Diffuse Sensitivities of TAMBO

TAMBO Collaboration Meeting, Fall 2026

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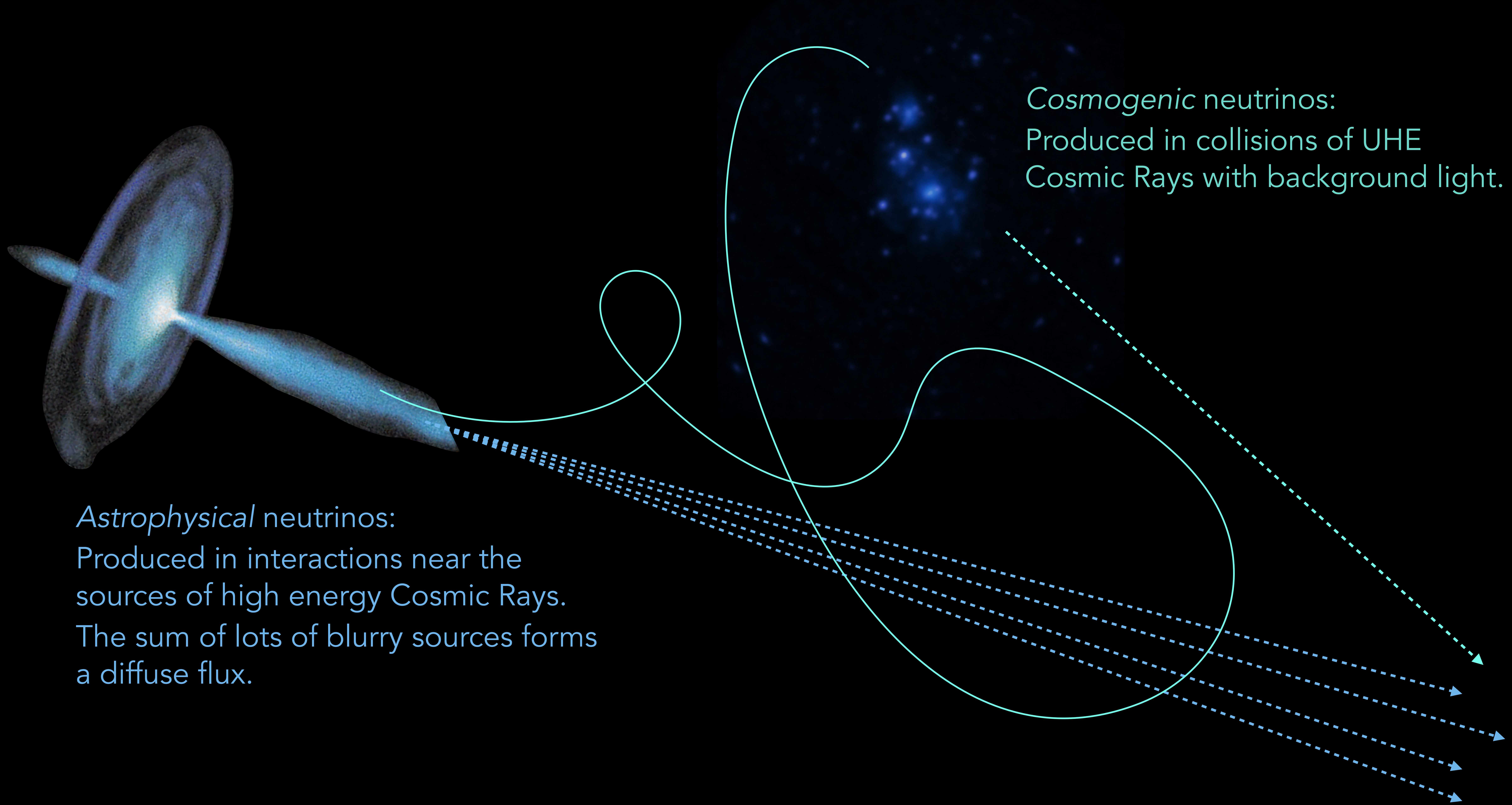
JOHN TEMPLETON FOUNDATION
Inspiring Awe & Wonder

The "diffuse" sensitivity of a neutrino observatory is
the sensitivity to a uniform all-sky flux of astrophysical or cosmogenic neutrinos,
as opposed to a particular object (source) at a particular point in the sky.

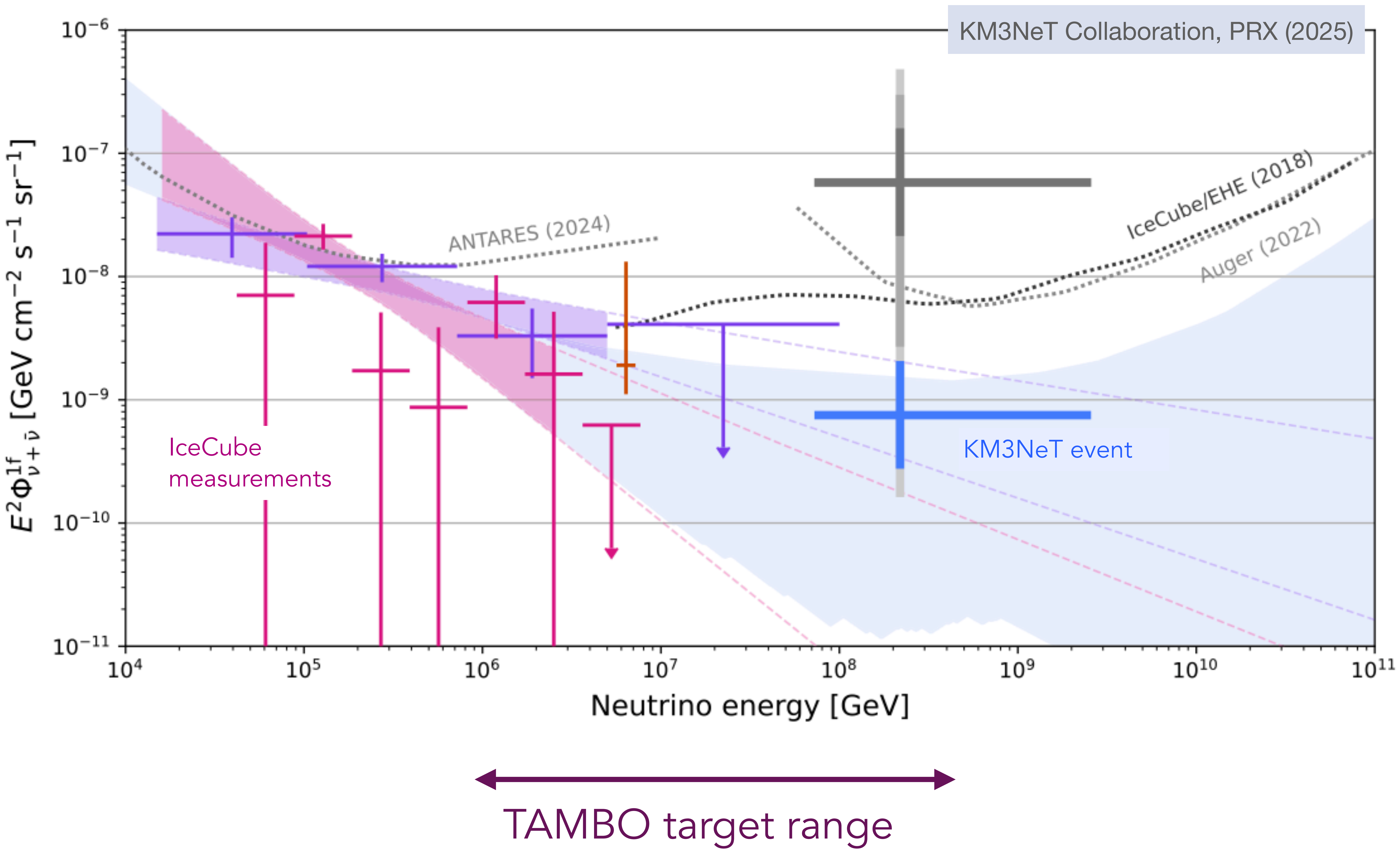
Diffuse source (of light)

Point source (of light)



Cosmogenic neutrinos:
Produced in collisions of UHE Cosmic Rays with background light.

