Latest results from solar neutrino measurement in the Super-Kamiokande detector

Poster ID 502

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1. Abstract

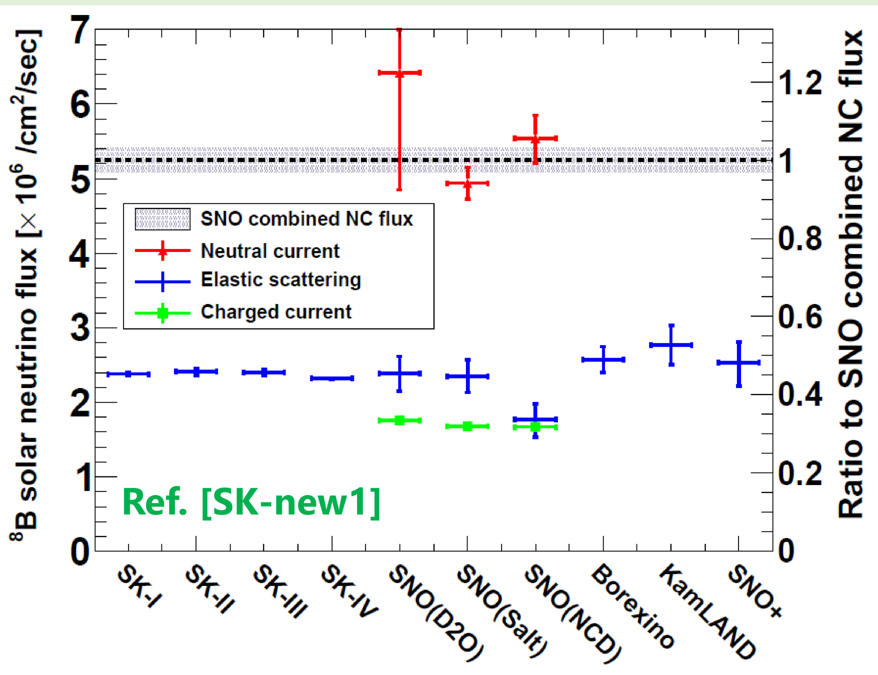
Super-Kamiokande (SK), a 50 kton water Cherenkov detector in Japan, is observing neutrinos from various natural sources. SK studies the effects of both the solar and terrestrial matter density on neutrino oscillations: a distortion of the solar neutrino energy spectrum would be caused by the edge of the Mikheyev-Smirnov-Wolfenstein resonance in the solar core, and terrestrial matter effects would induce a day/night solar neutrino flux asymmetry.

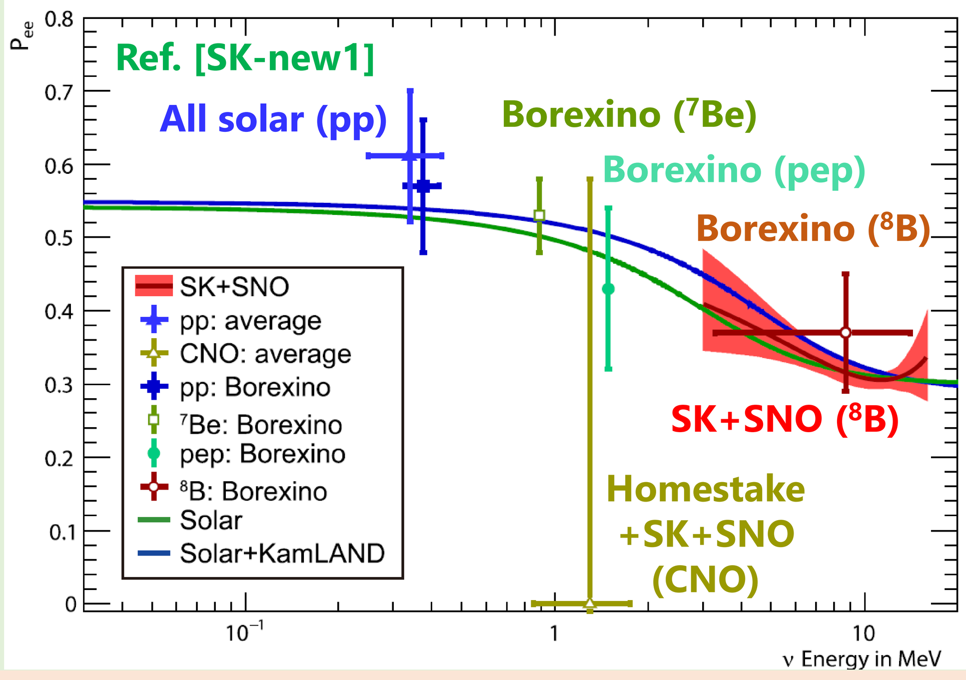
In this poster presentation, we overview the latest solar neutrino results using the data including the SK-Gd era, for example, the precise measurement of 8B solar neutrino flux, its energy spectrum, and oscillation parameters.

