

Neutrino Signals from Solar Neutralino Annihilations in AMSB Model

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based on

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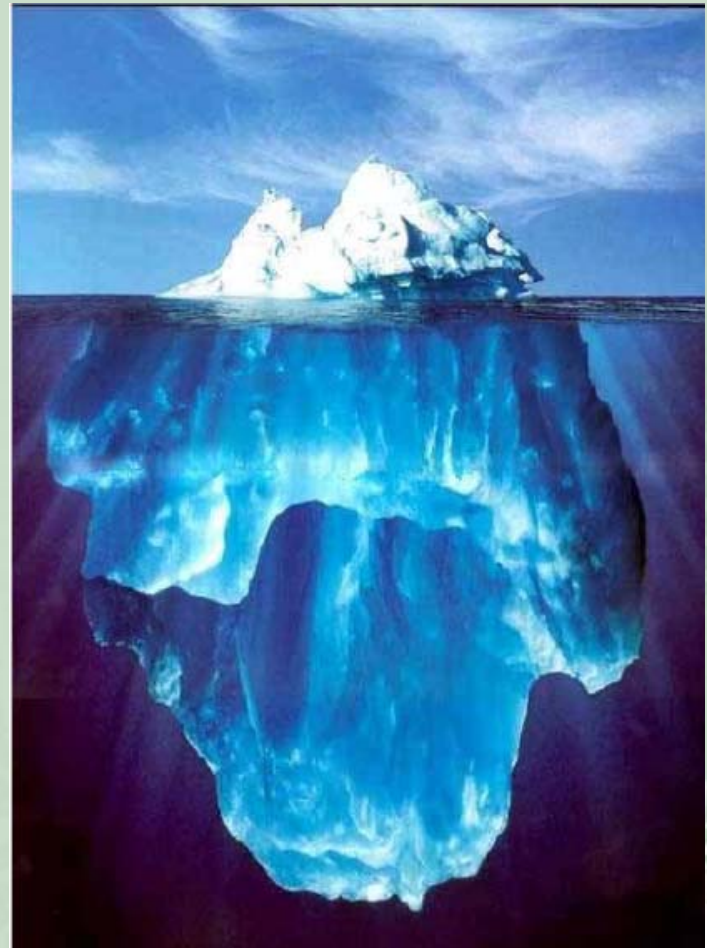
Outline

- Dark Matter
- Neutrino from neutralino annihilation in Sun
- Neutrino propagation
- Muon detection in IceCube
- Summary



Dark Matter

- Non-luminous matter with gravitation effects
- Galactic rotation curves
- Cold dark matter by analyses of structure formation
- WMAP
$$\Omega_{nbm} h^2 = 0.111 \pm 0.006$$
$$\Omega_b h^2 = 0.023 \pm 0.001$$



From SUSY07 public lecture

Candidate for Dark Matter

Conditions

- Stable on cosmological time scales
- Very weak electromagnetic radiation
- Right relic density

Candidates

- Weakly interacting massive particles(WIMP)
 - Neutralino in Supersymmetry
- Primordial black holes, Axions, KK particle



Experiment for Dark Matter

Direct WIMP search

- Detection of nuclear recoils
- Cryogenics detector, Noble liquid
- No positive identification (except DAMA)
- XENON10 $\sigma_{\chi-p}^{SI} < 4.5 \times 10^{-8} pb$ for 100GeV

