

Highlights from IceCube & KM3NeT

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on behalf of the IceCube and KM3NeT - IIHE group

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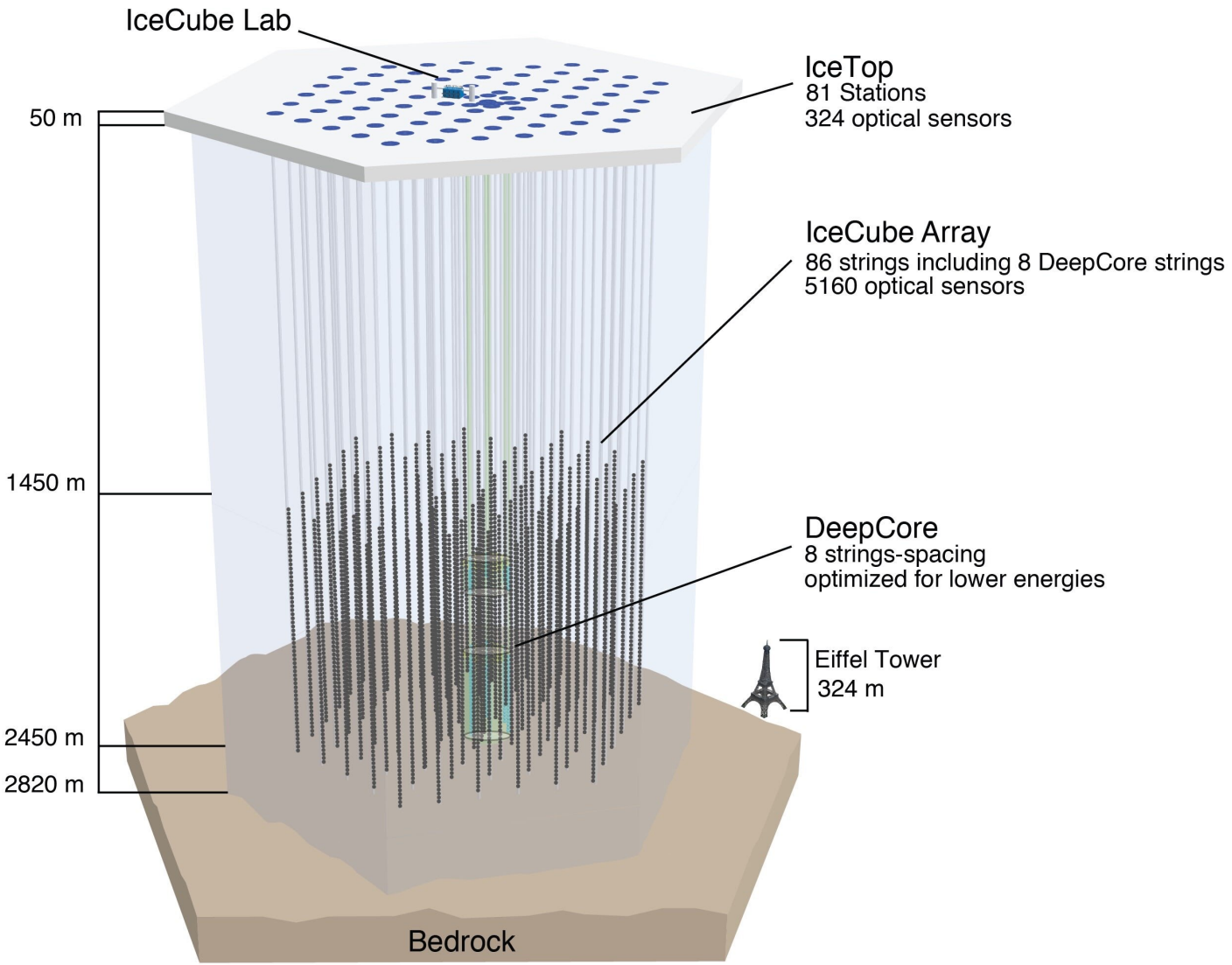

