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Author(s): G. E. Hogan, M. Ahmed, J. F. Amann, D. Barlow, K. Black, R. D. Bolton, M. Brooks, S. Carius, Y. Chen, A. Chernyshev, M. D. Cooper. P. S. Cooper, J. Crocker, M. Dzemidzic, A. Empl, R. J. Fisk, J. Flick, W. Foreman, C. A. Gagliardi, D. Haim, A. Hallin, R. Harrison, G. Hart, C. M. Hoffman, E. B. Hughes, E. V. Hungerford III, K. Johnston, C. Jui, G. J. Kim, J. E. Knott, D. D. Koetke, M. A. Kroupa, T. Kozlowski, K. Lan, V. Laptev, D. Lee, F. S. Lee, F. Liu, R. Manweiler, R. Marshall, B. W. Mayes II, R. E. Mischke, F. J. Naivar, B. M. K. Nefkens, J. Novak, M. A. Oothoudt, J. N. Otis, R. Phelps, L. E. Piilonen, C. Pillai, L. Pinsky, J. Price, M. W. Ritter, S. Schilling, T. D. S. Stanislaus, K. M. Stantz, J. J. Szymanski, W. Stephens, J. Sturrock, L. Tang, B. Tippens, R. E. Tribble, X.-L. Tu, L. A. Van Ausdeln, W. Vonwitsch, D. Whitehouse, C. Wilkinson, B. Wright, S. C. Wright, Y. Zhang, X.-G. Zhou, and K. O. H. Ziock

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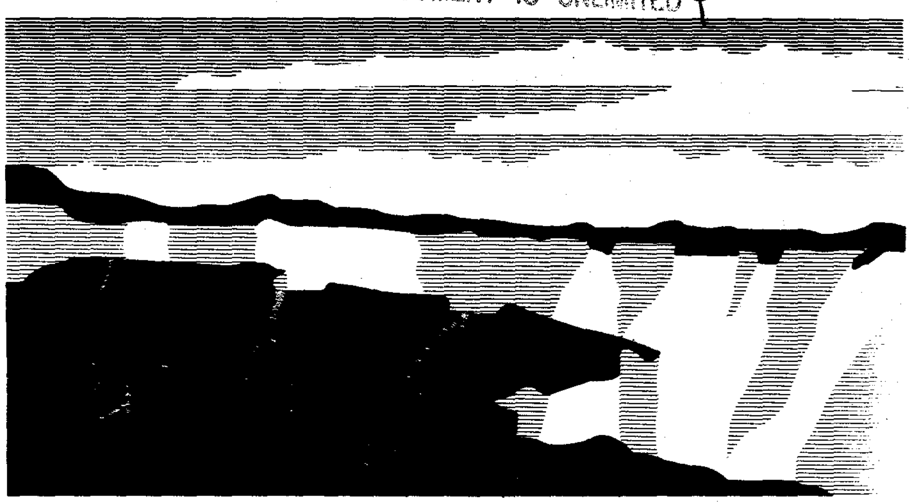

