GAMMA-RAY RESPONSE OF NE-213 MEASURED BETWEEN 2 AND 11.5 MeV

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ABSTRACT

Because of the capability to discriminate between neutrons and gamma rays, NE-213 scintillators are useful as both fast-neutron and gamma-ray spectrometers. However, measured NE-213 Compton-recoil spectra require unfolding to yield gamma-ray energy spectra which entails a detailed knowledge of the gamma-ray response of the NE-213 detector system.

We have made absolute measurements of the gamma-ray response of an NE-213 scintillator in the energy range of 2 to 11.5 MeV. The measurements were made using the University of Illinois superconducting electron microtron equipped with a gamma-ray monochromator. The response measurements will be used to construct a gamma-ray response matrix for NE-213 to be used with the FORIST unfolding code.

INTRODUCTION

The organic scintillator NE-213 has proven useful as a fast-neutron spectrometer. Because of pulse-shape discrimination capability, NE-213 can also be employed as a gamma-ray spectrometer. However, measured NE-213 Compton-recoil pulse-height spectra require unfolding to yield gamma-ray energy spectra. Unfolding the pulse-height data entails a detailed knowledge of the response of the detector in the form of a response matrix which is constructed from the responses of the detector to monoenergetic gamma-ray sources. The reliability of the unfolded spectrum is directly related to the accuracy of the response matrix.

In the past, gamma-ray response matrices for NE-213 scintillators were constructed using Monte Carlo calculations.[1,2] Although measured responses are preferred, the difficulty in obtaining a sufficient number

of monoenergetic sources in the energy range of interest had forced the use of calculated responses. The physics department of the University of Illinois operates a facility which is well suited for the measurement of gamma-ray response functions. Using the superconducting electron microtron[3] equipped with a bremsstrahlung monochromator,[4] we have measured the gamma-ray response of our NE-213 detector for gamma-ray energies between 2.0 and 11.5 MeV.

EXPERIMENT

The University of Illinois superconducting electron microtron is a unique accelerator capable of delivering a nearly continuous beam of electrons with better than 0.1% energy resolution. After acceleration, the beam is routed through a series of slits and focusing magnets and strikes a bremsstrahlung converter foil producing bremsstrahlung radiation which strikes the gamma-ray detector in a broadly collimated beam. The residual electrons which have lost energy through bremsstrahlung are bent by the spectrometer magnet and refocused onto an array of 12 electron detectors. The energy of a bremsstrahlung photon is determined from the energy of the electron beam and the energy of the coincident residual electron (determined from the magnetic field strength). In this way, twelve simultaneous gamma-ray sources at contiguous energies are provided.

The response measurements were made utilizing 2, 3, 4, and 5 passes of the 3-MeV accelerator. Nine runs were made with overlapping energies yielding a total of 95 unique response functions. For consistency with neutron applications, the detector was placed with the parallel beam of gamma rays impingent on the curved surface of our 4.80- by 4.65-cm diam NE-213 detector. The normalization of each spectrum was determined by replacing the NE-213 detector with a large NaI(Tl) detector of known efficiency, allowing the absolute source strength to be determined.

A PDP-15 computer was used to sort pulses from the analog-to-digital converter into a 28 by 64 channel memory. For each of the 12 coincidence spectra accumulated simultaneously, a corresponding accidental spectrum was also accumulated by analyzing pulses received 150-170 nsec after the

20 nsec coincidence window. The true spectrum was obtained by subtracting the accidental spectrum from the total coincidence spectrum.

RESULTS

Figure 1 shows four of the measured NE-213 gamma-ray responses. These Compton-recoil spectra were calibrated in terms of light units by defining the half-height of the 1.28 MeV ^{22}Na Compton edge as 0.89 light units.[5] The maximum electron recoil energy was taken at 2/3 the height of the Compton peak.[6] This yielded a pulse-height calibration that is linear in electron energy, and is shown in Fig. 2 with only 1/3 of the 95 points plotted.

Shown in Fig. 3 is the total efficiency of our NE-213 detector, determined by integrating each of the 95 responses above a bias level of 0.5 light units. To correct the error in the normalization of the low energy spectra, each response was renormalized so that the calculated total efficiency fell on a third-order curve which was least-squares fitted to the measured values. The correction above 3 MeV was less than 5% for most of the spectra.

