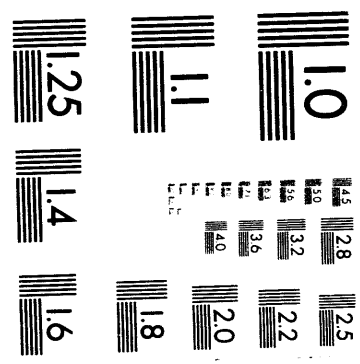
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DOE/ER/40416--6

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 1993 to 15 January 1994

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.

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 $\mu \rightarrow e\,\gamma$ to a sensitivity which, measured in terms of the branching ratio,

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

which will be 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 $\mu \rightarrow e\,\nu_\mu\,\nu_e$ to test the predictions 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

During past twelve months we have focussed on the analysis of data taken in 1992 and on preparations, repairs, and improvements which have now brought us to data collection for the MEGA experiment at LAMPF in 1993. In the search for the $\mu \rightarrow e\,\gamma$ decay, the muon is brought to rest in a passive target where it decays. The standard two neutrino $\mu \rightarrow e\,\nu_\mu\,\nu_e$ decays produce a background of positrons and no photons from the decay. Photons from the inner bremsstrahlung decay $\mu \rightarrow e\,\nu_\mu\,\nu_e\,\gamma$ or from positron annihilation in the apparatus constitute the photon 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 present 1993 running period at LAMPF, numerous milestones were achieved.

- The construction of all eight MWPC's for the positron detector was completed.
- These 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.
- 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. These efforts were largely successful prior to the 1993 running period.
- The last of the three concentric cylindrical layers of the photon pair spectrometer was installed in the superconducting solenoidal magnet, all electronics attached and tested. It is important to note that major modifications to the detector preamplifier electronics were made and found to be satisfactory.
- 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. (See Fig. 1 which gives an

indication of the alignment and resolution before the precision alignment corrections were applied. The corrections in nearly all cases were very small indicating that the visual alignments were done carefully and correctly.)

- Data were collected with the LAMPF beam for detailed detector calibration. (See Fig. 2 showing the measured efficiency of one of the small positron MWPCs using cosmic rays.)
- 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.
- The analysis of the data taken in 1992 is in process. These data were found to be non-ideal due primarily to electronics noise problems in the MWPC's in the positron detector. (As noted above, these problems were corrected prior to the 1993 LAMPF run.)

In summary, the detector is fully operational and we are taking data for a measurement of the $\mu \rightarrow e\gamma$ branching ratio. Shown in Fig. 3 is an on-line reconstruction of a $\mu \rightarrow e\gamma$ event candidate. The event is triggered by the e^+e^- pair in the pair spectrometer which satisfies the minimum energy criteria for a 52.8 MeV photon. The positron orbit is calculated from the on-line reconstructed position of the photon $\rightarrow e^+e^-$ pair conversion (r_γ, t_γ) and the termination of the positron orbit in a scintillator (r_e, t_e). The wire hits in the positron MWPCs must fall in the marked "windows" (slashes in the figure) along the calculated helical orbit for the event to pass the on-line filter. Later analysis of this event with off-line programs wi'l determine whether it remains in the sample of $\mu \rightarrow e\gamma$ candidates. The on-line cuts were tuned on Monte Carlo studies and are intentionally made rather loose to avoid dispatching potentially good candidates with the accidental background. We know the fraction of background events which will pass the on-line filter from these Monte Carlo studies. It is observed that the calculated (reconstructed) decay point lies within the target and that the photon momentum is approximately 180° opposite to that of the positron.

The data collected in this 1993 running period will form the basis for several Ph.D. theses. We estimate that these data should allow us to improve the present BR limit by approximately one order of magnitude. Additional data will be required to approach the design limit for the experiment.

Since 1987, Valparaiso University has made major contributions to the software development and testing for the experiment. We have also made significant and innovative contributions to detector design and to construction and 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 1445 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

This experiment, done with the same detector as the MEGA experiment, by the same collaboration, and in the same beam line at LAMPF, is an efficient and cost effective means of making a precise 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 in both the 1992 and the 1993 LAMPF running periods 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. Having collected $\sim 4 \times 10^6$ Michel triggers, this measurement will not be statistics limited. 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, based on the analysis of the 1992 data, our choice of various operating conditions were sufficient to allow us to understand the effect of the different systematic errors on the data. In parallel, modifications are made in the Monte Carlo to reflect the actual detector performance and these changes are likewise useful for the MEGA experiment since we share the Monte Carlo event generator. A Ph.D. thesis student from Texas A&M should complete the analyses of these data with help on ancillary measurements from others in the collaboration including Valparaiso University.

