

on a reaction whose neutrino capture cross section can be calculated with reasonable certainty, and it must be capable of distinguishing the very small solar-neutrino signal from the other, often large, sources of background. The low neutrino cross section usually necessitates experiments large on both a spatial and temporal scale.

Gallium. One such experiment has been proposed by a collaboration from Brookhaven, Princeton, Battelle Pacific Northwest Laboratories, the University of Pennsylvania, the Weizmann Institute,² and most recently from the Max Planck Institute at Heidelberg. They plan to use the neutrino capture by Ga^{71} to yield Ge^{71} with a reaction threshold of 0.233 MeV. Thus, the detector is sensitive to the p-p neutrinos. The experimenters have considered two schemes for collecting and detecting the Ge^{71} depending on whether the Ga^{71} is in solution or is in metallic form. Extraction procedures for both have been tested on 20-kg quantities of gallium, and an extractor for 200 kg is being designed as a pilot for the ultimate extractor of 1-2 ton capacity. For an event rate of one per day, the gallium experiment will require 50 tons, at a cost of perhaps \$25 million. The collaboration hopes to be able to obtain the expensive material through some form of rental or borrowing agreement. The inevitable problems of background are mitigated somewhat by features of the gallium that tend to make its background partly self monitoring.

Lithium. Brookhaven workers have investigated the possibility of studying neutrinos by the inverse beta decay in lithium. Such a reaction would be sensitive primarily to the intermediate-energy neutrinos such as those from the small percentage of proton-electron-proton reactions and those from the decay of N^{13} , O^{15} , B^8 and Be^7 . Thus it would yield different information than the gallium and chlorine flux measurements and would require only a few tons of lithium. The largest experimental problem with the lithium concept is the difficulty in measuring the Be^7 produced. Sam Hurst's group at Oak Ridge National Laboratory is exploring a laser-ionization technique for single-atom detection, which they will apply to measuring Be^7 and also Te^{71} . The other disadvantage of a lithium measurement, explained John Bahcall of the Institute for Advanced Study, is that it alone may not unambiguously resolve the differences among hypothetical explanations for the low B^8 neutrino flux.

Thallium. A very different approach has been suggested by Melvin S. Freedman and others at Argonne National Laboratory.³ Rather than wait for incoming neutrinos to convert atoms in a target chamber, they intend to measure those conversions that have been induced in natural materials over millions of years

(and hence would represent a time-averaged flux). If the product atoms have a sufficiently long half life, they can accumulate in the target and reduce the large masses required by the counting experiments. The candidate reaction selected by the Argonne team is the neutrino capture by Tl^{205} and conversion to Pb^{205} , a reaction whose 0.43-MeV threshold makes it sensitive mainly to p-p neutrinos. They anticipate using 10 kg of the rare thallium crystalline mineral lorandite from a deposit in Yugoslavia that appears to have a low enough content of natural lead impurity. Mass spectrometry of laser-resonance fluorescence would be used to detect the long-lived Pb^{205} .

Two major problems beset this proposal. The most serious is the inverse beta cross section for Tl^{205} is not sufficiently well known. Freedman claims that they now know the cross section to within $\pm 40\%$ and they are both conducting and planning experiments to lower that uncertainty to the $\pm 20\%$ needed for a meaningful flux measurement. Bahcall has pointed out an error in the original estimate and has suggested that the present uncertainty is at least a factor of two.⁴ The other problem concerns the background of Pb^{205} from other reactions: Has the sample been isolated from natural sources of radiation, and has it been embedded deep enough for long enough to ensure that cosmic-ray muon-induced radiation was below a manageable level?

Another similar capture by neutrinos in a mineral is the capture in Br^{81} that yields a long lived Kr^{81} . The target material would be a salt deposit that has a small amount of bromine present.

Indium. A final class of experiments consists of those that depart from the radio-chemical approach and directly measure the energy and perhaps the direction of the neutrino. The most advanced proposal of this type is one recently described by Ramaswamy Raghavan and his coworkers at Bell Telephone Laboratories.⁵ This experiment would be based on the inverse beta decay in In^{115} . The low threshold of this reaction (128 keV) makes it sensitive to p-p neutrinos. The energy of the promptly emitted electron is equal to the excess energy of the neutrino above threshold. The product—an excited state of Sn^{115} —decays with a half life of 3.26 microsec to two coincident gamma rays that, together with the electrons, constitute a unique signature of the event. To discriminate the anticipated one event per day from the very large background of 10^{11} beta decays of In^{115} per day in $3\frac{1}{2}$ tons of indium, Raghavan and his associates have devised a triple delayed coincidence scheme that incorporates spatial position as a criterion. This electronic counting experiment can detect temporal variations in the neutrino flux. Among several detector concepts being considered, the

Bell Labs group has recently become excited about a relatively simple one that uses modules of stacks of thin plastic scintillators interlaid with thin layers of indium. As a bonus, the neutrino-electron scattering in the plastic scintillator stack could enhance the sensitivity to B^8 neutrinos. If this scheme becomes feasible, it could be a powerful tool for neutrino spectroscopy.

Other direct measurement schemes that are not as extensively researched are based on the deuterium capture of boron-8 neutrinos and the neutrino-electron scattering.

Bahcall has surveyed all the proposed solar-neutrino measurements⁴ and examined them for their ability to advance our state of knowledge, for the accuracy with which the neutrino capture cross section is known and for the general feasibility of the experiment. He singles out four experiments as worth pursuing—chlorine, gallium, lithium, and indium—and argues more generally for a deliberate neutrino spectroscopy program to govern the next 20 years of research. —BGL

References

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NSF approves Cornell's synchrotron source

The National Science Foundation has approved a grant of \$1 million over the next three years for the construction of a synchrotron radiation facility at the Cornell Electron Storage Ring. The Cornell High Energy Synchrotron Source will produce x rays up to 100 keV, a higher energy than is available from other existing or planned sources in the US; it will thus complement synchrotron radiation facilities now operating or under construction at Brookhaven, Wisconsin and Stanford (see PHYSICS TODAY, March 1977, page 17). Conversion of the 12-GeV electron synchrotron at Cornell to a colliding-beam device for up to 8-GeV electrons and 8-GeV positrons is scheduled to be completed in the spring of 1979; the synchrotron-radiation facility should then be ready for users in the summer of 1979. □