Astrophysical neutrinos:
Produced in interactions near the sources of high energy Cosmic Rays.
The sum of lots of blurry sources forms a diffuse flux.



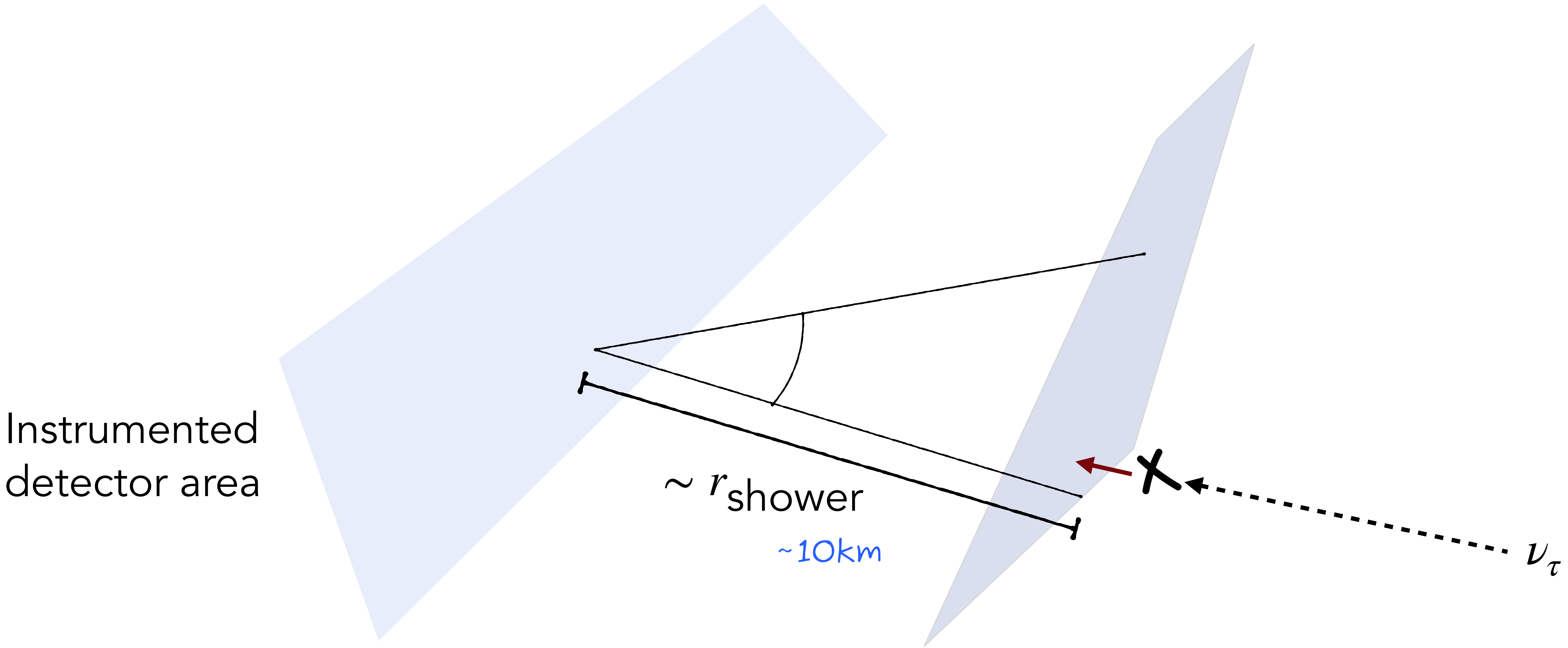
- IceCube has characterized the astrophysical flux from TeV to PeV energies.
- At EHE energies (many PeV and above), IceCube and Auger have placed limits.
- KM3NeT recently saw an EHE event…?

We estimate our sensitivity to the diffuse flux using a few different quantities:

Effective Aperture	Area × Solid Angle	How effective are we at observing neutrinos of a given energy?
Expected event rate	Counts	How many neutrinos do we expect to observe if we assume a given flux?
Differential sensitivity	Flux	What's the smallest possible flux we could detect, i.e. see X events in Y years?

Aperture $A\Omega \simeq$ [instrumented area] $\times$ [useful solid angle] $\times$ [probability neutrino $\to$ tau]

IceCube: ~500m²sr at 1PeV ~1 ~4×10^{-6}, at 1PeV



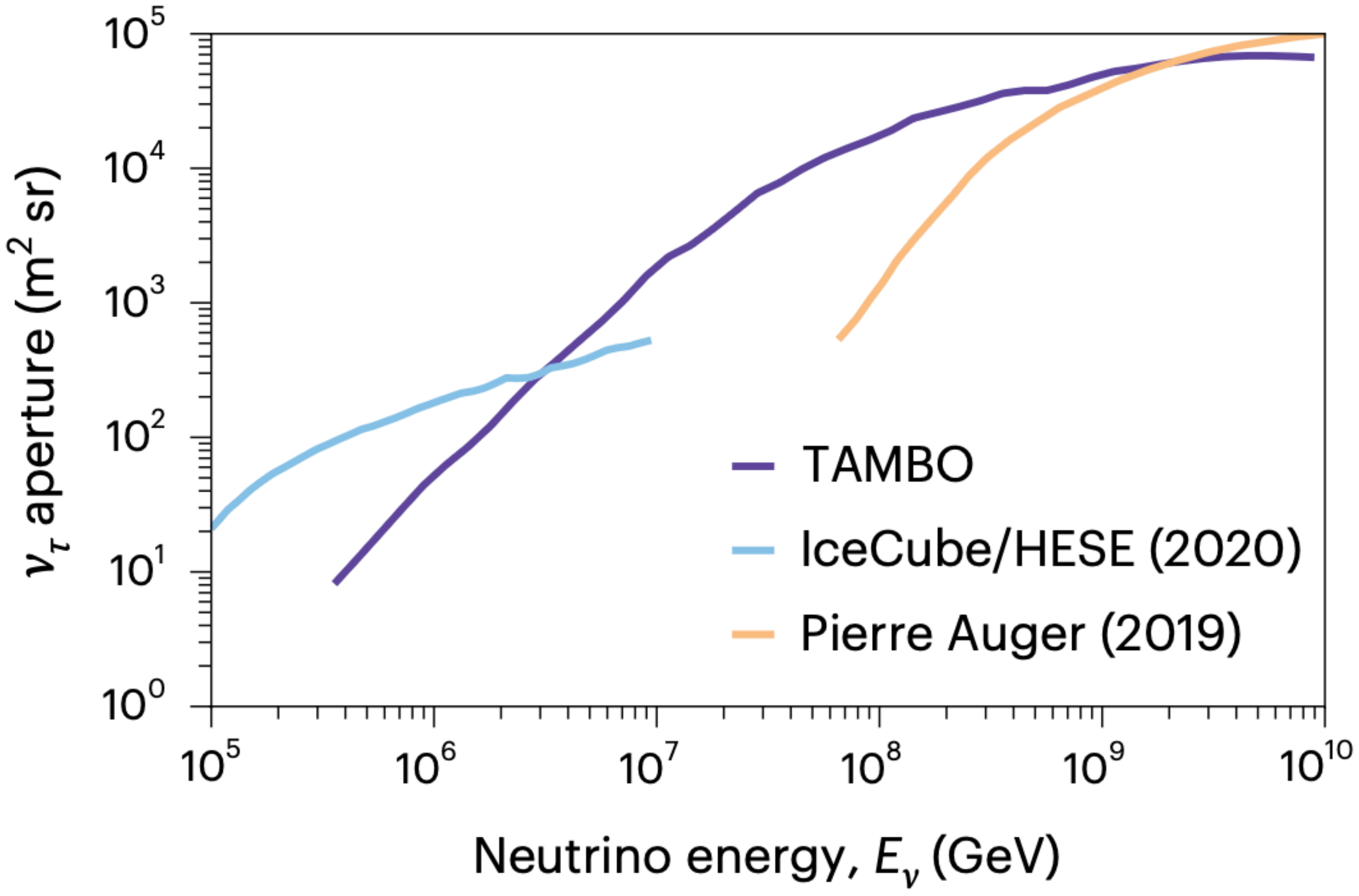
What have we previously computed?

