Solar Neutrinos and supernova burst neutrinos at Hyper-Kamiokande

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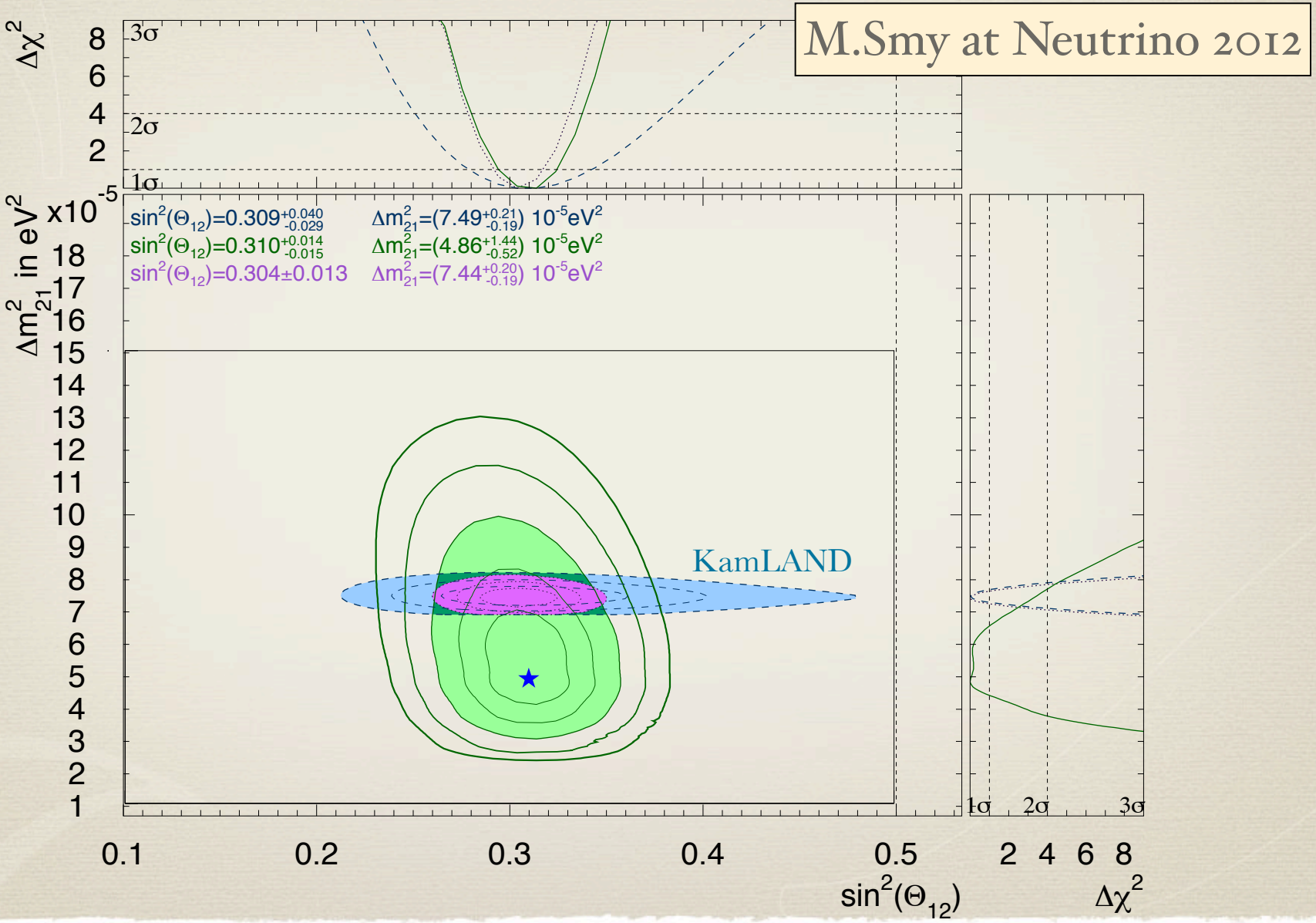
(Thanks for many suggestions from SK analysis group!)

