Proposal for LEPS2001B: Search for Z baryon

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Abstract

This is a proposal of the search for a Z^+ exotic baryon which quark state is $uudd\bar{s}$. In one of the chiral soliton models, the Z^+ mass is expected as 1530 MeV and the width is 15 MeV. The mass region in which experiments was performed is too high to find a Z^+ baryon. In this experiment, the missing mass of the reaction $\gamma+p\rightarrow \bar{K}^0+X$ is used to search Z^+ baryon. In the future plan, the detector to tag K^+ from Z^+ decay will be installed to be sure the baryon is an exotic one, i.e. has strangeness of +1.

The requested beam time is 36 shifts (12 days), and beam condition is the vertical polarized gamma beams with an intensity of 800 kcps. The required equipments are the tagging counter, liquid phydrogen target, trigger counters, vertex SSD, drift chamber and TOF counter and Aerogel cherenkov counter which index of 1.008.

Objectives and Impacts of the experiment

The chiral soliton model suggests the existence of a baryon anti-decuplet in addition to an octet and decuplet [1]. All candidates for the anti-decuplet are already discovered except for its vertex, Z^+. The situation is quite similar to 60's when the candidates of the decuplet were available except for the Ω^-. The vertex for the decuplet has a quark state sss and for the anti-decuplet has a states of an exotic $uudd\bar{s}$.

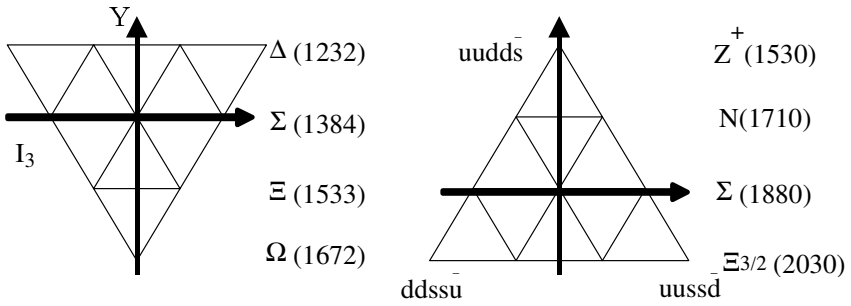

Fig. 1 Baryon decuplet and anti-decuplet.

The Z^+ baryon searches had been performed in 70's, and results are listed in particle data [2]. Some experiments found the Z^+ which mass is around 1780 MeV, but some of them could not. Partial wave analysis claimed that the mass peak does not come from Z^+ but P_{13} or other waves [3]. The Z^+ is removed from the particle data book from 1993.

Calculations based on the chiral soliton model [1] show the lower Z^+ mass 1.53 GeV than the mass region searched by the experiments. The decay width is also calculated as 15 MeV. In chiral soliton models, a baryon is formalized as one state in π, η and K fields. The lowest state corresponds to the octet with a spin 1/2 and next is the decuplet with a spin 3/2. The next candidate is an anti-decuplet with a spin 1/2 and the lightest in the group has an S=1 flavor, i.e. Z^+. All members of the anti-decuplet are shown in Fig. 1. By using the mass and decay width of N(1710) as input parameters, the mass and the width of other member can be determined. Other calculations also show the lower mass of 1.7 GeV [4] and 1.58 GeV [5].

The calculated Z^+ mass of 1530 MeV is lower than the mass region in which previous experiments had been performed. The kaon scattering by a neutron is a direct way to find a Z^+ baryon. However, the energy of kaon beams seems too high for the Z^+ search, normally. Photon beams provide one of the possibilities to search a Z^+ baryon. An existence of the Z^+ baryon in this mass region strongly supports the picture of the chiral soliton model and other anti-decuplet partners, which is still double start or triple star in particle data book.

[1] D. Diakonov et al., Z. Phys. **A359**(1997) 305.

[2] Particle Data Group, Phys. Lett. **B170** (1986) 289.

[3] Particle Data Group, Phys. Rev. **D45** (1992) VIII.58.

[4] H. Walliser, Nucl. Phys. **A 548**, 649 (1992).

[5] H. Weigel, hep-ph/0006191.

Experimental method and apparatus

The possible photo-nucleon Z^+ production reactions are following four.

