An alternative solution to the solar neutrino deficit

F. Vannucci

To cite this version:

F. Vannucci. An alternative solution to the solar neutrino deficit. 1996. <in2p3-00003175>

HAL Id: in2p3-00003175
http://hal.in2p3.fr/in2p3-00003175

Submitted on 16 Nov 1999

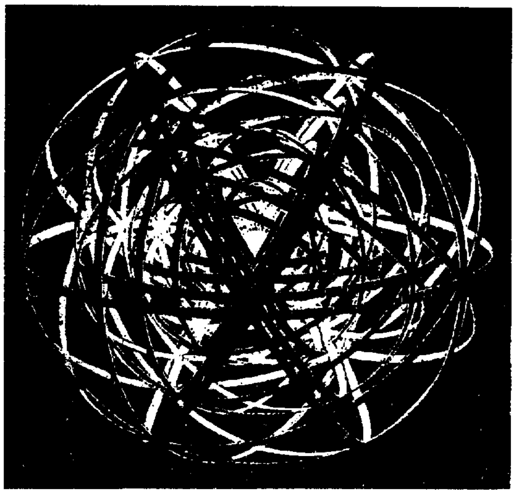
LPNHE 96-10

Laboratoire de Physique Nucléaire et de Hautes Energies

CNRS - IN2P3 - Universités Paris VI et VII

An alternative solution to the solar neutrino deficit

Francois Vannucci



4, Place Jussieu - Tour 33 - Rez-de-Chaussée
75252 Paris Cedex 05

Tél: 33(1) 44 27 63 13 - FAX: 33(1)44 27 46 38

AN ALTERNATIVE SOLUTION TO THE SOLAR NEUTRINO DEFICIT

F. Vannucci
LPNHE, Univ. Paris 7

Abstract

A continuous loss of energy in the sun's interior gives a coherent picture of the various solar neutrino experiments, and reconciles all measurements with the standard solar model predictions.

The sun produces abundantly neutrinos of type ν_e in its inner core.

Four experiments using different techniques measure fluxes of neutrinos on earth which are substantially lower than those predicted [1].

Figure 1 summarizes the spectra of the various contributions to the solar neutrino flux with the energy thresholds of the three detector techniques used so far.

- The Kamiokande experiment, with a threshold of 7 MeV, only measures the high energy part of the ^8B neutrinos. It finds a result which is about 50% lower than the level predicted by the standard model [2]. The arguments developed in the following, vary little with the standard model one chooses.
- The Homestake experiment with a threshold of 814 keV is essentially sensitive to the ^7Be and ^8B neutrinos with respective contributions of 1.2 and 6.2 SNU. One SNU corresponds to 10^{-36} capture per second and per target atom. The experiment measures a rate of 2.5 SNU which is only 30% of the total expected rate of 8 SNU.
- The Gallium experiments have a very low threshold of 233 keV, and are therefore sensitive to the main pp chain neutrinos. The standard model predicts 70.8 SNU from the pp neutrinos alone, together with 35.8 SNU from ^7Be and 13.8 SNU from ^8B. Additional small contributions give a total of 131 SNU while the experiments detect about 70 SNU.

Table 1 summarizes the contributions from the various sources together with the measurements of the experiments.

Assuming that all experiments are correct, and that the standard model gives an exact representation of what is happening inside the sun, it is difficult to understand why there is a deficit of neutrinos which seems to be maximum at intermediate energies.

An elegant solution which reconciles the measurements with the predictions, and in particular enables to understand the apparent complete disappearance of the 860 keV neutrinos from the ^7Be, is given by the MSW effect [3], namely the resonant oscillation of ν_e inside the sun. This implies the existence of a neutrino mixed with the ν_e, and resulting in an effective mass of about 3 10^{-3} eV.

Another solution is proposed in this paper. It considers the possibility of there being a continuous energy loss of the neutrinos, proportional to their energy, when traversing the sun.

Neutrinos are produced in the inner 10% of the sun's interior. They have to cross some 650,000 km before escaping. Near the centre, conditions are extreme and it is hypothesized that neutrinos undergo an interaction all along their trajectory which results in energy loss, a fatigue which grows linearly with their initial energy.

