6

И Н С Т И Т У Т
ЯДЕРНОЙ ФИЗИКИ СОАН СССР

ПРЕПРИНТ И Я Ф 74 - 12

V.V.Flambaum, I.B.Khriplovich and O.P.Sushkov

TESTS OF RENORMALIZABLE MODELS OF WEAK INTERACTIONS IN e^+e^- COLLISIONS

Новосибирск

1974

TESTS OF RENORMALIZABLE MODELS
OF WEAK INTERACTIONS
IN e^+e^- COLLISIONS

V.V.Flambaum, I.B.Khriplovich and O.P.Sushkov

Institute of Nuclear Physics
Novosibirsk 90, USSR

In the frames of Weinberg and Georgi-Glashow models the cross-sections of the processes $e^+e^- \to \mu^+\mu^-$ (in particular near the Z-resonance), $e^+e^- \to Z\gamma$, $e^+e^- \to W^+W^-$, $e^+e^- \to e^+e^-W^+W^-$ are calculated. The cross-sections of the two last reactions become equal already at the energy $2E = 14m_W$.

1. Processes with neutral vector boson

In the Weinberg model the reaction $e^+e^- \to \mu^+\mu^-$ in the second order in α is described by the two diagrams given at the fig.1. Simple calculations le-

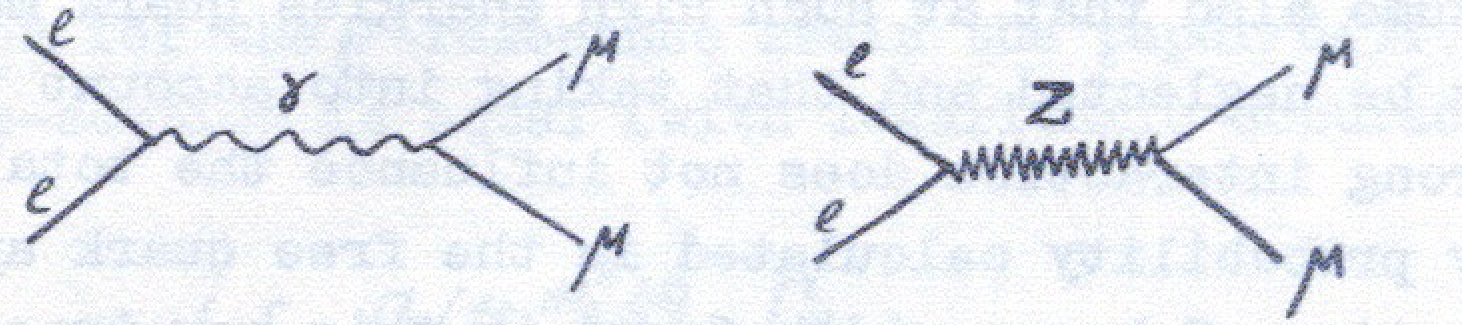

Fig.1.

ad to the following expression for the cross-section of the process

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{4s}\left\{\left[1 + \frac{(4\sin^2\eta - 1)^2}{2\sin^2 2\eta}\,\frac{s}{(s-m_Z^2)} + \frac{((4\sin^2\eta-1)^2+1)^2}{16\sin^4 2\eta}\,\frac{s^2}{(s-m_Z^2)^2}\right]\times \right.$$
$$\left. \times(1+\cos^2\theta) + \frac{1}{\sin^2 2\eta}\,\frac{s}{(s-m_Z^2)}\left[1+\frac{(4\sin^2\eta-1)^2}{2\sin^2 2\eta}\,\frac{s}{(s-m_Z^2)}\right]\cos\theta\right\} \qquad (1)$$

Here $s = 4E^2$ is the square of the total energy in c.m.s., θ is the angle between the μ^- and e^- momenta, m_Z is the Z-boson mass, η is the mixing angle characteristic for the Weinberg model.

The distinctions of this cross-section from the electromagnetic one, charge asymmetry including, are discussed in detail in other works/3,4/.

We shall consider the behaviour of this cross-section at $s \sim m_Z^2$ only. Find at first the Z-boson width. It decays into leptons (e^+e^-, $\mu^+\mu^-$, $\nu_e\tilde{\nu}_e, \nu_\mu\tilde{\nu}_\mu$) and into hadrons. To estimate the probability of Z-boson decays into hadrons we use the model of weak interaction of hadrons based on SU(4) symmetry/5/. Assume also that at such high energies quark masses may be neglected and that taking into account the strong interaction does not influence the total decay probability calculated in the free quark approximation. Z-boson width found in this way is equal to

$$\Gamma_Z = \frac{\alpha m_Z}{3}\left\{ ctg^2\eta + \left[2+(1-2Q)^2\right] tg^2\eta \right\} \qquad (2)$$

where Q is the p-quark charge.

