A First Look at Sky Anisotropies of High-Energy Neutrino Flavours

Bernanda Telalovic, Mauricio Bustamante

What are the astrophysical neutrino flavour arrival directions?

EuCAPT

Could we see new physics if they come from different directions?

NIELS BOHR INSTITUTE

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IceCube has seen a flux of high-energy astrophysical neutrinos!

Which new physics?

Say that ν_e, ν_μ and ν_τ have different arrival directions.

What could cause this?

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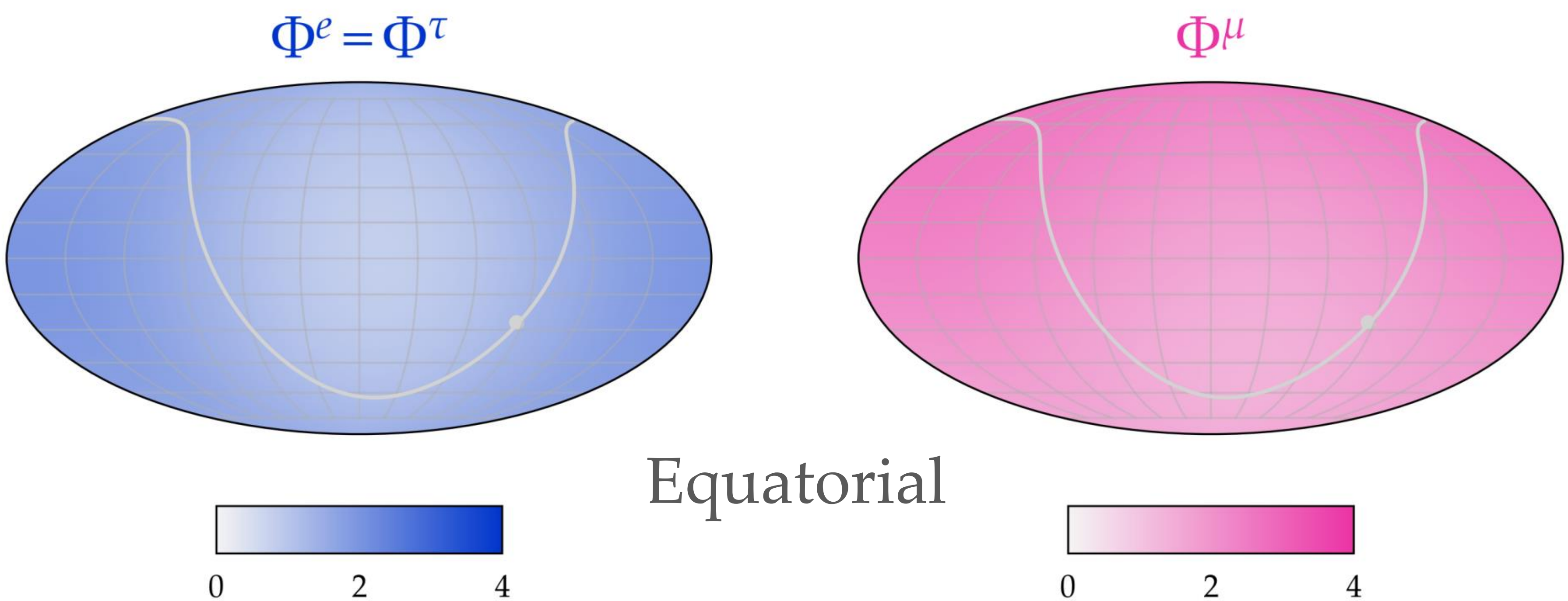
- **Astrophysics:** the high-energy … on mechanisms are different and di… nt, or
- **Fundamental physics**: neutrino flavour oscillations are affected in a directionally-dependent manner.

Different production mechanisms from different directions… seems unlikely

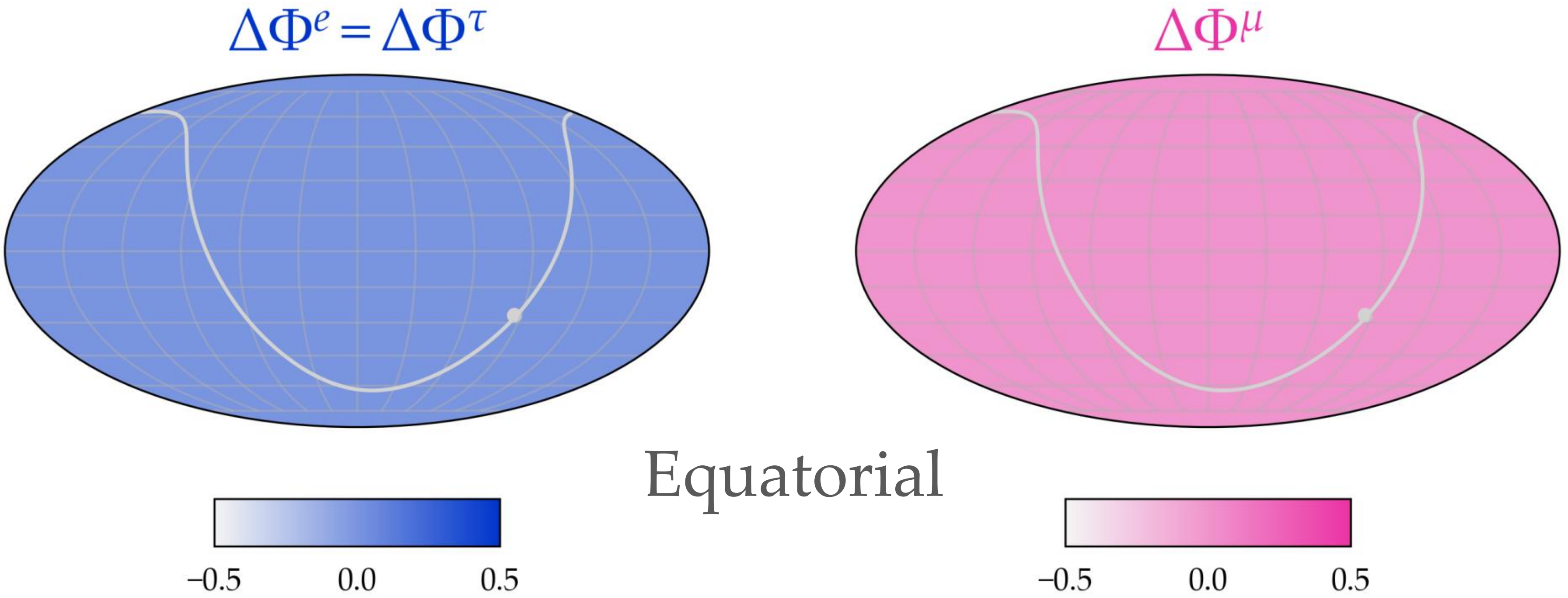
Ok, but are they the same?

We used 7.5 year HESE data to **recover arrival directions of flavours**.



Ok, but are they the same?

If the distributions were isotropic:



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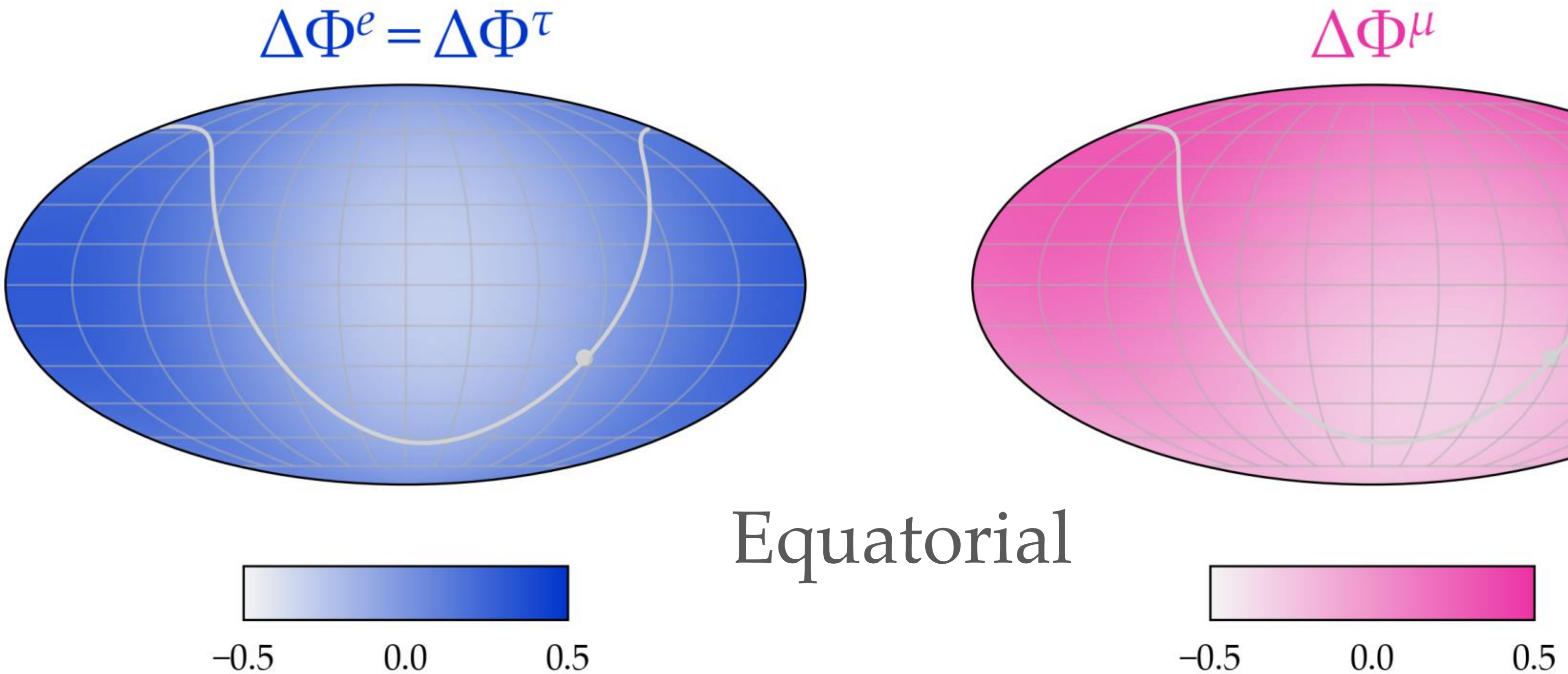
The flavour all-sky-average current **dipole** anisotropy best fits:



Currently large uncertainties–compatible with isotropy at 1σ.

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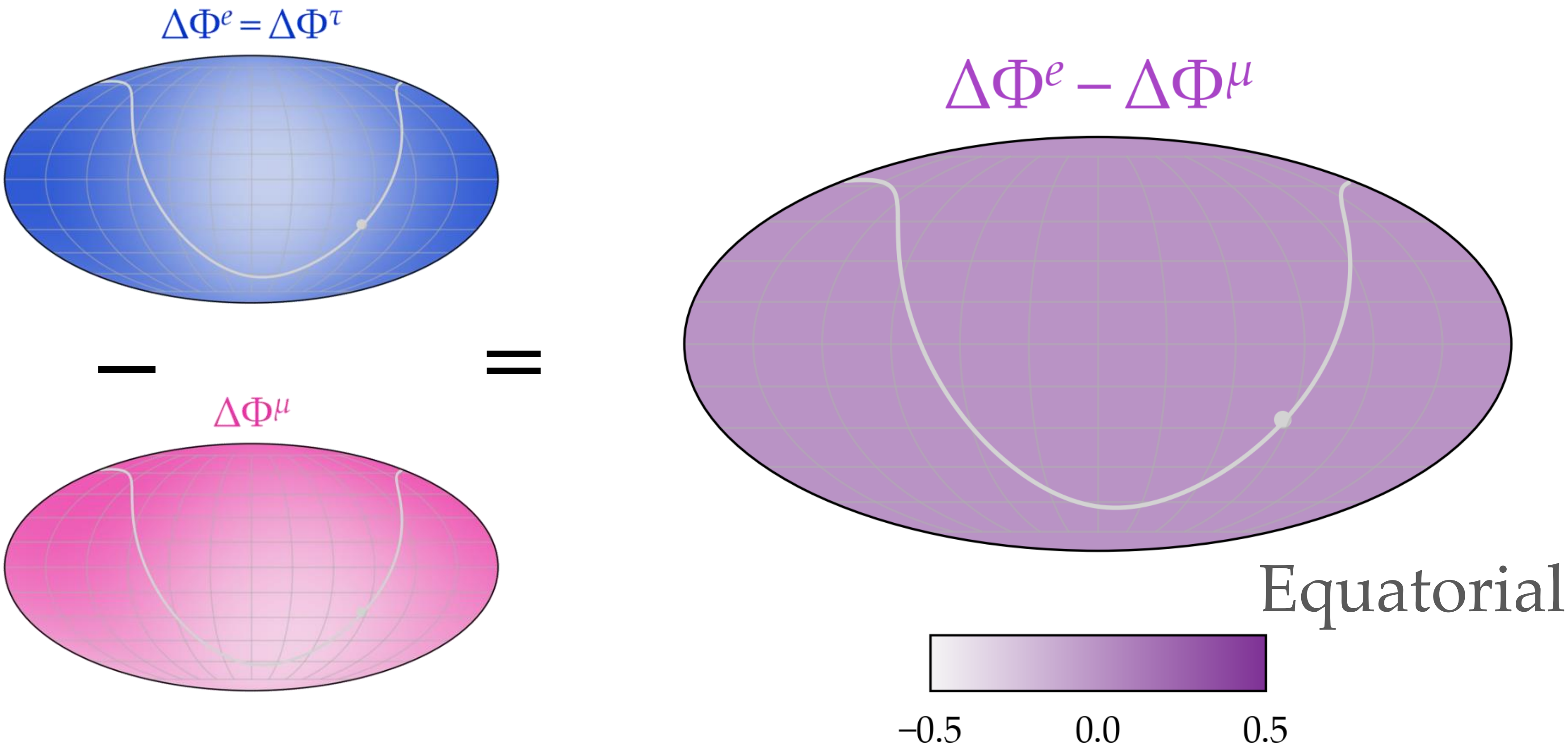

