A TRANSISTORIZED GAMMA-GAMMA COINCIDENCE SPECTROMETER

H. ABOU-LEILA, A.A. EL KAMHAWY[+], H.A. ISMAIL[++],
S.M. DARWISH[+++] and A.M. IBRAHIM[++]

Physics Department, University College For Girls,
Ein Shams University, Cairo, Egypt.

Abstract. A completely transistorized coincidence spectrometer which could be used to study direct and coincidence gamma-gamma spectra is shown. The constructed electronic circuits, characteristics and performances of such spectrometer are presented. Direct and coincidence spectra for the decay of ^{152}Eu are also presented.

Introduction

Study of decay schemes of radioactive nuclei offers one of the most important methods to study the nuclear structure[1]. Direct spectra, coincidence spectra as well as angular correlation measurements supply very important knowledege about the decay scheme of the studied nucleus. A coincidence spectrometer which could be also used for angular correlation experiments is one of the most important equipments for any nuclear physics laboratory. Therefore, we have found it useful to construct a completely transistorized coincidence spectrometer. This spectrometer could be used to study direct gamma spectra, gamma-gamma coincidence spectra and moments of excited levels by angular correlation methods. It is also possible to measure beta-gamma or alpha-gamma coincidence by simply choosing suitable scintillators for beta- or alpha-particles. The spectrometer could be easily modified to study beta-gamma, alpha-gamma or gamma-gamma coincidences using high resolution detectors such as Ge(Li) detectors or surface barrier detectors (under construction) for alpha or beta particles.

+ Atomic Energy Establishment, Cairo.

++ Faculty of Education, Ein Shams University, Cairo.

+++ Physics Department, Faculty of Science, Cairo University, Giza.

The purpose of this work is therefore to constract such a spectrometer. The spectrometer has been tested using ^{22}Na and ^{60}Co sources. For the completeness of the work ^{152}Eu has been simply investigated[2].

General Description

Fig. 1 shows a block diagram of the whole spectrometer. We have constructed two scintillation detectors[3] using two 153 AVP photomultipliers (PM) each of which is coupled to a 2" x 2" NaI(Tl) crystal. Pulses from the anode of each PM are fed to a variable resolving time fast coincidence circuit after suitable amplification and shaping. Part of the spectrum from one of the photomultiplier detectors PM(2) could be selected by a zero crossing single channel analyzer and then fed to one of the inputs of a slow coincidence circuit through a phase invertor and shaper. The other input of the slow coincidence circuit receives pulses from the output of the fast coincidence circuit after passing through a suitable delay circuit. The output pulses from the slow coincidence circuits are used to gate a 512 LABEN multichannel analyzer after being amplified, shaped and delayed by suitable circuits. The multichannel analyzer receives a direct spectrum from PM(1) through a suitable linear amplifier and a delay line.

The two detectors are mounted on an angular correlation table Fig. 2 with a movable source holder in the center of the table. Owing to the finite size of the detectors, the table permits coincidence measurements at angles varing from 60° to 240°.

Electronic Circuits

All the electronic circuits presented in fig. 1 except the linear amplifie and the zero crossing single channel analyzer in channel (2) have been construc for the present work[2], however, only fast circuits will be presented.

(i) Fast Amplifiers:

Two identical fast amplifiers have been constructed. Fig.3 shows the circ of one of these amplifiers. It consists of a capacitive differentiator (200 pf followed by an unsaturated differential amplifier (T_1 and T_2) and a gated ampli

(T_3). T_4 and T_5 act as an amplifing stage followed by an emitter follower. The gain of this amplifier has been found to be in the order of 100. Its band width mounts to about 20 M Hz. The input pulses (from the photomultiplier) have about 25 ns rise-time and 5 μs duration while the output pulses from the circuit have about 10 ns rise-time and 200 ns duration.

(ii) Fast Shapers:

Fig. 4 shows the circuit of one of the fast shapers used in the present work. It consists simply from a differentiating stage using a 25 pf capacitance followed by two amplifying stages (T_1 and T_2) and then an emitter follower T_3. The output pulses from such circuit are of about 7 volts amplitude and 20 ns duration.

(iii) Variable Resolving Time Fast Coincidence:

Fig. 5 shows the circuit used which consists of a fast coincidence stage, a fast discriminator stage and a fast shaper. The resolving time of the coincidence circuit could be changed by changing the discrimination level of the fast discriminator. The coincidence stage consists of two tunnel diodes whose biases are adjusted so that only negative pulses of amplitudes greater than 6 Volts can produce tunnel effects[4]. The output of the coincidence stage depends on the delay time between the two input pulses. For maximum overlap, the output pulses are of height $\simeq$ 0.5 volts and duration time $\simeq$ 40 ns. These pulses are fed to the discriminator through the emitter follower T_1. The fast discriminator used consists of two tunnel diodes followed by an amplifier T_2. The discriminator lower level and hence the resolution of the coincidence could be varied from 0 to 0.5 volt using two variable resistors 10 KΩ and 820 Ω.

Performance

Fig. 6 illustrates the resolving curves of the fast coincidence unit for ^{22}Na , ^{60}Co ,and ^{152}Eu sources. For ^{22}Na curve the resolution (2τ) was of the order of 36 ns while the slope of the curve has a $T_{\frac{1}{2}} \simeq$ 10 ns. The ratio of accidental to true coincidences is $\lesssim 2^{o}/_{o}$. The spectrometer has been tested by performing direct and coincidence spectra in ^{22}Na and ^{60}Co sources.

In case of ^{22}Na source fig. 7 it is clear that the 1.275 MeV line is completely absent from the coincidence spectra, while for ^{60}Co curves fig. 8 the ratio between the intensities of the 1.18 and 1.33 MeV lines are greatly affected according to the position of the choosen window.