In the resonance the total cross-section of the process $e^+e^- \to \mu^+\mu^-$ looks as follows

$$\sigma_{res} = \frac{3\pi}{16 m_Z^2}\left\{ \frac{(1-2\sin^2\eta)^2 + 4\sin^4\eta}{\cos^4\eta + [2+(1-2Q)^2]\sin^4\eta} \right\}^2 \qquad (3)$$

The numerical values of Γ_Z and σ_{res} at $\sin^2\eta = 0.3$ and $Q = 2/3$ are $\Gamma_Z = 0.6$ GeV, $\sigma_{res} = 2 \times 10^{-32}$ cm^2. Note that the cross-section of elastic e^+e^- scattering has in the resonance the same value (if one neglects the Rutherford growth at small angles); the cross-sections of annihilation into hadrons and into $\nu_e\tilde{\nu}_e, \nu_\mu\tilde{\nu}_\mu$ in the resonance are of the same order.

The cross-section of the process $e^+e^- \to \mu^+\mu^-$ de-

creases rapidly away of the resonance. Therefore, when the total energy is higher than the resonance one, the reaction with photon emission ($e^+e^- \to \gamma Z \to \gamma\mu^+\mu^-$) which returns the process back to the resonance, becomes more advantageous.(the corresponding calculation for the ρ-resonance seein the paper/6/). Its cross-section is equal (with logarithmic accuracy) to

$$\sigma_\gamma = 12\pi\alpha \ln\frac{s}{m_e^2}\, \frac{\Gamma_e(1+m_Z^4/s^2)}{m_Z(s-m_Z^2)}\, \frac{\Gamma_\mu}{\Gamma_Z} \qquad (4)$$

Here $\Gamma_e = \Gamma_\mu = \frac{\alpha m_Z}{12}\frac{(4\sin^2\eta-1)^2+1}{\sin^2 2\eta}$ are the widths of the decay channels $Z \to e^+e^-$ and $Z \to \mu^+\mu^-$. Formula (4) is valid when $\frac{(s-m_Z^2)}{m_Z\Gamma_Z} \gg 1$. The process $e^+e^- \to \gamma\mu^+\mu^-$ dominates over $e^+e^- \to \mu^+\mu^-$ when $\sqrt{s} - m_Z \gtrsim 1.4$ GeV.

Present also for completeness the cross-section of the process $\gamma e \to Ze$

$$\sigma(\gamma e \to Ze) = 6\pi\alpha \ln\frac{(s-m_Z^2)^2}{s m_e^2}\, \frac{\Gamma_e}{m_Z s}\left[1 - 2\frac{m_Z^2}{s} + 2\frac{m_Z^4}{s^2}\right] \qquad (5)$$

2. W-pair production

Consider now the process $e^+e^- \to W^+W^-$. In the Weinberg model this reaction is described by three diagrams (see fig.2). We do not take into account

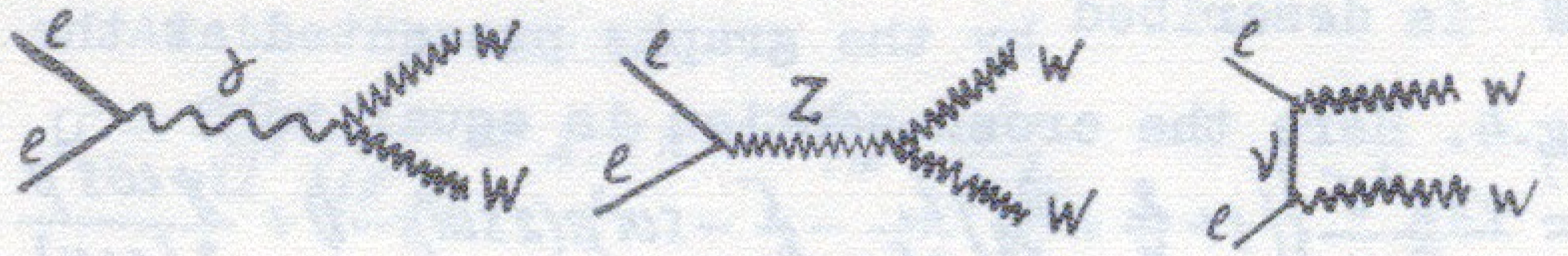

Fig.2.

the interaction with neutral scalar field since it leads to terms proportional to the electron mass.

After averaging over leptons polarizations and summing over those of W-bosons the total cross-section of the process is equal to

$$\sigma=\frac{\pi\alpha^2 v}{2\sin^4\eta\, s}\left\{\left(1+\frac{2}{x}+\frac{2}{x^2}\right)\frac{L}{v}-\frac{5}{4}+\frac{m_z^2(1-2\sin^2\eta)}{s-m_z^2}\left[\frac{2}{x^2}(1+2x)\frac{L}{v}-\right.\right. \tag{6}$$

$$\left.\left.-\frac{x}{12}-\frac{5}{3}-\frac{1}{x}\right]+\frac{m_z^4(8\sin^4\eta-4\sin^2\eta+1)v^2}{48(s-m_z^2)}(x^2+20x+12)\right\}$$

Here $x = s/m^2$, m is the W-boson mass, $v = \sqrt{1 - 4/x}$ is its velocity in c.m.s., $L = \ln\frac{1+v}{1-v}$.

