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GLAST Beam Test at SLAC

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Abstract

In May and June, a beam test for GLAST calorimeter technologies was conducted. A parasitic low intensity electron/tagged photon beam line into the End Station A at SLAC was commissioned and used. The preliminary stage of the test was devoted to measuring the performance of the parasitic beam. In the main test we studied the response of GLAST prototype CsI and scintillating fiber calorimeters to the electrons and photons. Results of this work are discussed.

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End Station A(ESA) beam line.

The SLAC A-line was designed 35 years ago to deliver electron beams from the linac to fixed target experiments in the End Station A experimental hall. It was later upgraded to support beams at energies up to 50 GeV [1].

Recently, a technique was developed to provide parasitic low intensity secondary electron and positron beams, with energies as low as 1 GeV and intensities averaging several electrons per pulse and 120 pulses per second [2]. Photons produced in the SLAC Linear Collider SLC beam collimators in the linac are converted to electrons in a target downstream from the SLC splitter magnet as shown in Figure 1. Some of these electrons go down the A-line where collimators select a momentum bite of 0.5% to 2%.

ESA data acquisition and data analysis

Data acquisition was accomplished using the E154 experiment data acquisition system [3], with minor modification. Experiment control functions and experiment monitoring are done on VAX VMS computers. The DAQ is capable of recording about 6 Kb of data from CAMAC modules per pulse at 120 pulses per second. Data logging from the experiment to the SLAC Computing Services SCS Silo system was done through the SLAC Staging system controlled by a remote data server. Any number of the on-line analysis jobs can be launched, on different computer platforms, to analyze the event data obtained on-line by way of network connection.

The main FORTRAN code of the data acquisition routine can incorporate user subroutines. These supply histograms and other data to the Physics Analysis Workstation (PAW) analysis program by shared memory segment and semaphores. PAW is a standard high energy physics data analysis package developed at CERN and freely distributed [4].

For the off-line analysis the on-line analysis software is used, now linked to the recorded data downloaded from tapes. The base part of the code translates the records into FORTRAN common blocks. User supplied subroutines process the data and define and fill out HBOOK histograms that can be saved for further analysis with the PAW program.

Test of the test beam.

To characterize the beam, the number of electrons per pulse was measured for various energy settings of the A-line between 1 - 40 GeV. At each energy, the optics of the beam was optimized for background and yield.

The measurements were done using a beam-defining set of 3/4-in.-wide plastic scintillator fingers and a lead glass calorimeter block shown in Figure 2. The fingers were used to obtain crude information about the beam's spatial distribution and to adjust the steering magnets. The pulse height distribution for 6 fingers is shown in Figure 3. Figure 4 shows the pulse height distribution from the lead glass. Each peak corresponds to a particular number of electrons per pulse. The first peak is the ADC pedestal. The A-line beam collimators were in full open position for these measurements.

A Poisson distribution was fitted to the amplitudes of these peaks to obtain the yield. Figure 5 shows the results of this fitting in 1.0 - 2.0 GeV range. We see that the maximum yield is approximately linear in energy in the studied range. The rate can be decreased using the A-line SL10 collimator. Figure 6 shows the rate is linear in the opening of SL10.

Beam test

The main purpose of the beam test was to study two prototype calorimeter technologies for GLAST. The test was conducted in June 1996. Two calorimeters were tested: a CsI(Tl) and a scintillating fiber calorimeter. Various configurations were used during the test (Figure 7). Both devices were studied in longitudinal and transverse positions to the beam line. A remotely controlled moveable X-Y table was useful for calibration of individual pixels and for temporary removal of particular devices from the beam line. The energies of the electron beams used were 1.3, 1.9, 5.0 and 9.5 GeV, with intensities from 0.1 to 2 electrons per pulse at 120 pulses per second. There were no significant problems with the A-line running, GLAST hardware, DAQ, and data logging during the experiment. We recorded seventeen 800-Mb tapes of data. Off-line data analysis of the results is currently being conducted at all participating institutions.

