TAMBO: Searching for ν_τ in the Peruvian Andes

Will Thompson

SILAFAE 2024

November 5th, 2024

Le Verrier

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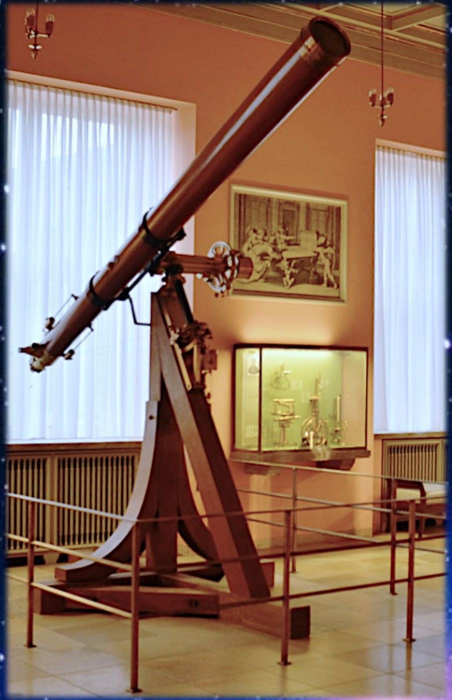

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TAMBO

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ICECUBE

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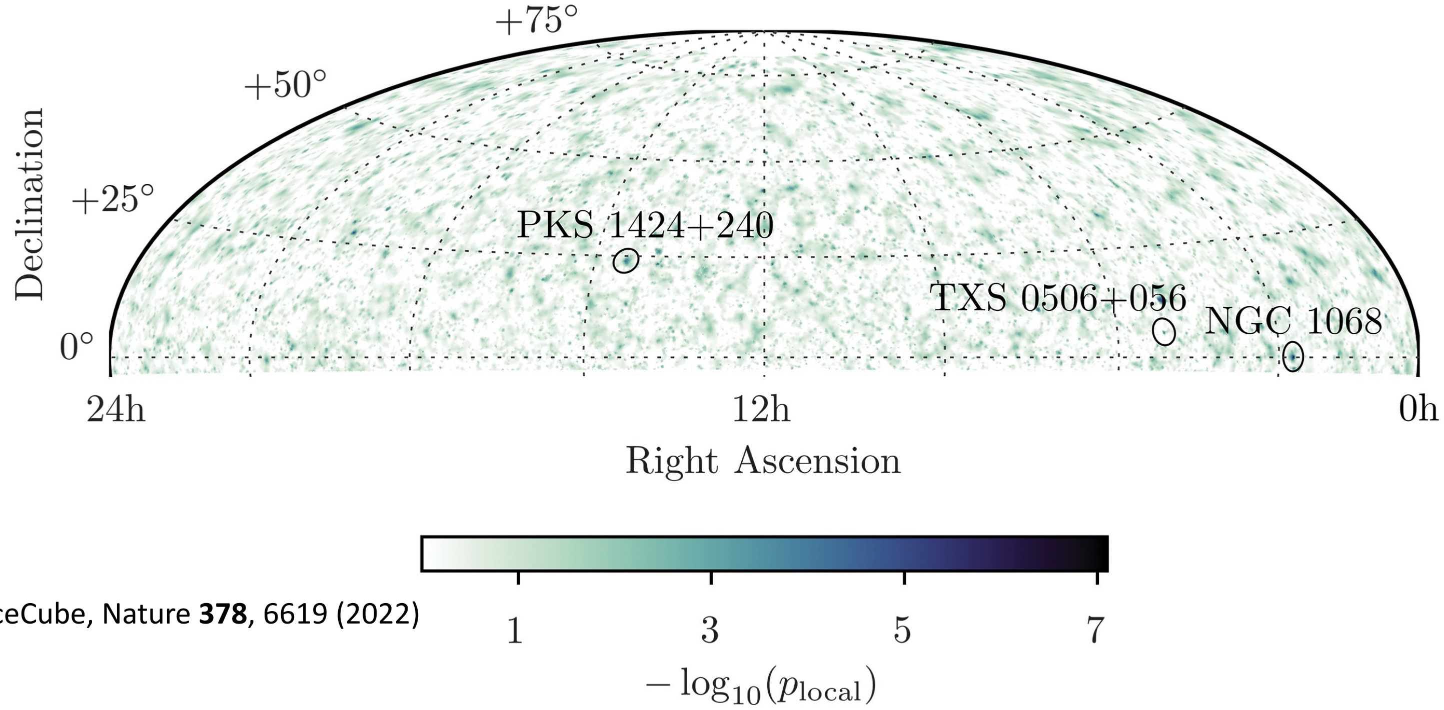
Where Are the Sources?



IceCube, Nature **378**, 6619 (2022)

- Number of known neutrino sources increased by ∞% in last six years

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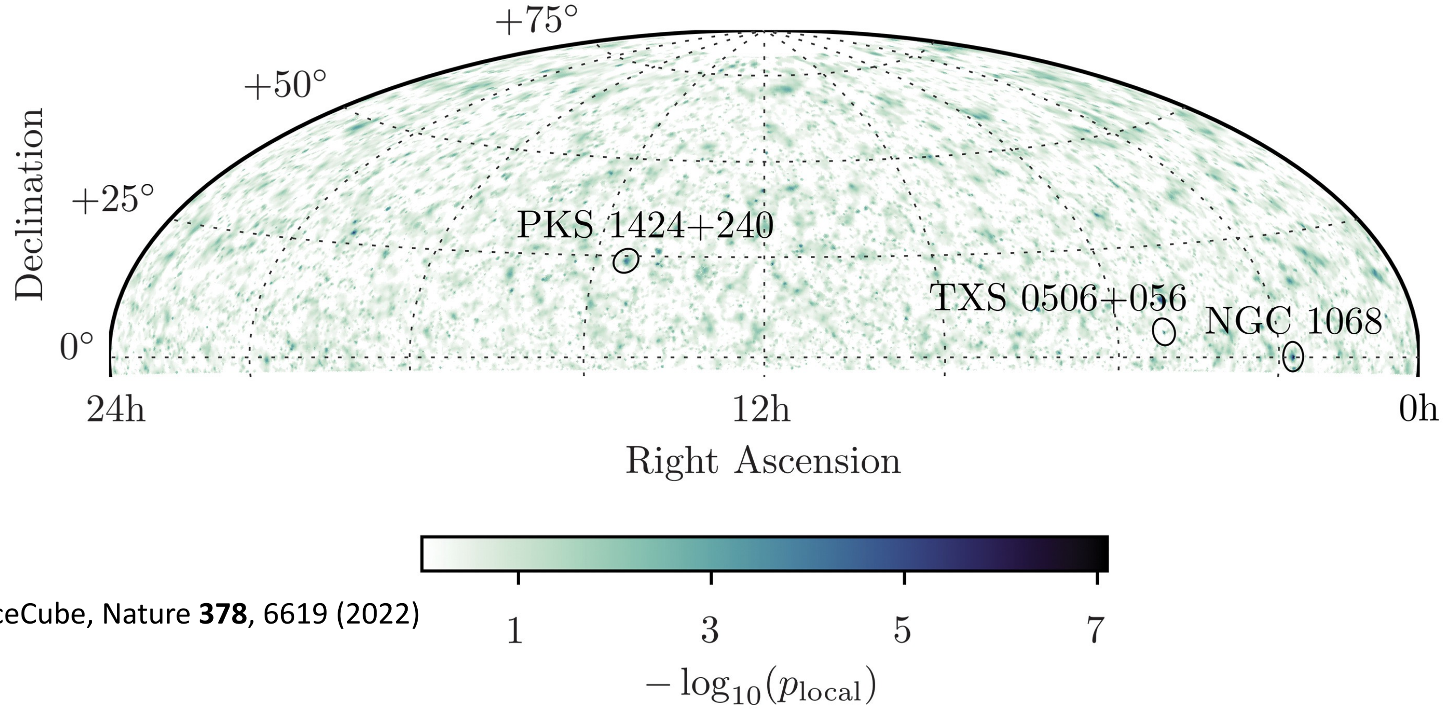

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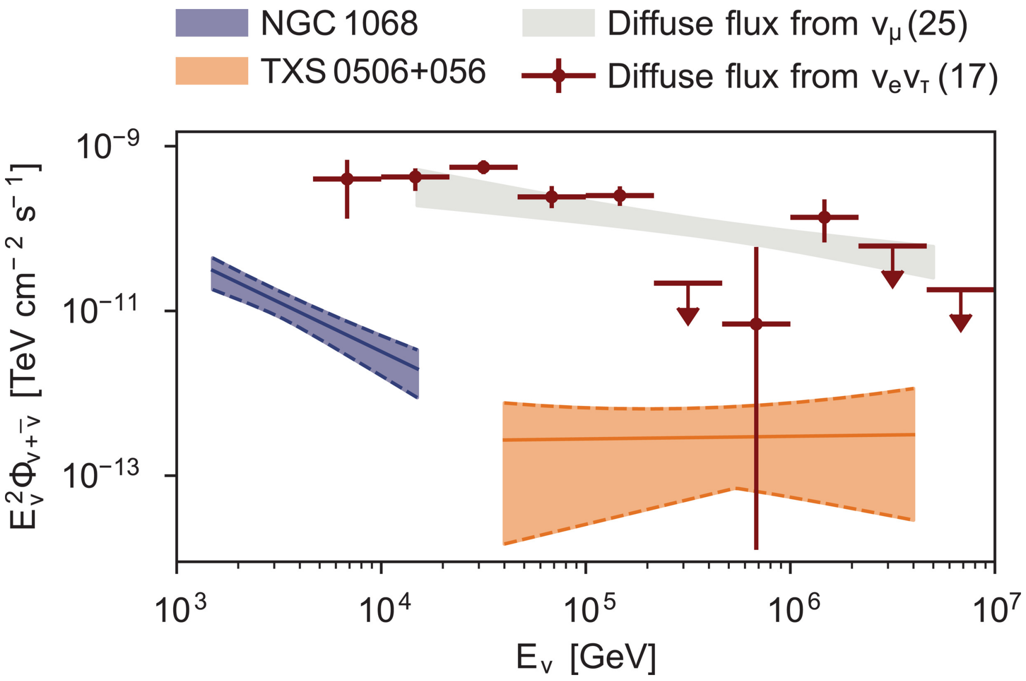
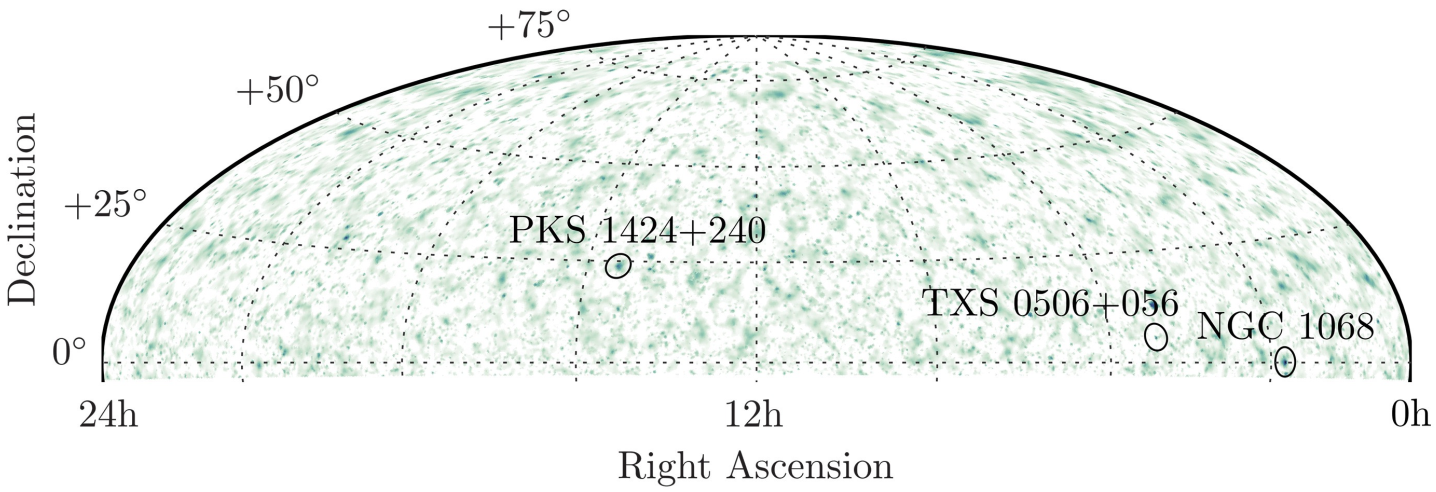
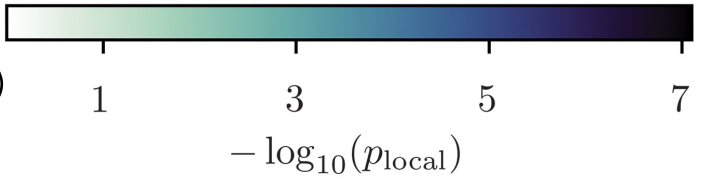


- Number of known neutrino sources increased by ∞% in last six years
- … but these comprise only a small fraction of the diffuse flux

Where Are the Sources?

