中山大學 物理与天文学院
SUN YAT-SEN UNIVERSITY SCHOOL OF PHYSICS AND ASTRONOMY

Performance studies for the NEON project

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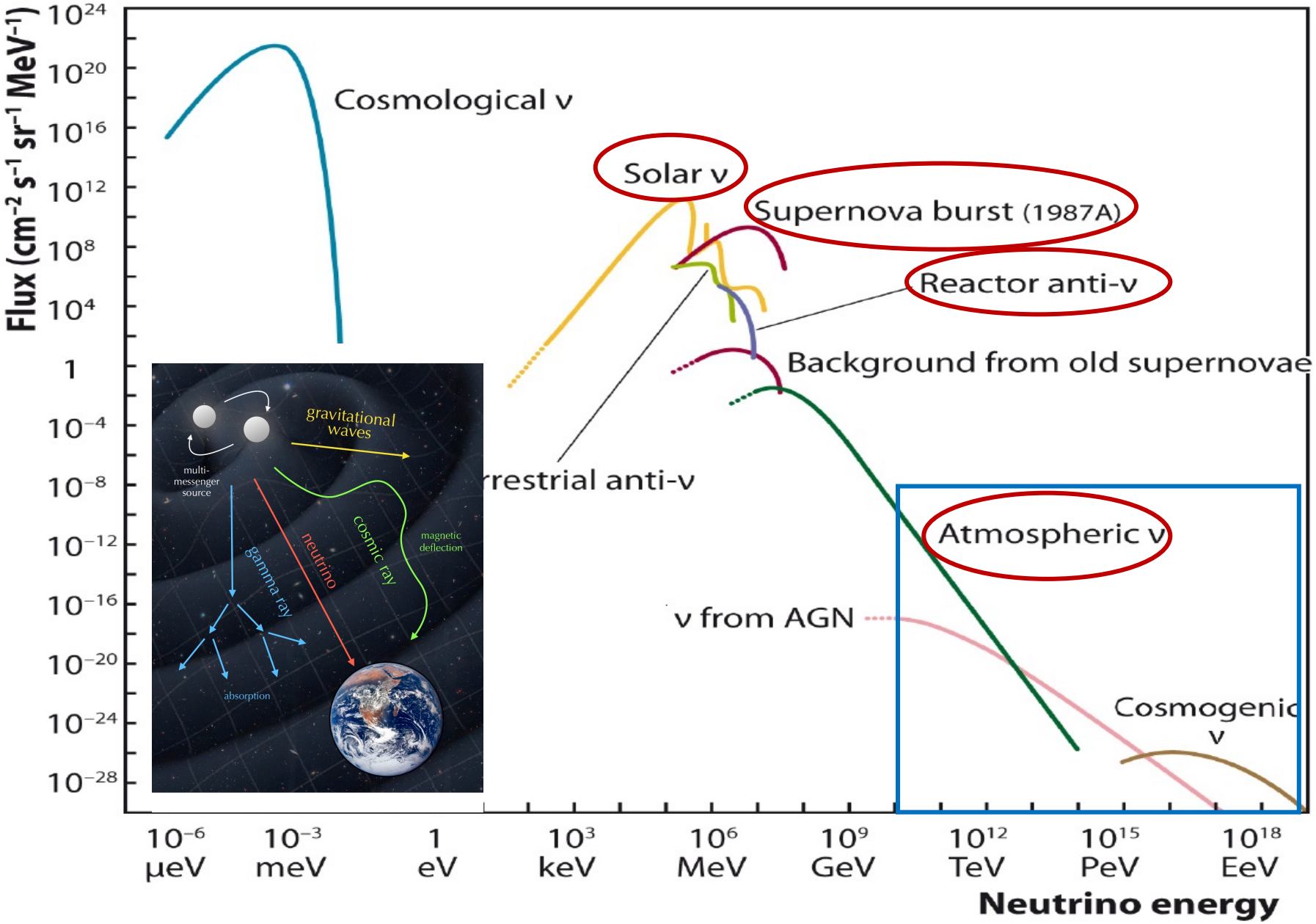
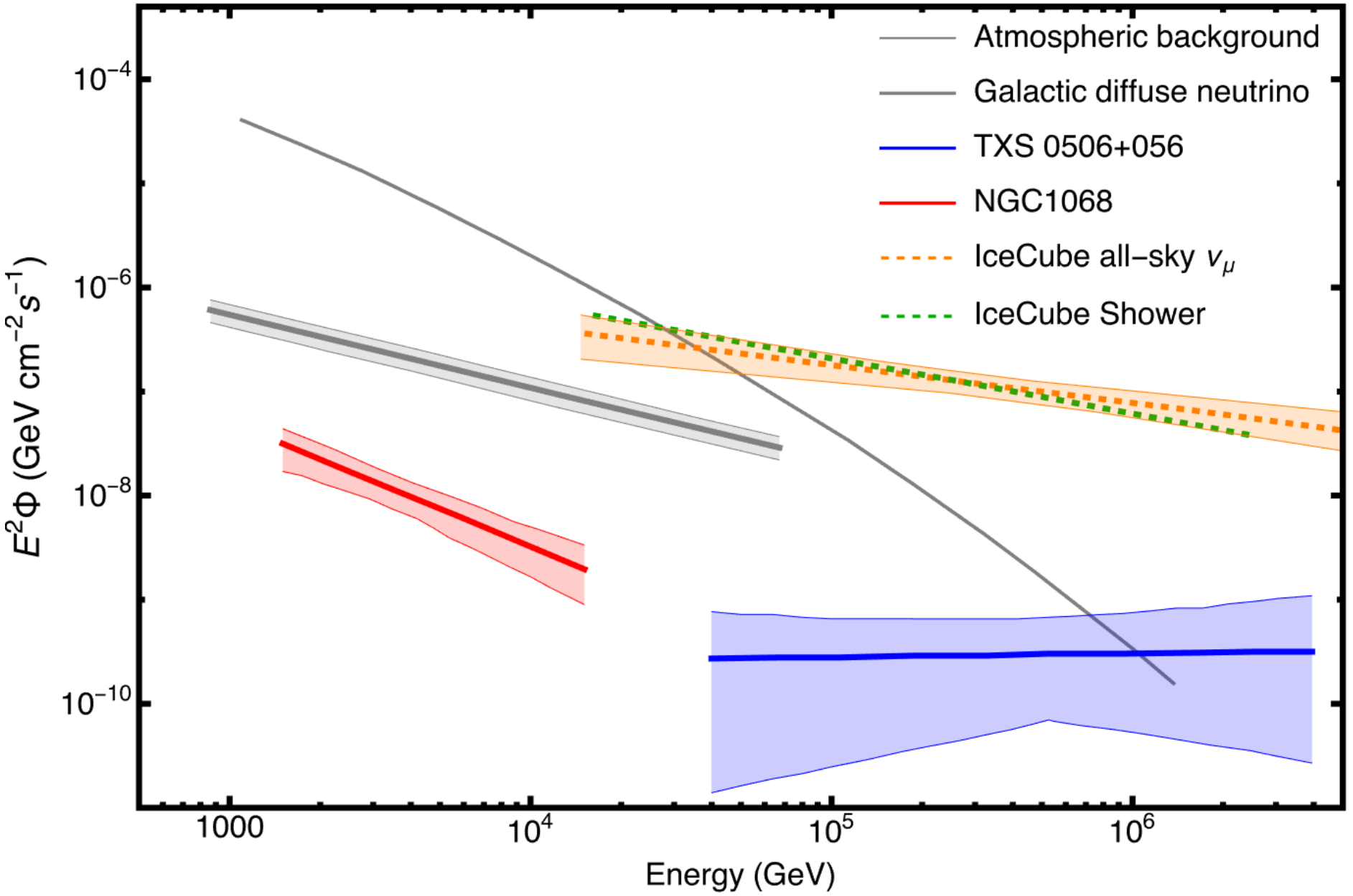
- Current achievements of neutrino astronomy
- High-energy neutrino detector array
- Performance studies
- Future plan

Neutrino astronomy



Current situation

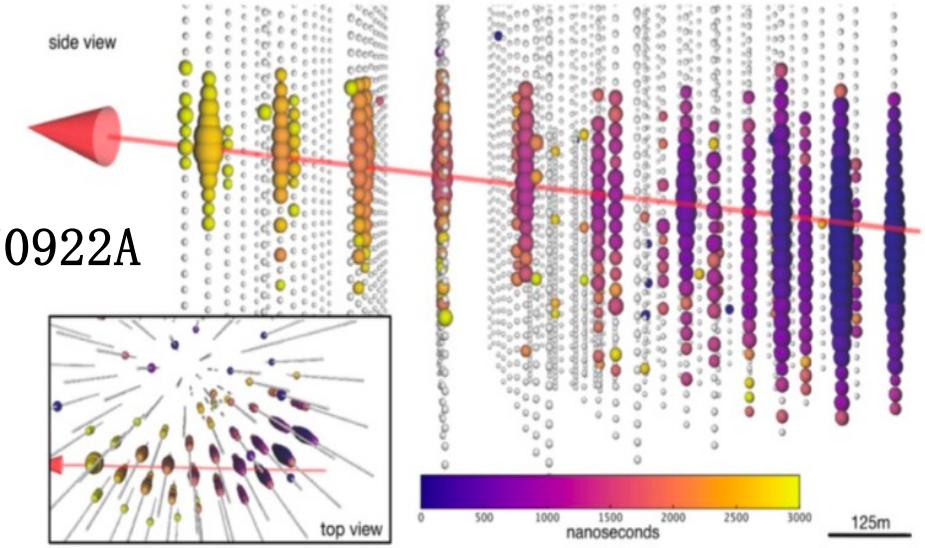


Astrophysical neutrino flux: $\sim E^{-2.37}$

Potential neutrino sources are found.

