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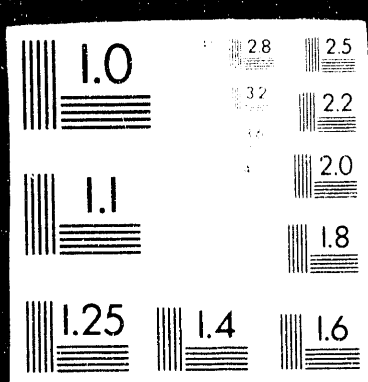

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DEPARTMENT OF PHYSICS AND ASTRONOMY

Valparaiso University

Valparaiso, Indiana 46383

High Sensitivity Tests of the Standard Model for Electroweak Interactions

SCIENTIFIC PROGRESS REPORT

for the period

16 January 1992 to 15 January 1993

DOE GRANT NUMBER: DE-FG02-88ER40416

A. Introduction

This report describes the work done by the Professor, Dr. Donald D. Koetke, PI, by Associate Professor of Physics, Dr. Robert W. Manweiler, and by Assistant Professor of Physics T.D. Shirvel Stanislaus, all of whom are on the physics faculty at Valparaiso University. In addition, the project benefited from the work of Technical Assistant Paul Nord, and Valparaiso University student Jay Dittmann.#

The work done on this project was focussed on two LAMPF experiments. The MEGA experiment,[1] a high sensitivity search for the lepton family number violating decay $\mu \to e \gamma$ to a sensitivity which, measured in terms of the branching ratio,

$$BR = [\mu \to e \gamma]/[\mu \to e \nu_\mu \nu_e] \sim 10^{-13}$$

is over two orders of magnitude better than previously reported values.[2] The second is a precision measurement of the Michel ρ parameter from the positron energy spectrum of $\mu \to e \nu_\mu \nu_e$ to test the V-A theory of weak interactions.[3] In this experiment we expect the uncertainty in the measurement of the Michel ρ parameter to be a factor of three lower than the present reported value.[4] This work was divided between that done at Valparaiso University and that done at LAMPF.

B. The MEGA Experiment

The past twelve months have been especially productive and rewarding for the MEGA experiment. In the search for the $\mu \to e \gamma$ decay, the muon is brought to rest in a passive target where it decays. The standard two neutrino $\mu \to e \nu_\mu \nu_e$ decays produce a background of positrons and no photons from the decay. Photons from the inner bremsstrahlung decay $\mu \to e \nu_\mu \nu_e \gamma$ or from positron annihilation in the apparatus constitute the background. However the rate of high energy photon (~52.8 MeV) production per muon decay is low and therefore, since the instantaneous muon decay rate is 500 MHz (30 MHz average) the detection of a high energy photon in the magnetic pair spectrometer constitutes the trigger. Searches are then made in eight, low-mass, cylindrical MWPC's for possible ~52.8 MeV positrons whose momentum at the muon decay vertex is opposite to the photon momentum.

Prior to, and during the 1992 running period at LAMPF, numerous milestones were achieved.

- The construction of all eight MWPC's for the positron detector was completed.
- All eight MWPC's were successfully conditioned, tested at high rates, and transferred to the large cylindrical "shell" which supports the wire tension in the MWPC's.
- Two of the three final concentric cylindrical layers of the photon pair spectrometer were installed in the superconducting solenoidal magnet, all electronics attached and tested. It is important to note that major modifications in these detectors were tested in this run for the first time and the performance of the entire pair spectrometer was found to be good.
- All eight MWPC's were transferred to the superconducting solenoidal magnet. All electronics were connected and tested. Extensive efforts were made to defeat the electronic noise and the electronic oscillations which occur in experimental situations with high density electronics and long cables for data communications.
- All FASTBUS elements required for detector readout were in place and tested.
- A MEGA designed trigger system using PAL chips for fast trigger decisions in firmware was installed.
- The completely re-designed trigger/gate routing box was installed and tested.
- The testing of the software used for on-line analysis of successful hardware triggers was sufficient to permit the transfer these codes to the workstation (DEC 5200) platforms on which the on-line analyses were done.
- The testing of software installed in the workstations was conducted with actual events and compared with analyses done with identical codes running in the VMS environment.
- Data were collected with cosmic rays for precision inter-detector and intra-detector alignment. Alignment codes were developed and tested.
- Data were collected with the LAMPF beam for detailed detector calibration.

- Data were collected at higher rates to test detector performance and to test the software which is designed to be applied to high rate data.
- Initial analyses of these data have begun and are continuing.

This was the first time any of these were done with the entire system in place. Several of these steps, especially software implementation in the workstations with real data, had not been done before.

