Experiments in Nuclear Biology and Nuclear medicine

EQUIPMENT NEEDED

- Agency Single-Channel Analyzer in Eurocard System
  - 2-in NaI crystal and phototube
  - 102 spectroscopy amplifier
  - 201 high voltage power supply
  - 301 timing SCA
  - 401 scaler-timer
  - 501 lin-log meter
  - 901 bin and power supply
  - 902 preamlifier power supply

- Multichannel Analyzer
  - Ortec
  - or Nucleus PCA-8000
  - or Canberra S-100 with extra ADC
  - or Canberra S-100 with integrated signal processor, Canberra 1510

- Converging collimator (focal point about 8 cm) with a rack
- Source Kit
- Source technetium
- Polyamid (this plastic board is equivalent to issue of body)
- Pulse generator
- Oscilloscope

INTRODUCTION

In broad terms nuclear medicine may be defined as the application of radionuclide techniques to the diagnosis and treatment of human disease. Contemporary clinical radionuclide methods may be divided broadly into three groups:

1. In vivo diagnostic procedures

   - organ imaging, e.g. brain scan for the detection of a tumour
   - whole body imaging, e.g. skletal survey for the detection of metastases
   - organ uptake, e.g. determination of thyroid function with radioiodine
   - whole body retention, e.g. measurement of the absorption of orally administered vitamin B-12
   - dynamic studies, e.g. the investigation of renal function (renography)
   - body spaces, e.g. measurement of plasma volume by isotope dilution analysis

2. Therapeutic

   - e.g. treatment of hyper-thyroidism with iodine-131

3. In vitro biochemical analysis:

   - Assays of hormones, enzymes and other substances by radioimmunoassay, saturation analysis and related techniques.

In radiation biology and nuclear medicine, as well as in radiation chemistry, it is often convenient to use radioisotope tracer. Therefore, when it is necessary to study the behavior of a particular chemical of molecular configuration, a sample can be synthesized with a small fraction of one of the elements replaced by a radioactive element in an amount and with a half-life that is compatible with the necessary measurement for the experiment. The compound is then assayed for its specific activity and is introduced into the system being studied.

For most radiobiological and medical studies, isotopes that decay by betas or gammas are used. Gammas are quite penetrating and so, where applicable, gamma-emissing isotopes can be used in "in vivo" studies. This means, for example, and isotope is injected into a patient or an animal and a gamma counter is used to follow the rate and/or concentration of the isotope as a function of time. The technology of nuclear medicine is emphasized on the biological function of organs or organ system with radioisotope tracer. On the other hand, particularly for beta-emitting isotopes, it is frequently necessary to perform "in vitro" measurements where a sample must be physically removed from animal or human body and measured externally with a counter.

In this series of experiments, we will study some geometrical considerations in radiobiologica and medical applications, measurement of the characteristics of collimators and perform some simple radiological imaging experiements. These three experiments with NaI scintillation counters form basic things in scanning and imaging which will be explained in the following lectures.

EXPERIMENT 1

Geometrical Considerations in Radiobiological and Medical Experiments

Purpose

For many bio-trace experiments the measurements can be made in vivo. For these measurements the major source of radioactivity is the thyroid gland, which is surrounded by flesh and tissue. There are also bones close to the gland, and they can cause Compton scattering and hence distort the measured spectra.

In this experiment, we will study some of the effects that are observed when there is material between the source and the detector or surrounding the source.

Procedure

1. Set up the electronics and physical arrangement as shown in Fig. 1. Be sure to allow room between the source and the detector for inserting several plastic boards during the experiment.

2. Adjust the gain of the amplifier and the high voltage for the photomultiplier so that the photopeak for ^{137}Cs (from the source kit) is near channel 600.

3. Store a spectrum in the MCA for a period of time long enough to obtain about 1000 counts at the top of the photopeak. Fig. 2 shows a typical ^{137}Cs spectrum. Read the data out of the MCA, store the spectrum in the first quarter.

