Eur Phys J A (2004) **19**, s01, 239–241
Digital Object Identifier (DOI) 10.1140/epjad/s2004-03-039-3

EPJ A direct
electronic only

New results from LEPS at SPring-8

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Received: 31 Jul / Accepted: 14 Nov 2003 /
Published Online: 6 Feb 2004 –

Abstract. The photon beam at SPring-8 is produced by backward-Compton scattering of laser photons from 8 GeV electrons. The maximum energy of the photon beam is 2.4 GeV which is above the $s\bar{s}$ production threshold. We report the status of the new facility and the prospect of hadron physics study with this high quality beam. Results from the first physics run on the subjects of ϕ photo-production and a $S = +1$ baryon are presented.

PACS. 13.60.Le Meson production – 13.60.Rj Baryon production

1 Laser-electron photon beam at SPring-8 (LEPS)

The Spring-8 facility is the most powerful third-generation synchrotron radiation facility in the world. The energy of the electrons in the storage ring is 8 GeV and the beam current is 100 mA. The laser-electron photon (LEP) beam at the SPring-8 is generated by Backward-Compton scattering of laser photons with the 8-GeV electrons (Fig. 1). The maximum energy of the beam is currently 2.4 GeV for a 351-nm (3.5 eV) Ar laser, which is well above the threshold for $s\bar{s}$ productions. The polarization of the LEP beam is about 95 % at the the maximum energy when laser lights are linearly polarized. The polarization drops as the photon energy decreases and crosses zero at the half of the maximum energy. An energy of laser photons can be changed so that the polarization remains reasonably high in the energy region of interest.

The LEP energy is determined by measuring the energy of a recoil electron with a tagging counter which measures the deviation of the recoil electron from the 8-GeV electron beam orbit. Since the tagging counter does not cover the region very near the beam orbit, a photon with an energy below 1.5 GeV cannot be tagged. The energy resolution of the tagged photon is 15 MeV (σ) mainly due to the energy spread of the electron beam and an uncertainty of a photon-electron interaction point in the 7.8-m straight section.

The operation of the laser-electron photon beam at SPring-8 started in July, 1999. The intensity of the beam is about 2.5×10^6 photons/sec for a 5 W laser-output, and a typical tagger rate is 8×10^5/sec.

2 LEPS detector

Figure 2 shows a schematic drawing of the LEPS detector. For the tracking of the charged particles, a silicon-strip vertex detector (SSD) and 3 drift chambers are used. The SSD consists of single-sided silicon-strip detectors (vertical and horizontal planes) with the strip pitch of 120 μm. The first drift chamber located before a 0.7-T magnet consists of 6 wire planes (3 vertical planes, 2 planes at $+45°$, and 1 plane at $-45°$), and the other two drift chambers after the magnet consist of 5 planes (2 vertical planes, 2 planes at $+30°$, and 1 plane at $-30°$). A time-of-flight (TOF) scintillator array is positioned 3 m behind the dipole magnet.

Electron-positron pairs produced before the target are rejected online by a plastic counter, and the pairs produced at the target are rejected by an aerogel Čerenkov counter (AC) with the index of 1.03. The electron and positorons which escape the online trigger rejections are blocked by lead bars which were set horizontally along the median plane inside the magnet gap. Pions with a momentum higher than ~ 0.6 GeV/c are vetoed online by the aerogel Čerenkov counter (AC). A 0.5-cm thick plastic scintillator (SC) located 9.5 cm downstream from the 5-cm thick liquid-hydrogen (LH_2) target ensures at least one charged particle produced in the LH_2 target. The events from the SC is turned out to be very useful to study events generated from neutrons in carbon nuclei at the SC

The angular coverage of the spectrometer is about ± 0.4 rad and ± 0.2 rad in the horizontal and vertical directions, respectively. The momentum resolution (σ) for 1-GeV/c particles is 6 MeV/c. The timing resolution (σ) of the TOF is 150 psec for a typical flight length of 4 m from the target to the TOF. The momentum-dependent mass resolution is about 30 MeV/c^2 for a 1-GeV/c kaon.

3 First physics run and results

The physics run with a 5-cm long liquid H_2 target wad carried out during December, 2000 to June, 2001. The

