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Continuous Scanning Method for Angular Correlation Measurement of Positron Annihilation Gamma Using Multiple Channel Analyzer

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In this report we describe a new automatic angular correlation measurement method for gamma-ray pairs arising from positron annihilation. An arm of a goniometer used in the angular correlation experiment is programmed to sweep an arc of certain angle continuously. The angular displacement of the moving arm is converted to D. C. voltage and fed to ADC of a multichannel analyzer as a sampling signal. The coincidence pulses of two gamma rays serve as sampling commands and are stored in the multichannel analyzer as a function of the sampling D.C. signal, e.g., the angular displacement of the goniometer arm.

The method makes one possible to set up inexpensive reliable measuremet system. With minor modification it can also be applied to other experiments.

INTRODUCTION

IN general, the angular correlation measurement of the positron annihilation photons is performed by using an automatic goniometer coupled with a data acquisition system(1),(2),(3). The goniometer has two arms. Those two arms are pivoted together at one end of each arm about the goniometer axis where the annihilation gamma source is situated. At the opposite ends of both arms, detectors and slits are fixed. One of the goniometer arm is movable about the goniometer axis so that one can change the angle subtended by three points: the detector 1, the gamma source and the detector 2. This movable arm is then programmed to sweep an arc of certain angle stepwise. In each step, the annihilation gamma quanta are detected by those two detectors. Coincidence counts are accumulated by a scalar and then printed out through the data acquisition system.

In this report we describe an alternative way for such an experiment. Our system consists of a multiple channel analyzer, a simple goniometer with its

(1) D. R. Gustafson, A. R. Mackintosh, and D. J. Zaffarane; Phys. Rev. 130, 1455 (1963).
(2) K. Fujiwara; J. Phys. Soc. Japan 20, 1533 (1966).
(3) R. E. Green and A.T. Stewart; Phys. Rev. 98. 486 (1955). (In order to change detector-source. detector angle, those author moved source vertical to the line of two stational detctors.)

driving, and a conventional detector electronics. The moving arm of the goniometer moves continuously and its detector signals are registered in the memory of the multiple channel analyzer as a function of the detector-source-detector angle. The cost of the whole system is considerably low owe to the mechanical simpleness of the goniometer and its driving. Furthermore, the low price of the multiple channel analyzer has now made itself a common equipment easily available in laboratories.

EXPERIMENTAL SETUP

A simplified block diagram of our system is shown in Fig. 1. A multiple channel analyzer, RIDL 34–12B, is used in the voltage sampling mode. A continuously varying voltage of a linear displacement transducer, which detects the detector-source-detector angle, is fed to the voltage input of the analog to digital convertor (ADC) in the analyzer as a sampling signal. The pulses, which came from the two detectors as well as their coincidence pulses, serve as signals for the sampling command. Meanwhile, the three kinds of signal (signals from detector 1, detector 2, and their coincidence signals) are used as routing commands to store the data in three memory groups (in our system we use 100-199 group or the second quarter of the memory for signals from detector 1, 300-399 group or the last quarter of the memory for detector 2, and ZOO-299 group of the second quarter of the memory for coincidence signals). Thus we obtain three

