



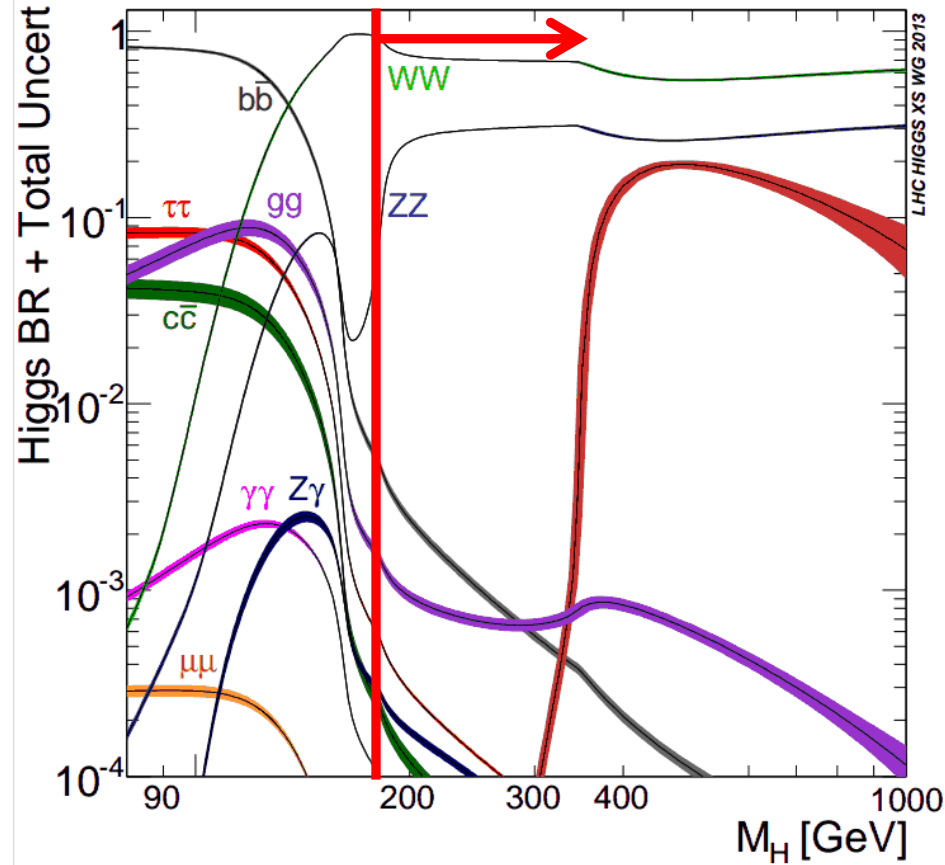
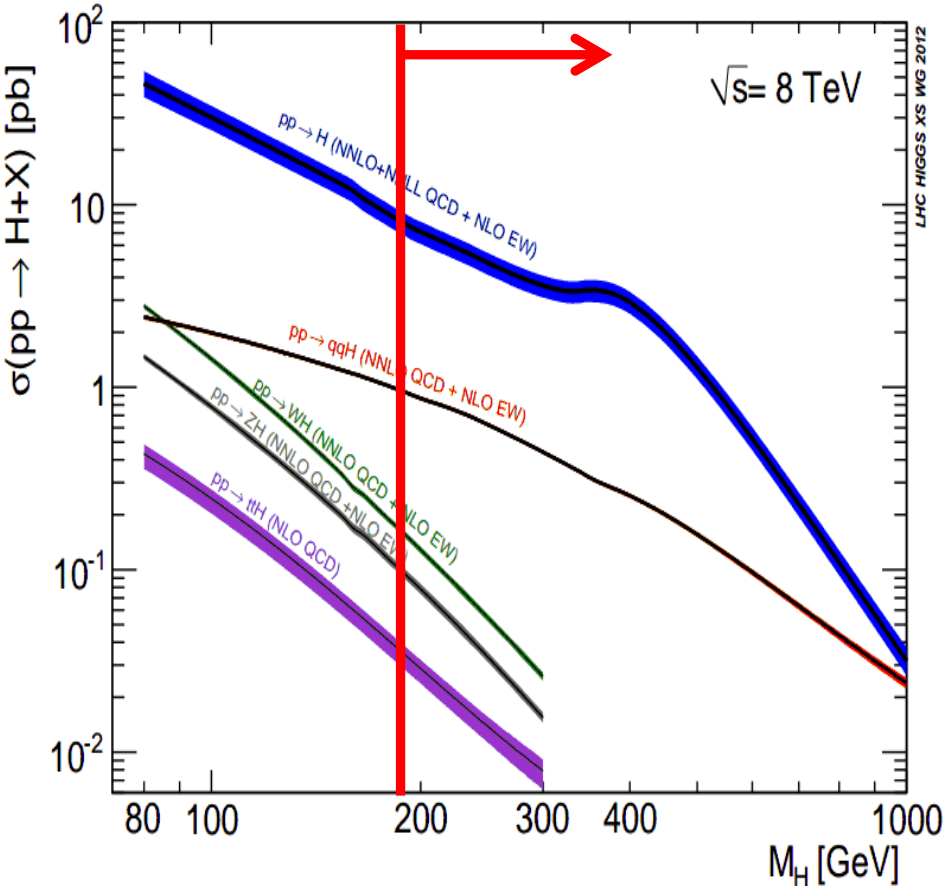
Overview of the Search for a Heavy Higgs in CMS

