Neutrinos at the South Pole - The PINGU Detector

Ken Clark
University of Toronto

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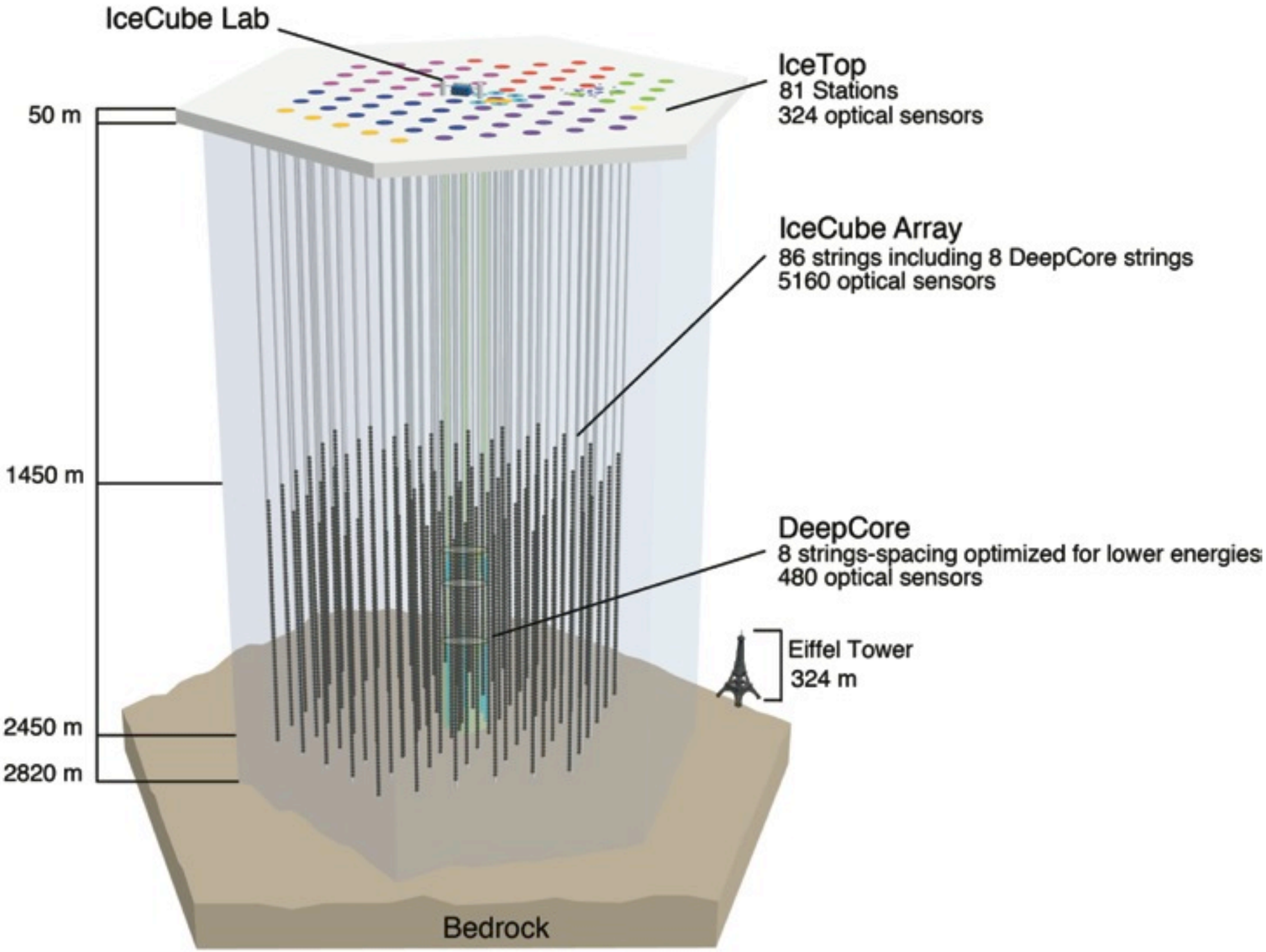
The IceCube Neutrino Telescope



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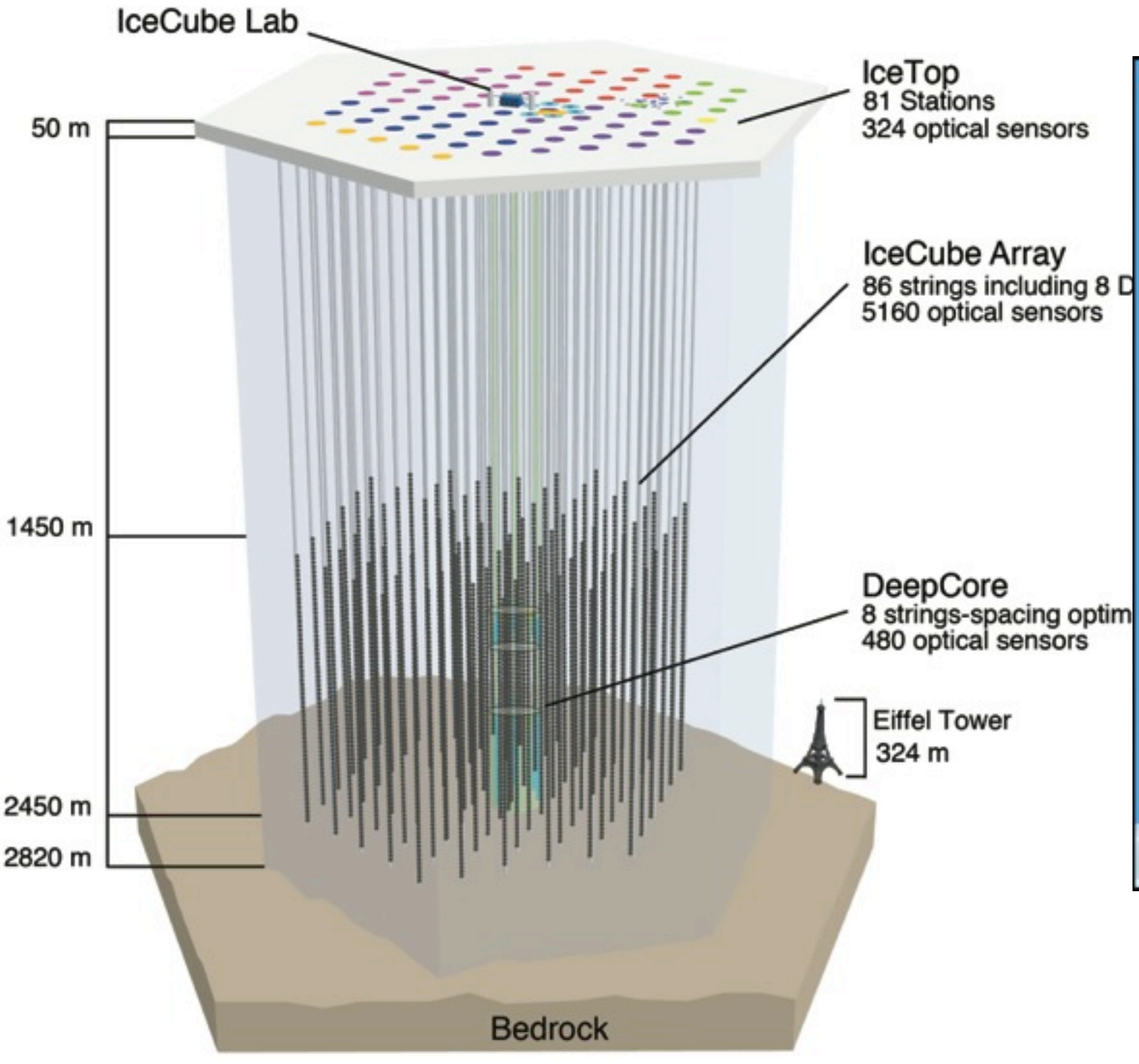
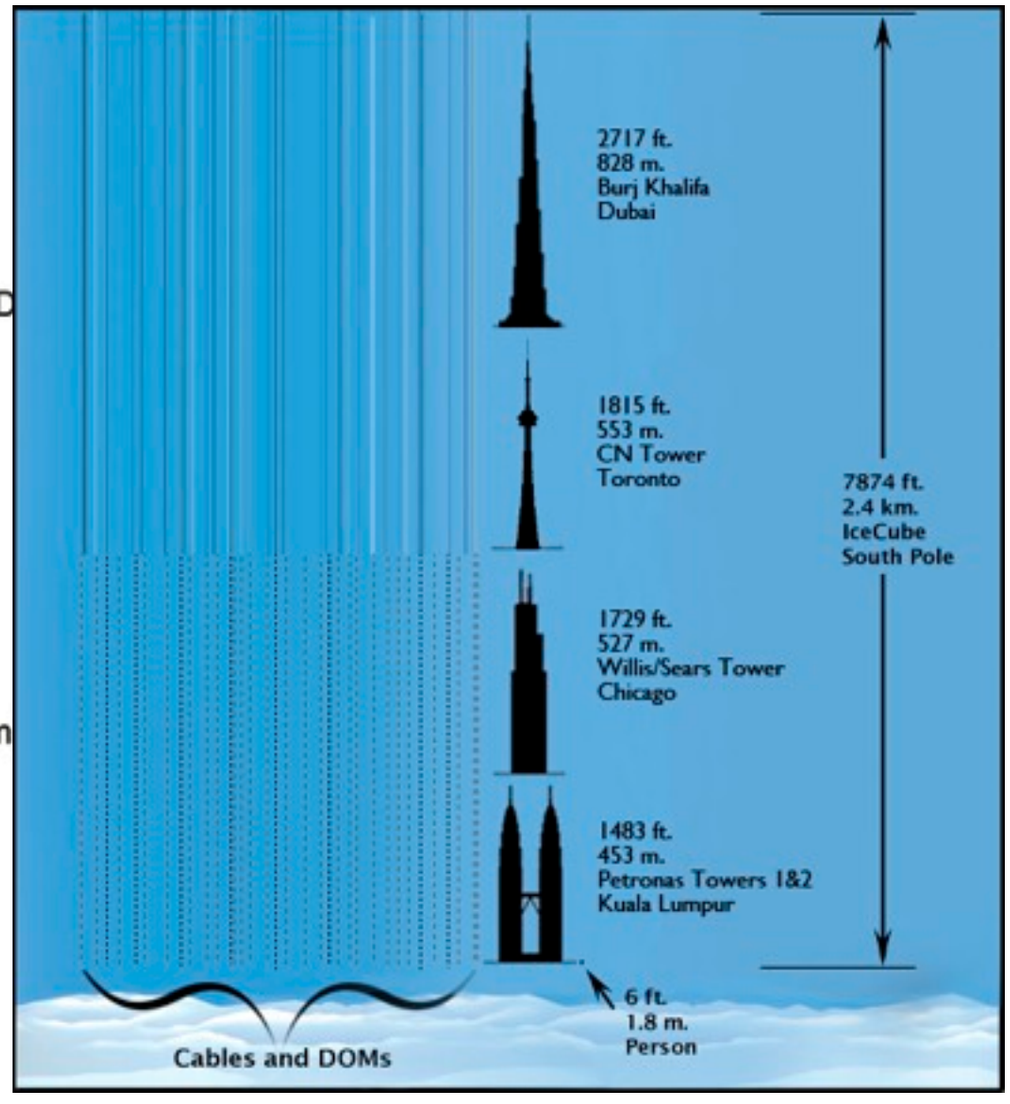
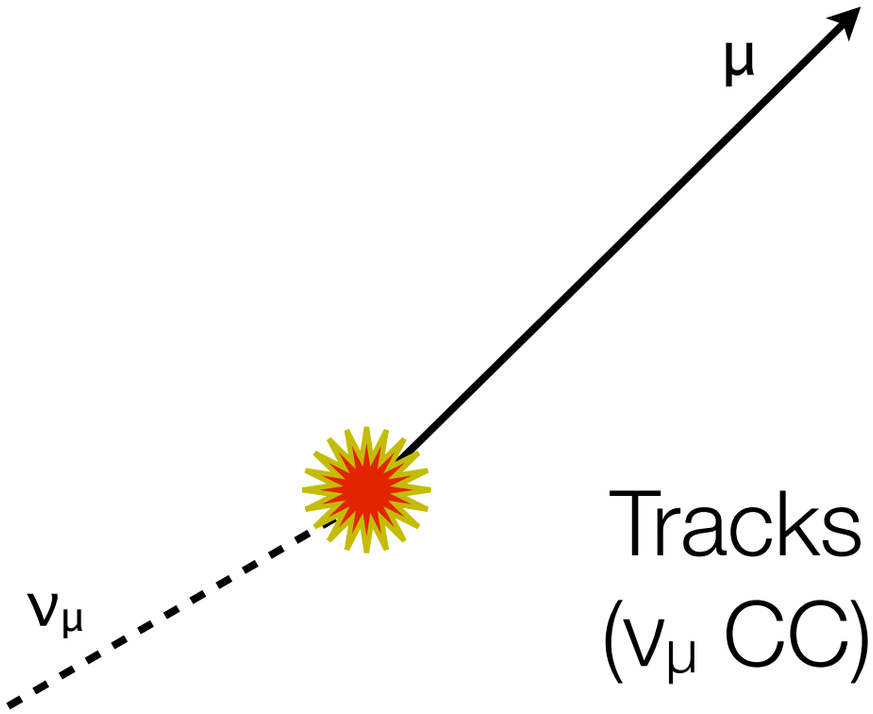