The spectrometer has been also used to study direct and coincidence spectra in the decay of $^{152}Eu \rightarrow {}^{152}Sm$ and $^{152}Eu \rightarrow {}^{152}Gd$. A simplified decay scheme including the investigated transitions is illustrated in fig. 9. The direct spectrum (I) obtained as well as coincidence spectra (II, III, IV) for different choosen windows are shown in fig. 10. When the multichannel analyzer was gated with the 122 KeV line in ^{152}Sm ($2^+ \rightarrow 0^+$ transition), the 0.245, 0.965, 1.09, 1.11 and 1.41 MeV lines are well observed while the 0.344 and 0.779 MeV lines due to ^{152}Gd, are highly attenuated. When the multichannel analyzer was gated in the 0.344 MeV line in ^{152}Gd ($2^+ \rightarrow 0^+$ transition) the most pronounced line was the 0.779 MeV. When gating the multichannel analyzer by the 0.779 MeV in ^{152}Gd, the most pronounced line was the 0.344 MeV.

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References

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2. A.M. Ibrahim, M. Sc. Thesis, to be submitted.
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4. E. Kowalski, Nuclear Electronics (Springer-Verlag, N.Y. 1970).

Figure Caption

Fig. (1) A block diagram of the apparatus.

Fig. (2) Gamma-gamma angular correlation table.

Fig. (3) A transistorized fast amplifier circuit.

Fig. (4) A transistorized fast shaper circuit.

Fig. (5) A transistorized variable resolving fast coincidence circuit.

Fig. (6) Resolving time curves of the fast coincidence unit for ^{22}Na, ^{60}Co and ^{152}Eu sources.

Fig. (7) Gamma-gamma coincidence spectrum using ^{22}Na source.

Fig. (8) Gamma-gamma coincidence spectra using ^{60}Co source.

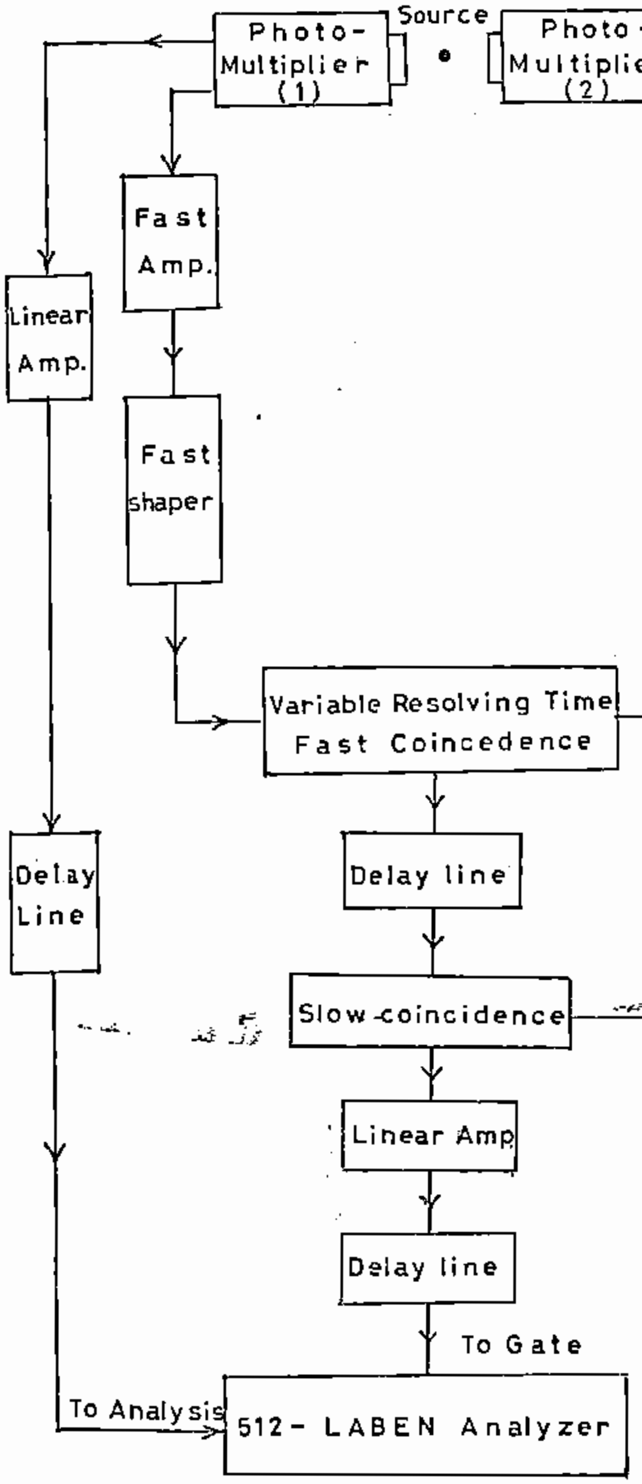
Fig. (9) Simplified decay scheme of the decay of ^{152}Eu. Energies indicated by arrows are those observed by the system.

Fig. (10) Gamma-gamma coincidence spectra using ^{152}Eu source.

مطياف جاما ـ جاما التطابقي

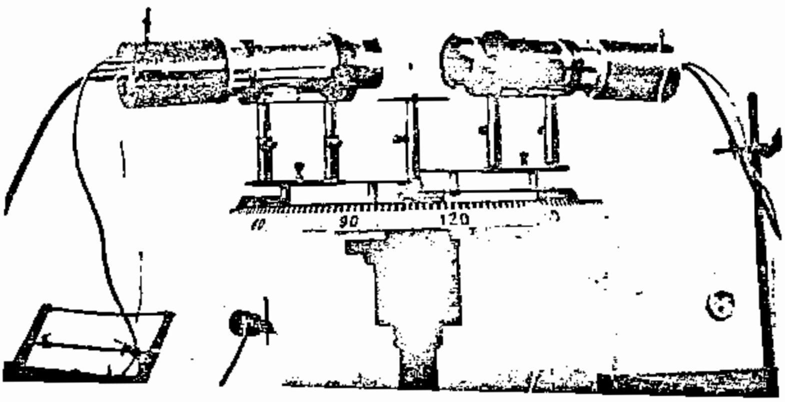
ح • أبوليلة — كلية البنات ـ جامعة عين شمس
ا. ا. القحصاوي — مؤسسة الطاقة الذرية ـ أنشاص
ح. ا. اسماعيل — كلية المعلمين ـ جامعة عين شمس
س • م . درويش — كلية العلوم ـ جامعة القاهرة
ا • م • ابراهيم — كلية المعلمين ـ جامعة عين شمس

