WIMP Annihilations in the Sun

A Search using the first year of operation of the completed IceCube neutrino telescope.

M. Rameez for the IceCube collaboration

UNIVERSITÉ DE GENÈVE

Rencontres de Moriond
Electroweak Session, La Thuile
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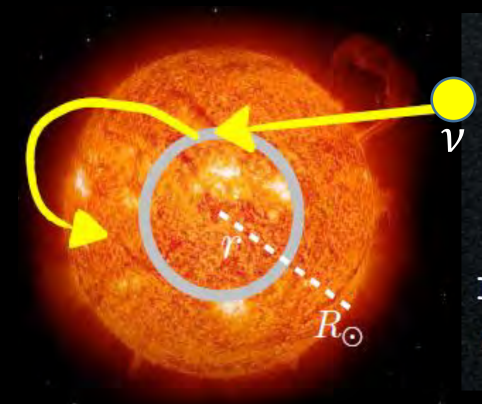
WIMP Capture and Annihilation in the Sun



$$\Gamma_{\rm capt} = \frac{\rho_{\rm DM}}{M_{\rm DM}} \sum_i \sigma_i \int_0^{R_\odot} dr\, 4\pi r^2\, n_i(r) \int_0^\infty dv\, 4\pi v^2 f_\odot(v) \frac{v^2 + v_{\odot \rm esc}^2}{v} \wp_i(v, v_{\odot\rm esc})$$

DM number density

Scattering Cross Section
$\sigma_{SD} \propto J(J+1)$
$\sigma_{SI} \propto A^2$

Number density of element i -> Solar Model

velocity distribution
(in solar frame, without Sun's gravity)

effect of solar gravity

Capture

$$\Gamma_A = \frac{C_C}{2} \tanh^2(t/\tau)$$

Equilibrium → $\Gamma_A^{equi} = \frac{1}{2} C_c$

Annihilation

$$\frac{dN}{dt} = C_c - C_A N^2$$

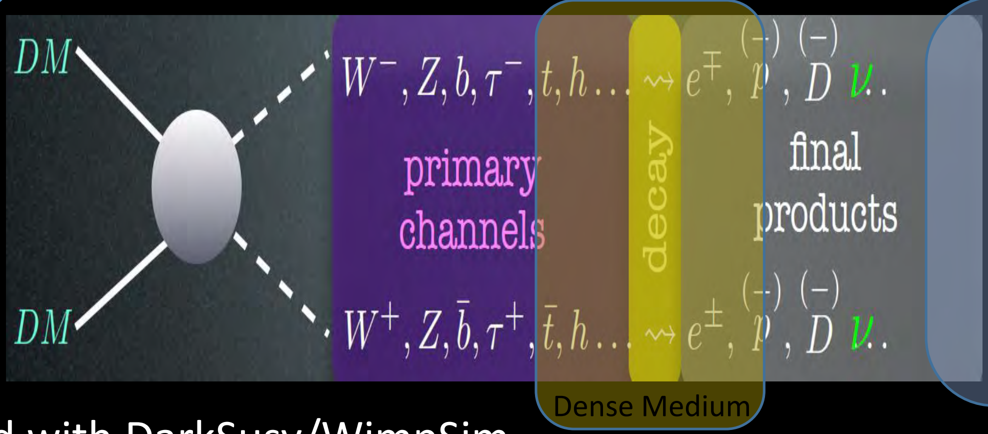
$$\tau = (C_C C_A)^{-1/2}$$

Spin Dependent Scattering

- Only the hydrogen in the Sun contributes significantly.
- Lower Event rates in direct detection experiments
- More Interesting for IceCube

