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PINGU - a low energy infill array for IceCube

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for the IceCube collaboration

International Workshop on Neutrino Telescopes
Venice
March 15th 2013

Towards a low-energy ν detector @ South Pole

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IceCube (build)

- 80 strings
- E_{thresh} ~ 100 GeV

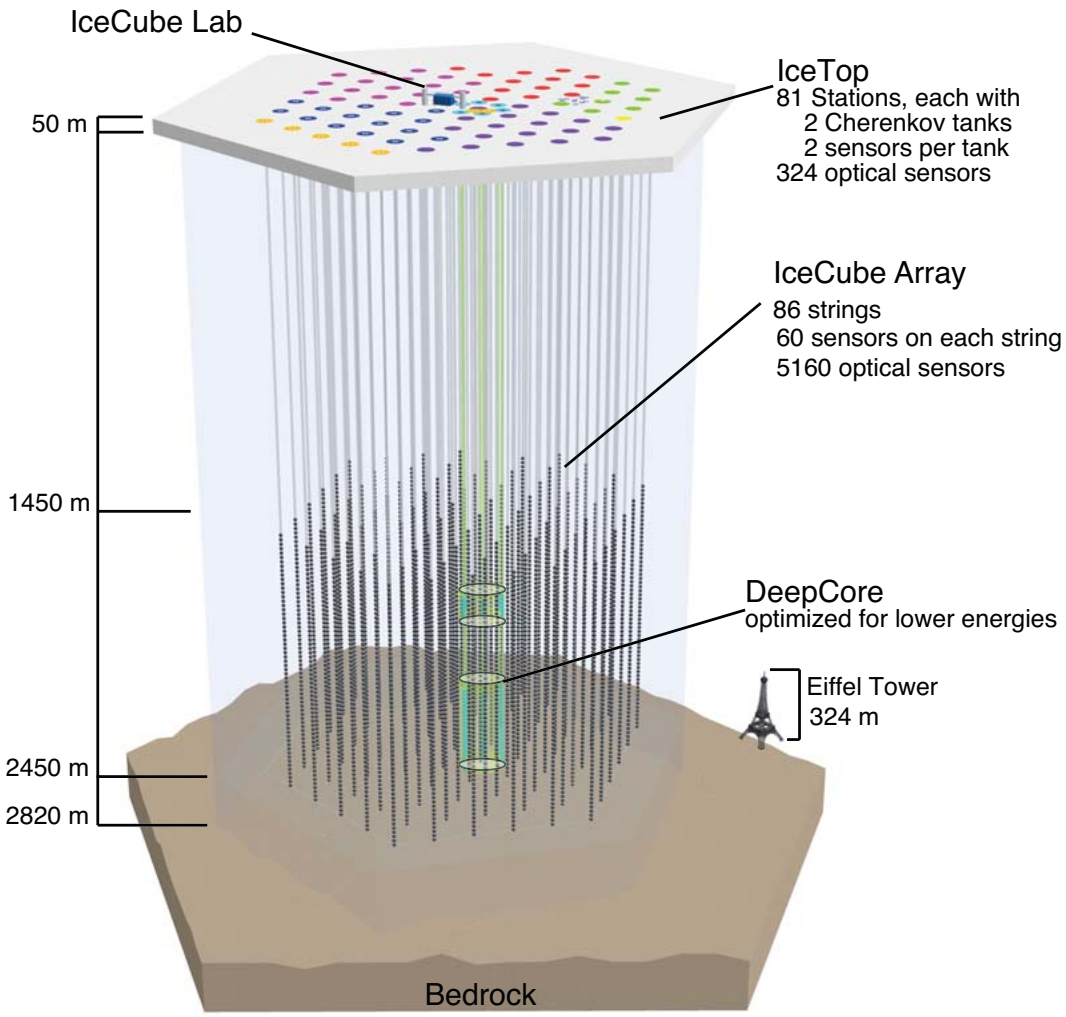
  ➔ astrophysical CR-sources

DeepCore (build)

- +6 strings
- E_{thresh} ~ 10 GeV
- O(10^5) atmospheric neutrino triggers per year

PINGU (concept study)

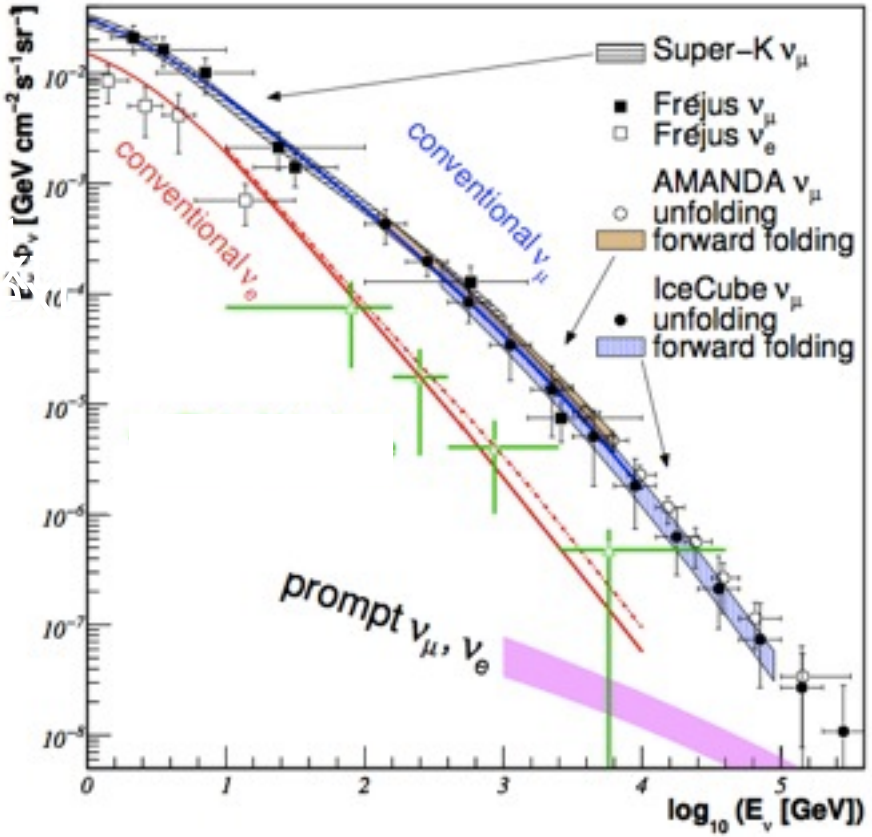
- E_{thresh} ~ 1GeV



Nested detector use surrounding detector layers as active veto

The science potential of PINGU - a denser infill array

- Large statistics of atmospheric *O*(10) GeV neutrinos:
  - Neutrino Mass Hierarchy
  - Precise measurement of $\sin\theta_{23}$, Δm_{23}^2
  - Earth density profile
- Indirect WIMP searches
- Neutrino-Astrophysics, e.g.
  - Gamma Ray Bursts (e.g. arXiv:1302.3915)
  - Core-collpse Supernovae