At the threshold ($s \to 4m^2$)

$$\sigma=\frac{\alpha G}{2\sqrt{2}}\frac{v}{\sin^2\eta}\approx 1.1\times 10^{-35}\,\mathrm{cm}^2\,\frac{v}{\sin^2\eta} \tag{7}$$

Present also for completeness the asymptotic behaviour of the cross-section at $s\to\infty$ $\left(\ln\frac{s}{m^2}\gg 1\right)$

$$\sigma=\frac{\pi\alpha^2}{2\sin^4\eta\, s}\ln\frac{s}{m^2} \tag{8}$$

The energy dependence of the cross-section for various values of the mixing angle are given at the fig.3.

In the Georgi-Glashow model the process $e^+e^-\to W^+W^-$ is described by the graphs presented at the fig.4. Here the cross-section is equal to

$$\sigma=\frac{4\pi\alpha^2 v}{s}\left\{\left(1+\frac{2}{x}+\frac{2}{x^2}\right)\frac{L}{v}-\frac{5}{4}-\sin^2\beta(2\sin^2\beta-1)+\frac{y\cos^2\beta}{2(1+y)}+\right.$$

$$\left.+\left[\sin^2\beta(2\sin^2\beta-1)\frac{1}{y}+\sin^4\beta-\frac{1}{2}\right]\ln(1+y)\right\} \tag{9}$$

where m_0 is the mass of X_0-lepton, β is the mixing angle, $y = sm_0^2/m^4$. This expression is obtained under the assumption $m_0^2\ll m^2$.

