Precise Measurement of Prompt γ-ray in the $^{14}N(n,\gamma)^{15}N$ Reaction

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The relative γ-ray intensities up to 11 MeV were determined within 0.2-1.0% accuracy. We used the liquid nitrogen target in the singles measurement. In order to investigate the level scheme in detail, we performed the γ-γ coincidence measurement with the deuterated melamine ($C_3D_6N_6$) target. Since these targets do not contain the ^1H, the γ-ray from $^1H(n, \gamma)$ reaction is hardly observed. Because backgrounds were reduced, nitrogen peaks were observed clearly below 2 MeV.

1 Introduction

Standard radioactive nuclides such as ^{133}Ba, ^{152}Eu, ^{60}Co and ^{56}Co are used in the energy region below 3.2 MeV as γ-ray intensity standards, but above 3.2 MeV it is difficult to find suitable radioactive sources that have reasonably long-lives. The γ-ray intensities in the $^{14}N(n,\gamma)^{15}N$ reaction are used as the primary intensity standard up to 11 MeV.

In the previous works, the intensities were measured with 2-4% accuracy using the melamine ($C_3H_6N_6$) target [1, 2]. In this work, we performed the singles measurement with the liquid nitrogen (N_2) target, and the γ-γ coincidence measurement with the $C_3D_6N_6$ target in order to avoid the influence of the $^1H(n,\gamma)$ reaction.

We aimed to reduce the influence of $^1H(n,\gamma)$ reaction and determine the intensities within 1.0% accuracy.

2 Experiments

The γ-ray measurements were carried out at the B-4 neutron beam guide tube at KUR. The neutron flux rate at the irradiation position is about 5×10^7 n/cm^2·s.

In singles measurements, the liquid nitrogen target was used. Capture γ-rays were measured with 22% and 38% HPGe detectors (Fig.1). Distances between the target and the detectors were 22 and 15 cm (22% HPGe), and 24, 15 and 15 cm (38% HPGe).

The γ-γ coincidence measurements were performed with the $C_3D_6N_6$ target. A 90% HPGe, 90% GMX, and LEPS detectors were used with a 1.5 cm distance.

3 Results

3.1 Background below 2 MeV

The γ-ray from the ^{1}H(n, γ) reaction is hardly observed by utilization of the liquid nitrogen and the $C_3D_6N_6$ target. Then, backgrounds below 2 MeV are reduced as shown in Fig. 2. As a result, nitrogen peaks such as 1.678, 1.681, 1.854, 1.885 and 1.999 MeV are observed clearly. Because these γ-rays are included in the balance method, it is important that they are measured clearly.

3.2 The singles measurement

We determined the intensities of γ-rays from ^{15}N by the balance method. This method is that the intensities are determined to balance input and output intensity for each level. The scattering of the primary γ-ray intensities obtained by five measurements is shown in Fig. 3. These intensities agree within 0.5%, namely we consider that the present result is consistent and reliable.

3.3 The γ-γ coincidence measurements

The balance method required well-established the level scheme. If unknown γ-rays are found newly, the known γ-ray intensities are influenced. Therefore, we investigated the level scheme in detail. The latest level scheme of ^{15}N is shown in Fig. 4. Four γ-rays of 0.977, 3.750, 3.600 and 10.447-MeV were newly observed by the present γ-γ coincidence measurements. These γ-ray intensities were so weak. The deviation of the γ-ray intensities caused by such a weak γ-ray is less than 0.3% in the case of that we lost the γ-rays ten times as strong as the weakest γ-ray we observed.

3.4 Comparison of the previous results with the present ones

Comparison of the previous intensities with the present ones is shown in Fig. 5. The previous results agree with the present ones within ± 2-3%. Fig. 6 shows comparison of errors. The errors in present work were 2-8 times as improved as previous ones. The match between input and output intensity is reasonably good as shown in Fig. 7.

4 Conclusions

We determined the γ-ray intensities in the ^{14}N(n,γ)^{15}N reaction with 0.3-0.9 % accuracy. Since the results of the five measurements were consistent, present results were reliable.

Using this intensity, it becomes possible to determine the intensity the high energy γ-rays up to 11 MeV precisely. In the future we are planning to determine the intensities up to 7 MeV in the ^{35}Cl(n,γ)^{36}Cl reaction for the secondly standard.

