Signal and Background of Standard Higgs Particle[+)]

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<u>Introduction</u> The detection of Higgs particle at colliders is one of the interesting problems in high energy physics. For several years, we have been studying a detection of the light standard Higgs particle ($M_H < M_W$ or M_Z) and its backgound (BG) contributions at SLC and LEP I and II energies. At the moment, we think that physics at SLC and LEP I and II is a gate way to "Physics at TeV Region" (which is the main subject of this Workshop).

To detect the light standard Higgs particle at $\sqrt{s} < 160$ GeV, the following reaction is a good process[1)]:

$$\text{Signal(S):} \quad e^+e^- \longrightarrow l^+ l^- H \quad (l = \mu \text{ or } e). \tag{1}$$

The Feynman diagram of the reaction (1) is given in Fig. 1. We show that the magnitude of the (S) depends on the total width of the Z-boson[2)] and, to determine the mass of the Higgs particle, a collinearity-angle distribution is better than the invariant mass distribution. For this we have to consider the BG contribution for the collinearity-angle distribution[3)].

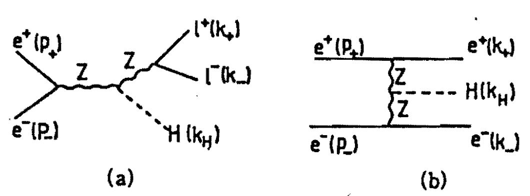


Fig. 1. Feynman diagrams of the reaction $e^+e^- \to l^+l^-H$. For $l=\mu$, only the diagram (a) remains.

<u>Production of the Higgs particle: Invariant mass distribution.</u>
The differential cross section of reaction (1) is given as follows:

$$d\sigma(e^+e^- \to e^+e^-H)/dx = d\sigma^{(a)}/dx + d\sigma^{(b)}/dx + d\sigma^{(c)}/dx\,, \tag{2a}$$

where

$$\frac{d\sigma^{(a)}}{dx} = \frac{g^2(Z)(C+D)}{24^2\cdot(2\pi)^3}\left|P(s)\right|^2 \frac{\lambda(12x+\lambda^2)}{(x-M_Z^2/s)^2+(M_Z\Gamma_Z/s)^2}, \tag{2b}$$

$$\frac{d\sigma^{(b)}}{dx} = \frac{g^2(Z)Cx}{16(2\pi)^4\sqrt{s}}\int_\alpha^\beta \frac{dE_+}{E_+^2E_-^2} J(\tilde{x},\tilde{y}) + \frac{g^2(Z)D}{16(2\pi)^4\sqrt{s}\,s}\int_\alpha^\beta \frac{dE_+}{E_+E_-} K(\tilde{x},\tilde{y}), \tag{2c}$$

$$\frac{d\sigma^{(c)}}{dx} = \frac{g^2(Z)D}{16(2\pi)^4\sqrt{s}}[P(s)P(sx)+\text{c.c.}]\int_\alpha^\beta dE_+ L(\tilde{x},\tilde{y}). \tag{2d}$$

and $x = (k_+ + k_-)^2/s$.

$d\sigma^{(a)}/dx$, $d\sigma^{(b)}/dx$ and $d\sigma^{(c)}/dx$ correspond to contribution of Fig. 1,(a) squared, (b) squared and an interference term of (a) and (b), respectively. For the reaction $e^+e^- \rightarrow \mu^+\mu^- H$, only the term of $d\sigma^{(a)}/dx$ remains. The explicit expressions are given in refs. 1) and 2).

The BG contribution. For the BG, we consider the following process:

$$e^+e^- \longrightarrow f\,\bar{f} \longrightarrow l^+l^-\,X\ . \tag{3}$$

The Feynman diagram of the BG is given in Fig. 2. The invariant mass distribution of the final leptons is given by

$$\frac{d\sigma}{dx}(\mathrm{BG}) = \sum_f \sigma(e^+e^- \rightarrow f\bar{f}) \cdot \{\mathrm{Br}(f \rightarrow lX)\}^2 \frac{dF}{dx}, \tag{4a}$$

where

$$\frac{dF}{dx} = \frac{176}{27}x^3 - 3x^2 - \frac{95}{27} - \left(\frac{16}{9}x^3 + 9x^2 + \frac{25}{9}\right)\ln x \quad \text{for } f=\tau \text{ and } b, \tag{4b}$$

$$\frac{dF}{dx} = \frac{128}{3}x^3 - 36x^2 - \frac{20}{3} - (16x^3 + 36x^2 + 4)\ln x \quad \text{for } f=c \text{ and } t. \tag{4c}$$

In eqs.(4a) ~ (4c) we have assumed that a velocity of f (Fermion) is that of light. We show comparisons of the (S) and BG at $\sqrt{s}$ = 93 GeV and 100 GeV in Fig. 3. The mass of M_H should be determined by the magnitude of the peak. We use the following parameters in our analysis: M_Z = 93 GeV, Γ_Z = 2.6 GeV, $\sin^2\theta_W$ = 0.22 and M_t = 40 GeV.

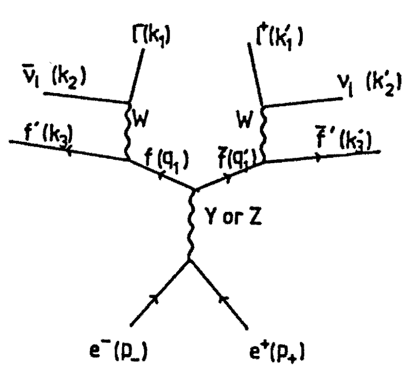
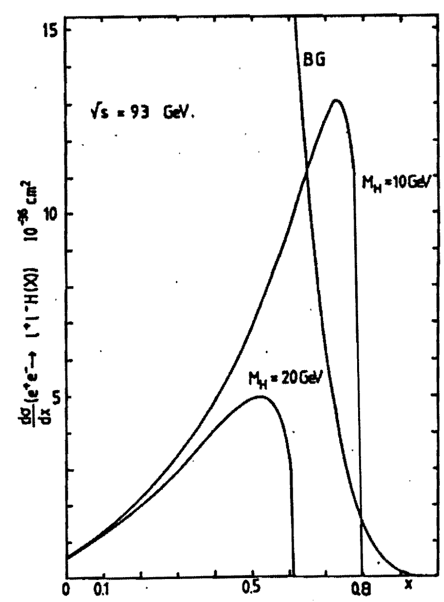


FIG. 2. Feynman diagram for the BG process.



(a)

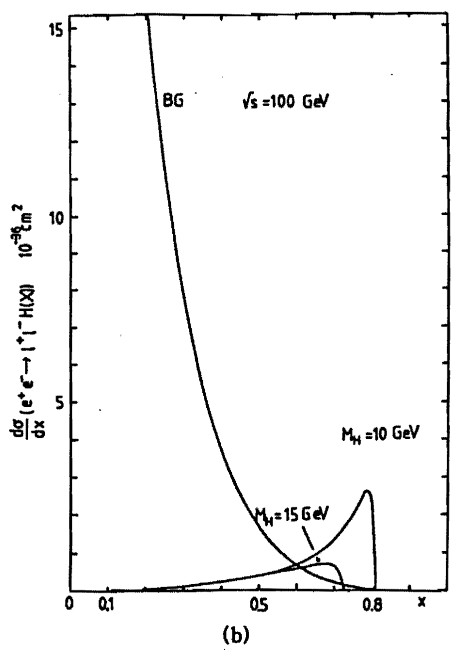
Fig. 3 Differential cross section of the reaction $e^+e^- \rightarrow l^+l^-H$ for $l=e$ or μ, and the BG. (a) $\sqrt{s}$=93 GeV, (b) $\sqrt{s}$=100 GeV.

Magnitude of the signal and the width of Z-boson According to the consideration made by Albert et al.[4], the total width of Z-boson is

Γ_Z = 2.6 GeV (without radiative correction),

and Γ_Z = 3.0 GeV (with radiative correction). (5)

As you see in Fig. 4, the magnitude of the (S) depends on the width. Thus to determine the mass of the Higgs particle, we have to look for a better physical quantity than $d\sigma/dx$.



