Current Status and Future Prospect of the LHC Experiment

Junichi TANAKA
ICEPP, the University of Tokyo

Contents

- LHC
- **Standard Model Higgs**
- BSM Higgs
- Other BSM
- Summary

This talk contents are completely biased…
SM Higgs > others
ATLAS > CMS
(I'm ATLAS member.)

"July 2012" is the historical days in the particle physics.

ATLAS+CMS seminar at CERN at the 4th July, 2012
(🡨 Japanese news paper)

ヒッグス粒子 発見か

新素粒子検出 年内に結論

日米欧2チーム

あらゆる物質に質量を与えたと考えられる仮説上の素粒子「ヒッグス粒子」を探しているジュネーブの欧州合同原子核研究所（CERN＝セルン）は4日、大型粒子加速器「LHC」による実験で、ヒッグス粒子とみられる新たな素粒子を見つけたと発表した。ヒッグス粒子は、万物に含まれる素粒子の基本理論として1960年代に提唱された「標準理論」で存在が予言された18種の素粒子のうち、唯一未発見だった。（3面にクローズアップ）

得られたデータからは発見された素粒子をヒッグス粒子と考えても矛盾がないが、ヒッグス粒子かを見極める方法は複数あり、さらなる実験や分析で確度を高める必要があるという。今年中には結論に至る見込み。

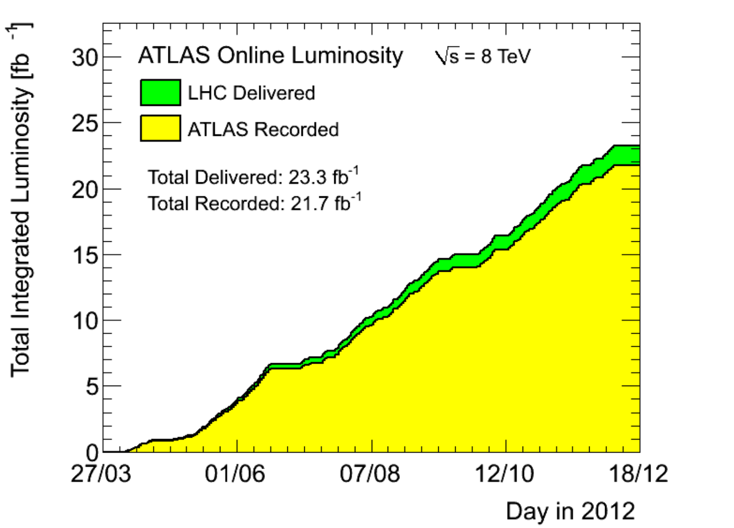
ヒッグス粒子は、英国の物理学者ピーター・ヒッグス博士(83)が提唱。宇宙誕生の大爆発(ビッグバン)直後、宇宙空間に漂っていた素粒子に質量を誕生させる過程で重要な役割を果たした「神の粒子」と呼ばれている。標準理論で存在が指摘された他の素粒子は88年ま

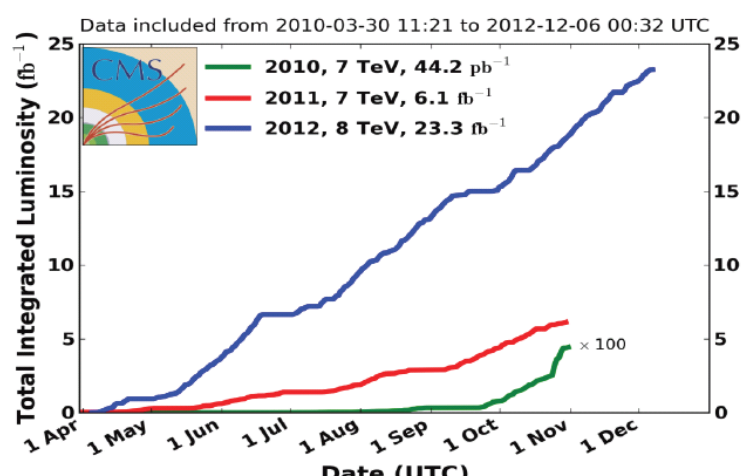
喜びあうヒッグス粒子の提唱者のピーター・ヒッグス博士(右)と研究代表者の一人ファビオラ・ジアノッティ博士＝ジュネーブで4日(ロイター)

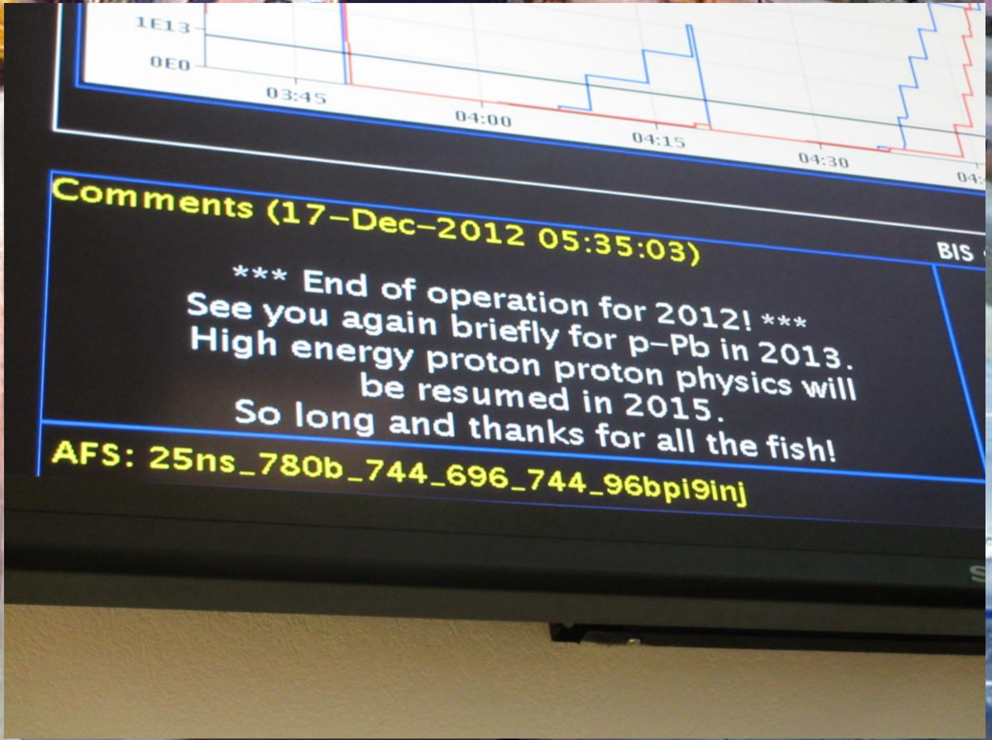
ATLAS Higgs WG celebration (4th July, 2012)

LHC

- LHC finished the first phase much successfully.
- LHC delivered ~6 fb^{-1} with 7TeV and ~23 fb^{-1} with 8TeV and ATLAS and CMS has recorded these data with a good detector operation.



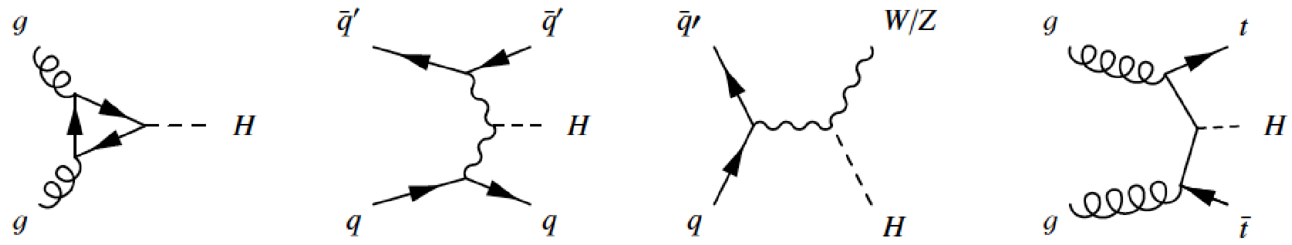




@Toyama in Japan

Standard Model Higgs

Higgs production and decay at LHC

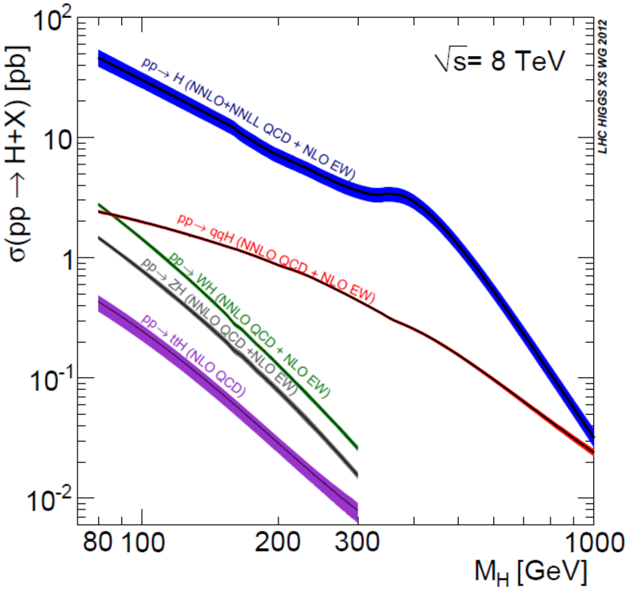


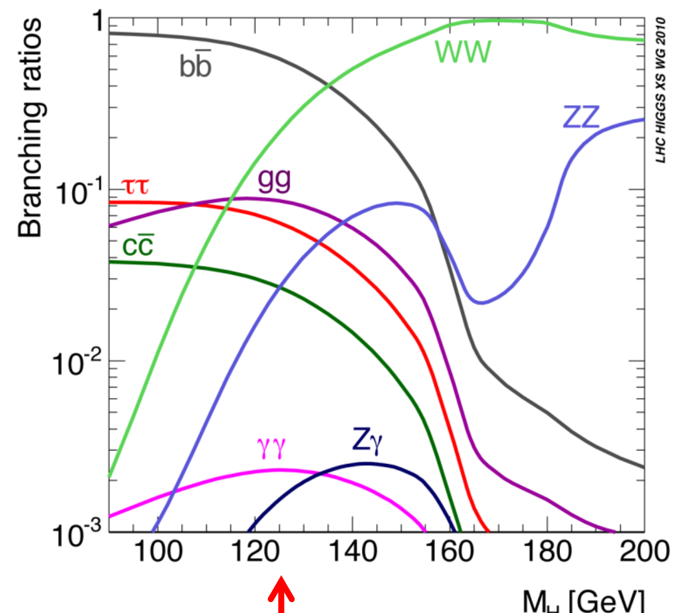
(a) $gg \to H$ (b) VBF (c) VH (d) $t\bar{t}H$

NNLO+NNLL(QCD soft-gluon)+NLO EW

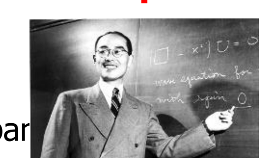
NNLO+NLO EW

NLO





M_H=125GeV: 19.5pb (ggF), 1.6pb(VBF), 0.7pb(WH), 0.4pb(ZH), 0.1pb(ttH) (8TeV)



Yukawa

SM Higgs analysis channels

Category = "tag"

ATLAS	Mass (GeV)	Data (fb^{-1})	untag	VBF-tag	VH-tg	ttH-tg	Spin/CP
$H \to \gamma\gamma$	110-150	5 + 13	✓	✓	✓		0^-, 2^+
$H \to ZZ^{(*)}$	110-600	5 + 13	✓				0^-, 2^+, 2^-
$H \to WW^{(*)}$	90-200	- + 13	✓			(✓7TeV)	
$H \to \tau\tau$	100-150	5 + 13	✓	✓	✓		
$H \to bb$	110-130	5 + 13			✓	(✓7TeV)	

CMS	Mass (GeV)	Data (fb^{-1})	untag	VBF-tag	VH-tg	ttH-tg	Spin/CP
$H \to \gamma\gamma$	110-150	5 + 5	✓	✓			
$H \to ZZ^{(*)}$	110-1000	5 + 12	✓				0^-, 2^+
$H \to WW^{(*)}$	110-600	5 + 12	✓	✓	(✓5+5)		
$H \to \tau\tau$	110-145	5 + 12	✓	✓	(✓7TeV)		
$H \to bb$	110-135	5 + 12			✓	(✓7TeV)	

Some channels are not yet included in the combined results.

SM Higgs analysis channels

Category = "tag"

8TeV

ATLAS	Mass (GeV)	Data (fb^{-1})	untag	VBF-tag	VH-tg	ttH-tg	Spin/CP
$H\to\gamma\gamma$	110-150	5 + 13	✓	✓	✓		0^-, 2^+
$H\to ZZ^{(*)}$	110-600	5 + 13	✓				0^-, 2^+, 2^-
$H\to WW^{(*)}$	90-200	- + 13	✓			(✓7TeV)	
$H\to\tau\tau$	100-150	5 + 13	✓	✓	✓		
H->bb	110-130	5 + 13			✓	(✓7TeV)	

CMS	Mass (GeV)	Data (fb^{-1})	untag	VBF-tag	VH-tg	ttH-tg	Spin/CP
$H\to\gamma\gamma$	110-150	5 + 5	✓	✓			
$H\to ZZ^{(*)}$	110-1000	5 + 12	✓				0^-, 2^+
$H\to WW^{(*)}$	110-600	5 + 12	✓	✓	(✓5+5)		
$H\to\tau\tau$	110-145	5 + 12	✓	✓	(✓7TeV)		
H->bb	110-135	5 + 12			✓	(✓7TeV)	

Some channels are not yet included in the combined results.

H->$\gamma\gamma$

H->$\gamma\gamma$

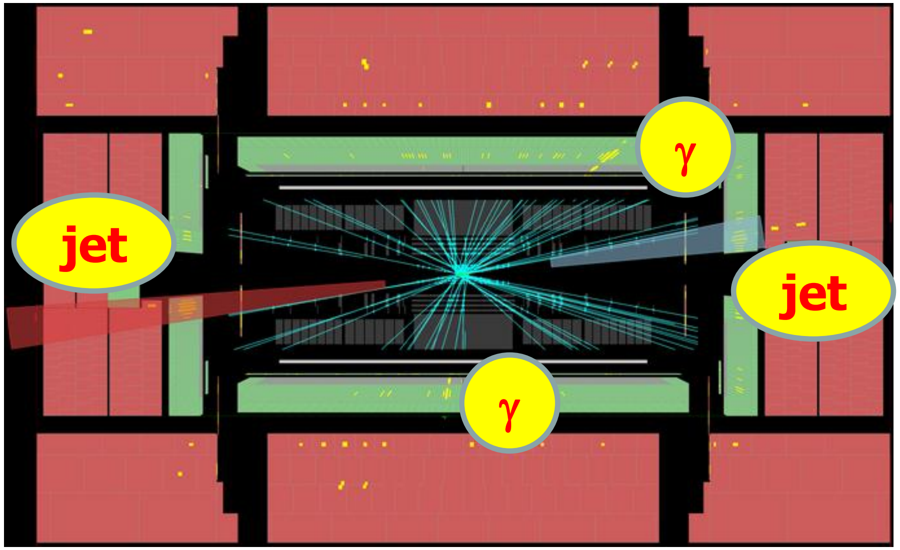
- Event selection
  - Two photons with
    E_T>40GeV and 30GeV (ATLAS)
    $E_T > m_{\gamma\gamma}/3$ and $m_{\gamma\gamma}/4$ (CMS)
    ($E_T > m_{\gamma\gamma}/2$ and $m_{\gamma\gamma}/4$ for CMS dijet-tag)

- Introduce categories to
  1) improve a global sensitivity
  2) enhance a certain "production" channel

  ATLAS : 12 categories (8TeV), 10 cate (7TeV)
  1 for lepton (for VH)
  2 for di-jets (for VH and VBF)
  9 for others (for ggF).

  CMS : 6 categories (8TeV), 5 cate (7TeV)
  2 for VBF
  4 for others using MVA

ATLAS H->$\gamma\gamma$ with 2jets

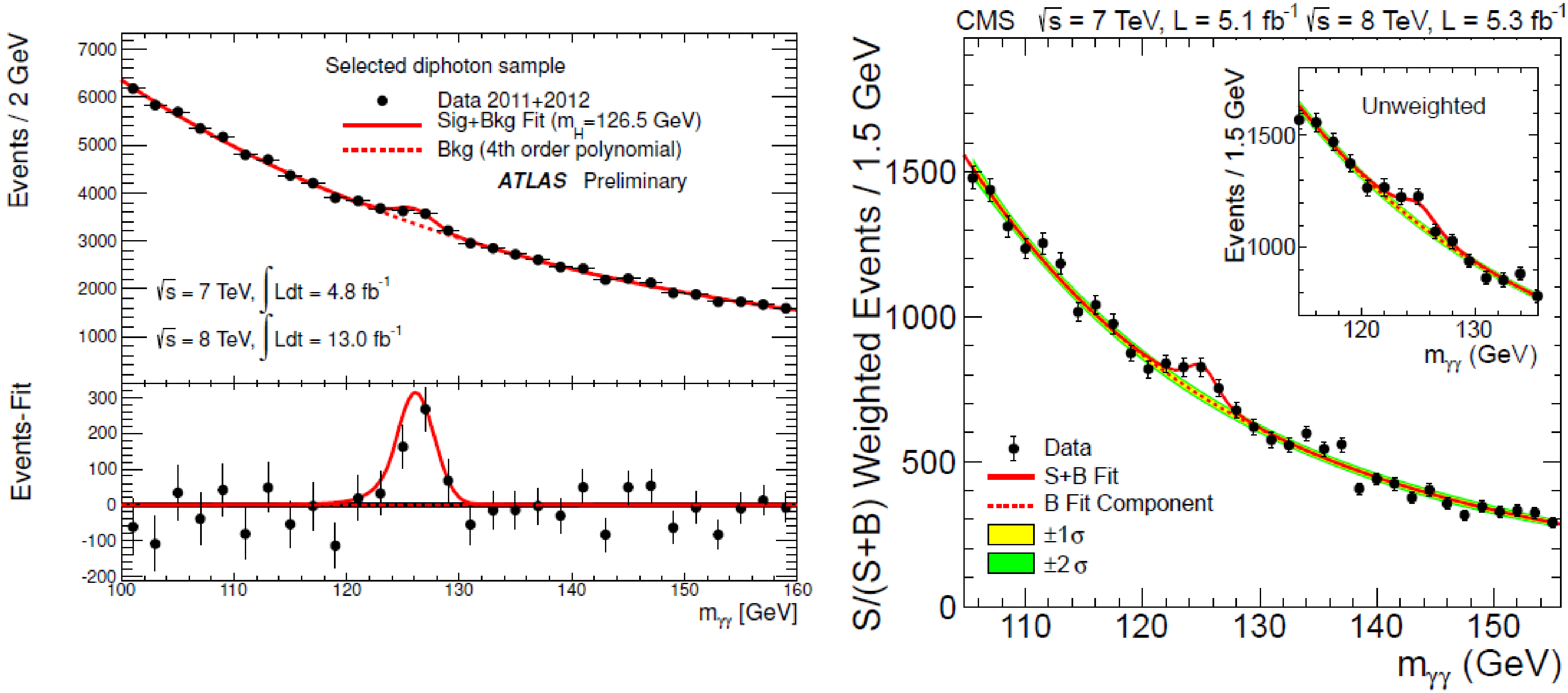


M_{jj}=1.6TeV, $\Delta\eta_{jj}$ =5.6

Typical cut for VBF tag (ATLAS/CMS)
- M_{jj} > 400-500GeV
- $\Delta\eta_{jj}$ > 3

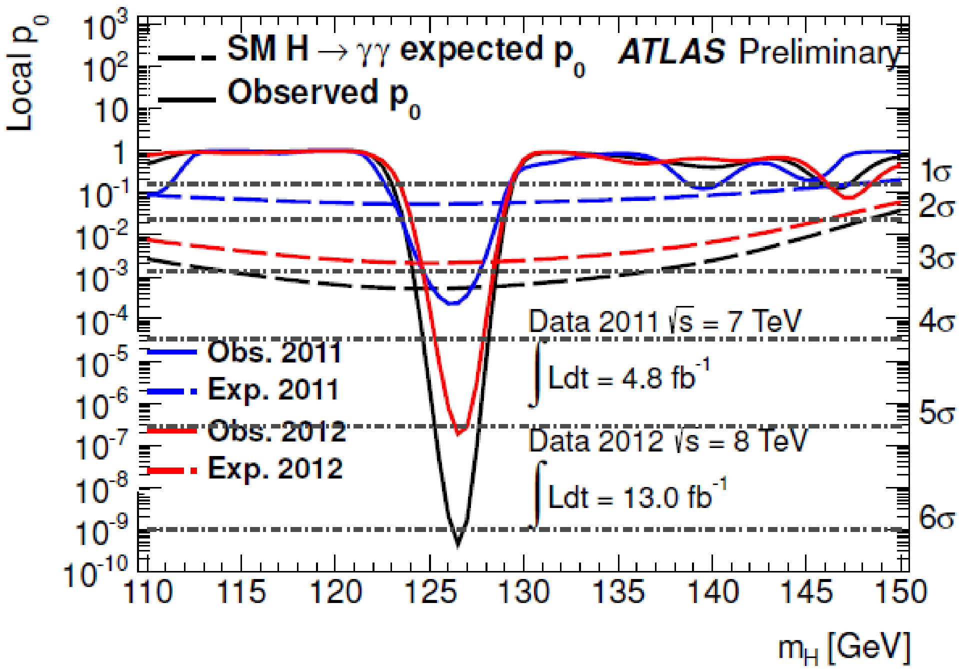
Purity of VBF process in VBF-tag
- ~70-80%

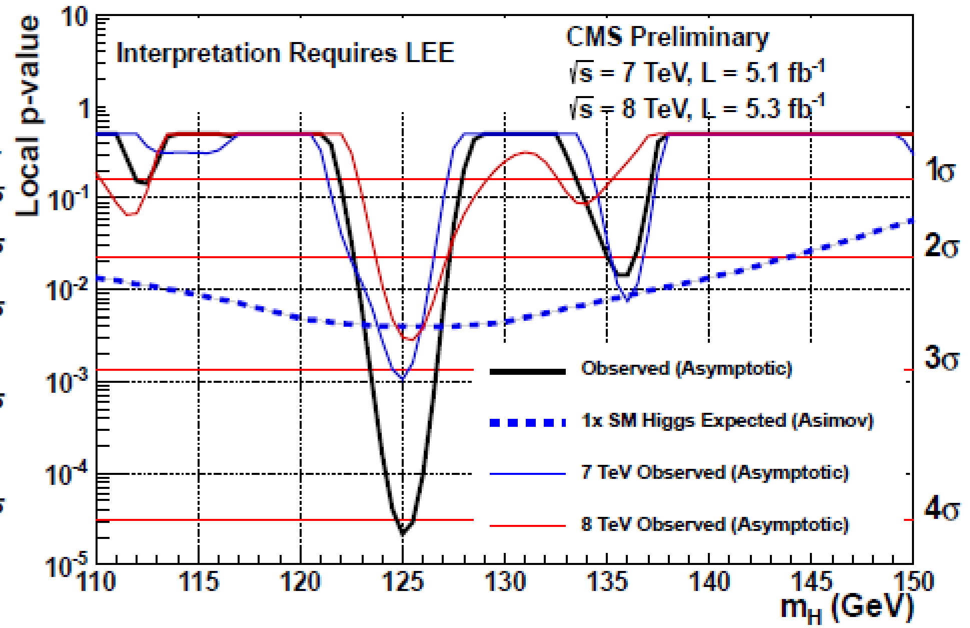
H->γγ



- Observed a significant peak around 126GeV in both experiments!

H->γγ





	ATLAS	CMS
Data (7TeV+8TeV)	4.8 + 13.0	5.1 + 5.3
Local p_0	4.4 x 10^{-10} (6.1σ) @126.5GeV	1.8 x 10^{-5} (4.1σ) @125GeV
Signal strength (μ)	1.80+0.42-0.36 @126.6GeV	1.56+-0.43 @125GeV

$H \to ZZ^* \to 4l$

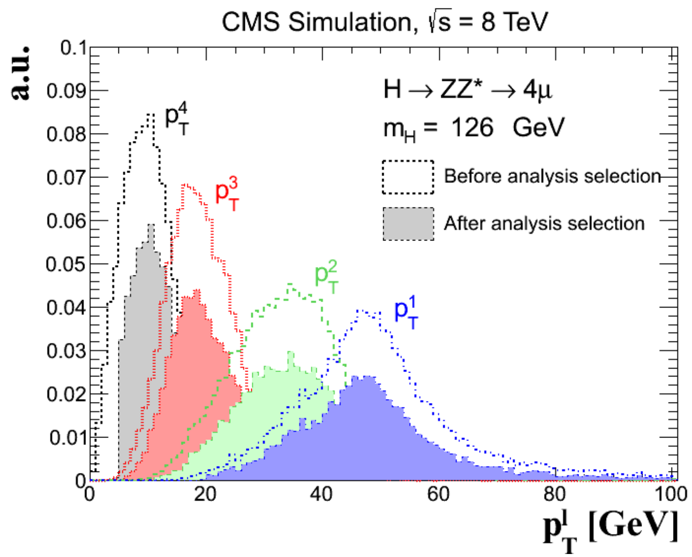
H->ZZ*->4l

- Clean but rare!
- Good mass resolution
  - 4l mass resolution (ATLAS, 125GeV)
    - 2.0GeV for 4μ
    - 2.3GeV for $2e2\mu$
    - 2.6GeV for 4e

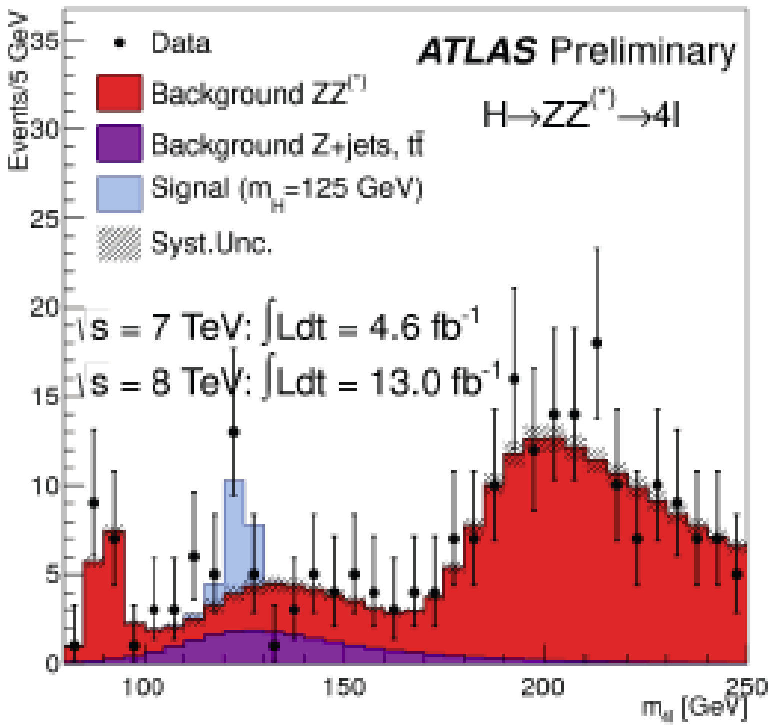
m_H [GeV]	$\sigma \cdot BR[fb^{-1}]$ @8TeV	Width [GeV]
125	15	0.005
200	33	1.4
400	13	29
600	2	120

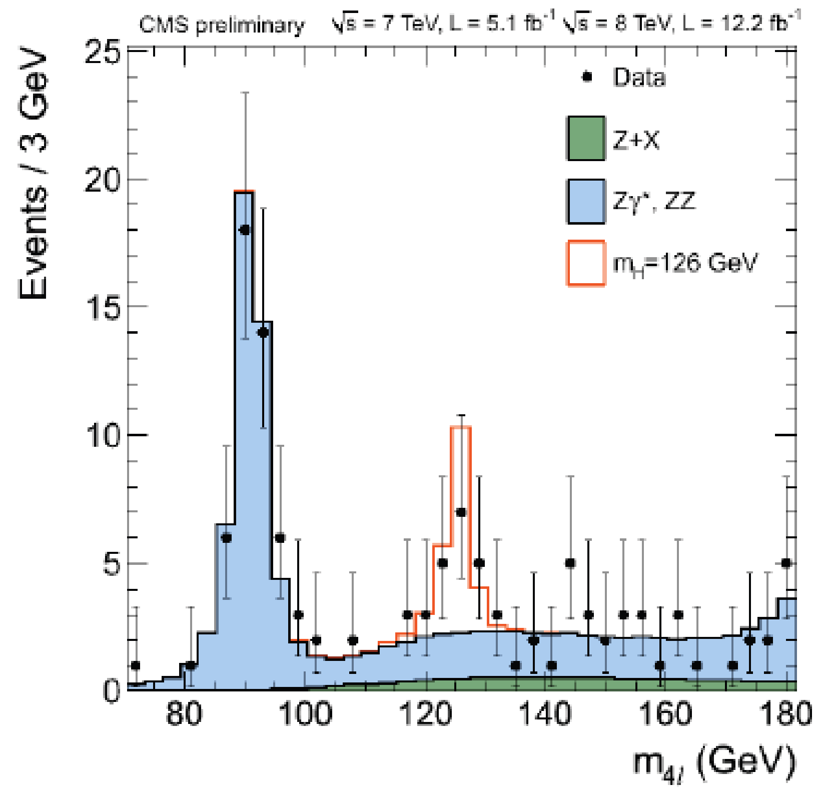
CMS includes $2l2\tau$ channel for high mass.

- Event Selection for low mass region -> leptons from Z* has low pT.
  - Lepton pT
    - ATLAS : p_T>20, 15, 10 and 7/6GeV (elec/muon)
    - CMS : p_T>20, 10, 7/5 and 7/5GeV (elec/muon)
  - Z/Z* mass window
    - ATLAS : 50<m(Z)<106GeV, 17.5<m(Z*)<115GeV
    - CMS : 40<m(Z)<120GeV, 12<m(Z*)<120GeV
  - Typical selection efficiency (ATLAS, 125GeV)
    - 37% for 4μ, 23% for $2e2\mu$, 20% for 4e

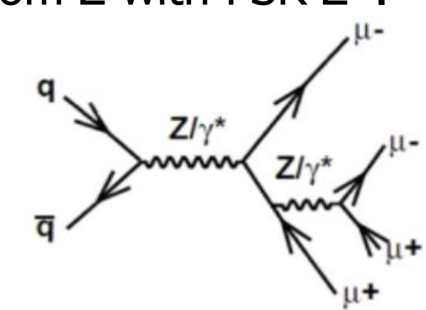


4 lepton invariant mass





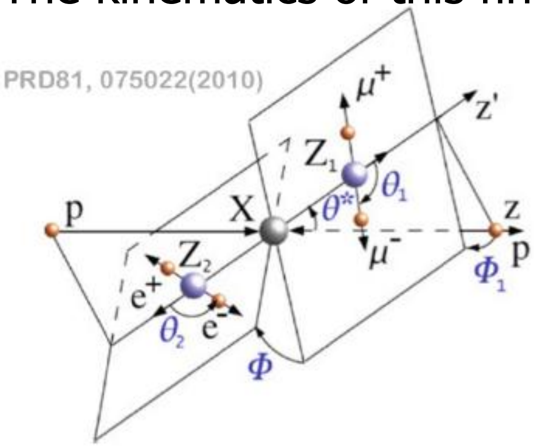
- Observed a peak around 126GeV in both experiments!
- Also we can see a peak around 90GeV, which comes from Z with FSR Z*.



MELA

~15% improvement

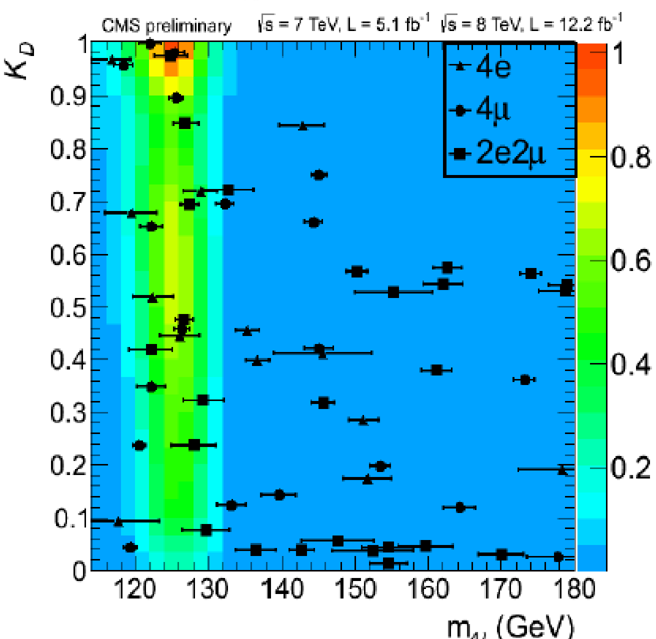
CMS uses MELA (Matrix element likelihood analysis) to get the final results.
The kinematics of this final state can be described by only 7 parameters.

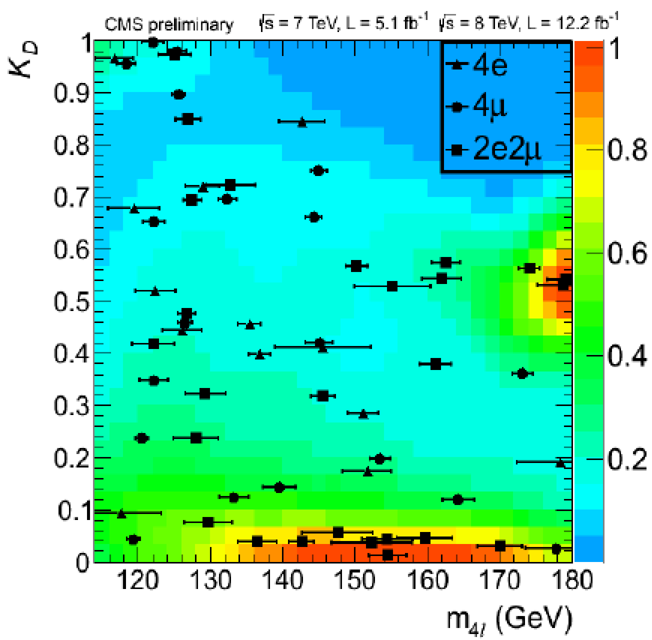


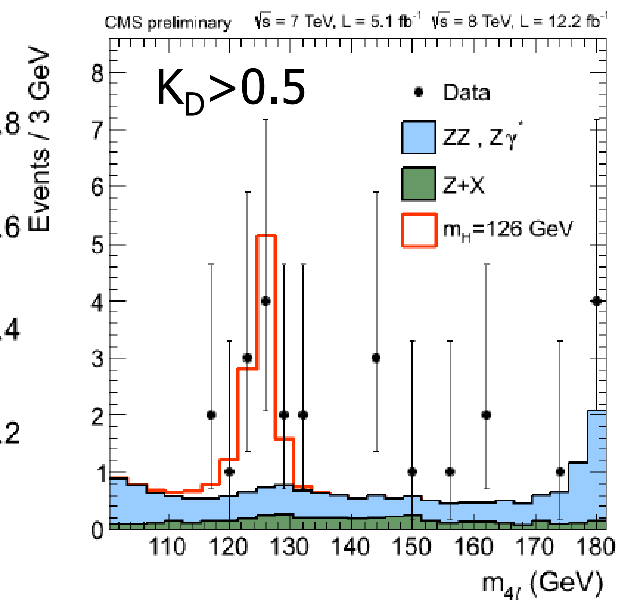
$$\mathrm{KD} = \frac{\mathcal{P}_{\mathrm{sig}}}{\mathcal{P}_{\mathrm{sig}} + \mathcal{P}_{\mathrm{bkg}}} = \left[1 + \frac{\mathcal{P}_{\mathrm{bkg}}(m_1, m_2, \vec{\Omega}|m_{4\ell})}{\mathcal{P}_{\mathrm{sig}}(m_1, m_2, \vec{\Omega}|m_{4\ell})}\right]^{-1}$$

$$\vec{\Omega} = \{\theta^*, \Phi_1, \theta_1, \theta_2, \Phi\}$$

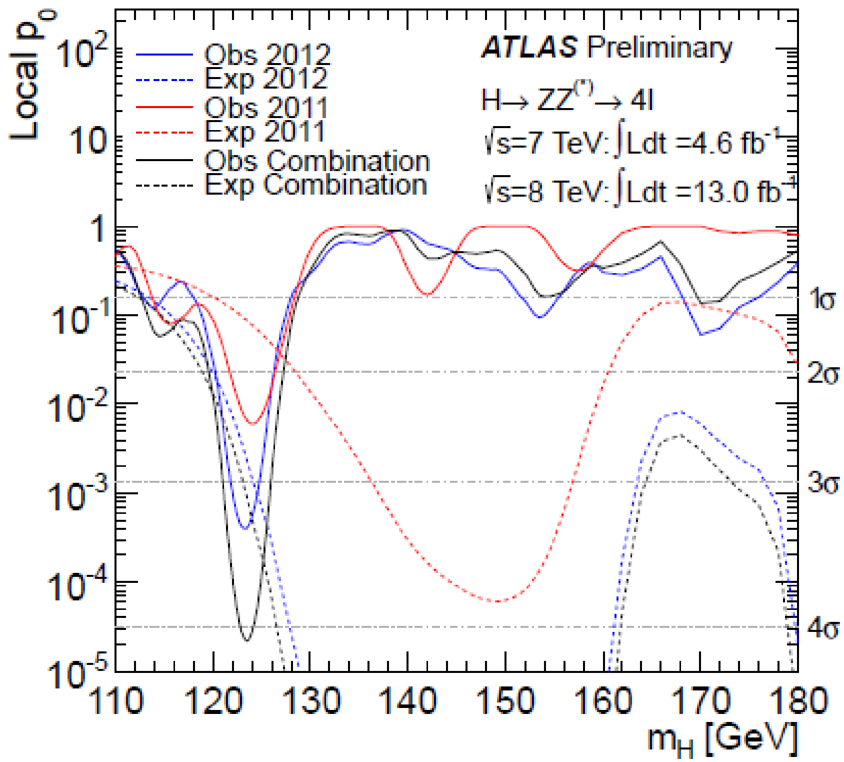
Signal-like events has a large K_D value.
6 categories based on (m_{4l}, K_D) are used.

