DOE/ER/40416--4

DE92 007537

DEPARTMENT OF PHYSICS AND ASTRONOMY
Valparaiso University
Valparaiso, Indiana 46363

High Sensitivity Tests of the Standard Model for Electroweak Interactions

SCIENTIFIC PROGRESS REPORT

for the period

16 January 1991 to 15 January 1992

DOE GRANT NUMBER: DE-FG02-88ER40416

A. Introduction

This report describes the work done by the Professor, Dr. Donald D. Koetke, PI, Assistant Professor of Physics, by Dr. Randall J. Fisk, Assistant Professor of Physics, and by Associate Professor of Physics, Dr. Robert W. Manweiler, all of whom were on the physics faculty at Valparaiso University. Effective 31 May 1991, Dr. Fisk terminated his service at Valparaiso University and hence also his work on this project. This report will also note work done by several Valparaiso University students and by a technical support person, all of whom were supported by this grant.

The work done on this project was focussed mainly on LAMPF experiment E969 known as 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 work done on MEGA during this period was divided between that done at Valparaiso University and that done at LAMPF. In addition, some contributions were made to a proposal to the LAMPF PAC to perform a precision measurement of the Michel ρ parameter, described below.

B. The MEGA Experiment

Contributions to the MEGA experiment by the Valparaiso University group centered on software development, testing and data analysis. Additional contributions were made to the development, fabrication, testing and conditioning of the positron arm MWPC's.

Data were taken in 1990 in the LAMPF stopped muon channel with the MEGA detector configured with three of the final eight MWPC's in the positron detector and one of the four layers of the photon detector. All components were placed in the large superconducting solenoidal magnet. Data were collected in several broad categories.

(a) Events with one positron track in the positron arm from one muon decay. These data were used to study the detector performance and to test the reliability of the Monte Carlo simulation of the positron arm of the detector. In addition, these data were used to determine the relative alignment of the detector components. An algorithm was developed by the Valparaiso University group to reconstruct positron helical orbits from hits in the MWPC's. This algorithm was tested extensively with Monte Carlo generated events prior to application to the data collected. It was discovered that the algorithm is remarkably sensitive to the relative orientation and position of the MWPC components within a given MWPC and between MWPC's. Specifically, rotation of the anode wires by 1 wire (1 *mm*) and a rotation of the cathode plane of stripes by less than one stripe (< 3 *mm*) was clearly detected by improved orbit reconstruction. A systematic process was developed whereby the detector components were allowed to move in the analysis of several data sets and showed that the entire system could be aligned to high precision in this process. This helical track alignment process was found to be complimentary to the process of alignment using tracks from single muon decays taken with the magnetic field off yielding straight tracks in the detector system. Along with straight line cosmic ray tracks, these straight tracks were advantageous for studying the relative alignment of the positron arm and the photon arm components, a process not possible with tracks from muon decays with the magnetic field on since the positron orbits never intersect the photon detector components. We believe that we have a reliable and efficient method of detector component precision alignment which has been tested with these data.

These data were also used to test the Monte Carlo simulation of the detector performance by comparing the distribution of reconstructed energies for these Michel positrons as obtained from the 1990 data with that obtained with Monte Carlo simulated events. The data were taken with only two working MWPC's. Furthermore, due to an unfortunate choice of trigger scintillator alignment, the orbits available for reconstruction and analysis were least amenable to precise reconstruction. Nonetheless, when these same conditions were put into the Monte Carlo, and the same orbit reconstruction algorithm was applied to these Monte Carlo generated events, the agreement between the Monte Carlo and the 1990 data was extremely encouraging. Essentially no disagreement between the Monte Carlo and the data was discerned. (See Fig. 1 attached.) This agreement is of course of significant importance since we rely on the Monte Carlo to properly simulate Michel decays ($\mu \rightarrow e\, \nu_\mu\, \nu_e$) not only at the low rate (one track per trigger) but also at the high rate (500 MHz instantaneous) in which we will run when collecting data for the $\mu \rightarrow e\, \gamma$ search. Under these high rate conditions, we expect our analysis codes to properly reject those events for which a photon triggers is not associated with a genuine $\mu \rightarrow e\, \gamma$ signal event while simultaneously finding the $\mu \rightarrow e\, \gamma$ events when enmeshed in the high rate of Michel decays in the positron MWPC's.

