Searches for Dark Matter with the IceCube Neutrino Telescope

SUSY 2010
Bonn, Germany

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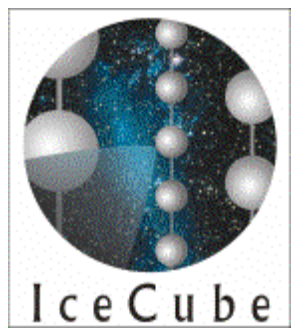


Overview

- Dark Matter Candidates
- Neutrino Detection with IceCube
- Searches for Solar WIMPs
- Searches for WIMPs from the Galactic Center and Halo

MSSM Neutralino Dark Matter

- R-parity conservation leads to a stable particle
- Collected in Massive Objects (Sun, Galactic Halo, …)
- Self-annihilation leads to SM particles and then neutrinos

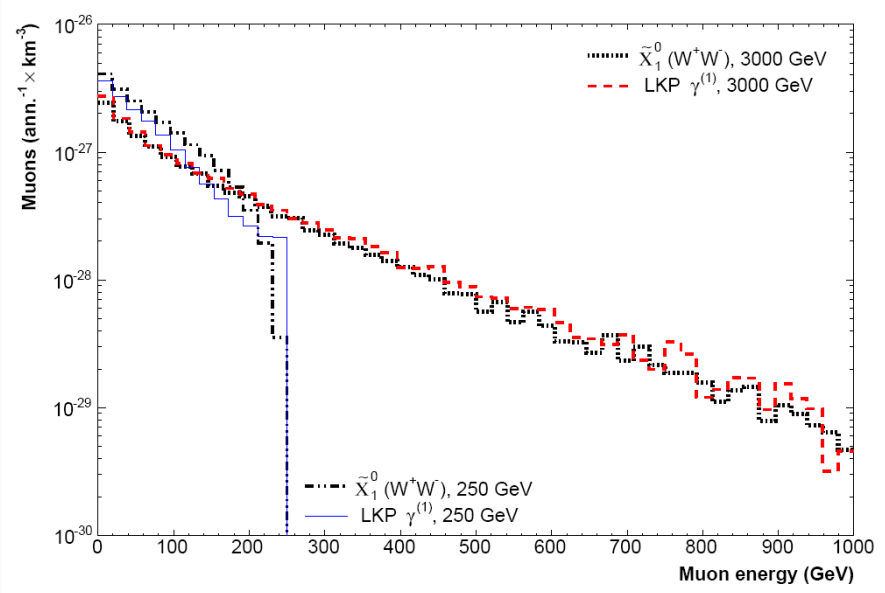
$$\chi\chi \rightarrow b\bar{b}, \tau^+\tau^-, W^+W^-, \ldots \rightarrow \nu s$$

- Event rates and energies depend on MSSM model parameters and astrophysics (relative velocities, galactic density profile)
  - few to 10^3 events per year
  - GeV to TeV energies

Kaluza-Klein Dark Matter

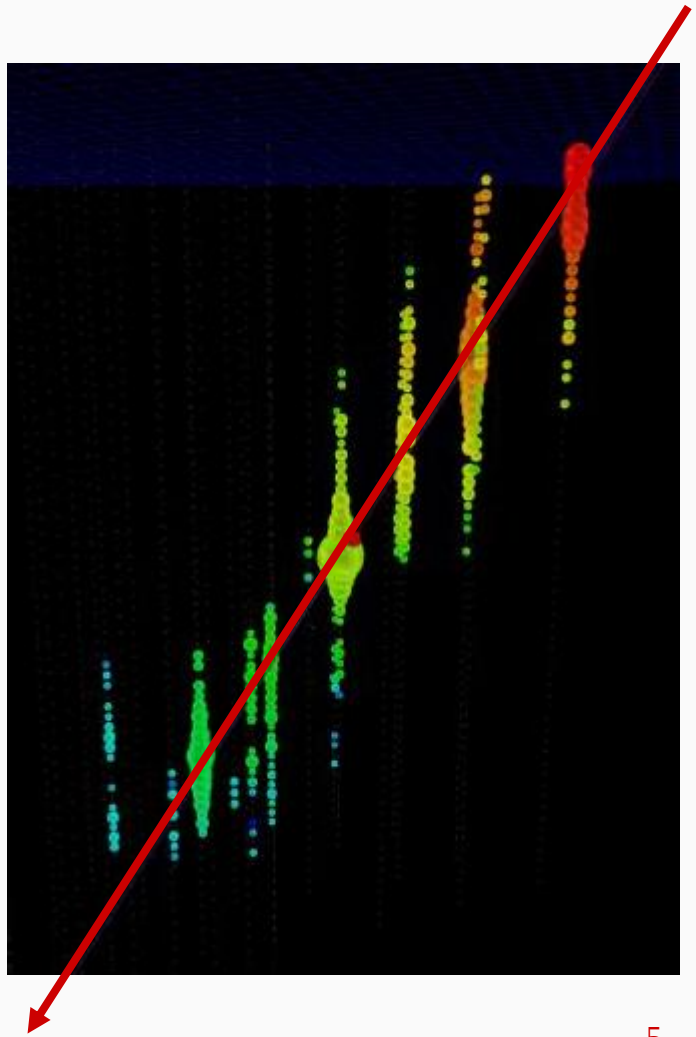
- In single extra dimension model, first KK excitation of $B^{(1)}$ can be a stable LKP.
- SI scattering cross-sections are small, but SD can be large enough to probe
- Similar energy spectrum to "hard" neutralino models

Abbasi et al., *Phys. Rev.* **D81** (2010) 057101



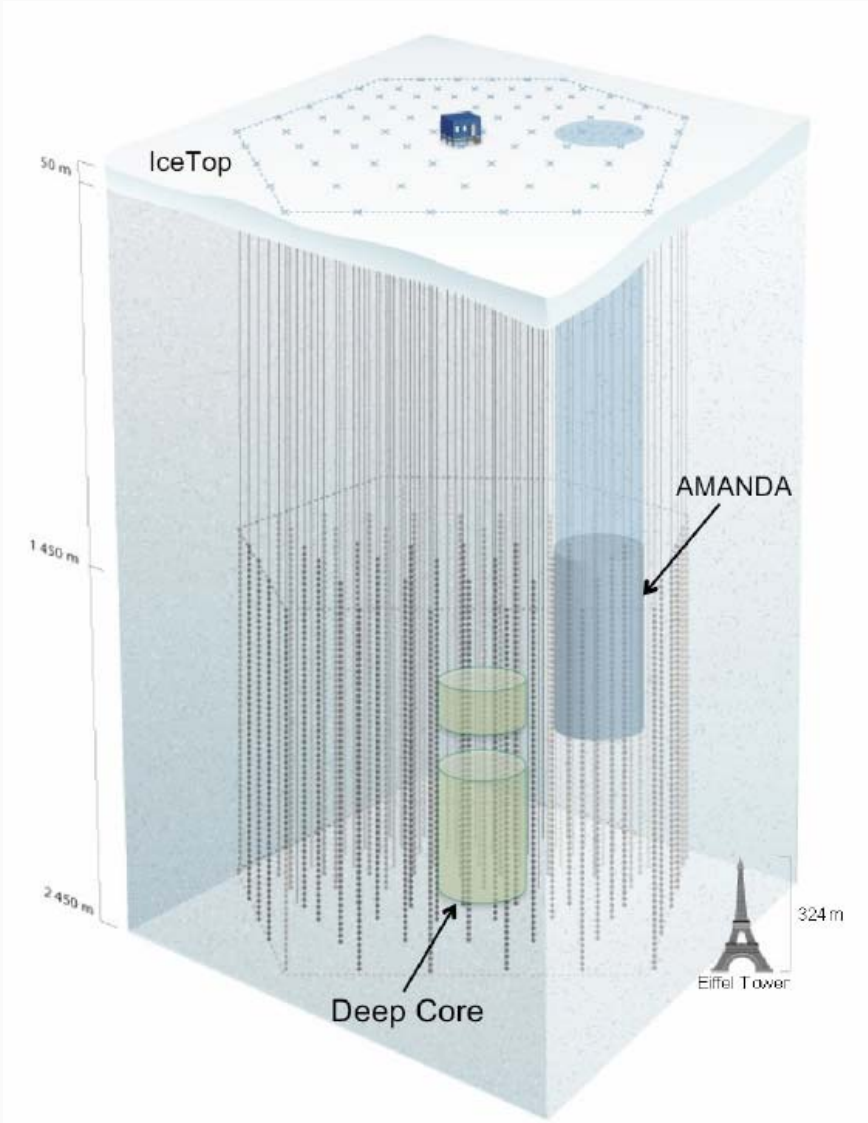
Neutrino Detection Principles

- Interaction in/near detector
  - Tracks (~km) (CC ν_μ)
  - Cascades (CC / NC ν_μ)
- Cherenkov radiation emitted by daughter lepton
- Optical sensors record arrival time and intensity of photons for reconstruction