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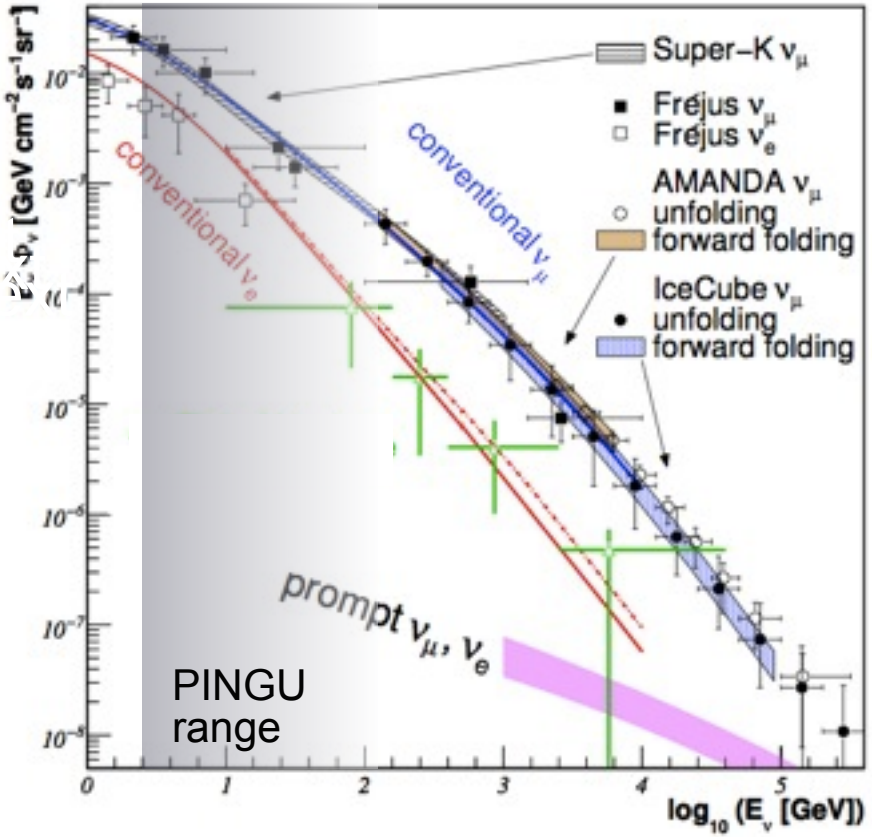

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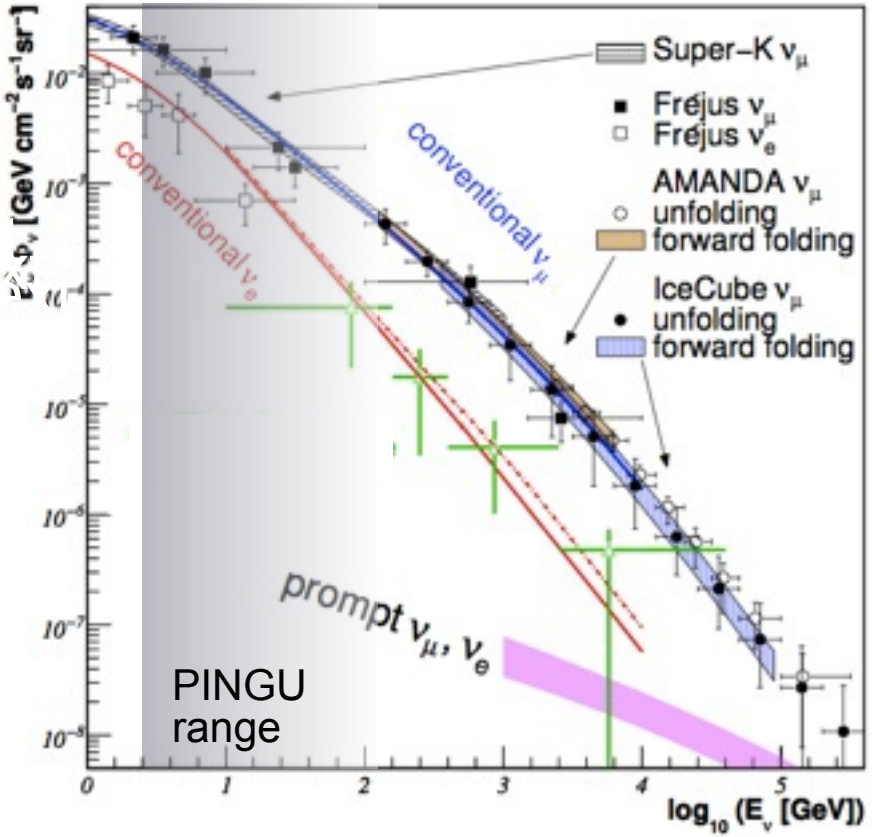
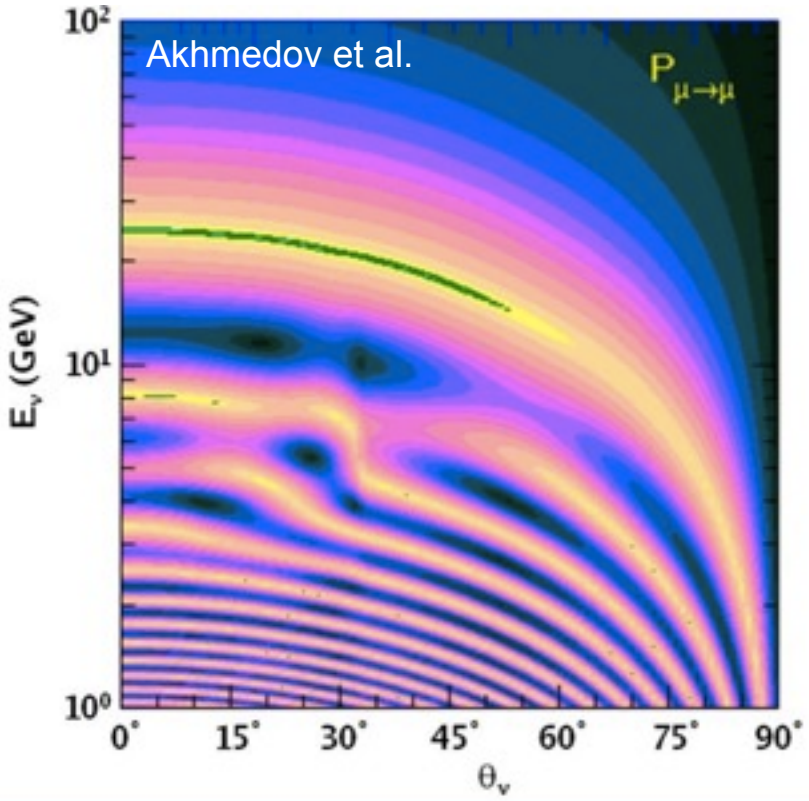
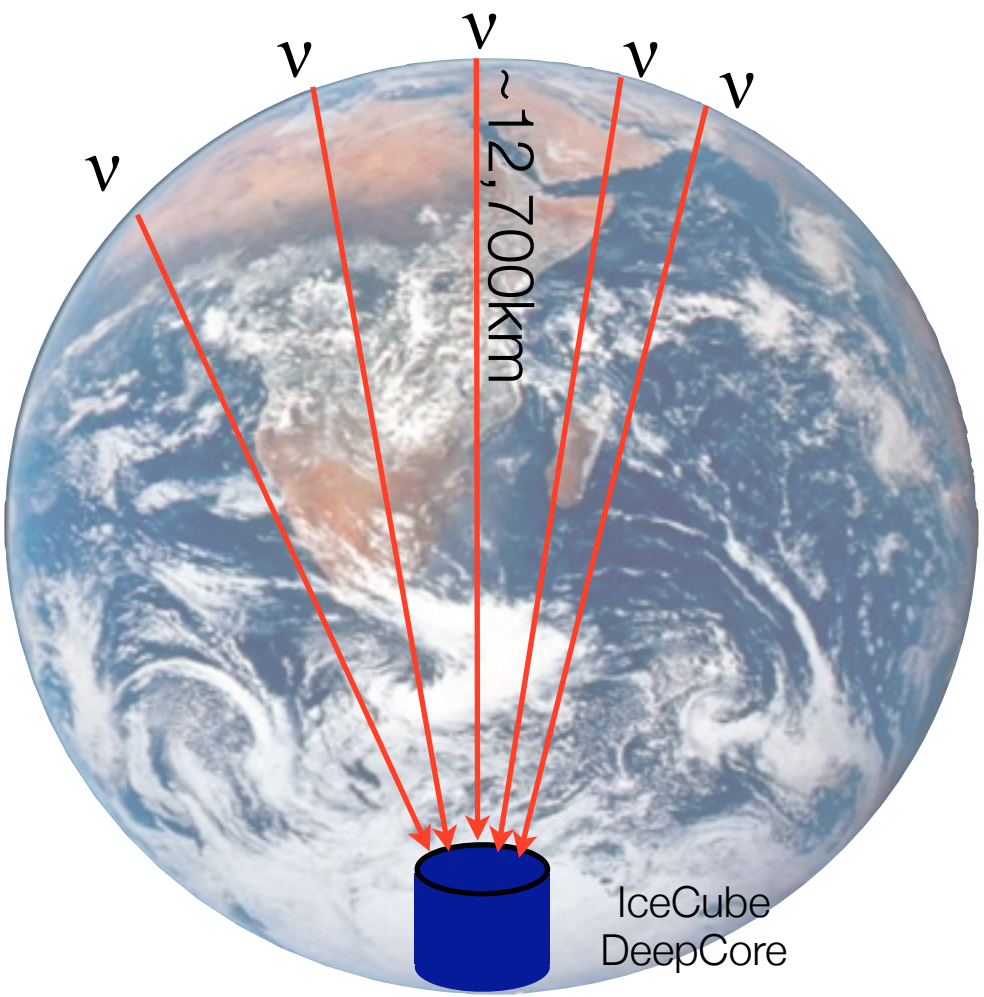