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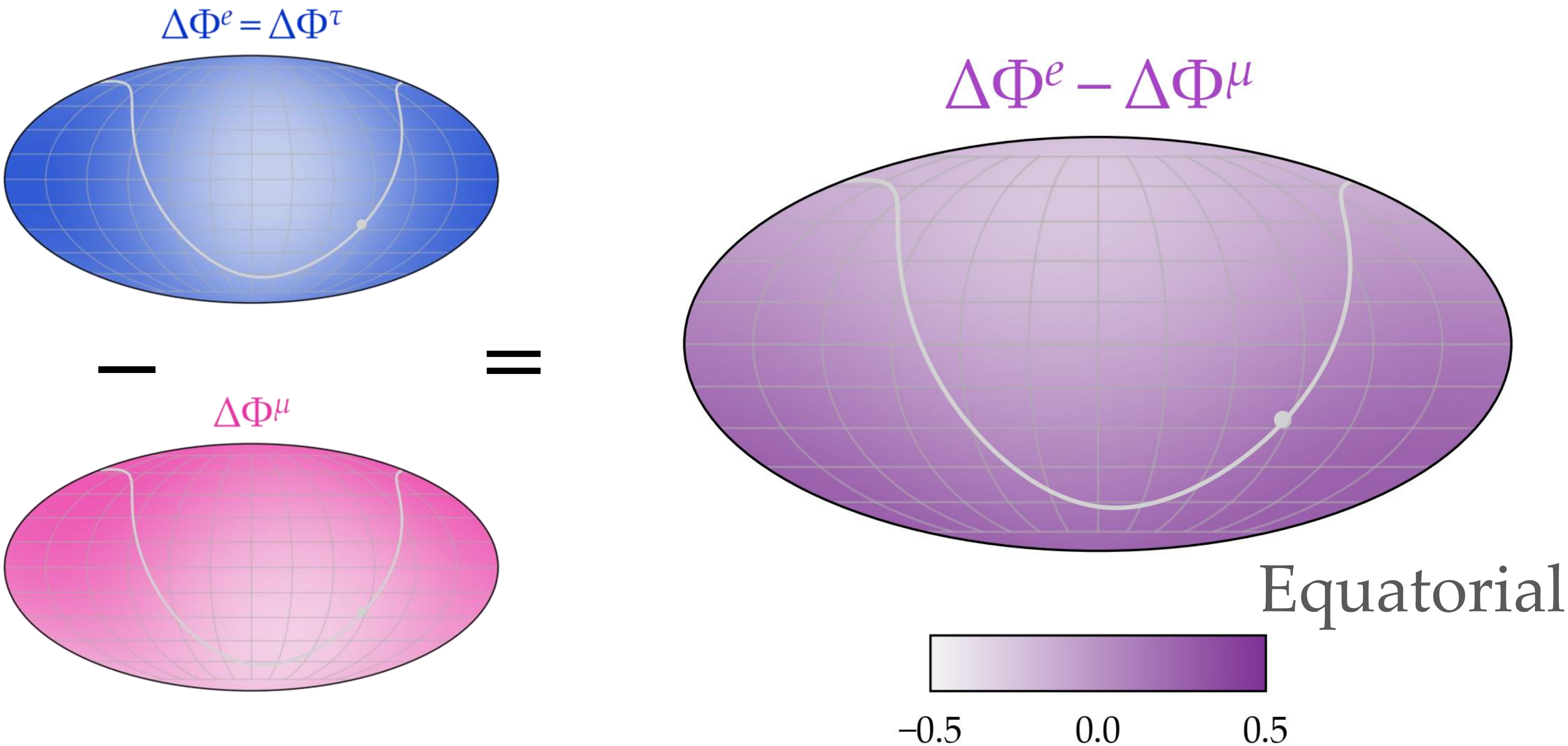

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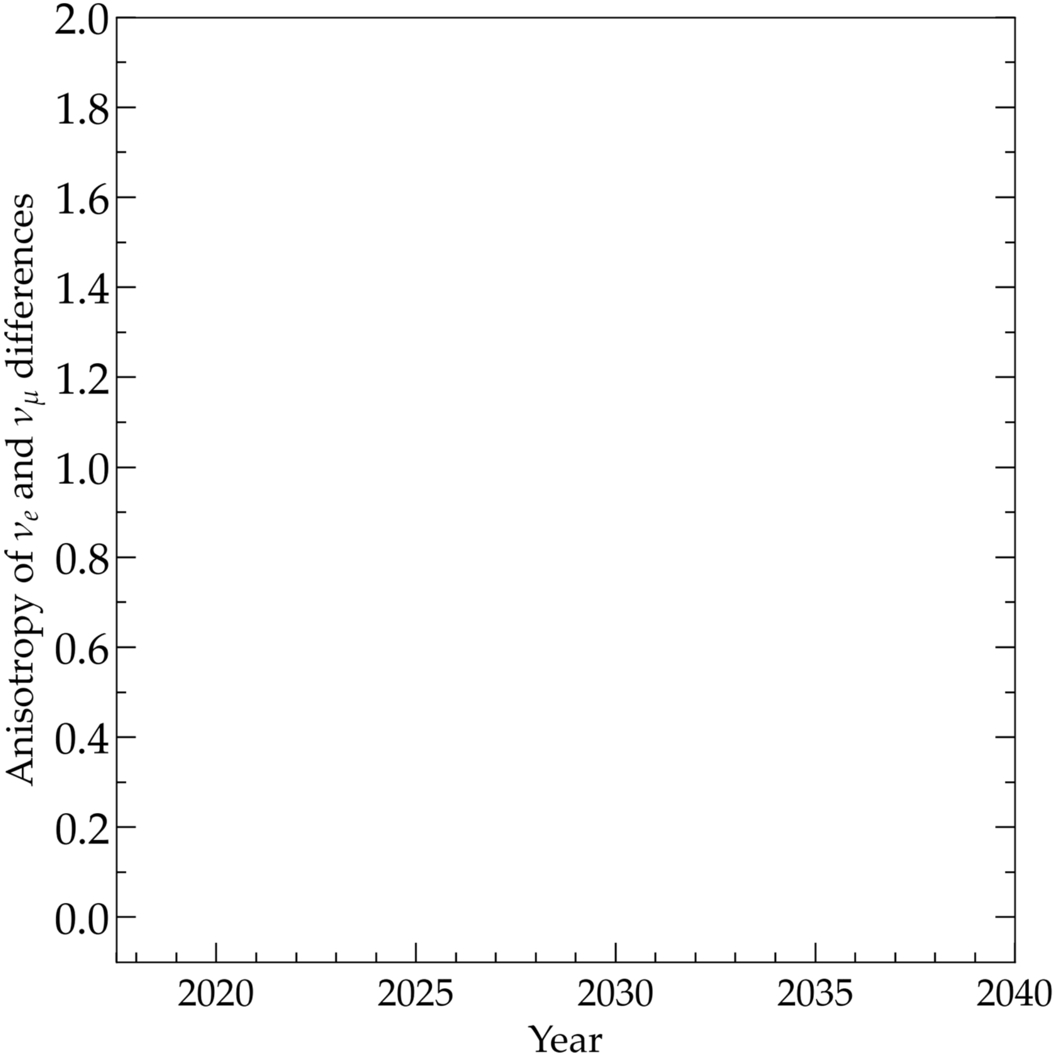
How well can we constrain isotropy over time?



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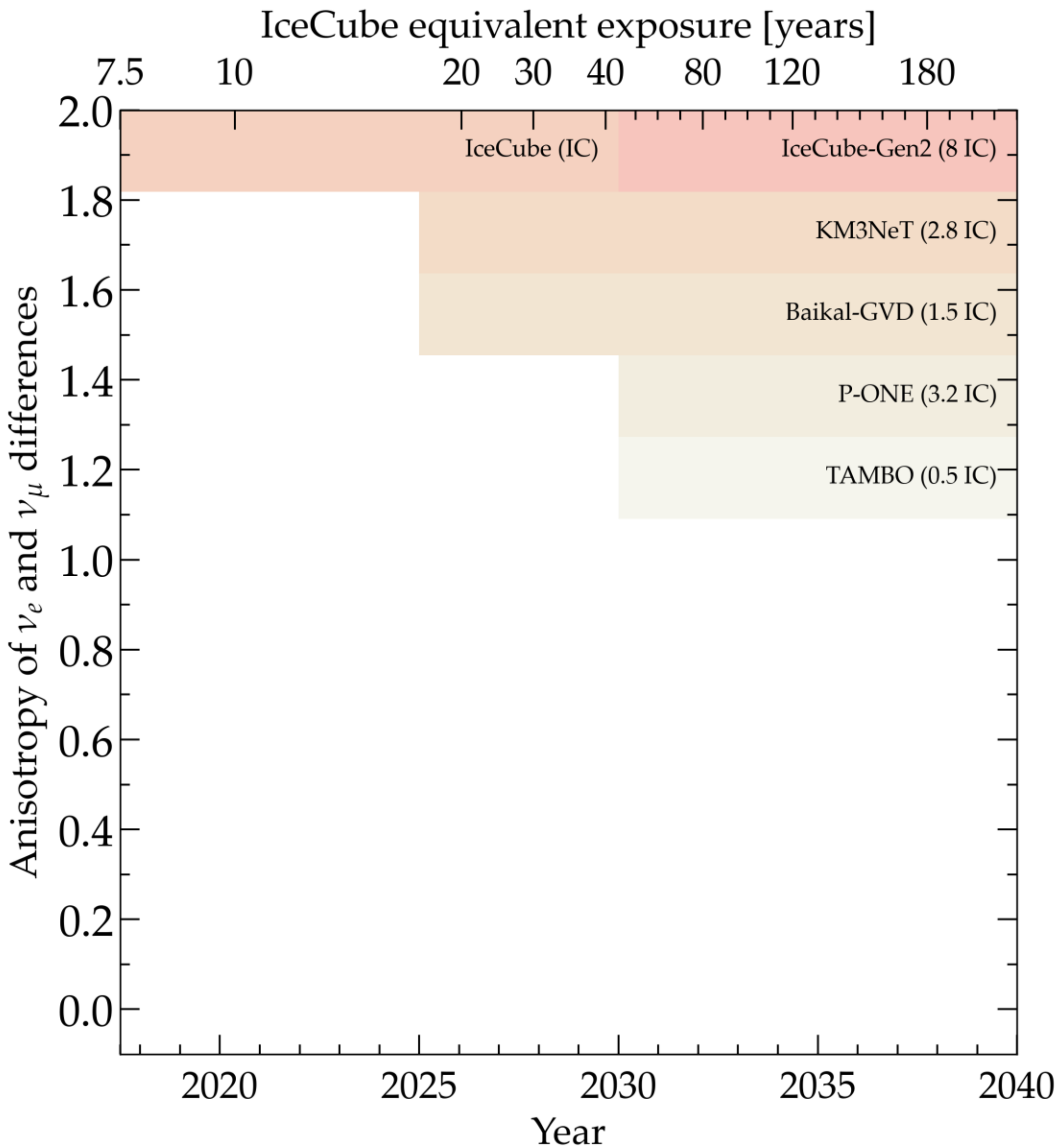

More detectors – better:

