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Standard Model Tests in Muon Decay with the MEGA Detector

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During the past year, we have continued our work on the photon detector for the MEGA experiment at Los Alamos. The MEGA photon detector is designed to observe the 52.83 MeV photon produced in a $\mu \rightarrow e\gamma$ decay with an energy resolution of 1.25 MeV, a position resolution of $2 \times 5 \text{ mm}^2$, a directional resolution of 10° , a time resolution of 500 ps, and an efficiency of about 5.4%. (All quoted resolutions are FWHM.) It consists of three independent concentric cylindrical pair spectrometers mounted within a 1.5 T magnetic field produced by a superconducting solenoid magnet. Each pair spectrometer includes two thin (0.045 radiation lengths each) Pb foils to convert photons into e^+e^- pairs. The two smaller pair spectrometers have three drift chamber layers to track the e^+e^- pairs and thereby determine both their locations and their vector momenta. The third pair spectrometer has four layers of drift chamber, together with a larger turning region, to provide better tracking information for high energy photons such as those from the $\pi^0 \rightarrow 2\gamma$ decay. The inner drift chamber layer in each of the spectrometers includes a delay line cathode to determine the z coordinates needed for track reconstruction. An MWPC located between the two Pb layers identifies the conversion layer so that energy loss corrections may be applied, while plastic scintillators provide timing information. The scintillators and MWPC's also participate in the first-stage trigger, which requires a hit pattern that is characteristic of showers produced by photons with transverse momenta of $> 35 \text{ MeV}/c$. The two outer drift chamber layers also provide the information necessary for the second-stage trigger, which rejects a large fraction of the first-stage triggers that are due to accidental coincidences while passing nearly all of the true e^+e^- pairs associated with high energy photons.

Our group, together with a group from the University of Houston, is

responsible for the design and construction of the photon detector, as well as developing the computer codes necessary for Monte Carlo simulations and data analysis. The division of labor between the two groups has the Houston group responsible for the construction of the wire chambers and their associated electronics, while our group is responsible for software development and construction of the scintillators and their electronics. We also were given the task of developing the delay line cathode read-out system for the drift chambers.

The MEGA collaboration achieved several major milestones during the past year. The inner two photon pair spectrometers were installed in essentially their final form for the summer, 1992, run cycle. These were the first pair spectrometers which have been constructed with delay line cathodes and reliable MWPC's, thus allowing us to obtain accurate z information regarding shower locations and evolution from the wire chambers and to utilize our scintillator-MWPC first-stage trigger, both for the first time. Since the summer run ended, construction of the final pair spectrometer has been completed, and its installation is well underway as this is being written. The summer, 1992, run cycle also represents the first time that the entire positron spectrometer system, consisting of eight cylindrical MWPC's to track the positrons and two scintillator barrels to measure their times, was assembled. Although the delay line z resolution was not as good as we had hoped, and there were significant noise and oscillation problems with the electron chamber electronics, the system worked sufficiently well that we also obtained our first physics data during the summer of 1992. At present, data taken during the run on both the $\mu \rightarrow e\gamma$ decay rate and the Michel parameter ρ in normal muon decay are being analyzed. We expect to reach a sensitivity for the $\mu \rightarrow e\gamma$ branching ratio close to that of the current world limit, based on approximately 6 days of

data at low beam intensities. Meanwhile, we expect to achieve overall uncertainties in the Michel parameter ρ of approximately ± 0.001 statistical and ± 0.0015 systematic, compared to the current best value 0.7518 ± 0.0026 . [1]

In addition to our work on the MEGA photon detector system, our group has played an active role in the measurement of the Michel parameter ρ in normal muon decay with the MEGA positron spectrometer. We made significant contributions to the original design and proposal for the measurement, and have continued to be one of the lead groups in this effort. At present, one of our students, F. Liu, is analyzing the ρ parameter data that was taken during the summer 1992 run cycle for her Ph.D. thesis. We also now have the primary responsibility for maintaining and upgrading SED, the graphical single-event display software for the experiment.

During the past year, our efforts have focused primarily on the 1992 run, analysis of its results, and preparation for data taking with the full three-layer detector beginning in July, 1993. We also completed the analysis of the inner Bremsstrahlung data that was taken during the summer of 1990. The rest of this report describes our recent work on the tasks outlined above.

