



Review

Higgs boson production and decay at hadron colliders

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ABSTRACT

Higgs physics at hadron colliders as the LHC is reviewed within the Standard Model (SM) and its minimal supersymmetric extension (MSSM) by summarizing the present state-of-the-art of theoretical predictions for the production cross sections and decay rates.

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1. Introduction

1.1. Organization of the review

In this work we will review all Higgs decay widths and branching ratios as well as all relevant Higgs boson production cross sections at the LHC within the SM and MSSM. Previous reviews can be found in Refs. [1]. This work is a substantial update of Ref. [2].

The paper is organized as follows. This Section 1 will provide an introduction to the SM and MSSM Higgs sectors. In Section 2 we will review the decay rates of the SM and the MSSM Higgs particles providing explicit analytical results of the individual partial decay widths where possible. Section 3 will discuss the production cross sections for the Higgs bosons of the SM and MSSM and the impact of the numerical results on the profile of the Higgs bosons at the LHC. A summary will be given in Section 4.

1.2. Standard model

The discovery of a resonance at the LHC [3] that is compatible with the Standard-Model (SM) Higgs boson [4] marked a milestone in particle physics. The existence of the Higgs boson is inherently related to the mechanism of spontaneous symmetry breaking [5] while preserving the full gauge symmetry and the renormalizability of the SM [6]. Its mass, the last missing parameter of the SM, has been measured to be (125.09 ± 0.24) GeV [4]. The existence of the Higgs boson allows the SM particles to be weakly interacting up to high-energy scales without violating the unitarity bounds of scattering amplitudes [7]. This, however, is only possible for particular Higgs-boson couplings to all other particles so that with the knowledge of the Higgs-boson mass all its properties are uniquely fixed. The massive gauge bosons and fermions acquire mass through their interaction with the Higgs field that develops a finite vacuum expectation value in its ground state thus hiding the still unbroken electroweak gauge symmetry. The minimal model requires the introduction of one weak isospin doublet of the Higgs field and leads after spontaneous symmetry breaking to the existence of one scalar Higgs boson, while non-minimal Higgs sectors predict in general more than one Higgs boson.

Within the SM with one Higgs doublet the Higgs mass is constrained by consistency conditions as the absence of a Landau pole for the Higgs self-coupling up to high energy scales and the stability of the electroweak ground state [8]. If the SM is required to fulfil these conditions for energy scales up to the scale of Grand Unified theories (GUTs) of $\sim 10^{16}$ GeV the Higgs mass is constrained between 129 GeV and about 190 GeV [9]. The last condition of vacuum stability can be relaxed by demanding the life-time of the ground state to be larger than the age of our universe [10]. This reduces the lower bound on the Higgs mass to about 110 GeV [9]. The measured value of the Higgs mass indicates that our universe is unstable with a large lifetime far beyond the age of the universe.

If the SM is extended to the GUT scale, radiative corrections to the Higgs-boson mass tend to push the Higgs mass towards the GUT scale, if it couples to particles of that mass order. In order to obtain the Higgs mass at the electroweak scale the counter term has to be fine-tuned to cancel these large corrections thus establishing a very unnatural situation that requires a solution. This is known as the hierarchy problem [11]. Possible solutions are the introduction of supersymmetry (SUSY) [12,13], a collective symmetry between SM particles and heavier partners as in Little Higgs theories [14] or an effective reduction of the Planck and GUT scales as in extra-dimension models at the TeV scale [15].

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