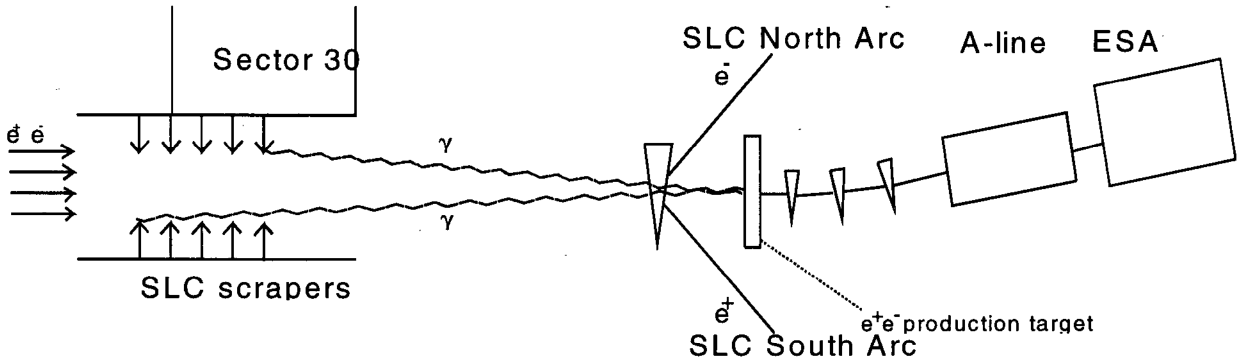


Figure 1. Parasitic beam generation

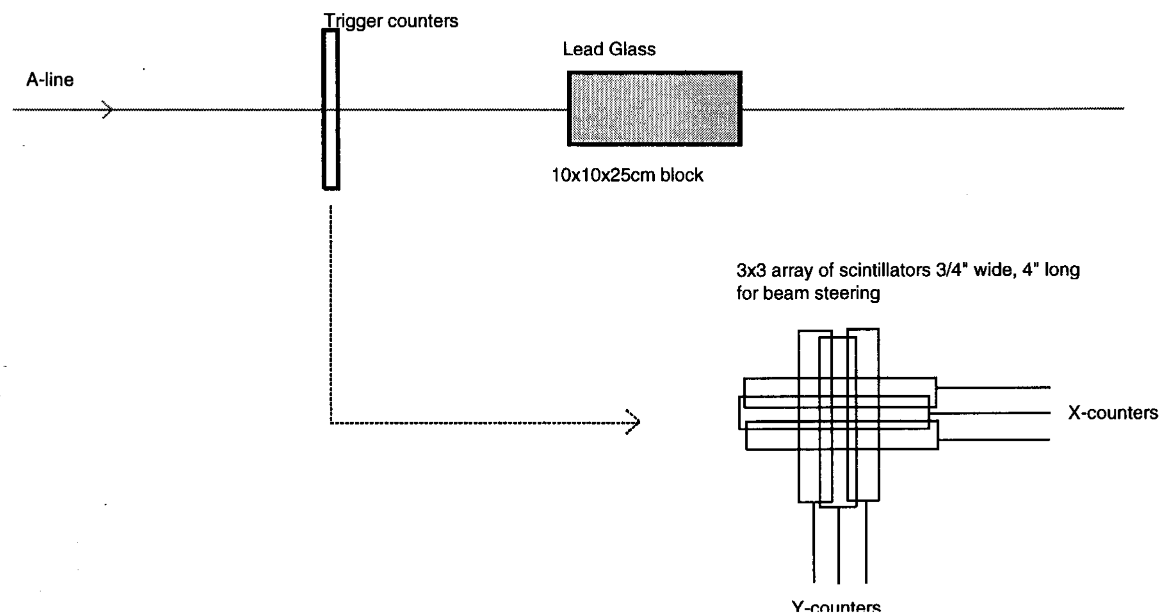


Figure 2. Test of the test beam experimental setup

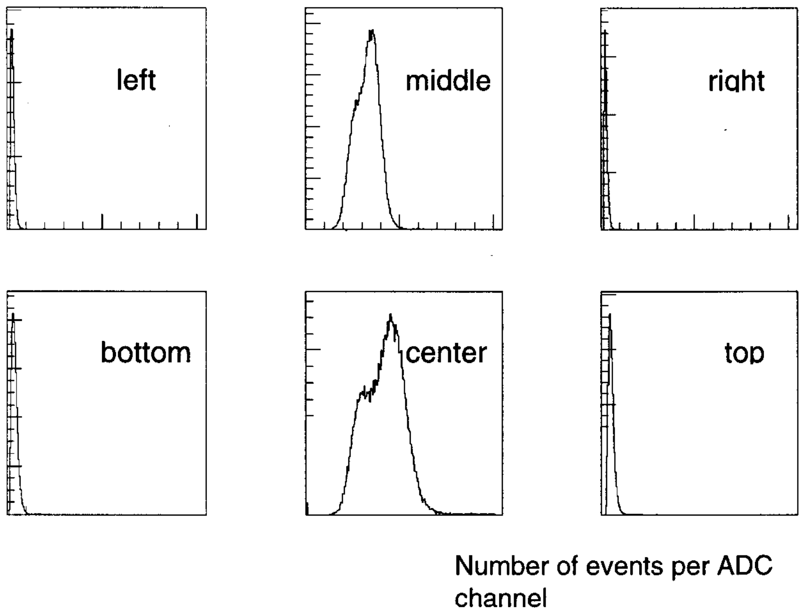


Figure 3. Fingers pulse height distribution. 20 GeV run.

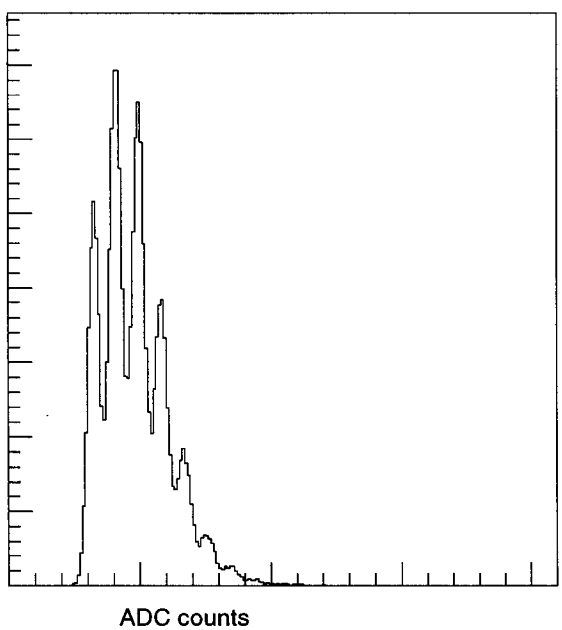


Figure 4. Lead glass pulse height distribution.