A preliminary comparison has been made between our measured gamma-ray responses and the calculated responses reported in Ref. 1. The results are shown in Fig. 4. Although the spectra compare reasonably well for 2-MeV gamma rays, the calculations under-predict the component contributing to the Compton peak at higher energies. This may be a consequence of over-estimating the average electron penetration depth for NE-213. A detailed investigation of the discrepencies between the measurements and the calculations will be made in order to more thoroughly understand the gamma-ray response of NE-213.

A preliminary version of a gamma-ray response matrix for NE-213 has been constructed and is shown in Figs. 5 and 6. The 95 by 167 matrix has been smoothed along the rows and columns using a 9-point least-squares formula and covers the gamma-ray energy range of 2 to 11.5 MeV. This preliminary version will be extended to below 1 MeV, and will be thoroughly tested before the final version will be made available for distribution.

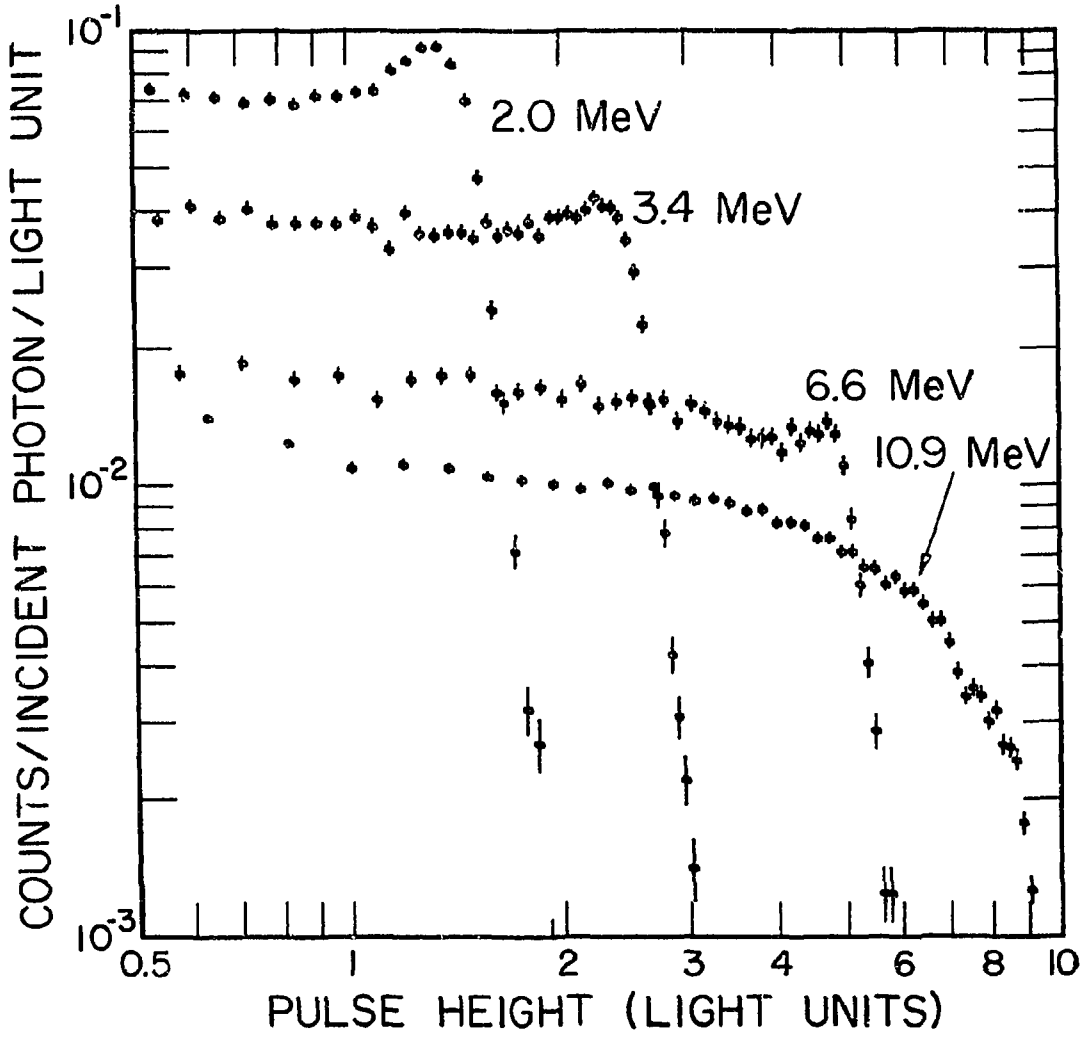

Fig. 1 Measured NE-213 Compton-recoil spectra. Using a bremsstrahlung monochromator, 95 spectra were measured in the energy range of 2.0 to 11.5 MeV. The energy label on each spectrum is the incident gamma-ray energy.

