WEAK INTERACTIONS

MEGA: A SEARCH FOR THE DECAY $\mu \to e\gamma$

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For the last several years, an IUCF group has been working on the MEGA experiment, which is located at Los Alamos National Laboratory. The MEGA experiment was designed to detect the decay $\mu \to e\gamma$ with a substantially improved sensitivity over previous measurements. Detector construction was completed in 1993, after a successful engineering run in 1992. Production data sets were acquired in 1993-1995 and roughly 450 million events are now on tape, which were acquired over 1.1×10^7 seconds. The 1993 data set is the thesis project of IU student Keith Stantz, who is the only student doing a thesis on new measurements of $\mu \to e\gamma$ performed by MEGA.

The decay mode $\mu \to e\gamma$ violates the conservation of separate muon- and electron-type lepton flavor number. This decay mode is the subject of much recent theoretical interest.[1,2] The recent interest is mostly because the $\mu \to e\gamma$ decay provides information on supersymmetric extensions to the standard model. The branching-ratio prediction for $\mu \to e\gamma$ is quite large in supersymmetric models; indeed, the most stringent limits set on supersymmetric model spaces generally arise from experimental limits on the decay $\mu \to e\gamma$.

The detector has been described elsewhere, a description that will not be repeated here [Refs. 3-7, and previous IUCF annual reports]. During the detector construction, the IU group was responsible for the trigger hardware. A paper has been published in Nuclear Instruments and Methods describing the trigger system and associated electronics for the photon chamber readout.[7]

Since the first production data were produced from the 1993 run, the IU group has assumed a large role in the data analysis. The group's analysis responsibilities include: high-rate positron arm event reconstruction, precision target location, analysis of some of the inner bremsstrahlung data sets, the final $\mu \to e\gamma$ signal determination, and production running of analysis codes.

The decay $\mu \to e\gamma$ is separated from backgrounds by determing that the e and γ are produced at the same time, originate from the same point in space, are produced back-to-back, and each has an energy equal to half the muon rest mass, or 52.8 MeV. Therefore, the parameters that the data analysis must determine are the energy, direction and decay time for each electron and photon considered in the analysis. In addition, the resolution functions in electron and photon energy, direction and decay time need to be determined (actually, it is the time difference between the electron and photon decay times that is relevant).

Thus, the major elements for a full analysis of the MEGA data are: an electron-arm reconstruction code, a photon-arm reconstruction code, precision timing algorithms and constants for both arms, alignment algorithms, and the analysis of many other calibration processes (for example, target location, delay-line calibration for the photon-arm z information, electron scintillator ADC-timing correlations, etc.). In addition, substantial computing facilities and software infrastructure are needed to do production computing on the data set. Finally, the analysis of several subsidiary reactions is done to check the above codes.

The photon-arm analysis was emphasized in last year's annual report and will not be discussed here. Also, the measurement of the muon decay parameter ρ is continuing and will not be presented here, because the analysis does not presently involve IUCF personnel. For his thesis project Keith Stantz's primary responsibility is to produce the algorithms needed to reconstruct events in the extremely high-rate environment of the MEGA positron detector. High-rate in this case means that hit rates in portions of positron multiwire chambers exceeded 3 MHz per wire during production running. One of the measures of the reconstruction code efficacy is how well it reproduces the energy spectrum for the dominant muon decay channel, $\mu \rightarrow e\nu\bar{\nu}$. The positron energy distribution produced by the reconstruction code for high-rate data is shown in Fig. 1. This spectrum demonstrates the quality of the reconstruction code with regard to energy resolution (the steepness of the high-energy fall-off) and background rejection (there is an accetable tail in the physically inaccessible energy range above 53.5 MeV).

The decision to provide production running of the analysis codes at IUCF was based on the fact that, at the time, IUCF had more computing resources available than any other MEGA collaborating institution. The IU group also had people available to run and monitor the production computing. The computing infrastructure available at IUCF enabled this process to go forward, which emphasizes the importance of the technical capability at IUCF, for both on- and off-site experiments.

We ran the first-level offline filter on the 1993 data set during the summer of 1995. This filter was outlined in last year's annual report. Its purpose is to decide if chamber hits with sufficient quality exist in the correct places to consider the event further. Running of the 1994 data set has proceeded at IUCF and the 1995 data set is being processed at Los Alamos.

