HIGGS BOSON PRODUCTION IN DEEP INELASTIC SCATTERING AND PHOTON STRUCTURE FUNCTION*

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The standard Higgs boson production in deep inelastic scattering is considered. The contribution from the quark and gluon structure of the photon is calculated. At HERA energies this production channel is below the weak boson fusion.

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Theoretical and experimental search for the Higgs boson [1] is one of the most important issues in high energy physics since its appearance in the theory of electroweak interactions. Many studies have been devoted to its production in hadron-hadron and lepton-lepton accelerators. Similar investigation in lepton-hadron scattering [2] concluded, that the dominant production mechanism goes via the weak boson fusion (Fig. 1(a)), others (Higgs bremsstrahlung from the quark or lepton (Fig. 1(b)), photon-photon fusion (Fig. 1(c)) being much smaller.

In this paper we consider the Higgs boson production in lepton-hadron scattering with one photon exchange in the kinematical range of HERA

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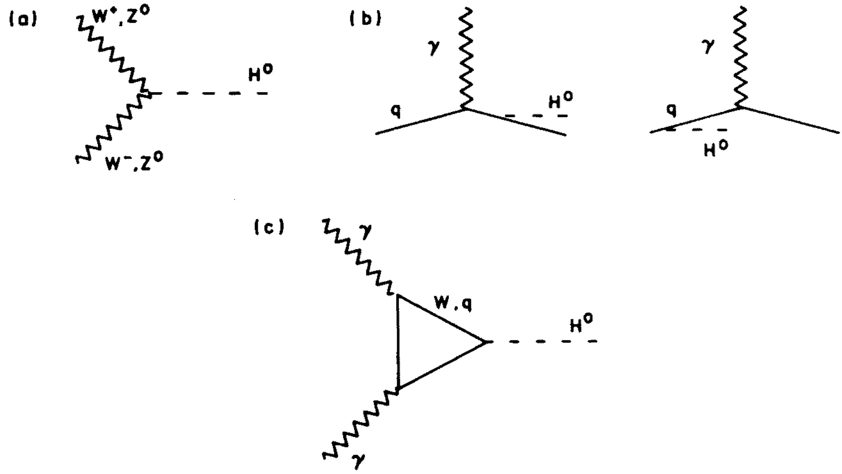

Fig. 1. Subprocesses contributing to the Higgs boson production in deep inelastic scattering: (a) weak boson fusion, (b) quark bremsstrahlung, (c) photon-photon fusion.

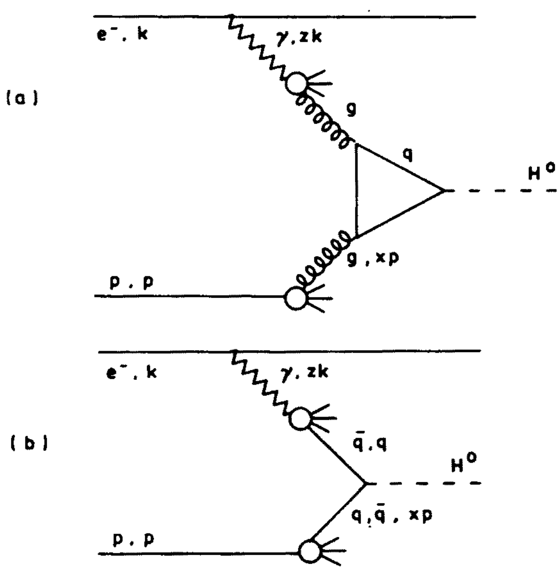

Fig. 2. The Higgs boson production with hadronic structure of the photon included: (a) gluon-gluon fusion, (b) quark-antiquark fusion.

accelerator. Let us concentrate on the scattering of the photon with momentum q off a parton with momentum xp (Fig. 2).

From the kinematical identity

$$M_{\rm H}^2 < (q + xp_{\rm p})^2 = -Q^2 + x^2 M_{\rm p}^2 + 2x\nu M_{\rm p}$$

with the standard definitions for

$$\nu = \frac{pq}{M_{\rm p}} \quad \text{and} \quad Q^2 = -q^2$$

one easily obtains

$$\nu > \frac{M_{\rm H}^2 + Q^2}{2xM_{\rm p}}.$$

This means that the kinematical configuration which allows the Higgs boson production forces the photon to be very energetic and nearly real. It is therefore plausible to take into account the photon structure function [3], and consequently the diagrams shown in Fig. 2. The total cross-section for this subprocess reads

$$\sigma = \sum_{i,j} \int_{M_{\rm H}^2}^{s} \frac{d\hat{s}}{s} \int_{\hat{s}/s}^{1} \frac{dx}{x} f_\gamma^{(\ell)}\left(\frac{\hat{s}}{s}, s\right) \times f_i^{(\gamma)}\left(x, M_{\rm H}^2\right) f_j^{(\rm p)}\left(\frac{M_{\rm H}^2}{x\hat{s}}, M_{\rm H}^2\right) \widehat{\sigma}_{ij}\,, \tag{1}$$

