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Title: MEGA — A Search for $\mu \to e\gamma$

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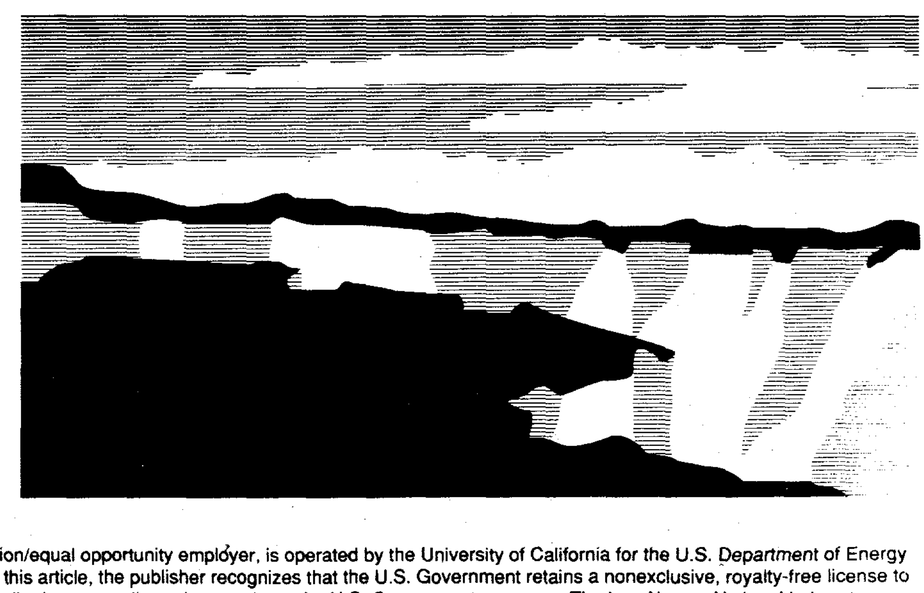

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MEGA - A Search for $\mu \rightarrow e\gamma$

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The MEGA experiment[1,2] is a search for the decay $\mu \rightarrow e\gamma$. Even though there is no fundamental reason to expect lepton number to be a conserved quantity, processes such as $\mu \rightarrow e\gamma$ have not been observed. (The present upper limit[3] for the branching ratio for $\mu \rightarrow e\gamma$ is 4.9×10^{-11}.) The minimal standard model of electroweak interactions, which is enormously successful, builds in lepton number conservation. However, the decay $\mu \rightarrow e\gamma$ is expected in many extensions to the standard model, in particular in supersymmetry models.[4]

The experimental signature for $\mu \rightarrow e\gamma$ from decays at rest is the observation of a positron and photon, each of 52.8 MeV, that are back-to-back, in time coincidence, and originate from a common spatial point. The MEGA detector consists of two spectrometers designed to measure the kinematic characteristics of positrons and photons to search for events with this signature. A schematic of the apparatus is shown in Fig. 1. The detectors are contained in a large solenoidal magnet with a 1.5-T field. A beam of 29 MeV/c muons is incident along the central axis of the magnet, and the muons stop in an extended thin Mylar target. All of the charged particles arising from muon decay are confined to the central positron region. The positron arm consists of scintillators for timing and a set of multi-wire proportional chambers[5] for momentum determination. The photon arm is three concentric pair-spectrometers,[6] each of which is made of lead converters, MWPCs, drift chambers, and scintillators.

The trigger for the experiment was designed to select events with a high-energy photon.[7] The data acquisition system included two levels of hardware trigger. An essential feature of the on-line filter (third-level trigger) was that the two spectrometers must be in time with one another. The only direct evidence of this timing is the observation of the allowed process $\mu \rightarrow e\gamma\nu\nu$. The clear peak observed in Fig. 2 at a time difference of zero demonstrates that the timing was correctly prepared and that the apparatus can observe a real coincidence process.

