KM3NeT: status and perspectives of neutrino astronomy

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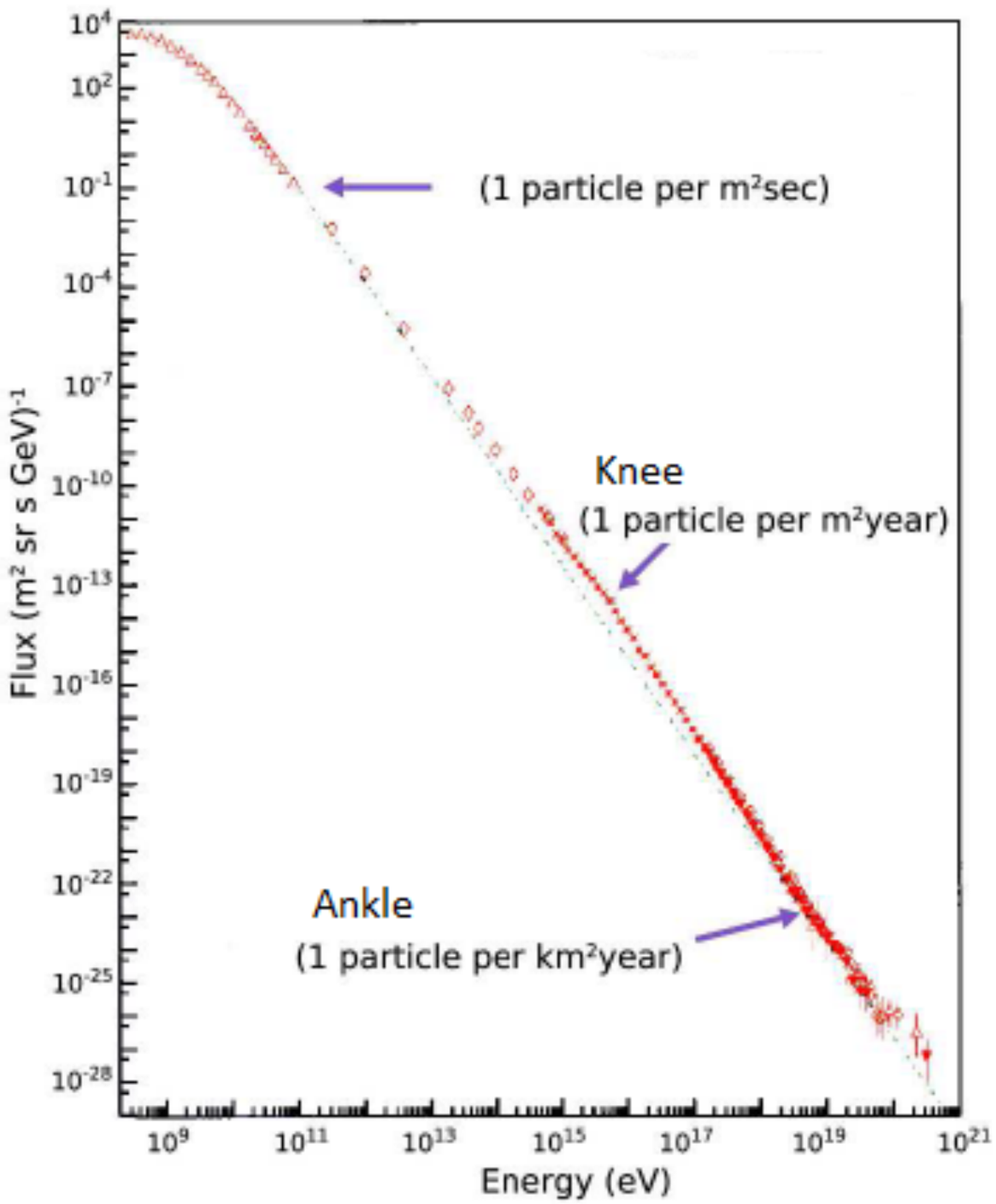
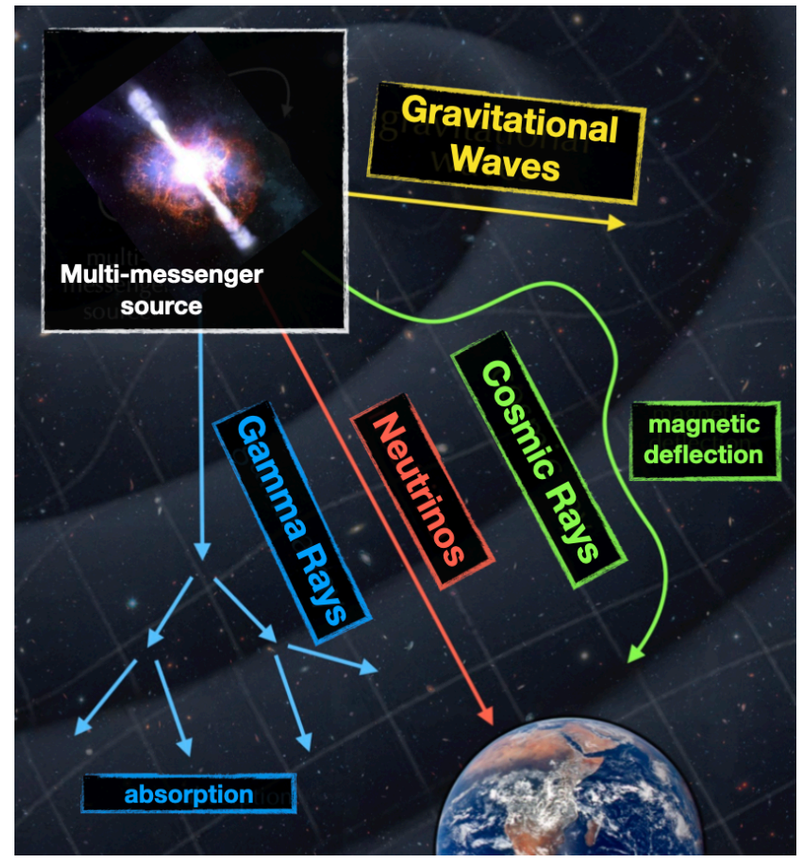
on behalf of the KM3NeT Roma group

Sapienza Università di Roma & INFN

INFN Roma1 Retreat - June 14th 2022

The local CR spectrum & the MM search for CR sources

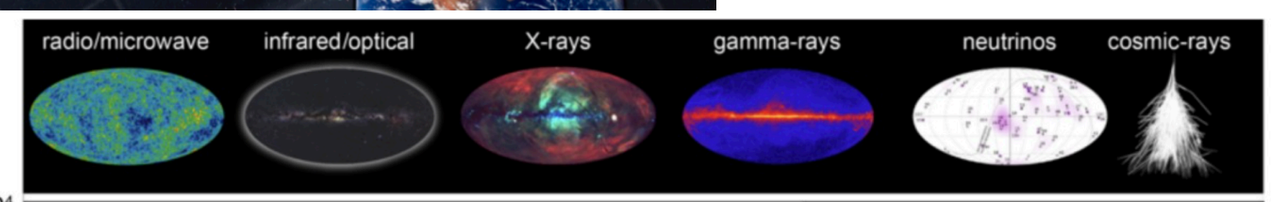


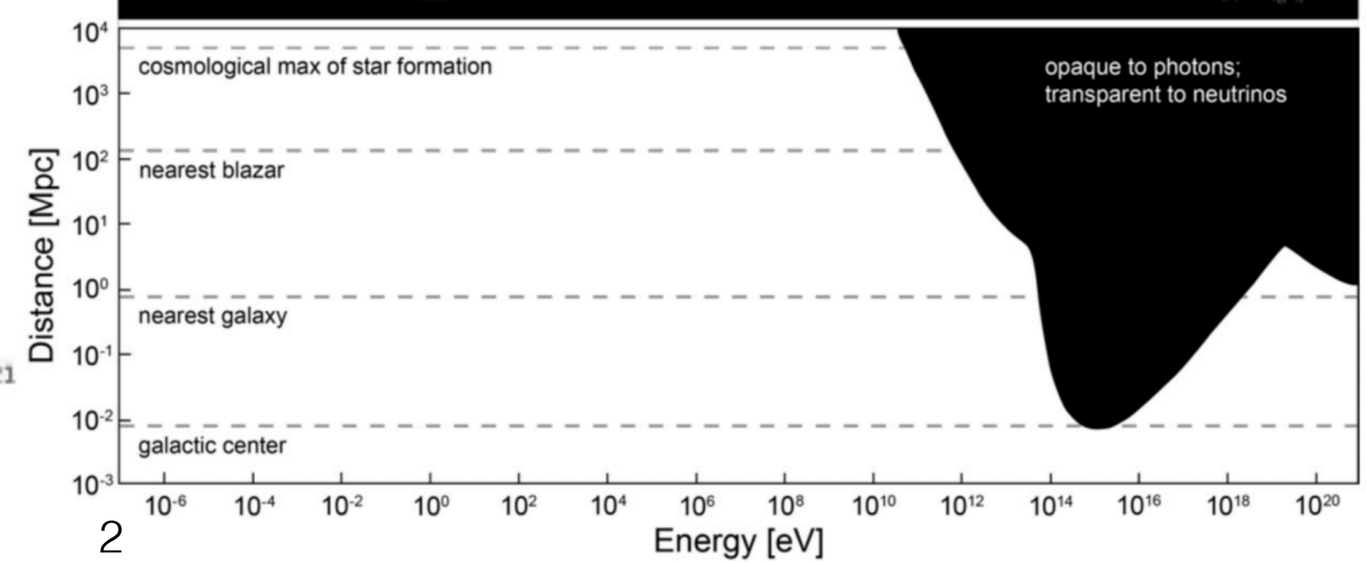


WHY NEUTRINOS?
- stable
- electrically neutral
- weakly interacting
- produced only at hadronic interactions

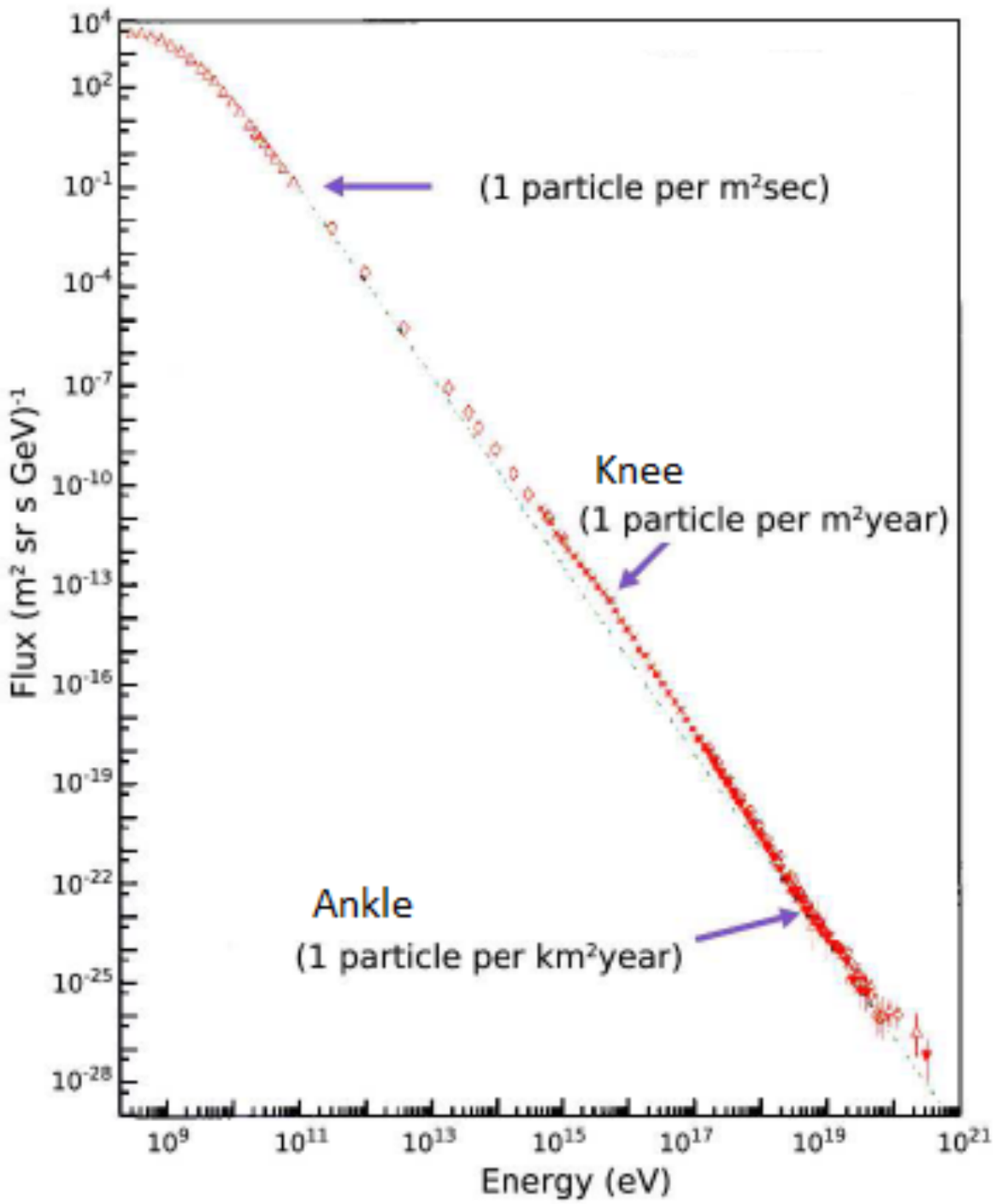
PROS:
→ can reach Earth **undeflected** from cosmological distances
→ unambiguous probes of **CR acceleration**

