Title
LUMINOSITIES FOR COLLISIONS OF INTERMEDIATE BOSONS AND OTHER PARTONS

Author
Dawson, S.

Publication Date
1984-08-01

Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

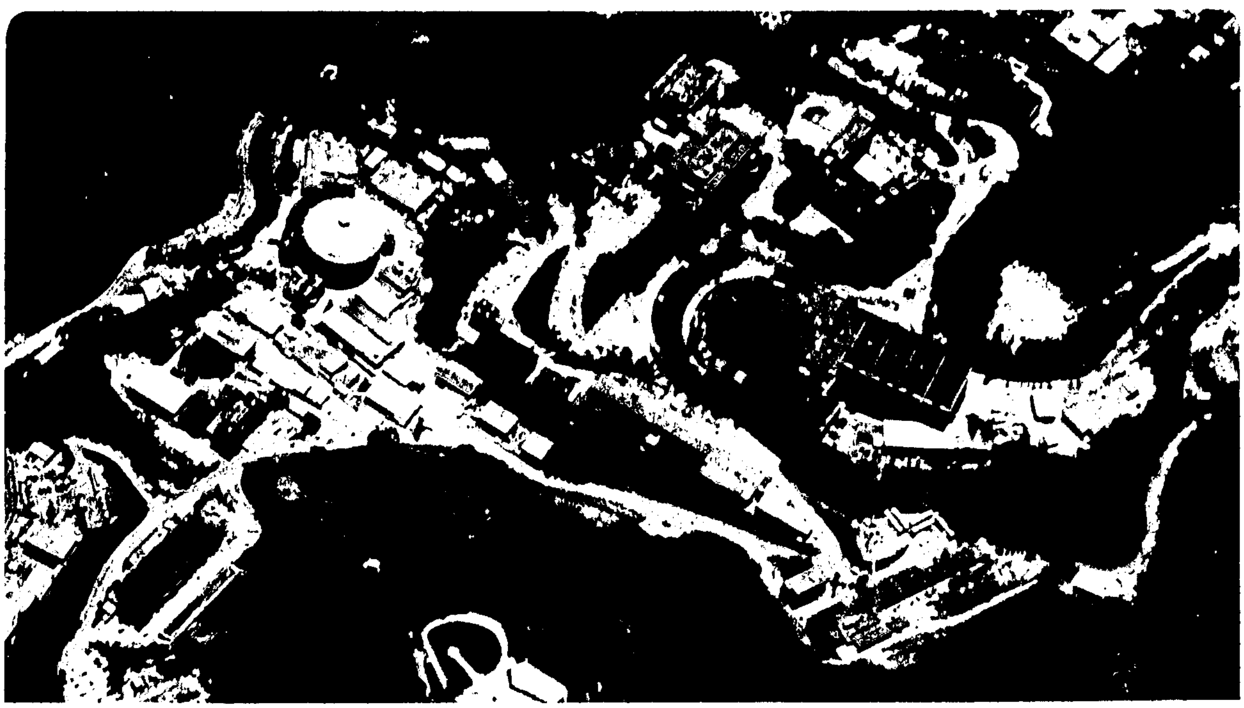
Physics Division

To be published in the Proceedings of the
1984 DPF Summer Study on the Design and Utilization
of the Superconducting Super Collider, Snowmass, CO,
June 23-July 13, 1984

LUMINOSITIES FOR COLLISIONS OF INTERMEDIATE
BOSONS AND OTHER PARTONS

S. Dawson

August 1984



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

DISCLAIMER

August 1984 LBL-18294

LUMINOSITIES FOR COLLISIONS OF INTERMEDIATE BOSONS AND OTHER PARTONS

A contribution to the Proceedings of the
1984 DPF Summer Study on the
Design and Utilization of the
Superconducting Super Collider

Sally Dawson

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720
U.S.A.

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.

LUMINOSITIES FOR COLLISIONS OF INTERMEDIATE BOSONS AND OTHER PARTONS

Sally Dawson

Lawrence Berkeley Laboratory
Berkeley, California 94720

Summary

Parton-parton luminosities (1/s) $d\mathcal{L}/d\tau$ are presented for WW, WZ, ZZ, γW, γZ, $\gamma\gamma$, Wg, Wq, Zg, and Zq collisions. A comparison between the exact calculation and the calculation using our luminosities for Higgs boson production from WW fusion is also presented.

