Search for a high-mass scalar in the $ZZ \to \ell^+\ell^-$+missing transverse energy final state

Hugo Delannoy on behalf of the CMS collaboration

Search for $H \to ZZ \to \ell^+\ell^-\nu\bar{\nu}$

Characteristics:

- High branching ratio: $BR(ZZ \to 2\ell 2\nu) \sim 6 \times BR(ZZ \to 4\ell)$
- Reduced background at high M_{ZZ}: better control than $ZZ \to 2\ell 2q$

Signal modelling is computed with interference with the SM Higgs for several mass points :

- $gg \to H$
- $qq \to H + 2jets$ (VBF)

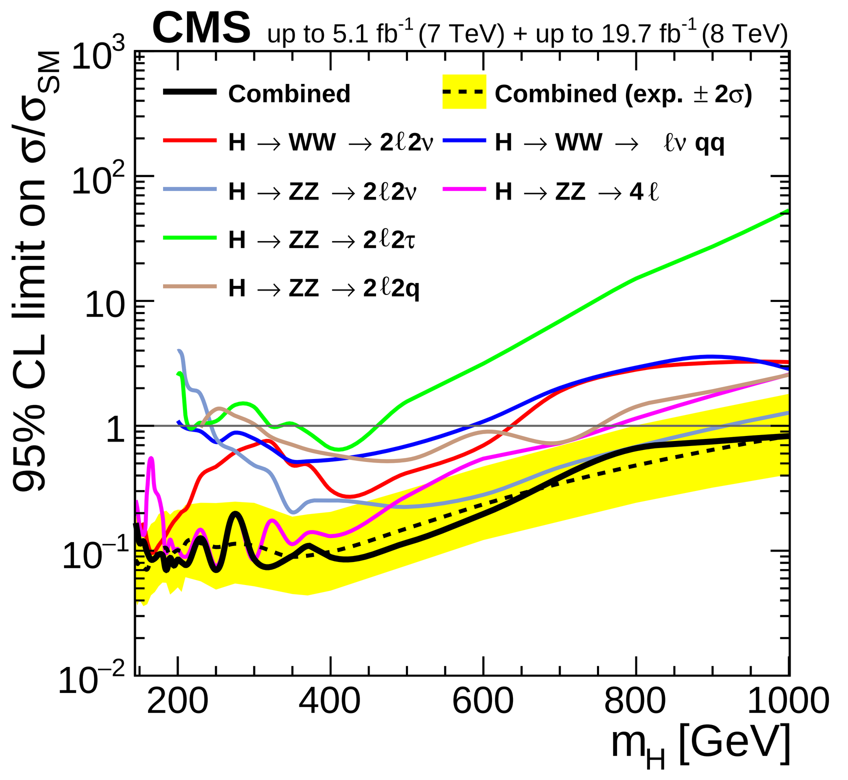
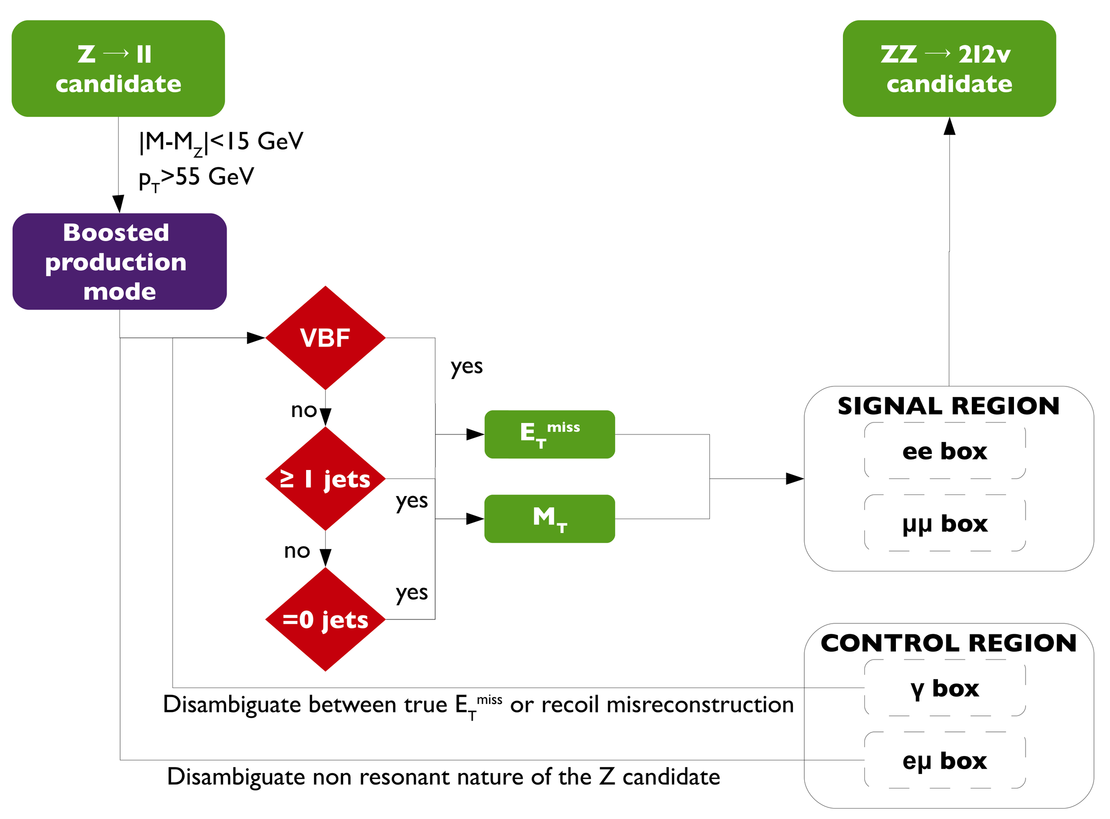