Spin Independent Scattering

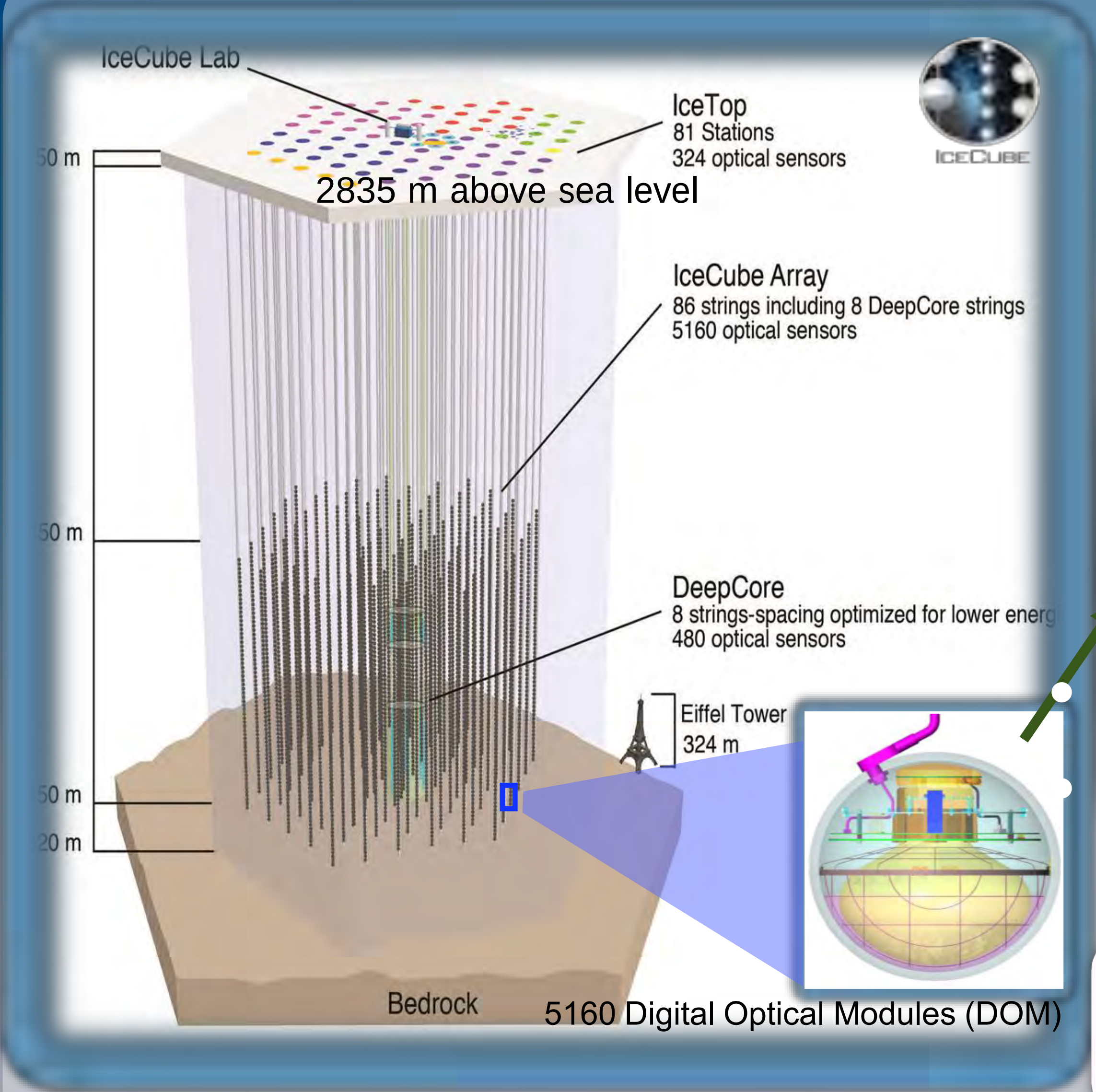
- Heavier Nuclei contribute more due to $\propto A^2$ enhancement.
- Better sensitivity using direct detection experiments such as LUX, XENON etc

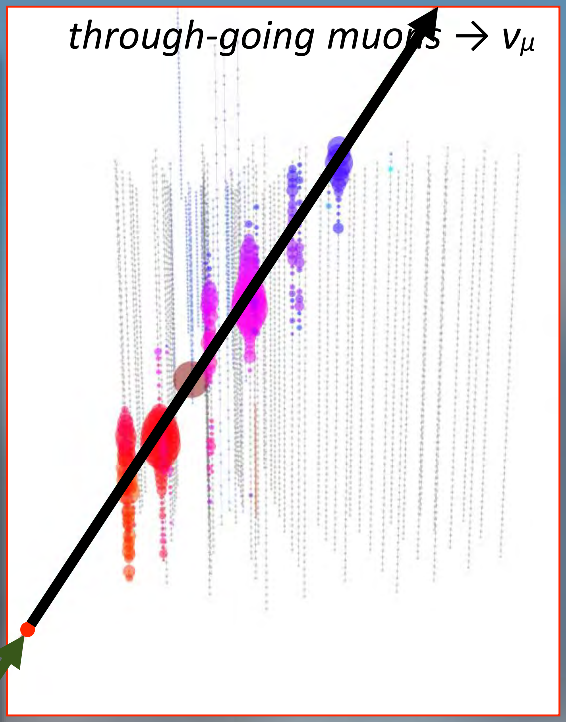


At Earth :
Enhanced neutrino flux in the direction of the Sun!

