SURVEYING THE HPGe GAMMA DETECTOR ABSOLUTE EFFICIENCY

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Abstract. In many nuclear experiments, the energy efficiency of detector is a parameter without negligibility. In this paper, the absolute efficiency of HPGe detector is surveyed and mearsured at different distances from detector and different gamma energies.

1. Introduction

In many nuclear experimental measurements, the determined results depend on experimental parameters, one of these parameters is absolute detector efficiency. But unfortunately the efficiency of nuclear detector is not constant, it depend on the energy of measuremental radiation. So that, making efficiency calibration of detector is necessary. In this paper, the absolute efficiency calibration of HPGe gamma detector is surveyed.

Absolute efficiency of detector η_{abs} at a energy value is determined through, photopeak area, S, by equation below:

$$\eta_{abs} = \frac{S}{A.I.t} \qquad (1)$$

where: A -activity of radioactivity source

I - radioactivity emission probability

t -measuremental time

As equation (1), the error of efficiency depend on the photopeak area (S). In order to decrease strongly the error of efficiency. The measuremental area of photopeak should determine with high precision. To resolve this problem, some determination photopeak area studied:

- The total peak area approximation
- The Covell method
- The Wasson method

Beside, the superposition, dead time, the effect are consided.

In this paper, the gamma HPGe detector efficiency is determined through the photopeak area of standard sources, the determination of detector efficiency is able to be performed by calculation. But with this method, the detector geometry has to be known. So, in experiment, the efficiency calibration method is combined with semi-empirial relation be come most reliable.

In order to reject the influence of the distortion of photopeak shape due to the high activity and by the counting loss due to the pile-up effects, the sample should be put at place with different distances to detector.

For fitting the experimental detector efficiency data with theorical fuction. In this paper, two theorical functions describing the dependence of efficiency on energy are used, such as:

$$\eta = \sum \alpha_i \ln(E)^{-i}$$

$$\eta = \sum \beta_i E^{-i}$$

2. Experimental absolute efficiency calibration

For getting experimental efficiency value. The sources with different gamma ray energies are used in our experiment: Eu^{152}, Cs^{137} and Am^{241}. The sources with shap of disk with 1 Cm radius are supplied by IAEA with parameters as following:

Source: Eu^{152}

Half-life: 12.7 Year

Date of produce: August 1st 2002

Activity initial: 3672.62 Bq

Source: Am^{241}

Half-life: 433 Year

Date of produce: July 15th 2002

Activity initial: 3759.2 Bq

Source: Cs^{137}

lf-life: 30.1 Year

Date of produce: December 1st 1994

Activity initial: 36445 Bq

For efficiency calibration of detector, in our experiment we have to know the activity of source at the experimental time. This work is not difficult by using equation:

$$A=A_0e^{-\lambda t}$$

The parameters of experiment with HPGe gammavision spectrometry are given in table 1 and plot of experimental efficiency calibration in fig.1.

Table1. The efficiency of detector depend on energies at 2 cm from detector

Order Number	Energy (KeV)	I_γ (%)	Count	Count per second	Activity of source	Detection efficiency
1	121.7793	30.6788	14020	46.7350	1057.0718	0.0442±2%
2	344.31	27.2	6977	23.2591	937.2056	0.0248±2.3%
3	411.13	2.2848	544	1.8189	78.7253	0.0230±9%
4	778.91	12.7187	1517	5.05667	438.2368	0.0115±4%
5	964.05	14.3344	1633	5.44500	493.9075	0.0110±4%
6	1085.81	10.0966	1072	3.57367	347.8895	0.0103±3%
7	1112.08	13.4042	1244	4.14667	461.8565	0.0090±4%
8	1408.08	20.7264	1562	5.20667	714.1509	0.0073±4%
9	(Am)59.739	35.75	5983	9.97200	1341.13114	0.0074±1.7%
10	(Cs)661.38	85.05	37674	418.5944	25278.6461	0.0166±6%