4. Place the first plastic board in position A, Fig. 1, and store a spectrum for the same amount of time that was used in step 3. Read the data out of the analyzer and store the spectrum in the second quarter.

5. Without disturbing the plastic board in position A, place another plastic board in position B. Count for the same time period used in step 3. Read the data out of the analyzer and store it in the third quarter.

6. Make the overlap of the first spectrum and the second, then make the overlap of the first and third to compare these spectra.

Exercises

(a) Plot on semilog paper the spectra recorded in step 2, with no plastic board. On the same paper, use different symbols and plot only the backscatter portion of the right of the spectra measured in step 3 and 4. Note that the photopeak remains the same for all spectra taken with plastic board in position A, but there is increase of Compton of the spectrum with plastic board in A position.

(b) On another piece of semilog paper, plot again the spectrum taken with the source and with plastic board in position A. On the same sheet, plot the spectrum that was taken with plastic board in position B.

Summary

In vivo biological and medical measurements almost always result in distorted scintillation measurements because materials between the source and detector can be expected to eliminate some counts from the peak and also enhance the Compton scattering distribution. The distortion is produced by the photoelectric effect and Compton scattering in the material that surrounds the effective source in the biological sample that is being studied. However, by knowing the magnitude of these distortions, accurate biological measurements can still be made for most systems.