Else


Louise


Thomas


Eliot

IceCube Neutrino Observatory





1 km^3 of clear ice at the South Pole

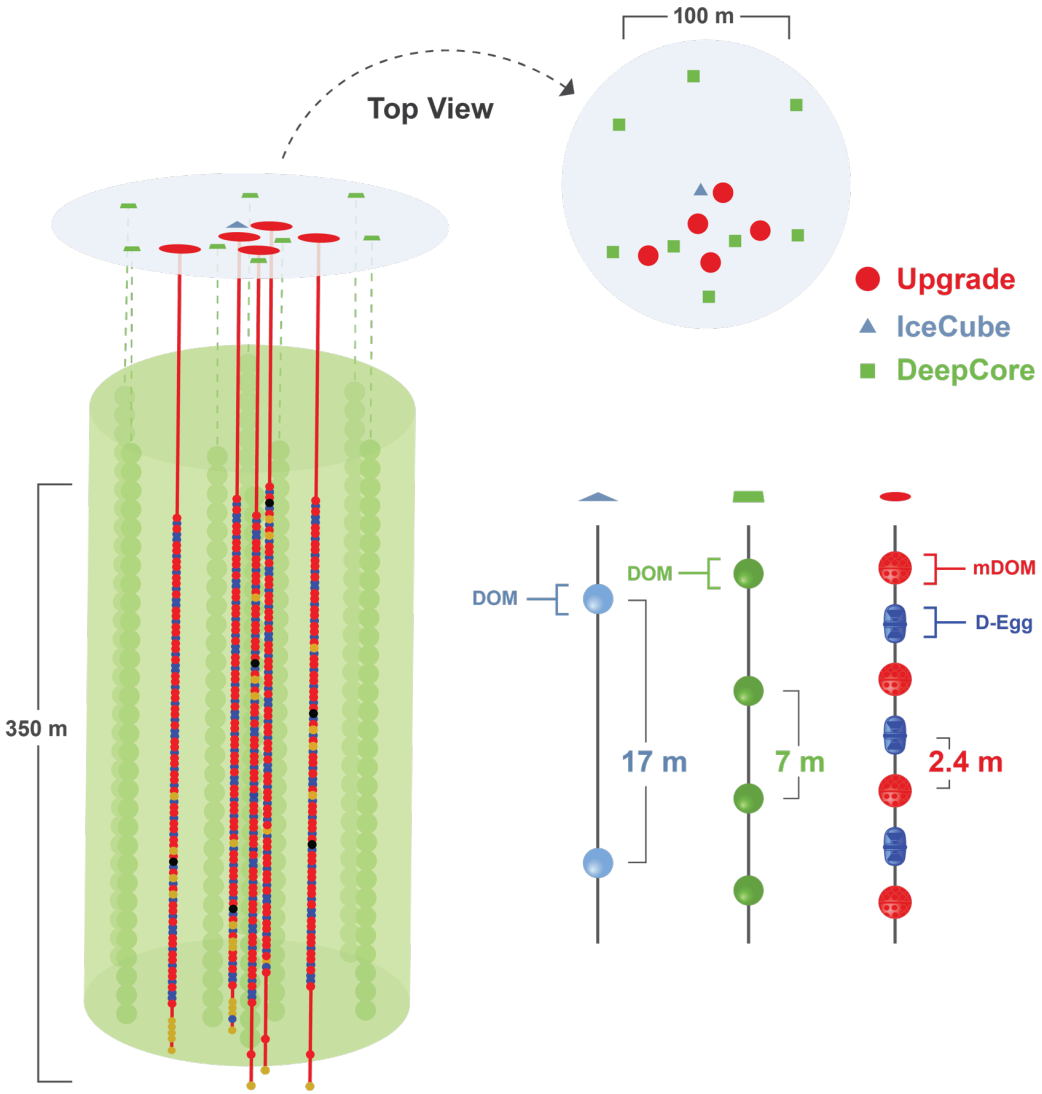


5160 Cherenkov light sensors

Extensive physics program:

- Neutrino astronomy
- Neutrino oscillations
- Beyond Standard Model physics
- Cosmic rays
- …

IceCube Upgrade





Drilling ice again after 15 years.

5 new strings successfully installed by February 2026.

505 **new modules**:

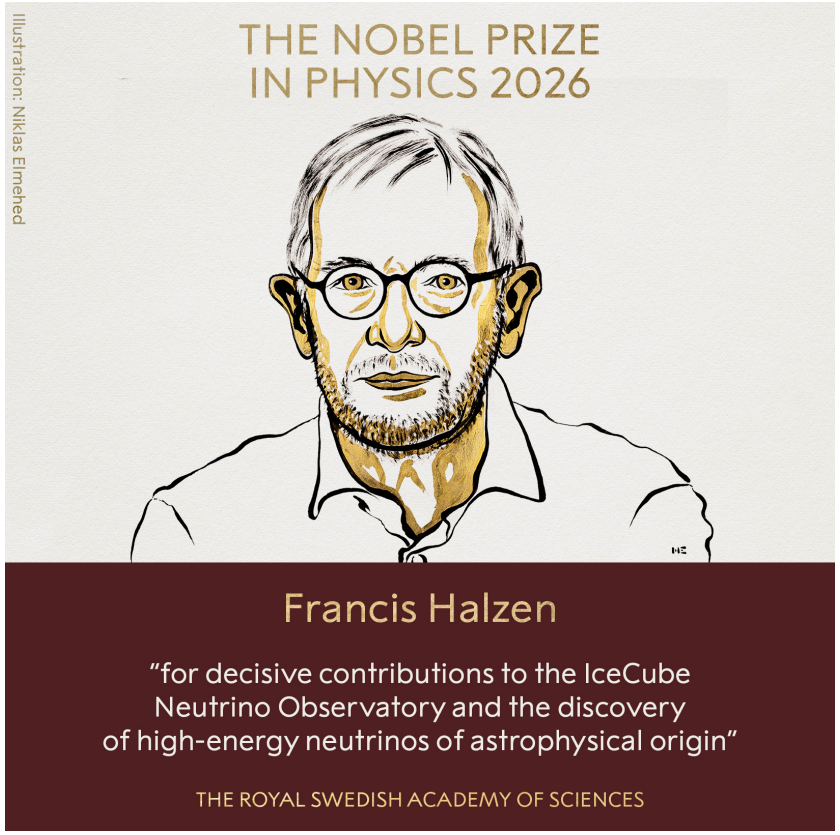
- 288 mDOMs
- 200 D-Eggs
- Other designs
- New calibration devices



Science impact:

- Improved sensitivity to low-energy studies
- Improved detector calibration

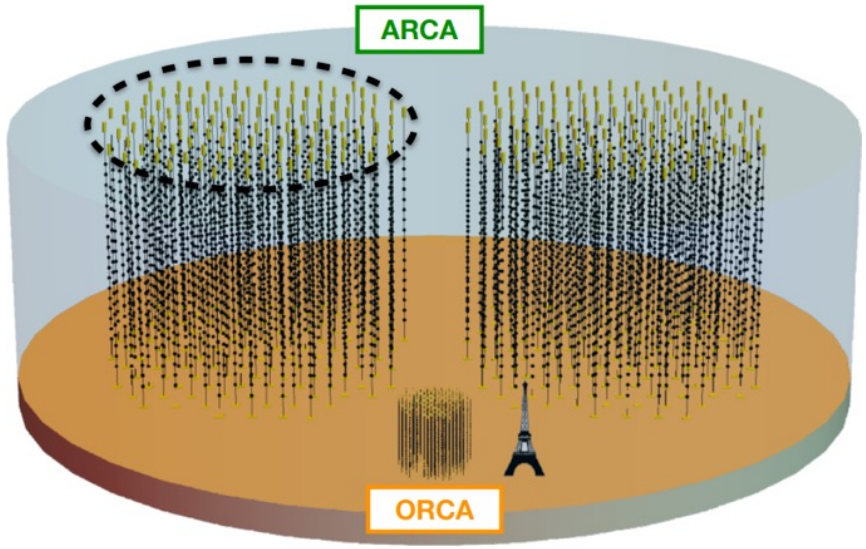
Nobel Prize in Physics 2026



IIHE (ULB/VUB) joined the AMANDA/IceCube experiment in 1998. It contributed to the construction of the IceCube detector and continues to play a key role in its scientific program. [iihe.ac.be]

KM3NeT





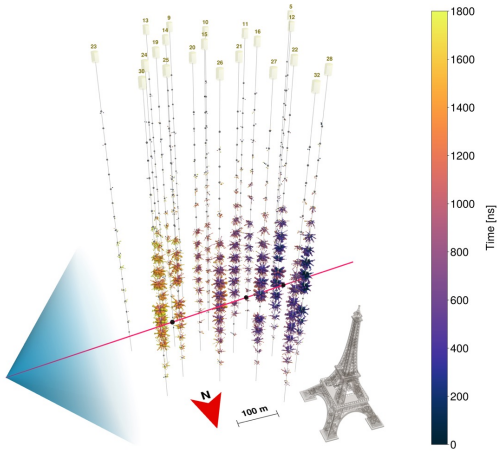
Deep-sea neutrino telescope in the Northern Hemisphere.

Ongoing deployment, completion foreseen by ~2030.

ARCA:
- 100 km from Sicily's coast
- 62/198 lines installed
- High-energy neutrino astronomy

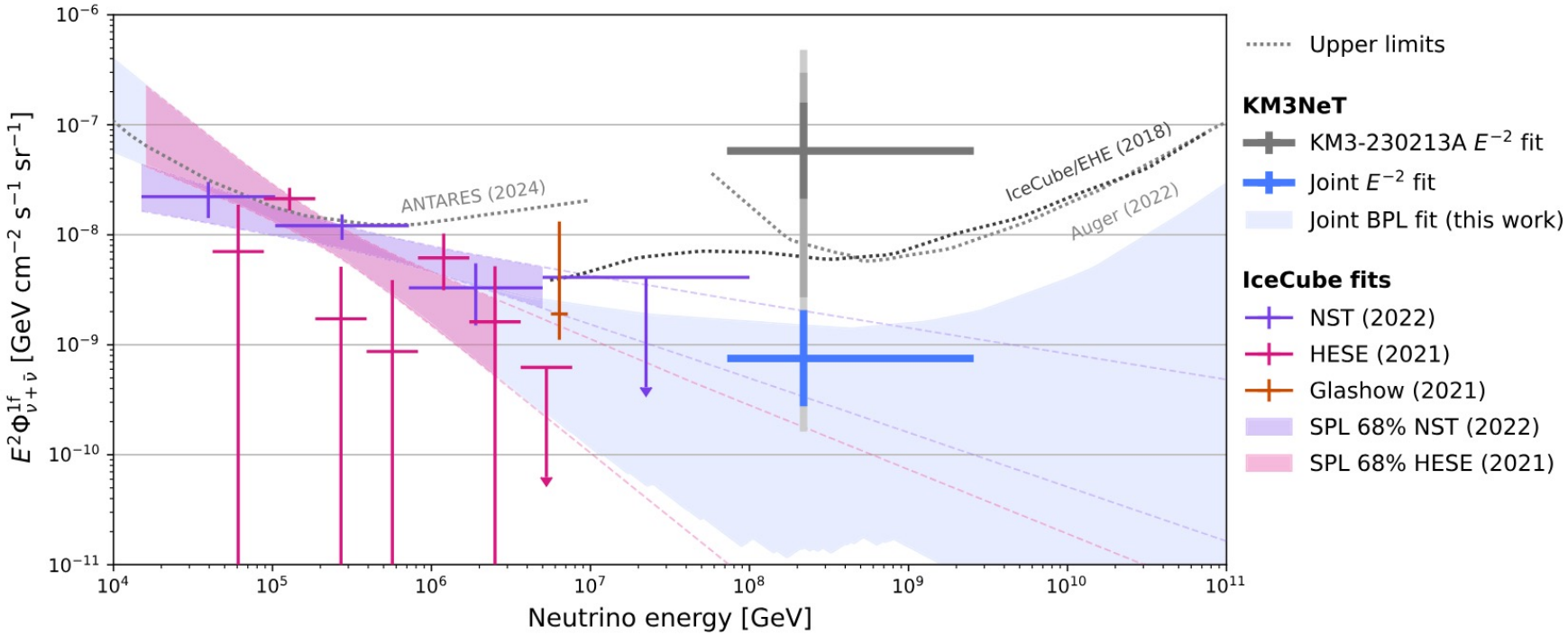
ORCA:
- 40 km from Toulon, France
- 44/108 lines installed
- Neutrino oscillations

