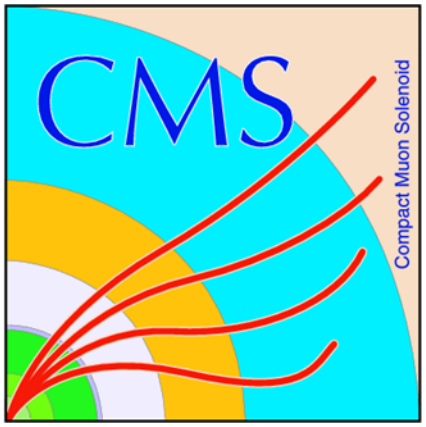
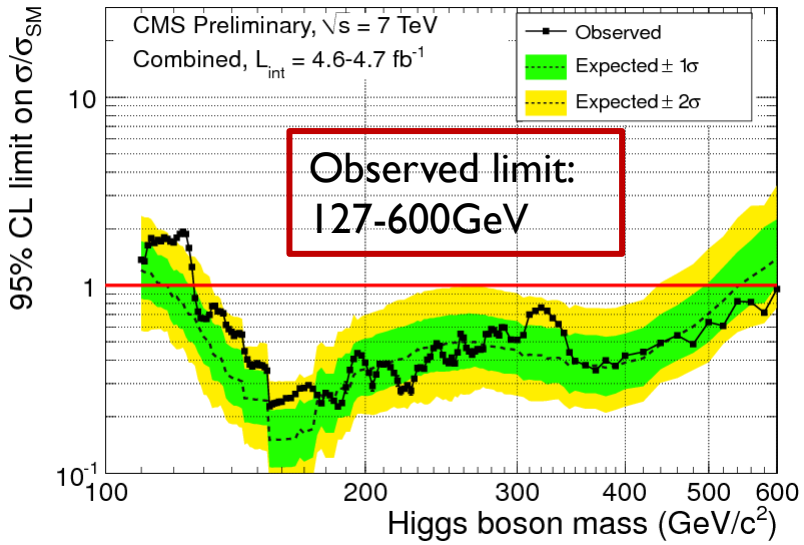


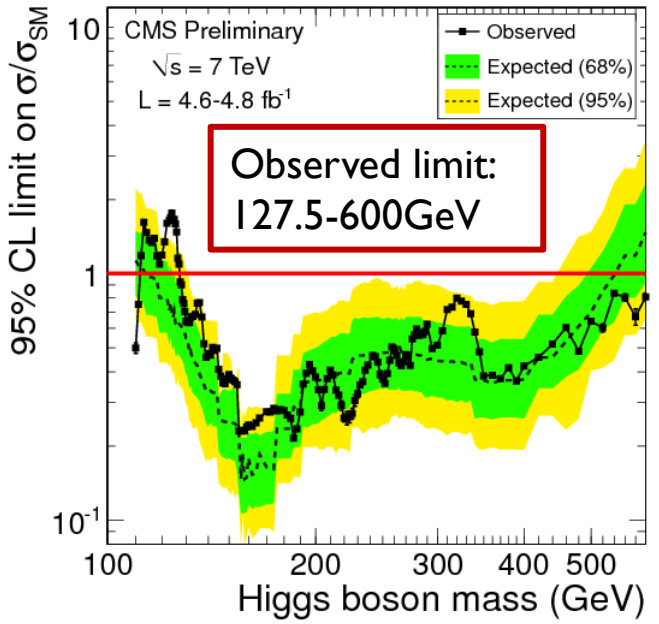
Latest Higgs results from CMS

Agni Bethani (DESY/KIT)
LHC Discussions 19/03/2012

SM Higgs at CMS

- Moriond 2012
  - Higgs search in the mass range 110-600 GeV
  - Data analysed correspond to 4.6-4.8 fb^{-1}
  - Expected limit: 114.5 – 543 GeV at 95% CL
    - (last expected limit was 117 – 543 GeV)





Higgs decay channels

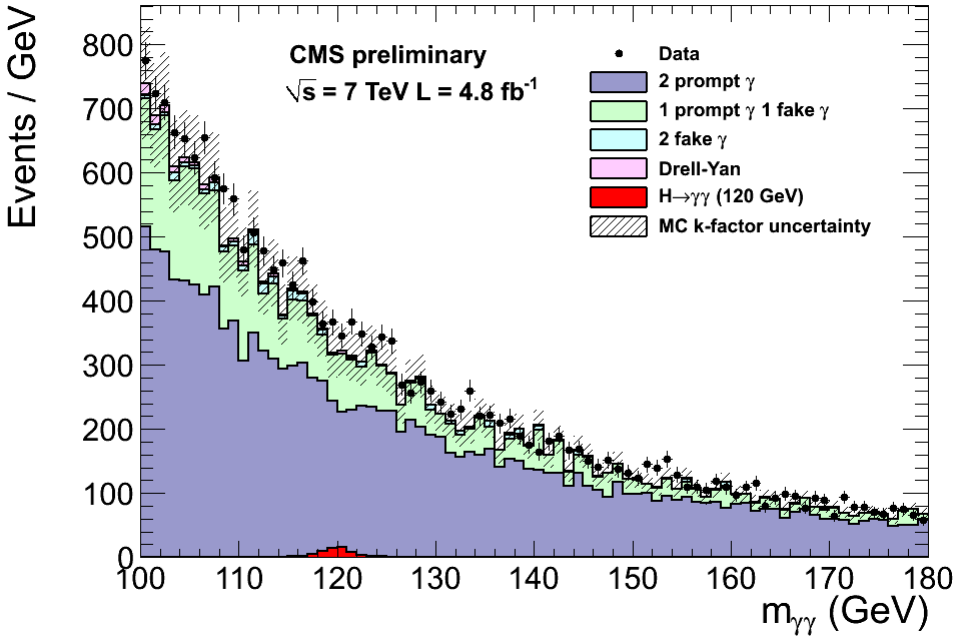
Channel	m_H range (GeV)	Luminosity (fb^{-1})	Sub-channels	m_H resolution	Comment
$H \to \gamma\gamma$	110–150	4.8	2	1–2%	updated
$H \to \gamma\gamma$ (fermiophobic)	110–150	4.8	4	1–3%	new
$H \to \tau\tau \to e\tau_h/\mu\tau_h/e\mu + X$	110–145	4.6	9	20%	unchanged
$H \to \tau\tau \to \mu\mu + X$	110–140	4.5	3	20%	new
$WH \to e\mu\tau_h/\mu\mu\tau_h + \nu$'s	100–140	4.7	2	20%	new
$(W/Z)H \to (\ell\nu/\ell\ell/\nu\nu)(bb)$	110–135	4.7	5	10%	unchanged
$H \to WW^* \to 2\ell 2\nu$	110–600	4.6	5	20%	unchanged
$WH \to W(WW^*) \to 3\ell 3\nu$	110–200	4.6	1	20%	new
$H \to ZZ^{(*)} \to 4\ell$	110–600	4.7	3	1–2%	unchanged
$H \to ZZ \to 2\ell 2\nu$	250–600	4.6	2	7%	unchanged
$H \to ZZ^{(*)} \to 2\ell 2q$	130–164 200–600	4.6	6	3% 3%	unchanged
$H \to ZZ \to 2\ell 2\tau$	190–600	4.7	8	10–15%	unchanged

DESY/ KIT

- 11 independent channels combined in the SM search
- Exclusion limits also calculated for the SM4 and fermiophobic Higgs;
  - Dedicated search by the H→γγ group

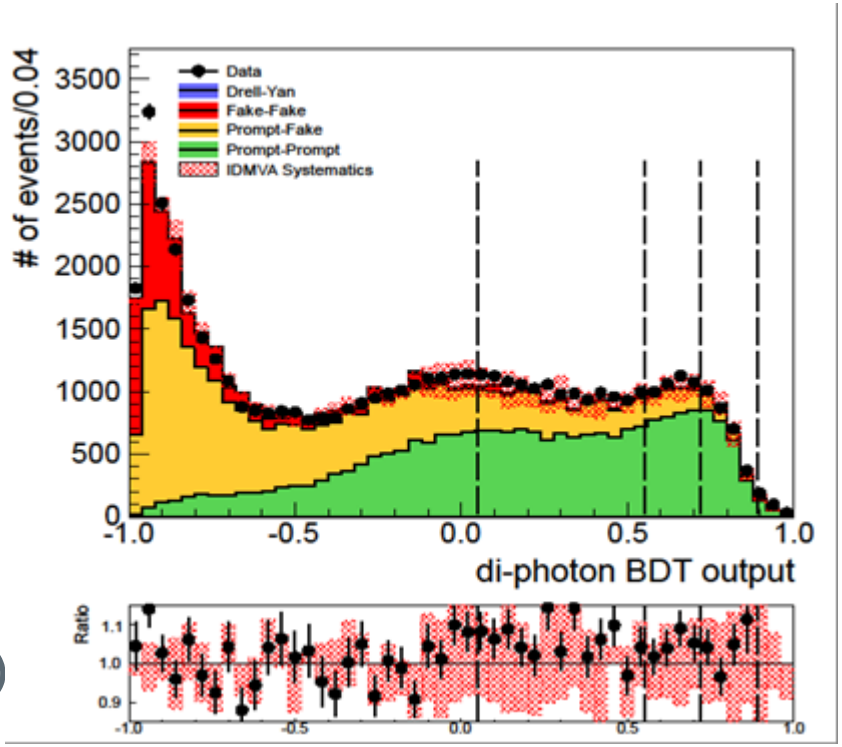
H→γγ

- Narrow peak in the diphoton mass distribution
- Preselection: two isolated high E_t photon candidates
- Main backgrounds:
  - Irreducible: QCD diphoton production
  - Reducible: pp→γ+jet, pp→jet+jet, DY→ee. (*fake* photons)