Loïc Quertenmont

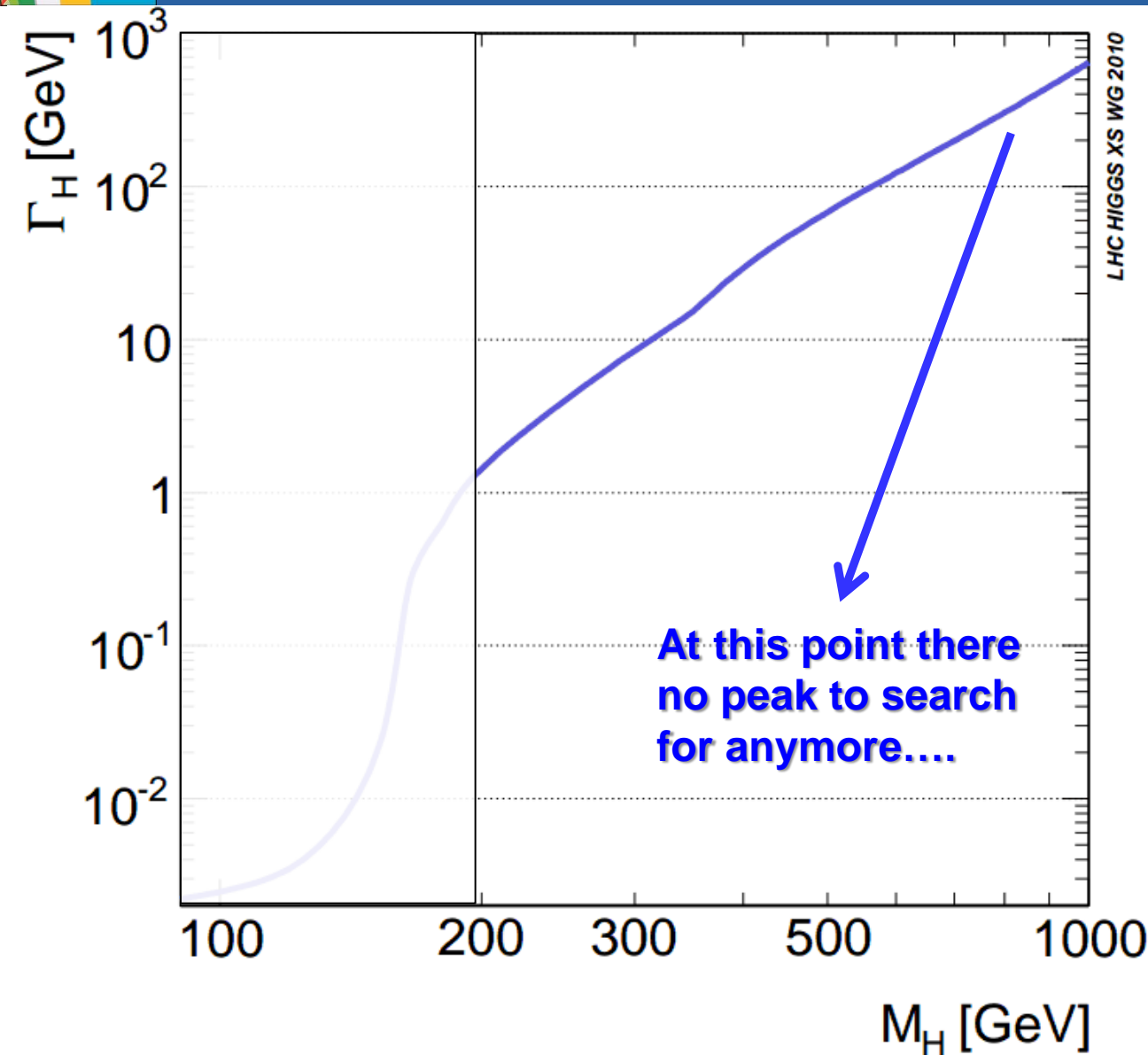
On behalf of the CMS collaboration

23-24 January 2014

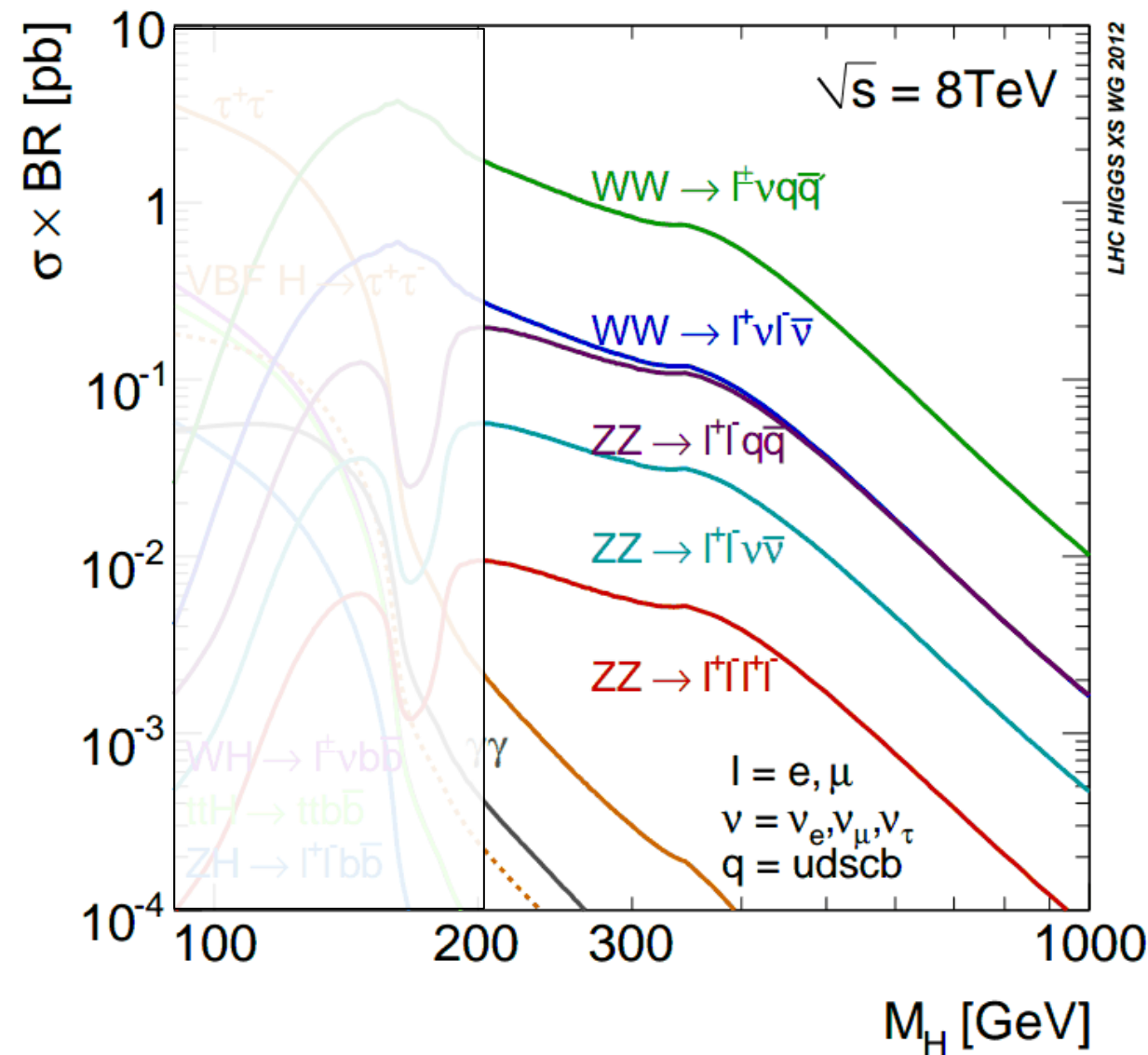
Blegian Scalar Sector Workshop, IIHE



- Phenomenology is quite different than for low mass searches
- Gluon Fusion production is dominant, but tends to be comparable with VBF
- Decay dominated by WW and ZZ channels,
 - $\tau\tau$ is subdominant but not negligible around the peak
- Different “Golden” channels than for a light scalar search



- Higgs width can become very large
- Almost as wide as massive
- Make the experimental search challenging...



WW

- Dominating
- Experimentally challenging

ZZ

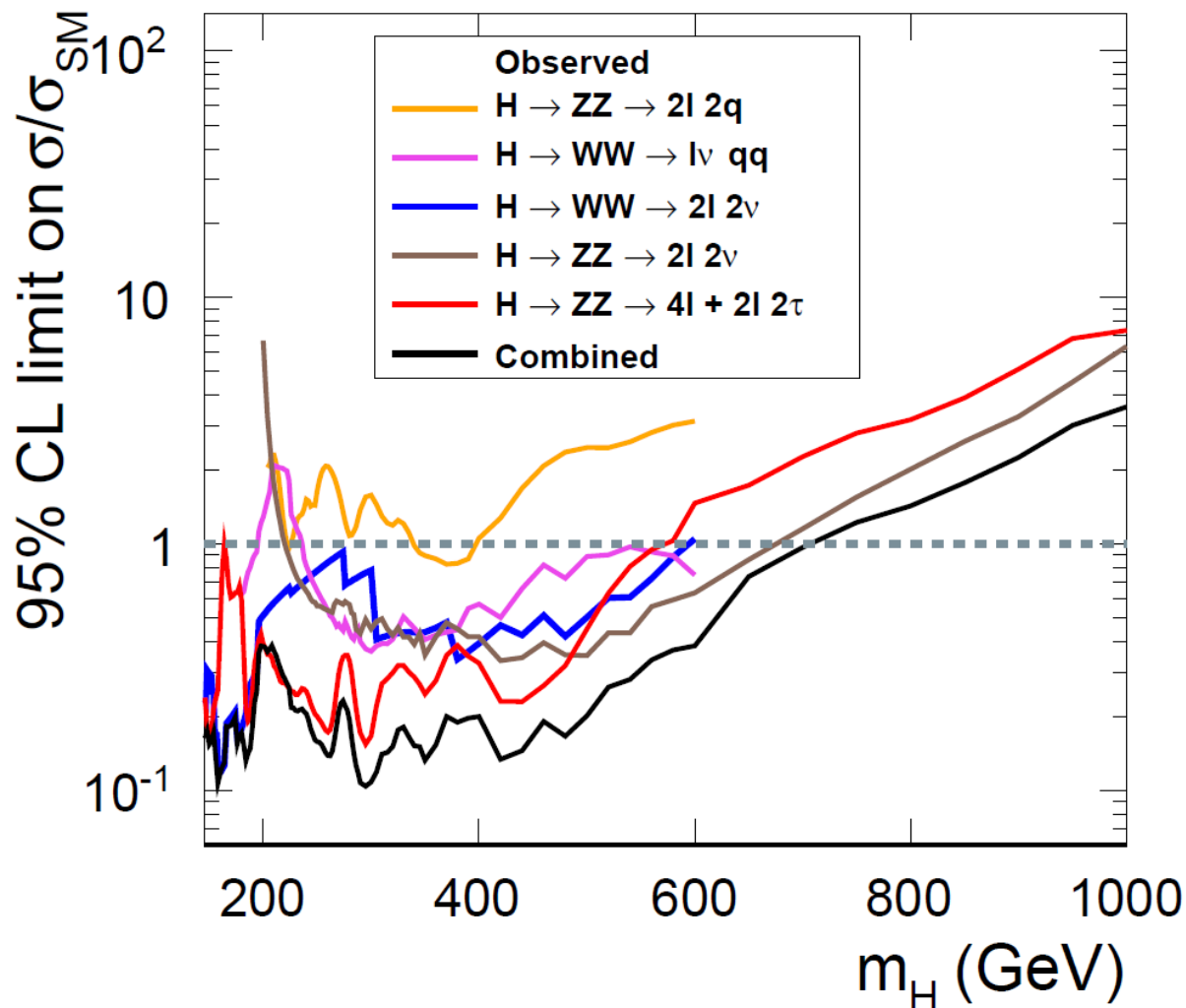
- Cleaner channels
- Mass peak searches
- Up to 4lepton final states

ll

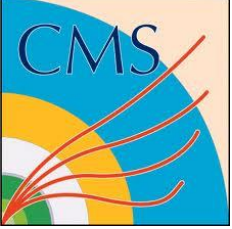
- Clearly subdominant
- Won't be considered in this talk

arXiv:1304.0213: Search for a standard-model-like Higgs boson with a mass in the range 145 to 1000 GeV at the LHC

CMS $\sqrt{s}=7$ TeV, $L \leq 5.1 \text{ fb}^{-1}$ $\sqrt{s}=8$ TeV, $L \leq 5.3 \text{ fb}^{-1}$



- **OBSERVED Limits**
- **5fb⁻¹@7TeV + 5fb⁻¹@8TeV**
- **The rate isn't all**
 - **Backgrounds !!!**
- **Channel order is swapped**
 - **ZZ** → 2l2v
 - **ZZ** → 4l
 - **WW** → lvqq
 - **WW** → 2l2v
 - **ZZ** → 2l2q



$ZZ \rightarrow \ell\ell \nu\nu$

Selection :

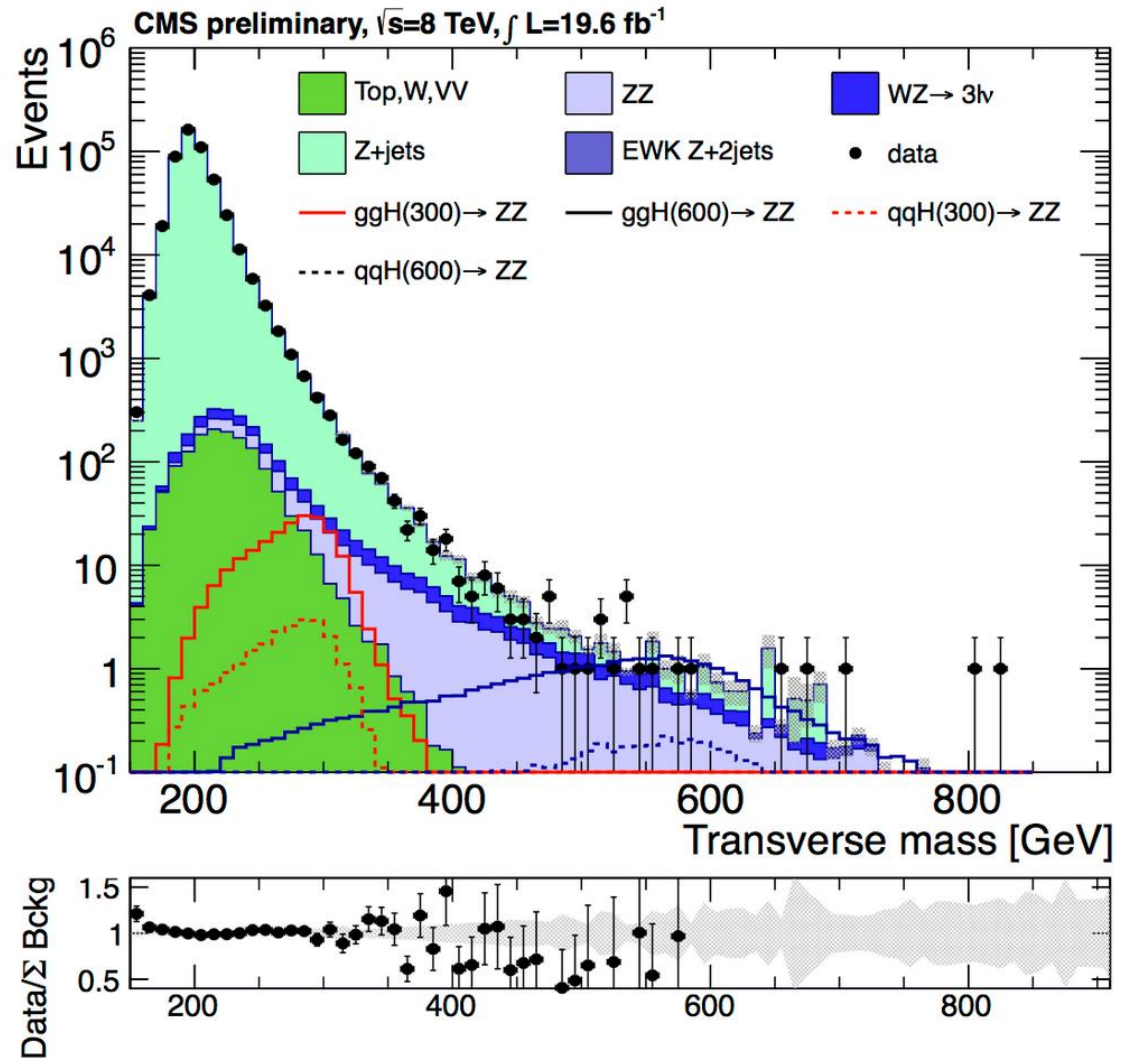
- Dilepton pair + MET
- Transverse Mass (m_T)

