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ABSTRACT

A method is reported for the detection of very-low-energy gamma rays. The method utilizes scintillation detection with NaI-Tl crystals especially split and mounted for the work, and selected single 5819 or 6292 photomultipliers. Typical performance is unit (2π) efficiency with background of 1 count per minute for gamma energies between 5 and 100 kev.

INTRODUCTION

A study of the properties of the neutron-deficient rubidium isotopes by the method of atomic beams[1] has prompted the development of high-efficiency low-background counters to detect K x-rays (~15 kev) emitted when the material K-captures or internally converts. The two methods in general use that satisfy the given requirements are gas counting using rather elaborate grid chambers and proportional techniques, or scintillation counting. Contrary to current conceptions, relatively high-resolution scintillation spectroscopy using single photomultipliers not only is feasible for the region of interest, but can with care be made to give extremely low backgrounds as well. The end product is definitely superior to existing gas counters in background and operational utility.

THE COUNTER

The counting head as designed for the purposes of our investigation (Fig. 1) is an aluminum cup which fits over the face of the photomultiplier and into which are cemented the gamma window of 0.5-mil 2-S aluminum, the

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[1]Hobson, Hubbs, Nierenberg, Silsbee, and Sunderland, to be published in the Physical Review.

crystal--0.25 by 0.5 inch by 1 mm--and the quartz light window. Care is taken to prevent a film of the cement, Myva Wax, from covering either face of the scintillator. The gamma-window transmission is approximately 90% for rubidium K x-rays; thin-film techniques might well be used to extend the useful lower limit of operation to 1 kev.

Sodium iodide crystals are purchased in large blocks and split to size in a dry box with relative humidity less than 5% at 30° C. Cleavages are made by delivering a light blow to a razor blade lying along a crystal plane, and acceptable fragments with no sign of fracture or discoloration are immediately sealed between the two windows to prevent surface decomposition.

Photomultiplier tubes are selected from the large number of tubes acquired by the Radiation Laboratory (Berkeley). Initially only 5819's were available. Perhaps one tube in a thousand would at that time meet the requirements of less than one dark-current pulse per minute above a pulse height equivalent to 5-kev gammas in NaI. The acceptance factor for the new Dumont 6292's does, however--at least for some lots--run as high as one tube in twenty. The common denominator of tubes so selected is a very large amplification for a given dynode voltage and presumably a relatively high photocathode conversion efficiency. The relative dark-current rate is very nearly independent of dynode voltage over the normal region of operation of the tubes. High voltage curing of the photomultipliers leads to no improvement of the noise figure.

OPERATION

Counting is performed with standard Radiation Laboratory preamplifiers and single-channel differential analyzers. The only stabilization used is that of the analyzer and a Sorenson regulator which is used to supply 110-v ac. The counter window is customarily set to accept at least 90% of the x-ray line, which for 15-kev x-rays results in a 100% window, i.e., from one-half to one and one-half of the peak center. Only a 50% window is required to achieve the same results above 50 kev. Under such adjustments as this, small drifts in window width and height contribute a negligible change in counter efficiency and background, a factor of paramount importance for counting periods which sometimes are as long as three months. The counters are shut down only after a counter electronics failure, which occurs in a mean time of about four months.

The counter head is shielded with a stagger system, with concentric cylindrical geometry and using 2.5 inches of lead, 1/8 inch brass, 1/4 inch iron, and 1/8 inch or more aluminum. For window settings above, the counter background in the shield is one count per minute or less for all energy settings between 5 kev and 100 kev. Minimum background occurs in the neighborhood of 40 kev, where it is typically 0.35 count per minute. Counter background outside the shield is approximately 5 counts per minute. Integral settings of the counter in the shield and with a threshold corresponding to 3 to 5 kev result in approximately 8 c/m background for a configuration in which all μ mesons, low-energy gamma rays, and medium-energy electrons are detected with unit efficiency. The integral contribution of dark-current pulses to counter background is, for a typical unit, approximately $10^4 \exp(-E/.5\ \text{kev})$ counts per minute between 1 and 10 kev.

LEGENDS FOR FIGURES

Fig. 1. Detail of scintillation head.

Fig. 2. Pulse-height distribution of rubidium K x-rays. The low-energy peak is dark current.

