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Searches for a high-mass Higgs boson in the ZZ and WW decay channels with the CMS detector

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Outline of the talk

- Motivation of the search
- Decays into WW:

  $\Rightarrow WW \to l\nu l\nu$ final state

  $\Rightarrow WW \to l\nu j(j)$ final state

- Decays into ZZ:

  $\Rightarrow ZZ \to 4l$ final state

  $\Rightarrow ZZ \to ll\nu\nu$ final state

  $\Rightarrow ZZ \to llj(j)$ final state

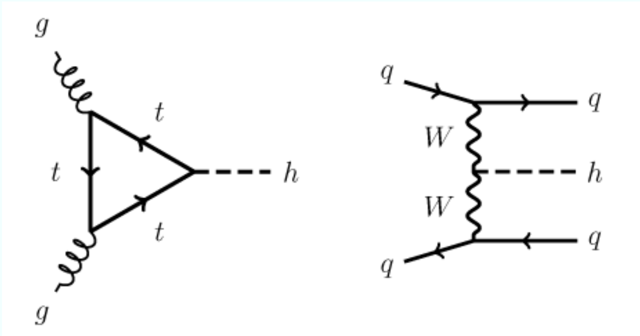
- Combination of the results and conclusions

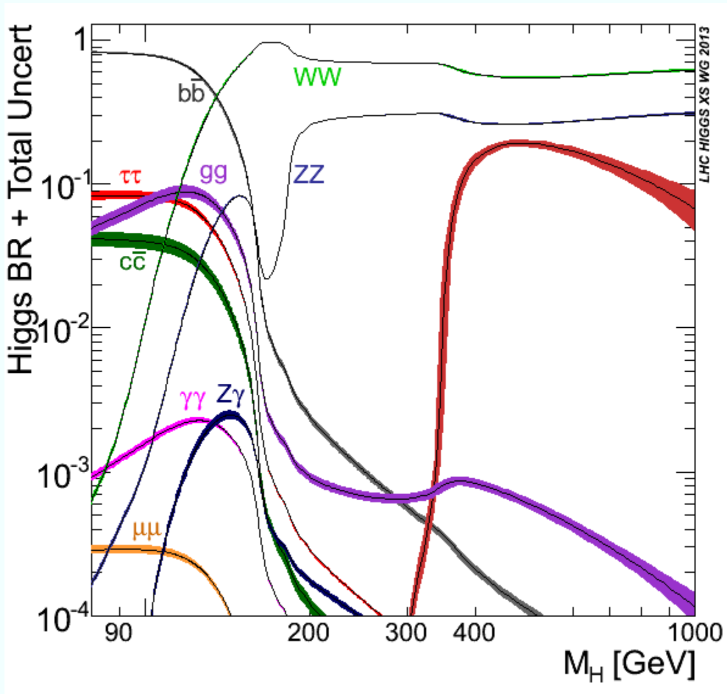
Motivation of the search

- A candidate for the SM Higgs boson has been found at 125 GeV... see other talks in the session!!!

Now searching for similar Higgses at higher masses

- Searches with the SM parameters as “benchmark“ reference.
- Unrealistic due to $h(125)$ but reasonable approach.
- Characteristics:
  - $\Rightarrow$ Diboson (ZZ/WW) decays are dominant (and motivated by EWKSB).
  - $\Rightarrow$ Main production channels (ggH, VBF).





- Another model that we are using is the so-called “EWK-singlet”.

The EWK singlet model (in a nutshell)

- Addition of an EW singlet field to the SM scalar sector, acquiring a non-zero vacuum expectation value.
- Providing a possible answer to the problem of the dark matter.
- Two mixing CP-even states:
  - Light state is the $h(125)$.
  - Heavy state is still to be found, but similar to the SM.
- Properties of the Higgs are modified accordingly to the following expressions:

Light state	Heavy state
$\sigma_h \times BR_h = C^2 \times \sigma_{SM} \times BR_{SM}$	$\sigma_H \times BR_H = C'^2 \times (1 - BR_{\text{new}}) \times \sigma_{SM}$
$\Gamma_h = C^2 \times \Gamma_{SM}$	$\Gamma_H = \frac{C'^2}{(1-BR_{\text{new}})} \times \Gamma_{SM}$
$\mu_h = \frac{\sigma_h \times BR_h}{\sigma_{SM} \times BR_{SM}} = C^2$	$\mu_H = C'^2 \times (1 - BR_{\text{new}})$

being BR_{new} a value to account for possibles new decays of the heavy state (e.g. $H \to hh$).