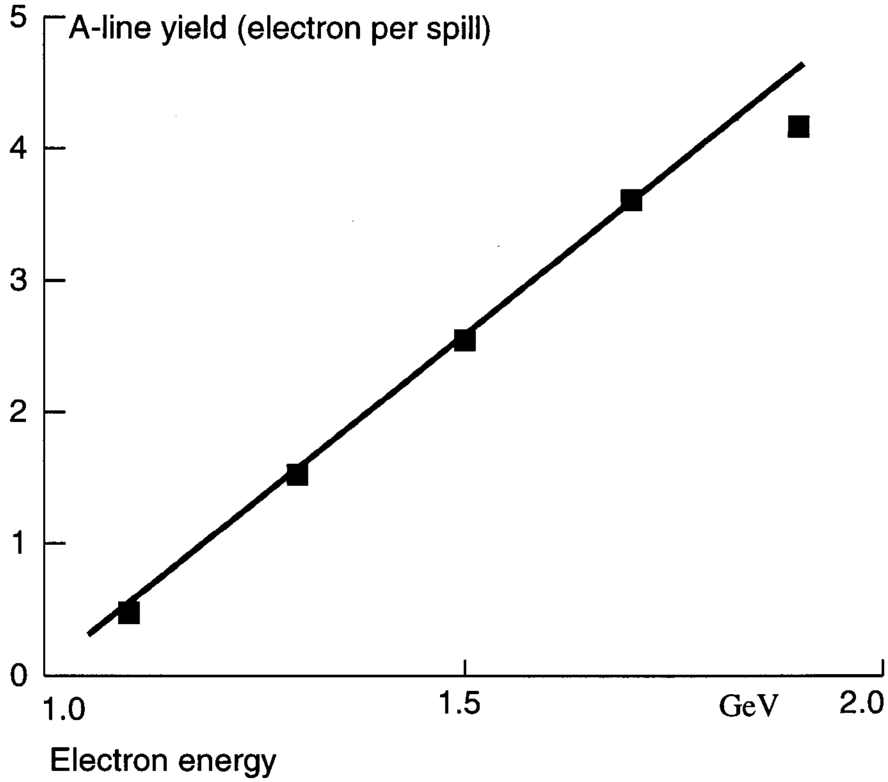


Figure 5. A-line yield.

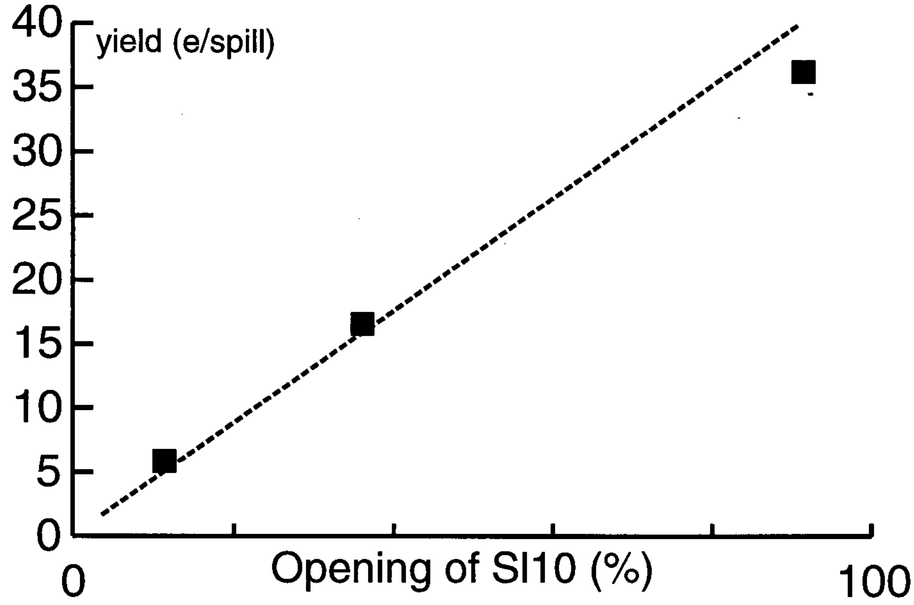
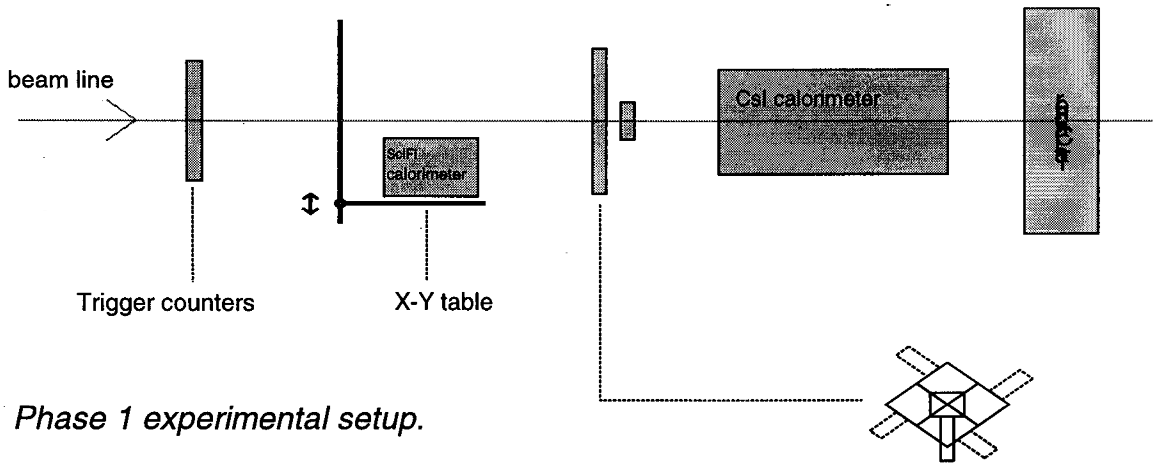
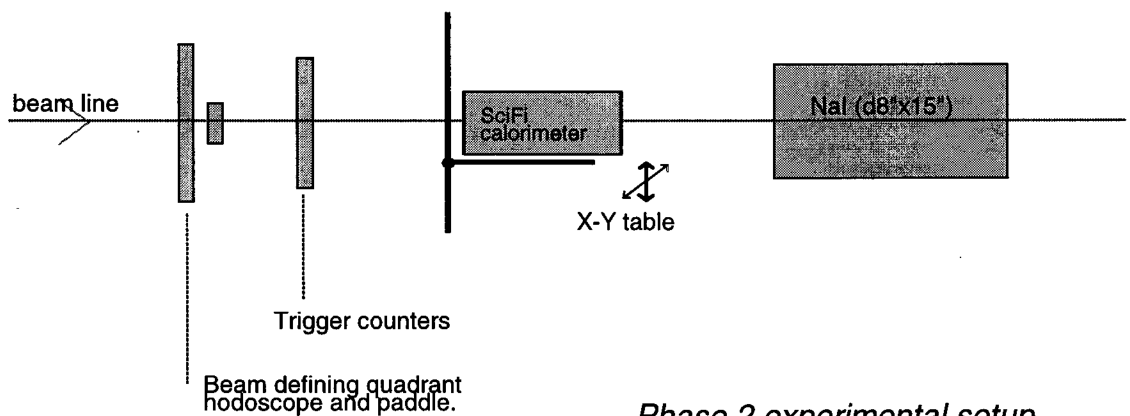