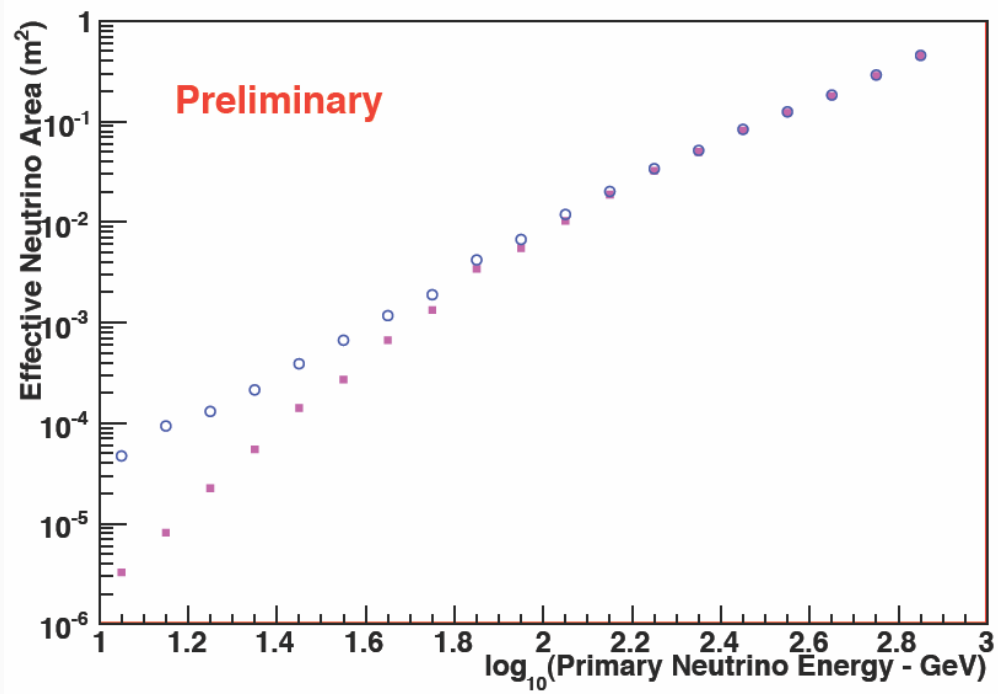
The IceCube Neutrino Telescope

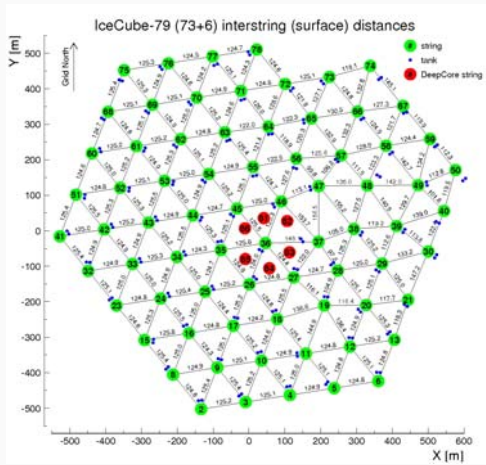
- Large Hybrid Detector
  - ~km^3 instrumented volume
- IceTop
  - Surface air shower array
  - ~300 TeV threshold
- AMANDA-II
  - Precursor Array
  - Decommissioned May 2009
- IceCube and DeepCore
  - 79 of 86 strings deployed
  - Complete in 2011



More on DeepCore

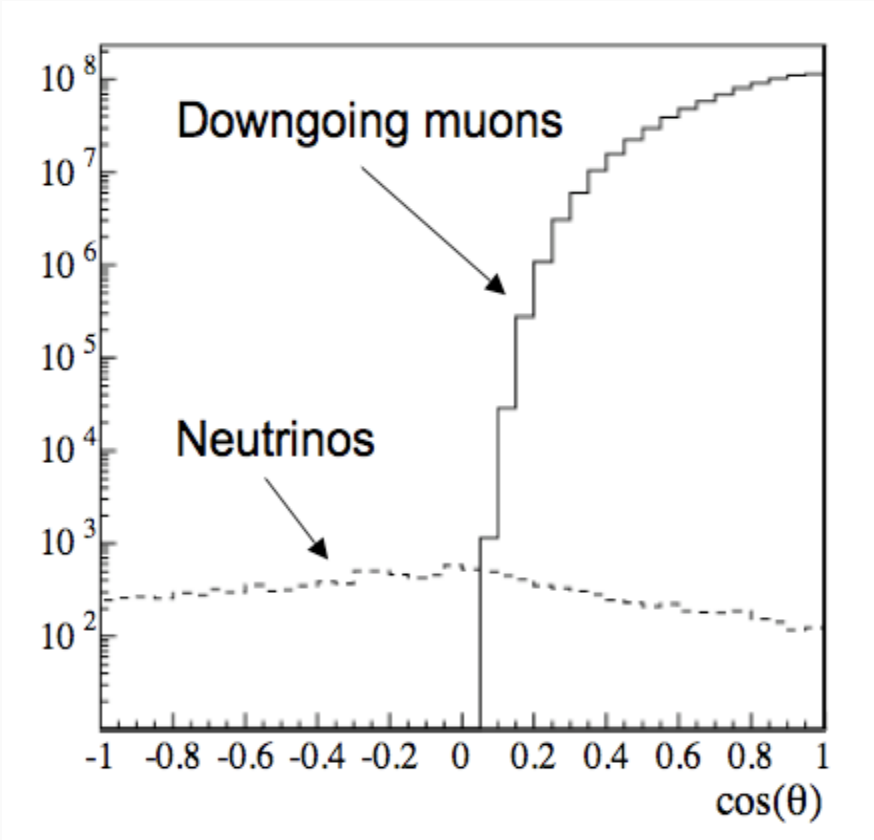
- 6 string sub-array
  - More densely instrumented
  - Closer string spacing
  - High quantum efficiency PMTs
  - Deployed in the deepest, clearest ice
- Extend sensitivity to ~10 GeV
  - Dark Matter Searches
  - Neutrino Oscillation
- Use of IceCube as a veto extends searches to the southern sky
  - More sources including the Galactic Center