Test type	Pre-trial p-value (p_{local})	Post-trial p-value (p_{global})
Northern Hemisphere scan	5.0×10^{-8} ($5.3\,\sigma$)	2.2×10^{-2} ($2.0\,\sigma$)





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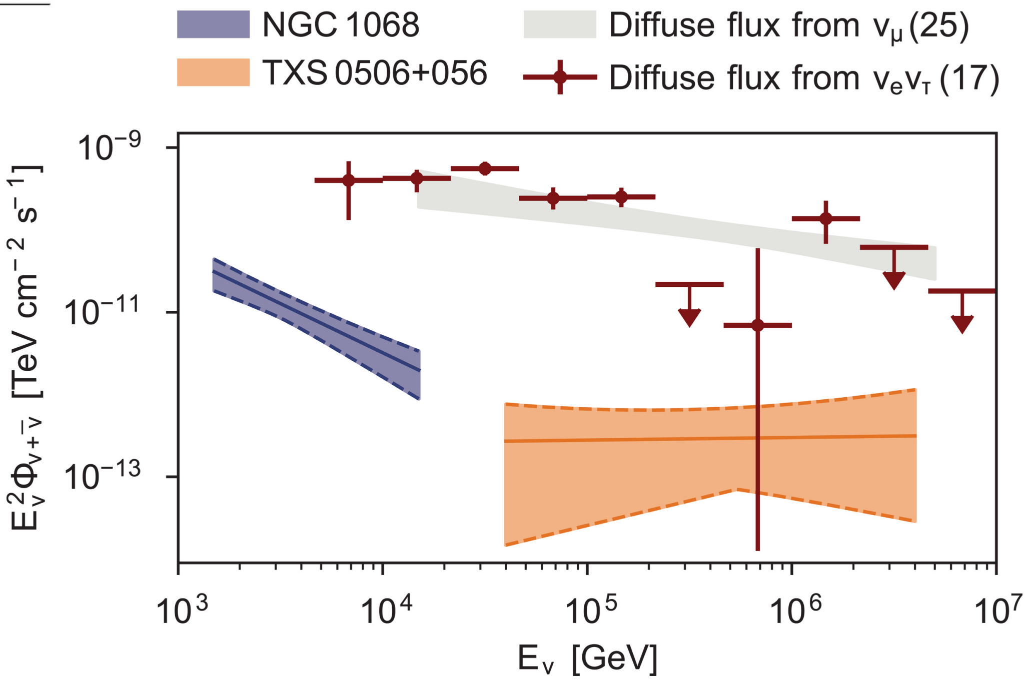

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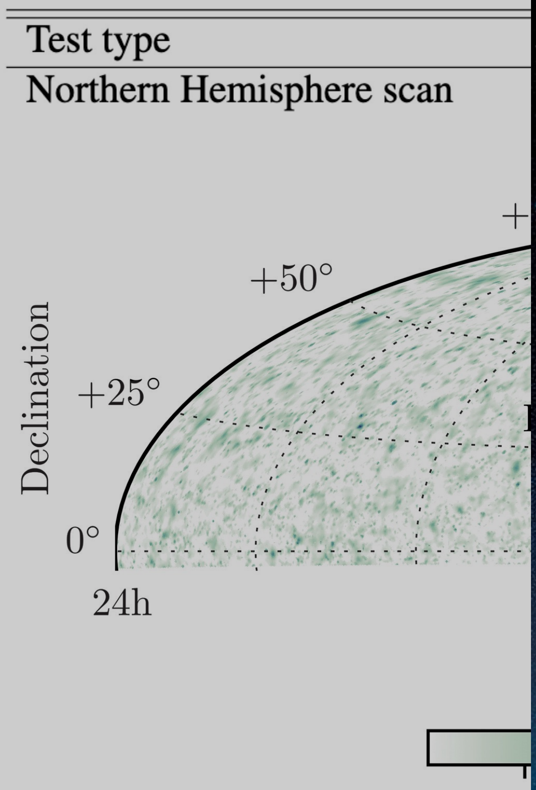

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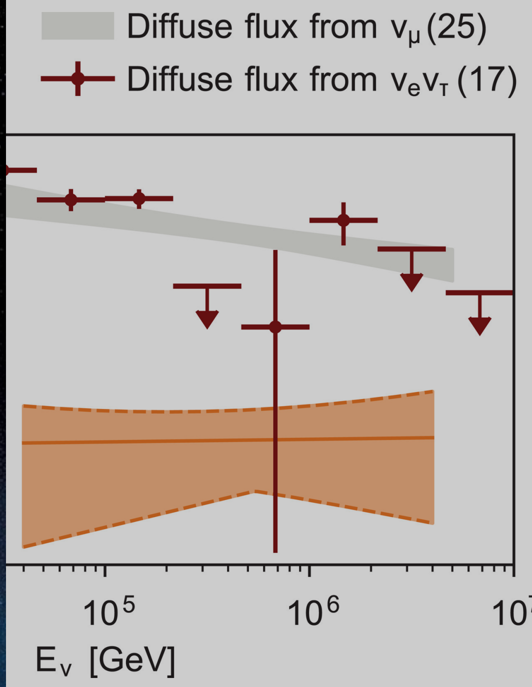
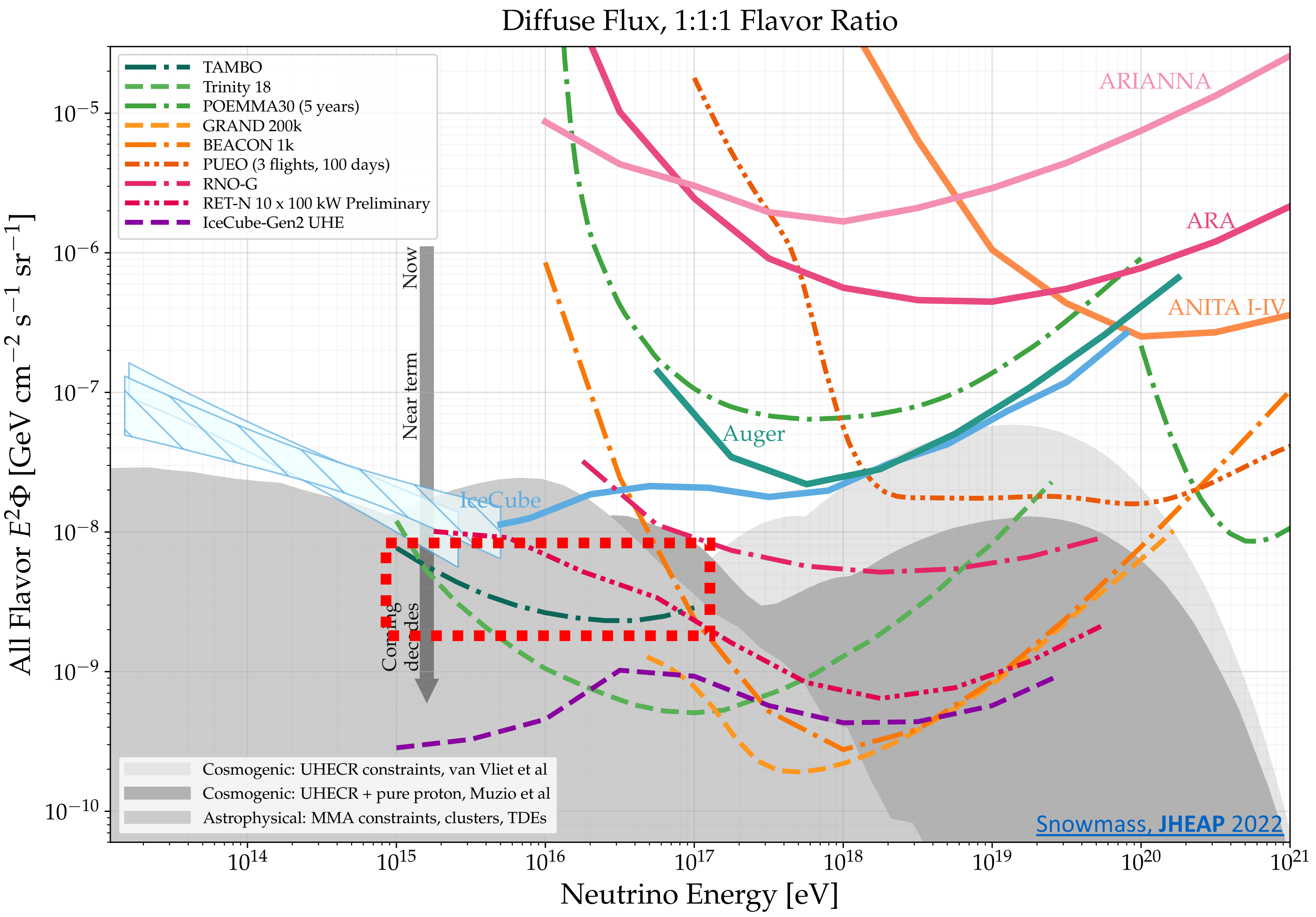
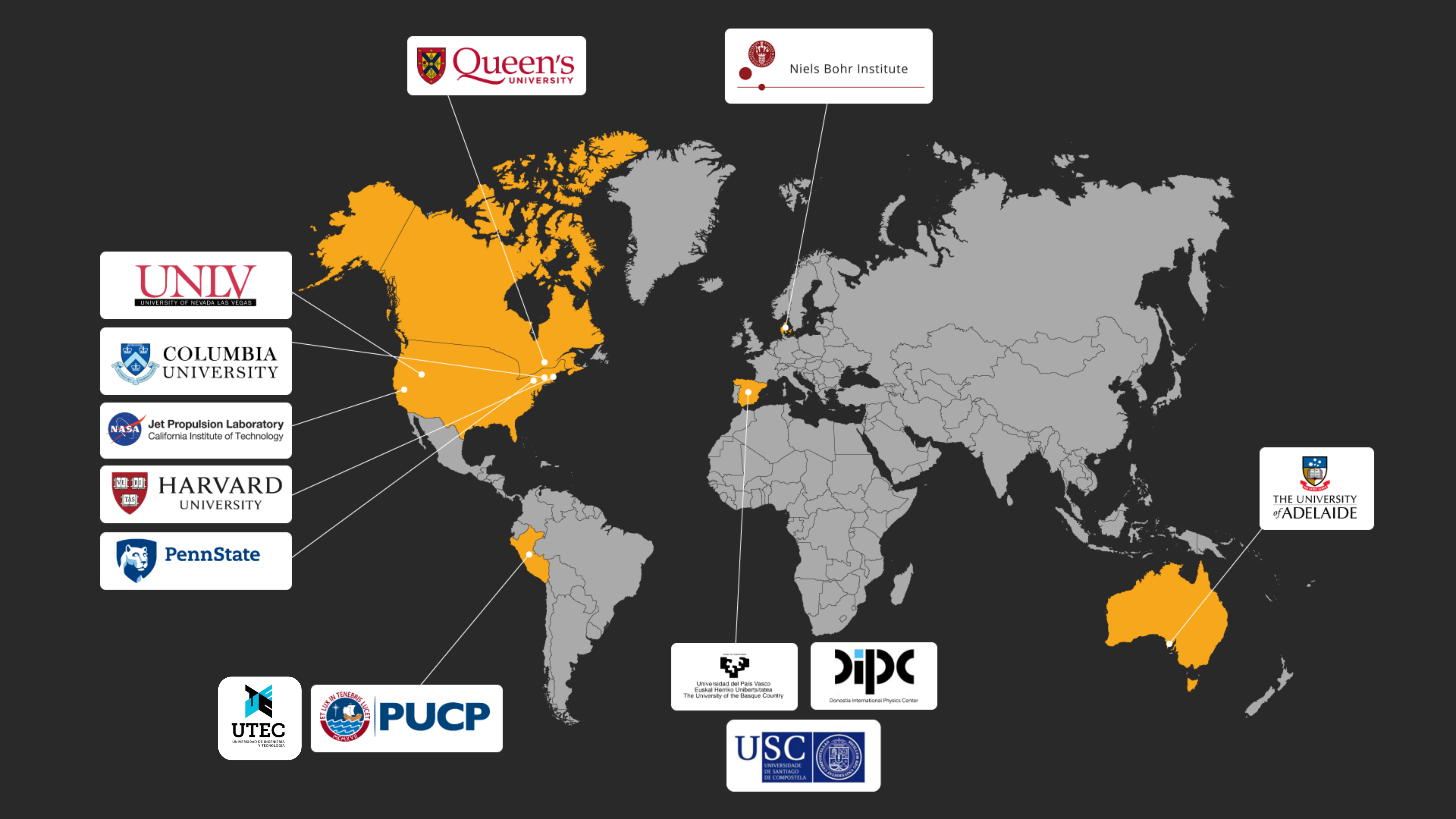