Figure 6. A-line yield in SL10 collimator opening for 20 GeV.



Phase 1 experimental setup.



Phase 2 experimental setup.

Figure 7. Experimental setup for the two phases of the beam test. Other configurations were also used.

Tagged photon production

To create photons, 3.5% of a radiation length of copper is placed in the electron beam as it enters ESA. Downstream from the radiator a large magnet bends the electrons into two multi-wire proportional chambers followed by a lead glass calorimeter (Figure 8). The wire chambers consist of two layers, x and y, 176 wires in each with 2 mm spacing. This gives a 1-mm resolution in determining the position of a hit. The calorimeter consists of three lead glass blocks (10 x 10 x 25 cm each). Radiated photon energy is then determined by subtracting electron energy from the energy of the beam. Given the energy spread of the beam to be about +/- 2% , it is feasible to tag photons down to 50 MeV, with about +/- 50% accuracy at the lowest photon energy. In the present preliminary analysis we did not go below 200 MeV.

The energy of the bent electron can be determined by two independent methods. The first method determines the energy by measuring electron energy in the Pb glass (Figure 9). It is calibrated by steering the beam into each of the three blocks. Then the sum of the energy is used to measure the energy of the radiating electron. In the second method electron deflection is compared with the deflection of the main beam. Figure 10 shows a 1.93-GeV beam scatter plot in wire chambers. Only the electrons with vertical position near the center of the beam are selected. Figure 11 shows a scatter plot of Pb glass energy versus wire chamber x hit position for a 1.9-GeV beam. The nonradiated beam spot has $\sigma_{x,y}$ ~20mm (due mainly to the intrinsic beam size). The beam is deflected by ~620 mm. This results in an energy resolution of ~60 MeV for the radiated photon. The resolution will be improved in the future by using an accurate beam-position-defining telescope upstream of the bend magnet. This yielded a photon energy resolution similar to that of a wire chamber (Figure 12).

