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LARGE-AREA MERCURIC IODIDE PHOTODETECTORS

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This article discusses the limits of the active area of mercuric iodide photodetectors imposed by the size of available crystals, electronic noise, and the uniformity of charge-carrier collection. Theoretical calculations of the photodetector electronic noise are compared with the experimental results. Different entrance contacts were studied including semitransparent palladium films and conductive liquids. HgI_2 photodetectors with active area up to 4 sq cm are matched with NaI(Tℓ) and CsI(Tℓ) scintillation crystals and are evaluated as gamma radiation spectrometers.

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ABSTRACT

This article discusses the limits of the active area of mercuric iodide photodetectors imposed by the size of available crystals, electronic noise, and the uniformity of charge carrier collection. Theoretical calculations of the photodetector electronic noise are compared with the experimental results. Different entrance contacts were studied including semitransparent palladium films and conductive liquids. HgI_2 photodetectors with active area up to 4 sq cm are matched with NaI(Tℓ) and CsI(Tℓ) scintillation crystals and are evaluated as gamma radiation spectrometers.

*This work was performed under the auspices of the U.S. Department of Energy under Contract No. DE-AC08-83NV10282.

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SUMMARY

This article will discuss the limits of the active area of mercuric iodide photodetectors imposed by the size of available crystals, electronic noise, and the uniformity of charge carrier collection. The currently used vapor growth technique, based on the periodic reversal of the temperature gradient between the source material and growing crystal, produces crystals of up to 700 g. Photodetectors of up to several sq cm can be made from crystals of this size. Theoretical calculations of the electronic noise of the photodetector will be compared with the experimental results. Dark leakage current, capacitance, series resistance of the photodetector electrodes, and the preamplifier noise all contribute to the electronic noise output. The dark leakage current and capacitance of the photocells were measured. Energy calibration of the electronic system was performed using a ^{241}Am gamma source (60-keV line) by direct interaction with the photocell. Uniformity of charge transport properties across the photocell active volume is an important factor in the photodetector's performance. Electron mobility, mean trapping time, and electric field distribution over the volume of the photodetector have been studied to evaluate uniformity of transport properties.

HgI_2 photodetectors with active area up to 4 cm^2 have been measured. Different entrance electrodes were investigated including semitransparent

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palladium films and a conductive liquid (salt water). The spectral response of photodetectors with different contacts were studied in the wavelength region of 300 to 600 nm.

Photodetectors were optically coupled with NaI(Tℓ) and CsI(Tℓ) scintillation crystals. HgI_2 photodetectors with palladium contacts were coupled to the scintillation crystals with silicon optical coupling gel. For the detectors with liquid contacts, the contacts themselves provided the optical coupling to the scintillators. Figure 1 presents a pulse height spectrum taken with NaI(Tℓ) mercuric iodide combination for ^{68}Ga positron source. The NaI(Tℓ) crystal was 0.5 inch diam by 0.5 inch long and the liquid contact active area of the HgI_2 photocell was 13 cm^2. The energy resolution of the 511-keV annihilation line was better than 14%. The electronic noise level, determined as the full-width-at-half-maximum (FWHM) of the artificial peak in the energy spectrum generated by a pulser, was 10%. Figure 2 shows a similar spectrum obtained using a photocell with a palladium entrance contact coupled to the NaI(Tℓ) (0.5 inch diam by 0.5 inch long) scintillation crystal. Figure 3 shows a ^{68}Ga positron source spectrum obtained using CsI(Tℓ) (0.5 inch diam by 0.5 inch long) scintillation crystal coupled to an HgI_2 photocell. The efficiency of light collection from the scintillation crystal to the HgI_2 photodetector was evaluated by calibration obtained from the spectrum produced by direct interaction of gamma-rays from ^{241}Am (60 keV) with the HgI_2 photocell. Figure 4 shows the ^{68}Ga positron source spectrum obtained using NaI(Tℓ) scintillation crystal coupled to a photocell with a liquid contact where the photocell bias was extremely low (5 V). Rapid shifts in the peak position toward the low energy end of the spectrum were observed using these low photocell bias values. Further study of the attractive possibility of low bias voltage photocell operation will be pursued.

