https://www.snowmass21.org/docs/files/summaries/NF/SNOWMASS21-NF3_NF2-CF7_CF1-TF9_TF8_Katori-073.pdf

New Physics with Astrophysical Neutrino Flavor

Test of neutrino properties
- Neutrino lifetime
- Number and nature of neutrinos
- Mass-varying neutrinos

Tests of signatures of a dark Universe
- Dark matter as source
- Dark matter as background
- Dark energy as background

Tests of fundamental physics:
- Non-standard interactions
- Neutrino self-interactions
- Long-range forces
- Modified neutrino-nucleus interactions
- Quantum decoherence
- Lorentz and CPT invariance violation
- Extra dimensions

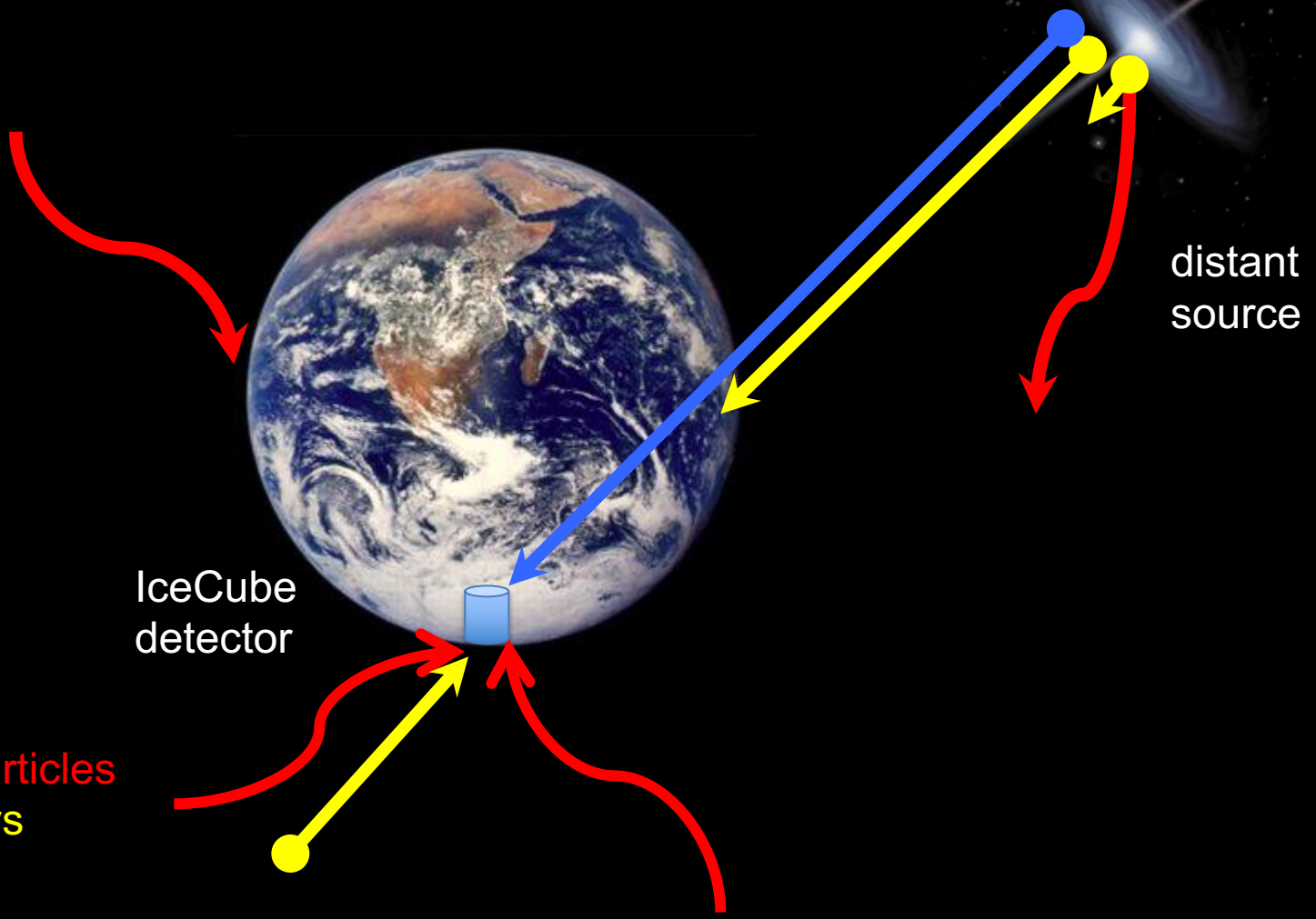
Carlos A. Argüelles (Harvard University)
Mauricio Bustamante (NBI, Univ. of Copenhagen)
Teppei Katori (King's College London)
Ali Kheirandish (The Pennsylvania State University)
Sergio Palomares-Ruiz (Universitat de València - CSIC)
Jordi Salvadó, Universitat de Barcelona)
Aaron C. Vincent (Queen's University)