The Highest-Energy Cosmic Neutrino

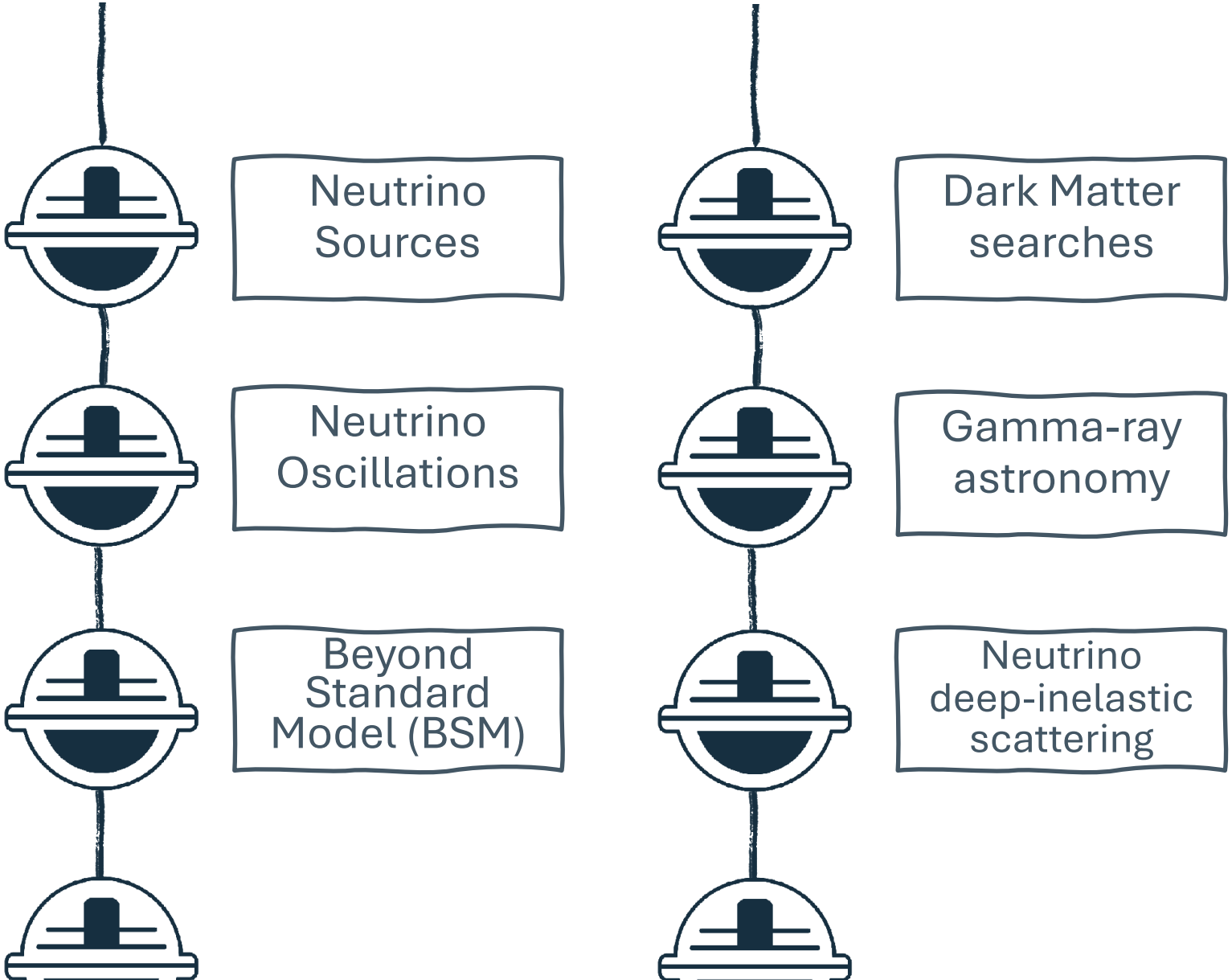


KM3-230213A: estimated $E_\nu \sim 220$ PeV

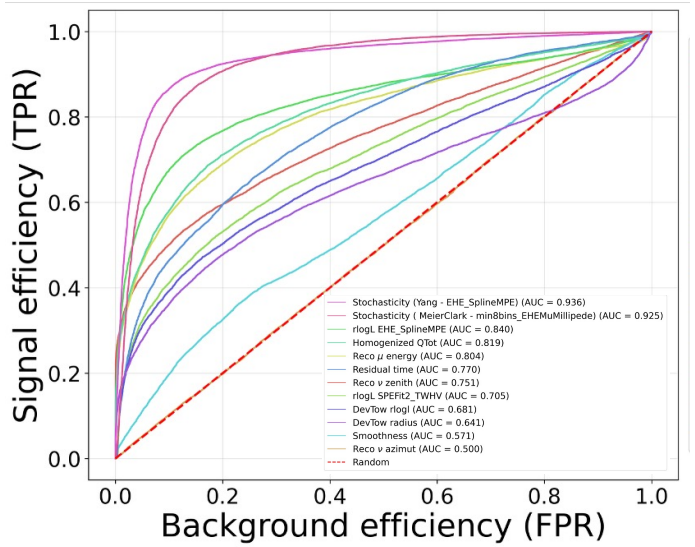
ARCA had 21 operational lines at the time. KM3NeT flux is in tension with limits from IceCube and Auger.

