A new limit on diffuse supernova neutrino flux

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Summary

- Introduction: diffuse supernova neutrino flux
- Present limits
- Improving the limit
- Conclusions

Diffuse supernova neutrinos

- • There is a diffuse neutrino emitted by past supernovae (Diffuse Supernova Neutrinos Flux, DSνF)
- • The DSν is correlated to various physics, such as supernova model, past supernova rate and neutrino oscillation.

By Constraining the DSνF, we can probe

ν oscillation, or the star formation in the universe

- • In this study we will reveal a new limit for DSνF for electron neutrino type.

Past supernova rate

We need to compute

$$\frac{d\phi}{dE} = \left(\frac{c}{H_0}\right) \int R_{SN}(z) \frac{dN_\alpha(E(1+z))}{dE'} \left|\frac{dt}{dz}\right| (1+z)dz$$

where E’=E(1+z).

$$\frac{dN_\alpha(E)}{dE} = \left(\frac{E}{E_w}\right)^{-\alpha_w} e^{-(E/E_w)(1+\alpha_w)}$$

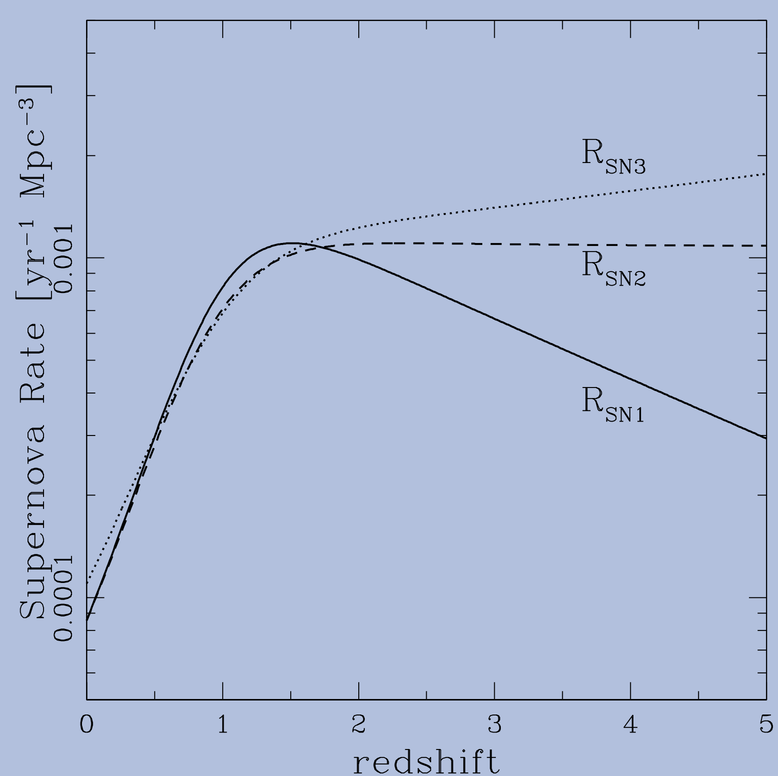
where E_w are the temperature of different α types of neutrinos,

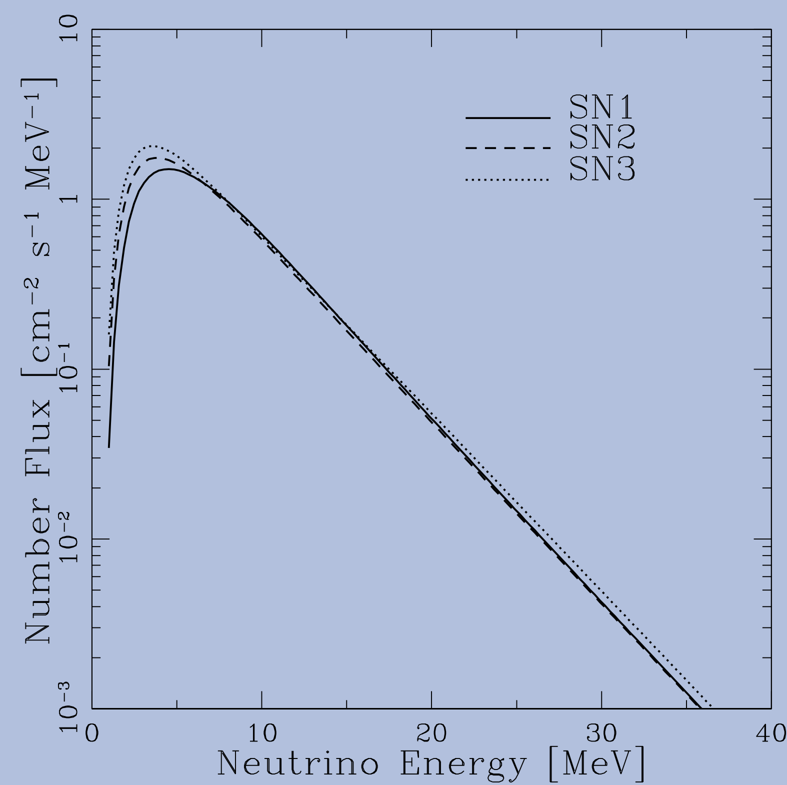
$E_{\nu_e} \sim 9 - 16$ MeV

$E_{\bar{\nu}_e} \sim 12 - 18$ MeV

$E_{\nu_\mu \nu_\tau} \sim 15 - 22$ MeV

Past supernova rate





Anto,Sato and Totani, Astr. Part. 18, 307(2003).