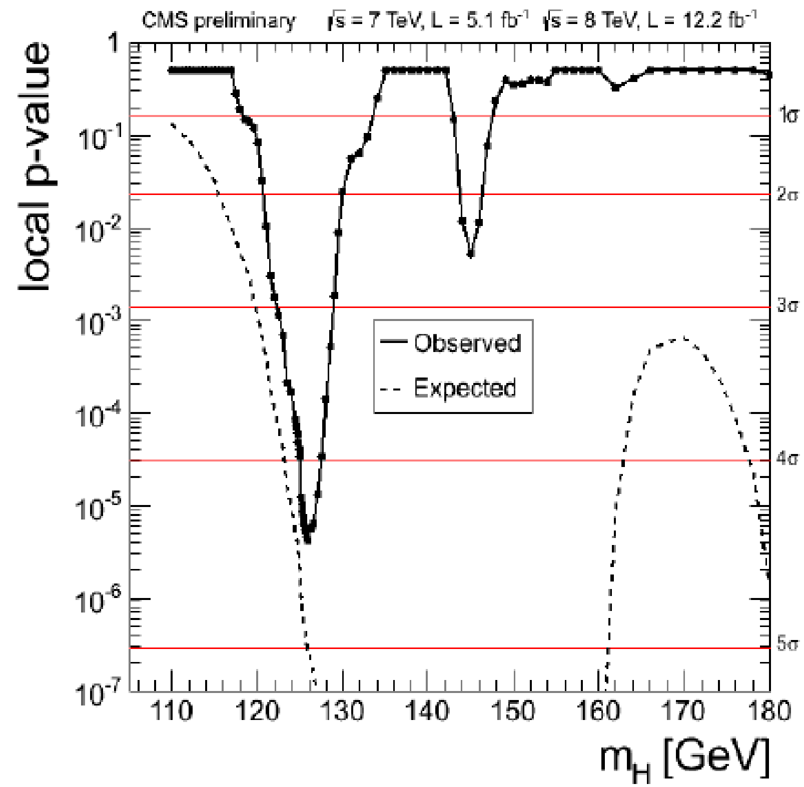






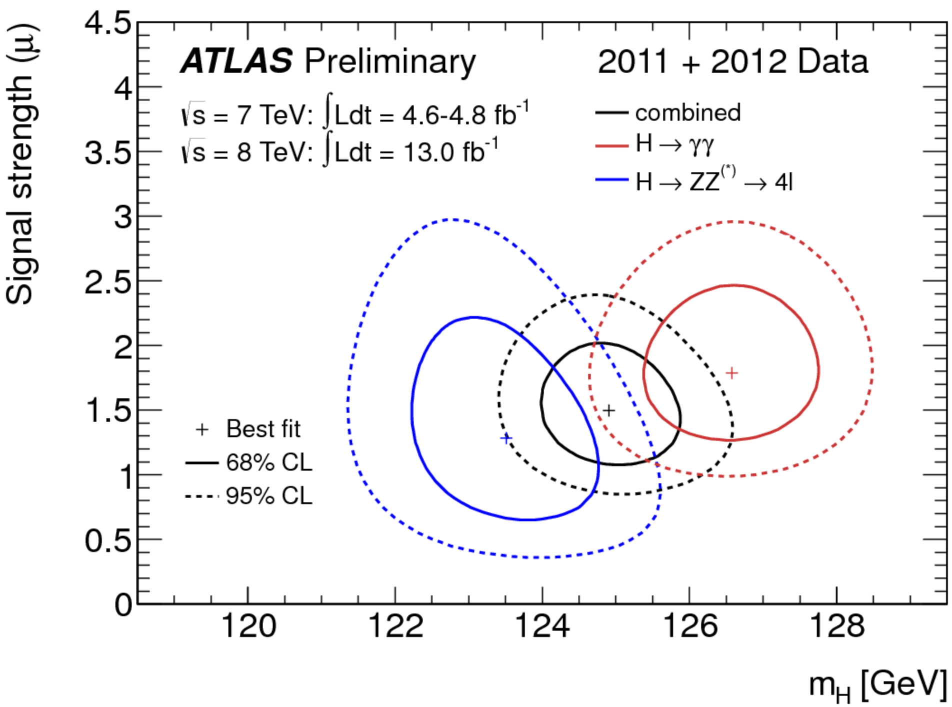
H->ZZ*->4l

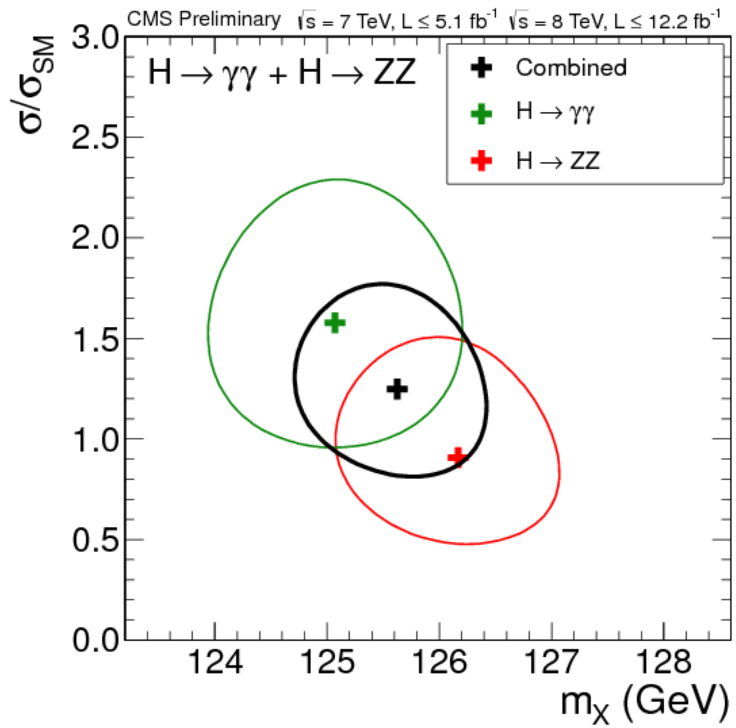




	ATLAS	CMS
Data (7TeV+8TeV)	4.6 + 13.0	5.1 + 12.2
Local p_0	2.1×10^{-5} (4.1σ) @123.5GeV	~7×10^{-5} (4.5σ) @125.9GeV
Signal strength (μ)	1.3+0.5-0.4 @123.5GeV	0.80+0.35-0.28 @126GeV

Mass with H->$\gamma\gamma$ and ZZ*->4l





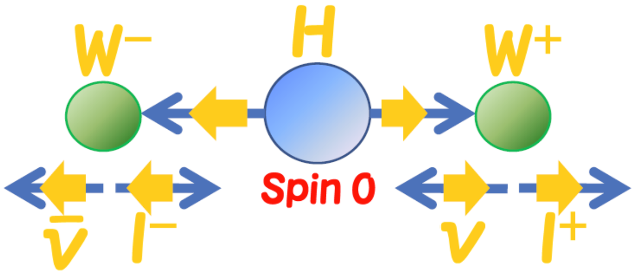
	ATLAS	CMS
H->$\gamma\gamma$	126.6+-0.3+-0.7	125 (no official value)
H->ZZ*->4l	123.5+-0.9+-0.3	126.2+-0.6+-0.2
Combined	125.2+-0.3+-0.6	125.8+-0.4+-0.4

~3σ difference (tension) between 2 channels is observed in ATLAS.

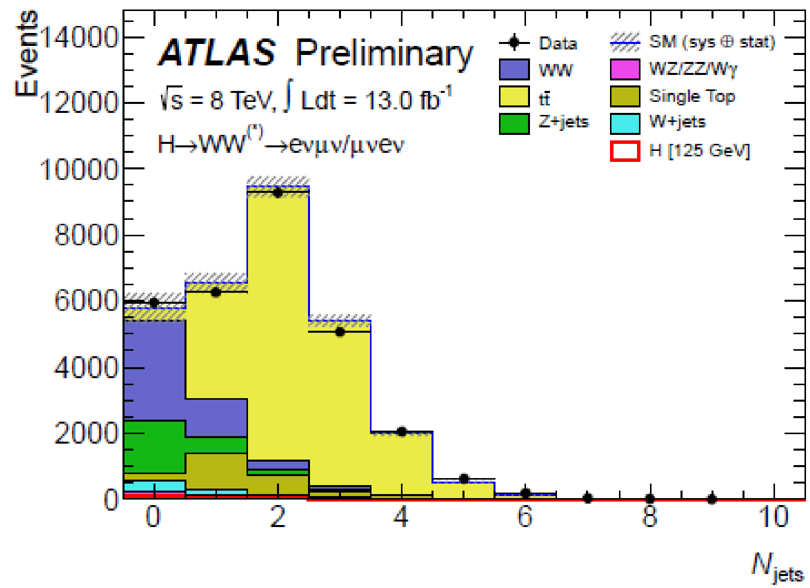
$H \rightarrow WW^* \rightarrow l\nu l\nu$

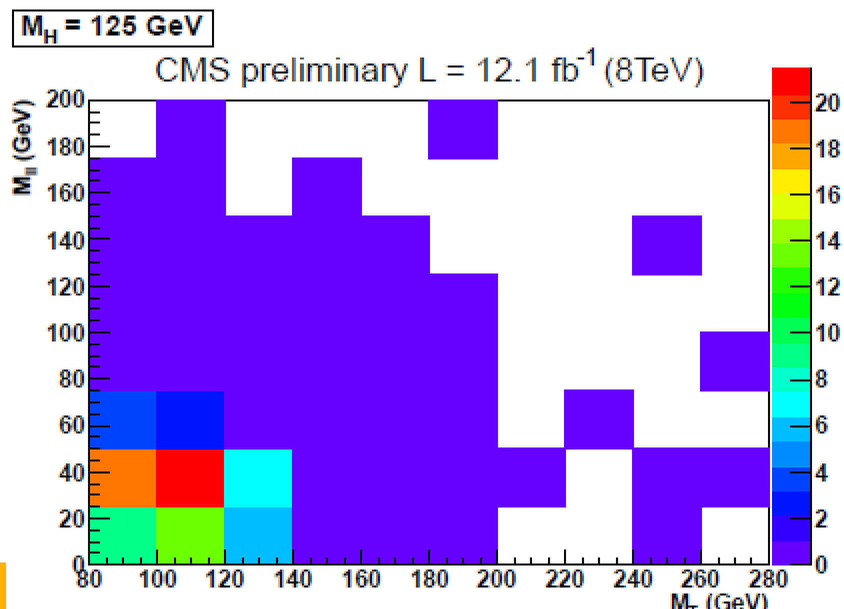
l = electron or muon

H->WW*->lνlν



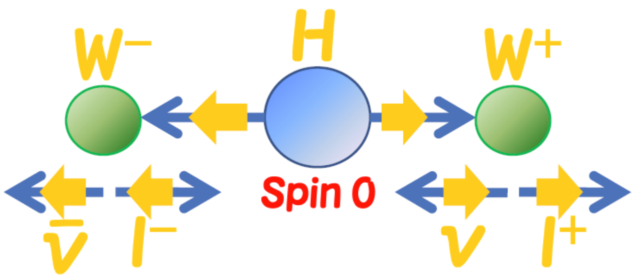
[1] cannot reconstruct Higgs mass due to 2 neutrinos
[2] ”Δϕ(ll)->small” due to spin 0 -> low dilepton inv. mass (m_{ll})



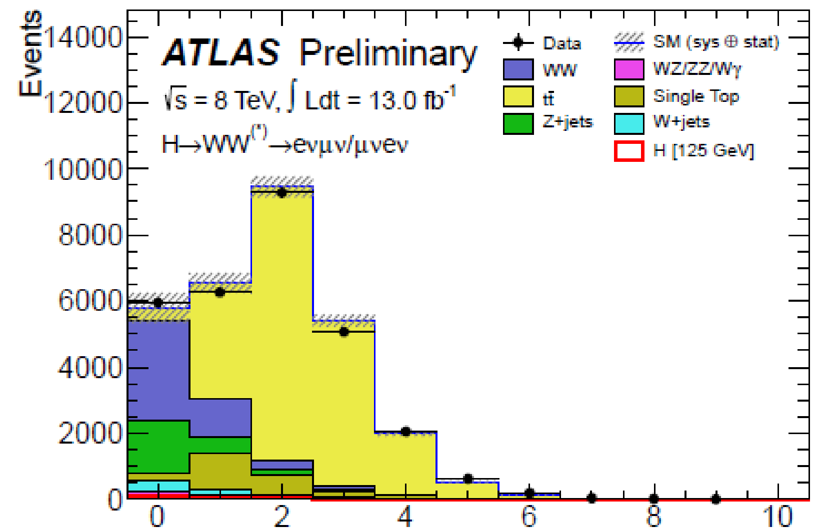


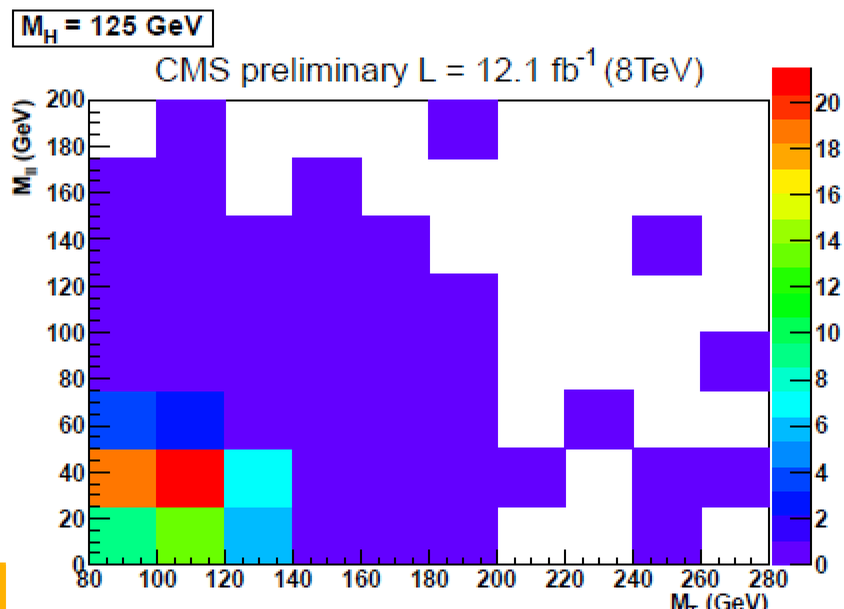
- Event topology
  - 2 isolated leptons (ATLAS 25/15GeV, CMS 20/10GeV) + MET (~25GeV)
- Jets are used for categories.
  - ATLAS p_T>25GeV, |eta|<4.5 -> 0/1
  - CMS p_T>30GeV, |eta|<4.7 -> 0/1/2
- CMS use both m_T and m_{ll} but ATLAS use only m_T for the final discriminant variables.

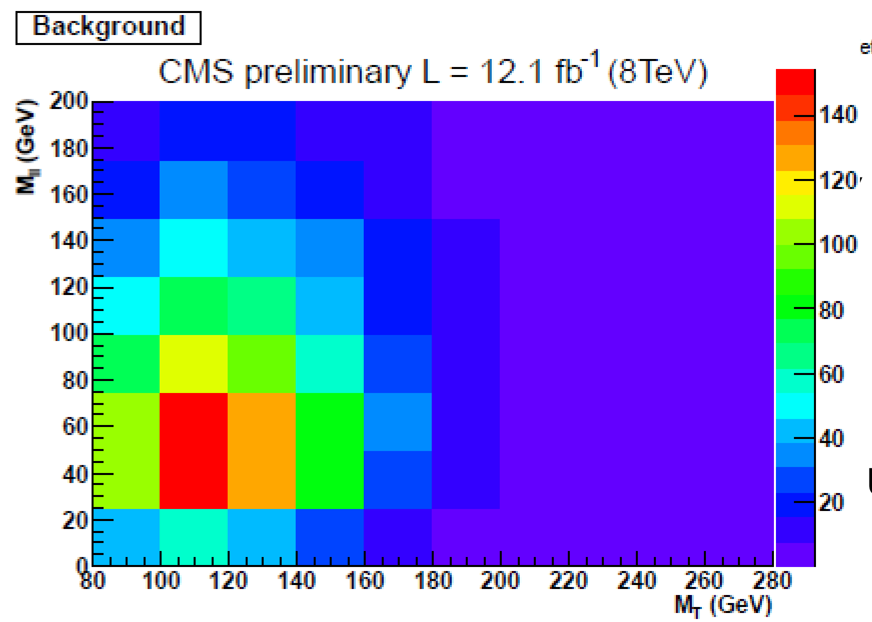
H->WW*->lνlν



[1] cannot reconstruct Higgs mass due to 2 neutrinos
[2] "Δφ(ll)->small" due to spin 0
-> low dilepton inv. mass (m_{ll})



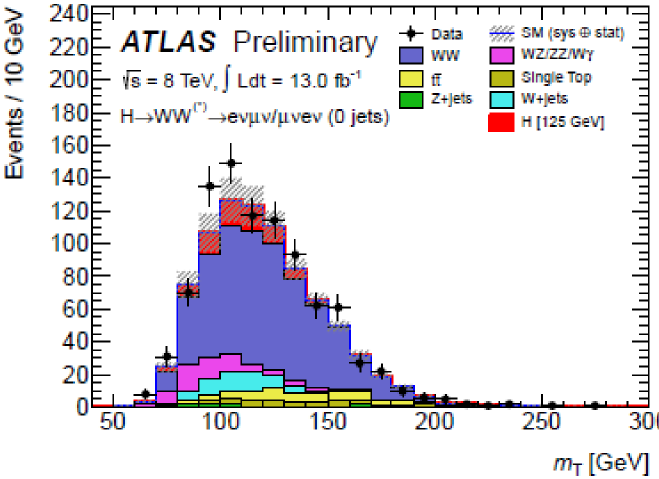




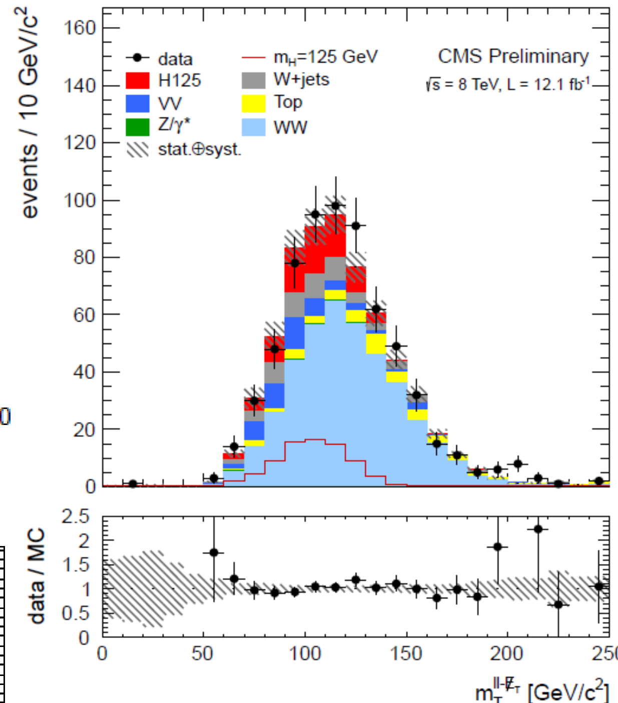
use

m_T distribution

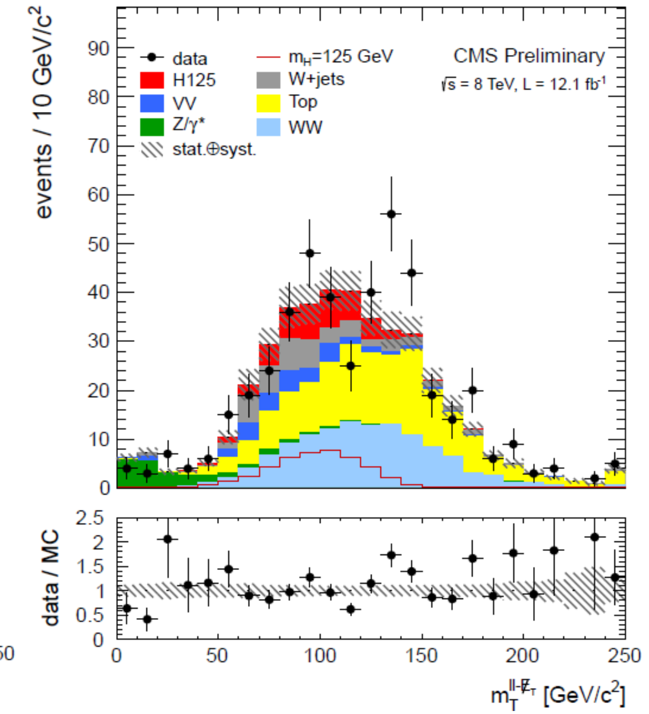
ATLAS eμ, 0jet



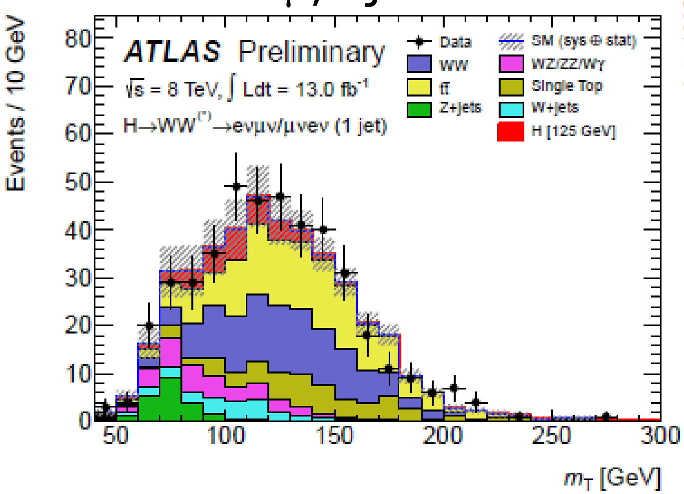
CMS eμ, 0jet (cut-based)



CMS eμ, 1jet (cut-based)



ATLAS eμ, 1jet

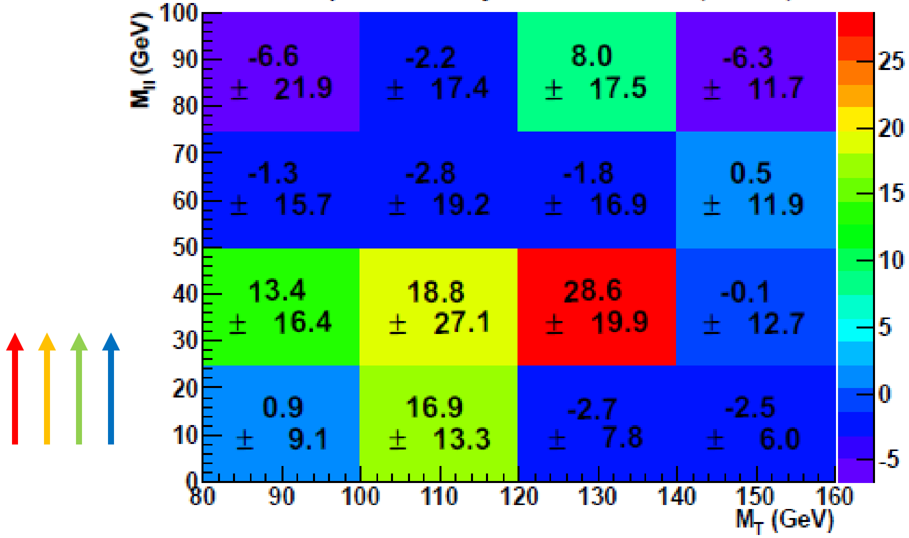


Broad excess can be found in all the distributions.
(no good mass resolution ~ 20%)

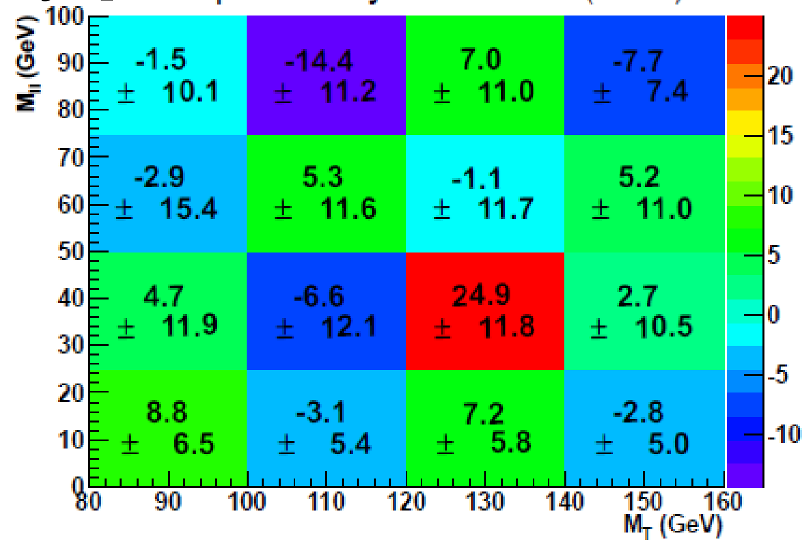
CMS eμ 0/1 jet categories use 2D(m_T, m_{ll}) to get the final results. -> ~50% improvement

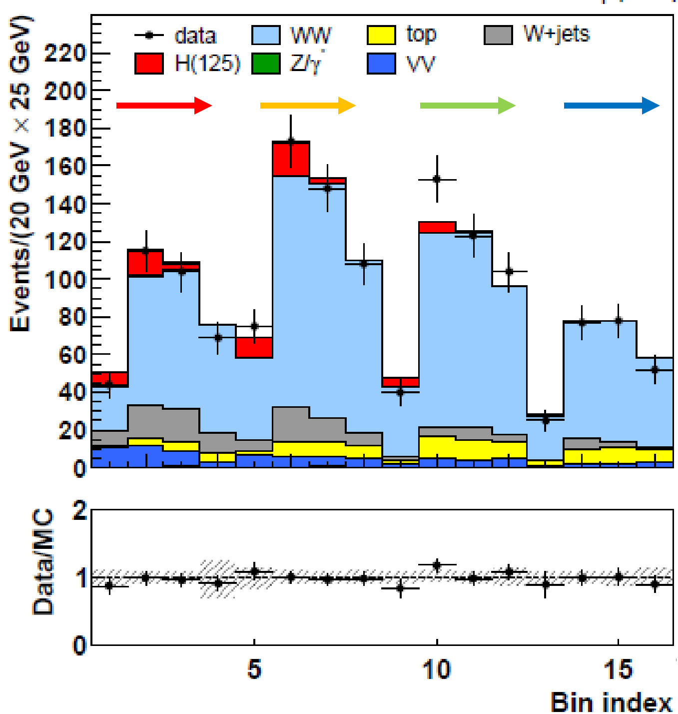
Data minus estimated BG (top) and data with estimated Signal+BG (bottom)

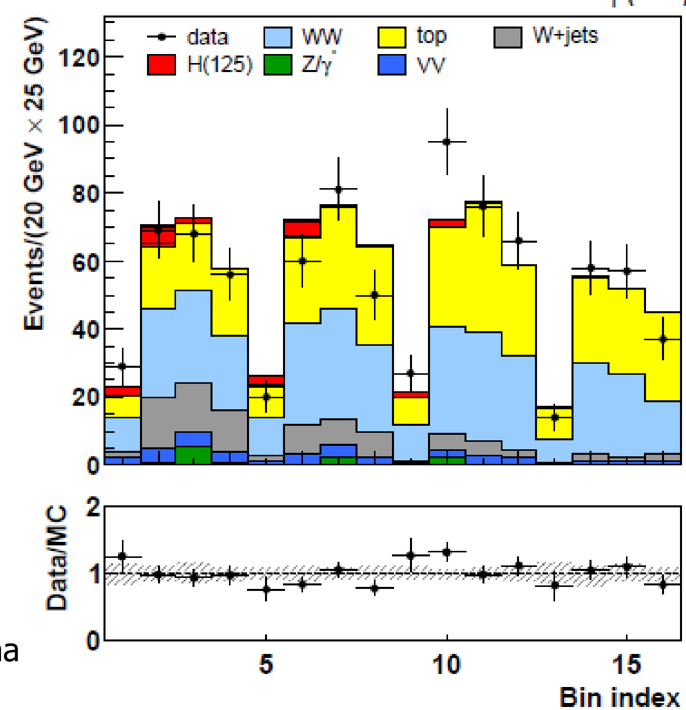
[0-jet] CMS preliminary L = 12.1 fb^{-1} (8TeV)



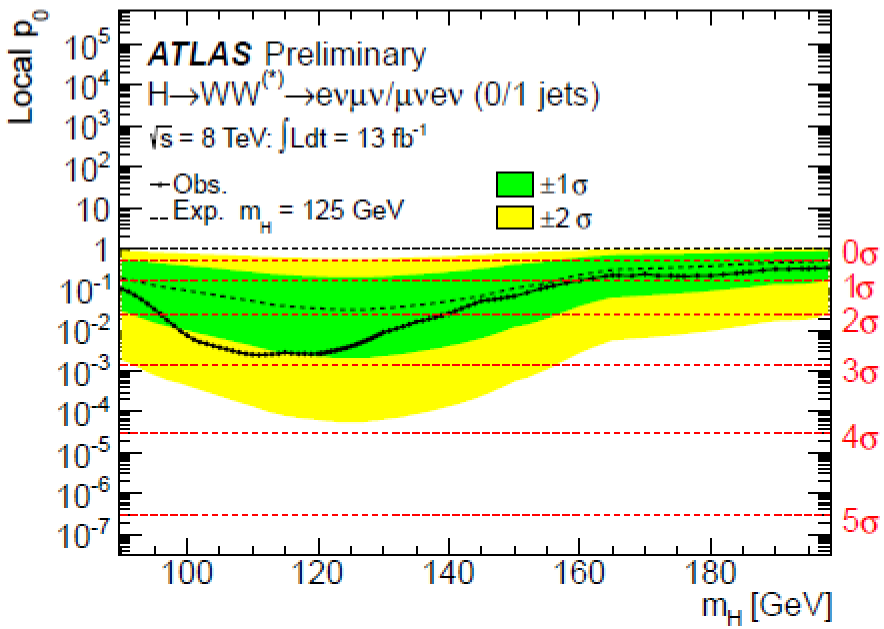
[1-jet] CMS preliminary L = 12.1 fb^{-1} (8TeV)

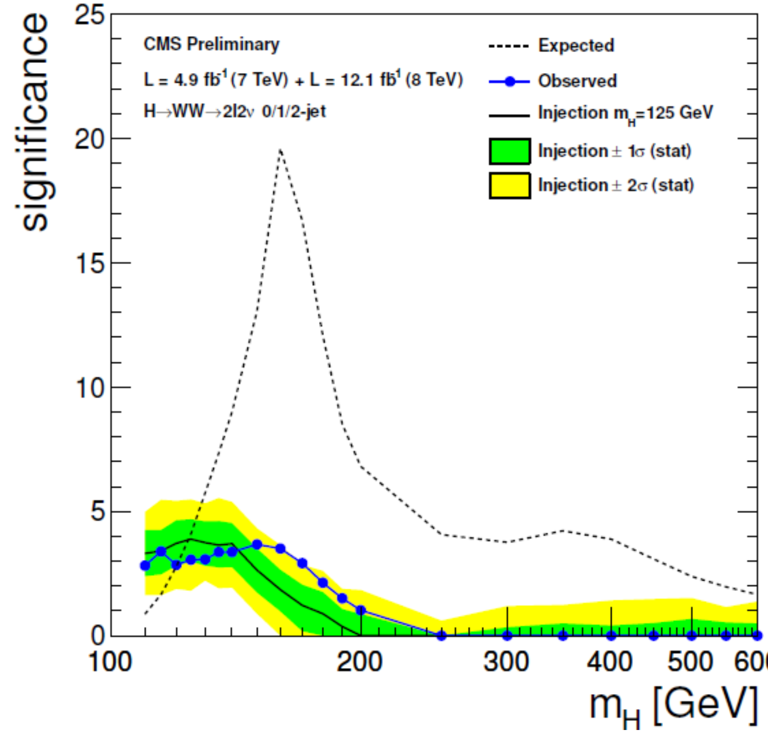






H->WW*->lνlν

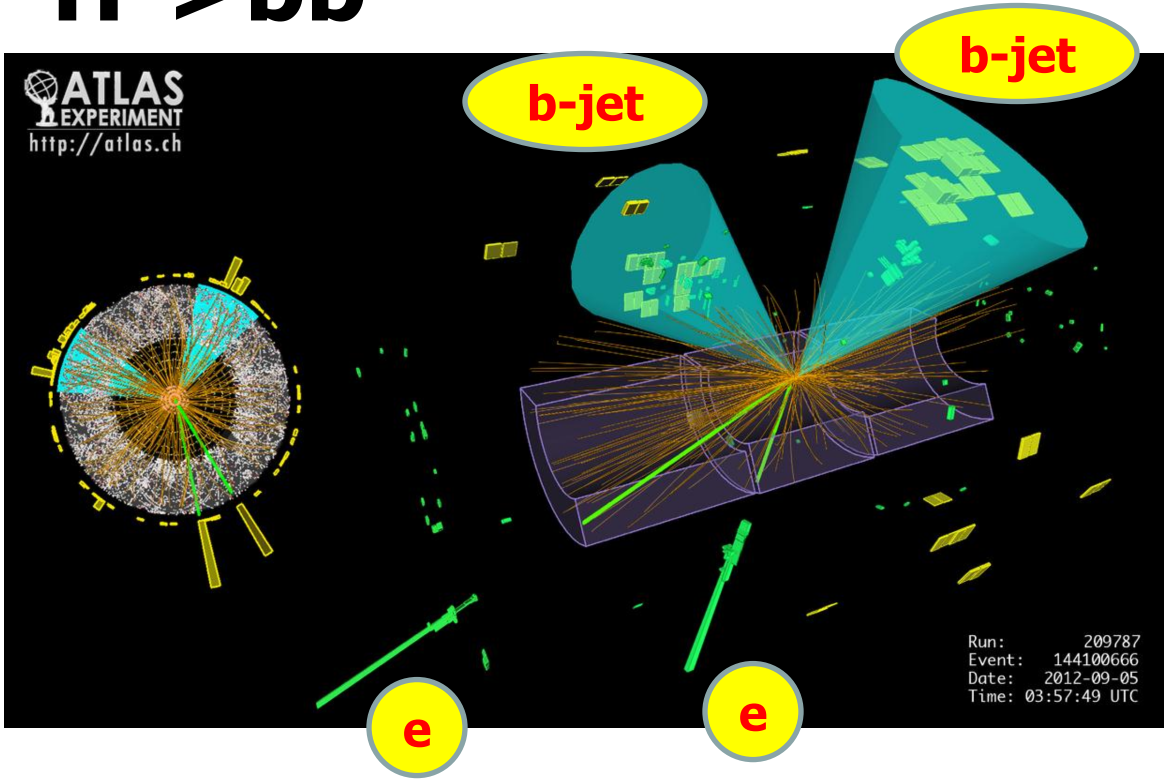




	ATLAS	CMS
Data (7TeV+8TeV)	- + 13.0	4.9 + 12.1
Z from Local p_0	2.6σ@125GeV (expected 1.9σ)	3.1σ@125GeV (expected 4.1σ)
Signal strength (μ)	1.5+-0.6@125GeV	0.74+-0.25@125GeV

H->bb

H->bb

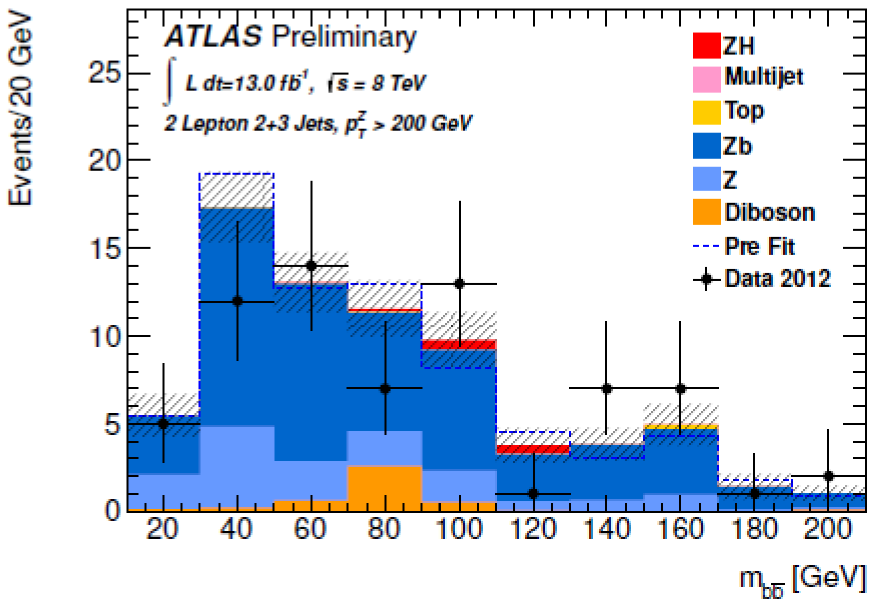


- Two production processes with 3 final states
  - WH->lνbb … 1lepton
  - ZH->llbb … 2lepton
  - ZH->ννbb … 0lepton
- B-tagging
  - Combining several information (track impact info, secondary vtx etc)

  Typical performance (b/c/l-jet)

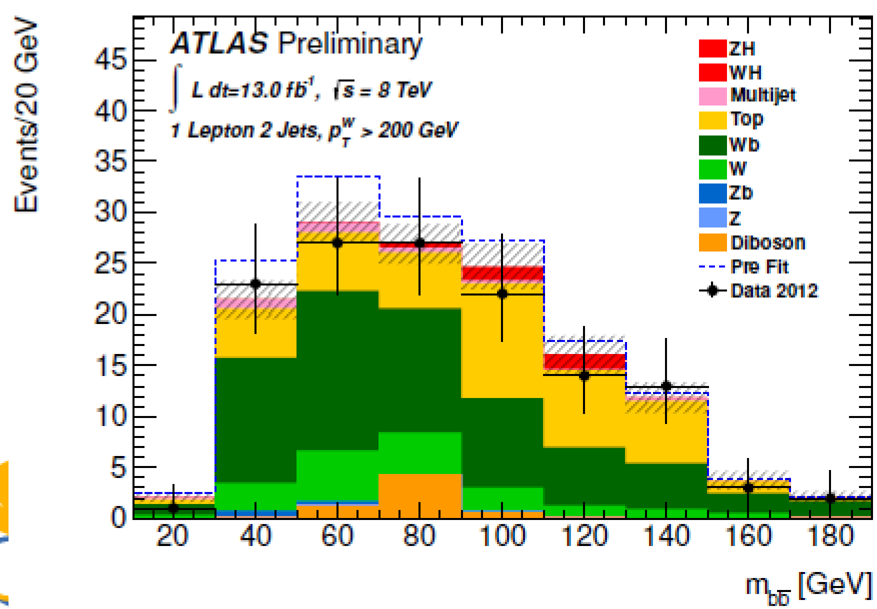
  - 70%, 20%, 0.7% (ATLAS)
  - 72%, 23%, 3% (CMS)
- pT(V) is used for further categorization to improve S/B.
  - ATLAS : 5 categories (1/2 lepton) and 3 categories (0 lepton)
  - CMS : 2 categories (only higher pT categories comparing to ATLAS)
- CMS uses MVA for two parts:
  - Improve mass(bb) resoluion -> 15% in $\sigma(m_{bb})$ -> 10-20% on the sensitivity
  - Use a MVA output for the final discriminant variable. -> ~20% on the sensitivity

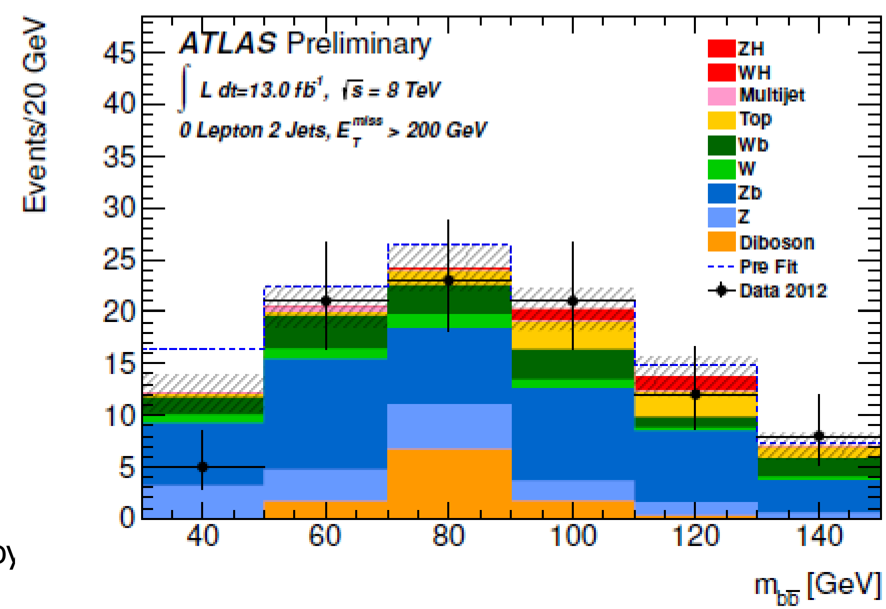
ATLAS VH, H->bb



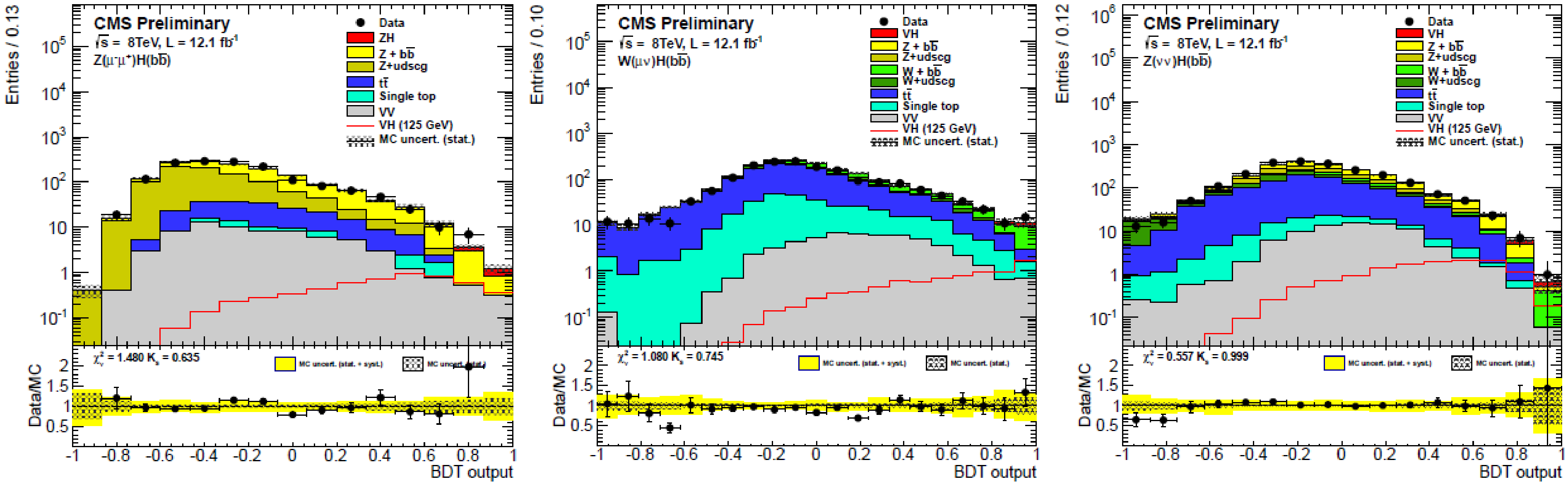
- m_{bb} of Highest pT(V) category
- Z+heavy flavor is dominant BG in 2 and 0 lepton categories (ZH).
- W+heavy flavor is dominant BG in 1 lepton category (WH).