The highest energy neutrino detected.

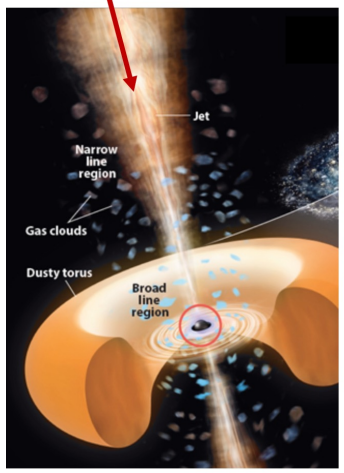
Play a key role in multi-messenger astronomy

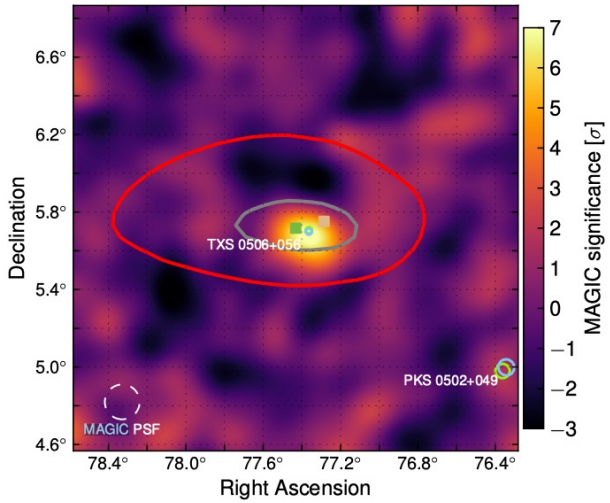


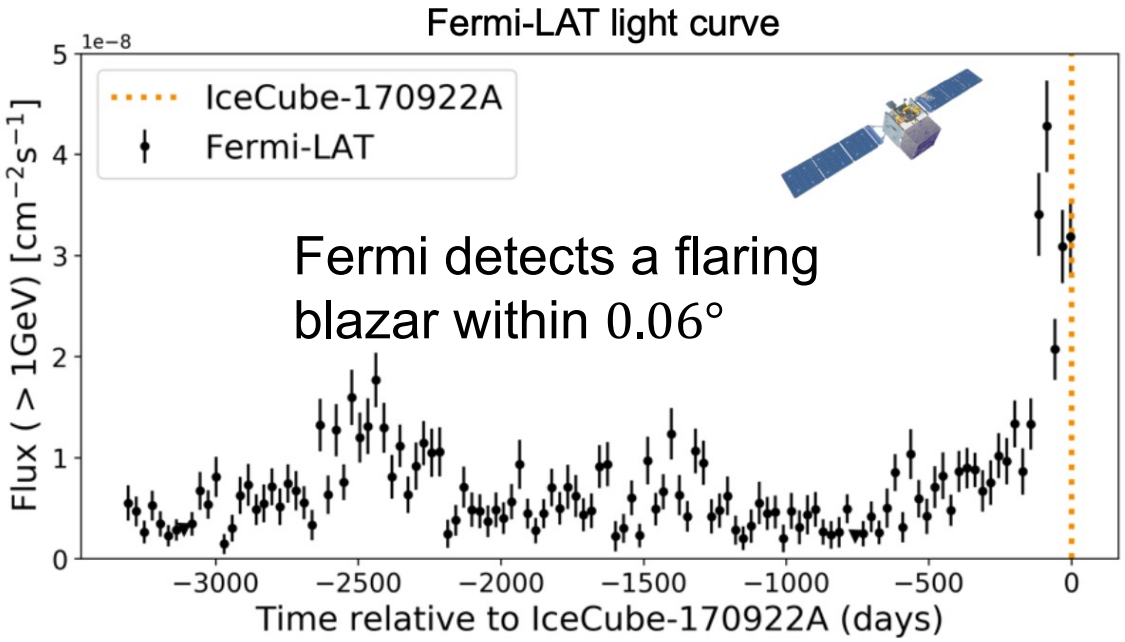
IC 170922A

290 TeV

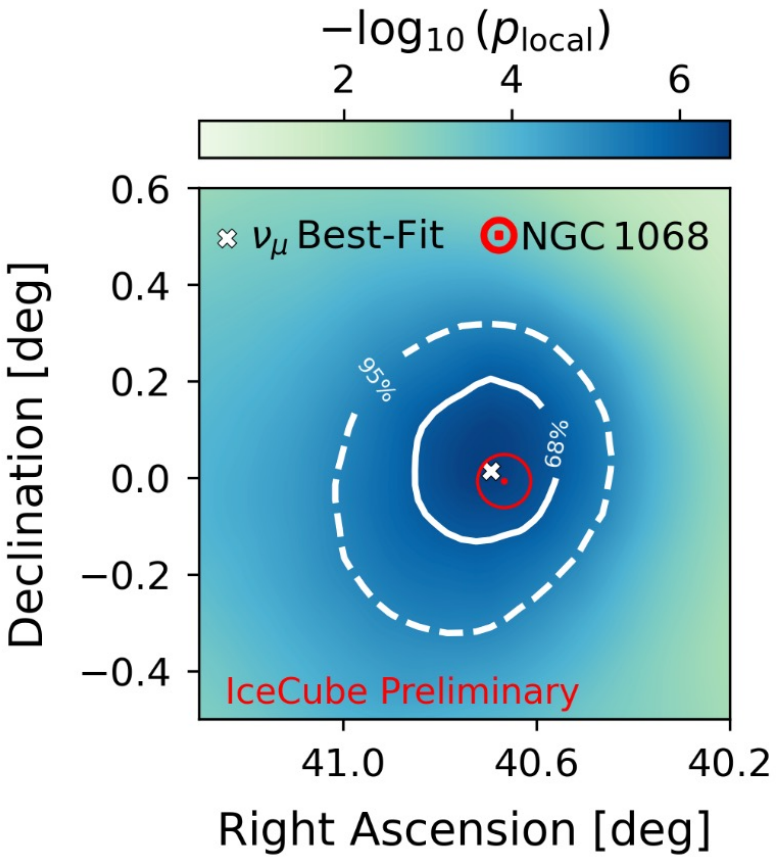
A global network of follow-up observations were organized.

