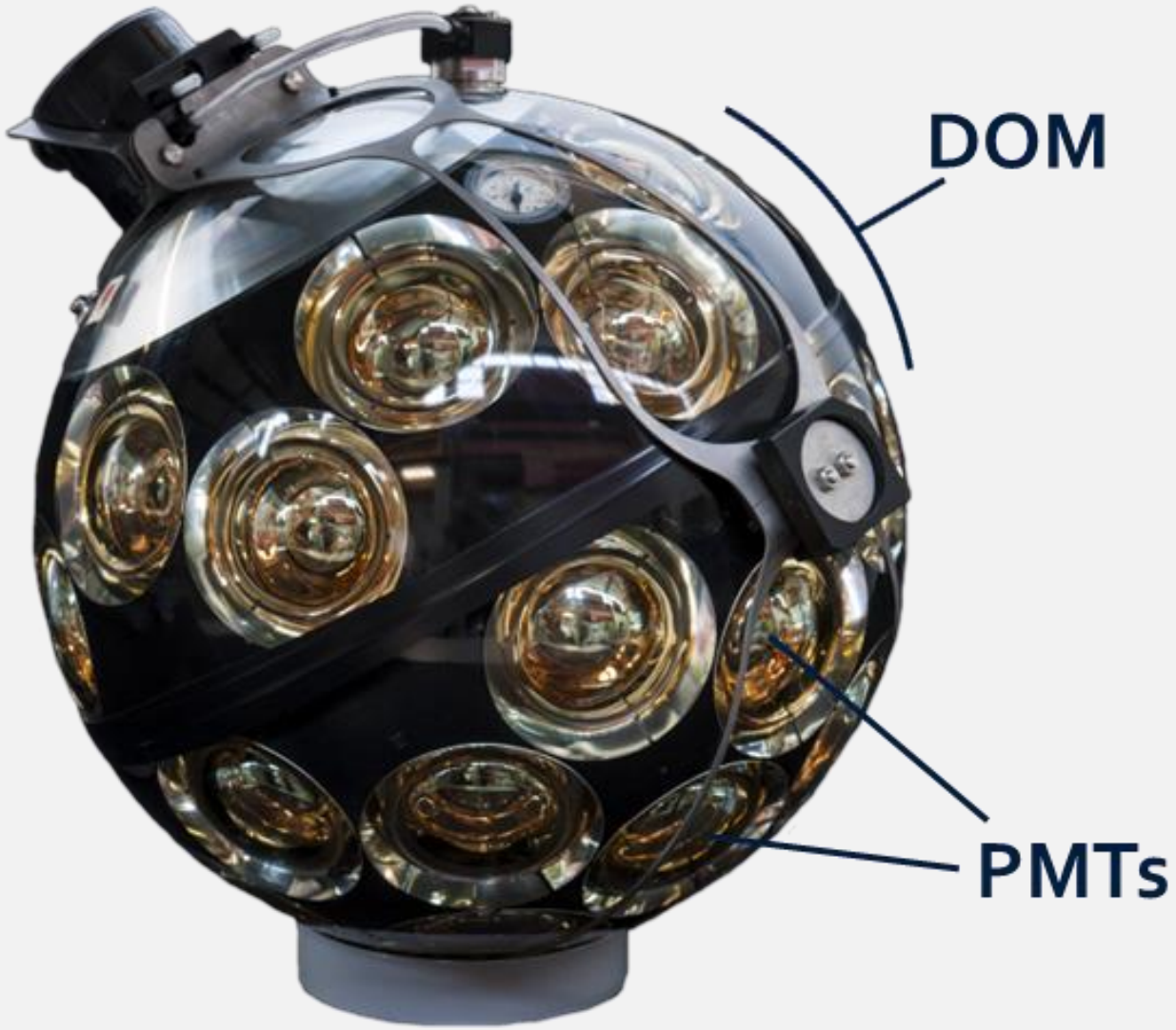
G. de Wasseige, K.Kruiswijk, on behalf of the **IceCube** Collaboration, "Probing neutrino emission at GeV energies from astrophysical transient events with the IceCube Neutrino Observatory", *PoS(ICRC2023)* **444** (2023)

It's possible to implement zenith reconstruction in the ELOWEN selection using Boosted Decision Trees.

