Poster ID 350

Latest solar neutrino analysis results from Super-Kamiokande

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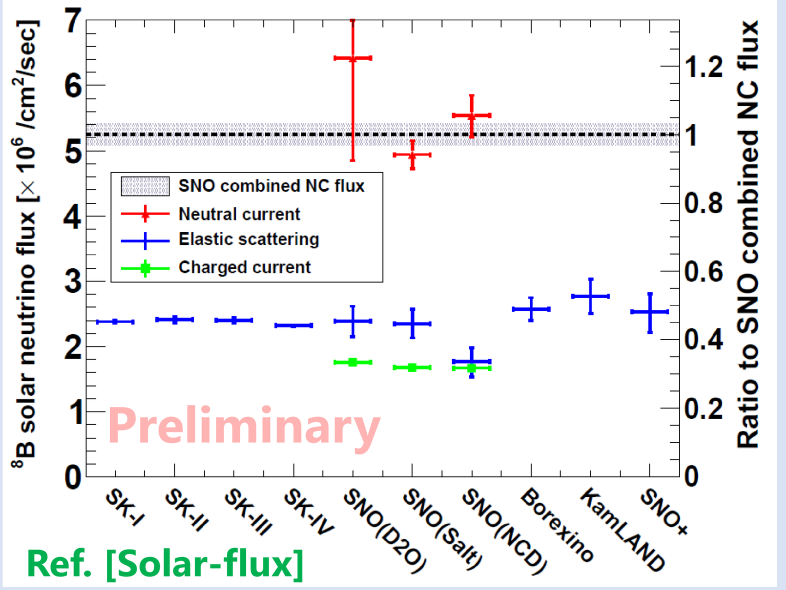
1. Abstract

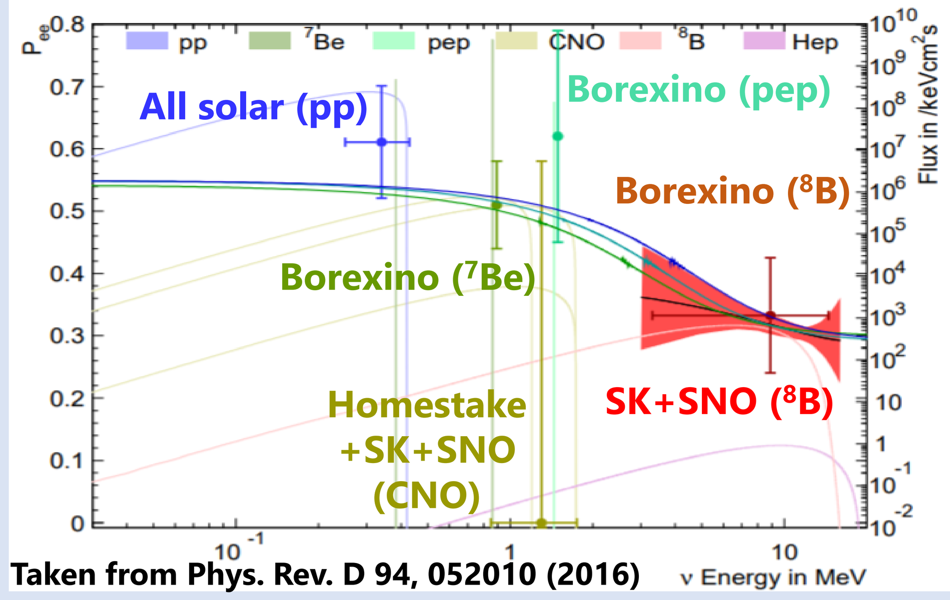
Super-Kamiokande (SK), a 50 kton water Cherenkov detector in Japan, is observing solar neutrinos studying the effects of both the solar and terrestrial matter density on neutrino oscillations: a distortion of the solar neutrino energy spectrum would be caused by the edge of the Mikheyev-Smirnov-Wolfenstein resonance in the solar core, and terrestrial matter effects would induce a day/night solar neutrino flux asymmetry. On 2018 May, we finished taking data of SK-IV and started the refurbishment work toward SK-Gd. In this poster presentation, we overview the latest solar neutrino results in SK-IV, for example, the precise measurement of ^{8}B solar neutrino flux, its energy spectrum and oscillation parameters. In addition, we discuss the future prospect of the new phase of SK-V (SK-Gd) including the background reduction thanks to the refurbishment work.

