Neutrino Signals from Solar Neutralino Annihilations in AMSB model

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based on

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arXiv:0803.2164

Nanjing, April 28, 2008

Outline

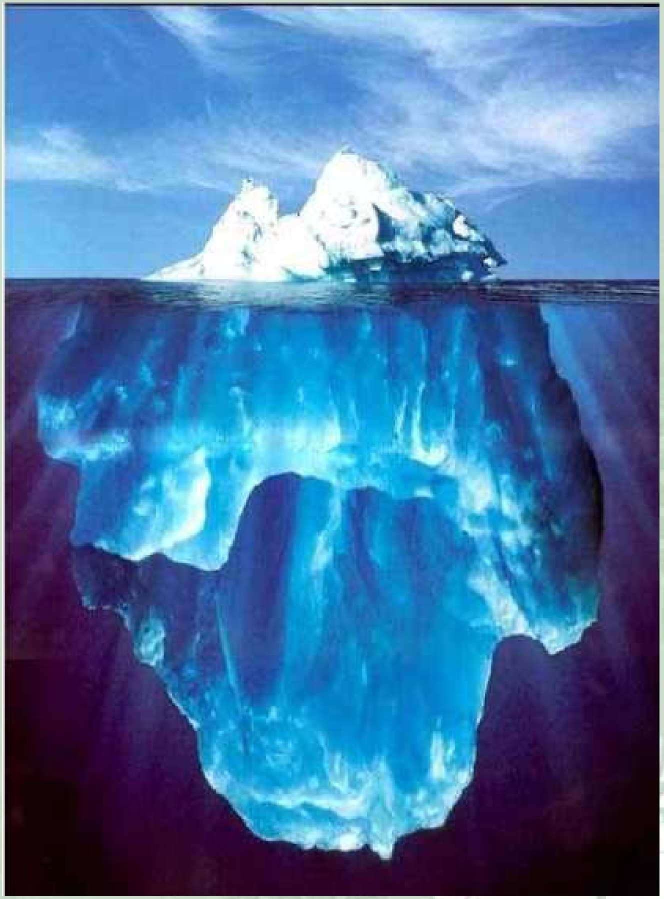
- Dark Matter
- Neutrino from neutralino annihilation in Sun
- Neutrino propagation
- Muon detection in IceCube
- Summary

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

Experiment for Dark Matter

Direct WIMP search

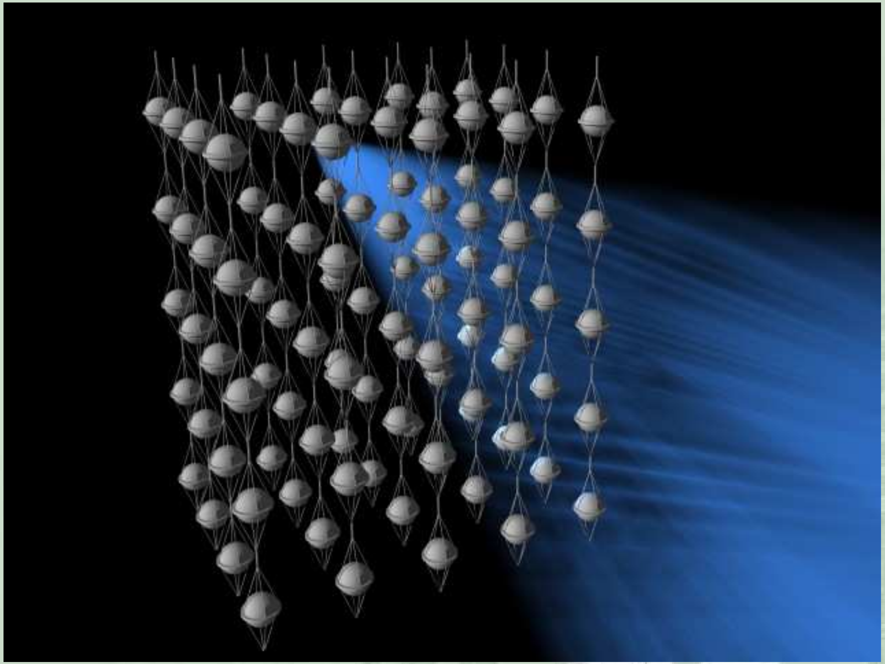
- Detection of nuclear recoils
- Cryogenics detector, Noble liquid
- No positive identification
- XENON10 $\sigma_{\chi-p}^{SI} < 4.5 \times 10^{-8}\ pb$

