NEUTRINO RADIOGRAPHY WITH ICECUBE NEUTRINO OBSERVATORY

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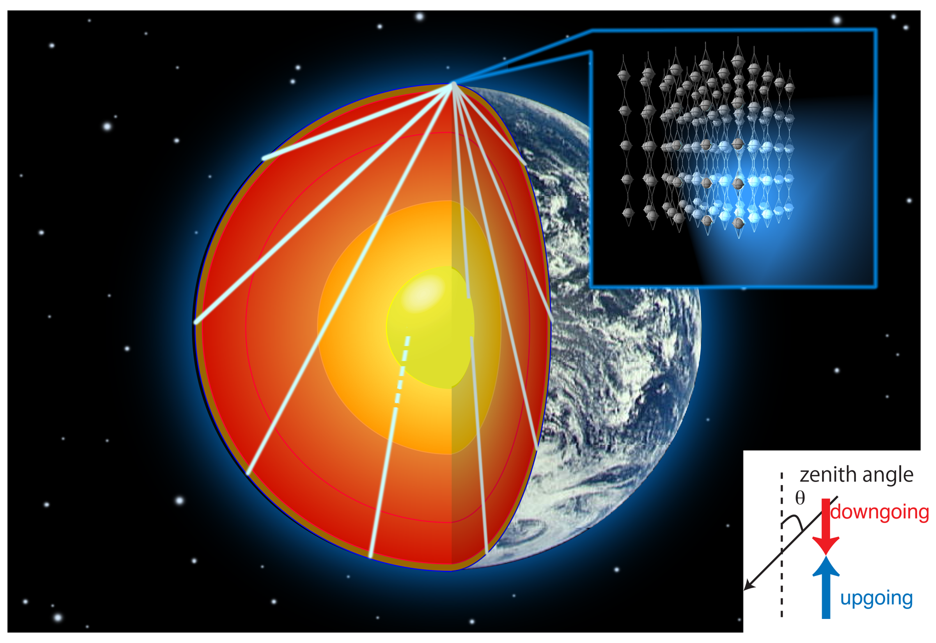
Introduction

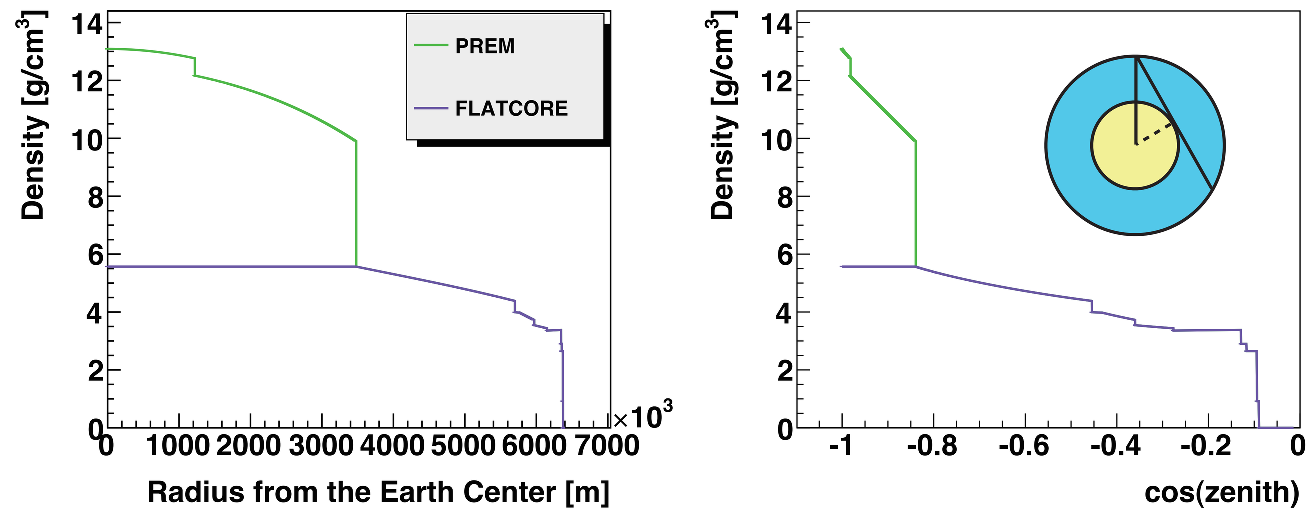
Our current knowledge of the interior structure of the Earth is based on seismic wave studies. To obtain its density profile, however, one must assume a Geophysical Earth Model which depends on chemical components, temperature, etc.

