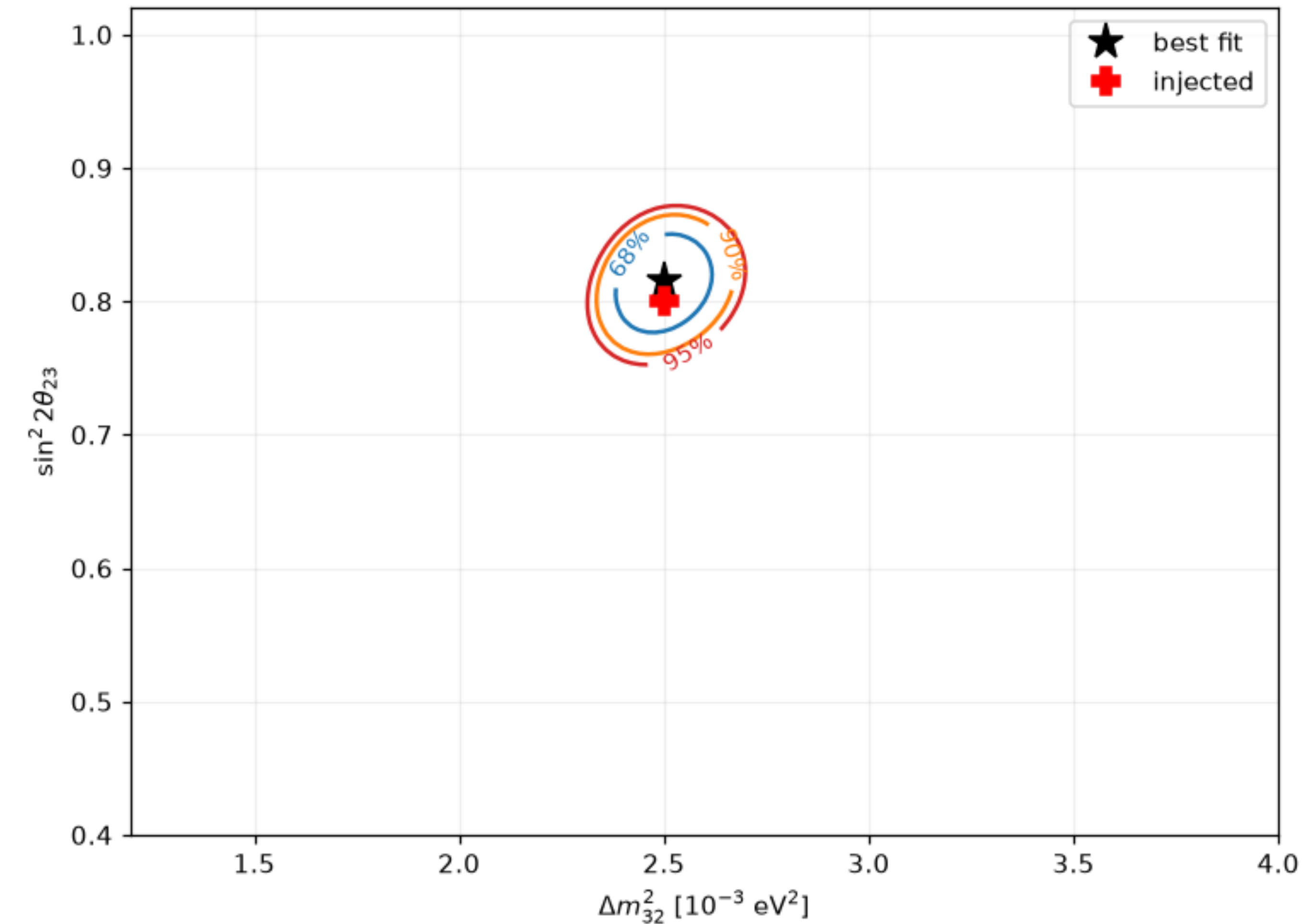


Neutrino Oscillation

Philipp Soldin

11.09.2026

Task: Measure the Neutrino Oscillation Parameters

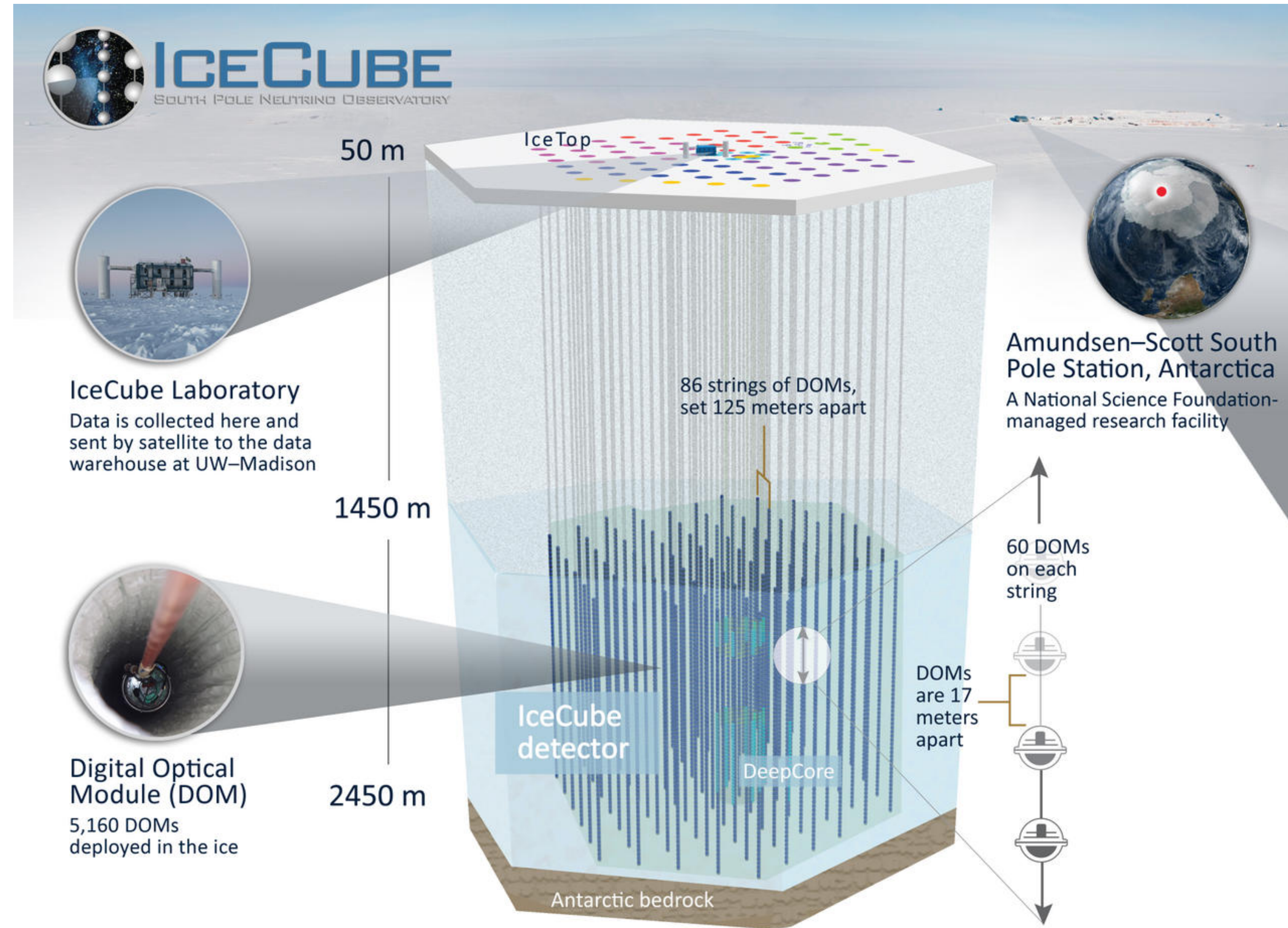


- Full Physics Analysis
- Analyse the data, perform reconstructions, fit the neutrino oscillation parameters

$$P(\nu_\mu \rightarrow \nu_\mu) = 1 - \sin^2(2\theta_{23}) \cdot \sin^2\left(1.267 \frac{\Delta m^2_{32}}{E_\nu}\right)$$