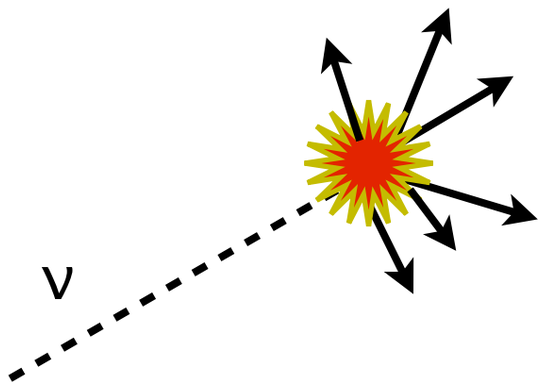


How do we Detect Neutrinos?

- IceCube separates neutrino interactions into two types:

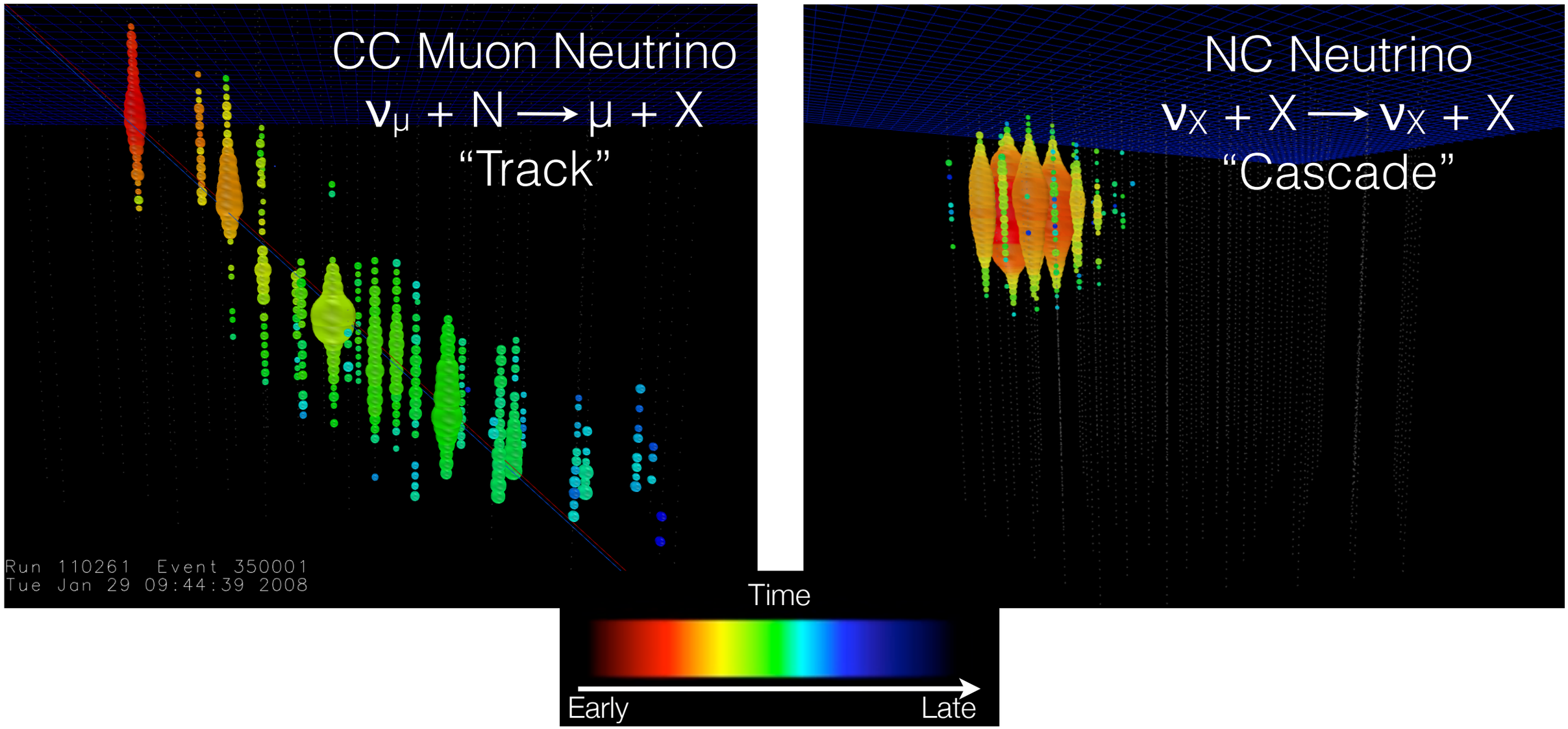


Tracks
(ν_μ CC)



Cascades
(ν NC)

Events in the Detector



- Events are separable using their signature in the detector

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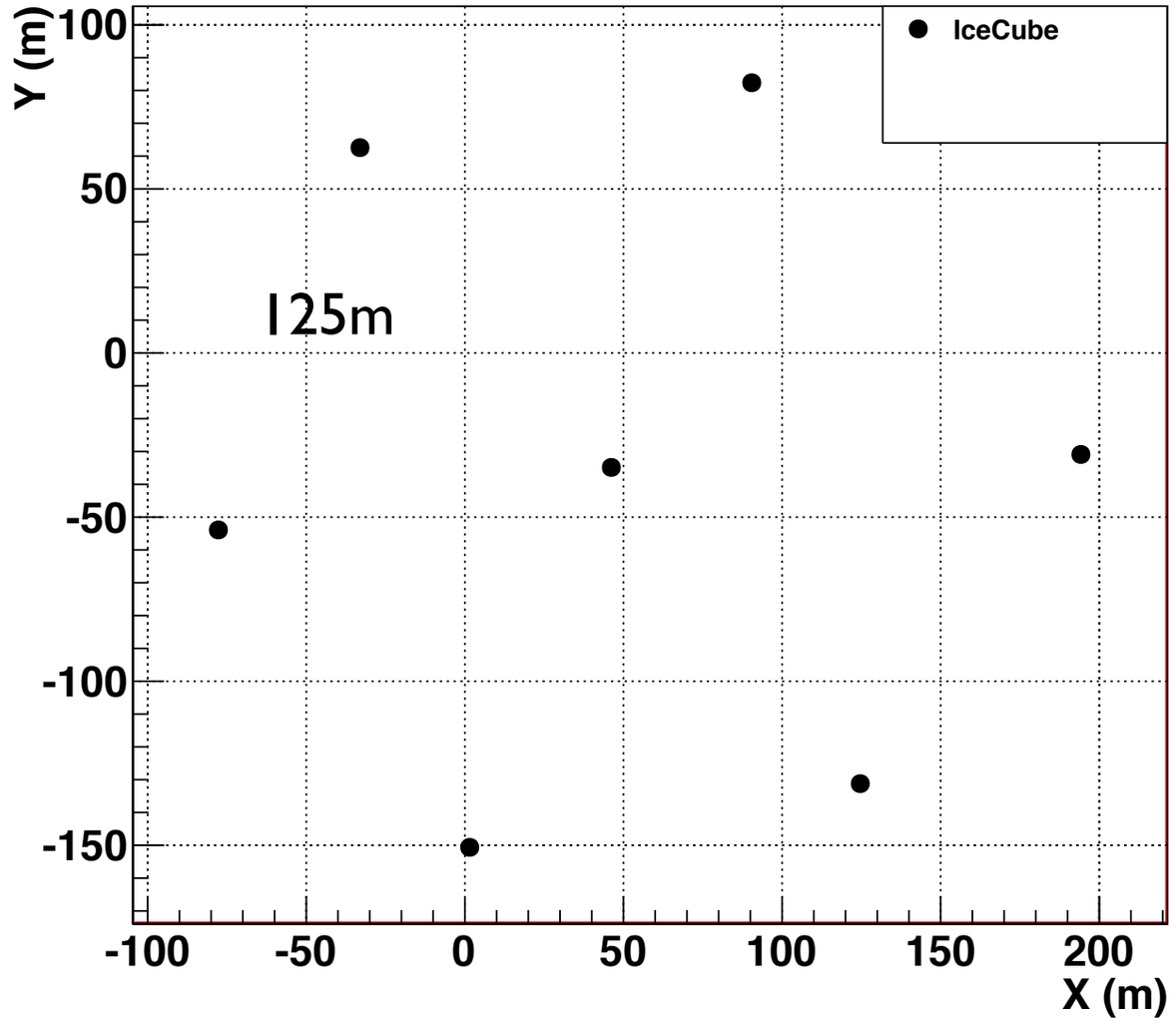
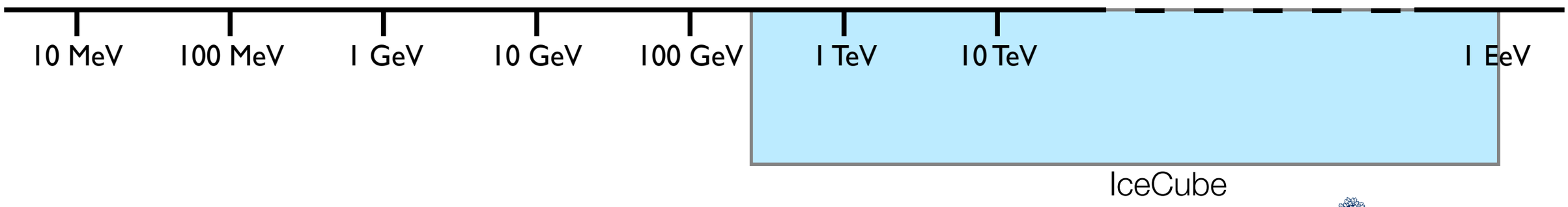
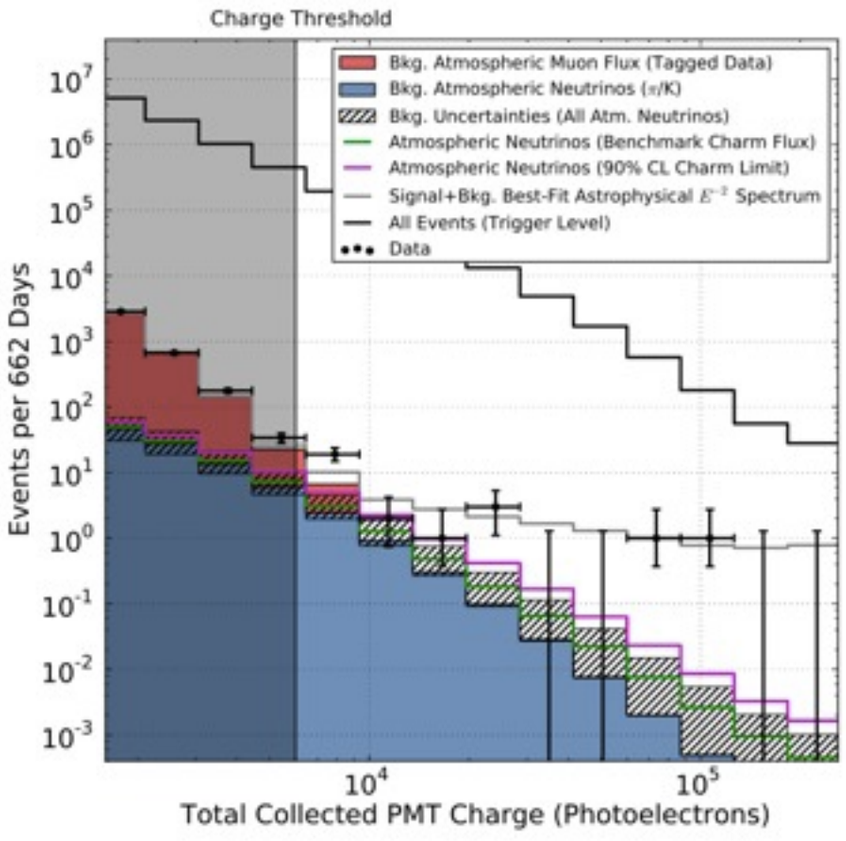
IceCube