Shape Based Search

Main backgrounds :

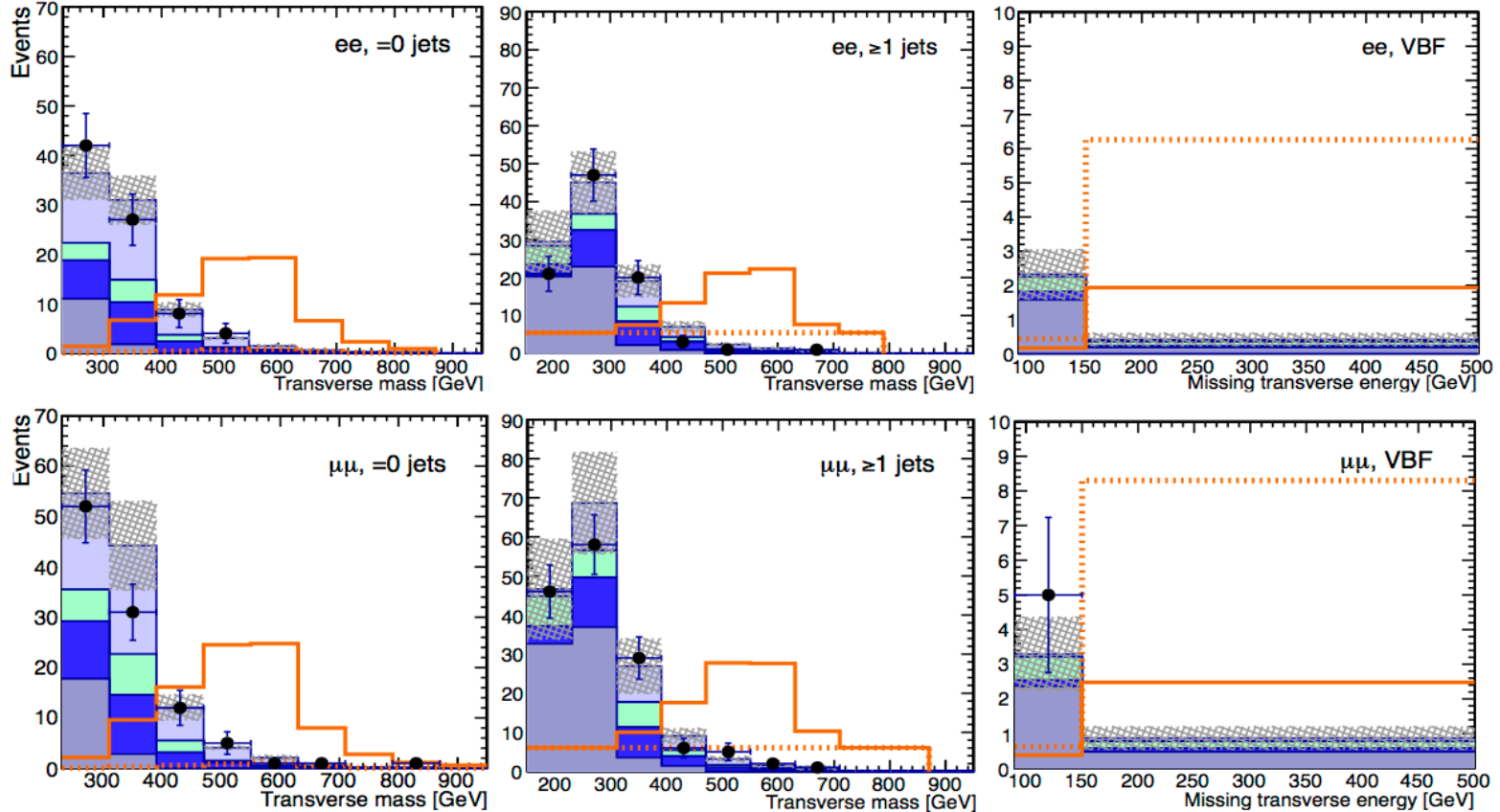
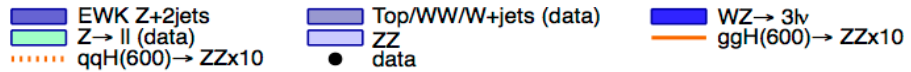
- **Z+Jets**
 - from Gamma+Jets
- **Non Resonants**
 - Top, W, WW
 - from $e\mu$ channels
- **Irreducible**
 - ZZ, WZ
 - From MC

$$m_T^2 = \left[\sqrt{(p_T^{\ell\ell})^2 + m_{\ell\ell}^2} + \sqrt{(E_T^{\text{miss}})^2 + m_{\ell\ell}^2} \right]^2 - \left[\vec{p}_T^{\ell\ell} + \vec{E}_T^{\text{miss}} \right]^2$$

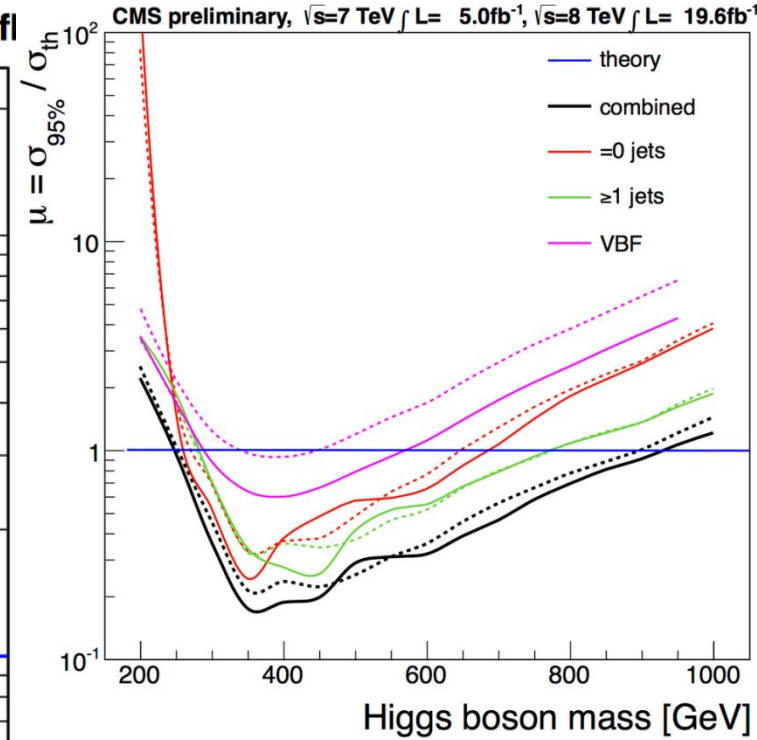
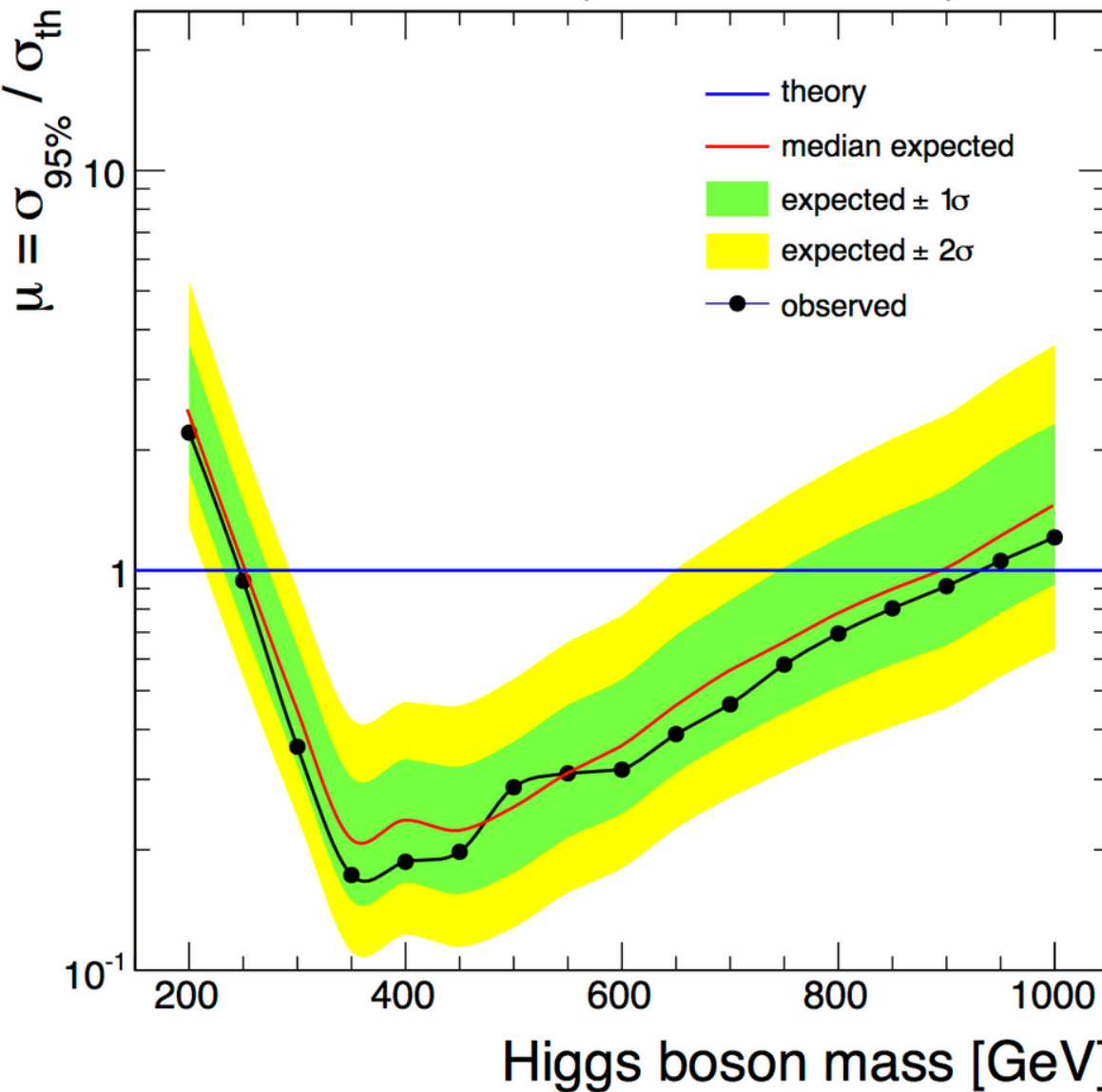