All calculations performed with DarkSusy/WimpSim

IceCube : Detector and Event Signatures

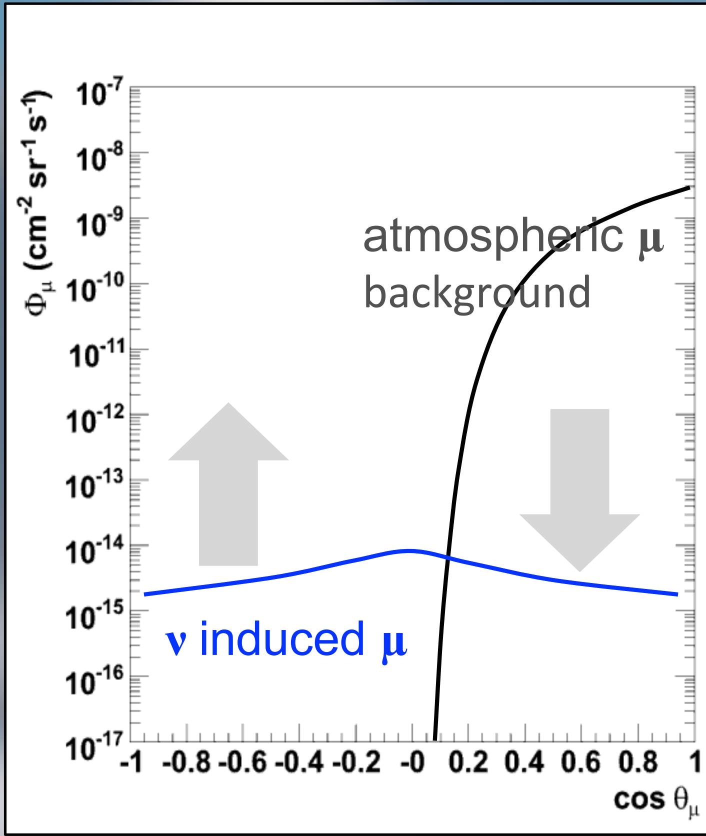




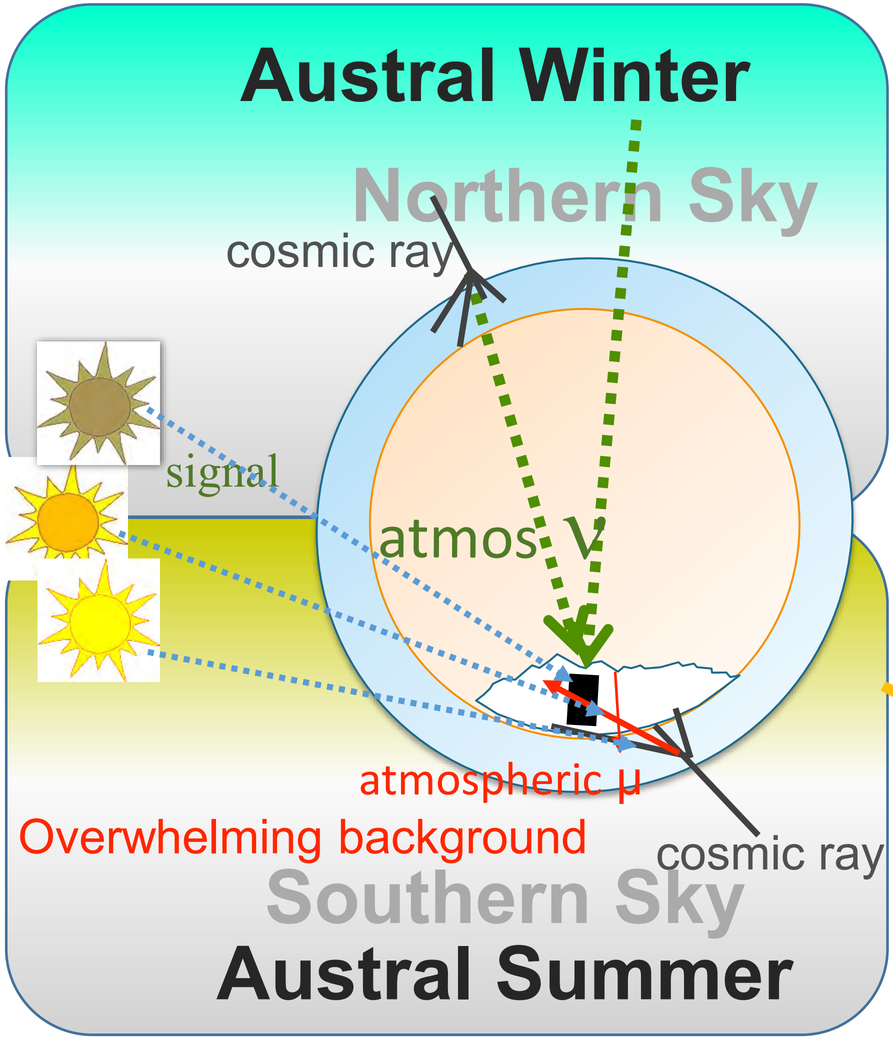
Good angular resolution: **Neutrino Astronomy**

