Title
PRODUCTION OF SINGLE W BOSONS IN e+e-COLLISIONS

Author
Cheyette, O.

Publication Date
1983-12-01

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Physics Division

Submitted for publication

PRODUCTION OF SINGLE W BOSONS IN e^+e^- COLLISIONS

O. Cheyette

December 1983

Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

December 1983 LBL-17083

PRODUCTION OF SINGLE W BOSONS IN e^+e^- COLLISIONS

Oren Cheyette

Lawrence Berkeley Laboratory

and

Department of Physics

University of California

Berkeley, California 94720

ABSTRACT

The cross section for single W production in e^+e^- collisions below the two W threshold is computed with an arbitrary W magnetic moment.

*This work was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Division of High Energy Physics of the U. S. Department of Energy under Contract DE-AC03-76SF00098

The now standard Glashow-Weinberg-Salam (GWS) model of weak and electromagnetic interactions has had many successes, notably the prediction of the recently detected W and Z bosons. One as yet untested aspect of the theory is the self interaction of the gauge bosons. There is very little freedom to adjust the form of these couplings: in the GWS model the WWγ coupling corresponding to the vertex shown in Fig. 1 is given by

$$ie[g_{\rho\nu}(p+p')_{\mu} + g_{\rho\mu}(\lambda q - p)_{\nu} + g_{\mu\nu}(-p' - \lambda q)_{\rho}]$$

with $\lambda = 1$. The gyromagnetic ratio of the W is $1+\lambda$, while its electric quadrupole moment is $-e\lambda/M_W^2$. Note that for a charged vector particle "minimally" coupled to the photon, $\lambda = 0$.[1]

A probe of the value of λ is provided by single W production in e^+e^- collisions at energies below the two W threshold. This process has been studied by a number of people. Choban[2] calculated the cross section for energies $\sqrt{s} \gg M_W$ as a function of λ , and our leading term agrees with his result. Ellis and Gaillard[3] cite a result for $\lambda = 1$ which differs from ours. Berends and West[4] have made a numerical estimate of the cross section for $\lambda = 0$, and our results are roughly in agreement with theirs.

Below the two W threshold the dominant contribution to $e^+e^- \to W^-e^+\nu$ is due to the two diagrams shown in Fig. 2. If the positron is scattered at a small angle the photon propagator becomes large, so that the cross section has a logarithmic singularity in the forward direction, and one may be able to tag the process cleanly by observing the positron.

We have used the Weizsäcker-Williams[5] approximation to find this cross section by first calculating the cross section $\sigma'(s_{e\gamma})$ for the process $e^-\gamma \to W^-\nu$. The total cross section for this process is (to lowest order in α and neglecting m_e),

$$\begin{aligned}\sigma'(s_{e\gamma}) = \frac{G\alpha}{4\sqrt{2}}\Big[&(\lambda-1)^2(1+4\log\tilde{s}) + 32\lambda \\ &-\left(\frac{1}{\tilde{s}}\right)(\lambda^2(4\log\tilde{s}+2) + \lambda(40\log\tilde{s}+12) + 20\log\tilde{s} - 22) \\ &+\left(\frac{1}{\tilde{s}}\right)^2(\lambda^2 - 18\lambda + 33 - 32\log\tilde{s}) \\ &-\left(\frac{1}{\tilde{s}}\right)^3(32\log\tilde{s}+56)\Big]\end{aligned}$$

where $\tilde{s} = \frac{s_{e\gamma}}{M_W^2}$. The Weizsäcker-Williams approximation then gives

$$\frac{d\sigma(s)}{d\cos\theta} = \int_{M_W^2/s}^{1} dy \; \frac{1+(1-y)^2}{y\left[1-\cos\theta + \frac{2m_e^2}{s}\left(\frac{y}{1-y}\right)^2\right]}\sigma'(ys)$$

for the cross section for $e^+e^- \to W^-e^+\nu$. The result of this integration is

$$\begin{aligned}\sigma = \frac{\alpha^2 G}{64\sqrt{2}\pi}f \times \\ \Big[&8(\lambda-1)^2\log^2\tilde{s} - 8(\lambda^2-18\lambda+1)\log\tilde{s} - 11\lambda^2 - 362\lambda - \frac{323}{9} \\ &+\left(\frac{1}{\tilde{s}}\right)(8(\lambda^2+10\lambda+5)\log^2\tilde{s} + 16(\lambda^2+8\lambda-3)\log\tilde{s} + 12\lambda^2 + 488\lambda + \frac{68}{3}) \\ &-\left(\frac{1}{\tilde{s}}\right)^2(32\log^2\tilde{s} - 2(\lambda^2-18\lambda+1)\log\tilde{s} + \lambda^2 + 126\lambda + 289) \\ &-\left(\frac{1}{\tilde{s}}\right)^3(\frac{128}{3}\log\tilde{s} + \frac{1088}{9})\Big]\end{aligned}$$

where, for $s \gg m_e^2$, we have $f \simeq \log \frac{s}{m_e^2}$ for the total cross section, or $f \simeq \log \frac{1-\cos\theta_2}{1-\cos\theta_1}$ for scattering of the positron at $\frac{m_e}{\sqrt{s}} \ll \theta_1 < \theta < \theta_2$.

