Sterile Neutrinos Searches with IceCube

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for the IceCube Collaboration

UNIVERSITY OF ALBERTA

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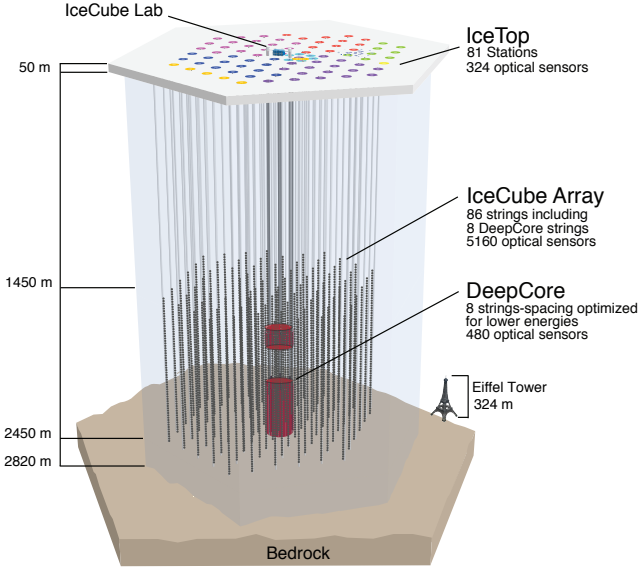
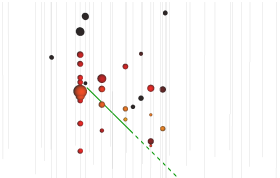
IceCube



- Instrumented 1 Gton of ice
- Optimized for TeV-PeV neutrinos
  - Astrophysical ν discovered!
- DeepCore
  - 10 Mton region with denser instrumentation
  - Pushes thresholds down to ≈ 5 GeV
  - Surrounding detector used as active veto against atmospheric μ