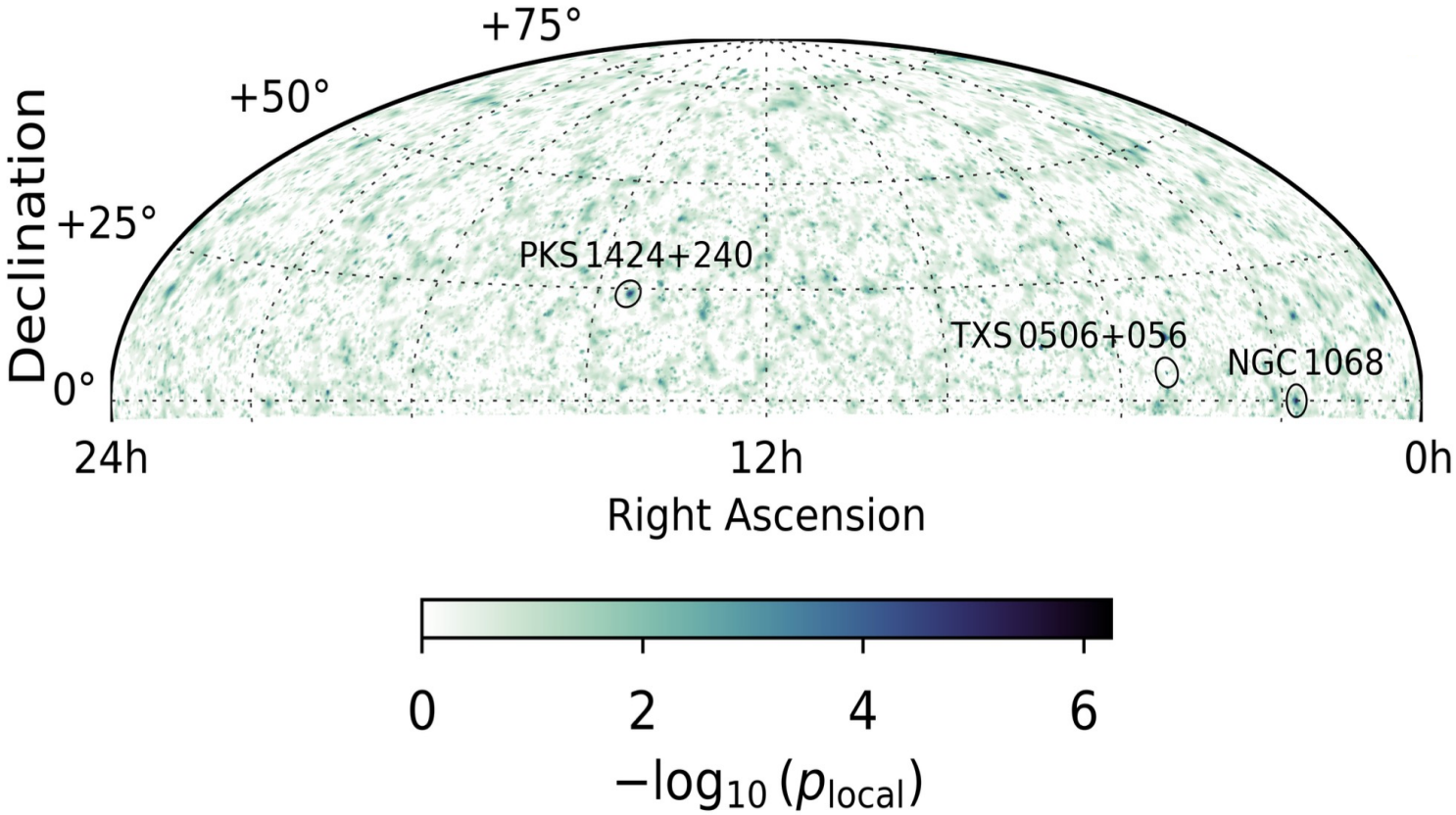






Science 361 (2018) 6398





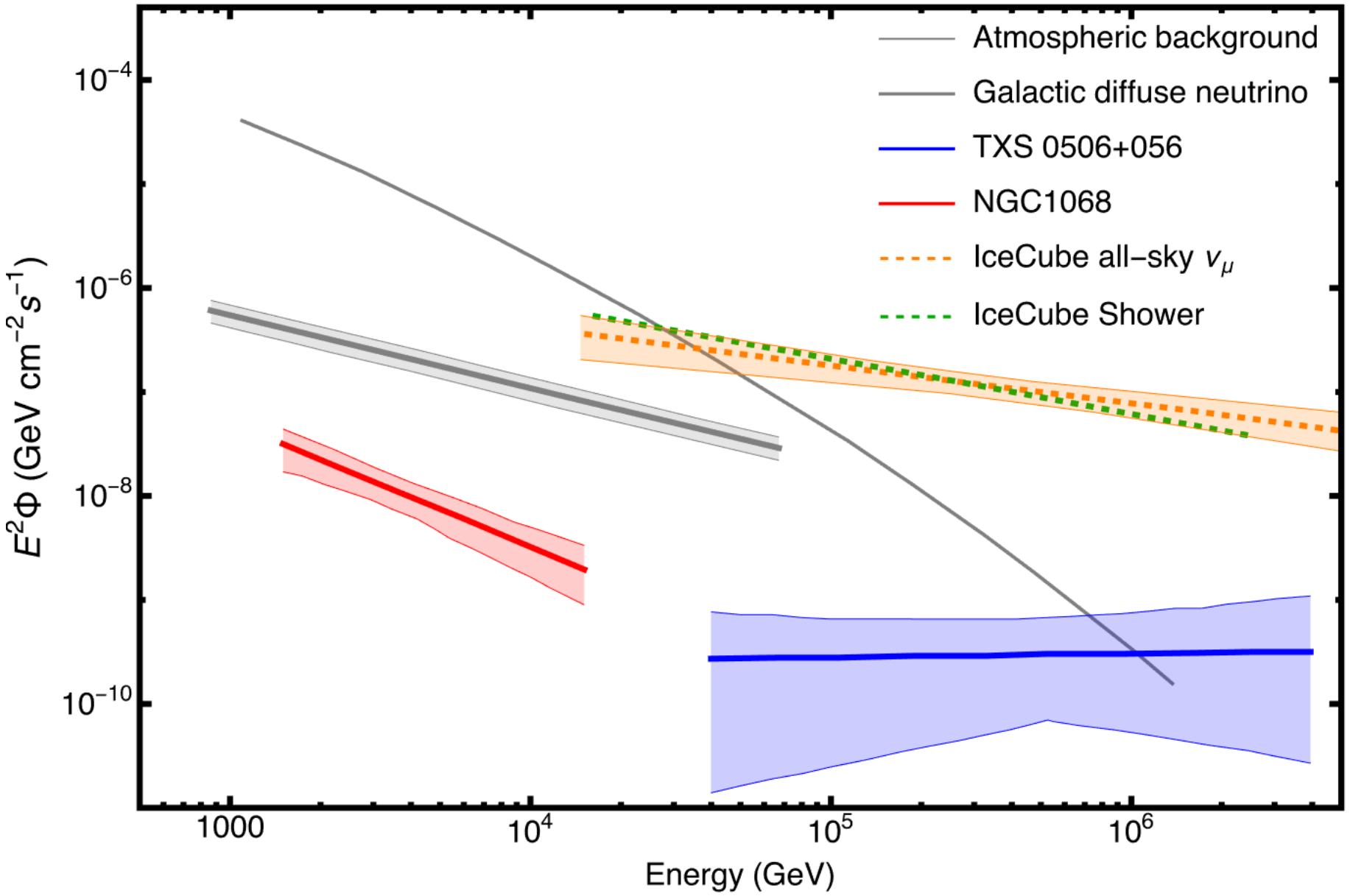
NGC 1068: 4.2 σ

TXS 0506+056: 3.5 σ

PKS 1424+240: 3.7 σ

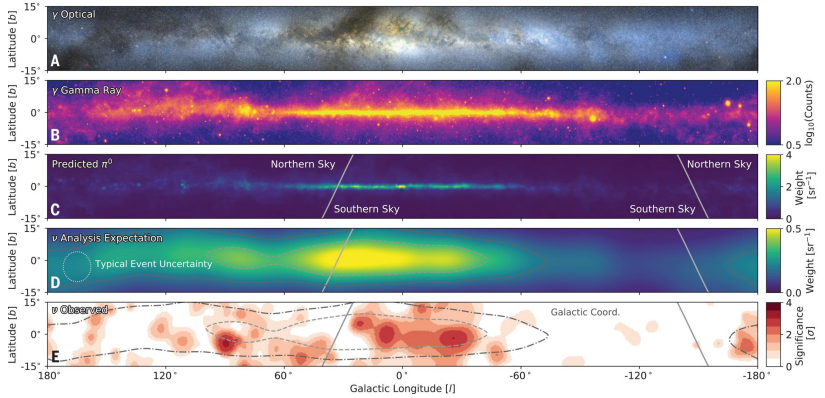
Sources in the northern sky

Science 378 (2022) 538-543



NGC 1068 and TXS 0506+056 present two types of sources, each only contributes less than 1%.

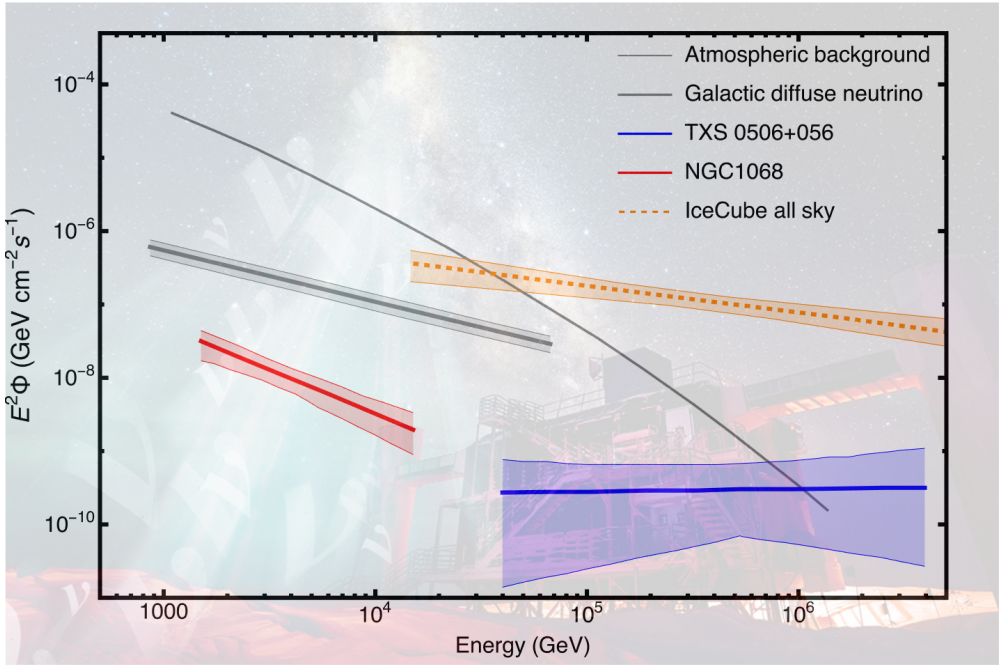
Neutrino excess from Galactic plane: 4.5σ



Contribute not more than 10%.

