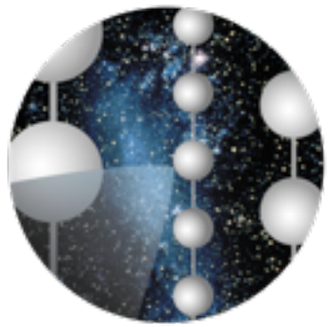
Particle Physics in Ice with IceCube DeepCore

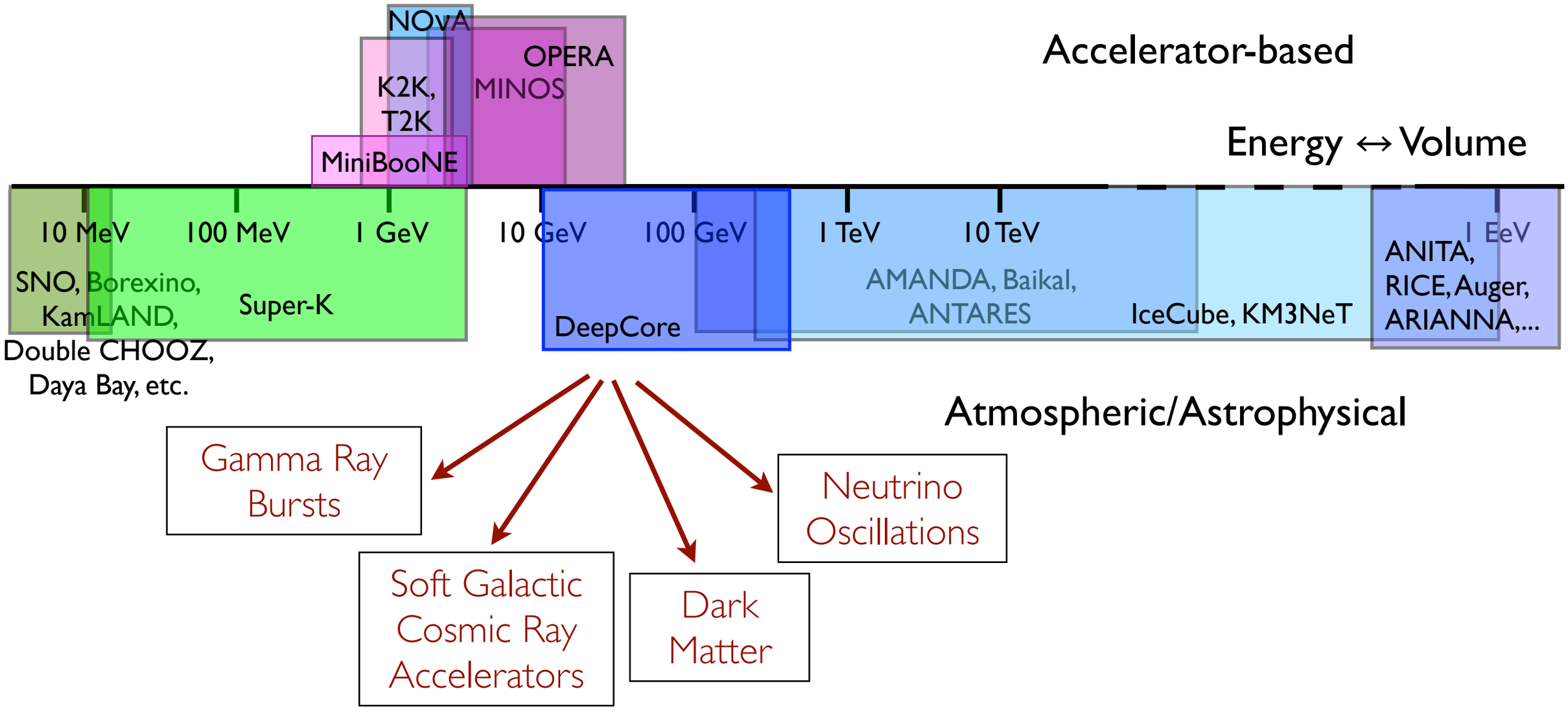
PENNSTATE

Tyce DeYoung
Department of Physics
Pennsylvania State University
for the IceCube Collaboration