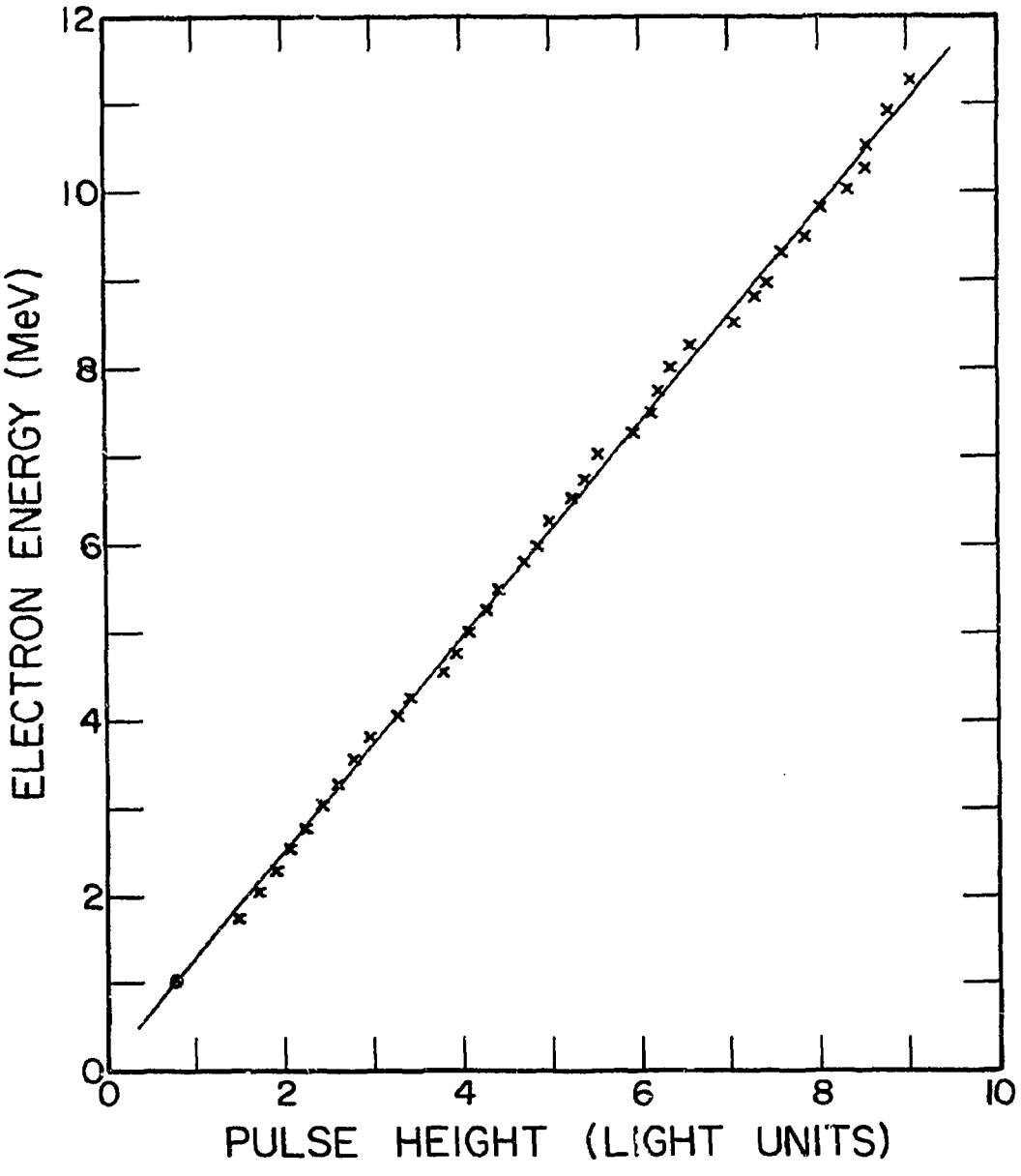

Fig. 2 Pulse-height calibration for the gamma-ray response measurements. The maximum electron recoil energy was taken to be at 2/3 the height of the Compton peak. The open circle represents the Na-22 response used in defining the light unit.