This will improve the sensitivty of IceCube to 0.5-5 GeV neutrinos from transients sources



Novel KM3NeT GeV selection



KM3NeT Collaboration, "The KM3NeT multi-PMT optical module", *JINST* **17** (2022)

KM3NeT's Digital Optical Module (DOM) is made of 31 3" PMTs.

KM3NeT's DOM allows for better reconstruction at high energies, and for noise rejection at single-DOM level.

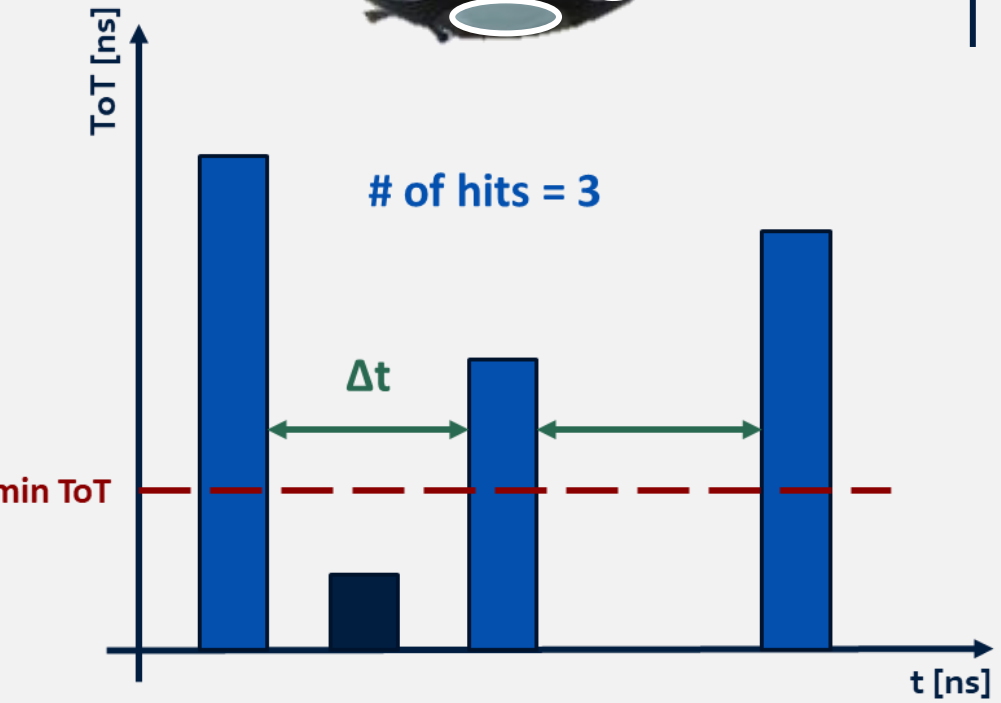
Low-level data stored by KM3NeT is filtered requiring at least two-hits coincidences on the same DOM.

Low-level data originates mostly from ^{40}K decay and bioluminescence

Single-DOM events are defined as group of PMT hits, that are recorded on the same DOM with a time offset **Δt < 30 ns**.

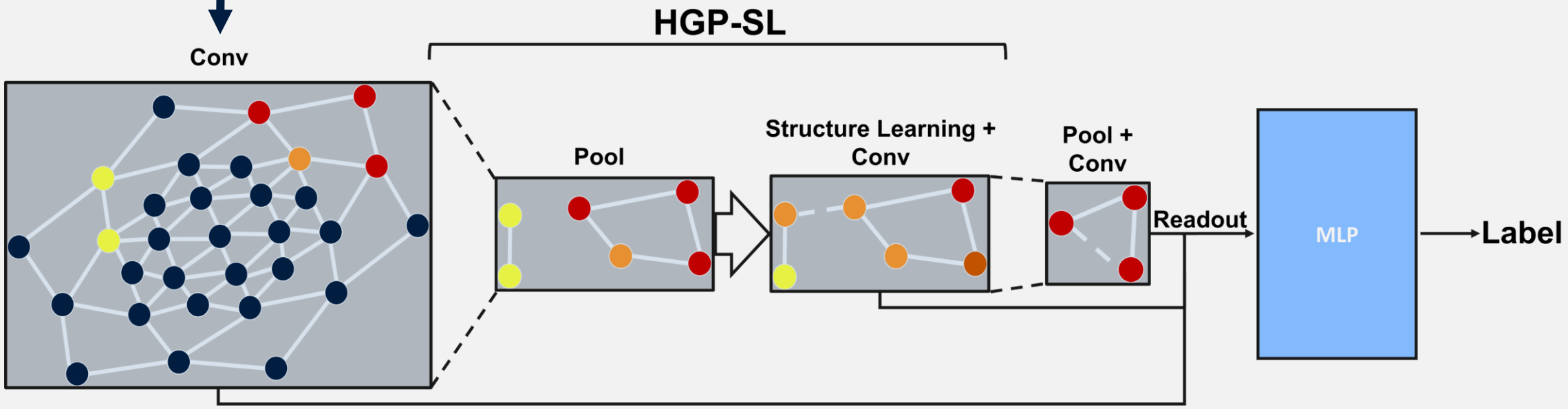
Only hits with **ToT > 5 ns** are used, and