- Statistics
- Angular resolution (KM3NeT)
- Sky coverage

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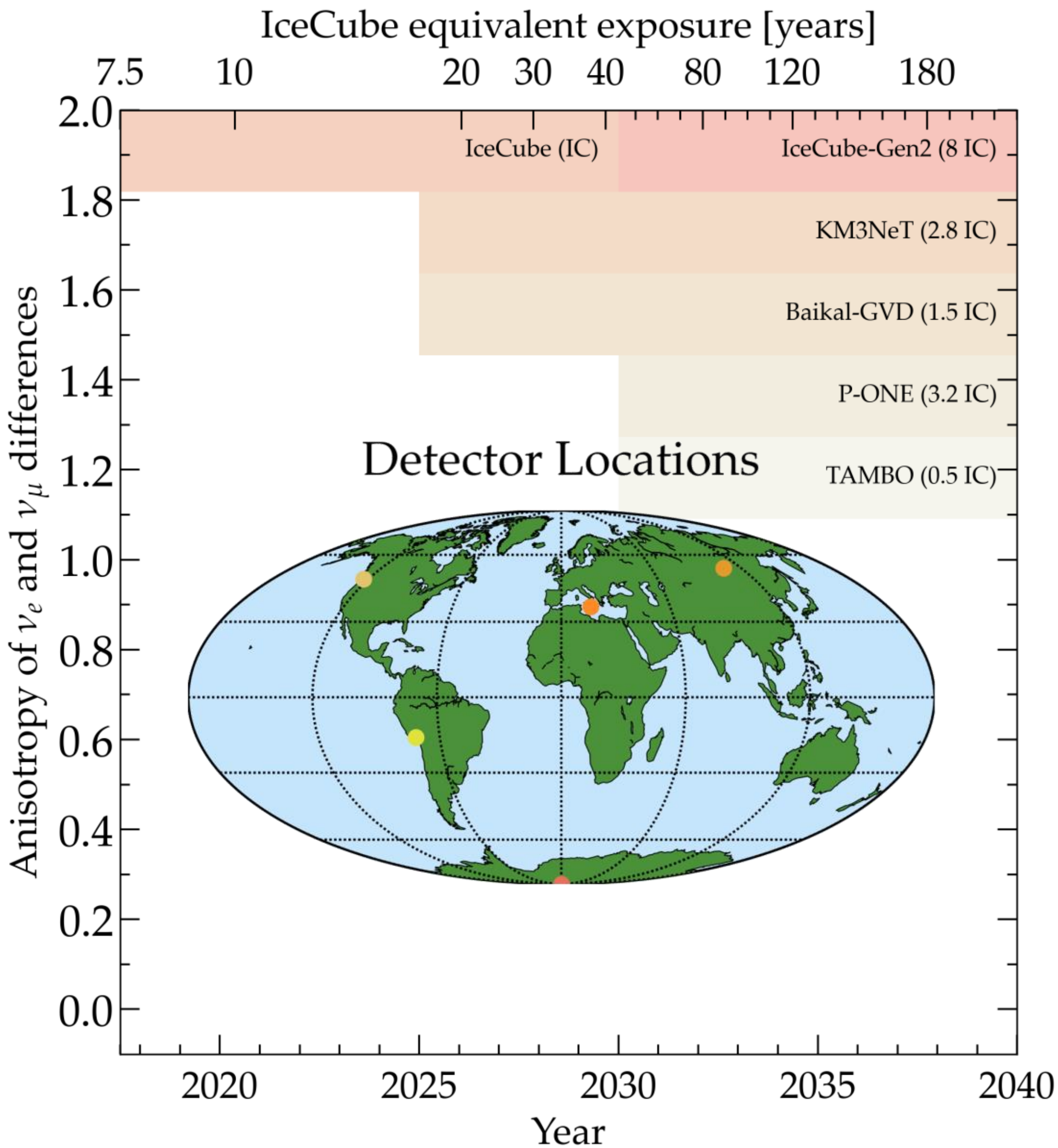

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- IceCube + Gen2 (current/2030)
- KM3NeT (2025)
- Baikal-GVD (2025)
- P-ONE (2030)
- TAMBO (2030)

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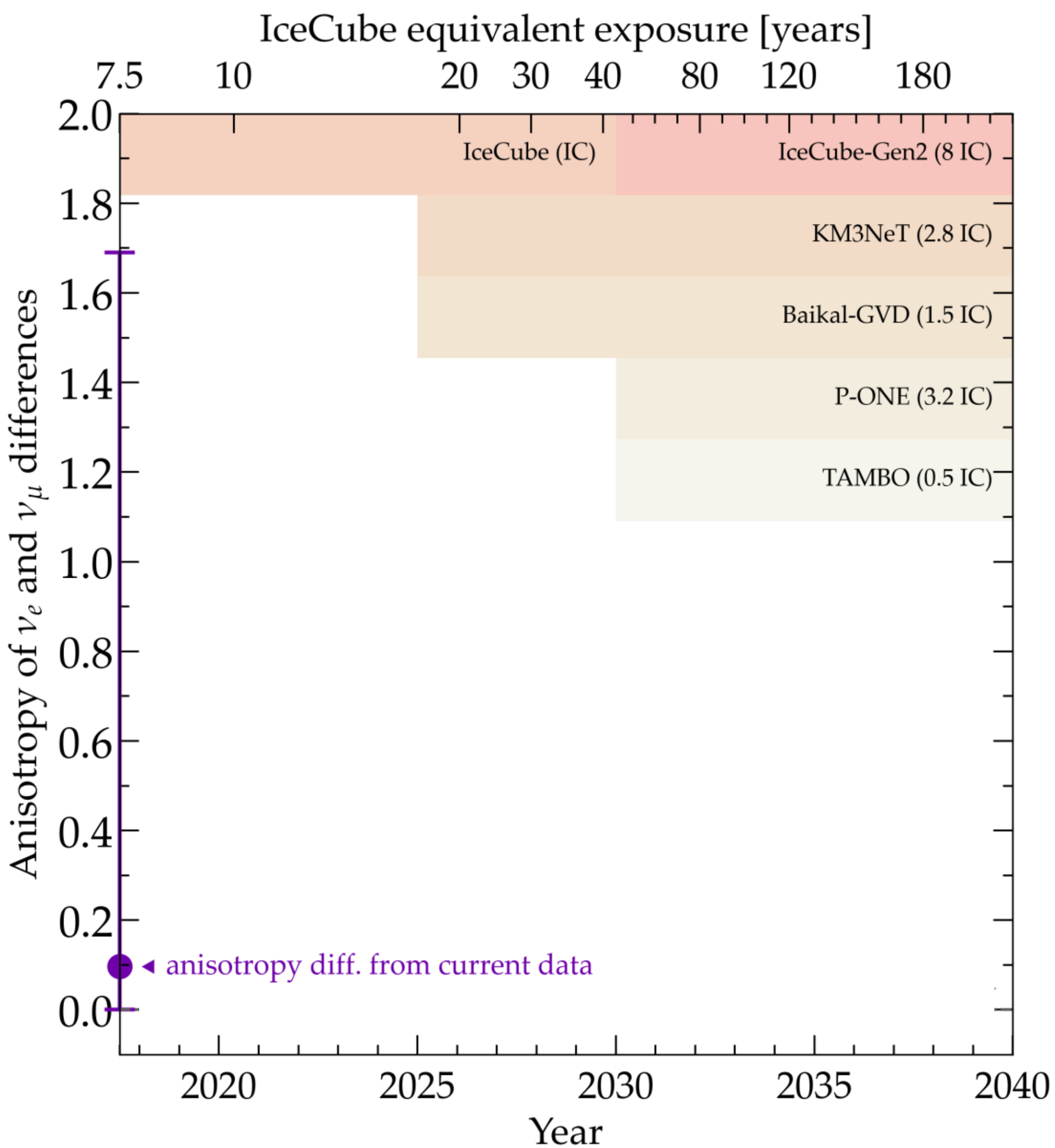

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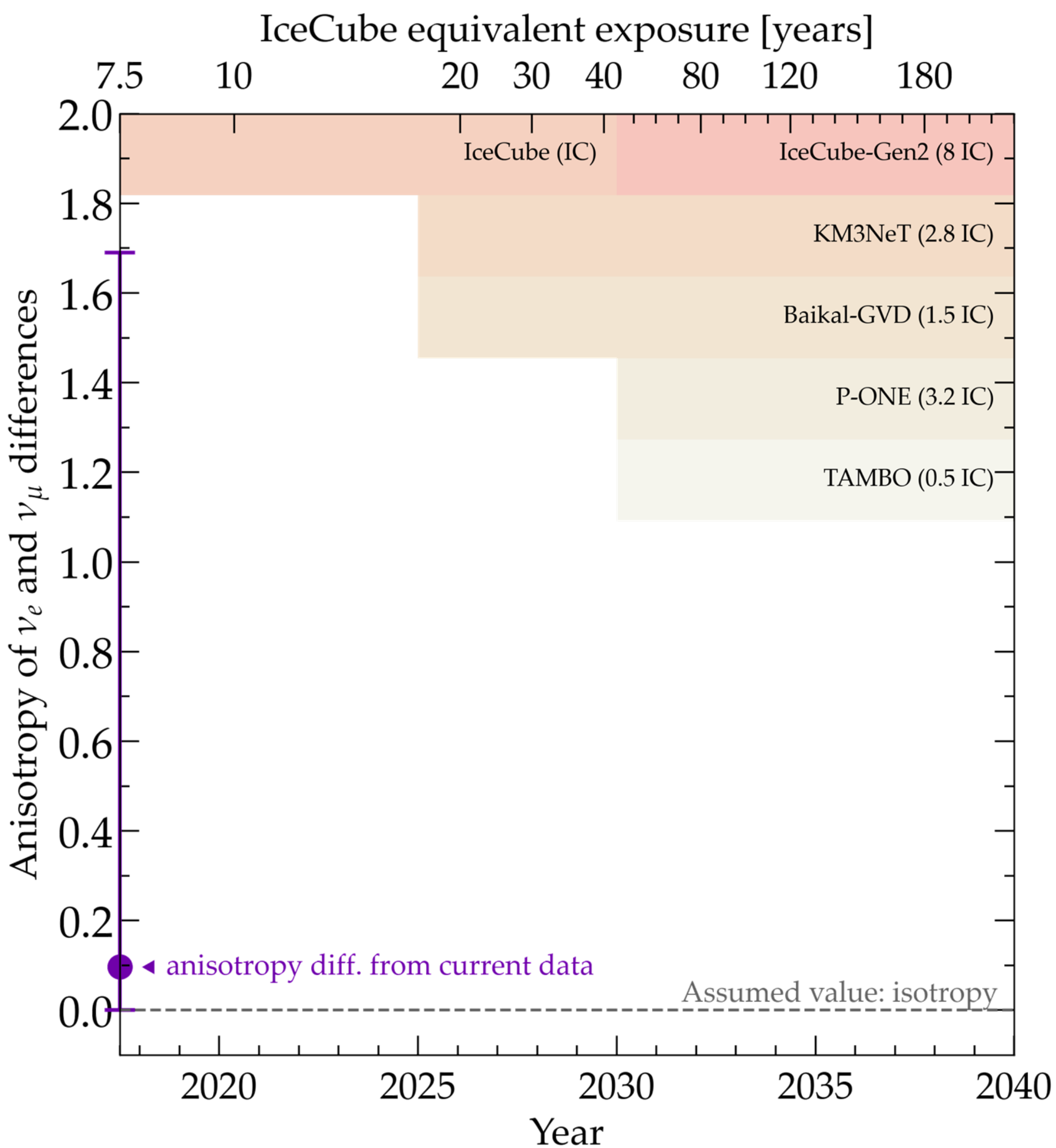