This study has brought to light the critical problems of transmission and reflection of light by the entrance contact, charge collection in the vicinity of the photocell surface, and efficient coupling to the scintillation crystal.

These preliminary results show that HgI_2 photodetectors as large as a few cm^2 are feasible for use with scintillation crystals. The possible application for an all solid-state, room-temperature, scintillator-photodetector device employing HgI_2 are numerous, embracing most present applications in which photomultiplier tubes are used with scintillators. There are several significant advantages over photomultiplier tubes. The quantum efficiency of photomultiplier tubes is typically less than 30%. Solid-state photodetectors have the potential for quantum efficiency approaching 100% for the wavelength produced by the most widely used scintillation crystals. They therefore present the possibility of achieving better energy resolution than can be obtained using photomultiplier tubes. HgI_2 photodetectors exhibit very low current, are not sensitive to magnetic fields, and may provide the ultimate detector miniaturization in scintillation gamma spectrometry.

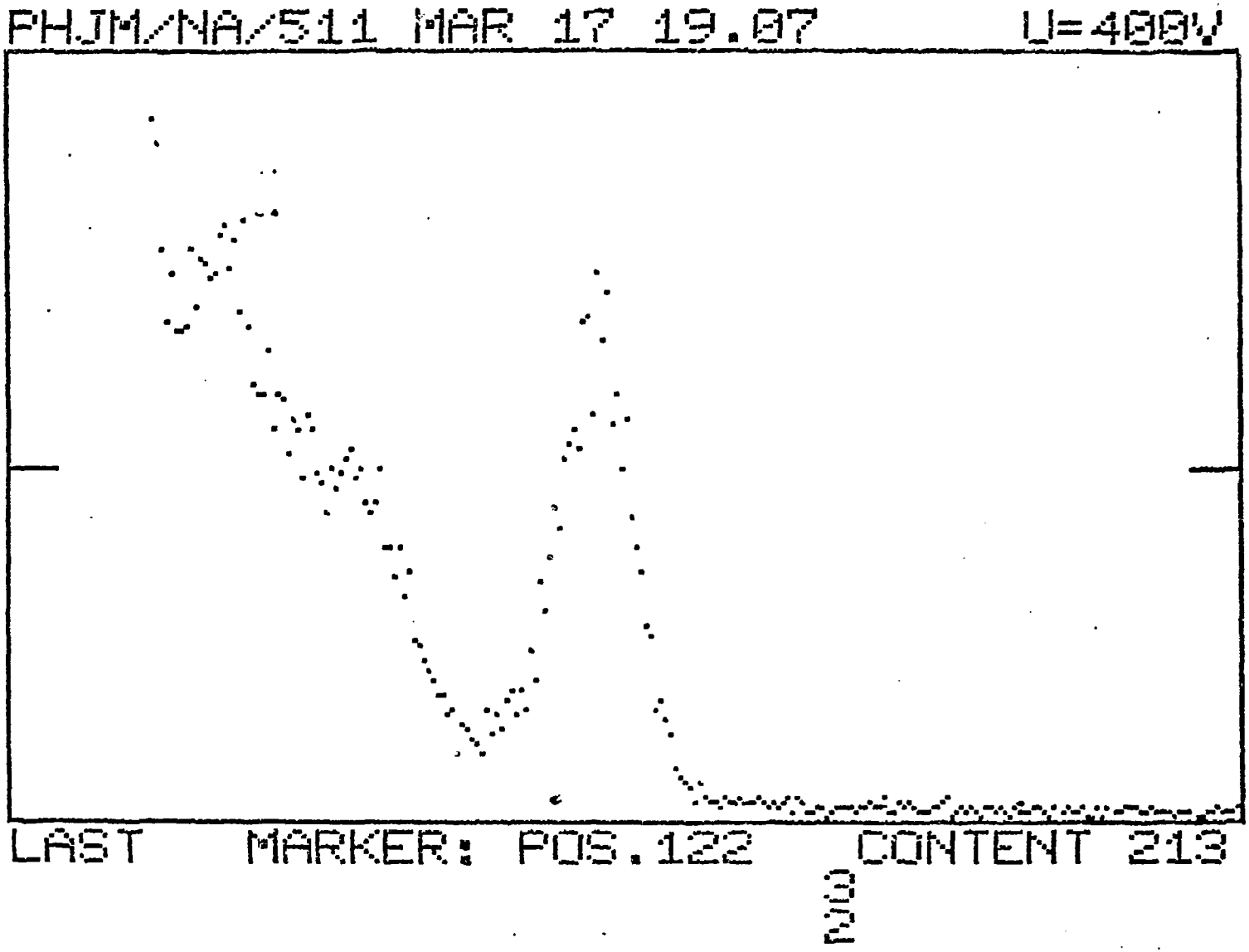

Figure 1. Pulse height spectrum from NaI(Tℓ) – liquid contact – HgI_2 combination for ^{68}Ga positron source.