Neutrino-Oscillations with IceCube/DeepCore

- First oscillation maximum around 24 GeV, i.e. DeepCore energies
- Hierarchy-dependent matter effects below 10 GeV – too low for DeepCore





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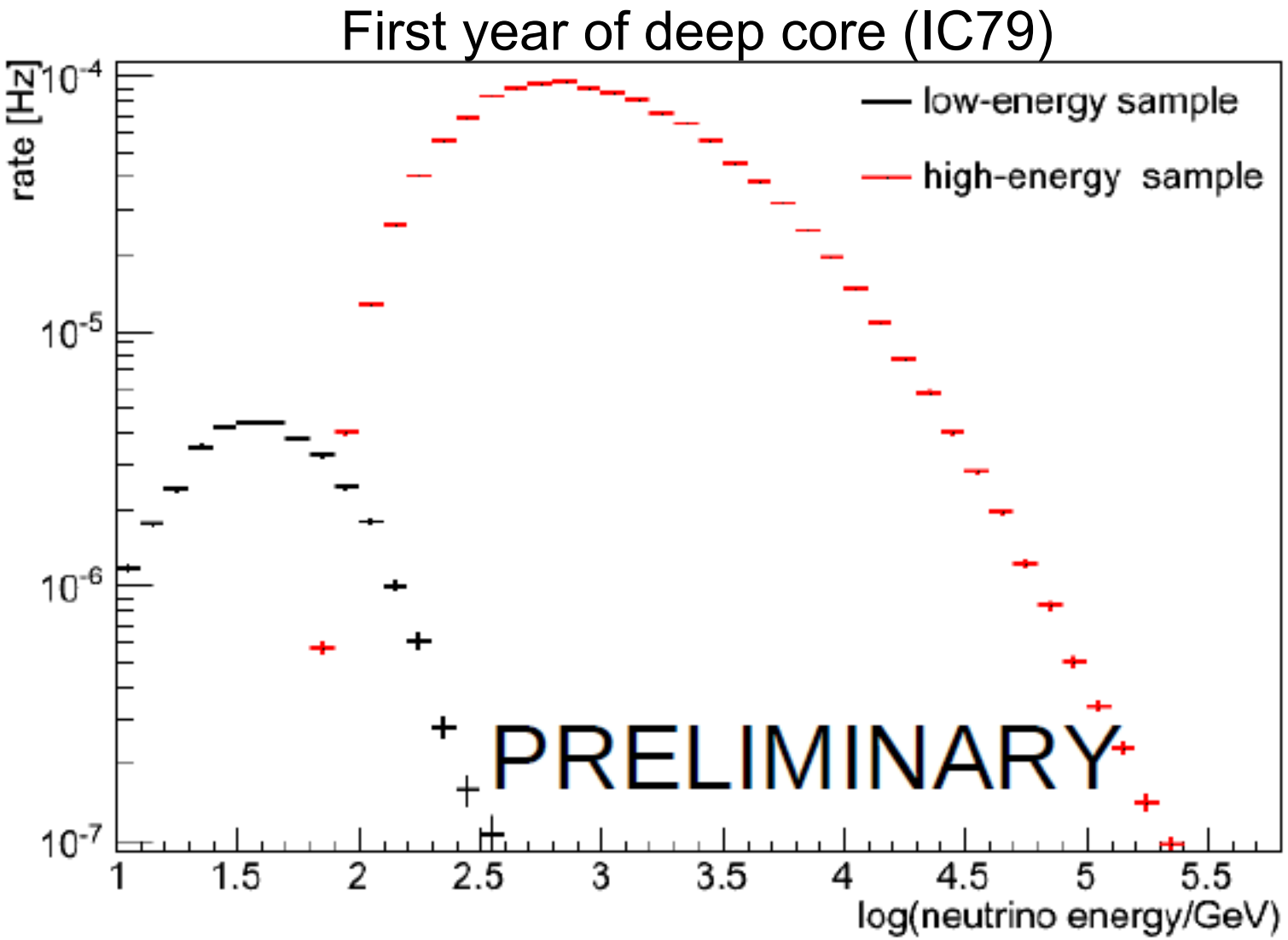
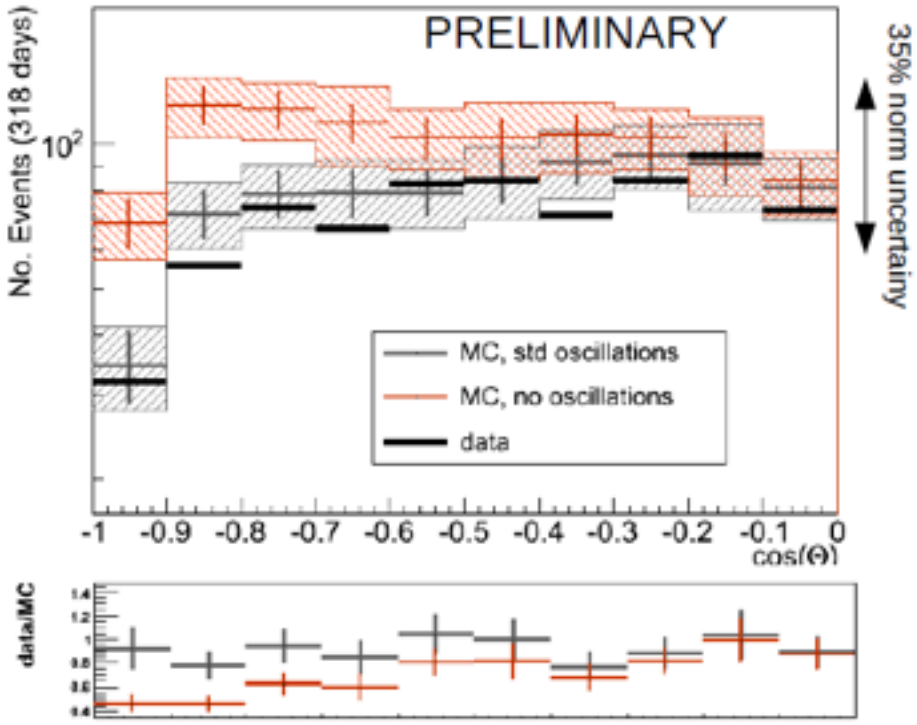
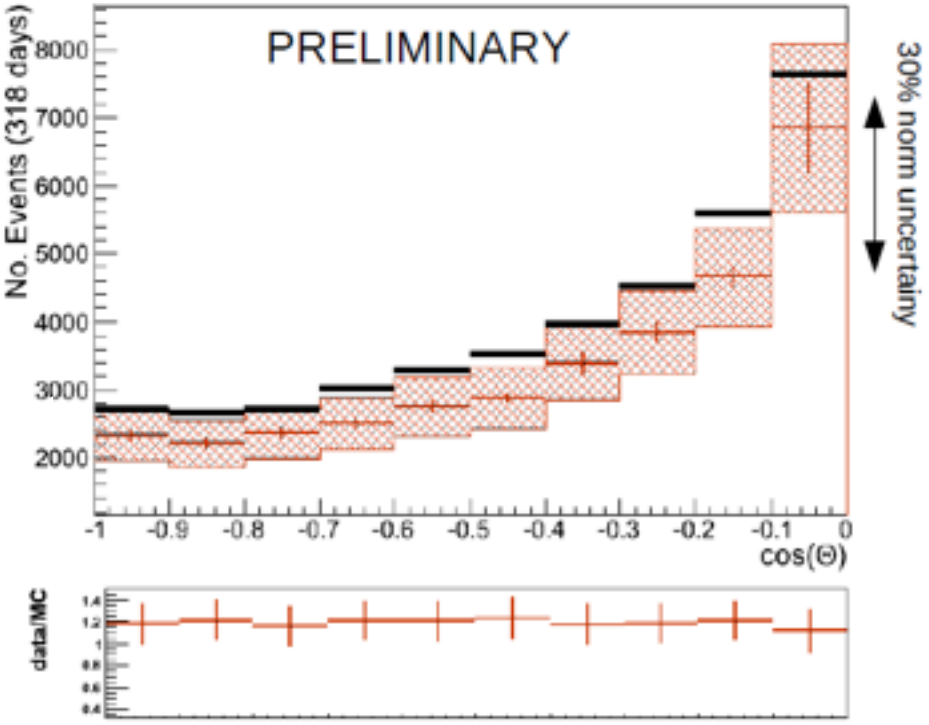