- We still need more data to confirm bb excess.



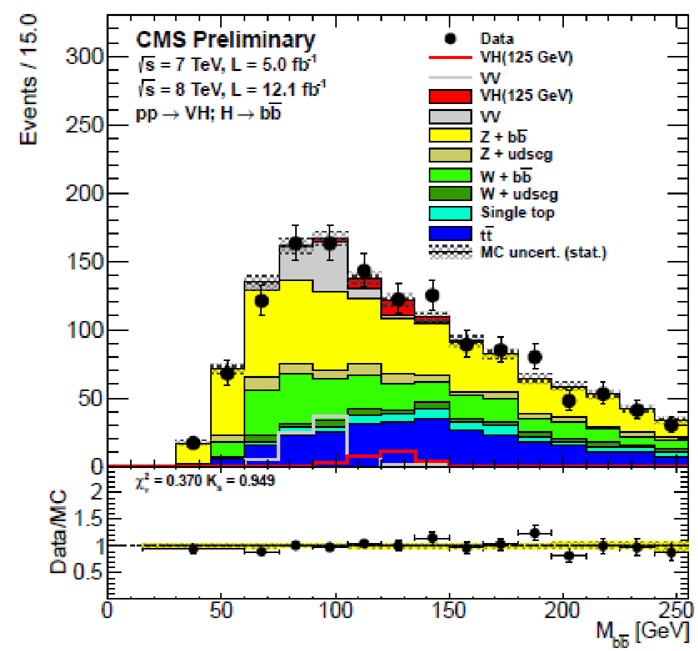


CMS VH, H->bb

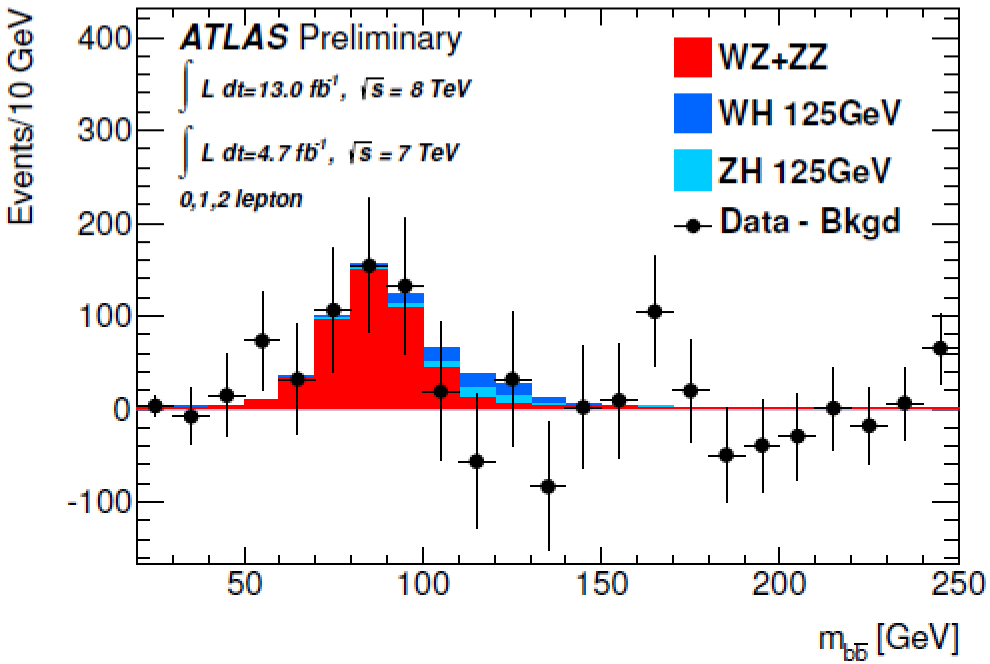


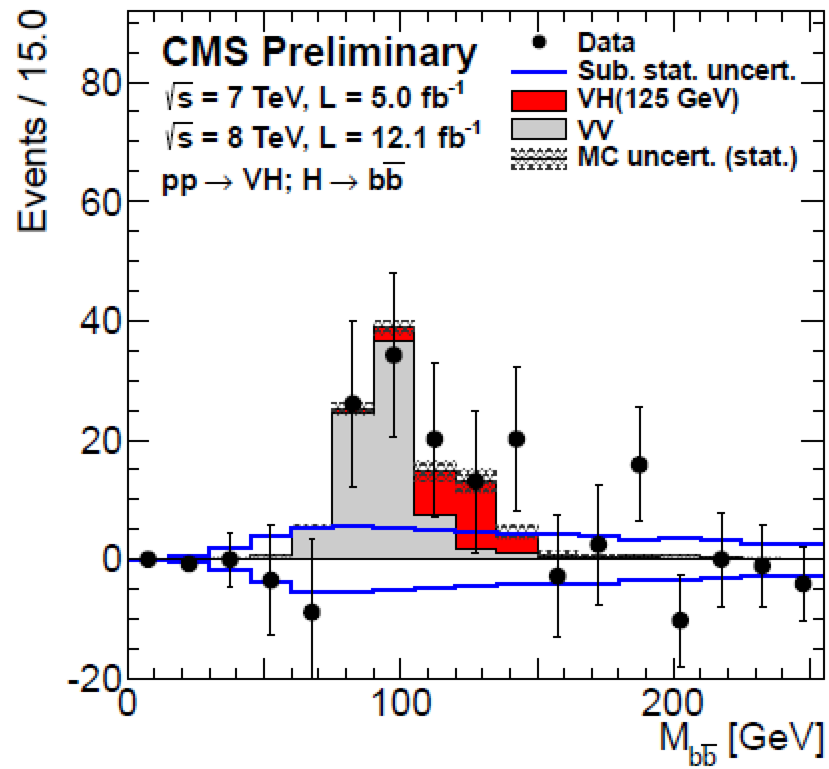
- Distribution of MVA output (3 top plots)
  -> See a high "output" region.
  - Z+heavy flavor (yellow) for ZH analysis
  - W+heavy flavor (green) for WH analysis

- m_{bb} with cut-based analysis for x-check.
  - Small excess can be seen around 120GeV. (mass resolution ~ 10%)



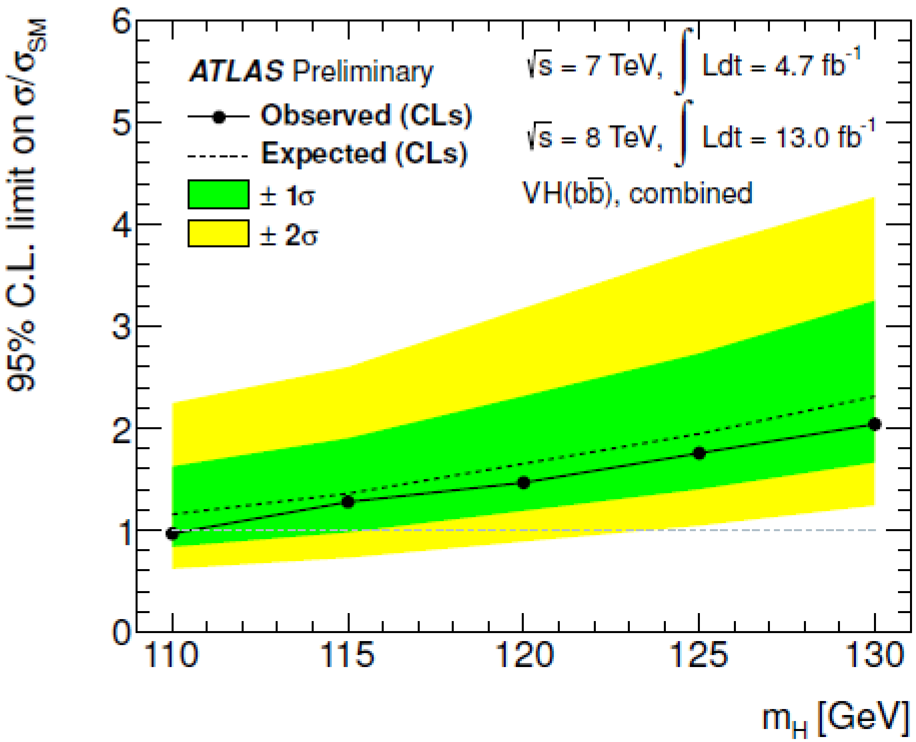
VV observation

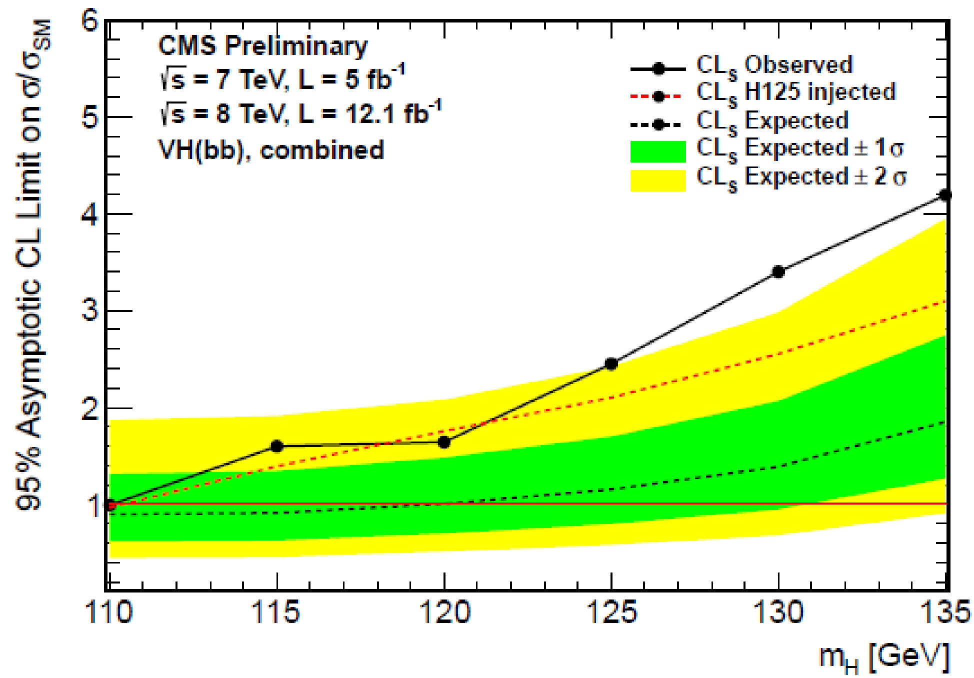




Observed VV excess with the same methods used in the H->bb search.
-> BG estimation works well.

H->bb results





	ATLAS	CMS
Data (7TeV+8TeV)	4.7 + 13.0	5.0 + 12.1
95% CL limit	1.8@125GeV (expected 1.9)	2.5@125GeV (expected 1.2)
Signal strength (μ)	-0.4+-0.11@125GeV	1.3+0.7-0.6@125GeV

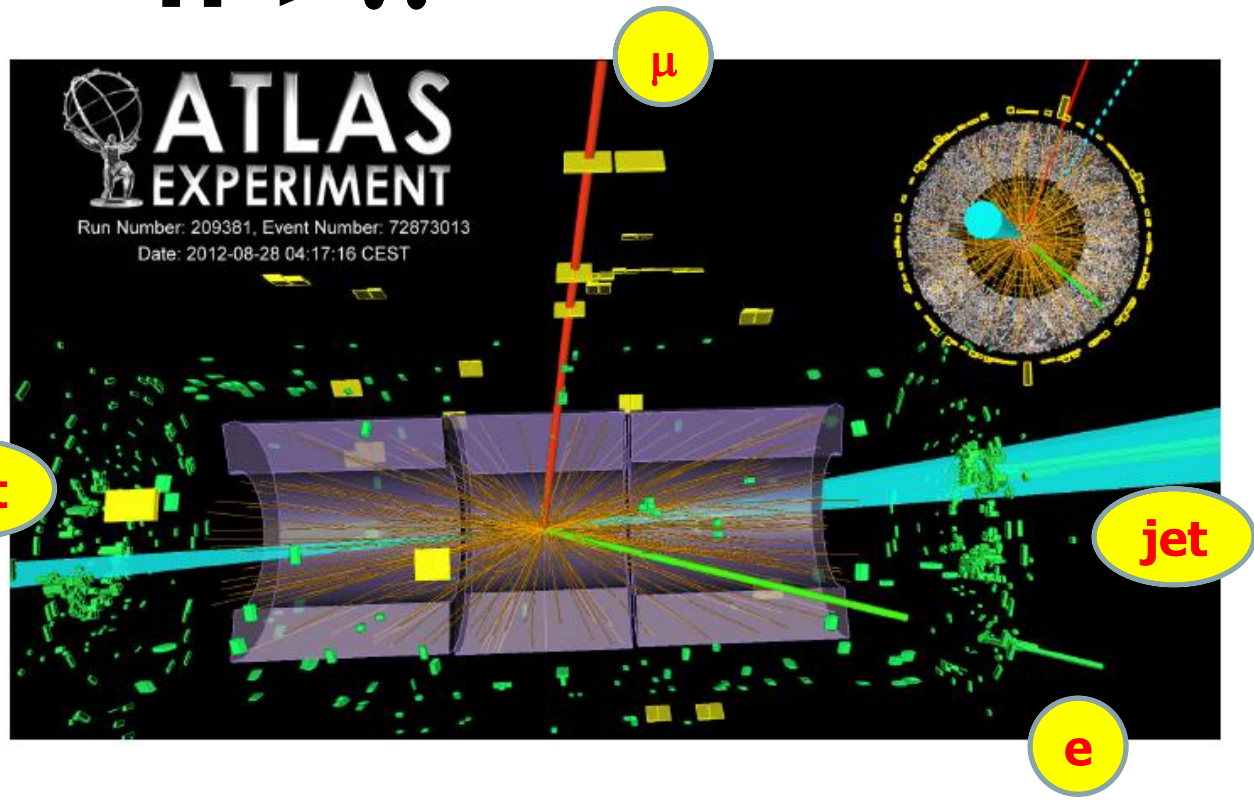
H->$\tau\tau$

H->$\tau\tau$

- 3 final states
  - ll, lh and hh

- Categories based on event topology (ll/lh/hh)
  - ATLAS 10 (4/4/2) categories
  - CMS 8 (3/3/2) categories

-> Focus on "VBF-tag" because S/B is better by requiring two jets.



Typical cut for VBF tag (ATLAS/CMS)
- M_{jj} > 350-500GeV
- $\Delta\eta_{jj}$ > 2.6-3.5

Purity of VBF process in VBF-tag
- ~70-80% (ATLAS)

ATLAS introduces "boosted" category.
- pT(h=$\tau\tau$)>100GeV etc

VH process is enhanced but a gluon-fusion process is still dominant.

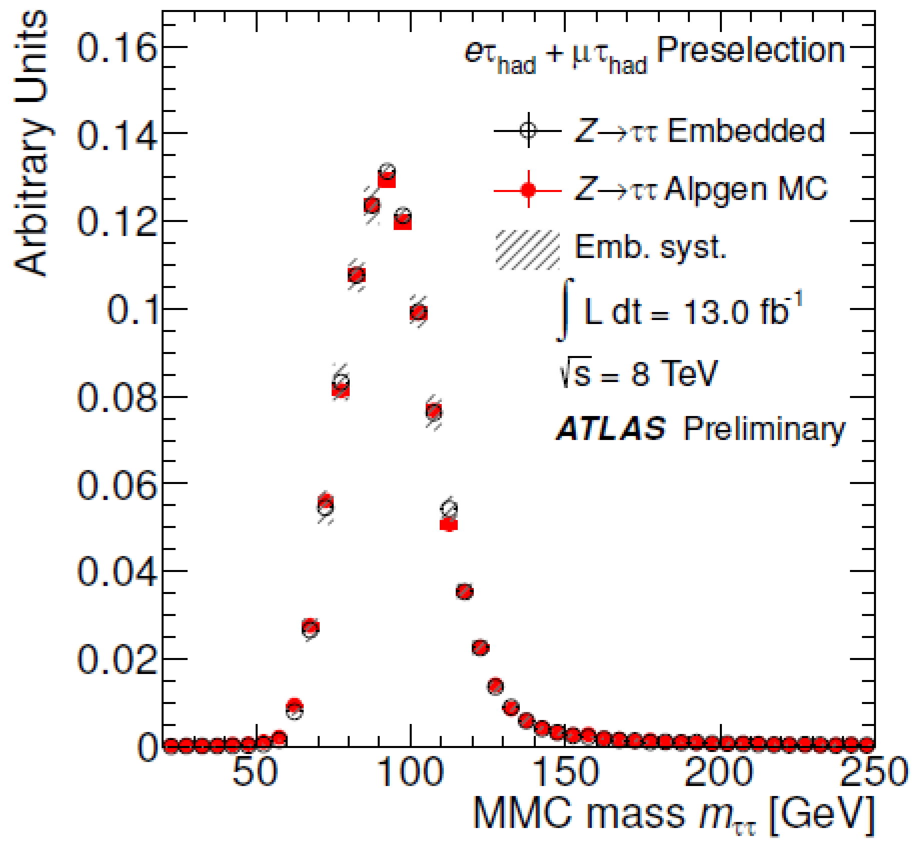
ggF:VBF:VH = ~4:~1:~0.5-1

Z->ττ BG and mass calculation

- Z->ττ (+jets) process is irreducible BG.
- Use data to estimate Z->ττ BG shape.
  - No (or small) systematic uncertainties on jets, UE, pile-up etc.

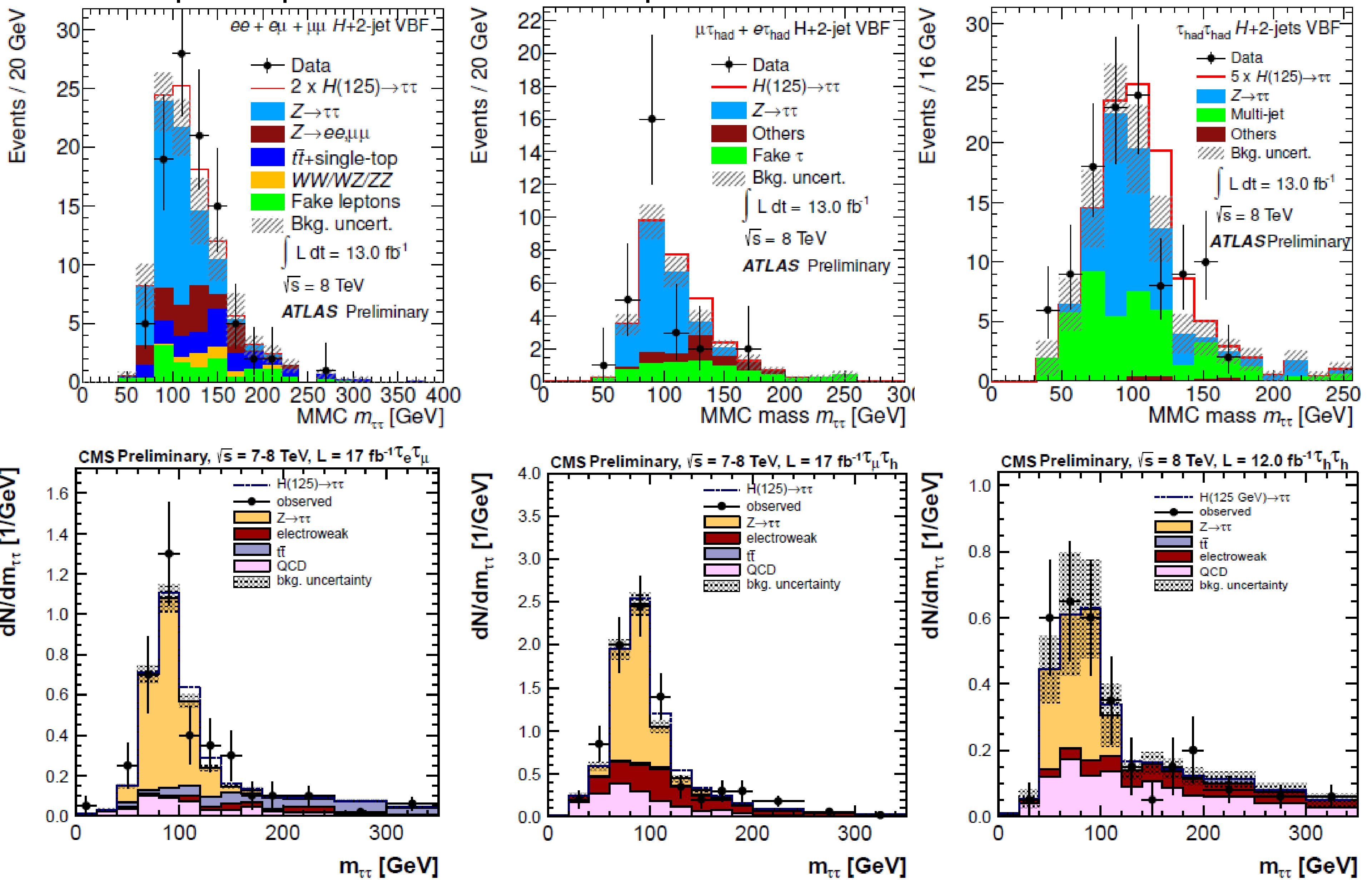
  [Method]
  - Take Z->μμ candidates from data and replace μ with simulated tau. ("embedded" method)
- Mass calculation
  - A "collinear mass approximation" has been used but now we are using more sophisticated method to get ττ-mass.
    - ATLAS … MMC
    - CMS … SVFit

    -> Take into account neutrino direction. Ineff of the calculation is almost 0.

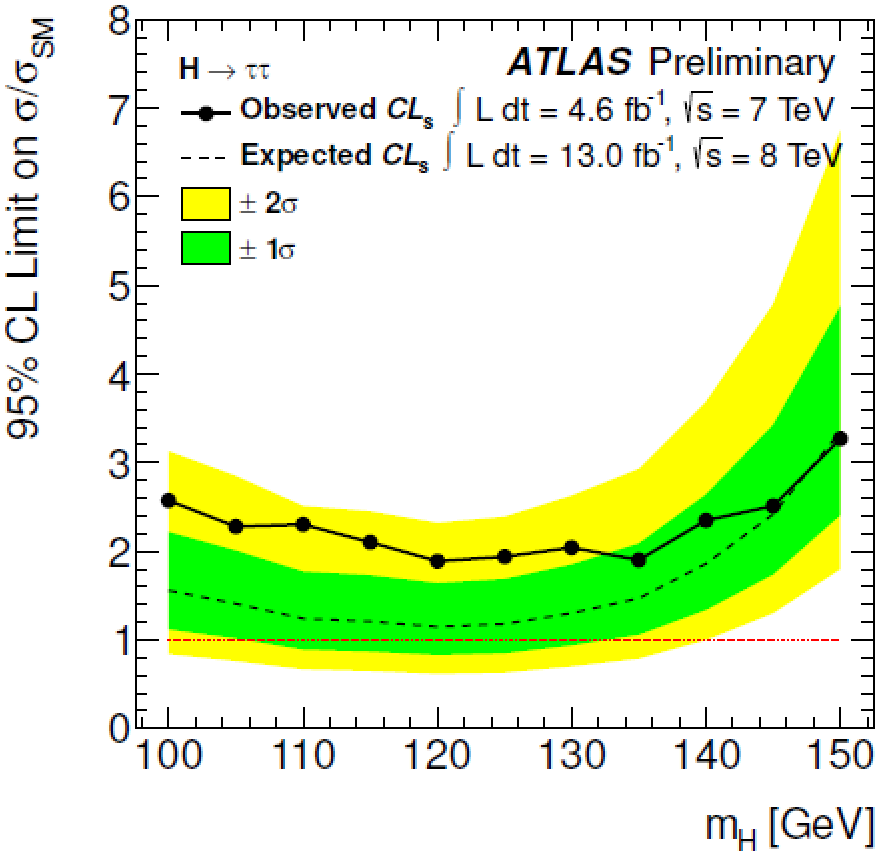


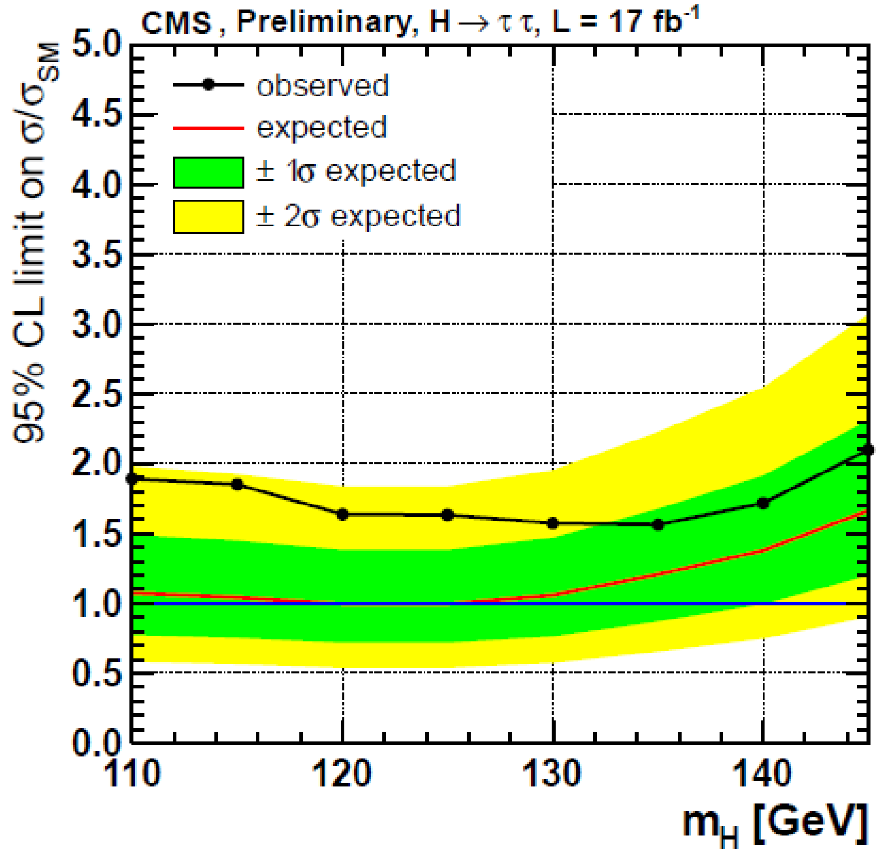
ττ mass for VBF(2-jet)-tag

Lepton-lepton | Lepton-hadron | Hadron-hadron



H->ττ result



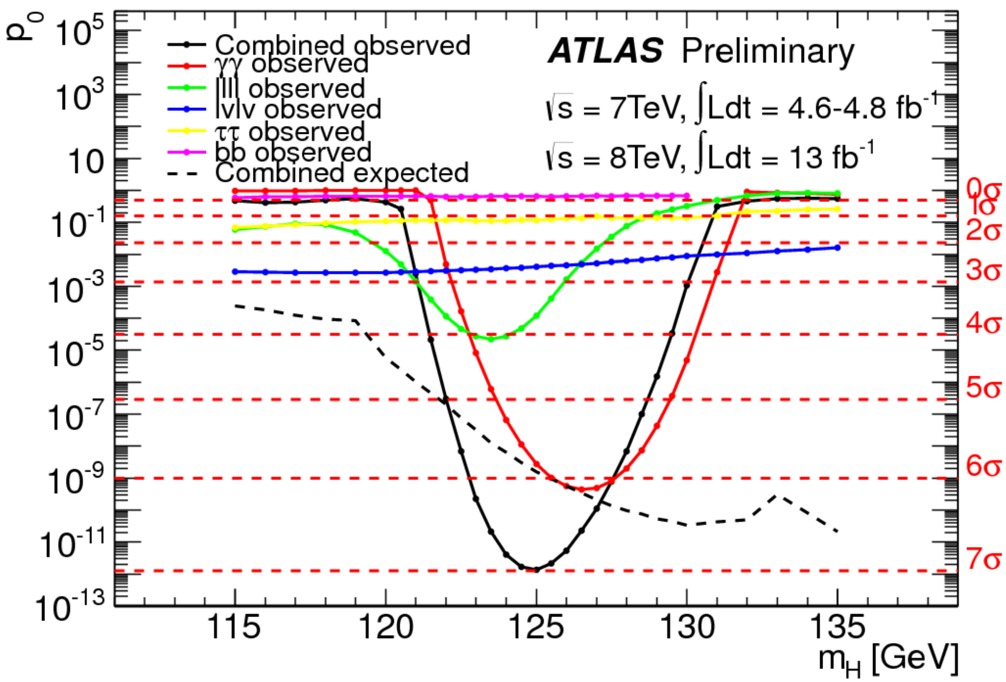


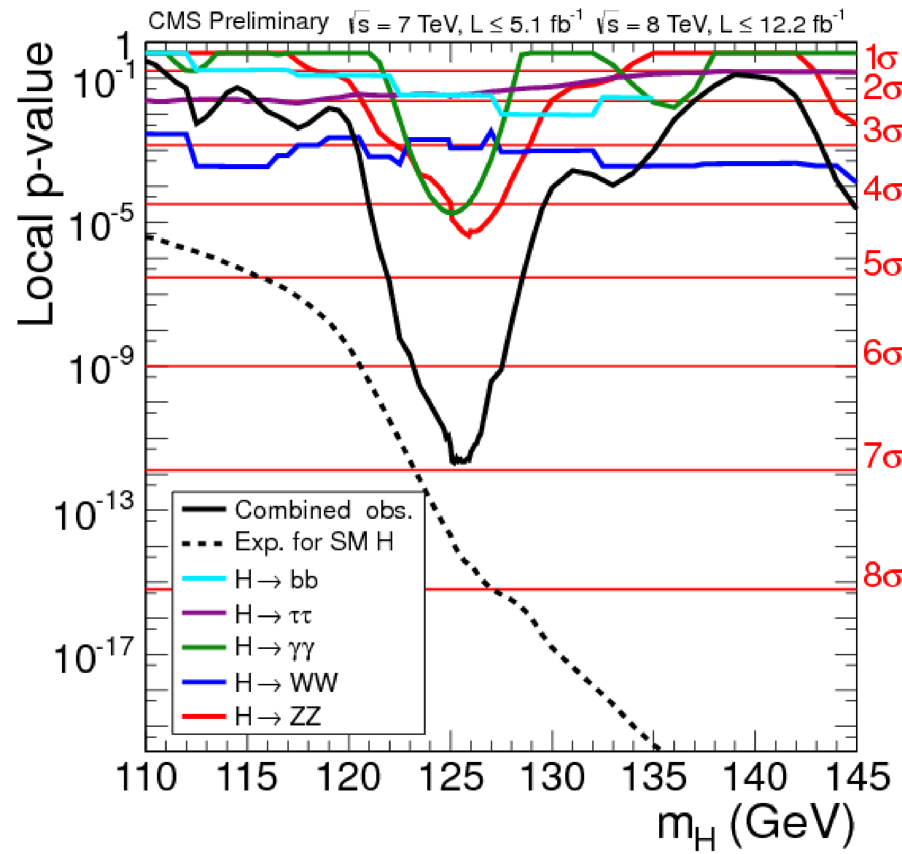
	ATLAS	CMS
Data (7TeV+8TeV)	4.6 + 13.0	4.9 + 12.1
95% CL limit	1.9@125GeV (expected 1.2)	1.63@125GeV (expected 1.00)
Signal strength (μ)	0.7+-0.7@125GeV	0.7+-0.5@125GeV

Combination

p_0-value

A probability that background-only experiment is more signal-like than that observed.





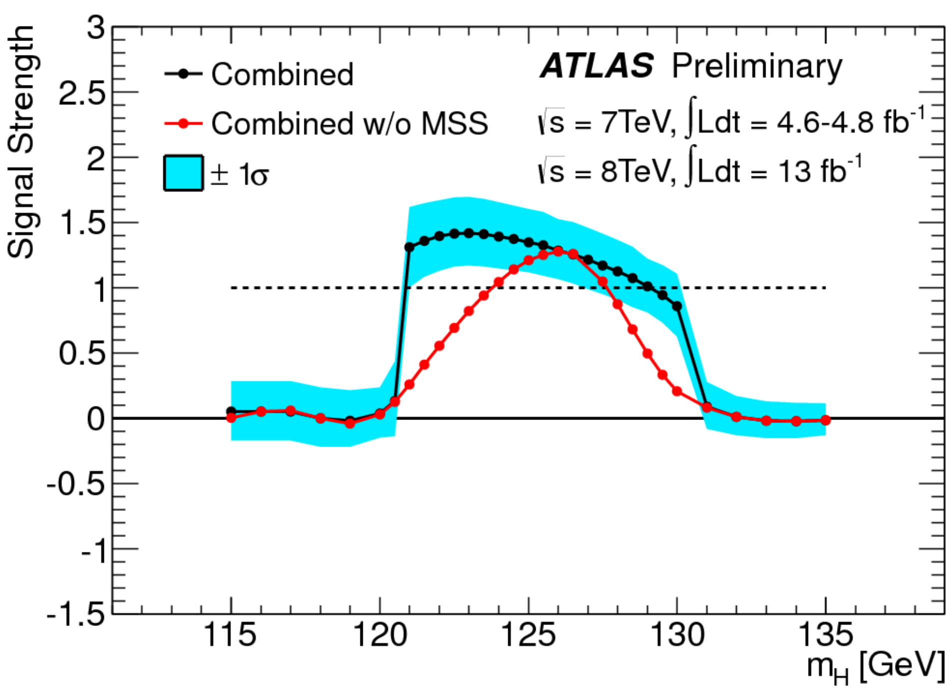
Observed significance
ATLAS : 7.0σ (125GeV)
CMS : 6.9σ (125.8GeV)

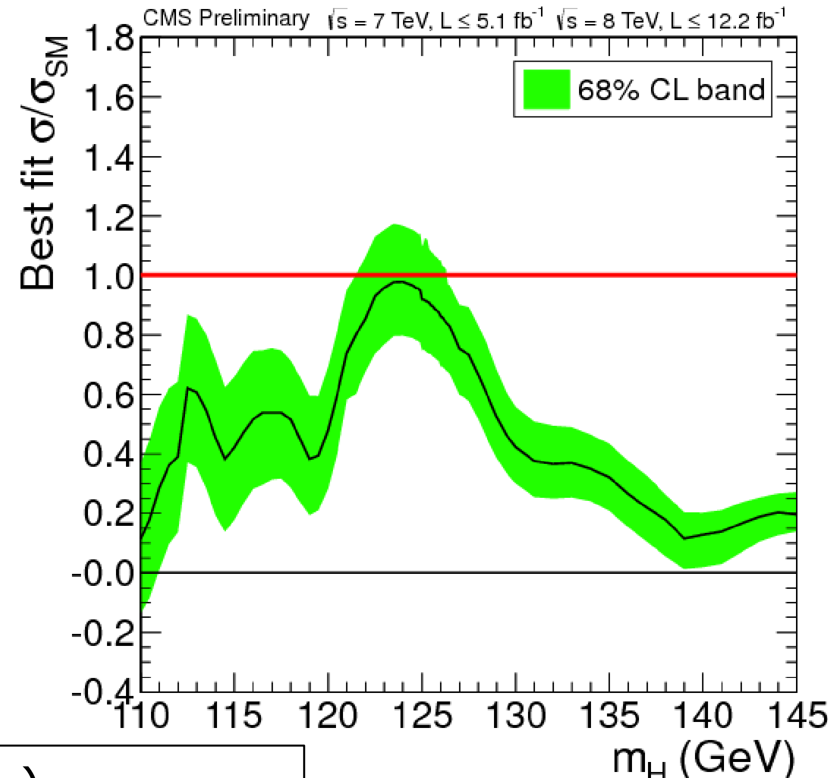
CMS results

Decay mode or combination	Expected (σ)	Observed (σ)
ZZ	5.0	4.4
γγ	2.8	4.0
WW	4.3	3.0
bb	2.2	1.8
ττ	2.1	1.8
γγ + ZZ	5.7	5.8
γγ + ZZ + WW + ττ + bb	7.8	6.9

Signal strength (μ)

The compatibility of the observed excess with the expected signal(=SM Higgs)
-> μ is a signal strength in units of SM Higgs cross section(x BR).