Only events with **number of hits > 2** are kept.



By comparing data (background) with neutrino simulations (signal), we optimise the cuts on Δt, min ToT, and min # of hits by looking at fractional increments in the percentage of survived ToT.

Hierarchical Graph Pooling	Structure Learning
It selects the subset of most representative nodes to produce a lower dimensional representation of the graph.	It learns a refined structure of the graph by computing a similarity between nodes. It allows to avoid highly disconnected graphs after pooling.

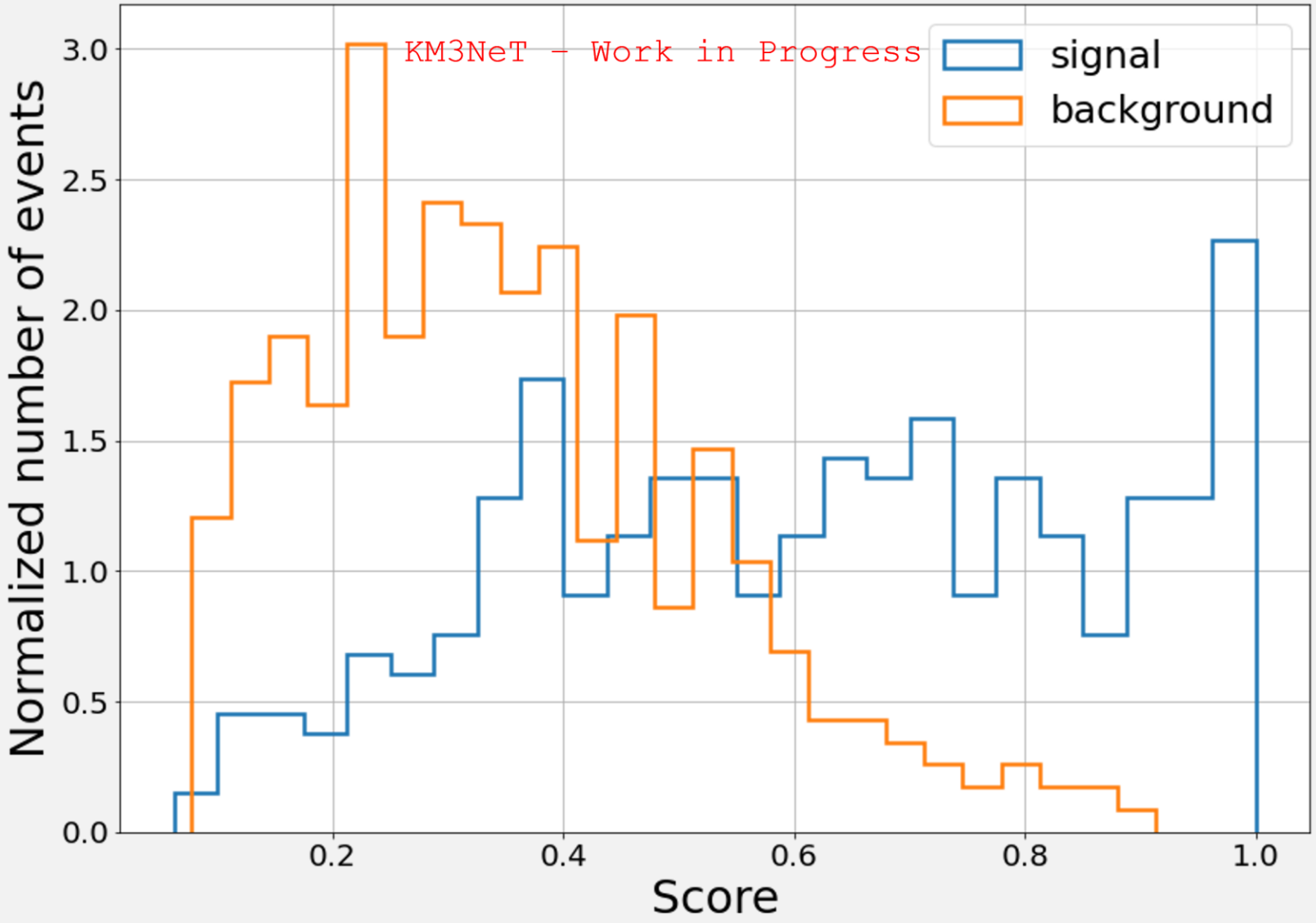


Best epoch of 100 on the validation sample:

JM, G. de Wasseige, on behalf of the **KM3NeT** Collaboration "Improving the sensitivity of KM3NeT to MeV-GeV neutrinos from solar flares", *PoS* **ICRC2023** (2023)

875 background events (data), and 875 signal events (simulations)

Dataset split into 50% training, 10% validation, and 40% test



IceCube Upgrade

IceCube Collaboration, "Acceptance Tests of more than 10 000 Photomultiplier Tubes for the multi-PMT Digital Optical Modules of the IceCube Upgrade", *JINST* **19** (2024)

Credit: Timo Karg (DESY)

The upcoming IceCube Upgrade will include new multi-pmt DOMs (mDOMs)

IceCube mDOMs are made of 24 3.1" PMTs.

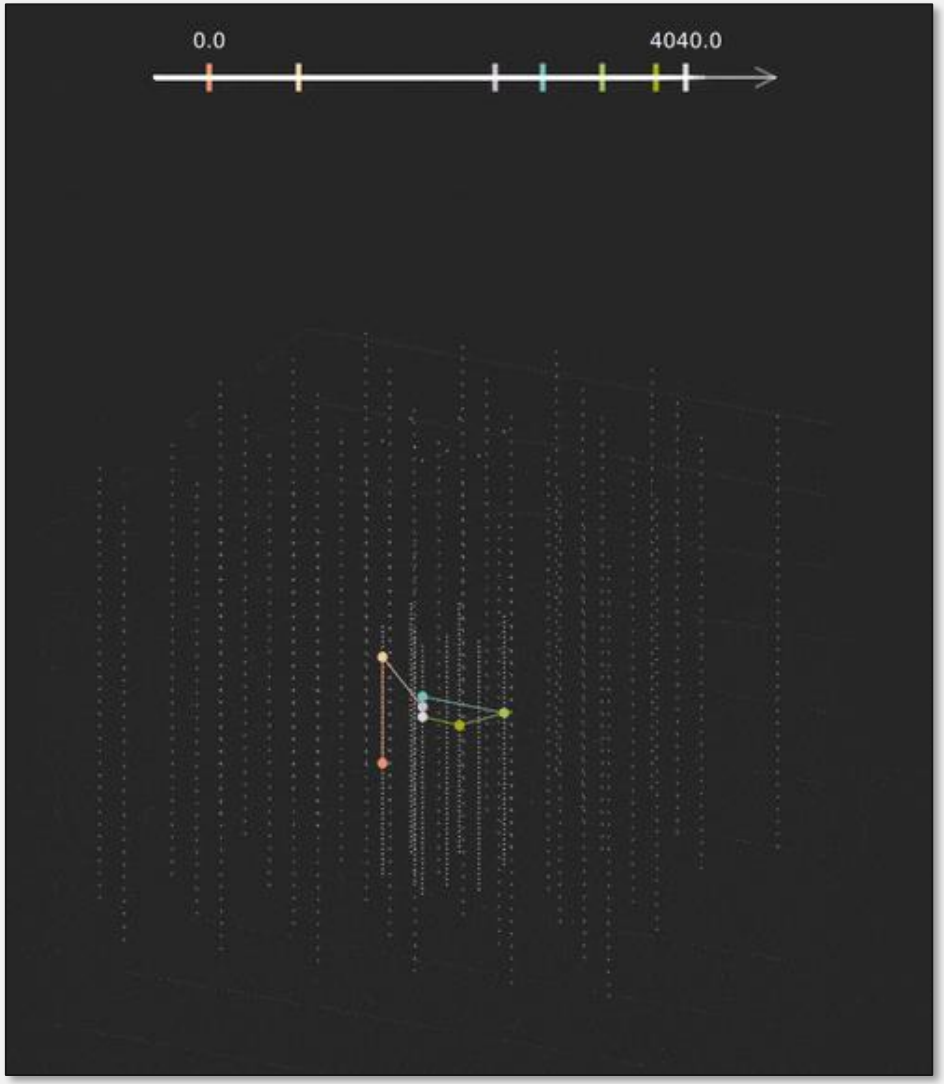
This represents an opportunity to improve the current low-energy selections using the information provided by the individual DOMS.