Indirect WIMP search

- WIMP annihilation and decay
- Photon, neutrino, positron, anti-nuclei

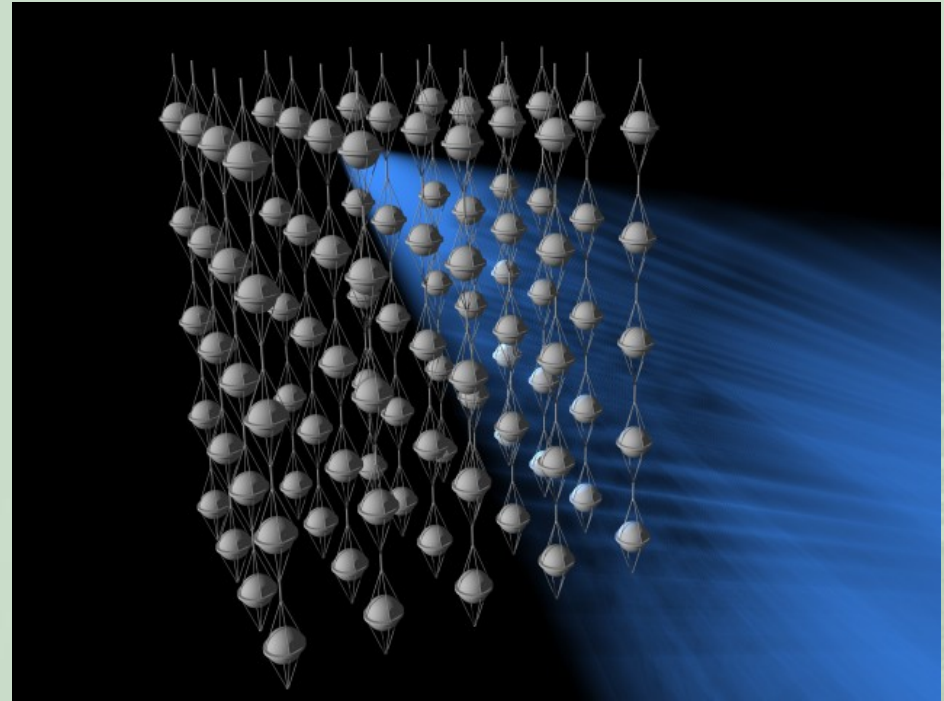


IceCube neutrino detector

- Surpass the sonic barrier
- Muon surpass the speed of light



- Cerenkov light passing through the IceCube neutrino detector



- Courtesy
Steve Yunck/NSF



Neutrino signal from Solar center

- Dark matter scatters off nucleus in Sun
- Trapped by gravitation of Sun

$$\dot{N} = C_{\odot} - C_A N^2$$

- Capture rate equals annihilation rate

$$\Gamma = \frac{1}{2} C_A N^2 = \frac{1}{2} C_{\odot} \tanh^2(\sqrt{C_{\odot} C_A} t)$$

$$C_{\odot} = 3.4 \times 10^{20} s^{-1} \frac{\rho_{local}}{0.3 GeV / cm^3} \left(\frac{270 km / s}{v_{local}} \right) \left(\frac{\sigma_{SD}^H + \sigma_{SI}^H}{10^{-6} pb} \right) \left(\frac{100 GeV}{m_{\tilde{\chi}_0^{-1}}} \right)^2$$

Elastic scattering of nucleus and neutralino

- Spin-dependent interaction
- Axial-vector interaction
- Exchanging Z, squark
- In our paper, SD is dominant
- Experiments in 07

$$\sigma_{SD} < 0.1 pb \sim 1 pb$$

- Spin-independent interaction
- Scalar interaction
- Exchanging H, h, squark
- Dominant in heavy nuclei
- XENON10 for a 100GeV WIMP

$$\sigma_{\chi-p}^{SI} < 4.5 \times 10^{-8} pb$$



Dark matter annihilation in Anomaly Mediated Supersymmetry Breaking Model

- In AMSB SUSY breaking via superconformal anomaly
- Free parameter of Minimal AMSB