2. Physics motivation

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



Ref. [Solar-flux]



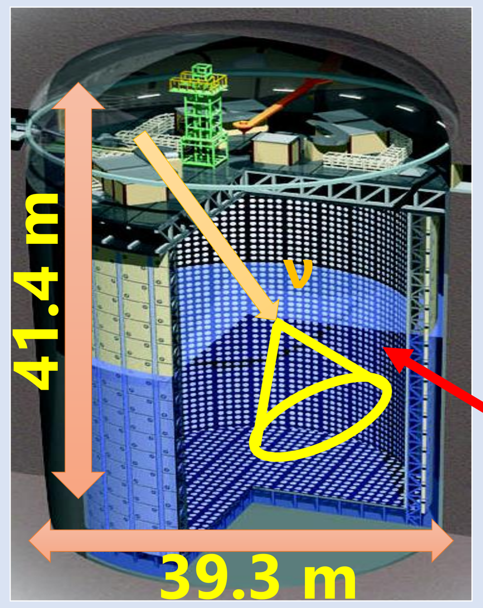
Taken from Phys. Rev. D 94, 052010 (2016)

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.



(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
(2)	SK-I						SK-II				SK-III			SK-IV										SK-V SK-Gd	
(3)	PMT 11,146 (40%)						5,182 (19%)				11,129 (40%)														
(4)	4.5 MeV						6.5 MeV				4.0 MeV			3.5 MeV											
(5)	1496 days						791 days				548 days			2970 days											

(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.

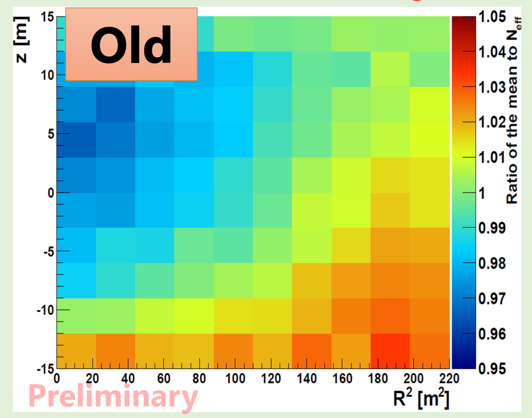
4. Improvement in analysis

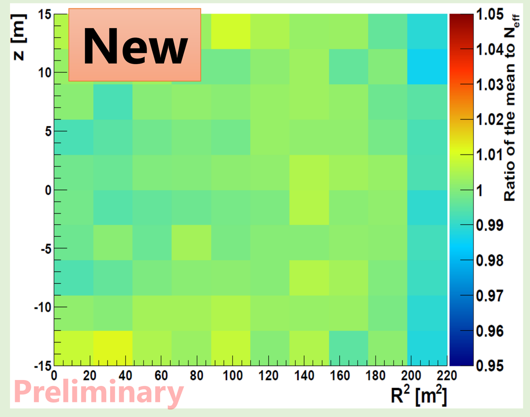
◆ Software progress

(1) New spallation cut with improved tagging efficiency
(Spallation studies: S. Locke, Poster ID 166)
(2) Position dependence of energy reconstruction
(A) Non-uniformity of water transparency
→ Consider position of hit-PMT and reconstructed vertex.
(B) PMT photo coverage
→ Realistic response of PMTs in cylindrical shape is re-evaluated.

◆ Impact to analysis

- Position dep. of effective hit is reduced (1.7%→0.5%).
- Successfully reduce systematic uncertainties < 5.49 MeV.





