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NUCLEAR TRANSPARENCY AND DOUBLE BETA DECAY OF MOLYBDENUM 100

Annual Progress Report
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ABSTRACT

For the past two years work has been underway on a Physical Review paper with the final results of a search for neutrinoless double- β decay of molybdenum 100 with collaborators from the Lawrence Berkeley Laboratory, the University of New Mexico, and the Idaho Engineering Laboratory. This paper has been held up because of difficulties in obtaining a rigorous final statistical analysis of the data. We have recently worked out an extension of the statistical procedures discussed in the Particle Data Group's (PDG) 1994 Review of Particle Properties ¹, which correctly reduces to the examples described in PDG. With this new procedure in hand, we expect to complete the Physical Review paper and we are considering publishing another short paper on the extended statistical analysis before the end of the 1995 calendar year.

Professor Nicholson, who is currently on sabbatical during the 1995-96 academic year, now has the principal responsibility for overseeing the rebuilding of the EVA superconducting magnet whose cryostat failed catastrophically during the January to June High Energy Physics run at Brookhaven National Laboratory. In addition he is constructing a fast readout and display circuit for the beam hodoscope in the EVA detector and is peripherally involved in straw tube improvements. Professor Nicholson is also a collaborator on the SLAC B Factory experiment working on the packaging and readout of the thallium doped cesium iodide (CsI(Tl)) crystals for the calorimeter. He will take part in the beam test of a CsI(Tl) module at PSI in Zurich in September and October, 1995.

Professor Sutton continues to spend the majority of his research time working on the international NEMO 3 double beta decay experiment involving molybdenum 100 and other isotopes. His principal responsibility to date has been to characterize the purification process which was used in the Lawrence Berkeley Laboratory, Mount Holyoke, University of New Mexico, Idaho National Engineering Laboratory molybdenum 100 double beta decay experiment and compare it to various processes which have been developed at ITEP in Russia. He has also begun to work on the wire detector development with collaborators from Orsay and has initiated a search in the United States for a postdoctoral fellowship for NEMO.

¹Phys. Rev. D, 50 1173 (1994)

NARRATIVE

During the past year, Professor Nicholson has continued to work with Dr. Margaret Garnjost, Dr. Robert Kenney and Dr. Robert Tripp, former collaborators from Lawrence Berkeley Laboratory (LBL), to develop a statistical analysis procedure for extracting confidence limits in experiments in which the data sample, contaminated with background, is small but the shape of the signal and background distributions are known throughout the region of interest. Dr. Garnjost has recently developed a procedure which is applicable to our experiment and which reduces to well established methods described by the Particle Data Group as special cases. Professor Nicholson and Dr. Garnjost are now comparing the results of Monte Carlo and interpolation procedures developed primarily by Professor Nicholson to the results of the new procedure to check that it gives reasonable answers to our experimental data. With this procedure finally in hand, we expect to complete a final Physical Review article on the Lawrence Berkeley Laboratory, Mount Holyoke, University of New Mexico, Idaho National Engineering Laboratory (INEL) molybdenum 100 double- β decay experiment in the coming months.

Both Professor Nicholson and Professor Sutton have continued to collaborate on Brookhaven Laboratory's AGS Experiment #850 to study color transparency over an incident particle momentum range from 6-20 GeV/c taking shifts during the January to June running period and working on maintaining and improving various detector systems on the EVA detector. However, during this last run, many problems developed with the EVA detector's superconducting solenoid whose vacuum system finally failed in a catastrophic way in April and effectively ended the data run. Professor Nicholson, who has been peripherally involved with magnet problems throughout the history of the EVA detector, recently agreed to take on, with Dr. Barton of Brookhaven, the responsibility of overseeing the repair and redesign of this magnet.

Since the middle of June, a group of cryogenics engineers, mechanical engineers and physicists have been meeting every two weeks at Brookhaven Laboratory to identify problems with the previous magnet design and correct them. The principal problems that have been identified are related to the support system of the coil, which has allowed it to shift relative to the cryostat, a very constricted lead pot area which has resulted in several heat

leaks, a poorly designed liquid nitrogen heat shield, and a mechanical restraint system failed to provide adequate support for the coil against 32 ton magnetic forces pushing it upstream when energized. At the present time, the magnet has been completely disassembled and new mechanical and cryogenic designs have been developed. We expect to begin the actual repair and redesign work after a final technical review at the end of August.

