A POSSIBLE SOLAR NEUTRINO DETECTOR BASED ON INDIUM NEUTRINO REACTION AND USING WELL KNOWN TECHNIQUES

M. SPIRO
Département de Physique des Particules Elémentaires, CEN-Saclay,
91191 Gif-sur-Yvette Cedex, France.

ABSTRACT

The interest for using Indium as a target for solar neutrino is stressed again. A possible solar neutrino detector using well known techniques (liquid scintillator and multiwire chambers) is described. It would be a large size heavy detector but it appears feasible and modular.

In 1976, Raghavan [1] suggested that Indium might be the most suitable target for a solar neutrino detector, and tried to design a possible detector on ν_eIn reaction [2], [3].

In my talk I want first to show you that Indium is still very attractive for solar neutrino detection and second that it might be possible nowadays to design a modular detector based on very well known standard techniques. Such a detector however will be very heavy at full scale.

There is a working group at Saclay [4]. Other solutions are also being studied, which are listed at the end.

SOLAR NEUTRINO DETECTION

Three main nuclear reactions [5] in the sun are neutrino sources:

Nuclear reaction	ν_e flux on earth ($cm^{-2} sec^{-1}$)	ν_e energy range
(1) $pp \rightarrow de + e^+ + \nu_e$	6×10^{10}	100 ÷ 420 keV
(2) $^7Be + e^- \rightarrow {}^7Li + \nu_e$	4.3×10^9	861 keV (monoenergetic)
(3) $^8B \rightarrow {}^8Be + e^+ + \nu_e$	5.6×10^6	5 ÷ 14 MeV

Other reactions contribute to the ν_e flux but with a much lower rate in their particular own ν_e energy range. At this stage it must be stressed that the ν_e flux from reaction (1) is almost model independent (< 10% uncertainty) while the ν_e flux from reaction (3) which depends on the amount of ^8B in the sun is sensitive to the whole stellar nuclear reaction chain leading to ^8B production and can then vary by a factor 2 according to the sun stellar model.

Up to now the only experiment which recorded solar neutrino events [6] is the R. Davis experiment based on transmutation of ^{37}Cl into ^{37}Ar. However this reaction has a high threshold which makes it only sensitive to the ν_e flux from reaction (3).

The experiment found 3 times a lower flux than expected in the sun standard model. This discrepancy can be attributed either to neutrino oscillations based on 3 neutrino species or to wrong predictions from the sun standard model. A detector sensitive to all 3 reactions and allowing to separate the 3 kind of sources will be able to disentangle the puzzle. If a constant discrepancy factor for the 3 kind of fluxes is found then neutrino oscillations would be the only known possible explanation for the present time. If the discrepancy only remains for the ν_e flux from reaction (3) it is then most likely to be due to solar nuclear reactions leading to ^8B production [7]. So, by measuring solar neutrino fluxes from each of the 3 nuclear reactions, one provides with informations of considerable interest for both astrophysics and elementary particle physics :

- for astrophysics it is a very powerful way to study the interior of the sun.
- for elementary particle physics an experiment with solar neutrinos will be extremely sensitive to neutrino oscillations due to the enormous distance between the sun and the earth and the low energy of these neutrinos. It will be possible to test mass differences of the order of 10^{-6} eV.

The idea of using Indium for detecting solar neutrinos from the proton proton primary reaction in the sun has been suggested since a long time by R.S. Raghavan [1]. The basic reaction is the β inverse decay of ^{115}In to the 614 keV excited state of Sn :

$$\nu_e + In \rightarrow Sn^{**}(7/2^+) + e^- \qquad (4)$$

This reaction (4) has a threshold of 120 keV so that :

$$E_e \simeq E_\nu - 120 \text{ keV}$$

The electron energy spectrum obtained from folding the solar neutrino spectrum with the cross sections of reaction (1), (2) and (3) is given in fig.1. Such a ν_e In reaction is then mostly sensitive to reaction (1) and (2) and will then give information complementary to the Davis experiment.

Reaction (4) is followed by a double desexcitation of Sn^{**}

$$Sn^{**}(7/2^+) \rightarrow \gamma\,(100 \text{ keV}) + Sn^*(3/2^+) \qquad (5)$$

$$Sn^*(3/2^+) \rightarrow \gamma\,(500 \text{ keV}) + Sn(1/2^+) \qquad (6)$$

The half life time of $Sn^{**}(7/2^+)$ is 3.26 μs. The life time of $Sn^*(3/2^+)$ is less than 10^{-10} sec.

In reaction (5) the photon internal conversion probability is $\simeq$ 50 % .

The delayed concidence signature will be the only way to remove the background coming from Indium radioactivity :

$$^{115}In \rightarrow {}^{115}Sn + e^- + \overline{\nu_e} \qquad (7)$$

The half life of ^{115}In is $5x10^{14}$ years. The maximum energy of the electron is 490 keV. It is clear that unless great care is taken the accidental coincidence rates could make the experiment unfeasible. These features have been discussed in great details by R.S. Raghavan and by Booth [2], [3], [8].

