# $Q_\beta$ Measurement Using a Well-type HPGe Detector


H. Hayashi[1], O. Suematsu[2], M. Shibata[3], Y. Kojima[4], A. Taniguchi[5] and K. Kawade[2]

[1]Department of Nuclear Engineering, Nagoya University

[2]Department of Energy Engineering and Science, Nagoya University

[3]Radioisotope Research Center, Nagoya University

[4]Quantum Energy Applications, Hiroshima University

[5]Research Reactor Institute, Kyoto University

e-mail: h032414m@mbox.nagoya-u.ac.jp



We demonstrated that $Q_\beta$-values were measured by using a well-type HPGe detector with a BGO detector based on the total absorption method. Four β-sources ($^{142}$Pr, $^{90}$Y, $^{42}$K, $^{38}$Cl) were measured. In the analysis, following four process were discussed; random pile-up, electron response functions, γ-ray response functions and a folding method. We consider that our detector may decide the $Q_\beta$-values within accuracy of 10 keV, even if there is no information about decay schemes.


## 1. Introduction

Mass data of nuclei far from β stability are one of the most important nuclear data. One of the ways to determine atomic masses is to measure β endpoint energies ($Q_\beta$). The β-γ coincidence method was mainly used. The method needs precise information about decay scheme and intense sources. The total absorption method isn't under these restrictions (Fig.1). The BGO total absorption detector, which had a high efficiency, was used by Shibata *et al.* [1] and determine the $Q_\beta$ within an accuracy about 200 keV. In this work, we aimed at demonstrating a HPGe total absorption detector, has a good resolution in addition to a high efficiency, and achieving precise $Q_\beta$ measurement about 10 keV.

## 2. Experiments

Our detector consisted of a well-type HPGe detector (85 mm$^\phi$×89 mm$^l$) and a BGO scintillator (25 mm$^t$×150 mm$^l$) for Compton suppression. Four nuclides ($^{142}$Pr, $^{90}$Y, $^{42}$K, $^{38}$Cl), which had a simple decay scheme, were prepared by a thermal neutron irradiation at the Kyoto University Reactor. By controlling total counting rate, less than 1k CPS, random pile up was inhibited as low as possible. Singles spectra of the HPGe, the BGO detector and their coincidence data were taken.