Neutrino Radiography (measuring neutrino absorption to deduce column depth) on the other hand, gives density information that is totally independent of any geophysical model.

IceCube is the first possible candidate to perform the neutrino radiography. In 10 years operation, we expect detecting core-mantle boundary and measuring density of the core.[1]

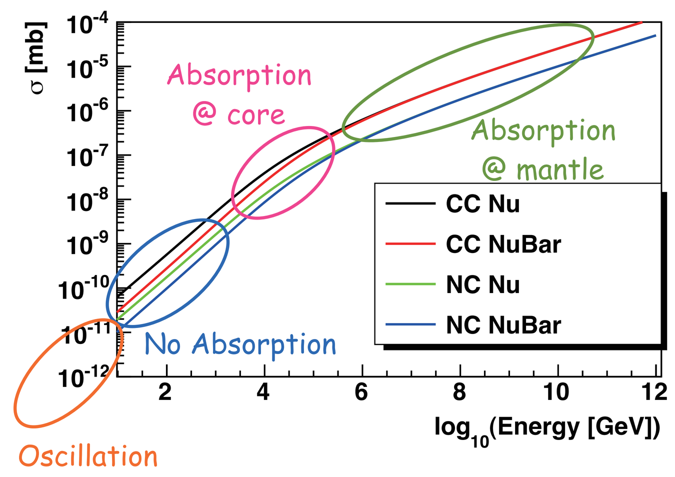


Conceptual drawing of Neutrino Radiography with the Preliminary Reference Earth Model (PREM)[2]. Due to high-density at core, part of high-energy neutrino will be absorbed inside the core.
By measuring arriving zenith angle of high-energy neutrinos, IceCube will detect event deficit at large zenith angle ($\theta > 147°$).
We use high-energy tail of atmospheric neutrino, for neutrino source, which is currently the unique available candidate for performing neutrino radiography.