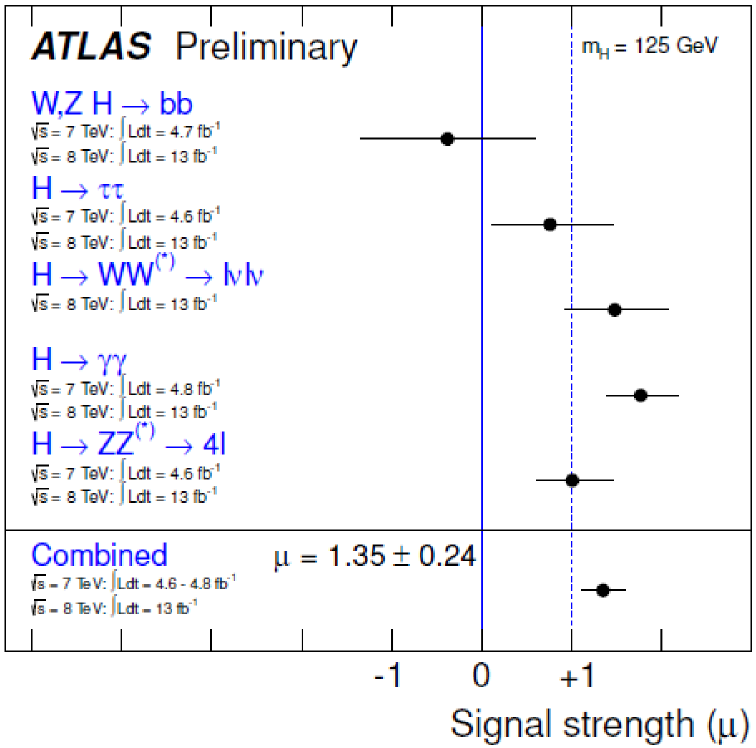




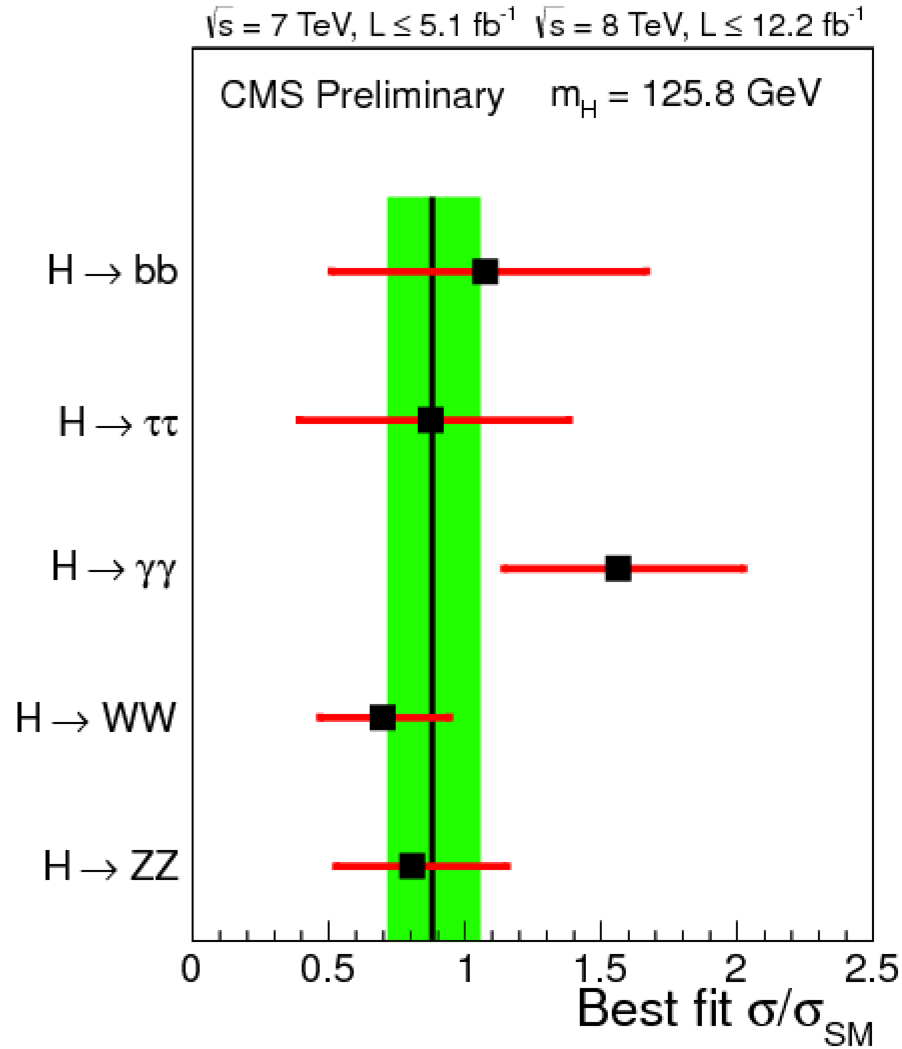
Signal strength (μ)
ATLAS : 1.35+-0.24 (125GeV)
CMS : 0.88+-0.21 (125.8GeV)

Measured mass
ATLAS : 125.2+-0.3+-0.6 GeV
CMS : 125.8+-0.4+-0.4 GeV

μ-value for each decay mode

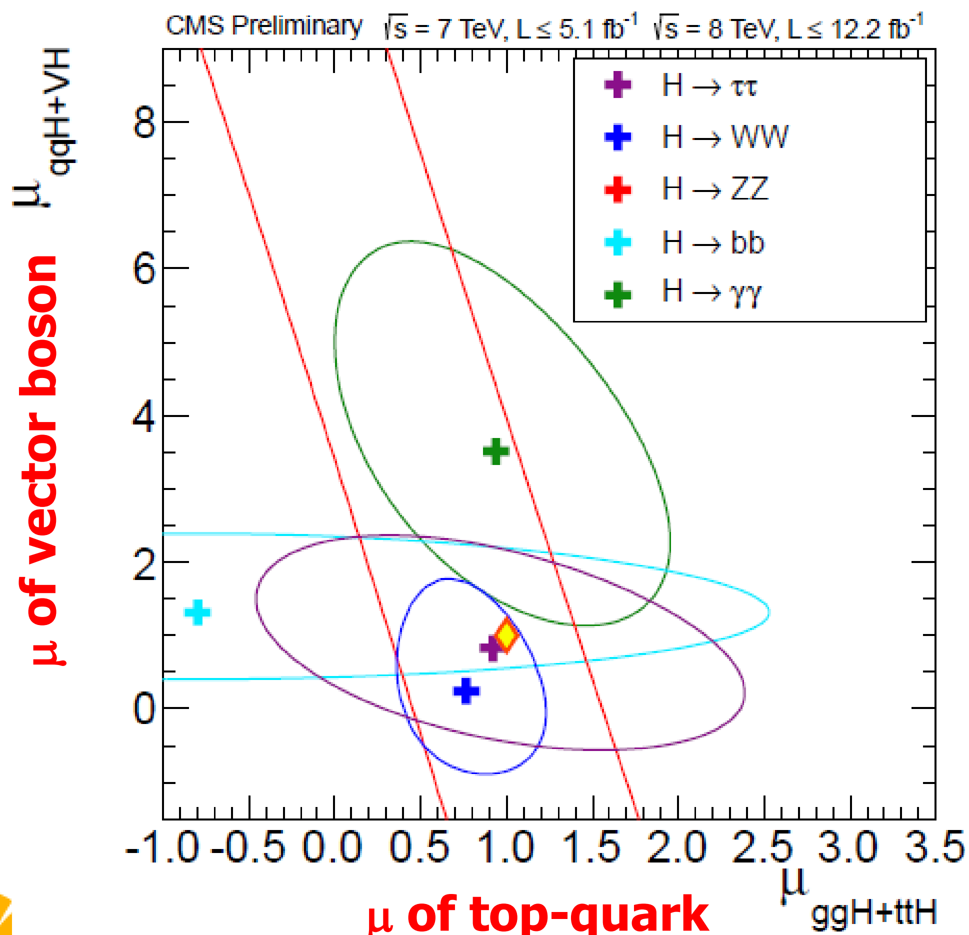


Higgs Boson Decay	**ATLAS** μ (m_H=125 GeV)
$VH \to Vbb$	-0.4 ± 1.0
$H \to \tau\tau$	0.8 ± 0.7
$H \to WW^{(*)}$	1.5 ± 0.6
$H \to \gamma\gamma$	1.8 ± 0.4
$H \to ZZ^{(*)}$	1.0 ± 0.4
Combined	1.35 ± 0.24



μ with different production

- μ for gluon fusion and ttH -> top-quark couplings
- μ for VBF and VH -> vector boson couplings



ττ and bb can determine vector boson's μ.

No power on vector boson's μ from ZZ since there is no special category for VBF and VH.

So far, all the results are consistent with SM prediction.

Spin and Parity

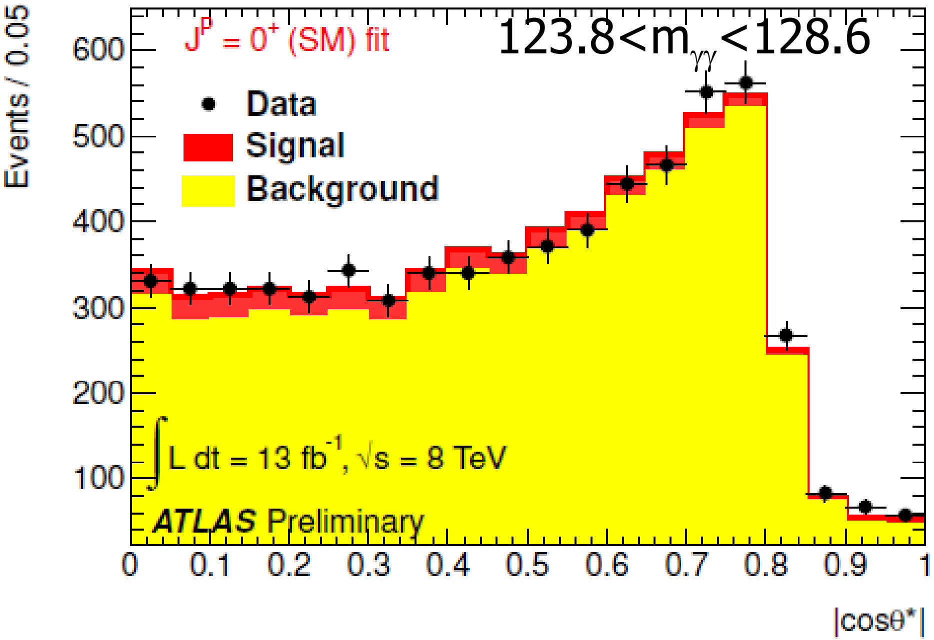
- ATLAS and CMS have started to check if the observed particle has 0^+.
- They use H->$\gamma\gamma$ and H->ZZ->4l channels so far.
  H->WW->lnln channel will be involved in for this measurement in future.

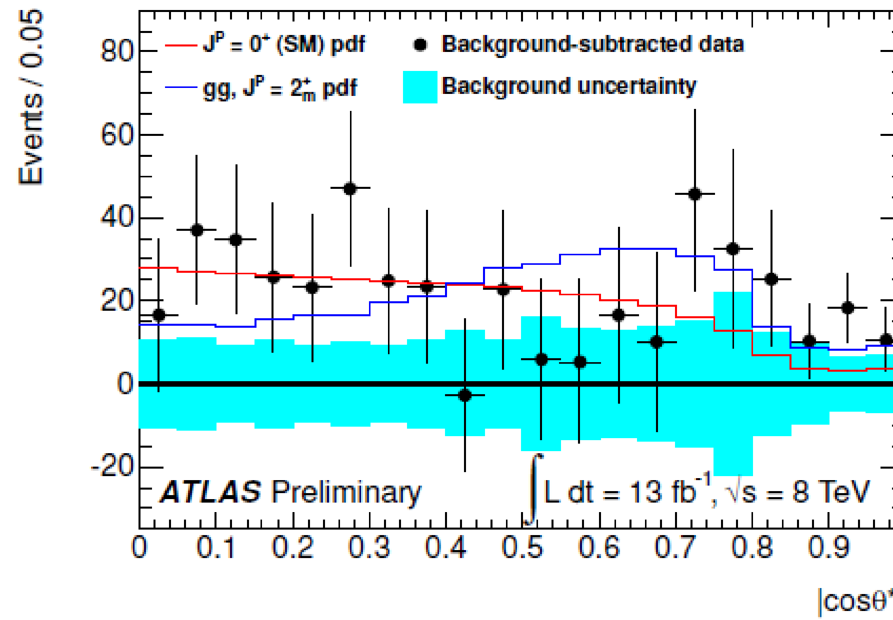
- H->$\gamma\gamma$ (ATLAS)
  - cos(θ^*) … angle between a photon in the "Higgs" rest frame and a Higgs in the lab frame with some modifications (so-called Collins-Soper frame) -> see ATLAS note (ATLAS-CONF-2012-168).
  - Events in 123.8<m($\gamma\gamma$)<128.6 are used to see spin and parity.

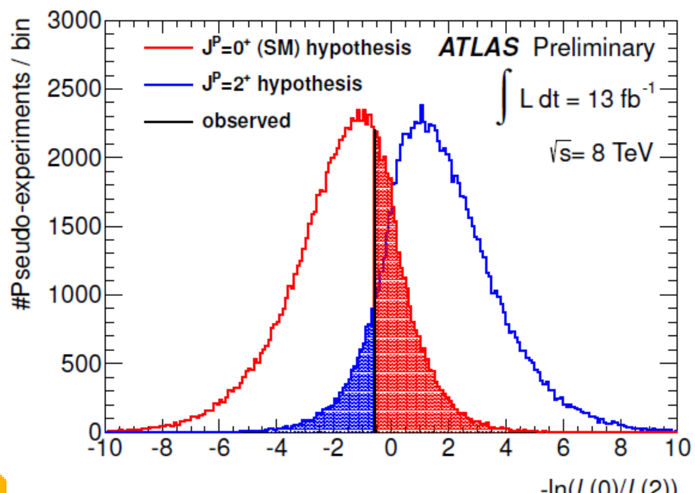
- H->ZZ->4l (ATLAS and CMS)
  - 5 angles (θ^*, Φ_1, Φ, θ_1, θ_2) and 2 mass (m_{12}, m_{34}) are basically used.
    - ATLAS BDT-based analysis for 0+ vs 0- … (θ^*, Φ_1) are not used.
  - ATLAS : 115-130GeV, CMS : 106-141GeV(?)

- JHU event generators are used to model "resonance" events in ATLAS/CMS.

Spin and Parity (ATLAS H->γγ)





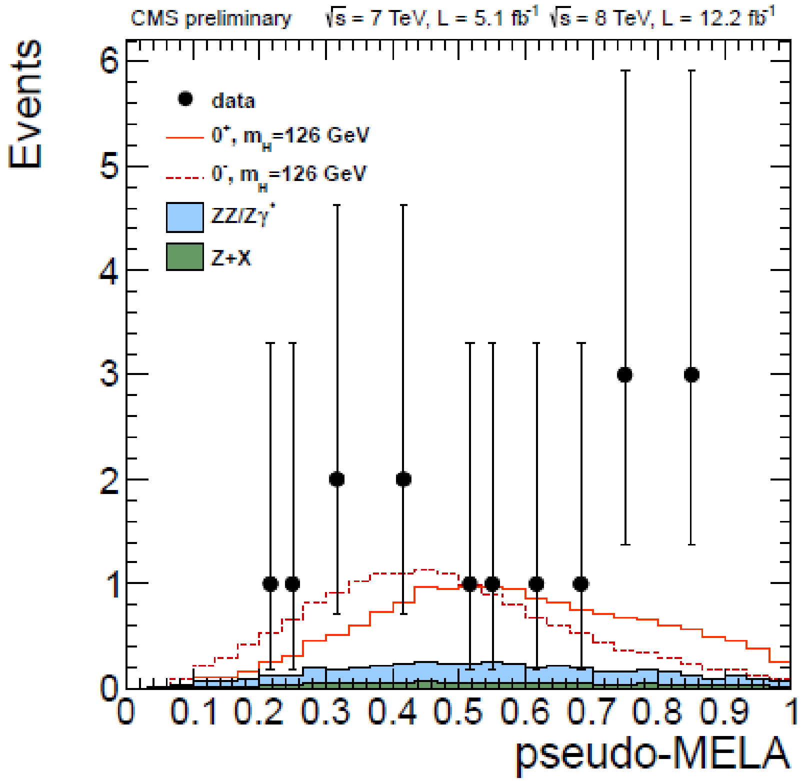


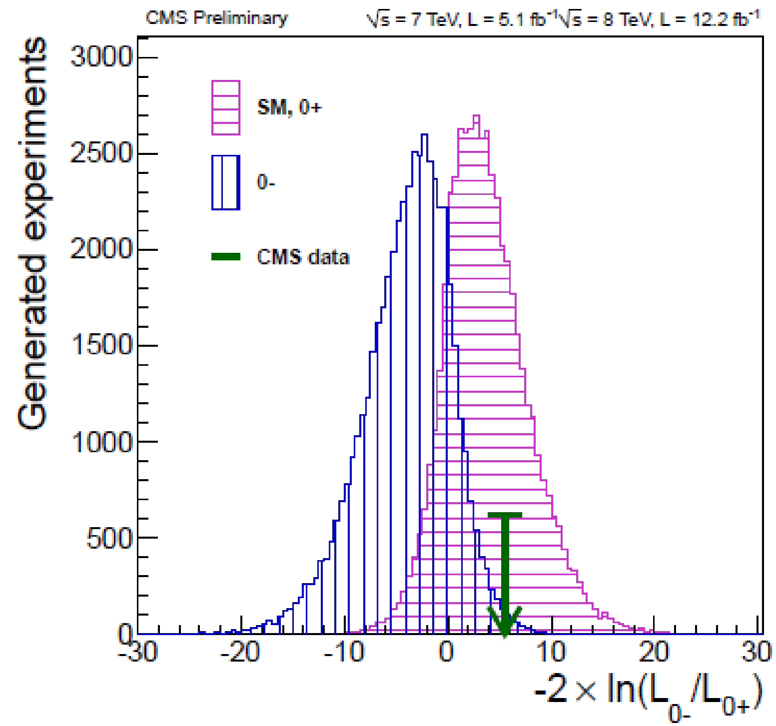
2^+_m : graviton-like spin-2
with minimal couplings

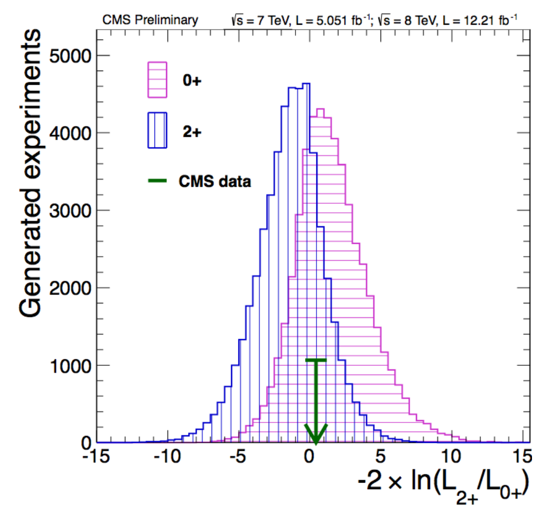
Observed p-value :
$p(2^+_m)$ = 8.6% (1.4σ) assuming 0^+
$p(0^+)$ = 29% (0.55σ) assuming 2^+_m

0^+ is preferred.

Spin and Parity (CMS H->ZZ->4l)



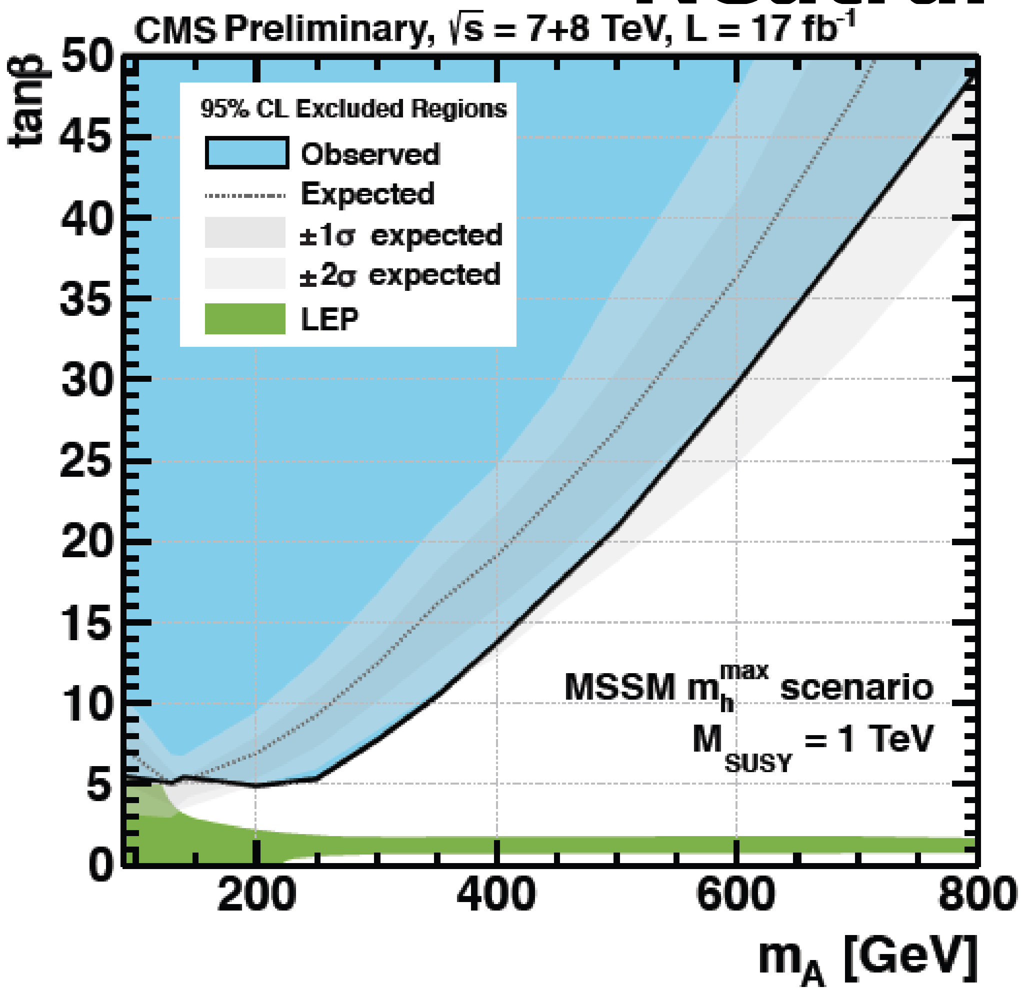


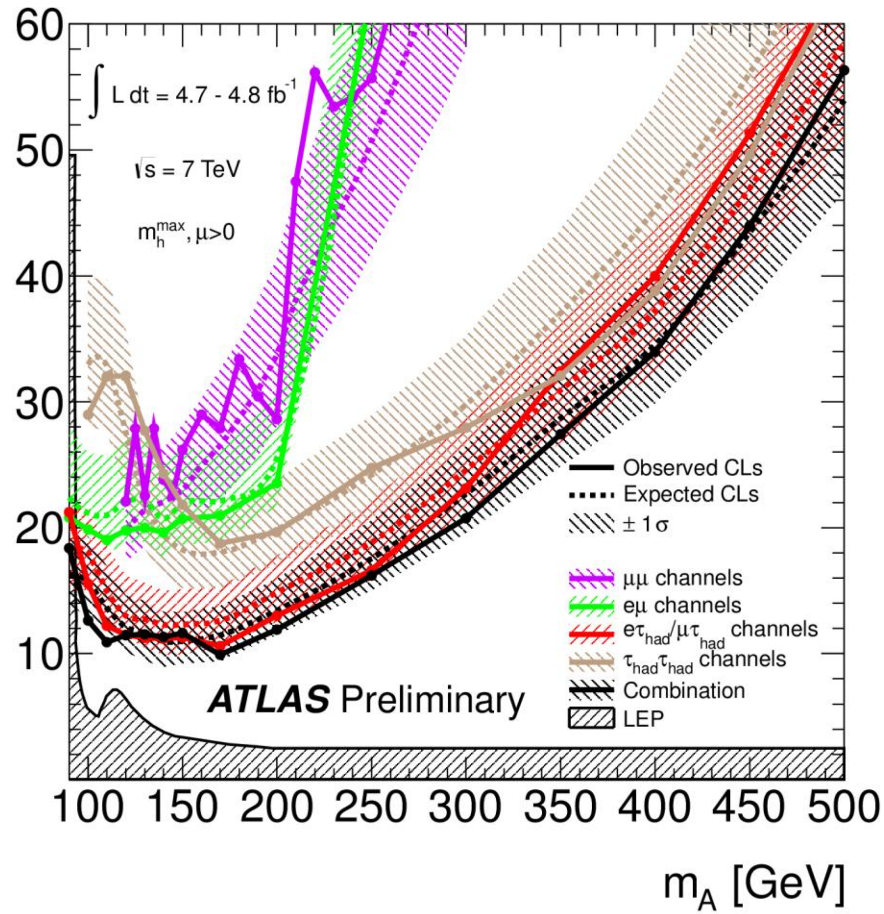


- Data disfavor 0^- hypothesis with CLs of 2.4%. (under the assumption of SM Higgs)
- No value for 2^+ (only distribution is available.)

BSM Higgs

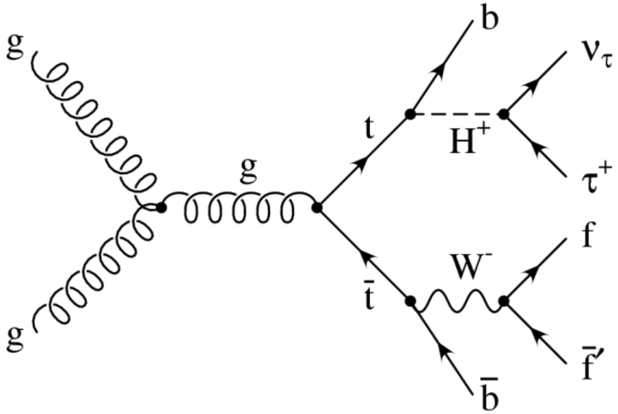
Neutral Higgs

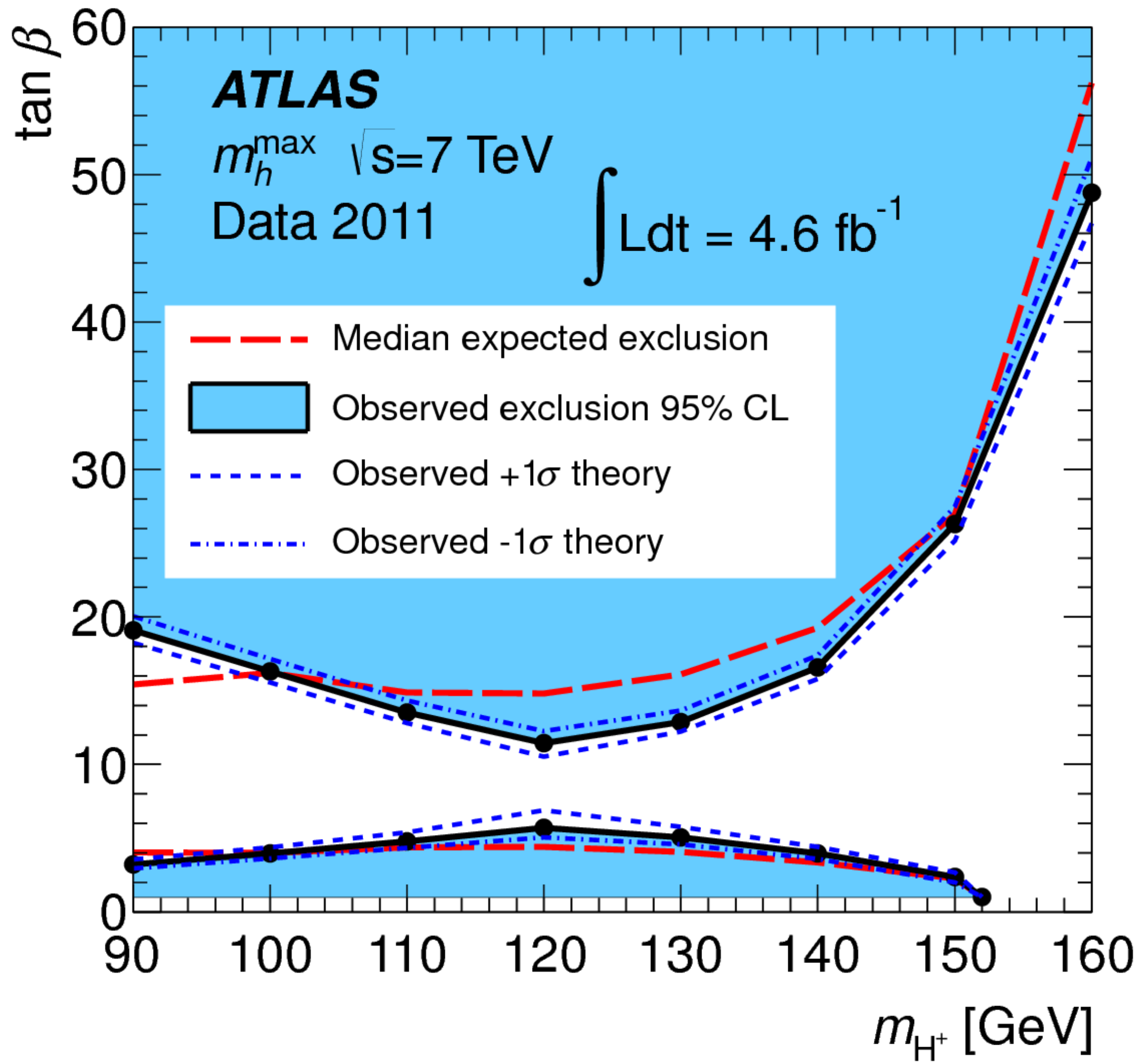




- CMS provides a wider exclusion region in (m_A, tanβ) plan by adding 8TeV.
- A low mass region is being closed in all tanβ range.

Charged Higgs



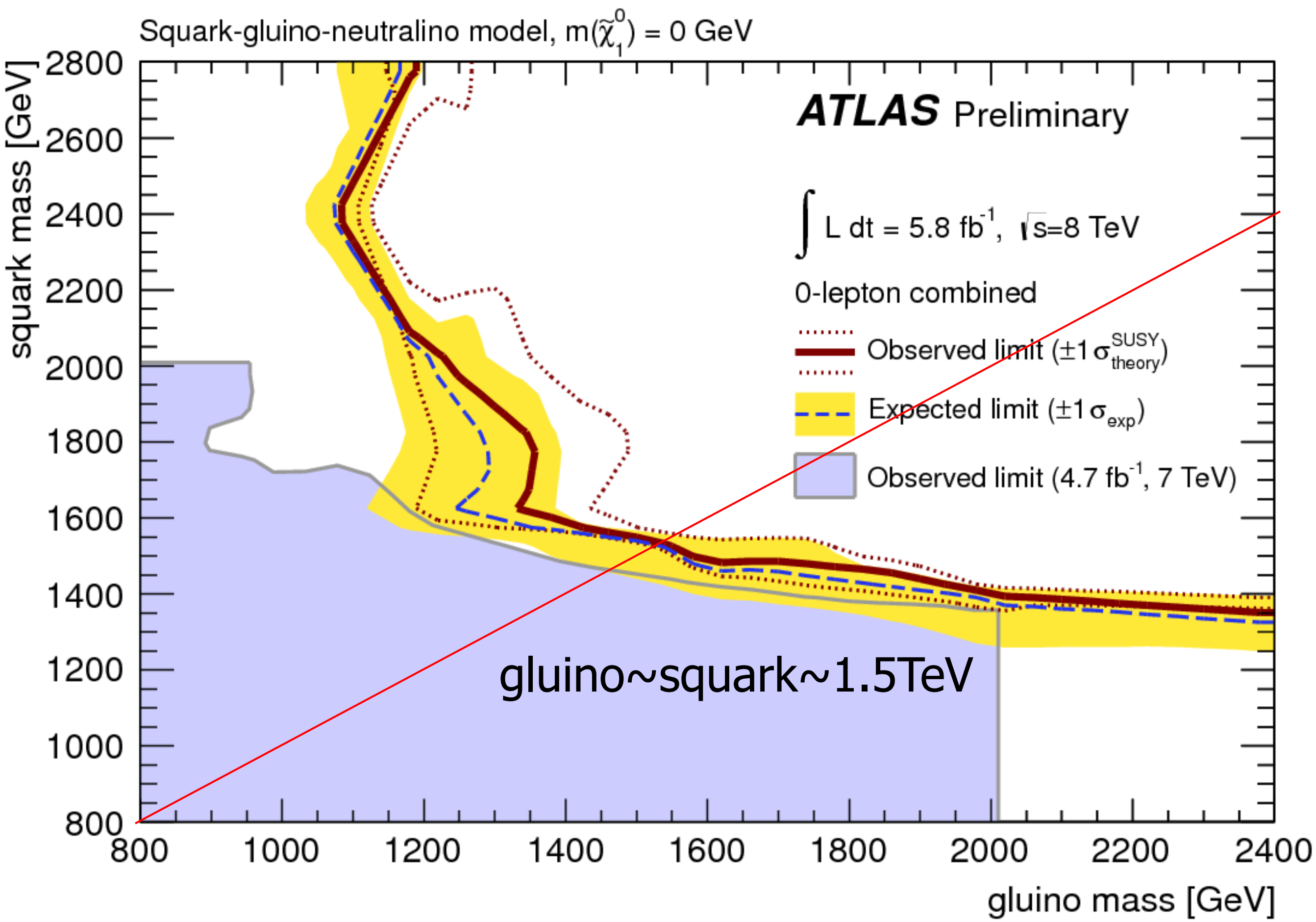


- A low mass charged Higgs search with τν and cb has been done. -> No signal so far.
- Update results with 8TeV data.
- Search for high mass changed Higgs needs to be prioritized.

SUSY and other BSM

SUSY search with Jets + MET

mSUGRA is almost gone -> "Our idea before the LHC start was too optimistic(?)". We need to re-consider what SUSY can be found at the present LHC data (8TeV).



Stop search (Natural SUSY)

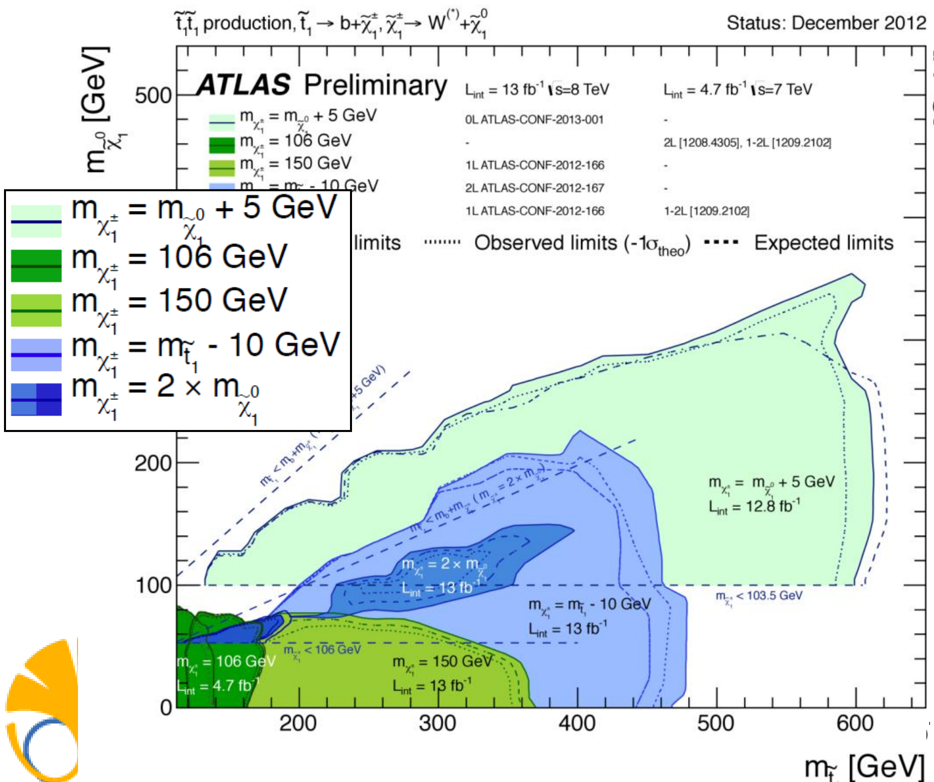
- To avoid hierarchy problems, roughly speaking "Higgs mass ~ stop mass ~ gluino mass" can be expected. ("Natural SUSY")
- HOWEVER, from LHC results a "mild" hierarchy should exist, that is,

Higgs mass < stop mass < gluion mass

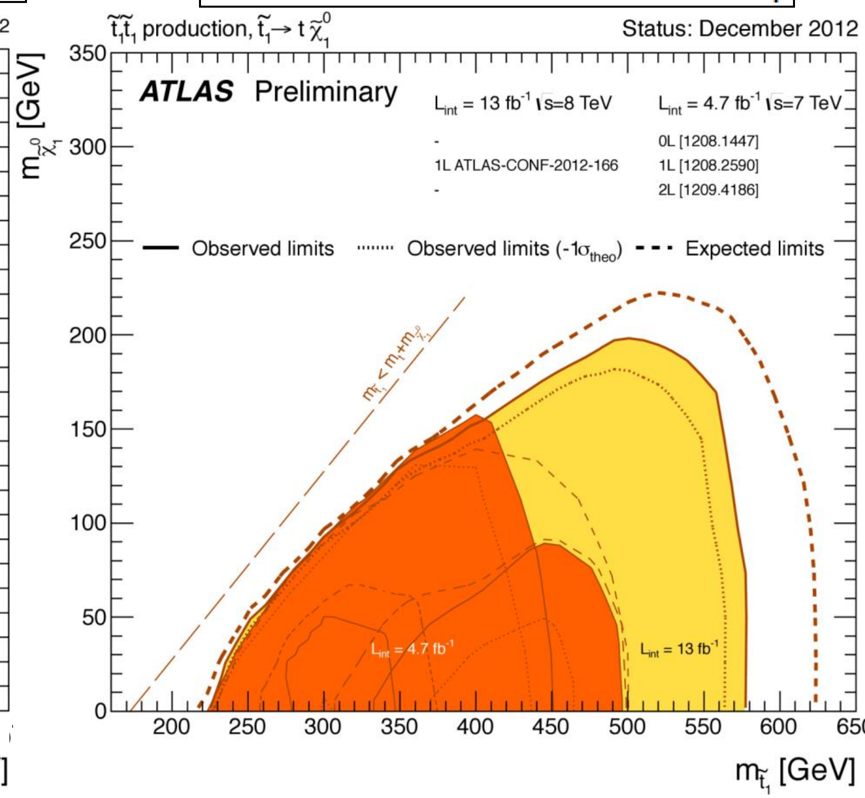
x ~3-4 x ~3-4

In this scenario, stop (<500-600GeV) could be found in LHC.