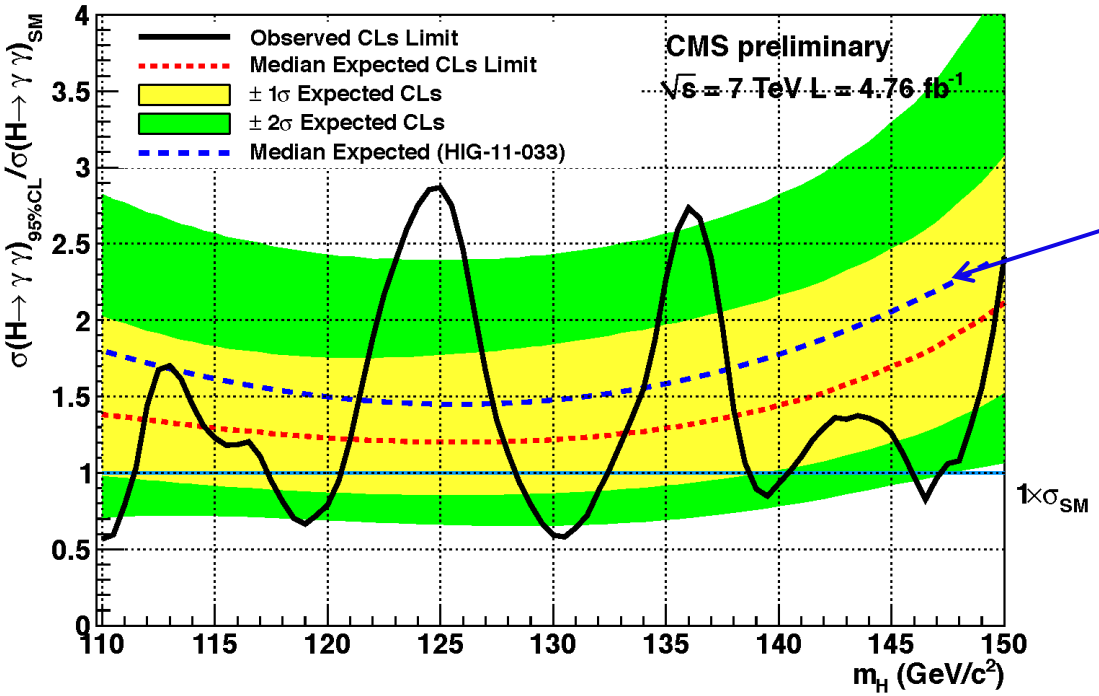
H→γγ

- Use of multivariate analysis discriminator (BDT)
  - kinematic properties of photons
  - relative diphoton mass resolution
  - photon identification BDT output
- Event Categories
  - VBF topology (improves the analysis sensitivity 10%)
  - remaining events (99% of the events)
    - Further splitting in four categories, based on the MVA discriminant, in order of decreasing signal sensitivity (best expected exclusion limit)



cat1	cat2	cat3	cat4
0.05-0.55	0.55-0.72	0.72-0.89	0.89-1.00

H→γγ : Results



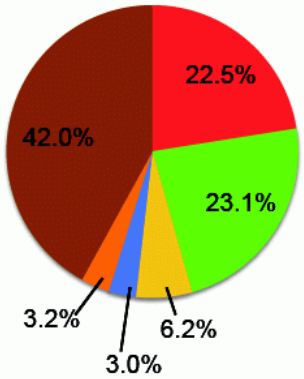
Cut based analysis

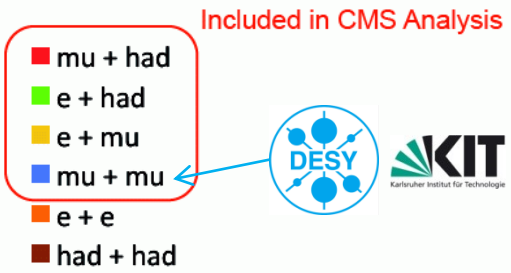
the use of multivariate analysis technique improved the sensitivity ~ 20%

- Expected 95% CL exclusion: 1.2-2 x SM
- Excluded at 95% CL:
  - 110.0-111.0, 117.5-20.5, 128.5-132.0, 139.0-140.0,146.0-147.0 GeV
- Local significance 2.9 σ, Global significance1.6 σ

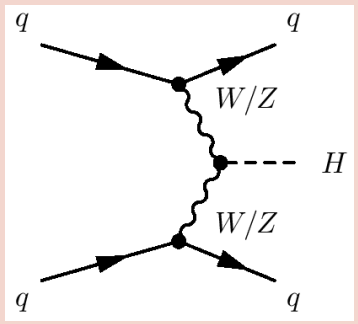
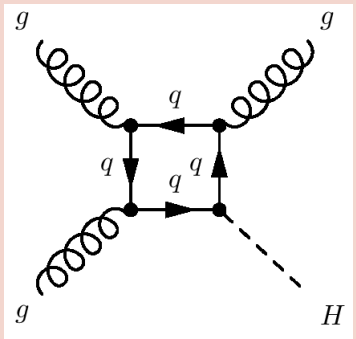
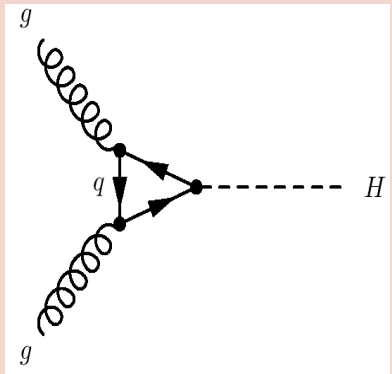
H→ττ

- Final states:





- Event Categories

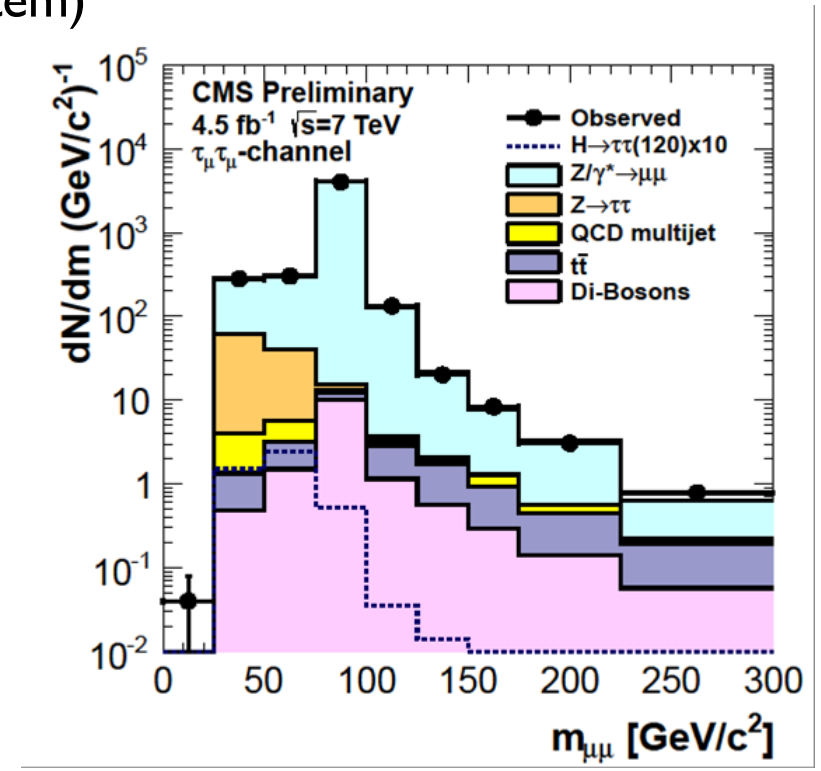
Vector Boson Fusion (VBF) (2 jets with big η gap)	Boosted Higgs (one high p_T jet)	1/0 jets (gluon fusion)
		

- Also considered : WH→ττ
  - $e\mu\tau_h$
  - $\mu\mu\tau_h$
    - (same sign leptons)
  - sensitive to WH→WWW

