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A MAGNETIC-LENS – MINI-ORANGE COINCIDENCE SPECTROMETER

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A Magnetic-Lens – Mini-Orange Coincidence Spectrometer

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Abstract

A coincidence spectrometer consisting of a Gerholm type magnetic lens and a permanent magnet mini-orange spectrometer is described. Electron–electron or electron–positron coincidences may be registered in various angular settings. The spectrometer has been developed mainly to search for anomalous contributions to Bhabha scattering of positrons and is at present used for such studies.

1 Introduction

Magnetic selection has for a long time been a main means for energy, or rather momentum, selection in the study of electron and positron spectra. High resolution has proved essential in several applications, e.g. for determining the neutrino mass and in the study of conversion electron spectra of complicated nuclear decays. In other situations high transmission is more important than good resolution. Coincidence applications depend on two acceptance angles and thus make the transmission a critical feature. In this laboratory high transmission has been achieved by using long-lens spectrometers of the Gerholm type [1].

Investigations of possible Bhabha anomalies in the scattering of positrons on thorium [2] have been carried out using two Gerholm lenses in a 180° geometry. Scattered positrons and electrons were recorded in coincidence. The ^{68}Ga source was directly applied on a thorium foil placed at the ordinary source position. In the more recent measurements, to be published, the source was somewhat detached from the foil similarly to the arrangement in our study of electron scattering [3].

In one of the first experiments to investigate Bhabha scattering anomalies positrons with a continuous energy distribution (from a ^{68}Ge-^{68}Ga source) were scattered on thorium. Deviations from the expected spectrum were reported at measured positron energies (corrected for energy loss in the target) of about 345 keV [4]. These measurements employed two mini-orange magnetic spectrometers positioned at angles ±45° with respect to the normal to the thorium foil target, an arrangement in the following referred to as a 90° geometry. A setup of this kind, however, is rather compact and open and may give undesired coincidence events due to e.g. scattering of annihilation quanta. This kind of problems are effectively dealt with through the use of two Gerholm lenses.

In the search for anomalies in the scattering process a region of positron and electron energies has to be investigated. In our experiment [2] energies were selected by varying the lens currents, but since in each channel only one energy can be measured at a time, scanning over the energy region of interest, in our case 210–465 keV, becomes very time consuming. By substituting one of the Gerholm lenses for a mini-orange spectrometer we can measure all electron energies simultaneously. Another reason for using a mini-orange device is the possibility to study the coicidence spectrum for varying angles between emitted electrons and positrons.

2 The coincidence spectrometer

2.1 The mini-orange spectrometer

Van Klinken et al. have described in detail [5] the construction of various mini-orange systems. Here we describe an electron(positron)–electron(positron) setup consisting of a Gerholm magnetic lens and a mini-orange device, a setup which we at present use for further investigations of anomalous positron scattering.

The mini-orange spectrometer consists of three or four wedge shaped magnets (Fig. 1) mounted on an aluminium ring and centered by a lead plug. The magnets are manufactured from a NdFeB alloy, a permanent magnetic material amenable to high-field magnetization. The central lead plug serves as a shield for photons emitted from the source or the target. The shape of the magnets is chosen to provide focusing and thus enhance the transmission.

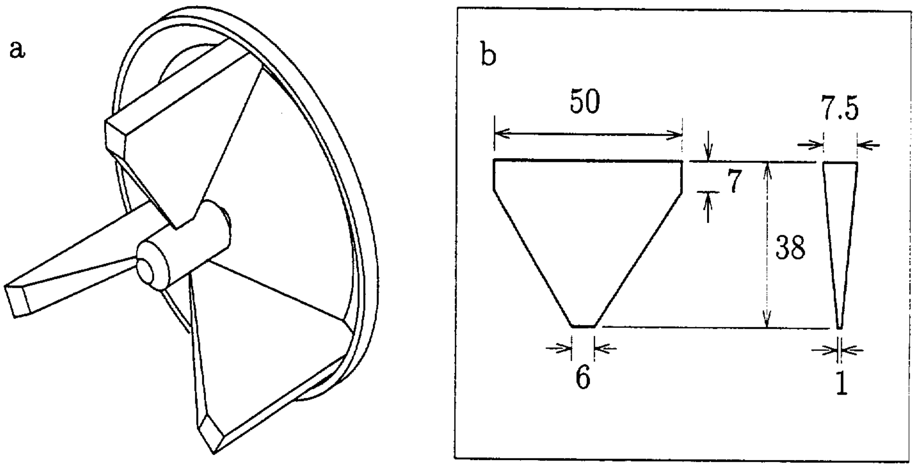

Figure 1: a: The mini-orange unit. b: The wedge shaped magnets. Dimensions in mm.