for IceCube-Gen2 collaboration

https://www.snowmass21.org/docs/files/summaries/NF/SNOWMASS21-NF3_NF2-CF7_CF1-TF9_TF8_Katori-073.pdf

New Physics with Astrophysical Neutrino Flavor

High-energy astrophysical neutrinos have a unique role in Multi-messenger astronomy



https://www.snowmass21.org/docs/files/summaries/NF/SNOWMASS21-NF3_NF2-CF7_CF1-TF9_TF8_Katori-073.pdf

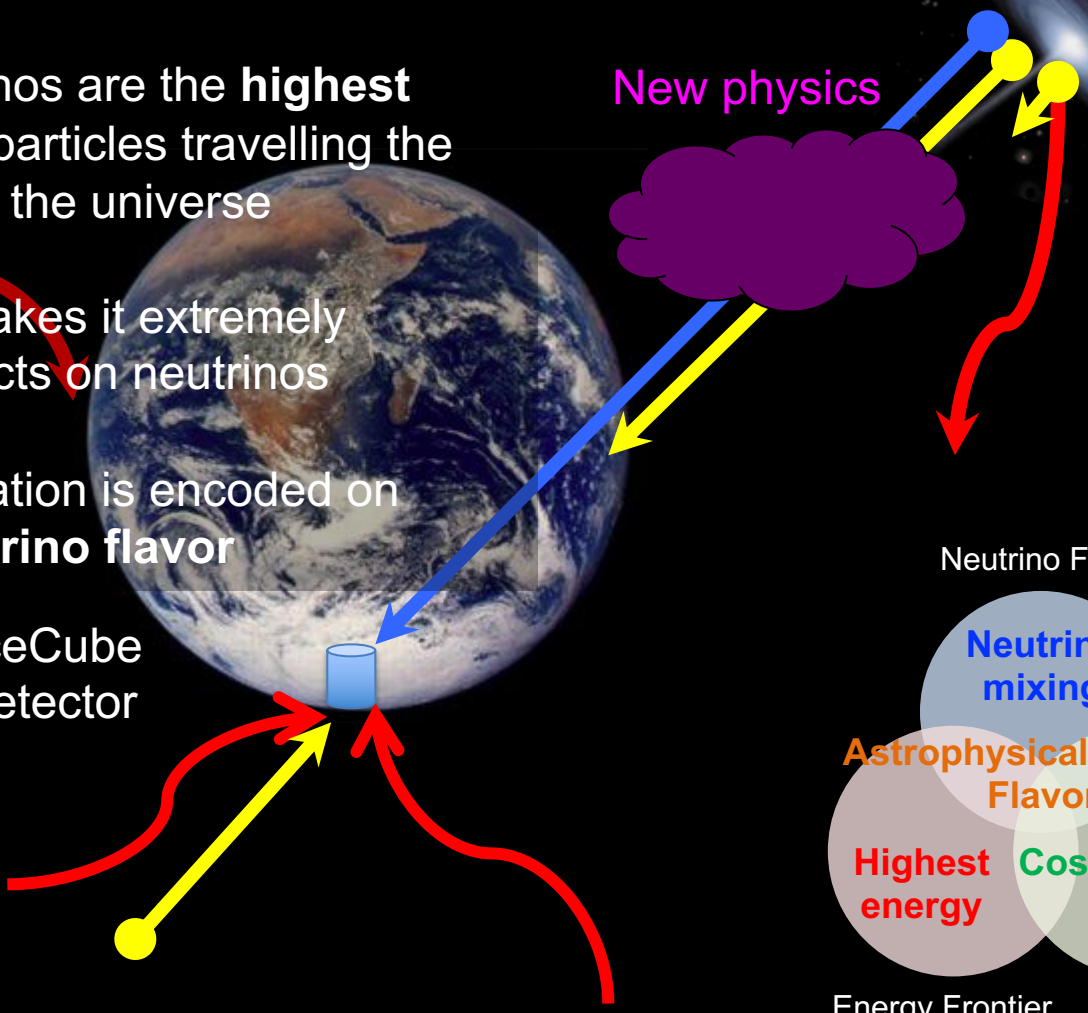
New Physics with Astrophysical Neutrino Flavor