Trigger Rates

The 1992 run represents the first time that we have utilized on-line event filtering during $\mu \rightarrow e\gamma$ data taking. The photon arm part of this code, called PAIRS, is the pattern recognition algorithm that we have developed over the past several years based on studies of Monte Carlo data and analysis of the 1990 inner Bremsstrahlung photon data. Unfortunately, the CPU requirements of the on-line codes were greater than had been anticipated, so they limited the data rate that we were able to sustain.

This came about for several reasons.

As noted above, the 1992 run was the first time that we have had a reliable MWPC system in the photon detectors, so we were able to utilize our scintillator-MWPC first-stage trigger for the first time. This trigger requires at least 3 MWPC clusters to be hit in a span of 9-13 wide in coincidence with at least 2 scintillators in the same region. It simultaneously increases our acceptance for photons from $\mu \rightarrow e\gamma$ and reduces our acceptance for inner Bremsstrahlung photons, relative to our alternate first-stage trigger which requires 3 scintillators to be hit in a span of 4-6 wide. Preliminary analysis of 1992 data that was taken without filtering, in order to investigate the rate-dependence of the trigger and backgrounds, indicates that the scintillator-MWPC trigger has a larger random contribution than the scintillator-only trigger. Past background studies have shown that the rate of nearest neighbor scintillator hits is very high, due largely to soft photons that interact near the boundary between two scintillators. We are currently investigating if this is the cause of the high random trigger rates. If so, we will eliminate the nearest neighbor scintillator pairs from the first-stage trigger by changing some of its ECL PAL's. (The scintillator PAL's in the first-stage trigger were installed in sockets to allow for just this possibility.) This change would reduce the random background rates in the first-stage trigger considerably.

Meanwhile, we did not have the second-stage trigger available for the 1992 run. Although the second-stage trigger for the innermost pair spectrometer was built and tested during 1990, that for the second pair spectrometer was not completed in time for the run. The data acquisition system design requires that, if we wish to implement our second-stage trigger, we must have it available for all pair spectrometers. The unfiltered data mentioned above shows that the second-stage trigger would

have reduced our data rate by over a factor of two. Finally, we found that, although PAIRS requires very little CPU time, the CPU overhead associated with unfolding events before PAIRS can analyze them was much larger than expected. During the run, we worked together with collaborators from Los Alamos, Fermilab, and Valpariso to speed up the event preparation routines as much as practical and to modify the operational order of the pattern recognition routines to minimize the amount of event preparation overhead per event. The best event throughput that we achieved during the run was a sustained rate of approximately 7×10^6 μ /sec (time average), or about 25% of the nominal beam intensity.

Since the run, we have been investigating ways to reduce the event preparation overhead associated with photon arm analysis even further, while other collaborators are considering the electron arm codes. The collaboration is currently increasing the CPU capabilities of our microprocessor farm by a factor of 3. These changes, together with the second-stage trigger and possibly the modified PAL's in the first-stage trigger, should be adequate to handle the full beam intensity.

Software Development

In addition to the photon arm pattern recognition and event reconstruction routines, our group has the responsibility for maintaining and upgrading the experiment-wide event display package SED and the photon arm Monte Carlo program PARMMC.

SED is one of the primary tools that we use to evaluate the MEGA detector system. Several features have been added to SED over the past year, some dictated by the evolution of our hardware, but many to integrate SED more closely with our analysis codes. SED now displays the photon arm enable gates that drive the "intelligent multiplexing" system, the MWPC

cluster latches, and the delay line information. All of these were implemented in the photon arm for the first time during the 1992 run. It also displays the results from PAIRS and the best-fit tracks from cosmic ray events and the rho analysis code. The latter required that a new view be added to SED to provide an unrolled image of the positron helix through the electron MWPC's. The $\mu \rightarrow e\gamma$ experiment uses ARC (Analytic Reconstruction Code), which was developed at Valpariso University, to filter the electron arm. Given a candidate $\mu \rightarrow e\gamma$ photon, ARC defines a "road" through the electron chambers where a coincident positron would have to be. It then looks for hits within this road that represent a valid 52.83 MeV positron. The output filter codes from ARC were added to the SED display for the 1992 run. At present, a new view is being added that shows the road through the chambers that ARC has identified. Finally, several modifications have been made to SED over the past year to make it more convenient, and a hard-copy output capability has been added.

