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ARGONNE NATIONAL LABORATORY

Jan. 12, 1975

To: James R. Sanford; Associate Director, Fermi National Accelerator Laboratory

From: Melvin S. Freedman; Chemistry Division, Argonne National Laboratory

Re: Proposal for parasitic dual target irradiation with muon spill beam behind FNAL experiment 319.

An experiment to measure the flux of solar neutrinos on earth is being planned. The experiment seeks to detect the very small concentration ($10^{-19}$) of 16 million year radioactive $^{205}$Pb accumulated in old thallium minerals by the neutrino capture reaction on $^{205}$Tl. The experiment is analogous to the experiment of R. Davis of Brookhaven which determines the rate of neutrino capture in $^{37}$Cl to produce 35 day $^{37}$Ar. This experiment has thus far indicated a neutrino flux at the background level, only one sixth of the rate predicted by current theoretical solar models. The planned experiment with thallium has the advantage of a much lower neutrino energy threshold than for $^{37}$Cl, enabling the detection of the abundant low energy component of the solar neutrino flux, to which Davis's experiment is insensitive.

The ultimate limitation on both experiments is the background which arises from energetic cosmic ray muons. These penetrate deep underground, to the thallium mineral in situ or to the tank containing the chlorine, and generate energetic protons by interaction with the medium weight elements composing rock. The protons in turn, after slowing down to produce a smeared out proton energy spectrum, generate either $^{205}$Pb (or $^{37}$Ar) by (p,n) reactions on the $^{205}$Tl (or $^{37}$Cl) targets. None of the factors entering the estimation of this complex process are either well known or can be calculated with the requisite accuracy or reliability, for either target isotope. The production of the primary proton spectrum is a very difficult calculational enterprise, complicated by uncertainties in the Fermi motions of nucleons and of nuclear structure factors; Luke Mo has advised on this topic. Either measuring or attempting to calculate the unknown (p,n) cross sections for $^{205}$Tl or $^{37}$Cl over an appropriately large range of proton energies is a very difficult task.

We propose a direct measurement of the overall process for both nuclei by a simultaneous irradiation of thallium and chlorine adjacent targets in the muon beam at FNAL. The irradiation would use the spill beam from experiment 319.



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The targets would be placed inside a small cubicle made of three-foot cubical concrete blocks located behind (north of) the muon experimental building about 20 feet from the end wall of the muon building, so as not to interfere with the road passage to the Wonder building. The concrete block in line with the muon beam serves as muon-proton converter, simulating rock in the natural environment of the solar neutrino targets, and the small cubicle with a bent entrance passage will protect the targets during the hoped for 1-2 months of irradiation time while the experiment 319 is running this spring. Whatever schedule of beam-on-time and muon energy is adopted by experiment 319 is useful and acceptable for our irradiation. We would hope for total muon integrated fluxes of ca. $10^{11}$ muons, and would want as much as possible. We would request FNAL to assemble the cubicle.

The goal of the experiment is a relative rather than an absolute measurement of the effective overall cross sections for the muon-generated reactions producing $^{205}$Pb and $^{37}$Ar in the two targets. This ratio is just the ratio of product atoms if the targets see the same secondary proton flux. After irradiation the chlorine target will be shipped to Brookhaven for analysis of the 35 day $^{37}$Ar, and the assay of the thallium target for $^{205}$Pb will be done at Argonne. Apart from whatever survey instrumentation is needed to locate the muon beam in the cubicle at the start of the irradiation, no electronics are involved. We would request the help of the FNAL survey group in beam location. Owing to the 35 day half life of the $^{37}$Ar being comparable to the irradiation time, we would need the detailed irradiation schedule, times and proton beam intensities, to which the samples have been exposed, after the irradiation (but not necessarily adhering to any predetermined schedule).

The chlorine target will be either liquid tetrachlorethylene ($C_2Cl_4$) or solid hexachlorbenzene ($C_6Cl_6$) in a sealed container, probably stainless steel, with approximate dimensions 15 cm x 6 cm face area, normal to the muon beam, x 6 cm depth, containing about 500 cc. The container will incorporate appropriate valves and connections for subsequent attachment to a vacuum line for extracting the $^{37}$Ar. The thallium will be in the form of pure thallium carbonate powder, about one kilogram, in a thin flat container with dimensions 15 cm x 6 cm x 1.5 cm thick. The two containers will be placed side by side with flat faces toward the beam, splitting the beam intensity along their joining edges, up against the inside face of the concrete block wall. Heating or nuclear or chemical reaction during irradiation should be negligible in either sample. We would provide and assemble the targets and target mounting frames, and disassemble them after the run.

This experiment has been discussed with L. Voyvodic, who conducted me along the muon beam facility and suggested the arrangement here proposed, and with F. Nezrick and T. Yamanouchi, who provided data on the beam characteristics. W. Chen, spokesman for experiment 319, is informed of our proposal and sees no interference from it with his experiment.

Although the Brookhaven solar neutrino group of R. Davis is not formally a part of the group proposing this irradiation, the data on $^{37}Ar$ production by muon interaction to be obtained is of interest to their effort. The fact that they have already measured the actual $^{37}Ar$ production rate at various shallow depths underground, at which the production is predominately by muons, will enable us to normalize on their measurements to be able to predict the $^{205}Pb$ production rate by muons as a function of depth, based on the relative effective cross sections for the two reactions obtained in this experiment.

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