- Number of know years
- … but these com

Next-Generation Prospects



- Community has heeded call for UHE neutrino observatories
  - But fewer experiments planned for 1-100 PeV
- TAMBO bridges the gap between HE & UHE observatories



Queen's UNIVERSITY
Niels Bohr Institute
UNLV
UNIVERSITY OF NEVADA LAS VEGAS
COLUMBIA UNIVERSITY
Jet Propulsion Laboratory
California Institute of Technology
HARVARD UNIVERSITY
PennState
THE UNIVERSITY of ADELAIDE
Universidad del País Vasco
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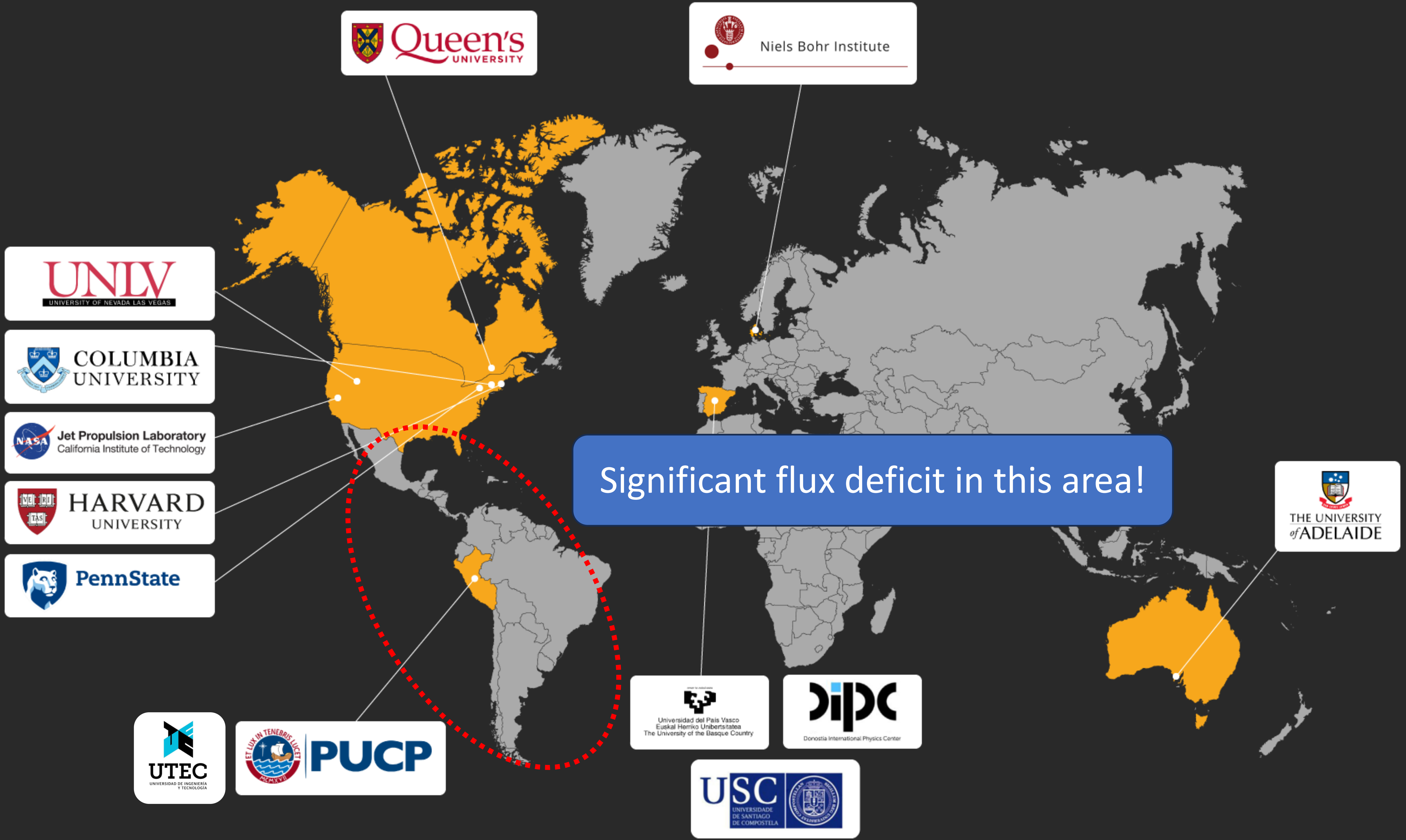
Significant flux deficit in this area!
Queen's UNIVERSITY
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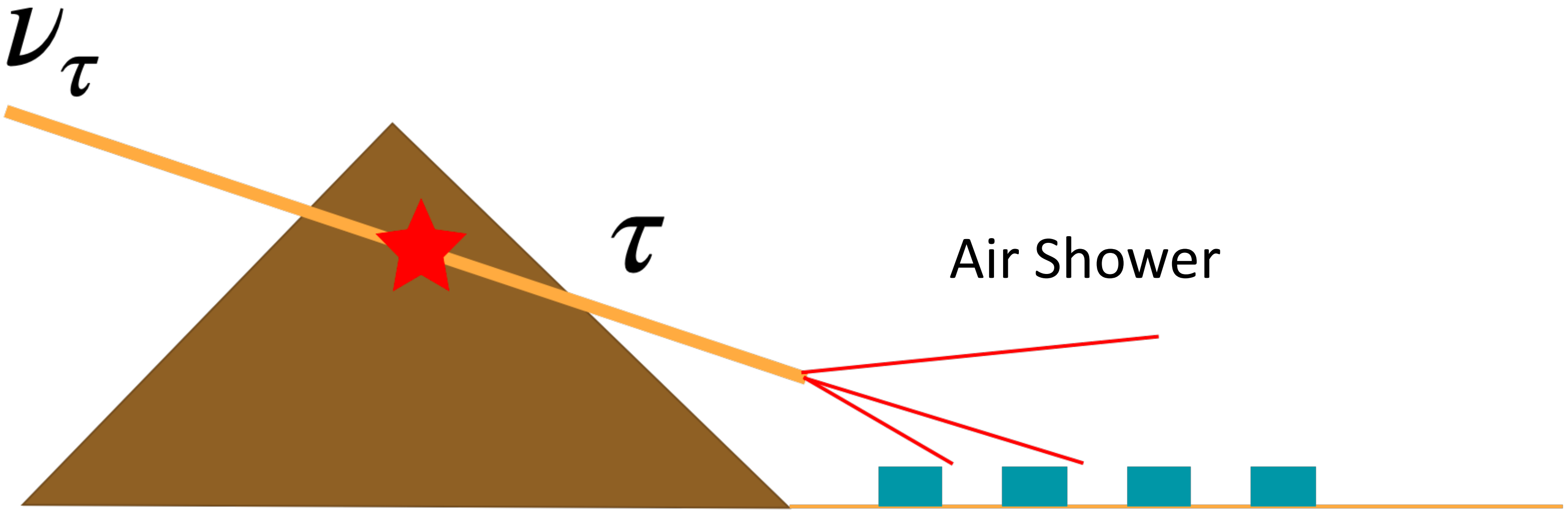
Why Put a Neutrino Telescope in a Canyon?



Inherently low geometrical acceptance

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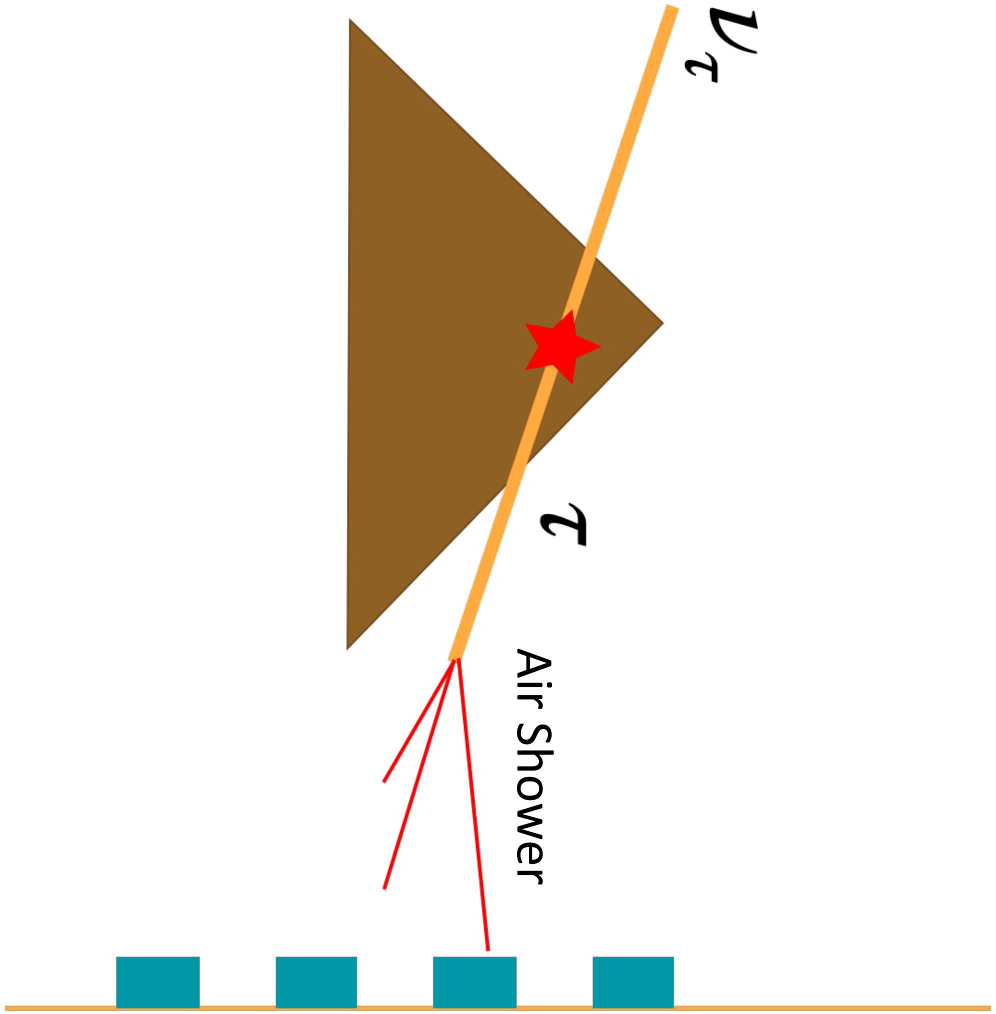
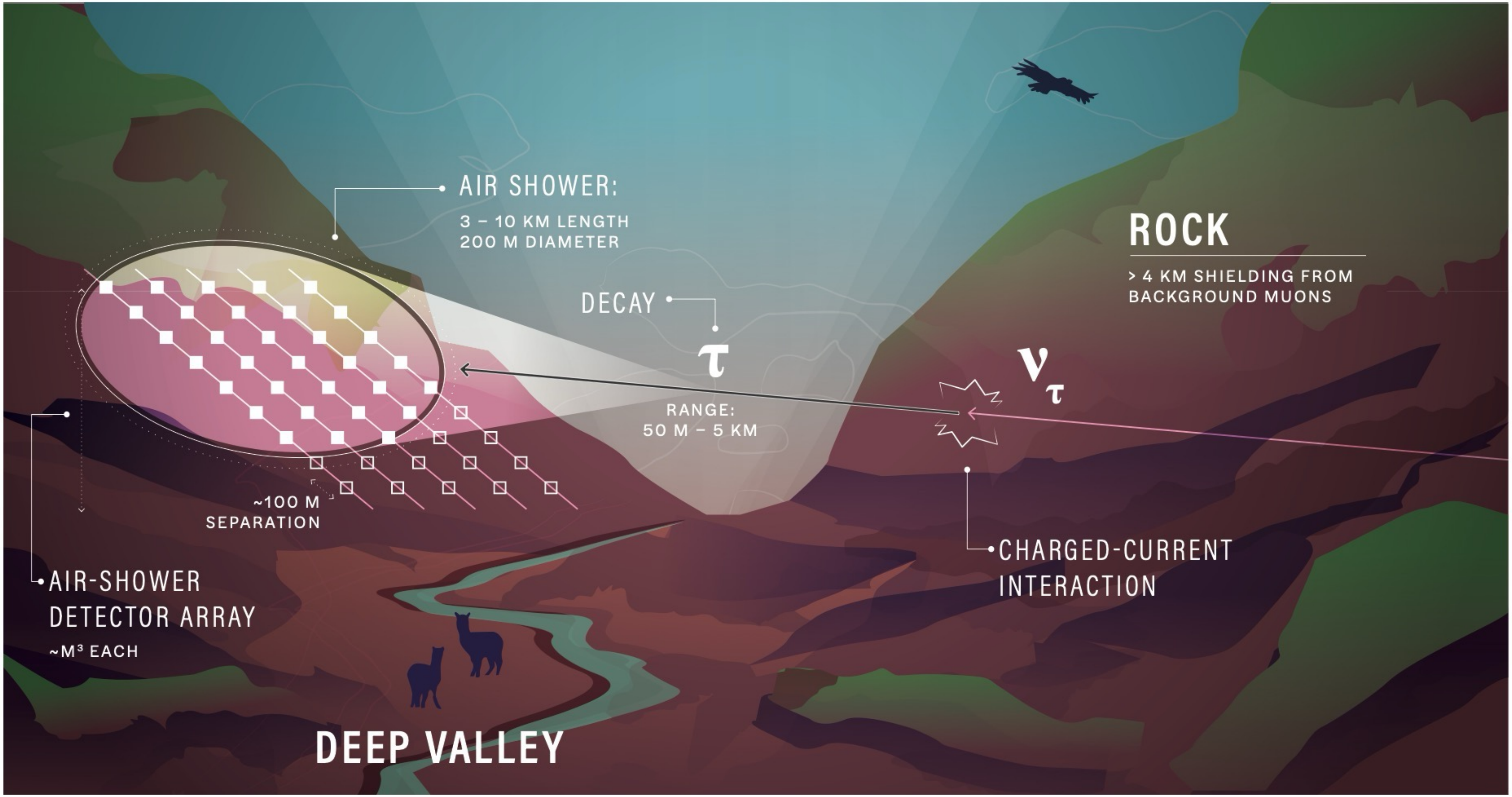