$\tilde{t}_1\tilde{t}_1$ production, $\tilde{t}_1 \rightarrow b+\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^{\pm} \rightarrow W^{(*)}+\tilde{\chi}_1^0$



$\tilde{t}_1\tilde{t}_1$ production, $\tilde{t}_1 \rightarrow t\,\tilde{\chi}_1^0$



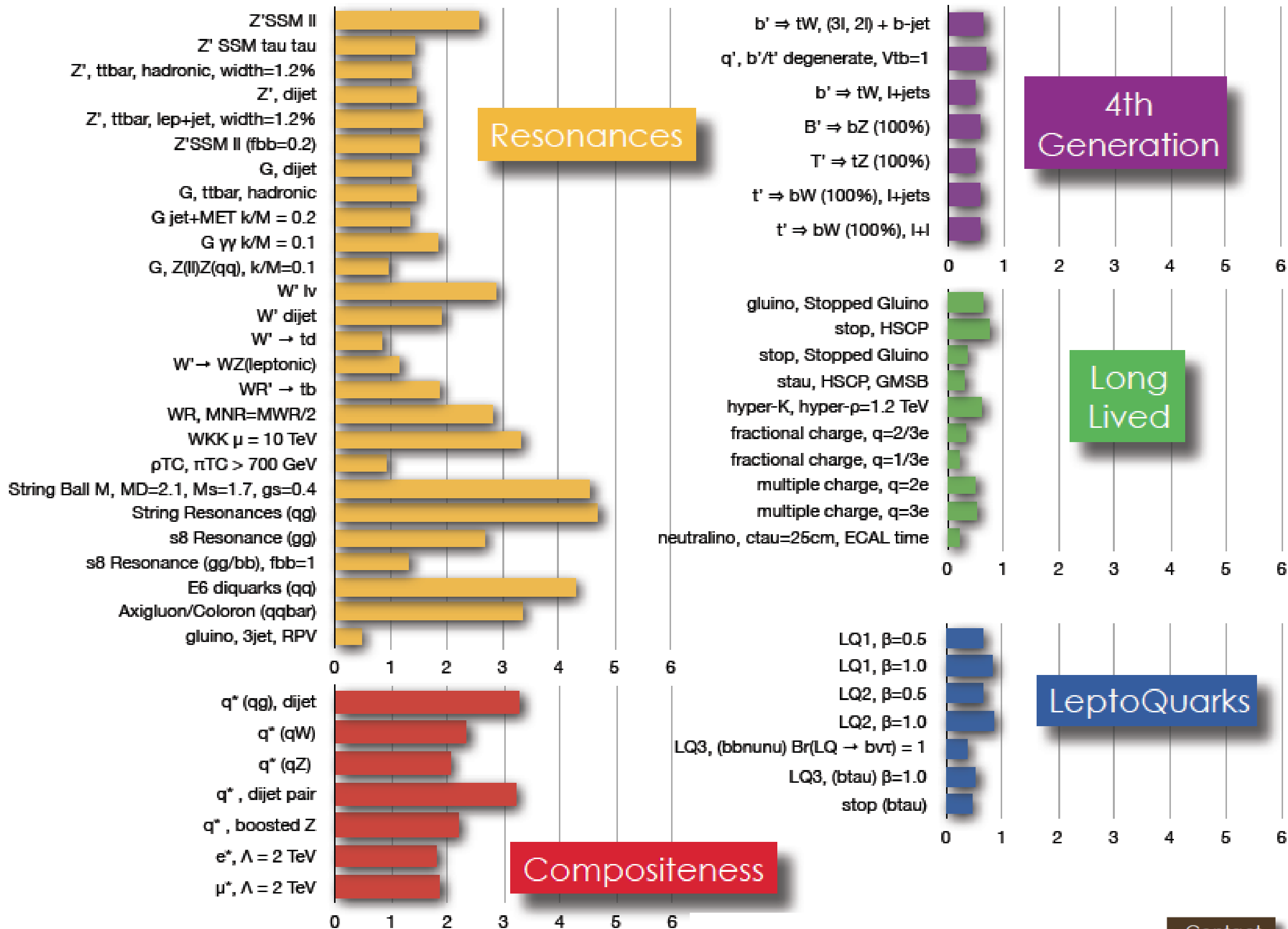
Other BSM

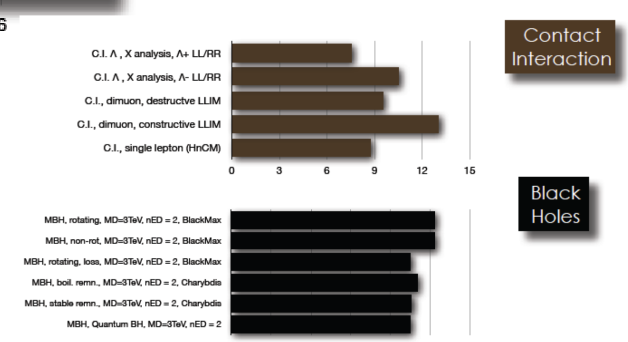
CMS results

- Many searches has been done for BSM scenario.
  - Resonances
    - Dilepon
    - Dijet
    - tt
    - VV
    - qγ/lγ

    etc
  - Enhancement (no clear resonance)
    - Dijet
    - Mono-jet
    - Multi-objects
    - Dilepton

    etc





No hint of these models
-> more data with higher energy

2015 and later

LHC schedule

Year	
2013	LHC-shutdown to go to the design energy and nominal energy (13-14TeV)
2014	
2015	**$\sqrt{s}$=13-14TeV**, ~1 x 10^{34} $cm^{-2}s^{-1}$, 25-50 fb^{-1} per year-> **~100 fb^{-1}**
2016	
2017	
2018	LHC-shutdown, upgrade to go to the full design luminosity
2019	**$\sqrt{s}$=13-14TeV**, ~2 x 10^{34} $cm^{-2}s^{-1}$, ~100 fb^{-1} per year -> **~400 fb^{-1}**
2020	
2021	
2022	LHC-shutdown for the high luminosity
2023	**$\sqrt{s}$=13-14TeV**, ~5 x 10^{34} $cm^{-2}s^{-1}$ (pileup~140) -> take data until **>3000 fb^{-1}**
~	
2030	

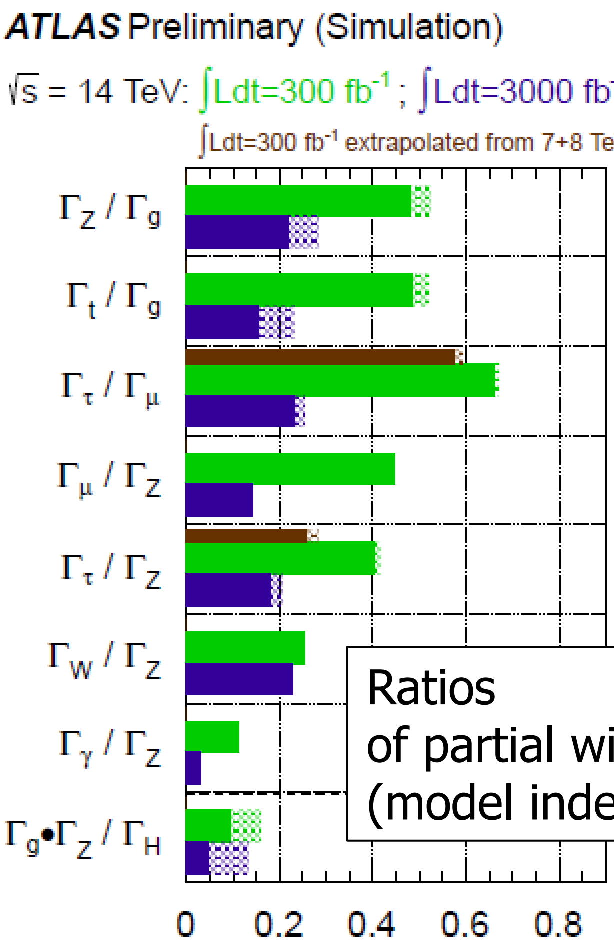
Results of 2015 will play important role for the future plans of the high energy particle physics.

HL-LHC

Not approved yet.

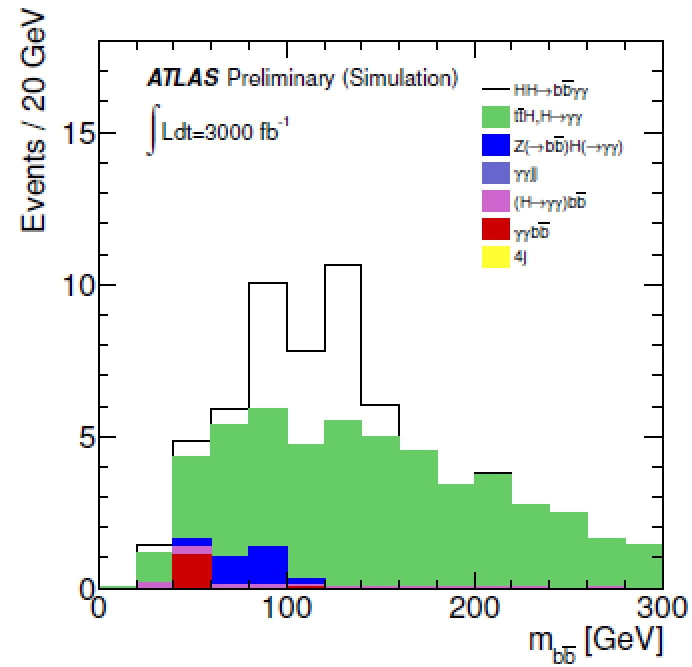
Higgs measurements

No way to measure Γ_h and absolute couplings at LHC w/o making theory assumptions.



Ratios
of partial widths
(model independent)

$$\frac{\Delta(\Gamma_X/\Gamma_Y)}{\Gamma_X/\Gamma_Y} \sim 2\frac{\Delta(\kappa_X/\kappa_Y)}{\kappa_X/\kappa_Y}$$

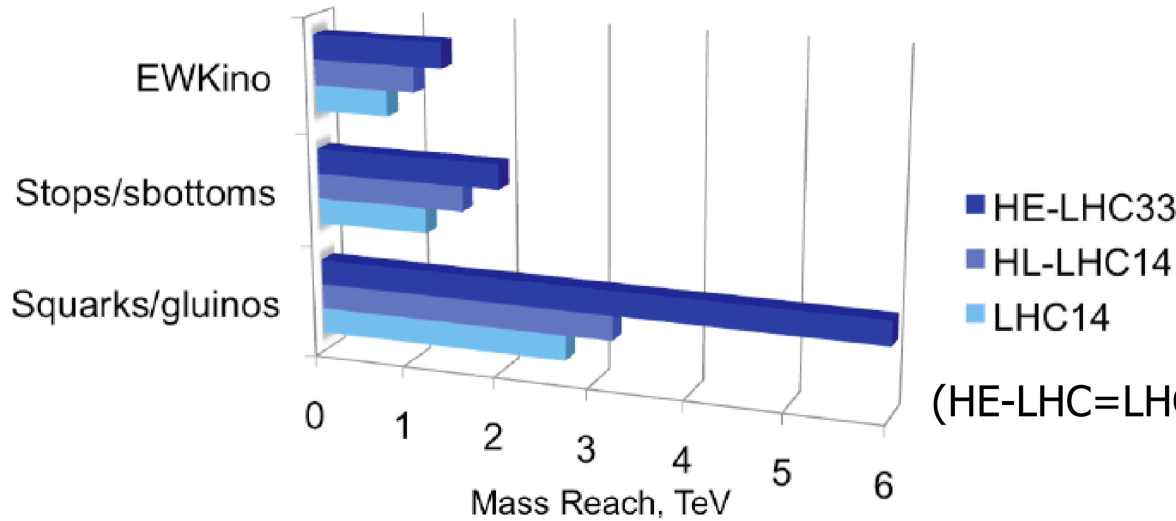


- Double higgs can be observed with bb$\gamma\gamma$ channel with ~3σ.

sample	$\sigma\times$BR (fb)
$HH \to b\bar{b}\gamma\gamma$ ($\lambda_{HHH} = 1$)	0.09
$HH \to b\bar{b}\gamma\gamma$ ($\lambda_{HHH} = 0$)	0.19
$HH \to b\bar{b}\gamma\gamma$ ($\lambda_{HHH} = 2$)	0.04

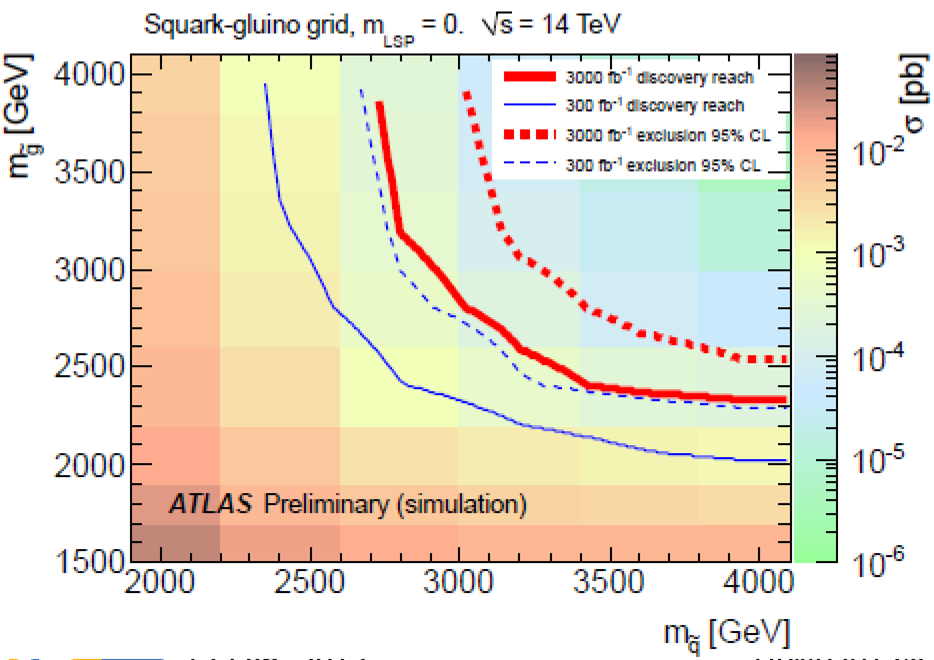
(λ_{HHH} : trilinear self-coupling)

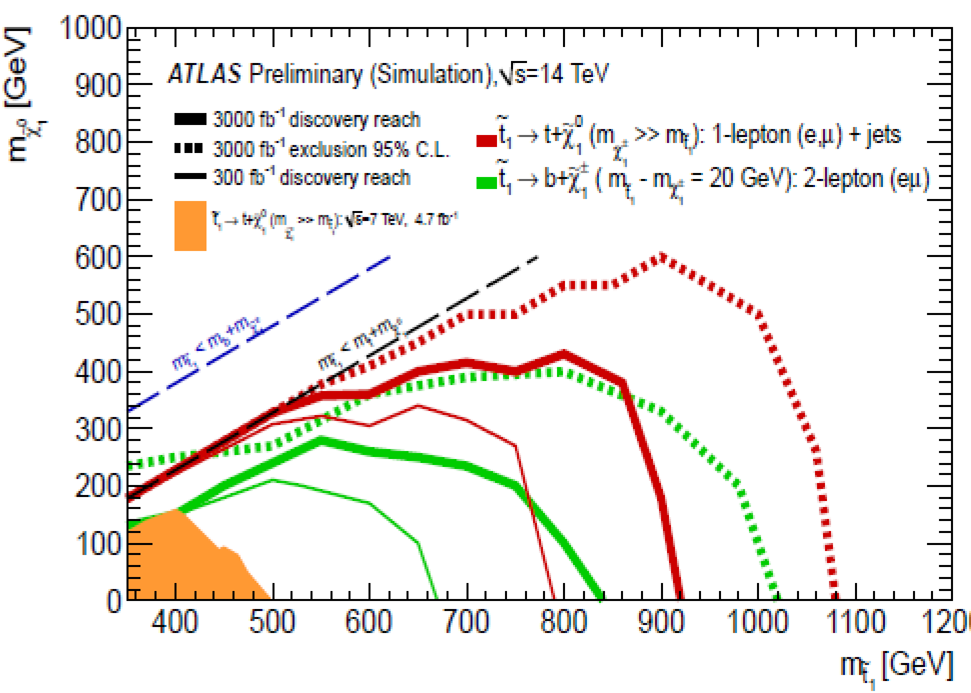
BSM direct search



- 20-30% improvement on the mass reach of many BSM models by HL-LHC.

(HE-LHC=LHC with √s=33TeV)





Summary

- LHC has finished the first run period with a great success.

- One of LHC physics goals, that is, "Higgs" discovery was achieved in 2012.
  - A new boson exists at ~126GeV.
  - A phase shift in the Higgs physics : "search" -> "measurements"
    - Couplings, spin/CP and mass
    - Need more data for the precise measurements in order to understand this new boson, in particular by using "coupling properties".

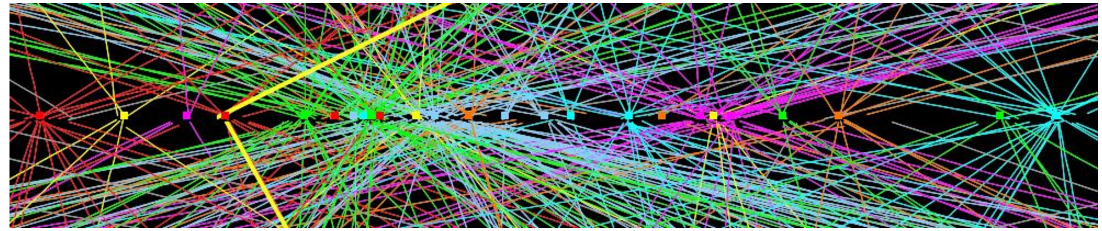
- No indication of BSM with 7/8TeV direct search
  - Adopt "new" search strategies for the existing data (7/8TeV)
  - Wait for 13/14TeV collision, which will start from 2015.

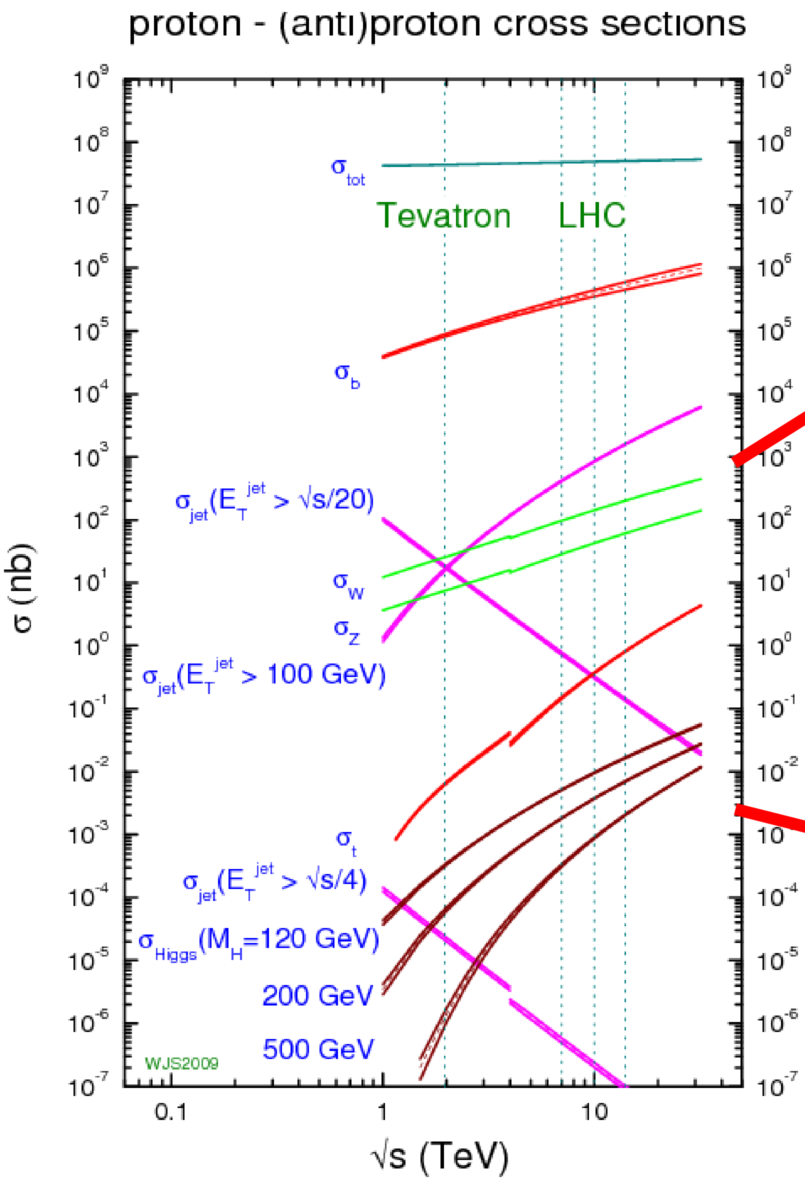
- Results from 13/14TeV collision are very important to decide what we should do for the particle physics in future.
  - HL-LHC, HE-LHC, VHE-HC, (HE-)LC etc

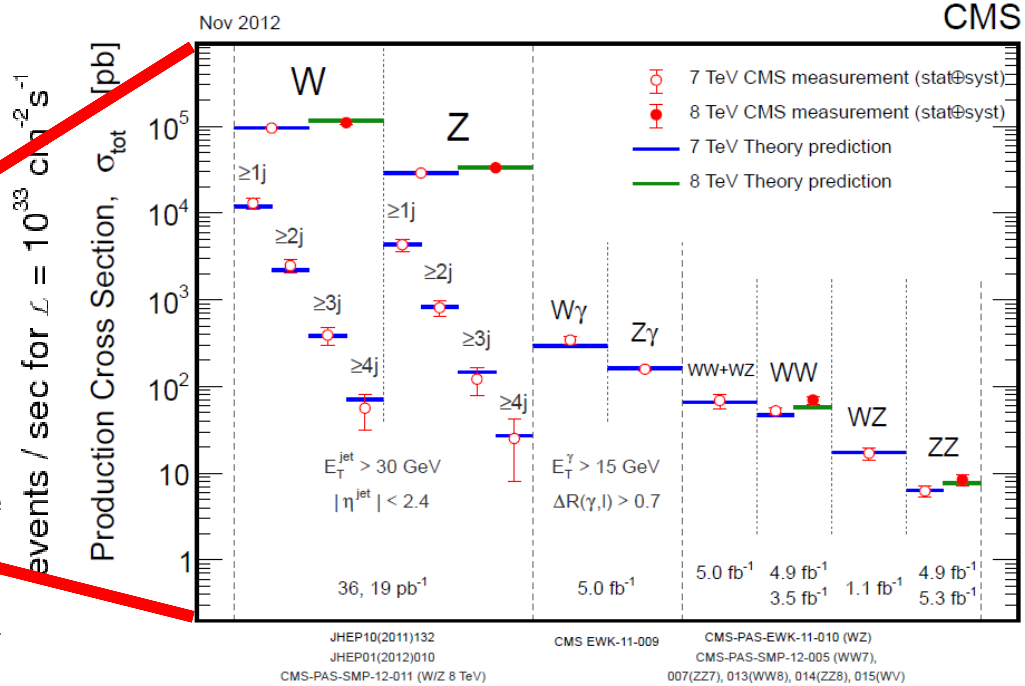
Backup materials

Challenging

Z->μμ candidate with 25 vtx

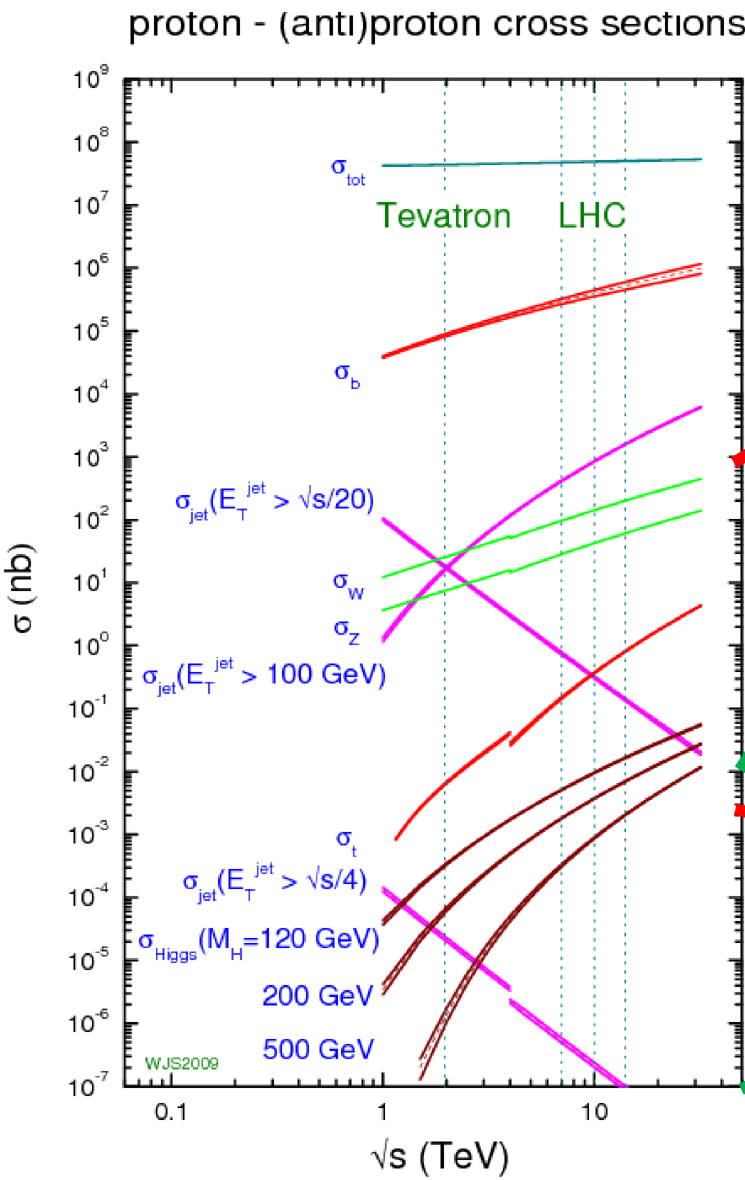




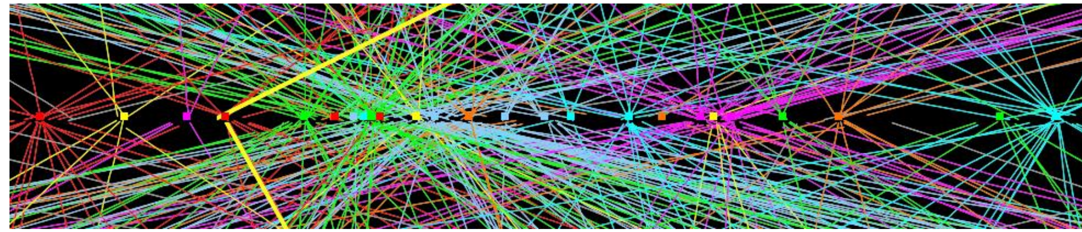


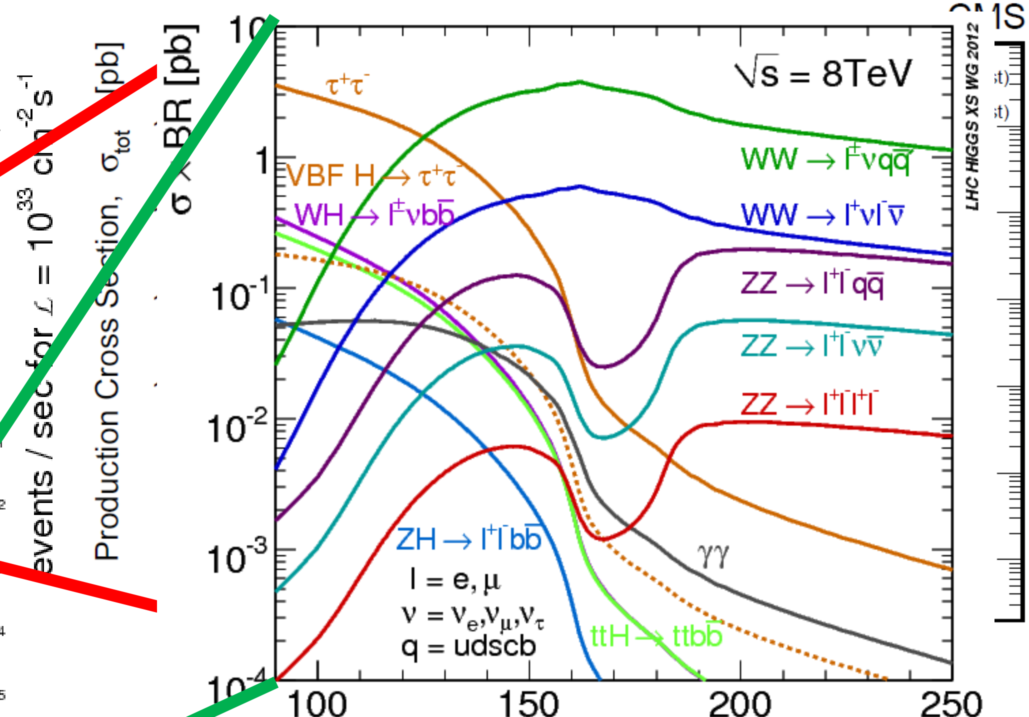
BG process for new physics search are measured very well!

Challenging



Z->μμ candidate with 25 vtx

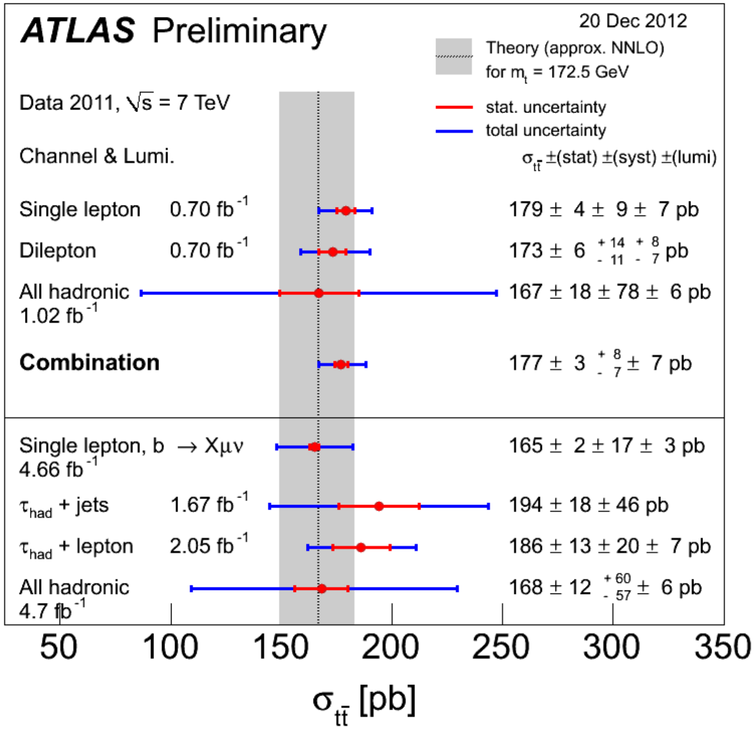


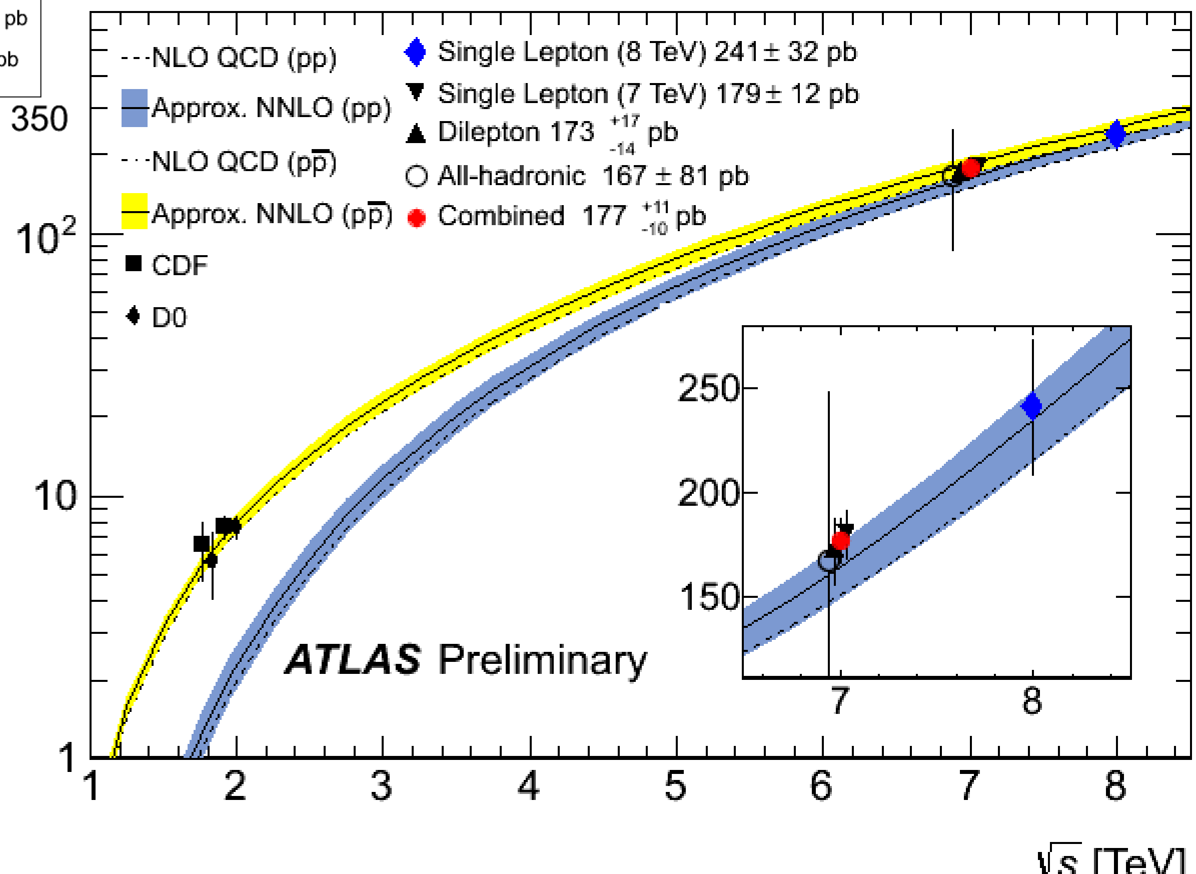


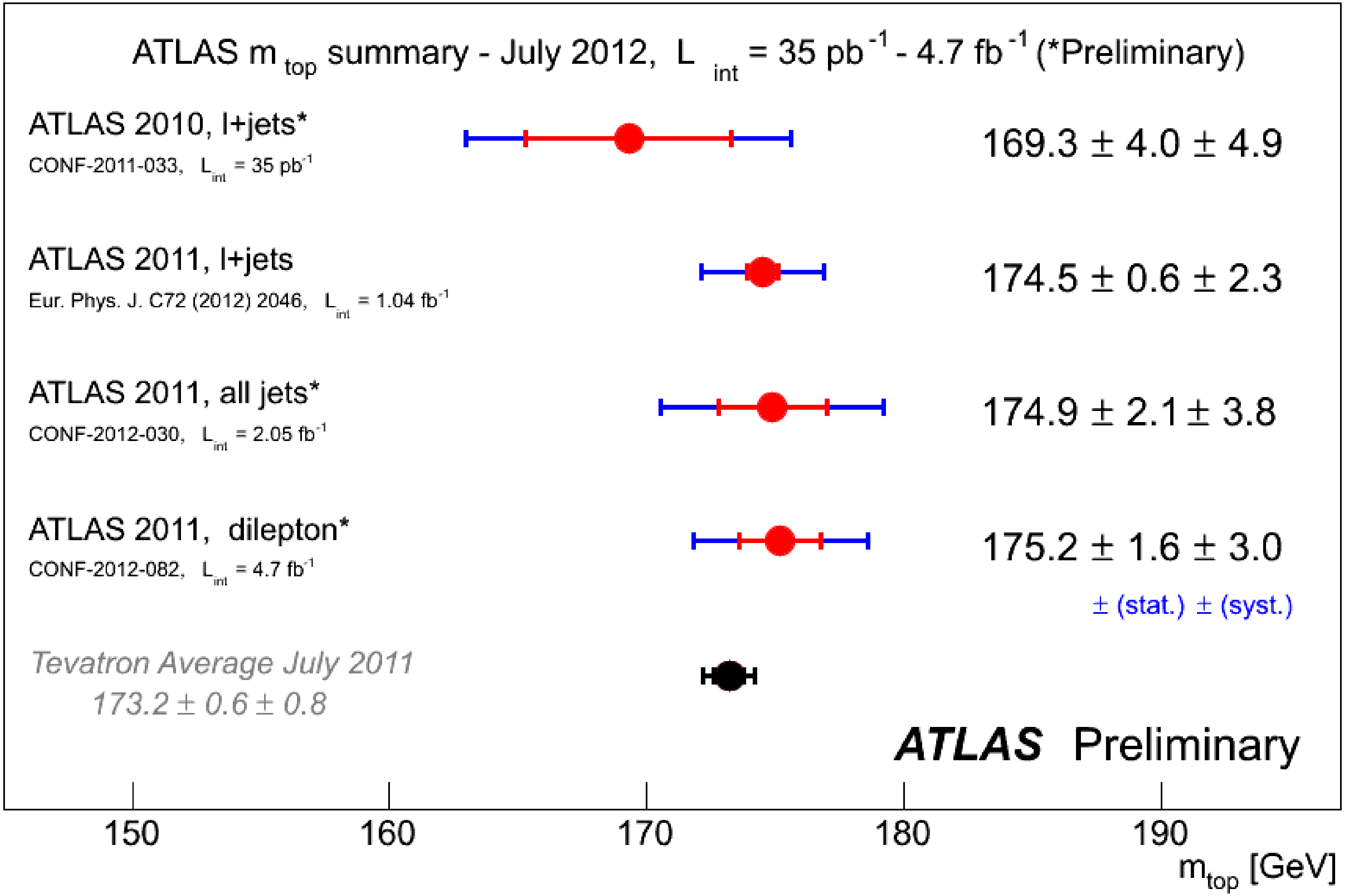
x-sec*BR ~ 10^{-11} x σ(QCD)

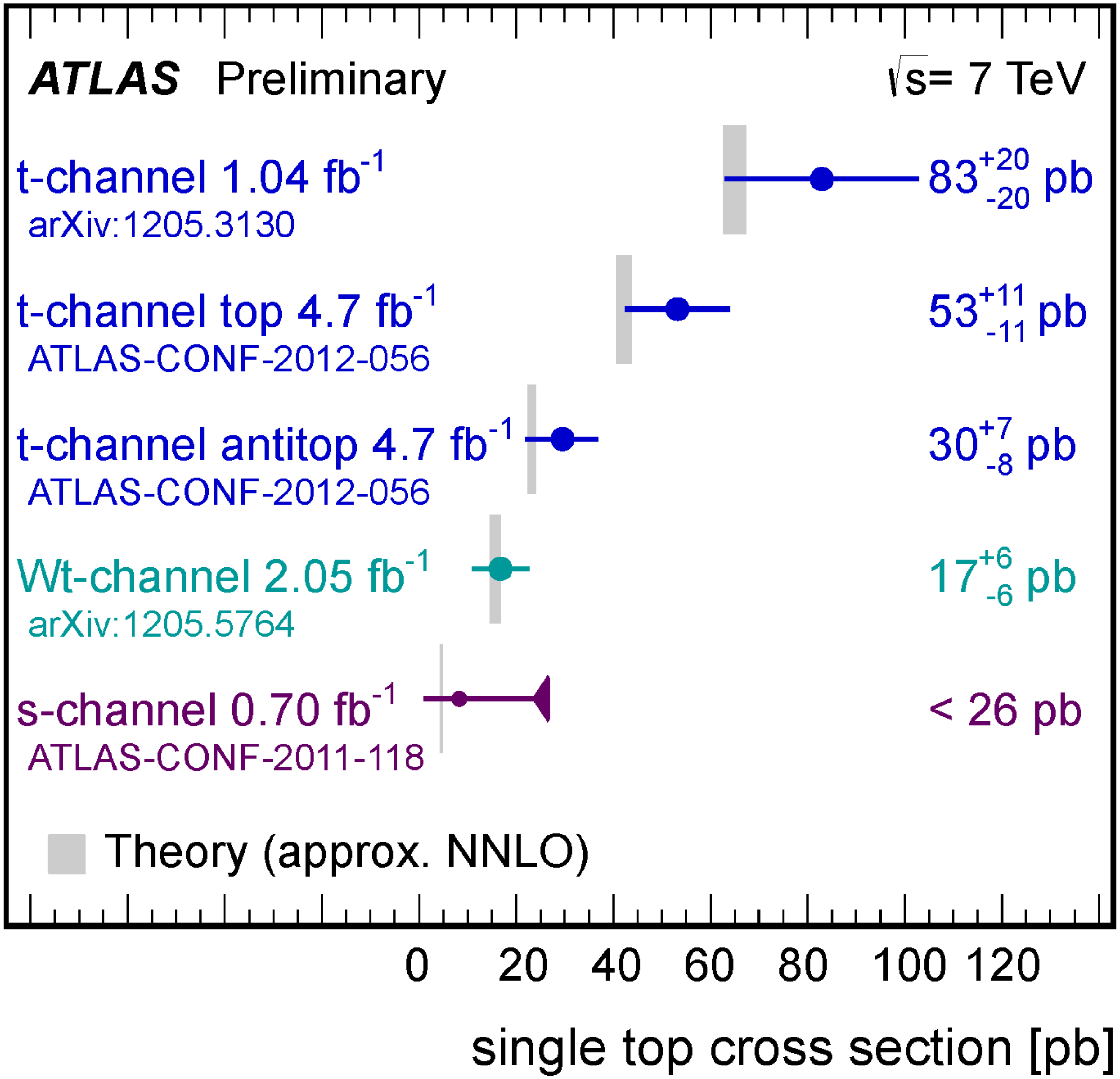
~ 10^{-5} x σ(W/Z)

Challenging to reduce BG and/or to separate signal from BG.