Higgs in the leptonic $WW \to l\nu l\nu$ channel

- Cleanest channel for $H \to WW$ that is investigated in all possible forms:
  - $\to$ In bins of jet multiplicities
  - $\to$ In main modes: ggH and VBF
  - $\to$ Also ZH and WH (even semileptonic)
- Kinematic differences exploited to maximize sensitivity.
- High-mass coverage independent of mass (up to 600 GeV).
- All results and combination available in

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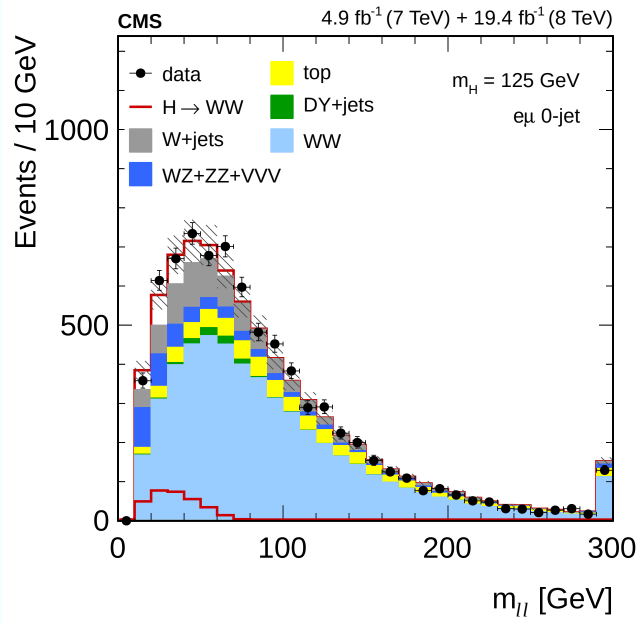
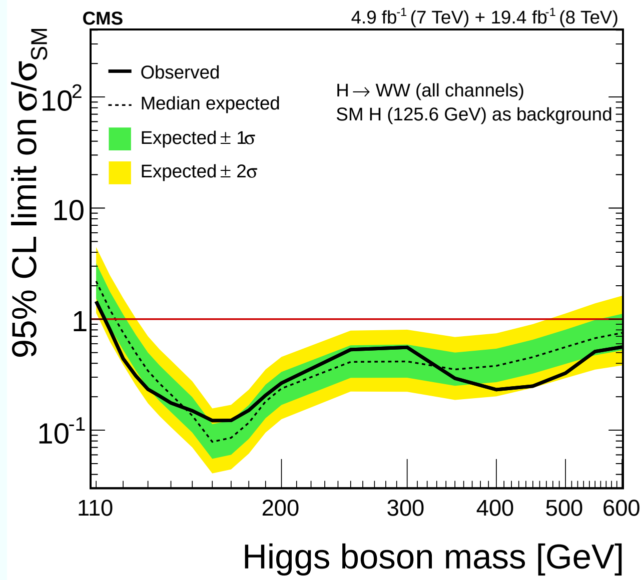
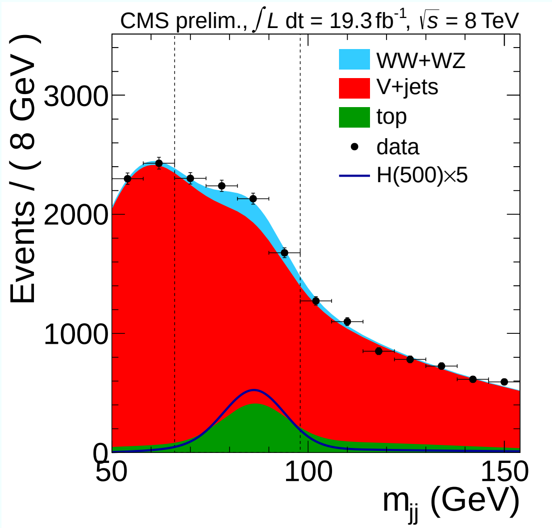
(See also talk by Pietro Govoni yesterday)