Work is also underway at Brookhaven Laboratory and at various collaborating institutions to develop ways of improving the overall efficiency of the EVA detector straw tube arrays. Professor Nicholson has carried out a calculation on the electrostatic forces which off-center signal wires experience when the tubes are not straight which reduces to the approximate expression given by Oh et al.² and has been trying to develop a system to mechanically fasten the signal wire near the center of the straw tube to a pin which can be inserted from the side of the tubes. Professor Sutton has also begun to look at various aspects of wire detectors, both from the standpoint of NEMO 3 wire detector design and development and the EVA straw tubes.

Along with work on the statistical analysis of the double- β decay paper and the Brookhaven color transparency experiment, Professor Nicholson has been doing research and development work on the cesium iodide CsI(Tl) calorimeter as part of the Stanford B-Factory collaboration and as part of a local collaboration between Dr. Richard Kofler and co-workers at the University of Massachusetts at Amherst. One aspect of this work has been to try to characterize the light output of various photodiodes being considered for the CsI(Tl) readout both in terms of direct readout and readout from waveshifter plates.³ One of Professor Nicholson's suggestions, based on a prototype he built and tested at Mount Holyoke, which is being actively researched by the calorimeter group at present is to stabilize the surface characteristics on the readout end of the CsI(Tl) by fastening to it a 2 mm thick lead glass plate with the same index of refraction as the CsI(Tl) crystal itself using optical epoxy. This provides a smooth and stable surface for mounting either waveshifter plates or photodiodes.

Professor Nicholson is one of a small group of physicists (6-8) from the United States who will be participating in the beam test of a prototype set of

²S.H. Oh et al. Nucl. Inst. Meth. A309 368 (1991)

³C. Jessop et al., Development of the front end readout for the BaBar CsI(Tl) calorimeter, BaBar Note 216, February 15, 1995

CsI(Tl) crystals in Zurich, Switzerland at PSI in October, 1995. Data from this test will be essential in finalizing a number of design parameters for the final calorimeter for the B-Factory.

Professor Sutton has spent the majority of his research time working on the NEMO 3 project. To date his main responsibility has been to determine whether existing procedures, which have been used to purify molybdenum from radioactive contaminants, can reach the level of purification required for the NEMO 3 detector to reach its design sensitivity for double- β decay.

Professor Sutton has organized the following program to carry out this work. Two Mount Holyoke students were hired during the summer of 1994 to purify samples of natural molybdenum at INEL under the supervision of INEL radiochemist Dr. John Baker. Uranium, thorium, and radium contamination was then measured in unpurified and purified samples at the low level counting facilities at the Lawrence Berkeley Laboratory and the underground laboratory of Modane, France. These measurements were used first to test the consistency of measurements between sites and then to determine the effective reduction in radioactive contamination. In addition, samples of the same natural molybdenum were purified by a radiochemist in France and measured in Modane.

The results of this study were presented at the second molybdenum purification meeting organized by Professor Sutton at Mount Holyoke College in January, 1995. This meeting was attended by radiochemists from the U.S. and France, the person responsible for the low level counting measurements in Modane, Russian and French spokespersons for the NEMO collaboration and Professors Sutton and Nicholson. It was concluded at this meeting that the French radiochemist needed to work in a clean room with very pure chemicals and that the INEL process was very good at removing uranium and thorium but less good at removing radium. Introducing barium into the INEL process should improve the radium removal, and a second pair of Mount Holyoke students have been hired and are currently purifying another molybdenum sample at INEL using the modified procedure.

Professor Sutton has also travelled to France to work on papers related to ongoing work in NEMO 2 and NEMO 3 and to present the conclusions of the molybdenum purification meeting to the semi-annual NEMO collaboration meeting in Arcachon, France. He has recently begun to work with D. Lalanne on the NEMO-3 open Geiger cells with 30 rather than 100 micron cathode wires, particularly with respect to performance and aging characteristics.

Recent papers of the NEMO collaboration include D. Dassié et *al.*, Nucl. Inst. Meth. **A354** 338 (1995), D. Dassié et *al.*, Phys. Rev. D **51** 2090, and R. Arnold et *al.*, JETP Lett. **61** 170 (1995).