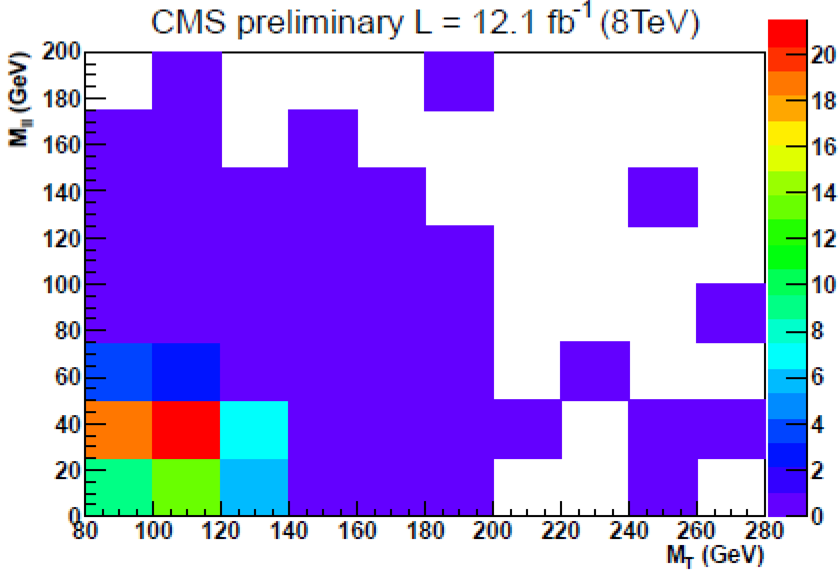

ATLAS Preliminary
20 Dec 2012
Theory (approx. NNLO) for m_t = 172.5 GeV
stat. uncertainty
total uncertainty
Data 2011, $\sqrt{s}$ = 7 TeV
Channel & Lumi.
$\sigma_{t\bar{t}}$ ±(stat) ±(syst) ±(lumi)
Single lepton 0.70 fb^{-1} 179 ± 4 ± 9 ± 7 pb
Dilepton 0.70 fb^{-1} 173 ± 6 $^{+14}_{-11}$ $^{+8}_{-7}$ pb
All hadronic 1.02 fb^{-1} 167 ± 18 ± 78 ± 6 pb
Combination 177 ± 3 $^{+8}_{-7}$ ± 7 pb
Single lepton, b → Xμν 4.66 fb^{-1} 165 ± 2 ± 17 ± 3 pb
τ_{had} + jets 1.67 fb^{-1} 194 ± 18 ± 46 pb
τ_{had} + lepton 2.05 fb^{-1} 186 ± 13 ± 20 ± 7 pb
All hadronic 4.7 fb^{-1} 168 ± 12 $^{+60}_{-57}$ ± 6 pb
50 100 150 200 250 300 350
$\sigma_{t\bar{t}}$ [pb]


NLO QCD (pp)
Approx. NNLO (pp)
NLO QCD ($p\bar{p}$)
Approx. NNLO ($p\bar{p}$)
CDF
D0
Single Lepton (8 TeV) 241± 32 pb
Single Lepton (7 TeV) 179± 12 pb
Dilepton 173 $^{+17}_{-14}$ pb
All-hadronic 167 ± 81 pb
Combined 177 $^{+11}_{-10}$ pb
ATLAS Preliminary
10^2
10
1
250
200
150
7
8
1 2 3 4 5 6 7 8
$\sqrt{s}$ [TeV]

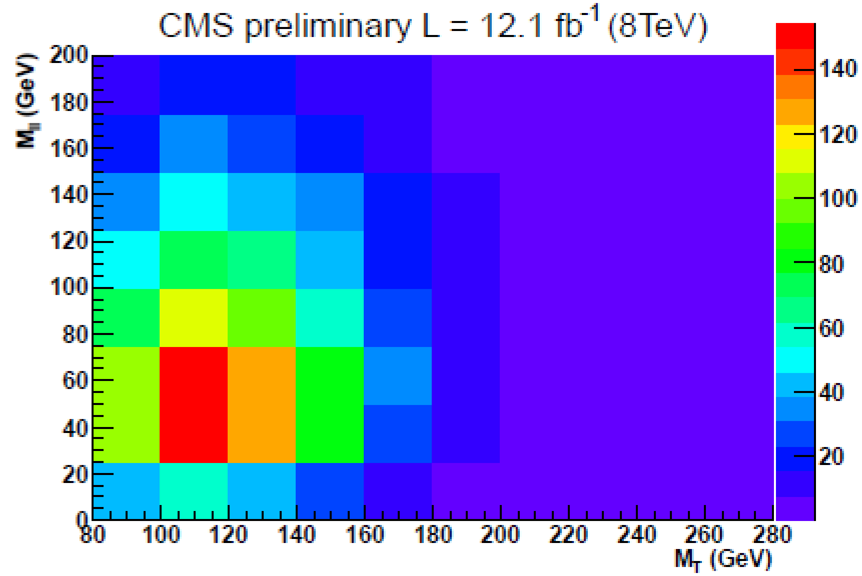

ATLAS m top summary - July 2012, L int = 35 pb -1 - 4.7 fb -1 (*Preliminary)
ATLAS 2010, l+jets*
CONF-2011-033, L int = 35 pb -1
169.3 ± 4.0 ± 4.9
ATLAS 2011, l+jets
Eur. Phys. J. C72 (2012) 2046, L int = 1.04 fb -1
174.5 ± 0.6 ± 2.3
ATLAS 2011, all jets*
CONF-2012-030, L int = 2.05 fb -1
174.9 ± 2.1 ± 3.8
ATLAS 2011, dilepton*
CONF-2012-082, L int = 4.7 fb -1
175.2 ± 1.6 ± 3.0
± (stat.) ± (syst.)
Tevatron Average July 2011
173.2 ± 0.6 ± 0.8
ATLAS Preliminary
150
160
170
180
190
m top [GeV]


ATLAS Preliminary
√s= 7 TeV
t-channel 1.04 fb-1
arXiv:1205.3130
83 +20 -20 pb
t-channel top 4.7 fb-1
ATLAS-CONF-2012-056
53 +11 -11 pb
t-channel antitop 4.7 fb-1
ATLAS-CONF-2012-056
30 +7 -8 pb
Wt-channel 2.05 fb-1
arXiv:1205.5764
17 +6 -6 pb
s-channel 0.70 fb-1
ATLAS-CONF-2011-118
< 26 pb
Theory (approx. NNLO)
0
20
40
60
80
100
120
single top cross section [pb]

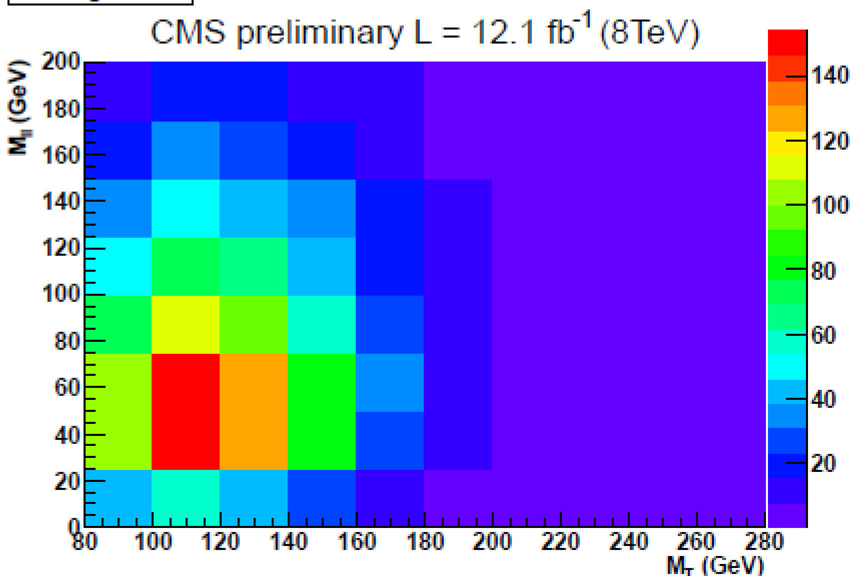
M_H = 125 GeV



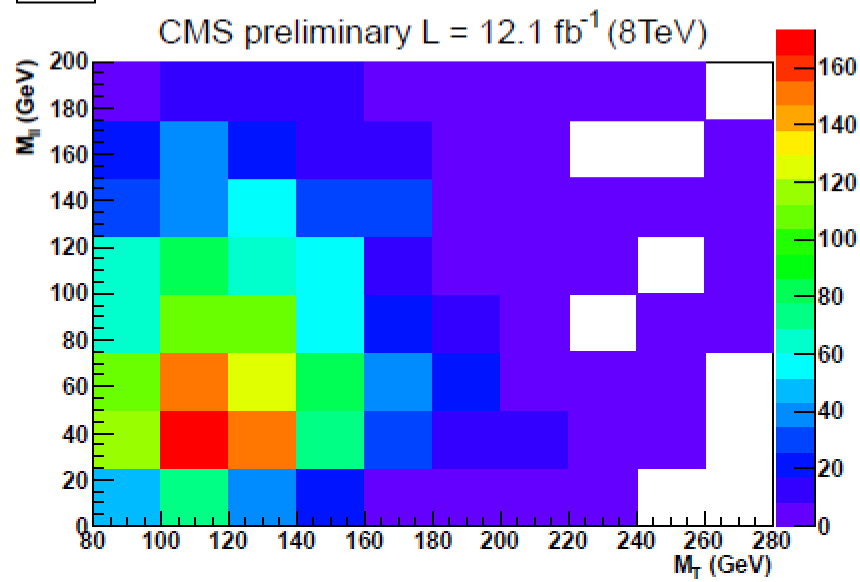
Background



Background

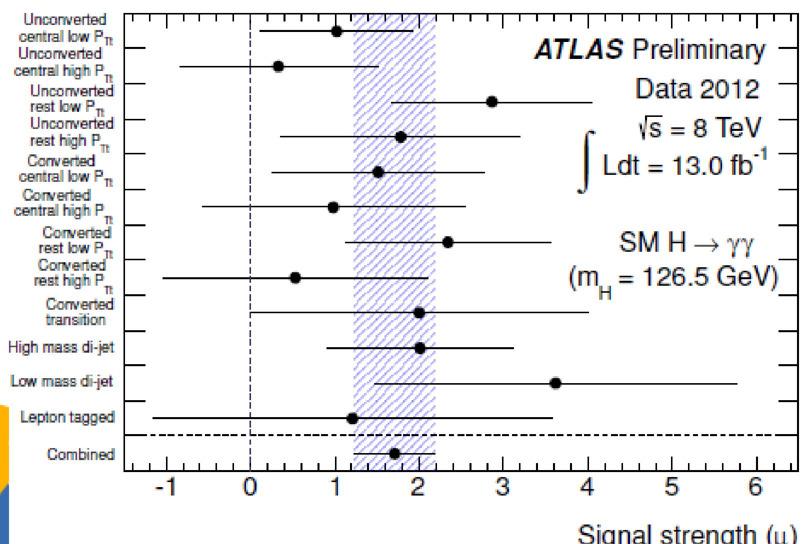


Data

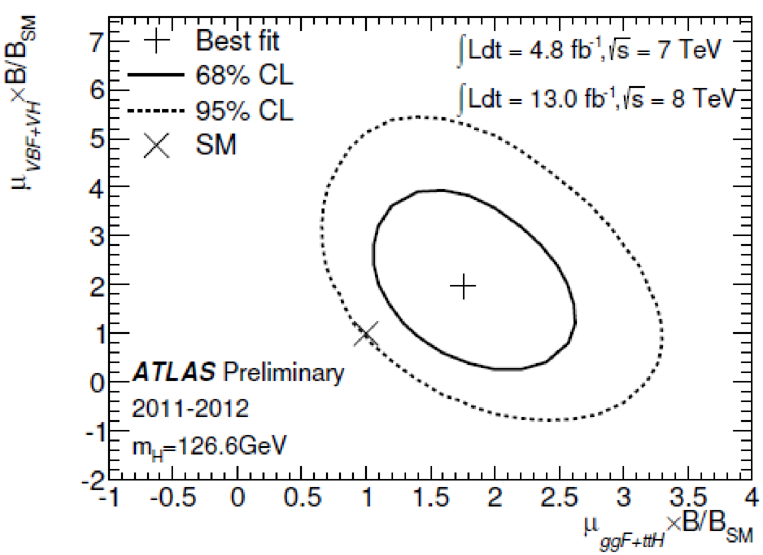


ATLAS H->γγ

$\sqrt{s}$	8 TeV					
Category	$\sigma_{CB}(GeV)$	FWHM (GeV)	Observed	N_S	N_B	N_S/N_B
Unconv. central, low p_{Tt}	1.47	3.45	569	29	538	0.053
Unconv. central, high p_{Tt}	1.37	3.22	25	4.2	25	0.168
Unconv. rest, low p_{Tt}	1.59	3.75	2773	61	2610	0.023
Unconv. rest, high p_{Tt}	1.52	3.59	148	8.7	138	0.063
Conv. central, low p_{Tt}	1.64	3.86	446	18	417	0.044
Conv. central, high p_{Tt}	1.49	3.51	18	2.8	17	0.163
Conv. rest, low p_{Tt}	1.83	4.32	2898	54	2763	0.019
Conv. rest, high p_{Tt}	1.7	4.00	144	7.4	138	0.053
Conv. transition	2.35	5.57	1872	25	1825	0.014
High Mass two-jet	1.55	3.65	47	6.8	33	0.204
Low Mass two-jet	1.46	3.45	62	4.2	45	0.093
One-lepton	1.63	3.85	18	1.7	16	0.108
Inclusive	1.64	3.87	8802	223	8284	0.027

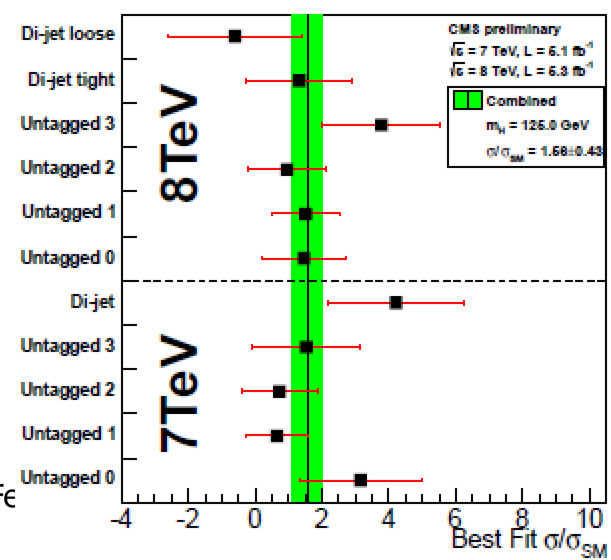


@Toya



CMS H->γγ

Expected signal and estimated background											
Event classes		SM Higgs boson expected signal (m_H=125 GeV)								Background $m_{\gamma\gamma}$ = 125 GeV (ev./GeV)	
		Total	ggH	VBF	VH	ttH	σ_{eff} (GeV)	FWHM/2.35 (GeV)			
7 TeV 5.1 fb^{-1}	Untagged 0	3.2	61%	17%	19%	3%	1.21	1.14		3.3	± 0.4
	Untagged 1	16.3	88%	6%	6%	1%	1.26	1.08		37.5	± 1.3
	Untagged 2	21.5	91%	4%	4%	–	1.59	1.32		74.8	± 1.9
	Untagged 3	32.8	91%	4%	4%	–	2.47	2.07		193.6	± 3.0
	Dijet tag	2.9	27%	73%	1%	–	1.73	1.37		1.7	± 0.2
8 TeV 5.3 fb^{-1}	Untagged 0	6.1	68%	12%	16%	4%	1.38	1.23		7.4	± 0.6
	Untagged 1	21.0	88%	6%	6%	1%	1.53	1.31		54.7	± 1.5
	Untagged 2	30.2	92%	4%	3%	–	1.94	1.55		115.2	± 2.3
	Untagged 3	40.0	92%	4%	4%	–	2.86	2.35		256.5	± 3.4
	Dijet tight	2.6	23%	77%	–	–	2.06	1.57		1.3	± 0.2
	Dijet loose	3.0	53%	45%	2%	–	1.95	1.48		3.7	± 0.4



ATLAS H->ZZ->4l

- The number of remaining events in 120<m(4l)<130GeV

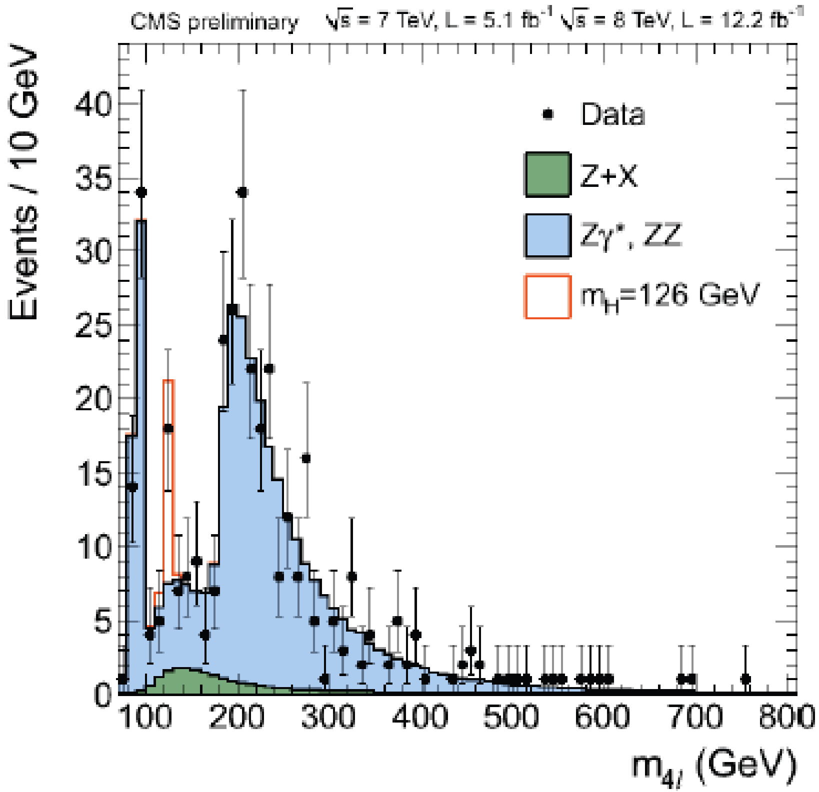
	Signal (m_H=125 GeV)	$ZZ^{(*)}$	$Z+$jets, $t\bar{t}$	Observed
$\sqrt{s}=8$ TeV				
4μ	3.1 ± 0.4	1.55 ± 0.07	0.31 ± 0.09	6
$2\mu 2e$	1.4 ± 0.2	0.56 ± 0.04	0.78 ± 0.16	1
$2e2\mu$	1.9 ± 0.3	0.80 ± 0.04	0.26 ± 0.07	3
$4e$	1.5 ± 0.2	0.77 ± 0.08	1.20 ± 0.19	4
total	7.9 ± 1.1	3.7 ± 0.2	2.6 ± 0.3	14
$\sqrt{s}=7$ TeV				
4μ	0.88 ± 0.11	0.48 ± 0.02	0.05 ± 0.02	2
$2\mu 2e$	0.32 ± 0.05	0.14 ± 0.01	0.43 ± 0.09	1
$2e2\mu$	0.48 ± 0.06	0.22 ± 0.01	0.04 ± 0.02	1
$4e$	0.28 ± 0.04	0.17 ± 0.02	0.52 ± 0.13	0
total	2.0 ± 0.3	1.0 ± 0.1	1.0 ± 0.2	4
$\sqrt{s}=8$ TeV and $\sqrt{s}=7$ TeV				
4μ	4.0 ± 0.5	2.03 ± 0.09	0.36 ± 0.09	8
$2\mu 2e$	1.7 ± 0.2	0.70 ± 0.05	1.21 ± 0.18	2
$2e2\mu$	2.4 ± 0.3	1.02 ± 0.05	0.30 ± 0.07	4
$4e$	1.8 ± 0.3	0.94 ± 0.09	1.72 ± 0.23	4
total	9.9 ± 1.3	4.7 ± 0.3	3.6 ± 0.3	18

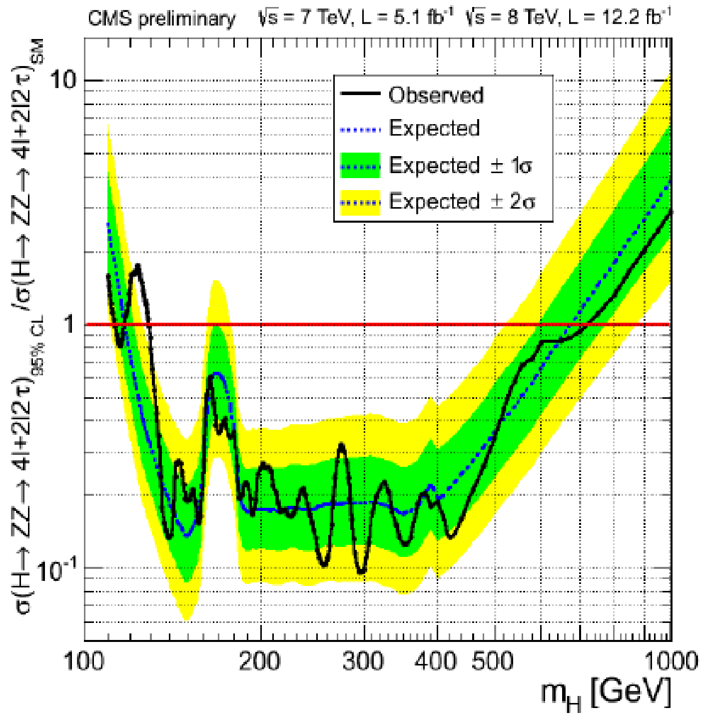
CMS H->ZZ->4l

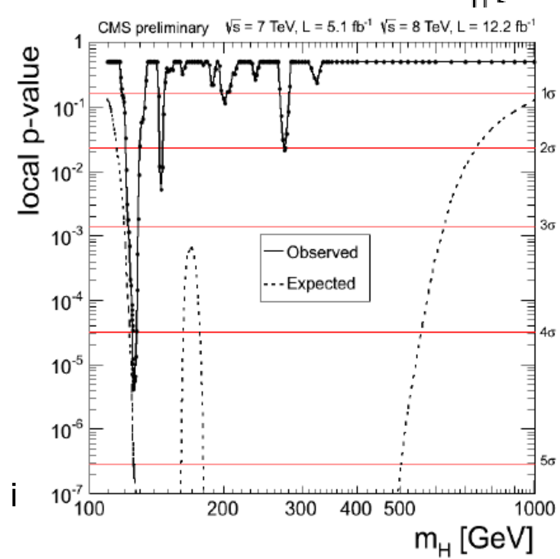
- The number of remaining events in 110<m(4l)<160GeV

Channel	4e	4μ	$2e2\mu$	4ℓ
ZZ background	4.7 ± 0.6	9.6 ± 1.0	12.5 ± 1.4	26.8 ± 1.8
Z+ X	$3.4^{+3.0}_{-2.3}$	$1.6^{+1.2}_{-0.9}$	$5.6^{+5.4}_{-3.6}$	$10.6^{+5.3}_{-4.4}$
All backgrounds	$8.0^{+3.1}_{-2.3}$	$11.2^{+1.6}_{-1.4}$	$18.1^{+5.6}_{-3.8}$	$37.3^{+6.6}_{-4.7}$
m_H = 125 GeV	2.4 ± 0.4	4.6 ± 0.5	5.9 ± 0.7	12.9 ± 0.9
m_H = 126 GeV	2.7 ± 0.4	5.1 ± 0.6	6.6 ± 0.8	14.4 ± 1.1
Observed	12	16	19	47

M(4l), High mass region







ATLAS H->WW->lnln

Cutflow evolution in the different signal regions

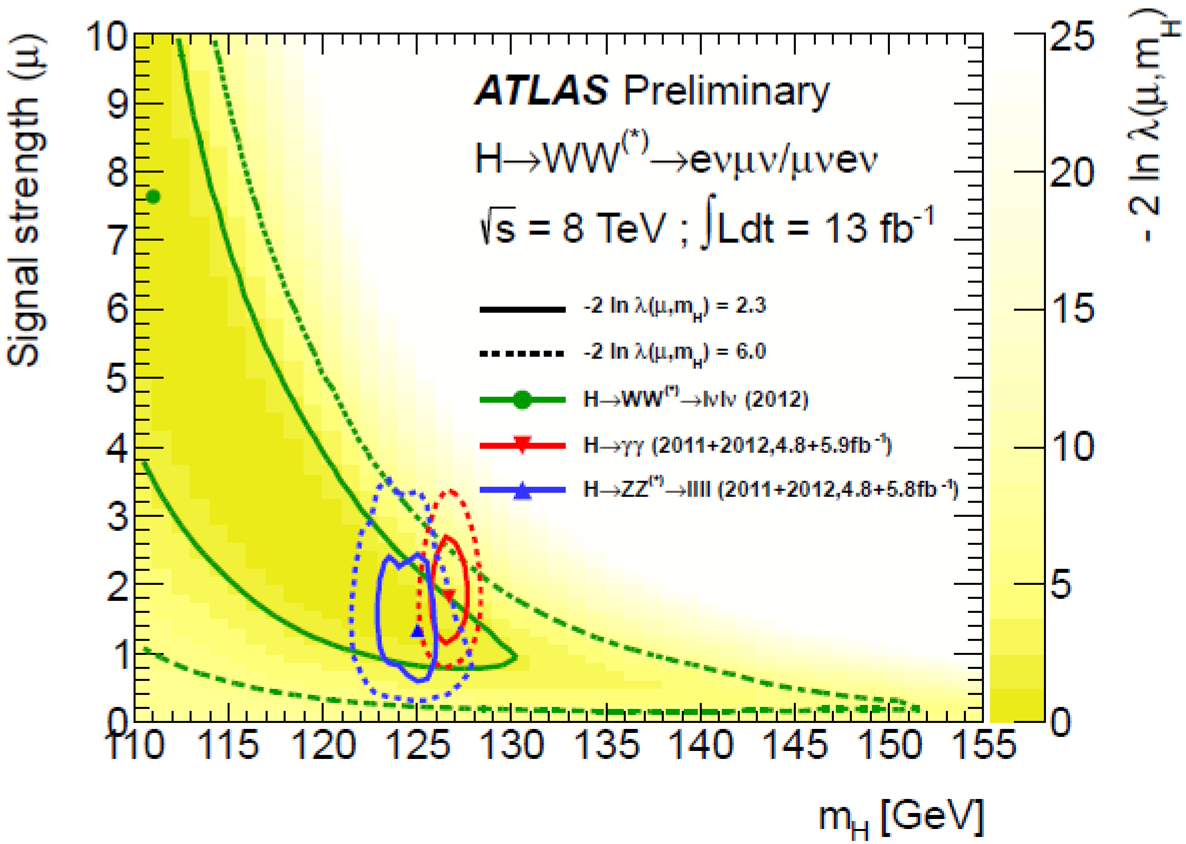
$H+0$-jet	Signal	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	$tW/tb/tqb$	Z/γ^* + jets	W + jets	Total Bkg.	Obs.
Jet veto	110 ± 1	3004 ± 12	242 ± 8	387 ± 8	215 ± 8	1575 ± 20	340 ± 5	5762 ± 28	5960
$\Delta\phi_{\ell\ell,E_T^{miss}} > \pi/2$	108 ± 1	2941 ± 12	232 ± 8	361 ± 8	206 ± 8	1201 ± 21	305 ± 5	5246 ± 28	5230
$p_{T,\ell\ell} > 30$ GeV	99 ± 1	2442 ± 11	188 ± 7	330 ± 7	193 ± 8	57 ± 8	222 ± 3	3433 ± 19	3630
$m_{\ell\ell} < 50$ GeV	78.6 ± 0.8	579 ± 5	69 ± 4	55 ± 3	34 ± 3	11 ± 4	65 ± 2	814 ± 9	947
$\Delta\phi_{\ell\ell} < 1.8$	75.6 ± 0.8	555 ± 5	68 ± 4	54 ± 3	34 ± 3	8 ± 4	56 ± 2	774 ± 9	917
$H+1$-jet	Signal	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	$tW/tb/tqb$	Z/γ^* + jets	W + jets	Total Bkg.	Obs.
One jet	59.5 ± 0.8	850 ± 5	158 ± 7	3451 ± 24	1037 ± 17	505 ± 9	155 ± 5	6155 ± 33	6264
b-jet veto	50.4 ± 0.7	728 ± 5	128 ± 5	862 ± 13	283 ± 10	429 ± 8	126 ± 4	2555 ± 20	2655
$Z \to \tau\tau$ veto	50.1 ± 0.7	708 ± 5	122 ± 5	823 ± 12	268 ± 9	368 ± 8	122 ± 4	2411 ± 19	2511
$m_{\ell\ell} < 50$ GeV	37.7 ± 0.6	130 ± 2	39 ± 2	142 ± 5	55 ± 4	99 ± 3	30 ± 2	495 ± 8	548
$\Delta\phi_{\ell\ell} < 1.8$	34.9 ± 0.6	118 ± 2	35 ± 2	134 ± 5	52 ± 4	22 ± 2	24 ± 1	386 ± 8	433

Signal region yield for $e\mu$ and μe channels separately

	0-jet $e\mu$	0-jet μe	1-jet $e\mu$	1-jet μe
Total bkg.	392 ± 7	382 ± 6	202 ± 6	184 ± 5
Signal	41.8 ± 0.6	33.8 ± 0.5	18.9 ± 0.4	16.0 ± 0.4
Observed	469	448	226	207

Source (0-jet)	Signal (%)	Bkg. (%)
Inclusive ggF signal ren./fact. scale	13	-
1-jet incl. ggF signal ren./fact. scale	10	-
PDF model (signal only)	8	-
QCD scale (acceptance)	4	-
Jet energy scale and resolution	4	2
W+jets fake factor	-	5
WW theoretical model	-	5
Source (1-jet)	Signal (%)	Bkg. (%)
1-jet incl. ggF signal ren./fact. scale	26	-
2-jet incl. ggF signal ren./fact. scale	15	-
Parton shower/ U.E. model (signal only)	10	-
b-tagging efficiency	-	11
PDF model (signal only)	7	-
QCD scale (acceptance)	4	2
Jet energy scale and resolution	1	3
W+jets fake factor	-	5
WW theoretical model	-	3

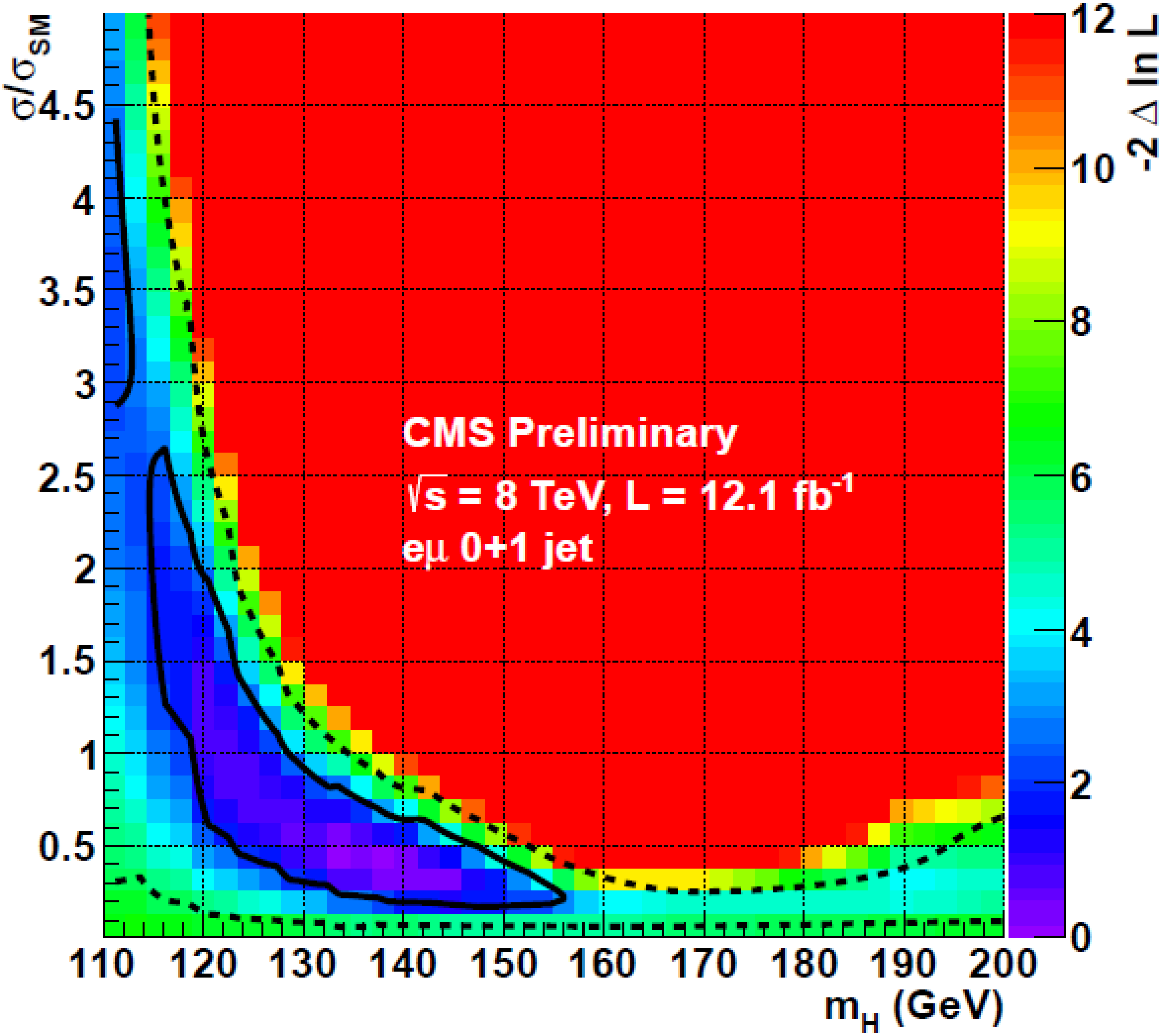
ATLAS H->WW->lnln



CMS H->WW->lnln

m_H	H $\to W^+W^-$	pp $\to W^+W^-$	WZ + ZZ $+Z/\gamma^* \to \ell^+\ell^-$	Top	W + jets	$W\gamma^{(*)}$	all bkg.	data
0-jet category $e\mu$ final state								
120	34.0 ± 7.3	162 ± 16	5.3 ± 0.5	8.6 ± 2.0	38 ± 14	23.1 ± 8.8	237 ± 23	285
125	58 ± 12	203 ± 19	6.6 ± 0.6	11.0 ± 2.5	44 ± 16	25.6 ± 9.5	291 ± 27	349
0-jet category $ee/\mu\mu$ final state								
120	20.8 ± 4.5	108 ± 10	48 ± 14	3.9 ± 1.1	24.5 ± 9.3	5.8 ± 2.5	191 ± 20	209
125	37.0 ± 8.0	140 ± 13	59 ± 18	5.2 ± 1.3	30 ± 11	6.7 ± 2.8	241 ± 25	266
1-jet category $e\mu$ final state								
120	14.9 ± 4.3	38.9 ± 6.4	5.3 ± 0.6	40.3 ± 3.0	19.1 ± 7.4	7.1 ± 3.4	111 ± 11	123
125	27.3 ± 8.0	47.9 ± 7.8	6.5 ± 0.7	49.5 ± 3.3	22.4 ± 8.6	7.1 ± 3.4	134 ± 13	160
1-jet category $ee/\mu\mu$ final state								
120	6.5 ± 1.9	19.2 ± 3.2	11.5 ± 3.0	20.6 ± 2.0	6.1 ± 2.6	2.0 ± 1.2	59.5 ± 5.6	77
125	11.8 ± 3.4	24.8 ± 4.1	13.1 ± 3.5	26.7 ± 2.3	6.5 ± 2.8	2.0 ± 1.2	73.0 ± 6.6	92
2-jet category $e\mu$ final state								
120	1.7 ± 0.2	0.8 ± 0.5	0.1 ± 0.0	0.9 ± 0.3	0.3 ± 0.2	0.1 ± 0.1	2.2 ± 0.6	2
125	2.8 ± 0.4	0.9 ± 0.5	0.1 ± 0.0	1.5 ± 0.5	0.3 ± 0.2	0.1 ± 0.1	2.9 ± 0.8	2
2-jet category $ee/\mu\mu$ final state								
120	1.0 ± 0.1	0.5 ± 0.3	3.2 ± 1.5	0.7 ± 0.2	0.8 ± 0.5	0.1 ± 0.1	5.2 ± 1.7	9
125	1.5 ± 0.2	0.5 ± 0.3	4.4 ± 1.3	0.7 ± 0.2	0.8 ± 0.5	0.1 ± 0.1	6.5 ± 1.5	11

