Atmospheric Neutrinos and IceCube

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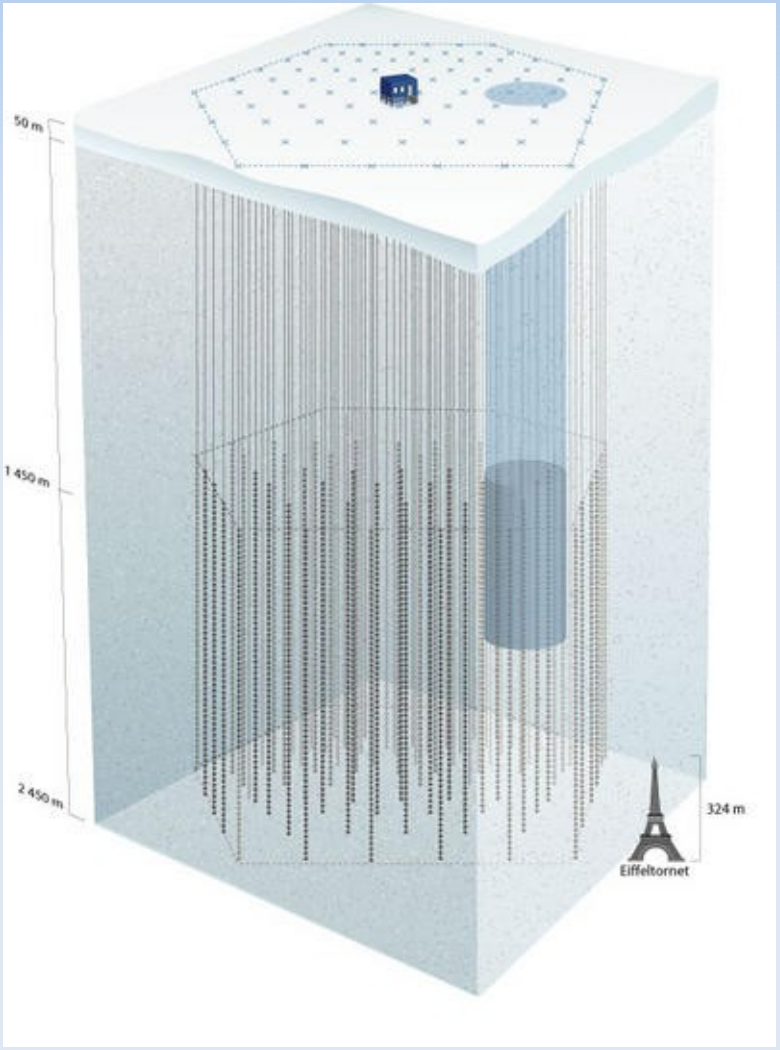
Introduction

Atmospheric neutrinos are produced by cosmic rays (CR) colliding with nucleons in the air.

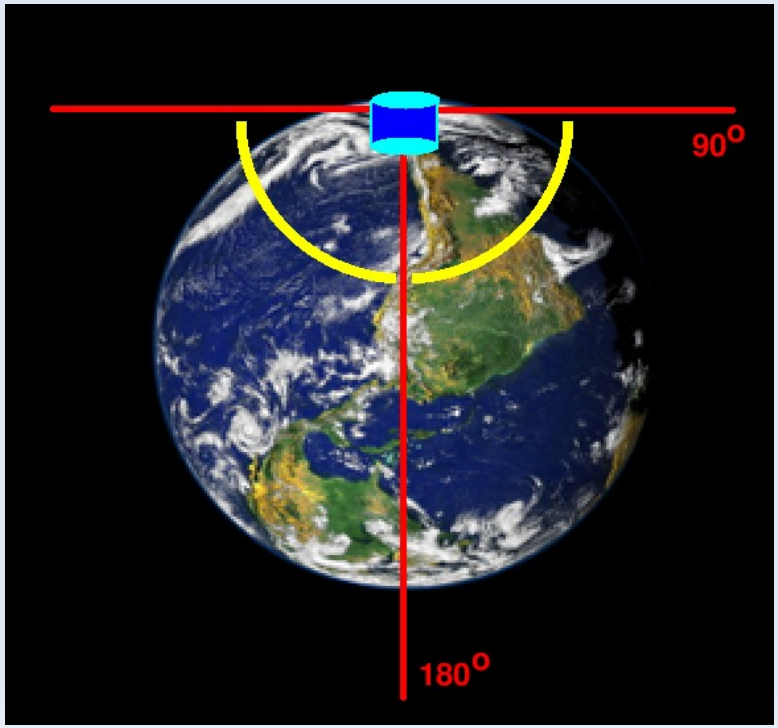
The properties of atmospheric neutrinos will depend on:
-- Incident CR spectrum /Flux
--Treatment of hadronic interactions
-- Density of the air / Earth