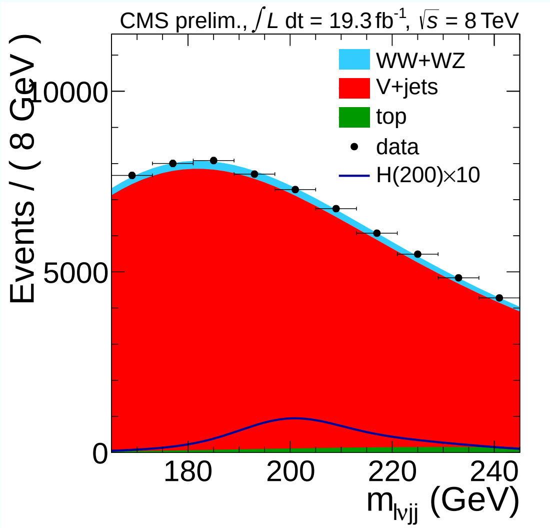




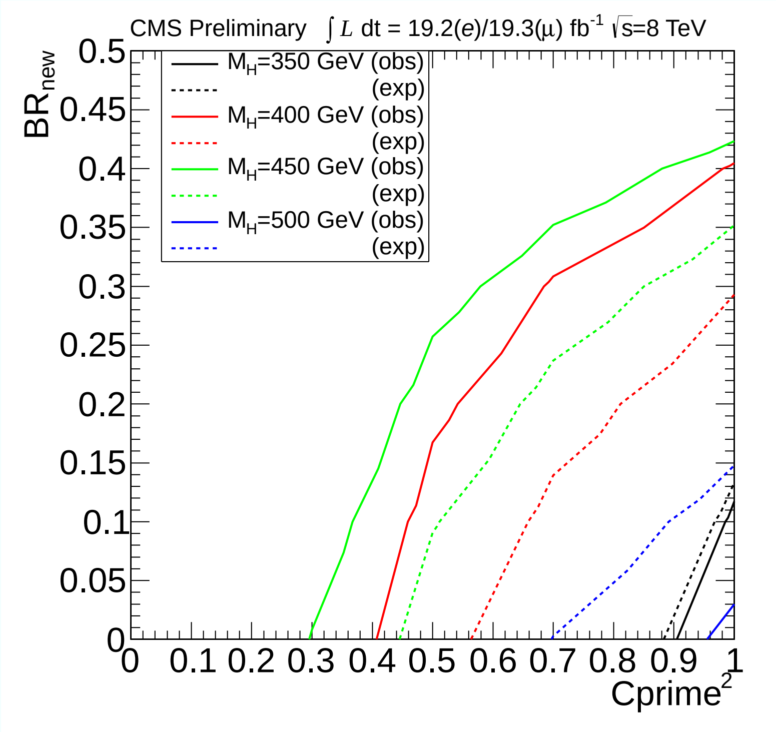
The semileptonic WW ($H \to WW \to l\nu jj$)

- To gain sensitivity at high masses, using W hadronic decays.
- $m(W[l\nu])$ constraint for complete WW mass ($m(W) \to p_{z,\nu}$).
- Using dijet mass to reduce QCD-induced background!





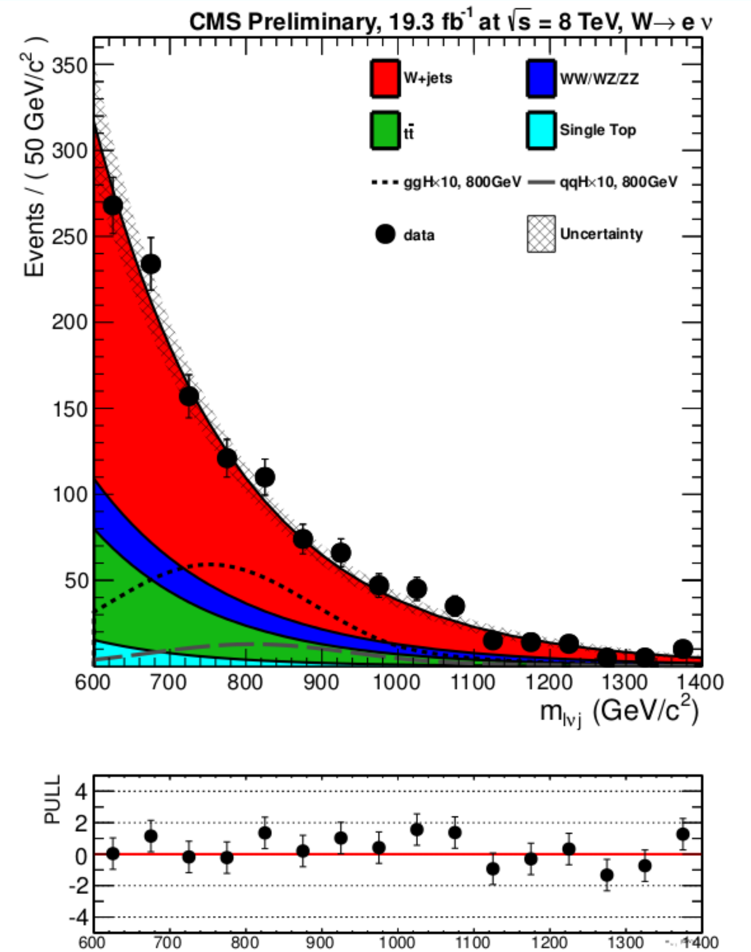
- Shape analysis of $m(WW)$ to look for resonance and extract limit.
- Results interpreted for SM-like Higgs and EWK singlet model.