- Events are categories in
 - VBF : 2Jets, Large Jet Eta Gap, Large Jet Invariant Mass
 - GF : 0Jet
 - GF : ≥ 1 Jets

CMS preliminary, $\sqrt{s}=8.0$ TeV, $\int L=19.6$ fb $^{-1}$



CMS preliminary, $\sqrt{s}=7\text{ TeV} \int L= 5.0\text{fb}^{-1}$, $\sqrt{s}=8\text{ TeV} \int L= 19.6\text{fb}^{-1}$

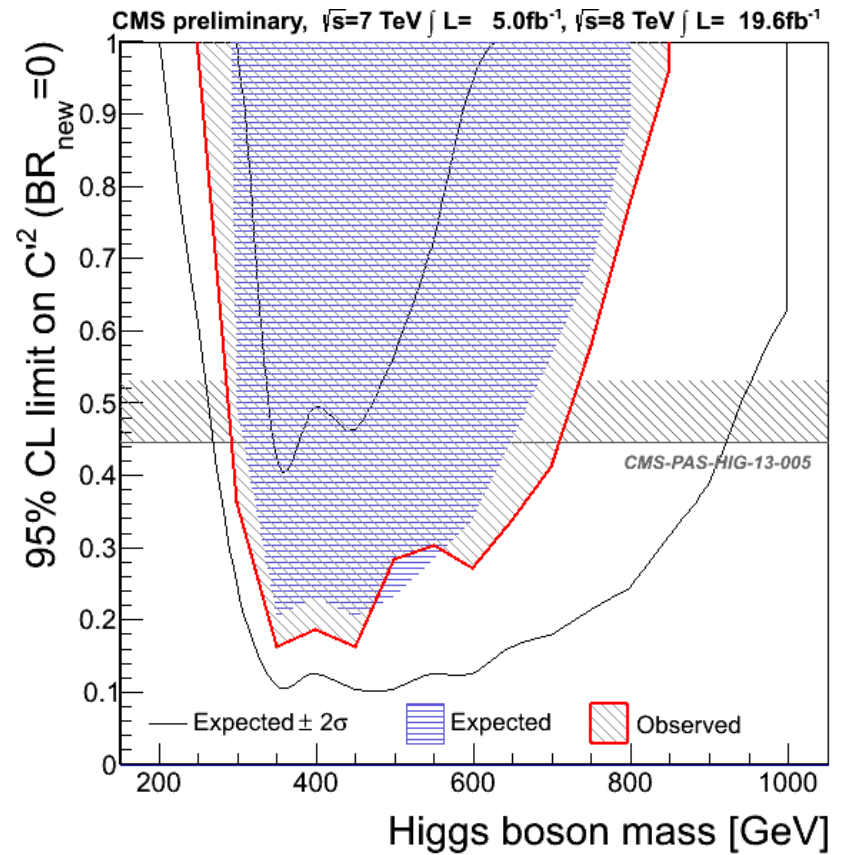
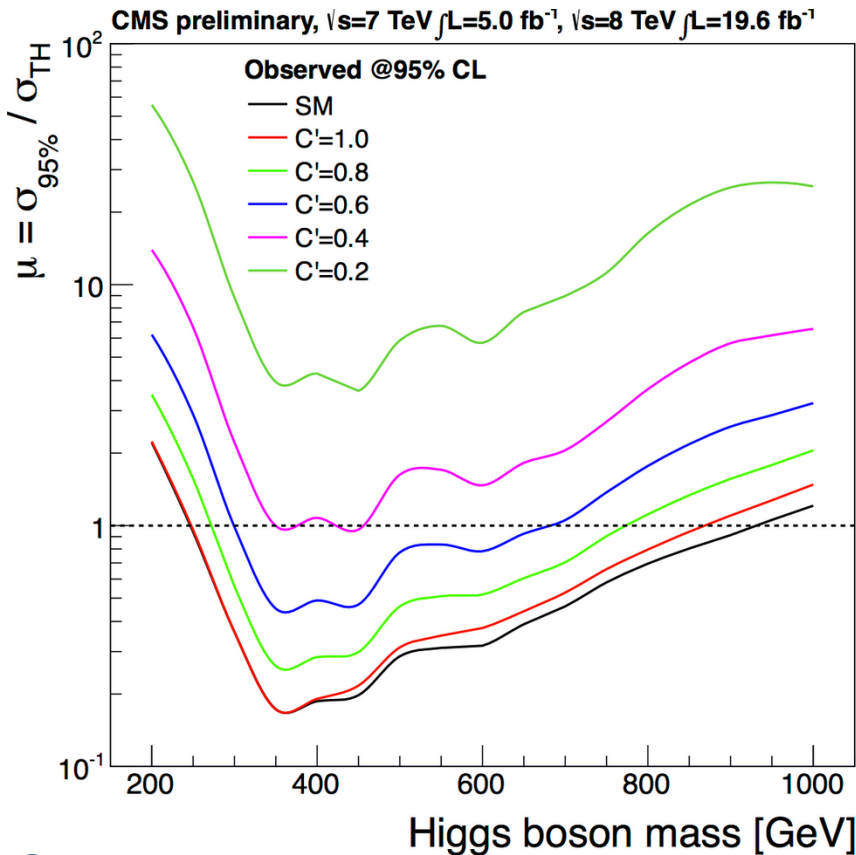


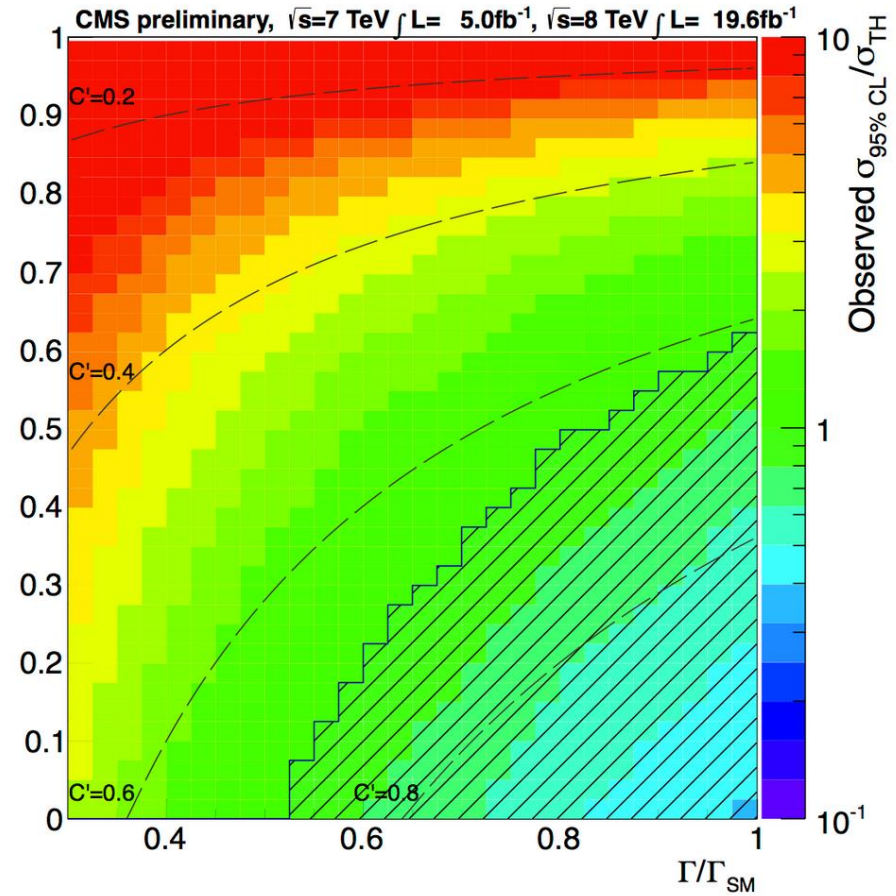
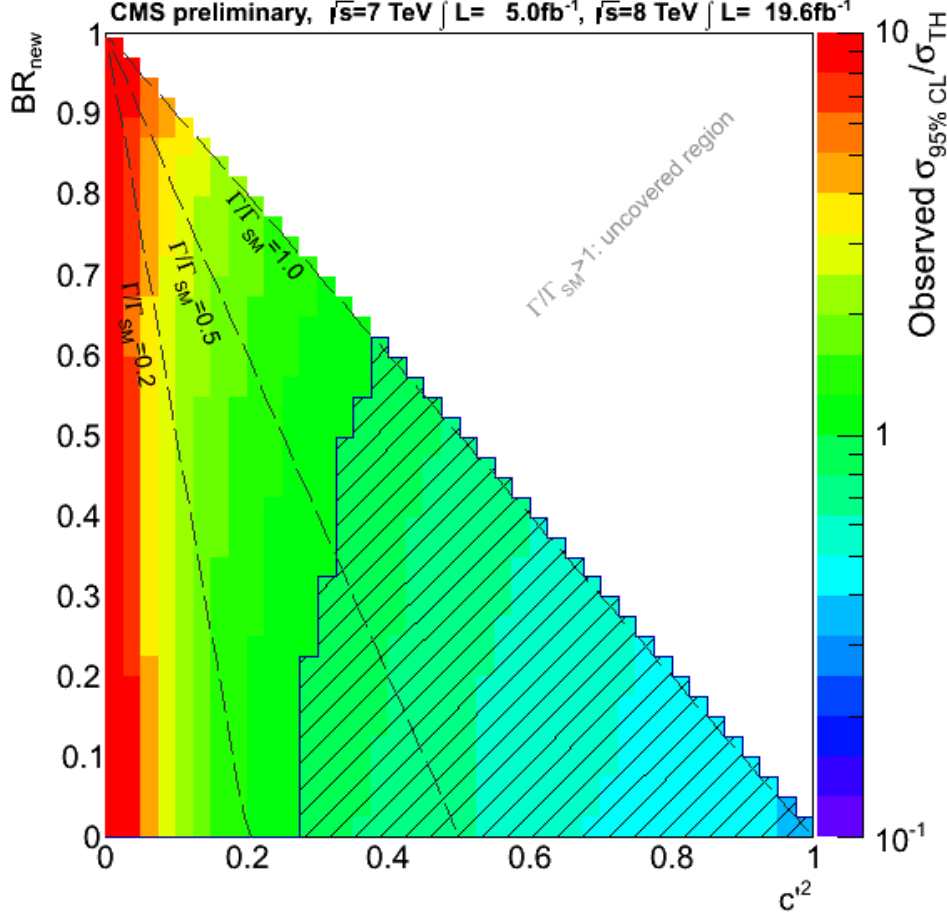
**SM-Like Higgs
excluded in
[248GeV , 930GeV]**