$$m_{3/2}, m_0, \tan \beta, \text{sign}(\mu)$$

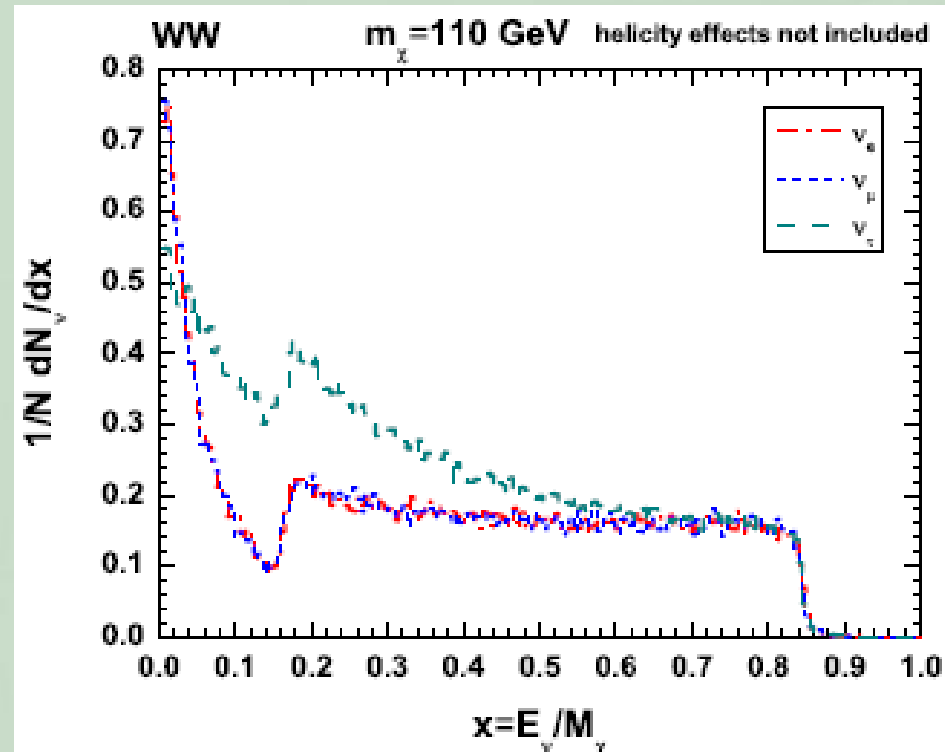
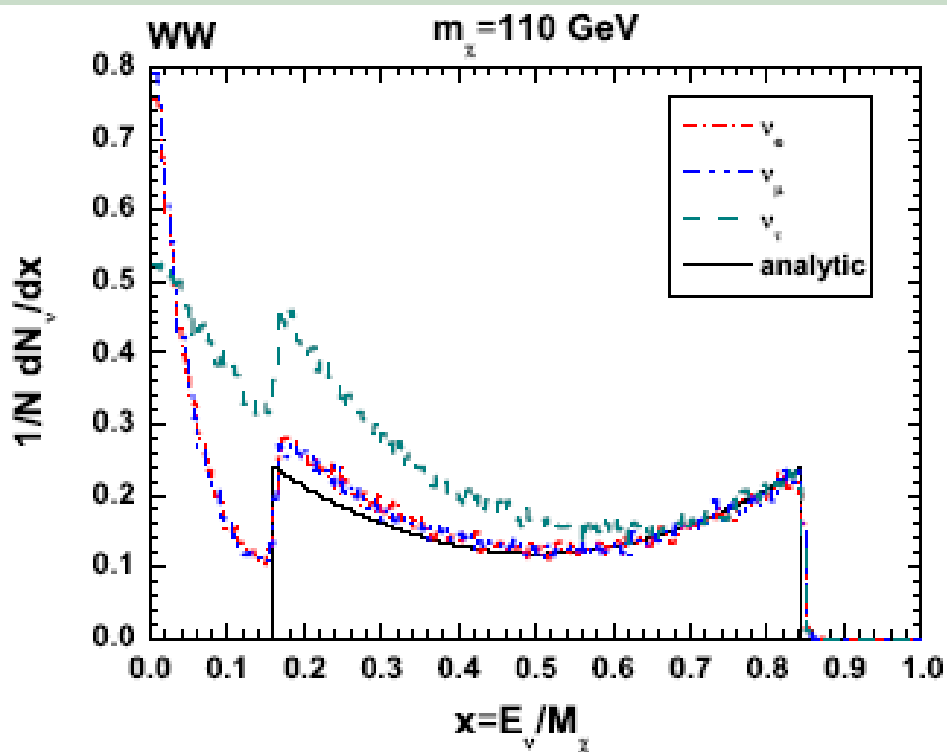
$$\tilde{\chi}_0^{\sim 1} = N_{11} \tilde{B} + N_{12} \tilde{W} + N_{13} \tilde{H}_d + N_{14} \tilde{H}_u$$