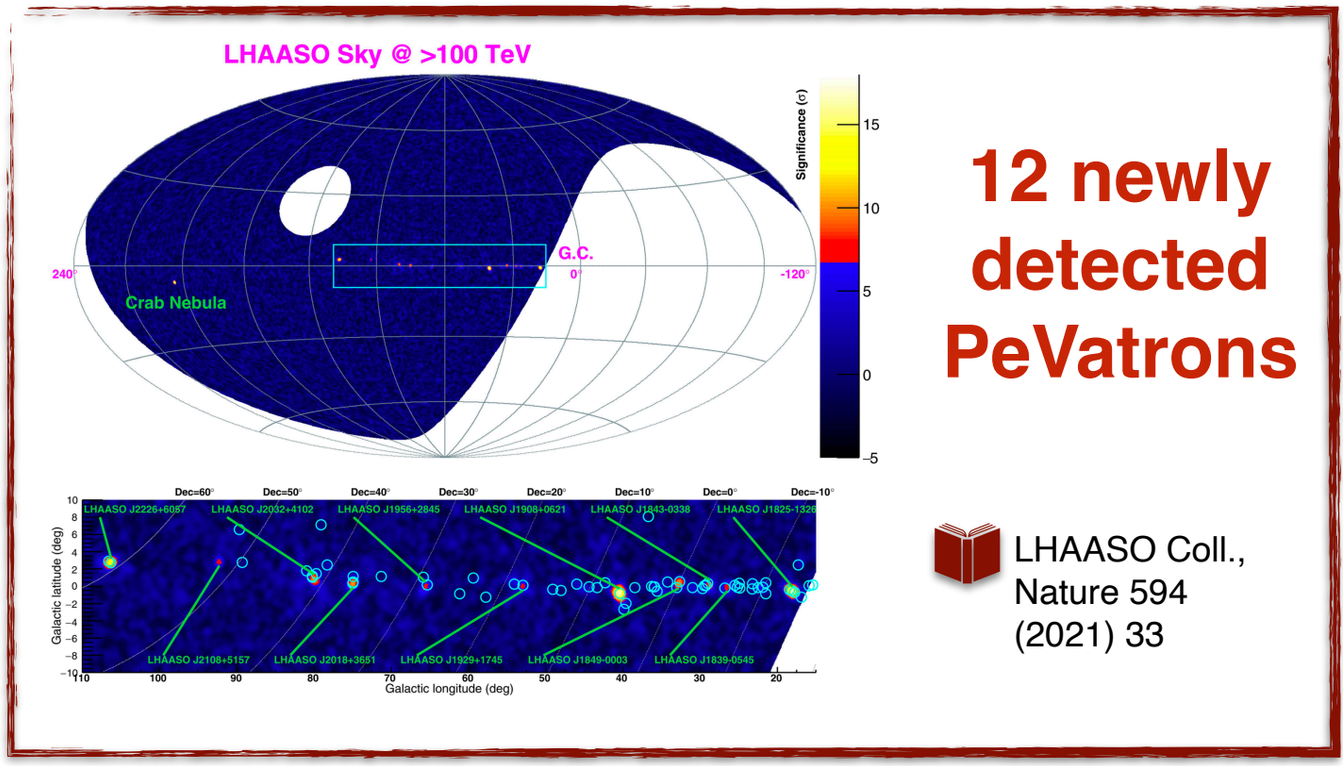
CONS:
→ low fluxes
→ large background





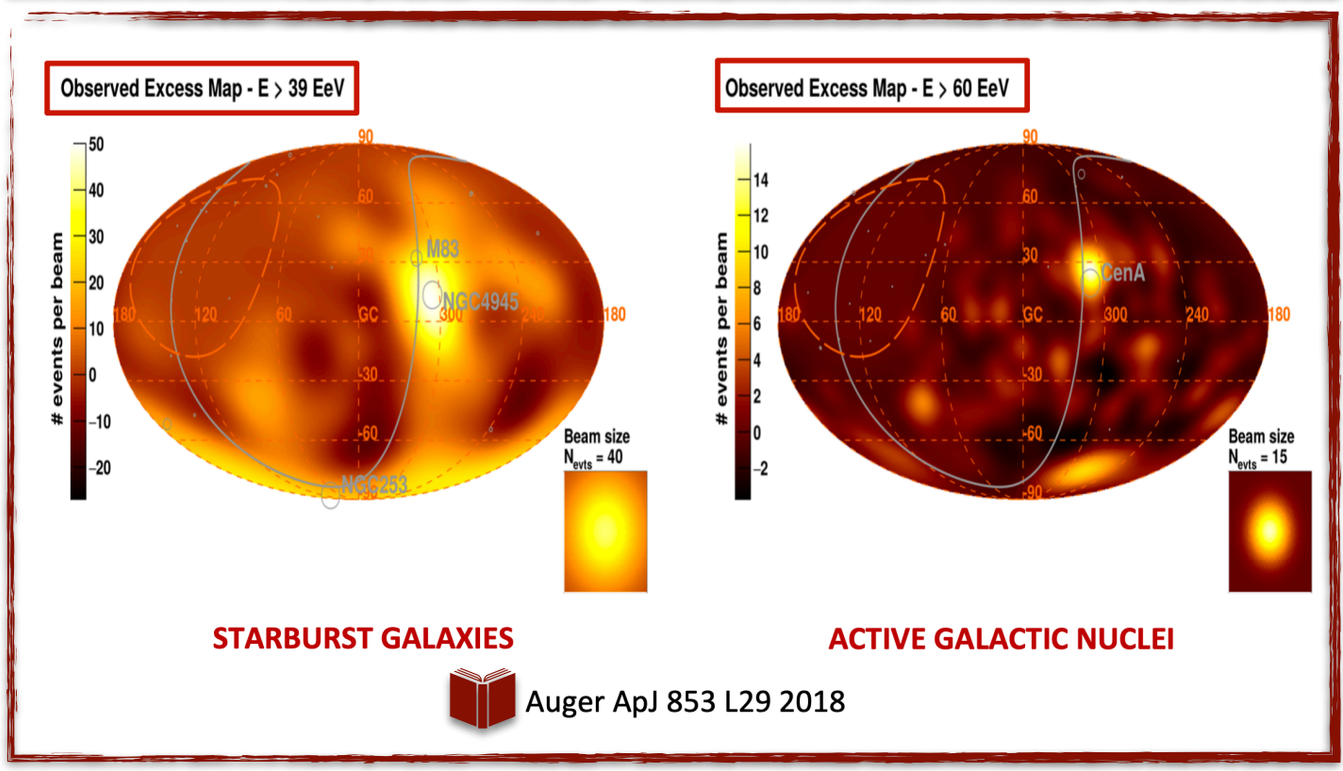
The local CR spectrum & the MM search for CR sources