البحث يتكون من وصف شامل لمطياف جاما ـ جاما تطابقي يمكن به دراسة الطيف الجامي المباشر والتطابقي كما يصلح أيضا لدراسة التوزيع الزاوي للأشعة المنبعثة من النواه • وقد تم بناء جميع دوائر المطياف من الترانزستور وكذلك كاشفين لأشعة جاما من النوع الوميضي • كما يمكن استعمال هذا المطياف باستخدام كواشف نصف موصلة تصلح لجسيمات/بيتا الفاوجيات وأشعة جاما • وقد ذكر في البحث جميع خصائص وامكانيات المطياف وقد تم تجريبه على بعض الأنوية العيارية مثل الصوديوم ٢٢ والكوبلت ٦٠ • وشمل البحث أيضا عرضا مبسطا لبعض القياسات التي تمت بواسطة الجهاز لدراسة نواة الأوروبيوم ١٥٢

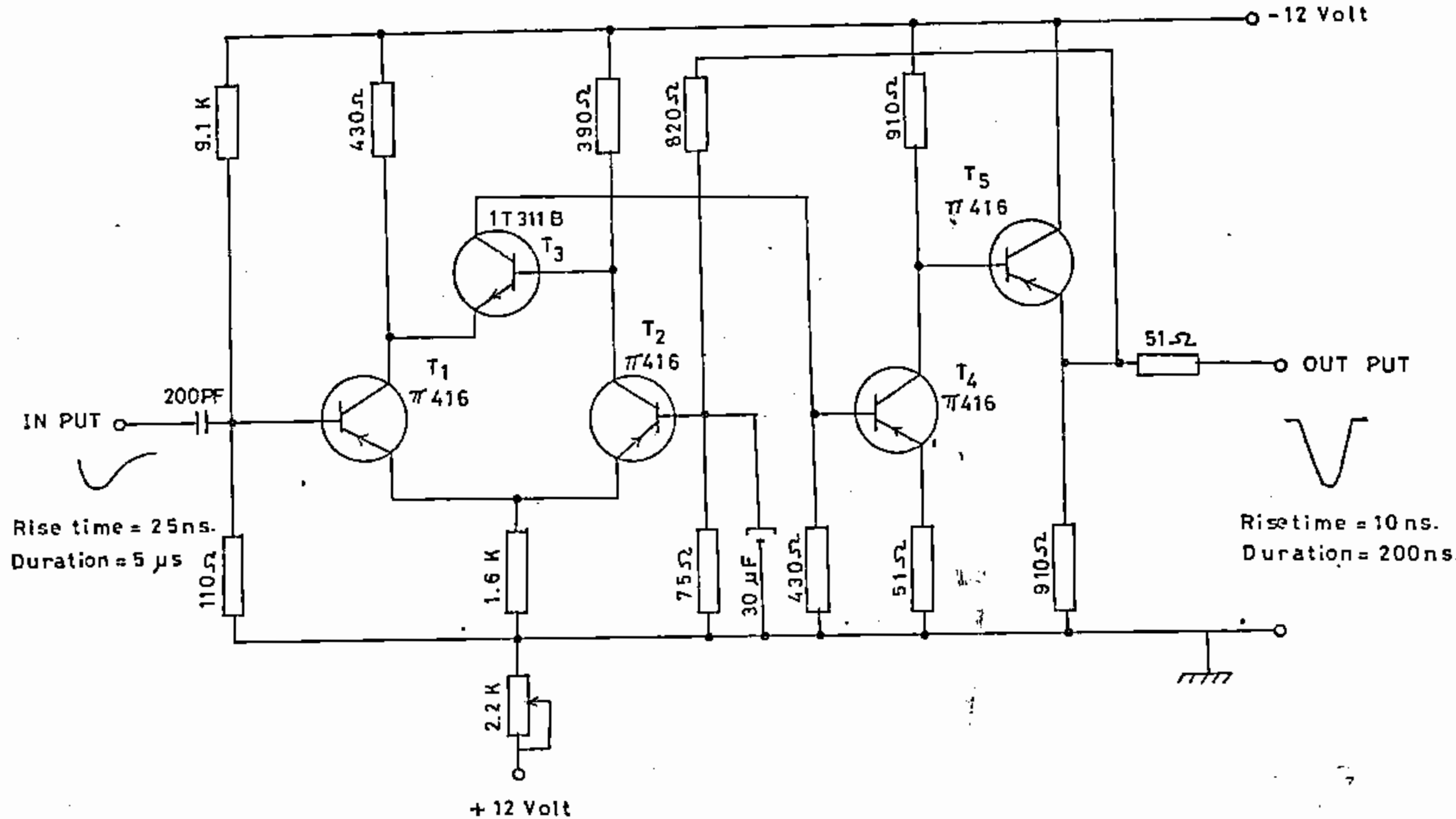


Source
Photo-Multiplier (1)
Photo-Multiplier (2)
Fast Amp.
Fast Amp.
Linear Amp.
Linear Amp.
Fast shaper
Fast shaper
S.C.A.
Variable Resolving Time Fast Coincidence
Phase Inu. + Delay Line
Delay Line
Delay line
Slow-coincidence
Linear Amp
Delay line
To Gate
To Analysis
512 - LABEN Analyzer

Fig 1



Fig



- 12 Volt
9.1 K
430Ω
390Ω
820Ω
910Ω
T_5
π 416
1T311B
T_3
T_2
π416
T_1
π416
T_4
π416
51Ω
OUT PUT
IN PUT
200PF
Rise time = 25ns.
Duration = 5 μs
110Ω
1.6 K
75Ω
30 μF
430Ω
51Ω
910Ω
Risetime = 10 ns.
Duration = 200ns.
2.2 K
+ 12 Volt