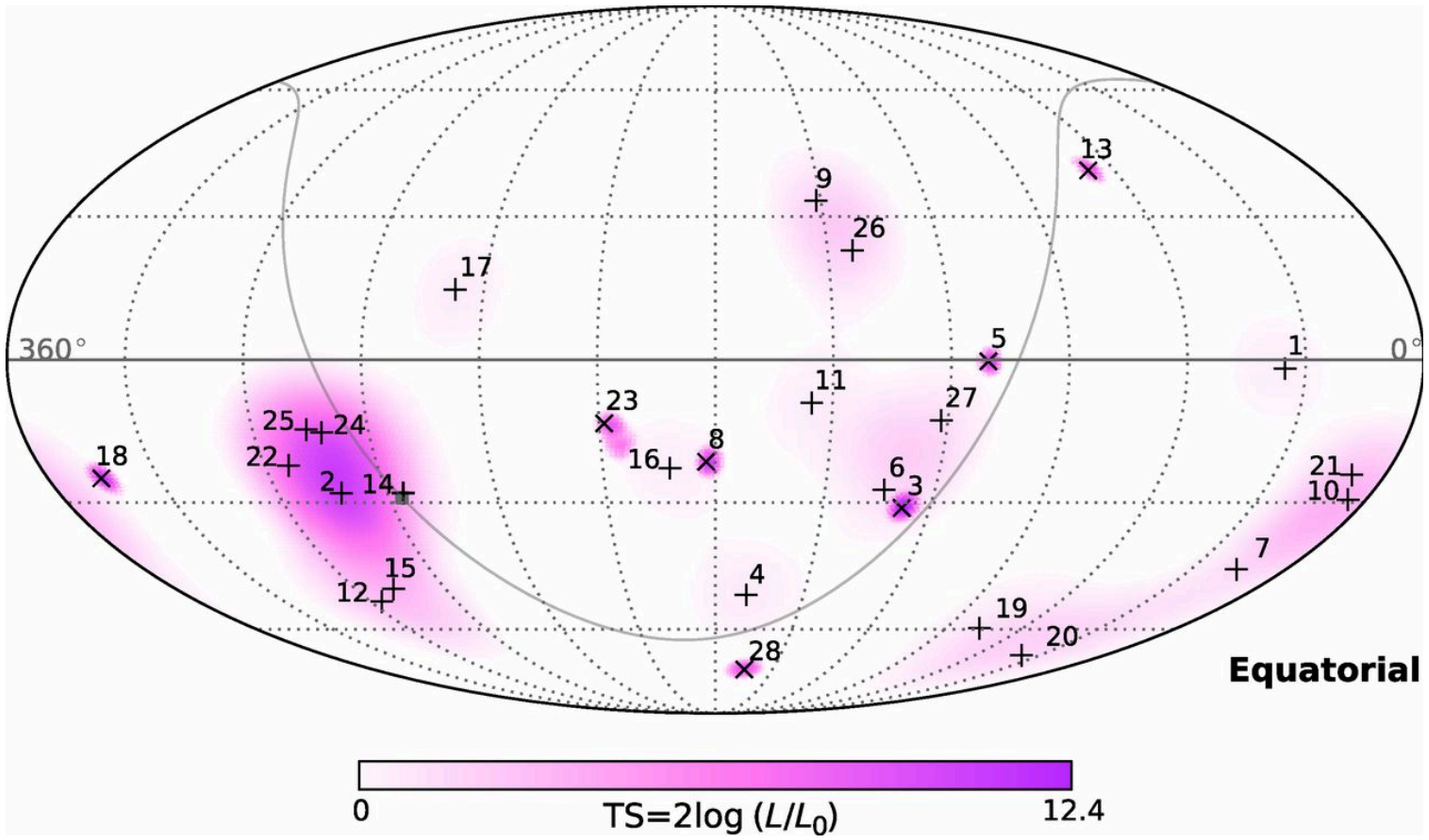
- 78 Strings
  - 125m string spacing
  - 17m DOM spacing