High-energy astrophysical neutrinos have a unique role in Multi-messenger astronomy

Astrophysical neutrinos are the **highest energy** elementary particles travelling the **longest distance** in the universe

Neutrino mixing makes it extremely sensitive to any effects on neutrinos

New physics information is encoded on **Astrophysical neutrino flavor**



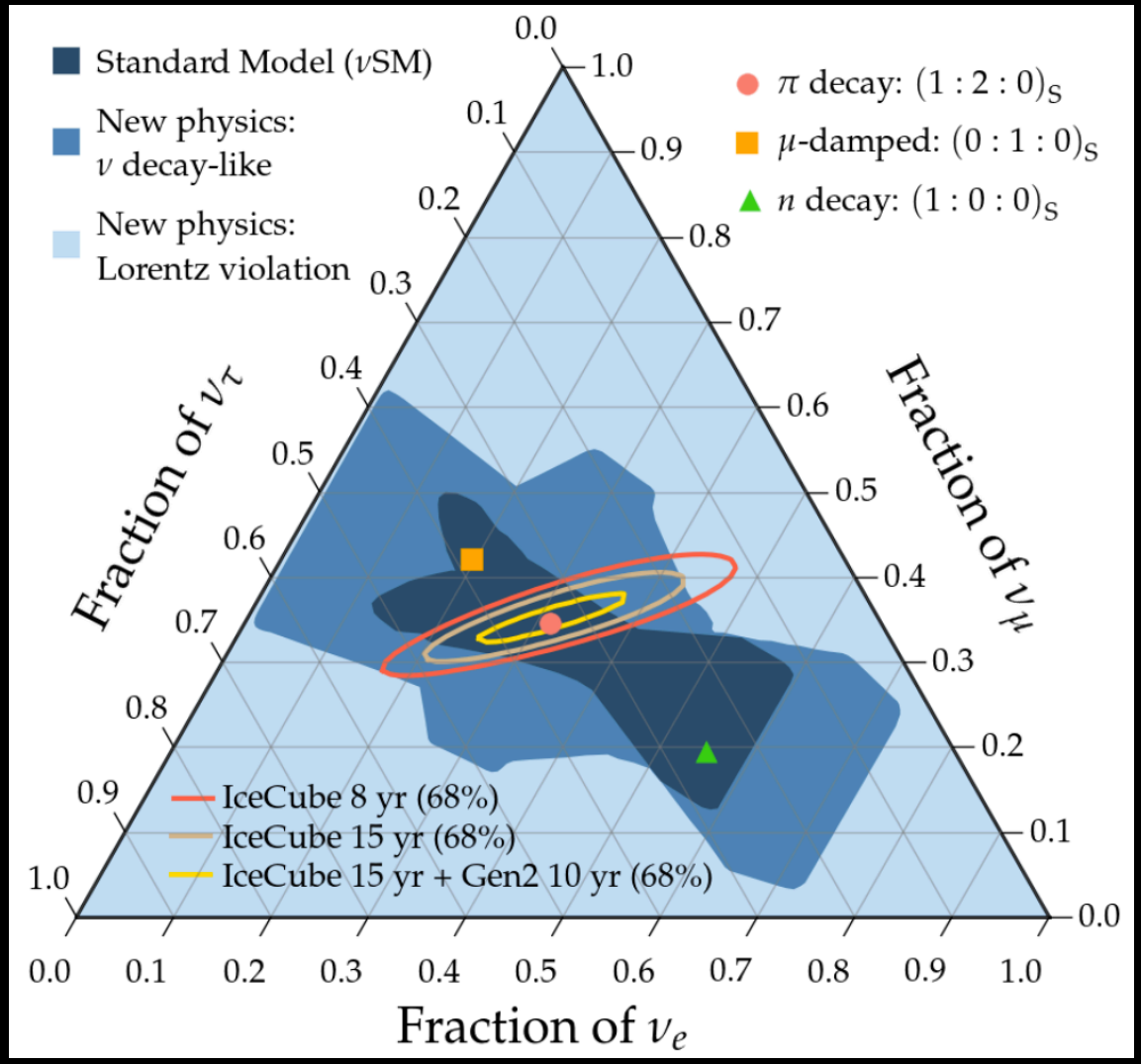
https://www.snowmass21.org/docs/files/summaries/NF/SNOWMASS21-NF3_NF2-CF7_CF1-TF9_TF8_Katori-073.pdf