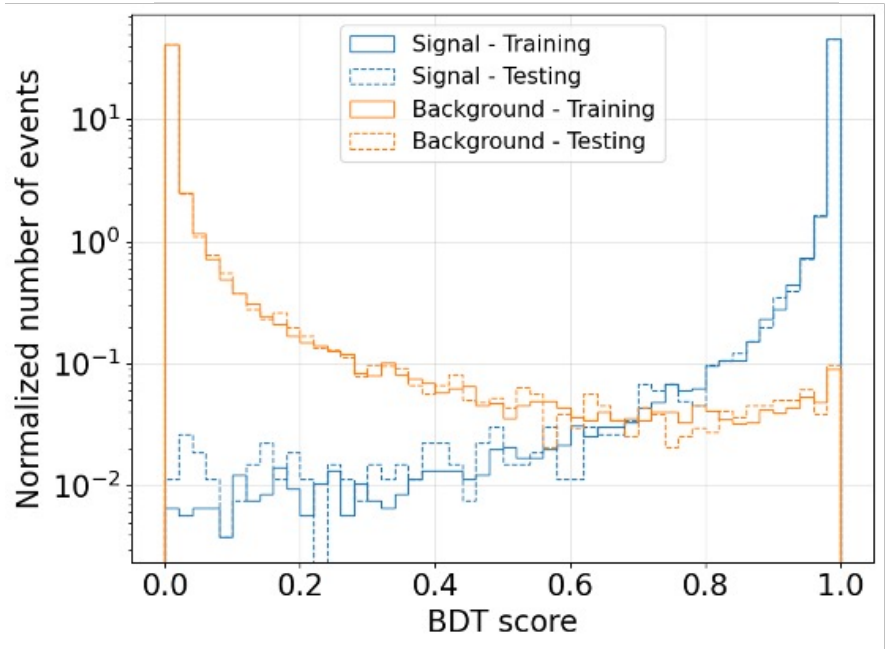


IIHE analyses



Extremely high-energy neutrinos







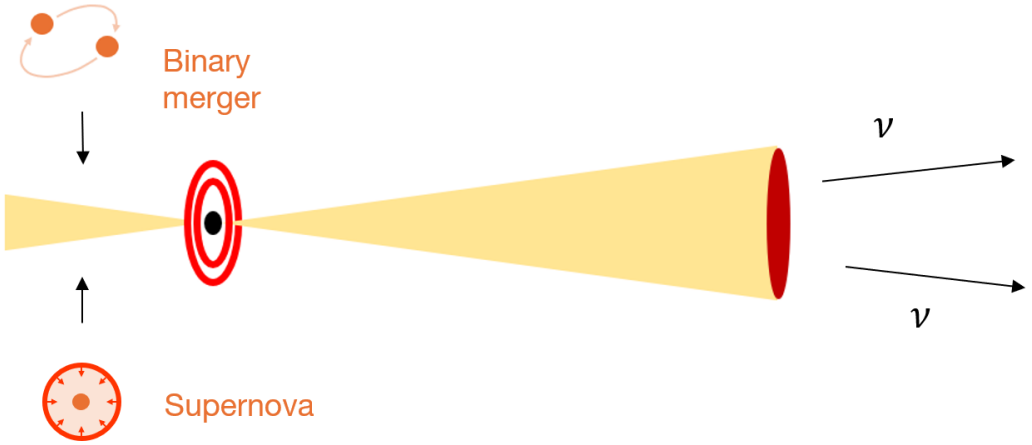
Earth is opaque to neutrinos of E > 1 PeV.

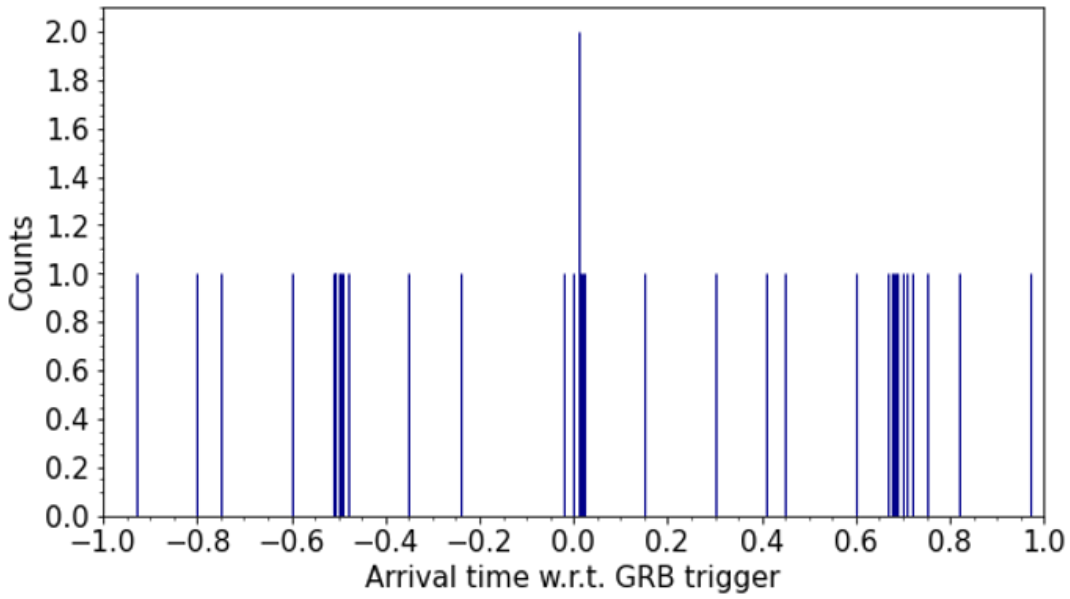
Down-going events: how to discriminate signal from cosmic rays?
Separate single muons from bundles.