Fluxes from past supernovae

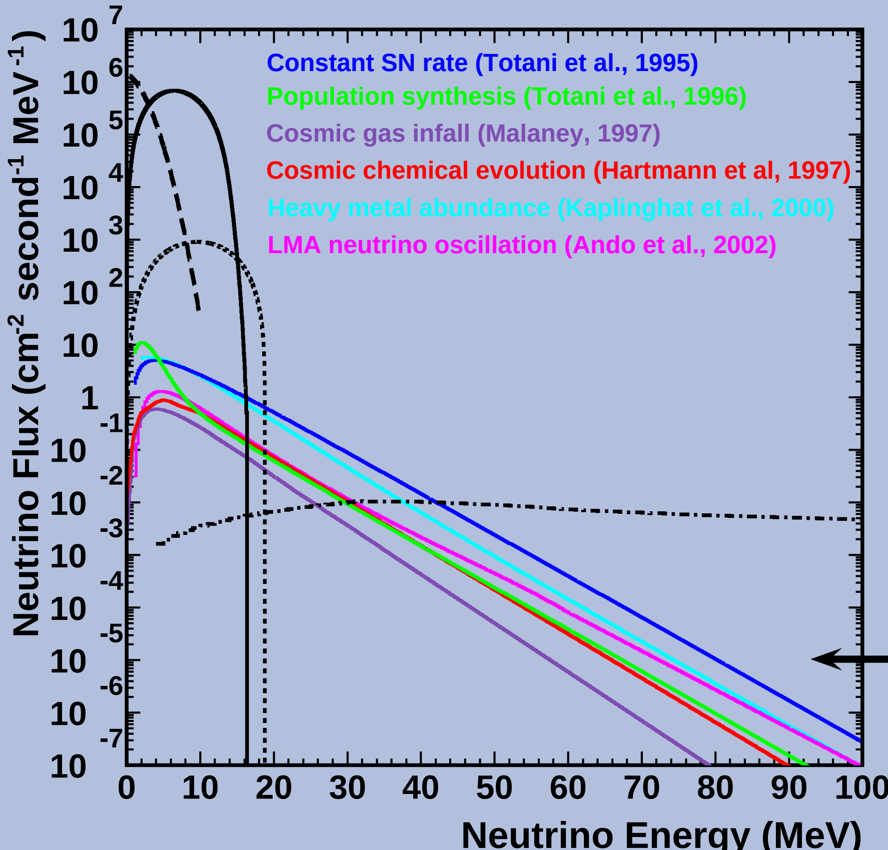
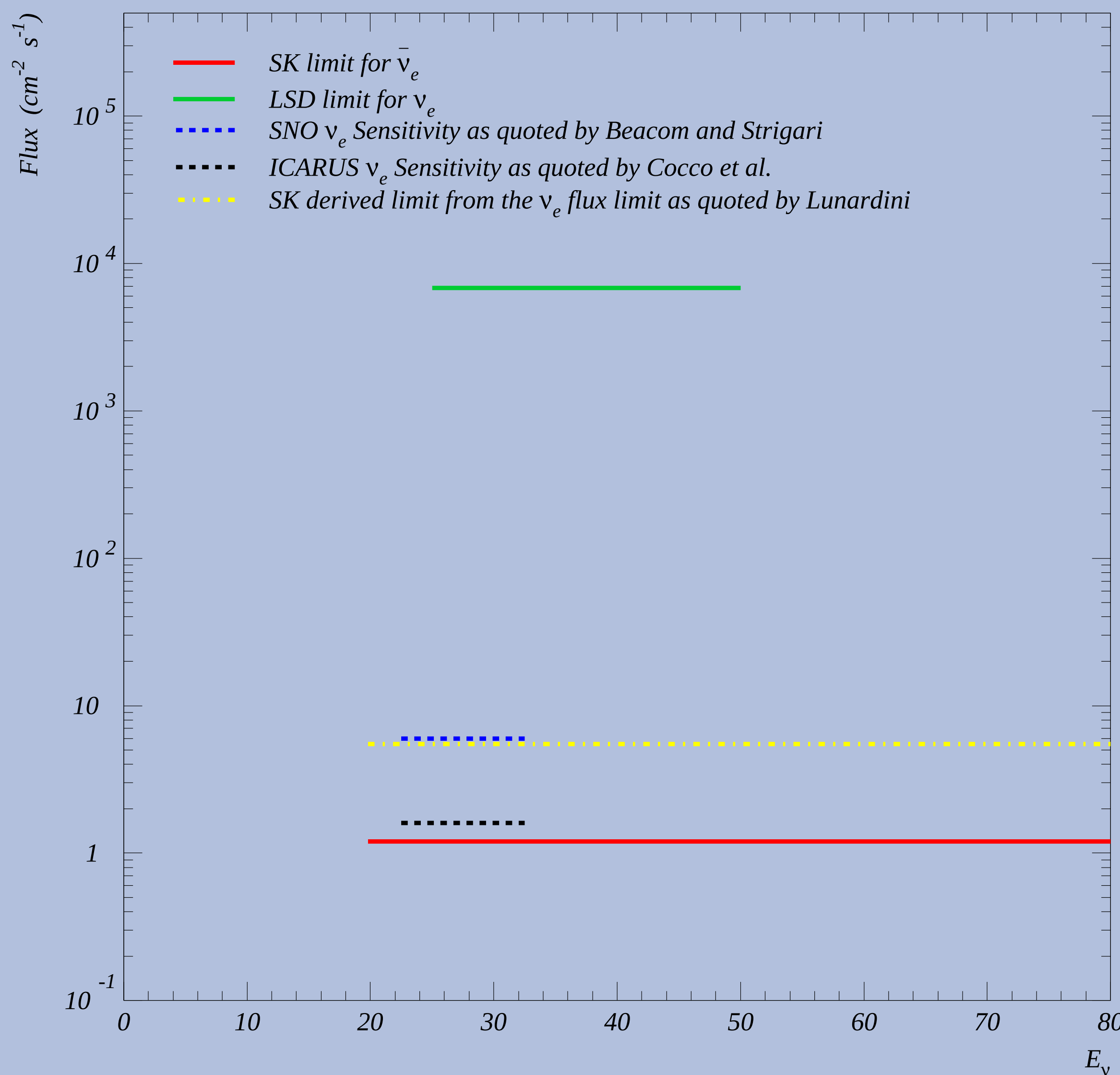


