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HUNT : An ultra-large-scale neutrino astronomy telescope

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Mainz, 15/09/2025

Outline

1, Motivation

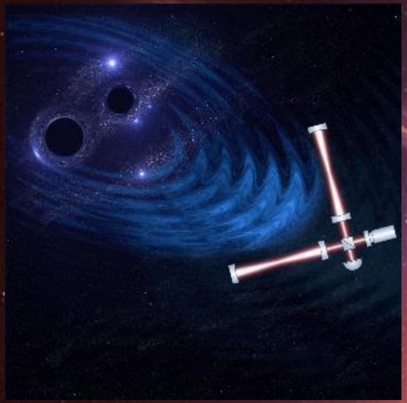
2, HUNT and its potential

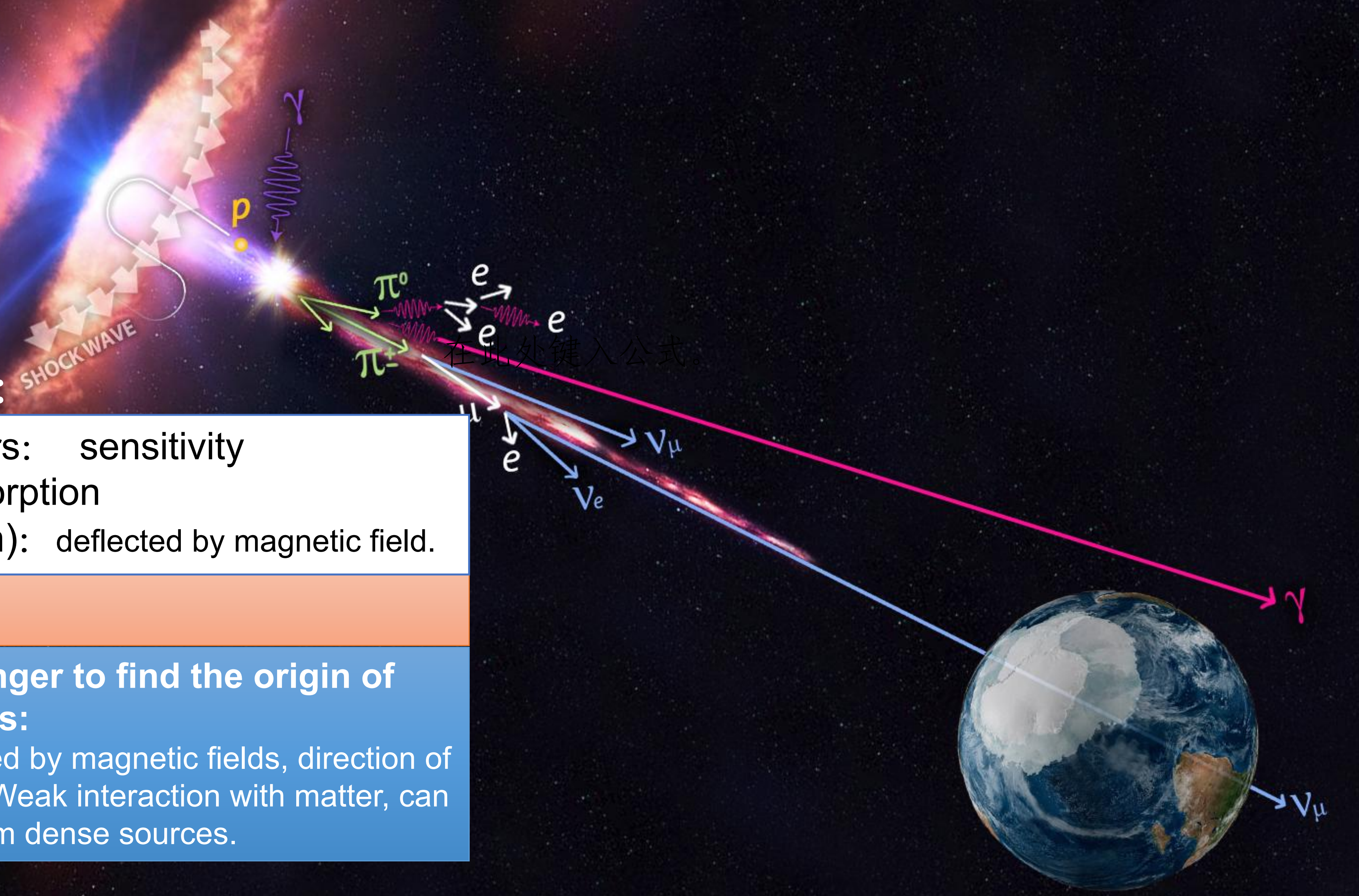
3, R&D of detector

4, Summary

Motivation

Multi-messenger astronomy





Four Messengers:

1. Gravitational wavers: sensitivity
2. **Gamma-ray**: absorption
3. **Cosmic ray**(proton): deflected by magnetic field.

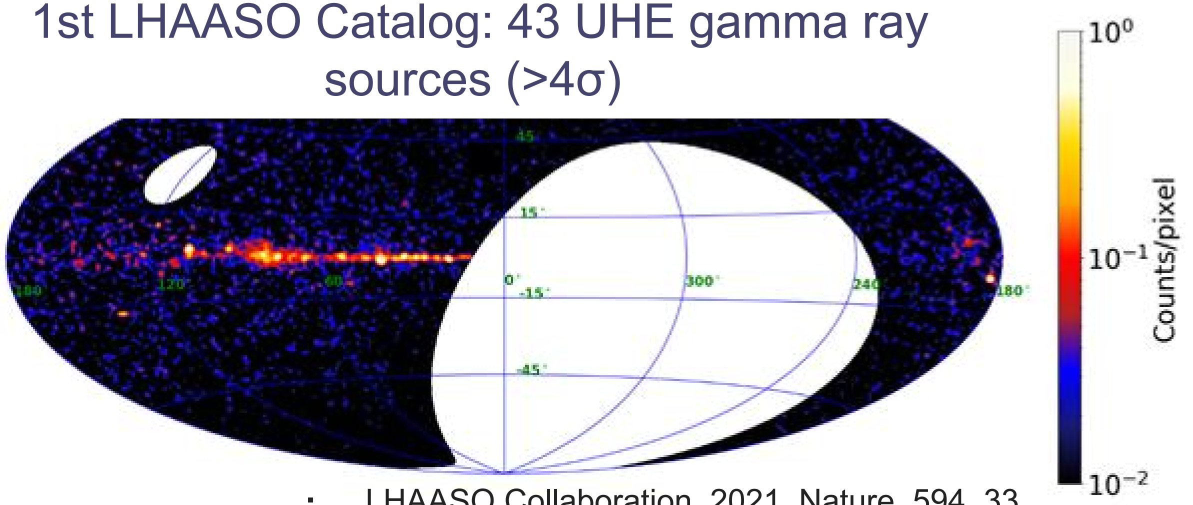
4. Neutrino

Almost the only messenger to find the origin of high-energy cosmic rays:

Electrically neutral, unaffected by magnetic fields, direction of arrival points to the source; Weak interaction with matter, can travel far, able to escape from dense sources.