where $M_{\rm H}$ is the Higgs boson mass, and s the total c.m. energy squared. The function $f_\gamma^{(\ell)}$ is the equivalent photon spectrum of the lepton, and $f_i^{(\gamma)}$ and $f_i^{(\rm p)}$ are the i-th parton (quark, antiquark or gluon) densities inside the photon and proton, respectively. The sum in Eq. (1) extends over gg and q$\bar{\rm q}$ pairs only and the corresponding partonic cross-sections read [4]

$$\widehat{\sigma}_{\rm gg} = \frac{\pi}{32}\left(\frac{\alpha_s}{\pi}\right)^2 \frac{G_{\rm F}}{\sqrt{2}} \frac{|N|^2}{9} \frac{M_{\rm H}^2}{\hat{s}}$$

$$\widehat{\sigma}_{\rm q\bar{q}} = \frac{\pi}{3} \frac{G_{\rm F}}{\sqrt{2}} \frac{m_q^2}{\hat{s}}, \tag{2}$$

with α_s being the strong coupling constant, $G_{\rm F}$ — the Fermi constant and N — a function [5,6] depending on the quark and Higgs masses. For the top quark mass about 140 GeV and $M_{\rm H}$ below 200 GeV $|N| \simeq 1$.

The cross-section for the Higgs boson production in e-p collision, Eq. (1), depends crucially on the equivalent photon spectrum and two structure functions. The spectrum of photons emitted by electron is of the Weizsäcker–Williams type [7]:

$$f_\gamma^{(\rm e)}(z, s) = \frac{\alpha_{\rm em}}{\pi} \frac{1 + (1+z)^2}{z} \ln \frac{\sqrt{s}(1-z)}{2m_e z},$$

There are several parametrizations of parton distributions inside photon and proton. Here we use following two sets for the photon structure functions:

(DG) Drees and Grassie [7] with $\Lambda_{QCD} = 0.4$ GeV and 5 quark flavours;

(ACL) Abramowicz, Charchula and Levy [8] with $\Lambda_{QCD} = 0.2$ GeV and 4 flavours (adding the b-quark spectrum equal to that of the s-quark).

We also take two sets for the proton structure functions:

(MRS) Martin, Roberts, Stirling [9] with $\Lambda_{QCD} = 0.2$ GeV and 5 flavours.

(EHLQ) Eichten, Hinchliffe, Lane, Quigg [6] with $\Lambda_{QCD} = 0.2$ GeV and 6 flavours.

Plugging the above functions into Eq. (1) we arrive at four sets of results. In Fig. 3 we present the results for the (ACL) + (EHLQ) parametrization. Replacing (EHLQ) by (MRS) structure functions reduces the result by a factor of about 0.9, while (DG) instead of (ACL) for the photon structure functions gives an additional factor of about 0.6.

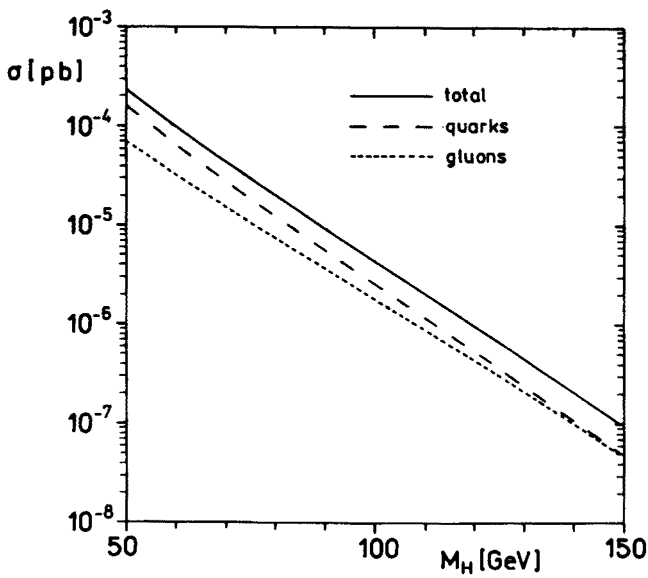

Fig. 3. Contributions from the diagrams of Fig.2 to the cross-section for the Higgs boson production.

To summarize, we have calculated a new contribution to the Higgs boson production cross-section in deep inelastic scattering. Our contribution goes up to 25% of the dominant one, the ZZ fusion, for the Higgs boson masses larger than 50 GeV. The total cross-section for this process remains, however, still very small, probably too low to allow the detection of the

Higgs boson even if its mass is in the kinematical range accessible in the HERA experiment.

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