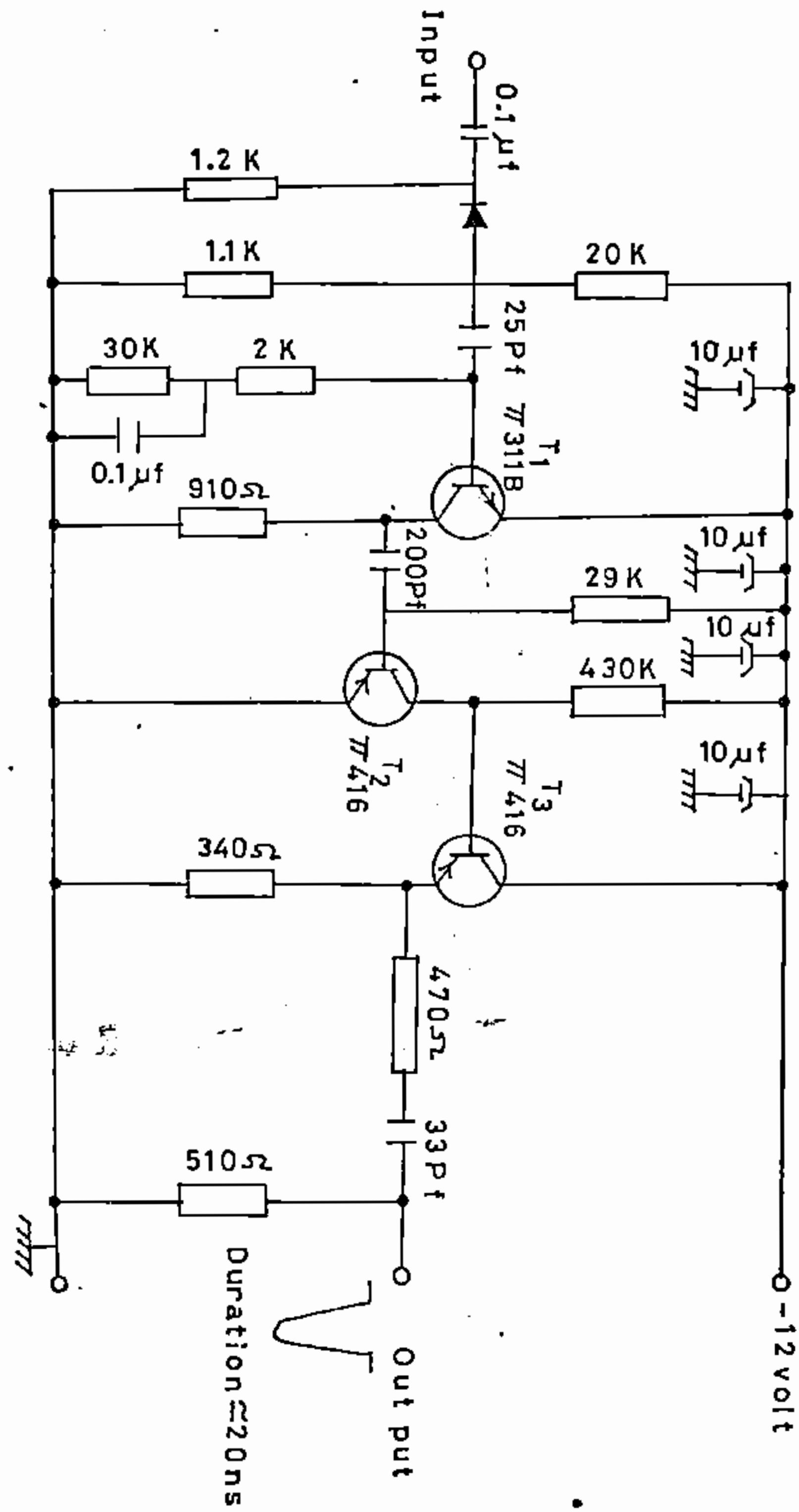
