Study of Coherent Vector Meson Photoproduction off Deuteron and a possible d^* resonance

T. Chetry and K. Hicks

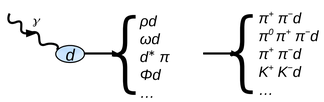
Department of physics + astronomy, Ohio University

Abstract

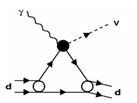
A vector meson is a $q_i\bar{q}_j$ pair with total spin 1 and an odd parity ($J^P = 1^-$). Coherent photoproduction of two vector meson channels, ρ and ω, from the deuteron have been studied separately using CLAS at Jefferson Lab as a function of the photon energy and the 4-momentum transfer. Tagged photons with beam energies between 0.8 and 3.5 GeV were bombarded on a deuterium target, during the experimental run *g*10. The final state particles detected are an energetic deuteron and a pair of charged pions from the meson decay. The ρ- and ω-events were each selected in a manner that ensures exclusive production in the final state. **As beams of these vector mesons cannot be produced in a lab, this study allows one to test models of hadronic scattering of ρ- and ω-mesons from the nucleon**. In addition, the final state ($\pi^+ \pi^- d$) is useful to investigate a possible d^*, dibaryon resonance, that has been seen in other reaction channels at CLAS, as well as in other partial-wave analyses of pion-deuteron scattering at a mass of about 2145 MeV [1].

Background

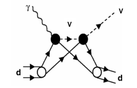
Photoproduction is a powerful tool to study structure of hadrons and to investigate meson properties. An initial state hadron is bombarded with photons which interact with the constituent quarks via some interaction enabling the study of several final state possibilities.



In photoproduction reactions, a vector meson can be produced via single scattering or a double scattering off the nucleons.

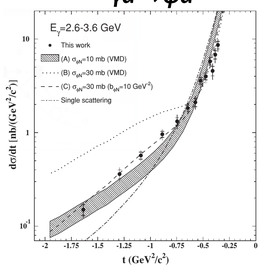


Single scattering:
Dominant at small -*t*



Double Scattering:
Probability increases at larger -*t*

γd →φd

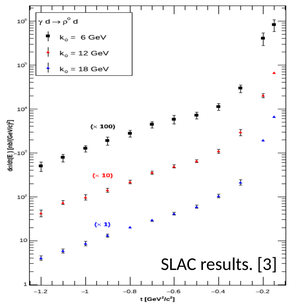


Curves A, B and C are calculations from rescattering model. The dot-dashed curve is a contribution from the single scattering. **[2]**

In the framework of Vector Meson Dominance the measurement of the differential cross sections of coherent vector meson photoproduction in a wide *t*-range allows to study the *V-N* interaction in both single and double scattering dominant regions.

The world data is very limited on coherent vector meson photoproduction off deuteron in low E_γ and high *t* regime.

The study will provide a robust analysis procedure to connect vector meson photoproduction and *d**.



Dibaryons are a large family of hypothetical particles which consists of six quarks or antiquarks of any flavors. Jaffe's prediction of dihyperon at 2150 MeV in the ΛΛ invariant mass plots motivated a lot of research groups. WASA-at-COSY Collaboration claimed to have found a narrow resonance at 2370 MeV [4].

Detection

The g10 experiment took place at Hall B of the Thomas Jefferson National Laboratory (Jlab) located at Newport News, VA.

The accelerator facility was able to produce electrons at energies up to 6 GeV (now up to 12 GeV). This experiment used an electron beam with incident energy of 3.8 GeV which produced photons by bremsstrahlung process and were tagged by the Hall B tagger.

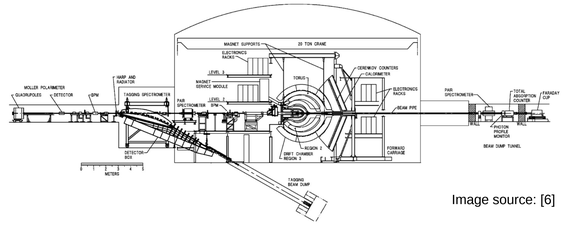


Image source: [6]

The beam is sent to bombard a liquid deuterium target. The reaction products are tracked by CLAS. Detection consists of determining a particle's TOF, momentum, and track information.

The recorded events were “cooked” into a form suitable for physics analysis. During this process all the detector subsystems were calibrated. The analysis efforts related to this research use the processed *g*10 data.

