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# EXPERIMENTAL PROGRAM AT SPring-8

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A highly-polarized photon beam produced via the backward Compton scattering of polarized laser photons off the high-energy electrons is utilized for nuclear and particle physics experiments at SPring-8. The present status of the experiments at the Laser Electron Photon beamline at SPring-8 (LEPS) is reported. From the recent results, the evidence for a five-quark baryon resonance is presented. A sharp baryon resonance peak was observed at $1.54 \pm 0.01$ GeV/$c^2$ with a width smaller than 25 MeV/$c^2$ in the $\gamma n \to K^+K^-n$ reaction on $^{12}$C. The resonance has the strangeness quantum number $S = +1$ and it can not be formed by three quarks.

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## 1. *Introduction*

A high-energy photon beam produced by laser-induced backward Compton scattering off the circulating electrons (laser electron photon) is utilized for hadron physics studies at SPring-8, the world's highest energy third-generation synchrotron radiation facility. The schematic view of the beamline is shown in Fig. 1. At SPring-8, the 8 GeV electron beam is circulating in the ring with $I_{\rm max} = 100$ mA. The laser beam is injected from the Laser Hutch to the straight section, or the interaction region. The Compton scattering of the laser photon with an 8 GeV electron produces GeV photons which are used for the hadron physics experiments in the Experimental Hutch. The maximum energy of the laser electron photon is determined by the electron energy and the laser wavelength. The LEPS facility produces the maximum photon energy of 2.4 GeV with a 350 nm Ar laser. The photon beam energy is higher than other laser electron photon facilities in the world [1, 2]. One of the advantages of the laser electron photon beam is its flat intensity distribution of the Compton photons. Thus, experiments do not suffer from high intensity low energy background, a common problem with bremsstrahlung beams. Another feature is the high polarization of photons. If laser photons are 100 % polarized, the LEP is also polarized at the maximum energy. The energy of the LEP is determined by measuring recoil electron with a tagging system. The bending magnet of the storage ring is used for analyzing the momentum of recoil electrons. The tagging system is a position-sensitive detector located at the downstream end (along the electron beam) of the bending magnet. It consists of two layers of silicon strip detectors with 100 $\mu$m pitch and two layers of plastic scintillator array. Photons with $E_\gamma > 1.5$ GeV can be tagged by measuring recoil electron with the momentum smaller than 6.5 GeV. The photon energy resolution is about 15 MeV, It is mainly determined by the energy and angular spread of incident electrons.

The operation of the LEPS beamline started in July, 1999. The intensity of the beam is about $2.5 \times 10^6$ photons/sec from a 5 W laser.

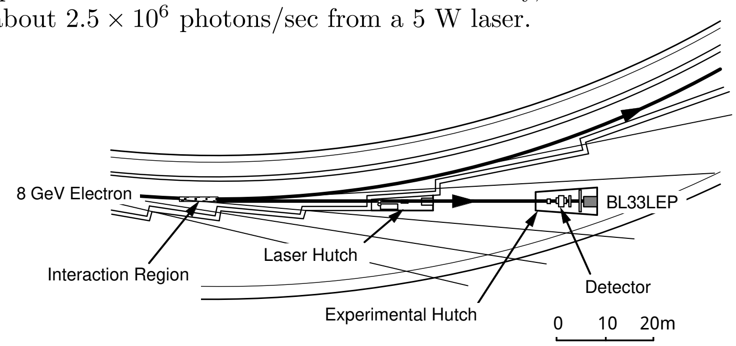


*Fig. 1. The laser electron photon beamline at SPring-8.*

## 2. LEPS experiments

In the Experimental Hutch, we have built the LEPS detector which is optimized for the $\phi$-photoproduction measurement at the forward angles. The detector consists of a plastic scintillator to detect charged particles after a target, an aerogel Cherenkov counter, silicon-microstrip detector, drift chambers, a dipole magnet, and time-of-flight TOF counters (Fig. 2). The trigger requires a tagging counter hit, charged particles after the target, and at least one hit on the TOF counters. Electrons, positrons, and high energy pions are vetoed by requiring no signal from the Cherenkov counter. The detector measures the momenta of the charged particles produced at the target with about 0.1 % resolution. The particle identification is performed by measuring the time of flight of momentum analyzed particles from the target to the TOF wall.

