Solar WIMP Annihilation Search with IceCube

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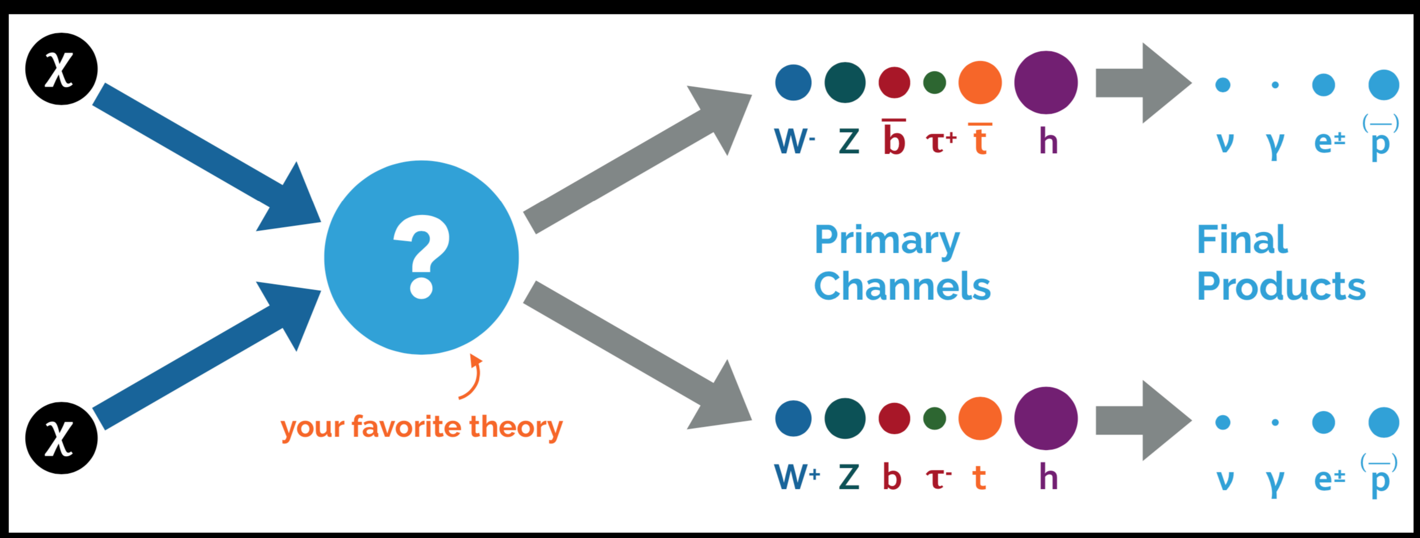
Dark matter refers to matter that neither emits nor absorbs light and does not interact electromagnetically. Thus, it cannot be seen directly by telescopes. Cosmology tells us that it must make up the bulk of the matter in the universe.

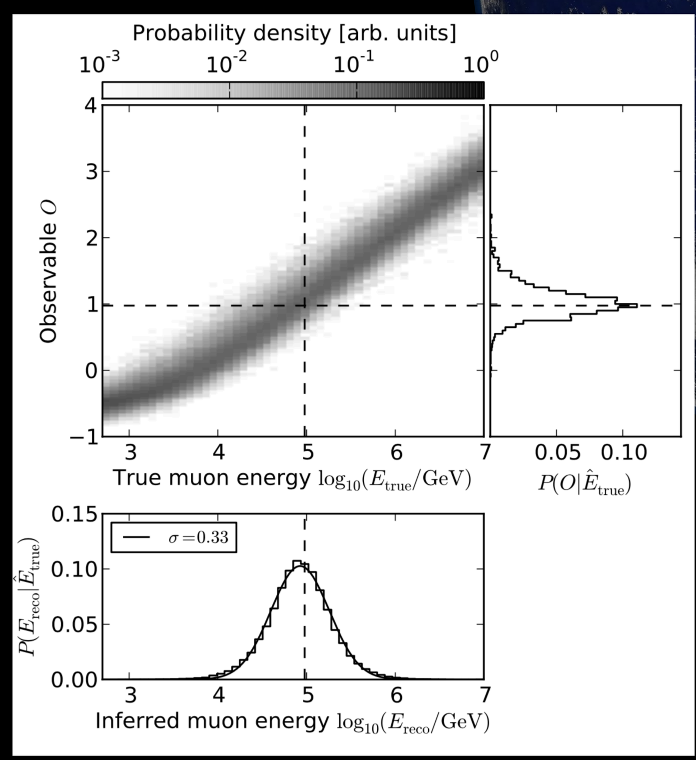
Weakly interacting massive particles (WIMPs) are a class of dark matter candidates. If they exist, they can scatter off nucleons in massive celestial bodies, losing energy, and eventually falling to the core of that body. There, they annihilate to Standard Model particles, producing neutrinos directly, or indirectly via subsequent decays.