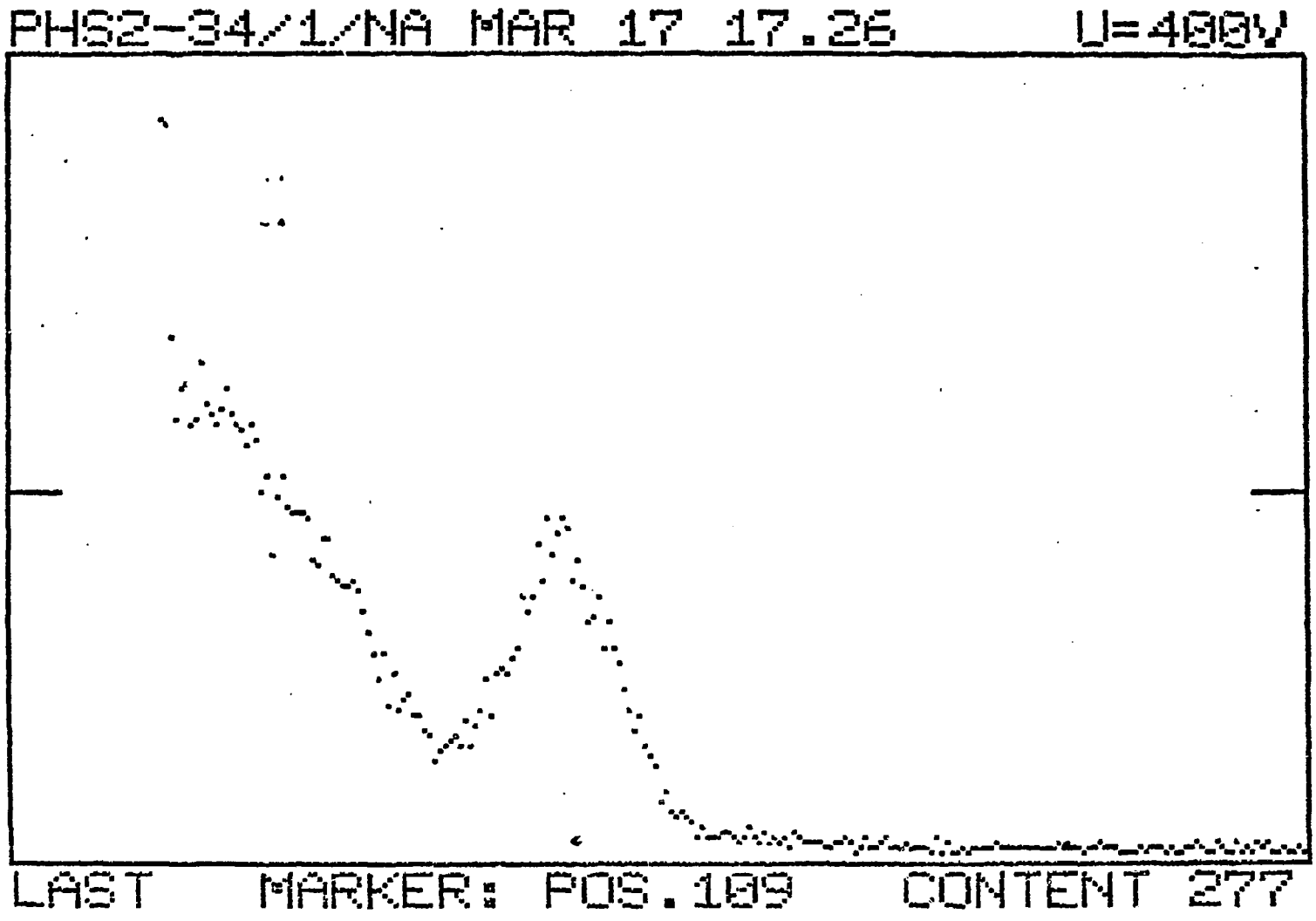

Figure 2. Spectrum from photocell with palladium entrance contact coupled to NaI(Tℓ) scintillation crystal.