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.

REFERENCES

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).

FIGURES

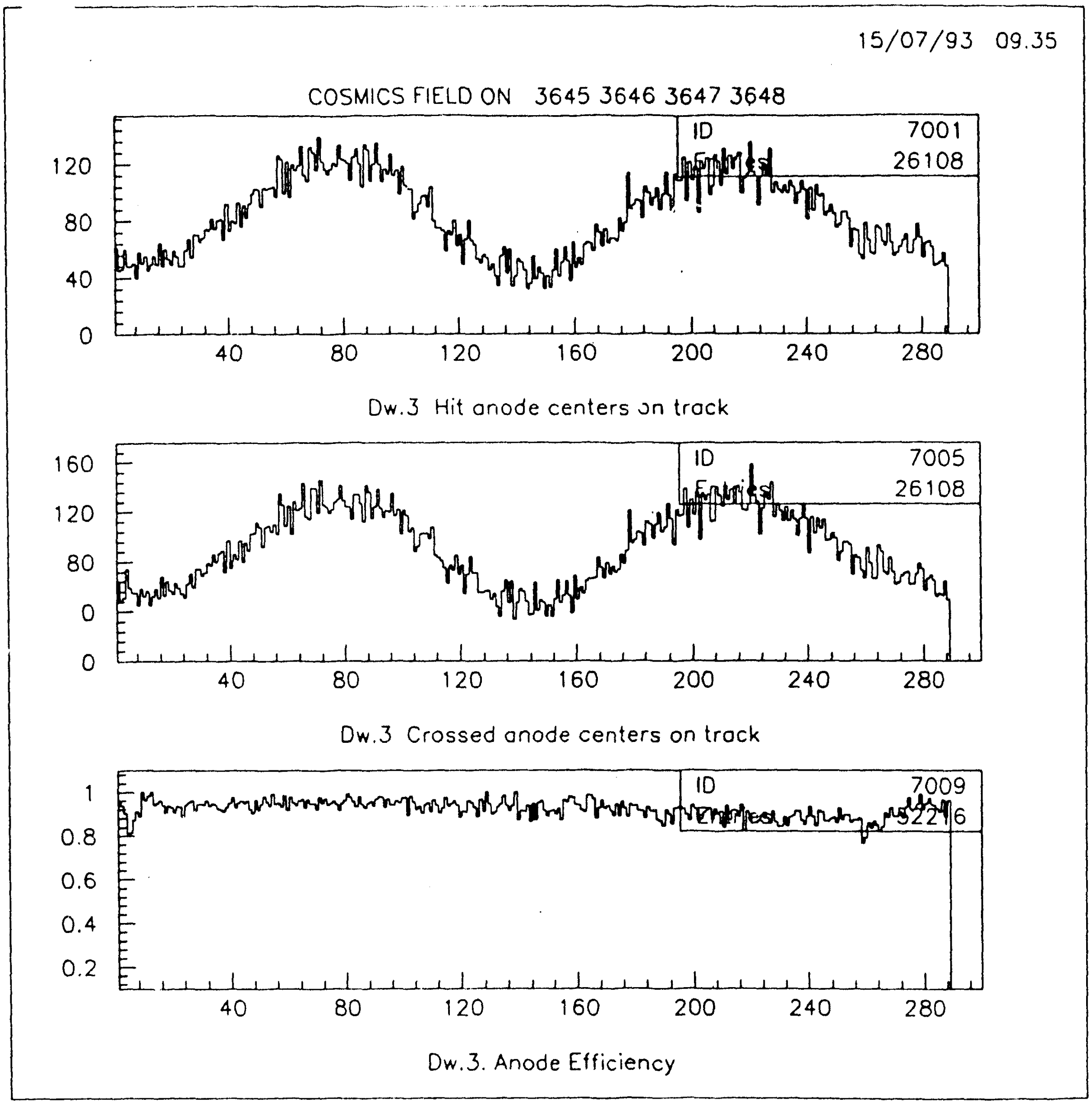

Figure 1. The figure illustrates our measurements of individual wire efficiencies for the positron MWPCs shown here for one chamber. The central figure is the histogram of the wire number crossed by the track. The top figure is the distribution of hit wires; an entry is made here if a hit wire appears sufficiently close to the track (see resolutions in Fig. 2). The bottom figure shows the ratio of the (top histogram)/(central histogram). Such individual wire efficiencies are measured for all detector elements.