I. Introduction

At the SSC, the energy will be sufficiently high that the parton sea of the proton will contain not only heavy quark pairs but also photons and the massive W and Z gauge bosons of the Weinberg-Salam SU(2) x U(1) model. By considering these bosons as partons, calculations involving gauge bosons in the intermediate states can be considerably simplified. In this note, we present luminosities for collisions of two gauge bosons in pp collisions at $\sqrt{s} = 40$ TeV.

The plan of this note is as follows: In Section II, we summarize the analytic results for the distributions of W's, Z's, and γ's in a quark and present numerical results for WW, WZ, ZZ, Wγ, Zγ, Wg, Zg, Wq, Zq, and $\gamma\gamma$ luminosities in hadronic collisions. In Section III, we discuss the accuracy of our luminosities by computing the cross section for $pp \to W^+W^-X \to HX$ exactly and comparing it with that obtained using our W^+W^- luminosities. (H is the Higgs boson of the Weinberg-Salam model).

II. Gauge Boson Distributions

The effective photon method[1] can be generalized to include massive gauge bosons of both transverse and longitudinal polarizations. In a small angle approximation, the effective number of W's and Z's in a quark can then be calculated.

A longitudinally polarized gauge boson of mass M and 4-momentum $k = (k_0, 0, 0, |\vec{k}|)$ is defined such that it has a polarization tensor,

$$\epsilon_L = 1/M\,(|\vec{k}|, 0, 0, k_0). \qquad (1)$$

The distribution of longitudinally polarized gauge bosons in a quark, q, is,[2,3]

$$f_L{}^q(x) = [(C_V{}^2 + C_A{}^2)/(4\pi^2)](1-x)/x, \qquad (2)$$

to leading order in M^2/E^2 where E is the quark energy. For W's,

$$C_V = -C_A = g/(2\sqrt{2}) \qquad (3a)$$

and for Z's,

$$C_V = g/\cos\theta_W\,(T_{3L}/2 - Q\sin^2\theta_W) \qquad (3b)$$

$$C_A = -g/\cos\theta_W\,(T_{3L}/2),$$

where $g = e/\sin\theta_W$, T_{3L} is the third component of weak isospin of q, and Q is its electric charge.

There are two transverse polarizations possible for a gauge boson,

$$\epsilon_1 = (0, 1, 0, 0)$$
$$\epsilon_2 = (0, 0, 1, 0) \qquad (4)$$

Summing over these polarizations and averaging over the azimuthal angle, the distribution of transversely polarized W's or Z's in a quark to leading order in M^2/E^2 is,[2,3]

$$f_T{}^q(x) = [(C_V{}^2 + C_A{}^2)/(8\pi^2 x)](x^2 + 2(1-x)) \ln(E^2/M^2). \qquad (5)$$

The corrections to Eqs. (2) and (3) of order M^2/E^2 are given in Ref. 2. Finally, the distribution of photons in a quark is,[1]

$$f_\gamma{}^q(x) = \alpha/(2\pi x)[x^2 + 2(1-x)]\ln(E^2/m_q{}^2) \qquad (6)$$

where m_q is the quark mass.

To obtain hadronic luminosities, the gauge boson distributions must be integrated with the quark structure functions. The distribution of gauge bosons in a proton $f_V{}^P(x)$ is,

$$f_V{}^P(x) = \sum_i \int dx'/x'\, f_i(x')\, f_{L(T)}{}^{qi}(x/x') \qquad (7)$$

Hadronic luminosities for two gauge bosons are then defined to be

$$d\mathcal{L}/d\tau\,|_{PP/VV} = \int dx/x\, f_V{}^P(x)\, f_V{}^P(\tau/x) \qquad (8)$$

Using Eqs. (2), (7), and (8), the luminosity of two longitudinally polarized W's or Z's in pp collisions can be calculated as a function of the energy, $\sqrt{\hat{s}}$, in the gauge boson subsystem and the result is shown in Fig. 1. Figure 2 shows the luminosities of two transversely polarized W's and Z's from Eqs. (3), (7), and (8). Similarly, the Wg and Zg luminosities and the Wγ, Zγ, and $\gamma\gamma$ luminosities are shown in Figs. 3 and 4, respectively. Finally, in Fig. 5, we show the W-quark and Z-quark luminosities. We use the structure functions of Eichten et al.,[4] with $\Lambda_{QCD} = .29$ GeV.

