Prospects for observing neutrino sources with the High-energy Underwater Neutrino Telescope

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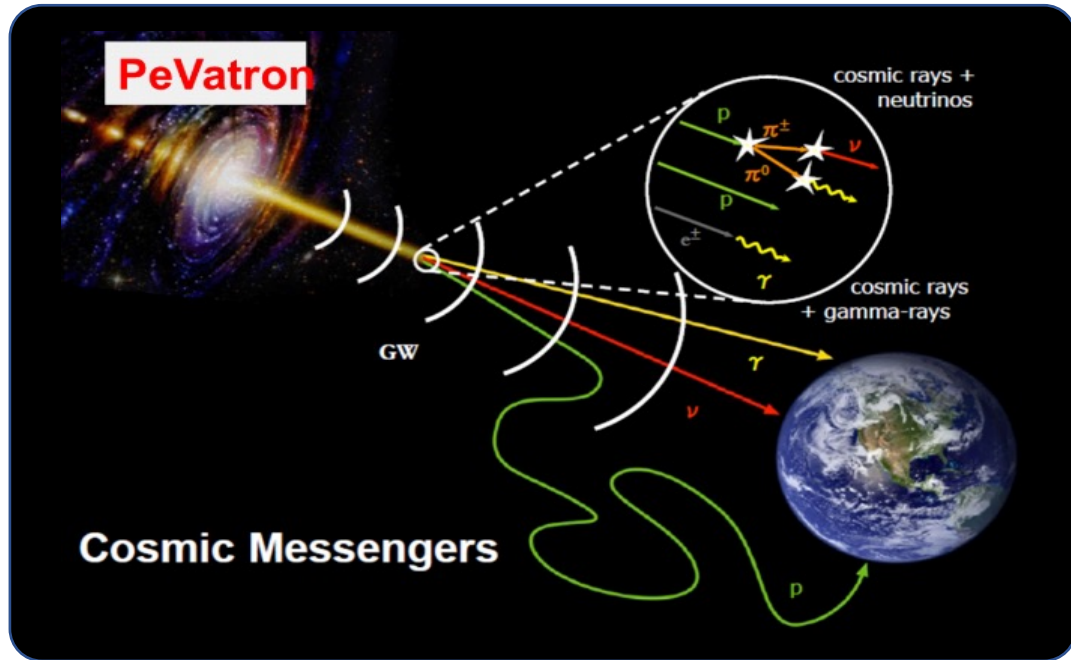
PeVatrons: accelerator of PeV cosmic-rays

Cao et al., 2024, ApJS
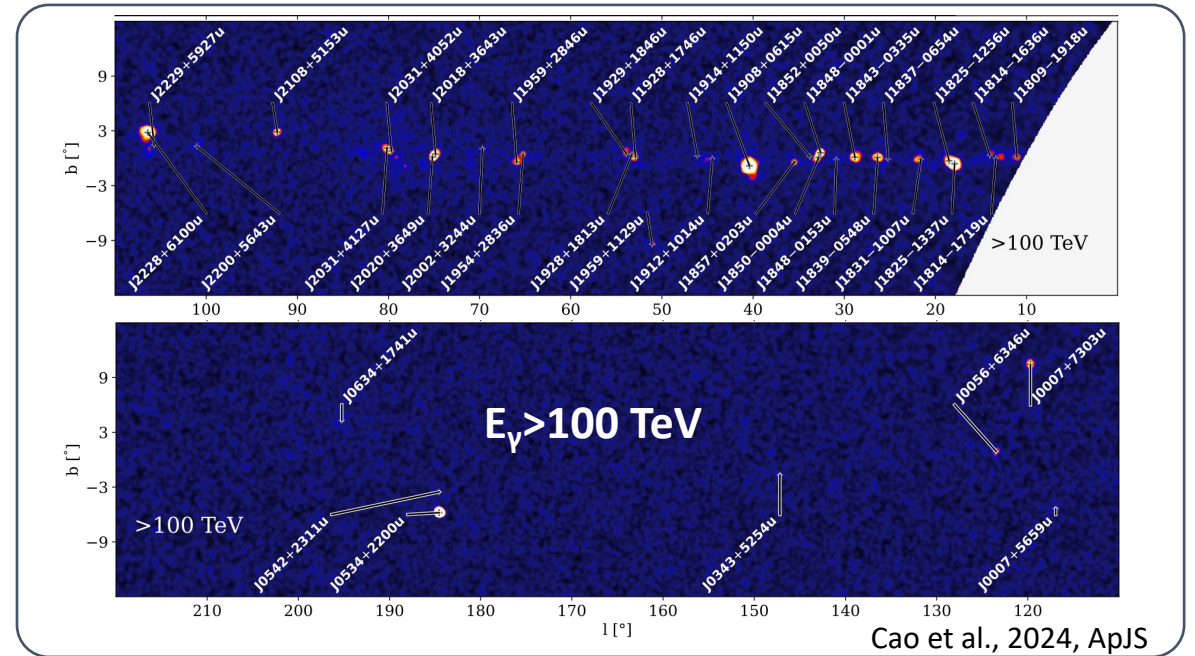
1LHAASO: 43 sources (>4σ); 22 sources (>7σ)