Indirect WIMP search

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

IceCube neutrino detector

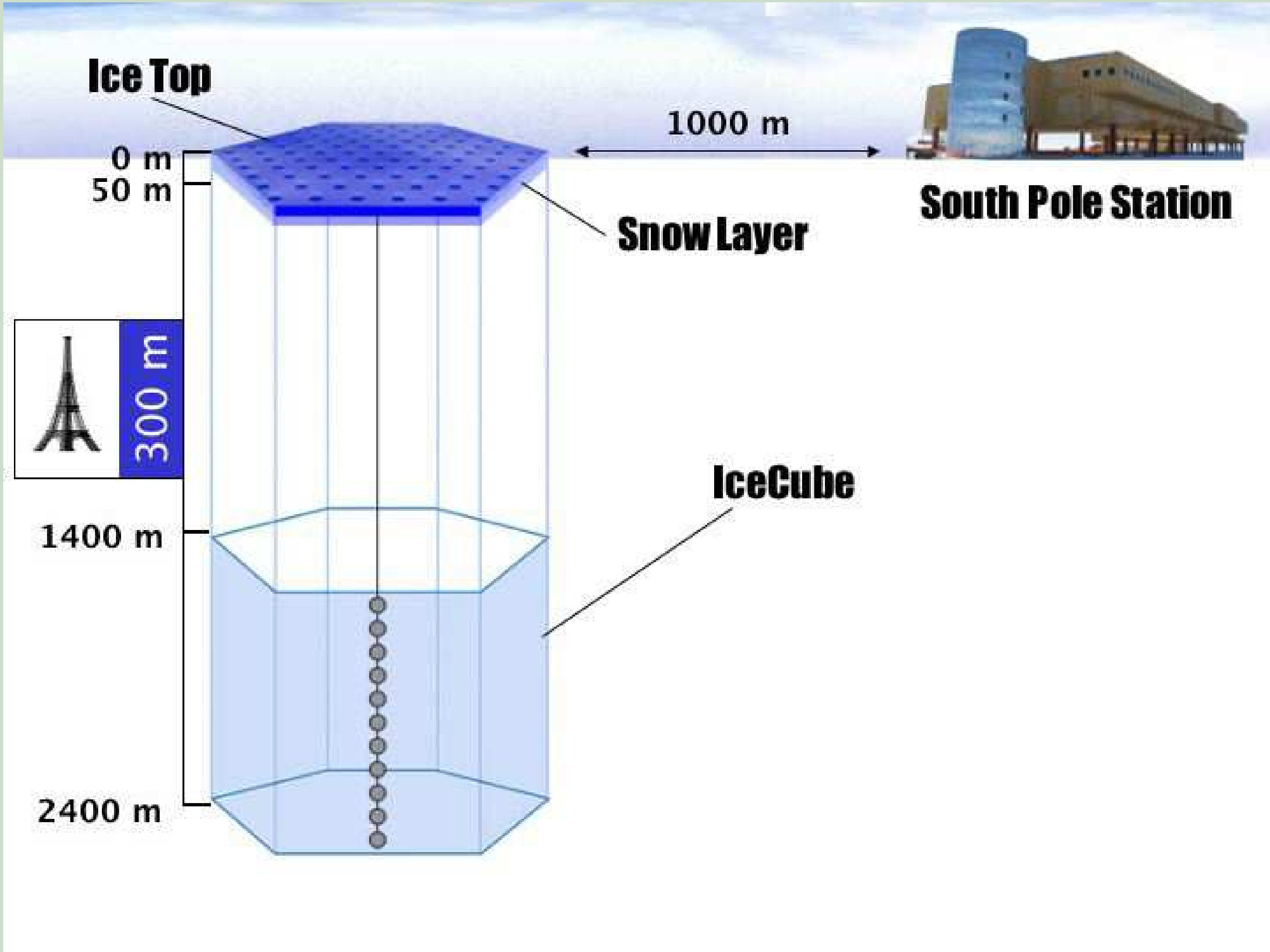
- Surpass the sonic barrier
- Muon surpass the speed of light