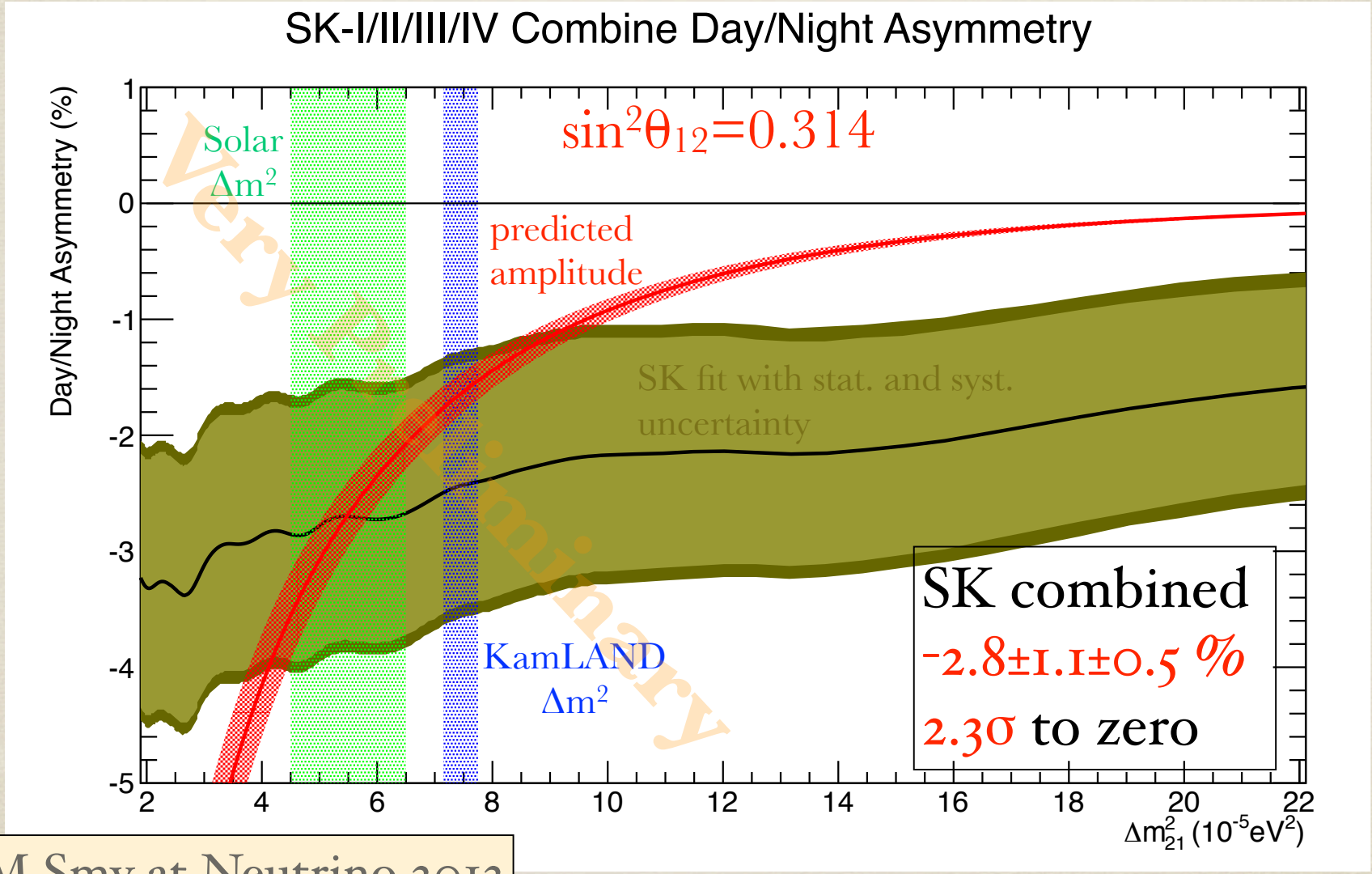
SOLAR NEUTRINOS

Latest solar neutrino result

M.Smy at Neutrino 2012



Latest solar neutrino result

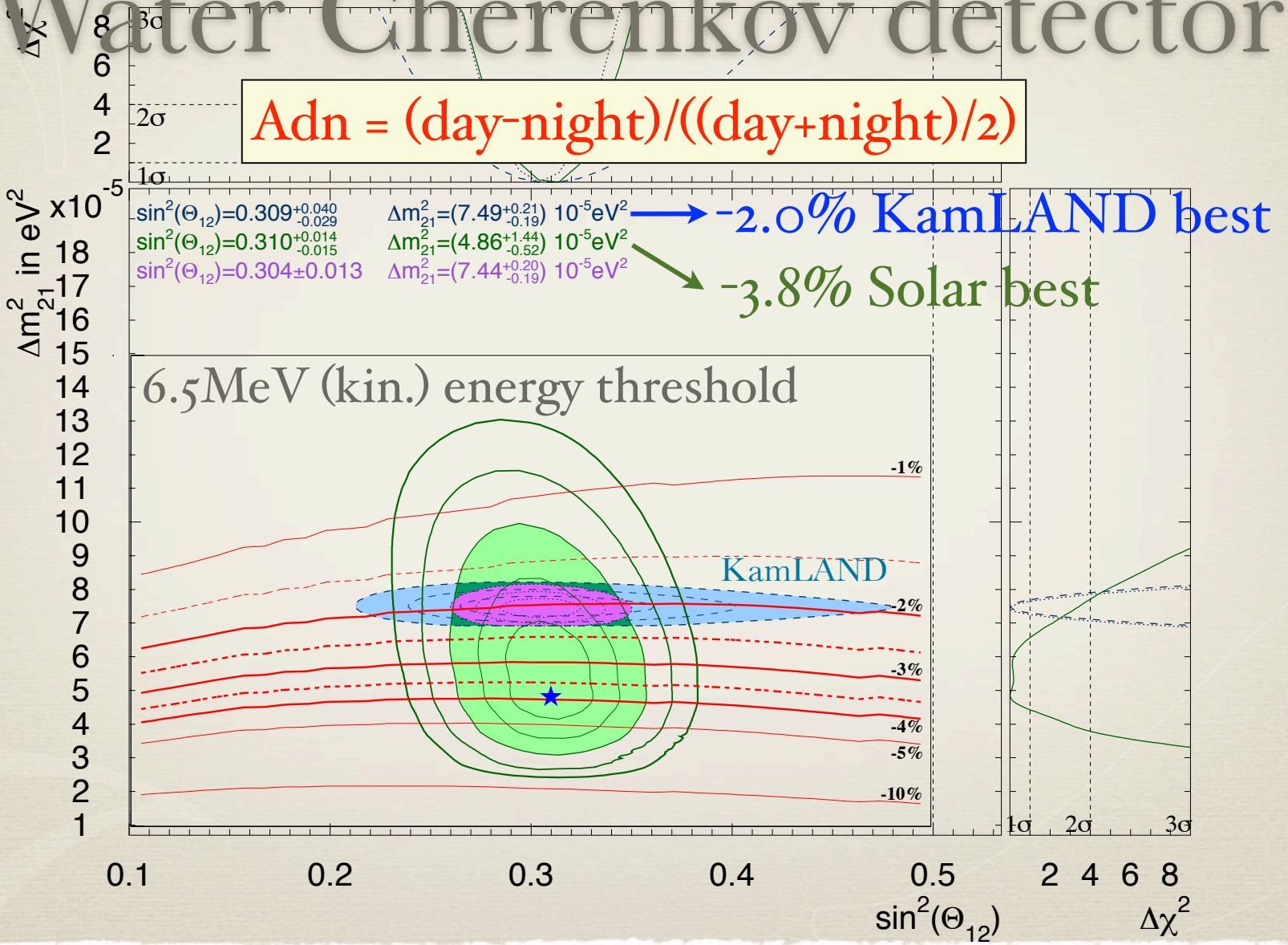


M.Smy at Neutrino 2012

What's for solar ν in HK?

- Can we see clear flux differences between day-night?
  - SK will see before HK starts?
- Can it make distinguish between Solar best and KamLand best?
- Can we see spectrum up-turn?
  - It seems to be difficult, since it is hard to make the energy threshold enough low if the coverage is 20% and QE is same...

