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Proposed ν_e Telescope to Detect Solar Neutrinos
by Elastic Scattering on e^-

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Introduction

The problem to which these comments are addressed is twofold: the detection of solar neutrinos and the observation of the elastic scattering process

$$\nu_e + e^- \rightarrow \nu_e + e^- \quad (1)$$

The importance to astrophysics of the detection of solar neutrinos per se has been amply discussed elsewhere¹. The importance to elementary particle physics of the observation of (1) has also been noted. Its consequences in astrophysics to urca processes are profound².

As pointed out by Reines and Kropp³ a positive observation of the solar neutrino via reaction (1) would constitute a verification of both the theory of solar energy generation and the existence of (1). A negative result would not definitely rule out one cause or the other although it can be argued that the better based of the two factors is reaction (1). Ultimately the absence of an effect from the sun would require a check via inverse beta decay, a process which has been amply tested⁴.

Assuming, for the present the existence of (1) as predicted by Feynman-Gell Mann, et. al⁵ we indicate the kinds of information which might be

OCT 12 1965

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extracted from the various experimental approaches to the solar ν_e problem. At best, a solar ν_e experiment can provide information as to flux, energy, and direction. The experimentally hopeful approaches suggested to date show promise of providing this information in varying proportions as indicated in Table I. The possibility of the direct counting experiments (1-4 inclusive) exists because the neutrinos from the B^8 decay process which is predicted to occur by theoretical calculations of the most favored⁶ solar models produce electrons of energy which is high (up to 14. MeV) relative to the energies (β , γ) produced in the decay of naturally radioactive substances.

Reaction 5 has the lowest/threshold of any of those listed and is actually sensitive to the solar ν_e from Be^7 , (0.86 MeV) as well. In all cases ordinary cosmic rays can be eliminated as a source of the signal by changing the depth of burial. In reactions 2, 3, and 4 the signal can be tested by replacing the target nucleus with an isotope of the same element, e.g. $Li^7 \rightarrow Li^6$. The most convincing and direct test would be the directionality check of reactions 1 and 3.

It is seen from this tabulation that of all the reactions listed only 1 and 3 can give the three features listed. We discuss here an experimental embodiment of a system designed to utilize reaction 1.

Proposed Experiment

The directional requirement suggests use of the cerenkov effect. Shown in Fig. 1 is a schematic of a possible experimental arrangement. In

TABLE I

Comparison of Solar ν_e Approaches

	Reaction Employed	Information Content			Remarks
		Spectrum	Flux	Direction	
1.	$\nu_e + e^- \rightarrow \nu_e + e^-$	yes	yes	yes	$\sim 7/\text{yr ton Ch}_2$, $E_\beta > 6 \text{ MeV}$, angular correlation excellent (no threshold).
2.	$\nu_e + \text{Li}^7 \rightarrow \text{Be}^7 + \beta^-$	yes ($\sim 6 \text{ MeV}$)	yes	no	$\sim 10^2/\text{yr ton normal Lithium}$, $E_\beta > 6 \text{ MeV}$ (threshold 0.86 MeV) weak angular correlation of β^- with ν_e direction.
3.	$\nu_e + \text{B}^{11} \rightarrow \text{C}^{11} + \beta^-$	yes ($\sim 6 \text{ MeV}$)	yes	yes	$\sim 15/\text{yr ton normal boron}$, $E_\beta > 6 \text{ MeV}$ (threshold 1.48 MeV) strong angular correlation of β^- with ν_e direction.
4.	$\nu_e + d \rightarrow p + p + \beta^-$	yes	yes	no	$\sim 0.1/\text{yr ton D}_2$, $E_\beta > 5 \text{ MeV}$ (threshold 1.44 MeV).
5.	$\nu_e + \text{Cl}^{37} \rightarrow \text{A}^{37} + \beta^-$	no (threshold 0.31 MeV)	yes (if spectrum assumed)	no	This is a radiochemical approach which gives the activation only. It could in principle be related to the sun by the inverse square variation ($7\%/\text{yr.}$) through the year. The essential argument that the solar ν_e is the source of the signal is to be based on the detailed consideration of backgrounds and the plausible elimination of cosmic neutrinos and more mundane candidates. A negative result has a more clean cut interpretation. $\sim 7/\text{yr ton normal C}_2\text{Cl}_4$.

Known status of solar neutrino experiments:

- (5) R. Davis - preparations underway in a mine (see Davis contribution to this conference).
- (2) Reines and Woods - preparation underway in a salt mine near Cleveland.
- (4) T. L. Jenkins - preparation underway in a salt mine near Cleveland.
- (1) Reines and Kropp - large liquid scintillation in deep South African mine operated by Case-Wits group being studied for possible use in detecting this reaction.