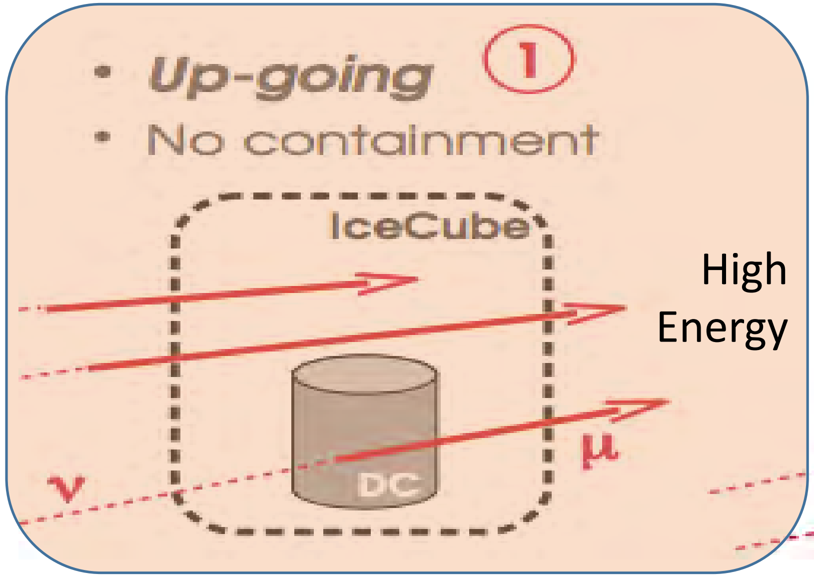
Vertex can be outside the detector: **Increased effective volume!**

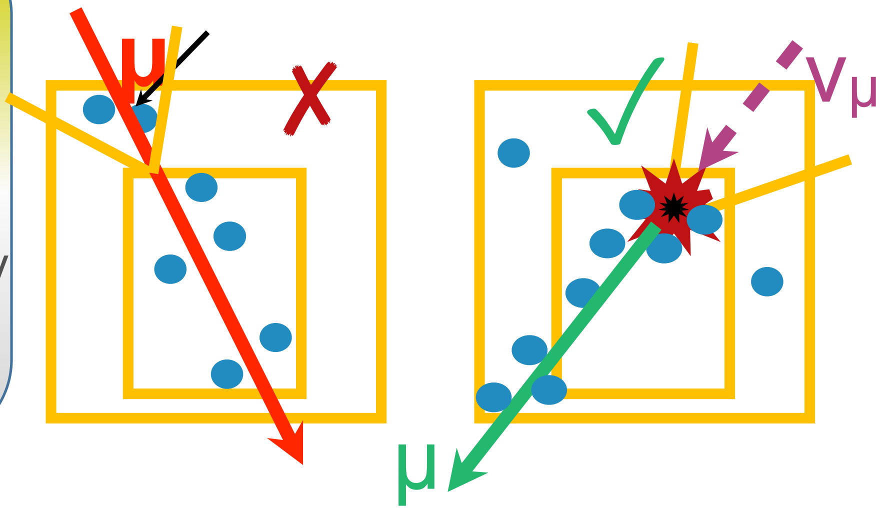
Other signatures such as cascades (ν_e, ν_τ and all-flavor neutral current) are not used in this analysis.