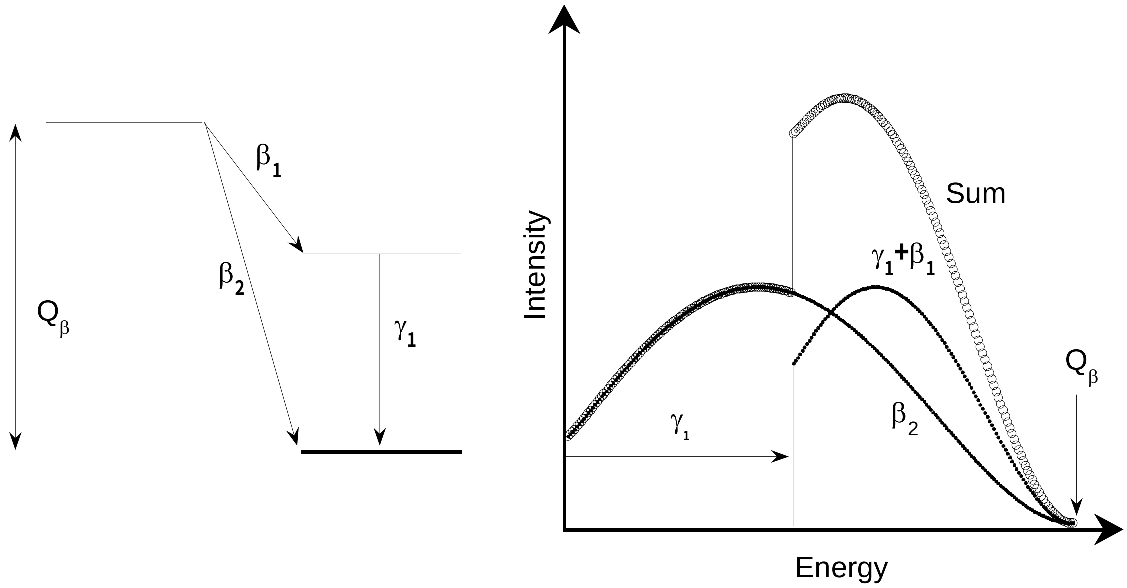

Fig.1 Concept of total absorption method. All β-rays and following γ-rays are completely absorbed by one detector. End-point energies of each β-component gives the same $Q_\beta$. $Q_\beta$ is determined without knowledge of the decay scheme, and good statistics around $Q_\beta$ is obtained.

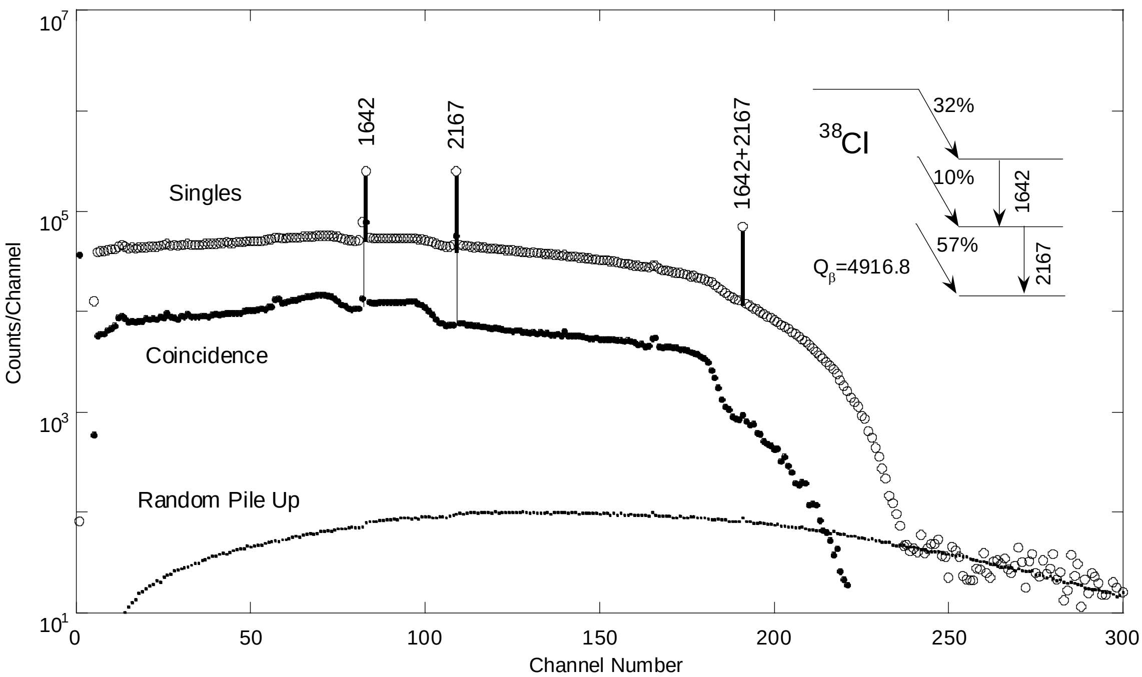


Fig.2 Spectrum of $^{38}Cl$. A random pile up spectrum was generated by Monte Carlo simulation.

## 3. Analysis methodology

In the ideal case, full energy of β-rays and γ-rays were completely absorbed. For a real detector, there are some distortions caused by energy losses, energy struggling, scatterings, escapes etc. Response functions enabled us to analyze experimental spectra.

Experimental data, subtracted background, were analyzed following four steps.