High-energy Underwater Neutrino Telescope (HUNT)
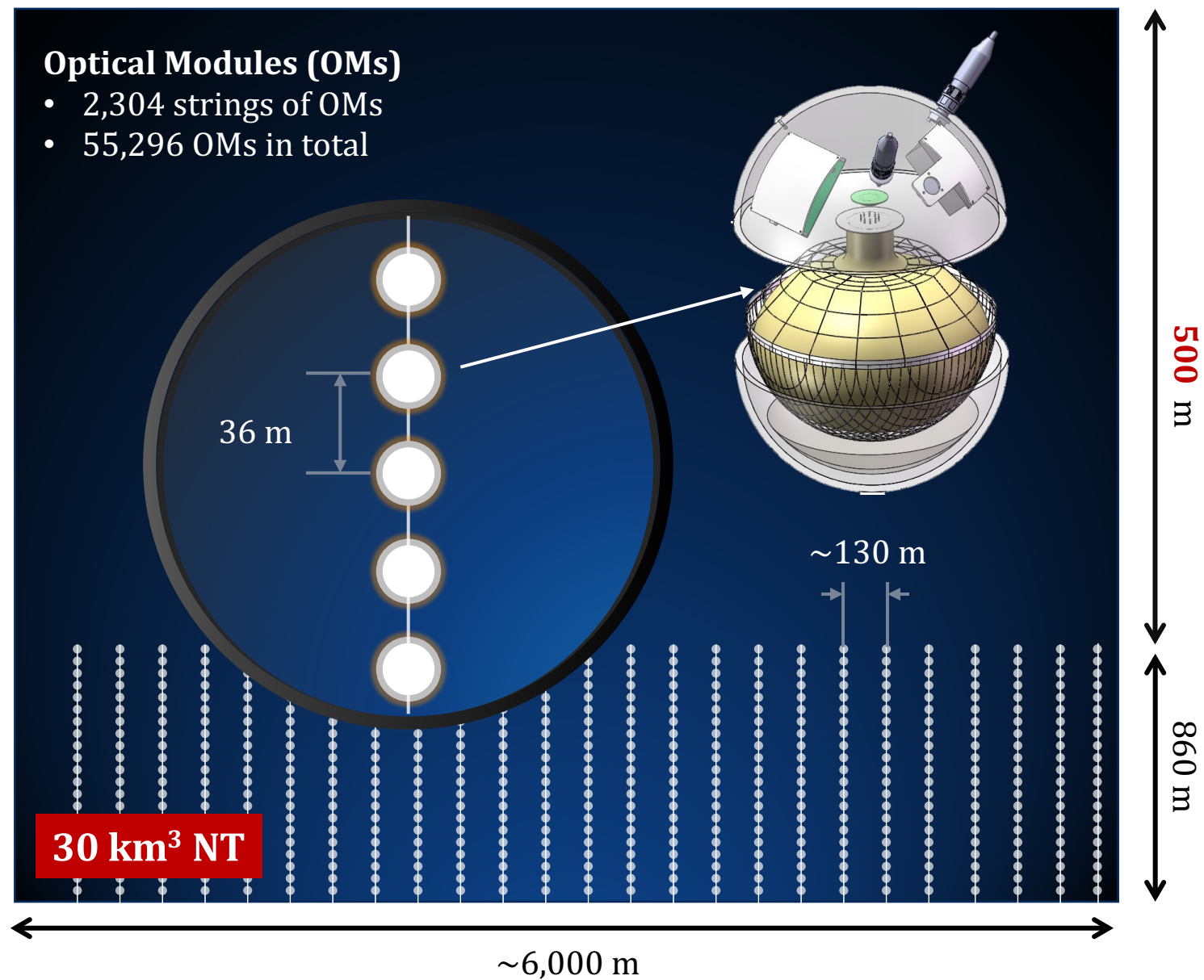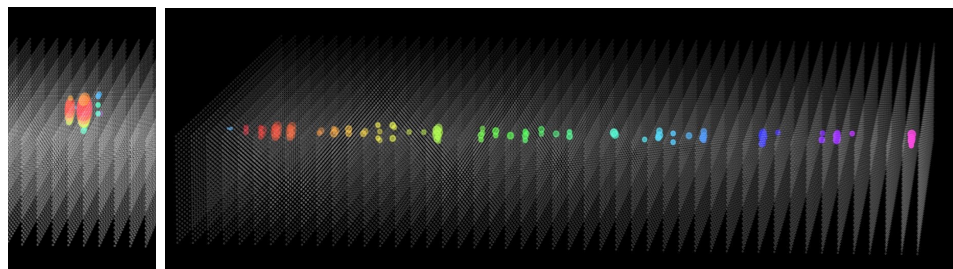
HUNT was publicly proposed in ICRC2023 .

