Moscow University
Physics Bulletin
Vol. 48, No. 4, pp. 85–87, 1993

Vestnik Moskovskogo
Universiteta. Fizika
UDC 539.12

## BRIEF COMMUNICATIONS

# W-BOSON PAIR PRODUCTION WITH UNDETECTED ELECTRONS — A NEW BASIC PROCESS FOR $\gamma e$ COLLIDERS

I. F. Ginzburg*, V. A. Il'in, A. E. Pukhov, and V. G. Serbo**

**The total cross section of the process $\gamma e \to eWW$ at energies up to 2 TeV has been calculated. The contributions to the process come from the three- and four-boson vertices ($\gamma WW$, $ZWW$, $\gamma\gamma WW$ and $\gamma ZWW$). The large magnitude of the cross section suggests that this will be one of the most interesting processes in studying the structure of the electroweak sector of the Standard Model using the linear colliders that are now being designed.**

The linear $e^+e^-$, $\gamma e$, and $\gamma\gamma$ colliders that are now being designed will provide strong possibilities for both precision measurement of the parameters of the Standard Model (SM) and a search for deviations from the standard three- and four-boson SM vertices in the energy range up to 1–2 TeV (see, e. g., [1–5]).

In this paper we consider $\gamma e$ collisions. Here the basic process is $\gamma e \to \nu W$, and for energy of 500 GeV its total cross section is equal to 42 pb (in the tree approximation). The vertex $\gamma WW$ can be checked in this process. We note that at the tree level the vertices $ZWW$ and $\gamma\gamma WW$ enter the basic processes $ee \to WW$ and $\gamma\gamma \to WW$.

The other vertices describing in the SM the interaction of gauge bosons make contributions to processes of the 3rd and 4th orders relative to the electroweak coupling constant. We have found that the process of the 3rd order $\gamma e \to eWW$ can be of particular interest in the investigation of the gauge nature of electroweak interactions.

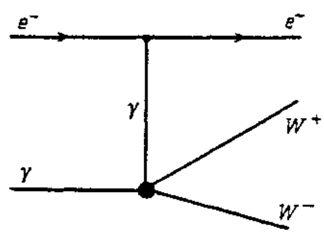


**Fig. 1**

The major contribution to this process is given by diagrams with a virtual photon exchange in the $t$-channel (Fig. 1): the expression for the cross section involves the large factor $\ln(s/m_e^2)$ originating from the integration near the $t$-channel pole with respect to the transferred momentum.

We calculated on a computer the total cross section of the process with consideration for all Feynman diagrams in the tree approximation (altogether 14 diagrams not including the contribution from the Higgs boson) with the aid of a CompHEP package [6]. For the integration over the phase volume a BASES package

* Institute of Mathematics, Siberian Division of Russian Academy of Sciences, Novosibirsk.
** Novosibirsk State University.

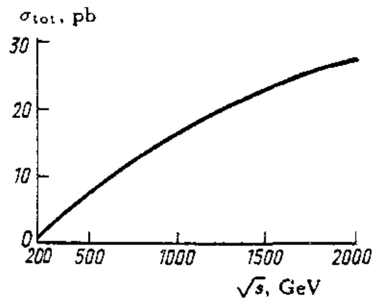


**Fig. 2**

**Table 1**

| $\sqrt{s}$ (GeV) | $\sigma_{tot}$ (pb) | EPM (pb) | $\sigma(\cos\theta < 0.99)$ (pb) |
|---|---|---|---|
| 200 | 0.65 | 0.57 | 0.25 |
| 500 | 7.75 | 7.60 | 1.43 |
| 1000 | 16.7 | 16.2 | 2.0 |
| 1500 | 22.6 | 22.0 | 2.1 |
| 2000 | 27.2 | 26.4 | 1.9 |

[7] was used. Besides, the results of exact calculations were compared with those estimated by the equivalent photon method (EPM) [8]. The calculation data are presented in Fig. 2 and Table 1.*

The EPM formula for this process has the form

$$d\sigma_{e\gamma\to eWW} \approx \sigma_{\gamma\gamma\to WW}(xs)\frac{\alpha}{\pi}\left(1-x+\frac{x^2}{2}\right)\ln\frac{(1-x)}{x^2\delta}\,\frac{dx}{x},$$

where $\delta = m_e^2/4M_{W^2}$ and $4M_{W^2}/s < x < 1$.

As is seen, the EPM formula provides an adequate result and can be used for crude (but fast) simulation of experiment.

The major contribution to the cross section is produced by electrons with very small escape angles. Consequently, the designed experiment must not include electron detection.

The cross section turns out to be large: for $\sqrt{s} \approx 500$ GeV it is about 8 pb and for $\sqrt{s} \approx 2$ TeV it amounts to more than half the cross section of the basic process $\gamma e \to \nu W$. Hence, the process under study can give a substantial background for this basic process and compete with it.

The studied process is of considerable interest. Indeed, it can provide an additional possibility of checking the gauge nature of the electroweak interaction: the four vertices of the interaction of gauge bosons ($\gamma WW$, $ZWW$, $\gamma\gamma WW$, and $\gamma ZWW$) are accessible for analysis even at the tree level, one of them ($\gamma ZWW$) being inaccessible to study at all with 2nd order processes. Of course, all these vertices are interrelated via gauge invariance.

---

* The following values of the parameters were used in the calculations: the fine structure constant $\alpha = \alpha(M_Z) = 1/128$; the $W$-boson mass $M_W = 80.2$ GeV; $\sin^2\theta_W = 0.226$; and the electron mass $m_e = 5.11 \times 10^{-4}$ GeV. We set $M_H = \infty$ for the mass of the Higgs boson. And $\theta$ is the electron escape angle. All calculations were carried out to an accuracy of 0.5%.

## REFERENCES

1. *Proc. of the First Workshop on JLC,* KEK 90-2, 1990.
2. *Proc. of the Second Workshop on JLC,* KEK 91-10, 1991.
3. *Proc. of the 2nd Workshop "Physics at VLEPP"* (in Russian), Protvino, 1992.
4. *Proc. of the Workshop "$e^+e^-$ Collisions at 500 GeV: the Physics Potential"*, DESY 92-123A, 1992.
5. I. F. Ginzburg, et al., *Nucl. Phys.,* vol. B228, p. 285, 1983; vol. B243, p. 550, 1984.
6. E. E. Bools, et al., in: D. Perret-Gallix, ed., *New Computing Techniques in Physics Research II,* p. 665, World Sci., Singapore, 1992.
7. S. Kawabata, *Comp. Phys. Comm.,* vol. 41, p. 127, 1986; S. Kawabata and T. Kaneko, *Comp. Phys. Comm.,* vol. 48, p. 353, 1988.
8. V. M. Budnev, et al., *Phys. Reports,* vol. 15C, p. 181, 1975.

17 March 1993
Research Institute for Nuclear Physics