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PRODUCTION OF ρ^0 AND ω^0

IN HIGH ENERGY PROTON-PROTON COLLISIONS

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A number of experiments ^{1),2)} have recently been carried out which investigate multiple particle production in high energy proton-proton collisions. Very often in such experiments the emphasis of the investigation is on a study of final states of the form N^*N . However, in the experimental data we refer to above a study has been made of the final states $pp+M^0$, i.e., production of neutral bosons. As one might expect the spectrum for M^0 includes π^0 , η^0 and ω^0 but surprisingly there appears to be little or no ρ^0 production for beam momenta varying from three up to 19 GeV. On the other hand ω^0 seems to be produced in abundance and at 12 GeV ¹⁾ it accounts for 6 % of reactions of the type $pp \rightarrow ppM^0$. The purpose of this note is to suggest a simple mechanism which inhibits the production of ρ^0 in favour of ω^0 and then to compare the data for ω^0 production with our model.

The mechanism we employ is the so-called double Regge pole model ³⁾ which has been used with success in analysis of single particle production and has recently been generalized to the case of multiple production ⁴⁾. Figure 1 shows our graph for $pp \rightarrow ppV^0$ where V^0 represents either ρ^0 or ω^0 . T_a and T_b are Regge poles with momentum transfers t_a and t_b respectively and we shall denote by s_{1V} and s_{2V} the invariant masses squared of the two particle subsystems of V^0 and proton 1 and V^0 and proton 2. The set of trajectories we shall refer to is commonly denoted by P, P', ρ, R or A_2 and ω, ϕ . Since the protons are indistinguishable there are two graphs for ρ^0 production: (i) with $T_a = P$ or P' ; $T_b = \rho$ and (ii) $T_a = R$; $T_b = \omega, \phi$ while similarly for ω^0 we have (i) with $T_a = P$ or P' ; $T_b = \omega, \phi$ and (ii) $T_a = R$; $T_b = \rho$. We can neglect graphs of type (ii) because we expect the cross-sections to be dominated by the higher trajectories P and P' at higher energies. Retaining only the graphs of type (i) implies that we are describing the situation very similar to one in which an exchanged virtual meson from one proton undergoes diffraction scattering off the other proton. This device has been used for some years to explain the kinematical effects in three particle states and is called the Deck effect ⁵⁾.

Employing the usual assumption that the residues can be factorized, then the graph of Fig. 1 contains a product of three couplings. It seems reasonable to expect the Pomeranchuk to have a coupling to the ρ^0 of the same order of magnitude as its coupling to the ω^0 so that we would expect the relative productions of ρ^0 and ω^0 to be determined by the relative couplings to the proton of the ρ and ω, ϕ trajectories. We already know, from Regge pole analysis of total nucleon-nucleon cross-sections that the difference $(\sigma_{\bar{p}p} - \sigma_{pp})$ is due to an exchange of the ρ and ω, ϕ trajectories while the difference $(\sigma_{np} - \sigma_{\bar{n}p})$ is due only to the ρ . At 12 GeV these differences are about 12 mb and 0.5 mb respectively, indicating that $g_{pp\rho^0} < g_{pp\omega, \phi}$. Therefore such a model is bound to lead to dominance of ω^0 over ρ^0 production.

The amplitude for $pp \rightarrow pp\rho^0$ takes the form :

$$\begin{aligned}
 F_{\rho^0} = & \frac{[2\alpha_\rho + 1]^{\frac{1}{2}} \Gamma(2\alpha_\rho + 1) [\exp(-i\pi\alpha_\rho) - 1]}{2^{\alpha_\rho + 1} \sin \pi\alpha_\rho} (\cos \Theta)^{\alpha_\rho} \times \\
 & \times \frac{[2\alpha_{p,p'} + 1]^{\frac{1}{2}} \Gamma(2\alpha_{p,p'} + 1) [\exp(-i\pi\alpha_{p,p'}) + 1]}{2^{\alpha_{p,p'} + 1} \sin \pi\alpha_{p,p'}} (\cos \Theta)^{\alpha_{p,p'}} \times \\
 & \times \beta_\rho(t_b) \beta_{p,p'}(t_a) \gamma_{\rho, p, p'}^{\rho^0}(t_a, t_b)
 \end{aligned} \tag{1}$$

where $\alpha_\rho = \alpha_\rho(t_b)$; $\alpha_{p,p'} = \alpha_{p,p'}(t_a)$. $\cos \Theta$ and $\cos \theta$ are rather complicated expressions but at high energies behave as s_{2V} and s_{1V} respectively. β_ρ is the coupling of the ρ trajectory to the proton, $\beta_{p,p'}$ that of P (or P') to the proton and $\gamma_{\rho, p, p'}^{\rho^0}$ represents the coupling of the ρ^0 to the P (or P') and ρ trajectories. It is common to suppose the residues fall off exponentially with momentum transfer and we take the slope parameters of Ref. ⁶). Strictly speaking each of the residues is a function of the helicities of the five external

particles which in this problem would lead to a great number of amplitudes. However, we shall be fairly naïve and suppose that the cross-section is dominated by a spin-averaged amplitude. This is analogous to early analyses of elastic pp scattering ⁷⁾ where the problem was similarly reduced to a scalar one.

