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20 - 200 MeV neutrinos in SNO and the MSW adiabatic region.

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One of the possible resolution of the 25-year old solar-neutrino anomaly [Dav] is provided by the Mikheyev-Smirnov-Wolfenstein (MSW) [MSW] effect. According to MSW the observed depletion of the flux of electron neutrinos arriving from the sun can be explained through a resonant enhancement of neutrino oscillations in the interior of the sun.

A thorough study of the MSW effect yields three families of solutions in the parameter space of neutrino mixing angles ($\sin^2 (2\theta)$ and mass difference (Δm^2). These are the adiabatic [B86], the nonadiabatic [RG86, KTW86] and the large-mixing-angle [P86] solutions.

Recent data from Kamiokande II Collaboration [Hir], give more information on the flux of ^{8}B solar neutrinos. Leaving aside the large-angle solution, it has been argued [BB1, BW, BB2] that this new result – when considered together with that of the chlorine experiment of Davis [Dav] leaves the nonadiabatic solution to the solar-neutrino problem as essentially the only viable possibility. The results from GALLEX do not resolve the problem. It allows for both the nonadiabatic solution as well as for "no new physics". Thus, the overall situation is still ambiguous. It might be of interest to obtain some information pertaining to the relevant region of Δm^2 in an independent way.

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Up to now, terrestrial accelerator experiments have been able to reach the $\Delta m^2 \sim 0.1$ eV^2 region, (0.01 eV^2 for large mixing angles). A search for neutrino oscillations with smaller mass differences requires long-baseline experiments and has been recently discussed by Bernstein and Parke [BP]. The original motivation for their proposal was to study the region $\Delta m^2_{\mu e} \sim 10^{-2\pm0.5}$ eV^2, $\Delta m^2_{\mu\tau} \sim 10^{-2\pm1}$ eV^2. (Neutrino mass differences of this size might provide the explanation for the observed deficit of the ν_μ flux of atmospheric neutrinos.) In order to reach the relevant region of small Δm^2, Bernstein and Parke proposed use of the Fermilab ν_μ neutrino beam (with energy in the range 10-50 GeV) in a large distance (> 300 km) experiments.

We would like to point out that a similar long distance experiment involving neutrinos with energies in the range 20-200 MeV could reach the Δm^2 region singled out by the adiabatic solution of the solar neutrino problem. Although this region seems to be ruled out by solar experiments, it should be of some interest to have an independent "laboratory" confirmation of this conclusion.

Bernstein and Parke calculate the probability of producing one flavour of a relativistic neutrino ν_a at the source, letting the neutrino propagate to the detector, a large distance L away, and then detecting the neutrino as a different flavour ν_b.

The relevant transition probability is

$$P_{ab} = \sin^2(2\theta)\sin^2(1.27\,\Delta m^2 L/K) \tag{1}$$

where K is the momentum of the incident neutrino and Δm^2, K, and L are measured in eV^2, GeV and kilometers respectively.

One can measure P_{ab} as long as it is greater than a minimum oscillation probability (ϵ). In ref [BP], regions in the $\Delta m^2 - \sin^2(2\theta)$ plane accessible to experiments characterized by the detection limit ϵ have been shown for neutrino momentum K = 20 GeV. Since K enters into formula (1) in combination $\Delta m^2/K$, lowering the neutrino momentum to 20 MeV makes it possible to study a region of Δm^2 three orders of magnitude below the limits considered in [BP] (only for ν_τ one might encounter a nonrelativistic regime invalidating such a scaling). For L = 750 km corresponding to the distance Fermilab-Sudbury the contours of regions accessible to experiments with K = 20, 40, 100, 250 MeV are shown in Fig. 1. (Fig. 1 has been obtained from Fig. 2 of [BP] through appropriate scaling). In this figure the region of the nonadiabatic solution of the solar neutrino problem is indicated by a vertically hatched slant area [BW, BB2]; the adiabatic solution is represented by a dotted area (this region combines the original estimate of Bethe [B86] as well as results of Rosen and Gelb [RG86]).