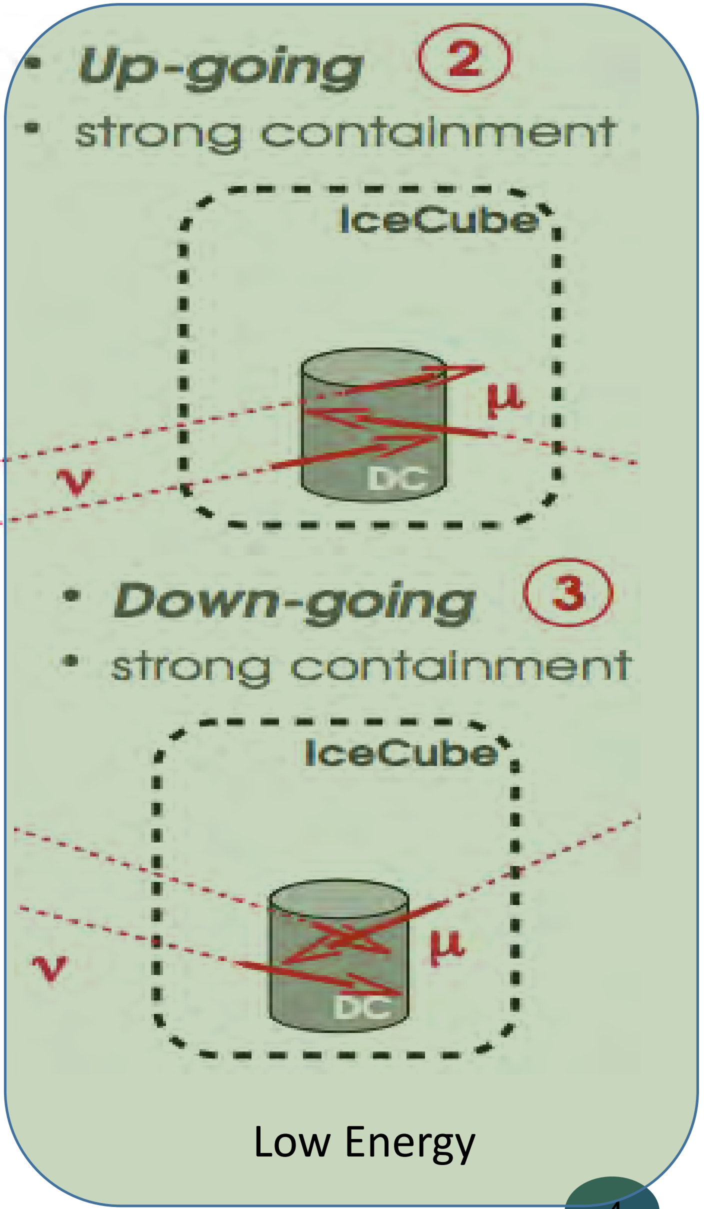


Event Selections









All three samples are non overlapping and hence combined in likelihood.

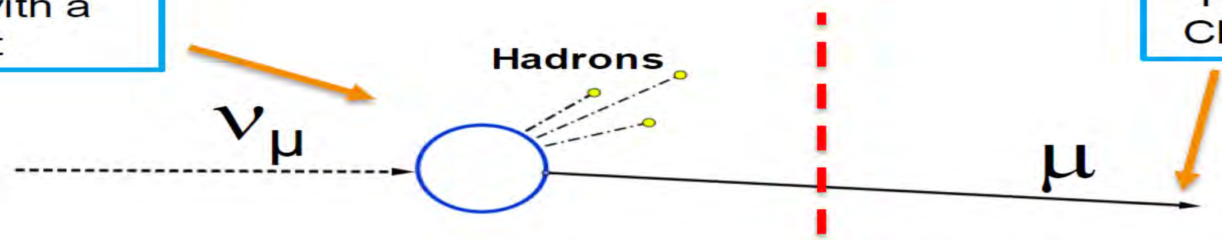
Energy Reconstruction

A full energy estimator (for contained tracks)

$$E_{\text{reco}} = E_{\mu}(R_{\mu}) + E_{\text{vertex}}(E_{\text{had}}, \vec{x}_{\text{vertex}})$$

Fit of a cascade with a track segment

Find last point of Cherenkov emitter

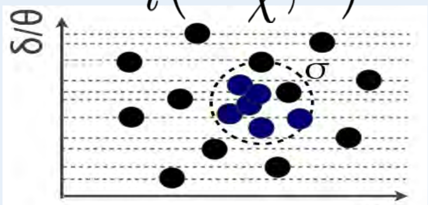


Analysis Method

Signal

$$S_i(m_{\chi}, c) = Kent(\alpha_{sun}, \delta_{sun}, \alpha_i, \delta_i, \sigma_i).P(E_i|m_{\chi}, c)$$