The nature of these interactions is unknown. Standard electroweak interactions are certainly much too small to come close to the necessary effect. They could be of a new type, for example non-standard interactions mediated by majorons, or they could be electromagnetic. It has been shown that even massless neutrinos acquire an induced charge and an induced magnetic moment in a medium [4]. This in turn can give Cherenkov or transition radiations [5]. Also interactions of the toroid dipole moment of neutrinos have been considered [6]. Present calculations do not give effects which are large enough, but several articles have calculated very large enhancements of electromagnetic interactions of neutrinos in matter or external fields [7]. All the possibilities may not yet have been envisaged.

Some of these interactions give energy losses which vary like the γ of the neutrinos, and for a given neutrino species the variation with energy is linear. This is the dependence that we will consider here.

Irrespective of the nature of the interaction, let us assume a continuous energy loss in the sun. This will give a consistent solution to the various neutrino deficits.

Let us first consider the Kamiokande result. The 7 MeV threshold is just at the peak of the ^{8}B spectrum. If neutrinos lose a fraction of their energy, part of the flux will fall below the threshold and will be undetectable. For the neutrinos remaining above the 7 MeV threshold, their interaction cross-section will be diminished and the corresponding number of events will decrease. In the range of interest, this cross-section grows linearly with energy. Figure 2 shows the original spectrum of ^{8}B neutrinos from the standard model, together with a new spectrum shifted by 20%. The 7 MeV threshold is indicated. With the shifted spectrum, the experiment detects only neutrinos which originally had energies higher than 8.7 MeV. Integrating the new flux above 7 MeV gives a total number of events which is half the original one. Thus a 20% energy loss of the ^{8}B neutrinos explains the Kamiokande result. This corresponds to an extremely small average loss of 3 10^{-3} eV/m for a 10 MeV neutrino and is 10^{11} times smaller than the normal energy loss of a minimum ionizing particle.

For the Homestake experiment a 20% energy loss moves the ^{7}Be 860 keV line below the threshold. These neutrinos, which represent 15% of the standard contribution, become undetectable. Furthermore, the cross-section of neutrino capture on ^{37}Cl varies very rapidly with energy. Between 1 MeV and 10 MeV, the cross section increases by more than 5000. Figure 3 shows this variation over the energy range of interest. The energy dependence is roughly proportional to E^5 between 7 and 10 MeV. A shift in energy of 20% results in a major decrease in the number of ^{8}B neutrino events. Thus, for the ^{37}Cl experiment, one expects a total rate of about 2.45 SNU, in agreement with observations.

Finally the Gallium experiments. The pp flux arriving on earth has a maximum energy of 336 keV instead of the original 420 keV. The experiments having a threshold of 233 keV will detect a substantially smaller pp flux. They will not see neutrinos initially produced with less than 295 keV. Instead of 71 SNU, one expects about 37 SNU from this source. For the more energetic neutrinos, the cross-section is proportional to $E^{1.5}$ in the region of the ^{7}Be neutrinos and $E^{3.5}$ for higher energies. Figure 3 also shows the energy dependence of this cross-section. A 20% shift of the energy spectrum will leave about 22 SNU for the ^{7}Be neutrinos and 6 SNU for the ^{8}B neutrinos for a total rate of about 75 SNU.

Table 1 gives the rates expected after the shift in energy. They are now in good agreement with observations.

Thus a simple picture based on a continuous energy loss of the neutrinos inside the sun gives a consistent account of the very different deficits measured for the different energy ranges. This energy loss does not change the global energy considerations in the sun as the neutrinos carry only 2% of the solar energy. More generally this model does not seem to contradict any known experimental results.

This continuous loss is not substantiated by the theory, but it can be tested in forthcoming experiments:

- Superkamiokande with a 5 MeV threshold should find a ratio slightly increased compared to the standard model, and its high statistics will allow the spectrum shape to be verified.
- SNO should not see any deviation of the NC/CC ratio.
- Borexino should find a peak not at 860 keV but at around 700 keV.

- Laboratory tests can be envisaged at reactors or accelerators. The energy loss per neutrino is extremely small and would not have been observed up to now. The detection must rely on integrating the loss of many neutrinos and can be tested with specially designed detectors.

I wish to thank Charling Tao, J.M. Lévy and A. de Rujula for useful discussions.