Novel IceCube sub-GeV selection

Sub-trigger neutrino events with unsupervised learning techniques.

From IceCube's HitsPool data acquisition system, clustering methods are used to find bursts imposing minimal spatial and temporal coincidences.

<u>Structure found in data may be evidence of the existence of multiple classes (e.g., detector noise and sub-GeV neutrinos).</u>



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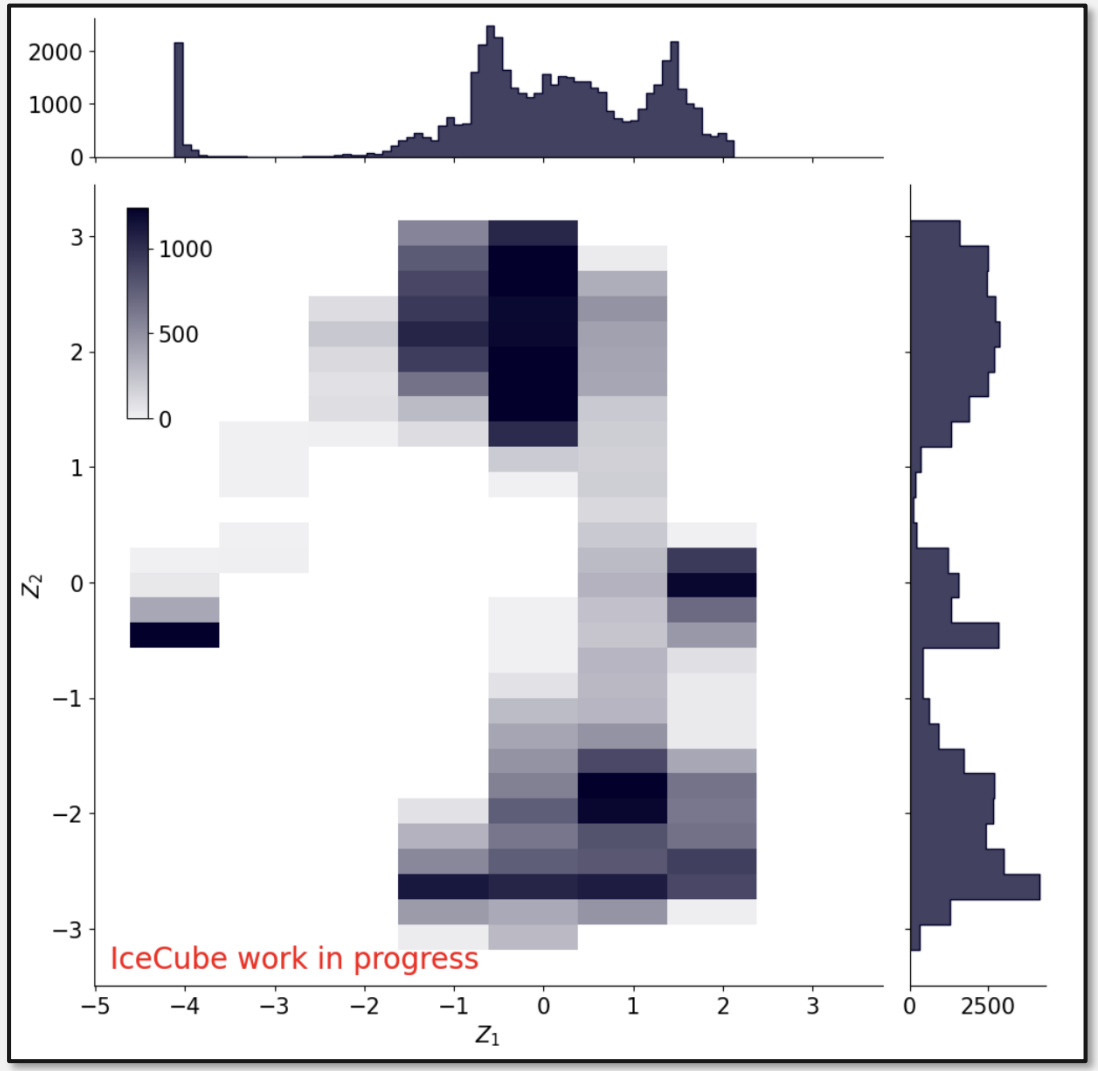