Atmospheric neutrinos are the primary background for detecting astrophysical neutrinos with IceCube

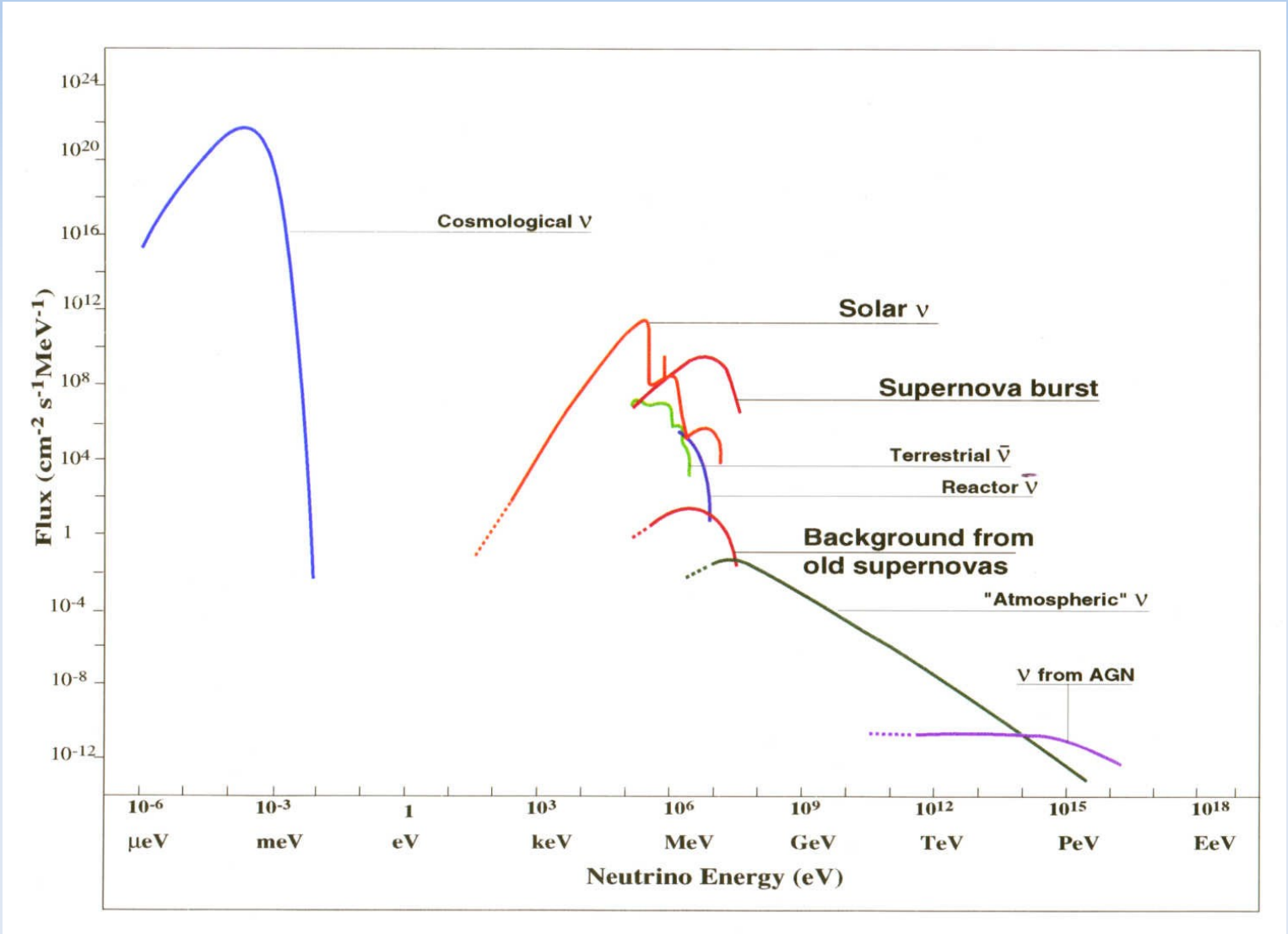
So what is this IceCube thing?