Phys.Rev.D 108 (2023) 6, L061305

Questions remain



Origin of cosmic rays

Astrophysics studies

Neutrino properties and fundamental physics

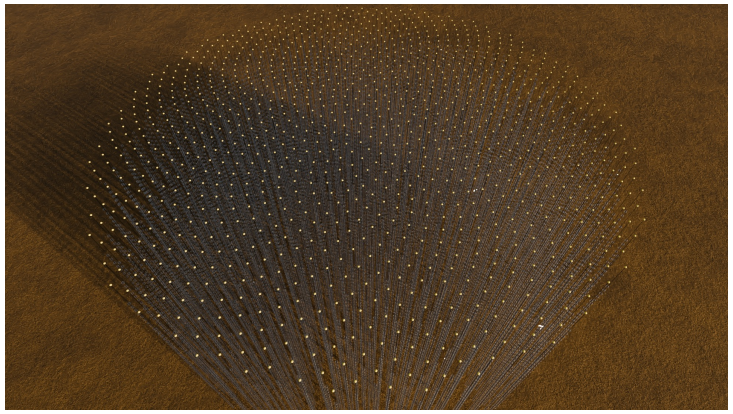
The next generation neutrino observatory is needed.

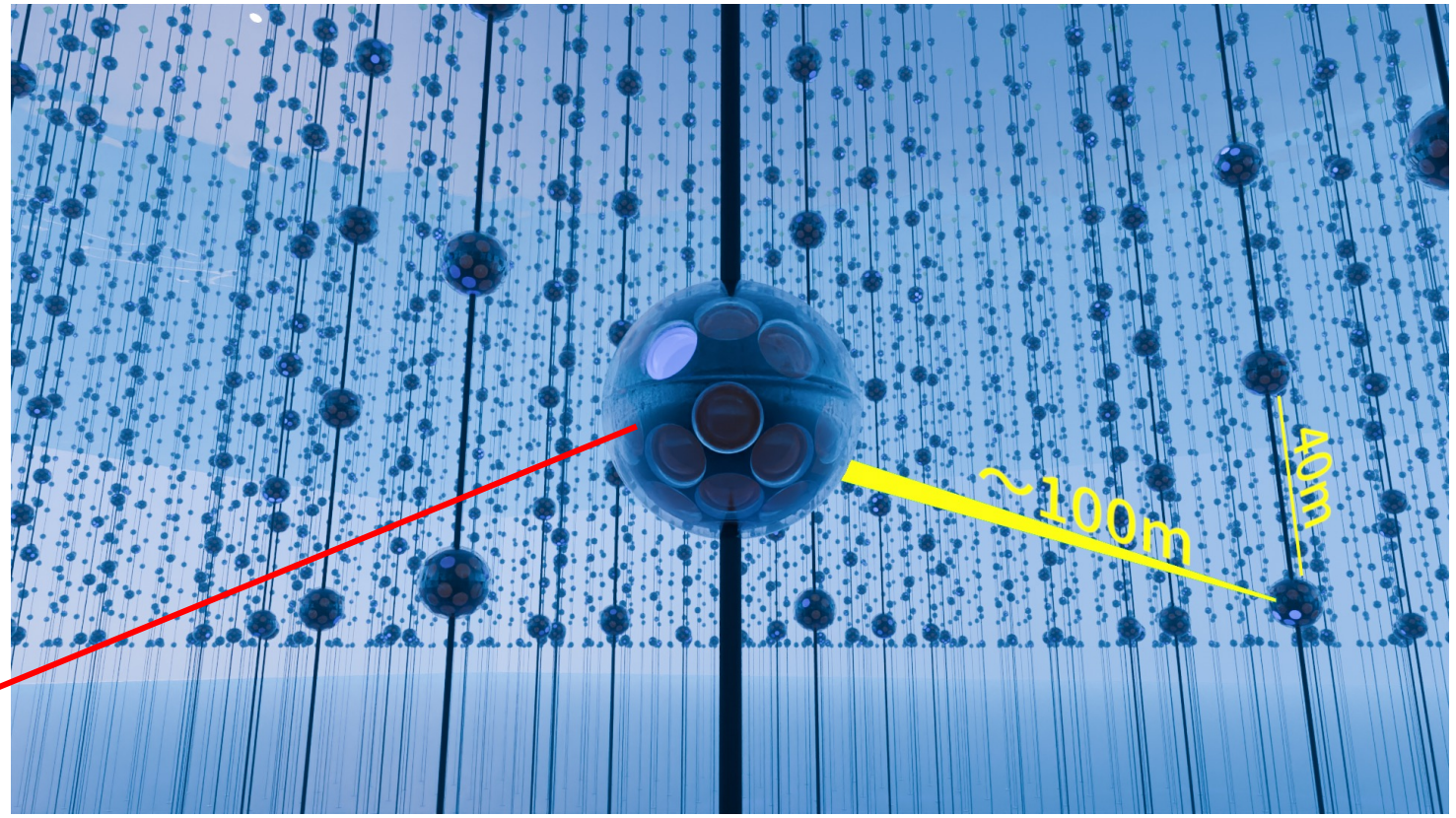
Higher statistic
Better resolution

→ Bigger, denser, deeper

Neutrino Observatory in the Nanhai (NEON)

arxiv: 2408.05122





Coverage: 10 km^3

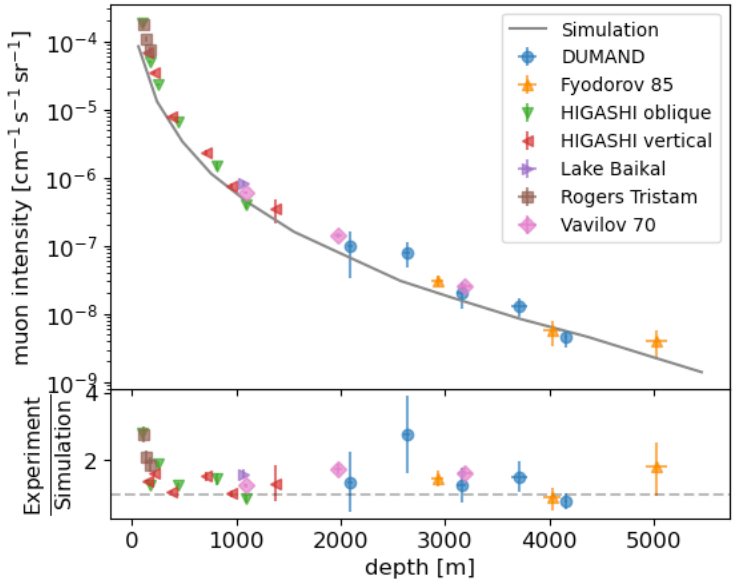
Depth: 1700 and 3500 meters

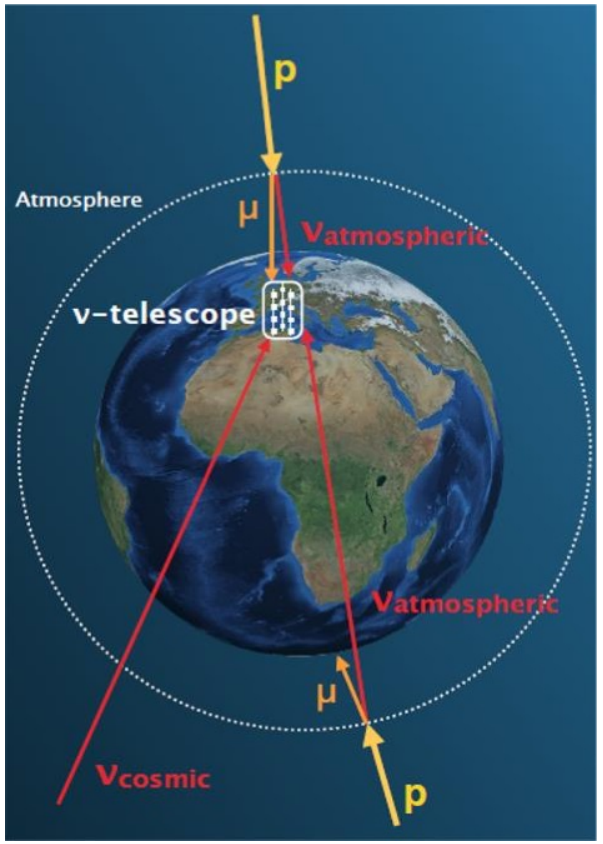
1200 strings, 6.6 million PMTs

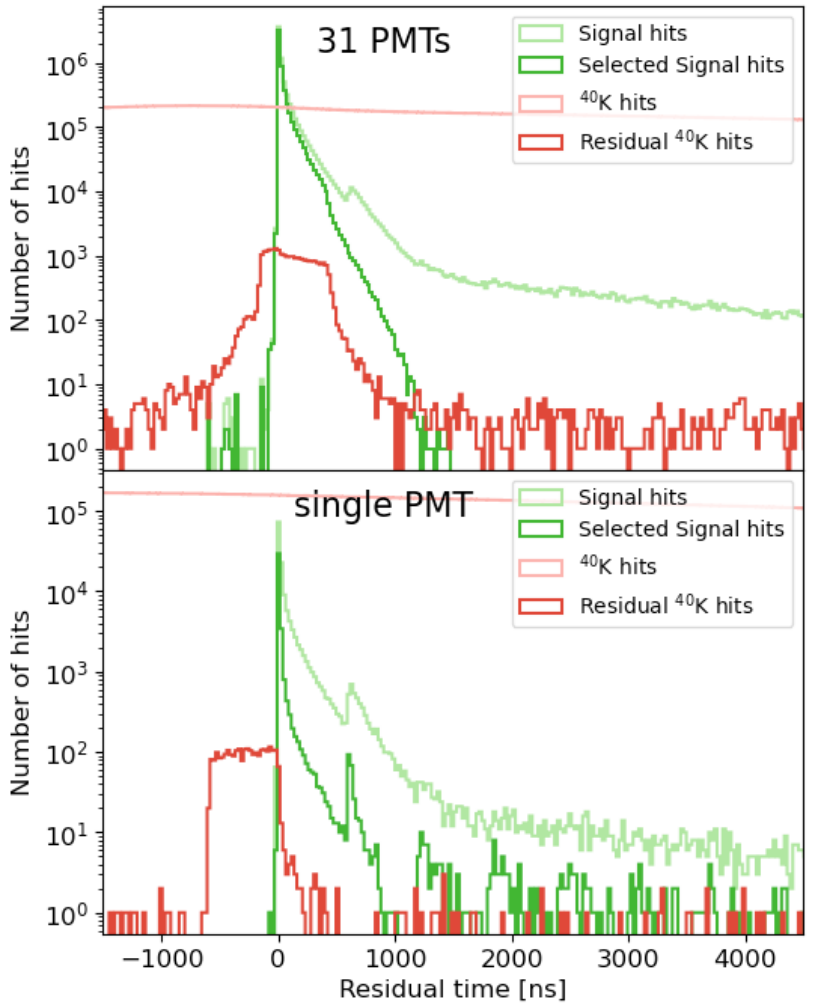
Deep-sea background study

Atmospheric muons:
Removable (directions)