The primary modification to PARMMC that we made this past year was to configure it to handle the new geometry of the outermost pair spectrometer that was adopted at a collaboration meeting in January, 1992. Each of the two inner pair spectrometers have three contiguous, 0.8 cm thick, wire mesh drift chamber layers, located just outside the cylinder which supports the delay lines and the outer Pb converter foil of that spectrometer. The outer pair spectrometer includes three drift chamber layers in the same geometry as the inner two pair spectrometers. But it also contains a fourth wire mesh drift chamber layer located 2 cm outside the third layer, as well as "charge-sweeping" wires between layers 3 and 4 and outside of layer 4. The extra drift chamber layer helps to reconstruct high energy photon showers such as we obtain during our $\pi^0 \rightarrow 2\gamma$ calibration runs, while the charge-sweeping wires reduce cross talk due to ionization outside of the drift

chamber cells themselves. PARMMC now includes these additional elements in its simulations.

Electronics

In last year's report, we discussed the changes that were made in the electronics following the '90 test run. The scintillator electronics that we used in the '92 run performed well and no subsequent modifications have been made to them. All of the electronics for the full detector system were completed during this past year and are now being installed at Los Alamos for a data run with the full three layers of photon detector this summer.

Major modifications to the delay line preamplifier design were made after the '92 run. We experienced two electronic problems with the preamps that forced us to make revisions. One problem was that about 20% of the preamps oscillated when they were plugged into the motherboard. In some cases, the problem was traced to a slight misalignment of the components while in other cases we could not locate the problem. A slightly larger feed-back capacitor on the first stage eliminated the oscillation on some boards. The other problem was that the gain of the preamp was dependent on the dc voltage supplied to the board. This is a feature of the MAR-1 amplifier which was used for the second stage of the preamp. An additional concern was the large power dissipation in the preamp, 44 mA/channel after warm-up. Finally, as noted below, the z resolution that we obtained with the delay lines was approximately 1 cm FWHM, compared to the 5-6 mm FWHM that we were anticipating. This was due in part to the low CFD threshold settings that we were forced to use because the delay line pulse heights were less than we observed in the test chamber in 1990.

Since the run, we have redesigned the delay line preamplifier in conjunction with the U of H electronics group. The basic two-stage

amplifier design has been preserved. In the original version, the first stage consisted of a Burr-Brown OPA-621 op-amp configured as a differential amplifier with approximately 40 dB common mode rejection. The latter feature is important because bench tests demonstrated that the delay lines propagate a prompt common mode signal that is 7-10 times larger than the delayed differential signal of interest. The new design replaces the OPA-621 with an Analog Devices AD829, while modifying the feedback components to increase the gain and decrease the bandwidth. The second stage of the original preamp design consisted of a Mini-Circuits MAR-1 monolithic amplifier. It has been replaced by an Analog Devices AD811 current-mode op-amp, again configured for increased gain and decreased bandwidth. The net result of these changes is to increase the overall gain from 120 to ≈ 300 , slow the rise time from 5 ns to 12 ns, and leave the peak-to-peak noise unchanged (≈ 6 mV). The power supply requirement has been reduced to < 20 mA/channel, while the power supply voltage may vary from ± 5 V to ± 12 V with minimal gain shifts. The reduced bandwidth should improve the system stability without degrading the time resolution significantly, since the intrinsic rise time of the delay lines is 15-25 ns depending on the propagation distance. Clearly the improved signal-to-noise should improve the time resolution, and thus the z resolution, of the delay line CFD's. As this is being written, the U of H group is beginning to test the first batch of preamplifiers which were mass produced using the new design.

The CFD's for the delay lines were described in last year's report. Generally they worked well during the 1992 run after a minor modification was made to the gate circuitry to eliminate cross talk problems on the backplanes to which they mounted. U of H has now fabricated the remaining CFD's required for the third pair spectrometer using the same design.