$\gamma+p\rightarrow \bar{K}^0+Z^+\rightarrow \bar{K}^0+K^++n$ or K^0+p

$\gamma+n\rightarrow K^-+Z^+\rightarrow K^-+K^++n$ or K^0+p

We will use the reaction of $\gamma+p\rightarrow \bar{K}^0+Z^+\rightarrow \bar{K}^0+K^++n$ which threshold is 1.7 GeV. There are sigma baryons around the mass region of Z^+. Thereby, a positive kaon from the Z^+ must be tagged to identify an exotic state with +1 strangeness. And detection of neutrons with a large solid angle and a good momentum resolution is difficult. Therefore we choose a missing mass measurement with a $\bar{K}^0$ and a K^+ tagging. Because a nuclear target makes the missing-mass measurement difficult, we employ the liquid hydrogen target. The design of a detector for the K^+ tagging is now in progress. The emission-angle distribution of a K^+ is calculated by GEANT and shown in Fig. 2. In this proposal, before installing of the K^+ tagging detector, a measurement is focused on the performance of the LEPS spectrometer about a $\bar{K}^0$ identification from two daughter pions and a missing-mass resolution.

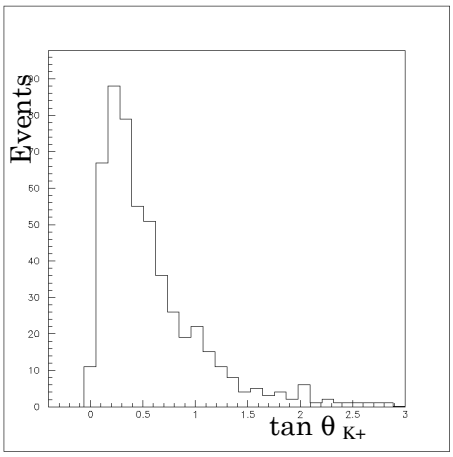

Fig.2 GEANT calculation of the K^+ angle distribution from the Z^+ decay.

The experimental setup consists of the tagging counter, liquid hydrogen target, trigger counters, AC, vertex SSD, drift chamber and TOF counter (Fig. 3). In the current LEPS spectrometer, the aerogel-Cherenkov counter (AC) with an index of 1.03 is used in order to reject electron positron pairs in the trigger level. However most of pions we interested are also rejected. A higher momentum of two pions from a Ks decay is calculated by using GEANT and shown in Fig.4. The index of 1.03 corresponds the threshold momentum for a pion of 0.57 GeV/c. Therefore we will use an AC with an index of 1.008 and pion momentum-threshold of 1.1 GeV/c. Not only the trigger rate due to pion events but also that due to electron-positron pairs will increase because of a less efficiency of the n=1.008 AC. The n=1.03 aerogel and the 5-cm length liquid-hydrogen target are currently used and the trigger rate about 20 Hz at the tagger rate of 800 kHz. The data acquisition dead time is about 1.5 msec per event. Event if the aerogel inefficiency is 10 times larger, the dead time correction factor about 30 %. The dead time is acceptable for this purpose.

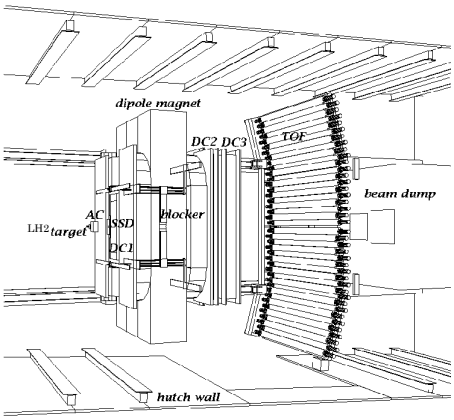

Fig.3 Experimental set up.

The gamma beams with a vertical polarization have advantages of its higher intensity and background suppression power. An event from a rho-meson decay is a main background for the identification of a $\bar{K}^0$ by an invariant mass of the two-pion system. A rho meson is one of the vector

mesons and follows vector meson dominance model. The angular distribution of the daughter pions aligns to the polarization direction of an incident photon. The vertical acceptance of LEPS spectrometer is smaller than the horizontal one. Therefore rho mesons from vertical polarized photon are suppressed.

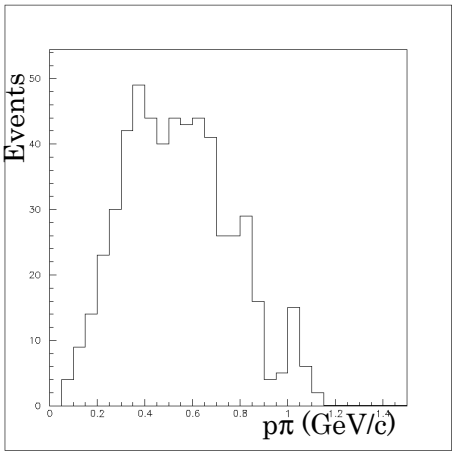

Fig.4 GEANT calculation of higher momentum of two pions from the Ks decay in the $\gamma+p\rightarrow \bar{K}^0+Z^+$ reaction.