An optimum in transmission has been found by varying the distances between the center of the magnet system and the target, and the detector, respectively. Our setup permits adjustments by moving the detector along the axis of the spectrometer. Due to the simple design of the mini-orange device the magnetic field can easily be reversed should one wish to use it for positrons instead of electrons.

A housing for our present experiment has been manufactured in the workshop of the Department. This housing permits two different mounting positions for the mini-orange device, corresponding to a 180° and a 90° geometry.

Using cooled silicon detectors in the housing would introduce practical problems, e.g. warm up periods prior to accessing the interior of the housing. An external Si detector with a beryllium window was used in the initial phase. In the completed setup two fully depleted Si (Canberra FD300-17-700RM **P**assivated **I**mplanted **P**lanar Silicon) detectors in file were installed in the housing, detectors which operate at room temperature. By using two detectors we may add an anticoincidence gate to discriminate against particles not stopped in the first. The active area of the detectors is 300 mm^2 and the nominal depletion depth is 700 μm. For electrons and positrons the energy resolution is 10 keV (FWHM).

In order to obtain a maximum in the transmission for 300 keV electrons we have chosen a distance of 50 mm from the center of the mini-orange to the target, and a distance of 40 mm from the center to the detector. Using a ^{154}Eu source electron spectra were measured with and without the mini-orange respectively, the quotient defines the instrument function shown in Fig. 2.

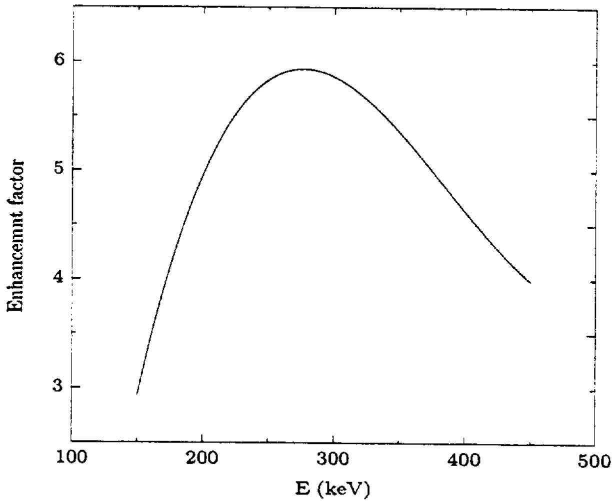

Figure 2: Instrument function for the mini-orange spectrometer.

In the energy region under investigation we have an enhancement of at least a factor 4. Our mini-orange spectrometer consists of three magnets. With a different mounting ring and lead plug a fourth magnet can be added, yielding a stronger magnetic field.

2.2 The Gerholm lens

The Gerholm magnetic lens is described in detail in [1]. We use the original design, in the version intended for electron–gamma coincidence measurements, i.e. with the source (in our case target) position somewhat displaced compared to the electron–electron version. In our present setup the transmission is 1.4% and the momentum resolution (both adjustable through the baffle) 3.6%. A twisted baffle [1] letting only positrons pass from the source to the detector was inserted in the lens. For the detection of positrons we use a plastic scintillator together with a PM tube. In order to reduce the volume of the scintillator and thus suppress the detection of annihilation quanta, the homogeneous conic scintillator was replaced by a cone where the thickness of the active material is about 2 mm. The inner part of the scintillator is made from lucite.

2.3 The coincidence arrangement

For an overview of the Gerholm lens-mini-orange coincidence arrangement we refer to Fig. 5.

Investigations of the 180° setup have shown that the conjunction of the two spectrometers does not introduce any problems regarding the magnetic influence of either of the magnetic spectrometers on the other. In the 90° mode however, the magnetic field from the mini-orange device modifies the particle trajectories in the lens.

Previous experiments [2] have indicated the appearance of undesired coincidence events. The mechanism behind these is the following: positrons detected and subsequently annihilated in the scintillator create annihilation quanta which may eject electrons due to Compton scattering or photoeffect. Electrons from these scattering events may, if their energy matches the setting of the Gerholm lens, be transmitted 'backwards' through the lens and registered in the other channel. Due to an insufficient time resolution of the PIPS detectors we cannot discriminate against these events.