REFERENCES

1] GALLEX Collaboration, Phys.Lett. B327 (1994) 377.
SAGE Collaboration, Phys.Lett. B328 (1994) 234.
Homestake Collaboration, Nucl.Phys.B38 (1995) 47.
Kamiokande Collaboration, Nucl.Phys. B38 (1995) 55.
2] J.N. Bahcall and M.H. Pinsonneault, Rev.Mod.Phys. 64 (1992) 885.
S. Turk-Chièze and I. Lopes, Astrophysics J. 408 (1993) 347.
3] L. Wolfenstein, Phys.Rev. D17 (1978) 2369.
S.P. Mikheyev and A.Yu. Smirnov, Nuovo Cimento 9C (1986) 17.
N. Hata and P. Langacker, Phys.Rev. D50 (1994) 632.
4]J.F. Nieves and P.B. Pal, Preprint CPP-93-12.
5]N.L. Balazs, Phys.Rev. D104 (1956) 1220.
W. Grimus and H. Neufeld, Phys.Lett. B315 (1993) 129.
M. Sakuda, Phys.Rev.Lett. 72 (1994) 804.
6] V.M. Dubovik and V.E. Kuznetsov, JINR Preprint E2-96-53.
7]J.C. D'Olivo et al, Phys.Rev.Lett. 64 (1990) 1088.
C. Giunti et al,.Phys.Rev. D43 (1991) 164.
A.A. Gvozdev et al, Phys.Lett. B289 (1992) 103, Phys.Lett. B313 (1993) 161.

FIGURE CAPIONS

1] Energy spectrum of the solar neutrinos.

2] Energy spectrum of the ^{8}B from the standard model and after a 20% shift.

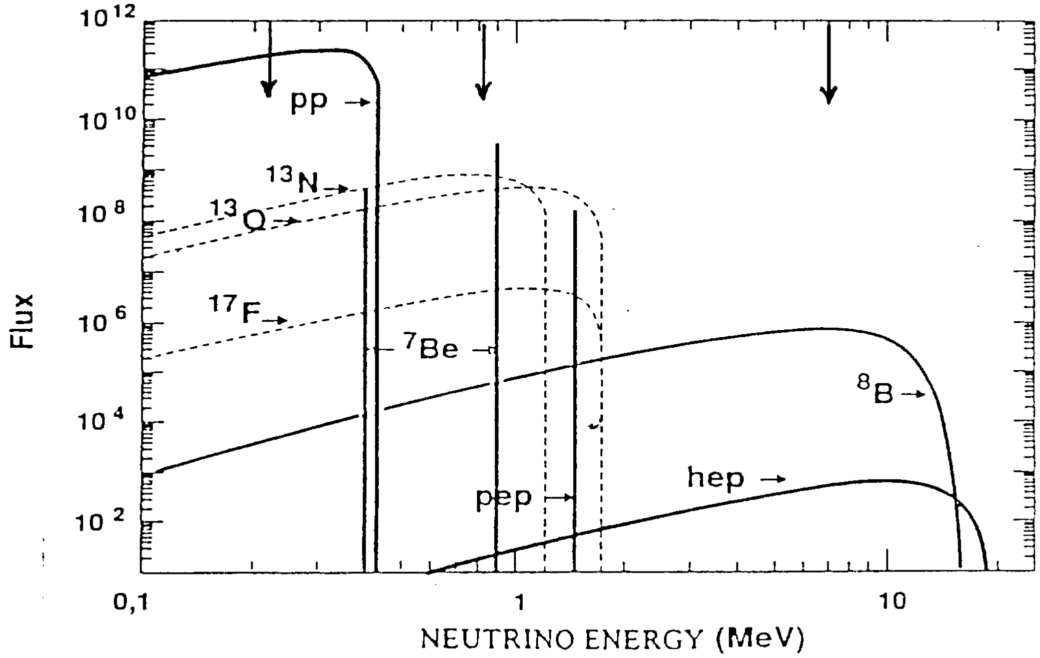
3] Capture cross-sections of ν_e in the chlorine and gallium experiments.

TABLE 1.
The various solar neutrino experiments with their measurements compared to the predictions of the standard model. Results after an energy shift are also shown.