Los Alamos
NATIONAL LABORATORY

A STUDY OF THE DECAY $\mu \rightarrow e\gamma$ BY THE MEGA EXPERIMENT

G.E. HOGAN,[a] M. AHMED,[e] J.F. AMANN,[a] D. BARLOW,[j] K. BLACK,[a] R.D. BOLTON,[a] M. BROOKS,[a] S. CARIUS,[a] Y. CHEN,[e] A. CHERNYSHEV,[a] M.D. COOPER,[a] P.S. COOPER,[c] J. CROCKER,[b] M. DZEMIDZIC,[e] A. EMPL,[e] R.J. FISK,[k] J. FLICK,[e] W. FOREMAN,[a] C.A. GAGLIARDI,[i] D. HAIM,[m] A. HALLIN,[g] R. HARRISON,[a] G. HART,[a] C.M. HOFFMAN,[a] E.B. HUGHES,[h] E.V. HUNGERFORD III,[e] K. JOHNSTON,[e] C. JUI,[h] G.J. KIM,[i] J.E. KNOTT,[f] D.D. KOETKE,[k] M.A. KROUPA,[a] T. KOZLOWSKI,[a] K. LAN,[e] V. LAPTEV,[a] D. LEE,[a] F.S. LEE,[m] F. LIU,[i] R. MANWEILER,[k] R. MARSHALL,[l] B.W. MAYES II,[e] R.E. MISCHKE,[a] F.J. NAIVAR,[a] B.M.K. NEFKENS,[j] J. NOVAK,[a] M.A. OOTHOUDT,[a] J.N. OTIS,[h] R. PHELPS,[e] L.E. PIILONEN,[m] C. PILLAI,[a] L. PINSKY,[e] J. PRICE,[j] M.W. RITTER,[h] S. SCHILLING,[a] T.D.S. STANISLAUS,[k] K.M. STANTZ,[f] J.J. SZYMANSKI,[f] W. STEPHENS,[l] J. STURROCK,[a] L. TANG,[d] B. TIPPENS,[j] R.E. TRIBBLE,[i] X.-L. TU,[i] L.A. VAN AUSDELN,[i] W. VONWITSCH,[e] D. WHITEHOUSE,[a] C. WILKINSON,[a] B. WRIGHT,[l] S.C. WRIGHT,[b] Y. ZHANG,[m] X.-G. ZHOU,[i] and K.O.H. ZIOCK[l]

[a] *Los Alamos National Laboratory, Los Alamos, NM 87545*

[b] *University of Chicago, 5630 Ellis Chicago, IL 60637*

[c] *Fermilab, P.O. Box 500 Batavia, IL 60510*

[d] *Hampton University, Hampton, VA 23668*

[e] *University of Houston, 4800 Calhoun Road Houston, TX 77004*

[f] *Indiana University, Bloomington, IN 47405*

[g] *Princeton University, Princeton, NJ 08544*

[h] *Stanford University, Stanford CA 94305*

[i] *Texas A&M University, College Station, TX 77843*

[j] *UCLA, Los Angeles CA 90024*

[k] *Valparaiso University, Valparaiso, IN 46383*

[l] *University of Virginia, Charlottesville, VA 22901*

[m] *Virginia Polytechnic Institute & State University, Blacksburg, VA 24061*

The MEGA experiment is designed to search for the lepton-flavor number non-conserving rare decay $\mu \rightarrow e\gamma$. Data-taking is complete, with 450 million events on tape taken over approximately 10^7 seconds. A small portion of the data sample has been processed through the complete event reconstruction codes to search for the $\mu \rightarrow e\gamma$ process. No evidence for the $\mu \rightarrow e\gamma$ decay is observed at a sensitivity of ~7×10^{-11} (90% confidence).

1 Introduction

The MEGA (Muon decays into an Electron and a GAmma ray) experiment is a search for the rare muon decay $\mu \rightarrow e\gamma$ at the Los Alamos Meson Physics Facility. The decay $\mu \rightarrow e\gamma$ violates the conservation of separate muon- and electron-type lepton flavor number. This decay mode is the subject of much recent theoretical interest,[1] mostly because the decay $\mu \rightarrow e\gamma$ provides information on supersymmetric extensions to the standard model. Among the possible muon-number-nonconserving rare decays, the branching ratio for $\mu \rightarrow e\gamma$ is also relatively large in models employing right-handed neutrinos, extra Higgs doublets, and composite particles.

2 The Experimental Apparatus and Technique

The signature for the decay $\mu \rightarrow e\gamma$ at rest is purely kinematic: the positron and photon are emitted back-to-back, are emitted at the same time, and each have an energy of 52.8 MeV, which is one-half of the muon rest mass. Photons are detected in one of three, coaxial, independent pair spectrometers. Helical tracks produced by positrons are measured in eight cylindrical MWPCs and two annuli of scintillators. These positron MWPCs are subject to extremely high instantaneous rates (2.5×10^8 muon decays per second instantaneous). The chambers are very thin (3×10^{-4} radiation lengths) to minimize multiple scattering and the production of background photons. Further descriptions of the detector have been previously published.[2,3]

A surface muon beam is brought to rest in a thin target located at the center of the detector. The detector is triggered on high-energy (above 35 MeV) photons in hardware. Data are read into an online workstation farm in which a software filter correlates data in the positron and photon detectors and passes candidate $\mu \rightarrow e\,\gamma$ events to tape.