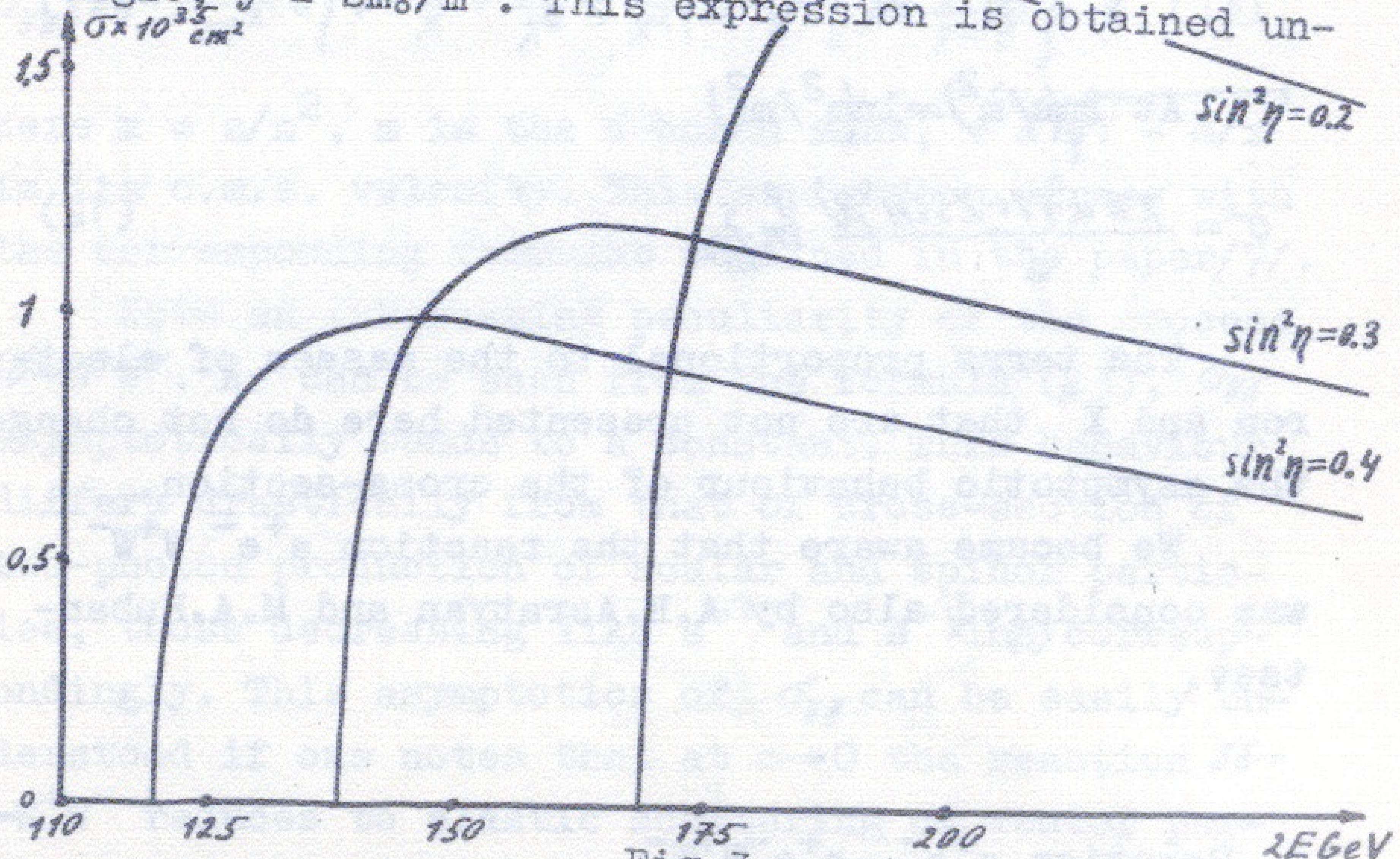

Fig.3.

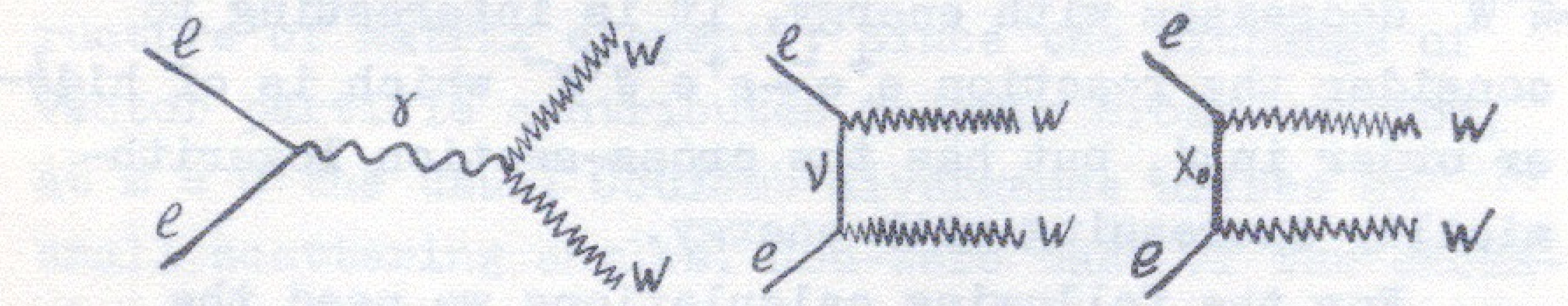

Fig.4.

At the threshold

$$\sigma=\frac{\alpha G}{\sqrt{2}}\frac{v}{\sin^2\beta}\approx 2.2\times 10^{-35}\,\mathrm{cm}^2\,\frac{v}{\sin^2\beta} \tag{10}$$

In the most interesting region $s \ll m^4/m_0^2$ $(y \ll 1)$

$$\sigma = \frac{4\pi\alpha^2 v}{s}\left[\left(1+\frac{2}{x}+\frac{2}{x^2}\right)\frac{L}{v} - \frac{5}{4}\right] \qquad (11)$$

At $\ln(s/m^2) \gg \ln(m^2/m_0^2)$

$$\sigma = \frac{2\pi\alpha^2(1+2\sin^4\beta)}{s}\ln\frac{s}{m^2} \qquad (12)$$

The terms proportional to the masses of electron and X^0 that are not presented here do not change the asymptotic behaviour of the cross-section.

We became aware that the reaction $e^+e^- W^+W^-$ was considered also by A.E.Asratyan and M.A.Kubantsev.

3. Reaction $e^+e^- \to e^+e^-W^+W^-$

Since the cross-section of the process $e^+e^- \to W^+W^-$ decreases with energy, it is interesting to consider the reaction $e^+e^- \to e^+e^-W^+W^-$ which is of higher order in α, but has the cross-section logarithmically increasing with energy.

For the following calculations we need the cross-section of the process $\gamma\gamma \to W^+W^-$ (fig.5). Di-

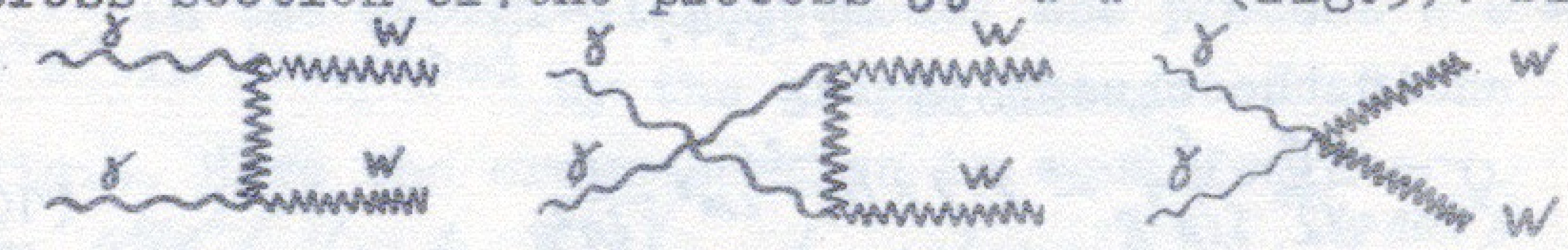

Fig.5.