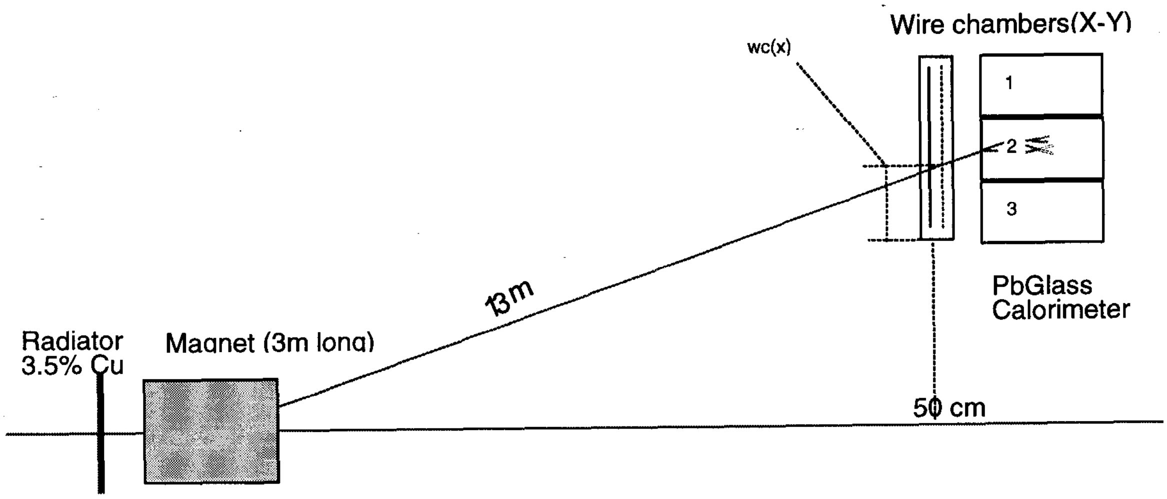


Figure 8. Photon tagging setup

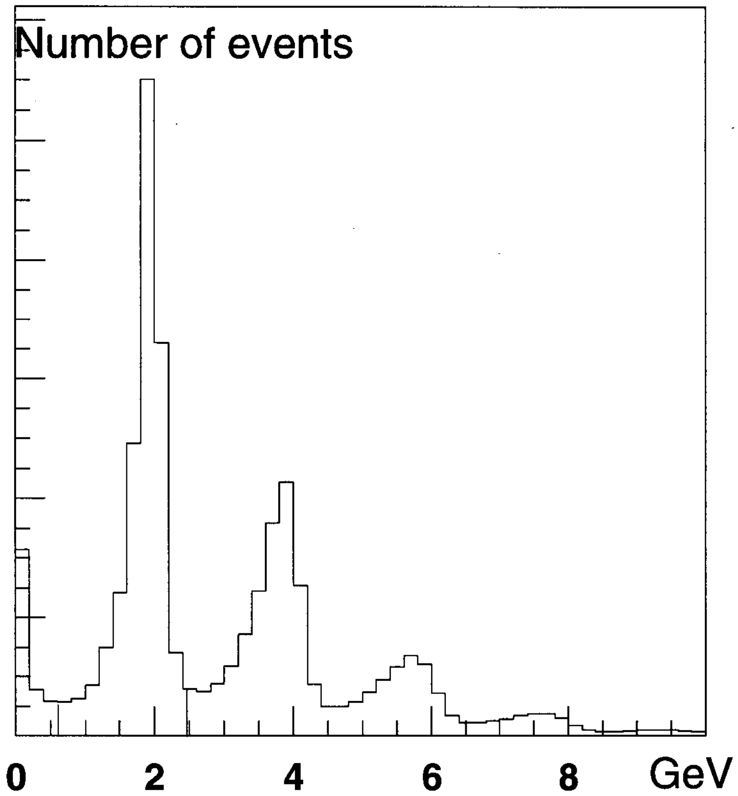


Figure 9. Pb glass total energy distribution. Single electron peak is selected.

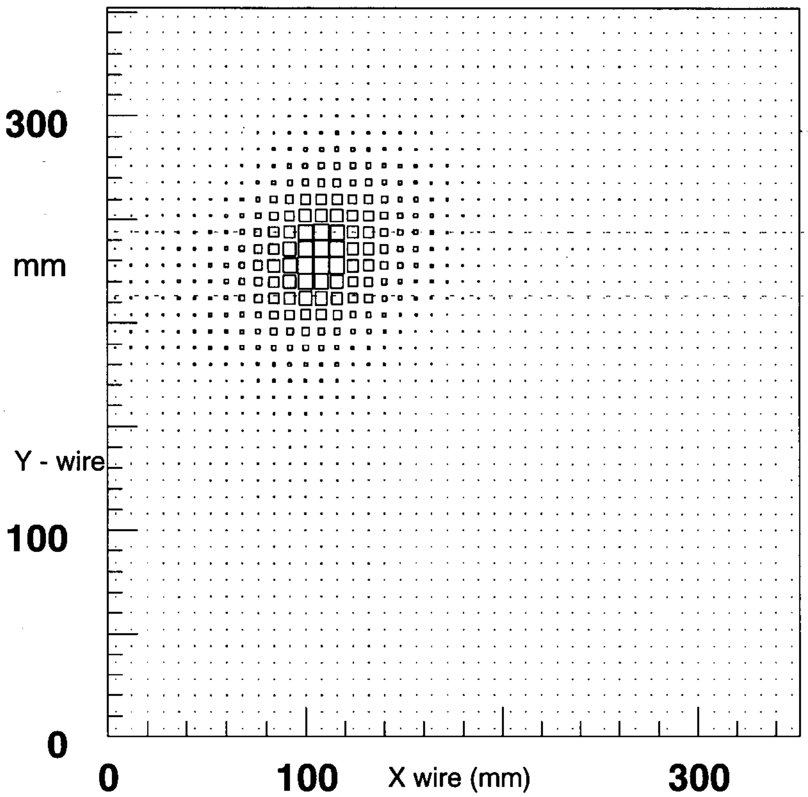


Figure 10. 1.93-GeV beam scatter plot in wire chambers. Events between dashed lines are used.

