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IMPLICATIONS OF INELASTIC ELECTRON SCATTERING DATA
FOR VECTOR MESON DOMINANCE

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A B S T R A C T

An analysis of the recent high energy inelastic electron proton scattering data cast doubts on the validity of successful vector meson dominance relations for photoproduction.

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Of central importance in all applications of the hypothesis of vector meson dominance, V.M.D., is the assumption that matrix elements of the vector meson source currents are smooth functions of q^2 near $q^2 = m_V^2$, where q is the four momentum of the vector meson, and m_V is its mass. In particular, relations between photon and vector meson cross-sections have been obtained neglecting variations of these matrix elements in the interval $0 \leq q^2 \leq m_V^2$, which appear to be in good agreement with experiments ^{1),2)}. On the other hand, it has been known for some time that measurements of the elastic electromagnetic form factor of the nucleons indicate that the q^2 dependence of the corresponding vector meson current matrix elements cannot be neglected for spacelike q^2 . More recently, high energy inelastic electron proton scattering experiments have shown that the same is true for the inelastic form factors of the proton ^{3),4)}. In this case, however, the timelike region near $q^2 = m_V^2$ can be observed by vector meson nucleon scattering, and we should therefore be able to check the validity of the smoothness assumption of V.M.D. experimentally. In this note, we discuss the status of this problem in the light of present experimental results.

In a recent phenomenological analysis of the SLAC-MIT 6° and 10° inelastic electron scattering data ⁵⁾, it was pointed out that the observed inelastic proton form factor σ_T , corresponding to the transverse virtual photon-proton cross-section, can be approximated by the inverse of a polynomial in q^2 . The coefficients of this polynomial, which are obtained by a least square fit to the data, are in disagreement with the prediction of V.M.D., if one neglects the q^2 dependence of the vector-meson current form factor. We will take the point of view here that the data determines the q^2 dependence of this form factor for spacelike q^2 , and examine the implications of the V.M.D. smoothness assumption in the interval $0 \leq q^2 \leq m_V^2$. We take in this domain the current experimental values for the total photo-production cross-section σ_γ , the total vector meson-nucleon cross-section σ_V , and the fundamental vector-meson photon coupling constant γ_V ²⁾.

According to V.M.D.,

$$\sigma_T = \sum_V \left(\frac{e}{2\chi_V} \right)^2 \frac{\sigma_V(K)}{(1 - q^2/m_V^2)^2} \Gamma_V(q^2, K) \quad (1)$$

+ interference terms

where K is the equivalent energy for real photons, and the sum is carried over the presently known vector mesons $V = \rho, \omega, \phi$.

$\Gamma_V(q^2, K)$ is the inelastic vector-meson source current form factor normalized to unity at $q^2 = m_V^2$, and "interference terms" denote possible contribution from the products of matrix elements of different vector meson currents. At high energies where diffractive processes dominate, the interference terms are expected to be relatively small. Neglecting these terms and assuming the form factors Γ_V to be q^2 independent in the range $0 \leq q^2 \leq m_V^2$, it is found that at $q^2 = 0$ where $\sigma_T = \sigma_\gamma$, Eq. (1) is in good agreement with experimental data⁶⁾. On the other hand, if we extend the approximation $\Gamma_V = 1$, to spacelike q^2 , the q^2 dependence of Eq. (1) is in clear conflict with the inelastic electron data for $q^2 \lesssim -1$ where q^2 is in units of $(\text{GeV}/c)^2$. (In the range $-1 < q^2 < 0$ the separation of σ_T and σ_L has not yet been obtained, and no such firm conclusions can be reached.) We shall therefore assume that Γ_V has a q^2 dependence which we parametrize near $q^2 = m_V^2$ in the form

$$\Gamma_V = 1 + b_V(K) (q^2/m_V^2 - 1) \quad (2)$$

where $b_V(K)$ is a coefficient which may depend on K . We now examine the implications of this form factor assuming that it is also a good approximation for not too large spacelike q^2 , by substituting Eq. (2) in Eq. (1) and comparing the result with the inelastic electron scattering experiments. Neglecting the $\omega - \rho$ mass difference, we obtain

$$(1 - q^2/m_\rho^2)^2 \sigma_T = \sigma_\gamma(K) + S(K) q^2/m_\rho^2 + O(q^4) \quad (3)$$

where

$$\sigma_{\gamma}(K) = \sum_V \left(\frac{e}{2\gamma_V} \right)^2 \sigma_V(K) (1 - b_V(K)) \quad (4)$$

and

$$S(K) = \left(\frac{e}{2\gamma_p} \right)^2 \sigma_p b_p + \left(\frac{e}{2\gamma_\omega} \right)^2 \sigma_\omega b_\omega + \left(\frac{e}{2\gamma_\phi} \right)^2 \frac{\sigma_\phi}{m_\phi^2} \left[b_\phi (2m_\phi^2 - m_p^2) - 2(m_\phi^2 - m_p^2) \right] \quad (5)$$

The Table gives the values of $\sigma_{\gamma}(K)$ and $S(K)$ obtained from a least square fit of a quadratic polynomial in q^2 to the 6° and 10° data with $\sigma_L/\sigma_T = 0.2$, and to the extrapolated photoproduction cross-section from the 1.5° data ³⁾. The main point to notice is that $S(K)$ is of comparable magnitude to $\sigma_{\gamma}(K)$. According to Eqs. (4) and (5), we therefore expect that b_V is of order unity, and not zero as is usually assumed. In the light of this result the striking agreement with experiments ⁶⁾ obtained by setting $b_V = 0$ in Eq. (4), must be considered accidental.

As was pointed out earlier, the ratio σ_L/σ_T has not been measured for $-1 \lesssim q^2 < 0$. Hence it may be possible that the form factors Γ_V vary rapidly with q^2 in this domain ⁷⁾ in order to fit both the inelastic electron data and the photoproduction relation ⁶⁾ obtained from Eq. (1) at $q^2 = 0$, setting $\Gamma_V = 1$ for $0 \leq q^2 \leq m_p^2$. Although such a possibility would not be expected from the smoothness assumption of V.M.D., it would be plausible if there

exists a so-called deep inelastic domain which starts near $q^2 \sim -1$ where the scaling hypothesis is valid ^{3),4)}. It is therefore of great interest to observe σ_L/σ_T experimentally in this domain.

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$K(\text{GeV})$	$\tilde{\sigma}_T(K) \mu^b$	$S(K) \mu^b$
2.2	150 ± 4	-159 ± 6
2.9	146 ± 4	-147 ± 3
4.4	138 ± 6	-116 ± 5
6.1	133 ± 5	-98 ± 7
8.1	133 ± 5	-77 ± 9
9.9	130 ± 5	-73 ± 13
12	128 ± 5	-65 ± 28

Values of $\tilde{\sigma}_T(K)$ and $S(K)$ in μ^b ,
 Eq. (3) and Eq. (4), obtained from the
 1.5° , 6° and 10° inelastic electron
 scattering data ³⁾.

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