rect calculation of this cross-section gives

$$\sigma_{\gamma\gamma}(s) = \frac{2\pi\alpha^2}{m^2}v\left\{4+\frac{3}{x}+\frac{12}{x^2}-\frac{12}{x^2}\left(1-\frac{2}{x}\right)\frac{1}{v}\ln\frac{1+v}{1-v}\right\} \qquad (13)$$

Here $x = s/m^2$, m is the W-boson mass, $v = \sqrt{1-4/x}$ is its c.m.s. velocity. This expression agrees with the corresponding formulae obtained in the paper/7/.

Note an interesting peculiarity of the process $\gamma\gamma \to W^+W^-$. As can be seen from the formula (13), $\sigma_{\gamma\gamma}$ asymptotically tends to a constant. This behaviour differs drastically from that of cross-section of two-photon production of scalar and spinor particles, those decreasing like s^{-1} and $s^{-1}\ln(s)$ correspondingly. This asymptotics of $\sigma_{\gamma\gamma}$ can be easily understood if one notes that at $m \to 0$ the reaction $\gamma\gamma \to W^+W^-$ reduces to elastic scattering of vector particles in fact (one can verify easily that the presence of charge exchange does not influence the structure of matrix element). Since the exchange of vector particle contributes to this cross-section, at m = 0 the usual Coulomb divergence arises at small scattering angles. Non-zero mass of the exchange quantum makes the cross-section finite and not decreasing with energy. The cross-section is constant for W-boson helicities ± 1. For zero-helicity W-boson the cross-section decreases with energy like the production cross-section of scalar or spinor particles, due to change of helicity of real particles in vertices of exchange graphs.

Note that the specific feature of renormalizable theory, due to which the cross-section does not increase with energy, is that in this theory the g-factor of W-boson is equal to 2 (see also/7/).

We shall make all the following calculations restricting to the region $s \gg m^2$, $\ln(s/m_e^2) \gg \ln(s/m^2)$.

Knowing $\sigma_{\gamma\gamma}$, it is easy to compute the cross-section of the process $\gamma e \to eWW$. Non-decreasing with energy contribution to the cross-section is given only by the diagram 6. Using the covariant Weizsae-

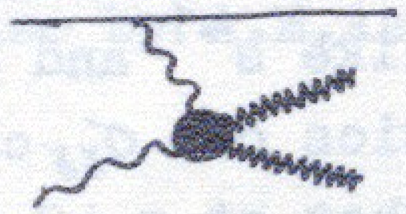

Fig.6.

cker-Williams method/8/ and the expression (13) for $\sigma_{\gamma\gamma}$ we obtain

$$\sigma(\gamma e \to eWW) = \frac{8\alpha^3}{m^2} \ln\frac{s}{m_e^2}\left[\ln\frac{s}{m^2} - \frac{8}{3}\right] \qquad (14)$$

The cross-section of this process for nonrenormalizable electromagnetic interaction of W-bosons (which was found to be increasing linearly with energy) was calculated in the work/9/.

Return to the process $ee \to eeWW$. The major contribution to its cross-section is given first of all

by the diagram 7. Two photon poles at this graph

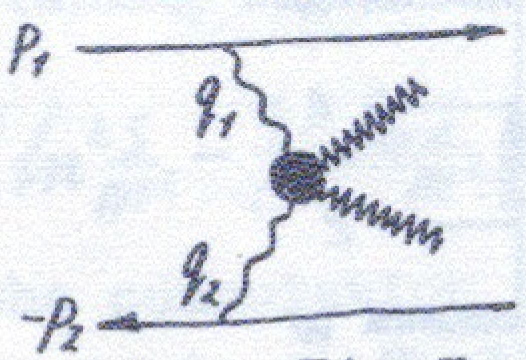

Fig.7.

amplify its contribution $\sim \ln^2(s/m_e^2)$. It is necessary also generally speaking to take into account the diagrams 8, also doubly logarithmically amplified

