— Solar ν Experiments —

Theoretical calculations of the expected solar rate are shown for comparison with experiment. Note that the expected value in "solar neutrino units" (SNU; 1 SNU = 10^{-36} captures atom^{-1} s^{-1}) depends on the detection reaction.

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
$79 \pm 10 \pm 6$ SNU		[48] ANSELMANN	94	GALX	^{71}Ga $\rightarrow$ ^{71}Ge
$20^{+15}_{-20} \pm 32$ SNU		[49] ABAZOV	91B	SAGE	^{71}Ga $\rightarrow$ ^{71}Ge
< 79 SNU	90	[49] ABAZOV	91B	SAGE	^{71}Ga $\rightarrow$ ^{71}Ge
$(0.46 \pm 0.05 \pm 0.06)\times$SSM		[50] HIRATA	90	KAM2	Water Cerenkov
2.33 ± 0.25 SNU		[51] DAVIS	89	HOME	^{37}CL radiochemical
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$87 \pm 14 \pm 7$ SNU		[52] ANSELMANN	93	GALX	Repl. by ANSELMANN 94
		[53] BAHCALL	93		
		[54] HAMPEL	93	RVUE	
6.4 ± 1.4 SNU		[55] TURCK-CHI...	93B	THEO	^{37}CL radiochemical
$(4.4 \pm 1.1) \times 10^{-6}$ cm^{-2}s^{-1}		[55] TURCK-CHI...	93B	THEO	Water Cerenkov, $E \geq 7.5$ MeV
123 ± 7 SNU		[55] TURCK-CHI...	93B	THEO	^{71}Ga $\rightarrow$ ^{71}Ge
$83 \pm 19 \pm 8$ SNU		[56] ANSELMANN	92	GALX	^{71}Ga $\rightarrow$ ^{71}Ge
		[57] ANSELMANN	92B		
8.0 ± 3.0 SNU		[58] BAHCALL	92		^{37}Cl prediction
132^{+21}_{-17} SNU		[58] BAHCALL	92		^{71}Ga prediction
		[59] GARCIA	91	CNTR	Nuclear physics
		[60] HIRATA	91	KAM2	
		[61] FILIPPONE	90	THY	
		[62] HIRATA	90B	KAM2	
7.9 ± 2.6 SNU		[63] BAHCALL	88	THEO	^{37}Cl prediction; total theor. range
132^{+20}_{-17} SNU		[63] BAHCALL	88	THEO	^{71}Ga prediction; total theor. range
5.8 ± 1.3 SNU		TURCK-CHI...	88	THEO	^{37}Cl prediction
125 ± 5 SNU		TURCK-CHI...	88	THEO	^{71}Ga prediction
5.6 SNU		FILIPPONE	83	THEO	^{37}Cl prediction
7.6 ± 3.3 SNU		[64] BAHCALL	82		^{37}Cl prediction
106^{+13}_{-8} SNU		[64] BAHCALL	82		^{71}Ga prediction
7.0 ± 3.0 SNU		FILIPPONE	82	THEO	^{37}Cl prediction
6.9 ± 1.0 SNU		FOWLER	82	THEO	^{37}Cl prediction
7.3 SNU		BAHCALL	80	THEO	^{37}CL prediction

See also the reviews by BAHCALL 89 and DAVIS 89.

[48] ANSELMANN 94 result is for a total of 15 initial runs ("GALLEX I") (see footnote for ANSELMANN 93) and 15 new runs ("GALLEX II"). The new runs yield $78 \pm 13 \pm 5$ SNU, confirming to the intitial result.

[49] ABAZOV 91B uses a 30 ton gallium detector to search for the reaction ^{71}Ga$(\nu_e, e)^{71}$Ge. Result is for the first 6 months of operation. The conference report GAVRIN 92 updates this result to $58^{+17}_{-24} \pm 14$ SNU. Since this reaction has a threshold neutrino energy of 0.236 MeV, it is sensitive to the low-energy neutrinos from the main pp chain (whose maximum energy is 0.420 MeV). The upper limit quoted is to be compared with the theoretical expectation of about 130 SNU; see BAHCALL 89B and references therein.

[50] HIRATA 90 data consists of 1040 days with threshold $E_e > 9.3$ MeV (first 450 days) or $E_e > 7.5$ MeV. "The total data sample is also analyzed for short-term variations; within the statistical error, no significant variation is observed." The flux is scaled by the value relative to the standard solar model (SSM) prediction. A theoretical flux of $(5.8 \pm 2.1) \times 10^6$ cm^{-2} s^{-1} is cited, with the central value corresponding to 7.9 SNU for ^{37}Cl experiment (but see TURCK-CHIEZE 93B and other theoretical calculations.) The analysis is more fully reported in HIRATA 91B.

[51] DAVIS 89 is the average from the ^{37}CL experiment at the Homestake Mine (HOME) from 1970–1988. Earlier averages are given in the references therein.

[52] ANSELMANN 93 result is for 21 runs of combined GALLEX I and GALLEX II data from inverse beta decay reactions in an aqueous solution of Ga^{3}Cl (30.3 tons of natural Ga) in the Gran Sasso underground laboratory. The 15 runs of GALLEX I yield $81 \pm 17 \pm 9$, which replaces the preliminary result of ANSELMANN 92. The first 6 runs with GALLEX II yield $97 \pm 23 \pm 7$ SNU. A typical solar model rate prediction is for 132 SNU, but see the reviews by Bahcall and others.

