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NUCLEAR TRANSPARENCY AND
DOUBLE BETA DECAY OF MOLYBDENUM 100

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ABSTRACT

The analysis of the data obtained in an experiment to search for double beta decay in molybdenum 100 with collaborators from the Lawrence Berkeley Laboratory, the University of New Mexico, and the Idaho National Engineering Laboratory has nearly been completed, and a paper giving a lower limit of 0.44×10^{23} years on the lifetime of the $0^+ \rightarrow 0^+$ neutrinoless double beta decay mode has been accepted for publication in Physical Review Letters. This limit is a factor of 11 larger than the limit we published previously in Physical Review Letters in 1989.¹ A Physical Review paper with the data analysis on the $0^+ \rightarrow 2^+$ and the 2 neutrino decay modes is in preparation.

A scintillating fiber beam hodoscope has been designed, built, and tested and used in the EVA detector during the June-July run of AGS Experiment 850 at the Brookhaven National Laboratory. The EVA detector is designed to study color transparency in nuclei and large angle exclusive reactions for momenta between 6 and 20 GeV/c incident beam momenta. At present, the construction of all systems of the EVA detector, which consists of a large superconducting solenoid, 5500 straw tubes arranged in four cylinders, and 500 trigger scintillation counters arranged in two rings and 100 channels of beam hodoscope, has nearly been completed, and the detector is currently being calibrated and is taking data at 6 GeV/c incident beam momentum.

We have also been invited to join the NEMO international collaboration which is involved in a series of experiments to look for double beta decay in molybdenum 100. To date, Professor Sutton has attended two group meetings in Paris and has toured the experimental site in the Frejus Underground Laboratory, and he is beginning to study the problems involved in purifying molybdenum 100 as a source for the NEMO 3 detector currently being designed.

¹ M. Alston-Garnjost et al., Phys. Rev. Lett. 63, 1671 (1989)

NARRATIVE

During the last year, Professors Nicholson and Sutton have been involved in the data analysis of the molybdenum 100 double beta experiment which was carried out with experimenters from the Lawrence Berkeley Laboratory (LBL), the University of New Mexico, and the Idaho National Engineering Laboratory (INEL). At the present time one paper, which has been accepted for publication in Physical Review Letters, has been completed. In it, we have used a maximum likelihood technique to obtain a lower lifetime limit of 0.44×10^{23} years for the $0^+ \rightarrow 0^+$ neutrinoless double beta decay of molybdenum 100. This lifetime is a factor of 11 larger than our previous limit of $.4 \times 10^{22}$ years for this decay mode which was published in October, 1989 in the paper "Search for Neutrinoless Double- β Decay of ^{100}Mo ", M. Alston-Garnjost et al., Phys. Rev. Lett. 63, 1671 (1989) and is the most sensitive result in the search for the $0^+ \rightarrow 0^+$ neutrinoless double beta decay mode of molybdenum 100 to date.

We are continuing to analyze the data in the region between 2.1 and 2.7 MeV in an attempt to obtain a lifetime for the $0^+ \rightarrow 2^+$ neutrinoless double beta decay and two neutrino double beta decay modes. These decays are considerably more complicated to extract from our data since our experiment was optimized to study the $0^+ \rightarrow 0^+$ neutrinoless double beta decay and has considerably larger backgrounds in the relevant energy regions of the other double beta decay modes. Lifetime measurements or limits for these other modes will therefore be less sensitive and precise than for the $0^+ \rightarrow 0^+$ mode. Nevertheless, we expect to complete the remainder of the analysis in a few months and submit the final results to the Physical Review.

Professor Nicholson and more recently Professor Sutton have also been heavily involved in the development, construction and use of a scintillating fiber beam hodoscope and its support system for the EVA detector which has been constructed by physicists and students from Brookhaven National Laboratory, Pennsylvania State University, the University of Minnesota, the University of Massachusetts at Dartmouth, Tel Aviv University, and Mount Holyoke College to study nuclear color transparency in Alternating Gradient Synchrotron (AGS) Experiment 850 at the Brookhaven National Laboratory (BNL). Seven of the fibers were tested in the AGS beam during the early weeks of the June-July 1993 high energy physics run at BNL, and, at present, the hodoscope's vertical fibers have been instrumented and are being used in the event trigger for the experiment.