Figure 3 shows the total cross section as a function of λ for several values of $\sqrt{s}$ expected to be available at LEP I, and the total cross section as a function of $\sqrt{s}$ for $\lambda = -1, 0, 1$. At relatively low energy the minimum of σ occurs near $\lambda = 0$; at high energy one observes that the minimum moves to $\lambda = 1$, reflecting the gauge theory cancellation of the leading term. One promising observation is that at low energy the cross section is rapidly varying around $\lambda \sim 1$, changing by about a factor of three from $\lambda = 0$ to $\lambda = 1$ at $\sqrt{s} = 140$ GeV. Unfortunately, if tagging of the positron is necessary, the cross section at 140 GeV and $\lambda = 1$ is only about 2×10^{-38} cm^2. Including W^+ production ($e^+e^- \to W^+e^-\overline{\nu}$) doubles this value, but even with an integrated luminosity of $10^{39} cm^{-2}$ this still yields only about 40 events. The total cross section with no tagging is about a factor of 5 greater than this, giving about 200 events. Even with only 40 events, though, one should be able to distinguish $\lambda = 0$ from $\lambda = 1$.

We conclude that running at the highest LEP I energy should yield a sensitivity to λ competitive with or better than that which could be attained in moderate energy hadron colliders by studying inclusive $W\gamma$ production.[6]

Acknowledgement

I would like to thank Ian Hinchliffe and especially Mary K. Gaillard for many helpful conversations. I am also indebted to the authors of the computer algebra routine which did many of the computations.

References

(1) T. D. Lee and C. N. Yang, Phys. Rev. **128** *885* (1962).

(2) É. A. Choban, Soviet J. Nucl. Phys. **13** *354* (1971).

(3) J. Ellis and M. K. Gaillard, *Physics With Very High Energy e^+e^- Colliding Beams*, **CERN 76-18** (1976).

(4) F. A. Berends and G. B. West, Phys. Rev. D **1** *122* (1970).

(5) L. Camilleri, J. H. Field, E. Gabathuler and G. Preparata, *Physics With Very High Energy e^+e^- Colliding Beams*, **CERN 76-18** (1976).

(6) M. K. Gaillard, private communication.