RICAP ’11
Rome, Italy
May 25, 2011

The Neutrino Detector Spectrum

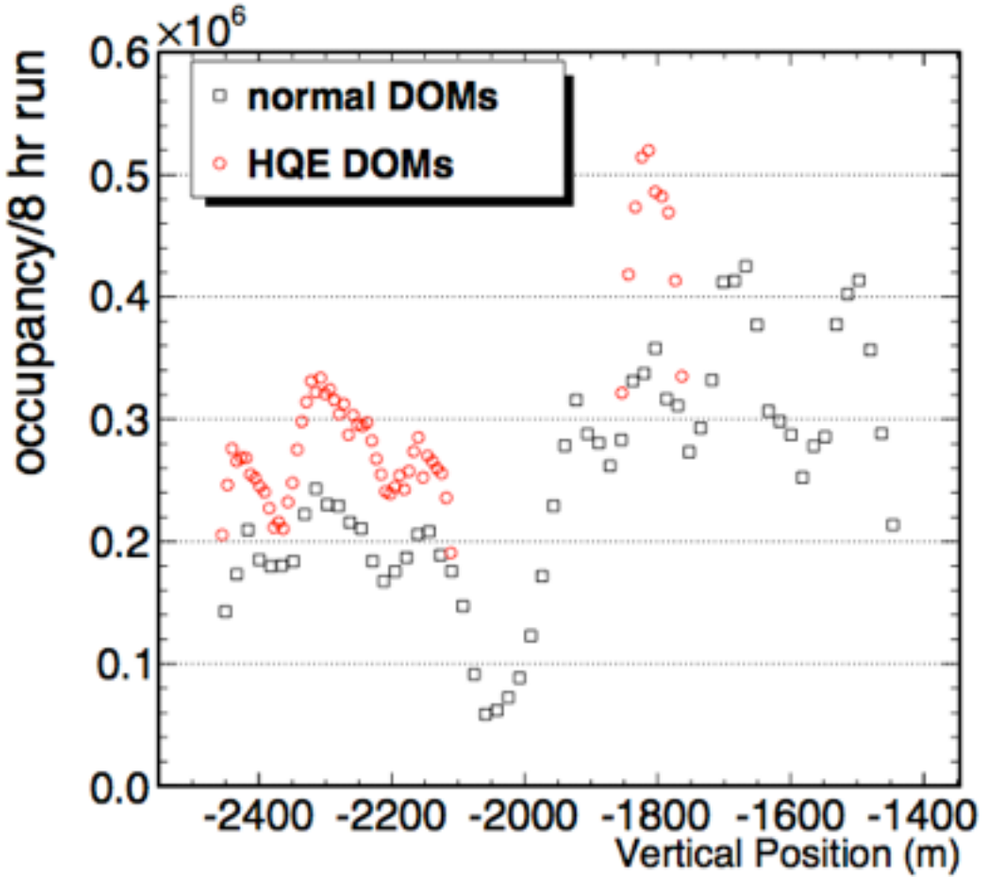


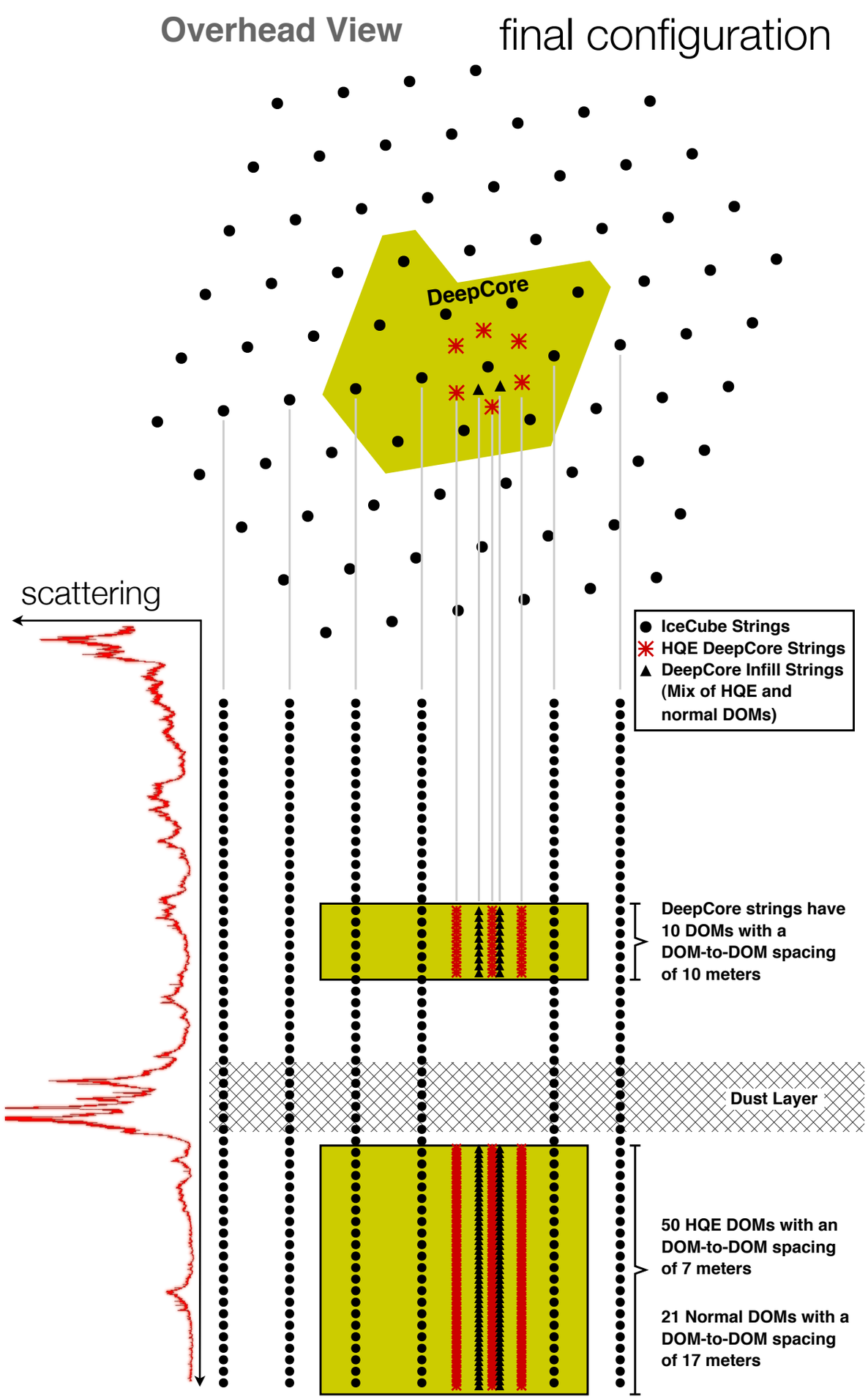
IceCube DeepCore

- IceCube collaboration decided to augment “low” energy response with a densely instrumented infill array: DeepCore
  - Significant improvement in capabilities from ~10 GeV to ~100 GeV (ν_μ)
- Primary scientific rationale is the indirect search for dark matter
- Particle physics using atmospheric neutrinos
  - Neutrino oscillations, including tau neutrino appearance
- Neutrino sources in Southern Hemisphere
  - Galactic cosmic ray accelerators, dark matter in the Galactic center
- Neutrino astronomy at low energies (e.g. GRBs)

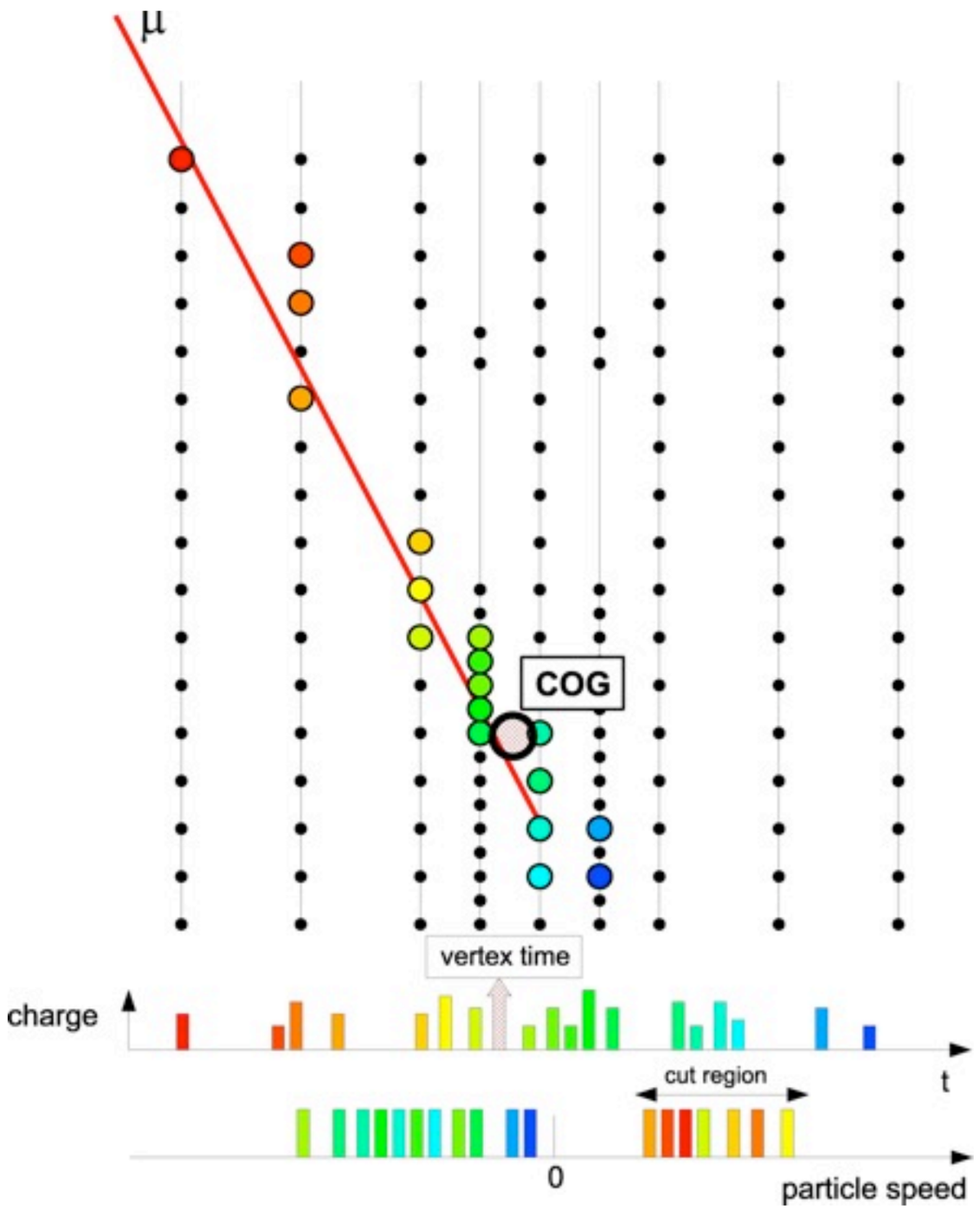
IceCube DeepCore

- DeepCore extends the reach of IceCube to lower energies
  - Denser module spacing
  - Hamamatsu super-bialkali PMTs
  - Deployed in the clearest ice