THE DETECTOR

Although all parameters have to be optimized, we present here a tentative description of what could be one possible solar neutrino Indium detector.

It is based (fig.2) on a stack of 1 m^2 multiwire proportional chamber with 3 mm gap and with common cathodes made of 5 μm mylar on which are deposited on both sides 5 μm thick Indium strips, 2 or 3 mm wide. 340 chambers are stacked in that way (2 m long stack) providing with an elementary cell of 25 kg of Indium. The read out of the coordinates is arranged to provide separately x, y and z coordinates which means that all same x wires or strips (< 500) are "ored" and in the same way that all same y and all same z are "ored". This leads to $\simeq$ 1000 electronic channel read out.

Ten cm's MWPC stacks will have to be interleaved with 10 cm thick tank of liquid scintillator to allow for the 500 keV γ detection from reaction (7) (Sn^* deexcitation). This corresponds to 2 tons of scintillator and will bring the volume of an elementary cell to 4 m^3.

PERFORMANCES

Event identification

By using only photon internal conversion in reaction (1) to identify an event, two tracks must be seen in a gate of 10 μsec, coming from the same Indium source point. The Indium source point can be located within 1 mm^3. Furthermore in coincidence with the second electron (photon internal conversion) there should be a pulse in the photomultipliers coming from the 500 keV γ (or another track in the chamber far away from the 2 coincident tracks).

Resolution on the energy of the incident ν_e is poor but should allow separation between reaction (1) and (2). Monte-Carlo is under way.

Efficiency

The efficiency for Indium radioactivity β^- detection is $\simeq$ .8.

The efficiency to solar ν_e In reaction detection has been calculated by taking into account :

- probability of photon internal conversion in reaction (6) : .45
- probability that both electrons from the ν_e reaction and from the photon internal conversion traverse a gap : .66
- probability of detecting the 500 γ from reaction (7) : .8
- dead time after reaction (4) : .90

This leads to .0015 event per day for an elementary cell of 4 m^3, 2 tons of scintillator and 25 kg of Indium.

Background

The number of "events" made of 2 accidental radioactivities at the same location (1 mm^3 of Indium) within 10 μsec is 3. per day for an elementary cell.

Additional rejection comes from the requirement of an extra γ in coincidence with the second electron to be observed, which means that in order to fake a ν_e event a third radioactivity should take place in coincidence ($\simeq$ 100 nsec) with the second one, or what is more likely, the second radioactivity β^- has to produce a bremstrahlung γ of energy > 200 keV. This probability plus the reduced efficiency for detecting the second β^- which has produced a bremstrahlung γ gives an additional factor of 10000 to 50000 depending on the energy resolution of the scintillator plus light collection system [2].

This leads to a signal/noise ratio of 5 to 25. However at this stage a lot of further studies and optimizations are needed to estimate this ratio.

CONCLUSION

The detector we describe offers a powerful background rejection and uses only well known techniques. It appears feasible. However the main drawbacks are the modest efficiency (.21) which induces a need of 2.5 tons of Indium to get .15 event per day, the big corresponding amount of scintillator ($\simeq$ 200 tons) and the corresponding overall size of the detector (400 to 800) m^3). Nevertheless it seems to us that such a possibility could be seriously worked out. Specially an attracting feature in that spirit is the modularity of the detector.

Other much more compact techniques are being also investigated at Saclay. Two of them may be promissing :

- Low pressure chambers with BaF^2 + Indium, U.V. scintillator windows.

- Solid chemical Indium compound window with good mobility and long absorption lengths (few mm's) for ionization electrons coupled to multiwire proportional chambers.

These two possibilities are at the stage of feasibility studies at the present time.

Aurouet, Blumenfeld, Michau, Micolon, Soirat, Thevenin are also involved in one part or another of the studies.

