Search for SM Higgs in the High Mass Region

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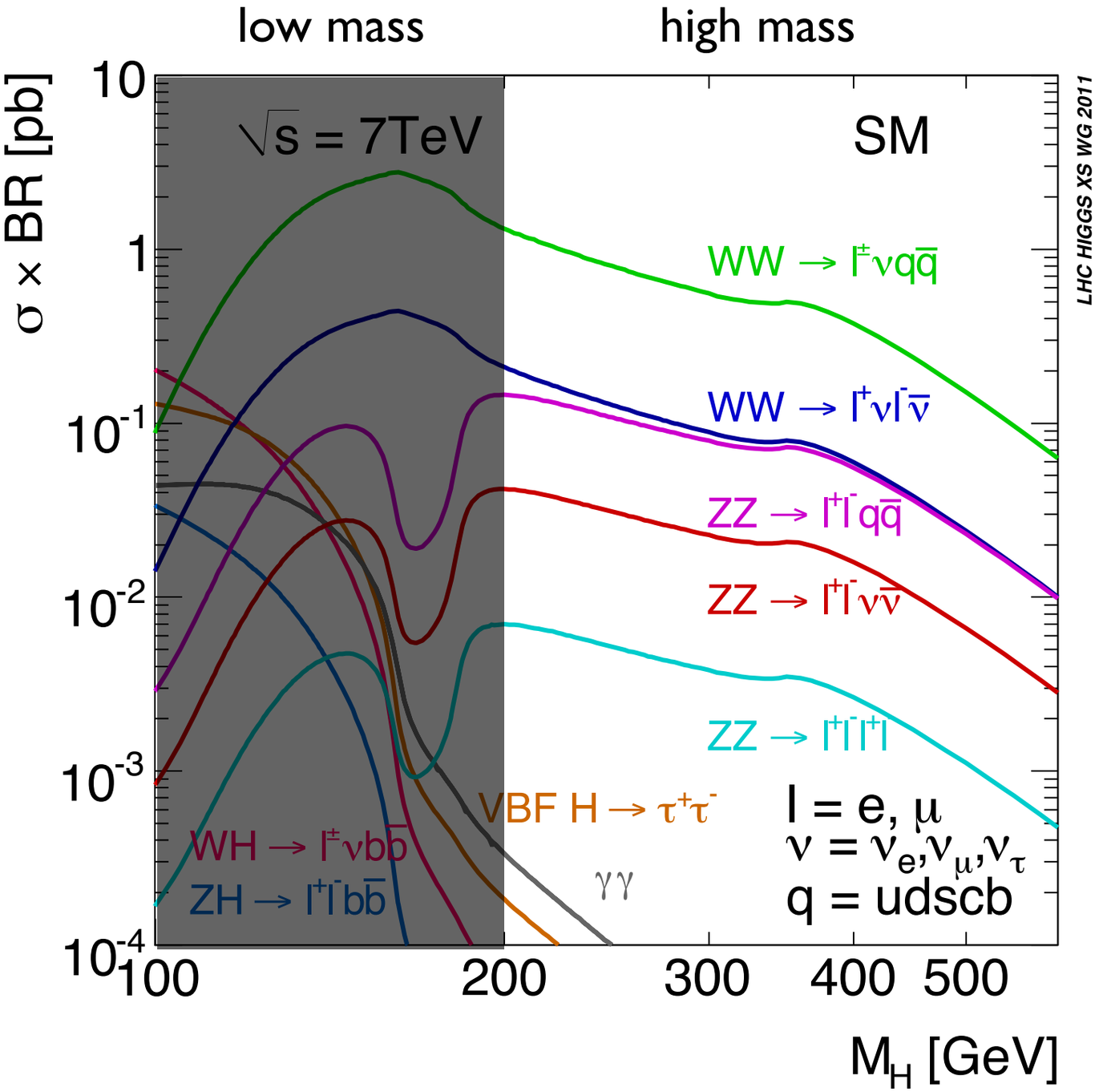
On behalf of the CMS and ATLAS Collaborations

24th Rencontres de Blois, May 30th, 2012

The SM Higgs Branching Ratio

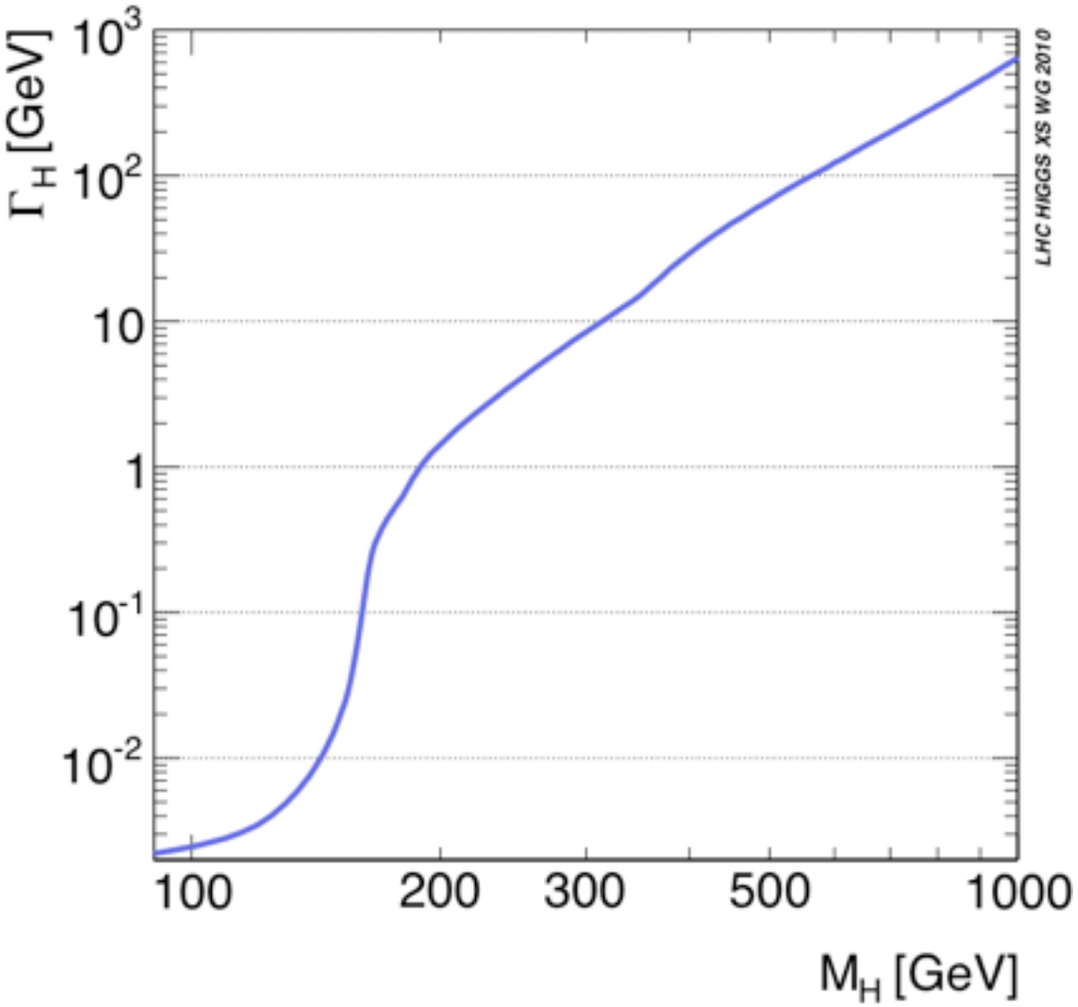


- In the high mass region (mH>200 GeV), Higgs decays predominantly into WW and ZZ
- Though not favored by EWK precision measurements, Higgs mass region is very sensitive to BSM Higgs mechanism
  - Especially in studying the unitarity violation in VV scattering
- The relative sensitivity of each channel also depend on trigger and respective backgrounds
  - Final states with quarks usually suffer from large background, resulting in poor S/B

The Higgs Mass Resolution

- In the high mass region the SM Higgs natural width is large
  - For very high mass region > 500 GeV, the natural width dominates (> 20%)
- The experimental Higgs mass resolution depends on final state

Higgs Natural width

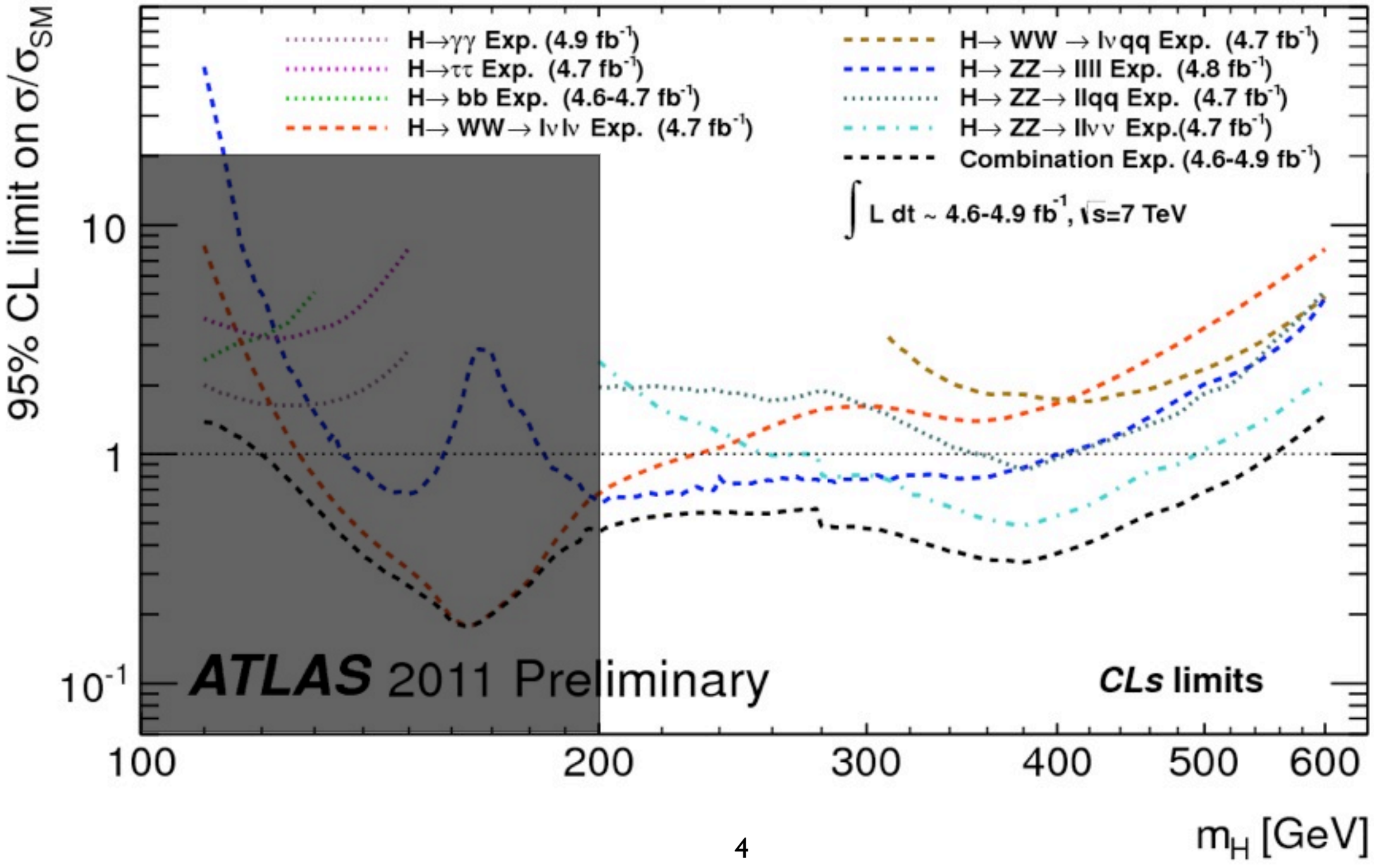


Higgs experimental mass resolution

Channel H →	mH resolution
ZZ→4l	1-2%
ZZ→2l2ν	~10%
ZZ→2l2q	3%
WW→lνlν	~20%
WW→lνqq	~15%

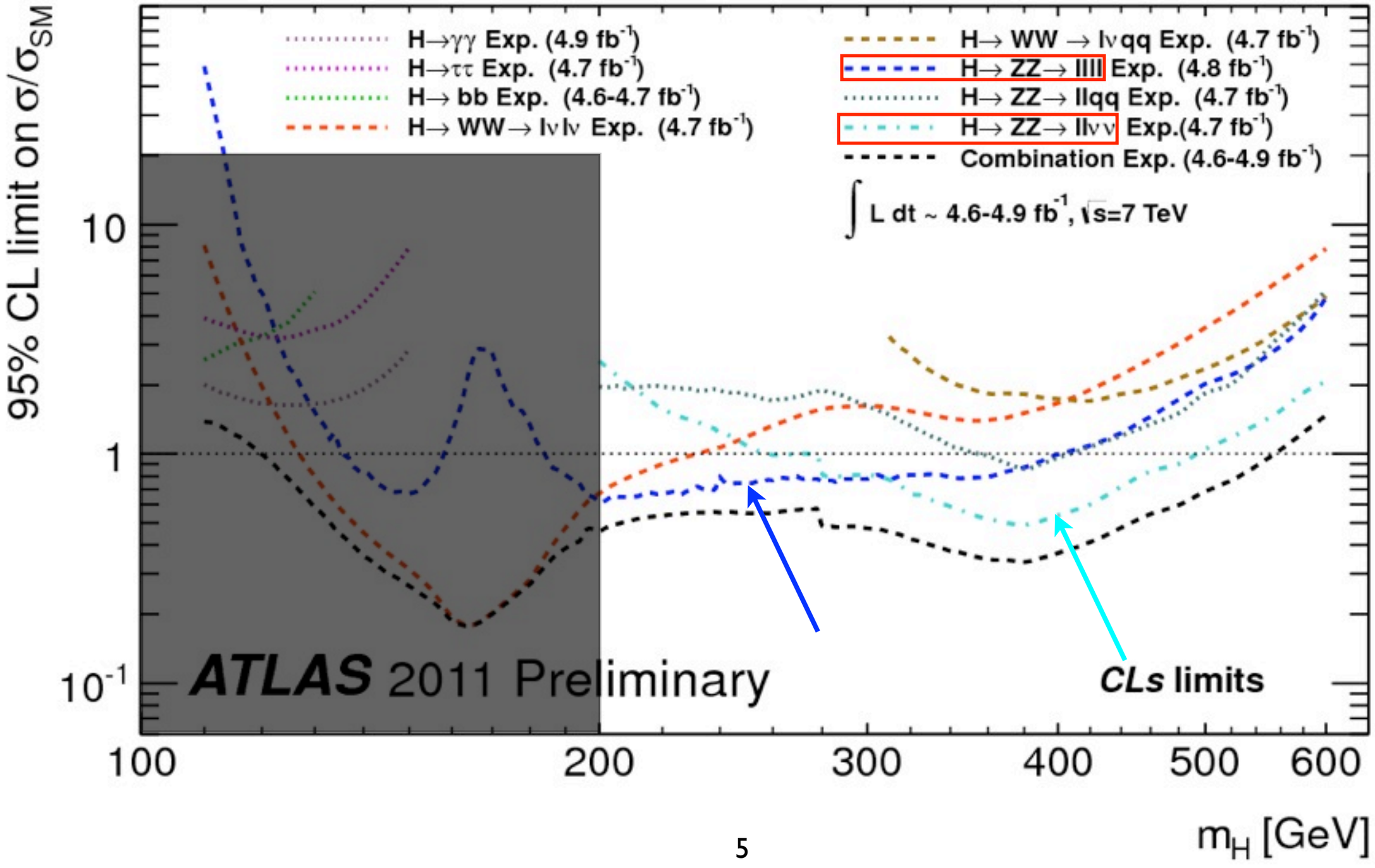
Expected Sensitivity of Each Channel

- We expect to exclude a wide range up to ~ 600 GeV



Expected Sensitivity of Each Channel

- We expect to exclude a wide range up to ~ 600 GeV
  - Higgs mass < 300 GeV: H→ZZ→4l is the most sensitive channel
  - Higgs mass >300 GeV: H→ZZ→(ll)(νν) is most sensitive channel