- Reinterpretation in the context of an electroweak singlet scalar mixing with the 125GeV Higgs
- Unitarity $\rightarrow C^2 + C'^2 = 1$ C (C') is h (H) coupling scale factor
 - $C'^2 < 1 \rightarrow$ Narrower resonance than SM-Like Higgs
- BR_{new} : BR of H to non SM-like decay mode

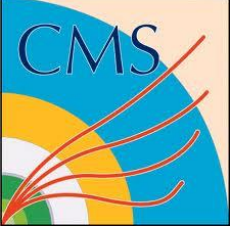
$$\mu' = C'^2 \cdot (1 - BR_{new})$$

$$\Gamma' = \Gamma_{SM} \cdot \frac{C'^2}{1 - BR_{new}}$$





- Limits can also be set on BR_{new} vs $H C'^2$ or BR_{new} vs H Width
- Limits are shown for $m_H = 600\text{GeV}$
- More Results in CMS-PAS-HIG-13-014 « Search for a heavy Higgs boson in the $H \rightarrow ZZ \rightarrow 2l2\nu$ channel in pp collisions at $\sqrt{s} = 7$ and 8 TeV »



$ZZ \rightarrow \mu\mu$

The GOLDEN channel

Selection :

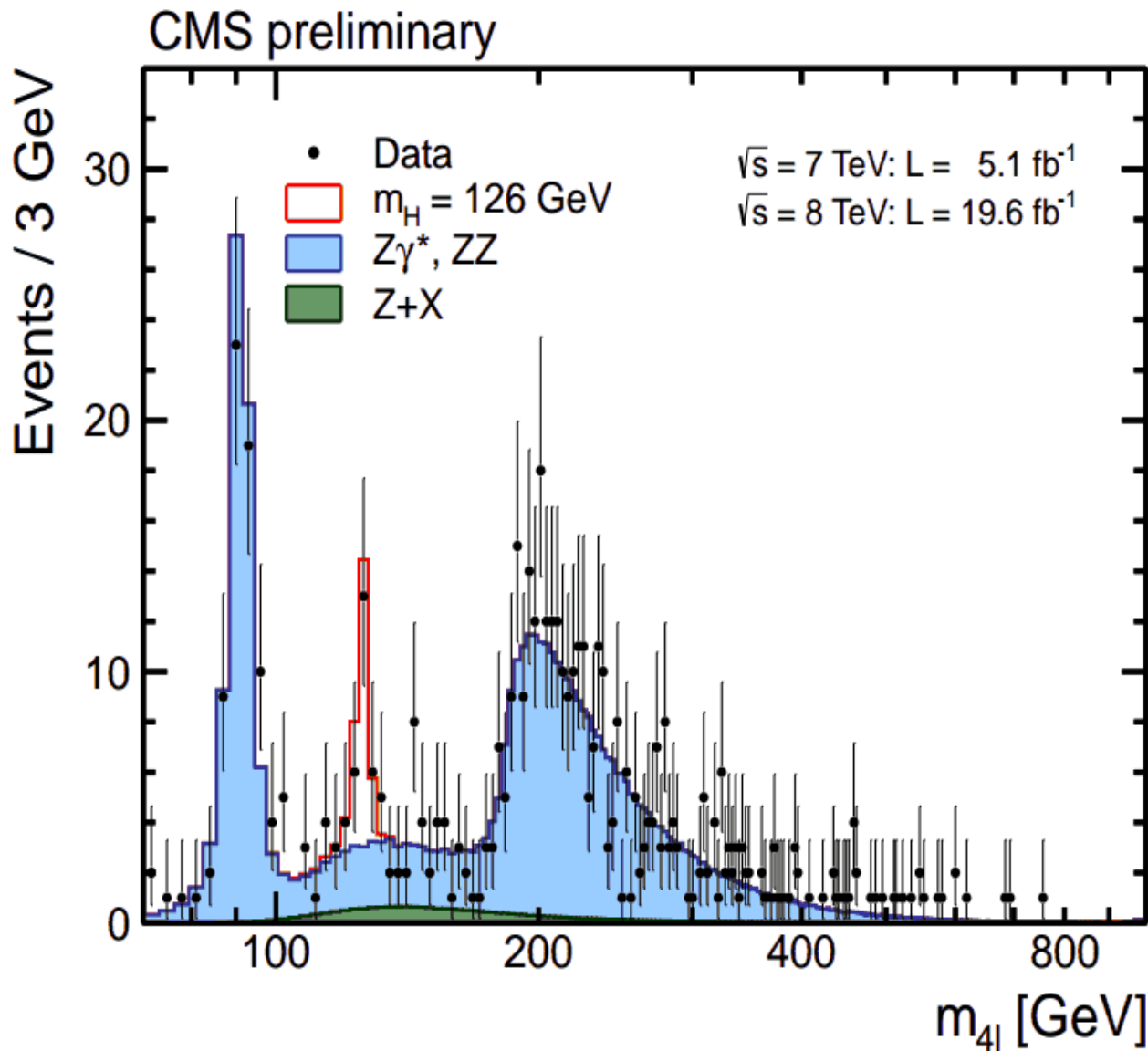
- **2 dilepton pairs !**

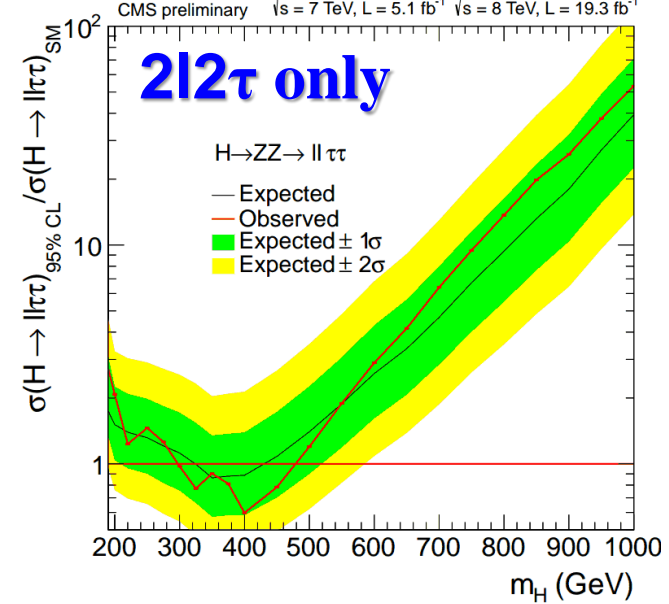
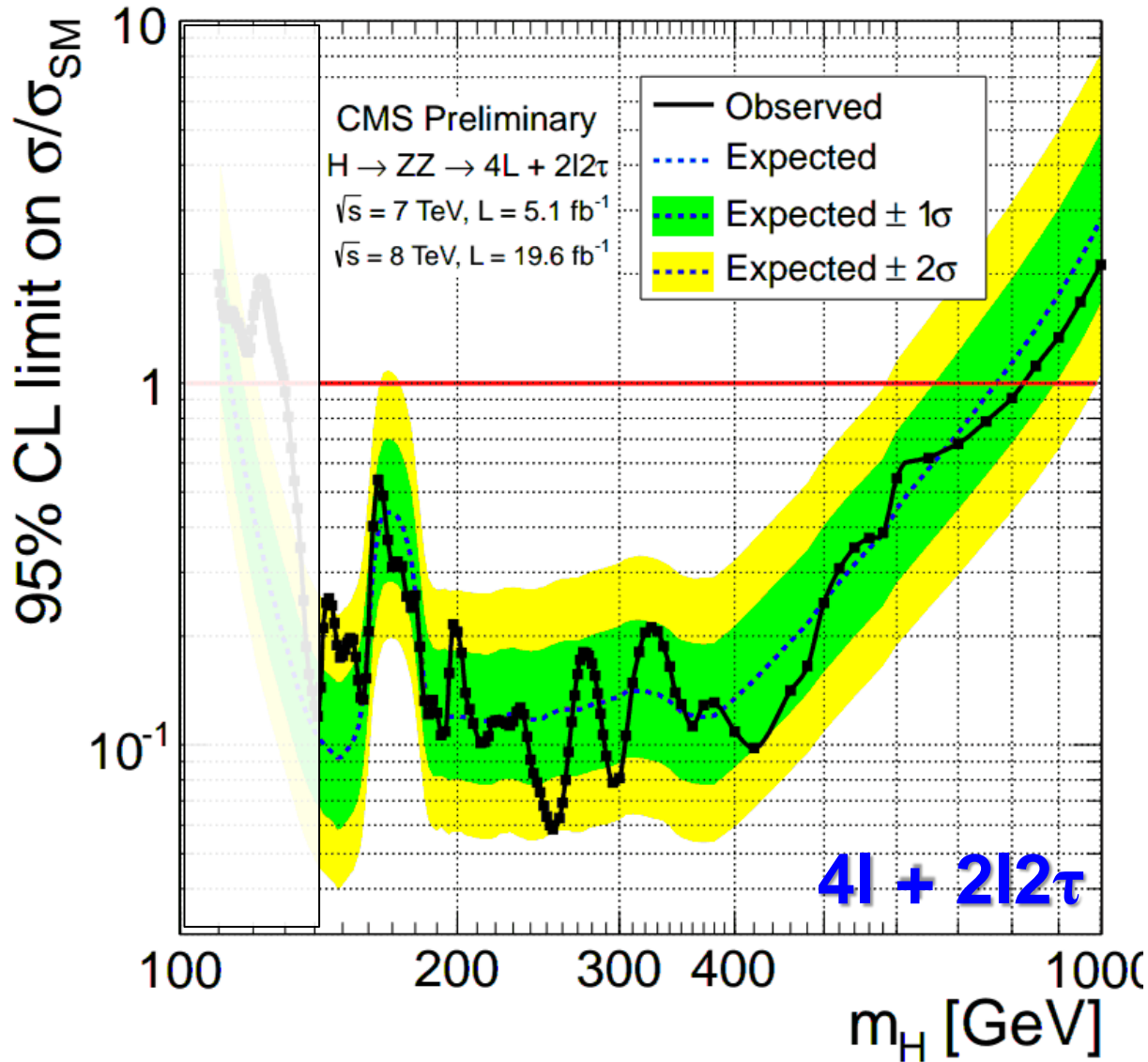
Main backgrounds :