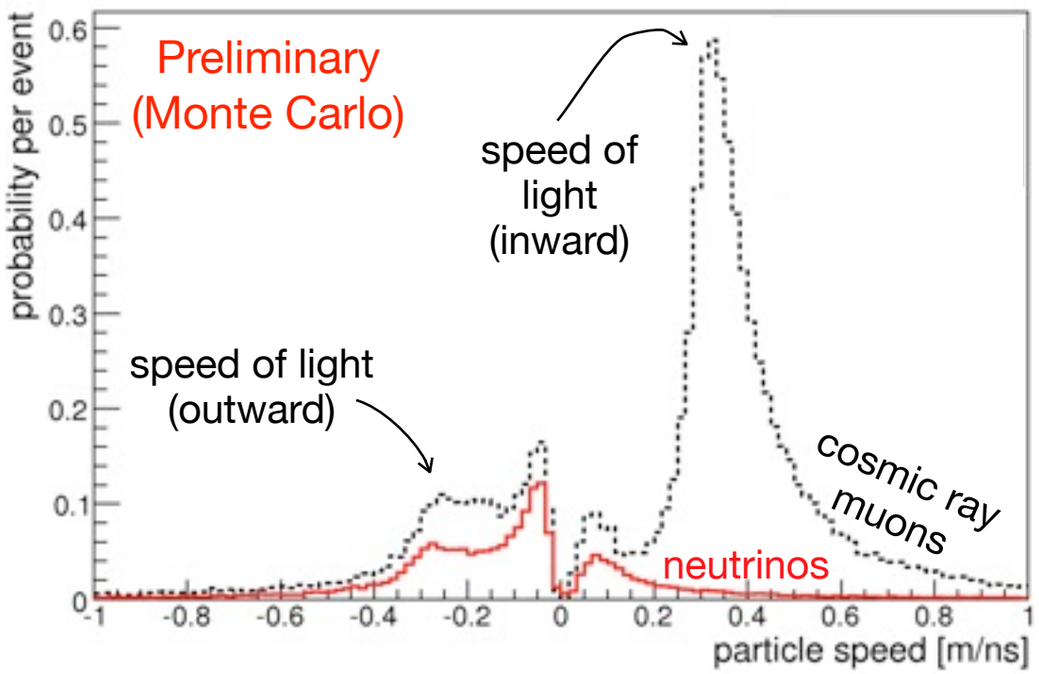




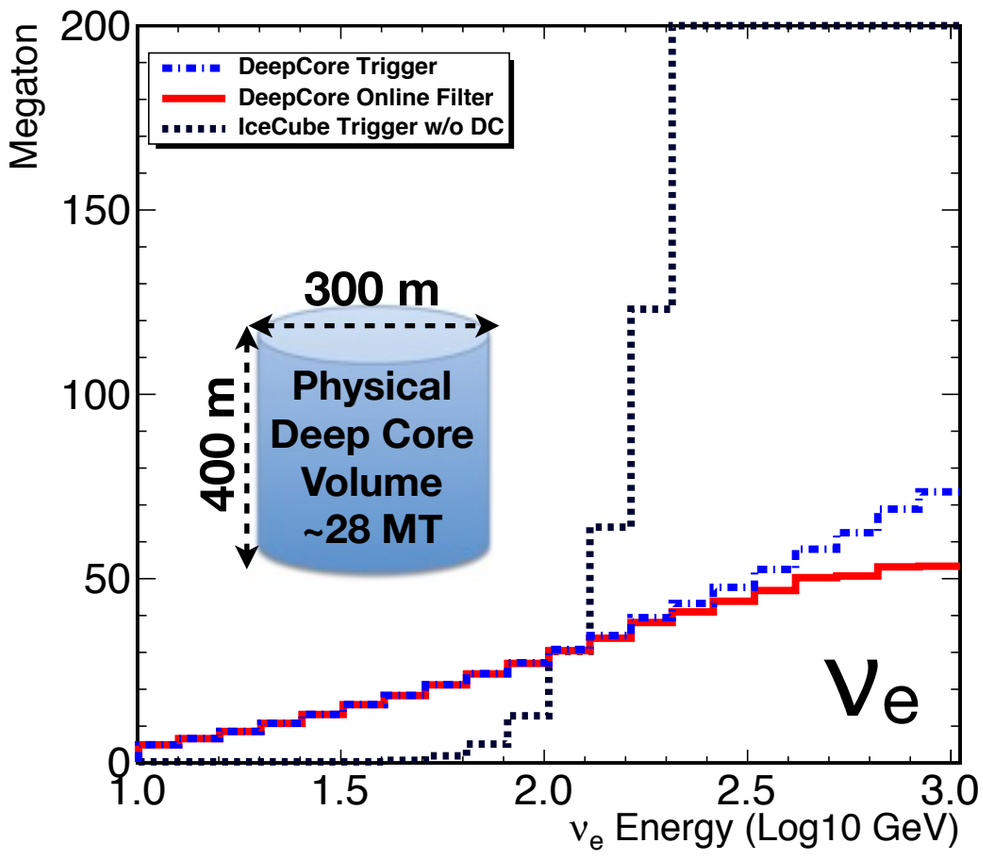
Online Atmospheric Muon Veto

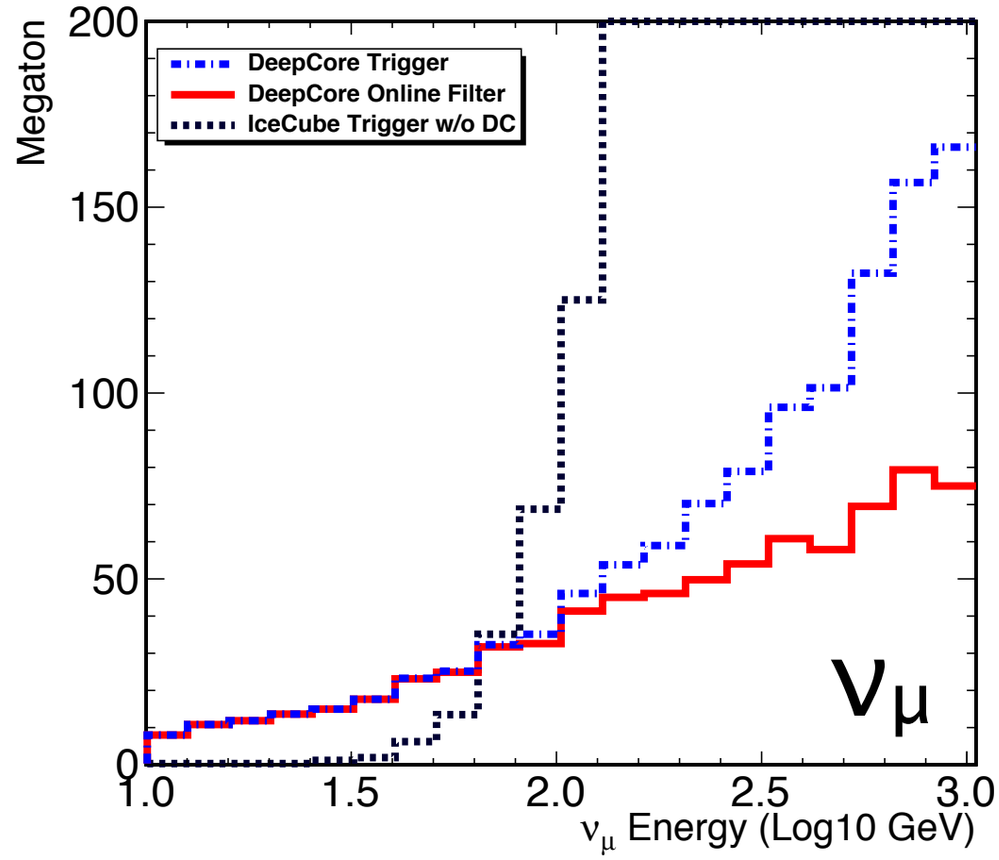


- Look for hits in veto region consistent with speed-of-light travel time to hits in DeepCore
  - Achieves 7 x 10^{-3} rejection of cosmic ray muon background
  - Loss of <2% of fiducial neutrinos