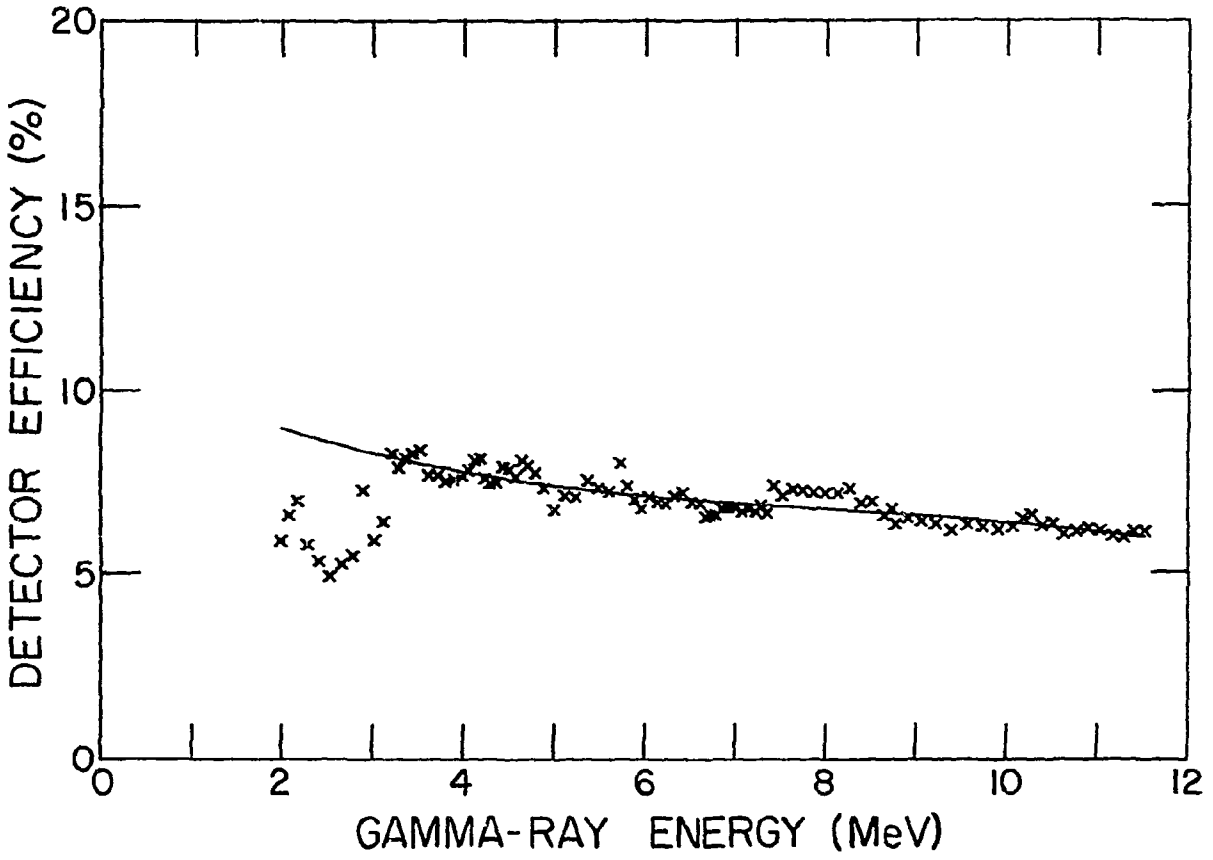

Fig. 3 Total detector efficiency in counts per incident photon (%). The 95 spectra were renormalized to place the total efficiencies on the curve which was fitted to the measured values. The bias level is 0.5 light unit.

