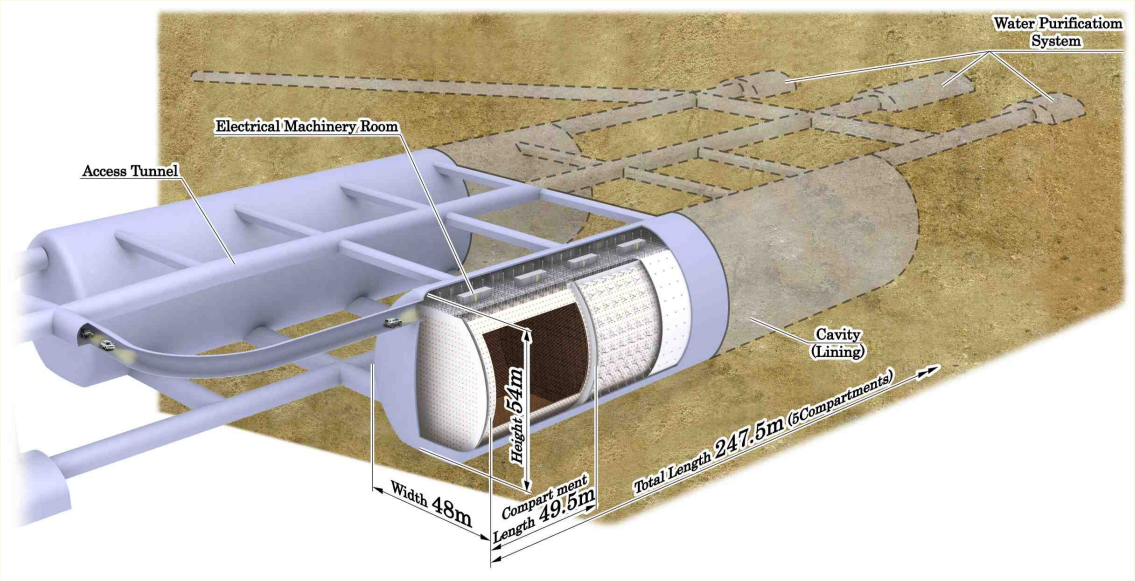
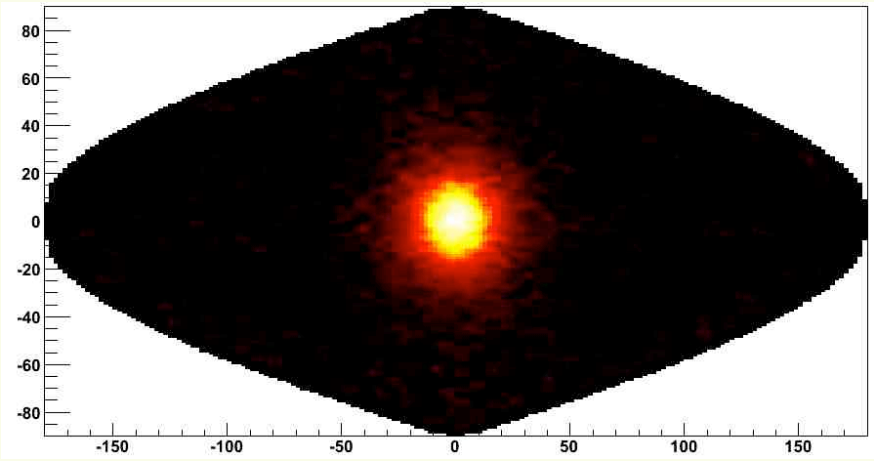
Solar neutrino measurement in Hyper-Kamiokande





Yusuke Koshio
Okayama university
for HK astrophysics working group

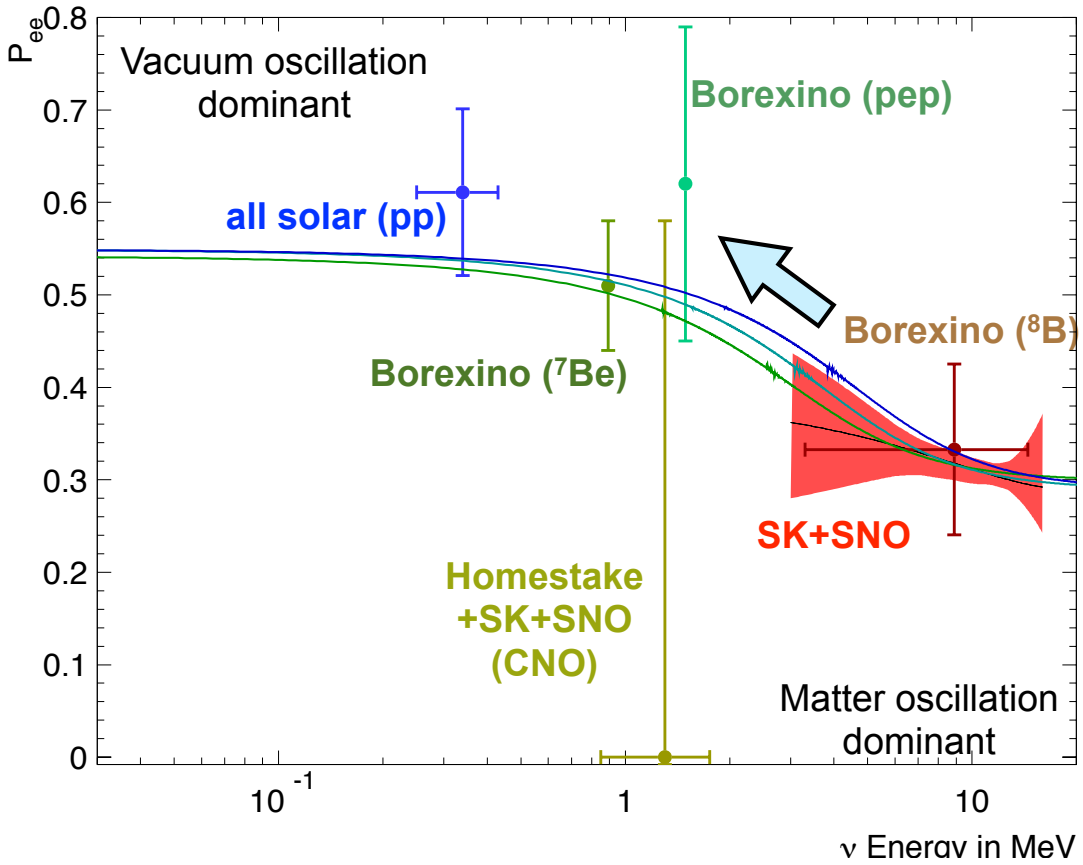
5th HK open meeting / 21st July, 2014 / University of British Columbia

Physics motivation

- Neutrino oscillation
  - ✓Can see the spectrum up-turn to the vacuum oscillation dominant region?
  - ✓Can see the day-night asymmetry more precisely?
- Astrophysical point
  - ✓Can separate high/low heavy metal model?
  - ✓Short term flux variation?