[53] BAHCALL 93 is a study of 1000 solar models in which each input parameter is chosen from a normal distribution with the appropriate mean and error. It is concluded that "Even if one abuses the solar models by artifically imposing consistency with the Kamiokande experiment, the resulting predictions of all 1000 of the 'fudged' solar models are inconsistent with the result of the chlorine experiment."

[54] HAMPEL 93, by a member of the GALLEX collaboration, is a discussion of possible scenarios to explain the combined solar neutrino experimental data.

[55] TURCK-CHIEZE 93B proposes new results on the solar neutrino predictions and acoustic mode frequencies. See also TURCK-CHIEZE 93 for an extensive review (233 pages, 524 references) concerning the solar interior. Table 17 provides a particularly useful comparison of experiment and theory as of mid-1993.

[56] ANSELMANN 92 reports first observation of solar neutrinos from the pp reaction, using the GALLEX solar neutrino detector in the Gran Sasso Underground Laboratory. The total rate is 2σ below the solar model predictions in the range 124–132 SNU's, but they state that "Our result is consistent with the presence of the full pp neutrino flux expected according the the 'standard solar model' together with a reduced flux of ^{8}B and ^{7}Be neutrinos as observed by the Homestake and Kamiokande experiments."

[57] ANSELMANN 92B discusses implications of the GALLEX observations reported in ANSELMANN 92. They state that "To fit this result together with those of the chlorine and Kamiokande experiments requires severe stretching of the solar models but does not rule out such a procedure, leaving the possibility of massless neutrinos... The Mikheyev-Smirnov-Wolfenstein mechanism provides a good fit, and the GALLEX result fixes the $\Delta(m^2)$ and $\sin^2 2\theta$ parameters in two very confined ranges (around $\Delta(m^2) = 6 \times 10^{-6}$ eV^2 and $\sin^2 2\theta = 7 \times 10^{-3}$ or $\Delta(m^2) = 8 \times 10^{-6}$ eV^2 and $\sin^2 2\theta = 0.6$). Explanations of the solar neutrino problem based on the decay or magnetic interactions of neutrinos are disfavored."

[58] BAHCALL 92 is an extensive up-to-date discussion of the solar neutrino flux calculations with predicted event rates for various different solar neutrino detectors. First published calculation that includes diffusion. "The quoted errors represent the total theoretical range and include the effects on the model predictions of 3σ errors in measured input parameters."

[59] GARCIA 91 reports a new study of ^{37}Caβ decays, with the result that the BAHCALL 88 SSM prediction for ^{37}Cl should be increased from 7.9 to 8.1 SNU.

[60] HIRATA 91 reports a search for day-night and semi-annual variations in the solar neutrino flux observed in the Kamiokande II Detector. The sample is the same 1040 day counting period used for HIRATA 90 and HIRATA 90B. "Within statistical error, no such short-time variations were observed." This result was used to constrain neutrino oscillation parameters, in the framework of oscillations between two mass eigenstates. "A region defined by $\sin^2 2\theta > 0.02$ and 2×10^{-6} eV^2 $< \Delta(m^2) < 1 \times 10^{-5}$ eV^2 is excluded at the 90% CL without any assumptions on the absolute value of the expected solar neutrino flux."

[61] FILIPPONE 90 is a statistical analysis of solar neutrino data to test hypotheses of time dependence. The authors state "we have shown that in our unbiased analysis, the hypothesis of a time-independent ^{37}Cl neutrino capture rate is marginally rejected, having only 2% probability. However, it is disturbing that we are not able to find a simple hypothesis of time variation that would describe the data well. A capture rate anticorrelated with sunspot number, although more probable than the constant rate hypothesis, has a probablity of only 6%. One possible explanation of these results is simply the poor statistics of the ^{37}Cl experiment."

[62] HIRATA 90B gives an analysis of the implications of these data for allowed values of $\Delta(m^2)$ and $\sin^2 2\theta$ describing neutrino mixing between two mass eigenstates, in the model of resonant (MSW) neutrino oscillations. The possibility of regeneration as the neutrinos pass through the earth is neglected. Two limits are given, the first from the measured event rate alone, and the second from the combination of the measured event rate and the recoil electron energy spectrum. The latter "disfavor the region of adiabatic solutions $\Delta(m^2) \sim 1.3 \times 10^{-4}$ eV^2 and $7.2 \times 10^{-4} < \sin^2 2\theta < 6.3 \times 10^{-3}$ at 90%CL." The allowed regions in $\sin^2 2\theta$ vs. $\Delta(m^2)$ are given graphically; see Figs. 2(a) and 2(b) in the paper.

[63] BAHCALL 88 "total theoretical range is calculated by evaluating the 3σ uncertainties for all measured input parameters and using the full spread in calculated values for input quantitites that cannot be measured; the uncertainties from different quantities are combined quadratically." (Quotation from BAHCALL 89, p. 301.)

[64] BAHCALL 82 quotes "effective 3σ errors." First extensive discussion of formal uncertainties in the problem.