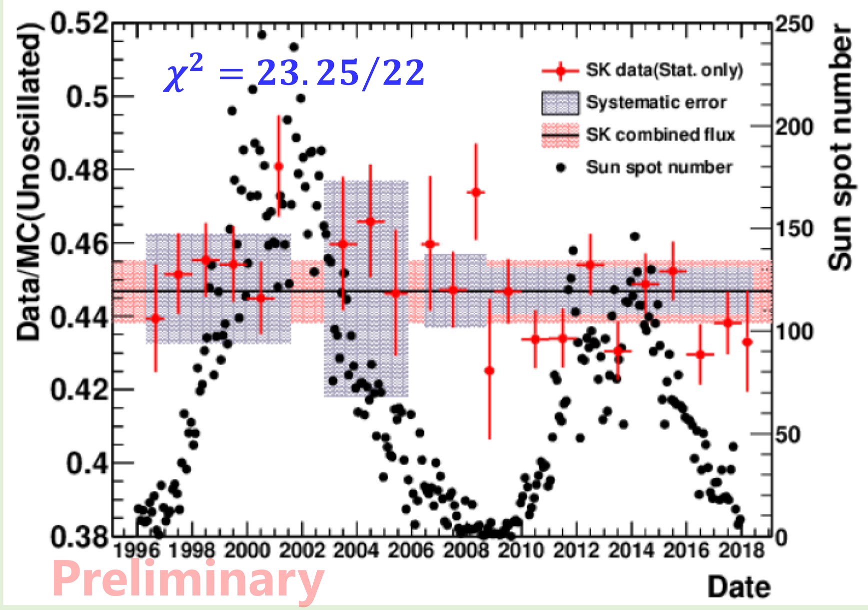
Energy [MeV]	3.49-3.99	3.99-4.49	4.49-4.99	4.99-5.49
Trigger	±1.8%	±0.7%	--	--
Event quality cut	±0.2%	±0.1%	±0.1%	±0.1%
Hit pattern cut	--	--	--	--
Small cluster cut	±1.0%	±0.7%	±0.5%	--
External cut	±0.1%	±0.1%	±0.1%	±0.1%
Vertex shift	±0.5%	±0.4%	±0.2%	±0.2%
Background shape	±2.9%	±1.0%	±0.8%	±0.2%
Signal extraction	±2.1%	±2.1%	±2.1%	±0.7%
Cross section	±0.2%	±0.2%	±0.2%	±0.2%
MSG	±0.5%	±0.4%	±0.4%	±0.4%
Total	±4.2%	+2.7% / -2.6%	±2.4%	±0.9%