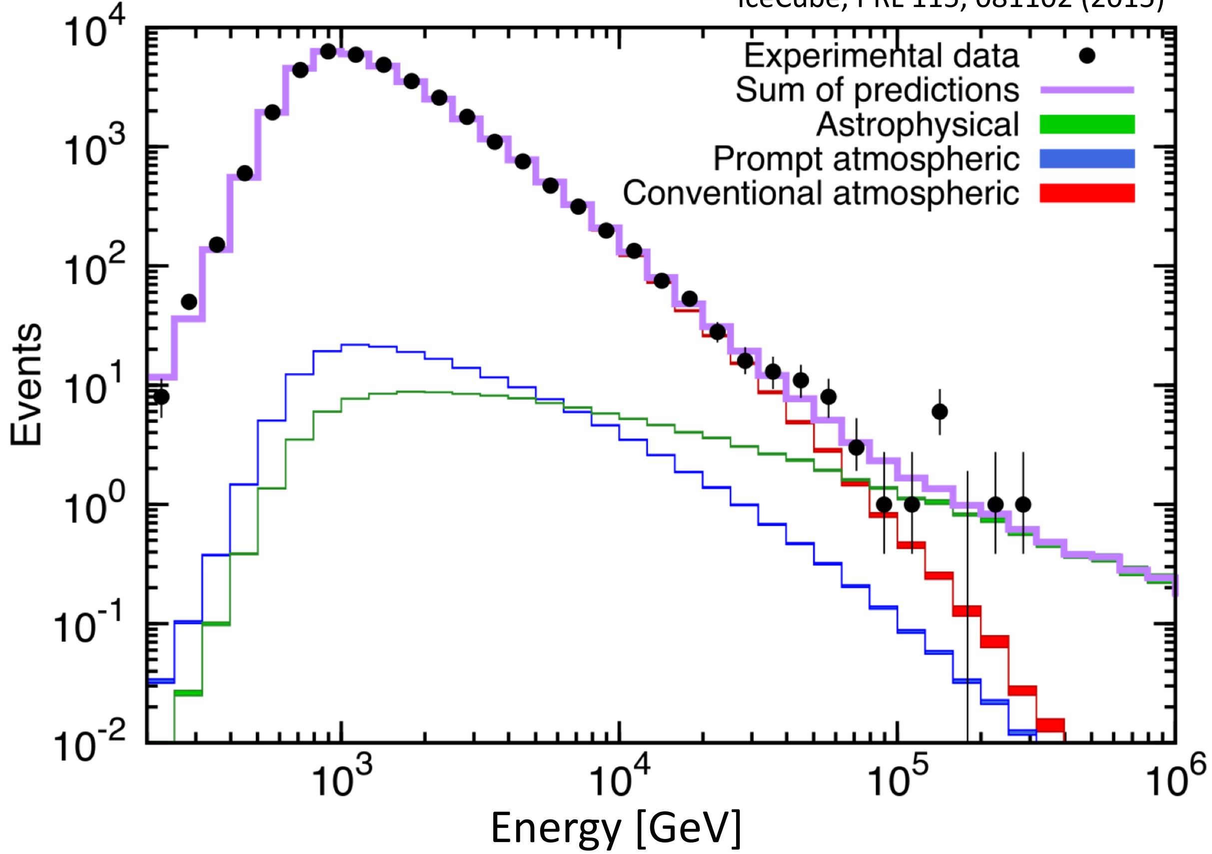
Better for physics, but the engineers didn't seem to like it



TAU AIR-SHOWER MOUNTAIN-BASED OBSERVATORY (TAMBO) · COLCA VALLEY, PERU

Why ν_τ?

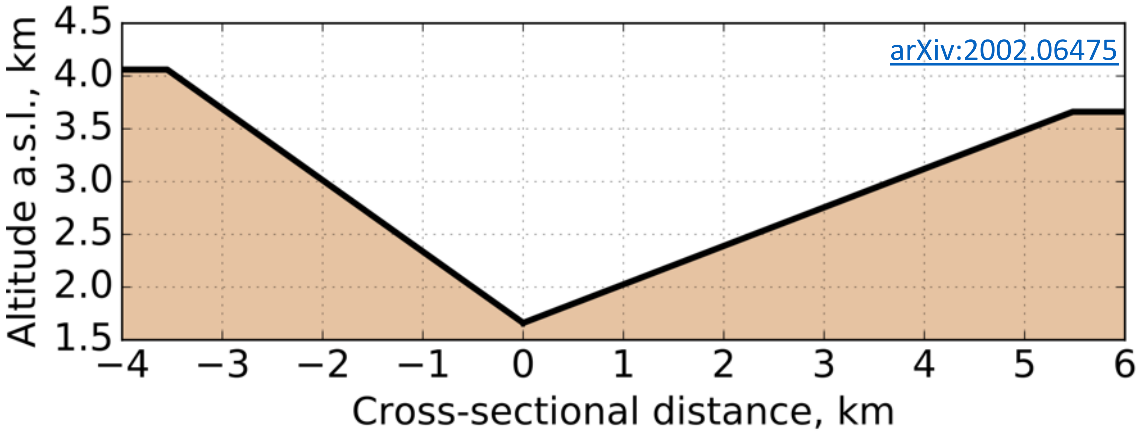
IceCube, PRL 115, 081102 (2015)



- Complementary flavor measurements with IceCube-style detectors
- High-purity astrophysical neutrino sample
  - Astrophysical flux dominates ≳100 TeV
  - Atmospheric flux is τ-poor

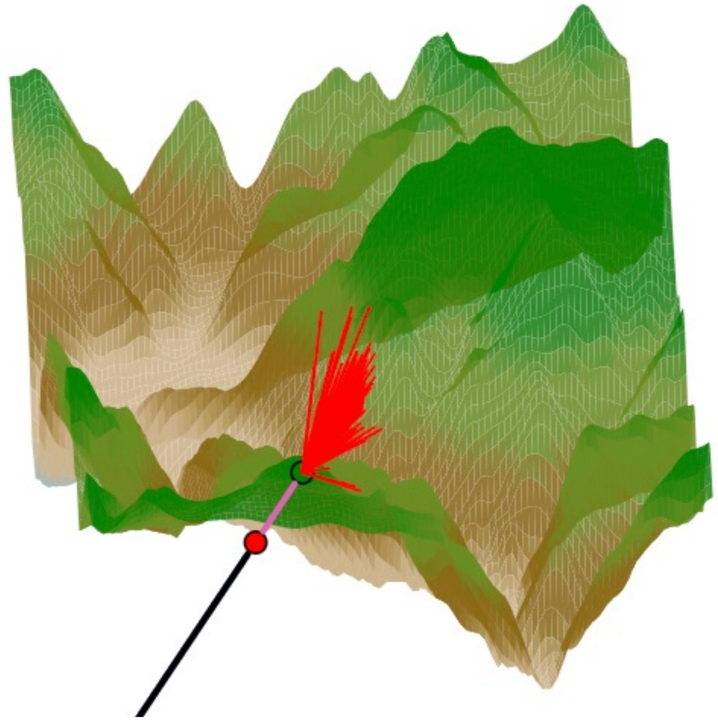
Developing Full Simulation

Preliminary Simulation



- Simplified geometry
- No treatment of τ energy losses
- Approximation of air shower physics

Updated Simulation



- Realistic geometry
- Full treatment of τ energy losses
- Air shower simulation with CORSIKA 8

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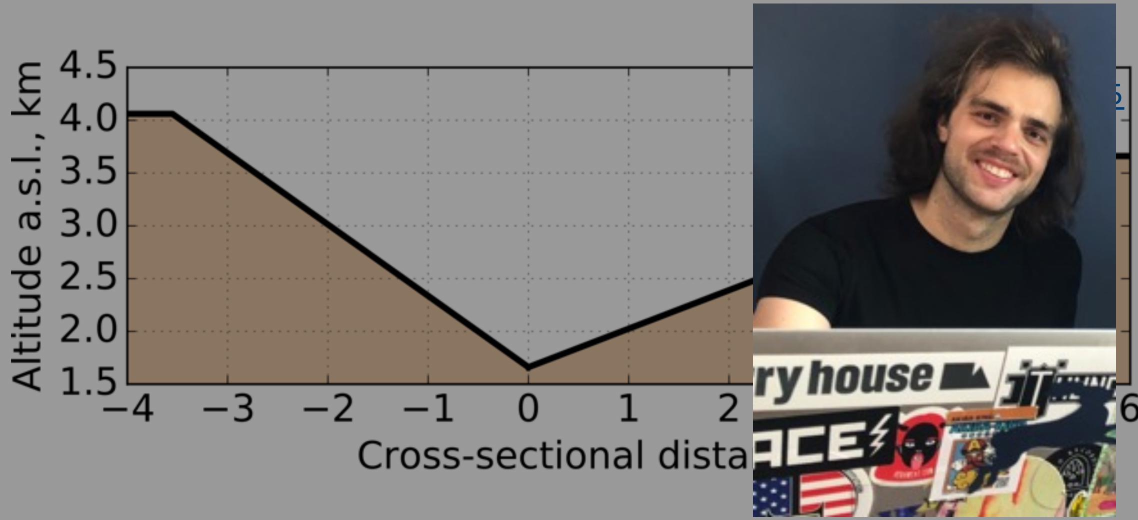