Analysis

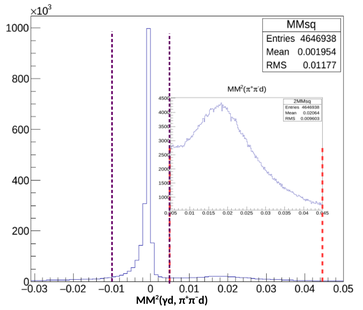
The channels used to observe cross section features are

$$\gamma d \rightarrow \rho d \rightarrow \pi^+ \pi^- d \ (100\%)$$
$$\gamma d \rightarrow \omega d \rightarrow \pi^0 \pi^+ \pi^- d \ (88.8\%)$$

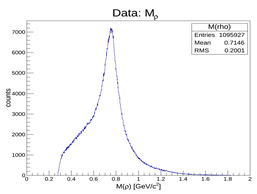
An event of interest for both channels can be found by investigating the square of missing mass given by

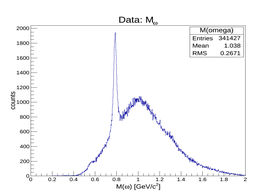
$$MM^2(\gamma d, \pi^+\pi^- d) = (p_\gamma + p_t - p_{\pi^+} - p_{\pi^-} - p_d)^2$$

From the same data set, coherent ρ-meson events are selected by making a cut around zero missing mass squared as shown by violet dashed lines, while a missing mass squared cut (red dashed lines) was applied to select the missing π^0 for the exclusive ω-meson events.

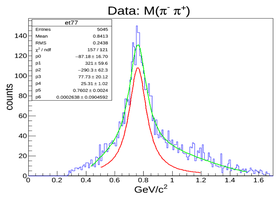


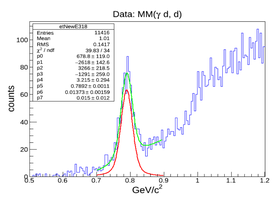
After few basic detector cuts applied to the data to reduce the background, the global spectra for the channels show a peak on top of smooth background.





These are binned in different incident photon energy ranges and momentum transfer bins. A third order polynomial function is used to fit the background while the signal events are extracted using a Voigt profile.





Obtaining the yield for each energy and momentum transfer (*t*), allows the differential cross section to be determined.

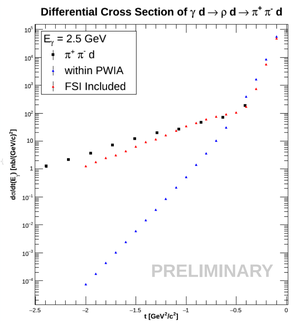
$$\frac{d\sigma}{dt} = \frac{Yield(E_\gamma, t)}{(\delta t) A(E_\gamma, t) L(E_\gamma)}$$

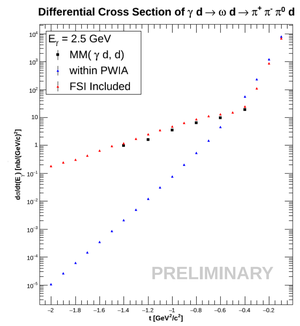
where δt is the momentum transfer bin size, $L(E_\gamma)$ is the luminosity and $A(E_\gamma, t)$ is the detector acceptance.

A GEANT based Monte-Carlo simulation package is used to process events generated by an event generator by propagating the particles through code-embedded CLAS detector. Those events are used to calculate $A(E_\gamma, t)$.

Results and Discussions

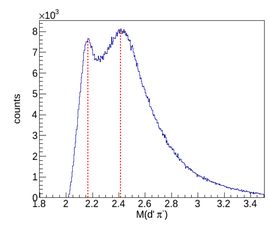
Differential cross section as a function of E_γ and *t* is calcuated for both channels. Shown below are the results for one energy bin.

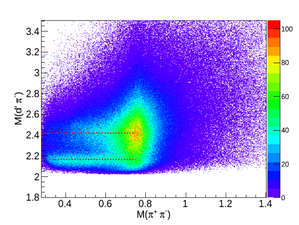


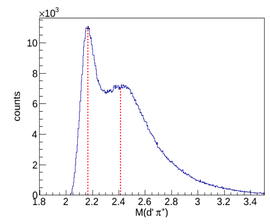


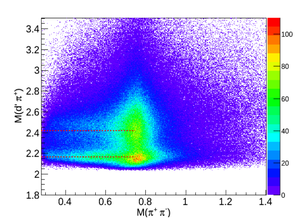
The red points are results obtained by including the final state interaction while the blue points represent results within plane-wave Impulse approximation [7]. The black points are the preliminary results obtained from *g*10 data set for E_γ centered at 2.5 GeV.

An indication of a possible *d** resonance which could interfere with the vector meson channels can be guessed at this point. Peaks in the $d\pi$ mass spectrum can be seen below. The red dashed lines are to guide the eye.









Similar features are found in ω-channel as well. More investigations are required to clearly state about the *d** resonance.

Acknowledgments

[1] R. A. Arndt *et al*., Phys. Rev. D 35, 128 (1987)
[2] T. Mibe *et al*., Phys. Rev. C 76, 052202(R) (2007)
[3] R. L. Anderson et *al*., Phys. Rev. D4, 3245 (1971)
[4] P. Adlarson et *al*., Phys. Rev. Lett., 112:202301, May 2014
[5] *https://www.jlab.org/Hall-B/int-web/*
[6] B. A. Mecking et *al*., NIM, 3:513–533, 2003
[7] Private Communications with M. Sargsian.