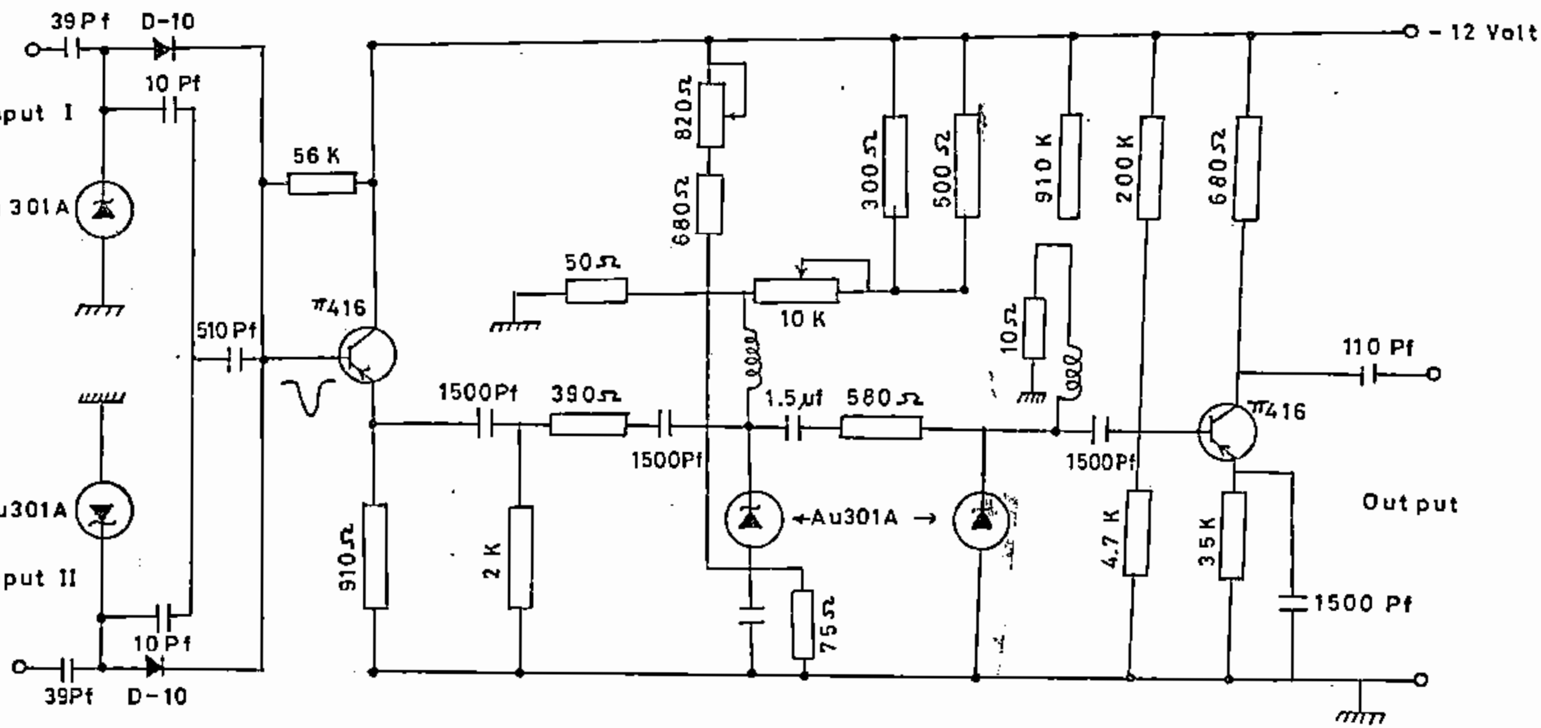
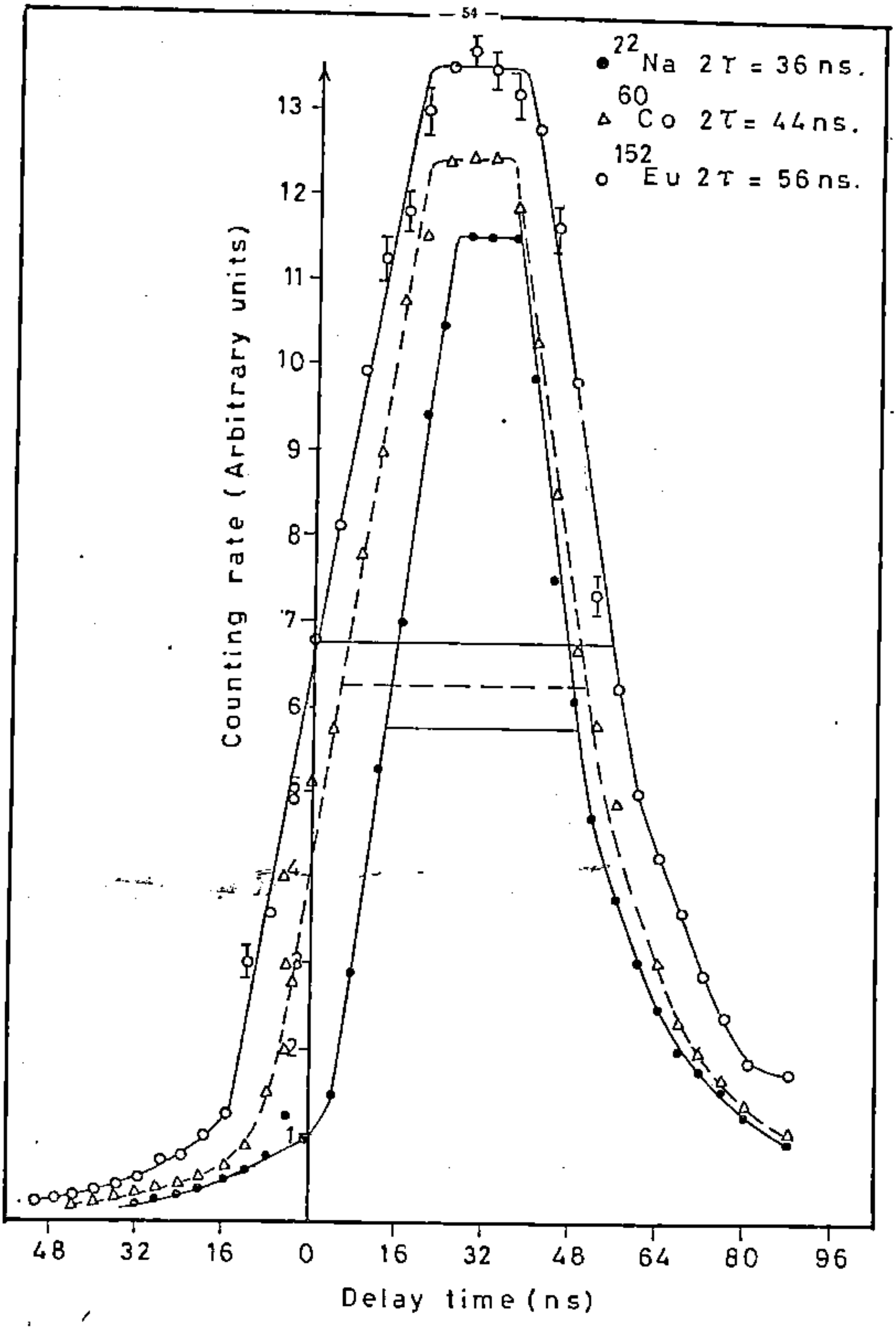
