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Short note

Search for narrow dibaryon resonances in neutral pion photoproduction from the deuteron

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Abstract. The reaction $\gamma d \to \pi^0 X$ has been measured with TAPS at MAMI in the energy range $E_\gamma = 140$–300 MeV. Using the Glasgow tagging spectrometer a photon energy resolution of 0.8 MeV was achieved. The energy excitation functions of integral and differential total cross-sections show no structures of statistical significance $> 2\sigma$. Upper limits for the production of narrow isoscalar or isovector dibaryons with masses $m \leq 2100$ MeV/c^2 were deduced. They are in the range 2–5 μb averaged over the 0.8 MeV energy resolution.

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The question, do there exist more eigenstates in the system of two baryons than just the "trivial" deuteron groundstate and the virtual $^1S_0$ state, has been awaiting an answer for decades despite many dedicated experimental searches. In fact, phase shift analyses of NN-scattering and $pp \to d\pi^+$ reactions have recently revealed [1] broad structures in some partial waves which exhibit resonant behaviour in the Argand diagram. These structures, however, may be associated with ordinary $N\Delta$ states and as such are not much of a surprise. States of more exotic nature like true six-quark configurations would be much more exciting. Of particular interest would be narrow dibaryon resonances, since their decay would need to be hindered either dynamically due to an exotic configuration or due to quantum numbers which prohibit their fall-apart decay into two baryons. No definite evidence for such states has ever been found. Though many candidates have been reported in the past, they either have been of low statistical significance or could not be reproduced by follow-up experiments [2]. New candidates have been reported very recently [3,4] in the $pp \to pp\gamma\gamma$ reaction measured at MEPI and Dubna, though a similar investigation [5] with the WASA/PROMICE setup at CELSIUS has given no positive results. Another candidate of recent interest has been the so-called d', a so far hypothetical πNN resonance with $I(J^\pi) = $ even (0^-), $m \approx 2.06$ GeV/c^2 and $\Gamma_{\pi NN} \approx 0.5$ MeV. Evidence for such an NN-decoupled resonance stems from a resonance-like structure observed [6–9] in the double charge exchange reaction on nuclei at energies below the Δ-resonance. Also a narrow structure of 2–3σ significance observed [10] in the invariant mass spectrum $M_{pp\pi^-}$ from the $pp \to pp\pi^-\pi^+$ reaction was tentatively interpreted as a possible signal of d', provided a detector artifact could be excluded.

The present investigation focuses on the search for narrow isoscalar or isovector resonances, which couple to the γd channel. Previously such searches [11,12] concentrated on charged pion production channels. However, the π^0 production channel appears to be much better suited, since in the energy region of interest below the Δ-resonance

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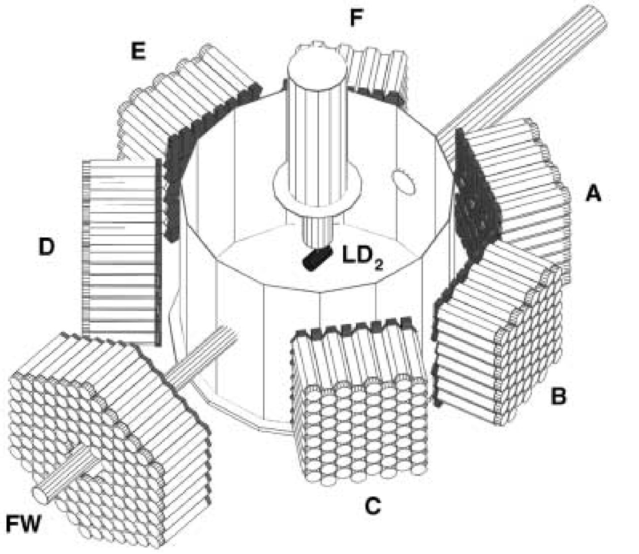

Fig. 1. TAPS detector setup at MAMI 1996. Six TAPS blocks containing $8{\times}8$ BaF_2 modules each (A–F) and the forward wall containing 120 BaF_2 modules (FW) are placed in the plane around the target chamber containing the liquid deuterium target.