Day-Night asymmetry in Water Cherenkov detector



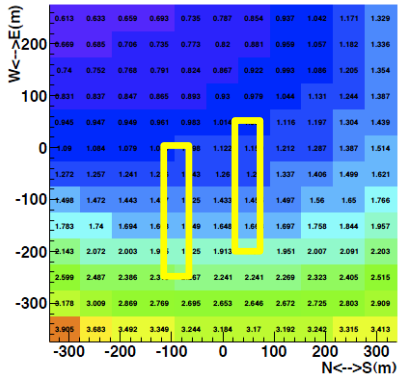
Spallation background

3. Spallation events in HK:

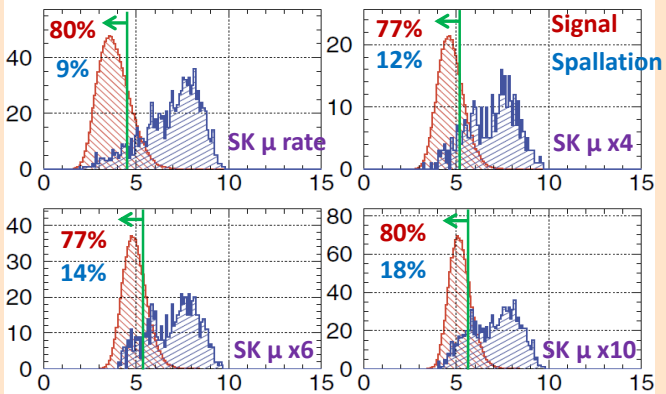
Y.Takeuchi at Neutrino 2012

The major background sources for the low-energy neutrinos in HK will be the radioactive spallation products created by cosmic-ray muons. In the current design, the cosmic-ray muon rate is expected to be increased by a factor of about 10 in equal volumes. However, the average energy of the cosmic-ray muons (indicated in parenthesis) at the shallower HK site (~300 GeV) is expected to be lower than that at the deeper SK site (~560 GeV). Considering that the spallation production cross section is proportional to the 0.7-th power of the cosmic-ray muons' energy, the density of spallation products will be increased by a factor of 6 to 7 in the HK site.

We found the remaining spallation products will be increased by another factor of 3 at most with the current analysis tools, if HK has the same resolutions with SK-I. This is due to decreasing efficiency for separating spallation products from signal events with increasing the cosmic-ray muon rate. So, the density of the remaining spallation products will be increased by a factor of 20 at most in HK, if HK has the same resolutions with SK-I. However, this could (and most likely will) be reduced by ongoing improvements of the analysis tools.



Expected cosmic-ray muon rates in HK site. Text and color represents expected muon flux in units of 10^{-6}/sec/cm^2. The yellow boxes indicate the current candidate site. See, LoI for details.



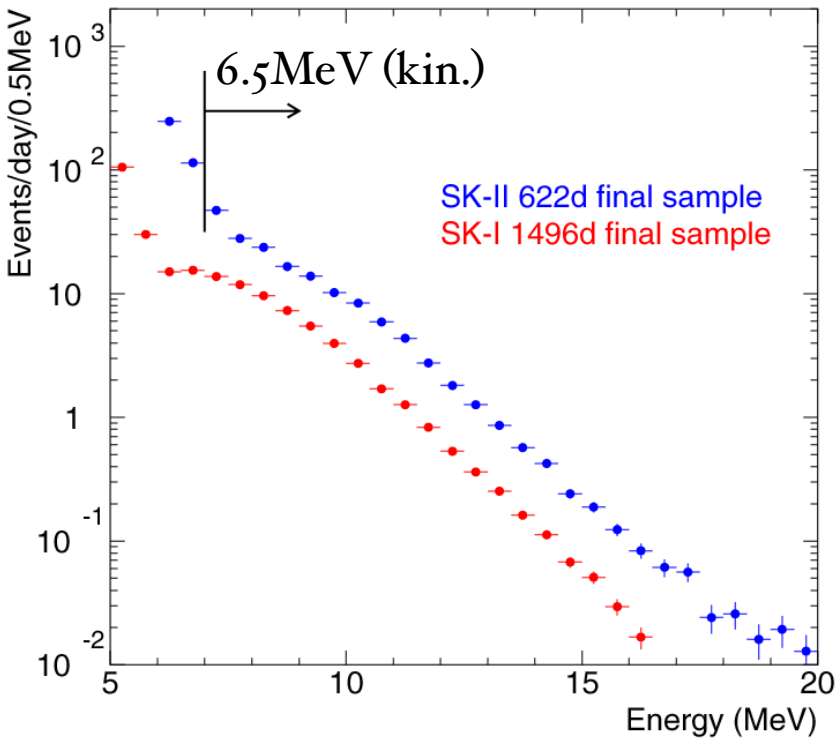
Typical spallation likelihood distributions with increased cosmic-ray muon rates (simulation). Horizontal and vertical axes are likelihood (larger is spallation-like) and area-normalized number of events. The green lines indicate typical cut points with ~20% signal loss.

The remaining spallation products will be increased by a factor of 20 with the same algorithm in SK and the same dead time (20%)