LHAASO discovered UHE γ sources in the Milky Way

1st LHAASO Catalog: 43 UHE gamma ray sources (>4σ)



- LHAASO Collaboration, 2021, Nature, 594, 33.
- LHAASO Collaboration, 2024, ApJS, 271, 25.

Main process:

$$\mathbf{p} + p \longrightarrow N(\pi^+ + \pi^- + \pi^0) + X$$

$$p + \gamma \longrightarrow n + \pi^+$$

$$E_\gamma \approx 10\% E_p$$

$$E_\nu \approx 5\% E_p$$

$$\pi^+ \longrightarrow \nu_\mu + \mu^+ \longrightarrow \nu_\mu + (e^+ + \bar{\nu}_\mu + \nu_e)$$
$$\pi^- \longrightarrow \bar{\nu}_\mu + \mu^- \longrightarrow \bar{\nu}_\mu + (e^- + \nu_\mu + \bar{\nu}_e)$$
$$\pi^0 \longrightarrow 2\gamma$$

Two sources of PeV photons:

Leptonic origin -- Synchrotron radiation produced by relativistic electrons and inverse Compton scattering of low-energy photons. No neutrinos

Hadronic origin -- Interaction of PeV energy cosmic rays with source region matter or photon fields. a large number of neutrinos

Neutrino and Photon both measured, can point back to the source (**p**).

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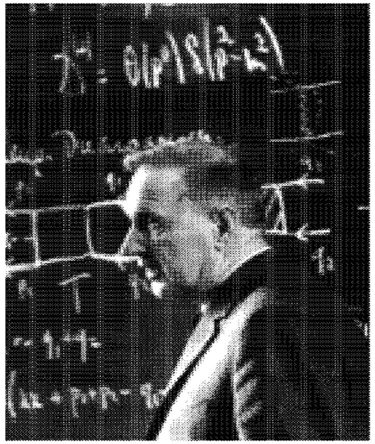
Solve the problem of the origin of high-energy cosmic rays!

Status of Neutrino Astronomy



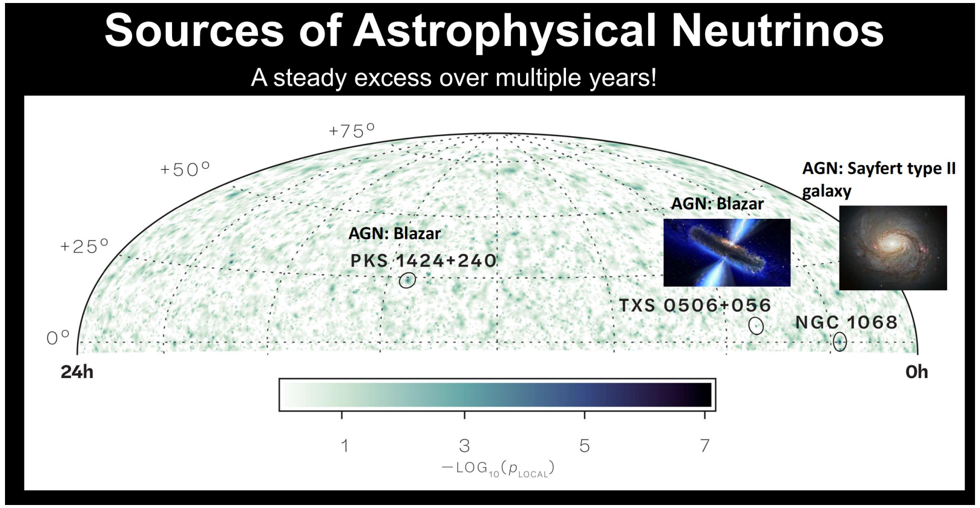
M.A. Markov, Seminar at JINR, Dubna in the middle of the 50th

1960:
deep underground and deep underwater detection of high-energy cosmic neutrinos were firstly suggested by **Moisey Markov.**

1998-2003: NT200, Detection principle was verified for the first time.
2013: First high energy neutrino event (290 TeV).
2018 - Now
- Blazar TXS 0506+056 (3.5σ)
- NCG 1068 (2.9σ –> 4.2 σ)
- Diffuse neutrino source in the Milky Way， ~5.7σ

1976 - Now
- Hawaii（4,500m）： DUMAND
- Mediterranean（3,000m）： ANTARES, KM3NeT
- South Pole（2,500m）： AMANDA, IceCube
- Lake Baikal（1,300m）： NT series, Baikal-GVD ……

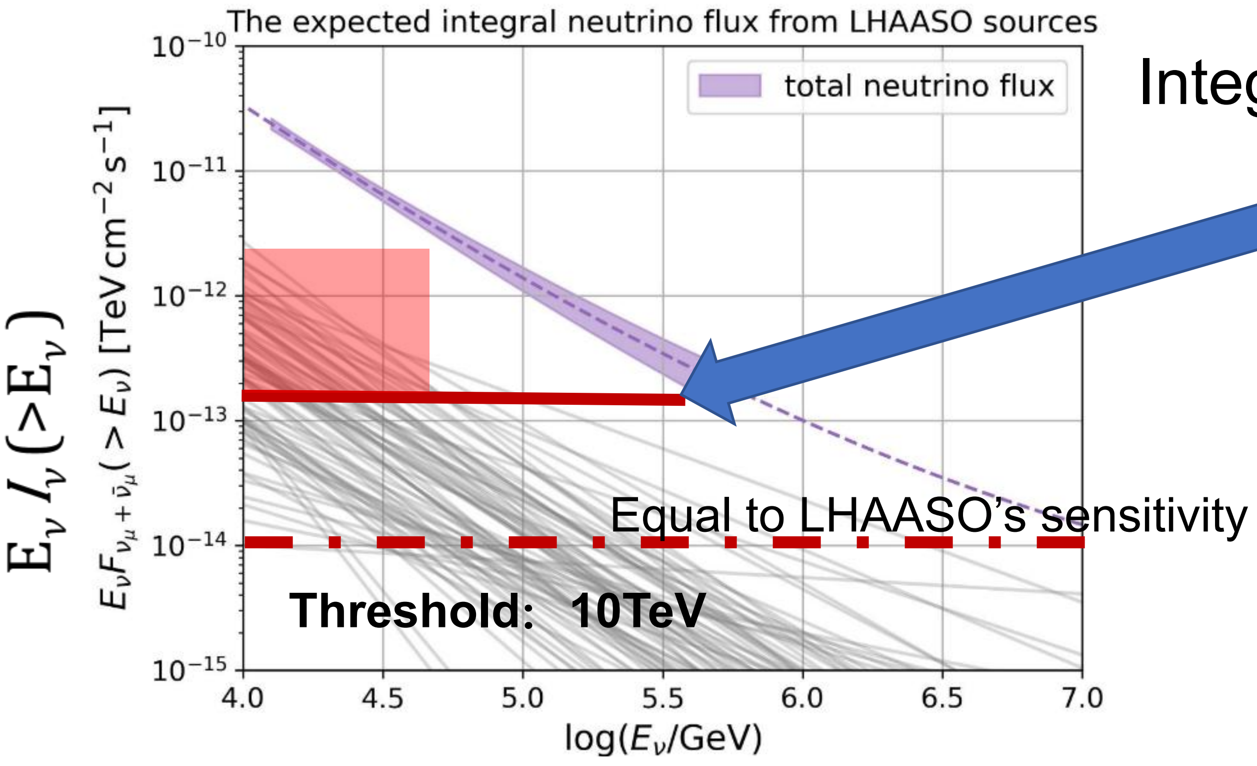
5σ is critical.