Two alternative site options
- **Lake Baikal**
- South China Sea
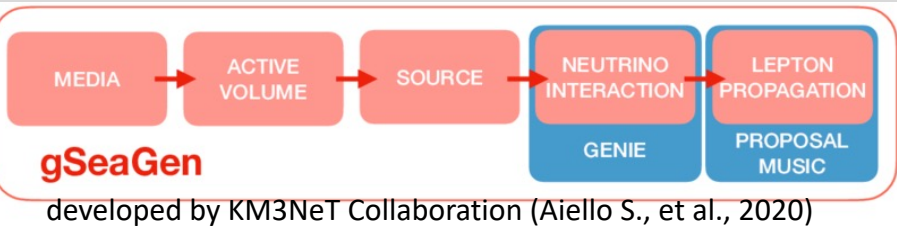
Detector design
- Angular resolution: ~0.1° (**tracks**), <3°(**cascades**)
- Energy resolution: $\Delta \log E \sim 0.3$ (tracks), $\Delta E \sim 10\text{-}30\%$ (cascades)
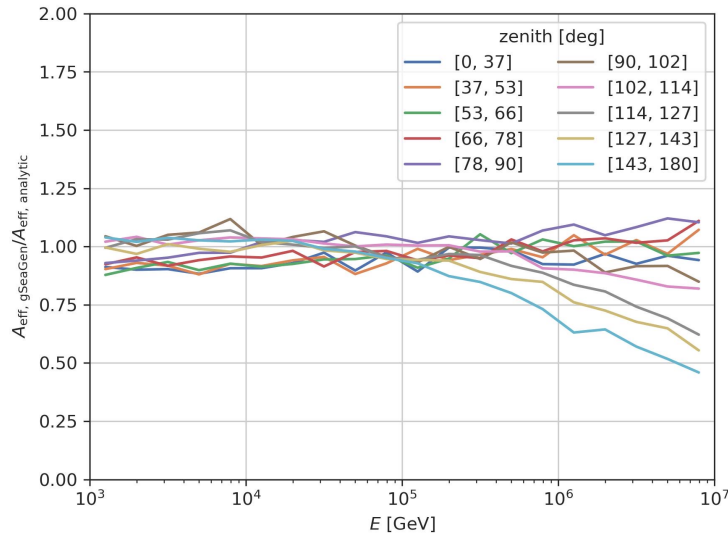- Discovering the neutrino sources (>100 TeV)