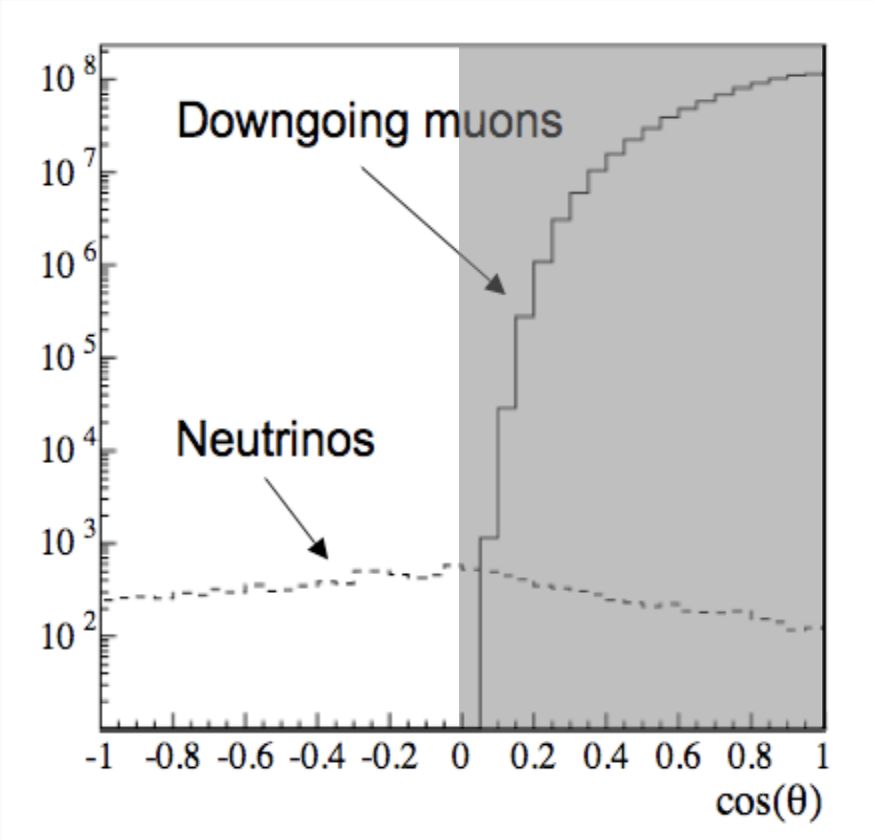
Detection Challenges

- Down-going muons from Cosmic Ray showers dominate by 6 orders of magnitude



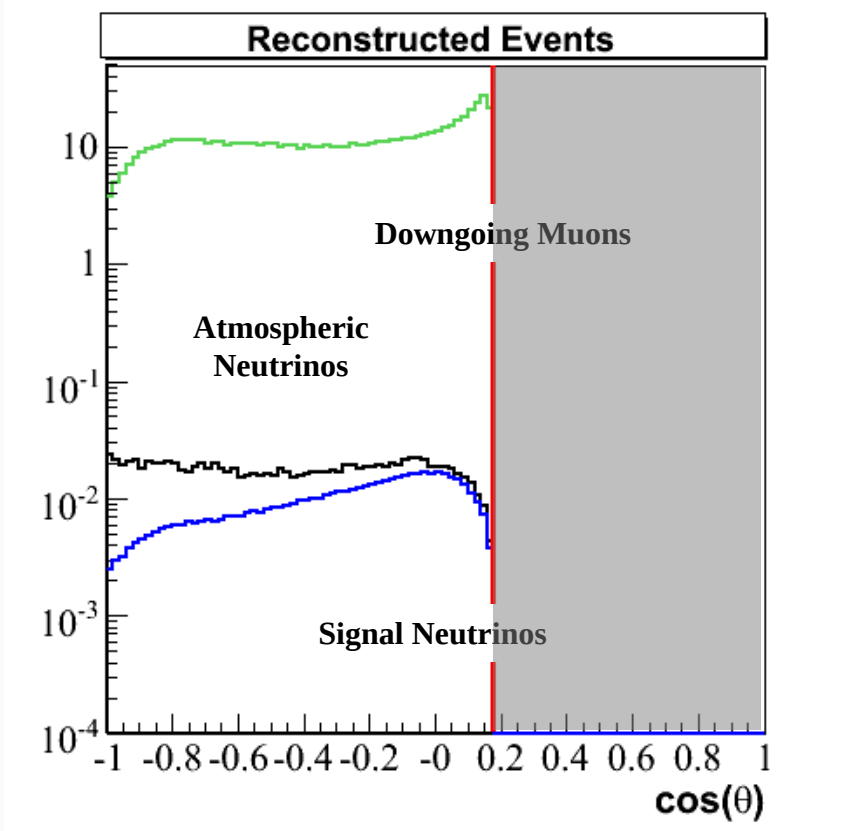
Detection Challenges

- Down-going muons from Cosmic Ray showers dominate by 6 orders of magnitude
  - Restrict Searches to Northern Sky



Detection Challenges

- Down-going muons from Cosmic Ray showers dominate by 6 orders of magnitude
  - Restrict Searches to Northern Sky
- Mis-reconstructed muons dominate by 3 orders of Magnitude
  - Especially troublesome are coincident muons
- Atmospheric Neutrinos typically dwarf potential signals
  - Isotropically distributed

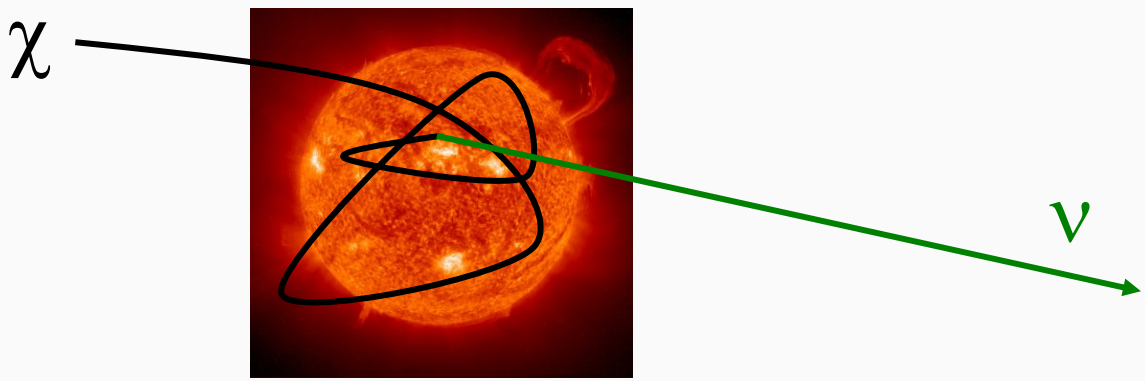


Dark Matter from the Sun

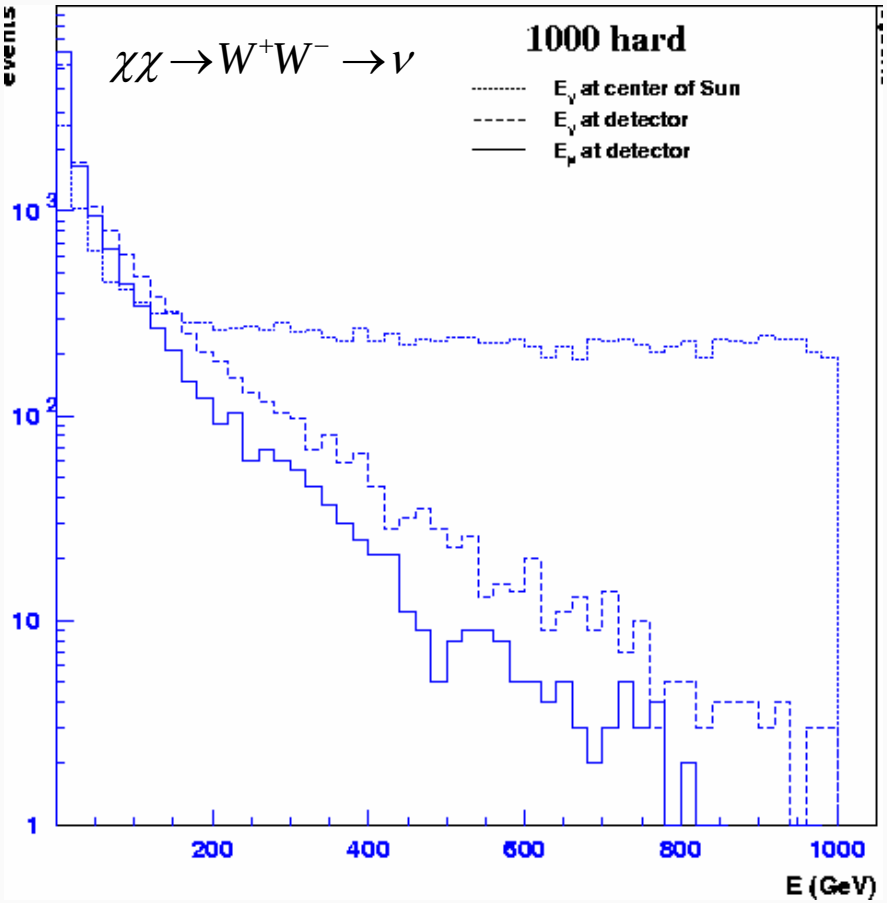
- DM swept up from the halo by the Sun's passage over its history
- Scattering with protons leads to capture
- Measurement of the neutrino flux probes the scattering cross-section

