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EXPERIMENT TO SEARCH FOR FINITE MASS NEUTRINOS AT LOS ALAMOS

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ABSTRACT

The strong current interest among physicists of the possibility of finite mass neutrinos has resulted in several proposals at Los Alamos for experiments to detect nonzero neutrino masses. I will discuss here three experiments which are now underway and three proposed experiments at LAMPF.

Two experiments are now underway at Los Alamos to look for the oscillation channel $\bar{\nu}_\mu \to \bar{\nu}_e$ by observing $\bar{\nu}_e + p \to n + e^+$. These experiments are being done at the LAMPF beam dump where pion and muon decay at rest generate $\bar{\nu}_\mu$, ν_μ, and ν_e with average energies of about 35 MeV. The contamination of $\bar{\nu}_e$ from μ^- decay is about 1 part in 5000 since these neutrinos originate from π^- production which are strongly absorbed before they can decay. Thus the observation of the $\bar{\nu}_e$ induced reaction $\bar{\nu}_e + p \to n + e^+$ at rates higher than that expected from the small amount of $\bar{\nu}_e$ produced in the beam dump would be taken as evidence for $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillation.

The first of these experiments is a University of California at Irvine - Los Alamos collaboration (H. Chen et al.). The primary purpose of this experiment is to measure accurately (±10%) the ν_e - e elastic scattering cross section. However, it will also set a limit of $\Delta m^2 \gtrsim 0.3$ eV^2 for $\bar{\nu}_\mu \to \bar{\nu}_e$. The 14-ton detector is a sandwich detector comprised of plastic scintillator and flash chambers which provide position information on the e^+ in the final state. The assembly sits 10 meters from the LAMPF beam dump and is surrounded by an anticoincidence counter and iron shielding to suppress cosmic-ray backgrounds. The limit of sensitivity of this experiment is due to ν_e interactions on materials like aluminum, ^{13}C, and chlorine in the detector.

The second experiment is a LASL experiment (H. Kruse et al.) originally designed to search for $\bar{\nu}_e$ oscillations at the Nevada Test Site (NTS) using fission weapons tests as the neutrino source and measuring $\bar{\nu}_e$ fluxes at distances up to a kilometer from the source. The detector being developed for the NTS is now being modified to search for $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillations at LAMPF by observing $\bar{\nu}_e + p \to n + e^+$. The detector consists of 4470 liters of gadolinium loaded liquid scintillator. The positron gives a prompt signal in the scintillator, and the neutron moderates and is captured by the gadolinium with a capture time of a few tens of microseconds. The neutron capture produces 8 MeV of cascade gammas with an average multiplicity of 4. This detector is to be located 33 m from the LAMPF beam dump and is surrounded by an anticoincidence counter and covered by 8 m of tuff (compacted volcanic ash) to suppress cosmic-ray background. Since this experiment requires a coincidence, signal to noise should be high. However, correlated neutral events in the detector may be a limit on the sensitivity. If these kinds of backgrounds prove to be small, the expected sensitivity is $\Delta m^2 \sim 0.1$ eV^2. Following the experiment at LAMPF, the detector will be taken to the NTS where limits on Δm^2 for $\bar{\nu}_e$ disappearance are expected to be less than 0.005 eV^2.

There are three new proposals to study neutrino oscillations at LAMPF. One is the Rice-Houston-LASL proposal (M. Duong-Van et al.) which has been discussed in another contribution to this conference. The second is an Ohio State - Argonne National Laboratory proposal (T. Romanowski et al.) to study ν_e disappearance ($\nu_e \rightarrow$ anything) by observing the $\nu_e + D \rightarrow p + p + e^-$ reaction. They propose to build two 30-ton detectors which are sandwich detectors comprised of layers of D_2O Cherenkov detectors and drift chambers which are used to track the electron. Both detectors are surrounded by anticoincidence shields and sit in a tunnel covered by 6 m of tuff. One detector is stationary at about 30 m from the LAMPF beam dump and the second detector is moveable within the tunnel at distances up to 100 m from the beam dump. This provides a test of ν_e disappearance independent of the neutrino spectrum and flux. The expected sensitivity is $\Delta m^2 = 0.1$ eV^2.

The third proposal is a LASL proposal (T. Dombeck et al.) to search for the oscillations: $\nu_\mu \rightarrow$ anything, $\bar{\nu}_\mu \rightarrow$ anything, $\nu_\mu \rightarrow \nu_e$, and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$. This proposal involves building a new neutrino facility at LAMPF as well as a 50-ton detector. This new facility would take up to 200 μA of the LAMPF beam which would be transported down line D (where the proton storage ring is to be built) to a thin carbon production target. Pions produced would decay in flight in a 30-m long decay region yielding ν_μ and $\bar{\nu}_\mu$ at energies up to 250 MeV with an average energy of 150 MeV. The target to detector distance can be varied from 30 m to 200 m by moving the production target. The detector is a sandwich detector with scintillator planes and drift chamber or flash chamber position readout planes. Neutrino interactions with ^{12}C in the scintillator produce μ^+, μ^-, e^+, or e^- which are detected and particle identified. The detector is surrounded by an anticoincidence shield and 6 m of tuff. When the proton storage ring comes on line, this detector and neutrino facility would be used to observe a broad range of neutrino interactions including improved sensitivity to neutrino oscillations. The expected sensitivity for oscillations of this experiment and the other proposals described above are listed in Table I.