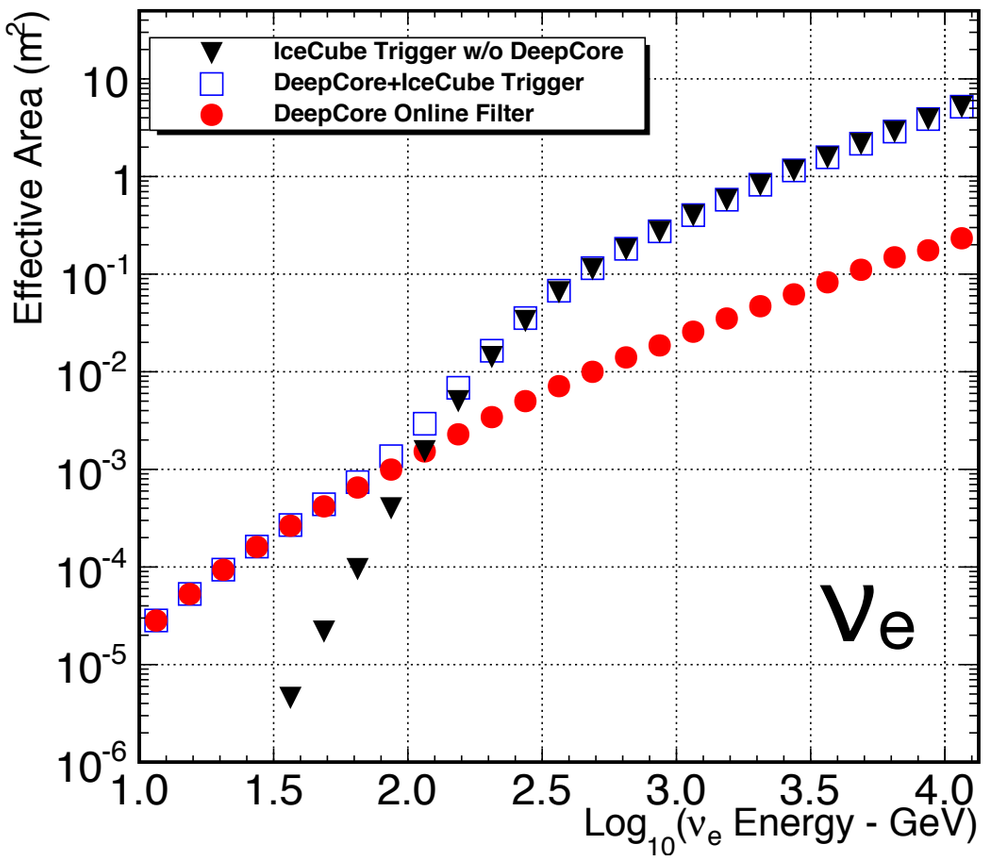
DeepCore Lepton Effective Volume

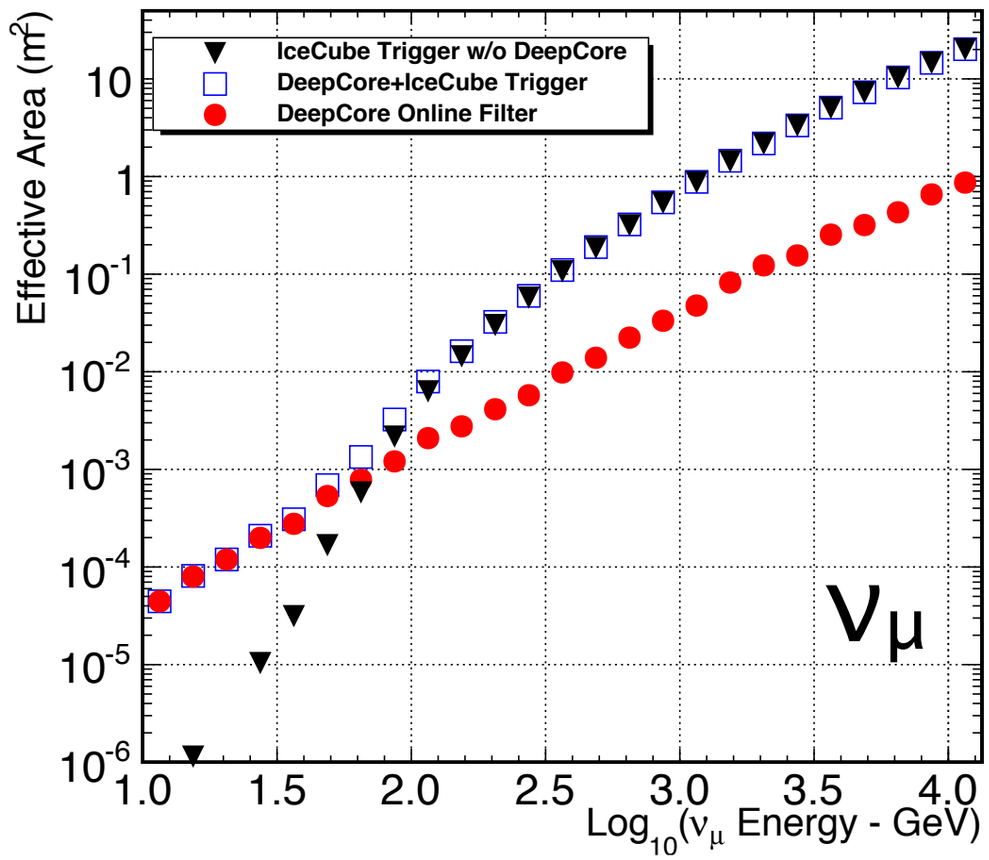




- Many DeepCore triggers are events occurring in the rest of IceCube
  - These events are rejected by the online veto algorithm
  - Online efficiency for neutrinos interacting in the DeepCore volume is >98%
  - Efficiency in final analysis will be significantly lower; losses to reconstruction efficiency, background rejection