- NEW Result! (see CMS PAS HIG-13-027)

Boosted-jet topology: $H \to WW \to l\nu J$

- To reach higher masses, need to take into account that the bosons are boosted and their decay products get merged.
- Specific reconstruction needed for going beyond 600 GeV.



Large-radius jets (CA8)

↓

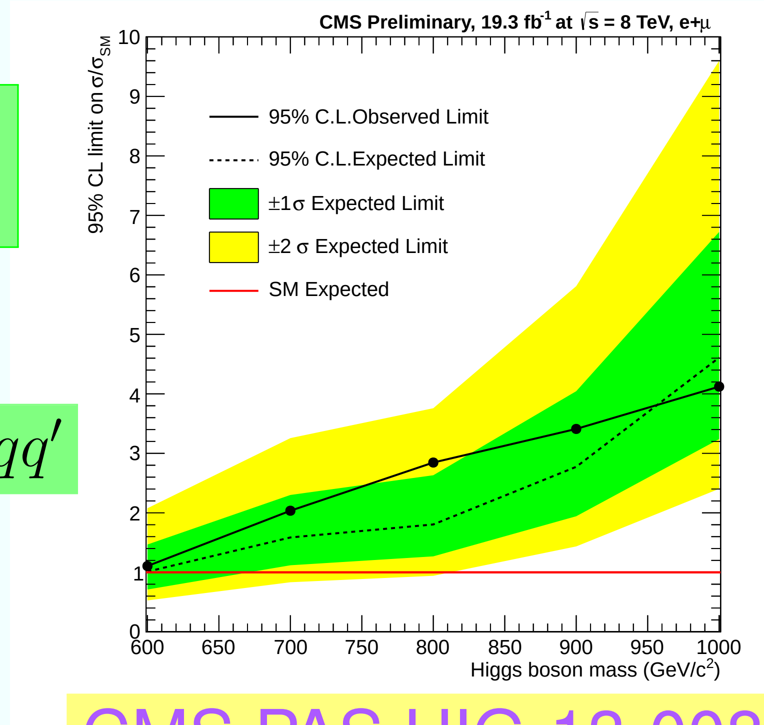
Internal topology (subjets)

↓

Identify jet as $W \to qq'$

↓

High sensitivity!!!



CMS PAS HIG-13-008

Higgs in the ZZ decay

- Decay to ZZ is studied in addition to WW.
- The cleanest fully-leptonic decay provides one golden channel to study the particles decaying to ZZ.
- Sensitive to the $h(125)$ but also to resonance at higher masses.
- All possible channels and production modes studied
- High precision achievable with this channel: simple background.
- Statististically limited, so will improve a lot in Run 2 (including high-mass resonances).
- Also including $ll\tau\tau$ channel.

More information about these final states on specific talks.