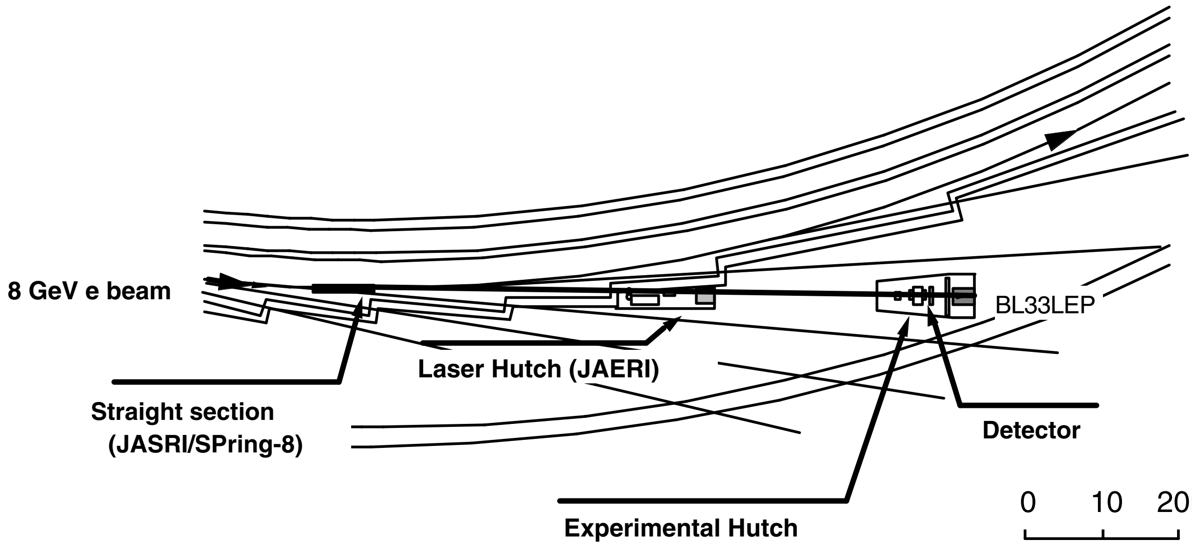

Fig. 1. The LEPS beamline (BL33LEP)

trigger required a tagging counter hit, no charged particle before the target, charged particles after the target, no signal in the aerogel Čerenkov counter, at least one hit on the TOF wall. A typical trigger rate was about 20 counts per second.

3.1 ϕ photo-production

A ϕ meson is almost pure $s\bar{s}$ state. Therefore, diffractive photo-production of a ϕ meson off a proton in a wide energy range is well described as a pomeron-exchange (multi gluon-exchange) process [1,2,3]. However, at low energies other contributions arising from meson (π, η)-exchange [3], a scaler (0^{++} glueball)-exchange [4], and $s\bar{s}$ knock-out [5] are possible. These contributions fall off rapidly as the incident γ-ray energy increases, and can be studied only in the low energy region near the production threshold. The experimental separation of these contributions are difficult if one measure only differential cross-sections because they have similar photon-energy and momentum transfer dependences. Linearly polarized photons are an ideal probe to decompose these contributions. For natural-parity exchange such as pomeron and 0^{++} glueball exchanges, the decay plane of K^+K^- is concentrated in the direction of the photon polarization vector. For unnatural-parity exchange processes like π and η exchange processes, it is perpendicular to the polarization vector.

Pichowsky and Lee [3] predicts that the meson exchange processes dominate in the low photon energy region around 2.3 GeV. However, a preliminary analysis of the KK decay asymmetry in the forward angles showed the natural-parity exchange contributions were still dominant in the region. [6].

3.2 Observation of a $S = +1$ baryon resonance

We searched for baryon resonances with strangeness quantum number S=+1 in the K^- missing mass spectrum for the $\gamma + n \to K^+ + K^- + n$ reaction [7]. The search was motivated in part by a recent paper by Diakonov, Petrov and Polyakov [8] where masses and widths of an anti-decuplet baryons were predicted from the chiral soliton model. The lightest member of the anti-decuplet is the Θ^+ which is an exotic 5-quark state with a quark configuration of $uudd\bar{s}$ that subsequently decays into a K^+ and a neutron. The model predicts the mass of the Θ^+ to be ~ 1530 MeV/c^2 with a narrow width of ≤ 15 MeV/c^2.

For the present analysis, we selected K^+K^- pair events produced in the SC, which accounted for about half of the K^+K^--pair events. The missing mass $MM_{\gamma K^+K^-}$ of the N(γ, K^+K^-)X reaction was calculated by assuming that the target nucleon (proton or neutron) has the mean nucleon mass of 0.9389 GeV/c^2 (M_N) and zero momentum. Subsequently, events with $0.90 < MM_{\gamma K^+K^-} < 0.98$ GeV/c^2 were selected. The main physics background events due to the photo-production of the ϕ meson were eliminated by removing the events with the invariant K^+K^- mass from 1.00 GeV/c^2 to 1.04 GeV/c^2.

In order to eliminate photo-nuclear reactions of $\gamma p \to K^+K^-p$ on protons in ^{12}C and ^{1}H at the SC, the recoiled protons were detected by the SSD. The direction and momentum of the nucleon in the final state was calculated from the K^+ and K^- momenta. And we rejected such events in which the recoiled nucleon was out of the SSD acceptance or the recoiled proton hit was found in the SSD. A total of 109 events satisfied all the selection criteria ("signal sample").