Neutrino-Oscillations with IceCube/DeepCore

low energy sample



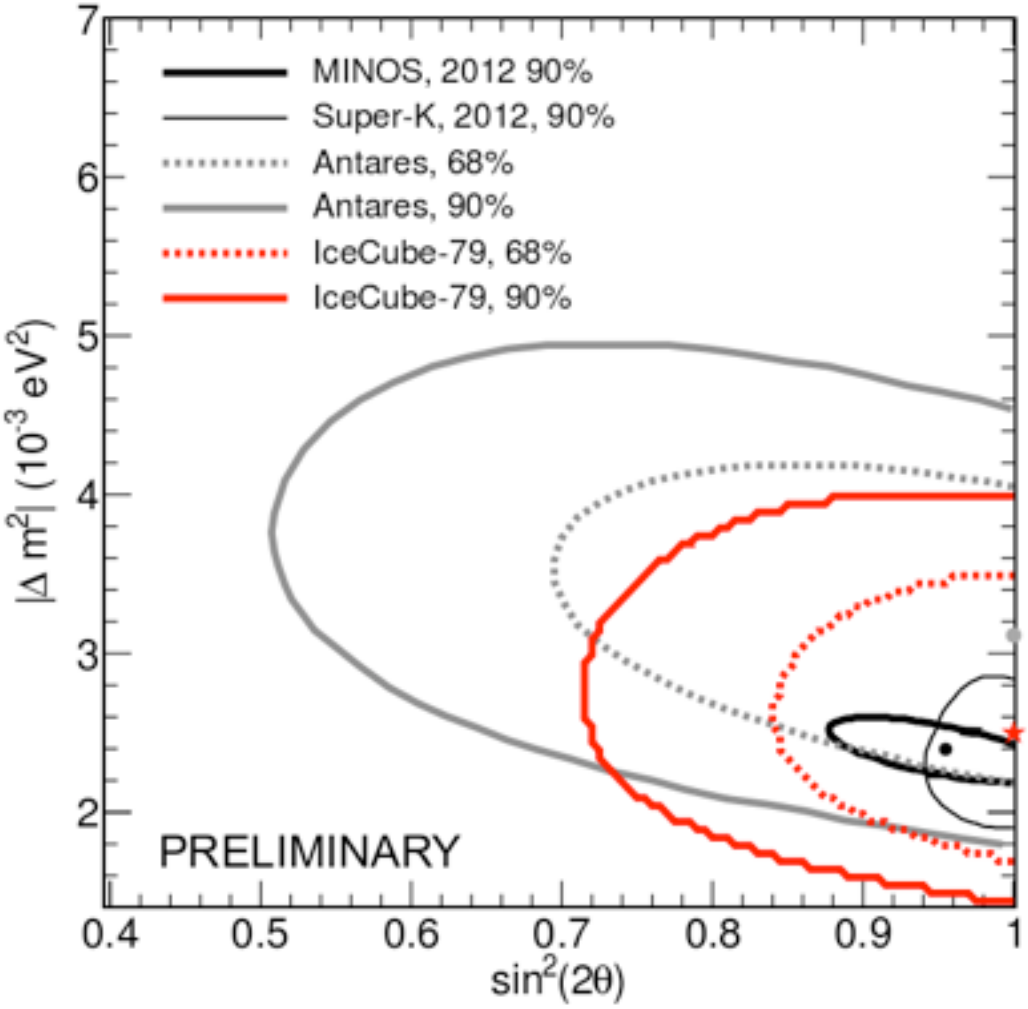
high energy sample



χ^2 / ndof = 52.7/20 (w/o oscillations)
χ^2 / ndof =19.4/20 (std. oscillations)

Neutrino-Oscillations with IceCube/DeepCore

- Oscillation parameter allowed regions extracted from zenith distributions
  - Systematics included in contours
- Results in agreement with with other (more precise) measurements
- Optimized analyses yields order of magnitude more low energy events