(b) The second major class of data collected was used to perform a crude $\mu \rightarrow e\, \gamma$ search. These data corresponded to a photon trigger in the photon arm of the spectrometer with multiple tracks in the positron arm MWPC's. The minimal configuration of both arms of the spectrometer create severe limitations on the ability to do a precision search. The principal goal of this exercise was to test the fully integrated system including the detector components, the data acquisition FASTBUS, the CERN Host Interface which collects the data buffered in FASTBUS into a large data buffer for a given LAMPF macropulse, and the on-line computing environment. The 1990 data were taken with the original ACP microprocessors as the on-line computing resource. (This has now been replaced by a network of DECstations [RISC 5000/200] each of which has a processing power of 18.7 VAX 11/780's.) Overall, the system preformed well enough for the data collection and for us to diagnose problems, outline improvements, and test out both software and hardware. The analysis of these $\mu \rightarrow e\, \gamma$ data is process and will be completed soon. It is not expected that these data will approach the present published limit.

During this period, one of us (RWM) spent 14 months at LAMPF working on MEGA. Much effort was made in improving the fabrication techniques for the cylindrical (nearly massless) MWPC's for the positron arm. The tolerances required to make these chambers operate reliably in the high rate environment make this process very challenging. Further laboratory studies were made on techniques to condition the chambers for optimum performance. The transfer of the chambers from the fabrication environment to the detector housing in the magnet in the stopped muon channel at LAMPF was likewise further refined. Four newly constructed MWPC's were conditioned, tested, and placed in the magnet for the planned summer run.

Regrettably, the plans to collect $\mu \rightarrow e \gamma$ data during the summer 1991 were thwarted by an accident in the MWPC gas system which rendered the four chambers inoperable. The accident set back the MWPC fabrication by approximately 3 months and raised serious concerns for the present design of the complicated gas system for the eight MWPC's in the positron arm. The gas system is under review and will require a redesign of at least a portion of the control and feedback system. Improved monitoring will likely also result. These matters are presently underway. In addition, three new MWPC's have been fabricated using modified and improved techniques. The present plan is to complete five of the eight MWPC's by the conclusion of this period (15 January 1992) with the remaining three being completed by February 1992.

We are approved for a major data collection run for the $\mu \rightarrow e \gamma$ search in 1992. Accordingly, we are porting our software to the DECstation environment both at LAMPF and at Valparaiso University. Contributions by Valparaiso University students in this process have been especially valuable.

In parallel with these efforts, software development at Valparaiso University which focused on analysis of tracks in the positron arm of the spectrometer showed distinct improvement. As seen in Table I (attached) both the on-line filter programs and the off-line analysis codes have been extensively developed and tested with Monte Carlo simulated events. The off-line programs begin with those events which pass through the efficient on-line programs which will run in the DECstation environment and are written to tape. It is clearly seen that the off-line analysis is able to reduce the background by an additional factor of 10 while retaining an 87% efficiency for finding true $\mu \rightarrow e \gamma$ events if they are present. The average CPU time per event for the off-line analysis is much longer than the corresponding on-line filter code since the algorithms used in the off-line analysis require combinatorial studies of the hit patterns in selected regions of the MWPC's. However, we can manage these times in the workstations. In addition, the off-line analysis has achieved the expected resolutions in the positron energy and in the direction of the positron at the decay point as it was noted in the experiment proposal. Further work on these programs is aimed at improved background rejection.

The muon stopping target used by MEGA is an inclined planar ellipse located on the axis and at the center of the cylindrically symmetric spectrometer. It is to be sufficiently thick to stop the low energy muons and thin enough to provide minimal multiple scattering and energy loss for the positrons from the muon decay. The present target, developed and constructed at Valparaiso University is made of 0.003 *inch* mylar. It is held in space by attaching it to a cylindrical bag of 0.00025 *inch* mylar using a photo-reactive cement. The target and the bag are kept in their respective planar and cylindrical shapes with differential gas pressures. The surface of the target is measured flat to 1 *mm* and the position of the target is measured to less than 1 *mm* in space. These spatial qualities of the target are important for the $\mu \rightarrow e\gamma$ search since we must reconstruct the muon decay point in the target and use this to determine the positron vector momentum at that point. We believe that we have the target fabrication, installation, and positioning techniques developed and ready for the final target fabrication and installation.