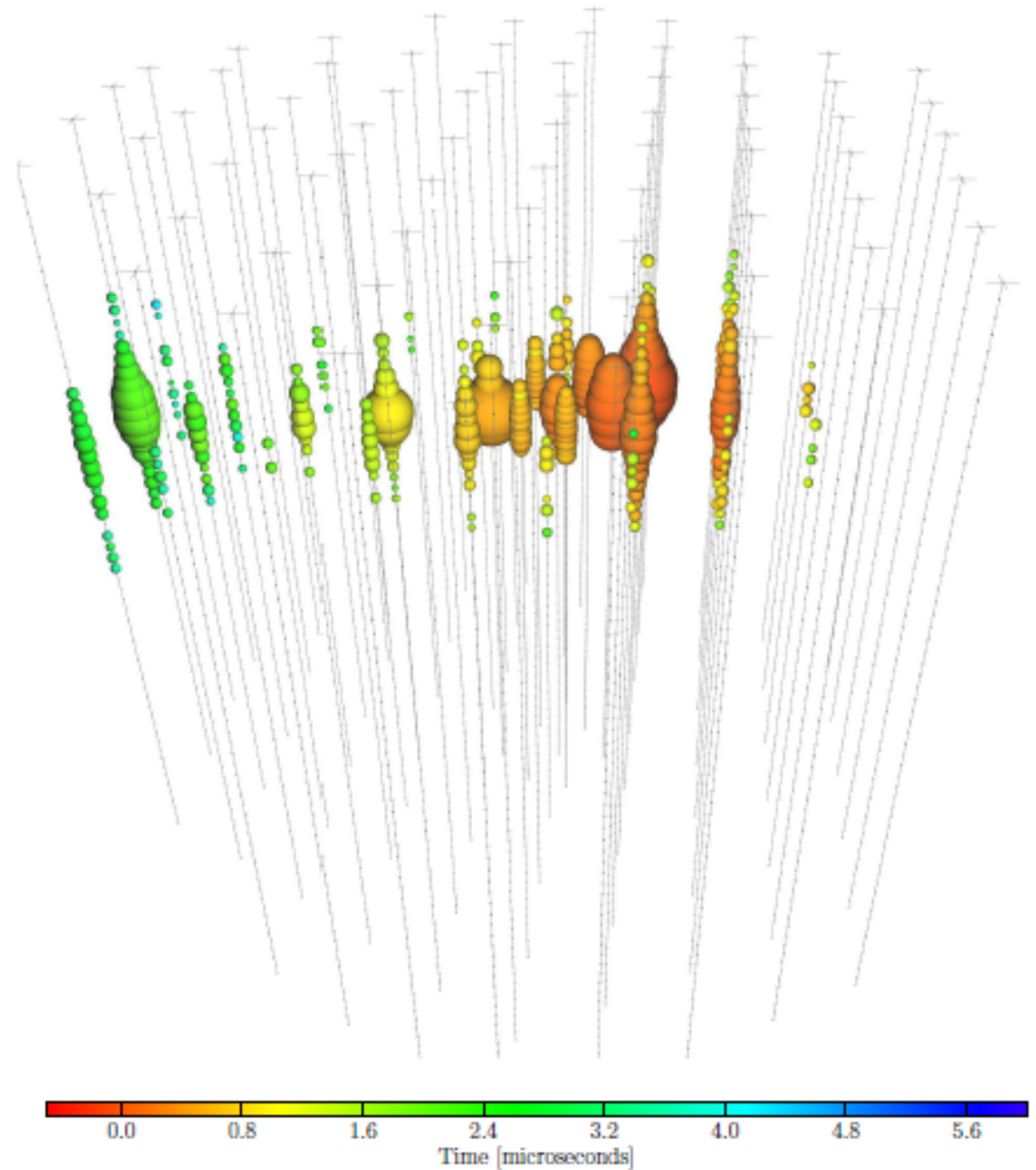
Detector

- Simulated Detector similar to Km3Net Orca or a more dense IceCube detector
- Measures ν_μ via CC interactions
Muon tracks in the detector
- Muons produce light via Cherenkov radiation and stochastic processes
- DOMs measure light, the track can be reconstructed with these information
- You get tracks starting in the detector
→ direct ν_μ energy access