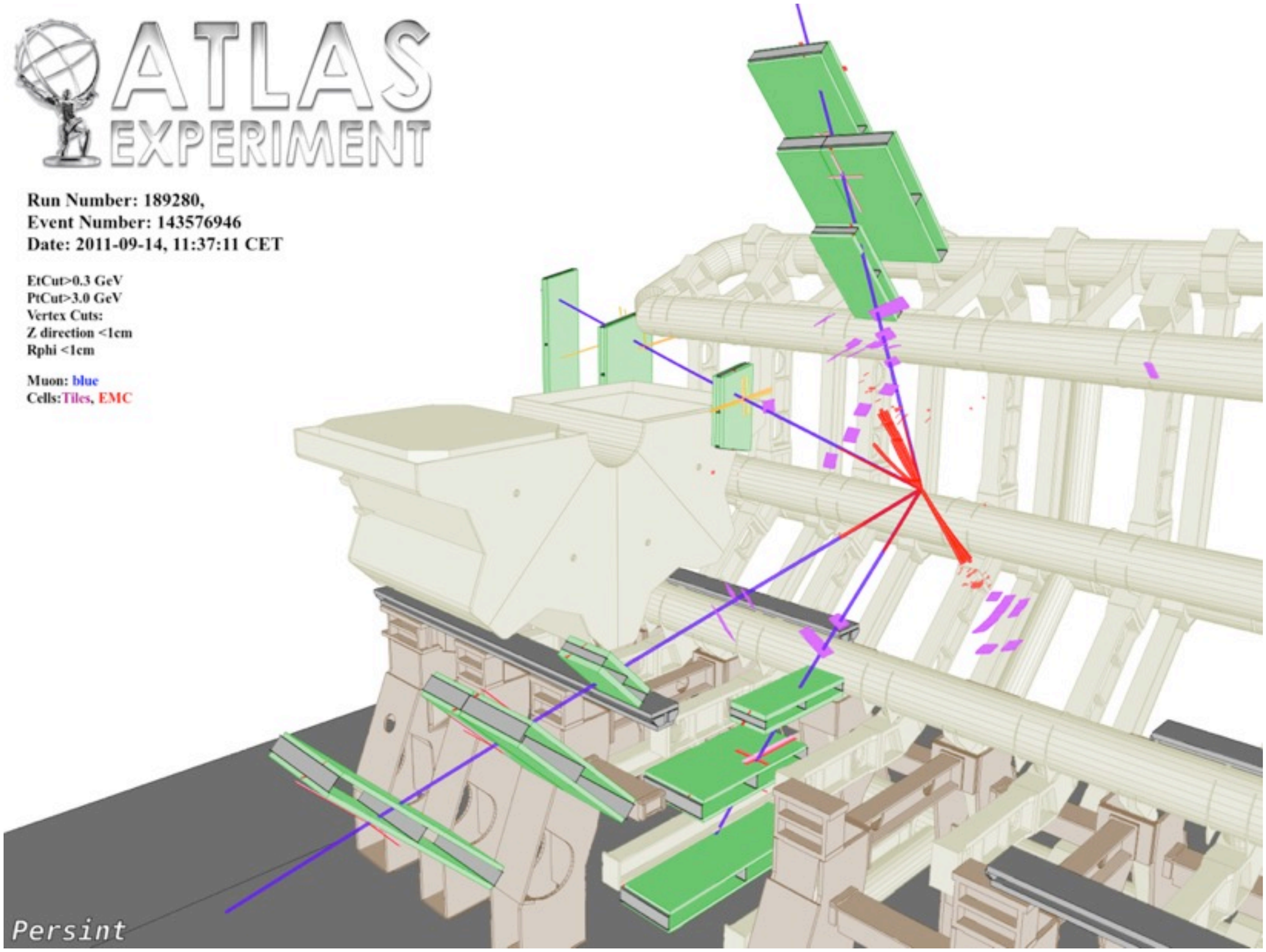


Outline

- $H \rightarrow ZZ \rightarrow 4l$ search strategy and results
- $H \rightarrow ZZ \rightarrow (ll)(\nu\nu)$ search strategy and results
- $H \rightarrow WW \rightarrow (l\nu)(l\nu)$ search strategy and results
- $H \rightarrow WW \rightarrow (l\nu)(qq)$ search strategy and results
- $H \rightarrow ZZ \rightarrow (ll)(qq)$ search strategy and results
- Conclusion: combined search results

"The Golden Channel" H→ZZ→4l

4 high momenta, isolated leptons, 1-2% mass resolution



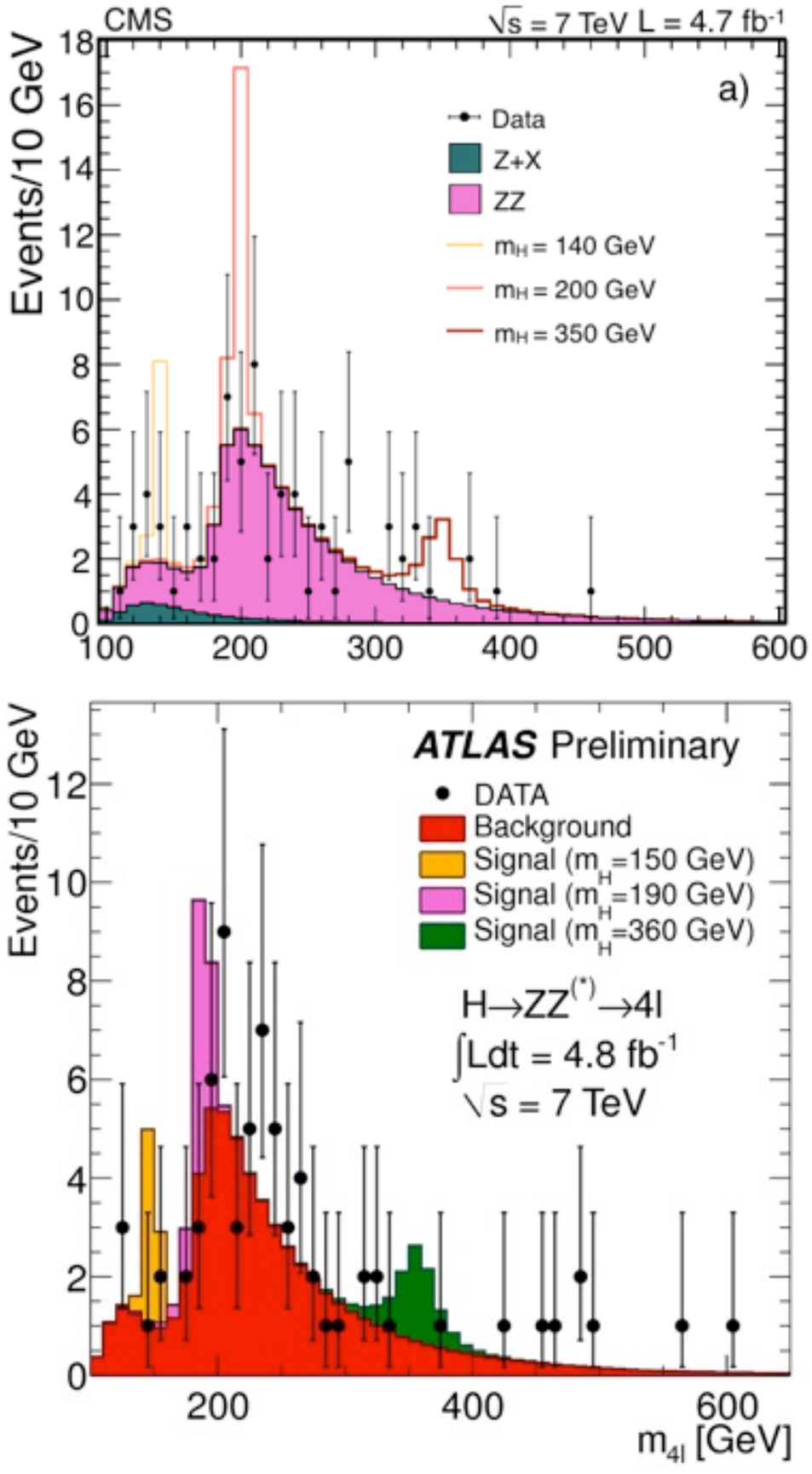
H→ZZ→4l Search Strategy

- Channel features
  - Fully reconstructed Higgs mass with excellent resolution
  - Main drawback is the limited statistics
- Main Background is the continuum ZZ
  - The solid understanding of ZZ m(4l) spectrum is the key of the analysis. The current theoretical uncertainty is ~10%
    - One of the most limiting factor in improving the analysis

Number of 4l candidates (CMS) with m(4l) [100-600] GeV

ZZ	Z+X	Total Background	Signal (350 GeV)	Obs
61.6 ± 3.5	5.5 ± 1.2	67.1 ± 3.7	9.2	72

