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Search for the $H \to hh \to bb\tau\tau$ and $A \to Zh \to ll\tau\tau$ processes with 8 TeV data in CMS

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Summary. — In this presentation I will report on the search for the heavy boson H decaying to a pair of 125 GeV SM-like Higgs bosons h using the final state of two τ leptons and two b-jets and the search for a heavy boson A decaying to a SM-like Higgs boson h and a Z boson using the final state of two τ leptons and two leptons $\ell\ell$ (ee or $\mu\mu$). The mass range considered in the analysis extends from $m_{A/H} \simeq 250$ GeV up to $m_{A/H} \simeq 350$ GeV. The analysis is performed on a dataset corresponding to an integrated luminosity of $\mathcal{L} = 19.7\,\mathrm{fb}^{-1}$ proton-proton collision data collected in 2012 by the CMS experiment at $\sqrt{s} = 8$ TeV.

1. – Introduction

After the discovery of the 125 GeV particle [1, 2], the observation of additional Higgs bosons at the LHC would provide direct evidence of physics beyond the standard model (SM). There are several types of models that require two Higgs doublets (2HDM) [3], one example is the minimal supersymmetric extension of the SM (MSSM) [4]. This leads to the prediction of five Higgs particles: one light and one heavy CP-even, h and H, one CP-odd A, and two charged $H^{\pm}$. The masses and couplings of these bosons are interrelated and, at tree level, can be described by two parameters, which are often chosen to be the mass of the pseudoscalar boson m_A and the ratio of the vacuum expectation values of the neutral components of the two Higgs doublets $\tan\beta$.

In the mass region below $2m_{top}$ and at low values of $\tan\beta$, the decay mode of the heavy scalar $H \to hh$ and that of the pseudoscalar $A \to Zh$ can have sizeable branching fractions. The choice of τ pair final state is driven by its quite clean signature, the large expected branching ratio and by the most recent results, which show strong evidence for the 125 GeV Higgs boson coupling to fermions [5].

This analysis [6] investigates the low $\tan\beta$ region which has not yet been excluded by the direct or indirect searches for a heavy scalar or pseudoscalar Higgs boson.

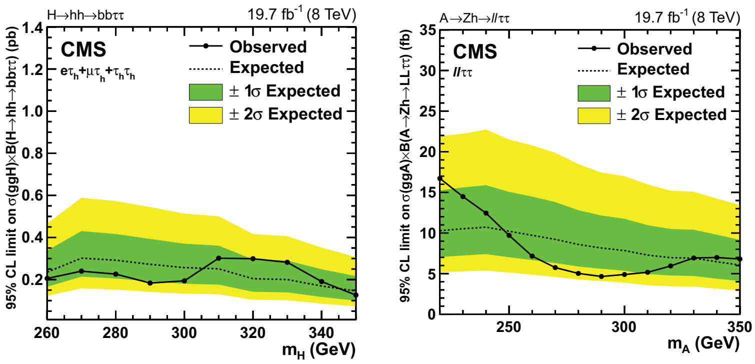

Fig. 1. – Exclusion limits for $H \to hh \to bb\tau\tau$ (left) and $A \to Zh \to \ell\ell\tau\tau$ (right).

2. – Analysis strategy

The analysis strategy is similar for both processes. At first, the events are split in different channels, according to the decay of the τ pair. For the $H \to hh$ process, only three decay channels are considered: $e\tau_h$, $\mu\tau_h$ and $\tau_h\tau_h$, where e/μ stand for the leptonic decay of the τ, while τ_h represents hadronic decays. For the $A \to Zh$ process the decay channels cosidered are $e\tau_h$, $\mu\tau_h$, $\tau_h\tau_h$ and $e\mu$.

For the $H \to hh$ process, each event must satisfy the $\tau\tau$ selection criteria and contain at least two jets with $p_T > 20$ GeV and $|\eta| < 2.4$. This requirement is necessary to further divide events in three categories: 0-tag, 1-tag and 2-tag, depending on the number of jets tagged as b-jets. The further categorisation of $A \to Zh$ events is based on the decay of the Z boson, either $Z \to ee$ or $Z \to \mu\mu$.

