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Measuring the neutrino cross section using the IceCube detector

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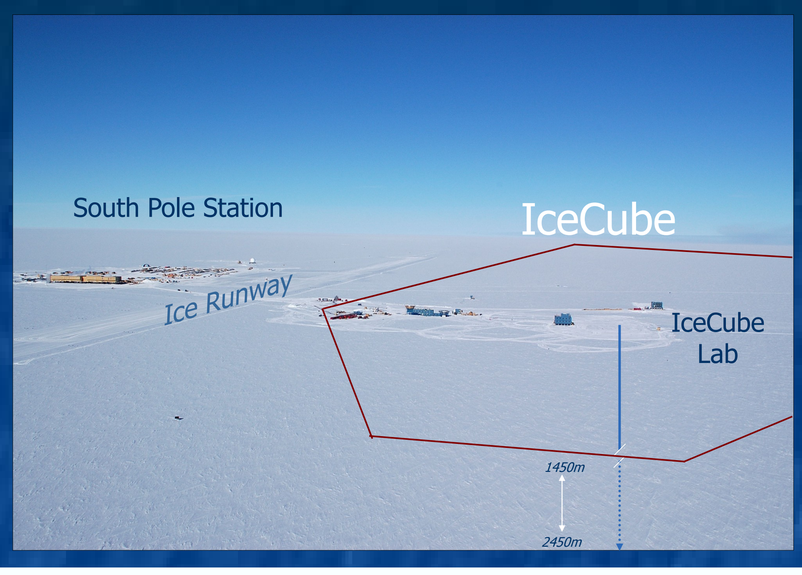
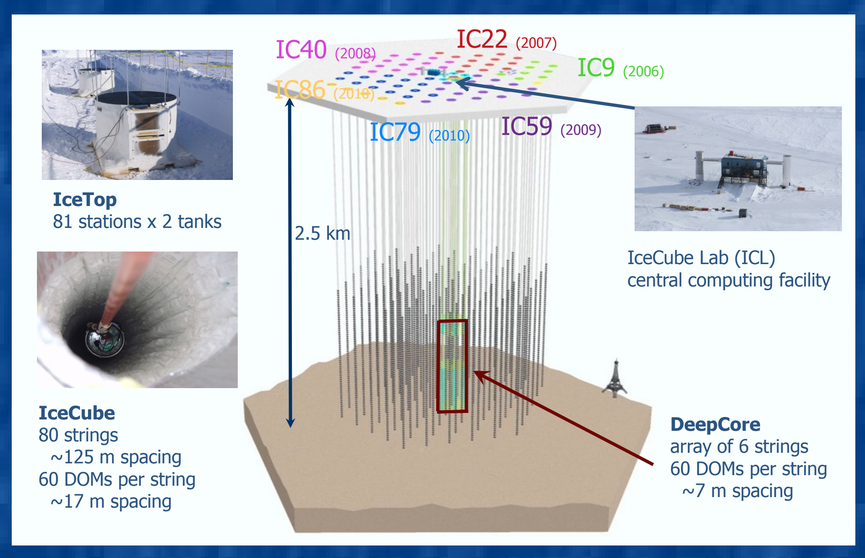
IceCube Detector

- Neutrino astrophysics using world's largest neutrino telescope
- Located at the South Pole in deep ice (1450 to 2450 m down)
- Detector built in stages, completed December 2010
- Final fiducial volume of detector 1 km^3
- Studies high-energy cosmic rays and their origins
- Searches for "new physics" in particle interactions
- 5160 optical sensors (digital optical modules, DOMs) deployed on 86 strings, 60 per string, plus surface array called IceTop
- Energy range ~ 10 GeV – 1 EeV
- Approximately 70,000 upgoing muons detected per year
- Capable of measuring neutrino source direction within 1 deg
- Collaboration of 250 members, 36 international institutions