After fitting the expeimental data with the theorical function:

$$\eta = \sum \beta_i E^{-i}$$

and

$$\eta = \sum \alpha_i \ln(E)^{-i}$$

the absolute efficiency function of HPGe gammavision spectrometry is as following:

$$\eta_1(E) = 11.5436\, E^{-1} - 1110.34\, E^{-2} + 60344.9\, E^{-3} - 2008730\, E^{-4}$$

$$\eta_2(E) = -3.09414(\ln E)^{-1} + 73.7661(\ln E)^{-2} - 687.098(\ln E)^{-3} + 2967.11(\ln E)^{-4} - 4814.21(\ln E)^{-5} \quad (3)$$

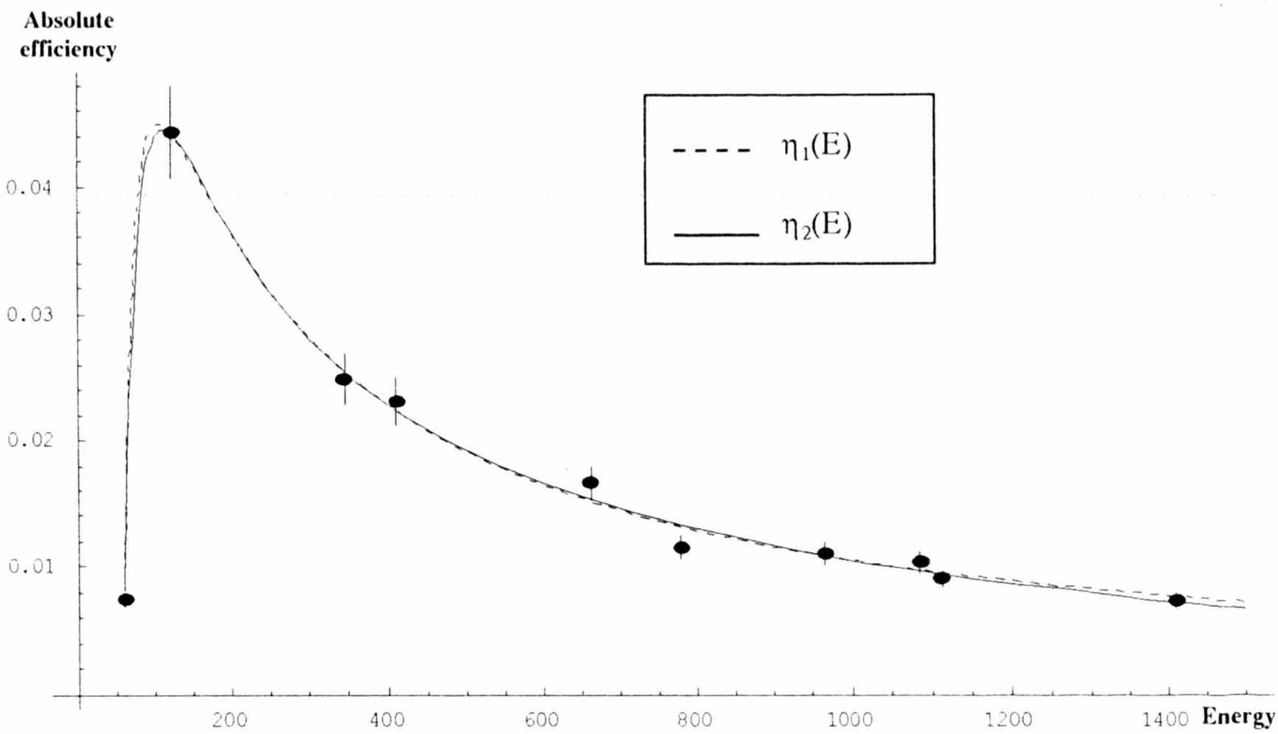

Fig.1 The dependence of efficiency of detector on energies at 2 cm from detector

Table2. The efficiency of detector depend on energies at 5 cm from detector

Order Number	Energy (KeV)	I_γ (%)	Count	Count per second	Activity of source	Detection efficiency
1	121.7793	30.6788	37400	10.3889	1057.0718	0.0098±1.72%
2	244.6927	7.7193	5740	1.5944	265.9770	0.0060±2.71%
3	295.96	0.4324	269	0.0747	14.8988	0.0050±1.16%
4	344.32	27.2	15500	4.3056	937.2059	0.0046±2.01%
5	444.03	2.8832	1320	0.3667	99.3438	0.0037±4.82%
6	688.62	0.8514	220	0.0611	29.3359	0.0021±13.6%