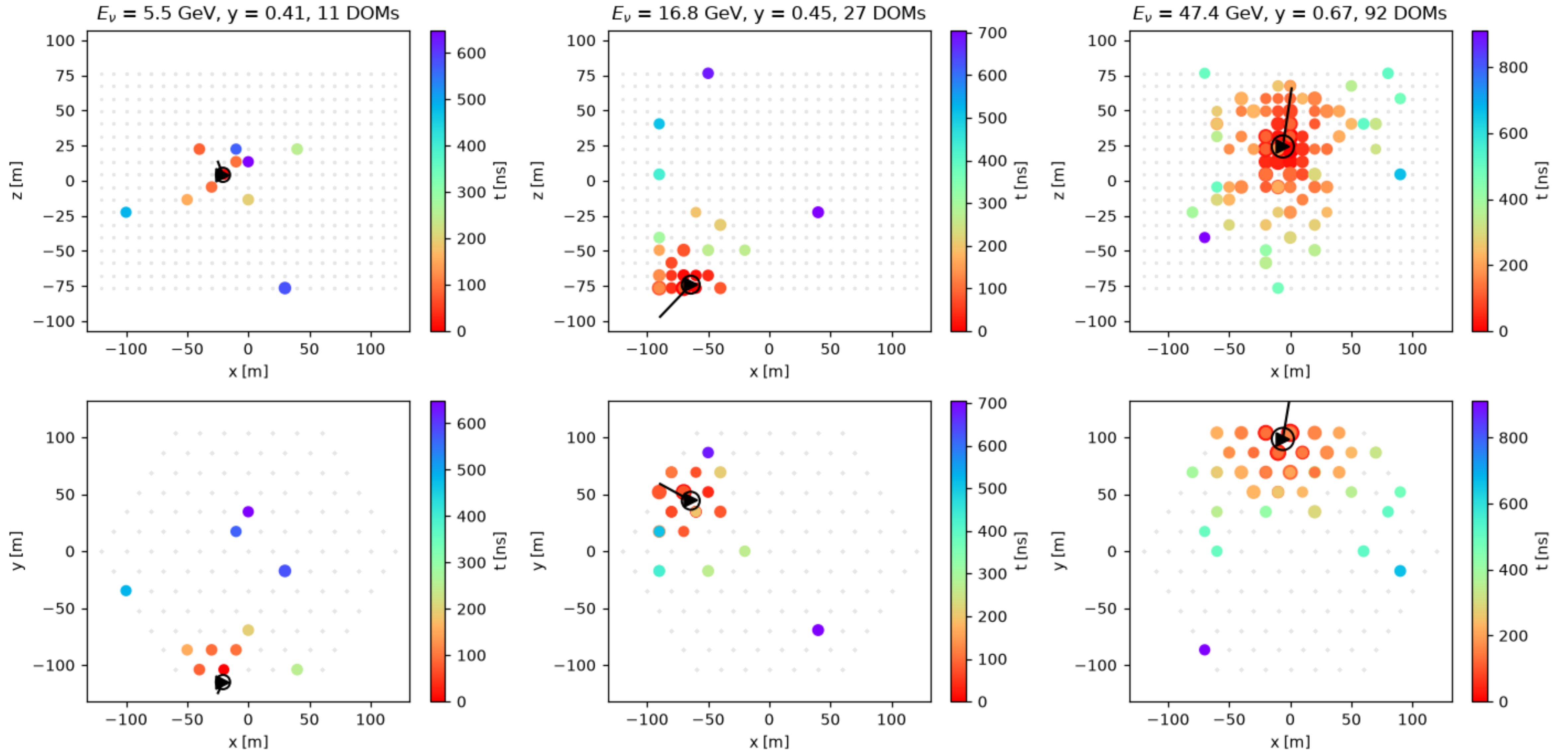


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