- Wino-like neutralino
- Mainly annihilate to WW pair
- Other channel-ZZ, Zh, top pair



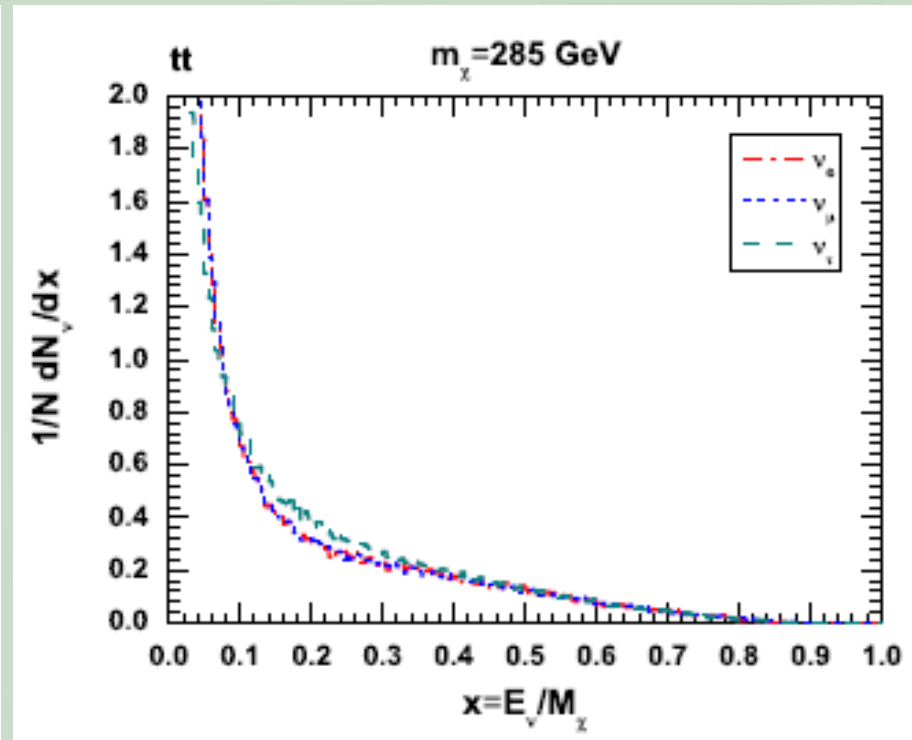
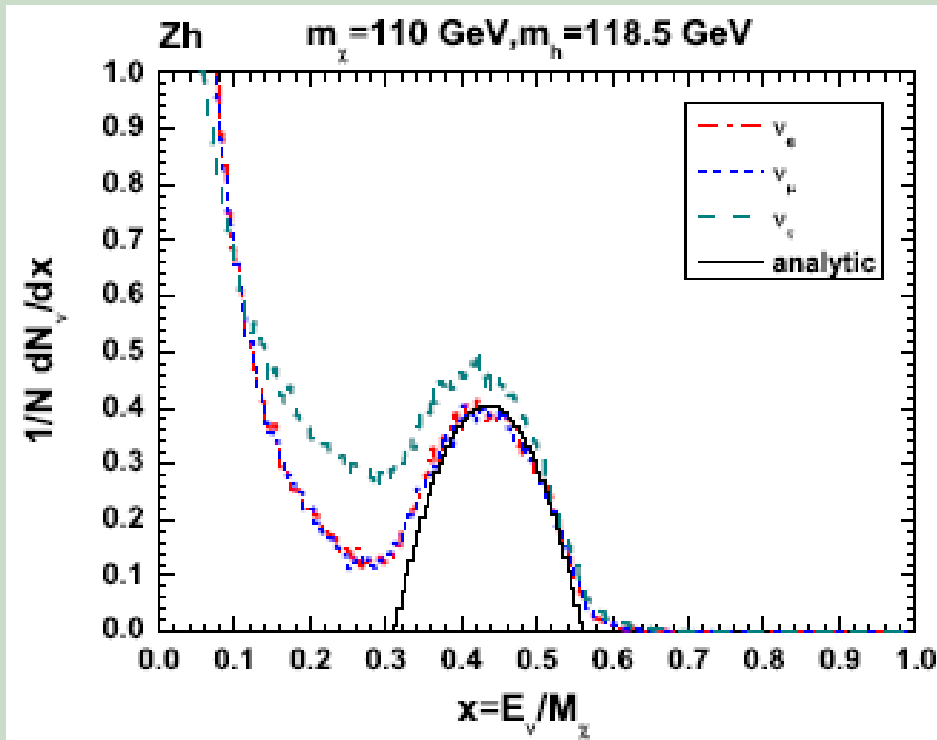
Helicity effects and secondary neutrinos