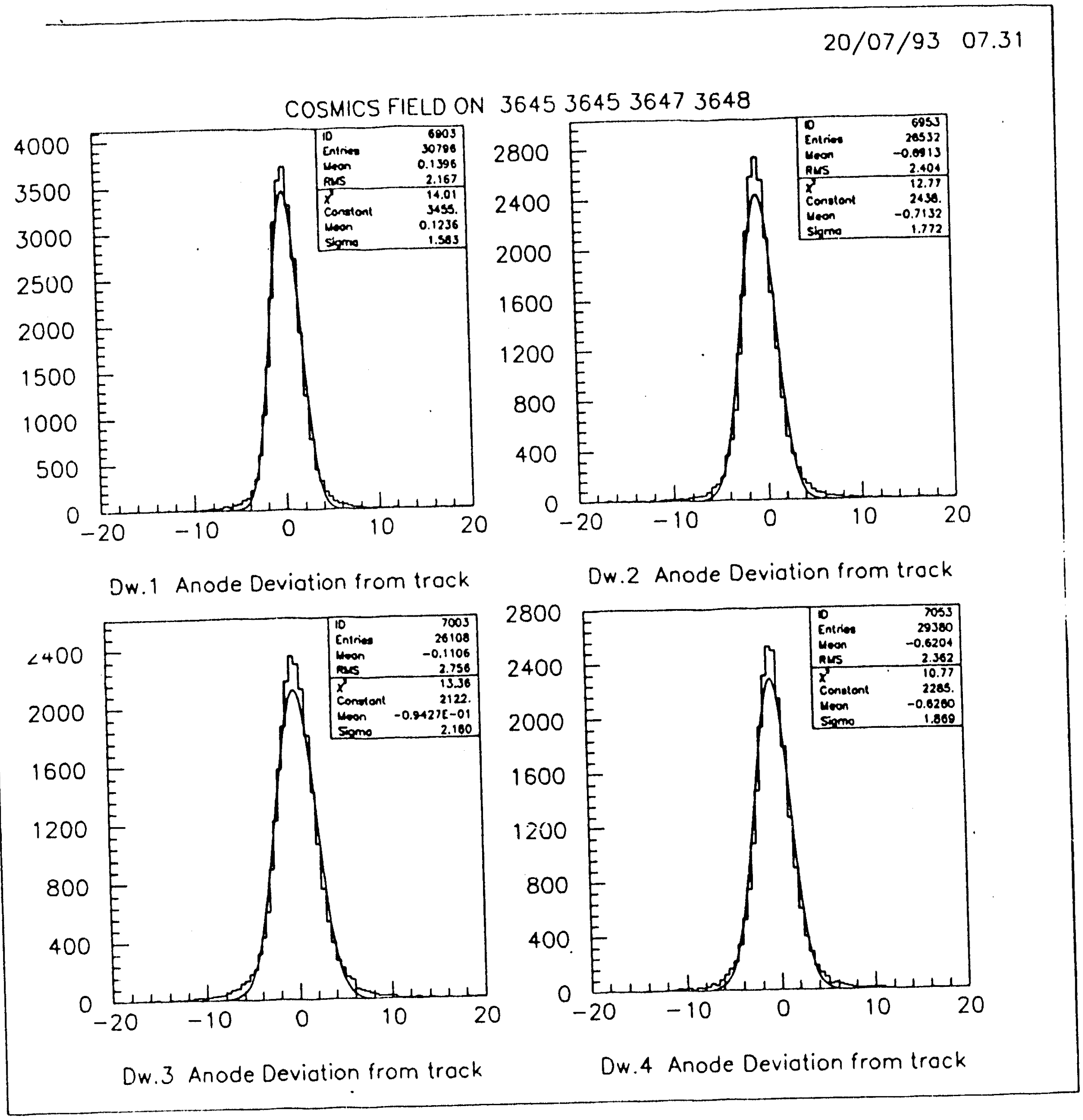

Figure 2. Shown here are the residuals of the hit anodes in several of the positron MWPCs from circular tracks associated with cosmic rays. The 15 kG solenoidal field was on. The track trajectory was determined entirely by the hits in the photon detector (pair spectrometer) MWPCs and drift chambers. The units along the abscissa are in wire numbers where the distance between anode wires is 1.3 mm. These were obtained for all anode and cathode elements in the detectors.