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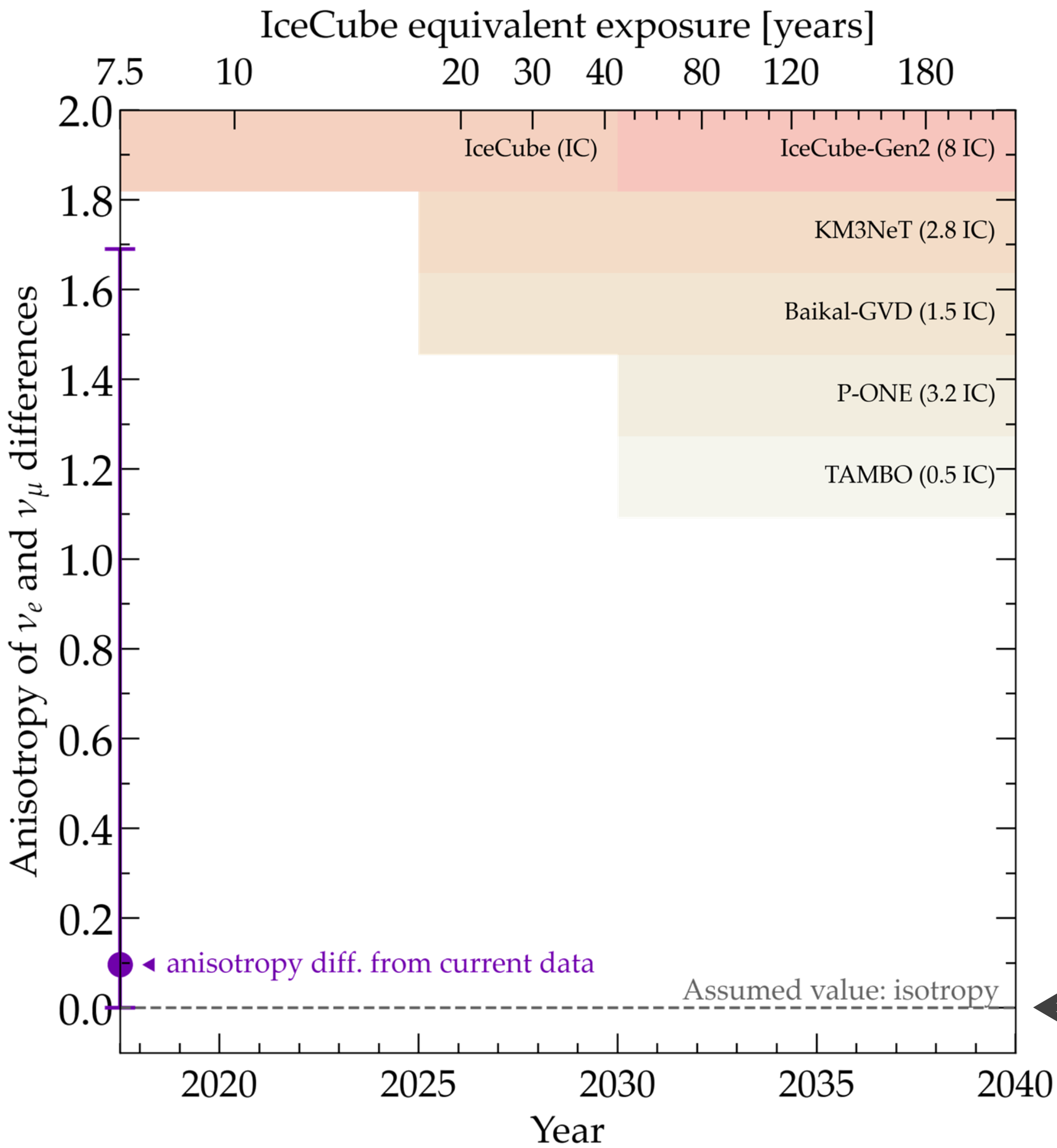

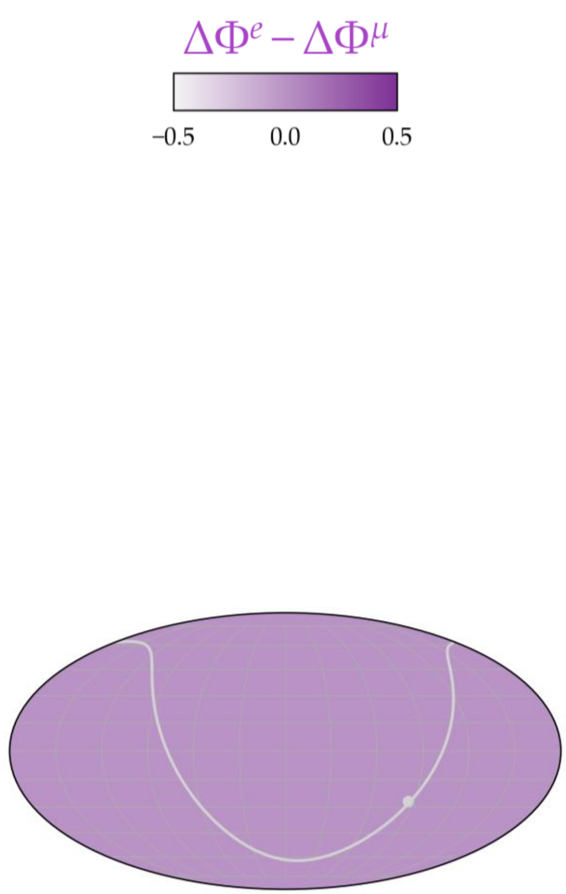

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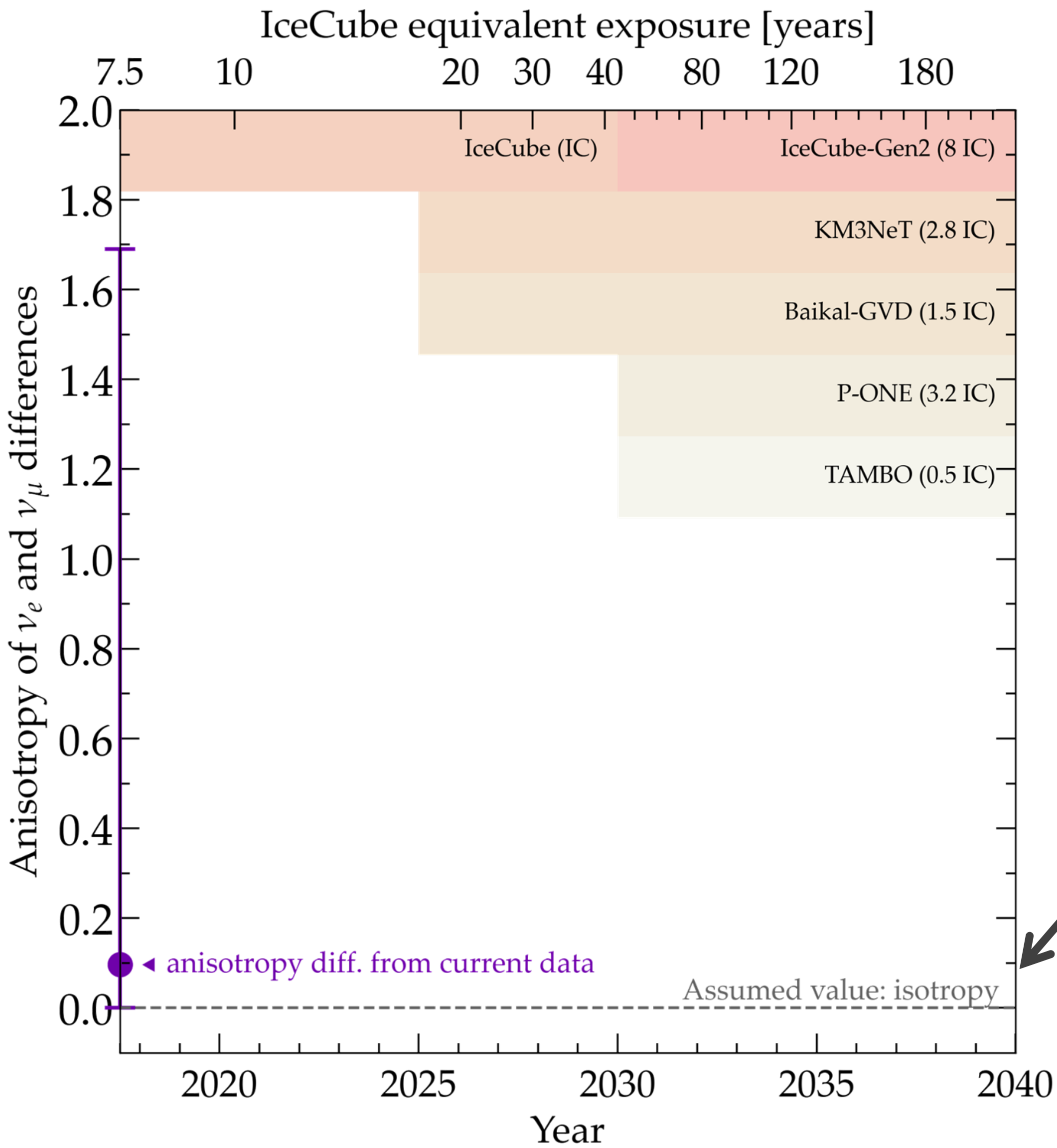

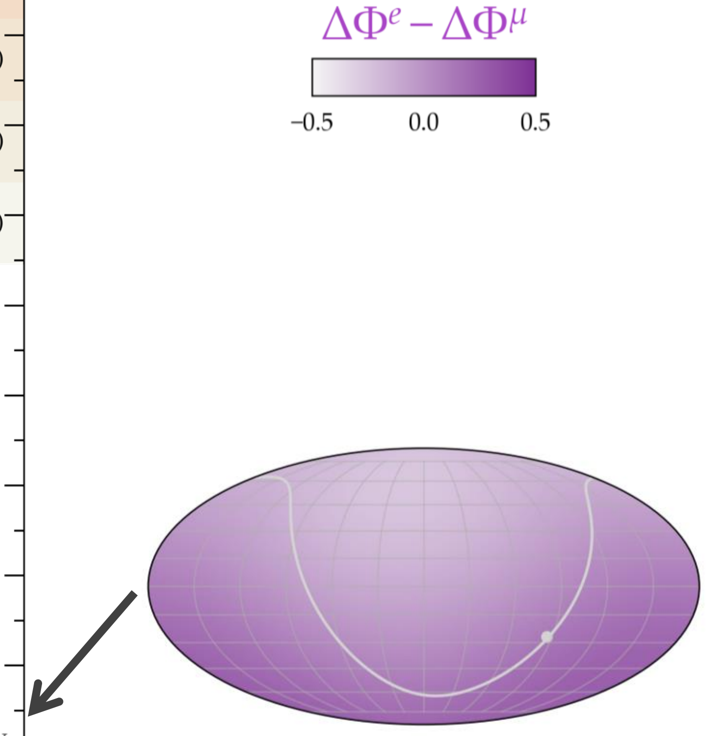

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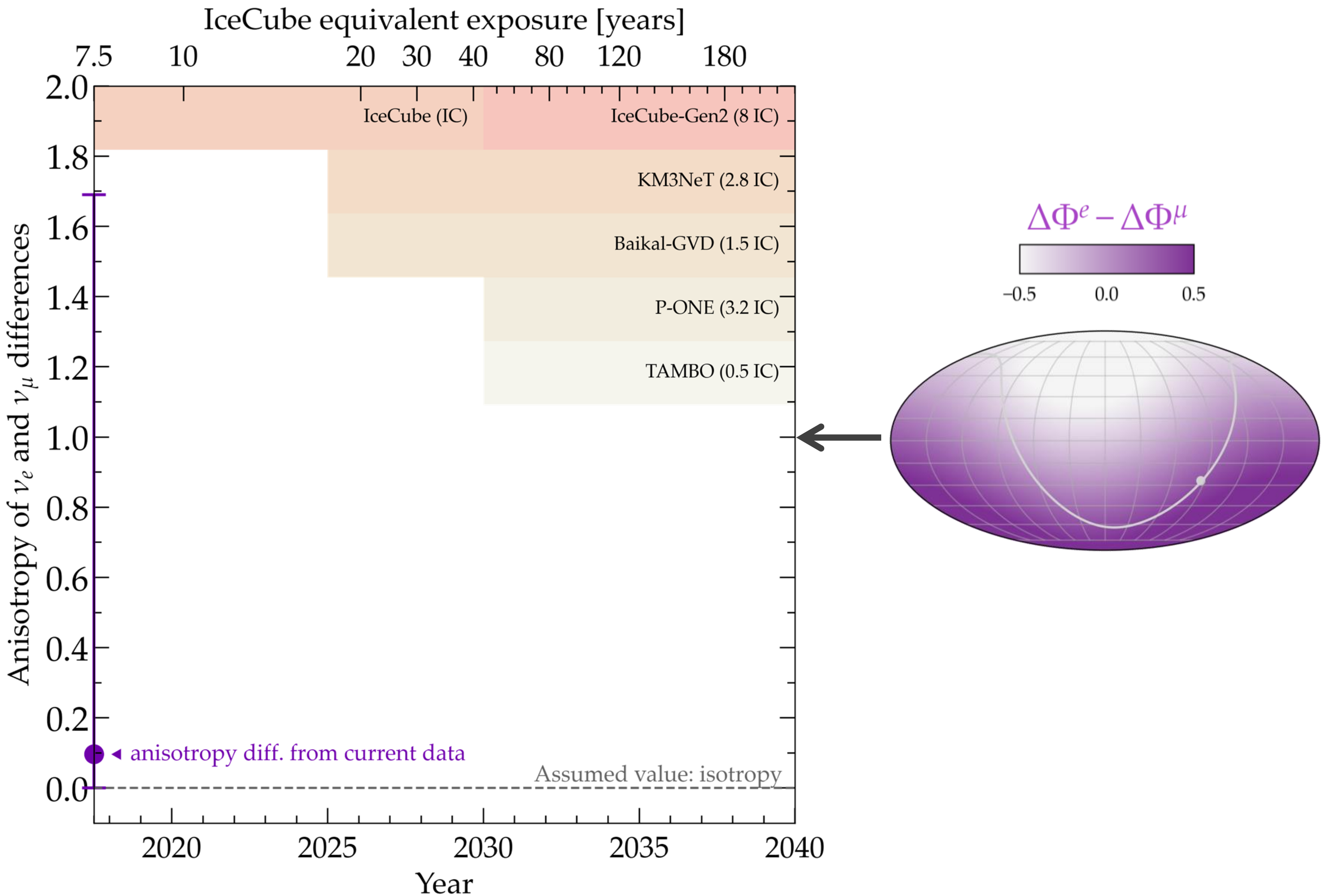