Estimation of the beam time requested

The yield estimation is performed using data in Jun 2000. The number of tagged photons that linearly polarized to vertical direction is $35X10^9$. An AC with an index of 1.008 and a CH2 target with a 6-cm thickness are used in the measurement. Figure 5 shows an invariant-mass distribution of the events which missing mass is consistent with a sigma mass (1.2 GeV). One can see the peak at the around 0.5 GeV comes from short life neutral-kaon (Ks) decays. While an invariant mass distribution with a missing mass around 1 GeV has no peak at 0.5 GeV (Fig. 6). Figure 7 is a missing mass distribution with an event-selection gate for a Ks. There is a peak for sigma baryons. There are about 50 Ks's in this measurement.

The factor for the target-thickness difference between 6-cm CH2 and 5-cm LH2 is 8.4. The mass number dependence of the cross section is taken as $A^{2/3}$.

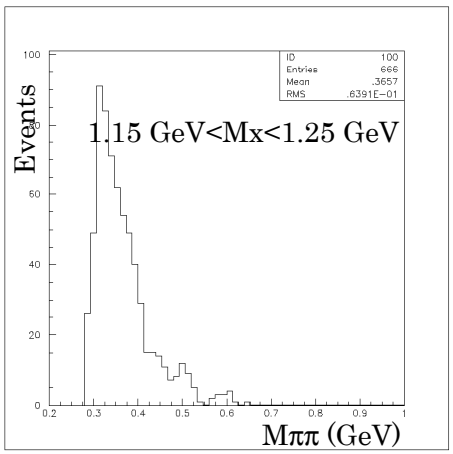

Fig.5 invariant mass of two-pion systems. Events with a missing mass of 1.15~1.25 GeV are selected.

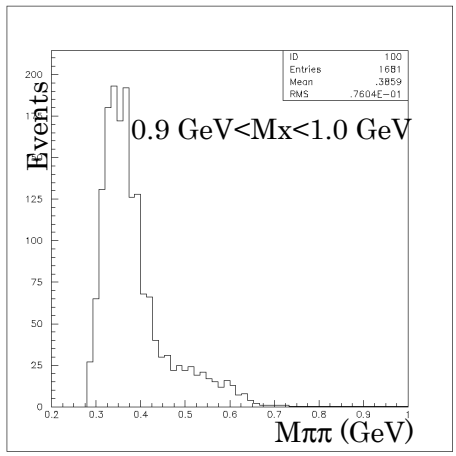

Fig.6 Invariant mass of two-pion systems. Events with a missing mass of 0.9~1.0 GeV are selected.

$$\frac{6cm\times 0.95g/cm^3/14\times(2+12^{2/3})}{5cm\times 0.07g/cm^3/2\times 2}=8.4$$

The current photon rate measured with the tagging counter is 800 kcps and 69X10^9 per day. We will have 150 Ks-events from 12 days measurement for the further study.

Experimental schedule

Setup of the AC and LH2 target (2shift without beam), beam tuning and trigger study (1shift) and calibration run with the electron-positron trigger (1shift) and data taking (35 shift).

Request for the beam condition and experimental equipment

- Beam condition: Vertical polarization, 800 kcps tagging rate, longer lifetime of the SPring-8 storage ring is preferable.
- Experimental equipment: Current LEPS spectrometer but AC index is 1.008.
- Travel budget support for Osaka, Chiba and Wakasa-wan collaborators and LEPS supporting stuffs.

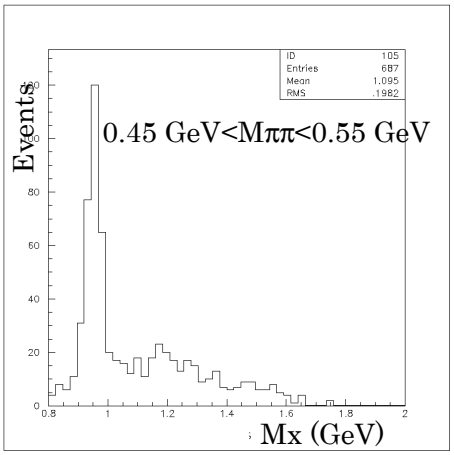

Fig.7 Missing mass of the reaction of the γ incident on the CH2 target and the detection of two pions. The target is assumed as a free proton. Events with a ππ invariant-mass of 0.45~0.55 GeV are selected.