Development of a tau neutrino based real-time alert stream for IceCube

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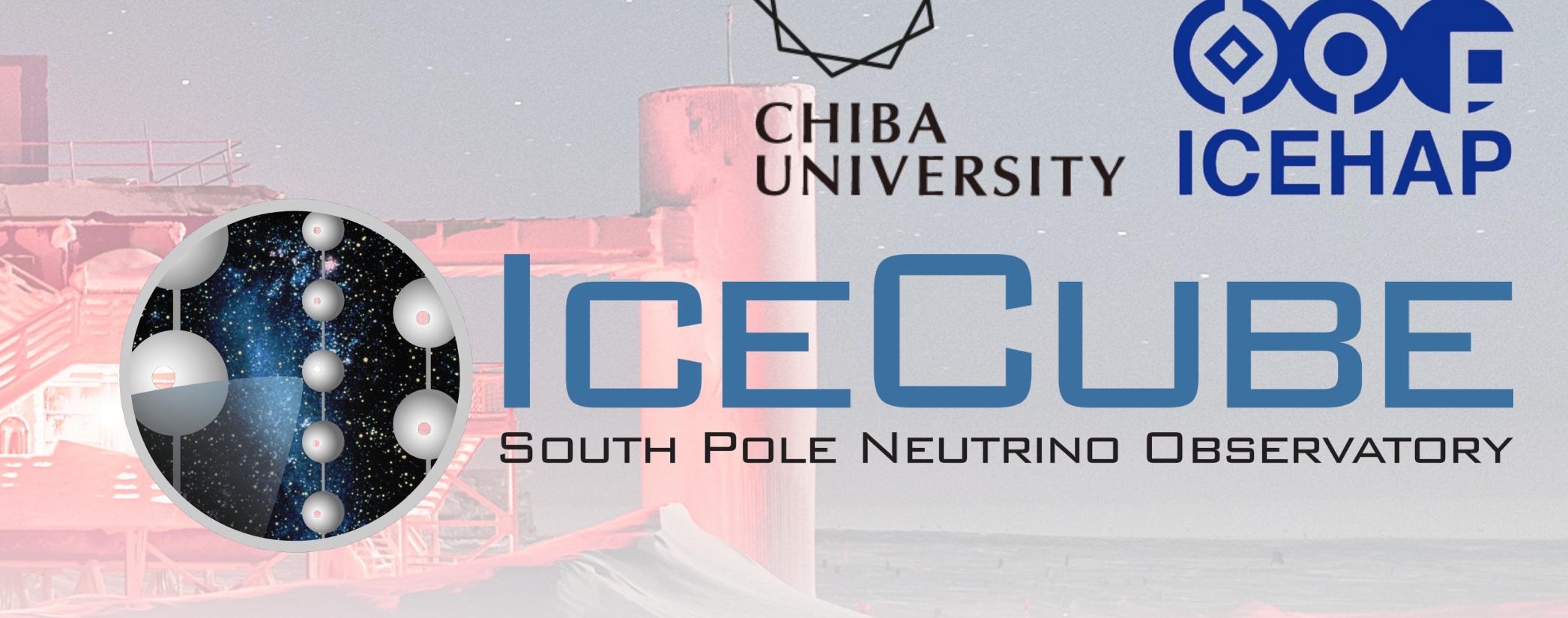
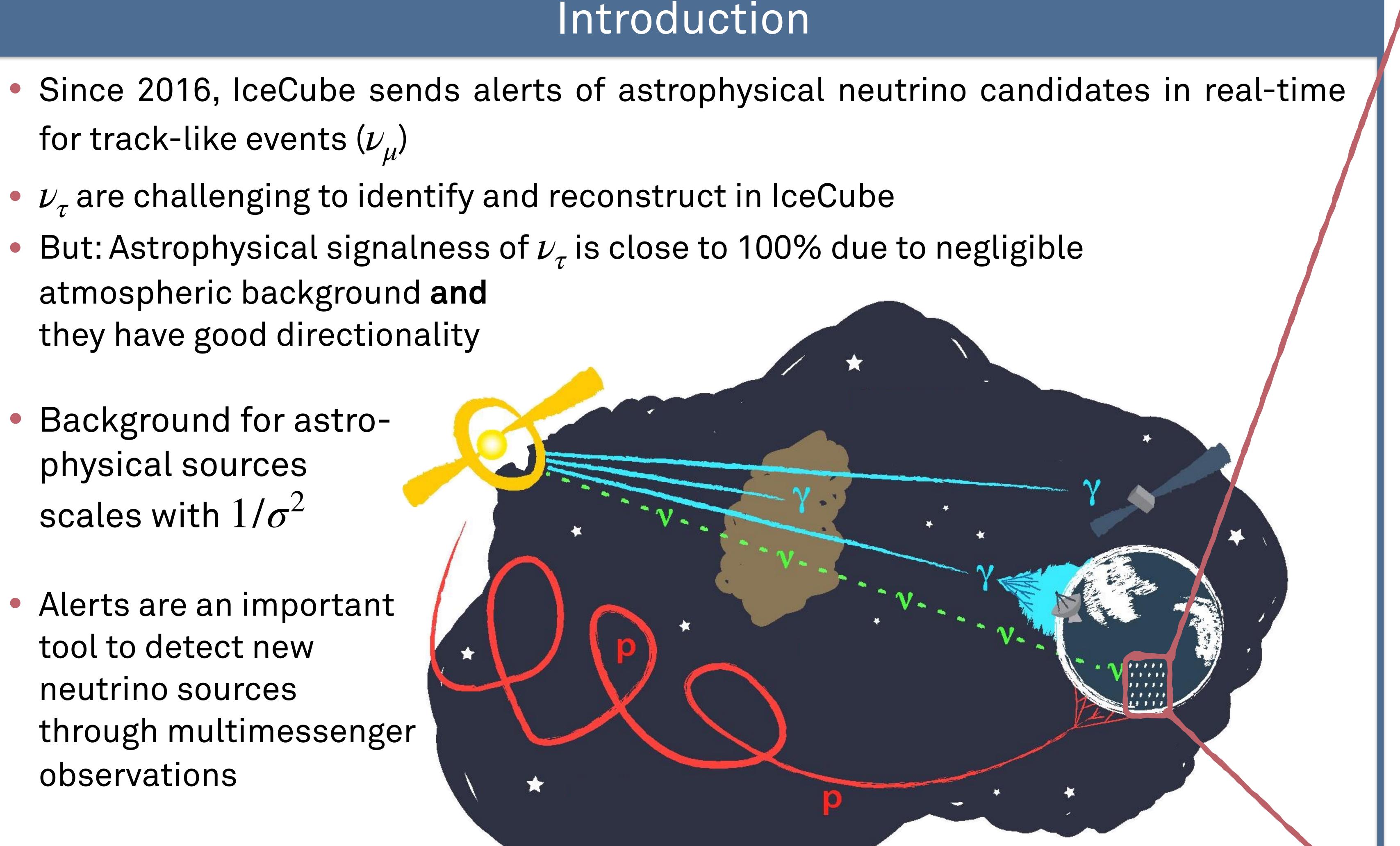
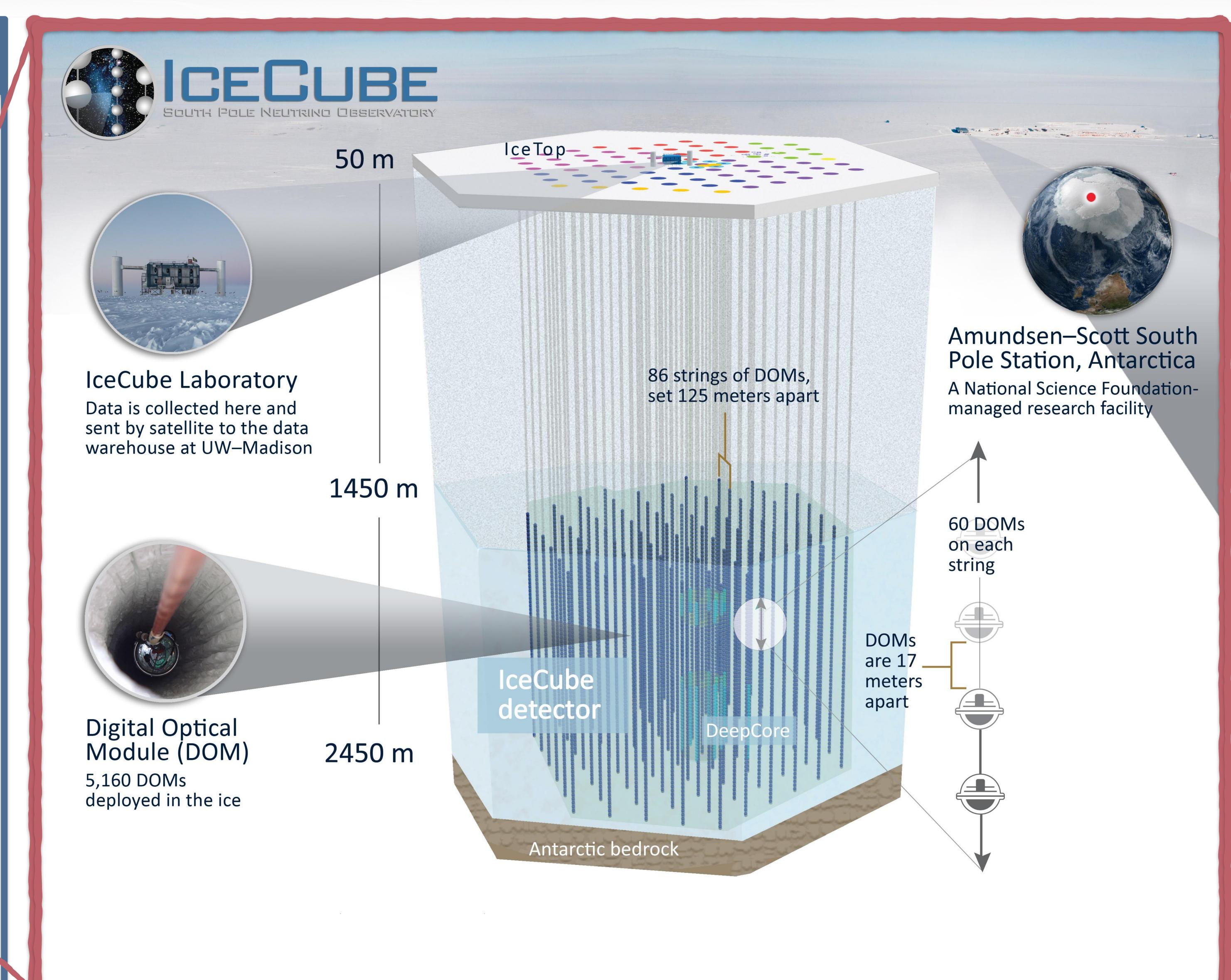