Remaining B.G. in SK

Y.Takeuchi at SK meeting, 2005

SK-I & II Final data samples



Y.Takeuchi@SK meeting, May 2005

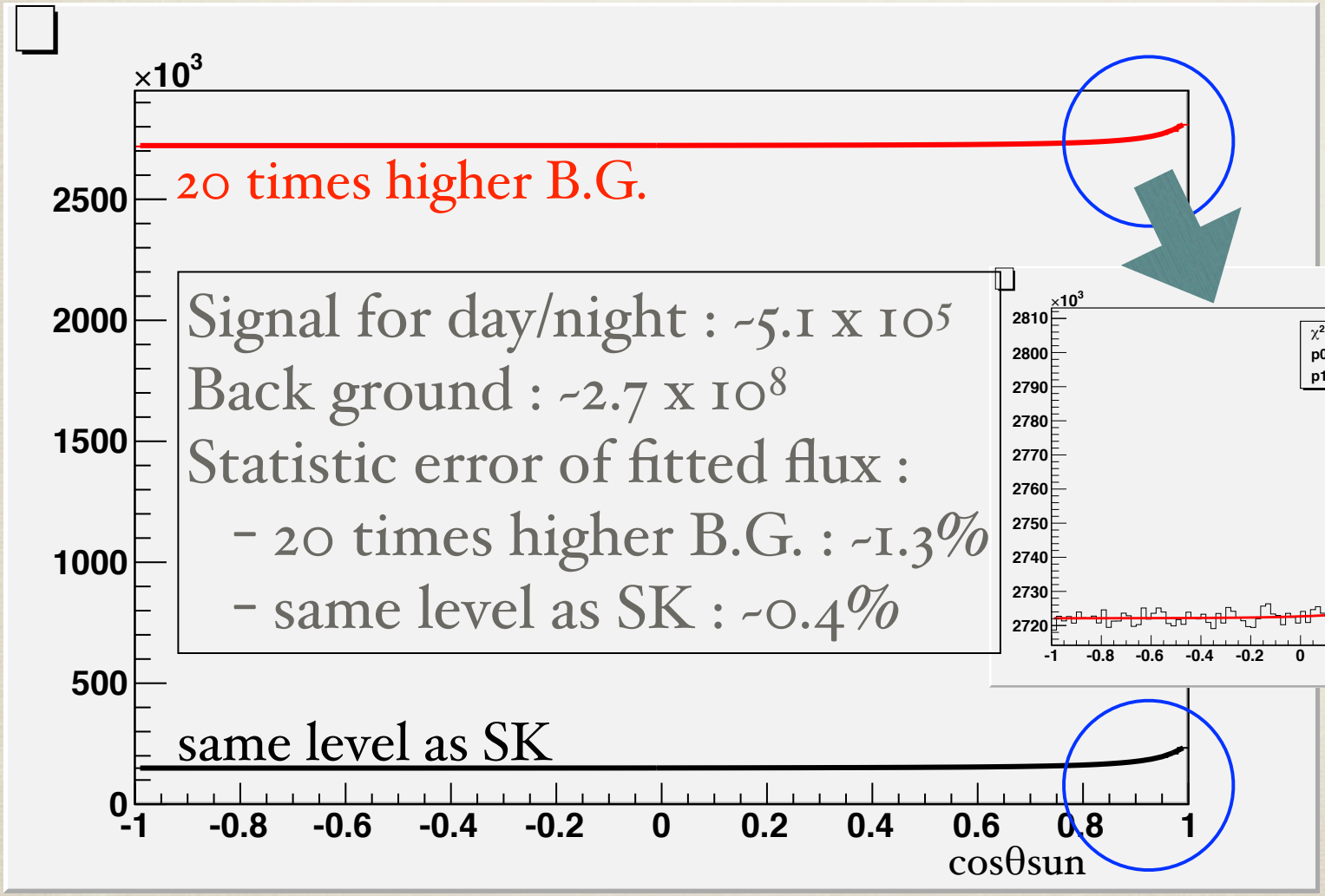
- **Event rate of SK-II is still higher than SK-I.**
- **Dominant BG source in low-e region is external events from outside fiducial volume.**
- **Could the energy and vertex resolution explain the difference?**

High-e region could be explained by
energy resolution
vertex resolution at spallation cut
different 2nd reduction

Assumption

- Same condition as SK-II.
  - Event rate : 328 events/day/22.5kton/(6.5-19.5MeV)
  - 6.5MeV (kin.) energy threshold
- HK 10 years sensitivity with the Solar best parameters.
- Spallation background is 20 times larger than SK and also same level as SK.
- 100,000 toy-MCs are generated.