References

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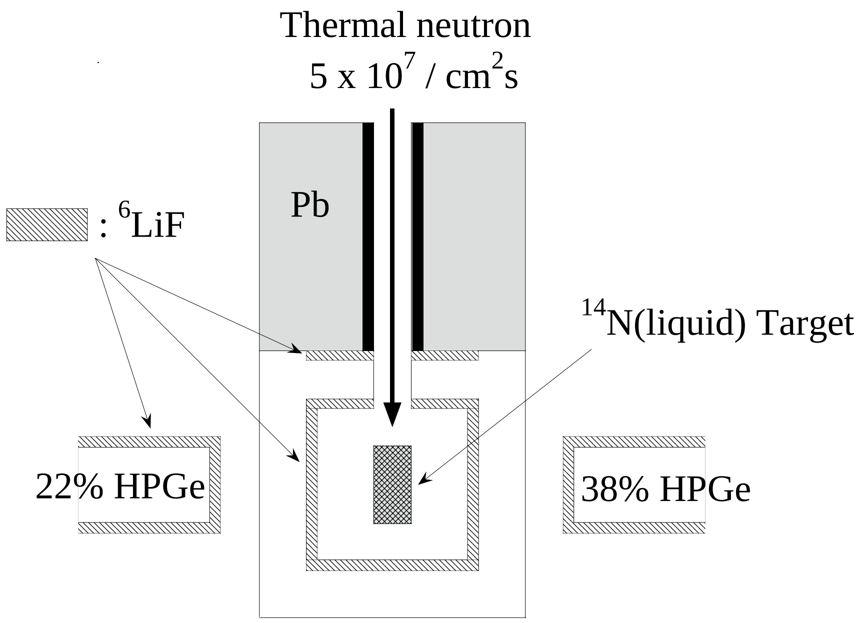

Fig. 1 Schematic view of the liquid nitrogen target system. The HPGe detectors and the target are surrounded by ^{6}LiF. It makes for the purpose of the shield from scattered neutrons, and reduces background of prompt γ-rays from the structure materials.

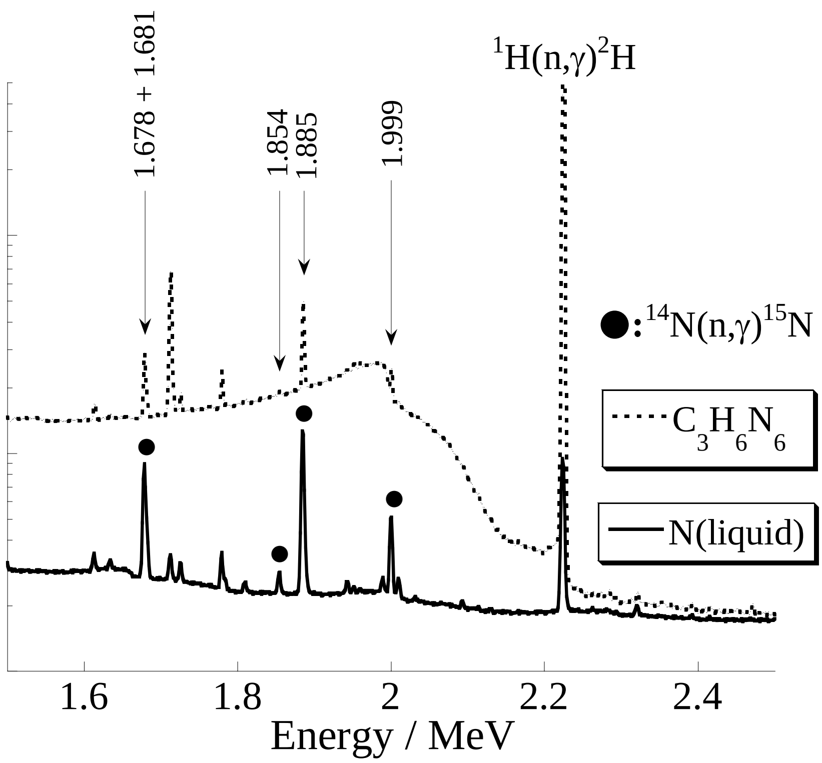

Fig. 2 The γ-ray spectra in the $^{14}N(n,\gamma)^{15}N$ reaction using the melamine and the liquid nitrogen target. The melamine ($C_3H_6N_6$) target emits 2.2 MeV γ-ray strongly via $^{1}H(n,\gamma)$ reaction. It is clearly seen that the liquid nitrogen target can reduce background.