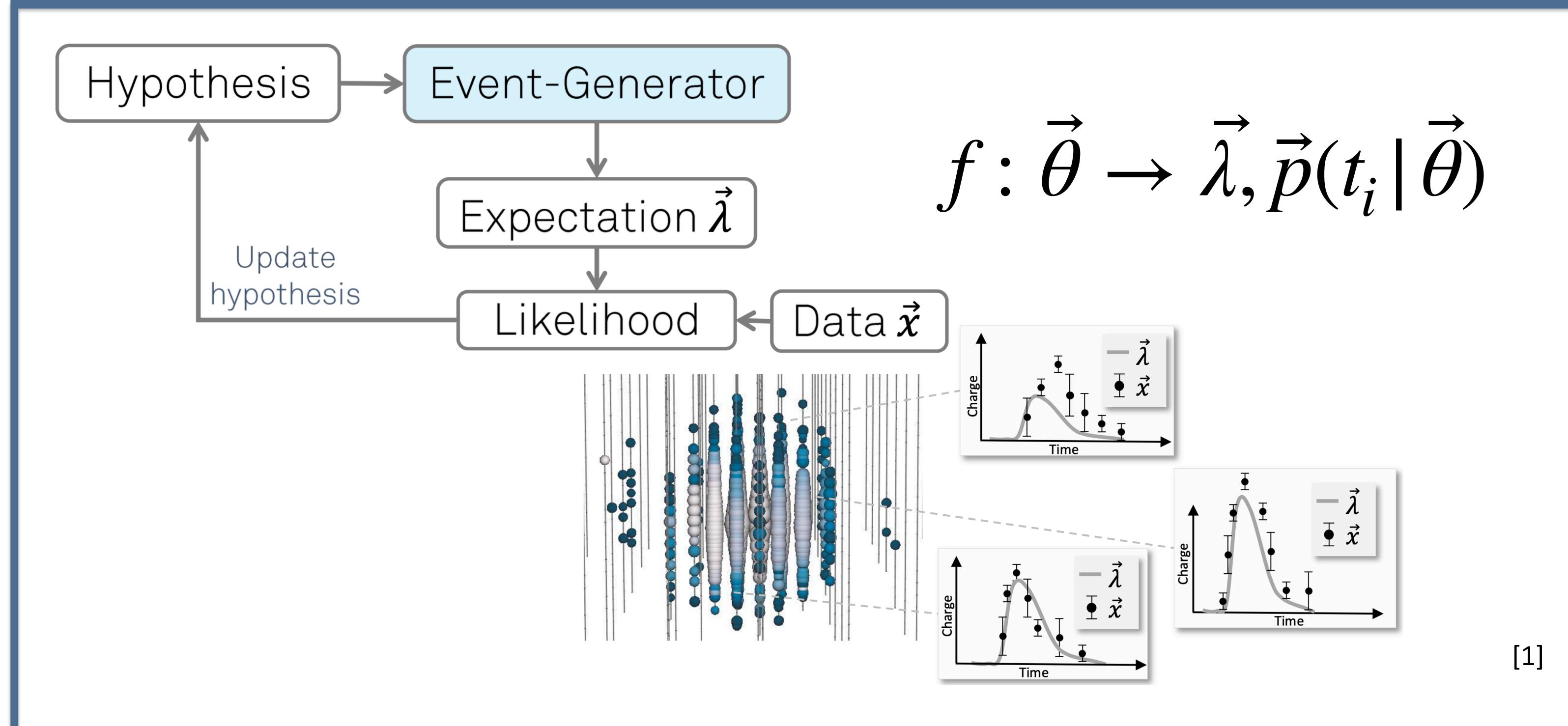
Photo by Johannes Werthebach





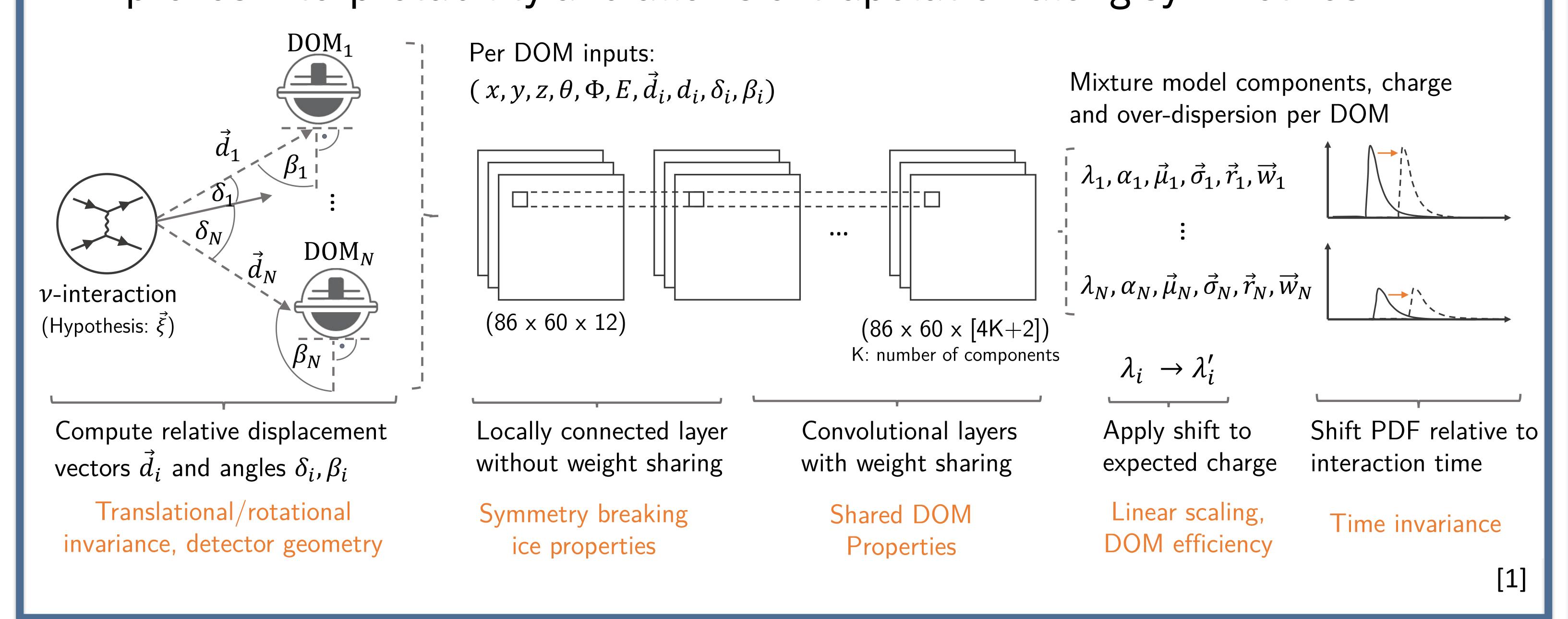
 ν_{τ} Selection & Performance

Combining Maximum-Likelihood with Deep Learning



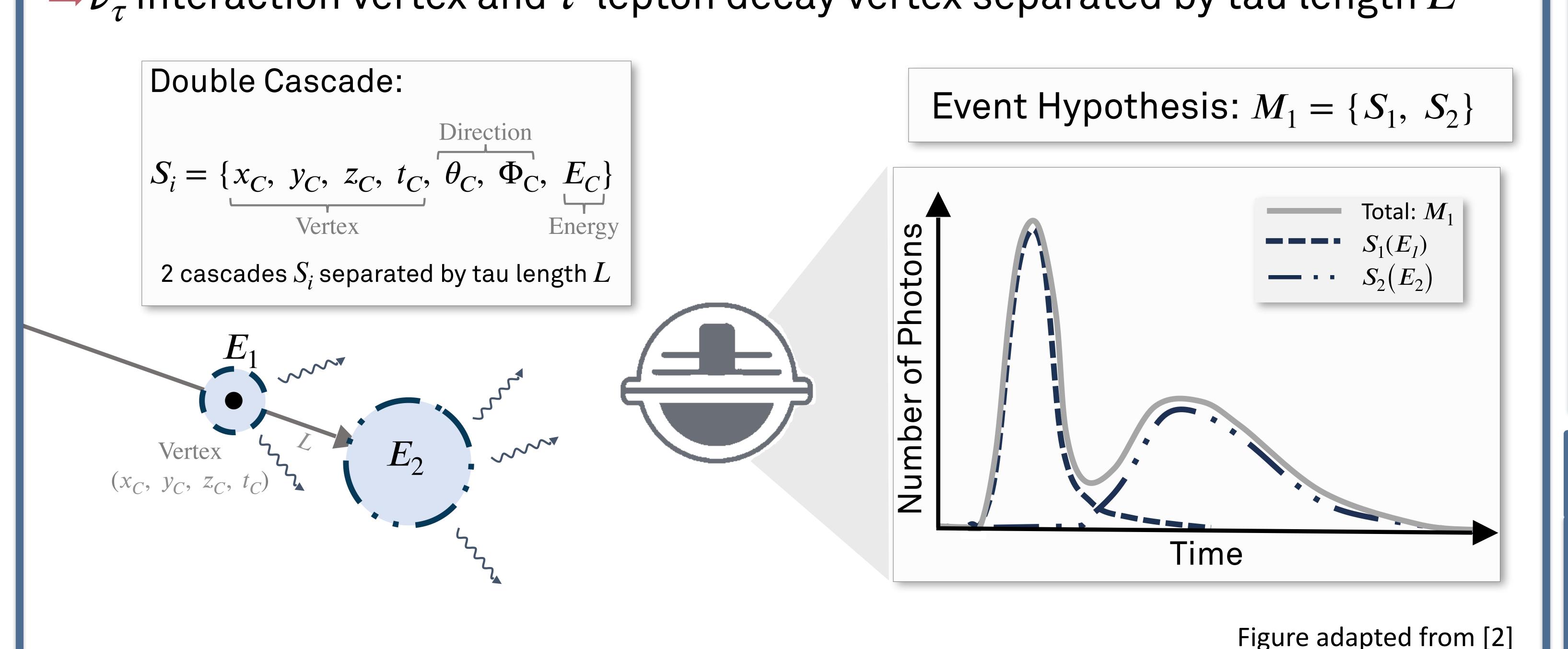
Exploit available domain knowledge and symmetries

- Model high-dimensional probability density functions (PDFs) via neural networks
- Directly incorporating information and symmetries into network architecture
- Improves interpretability and allows extrapolation along symmetries



ν_{τ} Reconstruction

High-energy $u_{ au}$ can be reconstructed via 2-cascade composite hypothesis $ightharpoonup
u_ au$ interaction vertex and au-lepton decay vertex separated by tau length L



[1] IceCube Collaboration, M. Huennefeld, PoSICRC2021 (2021) 1065 [2] M. Huennefeld, PhD thesis, TU Dortmund (2023). [3] IceCube Collaboration, Science 380, 6652, (2023). [4] IceCube Collaboration, arXiv:2507:22233, submitted to PRL.