12 newly detected PeVatrons

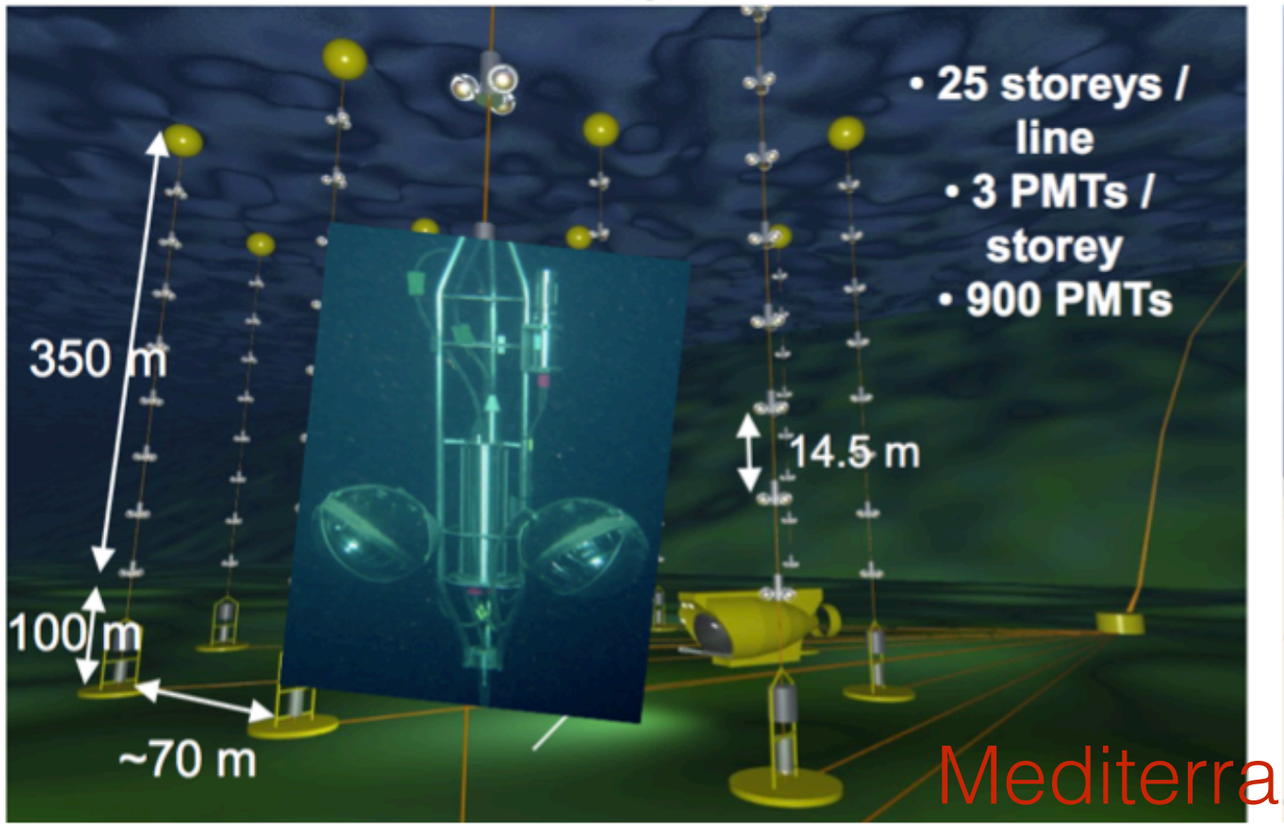
LHAASO Coll., Nature 594 (2021) 33



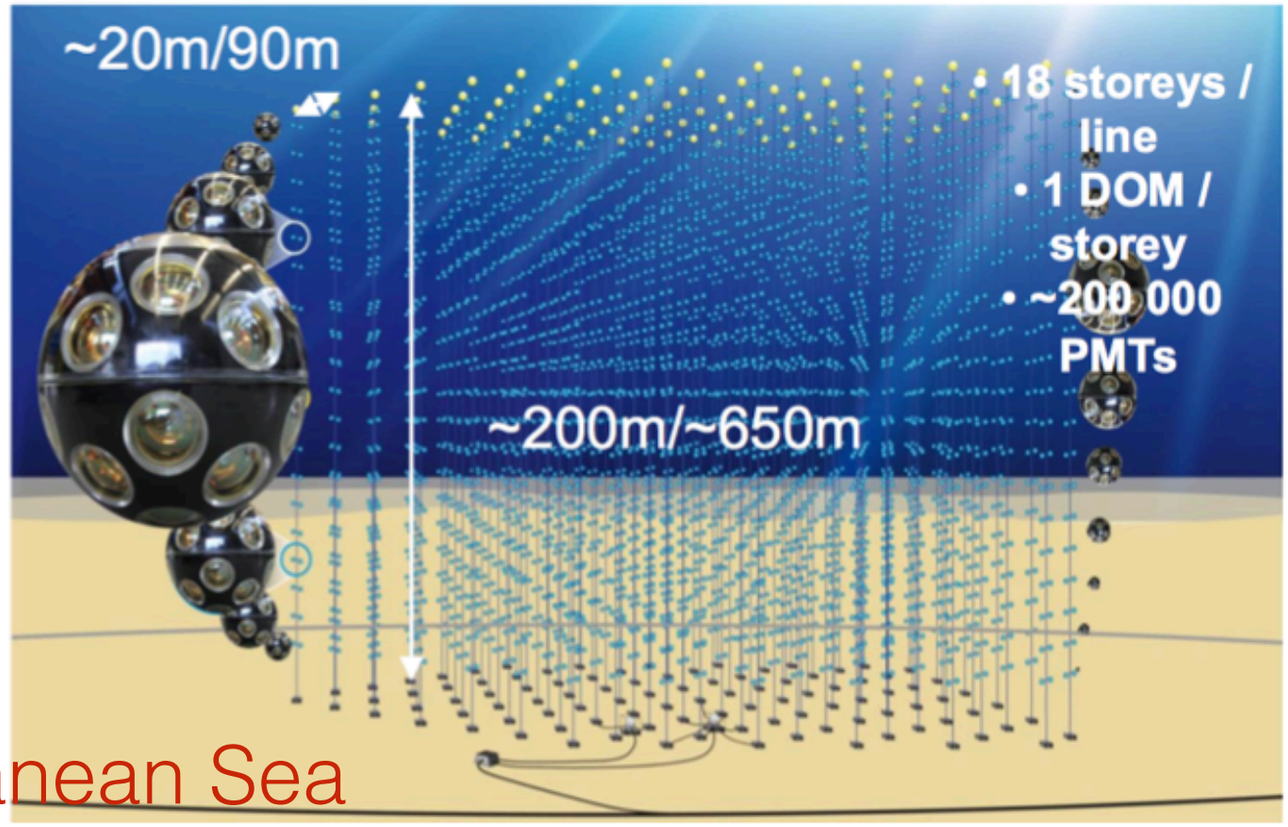
Auger ApJ 853 L29 2018

Neutrino telescopes around the world

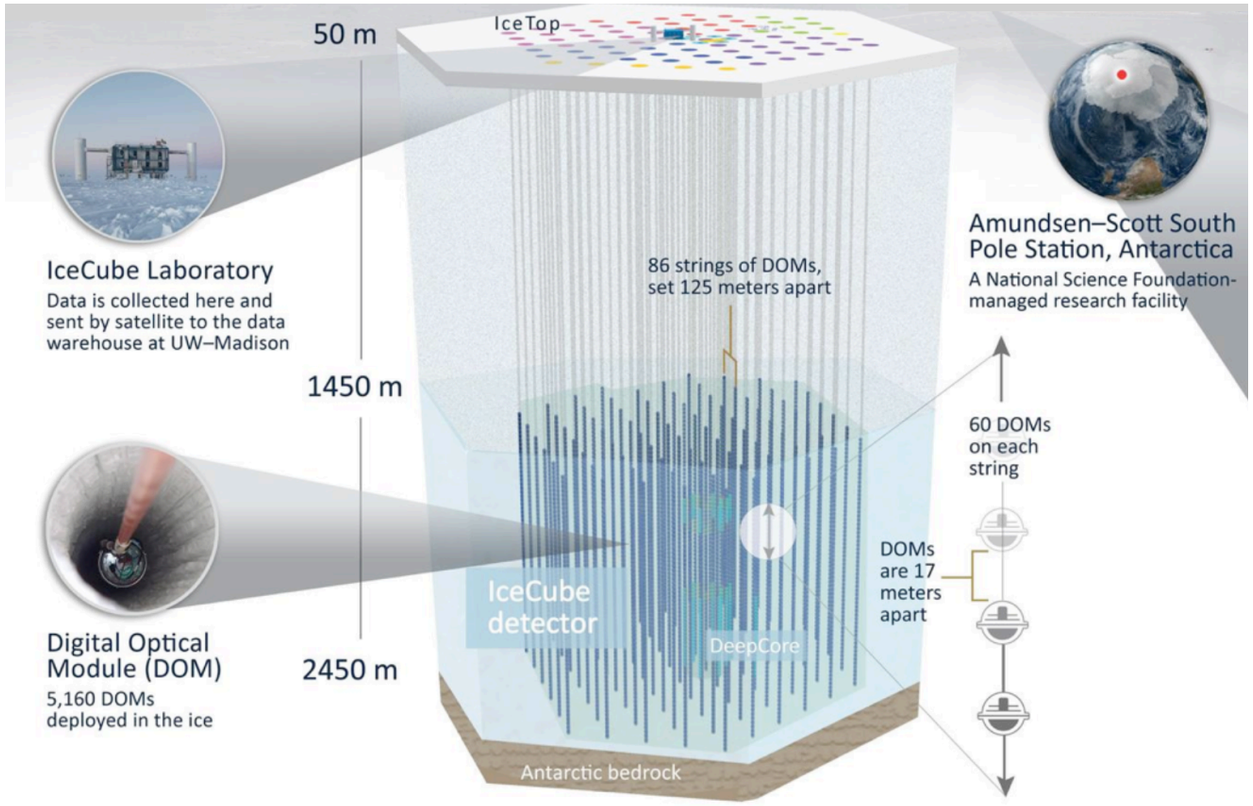
ANTARES Complete since 2008



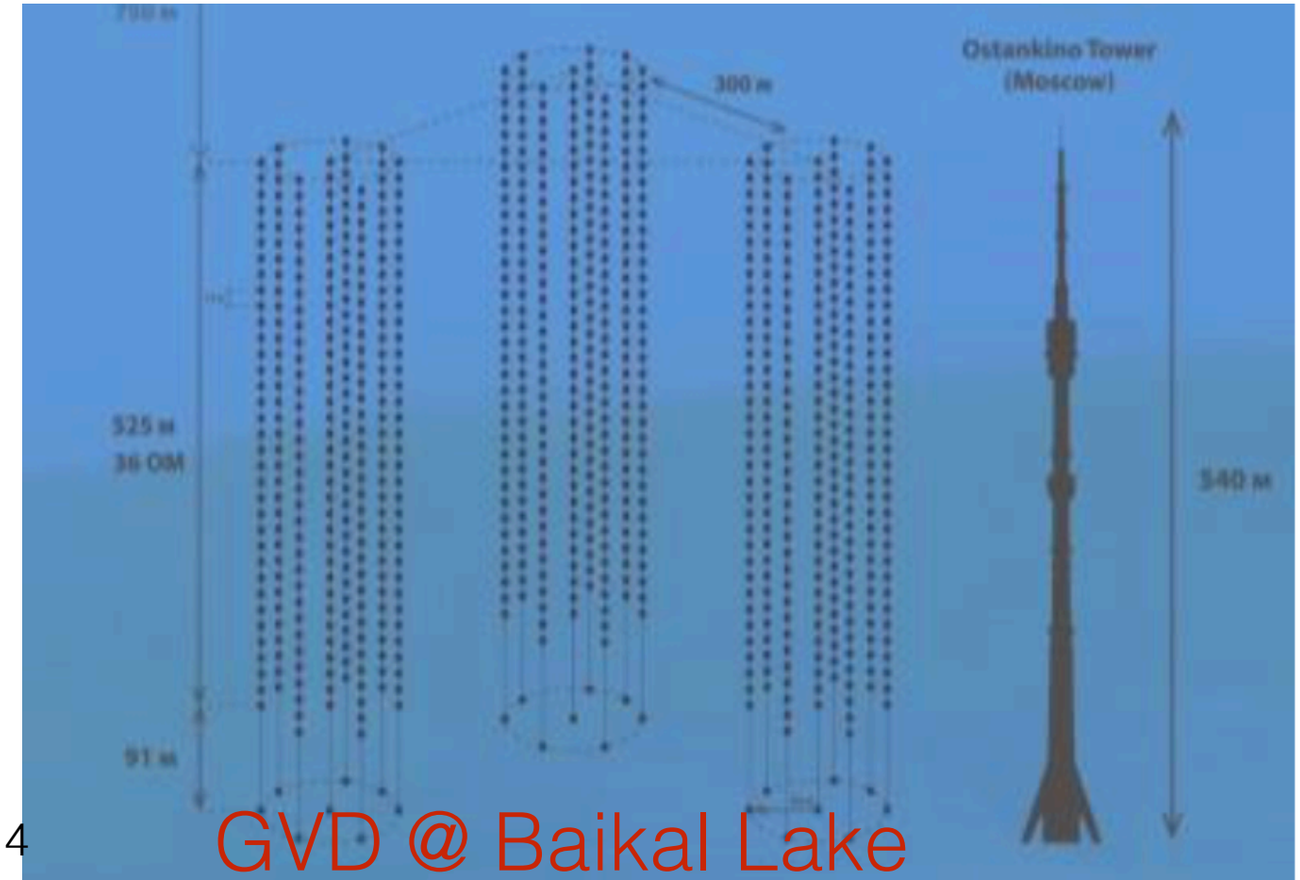
KM3NeT Under Construction



Mediterranean Sea



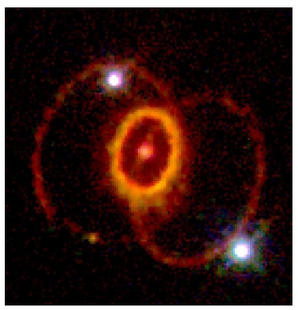
IceCube @ South Pole

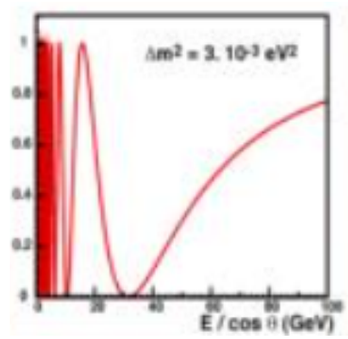


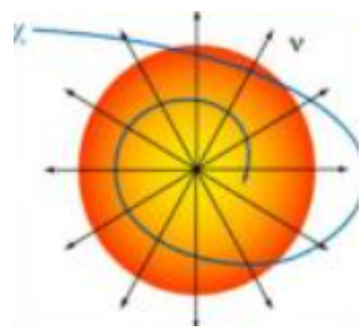
GVD @ Baikal Lake

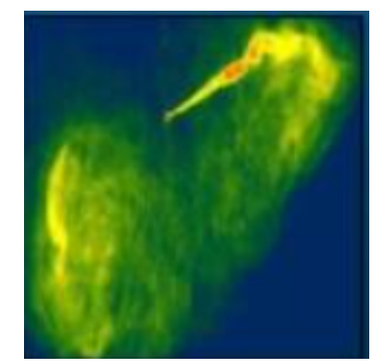
The scientific program of high energy neutrino telescopes

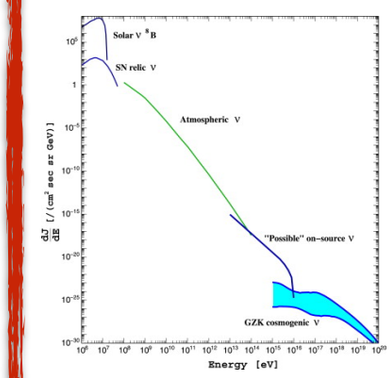
SN ν | ν oscillations | indirect DM | extreme cosmic sources | GZK ν



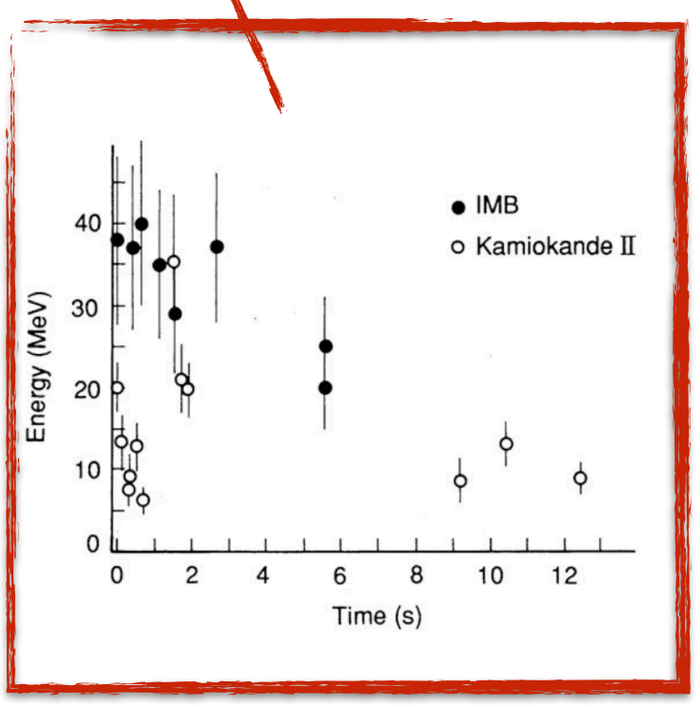


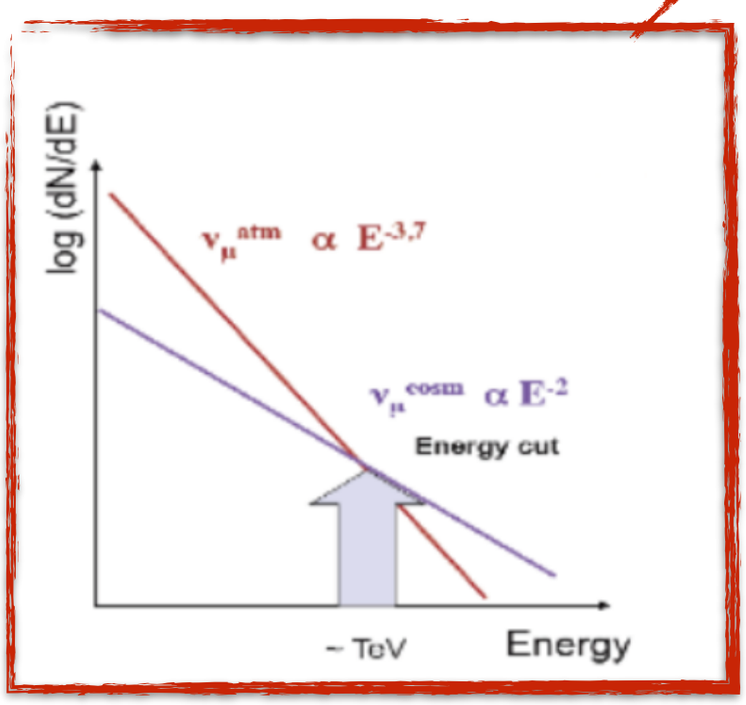




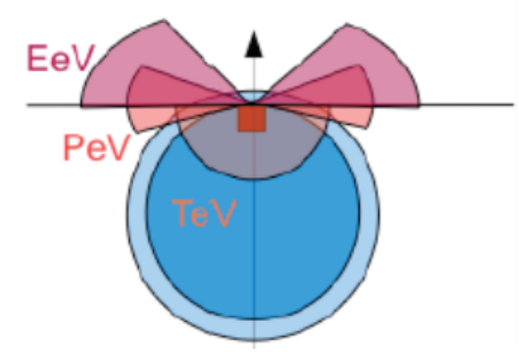


MeV | **10-100 GeV** | **GeV-TeV** | **TeV-PeV** | **PeV-EeV** | **>EeV**





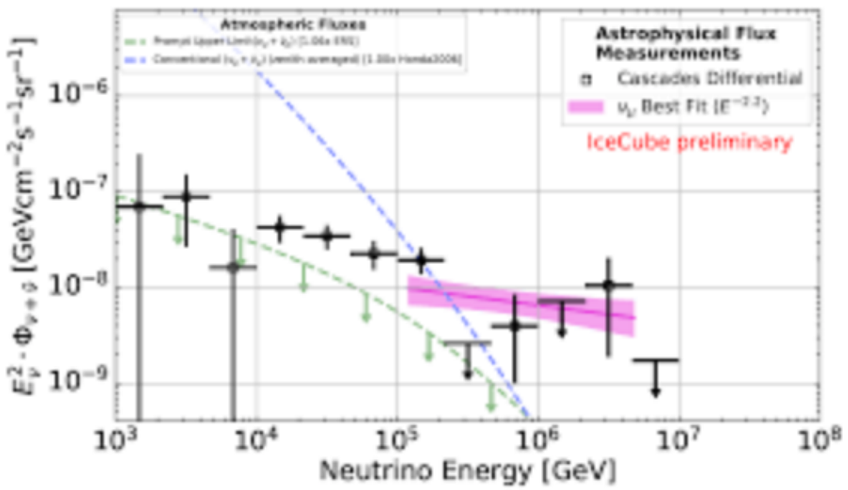
Remember, the Earth is opaque also for ν at very high energies



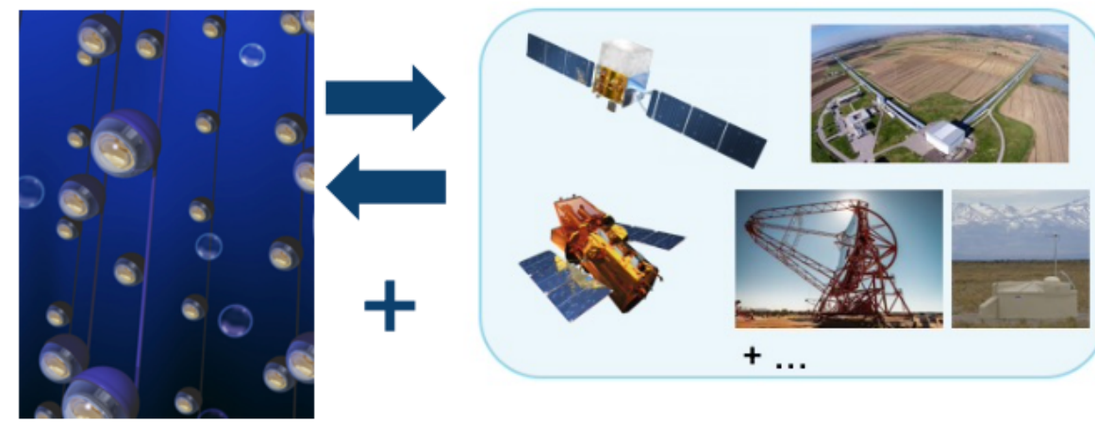
+ exotic physics (sterile neutrinos, magnetic monopoles,…)

Neutrino search methods

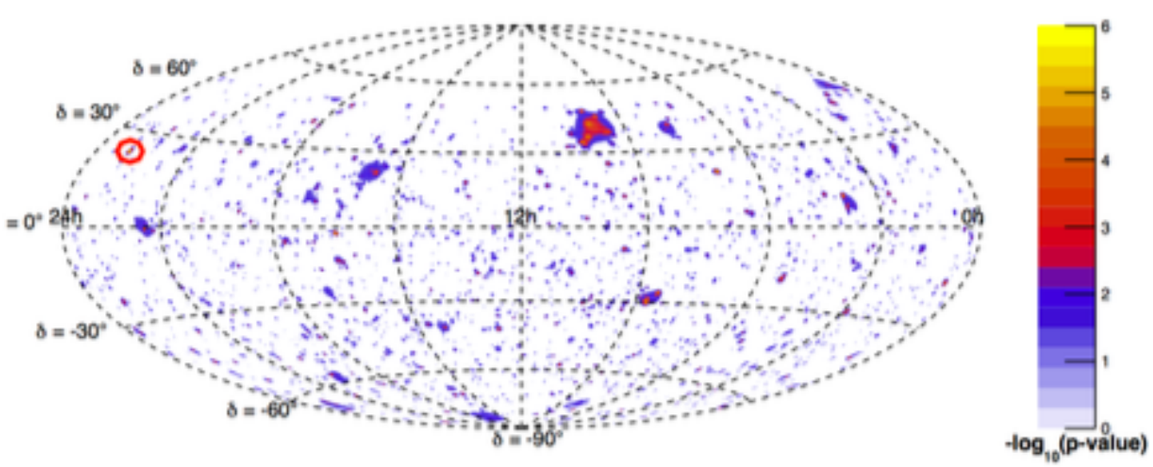
Diffuse search



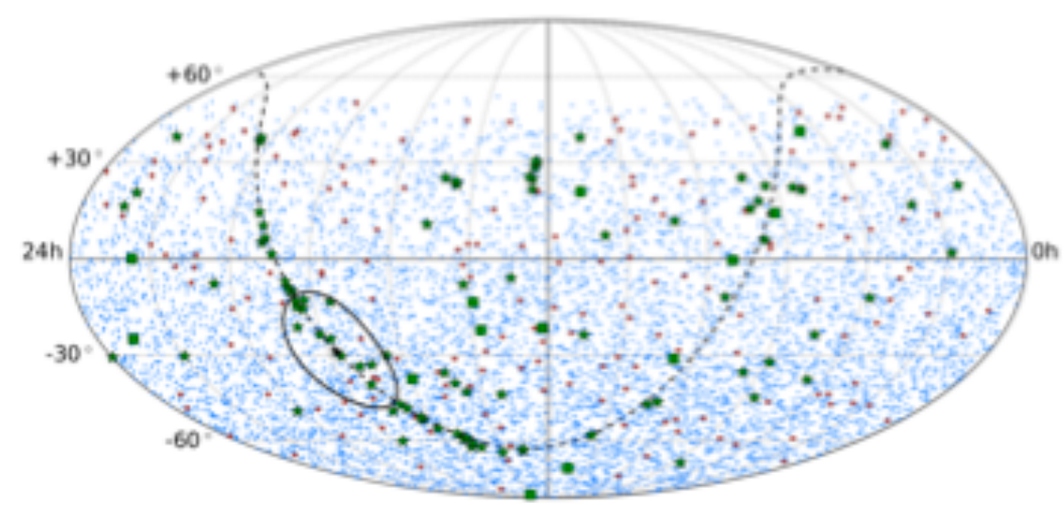
Multi-messenger search



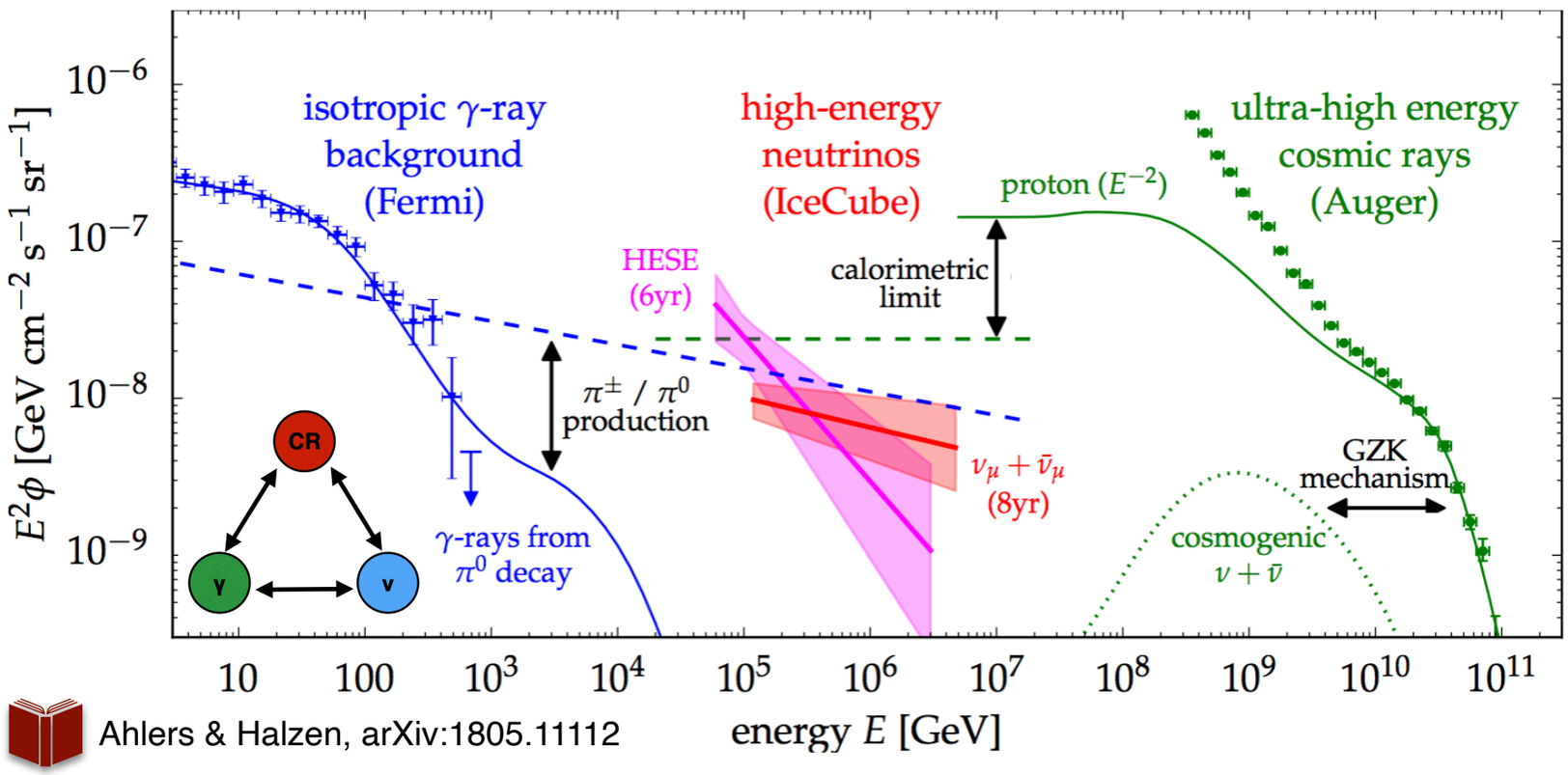
Point source search (auto-correlation)



