# PHOTOPRODUCTION OF VECTOR MESONS ON NUCLEONS: RELATIVE ROLE OF POSSIBLE THRESHOLD MECHANISMS

**T. BABACAN, H. BABACAN, A. GÖKALP and O.YILMAZ**
*Physics Department, Middle East Technical University, 06531 Ankara, Turkey*

**ABSTRACT:**

We analyze the photoproduction of ω-meson on nucleons in order to understand the relative role of different possible threshold mechanisms. Therefore, we propose a set of models with the different contributions of the exchange mechanisms which are equally good for the differential cross-section of $\gamma+p\rightarrow p+\omega$: pseudoscalar (π) and scalar exchanges (σ) in t-channel and the s+u nucleon term. We fit our model results to the experimental data about the differential cross-section in the energy ranges 1.4 GeV < $E_\gamma$ <1.8 GeV and 1.8 GeV< $E_\gamma$ < 2.5 GeV, simultaneously, and obtain some sets for the coupling constants, $g^T_{\omega NN}$ and $g^V_{\omega NN}$. All calculations are done at $E_\gamma$ = 1.6 GeV ( for the energy range 1.4 GeV < $E_\gamma$ < 1.8 GeV ) , and $E_\gamma$ = 2.2 GeV (for the energy range 1.8 GeV< $E_\gamma$ < 2.5 GeV). We found some sensitivity of the differential cross-section on neutron targets and the beam asymmetry on proton and neutron targets as well, to the variations of the different models which are equivalently good for the differential cross-section on proton target.

The existing experimental data [1] about the process of photoproduction of ω-meson on proton do not allow now to establish definitely the relative role of different possible mechanisms which are typically considered in near threshold region: pseudoscalar and scalar t-channel exchanges, s+u nucleon terms, nucleonic resonance excitations and dfifractive exchange (Pomeron) etc. Therefore, a set of models can be suggested for $\gamma+p\rightarrow p+\omega$, with different contributions of the above mentioned mechanisms, which are almost equivalently good for the differential cross-section of $\gamma+p\rightarrow p+\omega$.

For t-channel, we consider the pseudoscalar (π) and scalar exchanges (σ), Fig.1(a). The pseudoscalar exchange amplitude can be obtained from the Lagrangian,

$$\mathbf{L}_\pi = g_{\omega\pi\gamma}\,\varepsilon^{\mu\nu\alpha\beta}\partial_\mu V_\nu \partial_\alpha A_\beta \pi \; - i\, g_{\pi NN}\,\overline{N}\gamma_5 \pi N \tag{1}$$

where $A_\mu$ is the photon field. Following Ref. [2] , we use the coupling constants as $g^2_{\omega\pi\gamma}$ = 3.315 and $g^2_{\pi NN}/4\pi$=14.0 The form factors that we have used are as follows:

$$F_{\pi NN} = \frac{\Lambda_\pi^2 - M_\pi^2}{\Lambda_\pi^2 - t}, \qquad F_{\omega\pi\gamma} = \frac{\Lambda_{\omega\pi\gamma}^2 - M_\pi^2}{\Lambda_{\omega\pi\gamma}^2 - t}, \tag{2}$$

where $\Lambda_\pi$ = 0.7 and $\Lambda_{\omega\pi\gamma}$ = 0.77 in GeV unit. [3]

The scalar (σ) exchange amplitude can be obtained from the Lagrangian,

$$\mathbf{L}_{\sigma} = \frac{e\, g_{\omega\sigma\gamma}}{M_{\omega}} (\partial^{\mu} V^{\nu} \partial_{\mu} A_{\nu} - \partial^{\mu} V^{\nu} \partial_{\nu} A_{\mu}) \sigma + g_{\sigma NN} \bar{N} N \sigma \quad (3)$$

The form factors for this exchange are given as,

$$F_{\sigma NN} = \frac{\Lambda_{\sigma}^{2} - M_{\sigma}^{2}}{\Lambda_{\sigma}^{2} - t}, \qquad F_{\omega\sigma\gamma} = \frac{\Lambda_{\omega\sigma\gamma}^{2} - M_{\sigma}^{2}}{\Lambda_{\omega\sigma\gamma}^{2} - t} \quad (4)$$

where $\Lambda_{\sigma}$ = 1.0 GeV, $\Lambda_{\omega\sigma\gamma}$ = 0.9 GeV, $M_{\sigma}$ = 0.5 GeV and the coupling constant, $g^{2}_{\sigma NN}/4\pi$=8.0 [2] .

Our final consideration for the exchange mechanisms is the (s+u) nucleon term shown in Figure 1(b,c)

$$\mathbf{L}_{N} = \bar{N}\left[ g^{V}_{\omega NN} \gamma_{\mu} V^{\mu} - \frac{g^{T}_{\omega NN}}{2M_{N}} \sigma_{\mu\nu} \partial^{\nu} V^{\mu} \right] N - e\bar{N}\left[ Q_{N} \gamma_{\mu} A^{\mu} - \frac{\kappa_{N}}{2M_{N}} \sigma_{\mu\nu} \partial^{\nu} A^{\mu} \right] N \quad (5)$$

where $\kappa_{N}$ is the anomalous magnetic moment of the nucleon ($\kappa_{p}$= 1.79 $\kappa_{n}$ = -1.91) , $g^{T}_{\omega NN}$ and $g^{V}_{\omega NN}$ are the tensor and vector coupling constants, respectively.