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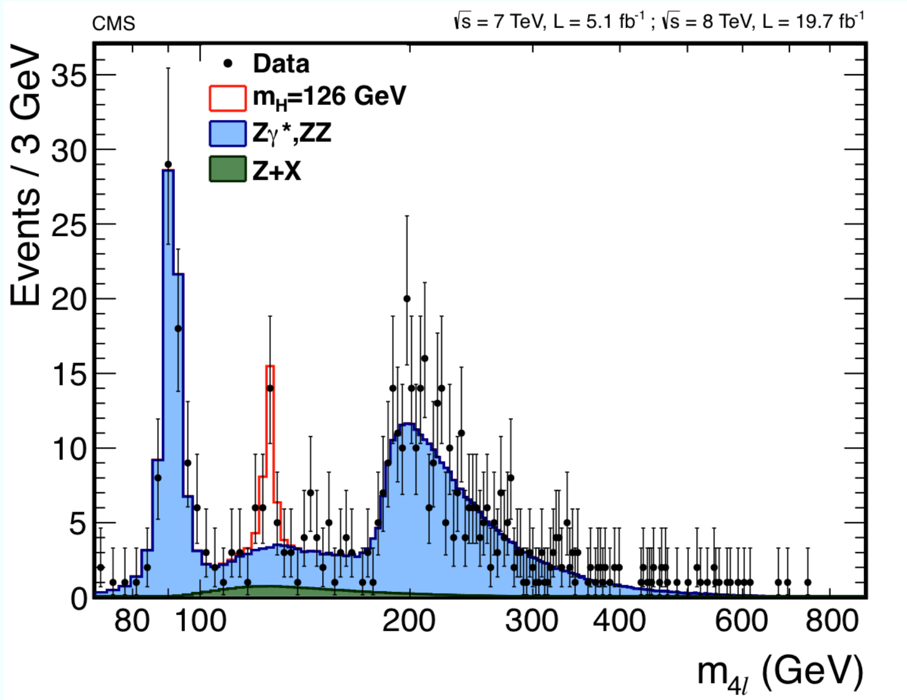
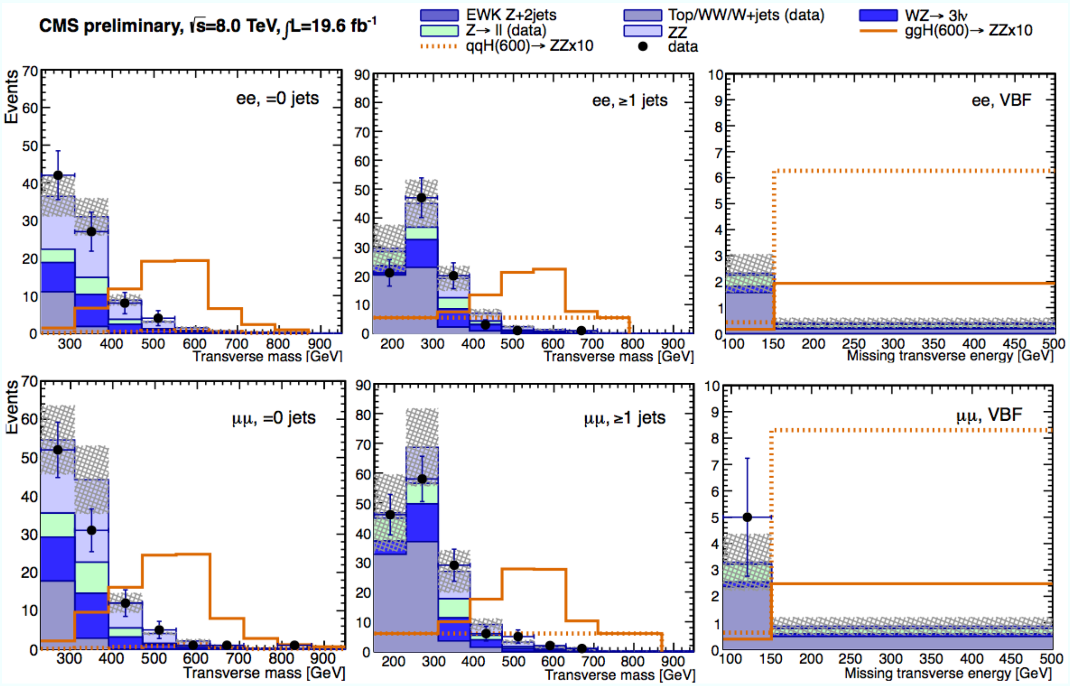