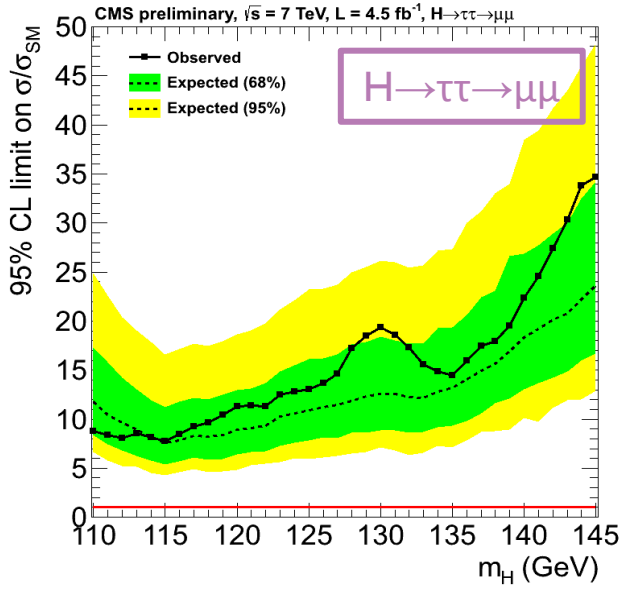
e,μ : $\tau \rightarrow l\nu_l\nu_\tau$
τ_h : $\tau \rightarrow$ hadrons+ν_τ

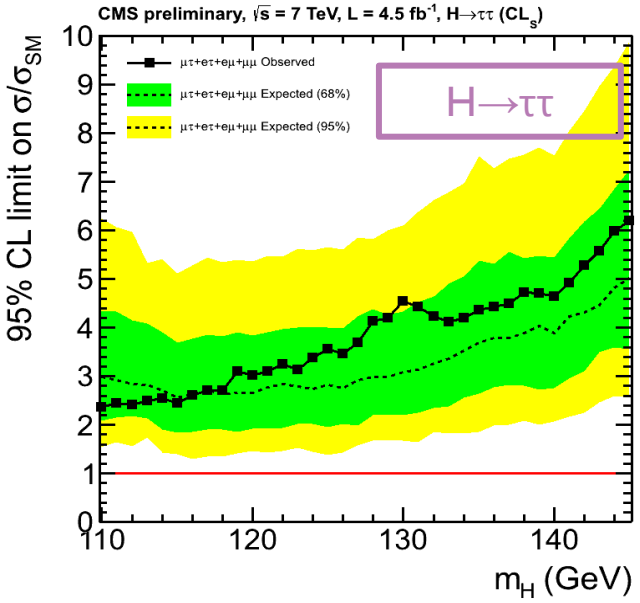
H→ττ

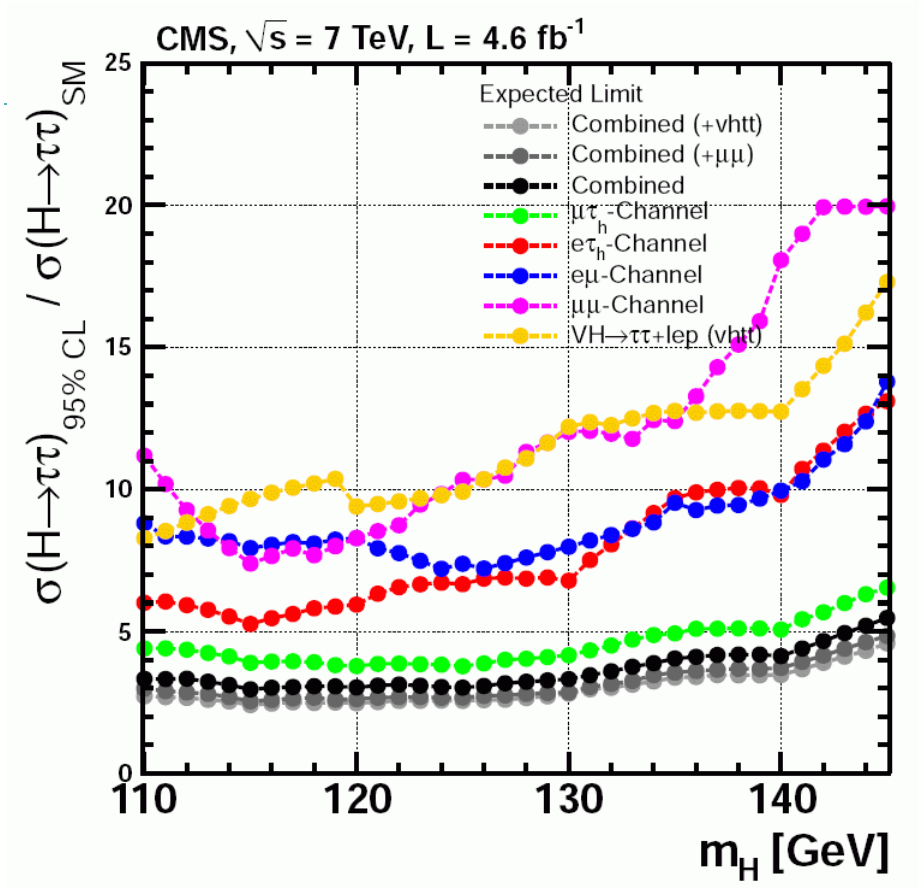
- H→ττ→eμ,μμ,eτ_h,μτ_h
  - Irreducible background: Z→ττ
    - Embedding method (in Z→μμ events from data the dimuon system is replaced by a simulated ditau system)
- H→ττ→μμ
  - Irreducible background: Z→μμ
    - estimated by fitting the distance of closest approach significance
  - Very challenging channel!
  - Use of likelihood function



H→ττ



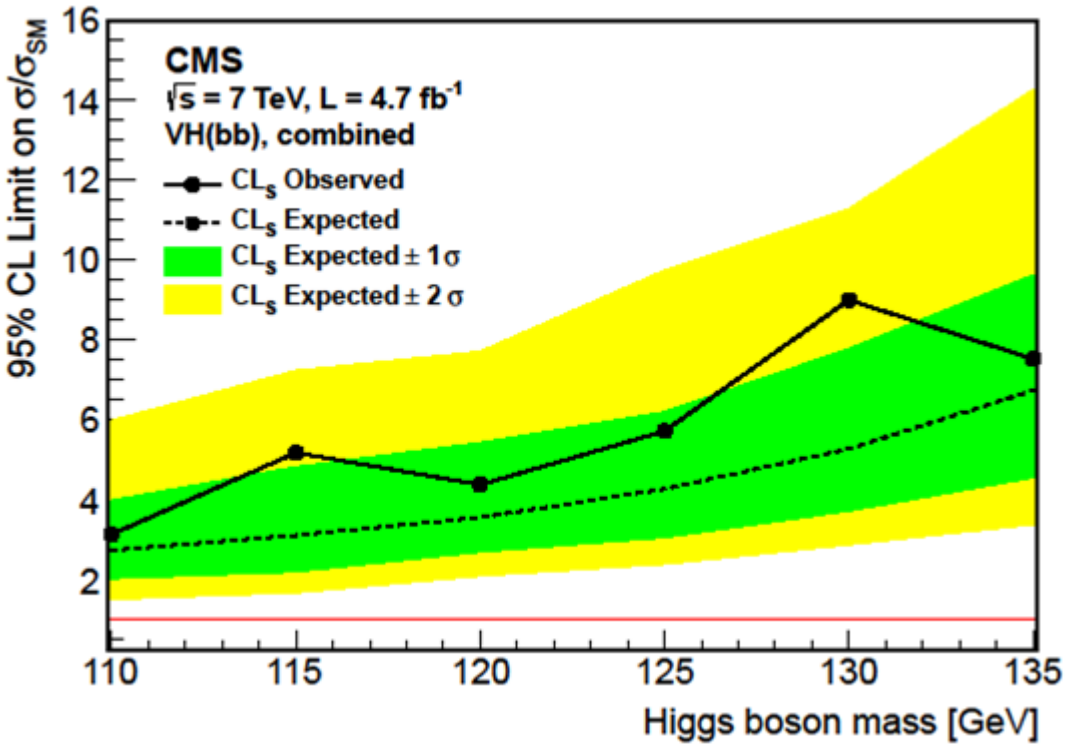




- Expected limits on SM Higgs cross section in the H→ττ search improved by 10-17%
- Observed limits: 2.5-6 x SM

H→bb

- Higgs production in association with W or Z
- Final states:
  - W→eν,μν
  - Z→ee,μμ,νν (Z→νν identified by large Etmiss)
- Dijet system: both jets tagged as b-quark jets
- Multivariate analysis techniques (cut on MVA output)



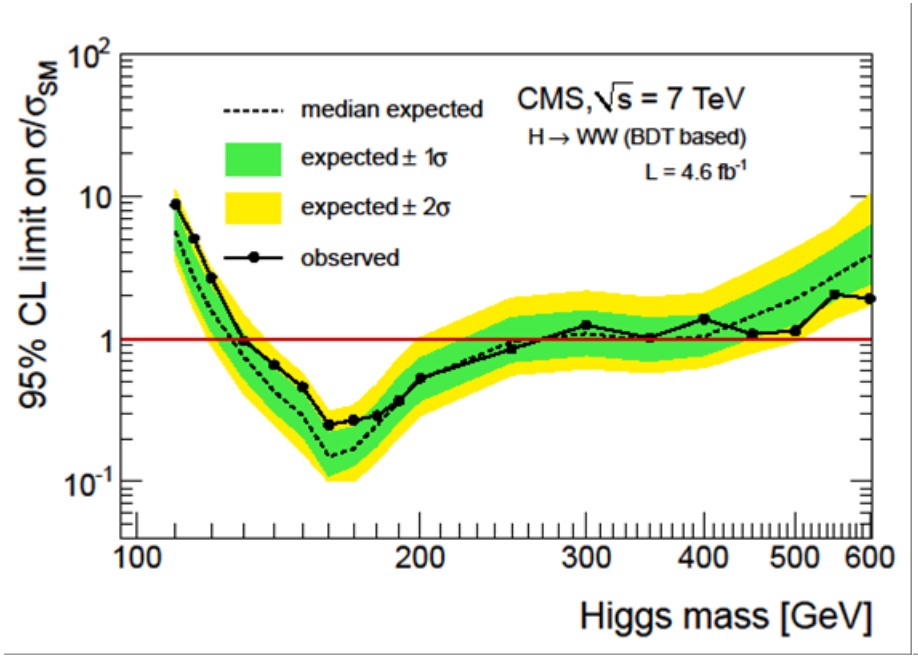
- observed 95% CL upper limits: 3.4-7.5 x SM
- expected limits: 2.7-6.7 x SM

