THREE-PARTICLE DECAYS OF HEAVY HIGGS
BOSONS IN THE WEINBERG–SALAM MODEL

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We investigate the three-particle decays of heavy Higgs bosons in the Weinberg–Salam model with two Higgs doublets. The dominant decay mode is $H \rightarrow VH' \rightarrow \gamma f f'$, if the mixing angles in the Higgs sector are not very extreme. The decay width is a few percent of the decay $H \rightarrow VH'$, at $m_H = 100–150$ GeV it is about a few MeV. The fermion energy distribution can discriminate from the case of one Higgs doublet.

1. Introduction

In a previous paper [1] we have studied the decays of heavy Higgs bosons in the Weinberg–Salam model with two Higgs doublets and found that the decay $H_1 \rightarrow VH_2$ generally exceeds the known decay mode $H_1 \rightarrow VV'$ [2] as well as the decay into a fermion pair. The decays $H_1 \rightarrow H_2 H_3$ may be also large in some cases but these are not controllable easily because of the complicated couplings.

In this paper we go into the details of the above processes, investigating the three-particle decays of heavy Higgses. We consider the possible decay types, and give their widths, then we discuss their relevance. The concrete analyses are performed for the case of charged and pseudoscalar Higgses. It turns out that in general the main decay modes are $H_1 \rightarrow H_2 V \rightarrow H_2 f f'$.

In the Appendices we make general statements on the interference terms and give useful formulae for the evaluation of three-particle decays.

2. The possible decay types

We work in the standard electroweak model with two Higgs doublets [3], [4] because here there appear the typical features of the models with more than one doublet, but the Higgs sector is still rather simple. The five physical Higgs bosons are $H^\pm$, $h^0$, $\Phi^0$, $H^0$, their masses and two mixing angles $\alpha$ and $\beta$, $0 < \beta < \pi/2$, $-\pi/2 < \alpha < -\pi/2 + \beta$, are free parameters. This is not too strong, so the phenomenology is relatively fixed.
From the trilinear interaction term of the model [4] we get the possible decays:

\[ H^\pm \rightarrow W^\pm h^0, W^\pm \phi^0, W^\pm H^0; \]
\[ h^0 \rightarrow W^\pm H^\mp, ZH^0; H^+ H^-, \phi^0 \phi^0, H^0 H^0; \]
\[ \phi^0 \rightarrow W^\pm H^\mp, ZH^0; H^+ H^-, h^0 h^0, H^0 H^0; \]
\[ H^0 \rightarrow W^\pm H^\mp, Zh^0, Z\phi^0. \]

If the virtual particle is the same as the decaying one there are also other possible decays, e.g. \( H \rightarrow H h \rightarrow ff h \), here \( H = H^0, H^\pm; h = h^0, \phi^0 \), but we shall see that these are not important. We investigate the three-particle decays where one of the secondary particles decays into a fermion pair.

![Fig. 1. The possible decay types of Higgs bosons in the model with two Higgs doublets](image)

All of the above decays belong to one of the following four types (Fig. 1):

A) \( H_1 \rightarrow VH_2 \rightarrow Vff \)
B) \( H_1 \rightarrow H_2 V \rightarrow H_2 ff \)
C) \( H_1 \rightarrow H_2 H_1 \rightarrow H_2 ff \)
D) \( H_1 \rightarrow VH_1 \rightarrow Vff \)

In the next Section we evaluate these processes. The concrete model will appear only in the coupling constants.