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Double π^0 photoproduction on the neutron at GRAAL

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Abstract

The photoproduction of double π^0 on the neutron is studied in the beam energy range of 0.6 up to 1.5 GeV, using a liquid deuterium target. The cross section and the beam asymmetry are extracted and compared to those previously obtained on a proton target. The theoretical interpretation of these results is given using different models.

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The double pion photoproduction on the nucleon is now used, as well as the single pion photoproduction, to study the excitation of nucleon resonances [1–10]. Such experiments have become possible with the advent of new accelerators and large acceptance detectors. At GRAAL, a study of the double π^0 photoproduction on the free proton has been performed and showed a prominent peak at the nucleonic resonance mass of 1700 MeV [9]. The interpretation was performed with Valencia Group model and Laget model involving mostly the excitation of P_{11} and D_{13} baryon resonances. The double π^0 photoproduction on the neutron is another fundamental channel which is accessible at GRAAL with a deuterium target. The study of this channel is interesting to see if there is also a prominent peak in the total cross section at the resonance mass of 1700 MeV. The question is particularly important since, according to a chiral soliton model [11], the 1700 MeV mass location happens to be that of the nonstrange member of the baryon antidecuplet. Furthermore, the authors of the soliton model proposed to disentangle between octet and antidecuplet baryon components by studying simultaneously the photoproduction of π^0, $2\pi^0$ and η mesons on both the proton and the neutron [12]. So, the aim of the present Letter is to study the double π^0 photoproduction

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on the neutron as a fundamental channel and also to find some difference with the double π^0 photoproduction on the proton by comparing their respective observables of cross section and beam asymmetry.

The data have been obtained with the GRAAL setup using a tagged and linearly polarized photon beam, a liquid deuterium target 6 cm thick, and a large acceptance detector [13]. The photon beam of 0.6 up to 1.5 GeV is produced by backscattering a laser beam on the electron beam of 6.04 GeV in the ring of the European Synchrotron Radiation Facility (ESRF) at Grenoble. The energy spectrum of this type of beam is flat and the degree of polarization is close to 100% at maximum energy. In the beam energy range considered here the degree of polarization varies from 0.6 to 0.98, using the green or the UV lines of the laser.

When a laser photon is backscattered on an electron in the ring, the scattered electron is deflected by a magnet of the ring towards a position sensitive detector (tagging detector) allowing to deduce its energy with a resolution of 16 MeV (full width at half maximum). As to the backscattered photons of high energy and small angular divergence, they constitute the photon beam which hits the target and continues in air until reaching first a thin monitor then a full absorption lead-scintillator detector. A flux intensity close to $1.0 \times 10^6 \gamma/s$ was used.

The large acceptance detector consists of three layers: wire chambers, scintillators and calorimeters. In the central part ($25° \leqslant \theta \leqslant 155°$), a bismuth germanate (BGO) calorimeter covering 90% of 4π, centered on the target and vetoed by a barrel of scintillators, detects with a good resolution the γ's [14]. In the forward direction ($\theta \leqslant 25°$), a double wall of scintillators and a shower wall measure the time of flight of the proton and the neutron respectively [15].

Here, we study the reaction $\gamma n \to n\pi^0\pi^0$, using a deuterium target. We select the events of the reaction $\gamma d \to n\pi^0\pi^0 p$ where the γ interacts, in a quasi-free process, with the neutron weakly bound inside the deuterium nucleus while leaving the partner proton as spectator. In such a process, the neutron target has a given Fermi momentum and the proton keeps, in the final state, a momentum of opposite value. Consequently, we propose to select the quasi-free events as those for which the proton in the final state has a characteristic Fermi kinetic energy E_p of a few MeV, which is below the energy threshold for charged particle detection in the GRAAL setup (≈20 MeV). In the analysis, the experimental events with five neutral particles detected in the final state were selected, in order to reconstruct two π^0's and a neutron, the π^0 being detected through its decay into 2γ's. A further selection is imposed by requiring the detection of the two π^0's in the central detector (BGO). This condition ensures good angular and energy measurements of the γ's and consequently of the two π^0's. The neutron is detected either in the central detector or in the forward detector and its angles θ and ϕ are measured through the cellular structure of the detector. In the forward directions, the neutron is discriminated from the γ's by the time of flight given by the shower wall. In the central detector, the neutron is taken as the neutral particle left when the four others give the best reconstruction of two π^0's. The use of the four energy and momentum conservation laws allows to deduce the energy of the neutron and the angles and the energy of the undetected proton. The plot on Fig. 1 shows the invariant masses for the best combination of two pairs of γ's to reconstruct a double π^0. The resolution (full width at half maximum) of the reconstructed invariant mass of π^0 is 25 MeV. In Fig. 2, the plot with a thick line displays the energy spectrum of the undetected proton, where the peak close to zero originates from the quasi-free process and the background visible at higher energy comes from other processes.

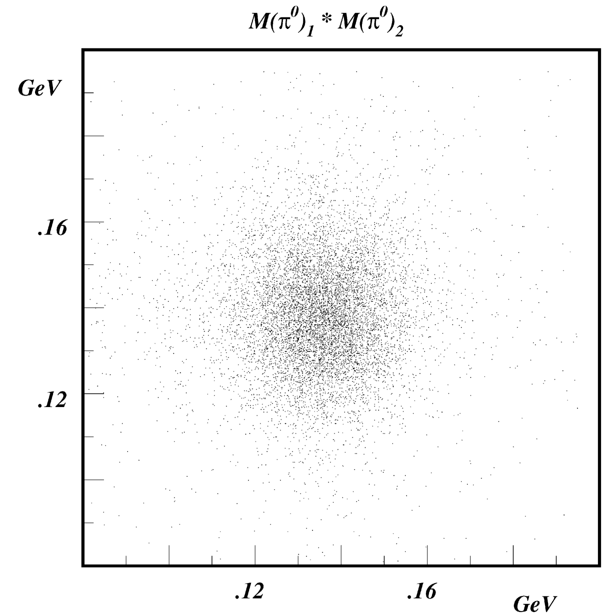

Fig. 1. Bidimensional plot of the invariant masses of two pairs of γ's corresponding to the best combination (see text). For this plot, events of the reaction $\gamma d \to n\pi^0\pi^0 p_{sp}$, with the energy of the undetected proton lower than 50 MeV, were selected.

In parallel to the analysis of the experimental data, a simulation was carried out using the code LAGGEN of GRAAL built on an event generator and on the GEANT3 code from the CERN library. The generator was used to produce events for the reaction $\gamma d \to \Delta^0\pi^0 p \to n\pi^0\pi^0 p$, where the gamma interacts with a neutron bound inside the deuterium and having a Fermi motion. The GEANT3 code provides the tracking of the produced particles in the detector. The results of the simulation were used for two purposes: to check the event selection criteria and to determine the acceptance. In the simulation the events were analyzed as those corresponding to the experimental data. The energy spectrum of the undetected proton is shown as a thin line in Fig. 2. A pronounced peak is obvious at $E_p \approx 0$ and a flat and low background at higher energy. The comparison of the experiment and simulation curves in Fig. 2 suggests that the desired events can be selected by: (i) keeping events with $E_p \leqslant 0.05$ GeV, (ii) rejecting events with $E_p \geqslant 0.10$ GeV and (iii) subtracting events with $0.05 \leqslant E_p \leqslant 0.10$ GeV. This filter was applied for both the experimental and simulated data, in order to correct for the part of true events cut in these operations. In the inset of Fig. 2, the resulting spectra are shown. A good consistency in shape and width is observed between the experiment and simulation spectra. In the experimental spectra, the