Jeff Lazar

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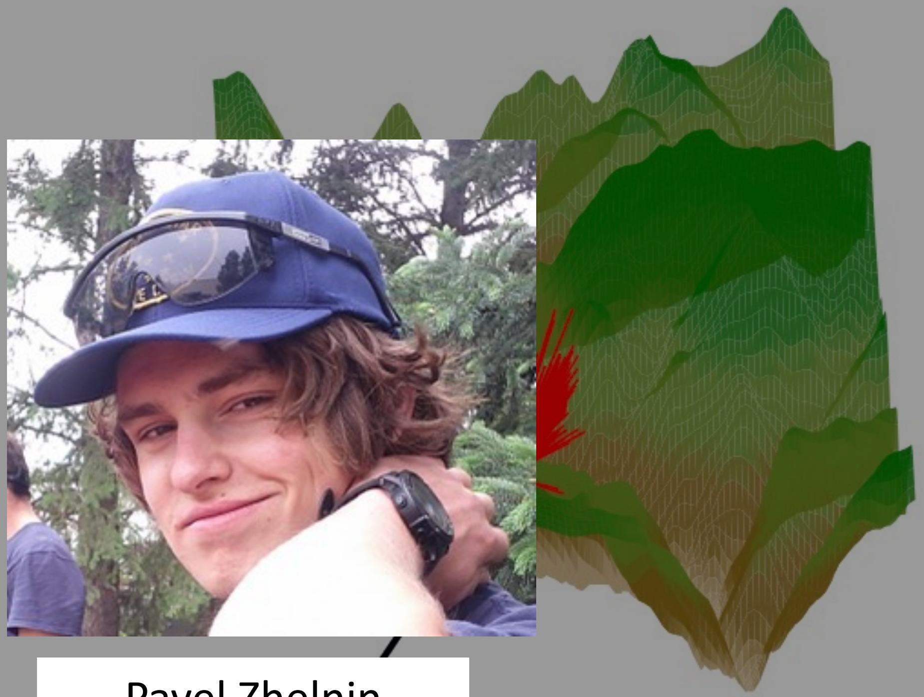
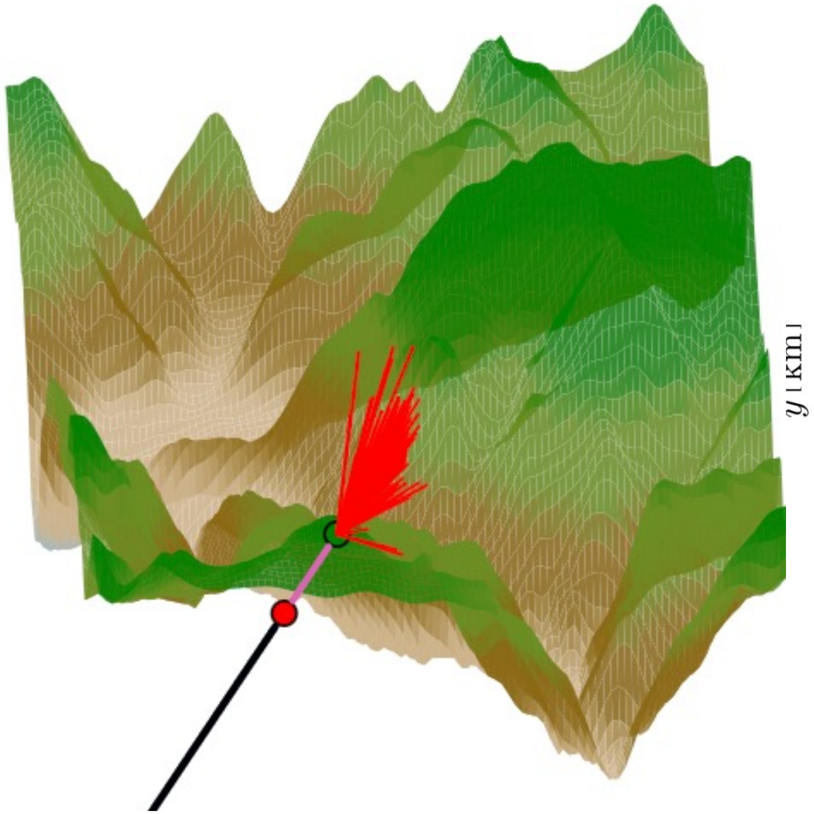


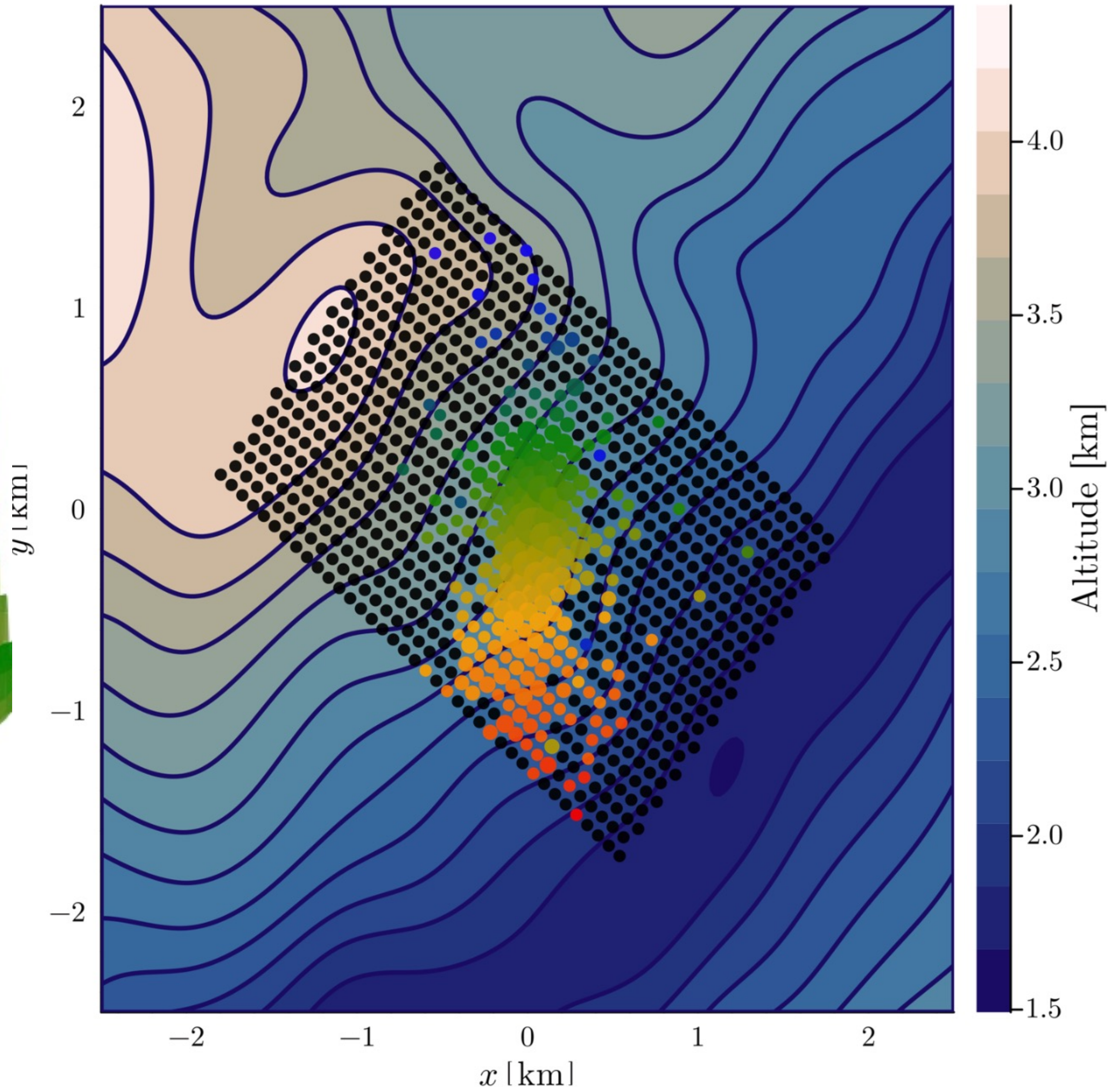
Pavel Zhelnin

- Realistic geometry
- Full treatment of τ energy losses
- Air shower simulation with CORSIKA 8