- **ZZ / gammaZ**
- **Well controlled !**

Kinematic Discriminant :

- $MZ_1, MZ_2, 5$ angles
- Signal/Bckg hypothesis





Nothing else than a discovery at 125GeV...

SM-Like Higgs excluded in [130GeV , 827GeV]

$ZZ \rightarrow ll \quad qq$

Selection :

- 1 Dilepton pair
- 1 Jet pair

Categorization

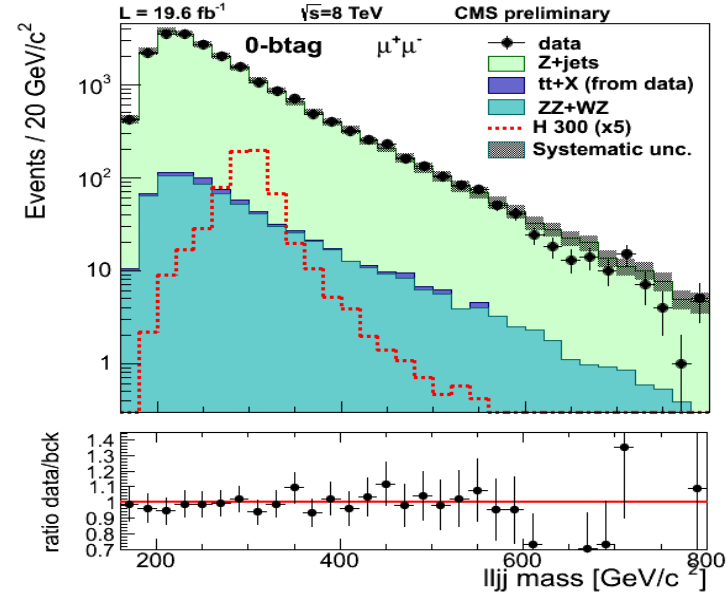
- 0, 1 and 2 BTags Jets

Main backgrounds :

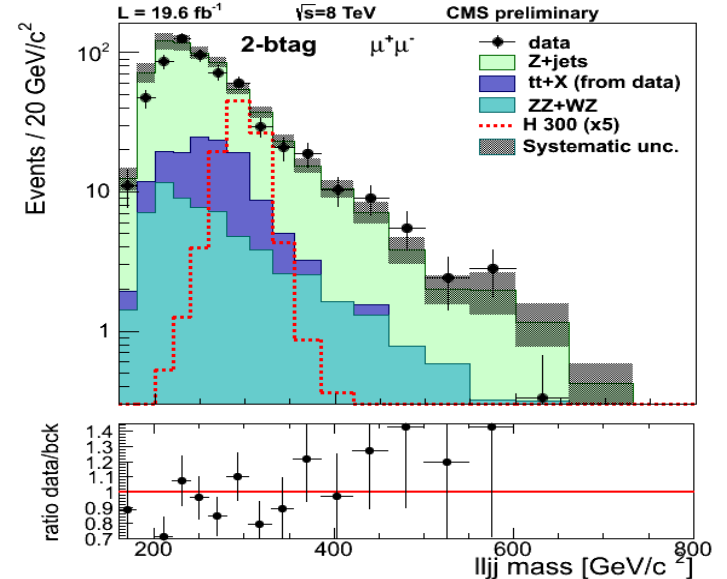
- Z+Jets
- Diboson
 - Estimated from M_{jj} sidebands
- Ttbar
 - from $e\mu$

Angular Discriminant :

