CM-P00057537

Ref. TH. 736

SUPPRESSION OF THE φ PHOTOPRODUCTION IN THE QUARK MODEL

K. Kajantie ^{*)} and J.S. Trefil ^{**)}
CERN--Geneva

ABSTRACT

The ratio of the total photoproduction cross-sections $\sigma_{\varphi} / \sigma_g$ is calculated in the quark model. Good agreement is found with recent experimental data.

^{*)} On leave from the Department of Nuclear Physics, University of Helsinki, Helsinki, Finland.

^{**)} Postdoctoral Research Fellow (Air Force Office of Scientific Research).

The explanation of the relative production rates of the rho and phi mesons in photoproduction processes is, at the moment, an unsolved theoretical problem ¹⁾. The purpose of this note is to show that the ratio of the total cross-sections, $\sigma_\varphi : \sigma_\rho$, can be related to total KN and πN cross-sections through the use of the quark model.

We assume that the mechanism of photoproduction is that shown in the following Figure ²⁾,

and write the photon as a U spin scalar with $\omega - \varphi$ mixing as

$$\gamma = \frac{1}{\sqrt{3}} (3\rho^0 + \omega - \sqrt{2}\varphi) \equiv \sum_V C_V V \quad (1)$$

We then treat the vector meson-baryon scattering in the quark model ³⁾. For a given helicity configuration, denoted by h , we find that

$$\langle VP | \gamma P \rangle_h = \sum_{V'} C_{V'} F_{V',V}^h \langle VP | V' P \rangle_h \quad (2)$$

where $C_{V'}$ is defined in Eq. (1), and $F_{V',V}^h$ is a function, in general unknown, which arises because the vector mesons in Eq. (1) are virtual, while those which appear in the quark matrix elements are real. In what follows, we shall assume that due to the approximate equality of the ρ , ω , and φ masses the function $F_{V',V}^h$ is the same for production of all three mesons, and is independent of h .

2.

In the quark model, it is possible to calculate differential cross-sections for forward scattering in a natural way ³⁾. Unfortunately, the data at the present time do not allow us to compare these quantities with experiment, so some way must be found to relate the ratio of differential cross-sections at forward angles to the ratio of the total cross-sections. The simplest assumption is that the ρ , ω and φ will have forward peaks of the same shape, so that these ratios will in fact be equal. There seems to be no reason to doubt this assumption at the moment, and, of course, it can be checked when data become available.

We can calculate the scattering amplitudes in Eq. (2) using the method of Refs. ^{3),4)}, and we find that for arbitrary scattering angle,

$$\begin{aligned}\langle \rho P | \rho P \rangle_h &= \langle \omega P | \omega P \rangle_h \\ \langle \omega P | \rho P \rangle_h &= \langle \rho P | \omega P \rangle_h\end{aligned}\tag{3}$$

Since φ contains only strange quarks,

$$\begin{aligned}\langle \rho P | \varphi P \rangle &= \langle \omega P | \varphi P \rangle = \\ &= \langle \varphi P | \rho P \rangle = \langle \varphi P | \omega P \rangle = 0\end{aligned}\tag{4}$$

If we make the following two assumptions :

- i) all quark-quark and quark-antiquark scattering amplitudes are equal :

$$(qq)_h = (\bar{q}q)_h = (\lambda q)_h = (\bar{\lambda}q)_h$$

where q refers to any non-strange quark,

and

ii) $\langle \rho P | \omega P \rangle = 0$

we recover the result of Freund ²⁾ that

$$\sigma_s : \sigma_\omega : \sigma_\varphi = 9 : 1 : 2 \quad (5)$$

We shall argue that by modifying assumption i), the discrepancy between theoretical and experimental values of $\sigma_\varphi / \sigma_s$ can be eliminated. We shall estimate the effect arising from dropping assumption ii) by fitting the observed value of σ_ω / σ_s , and shall find that assumption ii) plays only a very minor role in the theoretical value of the ratio $\sigma_\varphi / \sigma_s$.

