The Split-Detector Proposal

SNO-STR-90-141

The Guelph Group

1. Introduction

It is desirable to be able to determine simultaneously the CC reaction and the NC reaction of solar neutrinos with the deuteron. Simultaneous detection of these reactions could also be very useful in the event of a nearby supernova. The present SNO plan, in which the first choice is to use salt in the D2O to effect the NC measurement, is to carry out sequential measurement of no salt followed by salt. D. Sinclair has suggested that during the run with salt it will also be possible to extract the CC reaction at the same time by its angular distribution. Another way is to divide the vessel (probably vertically) in two with a thin, transparent divider and add salt only in one half. Initially it was suggested that the divider could be thin acrylic, but there may be other better choices.

In comparing the present plan and the split-detector proposal, it will be assumed that salt (or some equivalent n-capturing additive) can be used in the heavy water, and that a suitably thin, transparent and low radioactivity divider can be installed.

The first question to be answered is, what is the advantage of measuring the CC and NC simultaneously in a divided detector relative to the situation of having salt in the whole detector.

2. Solar Neutrino Detection

Let us assume that there are 2500 CC detectable events/year in the whole detector (1/3 SSM) and 2800 NC events/yr (full SSM) (table 2.2, SNO-87-12). Assuming no CC background or NC background of neutrons (for simplicity), the divided detector would measure 2500 +/- 71 CC events and 2800 +/- 133 NC events/year.

Consider now the undivided detector incorporating salt. The CC events have an angular distribution, w(theta) = A(1 - 1/3 cos theta). If we divide the CC

event into those in the hemisphere
away from the sun and those in the hemisphere toward the sun, the away/toward ratio is 5/7.

Defining F to be the total number of all events in the away hemisphere, B the total number
of all events in the toward hemisphere, C the total number of charged current events, N the total
number of neutral current events, and NB the total number of neutral current background events,
then it is easy to show that

B-F]
and N = 7F - 5B - NB
The errors on C and N are
(DB)**2 + (DF)**2]**0.5 = 6(B+F)**0.5
(7DF)**2 + (5DB)**2 + (DNB)**2]**0.5
49F + 25B + (DNB)**2]**0.5

where DNB is the error on the neutral current background events (which may not be just NB**0.5
because NB must be estimated from subsidiary measurements).

For the example above, the estimated CC events are C = 2500 +/- 480 and (with NB = 0)
N = 2800 +/- 437. It is seen that the errors are substantially larger than for the split detector. The
situation gets worse by narrowing the forward and backward acceptance angles.

3. Supernova Neutrinos

The situation may be even more dramatic for the detection of supernova neutrinos. Let us
consider only reactions I and III of the table on p. 40, SNO-87-12, and assume that nu(sub mu) and
nu(sub tau) arrive at the same time as nu(sub e), and that we get no help in separating reactions I
and III from energy (since this would probably be model dependent, although undoubtedly some
reaction I neutrinos will be high enough in energy that they would be clearly separated from the Cl
gamma rays). Then, for the divided detector with salt in one half, we would get the following
estimates;

Burst phase,	reaction I	10 +/- 4.5
	reaction II	6 +/- 7.2
Cooling phase,	reaction I	33 +/- 8

reaction III 760 +/- 40

On the other hand, if the whole detector were filled with salt, and in addition we knew where the supernova was, then using the forward-backward asymmetry of reaction I, we would get the following estimates;

Burst phase,	reaction I	10 +/- 24
	reaction III	6 +/- 24
Cooling phase,	reaction I	33 +/- 170
	reaction II	760 +/- 170

It is thus clear that no meaningful separation of reaction I from reaction III could be made in this case. (Note that the error estimates for small numbers of events are not quite correct, because the number of reaction events cannot be negative.)

4. Some other possibilities

A split detector would allow for some other possibilities. If boron could be added to the side without salt, then many background neutrons from the unsalted side might be gobbled up before they wandered into the salty side.

Another wild possibility would be to have 3He detectors in the unsalted side. Since the NC background may be quite different for the two NC methods (salt vs 3He), getting the same result on both sides would reassure us that the NC result was correct.

Finally, it might be that the ultimate fall-back position could have boron on one side and nothing on the other side, and the NC events extracted from neutron capture on the deuteron. Although many NC neutrons will leak out of the non-boronated side, if we had even a detection efficiency of one-seventh of the SSM value used in the above examples (i.e. 1/7 of 1400 events in the one side) we would get a NC measurement with 50% accuracy in one year.

5. Conclusions

In the event that salt is used for NC detection, there is a definite advantage from a purely physics point of view to having a split detector. In addition, only half the amount of salt is used, making clean up a little easier (or cheaper). The problems are associated with what is the divider made of and how is it to be installed. Presumably the spherical bladder method, if it divides the detector into equal volumes of salted and unsalted D2O, has similar advantages to the divided detector discussed here. It would seem to be more technically challenging, however, and more difficult to calibrate.