Neutron Background Study for LAMPF Experiment #53:

Study of the neutrino capture cross sections in

^{37}Cl with μ^+ decay neutrinos. March 1975

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Introduction:

In order to measure the neutrino capture cross section in ^{37}Cl , sources of experimental background must be well understood and minimized. The two dominant sources of background are cosmic rays and energetic neutrons associated with the incident proton beam. The cosmic ray background is well understood from previous experience with the ^{37}Cl system. It will be minimized by adequate shielding to remove the hadronic component of cosmic rays (3 meters of Fe). This represents a known limitation on the experiment and cannot be significantly improved. A machine associated neutron background can simulate a neutrino signal and must be totally eliminated or accurately estimated. The nature of this background source appears to be rather complex and is not readily accessible to calculations. An experimental program has then been initiated to measure the neutron background with the following major goals:

1. Ultimate feasibility of a cross section measurement at various beam current levels.
2. Minimum shielding requirements.
3. Optimal detector configuration in the neutrino house.

Experimental Results:

The present experimental configuration is shown in Figure 1. The two BNL detectors (A1,A2) are simply 7'x7'x2' 750 gallon flat steel tanks. A1 is currently filled with $\text{Ca}(\text{NO}_3)_2$ solution for increased neutron sensitivity while A2 is a 1/4 scale prototype of the final detector filled with C_2Cl_4 . The Ca detector makes use of the $^{40}\text{Ca}(n,\alpha)^{37}\text{Ar}$

reaction to detect neutrons. Neutrons register in Cl by a two step process, $^{35}\text{Cl}(n,p)^{35}\text{S}$ followed by $^{37}\text{Cl}(p,n)^{37}\text{Ar}$. The sensitivity of the two detectors is dependent on energy. Ca is about 2000 times more sensitive than Cl for 14 MeV neutrons but only 60 times more sensitive to the hadronic component of cosmic rays. This wide range in sensitivity complicates interpretation somewhat. ^{37}Ar is purged from either tank by a He gas stream and is removed from the gas stream by a gas handling system in the Yale-LASL experimental trailer. Gas purification is carried out at the LOB in laboratory space provided by CNC-11. Final purification and counting is done at BNL. To date 14 runs have been carried out in the Ca tank and 6 in the C_2Cl_4 tank. The most significant of these results are summarized in Tables 1&2. Beam current monitoring is done by use of the 6ACM01 and 6ACM02 current transformers as given by the DE1044 computer printout requested from CCF before and after each run. The measurements shown on Tables 1&2 were taken during runs in November and December 1974. An earlier series of measurements was made in June 1974. At that time, the beam current monitor was not functioning properly and only a factor of two estimate of the flux was available. In the June run, only the Ca tank was present. It was physically located in the A2 position (see Fig. 1). Those results showed a neutron flux in the A2 position at least 5 to 10 times higher than in the A1 position. In December 1974 a series of measurements were made with a 0.75 m iron plug (D) removed from the area directly in front of the beam stop. This in principle allowed a measurement of the mean attenuation length of neutrons in iron. The measurement must be viewed somewhat

with suspicion since some shadowing was experienced by the BNL detector. The Yale-LASL(B) and UCI(C) detectors were set far enough back to be completely unshadowed when the plug was removed. The mean attenuation length found for calcium is 171 gm/cm^2 in good agreement with the value found by the UCI group (UCI-Neutrino #11, internal report, Feb. 1975) by proton recoil studies, and with that calculated by a nucleon cascade model. Due to the large discrepancy between the last two measurements, however, the error is large. The discrepancy appears to be real and is not easily understood. It may be related in some way to biased operations. This will have to be carefully investigated in the future. The chlorine tank gave a considerably higher result, possibly indicating a harder neutron component forward of the beam stop (see Fig. 1). These measurements must be repeated, however, since there were known experimental difficulties with the C_2Cl_4 detector. At 4 m of iron shielding the ratio of production rates between the Ca and Cl tank was only 8:1. This ratio is impossibly low and cannot by any known process be less than 60:1. This indicated a large spacial anisotropy of energetic neutrons in the room of a factor of at least 7 or 8. This is also in agreement with the Ca measurement in the A2 position. Such an anisotropy is not surprising since for incident protons of 800 MeV the secondary neutron flux should be forward peaked in the laboratory system. This suggests that the geometrical configuration for the detectors originally proposed for this experiment is not optimal. This effect needs to be explored further.

Conclusions:

Further experiments are clearly needed before the final shielding arrangement can be decided with certainty. However, measurements at this point seem to indicate a rather unfavorable background situation with at least 6.5 meters of iron required and all four tanks located near the Al position shown on Fig. 1 (alternatively it might be desirable to move the beam stop forward). At that distance a full 1 ma beam at the beam stop is required.

Future plans:

When the accelerator returns to full operation in July a series of measurements will be made with the present configuration. After correcting a number of technical difficulties on the chlorine tank, those measurements should be more reliable. It will also be necessary to repeat the Ca measurements to resolve the rather large discrepancy encountered in the last two measurements. Some arrangement will have to be made at this time to test the effect of the biomed target. It is currently planned that the BNL detectors will then have to be removed in order to add another 1 m of iron shielding. At that time some smaller portable Ca detectors will be installed. It will be possible to explore the spacial anisotropy effect with these detectors. Due to their small size and the extra shielding, 50-100 μ a will be required. That should, however, be available by that time.

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Table 1

750 gallon Calcium Tank Measurements

4 Meters of Iron Shield

Run #	$\mu\text{a}\cdot\text{hrs}$	^{37}Ar atoms per $\mu\text{a}\cdot\text{hr}$	
7	69	356	Average = 360 $\pm$ 65
8	37	385	
9	131	272	
11	126	425	

3.25 Meters of Iron Shield

12	36	13,700	Average = 11,000 $\pm$ 4,000
13	89	8,050	

Mean Attenuation Length in Iron = $171 \pm \frac{38}{22} \text{ gms/cm}^2$

Table 2

750 gallon Chlorine Tank Measurements

4 Meters of Iron Shield

Run #	$\mu\text{a}\cdot\text{hrs}$	^{37}Ar atoms/ $\mu\text{a}\cdot\text{hr}$	
1	258	50	} Average = 45 $\pm$ 8
3	238	39	

3.25 Meters of Iron Shield

4	118	570
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Mean Attenuation Length in Iron $\approx 230 \text{ gms/cm}^2$

Fig. 1