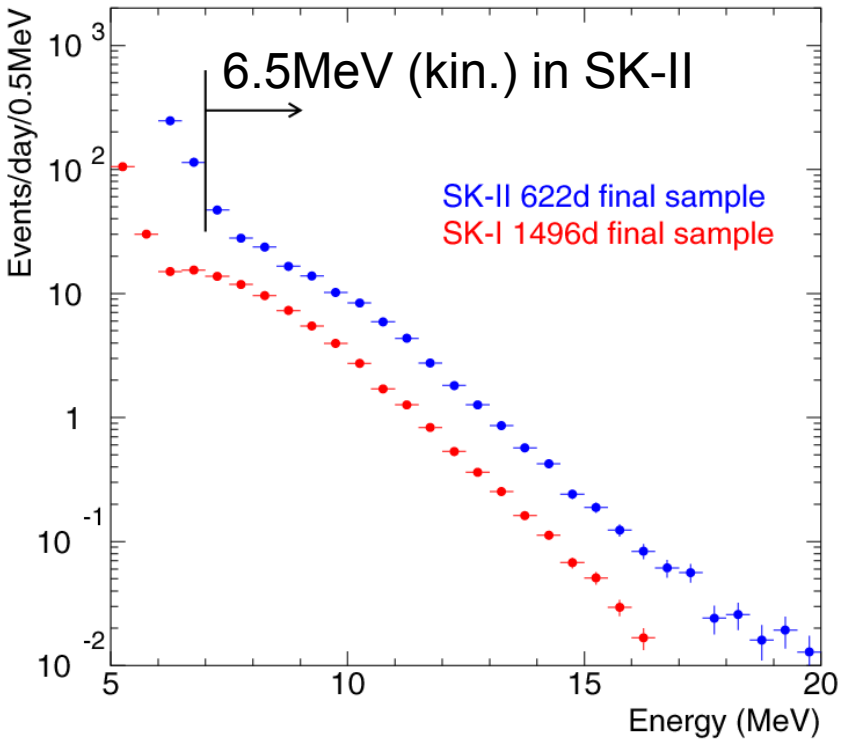
Spectrum distortion

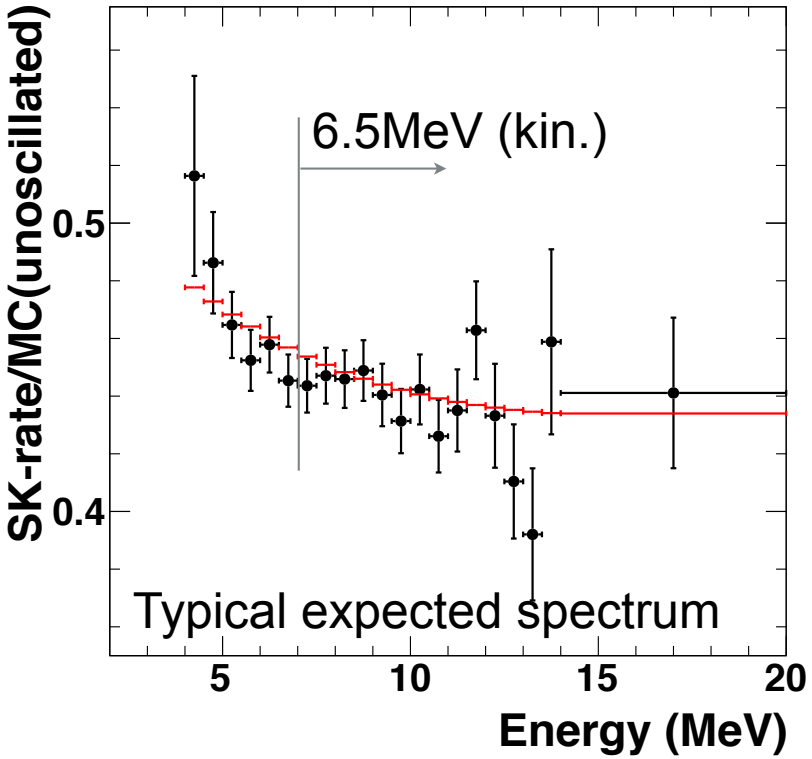
Survival probability as a function of neutrino energy



Spectrum up-turn

- Lowering energy threshold is crucial
- It strongly depends on the photo-coverage / Q.E.
- The current HK configuration is same as SK-II