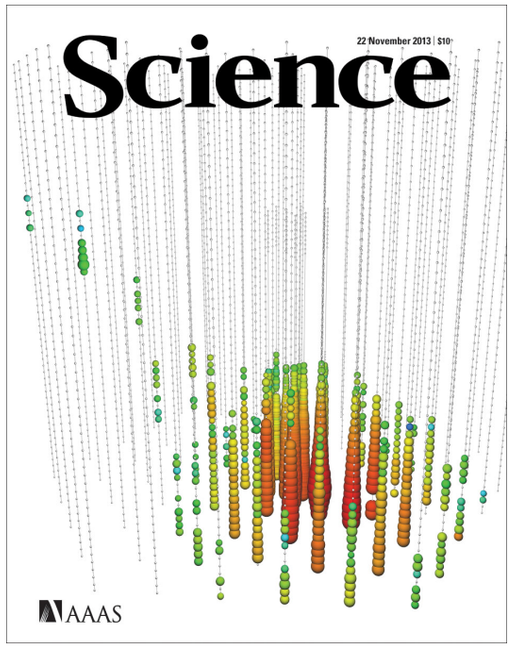




IceCube Results

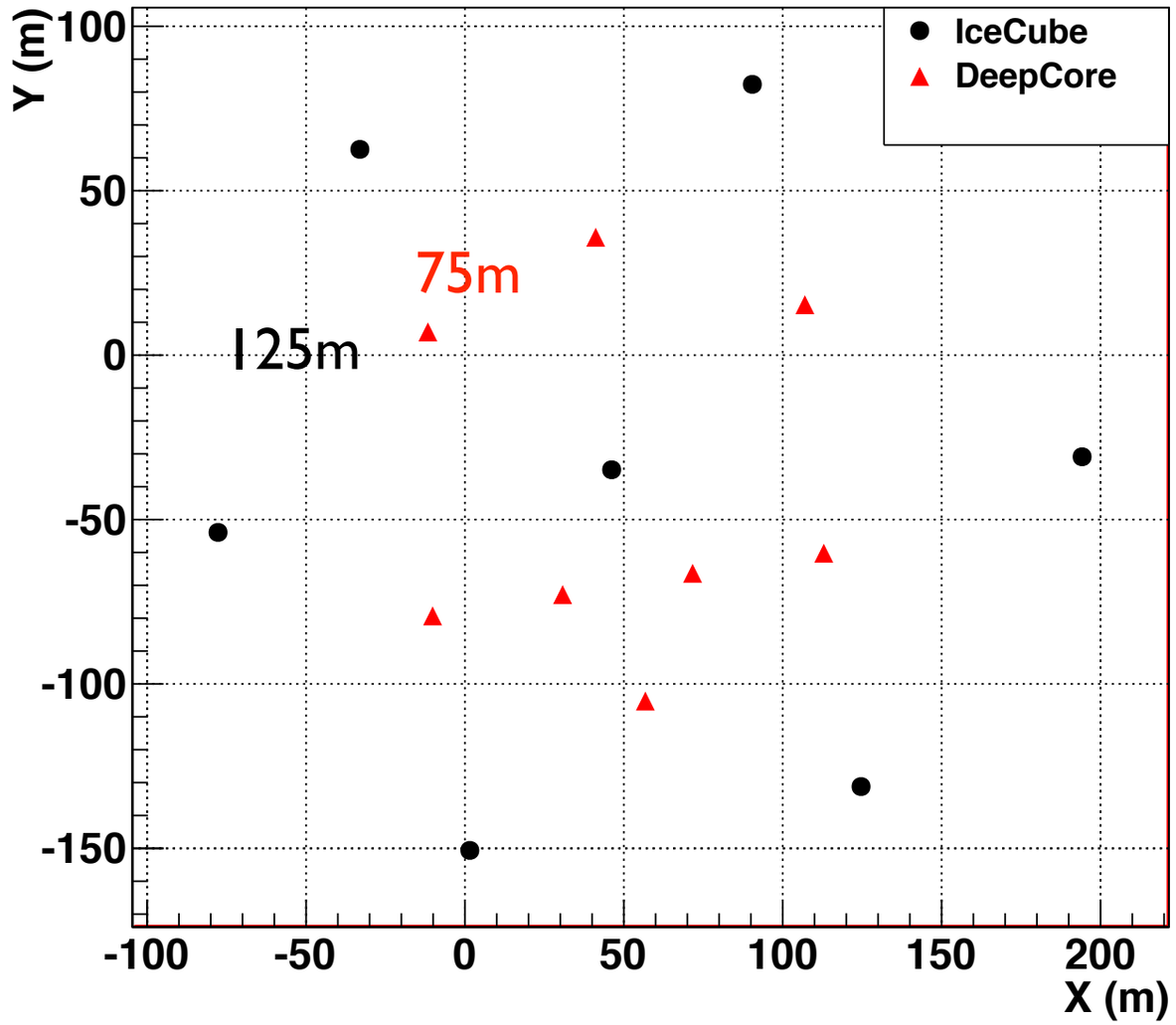


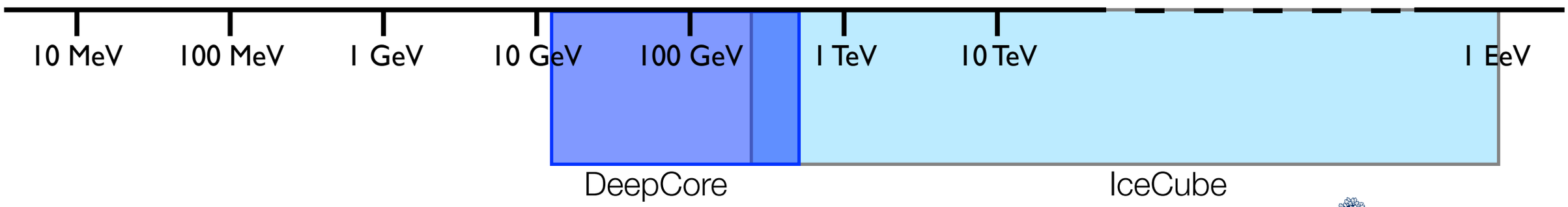




IceCube + DeepCore

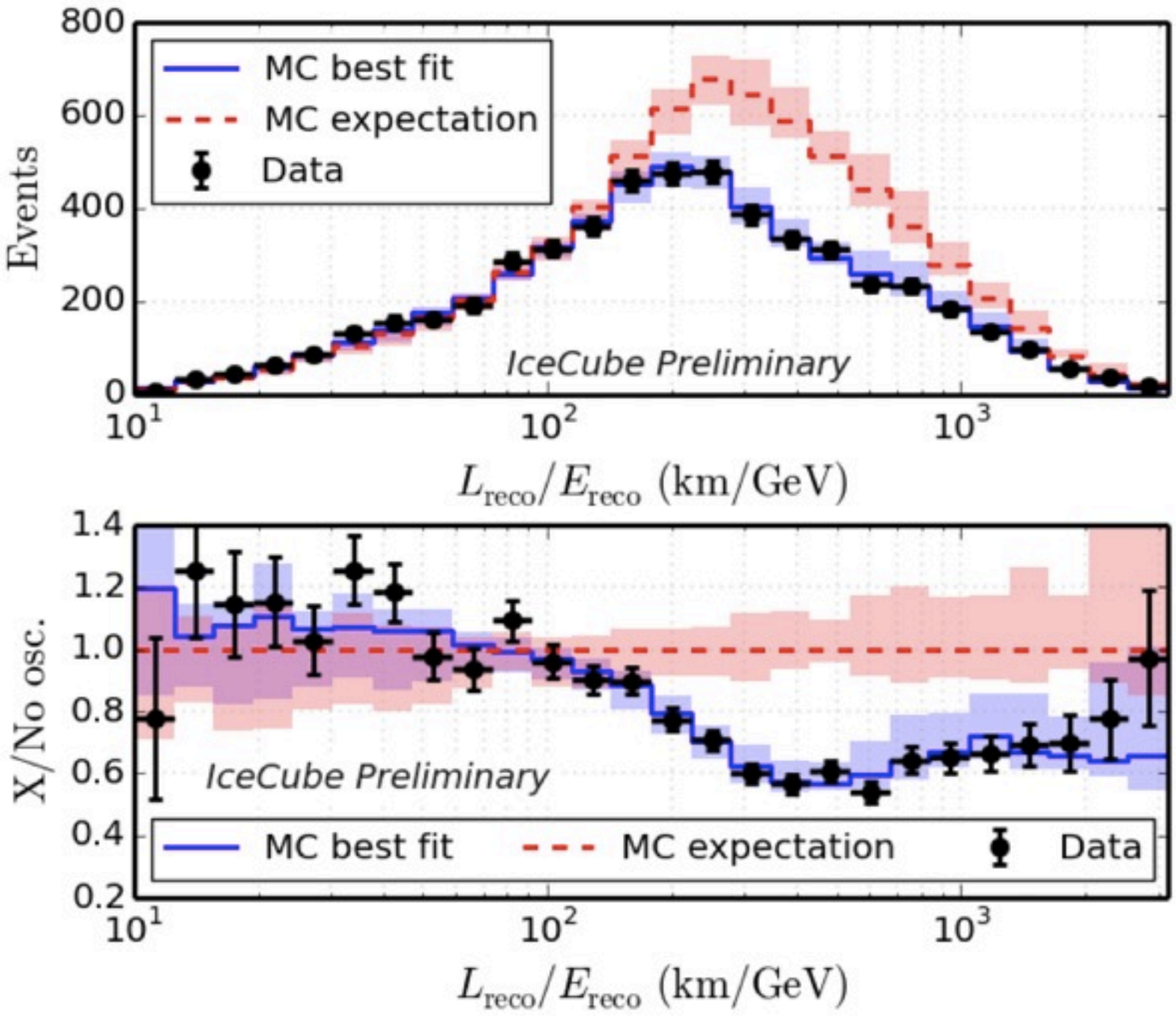
- 78 Strings
  - 125m string spacing
  - 17m DOM spacing
- Add 8 strings
  - 75m string spacing
  - 7m DOM spacing





DeepCore Results

- Approximately 1 year of data analyzed
- High rate in detector provides large event sample
- No-oscillation hypothesis rejected at 5.6σ



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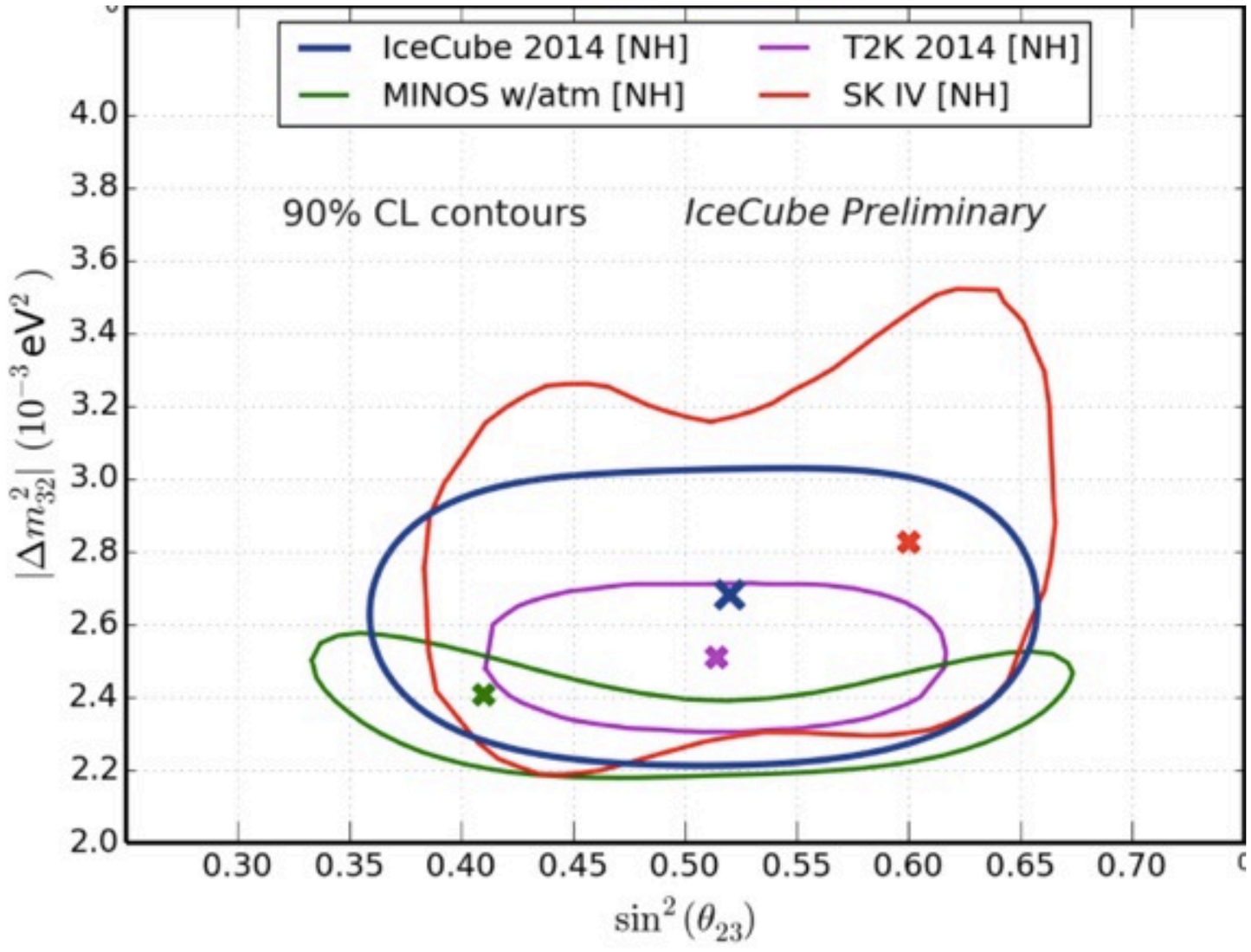
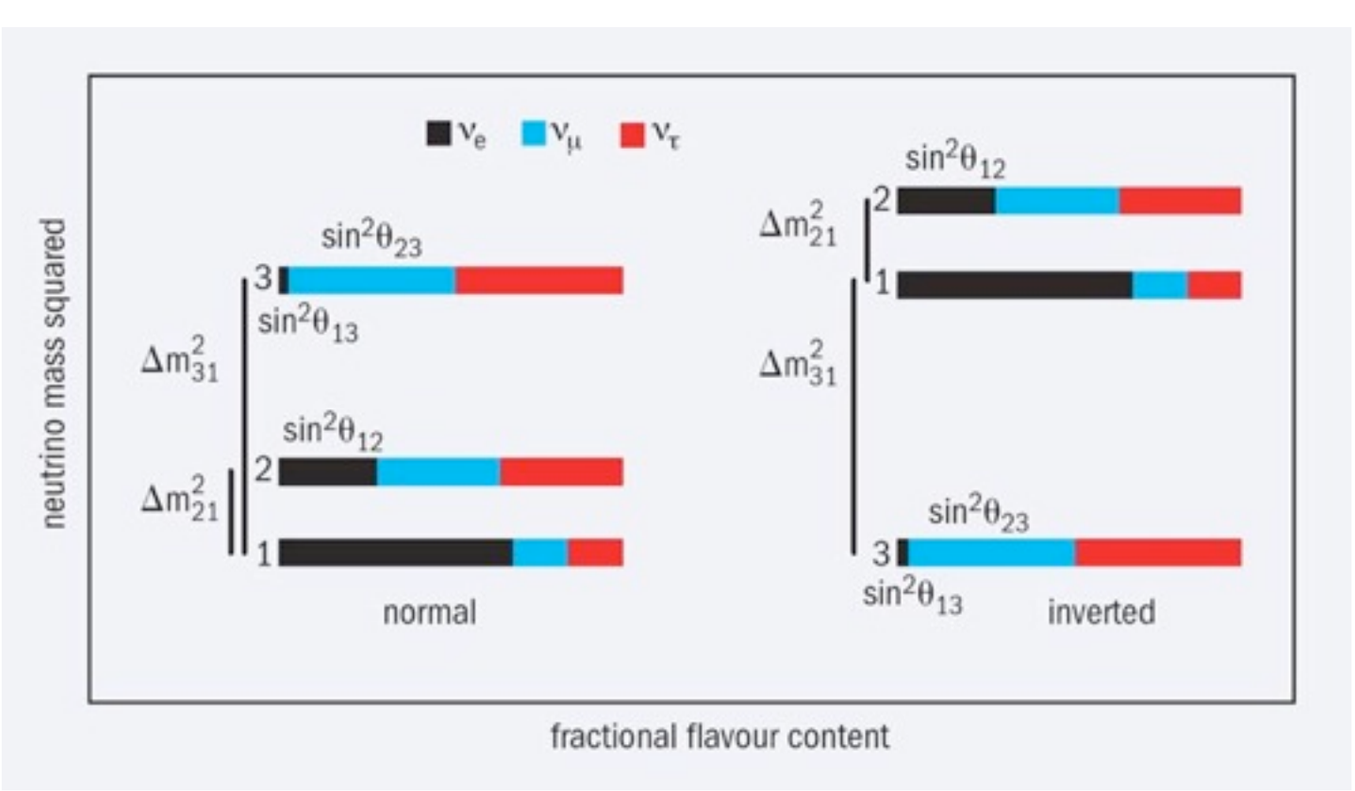