The ZZ dilepton channel: $H \to ZZ \to ll\nu\nu$

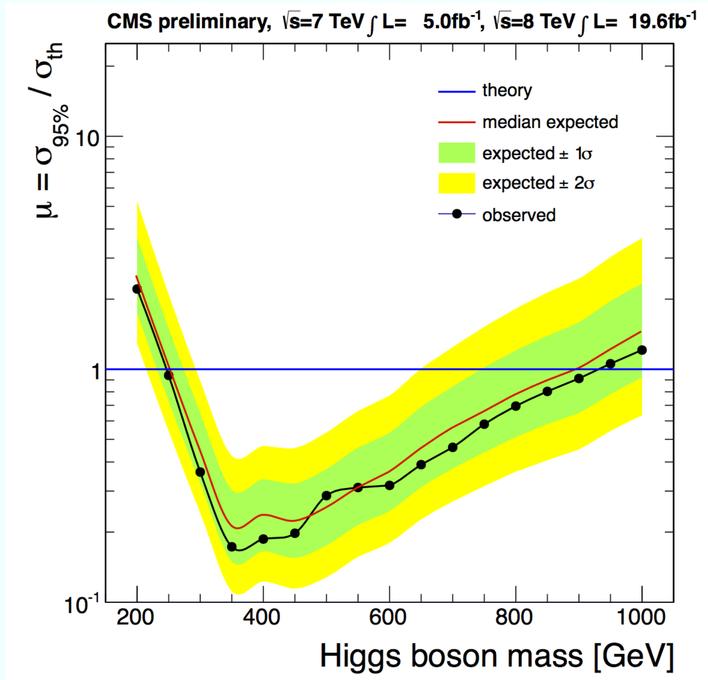
When going to higher masses the weight of the BR becomes larger, and the cleanest channel ($4l$ and $ll\tau\tau$) loses relevance.

- The most relevant gains a factor > 2 with the neutrino decay.
- Also the topology (boosted Z from very massive object) benefits this final state.