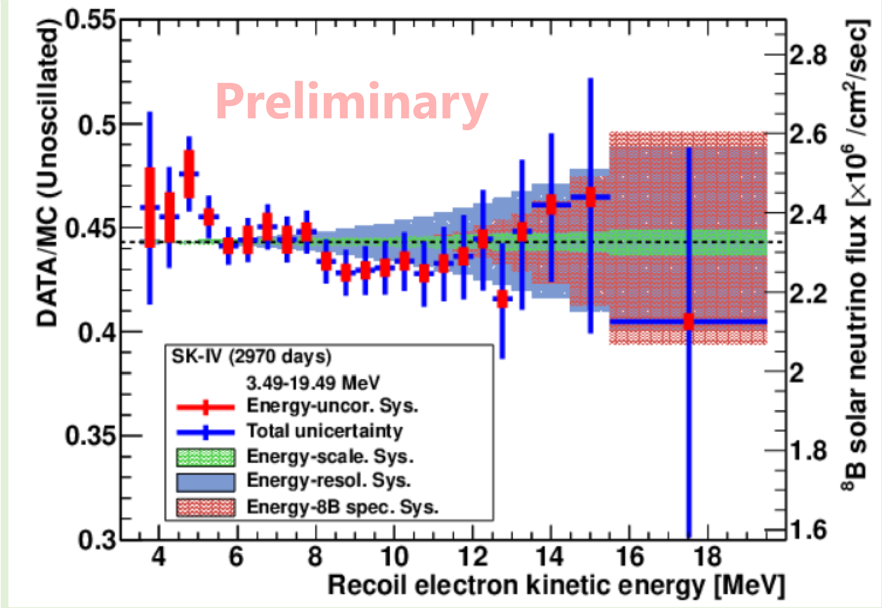
Preliminary

5. Results from SK-IV

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

- SK-combined: 2.346±0.011(stat.)±0.043(syst.) [10^6 cm^{-2}sec^{-1}]
  Cf.) SNO NC $5.25 \pm 0.16^{+0.11}_{-0.13}$ [10^6 cm^{-2}sec^{-1}]

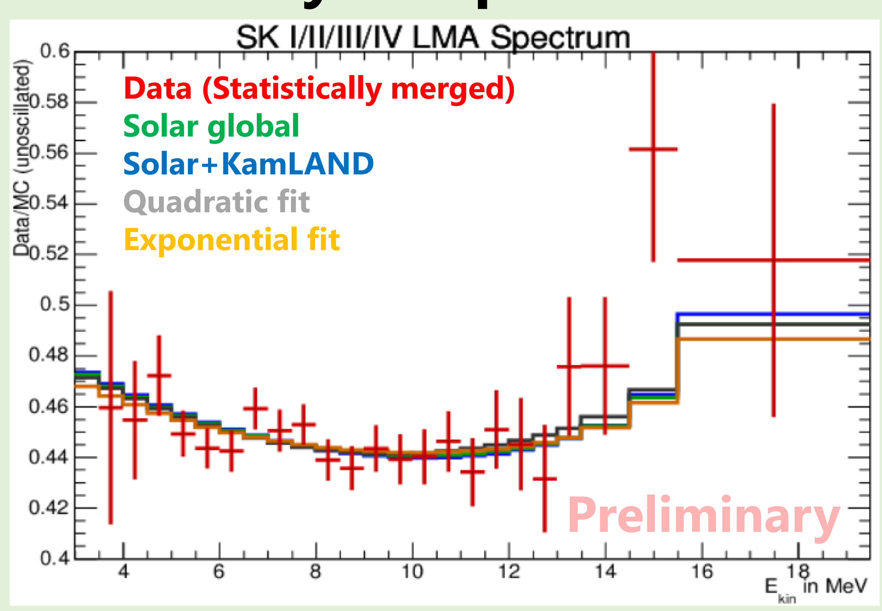


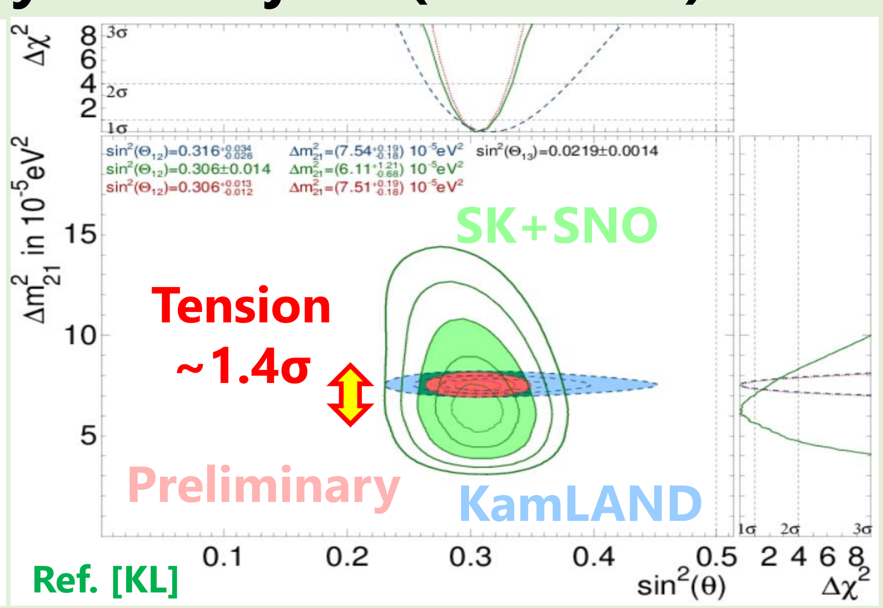


◆ Energy spectrum measurement

Ref. [SK-solar]