C. Measurement of the Michel ρ Parameter

During this period, a small group from the collaboration worked to prepare a experiment proposal to measure the Michel ρ parameter. This proposal was presented to the LAMPF PAC in August, 1991 . In the MEGA experiment, the lepton family number conserving muon decay mode $\mu \rightarrow e\nu_{\mu}\nu_{e}$ constitutes the background in which we search for the lepton family number violating decay $\mu \rightarrow e\gamma$. The energy spectrum of positrons from the muon decays at rest is well described by the Michel formula which is obtained from the V-A matrix element for the weak decay. Of the five parameters in this formula, the value for each of which is predicted in the calculation, the parameter ρ is most important for the spectrum shape near the endpoint at

52.8 MeV. Its value is predicted to be exactly 3/4, and the present reported value is not in disagreement with that prediction.[3] A deviation from the prediction of the V-A martix element (including radiative corrections) will signal new physics.

This proposal takes advantage of the fact that the positron arm of the MEGA spectrometer has been designed to be most sensitive to just the 52.8 MeV region of the positron spectrum since positrons from muons decaying at rest via $\mu \rightarrow e\,\gamma$ are to have exactly 52.8 MeV. Therefore, it seemed entirely natural, efficient, and cost effective for us to use this same spectrometer to precisely map the positron energy spectrum.

Extensive Monte Carlo studies were conducted in the process of preparing the proposal. The algorithm to reconstruct helical tracks from hits in the cylindrical MWPC's was tested and improved. The proposal describing the experimental procedures, data analysis and studies of the systematics of our detector systems was approved by the LAMPF PAC with an A+ rating. We are scheduled to collect data in summer 1992.

REFERENCES

1. M. Cooper, *et al.*, LAMPF Proposal No. 969 (1985).

2. R. D. Bolton, et al., *Phys. Rev. Lett.*, **56**, 2461 (1986).

3. Particle Data Group, *Phys. Lett. B* **239** (1990).

FIGURES

1. Distribution of positron energies from $\mu \rightarrow e\, \nu_\mu\, \nu_e$ decays obtained from the reconstruction of the positron helical track from hits in the positron MWPC's. The squares are from data collected in fall 1990. The solid line represents the identical analysis applied to the positron arm Monte Carlo set up to describe the limited positron detector used in this 1990 run. The agreement between the two is evident.

2. Computer generated Monte Carlo simulations of MWPC's from the positron detector.
   - The $\mu \rightarrow e\, \gamma$ signal track is seen from the end view (looking along the beam axis) and from a side view (perpendicular to the beam). The photon conversion point is seen on the cylinder at the left in the end view.
   - Two unrolled views of chamber 6 (the view on the right is an enlargement) show the hit anodes (horizontal lines) as well as the helical cathode stripes on which there was a charge induced. Intersections of contra-spiraling cathode stripes and hit anode(s) constitute a triple coincidence giving evidence of a probable track crossing. The squares show the reconstructed crossing points; the dots show the actual crossing from the Monte Carlo.
   - The enlarged end view of the MWPC's seen along the beam axis showing the hit anodes at locations around the circles (cylinders), the hit scintillators (approximate rectangles) and the target circle (projection of the inclined planar ellipse on this plane). The occupancy of these components is appreciated from these plots.

TABLE 1.