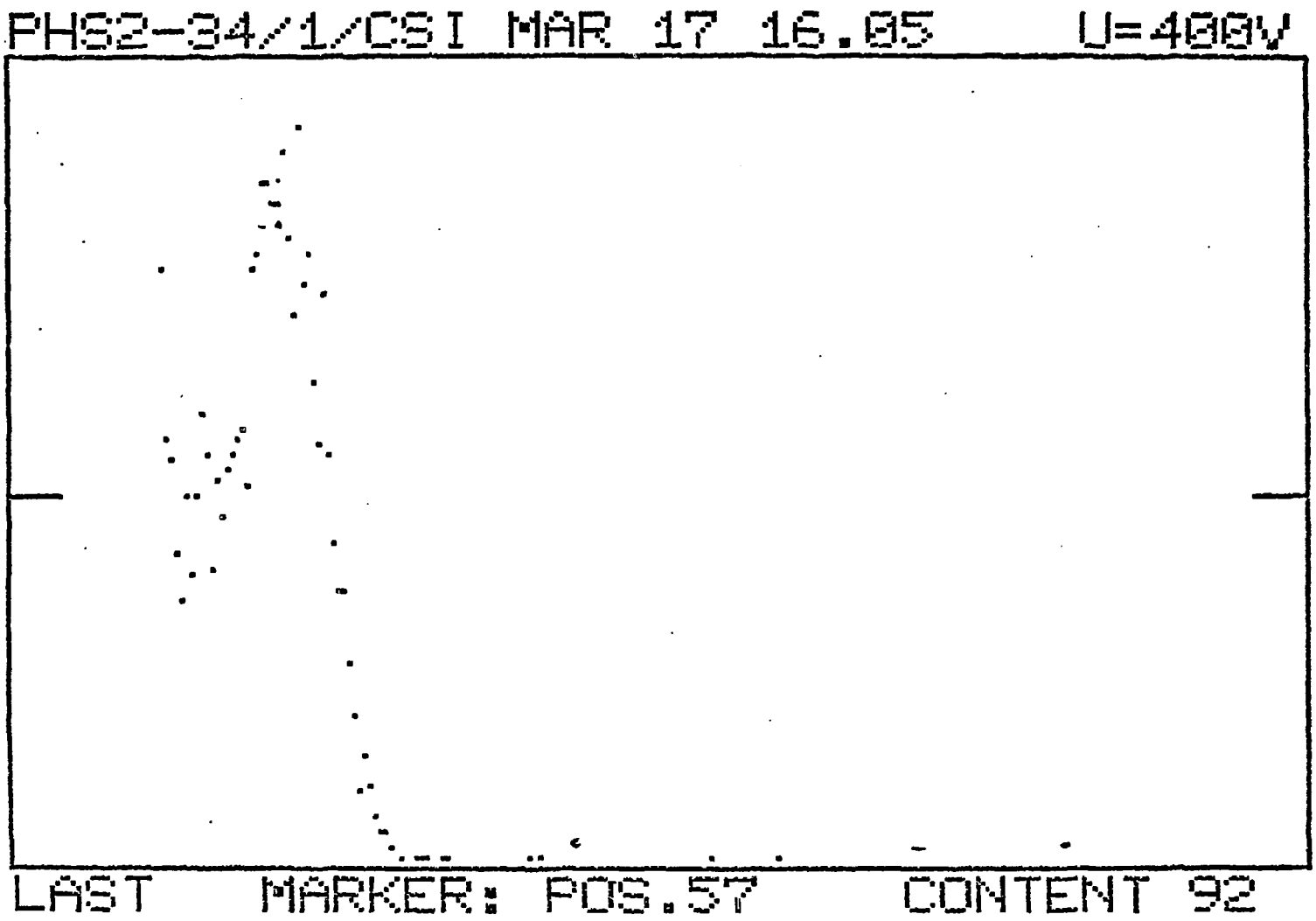

Figure 3. ^{68}Ga positron source spectrum using CsI(Tℓ) crystal coupled to HgI_2 photocell.

