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Heavy Higgs Line Shape and Interference effects

At LHC, the heavy Higgs searches are carried out in gg H WW l l ,l qq, gg H ZZ llll,ll ,llqq channels. The current searches for a heavy Higgs boson assume on-shell (stable) Higgs boson production. The Higgs boson is then decayed via an ad hoc Breit-Wigner (either fixed-width or running-width scheme) implemented in the MC simulations [1]. Therefore the question remains what is the limitation of narrow Higgs width approximation for decoupling Higgs production and decay, and what is the effect of interference due to large Higgs width with Standard Model (SM) backgrounds.

Recent studies show that the effects due to off-shell Higgs boson production and decay, and due to the interference with the SM backgrounds, may become sizable for Higgs boson masses $m_H > 300$ GeV. The Higgs boson mass line shape is expected to be altered as well [2], [3],[4],. In Ref. [5], [6], the default-scheme (purely Higgs signal cross-section) in iHixs program has been compared to zero-width approximation and Seymour-scheme (improved s-channel approximation which is a prescription based on the resummation of VV VV scattering amplitudes). Seymour-scheme tries to simulate the effects of signal-background interference off the resonant peak. In Figure 6 of Ref. [5], a deviation of default-scheme and Seymour-scheme with respect to the zero-width approximation is observed to be +30% ~ -20% difference in cross-section for $M_H < 600$ GeV. Also in Figure 7, significant distortion of Higgs line shape of Seymour-scheme with respect to the default-scheme is demonstrated, and the effect becomes increasingly important for heavy Higgs. The heavy Higgs line shape has being also studied in the CERN Report 2, Handbook of LHC Higgs cross sections: 2. Differential distributions [7]

Contrary to the narrow-width-approximation in Higgs boson production and decay, now the theory framework in complex-pole-scheme with proper Higgs propagator exists, based on studies reported in [3].

In the SM Higgs case, there are large interference effects with continuum backgrounds in gg->H->WW/ZZ channels, and it is know that the interference is very large for WW case in particular. The interference effect has been studied in Ref.[8], where cross section of gg W^+W^- has been studied for Higgs signal and background diagrams. As shown in Figure 6 of Ref.[4], for $M_H = 120$ GeV, the prediction for the Higgs cross section including interference effects ($_{H,i}$, though non-physical quantity) is 10-15% lower than Higgs diagram only ($_H$). For $M_H > 400$ GeV the interference becomes large and constructive, reaching above +30% for $M_H = 600$ GeV. The effect of the interference has also been studied in [9], [10] and [11].

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