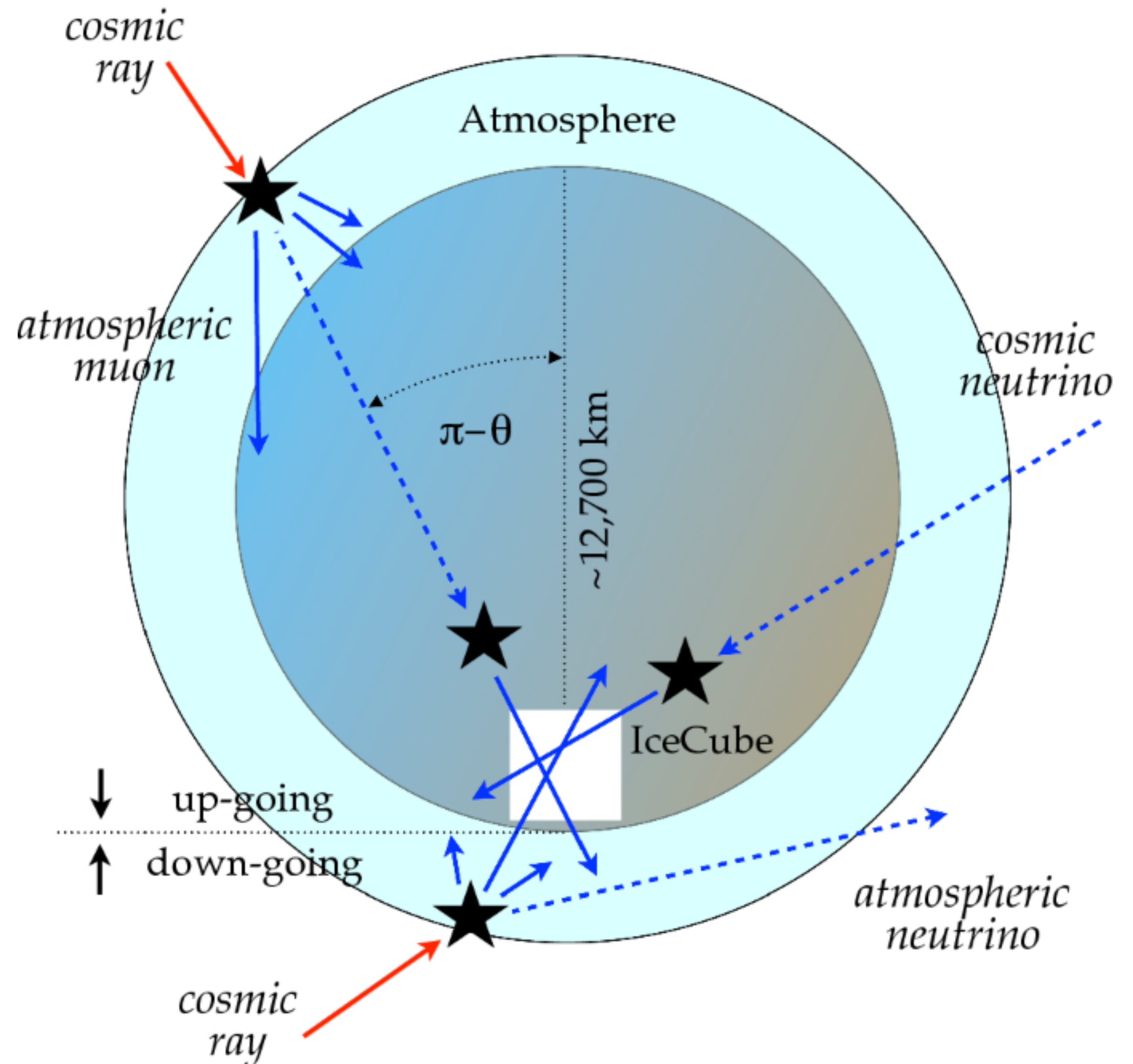


Exemplary Event Data



How to measure neutrino oscillation?