PINGU Feasibility Study

One of several candidate geometries:

Add 20 strings

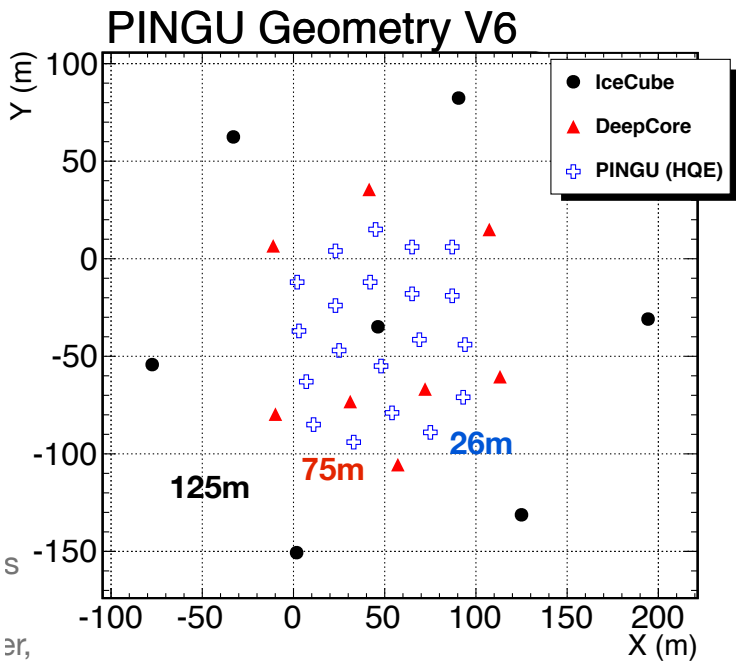
- 26m string spacing
- 5m DOM spacing

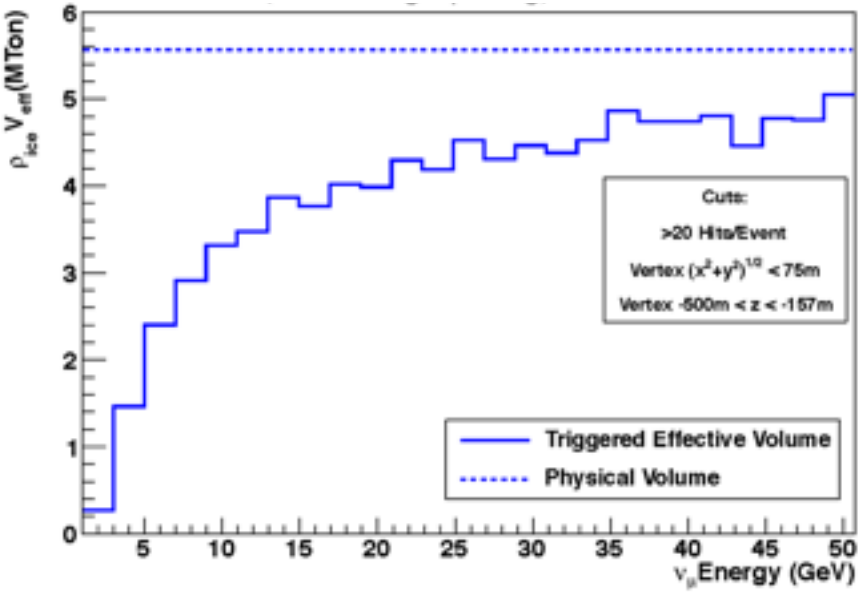
in addition to 78 IceCube strings

- 125m string spacing
- 17m DOM spacing

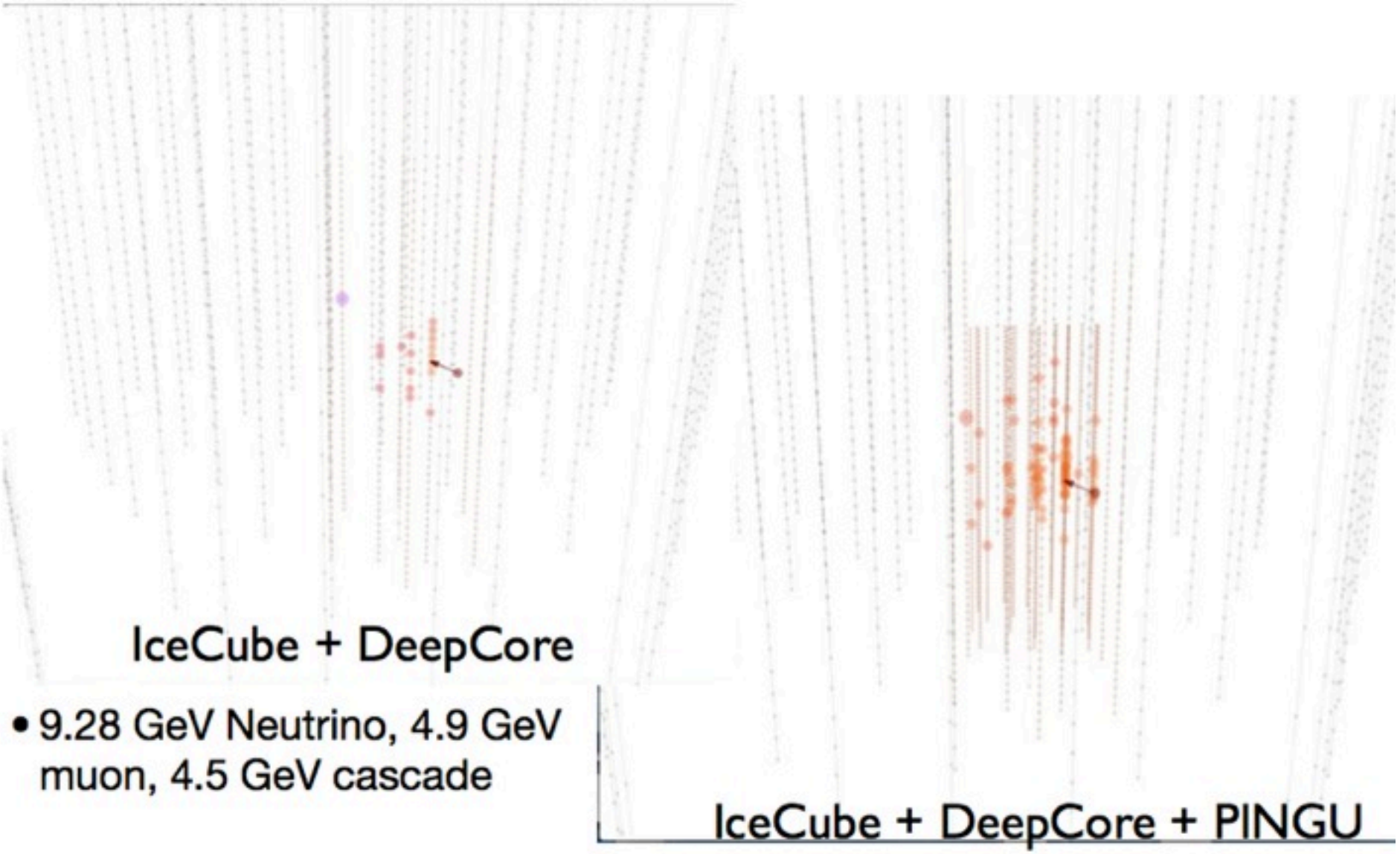
and 8 DeepCore strings