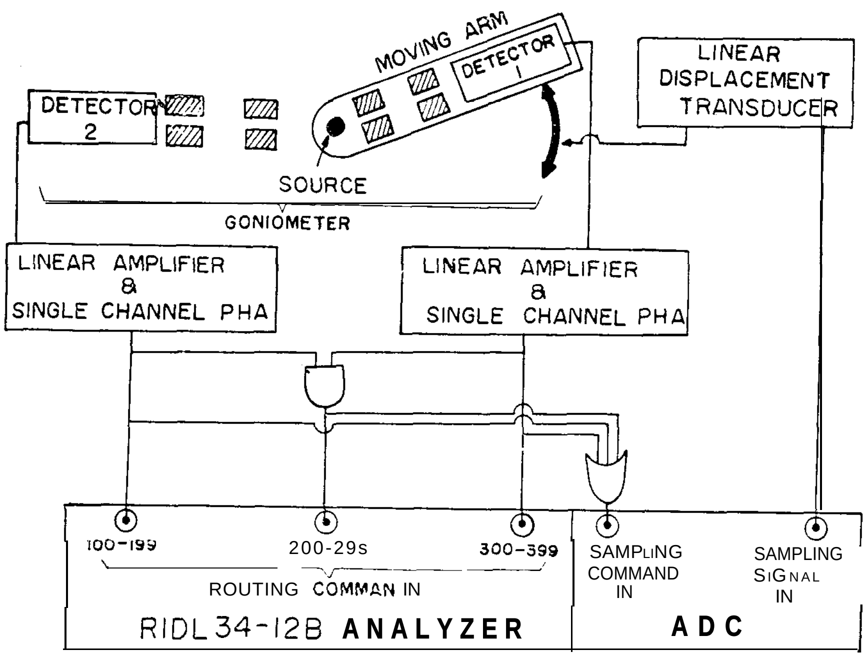

Fig. 1. Schemetic diagram of the measuring system

spectrums: the counting rate of detector 1 vs. the angle (we call it monitoring spectrum 1), the counting rate of detector 2 vs. the angle (monitoring spectrum 2), and the counting rate of the coincidence signal vs. angle (coincidence spectrum). The monitoring spectrums are necessary when the motion of the moving arm of goniometer is not sweeping uniformly. Later it will be shown that we do not use any regulator mechanism to keep the sweeping motion of the goniometer arm uniform. Thus, the amount of time among the registration of the data in each channel are not excatly equal to each other. Therefore the coincidence spectrum will be meaningful only after the coincidence spectrum has been normalized by monitoring spectrums.*

In the angular correlation experiment of positron annihilation gamma we are interested only in the small region of the detector-source-detector angle around 180 degrees. Thus the goniometer arm is driven at the end of the arm by a lathe-type linear driving which actuate by an electric motor. The arm swing back and forth between two limiting microswitches. Whenever the moving end of the arm hits of one of those limiting switches, the rotary direction of the motor is reversed, caussing the arm to swing back. We use a potentiometer as the main part of the linear displacement transducer. As shown in Fig. 2, the rotating axis X of the potentiometer is coupled with the moving arm M of the

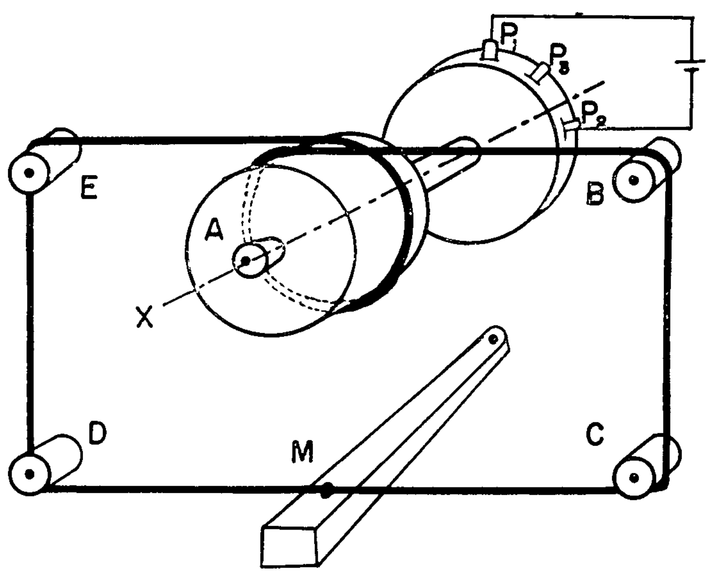

Fig. 2. Diagram of linear displaclement transducer. A, B, C and D are wheels. M as moving arm, P_1 and P_3 the end the terminals of the potentio meter. P_2, the variable terminal of the potentiometer, and X, the rotating axis of the potentiometer

*Since in our experiment the total counting rate of the monitoring spectrum is adjusted in such a way that the statistic21 accurtcy of the monitoring spectrum is at least 4 times higher than that of coincidence spectrum, the former error will not degrade the coincidence spectrum after normalization.

goniometer through a wire in such a way that the angular displacement of the moving arm without any backlash. For this purpose, the wire is subtained at four corners of the square by four wheels BCD and E and is fixed on the moving arm at a point M of the goniometer. Above the point M the same wire forms a loop and ties tightly a wheel A which is attached on the axis X of the potentiometer rigidly. As long as the wire is subtained by the four wheels under enough tension, the rotation of the wheel A and the potentiometer axis would precisely follow the linear motion of M. Since a constant voltage is applied between two fixed end terminal P_1 and P_2, the voltage between P_2 and the variable terminal P_3 of the potentiometer has a close linear relation with the linear motion of the moving arm M.