Final Analysis of the 1990 Data

1992 saw the conclusion of the ongoing analysis of MEGA photon arm data obtained in late 1990. The algorithms developed during the analysis of a substantial subset of the available Inner Bremsstrahlung data set were applied to the entire data set. The original data set contained 1.87×10^6 first-stage high energy gamma triggers. The trigger required that 3 scintillators fire in a range of 4-6. This data set was reduced by 55% because of the exclusion of the half of the detector containing most of the missing or dead drift chamber sense wires. The presence of these drift cells in the analysis was found to have a profound effect on the analysis algorithms and to lead to substantial inaccuracies. Future chambers should have little or no such drift cells so that the exclusion of this data subset has no effect on further analysis other than statistical. The final data set, after application of the second stage trigger and fitting algorithms, and the filtering out of background including Compton scattered electrons and hard Bremsstrahlung events, contained $\approx 67,500$ good shower events. The resultant perpendicular momentum spectrum is shown in Fig. 1. A statistically equivalent Monte Carlo data set is shown for comparison. In general the agreement is very good. The only notable discrepancies are that Monte Carlo slightly overestimates the yield at the peak and underestimates it near 46 MeV/c. Figure 2 shows the agreement in the endpoint region. This is the most important area for understanding the background that inner Bremsstrahlung will present in the $\mu \rightarrow e\gamma$ search. It is worth noting that the good agreement between the Monte Carlo and the real data demonstrated by Figs. 1 and 2 were only obtained after a previously underestimated source of background photons was investigated. The Monte Carlo simulation was modified to include the effect of photons produced in the planar 0.5 mm Mylar target through the annihilation in flight of energetic Michel

positrons traversing the target. Meanwhile, there is a 10% uncertainty in the muon stopping rate, which provides a relative normalization uncertainty between the data and the Monte Carlo.

A notable characteristic of Fig. 1 is the periodic substructure of the spectra. Closer examination indicates that this substructure, manifested by local peaks occurring approximately 2-2.5 MeV/c apart, occur approximately at the locations of drift cells in the inner drift chamber. The causes of this structure may be two-fold. Firstly, a secondary hit caused by an e^+e^- pair member re-entering the same drift cell on a subsequent orbit may traverse the cell closer to the sense wire. Since the orbital period of the pair members is well below the drift times involved, the secondary hit will stop the TDC, resulting in an artificially low measured drift time. This effect will tend to produce more hits closer to the sense wire and lead to the substructure seen. The second possible explanation of the substructure seen is in the fitting algorithm. Specifically, Monte Carlo studies have demonstrated that when the vertex cell hit in the inner drift chamber is traversed by both pair members, and is assigned a larger uncertainty in circle fitting, the algorithm has a weak tendency to fit a circle with the particle passing on the wrong side of a given drift cell at the outer edge of the particle orbit due to lack of constraints at the vertex region. This may result in the clumping as seen. This effect may be eliminated by constraining the track to traverse the DC1 vertex cell outside of the drift circle. Studies of this constraint will be performed on the improved data from the 1992 LAMPF run.

Analysis of the 1992 $\mu \rightarrow e + \gamma$ Data

M. Dziedzic of U of H is the primary individual working on the analysis of the summer 1992 photon arm data. He will use this data for his

Ph.D. thesis. We are working closely with him on developing new algorithms for unraveling photon arm events using the z information that is available from the delay lines. Much of the work to date has focused on determining drift chamber efficiencies and the z resolution of the delay lines. The z resolution is determined by using the electron arm chambers to track cosmic rays and then project these events out to the photon arm. Comparing the measured and predicted z position of the events provides a determination of the z resolution. This technique depends on a thorough understanding of the alignment of the electron arm relative to the photon arm and on the pointing accuracy of the electron arm. From early comparisons between the measured and predicted z values, we found that it is necessary to account for the break that occurs in the center of the chamber where two short delay lines are joined to produce a "single" delay line that runs the full length of the photon chamber. Figure 3 shows a composite of ten delay lines where the residuals from predicted z and measured z have been plotted. The results from this set of delay lines indicates that the z resolution is on the order of 1 cm (FWHM), after removing the pointing uncertainty. This result is preliminary since electron arm analysis is still continuing and changes in the electron arm geometry will affect the z resolution that we observe in the photon arm.