We have fitted our model results to the experimental differential cross-section data on proton targets [1] in the energy ranges 1.4 GeV < $E_{\gamma}$ < 1.8 GeV and 1.8 GeV < $E_{\gamma}$ < 2.5 GeV, simultaneously, and found some set of values for the coupling constants, $g^{T}_{\omega NN}$ and $g^{V}_{\omega NN}$. The values are shown in Table 1.

| Models used in fitting process | $g^{V}_{\omega NN}$ | $g^{T}_{\omega NN}$ | $g_{\omega\sigma\gamma}$ |
|---|---|---|---|
| Model 1 ( π,s,u ) | 0.96 | 0.46 | - |
| Model 1 ( π,s,u ) | -2.52 | 0.1 | - |
| Model 2 ( π,σ,s,u ) | 0.85 | 0.55 | 0.182 |
| Model 2 ( π,σ,s,u ) | -2.54 | 0.0 | 0.182 |

**Table 1:** The fitted values of the coupling constants, $g^{T}_{\omega NN}$ and $g^{V}_{\omega NN}$ obtained from two different models

In model 1, we have obtained our fitted values for the coupling constants, $g^{T}_{\omega NN}$ and $g^{V}_{\omega NN}$, by using π,s,u exchange mechanisms. In model 2, we have obtained another set for the coupling constants, $g^{T}_{\omega NN}$ and $g^{V}_{\omega NN}$, by using π,σ,s,u exchange mechanisms. In this fitting process, the coupling constant, $g_{\omega\sigma\gamma}$, is kept fixed and its value is taken as $g_{\omega\sigma\gamma} = 0.182$ by following Ref.[4] and using the effective $\omega\sigma\gamma$ interaction Lagrangians of Ref.[5].

Calculations are done at $E_\gamma = 1.6$ GeV ( for the energy range 1.4 GeV < $E_\gamma$ < 1.8 GeV ) and $E_\gamma = 2.2$ GeV ( for the energy range 1.8 GeV < $E_\gamma$ < 2.5 GeV ). The calculation results for the differential cross-section and beam asymmetry on proton and neutron targets are shown in Figure 2(a,b,c,d) and Figure 3(a,b,c,d). In Figure 2(a) and 2(b), the differential cross-section on proton target at $E_\gamma = 1.6$ and $E_\gamma = 2.2$ GeV is shown with the different sets of the coupling constants, $g^T_{\omega NN}$ and $g^V_{\omega NN}$, which are equally good for the differential cross-section. We have taken two different sets from π,s,u model. The first set is $g^V_{\omega NN} = 0.96$ and $g^T_{\omega NN} = 0.46$. The second set is $g^V_{\omega NN} = -2.52$ and $g^T_{\omega NN} = 0.1$. Another two different sets from π,σ,s,u model are taken. The first set is $g^V_{\omega NN} = 0.85$, $g^T_{\omega NN} = 0.55$ and $g_{\omega\sigma\gamma} = 0.182$. The second set is $g^V_{\omega NN} = -2.54$, $g^T_{\omega NN} = 0.0$ and $g_{\omega\sigma\gamma} = 0.182$. From the curves, we can see the variations in the beaviour of the differential cross-section for two different sets of the coupling constant values.In Figure 2(c) and 2(d), we predict the behaviour of the differential cross-section on neutron targets at $E_\gamma = 1.6$ GeV and $E_\gamma = 2.2$ GeV with the same sets of coupling constants mentioned above, respectively. From curves, we can also see the variations in the beaviour of the differential cross-section on neutron targets for two different sets of models. In figure 3(a,b,c,d), the behaviour of the beam asymmetry on proton and neutron targets at $E_\gamma = 1.6$ GeV and $E_\gamma = 2.2$ GeV with the above sets of different models is also shown, respectively. The differentiation between models can be seen.

As a result, we found some sensitivity of the differential cross-section on neutron targets and the beam asymmetry on proton and neutron targets as well, to the variations of the different models which are equivalently good for the differential cross-section on proton target.

**Acknowledgement:**

We thank M.P.Rekalo for suggesting this problem to us and for his interest during the course of our work.

## REFERENCES:

1. ABBHHM Collab., R. Erbe et al., Phys Rev. 175, 1669 (1968)
2. B.Friman and M.Soyeur, Nucl.Phys.A.600, 477 (1996)
3. A.I Titov et al., Phys.Rev C 60, 035205 (1999)
4. M.Soyeur, Nucl.Phys.A 671, 532 (2000)
5. M.Chemtob in Mesons and Nuclei (Eds. M. Rho and D.Wilkinson, North-Holland, 1979), Vol. II, p 495