7	778.91	12.7187	3310	0.9194	438.2368	0.0021±3.16%
8	867.39	4.0963	852	0.2367	141.1425	0.0017±6.36%
9	964.05	14.3344	2990	0.8306	493.9075	0.0017±3.17%
10	1005.06	0.6364	134	0.0372	21.9306	0.0017±16.81%
11	1085.81	10.0966	1960	0.5444	347.8895	0.0016±3.6%
12	1089.73	1.8115	356	0.0989	62.4172	0.0016±1.16%
13	1112.08	13.4042	2560	0.0711	461.8565	0.0015±3.02%
14	1212.94	1.496	230	0.0639	51.5463	0.0012±11.24%
15	1299.2	1.74624	246	0.0683	60.1686	0.0011±1.16%
16	1408.08	20.7264	3140	0.8722	714.1509	0.0012±2.81%

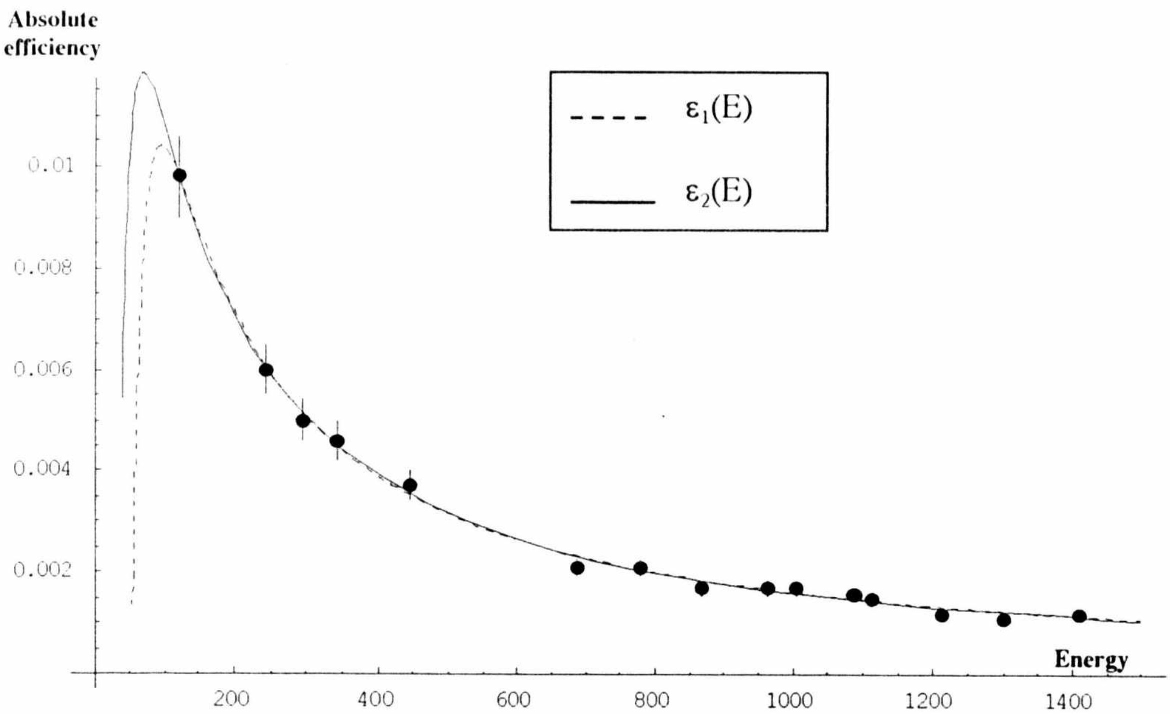

Fig.2. The dependence of detector efficiency on the energies at 5cm from detector

After fiting the expeimental data with the theorical function:

$$\eta = \sum \beta_i E^{-i}$$

and

$$\eta = \sum \alpha_i \ln(E)^{-i}$$

the absolute efficiency function of HPGe gammavision spectrometry is as following:

$$\varepsilon_1(E) = 1.65095\ E^{-1} - 30.281\ E^{-2} - 3103.08\ E^{-3}$$

$$\varepsilon_2(E) = 0.360458(\ln E)^{-1} - 7.62022\ (\ln E)^{-2} + 43.9916(\ln E)^{-3} - 84.6571(\ln E)^{-4} \quad (4)$$