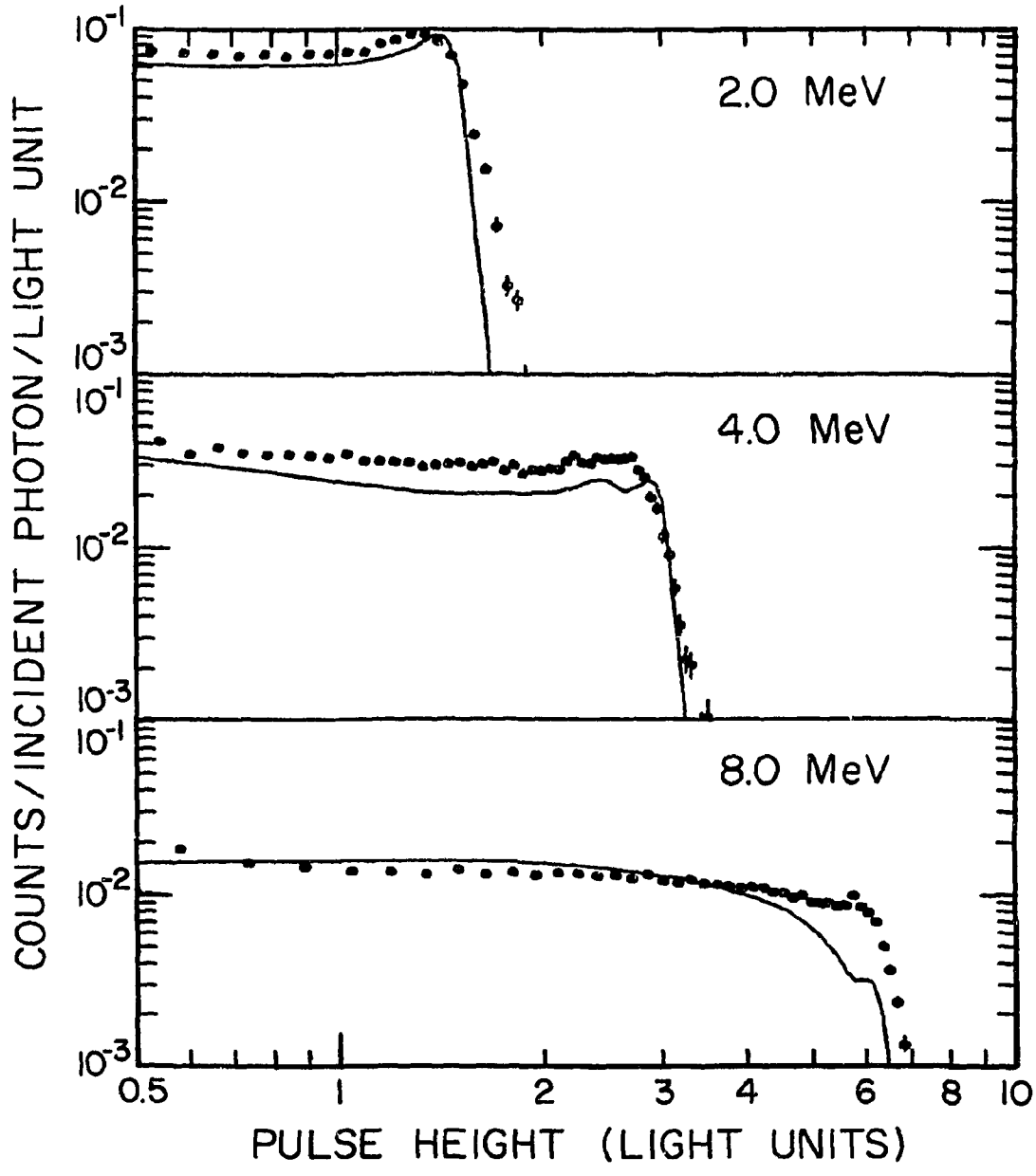

Fig. 4 Comparison of measured gamma-ray responses with the calculated responses reported in Ref. 1. The response functions for 2-, 4-, and 8-MeV gamma rays are shown. The degradation of the Compton peak at 8 MeV is probably due to the large penetration depth of high-energy electrons relative to the size of the NE-213 detector.