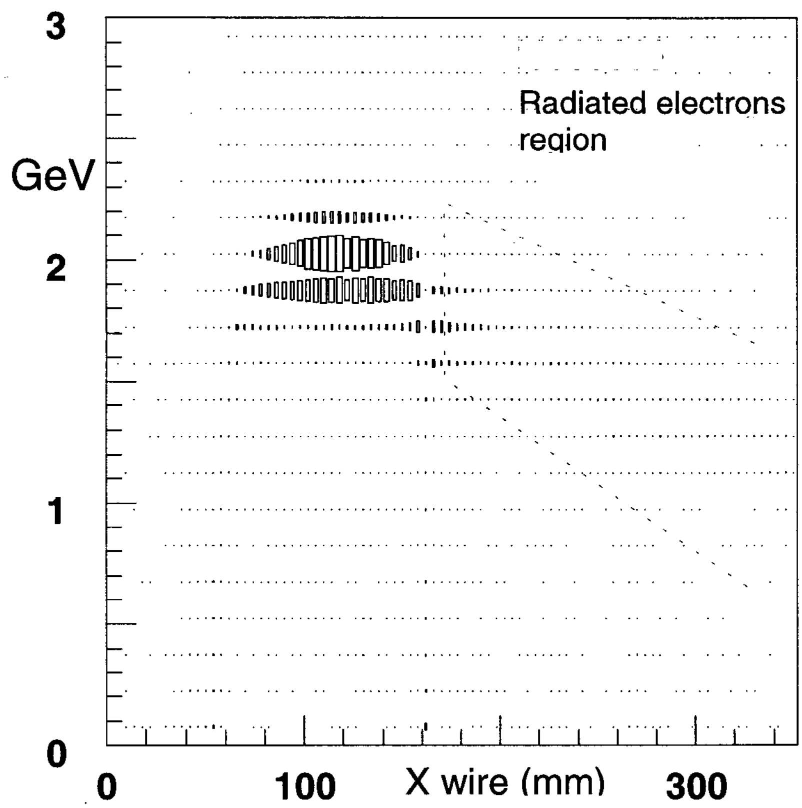


Figure 11. Scatter plot of Pb glass energy versus wire chamber hit position for a 1.93-GeV beam. Single electron events selected.

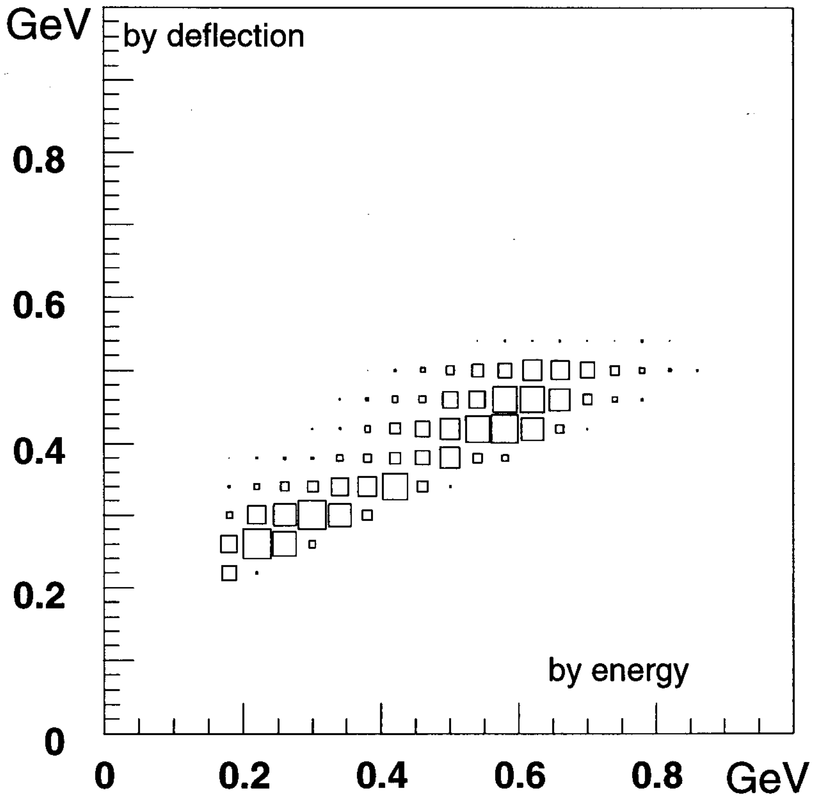


Figure 12. Photon energy calculated by electron deflection versus that calculated by Pb glass energy deposition.

CsI calorimeter

The CsI calorimeter, built at NRL, consists of a 5 by 5 array of CsI(Tl) crystals, each of dimensions 3 cm x 3 cm x 10 radiation lengths. They are each read out by two PIN Hamamatsu S3590 photodiodes, each placed on the ends of the crystal. The calorimeter is calibrated by putting a 1.3-GeV electron beam into the center of each crystal. Figure 13 shows the pulse height distribution and single electron peak for one crystal. The readout saturated at higher beam energies. We also recorded runs with the CsI calorimeter placed sideways into the 1.3, 1.9, 5.0 GeV electron beams and into photon beams.

It was possible to detect non-tagged photons with energy down to 5 MeV. A technique for determining the position of the beam using light attenuation along the crystal was tested. It allows us to measure the position of the beam with accuracy comparable with its size by comparing readouts on both ends. Analysis of the results, which entails comparing the observed behavior with Monte-Carlo studies, is under way at NRL and other participating institutions.