Let us assume that the quark amplitudes which contribute to the optical theorem are pure imaginary. We then find that

$$\left. \frac{d\sigma}{dt}(\gamma p \rightarrow \varphi p) \right|_{\theta=0} = \frac{2 \left| 3 \sum_{h=1,3} [(\lambda p)_h + (\bar{\lambda} p)_h] \right|^2}{9(1 + \frac{2}{3}y) \left| \frac{3}{2} \sum_{h=1,3} [(\rho p)_h + (\rho n)_h + (\bar{\rho} p)_h + (\bar{\rho} n)_h] \right|^2} = \quad (6)$$

$$= \frac{\sigma_\varphi}{\sigma_s} = \frac{2 \left| \sigma_{K^+p} + \sigma_{K^+n} - \sigma_{\pi^+p} \right|^2}{9(1 + \frac{2}{3}y) \left| \frac{1}{2} \sigma_{\pi^+p} + \frac{1}{2} \sigma_{\pi^+n} \right|^2} \equiv \frac{2x^2}{9(1 + \frac{2}{3}y)}$$

where h refers to the helicity index of Table I of Ref. ³⁾, and y is defined by

$$y = \frac{\sum_h \text{Re}[\langle \varphi p | \omega p \rangle_h \langle \varphi p | \varphi p \rangle_h^*]}{\sum_h |\langle \varphi p | \varphi p \rangle_h|^2} \quad (7)$$

and where we have dropped terms quadratic in $\langle \varphi p | \omega p \rangle_h$.

4.

The parameter y also occurs in the theoretical expression for the ratio $\sigma_s : \sigma_\omega$. If we insert the experimental value of Ref. ⁵⁾ into this expression, we find

$$y = 0.2 \pm 0.1 \quad (8)$$

Of course, we expect that at higher energies, y will approach zero, since it involves an inelastic process.

At 6 GeV/c, we find from Eq. (6)

$$\sigma_\varphi / \sigma_s = 0.030 \pm 0.005 \quad (9)$$

which is in remarkably good agreement with the experimental value of ⁵⁾

$$\sigma_\varphi / \sigma_s = 0.026 \pm 0.010 \quad (10)$$

Because total cross-sections do not vary rapidly with energy, the suppression of φ production in this model is expected to persevere to quite high energies. For example, at 20 GeV/c, we have

$$\sigma_\varphi / \sigma_s = 0.064 \pm 0.020 \quad (11)$$

and, if we use extrapolated total cross-sections ⁶⁾, we estimate that at 100 GeV/c

$$\sigma_\varphi / \sigma_s = 0.10 \quad (12)$$

Another photoproduction model has been presented recently in which the vector meson-baryon scattering is treated by Regge exchange ⁷⁾. Although both models give similar results for $\sigma_\varphi / \sigma_s$, both as to magnitude and energy dependence, the model presented here contains no free parameters, such as coupling constants. In both models, the energy

dependence of φ production is related to total KN and π N cross-sections ; in the Regge model by fitting the intercept of the various trajectories to the energy dependence of the total cross-sections, and in the quark model directly through Eq. (6).

ACKNOWLEDGEMENTS

The authors wish to thank Professor J. Prentki and Professor L. Van Hove for the hospitality of the CERN Theoretical Study Division.

R E F E R E N C E S

- 1) For a detailed theoretical review of neutral vector meson photo-production, see : H. Harari, SLAC-PUB-239, October (1966).
- 2) P.G.O. Freund, Nuovo Cimento 44A, 411 (1966).
- 3) J.L. Friar and J.S. Trefil, CERN preprint TH. 723 (1966).
- 4) C. Itzykson and M. Jacob, Saclay preprint, August (1966).
- 5) German Bubble Chamber Collaboration, DESY report 66/32, November (1966).
- 6) N. Cabibbo, L. Horwitz, J.J.J. Kokkedee and Y. Ne'eman, Nuovo Cimento Letters 45, 275 (1966).
- 7) F. Buccella and M. Colocci, Firenze preprint TH. 66/20 (1966).