THE FIRST RESULTS FROM SUPER-KAMIOKANDE

SUPER-KAMIOKANDE Collaboration

Presented by

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Abstract

The first results from Super-Kamiokande are reported.

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Experimental phase	Period	Livetime	Energy threshold
Kam-II before PMT gain doubling	Jan. 1987 ~ May 1988	449 days	9.3 MeV
Kam-II after PMT gain doubling	Jun. 1988 ~ Apr. 1990	594 days	7.5 MeV
Kam-III A	Dec. 1990 ~ Nov. 1991	200 days	7.5 MeV
Kam-III B	Nov. 1991 ~ Feb. 1995	836 days	7.0 MeV
Super-Kamiokande	Apr. 1996 ~ Mar. 1996	202 days	6.5 MeV

Table 1: Run summary for solar neutrino analysis at Kamioka.

1 INTRODUCTION

Super-Kamiokande (SUPER KAMIOKA Nucleon Decay Experiment) is the next phase of Kamiokande [1][2][3][4]. It is a large cylindrical imaging water Čerenkov detector, which is constructed from 50000 ton of pure water, 11146 of 20 inch PMTs, 1867 of 8 inch PMTs, water and air purification system, 5 electronics huts, 948 front-end electronics modules (TKO ATM modules), about 15 UNIX work stations for on-line DAQ system, and so on. They are located about 1000m underground (2700m water equivalent) in the Mozumi mine at Kamioka town, and connected electrically to a computer and office building at the ground surface via light fibers. In the computer and office building at Kamioka town, there are a super computer (Fujitsu VPX), a magnetic tape library (MTL) system with about 8000 CMTs, 20 work stations for analysis (30CPUs), and 20 work stations for user operation. The data from Super-Kamiokande are processed at the office building, then stored in the MTL.

The detection method for Solar neutrinos in Kamiokande and Super-Kamiokande is the following:

$$\nu + \mathrm{e}^- \rightarrow \mathrm{e}^- + \nu. \tag{1}$$

The detector catches the Čerenkov light radiated from the recoil electron in the water. The current energy threshold of Super-Kamiokande detector is 6.5MeV (as of March 1997).

The solar neutrino observation at Kamiokande was started since January 1987 in Kam-II phase, and it had been carried out till February 1995 in Kam-III phase. Total live times of the Kamiokande detector were 1043 days for Kam-II, 1036 days for Kam-III, and 2069 days from the beginning of Kam-II until February 1995. Then, Super-Kamiokande was started its observation since April 1, 1996 as scheduled. A summary of solar neutrino observation is listed in Table 1.

2 CURRENT STATUS

The observation at Super-Kamiokande was started on April 1, 1996, and continues its observation. The integrated run time of the detector is increasing smoothly, and reached 292days on March 8, 1997. The efficiency of the detector is 85.4% for the overall period, and 91.5% recently.