DeepCore Neutrino Effective Area



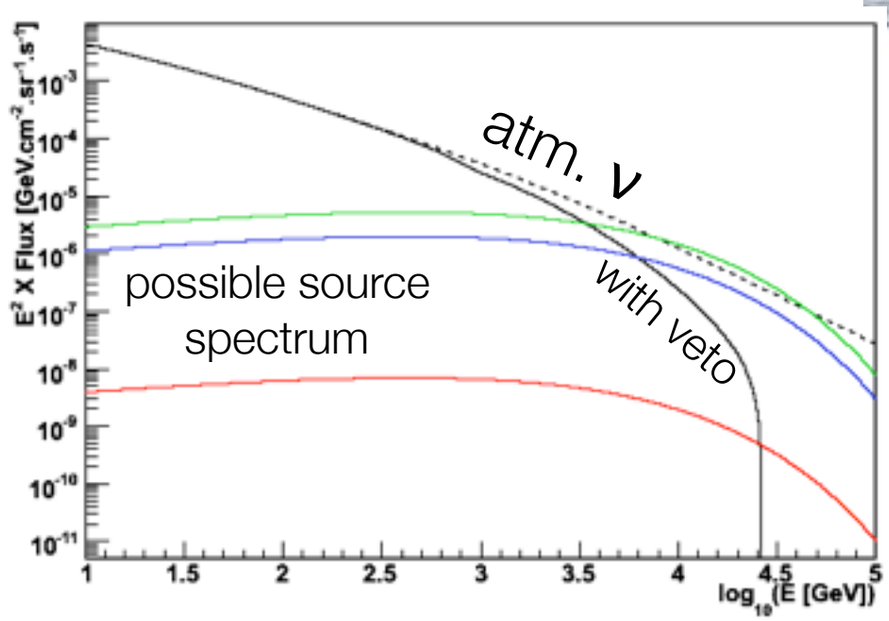


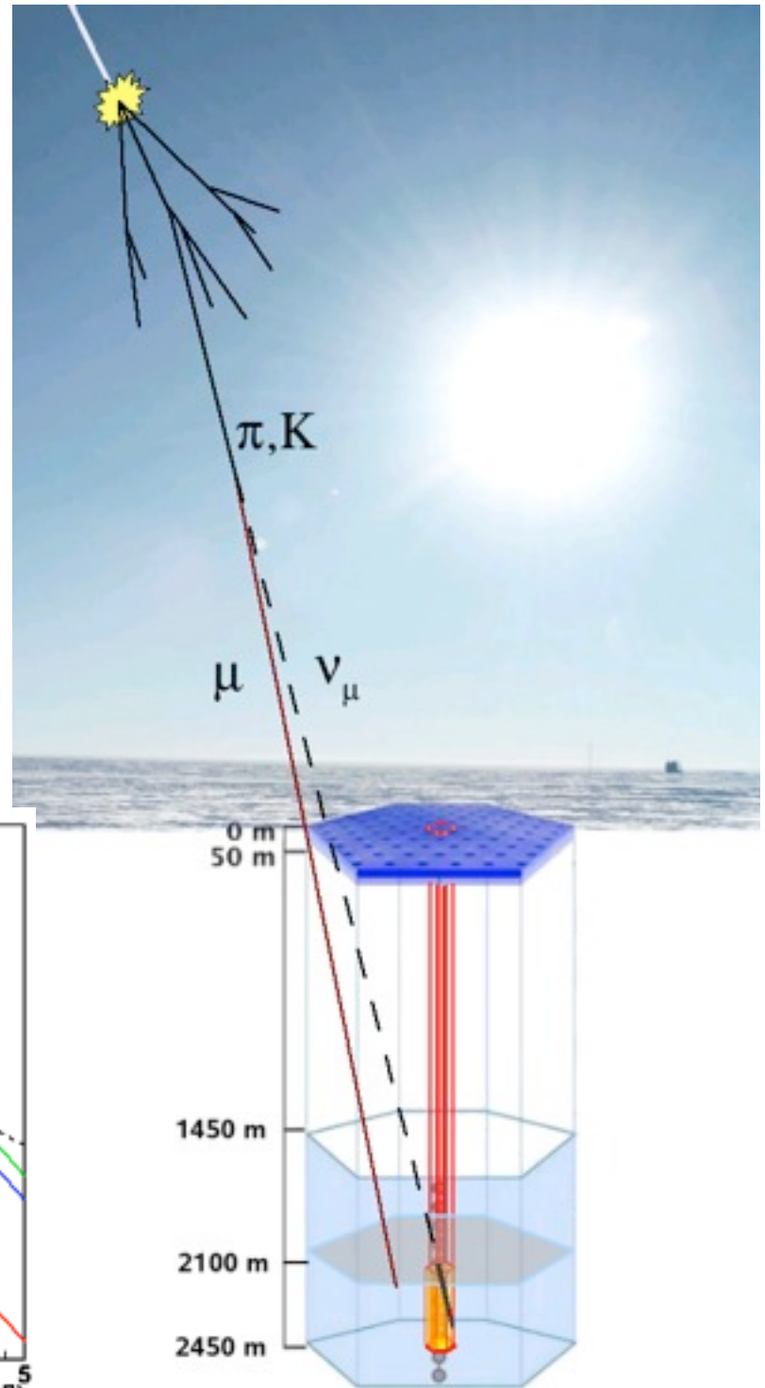
- DeepCore dominates total response for E_ν below ~100 GeV, depending on flavor
  - Improved trigger efficiency overcomes much smaller volume
  - Linear growth at high energies reflects neutrino interaction cross section, not detector efficiency

Neutrino Astronomy with DeepCore

- Atmospheric neutrino veto
  - May allow observation of sources in the Southern hemisphere with fluxes too low to be seen above atmospheric background
    (Schönert et al. 2009)

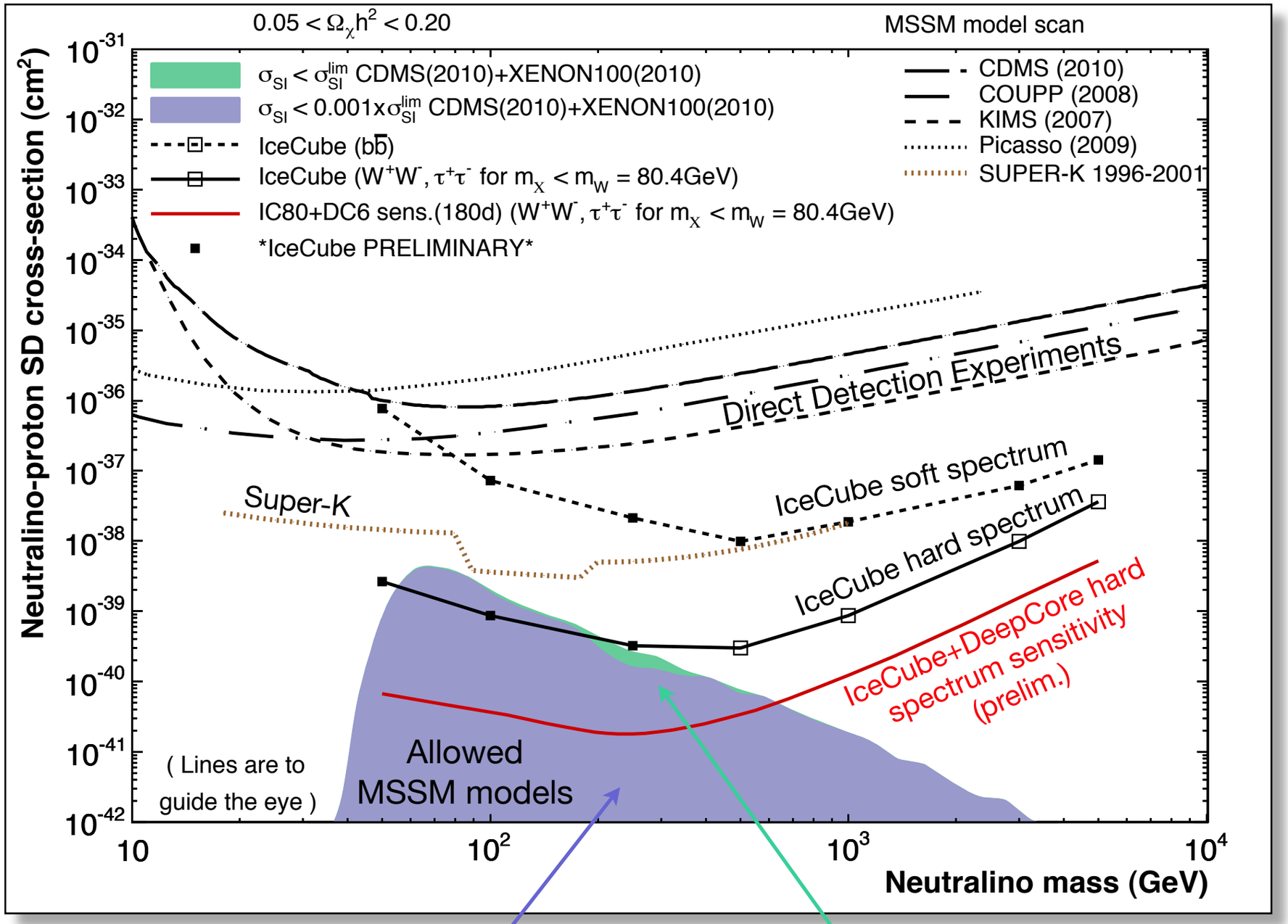
- Sensitivity to low energy neutrinos from transients
  - E.g. choked or magnetically dominated GRBs
    (e.g., Ando & Beacom 2005; Razzaque, Meszaros & Waxman 2005; Meszaros & Rees 2011)