In summary, the performance of each element in the entire system was remarkably good. We now have sufficient data on tape to permit two students to conclude theses on the $\mu \rightarrow e\gamma$ search. These data will permit us to do a sufficiently complete analysis to certify the detector performance, test the reliability of our codes when applied to real data, make detailed comparisons with the experiment Monte Carlo, and conduct further studies of the on-line processing speed. We are aware of improvements we intend to make in several of these areas and we expect others to become evident from our analysis. However, we are confident at this time that there are no serious stumbling blocks which would prevent us from achieving the proposed branching ratio limit.

Since 1986, Valparaiso University has made major contributions to the software development and testing for the experiment. We have also made contributions to detector design and to construction and testing. In this past year, members of our group were central to the successful construction and testing of the positron detector MWPC's, to their installation and *in situ* testing. We provided all of the R & D and the fabrication of the muon stopping targets for the various target configurations required for calibrations and data taking. We developed the monitoring and controlling program to interface with the LeCroy 1440 HV system, did all the testing and certification, and the installation. We have written, tested, and implemented the major software pieces for the positron detector analyses. We were at LAMPF during the running periods to assist in detector implementation, software testing and certification, and data analysis. Our internet connection at Valparaiso University permitted continued software work and data analysis from Valparaiso as these data were being collected.

C. Measurement of the Michel ρ Parameter

It has been noted that this experiment, done with the same detector as the MEGA experiment, by the same collaboration, and in the same beam line at LAMPF, and is therefore an efficient and cost effective means of making a precision measurement of the Michel ρ parameter. With only minor modifications in the beam tuning and the use of a suitable target, we were able to collect data which will permit us to determine the Michel ρ parameter to a precision which is expected to be ~3 times better than the present reported value. Event rates are sufficiently high that collecting sufficient statistical precision is not a limitation for this measurement. The experiment focuses on the need to understand the contributions to the measurement which come from systematic sources such as asymmetries in the positron detector (variable detector efficiencies, target location, etc.), non-uniformities in the magnetic field of the superconducting solenoid, bias in the energy spectrum due to event selection, and the like. We believe that we have collected sufficient data under varied running conditions to understand the effects of the different sources of systematic errors, to compare the data in detail with the Monte Carlo, and to extract a good measurement. One student will conclude a thesis with the analysis of these data.

Moreover, the analysis of these data have already allowed us to sharpen our understanding of our detector performance, and along with comparisons with the Monte Carlo we expect the Michel ρ measurement to provide useful information for the MEGA experiment.

D. Measurement of the Cross Section for $\nu_\mu\ ^{14}C \rightarrow \mu^- X$

The cross section measurement for this neutrino charged-current inclusive channel and the corresponding exclusive channel $\nu_\mu\ ^{14}C \rightarrow \mu^-\ ^{14}N$ was accepted for publication in Physical Review C. This is the conclusion of the work done by the E764 collaboration at LAMPF of which the Valparaiso group was a member and one of us (DDK) was the principal author of the paper. These measurements are not only of intrinsic interest, but are of special interest for those who seek to analyze data of probable ν_μ interactions in large underground, water-filled detectors where the ν_μ source is most likely cosmic. In Figures 1 and 2, we display several results of these measurements along with extended explanatory comments.[5] Valparaiso University is also a member of the LSND collaboration in which experiment we will repeat this measurement but with much better statistics.[6]