Reaction: (2) also suggested by J. Bahcall and G. Zatsepin

(4) " " " G. Zatsepin

(3) suggested by Reines and Woods

Fig. 1 the cerenkov light will travel preferentially to the end marked P because the struck electron recoils close to the same direction* as the incident solar ν_e . A would therefore see no signal from the sun except for that resulting from a change in direction of the elastically scattered electron due to multiple coulomb scattering.

Figure 1

Schematic of ν_e telescope for solar observation.

To estimate how large a detector is required we calculate the recoil spectrum expected from reaction 1 for neutrinos from the decay of B^8 and the Feynmann-Gell Mann theory. Fig. 2 assumes the theoretical estimate⁶

*A point first emphasized by J. Bahcall.

of the neutrino flux at earth due to decay of B^8 in the interior of the sun.

end point 14.06 MeV $f = 2.5 \pm 1 \times 10^7 \nu_e/\text{cm}^2 \text{ sec}$ at earth.

Figure 2

Count rate/ton CH_2/yr vs. minimum recoil electron kinetic energy (MeV).

If we assume a threshold energy of 6 MeV so as to rule out the background counts from natural radioactivity and also require a predicted count rate of ~ 50 /year, a detector mass of 7 metric tons of mineral oil is required.

A search for the optimal cerenkov medium (high refractive index, low density, optical clarity) which at the same time has the largest possible number of electrons per unit mass led to the selection of mineral oil.

$$\text{CH}_2, \quad \rho = 0.9 \text{ gm/cm}^3, \quad n = 1.5$$

optical mfp > 5 meters for cerenkov light.

This substance has, in addition to these desirable features, low Z which means lesser coulomb scattering, so minimizing the loss of signal due to variation in the direction of the product electron. Mineral oil is benign and inexpensive (\$1/gal) and can be readily obtained in very large quantities. It has a high flash point ($> 180^\circ \text{ F}$), can be used directly as obtained from the manufacturer without purification and does not attack plexiglass which can therefore be used as a totally internally reflecting container.

Experimental Questions

The approach here described in principle is in an early stage of development. Several problems which have been considered but which have been considered but which require much more study relate to the questions of backgrounds due to natural radioactivity, cosmic rays, tube noise, and by no means least the asymmetry remaining in the response of the far sun (A) to near sun edge (P) after the recoil electron has suffered multiple coulomb scattering.

We will not go into these matters in the present talk except to remark that a preliminary consideration indicates the problems are difficult

but probably soluble through the use of: a deep underground location (~ 4000 m.w.e.), a charged particle anticoincidence, low noise tubes (e.g. Amperex or RCA) operated in fast (5×10^{-9} sec) coincidence, and an environment well shielded from natural radioactivity.

In any event it is a relatively simple matter to check out these ideas of detector design in the laboratory using a single smaller cylinder, and a group of us at this conference⁷ have started discussions in this direction.

As to the timing of the experiment it is apparent that other approaches, e.g. that of Davis and the Li^7 experiment of Reines and Woods⁸ will give some evidence which would then be a basis on which to proceed with the present proposal to check the directionality of the source.

Although it is probably best to await results from these other experiments before proceeding with the full effort required to develop the present approach into an actual experiment, it nevertheless seems worthwhile to explore the problems and be ready with a design if these results are positive and encouraging.

REFERENCES

1. W. A. Fowler and his colleagues have discussed the astrophysics of neutrinos extensively, e.g. J. N. Bahcall, W. A. Fowler, I. Iben, Jr., R. L. Sears, *Astrophys. J.*, 137 344 (1963).
2. H. Y. Chiu, *Ann. Nuclear Phys.*, 15 1 (1961).
3. F. Reines and W. R. Kropp, *Phys. Rev. Ltrs.*, 12 457 (1964).
4. F. Reines and C. L. Cowan, *Phys. Rev.*, 113 273 (1959).
5. R. P. Feynman and M. Gell-Mann, *Phys. Rev.*, 109 193 (1964); R. E. Marshak and E. C. G. Sudarshan, *Phys. Rev.*, 109 1860 (1958).
6. R. L. Sears, *Astrophys. J.*, 140 477 (1964).
7. J. Biedlein, F. Krienen, H. Jürg Gerber, M. Reinharz, F. Reines.
8. F. Reines and R. Woods, *Phys. Rev. Ltrs.*, 14 20 (1965).