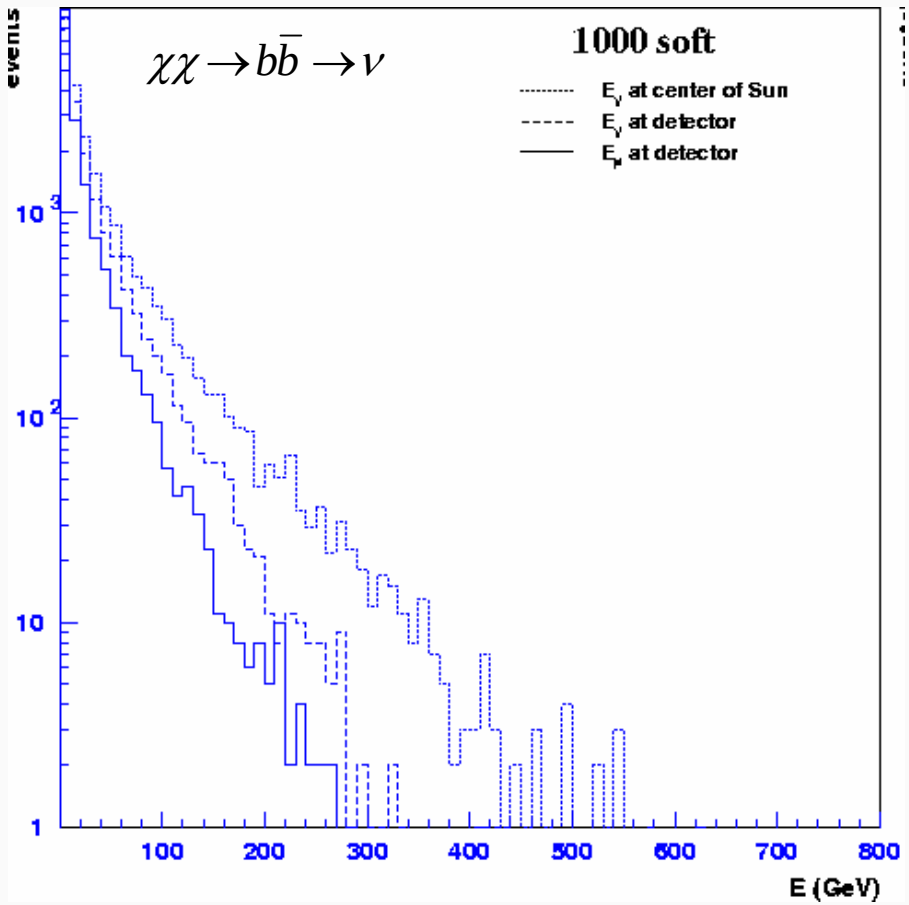
$$C_{sun} \propto \frac{\rho_\chi \sigma_{\chi p}}{\bar{v}_\chi^3 m_\chi^2}$$

$$\Gamma_A = \frac{1}{2} C_{sun}$$



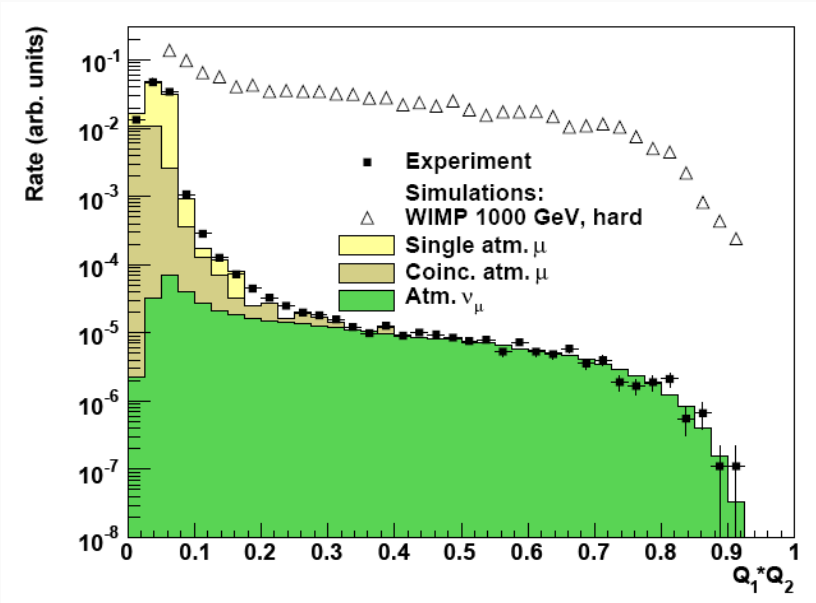
Produced Energy Spectrum



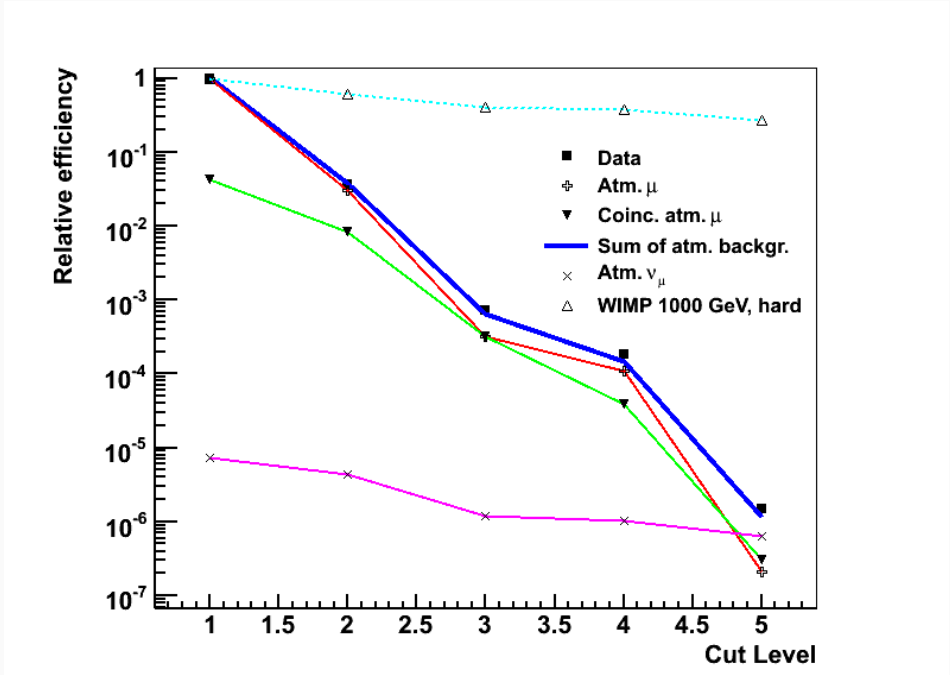


IceCube-22 Dark Matter Search

- 104.3 days livetime (2007)
- Stringent event selection reduces the muon and atmospheric neutrino backgrounds



Abbasi et al., *PRL* **102**, 201302 (2009)