- The m(4l) shape is used to extract final results

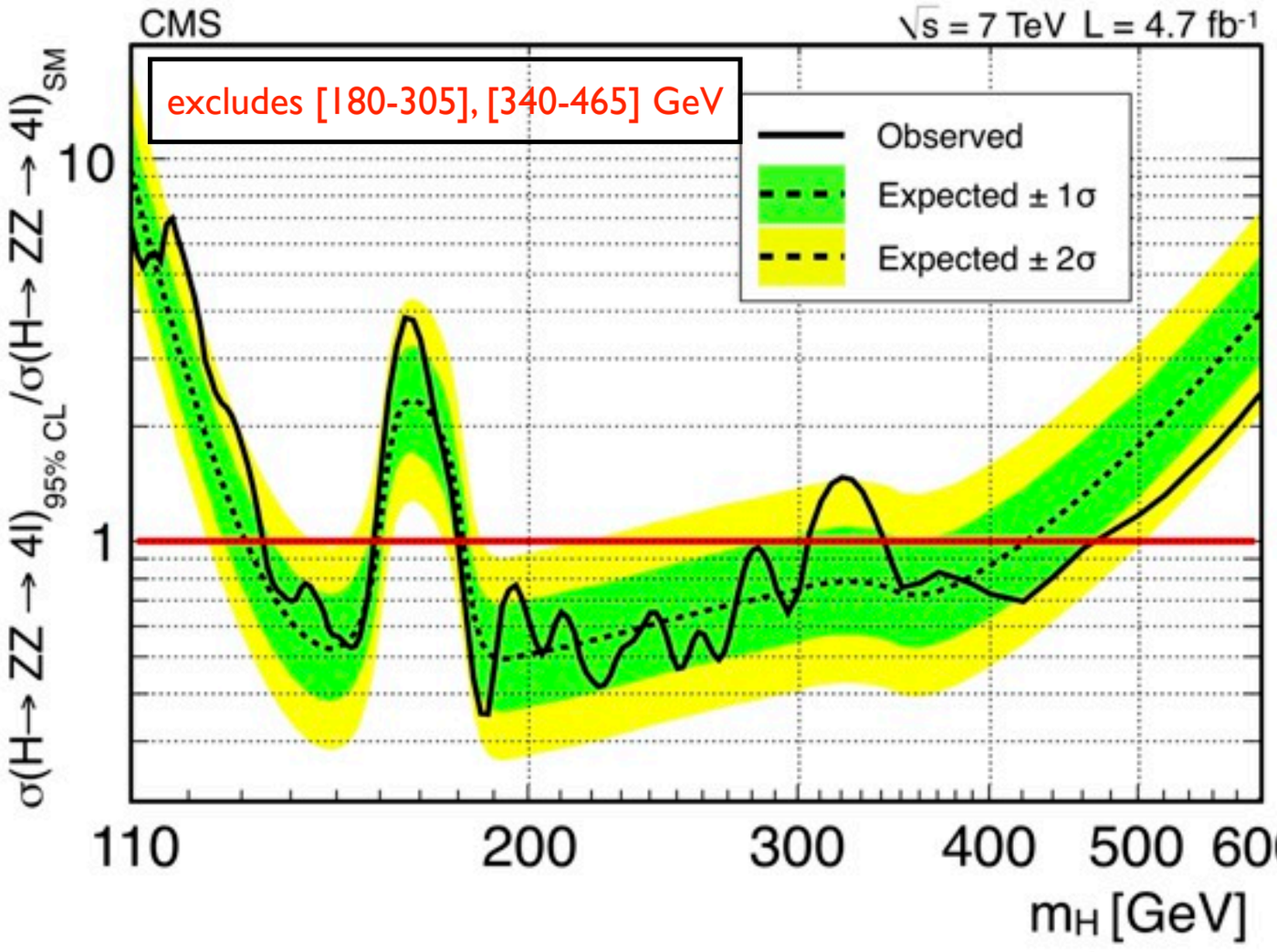


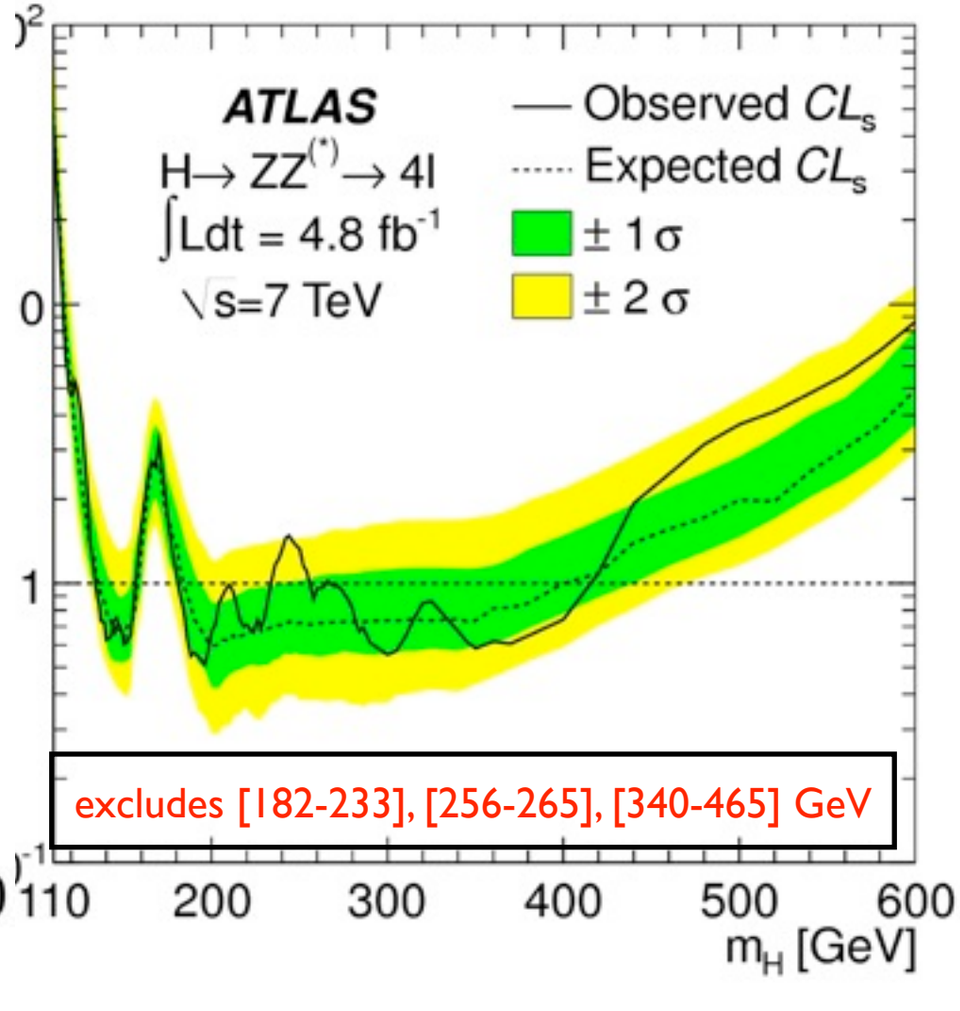
H→ZZ→4l Search Results

- The expected exclusion region from both experiments are comparable

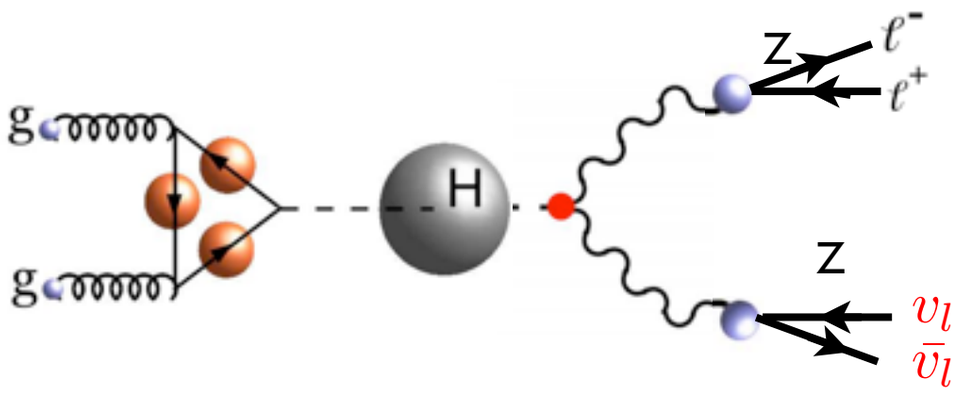
	CMS	ATLAS
Expected Exclusion Region	[180-420] GeV	[184-400] GeV

- No excess is found and the observed limit is consistent to the expected
  - The observed result is subject to large statistical fluctuations



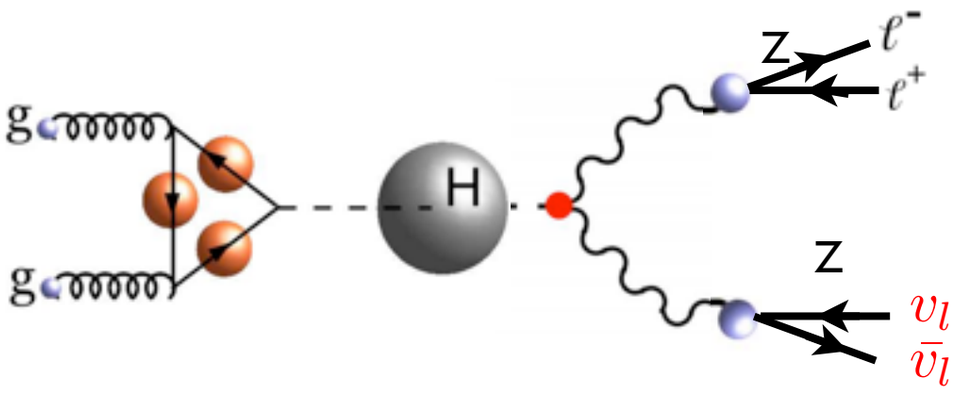


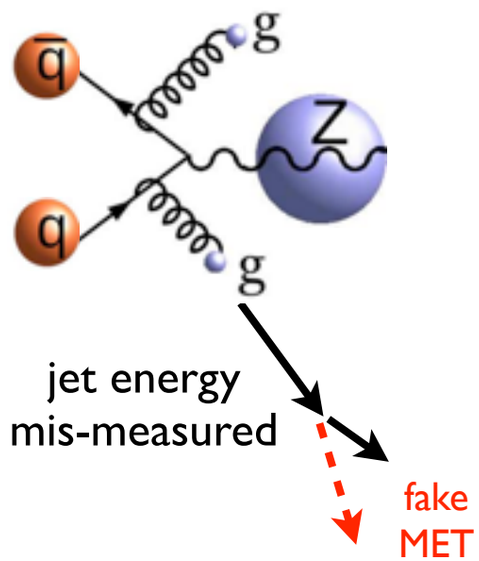
H→ZZ→(ll)(νν) Search Strategy

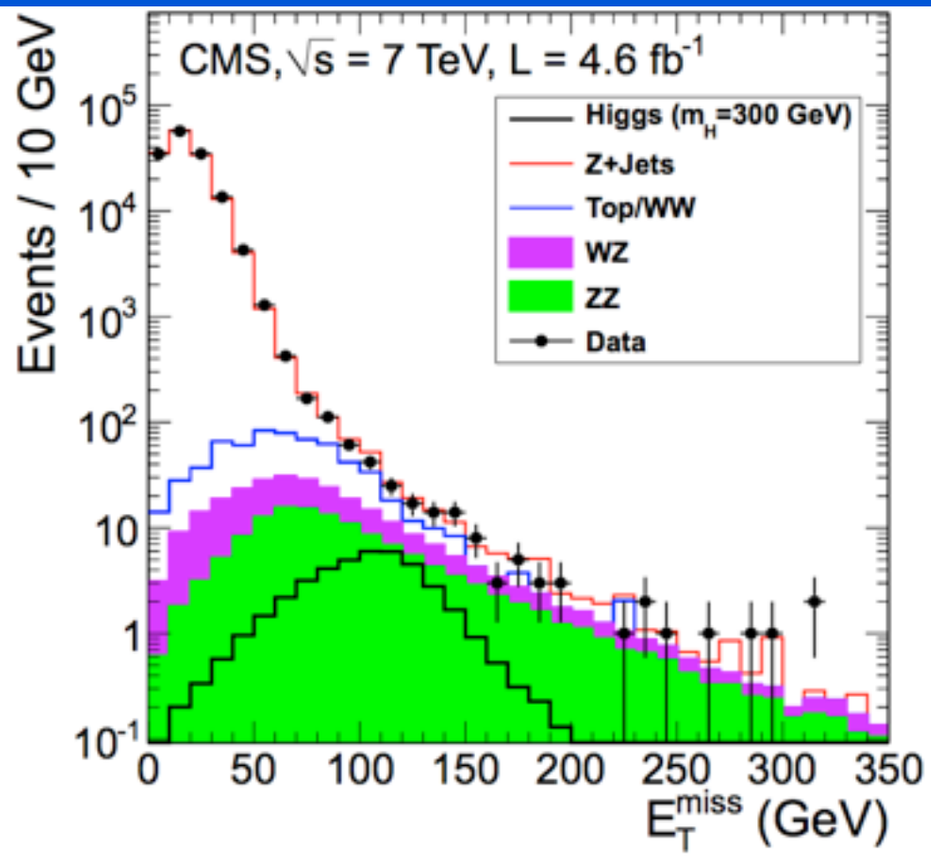


- Dileptons and large MET → good S/B
  - Two missing neutrinos → no mass peak
  - The large mH gives large boost to the Zs, creating high MET and large transverse activity

H→ZZ→(ll)(νν) Search Strategy







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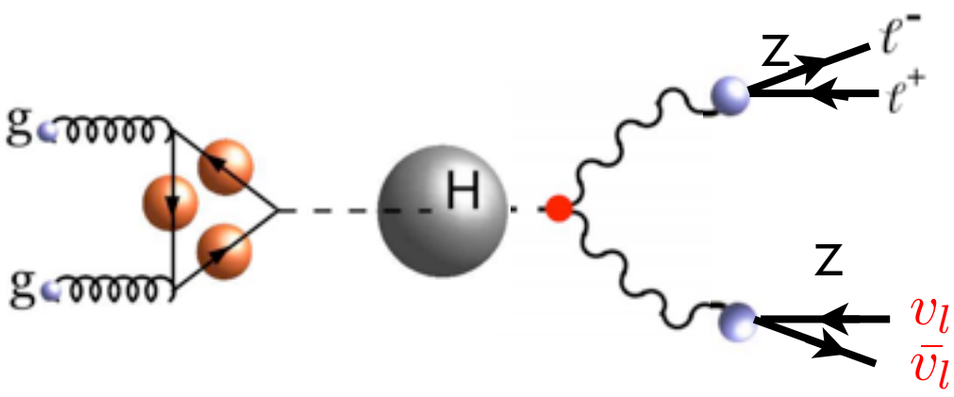
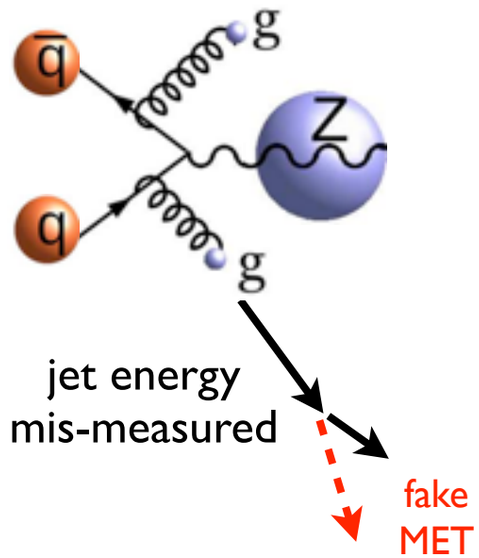
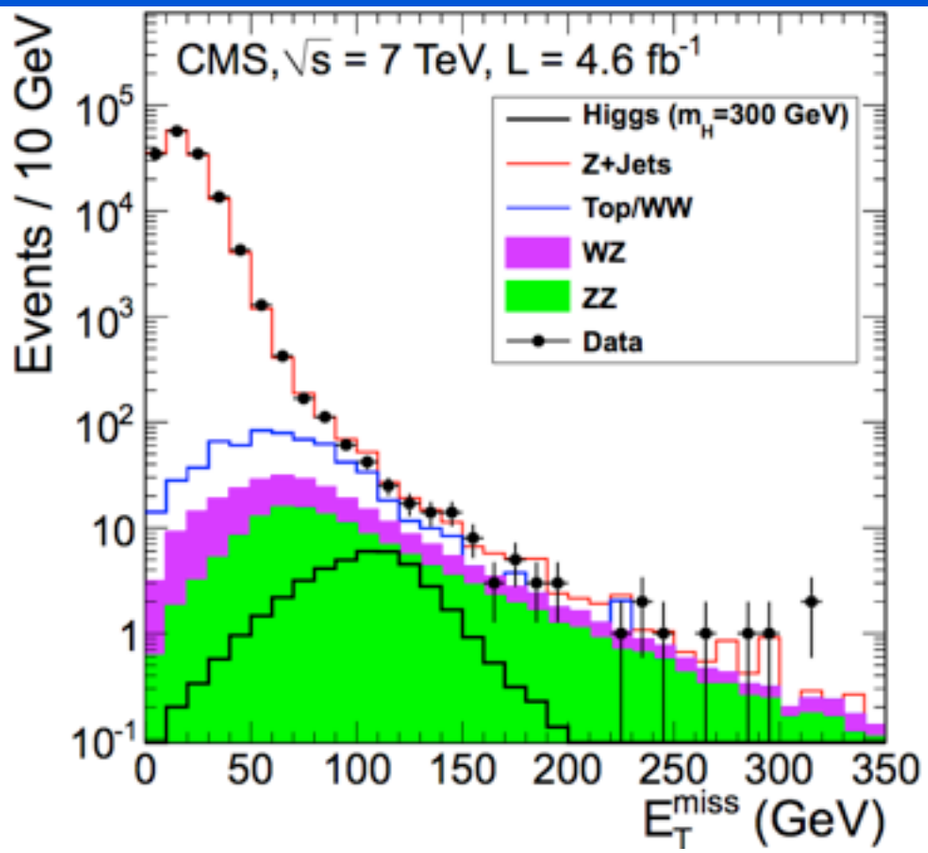
  - The large mH gives large boost to the Zs, creating high MET and large transverse activity
- Main challenge is Z+Jets background
  - Cut on MET and veto jets faking MET topology
    - CMS: simulate the MET from γ+Jet data
    - ATLAS: taken from MC, verified with data

