MEGA: A SEARCH FOR THE DECAY $\mu^+ \rightarrow e^+\gamma$

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The MEGA (Muon decays into an Electron and a GAMma ray) experiment is the search for the rare muon decay $\mu^+ \rightarrow e^+\gamma$ at the Los Alamos Meson Physics Facility (LAMPF experiment 969). The experiment is designed with a branching-ratio sensitivity of $2 \times 10^{-13}$, which represents a factor of 300 improvement over the existing limit. The decay $\mu^+ \rightarrow e^+\gamma$ violates conservation of lepton-family number, and the observation of this decay would signal new physics not explained by the minimal standard model. Among the possible muon-number-violating rare decays, the branching ratio for $\mu^+ \rightarrow e^+\gamma$ decay is relatively large in models employing more than three generations, right-handed neutrinos, extra Higgs doublets, composite particles, or supersymmetry.

The signature for the decay $\mu \rightarrow e \gamma$ is purely kinematic and distinct from all prompt backgrounds; the positron and photon are back-to-back in time and have the fixed energy 52.8 MeV, which is one-half of the muon rest mass. The experiment is, therefore, designed to detect positrons and photons with energy near 50 MeV with good energy, spatial, and time resolutions.

A side view of the MEGA detector is shown in Fig. 1. The detector is contained within a superconducting solenoid with clear bore 2.2 m long by 1.9 m in diameter and 15 kG magnetic field. A positive muon beam of average intensity $3 \times 10^7$/sec is brought to rest in a CH$_2$ target that is located in the center of the detector. Each muon produces a positron via the normal muon decay $\mu \rightarrow e^+\nu\bar{\nu}$, and the magnetic field confines these positrons within a radius of 30 cm from the beam center. This inner region is instrumented with eight cylindrical multiwire proportional chambers (MWPC's) and two scintillator arrays, and serves as the positron spectrometer. The positron spectrometer resolution is designed to be 0.6% in angle, 0.6% (FWHM) in energy and 0.5 nsec in time.

Photons are detected in one of four independent, cylindrical pair spectrometers that surround the positron spectrometer. Photons are converted into $e^+ e^-$ pairs in one of two 0.025-cm thick lead converters located on the inner and outer radii of an MWPC. The MWPC determines the lead layer in which the photon converted and is an essential part of the trigger signal. A barrel of $1 \times 5 \times 180$ cm$^3$ scintillators is located just inside of the first lead layer for timing and trigger information. Outside of the second lead layer are three layers of drift chambers which provide tracking information to measure the pair energy. The photon spectrometer resolution is designed to be 10% in angle, 3% in energy, and 0.5 nsec in time.

The IUCF contribution to the MEGA experiment consists of major portions of the first- and second-level trigger systems, and responsibility for integrating the parts of the trigger system into the overall experiment. Figure 2 contains a schematic drawing of the MEGA trigger system. To reduce deadtime in the data acquisition, there are separate banks of FASTBUS (FB) modules for each photon spectrometer. There is also a pattern recognition module (p.r.m.) for each photon spectrometer, which gives a trigger if a photon with more than $\sim 37$ MeV is detected. Each bank of FB modules is only triggered if a
Figure 1. Side view of the MEGA detector.

A photon is detected in that particular spectrometer. To further reduce deadtime, all of the scintillators in the positron spectrometer are connected to two banks of TDC’s, which are triggered on alternate events. This highly parallel readout system needs a device called the routing box to route trigger signals to the proper bank of FB modules, after testing to see if all the FB modules in the bank are not busy and can accept data. The triggers produced in the p.r.m.’s represent basic cuts, such as a photon energy threshold. The routing box makes logical combinations of the basic trigger signals from one or more p.r.m.’s to produce the more restrictive triggers needed to make physics measurements, to calibrate the detector or to do other tests. A second level trigger p.r.m. takes information from the photon spectrometer drift chambers and provides an additional photon energy cut.

The output of the routing box is sent to trigger fanout and busy modules (TF/B) one of which is located in each FB crate. These modules fanout the trigger signals to each of the FB modules, and fan in the busy outputs of the FB modules. The communication of the TF/B modules with particular FB modules is under computer control. Computer control of the TF/B modules allows us, for example, to easily re-configure the trigger system from a production data acquisition mode to a calibration mode.

The specific IUCF hardware responsibilities are: the design, fabrication and testing of the routing box and the TF/B modules. We also
have the responsibility for integrating the entire trigger system (including the p.r.m.'s), testing it as a system and analyzing test results.

A first generation routing box has been in place and working at LAMPF for several years, along with approximately half the TF/B modules. Design, fabrication and testing of the final routing box and TF/B modules will be done over the next twelve months in preparation for MEGA data runs in 1992 and 1993. A graduate student, Keith Stantz, will be joining IUCF in June 1991 to work on this project.

3. See, for example, J.D. Vergados, Phys. Reports, 133, 96 (1986).