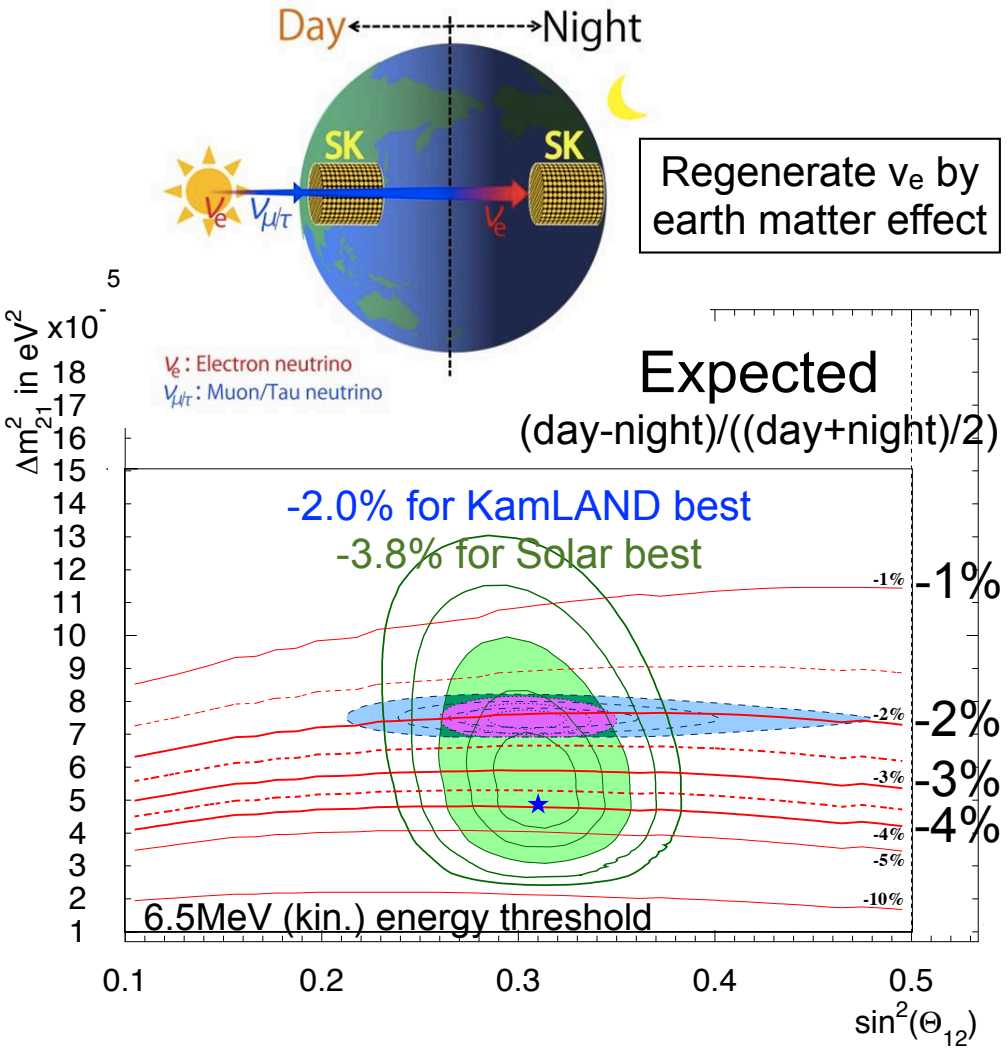


Hard to see the up-turn in the current config...

Physics motivation

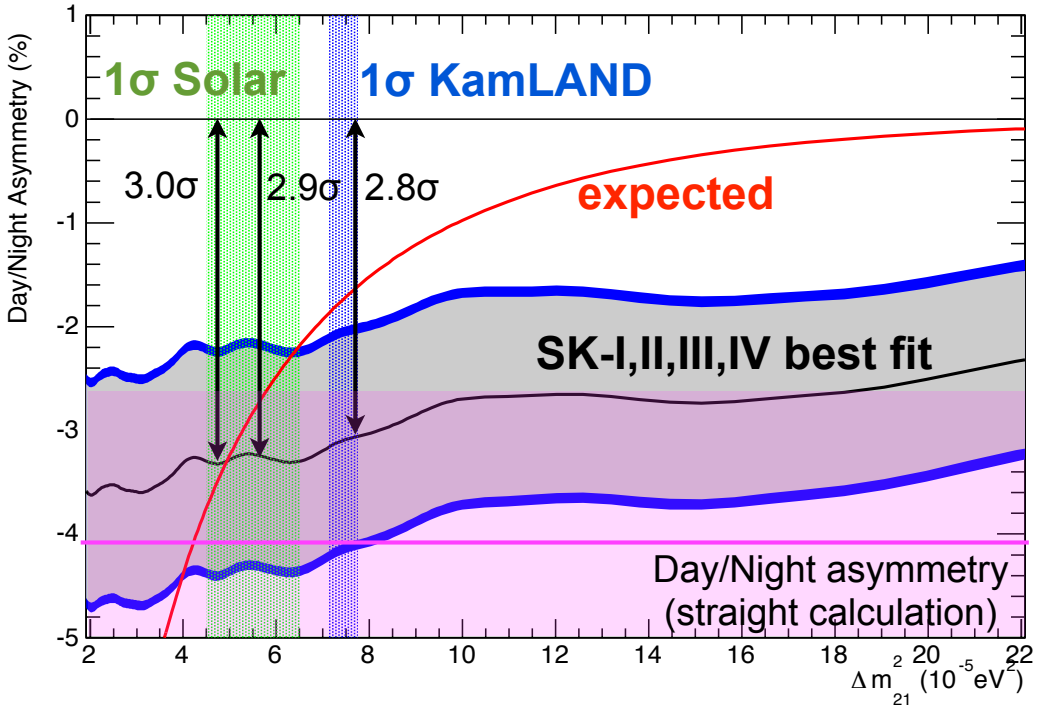
- Neutrino oscillation
  - ✓Can see the spectrum up-turn to the vacuum oscillation dominant region?
  - ✓Can see the day-night asymmetry more precisely?
- Astrophysical point
  - ✓Can separate high/low heavy metal model?
  - ✓Short term flux variation?

Day-Night flux asymmetry



Indication of Day-Night asymmetry in SK 17yrs

	Amplitude fit		Straight calc.
	$\Delta m^2_{21}=4.84\times10^{-5}$ eV^2	$\Delta m^2_{21}=7.50\times10^{-5}$ eV^2	(D-N)/((D+N)/2)
SK-I	-2.0±1.8±1.0%	-1.9±1.7±1.0%	-2.1±2.0±1.3%
SK-II	-4.4±3.8±1.0%	-4.4±3.6±1.0%	-5.5±4.2±3.7%
SK-III	-4.2±2.7±0.7%	-3.8±2.6±0.7%	-5.9±3.2±1.3%
SK-IV	-3.6±1.6±0.6%	-3.3±1.5±0.6%	-4.9±1.8±1.4%
combined	**-3.3±1.0±0.5%**	**-3.1±1.0±0.5%**	**-4.1±1.2±0.8%**
non-zero significance	3.0 σ	2.8 σ	2.8 σ