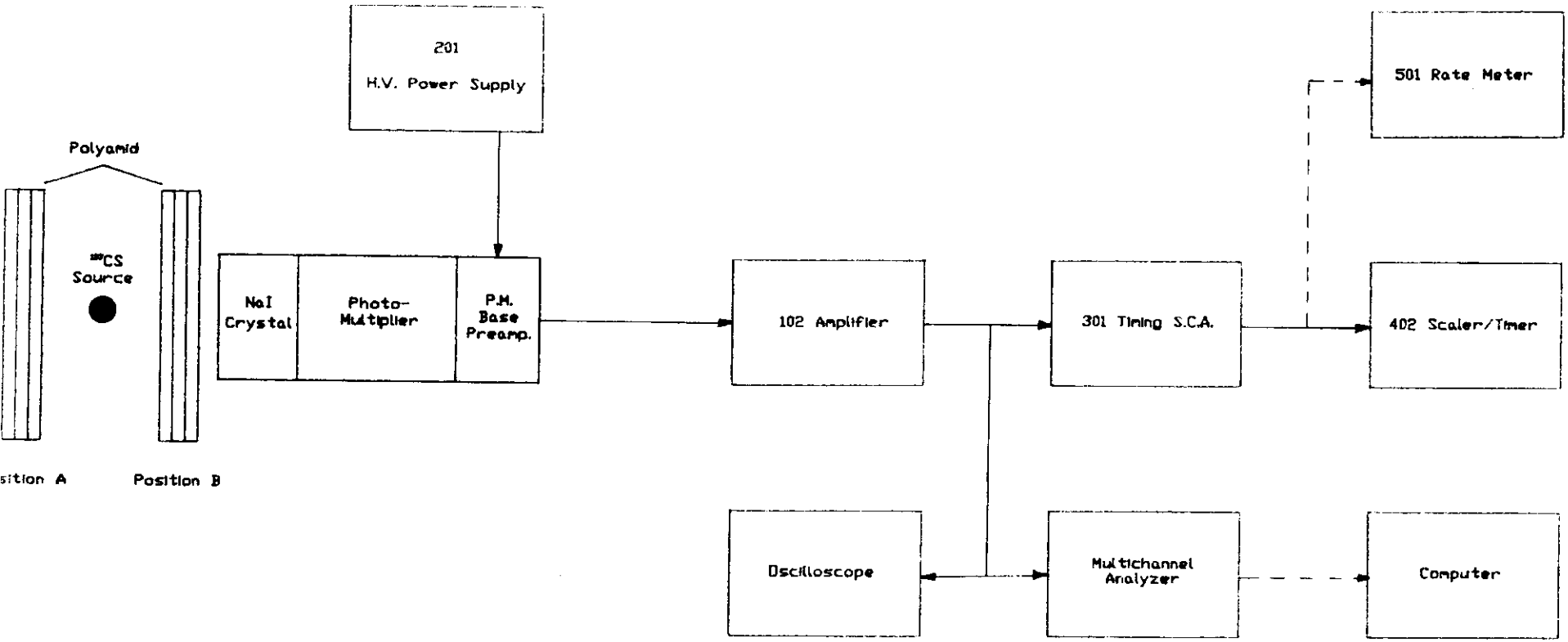

Fig. 1: GammaSpectra Measurements with Material Surrounding the Source.