Aya Ishihara’s report， Lepton-Photon2025

HUNT and its potential

Sensitivity for next generation NT



Grey lines: neutrino flux of 43 LHAASO gamma ray sources.

Integral Sensitivity(E_ν $I_\nu(>E_\nu) = \int_{E_\nu} J_\nu(E_\nu)\, dE_\nu$:

10^{-13} TeV/cm^2/s @10TeV

IF we can observe the neutrino sources in the Milky Way, then we also can combine photon data (such as LHAASO).

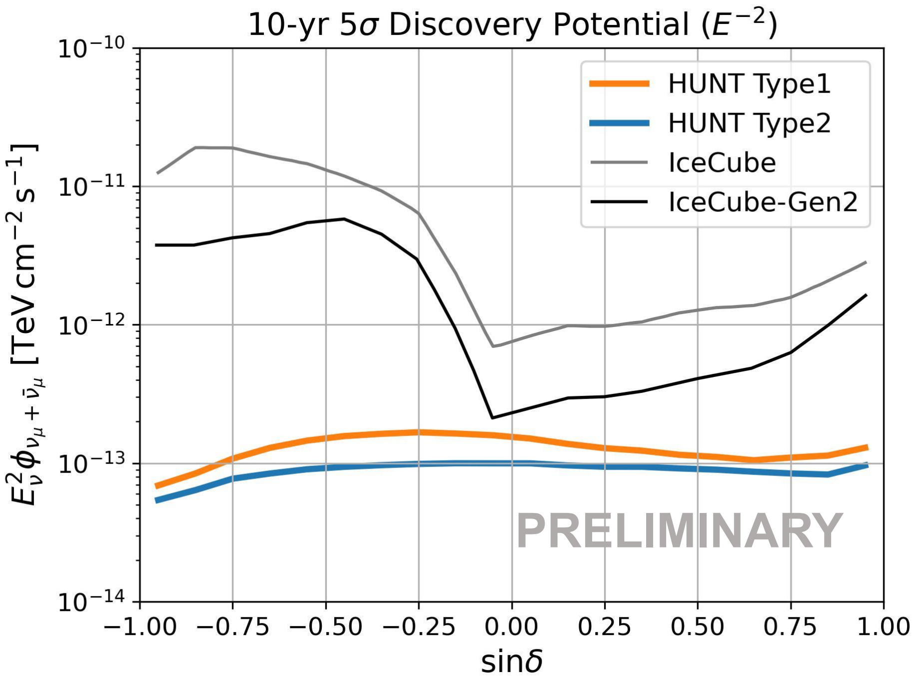
30 times volume of IC !

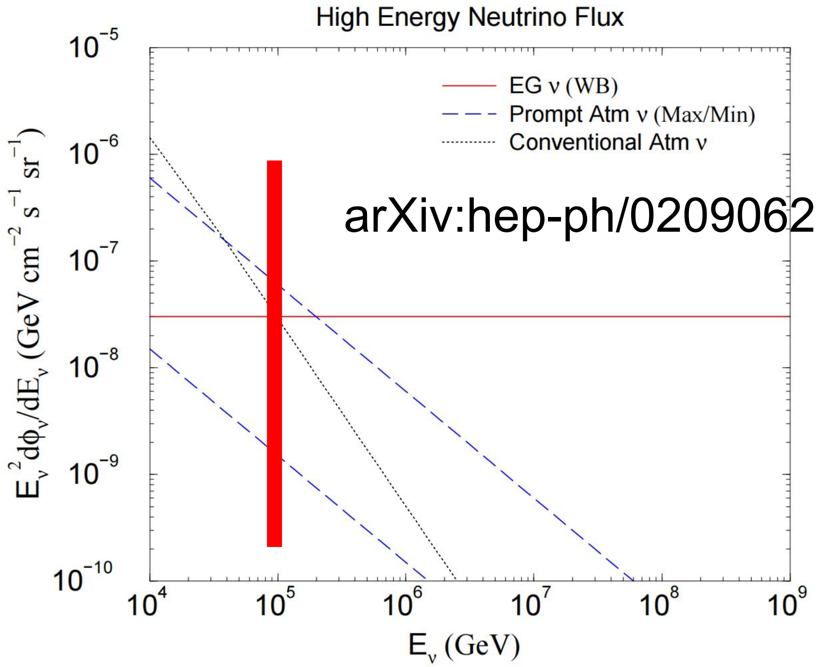
- Candidates of PeV cosmic ray in the Milky Way;
- Lots of neutrino sources in the extragalacitic space.

Scientific Goals

High-energy Underwater Neutrino Telescope (HUNT)

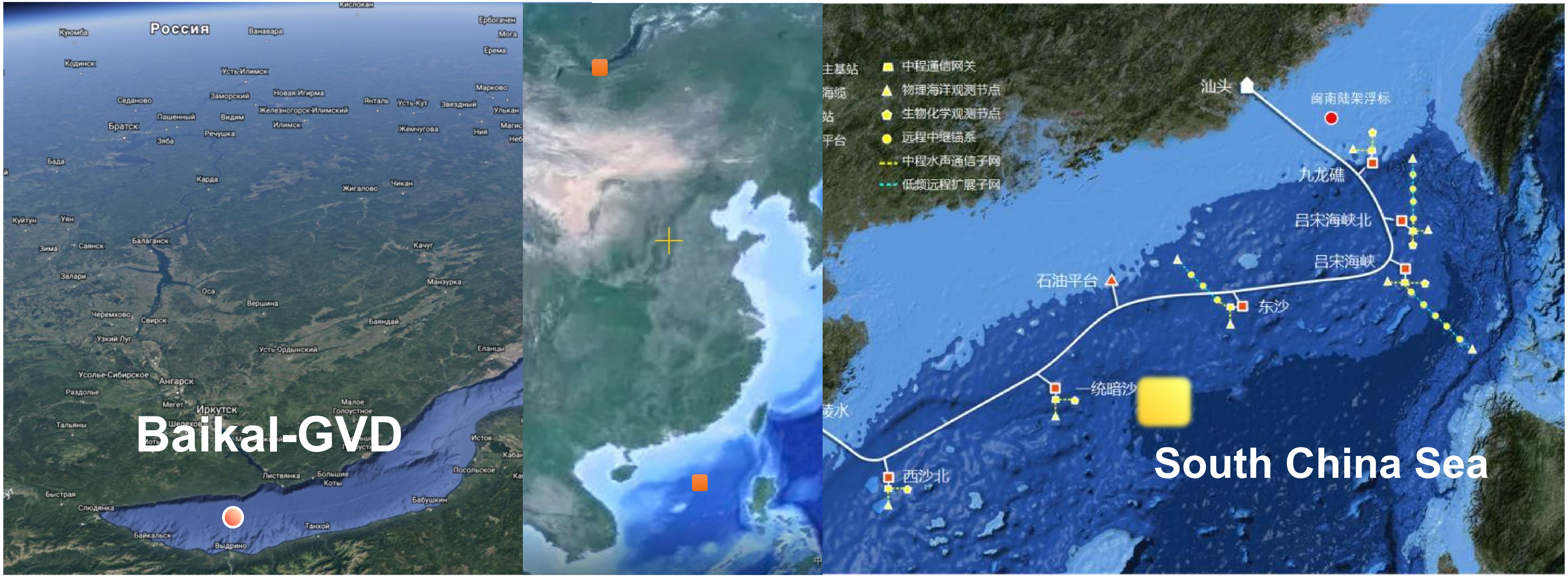
- Identifying the **hadronic PeVatrons** in our Galaxy(>100TeV)
- Resolving the high energy neutrino sky
- Understanding the propagation mechanism of high energy cosmic-rays
- Exploring the frontiers of neutrino physics and new physics