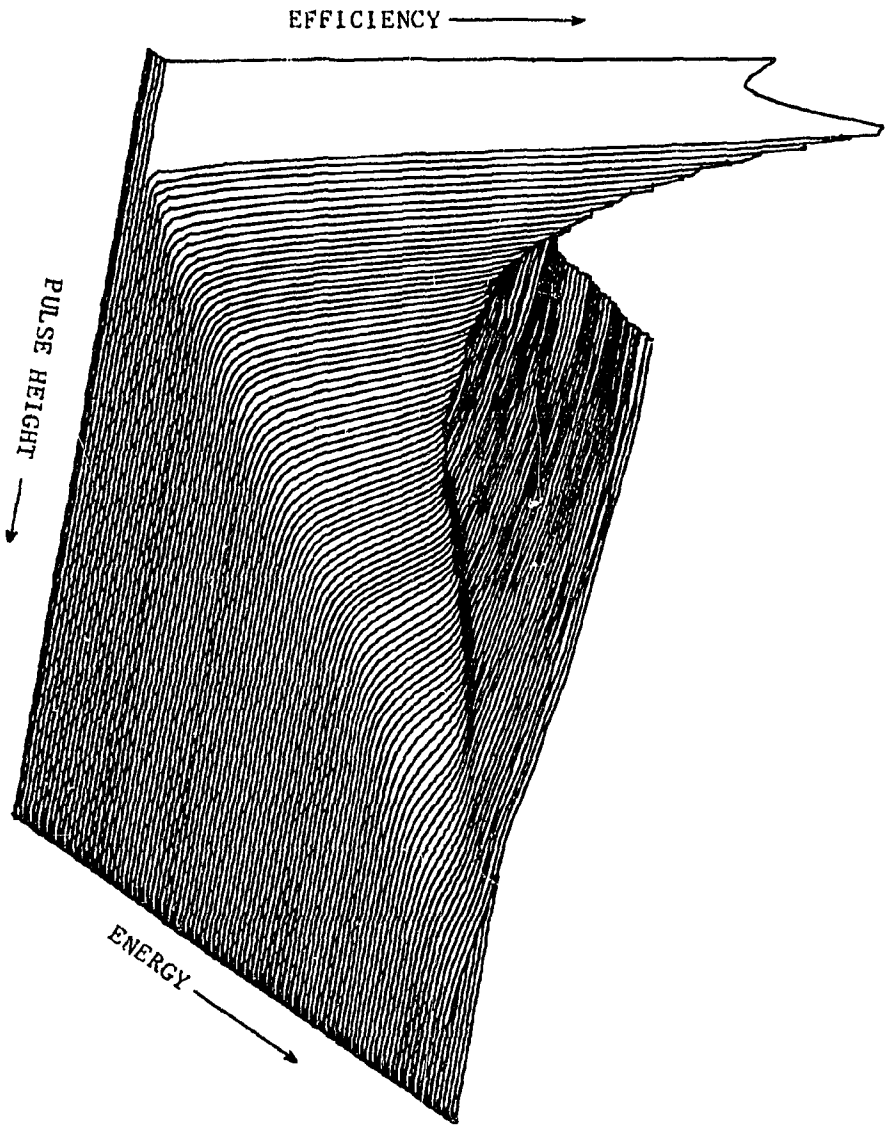

Fig. 5 Isometric representation of the preliminary version of the Illinois gamma-ray response matrix for NE-213. Linear efficiency is plotted to emphasize the low energy response. The pulse-height and energy scales are somewhat distorted for plotting purposes.