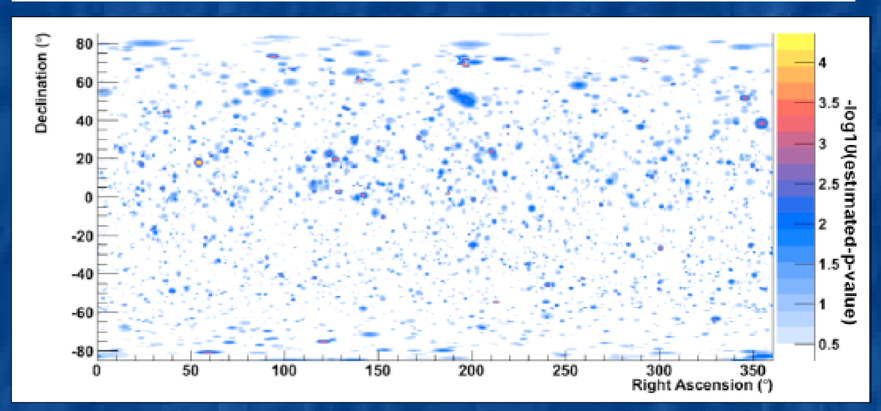


How IceCube Works

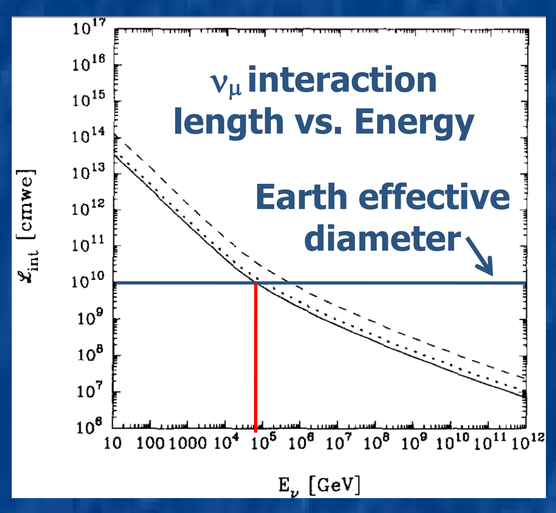
- Cherenkov photons are radiated by muons and other charged particles produced in neutrino interactions
- Photons are emitted at Cherenkov angle, ~ 41 degrees in ice
- Photon scattering in ice affects photon trajectory
- IceCube DOMs record light received and send data to surface
- Reconstruction algorithms determine the neutrino energy and direction, accounting for optical scattering and absorption

Diverse Science in IceCube

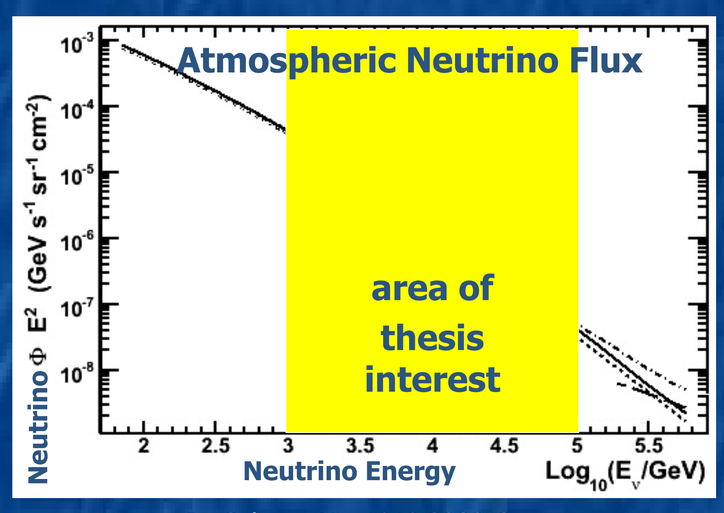
- Searches for diffuse and point sources of high-energy neutrinos
- Watching for neutrino bursts preceding new supernovae
- Atmospheric neutrino studies, including searches for "new physics" such as Supersymmetry
- Searches for WIMPs (Weakly Interacting Massive Particles); if they exist, they may be gravitationally captured in the earth and sun, then annihilate to produce a neutrino signal
- Gamma Ray Bursts (GRBs) from transient sources
- Exotics: magnetic monopoles, strangelets, Qballs