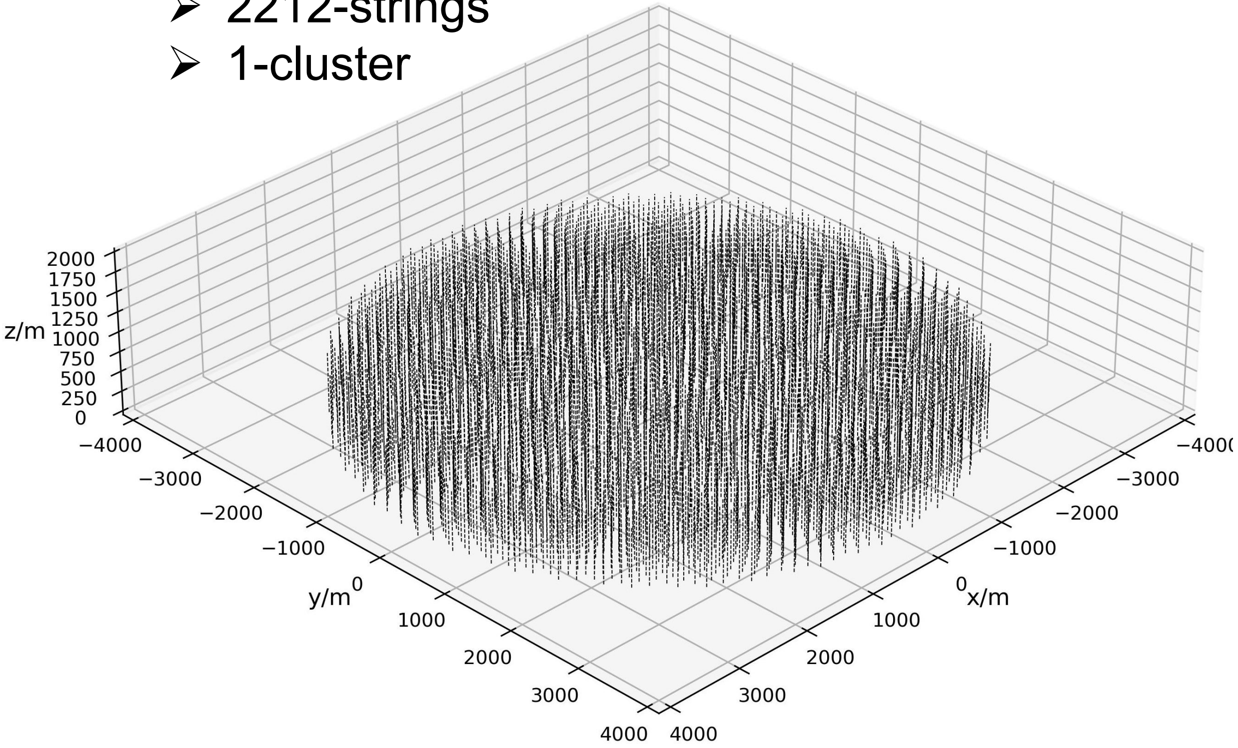
Energy spectrum of the astrophysical neutrino flux