III. Discussion

The gauge boson luminosities presented in Figs. 1-5 have been calculated using the effective photon method, which is equivalent to a small angle approximation. These luminosities are valid in the limit $M^2/\hat{s} << 1$. We can test the accuracy of the approximation by computing Higgs production from WW fusion.[5]

The resonance cross section for $pp \to W^+W^-X \to HX$ is,

$$\sigma = \alpha\pi^2/(M_W{}^2\sin^2\theta_W)\,(\tau\, d\mathcal{L}/d\tau)|_{PP/WW} \qquad (9)$$

where $\tau = M_H{}^2/s$. Since the dominant contribution to $W^+W^- \to H$ is from longitudinally polarized W's, we will evaluate (9) using $d\mathcal{L}/d\tau$ for longitudinal W's (Fig. 1). We can compare this result with that obtained by calculating $\sigma(pp \to W^+W^-X \to HX)$ numerically without any approximations. The results are shown in Fig. 6. For $M_H < 500$ GeV, (i.e. small τ), the results obtained from the two methods agree to within 20% while for $M_H = 1$ TeV, the discrepancy is about 30%.

IV. Conclusion

We have presented luminosities for collisions of intermediate gauge bosons and photons at SSC energies. A comparison of the results obtained using our luminosities with an exact calculation of Higgs production from WW fusion shows that the approximations used to derive the distributions of gauge bosons are valid to within about 30% at $\sqrt{s} = 40$ TeV.

Acknowledgment

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.

References

1. C. Weizsäcker and E. J. Williams, *Z. Physik* 29, 315 (1924); S. Brodsky, T. Kinoshita, and H. Terazawa, PR D4, 1532 (1971).
2. S. Dawson, "The Effective W Approximation", LBL-17497, to be published in *Nucl. Phys. B*.
3. G. Kane, W. Repko, and W. Rolnick, "The Effective W±, Z Approximation for High Energy Collisions", MSU/TH/April, 1984.
4. E. Eichten, I. Hinchcliffe, K. Lane, and C. Quigg, "Supercollider Physics", FERMILAB-Pub-84/17-T, LBL-16875, to be published in reviews of modern physics.
5. R. N. Cahn and S. Dawson, PL 136B, 196 (1984); M. Chanowitz and M. K. Gaillard, PL 142B, 85 (1984).

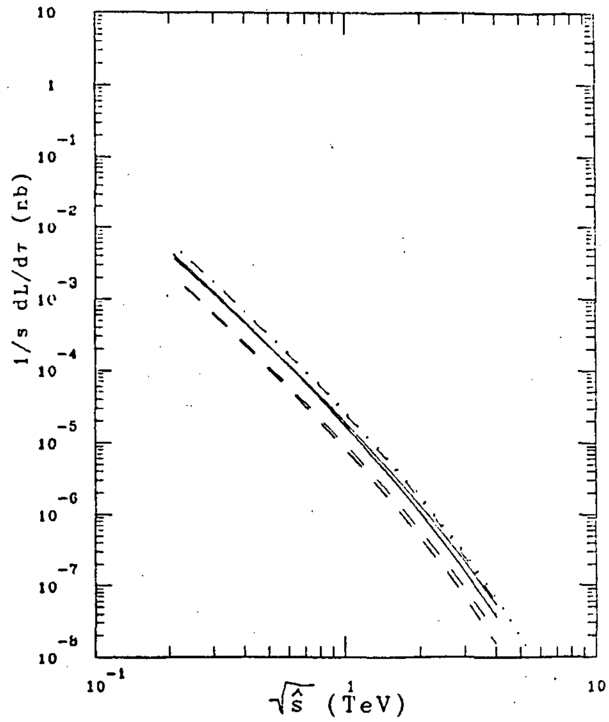


Fig. 1. Luminosities for production of two longitudinal gauge bosons. Figures 1-5 are for pp collisions at $\sqrt{s} = 40$ TeV. The curves are for $W_L^+W_L^-$ (dot-dashed), $W_L^+W_L^+$ (upper solid) $W_L^-W_L^-$ (upper dashed), $W_L^+Z_L$ (dotted), $W_L^-Z_L$ (lower solid) and Z_LZ_L (lower dashed).