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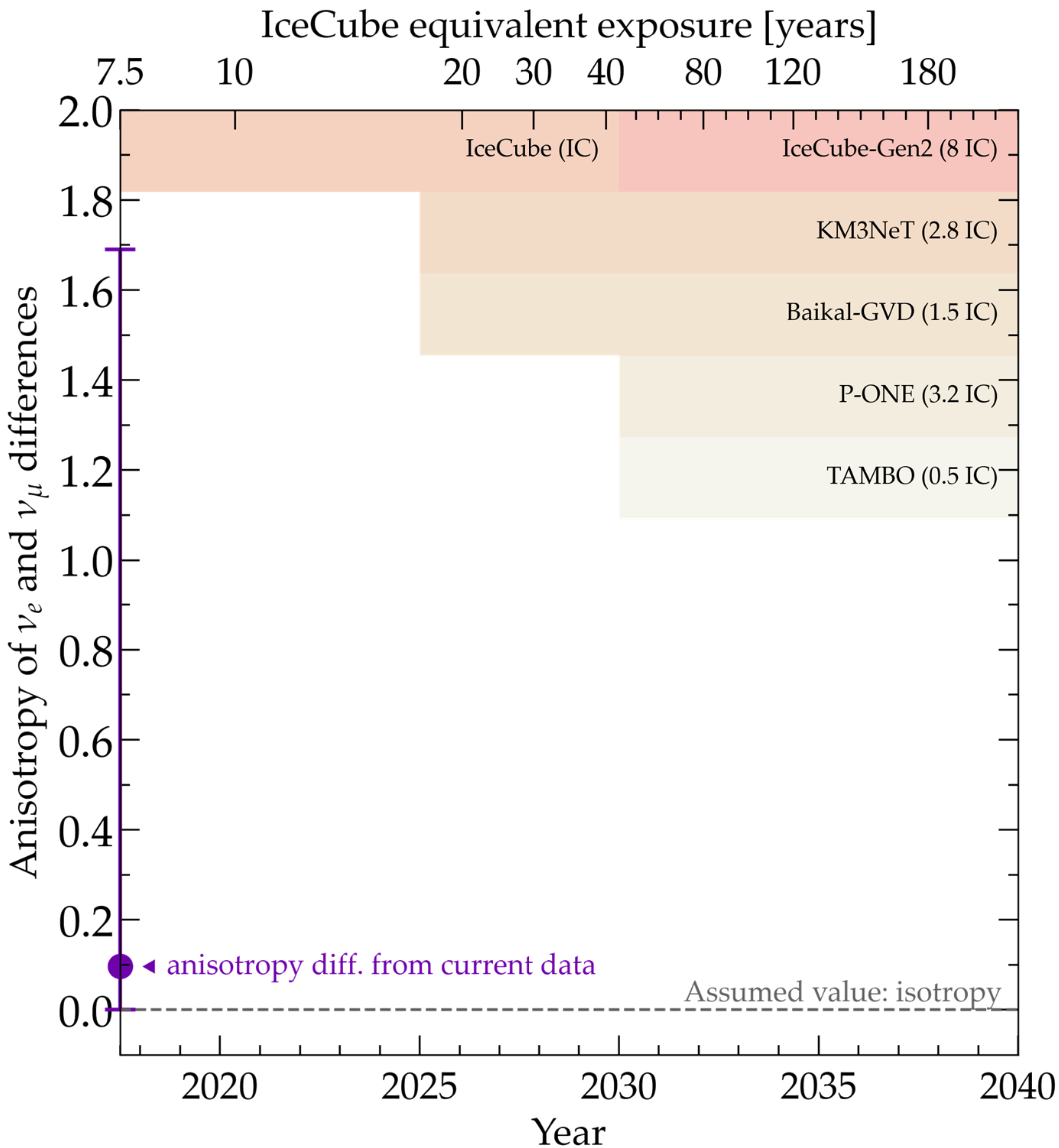

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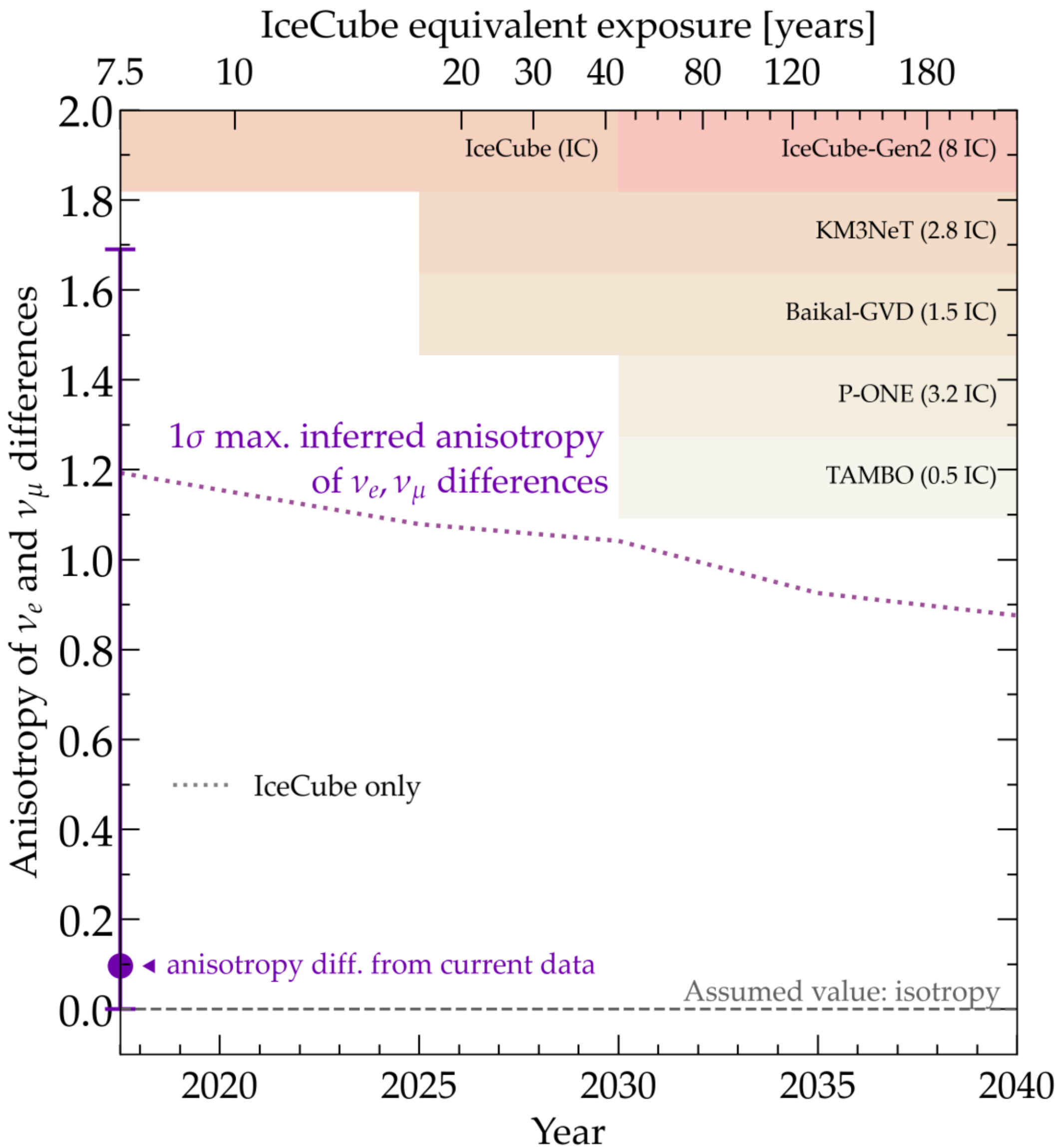

Improvement by 2040:

- IC only: 25%

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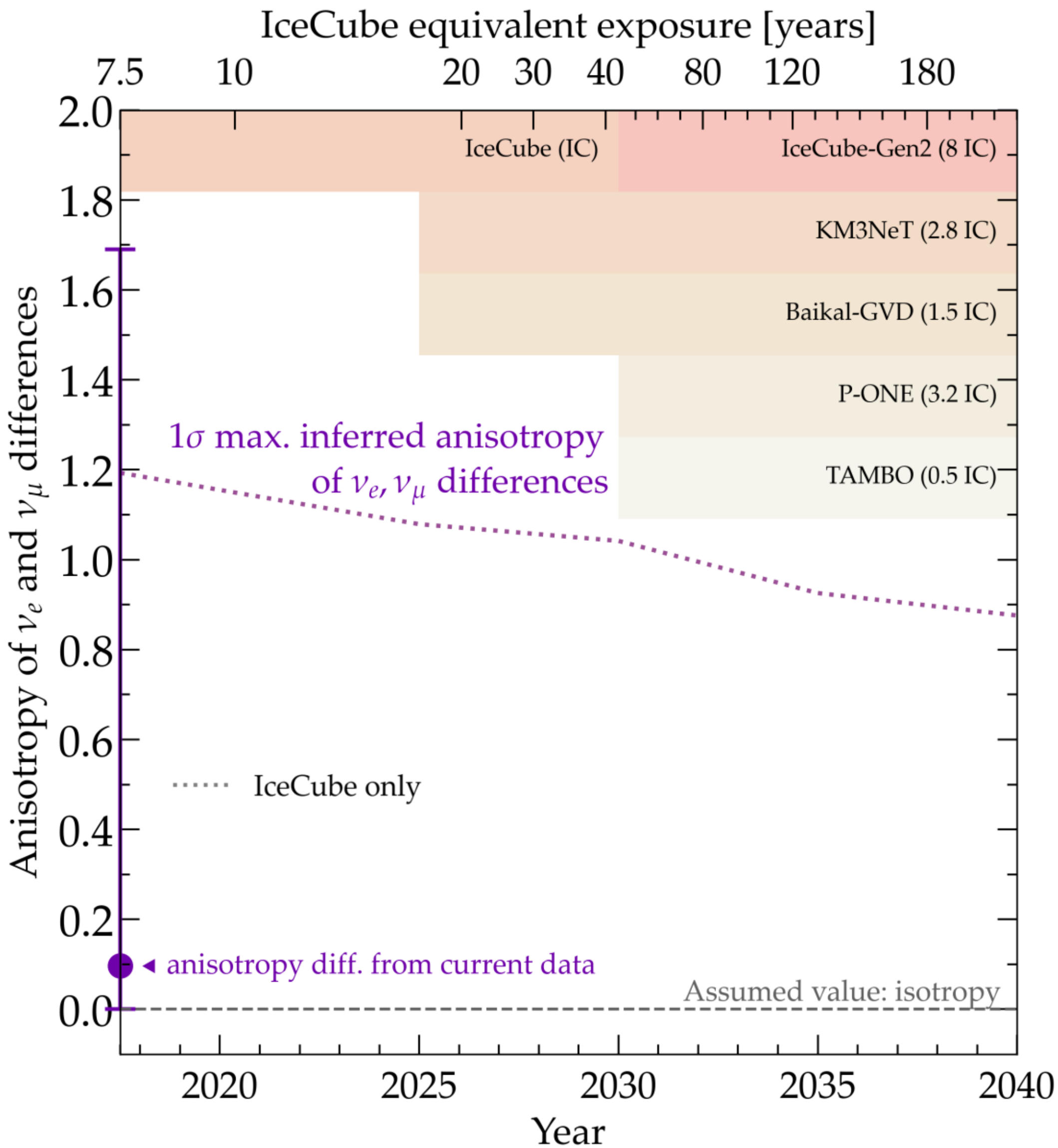

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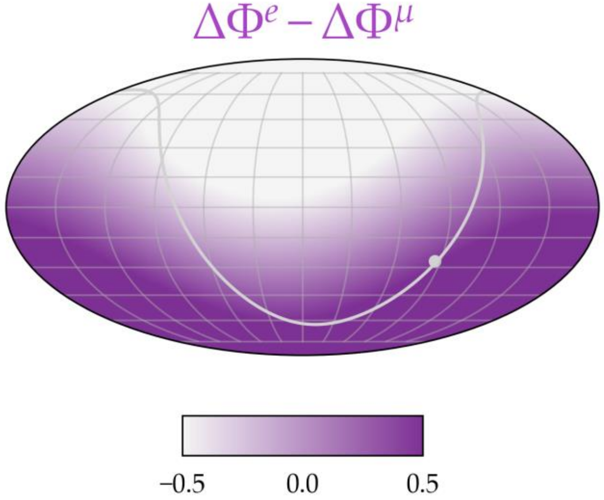