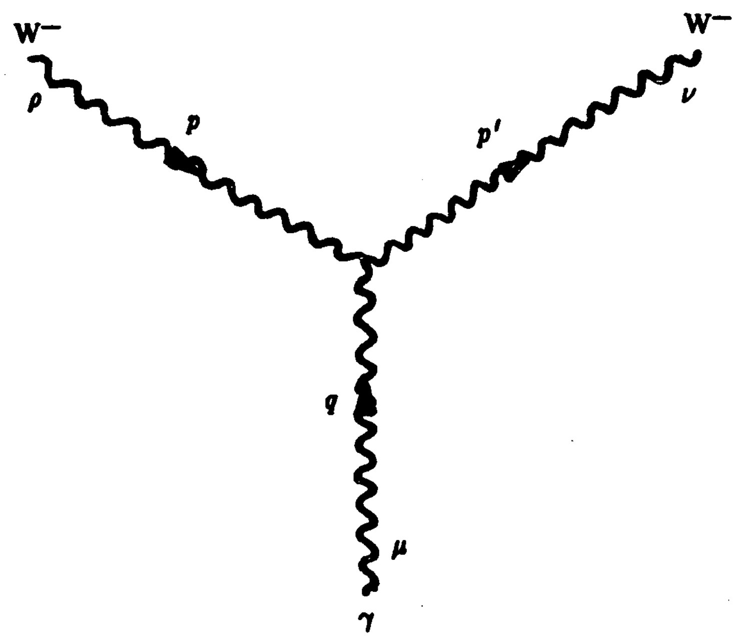


Figure 1

WWγ vertex

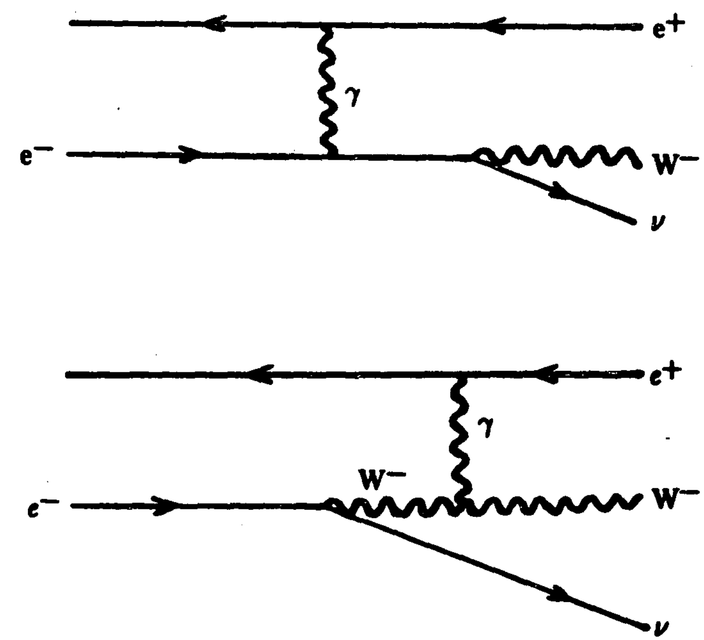
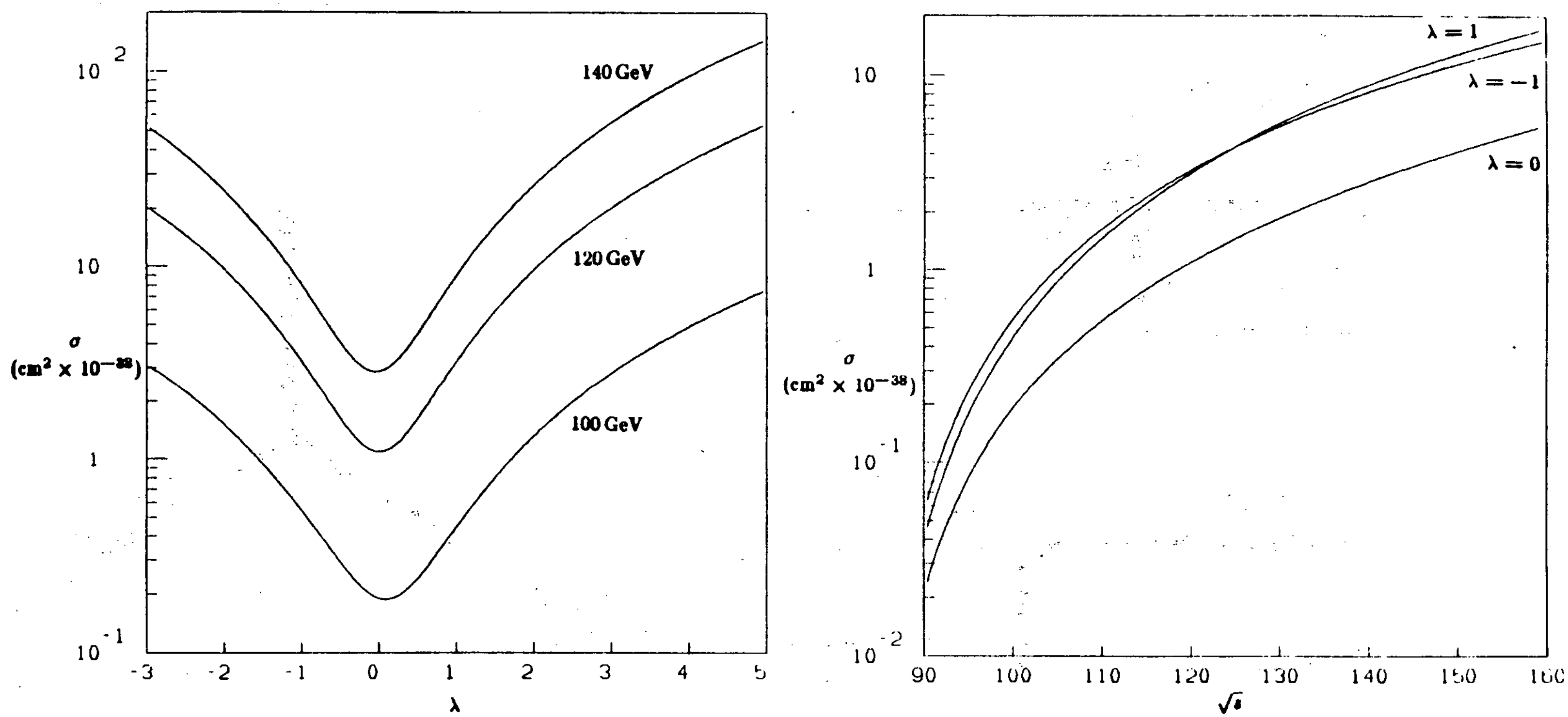


Figure 2

Dominant contributions to $e^+e^-\rightarrow e^+W^-\nu$ below the 2W threshold.



(a) total cross section *vs.* λ

(b) total cross section *vs.* $\sqrt{s}$

Figure 3

Cross section for $e^+e^- \rightarrow e^+W^-\nu$ $(M_W = 83\text{ GeV})$

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720