- 75m string spacing
- 7m DOM spacing





PINGU events

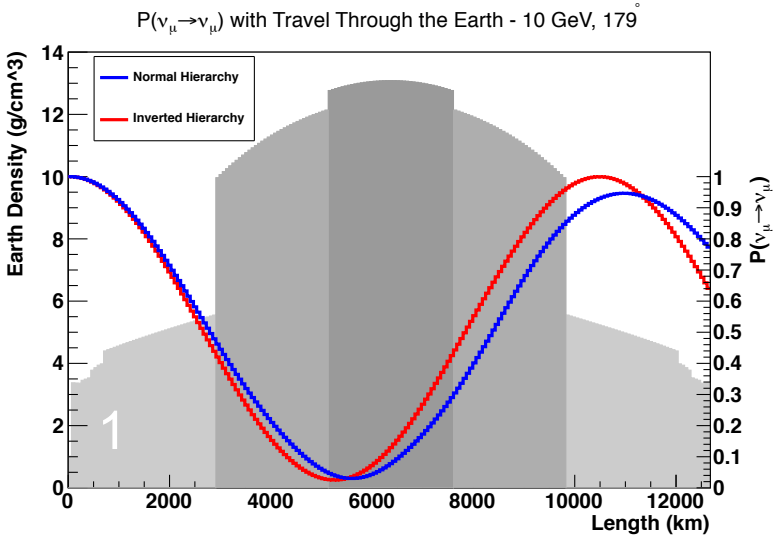


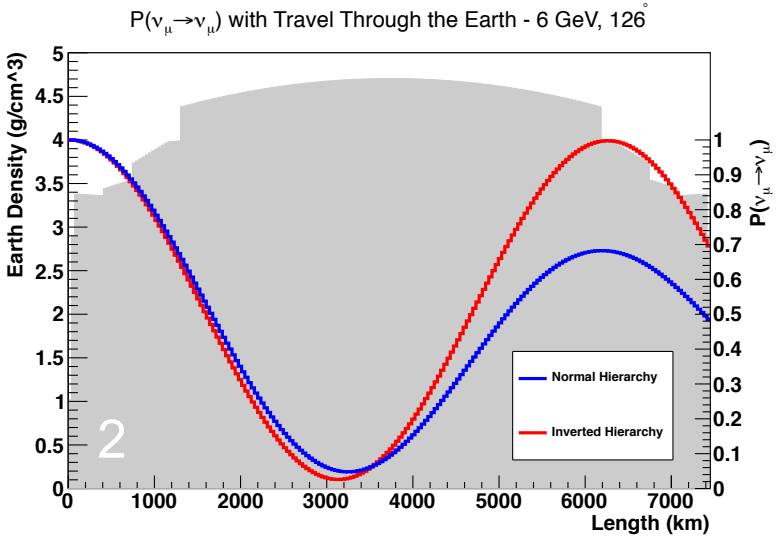
- 9.28 GeV Neutrino, 4.9 GeV muon, 4.5 GeV cascade

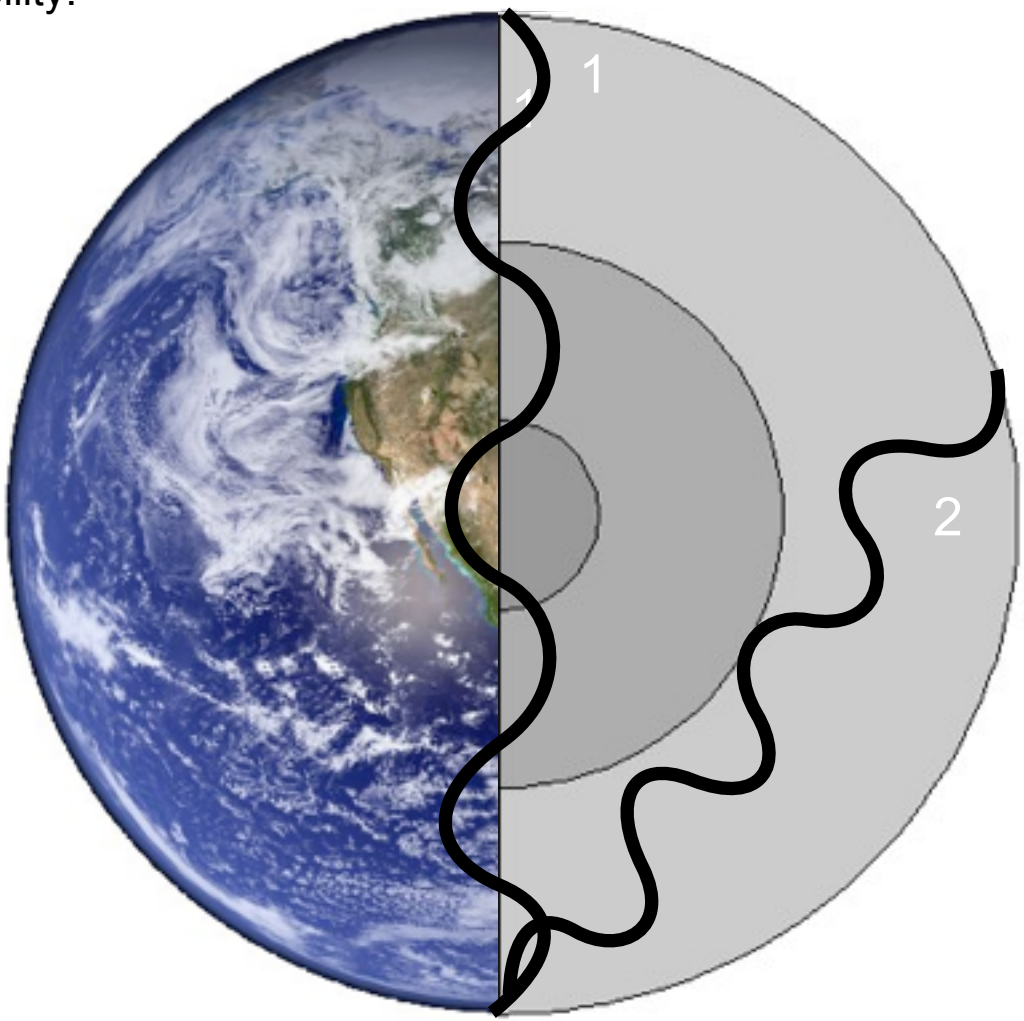
Neutrino Mass Hierarchy

NMH sensitivity through neutrino/anti-neutrino asymmetries and matter oscillation effects.