- Cerenkov light passing through the IceCube neutrino detector
- Courtesy

  Steve Yunck/NSF

IceCube neutrino detector



Neutrino signal from Solar center

- Dark matter scatters off nucleus in Sun
- Trapped by gravitation of Sun
- Capture rate equals annihilation rate

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

- 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

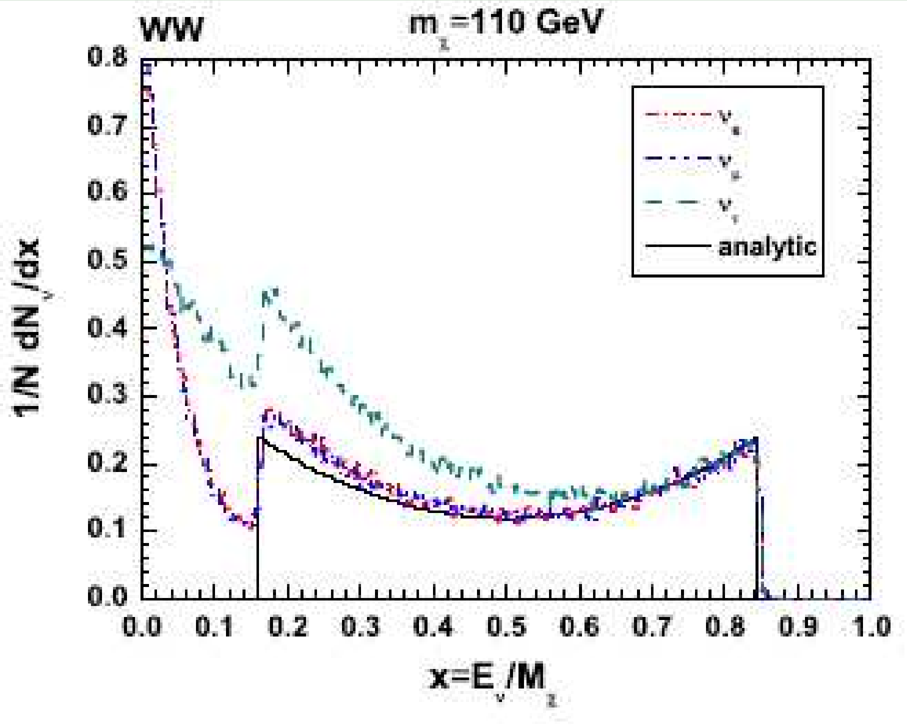
$$m_{3/2}, m_0, \tan\beta, sign(\mu)$$

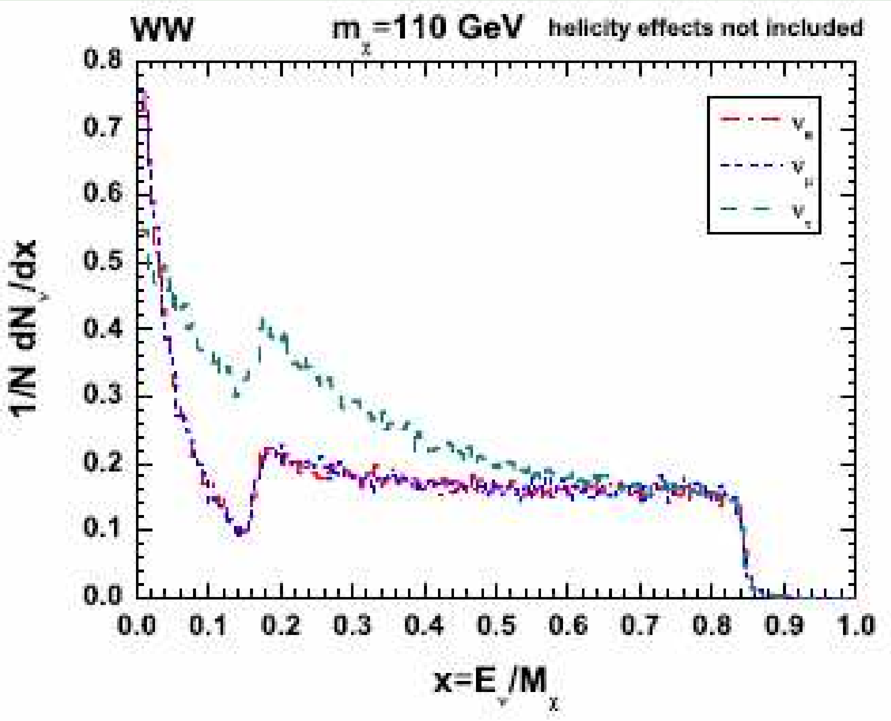
$$\tilde{\chi}_0^1 = N_{11}\tilde{B} + N_{12}\tilde{W} + N_{13}\tilde{H}_d + N_{14}\tilde{H}_u$$