H→ZZ→(ll)(νν) Search Strategy







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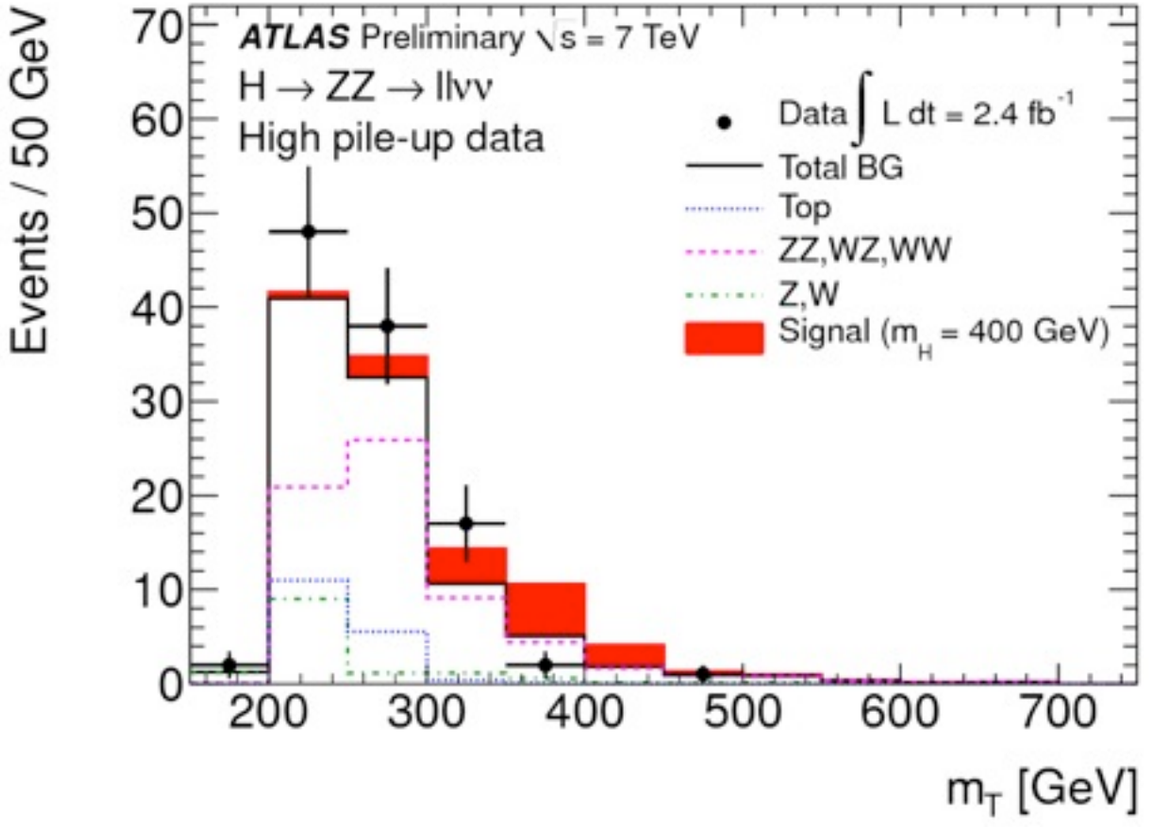
  - Cut on MET and veto jets faking MET topology
    - CMS: simulate the MET from γ+Jet data
    - ATLAS: taken from MC, verified with data
- M_T shape is used to extract final results

$$M_T^2 = \left(\sqrt{p_T(\ell\ell)^2 + M(\ell\ell)^2} + \sqrt{E_T^{miss\,2} + M(\ell\ell)^2}\right)^2 - (\vec{p}_T(\ell\ell) + \vec{E}_T^{miss})^2$$

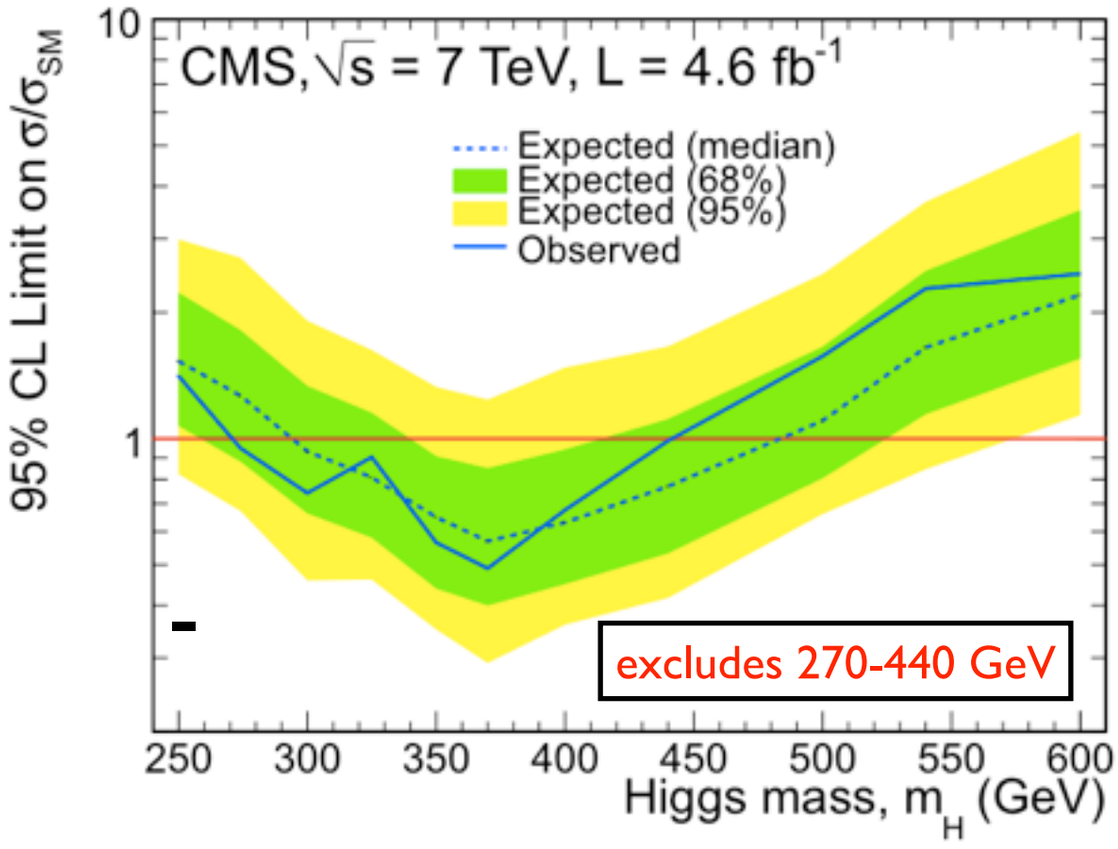


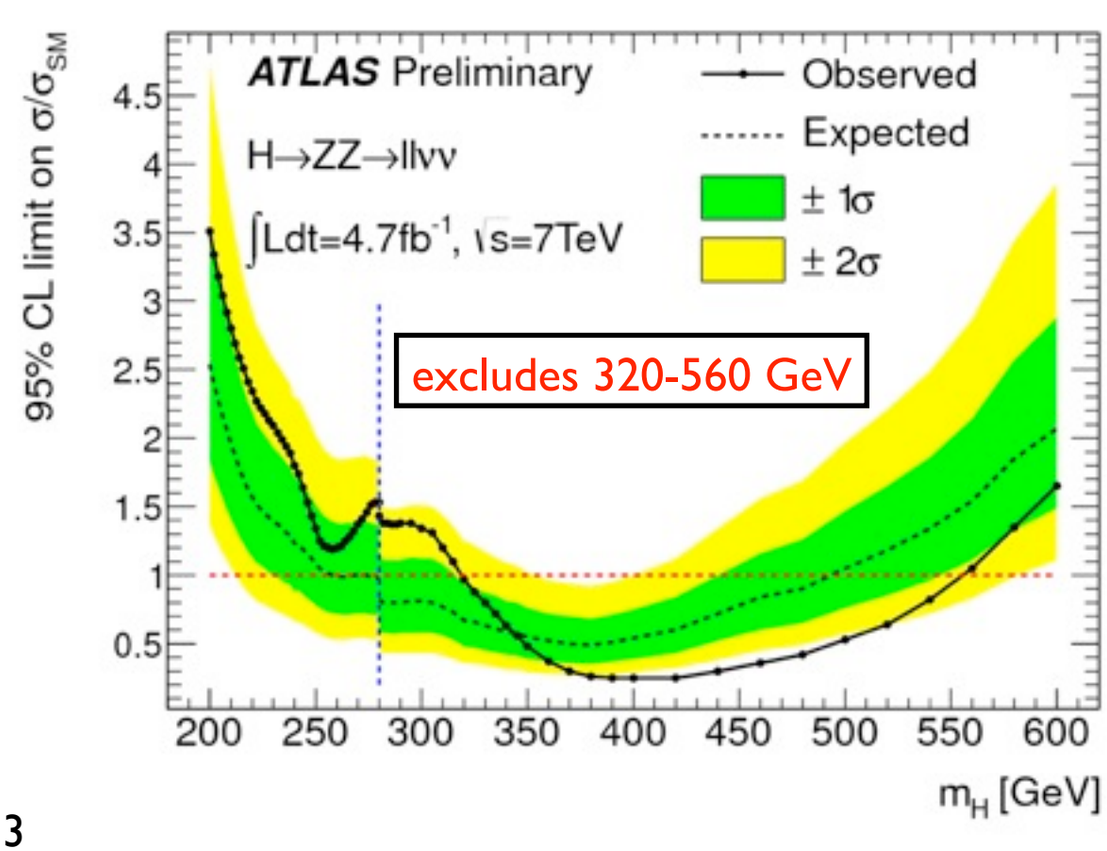
H→ZZ→(ll)(νν) Search Results

- Some differences between CMS and ATLAS
  - The CMS search is optimized for each mH, while the ATLAS search is divided in two regions
  - The ATLAS search includes Higgs signals H→WW→(lν)(lν), ZZ→(2l)(2q)/4l
    - The H→WW→(lν)(lν) contribution is [70%-13%] for Higgs with mass [200-300] GeV

	CMS	ATLAS
Expected Exclusion Region	[305-470] GeV	[260-490] GeV

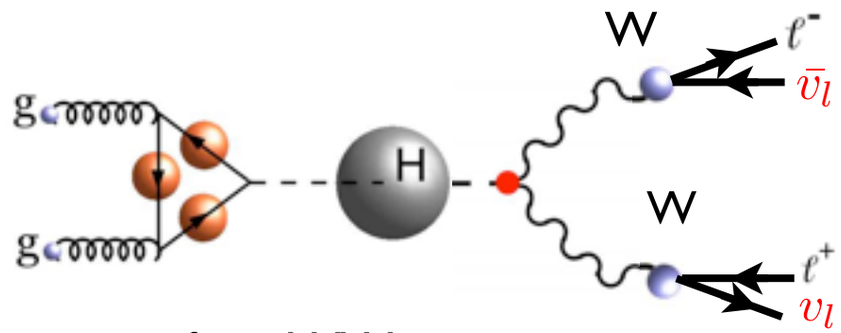
- No excess is found, ATLAS observed a slight downward fluctuation





H→WW→(lν)(lν) Search Strategy

- Final state include 2 good leptons, large MET → Good S/B
  - No mass peak→poor mass resolution
  - High mass H→WW decays longitudinally, as in non-resonant WW
    - No small opening angle signature as in low mass → difficult to separate from WW



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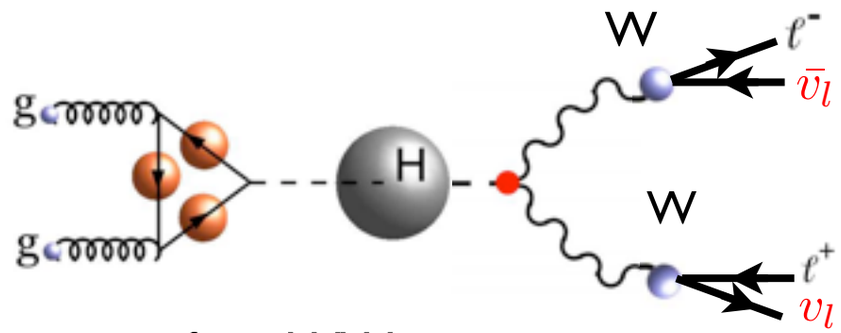

- Without a distinct signature, solid background estimation is the key of the analysis
  - The main background WW is taken from MC with appropriate theoretical uncertainties
  - The reducible backgrounds such as W/Z+jet and Top are estimated from data