The z information in the photon arm determines the longitudinal momentum of the pairs and the z location of the vertex. It also provides additional constraints for the pattern recognition algorithms. We first use the z information to group cells together in "clusters." Without z information, a group of continuous cells forms a "cluster" even if these hits occur from multiple spirals of the electron-positron pair. With the z -information, it is often possible to distinguish hits due to multiple spirals and hence increase the number of "clusters" while reducing the

"cluster" size. The patterns from the z projection can be used to help locate the vertex of converted pairs. Also they appear to do a good job of distinguishing between Compton scatters and pairs. Recently, we have been working with Mr. Dziedzic to include this information in the pattern recognition algorithms that we have built up over the past few years. In the past, one of the problems that we have encountered in using "end views" for pattern recognition is that the vertex for some events gets obscured when one member of the pair spirals back through the cells that are adjacent to the vertex region. Using the z information as we indicated above allows us, in many cases, to distinguish between the two different tracks and thus we can eliminate the ambiguity in these cases. We are incorporating a routine that gives a "best guess" for the vertex, based upon the pattern of hits in z, into the "end view" routines. Monte Carlo studies indicate that the z hit pattern yields an unambiguous "best guess" for $\approx 70\%$ of the candidate $\mu \rightarrow e\gamma$ events, and that this "best guess" cluster actually includes the pair conversion vertex $>92\%$ of the time. We expect to increase both the speed and the efficiency of the pattern recognition algorithm by merging the information from the two views.

Measurement of the Michel Parameter ρ

In the fall of last year, we collected the data for a measurement of the Michel parameter ρ as planned. We will refer to this experiment as RHO in the following. The objective of RHO was to measure ρ to an accuracy of $\delta\rho/\rho = 0.001$, which is about three times better than the current best value: $\rho = 0.7518 \pm 0.0026$. [1] This result will further test the Standard Model and allow us to search for evidence suggesting physics beyond it.

The experiment was carried out in the Stopped Muon Channel (SMC) at the Los Alamos Meson Physics Facility, using the existing MEGA detector system.

ρ can be determined by measuring the positron energy spectrum in normal muon decay. An end view of the positron spectrometer part of the MEGA detector is shown in Fig. 4. It consists of 180 strips of plastic scintillators and 8 multi-wire proportional chambers (MWPC's). The scintillators form two hollow barrels coaxial with the beam, located upstream and downstream from the target, which is installed at the center of the detector system. The chambers are arranged such that seven smaller chambers (12 cm in diameter) surround a larger central chamber (22 cm in diameter), often referred to as the seven dwarfs and Snow White respectively. The electron spectrometer is contained within the innermost region of the bore of a superconducting solenoid that generates (parallel to its own axis) a 15 kG magnetic field. The muon beam enters along the axis of the solenoid, stops in a thin vertical target and decays at rest. Under the influence of the magnetic field, the positron from a muon decay is confined to the central region. The trigger for a normal muon decay event is given by the OR of the finely segmented plastic scintillators. The track of the positron, which is a helix, can be reconstructed from the coordinates of chamber hits. The locations of the MWPC hit wires provide the (x,y) pairs, while the z-positions are calculated from the intersection of spiral cathode strips and the wires. The momentum of the positron is then derived from the parameters of the helix.

A surface μ^+ beam, which was produced by π^+ decay at rest at the SMC target, was tuned to have a momentum of 28 MeV/c with a relative momentum spread $\Delta P/P$ of 6% FWHM. The polarization of the muon beam was greater than 99%, with the muon spin opposite to its momentum. A second μ^+ beam, whose polarization was reversed, was also developed. It was produced by a 70 MeV/c π^+ beam decaying in flight. The resulting μ^+ beam was tuned to 28 MeV/c since the same target was used. RHO requires only single track events

in order to eliminate tracking ambiguities. The beam intensity was controlled by adjusting the slits along the beam line. The target was a circle made from two 10 mil mylar sheets glued together with a hole of 0.64 cm in diameter at the center. The target was placed normal to the beam and supported by a cylindrical plastic bag inflated with helium.

Although all eight MWPC chambers were installed and instrumented, only seven of them were used because dwarf 7 was unable to hold high voltage. The downstream cathodes of dwarf 3 had severe electronics feed-back oscillation problems and were also turned off. All the "live" chambers were operated at high voltages well on plateau, and the discriminator thresholds were adjusted to reasonable values. All scintillators were mounted, timed in and fully tested. In addition to the scintillator trigger, a "Snow White" trigger was constructed. This trigger used the signals from the central region of the Snow White inner and outer cathodes. Data taken with the Snow White trigger will be used for determining the absolute efficiencies of the scintillators.