Tests have been performed to investigate whether events of this kind contribute significantly to the total coincidence spectrum. For these tests the source was placed in a position facing the magnetic lens and, in order to reduce the number of Bhabha events, the thorium foil was removed. Coincidences between positrons hitting the scintillator, and ejected electrons passing backwards through the lens and detected in the PIPS, were registered. In Fig. 3 an example of a coincidence spectrum from the PIPS detector is shown. The number of coincidences was normalized on the number of detected positrons. Compared to the number of coincidences in an ordinary measurement, the number of undesired events is 3%, which is less than the statistical uncertainty in the coincidence data. This figure should in the actual measuring situation be even smaller since electrons from the lens are scattered in the thorium foil and only a part of them will reach the PIPS detector.

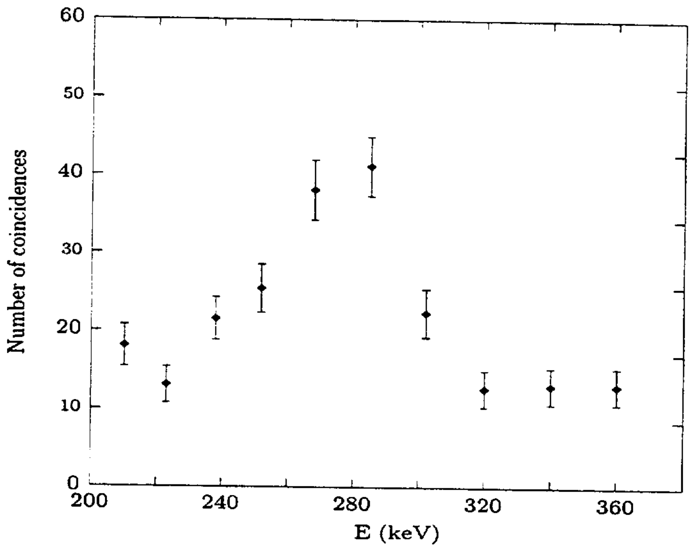

Figure 3: The number of coincidences between events in the positron detector, and electrons passing backwards through the spetrometer. The number of coincidences is normalized to 10^6 positron events. The lens current corresponds to positrons of 300 keV when the oridinary source position is used.

In the coincidence measurements, data were collected in order to cover an energy region of 210–465 keV for both electrons and positrons, i.e. to cover an energy matrix. As mentioned above, the mini-orange device gives us the possibility to measure all electron energies simultaneously. Positron energies on the other hand were chosen in intervals of 15 keV, matching the resolution of the magnetic lens.

Signals from the experimental setup are converted and stored on magnetic tape using a data acquisition system developed in the Department [6]. A layout of the entire system is shown in Fig. 4.

3 Developments

An extensive series of measurements was conducted using our experimental setup in the 180° configuration. Using a ^{68}Ga-^{68}Ge source and a thorium foil target with a thickness of 25 μm, backscattered positrons were detected through the Gerholm lens and electrons in the mini-orange spectrometer. Analysis of data from this experiment is concluded and will be published.

In a second series of measurements, now in progress, the lid covering the unoccupied 90° mounting position has been substituted for a thin film. A third (x-ray) detector has been placed close to the film outside the housing. This modification permits us to establish whether scattering events involve inner shell electrons, accompanied by coincident x-ray photons.

In order to investigate the angular dependence of the scattering, the possibility to vary the angle between the two spectrometers continuously may be desired. Such a development could be accomplished by mounting the mini-orange and the PIPS detectors in a common frame which can be moved along a semicircle.

We thank J. van Klinken for providing us with his report Mini-Orange Sketches.

[1] T. R. Gerholm, R. Othaz and M. S. El-Nesr, Ark. Fys. **21**, 253 (1962); T. R. Gerholm and J. Lindskog, Ark. Fys. **24**, 171 (1963)
[2] Chr. Bargholtz, L. Holmberg, K. E. Johansson, D. Liljequist, P.-E. Tegnér, L. Bergström and H. Rubinstein, J. Phys. G **13** L265 (1987); Chr. Bargholtz, L. Holmberg, K. E. Johansson, D. Liljequist, P.-E. Tegnér and D. Vojdani, Phys. Rev **C 40**, 1188 (1989)
[3] Chr. Bargholtz, L. Holmberg, D. Liljequist, P.-E. Tegnér and D. Vojdani, Phys. Rev. **C 48**, 1388 (1993)
[4] K. A. Erb, I. Y. Lee and W. T. Milner, Phys. Lett. **B 181**, 52 (1986)
[5] J. van Klinken, S. J. Feenstra and G. Dumont, Nucl. Instr. and Meth. **151**, 433 (1978) ; J. van Klinken, Univ. of Groningen, Kernfysisch Versneller Instituut, KVI Internal Report no. 122i (1986)
[6] T. Arctaedius and R. E. Ekström, Univ. of Stockholm, Institute of Physics USIP Report 86-09 (1986)