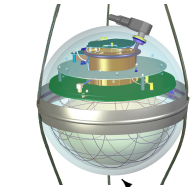
IceCube-DeepCore



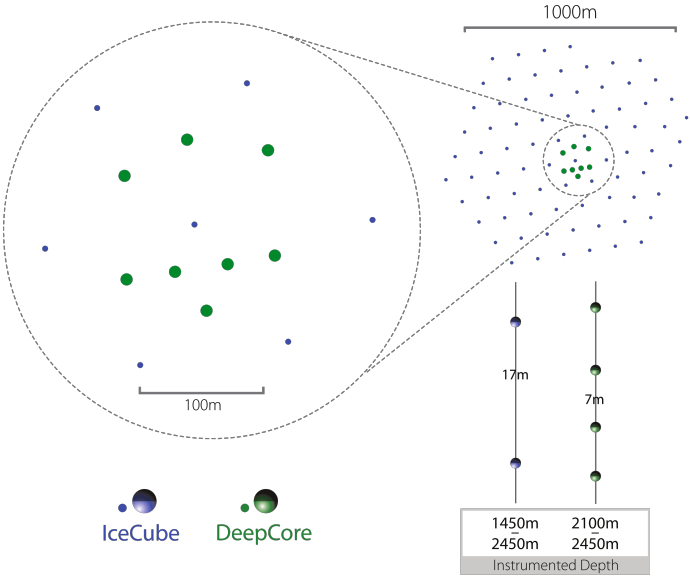
25 GeV ν_μ CC

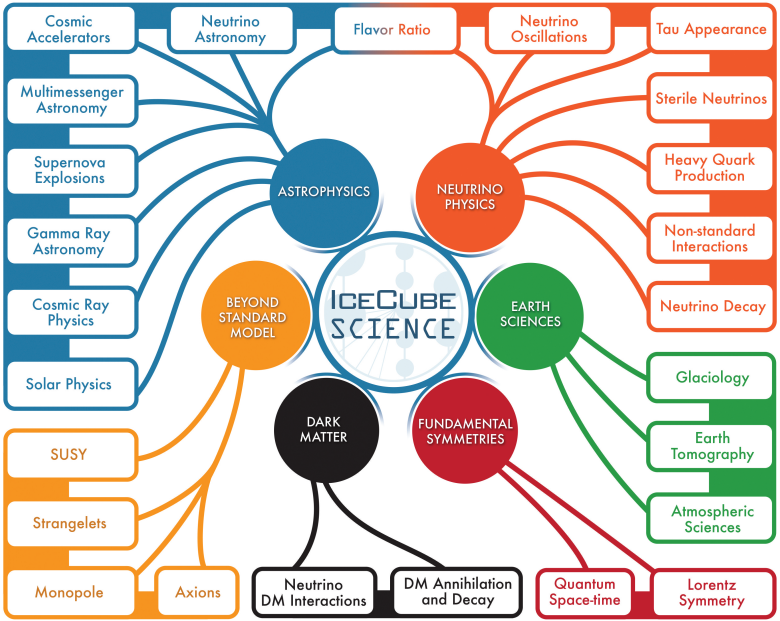
color → hit time
size → hit charge

IceCube DOM

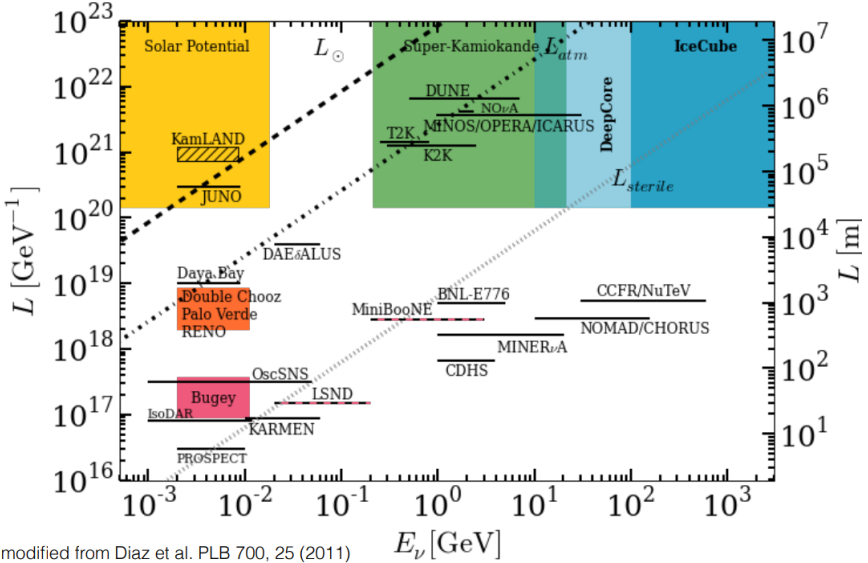


10” PMT




ICECUBE SCIENCE
ASTROPHYSICS
NEUTRINO PHYSICS
BEYOND STANDARD MODEL
EARTH SCIENCES
DARK MATTER
FUNDAMENTAL SYMMETRIES
Cosmic Accelerators
Neutrino Astronomy
Multimessenger Astronomy
Supernova Explosions
Gamma Ray Astronomy
Cosmic Ray Physics
Solar Physics
Flavor Ratio
Neutrino Oscillations
Tau Appearance
Sterile Neutrinos
Heavy Quark Production
Non-standard Interactions
Neutrino Decay
Glaciology
Earth Tomography
Atmospheric Sciences
SUSY
Strangelets
Monopole
Axions
Neutrino DM Interactions
DM Annihilation and Decay
Quantum Space-time
Lorentz Symmetry

IceCube/Short Baseline Connection



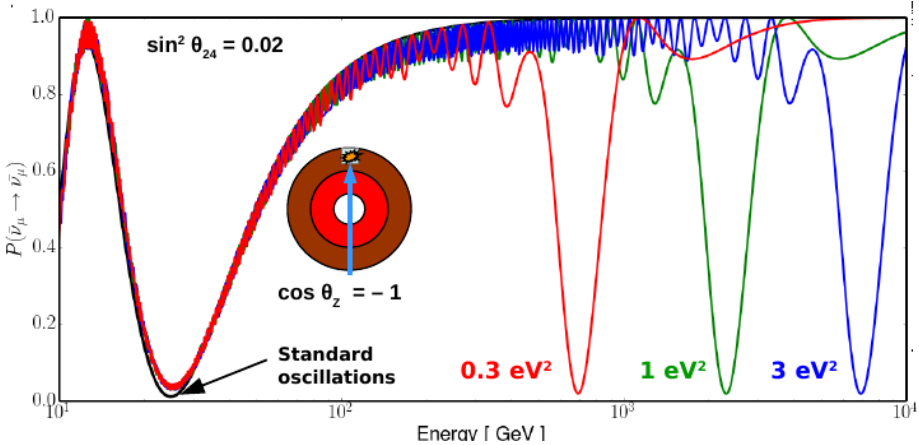
modified from Diaz et al. PLB 700, 25 (2011)

Sterile Neutrinos with IceCube

Resonance Effects

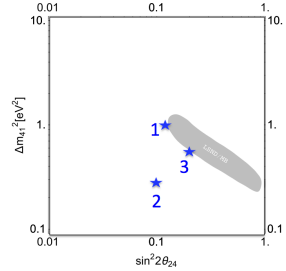
- In the Earth, for sterile neutrinos of $\Delta m^2 = \mathcal{O}(1eV^2)$ there is a matter-induced (parametric) resonant effect when:

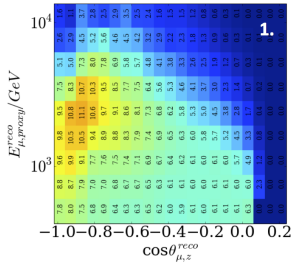
$$E_\nu^{res} = \frac{\Delta m^2 \cos 2\theta}{2\sqrt{2} G_F N} \sim \mathcal{O}(TeV)$$

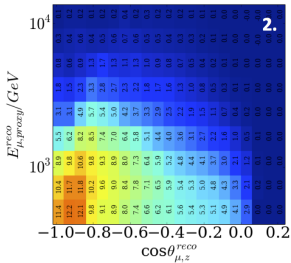


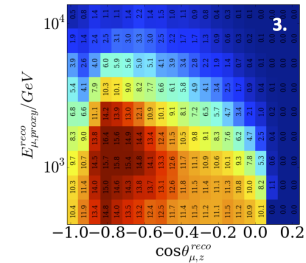
IceCube Sterile Neutrino: Signal

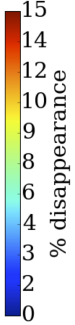
- Uses through going muon sample
  - only up-going ν_μ
  - very pure ν_μ sample
- Assumes:
  - $\Delta m^2_{41} > 0$ (conservative)
  - $|U_{e4}|^2 = 0$
  - $|U_{\tau 4}|^2 = 0$ (conservative)
- Measures $|U_{\mu 4}|^2 = \sin^2\theta_{24}$ as a function of Δm^2_{41}





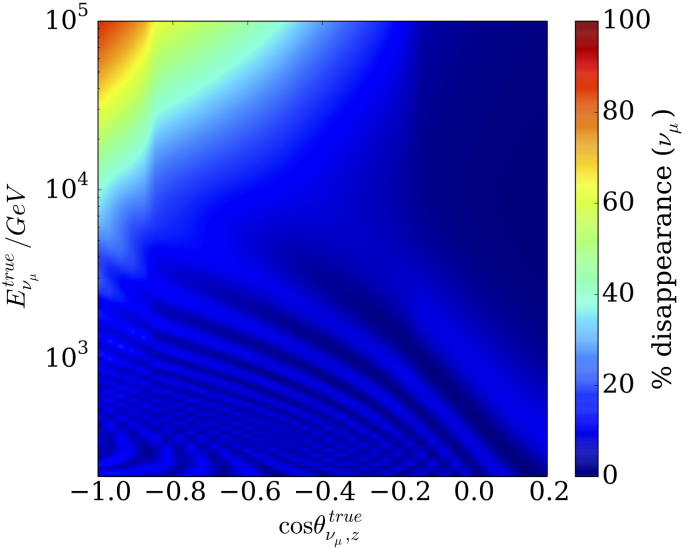




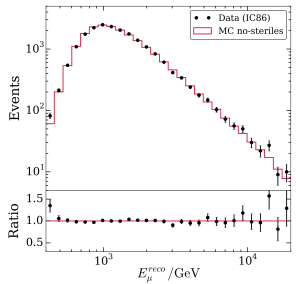


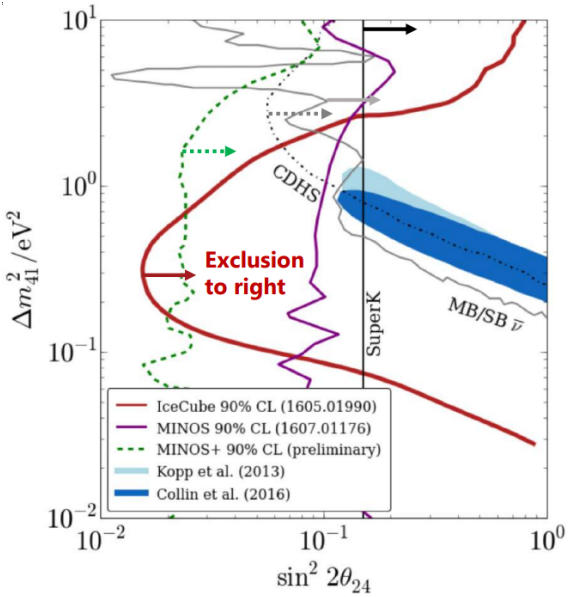
IceCube Sterile Neutrino: No Signal

- Uses through going muon sample
  - only up-going ν_μ
  - very pure ν_μ sample
- Assumes:
  - $\Delta m^2_{41} > 0$ (conservative)
  - $|U_{e4}|^2 = 0$
  - $|U_{\tau 4}|^2 = 0$ (conservative)
- Measures $|U_{\mu 4}|^2 = \sin^2 \theta_{24}$ as a function of Δm^2_{41}