As can be seen from Fig. 1, lowering the incident neutrino momentum to ~40 MeV should be sufficient to reach the region of Δm^2 mass differences favored by the adiabatic solution.

There remains a question whether the flux of neutrinos with relatively low energies (20 - 200 MeV) could be provided by Fermilab Main Injector would be sufficient to ensure measurable detection rates at SNO. Study of the low-energy spectrum of the flux of Fermilab neutrinos will be needed to answer this question.

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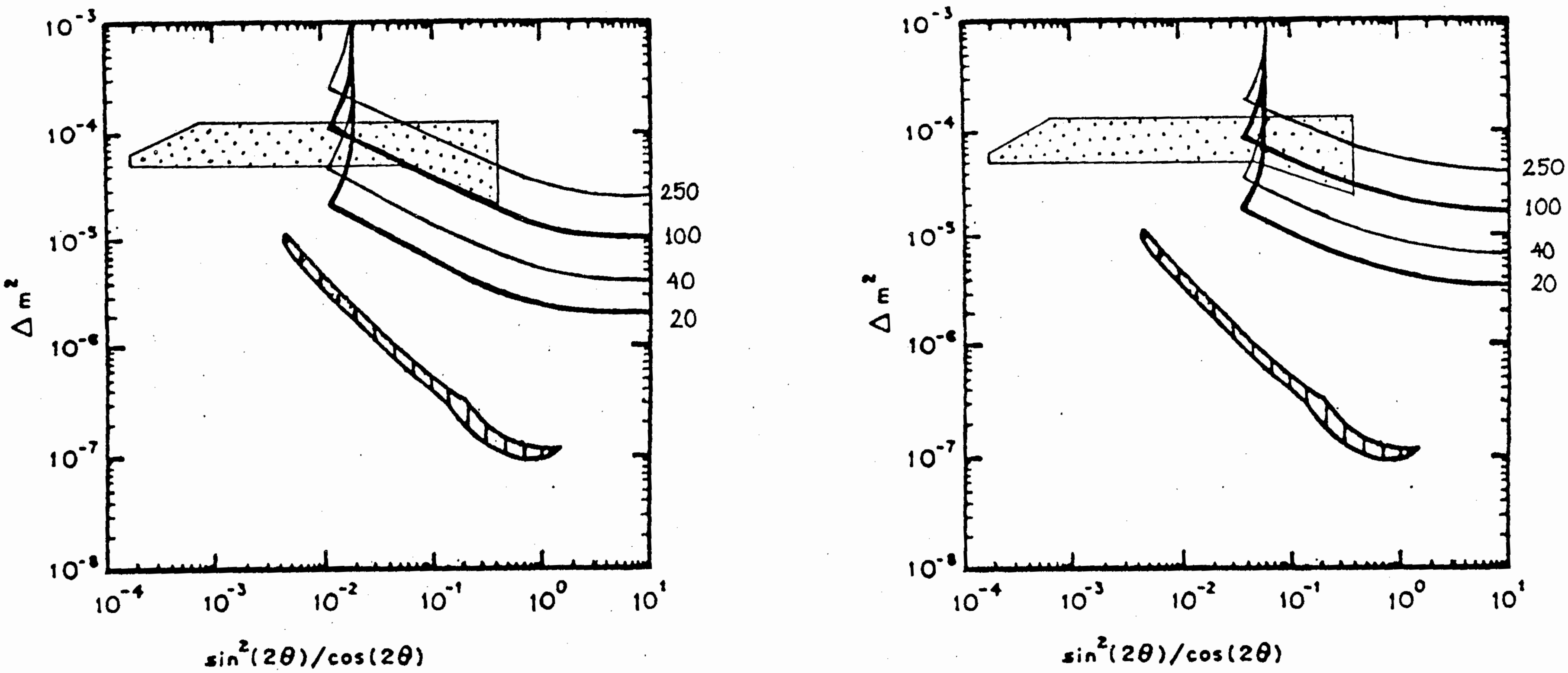

$\varepsilon = 1\%$ $\varepsilon = 3\%$

FIG. 1