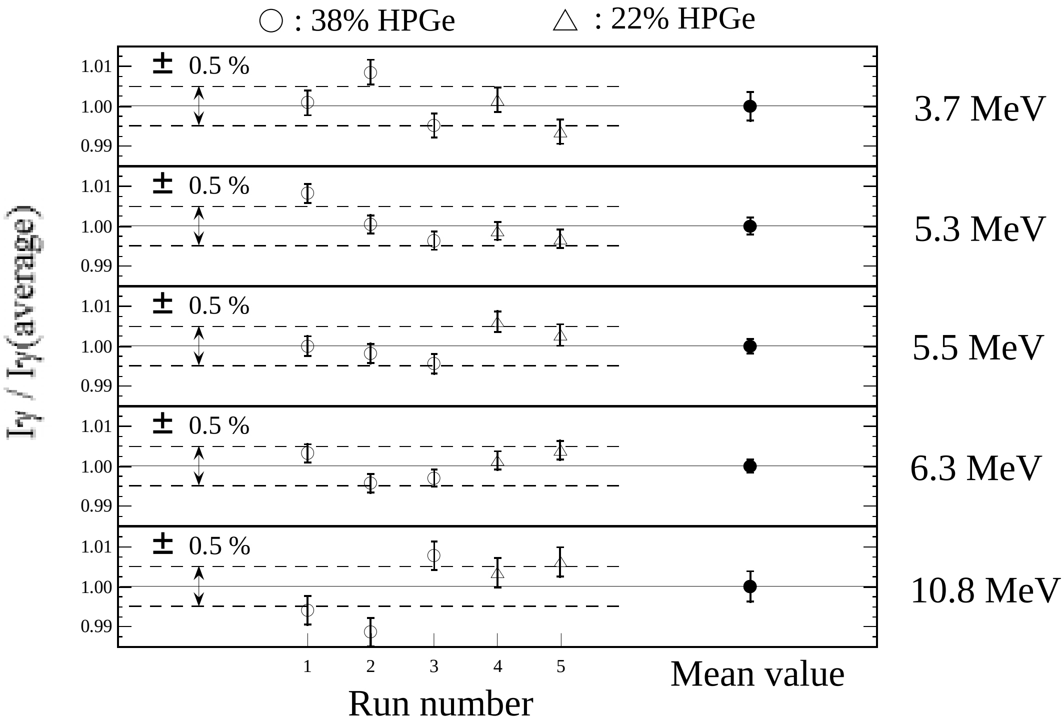

Fig.3 Scattering of intensities in the primary γ-rays. The various intensities of the five measurements differed from each other by < 0.5%.

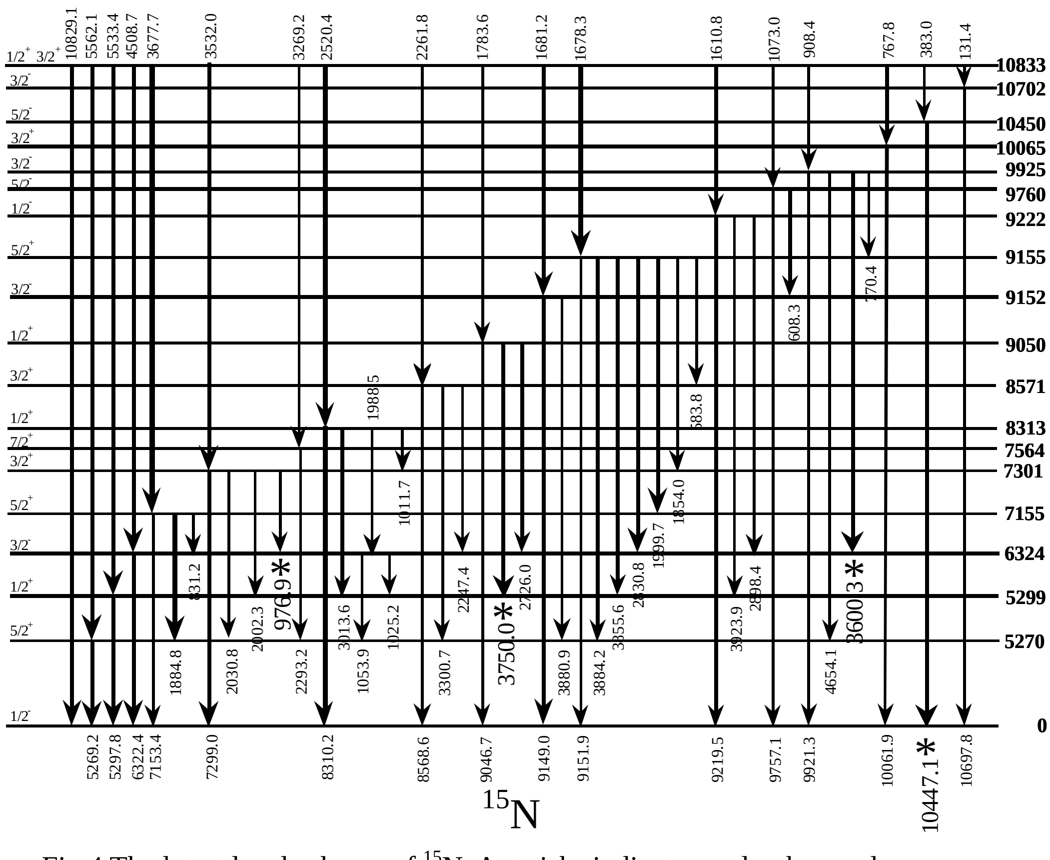

Fig.4 The latest level scheme of ^{15}N. Asterisks indicate newly observed γ-rays.