Optical Modules (OMs)
- 2,304 strings of OMs
- 55,296 OMs in total

36 m

~130 m

500 m

860 m

30 km³ NT

~6,000 m

Detector simulation

Injector	Optical Array + Optical Module	Pesudo-experiment

Injector

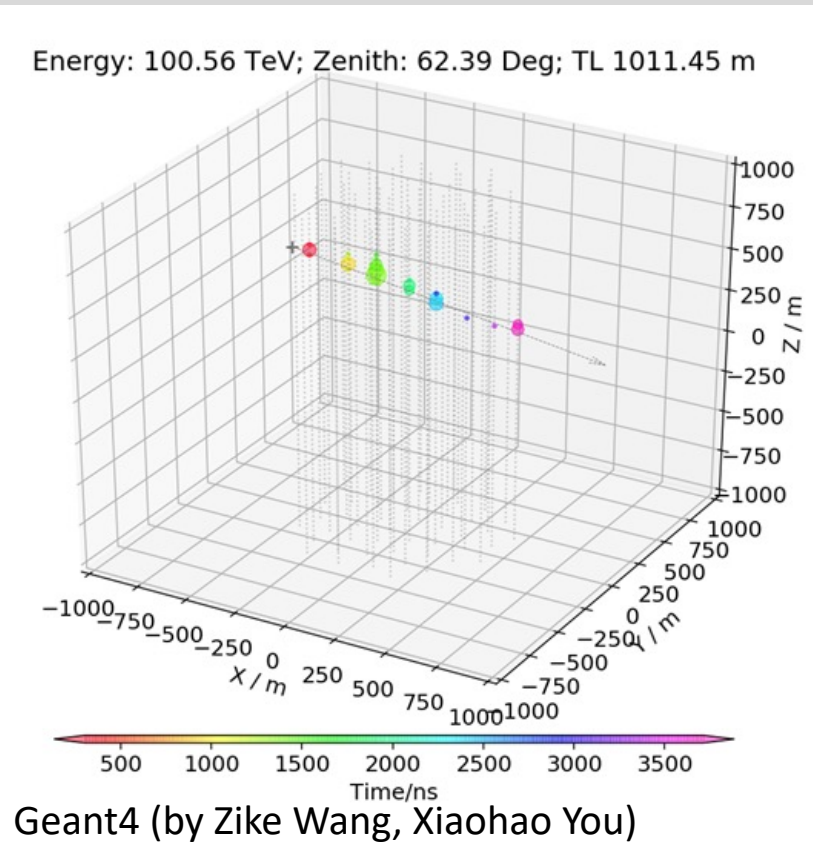developed by KM3NeT Collaboration (Aiello S., et al., 2020)