Even Lower Energies

- Deep Core is a success, but we get access to more physics with a lower threshold

- muon neutrino disappearance
- maximal θ_{23} measurement
- lower energy dark matter
- neutrino mass hierarchy



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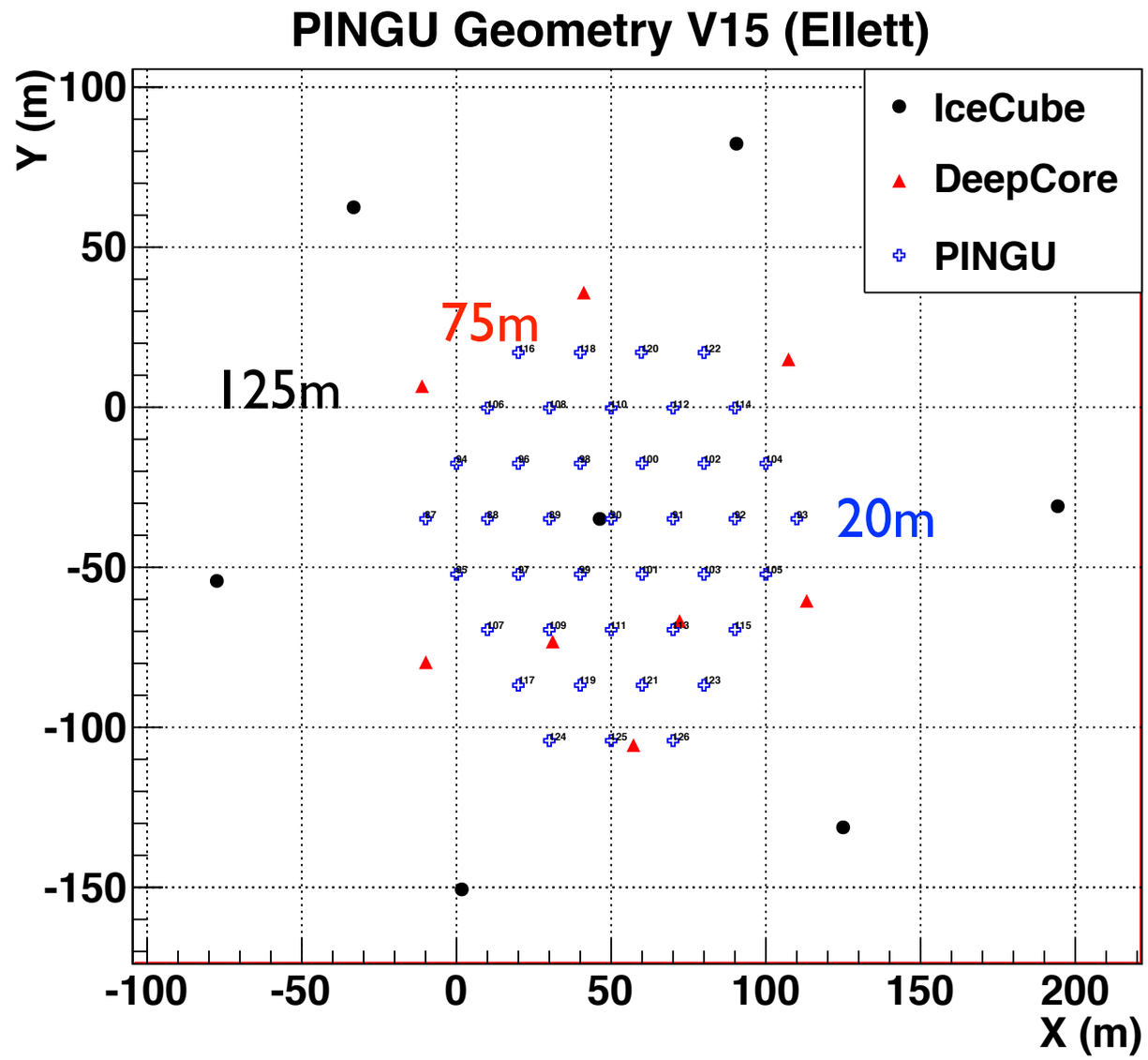
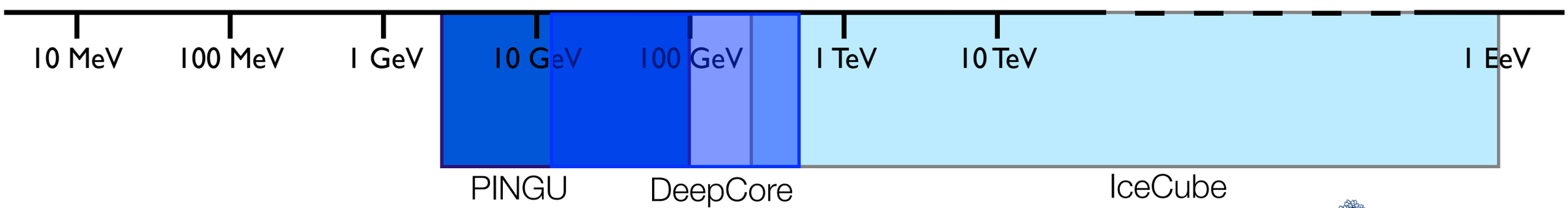
IceCube + DeepCore + PINGU

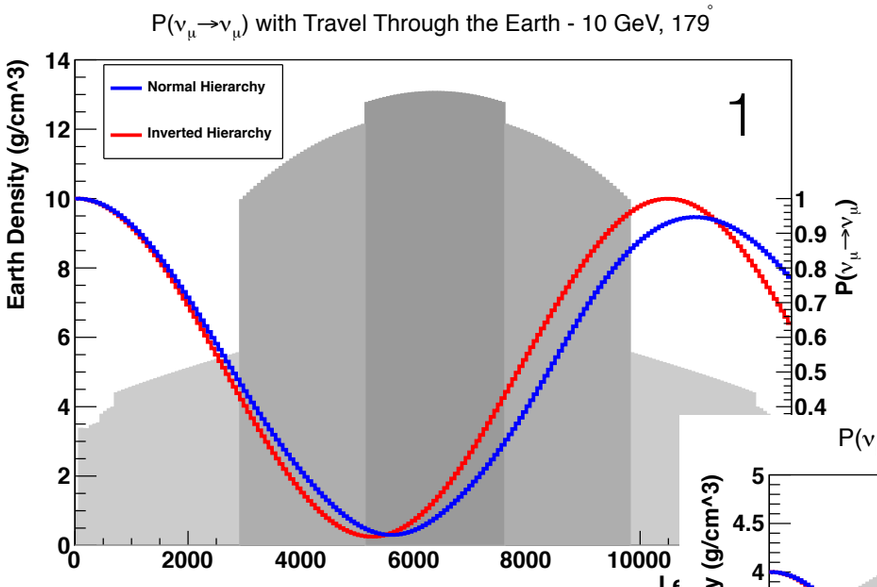
- 78 Strings
  - 125m string spacing
  - 17m DOM spacing
- Add 8 strings
  - 75m string spacing
  - 7m DOM spacing
- Add 40 strings
  - 20m string spacing
  - 5m DOM spacing