The first physics run with a liquid hydrogen target was started in December, 2000 and the data have been analyzed for several reaction channels. For the $\phi$-photoproduction at low energies, contributions from meson $(\pi, \eta)$-exchange [3], scaler glueball exchange [4], $s\bar{s}$-knockout [5, 6] have been considered, in addition to dominant diffractive Pomeron exchange mechanism. In order to investigate these contributions, the decay angular distributions of $\phi \to K^+K^-$ decay for $\phi$-photoproduction with linearly polarized photon beam are studied [7]. For single K-photoproducition, the photon-polarization asymmetry is very sensitive to the contribution from missing nucleon resonances. The LEPS collaboration has measured the asymmetries for $K^+\Lambda$ and $K^+\Sigma^0$ photoproduction at $E_\gamma = 1.5 - 2.4$ GeV [8]. The nature of the $\Lambda(1405)$ resonance, which is considered to be a meson-baryon resonance state, is also studied at LEPS. The missing mass spectra for the $(\gamma, K^+\pi^\pm)$ reaction are carefully analyzed to test the theoretical prediction [9].

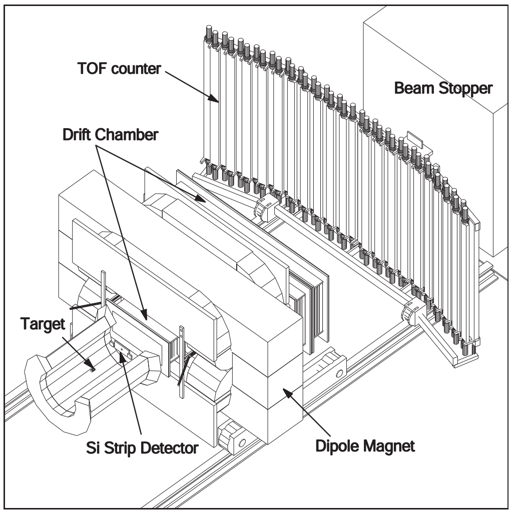


*Fig. 2. LEPSdetector.*

## 3. *Evidence for a 5-quark resonance*

Baryon resonances with the strangeness quantum number $S = +1$ have been searched for in the $K^-$ missing mass spectrum for the $\gamma n \to K^+K^-n$ reaction in carbon nuclei. The analysis was motivated in part by a recent theoretical prediction of the chiral soliton model by Diakonov, Petrov and Polyakov. They predicted the exotic five-quark ($uudd\bar{s}$) state $Z^+$, which was renamed to $\Theta^+$, at 1530 MeV/$c^2$ with a width narrower than 15 MeV/$c^2$. In our data analysis, $K^+K^-$ pair events generated from the plastic scintillator were selected. The main background due to photoproduction of $\phi$ meson was excluded by using $K^+K^-$ invariant mass. In order to eliminate photonuclear reactions of $\gamma p \to K^+K^-p$ on protons in $^{12}C$ and $^1H$ in the plastic scintillator, the recoiled protons were detected by the silicon strip detector. The direction and momentum of the nucleon in the final state was calculated from the measured $K^+$ and $K^-$ momenta. If the calculated momentum was out of the acceptance of the silicon strip detector, such events were rejected. The $(\gamma, K^-)$ missing mass spectrum is shown in Fig. 3. A sharp baryon resonance peak has been found at $1.54 \pm 0.01$ GeV/$c^2$. The Gaussian significance of the peak is 4.6 $\sigma$ and the width is estimated to be smaller than 25 MeV/$c^2$ [10].

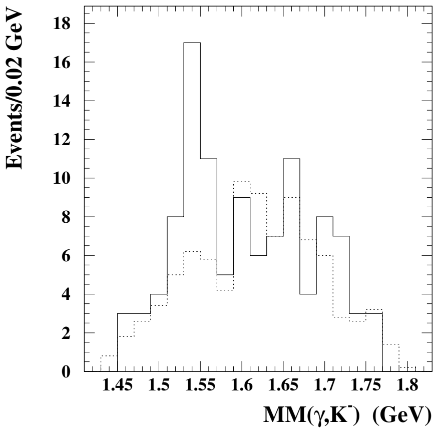


*Fig. 3. The* $(\gamma, \mathrm{K}^-)$ *missing mass distribution after the Fermi motion collection applied. The dashed histogram is an estimated background.*


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## EXPERIMENTALNI PROGRAM UZ SPring-8

Za istraživanja u nuklearnoj i čestičnoj fizici sa SPring-8 rabimo visoko-polarizirane fotone koji se postižu raspršenjem unatrag polariziranih laserskih fotona na elektronima visoke energije. Opisujemo napredak eksperimenata sa lasersko-elektronskim fotonskim snopom. U nedavnim mjerenjima utvrdili smo peto-kvarkovsku barionsku rezonanciju. Opaža se kao oštar barionski rezonantni vrh u reakciji $\gamma\mathrm{n} \to \mathrm{K}^+\mathrm{K}^-\mathrm{n}$ u meti $^{12}$C, na $1.54 \pm 0.01$ GeV/$c^2$, širine manje od 25 MeV/$c^2$. Ima kvantni broj stranosti $S = +1$ i ne može biti sastavljena od samo tri kvarka.