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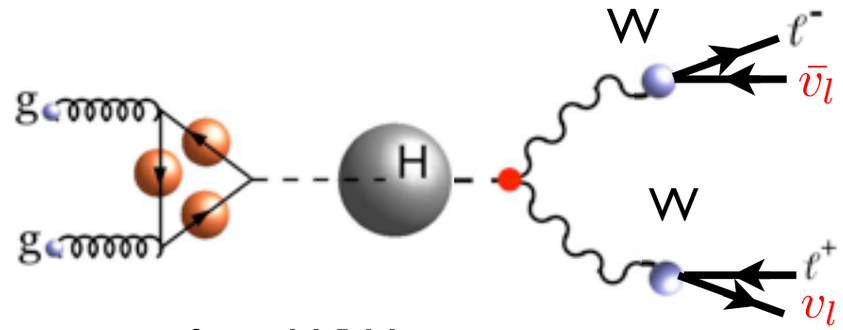
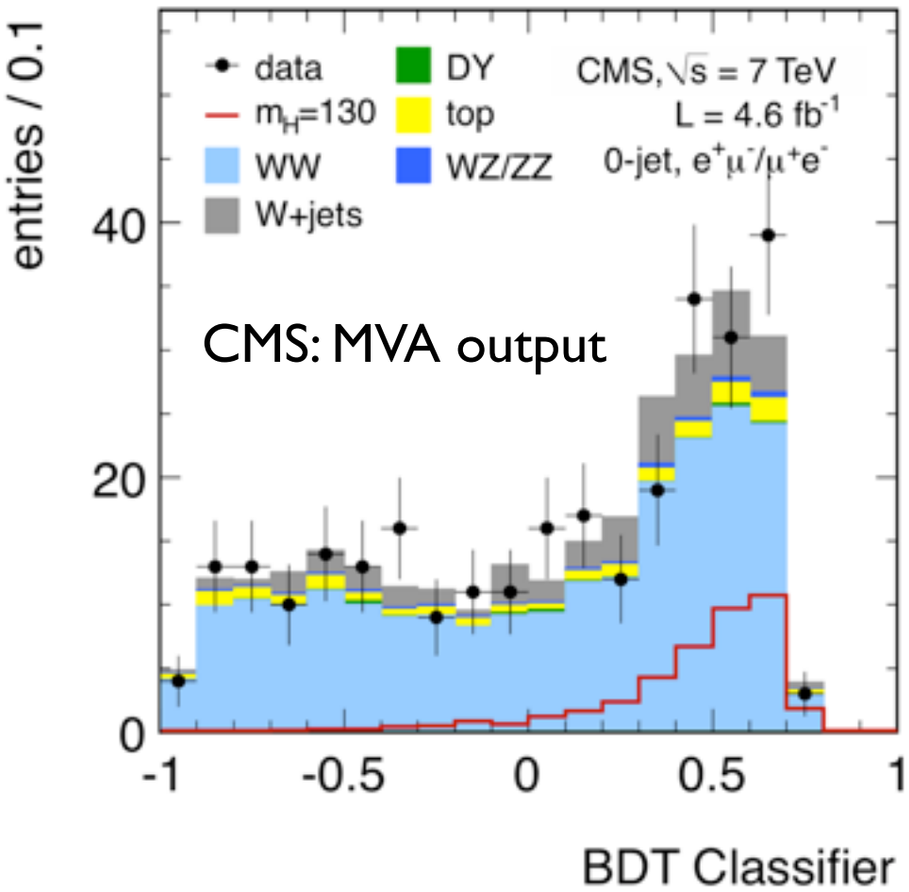
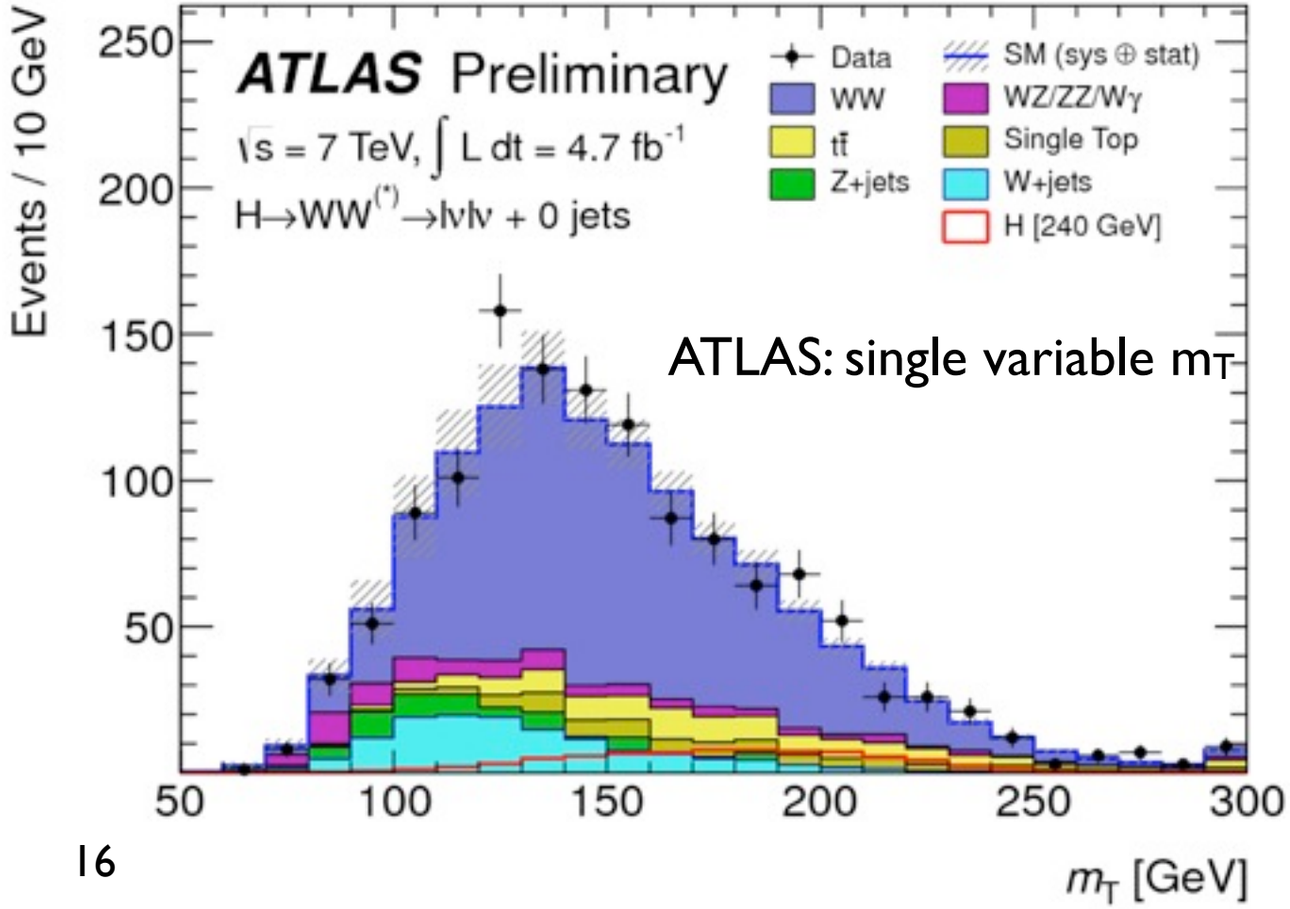


- Without a distinct signature, solid background estimation is the key of the analysis
  - The main background WW is taken from MC with appropriate theoretical uncertainties
  - The reducible backgrounds such as W/Z+jet and Top are estimated from data
- Perform shape analysis for the final results based on either MVA or the best single variable



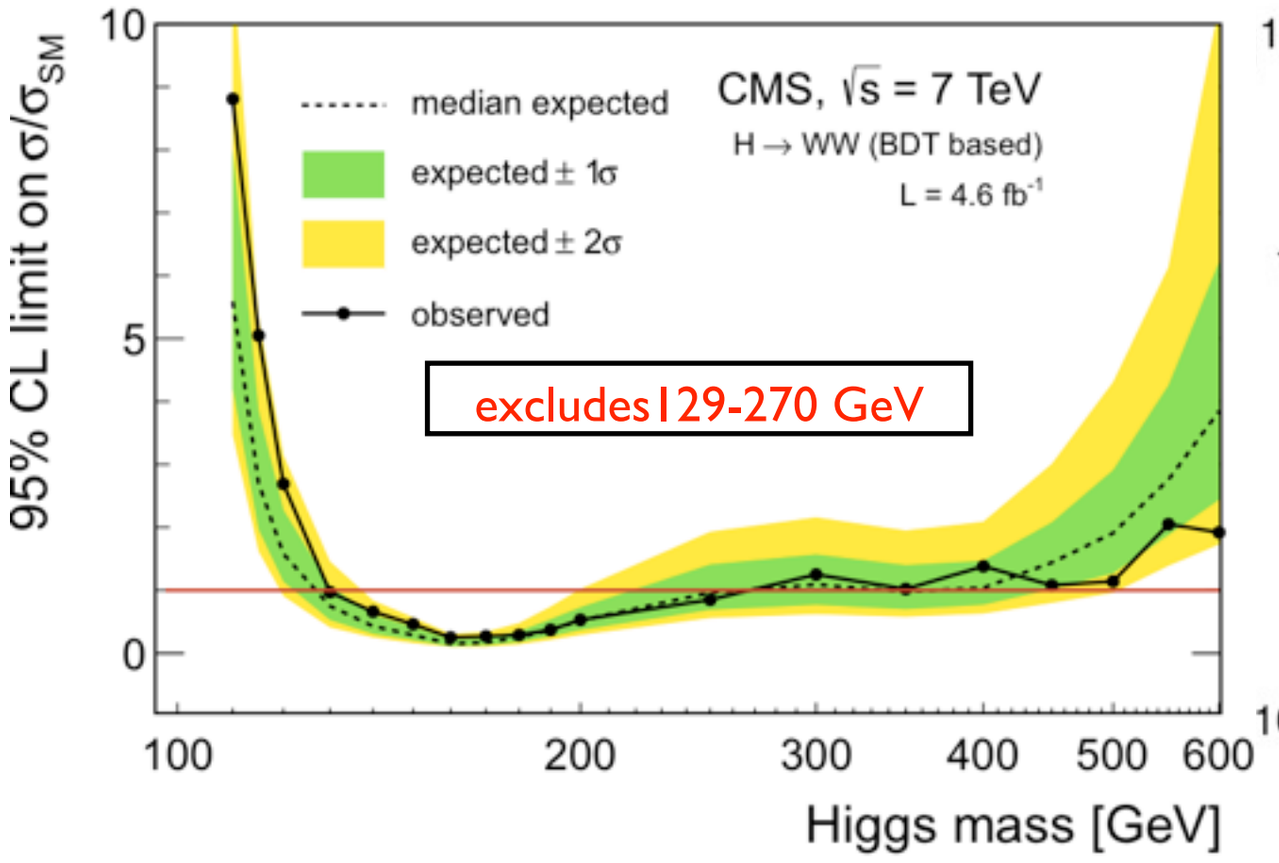


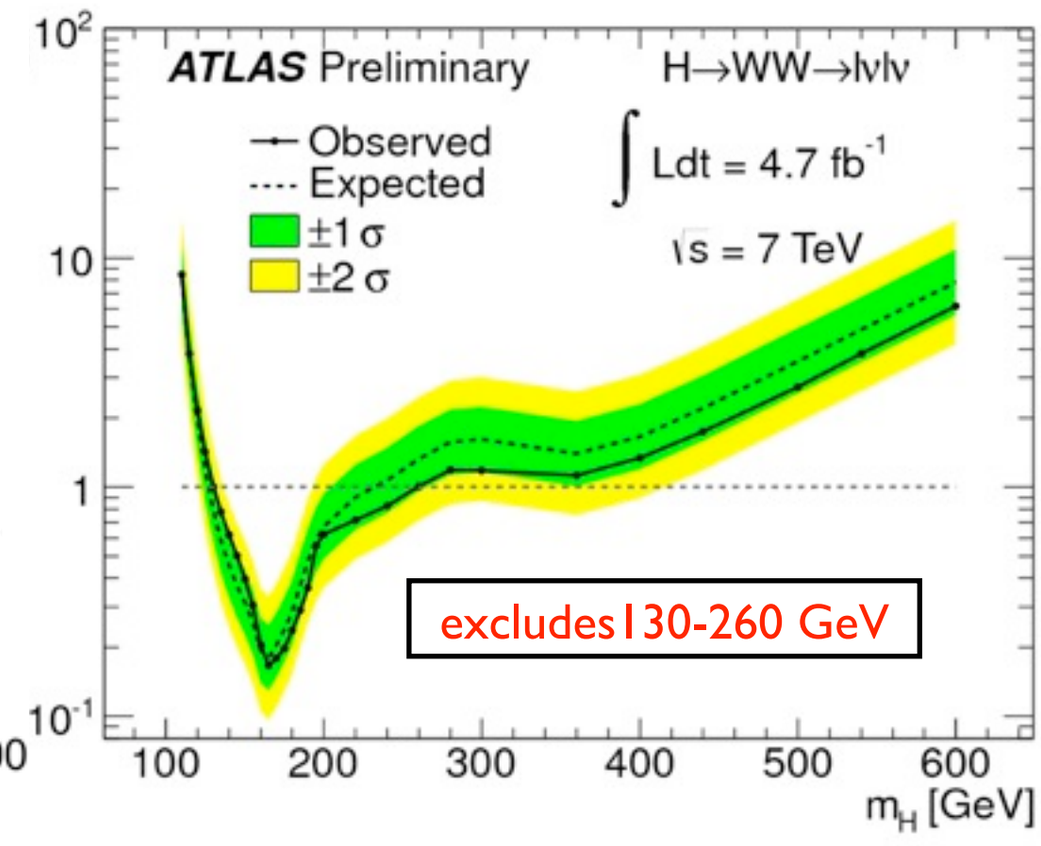
H→WW→(lν)(lν) Search Results

- The searches are split into sub-channels based on number of jets and lepton flavors
  - The 0-jet (eμ) channel is the most sensitive one
  - The CMS search benefits from MVA which uses more variables and explores their correlations

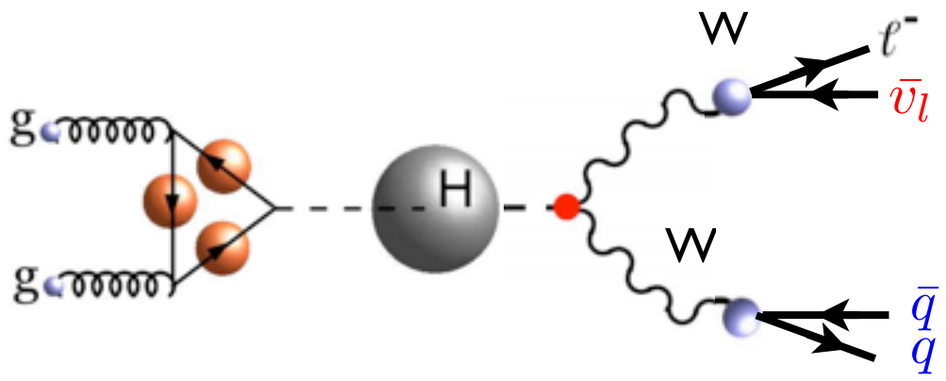
	CMS	ATLAS
Expected Exclusion Region	[127-270] GeV	[127-234] GeV