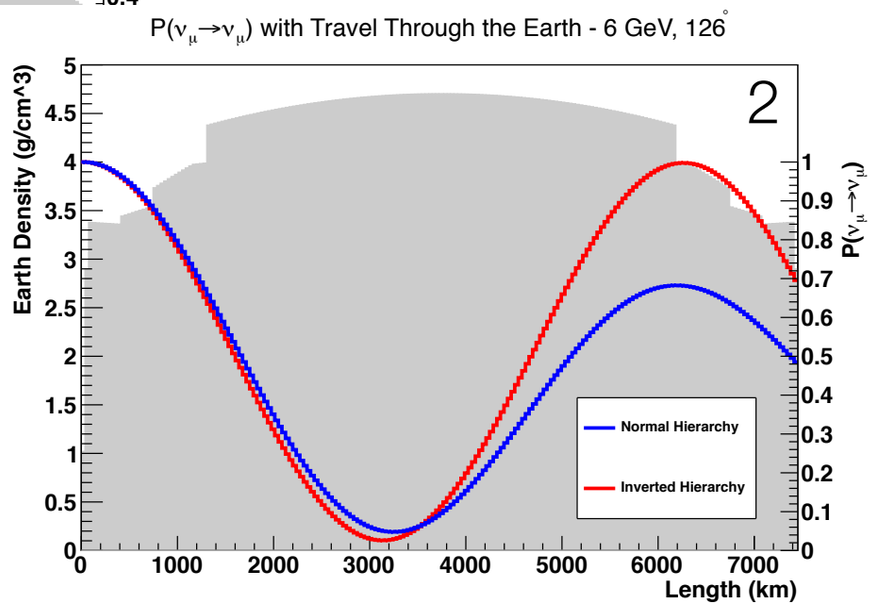


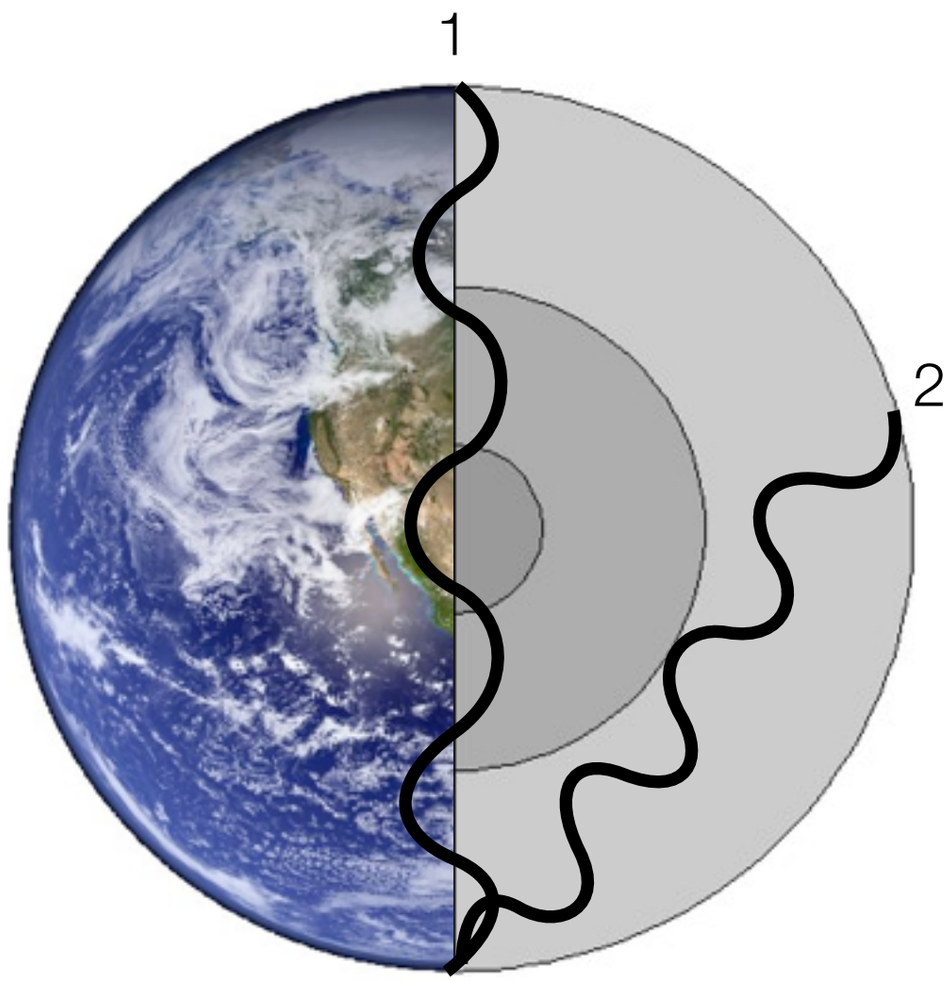


Mass Hierarchy Determination

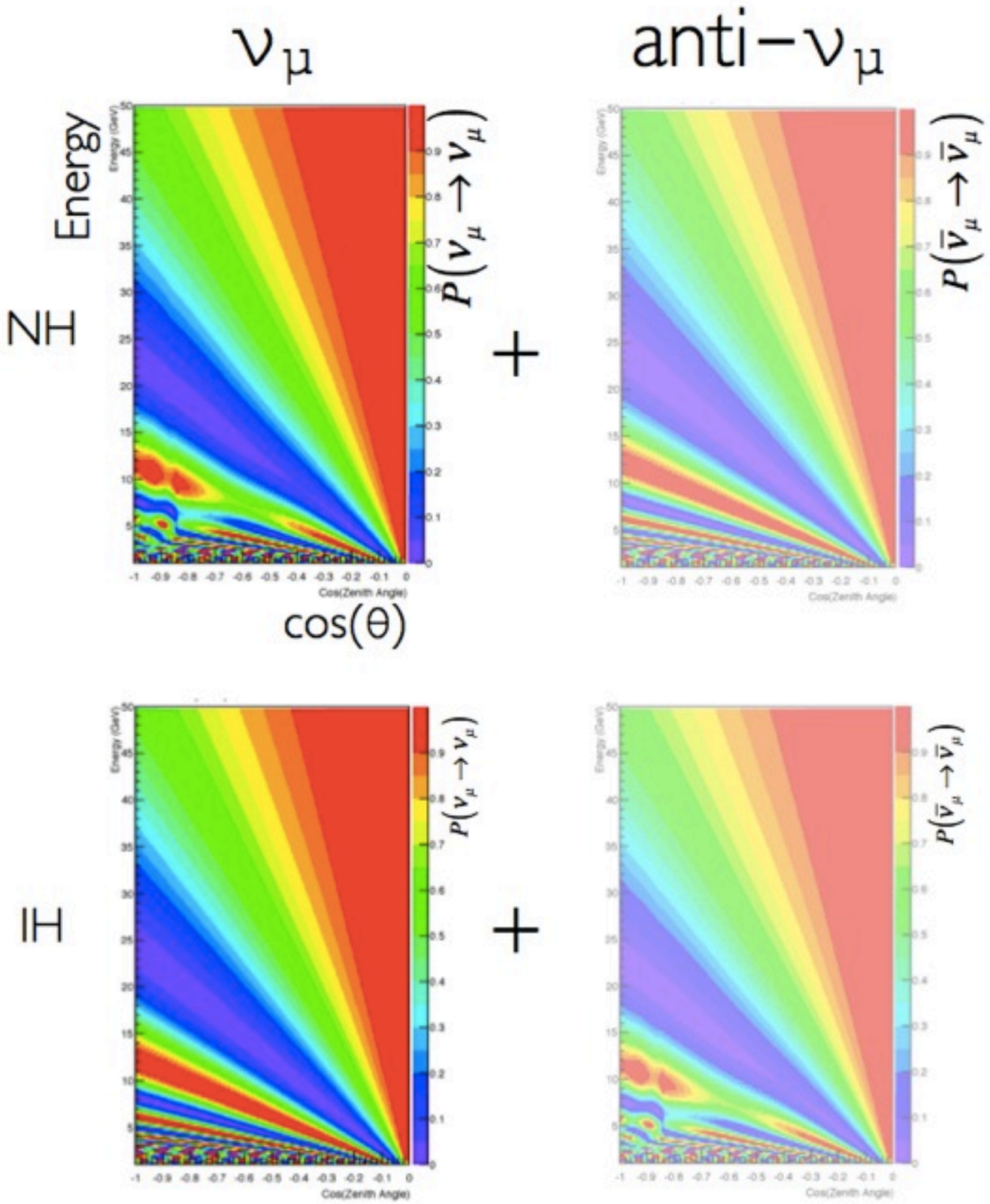
- Experiments use the difference in MSW effect for ν and anti-ν
- Combine with difference in ν and anti-ν cross-section







Neutrino Oscillograms



- The cross-section and flux are different for νμ and $\bar{\nu}$μ
- The patterns are therefore different!

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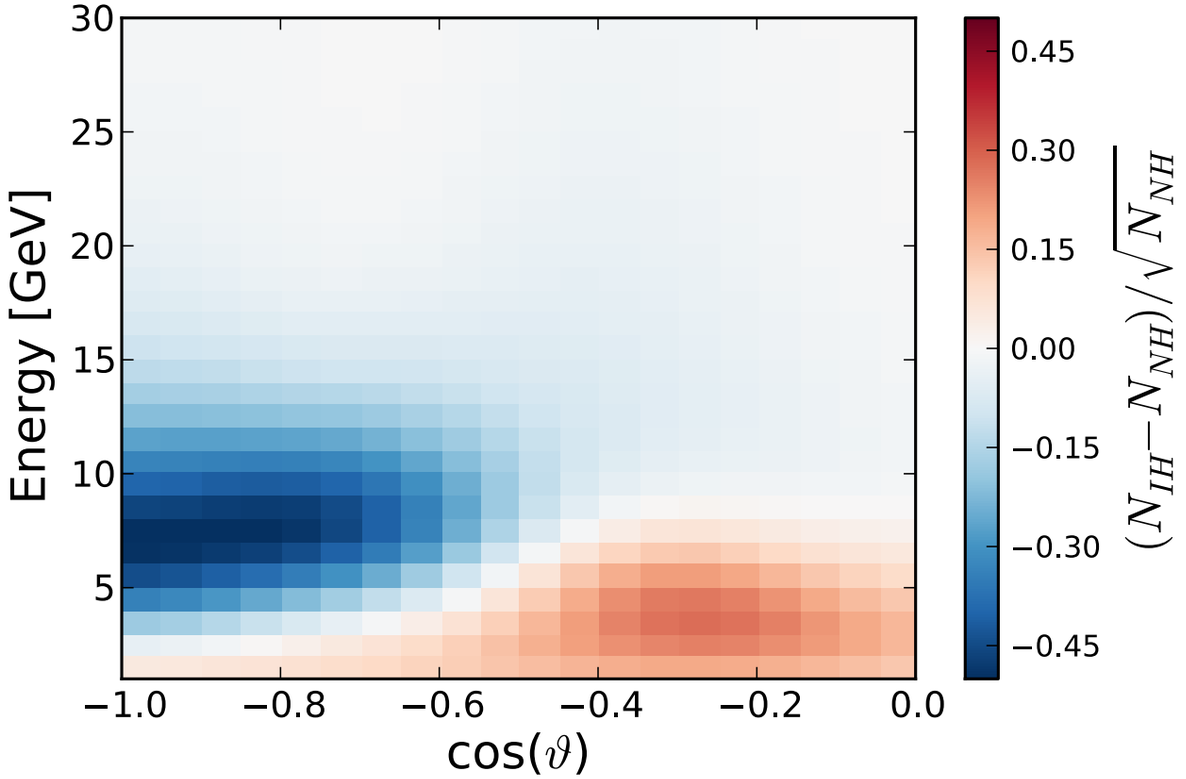
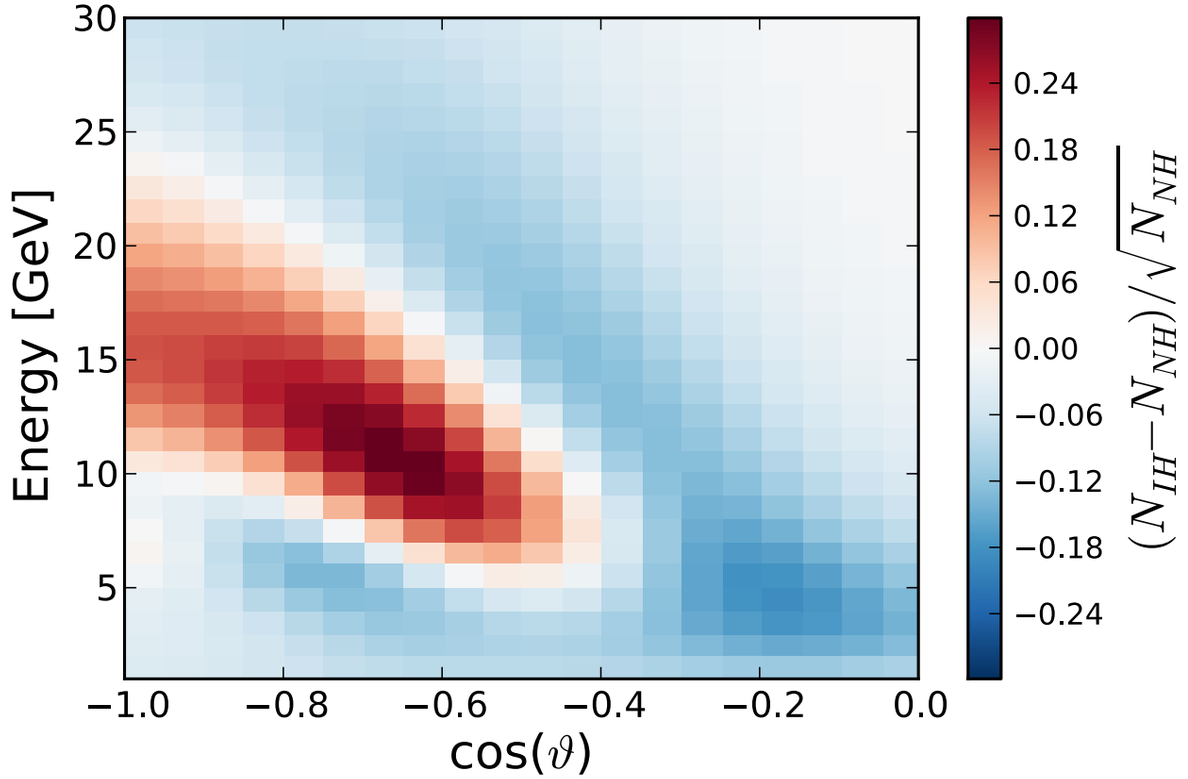
Mass Hierarchy Determination