BDT2

Background mostly other astrophysical neutrinos astrophysical purity 97.5%

Starting from a Cascade sample: DNNCascades [3]

Separate ν_{τ} from single cascades

 $\nu_{\tau} \text{ CC } (L \geq 6.5 \text{ m})$

 $\nu_{\rm e} \ {\rm CC} + \nu \ {\rm NC}$

IceCube Work in Progress

BDT Score

BDT Inputs: observables from 2-cascade reconstruction

Select $u_{ au}$ using two BDTs

BDT1

Goal: 90% ν_{τ} purity

 ν_{τ} expectation: ~0.8 events / year

Astro flux model [4] $\Phi_0 = 1.80 \cdot 10^{-18} \,\text{GeV}^{-1} \,\text{cm}^{-2} \,\text{s}^{-1} \,\text{sr}^{-1}, \, \gamma = 2.52$

IceCube Work in Progress

BDT Score

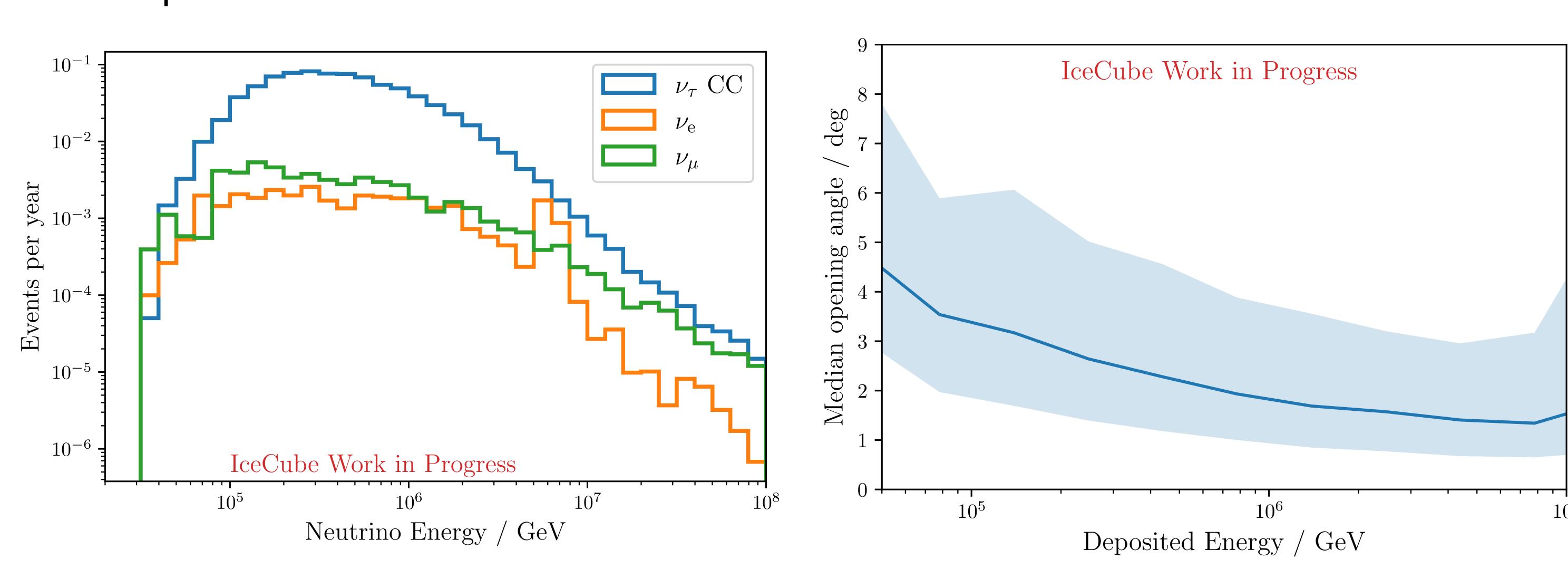
Separate ν_{τ} from track-like events

 $\nu_{\tau} \text{ CC } (L \geq 6.5 \text{ m})$

 $\nu_{\mu} \ \mathrm{CC}$

Most signal events within $[100 \, \text{TeV}, 2 \, \text{PeV}]$ with angular resolution $\lesssim 3^{\circ}$ 2nd order effects not yet included:

- Double cascades from charm hadrons
- Residual atm. µ background
- Atmospheric self-veto effect



IceCube's realtime alerts can be enhanced by adding a dedicated $u_{ au}$ stream

References

Adds $\mathcal{O}(1)$ alerts per year with near 100% astrophysical signalness and 2°-3° angular resolution