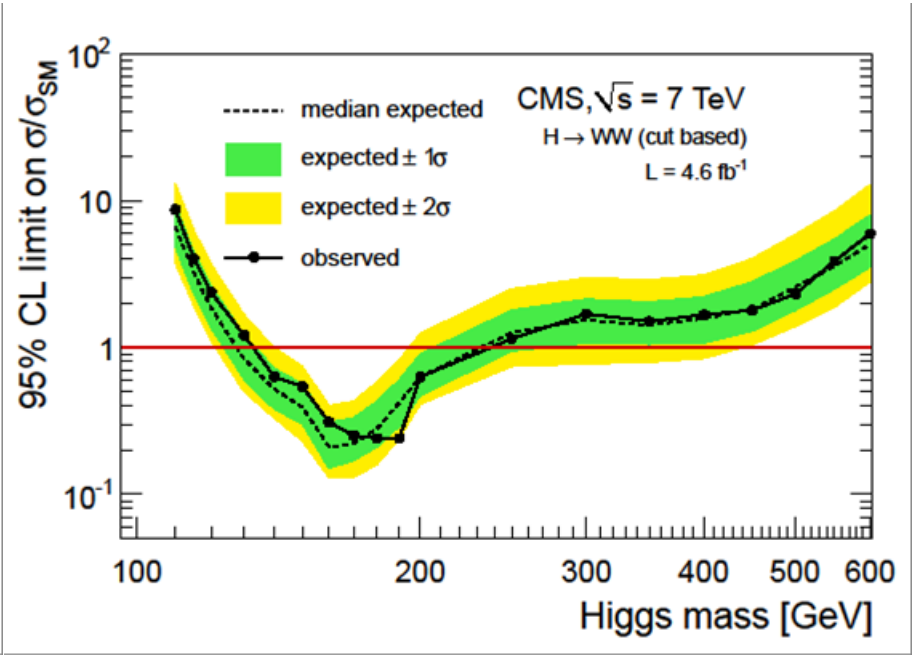
$H \rightarrow WW \rightarrow l\nu l\nu$

- Signature
  - 2 opposite sign leptons
  - high p_t
  - isolated
  - Large E_{tmiss}
- Event categories
  - 3 cat. according to jet multiplicity
    - 0,1 or 2 jets
  - 3 cat. according to final states
    - ee, μμ or eμ
- Two analysis performed for the categories 0 and 1 jets
  - Multivariate analysis
  - Cut based analysis
- Only cut based for the 2 jets category

The motivation for the event categories is the different background contributions for every topology

H→WW→lνlν





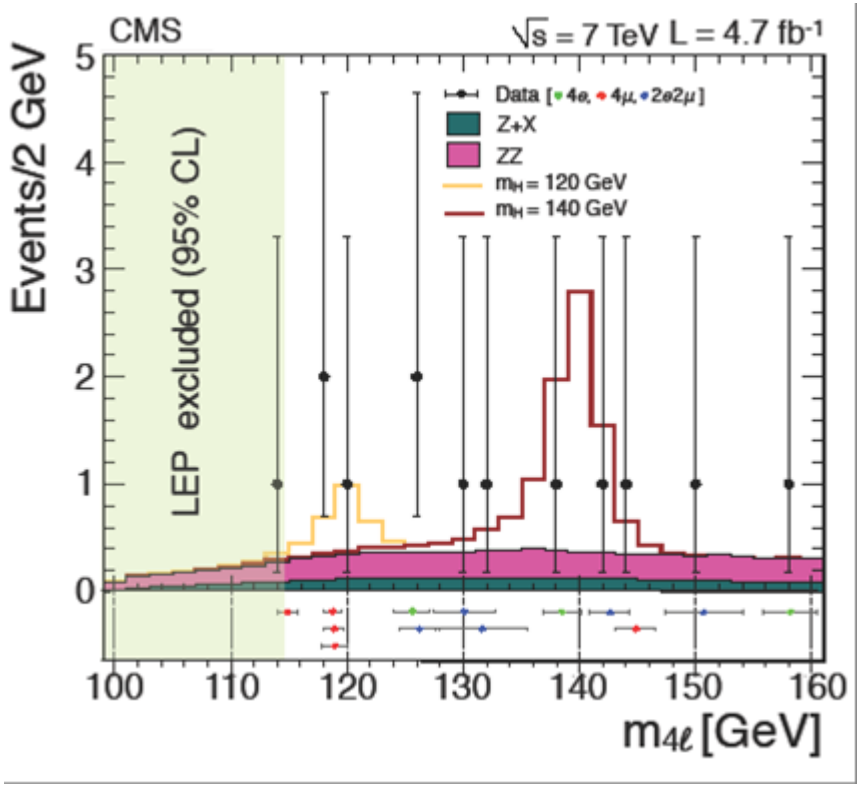
Multivariate analysis is more sensitive

- Multivariate analysis:
  - Expected limit: 127-270 GeV
  - Observed limit: 129-270 GeV
- Small excess in the low mass region

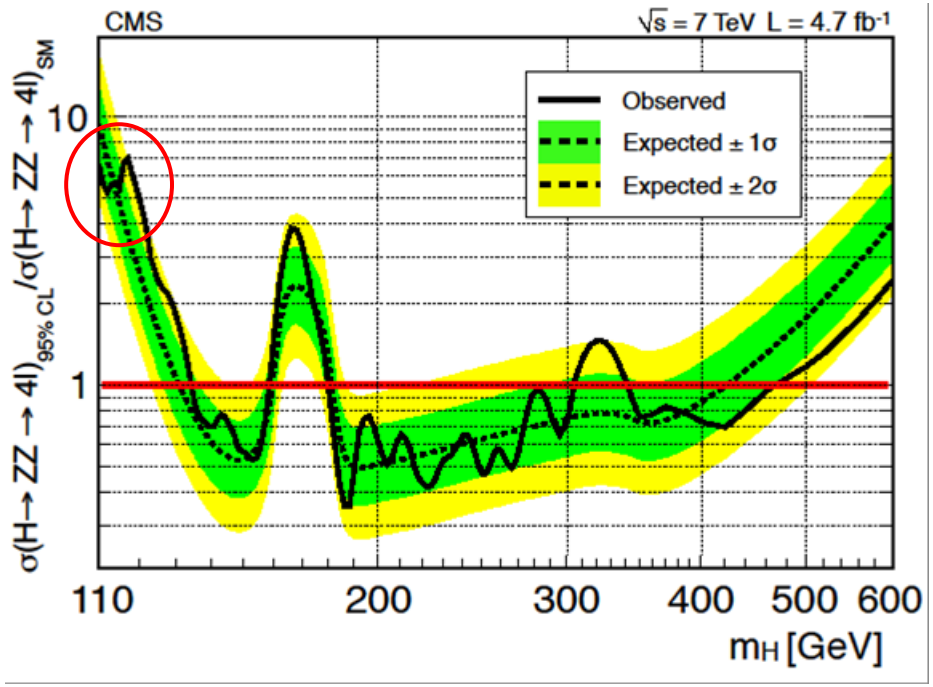
- Cut based analysis:
  - Expected limit: 129-236 GeV
  - Observed limit: 132-238 GeV