Cascade-Like Events

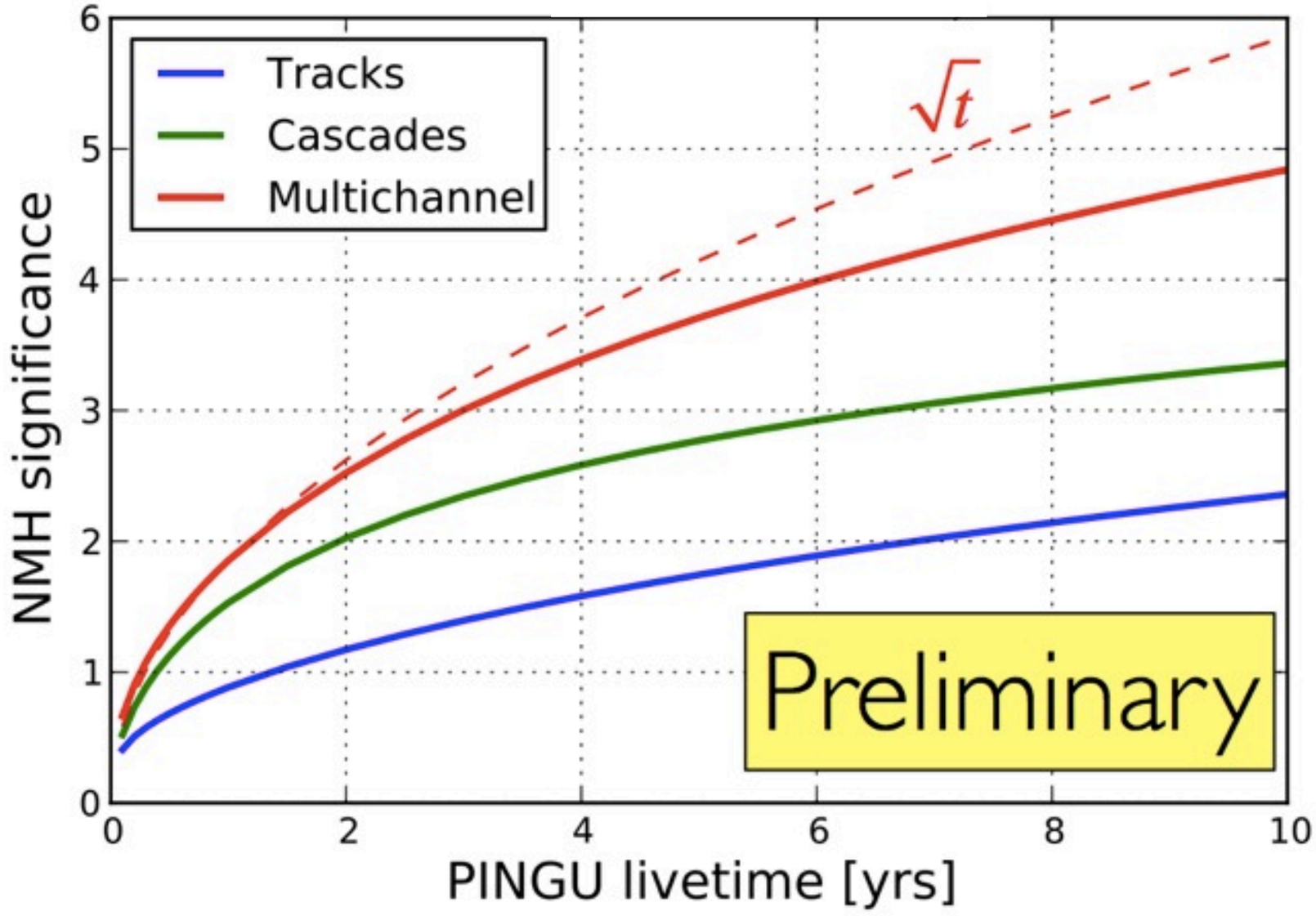


Track-Like Events



- Difference in counts between hierarchies illustrates distinguishability
- Event selection, reconstruction not included here

The Bottom Line



- Most important question is how long does it take to make a measurement?

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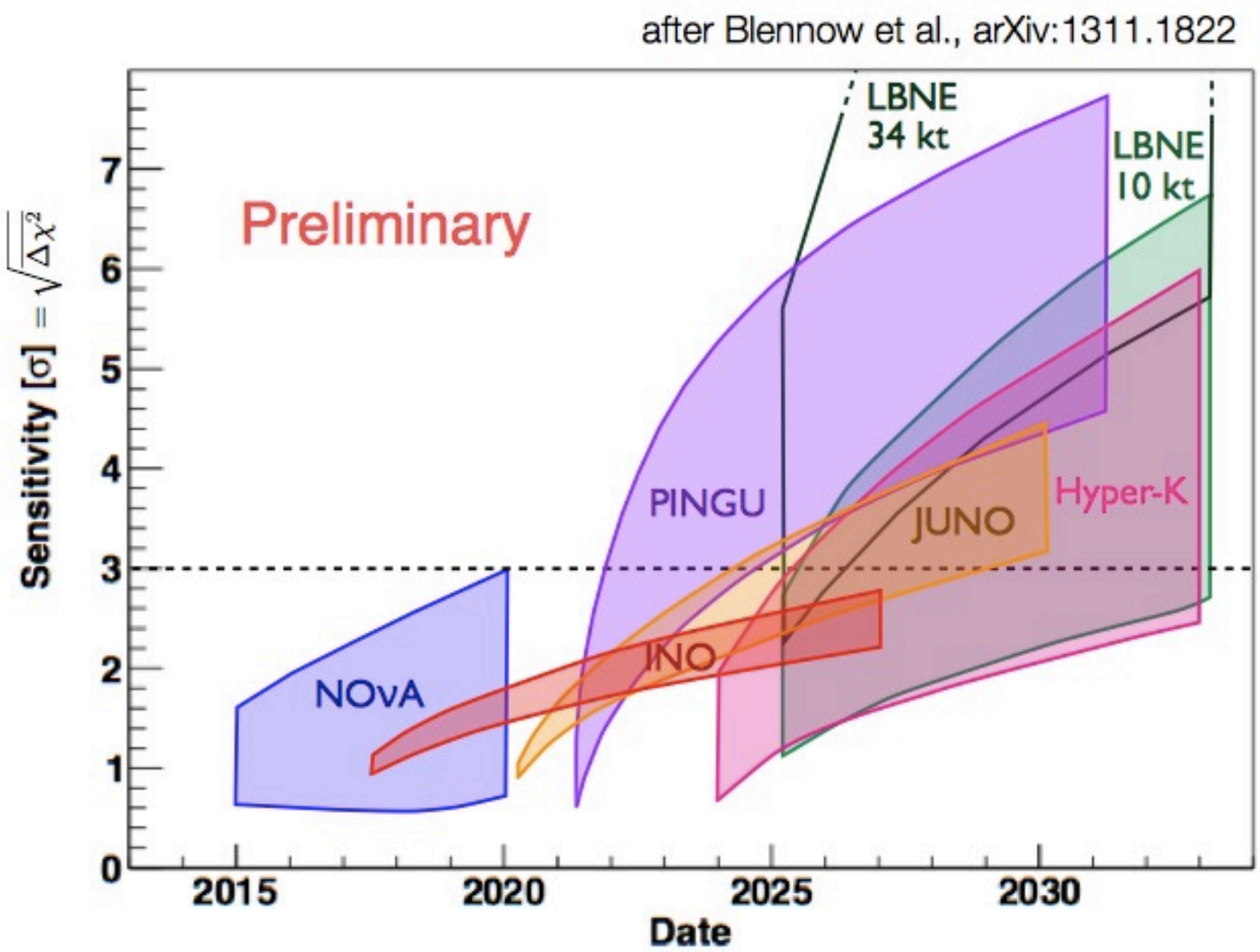
Future of the NMH Measurement

- **MANY** caveats
  - median outcome shown
  - width indicates effect of main uncertainty (δ_{CP}, θ_{23})
  - dates are also bound to change as time goes on



Conclusion

- IceCube and DeepCore have been very successful and have shown that particle physics is possible in ice
- PINGU will provide insight into the nature of the NMH
- Canada has taken a leading role in the development of PINGU, responsible for all simulation while contributing to analysis and reconstruction

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The IceCube–PINGU Collaboration

International Funding Agencies

Fonds de la Recherche Scientifique (FRS–FNRS)
Fonds Wetenschappelijk Onderzoek–Vlaanderen (FWO–Vlaanderen)
Federal Ministry of Education & Research (BMBF)
German Research Foundation (DFG)