(1)Subtraction of random pile-up

Random pile-up spectra were generated by the Monte Carlo calculations. Random pile-up spectra were made by using spectra, which didn't contain the pile-up, and amplified to fit intensity. Then they were subtracted from experimental spectra (Fig.2).

(2)Calculation of electron response function

Response functions for electrons were calculated by the Monte Carlo simulation code (EGS4), at the energy region 1-8MeV. These response functions were divided into three elements; peak, escape and scattering (Fig.3). However, they did not exactly fit single β-component spectrum such as $^{90}Y$, we modified a ratio of these elements to agree with experimental spectrum.

The β-rays were detected after passing an Al window (0.4 $mm^t$) and a dead layer of Ge detector. Energy losses from these effects were described later.

(3)Subtraction of distortions caused by γ-ray response functions

Because of not considering the information about the decay schemes, we could not use the information such as $I_\gamma$, $I_\beta$, $E_\gamma$ etc. Following approach shows that we didn't need γ-ray response functions. In γ-ray response functions, Compton scattering parts contributed to distort sum spectra. Some events including the scattering were distinguished; they were just coincidence spectra. Sum spectra subtracted coincidence spectrum didn't include the distortions.

The BGO detector covered only side of the HPGe detector. If we amplified the coincidence spectrum by 1.4, incomplete BGO detector can be regard as ideal BGO detector covering Ge with solid angle of 4π (Fig.4). The value of 1.4 was lead by simulation involved various γ-ray cascades.

(4)Folding-Method

The folding method was used. If folding spectrum agrees with experimental spectrum, a slope of a "ratio of experiment to the folding" equaled zero (Fig.5).

We also simulated that even if there were no information about β-transitions, the folding spectrum gave a nearly true $Q_\beta$ within 10keV.