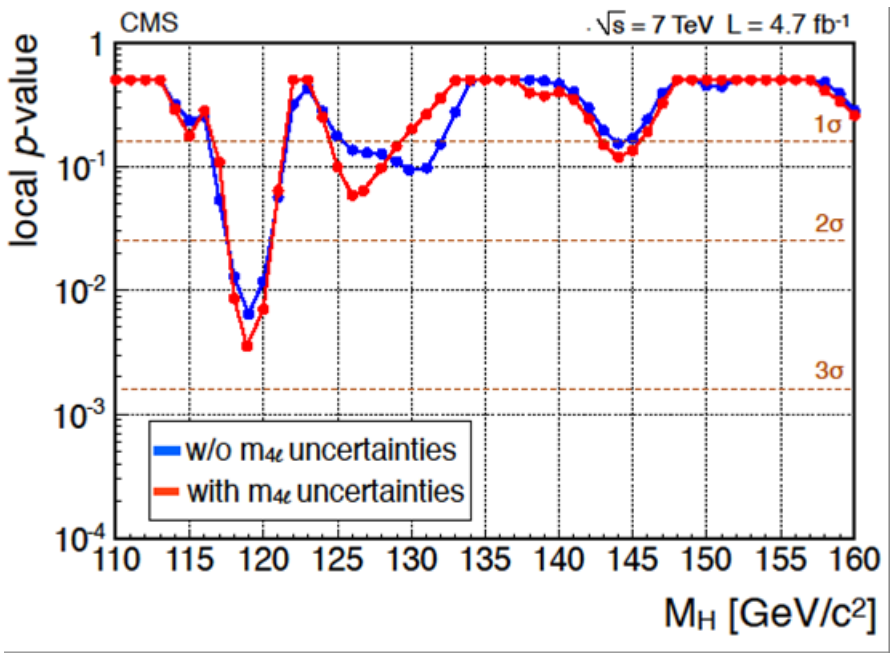
H→ZZ→4l

- Clear channel:
  - 2 high mass pairs of isolated e or μ
- Narrow mass peak
  - very good mass resolution
- The 3 sub-channels (4e,4μ,2e2μ) are analysed seperately
  - differences in the 4 lepton mass resolution
  - different background rates
- Main background : non-resonant ZZ production
  - estimated from simulation
- In 100-160 GeV
  - Bkg expected : 9.5±1.3
  - Data : 13



H→ZZ→4l

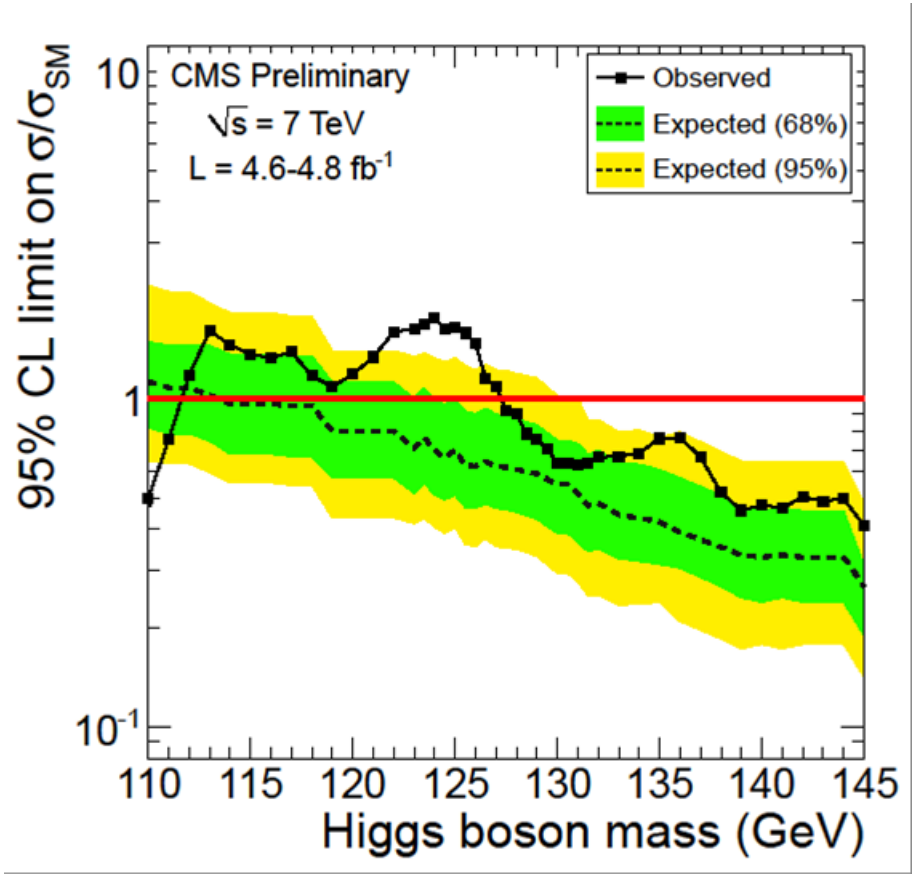




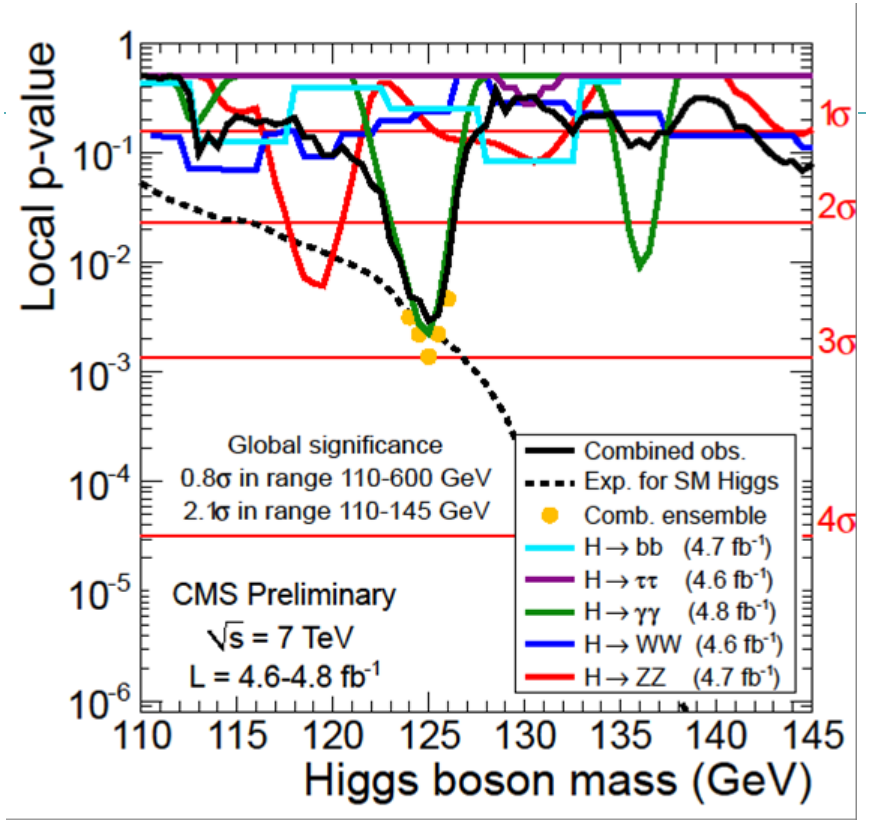
- Excess observed at 119.5 GeV
  - Local significance 2.5 σ
  - Global significance 1.0 σ in the full mass range, 1.6 σ in the 100-160 GeV mass range
- SM Higgs excluded at 95%CL for M_H in the ranges:
  - 134-158 GeV
  - 180-305 GeV
  - 340-465 GeV

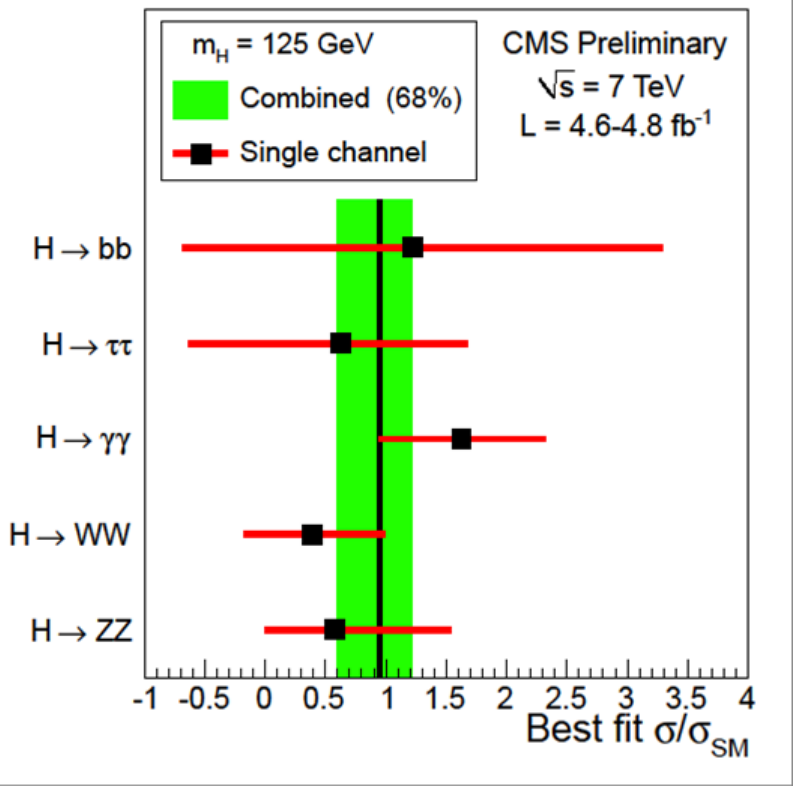
Combined results: SM

- Method for CL calculation was developed by the CMS and ATLAS collaborations in the context of the Higgs Combination Group
  - Frequentist CLs with profiled likelihood test statistics
- Expected : 95% exclusion M_H
  - 114.5-543 GeV
- Observed : 95% exclusion M_H
  - 127.5-600 GeV
- Observed lower limit higher than expected because of excess in data