Trigger

Online Filter

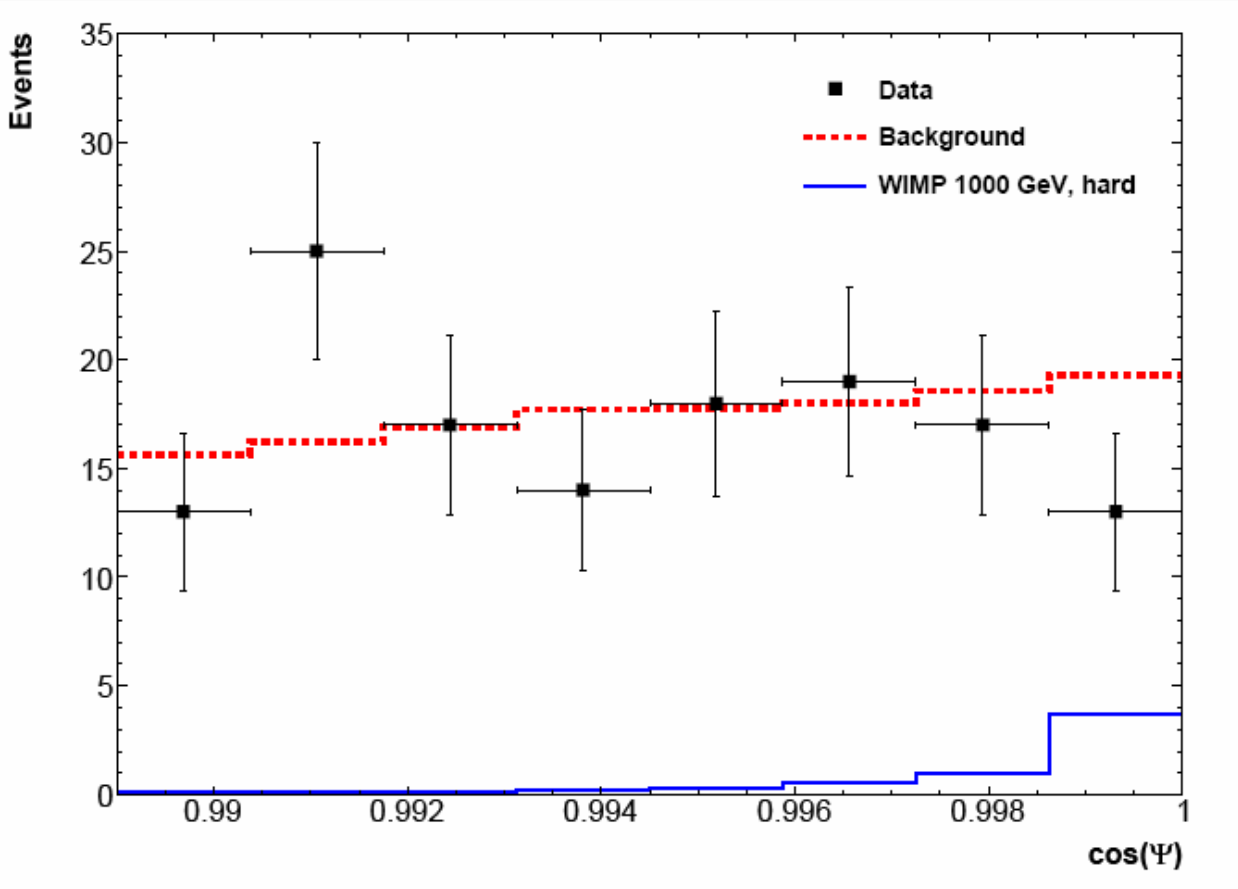
Angular Cuts

Track Quality

Shape Analysis

Correlation to the Sun

- Apply likelihood analysis to determine the flux from the direction of the Sun



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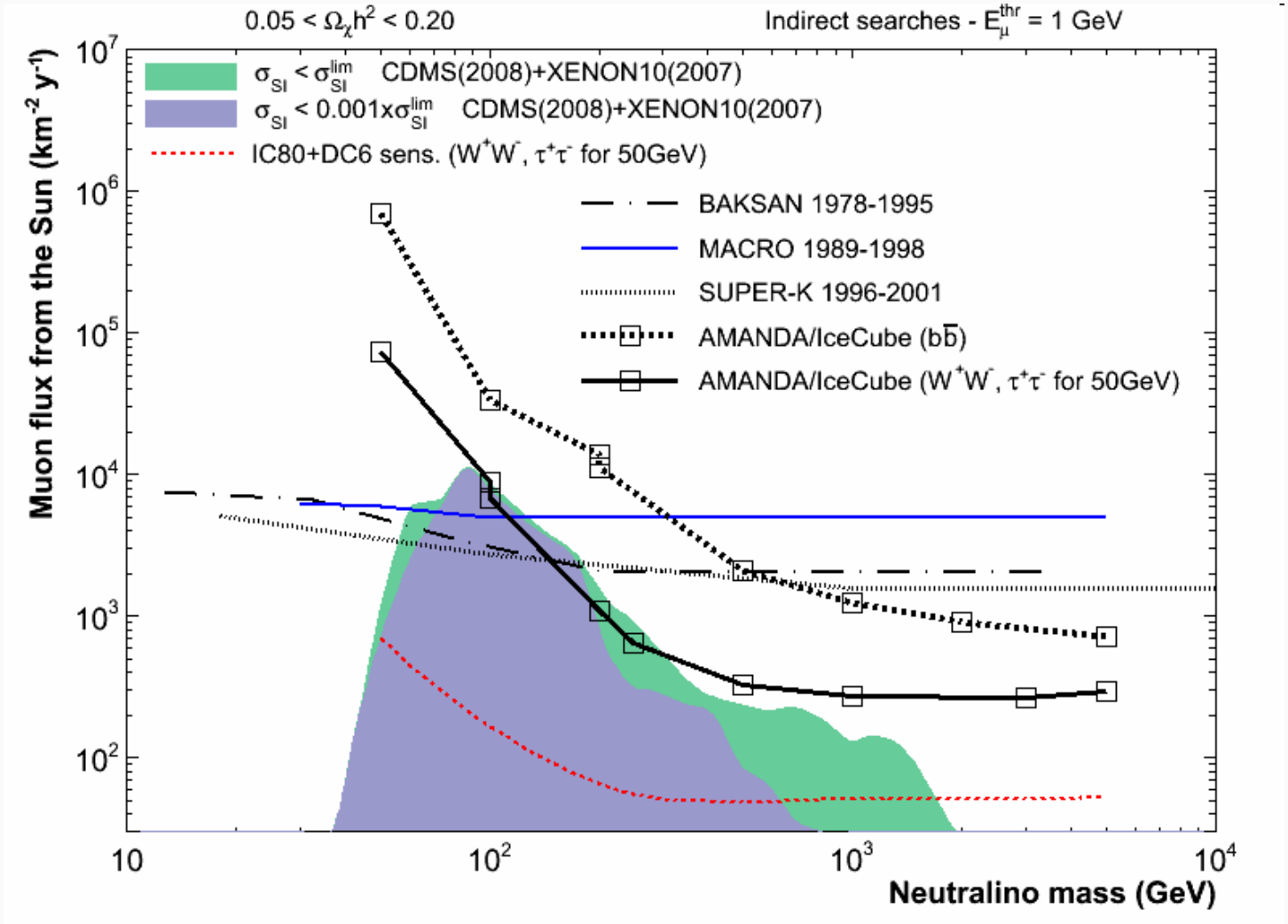
Neutralino Muon Flux Limit