- Transverse polarized W boson
- Tau lepton decay and quark hadronization



Other annihilation channel

- Z boson in Zh channel is longitudinal polarized
- ZZ is similar to WW



Propagation of neutrinos to Earth

- Density evolution equation of propagation

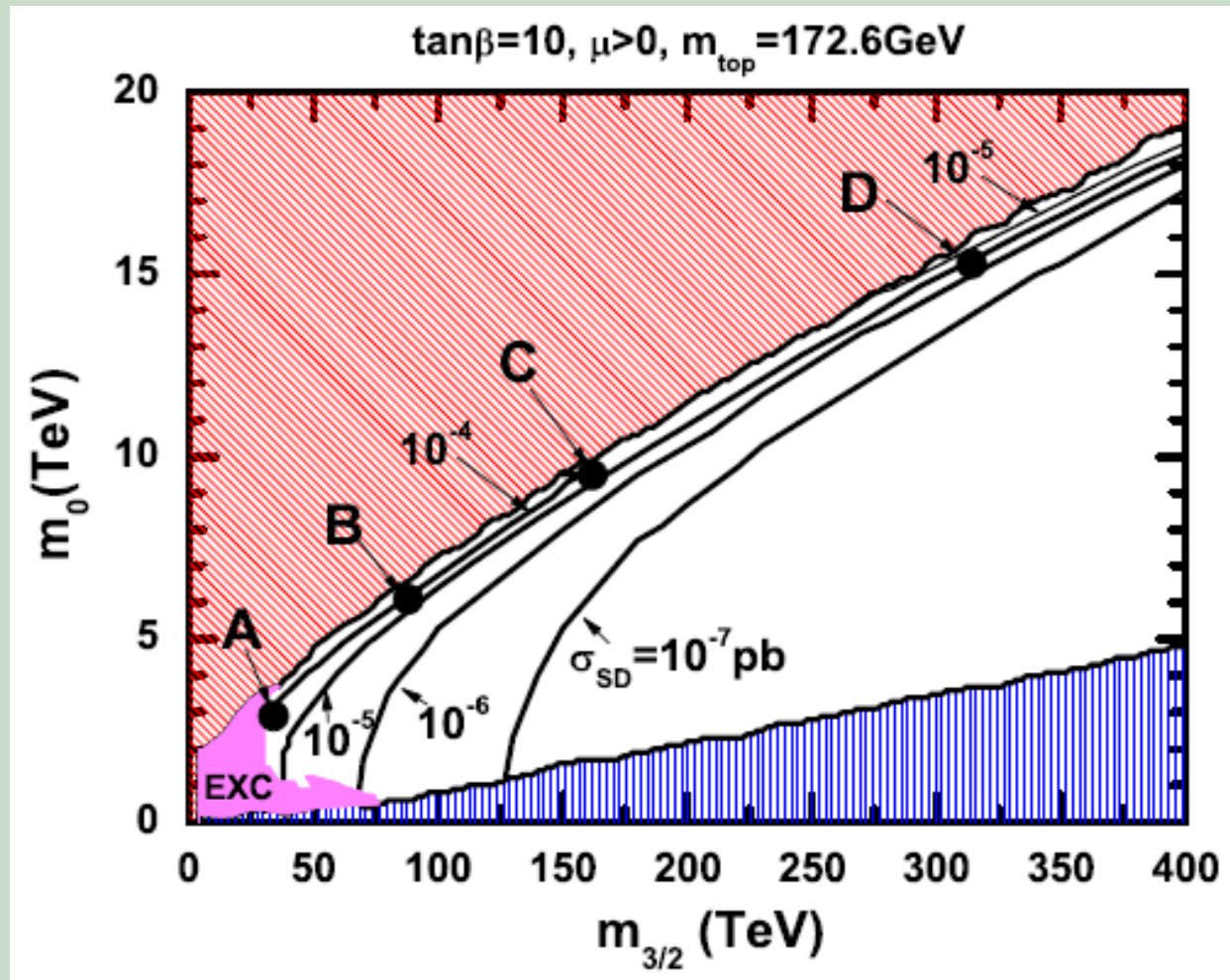
$$\frac{d\rho}{dr} = -i[H, \rho] + \left. \frac{d\rho}{dr} \right|_{NC} + \left. \frac{d\rho}{dr} \right|_{CC} + \left. \frac{d\rho}{dr} \right|_0$$