In our 2026 Nature Astronomy Perspective, we published our ν_τ aperture, computed by Pavel + Will based on 2025 simulation.

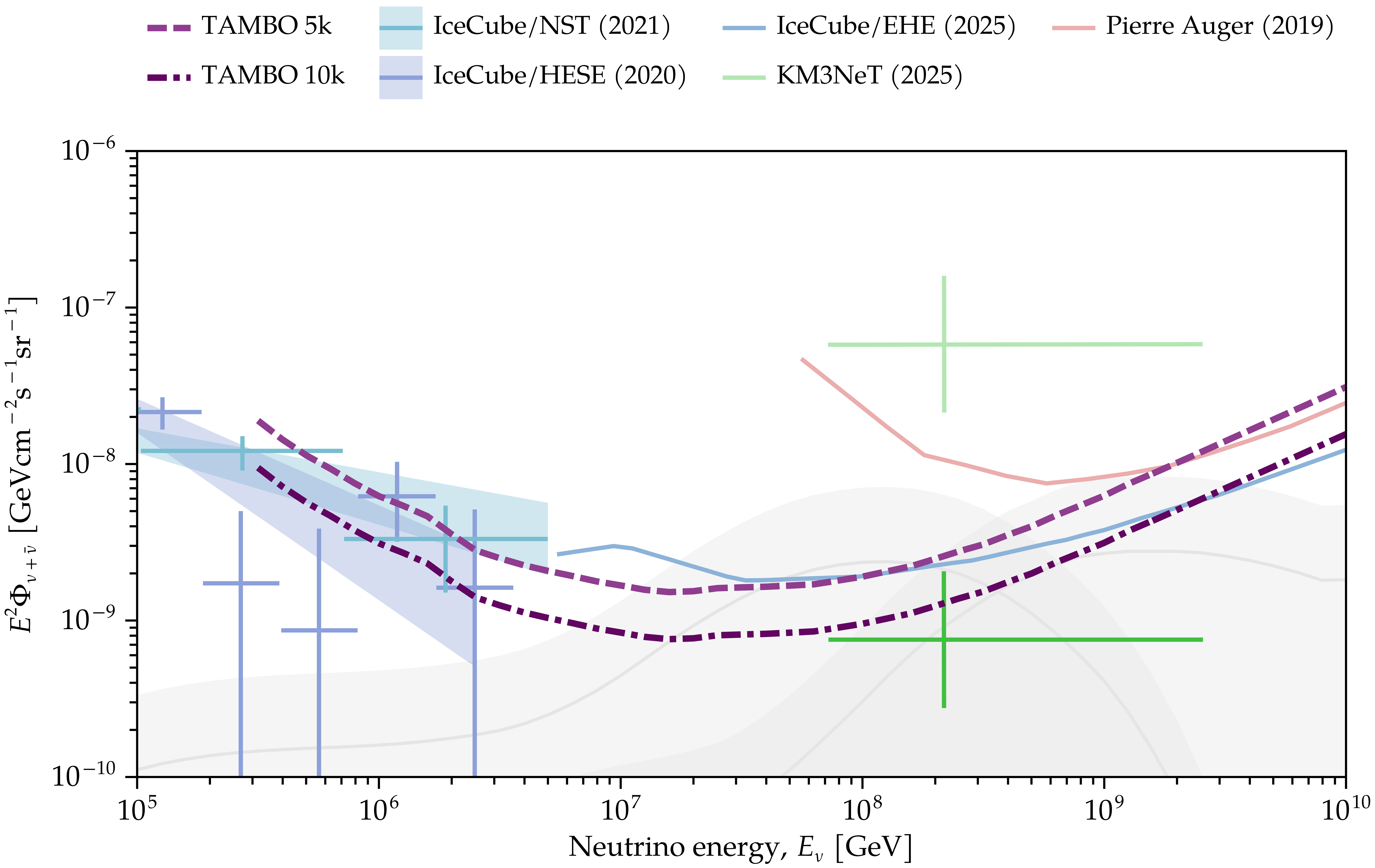
The calculation used:

- Simulated site = Valley of the Volcanoes, rescaled to 5000 detectors from 700
- $4m^2$ panel areas
- Trigger/cut conditions =
  - At least 3 modules with at least 3 hits
  - At least 30 hits total
  - At least 4km of rock overburden

$$A\Omega\,(1\text{PeV}) \simeq 50\text{m}^2\text{sr}$$
$$A\Omega\,(10\text{PeV}) \simeq 200\text{m}^2\text{sr}$$



We also computed our differential sensitivity with the same 2025 simulation.



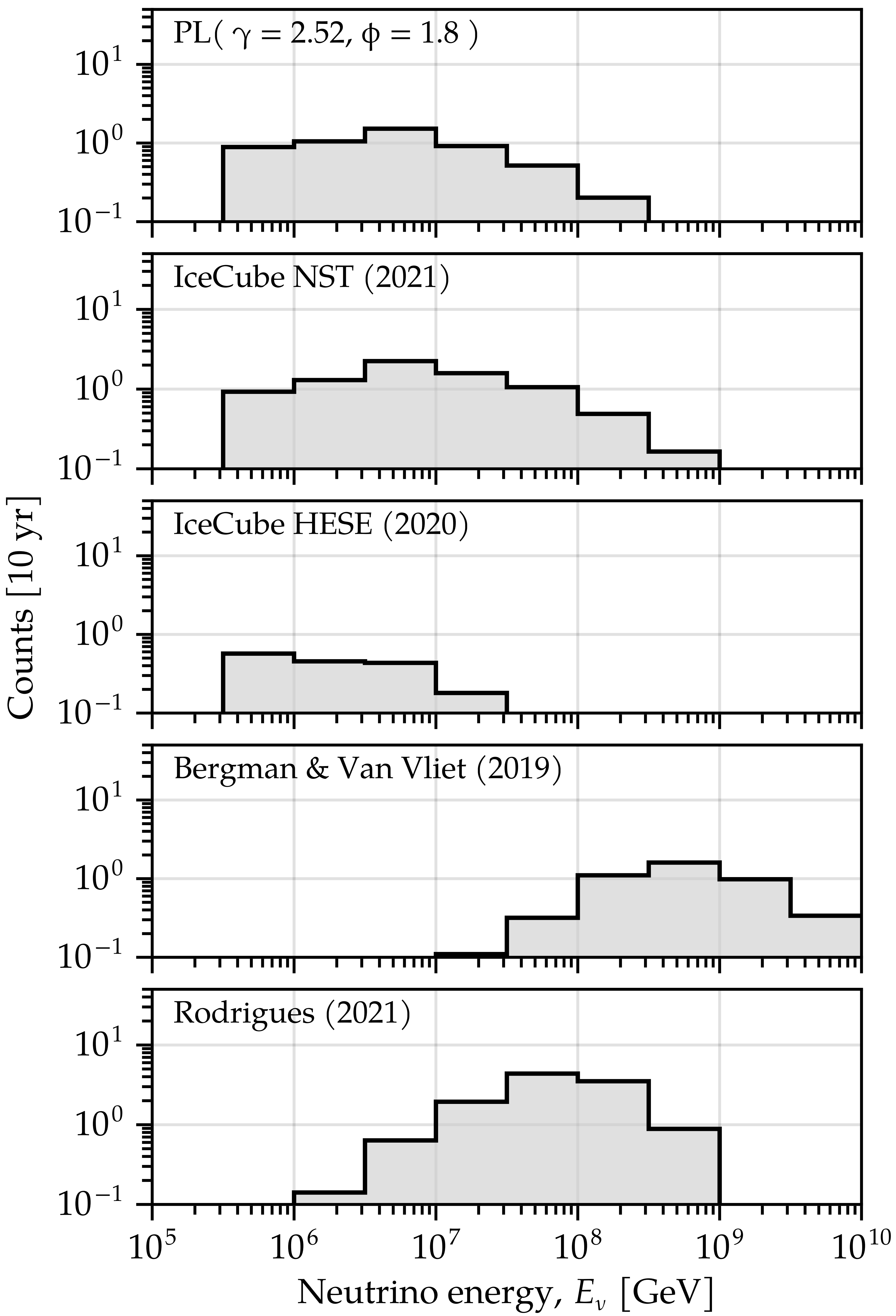
Note: there are some outstanding revisions for this plot I have not had a chance to make! These include:

- Fixing all curves to use the same spectral convention (IC EHE uses E^{-1}, Auger uses E^{-2})
- Cosmetic changes to axis and legend labels
- Cosmetic changes to IceCube measurements

As well as event rates based on different assumed flux models:

Note: there are some outstanding revisions for this plot I have not had a chance to make! These include:

- Annotating the total count in the top right
- Visually differentiate different classes of models
- Cosmetic changes to axis and legend labels



The 2025 simulation used an early draft of TamboSim.jl.
Since then we have made the following improvements:

- Added ability to differentiate sensor efficiencies to shower particles of different species / energies, based on GEANT4*
- Greatly improved interface for weighting, and (re)processing
- Correct treatment of the terrain in Julia and in CORSIKA, which was particularly important for backgrounds and timing-dependent studies
- Added CR backgrounds
- Added muon backgrounds and muon-neutrino signals*

*Not yet integrated into the main branch, but coming soon

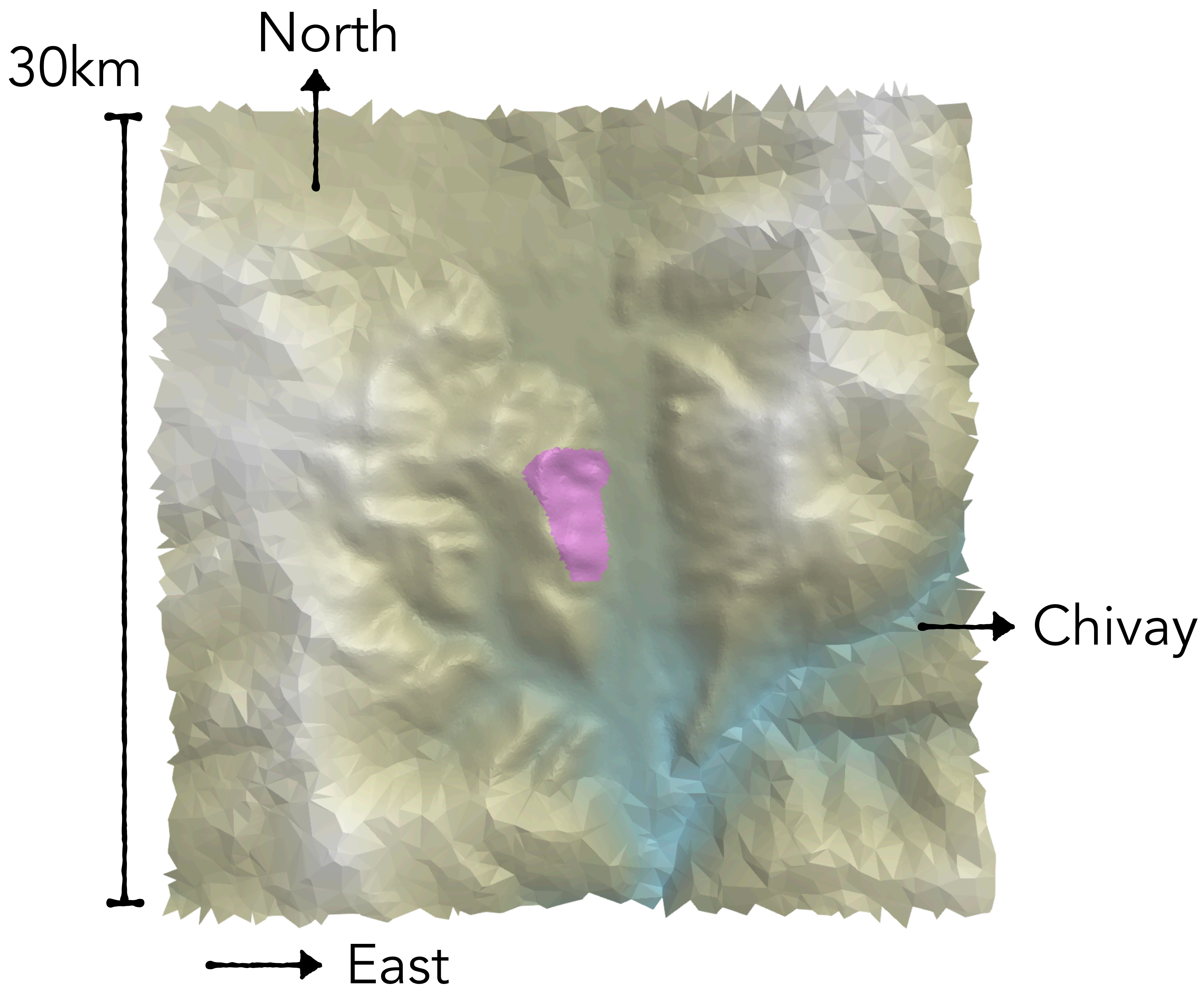
What results can we produce using 2026 simulation (TamboSim-v1) instead of 2025?

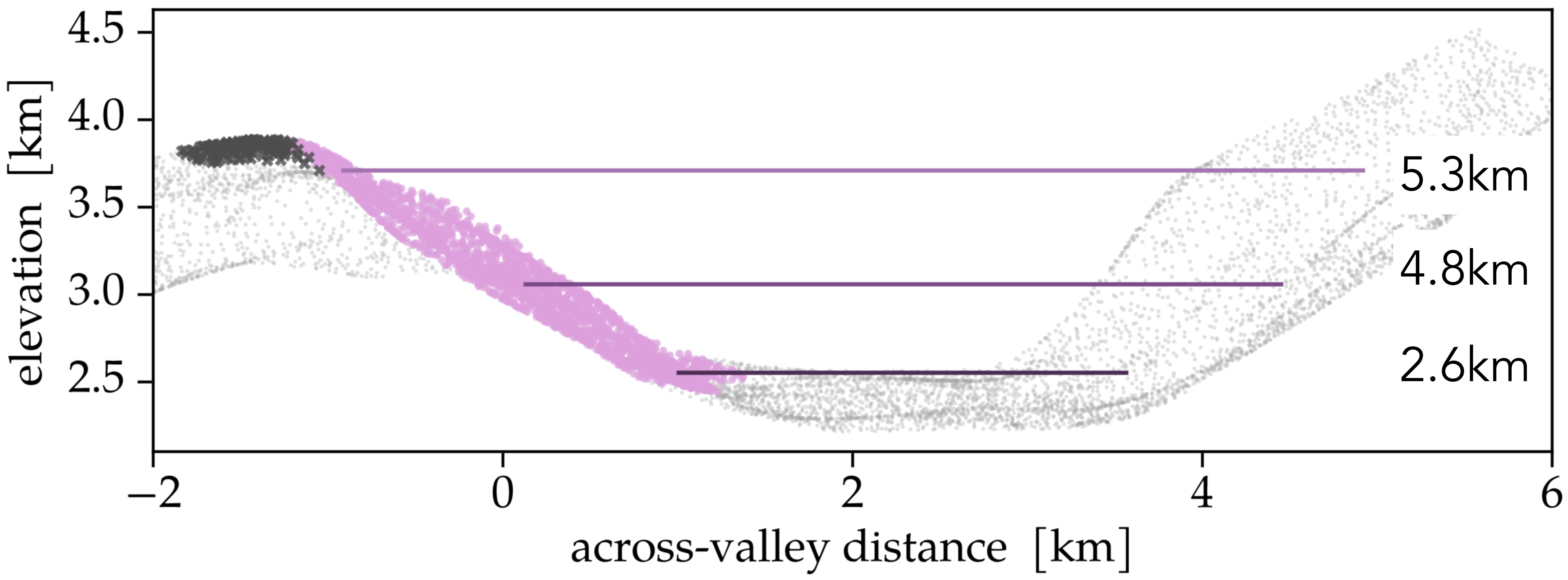
- We can use more realistic descriptions of the sensors (size, particle efficiency)
- We can describe rates and distributions at different processing and filter levels
- We can include background simulations (CRs, muons) and thus better motivate our signal purity
- We could include other neutrino flavors (ν_μ)