Figure 1: Limits on $H \to VV$ production from run 1 [1]

Search for a narrow resonance in two types of interpretations:

- Extra Singlet Model: new electroweak scalar singlet H mixing with the SM scalar h(125):
  - couplings of h and H rescaled by C and C', such as: $C^2 + C'^2 = 1$
  - $\mu' = C'^2(1 - B_{new})$, $\Gamma' = \Gamma_{SM} \frac{C'^2}{1-B_{new}}$
- 2 Higgs Doublet Model

Event selection



Pre-selection:

- di-lepton trigger
- $\geq 2e$ or $\geq 2\mu$
  - $p_T > 25\,\text{GeV}$
  - $|\eta| < 2.5(e)/2.4(\mu)$
  - tight ID
  - tight Iso
  - $|M_{\ell\ell} - 91| < 15\,\text{GeV}$
- $p_T^Z > 55\,\text{GeV}$
- 3^{rd} lepton veto
- b-tag veto
- $\Delta\phi_{j,\text{MET}} > 0.5$ for $p_T^j > 30\,\text{GeV}$

Drell-Yan background estimation

We use data-driven method to estimate this background. This allows us to take into account the fake MET due to the misreconstruction of jets in Drell-Yan events and to check/correct the simulation. Therefore, we need a process with:

- independent events
- with more statistics

We take $\gamma + jets$ events. To that extent, dedicated photon triggers have been set.

An important point of this process is the reweighting of the p_T^γ to match the p_T^Z.