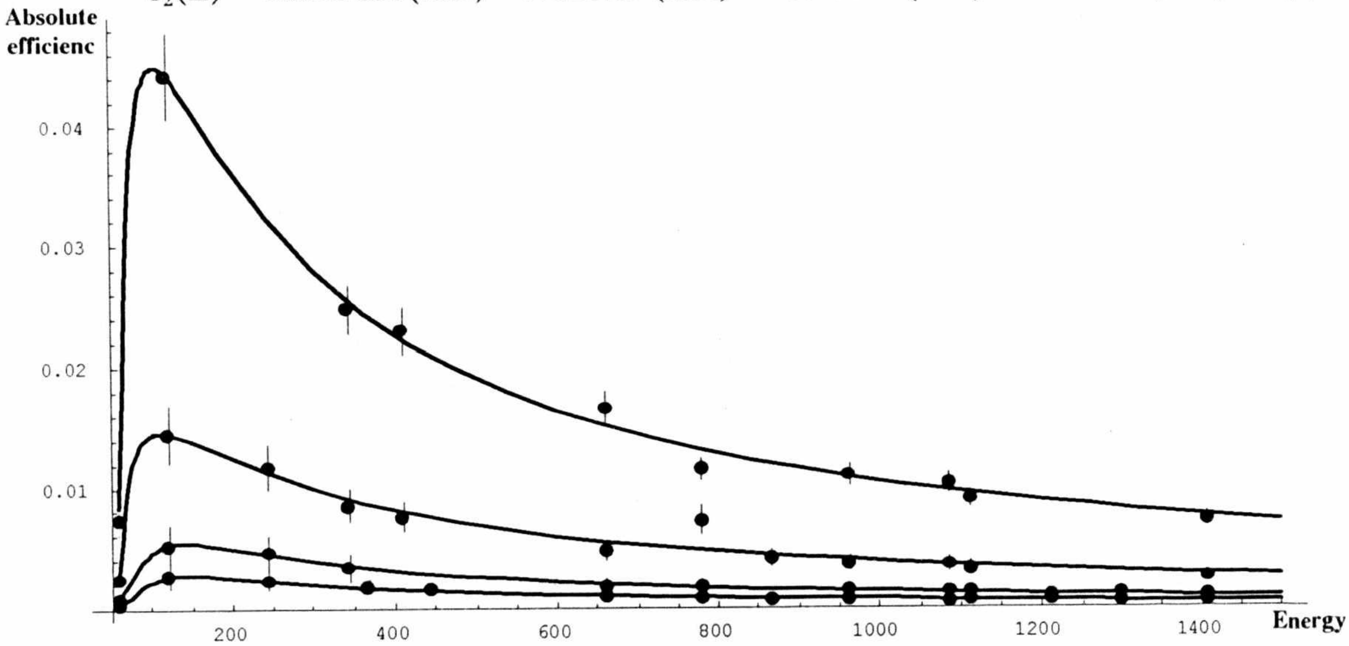

Fig.3. The dependence of absolute efficiency of detector on energies of HPGe gamma Gammavision spectrometry.