The primary difficulty in the analysis of these data has been the development of reconstruction algorithms that balance efficiency and resolution. Also, many calibrations and corrections are needed to get optimum resolutions. Most surviving candidate events are accidentals. Each part of Fig. 3 has three distributions superposed. In Fig. 3a is shown the positron spectrum, which follows the characteristic normal muon-decay shape and a tail of high-energy events. The narrow spectrum is from Monte Carlo simulation of $\mu \rightarrow e\gamma$ events. The few, scattered events are what remain after cuts are applied on the other kinematic variables to include about 80% acceptance. In Fig. 3b, the photon energy spectrum reproduces a characteristic bremsstrahlung shape with an endpoint at 52.8 MeV and a tail of events at higher energies. Figure 3c shows the positron-photon timing and Fig. 3d shows the back-to-back angle. Figure 4 shows the positron and photon energies for events cut on the other variables. These are the surviving candidates from about 10^8 events that passed the on-line filters and were recorded during the 1993 run. These data represent about 16% of the data and yield a background-free upper limit of 4.2×10^{-11}.

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*Supported in part by the U.S. Department of Energy, the National Science Foundation, and the R. A. Welch Foundation.

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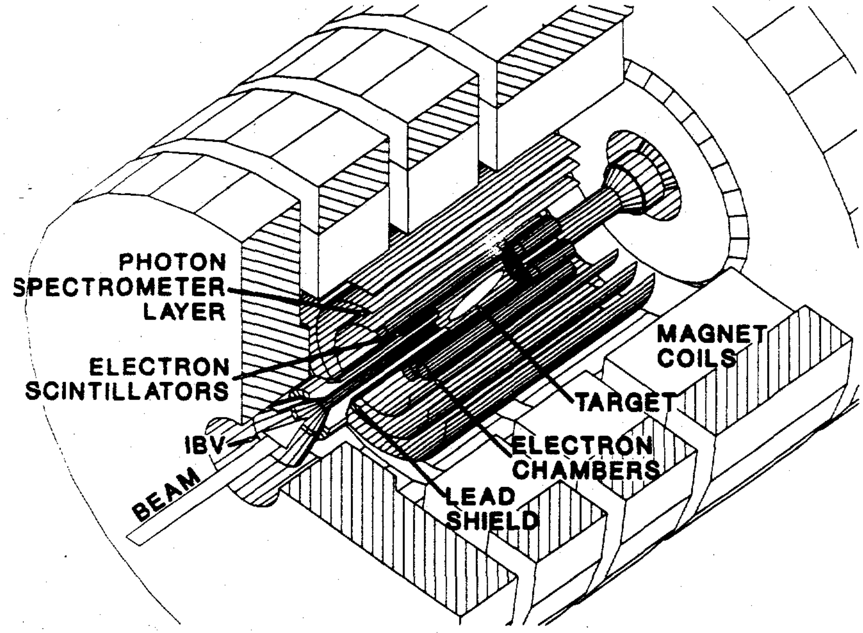

Fig. 1. A simplified cutaway view of the MEGA apparatus. The detector is mounted inside a superconducting solenoid with a 1.5-T field. The muons enter along the magnetic field and stop in the target. Positrons from muon decays are detected in the eight cylindrical wire chambers and the cylindrical arrays of scintillators surrounding the beam pipes. The three large cylinders are pair spectrometers for photon detection.

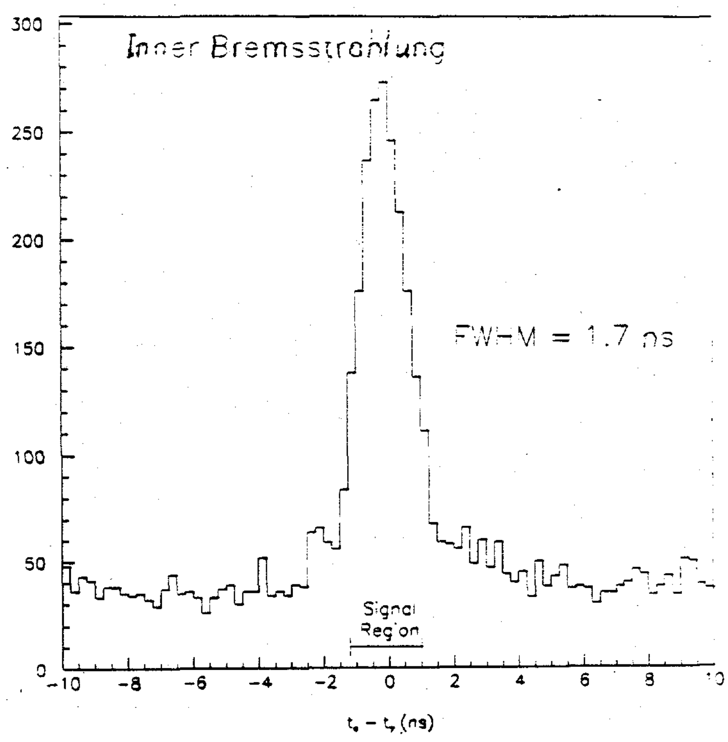

Fig. 2. The timing spectrum that indicates the presence of coincidences of positrons and photons from the expected process $\mu \to e\gamma\nu\nu$.