The timing resolution function of the MEGA detector is measured using the decay $\mu \rightarrow e\gamma\nu\bar{\nu}$ (muon inner-bremsstrahlung (IB) decay). Figure 2 shows a spectrum of the time-difference taken between the positron and photon spectrometers for IB decay. This spectrum was produced with the 1993 data. The peak near zero time difference clearly shows the presence of the muon IB decay in the data set. The observation of this decay mode proves that the detector is capable of measuring a process that has a single muon decaying into a positron and a gamma, as for $\mu \rightarrow e\gamma$. The resolution is expected to improve to 1 ns or better after walk corrections in the positron scintillators are made and the optimal use of all scintillator times is included. The IB decay has also been observed in the high-rate MEGA production data, where online cuts limit the acceptance for IB.

The statistical weight of the full data set is sufficient to allow the collaboration to set an upper limit for the branching ratio of 7×10^{-13} with 90% confidence. This expectation

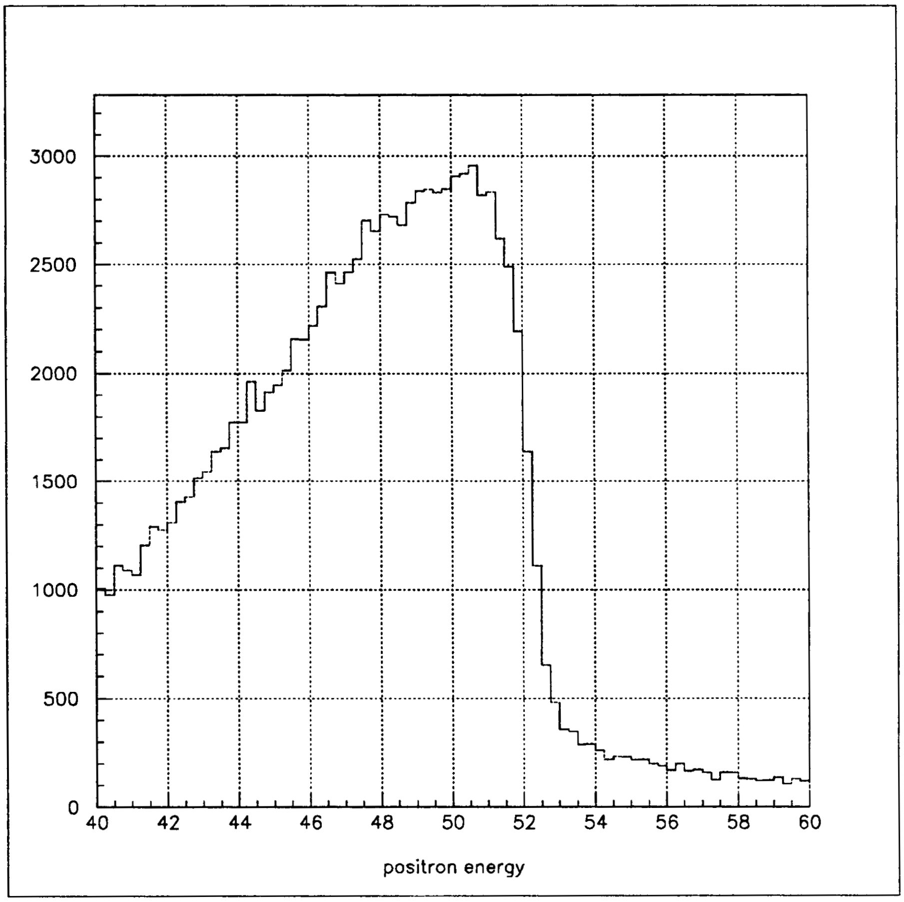

Figure 1. Energy spectrum for the decay $\mu \rightarrow e\nu\bar{\nu}$. This spectrum has the expected shape, reasonable resolution and an acceptable background in the physically inaccessible energy range above 53.5 MeV.

is based on our present estimates of the resolutions and efficiencies of the many detector elements. A challenge for the analysis is to achieve the expected high level of performance from the detector; deviations from our current estimates could reduce the sensitivity. The IUCF contributions during the time period for this proposal include: code development (the high-rate reconstruction codes, target location), about half of the production computing, $\mu \rightarrow e\gamma$ signal determination, and development work on 'afterburner' codes as needed to improve resolutions.