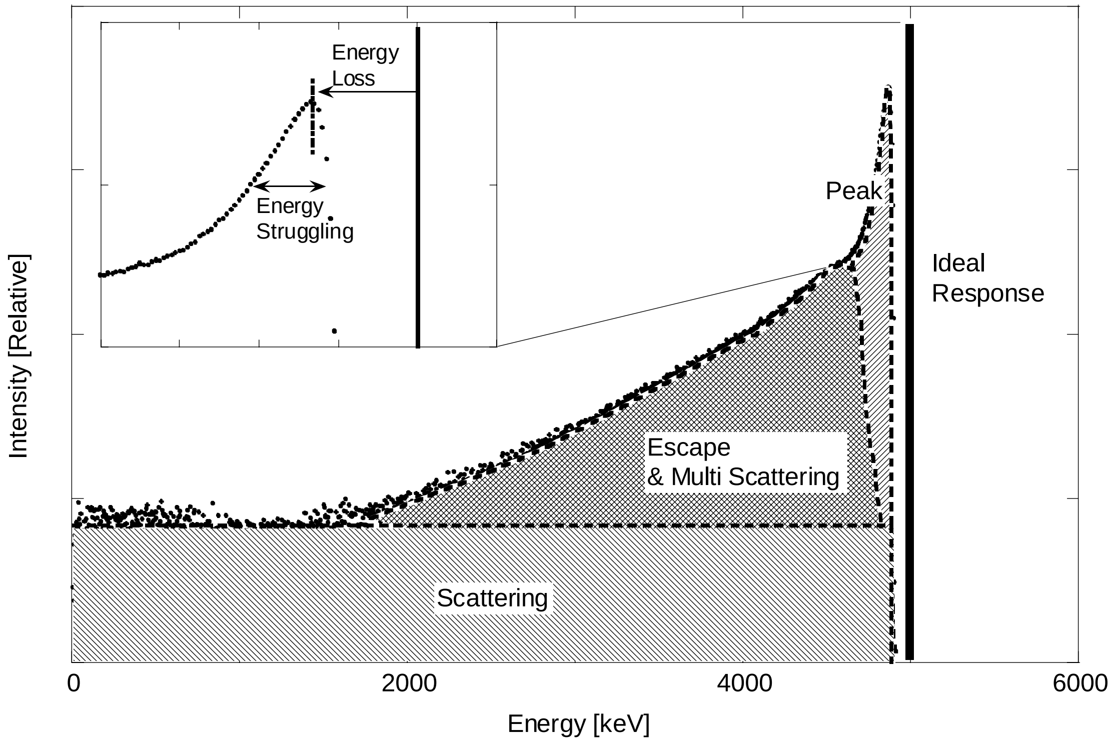


Fig.3 Response function for 5MeV electron. The response function is divided by three parts.

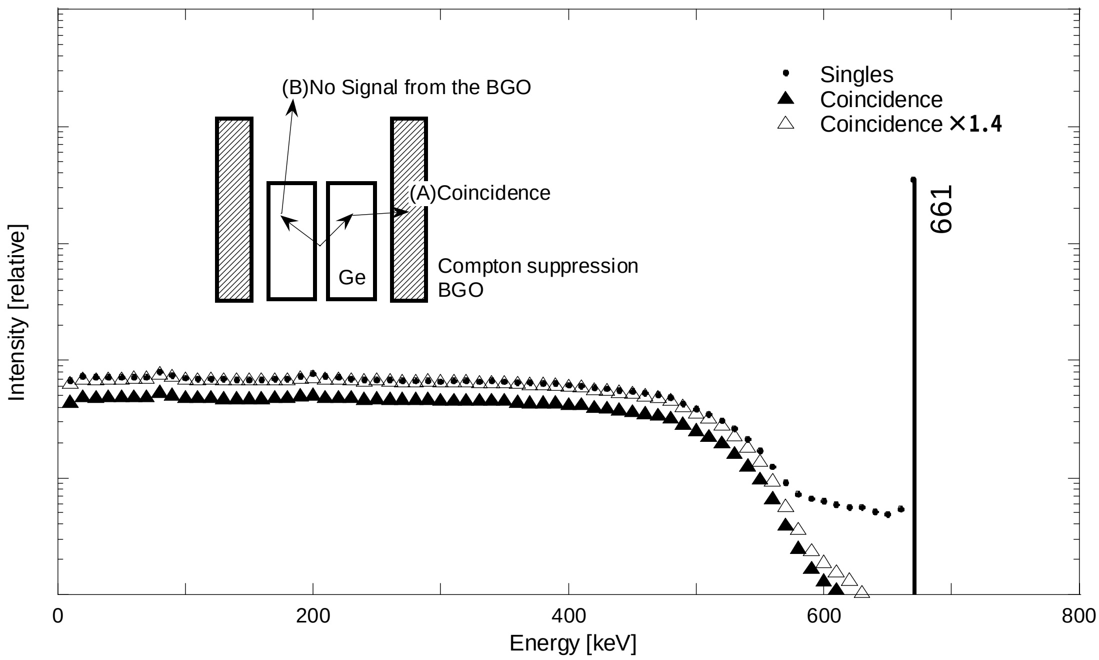


Fig.4 Gamma-ray response function. Because top and bottom of the HPGe are not covered by the BGO, there are some photons that escape through the region (B). Lost photons are compensated by 1.4 timed coincidence spectrum.

## 4. Results

A comparison of experimental values with evaluated vales was shown in fig.6. Line for the β-ray measurement was uniformly shifted from the gamma one within fluctuation of 5 keV for the region 2-5 MeV. A difference between two lines indicated energy losses for electrons. 5 keV uncertainty was satisfied the demand (10keV). An energy loss of 164 keV is consistent with the thickness of Al window (0.4mm$^t$) and the dead layer (15μm$^t$).