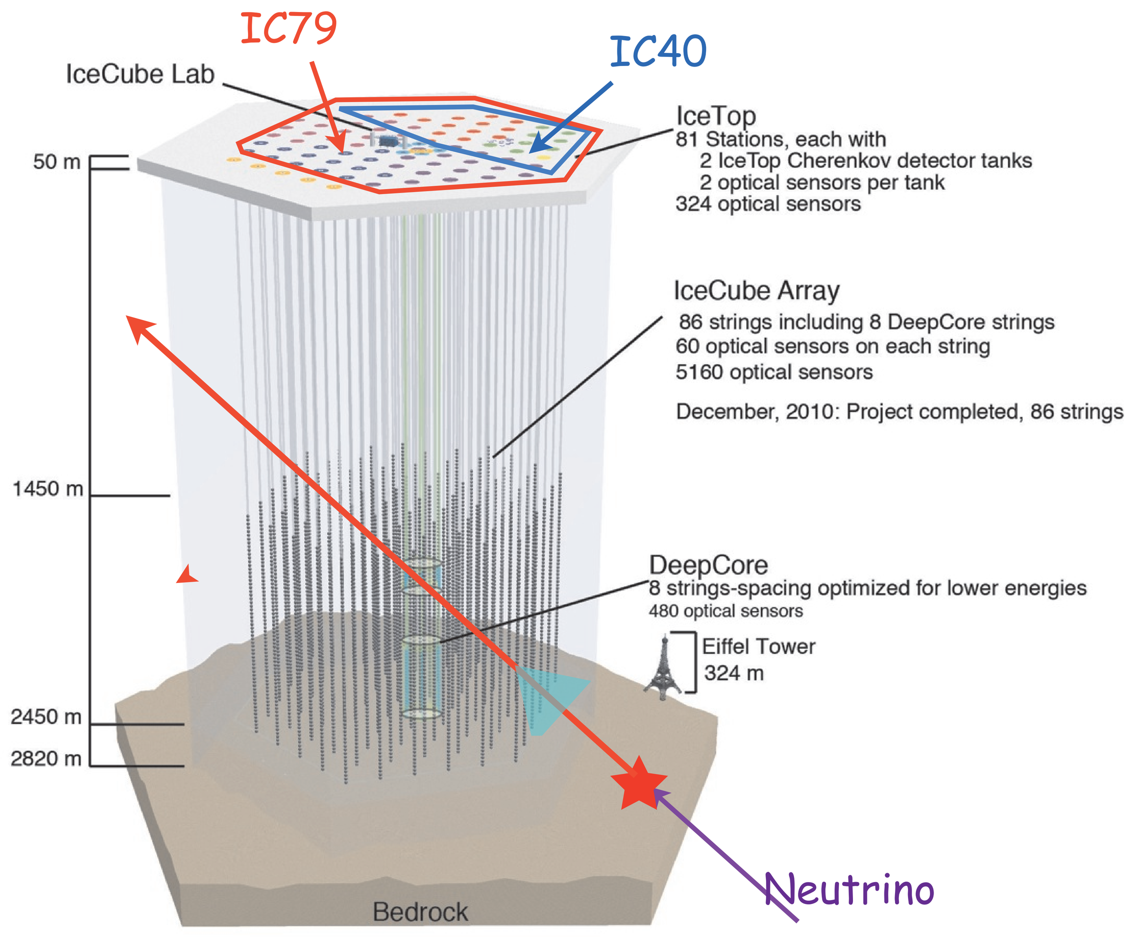


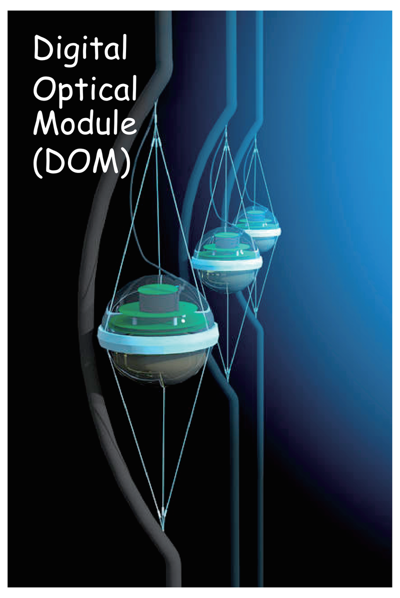
Density profiles of the Earth as a function of (a) radius and (b) cosθ of tangent line of equi-density sphere. The green curve represents standard PREM model and the purple curve shows a hypothetical "core-less" model which we named "FLATCORE" model.

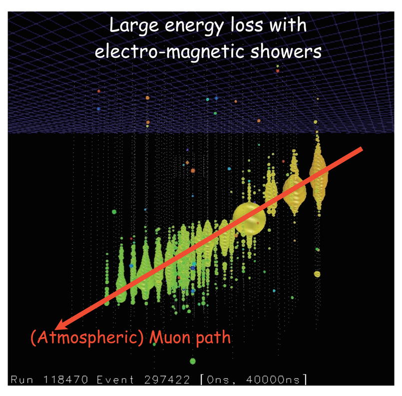
Charge current interaction length for 40TeV neutrino is equivalent to Earth' s diameter. High-energy atmospheric neutrinos are thus utilized for neutrino radiography of the core of the Earth.



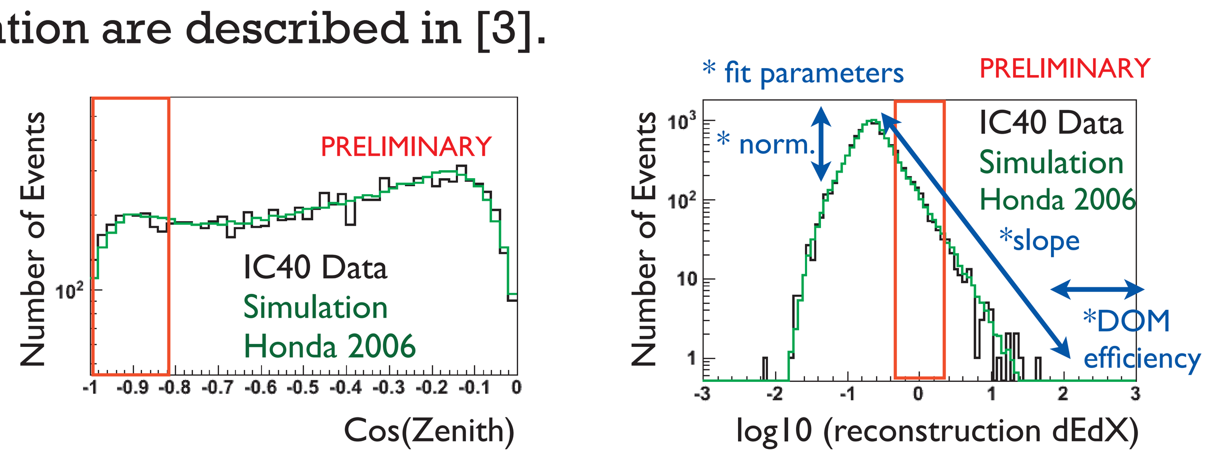
Detection and Event Selection







In order to perform neutrino radiography, we selected neutrino-induced muon events that penetrate through the Earth. Since all atmospheric muons are absorbed inside the Earth, this is equivalent selecting well-reconstructed upgoing muons while rejecting fake atmospheric muons that are reconstructed as upgoing. Details of the event purification are described in [3].