The final point I want to discuss is a Michigan State University - Los Alamos (R. G. H. Robertson et al.) collaboration now getting underway at Los Alamos to search for a finite neutrino mass in tritium beta decay. Recent reports by Tretyakov et al. claim evidence for an electron antineutrino mass of 14 to 46 eV with a most probable value of 34 eV. These results have been discussed in another contribution to this conference. While no one has yet found any specific problems with the Russian measurement, many of us are concerned with the tritiated valine source used. These concerns are 1) that the betas scatter upon leaving the source, and that these energy losses are probably quantized in the few eV to few tens of eV region, 2) that the atomic and molecular final states are not completely understood, 3) that backscattering may distort the spectrum, and 4) that tritium migration across the nonequipotential source may be a problem. In order to avoid these problems, we plan to measure tritium beta decay using a monatomic tritium beam as the source. Molecular tritium is dissociated in a microwave discharge and transported in a teflon tube to a teflon-coated quartz tube which is at about 10° K. The atomic tritium reaches equilibrium with this tube after three to four collisions with the wall and forms a cold atomic beam upon leaving the tube. Beam intensities of greater than 10^{16} atoms/sec may be achievable. The atomic tritium beam will be collimated and possibly focused by a sextupole magnet into a 1-m long solenoidal magnet decay region. The tritium atoms beta decay in this region, and the betas spiral along the field lines to the end of the solenoid where they are extracted. The betas are then accelerated by about 20 KV to an effective endpoint of about 40 keV. They are then transported to a magnetic spectrometer where the beta spectrum is accurately measured. The spectrometer will be either a dispersive magnetic system or a toroidal beta spectrometer. The focal plane detector will be a position sensitive gas proportional counter.

Accelerating the betas improves the extraction efficiency from the solenoid and more importantly provides a strong means of background rejection: the extraction system will be designed so that only decays from tritium atoms along the axis of the spectrometer are observed and any decays of tritium atoms on the walls of the solenoid are not observed. In addition, since the decays from the region of interest of the solenoid have an effective endpoint energy of 40 keV after extraction, any tritium atoms decaying anywhere else in the system or in the spectrometer have at least 20 keV lower energy than the betas of interest and can be rejected by an energy cut on the focal plane detector.

In approximately the next year, we expect to have an operating atomic tritium beam. Design and construction of the decay region and spectrometer should be completed in two to three years followed by about one year of data acquisition. We plan to first measure the population of both bound and unbound final states of the ^{3}He daughter atom using the atomic tritium beam. Coupled with a measured detector resolution, we will be able to predict accurately the beta spectrum we should observe in a manner free from the systematic effects that are associated with measurements using solid sources. We expect to be able to either confirm or deny the Russian claim of a 35 eV neutrino mass by at least two standard deviations using this technique.

TABLE I

Institutions	E_ν(MeV)	Detector Distance (m)	Transition	Reaction	$\Delta m^2(eV^2)$†
Irvine-+ LASL	20-53	10	$\bar{\nu}_\mu \to \bar{\nu}_e$	$\bar{\nu}_e + p \to n + e^+$	< 0.3
LASL+	20-53	32**	$\bar{\nu}_\mu \to \bar{\nu}_e$	$\bar{\nu}_e + p \to n + e^+$	< 0.15***
LASL (NTS)+	1.8-8	200-1200*	$\bar{\nu}_e \to$ anything	$\bar{\nu}_e + p \to n + e^+$	< 0.005***
Houston-++ Rice- LASL	20-53	40-200**	$\bar{\nu}_\mu \to \bar{\nu}_e$	$\bar{\nu}_e + p \to n + e^+$	< 0.003***
Ohio State-++ < 0.1 Argonne	20-53	20-100*	$\nu_e \to$ anything	$\nu_e + D \to p + p + e^-$	
LASL++	60-250	30-200*	$\nu_\mu \to$ anything $\bar{\nu}_\mu \to$ anything $\nu_\mu \to \nu_e$ $\bar{\nu}_\mu \to \nu_e$	$\nu_\mu + {}^{12}C \to {}^{12}N$ $\bar{\nu}_\mu + {}^{12}C \to {}^{12}B$ $\nu_e + {}^{12}C \to {}^{12}N$ $\bar{\nu}_e + {}^{12}C \to {}^{12}B$	< 0.06 < 0.2 < 0.05 < 0.1

* Experiment to be carried out at several distances from source.
** If positive signal is observed, detector will be moved.
*** Neutron is detected in coincidence with positron.

† Assuming maximum mixing.
\+ Approved experiment.
\++ Proposed experiment.