The analysis of these data requires pattern-recognition codes that work within the high-rate environment. These codes must preserve good resolution, have good efficiency, and not introduce false background tracks. The offline data analysis starts in the relatively low-rate environment of the photon detectors. If a high-energy photon is reconstructed, then hits in the appropriate sections of the positron chambers that are consistent with a $\mu \rightarrow e\,\gamma$ event are searched for a reconstructable track. All reconstructed helices are then subjected to final kinematic cuts to search for $\mu \rightarrow e\,\gamma$.

3 Results

The resolution functions in energy (positron and photon), time, position, and direction are important components of the $\mu \rightarrow e\,\gamma$ analysis. The timing resolution function of the MEGA detector is measured using the decay $\mu \rightarrow e\,\gamma\nu\bar{\nu}$ (muon inner-bremsstralung decay). The observation of this decay mode with good timing resolution (1.5 ns FWHM) proves that the detector is capable of measuring a process that has a single muon decaying promptly into a positron and a gamma, as for $\mu \rightarrow e\,\gamma$. The photon energy resolution (~2 MeV) is measured using gammas from π^0s produced by a stopping π^- beam and the positron energy resolution (~1 MeV) is measured by the steepness of the edge for high-energy positrons produced by the decay $\mu \rightarrow e\,\nu\bar{\nu}$.

All the resolutions are expected to improve as analysis techniques are refined.

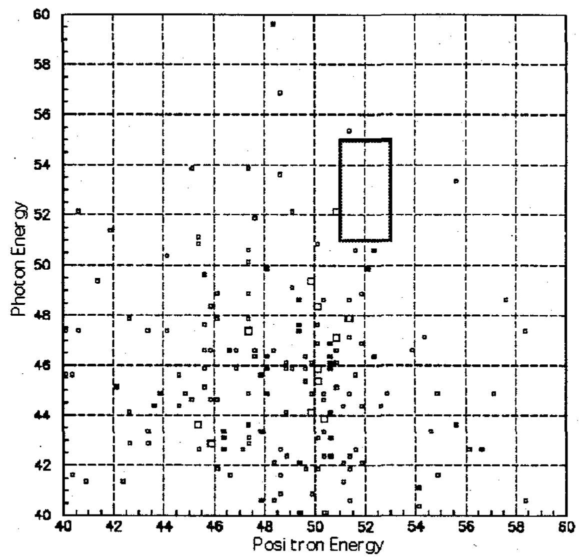

Figure 1: Photon energy versus positron energy for events passing kinematic parameter cuts.

Figure 1 contains a plot of photon energy versus positron energy. Events in this spectrum pass all trigger requirements, are fully reconstructed, and pass the following kinematic parameter cuts: the angle between the direction of the outgoing photon and the outgoing positron is larger than 178.5 degrees and the absolute decay time difference between the positron and photon is less than 1.75 ns. $\mu \rightarrow e\,\gamma$ signal events would be seen near 52.8 MeV in the photon energy and near 52 MeV in the positron energy (due to energy losses) and would appear within the signal box shown in the figure. No events appear in this box, which represents approximately two FWHM of the energy resolutions.

To measure the branching ratio limit this places on the $\mu \rightarrow e\,\gamma$ decay, the number of muons that decayed within the apparatus and the probability that a $\mu \rightarrow e\,\gamma$ would be detected are needed. The number of muon decays is scaled from scintillators and the acceptance of the detector is determined with Monte Carlo. The present data sample corresponds to a branching ratio limit of $\sim 7 \times 10^{-11}$ with 90% confidence. At the time of this writing there are still large uncertainties in the detector acceptance and efficiency. This analysis represents ~5% of the total data sample.

References

1. See, for example, R. Barbieri, L. Hall and A. Strumia, Nucl. Phys. B **445**, 219 (1995).
2. T.D.S. Stanislaus et al., Nucl. Inst. and Methods A **323**, 198 (1992); M. Barakat et al., ibid. **349**, 118 (1994); Y.K. Chen et al., ibid. **37,** 195 (1996).
3. J.J. Szymanski et al., *Intersections Between Particle and Nuclear Physics*, Ed. S.J. Seestrom, AIP Conference Proceedings Series **338**, (1994).