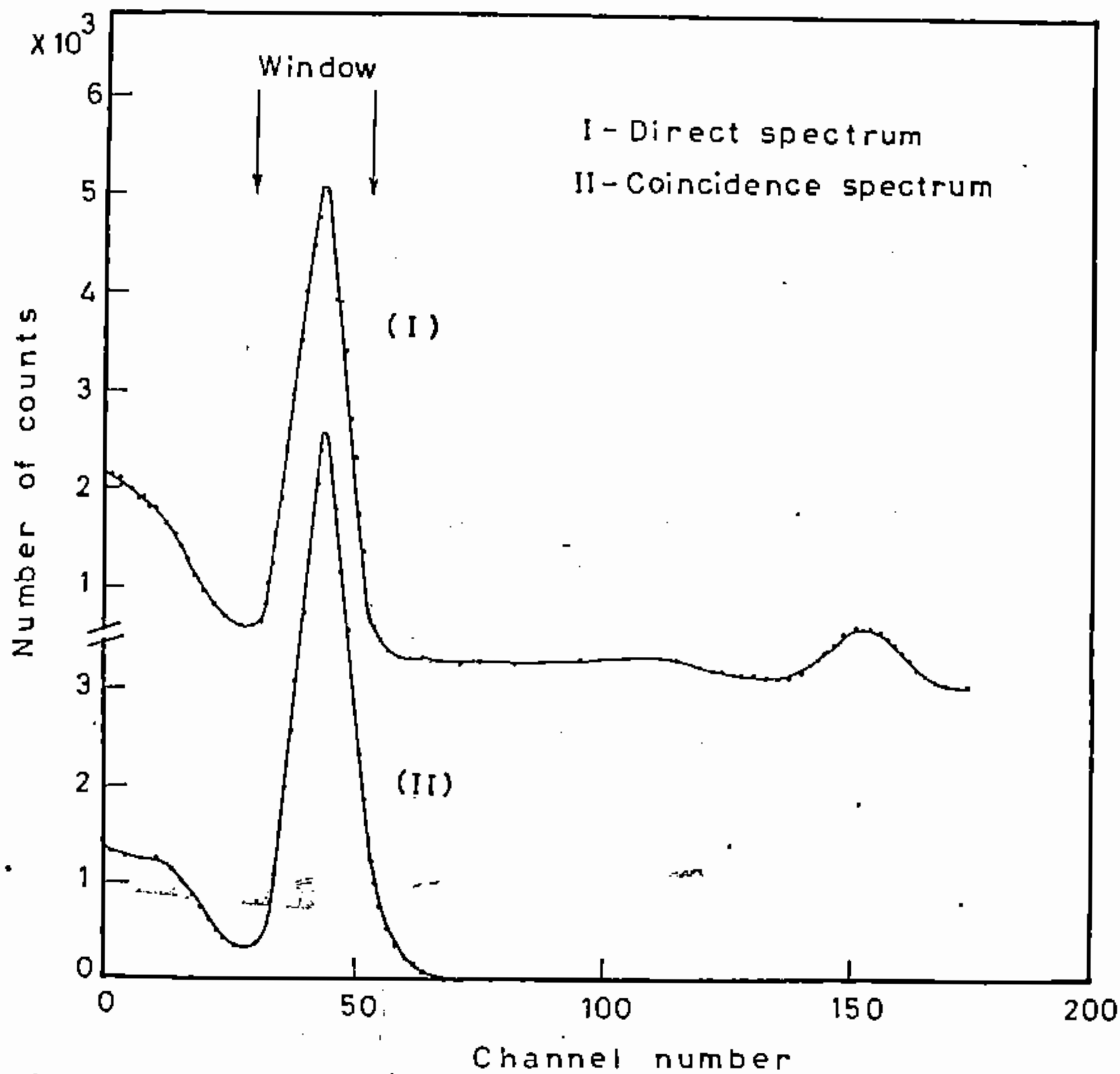