Combined results: SM

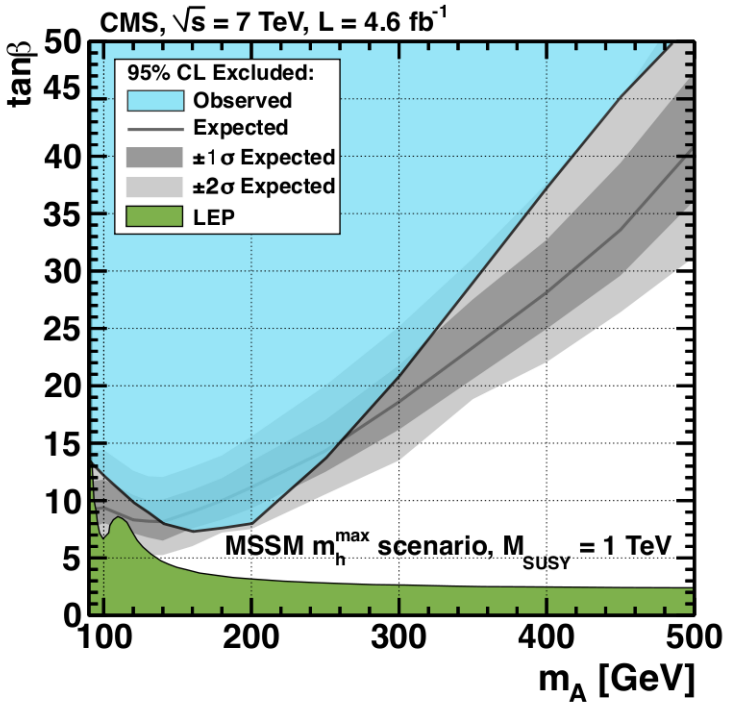


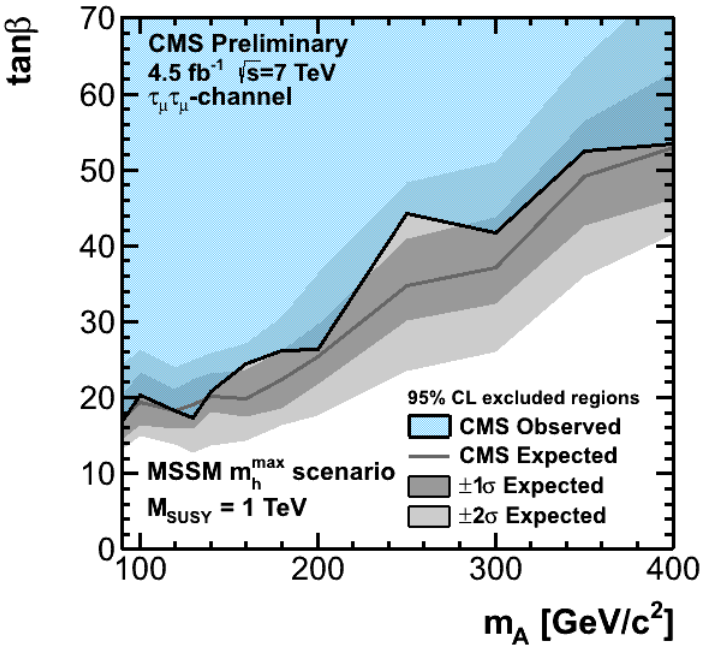


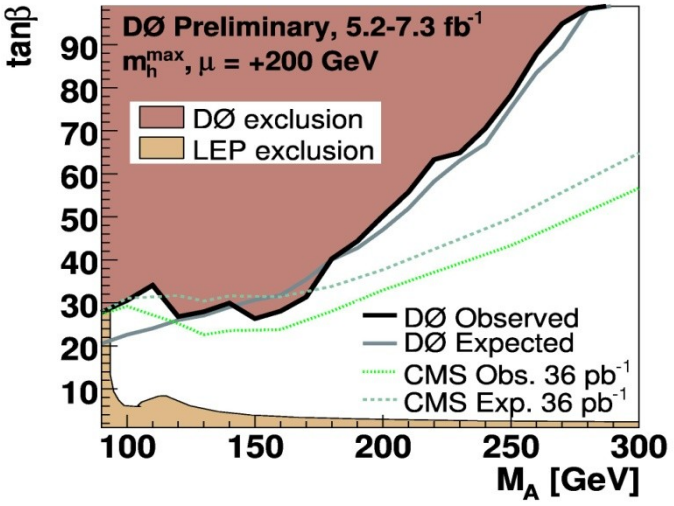
- Minimum p-value observed at 125 GeV
  - local significance 2.8 σ
  - global significance 0.8 σ in the 110-600 GeV mass range
  - global significance 2.1 in the 110-145 GeV mass range
- The fitted σ of the excess near 125 GeV is consistent with SM Higgs expectation
- Other channels show some excess in the low mass region
  - At 125 GeV all sensitive channels show an excess consistent with signal expectations

Beyond SM: MSSM

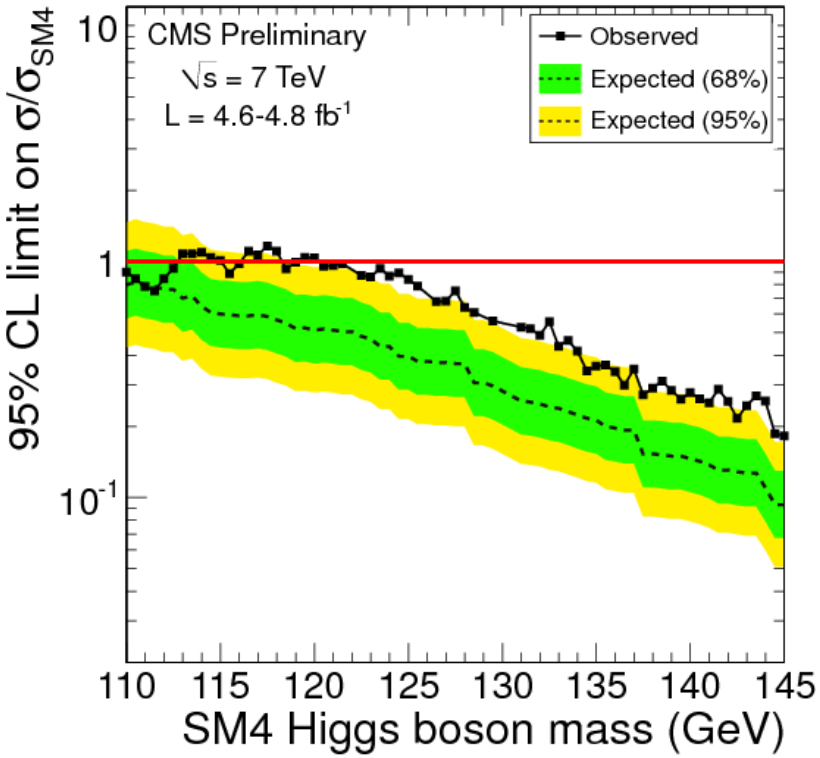
- Excluded 95% CL values of tanβ as low as 7.1 at m_A = 160 GeV
- The H→ττ→μμ alone "beats" the latest Tevatron results



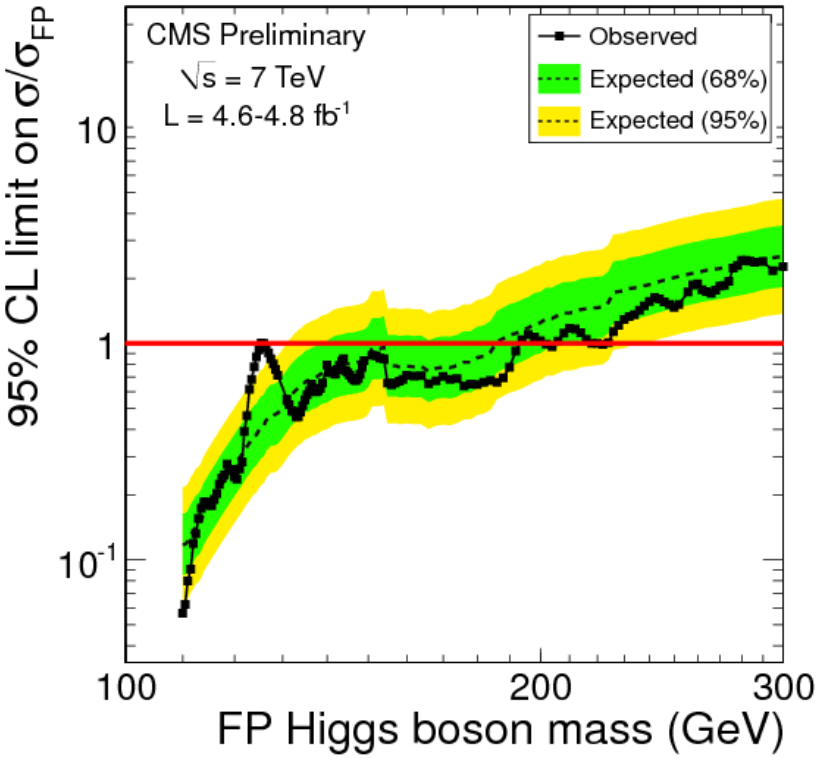




Beyond SM: SM4 and fermiophobic



- Extension of the SM including a 4th generation of fermions
- Excluded at 95% CL in the mass range 120-600 GeV