down to threshold the cross-section for the conventional π^0 production is much lower than in the $\pi^\pm$ production channels, thus causing less background for the search of narrow structures. Therefore, we have measured at MAMI the reaction $\gamma d \to \pi^0 X$ using tagged photons in the energy range $E_\gamma = 140$–300 MeV. Their good energy resolution of $\Delta E_\gamma \leq 1$ MeV is particularly well suited for the search for narrow structures $\lesssim$1 MeV in the cross-section, which previous studies had no chance to observe. The π^0 particles emitted from the LD_2 target were detected via their 2γ decay using the TAPS detector setup as shown schematically in fig. 1. It comprises 6 blocks, each containing 64 hexagonal BaF_2 modules with individual plastic veto detectors, together with a forward wall containing 120 BaF_2-plastic phoswich telescopes. The setup covered a solid angle of about 1/3 of 4π. Neutral particles were identified by time-of-flight and pulse-shape analyses. Details are given elsewhere [13]. The coherent ($\gamma d \to \pi^0 d$) and incoherent ($\gamma d \to \pi^0 np$) channels could be identified and fitted in the missing mass spectrum [14], provided the statistics per incident photon energy bin ΔE_γ was increased sufficiently, *i.e.* to $\Delta E_\gamma = 6 - 20$ MeV [14], where the first (last) number applies to the high- (low-)energy end of the energy region of interest. However, in order to keep the best energy resolution of 0.8 MeV in the search for narrow structures the total π^0 cross-section had to be exploited here. Also, since the tagging efficiency shows systematic modulations with a width of ≈ 10 MeV on the 2% level, we restrict this search to $E_\gamma \leq 245$ MeV, where these modulations are below the statistical accuracy.

The measured total cross-sections are in very good agreement with previous TAPS data [15] in the overlap region. Figure 2 shows the measured energy dependence of the integral total π^0 production cross-section as well

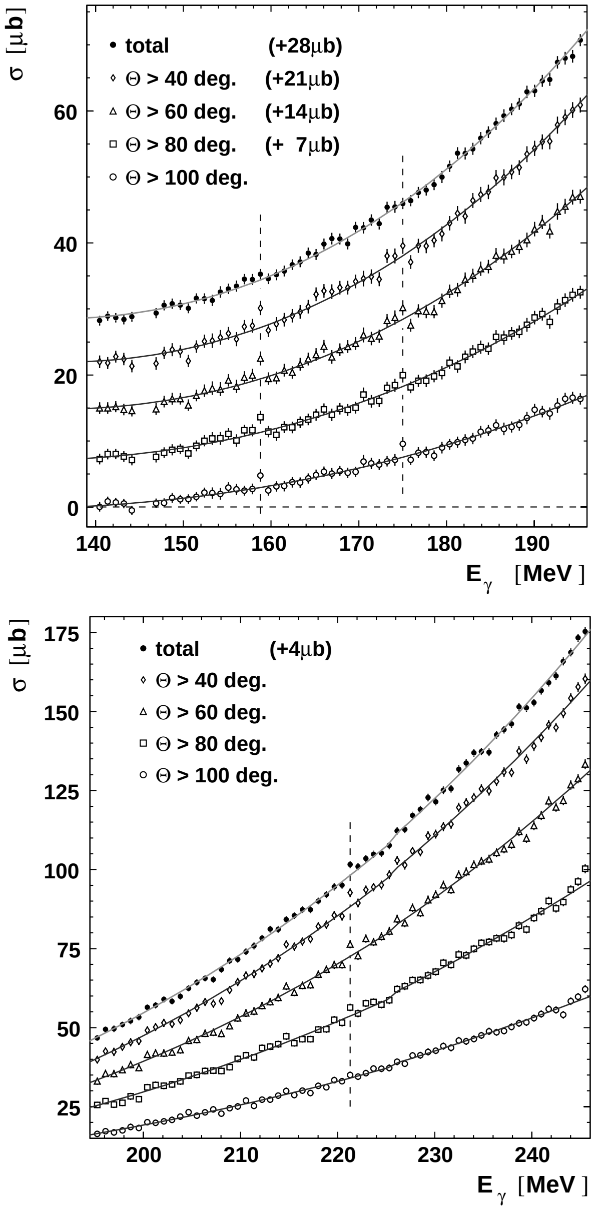

Fig. 2. Measured energy dependence of the $\gamma d \to \pi^0 X$ reaction. Shown is the integral cross-section as well as the partial integral cross-sections for $\Theta > 40, 60, 80$ and 100 degrees as indicated in the figure. The most prominent fluctuations extending over several angular bins are marked by vertical dashed lines. For clarity in the figure the data are displayed with an offset (numbers in brackets), which has to be added to obtain the correct cross-sections.