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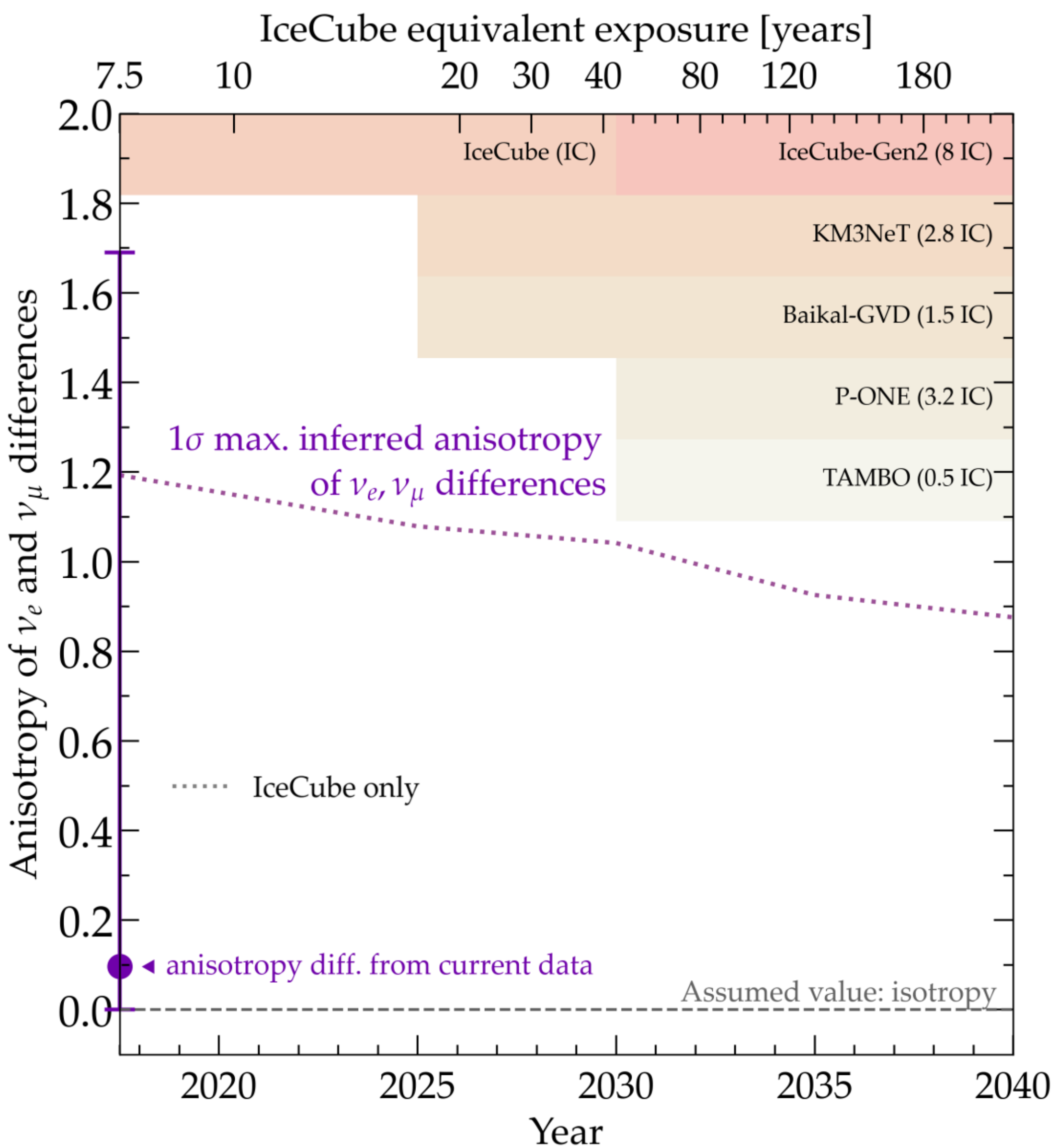

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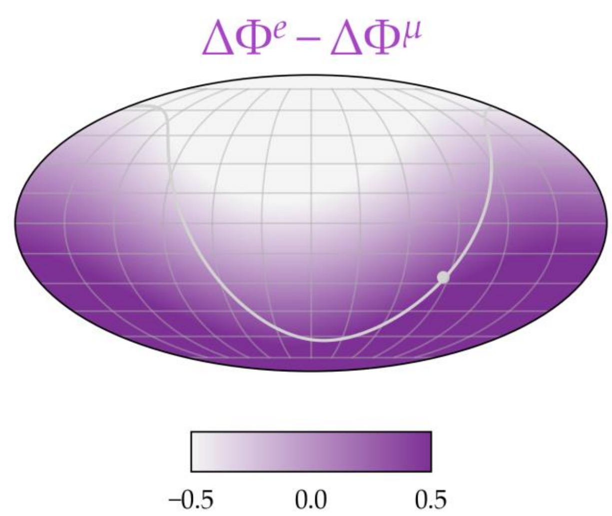

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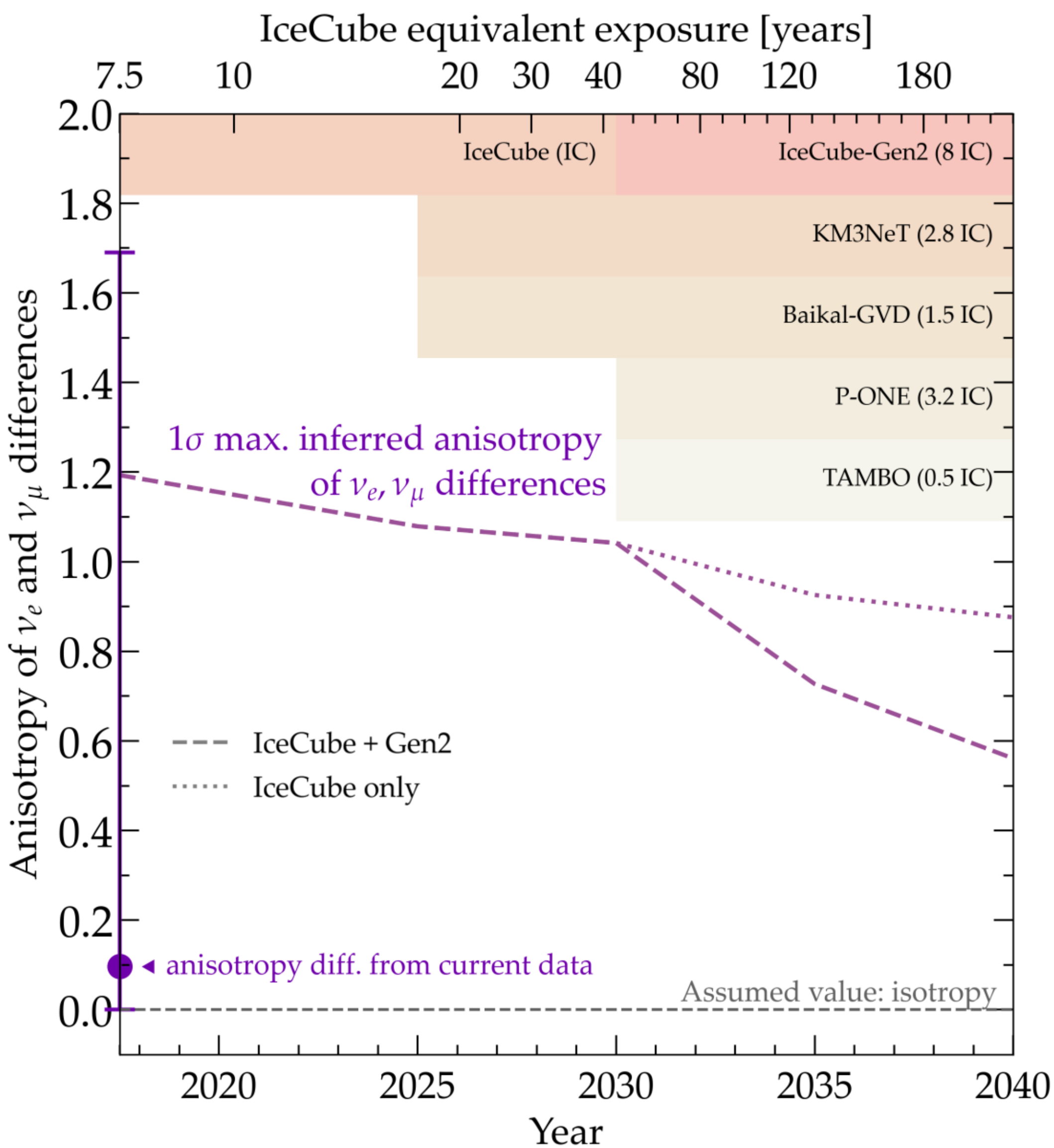

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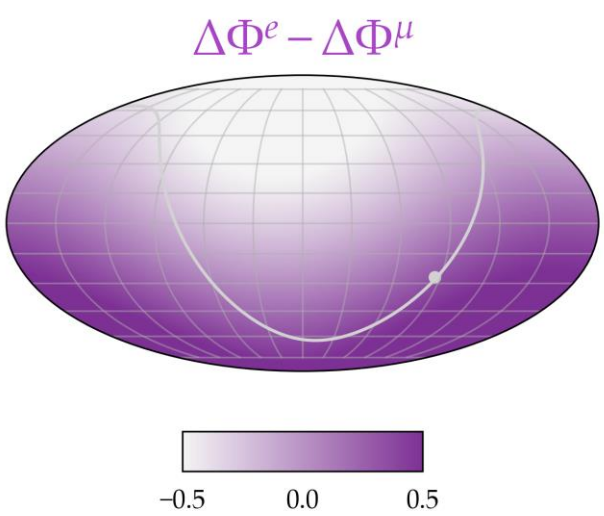

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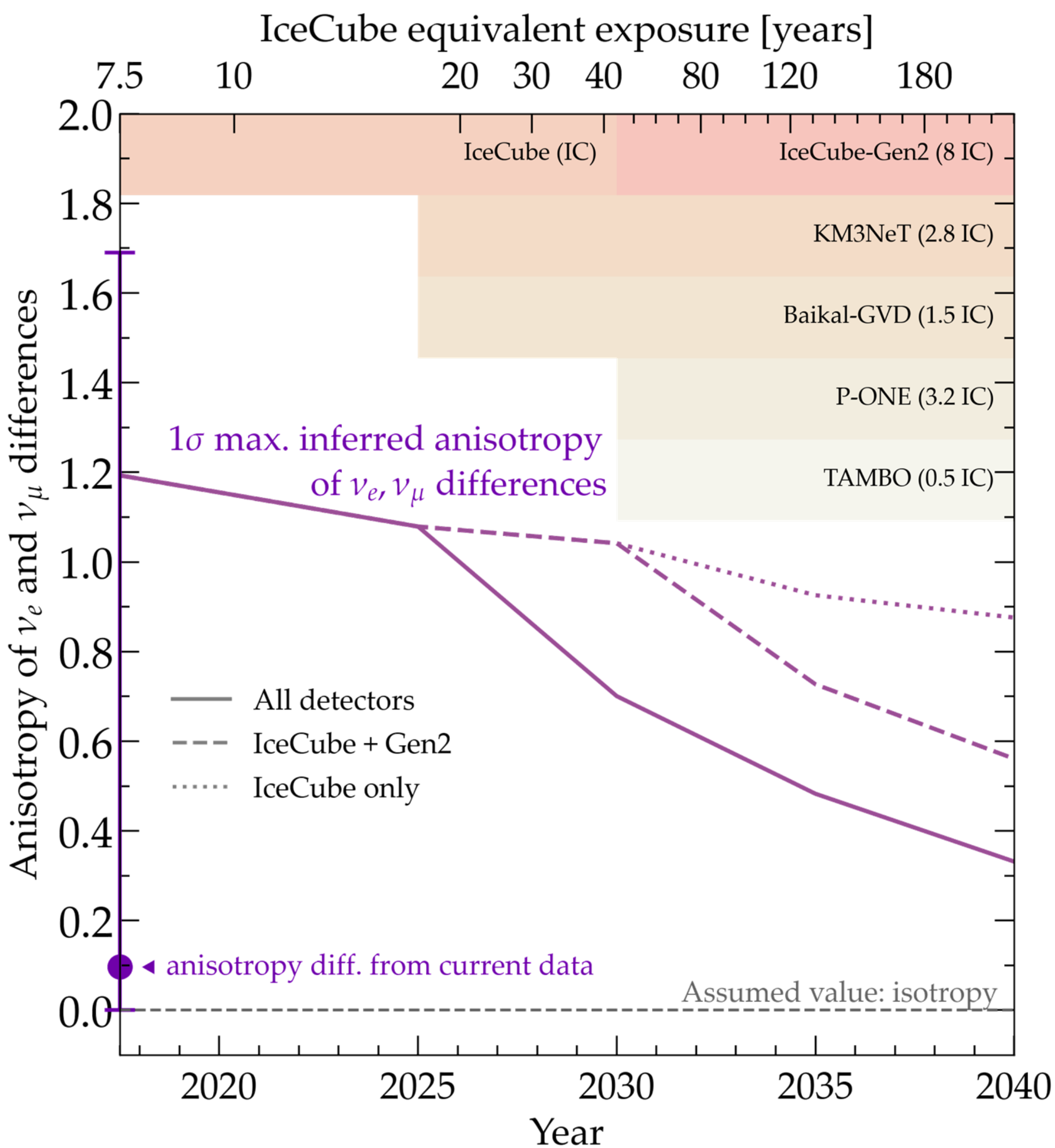