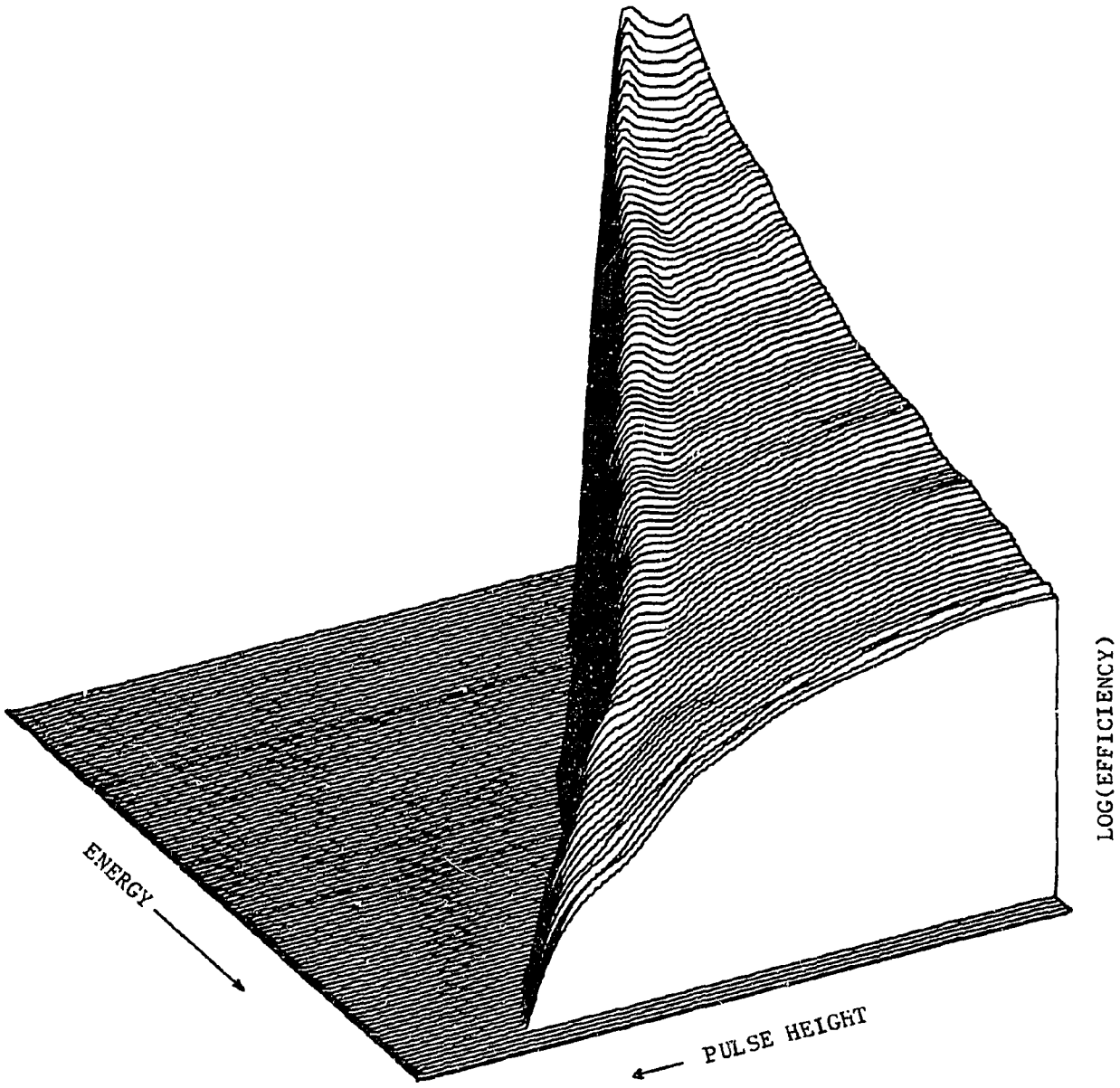

Fig. 6 Isometric representation of the preliminary version of the Illinois gamma-ray response matrix for NE-213. Logarithm of efficiency is plotted to emphasize the high energy response. The pulse-height and energy scales are somewhat distorted for plotting purposes.

We feel that the measured gamma-ray response of NE-213 is a significant contribution to the area of NE-213 spectroscopy. The response matrix constructed from these measurements will be made available with the FORIST unfolding code[7] and will provide the necessary information for accurate unfolding of NE-213 Compton-recoil data.

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