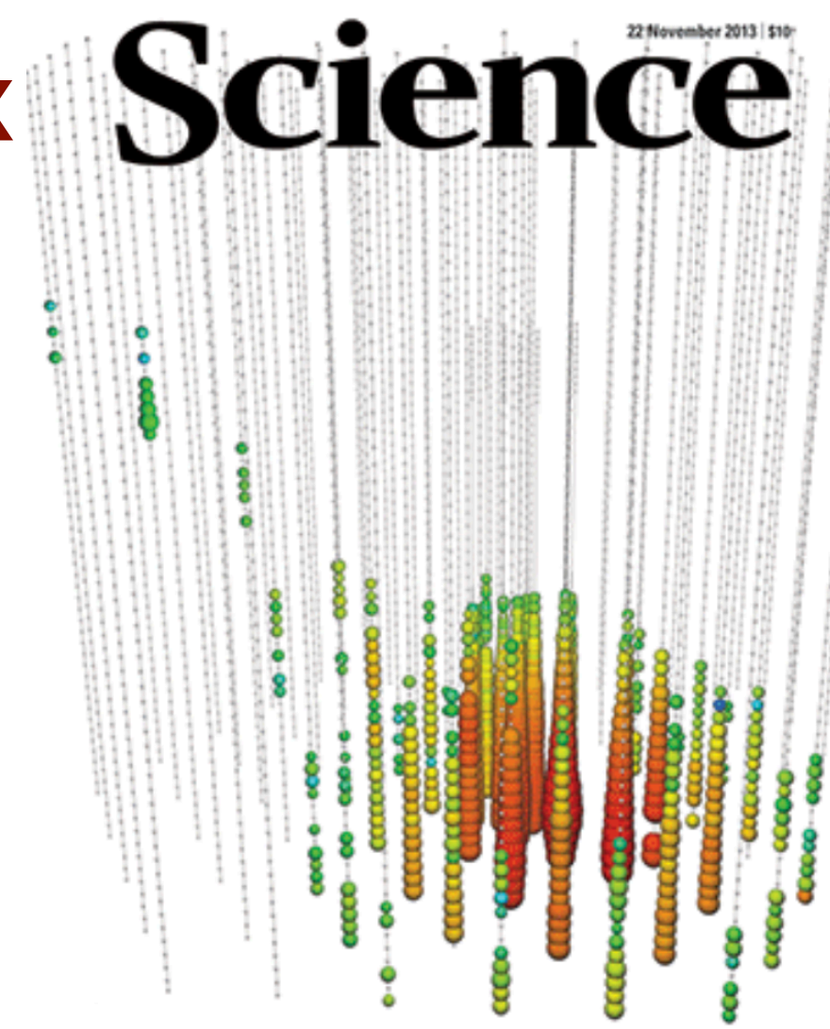
Point source search (catalog search)

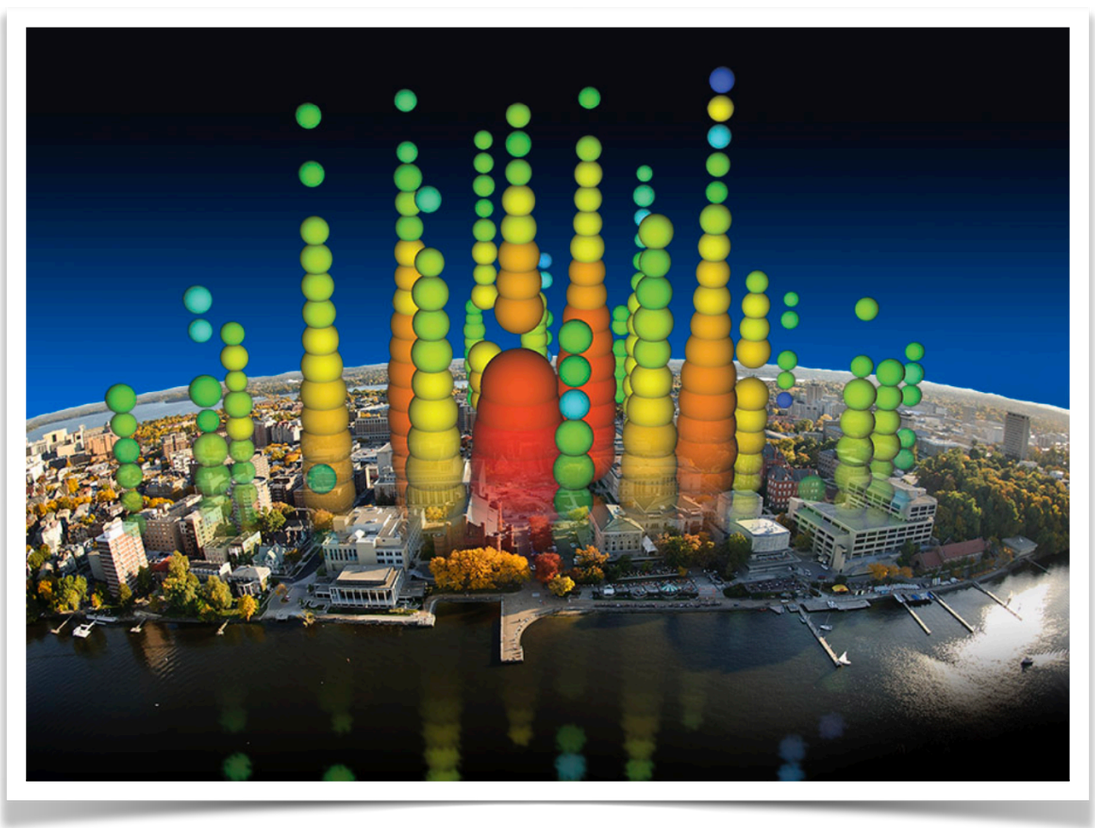


The diffuse cosmic neutrino flux

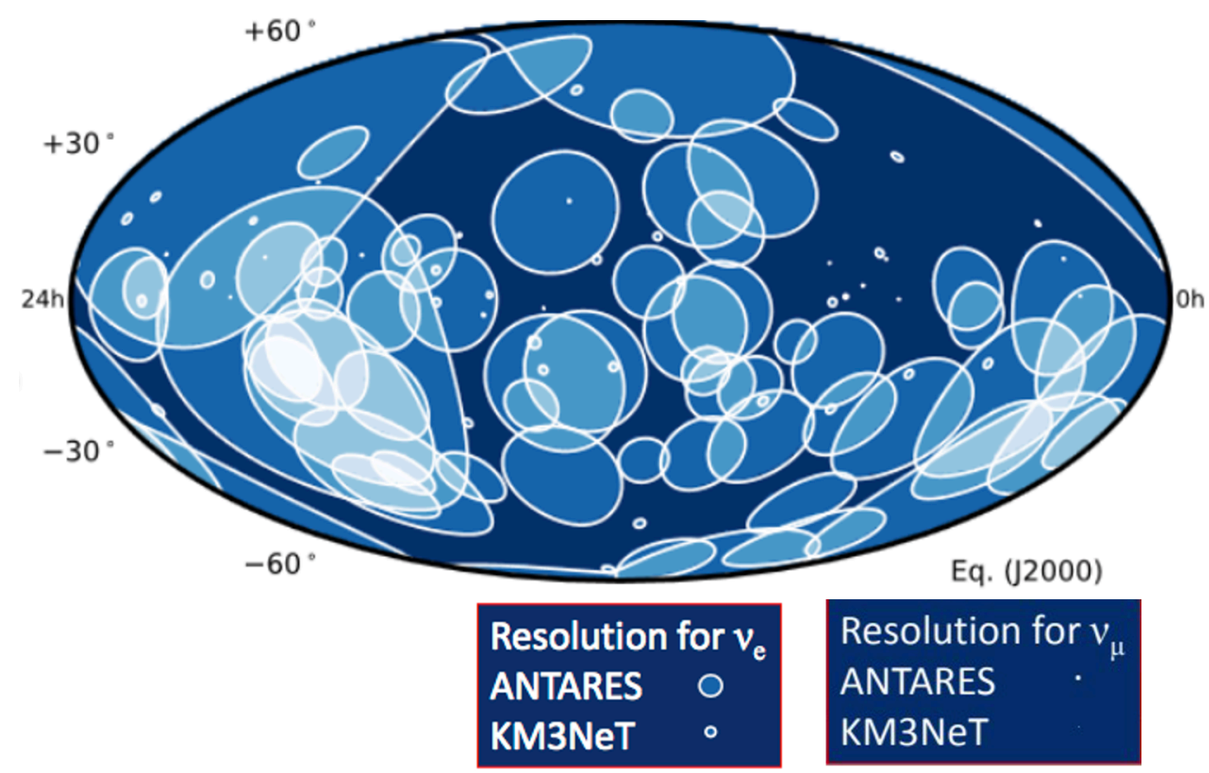


Ahlers & Halzen, arXiv:1805.11112





PeV ν_e (shower) event, > 300 sensors, > 10^5 photo-electrons reconstructed



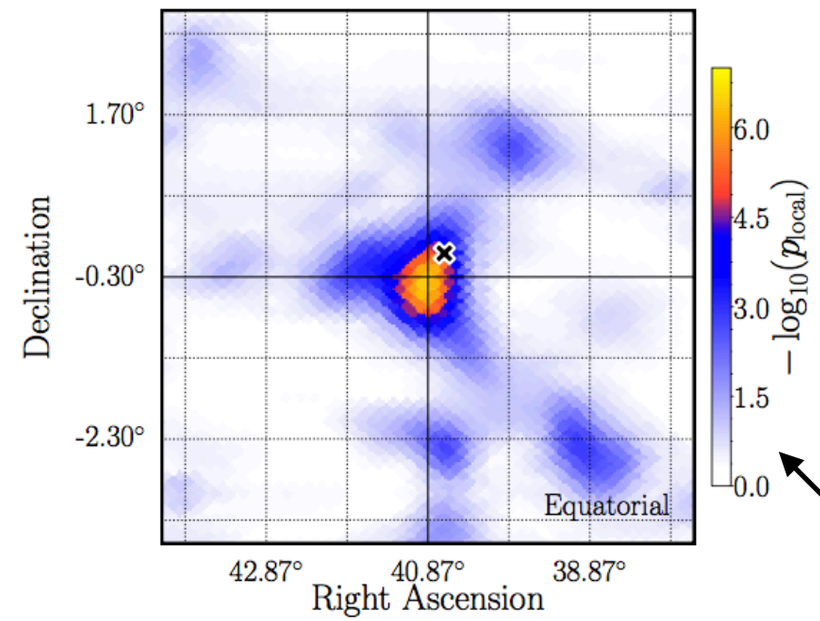
IceCube Coll., Neutrino 2022, PoS 998

Point source searches

1. IceCube all-sky clustering search: **10 years** of data point towards **no significant** excess over background.

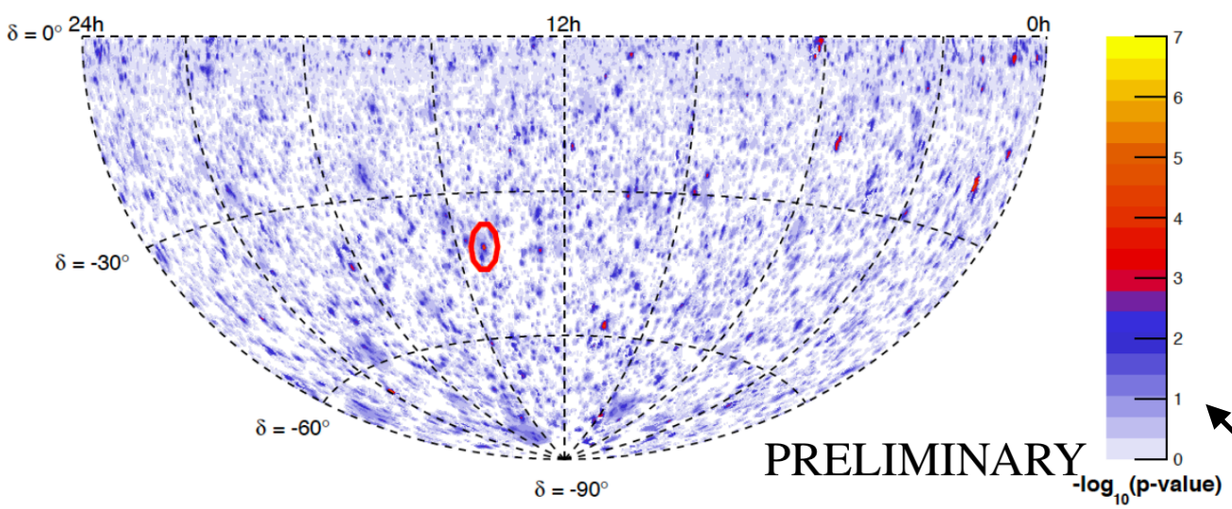
A hotspot seen in the Northern Hemisphere, located 0.35° from the active galaxy **NGC1068**, inconsistent with pure bkg @ **2.9σ** (post-trial)

IceCube Coll., PRL 124 (2020) 051103



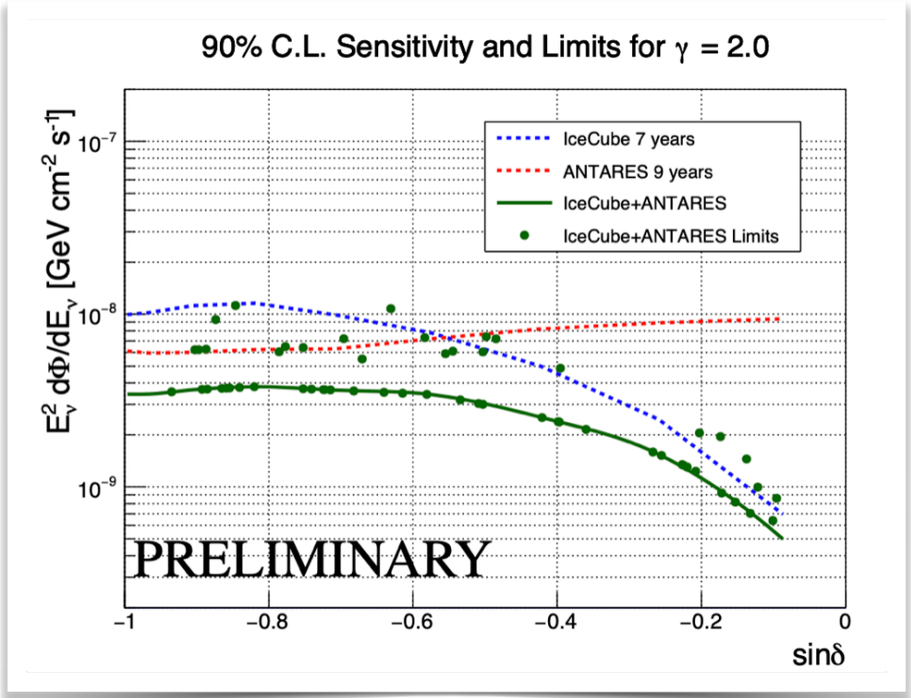
pre-trial

2. ANTARES+IceCube Southern Hemisphere clustering search: **9 years of ANTARES** data and **8 years of IceCube** data point towards **no significant** excess over background.