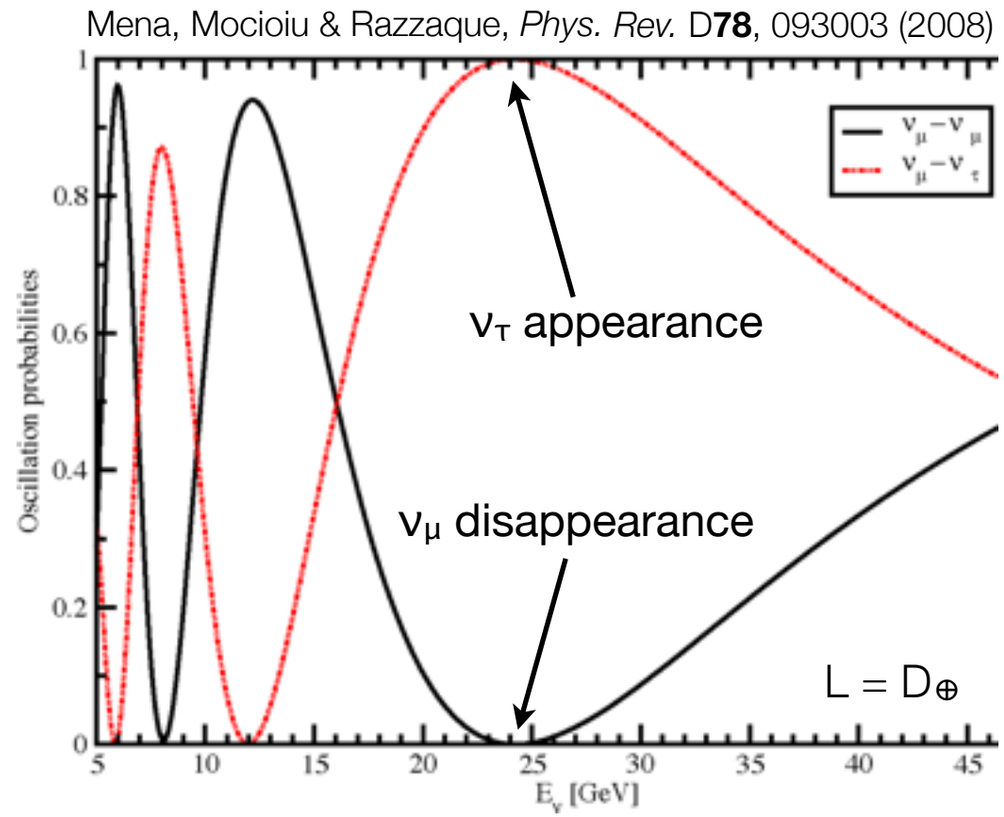
Sensitivity to MSSM WIMPs

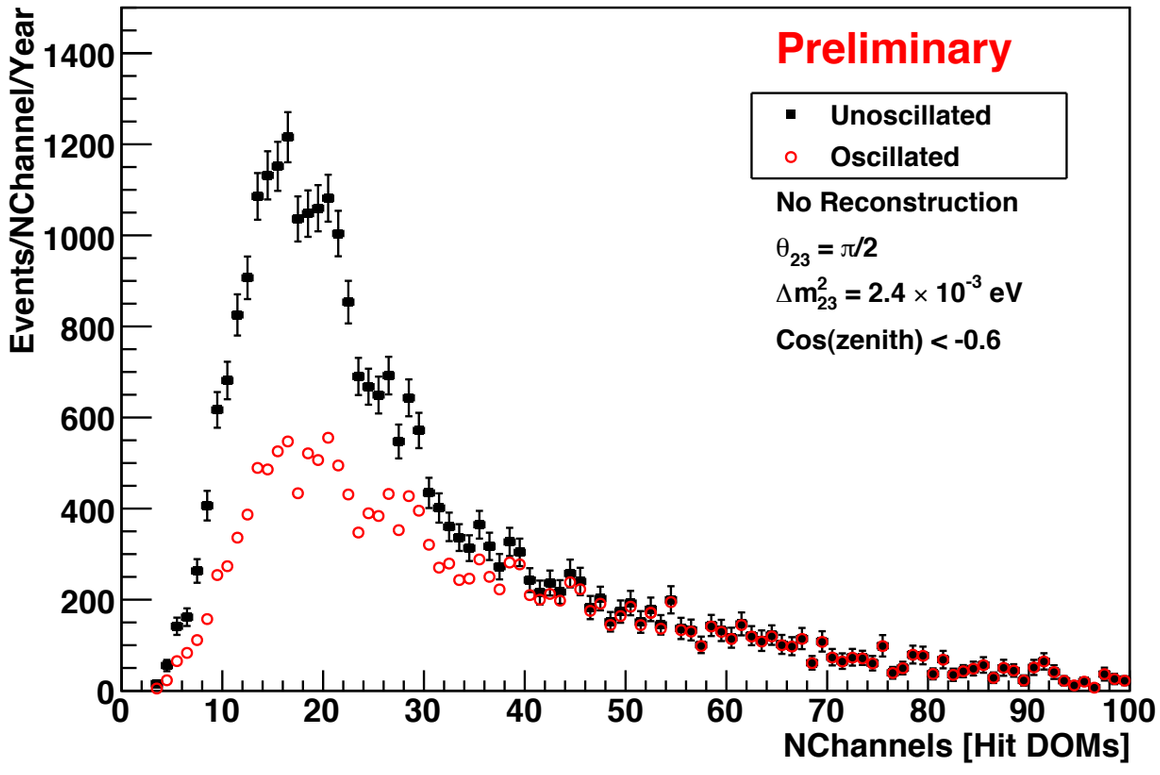
- Solar WIMP dark matter searches probe SD scattering cross section
  - SI cross section constrained well by direct search experiments
- DeepCore will probe large region of allowed phase space



Neutrino Oscillations

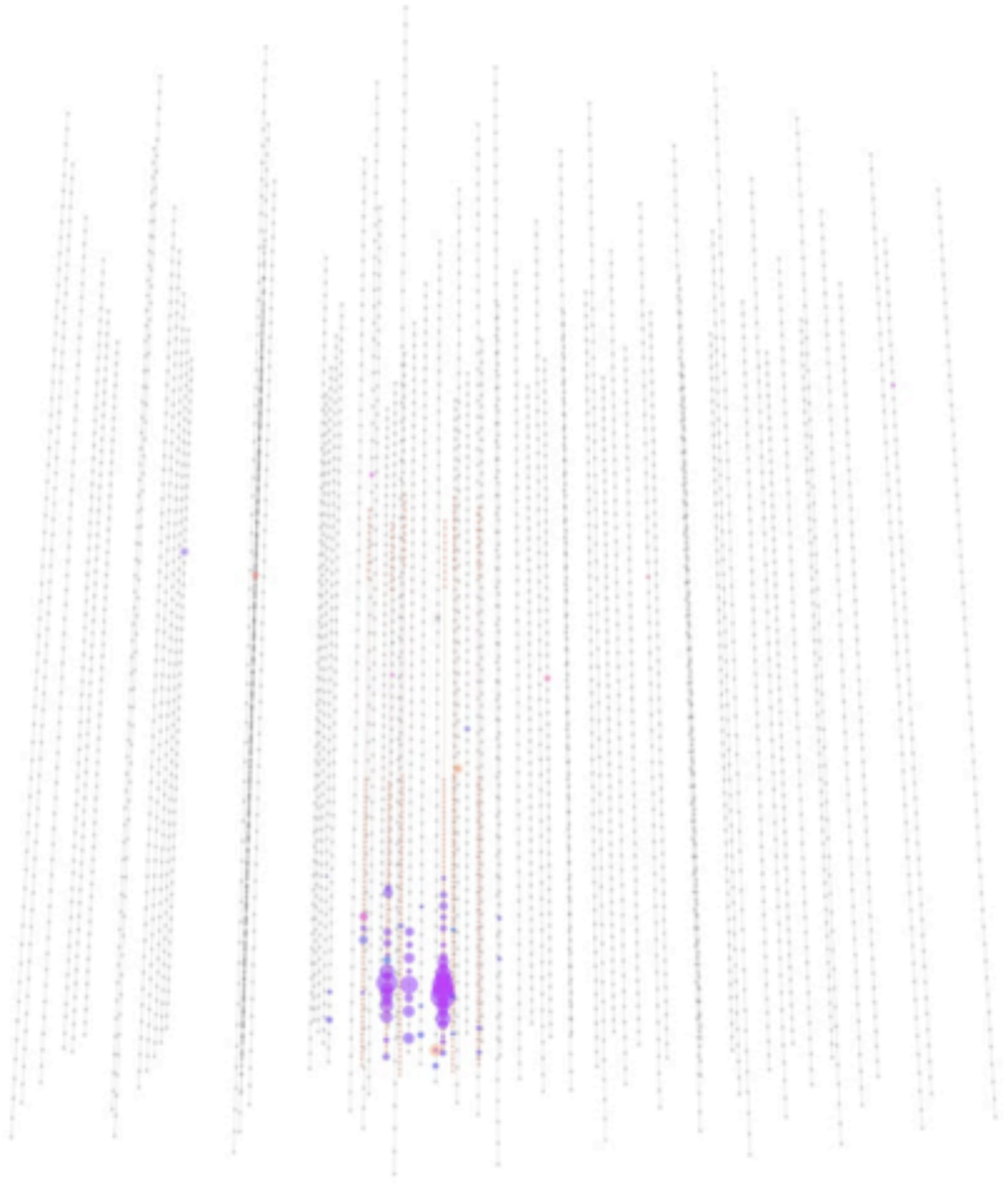
- Atmospheric neutrinos from Northern Hemisphere oscillating over one earth diameter have ν_μ oscillation minimum at ~25 GeV
  - Higher energy region than accelerator-based experiments
- Plot of ν_μ disappearance shows only simulated signal
  - Analysis efficiencies not included yet – work ongoing
  - Uses number of hit DOMs as a simple energy estimator