➢ atmospheric muons and neutrinos
➢ astrophysical neutrinos

Through-going tracks

Optical Array + Optical Module

Energy: 100.56 TeV; Zenith: 62.39 Deg; TL 1011.45 m

Geant4 (by Zike Wang, Xiaohao You)
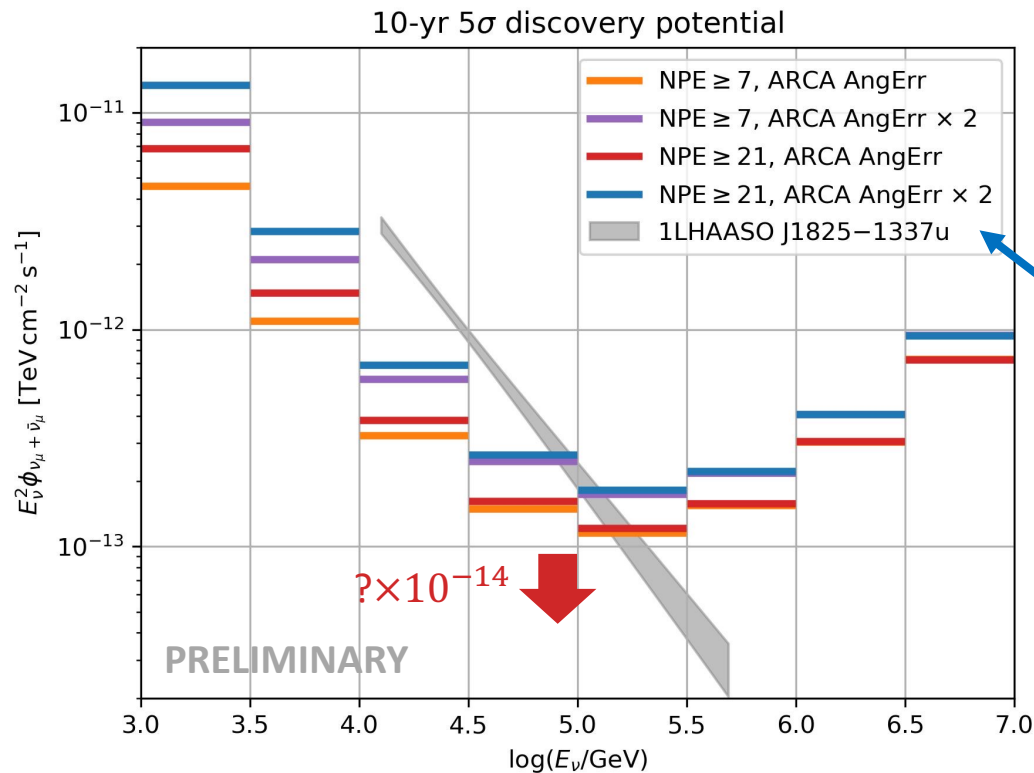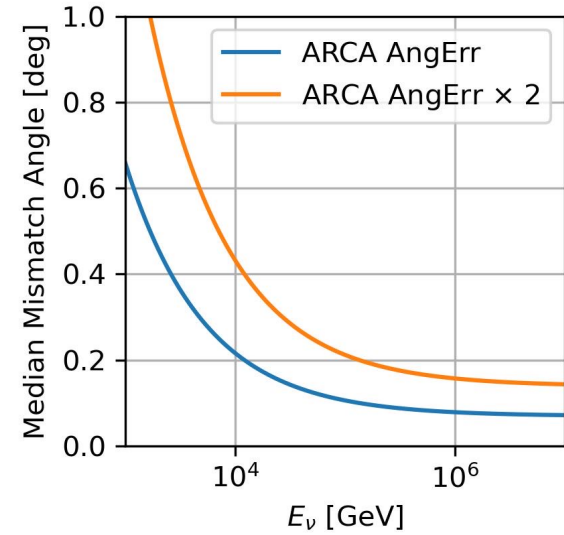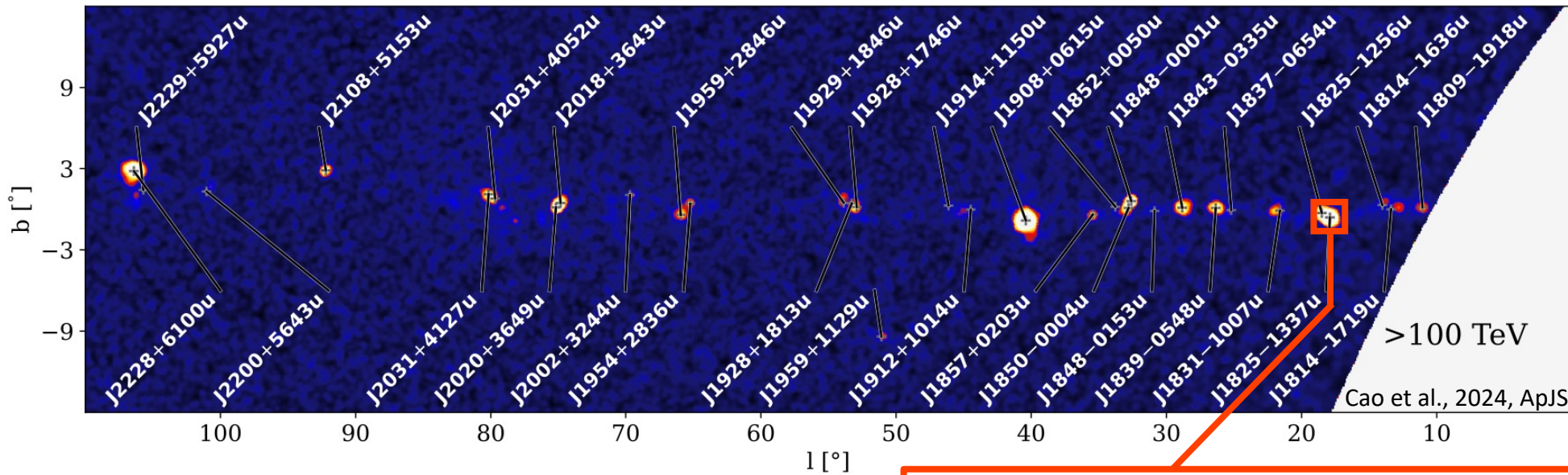
Pesudo-experiment

➢ Searching for neutrinos from point-like sources using through-going tracks
➢ Searching for neutrinos from **extended region** using cascade events
➢ Nhit>=7, Npe>=21
  ➢ r50=0.35 deg @ 100 TeV
  ➢ r50=0.2 deg enough?
➢ Nhit>=7, Npe>=7
  ➢ to explore the capability upper limit of this configuration

Cao et al., 2024, ApJS

>100 TeV

10-yr 5σ discovery potential

Legend:
- NPE ≥ 7, ARCA AngErr
- NPE ≥ 7, ARCA AngErr × 2
- NPE ≥ 21, ARCA AngErr
- NPE ≥ 21, ARCA AngErr × 2
- 1LHAASO J1825−1337u

$?\times 10^{-14}$

PRELIMINARY

1LHAASO J1825-1337u

The brightest point-like source at 50 TeV in the 1LHAASO catalog

If HUNT@LB can achieve the angular resolution
- ➤ same as KM3NeT-ARCA (ARCA AngErr)
- ➤ 2 times that of KM3NeT-ARCA (ARCA AngErr x 2)

Only the through-going tracks (zenith > 87°) induced by muon neutrinos are considered.