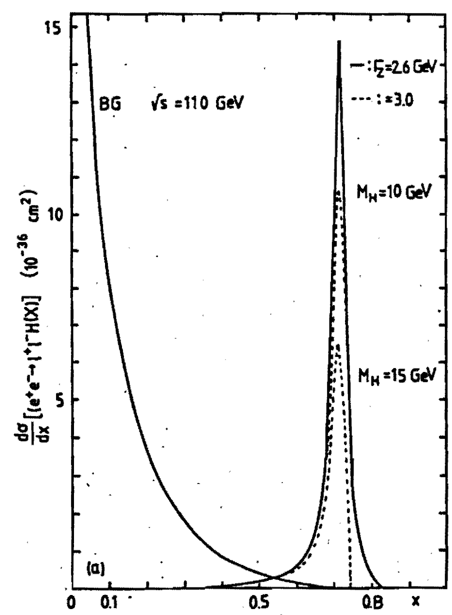


FIG. 4 The differential cross sections of $e^+e^- \to l^+l^- H$ (for $l=\mu$ or e) (a) $\sqrt{s}=110$ GeV.

Collinearity-angle distribution. A possibly better quantity for our aim has been studied by Kleiss[5]. It is the collinearity-angle distribution of the lepton pair in the reaction (1). The explicit expression (with $x_C = \cos\theta_C = \hat{k}_- \cdot \hat{k}_+$) is given by

$$\frac{d\bar{\bar{\sigma}}}{dx_c}(e^-e^+ \to l^-l^+H) = \left[\frac{\sqrt{2}G_F M_Z^2}{\pi}\right]^3 \frac{M_Z^2}{|12\, D(s,Z)|^2}[(\tfrac{1}{4}-\sin^2\theta_W)^2+(\tfrac{1}{4})^2]^2(1+\xi)M(\xi)\,, \quad (6)$$

for $l=e, \mu$, and τ, where

$$M(\xi) = \int_0^{1-y_H} dx \frac{\chi^2\,(1-y_H-x)^2}{(1-\xi x)\{[\xi x(1-y_H-x)-y_Z(1-\xi x)]^2+y_Z^2\gamma_Z(1-\xi x)^2\}}\,,$$

$$y_H = M_H^2/s,\ y_Z = M_Z^2/s,\ \gamma_Z = \Gamma_Z^2/M_Z^2\,,$$

Γ_Z is total width of Z particle, and $\xi=(1-x_c)/2$.

For the BG, we have calculated it in ref. 3). In Fig. 5, we present the BG contribution at $\sqrt{s}$ = M_Z = 93 GeV (with M_t = 40 GeV).

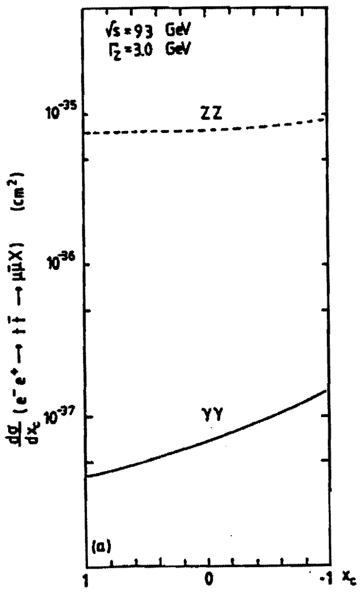


FIG. 5 The BG distribution for t quark at $\sqrt{s}$ =93 GeV. Solid, dashed, dashed-dotted lines are contributions from $\gamma\gamma$, ZZ, and γZ cross sections, respectively.