Solar region

✓ differ from zero by 2.9~3.0σ

✓ agree with expect by 1.0σ

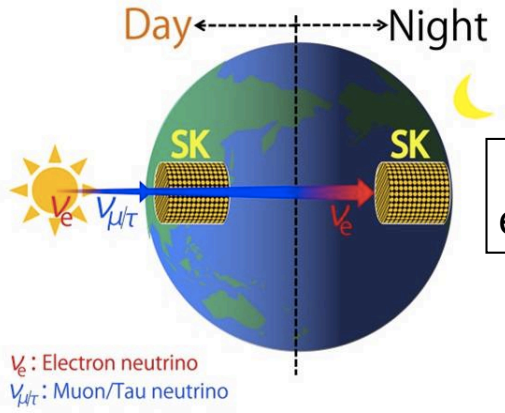
KamLAND region

✓ differ from zero by more than 2.8σ

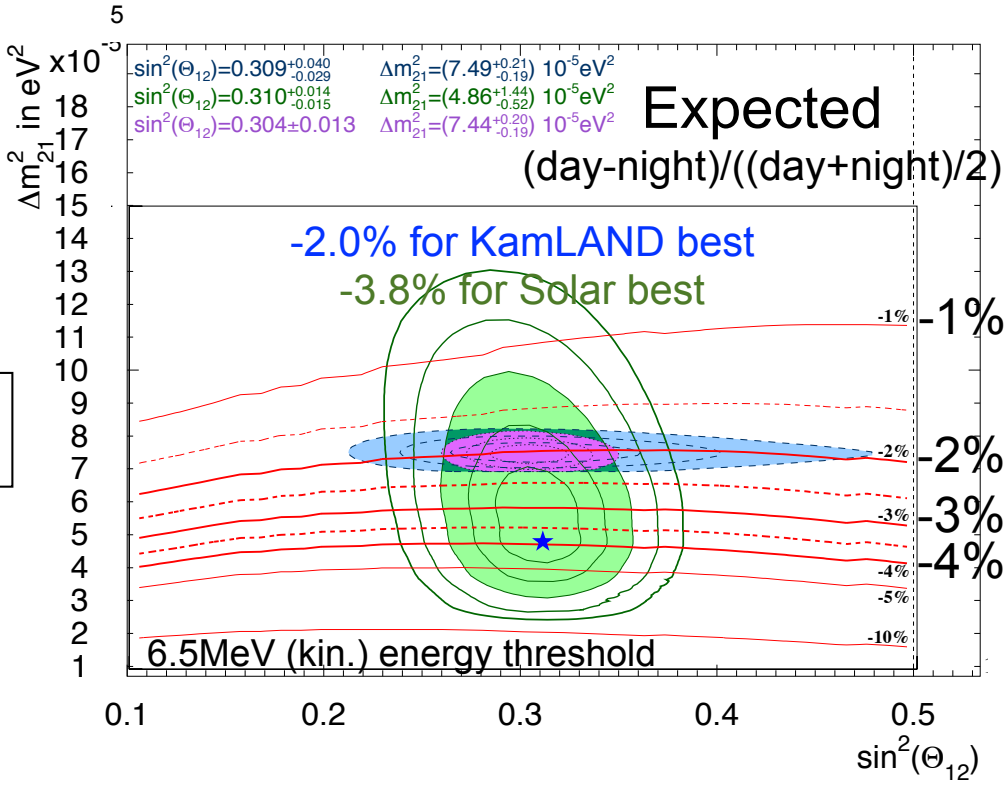
✓ agree with expect by 1.3σ

What's for Hyper-K?

Day-Night flux asymmetry



Regenerate ν_e by earth matter effect



Evidence / Discovery of day-night asymmetry?

Possible separation between Solar and KamLAND best?

Low energy backgrounds in SK

Reminder of 2nd HK meeting by Takeuchi-san

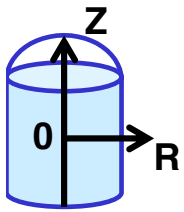
Spallation is dominant BG source in ~10-20MeV

Misfit

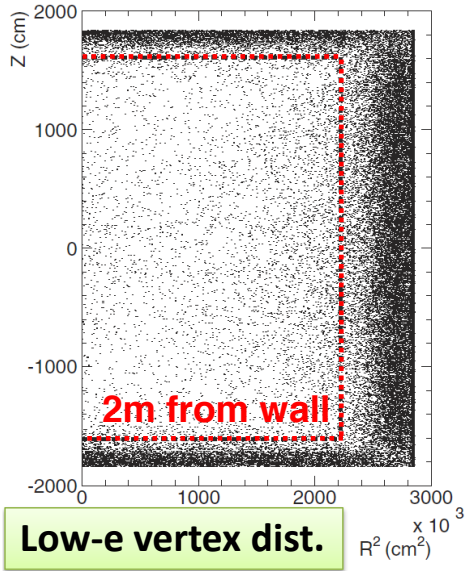
External gamma

Radon, Misfit, External gamma, etc.

Remaining spallation products (probably)