Solar neutrino signal in HK



Signal for day/night : ~5.1 x 10^5

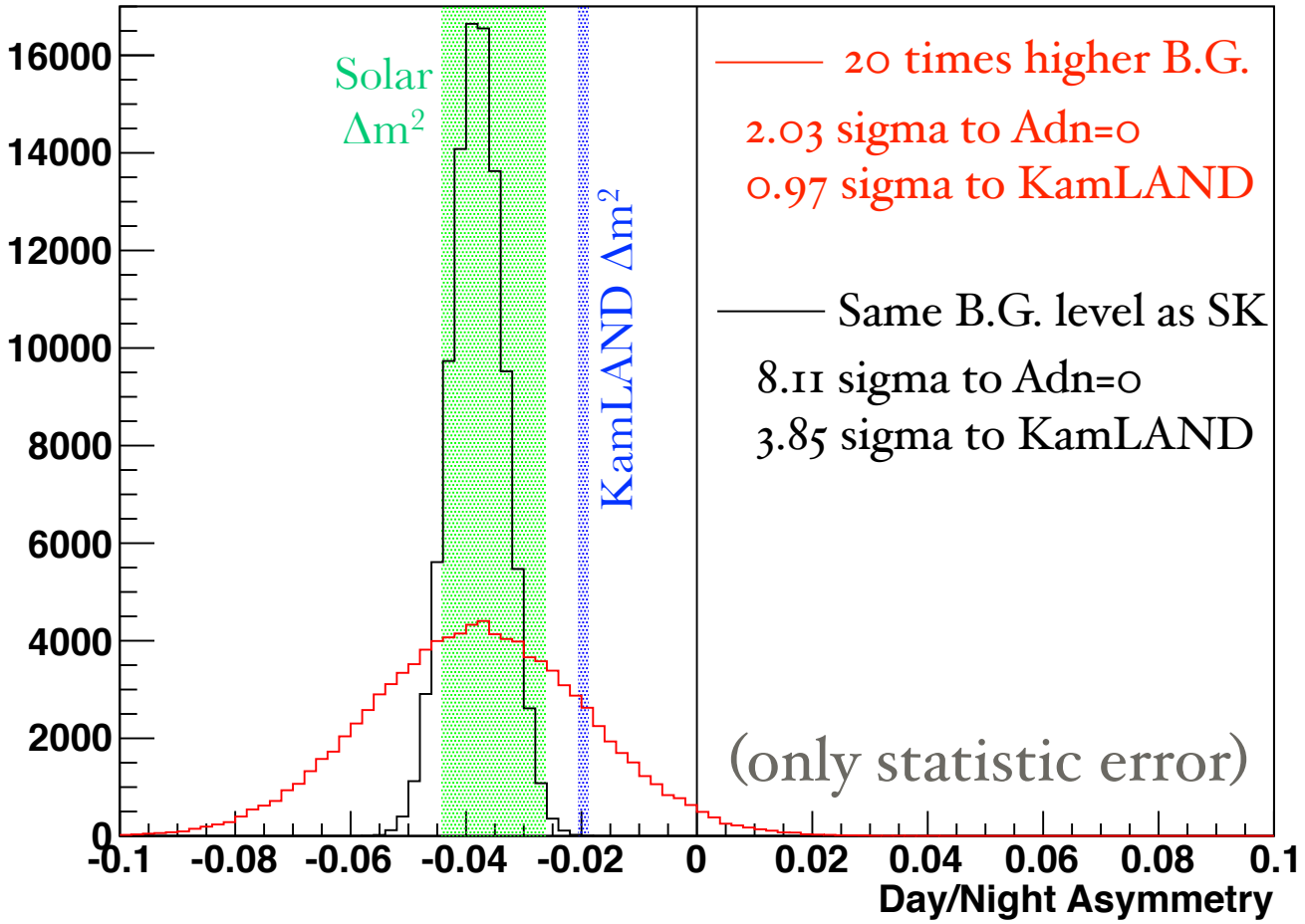
Back ground : ~2.7 x 10^8

Statistic error of fitted flux :

