Evidence for Θ^+ in Photo-production from Neutron

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We searched for baryon resonances with strangeness quantum number S=+1 in the K^- missing mass spectrum for the $\gamma + n \rightarrow K^+ + K^- + n$ reaction [1]. The search was motivated by a recent paper by Diakonov, Petrov and Polyakov [2] 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 $uudd\bar{s}$. 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 search, we selected K^+K^- pair events produced in the start counter (SC), which was located 9.5 cm downstream from the 5-cm thick liquid-hydrogen (LH_2) target. The SC was was composed of hydrogen and carbon nuclei (C:H $\approx$ 1:1). 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 $\gamma p \rightarrow K^+K^-p$ on protons in ^{12}C and ^{1}H at the SC, the recoiled protons were detected by 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

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

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

The corrected K^+ missing-mass distribution for the signal sample 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 (Fig 1(a)). This indicates that the signal sample is dominated by events produced by reactions on neutrons. Fig. 1(b) 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. The upper limit for the width was determined to be 25 MeV/c^2 with a 90 % C.L. by comparing the spectrum with Monte Carlo simulations. 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^+.

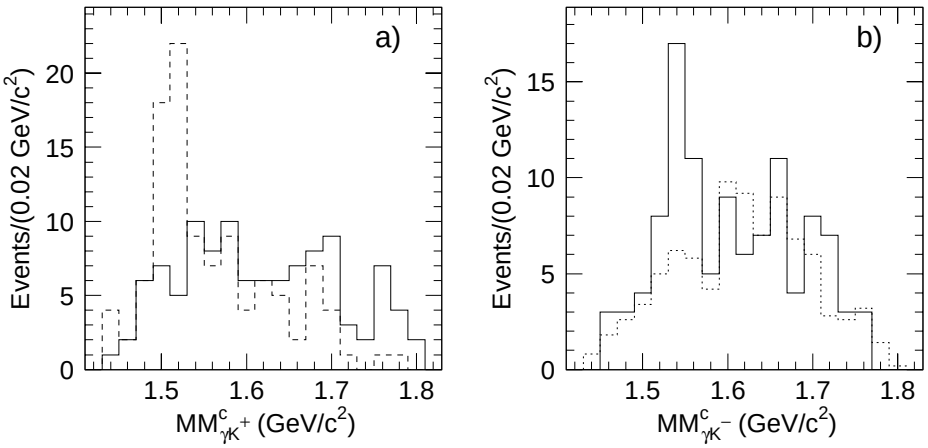

Figure 1: a) The $MM^c_{\gamma K^+}$ spectrum (Eq. 2) for K^+K^- productions for the signal sample (solid histogram) and for events from the SC with a proton hit in the SSD (dashed histogram). b) The $MM^c_{\gamma K^-}$ spectrum for the signal sample (solid histogram) and for events from the LH_2 (dotted histogram) normalized by a fit in the region above 1.59 GeV/c^2 (from Ref. [1]).

References

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[2] D. Diakonov, V. Petrov, and M. Polyakov, Z. Phys. A 359, (1997) 305.