Two Candidate sites



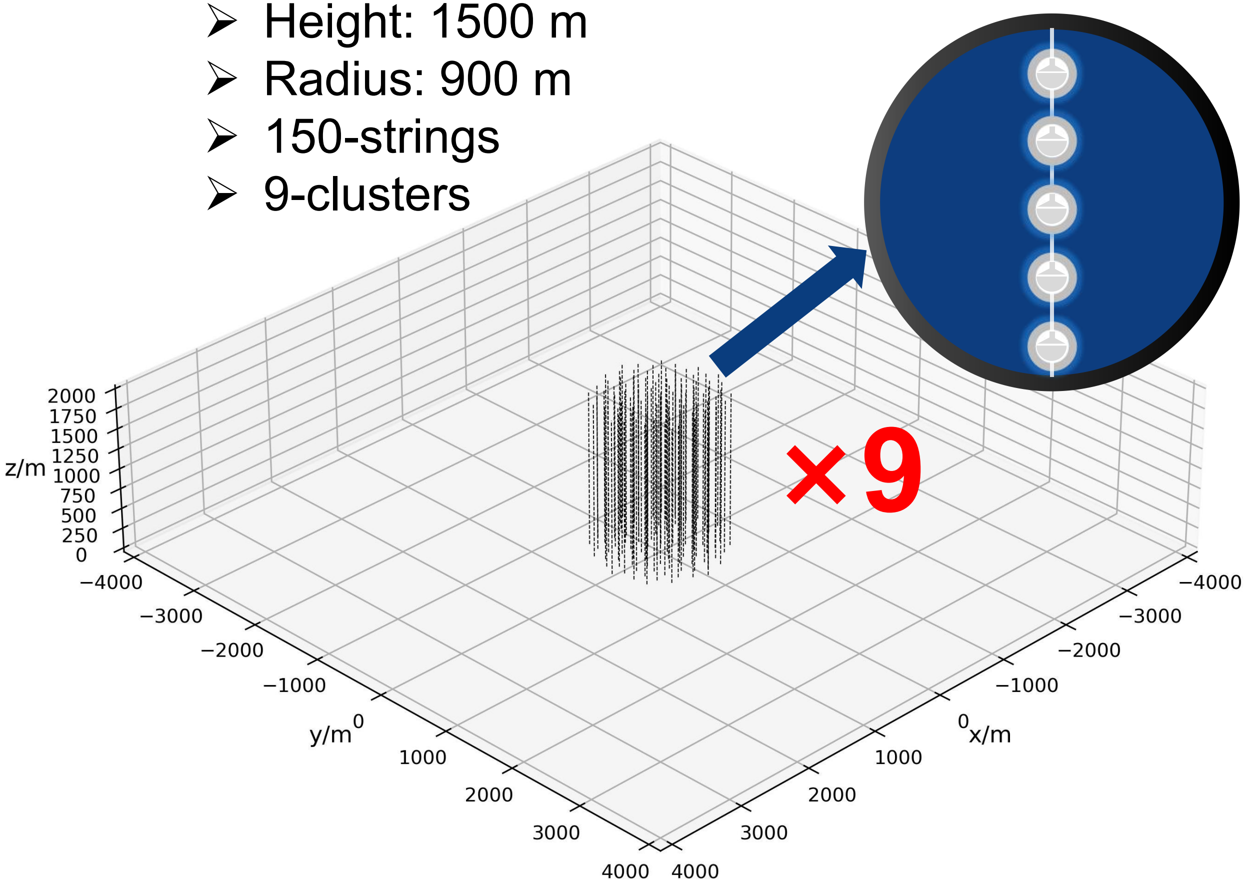
Configuration

Type 1
- Height: 720 m
- Radius: 3.8 km
- 2212-strings
- 1-cluster



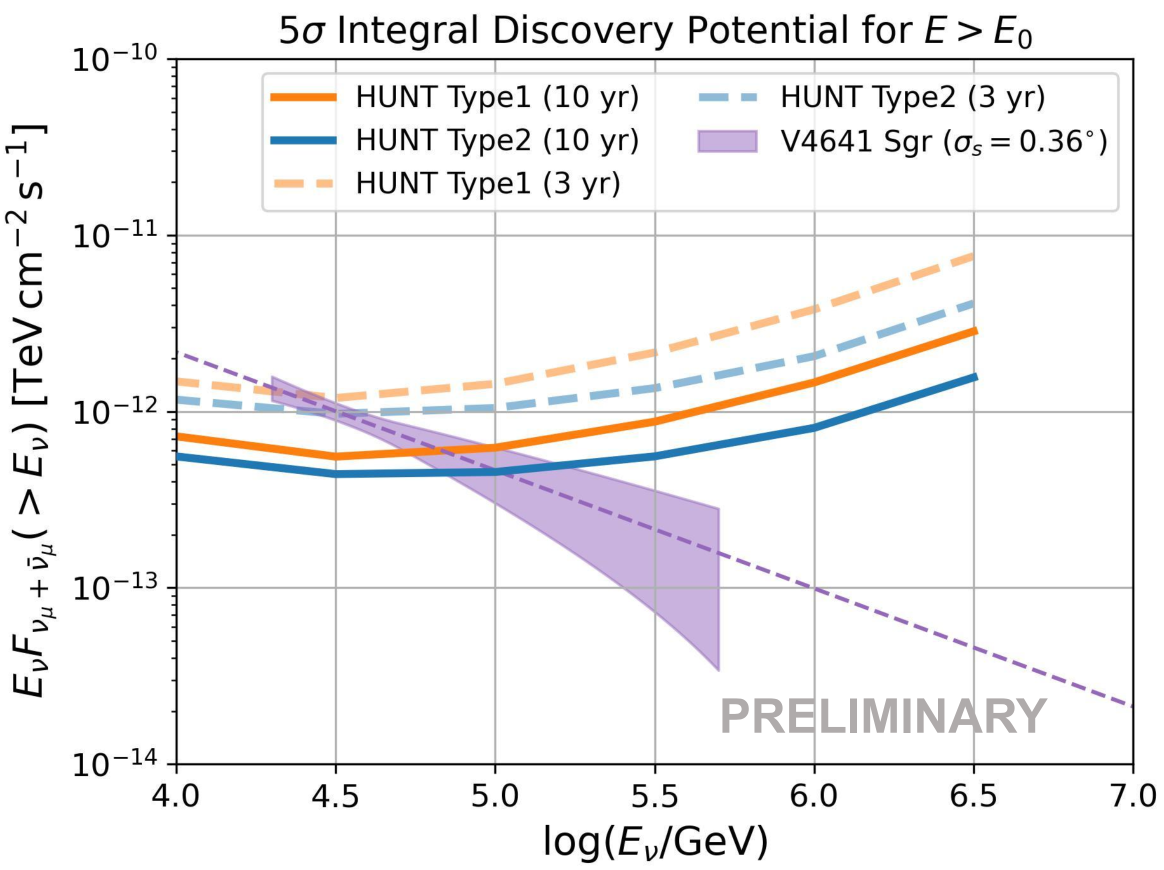
Lake Baikal (water depth ~ 1300 m)

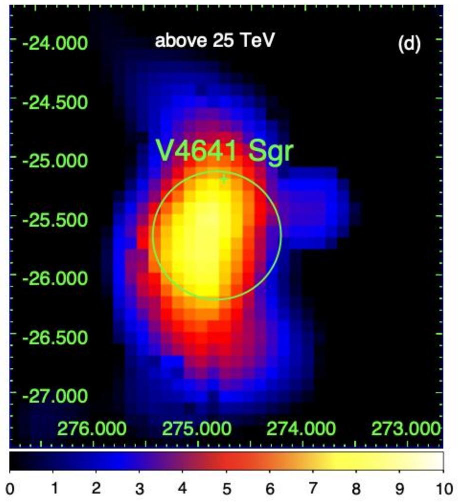
Type 2
- Height: 1500 m
- Radius: 900 m
- 150-strings
- 9-clusters



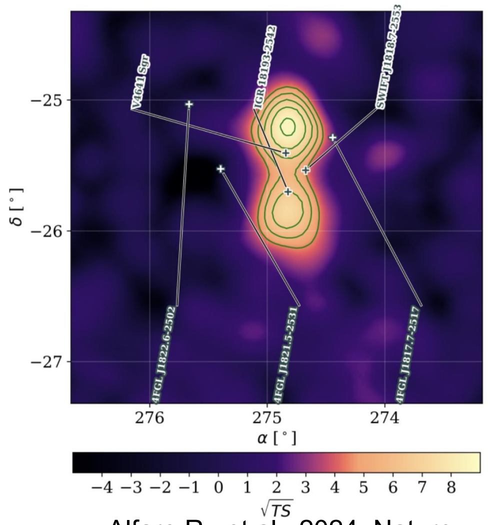
South China Sea (water depth ~ 3000 m)