- 20 times higher B.G. : ~1.3%
- same level as SK : ~0.4%

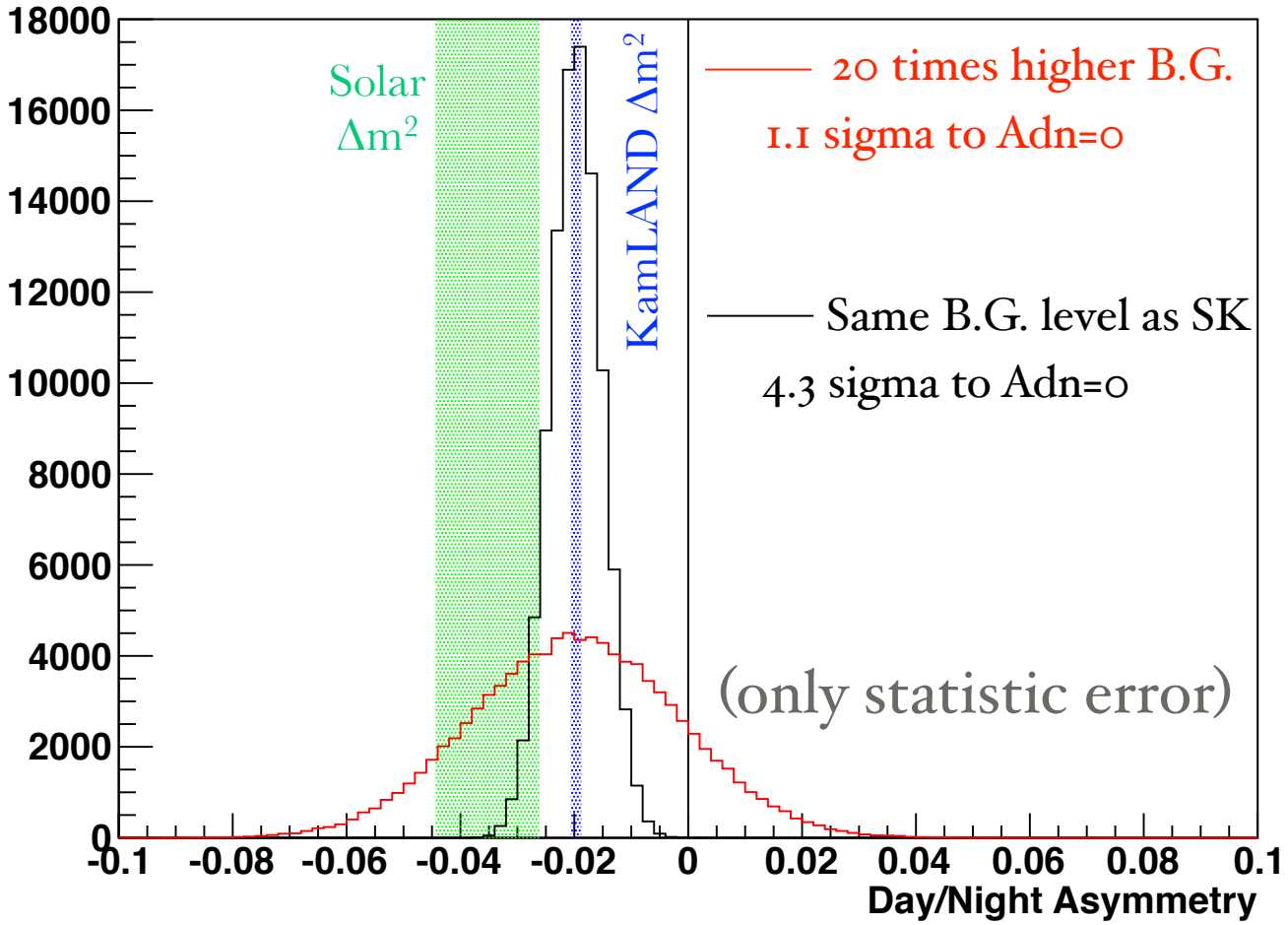
Day/Night asymmetry in 100,000 toy-MCs

in case of solar best is the solution



Day/Night asymmetry in 100,000 toy-MCs

in case of kamland best is the solution



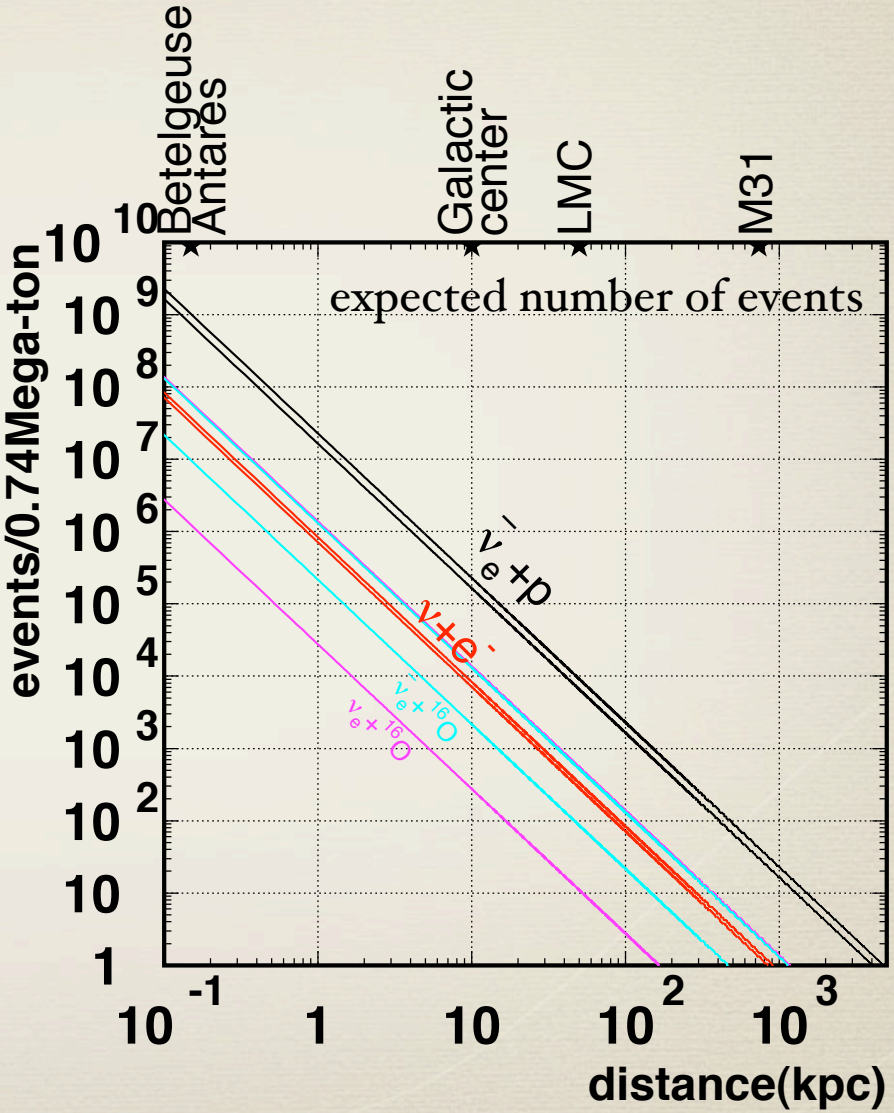
Summary

- The mega-ton scale WC detector has physics potential for solar neutrino oscillation, especially sensitive to Δm^2_{21}, however, a spallation background should be reduced at the same level as SK for a meaningful result, and it seems not to be easy with the current condition and analysis algorithm…
- Next to study
  - In case of several conditions of number of PMTs, QE and depth.
  - How to reduce spallation background by software : the spallation cut used for the SNR analysis (in which longitudinal vertex correlation was also used) could help some factors?
  - Systematic error : it can be estimated by precise monitoring of the detector asymmetry by spallation sample.

SUPERNOVA BURST NEUTRINOS

Supernova burst neutrinos

- In case of a galactic SuperNova, very large statistics, precise directionality and time profile are available.
- Detection of burst neutrinos from SuperNova in nearby galaxies is also possible.



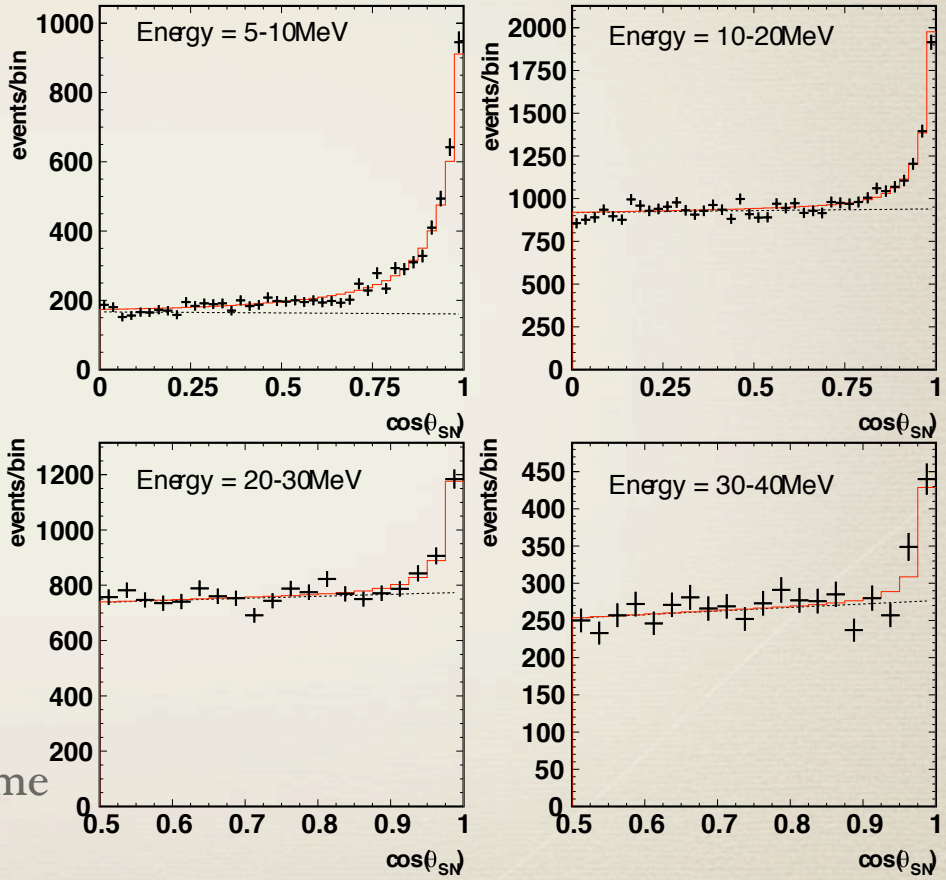
Supernova burst neutrinos

@ 10 kpc

Inverse beta ($\bar{\nu}_e + p \rightarrow e^+ + n$)	162,000~228,000
electron scattering ($\nu + e^- \rightarrow \nu + e^-$)	6,000~7,000
ν_e ^{16}O charged current	300~14,000
$\bar{\nu}_e$ ^{16}O charged current	2,000~13,000
total	170,000~260,000

6.5MeV (kin.) energy threshold / 0.74Mton volume
No/NH/IH neutrino oscillation are assumed
spallation B.G. is ignorable.
(~20 events/0.74Mton/18sec.)