Up to 20 % difference in oszillation probability:







Preliminary Hierarchy Sensitivity Studies

As a preliminary metric, use the significance estimate of Akhmedov, Razzaque & Smirnov (arXiv:1205.7071) to evaluate potential

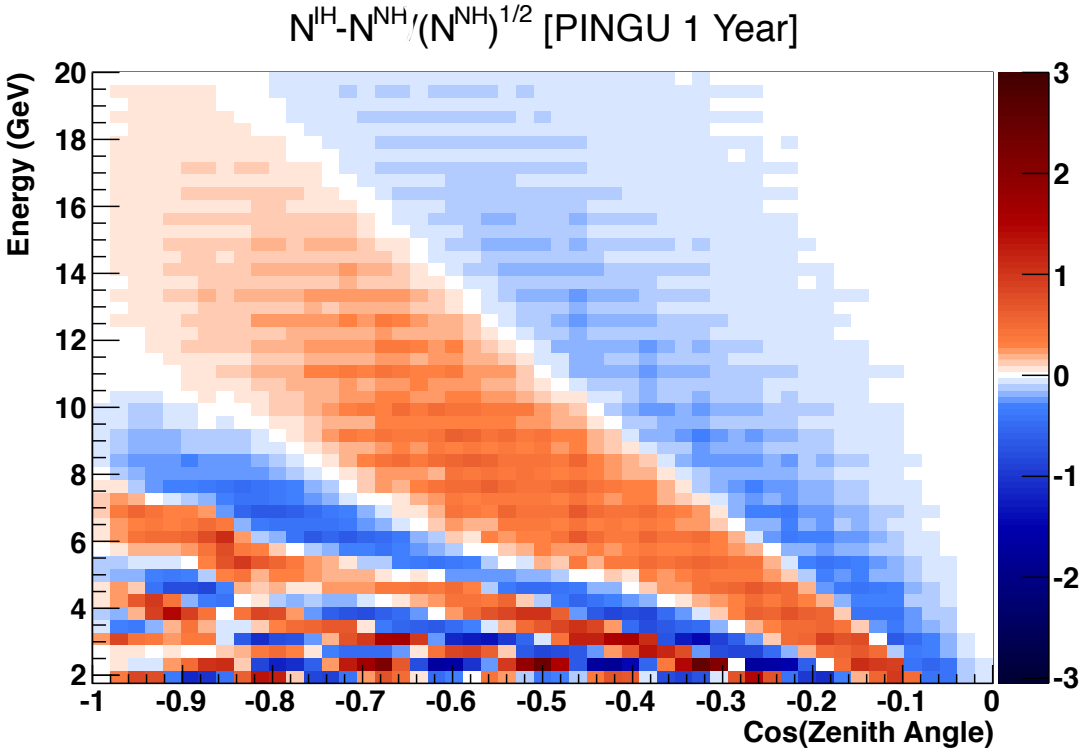
- Binned counting experiment in energy and zenith angle, comparing difference in expected number of events for normal vs. inverted hierarchy due to mass effects

$$S_{tot} = \sqrt{\Sigma_{ij} \frac{(N_{ij}^{IH} - N_{ij}^{NH})^2}{N_{ij}^{NH}}} \qquad \begin{aligned} i &= \cos(zenith) \\ j &= energy \end{aligned}$$

- Evaluation of angular and energy resolution, as well as flavor ID is ongoing

Preliminary Hierarchy Sensitivity Studies

Idealized case with no background, flavor ID, 100% signal efficiency

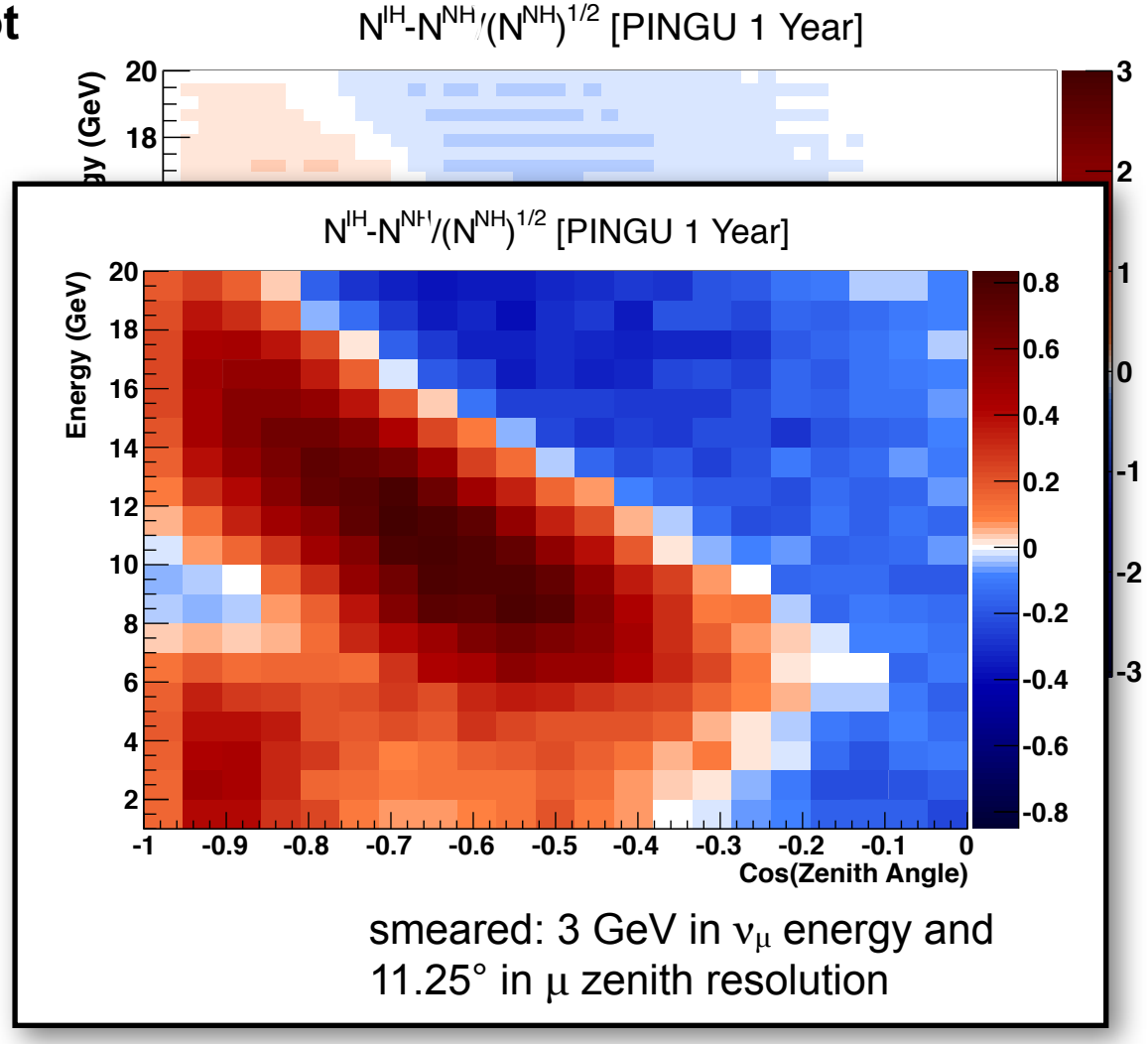


Preliminary Hierarchy Sensitivity Studies

Idealized case with no background, flavor ID, 100% signal efficiency

Detector resolution effects smear signature but do not eliminate it

- NB: angular resolution is for muon – kinematic effects are included
- Expected efficiencies and resolutions under investigation now