- Vacuum oscillation
- Neutrino scattering
- Neutrino absorption and tau-neutrino re-injection
- Monte carlo simulation-WimpSim (by J.Edsjo)



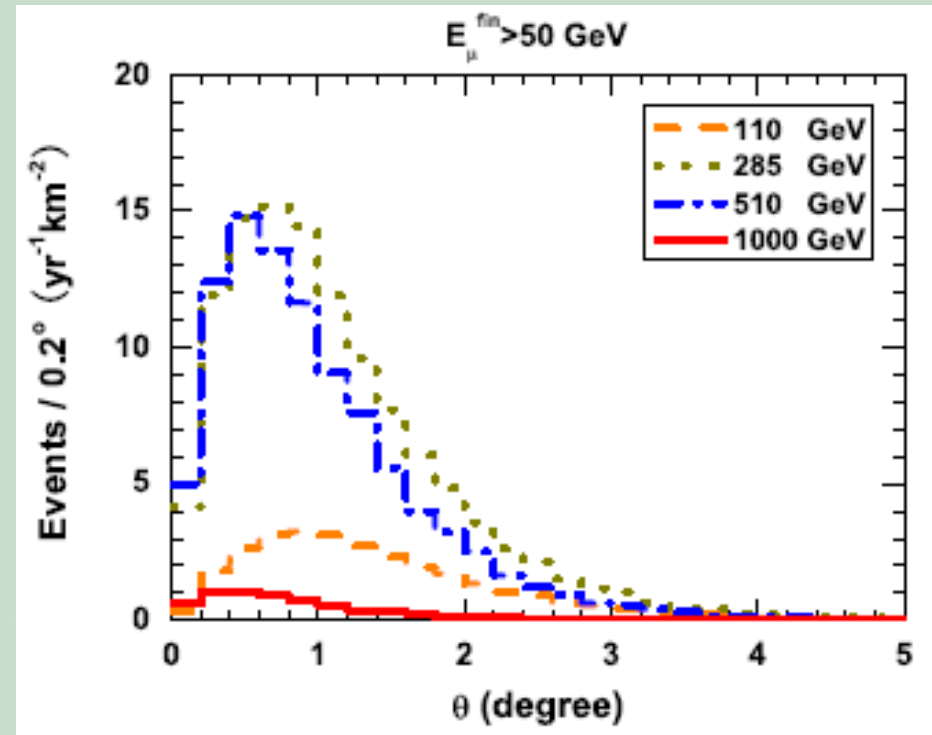
Main conclusions of our paper