RESULTS AND DISCUSSIONS

Fig. 3-a, -b and -c show an example of the obtained spectra the monitoring spectrum 1 Fig. (3-a), the monitoring Fig. (3-b) and the coincidence spectrum Fig. (3-c) when an iron sheet is used as the target of positron annihilation. The fluctuations of the data points of those spectrums are much larger than those which can be expected from the statistical nature of the experiment. This is partly due to the non-uniform motion of the moving arm caused by the defetctive functioning of the lathe-type driving mechanism. The resulting monitoring spectrums, which are supposed to form a flat curve, fluctuates considerably from one data point to another. As discussed before, we need to normalize the coincidence spectrum. This can be done in the following; The data stored at each channe

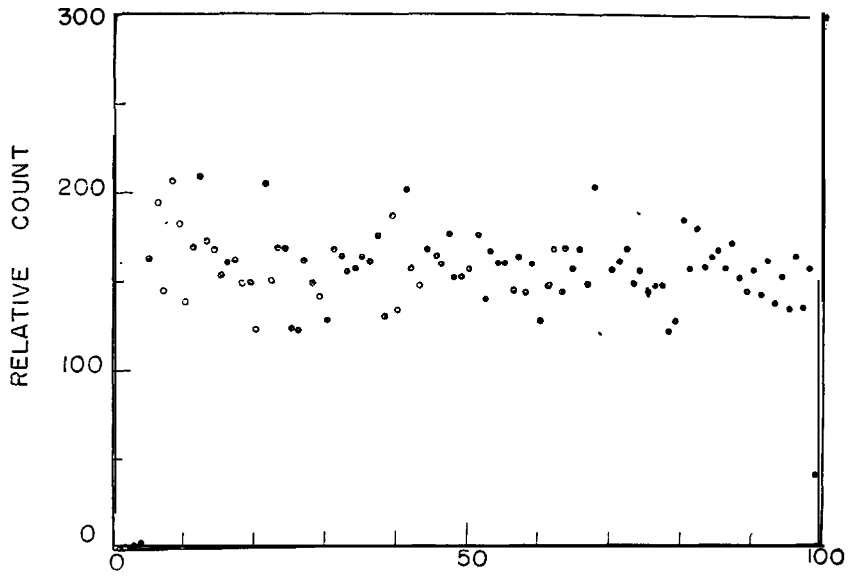

Fig. 3-a an example of the monitoring spectrum I

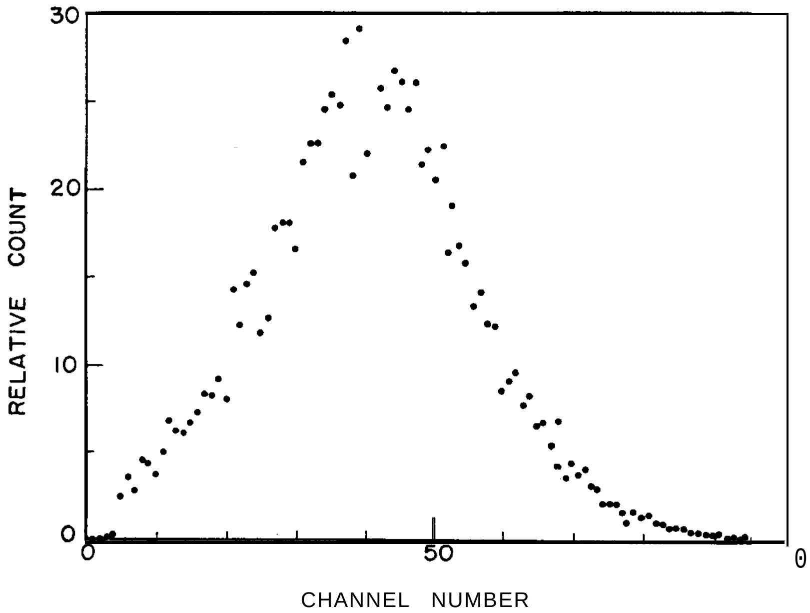

Fig. 3-6 an example of the coincidence spectrum

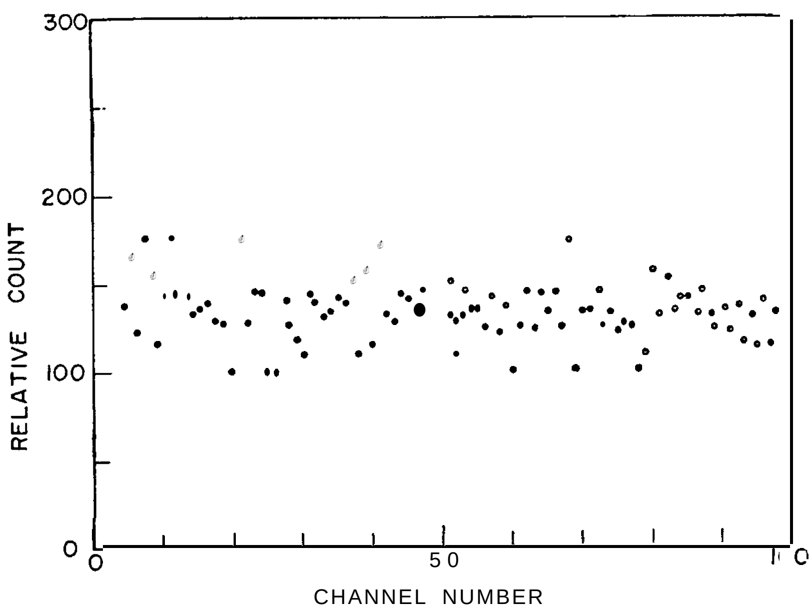

Fig. 3-c an example of the monitoring spectrum II.

of the coincidence spectrum is divided by the data of the corresponding channel of the monitoring spectrum. Fig. 4 shows such a final spectrum.**

All the equipment except the analyzer and a few detector electronics have