In case of reactions on nucleons in nuclei, the Fermi motion has to be taken into account to obtain appropriate missing-mass spectra. The missing mass corrected for the Fermi motion, $MM^c_{\gamma K^\pm}$, is deduced as

$$MM^c_{\gamma K^\pm} = MM_{\gamma K^\pm} - MM_{\gamma K^+K^-} + M_N. \qquad (1)$$

The validity of the correction was checked with the $\gamma n \to K^+\Sigma^- \to K^+\pi^- n$ sequential process, where the K^+ and π^- were detected.

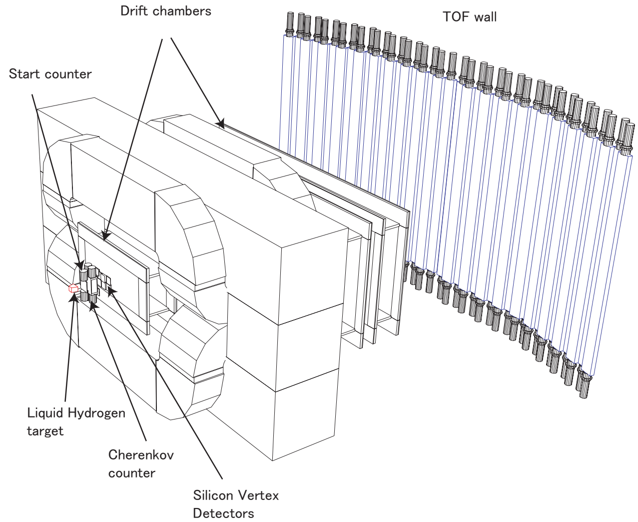

Fig. 2. The LEPS detector setup

The corrected K^+ missing-mass distribution for the events that satisfy all the selection conditions is compared with that for the events for which a coincident proton hit was detected in the SSD. In the latter case, a clear peak due to the $\gamma + p \to K^+\Lambda(1520) \to K^+K^-p$ reaction is observed while the $\Lambda(1520)$ peak does not exist in the signal sample. This indicates that the signal sample is dominated by events produced by reactions on neutrons. Fig. 3 shows the corrected K^- missing mass distribution of the signal sample. A prominent peak at 1.54 GeV/c^2 is found. The broad background centered at $\sim$ 1.6 GeV/c^2 is most likely due to non-resonant K^+K^- production and the background shape in the region above 1.59 GeV/c^2 has been fitted by a distribution of events from the LH_2. The estimated number of the events above the background level is 19.0 ± 2.8, which corresponds to a Gaussian significance of 4.6 σ.

After subtracting the background from the signal sample, the spectrum in the region of $1.47 \leq MM^c_{\gamma K^-} < 1.61$ GeV/c^2 was compared with Monte Carlo simulations assuming a Breit-Wigner function for a resonance distribution. The best fit to the spectrum gives the mass of the resonance to be 1.54 ± 0.01 GeV/c^2. And the upper limit for the width was determined to be 25 MeV/c^2 with a 90 % C.L.. This narrow peak strongly indicates the existence of an $S = +1$ resonance which may be attributed to the exotic 5-quark baryon proposed as the Θ^+.

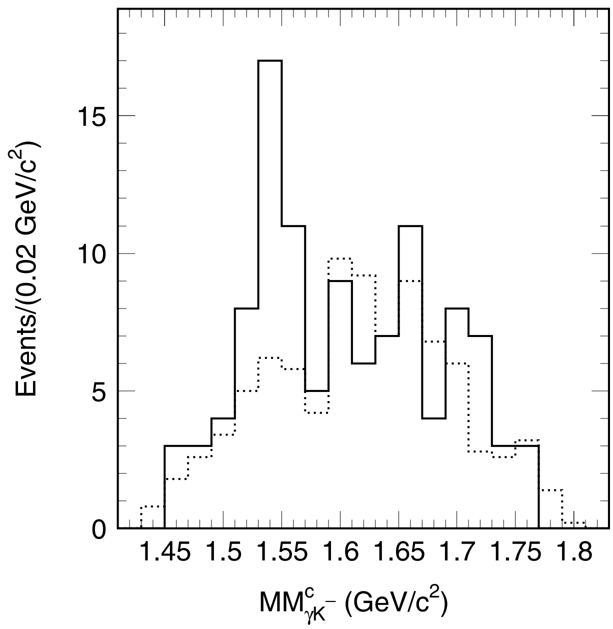

Fig. 3. The $MM^c_{\gamma K^-}$ spectrum for the signal sample (*solid histogram*) and for events from the LH_2 (*dotted histogram*) normalized by a fit in the region above 1.59 GeV/c^2

Acknowledgements. The authors gratefully acknowledge the dedicated efforts of the staff of the SPring-8 for providing a good quality beam. This research was supported in part by the Ministry of Education, Science, Sports and Culture of Japan, by the National Science Council of Republic of China (Taiwan), and by KOSEF of Republic of Korea.

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