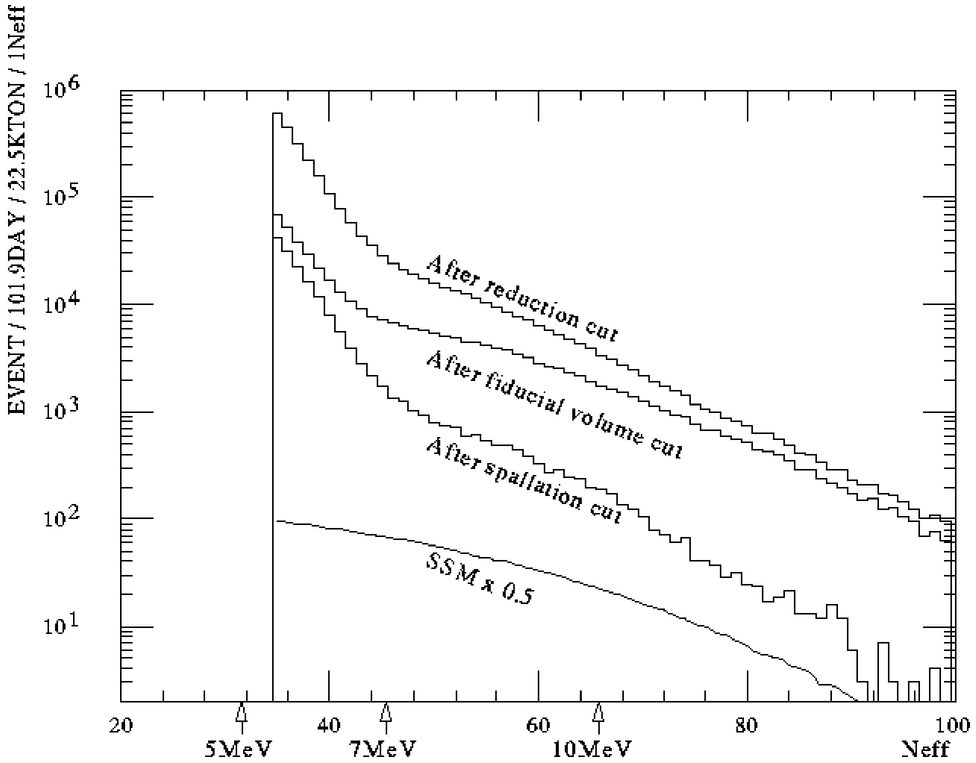

Figure 1: Energy spectra at each low-energy data reduction step. Expected event rate (×0.5) from BP92 SSM is also shown.

Solar neutrino and atmospheric neutrino analyses were started on May 31, 1996 and May 27, 1996, respectively, because the quality (transparency) of the pure water in the detector was worse at the beginning of the experiment. In this article, first results based on May $\sim$ Oct., 1996 data are reported.

3 SOLAR NEUTRINO

Low-energy data which were obtained since May 31, 1996 until October 7, 1996 were used for this time analysis. Total run time was 129.7 calendar day, and live time was 101.9 day for the same periods after good run selection. Analysis energy threshold for this periods was 7.0MeV which was same as that value at Kamiokande-III.

During this period, we obtained about 8×10^7 events as raw data, and reduced to 14376 events ($7 \leq$ E $<$ 20MeV, 22.5kton fid. vol.) by applying first reduction, vertex reconstruction, fiducial volume cut, energy cut, and spallation cut.

As the first reduction step, cosmic ray muons, decay electrons from cosmic ray stopping muons, noise events, and flash PMT events are removed. After the first reduction, number of events became 4.75×10^7. Then, vertex, energy, and direction reconstruction were applied. The number of events became 8.0×10^5 before spallation cut above 5MeV in 22.5 kton fid. vol. At the spallation cut, though we lost 37.8% solar neutrino events (estimated by MC), reduce number of events by about factor 2. Then, the final data sample was obtained. Figure 1 shows the energy spectra at each reduction step.

Observed solar neutrino fluxes at Super-Kamiokande are listed in Table 2. We used the

Time period	Live time (day)	Observed flux ($\times 10^6/\mathrm{cm}^2/\mathrm{s}$)
All	101.9	$2.51^{+0.14}_{-0.13}$(stat.) $\pm$ 0.18(syst.)
Daytime	56.3	$2.30^{+0.18}_{-0.17}$(stat.) $\pm$ 0.17(syst.)
Nighttime	45.6	$2.75^{+0.21}_{-0.20}$(stat.) $\pm$ 0.20(syst.)

Table 2: Observed solar neutrino fluxes during 101.9 days data at Super-Kamiokande. (preliminary)

Error source	Error(%)
Uncertainties in energy scale of the detector	5.7
Solar neutrino signal extraction	3.0
Spallation cut	2.4
Fiducial volume cut	1.9
Event reduction	0.5
$\sigma_{\nu_e e}$	0.5
Direction reconstruction	0.4
Non-flat background	0.2
Live time	0.1
Total	7.2

Table 3: Possible sources of systematic errors in the flux determination for Super-Kamiokande 101.9 days data. (preliminary)

Standard Solar Model published by Bahcall and Pinsonneault in 1992 ($\mathrm{SSM}_{\mathrm{BP92}}$) as expected flux.[5][6] The measured ^{8}B solar neutrino flux at Super-Kamiokande were consistent with those at Kamiokande, and it was confirmed there still exists the deficit of the ^{8}B solar neutrino flux. Figure 2 shows the directional correlation between each event in the final data sample and the Sun. A clear peak at the direction from the sun can be recognized in this figure. Figure 3(a) and (b) are same plots as Fig. 2 for daytime and nighttime data, respectively. Possible sources of the systematic errors are listed in Table 3

Figure 4 shows the energy spectrum of ^{8}B solar neutrinos at Super-Kamiokande. Error bars in Fig. 4 correspond to only statistical errors. Systematic errors for this plot are now under studying. There is no evidence for a distortion of the energy spectrum with in error.