The goal is to have a cubic km of ice underneath the South Pole instrumented with photo-multipliers. Currently 40 strings in-ice, and the new season of drilling has just begun.



The overall neutrino flux



Cosmic Ray input flux

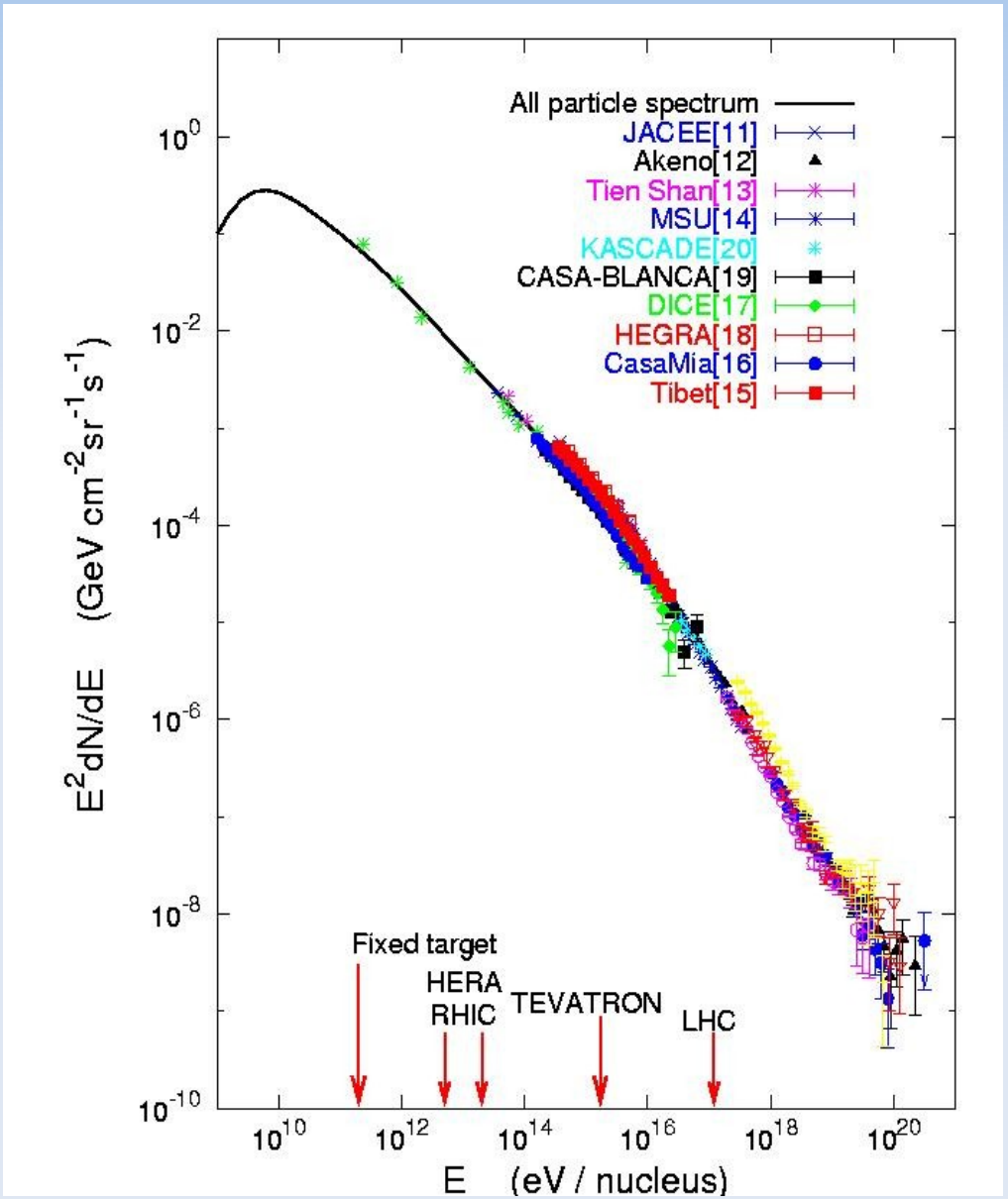
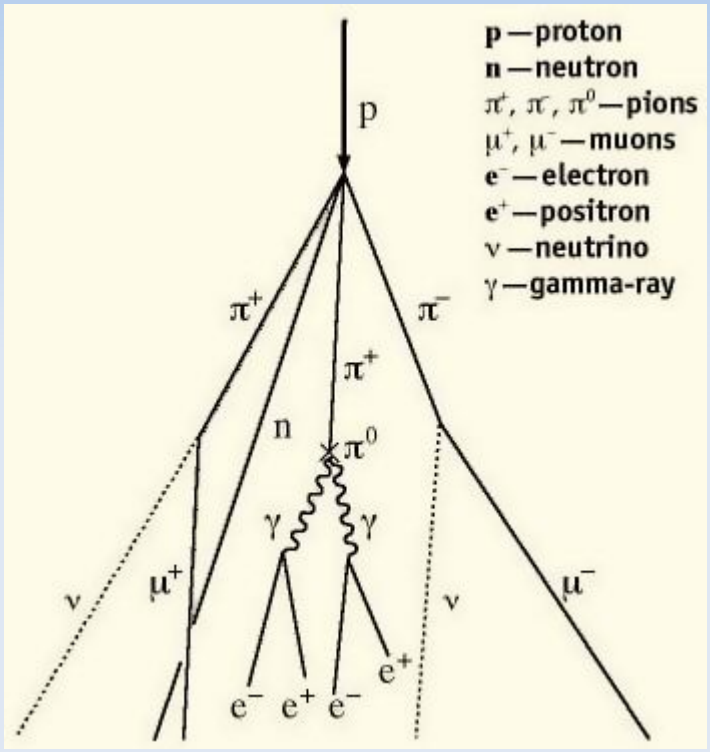