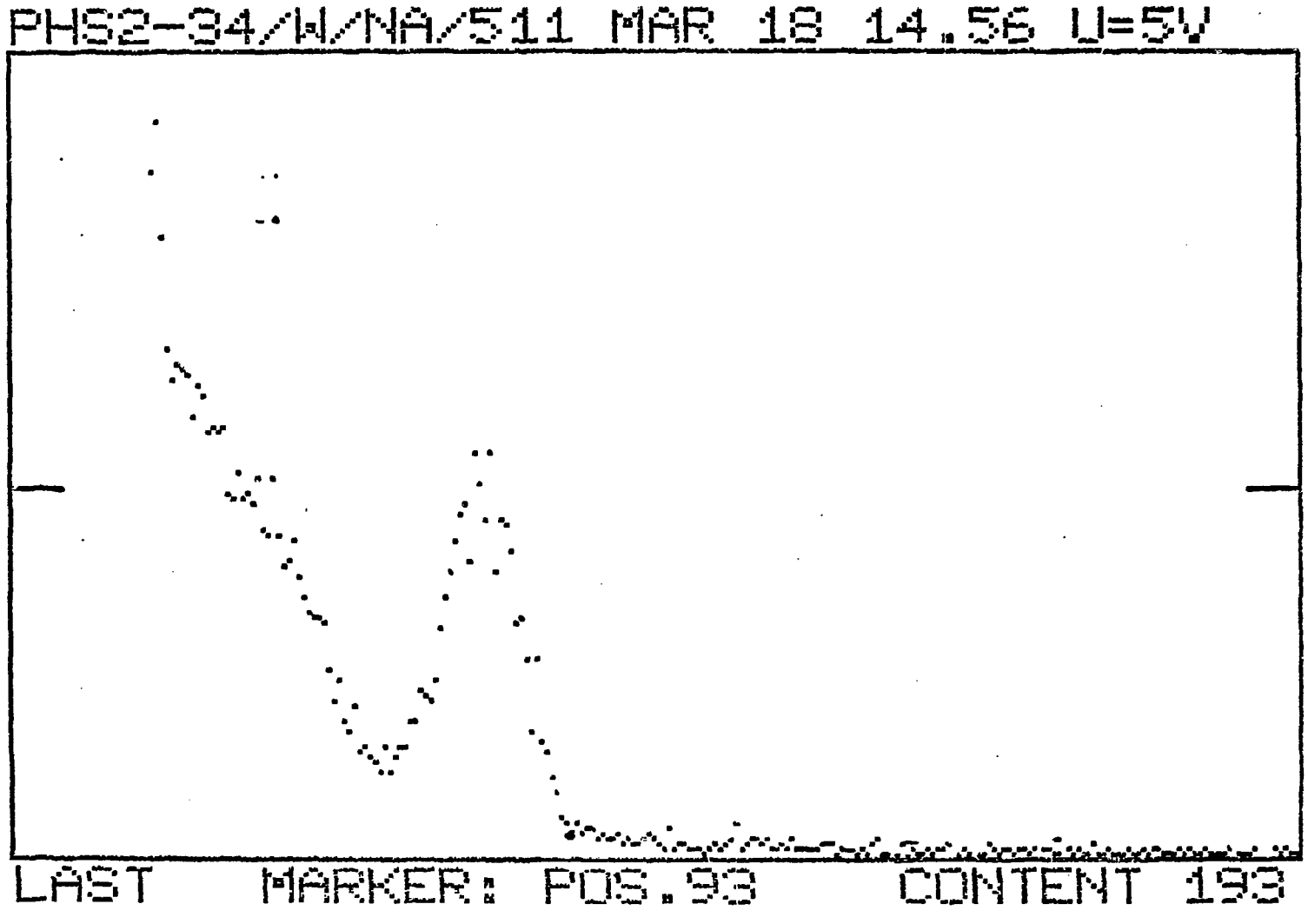

Figure 4. ^{68}Ga positron source spectrum using NaI(Tℓ) scintillation crystal coupled with liquid contact to photocell where bias is 5 V.