If a signal for the $\mu \rightarrow e\gamma$ decay were observed, the present published upper limit would allow as many as 170 signal events in our data, at the sensitivity described above. The detector has been mothballed and could be revived if there is a need to take additional data.

1. R. Barbieri, L. Hall and A. Strumia, Nucl. Phys. **445**, 219 (1995).
2. L. Wolfenstein and Y.L. Wu, preprint.
3. M. Barakat *et al.*, Nucl. Instrum. and Methods **A349**, 118 (1994).

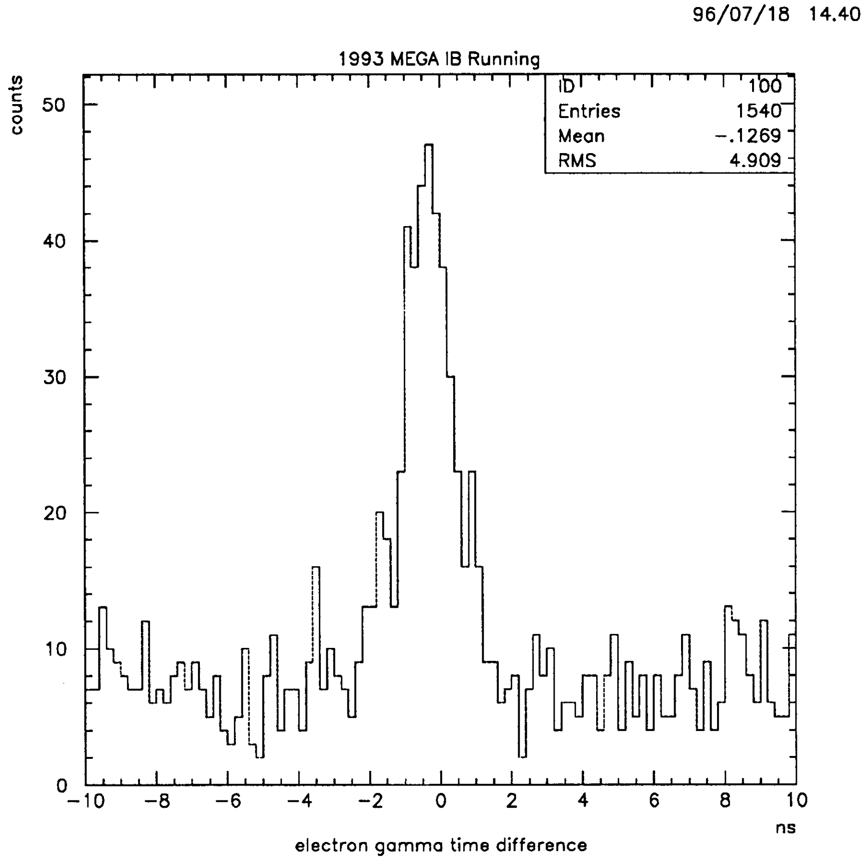

Figure 2. Time difference spectrum between the photon and electron arms. This spectrum is shown for a special data set taken during the 1993 run to see muon inner-bremsstrahlung decay ($\mu \to e\gamma\nu\bar{\nu}$). This spectrum clearly shows a peak near a time difference of zero, which indicates the inner-bremsstahlung decay is present in the data sample. The large accidental background in this spectrum is expected from the high rates at which this spectrum was taken.

4. D.D. Koetke *et al.*, *Intersections Between Particle and Nuclear Physics*, ed. W.T. Van Oers (AIP Conf. Proc. 243, 1991).
5. T.D.S. Stanislaus *et al.*, Nucl. Instrum. and Methods **A323**, 198 (1992).
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7. Y.K. Chen, M.D. Cooper, P.S. Cooper, M. Dzemidzic, C.A. Gagliardi, G.E. Hogan, E.V. Hungerford, G.J. Kim, J.E. Knott, K.J. Lan, F. Liu, B.W. Mayes, R.E. Mischke, R. Phelps, L.S. Pinsky, K.M. Stantz, J.J. Szymanski, L.G. Tang, R.E. Tribble, X.L. Tu, L.A. Van Ausdeln, W. Von Witsch and C.S. Wright, Nucl. Instrum. and Methods **A372**, 195 (1996).