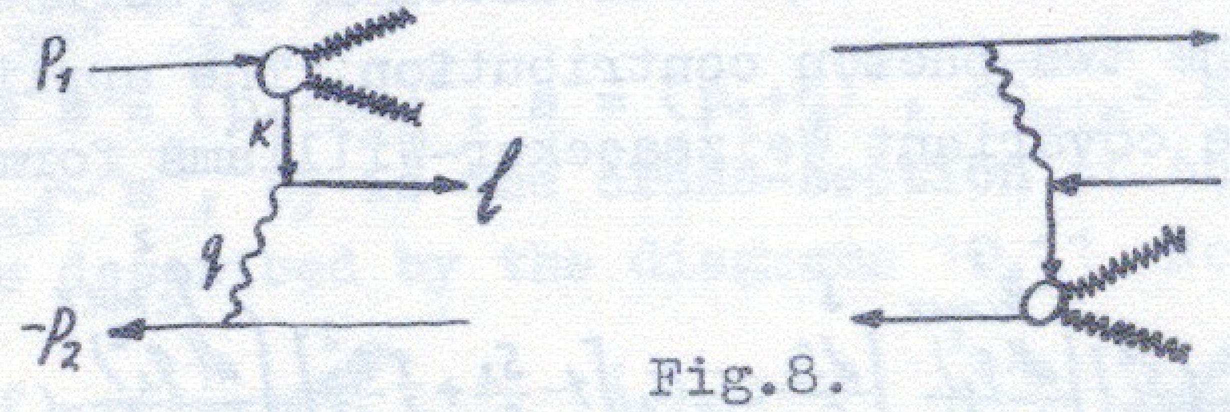

Fig.8.

by photon and fermion poles. These three diagrams do not interfere with the taken accuracy. Indeed, in the c.m.s. of initial particles under the two-photon mechanism the electron and positron almost do not change their directions of motion. At the same time, due to the presence of the fermion pole near the physical domain at the diagrams 8, the final e^+e^- in this case move in the narrow cone along the direction of the particle which emits the exchange γ-quantum.

Besides the diagrams 7,8, there are some graphs whose contributions do not decrease with energy (e.g., that at the fig.9). However, all of them contain

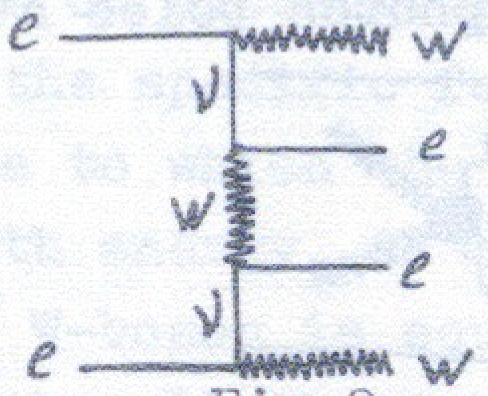

Fig.9.

lower degrees of $\ln s/m_e^2$ and therefore can be neglected with taken accuracy.

Compute at first the cross-section σ_1 corresponding to the two-photon contribution. The application of the covariant Weizsaecker-Williams formula gives

$$\sigma_1=\frac{\alpha^2}{\pi^2}\int\limits_{4m^2}^{s}\frac{ds_1}{s_1}\left[1-\frac{s_1}{s}+\frac{1}{2}\frac{s_1^2}{s^2}\right]\int\limits_{-q^2_{1min}}^{-q^2_{1max}}\frac{d(-q_1^2)}{(-q_1^2)}\int\limits_{4m^2}^{s}\frac{ds_2}{s_2}\sigma_{\gamma\gamma}(s_2)\left[1-\frac{s_2}{s_1}+\frac{1}{2}\frac{s_2^2}{s_1^2}\right]\int\limits_{-q^2_{2min}}^{-q^2_{2max}}\frac{d(-q_2^2)}{(-q_2^2)} \quad (15)$$

Here $s_1 = (q_1+p_2)^2$, $s_2 = (q_1+q_2)^2$, $s = (p_1+p_2)^2$ (the notations of momenta see at the diagram 7), $-q^2_{1min}=m_e^2 s_1^2/s(s-s_1)$, $-q^2_{1max}\sim m^2$, $-q^2_{2min}= m_e^2 s_2^2/s_1(s_1-s_2)$, $-q^2_{2max}\sim m^2$. Perform the integration over q_1^2 and q_2^2 in (15) and then after the interchange of the integration order integrate over s_1 with logarithmic accuracy. These operdtions lead to

$$\sigma_1=\frac{\alpha^2}{\pi^2}\ln^2\frac{s}{m_e^2}\int\limits_{4m^2}^{s}\frac{ds_2}{s_2}\sigma_{\gamma\gamma}(s_2)\left[\left(1+\frac{1}{2}\frac{s_2}{s}\right)^2\ln\frac{s}{s_2}-\frac{3}{2}+\frac{s_2}{s}+\frac{1}{2}\frac{s_2^2}{s^2}\right] \quad (16)$$

Substituting the expression (13) for $\sigma_{\gamma\gamma}$ into (16)

and integrating over s_2, we obtain (holding only terms non-decreasing with energy)

$$\sigma_1=\frac{4\alpha^4}{\pi m^2}\ln^2\frac{s}{m_e^2}\left[\ln^2\frac{s}{m^2}-\frac{41}{6}\ln\frac{s}{m^2}+\frac{215}{12}-\frac{\pi^2}{3}\right] \quad (17)$$