Input
0.1 µf
1.2 K
1.1 K
20 K
25 Pf
30K
2 K
10 µf
0.1 µf
T1
π 311B
910 Ω
200Pf
10 µf
29 K
10 µf
430K
T2
π 416
T3
π 416
10 µf
340 Ω
470 Ω
33 Pf
510 Ω
Duration ≃ 20 ns
Out put
-12 volt

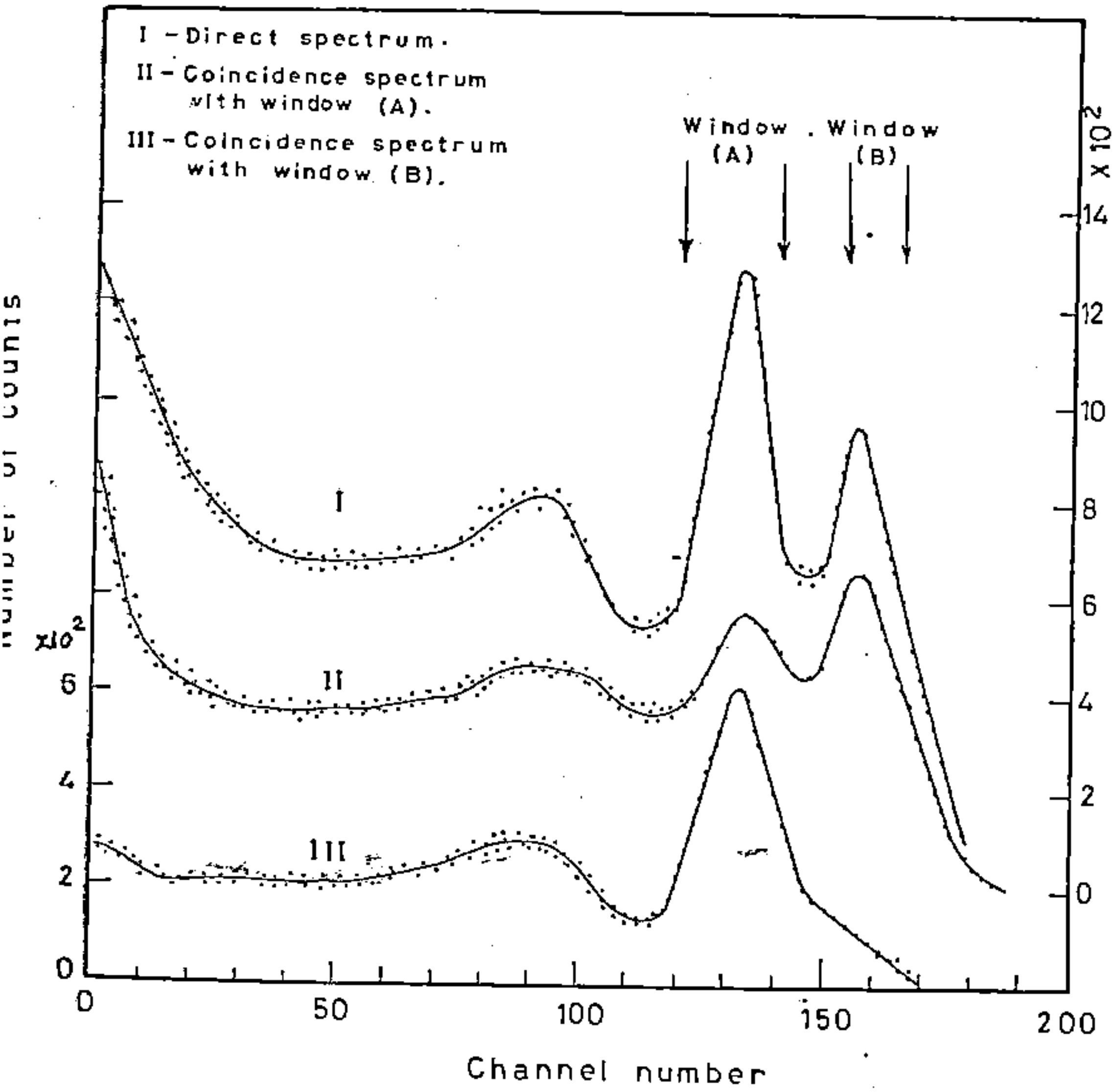
Fig 4


39Pf
D-10
10 Pf
Input I
Au 301A
510 Pf
56 K
π416
Au301A
Input II
10 Pf
39Pf
D-10
910Ω
1500Pf
2 K
390Ω
1500Pf
50Ω
820Ω
680Ω
10 K
1.5μf
580Ω
←Au301A →
75Ω
300Ω
500Ω
910 K
10Ω
200 K
4.7 K
680Ω
1500Pf
π416
35 K
1500 Pf
110 Pf
Out put
- 12 Volt



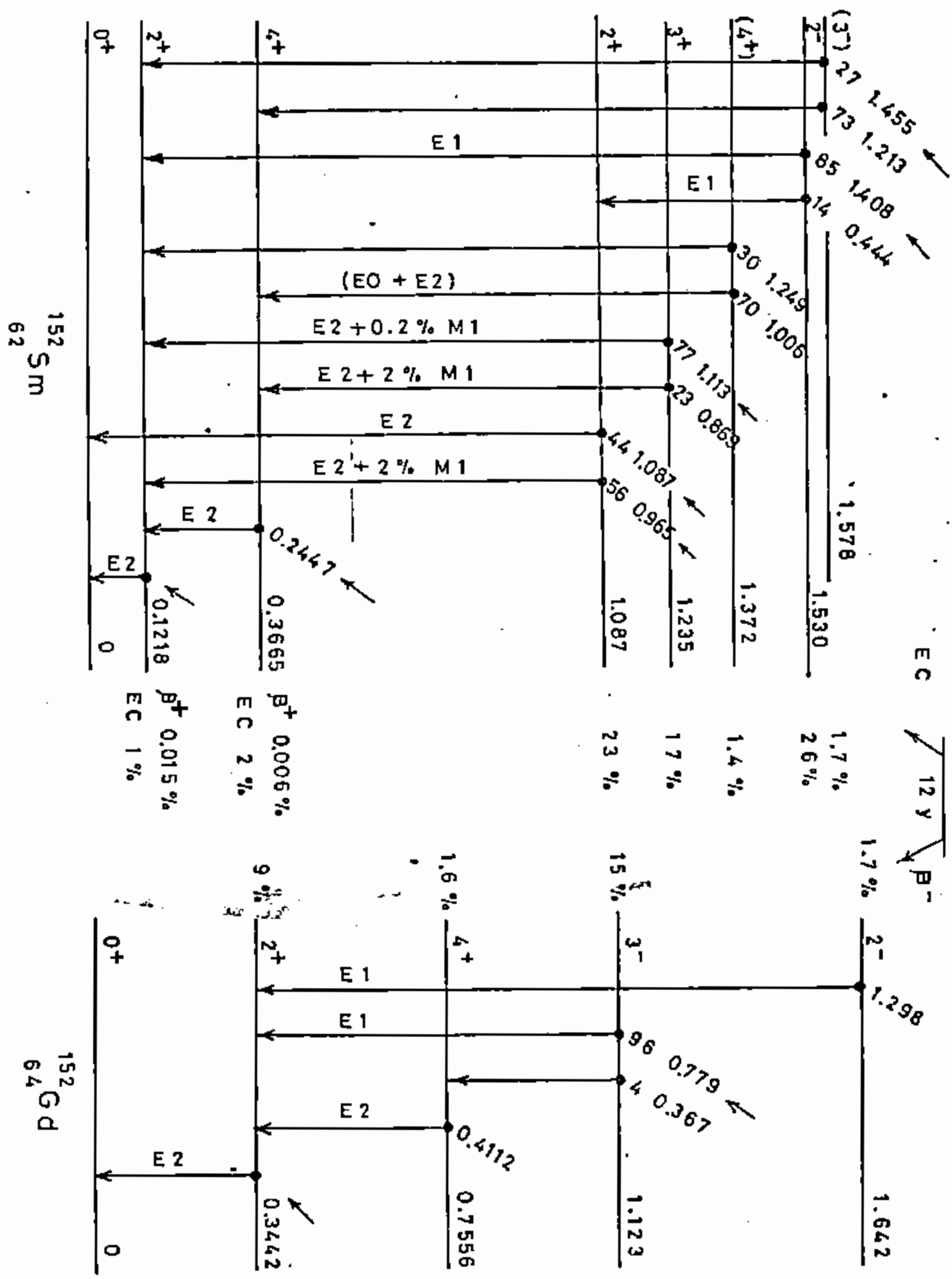
^{22}Na 2τ = 36 ns.
^{60}Co 2τ = 44 ns.
^{152}Eu 2τ = 56 ns.
Counting rate (Arbitrary units)
13
12
11
10
9
8
7
6
5
4
3
2
1
48
32
16
0
16
32
48
64
80
96
Delay time (ns)