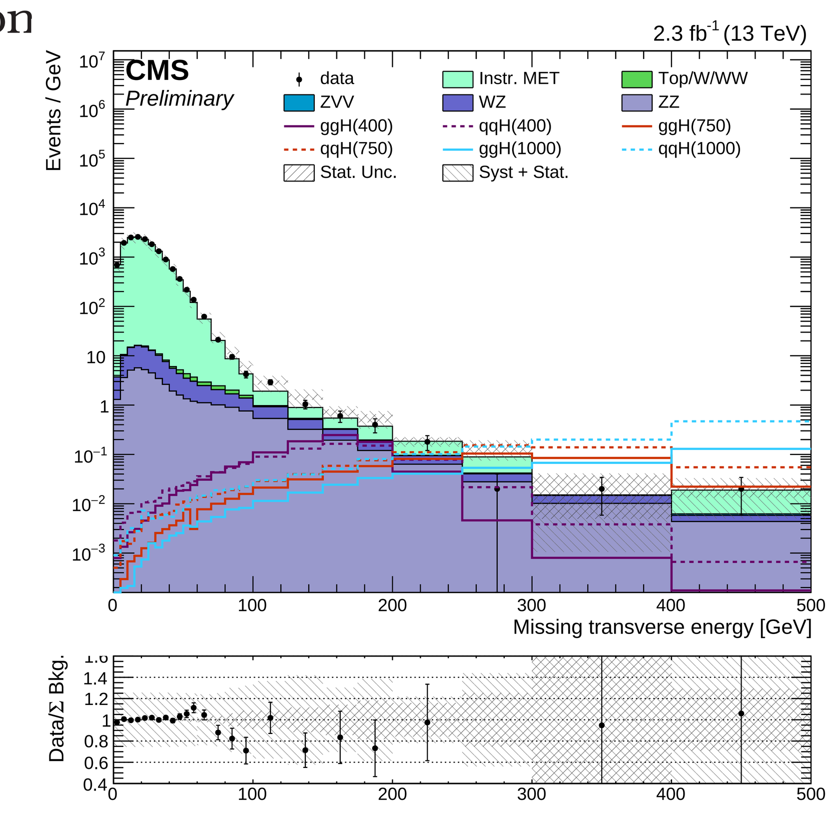


Figure 2: Missing transverse energy. [2]

Non-resonant background estimation

The non-resonant di-lepton background is also estimated using data-driven methods, based on the $e\mu$ final state.

$$N_{\mu\mu} = \alpha_\mu \times N_{e\mu}, \qquad N_{ee} = \alpha_e \times N_{e\mu}$$

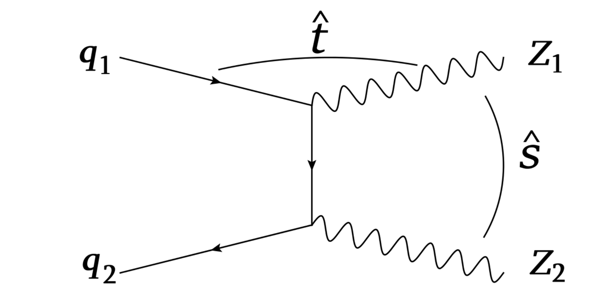
$$\text{with} \quad \alpha_\mu = \frac{N_{\mu\mu}^{SB}}{N_{e\mu}^{SB}}, \qquad \alpha_e = \frac{N_{ee}^{SB}}{N_{e\mu}^{SB}}$$

The N^{SB} are the numbers of events in a top-enriched sample of e^+e^-, $\mu^+\mu^-$ and $e^\pm\mu^\pm$ where we asked $E_T^{\text{miss}} > 70\,\text{GeV}$, b-tagged events and events in the sidebands : $40\,\text{GeV} < M_{\ell\ell} < 70\,\text{GeV}$ or $110\,\text{GeV} < M_{\ell\ell} < 200\,\text{GeV}$

Precise modeling of the ZZ background

The ZZ represents our most important irreducible background. Therefore, precise modelling is done:

- $qq \to ZZ$:
  - NLO electroweak corrections as a function of Mandelstam variables and quark flavors
  - NNLO QCD corrections as a function of M_{ZZ}
- $gg \to ZZ$:
  - NNLO/LO k-Factor as a function of M_{ZZ}



$\hat{s} = (p_{q_1} + p_{q_2})^2 = (p_{Z_1} + p_{Z_2})^2$
$\hat{t} = (p_{q_1} - p_{Z_1})^2$