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

Helicity effects and secondary neutrinos

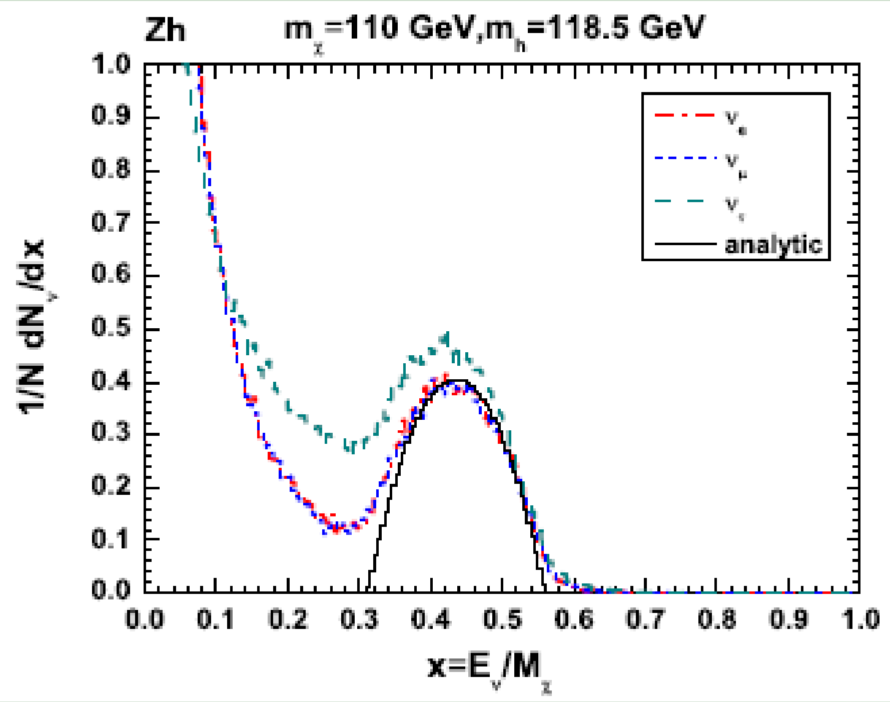
- Transverse polarized W boson
- Leptonic decay and hadronization

