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Physics Letters B 651 (2007) 269–274
PHYSICS LETTERS B
www.elsevier.com/locate/physletb

Photo-production of neutral kaons on ^{12}C in the threshold region

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Received 18 July 2006; received in revised form 13 June 2007; accepted 14 June 2007

Available online 19 June 2007

Editor: D.F. Geesaman

Abstract

The kaon photo-production process on ^{12}C has been studied by measuring neutral kaons in the photon energy range of 0.8–1.1 GeV. Neutral kaons were identified by the invariant mass constructed from two charged pions emitted in the $K^0_S \to \pi^+\pi^-$ decay channel. The differential and integrated cross sections in the threshold photon energy region were obtained. The obtained momentum spectra were compared with a Spectator model calculation using elementary amplitudes of kaon photo-production given by recent isobar models. The present results provide the first information on the $n(\gamma, K^0)\Lambda$ reaction, which is expected to play an important role in constructing models of strangeness production by electromagnetic interactions. The experimental results show that the cross section of $^{12}\mathrm{C}(\gamma, K^0)$ is of the same order as that of $^{12}\mathrm{C}(\gamma, K^+)$ and suggest that a slightly backward K^0 angular distribution is favored in the $\gamma n \to K^0\Lambda$ process.

PACS: 13.60.Le; 25.20.Lj

Keywords: Photo-production; Strangeness; Neutral kaon; Quasi-free reaction; Cross section; Isobar model

1. Introduction

Strangeness photo-production processes near the threshold have attracted considerable interest in the context of baryon resonances coupled with kaon/hyperon channels. Integrated and differential cross sections as well as hyperon polarizations in the $\gamma + p \to K^+ + \Lambda$ and $\gamma + p \to K^+ + \Sigma^0$ reactions have been measured with high statistics by the SAPHIR Collaboration [1]. A theoretical analysis in the framework of the isobar model has shown that the observed structure around 1900 MeV can be explained well by including a new D_{13} resonance of 1895 MeV [2]. It has also been pointed out that the values of the extracted resonance parameters are strongly influenced by the treatment of the background processes, namely, the choice of the meson and hyperon resonances in the t- and u-channels, and the adopted recipes for the phenomenological hadronic form factors [3]. Recent CLAS [4,5] and SAPHIR [6] data show a more pronounced structure around 1900 MeV than the old

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doi:10.1016/j.physletb.2007.06.033

SAPHIR data. Attempts to fit models to these data have been made [7]; however, new experimental data on spin observables [4,8] and other isospin channels are required to properly construct theoretical models and to obtain clear conclusions on the resonances. Strangeness photo-production processes are expected to reveal rich characteristics of hadron structures and strangeness-involving reactions.

From the viewpoint of the isobar model, the reaction channel, $\gamma + n \to K^0 + \Lambda$, in the threshold region has the following unique features: (1) The t-channel Born term does not contribute to the reaction channel. (2) The reaction is a mirror of $\gamma + p \to K^+ + \Lambda$. The coupling constant, $g_{K\Sigma N}$, has a different sign for the two reactions because of isospin symmetry, $g_{K^0\Sigma^0 n} = -g_{K^+\Sigma^0 p}$, resulting in a different interference effect. This is also the case for the exchange terms of the isovector hyperon resonance in the u-channel. (3) The contribution of higher mass resonances are suppressed in the threshold region.

It has also been suggested that the angular distribution of neutral kaons could be backward peaked [9]. Furthermore, the amplitude of the $K^0\Lambda$ channel is sensitive only to couplings of neutral particles, and hence can be used to better differentiate diagrams in isobar models. Thus, the neutral reaction channel is expected to play a unique role in the investigation of the photo-production of strangeness, which cannot be fully studied by measuring charged kaon channels.

In this Letter, we report the first measurements of the (γ, K^0) reaction on a nucleus (^{12}C) using a tagged photon beam. Integrated and differential cross sections are presented as functions of the incident photon energy, E_γ. The experimental results are compared with predictions of a Spectator model that assumes elementary amplitudes of $\gamma + n \to K^0 + \Lambda$ given by isobar models.