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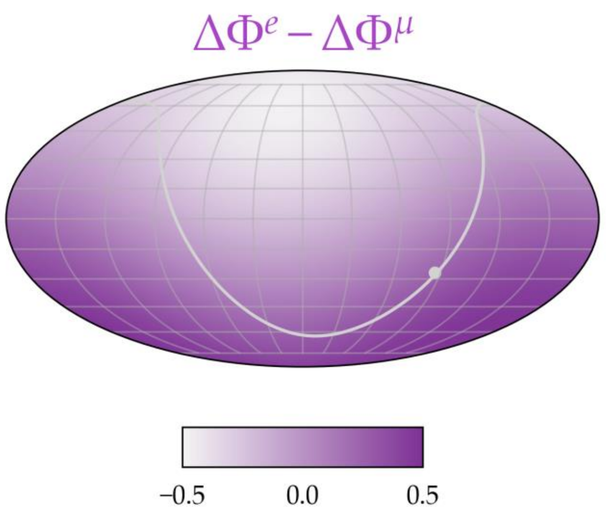

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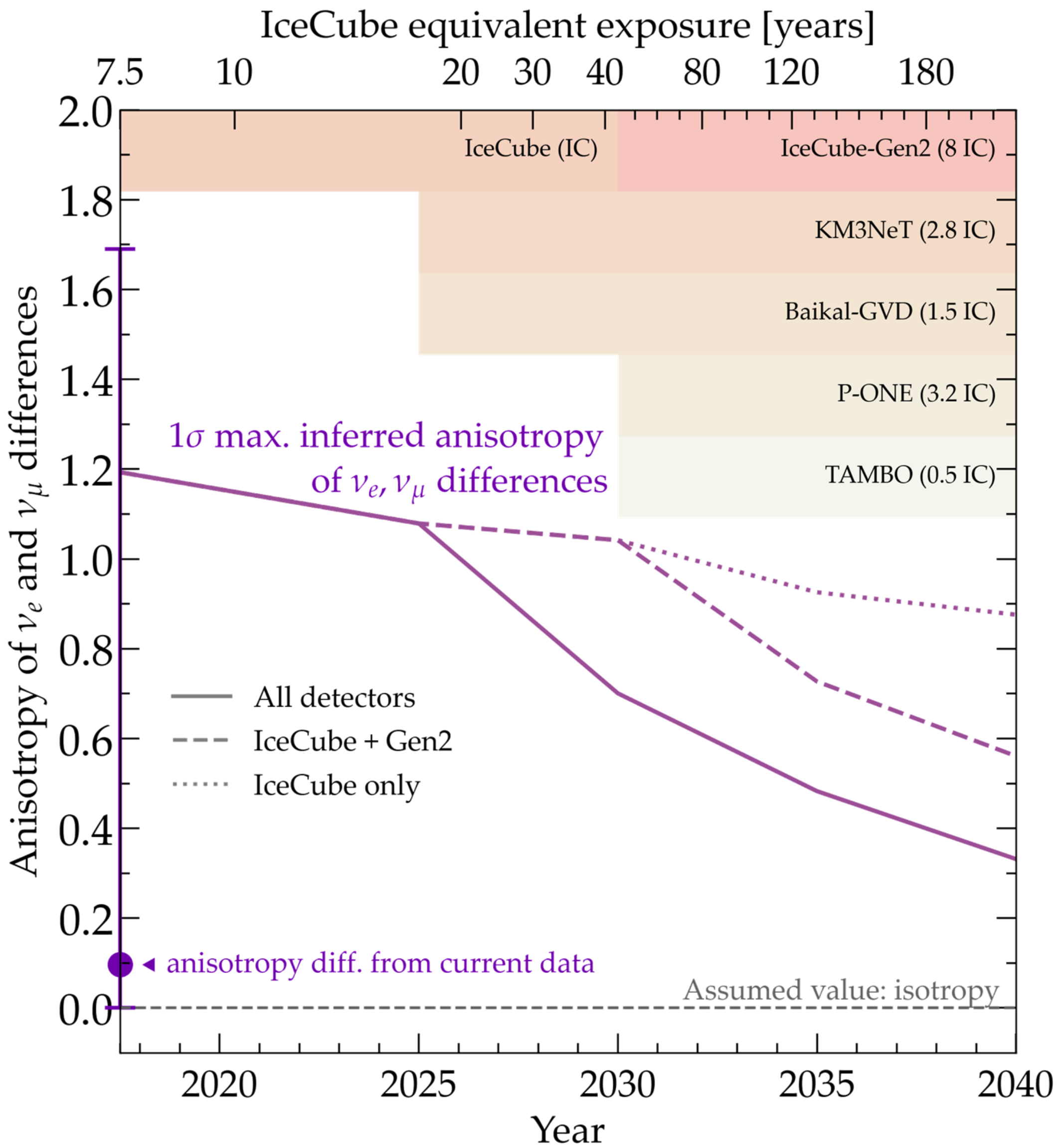

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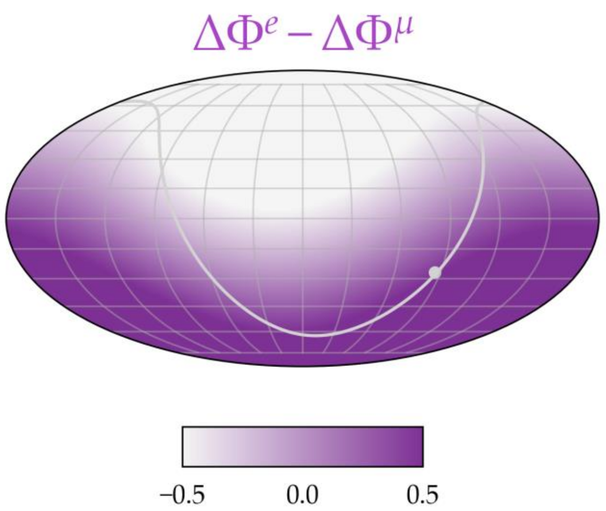

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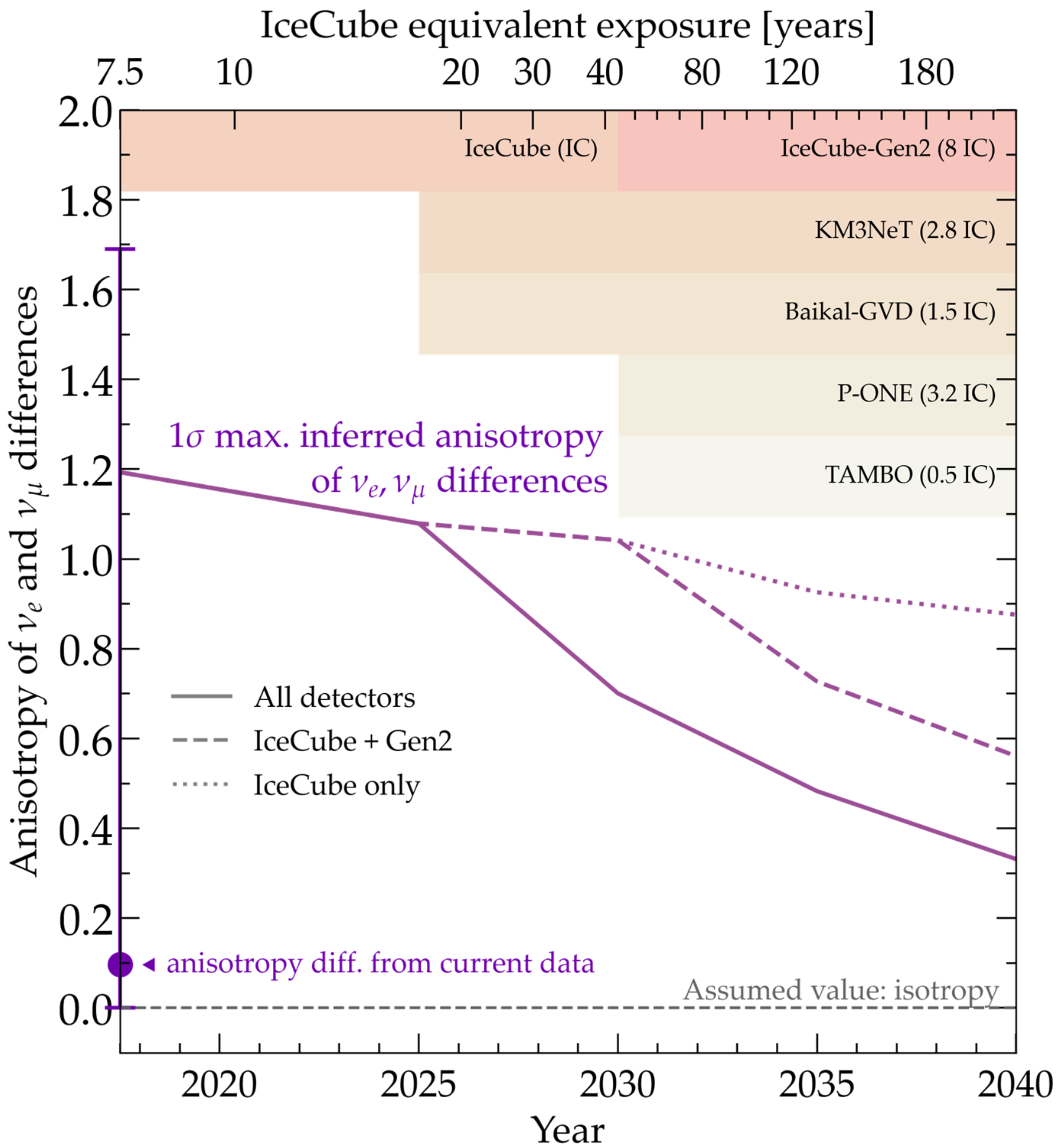

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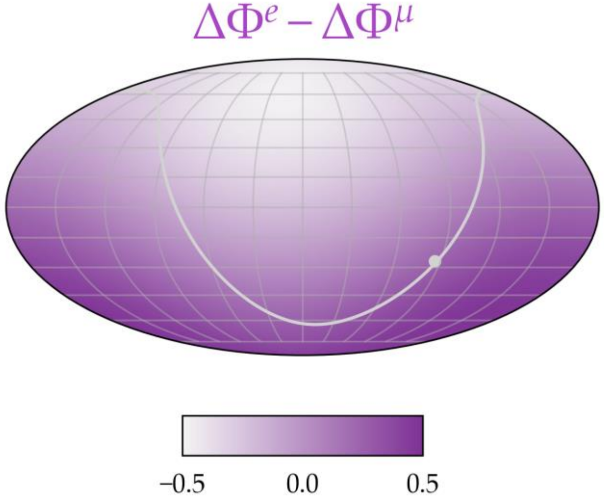