Figure 1.5: The expected SRN flux, calculated from six theoretical models, is presented. The SRN flux predictions are compared to the fluxes from the reactor $\bar{\nu}_e$ (dashed line), the ^{8}B solar ν_e (solid line), the *hep* solar ν_e (dotted line), and the atmospheric $\bar{\nu}_e$ (dot-dashed line).

Exponential decay

Fluxes used by Super-Kamiokande experiment.

Present limits for DSνF



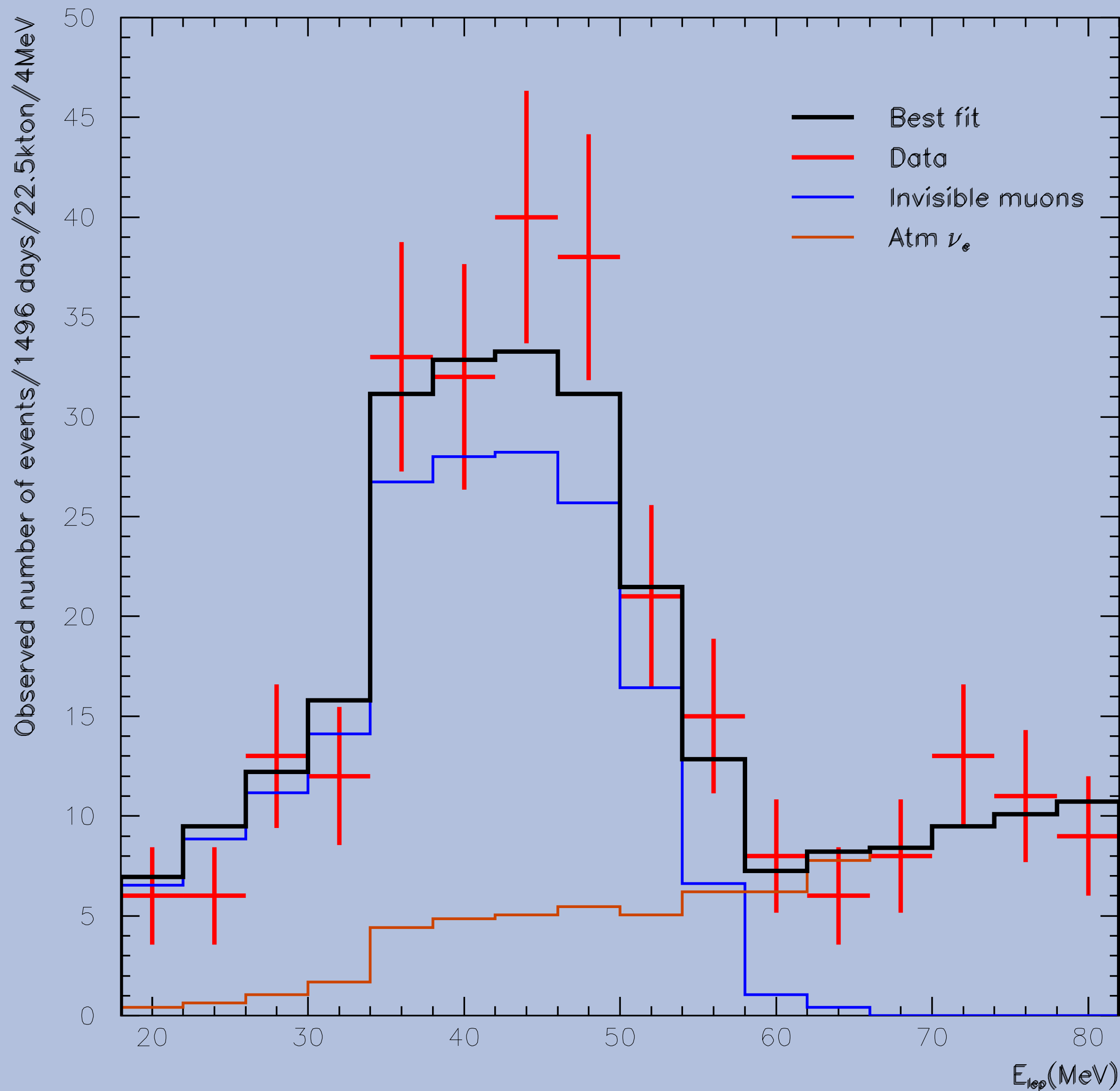
LSD: $\nu_e{}^{12}C$

SK: $\bar{\nu}_e p$

SNO: $\nu_e D$

ICARUS: $\nu_e{}^{37}$Ar

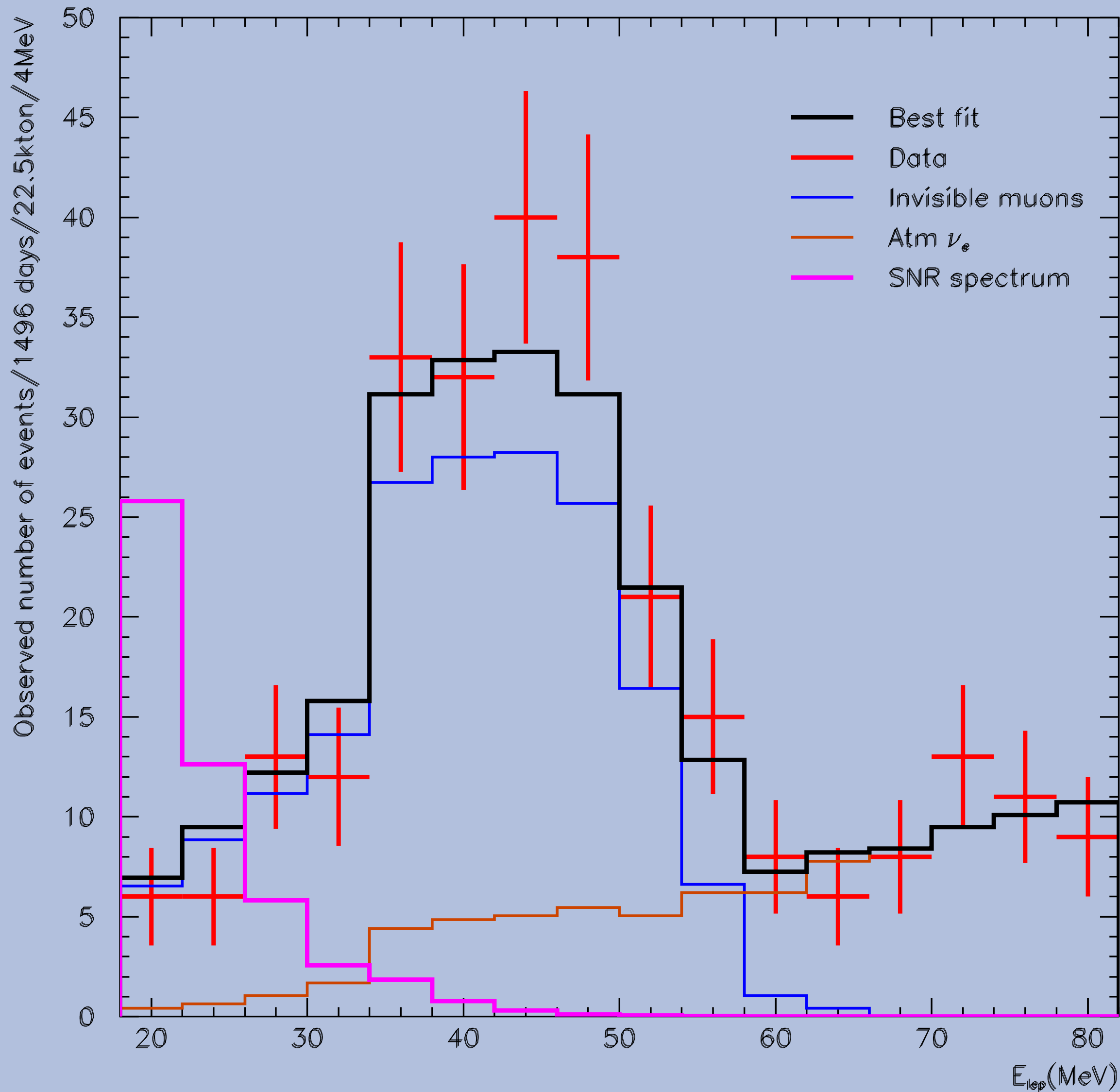
SK limit for $\bar{\nu}_e$



$\bar{\nu}_e$: $\sigma(\bar{\nu}_e p \rightarrow e^+ n)$

no charge ID

SK limit for $\bar{\nu}_e$



Analysis of SK data

We need to compute

$$\chi^2 = \Sigma_{l=1}^{16} \frac{\left(-N_l^{data} + \alpha A_l + \beta B_l + \gamma C_l\right)^2}{(\sigma_l^{data})^2 + \sigma_{sys}^2}$$

α is the DSνF total number of events, as well β (γ) is the total number of events for invisible muons (atmospheric electron neutrinos). A_l, B_l, C_l are the respectively normalized spectrum of DSνF, invisible muons and atmospheric neutrinos. The factors α, β and γ are free parameters.

SK limits for $\bar{\nu}_e$ DSνF

We compute the χ^2 function, computing the DSν number of events,

$$N = \tau \mathcal{N} \int_{E_{th}}^{\infty} dE_l \int_{E_{th}^{\nu}}^{\infty} \sigma(E_\nu, E_l) \mathcal{E}_\nu(E_l) \phi(E_\nu) \ ,$$

For high energy, ($E_\nu > 19.8$ MeV) we can parametrize the supernova spectrum by

$$\boxed{\phi(E_\nu) = \phi_0 e^{-E_\nu/E_0},}$$

where E_0 is the slope.