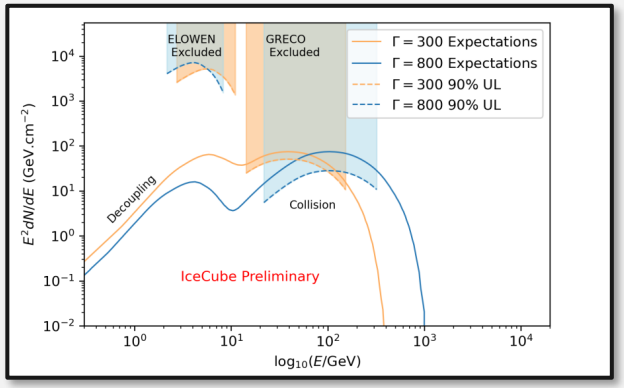
Recap

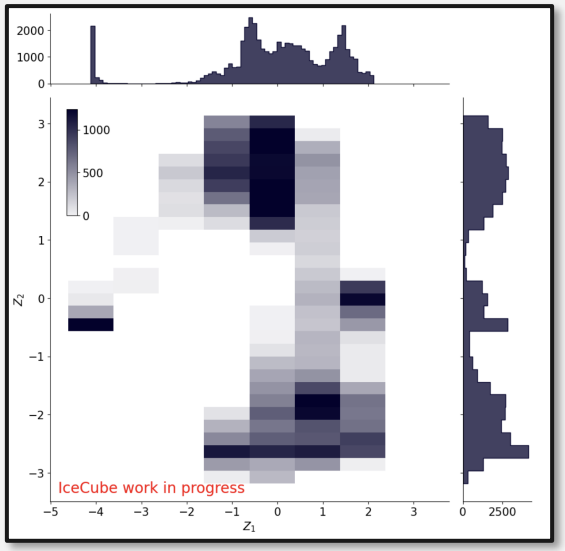
Large-volume neutrino telescopes are a powerful tool in the search for low energy neutrinos from astrophysical transients

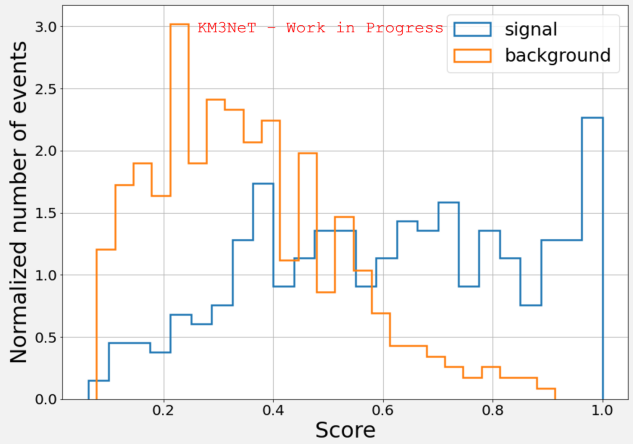
Important results have been already obtained (GRBs, GW, Solar Flares)

Using machine learning it is possible to further boost the sensitivities in the MeV-GeV range

Multi-PMT modules provide important additional information to help filter low-level noise







Thanks for your attention :)

BACKUP SLIDES