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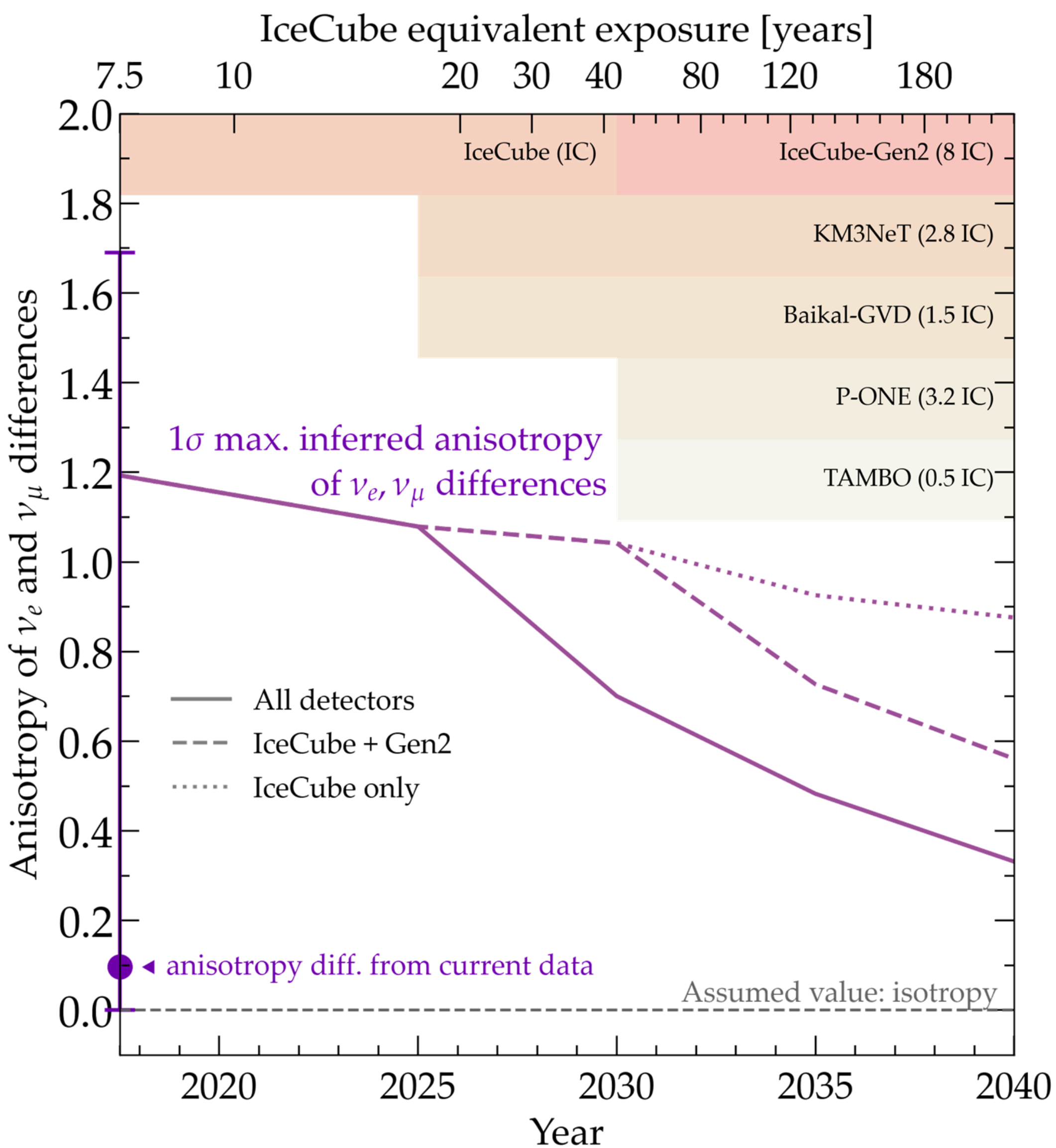

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Assuming IC-like sensitivity

Now we use these for… (ongoing work)

Constraining anisotropy-generating parameters in beyond-Standard Model physics:

- **Lorentz-invariance violation** as a mechanism of anisotropy,

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Anisotropy-generating parameters not yet explored with high energies (TeV-PeV)

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Constraining anisotropy-generating parameters in beyond-Standard Model physics:

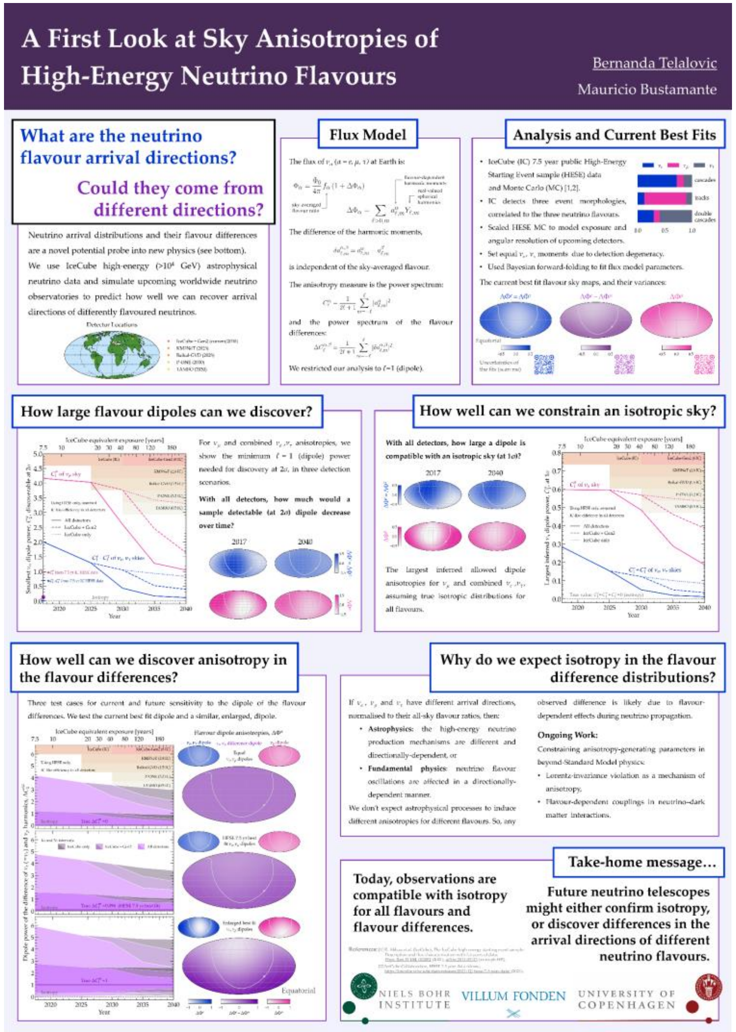
- **Lorentz-invariance violation** as anisotropy,
- **Neutrino–dark matter interactions** with flavour-dependent couplings.

Anisotropy-generating parameters not yet explored with high energies (TeV-PeV)

Thanks!

Questions?

Interested? – come see me at the poster session!

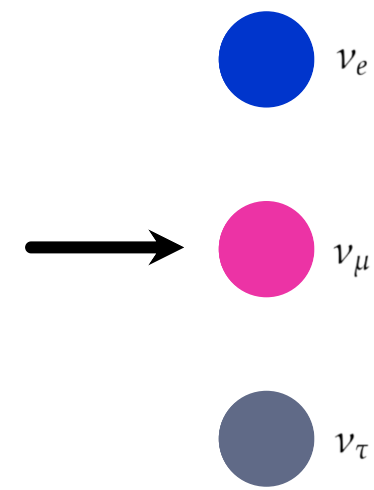


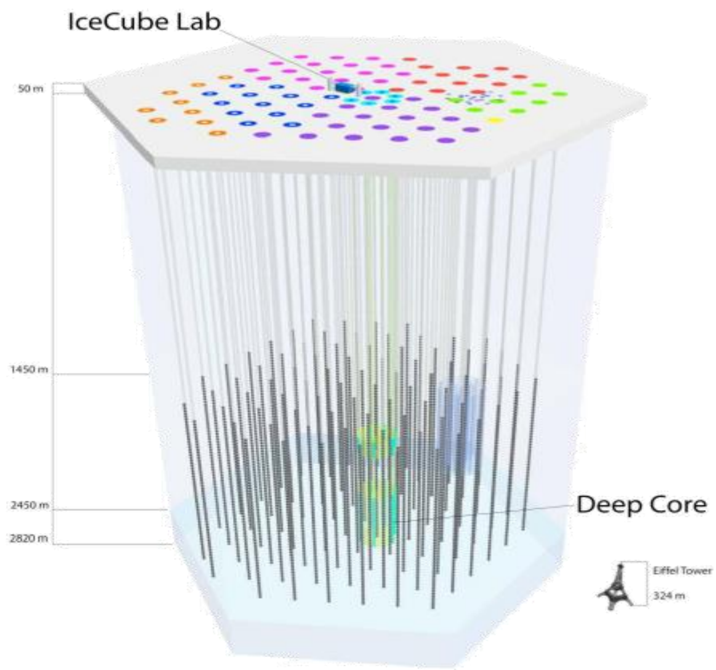
References

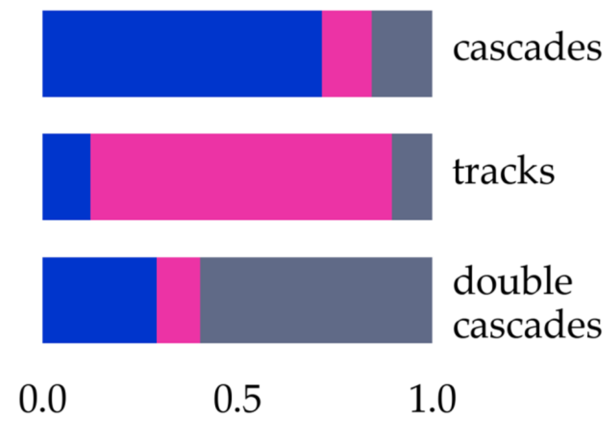
- R. Abbasi *et al*. (IceCube), The IceCube high-energy starting event sample: Description and flux characterization with 7.5 years of data, Phys. Rev. D **104**, 022002 (2021), arXiv:2011.03545 [astro-ph.HE].

- IceCube Collaboration, HESE 7.5 year data release, https://icecube.wisc.edu/data-releases/2021/12/ hese-7-5-year-data/ (2021).

Neutrino detected in IceCube as morphology:

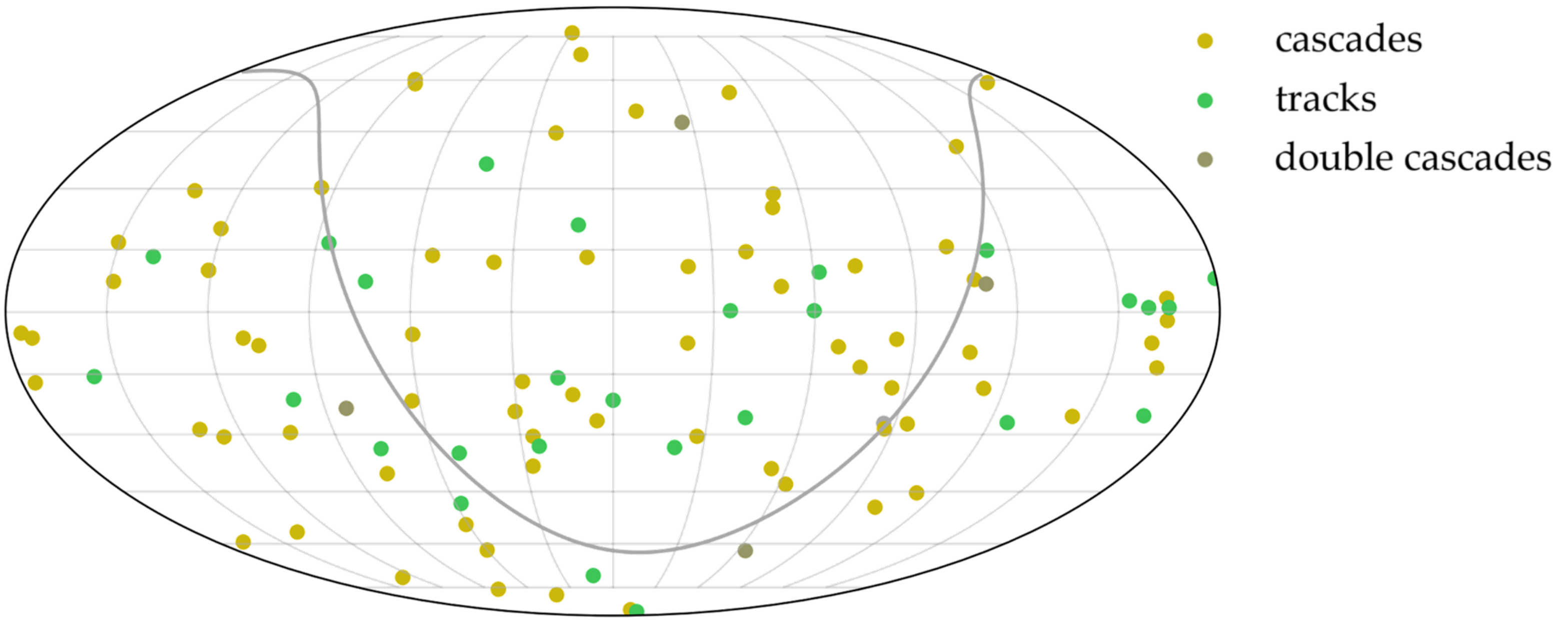






HESE dataset

IceCube HESE 7.5 year event sample – best fit locations (102 events)



The Flux Model

The flavour-flux:

$$\Phi_\alpha = \frac{\Phi_0}{4\pi} f_\alpha \left(1 + \Delta\Phi_\alpha\right) \qquad \Delta\Phi_\alpha = \sum_{\ell>0,m} a^\alpha_{\ell,m} Y_{\ell,m}$$

The anisotropy measure (power spectrum):

$$C^\alpha_\ell = \frac{1}{2\ell+1} \sum_{m=-\ell}^{\ell} |a^\alpha_{\ell,m}|^2$$

$$\Delta C^{\alpha,\beta}_\ell = \frac{1}{2\ell+1} \sum_{m=-\ell}^{\ell} |\delta a^{\alpha,\beta}_{\ell,m}|^2 \qquad \delta a^{\alpha,\beta}_{\ell,m} = a^\alpha_{\ell,m} - a^\beta_{\ell,m}$$