Flavor triangle ($\nu_e : \nu_\mu : \nu_\tau$)

Astrophysical neutrino flavor is measured as **flavor ratio**.

Standard Model predicted observable flavor ratio within the dark blue region (~1:1:1).

Very small amount of new physics can deviate flavor ratio from 1:1:1.



IceCube-Gen2, arXiv:2008.04323 (to be published, JPhysG)

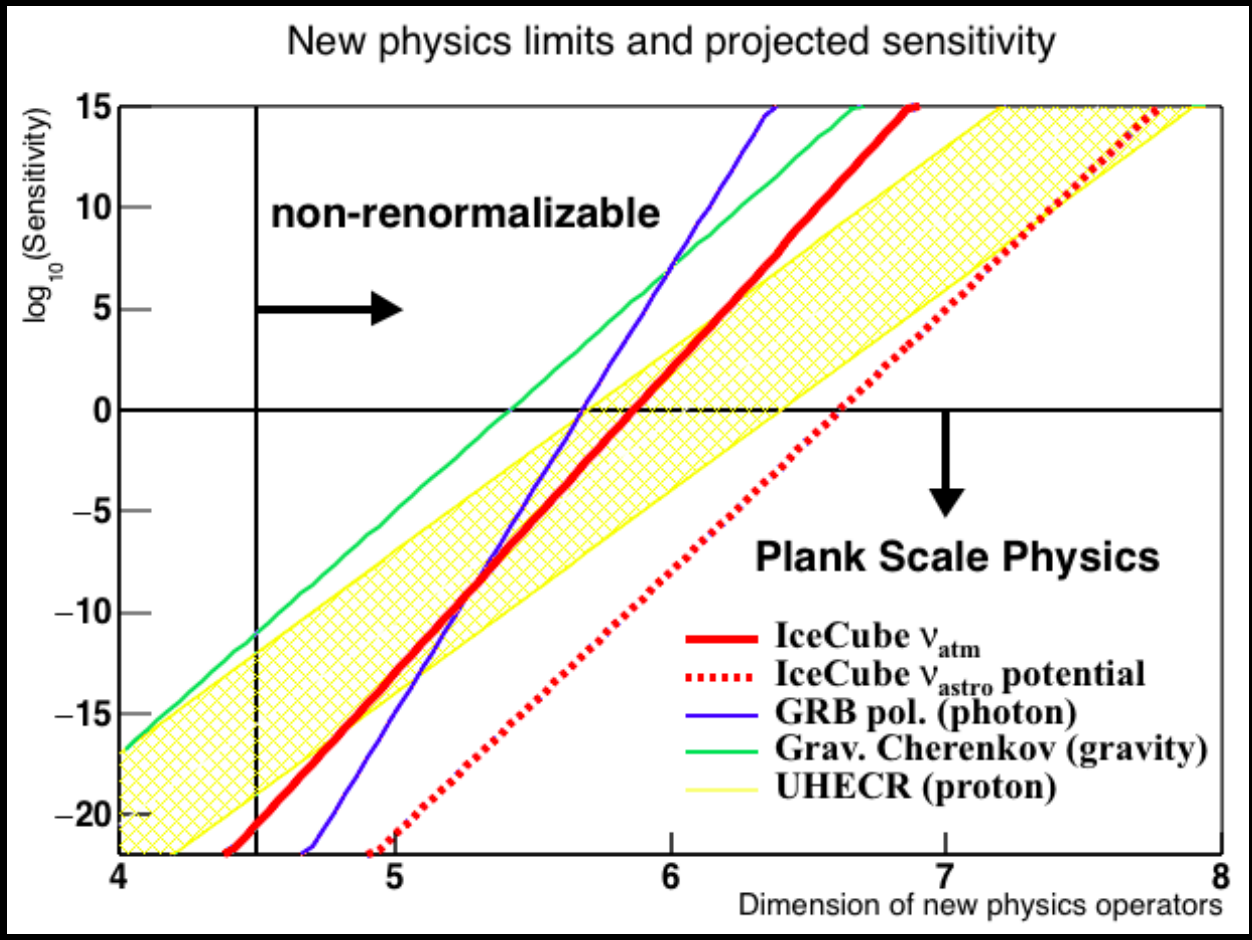
https://www.snowmass21.org/docs/files/summaries/NF/SNOWMASS21-NF3_NF2-CF7_CF1-TF9_TF8_Katori-073.pdf