The data acquisition system was configured separately for RHO since a compressed data format had to be employed. An on-line analysis which reconstructed the helical track and a single event display system which showed the track on a screen helped monitor and ensure the quality of the data as they came in.

During six days of data taking, we were able to collect 2×10^8 trigger events under various conditions. Three modes of data were taken with scintillator triggers as well as with the Snow White trigger. The three modes distinguish themselves by the type of beam used and magnetic field values. Two of them were taken with the surface muon beam and magnetic field at 15 kG and 14.25 kG respectively. For the third mode, the magnetic field was set at 15 kG and the beam was switched to that of reversed

polarization. The three data sets will help check and understand systematic errors.

After data taking was finished, the analysis immediately began. We first modified the track reconstruction program and updated the cuts used by it. Originally, the reconstruction program only passed ideal events in which pure single tracks were present. Unfortunately, during last year's run electronics oscillations occurred frequently in some of the chambers. The reconstruction program was modified to extract these contaminated events. The track reconstruction efficiency of the revised version is about 10% per trigger for the events that made one complete revolution. These events will enter in the spectrum for the final fitting.

Before further analysis could be pursued, channel mapping and alignment were necessary. Helical track and cosmic ray events were used to verify the FASTBUS-to-detector-channel mapping of the positron chambers and to check the alignment of the detector elements. Initially, the intercepting angle ϕ between inner and outer cathode stripe pairs was compared to that of the nearest anode cluster. The azimuthal angle difference was noted as $\delta\phi$. A 2-d histogram of $\delta\phi$ vs. the anode or cathode clusters was made for each chamber. If the map was correct, the resulting scatter plot would show a well-defined band at $\delta\phi=0$. Any displacements indicated errors in the map and were corrected accordingly. Following this, both the internal alignment of the chambers themselves and the relative alignment between the chambers were examined. The first pass of anode alignment has been completed. To avoid complications choosing the parameters to be determined, only a subset of the chambers were selected at a time. The orientation of the dwarves about their respective axes and the angular coordinates of their axes in the Snow White coordinate system were determined using combinations of Snow White plus two dwarfs. Two dwarf combinations determined the radial

distances from the dwarf chamber axes to the Snow White axis. These parameters were determined by minimizing the cumulative χ^2 from fitting tracks from magnet on events, as well as cosmic rays, that left hits in the selected chambers. With these alignment results implemented in the analysis, the energy resolution improved by about 100 KeV FWHM. Some typical current positron energy spectra are shown in Fig. 5. The cathode alignment is being studied at present.

Helical track data were used for scintillator alignment. A coarse tuning, with a precision of one unit scintillator, was performed by employing a 2-d scatter plot of the predicted scintillator number vs. the actual hit scintillator number. The deviation of the diagonal band from the origin showed a gross offset of the scintillators. Fine tuning utilized Snow White anode hits checked against scintillator hits. The reconstructed track was used to calculate the ϕ 's of the track crossing the Snow White anode plane and scintillator inner radius. The difference was subtracted from the hit anode position in a window of ± 40 wires around the track to project the wire position to the scintillator position. The intercept of a linear least-squares fit to this predicted scintillator number, as a function of the actual hit scintillator number, gave the scintillator displacements. The final offsets for the upstream and downstream scintillators were -0.0375 and -0.0449 radians respectively.

The first task, following the completion of the channel mapping and the preliminary alignment, was locating the position of the target in z and obtaining the transverse beam spot at the target. The process of calculating the two were coupled together. First the target location was estimated by finding the centroid of the average z -coordinate of the two extrapolated points between the reconstructed track and the target bag. The transverse beam distribution described by (x,y) pairs was then given by the

crossing point of the track at the target plane. If the target position was found correctly, then the beam spot would be the smallest because otherwise it would be "out of focus". To achieve this, the same procedure was repeated at different z 's away from the base z value described above. It was found that the smallest spot occurred at about $z = -1$ cm, i.e. the target was off center by 1 cm upstream in the Snow White coordinate system. This was confirmed by the asymmetric distribution of P_z , which is a sensitive quantity for the upstream and downstream acceptance.