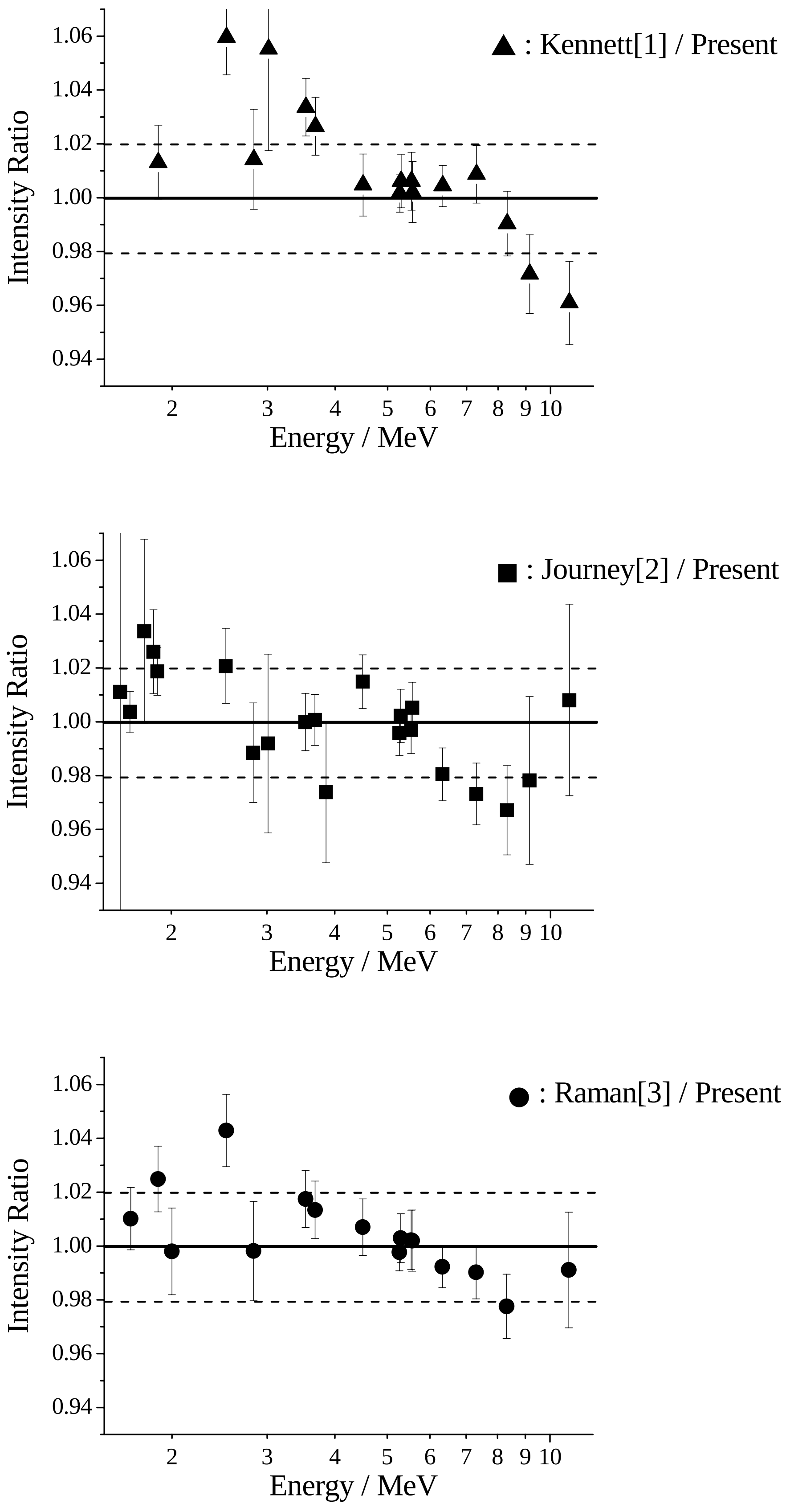

Fig. 5 Comparison of the previous intensities and the present ones.