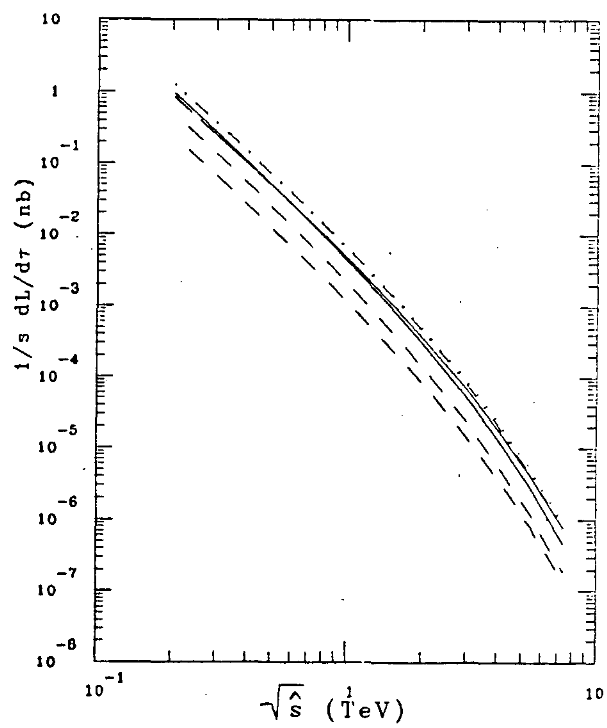


Fig. 2. Luminosities for production of two transverse gauge bosons. The curves are for $W_T^+W_T^-$ (dot-dashed) $W_T^+W_T^+$ (upper solid), $W_T^-W_T^-$ (upper dashed), $W_T^+Z_T$ (dotted), $W_T^-Z_T$ (lower solid), and Z_TZ_T (lower dashed).

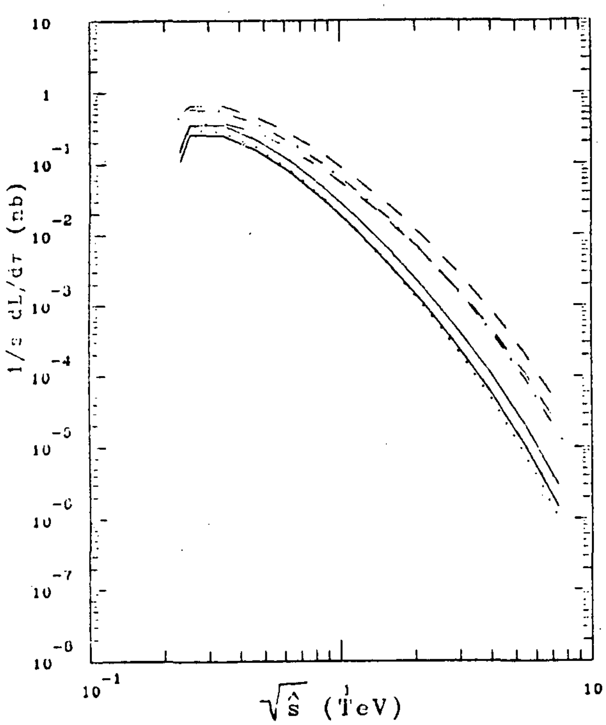


Fig. 3. Luminosities for production of a gluon and a W or Z boson. The curves are for $W_L{}^+g$ (upper solid), $W_T{}^+g$ (upper dashed), $W_T{}^-g$ (dot-dashed), $W_L{}^-g$ (dotted), Z_Lg (lower solid), Z_Tg (lower dashed).