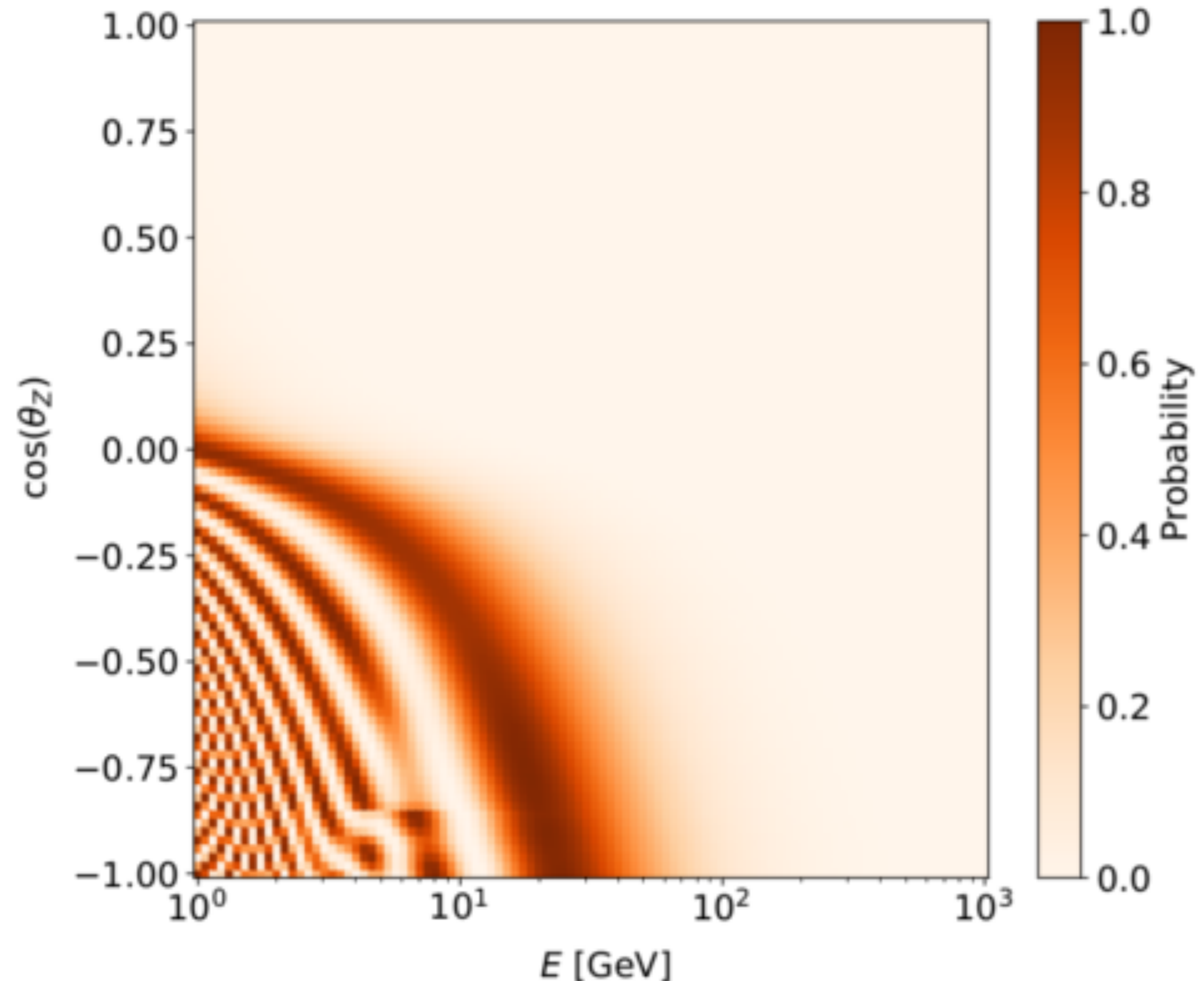
- Neutrinos oscillate as a function of distance and energy and produce an observable deficit
- Assume all neutrinos are generated in the atmosphere, the zenith angle gives a direct distance measure and energy comes from starting tracks
- Only vacuum oscillation is assumed here
- Earth radius: 6,371 km
- Neutrino production altitude: 15 km above Earth's surface
- Detector depth: 2.5 km below the surface



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$$P(\nu_\mu \rightarrow \nu_\tau)$$

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What is your task?

- Take the data from simulated detector and reconstruct the direction and energy of the neutrino
 - 400'000 simulated neutrino events
 - One popular choice is GraphNet, a graph neural network library developed within IceCube
 - The simulation data are produced with E^{-1} energy spectrum, but can be reweighed to follow a $E^{-1.7}$ powerlaw
- Perform a likelihood fit using the two neutrino oscillation parameters Δm^2 and $\sin^2(2\theta)$
 - Use the two observables $\cos(\theta_{\text{zenith}})$ and E_ν



GraphNet

Have fun!

- Files can be downloaded here:
<https://gigamove.rwth-aachen.de/en/download/cee08d6b0104d326384ef2f2030de308>
- Tar file contains training and measurement data, as well as an example notebook to read the data and use GraphNet