Finally, some additional cuts are applied in order to reduce the background contributions. For $H \to hh$, the signal-to-background ratio is greatly improved by selecting events that are consistent with a mass of 125 GeV for both the di-jet (m_{bb}) mass and the di-tau mass ($m_{\tau\tau}$): the mass windows correspond to $70 < m_{bb} < 150$ GeV and $90 < m_{\tau\tau} < 150$ GeV. For $A \to Zh$, a requirement on L_T^h, which is the scalar sum of the visible transverse momenta of the two τ candidates, is applied to lower the background contribution from ZZ production; moreover, the invariant mass of the two leptons coming from the Z decay must be between 60 and 120 GeV.

The signal extraction is performed through a binned maximum-likelihood fit to the invariant mass of the heavy bosons A/H. The mass m_H is reconstructed using a kinematic fit, which takes as input the 4-momenta of the four bodies ($\tau\tau bb$) and the missing transverse energy and imposes kinematic constraints requiring $m_{\tau\tau} = m_{bb} = m_h = 125$ GeV. The mass of the A boson is estimated from the 4-vectors information of the intermediate bosons: the Z boson is reconstructed from the $ee/\mu\mu$ momenta; the h boson is reconstructed through the SVFit algorithm [7].

3. – Results

In neither search the invariant mass spectra show any evidence of a signal, thus model independent upper limits at 95% confidence level (CL) are set on the parameter of interest $\sigma \times BR$ for the $H \to hh \to bb\tau\tau$ and $A \to Zh \to \ell\ell\tau\tau$ processes, fig. 1.

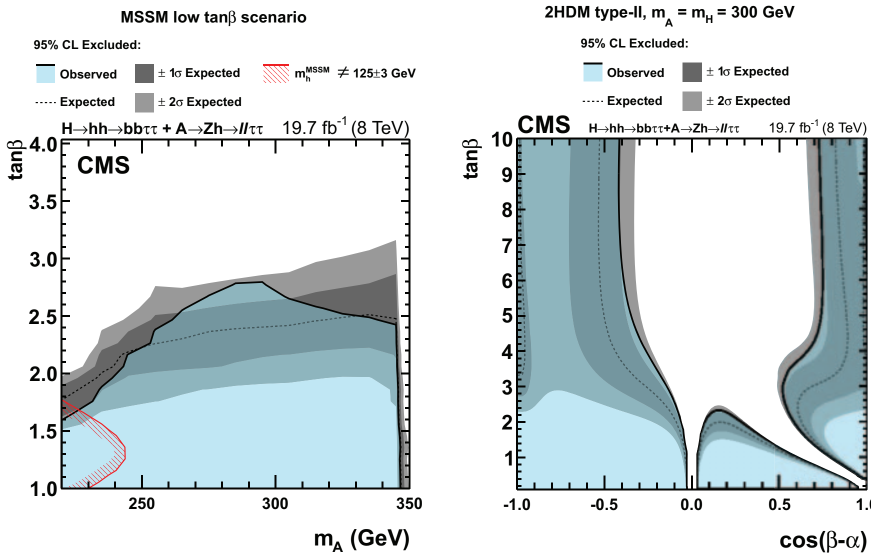

Fig. 2. – Interpretation of the exclusion limits in the *low* $\tan\beta$ MSSM scenario (left) and in a Type-II 2HDM model (right).

Exclusion limits are determined using the CLs method [8], where systematic uncertainties are taken into account as nuisance parameters, profiled in the fit procedure.

The observed limits on cross section times branching fraction can be interpreted in the MSSM and 2HDM frameworks, as shown in fig. 2. Especially, this analysis proves to be powerul in the investigation and exclusion of low $\tan\beta$ regions in the mass range between 250 and 350 GeV.

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