Pass to the computation of σ_2 corresponding to the diagrams 8. Again we shall use the covariant formulation of the Weizsaecker-Williams method:

$$\sigma_2=\frac{\alpha}{\pi}\int\limits_{4m^2}^{s}\frac{ds_\gamma}{s_\gamma}\int\limits_{-q^2_{min}}^{-q^2_{max}}\frac{d(-q^2)}{(-q^2)}\left[1-\frac{s_\gamma}{s}+\frac{1}{2}\frac{s_\gamma^2}{s^2}\right]\sigma_\gamma(s_\gamma, q^2) \quad (18)$$

Here $s = (p_1+p_2)^2$, $s_\gamma = (p_1+q)^2$, $-q^2_{min}= s_\gamma^2 m_e^2/s(s-s_\gamma)$, $-q^2_{max}\sim m^2$, σ_γ is the cross-section of the photoprocess described by the diagrams 10,11. Note that in

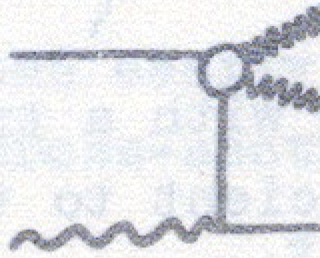

Fig.10.

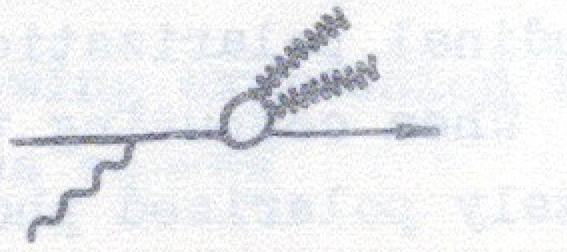

Fig.11.

the formula (18) it is necessary to take into account the dependence of the σ_γ on the photon mass q^2. This circumstance is connected with the nearness of the fermion pole to the physical domain.

For the computation of the photoprocess cross-section the covariant summation over photon polarizations is inconvenient since it should be carried out with gauge-invariant block, i.e., it requires taking into account both diagrams 10,11.

Under uncovariant summation it is necessary, generally speaking, to take into account the longitudinal polarization of γ-quantum. This polarization vector is as follows:

$$\varepsilon_\mu = \frac{1}{\sqrt{q^2}} q_\mu + \frac{\sqrt{q^2}}{q_0 + |\vec{q}|}\left(-1, \frac{\vec{q}}{|\vec{q}|}\right)$$

The first term does not contribute, due to gauge invariance. The second term is proportional to the photon mass $\sqrt{q^2}$ and therefore after integration over q^2 in the formula (18) it will not lead to logarithmic amplification. Thus with taken accuracy one can neglect the contribution of the photon longitudinal polarization.

When computing the cross-section with a transversely polarized photon, it is sufficient to take into account the diagram 10 only since it contains a fermion pole near the physical domain and is therefore logarithmically amplified by itself. Square of the amplitude corresponding to the diagram 10 averaged over polarizations of initial electron and summed over polarizations of final one, after integration over W-boson momenta looks as follows

$$\overline{M^2} \sim Sp\left\{\hat{l}\,\hat{\varepsilon}\,\frac{\hat{k}}{k^2-m_e^2}\,\hat{\rho}(p,k)\,\frac{\hat{k}}{k^2-m_e^2}\,\hat{\varepsilon}\right\} \qquad (19)$$

Here ε_μ is the three-dimensionally transverse polarization of the photon, $\hat{\rho}(p,k)$ is a matrix that describes the interaction in the upper block (the momenta notations are given at the diagram 10). General representation of the matrix $\hat{\rho}$ is the following:

$$\hat{\rho} = a\hat{p} + b\hat{k} \qquad (20)$$

(It can be verified easily that other combinations of γ-matrices drop out when the trace is taken). In the formula (19) it is necessary to hold only the terms with a pole in k^2. This circumstance allows one to neglect the second term in the formula (20), i.e.,

$$\hat{\rho} = a\hat{p} \qquad (21)$$

One can easily obtain the following expression for the cross-section of the process ee→WW

$$\sigma_{ee}(s_1) = \frac{(2\pi)^4}{8 s_1} Sp\,\hat{\rho}\,\hat{k} = \frac{(2\pi)^4}{4} a \qquad (22)$$

Using the formulae (20)-(22) and carrying out the summation over photon transverse polarizations, we obtain

$$\sigma_\gamma = \frac{\alpha}{2\pi s_\gamma} \int\limits_{4m^2}^{s} ds_1 \int\limits_{-k^2_{min}}^{-k^2_{max}} \frac{d(-k^2)}{m_e^2 - k^2}\, \sigma_{ee}(s_1) \left[1 - 2\frac{s_1}{s} + 2\frac{s_1^2}{s^2}\right] \qquad (23)$$

where $-k^2_{min} \sim -q^2 s_1/s$, $-k^2_{max} \sim m^2$.

Note that the way of calculation of the pole contribution to the cross-section presented above, is in fact the covariant formulation of the so-called method of quasireal electrons given in the works/10, 11/.