Some newer results using TamboSim-v1:
[work in progress]

Valley of the Volcanoes

- Instrumented area ≃ 13km²
- Inclination ~ 30°





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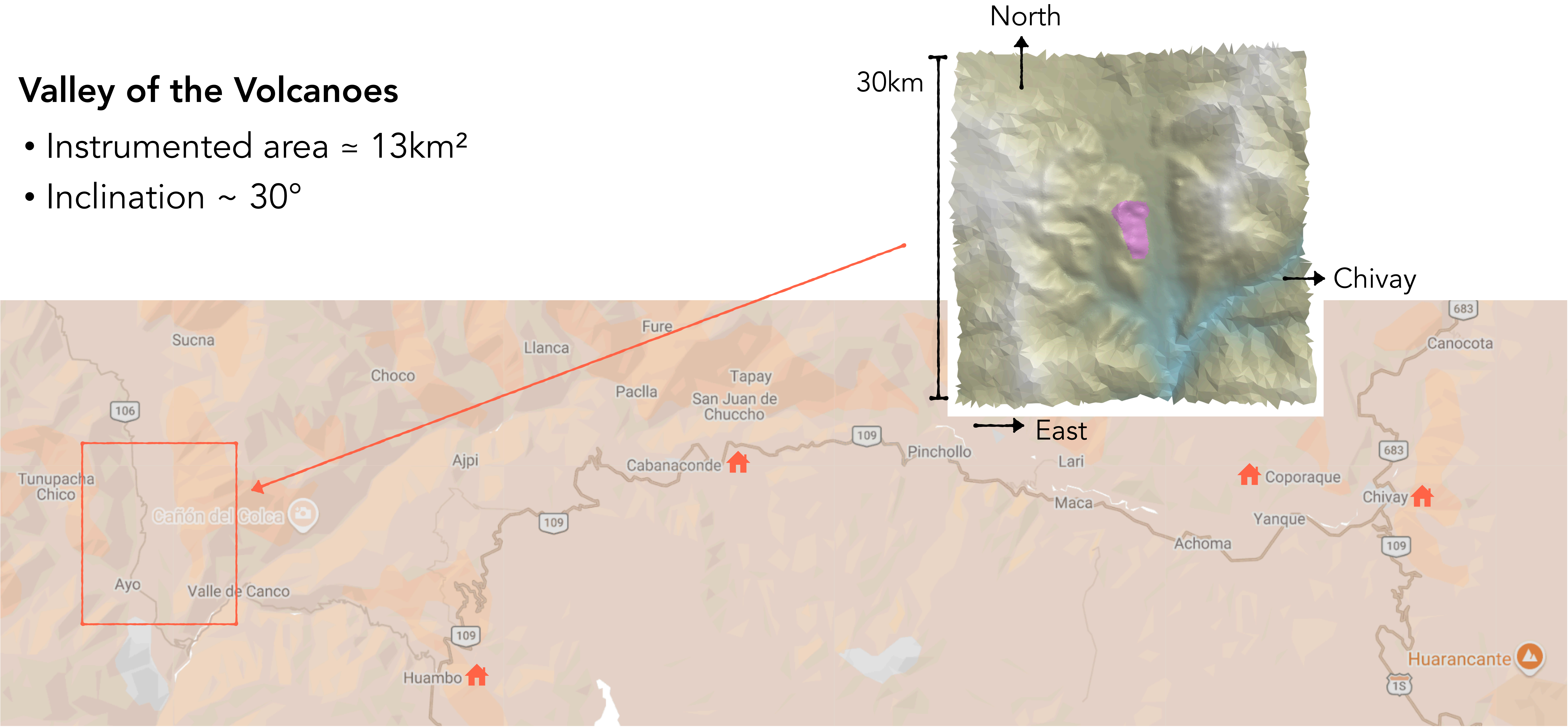
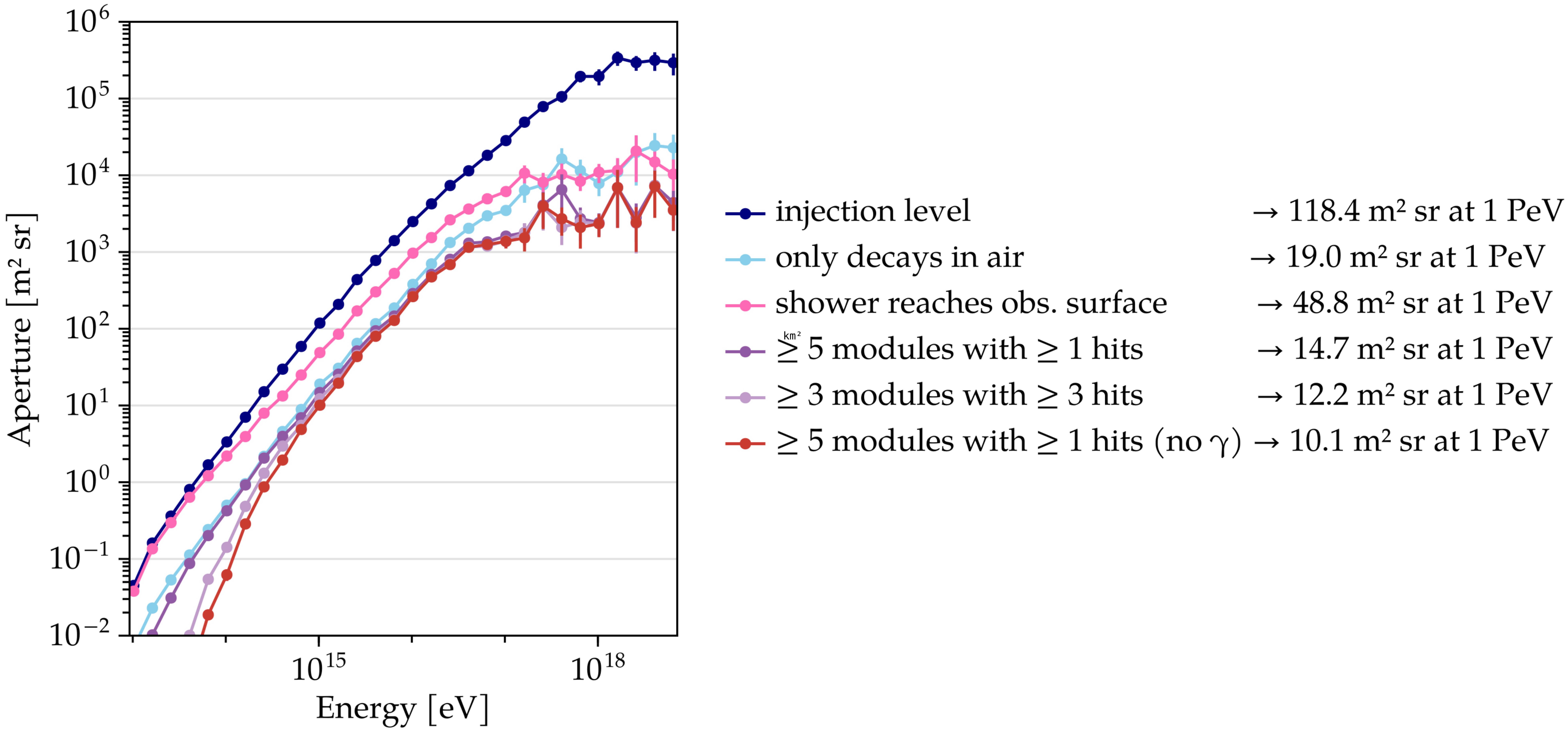