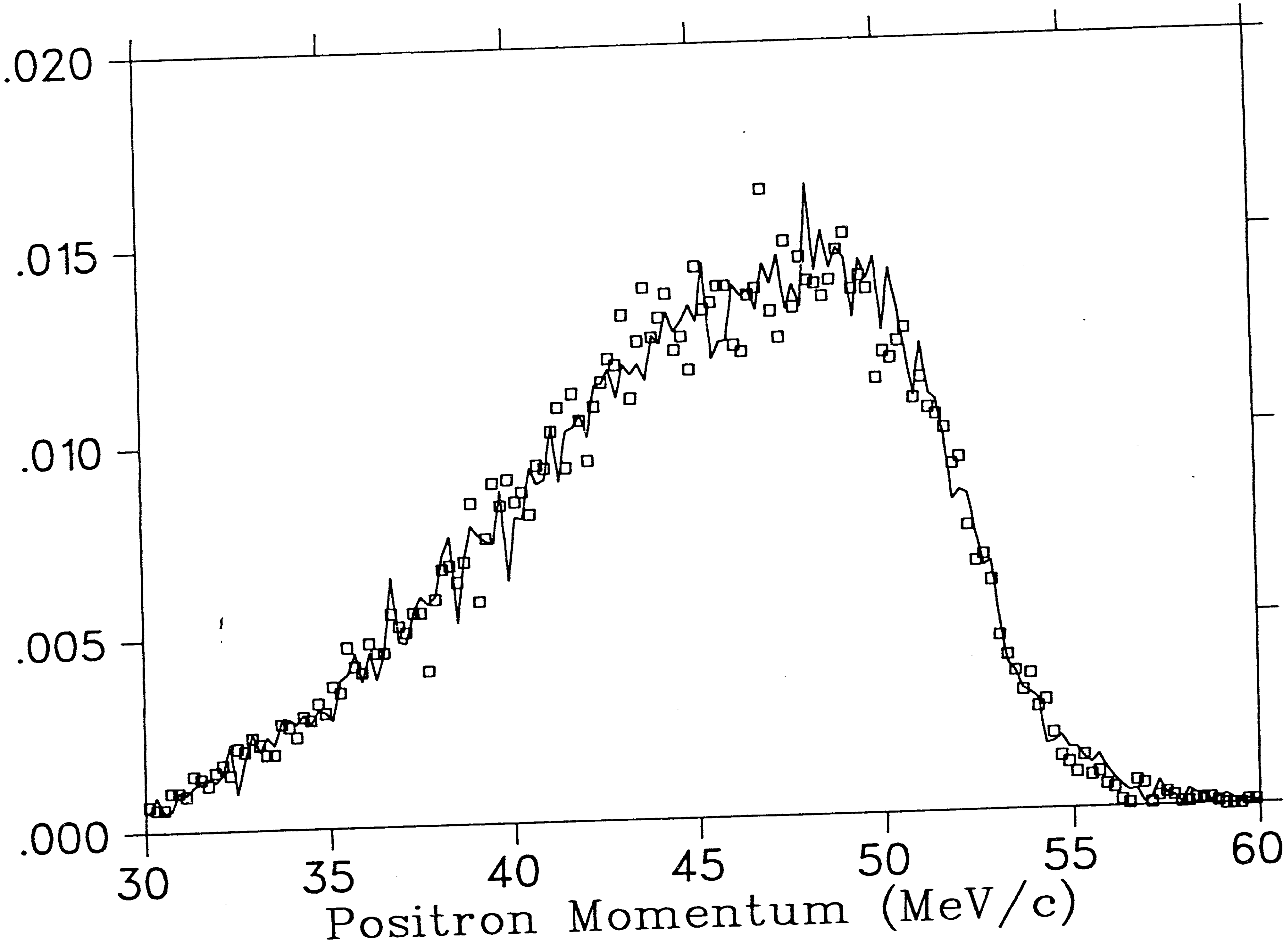
Results of the on-line filter programs as applied to Monte Carlo events consisting of positrons in the MWPC's from $\mu \rightarrow e\, \nu_\mu\, \nu_e$ decays at the full expected intensity corresponding to 500 MHz instantaneous decay rate. With no $\mu \rightarrow e\, \gamma$ signal present, the "background" events (B) correspond to a random photon trigger and uncorrelated positrons in the MWPC's. The goal of the on-line filter is to reject as many of these as possible, the remaining ones being written to tape for later, off-line analysis. With a $\mu \rightarrow e\, \gamma$ signal event superimposed in the Monte Carlo with the positrons from $\mu \rightarrow e\, \nu_\mu\, \nu_e$ decays (S), the goal of this same on-line code is to detect the $\mu \rightarrow e\, \gamma$ signal and write these events off to tape for later analysis as well. In real data the distinction between those events (B) which passed through the on-line filter and the genuine (S) events with a $\mu \rightarrow e\, \gamma$ signal is not known *apriori*.

The off-line analysis codes operate on those events written to tape by the on-line analysis. These codes apply a more detailed and complete analysis of the helical tracks, locating the muon decay point, and testing a precise measure of the track energy and vector momentum at the muon decay point. As applied to the Monte Carlo events, it is again intended that we remove the (B) events with no $\mu \rightarrow e\, \gamma$ signal present while finding the positrons from the real $\mu \rightarrow e\, \gamma$ decays (S) when they are present.