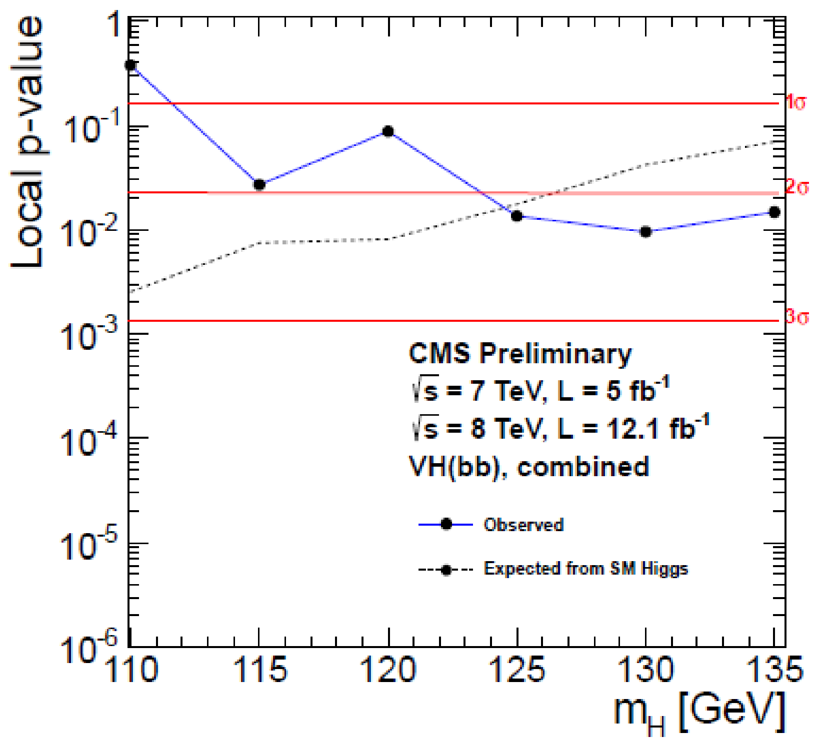
CMS H->WW->lnln

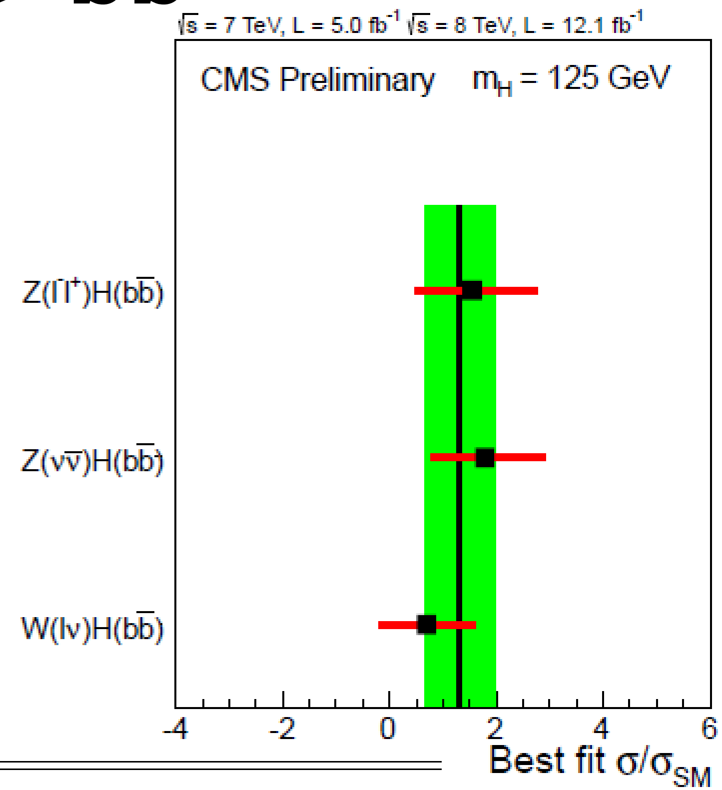

CMS Preliminary
√s = 8 TeV, L = 12.1 fb-1
eμ 0+1 jet
σ/σSM
4.5
4
3.5
3
2.5
2
1.5
1
0.5
110
120
130
140
150
160
170
180
190
200
mH (GeV)
-2 Δ ln L
12
10
8
6
4
2
0

ATLAS H->bb

	0-lepton, 2 jet			0-lepton, 3 jet			1-lepton					2-lepton				
Bin	E_T^{miss} [GeV]						p_T^W [GeV]					p_T^Z [GeV]				
	120-160	160-200	>200	120-160	160-200	>200	0-50	50-100	100-150	150-200	> 200	0-50	50-100	100-150	150-200	>200
ZH	2.9	2.1	2.6	0.8	0.8	1.1	0.3	0.4	0.1	0.0	0.0	4.7	6.8	4.0	1.5	1.4
WH	0.8	0.4	0.4	0.2	0.2	0.2	10.6	12.9	7.5	3.6	3.6	0.0	0.0	0.0	0.0	0.0
Top	89	25	8	92	25	10	1440	2276	1120	147	43	230	310	84	3	0
$W + c$,light	30	10	5	9	3	2	580	585	209	36	17	0	0	0	0	0
$W + b$	35	13	13	8	3	2	770	778	288	77	64	0	0	0	0	0
$Z + c$,light	35	14	14	8	5	8	17	17	4	1	0	201	230	91	12	15
$Z + b$	144	51	43	41	22	16	50	63	13	5	1	1010	1180	469	75	51
Diboson	23	11	10	4	4	3	53	59	23	13	7	37	39	16	6	4
Multijet	3	1	1	1	1	0	890	522	68	14	3	12	3	0	0	0
Total Bkg.	361	127	98	164	63	42	3810	4310	1730	297	138	1500	1770	665	97	72
	± 29	± 11	± 12	± 13	± 8	± 5	± 150	± 86	± 90	± 27	± 14	± 90	± 110	± 47	± 12	± 12
Data	342	131	90	175	65	32	3821	4301	1697	297	132	1485	1773	657	100	69

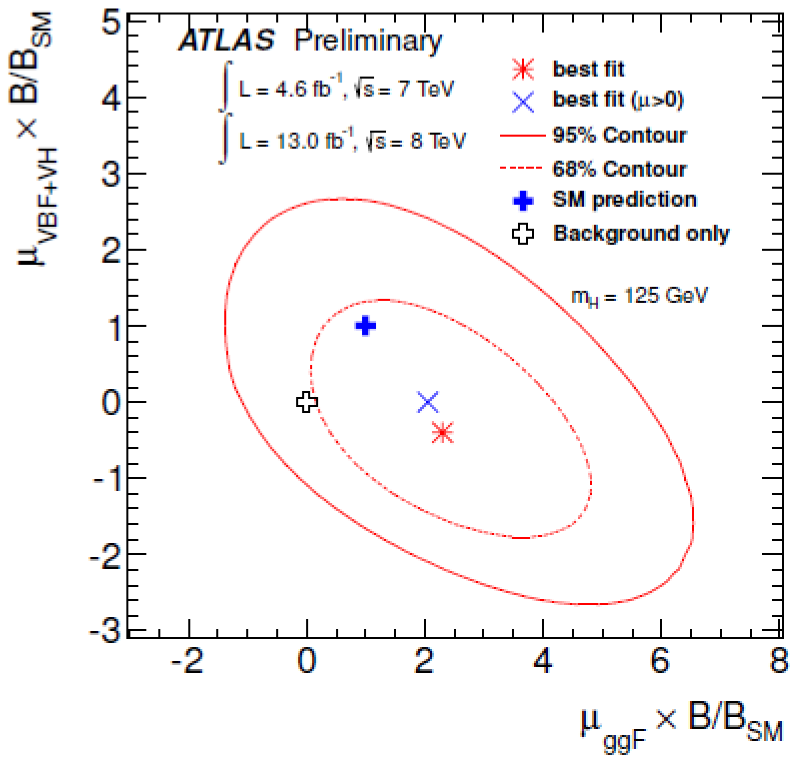
CMS H->bb





Variable
p_{Tj}: transverse momentum of each Higgs daughter
$m(jj)$: dijet invariant mass
$p_T(jj)$: dijet transverse momentum
$p_T(V)$: vector boson transverse momentum (or E_T^{miss})
CSV_{max}: value of CSV for the Higgs daughter with largest CSV value
CSV_{min}: value of CSV for the Higgs daughter with second largest CSV value
$\Delta\phi(V,H)$: azimuthal angle between V (or E_T^{miss}) and dijet
$\lvert\Delta\eta(jj)\rvert$: difference in η between Higgs daughters
$\Delta R(jj)$: distance in η–ϕ between Higgs daughters
N_{aj}: number of additional jets
$\Delta\phi(E_T^{miss}, jet)$: azimuthal angle between E_T^{miss} and the closest jet (only for $Z(\nu\nu)H$)
$\Delta\theta_{pull}$: color pull angle [35]

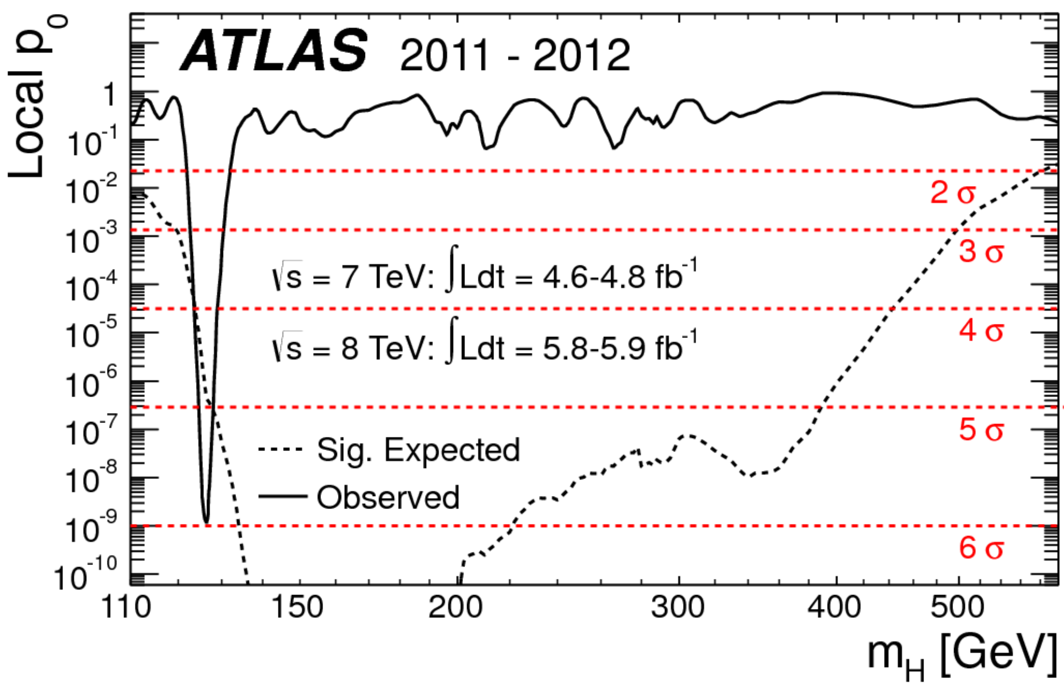
H->ττ



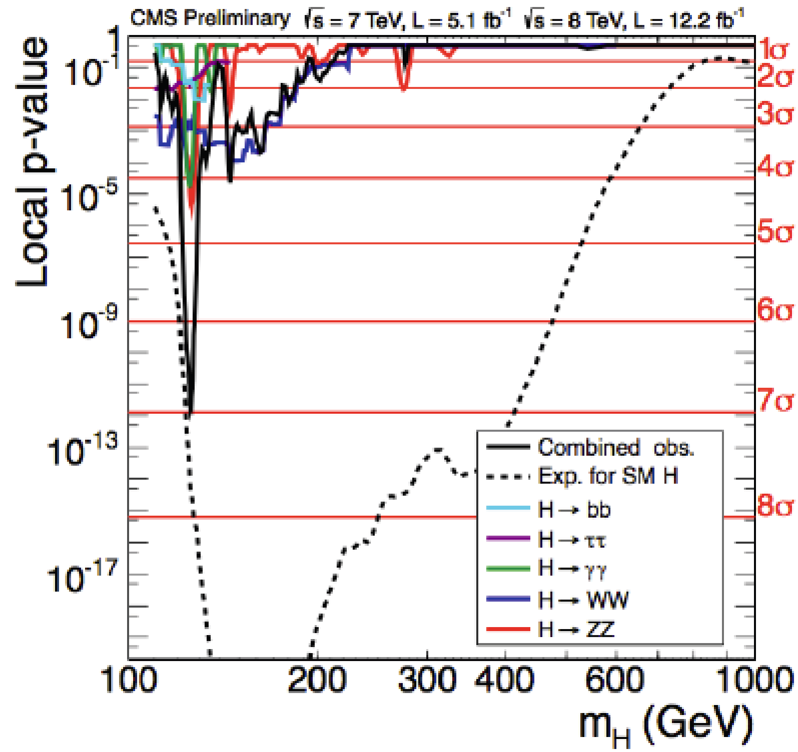
ATLAS Preliminary
∫L = 4.6 fb⁻¹, √s = 7 TeV
∫L = 13.0 fb⁻¹, √s = 8 TeV
best fit
best fit (μ>0)
95% Contour
68% Contour
SM prediction
Background only
m_H = 125 GeV
μ_VBF+VH × B/B_SM
μ_ggF × B/B_SM

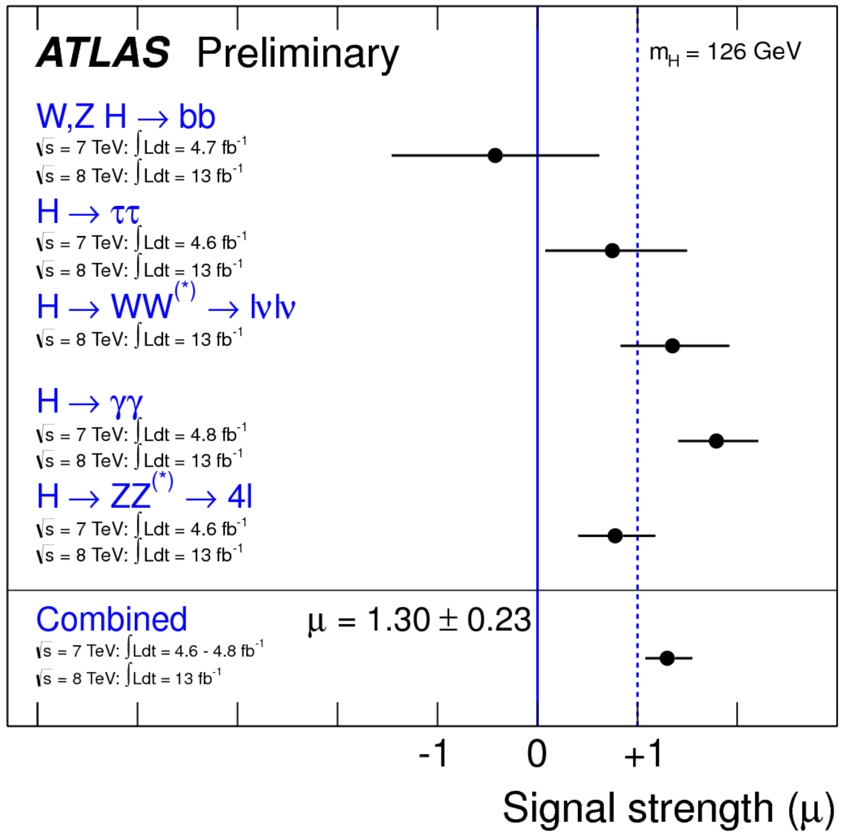
p_0-value (full mass range)

ATLAS July result

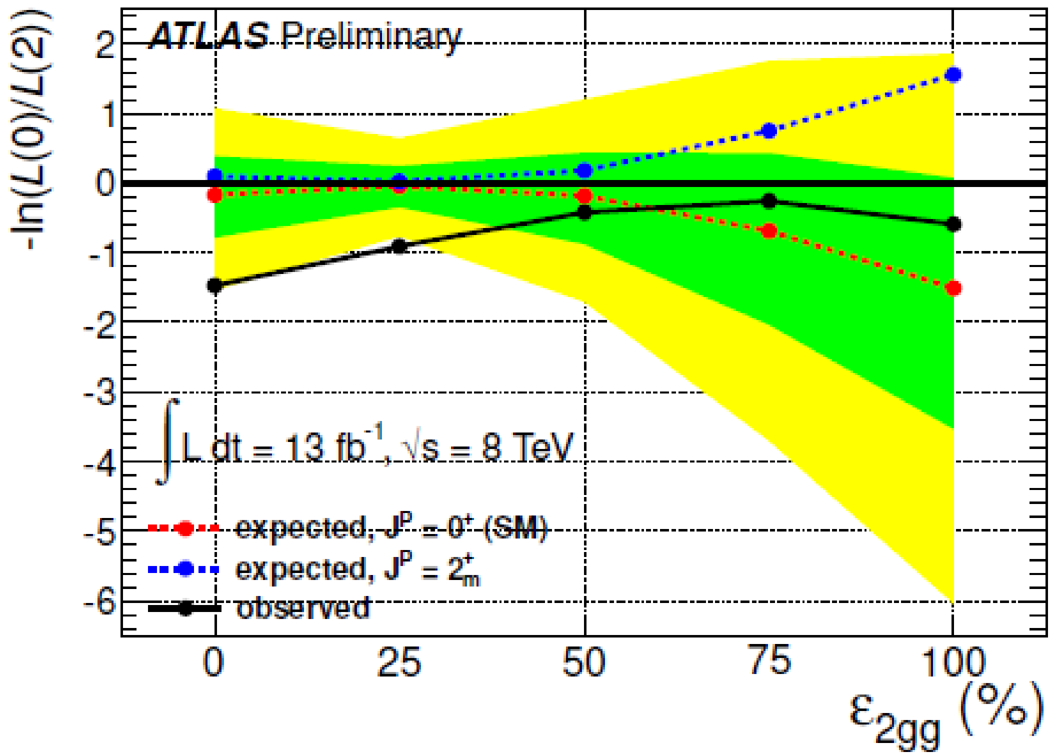


CMS latest result



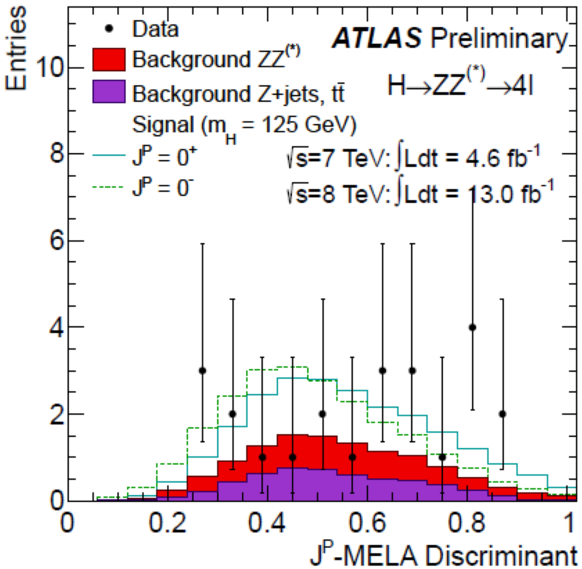

ATLAS Preliminary
m_H = 126 GeV
W,Z H → bb
√s = 7 TeV: ∫Ldt = 4.7 fb⁻¹
√s = 8 TeV: ∫Ldt = 13 fb⁻¹
H → ττ
√s = 7 TeV: ∫Ldt = 4.6 fb⁻¹
√s = 8 TeV: ∫Ldt = 13 fb⁻¹
H → WW(*) → lνlν
√s = 8 TeV: ∫Ldt = 13 fb⁻¹
H → γγ
√s = 7 TeV: ∫Ldt = 4.8 fb⁻¹
√s = 8 TeV: ∫Ldt = 13 fb⁻¹
H → ZZ(*) → 4l
√s = 7 TeV: ∫Ldt = 4.6 fb⁻¹
√s = 8 TeV: ∫Ldt = 13 fb⁻¹
Combined
μ = 1.30 ± 0.23
√s = 7 TeV: ∫Ldt = 4.6 - 4.8 fb⁻¹
√s = 8 TeV: ∫Ldt = 13 fb⁻¹
-1
0
+1
Signal strength (μ)

Spin and Parity with ATLAS H->$\gamma\gamma$

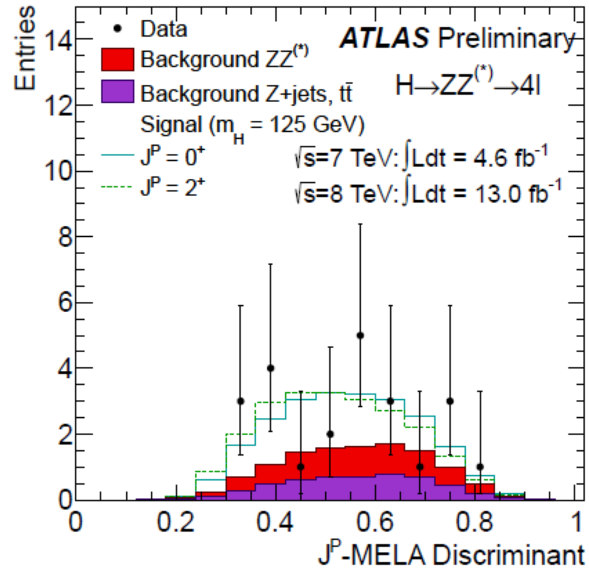


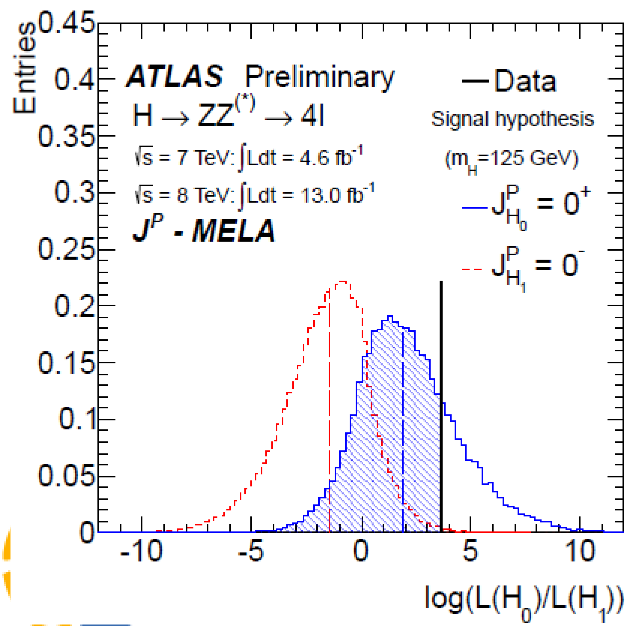
Spin and Parity (ATLAS H->ZZ->4l)

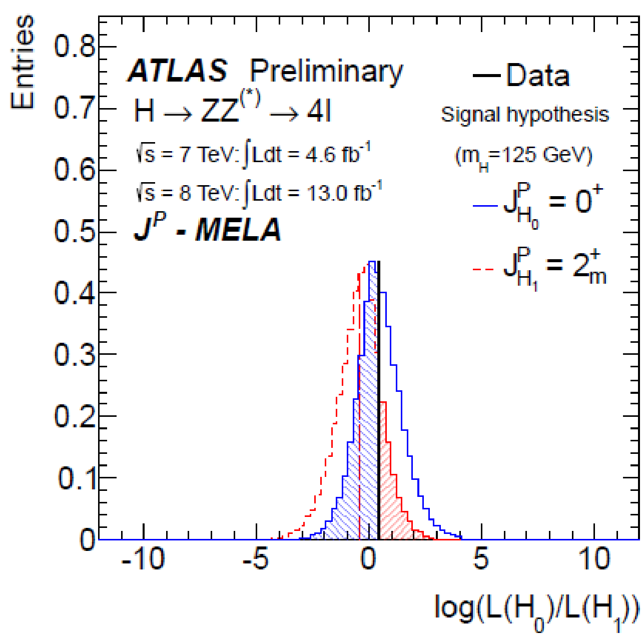
0^- vs 0^+



0^- vs 2^+_m







<u>Results with J^P-MELA</u>
(observed p-value)

$p(0^-) = 0.28\%\ (2.7\sigma)$
$p(0^+) = 75\%\ (-0.72\sigma)$

$p(2^+_m) = 17\%\ (0.97\sigma)$
$p(0^+) = 53\%\ (-0.08\sigma)$

$p(2^-) = 2.5\%\ (2.0\sigma)$
$p(0^+) = 56\%\ (-0.15\sigma)$

0^+ is preferred.

ATLAS-CONF-2012-127

$$\sigma \times BR(ii \to \mathrm{H} \to ff) = \frac{\sigma_{ii} \cdot \Gamma_{ff}}{\Gamma_{\mathrm{H}}}$$

"μ"

Ex)

$$\boxed{(\sigma \cdot \mathrm{BR})(gg \to \mathrm{H} \to \gamma\gamma) = \sigma_{\mathrm{SM}}(gg \to \mathrm{H}) \cdot \mathrm{BR}_{\mathrm{SM}}(\mathrm{H} \to \gamma\gamma) \cdot \frac{\kappa_g^2 \cdot \kappa_\gamma^2}{\kappa_{\mathrm{H}}^2}}$$

Production modes

$$\frac{\sigma_{ggH}}{\sigma_{ggH}^{SM}} = \begin{cases} \kappa_g^2(\kappa_b, \kappa_t, m_H) \\ \kappa_g^2 \end{cases}$$

$$\frac{\sigma_{VBF}}{\sigma_{VBF}^{SM}} = \kappa_{VBF}^2(\kappa_W, \kappa_Z, m_H)$$

$$\frac{\sigma_{WH}}{\sigma_{WH}^{SM}} = \kappa_W^2$$

$$\frac{\sigma_{ZH}}{\sigma_{ZH}^{SM}} = \kappa_Z^2$$

$$\frac{\sigma_{t\bar{t}H}}{\sigma_{t\bar{t}H}^{SM}} = \kappa_t^2$$

Detectable decay modes

$$\frac{\Gamma_{WW^{(*)}}}{\Gamma_{WW^{(*)}}^{SM}} = \kappa_W^2$$

$$\frac{\Gamma_{ZZ^{(*)}}}{\Gamma_{ZZ^{(*)}}^{SM}} = \kappa_Z^2$$

$$\left.\begin{aligned} \frac{\Gamma_{b\bar{b}}}{\Gamma_{b\bar{b}}^{SM}} &= \kappa_b^2 \\ \frac{\Gamma_{\tau^-\tau^+}}{\Gamma_{\tau^-\tau^+}^{SM}} &= \kappa_\tau^2 \end{aligned}\right\}$$

-> Yukawa

$$\frac{\Gamma_{\gamma\gamma}}{\Gamma_{\gamma\gamma}^{SM}} = \begin{cases} \kappa_\gamma^2(\kappa_b, \kappa_t, \kappa_\tau, \kappa_W, m_H) \\ \kappa_\gamma^2 \end{cases}$$

$$\frac{\Gamma_{Z\gamma}}{\Gamma_{Z\gamma}^{SM}} = \begin{cases} \kappa_{(Z\gamma)}^2(\kappa_b, \kappa_t, \kappa_\tau, \kappa_W, m_H) \\ \kappa_{(Z\gamma)}^2 \end{cases}$$

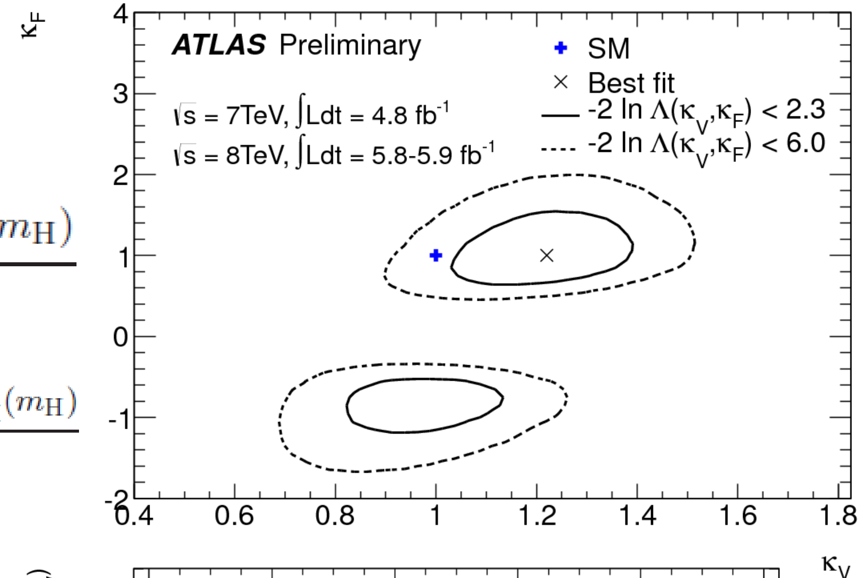
κ_F vs κ_V

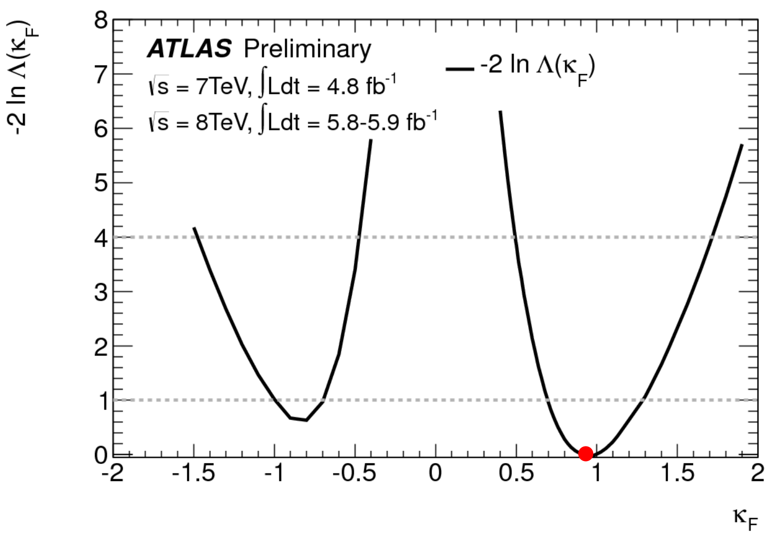
$$\kappa_F = \kappa_t = \kappa_b = \kappa_\tau$$

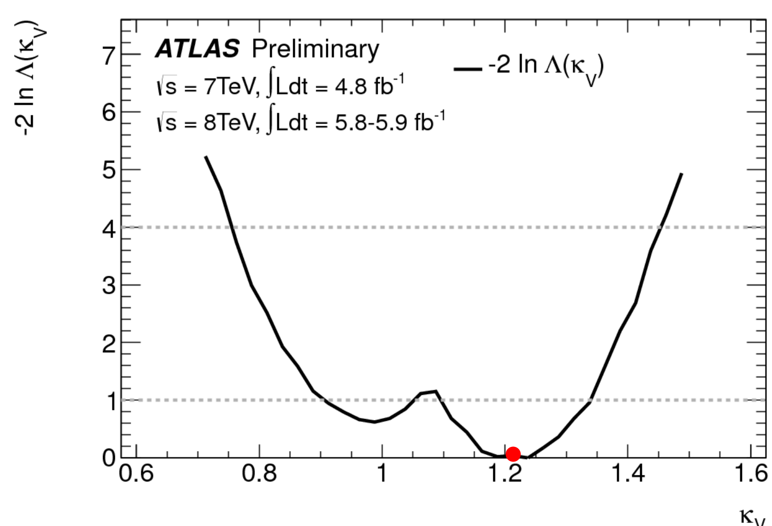
$$\kappa_V = \kappa_W = \kappa_Z$$

$$\kappa_{\mathrm{VBF}}^2(\kappa_W, \kappa_Z, m_H) = \frac{\kappa_W^2 \cdot \sigma_{WF}(m_H) + \kappa_Z^2 \cdot \sigma_{ZF}(m_H)}{\sigma_{WF}(m_H) + \sigma_{ZF}(m_H)}$$

$$\kappa_g^2(\kappa_b, \kappa_t, m_H) = \frac{\kappa_t^2 \cdot \sigma_{ggH}^{tt}(m_H) + \kappa_b^2 \cdot \sigma_{ggH}^{bb}(m_H) + \kappa_t\kappa_b \cdot \sigma_{ggH}^{tb}(m_H)}{\sigma_{ggH}^{tt}(m_H) + \sigma_{ggH}^{bb}(m_H) + \sigma_{ggH}^{tb}(m_H)}$$





