Search for indirect signal of WIMPs in Super-Kamiokande

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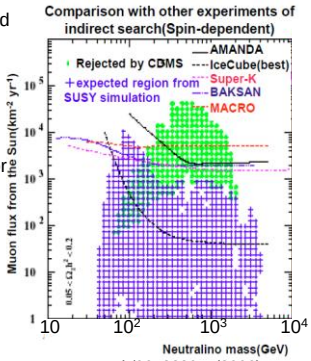
Abstract: We present the result of indirect search for Weakly Interacting Massive Particles(WIMPs) using upward-going muon(upmu) events of Super-K detector.This search aims to detect the neutrino signals from WIMPs annihilation in the Sun. Data set from SKI-SKIII(2828.3 days) are used for analysis, and looked for the excess of neutrino signal from the Sun as compared with expected atmospheric neutrino background, and no significant excess was observed. We calculated the flux limit of upmu in various angular cones around the Sun which is corresponding to WIMP masses. As a result, we improved previous Super-K limit by ~1.4 times, and approached to expected flux region in the wide mass range.

Aim of this WIMP search in Super-K

Super-K published the result for the flux limit of the upward through going muon generated from WIMP induced neutrino using SKI data(1679.6days). Advantages of search for neutrino from WIMP annihilation from the Sun at Super-K are as shown below.

• We use the method of indirect search. For the spin-dependent(SD) search, the event rate in a 50-g H detector for direct search is roughly equivalent to that in a neutrino telescope of area 10 to 500 m^2 which signal comes from the Sun.(On the other hand,for the spin-independent search,the event rate in a kg of Ge detector is roughly equivalent to that in a neutrino telescope of area 10^5 to $10^7 m^2$ which signal comes from the Earth and the Sun.) [M.kamionkowski,Phys.Rev. Lett. 74 5174]

•Super-K has low energy threshold comparing with other neutrino detector and have advantage at the search for low mass WIMP(<100 GeV)



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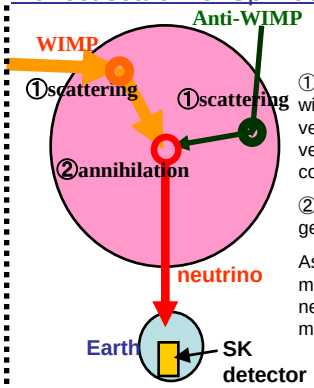
Indirect search for Spin-dependent interaction



①,In the Sun, SD interaction of WIMPs with nuclei is dominant. When WIMP velocity becomes smaller than escape velocity, they are accumulated into the core.

②In the core WIMPs annihilate and generate neutrino in the final state.

Assuming WIMP as neutralino which mass is expected 40GeV/c^2-10TeV/c^2, neutrino energy is 1/2~1/3 of neutralino mass.

Excess search of upward going muon for the direction of the Sun

Excess search in cosθsun(SKI+SKII+SKIII:2828.3day) compared with atmospheric neutrino was done. This time 3 categories of upmu event was used for analysis.

A.Stopping muon(parent venergy 1~a few 10GeV)

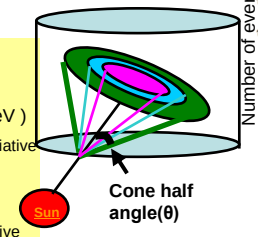
Upward going muon which stops inside the detector

B.Non-showering through going muon(> a few 10 GeV)

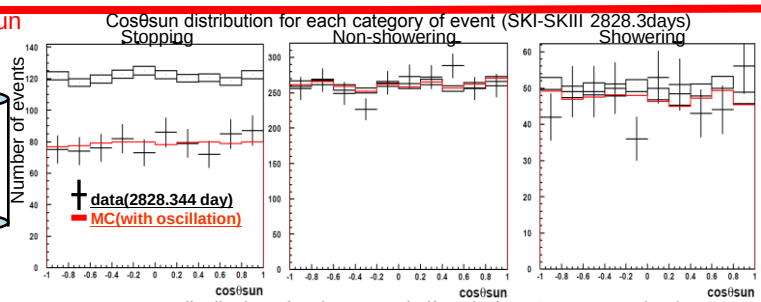
Upward going muon which penetrate the detector without radiative energy loss

C:Showering through going muont(>a few 100GeV)