Spatially Clustered around the Sun



Background

$$B_i = B(\theta_i).P_{atm}(E_i)$$

Estimated from Scrambled data

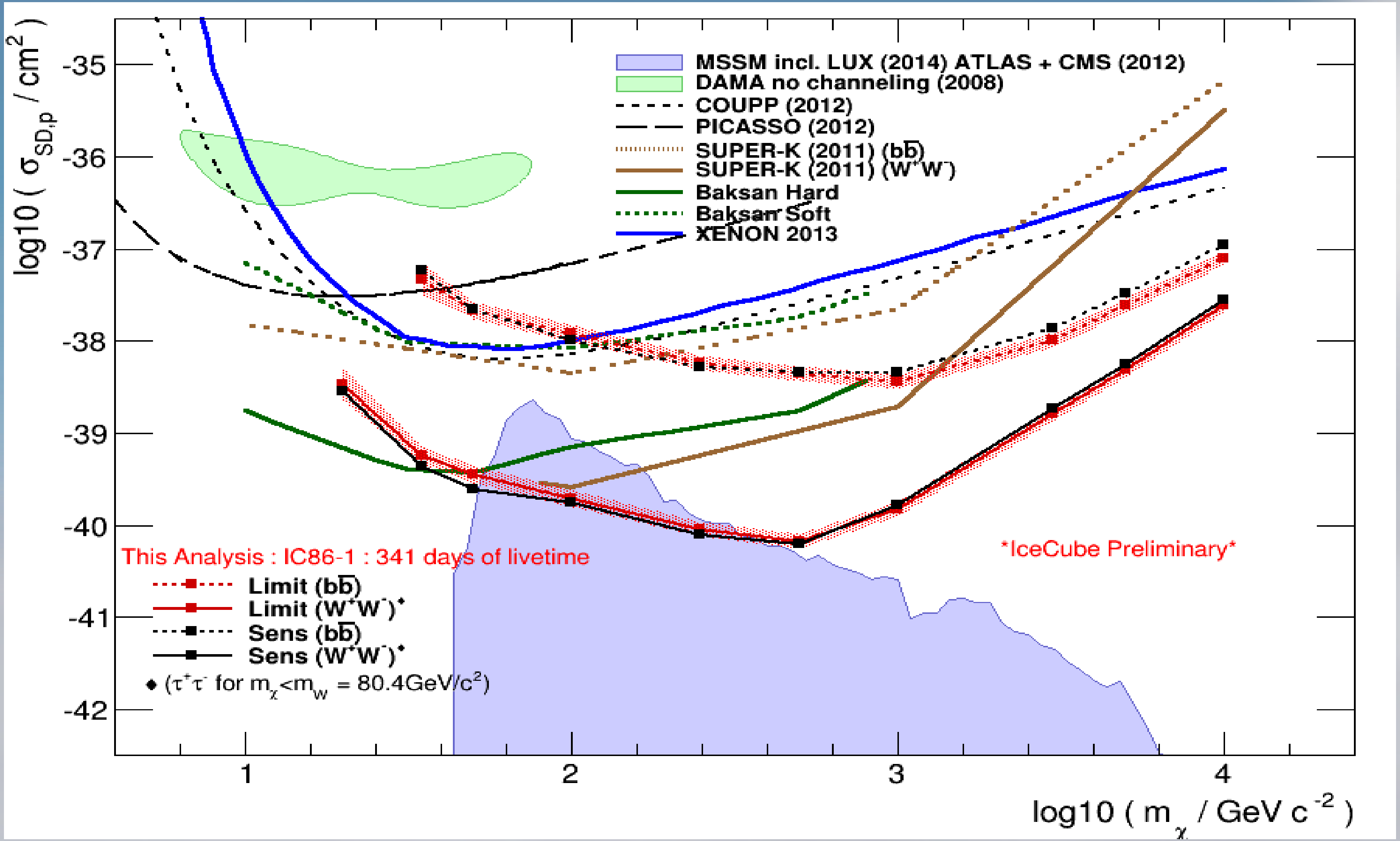
Likelihood

$$\mathcal{L}(n_s) = \prod_{i=1}^{N}\left(\frac{n_s}{N} S_i(m_{\chi}, c) + (1 - \frac{n_s}{N}) B_i\right)$$

$$log(\lambda) = log\left(\frac{\mathcal{L}(\hat{n}_s)}{\mathcal{L}(n_s = 0)}\right)$$

The likelihood ratio is maximized w.r.t n_s to obtain $\hat{n}_s$. Confidence intervals on n_s are built using the method of Feldman and Cousins.