Present address: Duke University Department of Physics

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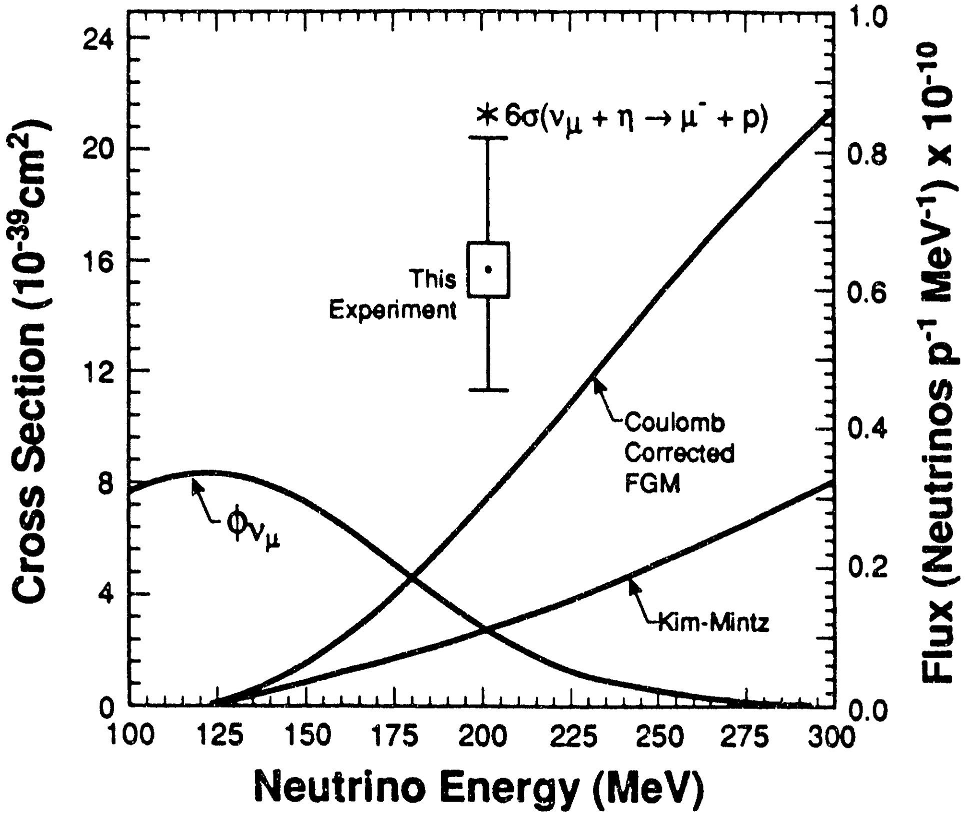
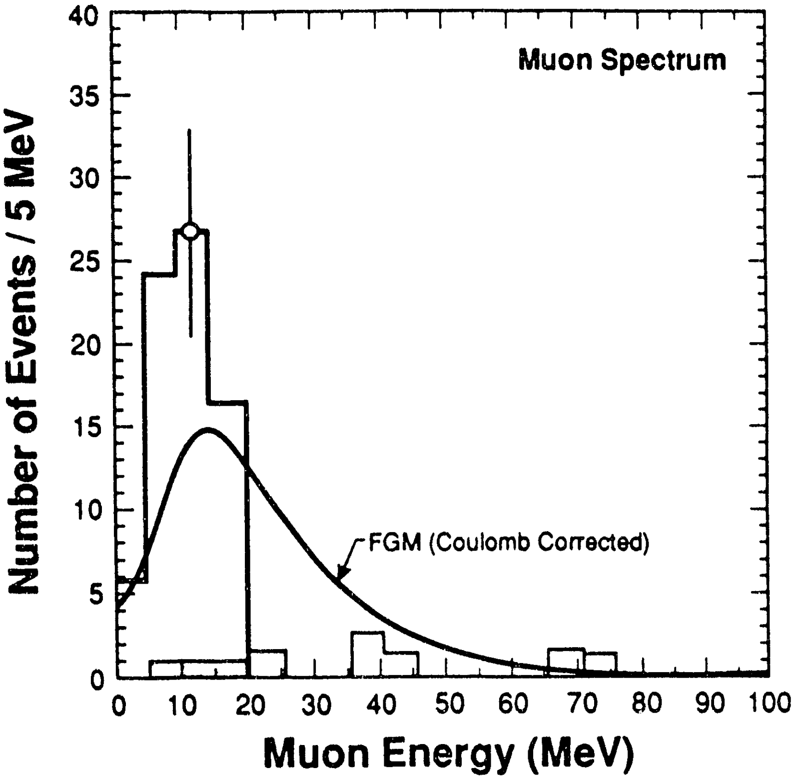
1. M. Cooper, et al., LAMPF Proposal No. 969 (1985).
2. R. D. Bolton, et al., *Phys. Rev. Lett.*, **56**, 2461 (1986).
3. M. Cooper, et al., LAMPF Experiment No. 1240 (1991).
4. Particle Data Group, *Phys. Lett. B* **239** (1990).
5. These figures, captions, and comments will appear in the Phys. Rev. C publication.
6. W. C. Louis, et al., LAMPF Experiment No. 1173 (1990).

FIGURES



1. Our measured inclusive ν_μ ^{14}C section result is given by the data point. Folding the Fermi Gas Model (FGM) cross section with our neutrino flux spectrum we calculate a mean neutrino interaction energy of 202 MeV for our flux-weighted cross section measurement. Theoretical predictions for the cross section are given for the Coulomb-corrected FGM, and for the calculation of Kim and Mintz. The free nucleon cross section, $n(\nu_\mu,\mu^-)p$, is shown for comparison as the single point.



2. The histogram of our measured spectrum of muon energies, with random backgrounds subtracted. The curve was generated from the FGM and was normalized to the total number of measured events in the inclusive reaction channel. Events with ^{12}N beta decay are shown as shaded. The data in the first two bins have been corrected to take into account the losses due to the energy thresholds. It is observed that the theoretical cross section does not go to zero as the muon energy goes to zero when the correction for final state coulomb interaction is included. These data show a marked depletion of events at higher muon energies and an evident increase in the spectrum at low muon energies compared to the FGM prediction. Since the FGM reflects the average behavior of the interaction, and does not contain mechanisms for the transfer of energy to the specific nuclear degrees of freedom, it is not expected to account in detail for the relative strengths of highly-excited nuclear states. Consequently, perhaps it is not surprising that significant differences between the FGM and this measured muon kinetic energy distribution exist.

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