- Possible to observe muons at IceCube if $\sigma_{SD} > 10^{-5} pb$

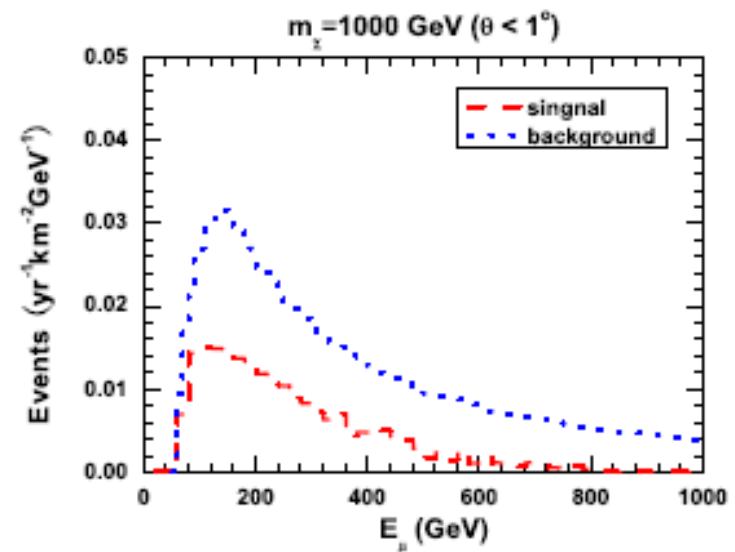
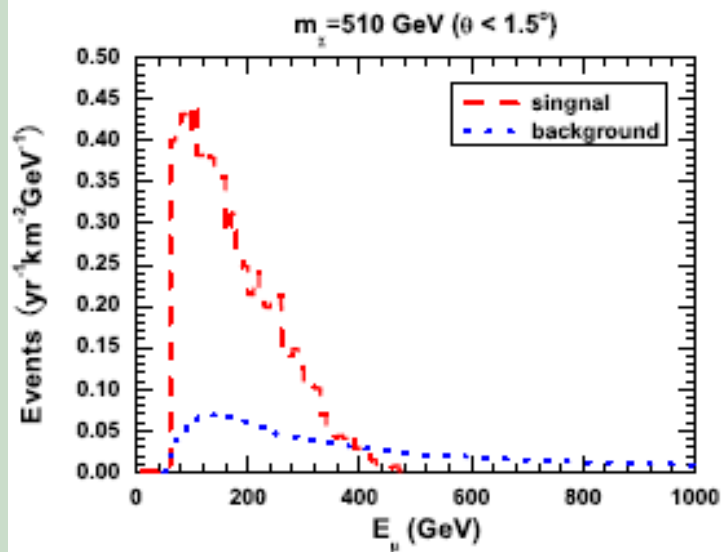
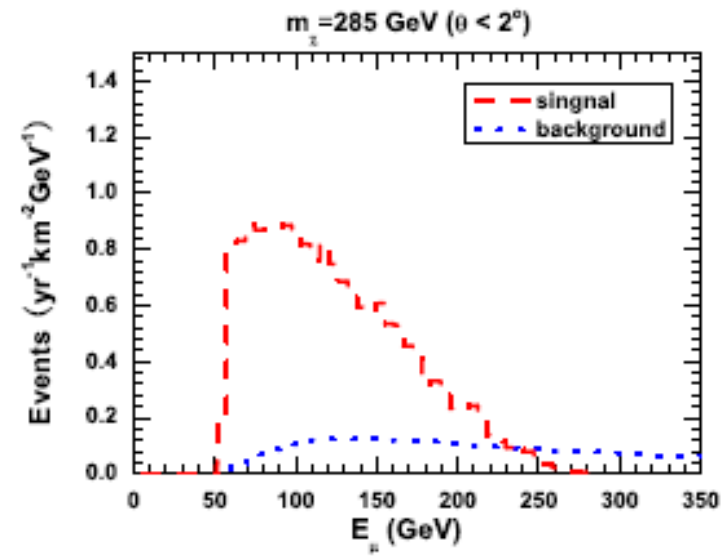
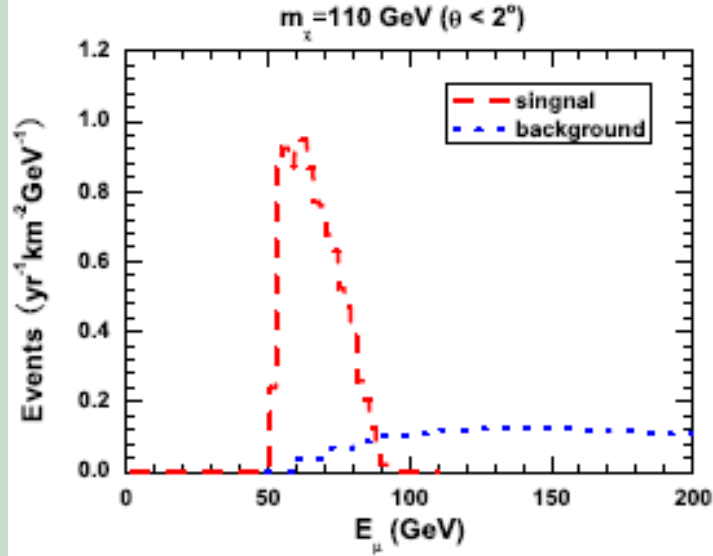