Results

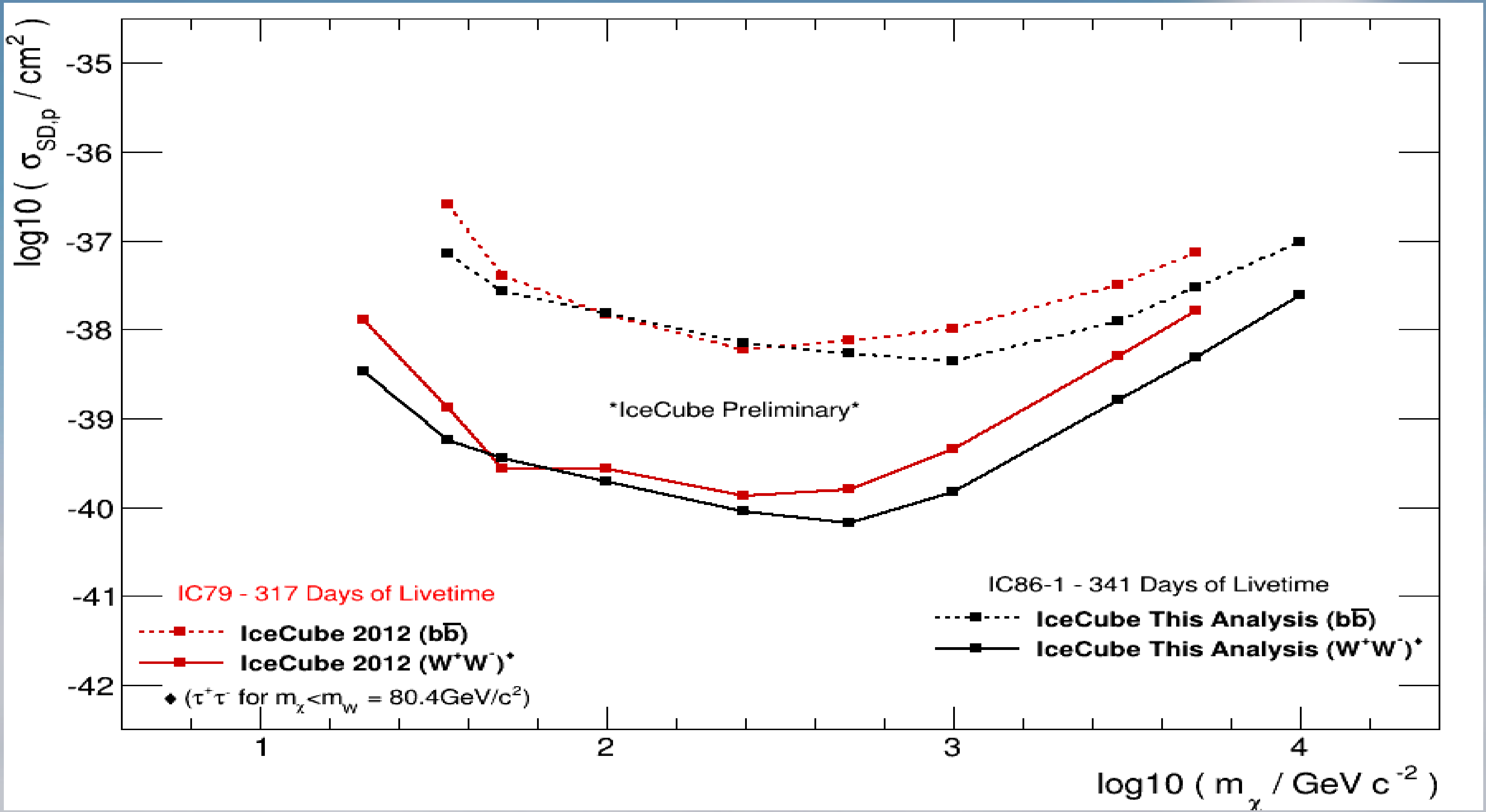


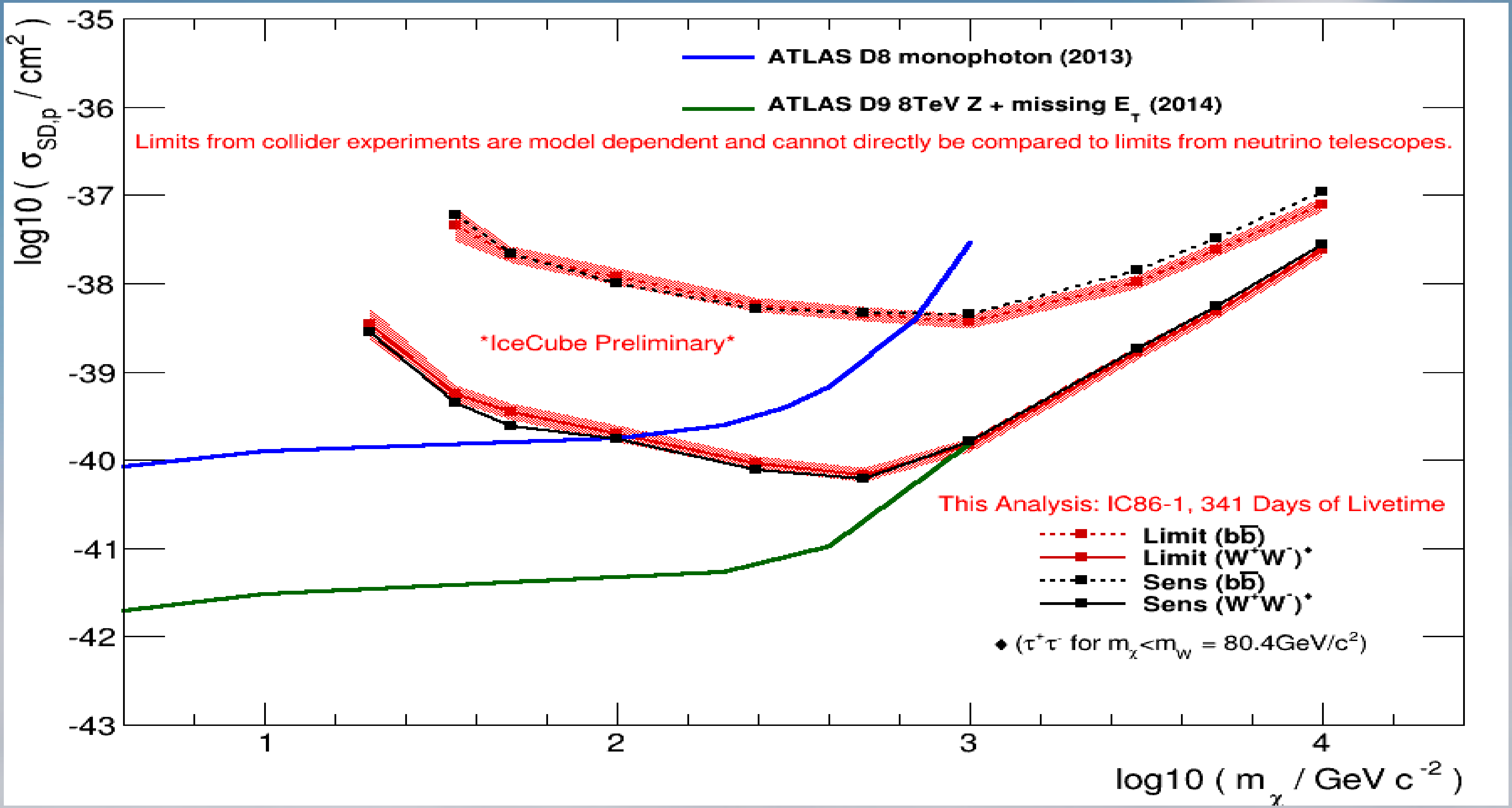
Assume equilibrium between capture and annihilation in the sun -> Set limit on WIMP-Nucleon scattering cross section

Comparable to direct detection experiments.

Backup Slides

Comparison with previous IceCube Analysis




ATLAS D8 monophoton (2013)
ATLAS D9 8TeV Z + missing E_T (2014)
Limits from collider experiments are model dependent and cannot directly be compared to limits from neutrino telescopes.
IceCube Preliminary
This Analysis: IC86-1, 341 Days of Livetime
Limit ($b\bar{b}$)
Limit (W^+W^-)*
Sens ($b\bar{b}$)
Sens (W^+W^-)*
* ($\tau^+\tau^-$ for $m_\chi < m_W$ = 80.4GeV/c^2)
$\log10(\sigma_{SD,p} / cm^2)$
$\log10(m_\chi / GeV\ c^{-2})$
-35
-36
-37
-38
-39
-40
-41
-42
-43
1
2
3
4

Spin Independent Scattering