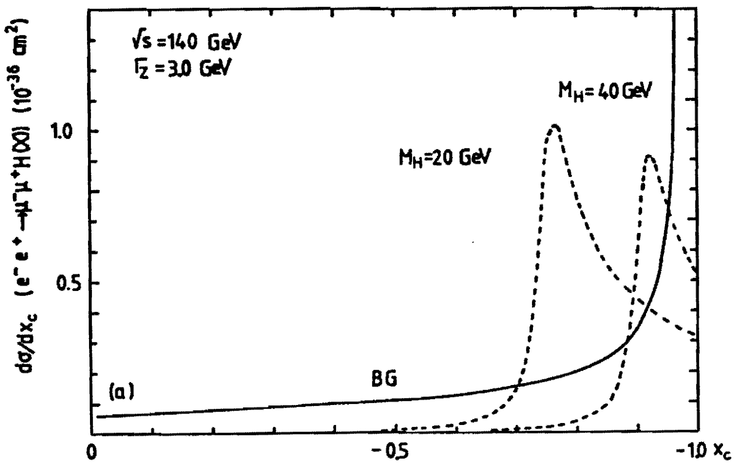
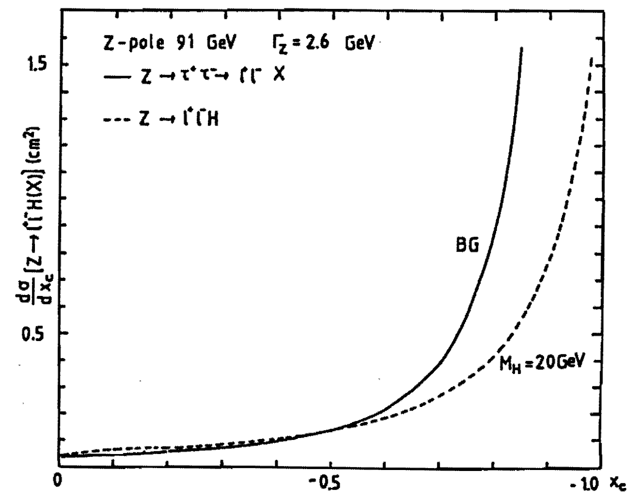


FIG. 6. The distributions of the signal (dashed lines) and the BG process (solid line) from τ, b, c, and t.

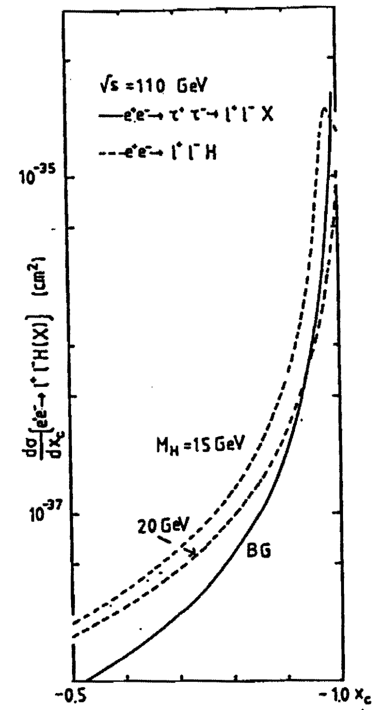
<u>Comparison of the signal and BG</u> We show a comparison of (S) and BG at $\sqrt{s}$ = 140 GeV in Fig. 6. Indeed we can determine the mass of the Higgs particle by collinearity-angle distribution, because of a clean peak, provided M_H <40 GeV.

<u>New analyses at Z-pole and $\sqrt{s}$ = 110 GeV</u> Very recently the mass of Z-boson and the total width of Z-boson are reported by OPAL[6]: M_Z = 91 GeV and Γ_Z = 2.6 GeV. With these values we calculate the collinearity-angle distribution and its BG from $\tau^+\tau^-$-decays, since b and c quarks decays associate with the jets and could be rejected from the BG. Contributions from d quark and μ are negligibly small. Our result is shown in Fig. 7. Obviously BG is larger than (S), as the Higgs particle with $M_H \lesssim$ 20 GeV exists at Z-pole.

Moreover, we show our result at $\sqrt{s}$ = 110 GeV. The (S) is comparable with the BG, as $M_H \lesssim$ 20 GeV.



(a)



(b)

Fig.7 Collinearity-angle distributions of BG from $\tau^+\tau^-$ decay and (S) (a) at Z-pole and (b) $\sqrt{s}$ = 110 GeV.

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References

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1) T. Morioka, M. Biyajima and O. Terazawa, Prog. Theor. Phys. 76(1986) 1089.
2) M. Biyajima, K. Shirane and O. Terazawa, Phys. Rev. D36 (1987)2161.
3) O. Terazawa and M. Biyajima, Phys. Rev. D39(1989) 736. (E) ibid D40(1989) 922. Eq. (6) should contain x^2 in the numerator.
4) D. Albert, W. Marciano, D. Wyler and Z. Parsa, Nucl. Phys. B166 (1980) 460.
5) R. Kleiss, Phys. Lett. 141B (1984) 261.
6) OPAL Collab., M. Z. Akrawy et al., CERN-EP/89-133(1989).