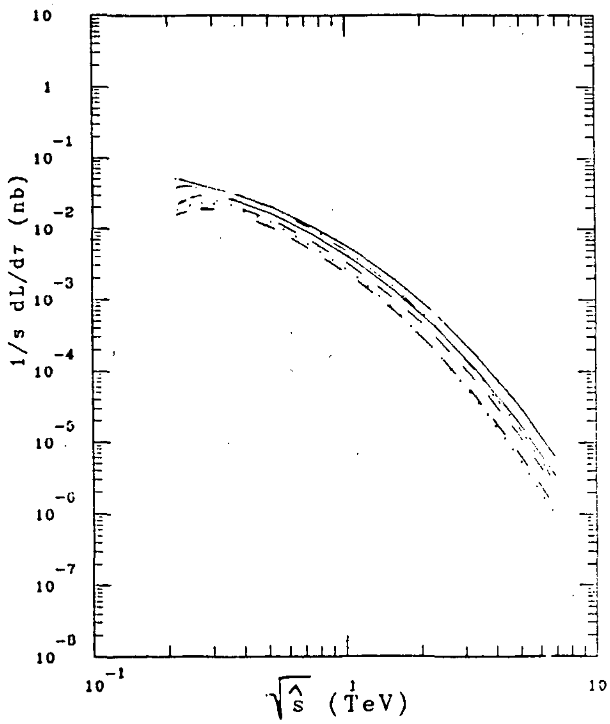


Fig. 5. Luminosities for production of a gauge boson and a quark. The curves are for u-$W_L{}^+$ (upper solid), d−$W_L{}^+$ (upper dashed), u-$W_L{}^-$ (dot-dashed), d-$W_L{}^-$(dotted), u-Z_L (lower solid), d-Z_L (lower dashed).

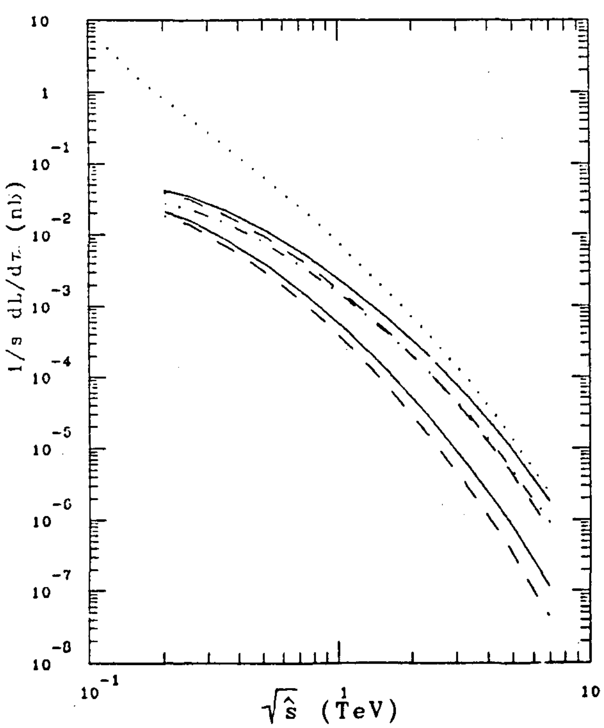


Fig. 4. Luminosities for production of a photon and a W or Z boson. The curves are for $\gamma W_T{}^+$ (upper solid), $\gamma W_T{}^-$(upper dashed), γZ_T (dot-dashed), $\gamma\gamma$ (dotted), $\gamma W_L{}^+$ (lower solid), $\gamma W_L{}^-$ (lower dashed).

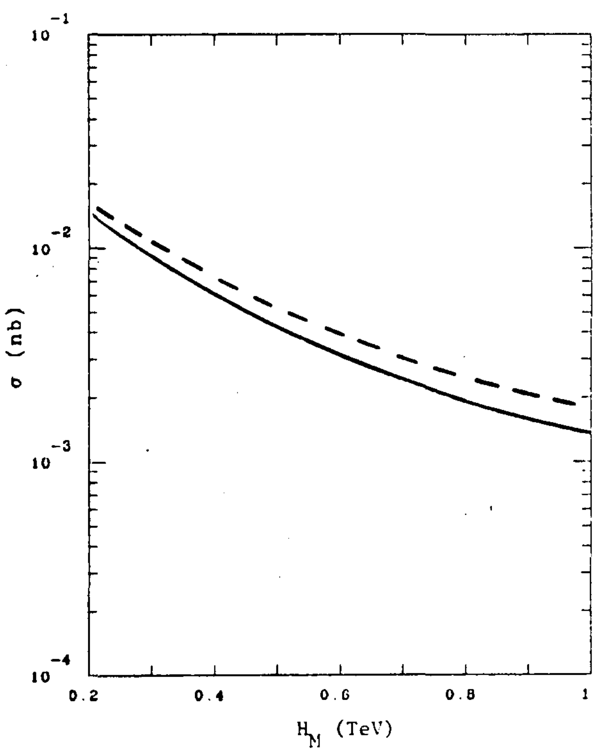


Fig. 6. Higgs production from WW fusion at $\sqrt{s}$ = 40 TeV. The solid line is the exact calculation and the dotted line is the result using Eq. (9) and the $W_L{}^+W_L{}^-$ luminosity of Fig. 1.

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