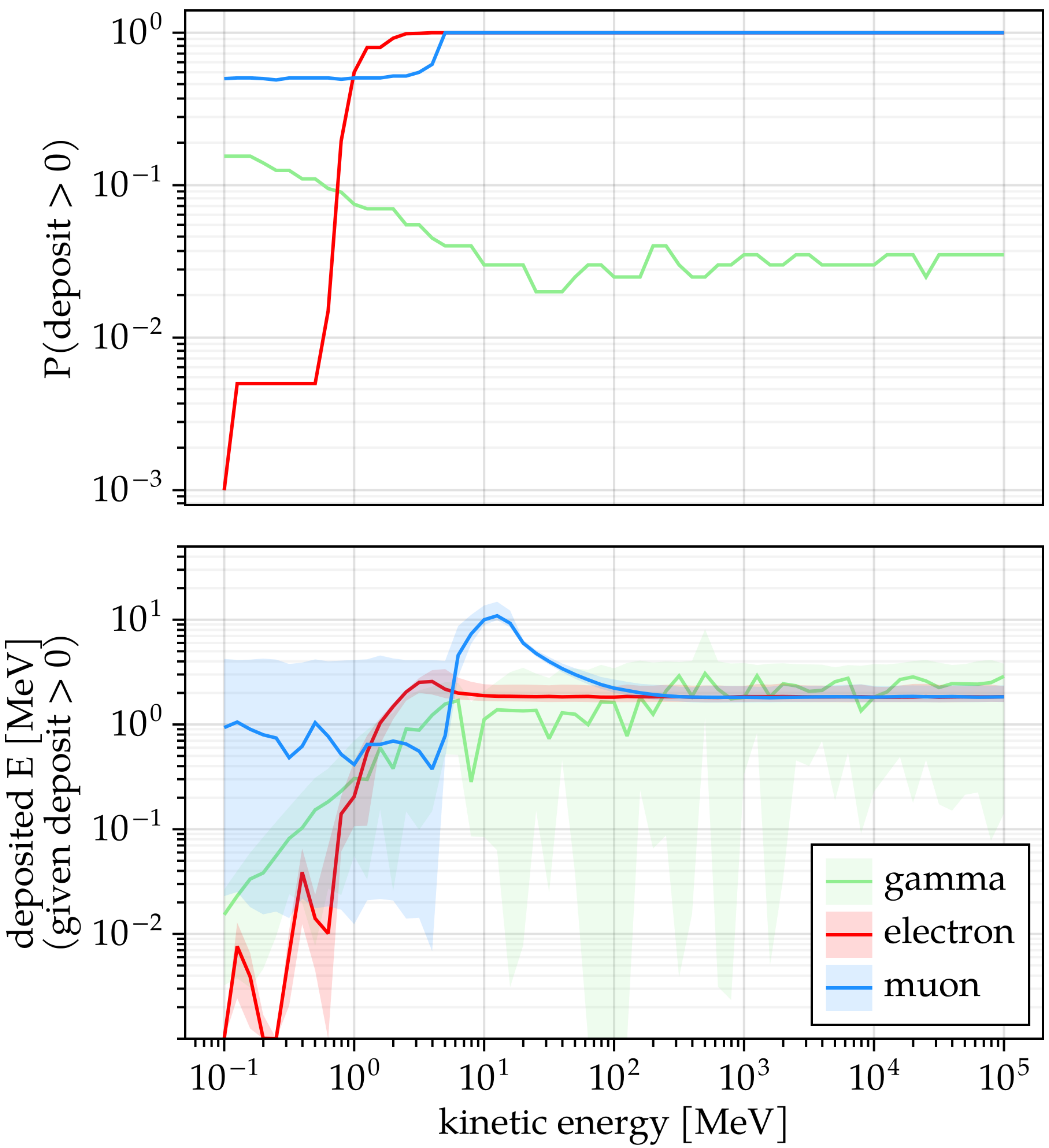
Valley of the Volcanoes: 2026 simulation results
(4m² panels, 900 modules / 13km² area — not rescaled)



Energy deposition curves, for:

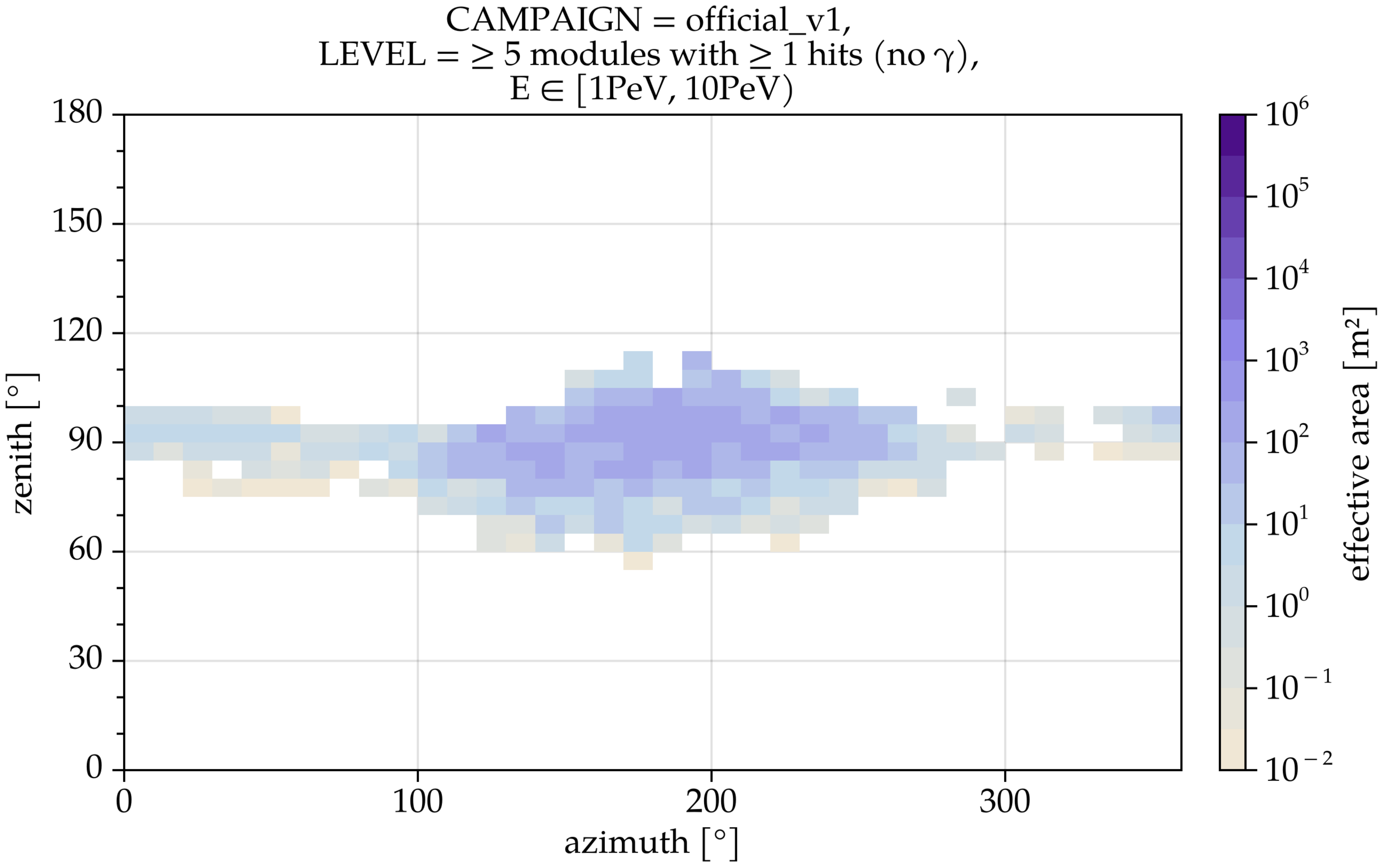
- 1cm thick Fermilab scintillator
- 1mm aluminum housing.