Effective operator sensitivity

$$\mathcal{H} = \mathcal{H}_{\nu SM} + \frac{\mathcal{O}^{(5)}}{M_{Pl}} E^2 + \frac{\mathcal{O}^{(6)}}{M_{Pl}^2} E^3 + \frac{\mathcal{O}^{(7)}}{M_{Pl}^3} E^4 \cdots$$

Assuming new physics is Planck scale origin, astrophysical neutrino flavor can reach discovery region.

The sensitivity of astrophysical neutrino flavor to new physics vacuum operators are beyond any other technology, from tabletop experiment to cosmology



IceCube (CPT and Lorentz Symmetry 19), arXiv:1906.09240

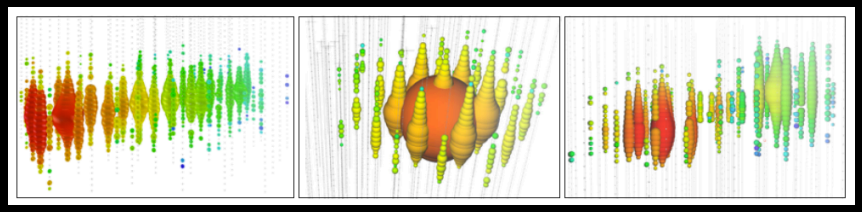
https://www.snowmass21.org/docs/files/summaries/NF/SNOWMASS21-NF3_NF2-CF7_CF1-TF9_TF8_Katori-073.pdf