4 P-DECAY AND ATMOSPHERIC NEUTRINO

Middle and high energy data which were obtained since May 27, 1996 until October 20, 1996 were processed. Total live time was 111 day, and the Fully Contained (FC) final data set was obtained for that periods. In order to obtain the FC final data sample, we processed as the following steps. At first, We applied three reduction steps for the raw data (8×10^5

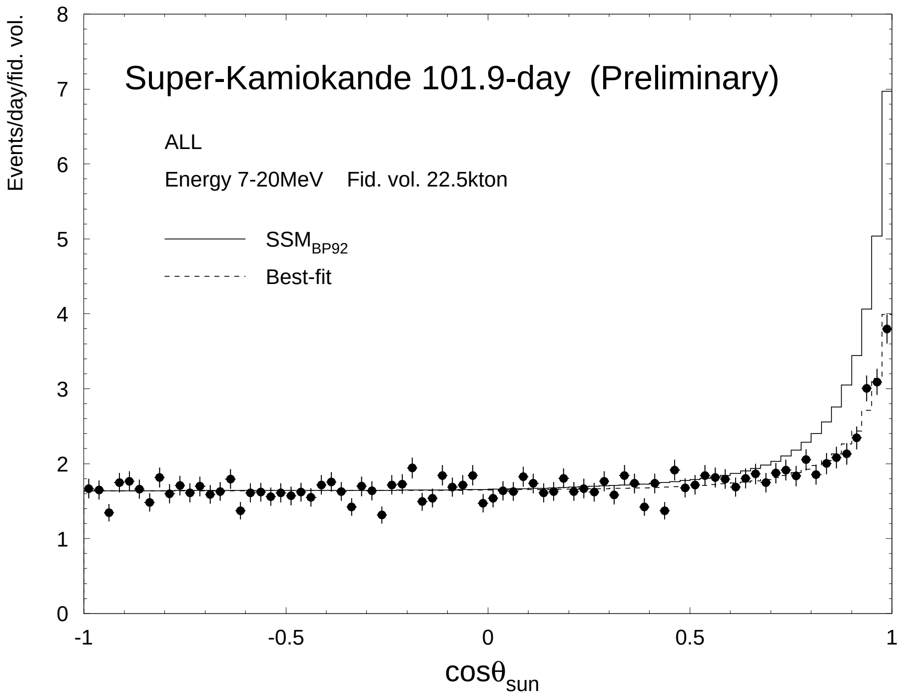

Figure 2: Distribution of cosθ_{sun} for the entire data of the final sample of the Super-Kamiokande. (preliminary) θ_{sun} is the angle between the direction from the Sun and that of the scattered electron. The solid and dashed line correspond to the signal expected from the BP92 SSM and the best-fit ($SSM \times 0.441$), respectively. This plot was derived from Super-Kamiokande 101.9 days data.

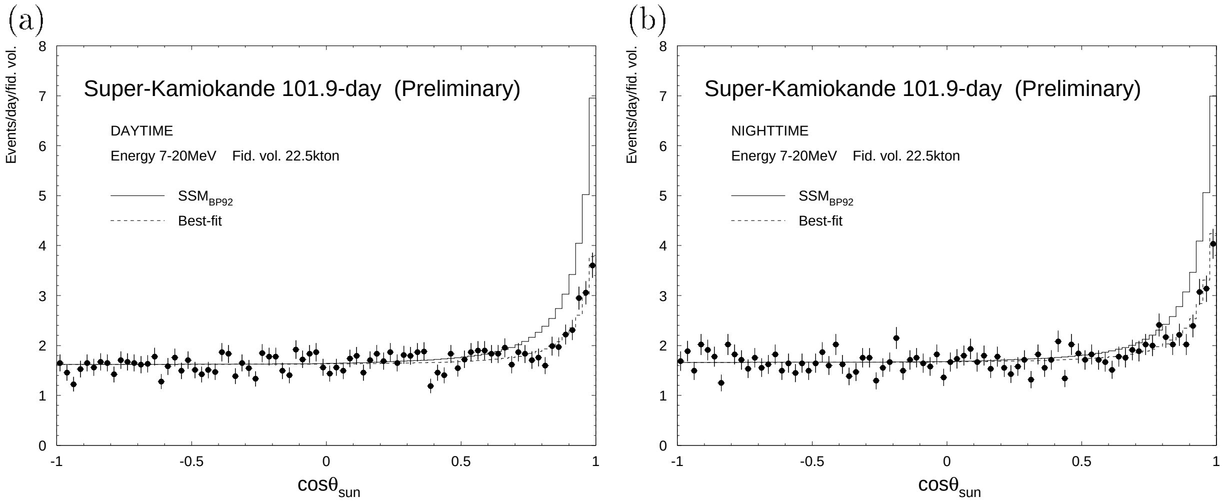

Figure 3: Distribution of cosθ_{sun}. (preliminary) (a) is for daytime data, and (b) is for nighttime data.