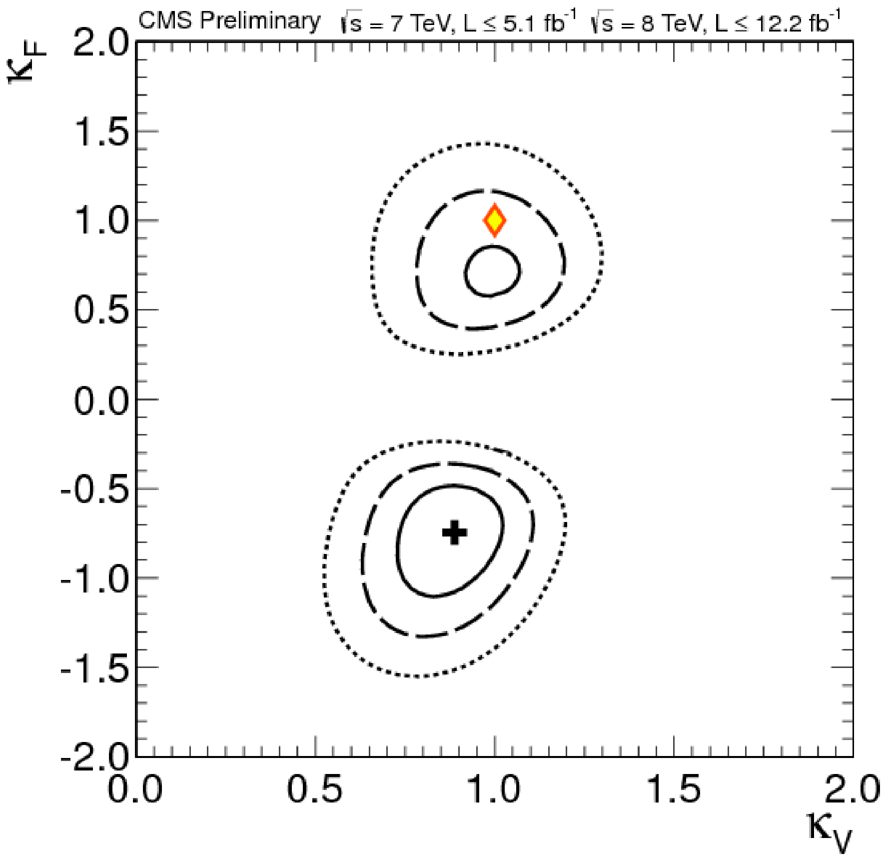


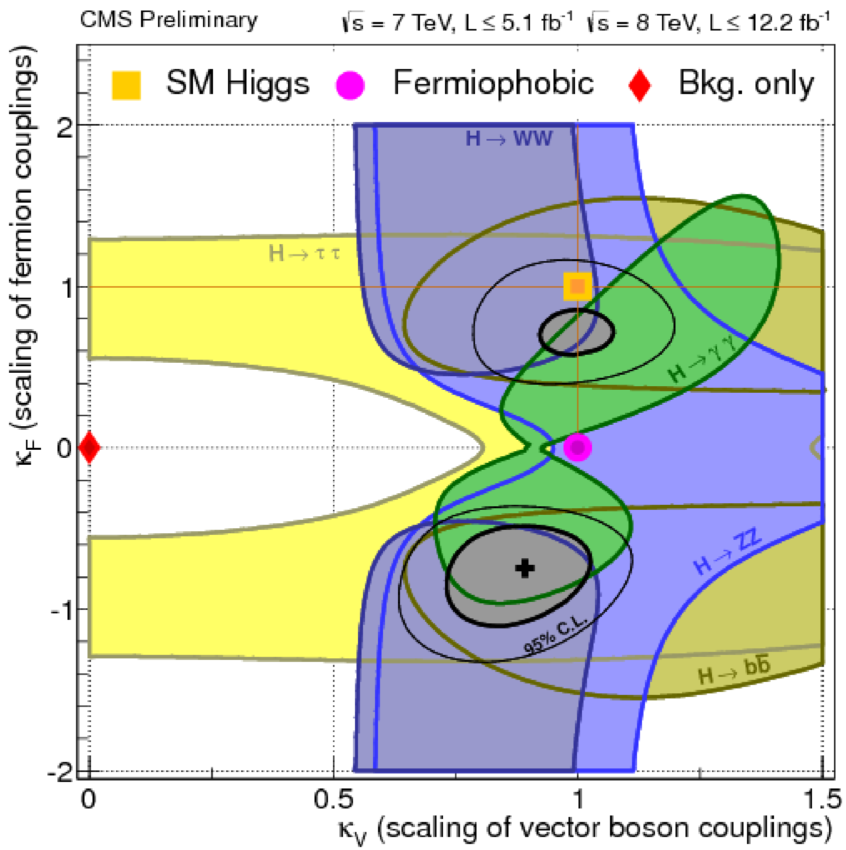
68% CL

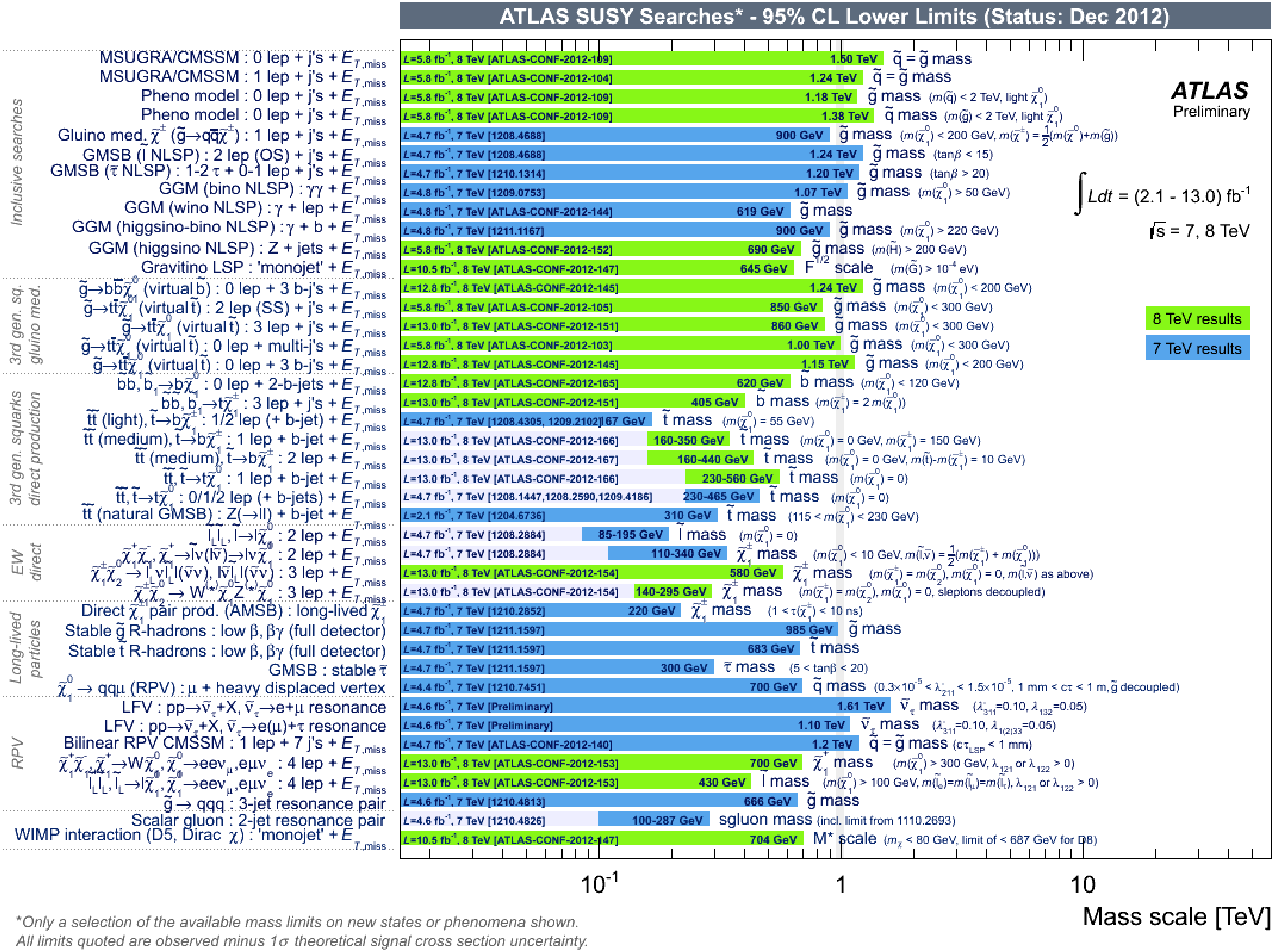
$$\kappa_F \in [-1.0, -0.7] \cup \boxed{[0.7, 1.3]}$$

$$\kappa_V \in [0.9, 1.0] \cup \boxed{[1.1, 1.3]}$$

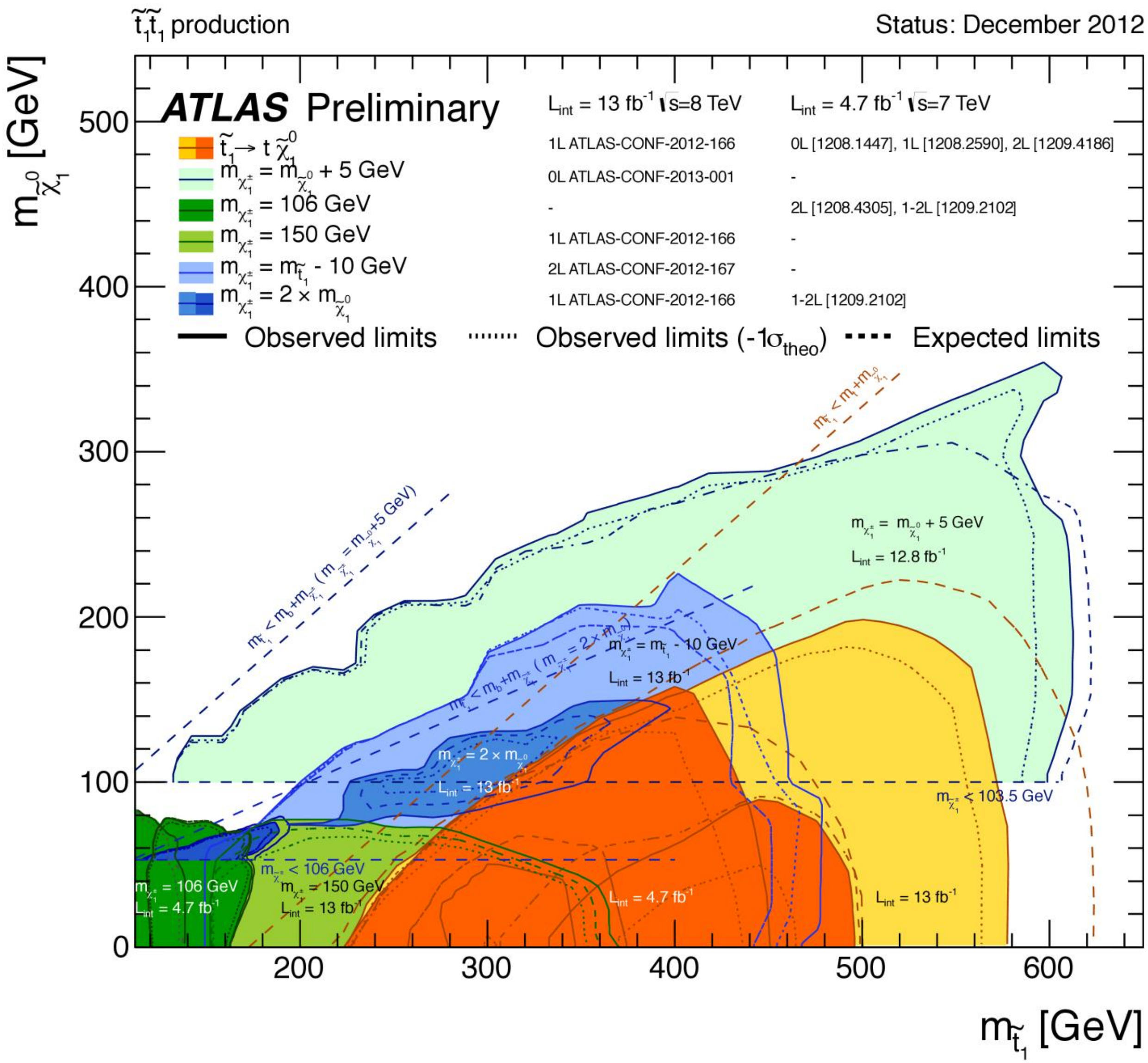
κ_F vs κ_V



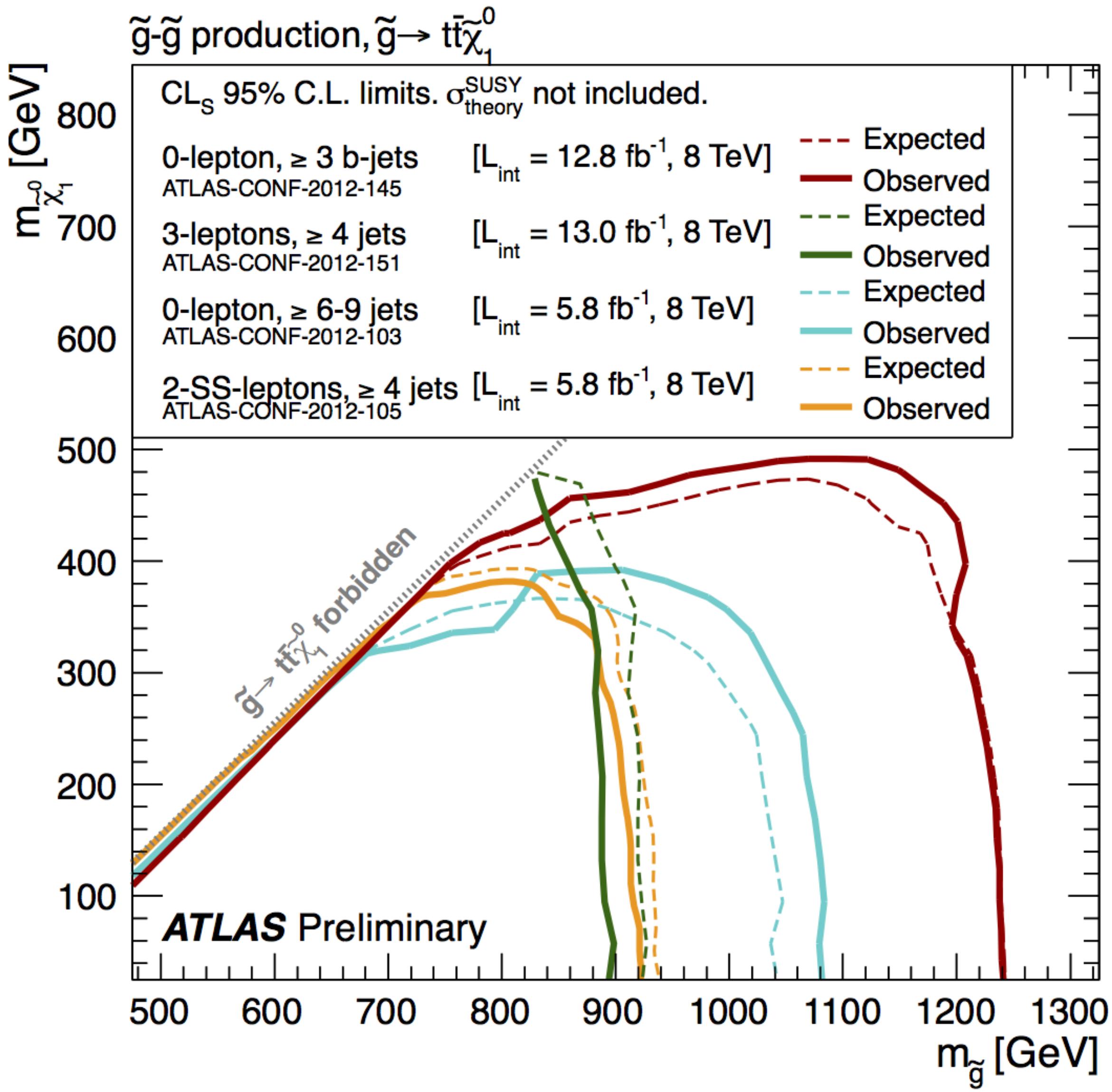




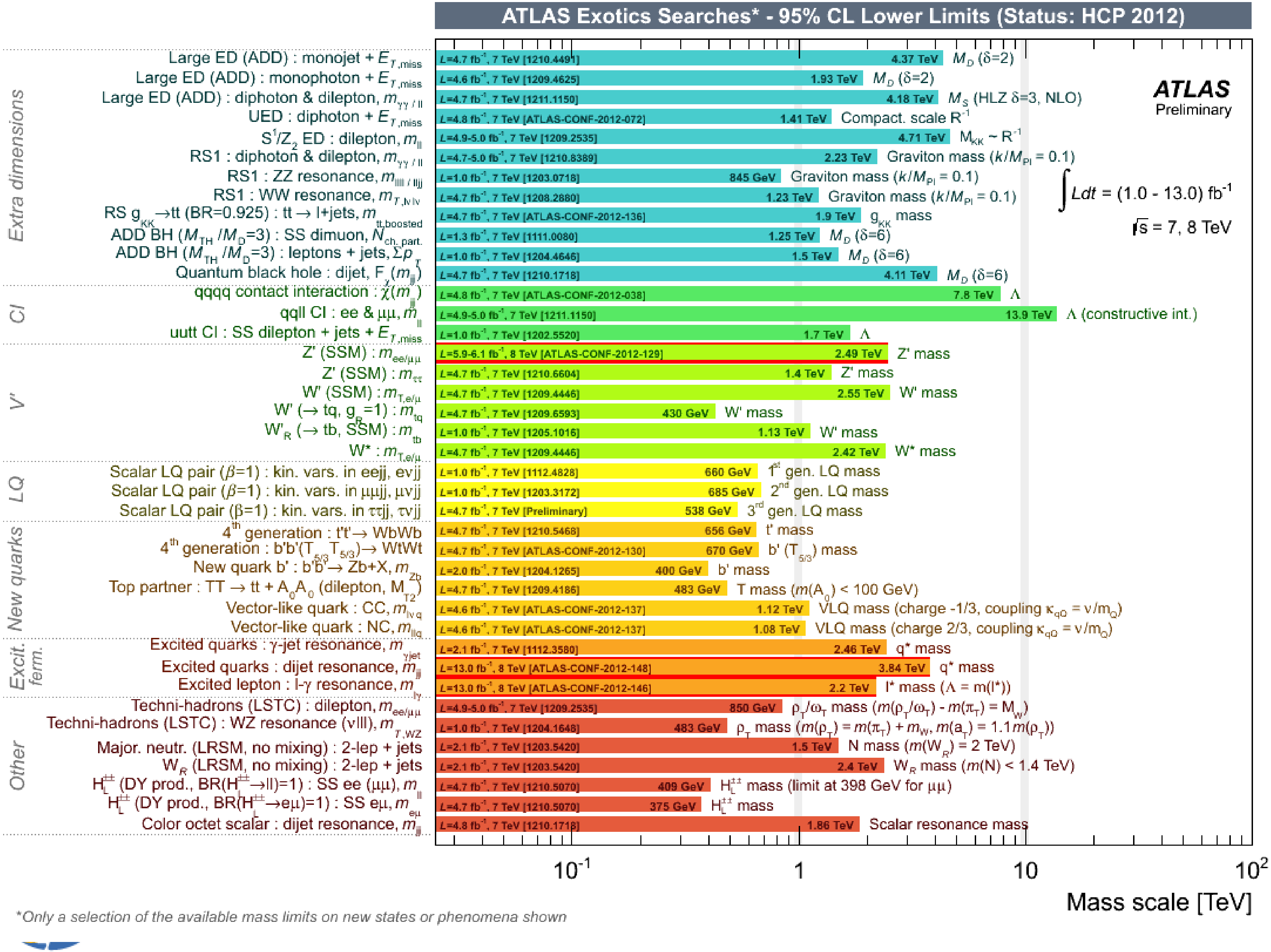
ATLAS SUSY Searches* - 95% CL Lower Limits (Status: Dec 2012)
ATLAS
Preliminary
∫Ldt = (2.1 - 13.0) fb⁻¹
√s = 7, 8 TeV
8 TeV results
7 TeV results
Inclusive searches
3rd gen. sq. gluino med.
3rd gen. squarks direct production
EW direct
Long-lived particles
RPV
MSUGRA/CMSSM : 0 lep + j's + E_T,miss | L=5.8 fb⁻¹, 8 TeV [ATLAS-CONF-2012-109] | 1.50 TeV | q̃ = g̃ mass
MSUGRA/CMSSM : 1 lep + j's + E_T,miss | L=5.8 fb⁻¹, 8 TeV [ATLAS-CONF-2012-104] | 1.24 TeV | q̃ = g̃ mass
Pheno model : 0 lep + j's + E_T,miss | L=5.8 fb⁻¹, 8 TeV [ATLAS-CONF-2012-109] | 1.18 TeV | g̃ mass (m(q̃) < 2 TeV, light χ̃₁⁰)
Pheno model : 0 lep + j's + E_T,miss | L=5.8 fb⁻¹, 8 TeV [ATLAS-CONF-2012-109] | 1.38 TeV | q̃ mass (m(g̃) < 2 TeV, light χ̃₁⁰)
Gluino med. χ̃± (g̃→qq̄χ̃±) : 1 lep + j's + E_T,miss | L=4.7 fb⁻¹, 7 TeV [1208.4688] | 900 GeV | g̃ mass (m(χ̃₁⁰) < 200 GeV, m(χ̃±) = ½(m(χ̃⁰)+m(g̃)))
GMSB (l̃ NLSP) : 2 lep (OS) + j's + E_T,miss | L=4.7 fb⁻¹, 7 TeV [1208.4688] | 1.24 TeV | g̃ mass (tanβ < 15)
GMSB (τ̃ NLSP) : 1-2 τ + 0-1 lep + j's + E_T,miss | L=4.7 fb⁻¹, 7 TeV [1210.1314] | 1.20 TeV | g̃ mass (tanβ > 20)
GGM (bino NLSP) : γγ + E_T,miss | L=4.8 fb⁻¹, 7 TeV [1209.0753] | 1.07 TeV | g̃ mass (m(χ̃₁⁰) > 50 GeV)
GGM (wino NLSP) : γ + lep + E_T,miss | L=4.8 fb⁻¹, 7 TeV [ATLAS-CONF-2012-144] | 619 GeV | g̃ mass
GGM (higgsino-bino NLSP) : γ + b + E_T,miss | L=4.8 fb⁻¹, 7 TeV [1211.1167] | 900 GeV | g̃ mass (m(χ̃₁⁰) > 220 GeV)
GGM (higgsino NLSP) : Z + jets + E_T,miss | L=5.8 fb⁻¹, 8 TeV [ATLAS-CONF-2012-152] | 690 GeV | g̃ mass (m(H̃) > 200 GeV)
Gravitino LSP : 'monojet' + E_T,miss | L=10.5 fb⁻¹, 8 TeV [ATLAS-CONF-2012-147] | 645 GeV | F^1/2 scale (m(G̃) > 10⁻⁴ eV)
g̃→bb̄χ̃₁⁰ (virtual b̃) : 0 lep + 3 b-j's + E_T,miss | L=12.8 fb⁻¹, 8 TeV [ATLAS-CONF-2012-145] | 1.24 TeV | g̃ mass (m(χ̃₁⁰) < 200 GeV)
g̃→tt̄χ̃₁⁰ (virtual t̃) : 2 lep (SS) + j's + E_T,miss | L=5.8 fb⁻¹, 8 TeV [ATLAS-CONF-2012-105] | 850 GeV | g̃ mass (m(χ̃₁⁰) < 300 GeV)
g̃→tt̄χ̃₁⁰ (virtual t̃) : 3 lep + j's + E_T,miss | L=13.0 fb⁻¹, 8 TeV [ATLAS-CONF-2012-151] | 860 GeV | g̃ mass (m(χ̃₁⁰) < 300 GeV)
g̃→tt̄χ̃₁⁰ (virtual t̃) : 0 lep + multi-j's + E_T,miss | L=5.8 fb⁻¹, 8 TeV [ATLAS-CONF-2012-103] | 1.00 TeV | g̃ mass (m(χ̃₁⁰) < 300 GeV)
g̃→tt̄χ̃₁⁰ (virtual t̃) : 0 lep + 3 b-j's + E_T,miss | L=12.8 fb⁻¹, 8 TeV [ATLAS-CONF-2012-145] | 1.15 TeV | g̃ mass (m(χ̃₁⁰) < 200 GeV)
b̃b̃, b̃₁→bχ̃₁⁰ : 0 lep + 2-b-jets + E_T,miss | L=12.8 fb⁻¹, 8 TeV [ATLAS-CONF-2012-165] | 620 GeV | b̃ mass (m(χ̃₁⁰) < 120 GeV)
b̃b̃, b̃₁→tχ̃₁± : 3 lep + j's + E_T,miss | L=13.0 fb⁻¹, 8 TeV [ATLAS-CONF-2012-151] | 405 GeV | b̃ mass (m(χ̃₁±) = 2 m(χ̃₁⁰))
t̃t̃ (light), t̃→bχ̃₁± : 1/2 lep (+ b-jet) + E_T,miss | L=4.7 fb⁻¹, 7 TeV [1208.4305, 1209.2102] | 167 GeV | t̃ mass (m(χ̃₁⁰) = 55 GeV)
t̃t̃ (medium), t̃→bχ̃₁± : 1 lep + b-jet + E_T,miss | L=13.0 fb⁻¹, 8 TeV [ATLAS-CONF-2012-166] | 160-350 GeV | t̃ mass (m(χ̃₁⁰) = 0 GeV, m(χ̃₁±) = 150 GeV)
t̃t̃ (medium), t̃→bχ̃₁± : 2 lep + E_T,miss | L=13.0 fb⁻¹, 8 TeV [ATLAS-CONF-2012-167] | 160-440 GeV | t̃ mass (m(χ̃₁⁰) = 0 GeV, m(t̃)-m(χ̃₁±) = 10 GeV)
t̃t̃, t̃→tχ̃₁⁰ : 1 lep + b-jet + E_T,miss | L=13.0 fb⁻¹, 8 TeV [ATLAS-CONF-2012-166] | 230-560 GeV | t̃ mass (m(χ̃₁⁰) = 0)
t̃t̃, t̃→tχ̃₁⁰ : 0/1/2 lep (+ b-jets) + E_T,miss | L=4.7 fb⁻¹, 7 TeV [1208.1447,1208.2590,1209.4186] | 230-465 GeV | t̃ mass (m(χ̃₁⁰) = 0)
t̃t̃ (natural GMSB) : Z(→ll) + b-jet + E_T,miss | L=2.1 fb⁻¹, 7 TeV [1204.6736] | 310 GeV | t̃ mass (115 < m(χ̃₁⁰) < 230 GeV)
l̃_L l̃_L, l̃→lχ̃₁⁰ : 2 lep + E_T,miss | L=4.7 fb⁻¹, 7 TeV [1208.2884] | 85-195 GeV | l̃ mass (m(χ̃₁⁰) = 0)
χ̃₁⁺χ̃₁⁻, χ̃₁⁺→l̃ν(lν̃)→lνχ̃₁⁰ : 2 lep + E_T,miss | L=4.7 fb⁻¹, 7 TeV [1208.2884] | 110-340 GeV | χ̃₁± mass (m(χ̃₁⁰) < 10 GeV, m(l̃,ν̃) = ½(m(χ̃₁±) + m(χ̃₁⁰)))
χ̃₁±χ̃₂⁰→l̃_Lνl̃_Ll(ν̃ν), l̃νl̃_Ll(ν̃ν) : 3 lep + E_T,miss | L=13.0 fb⁻¹, 8 TeV [ATLAS-CONF-2012-154] | 580 GeV | χ̃₁± mass (m(χ̃₁±) = m(χ̃₂⁰), m(χ̃₁⁰) = 0, m(l̃,ν̃) as above)
χ̃₁±χ̃₂⁰ → W(*)χ̃₁⁰Z(*)χ̃₁⁰ : 3 lep + E_T,miss | L=13.0 fb⁻¹, 8 TeV [ATLAS-CONF-2012-154] | 140-295 GeV | χ̃₁± mass (m(χ̃₁±) = m(χ̃₂⁰), m(χ̃₁⁰) = 0, sleptons decoupled)
Direct χ̃₁ pair prod. (AMSB) : long-lived χ̃₁± | L=4.7 fb⁻¹, 7 TeV [1210.2852] | 220 GeV | χ̃₁± mass (1 < τ(χ̃₁±) < 10 ns)
Stable g̃ R-hadrons : low β, βγ (full detector) | L=4.7 fb⁻¹, 7 TeV [1211.1597] | 985 GeV | g̃ mass
Stable t̃ R-hadrons : low β, βγ (full detector) | L=4.7 fb⁻¹, 7 TeV [1211.1597] | 683 GeV | t̃ mass
GMSB : stable τ̃ | L=4.7 fb⁻¹, 7 TeV [1211.1597] | 300 GeV | τ̃ mass (5 < tanβ < 20)
χ̃₁⁰ → qqμ (RPV) : μ + heavy displaced vertex | L=4.4 fb⁻¹, 7 TeV [1210.7451] | 700 GeV | q̃ mass (0.3×10⁻⁵ < λ'₂₁₁ < 1.5×10⁻⁵, 1 mm < cτ < 1 m, g̃ decoupled)
LFV : pp→ν̃_τ+X, ν̃_τ→e+μ resonance | L=4.6 fb⁻¹, 7 TeV [Preliminary] | 1.61 TeV | ν̃_τ mass (λ'₃₁₁=0.10, λ₁₃₂=0.05)
LFV : pp→ν̃_τ+X, ν̃_τ→e(μ)+τ resonance | L=4.6 fb⁻¹, 7 TeV [Preliminary] | 1.10 TeV | ν̃_τ mass (λ'₃₁₁=0.10, λ₁(2)33=0.05)
Bilinear RPV CMSSM : 1 lep + 7 j's + E_T,miss | L=4.7 fb⁻¹, 7 TeV [ATLAS-CONF-2012-140] | 1.2 TeV | q̃ = g̃ mass (cτ_LSP < 1 mm)
χ̃₁⁺χ̃₁⁻, χ̃₁⁺→Wχ̃₁⁰, χ̃₁⁰→eeν_μ, eμν_e : 4 lep + E_T,miss | L=13.0 fb⁻¹, 8 TeV [ATLAS-CONF-2012-153] | 700 GeV | χ̃₁± mass (m(χ̃₁⁰) > 300 GeV, λ₁₂₁ or λ₁₂₂ > 0)
l̃_L l̃_L, l̃_L→lχ̃₁⁰, χ̃₁⁰→eeν_μ, eμν_e : 4 lep + E_T,miss | L=13.0 fb⁻¹, 8 TeV [ATLAS-CONF-2012-153] | 430 GeV | l̃ mass (m(χ̃₁⁰) > 100 GeV, m(l̃_e)=m(l̃_μ)=m(l̃_τ), λ₁₂₁ or λ₁₂₂ > 0)
g̃ → qqq : 3-jet resonance pair | L=4.6 fb⁻¹, 7 TeV [1210.4813] | 666 GeV | g̃ mass
Scalar gluon : 2-jet resonance pair | L=4.6 fb⁻¹, 7 TeV [1210.4826] | 100-287 GeV | sgluon mass (incl. limit from 1110.2693)
WIMP interaction (D5, Dirac χ) : 'monojet' + E_T,miss | L=10.5 fb⁻¹, 8 TeV [ATLAS-CONF-2012-147] | 704 GeV | M* scale (m_χ < 80 GeV, limit of < 687 GeV for D8)
10⁻¹
1
10
Mass scale [TeV]
*Only a selection of the available mass limits on new states or phenomena shown.
All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.



t̃1t̃1 production
Status: December 2012
ATLAS Preliminary
Lint = 13 fb-1 √s=8 TeV
Lint = 4.7 fb-1 √s=7 TeV
1L ATLAS-CONF-2012-166
0L [1208.1447], 1L [1208.2590], 2L [1209.4186]
0L ATLAS-CONF-2013-001
2L [1208.4305], 1-2L [1209.2102]
1L ATLAS-CONF-2012-166
2L ATLAS-CONF-2012-167
1L ATLAS-CONF-2012-166
1-2L [1209.2102]
Observed limits
Observed limits (-1σtheo)
Expected limits
Lint = 12.8 fb-1
Lint = 13 fb-1
Lint = 4.7 fb-1
mχ̃±1 = 106 GeV
mχ̃±1 = 150 GeV
mχ̃±1 < 106 GeV
mχ̃±1 < 103.5 GeV
m_χ̃01 [GeV]
m_t̃1 [GeV]



$\tilde{g}$-$\tilde{g}$ production, $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$
CL$_S$ 95% C.L. limits. σ^{SUSY}_{theory} not included.
0-lepton, ≥ 3 b-jets [L_{int} = 12.8 fb^{-1}, 8 TeV]
ATLAS-CONF-2012-145
3-leptons, ≥ 4 jets [L_{int} = 13.0 fb^{-1}, 8 TeV]
ATLAS-CONF-2012-151
0-lepton, ≥ 6-9 jets [L_{int} = 5.8 fb^{-1}, 8 TeV]
ATLAS-CONF-2012-103
2-SS-leptons, ≥ 4 jets [L_{int} = 5.8 fb^{-1}, 8 TeV]
ATLAS-CONF-2012-105
Expected
Observed
Expected
Observed
Expected
Observed
Expected
Observed
$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ forbidden
ATLAS Preliminary
$m_{\tilde{\chi}_1^0}$ [GeV]
$m_{\tilde{g}}$ [GeV]


ATLAS Exotics Searches* - 95% CL Lower Limits (Status: HCP 2012)
ATLAS
Preliminary
$\int Ldt = (1.0 - 13.0)\ fb^{-1}$
$\sqrt{s} = 7, 8$ TeV
Extra dimensions
Large ED (ADD) : monojet + $E_{T,miss}$ | $L=4.7\ fb^{-1}$, 7 TeV [1210.4491] | 4.37 TeV | M_D (δ=2)
Large ED (ADD) : monophoton + $E_{T,miss}$ | $L=4.6\ fb^{-1}$, 7 TeV [1209.4625] | 1.93 TeV | M_D (δ=2)
Large ED (ADD) : diphoton & dilepton, $m_{\gamma\gamma / ll}$ | $L=4.7\ fb^{-1}$, 7 TeV [1211.1150] | 4.18 TeV | M_S (HLZ δ=3, NLO)
UED : diphoton + $E_{T,miss}$ | $L=4.8\ fb^{-1}$, 7 TeV [ATLAS-CONF-2012-072] | 1.41 TeV | Compact. scale R^{-1}
S^1/Z_2 ED : dilepton, m_{ll} | $L=4.9\text{-}5.0\ fb^{-1}$, 7 TeV [1209.2535] | 4.71 TeV | $M_{KK} \sim R^{-1}$
RS1 : diphoton & dilepton, $m_{\gamma\gamma / ll}$ | $L=4.7\text{-}5.0\ fb^{-1}$, 7 TeV [1210.8389] | 2.23 TeV | Graviton mass (k/M_{Pl} = 0.1)
RS1 : ZZ resonance, $m_{llll / lljj}$ | $L=1.0\ fb^{-1}$, 7 TeV [1203.0718] | 845 GeV | Graviton mass (k/M_{Pl} = 0.1)
RS1 : WW resonance, $m_{T,l\nu l\nu}$ | $L=4.7\ fb^{-1}$, 7 TeV [1208.2880] | 1.23 TeV | Graviton mass (k/M_{Pl} = 0.1)
RS $g_{KK} \rightarrow tt$ (BR=0.925) : $tt \rightarrow$ l+jets, $m_{tt,boosted}$ | $L=4.7\ fb^{-1}$, 7 TeV [ATLAS-CONF-2012-136] | 1.9 TeV | g_{KK} mass
ADD BH (M_{TH}/M_D=3) : SS dimuon, $N_{ch. part.}$ | $L=1.3\ fb^{-1}$, 7 TeV [1111.0080] | 1.25 TeV | M_D (δ=6)
ADD BH (M_{TH}/M_D=3) : leptons + jets, Σp_T | $L=1.0\ fb^{-1}$, 7 TeV [1204.4646] | 1.5 TeV | M_D (δ=6)
Quantum black hole : dijet, $F_\chi(m_{jj})$ | $L=4.7\ fb^{-1}$, 7 TeV [1210.1718] | 4.11 TeV | M_D (δ=6)
CI
qqqq contact interaction : $\chi(m_{jj})$ | $L=4.8\ fb^{-1}$, 7 TeV [ATLAS-CONF-2012-038] | 7.8 TeV | Λ
qqll CI : ee & $\mu\mu$, m_{ll} | $L=4.9\text{-}5.0\ fb^{-1}$, 7 TeV [1211.1150] | 13.9 TeV | Λ (constructive int.)
uutt CI : SS dilepton + jets + $E_{T,miss}$ | $L=1.0\ fb^{-1}$, 7 TeV [1202.5520] | 1.7 TeV | Λ
V'
Z' (SSM) : $m_{ee/\mu\mu}$ | $L=5.9\text{-}6.1\ fb^{-1}$, 8 TeV [ATLAS-CONF-2012-129] | 2.49 TeV | Z' mass
Z' (SSM) : $m_{\tau\tau}$ | $L=4.7\ fb^{-1}$, 7 TeV [1210.6604] | 1.4 TeV | Z' mass
W' (SSM) : $m_{T,e/\mu}$ | $L=4.7\ fb^{-1}$, 7 TeV [1209.4446] | 2.55 TeV | W' mass
W' ($\rightarrow$ tq, g_R=1) : m_{tq} | $L=4.7\ fb^{-1}$, 7 TeV [1209.6593] | 430 GeV | W' mass
W'_R ($\rightarrow$ tb, SSM) : m_{tb} | $L=1.0\ fb^{-1}$, 7 TeV [1205.1016] | 1.13 TeV | W' mass
W* : $m_{T,e/\mu}$ | $L=4.7\ fb^{-1}$, 7 TeV [1209.4446] | 2.42 TeV | W* mass
LQ
Scalar LQ pair (β=1) : kin. vars. in eejj, eνjj | $L=1.0\ fb^{-1}$, 7 TeV [1112.4828] | 660 GeV | 1^{st} gen. LQ mass
Scalar LQ pair (β=1) : kin. vars. in $\mu\mu$jj, $\mu\nu$jj | $L=1.0\ fb^{-1}$, 7 TeV [1203.3172] | 685 GeV | 2^{nd} gen. LQ mass
Scalar LQ pair (β=1) : kin. vars. in $\tau\tau$jj, $\tau\nu$jj | $L=4.7\ fb^{-1}$, 7 TeV [Preliminary] | 538 GeV | 3^{rd} gen. LQ mass
New quarks
4^{th} generation : $t't' \rightarrow$ WbWb | $L=4.7\ fb^{-1}$, 7 TeV [1210.5468] | 656 GeV | t' mass
4^{th} generation : $b'b'(T_{5/3}T_{5/3}) \rightarrow$ WtWt | $L=4.7\ fb^{-1}$, 7 TeV [ATLAS-CONF-2012-130] | 670 GeV | b' ($T_{5/3}$) mass
New quark b' : $b'b' \rightarrow$ Zb+X, m_{Zb} | $L=2.0\ fb^{-1}$, 7 TeV [1204.1265] | 400 GeV | b' mass
Top partner : TT $\rightarrow$ tt + A_0A_0 (dilepton, M_{T2}) | $L=4.7\ fb^{-1}$, 7 TeV [1209.4186] | 483 GeV | T mass ($m(A_0)$ < 100 GeV)
Vector-like quark : CC, $m_{l\nu q}$ | $L=4.6\ fb^{-1}$, 7 TeV [ATLAS-CONF-2012-137] | 1.12 TeV | VLQ mass (charge -1/3, coupling $\kappa_{qQ} = \nu/m_Q$)
Vector-like quark : NC, m_{llq} | $L=4.6\ fb^{-1}$, 7 TeV [ATLAS-CONF-2012-137] | 1.08 TeV | VLQ mass (charge 2/3, coupling $\kappa_{qQ} = \nu/m_Q$)
Excit. ferm.
Excited quarks : γ-jet resonance, $m_{\gamma jet}$ | $L=2.1\ fb^{-1}$, 7 TeV [1112.3580] | 2.46 TeV | q* mass
Excited quarks : dijet resonance, m_{jj} | $L=13.0\ fb^{-1}$, 8 TeV [ATLAS-CONF-2012-148] | 3.84 TeV | q* mass
Excited lepton : l-γ resonance, $m_{l\gamma}$ | $L=13.0\ fb^{-1}$, 8 TeV [ATLAS-CONF-2012-146] | 2.2 TeV | l* mass (Λ = m(l*))
Other
Techni-hadrons (LSTC) : dilepton, $m_{ee/\mu\mu}$ | $L=4.9\text{-}5.0\ fb^{-1}$, 7 TeV [1209.2535] | 850 GeV | ρ_T/ω_T mass ($m(\rho_T/\omega_T) - m(\pi_T) = M_W$)
Techni-hadrons (LSTC) : WZ resonance (νlll), $m_{T,WZ}$ | $L=1.0\ fb^{-1}$, 7 TeV [1204.1648] | 483 GeV | ρ_T mass ($m(\rho_T) = m(\pi_T) + m_W$, $m(a_T) = 1.1m(\rho_T)$)
Major. neutr. (LRSM, no mixing) : 2-lep + jets | $L=2.1\ fb^{-1}$, 7 TeV [1203.5420] | 1.5 TeV | N mass ($m(W_R)$ = 2 TeV)
W_R (LRSM, no mixing) : 2-lep + jets | $L=2.1\ fb^{-1}$, 7 TeV [1203.5420] | 2.4 TeV | W_R mass ($m(N)$ < 1.4 TeV)
$H_L^{\pm\pm}$ (DY prod., BR($H_L^{\pm\pm} \rightarrow ll$)=1) : SS ee ($\mu\mu$), m_{ll} | $L=4.7\ fb^{-1}$, 7 TeV [1210.5070] | 409 GeV | $H_L^{\pm\pm}$ mass (limit at 398 GeV for $\mu\mu$)
$H_L^{\pm\pm}$ (DY prod., BR($H_L^{\pm\pm} \rightarrow e\mu$)=1) : SS e$\mu$, $m_{e\mu}$ | $L=4.7\ fb^{-1}$, 7 TeV [1210.5070] | 375 GeV | $H_L^{\pm\pm}$ mass
Color octet scalar : dijet resonance, m_{jj} | $L=4.8\ fb^{-1}$, 7 TeV [1210.1718] | 1.86 TeV | Scalar resonance mass
10^{-1}
1
10
10^2
Mass scale [TeV]
*Only a selection of the available mass limits on new states or phenomena shown

2elec+2muon candidate with m_{4l}=124.3GeV
$m_{12(ee)}$=76.8GeV, $m_{34(\mu\mu)}$=45.7GeV