Abbasi et al., *PRL* **102**, 201302 (2009)
Proc. 31st ICRC ArXiv:0906.1615



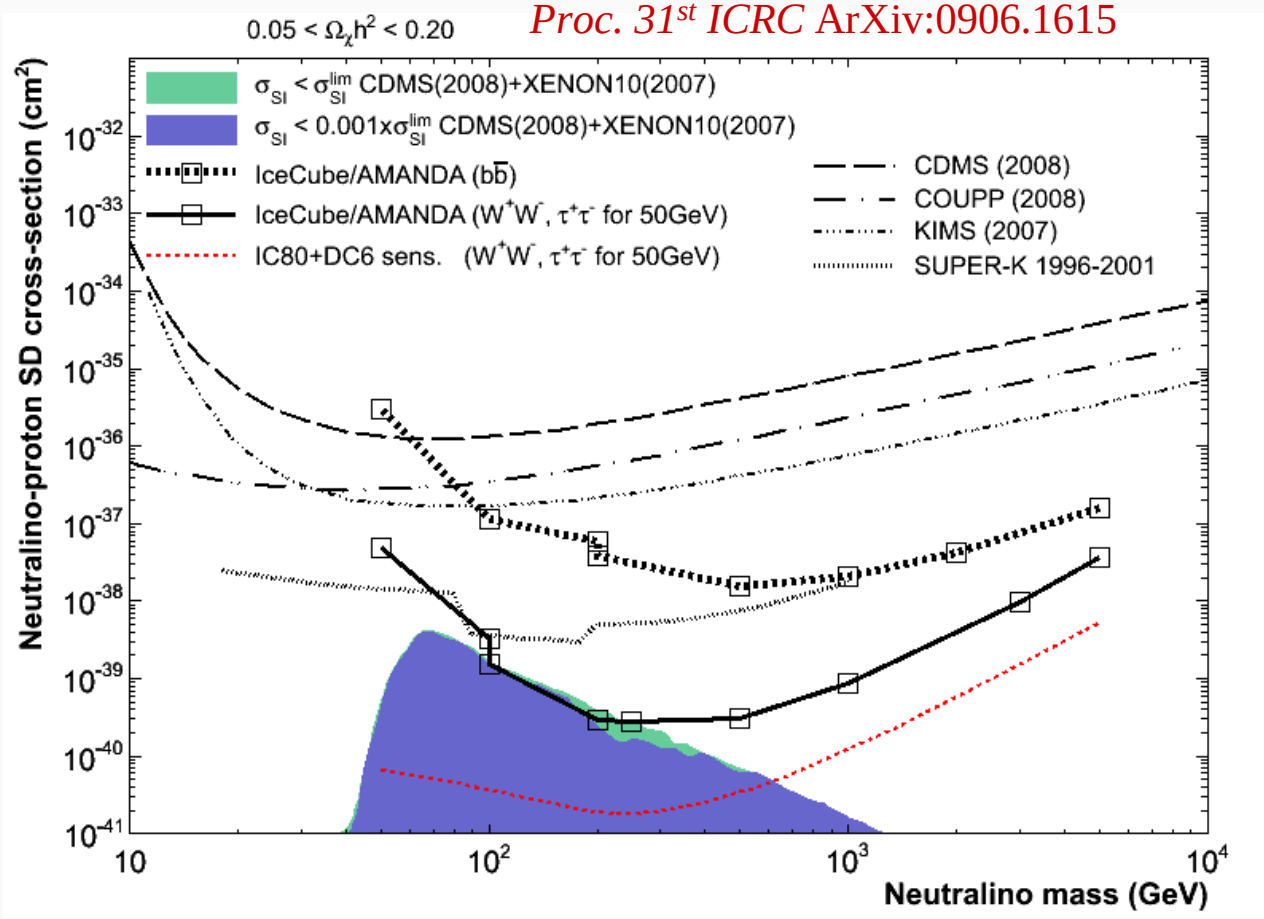
Neutralino SD Cross Section Limit

- Calculate the corresponding limit on the SD WIMP-nucleon scattering cross-section
- Compare hard and soft annihilation channels
- Allowed SUSY parameter space has:

Corresponding σ_{SI} within factor 10^3 of current direct limits

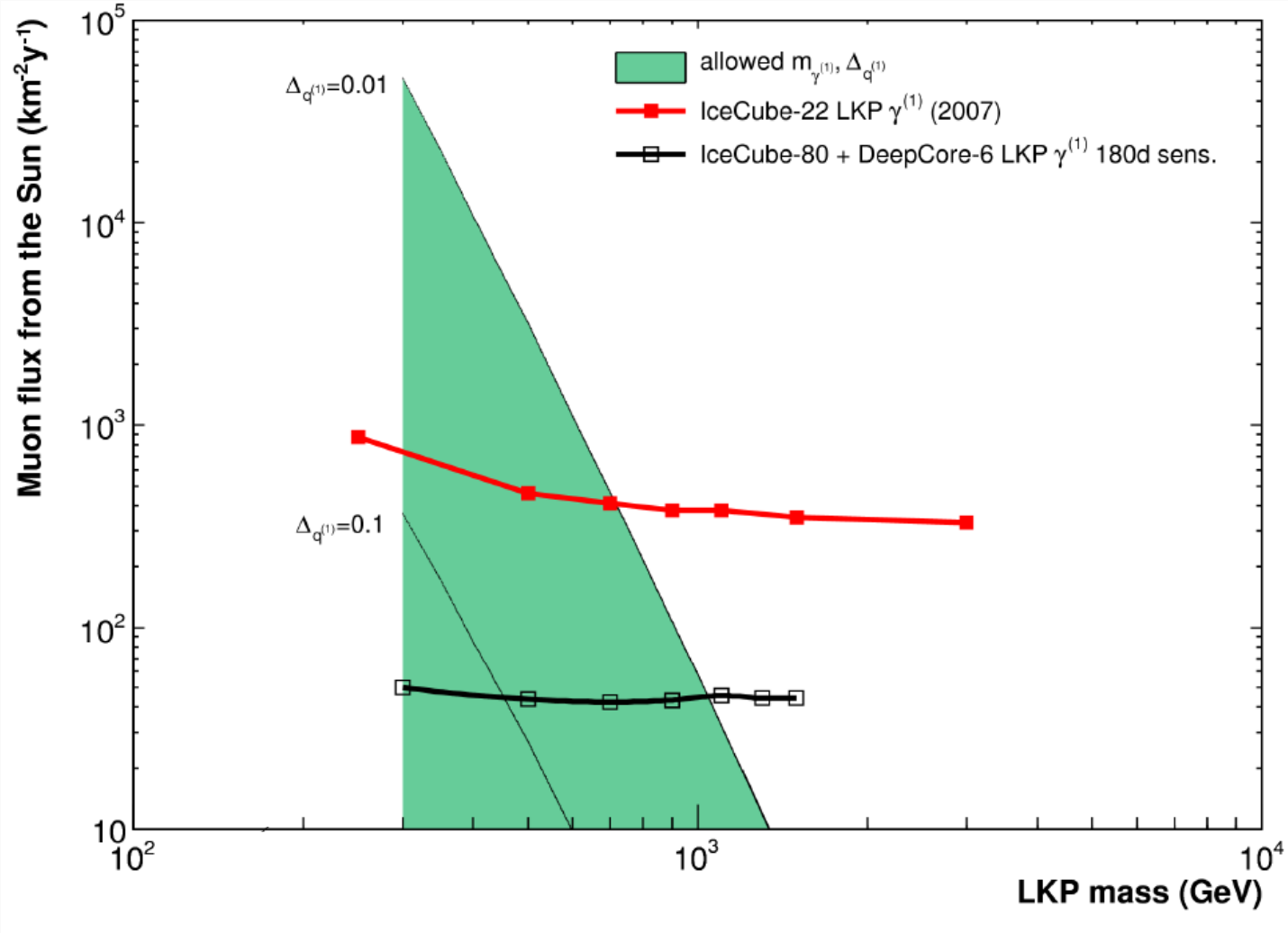
Corresponding σ_{SI} more than factor 10^3 below current direct limits