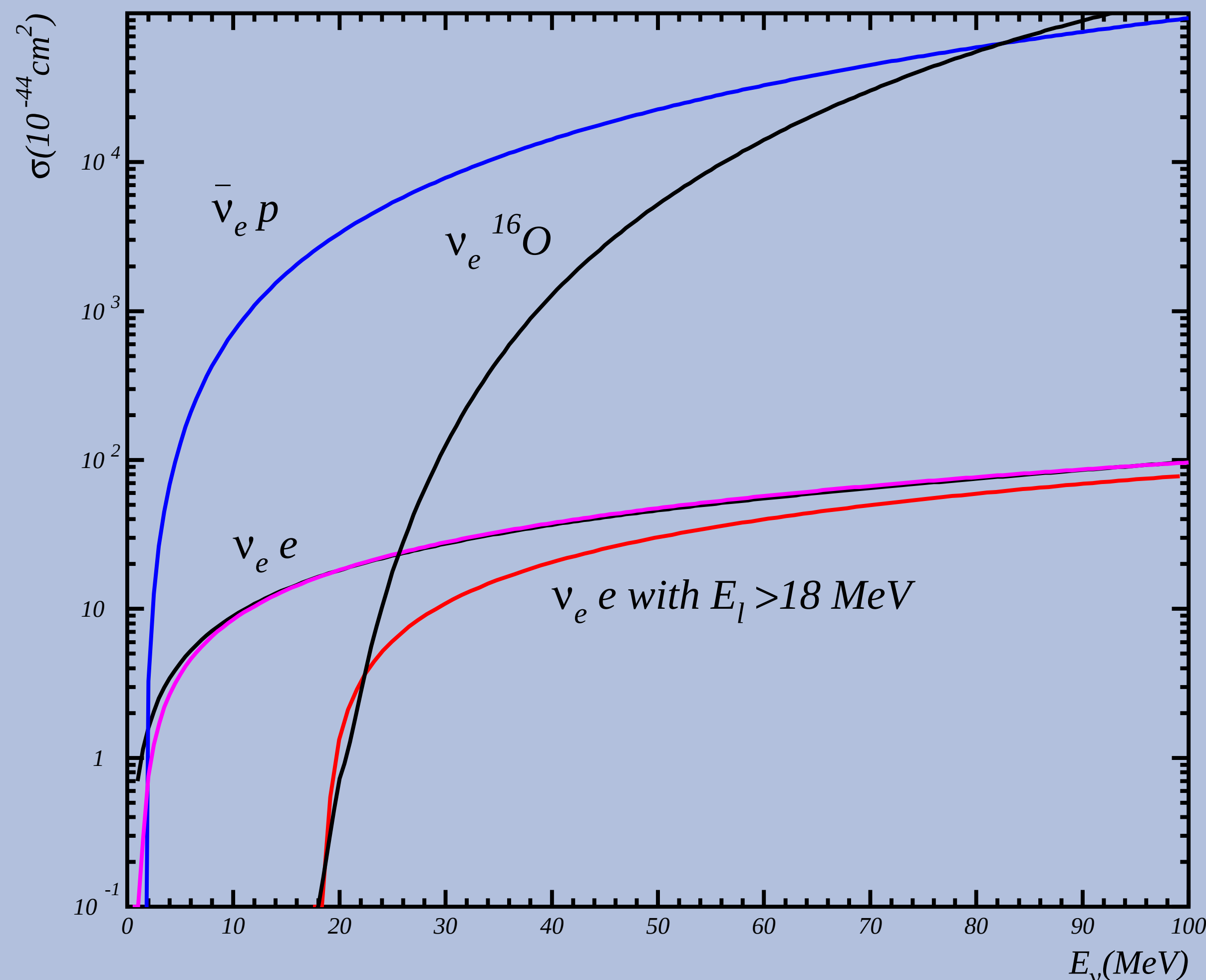
Typical values are $E_0 = (3.5 - 8.5)$ MeV.