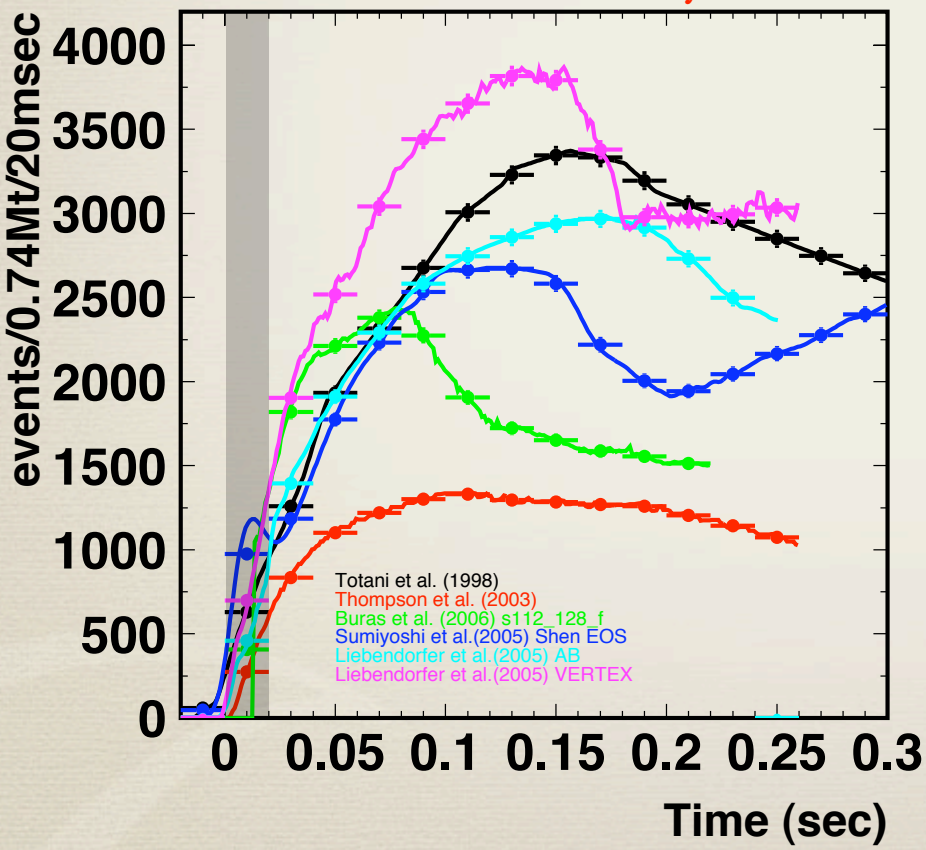
angular distributions

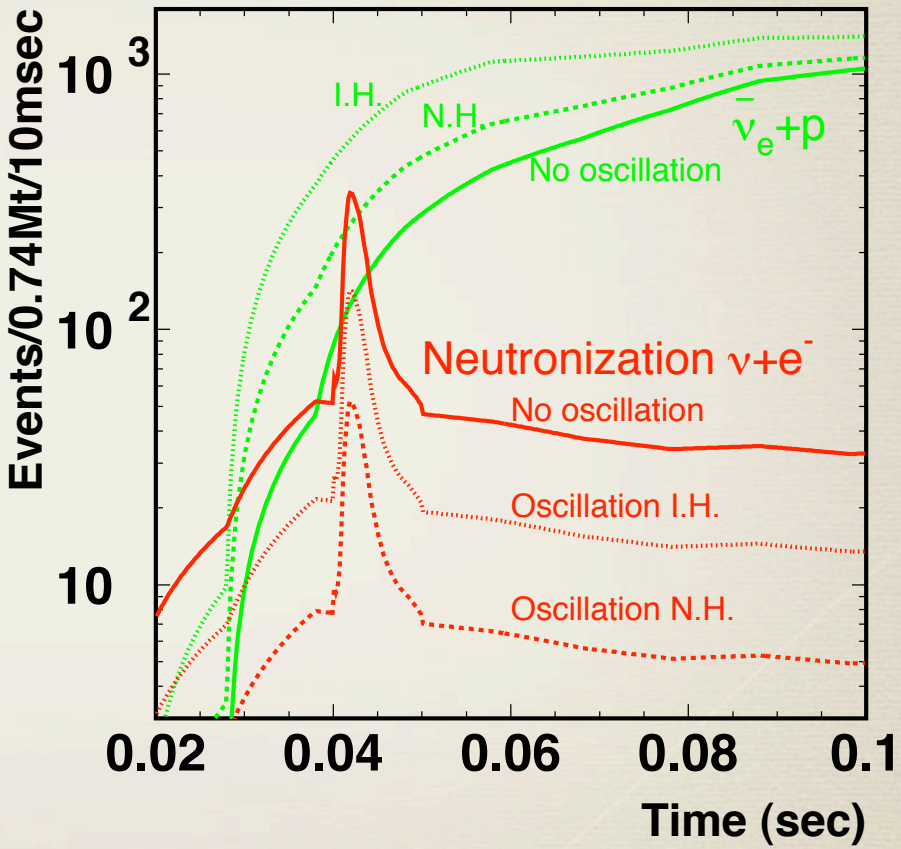


Supernova burst neutrinos

time profile @ 10 kpc

determine starting time
⇔ with 1 msec accuracy

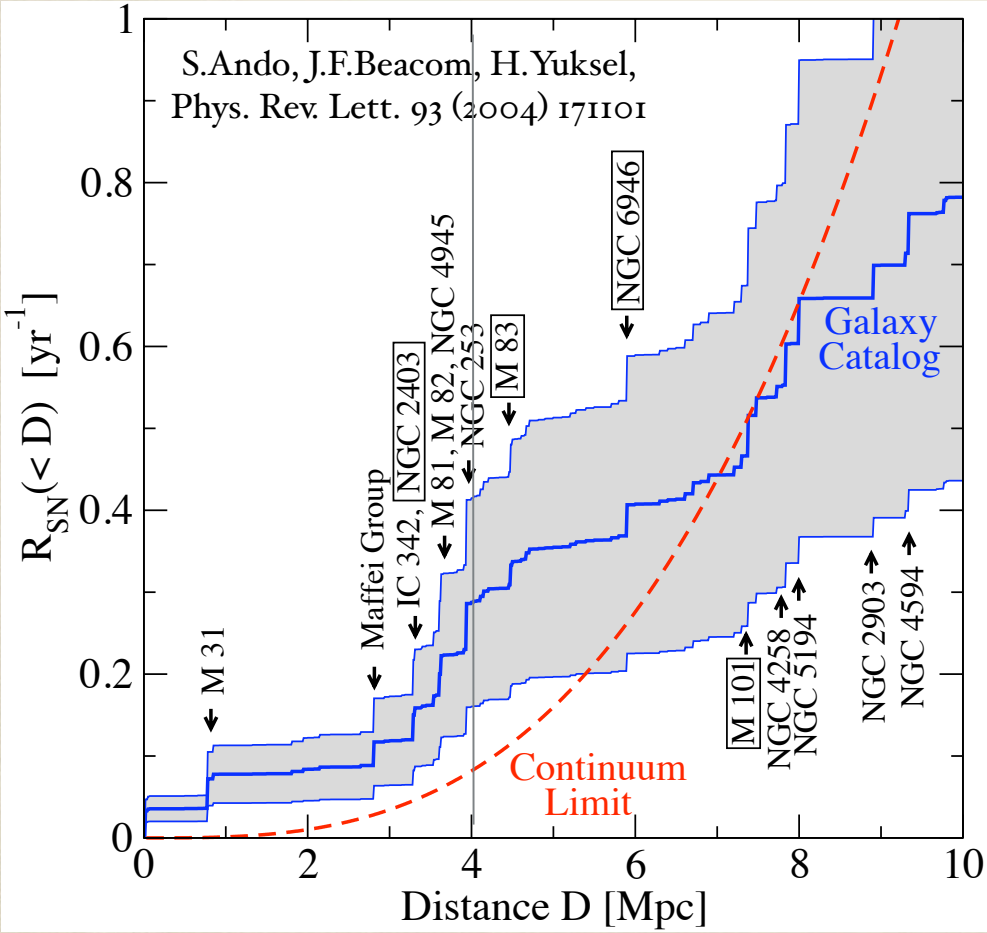




spallation B.G. is ignorable
(~0.01 events/0.74Mton/10 msec)

Supernova burst neutrinos

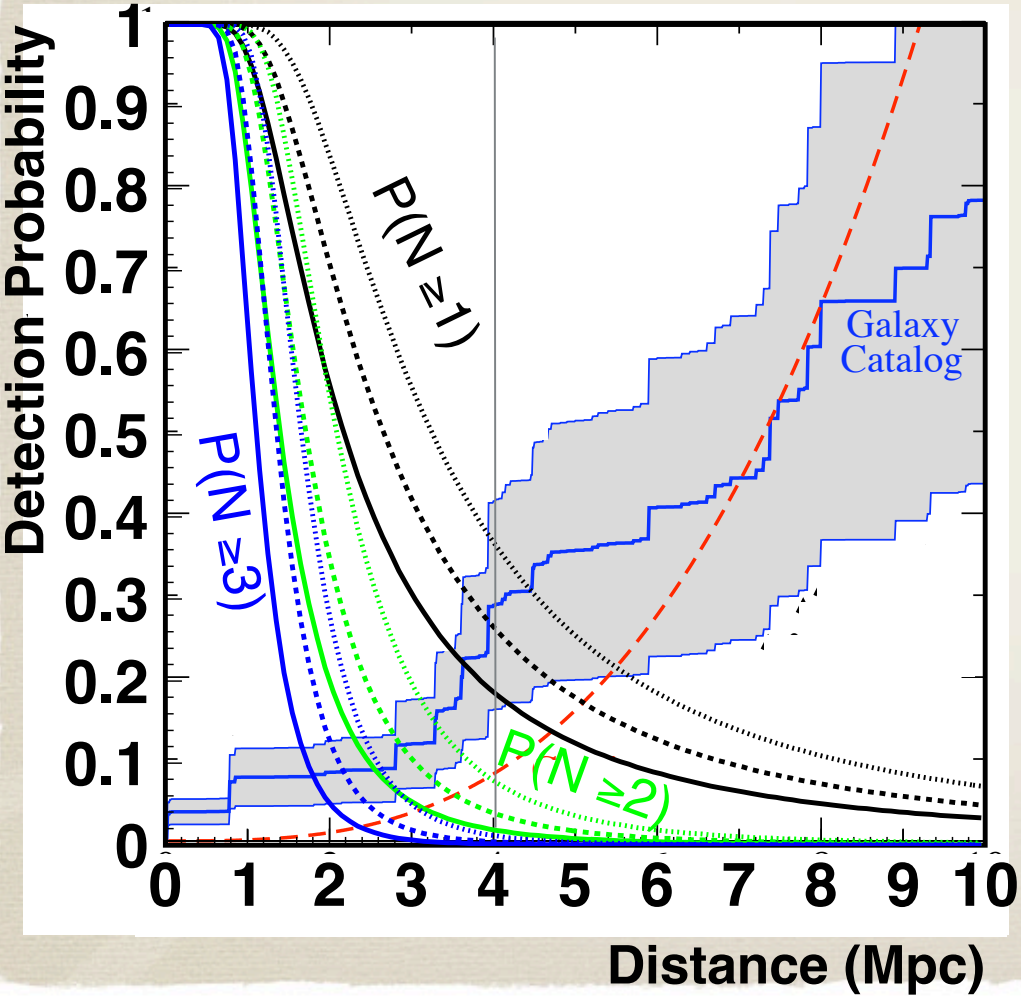
in nearby galaxies



- ~0.3 SN/year is expected to 4Mpc.
- If the analysis energy threshold for HK is set to 18MeV for reduce B.G., which comes from SK-2 experiences, the detection probability is 19-37% (N≧1)
- The expected accidental B.G. becomes 1.23e-03 events/18sec. The probability of an accidental event is 0.12% (N≧1)

Supernova burst neutrinos

in nearby galaxies



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Summary

- Galactic supernova detection in HK is promising for various studies about the detailed mechanism of SuperNova explosion.
- A detection of supernova burst neutrino events from nearby galaxies (~4Mpc) is expected. The more photo-coverage and/or Gd doped is preferable to lowering threshold (less than 18MeV) for better sensitivity.
- Next to study :
  - The detection probability and background estimation in several cases, (depth, number of PMTs, QE, Gd doped etc.)