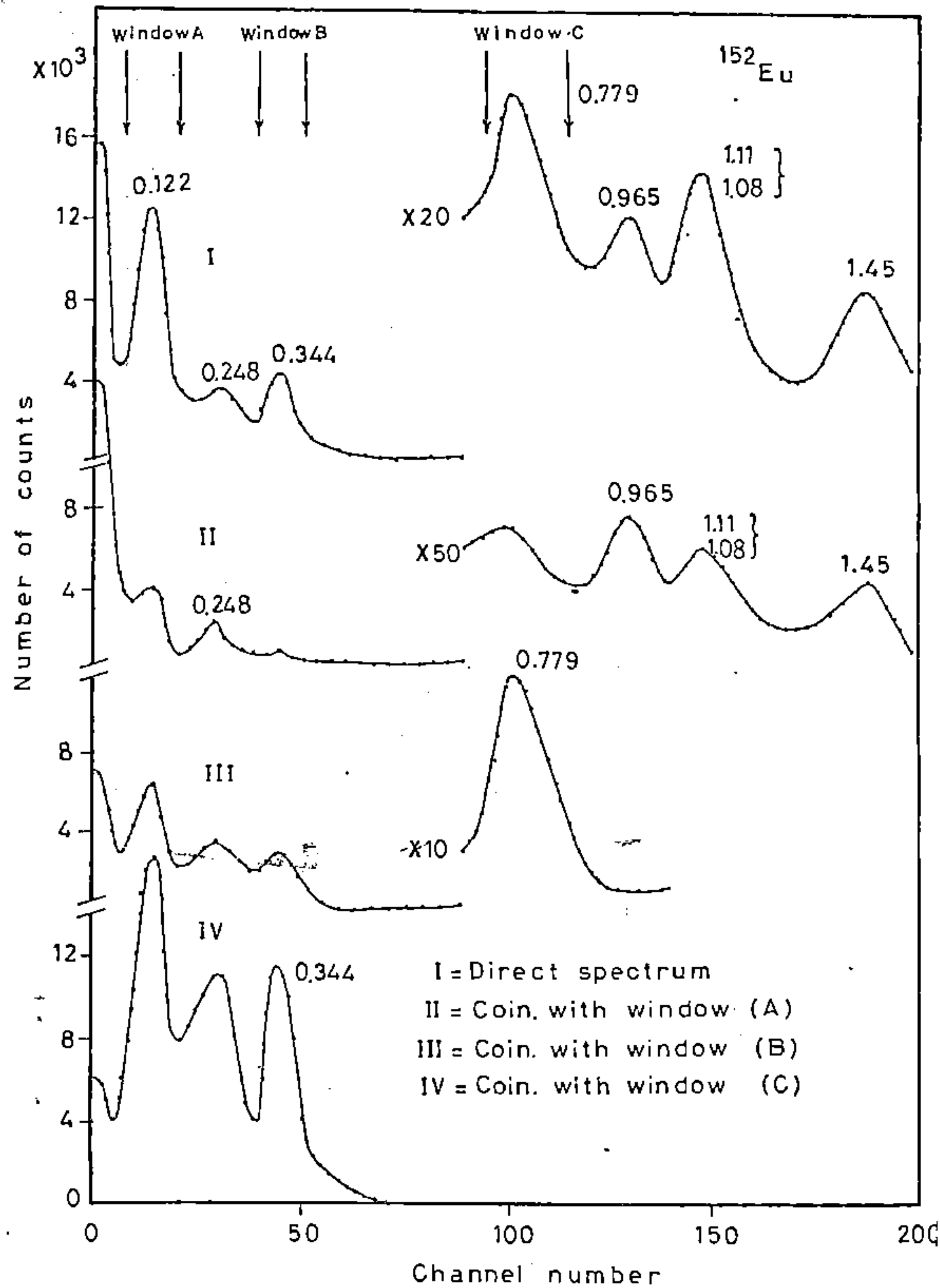

X 10^3
Window
I - Direct spectrum
II - Coincidence spectrum
(I)
(II)
Number of counts
Channel number
0
1
2
3
1
2
3
4
5
6
0
50
100
150
200



Vertical scale on the left represents spectrum III
Vertical scale on the right represents spectra II & I

Fig 8


152 63 Eu
12 y
EC
β⁻
152 62 Sm
152 64 Gd
(3⁻)
2⁻
(4⁺)
3⁺
2⁺
4⁺
2⁺
0⁺
27 1.455
73 1.213
85 1.408
14 0.444
30 1.249
70 1.006
77 1.113
23 0.869
44 1.087
56 0.965
0.2447
0.1218
E 1
E 1
(E0 + E2)
E 2 + 0.2 % M 1
E 2 + 2 % M 1
E 2
E 2 + 2 % M 1
E 2
E 2
1.578
1.530
1.372
1.235
1.087
0.3665
0.1218
0
1.7 %
2.6 %
1.4 %
17 %
23 %
β⁺ 0.006 %
EC 2 %
β⁺ 0.015 %
EC 1 %
1.7 %
15 %
1.6 %
9 %
2⁻
3⁻
4⁺
2⁺
0⁺
1.298
96 0.779
4 0.367
0.4112
E 1
E 1
E 2
E 2
1.642
1.123
0.7556
0.3442
0


Window A
Window B
Window C
^{152}Eu
X10^3
0.779
0.122
1.11
1.08
0.965
X20
I
1.45
0.248
0.344
II
X50
0.965
1.11
1.08
1.45
0.248
0.779
III
X10
IV
0.344
I = Direct spectrum
II = Coin. with window (A)
III = Coin. with window (B)
IV = Coin. with window (C)
Number of counts
Channel number
0
50
100
150
200
16
12
8
4