GENERATION OF POLARIZED POSITRONS VIA LASER-COMPTON SCATTERING AT THE KEK DAMPING RING

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Abstract

We have observed e^+ production for the first time on the basis of a new idea that γ-rays produced via Compton backscattering of laser-lights off e^- beams of 1.26 GeV/c allows to pair-create e^+. For $6x10^9$ e^- / pulse produce by the ATF dumping ring and laser lights of 532 nm and 200 mJ, we observed 16.2+/-2.6 e^+ / pulse being consistent with theoretical predictions.

Linear colliders, as compared with circular accelerators, have a significant advantage to accelerate polarized particles. The controllability of the chirality of initial e^+ beams as well as the e^- beams in future linear colliders enables us to study cleanly various important processes predicted by the standard model and to reveal effectively exotic phenomena beyond the standard model [1,2]. So far we have been developing polarized e^+ beams on the basis of a new idea that polarized γ-rays produced via Compton scattering of circularly polarized laser-lights off high energy e^- beams allows to pair-create highly polarized e^+ beams if one selects e^+'s in its high energy region. Furthermore in ref.3, we presented a conceptual design of polarized e^+ beams for a future linear collider JLC [4] which requires a sophisticated multi-bunch structure of e^+ beams with high intensity of 10^{10} e^+ / pulse. In 1979, Balakin and Mikhailichenko have proposed to produce polarized γ-rays by utilizing a high intensity e^- beam traveling through a long helical undulator [5]. It should be emphasized that our method is based on well-understood QED processes thus leading to reliable estimation of polarization and intensity of generated e^+'s.

Utilizing HELAS [6] for the calculation of helicity amplitudes and BASES [7] for a numerical integration, we obtain the differential cross section of the Compton-scattering process that circularly polarized laser lights of 2.33 eV are scattered by unpolarized e^- beams of 1.26 GeV as shown in fig.1 separately for scattered γ-rays with right handed and left handed helicities. As seen in fig. 1, high polarization is expected for the γ-rays near the high energy end of the spectrum. Taking into account the energy and helicitiy distributions, we calculate the differential cross section for pair-created e^+ with right handed and left handed helicities on a 3 mm W-target as given in fig. 2 which clarifies that the polarization of 80% is achieved if e^+'s with the energy higher than 29 MeV are selected.

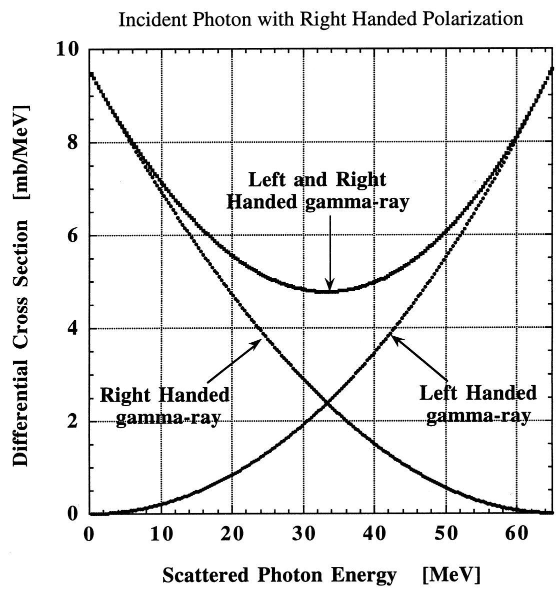

Fig. 1 Differential cross section of Compton scattering as a function of scattered γ-ray energy.

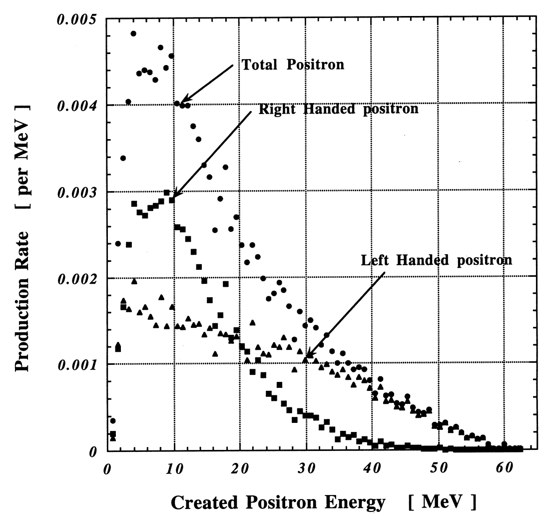

Fig. 2 Differential cross section of pair-creation as a function of created e^+ energy for left handed e^+, right handed e^+, and total e^+.