We need to test more configurations (e.g., multiple blocks of arrays) to enhance the telescope capability.

>100 TeV

Cao et al., 2024, ApJS

Median Mismatch Angle [deg]

— ARCA AngErr
— ARCA AngErr × 2

E_ν [GeV]

10-yr 5σ discovery potential

$E_\nu^2 \phi_{\nu_\mu + \bar{\nu}_\mu}$ [TeV cm^{-2} s^{-1}]

— NPE ≥ 7, ARCA AngErr
— NPE ≥ 7, ARCA AngErr × 2
— NPE ≥ 21, ARCA AngErr
— NPE ≥ 21, ARCA AngErr × 2
■ 1LHAASO J1825−1337u

IceCube-Gen2 (Dec = 0°)

$? \times 10^{-14}$

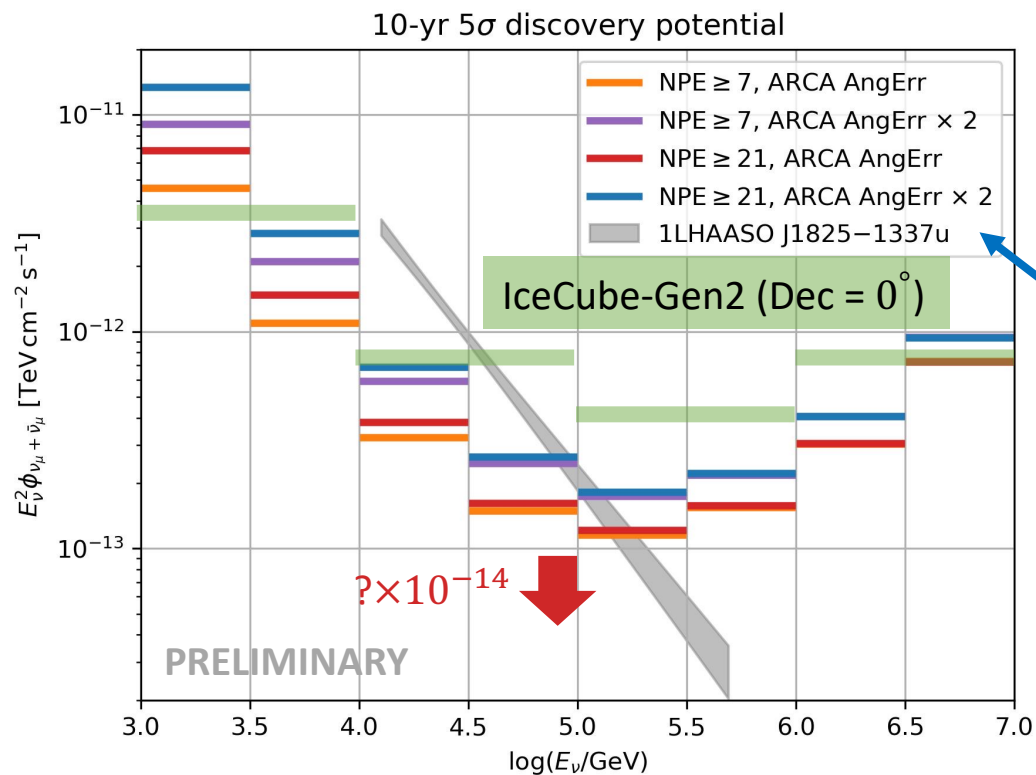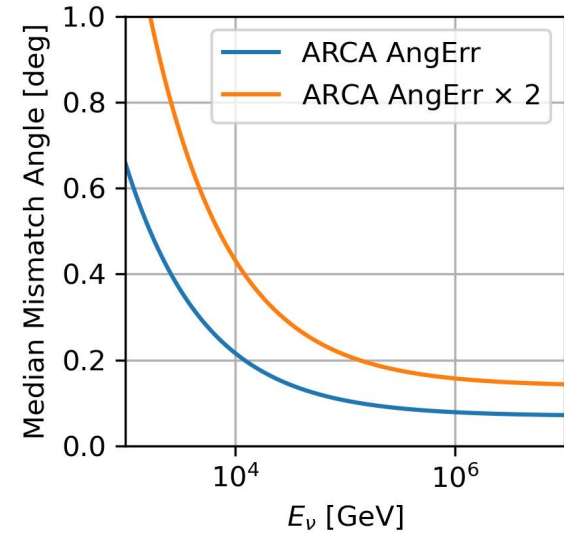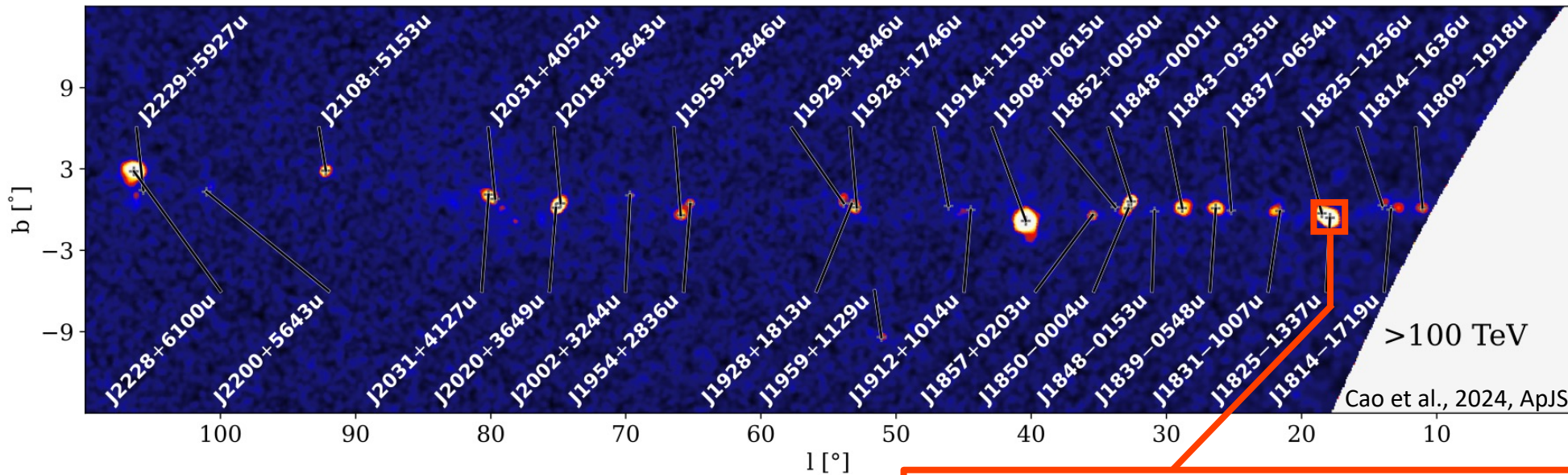PRELIMINARY