Figure: Halzen, Bad Honnef (2004)

Cosmic rays are highly energitic particles, mainly protons, which come from outer space and collide with the atmosphere.

The energies of cosmic rays exhibits a broken power-law spectrum.



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Atmospheric neutrinos are produced as daughter particles of CR - air interactions.

We can also get an idea of the downgoing muon neutrino flux at the surface of the Earth by looking at muon flux.

What kinds of reactions make atmospheric neutrinos?

- Charged Pion decays to muon and nu-mu
- Kaons can decay to muon and nu-mu
  (also can make pions)
- Also charmed mesons
  - Decay rapidly, 'Prompt flux'

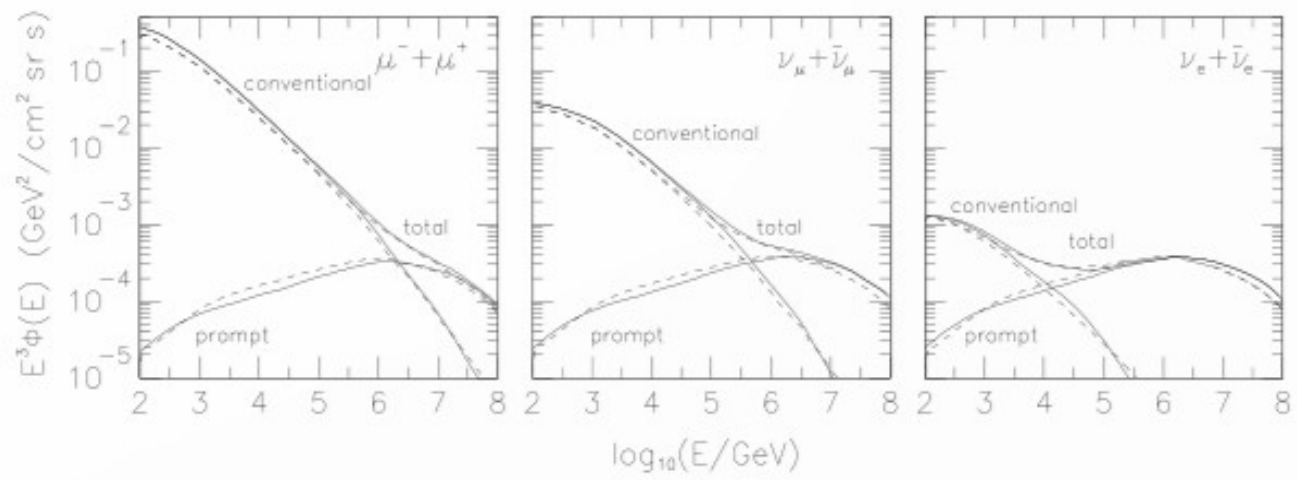
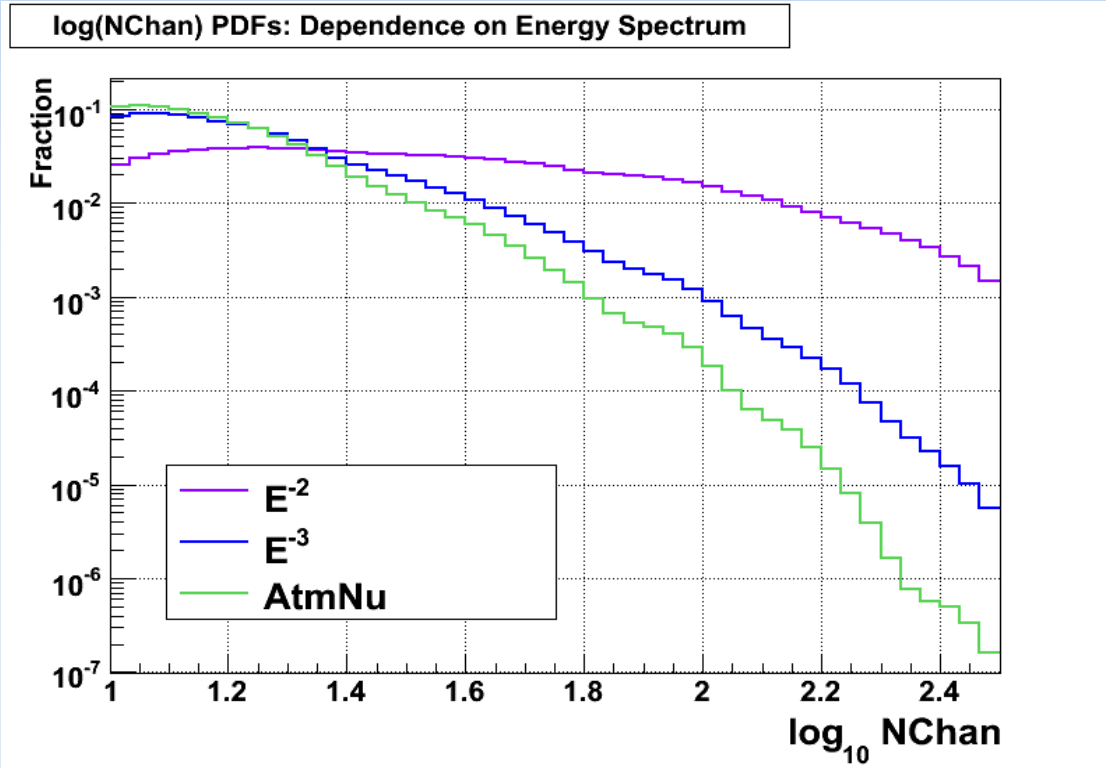