- No excess is found and the observed result is consistent with the expectation



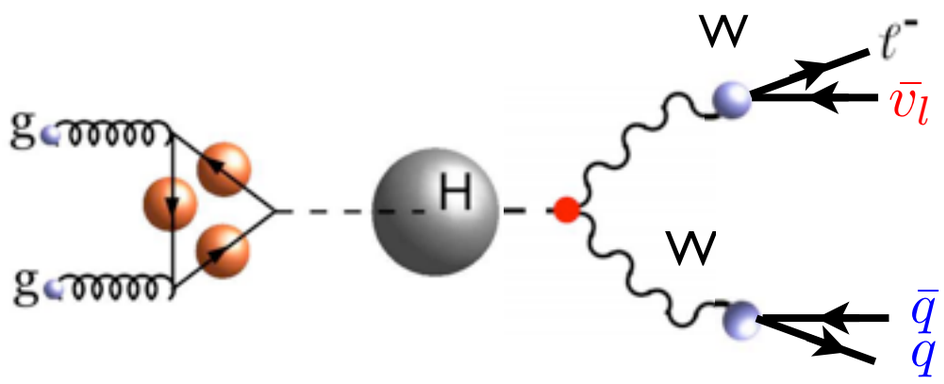


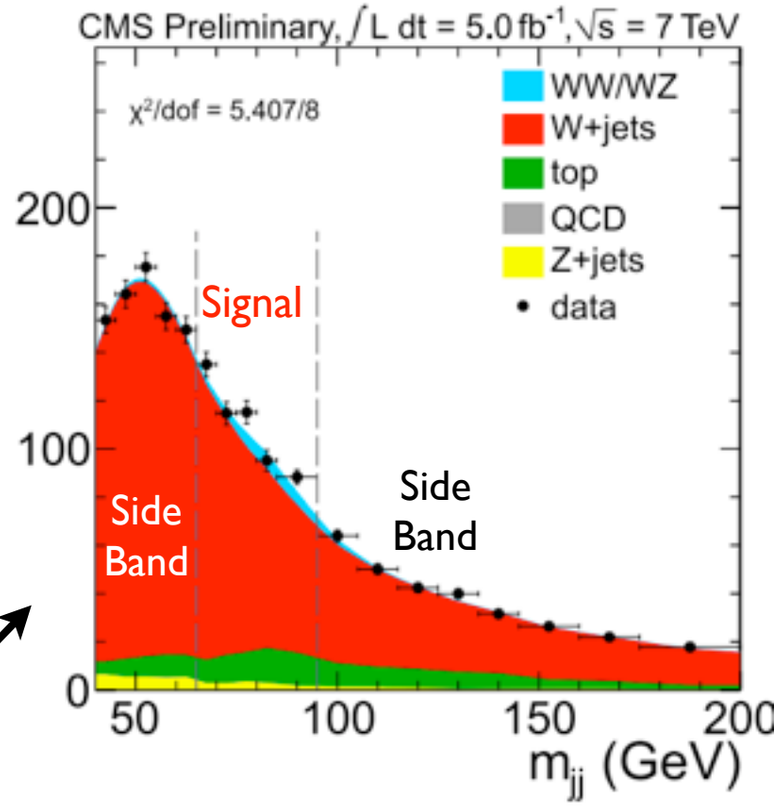
H→WW→(lν)(qq) Search Strategy



- Channel features
  - Final state: 1 lepton, 2jets, and large MET
  - Largest signal size
  - Higgs mass is reconstructed by constraining m(lν) = m(W)

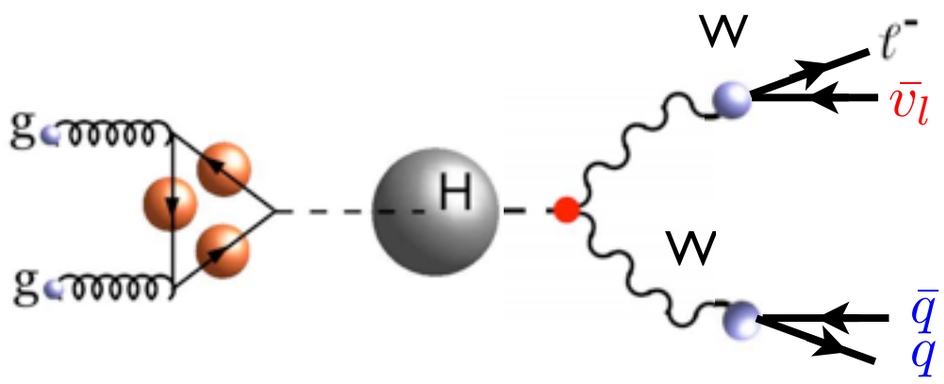
H→WW→(lν)(qq) Search Strategy





- Channel features
  - Final state: 1 lepton, 2jets, and large MET
  - Largest signal size
  - Higgs mass is reconstructed by constraining m(lν) = m(W)
- Main Challenge
  - Large W+jet background → Poor S/B
    - Use events in the m(jj) side band (SB) to extrapolate to the signal region

H→WW→(lν)(qq) Search Strategy



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  - Final state: 1 lepton, 2jets, and large MET
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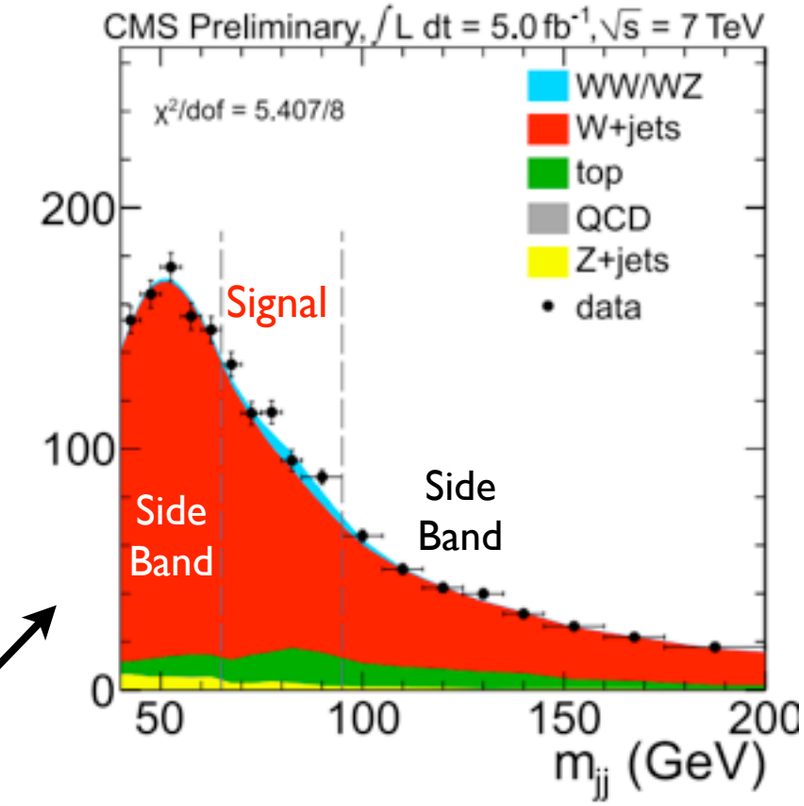
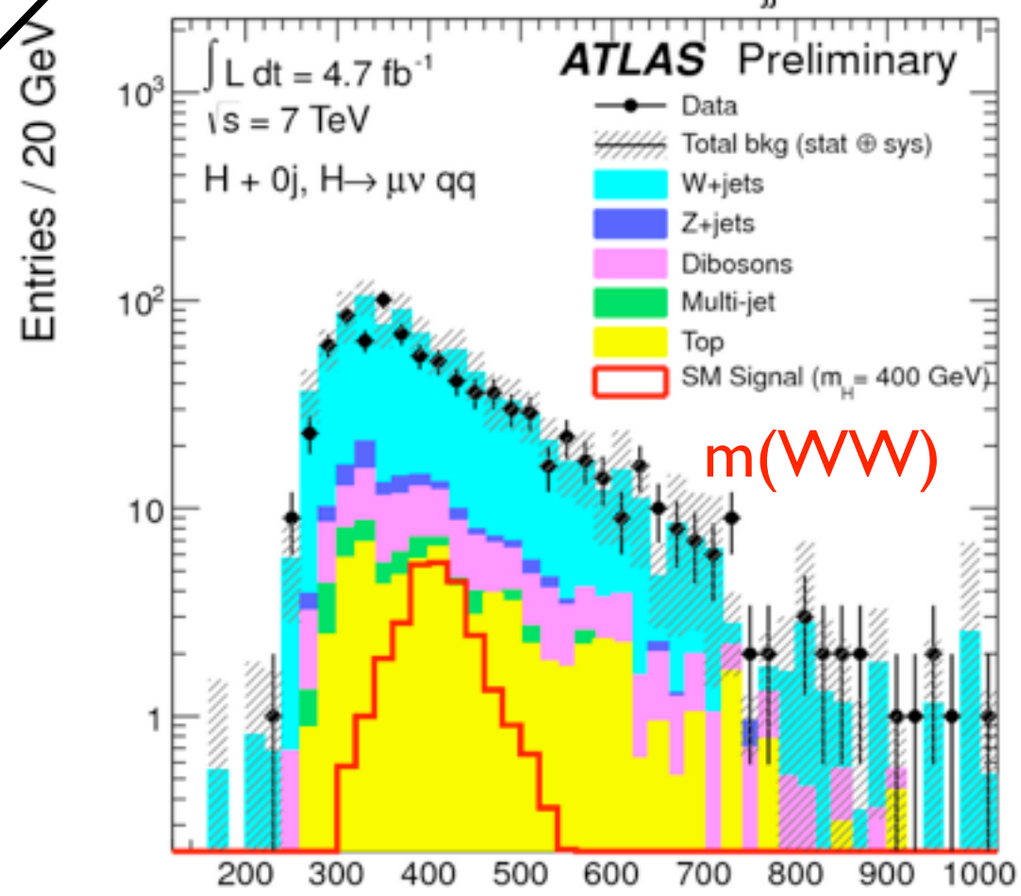
  - Higgs mass is reconstructed by constraining m(lν) = m(W)
- Main Challenge
  - Large W+jet background → Poor S/B
    - Use events in the m(jj) side band (SB) to extrapolate to the signal region
- Use m(lnqq) shape to extract final result
  - In higher mass region, apply additional selections, exploring the large mH