Most sensitive channel for $X \to ZZ$ at the high end

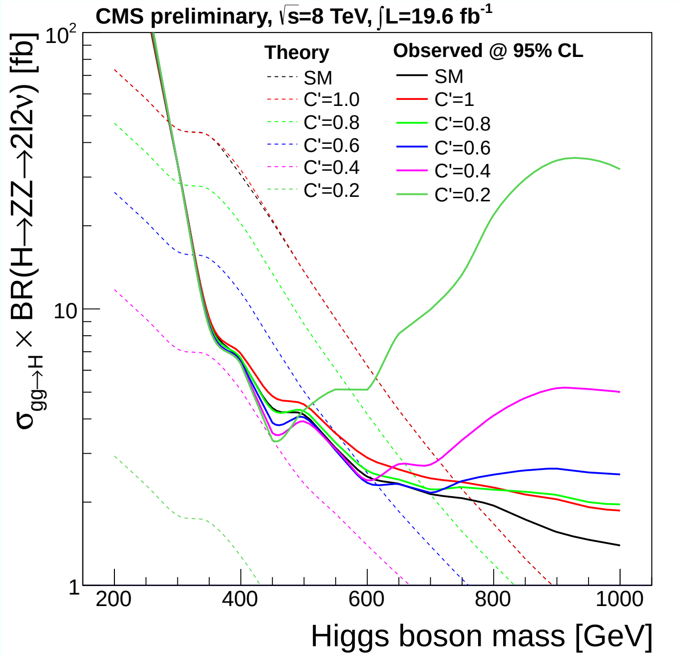


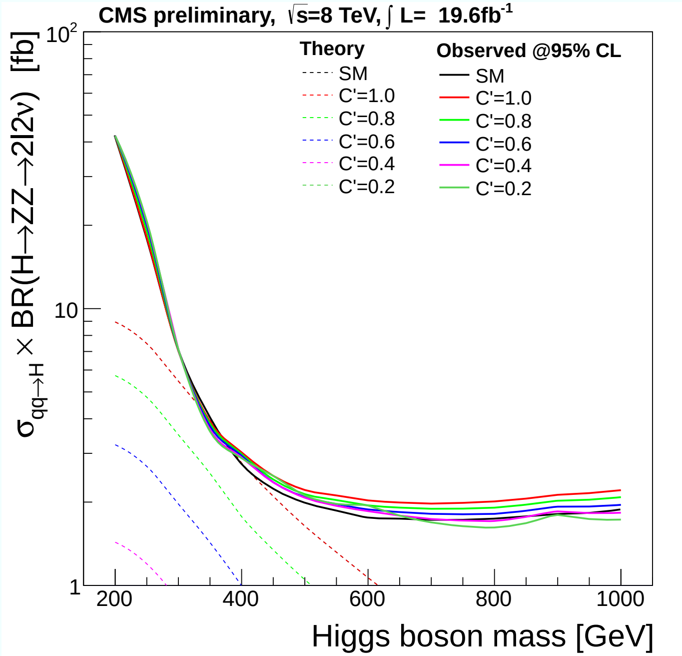
CMS PAS HIG-13-014

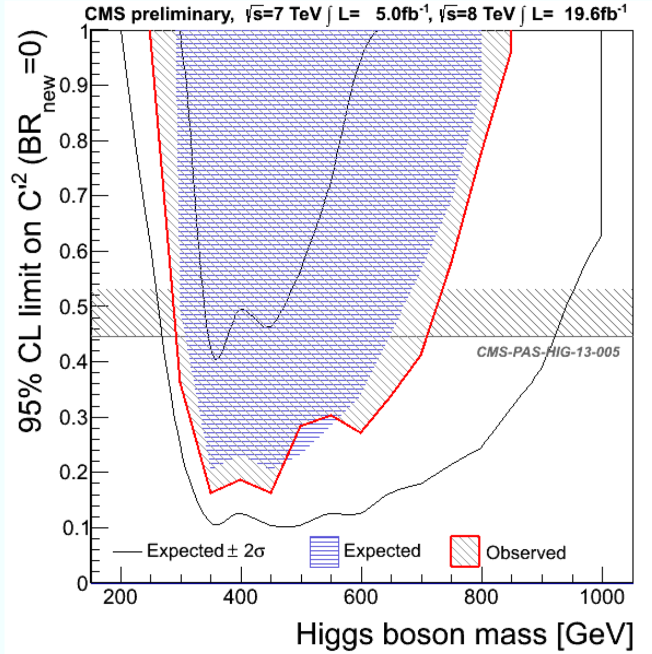


$H \to ZZ \to ll\nu\nu$: EWK singlet interpretation

- Results are also interpreted in the EWK singlet model.
- Multiparameter space: m_H, C'^2 and $BR_{\rm new}$







- It should be noted that there are large correlations with how much SM-like is the $h(125)$.
- e.g. $\mu_h \to 1$ implies less sensitivity to H (excluded high C'^2).

The ZZ semileptonic decay: $H \to ZZ \to lljj$

- As the W, Z decays mostly to hadrons.
- The semileptonic channel allows to get a high yield but with a huge background.

but the full final state is reconstructed:

$\Rightarrow$ Mass fully reconstructed.

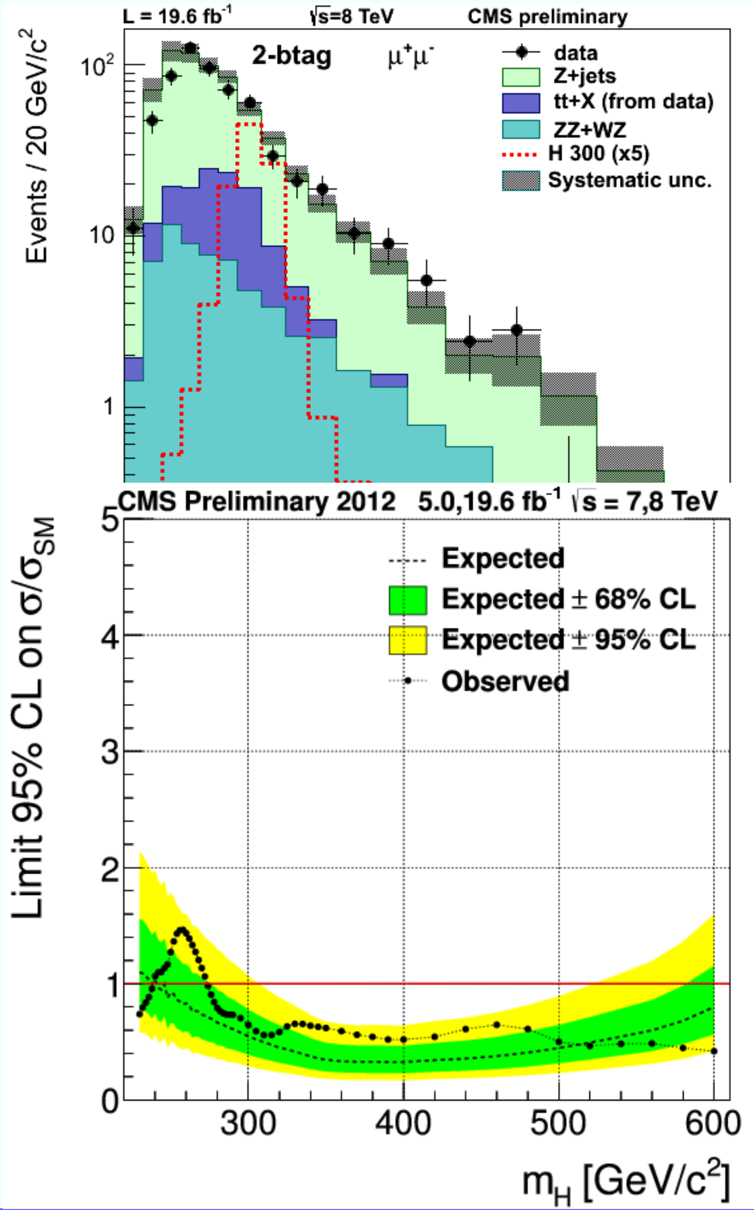
$\Rightarrow$ Discrimination using angular variables for spin-0 candidates.