Observation of Neutrino Cascades (Preliminary)

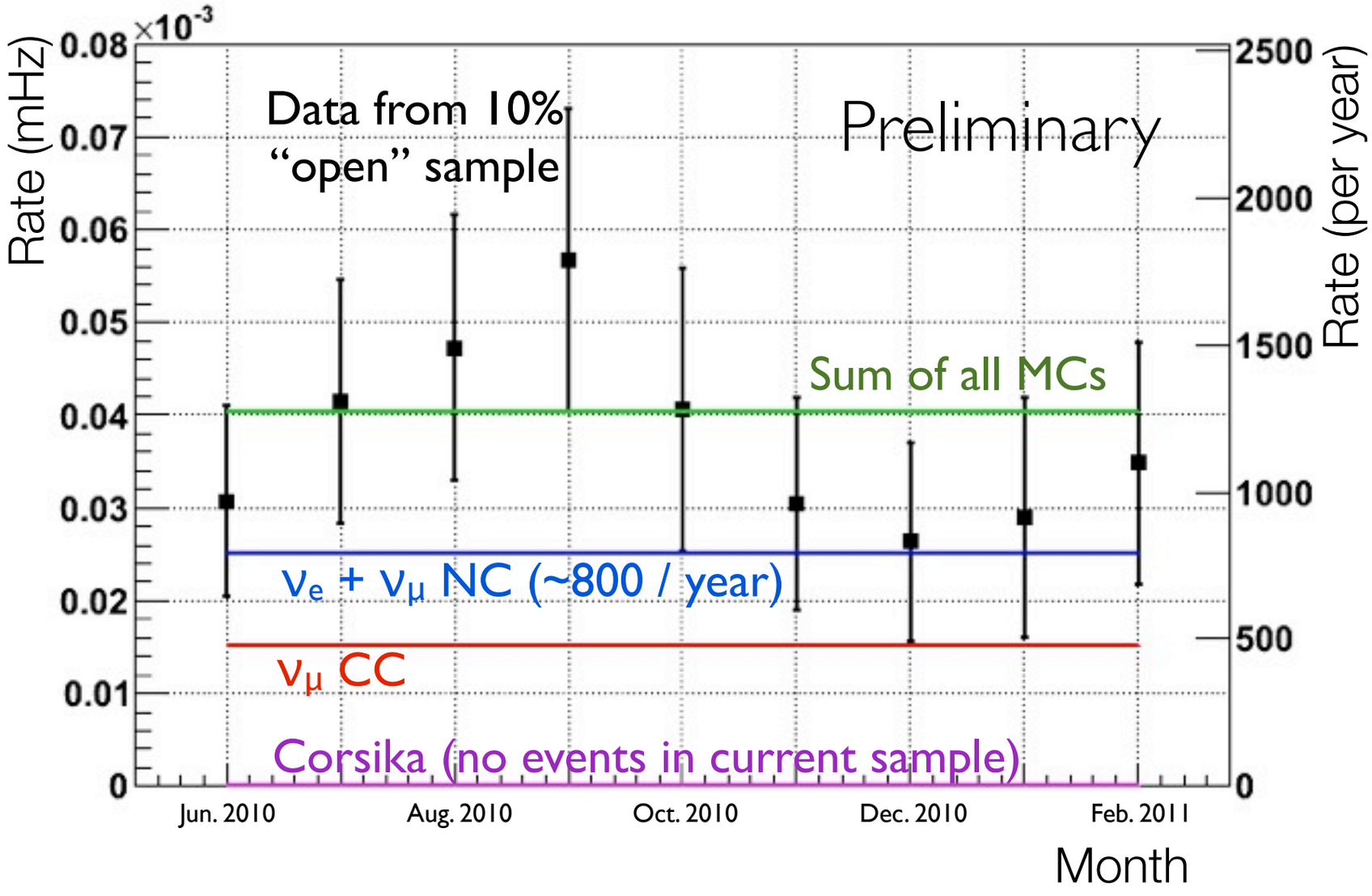
- Disappearing ν_μ should appear in IceCube as ν_τ cascades
  - Effectively identical to neutral current or ν_e CC events
  - Could observe ν_τ appearance as a distortion of the energy spectrum, if cascades can be separated from muon background
- We believe we see neutrino cascade events for the first time
  - The dominant background now is CC ν_μ events with short tracks



Candidate cascade event
Run 116020, Event 20788565, 2010/06/06

Observation of Neutrino Cascades (Preliminary)

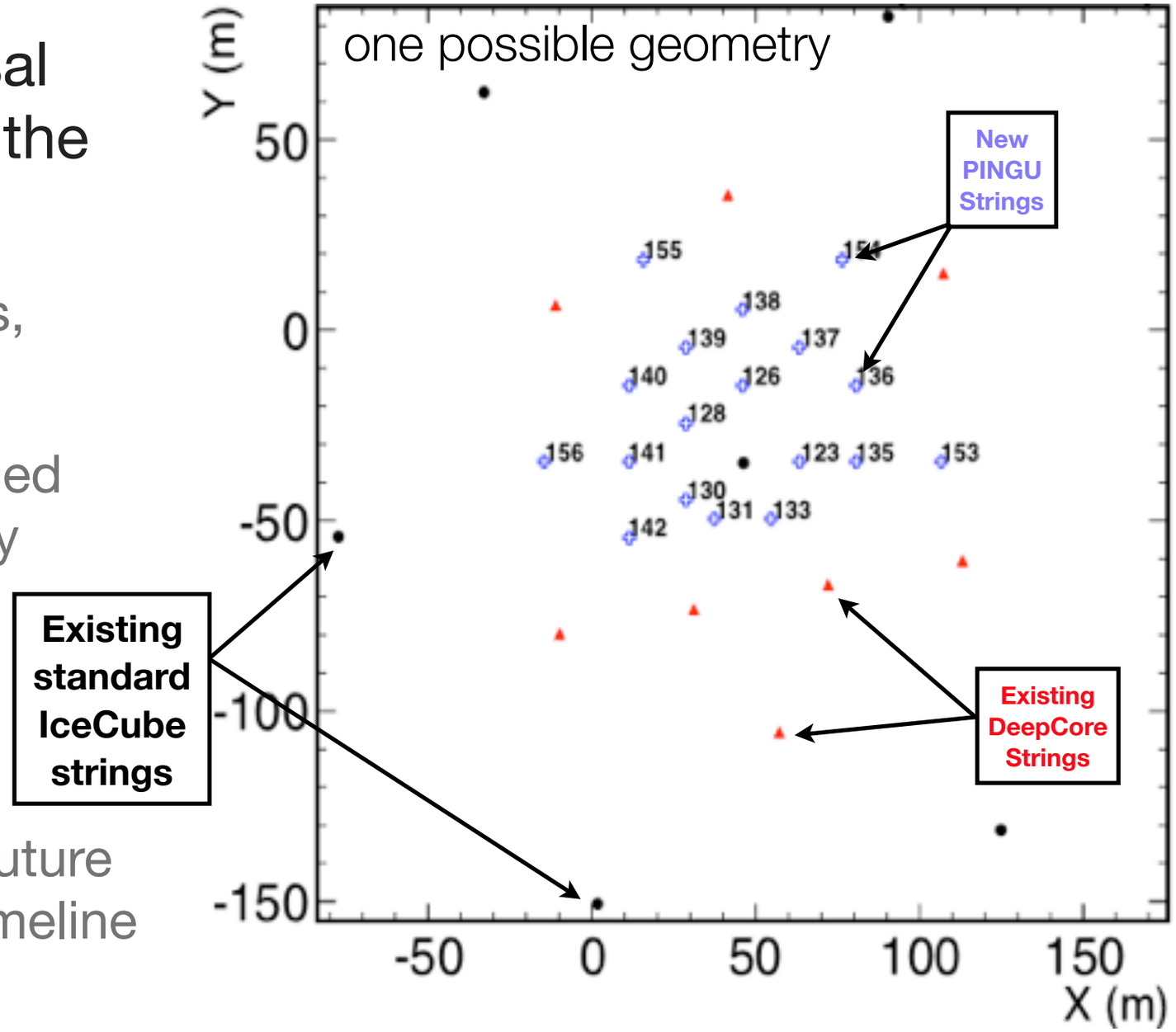
- With harsh cuts to eliminate the ν_μ background we expect to obtain a sample of ~800 neutrino cascades per year
  - Approximately 500 background ν_μ CC events expected
  - Contamination from atmospheric muons still being evaluated