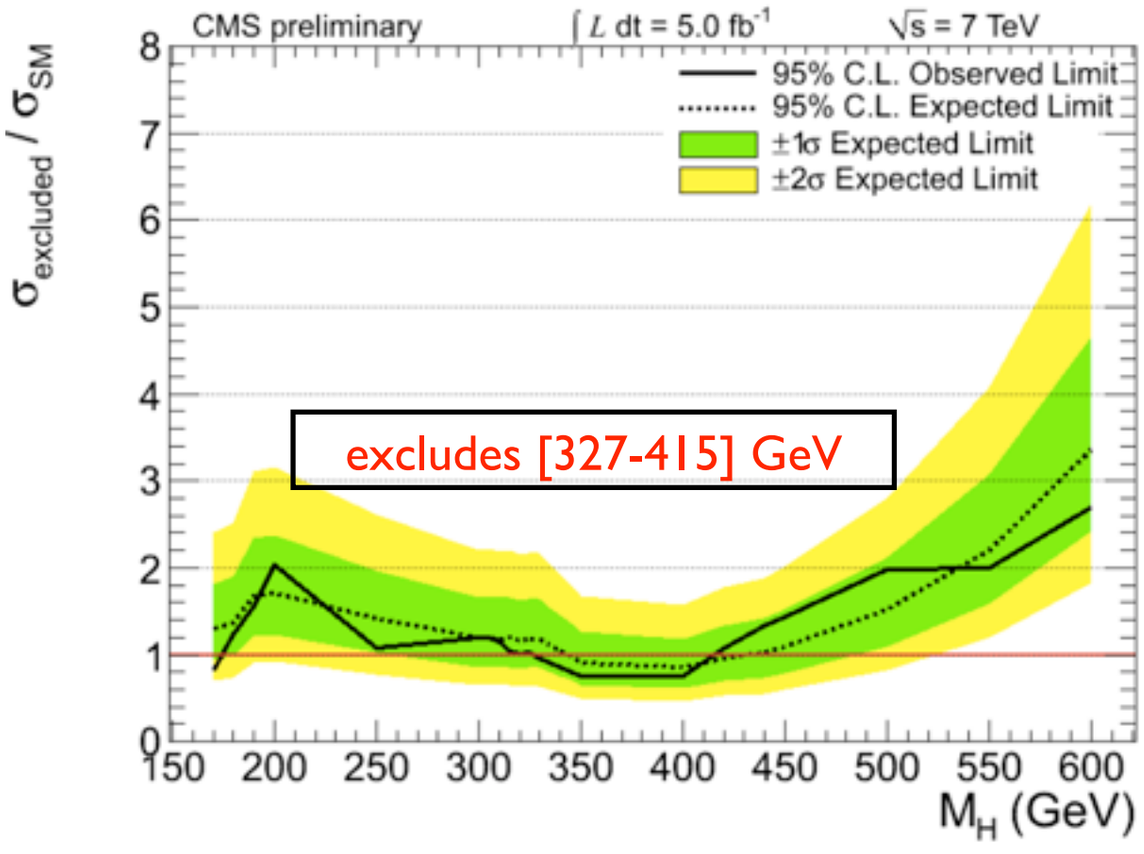
H→WW→(lν)(qq) Search Results

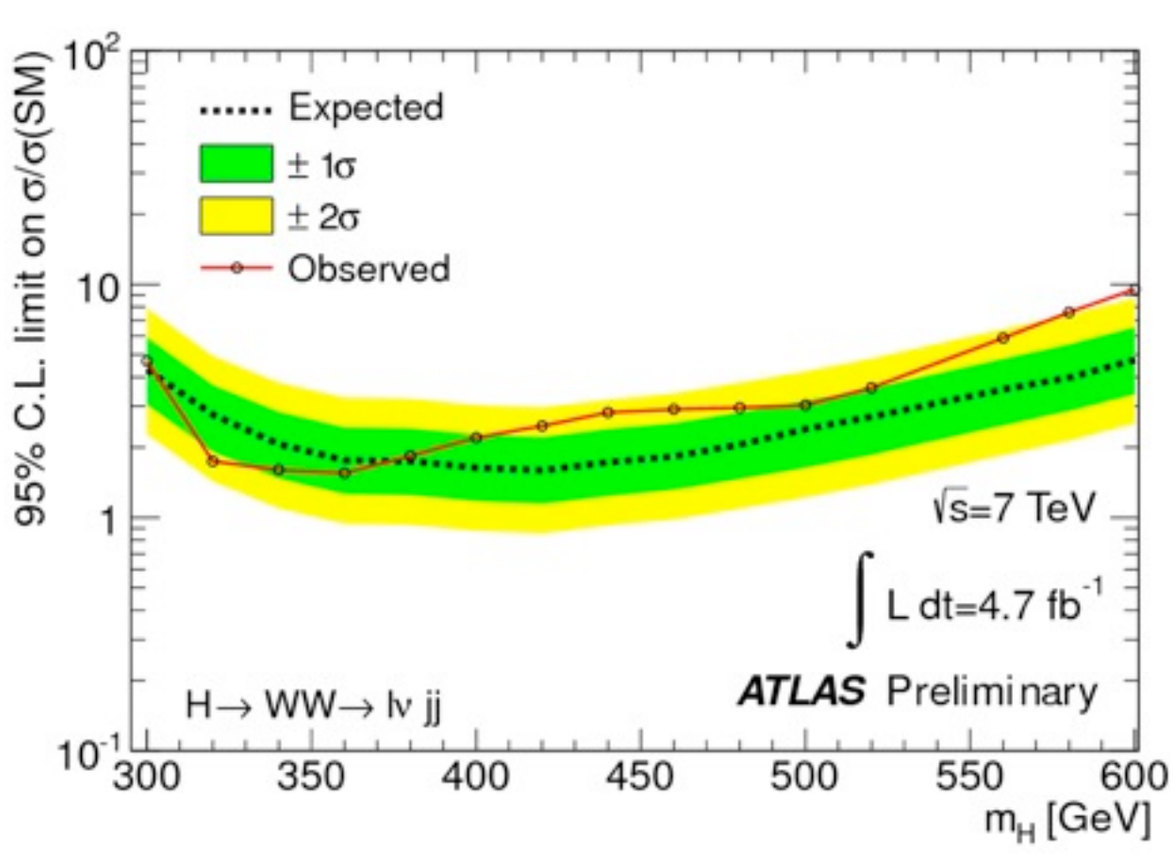
- The expected exclusion region

	CMS	ATLAS
Expected exclude region	[345-430] GeV	-

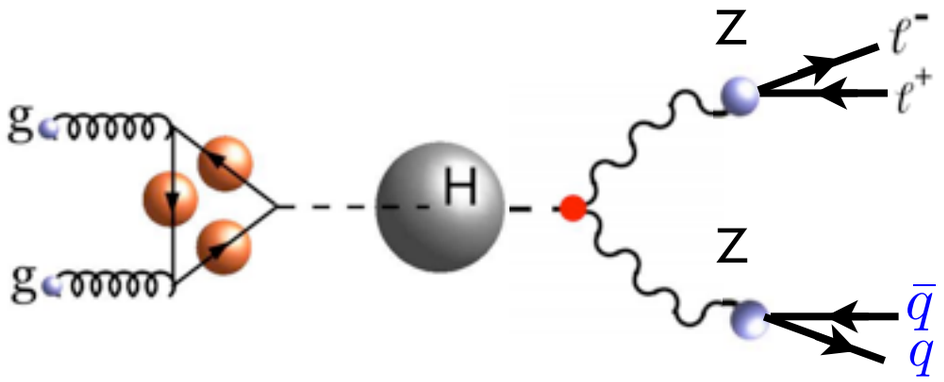
  - The CMS search window extends down to 170 GeV

- No excess is found and the observed limit is consistent to the expected



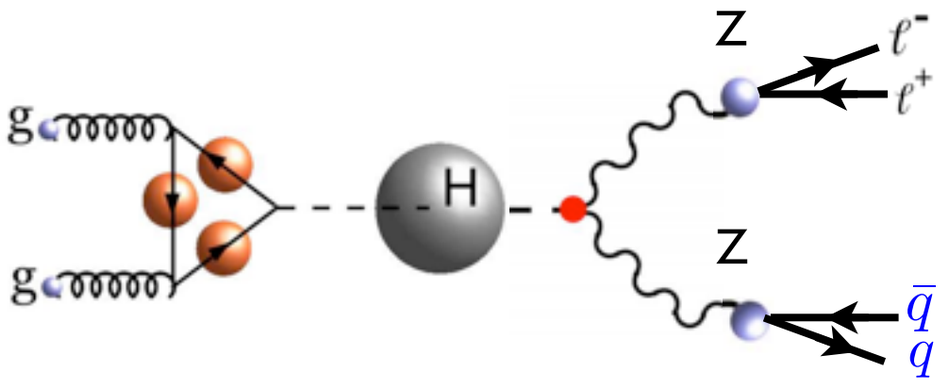


H→ZZ→(ll)(qq) Search Strategy

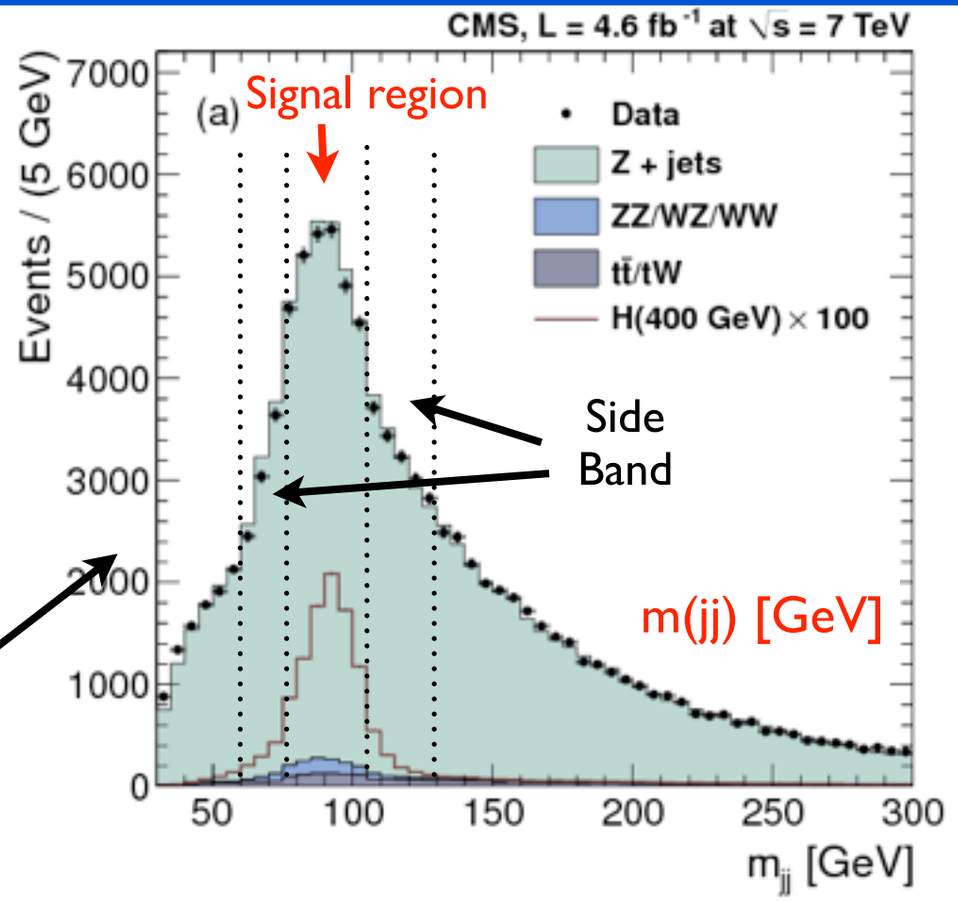


- Fully reconstructed final state
  - Good mass resolution if constraining event-by-event m(qq) = m(Z)

H→ZZ→(ll)(qq) Search Strategy



- Fully reconstructed final state
  - Good mass resolution if constraining event-by-event m(qq) = m(Z)
- Main Challenge
  - Large Z+jet background → Poor S/B
    - Use events in the m(jj) side band region to extrapolate to the signal region



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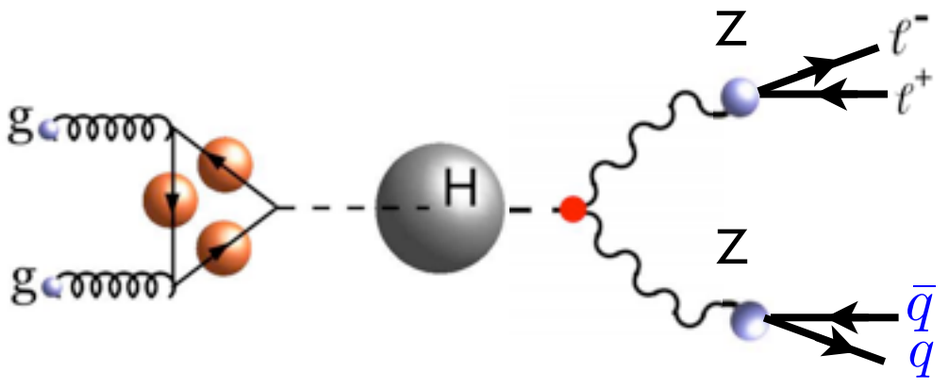
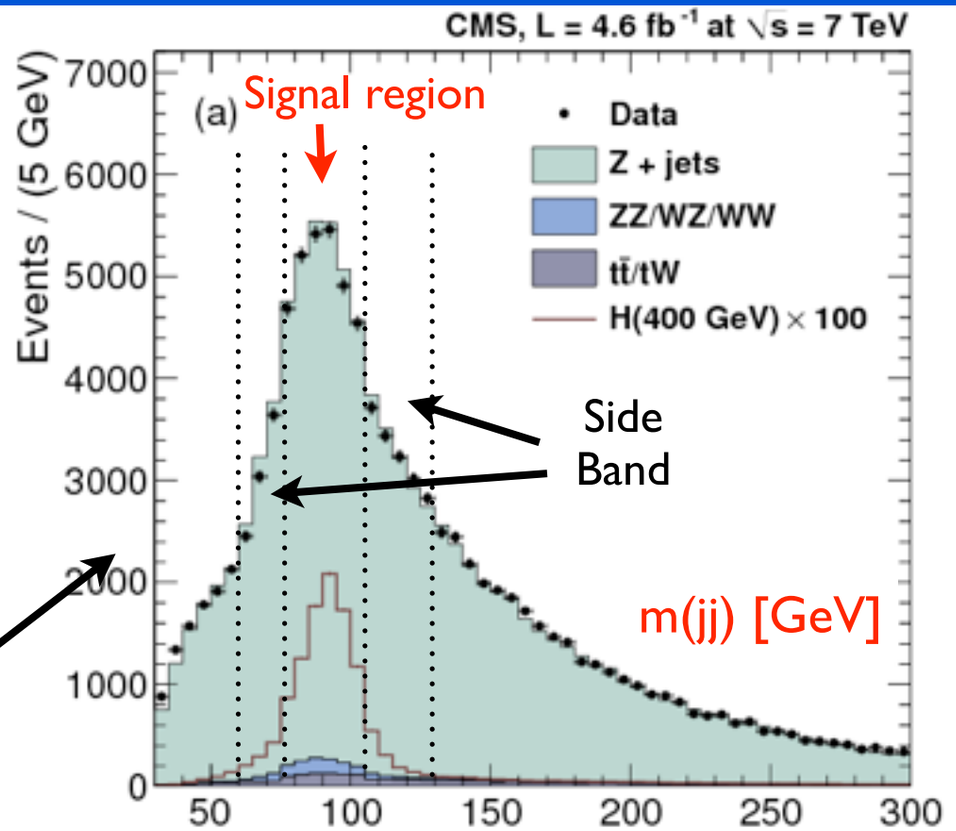
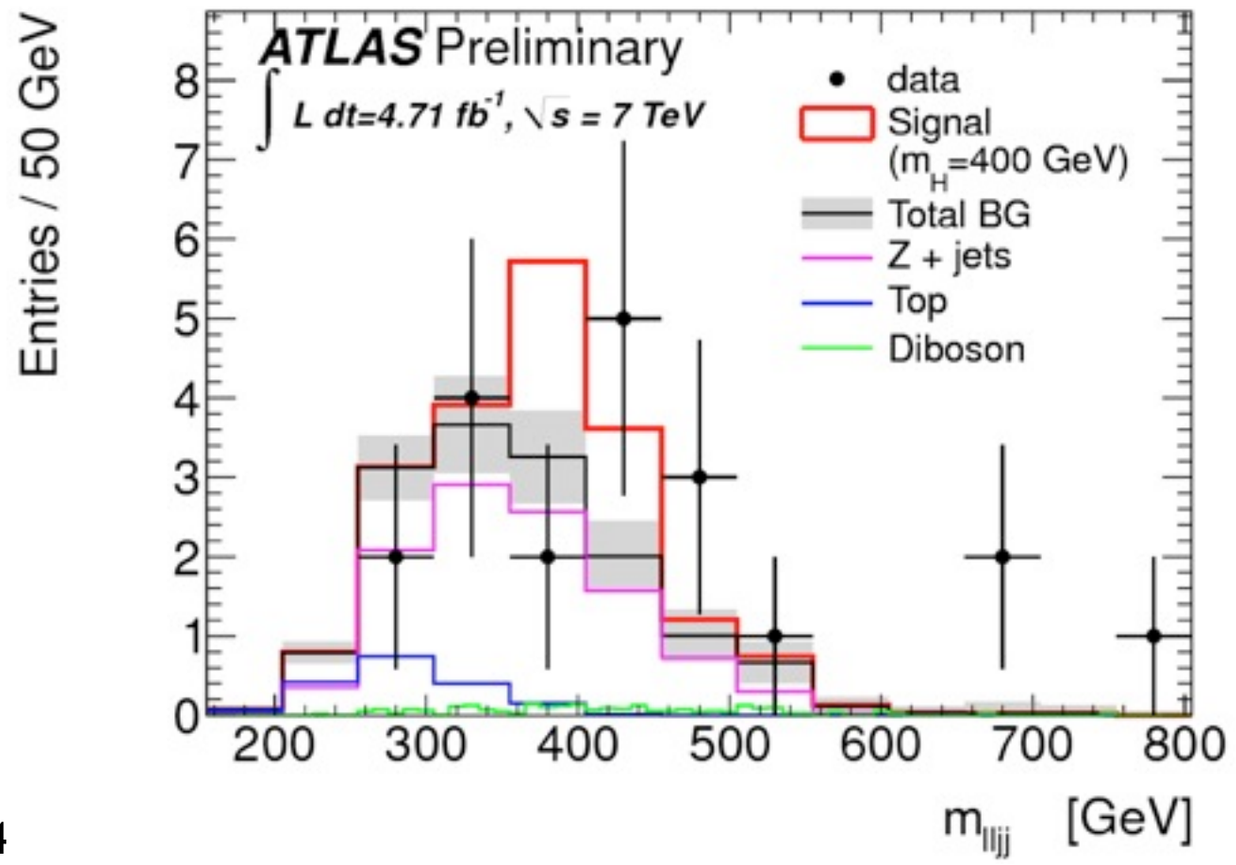


- Fully reconstructed final state
  - Good mass resolution if constraining event-by-event m(qq) = m(Z)
- Main Challenge
  - Large Z+jet background → Poor S/B
    - Use events in the m(jj) side band region to extrapolate to the signal region
- Use m(llqq) shape to extract final result
  - Split the search into different channels based on number of b-quarks
    - Best channel: events with 2 b-quarks
  - Apply additional kinematic/topological selections to explore the large mH