Indirect Detection Searches look for the products of WIMP annihilations, in this case muon neutrinos.



IceCube is a cubic-kilometer Cherenkov detector installed in the antarctic ice at the geographic South Pole[2] between 1450 m and 2450 m below the surface of the ice. Completed in 2013, it has detected a diffuse astrophysical neutrino flux extending to ~PeVs, as well as an atmospheric neutrino flux from cosmic rays from 100GeV to 400TeV.

Detection of the Cherenkov radiation allows reconstruction of energy, direction, and flavor.



Reconstructed muon energy versus true muon energy in IceCube[3]

The Strategy: Look for an excess of neutrinos over the atmospheric flux from the direction of the sun.

$$\dot{N} = C_C - C_A N^2 - C_E N$$

Capture rate — Proportional to $\sigma_{N\chi}/m_\chi$

Annihilation rate — Sets the rate at which neutrinos are produced and thus the number of neutrinos IceCube expects

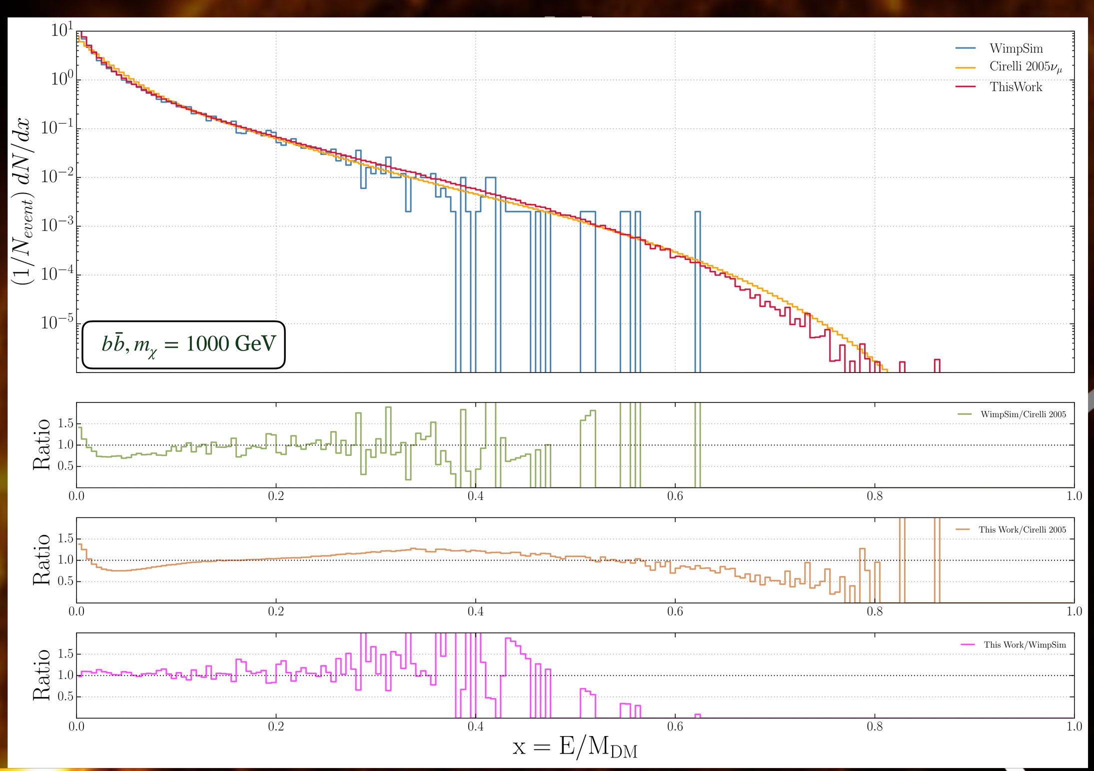
Evaporation rate — Is expected to be negligible for all WIMP masses to which this analysis is sensitive[4]