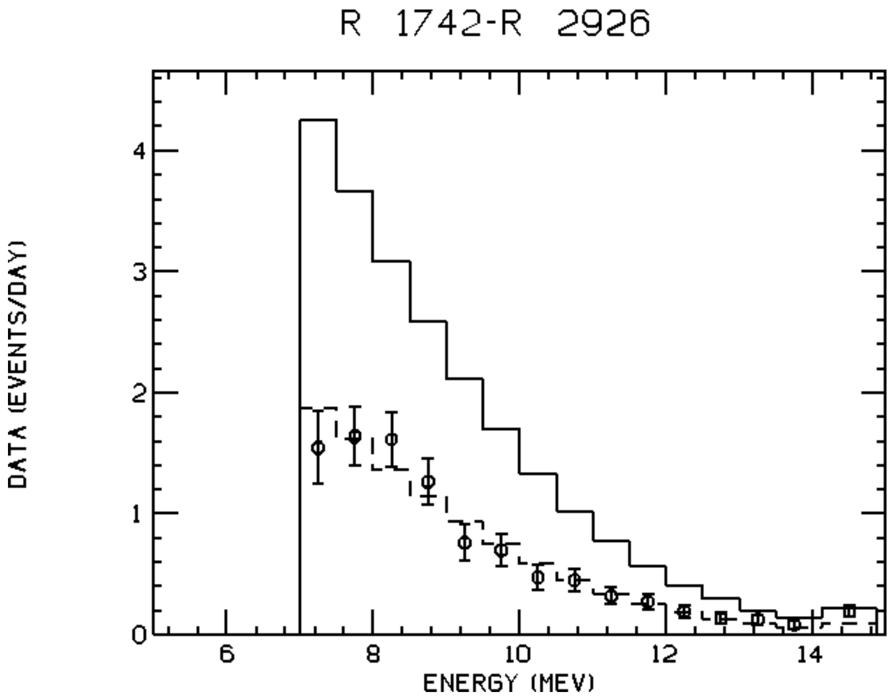

Figure 4: Observed flux of ^{8}B solar neutrinos against the BP92 SSM as a function of the electron energy. (preliminary) The unit of the vertical axis is number of solar neutrino signal (events/day/22.5kton/bin). Error bars correspond to only statistical errors. The solid and dashed line correspond to the signal expected from the BP92 SSM and the best-fit ($SSM \times 0.441$), respectively. This plot was derived from Super-Kamiokande 101.9 days data.