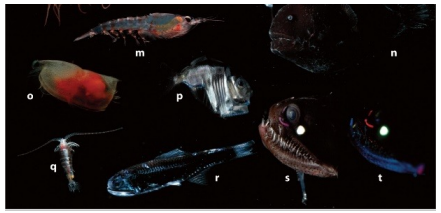
Atmospheric neutrinos:
Physics studies (oscillation, mass ordering)







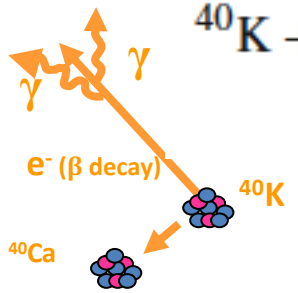
Environment noise:
^{40}K decay
Bioluminescence



$$^{40}\mathrm{K} \rightarrow {}^{40}\mathrm{Ca} + e^- + \overline{\nu}_e \quad (89.3\%)$$

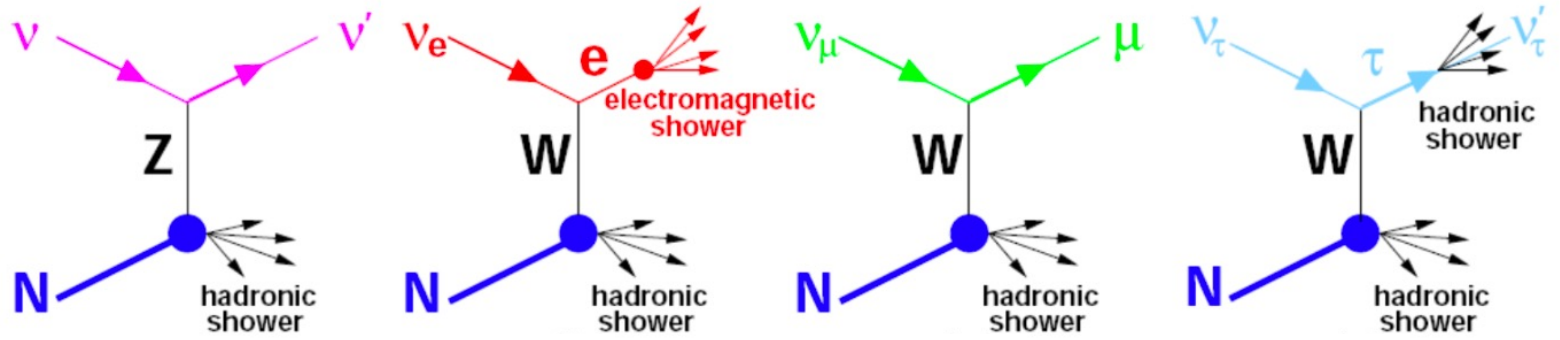
$$^{40}\mathrm{K} + e^- \rightarrow {}^{40}\mathrm{Ar}^* + \nu_e \quad (10.7\%)$$