Discovery Potential | Microquasar V4641

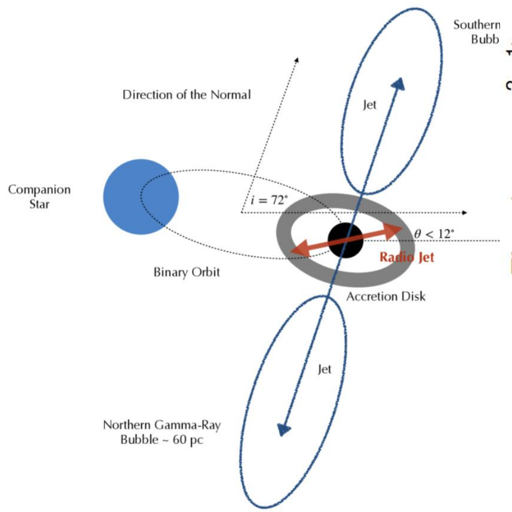


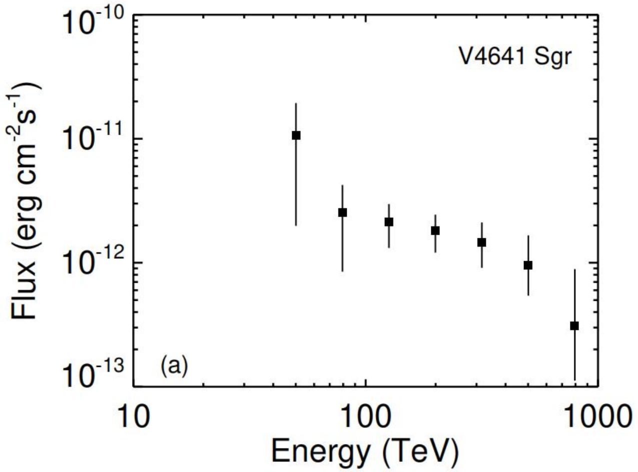


LHAASO, 2024, arXiv:2410.08988



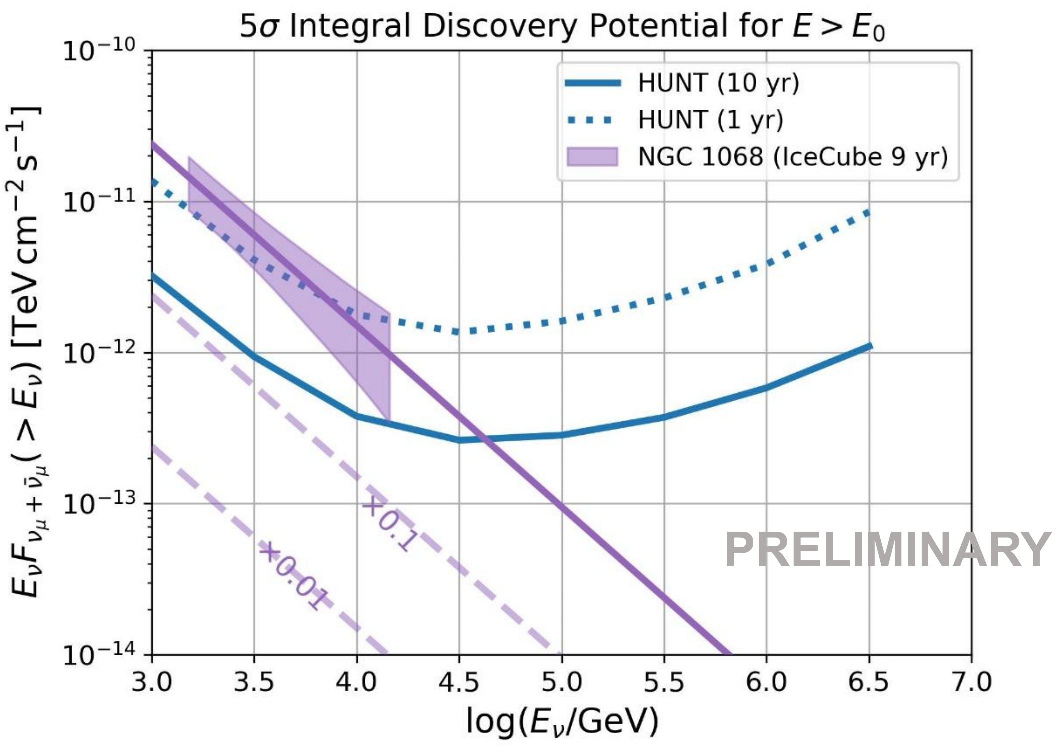
Alfaro R., et al., 2024, Nature

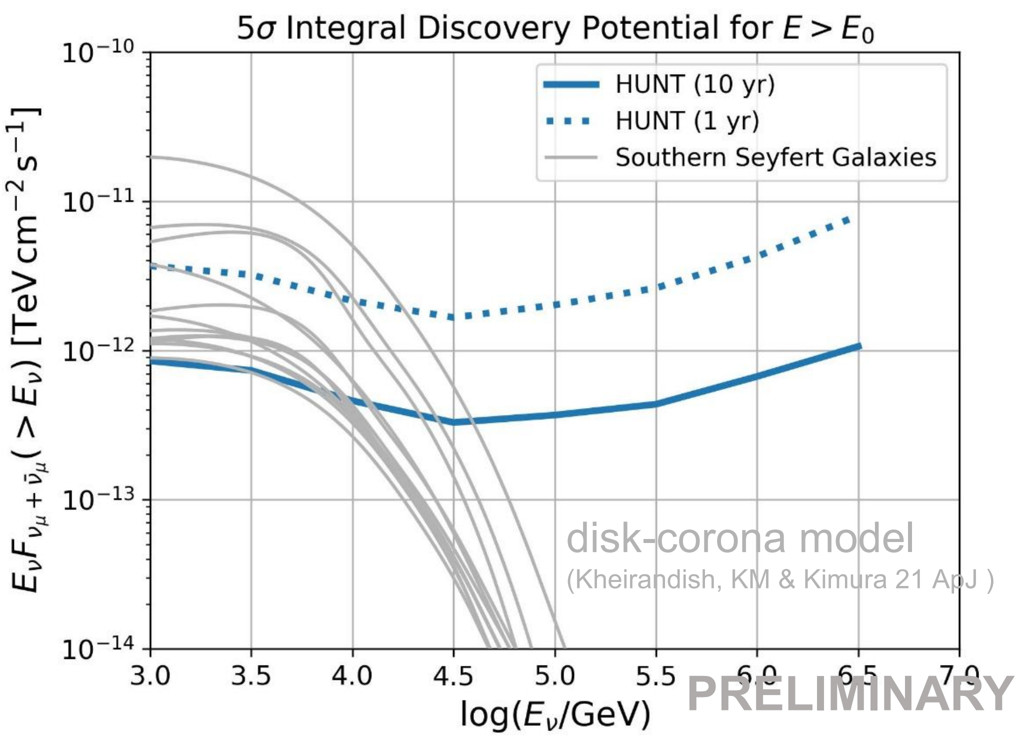




Spectal index ~ -2.67

Discovery Potential | Seyfert Galaxies



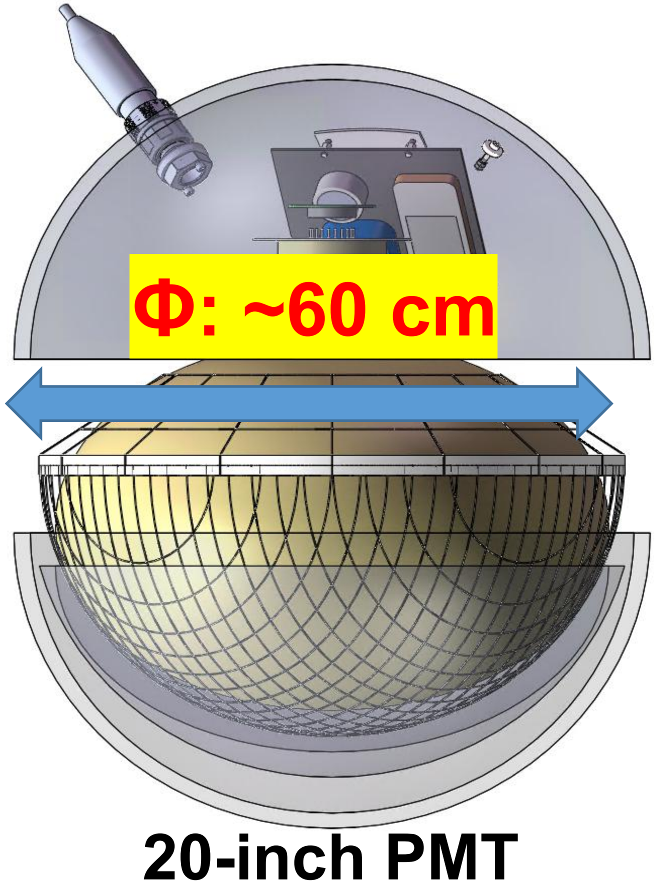


HUNT will discover tens of neutrino sources.