**The experimental results shown in Fig. 3 and Fig. 4 are the extreme example of the usefulness of the normalization of the coincidence spectrum. For more accurate measurement the smothness of the scanning motion would be essential. Nontheless, a slow variation of the speed in the scanning motion can be normalized effectively by the monitoring spectrum.

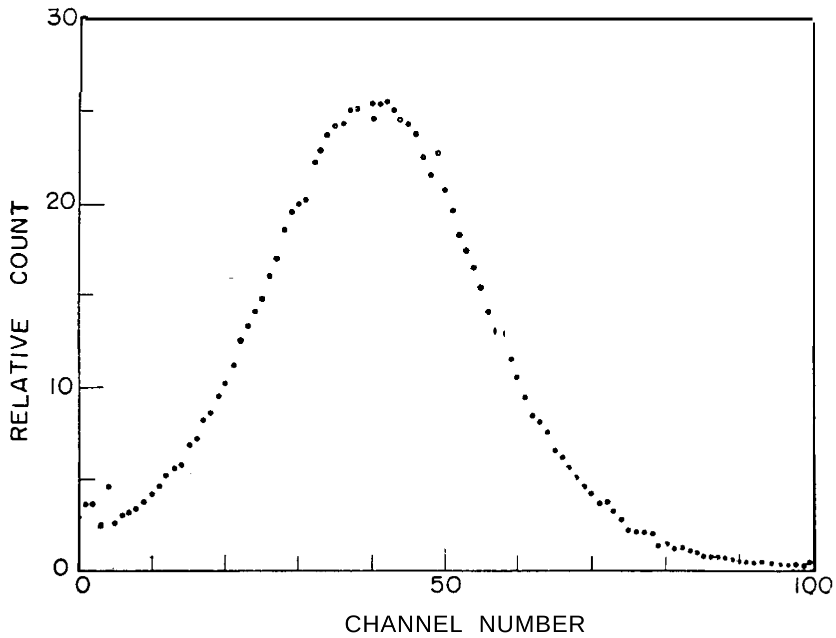

Fig. 4. The final angular correlation curve ' after normalizing the coinciderce spectrum by monitoring spectra I and II

been constructed in our laboratory. Even with the imperfect driver system of the goniometer mentioned above, the system as a whole is reliable and precise enough for our purpose. For by the continuous scanning motion instead of the stepwise discontinuous motion of the moving arm of the goniometer. Using the continuous scanning motion, we can increase the scanning speed in such a way that fluctuations in the detector system can be averaged out. Morever the simultaneous recording of the monitoring spectra also helps to elimenate the difficulties owe to the defective funciton of the goniometer. We would like to emphasize the fact that with the exception of the analyzer the cost of the system is so low that we have built them without any specific budget for this project.

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