Ongoing work:
- Identify discriminating features such as track stochasticity and time residuals
- Use ML classifiers

Goal: improve sensitivity to extremely high-energy neutrinos.

Gamma-ray bursts







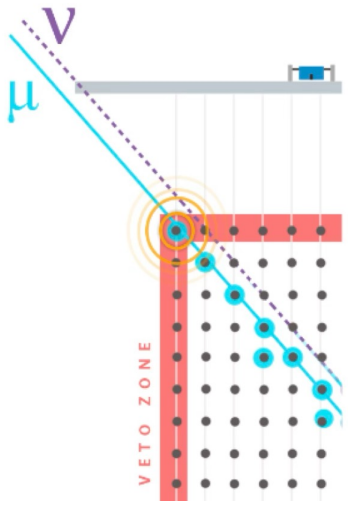
Gamma-ray bursts (GRBs) are ideal **candidates for high-energy neutrino sources**.
No coincidence between a GRB and a high-energy neutrino observed yet.

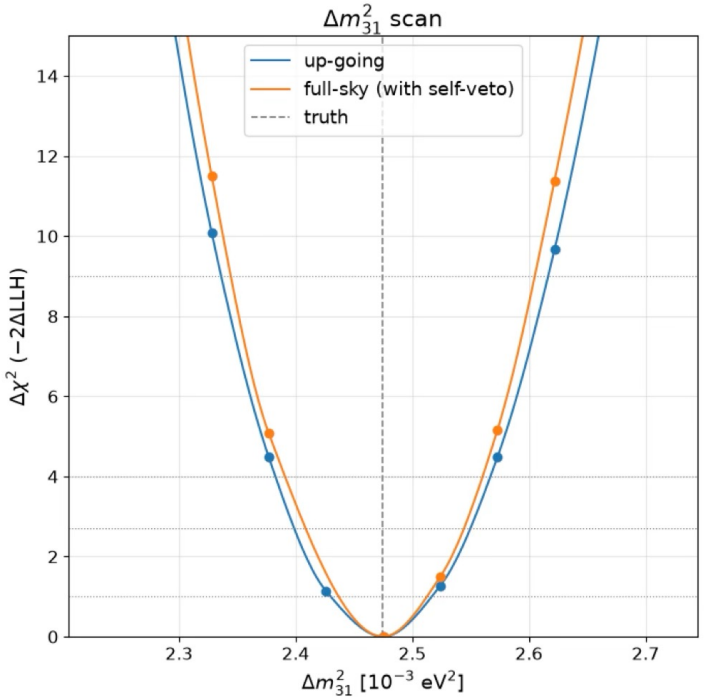
Ongoing work:

- Bayesian analysis, stacking time intervals between neutrino arrival times
- Performance studies on simulated dataset

Goal: perform search using IceCube alerts catalog.

Neutrino oscillations and self-veto effects





Neutrino oscillation studies are usually done using up-going events.

Down-going events can serve as a control sample for systematics and BSM searches, such as sterile neutrinos.

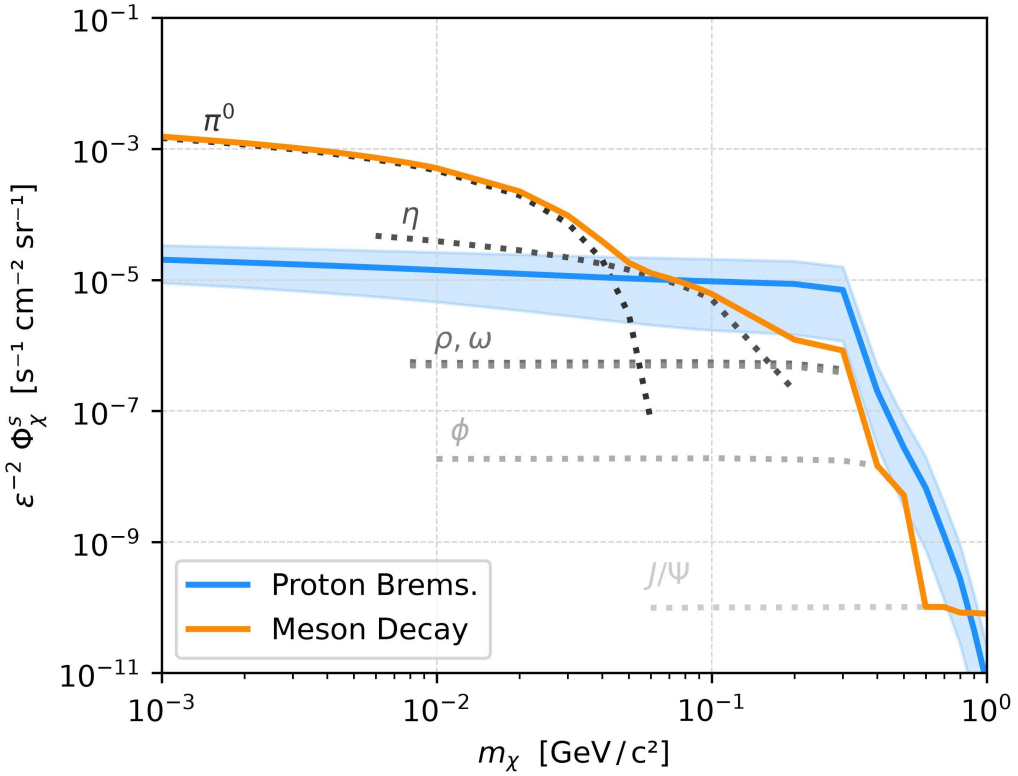
Ongoing work:

- Model effect of self-veto on neutrinos from the accompanying muon
- Sensitivity to oscillation parameters

Goal: study neutrino oscillations using a full-sky dataset.