In addition to them, we also present the time variation of observed solar neutrino flux and a possible correlation between the neutrino flux and the solar activity.

2. Physics motivation

- Search for MSW up-turn below ~5 MeV region.
  → Energy spectrum measurement with smaller uncertainty.
- 1-3% level of day/night flux asymmetry. Ref. [MSW]
  → Smaller background (BG) fluctuation.



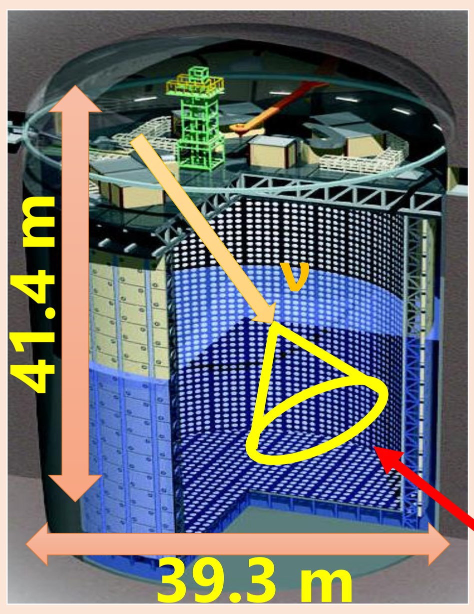


3. Super-Kamiokande

◆ Detector and data set

Ref. [SK-det]

- More than 11,000 of 20-inch PMTs for the inner detector.
- SK-IV ended in May 2018 for refurbishment work.
- Resumed data taking as SK-V since January 2019.
- First (second) Gd-loading in 2020, and 2022.



(1)	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
(2)	SK-I						SK-II				SK-III		SK-IV											SK-V		SK-VI		SK-VII	
(3)	PMT 11,146 (40%)						5,182 (19%)				11,129 (40%)															SK-Gd			
(4)	4.5 MeV						6.5 MeV				4.0 MeV			3.5 MeV															
(5)	1496 days						791 days				548 days			2970 days										379 days		561 days		Running	

(1) Year, (2) SK phase, (3) Photo coverage [%], (4) Recoil electron kinetic energy [MeV], (5)Livetime for analysis

Analysis fiducial volume 22.46 kton (FV).
(2 meters inside from the PMTs)

◆ Solar neutrino measurement

Ref. [SK-solar]

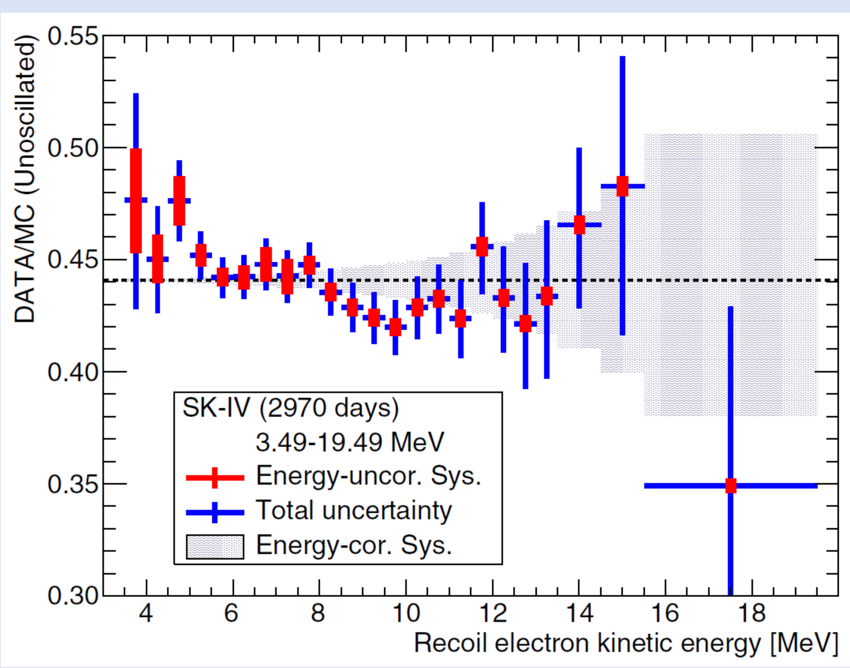
- Neutrino-electron elastic scattering ($\nu_X + e^- \rightarrow \nu_X + e^-$).
- Energy reconstruction by counting # of hit PMTs in 50 nsec and applying some corrections: water transparency, event-geometry dependent effective PMT coverage, etc.

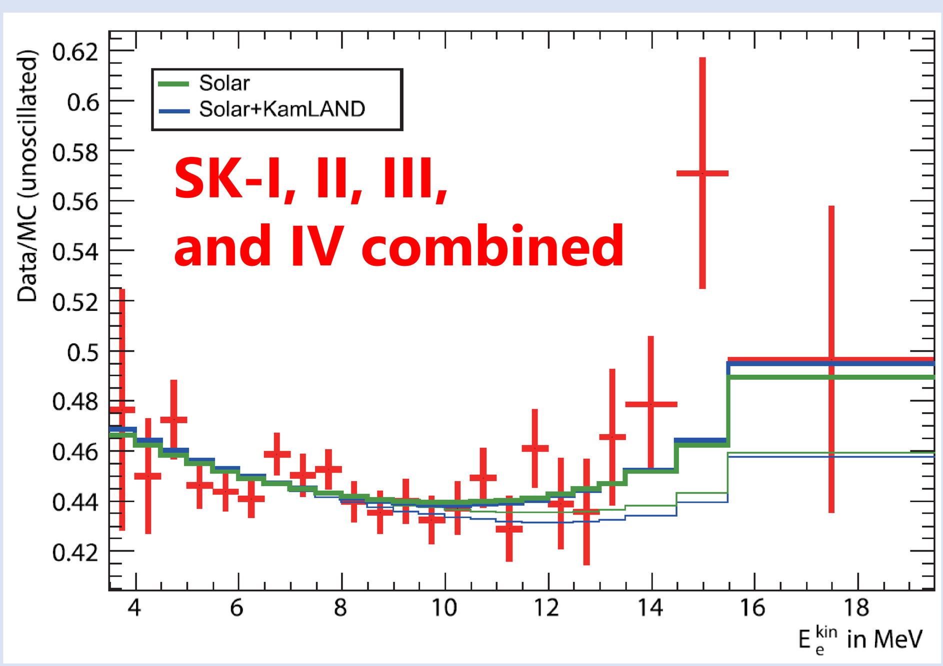
4. Energy spectrum in SK-IV

◆ Energy spectrum measurement

Ref. [SK-new1]

- SK recoil electron energy spectrum slightly favors up-turn.
- We also perform measurement below 3.49 MeV with a boosted decision tree method → poster #274 (A. Yankelevich).





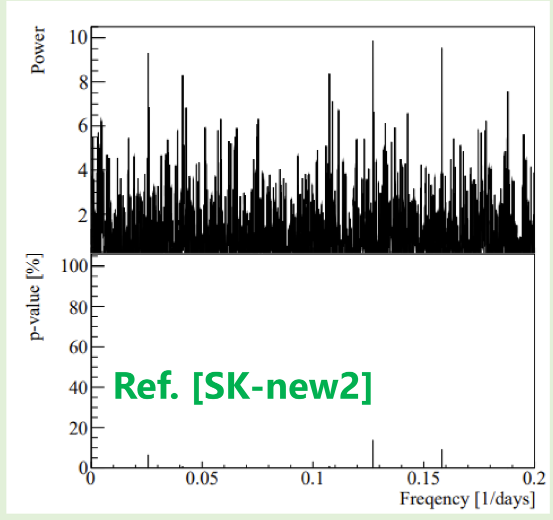
5. Flux and oscillation analysis

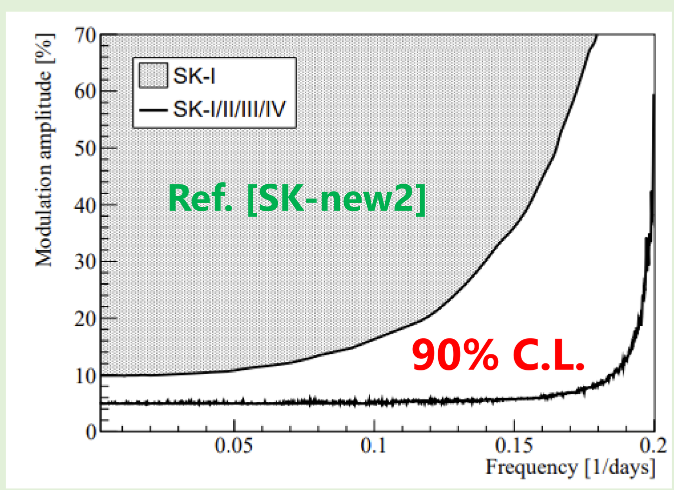
◆ Periodic analysis of ^{8}B neutrino flux

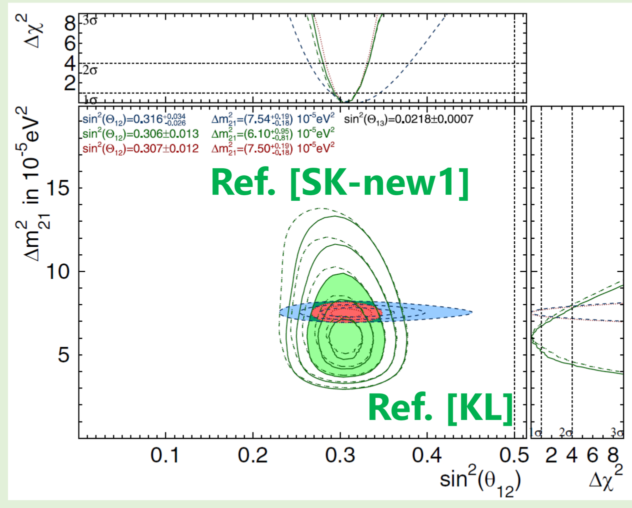
- Searched for periodic signal of ^{8}B solar ν in 5-days binned data.
  → Lomb-Scargle method.
- We found no significant periodic change of ^{8}B solar ν flux,
  (except for the modulation due to the elliptic orbit of the Earth around the Sun)
  and set the upper limits of modulation amplitude of solar ν.

◆ Oscillation analysis

- SK+SNO favors a lower Δm^2_{21} than KamLAND by ~1.4σ.



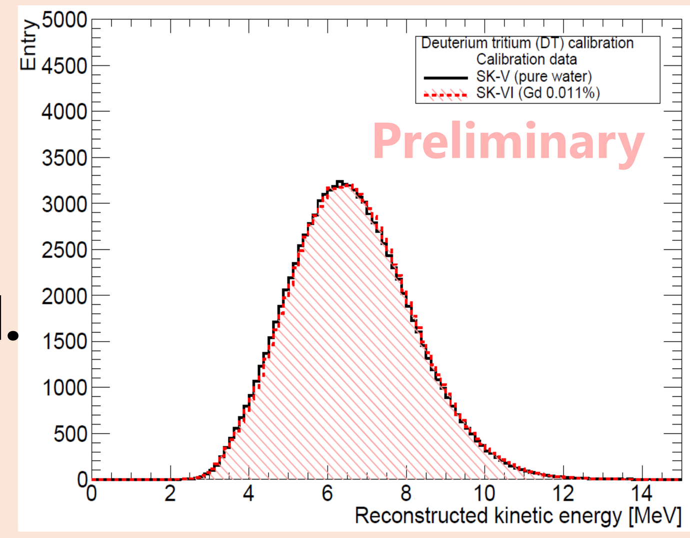




6. Solar neutrinos after SK-Gd

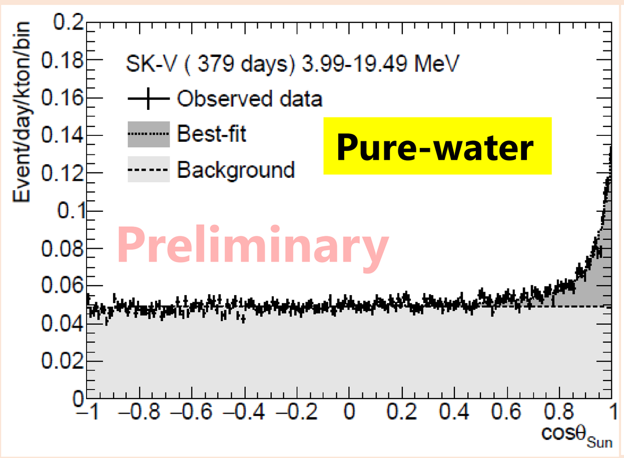
◆ Energy scale

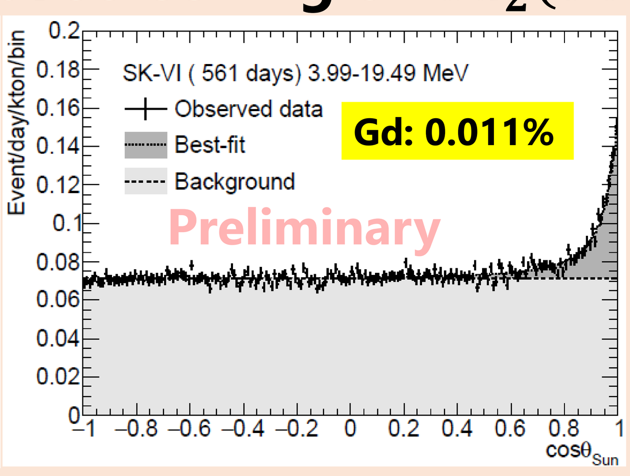
- Calibration before and after Gd-loading has been evaluated.
  → Energy scale is consistent within 1-2% level.
  → presented in poster #312 (S. Fujita).

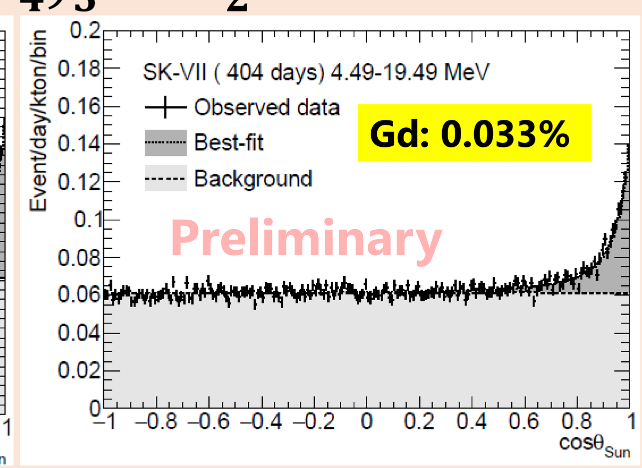


◆ Solar neutrino signals

- Optimized the reduction cuts to maximizing extracted solar ν signal.
- Clear solar ν peak has been observed.
  → Even after Gd-loading, the background rate does not change largely, because of careful screening of $Gd_2(SO_4)_3 \cdot 8H_2O$. Ref. [SK-Gd]



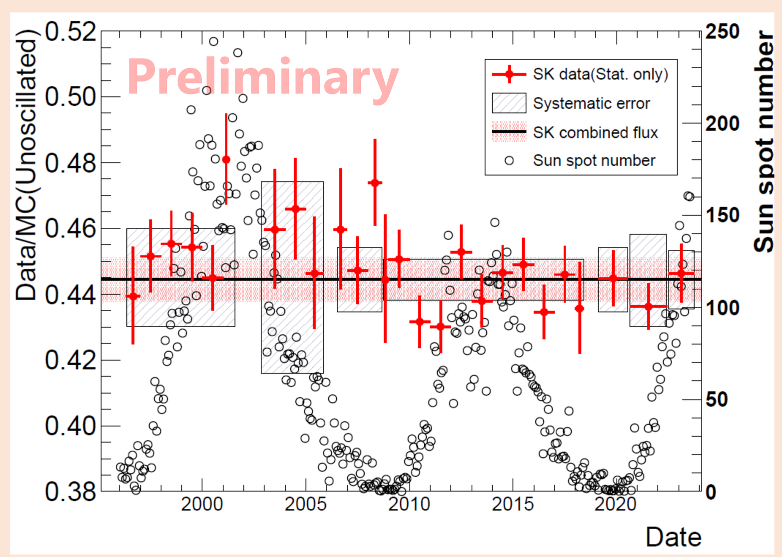


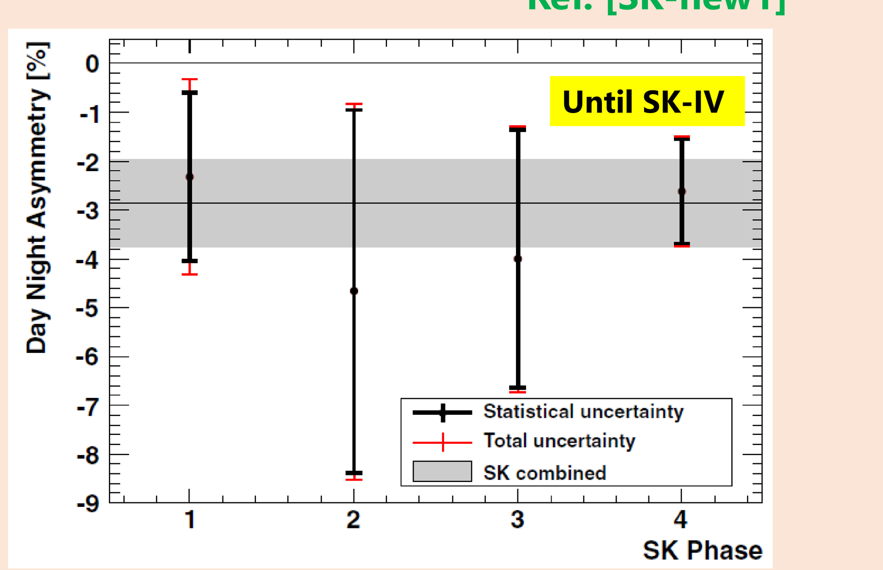


◆ Precise measurement of ^{8}B solar neutrino flux

- Fluxes after Gd-loading are consistent with past measurements.
- Day/night flux asymmetry until SK-IV reaches 3.2σ from zero.
  → Additional data will be analyzed near future.

Ref. [SK-new1]





7. Summary and future prospect

- The latest solar neutrino results from SK are presented.
- Spectrum measurement gives strong constraint of P_{ee} shape.
- No periodic signal of ^{8}B solar ν has been found.
- Tension between solar and KamLAND is about 1.4 σ.
- Solar ν data after SK-Gd era is also presented.
- Flux measurements are consistent with past studies.
- Spectrum and oscillation studies will be performed near future.

Reference: [MSW] Sov. Jour. Nucl. Phys. 42, 913 (1985), Phys. Rev. D 17, 2369 (1978).
[Solar-flux] Particle Data Group (2020). [SK-det] Nucl. Inst. Meth. A 501, 418 (2003), Nucl. Inst. Meth. A 737, 253 (2014).
[SK-solar] Phys. Rev. D 73, 112001 (2006), Phys. Rev. D 78, (2008), Phys. Rev. D 83, 052010 (2011),
Phys. Rev. D 94, 052010 (2016). [SK-new1] Phys. Rev. D 109, 092001 (2024). [SK-new2] Phys. Rev. Lett. 132, 241803 (2024).
[KL] Phys. Rev. D 88, 033001 (2013). [SK-Gd] Nucl. Inst. Meth. A 1027, 166248 (2022), Nucl. Inst. Meth. A 1065, 169480 (2024).