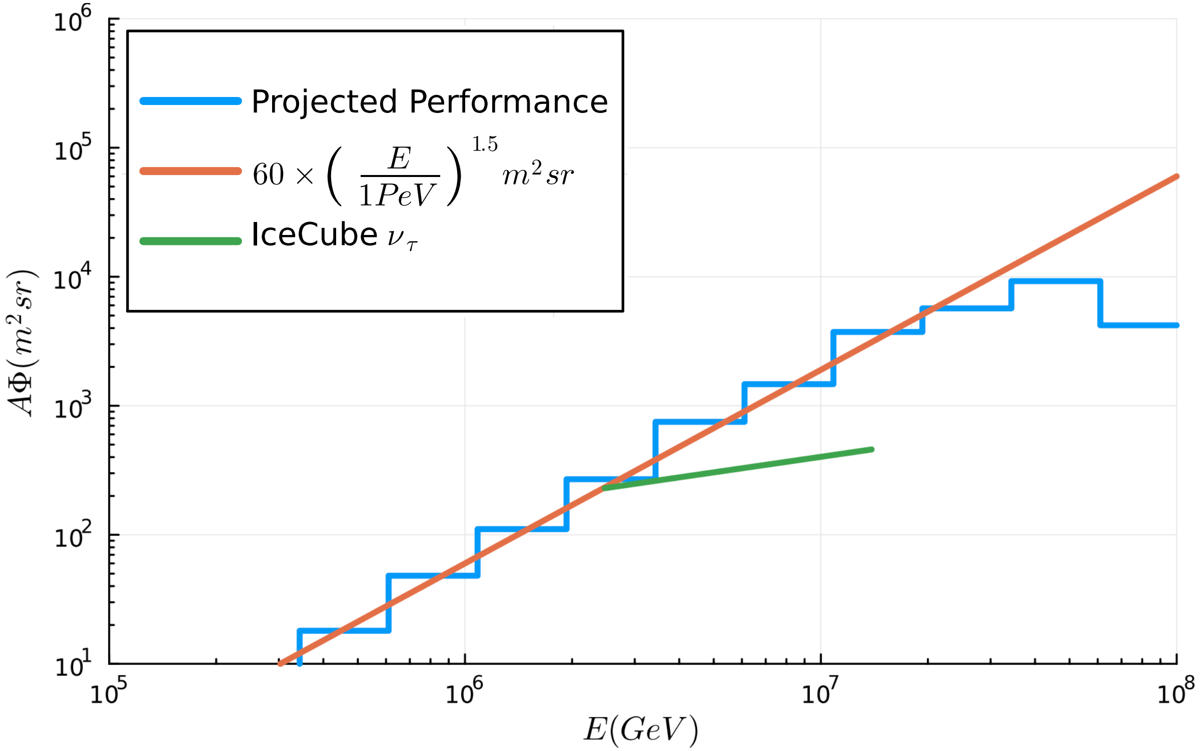
Air-Shower Simulation

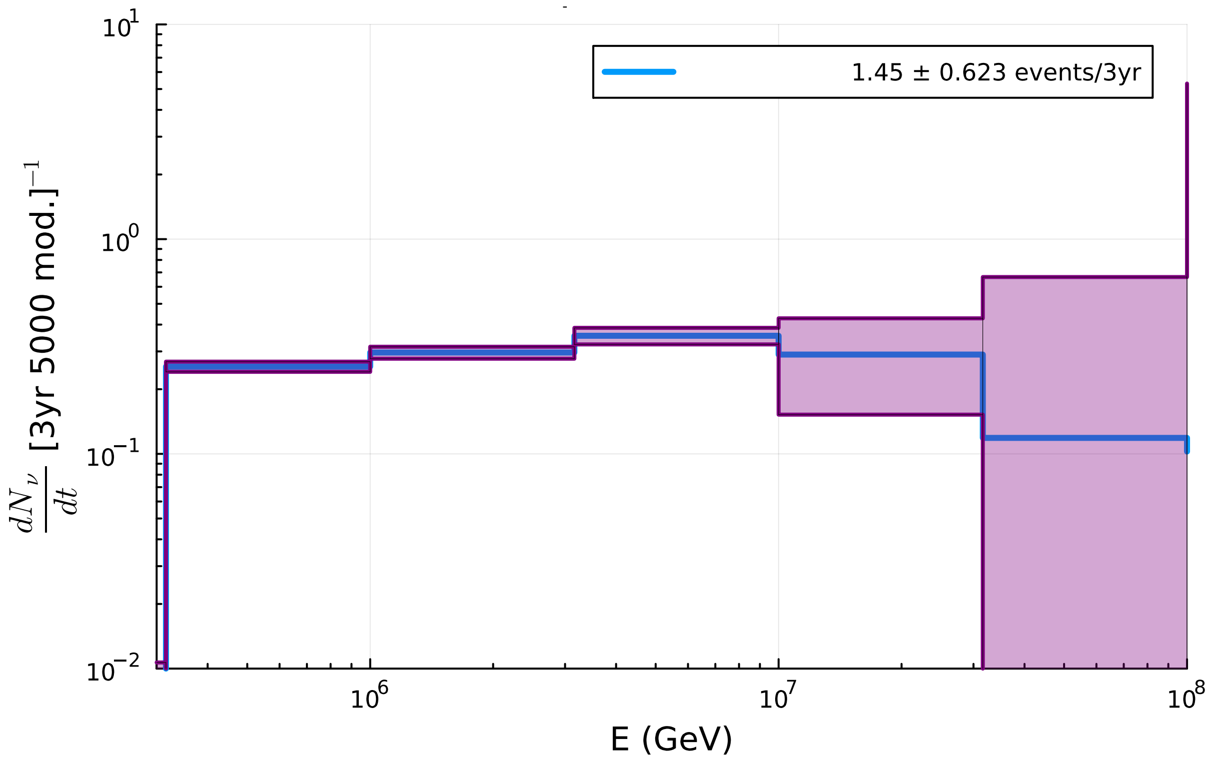
- CORSIKA8 tracks individual particle energies & arrival times
- Enables in-depth rate & reconstruction studies





TAMBO's Sensitivity Surpasses All-Flavor Observatories





- 5x higher ν_τ effective area than IceCube @ 10 PeV, before array optimization
- With 5000 modules TAMBO will:
  - Discover ~1 neutrino source per year (IceCube SPL flux)

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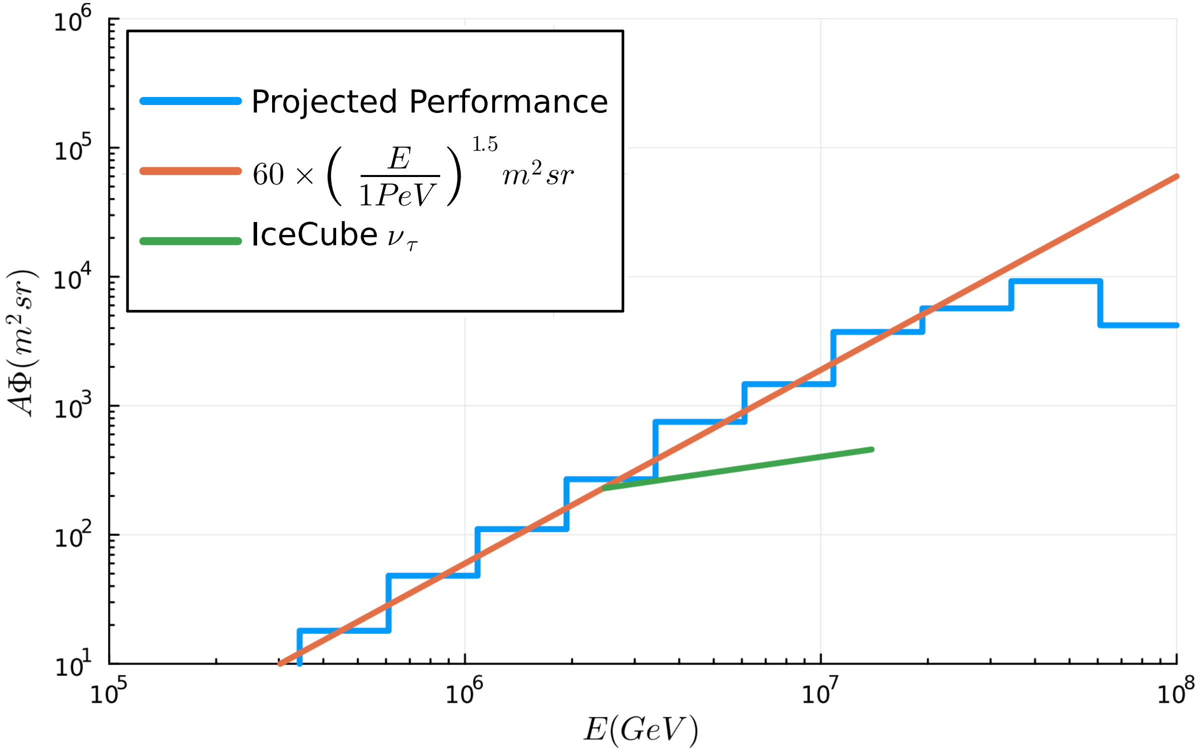
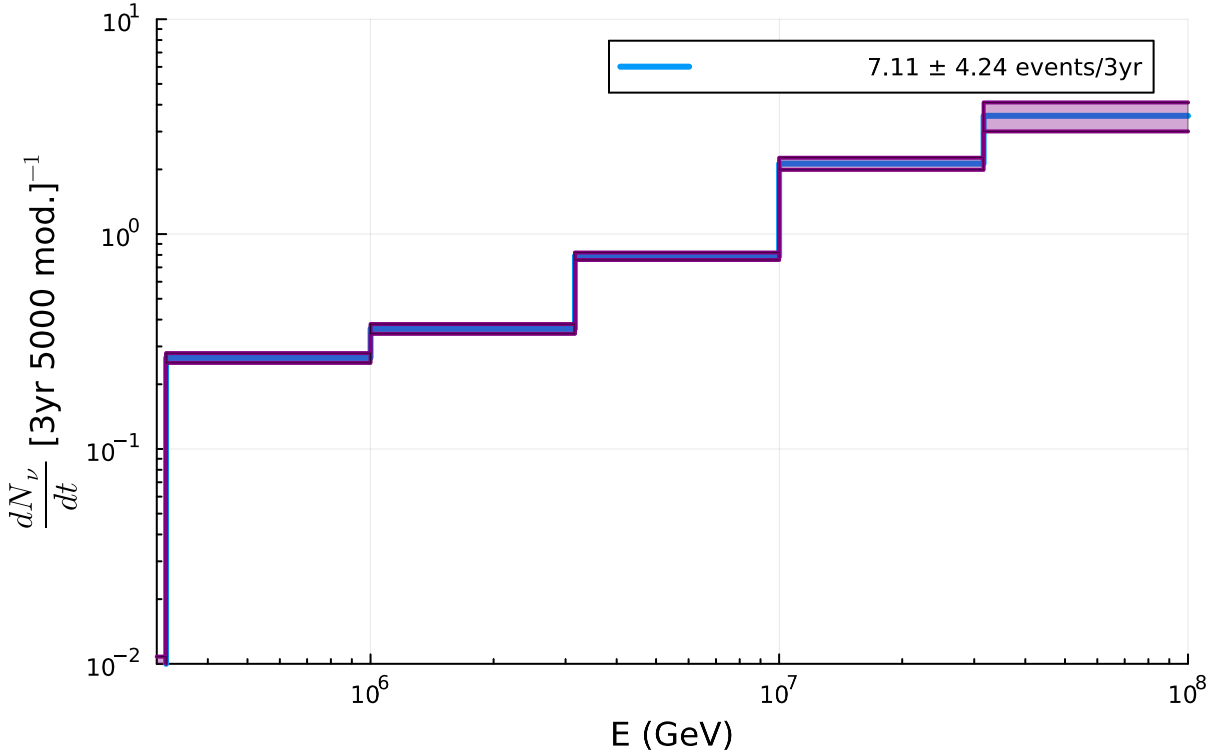




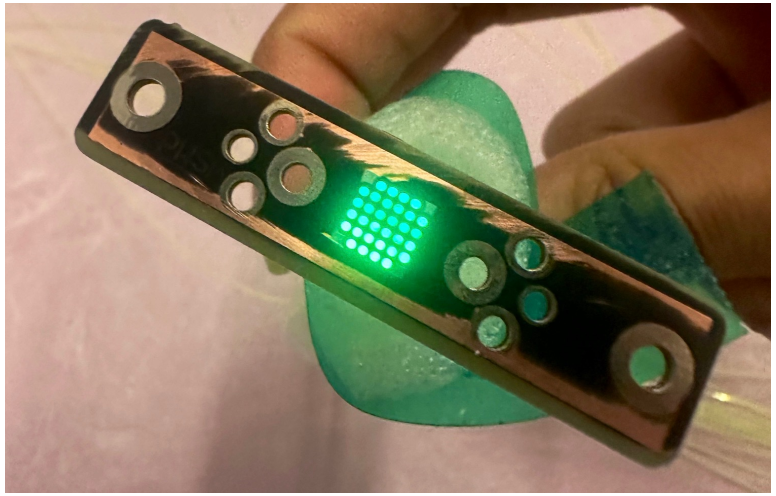
- 5x higher ν_τ effective area than IceCube @ 10 PeV, before array optimization
- With 5000 modules TAMBO will:
  - Discover ~1 neutrino source per year (IceCube SPL flux)
  - Discover cosmogenic neutrinos with ~2 per year (Rodrigues *et al.* cosmogenic flux)

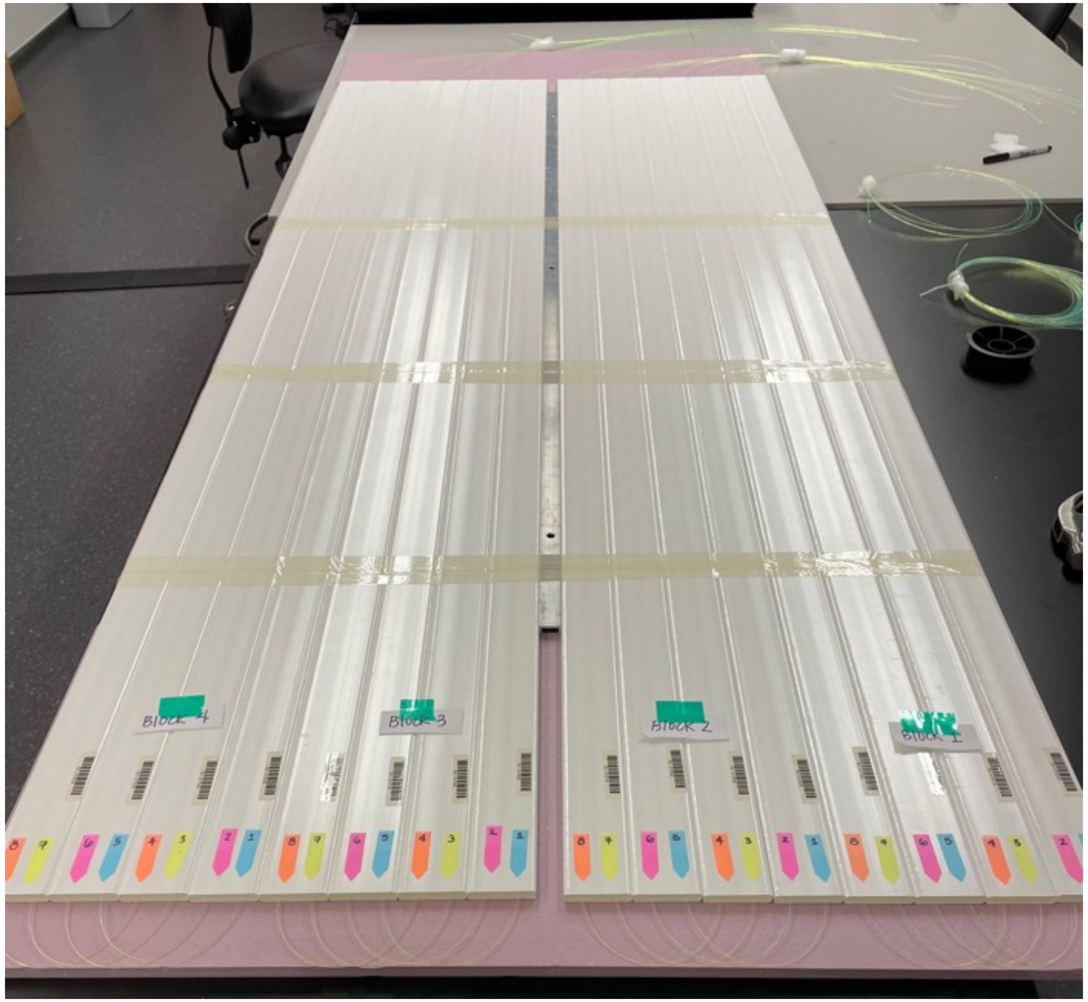
Detector Research & Development

- Detector technology: either water Cherenkov or plastic scintillator
  - Both well-experienced technologies!