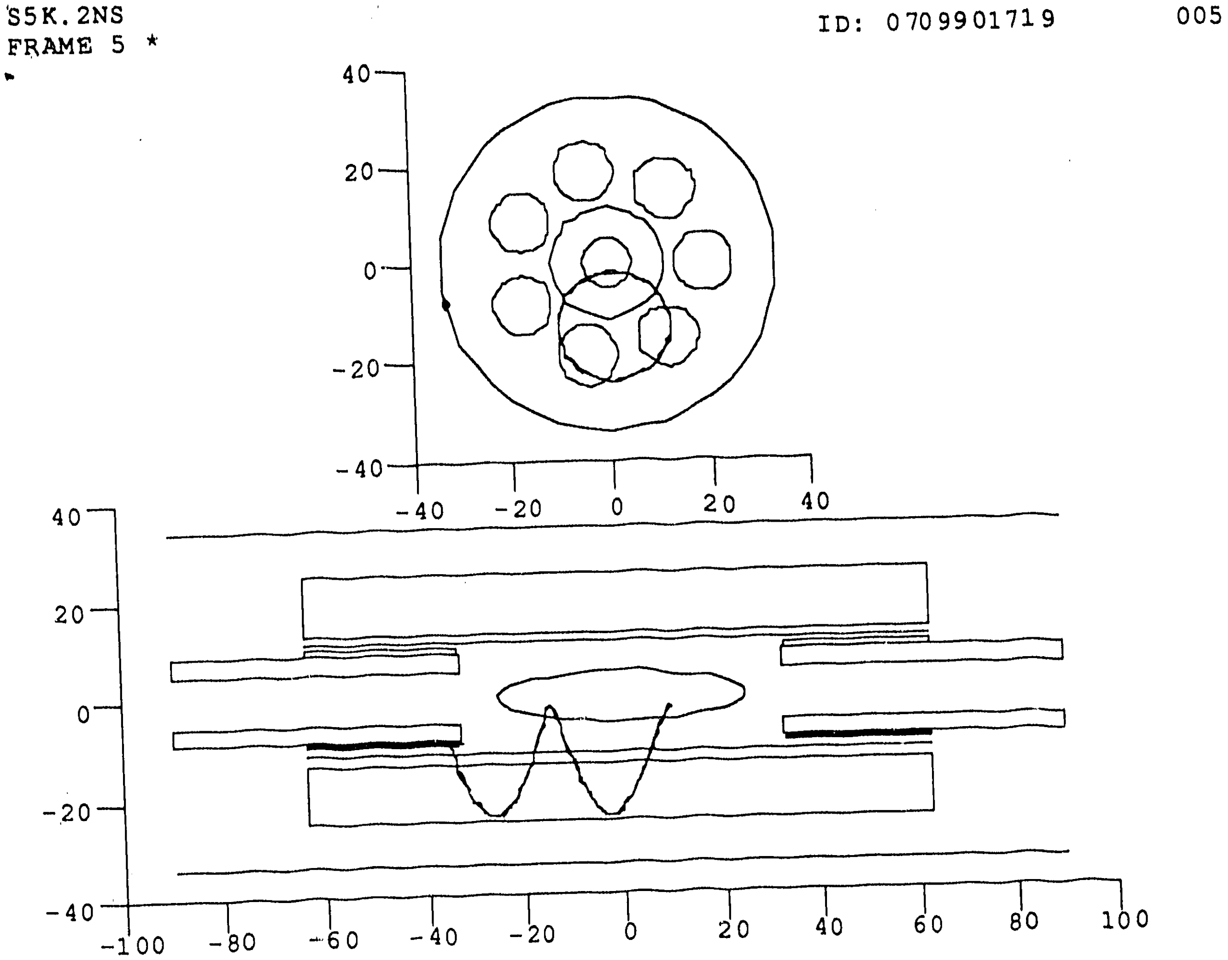
The results of these studies are shown in this table.