$$\hookrightarrow {}^{40}\mathrm{Ar} + \gamma$$

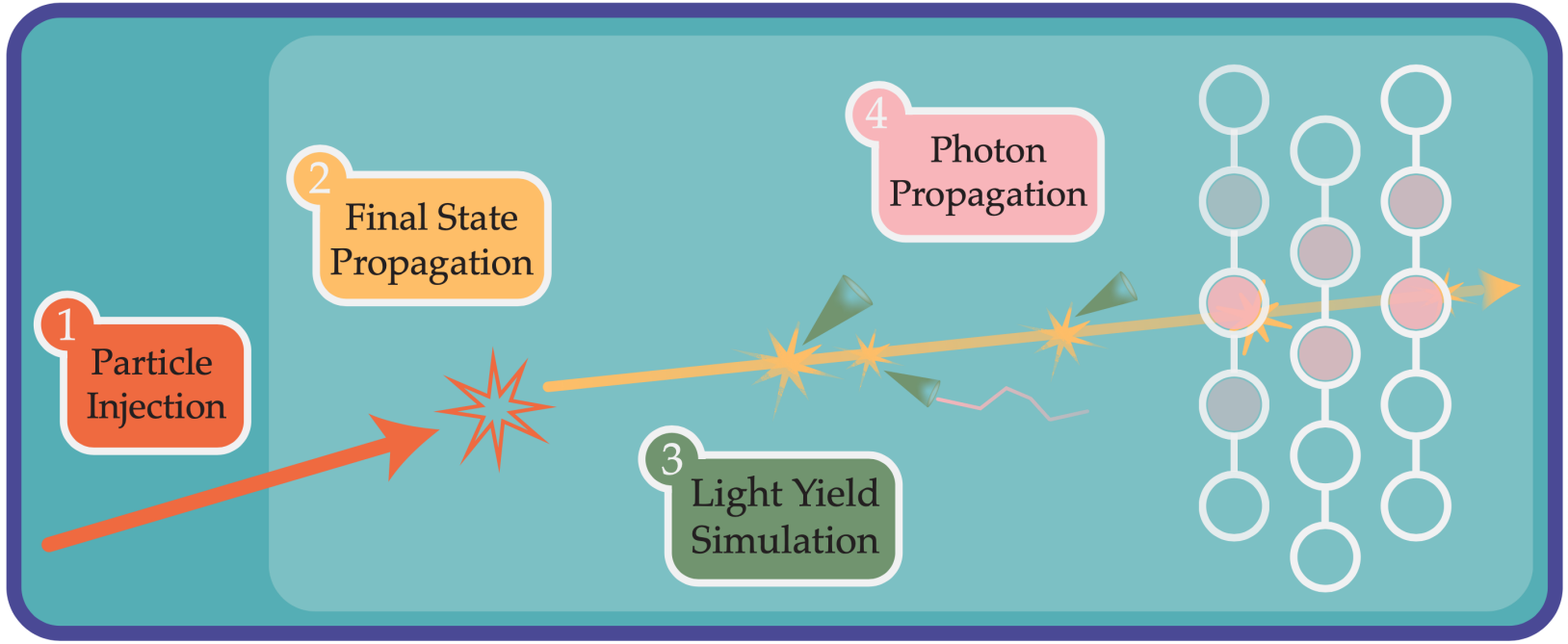


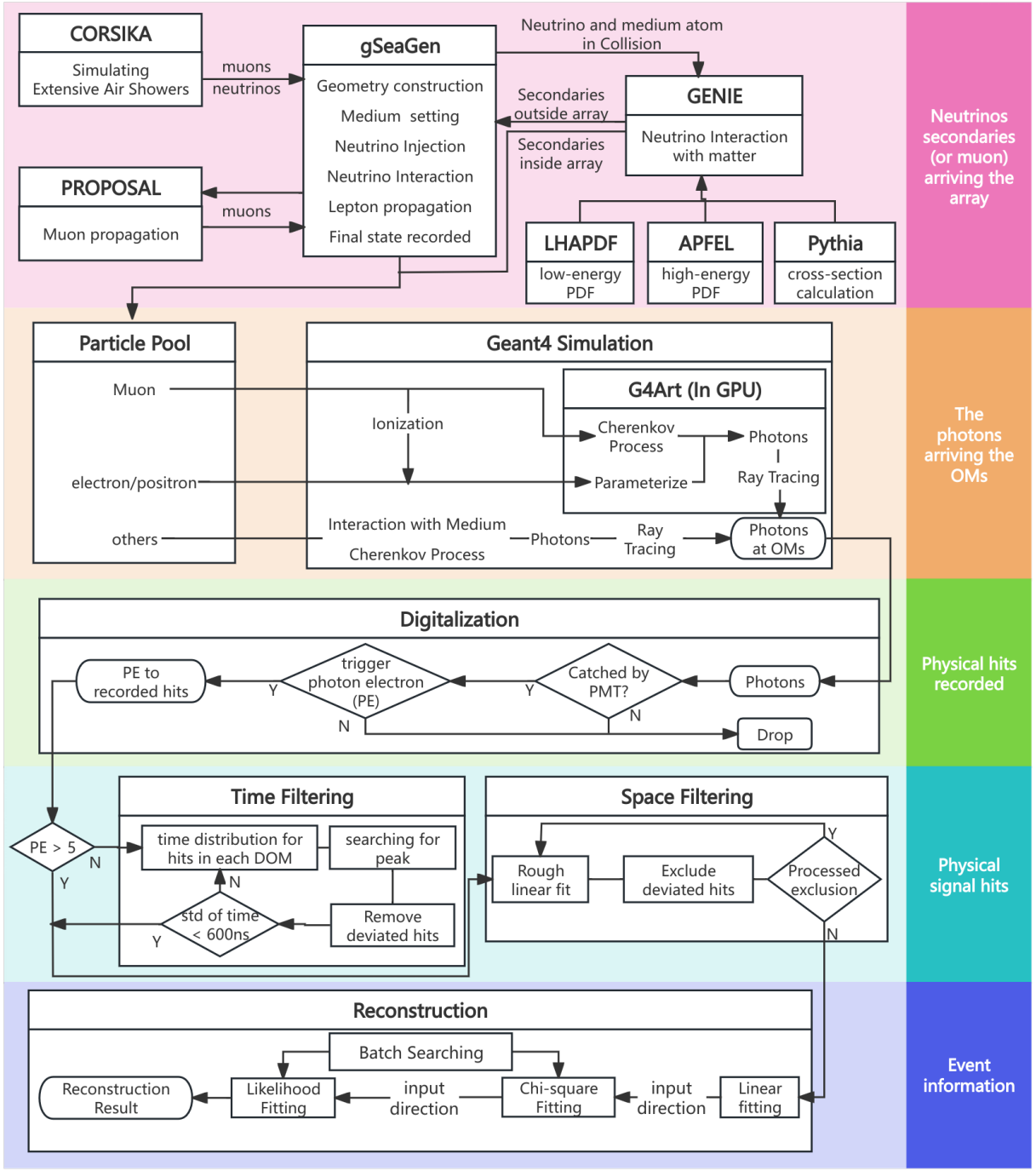
The simulation chain

- Neutrino interacts with water
- Secondaries propagating in water
- Photons are emitted secondary particles
- Propagation of photons, considering scattering and absorption



Neutrino interactions:
NC, $\nu_e CC, \nu_\mu CC, \nu_\tau CC$





Event generator:

- gSeaGen (Base on GENIE)
- High Energy Extension: APFEL

GEANT4 & G4ART:

Process Cherenkov Photons on the GPU

Energy range: 100keV - 100PeV
Neutrino type: All type

Reconstruction

1. Linear fit (fastest)

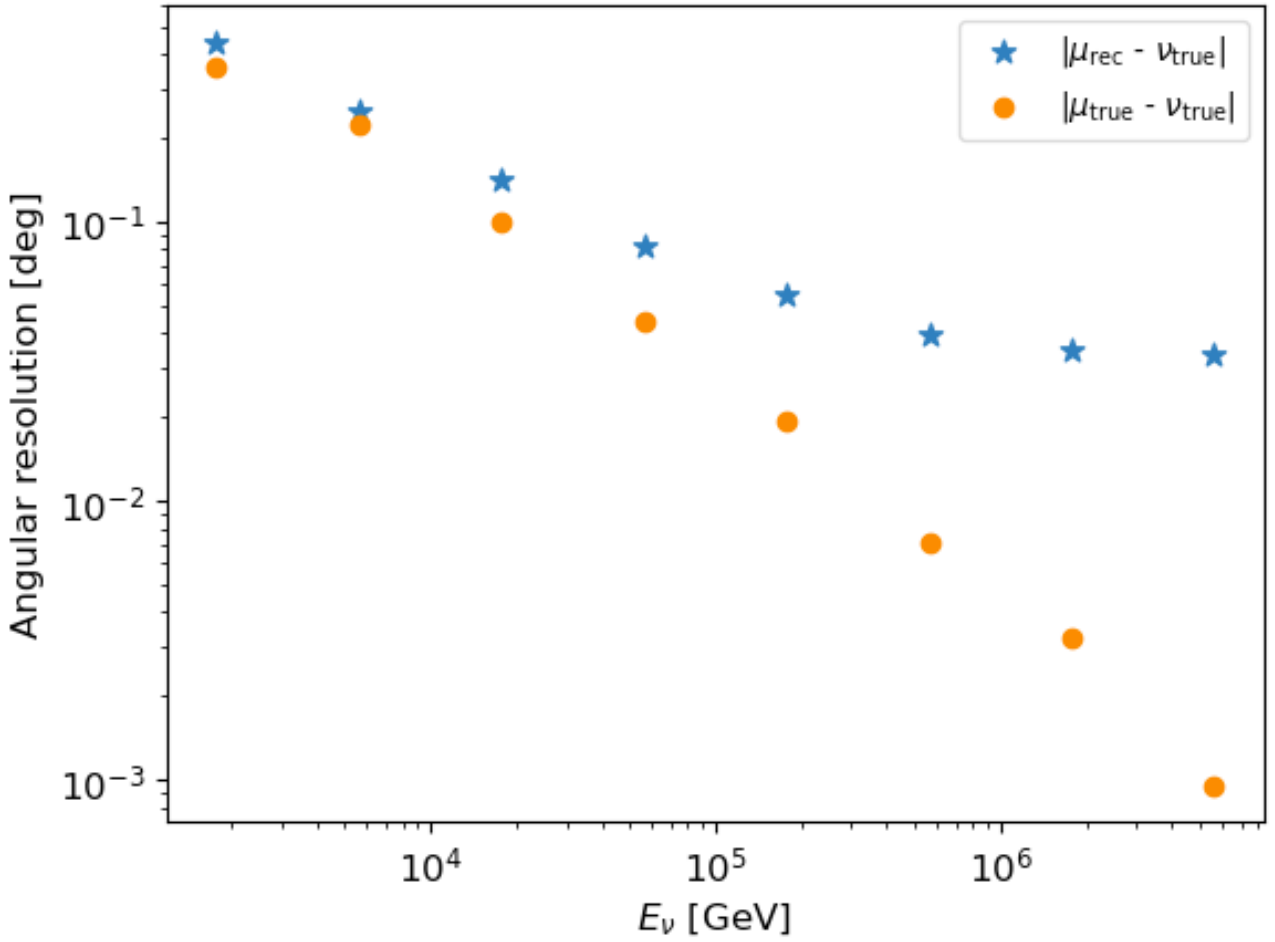
   $\vec{d} = \sum_{i,j\,(t_j>t_i)} w_{ij}\left(\overrightarrow{P_j} - \overrightarrow{P_i}\right)$, where $w_{i,j} = q_j + q_i$ and q is photon electron

2. Chi-square fit

   $\chi^2 = \sum_i (t^i_{\mathrm{res}})^2$

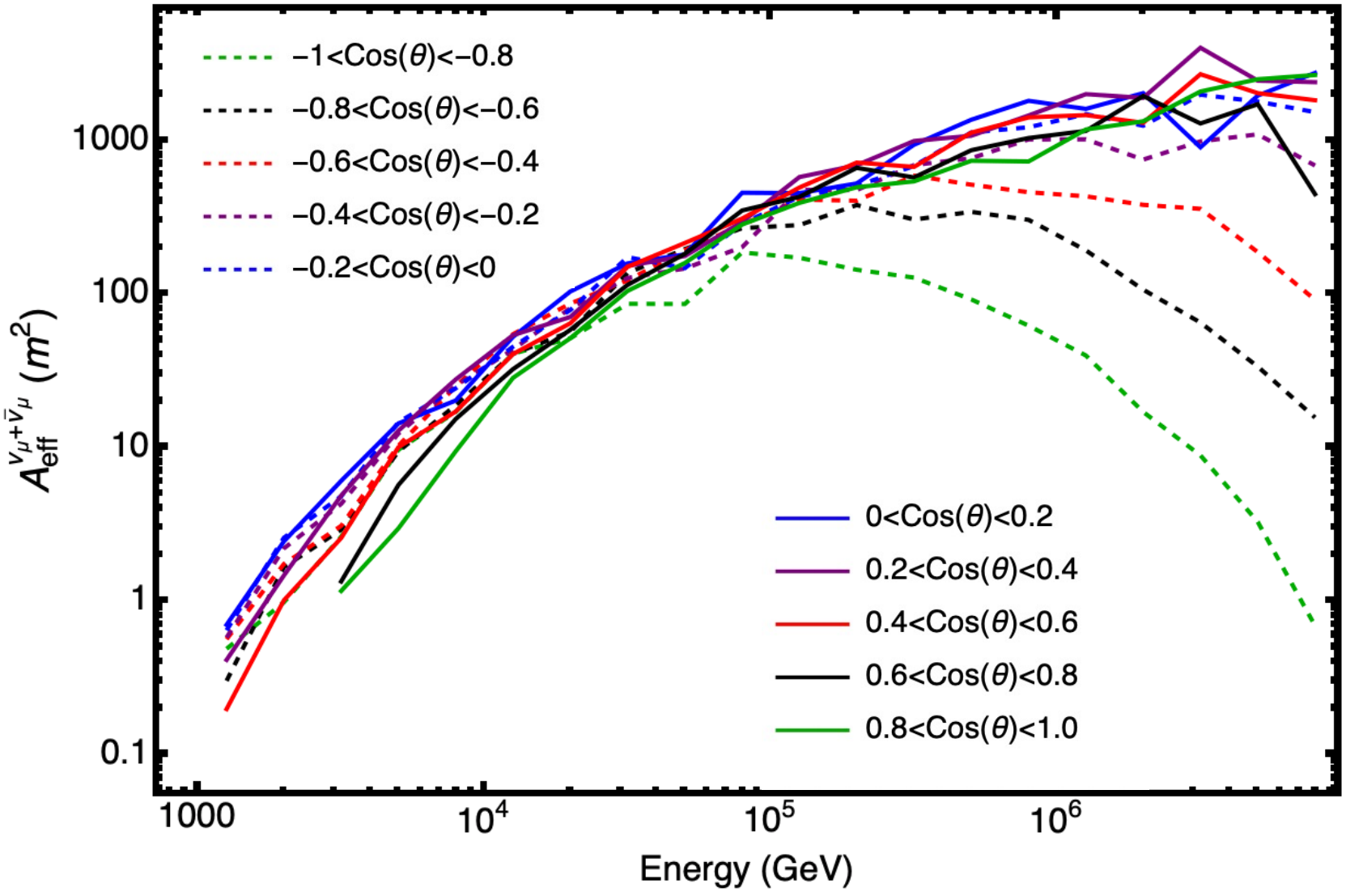
3. PDF fit (the most accurate)