Figure 3: *The E^3-weighted vertical flux of muons, muon-neutrinos and electron-neutrinos from conventional (π, K decays) and prompt (charm decays) sources and their sum ('total'). The solid lines are from the cascade simulation (section 3) and the dashed lines are from the analytic Z-moment method (section 4).*

Thunman, Ingelman, Gondolo
arXiv:hep-ph/9505417v2

Prompt atmospheric neutrinos have a much lower flux, and only dominates at energies above 1 PeV

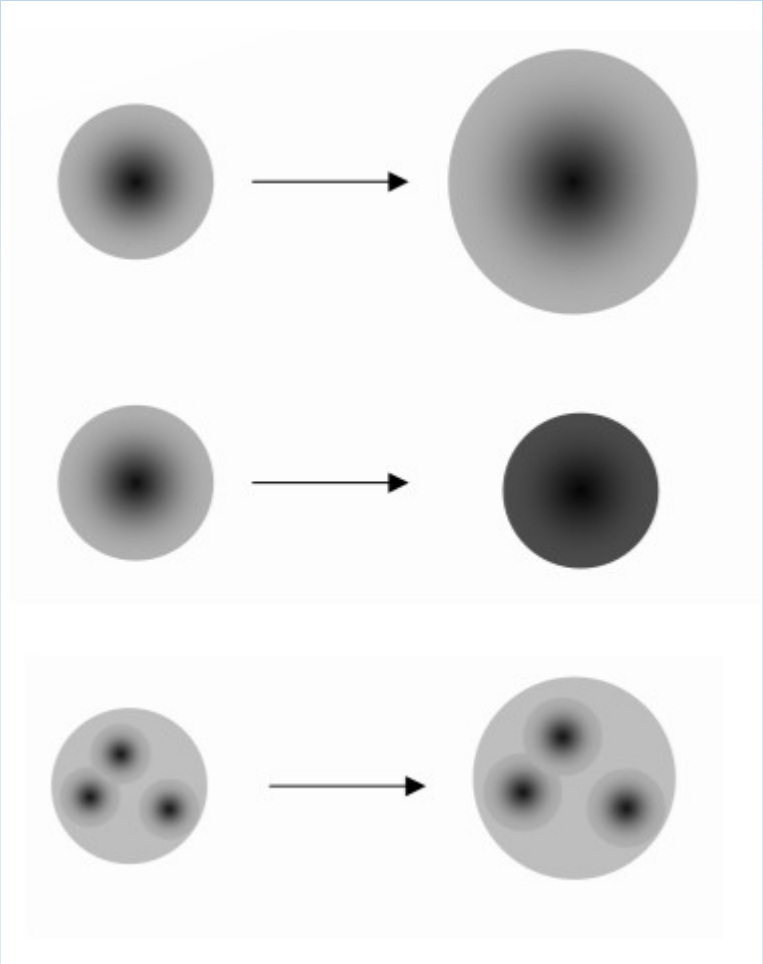
What would IceCube see for different spectra?



Here we see how IceCube with 22 strings sees different spectra of neutrinos.

Nchan is the number of optical modules hit, and is a method of determining energy.