- SK recoil electron energy spectrum slightly favors up-turn.
- SK+SNO favors a lower Δm^2_{21} than KamLAND by ~1.4σ.
  → Plenary talk presentation by Y. Nakajima (June 30th)





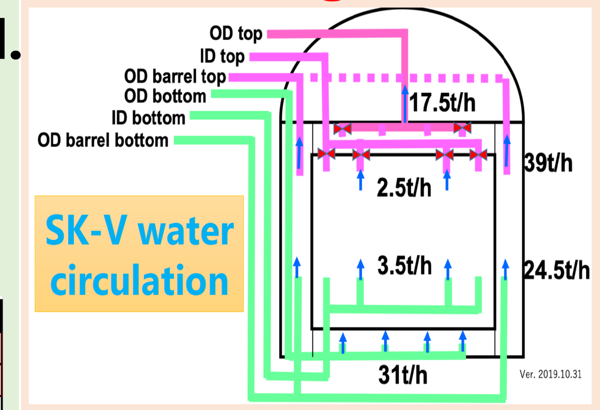
Ref. [KL]

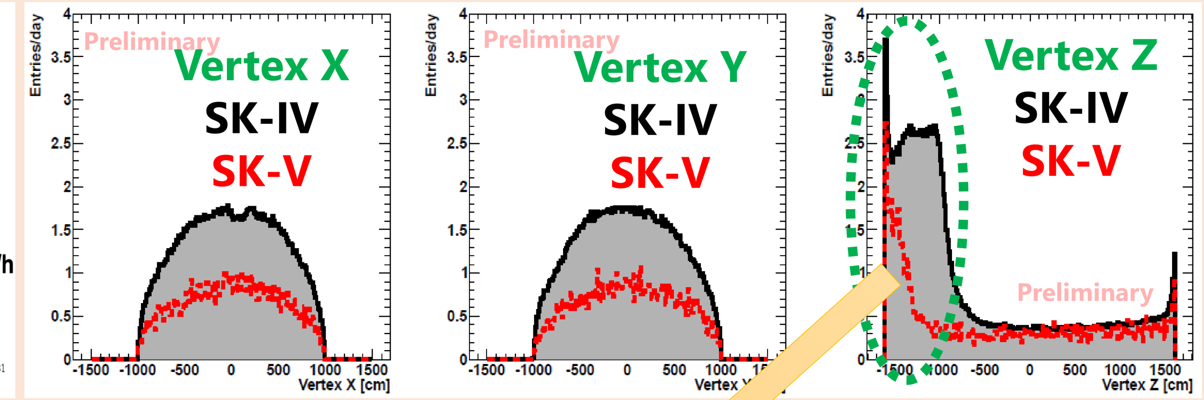
6. Status of SK-V data analysis

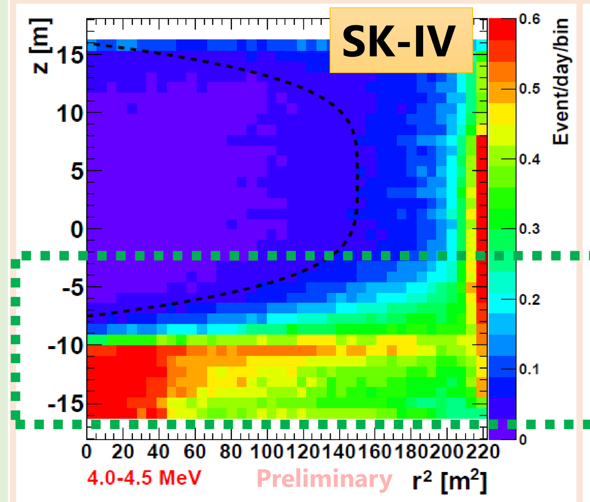
◆ Water flow optimization

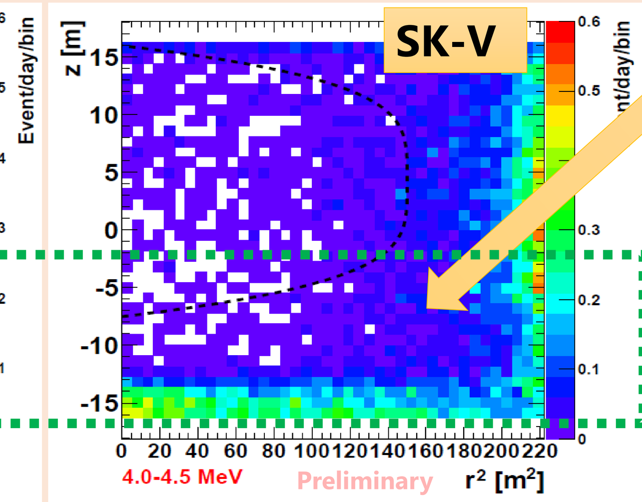
Ref. [SK-Rn]

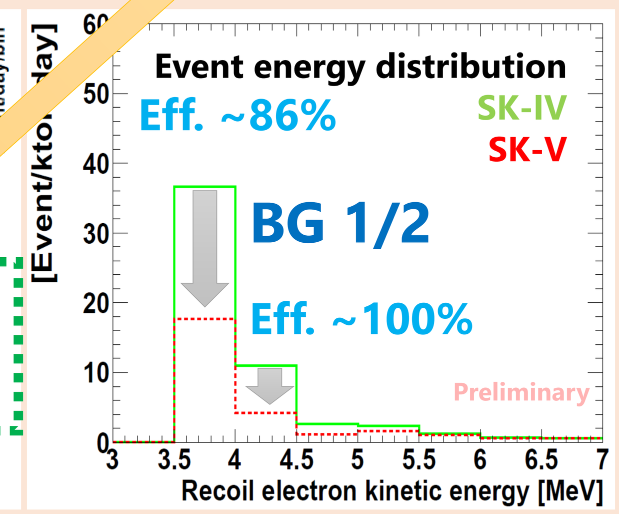
- BG events come from the detector structures (PMTs).
  → Emanating Rn diffuses into the FV. Cleaning/wiping wall.
  (Radon BG modeling in SK/HK: G. Pronost, Poster ID 65)
- Water flow (water temperature control) was optimized to avoid such BG from entering the FV.
  → Enlarge the FV and improve sensitivity to MSW up-turn.





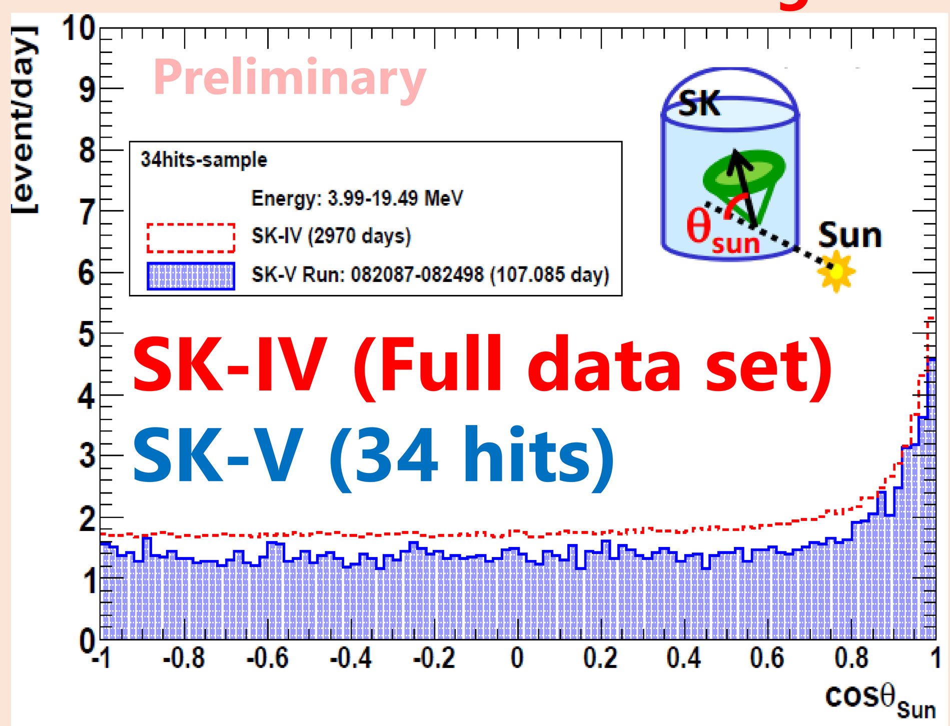


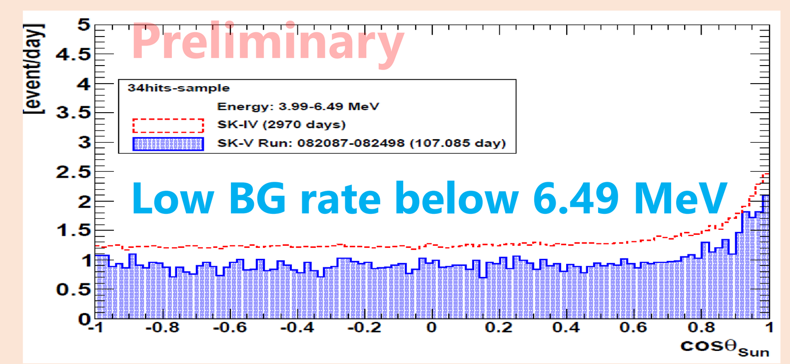


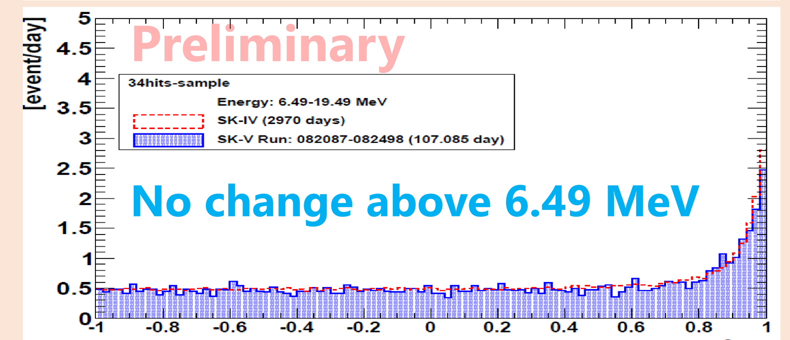


◆ Solar neutrino signal (after Rn BG reduction)

- Achieved lower BG rate below 6.49 MeV.
  → Clear solar neutrino signal in SK-V data.







7. Summary

- The latest solar neutrino results from SK are presented.
- New energy reconstruction enables SK to lower systematics.
- Spectrum measurement gives strong constraint of P_{ee} shape.
- Tension between solar and KamLAND changes ~2.0σ → 1.4 σ.
- Successfully reduce Rn BG events in SK-V.
- Further sensitivity to MSW up-turn is expected in 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. Instrum. Meth. A 501, 418 (2003), Nucl. Instrum. 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).
[KL] Phys. Rev. D 88, 033001 (2013). [SK-Rn] J. Phys. Conf. Ser. 888, 012191 (2017), arXiv: 1910.03823.