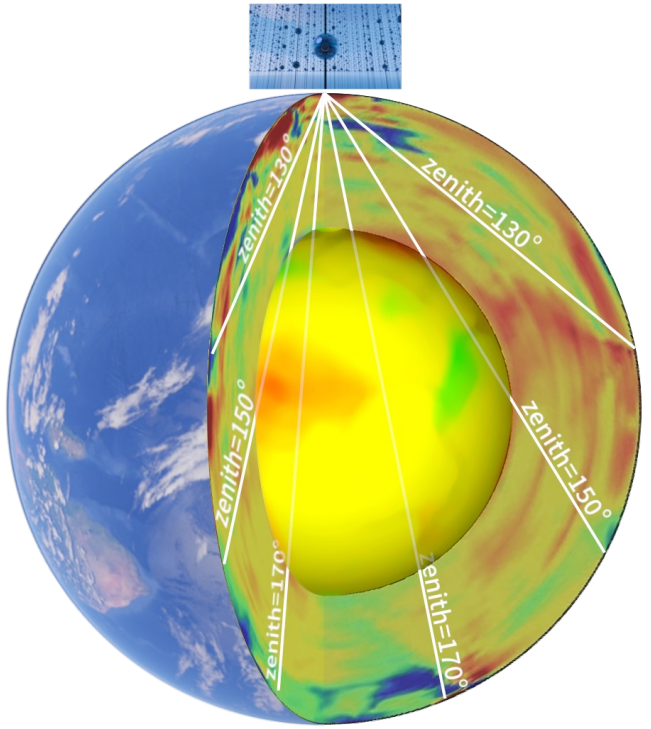
   $L(t^1_{\mathrm{res}}, t^2_{\mathrm{res}}, \ldots, t^n_{\mathrm{res}} \mid \overrightarrow{P}, \vec{d}) = \sum_i f(t^i_{\mathrm{res}} \mid \overrightarrow{P}, \vec{d})$



@ 1 PeV, the angular resolution can get to 0.03 degree

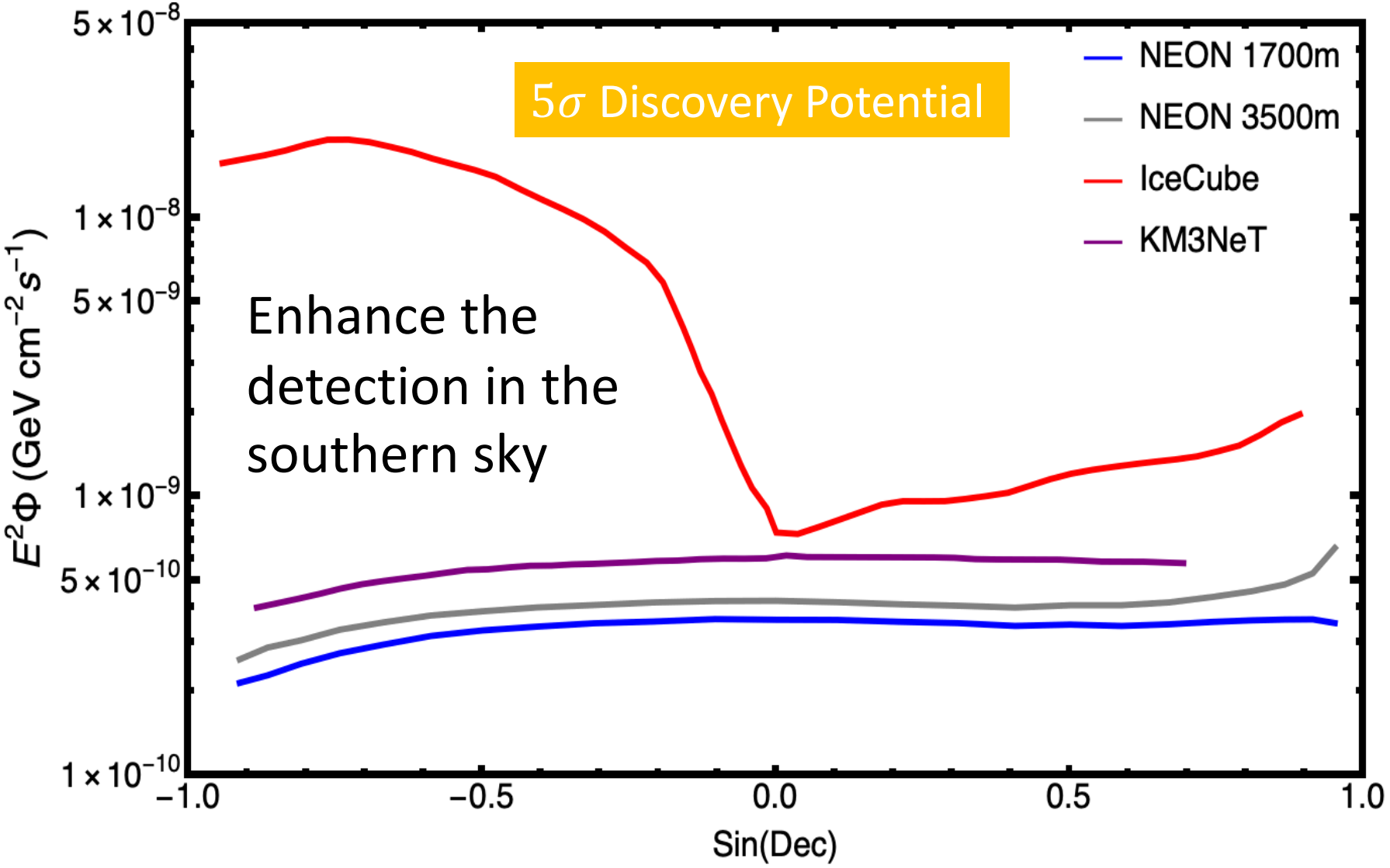
Effective Area

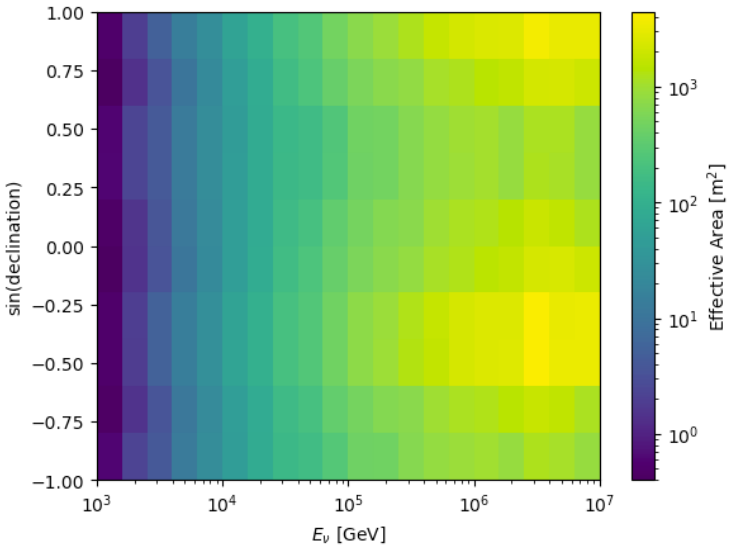


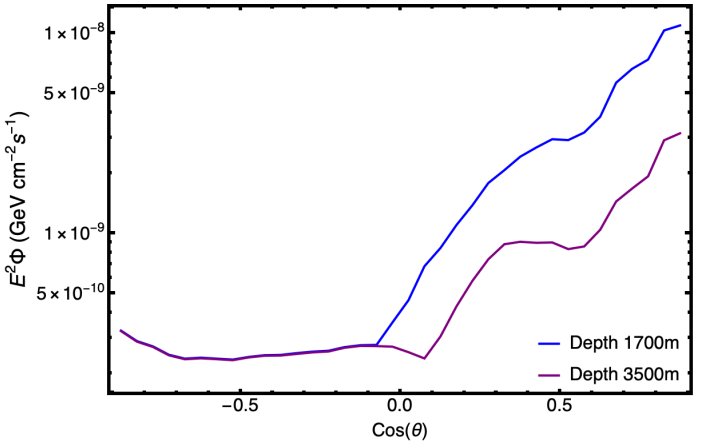


With different depth, the A_{eff} may differ by a factor of four for the down-going events