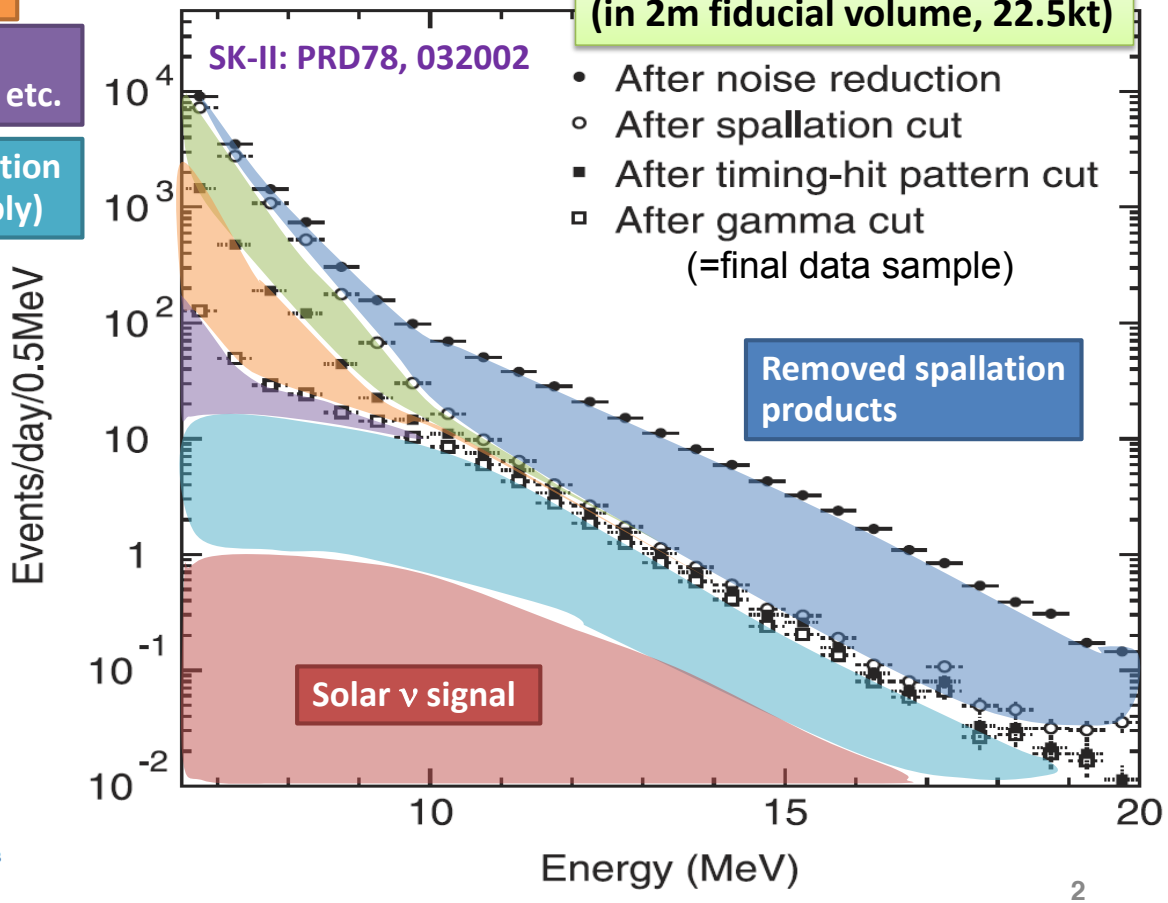
SK-I: PRD73, 112001



Low-e vertex dist.

Solar ν data reduction (in 2m fiducial volume, 22.5kt)

SK-II: PRD78, 032002

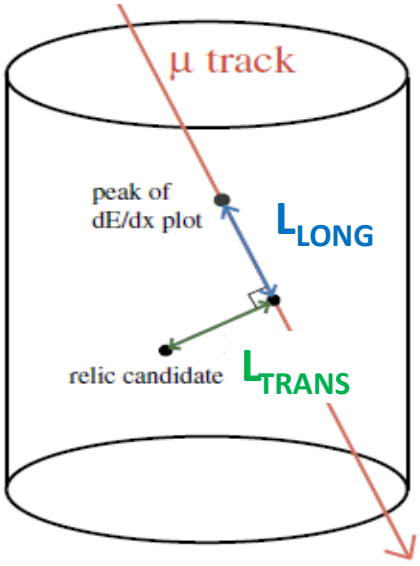


2

Spallation cut in SK

Reminder of 2nd HK meeting by Takeuchi-san

- **Likelihood method is used to reduce spallation products in SK**
- **"Solar spallation cut" (in PRD73, 112001)**
  - ***Likelihood*** **= PDF(Q_{RES}) * PDF(ΔT) * PDF(L_{TRANS})**
- **"(supernova) relic spallation cut" (in PRD85, 052007)**
  - ***Likelihood*** **= PDF(Q_{PEAK}) * PDF(ΔT) * PDF(L_{TRANS}) * PDF(L_{LONG})**
- **Improved likelihood function is used in "relic spallation cut"**



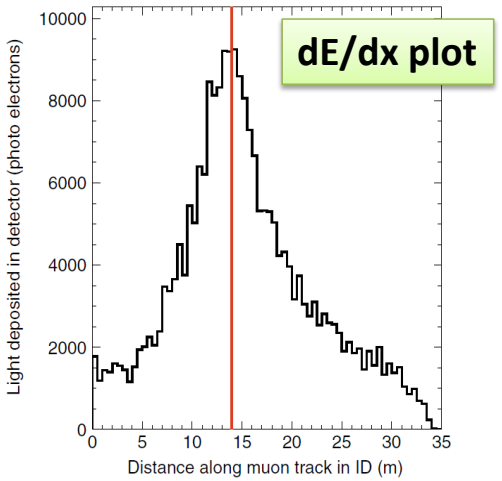


FIG. 2 (color online). Example of a dE/dx plot. The red line indicates where along the muon track the candidate was reconstructed. This example has particularly good correlation.

