INSTITUTE OF HIGH-ENERGY PHYSICS, SERPUKHOV
Report IHEP-STF-70-46

VECTOR DOMINANCE AND THE REDUCTION OF THE DIFFERENTIAL CROSS-SECTION OF LEPTON PAIR PRODUCTION AT HIGH ENERGIES AT LARGE ANGLES

M. Mestvirishvili

Serpukhov, 1970

Translated at CERN by A. Sanders
Revised by N. Mouravieff
(Original : Russian)

(CERN Trans. 71-14)

Geneva
March 1971

The present paper shows that on the basis of the hypothesis of vector dominance[1,2], the differential cross-section of lepton pair production $d\sigma/(dq^2\ d\cos\Theta\ d\phi)$ in the region of large angles Θ and ϕ decreases as the energy increases.

Let us consider the process when the lepton pair ℓ_+, ℓ_- is produced by a hadron collision:

$$a + b \to \overset{*}{\gamma} + A . \quad \overset{*}{\gamma} \to \ell_+ \ell_-$$

Here, a and b are strongly interacting particles, and A is a hadron group which is produced at the end of the reaction.

It can be shown[2] that in $\alpha = e^2/4\pi$ the approximation in the centre-of-mass system $(\vec{p}_a + \vec{p}_b = 0)$ is:

$$\frac{d\sigma}{dq^2} = \frac{\alpha^2}{2\pi} \frac{\pi(q^2)}{q^2} \sigma'(s, q^2) , \qquad (1)$$

where $q = P_{\ell_+} + P_{\ell_-}$ is the four-momentum of the virtual gamma quantum

$$\pi(q^2) = \frac{q^2 + 2m_e^2}{6\pi q^2} \sqrt{\frac{q^2 - 4m_e^2}{q^2}} ,$$

and

$$\sigma'(s, q^2) = \frac{1}{\sqrt{(P_a \cdot P_b)^2 - P_a^2 P_b^2}} \int \delta(P_a + P_b - q - \sum_{i\in A} k_i) \frac{d\vec{q}}{2q_o(2\pi)^3} \prod_{i\in A} \frac{d\vec{k}_i}{2k_{io}(2\pi)^3} \times$$

$$\times \langle P_a P_b | \overset{+}{S} | q, k_1 \ldots \rangle \langle q, k_1 \ldots | S | P_a, P_b \rangle .$$

By virtue of the hypothesis of vector dominance $\sigma'(s,q)^2$ can be written in the form:

$$\sigma'(s,q^2) = \frac{1}{f_\rho^2}\left(\frac{m_\rho^2}{q^2-m_\rho^2}\right)^2 \sigma^\rho(s) + \frac{1}{f_\omega^2}\left(\frac{m_\omega^2}{m_\omega^2-q^2}\right)^2 \sigma^\omega(s) + \frac{1}{f_\phi^2}\left(\frac{m_\phi^2}{q^2-m_\phi^2}\right)^2 \sigma^\phi(s) \tag{2}$$

plus interference terms, and here $\sigma^i(s)$ $i = \rho,\omega,\phi$ are the total cross-sections of the processes $a + b \to i + A$, $i = \rho,\omega,\phi$.

Ignoring the interference terms in (2), from (1) we find

$$\frac{d\sigma}{dq^2} = \frac{\alpha^2}{2\pi}\frac{\pi(q^2)}{q^2}\left[\frac{1}{f_\rho^2}\left(\frac{m_\rho^2}{q^2-m_\rho^2}\right)^2\sigma^\rho(s) + \frac{1}{f_\omega^2}\left(\frac{m_\omega^2}{q^2-m_\omega^2}\right)^2\sigma^\omega(s) + \frac{1}{f_\phi^2}\left(\frac{m_\phi^2}{q^2-m_\phi^2}\right)^2\sigma^\phi(s)\right] . \tag{3}$$