Meanwhile the scintillator and chamber efficiencies were studied. The scintillator efficiency was obtained using the Snow White cathode trigger, magnet on data. In this data set, the scintillator TDC's were recorded. The efficiency was calculated by comparing the projected scintillator location using the reconstructed positron track to any fired scintillator TDC's. Only one-loop reconstructed events were used since they are the only ones that we will use in the final ρ analysis. Efficiencies as a function of individual scintillators and segments in z were calculated using the following algorithm. For a track striking a particular scintillator, three quantities were looked for: 1) the TDC for that scintillator, 2) the low- ϕ neighbor scintillator's TDC, and 3) the high- ϕ neighbor scintillator's TDC. This procedure was used since a trigger was not necessarily from the primary scintillator but sometimes from a neighbor. The efficiencies calculated this way do not represent real scintillator efficiencies, but rather the trigger efficiency. A subroutine was written to mimic the three "efficiencies" in the Monte Carlo simulation. The implementation and the validation of the code is in process.

Three types of data are available to determine the MWPC chamber efficiencies. They are: 1) magnet on data, 2) magnet off data, and 3) cosmic ray data. Efficiencies with all three data sets are being studied,

with one being checked against another. Preliminary results have been obtained in the case of magnet on data. The efficiencies were calculated on a wire by wire basis using a similar scheme to that for the scintillators. When a track crossed a chamber, the hit wires within a window of ± 2 wires around the location of the track were looked for. The efficiency was then given by the ratio of the frequency of the hit wire to that of the track passing. Again this may not be the actual wire efficiency due to the counting scheme employed here. However, as long as we can reproduce this "efficiency" in the Monte Carlo simulation it serves our purpose.

We also studied the upper edge of the energy spectrum in attempting to determine both the centroid of the beam stopping distribution inside the target and the average magnetic fields upstream and downstream. Both of these effects influence the measured energy of the positron. The sharply falling edge of the spectrum at 52.8 MeV provides excellent sensitivity to them. The former can be obtained by comparing the energy loss between different loop events on the same side, e.g. upstream or downstream. This is based on the fact that the average effect of the magnetic field is the same for all events at one end. Therefore, observed energy differences come purely from the energy losses inside the target. Since the different loop events correspond to different emittance angles from the target, they experience different path lengths which are uniquely related to the energy losses. In our calculation we used 1, 2 and 3 loop events. The three combinations of any two of them gave consistent results. The average centroid of the beam distribution in the target was 7.5 mil for the surface beam and 7.9 mil for the decay beam, both measured from the incident surface. Once the beam centroid is determined and the energy loss is accounted for, the average magnetic fields can be obtained by comparing the two edges between upstream and downstream for the same loop events.

Although the results from the 1, 2 and 3 loop events differed, they are all reasonable when compared to the values calculated from the magnetic field map. We should note that the calculation so far has been very crude. An improved algorithm is being studied.

To conclude, we think that the data taken last year are adequate to achieve $\delta\rho = 0.001$. However, additional problems, e.g. the location dependent electronics noise and the target offset, will increase the systematic uncertainties. We expect the overall systematic error to be less than 0.0015. Hence, a final precision of $\delta\rho = 0.002$ should be achieved.

Reference

- [1] J. Peoples, Columbia University, thesis, Nevis147, 1966 (unpublished).

Figure Captions

- Fig. 1: Final comparison between the measured photon transverse momentum spectrum from the 1990 run and our Monte Carlo simulation. The solid curve includes the combined contributions of photons from inner Bremsstrahlung muon decay and positron annihilation in flight in the muon stopping target. The latter contribution, which is small but critical to obtain good agreement, is also shown separately as the dotted curve.
- Fig. 2: Final comparison between the observed photon spectrum from the 1990 run and Monte Carlo simulations, as in Fig. 1. This view focuses on the endpoint region which is important to estimate the random background contribution that these photons make to the $\mu \rightarrow e\gamma$ search.
- Fig. 3: The difference between the measured z coordinate from our delay lines and a fit to the remaining hits in the event, based on cosmic ray triggers. The solid curve is a smoothed version of the residual spectrum.
- Fig. 4: An end view of the positron spectrometer which is used for both the $\mu \rightarrow e\gamma$ search and for the ρ measurement.
- Fig. 5: Four positron energy spectra for "one-loop" events, showing the current state of the analysis. The two upper spectra have the muons polarized upstream, while the lower spectra have the muons polarized downstream. The two spectra on the left represent muon decays upstream, while those on the right represent muon decays downstream. Note that the spectrometer acceptances are different in the two directions because of geometric differences.

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