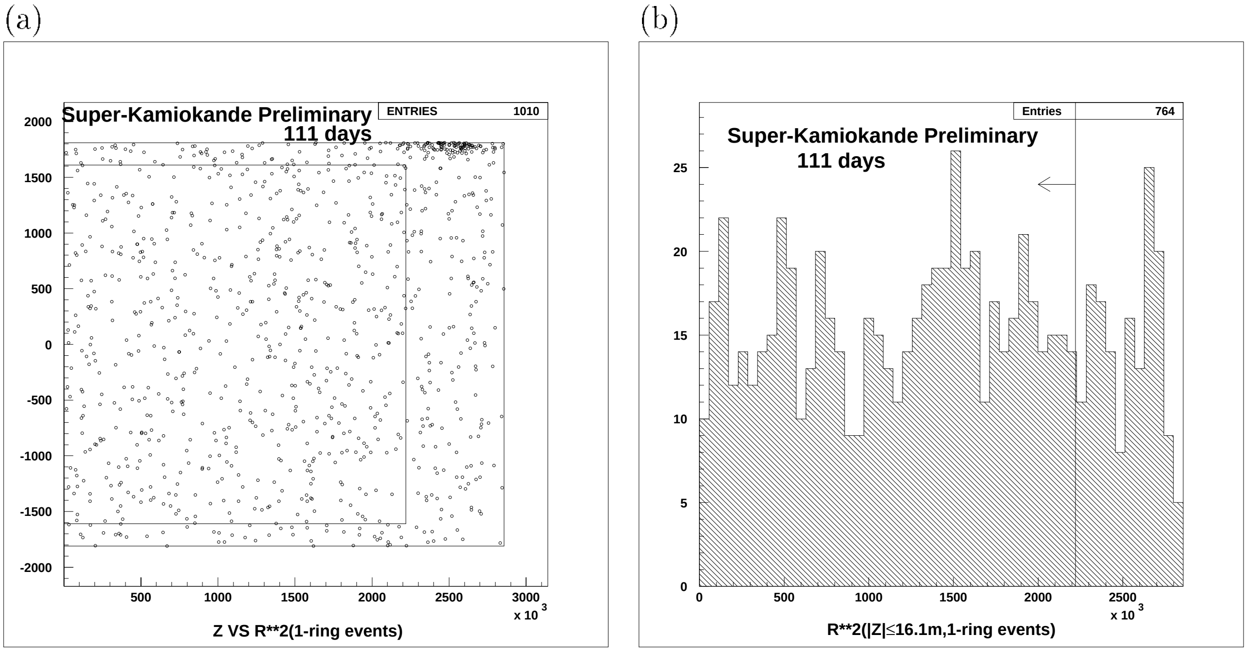

Figure 5: Vertex distribution of FC 1-ring events in the final data sample before fiducial volume cut. (preliminary) (a) horizontal and vertical axes correspond to Radius-square and Z-coordinates, respectively. The concentration of the vertexes around top of the detector is due to the weakness of the outer detector. (see text) (b) vertex distribution as a function of the Radius-square.

events/day), that is, eliminating low-energy events (4×10^3 events/day after this cut), choosing FC events (5×10^2 ev/day), and removing stopping cosmic ray muons and flash PMT events (30 ev/day). Then, two steps of independent eye-scans were performed. The ring number counting and vertex reconstruction were carried out at the final scan step. Finally, applying the fiducial volume (22.5kton) and energy cut (30MeV), the final FC data sample were obtained. The number of events in the final sample was 934 events (606 events for 1-ring events).

Figure 5 shows the vertex distribution of the FC 1-ring events in the final sample before fiducial volume cut. The concentration of the vertexes around top of the detector is due to the weakness of the outer detector. There are four large bundle of PMT cables around here. Some stopping cosmic ray muons which enter the inner detector through this bundle can remain, because those muon don't emit Čerenkov photons in the outer detector. Except for that area, the vertexes are distributed uniformly.

We are now studying MC data, so we have not obtained yet numerical results for 111days data.

5 FUTURE PLAN

We are planning to update and submit the first results from Super-Kamiokande in summer, 1997. We will process more data set (about 200days live time) by the first publication, and study more. One of the important studies for the next stage is LINAC calibration.

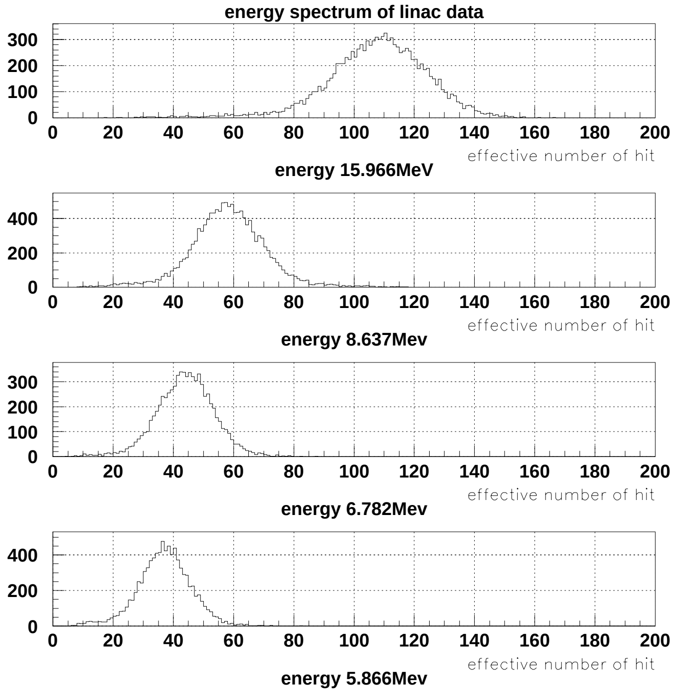

Figure 6: Energy spectra of four sets of LINAC data. Beam total energies were 15.966, 8.637, 6.782, and 5.866 MeV, respectively. The horizontal axes show effective number of hit PMTs. (preliminary)

We carried out the first several LINAC runs in January, 1997, and obtained the preliminary energy spectrum of LINAC data shown in Fig. 6. We are now tuning low-energy MC by using LINAC data, and carrying out various studies.

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