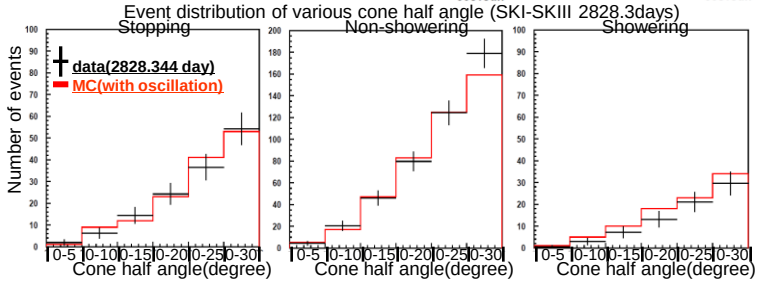
Upward going muon which penetrate the detector with radiative energy loss

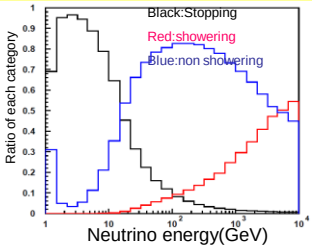


Cosθsun distribution for each category of event (SKI-SKIII 2828.3days)



Event distribution of various cone half angle (SKI-SKIII 2828.3days)

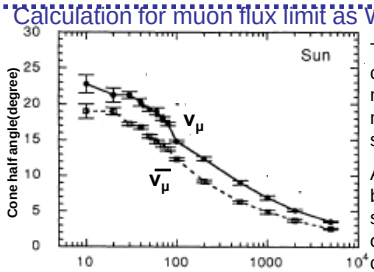




This figure shows the ratio of observed event at SK detector as parent neutrino energy(normalized to 1) estimated from MC simulation.

Assuming the energy of WIMP induced neutrino is 1/2~1/3 of WIMP mass, we can estimate the detection efficiency of each category of upmu for a WIMP mass(Mx) when calculating flux limit from this.

Calculation for muon flux limit as WIMP mass

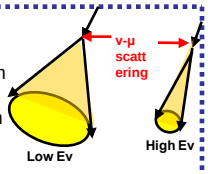


(M.Mori *et al.* Phys.Rev.D48:5505-5518(1993))

The left figure shows cone half angle which contain more than 90% of signal expected from neutralino annihilation in the Sun. This relation mainly come from the spread of neutrino-muon scattering.

Above Mx=10^4GeV/c^2, detector resolution becomes dominant(Stop:1.7 deg, Non-showering:1.1 deg, showering 1.63deg), and can't ignore the effect of resolution there. We calculated 90% window angle with considering resolution for the cone of Mx=10^4 GeV/c^2.

Using this, we calculated 90% window angle for corresponding several WIMP neutralino mass.



Checking event distribution of various cone half angles which are meaningful for WIMP search for each category and all upmu,no significant excess was observed.

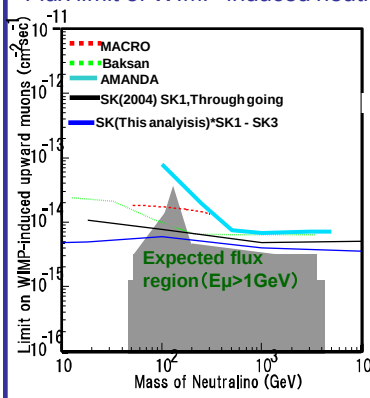
→Calculate the upper limit of upmu flux as WIMP mass considering detecting efficiency of each category of upmu

Table for calculating Flux limit

χMass (GeV)	Cone (degree)	A.stopping		B,nonshowering		C,showering		Efficiency (A:B:C)	N90*	Flux limit (×10^{-15}) ($cm^{-2}sec^{-1}$)
		data	MC	data	MC	data	MC			
10	19	19	22.1	71	73.1	15	11.7	94:5:1	7.51	4.95
10^2	12	9	9.4	23	27.9	8	4.4	17:75:8	9.27	6.11
10^3	5	1	1.9	5	4.3	1	0.5	4:80:16	6.31	4.16
10^4	A,C 3 B 2	0	0.6	2	1.0	1	0.2	1:54:45	5.56	3.64

*N90 is 90% upper poissonian limit for 3 categories of upmu calculating with considering detection efficiency.

Flux limit of WIMP-induced neutrino from the Sun



In this analysis, improve the previous limit by ~1.4 times. It's reasonable considering the increasing of statistics. (SK1:1679.6days -> SK1-SK3:2828.3days)

For low mass and high mass WIMP, more improvement is shown since we introduced new categories of events.

Shaded region is expected flux region calculated from DARKSUSY simulation. We are almost approaching this region at all WIMP mass range .