The substitution of the expression (23) into the formula (18) and integration over k^2, q^2 and S_γ with logarithmic accuracy give

$$\sigma_2=\frac{\alpha^2}{4\pi^2}\ln\frac{2s^2}{m^2m_e^2}\int_{4m^2}^{s}\frac{ds_1}{s_1}\left[\frac{2}{3}+\frac{1}{2}\frac{s_1}{s}-\frac{1}{2}\frac{s_1^2}{s^2}-\frac{2}{3}\frac{s_1^3}{s^3}-\frac{s_1}{s}\left(1+\frac{s_1}{s}\right)\ln\frac{s}{s_1}\right]\sigma_{ee}(s_1) \tag{24}$$

Computation of the integral over s_1 (accounting for the terms non-decreasing with energy only) leads to the following expressions for the cross-section: in the Georgi-Glashow model (at $m^2 \ll s \ll m^4/m_o^2$)

$$\sigma_2=\frac{139}{540}\frac{\alpha^4}{\pi m^2}\ln^2\frac{s}{m_e^2} \tag{25}$$

in the Weinberg model

$$\sigma_2=\frac{\alpha^4}{32\pi m^2\sin^4\eta}\,\xi\,\ln^2\frac{s}{m_e^2} \tag{26}$$

where ξ = 1.1; 1.15; 1.25 at $\sin^2\eta$ = 0.2; 0.3; 0.4 correspondingly.

The total cross-section of the process $ee\to eeWW$ is evidently equal to

$$\sigma=\sigma_1+2\sigma_2 \tag{27}$$

In this formula the second term is by one or two or-

ders of magnitude smaller than the first one, i.e., the contribution of the diagram 5 is small numerically. From the comparison of the formula (6) or (11) with (17) it can be seen that the process $ee\to eeWW$ dominates over $ee\to WW$ already at the energy $2E=\sqrt{s}\approx 14m$. In this region the cross-section found by means of the formula (17) differs from the result of the numerical computations using the formula (16) not more than by some per cent.

The cross-section of the process $ee\to eeWW$ was computed in the work/12/. The result for the contribution of the diagram 4 differs considerably fro[m] ours. We cannot point out the cause of this discre[-]pancy since the computation of $\sigma_{\gamma\gamma}$ in the mentione[d] work was made by numerical methods. Besides, in th[e] work/12/ the contribution of the diagram 8 was not considered.

The authors are grateful to A.N.Skrinsky and A.I.Vainshtein for valuable discussions.

References

1. S.Weinberg. Phys.Rev.Lett., 19,1264,1967.
2. H.Georgi and Sh.L.Glashow. Phys.Rev.Lett., 28, 1494,1972.
3. R.Budny. Phys.Lett., B45,340,1973.
4. D.A.Dicus. Phys.Rev., D8,338,1973.
5. S.Weinberg. Phys.Rev., D5,1412,1972.
6. V.N.Baier and V.S.Fadin. Phys.Lett., B27,223, 1968.
7. V.G.Kompaniyets. Yadernaya Fizika, 12,826,1970.
8. V.N.Gribov, V.A.Kolkunov, L.B.Okun' and V.M.Shekhter. JETP, 41,1839,1961.
9. N.L.Ter-Isaakyan and V.A.Khoze. Yadernaya Fizika, 15,87,1972; Izvestiya AN ArmSSR, 1973.
10. P.Kessler. Nuovo Cim., 17,809,1960.
11. V.N.Baier, V.S.Fadin and V.A.Khoze. Nucl.Phys., in press.
12. D.Pesic. Phys.Rev., D8,945,1973.

References

1. S.Weinberg. Phys.Rev.Lett., 19,1264,1967.
2. H.Georgi and Sh.L.Glashow. Phys.Rev.Lett., 28, 1494,1972.
3. R.Budny. Phys.Lett., 45B,340,1973.
4. D.A.Dicus. Phys.Rev., D8,338,1973.
5. S.Weinberg. Phys.Rev., D5,1412,1972.
6. V.N.Baier and V.S.Fadin. Phys.Lett., 27B,223, 1968.
7. V.G.Kompaniyets. Yadernaya Fizika, 12,826,1970.
8. V.N.Gribov, V.A.Kolkunov, L.B.Okun' and V.M.Shekhter. JETP, 41,1839,1961.
9. N.L.Ter-Isaakyan and V.A.Khoze. Yadernaya Fizika, 15,87,1972; Izvestiya AN ArmSSR, 1973.
10. F.Kessler. Nuovo Cim., 17,809,1960.
11. V.N.Baier, V.S.Fadin and V.A.Khoze. Nucl.Phys., in press.
12. D.Pesic. Phys.Rev., D8,945,1973.

Ответственный за выпуск С.Н.Родионов
Подписано к печати 1.1У-74 г. МН 08158
Усл. 0,8 печ.л., тираж 200 экз. Бесплатно.
Заказ № 12
Отпечатано на ротапринте в ИЯФ СО АН СССР, вг.