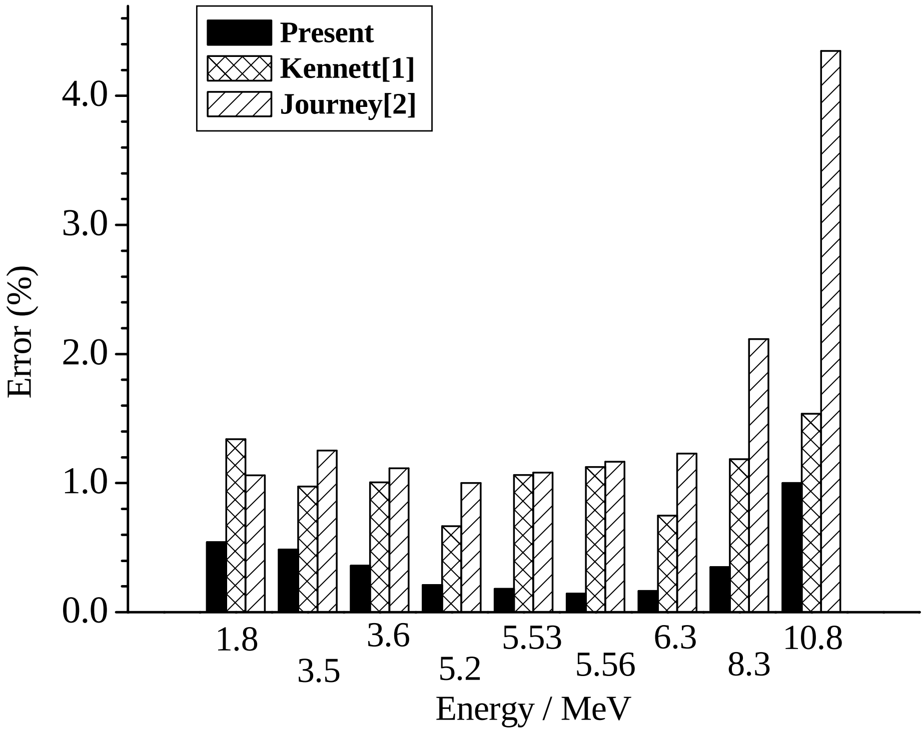

Fig. 6 Comparison of the previous errors and the present ones.

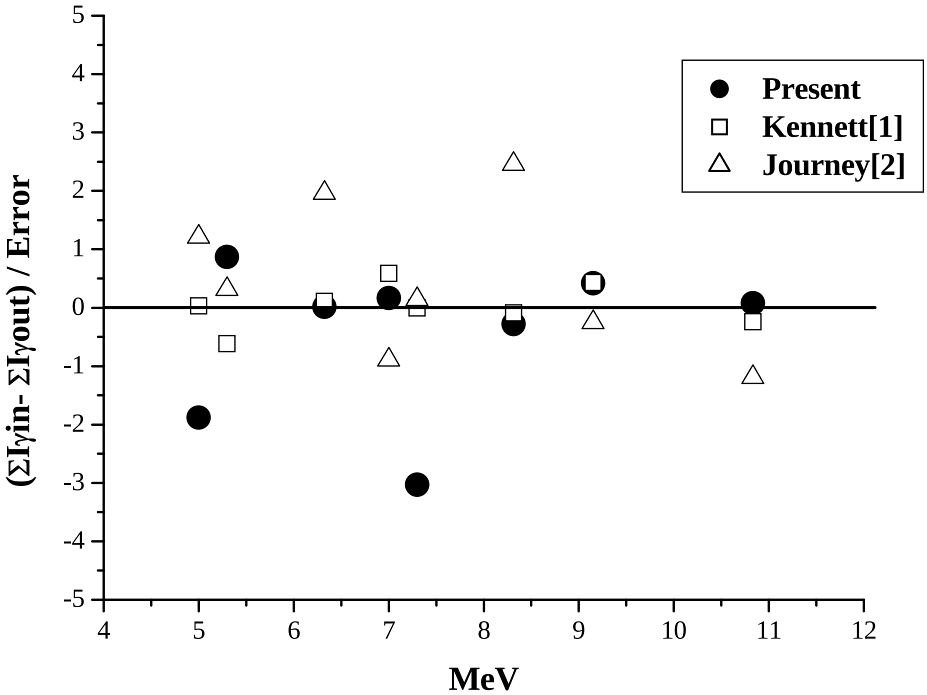

Fig. 7 Intensity balance of input and output contributors to ^{15}N levels.