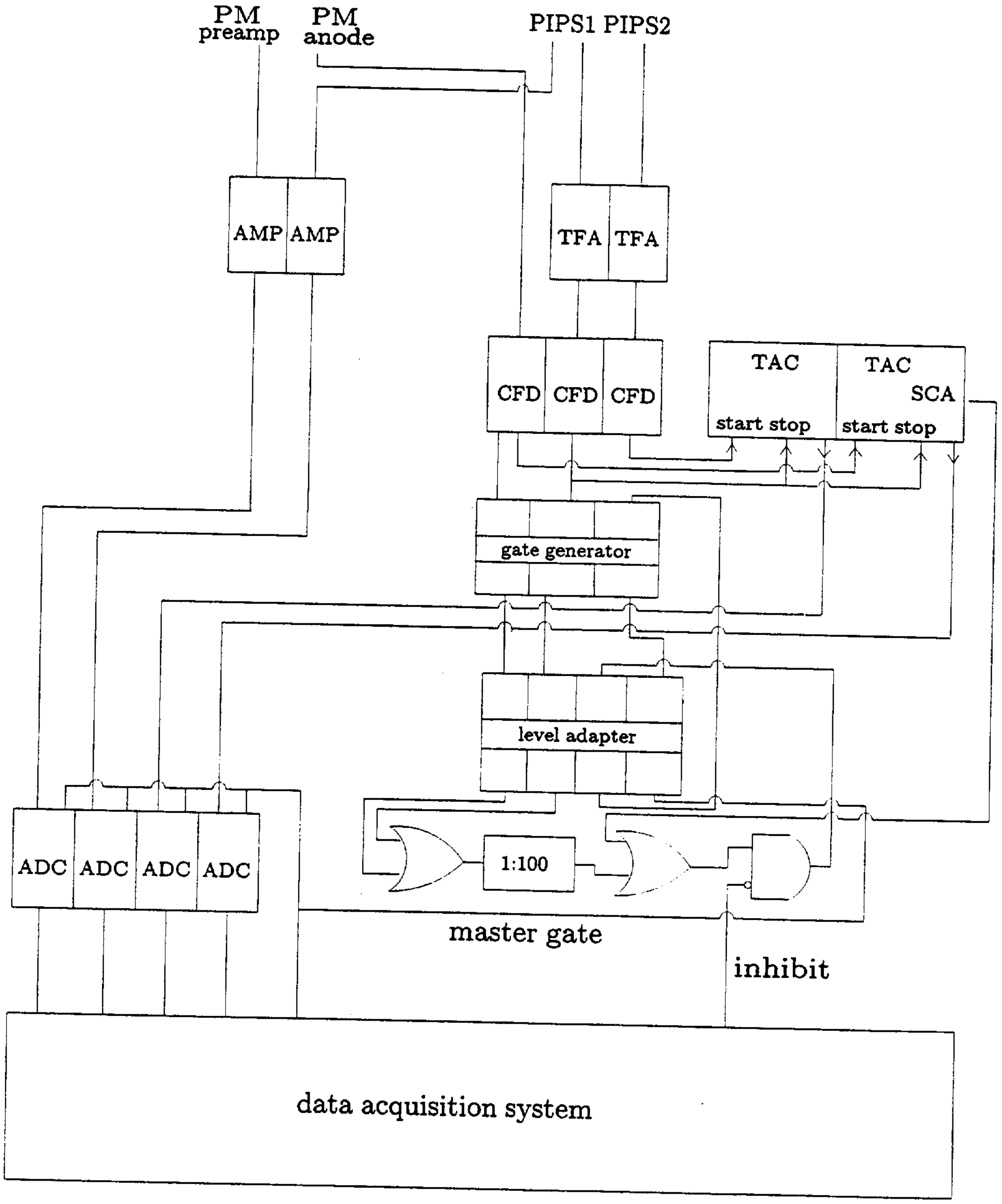

Figure 4: Hardware layout of the coincidence signal processing.

Caption for Fig. 5

A coincidence arrangement in the 180° configuration, with the Gerholm lens left and the mini-orange housing right is shown.

The exit opening of the electron baffle system of the lens, and thus the momentum resolution, can be changed by changing the position of the ring on the central lead plug. The additional twisted baffle, used to transmit only positrons passing from the source (D) to the scintillator (A), is not shown in the figure.

Removal of the right hand side cover of the housing provides access to the mini-orange spectrometer (B) as well as the Si detectors (C).