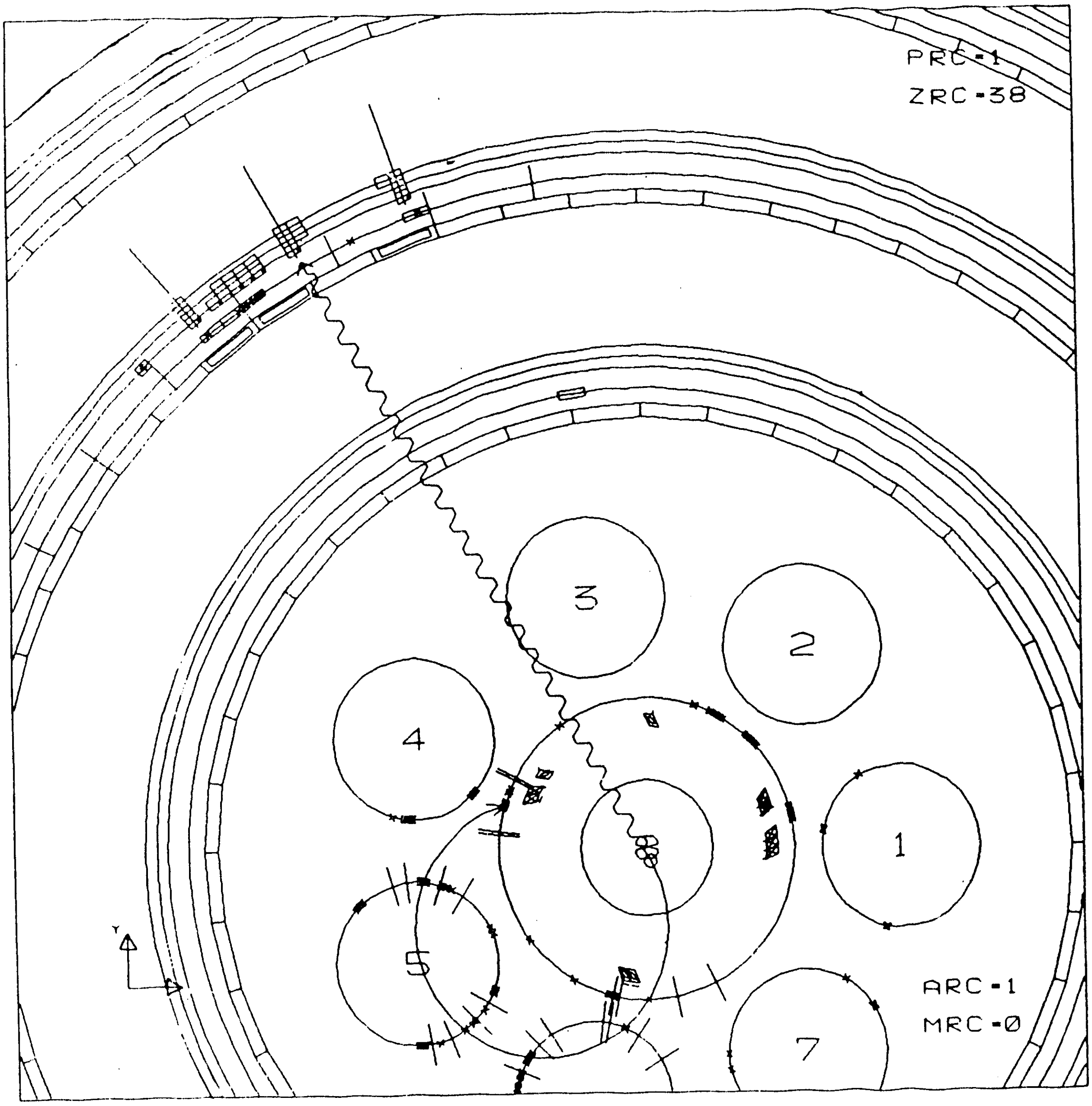

Figure 3. A reconstructed $\mu \rightarrow e\,\gamma$ event candidate from our on-line analysis programs. The wiggle line indicates the path of the candidate photon from the muon decay point in the target to its conversion point in the photon detector. The circle marks the axial view of the calculated helical orbit (looking along the solenoidal magnetic field). The slashes mark "windows" within which MWPC hits (shown as x) must be found for the event to pass our on-line analysis programs.

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