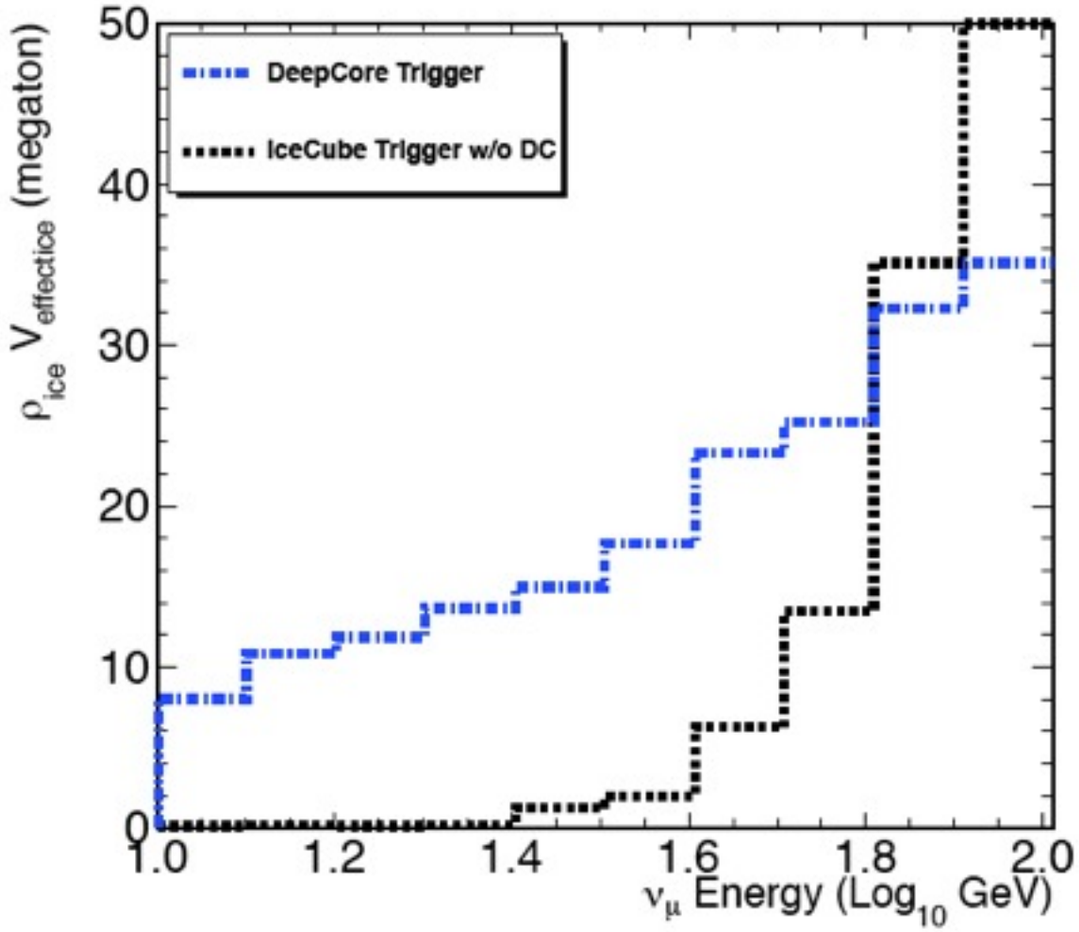
Deutsches Elektronen–Synchrotron (DESY)
Inoue Foundation for Science, Japan
Knut and Alice Wallenberg Foundation
NSF–Office of Polar Programs
NSF–Physics Division

Swedish Polar Research Secretariat
The Swedish Research Council (VR)
University of Wisconsin Alumni Research Foundation (WARF)
US National Science Foundation (NSF)

Backup

IceCube + DeepCore

- Addition of extra strings in closer proximity lowers the detection threshold energy



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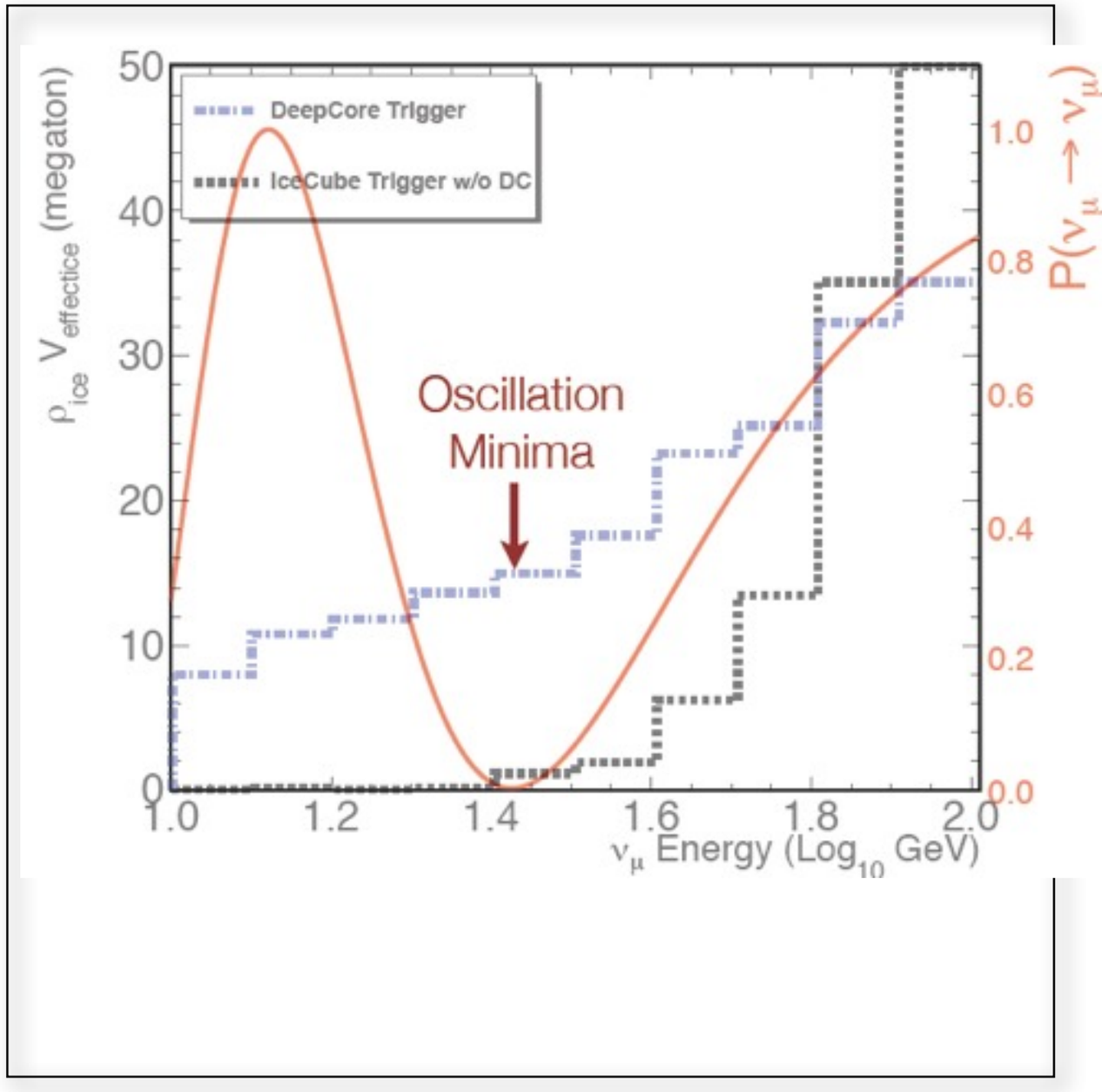
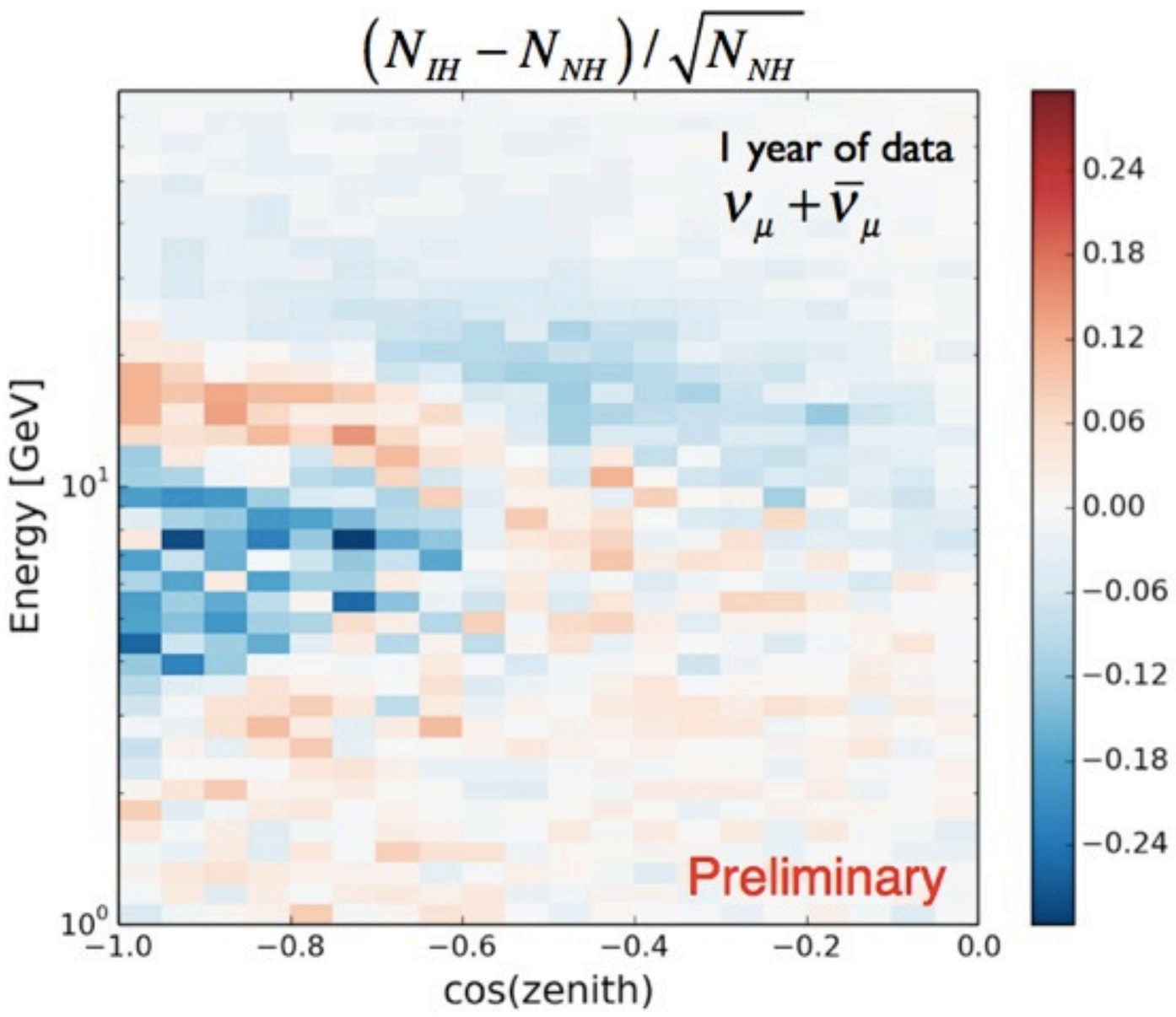
IceCube + DeepCore

- Addition of extra strings in closer proximity lowers the detection threshold energy
- This allows for sensitivity at the energy of an oscillation minimum



Distinguishability



- Add in the proper reconstruction of the events