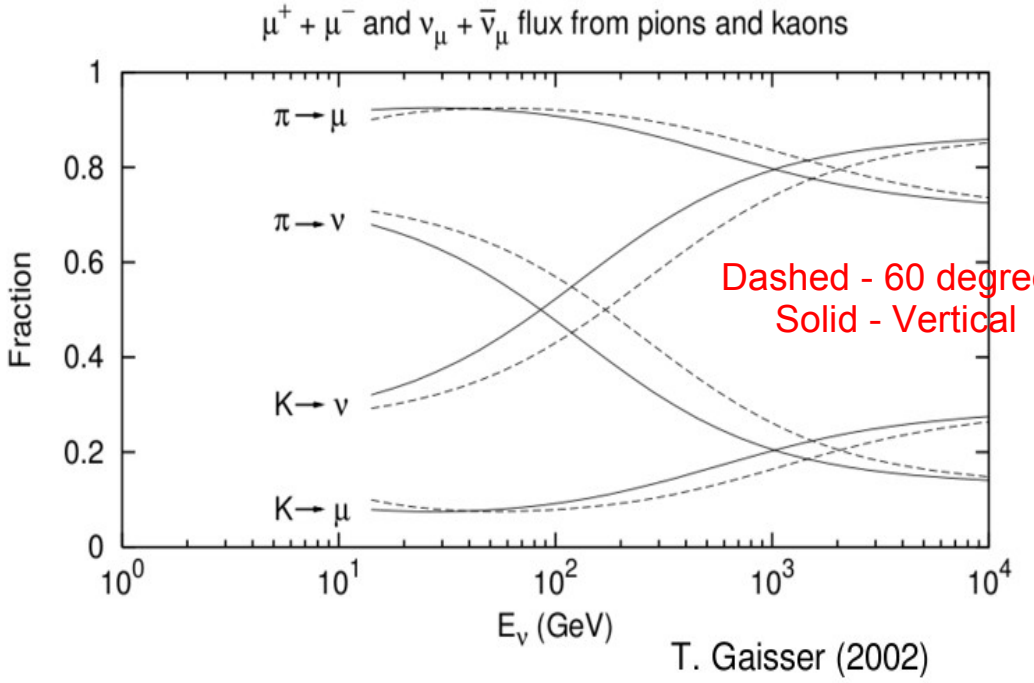
How does the Structure function scale?



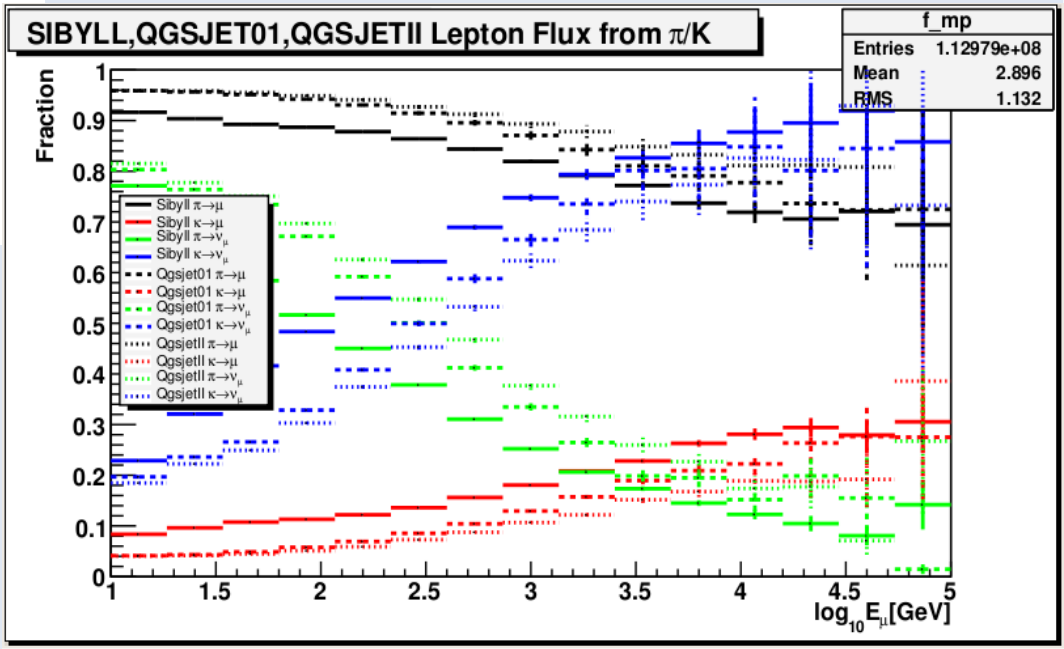
Accelerators on Earth haven't probed the energies in the upper tail of the CR spectrum, so it isn't clear how the structure function for pp or p-air collisions will trend.