Exper.	**Source**	**SSM**	**measure**	**this model**
KM	^{8}B	1	0.5	0.5
^{37}Cl	^{8}B	6.2		2.2
	^{7}Be	1.2		0
	^{15}O	0.3		0.15
	pep	0.2		0.1
	^{13}N	0.1		0
	total	8.0	2.5	2.45
^{71}Ga	pp	70.8		37.3
	^{8}B	13.8		6.0
	^{7}Be	35.8		25.4
	pep	3.1		2.0
	^{15}O	4.9		2.8
	^{13}N	3.0		1.9
	total	131.5	70	75.4

The various solar neutrino experiments with the expectations from the Standard Model compared with the measurements. Results after the energy shift are also shown.

Table 1



10^{12}
10^{10}
10^{8}
10^{6}
10^{4}
10^{2}
Flux
pp →
^{13}N →
^{13}O →
^{17}F →
← ^{7}Be →
^{8}B →
hep →
pep →
0,1
1
10
NEUTRINO ENERGY (MeV)

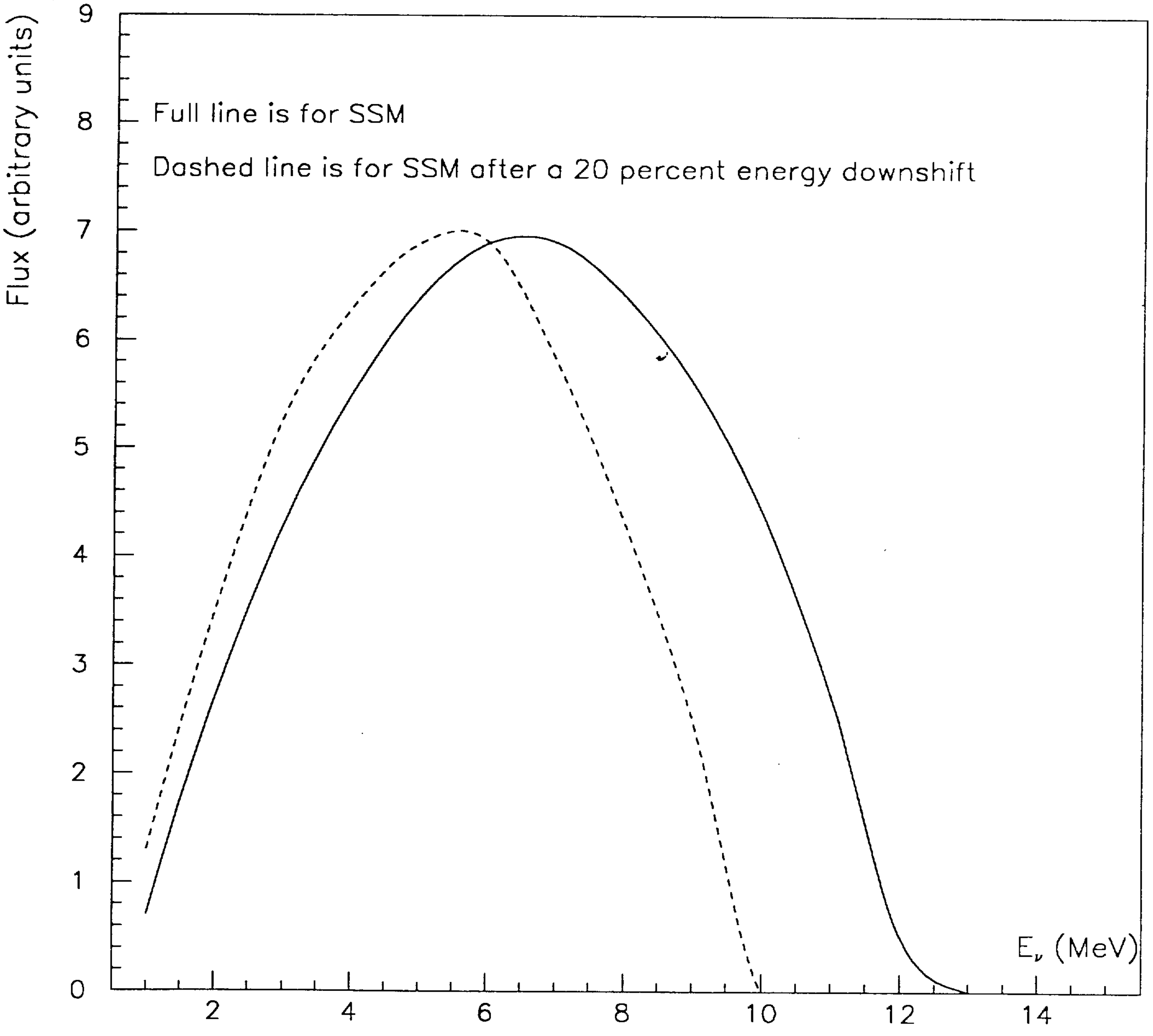


Fig.2 Energy spectrum of the ^{8}B neutrinos

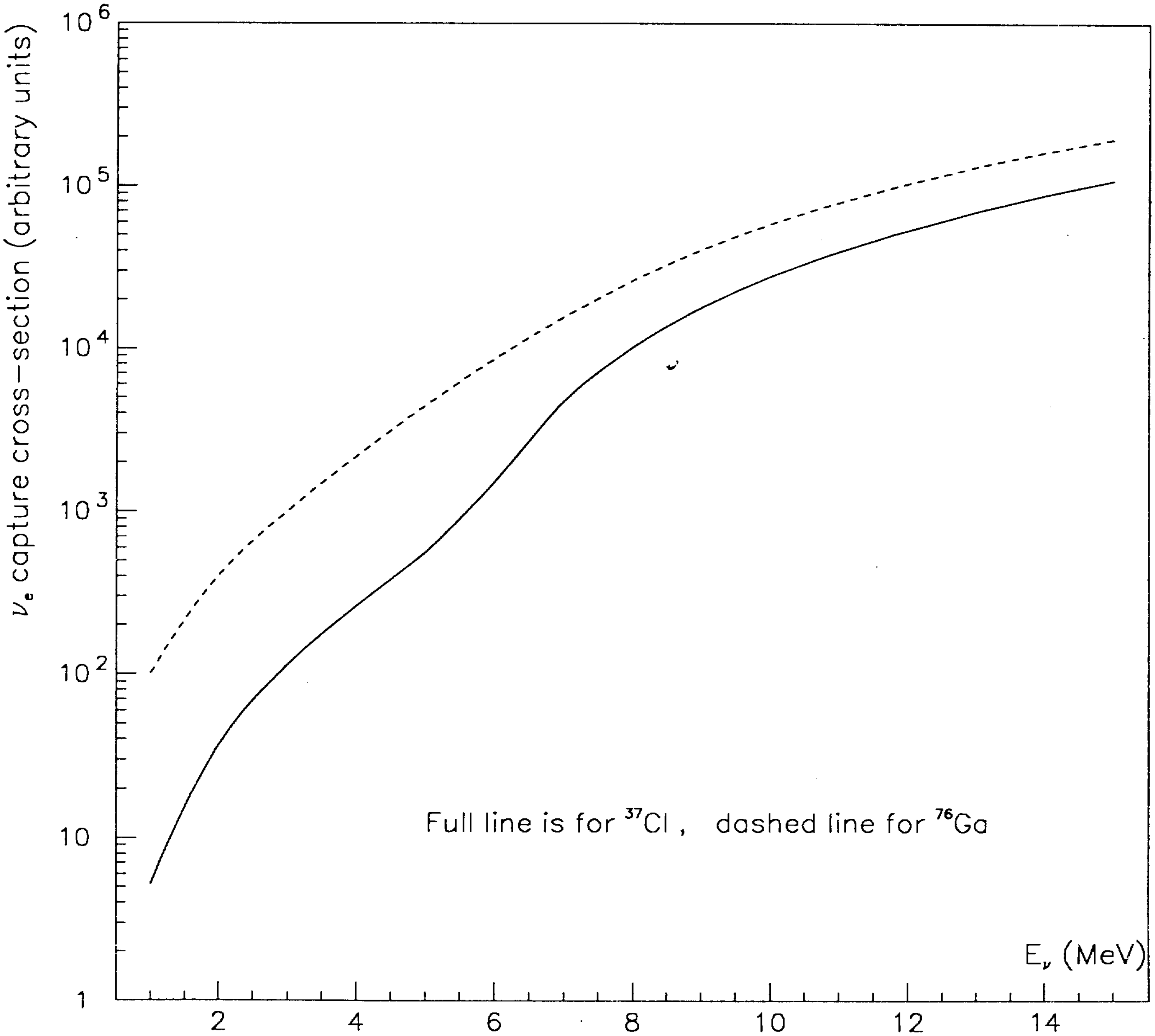


Fig.3 ν_e cross sections in the ^{37}Cl and ^{76}Ga experiments