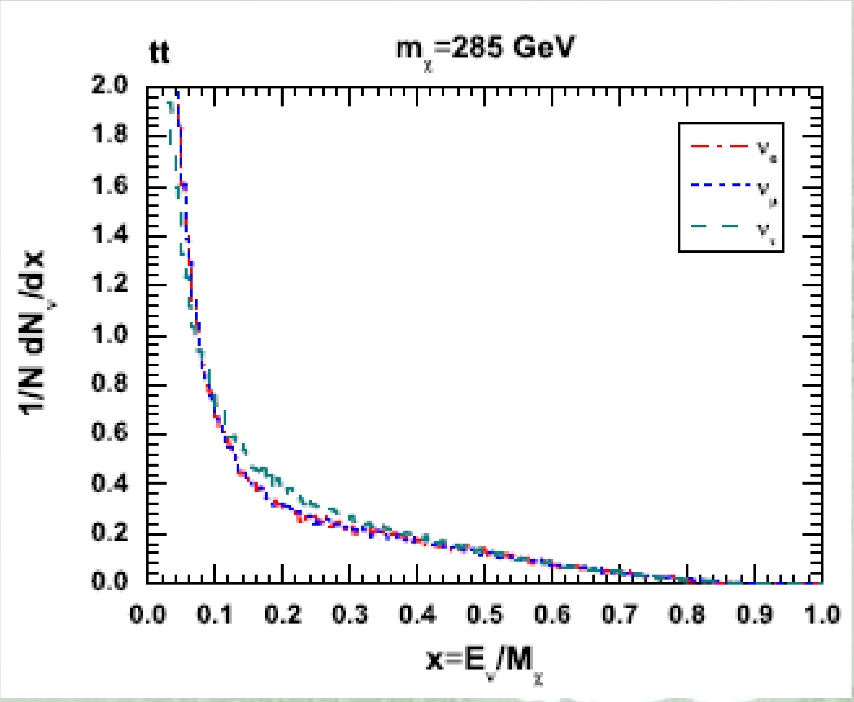




Other annihilation channel

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





Propagation of neutrinos to Earth

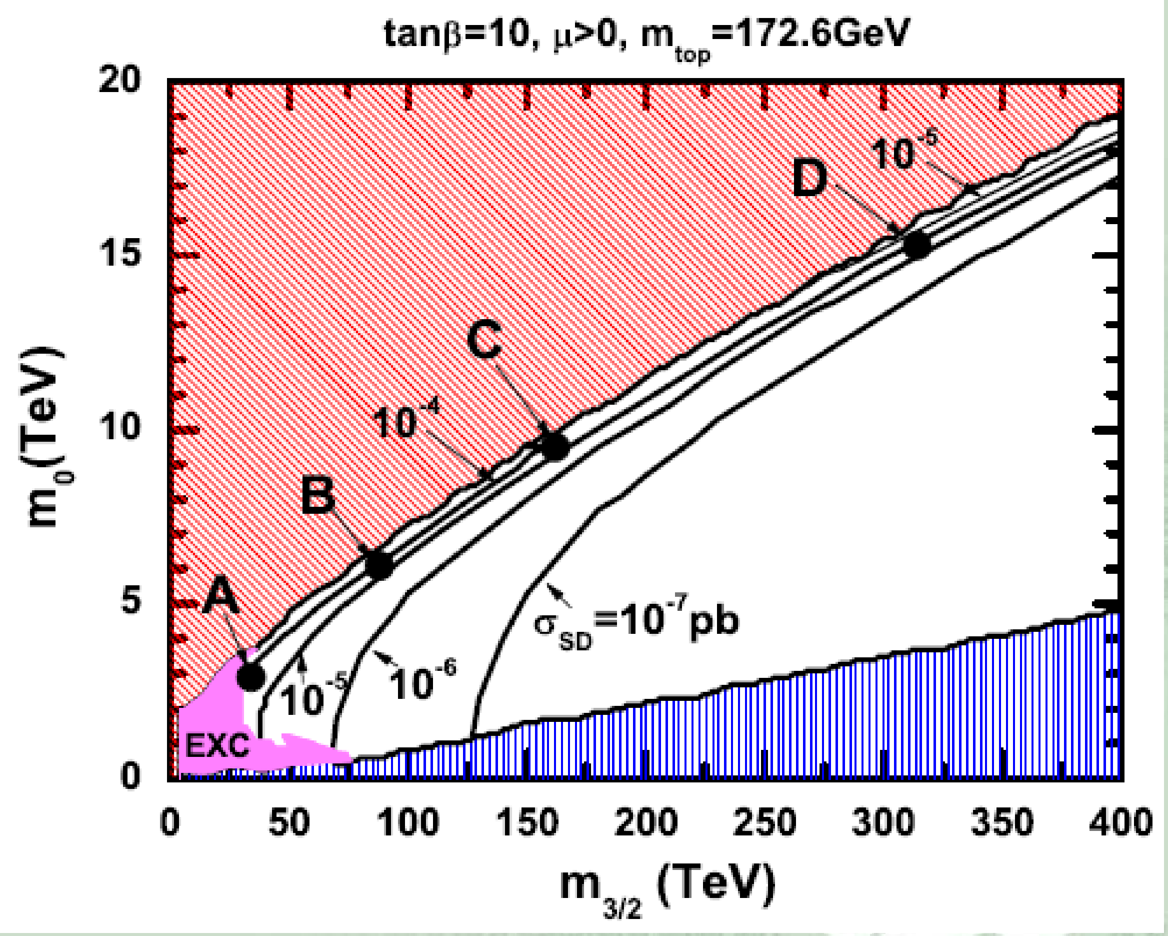
- Density evolution equation of propagation