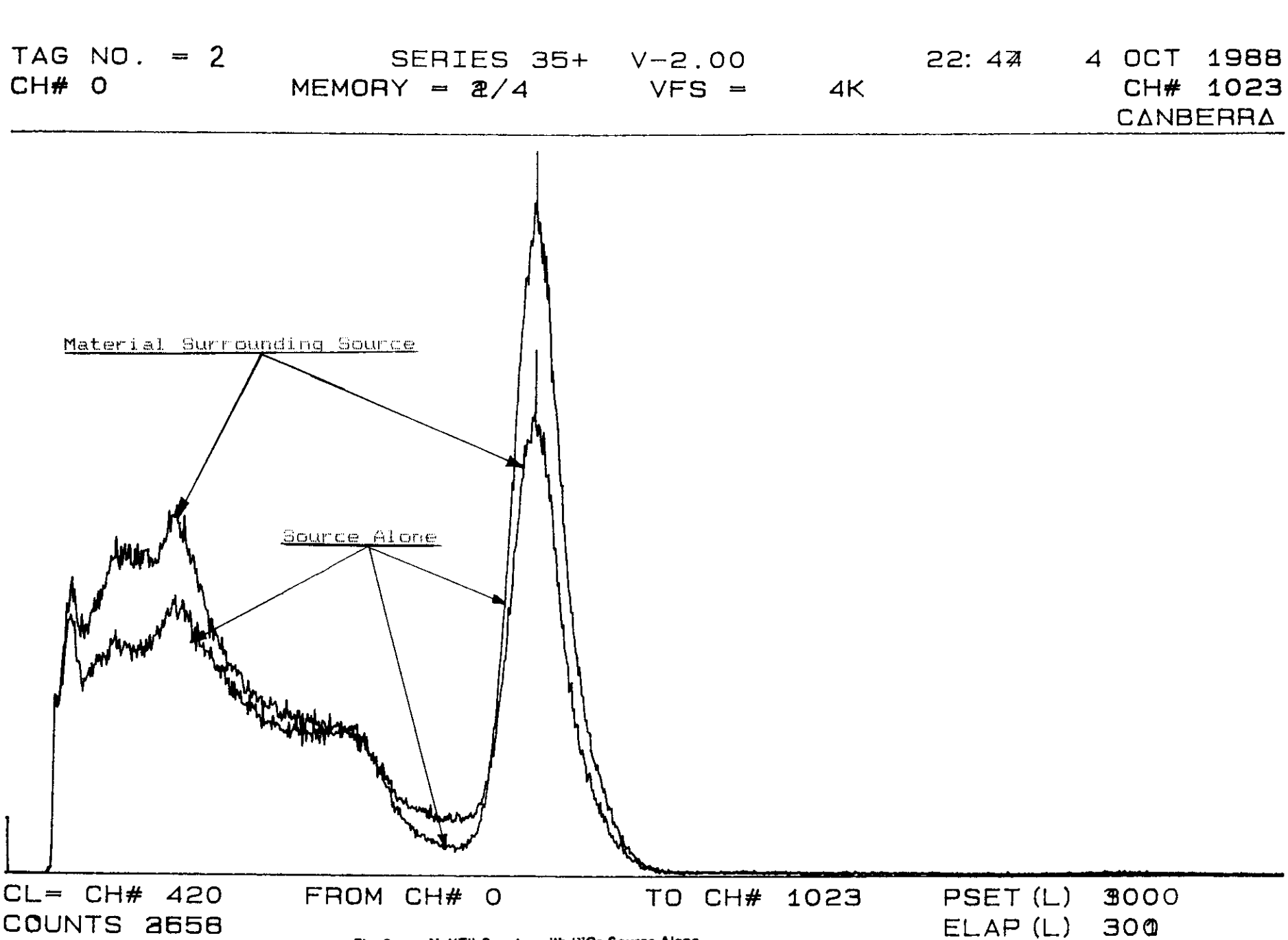

Fig. 2 NaI(Tl) Spectra with ^{137}Cs Source Alone and with Polyamid Surrounding the Source.

EXPERIMENT 2

Measurement of Collimator Resolution

Purpose

A collimator is essentially a block of lead larger than the detector, containing an arrangement of holes which allows gamma rays to pass through from a specified direction and form the image. The lead thickness is sufficient to absorb unwanted radiation, so that the radiation reaching the detector face must have originated from a known direction. This is determined by the orientation of the hole in the lead. The performance of the collimator in the scintillation camera is measured by the three quantities resolution, efficiency, and septum penetration, which in turn are determined by the three collimator dimensions height, hole diameter, and septum thickness. Only if these three separate problems are solved it is possible to arrive at that collimator best suited for a particular investigation. From a practical point of view it becomes necessary to group types of investigations such that a limited number of collimators may serve all types of studies.

In this experiment, we will study some characteristics of the collimator, e.g. resolution which is important to image of scanners and gamma cameras.

Procedure

1. Set up the electronics and physical arrangement as shown in Fig. 3. The focal point of our collimator is about 80 mm (from the face of the collimator)
2. Place one of the source kit (^{137}Cs, ^{133}Ba or ^{57}Co) at the central position of the focal point, i.e. position f.
3. Adjust the gain of the amplifier and high voltage for the photomultiplier so that the photopeak of the source is near the middle of total channel number.
4. Set the ROI of the MCA so that it brackets the main peak of the spectrum of the source used.
5. Set the window of SCA according to the ROl of MCA set in step 4.
6. Store a spectrum in the MCA for a period of time long enough to obtain about 1000 counts within the RO7 in MCA or the window in SCA.
7. Move the source from left (20mm) to right (20mm) by steps 1mm each and period of time taken in step 6. Note down number of counts both in ROI of MCA and in window of SCA.
8. Move the source along the axis of the collimator by step 5mm each and same period of time taken in step 6. Note down number of counts both in the ROl of MCA and in the window of SCA.

Exercises

(a) Plot on paper the point source response function for the source measured. Indicate the FWHM of the collimator on the paper.

(b) Plot on paper the isocount contour of the point source response function with the data obtained from step 7 and 8 (straight line connection between the points with almost the same counts for simplification within short exercise section).

Summary

In the focal plane there is rapid fall-off of sensitivity as we go away from the focus. Other planes have lower sensitivity on the axis, and the fall-off is not so rapid. If the source is in tissue the attenuation of the gamma rays will bring the point of maximum sensitivity nearer the surface.