$\Rightarrow$ Exploiting b-tagging ($Z \to b\bar{b}$)

It is a difficult final state due to the jets, that complicates the extension of the main search to high masses (merged jets) or VBF.

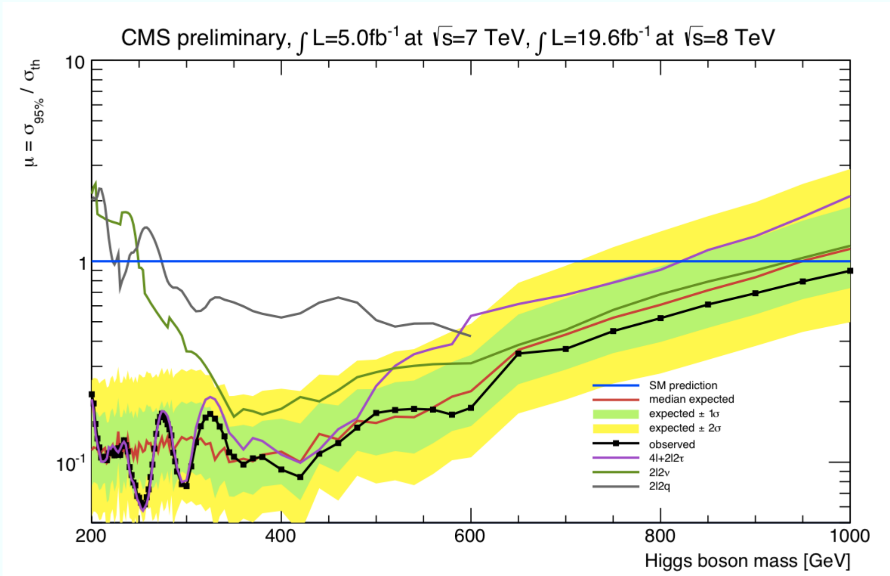
- Still nice sensitivity for medium masses.
- Working on extensions right now!

CMS PAS HIG-12-024



Combination, conclusions and prospects

- All the previous results are being combined for the global limit.
- Expecting very high sensititivity and complementarity due to the variety of channels.
- Last $H(ZZ)$ combination shows those are achievable:



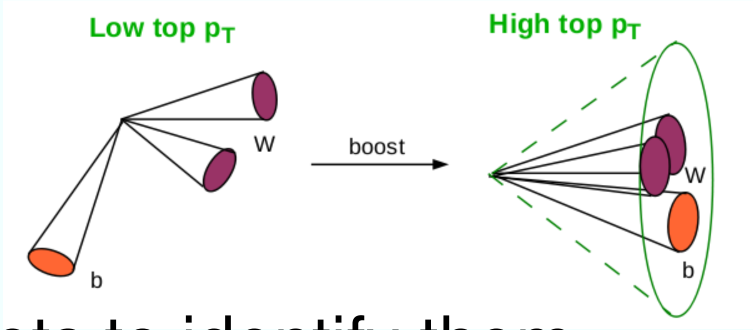
- Reinterpreting the data as a search for EWK singlet.
- Now completing the results and obtaining final combination.

CMS Run-I publication of these searches soon!!!

BACKUP SLIDES

Boosted jets and boson tagging

- The large energy available at the LHC allows a large cross section to the production of high-p_T "massive" objects.
- "Boosted" in the detector frame.
- Similar effect from the decays of very heavy particles decaying to W, Z, t.



- Need of a new aproach for leptons and jets to identify them.
- For jets using characteristics of the internal structure (subjets) and specific kinematic reconstructions (mass-drop, pruning, . . .)
- Standard&Common use for

W-tagging: see CMS PAS JME-13-006

top-tagging: see CMS PAS JME-13-007