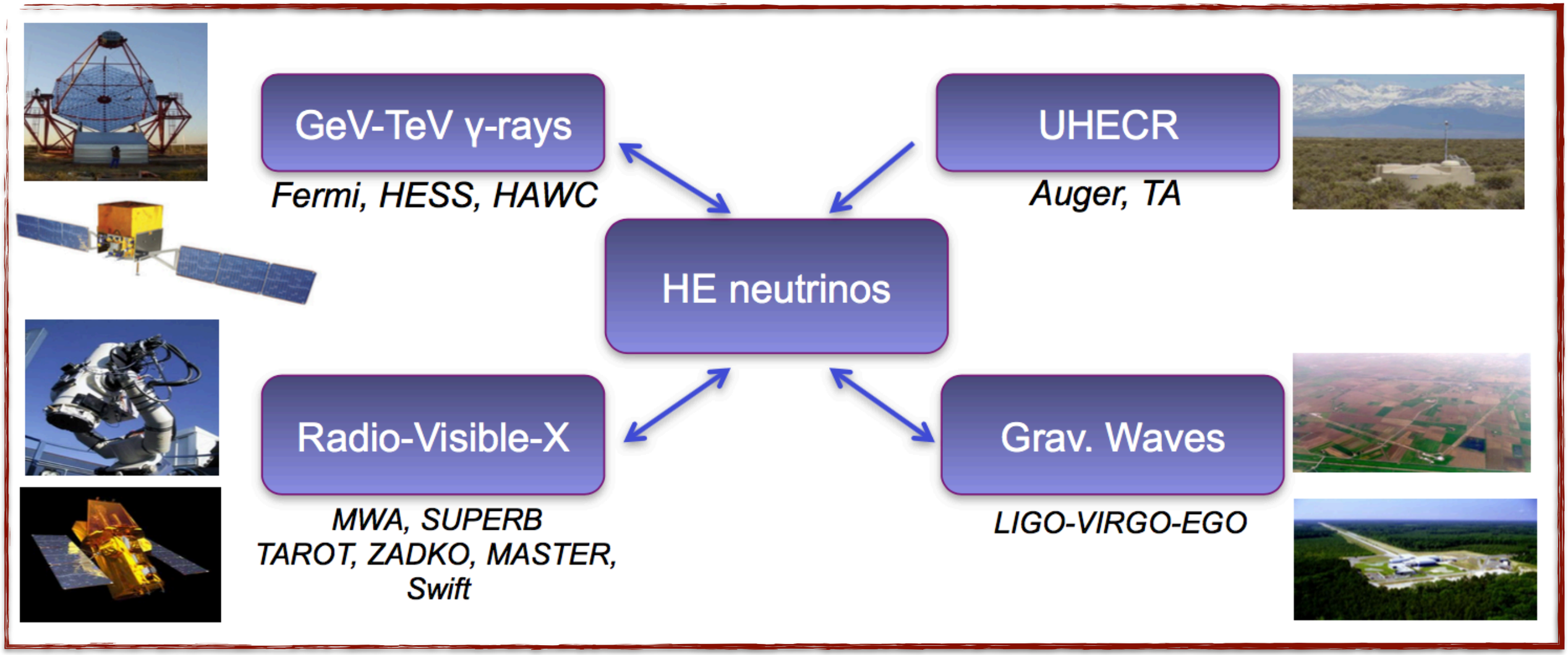


pre-trial

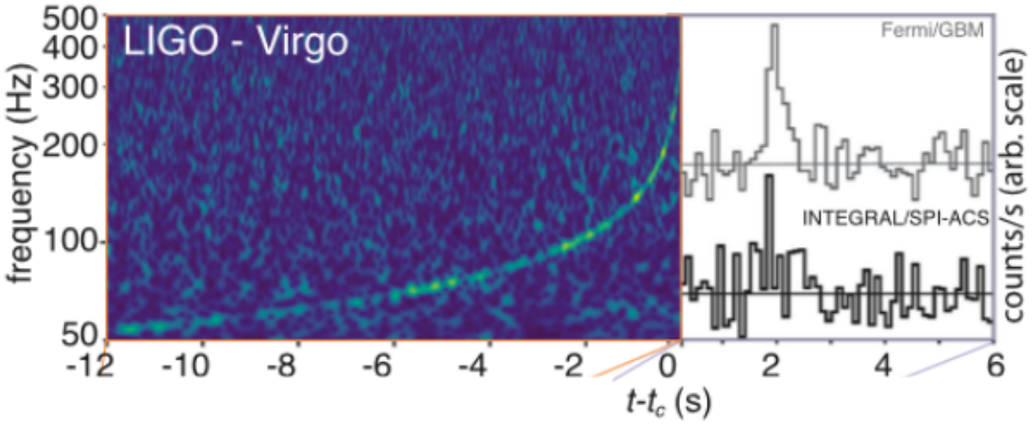
ANTARES & IceCube Coll., ApJ 892 (2020) 92



Real-time multi-messenger searches

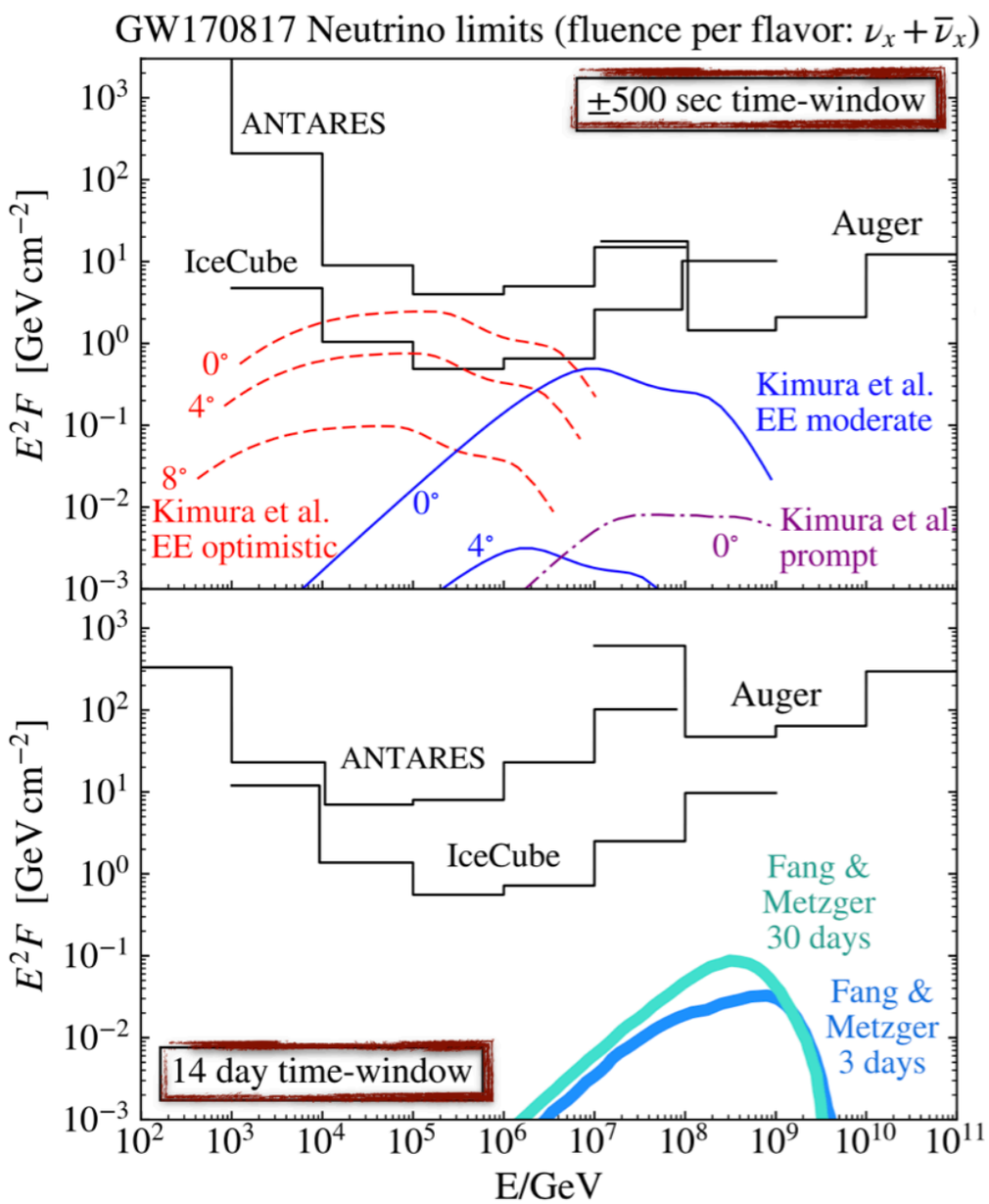


- Complementary view of physical processes occurring at the source;
- Better understanding of the source physics;
- Improvement in detector sensitivity (uncorrelated bkg);



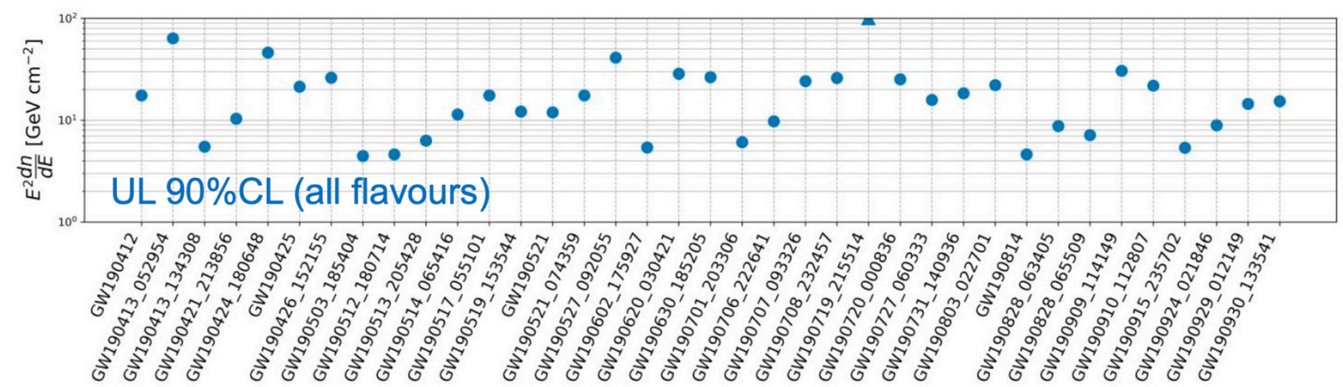
Multi-messenger studies: GWs

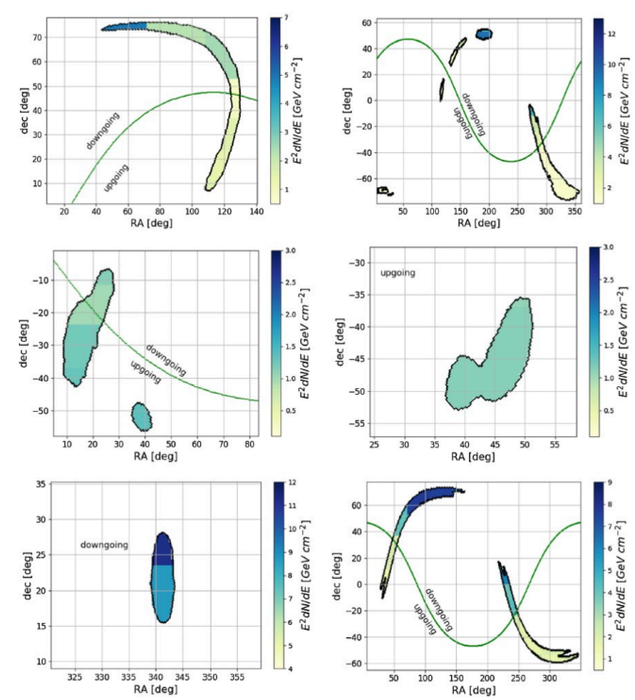
1. Neutrino follow up of GW170817

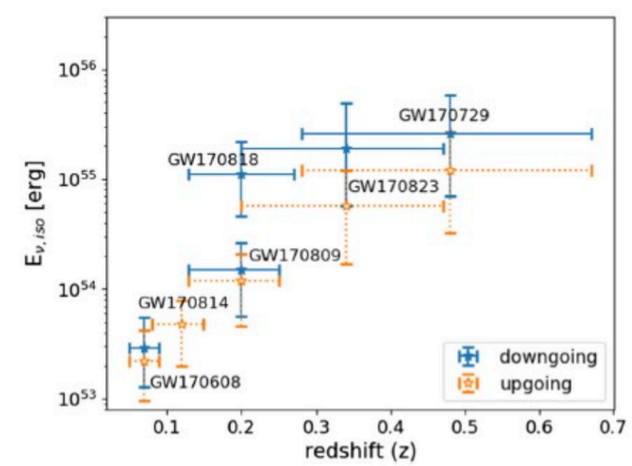


ANTARES, IceCube, Pierre Auger, LIGO, Virgo Coll., ApJL 850 (2017) L35

2. ANTARES follow up of LIGO/Virgo O2/O3



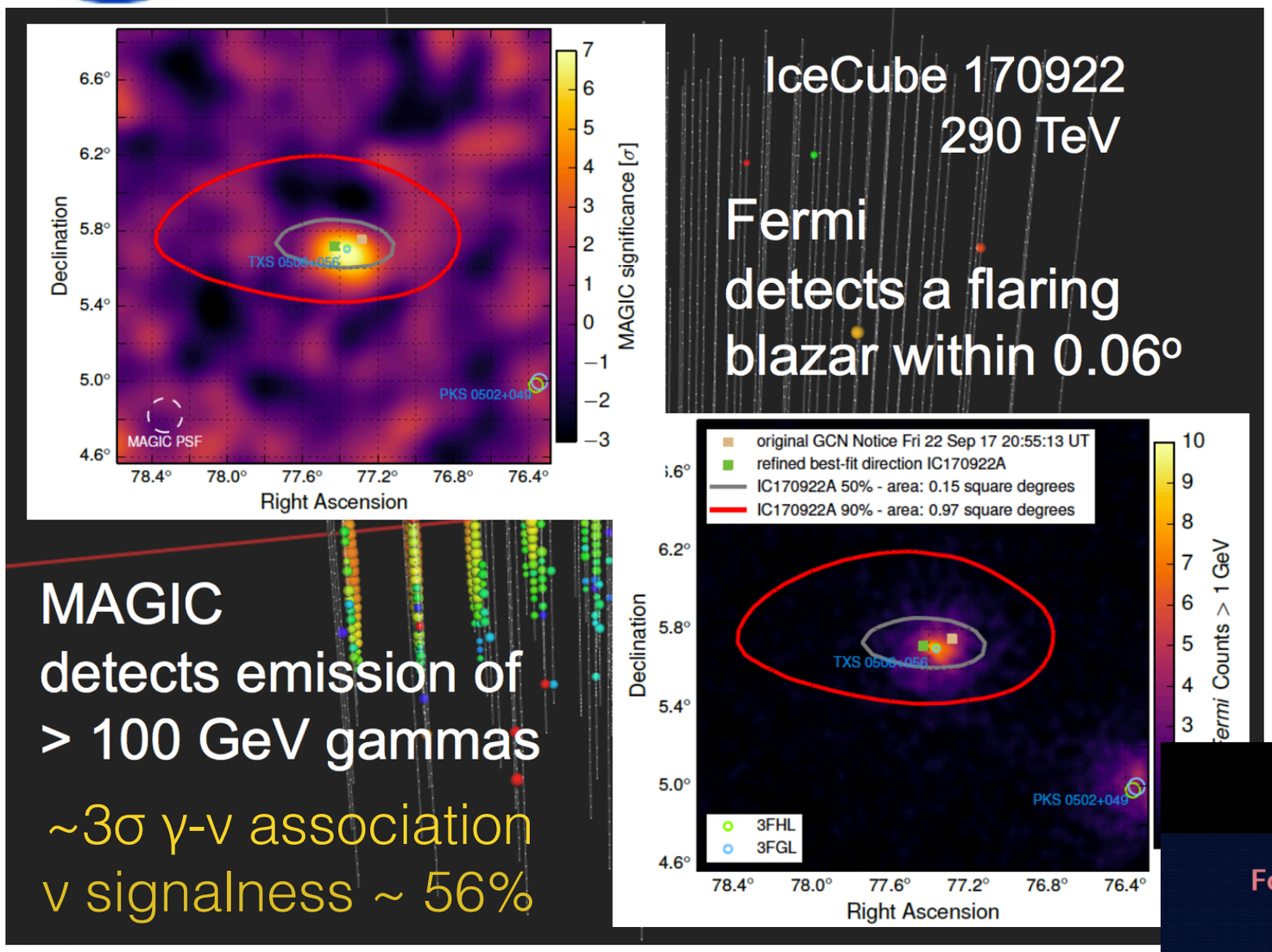




- Eur. Phys. J. C 80, 487 (2020)
- ApJ 870 (2019) 2
- ApJL 848 L12 (2017)
- ApJL 850 L35 (2017)
- Phys. Rev. D 96 (2017) 022005
- Phys. Rev. D 93 (2016) 122010
- JCAP06(2013)008