X-section for supernova neutrino

$\sigma(\bar{\nu}_e p \to e^+ n)$ Vissani and Strumia

$\sigma(\nu_e {}^{16}O \to e^- X)$ Kolbe,Langanke,Vogel

$\sigma(\nu_e e \to \nu_e e)$ standard SM

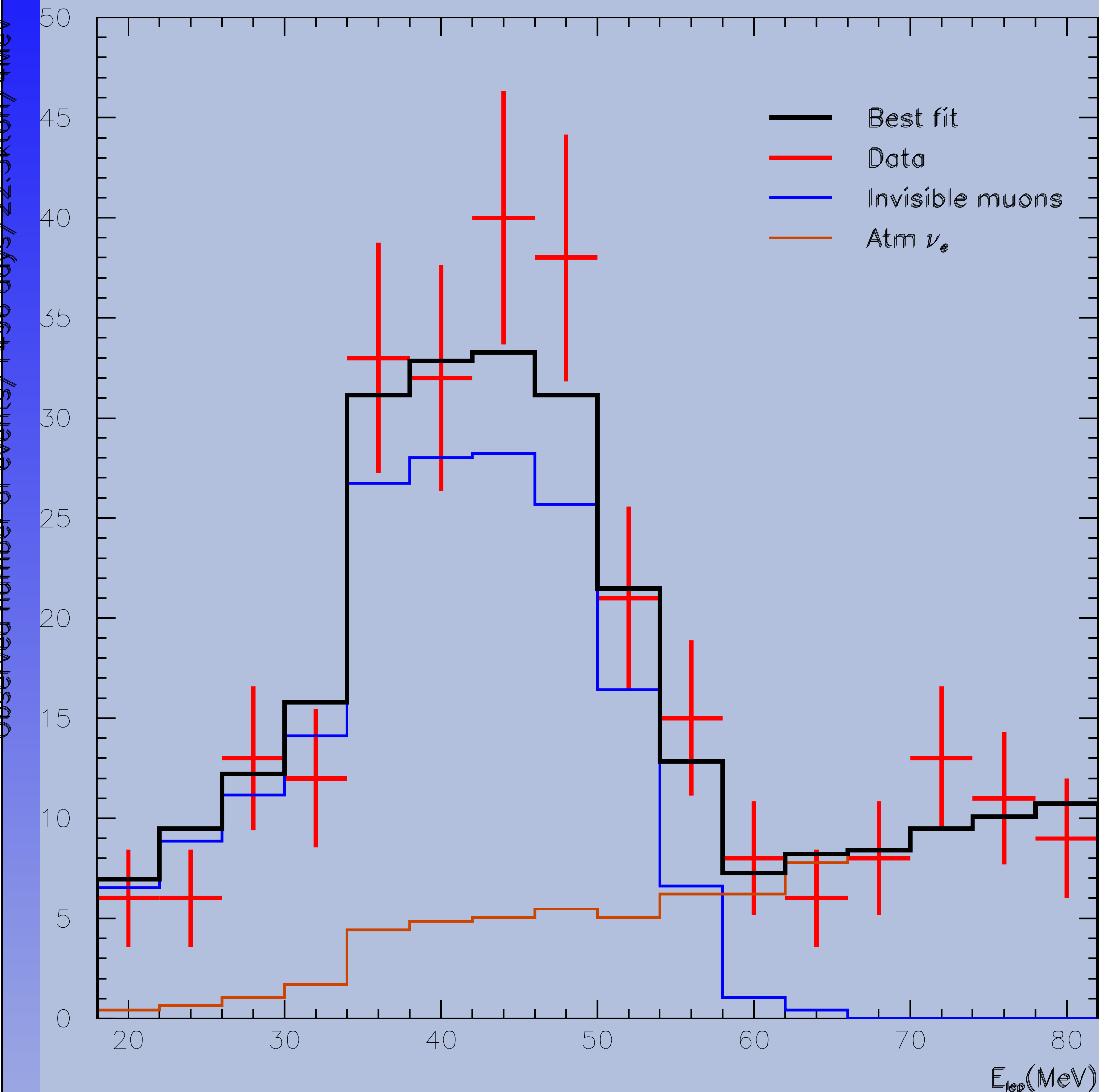


SK limits for $\bar{\nu}_e$ DSνF

For every model, the best fit point is $\rightarrow \alpha = 0$.
For each model, we have found the 90% C. L. confidence limit for the DSνF called , α_{90} for the exposure time of SK:1496 days X 22.5 kton. We found

E_0	$\alpha_{90\%C.L.}$	$\bar{\nu}_e$ Flux limit$(s^{-2}s^{-1})$
3.5	4.95	1.17
5.35	7.00	1.20
5.5	7.31	1.31
7.5	11.40	1.55
8.5	14.16	1.70