R&D of detector

NEW super-scale Optical Module (OM)

Much simpler, Lower cost and Better stability



Project progress

We actively support this initiative (R&D of HUNT)
Grigory V. Domogatsky, 11-2021

2020.8
Proposed by Zhen Cao.

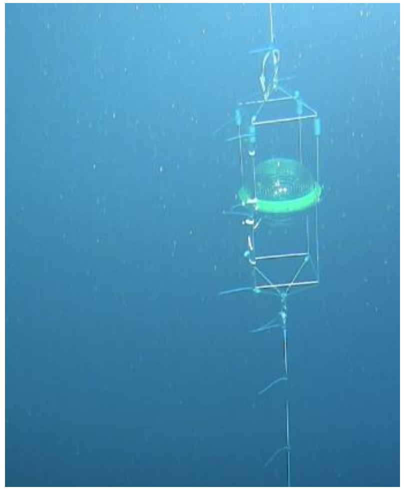
2022.7
8-inch PMT in LHAASO-WCDA (5m)

2023.2
2 8-inch PMTs in South China Sea (1,800m)

2024.3
12 23-inch OMs in Lake Baikal (1,300m)

2024.9
Funded by Key R&D program

2025.1
4 23-inch OMs in South China Sea (1,600m)

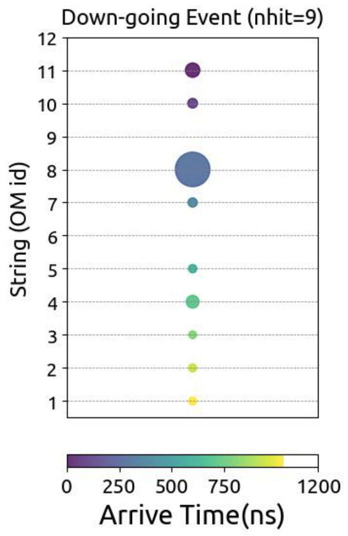


2025.3
24 23-inch OMs deployed in Lake Baikal (1,300m)

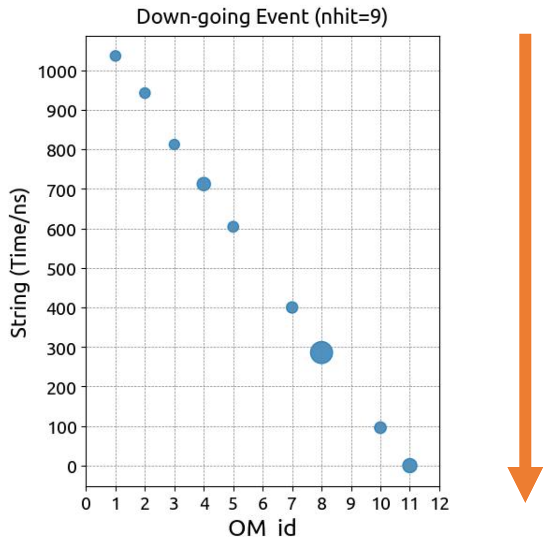
Prototype strings in Lake Baikal

1st Prototype String with 12 OMs

Size of signal

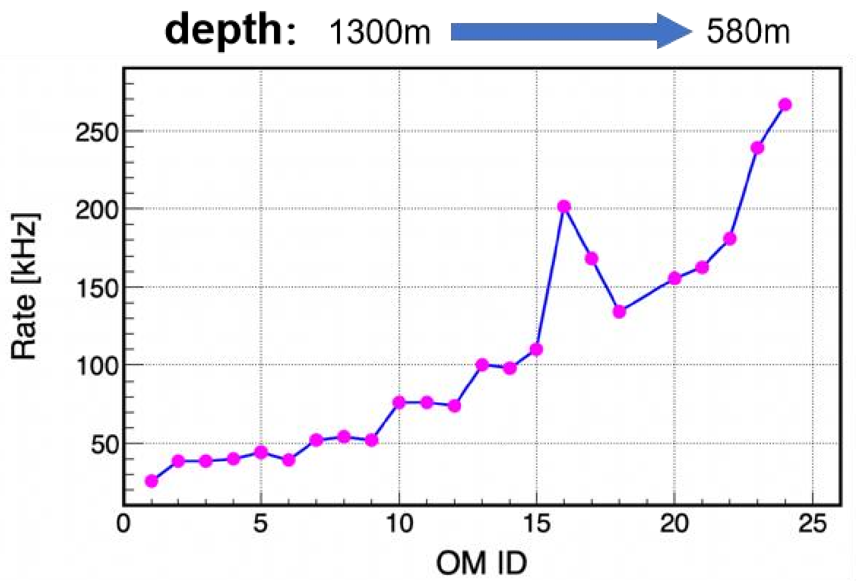


Arrival time



- Around 10 muon-like events (>=4 hits) per day.

2nd prototype string with 24 OMs



The relationship between single-channel noise rate vs different water depth.

The number of detected signals is ~6 times that of GVD's OM, Can make the arrangement of OMs very sparse (Density of OMs is smaller).

Collaborators

20 Chinese institutes or universities participate in the R&D work.

International members, Mous with：
a) INR & JINR （Baikal-GVD）.
b) Chiang Mai University, Thailand.
c) Two theoretical physicists from APC，France.

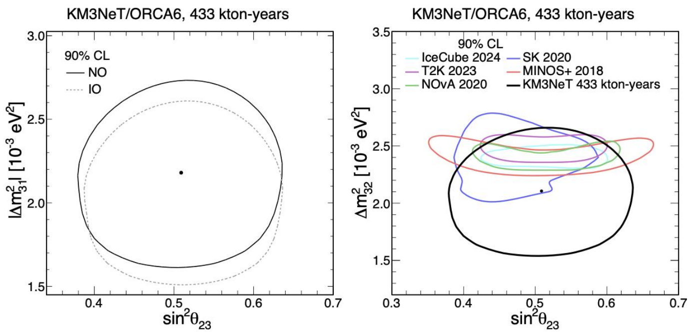
779th Xiangshan Science Conference in March

HUNT's scientific goals were written in the consensus of the meeting.