2. Experiment

The experiment were performed using the internal tagged photon beam facility [10] at the Laboratory of Nuclear Science, Tohoku University (LNS).

The 1.2 GeV electron beam in the Stretcher–Booster ring (STB ring) produces bremsstrahlung photons at the internal target of a thin carbon fiber of 15-μm-diameter. The photons were tagged over the energy range of $0.8 \leqslant E_\gamma \leqslant 1.1$ GeV with $\Delta E_\gamma = \pm 10$ MeV by bremsstrahlung-recoil electrons, the momenta of which were analyzed by a bending magnet of the STB ring. The average tagged photon rate was $\sim 2.5 \times 10^6 \gamma/\mathrm{s}$. The photons bombarded a 2.1 g/cm^2 thick graphite target (natural), which was placed at the center of the Neutral Kaon Spectrometer (NKS) as illustrated in Fig. 1.

Charged particles produced at the extraction window of the accelerator ring and the collimator for eliminating the beam halo were swept out by a sweep magnet and were further blocked by concrete shields. The beam line from the sweep magnet to the target was filled with a helium bag to suppress the conversion positron–electron pairs, which was one of the major sources of trigger backgrounds. As shown in Fig. 1, a CsI(pure) counter was placed downstream of the NKS to measure the photon tagging efficiency in separate runs with low intensity beams. The averaged efficiency was measured to be $78 \pm 1\%$.

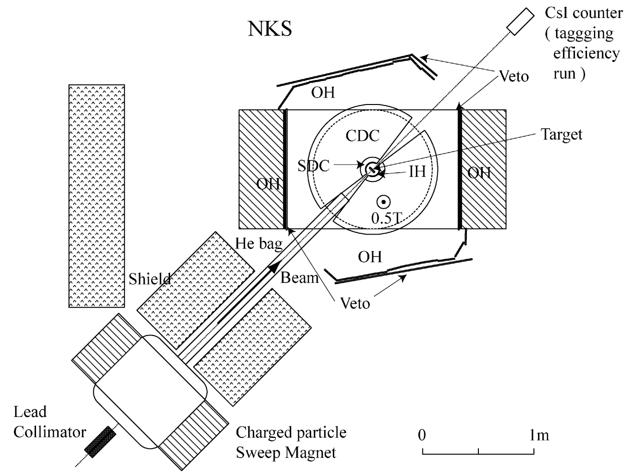

Fig. 1. Plan view of the Neutral Kaon Spectrometer (NKS) for ^{12}C(γ, K^0) experiment.

Neutral kaons were measured by detecting positive and negative pions in coincidence emitted in the $K^0_S \to \pi^+\pi^-$ decay channel. The NKS is based on the TAGX spectrometer [11]. It was originally built at the Electron Synchrotron Laboratory of the Institute for Nuclear Study (INS-ES) and re-assembled at LNS. It comprises a dipole magnet of 107-cm-diameter pole and 60-cm gap, straw (SDC), and cylindrical (CDC) drift chambers in a magnetic field of 0.5 Tesla, inner (IH) and outer (OH) plastic scintillator hodoscopes, and a set of veto plastic counters (Veto) in the beam plane. It covers 25% of the whole solid angle.

Since background triggers due to the conversion process along the beam line were dominant, a Veto of 4-cm high was installed in the mid-plane behind the OH counter arrays to suppress the triggers. The trigger rate was typically 100–200 Hz, and more than half of this rate was due to background triggers. The background triggers themselves were due to accidental coincidences between the NKS trigger and the tagger trigger, and were easily rejected by offline analysis.

3. Analysis

The horizontal momentum of a charged particle was reconstructed by the hit position information of the SDC and the CDC using a magnetic field map calculated by a 3D magnetic field program, TOSCA. The vertical component of the trajectory was calculated from the approximate height at the target, which was assumed to be the same as that of the beams, and the hit position at the OH, which was obtained from the time difference between two PMT signals. The time of flight was measured between the IH and the OH, separated by about 1 m. The time resolution was 0.6 ns (rms), which was good enough to separate pions from protons below 0.7 GeV/c, the maximum momentum of the decay pions in the present kinematics. The e^+e^- events were removed by rejecting events with a vertex position upstream of the target.