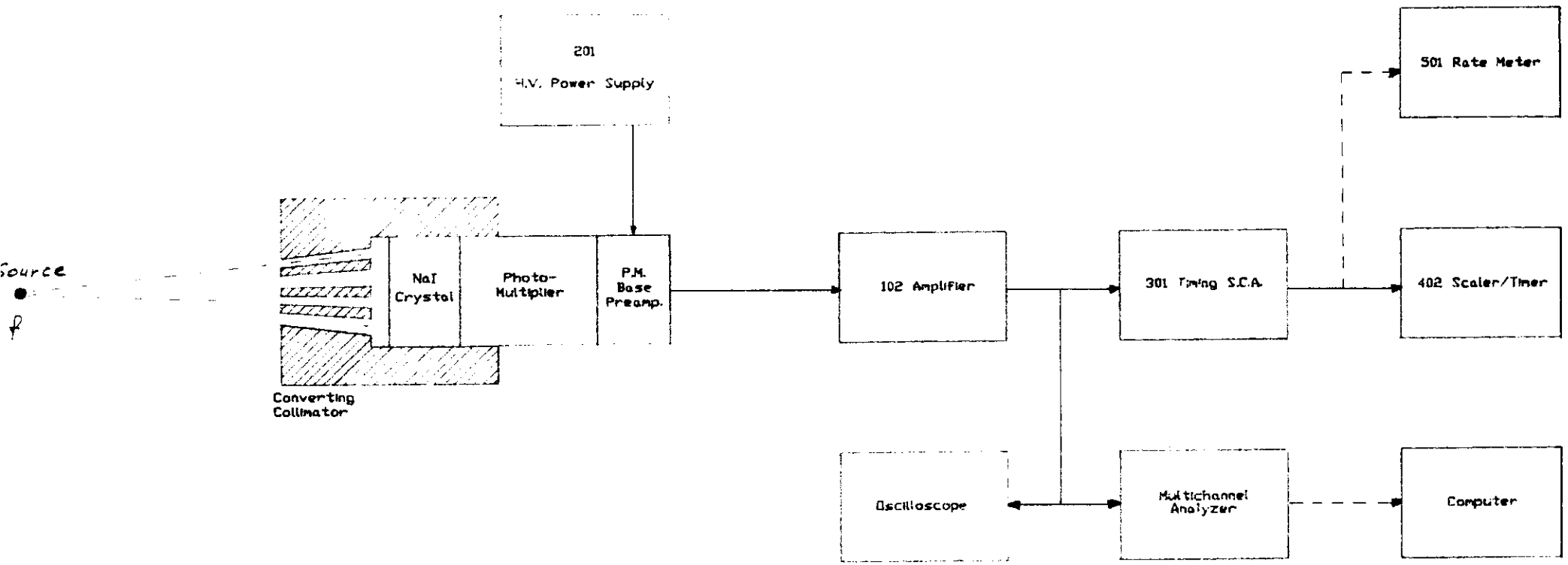

Fig. Nr.3 Resolution mesurement for converging collimator with a point radiation source.

EXPERIMENT 3

Configuration and Operation of a Rectilinear Scanner with Agency SCA in Eurocard System

Purpose

The distribution of a radiopharmaceutical within the body can provide important diagnostic information. The rectilinear scanner is a device for imaging the distribution of radioactive material within the body. it is a systematic point sampling device that forms its image by moving over (scanning) the field of interest.

In this experiment, we will configurate a simplest rectilinear scanner with a SCA system which is calibrated by a MCA. During and after operation of such a scanner, accuracy of the system should be defined.

Procedure

1. Set up the electronics and physical arrangement as shown in Fig. 4.

2. Put a paper with two dimension scales right under the detector.

3. Adjust the distance between the detector and paper to 80mm. Place the envelop with a source inside on the paper. Be sure to locate the center of the envelop at f position.

4. Repeat steps 2-6 as described in experiment 2.

5. Move the envelop with big steps (e.g. 10mm each) in a rectilinear manner over the area of the envelop.

6. Move the envelop with small steps (e.g. 1mm each) along the source outline which was defined by step 5.

Exercises

(a) Plot on a paper with two dimension scalers the isocounts contour which is half of the maximum count measured during scanning.

(b) Open the envelop and compare the source shape with one plotted on the paper.

(c) Define the difference between the source shape and its image, and describe the reason of the differences.

Summary

The accuracy of the scanner depends on many factors, e.g. resolution and sensitivity of the detector used, resolution and sensitivity of the collimator, radiation source detected, quality and adjustment of the electronics parts, and accuracy and steps of the scanning operation, media between the source and detectors, etc. But radiation source, detector and collimator intrinsically decide the accuracy of the scanner if nothing goes wrong in the whole system and implemented procedures.