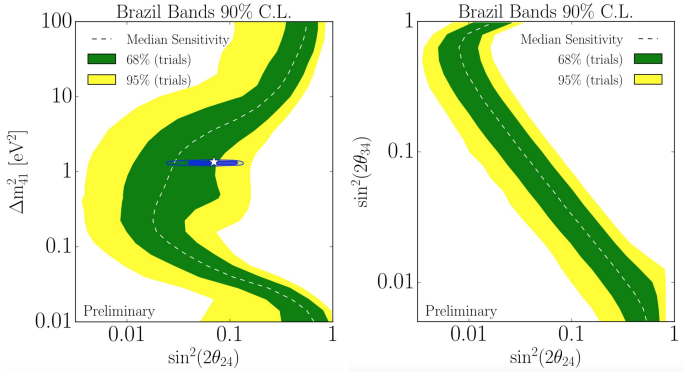


IceCube Sterile Results





Future Prospects for IceCube Steriles

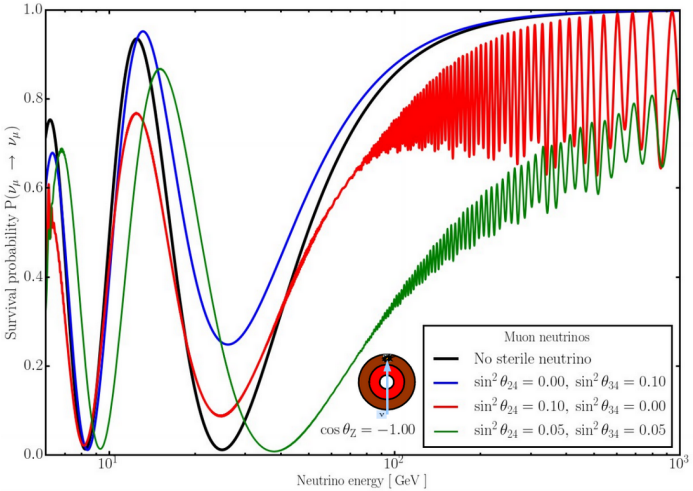


- New results currently in progress
  - Based on 7 years of data instead of just 1
  - Better understanding and handling of many systematics
    - ★ New treatment of holeice, bulkice, and flux
  - Will include limits on both θ_{24} and θ_{34}
- Will completely cover current global fit results!

Sterile Neutrinos with DeepCore

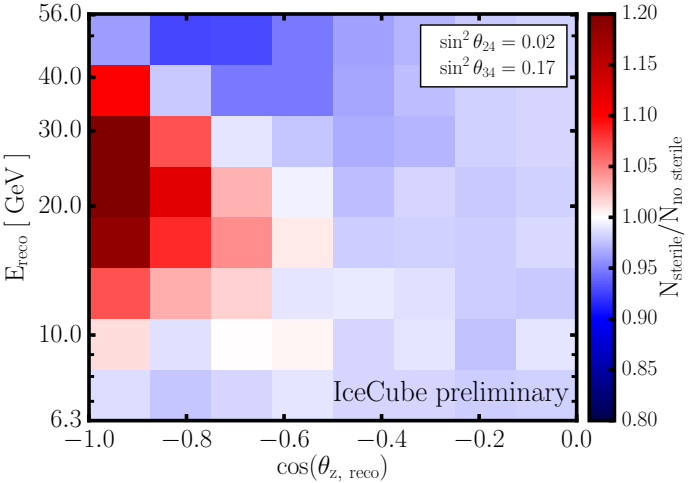
Sterile ν Search with DeepCore

- Effects of sterile neutrinos below 100 GeV
  - Modifies standard neutrino oscillations
  - Effect is proportional to amount of matter along neutrino path
- ν_μ disappearance minimum:
  - Change of depth
  - Shifts in energy
  - Independent of sterile neutrino mass (for $\Delta m^2_{14} > 0.3 eV^2$)