Reconstructed zenith and energy deposit after event selection. In this analysis, 10588 neutrino candidates are obtained from data collected in 2008 with IceCube 40 strings. PREM is assumed for simulation. Fitting nuisance parameters noted in the right panel are for presentation and no fit is applied yet.

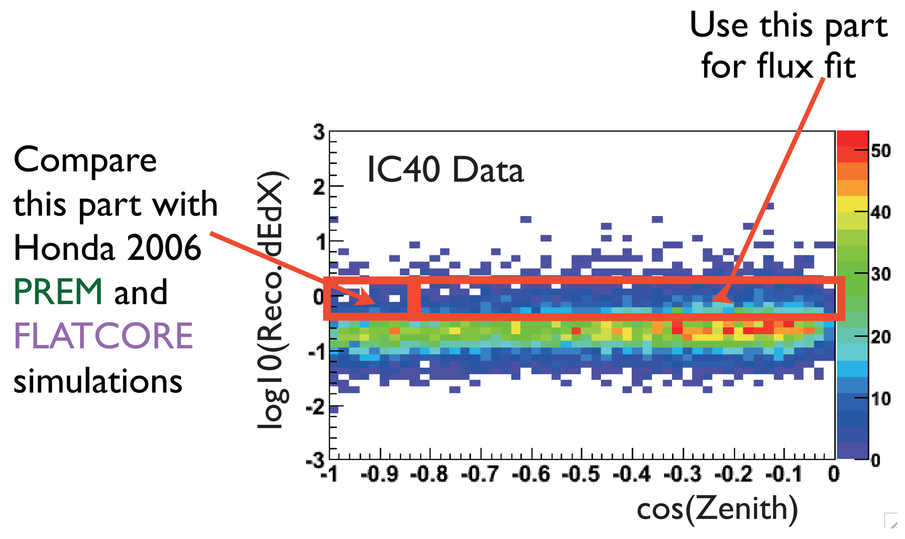
Analysis and Result

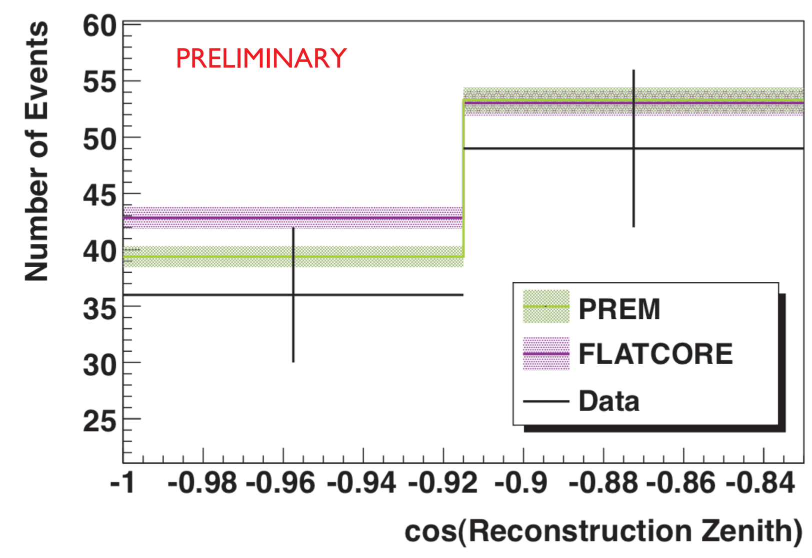
In order to estimate the absorption at core, we generated two simulation set using PREM and FLATCORE. These simulations are identical except for the density profile inside the core.

The neutrino candidate contains large number of events with energy less than ~10TeV (in MC truth, muon energy at near by the center of IceCube). Since they are not sensitive to the difference of density between PREM and FLATCORE, we chose an reconstructed-energy window $-0.3 < \log_{10}(dEdX) < 0.3$ [GeV/m]. The higher bound is set to suppress statistical fluctuation due to the limited event-statistics at the high-energy tail of our sample.

Because PREM and FLATCORE are identical at the mantle area, we fit our simulations to data at $\cos\theta > -0.83$ with three nuisance parameters: a normalization factor of atmospheric neutrino spectrum(n), a spectral index correction for the atmospheric neutrino spectrum(γ), and a ratio between assumed and normal DOM efficiency(δ).