## 5. Conclusion and Future Plans

We can demonstrate the $Q_\beta$ measurement using a well-type HPGe detector based on the total absorption method. We consider that our detector may decide the $Q_\beta$-values within accuracy of 5 keV for the nuclides, which have precise information about decay schemes. Even if there is no information about decay schemes, from simulation, our detector may decide $Q_\beta$-values within accuracy of 10 keV.

For the precise estimation of energy losses and check of the analysis way against nuclides, which have more complex decay schemes, we must measure many nuclides. Then we will determine the $Q_\beta$ of neutron-rich isotopes far from β stability, using the isotope separator on-line.

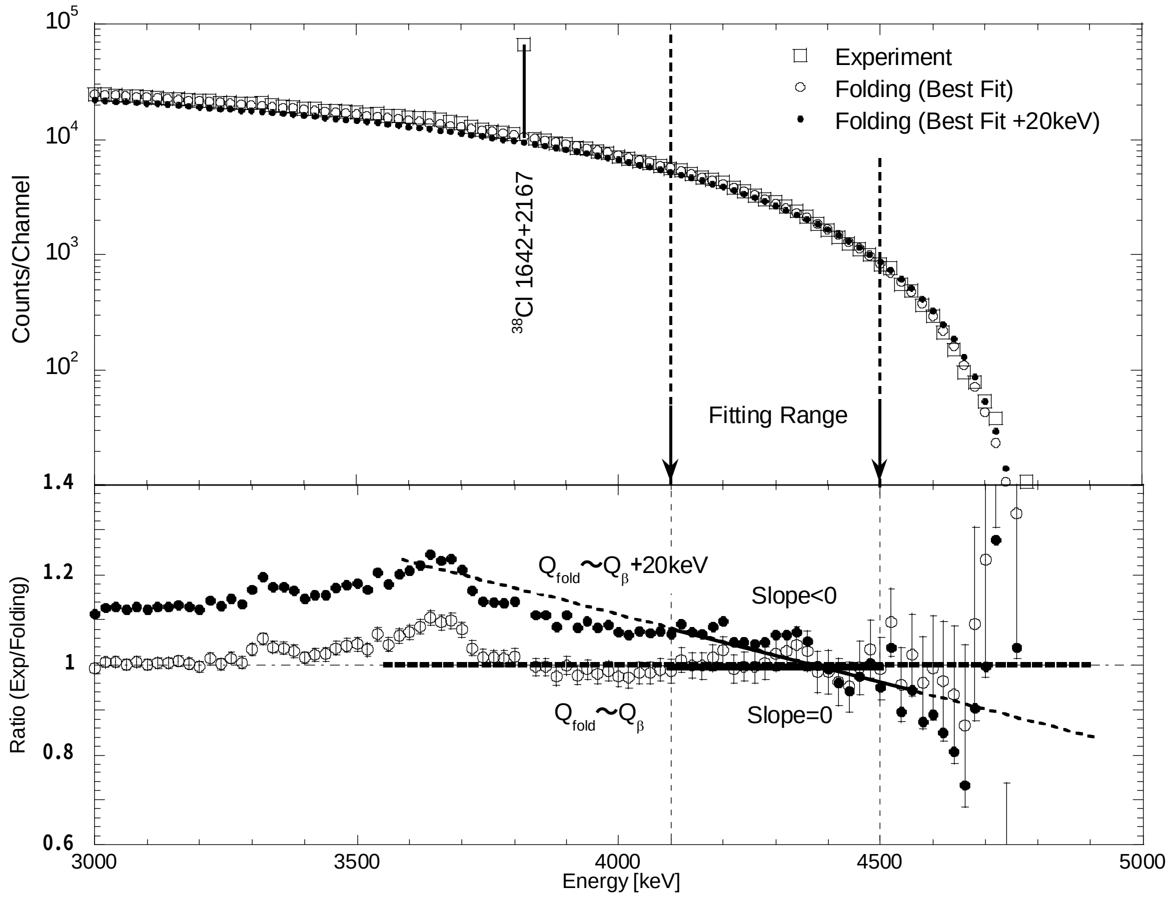


Fig.5 Experimental and folding spectrum for $^{38}$Cl. If a $Q_{fold}$, which is obtained by folding method, nearly equals $Q_\beta$, a slope of the ratio becomes zero.