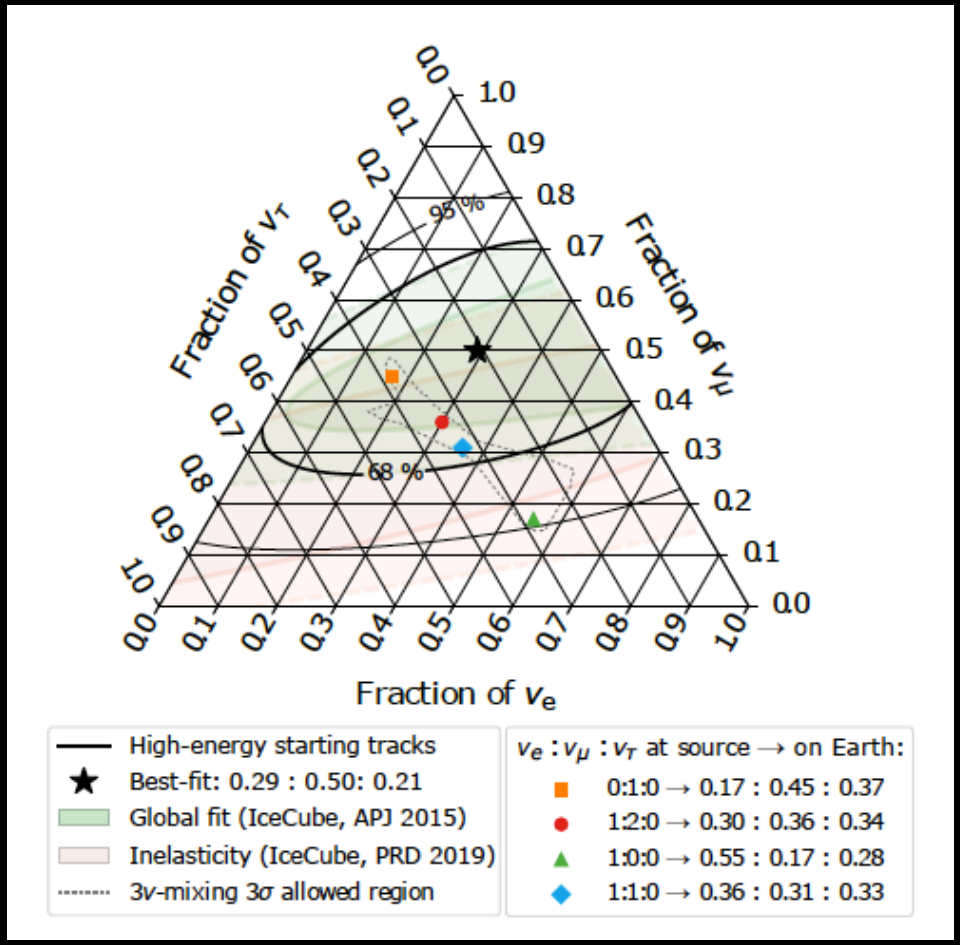
Flavor triangle ($\nu_e : \nu_\mu : \nu_\tau$) in IceCube

Astrophysical neutrino morphology
- Track: muon neutrino CC
- Cascade: electron, tau CC or NC
- Double cascade: tau

Current data statistics and systematics accept large area as astrophysical neutrino flavor ratio

ν_μCC ν_eCC,ν_τCC,NC ν_τCC





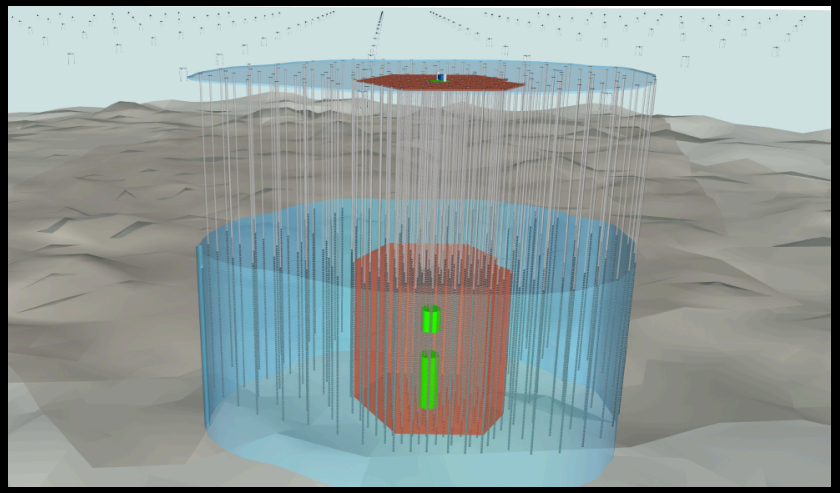
IceCube-Gen2, arXiv:2008.04323 (to be published, JPhysG)

https://www.snowmass21.org/docs/files/summaries/NF/SNOWMASS21-NF3_NF2-CF7_CF1-TF9_TF8_Katori-073.pdf

Flavor triangle ($\nu_e : \nu_\mu : \nu_\tau$) in IceCube-Gen2

Higher statistics with larger effective area

Improved particle identification
- Improved optical sensors
- New calibration
- New PID algorithm (machine learning, etc)



Higher energy neutrinos
- Larger effective area
- Radio arrays

More transient events
- Better constraint of production model

Astrophysical neutrino flavor physics is a new sub-field, it's an old idea but has been developed to the reality only in last few years. This approach uses the best of neutrino, energy, and cosmic frontiers, and it has a high discovery potential for many new physics models.

IceCube-Gen2, arXiv:2008.04323 (to be published, JPhysG)