With the fit results, we estimated number of events at the core using PREM and FLATCORE simulations.





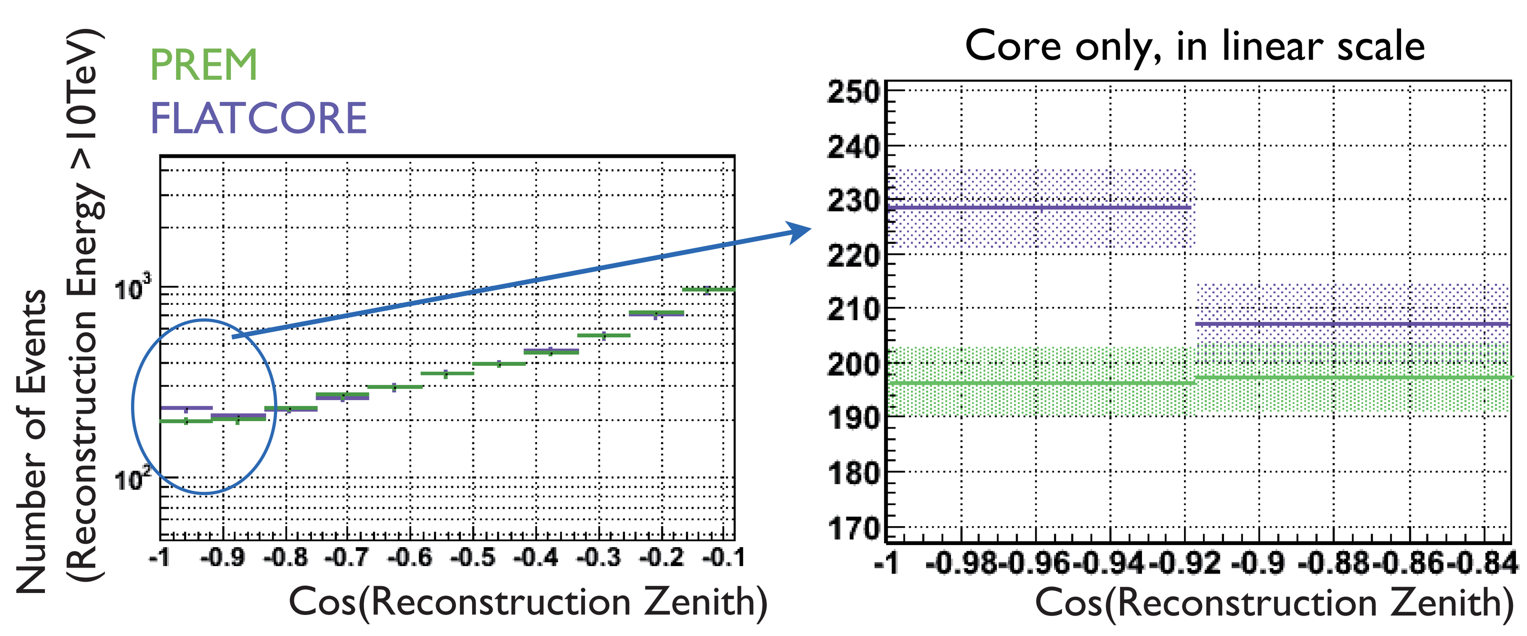
Number of events at core area, with muon energy $-0.3 < \log_{10}(dEdX) < 0.3$ [GeV/m]. n=0.978, γ=-0.001 and δ=0.998 are used for correction of simulations. Shadow areas are uncertainty of predictions due to limited statistics of simulation.

Since the observed difference of two models is within the statistical error of the data, one-year data of IceCube 40 strings is not sensitive to detect difference of densities between core and mantle. This is mainly due to the limited statistics of events with energy over ~10TeV.

Outlook

Applying the same event selection and analysis as IceCube 40 strings, we estimate one sigma separation with full-size IceCube ten years operation. Optimizing analysis for full-size IceCube is ongoing and will significantly improve the separation.

Systematic studies will be carried out for zenith-dependent uncertainty of atmospheric neutrino flux, neutrino cross section and zenith-dependent uncertainty of detector simulation.



References

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[2] A. M. Dziewonski and D. L. Anderson, Physics of the Earth and Planetary Interiors **25** (1981) 297.
[3] R. Abbasi et al. (IceCube Collaboration), Phys. Rev. D **84**, 082001 (2011).

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