SK SRN: PRD85, 052007

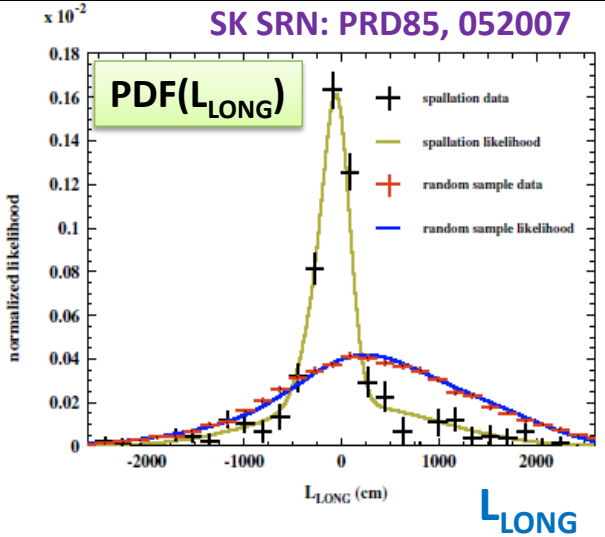


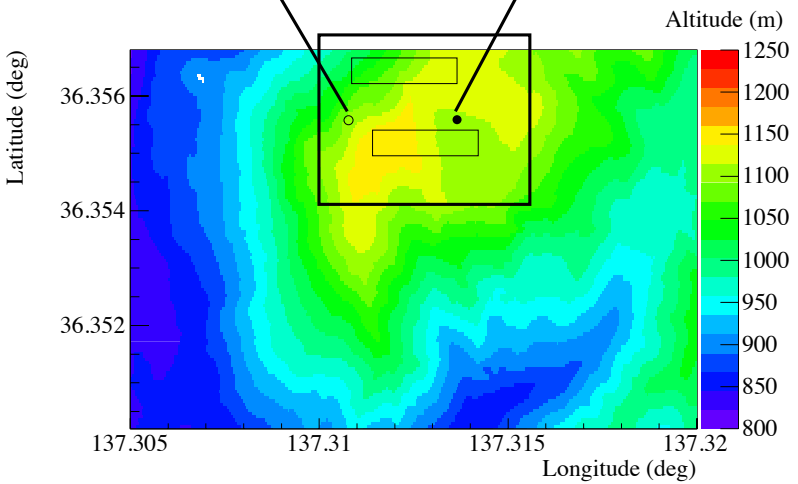
FIG. 4 (color online). SK-I/III data with likelihood functions overlaid for single through-going muons. Top shows transverse distance; bottom shows longitudinal distance.

[4]

Muon flux in HK

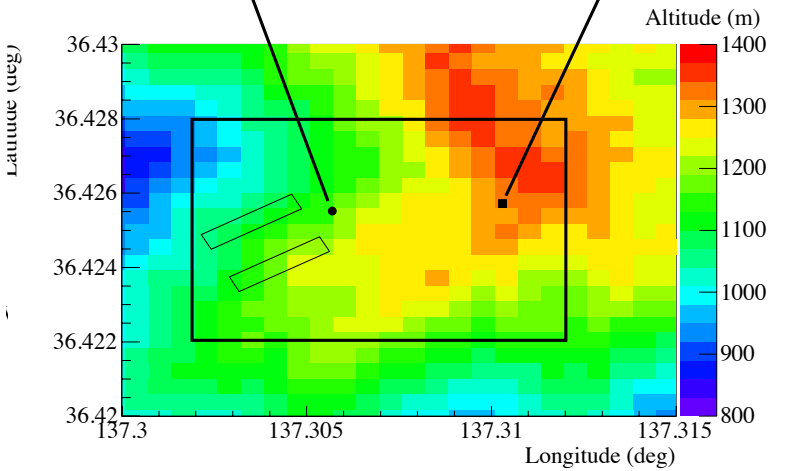
estimated by Shimizu-san

HK position **LOI** **New (Basing point)** HK(Tochibora)



Altitude

HK position **Boring survey origin** **SK** HK(Mozumi)



200GeV

muon average energy
258GeV in SK

227GeV

5.36 ± 1.07

Ratio of muon flux
HK/SK

2.23 ± 0.45

~4

density of spallation product
apply factor 0.8 to the muon flux

~2

Spallation cut in HK

Reminder of 3rd HK meeting by Yano-san

- **Likelihood method is used to reduce spallation products in SK**
- **"Solar spallation cut" (in PRD73, 112001)**
  - ***Likelihood*** = PDF(Q_{RES}) * PDF(ΔT) * PDF(L_{TRANS})
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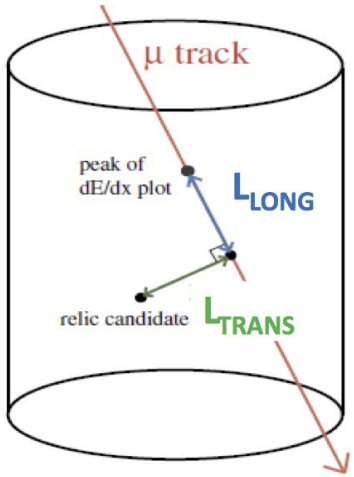
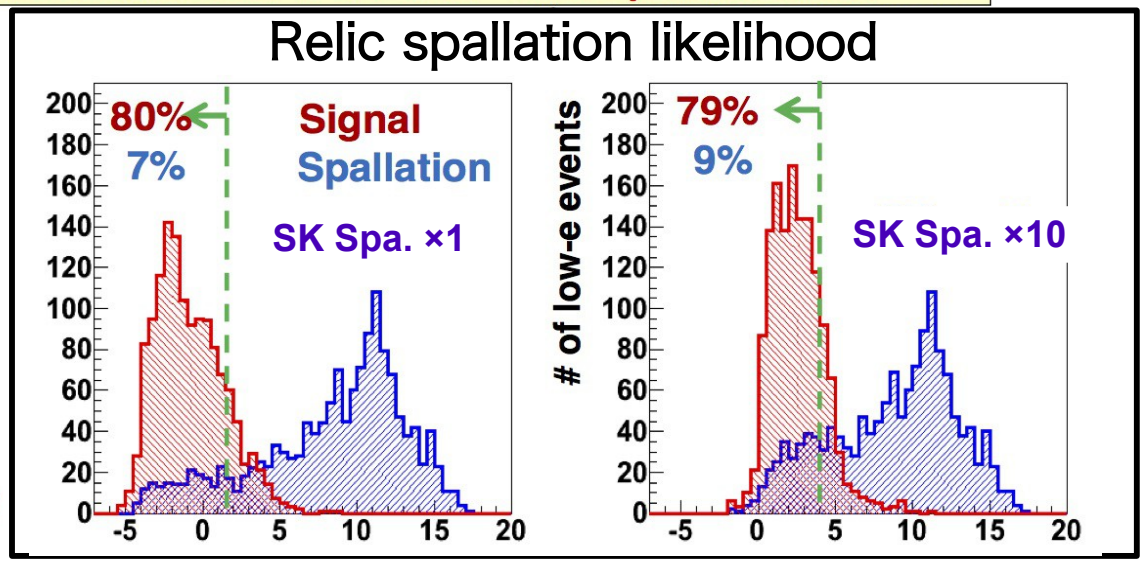
- **Improved likelihood function is used in "relic spallation cut"**

Y. Takeuchi, 2nd HK open meeting





SK-II relic spallation likelihood and event samples are used for estimating HK. (SK-II: photo coverage 19%)