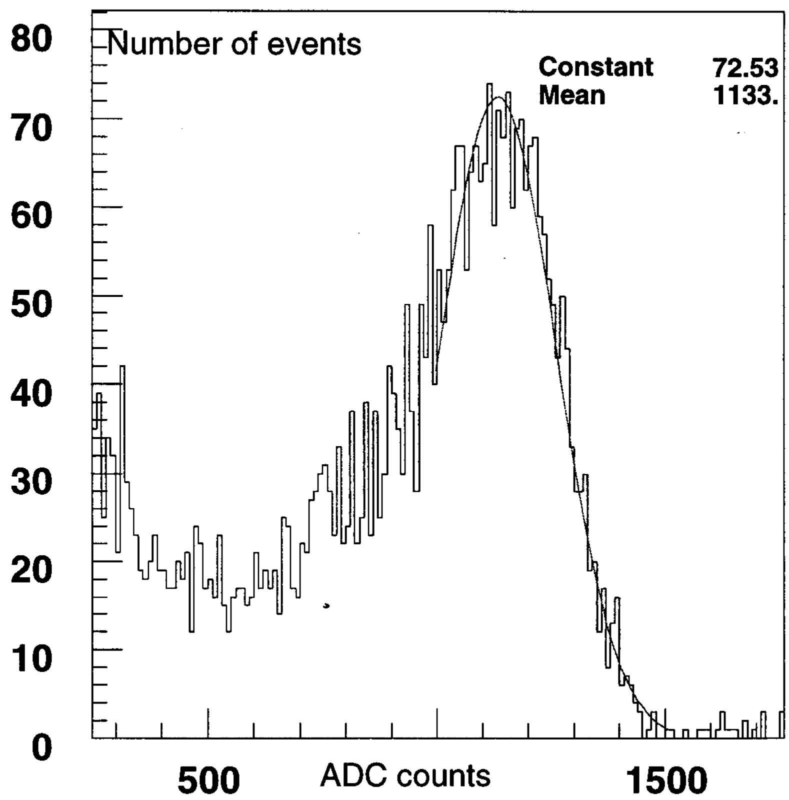


Figure 13. CsI calibration at 1.3 GeV. Single electron peak fitted.

Scintillating fiber calorimeter.

To study the properties of modern scintillating fiber calorimeters, and to check the Monte Carlo modeling of such materials, a crude calorimeter module was constructed at the University of Chicago. Pb/fiber material in the volume ratio 42%:58% was donated (courtesy of Prof. G. Barbiellini) by the KLOE Collaboration, which has constructed a large HEP calorimeter with this material. Enough material was obtained to construct a rectangular block measuring 14.9 cm x 14.9 cm x 18.8 cm, with the fiber axis along one of the shorter axes; this machining was performed at the University of Chicago. The KLOE material has L_{rad} = 1.6 cm and $R_{moliere}$ = 3.8 cm, giving depths of 9.3 L_{rad} transverse to the beam and 11.75 L_{rad} along the beam direction. The Pb/scintillating fiber material has eighteen 1"x1" pixels and four 1/2"x3/4" pixels that are readout by PMTs. The calorimeter was calibrated by directing beams of 1.3, 1.9 and 5 GeV electrons into the center of each pixel. The beam direction was along the fibers.

Figure 14 shows the single electron pulse height distribution at 1.9 GeV for one central pixel. Figures 15 and 16 show calorimeter performance for photons radiated from a 1.9 GeV beam. The preliminary analysis shown here was done at the University of Chicago and SLAC. Further analysis is continuing.

Conclusions

A new parasitic electron/tagged photon test beam was commissioned at SLAC and its yield was measured at various energies between 200 MeV to 40 GeV. Experience in the use of the ESA beamline and DAQ was gained by GLAST collaborators. This test beam will be used for future GLAST prototype studies. The test discussed here determined the properties of GLAST prototype CsI and scintillating fiber calorimeters. Energy resolution and leakage analysis are continuing for both calorimeters.

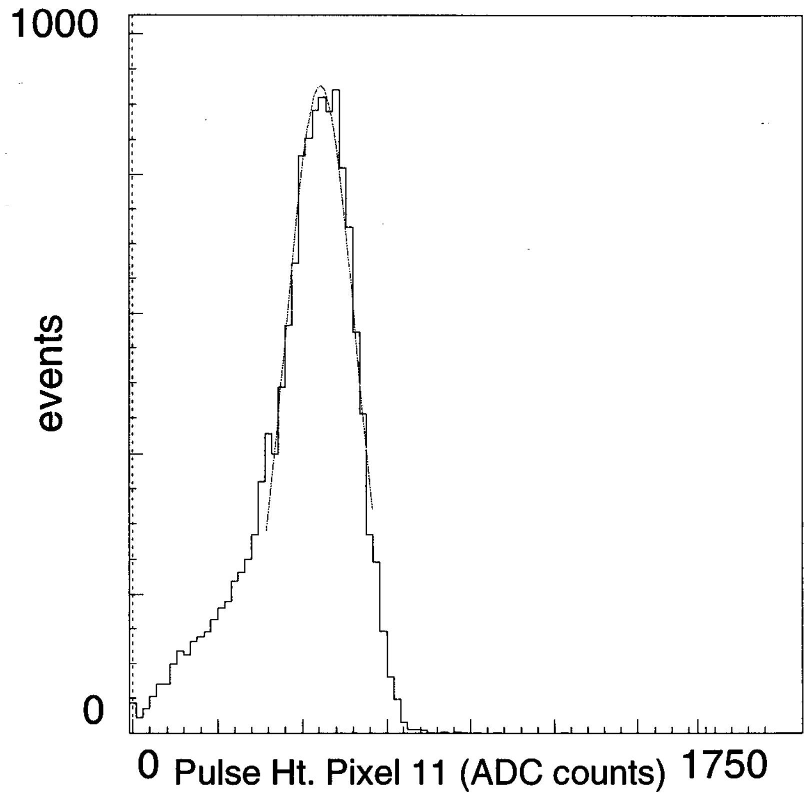


Figure 14. Calibration spectrum of the central pixel. 5.07 GeV electrons, cut on singles.