Abbasi et al., *PRL* **102**, 201302 (2009)
Proc. 31st ICRC ArXiv:0906.1615



KK Muon Flux Limit

Abbasi et al., *Phys. Rev.* **D81** (2010) 057101



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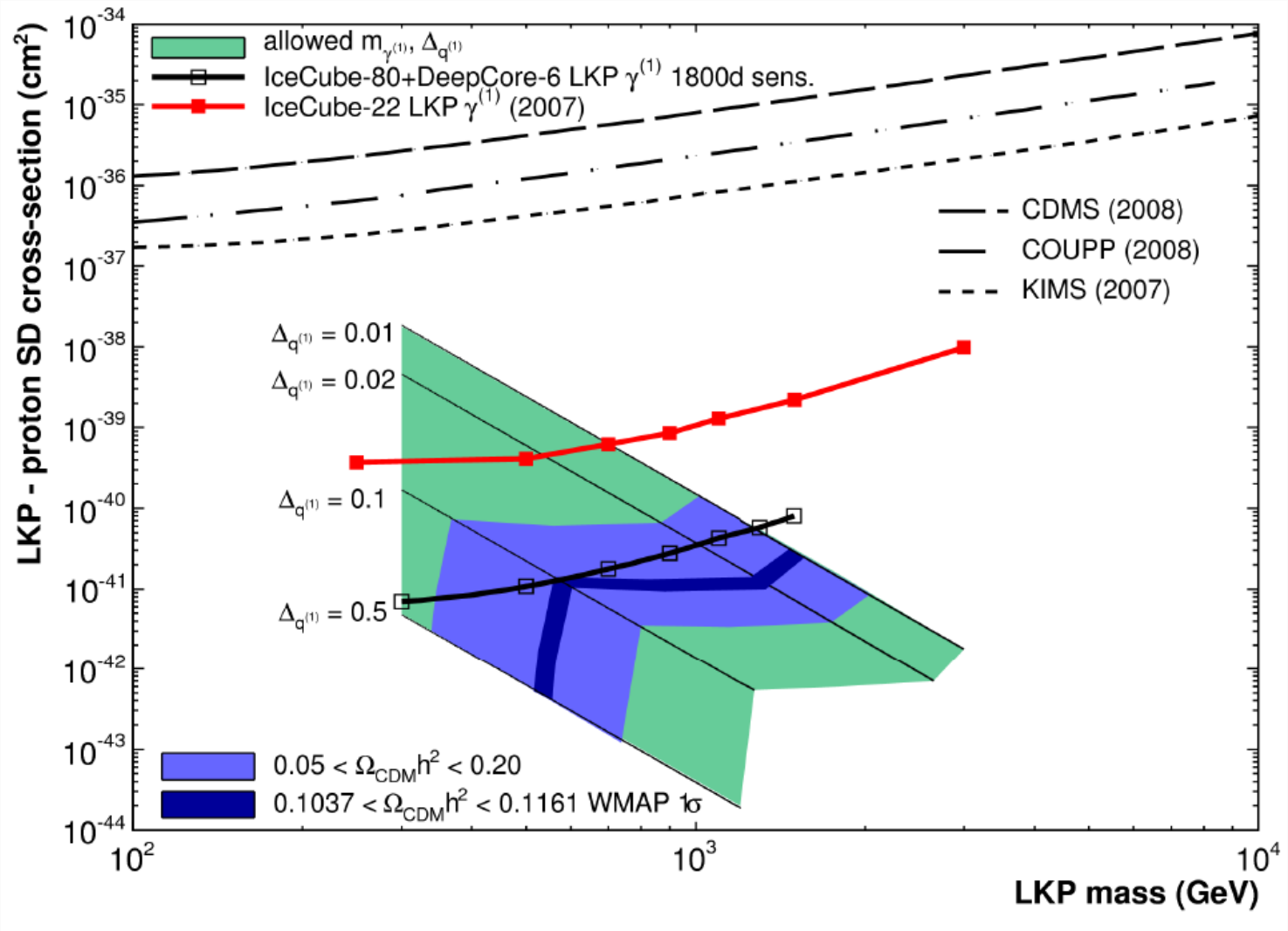
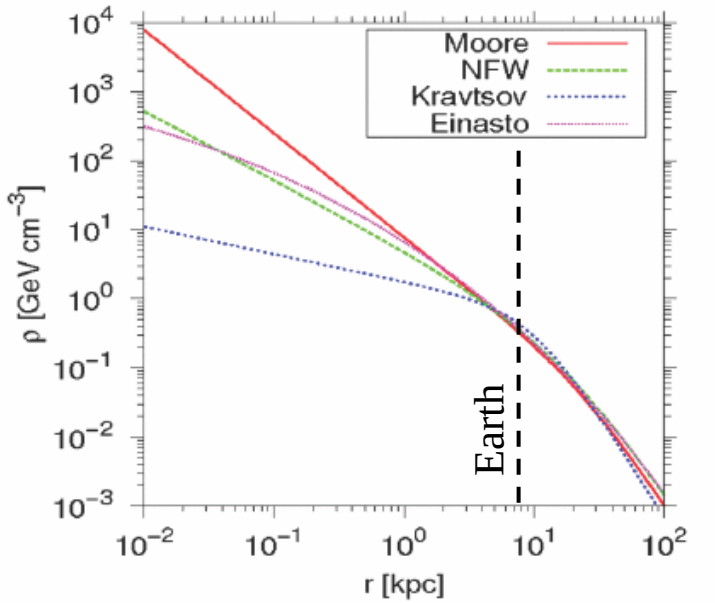


Dark Matter from the Galaxy

- Select halo density profile
- Select SUSY model to determine produced neutrino spectrum
- Measure flux at Earth to constrain the self annihilation cross-section



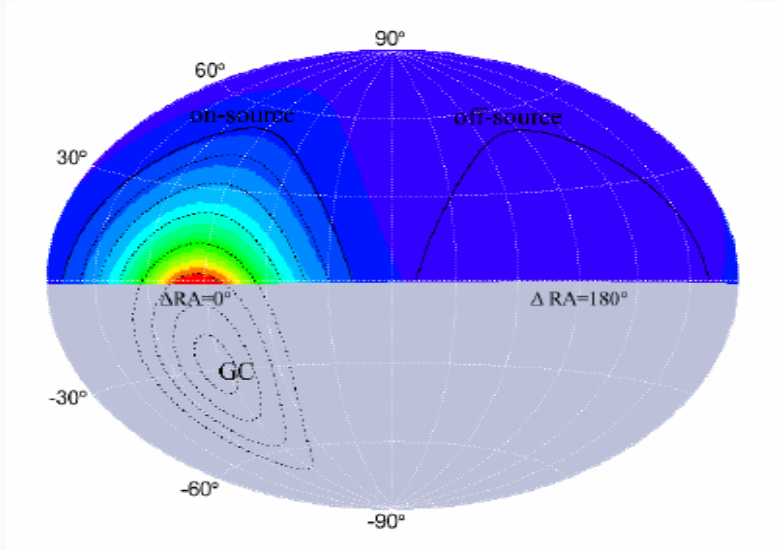
$$\frac{d\Phi_\nu}{dE} = \frac{\langle \sigma_A \upsilon \rangle}{2} J(\psi) \frac{R_{sc}\rho_{sc}^2}{4\pi m_\chi^2} \frac{dN_\nu}{dE}$$

