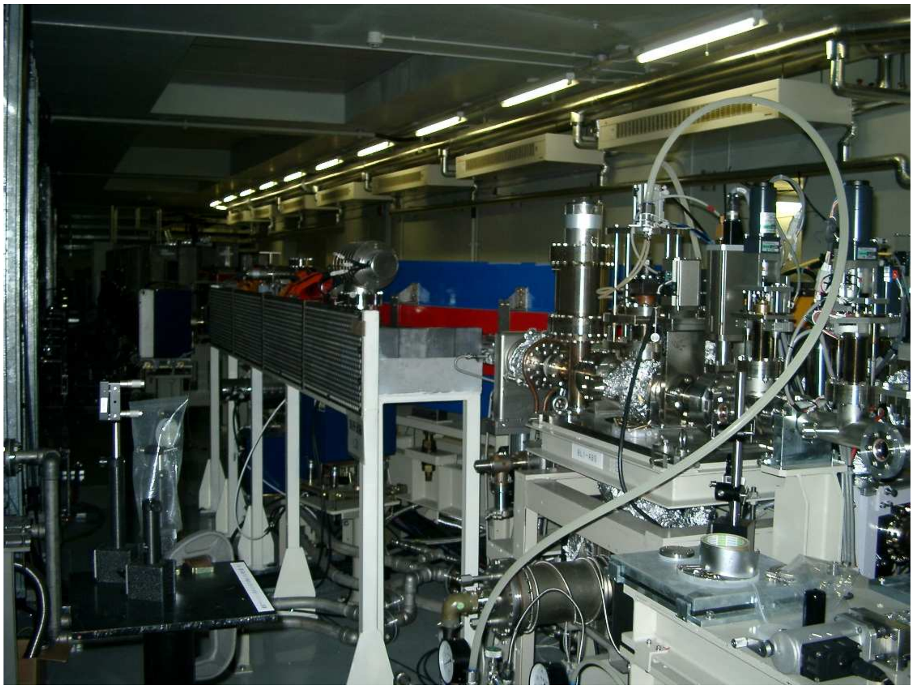

Figure 1: NewSUBARU BL01 beam line for generating MeV γ rays via laser-Compton backscattering.

A new laser-Compton backscattered γ-ray source at NewSUBARU

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1 Introduction

Photonuclear reactions in the energy region from the reaction thresholds up to the energies beyond giant dipole resonances (GDRs) provide useful tools for studies of nuclear physics as well as nuclear astrophysics. In nuclear physics, since the photonuclear reactions are caused by well-known electromagnetic interactions, they are useful for precise studies of nucleon-nucleon (NN) [1, 2, 3] and three-nucleon (3N) [1, 3, 8] interactions, meson exchange currents [4, 5], charge symmetry of nuclear forces [6, 7], properties of the giant resonance states with various electromagnetic moments [9], and so on. In nuclear astrophysics, accurate data of photonuclear reactions are demanded for theoretical calculations of various processes of nucleosynthesis caused by nuclear photodisintegrations as well as inverse radiative-capture reactions. Since the nuclear reactions relevant for those processes are considered to occur in the energy region below a few tenth MeV, the nuclear data at low energies are especially important. In addition, photonuclear reactions in the GDR energy regions have recently attracted a considerable amount of interests, because they provide important information about the analogous processes of the neutrino-induced nuclear reactions occurring in Type-II supernova explosions [10, 11, 12, 13, 14, 15].

A laser-Compton backscattered (LCS) γ ray is expected to be one of the ideal photon sources for high-precision experiments of photonuclear reactions because of the following features:

· variable and quasi-monochromatic energy ($\Delta E/E \sim$10%),

· well-collimated beam (beam size < a few mm),

· considerable intensity ($10^4 \sim 10^6$ photons/s),

· high polarization ($\sim$100· capability for pulsed γ-ray generation,

and so on. The NewSUBARU LCS γ-ray source has been newly developed. One of the special feature of the NewSUBARU LCS γ-ray source is its excellent stabilities in the energy distribution and the intensity due to long lifetime ($\sim$10 hours) of the electron beam, which is essential for high-precision measurements of the photonuclear reactions.

