§2. R&D of High Energy Gamma-ray Imaging System with Tandem Accelerator

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It is important to study plasma physics on the confinement of the energetic particles, which are produced by DT and/or DD reaction in a burning plasma. The diagnostics of the distribution of energetic particle loss site have been proposed. The fundamental principle is the detection of 4.44-MeV gamma rays produced by the interaction between the energetic particles come from the plasma and the first wall. To study the loss of the high energy alpha particles, it is need to obtain an image of the gamma-ray production points on the first wall. The aim of this study is a development of the imaging system for high energy gamma rays.

The HP-Ge detector was set at the end of beam line on the 1.7 MV tandem accelerator at Kobe University. Gamma rays can be produced by some reactions such as Be(α, nγ), Be(p, γ), Be(d, γ), C(d, γ) reactions. Be(α, nγ) reaction has been typically used for recent experiments and the incident ion is 4.1-MeV helium. The energy of the gamma ray is 4.439 MeV. Because the energy is higher than the energy of environmental gamma ray, a conventional gamma camera can't be applicable for this usage. To fabricate a high-energy-gamma-ray camera, some components should be developed, Since measurement of the gamma-rays gives information about α particles, we obtain the plasma condition. The simultaneous measurement of the incident position and the incident angle of the α particle on the wall has a benefit for this diagnostics.

Fig. 1 shows an experimental set up for a gamma ray detection. The gamma-rays generated by the reaction, ^{9}Be(α, nγ)^{12}C, was measured with a HPGe (EG&G, model GMX25P4-70) detector. The detection efficiency for 4.439 MeV gamma-ray is 8.4 %. A Be target of 20 mm diameter and 0.1 mm thickness is set in a Faraday cup (FC). A current of the incident helium ions was measured by the FC, and it is typically 20 nA. A HPGe was placed at the angle of θ, and the spectrum was measured. Since the excited nucleus in the reaction emits the gamma-ray before the nucleus stops, the gamma-ray spectra suffers from the Doppler effect.

The Doppler shift was observed as functions of detection angle. The comparison between the spectra for the detection angle of θ = 0 [°] and θ = 90 [°] is shown in Fig. 2. The difference of the two peaks is 35 keV. It is convenient to use the difference in rough treatment. Since the spectral shapes are not the same for a different detection angle, a treatment includes the needed shape.

Energy dependence of the gamma-ray yield was measured at θ = 0 [°]. The energy of the incident helium is 2.0, 2.8, 3.8, 4.1 MeV. Doppler broadening is caused by neutron emission. The energy resolution of HGPe is sufficiently large, and the width of spectra does not represent the detector resolution. All spectra are corrupt by the Doppler broadening. The broadening does not have angular dependence.

In this study, high-energy gamma-ray spectra to diagnose the escaping helium from a fusion plasma were investigated. The Doppler shift and the broadening were observed as functions of detection angle. A computer simulation of the reaction including these effects was conducted. The comparison of these effects were in agreement with the experimental results. It shows that there is a capability for diagnostics on the escaping helium particles from burning plasmas using a detector of high-energy resolution.

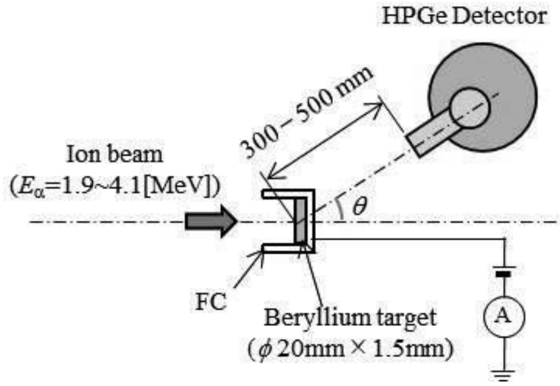

Fig. 1. Experimental set up.

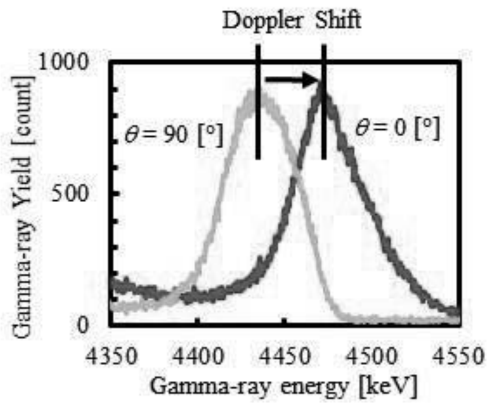

Fig. 2. An example of Doppler shift.

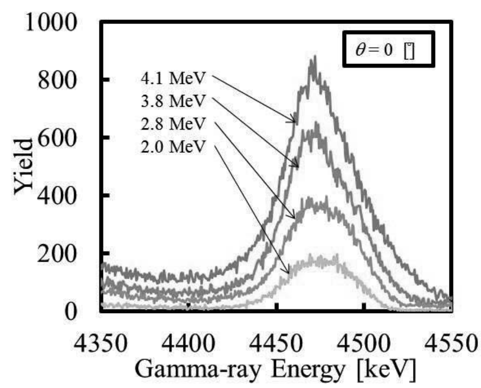

Fig. 3. Energy dependence of the gamma-ray yield.