It is well-known that when $s \to \infty$ $\sigma^i(s)$, $i = \rho,\omega,\phi$ are limited from above by the expression $(\pi/m_\pi^2)\ \ln^2 P(s)$: where $P(s)$ is a certain s polynomial. Therefore in the region $s \to \infty$ and $q^2 \to \infty$ from (3) we obtain

$$\frac{d\sigma}{dq^2} < \frac{\alpha^2}{12\pi}\frac{\ln^2 P(s)}{m_\pi^2 q^6}\left(\frac{m_\rho^4}{f_\rho^2} + \frac{m_\omega^4}{f_\omega^2} + \frac{m_\phi^4}{f_\phi^2}\right).$$

Let us designate by Θ the angle of flight of the particles ρ, ω, and ϕ in relation to the direction of the relative momentum $\vec{p} = \vec{p}_a = -\vec{p}_b$, and by ϕ, the angle between the planes passing through vectors $\vec{p}$, $\vec{q}$ and $\vec{q}$, $\vec{k}$, where $\vec{k}_1$ is the momentum of a certain fixed particle from A.

Then, as was shown elsewhere[3], using unitarity and analyticity, according to the variables cos Θ and $e^{i\varphi}$, one can establish the limitation for fixed Θ and ϕ namely:

$$\left.\frac{d\sigma^{i}(s)}{d\cos\Theta d\phi}\right|_{\substack{\Theta\neq 0,\pi\\ \phi\neq 0,\pi\\ s\to\infty}} \leq \text{const}\ \frac{\ln^{12}(s/s_0)}{s\sin^5\Theta\sin^8\phi}, \quad i=\rho,\omega,\phi. \tag{4}$$

By substituting (4) in (3) we find

$$\left.\frac{d\sigma}{dq^2 d\cos\Theta\, d\phi}\right|_{\substack{\Theta\neq 0,\pi\\ \phi\neq 0,\pi\\ s_2\to\infty\\ q\to\infty}} \leq \text{const}\ \frac{\ln^{12}(s/s_0)}{q^6 s\sin^5\Theta\sin^8\phi}\ . \tag{5}$$

This latter inequality shows that as the energy increases, the differential cross-section of the production of the pair (ℓ_+, ℓ_-) for large Θ and ϕ decreases.

Finally, let us note that for the value of the angles $\Theta = 0,\pi$ and $\phi = 0,\pi$, one can obtain more accurate estimates than (5) [3]:

$$\left.\frac{d\sigma}{d\cos\Theta\, d\phi\, dq^2}\right|_{\substack{\Theta=\phi=0,\pi\\ q^2\to\infty\\ s\to\infty}} \lesssim \text{const}\ \frac{s}{q^6}\ln^4(s/s_0)\ ,$$

$$\left.\frac{d\sigma}{dq^2 d\cos\Theta\, d\phi.}\right|_{\substack{\phi=0,\pi\\ \Theta\neq 0,\pi\\ s\to\infty\\ q^2\to\infty}} \leq \text{const}\ \frac{1}{q^6}\ \frac{s^{7/6}\ln^{13/3}(s/s_0)}{\sin^{2/3}\Theta\cos^{1/3}\Theta}\ .$$

In conclusion, the writer wishes to express his warmest thanks to G.G. Volkov, S.S. Gerstein, V.V. Ezhela, A.A. Logunov, V.A. Matveev and R.M. Muradyan for fruitful discussions.

REFERENCES

1) J.J. Sakurai, Currents and mesons (University of Chicago Press, Chicago, Ill., 1969).
J.J. Sakurai, Phys. Rev. Letters 22, 981 (1969).
C.F. Cho and G.J. Gounaris, Phys. Rev. 186, 1619 (1969).

2) V.A. Matveev, R.M. Muradyan, A.N. Tavkhelidze, Preprint E2 4968, Dubna, 1970.

3) V.V. Ezhela, A.A. Logunov, M.A. Mestvirishvili, Preprint IHEP 70-43, Serpukhov, 1970.