- The Higgs doesn't couple to fermions
- Dedicated analysis from the H→γγ group
- Excluded at 95% CL in the mass range 110-192GeV

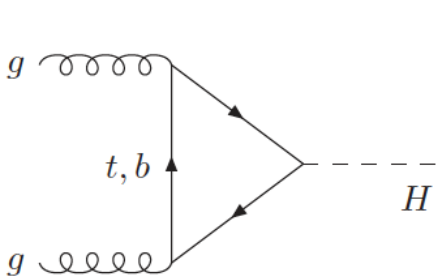
Summary

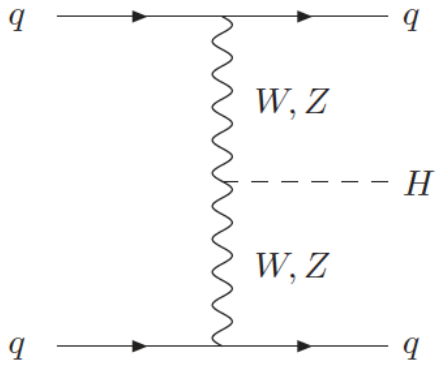
- Search for standard model Higgs boson were performed in 11 channels
- The SM Higgs is not excluded (at 95% CL) in the mass range 114.4-127.5 GeV
- Most significant excess around 125 GeV
  - Local significance 2.8 σ; Global 0.8 σ; In the low mass range (110-145) 2.1 σ
  - Consistent with SM Higgs and background fluctuation
- Searches are performed in BSM models (MSSM, SM4 fermiophobic)

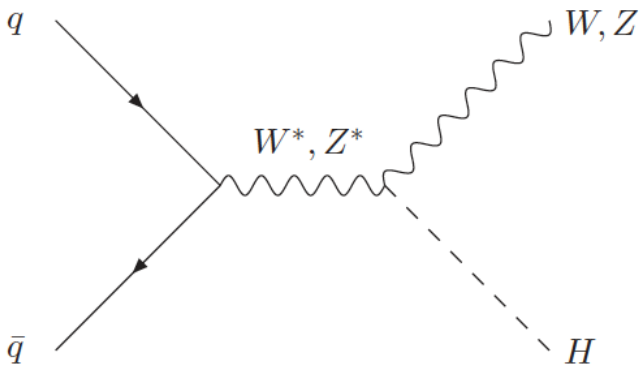
By the end of 2012 we will know!