2 NewSUBARU LCS γ-ray source

The setup of the LCS γ-ray source at the BL01 beam line of NewSUBARU is schematically shown by Fig. 2 [**?**]. NewSUBARU is a third-generation electron storage ring with race-track shape, and has two long straight sections. A laser beam is introduced and focused at the center of a straight section, and collide with the electron beam with the energy of between 1.0 and 1.5 GeV. Backscattered γ rays are extracted to an experimental hatch, and collimated by a beam slit made of lead.

Using a Nd:YVO_4 laser with the fundamental frequency as well as its harmonics, one can generate LCS γ rays with maximum energies listed in Table 1.

Table 1: Energy ranges of the NewSUBARU LCS γ rays (unit: MeV).

	E_e [GeV]	
Laser wavelength [nm]	0.97	1.46
1064	16.7	35.3
532	33.4	70.6
355	50.1	105.9

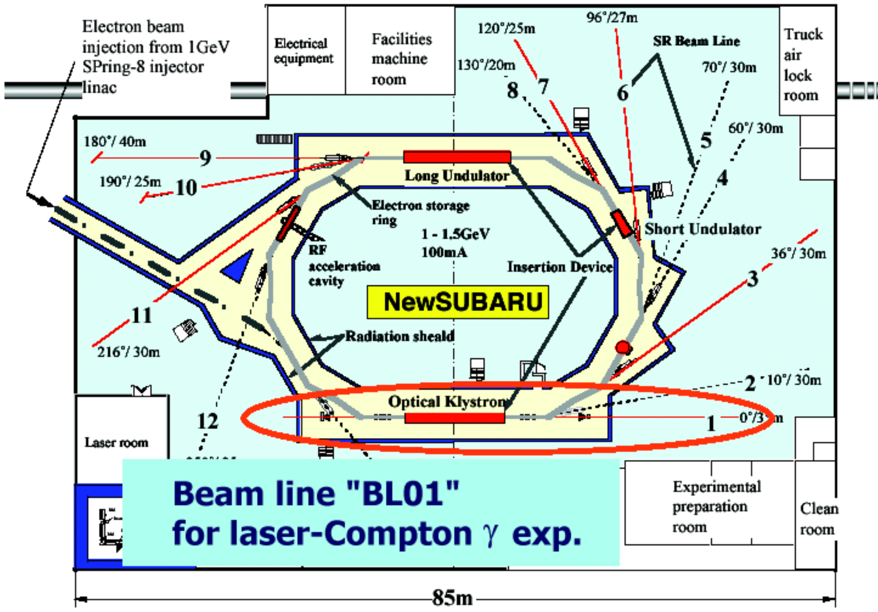

Figure 2: Top view of the LCS beam line BL01 at the NewSUBARU synchrotron facility.

3 γ-ray intensity

The intensity of the non-collimated LCS γ ray has been measured by using scintillation counters. First, we measured the 16.7 MeV LCS γ ray at relatively low intensity ($\sim 10^3$ photons/s) using a GSO scintillator and a plastic scintillator. Since the GSO crystal was as large as 38 mm (W)$\times$38 mm (H)$\times$180 mm (D), its detection efficiency was nearly 100%. The plastic scintillator had a thickness of 10 mm, and had a 1 mm thick lead sheet in front of it in order to increase the sensitivity to the γ rays. Comparing the counting rates of the GSO scintillator and the plastic scintillator, the absolute efficiency of the latter detector has been calibrated. Using the plastic scintillator, the γ-ray intensities for higher electron beam currents and laser powers were measured. Fig. 3 shows the energy-integrated (not collimated) γ-ray intensity as a function of the product of the electron beam current and the laser power.

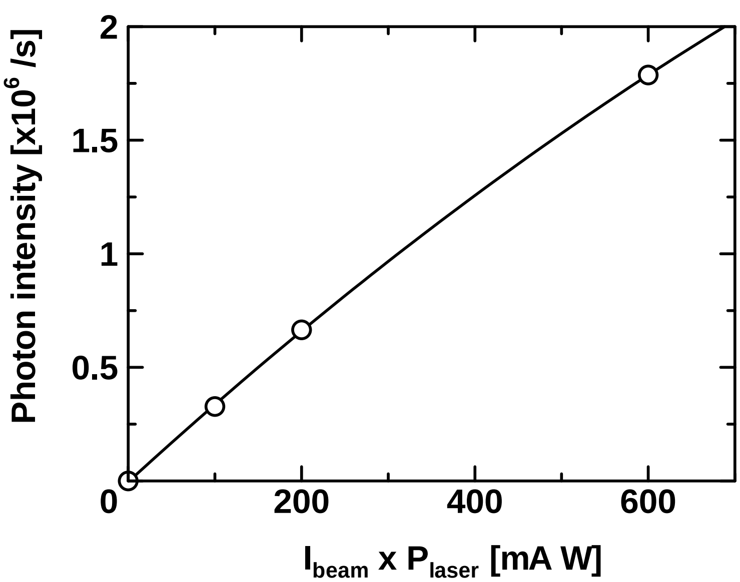

Figure 3: Energy-integrated intensity of the NewSUBARU LCS γ ray. Open circles are the measured intensities, and the solid curve is a fitting.

As shown in Fig. 3, the maximum intensity of about 2×10^6 photons/s has been achieved.

Table 2: Energy spread and production rate of the NewSUBARU 16.7 MeV LCS γ rays.

Diameter of collimator hole [mm]	Energy spread (FWHM) [%]	Production rate [photons/s/mA/W]
6	15.6	110
3	10.2	34

4 Energy distribution of collimated beam

The intensity and the energy distribution of the collimated beams have been measured using a 195 cc Ge detector, whose response functions have been calculated with a Monte Carlo method and calibrated with standard γ-ray sources of ^{60}Co and ^{88}Y and 2614.5 keV γ rays from natural radioactivity of ^{208}Tl. The intrinsic distribution of the γ-ray energy was determined using the response functions of the Ge detector so as to reproduce the measured one. Fig. 4 shows the measured and the intrinsic energy spectra with a collimator hole of 3 mm ϕ.

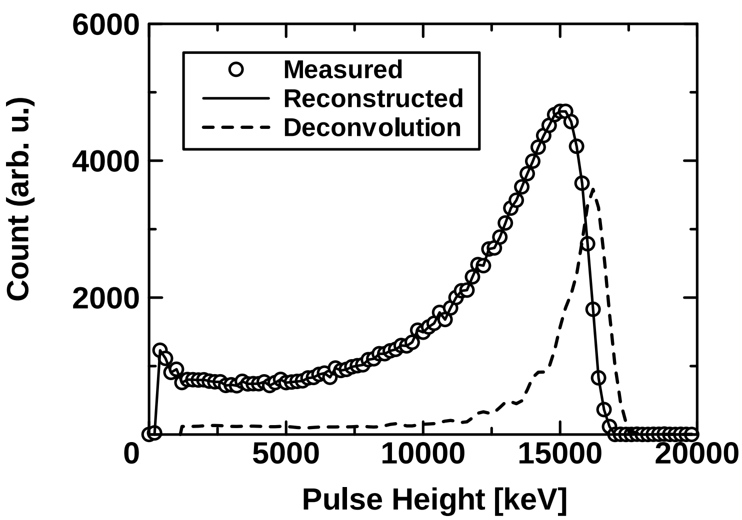

Figure 4: Energy distribution of the NewSUBARU LCS γ ray with a 3 mm ϕ collimator. The energy spread was evaluated to be 10.2% (FWHM).

The energy spreads and the production rates of the NewSUBARU LCS γ rays are summarized in Table 2. Because of a small angular divergence of the electron beam, the production rate of γ rays is significantly better than typical values of existing low-energy LCS γ-ray facilities.

5 Summary

The NewSUBARU LCS γ-ray source has nice features such as a high intensity, a good stability, and so on, and is considered to be a useful tool for precise experimental studies of nuclear physics and nuclear astrophysics. The following experimental studies are currently ongoing or planned ;

(1) photodisintegrations of light nuclei relevant for few-nucleon physics and nuclear astrophysics,
(2) (γ, α) reactions relevant for α-process and γ-process,
(3) (γ, n) reactions of heavy nuclei relevant for p-process,
(4) isomers populated by (γ, n) reactions in relation to heavy element synthesis and nuclear cosmochronology, and
(5) photo-excitations of isobaric analog states to simulate nuclear spin excitations by neutrinos.

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