- Above ~100MeV, **gammas** have a ~3% probability of depositing ~2MeV of energy (via pair production)
- Above ~5MeV, **muons** and **electrons** have a ~100% probability of depositing ~2MeV of energy



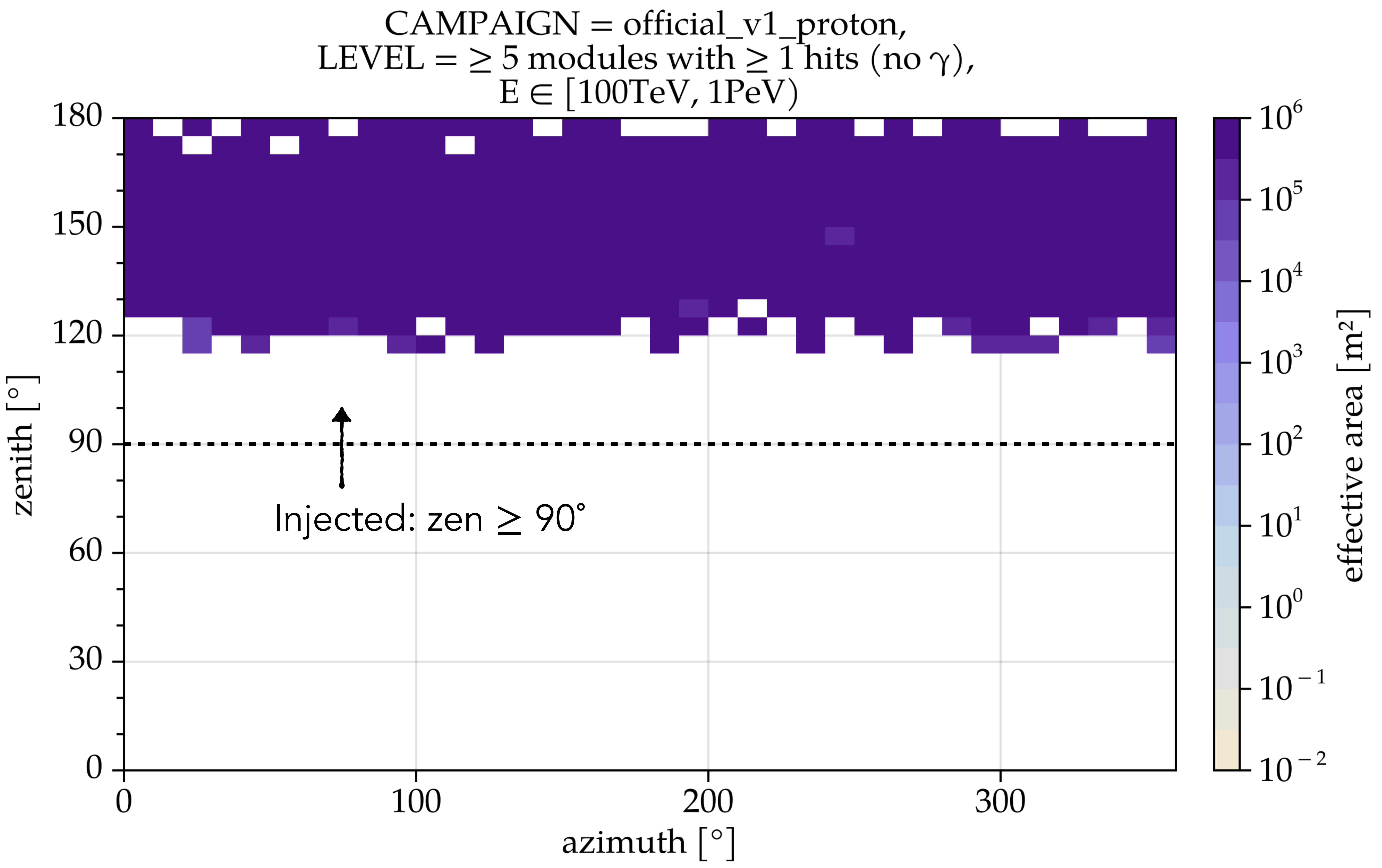
Valley of the Volcanoes: 2026 simulation results
(4m² panels, 900 modules / 13km² area — not rescaled)

Tau neutrinos:
directionally dependent effective area, at 1-10PeV



Valley of the Volcanoes: 2026 simulation results (4m² panels, 900 modules / 13km² area — not rescaled)

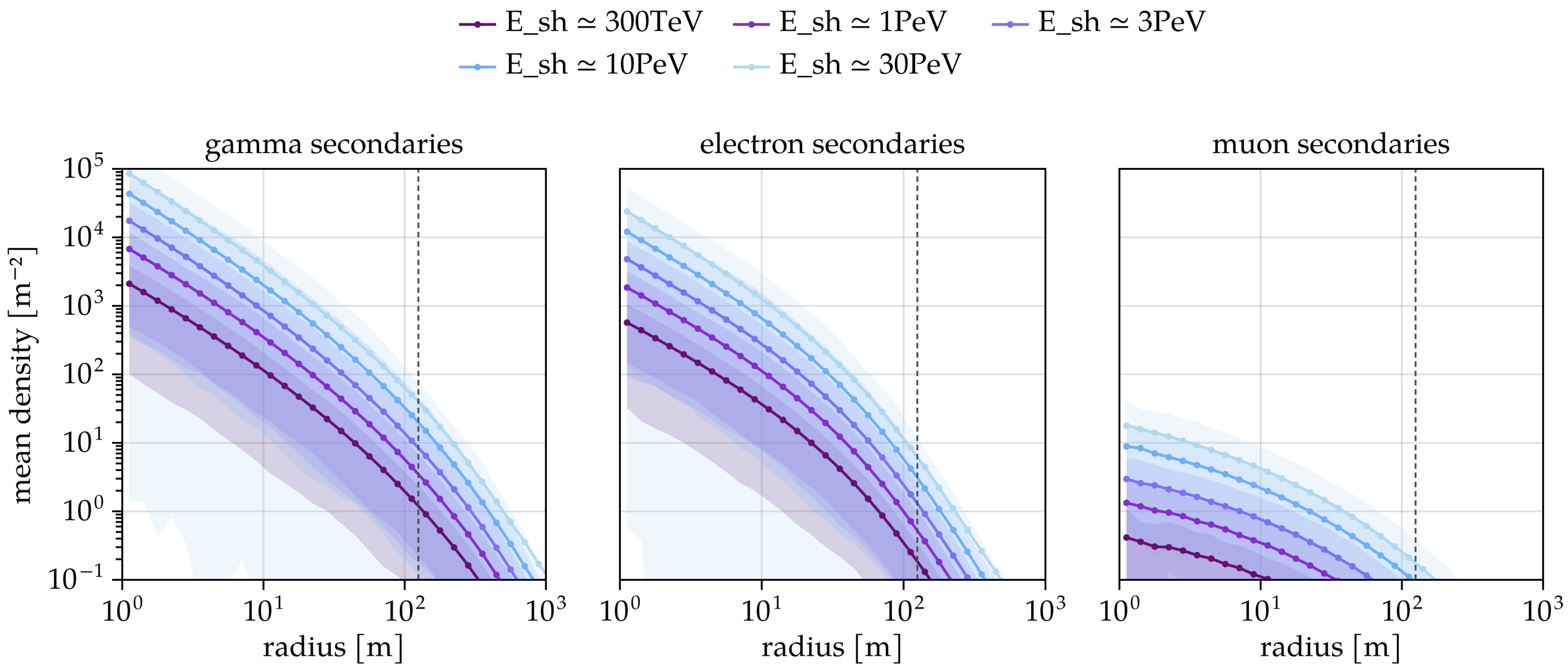
Cosmic Ray protons: directionally dependent effective area, at 0.1-1PeV