- Special considerations for TAMBO:
  - Difficulty of deploying detectors in canyon
  - Cost of producing thousands of detectors

Diyaselis Delgado





Societal Impact

- Want local community to embrace project, not just accept
- First steps: workshop with Peruvian social scientists & officials

Summary

- TAMBO will:
  - Enable the discovery of hidden neutrino sources
  - Bridge gap between HE and UHE neutrino telescopes
- Fully-featured simulation nearing completion
- Development of prototype detectors underway
- Interested in joining? Contact (me or Carlos Argüelles) at will_thompson@g.harvard.edu, carguelles@g.harvard.edu


Thanks for your attention!

Why Neutrino Astronomy?

- Neutrinos are:
  - (Very) weakly interacting
  - Electrically neutral
- They also:
  - Can pass through dense areas of space unimpeded
  - Are not bent by magnetic fields
- But also makes them difficult to detect; enormous detectors

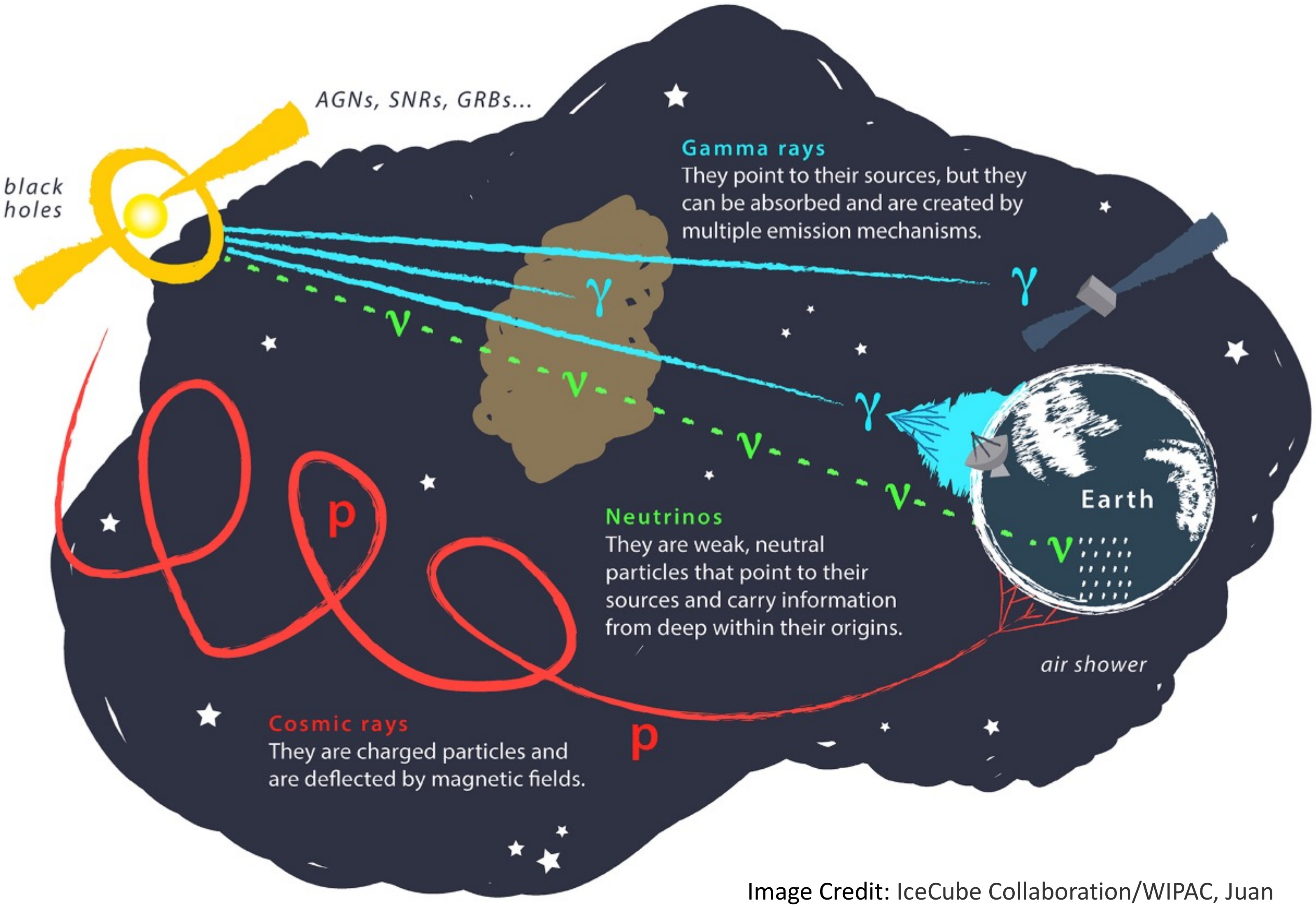


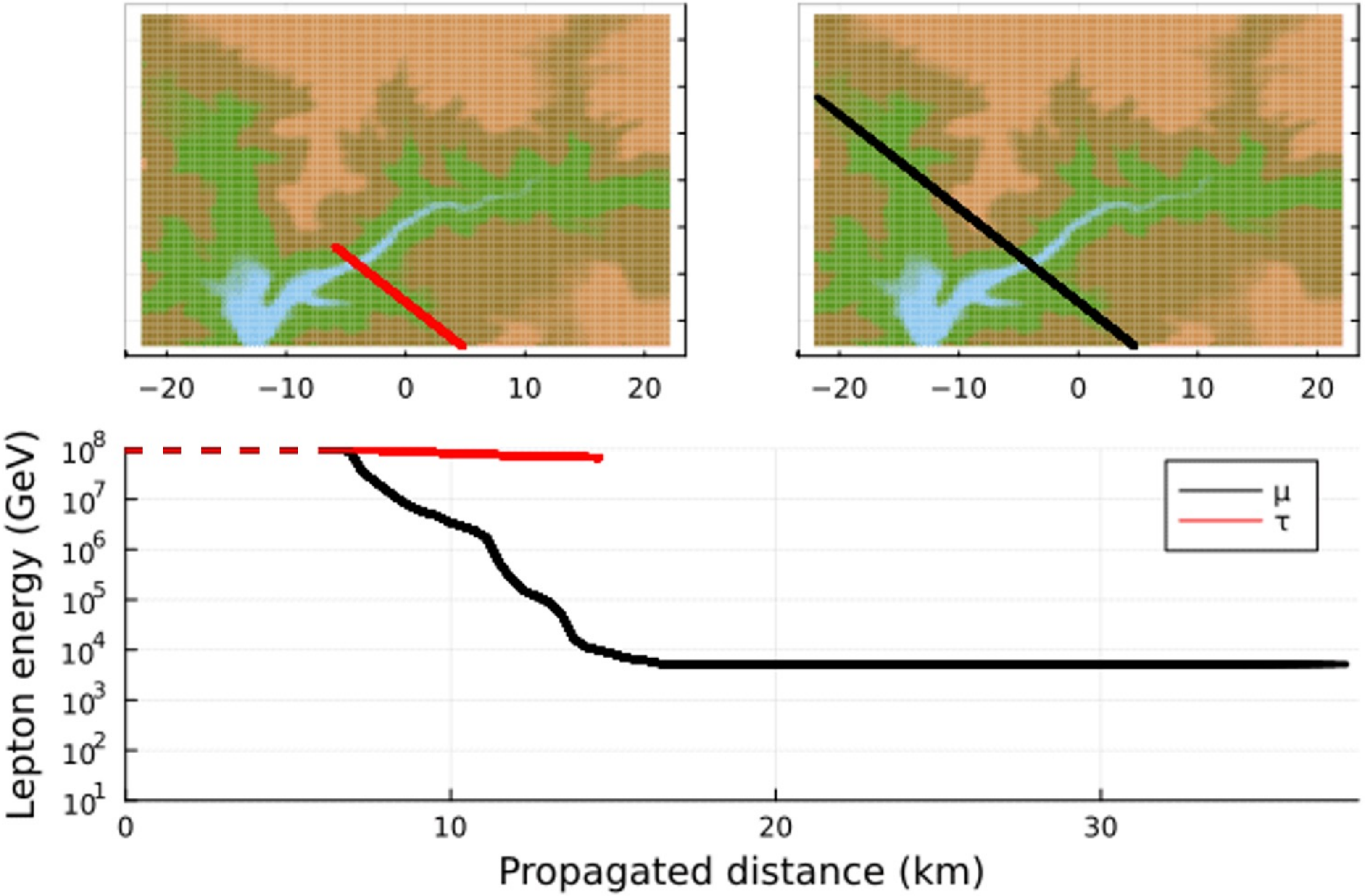
Image Credit: IceCube Collaboration/WIPAC, Juan Antonio Aguilar, and Jamie Yang.

Observatory Scale

- Expect to observe ~3 ν_τ /year with 5000 modules
  - 150 meter spacing on triangular grid → ~33 (16.5) km along and 3km up canyon if single- (double-) sided

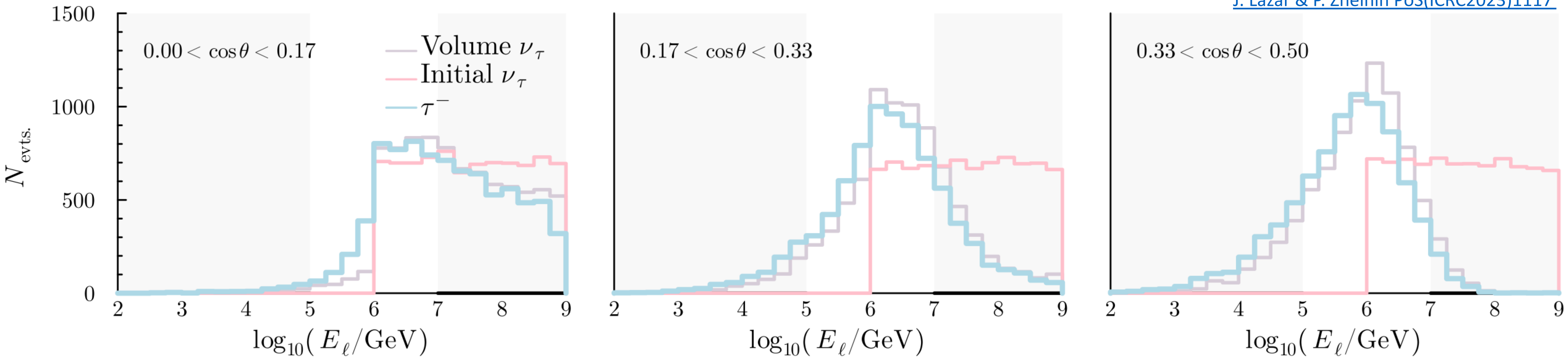
ν_τ Exclusivity

- Air-shower is exclusive to ν_τ
- μ^- energy greatly attenuated
- e^- entirely shielded by rock