- Efforts to increase ν_e yield and reduce ν_μ CC background ongoing

Beyond DeepCore: PINGU

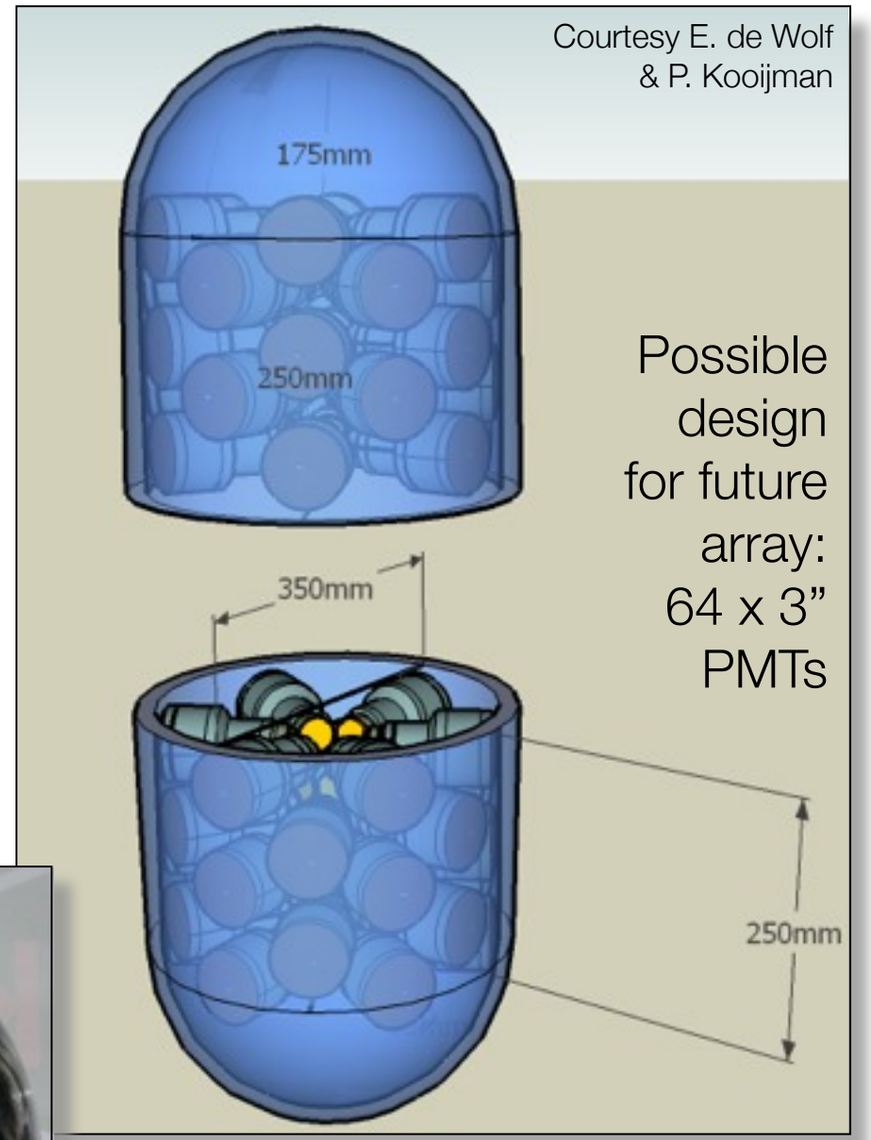
- Now developing a proposal to continue to instrument the DeepCore volume
  - An additional 18-20 strings, 1000-1200 DOMs
  - Make use of well-established IceCube drilling technology
  - Might get to a threshold of ~1 GeV in a ~10 MTon volume
  - Also an R&D platform for future detectors on a ~decade timeline

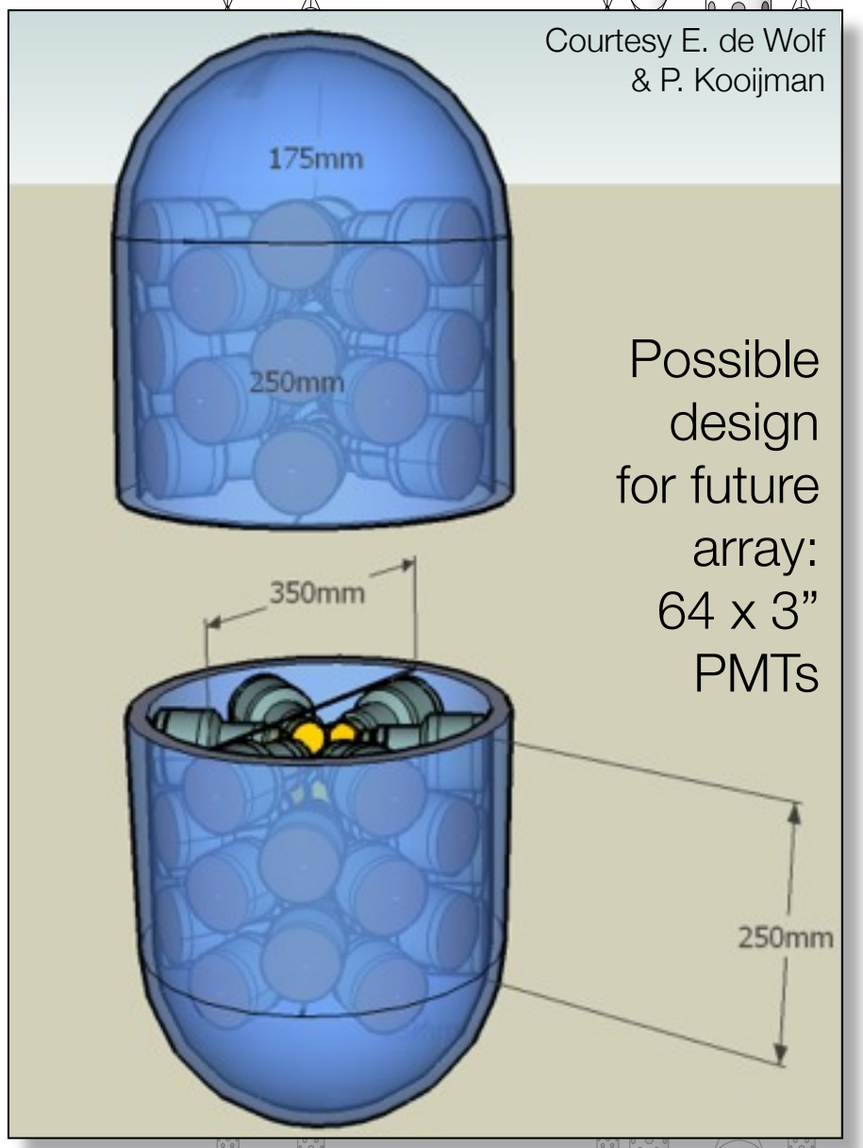


- Price tag expected to be around $25M – $30M

R&D: Multi-PMT Digital Optical Module

- Based on a KM3NeT prototype
- Glass cylinder containing 64 3” PMTs and associated electronics
  - Effective photocathode area >6x that of a standard IceCube 10” PMT
  - Diameter similar to IceCube DOM, single connector
- Might enable Cherenkov ring imaging in the ice
  - Feasible to build a multi-MTon detector in ice with an energy threshold of 10’s of MeV?





Possible design for future array: 64 x 3” PMTs

Conclusions

- DeepCore has been running for 1 year, just commenced taking data in final configuration
  - Additional 8 strings, densely instrumenting the inner 30 MTon of IceCube
  - Reduce energy threshold to ~10 GeV
- Significant improvement in sensitivity to dark matter, potential for measurements of neutrino oscillations, low energy astrophysical neutrinos
  - Preliminary analysis suggests we may have detected atmospheric electron neutrinos for the first time in a high energy neutrino telescope
- Thinking about a future upgrade of IceCube to further extend its particle physics capabilities – PINGU
  - In the more distant future, could we build a Cherenkov ring imager in ice?