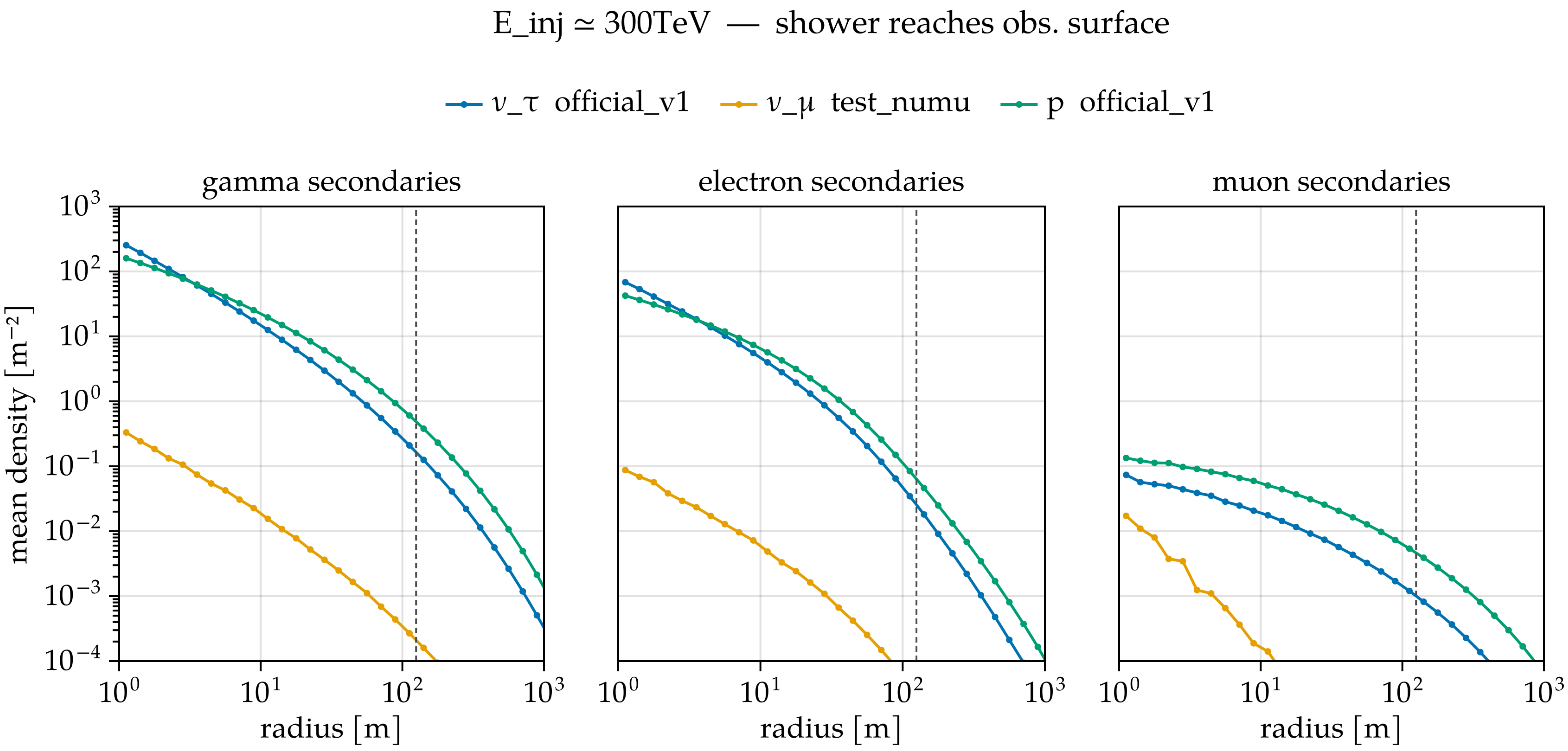


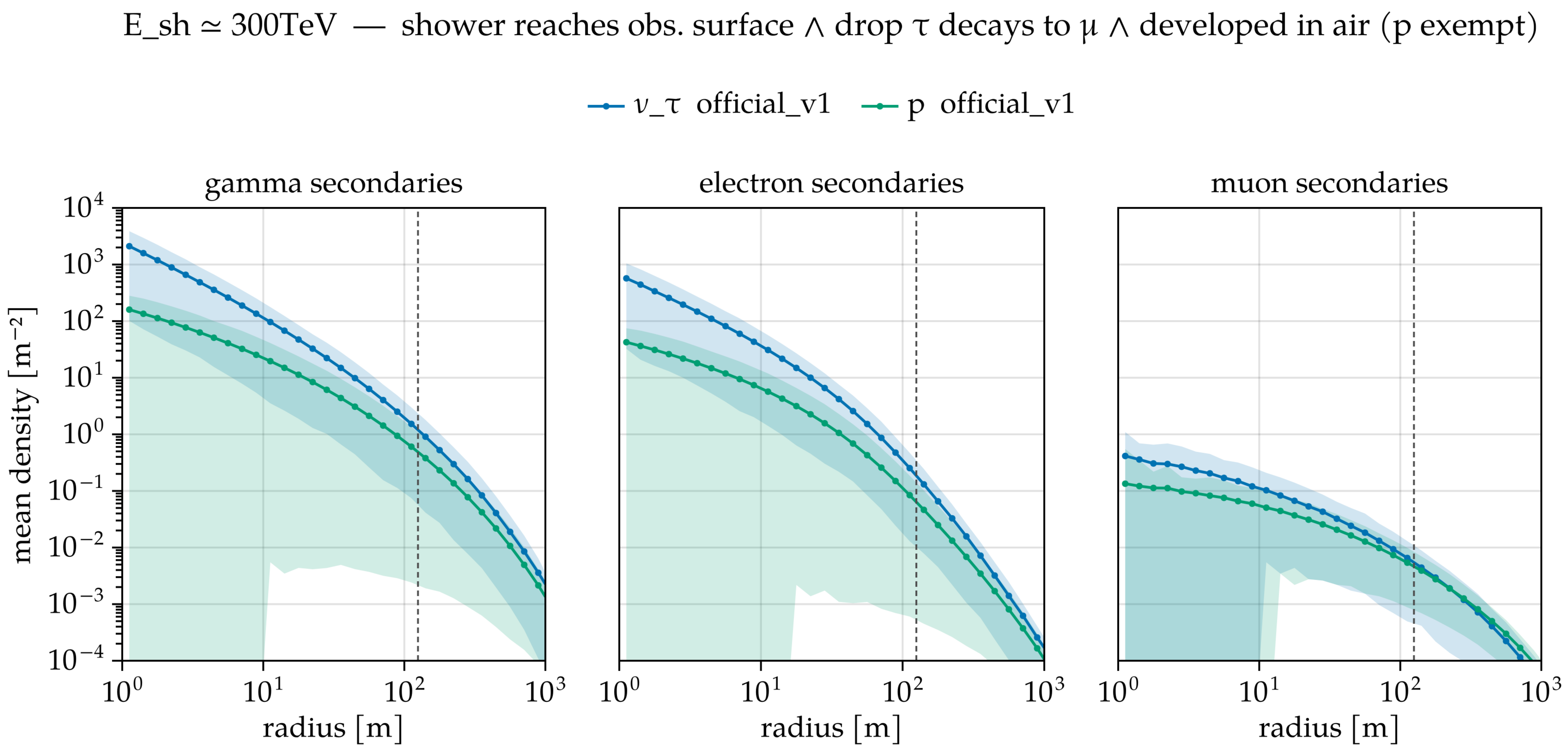
Conclusions:

- Aperture computed with 2026 simulation (TamboSim-v1) is consistent with 2025 results
- TamboSim-v1 enables us to treat sensor modules more realistically and to do further studies of triggers, cuts, directional reconstruction, and backgrounds

ν_τ official_v1 — shower reaches obs. surface ∧ drop τ decays to μ ∧ only decays in air




E_inj ≃ 300TeV — shower reaches obs. surface
ν_τ official_v1
ν_μ test_numu
p official_v1
gamma secondaries
electron secondaries
muon secondaries
mean density [m⁻²]
radius [m]
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
10^-4


E_sh ≃ 300TeV — shower reaches obs. surface ∧ drop τ decays to μ ∧ developed in air (p exempt)
ν_τ official_v1
p official_v1
gamma secondaries
electron secondaries
muon secondaries
mean density [m⁻²]
10^4
10^3
10^2
10^1
10^0
10^−1
10^−2
10^−3
10^−4
10^0
10^1
10^2
10^3
radius [m]