BSM: millicharged particles





Millicharged particles could be produced in the atmosphere.

$$q_\chi = \epsilon e, \epsilon \ll 1$$

Signature: **long, faint tracks**.

Ongoing work:

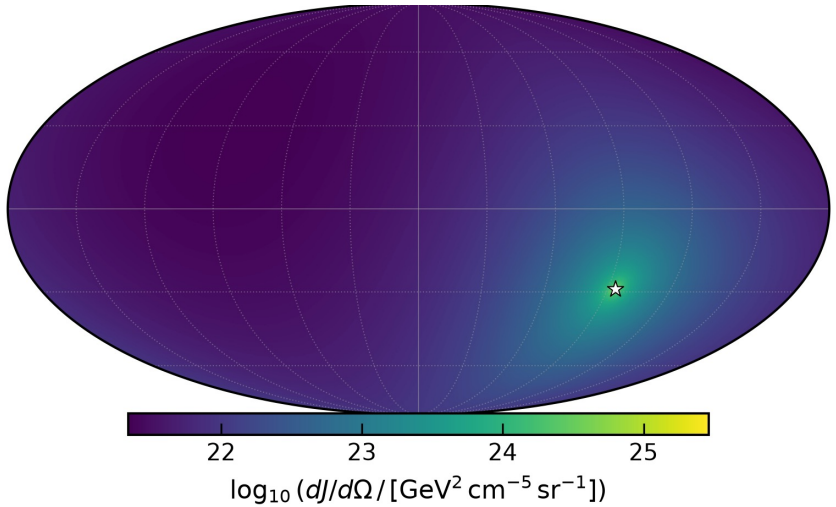
- Dedicated IceCube Upgrade trigger
- Simulation framework in collaboration with milliQan

Goal: constrain mass and charge.

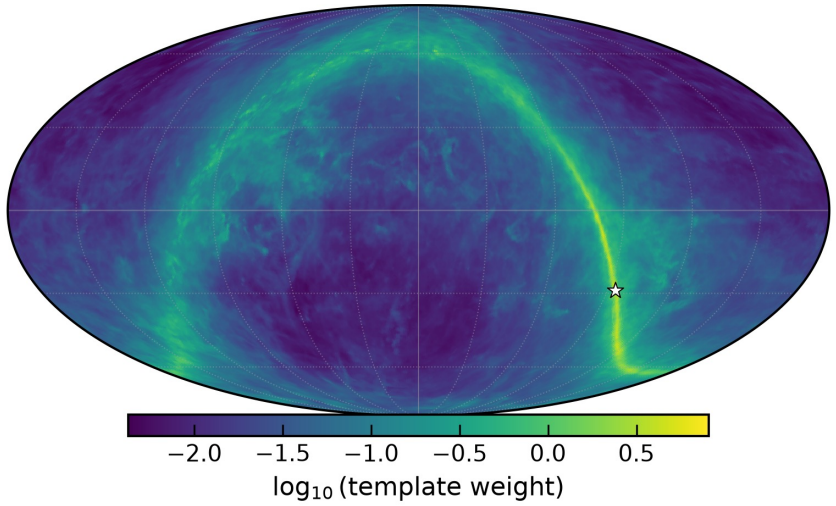
BSM: Galactic Center dark matter



DM annihilation template (NFW)



Galactic neutrino emission template



Dark matter (DM) annihilation in the Galactic halo can produce a neutrino signal, peaking at the **Galactic center**.

Overlap with the diffuse Galactic neutrino emission.

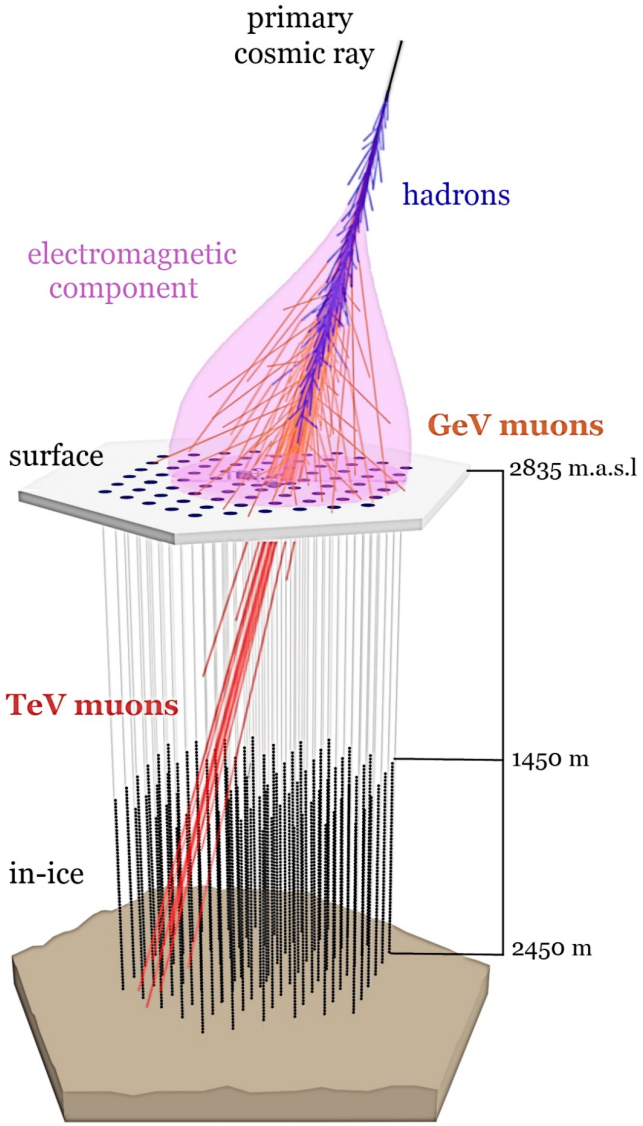
Ongoing work:

- Profiling of the Galactic neutrino emission
- Sensitivity to different DM channels

Goal: expand the search to additional DM masses and improve on previous IceCube limits.

PeV gamma-ray searches





LHAASO has detected **PeV gamma rays** for the first time.

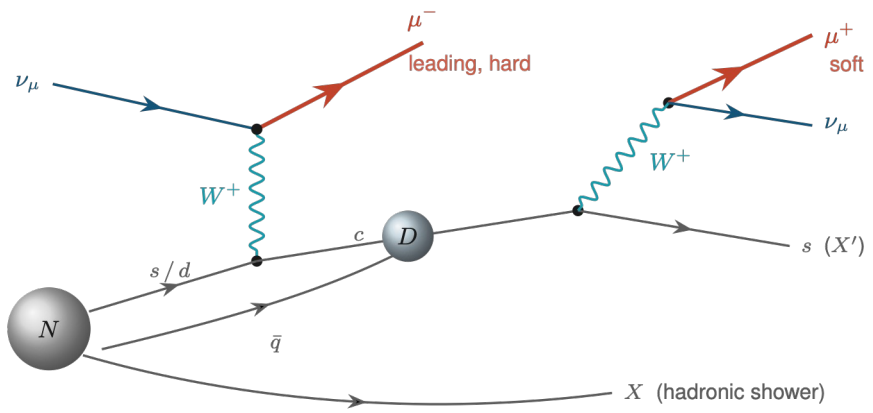
Separate gamma rays from cosmic rays with the air-shower muonic component.
IceCube: use **in-ice detector as veto**.

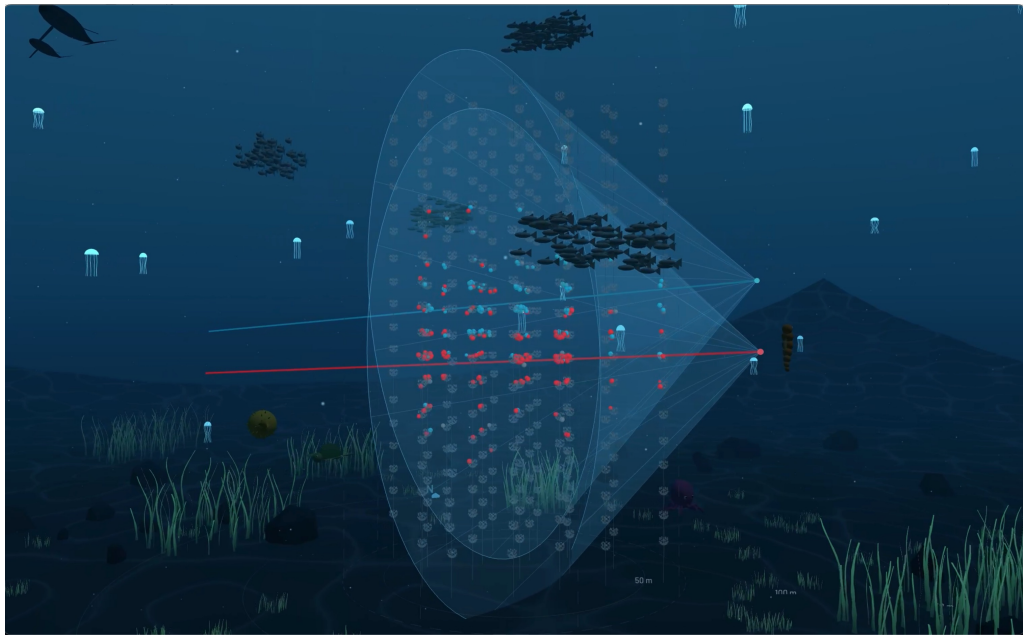
Ongoing work:
- Simulation production of multiple years
- Energy calibration for gamma-ray showers

Goal: search for diffuse PeV gamma-ray emission with 10+ year dataset.

Charm dimuons with KM3NeT







1% of ν_μ CC interactions produce a charm dimuon. Search with **ORCA-18**.

The two muons are nearly collinear, therefore hard to resolve.

Ongoing work:

- Likelihood test for track-like events with a second muon
- 7.6 years of ORCA-18 exposure needed for 3σ detection

Goal: perform a dimuon search with the expanding ORCA detector.

Conclusions

The past year was very eventful for IceCube!
The **Upgrade** installation and the **Nobel Prize** are major highlights.

The IceCube and KM3NeT group at IIHE is **involved in many analyses** covering a wide range of topics.

Fifteen years after its completion, IceCube is still delivering new results. With KM3NeT joining in, more discoveries are on the horizon!