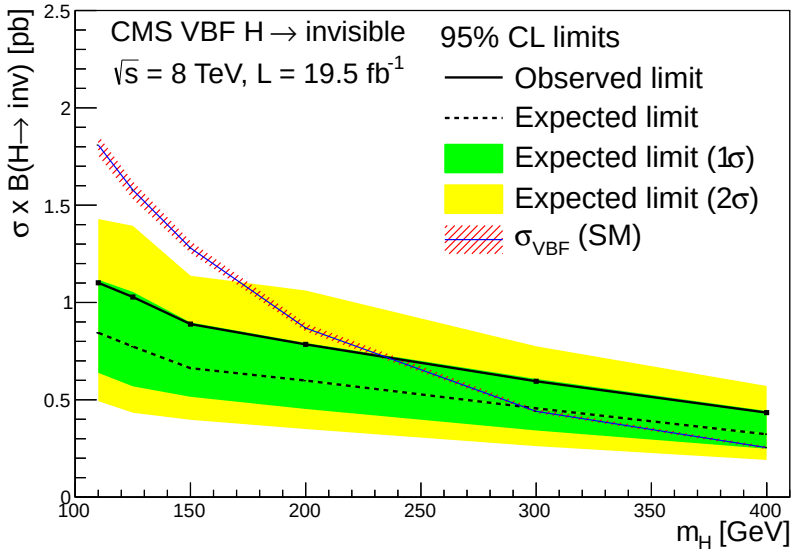
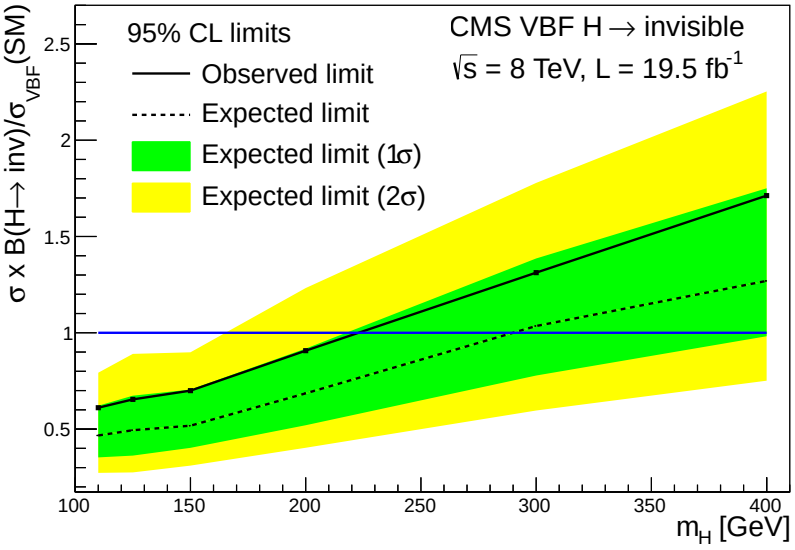
As no excess is observed, the asymptotic CL_S technique, described in Section 1.4, is used to place an upper limit on the production cross-section times branching fraction, $\sigma \times \mathcal{B}$, at 95% CL. Under the assumption of SM production this limit can be interpreted as a limit on $\mathcal{B}(\mathrm{H} \to \mathrm{inv})$. All systematic uncertainties are modelled as log-normally distributed nuisance parameters, with the exception of the statistical uncertainty on the $Z \to \nu\nu$ background, which is modelled as a gamma-normally distributed nuisance due to the low number of events in the dimuon control region. A gamma-normal distribution is used in the case of control regions with low numbers of events because in this case the central limit theorem does not apply so the Poisson probability of observing a certain number of events is very asymmetric; this asymmetry is well modelled by a gamma-normal distribution [102].

The resulting upper limits are shown as a function of Higgs boson mass in Figure 4.12, with the 95% CL observed (expected) limit on $\mathcal{B}(\mathrm{H} \to \mathrm{inv})$ for a 125 GeV Higgs boson being 65% (49%). The green and yellow bands shown in Figure 4.12 denote the one and two sigma uncertainty bands respectively of the expected limit, also calculated using the asymptotic technique. The one (two) sigma band represents the region that the observation is expected to lie in 68% (95%) of the time if the background only hypothesis is true.

This was the first published search for invisibly decaying Higgs bosons in the VBF channel. It can be seen that for all values of Higgs boson mass investigated the observed limit is approximately one sigma above the expected limit. If the measurements of the limit at each Higgs boson mass were not correlated, this could be seen as evidence for an excess. However, as this analysis has only a single bin, and no information on the shape of the event variable distributions is used, the measurements for the different Higgs boson masses are 100% correlated with each other. The analysis therefore sees no significant evidence of non-SM behaviour.



(a)



(b)

Figure 4.12.: Expected and observed 95% CL upper limits on the VBF $\sigma \times \mathcal{B}$ in pb (a) and normalised to the SM VBF Higgs boson production cross-section (b) [1]. The green and yellow bands indicate the 68% and 95% confidence intervals on the expected limit respectively.

Chapter 5.

Search for invisibly decaying Higgs bosons in Run 1 parked data

The parked data, described in Section 2.2.5, used for this analysis was collected using a range of triggers with similar but looser requirements than those used for the prompt data ("prompt") analysis described in the previous chapter. These looser requirements allow areas of phase space which were previously removed by the prompt trigger to be used. However, these areas also have very large QCD backgrounds, and require the analysis selection and some background estimation methods to be redesigned compared to the prompt analysis. As it was reconstructed later the parked data also uses different, better, detector calibrations (such as the jet energy calibrations), calculated with the full Run 1 LHC dataset. The parked data analysis was also carried out using a new code framework, which was fully validated against that used in the prompt analysis. This analysis was made public in Ref. [2].

5.1. Trigger

The triggers used to collect the parked data varied throughout Run 1, due both to the available trigger bandwidth changing, and to the rate of the triggers used varying as the LHC instantaneous luminosity increased during the run. Run 1 was split into 4 "eras": A, B, C and D, with 0.9, 3.9, 7.2 and 7.3 fb^{-1} of integrated luminosity collected in each respectively. During era A data were not parked, so the prompt data are used. The two other triggers used, one for eras B and C, and one for era D, differed from the prompt trigger in that there was no requirement on the $\not\!\!E_{\text{T}}$ present at the HLT level and the jet p_{T} and M_{jj} requirements were looser. The exact values of the trigger selection cuts are