The source (D) is placed in a copper cavity covered by a thin film to prevent evaporation of the source material. The thorium foil (E) is mounted on an aluminium ring fixed to an arm which can be moved in two directions (along the spectrometer axis and perpendicular to it) from the outside. In our most recent series of experiments the ring was slightly inclined with respect to the axis in order to facilitate detection of x-rays in the high purity Ge detector (F).

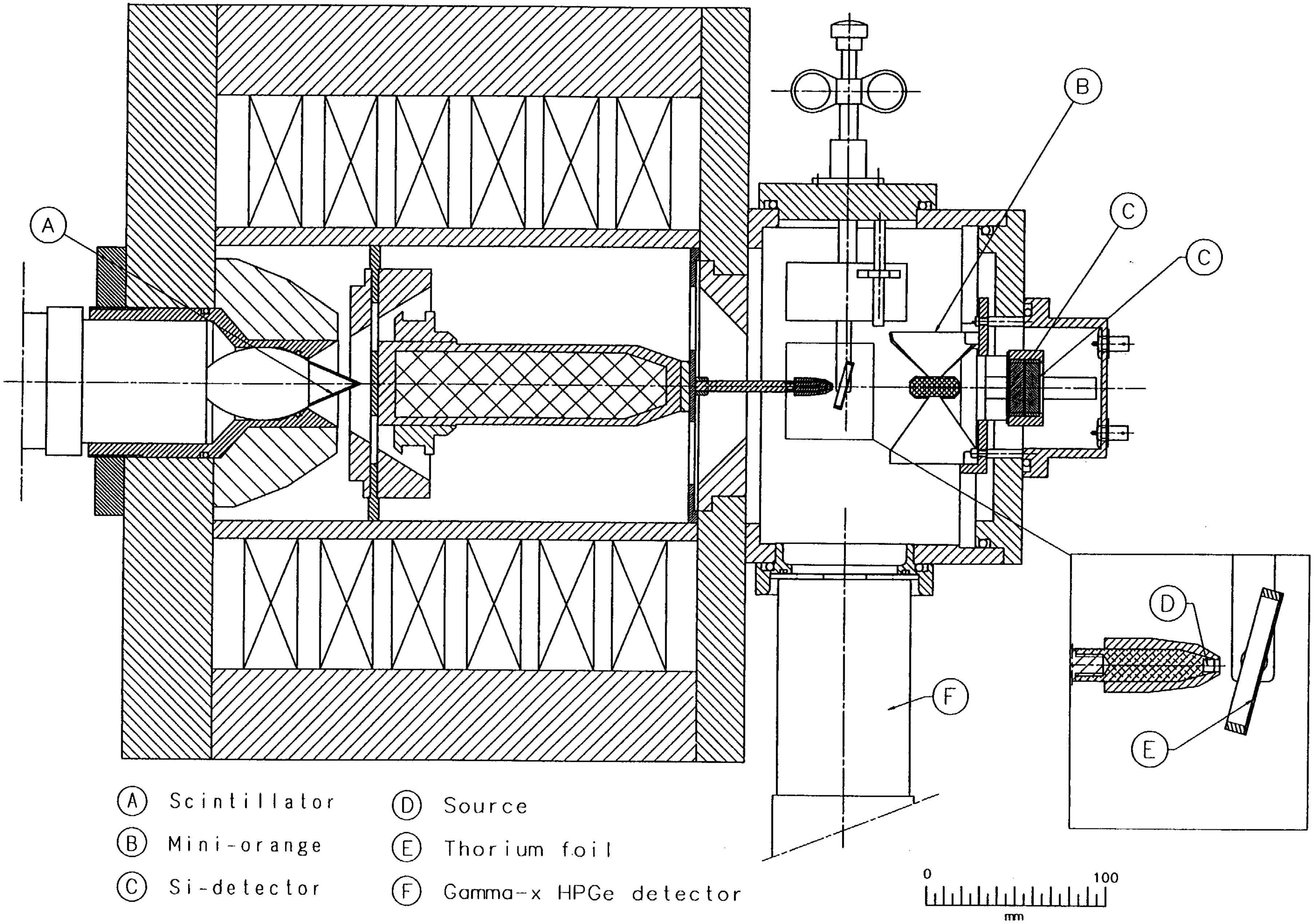
A
B
C
C
D
E
F
Ⓐ Scintillator
Ⓑ Mini-orange
Ⓒ Si-detector
Ⓓ Source
Ⓔ Thorium foil
Ⓕ Gamma-x HPGe detector
0
100
mm

Figure 5