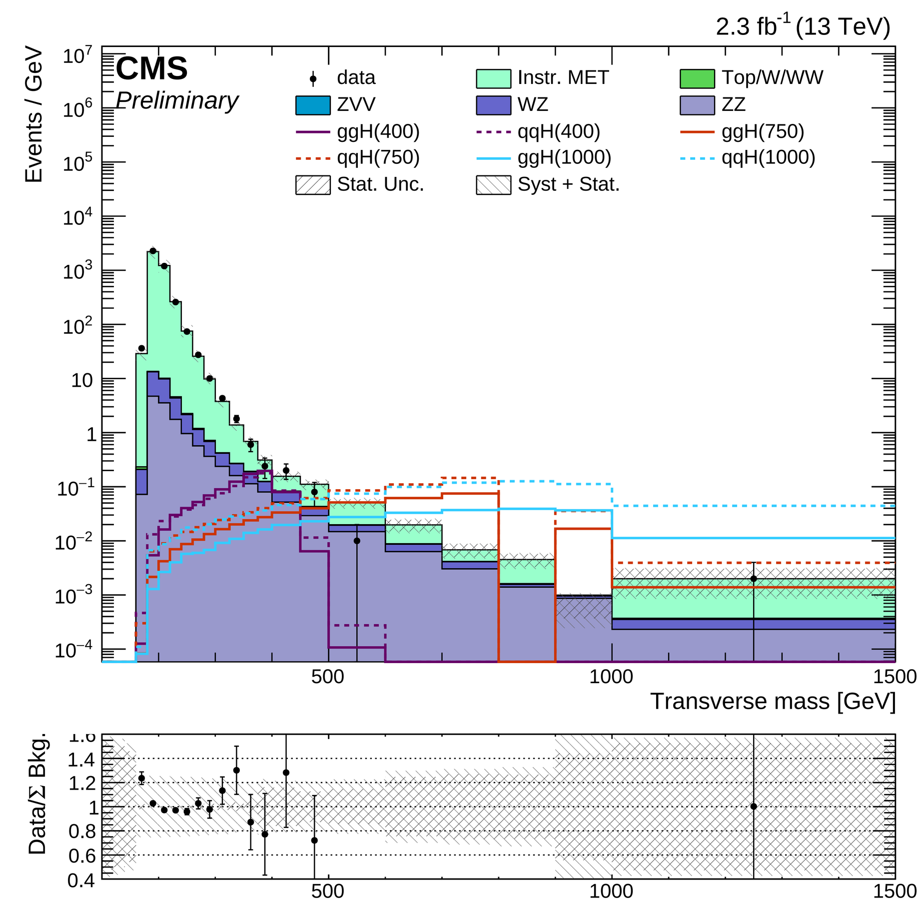


Figure 3: Transverse Mass after event selection [2]

First results at 13 TeV for $2.3 fb^{-1}$

This search for a heavy scalar has been performed using a data sample corresponding to an integrated luminosity of $2.3 fb^{-1}$ at 13 TeV. The Figure 4 shows the M_T distributions in our different production modes: the gluon-fusion (the 0-jets and ≥ 1 jet) and VBF categories correspondingly. The top row plots shows the ee channel, while the bottom row is for the $\mu\mu$ selection.

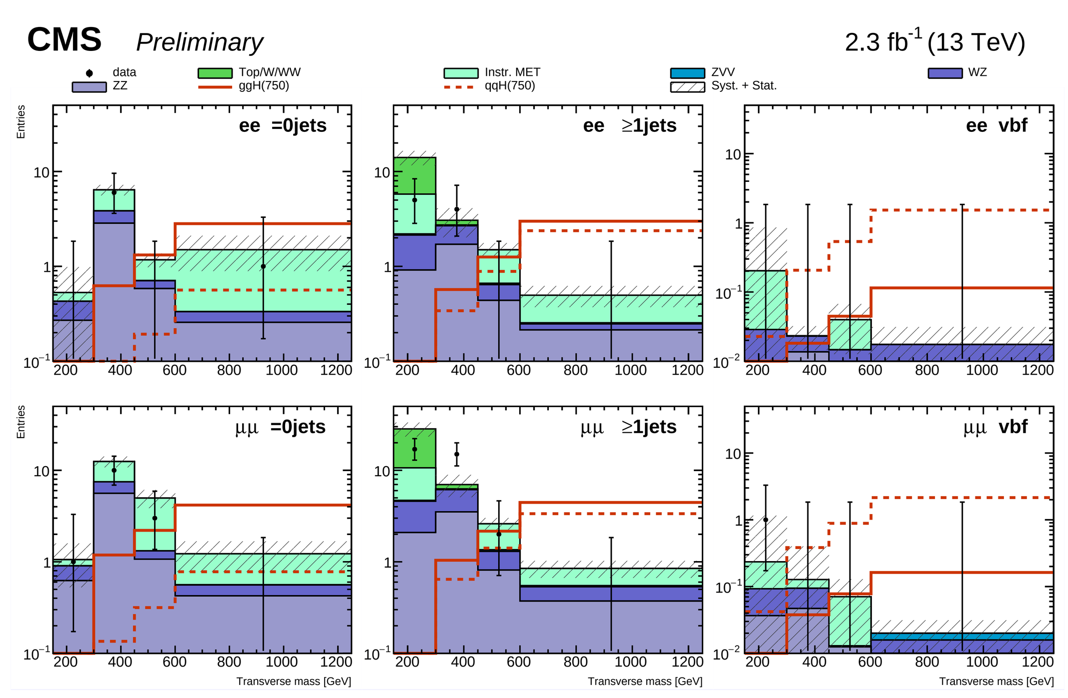


Figure 4: Final M_T distributions. [2]

The distributions correspond to a 750 GeV scalar of 250 GeV width scenario. The data show no particular deviation from the SM background predictions. Therefore limits have been derived on the production cross section of a heavy scalar. We interpret those in the case of ESM (see Figure 5) and 2HDM models.