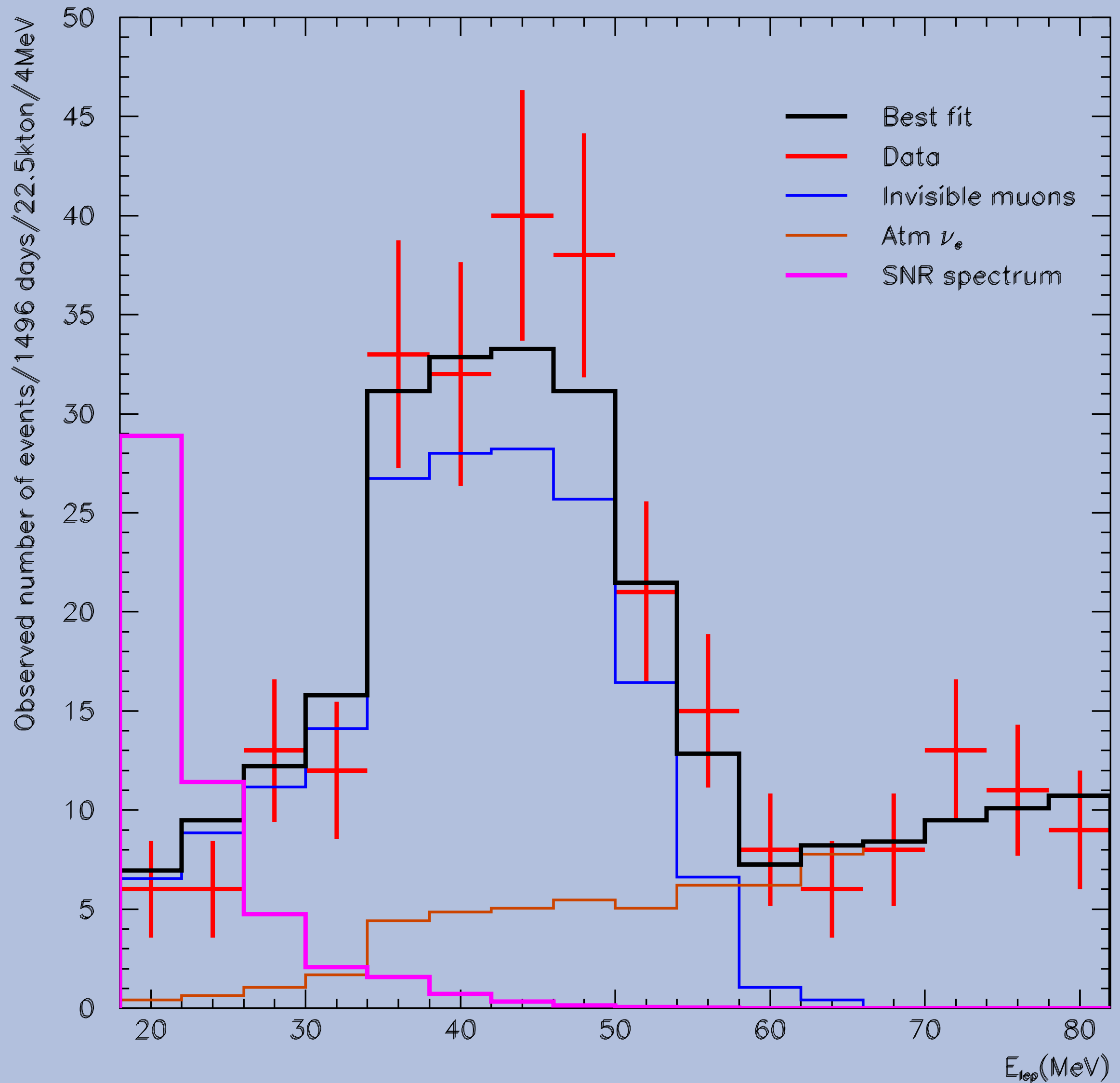
ν_e DSνF in SK



ν_e: $\sigma(\nu_e {}^{16}O \rightarrow e^- X)$

ν_e: $\sigma(\nu_e e \rightarrow \nu_e e)$

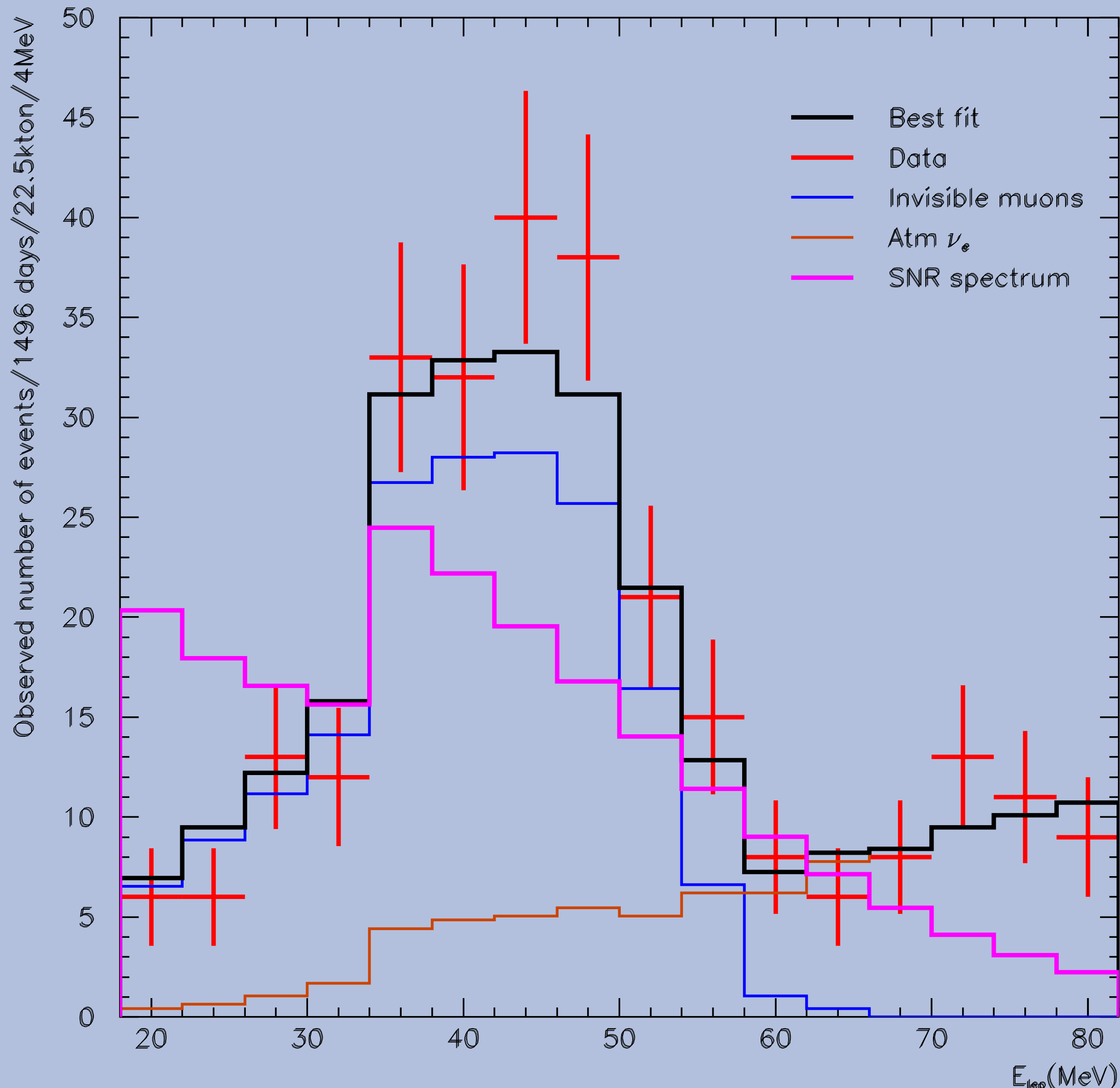
ν_e DSνF in SK



$E_0 = 3.8$ MeV

For small E_0, the elastic cross dominate.