The hodoscope consists of 23 vertical fibers arranged in two planes, one with 13 fibers and one with 12 fibers, and 48 horizontal fibers arranged in two planes, each with 24 fibers. The two planes of vertical fibers are displaced relative to each other so each fiber in one plane (with the exception of the fibers on the end of the plane) overlaps half of each fiber nearest it on the adjacent plane. The planes of horizontal fibers are similarly displaced.

The BCF-10 scintillating fibers were manufactured and polished on both ends by Bicron Corporation. Each fiber has a square cross section 2 mm on a side and is 3.25 meters long so the photomultiplier tubes on one end can be placed in a low magnetic field region outside the superconducting EVA solenoid when the hodoscope is positioned just upstream of the targets close to the center of the solenoid's 1 Tesla field. Reflecting metallic tape is used at

the hodoscope end of the fibers to reflect light travelling away from the phototubes back toward the tube. This almost doubles the light reaching the phototubes. The hodoscope is designed to handle between 5×10^7 and 1×10^8 total beam particles per spill, to provide beam position resolution of approximately 350 microns, and to measure beam divergence to 1 mrad.

Tests on individual fibers in a light box conducted at Brookhaven by collaborators Steve Gushue of Brookhaven Laboratory and Nelson Christensen of the University of Minnesota demonstrated that a typical 3 meter long, 2 mm square BCF-10 Bicron fiber with one end covered with reflecting tape will produce 6-7 photoelectrons into a typical phototube at the end far from the tape when minimum ionizing electrons traverse it near the taped end. Efficiency tests carried out on seven vertical hodoscope fibers instrumented with Amperex 2212A phototubes by Professor Nicholson during the current run show that the individual fibers are between 92% and 95% efficient detecting beam particles, and that this efficiency plateaus with increasing phototube voltage. To date, no deterioration in fiber efficiency has been detected over time.

At the present time the complete downstream hodoscope has been constructed, all the phototubes are ready to be mounted to the fibers, and parts for the upstream hodoscope, which will be manufactured at Brookhaven, are in hand. Space limitations upstream of the target made it impossible to install the complete phototube array during this run, but provisions are being made so that the entire hodoscope will be operational for the 1994 spring high energy physics run at the AGS.

Along with the hodoscope development work, Professor Nicholson has been

involved in the trigger hodoscope and fast logic development as well as taking regular shifts during the June-July AGS run.

In addition to the activities mentioned above, Professor Sutton has become involved in preparations for an upgraded NEMO detector (Neutrinoless Experiments with Molybdenum), NEMO 3 which is being designed as a new generation detector for high sensitivity measurements of double beta decay, particularly in molybdenum 100. The NEMO collaboration, which has traditionally consisted of French, Russian, and Ukrainian physicists, has already build two generations of NEMO detectors to study double beta decay. These detectors were operated in the Frejus Underground Laboratory located under the Alps in a tunnel which connects southern France to Italy. They have consisted of a central frame to hold the source foil surrounded by Geiger cells for tracking and scintillator walls to provide energy and time-of-flight measurements. NEMO 2 has successfully demonstrated that it is capable of acquiring a two neutrino double beta decay spectrum with no events near the endpoint energy. The proposed NEMO 3 will be a similar detector with a cylindrical geometry which will study 10 kilograms of material, 10 times the amount in NEMO 2.

In the Lawrence Berkeley Laboratory, Mount Holyoke College, University of New Mexico, Idaho Engineering Laboratory collaboration experiment which has just been completed levels of radioactive impurities associated with the decay chains of uranium 238 and thorium 232 which were too low to measure were achieved by chemical purification means developed by John Baker of INEL. Professor Sutton is beginning to investigate scaling up this purification process to remove uranium and thorium from kilogram the quantities of

molybdenum 100 available from Russia using the INEL technique and to develop ways of evaluating the material after purification for the NEMO 3 collaboration.

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