To get values for the residues β at $t_a=0$ and $t_b=0$ we look at pp total cross-sections. Barger and Olsson ⁸⁾ decompose the total cross-section of 39.5 mb at 12 GeV into parts contributed by each trajectory as follows :

$\sigma_p = 37.8$ mb $\sigma_{p'} = 7.5$ mb $\sigma_\rho = -0.5$ mb $\sigma_{\omega,\phi} = -5.7$ mb
(the minus signs because of negative signature). Although only non-flip amplitudes contribute to these cross-sections we analyse them in terms of our residues β which are spin-independent and obtain their relative magnitudes as follows :

$$\beta_p : \beta_{p'} : \beta_\rho : \beta_{\omega,\phi} = 2.62 : 2.43 : 0.62 : 2.10$$

Finally we need to know something about the couplings of a vector meson with two trajectories at zero momentum transfers. To do this we use the SU(3) vertices and obtain the relative strengths of the couplings for ρ^0 and ω^0 , taking the ω,ϕ mixing angle as approximately 40° as in Ref. ⁸⁾. To relate the couplings involving P to those with P' we have assumed P to be SU(3) singlet and P' the octet member (no mixing of P and P' can correspond to the identification of s^0 with Pomeranchuk trajectory - see Ref. ⁹⁾). These residues are then inserted into Eq. (1) and into the corresponding amplitude F_{ω^0} , and in Figs. 2 and 3 we show our results.

As can be seen from Fig. 2, both cross-sections fall off fairly quickly with increasing beam momentum. However, the ratio

$\sigma_{\rho^0}/\sigma_{\omega^0}$ remains almost constant over a large range, varying from 0.12 at 8 GeV to around 0.09 at 18 GeV. The model, however, is unable to describe the magnitudes of the cross-sections. In Fig. 3 we show

the behaviour of the differential cross-section for ω^0 production in comparison with the data from the counter-experiment at 12.3 GeV¹⁾. The sharp rise for low $p\omega^0$ mass is typical of the Deck effect which is characterized by low mass enhancements and is evidence in favour of a graph of the type shown in Fig. 1.

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REFERENCES

- 1) H.L. Anderson, S. Fukui, D. Kessler, K.A. Klare, M.V. Sherbrook, H.J. Evans, R.L. Martin, E.P. Hincks, N.K. Sherman and P.I.P. Kalmus - Phys.Rev.Letters 18, 89 (1967).
- 2) E.L. Hart, R.I. Louttit and T.W. Morris - Phys.Rev.Letters 9, 133 (1962) ;
 C. Caso, G. Tomasini, L. Mosca, S. Ratti, I. Bloodworth, L. Lyons and A. Norton - Proceedings of the XIIIth International Conference on High Energy Physics, Berkeley (1966) ;
 G. Alexander, O. Benary, G. Czapak, B. Haber, N. Kidron, B. Reuter, A. Shapira, E. Simoulou and G. Yekutieli - Phys.Rev. 154, 1284 (1967) ;
 A.P. Colleraine and U. Nauenberg - Phys.Rev. 161, 1387 (1967) ;
 19 GeV collaboration by Universities of Copenhagen, Helsinki, Oslo and Stockholm - Proceedings of the 1967 Heidelberg Conference.
- 3) K.A. Ter Martirosyan - JETP 17, 233 (1967) ; Nuclear Phys. 68, 591 (1965) ;
 M.S.K. Razmi - Nuovo Cimento 31, 615 (1964) ;
 Chan Hong-Mo, K. Kajantie and G. Ranft - Nuovo Cimento 49, 157 (1967) ; CERN Preprint TH. 764 (1966) ;
 R.G. Roberts and G.M. Fraser - Phys.Rev. 159, 1297 (1967) ;
 G.M. Fraser and R.G. Roberts - Nuovo Cimento 47, 339 (1967) ;
 N.F. Bali, G.F. Chew and A. Pignotti - Phys.Rev.Letters 19, 614 (1967) ; Phys.Rev. to be published.
- 4) Chan Hong-Mo and J. Loskiewicz - unpublished ;
 K. Kajantie - CERN Preprint TH. 813 (1967) ;
 F. Zachariasen and G. Zweig - Phys.Rev. 160, 1322 and 1326 (1967).
- 5) A comprehensive list of references for the Deck and related effects is given by Marc Ross and Y.Y. Yam - Phys.Rev.Letters 19, 546 (1967).
- 6) R.J.N. Phillips and W. Rarita - Phys.Rev. 139, B1336 (1965).
- 7) F. Hadjioannou, R.J.N. Phillips and W. Rarita - Phys.Rev.Letters 9, 183 (1962).
- 8) V. Barger and M. Olsson - Phys.Rev.Letters 15, 930 (1965), 16, 545 (1966) ; Phys.Rev. 146, 1080 (1966), 148, 1428 (1966).
- 9) N. Cabibbo, L. Horwitz and Y. Ne'eman - Phys.Letters 22, 336 (1966).

FIGURE CAPTIONS

- Figure 1 Double Regge pole graph for $pp \rightarrow pp + \text{vector meson } V^0$.
- Figure 2 Behaviours of σ_{p^0} , σ_{ω^0} and $\sigma_{p^0}/\sigma_{\omega^0}$ with beam momentum.
- Figure 3 Comparison with data of Ref. 1) at 12.3 GeV. The function plotted is $\partial^3 \sigma / \partial m_{p\omega^0}^2 \partial t_1 \partial \Omega_2$ where t_1 , the momentum transfer of the forward proton is approximately -0.95 GeV^2 and the other proton is at $\Omega_2 = -135^\circ$ in our system. The errors shown are statistical. The theoretical curve is normalized to total cross-section for $pp \rightarrow pp\omega^0$.

FIG.1

FIG.2