No neutrino counterpart of GW events detected so far

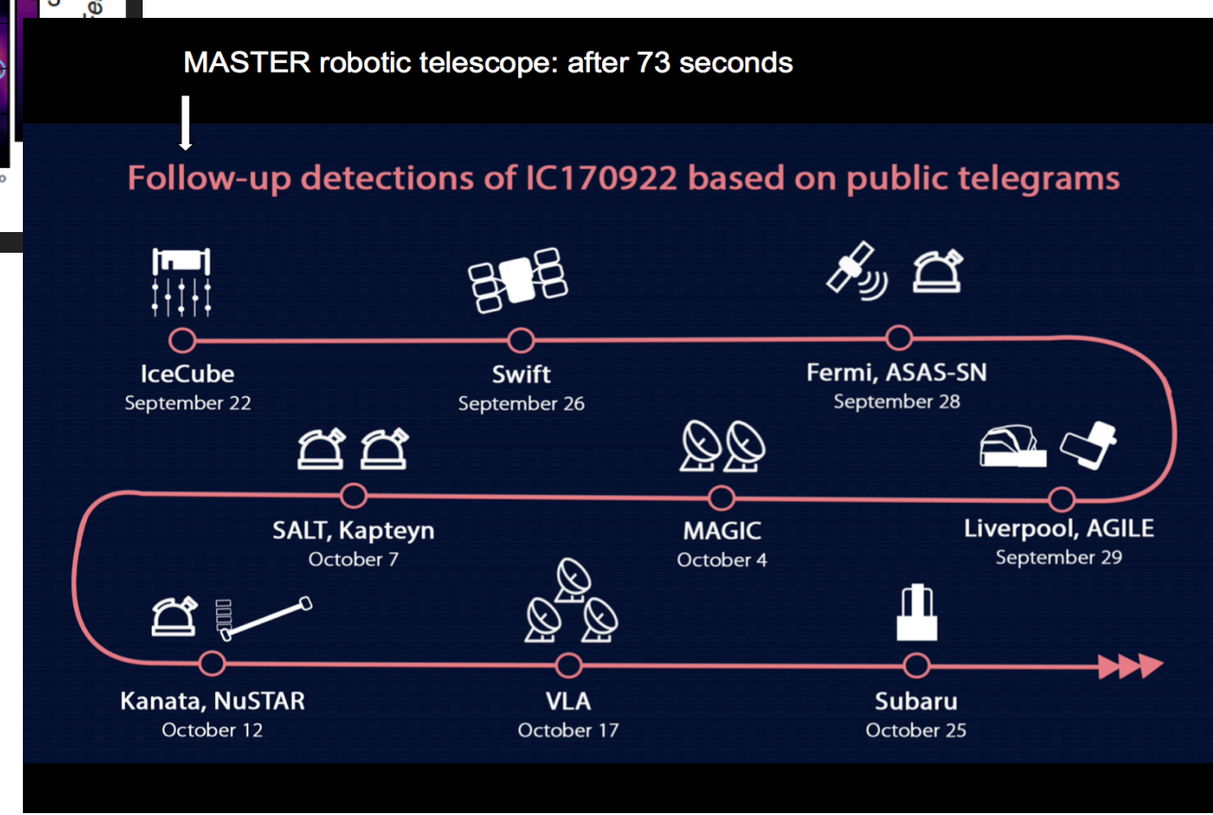
TXS 0506+056: a flaring blazar



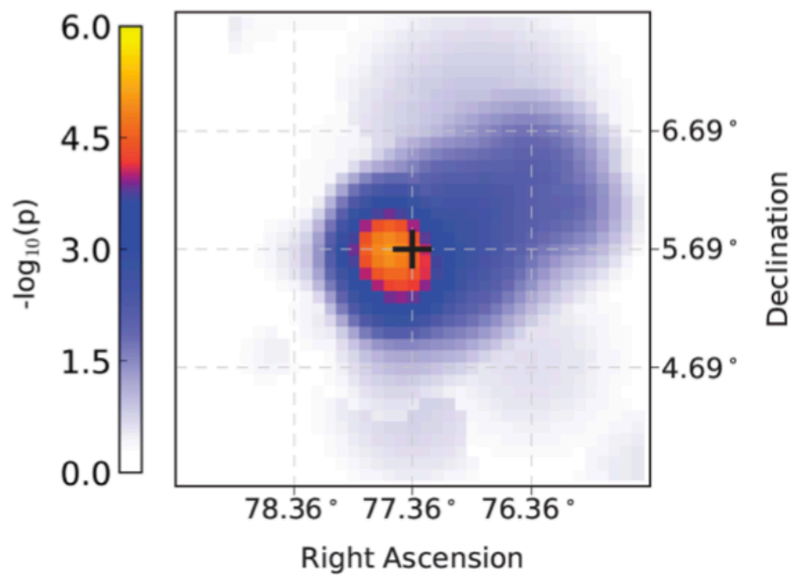
IceCube Coll. et al., Science 361 (2018) eaat1378

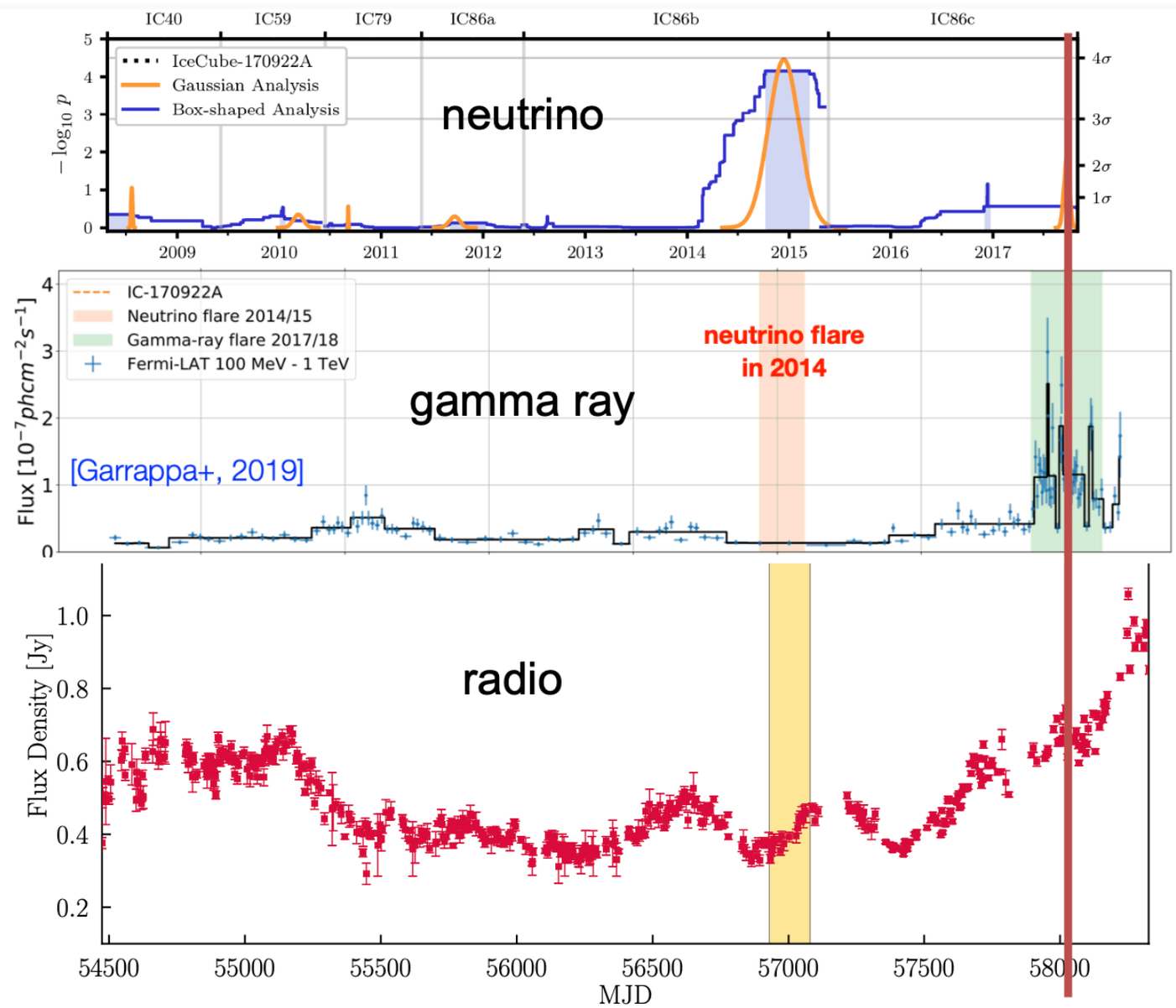
A follow up campaign was performed starting from IC public alert, allowing the identification of the source redshift **z=0.33**

GCN 21916



TXS 0506+056: a 3σ excess in arxival search





- **13±5** events in 110 days (ν flare in 2014-2015);
- energy range 68% CL: **32 TeV - 3.6 PeV**;
- coincidence probability (**post-trial**): p-value ~2×10^{-4} (~**3.5σ**)
- neutrino spectrum $\mathbf{E^{-2.2}}$
- $\mathbf{L_\nu > 10^{47}}$ **erg/s**

KM3NeT at a glance

Main detector elements:

- Digital Optical Modules (DOMs)
- Detection Units (DUs)
- Seafloor network: Junction Boxes (JBs) and electro-optical cables

DOM:

17” glass sphere containing:
31x3” PMTs
LED and Piezo
Front end electronics

- Uniform coverage
- Directional information
- Digital photon counting
- All data to shore

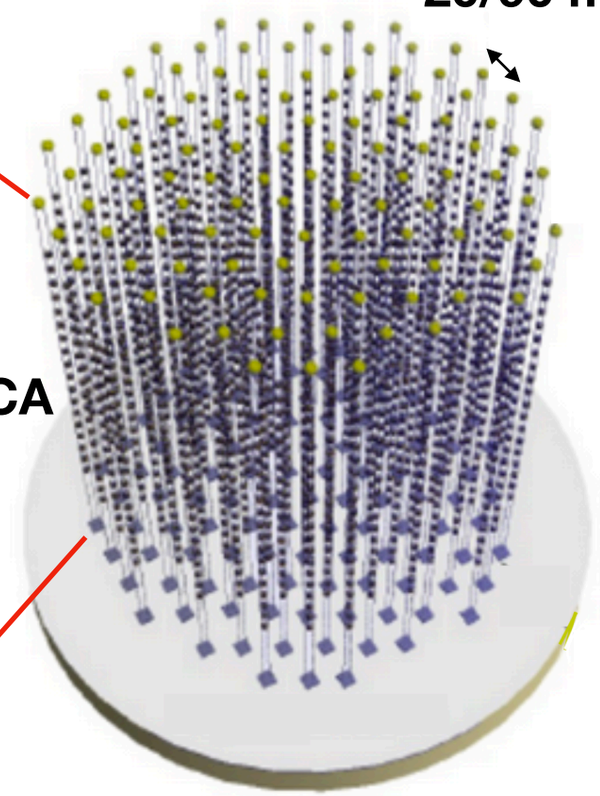
DOM

ORCA/ARCA
~200/700 m

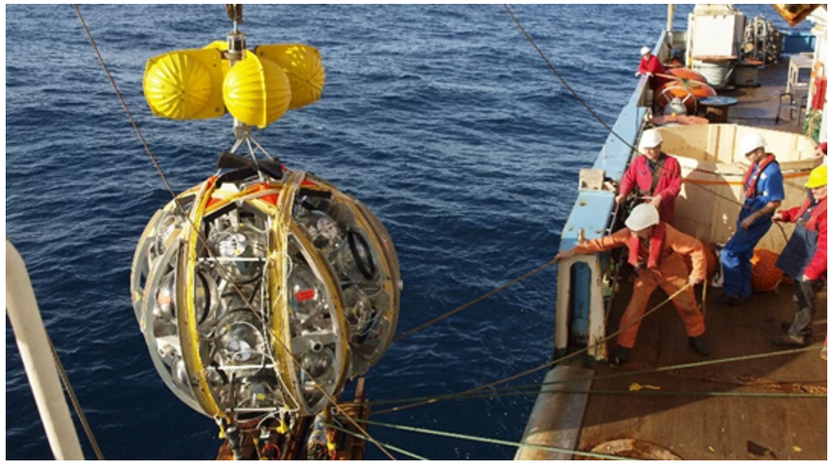
ORCA/ARCA
~9/36 m

DU
18 DOMs/DU

ORCA/ARCA
~20/90 m



BUILDING BLOCK
115 DUs/building block



LOM

KM3NeT at a glance

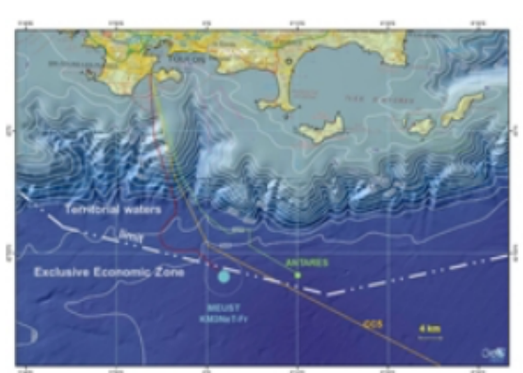
ARCA (1 GTon)

Astroparticle Research
with Cosmics in the Abyss

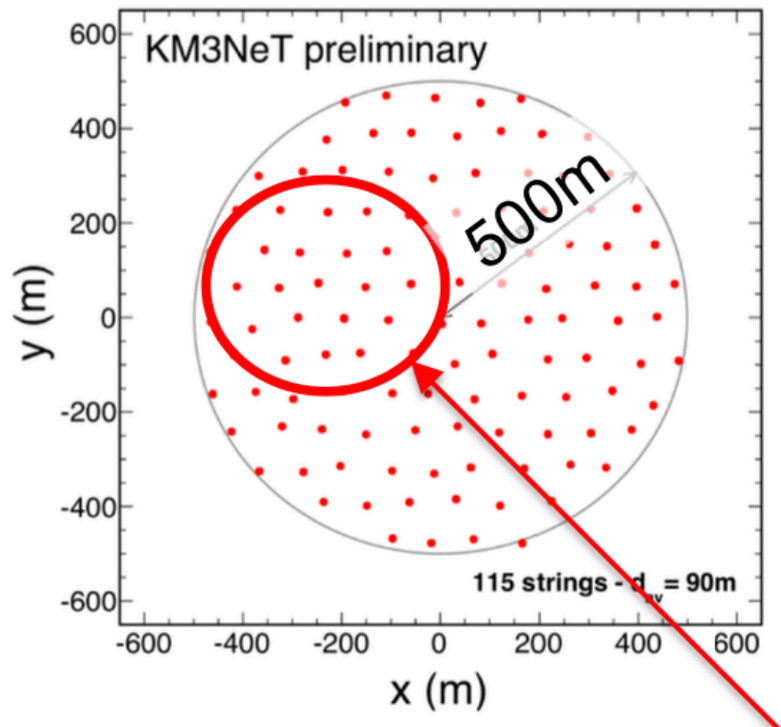
3500 m depth,
offshore Sicily

ORCA (6 MTon)