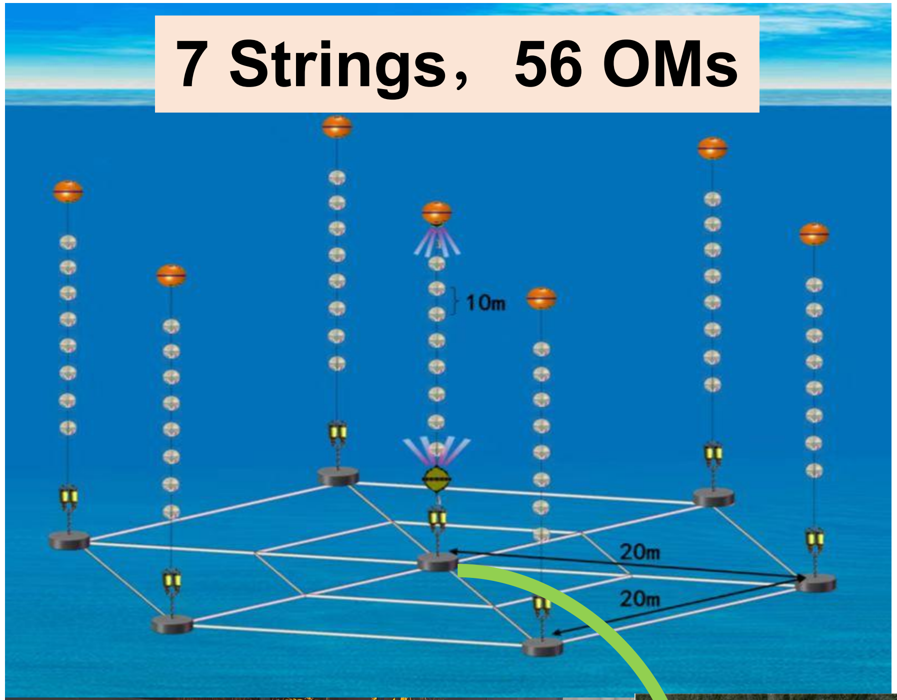
Prototype strings @ South China Sea

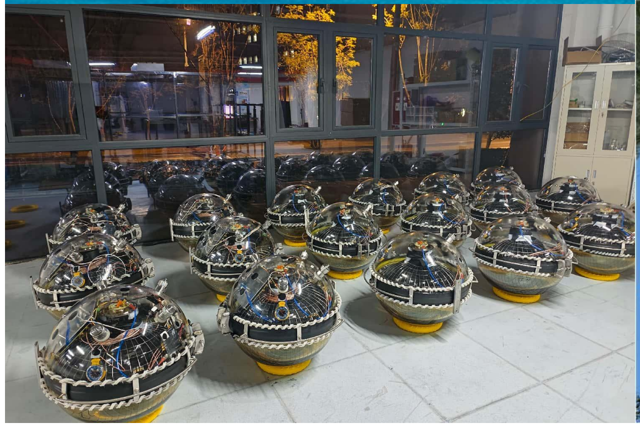
Phase I: Long-term monitor string (Jan 2025)
- 4 OMs, vertical spacing ~10 m

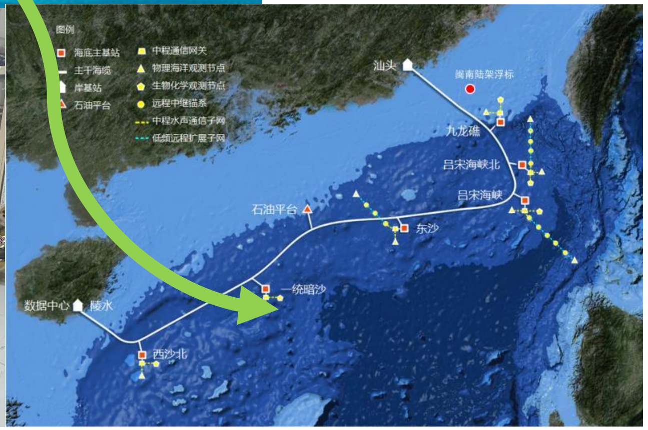
Phase II: Seven-string array (2025-2026)
- R&D of OM, APS, waterproof connectors, deployments,…….
- Measure the neutrino oscillation parameters.



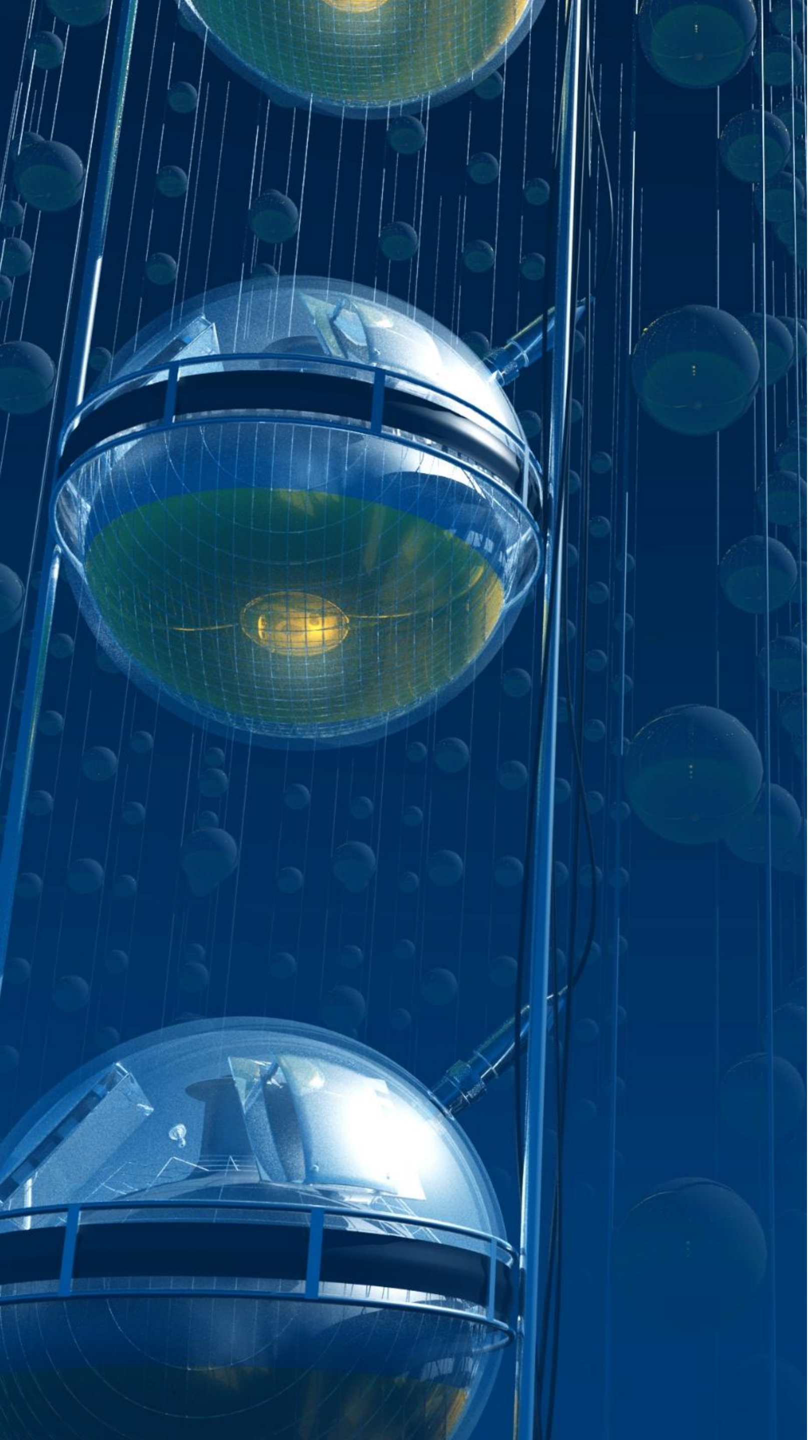
Aart Heijboer-KM3NeT-Neutrino 2022







Network and power support provided by Deepsea Network China.



Summary

- LHAASO has discovered tens of Galactic PeVatrons which are good candidates for high-energy neutrino sources.
- HUNT project will find a large number of neutrino sources in ten years.
- Prototype strings in Lake Baikal has observed muon-like events. We are going to deploy another string in 2026. The seven-string small array in South China Sea is coming.