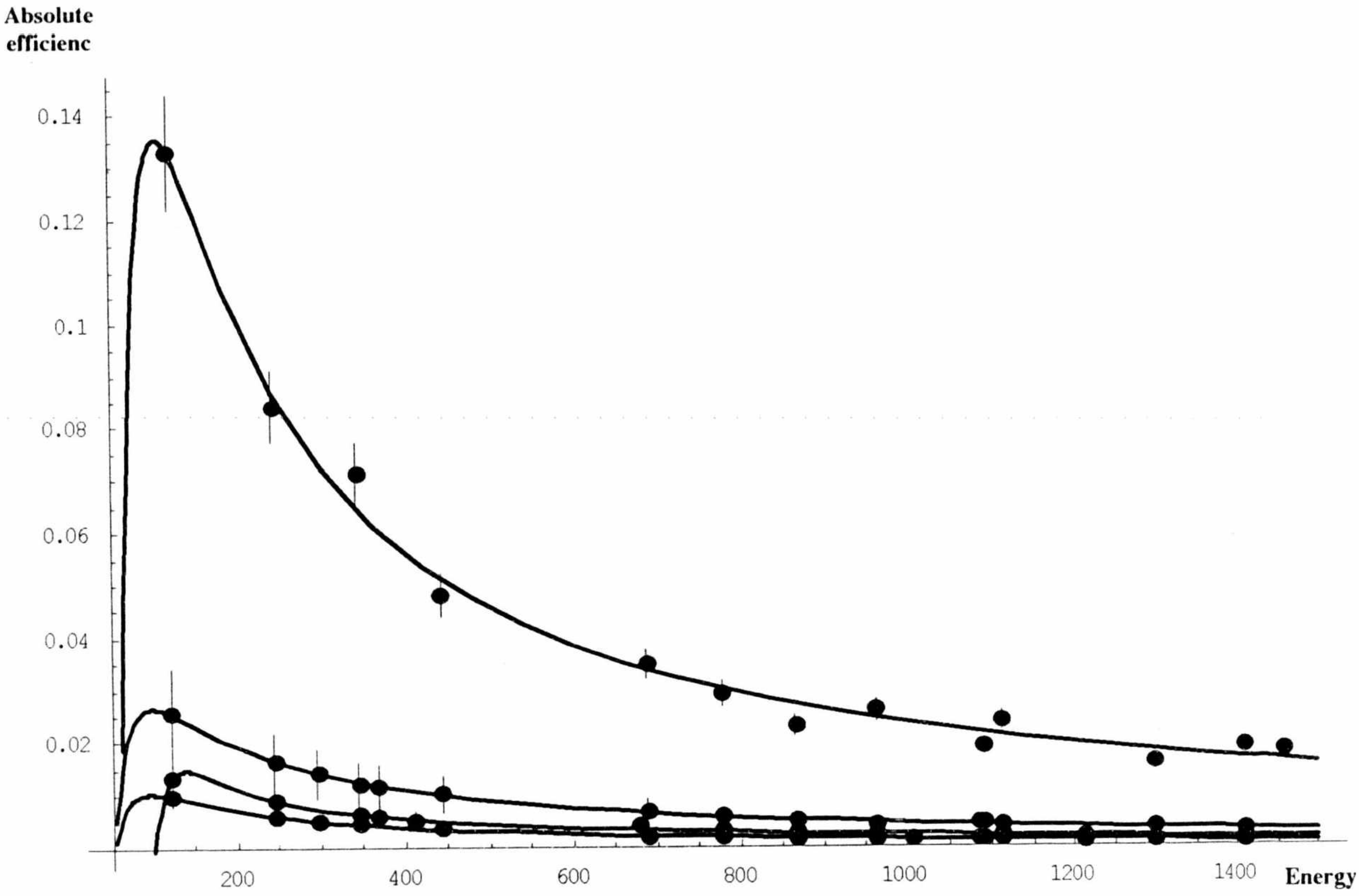

Fig.4. The dependence of absolute efficiency of detector on energies of HPGe gamma Gennie 2000 spectrometry

In order to determine the dependence of absolute detector efficiency on gamma energies at different distances from detector to source. Gamma sources are placed at different distances from detector surface. In our experiment, gamma sources are placed at position from 2 cm to 16 cm to surface of detector.

The absolute efficiency of HPGe gamma Gammavision spectrometry are shown in fig.3.

The absolute efficiency of HPGe gamma Gennie 2000 spectrometry are shown in fig.4.

3. Results and discussion

Fitting the experiment data for determining absolute efficiency of detector with theorical functions is carried out.

In order to select the most suitable theorical function for fitting with experimental data. The fitting parameters of experimental data wich theorical functions:

$$\eta = \sum \alpha_i \ln(E)^{-i} \quad (5)$$

and

$$\eta = \sum \beta_i E^{-i} \quad (6)$$

are compared.

In general, the fitting diagrams of these two functions are closing to experimental points. However, the function (2) is more suitable to high energentic radiations because B_i coefficients have smaller failures, therefore, error are small.

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