ν_e DSνF in SK



$E_0 = 8.5$ MeV

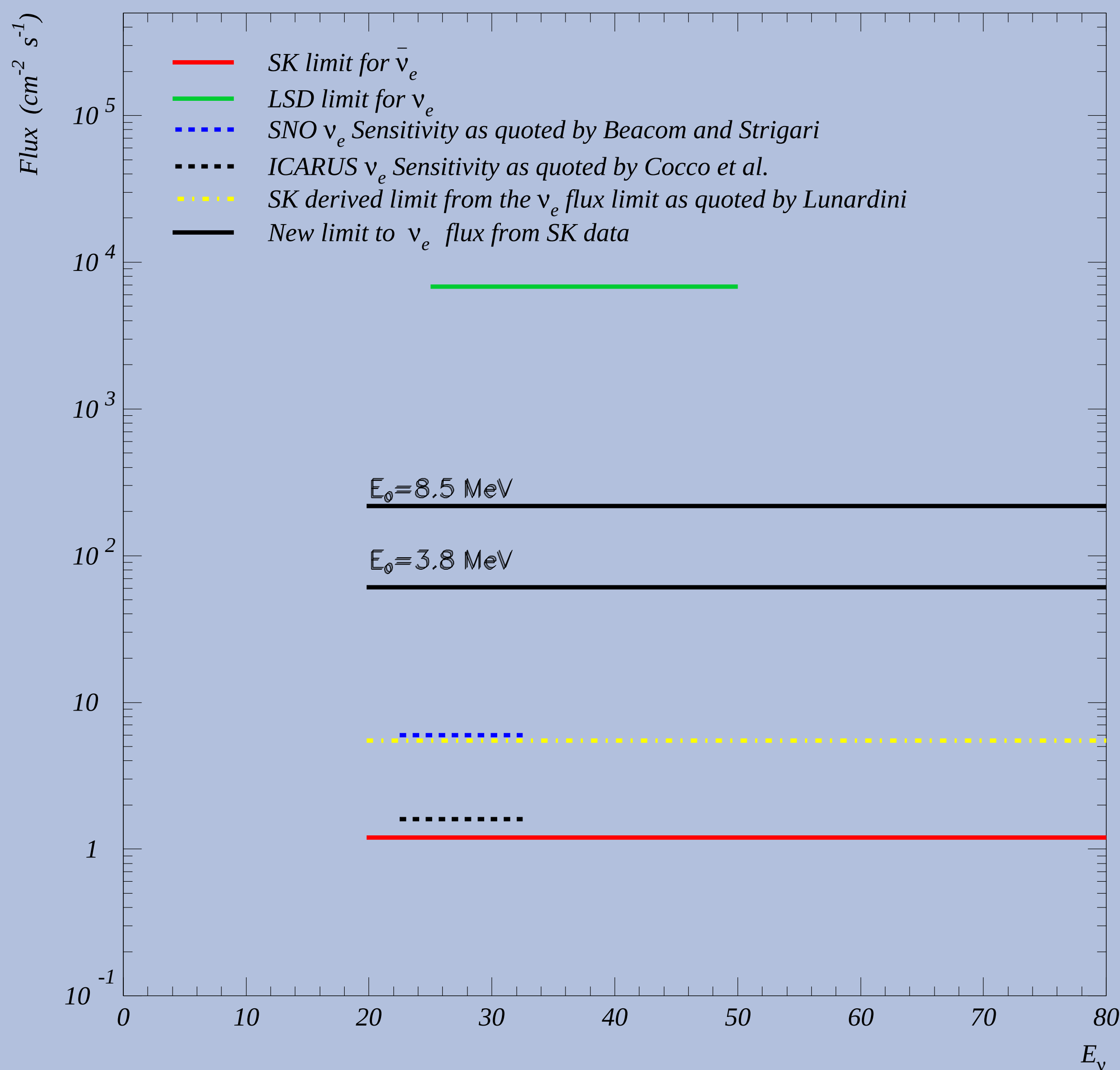
For larger E_0, $\nu_e e$ and $\nu_e {}^{16}O$ are equally important.

SK limits for ν_e DSνF

We repeat the same procedure for ν_e

E_0	α_{max}	ν_e Flux limit$(s^{-2}s^{-1})$
3.5	4.65	217.80
3.8	4.90	190.25
5.5	8.05	102.07
7.5	17.60	71.56
8.5	23.60	60.75

New limits for DSνF



Conclusions

- Most all? of diffuse supernova neutrino flux can be described by e^{-E_ν/E_0}, where E_0 is the slope,
- We analyze the SK data using a χ^2 function and successfully reproduce the results of SK for $\bar{\nu}_e$ diffuse flux. The same procedure can be applied to ν_e diffuse limit due lack of final lepton charge ID;
- We have found that the $\bar{\nu}_e$ flux limit, is from $\Phi_{\bar{\nu}_e}^{\max} < 1.2 - 1.68$ cm$^{-2}s^{-1}$.
- • We have found a new limit for the diffuse supernova electron neutrino flux, the limit is improved by a factor of 30-100: $\Phi_{\nu_e}^{\max} < 60 - 200$ cm$^{-2}s^{-1}$.

Typical values for E_0

Model	E_0
LMA	5.68
Pop. synthesis	5.35
Cons. SN rate	5.62
Lunardini	$4-7$
Fukujita-Kawasaki	$3.76-5.81$
Beacom-Strigari	$4.05-8.5$
Ando et al	$3.88-5.19$