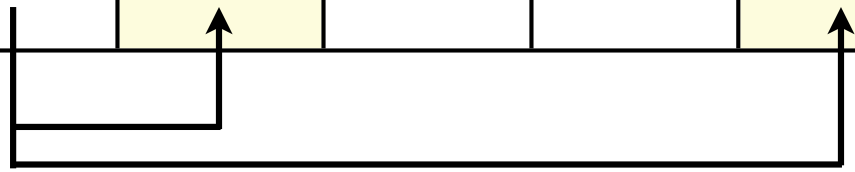
Spallation cut in HK

Reminder of 3rd HK meeting by Yano-san

- Keep ~80% signal efficiency in 17.5~20MeV

SK

Muon flux comparing to SK	Mu*1	Mu*2	Mu*3	Mu*4	Mu*5	Mu*7
Signal efficiency	80%	81%	81%	80%	80%	81%
Remaining spallation products	1.2%	2.1%	2.5%	3.0%	3.9%	4.6%



Increase factor from Super-K

HK(Mozumi) Factor ~1.8

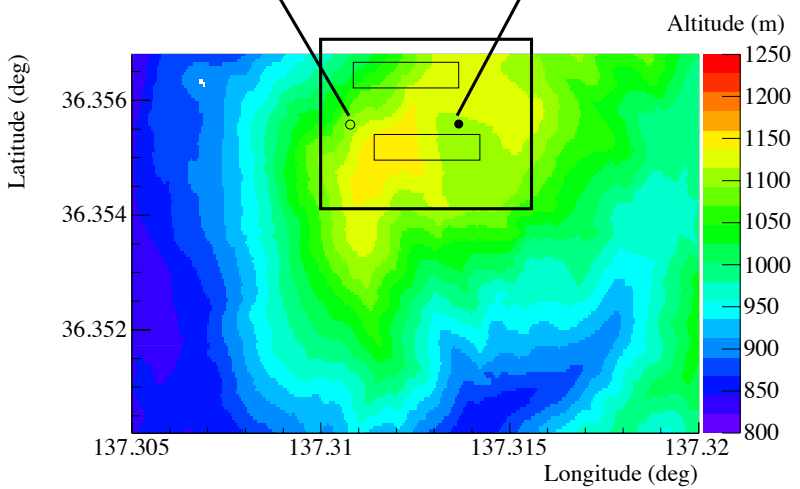
HK(Tochibora) Factor~3.3

How much increase spallation

estimated by Shimizu-san and Yano-san

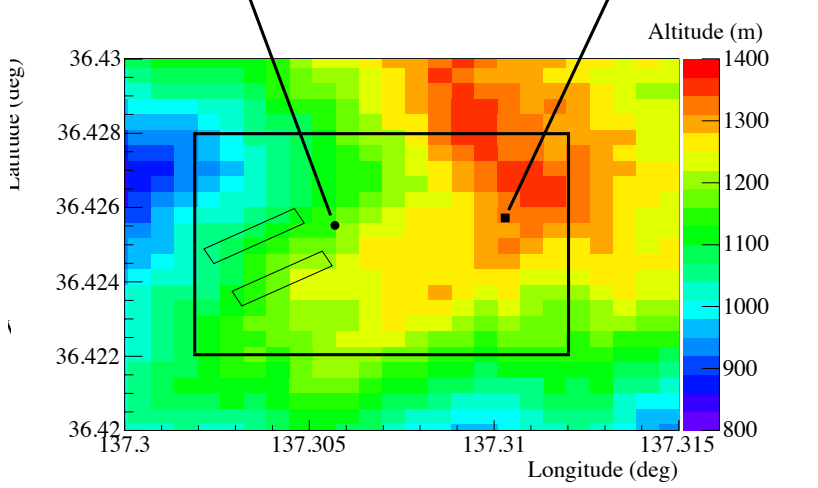
Neutrino 2014 poster by Yano-san

HK position **HK(Tochibora)**



Altitude

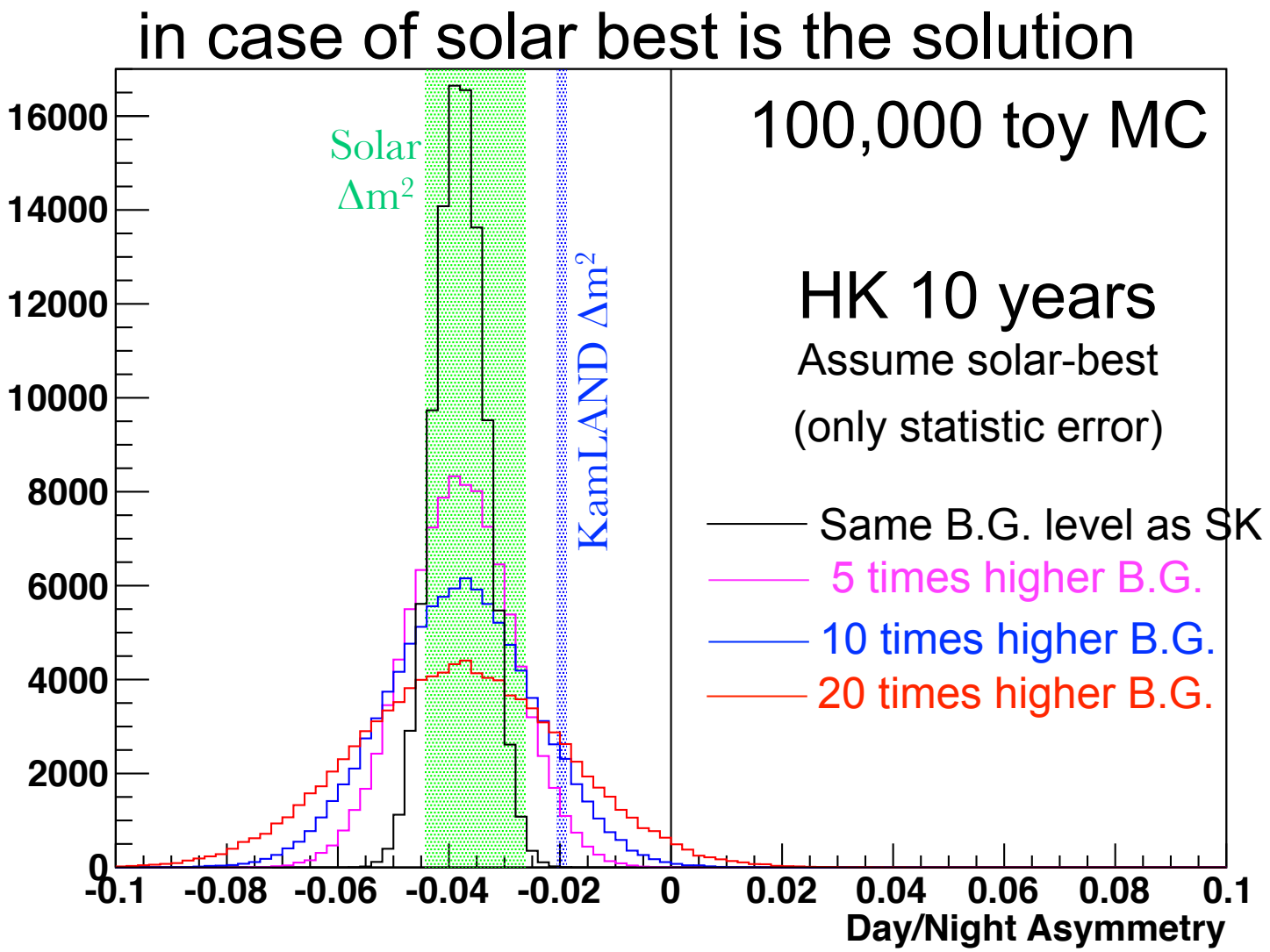
HK position **HK(Mozumi)**



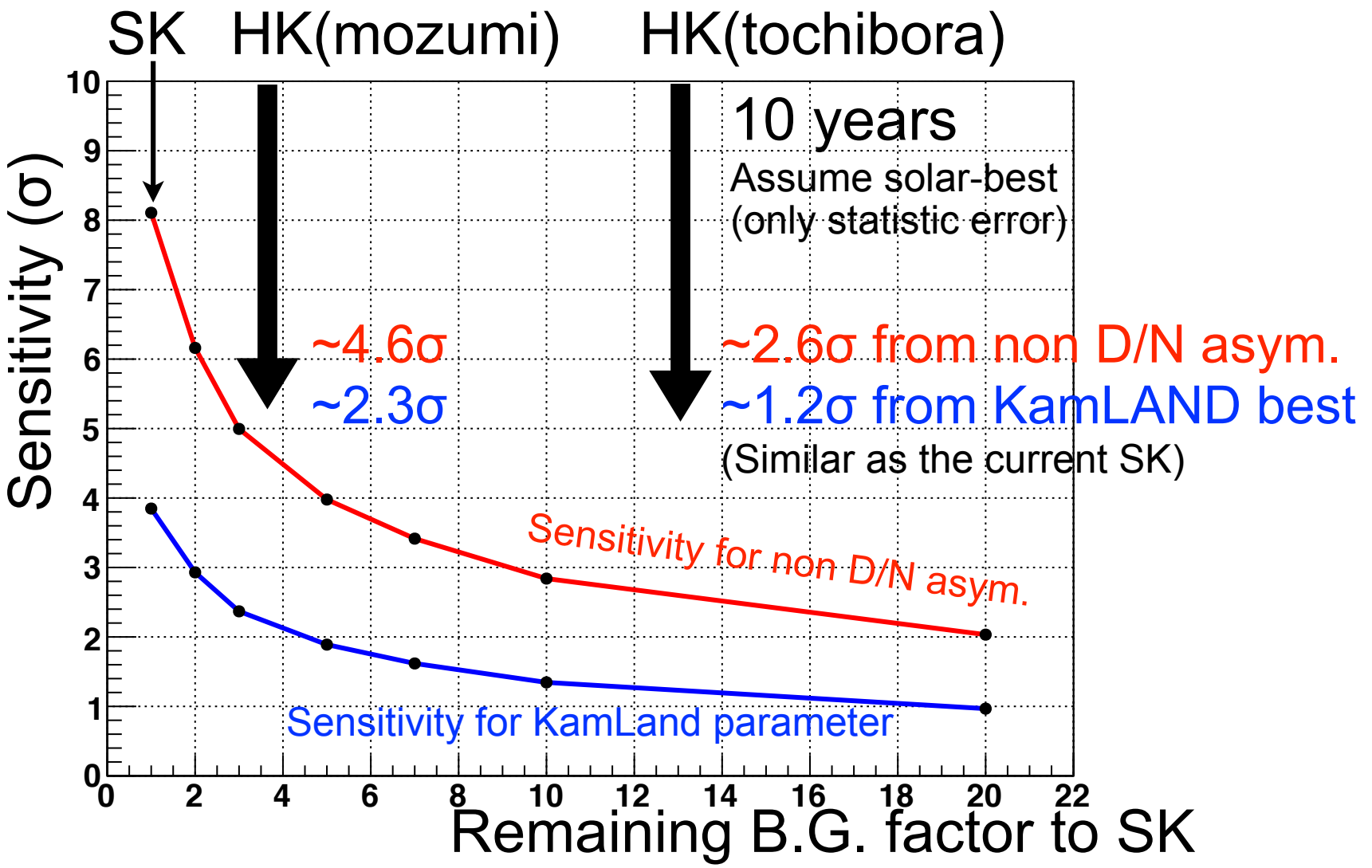
~4	density of spallation product (proportional to 0.7-th power of the energy)	~2
3.3	Factor of spallation cut	1.8
~13.2	Total	~3.6

Day-Night asymmetry in HK

Reminder of 2nd HK meeting by Koshio



Day-Night sensitivity in HK



Summary

The sensitivity of solar neutrino physics in HK is estimated.

- Hard to see the low-energy upturn expected by LMA-MSW effect because of the reduced photo-coverage.
- The day-night asymmetry in HK(Tochibora) is almost same as the current SK, while ~4.6σ (to zero asym.) and 2.3σ (to KamLAND best fit param.) is expected for HK(Mozumi).
  - Still have a possibility to be improved by the modification of the spallation reduction method.
  - The realistic study, such as detector shape, photo-sensor, dark noise and so on, which may change the energy threshold, should be done.