Oscillation Research
with Cosmics in the Abyss



2500 m depth,
offshore Toulon



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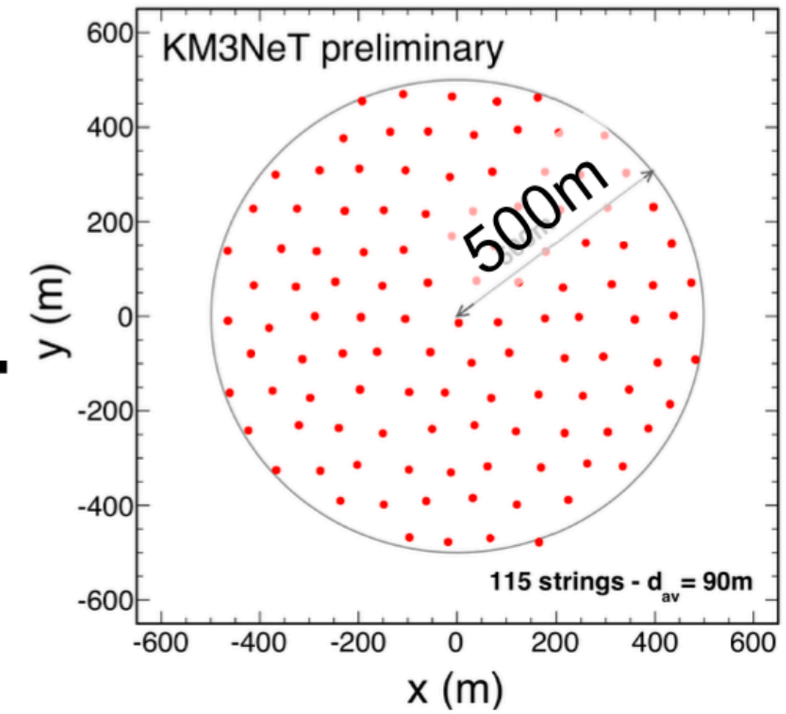
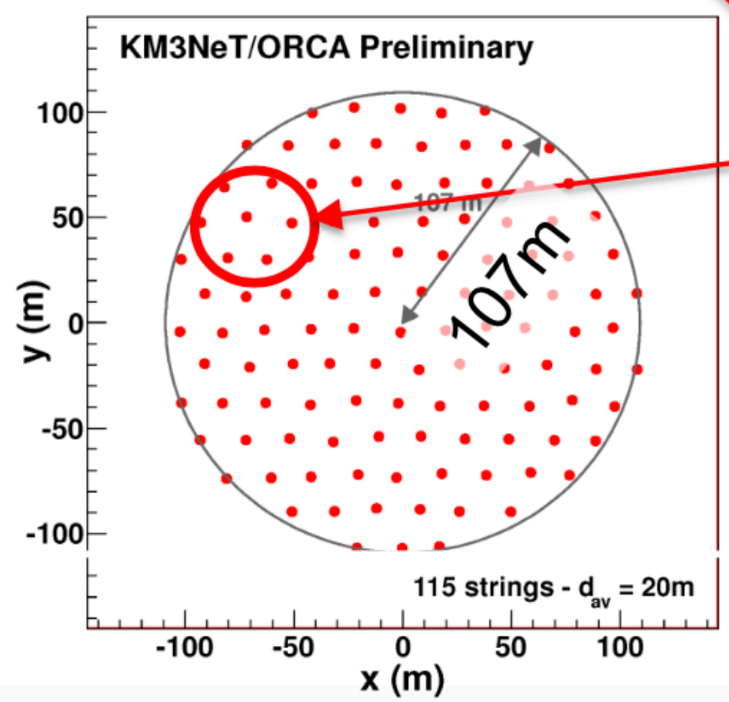
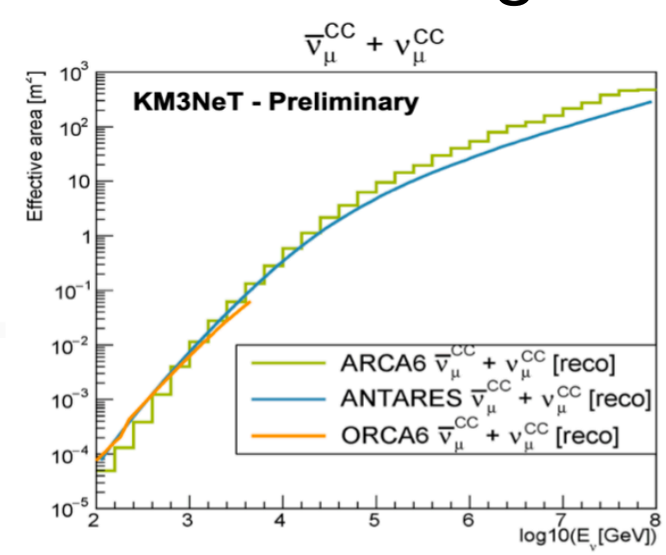




Phase 1 (fully funded)

Phase 2 partially funded

Phase 3 six building blocks



KM3NeT Coll., JPGNPP 43 (2016)

Production is ongoing

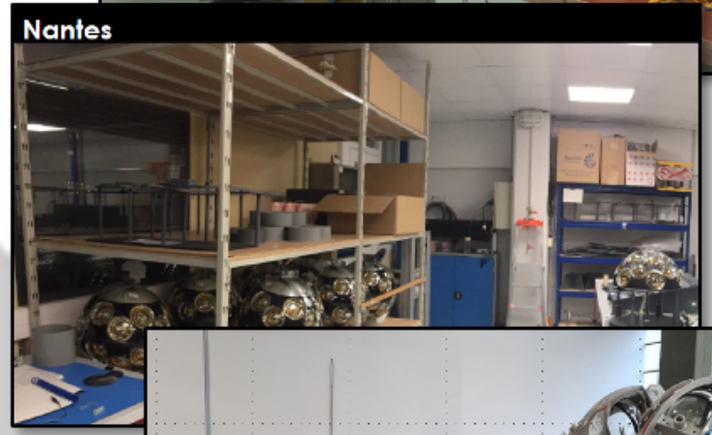
Amsterdam

Erlangen

Athens

Caserta

Nantes



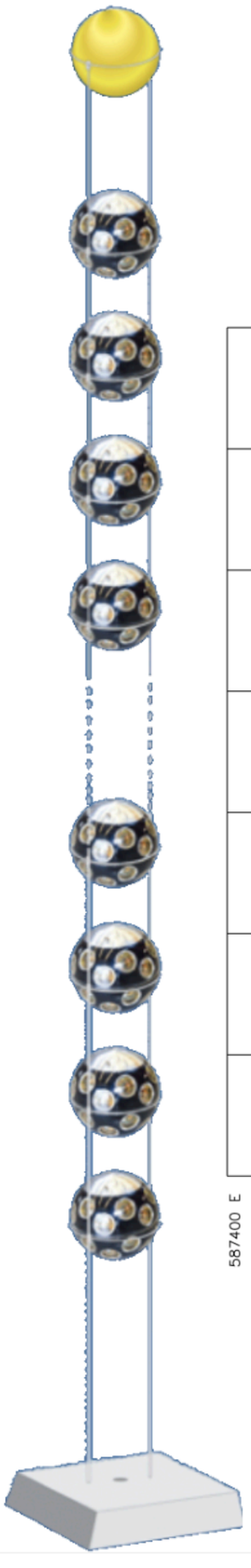
Genova

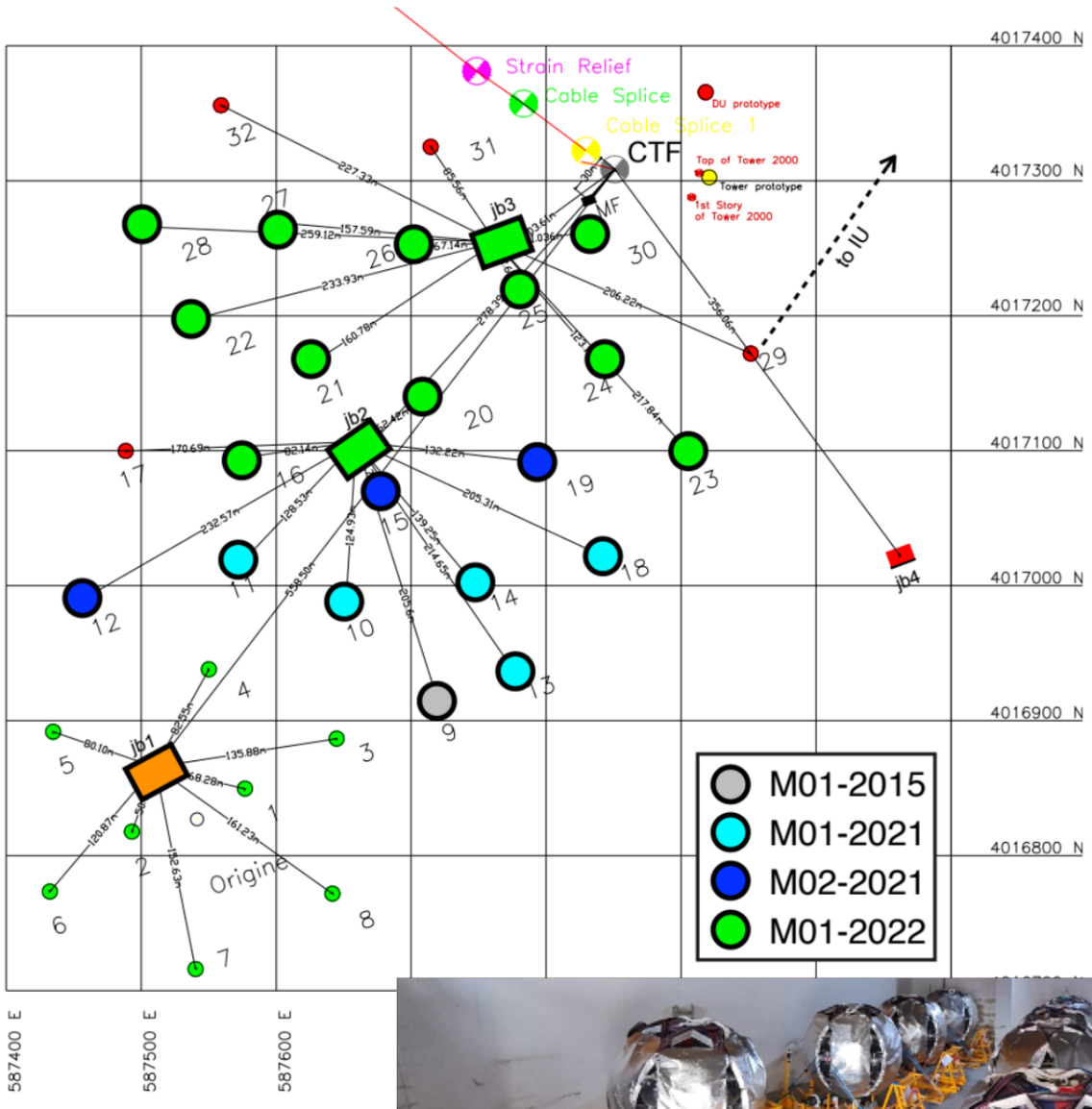
Bologna

Catania

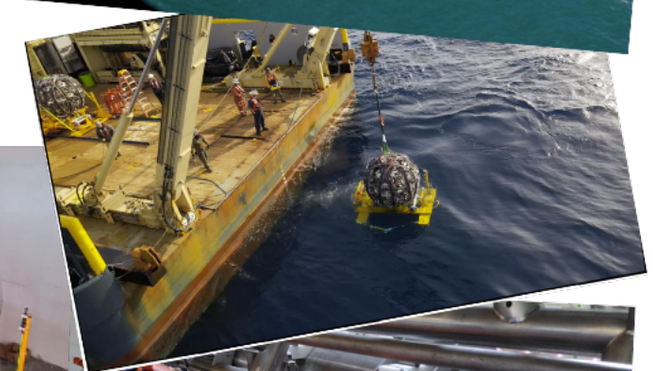
A. Girardi
R. Lunadei

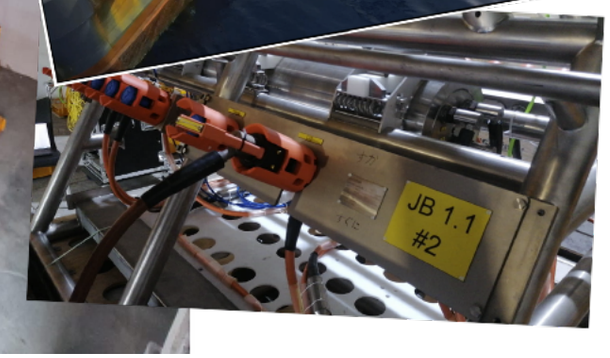
KM3NeT/ARCA: the current sea-bed infrastructure