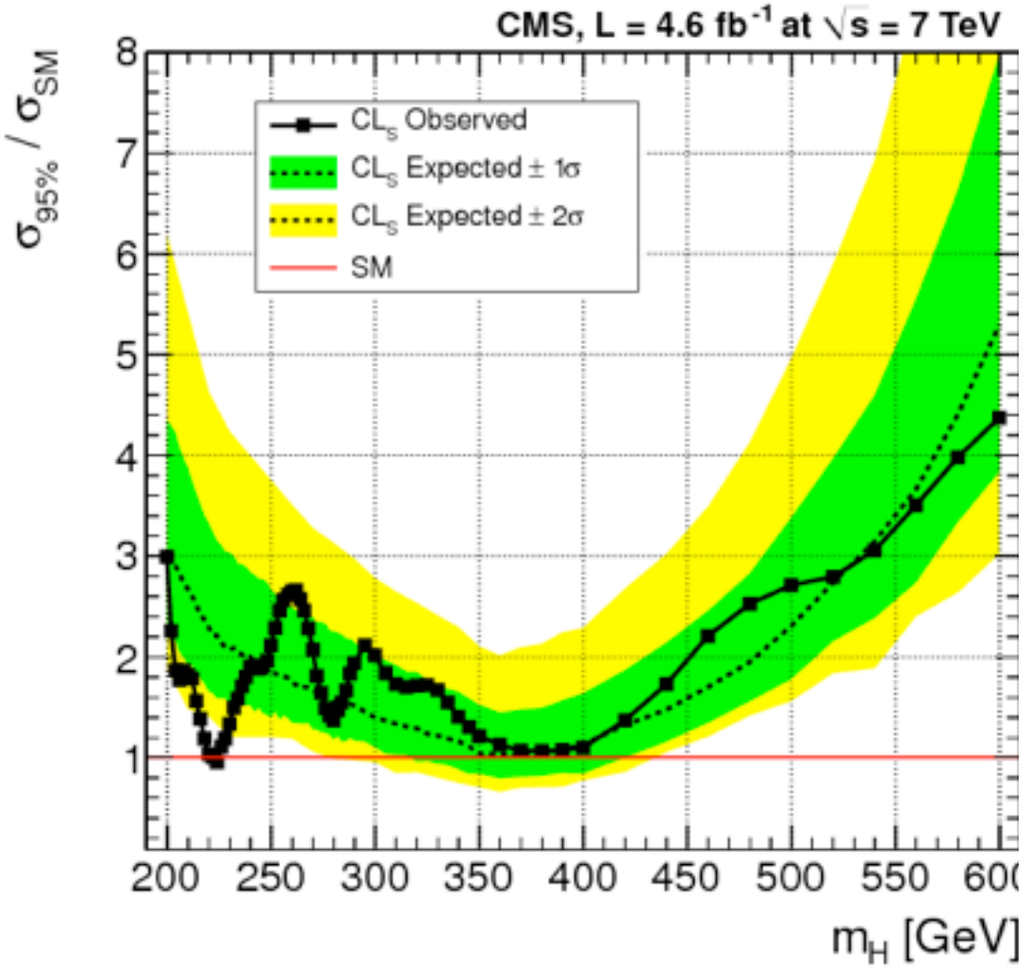


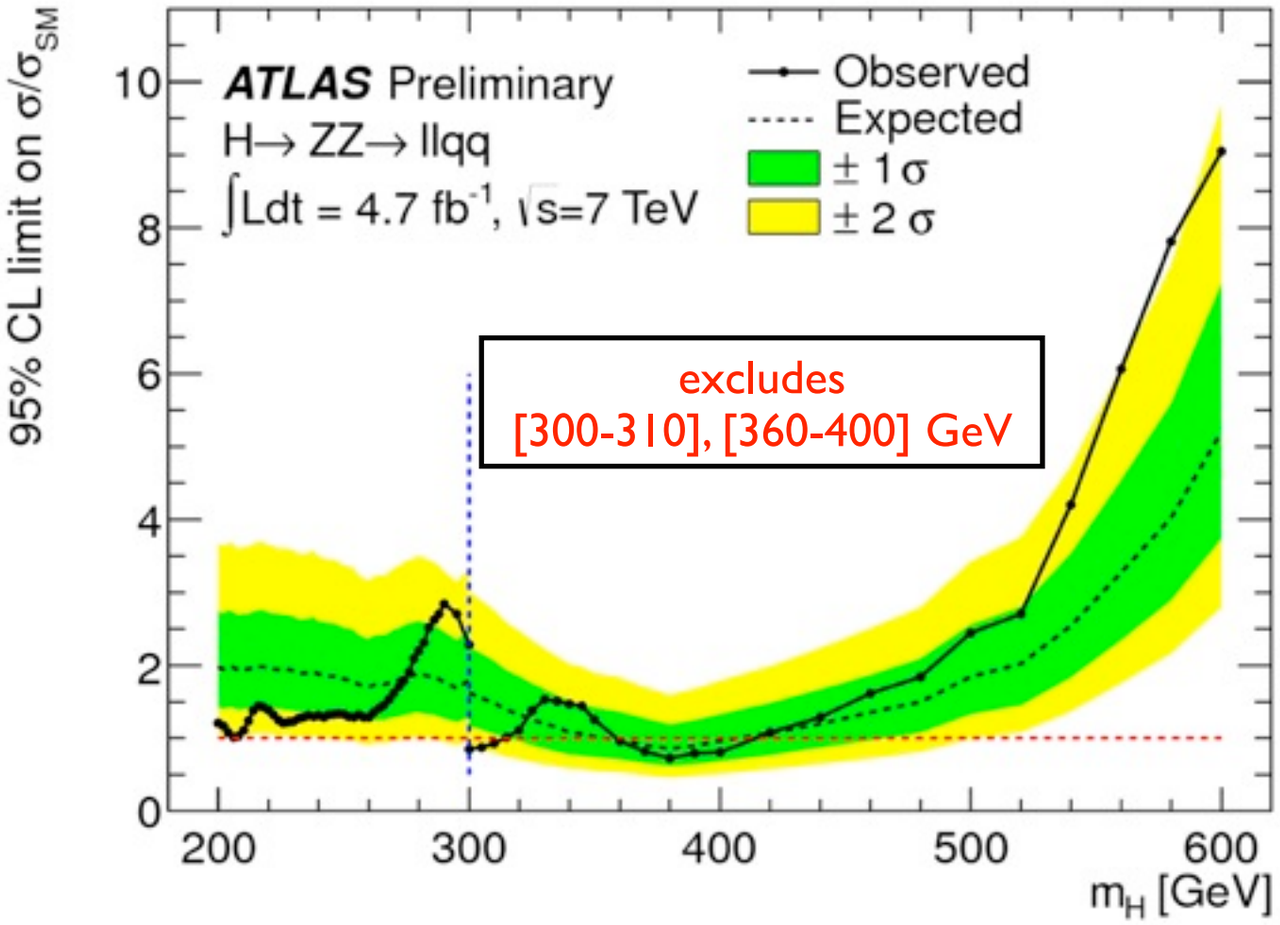
H→ZZ→(ll)(qq) Search Results

- The expected exclusion region

	CMS	ATLAS
Expected exclude region	-	[360-400] GeV

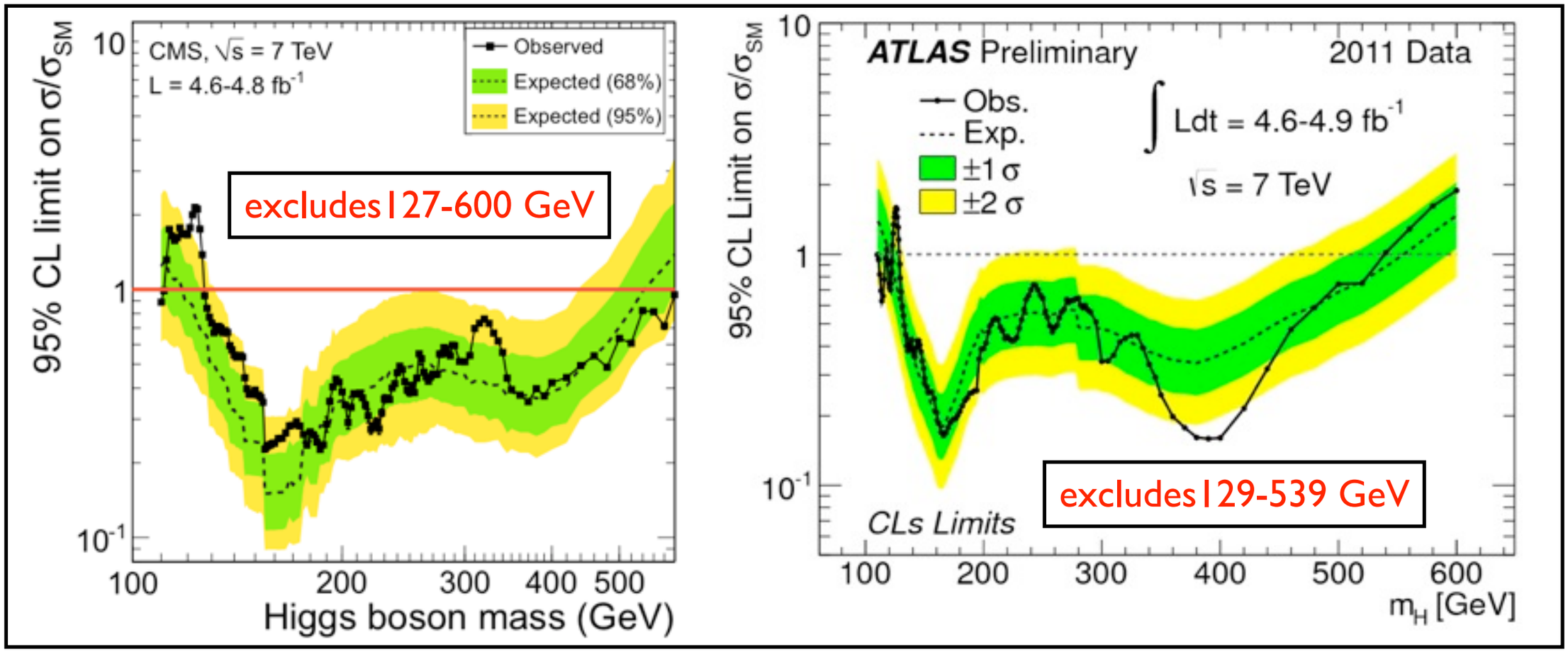
- No excess is found and the observed limit is consistent to the expected





Conclusion

- Using 5/fb data at 7 TeV, CMS and ATLAS searched for SM Higgs with mass < 600 GeV
  - No signal excess is found and the SM Higgs with a large mass range excluded as expected



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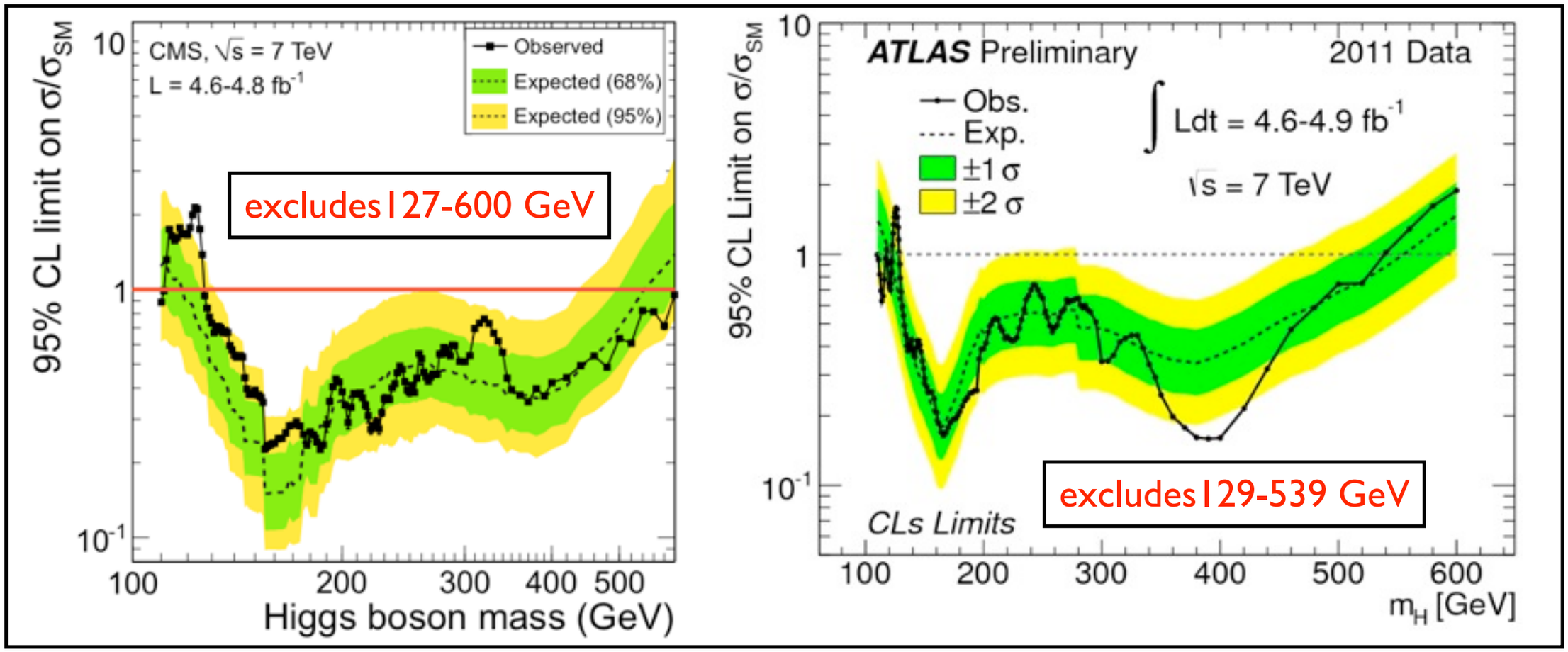
  - No signal excess is found and the SM Higgs with a large mass range excluded as expected



- SM Higgs is not the final destiny of HEP, it is important to keep the search open
  - With the ~15/fb data expected in 2012, the search will be extended up to ~ 1 TeV
    - The prospective results will continue to probe the EWK sector of the SM physics
    - In the absence of SM Higgs, studies of VV scattering at high $\sqrt{s}$ are important to explain the otherwise anomalous predictions such as unitarity violation in VV scattering