log(E_ν/GeV)

1LHAASO J1825-1337u
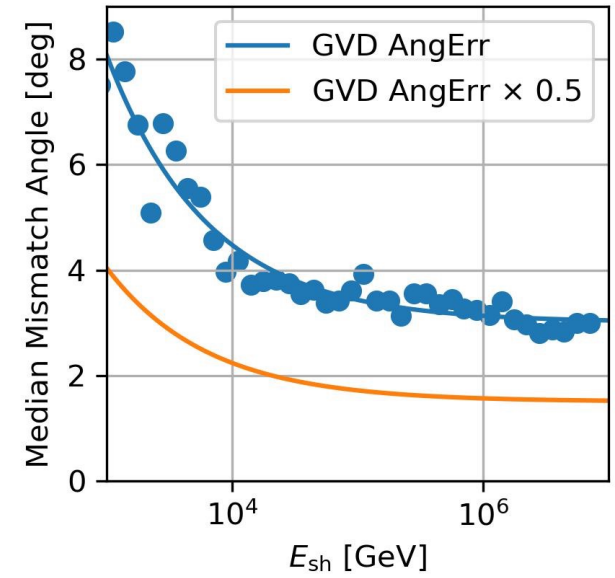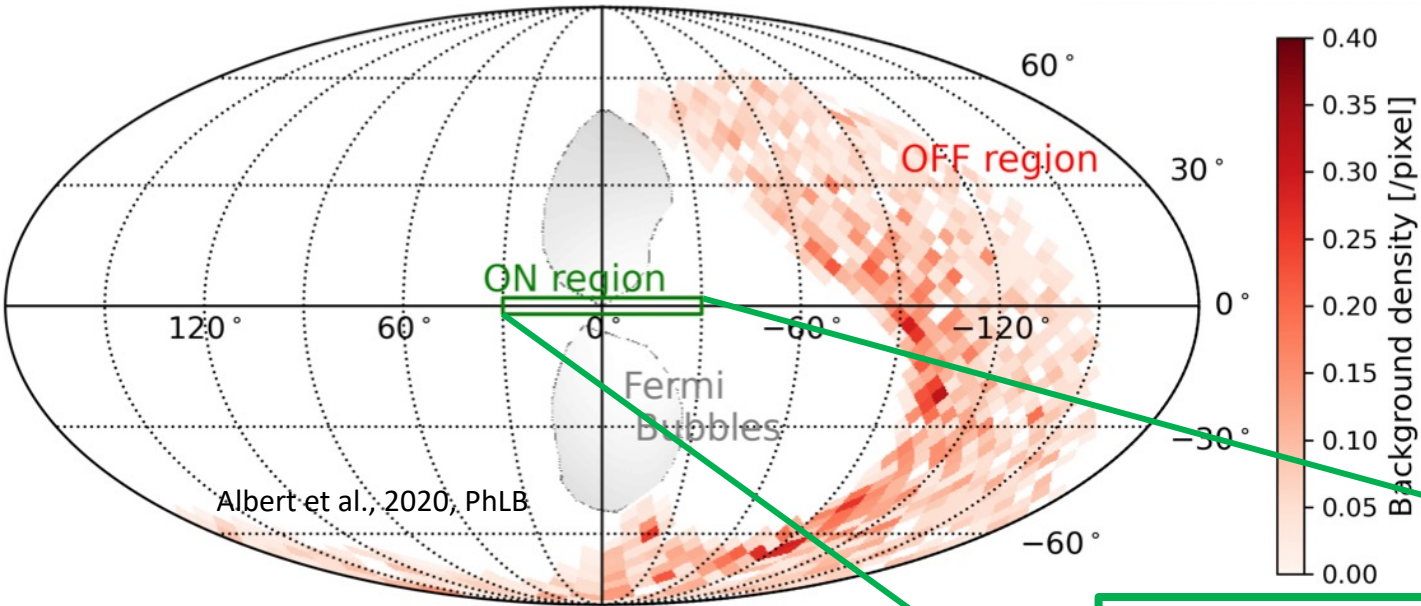
The brightest point-like source at 50 TeV in the 1LHAASO catalog

If HUNT@LB can achieve the angular resolution
➤ same as KM3NeT-ARCA (ARCA AngErr)
➤ 2 times that of KM3NeT-ARCA (ARCA AngErr x 2)

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We need to test more configurations (e.g., multiple blocks of arrays) to enhance the telescope capability.

ON region

OFF region

Fermi Bubbles

60°

30°

0°

−30°

−60°

120°   60°   0°   −60°   −120°

Albert et al., 2020, PhLB

Background density [/pixel]

0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00

Median Mismatch Angle [deg]

8
6
4
2
0

E_{sh} [GeV]

10^4 10^6

— GVD AngErr
— GVD AngErr × 0.5

Galactic Ridge

ANTARES observed the neutrinos from this region with a significance of 1.75σ.

If HUNT@LB can achieve the angular resolution
➤ same as Baikal-GVD (GVD AngErr)
➤ half that of KM3NeT-ARCA (GVD AngErr x 0.5)

Only the cascade events induced by electron neutrinos and muon neutrinos are considered.

Many details have not been considered yet (e.g., bioluminescence, tau neutrinos, track/cascade classification).

1-yr 5σ discovery potential

$E_\nu^2 \phi_{all-flavor}$ [GeV cm^{-2} s^{-1} sr^{-1}]

10^{-4}
10^{-5}
10^{-6}
10^{-7}

3.0   3.5   4.0   4.5   5.0   5.5   6.0

$\log(E_\nu/GeV)$

— NPE ≥ 7, GVD AngErr
— NPE ≥ 7, GVD AngErr × 0.5
— NPE ≥ 21, GVD AngErr
— NPE ≥ 21, GVD AngErr × 0.5
▨ Galactic Ridge

PRELIMINARY