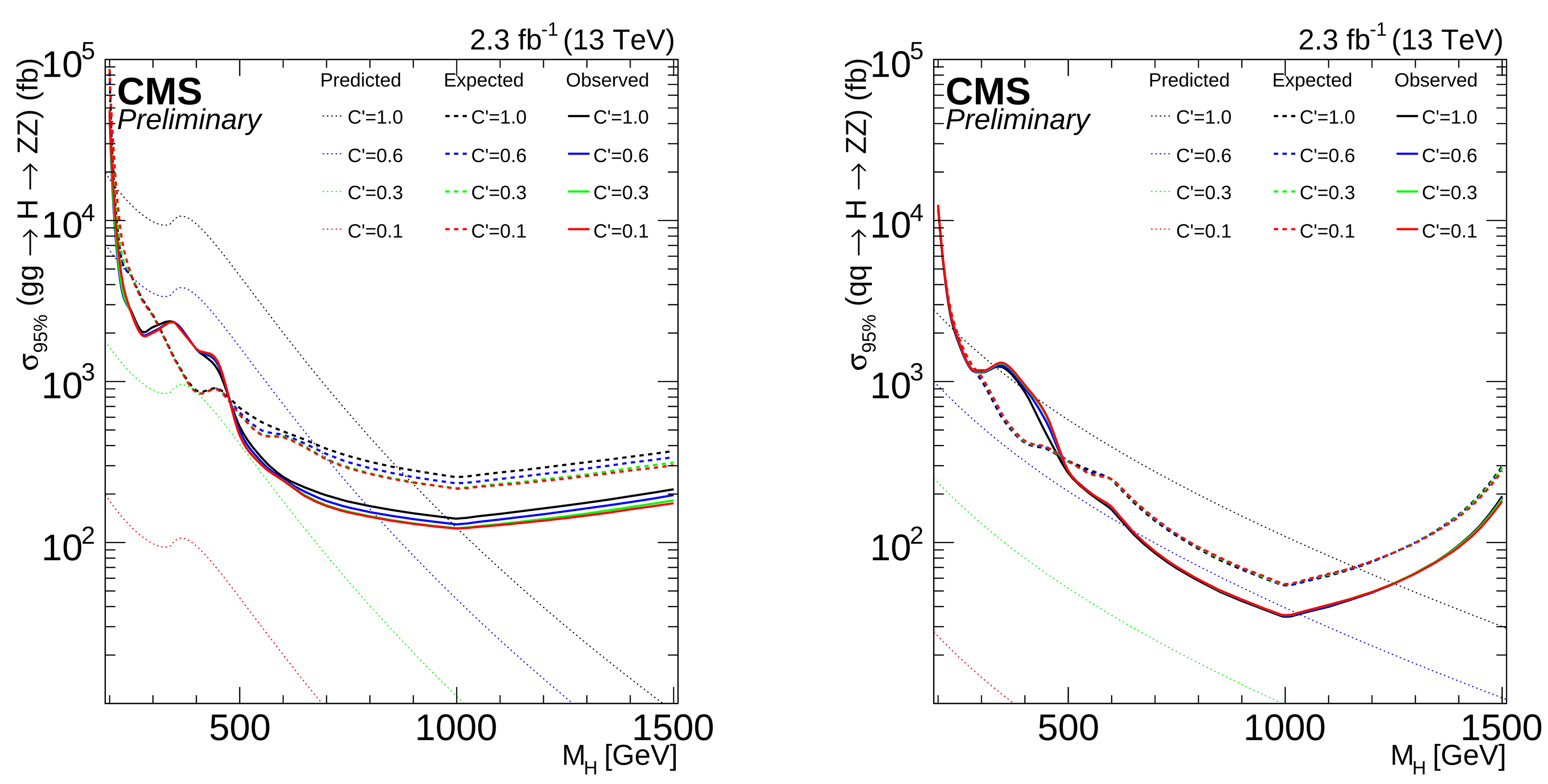


Figure 5: Upper limits at 95% CL set on the gluon-fusion (left) and VBF (right) production cross sections of a heavy scalar as function of its mass under the hypothesis that $B_{new} = 0$ and for various values of the mixing parameter C' [2].

References

[1] CMS collaboration. Search for a Higgs Boson in the Mass Range from 145 to 1000 GeV Decaying to a Pair of W or Z Bosons. *arXiv:1504.00936*, 2015.

[2] CMS collaboration. Search for a heavy scalar boson decaying into a pair of Z bosons in the 2ℓ2ν final state. *HIG-PAS-16-001*, 2016.