as partial integral cross-sections for π^0 angles $\Theta > \Theta_0$, with Θ_0 varying over the full angular range as indicated in fig. 2. This way any angular dependence of possible structures becomes apparent. Also, since coherent π^0 production is forward-peaked, whereas the incoherent channel dominates at backward angles [14,15], resonances present only in the latter should be enhanced by these large-angle cuts. For $\Theta > 100°$ the ratios for incoherent to coherent production are 0.5, 0.9 and 1.3 for $E_\gamma = 170$, 200 and 230

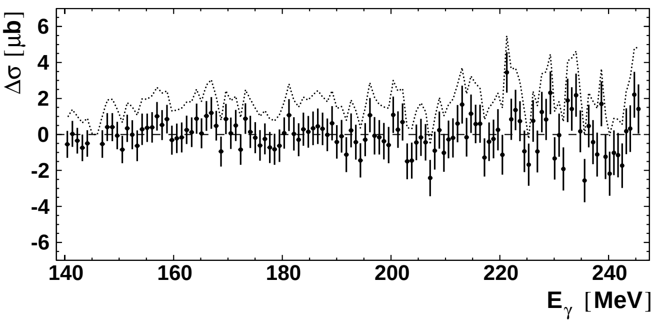

Fig. 3. Deviations $\Delta\sigma$ of the data for the integral total π^0 production cross-section from a smoothed energy dependence fitted to the data. The dotted curve represents upper limits (90% c.l.) for underlying narrow structures averaged over the experimental energy resolution.

MeV, respectively. Hence by the large-angle cuts the high sensitivity of these measurements is retained also for those resonances, which do not couple to the coherent channel.

The energy excitation functions obtained are smooth exhibiting only a few deviations on the 2σ level as expected from statistics. Deviations, which show up at several angle bins are indicated by vertical dashed lines in fig. 2. The most prominent one appears near $E_\gamma = 221$ MeV ($m = 2084$ MeV/c^2), but its significance is not large enough to associate it with a nonstatistical origin. We only note that this deviation is close to a line reported in ref. [16].

In order to obtain upper limits for possible production cross-sections of narrow dibaryons in this reaction, we have fitted the integral cross-section with a 4th-order polynomial, which accounts for the observed smooth energy dependence in a statistically adequate manner. The deviations $\Delta\sigma$ of the data from this smoothed cross-section are shown in fig. 3. Fitting these fluctuations with a Gaussian of FWHM = 1 MeV, the experimental resolution, leads to upper limits (90% c.l.) as indicated by the dashed line in fig. 3. In this way upper limits of $\int_{\Delta E} \sigma(E) \mathrm{d}E = 2$–$5\mu$b $\cdot$ MeV for dibaryon production in this reaction are obtained, where the integration over $\Delta E = 0.8$ MeV accounts for the experimental resolution.

Though this high-resolution measurement excludes — at least in this reaction — isoscalar and isovector dibaryon resonances for $m \leq 2100$ MeV/c^2 at the level of a few μb $\cdot$ MeV, and thus sets new stringent constraints, its sensitivity is still far below that needed for a sensitive d' search in this reaction. In ref. [17] the d' cross-section has been estimated to be as low as 0.5–1μb for $\Gamma_{\pi NN} = 0.5$ MeV leading thus to $\sigma_{d'} \cdot \Gamma_{\pi NN} = 0.2$–$0.5\mu$b $\cdot$ MeV, which is still an order of magnitude below the sensitivity of this measurement. An improvement by a factor of 10 appears, feasible, however, by exploiting a higher granularity of the tagger and an extended beamtime.

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