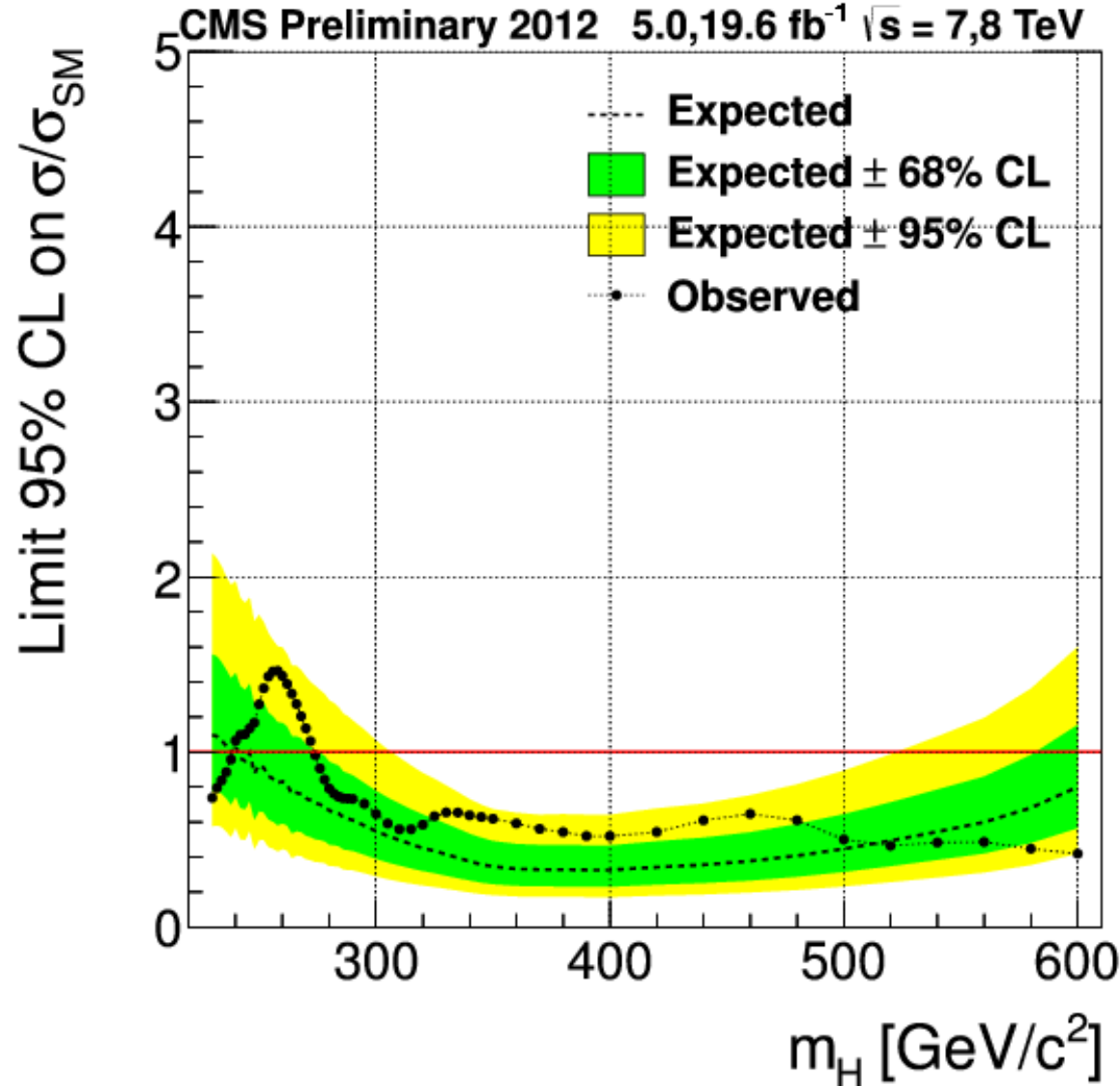
- 5 angles
- likelihood



0 BTag



2 BTags

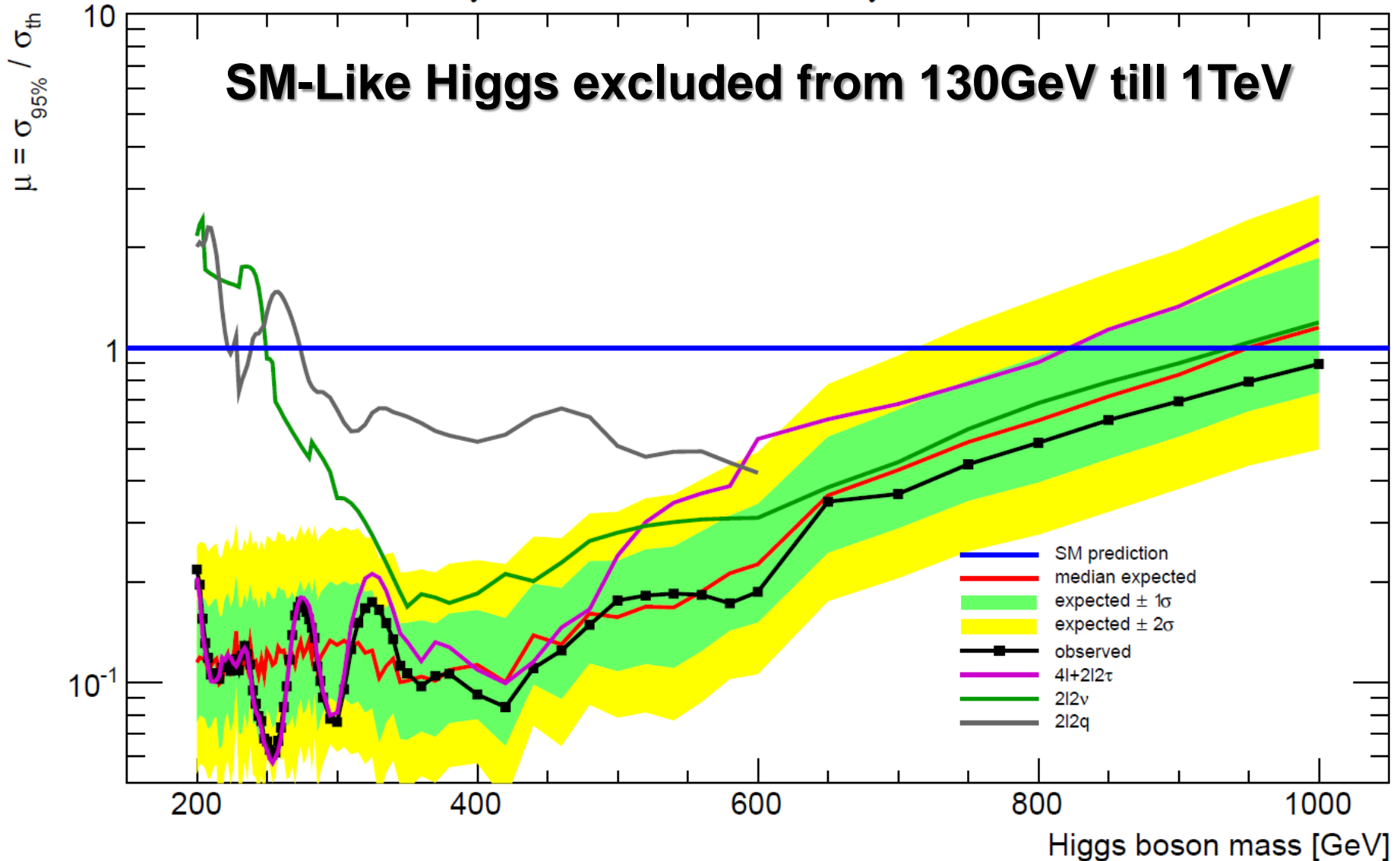


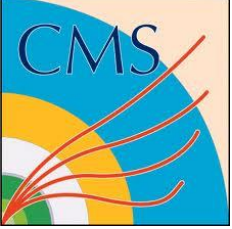
	0 btag		1 btag		2 btag	
	$\mu^+\mu^-jj$	e^+e^-jj	$\mu^+\mu^-jj$	e^+e^-jj	$\mu^+\mu^-jj$	e^+e^-jj
expected background	14809	13490	5478	4786	525	440
observed data	14697	13312	5458	4819	522	461
M_H (GeV/c ²)	signal expectation					
250	110.6	100.8	55.8	51.1	18.4	16.9
300	124.4	112.3	66.6	57.0	24.5	21.0
400	121.9	107.2	68.2	60.4	27.4	24.1
500	57.0	52.1	33.4	29.9	13.8	12.3
600	21.7	19.7	13.2	11.9	5.4	4.9

**SM-Like Higgs
excluded in
[275GeV , 600GeV]**

CMS preliminary, $\int L=5.0\text{fb}^{-1}$ at $\sqrt{s}=7\text{ TeV}$, $\int L=19.6\text{fb}^{-1}$ at $\sqrt{s}=8\text{ TeV}$

SM-Like Higgs excluded from 130GeV till 1TeV





$WW \rightarrow \nu \nu$

Selection :

- MET projected on lepton axis
- Transverse mass

$$m_T^{\ell\ell, E_T^{\text{miss}}} = \sqrt{2p_T^{\ell\ell} E_T^{\text{miss}} (1 - \cos \Delta\phi_{\ell\ell, E_T^{\text{miss}}})}$$

Categorization

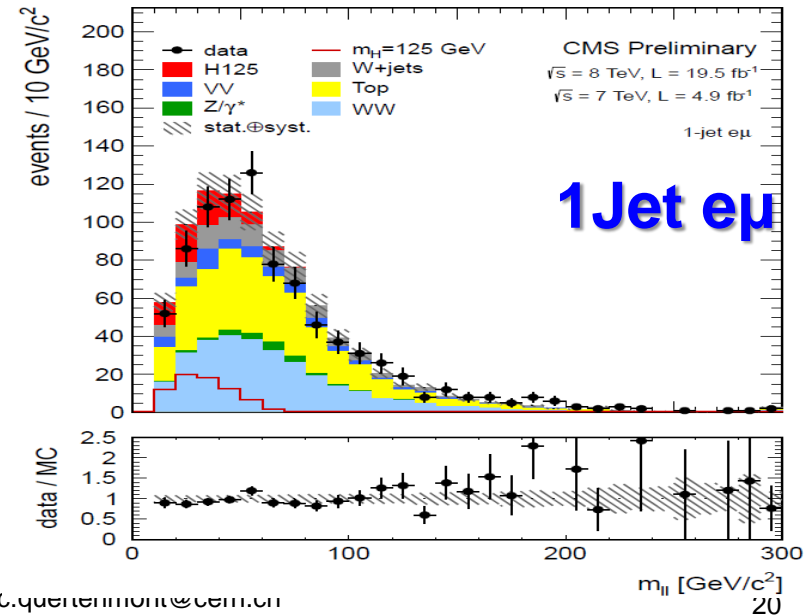
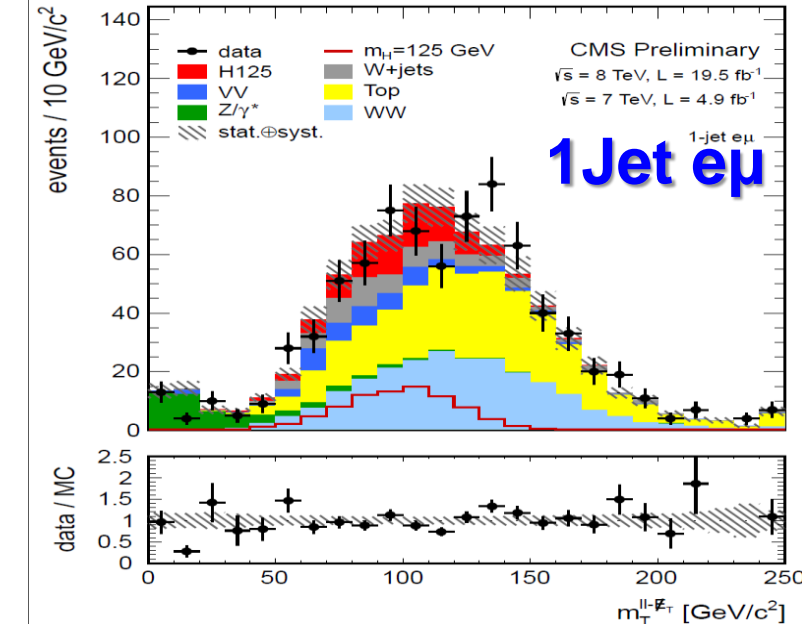
- GF: 0, 1 Jet
- VBF : ≥2Jets (VBF like)

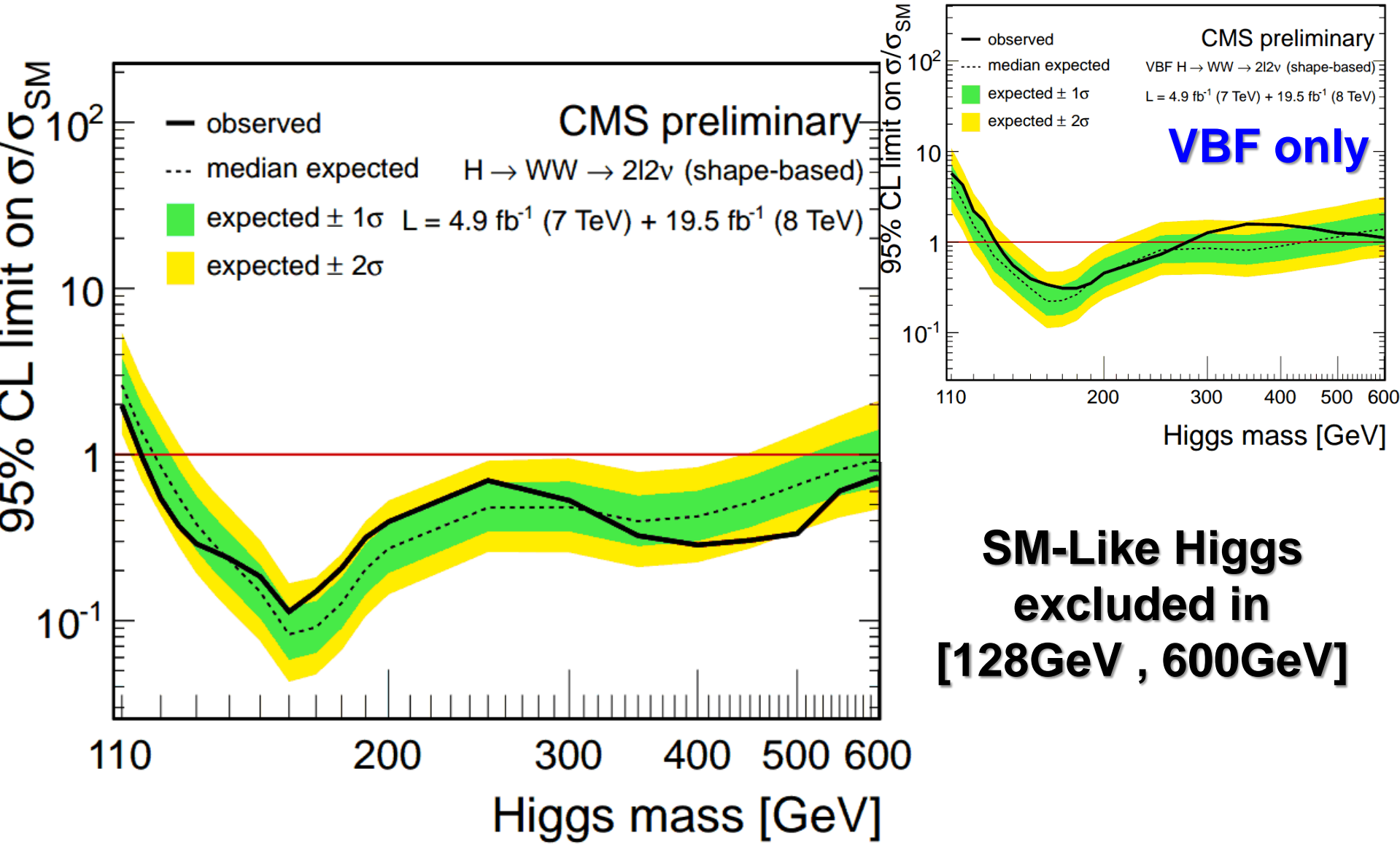
Main backgrounds :