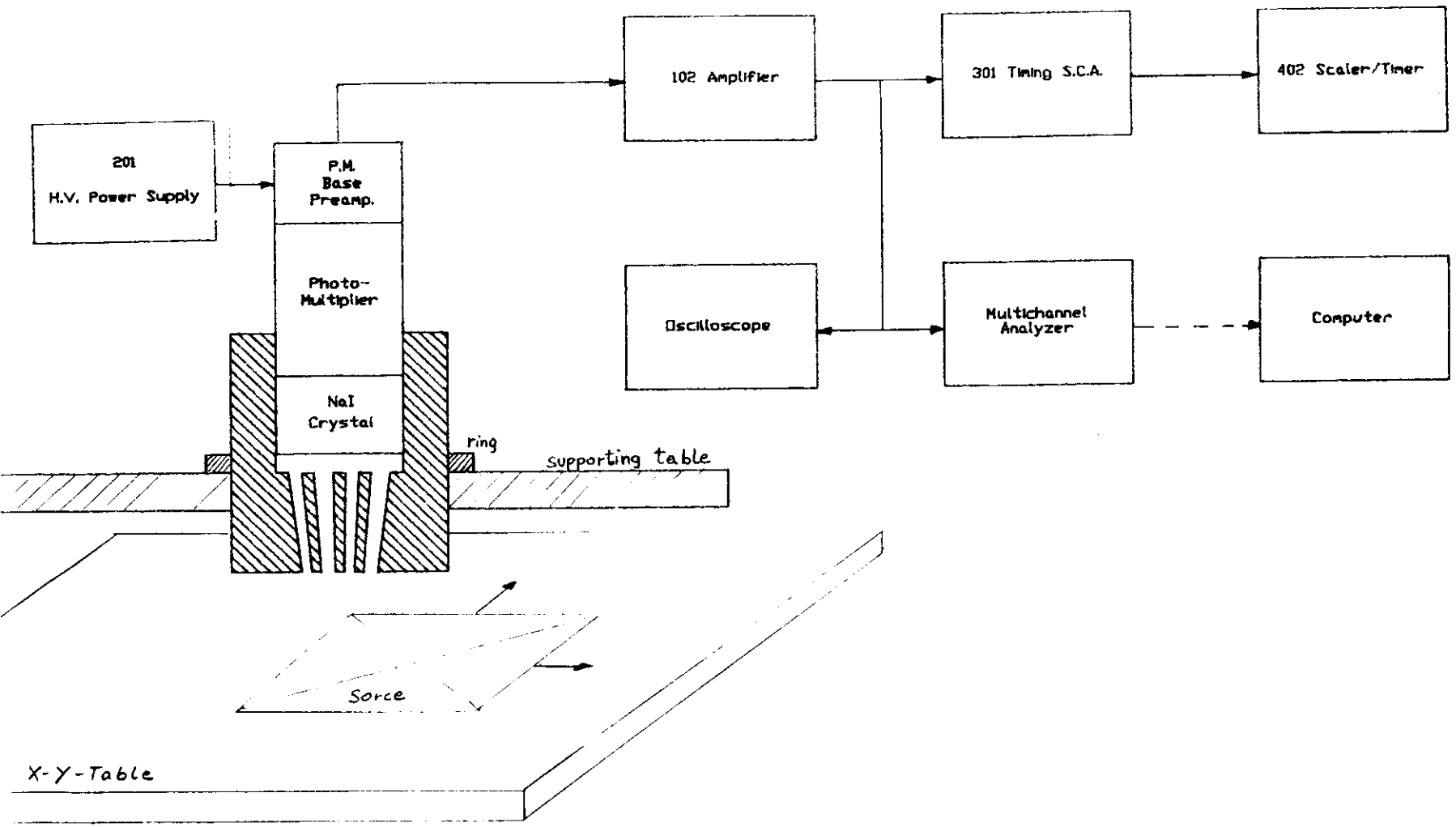

Fig. Nr.4: A rectilinear scanner with NaI counter and converting collimator