Taking Advantage of Tau Regeneration

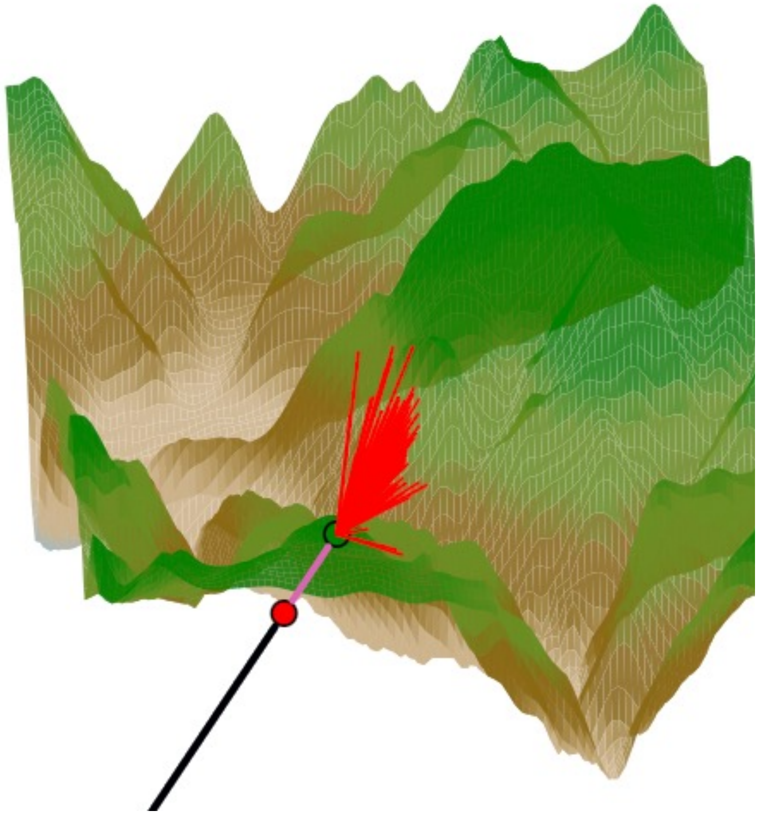
J. Lazar & P. Zhelnin PoS(ICRC2023)1117

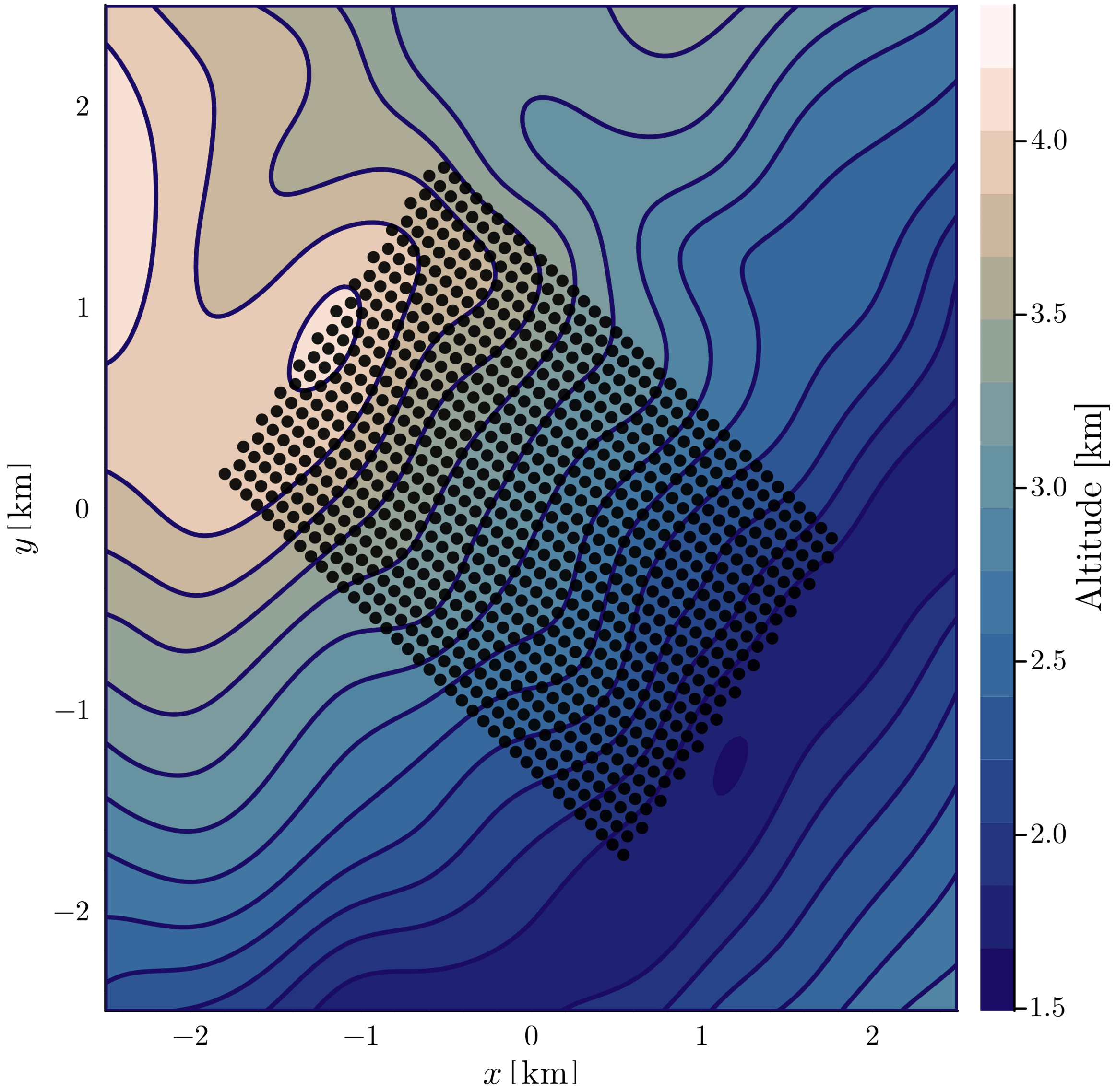


- Incoming ν_τ can undergo several $\nu_\tau \leftrightarrow \tau$ conversions in the Earth
- Results in higher rates than predicted by preliminary simulation
- Updated simulation handles tau regeneration via `TauRunner`

Air-Shower Simulation

- CORSIKA8 tracks individual particle energies & arrival times
- Enables in-depth rate & reconstruction studies





Peru Outreach Trip

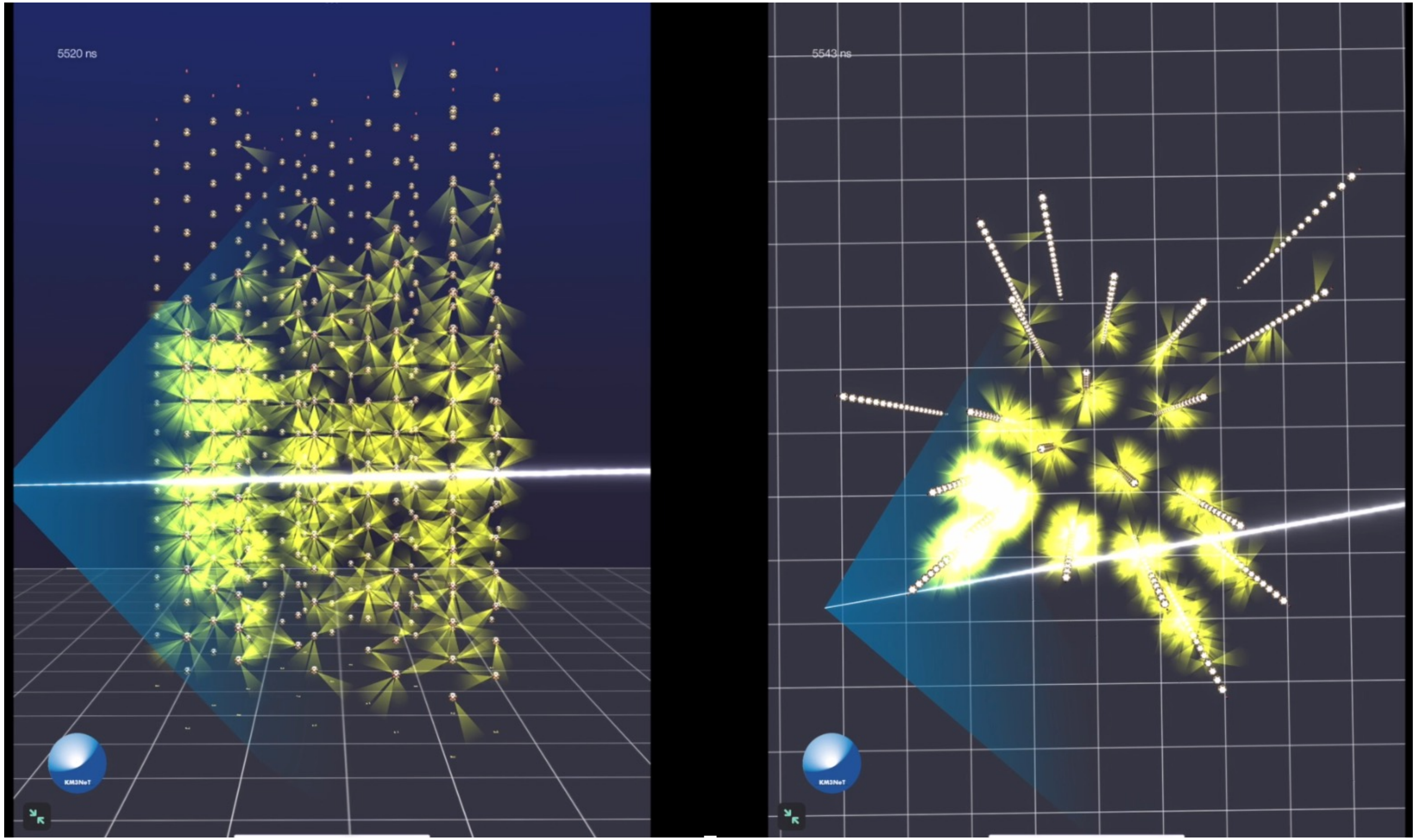
Photo Credit: Universidad Nacional de San Agustin de Arequipa

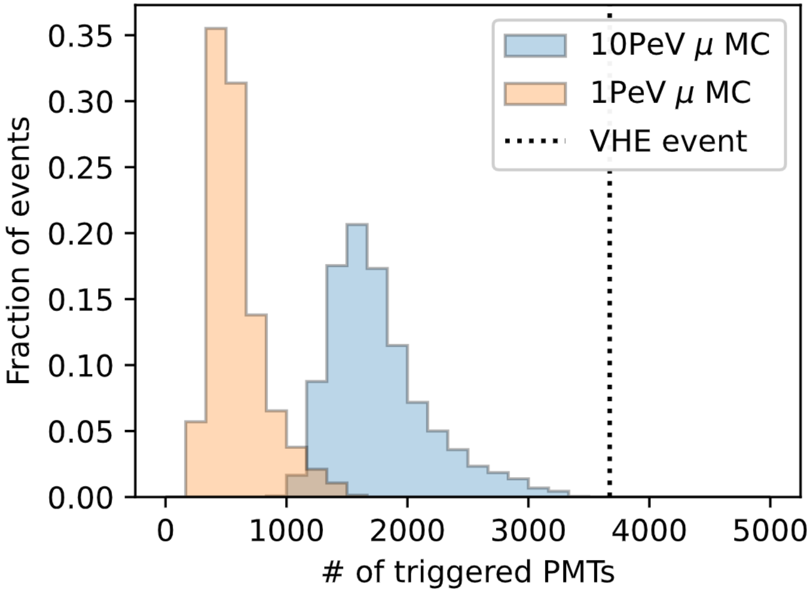
- Traveled to Peru in fall 2022 to meet with officials and visit site

TAMBO & the Canyon

Most promising location quite remote; closer areas for test array

KM3NeT Very High Energy Event





KM3NeT Collaboration, Neutrino 2024

Cosmogenic Flux Models