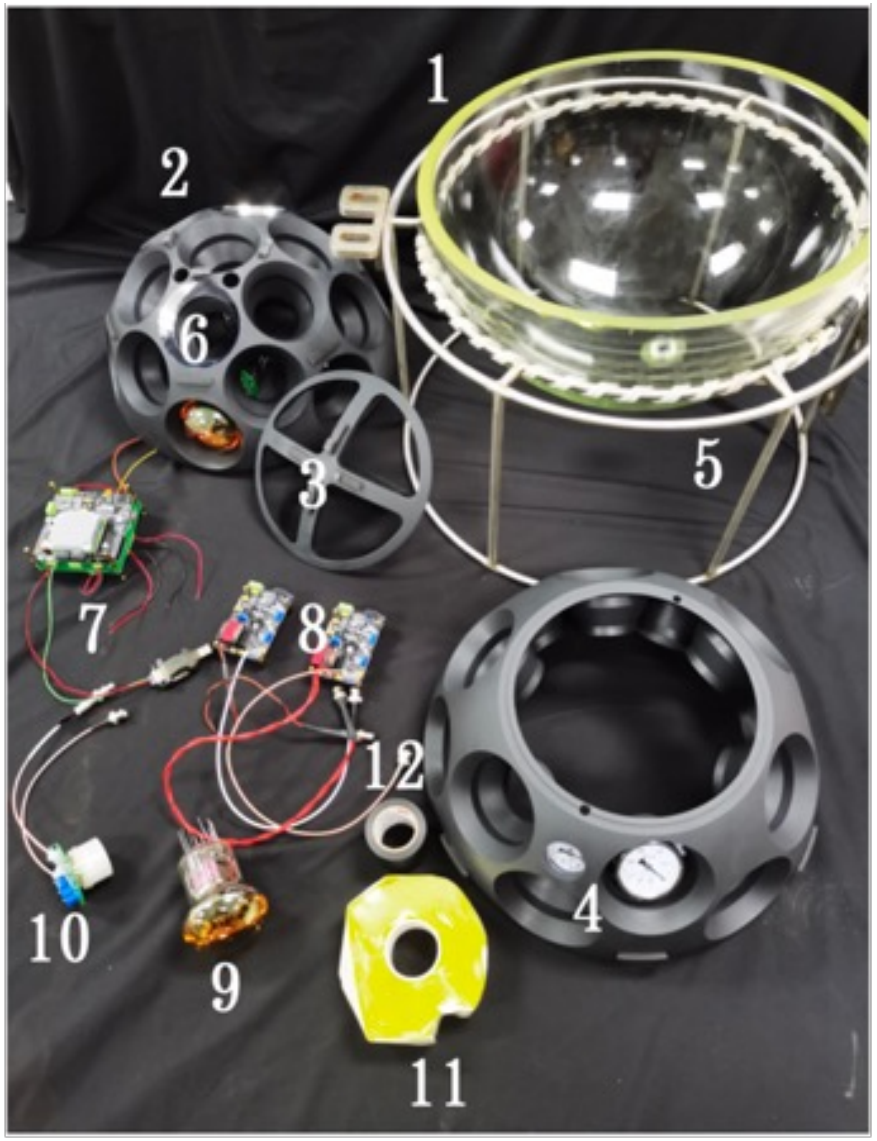
Sensitivity



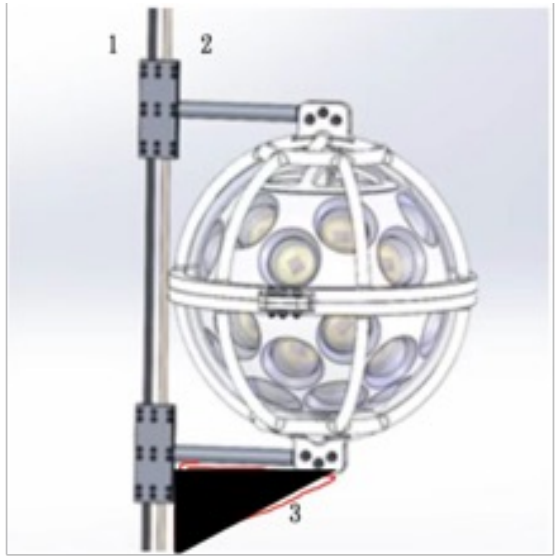




Current Status of optical module



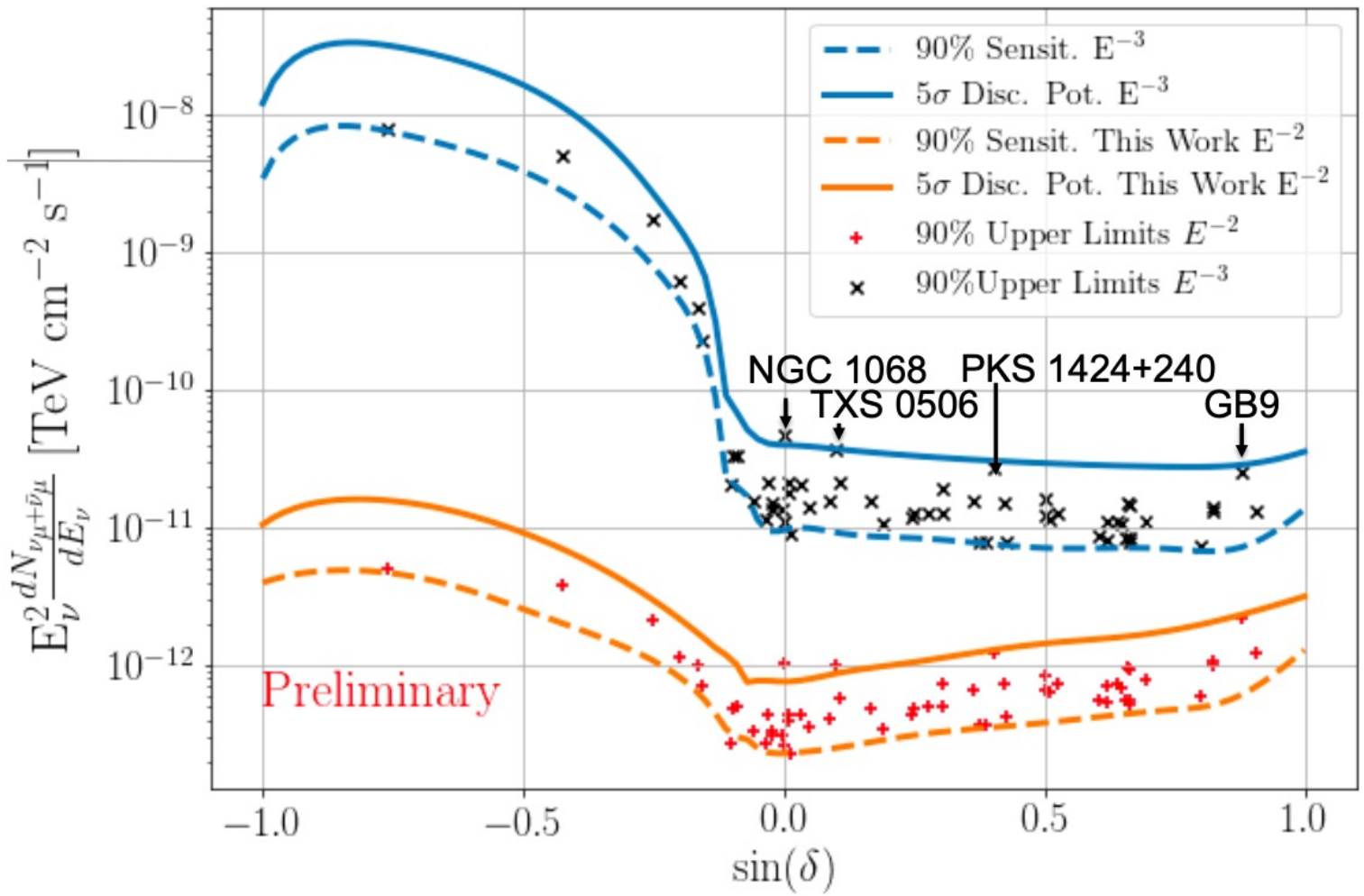
NVN N2031 and the Hamamatsu R14374



Future Plan

- As one of the most important member in multi-messenger astronomy, neutrinos telescopes should be constructed with better resolution and sensitivity.
- More improvements and hard work are planned and ongoing.
- The build and construction of deep-sea neutrino telescope is challenging, but super attractive.

Thank you!


90% Sensit. E^{-3}
5σ Disc. Pot. E^{-3}
90% Sensit. This Work E^{-2}
5σ Disc. Pot. This Work E^{-2}
90% Upper Limits E^{-2}
90%Upper Limits E^{-3}
NGC 1068
TXS 0506
PKS 1424+240
GB9
Preliminary
$E_\nu^2 \frac{dN_{\nu_\mu+\bar{\nu}_\mu}}{dE_\nu}$ [TeV cm^{-2} s^{-1}]
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
−1.0
−0.5
0.0
0.5
1.0
$\sin(\delta)$