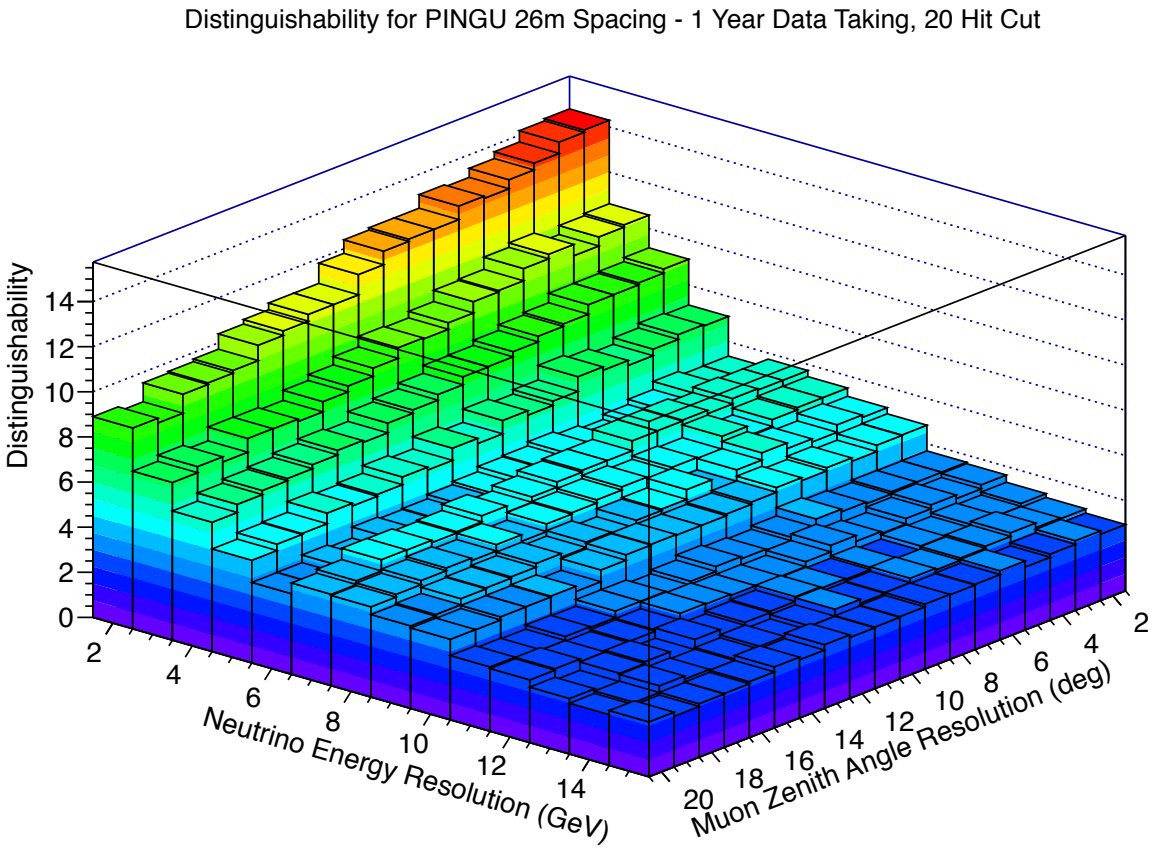


smeared: 3 GeV in ν_μ energy and 11.25° in μ zenith resolution

Sensitivity vs. Performance

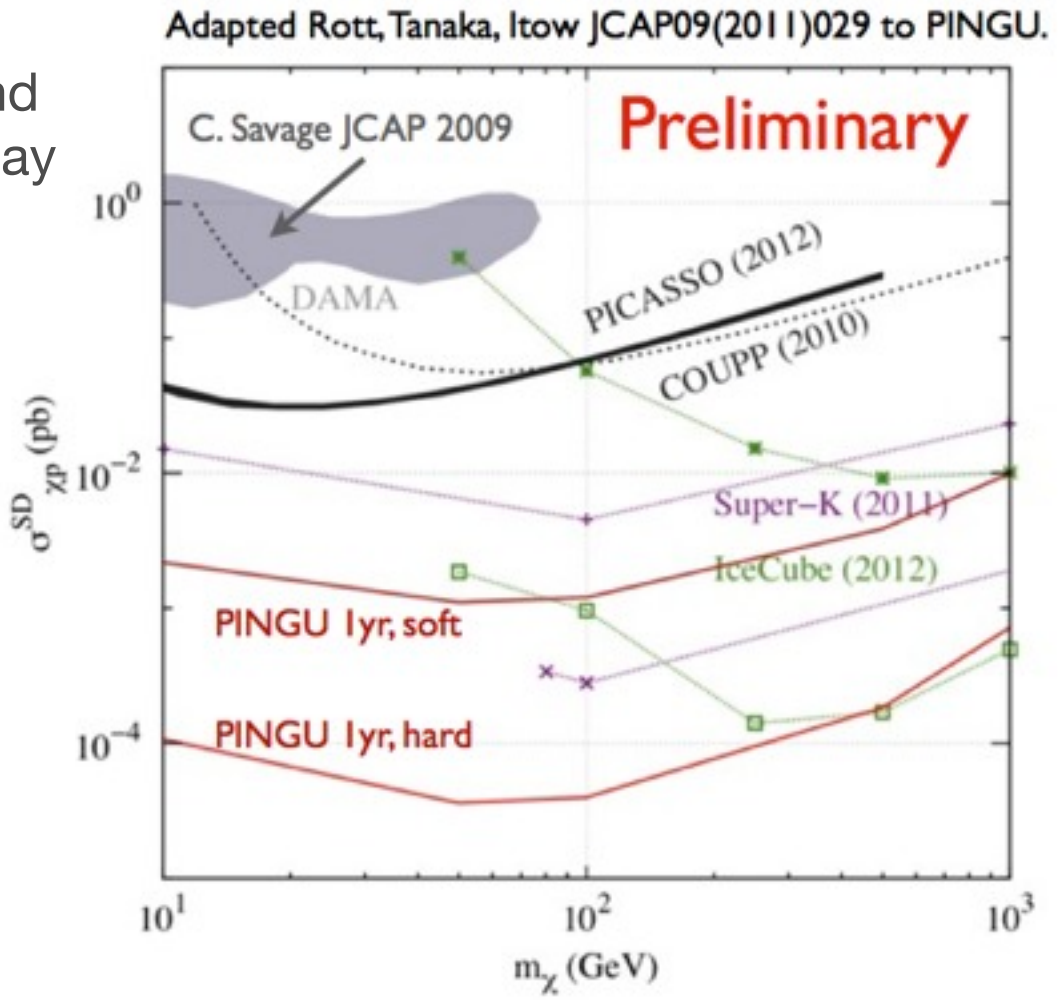
Require 20 DOMs hit in PINGU, and evaluate expected significance after (1 year x 100% efficiency) as a function of assumed energy and muon angular resolution

- Required performance parameters will drive detector design
- Systematics and physics degeneracies (e.g. Δm_{31}^2) not yet included
- More sophisticated resolution models will also be evaluated (e.g. energy/inelasticity dependence)



More PINGU science: WIMP sensitivity

- WIMP annihilation in the Sun and Earth ⇒ escape of neutrino decay products
- Sufficient statistics to test low-mass WIMP scenarios
- Detailed study with full PINGU simulation & reconstruction required



Conclusion & Outlook

- Well-established detector and construction technology
- Relatively low cost: ~$10M first string + ~$1.25M per extra string
- Rapid schedule: two season deployment could be complete by 2017-18, depending on final scope. First physics in 2018
- Provides a platform for more detailed calibration systems to reduce detector systematics
  - Enhance physics at DeepCore energies – e.g. tau appearance
  - Opportunity for R&D toward other future ice/water Cherenkov detectors
- Working toward a LoI now

The End