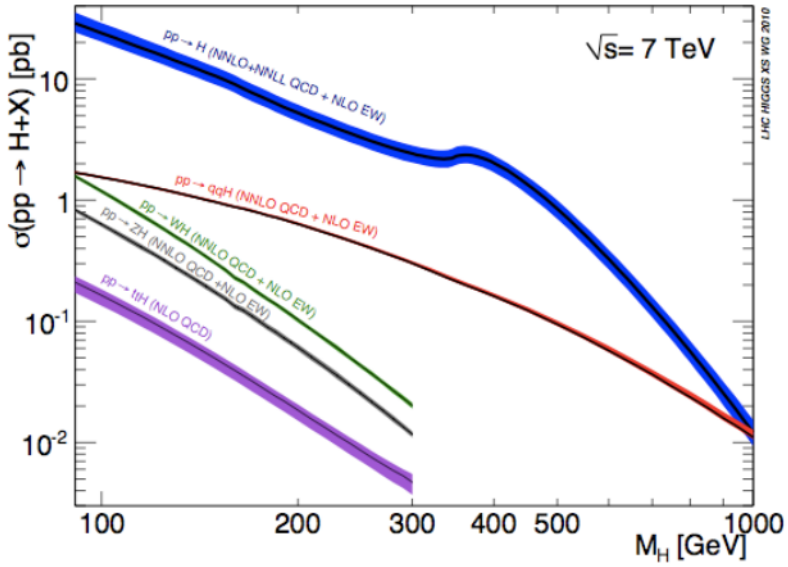
Back up slides

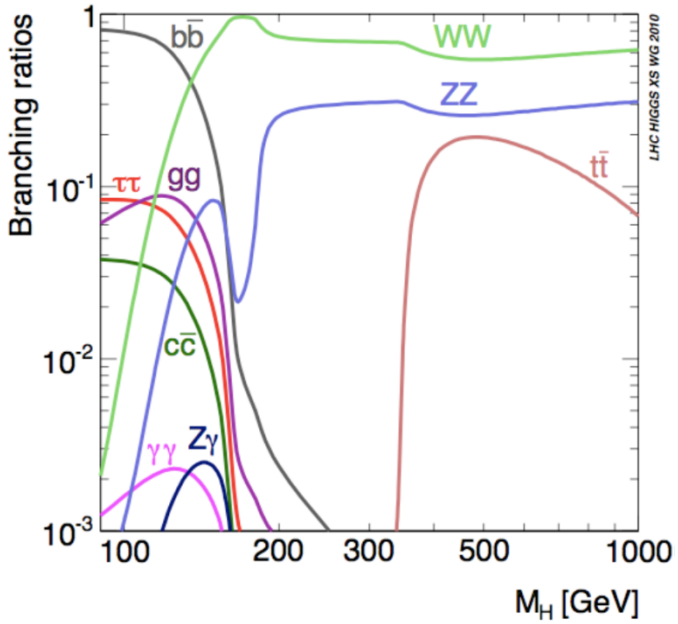
SM Higgs @ the LHC



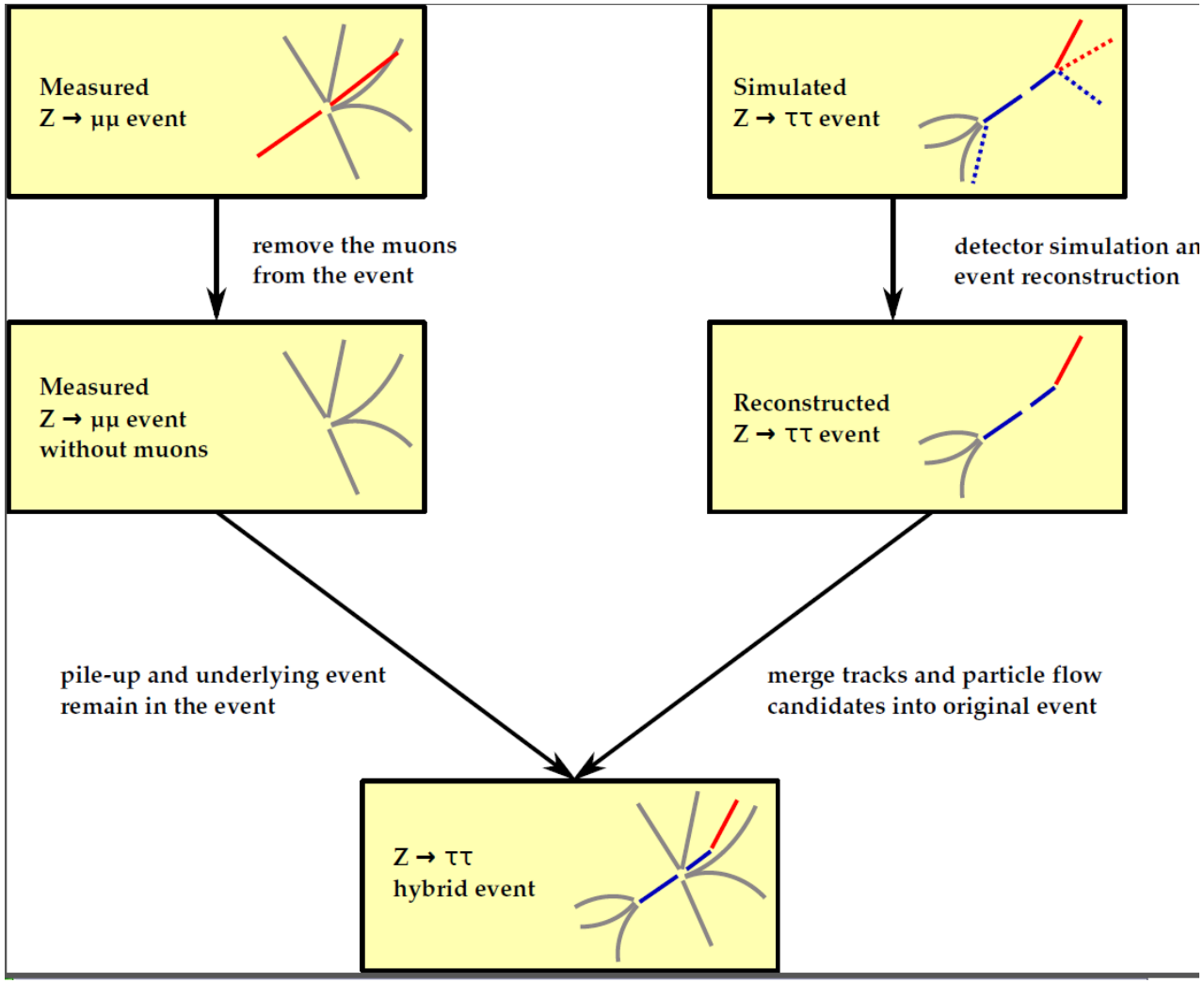








Embedding method

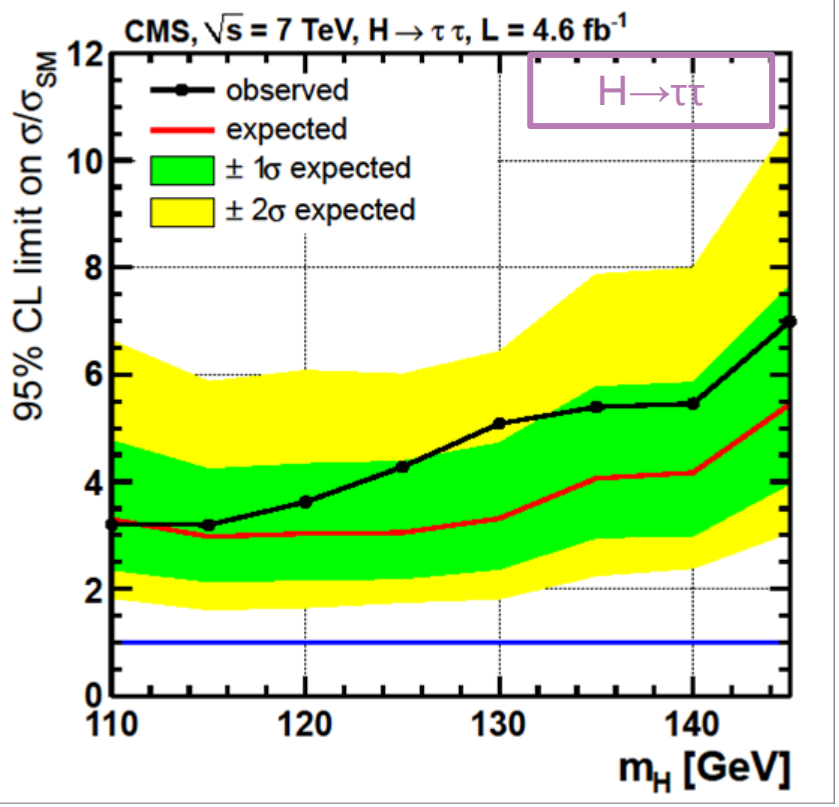


Fermiofobic $H \rightarrow \gamma\gamma$

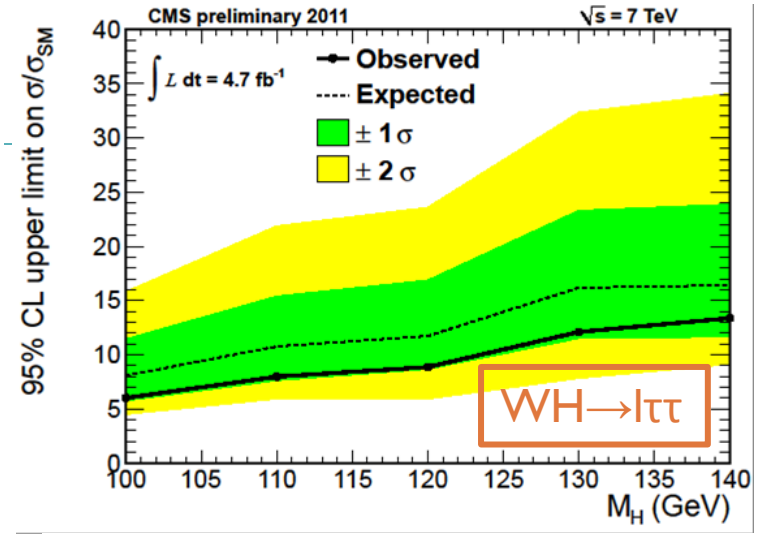
- Bratio enhanced by an order of magnitude
- Production cross section suppressed by an order of magnitude
- Allowed production mechanisms: VBF and assosiated production with W or Z
- Event Categorisation:
  - VBF
  - H+μ
  - H+e
  - remaining events; Subdivided in 4 categories based on the quality of the electromagnetic shower and the measurement position
- Final discriminants:
  - VBF, H+μ, H+e $m_{\gamma\gamma}$
  - remaining events: 2D distribution $m_{\gamma\gamma}$,$p_T^{\gamma\gamma}/m_{\gamma\gamma}$

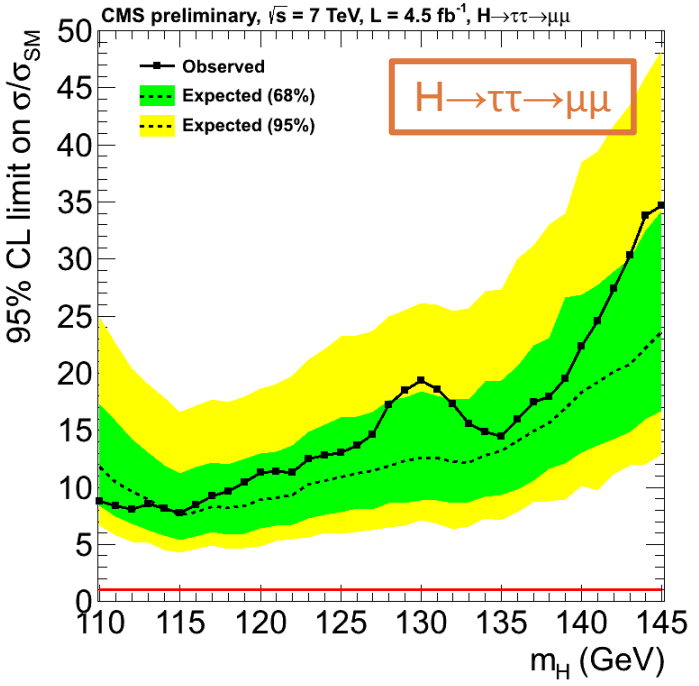
H→ττ

3 channels in the previous combination



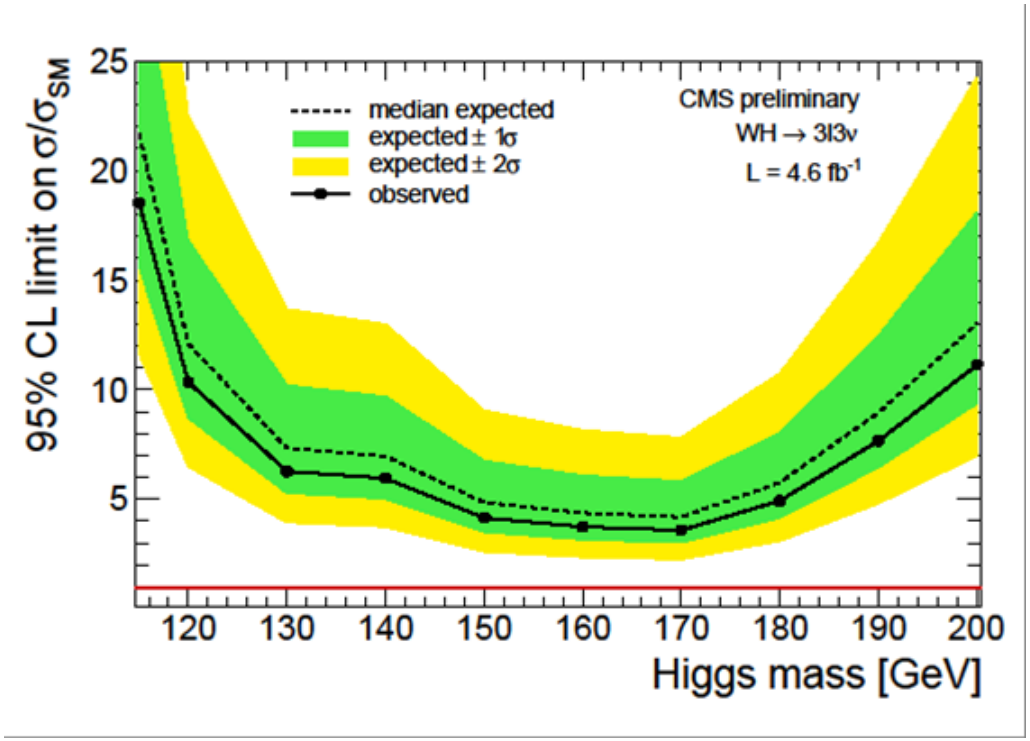
New Channels





WH→WWW→3l3ν

- Signature:
  - 3 leptons
  - E_{tmiss}
- Largest Background ZW→3lν
  - Requirement that the same flavour oppositely charged lepton pairs have dilepton mass ≠ m_Z
- Other backgrounds estimated from data
- ZZ→4l from simation



H→ZZ→4l (full mass range)

Baseline	$4e$	4μ	$2e2\mu$
ZZ	12.27 ± 1.16	19.11 ± 1.75	30.25 ± 2.78
Z+X	1.67 ± 0.55	1.13 ± 0.55	2.71 ± 0.96
All background	13.94 ± 1.28	20.24 ± 1.83	32.96 ± 2.94
$m_{\mathrm{H}} = 120\,\mathrm{GeV}/c^2$	0.25	0.62	0.68
$m_{\mathrm{H}} = 140\,\mathrm{GeV}/c^2$	1.32	2.48	3.37
$m_{\mathrm{H}} = 350\,\mathrm{GeV}/c^2$	1.95	2.61	4.64
Observed	12	23	37