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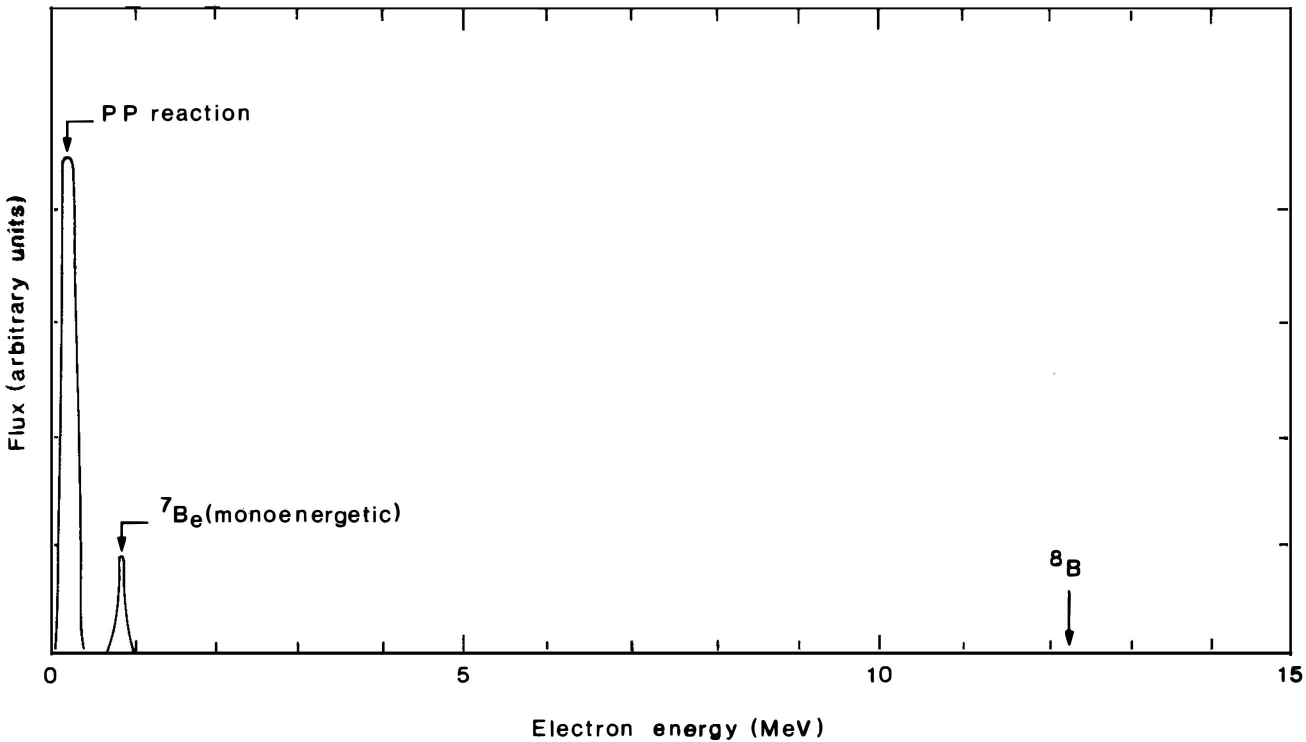

Fig.1 - Expected electron energy spectrum induced by solar neutrinos.

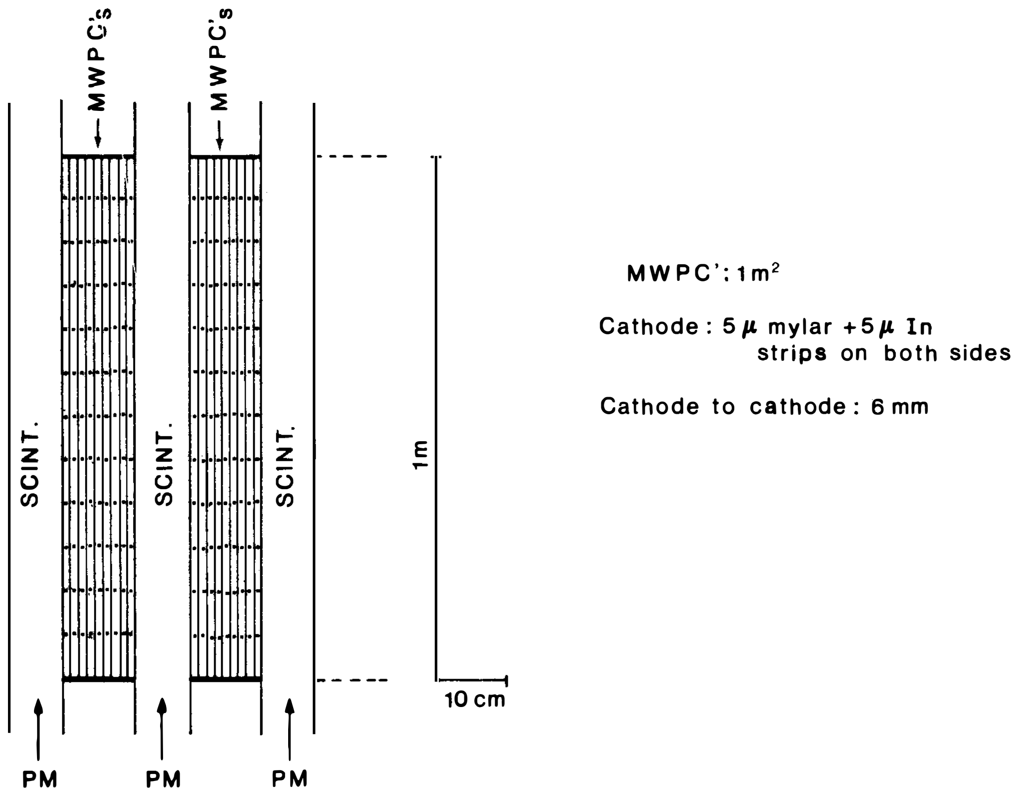

Fig. 2 - Sketch of the basic elements in the detector.