In order to create polarized e^+ with expected intensity and polarization, we have a plan to perform experiments divided into two steps, namely the observations of γ-rays via Compton scattering and e^+ via pair creation, and the measurement of e^+ polarization. This time we carried out the initial stage using the experimental set-up schematically shown in fig. 3. Extracted e^- beams having an energy of 1.26 GeV/c and the intensity of $6x10^9$ are provided by the ATF damping ring [8] designed as a test facility for the future linear collider JLC [4]. We used a pulse-laser Nd:YAG laser, Continuum NY81C-10 with the power of 200 mJ in a 6 ns pulse length at the wavelength of 532 nm (second harmonic) and the repetition of 0.78 Hz. Laser lights guided from the laser generator being set outside the radiation shield collide with extracted e^+ beams with a crossing angle of 0.007 rad. The backscattered γ-rays pair-create e^+ and e^- which are separated with a pair of magnets. Actually these magnets are designed to select effectively e^+ with the energy higher than about 29 MeV, thus yielding a higher polarization. Pair created e^+'s traveling through these magnets are measured with acrylic Cerenkov counters and Compton scattered γ-rays are measured with air Cerenkov counters. To suppress possible systematic errors due to beam fluctuation, we switched on and off the laser beam alternatively to each e^- bunch. Hence for 1000 e^- bunches containing 500 times of laser-e^- collisions and 500 times of backgrounds measured without laser beams, we counted, as a function of numbers of incident e^+ or γ-rays, collision frequencies for which Cerenkov counters generates signals.

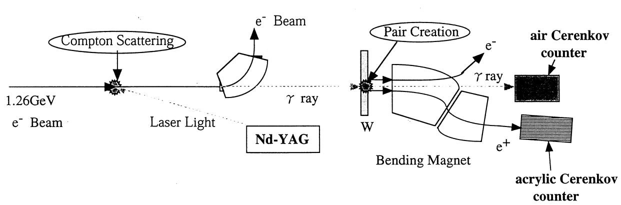

Fig. 3 Schematic illustration of an experimental system for generating polarized positrons..

The clear peak corresponding to γ-ray production being separated well from the background peak is observed in fig.4 where the ADC counts is proportional to numbers of incident γ-rays. In the similar manner, we also obtain the collision frequency of e^+ as shown in fig.5 resulting in the production rate of e^+ / pulse as 16.9 +/- 2.6. In order to confirm reliability of our measuring system, we attempted to do similar measurements without the W-target or the magnetic field and observed 0.5 +/- 3 e^+ / pulse. By reversing the polarity of the magnetic field, we observed 16.3 +/- 3.2 e^- / pulse being consistent with numbers of e^+. Although the damping ring is not yet completely tuned so that considerably high background due to beam loss emerges, all measurements are consistent each other within errors as summarized in fig.6.

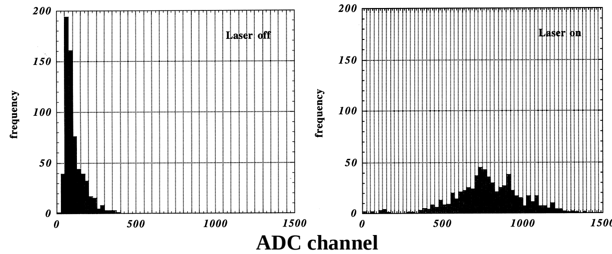

Fig.4 Collision frequencies measured with air Cerenkov counters for laser-on and laser-off.

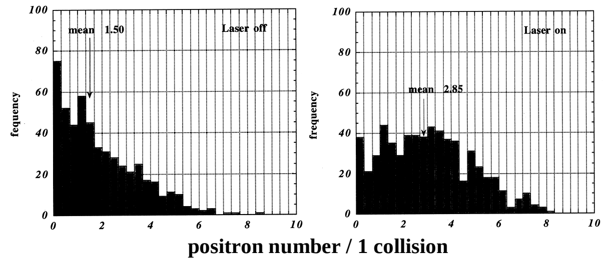

Fig .5 Collision frequencies measured with acrylic Cerenkov counters for laser-on and laser-off.

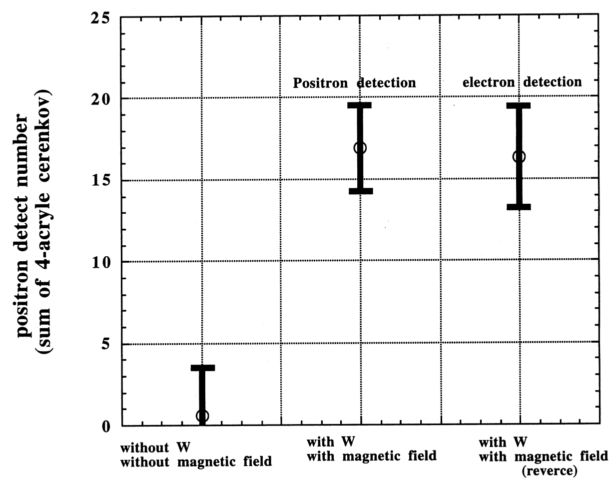

Fig. 6 Numbers of e+/ pulse detected under the conditions : (a) Without a W-target and magnetic field, (b) With a W-target and magnetic field, (c) With a W-target and magnetic field (reversed current)

We will soon measure the e^+ polarization by means of Bhabha scattering of e^+ on a magnetized iron. The conceptual design for JLC polarized e^+ beams has also been progressed from the previous results [2] where we planed to install 100 pieces of CO_2 lasers to create 100 bunches per one train with a repetition of 150 Hz.: Details of recent progresses are also reported in this conference by T. Omori [9, 10]. Now we are developing a CO_2 laser which can provide multi-pulses in collaboration with BNL.

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