Measure

Constrain

Halo

SUSY



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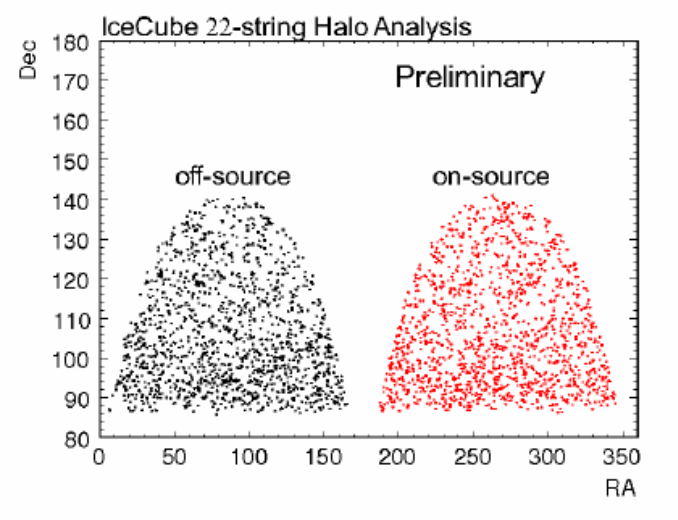
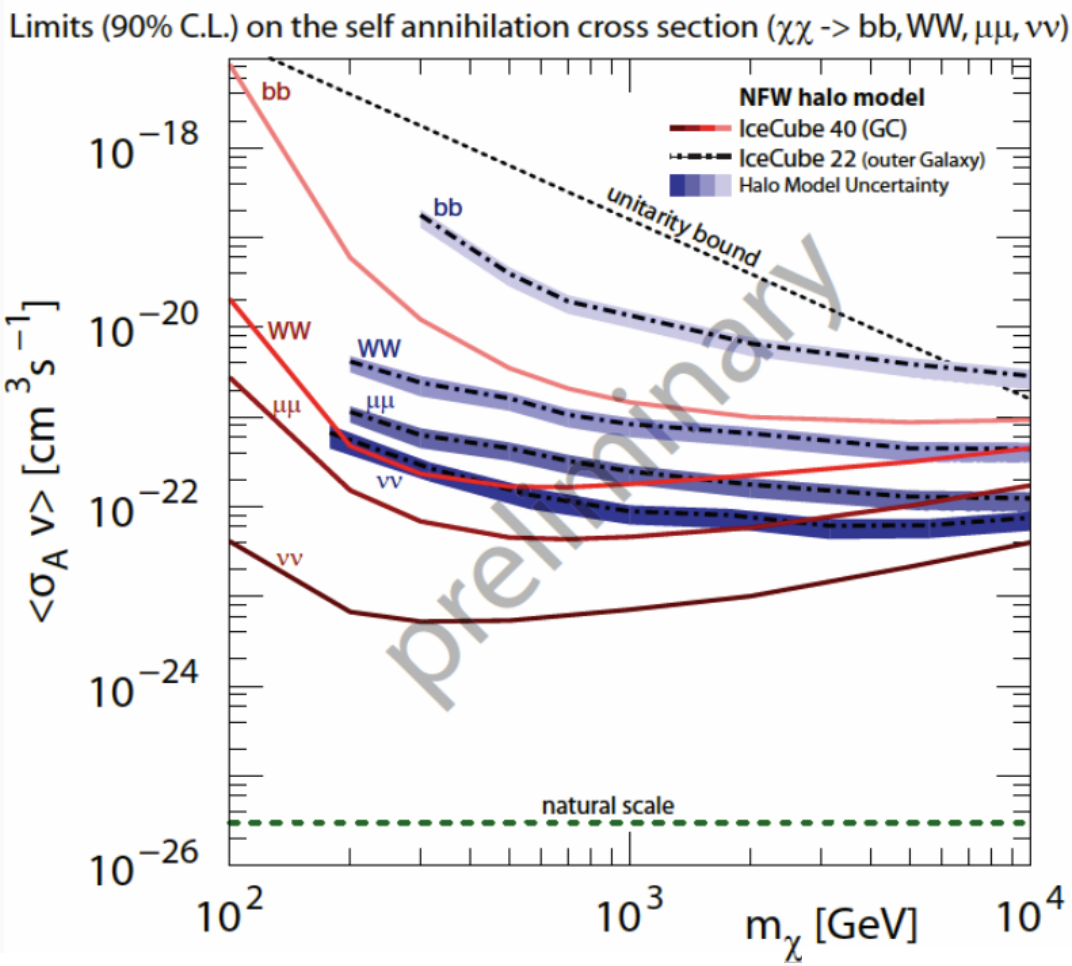
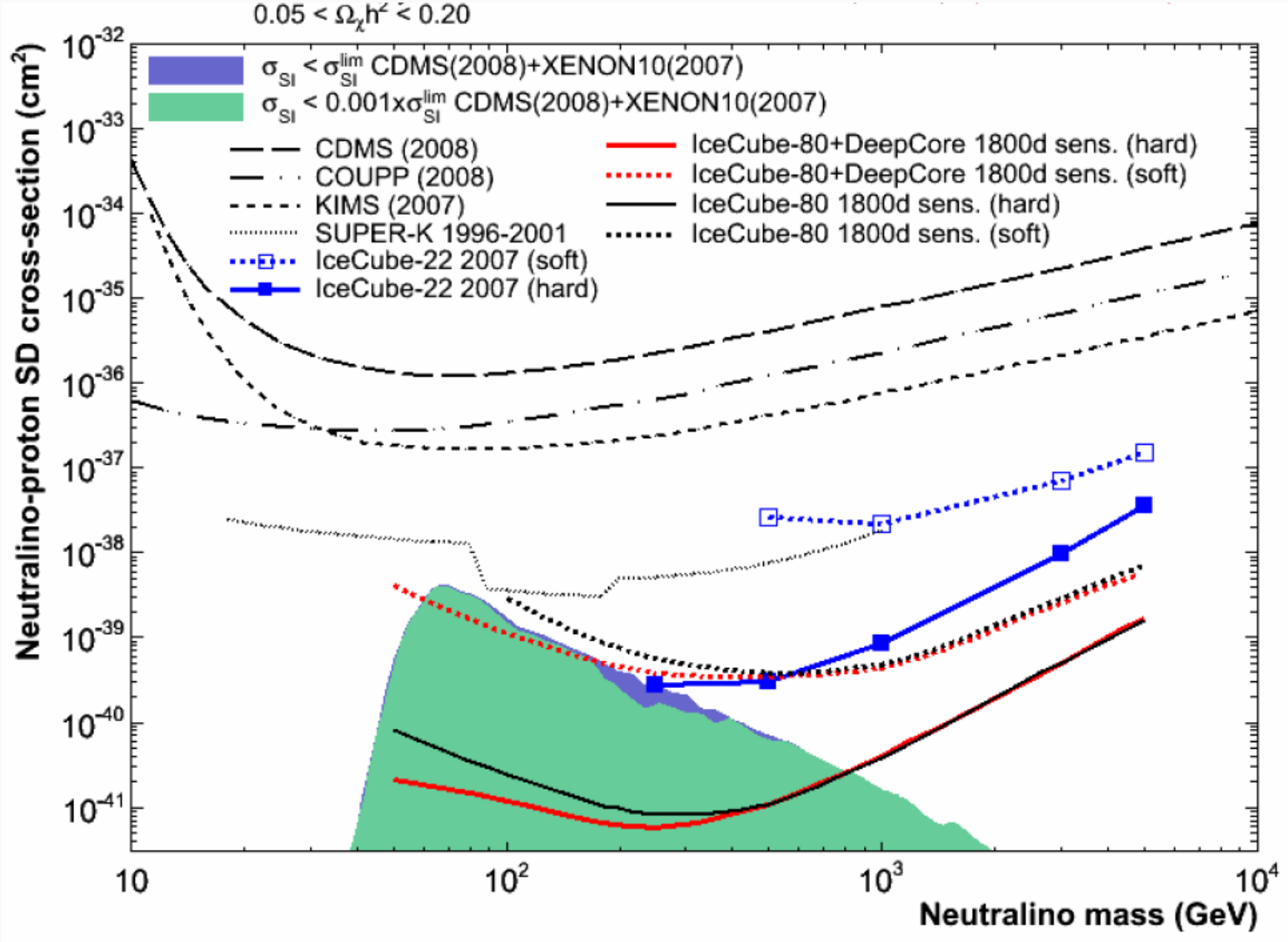




- Initial limits for various annihilation channels shown in blue
- Method improved using 40-string dataset (red)
  - Specially filtered to look at GC
  - Hint of improvements to come with DeepCore

The DeepCore Advantage



Conclusions and Outlook

- Indirect searches with neutrinos can probe the WIMP-nucleon scattering cross section (Sun) and the self-annihilation cross section (Galactic Halo / Center)

- First results from 22 and 40 string IceCube configurations have been published
  - 40 and 59 string analyses are underway
  - Final (6 yr.) AMANDA-II analysis finishing

- DeepCore installation complete, IceCube nearing completion
  - 79 string data taking and analysis have begun
  - New low energy triggers, filters, and reconstructions
  - Full year searches possible with active veto
  - Increased sensitivity to searches for low mass WIMPs (30-100 GeV)