To be submitted to
Physics Letters B

ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratori Nazionali di Frascati

LNF-84/84(P)
19 Novembre 1984

M.Greco: A NOTE ON HIGGS BOSON PRODUCTION IN HADRON COLLISIONS

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ABSTRACT

It is shown that if $M_H \sim O(100\ \mathrm{GeV})$ the production of the Higgs boson via the gluon fusion mechanism, and the subsequent decay into a heavy $Q\bar{Q}$ pair cannot be revealed by looking at the jet-jet invariant mass, due to initial state gluon bremsstrahlung.

The discovery of the Higgs boson would give the final confirmation of the standard electroweak theory(1) and the mechanism of spontaneous symmetry breaking of the $SU(2) \otimes U(1)$ symmetry. Consequently the importance of observing this scalar particle has led various authors(2-6) to consider a number of production mechanisms, relevant in particular for present and forthcoming hadron colliders. For $M_H \lesssim 2M_W$ the gluon fusion mechanism has been suggested by Georgi et al.(3) as a very promising source of Higgs bosons in hadron collisions. The subsequent decay into the heaviest accessible pair of quarks would lead to a significant signal in the jet-jet cross section.

In a recent letter Gaemers and Hoogeveen(7) have made the following interesting observation. The gluon fusion mechanism

$gg \to H \to Q\bar{Q}$ actually adds to the direct QCD process $gg \to Q\bar{Q}$, interfering clearly with it. Then for $M_H > 2M_Q$ the resulting total cross section possesses a peculiar shape typical of an interference process. This is shown in Fig.1, obtained in ref.(7) for $M_H = 100$ GeV and $m_t = 40$ GeV. The width of the Higgs boson Γ_H, which determines the interference pattern, is typically of the order of 50-100 MeV. From this result one draws the conclusion that in order to reveal the Higgs boson via this mechanism one would need an extremely good resolution in the bb or tt jet-jet invariant mass.

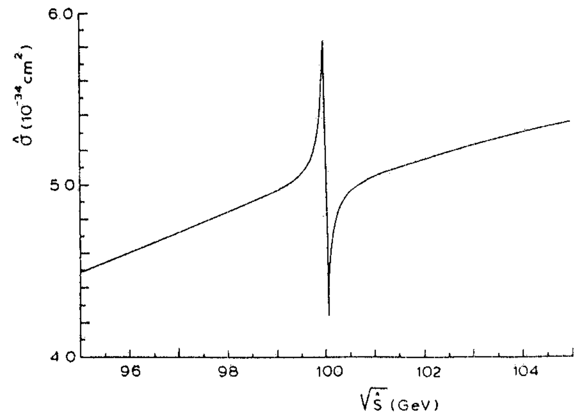

Fig. 1 - Cross section as a function of CM energy.

In the present note we add the following observation. Due to initial state gluon bremsstrahlung the jet-jet system is actually produced with an effective transverse momentum imbalance of order $\langle k_T^2 \rangle$, which corresponds to an "intrinsic" resolution in the parton c.m. energy squared $\Delta\hat{s} \sim \langle k_T^2 \rangle$. This radiation effect, with a proper width much larger than Γ_H, authomatically leads to an effective cross section which is quite insensitive to the production of the Higgs boson. Therefore the eventual existence of the Higgs with $M_H \sim 100$ GeV, cannot be revealed through this production and decay mechanism.

More quantitatively, the effective $gg \to Q\bar{Q}$ total cross section can be written as $(W \equiv \sqrt{\hat{s}})$

$$\sigma_{eff}(W) = \int dW' \; \sigma_{tot}(W') \; f(W',W) \qquad (1)$$

where

$$f(W',W) \sim \frac{1}{\sqrt{2\pi}\sigma}\, e^{-(W'-W)^2/2\sigma^2} \tag{2}$$

is an effective resolution function due to radiation emission and $\sigma_{tot}(W)$ is the total $gg \to Q\bar{Q}$ cross section (QCD + + Higgs + interference).

The process of multigluon emission from the initial state at the c.m. energy squared W^2 leads[8] to

$$\langle W'^2 \rangle = W^2 - \langle k_T^2 \rangle \tag{3}$$

with

$$\langle k_T^2 \rangle \simeq \frac{3}{\pi} \int_0^{M_H^2} dq^2 \left[\ln\left(\frac{M_H^2}{q^2}\right) - \frac{3}{2} \right] \alpha(q^2) . \tag{4}$$

Then comparing eqs.(2) and (3) one gets $\sigma \sim \frac{\sqrt{\pi}\langle k_T^2 \rangle}{2\sqrt{2}W} \approx 1.5$ GeV for $W \sim M_H \sim 100$ GeV and $\langle k_T^2 \rangle \simeq 225\ \mathrm{GeV}^2$. This result, together with eq.(1), shows that the fine structure of $\sigma_{tot}(W)$, of order Γ_H, is clearly washed out upon integration on W', independently of the experimental resolution in the jet-jet invariant mass.

In conclusion our observation shows that the gluon fusion mechanism for Higgs boson production and decay into a heavy $Q\bar{Q}$ pair is not a viable tool to reveal the desired signal if $m_H \sim O(100$ GeV), unless the Higgs boson couplings differ from those expected in the standard model.

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