Angular distribution of muons

- Angle of muon velocity
- In range $100\text{GeV} < m_{\tilde{\chi}_0} < 1\text{TeV}$
- Most of Muons are within 2 degree
- Important information to reduce spherical homogeneous atmosphere neutrino background



Muon spectrum and backgrounds



Benchmark Points

Point	$m_\chi(\text{GeV})$	$m_0(\text{TeV})$	$m_{3/2}(\text{TeV})$	$\mu(\text{GeV})$	R_h	σ_{SD}	$C_\odot(\text{yr}^{-1})$
A	110	2.9	34	420	4.4 %	5.1×10^{-5}	8.3×10^{29}
B	285	6.1	88	498	7.1 %	4.2×10^{-5}	1.0×10^{29}
C	510	9.5	162	620	19.2 %	5.0×10^{-5}	4.1×10^{28}
D	1000	15.3	314	1120	14.5 %	1.1×10^{-5}	2.2×10^{27}

Point	$\frac{\sigma_{WW}}{\sigma_{tot}}$	$\frac{\sigma_{ZZ}}{\sigma_{tot}}$	$\frac{\sigma_{t\bar{t}}}{\sigma_{tot}}$	$\frac{\sigma_{Zh}}{\sigma_{tot}}$	$\theta_{cut} (^\circ)$	Sig	BG	σ_{stat}
A	100.0%	0.0%	0.0%	0.0%	2.0	23.3	24.1	4.7
B	99.1%	0.0%	0.9%	0.0%	2.0	102.1	24.1	20.8
C	95.6%	0.2%	4.2%	0.0%	1.5	70.3	13.6	19.1
D	96.9%	0.1%	3.0%	0.0%	1.0	3.0	6.0	1.2

Summary

- Neutralino annihilation in Sun produces high energy neutrinos
- Neutrinos propagate to IceCube from Sun
- The condition for muon detection in AMSB
 $\sigma_{SD} > 10^{-5} pb$
- The angular distribution of muons
 $\theta < 2^\circ$
- Angular distribution is crucial to reduce atmosphere neutrino backgrounds



An aerial photograph of a vast, dense forest landscape. The terrain is a mix of dark green and brownish-green, suggesting a mix of tree types and possibly some cleared areas or different vegetation types. A bright, glowing horizon line runs across the upper portion of the image, likely representing the sun low on the horizon, creating a lens flare effect. The sky above the horizon is a deep, clear blue.

Thank you!