PHOTOMULTIPLIER TUBE – NaI (Tl) ASSEMBLY

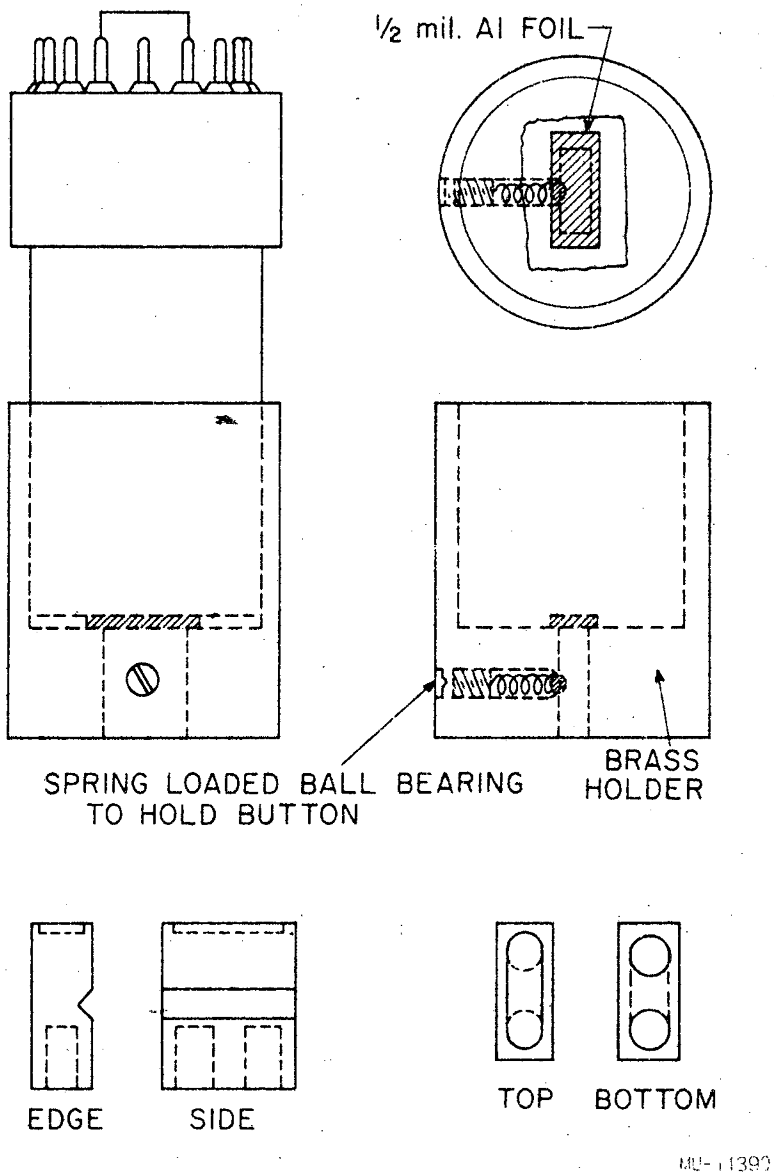

Fig. 1

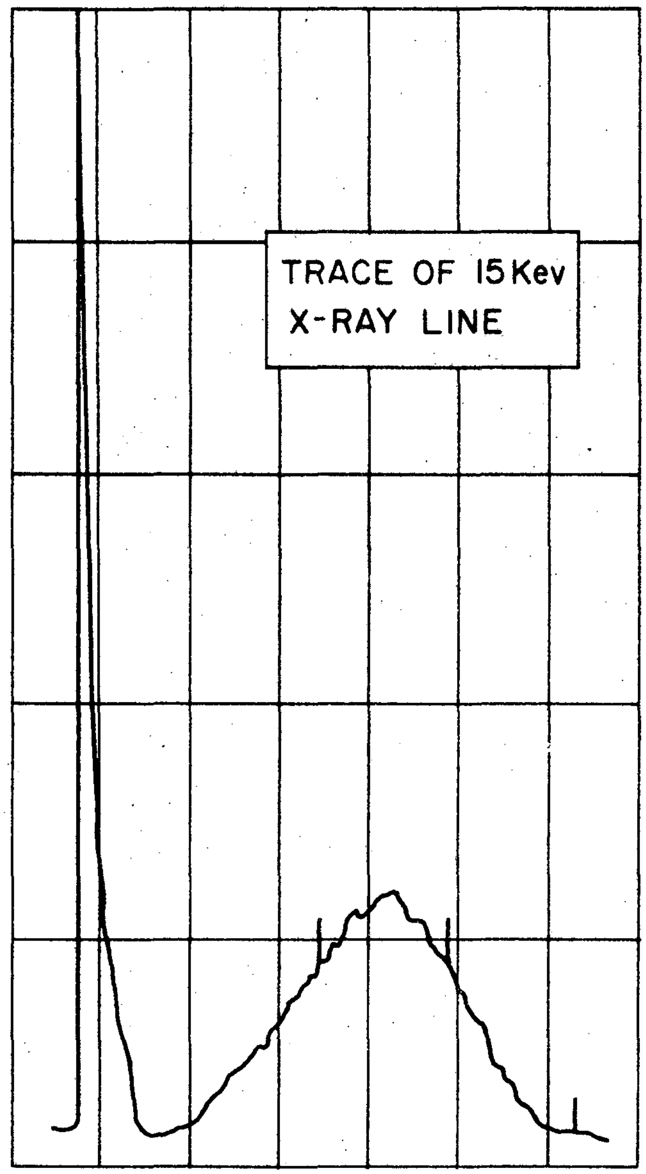

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Fig. 2