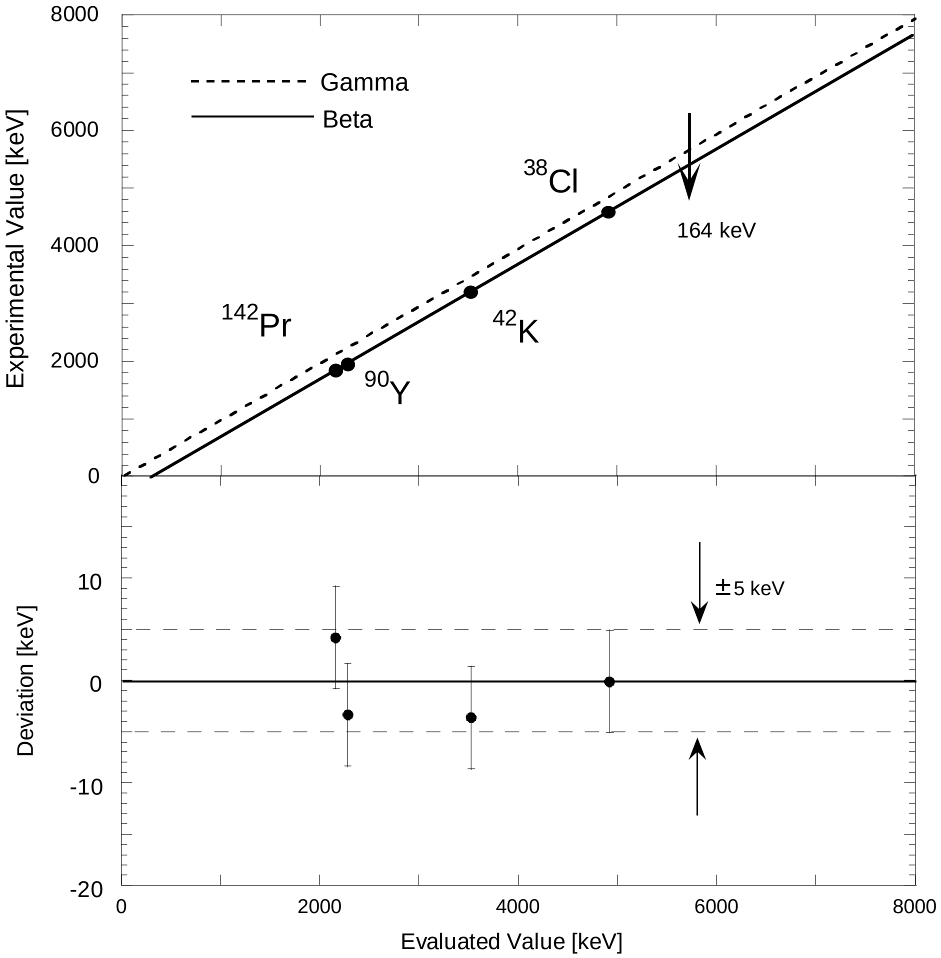


Fig.6 A comparison of experimental values with evaluated values. The broken line and the solid line are obtained from γ-rays and β-rays, respectively. Difference between these lines is caused by energy losses for electrons.

## Reference


[1] M. Shibata, Y. Kojima, H. Uno, K. Kawade, A. Taniguchi, Y. Kawase, S. Ichikawa, F. Maekawa, Y. Ikeda, "Application of a total absorption detector to $Q_\beta$ determination without the knowledge of the decay scheme," Nucl. Instr. and Meth. **A 459** (2001) 581-585