Rate of WIMPS entering sun — Is expected to be zero for stars the age of the sun for the WIMP masses to which this analysis is sensitive[4]

For the range of WIMP masses considered in this analysis, the number of neutrinos IceCube detects should be constrained only by the WIMP-nucleon cross section

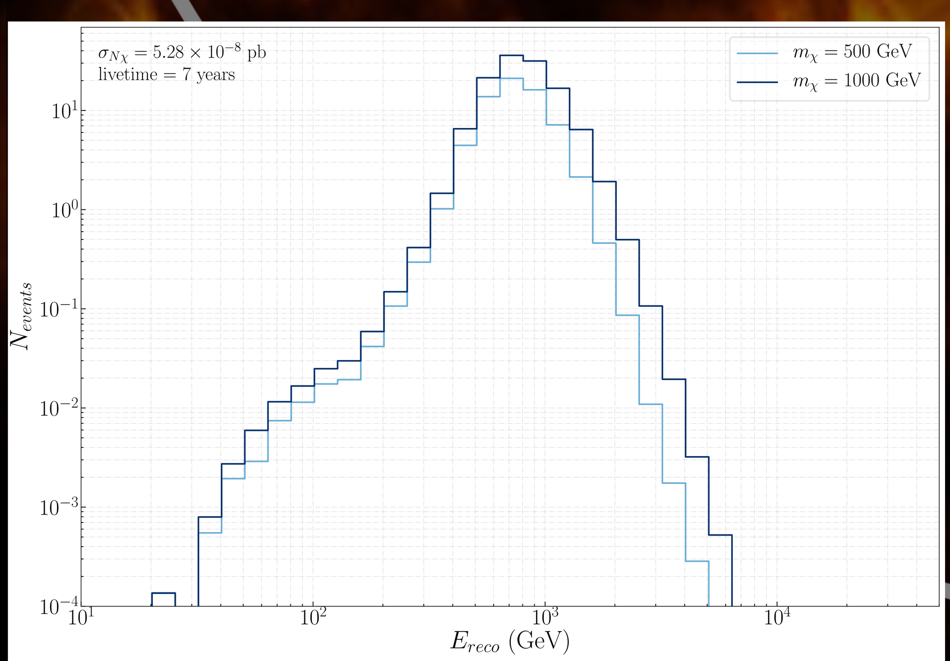
Step one: Signal simulation

Simulate WIMP annihilations in the sun to get neutrino energy spectra. In this work, we compared WIMPSim[5], Herwig[6], and Pythia[7] to better understand systematic uncertainties in signal generation.

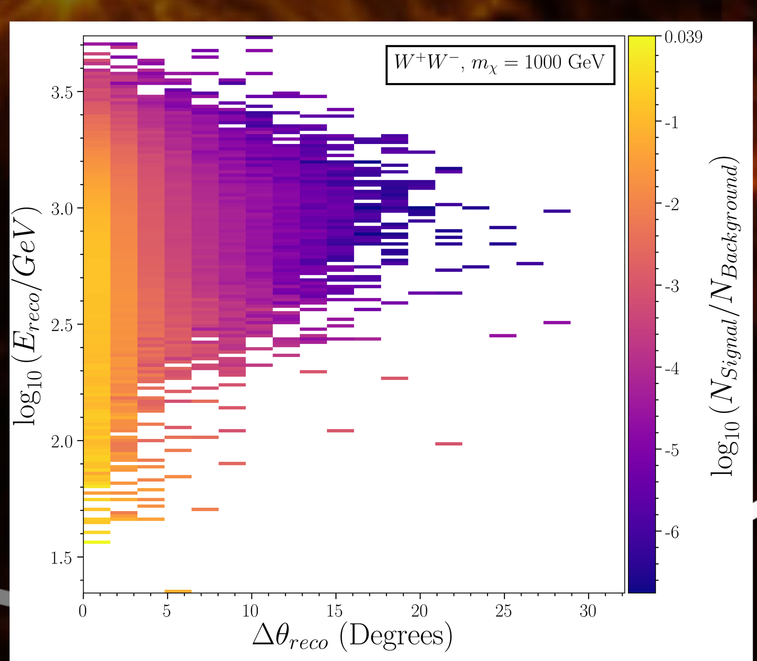


Step two: Detector response

Simulate IceCube's response in reconstructed muon energy, and reconstructed direction.