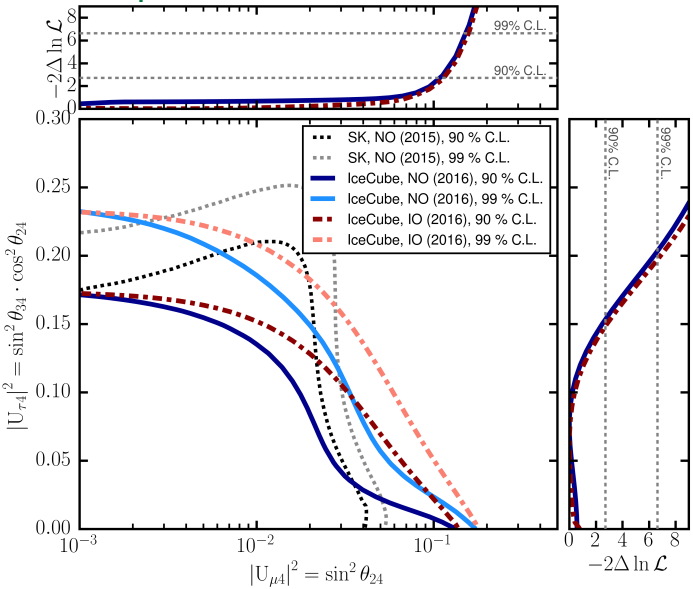
Sterile ν Search with DeepCore

- Uses Low Energy oscillation event selection
  - Total of 3 years worth of data
  - Simplified reconstruction compared to other standard LE oscillation results
- Sesnitive to both θ_{24} and θ_{34}

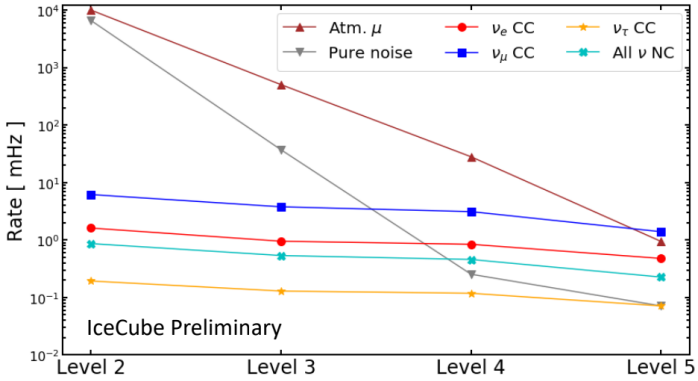


Results of Sterile ν Search with DeepCore

- Results based off three years of data
- Uses different event selection and reconstruction than "standard oscillation" results
- Probes $U_{\mu 4}$ and $U_{\tau 4}$ mixing to better than 10% for most of $0.1eV^2 < \Delta m^2_{41} < 10eV^2$ range



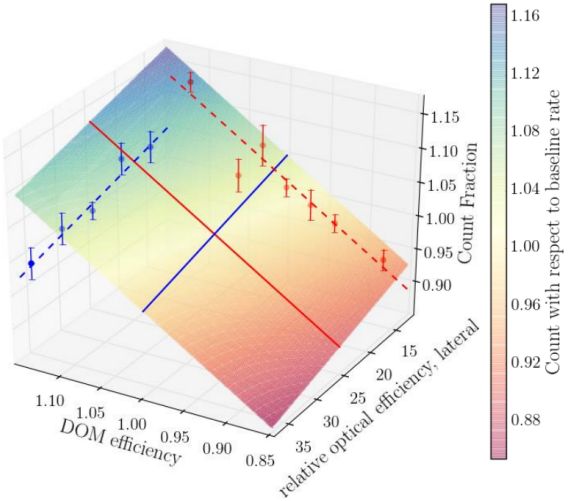
Future Prospect for DeepCore Steriles: Unified DeepCore Event Selection



- Improved background rejection:
  - Use new multivariate technique merges the most powerful discriminators from previous analyses
- Improved simulation with larger energy range and generation volumes
- Expect to go from 50k to 500k final level neutrino events!

Future Prospect for DeepCore Steriles: Analysis Tools and Techniques

- Parameterize detector systematics in a multidimensional space instead of 1D slices in E and cos(θ_{zenith})
- Direct modeling of neutrino flux and uncertainties using MCEq
- More flexibility in simulation to explore sub-leading detector effects.
- New faster reconstructions with similar precision.



Conclusions

- IceCube/DeepCore can look for sterile neutrinos using two different methods.
- First IceCube sterile neutrino measurement has been made.
  - Results consistent with no sterile neutrinos
  - Only used 1 years worth of data.
  - Updated results with 7 years of data underway!
- First DeepCore sterile results analysis has also been performed
  - Probes $U_{\mu 4}$ and $U_{\tau 4}$ directly to a precision better than 10%
  - New analysis using an order of magnitude more events coming out soon!