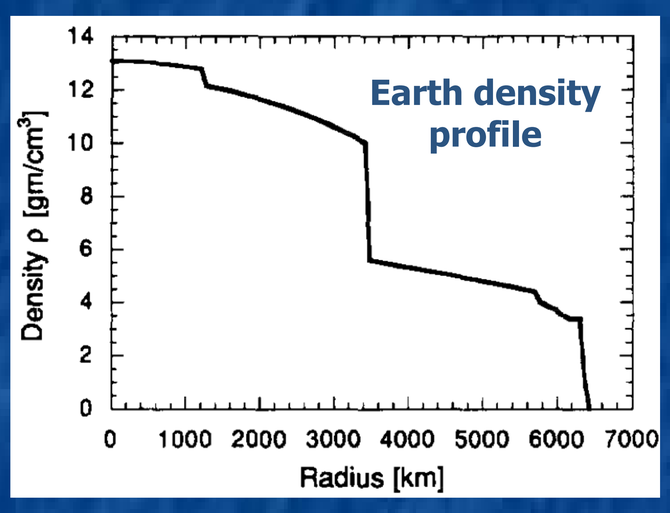
Neutrino Point Source Sky Map (40 String)
No statistically significant signal



R. Gandhi arXiv:hep-ph/9512364v1
dotted = charge current, dashed = neutral current



IceCube: arXiv:1010.3980v2



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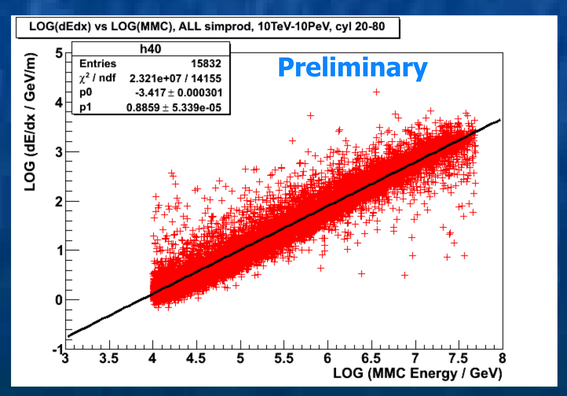
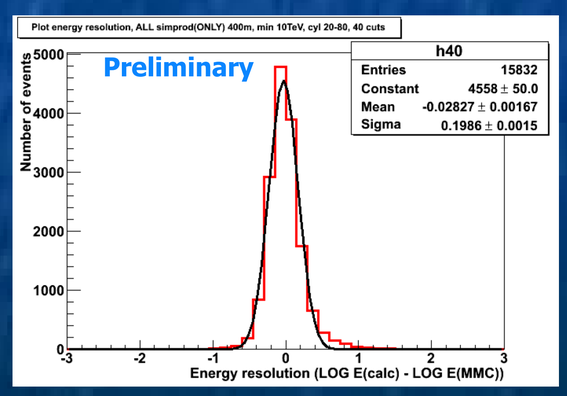
Total Neutrino Cross Section

- Atmospheric ν_μ flux ($E^{-3.7}$ spectrum) as the "source"
  - Isotropic cosmic rays interact with atmosphere
  - Resultant kaons and pions decay into ν_μ
    - Charmed decays not a significant contribution
  - Earth diameter is ~ ν_μ interaction length ~ 40 TeV
  - Use current Earth density model
- Count number of upgoing ν_μ detected in bins of zenith angle (100-180 degrees) and energy (1 TeV – 100 TeV)
  - Expect ~ 20,000 events per year (79 strings)
  - Track reconstructions within ~ 1 degree
  - Muon energy resolution (1 σ) ~ 0.2 in log10 of energy
- Fit the energy and zenith distributions to calculate the total neutrino-nucleon σ
  - Theoretical charge-current $\sigma \sim 4\times10^{-35}$ cm^2 at 10 TeV and $\sigma \sim 2\times10^{-34}$ cm^2 at 100 TeV





Energy Reconstruction Method

- Truncated Mean: similar method to wire chamber and calorimeter studies of charged particles
- Remove highest 30-50% of measurements to eliminate high-energy tail that skews the mean
- Correlation of dE/dx (energy loss per meter) to energy of the muon in the detector
- Improves energy resolution by up to 40%