A production of 2.9 GeV LEP beams by using a 266 nm-wavelength laser

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Laser-Electron Photon (LEP) beams are produced by backward Compton scatterings of laser photons from 7.960 GeV electrons at the LEPS experiment in SPring-8. The maximum energy (k_{max}) of the LEP beams is kinematically calculated by using laser energy (k_l), electron energy (E_e) and electron mass (m_e) with the following formula:

$$k_{max} = \frac{4E_e^2 k_l}{m_e^2 + 4E_e k_l}.$$

LEP beams with a maximum energy of 2.4 GeV had been obtained by using 351 nm-wavelength light from an Ar laser ($k_l = 3.53$ eV). Recently a new laser with 266 nm wavelength ($k_l = 4.66$ eV) was prepared in order to extend the maximum LEP energy up to 2.9 GeV. The new laser can be used, for example, to search for ω-bound nuclei [1].

The 266 nm laser photons were obtained from 'DeltaTrain', which is a continuous-wave laser produced by 'Spectra-Physics'. DeltaTrain contains a 532 nm 'pump-up' laser (a Nd:YVO_4 laser with a LBO crystal) inside. This frequency is doubled at a BBO crystal, which is a non-linear crystal causing second harmonic generation. The maximum power of the 266 nm laser was measured to be 1.3 W by raising the pump-up power up to 5.0 W. The maximum power highly depends on properties and damages of the BBO crystal. The 266 nm laser photons were injected into the electron storage ring through an expander, which focuses the beams at the 35 m-upstream straight section. The beam position at the straight section was optimized by changing vertical and horizontal angles of reflecting mirrors with stepping motors. The beam size near the focus point was measured to be $\sigma \sim 1$ mm, which was comparable to that of the Ar laser. A transmission factor of laser photons between DeltaTrain and the beam end was measured to be 35%, which was slightly worse than that of the Ar laser (50%) because optical elements were not fully optimized. Since the LEP intensity of $\sim 10^6$/second was usually obtained with a 6 W Ar laser, the intensity with the 266 nm laser was expected to be much higher than that of Bremsstrahlung photons, which were produced by the electron beams interacting with residual gas in the storage ring (1-10$\times 10^3$/second).

Two data sets were used for confirming a production of LEP beams which have the Compton edge at 2.9 GeV. One data set was obtained by injecting the 266 nm laser photons. The data collection was triggered by hits in tagging counters, which are two walls of plastic scintillators to detect a recoil electron from a backward Compton scattering. The LEP spectrum was reconstructed from energies of the recoil electrons, which were measured by 100 μm-pitch SSD strips between the two walls of the tagging counters. The LEP intensity of about 0.2$\times 10^6$/second was observed as expected. A relation between a SSD hit position at the tagging system and the corresponding LEP energy was calibrated by another data set. A pair of electron and positron were created at a 0.5 mm-thick lead plate by using

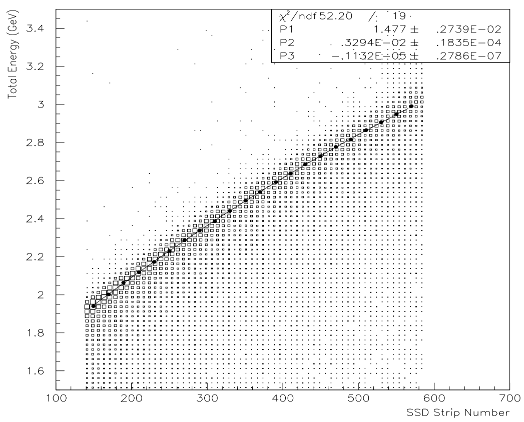

Figure 1: A scatter plot of the photon energy and the corresponding SSD strip.

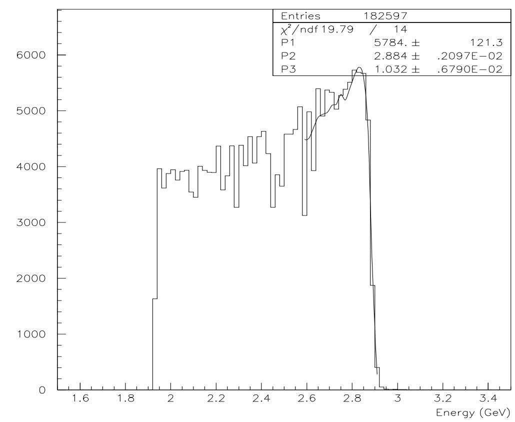

Figure 2: A LEP energy spectrum produced by a 266 nm laser.

Bremsstrahlung photons, and were detected at the LEPS spectrometer [2] with a special trigger for two oppositely-charged tracks. Momenta of them were measured at the spectrometer. The corresponding recoil electrons were simultaneously detected at the tagging system.

In the LEP energy calibration data a pair of electron and positron were selected by their velocities, which were calculated from reconstructed track lengths and time-of-flights from the converter to the most downstream scintillator wall. Figure 1 shows a scatter plot of the SSD strip fired by a recoil electron and the photon energy calculated by summing up e^+e^- energies. Lower energy tails are seen because of Bremsstrahlung radiations of pair-created electrons and positrons. The sample was divided into 22 regions in each 20 SSD strips, which corresponded to 50 MeV bins. Most probable energy in each bin was obtained by fitting a template shape of the e^+e^- energy sum, which were produced by a MC simulation taking into account detector resolutions and Bremsstrahlung processes. A χ^2 probability distribution for the 22 fits was reasonably flat. The SSD position dependence of the 22 e^+e^- energy sums was fitted by a second-order polynomial function in order to obtain the parameters for the photon energy calibration.

Figure 2 shows the LEP energy spectrum measured at the tagging system. Efficiency corrections of the tagging counters and photon energy calibrations obtained above were applied. A template shape of a LEP spectrum around the Compton edge was produced by a MC simulation, which smears 15 MeV resolution to LEP energies, and fitted to the real data triggered by the tagging counters. The Compton edge obtained from the fit, which had 12 MeV of a statistical error, was consistent with the kinematically calculated value. In summary it was confirmed that 2.9 GeV LEP beams were produced by using the 266 nm laser, and photon energy calibrations were made for the physics runs. A week of data collections have been done with a carbon target to search for ω-bound nuclei.

References

[1] E. Marco and W. Weise, nucl-th/0012052 (2000).

[2] T. Nakano et al., Nucl. Phys. A684 (2001), 71c; N. Muramatsu, Proceedings of MESON2002 - 7th International Workshop on Production, Properties and Interactions of Mesons (World Scientific, 2003) p.115.