Expected number of events at IceCube as a function of reconstructed energy, using current limits on WIMP-nucleon cross section from the IceCube 3 year solar WIMP search.

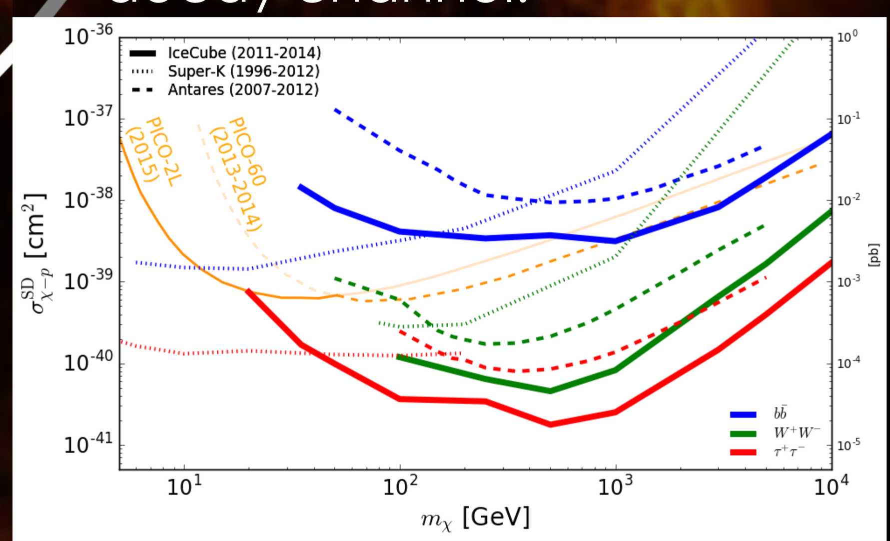


Signal to atmospheric background ratio as a function of energy, and angular distance from the sun.

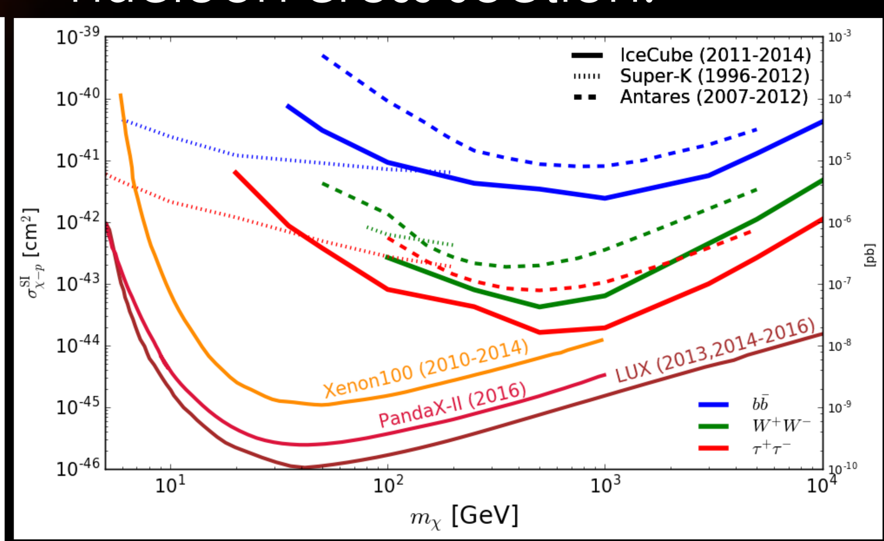
Step three: Fit observed data to signal + background

Excess observed → Evidence for WIMPs ! Find best fit for WIMP mass and decay channel.

No excess observed → Improve upon current IceCube limits on WIMP-nucleon cross section.



Current limits on spin-dependent cross section



Current limits on spin-independent cross section

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References

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