$$\frac{d\rho}{dr} = -i[H,\rho] + \left.\frac{d\rho}{dr}\right|_{NC} + \left.\frac{d\rho}{dr}\right|_{CC} + \left.\frac{d\rho}{dr}\right|_{0}$$

- Vacuum oscillation
- Neutrino scattering
- Neutrino absorption and tau-neutrino re-injection
- Monte carlo simulation-WimpSim

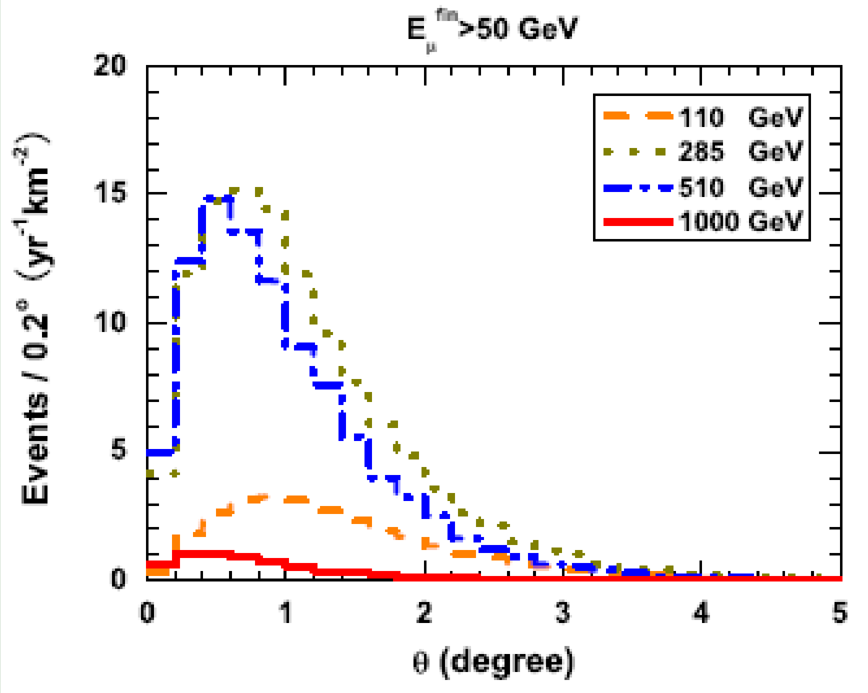
Main conclusions of our paper

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



Angular distribution of muons

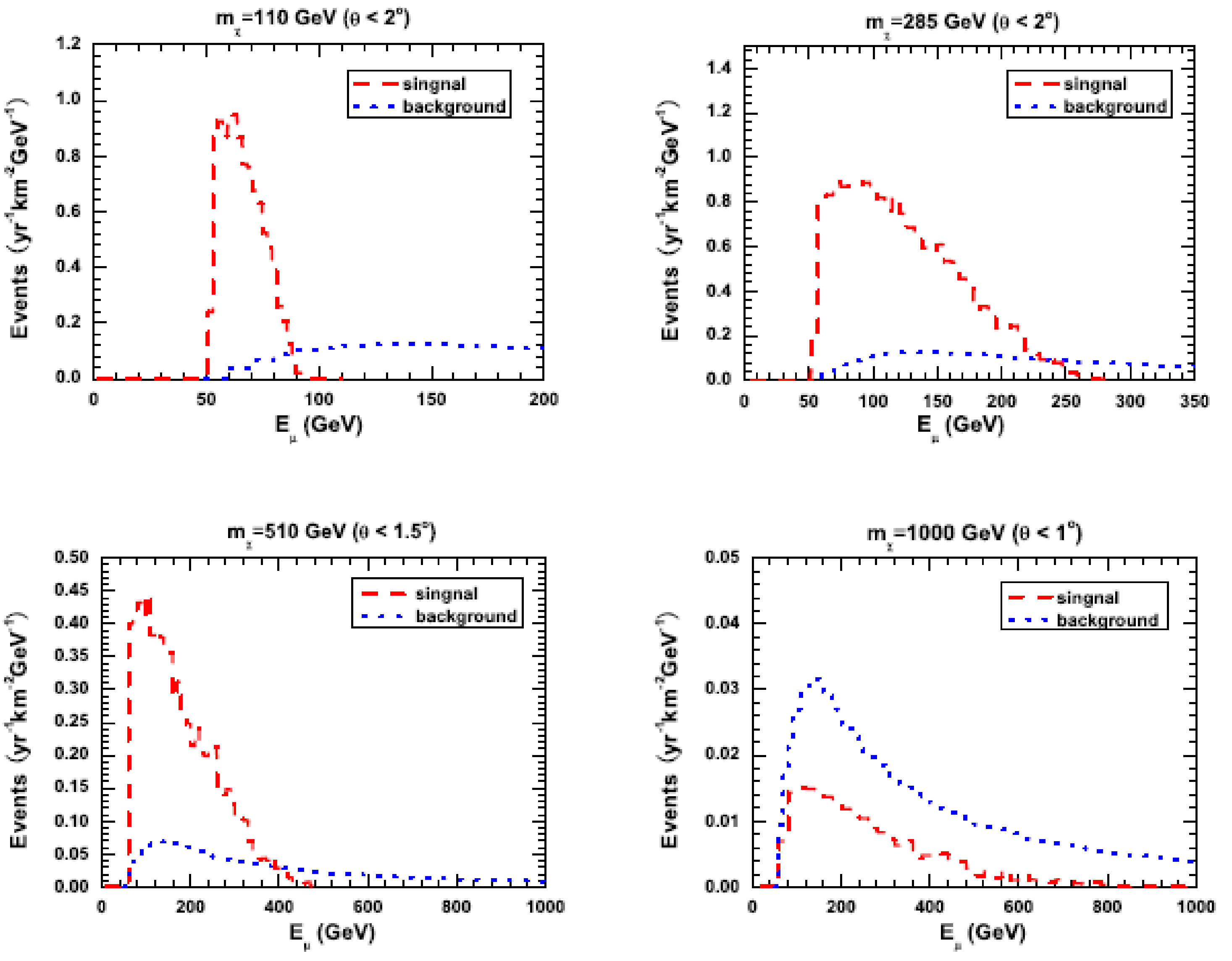
- Angle of muon velocity
- In range $100GeV < m_{\tilde{\chi}_0^1} < 1TeV$
- Most of Muons are within 2 degree
- Important information to reduce spherical homogeneous atmosphere neutrino background



Atmosphere neutrino background

- Cosmic ray interacts with atmosphere around the Earth, produces high energy neutrinos which can result in muons in detector
- Such neutrino have no special direction, thus can be reduced by angle cut of IceCube
- We use the estimated atmospheric neutrino flux from astro-ph/0611418 which considers muon data from Kamioka, Sudbury and Gran Sasso

Muon spectrum and backgrounds



Benchmark Points

Point	m_χ(GeV)	m_0(TeV)	$m_{3/2}$(TeV)	μ(GeV)	R_h	σ_{SD}	$C_\odot(yr^{-1})$
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	$\frac{\sigma_{WW}}{\sigma_{tot}}$	$\frac{\sigma_{ZZ}}{\sigma_{tot}}$	$\frac{\sigma_{t\bar{t}}}{\sigma_{tot}}$	$\frac{\sigma_{Zh}}{\sigma_{tot}}$	θcut (°)	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

Thank you!