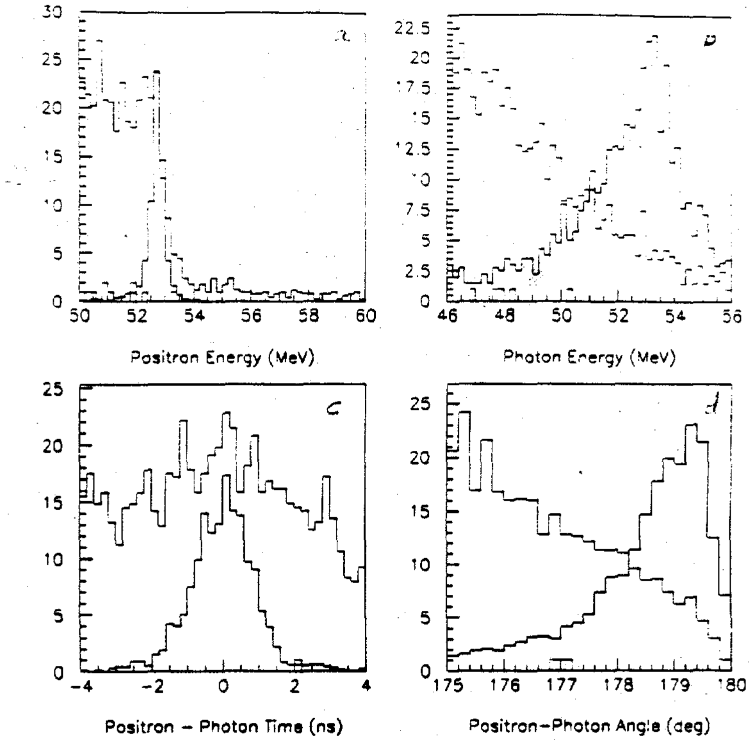

Fig. 3. Kinematic quantities of candidate events for $\mu \to e\gamma$. Each part of the figure has three distributions superposed. See text for details.

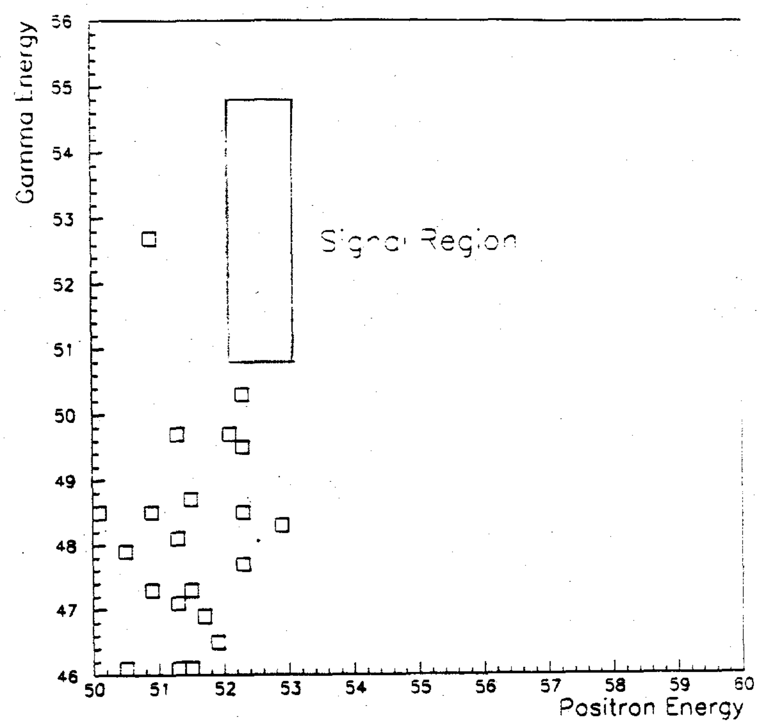

Fig. 4. Scatter plot of Ee and Eg for events closest to the signal region for $\mu \to e\gamma$.