Solution: Do tons of Monte-Carlo tests of a model and compare to data.

Comparing pi and K Contributions



Dashed - 60 degrees
Solid - Vertical



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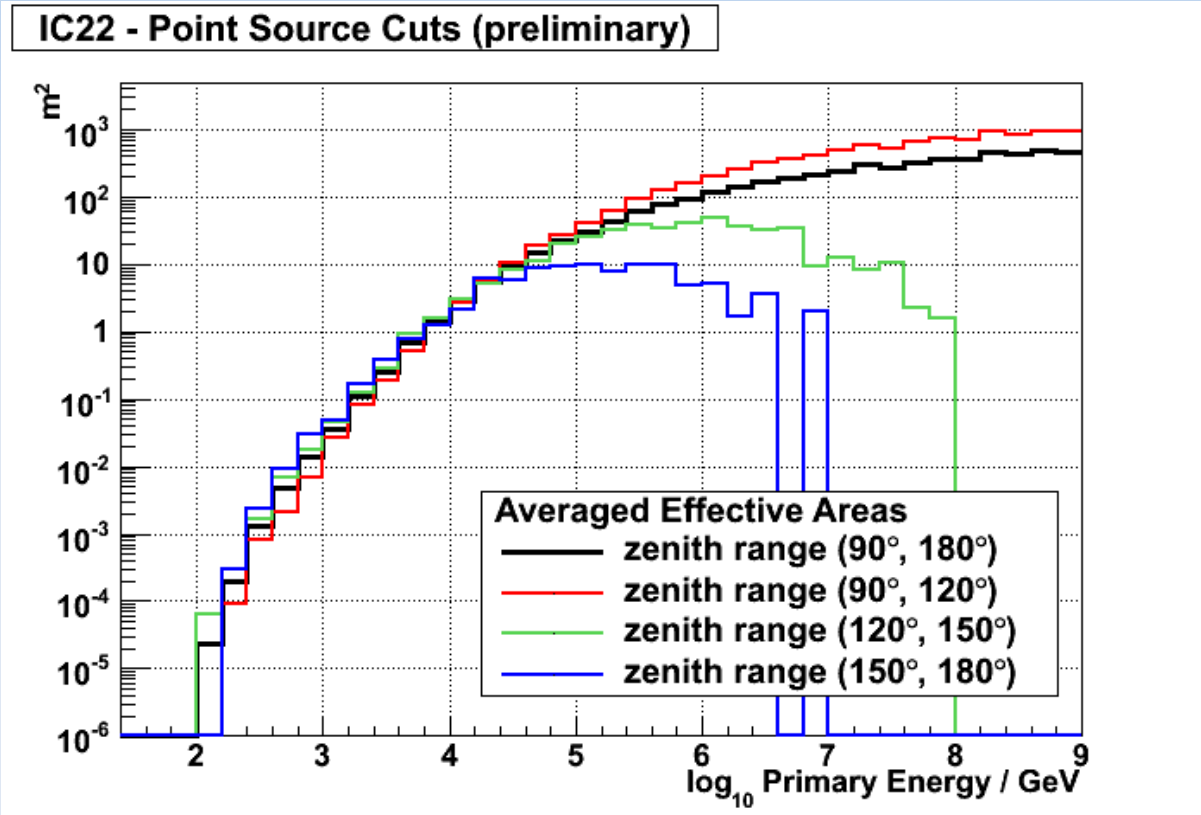
How the Earth's structure effects neutrino flux



IceCube 22 string configuration effective area for muon neutrinos

We can see that very high energy neutrinos are absorbed as they travel through the Earth's core.

Understanding the atmospheric neutrino flux is important to understand the background for astrophysical neutrinos.

It can also give us clues into proton interactions at energies above those achievable with terrestrial accelerator experiments, and is a way of probing the Earth's internal structure.