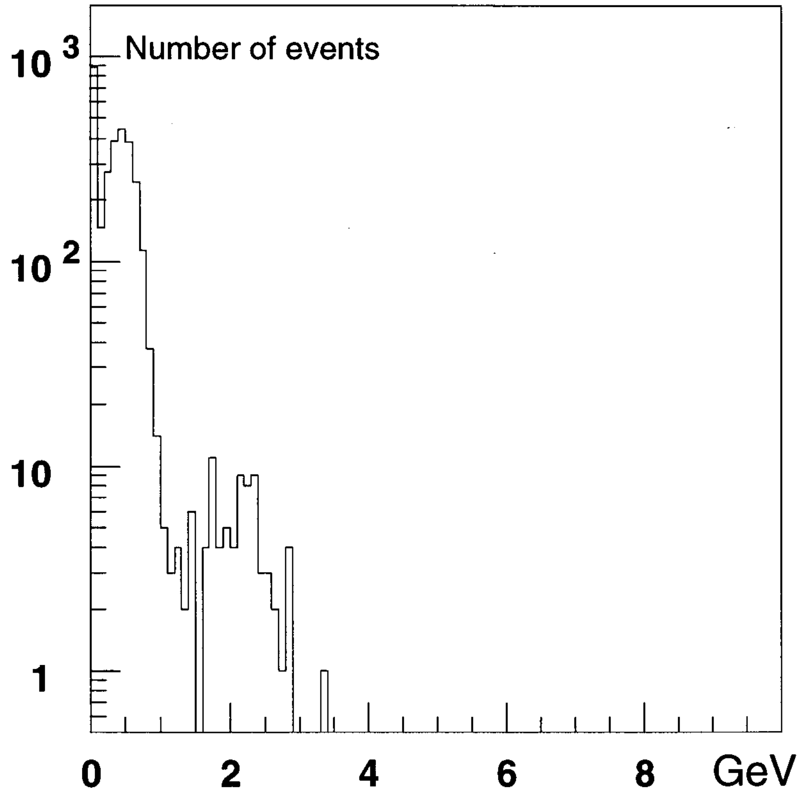


Figure 15. Total energy in SciFi calorimeter cut on photon events.

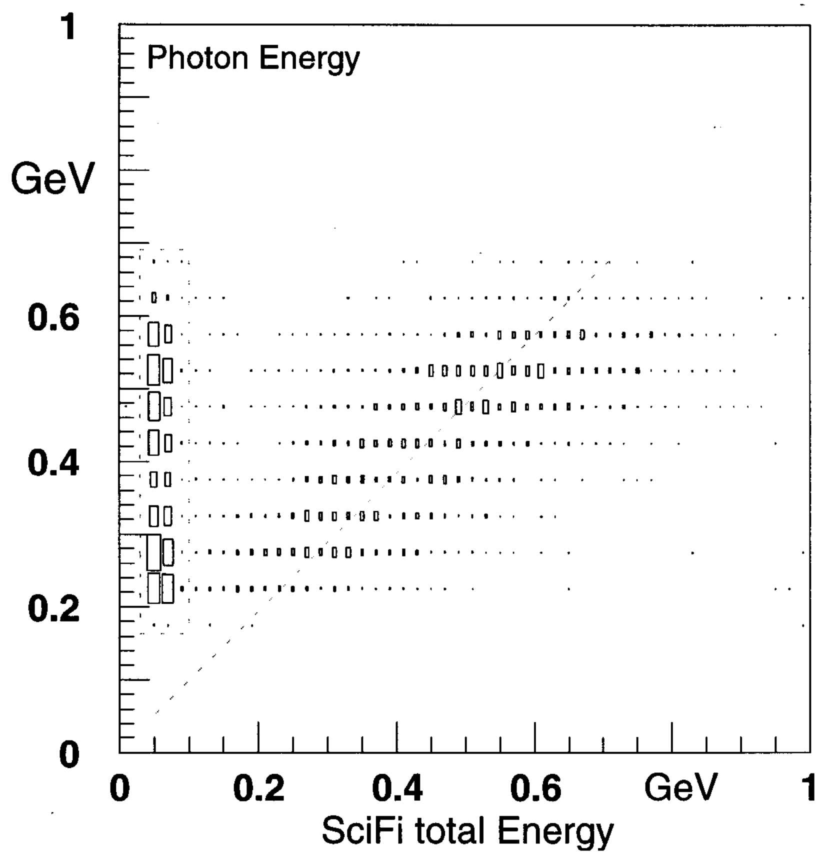


Figure 16. Tagged photon energy versus energy deposited in the scintillating fiber calorimeter. Selected region shows events when radiated photon missed the calorimeter.

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