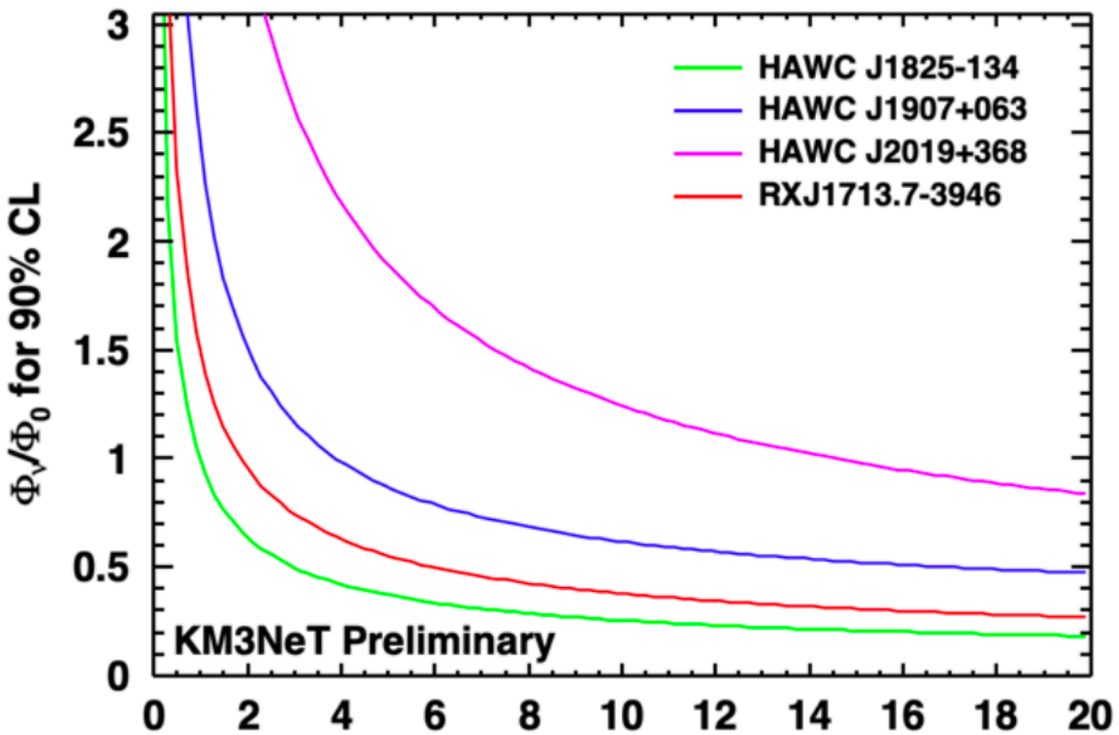


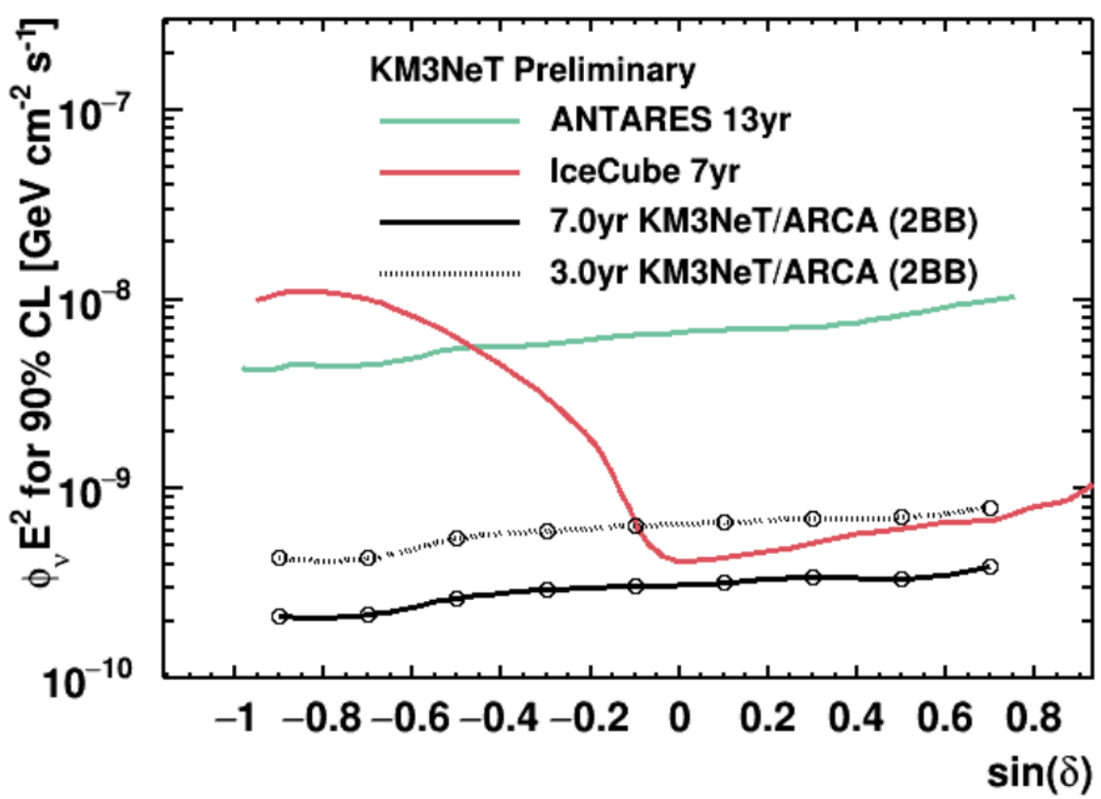
- Jan 2022: **ARCA9**, **ORCA10**;
- Jun 2022: **ongoing** sea campaign @ **ARCA** site (11 DUs + 2 JBs) ⟶ by the end of operations **20 DUs**, corresponding to ~x4 ANTARES;
- Further deployments planned by the end of the 2022 in both sites.





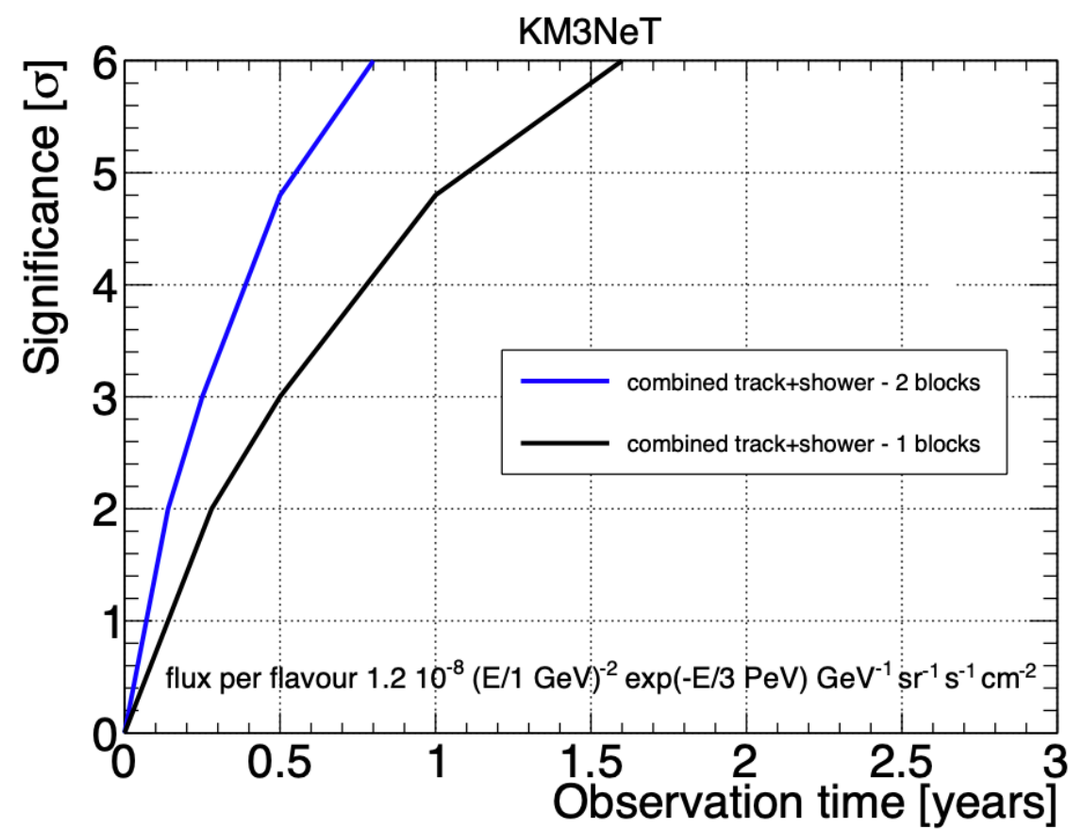
KM3NeT perspectives: Galactic sources & cosmic diffuse ν





Investigation of neutrino emissions from Galactic sources in few years

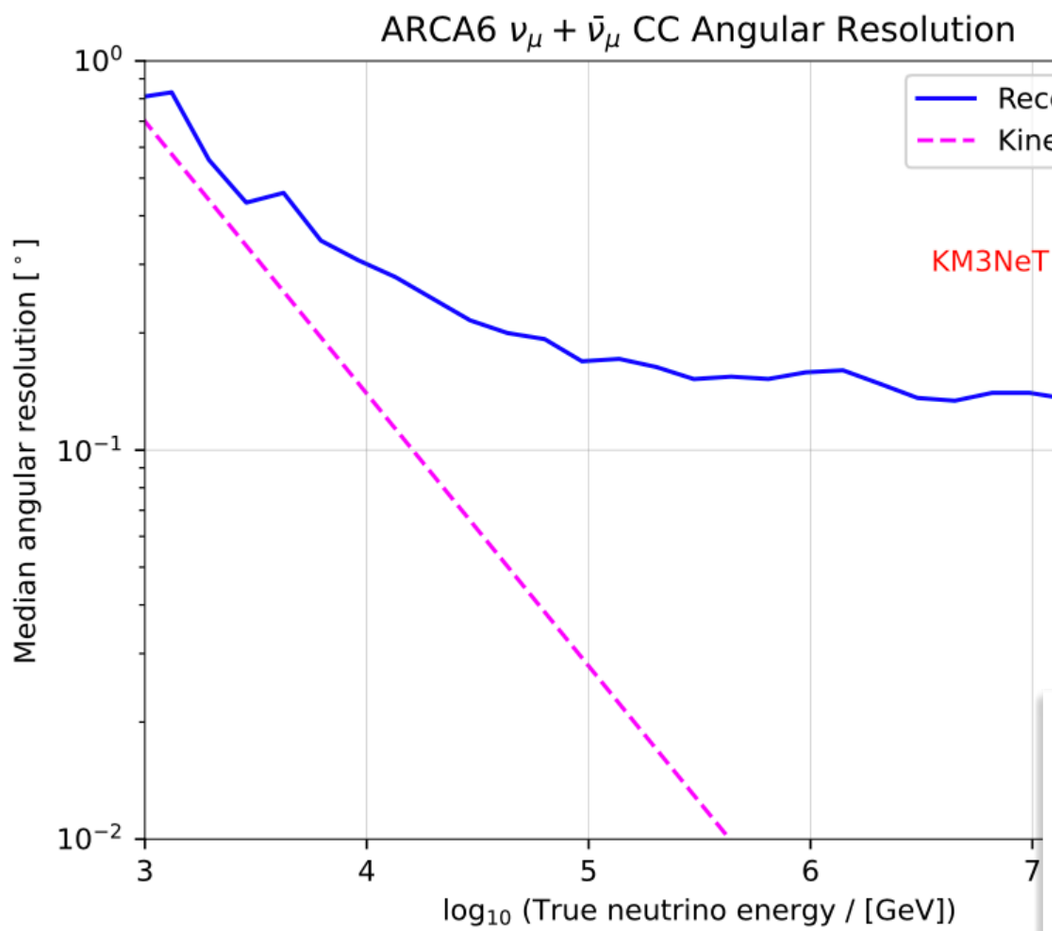
KM3NeT Coll., PoS (ICRC2021) 1077

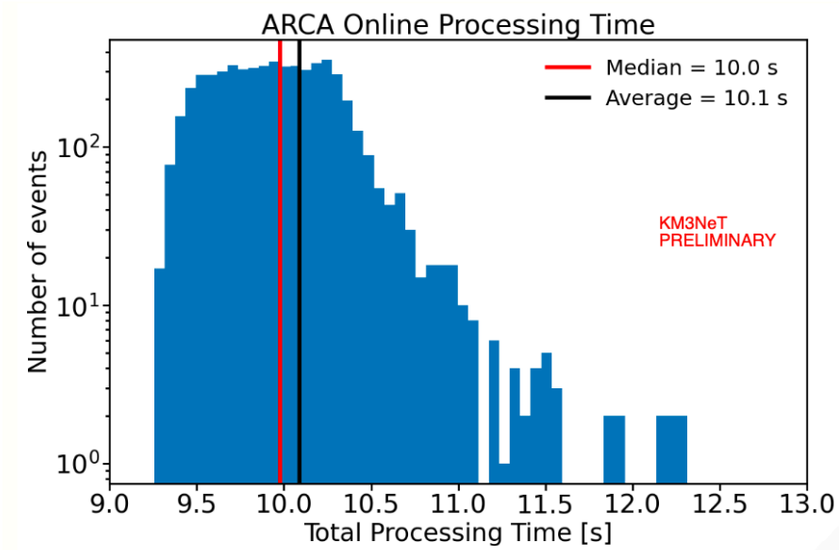


5σ detection in ~1 year with 1 building block

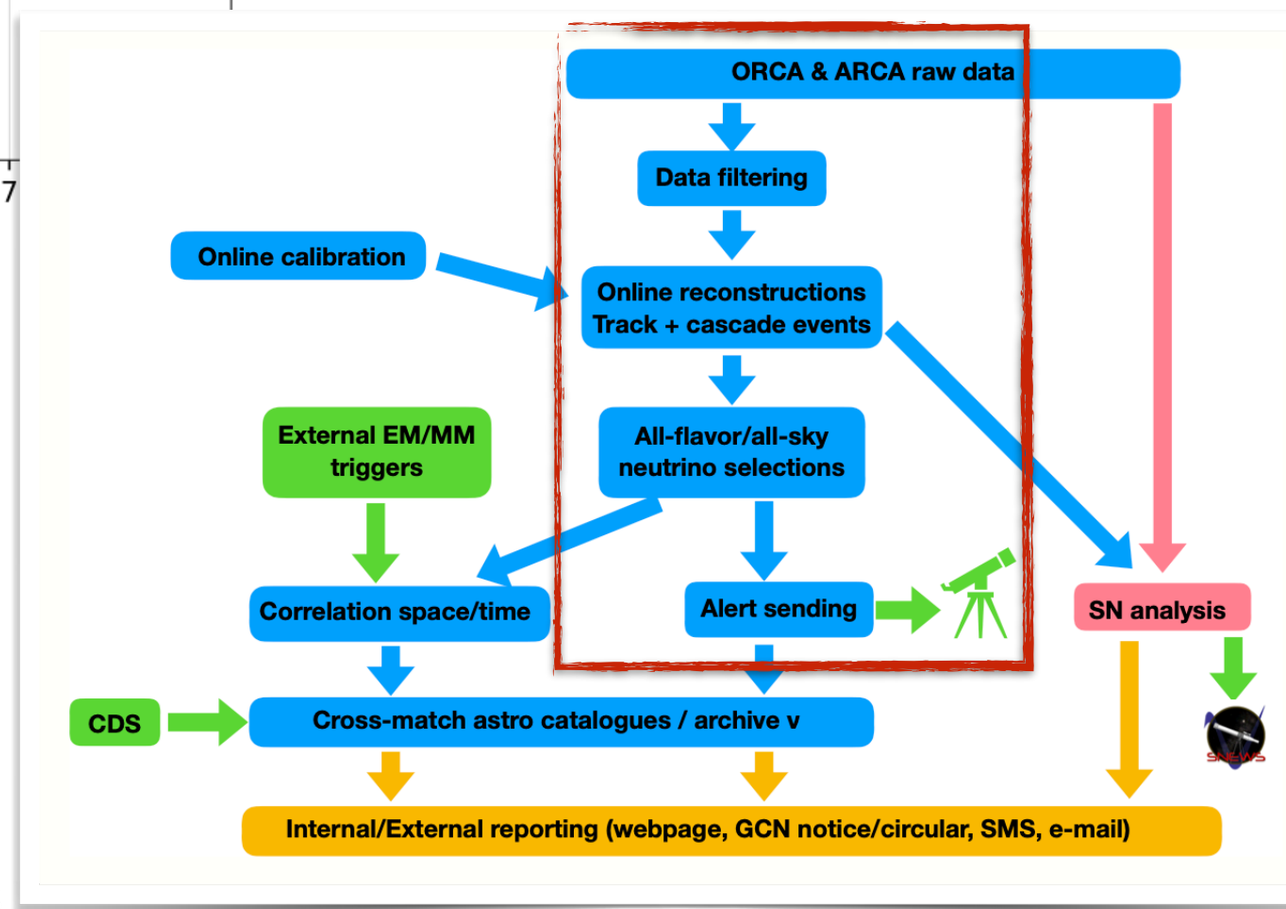
KM3NeT Coll., VLVnT-2021 proceedings, JINST

The KM3NeT real time alert system





KM3NeT Coll., Neutrino 2022



Contributions of the Roma group: people & activities

STAFF

- I. Di Palma (PA) ⟶ **KM3NeT/LIGO-Virgo** correlation analysis + KM3NeT **acoustic calibration**;
- A. Capone (senior INFN associated)
- F. Ameli (INFN) ⟶ Design and implementation of **DAQ & JB electronics**;
- C. Nicolau (INFN) ⟶ Design of **power distribution on JB and DU bases**;

SEZIONE DI ROMA - TECHNICAL STAFF CONTRIBUTION

- A. Girardi, R. Lunadei ⟶ **DU integration**;

RESEARCHERS

- S. Celli (RTDA) ⟶ Design and implementation of **KM3NeT/ARCA real-time alert system** + real-time **track-like** event reconstruction;
- M. Mastrodicasa (postdoc) ⟶ KM3NeT/ARCA real-time **shower-like** event reconstruction and **alert system monitoring**;
- S. Campion (postdoc) ⟶ **ANTARES/KM3NeT/LHAASO** correlation analysis;

STUDENTS

- A. Zegarelli (PhD) ⟶ GeV to multi-PeV **GRB-ν emissions** with ANTARES/KM3NeT + KM3NeT **DU calibration;**
- F. Carenini (Masters) ⟶ Sensitivity of KM3NeT/ARCA to **transient sources**;
- S. Gagliardini (Masters) ⟶ Neutrinos from **TeV emitting GRBs**;
- R. De Troia (Masters) ⟶ Neutrinos from **GRB afterglow**;
- T. Pernice (Masters) ⟶ **Galactic Plane neutrinos** with KM3NeT.