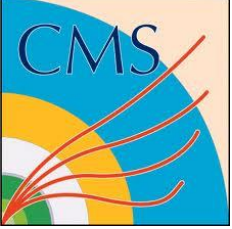
- Ttbar
- Z/W+Jets
- QCD
 - Datadriven technique from control regions

2D shape-based analysis

- M_{ll} - m_T







$WW \rightarrow lv \quad qq$

Selection :

- MET projected on lepton axis
- Transverse mass

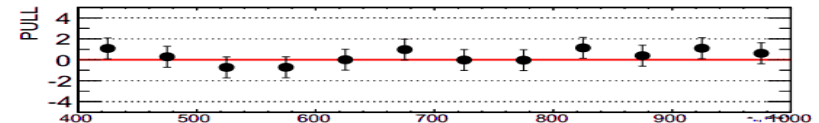
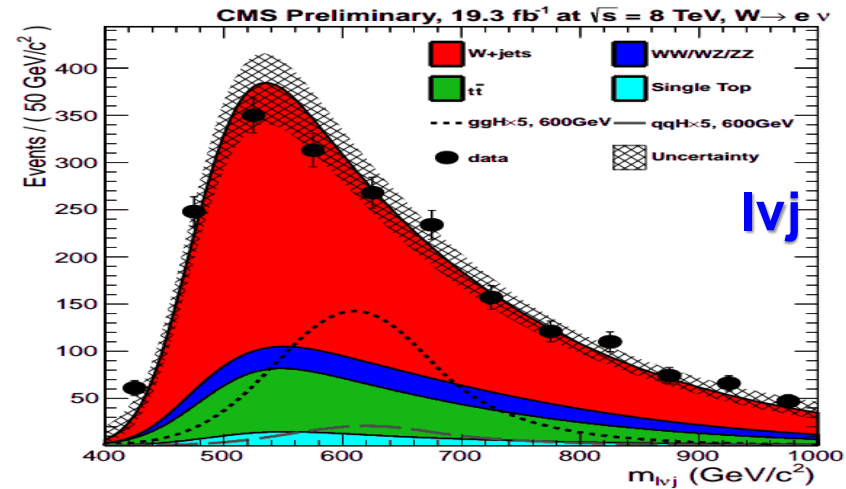
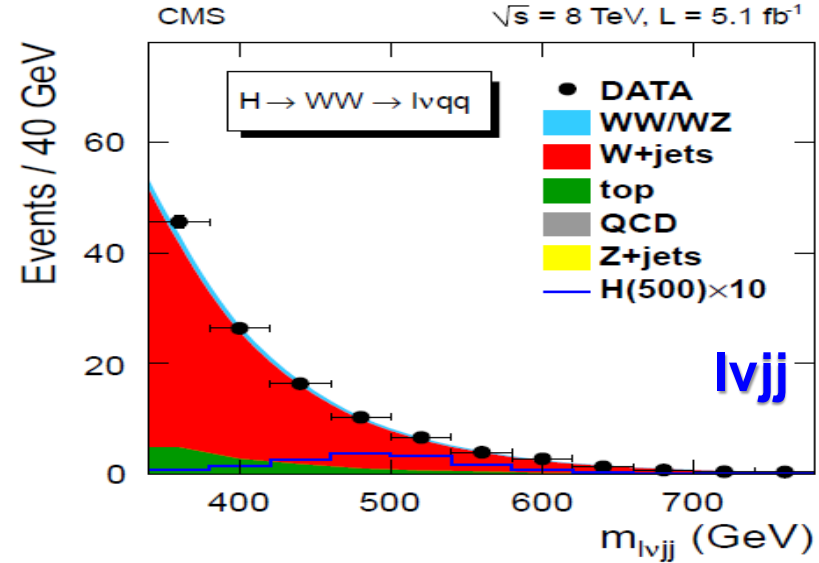
$$m_T^{\ell\ell, E_T^{\text{miss}}} = \sqrt{2p_T^{\ell\ell} E_T^{\text{miss}} (1 - \cos \Delta\phi_{\ell\ell, E_T^{\text{miss}}})}$$

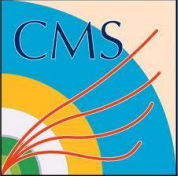
2 Analyses

- [200-600]GeV
 - 2 Separated Jets
 - Transverse mass
- [600-1000]GeV
 - 1 Jets (from 2 quarks)
 - Boosted Jet techniques
 - Jet SubStructure

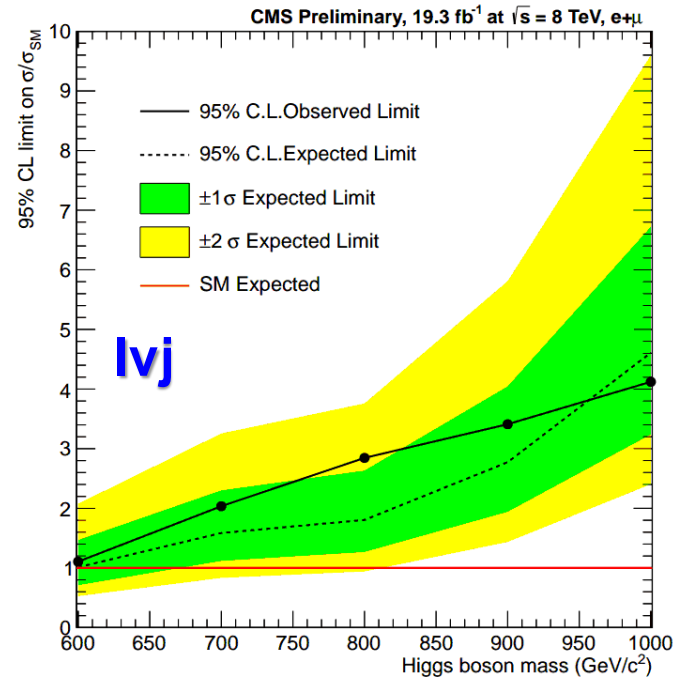
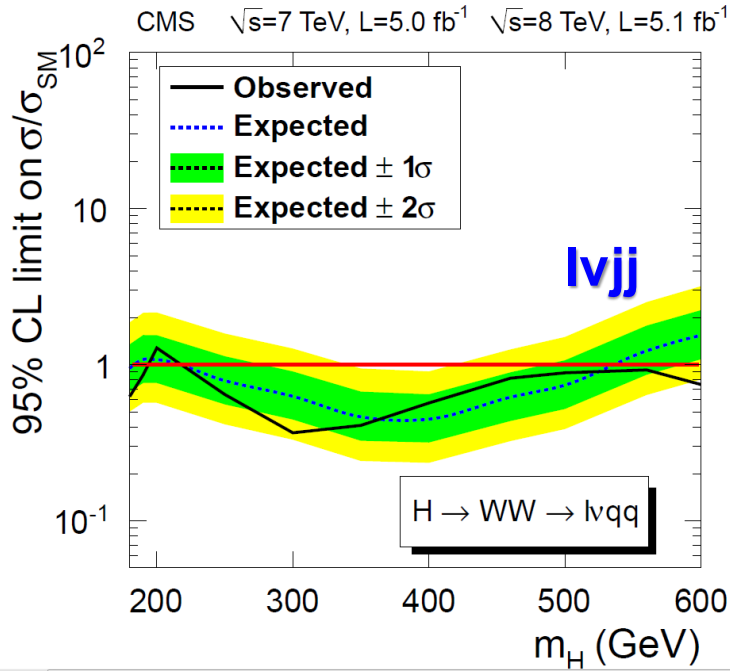
Main backgrounds :

- W+Jets
- Top
- VV

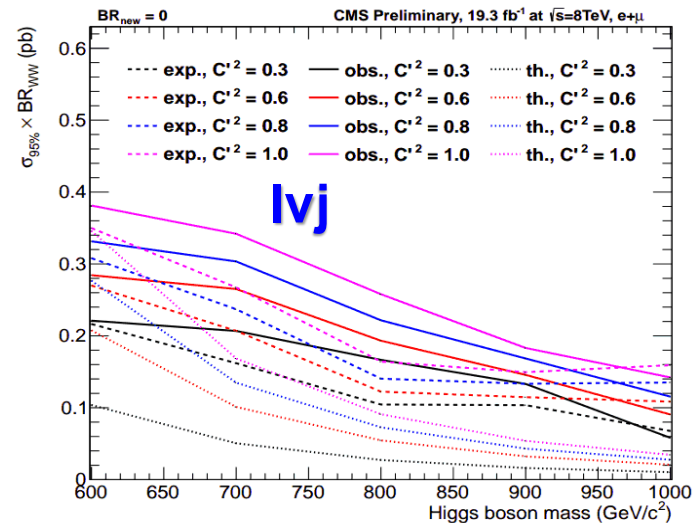


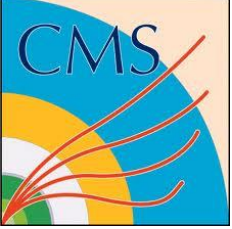


SM-Like + Singlet Higgs Limits



**SM-Like Higgs
 excluded in
 [215GeV , 600GeV]**





Summary

CMS preliminary, $\int L=5.0\text{fb}^{-1}$ at $\sqrt{s}=7\text{ TeV}$, $\int L=19.6\text{fb}^{-1}$ at $\sqrt{s}=8\text{ TeV}$