Background (B) Events ($\mu \rightarrow e\, \nu_\mu\, \nu_e$)	On-line	Off-line
Pass through rate	1.20%	0.13%
Average CPU time*	43 ms	467 ms
Signal Events ($\mu \rightarrow e\, \gamma$)	**On-line**	**Off-line**
Detection efficiency	89.0%	85.1%
Energy resolution		0.223 MeV
Angle resolution		1.23°
Average CPU time*	75 ms	50900 ms

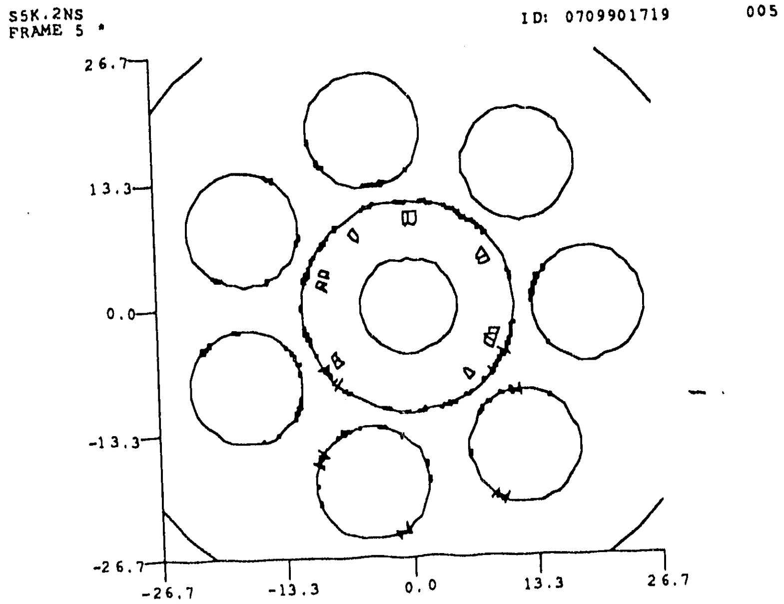
* Average CPU times are on ACP nodes which are approximately 0.7 VAX 11/780.


.020
.015
.010
.005
.000
30
35
40
45
50
55
60
Positron Momentum (MeV/c)

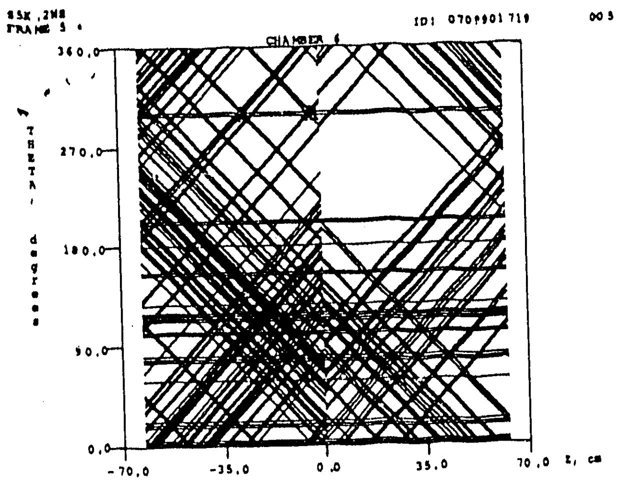
MEGA electron-arm *Monte Carlo* event

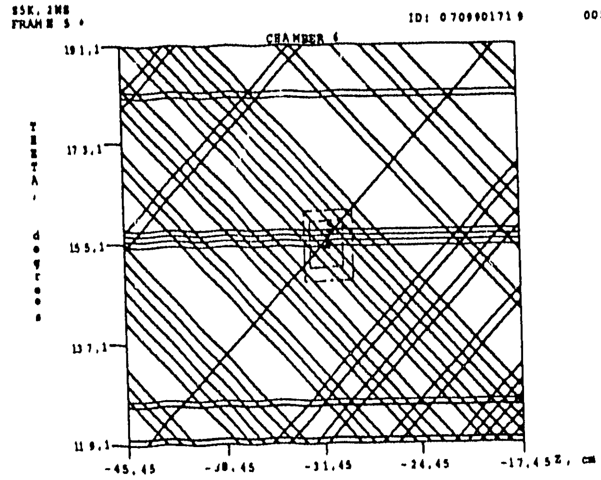


end-view chamber hits:



chamber 6 anode & cathode hits:





blow-up of end-view chamber hits: