The latest LHC results

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on behalf of the ATLAS and CMS experiments

For KILC12, Joint ACFA Physics / Detector Workshop and
GDE meeting on Linear Collider
23/04/2012

Outline

- Introduction
- LHC Results
  - Standard Model Higgs
  - BSM Higgs
  - Exotica
  - Supersymmetry
- Summary

Introduction

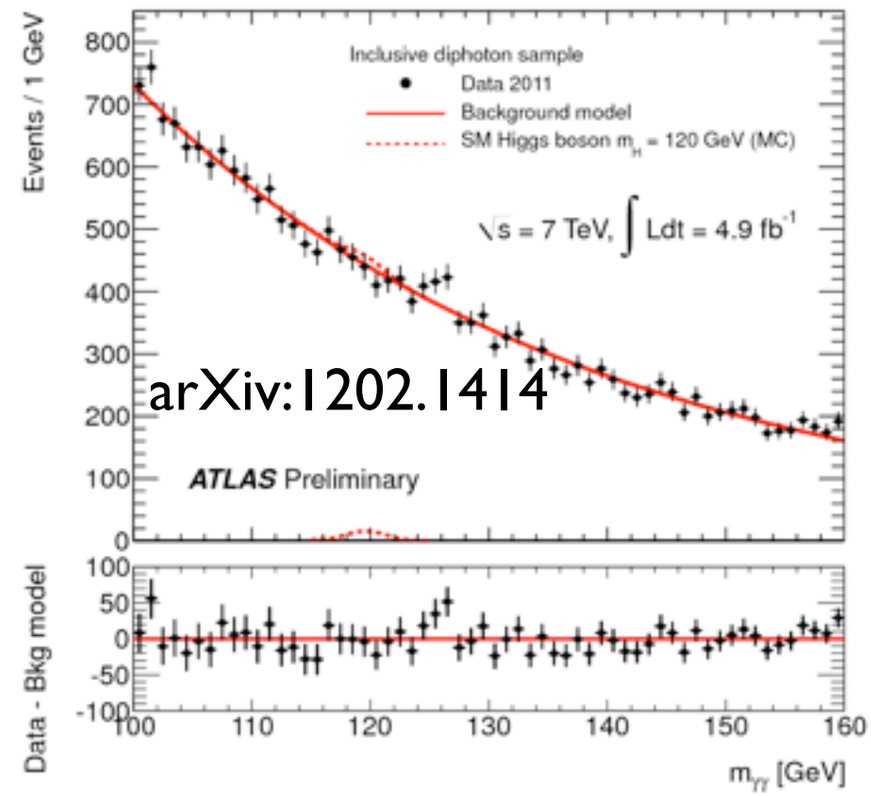
- LHC delivered more than 5 fb^{-1}
- <number of pileup> ~ 10
- Measured cross section of top quark and SM gauge bosons (W, Z)
- Extensive test of pQCD
- BSM has been searched since 2010.
- 2011 data opened SM higgs search.

SM HIGGS

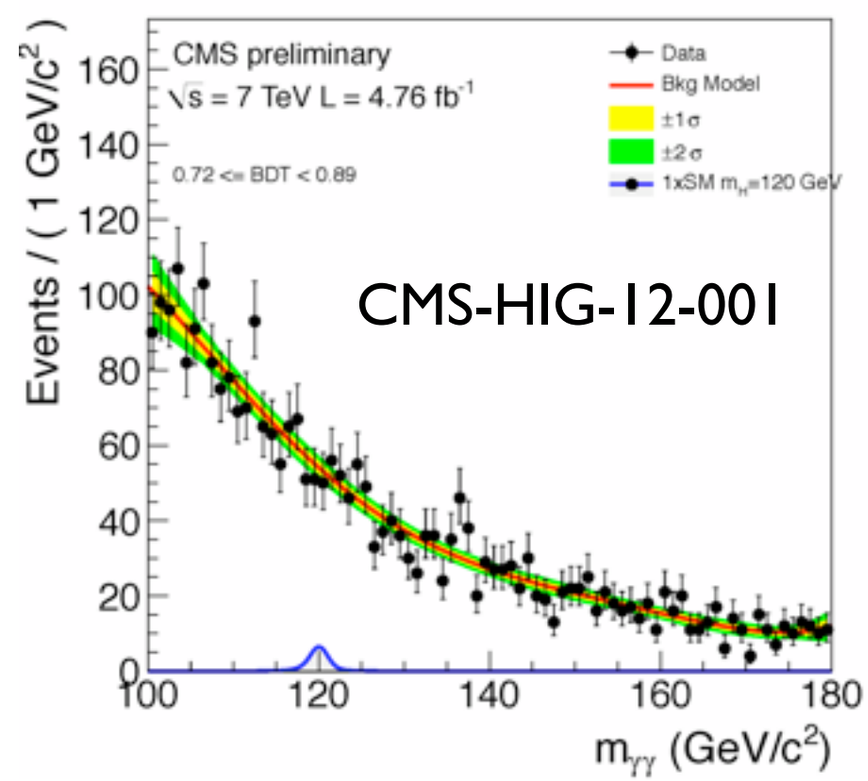
Higgs to γγ

- Clean signal
- One of most promising decay mode in low mass range

- ATLAS
  - 9 exclusive categories with different $M_{\gamma\gamma}$
  - Signal modeling : Crystal Ball and Gaussian.
  - Background modeling : exponential function.
- CMS
  - 5 event classes with MVA using kinematics and resolution of two photons and splitting the events successively
  - Signal modeling : Crystal Ball and Gaussian.
  - Background modeling : 5th order polynomial.



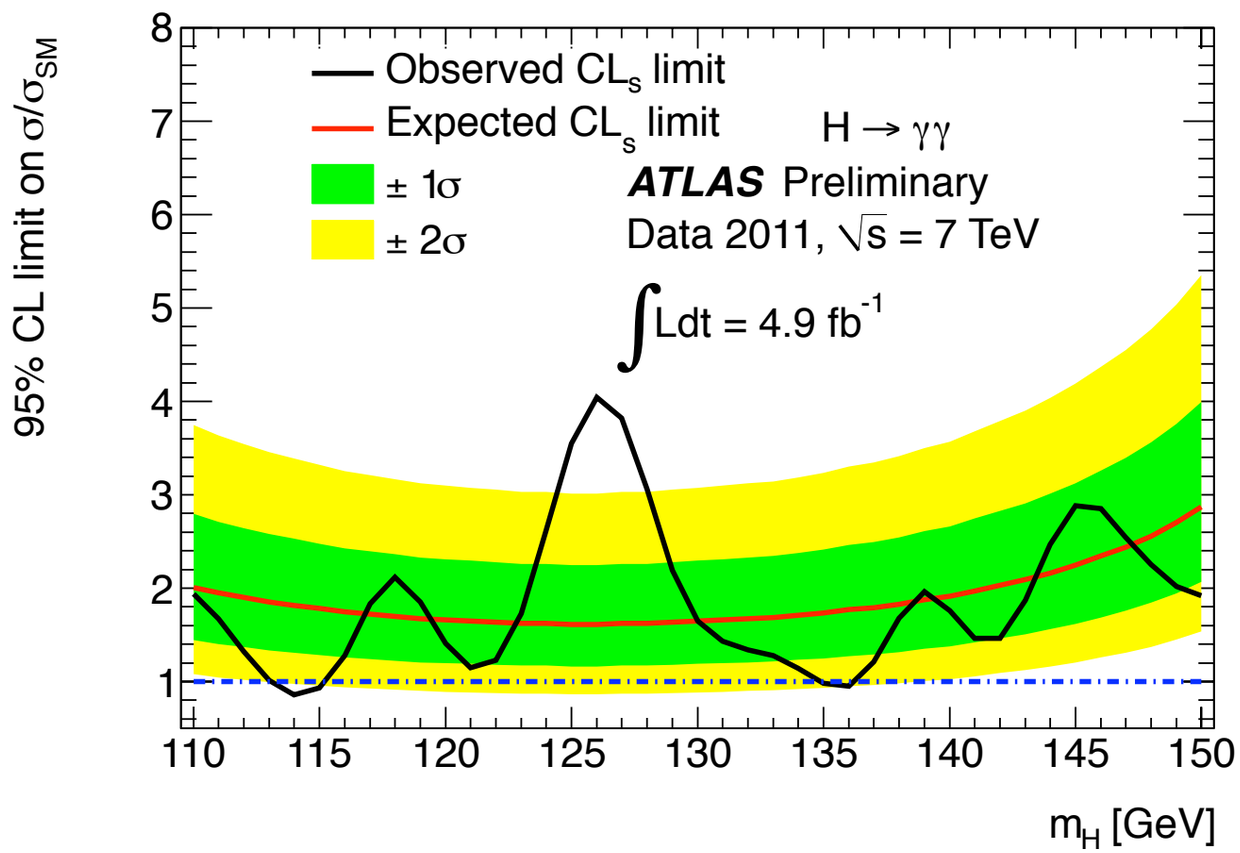
arXiv:1202.1414



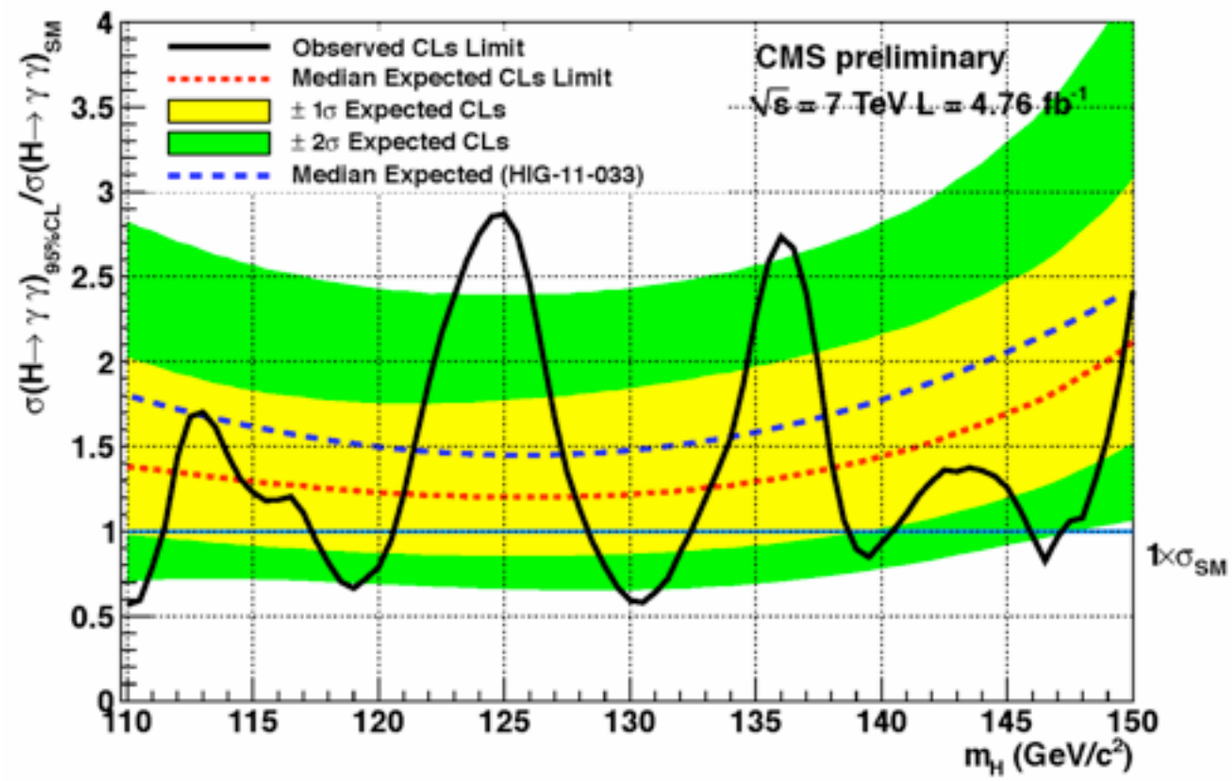
CMS-HIG-12-001

Higgs to γγ

ATLAS
arXiv:1202.1414



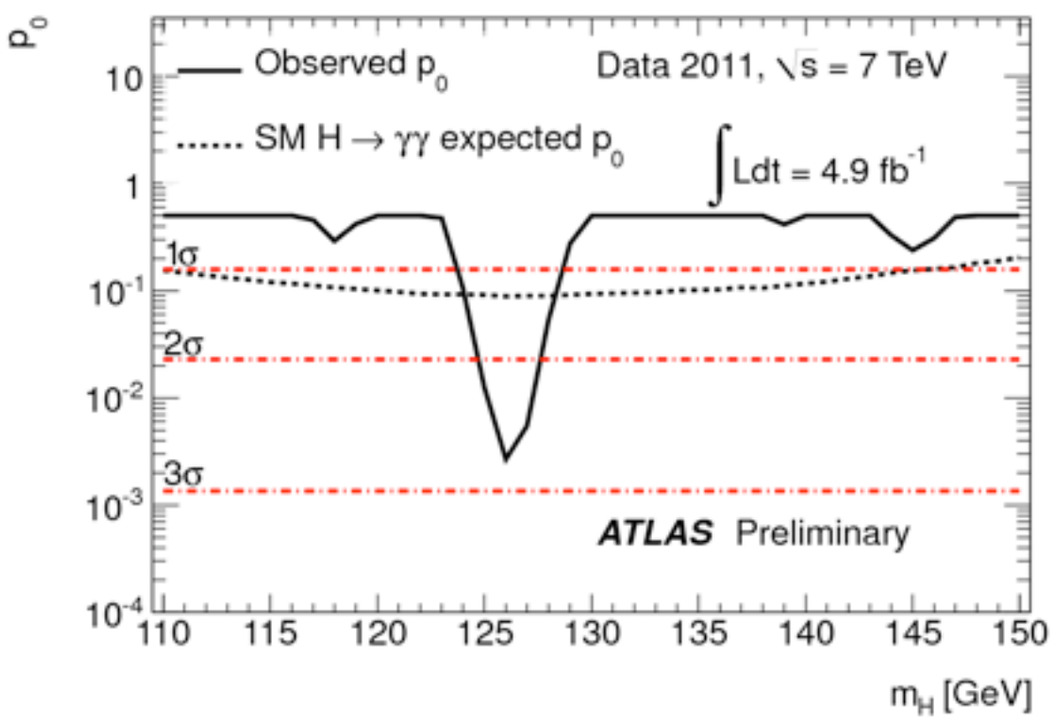
CMS-HIG-12-001



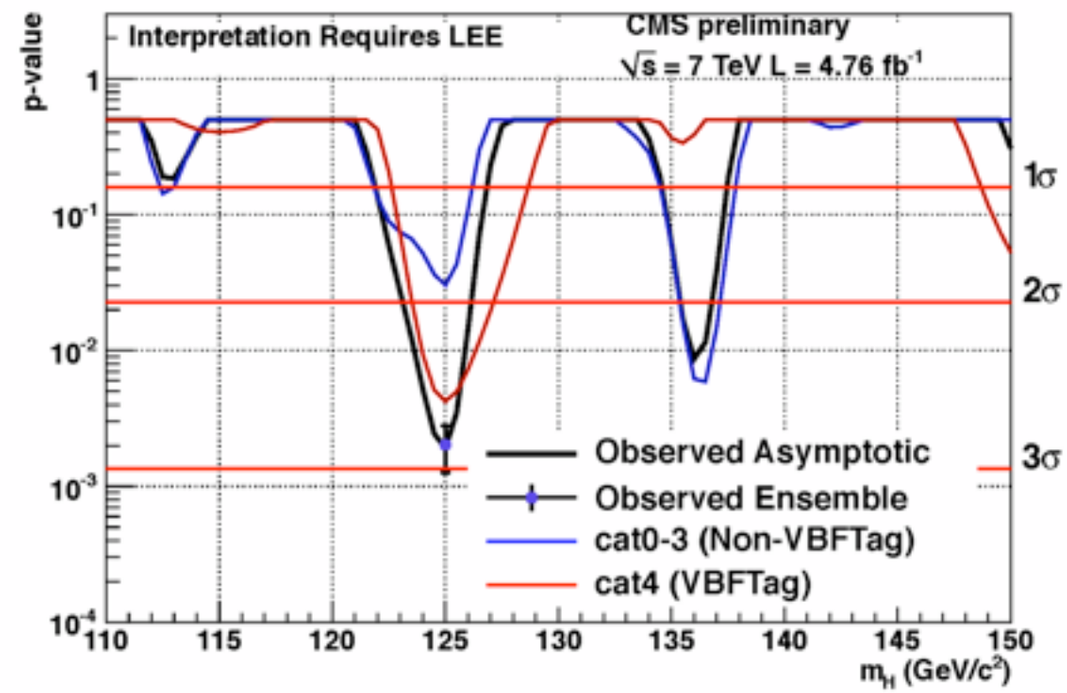
- ATLAS
  - Observed exclusion [113-115], [134.5-136]
- CMS
  - Observed exclusion [110.0-111.0], [117.5-120.5],[128.5-132.0],[139.0-140.0]

Higgs to γγ

arXiv:1202.1414



CMS-HIG-12-001

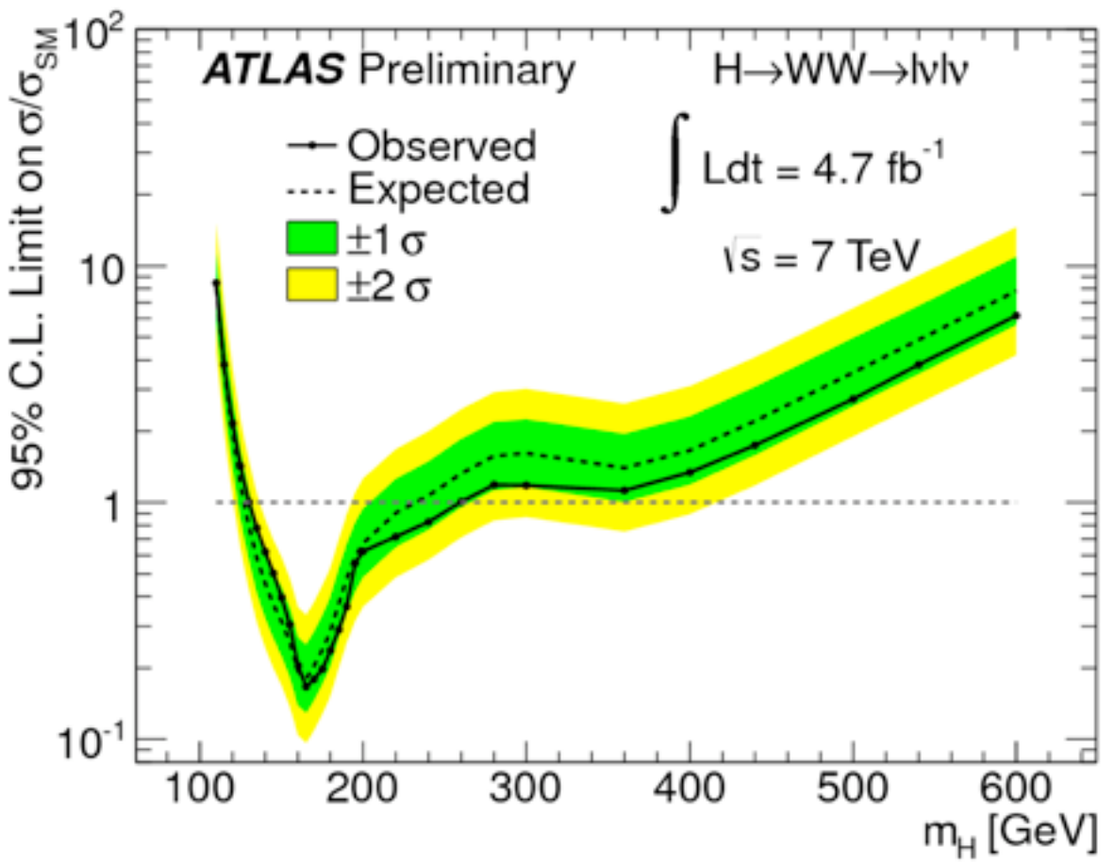


p-value = the probability for background to produce a fluctuation.

- ATLAS
  - local p-value = 2.8 σ at 126.5 GeV
  - global p-value = 1.5 σ in 110 < M_H < 150 GeV
- CMS
  - local p-value = 2.9 σ at 125 GeV
  - global p-value = 1.6 σ in 110 < M_H < 150 GeV

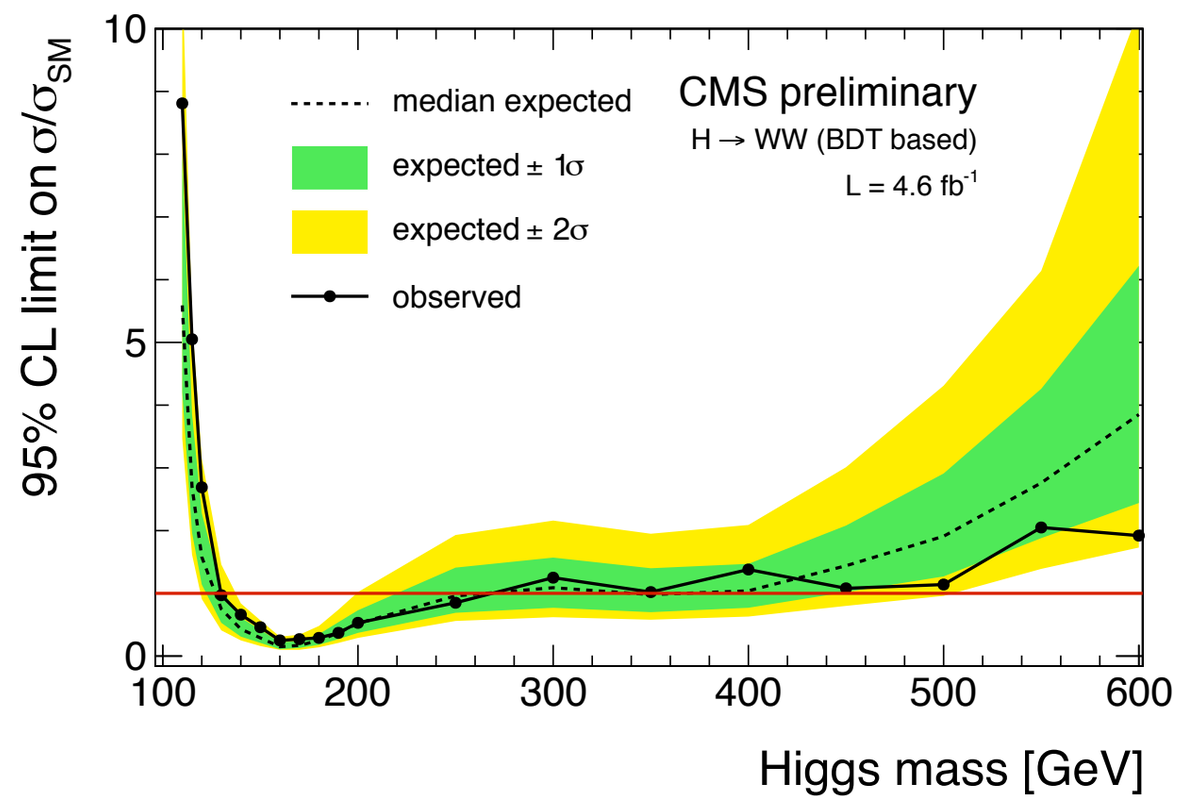
H → WW → lνlν

ATLAS-CONF-2012-012



Observed exclusion 130-260 GeV at 95%

CMS
arXiv:1201.1489
accepted by PLB



Observed exclusion 129-270 GeV at 95%

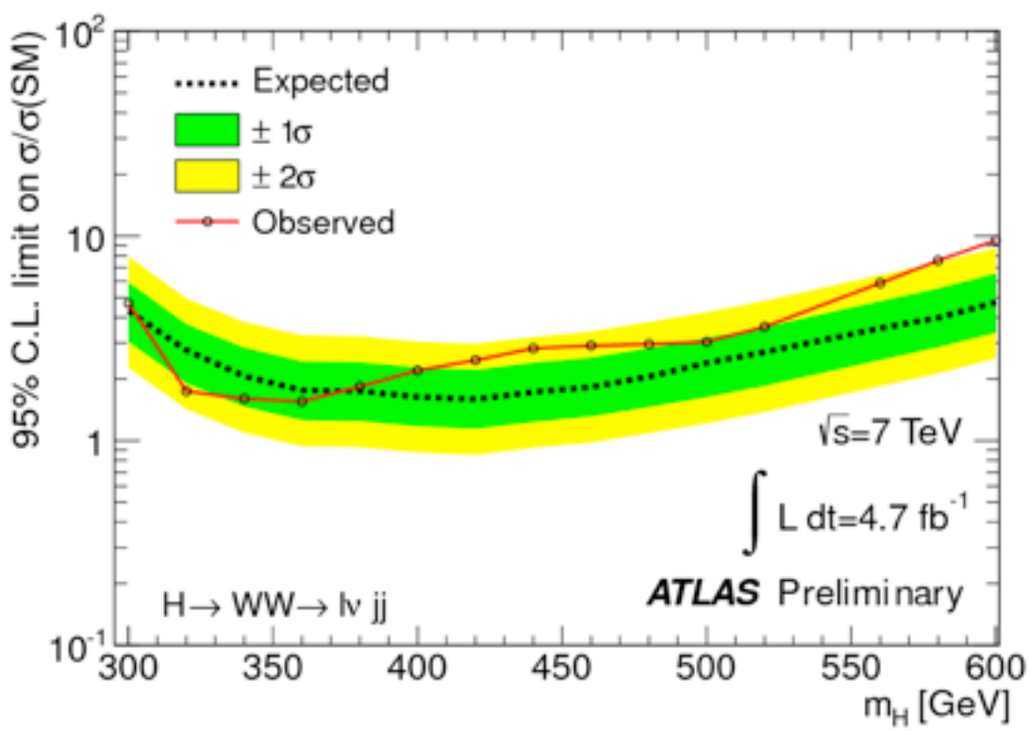
- ATLAS
  - transverse mass distribution
- CMS
  - MVA based analysis increased sensitivity.

Other H → WW channels

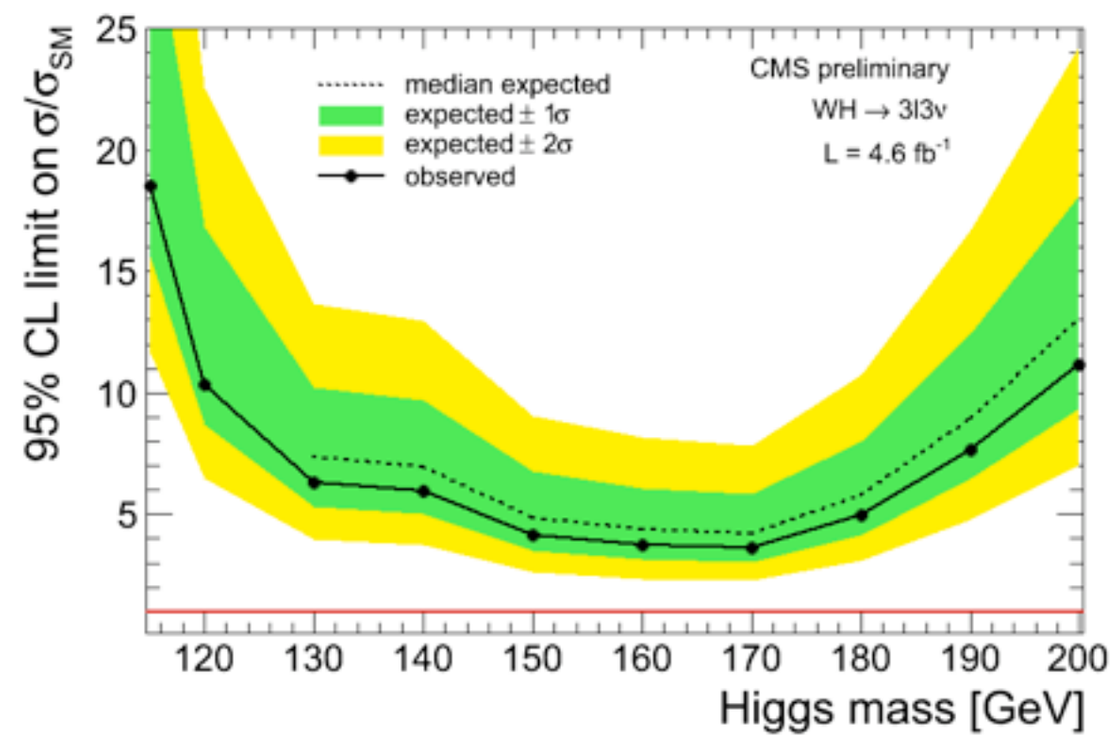
- H → WW → lνjj
- Search for a bump in $M_{l\nu jj}$ Distribution.

- WH→WWW→3l3ν
- Cut and count based

ATLAS-CONF-2012-018



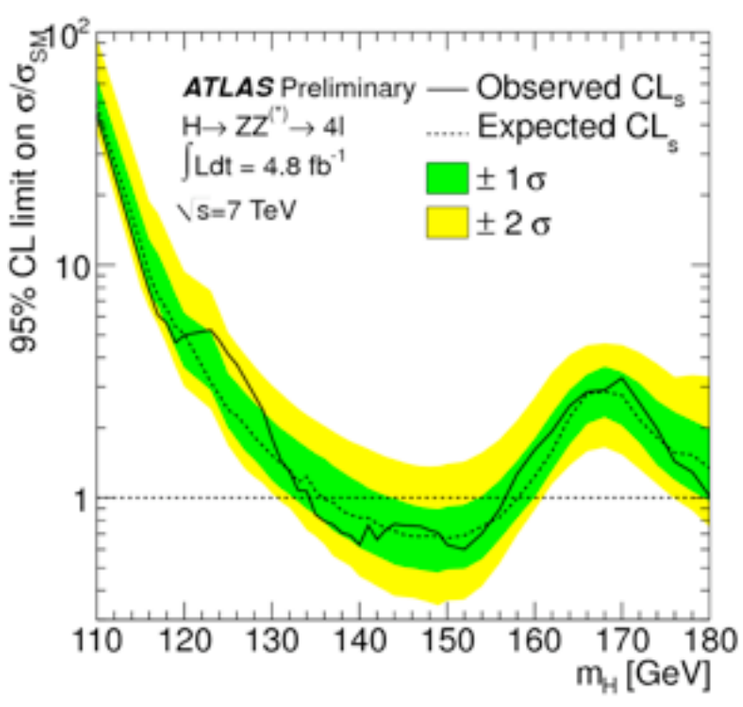
CMS-HIG-11-034

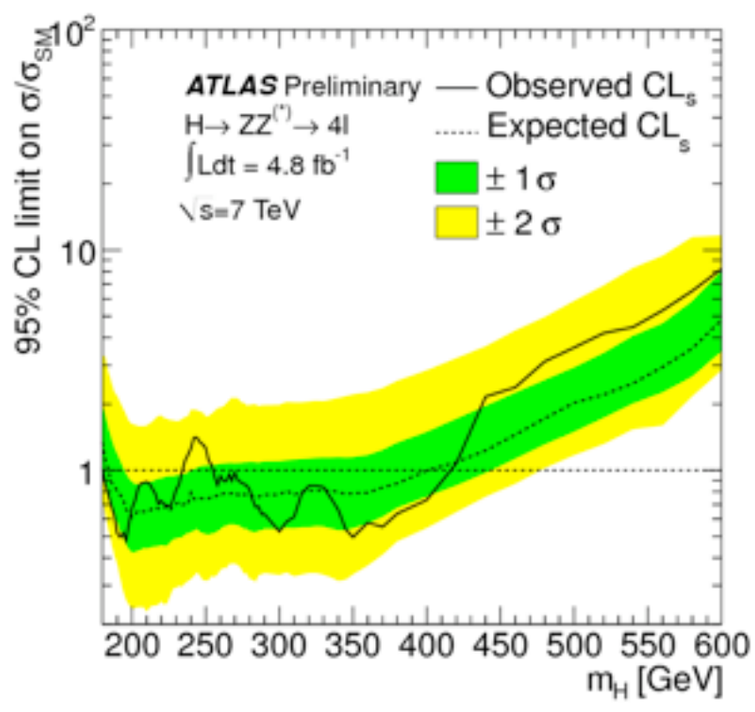


H → ZZ →4l

- Two hight mass pair of isolated e and μ
- Background : ZZ(irreducible), Z+jets, Zbb,tt,WZ
- Down to low p_T
- Good resolution 1-2%

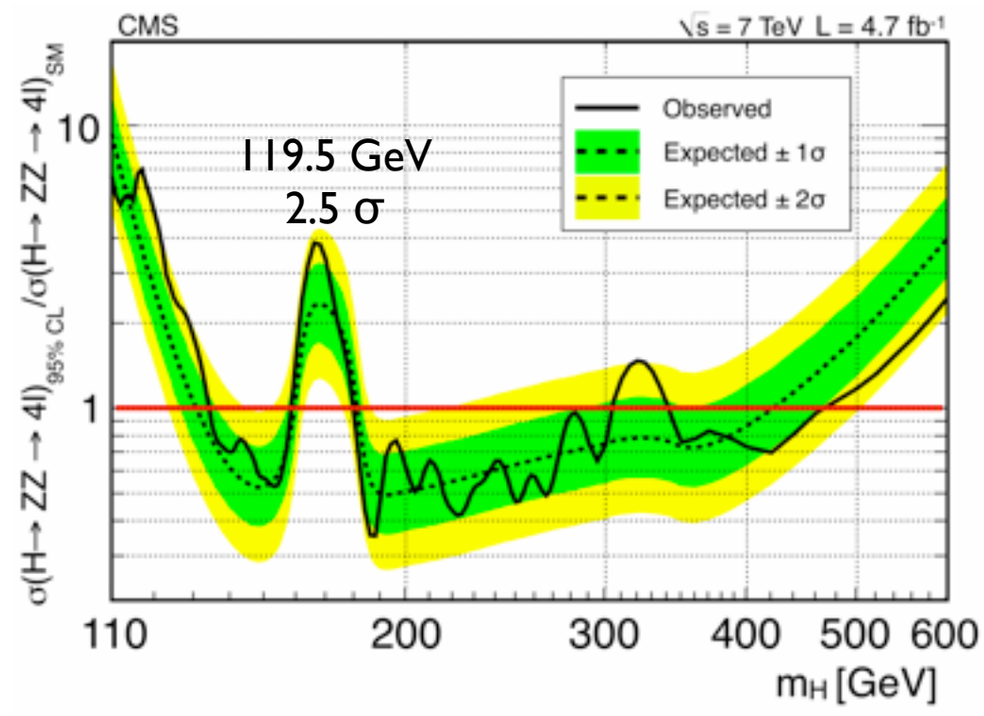
ATLAS-CONF-2011-162
arXiv:1202.1415





Observed exclusion
[134-156],[182-233],[256-265],[268-415] GeV

CMS
arXiv:1202.1997
accepted by PRL



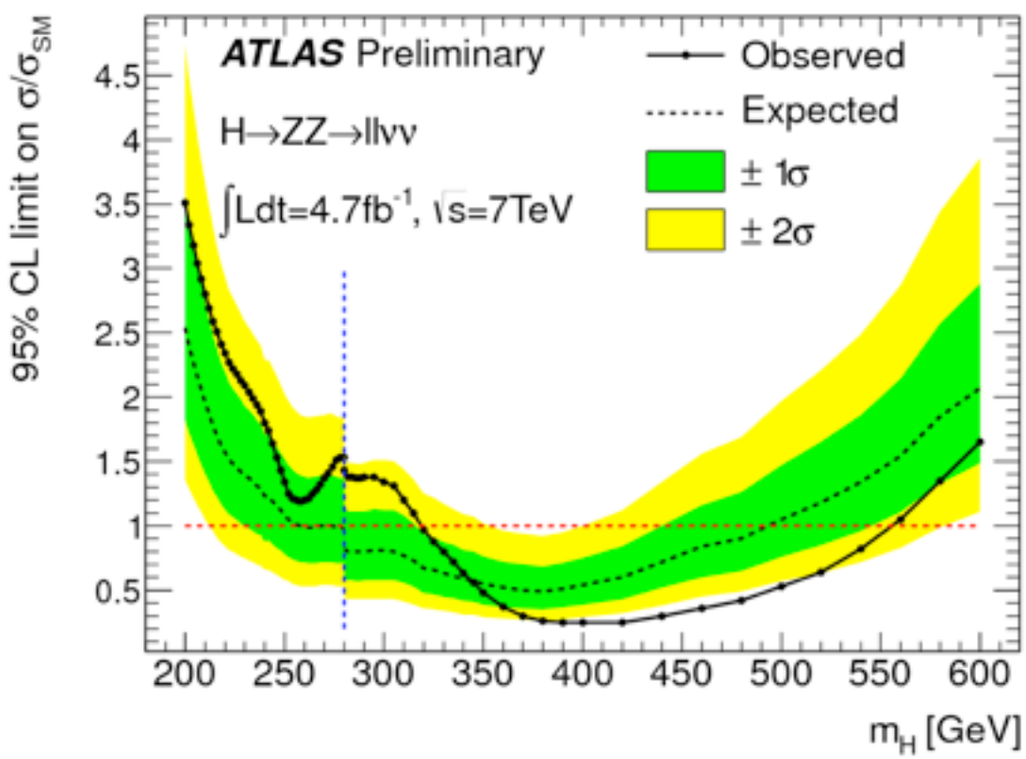
Observed exclusion
[134-158],[180-305],[340-465] GeV

H → ZZ →2l2ν

ATLAS

- Most sensitive in high mass
- M_T distribution for limit setting
- divide into low and high mass

ATLAS-CONF-2012-016

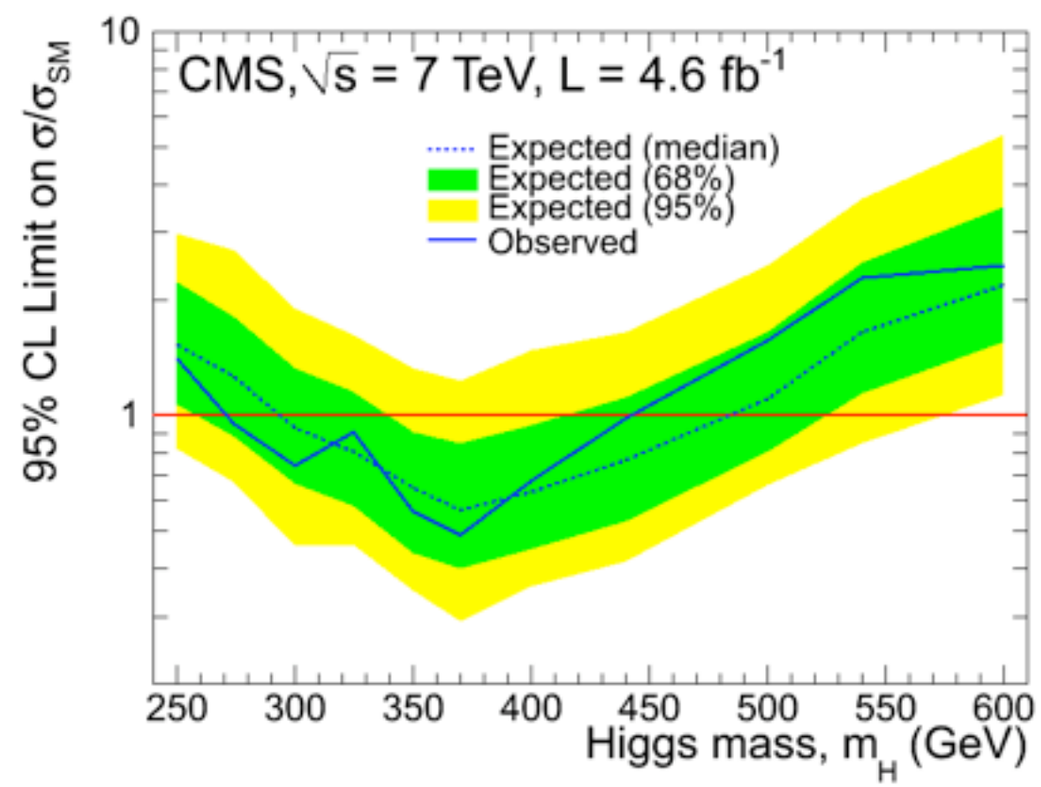


- Observed exclusion
  - [320-560] GeV at 95%

CMS

- large MET due to invisible decay
- cut and count
- mass shape

CMS-HIG-11-026
arXiv:1202.3478

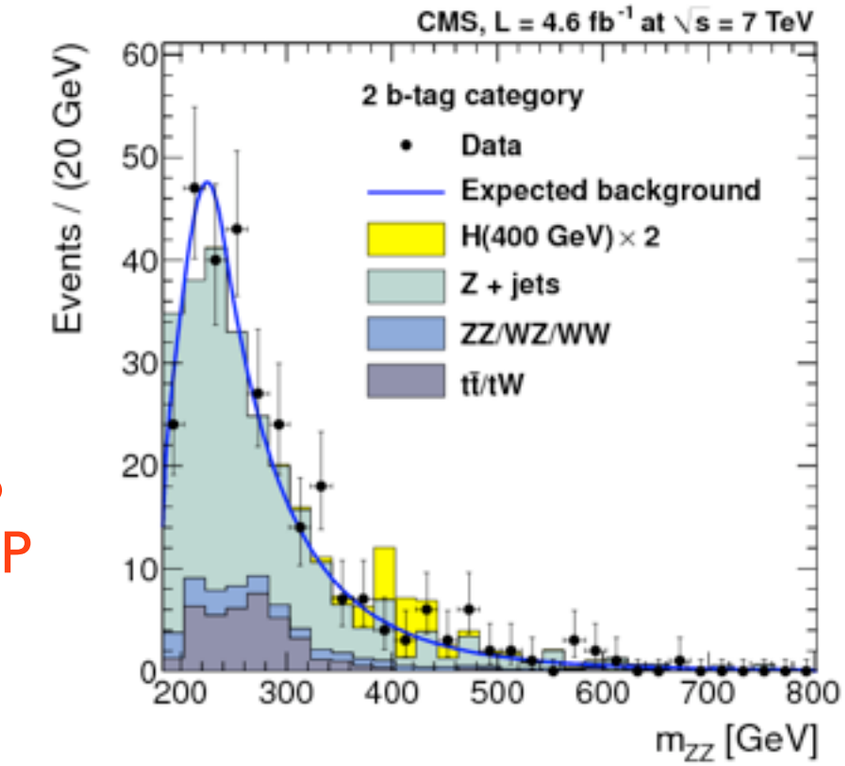


- Observed exclusion
  - [270-440] GeV at 95%

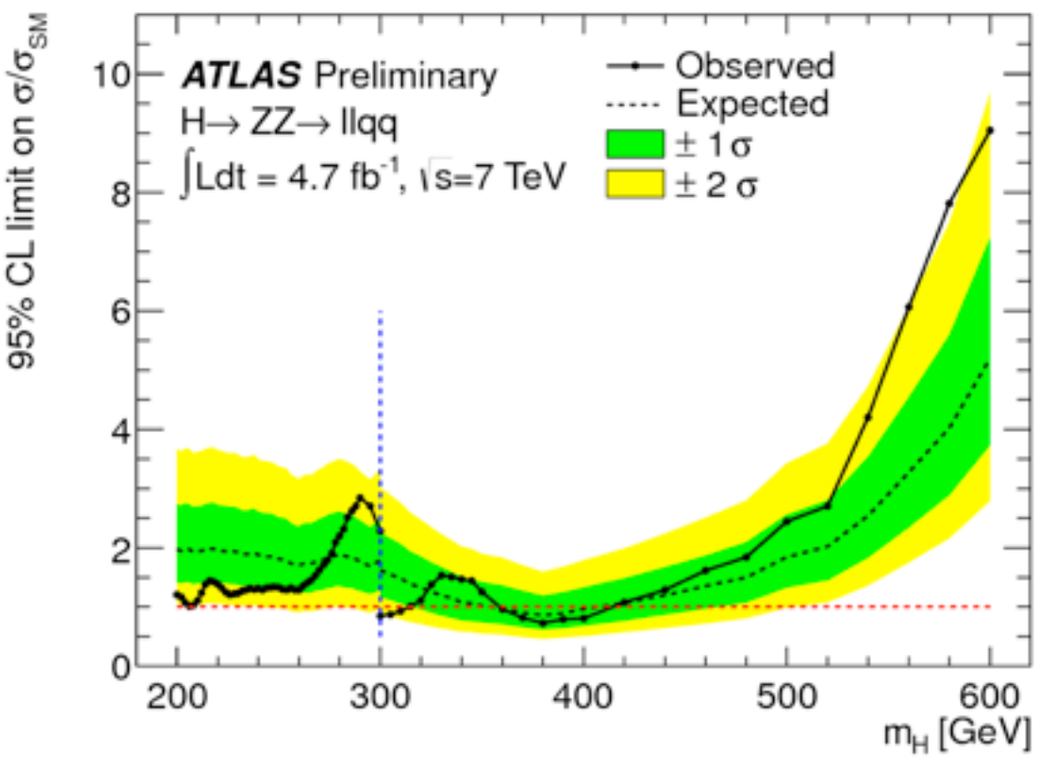
H → ZZ →2l2q

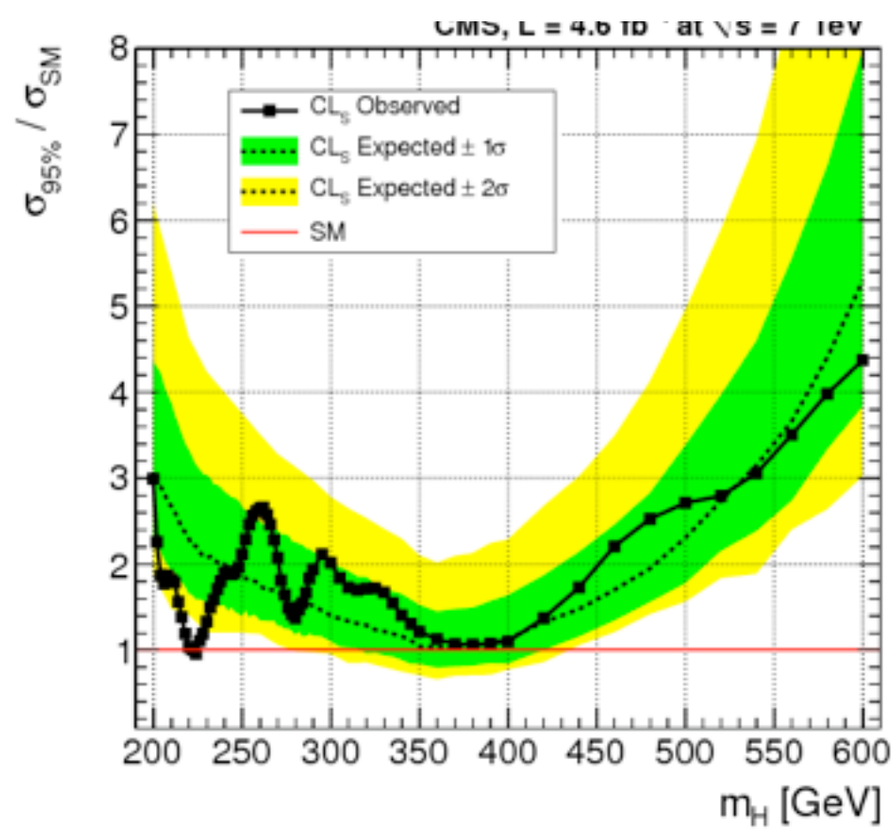
- ATLAS
  - 2 sub-channels (untag, b-tag)
  - M_{lljj} distribution for limit setting
- CMS
  - MVA analysis : kinematic and topological quantities.

CMS
arXiv:1202.1416
Submitted to JHEP



ATLAS-CONF-2012-017



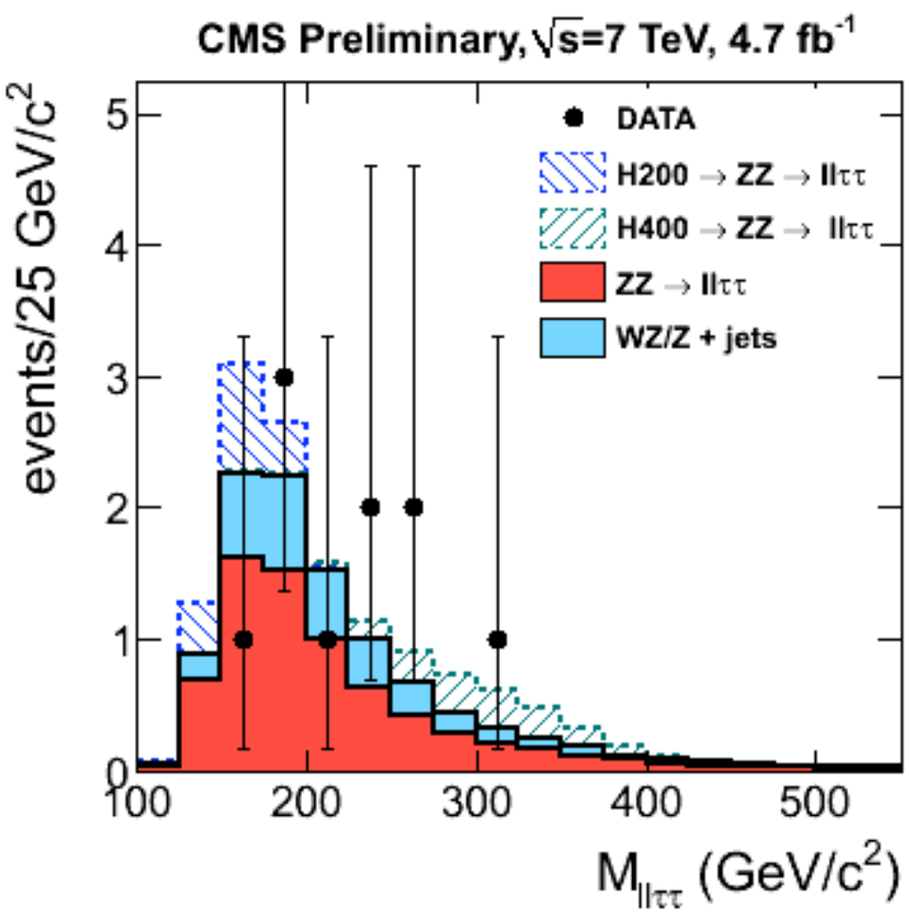


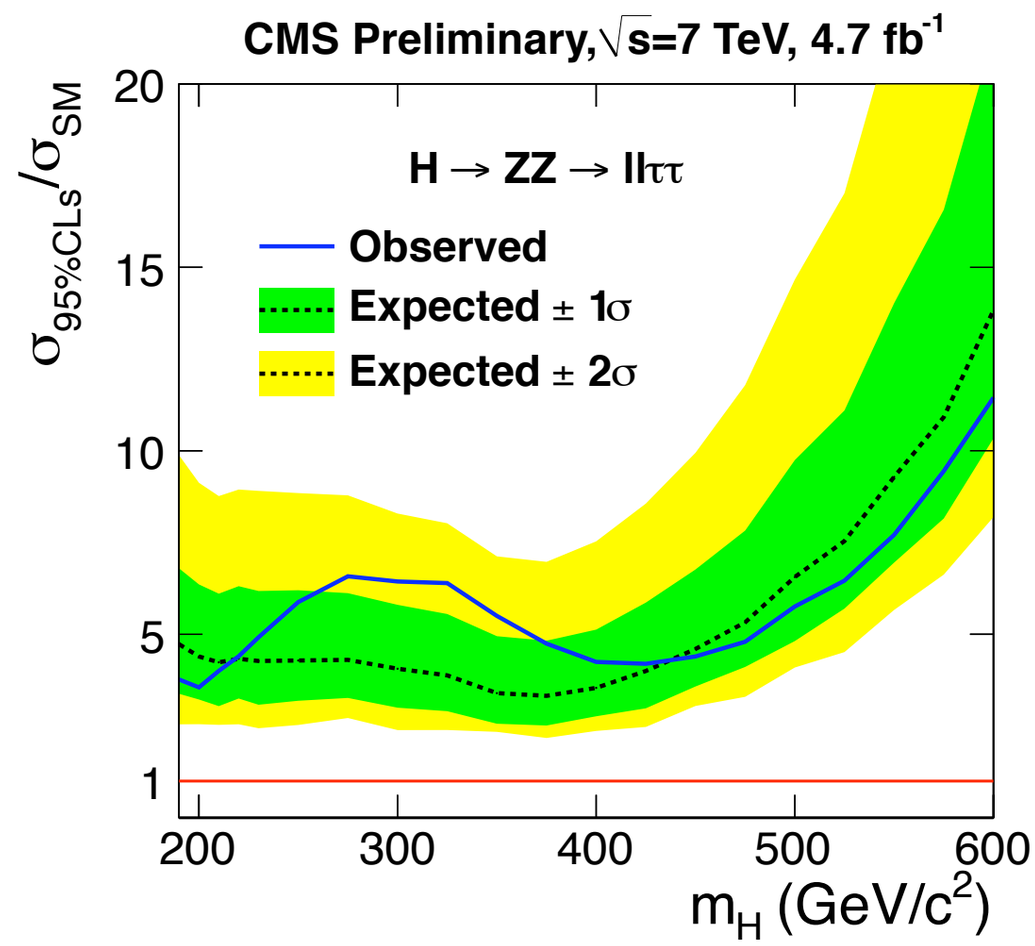
- Observed exclusion
  - [300-310],[360-400] GeV at 95%

H → ZZ →llττ (CMS)

- Searched in all τ decay

arXiv:1202.3617
Accepted by JHEP

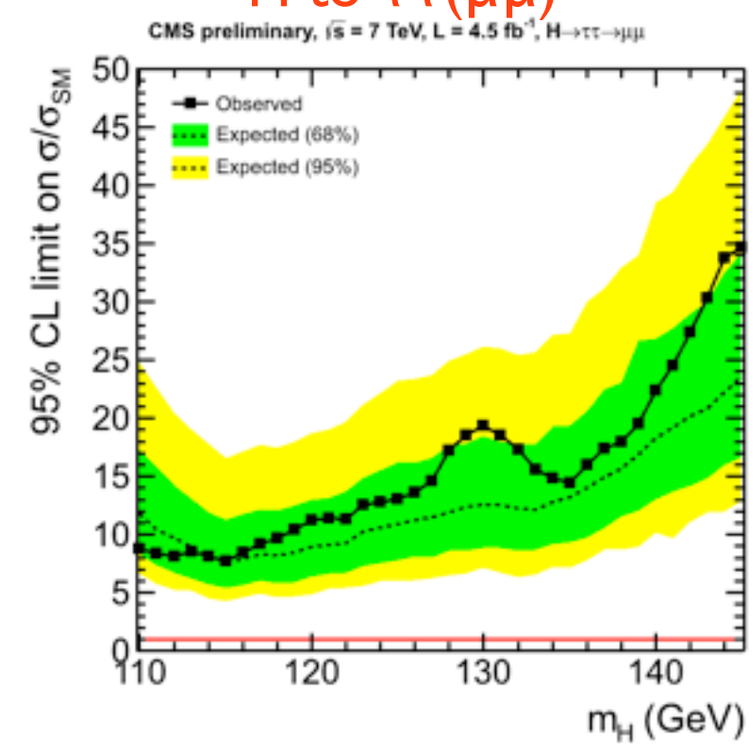




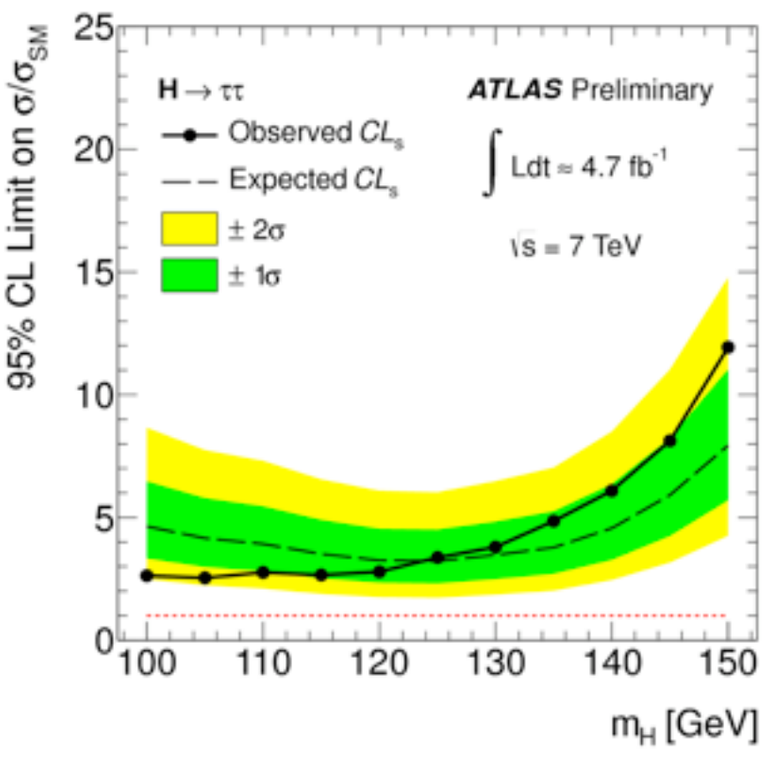
H → ττ

- No narrow mass peak (σ_M~20 %)
- ATLAS
  - Three sub channels based on tau decay
- CMS
  - VBF production, two additional forward jets
  - Boosted one jet with pT > 150 GeV
  - gg-fusion 0 or 1 additional jets

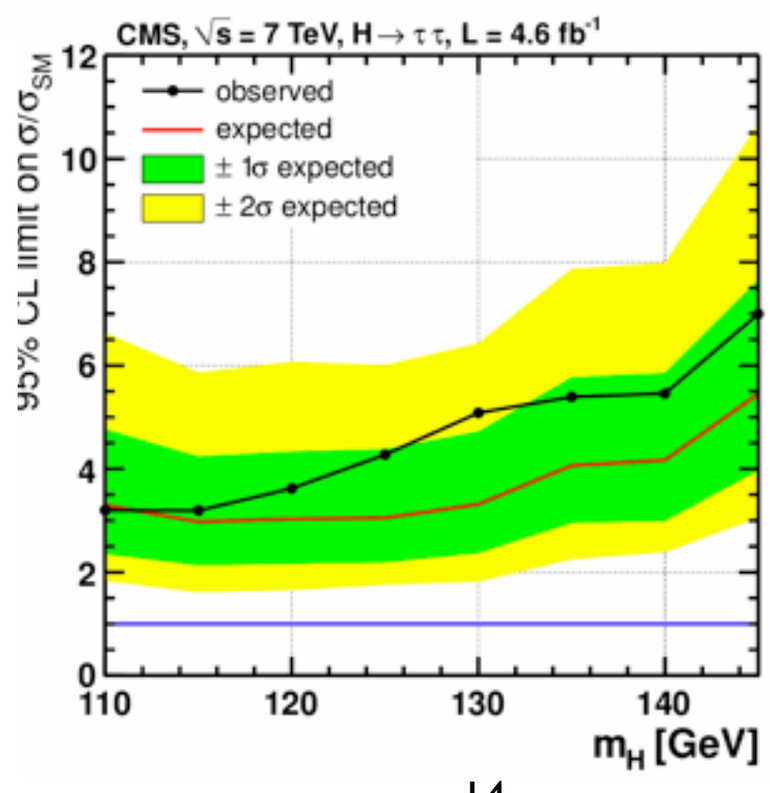
CMS-HIG-12-007
H to ττ(μμ)



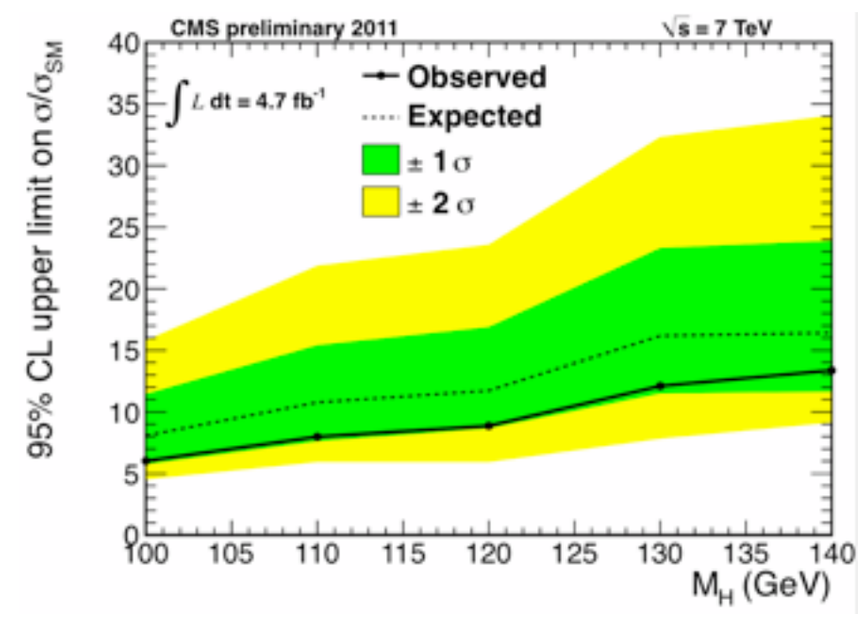
ATLAS-CONF-2012-014
H→ ττ→ll4ν,
lτ3ν,ττνν



CMS
arXiv:1202.4083
Submitted to PLB
H→ττ→μτ$_h$, μτ$_h$,eμ



CMS-HIG-12-006
WH→lττ→eμτ$_h$, μμτ$_h$

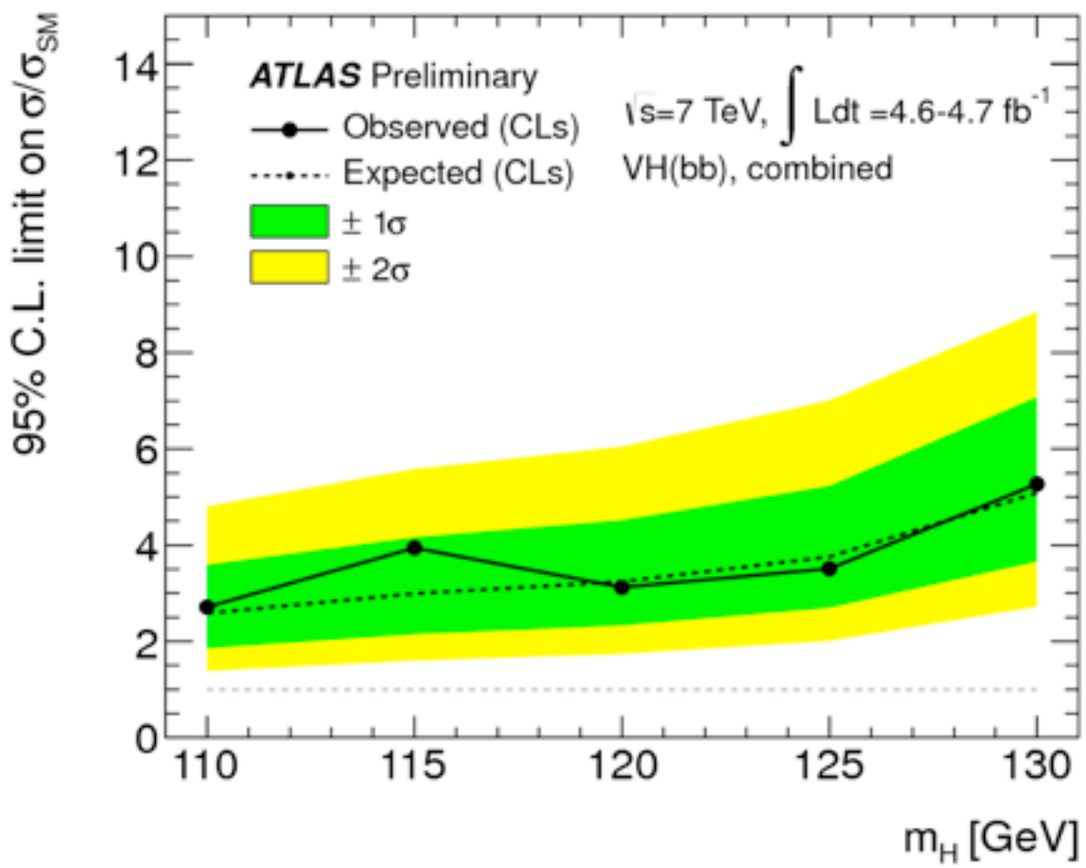


H → bb

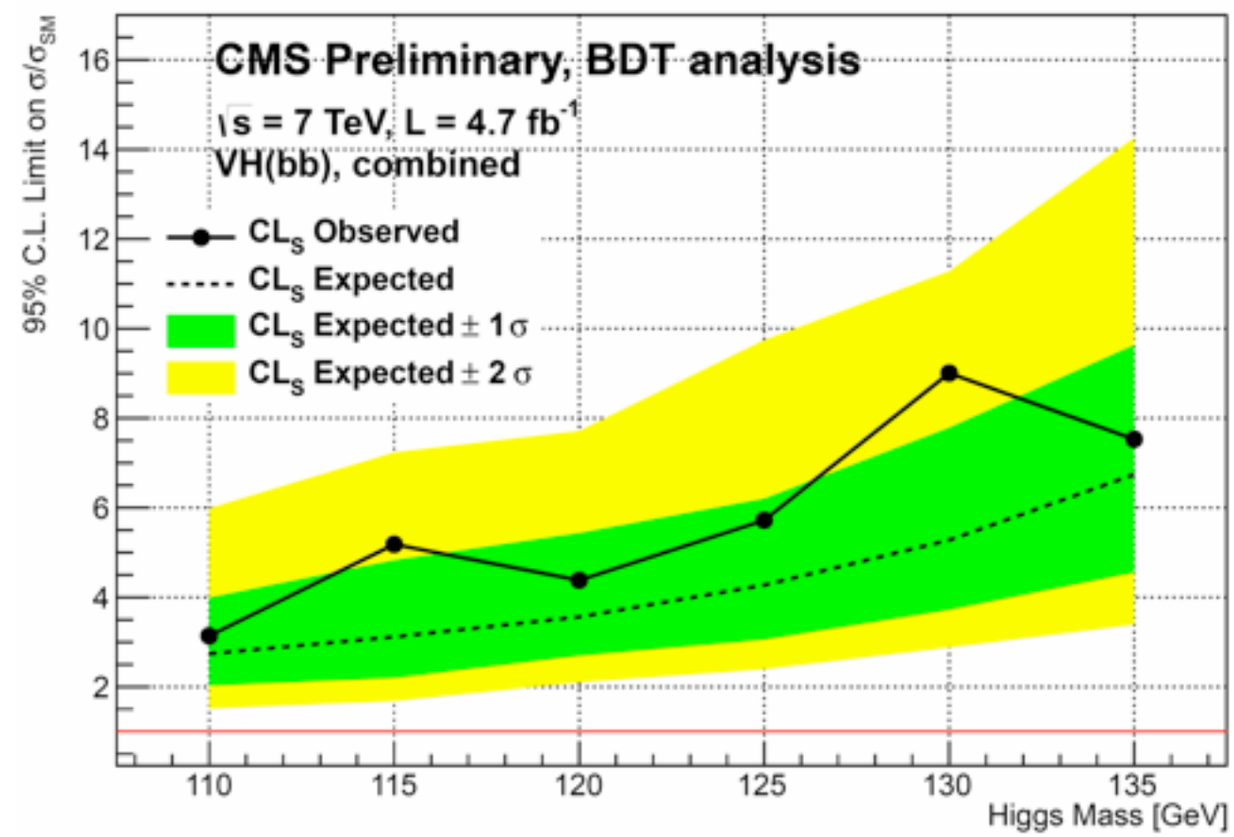
- Low mass
- Background is too large
- VH associated production

- W → e,μ
- Z →ee, μμ,νν

ATLAS-CONF-2012-015



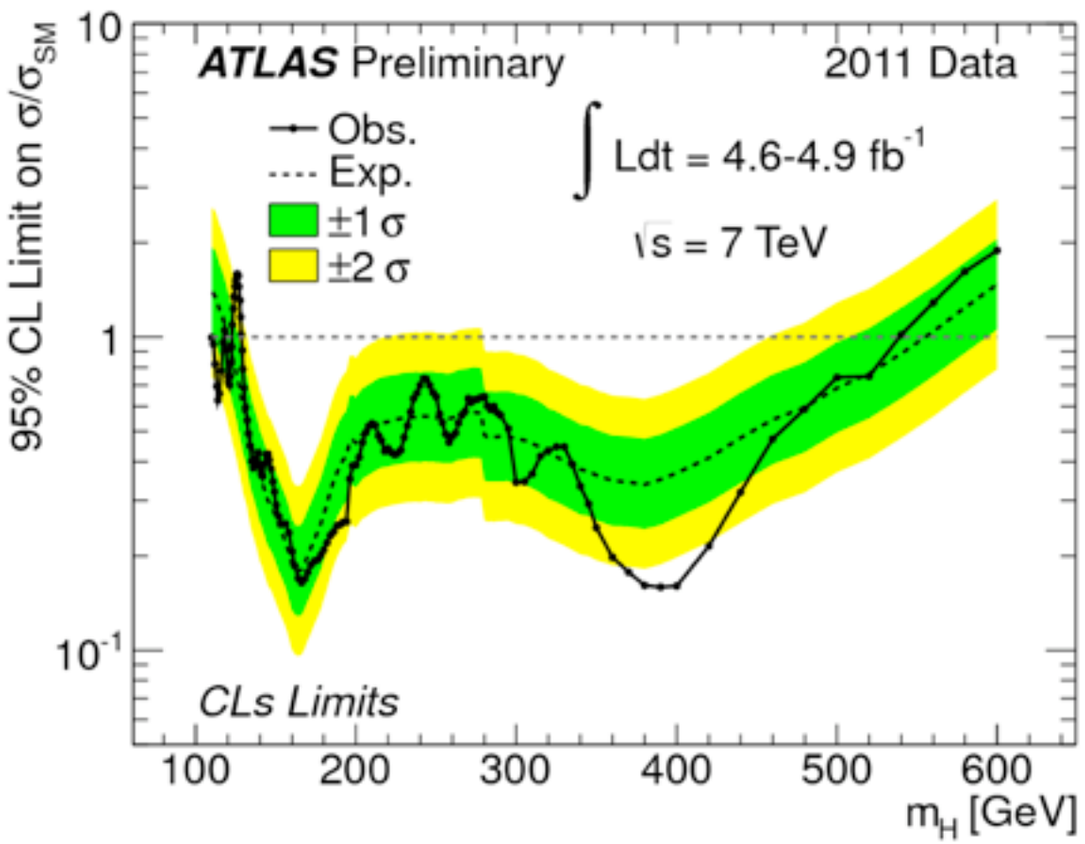
CMS
arXiv:1202.4195
submitted to PLB

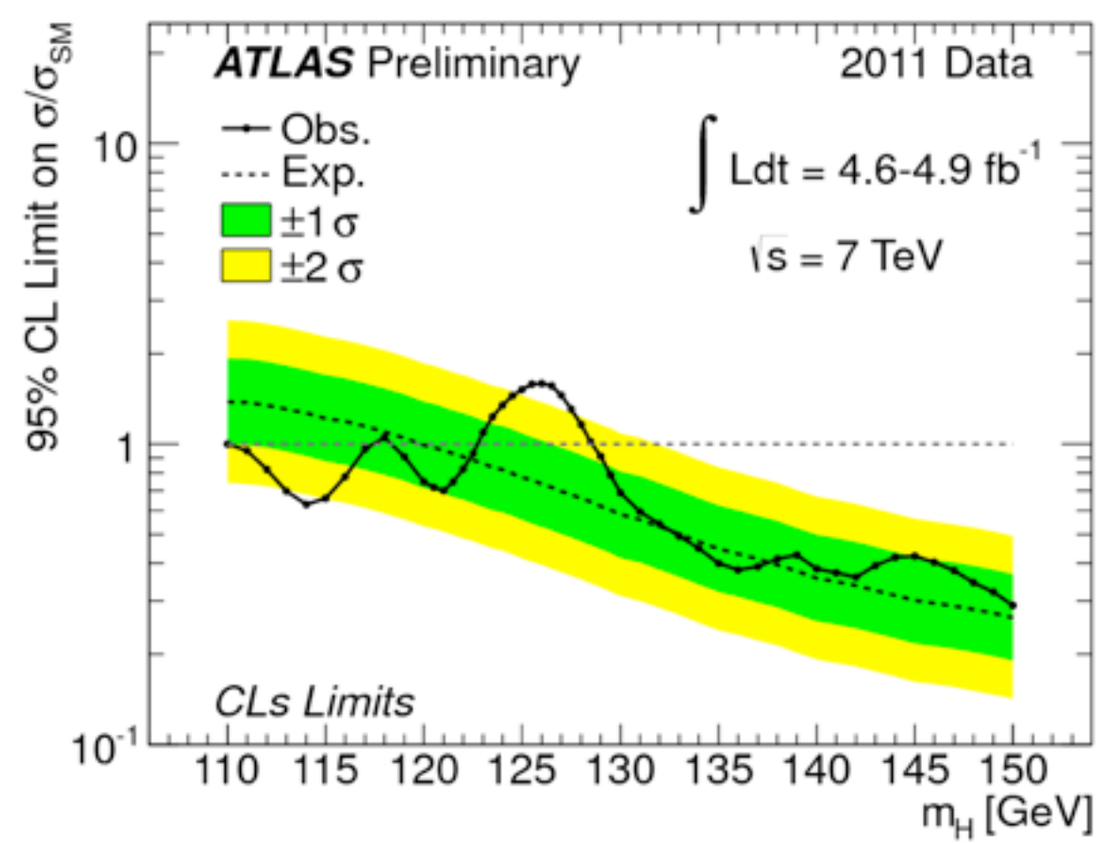


3-9×SM limit at 95 %

Combination SM (ATLAS)

ATLAS-CONF-2012-019
arXiv:1202.1408

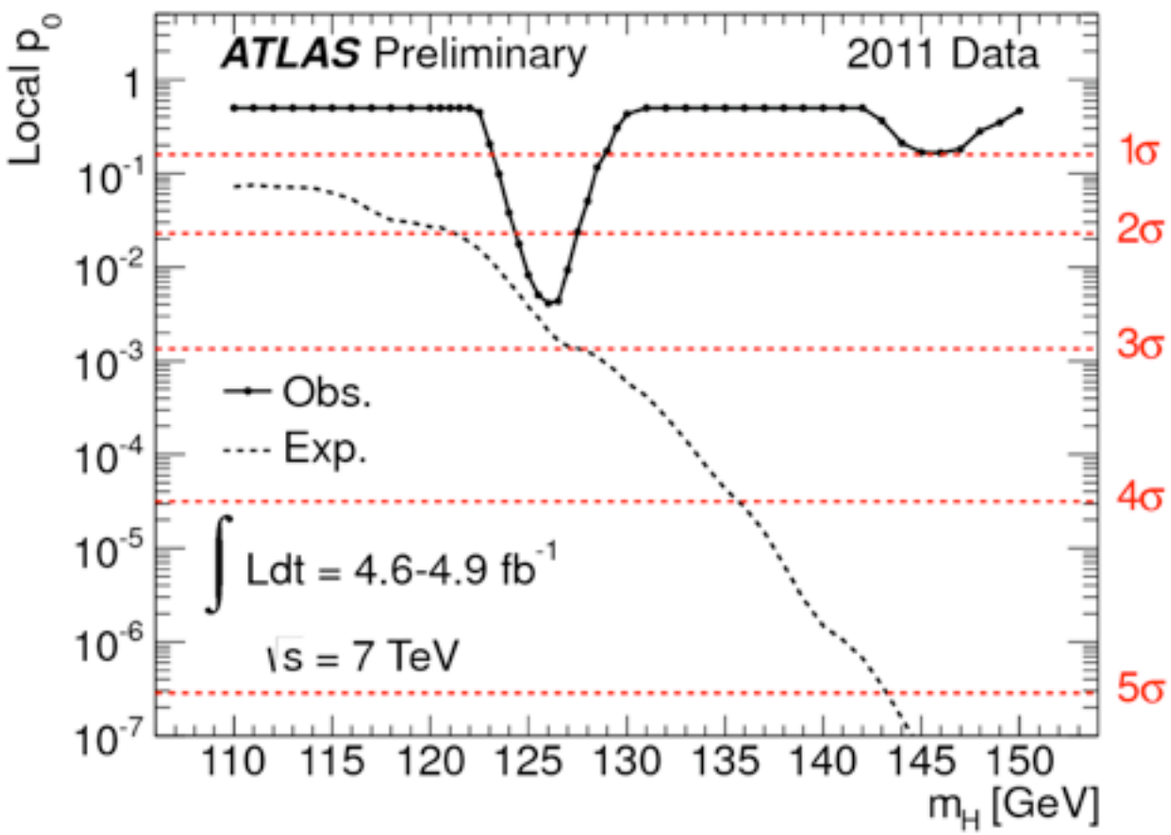


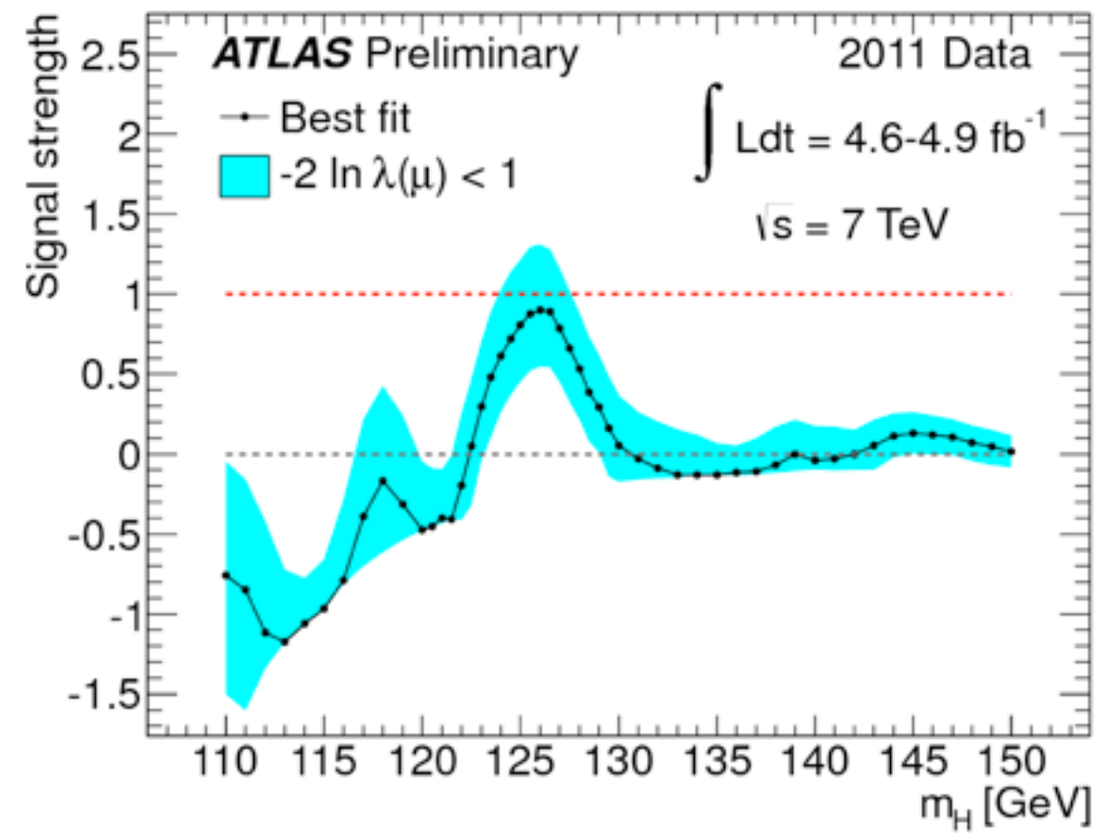


- Observed exclusion [110-117.5],[118.5-122.5],[129-539] GeV at 95%

Combination SM (ATLAS)

ATLAS-CONF-2012-019
arXiv:1202.1408



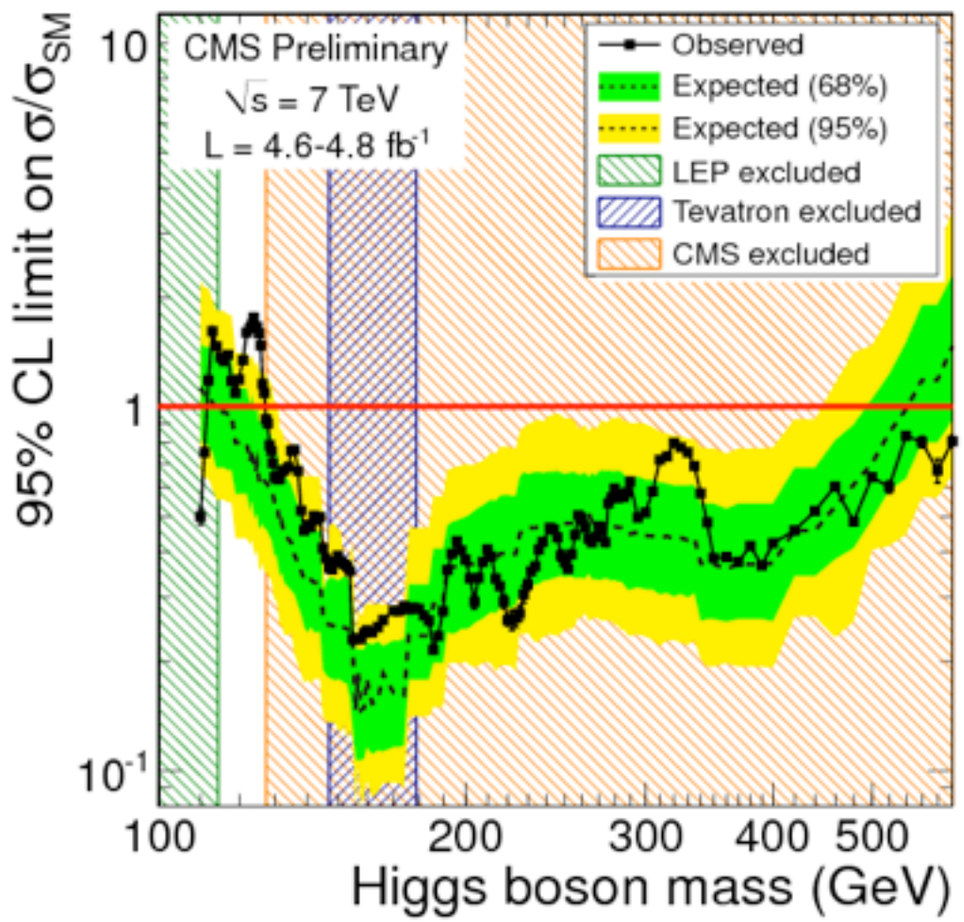


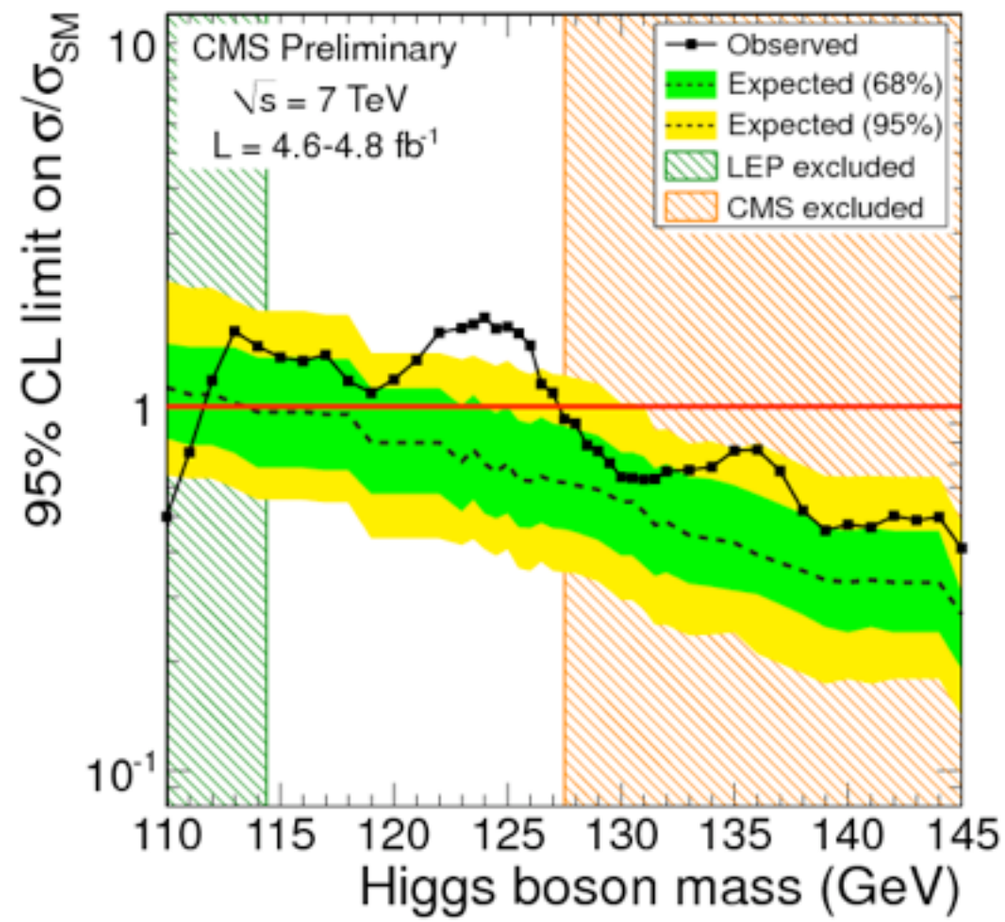
- Local significance : 2.5 σ at 126 GeV
- The probability
  - 30% in the range 110-600 GeV
  - 10% in the range 110-146 GeV

- Best fit signal strength at 126 GeV ~ 0.9

Combination SM (CMS)

CMS-HIG-12-008

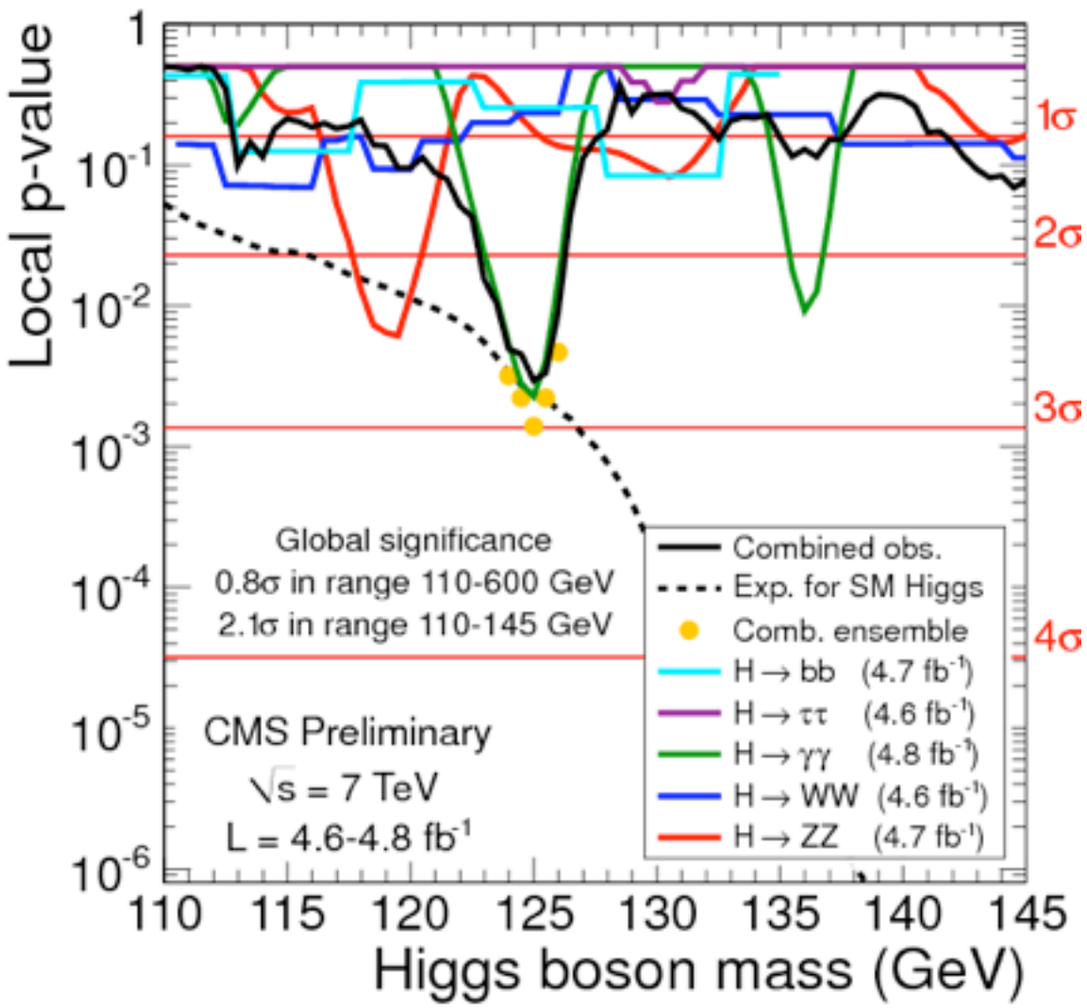


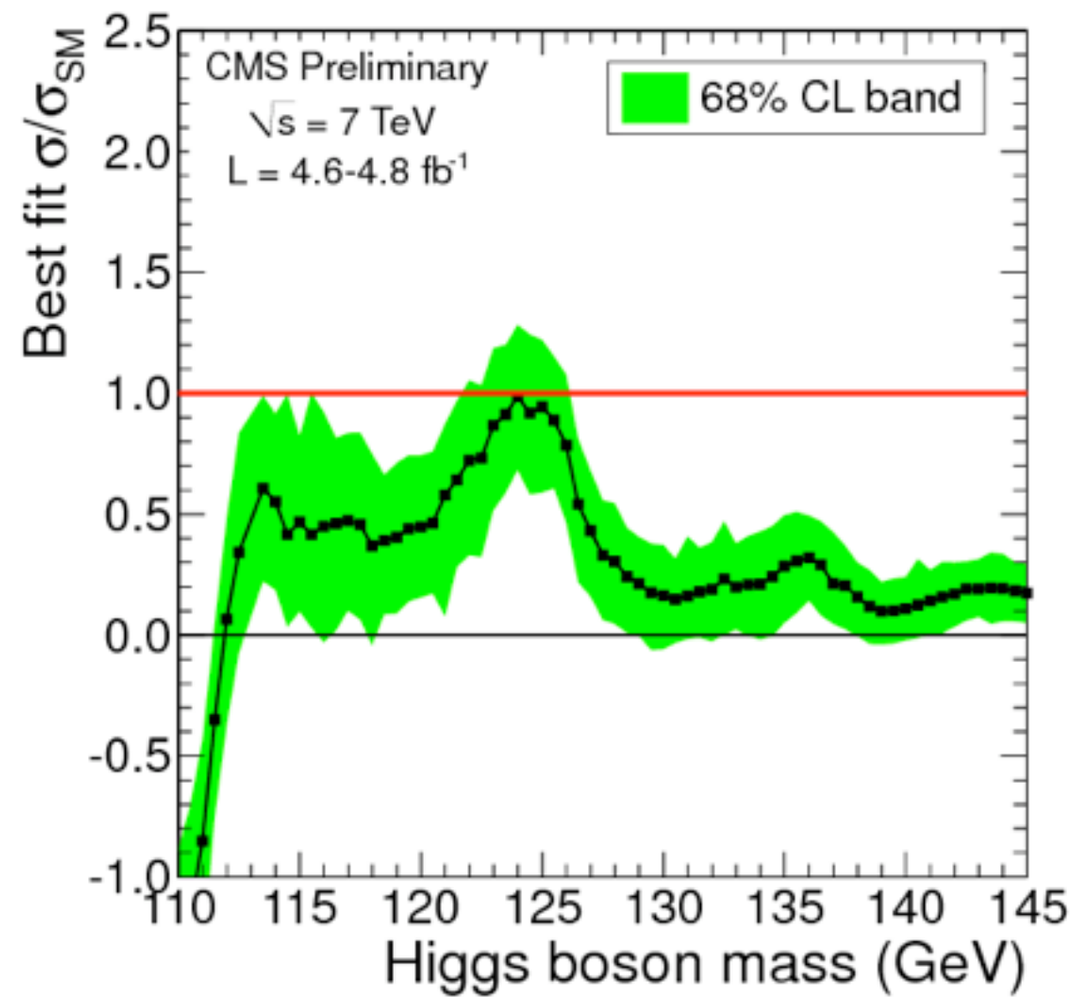


- Observed exclusion [127.5-600] GeV
- 95 % allowed mass range : 114.4-127.5 GeV
- Observed limit is higher than expected due to the excess in data at low mass.

Combination SM (CMS)

CMS-HIG-12-008





- Local significance : 2.8 σ at 125 GeV
- Global significance
  - 0.8σ in range 110-600 GeV
  - 2.1σ in range 110-145 GeV

- The fitted σ of the excess near 125 GeV is consistent with the SM scalar boson expectation.

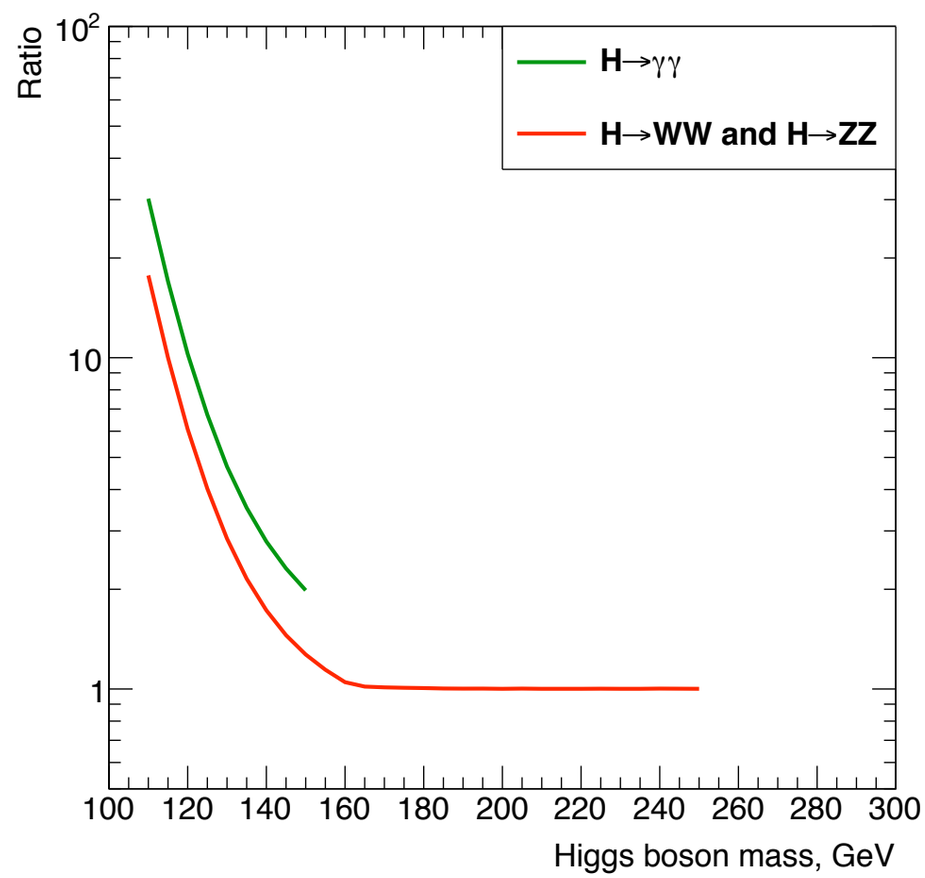
BSM HIGGS

BSM HIGGS

- Fermiophobic Higgs
- MSSM Higgs
- Light pseudoscalar Higgs
- Doubly charged Higgs
- 4th generation Higgs (SM4)

Fermiophobic higgs

- Gluon-gluon process (gg → H) and ttH production disappear.
- Production via Vector-Boson Fusion and associated VH.
- H →bb, H →ττ are impossible. H →γγ is enhanced.

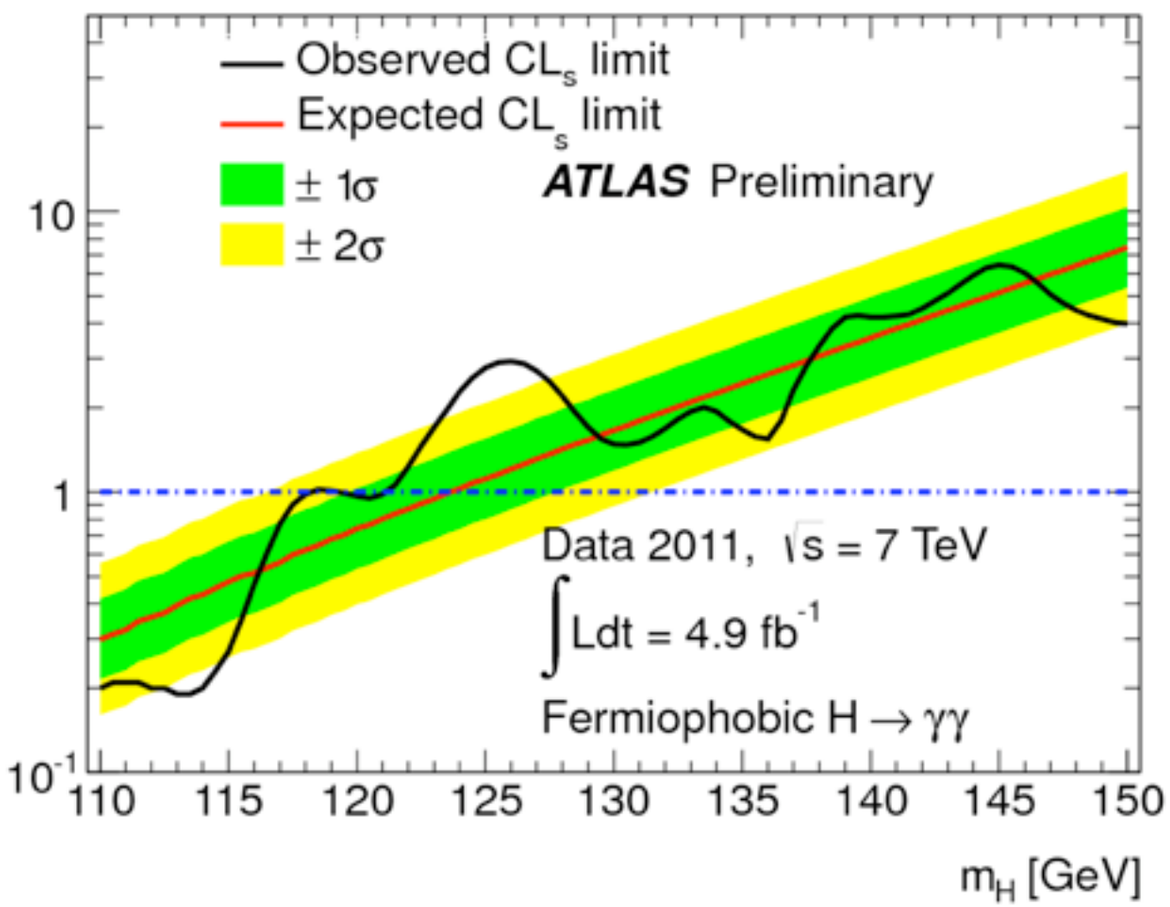


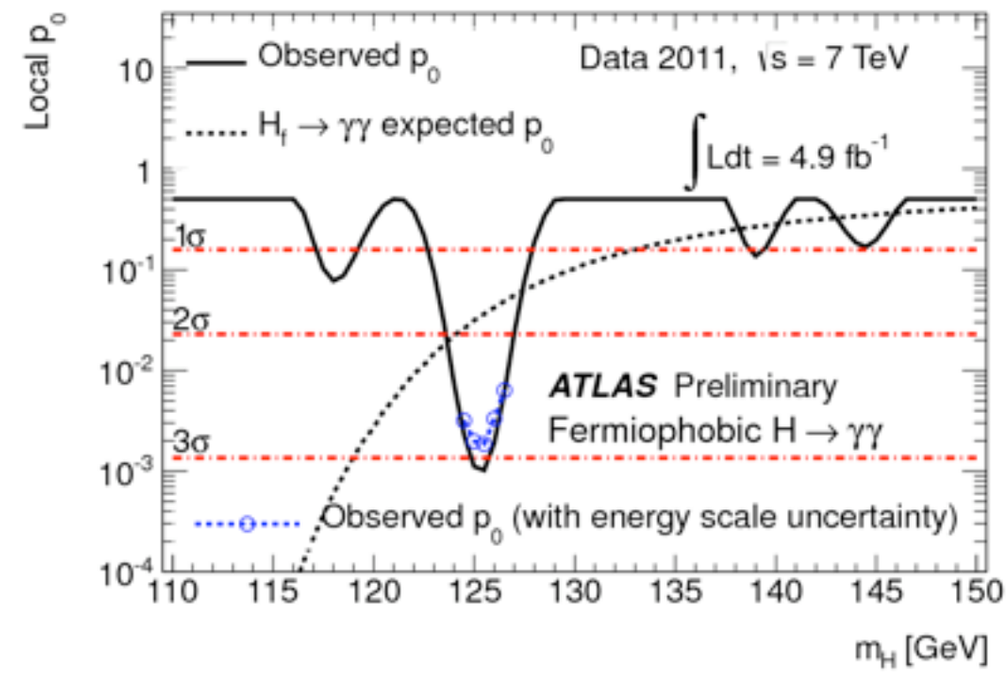
Fermiophobic Higgs (ATLAS)

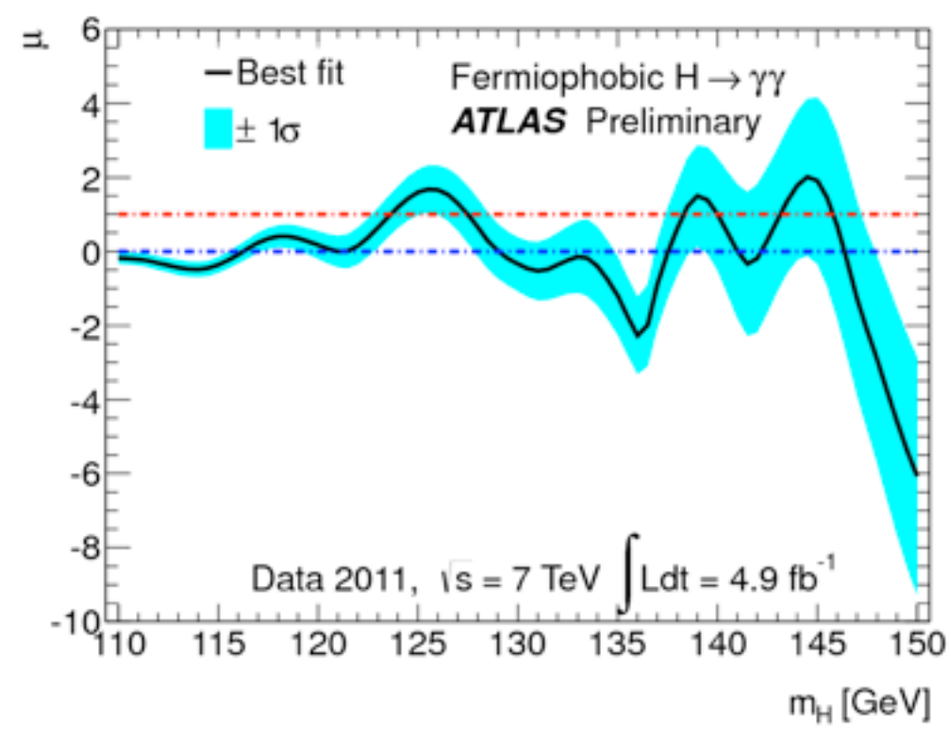
ATLAS-CONF-2012-013

1.6 σ (with look elsewhere)

H →γγ



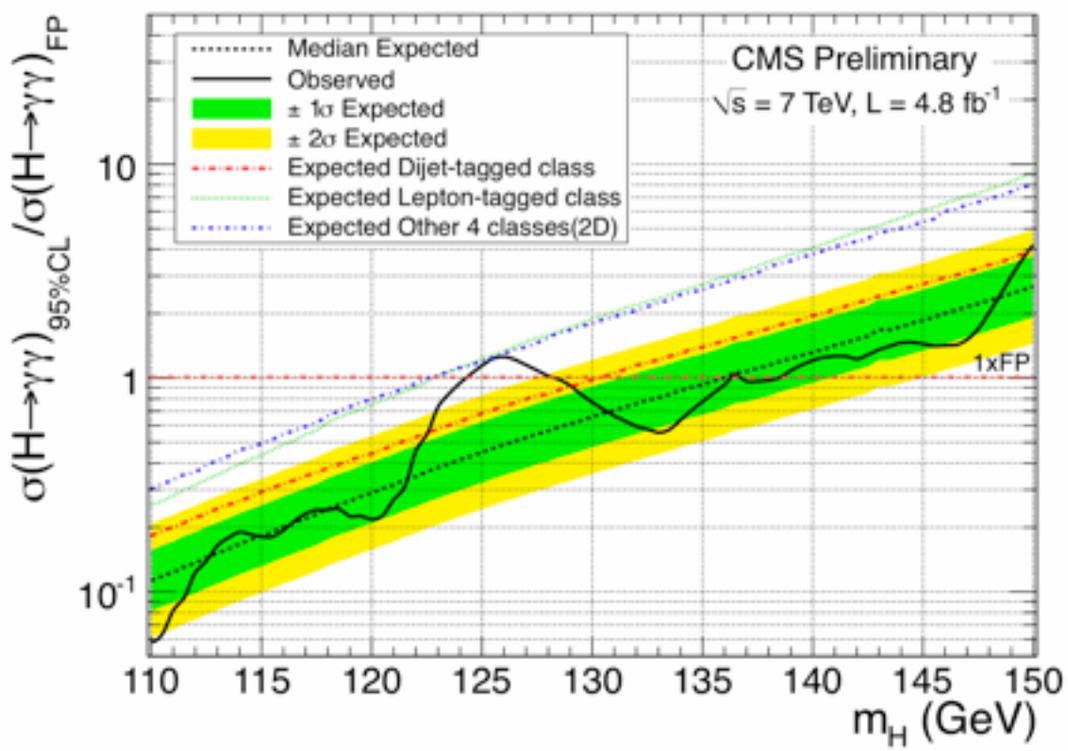




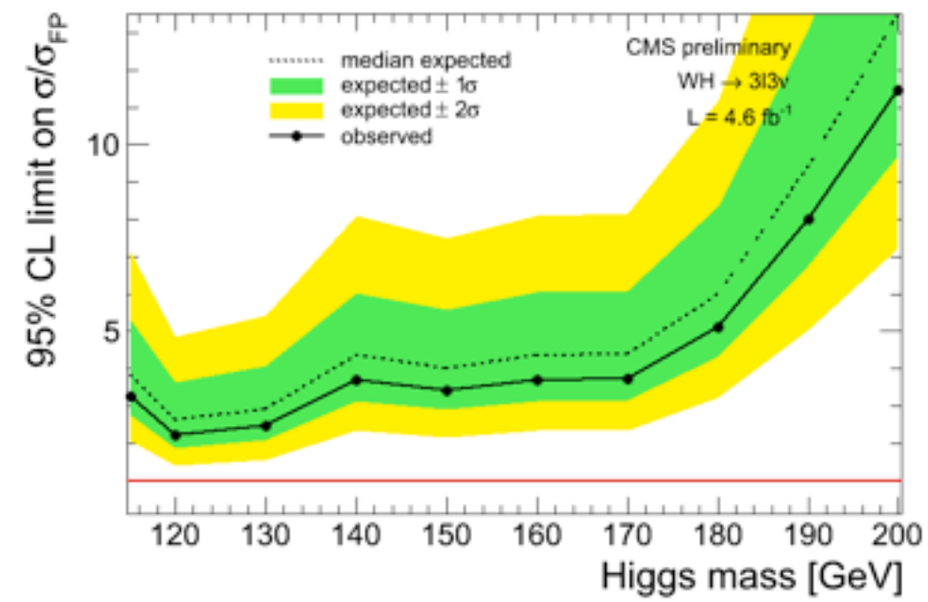
- Observed exclusion : [110,118.0],[119.5,121.0] GeV

Fermiophobic Higgs (CMS)

CMS-HIG-12-002
H →γγ

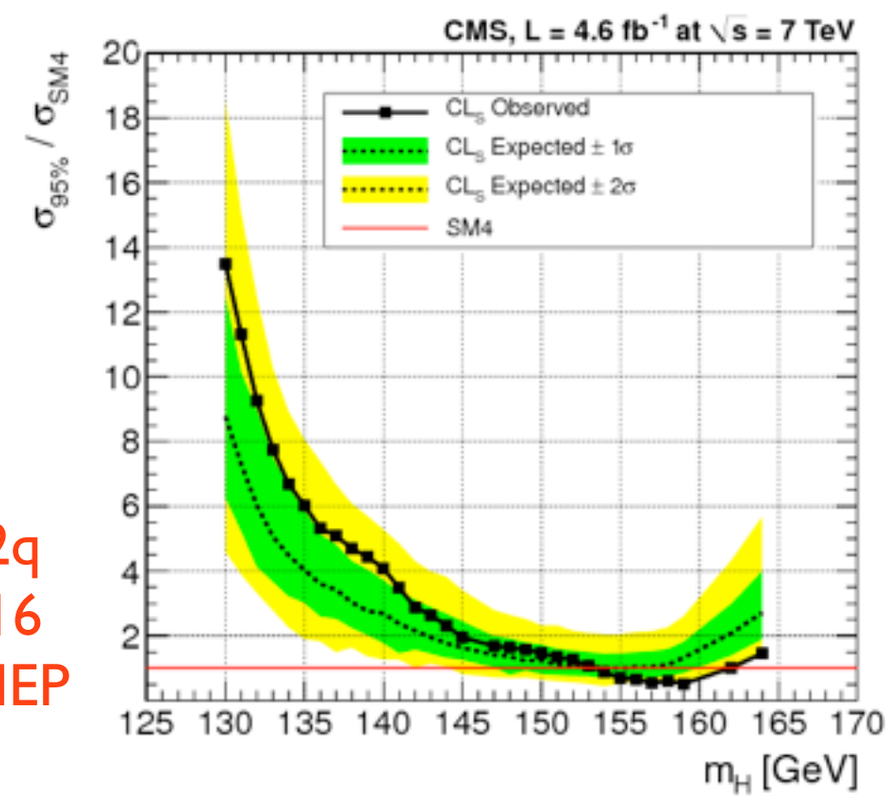


CMS-HIG-11-034
WH→WWW→3l3ν



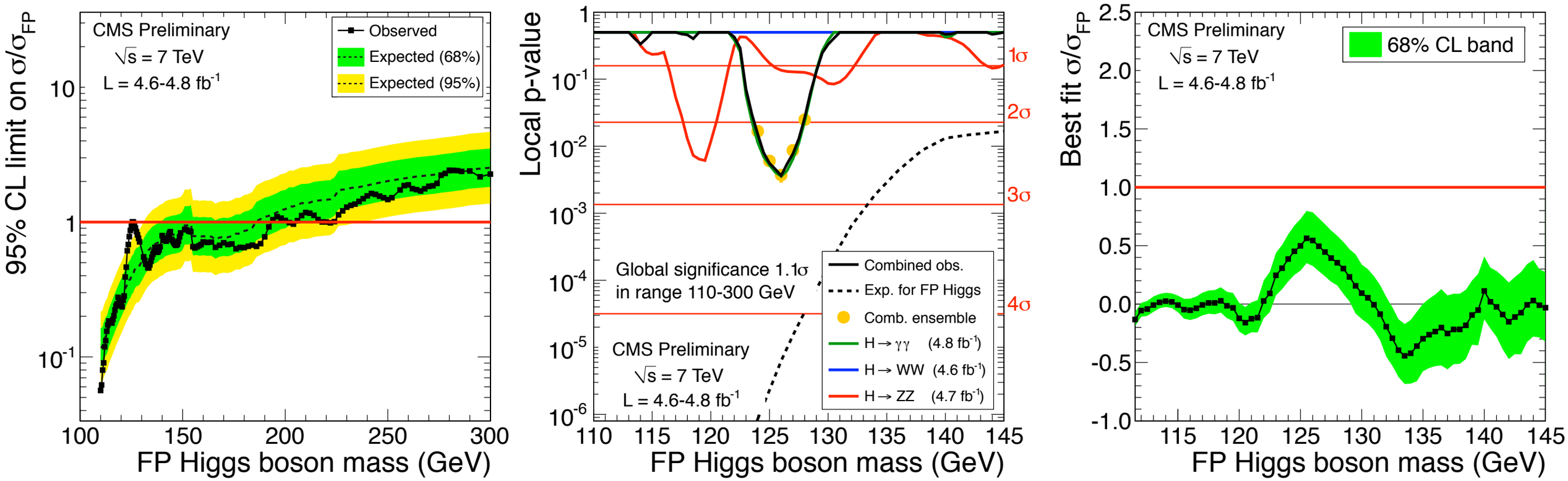
- Observed exclusion
  [110,124 GeV], [128-136 GeV]
- Local significance is 2.7 σ
- Global significance is 1.2 σ

CMS
H → ZZ →2l2q
arXiv:1202.1416
Submitted to JHEP



Fermiophobic Higgs (CMS)

Combination
CMS-HIG-12-008

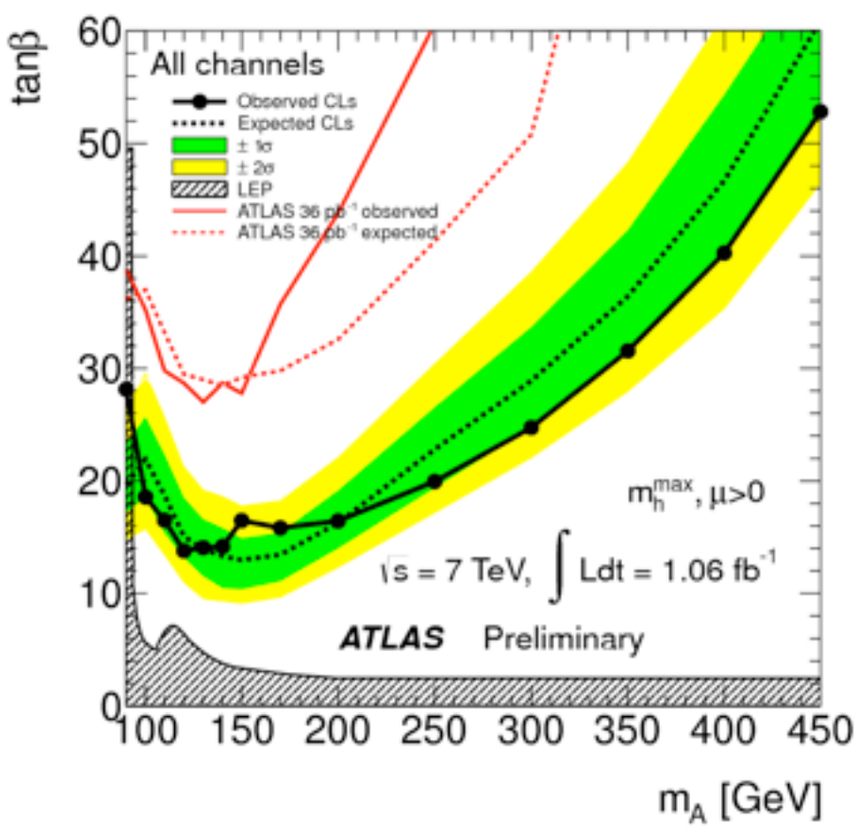


- The excess observed in the combination is too weak to be consistent with the fermiophobic higgs boson

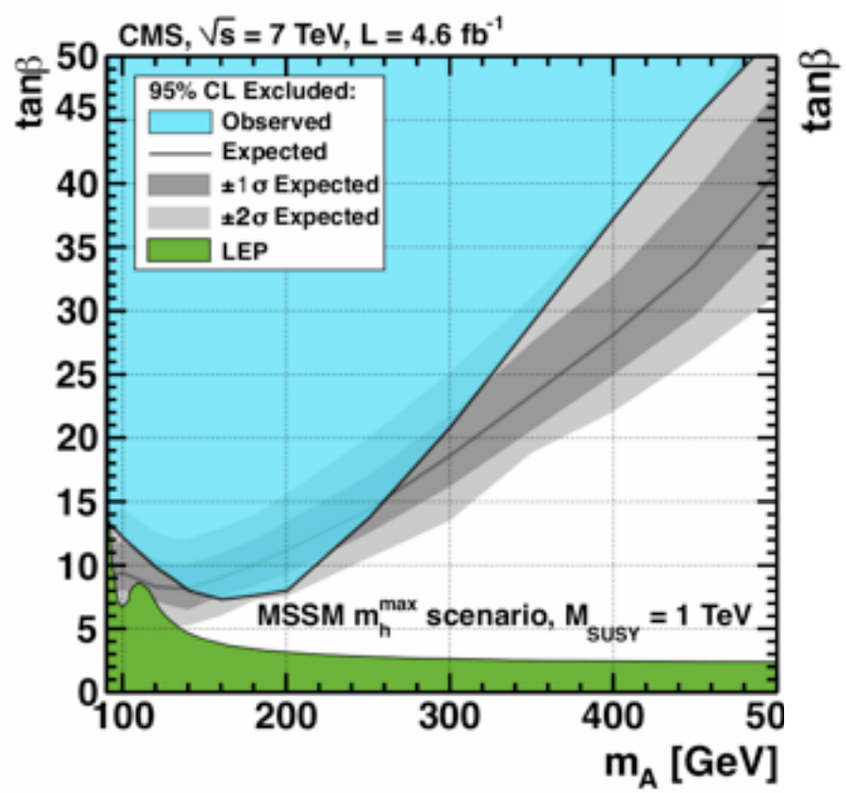
MSSM neutral higgs

- Dependence on $\tan\beta$ and M_A
- Search for $\tau\tau$ signature in $e\tau_h, \mu\tau_h, e\mu, \tau_h\tau_h$(ATLAS)
- Search for $\tau\tau$ signature in $e\tau_h, \mu\tau_h, e\mu$ (CMS)
- Search for $\tau\tau$ signature in $\mu\mu$ (CMS) → New!

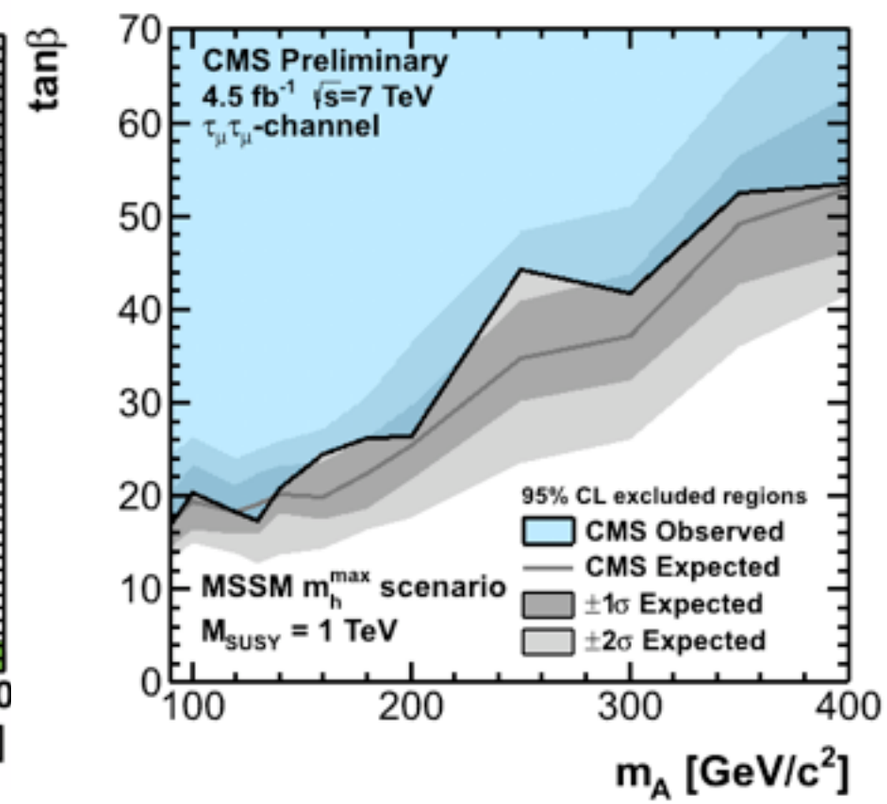
ATLAS
arXiv:1107.5003



CMS-HIG-11-027
arXiv:1202.4083



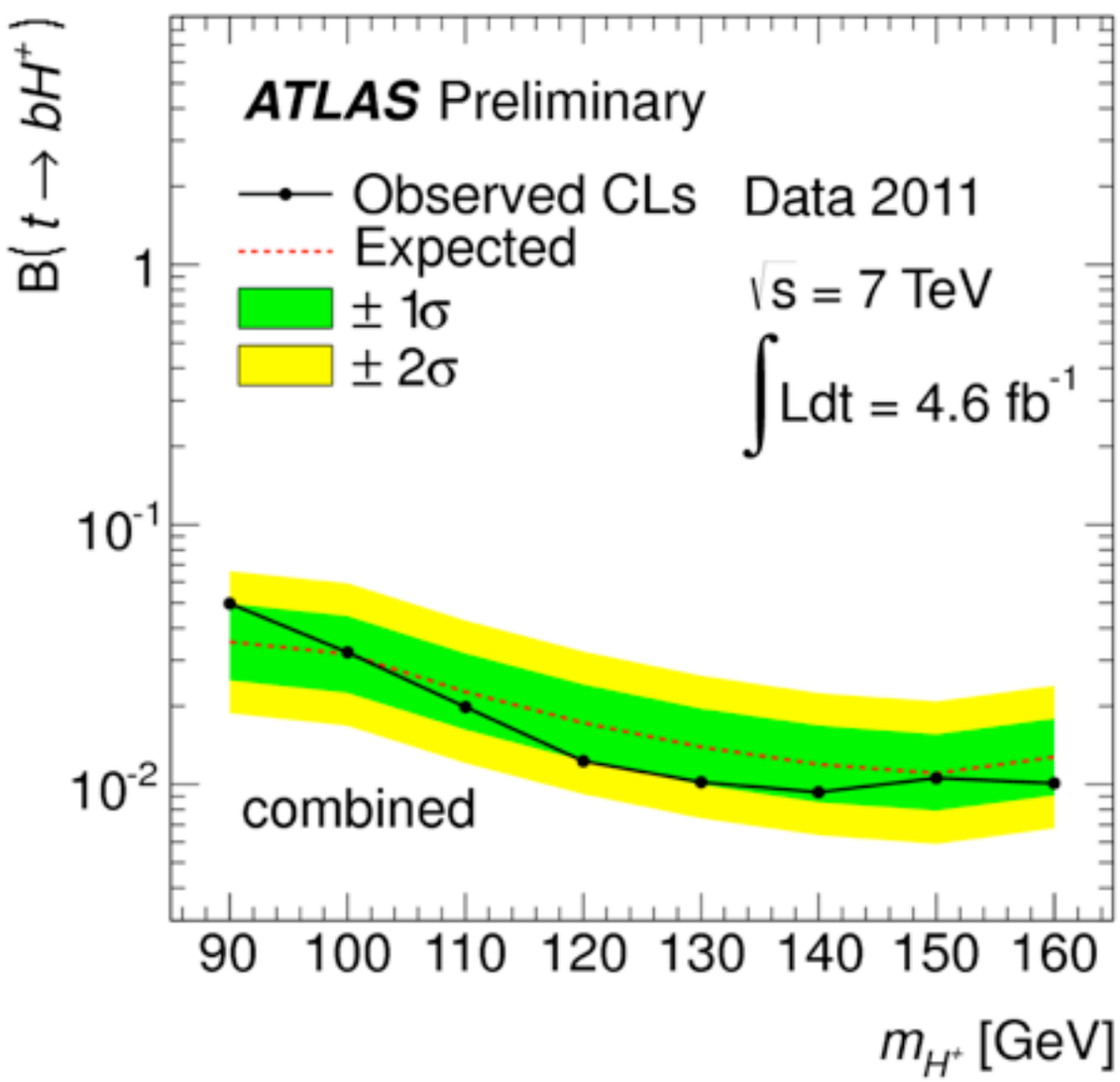
CMS-HIG-12-007
H to $\tau\tau(\mu\mu)$



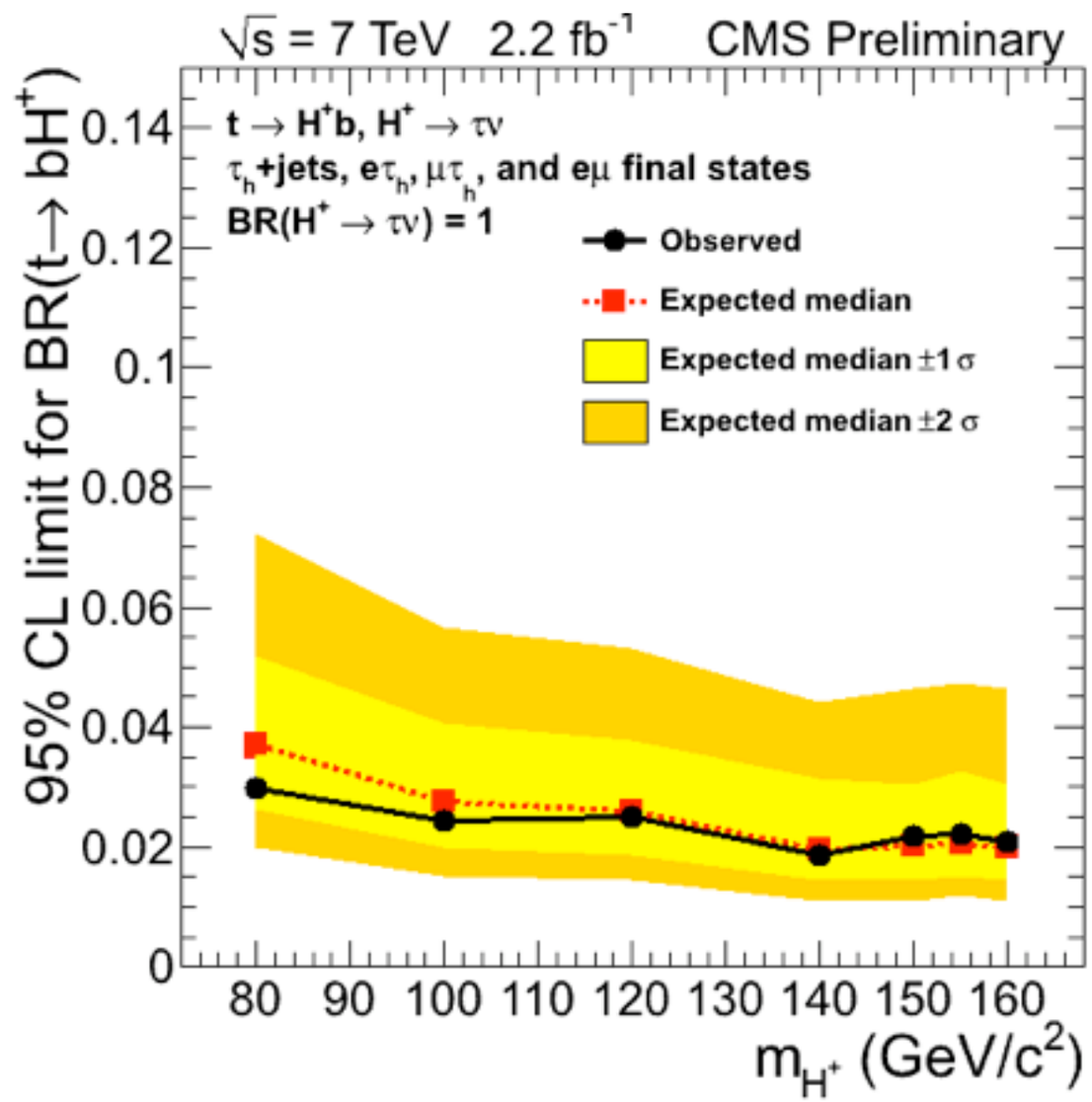
MSSM charged higgs

- If M(t) > M($H^{\pm}$), Higgs diagrams modify top pair production cross section.
- $H+ \rightarrow \tau^{+}\nu_{\tau}$
- Searched for τ_{lep} + jets, τ_h + lepton, τ_h + jets in ATLAS
- Searched for τ_{lep} + lepton, τ_h + lepton, τ_h + jets in CMS

ATLAS-CONF-2012-011



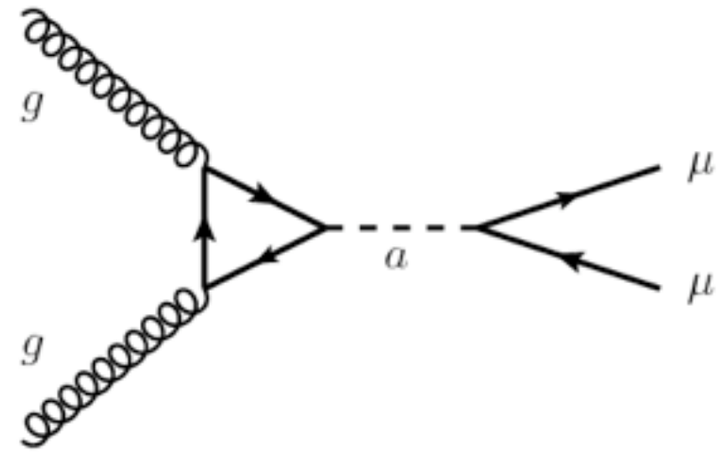
CMS-HIG-11-019

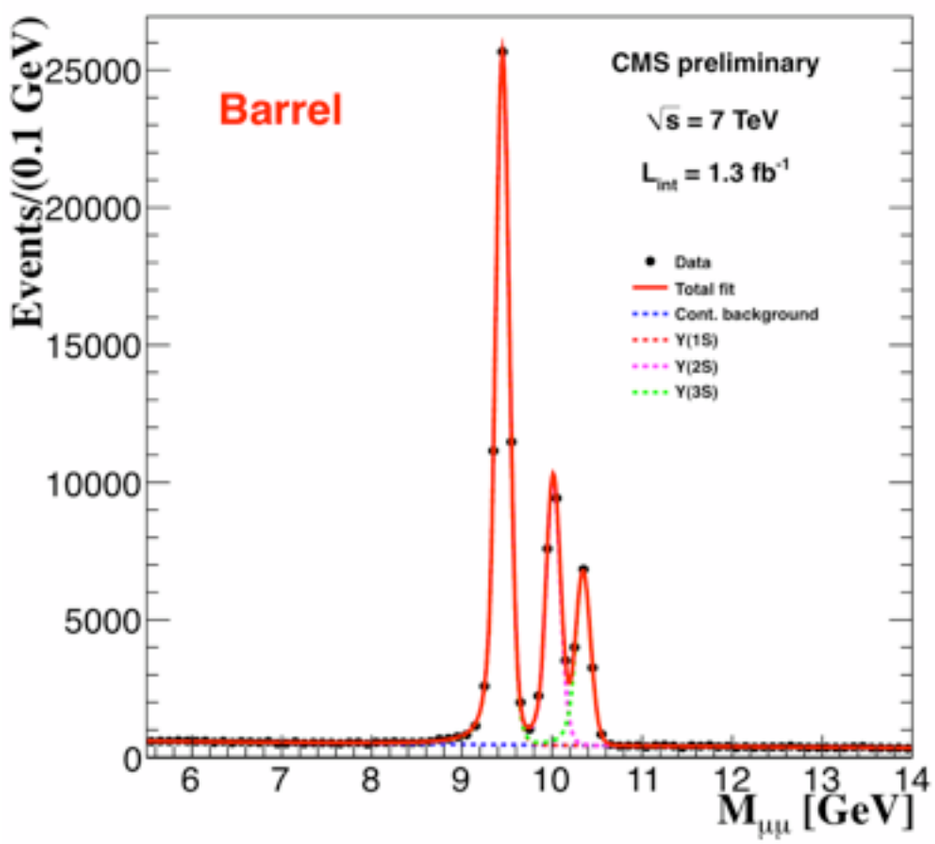


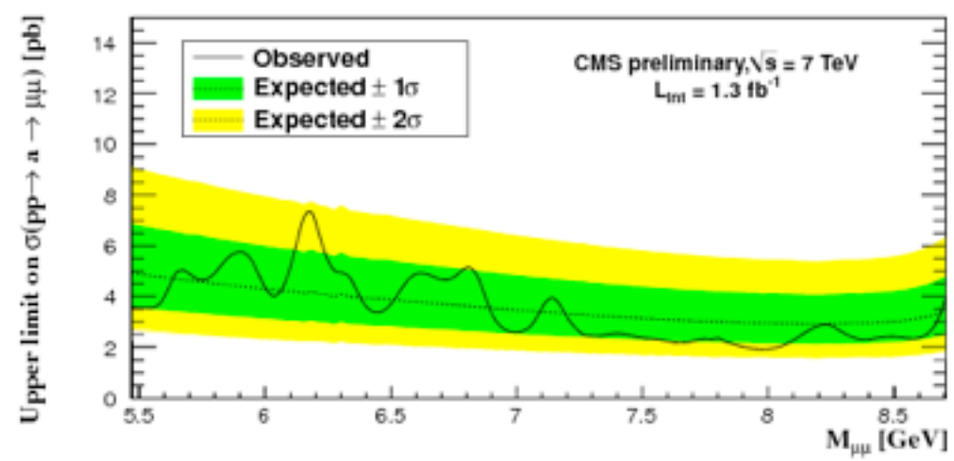
Light pseudoscalar Higgs boson

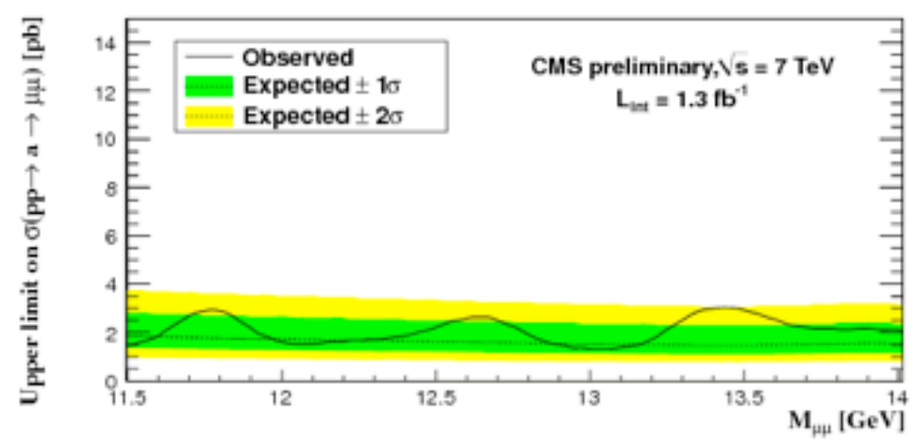
CMS-HIG-12-004

- In NMSSM, light CP-odd Higgs search
- Search in the sidebands of the Upsilions
  - 5.5 < M(μμ)< 9 GeV
  - 11.5 < M(μμ) < 14 GeV
- Isolated opposite sign dimuons
  - $p_T(\mu)$> 4 GeV and $p_T(\mu\mu)$ > 6 GeV

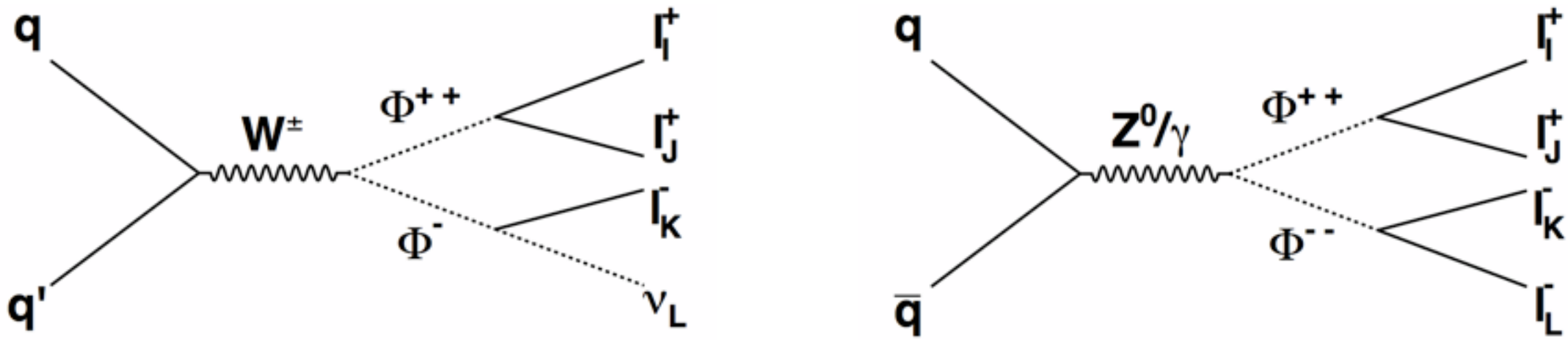




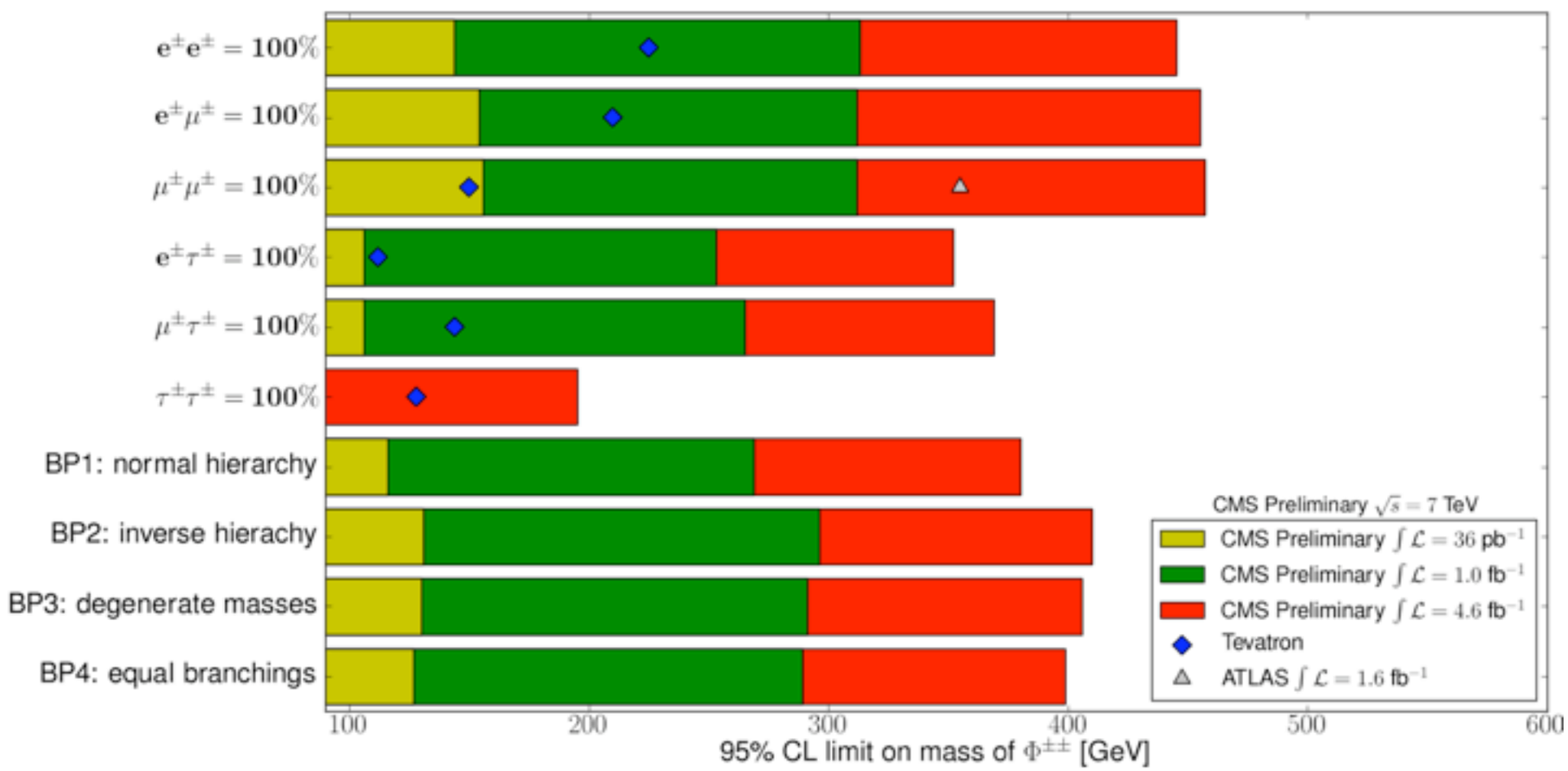




Doubly charged higgs



CMS-HIG-12-005

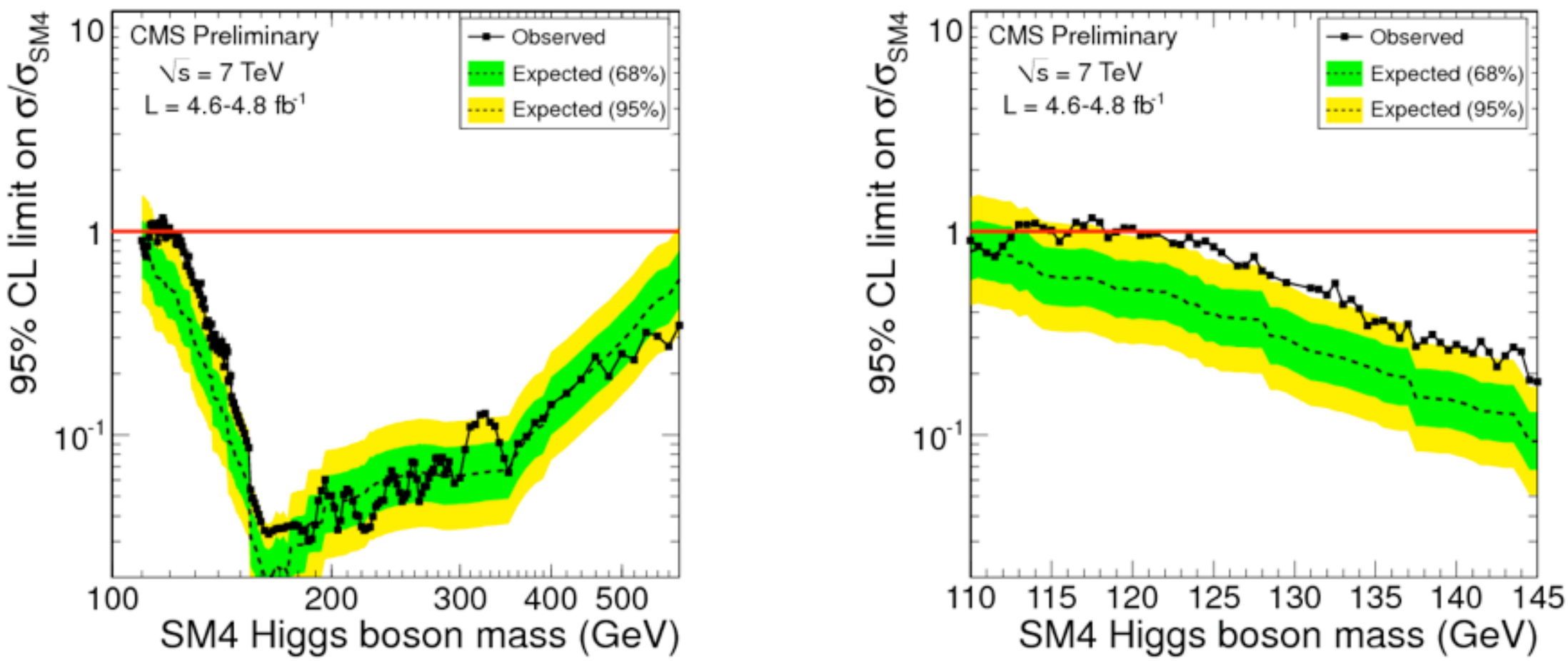


ATLAS : Doubly charge higgs with 1.6 fb-1 - arXiv:1201.1091 : Phys.Rev.D 88 (2012) 032004

SM4

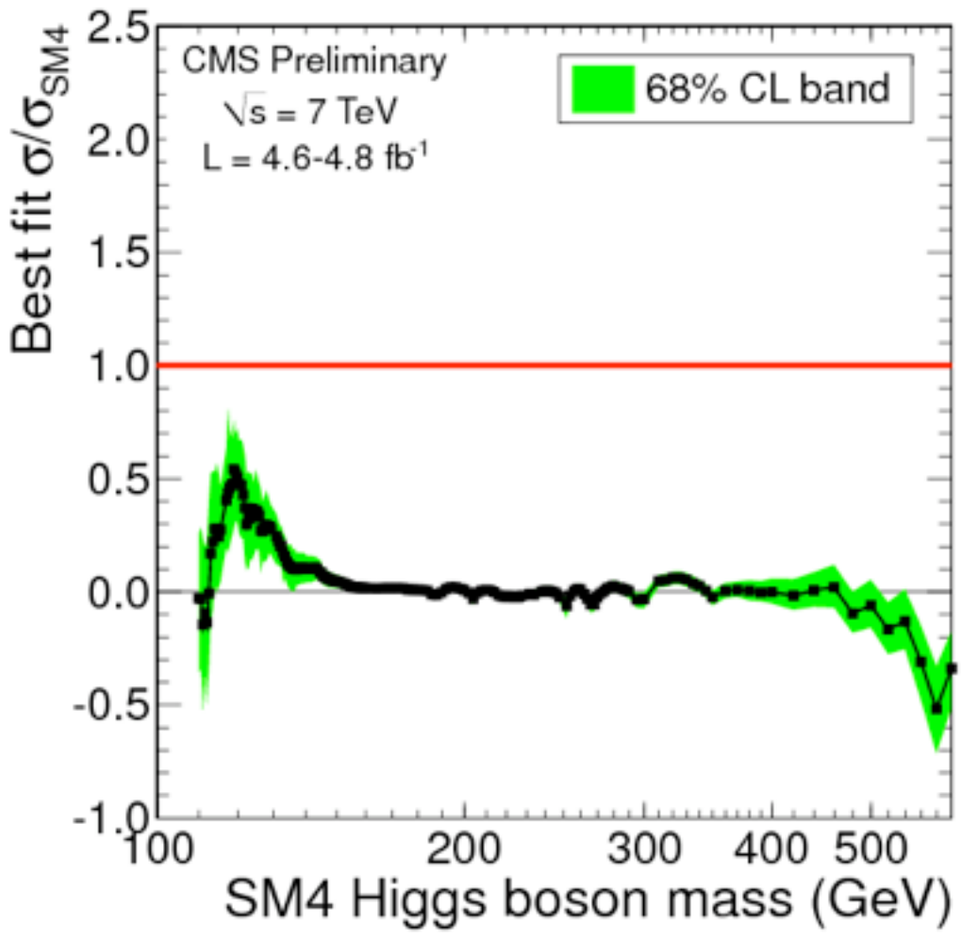
- Additional quarks enhance the higgs production cross section.
- The branch ratio is also affected by this heavy quark.

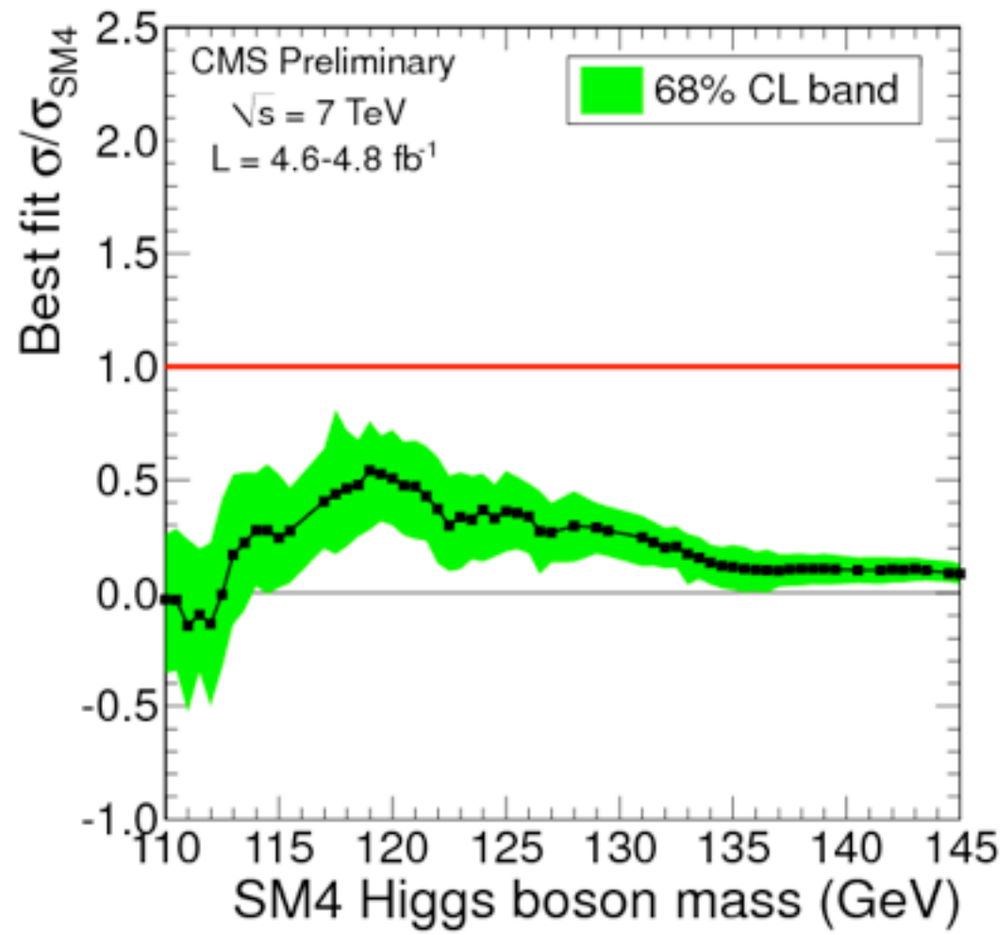
CMS-HIG-12-008



SM4

CMS-HIG-12-008



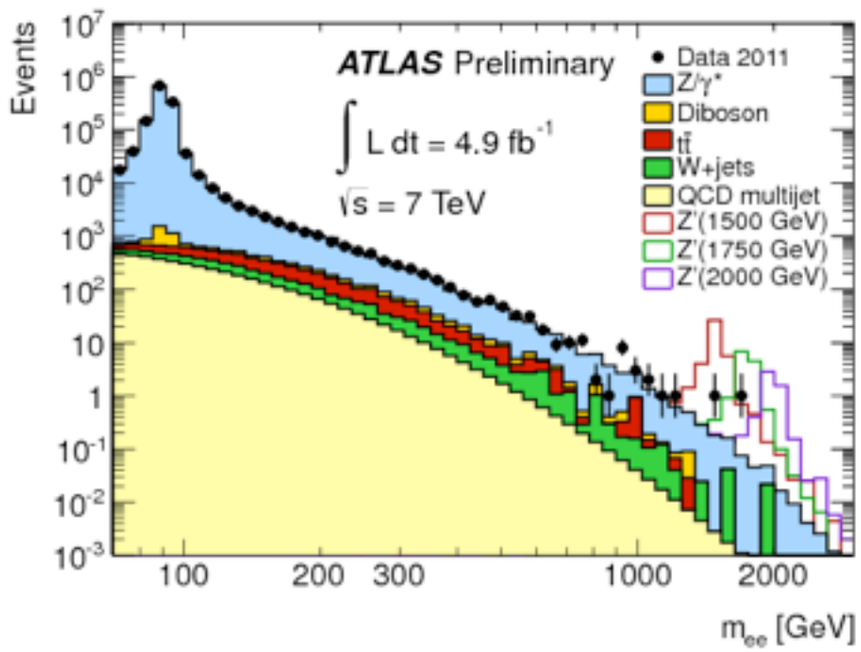


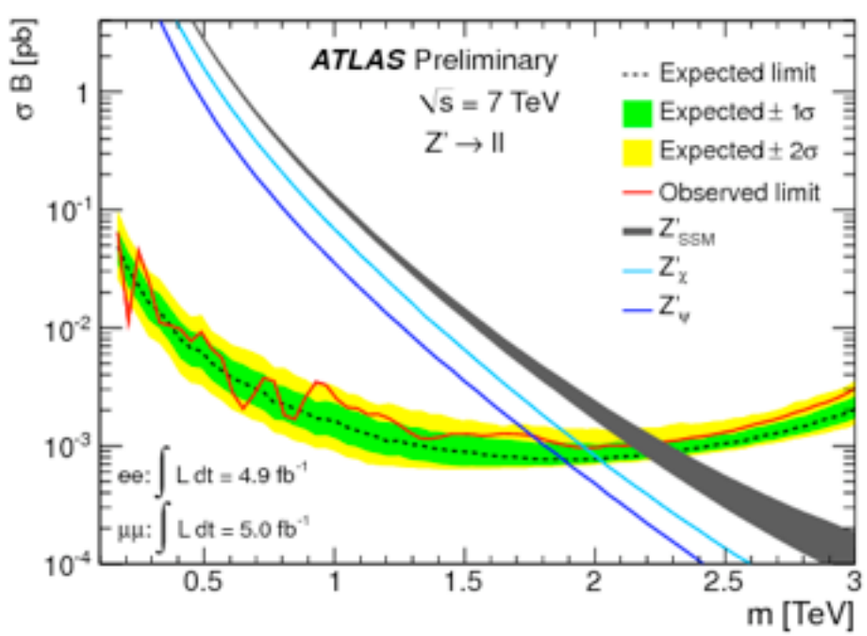
NEW PHYSICS BSM

Resonance in the Dilepton

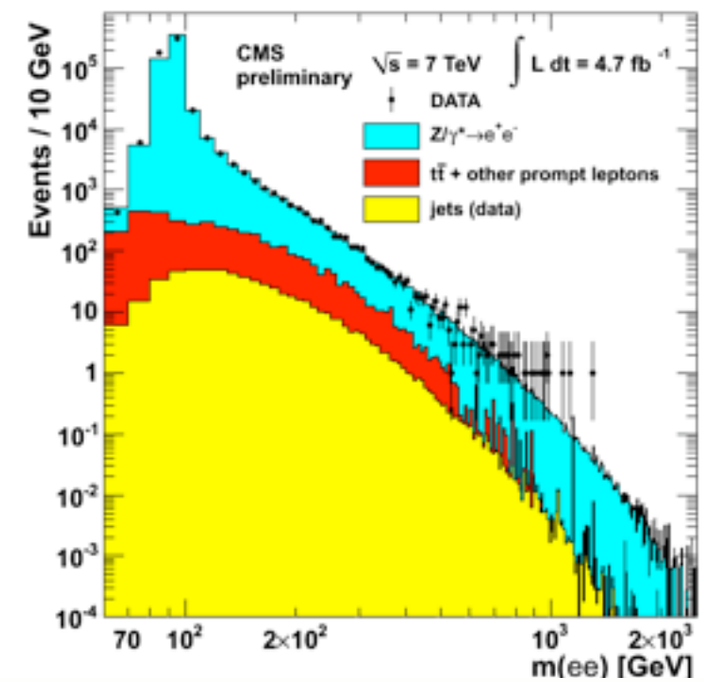
- Narrow high-mass resonance decaying into e^+e^- or $\mu^+\mu^-$ pairs.
- Data are consistent with SM prediction.

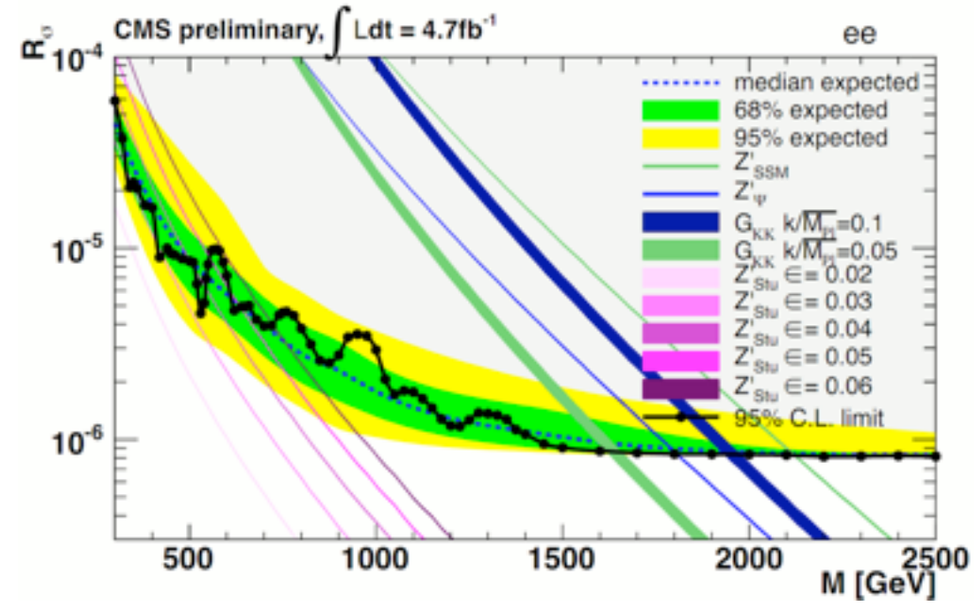
ATLAS-CONF-2012-007





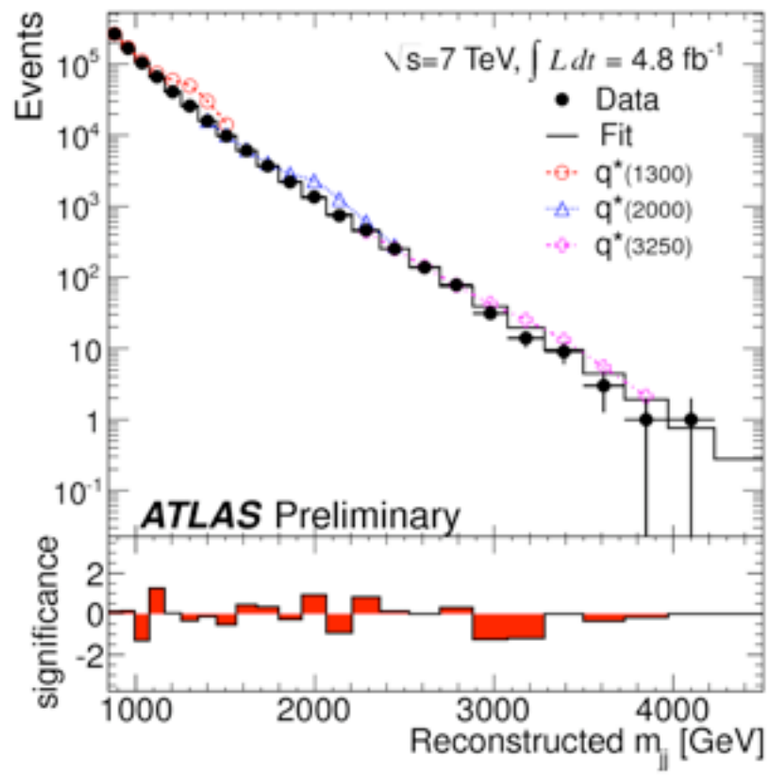
CMS-EXO-11-019



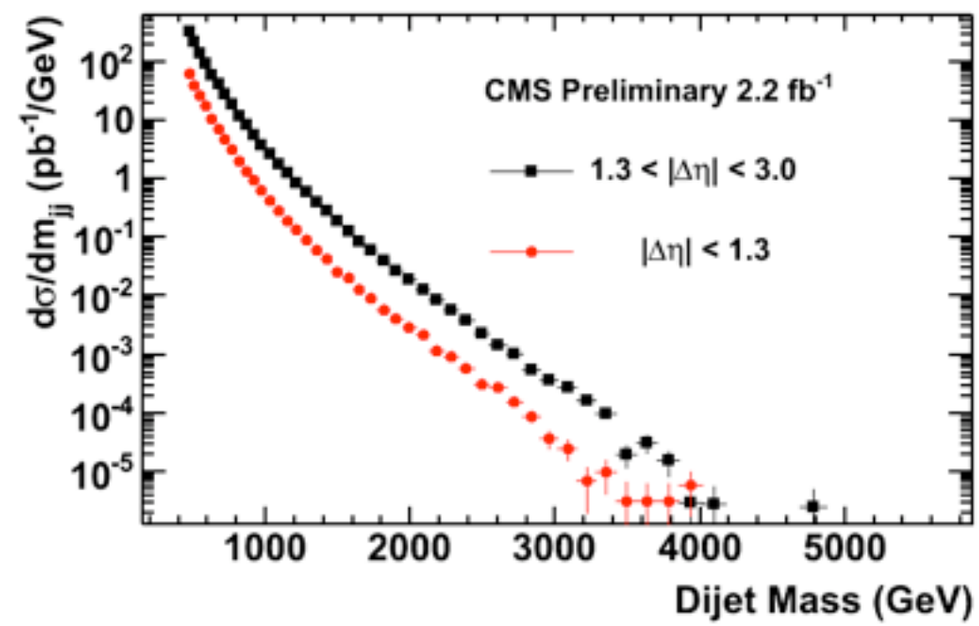


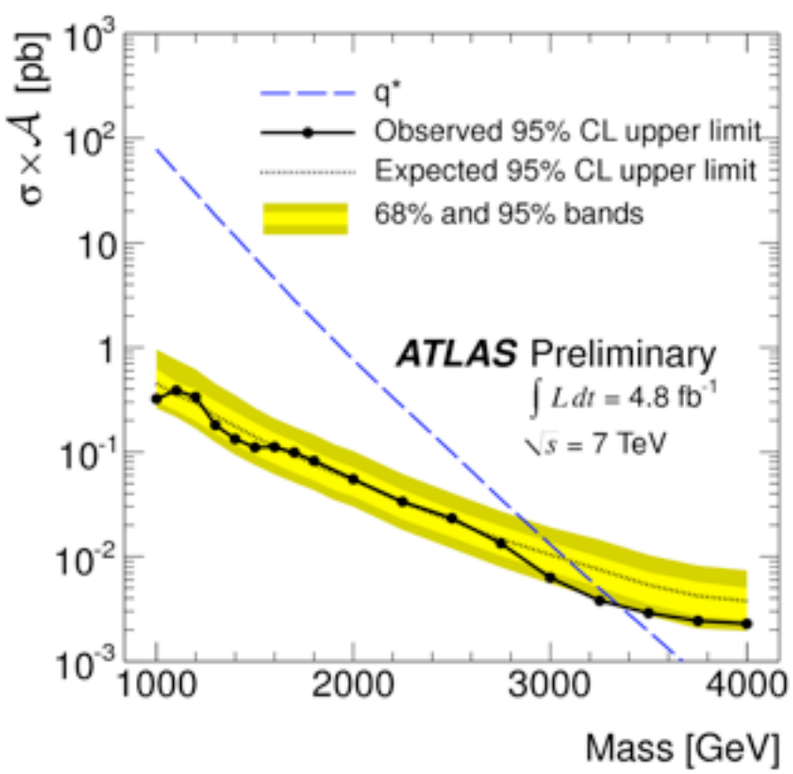
Dijet Mass

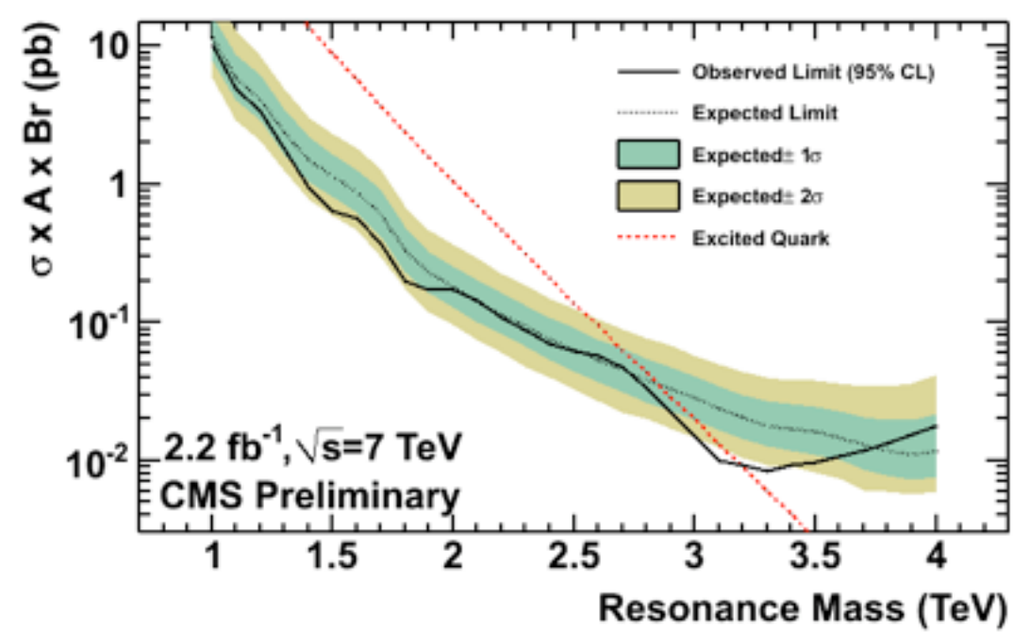
ATLAS-CONF-2012-038



CMS-EXO-11-026

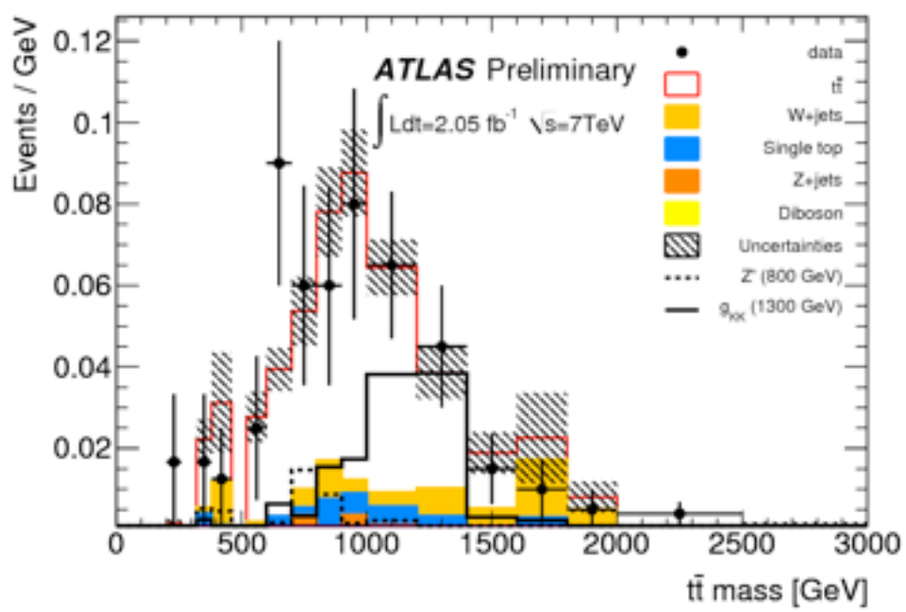


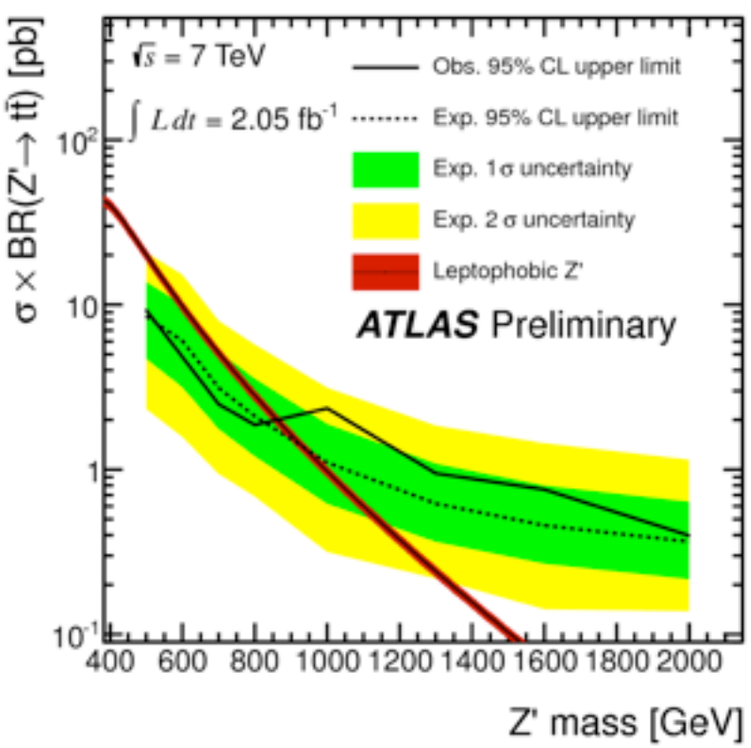




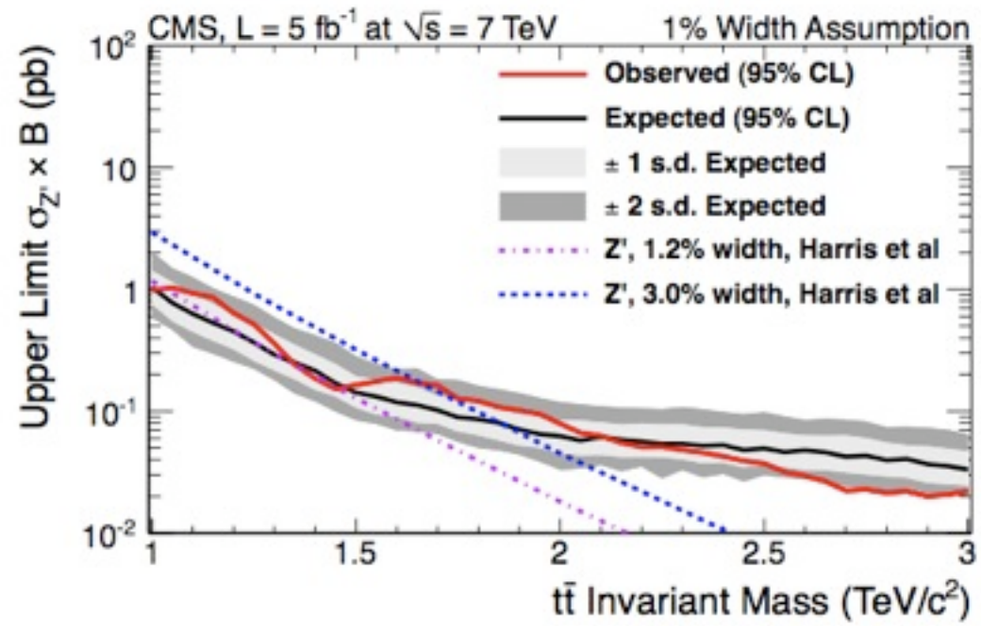
ttbar resonance

ATLAS-CONF-2012-029

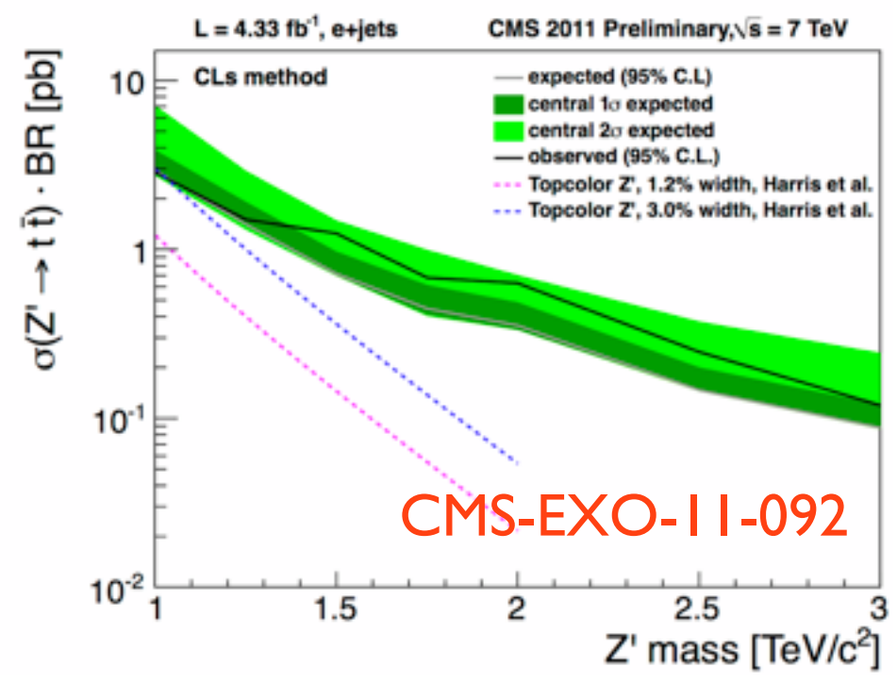




arXiv:1204.2488 boosted top in hadronic decay mode



focus on BSM high mass particles above 1 TeV



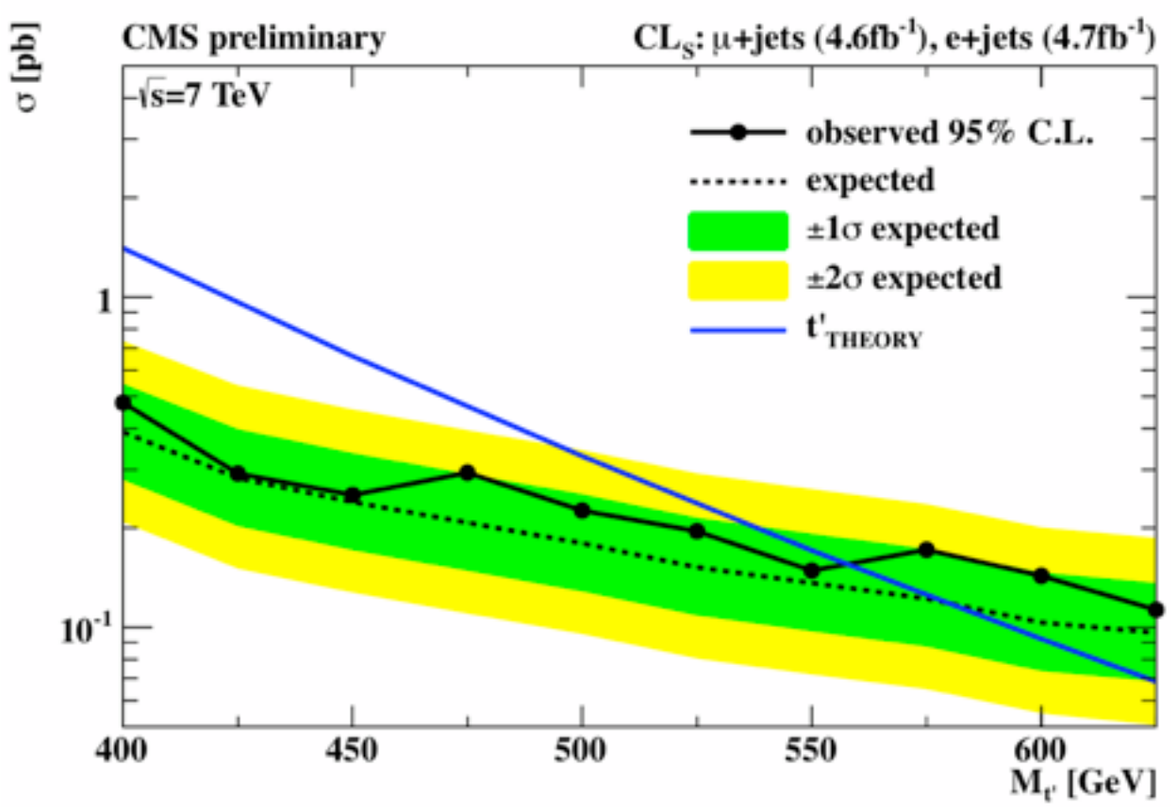
CMS-EXO-11-092

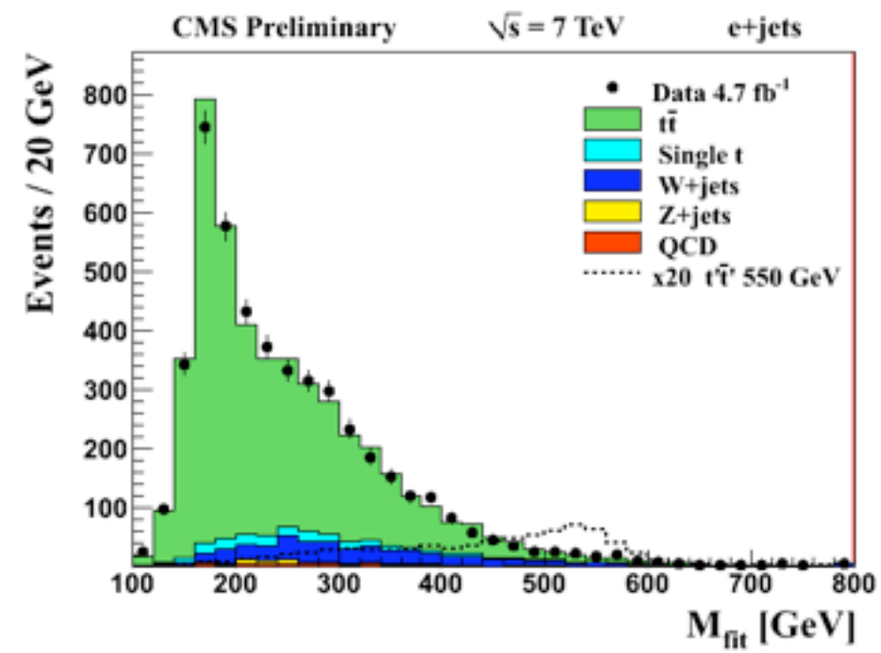
CMS-TOP-11-009, CMS-TOP-11-010 for low mass

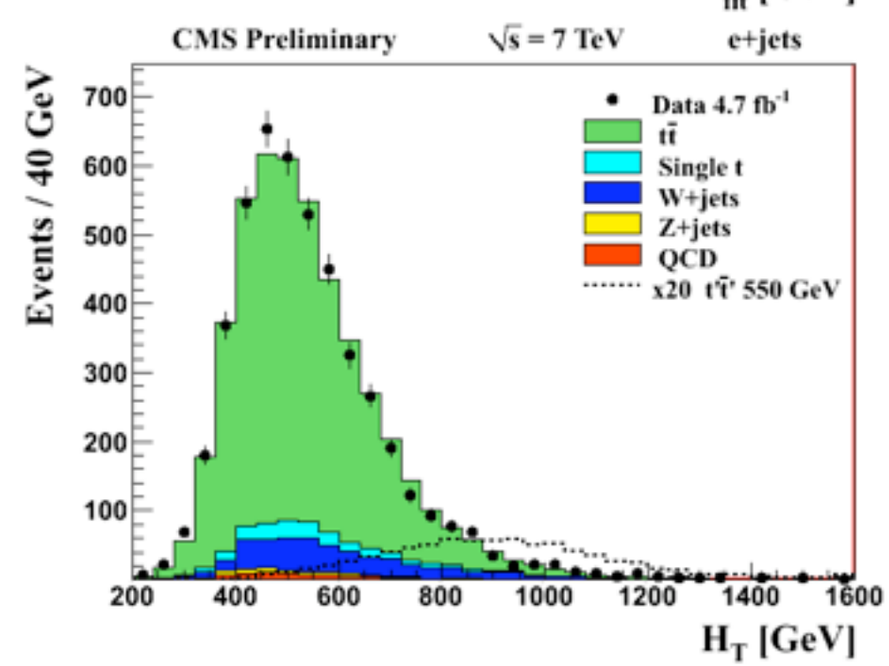
Fourth generation t´

- The existence of a fourth generation is consistent with precision electroweak data.
- Increase the upper limit on the mass of higgs boson.
- t´ → bW
- H_T(lepton + four jets + MET) and M_{fit}

CMS-EXO-11-099



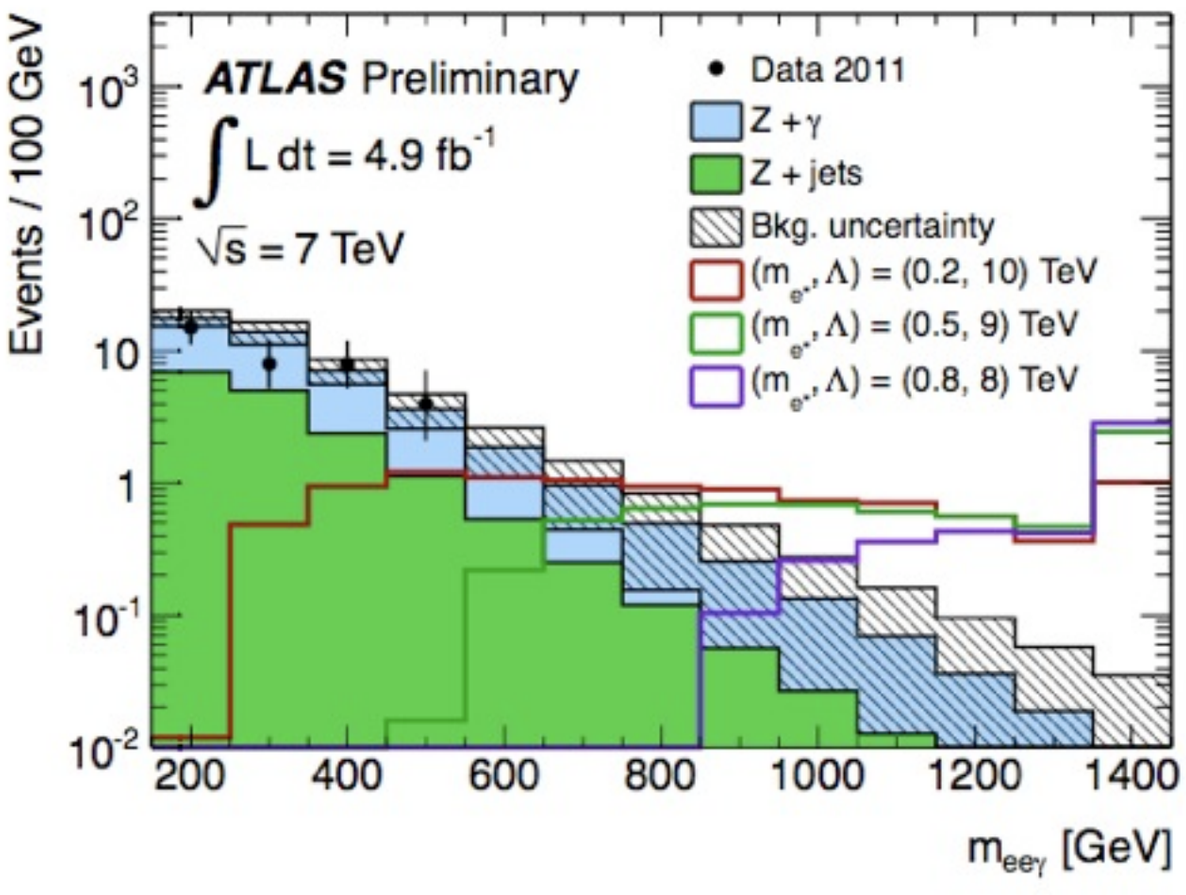


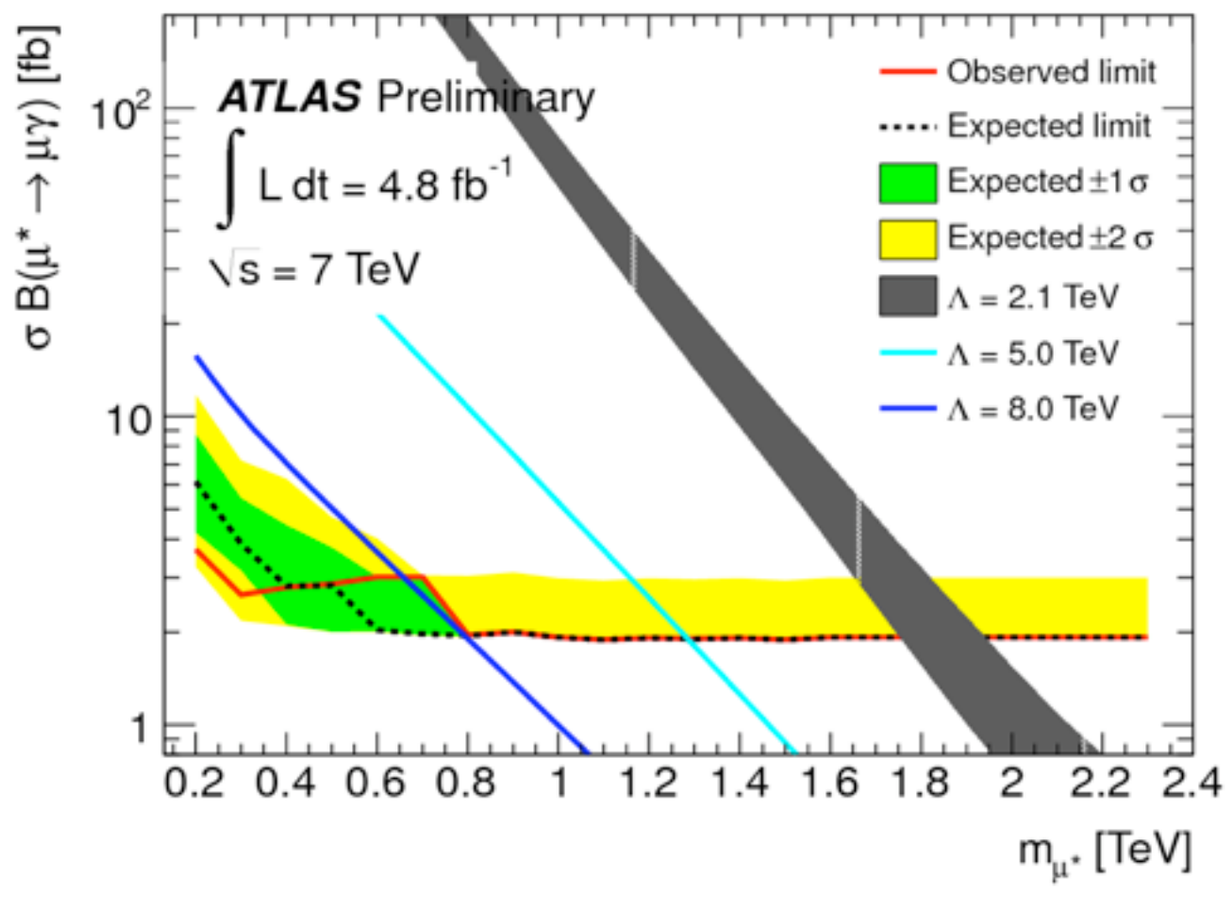


Search for excited e,μ

- Leptons can be the lowest-energy bound states in compositeness model.
- $q\bar{q} \to \ell^* \ell$ ($l^* \to l\gamma$ channel)
- Invariant mass of $ll\gamma$ system

ATLAS-CONF-2012-008





SUPERSYMMETRY

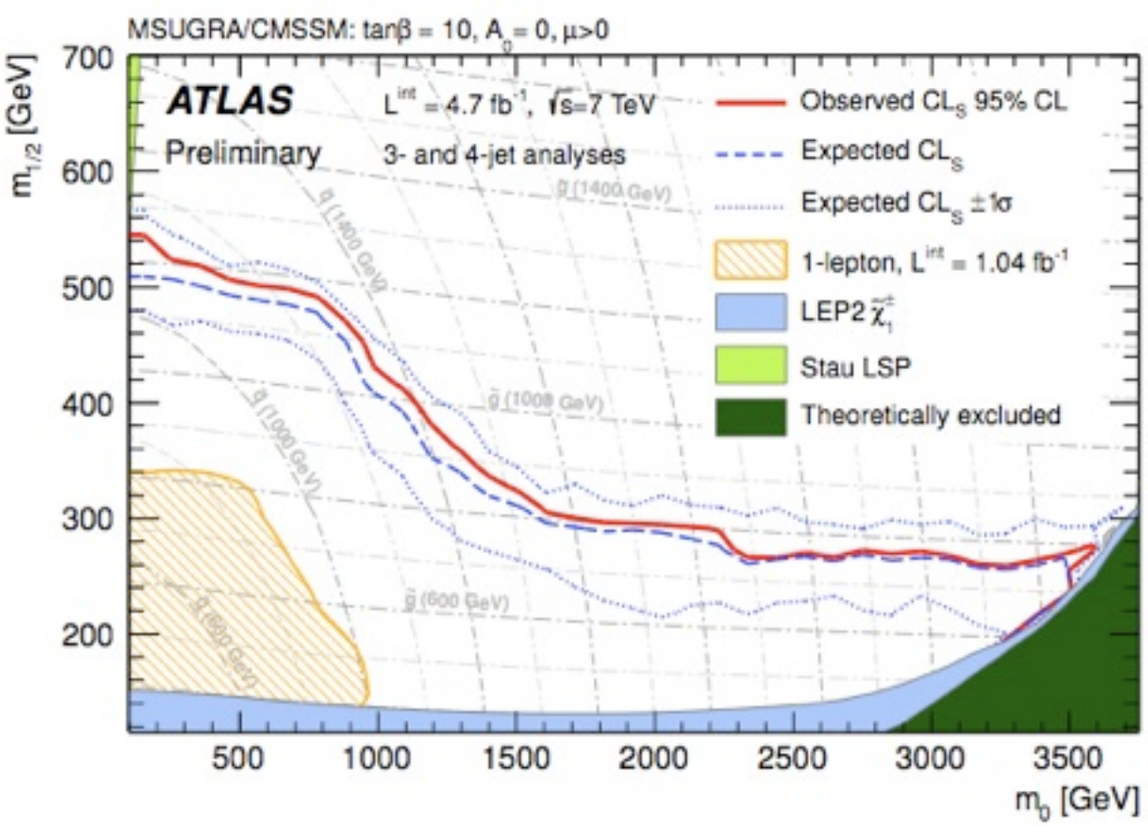
Single lepton

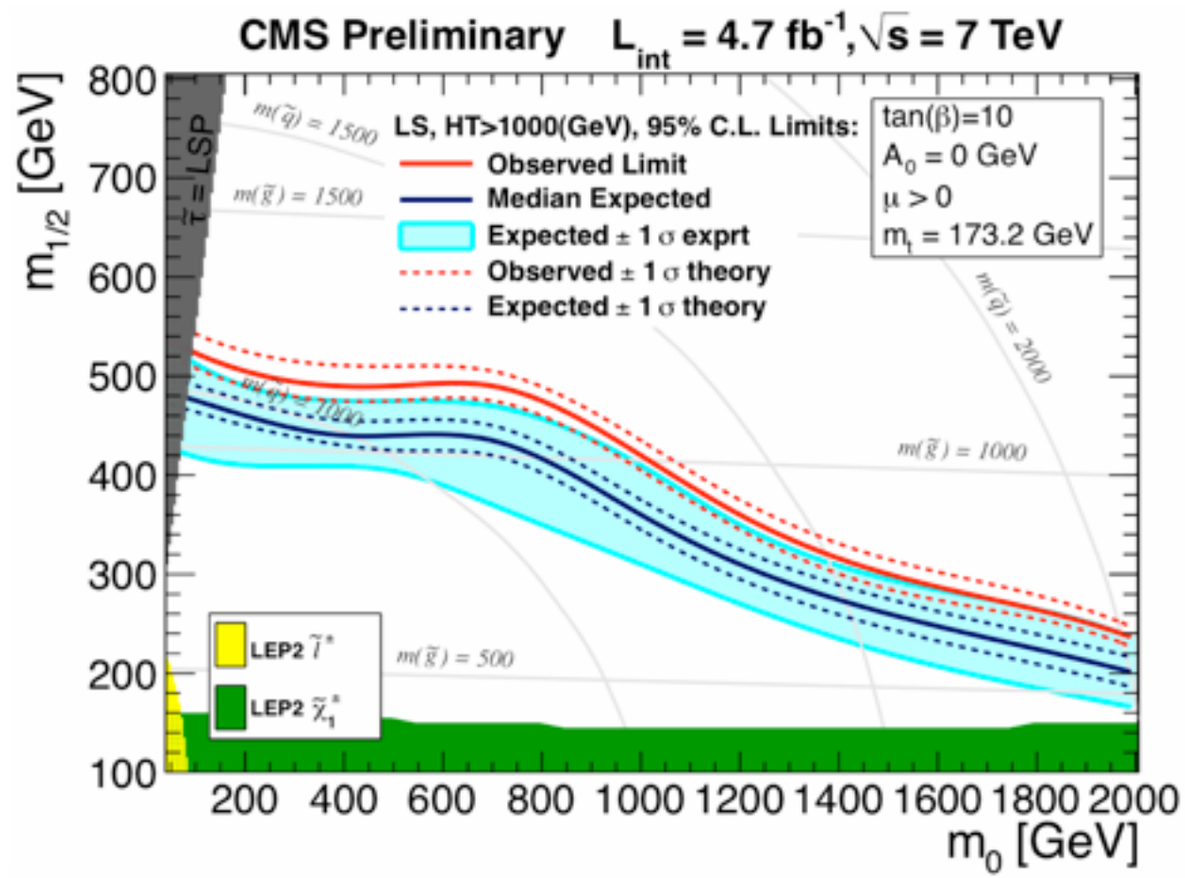
ATLAS-CONF-2012-041

- One lepton e, μ p_T > 20,25 GeV
- Number of jets > 3 or 4
- Three different event topologies.

CMS-SUS-12-010

- One lepton (e, μ) p_T > 20 GeV
- Number of jets > 3 or 4
- H_T > 500, 750 or 1000 GeV

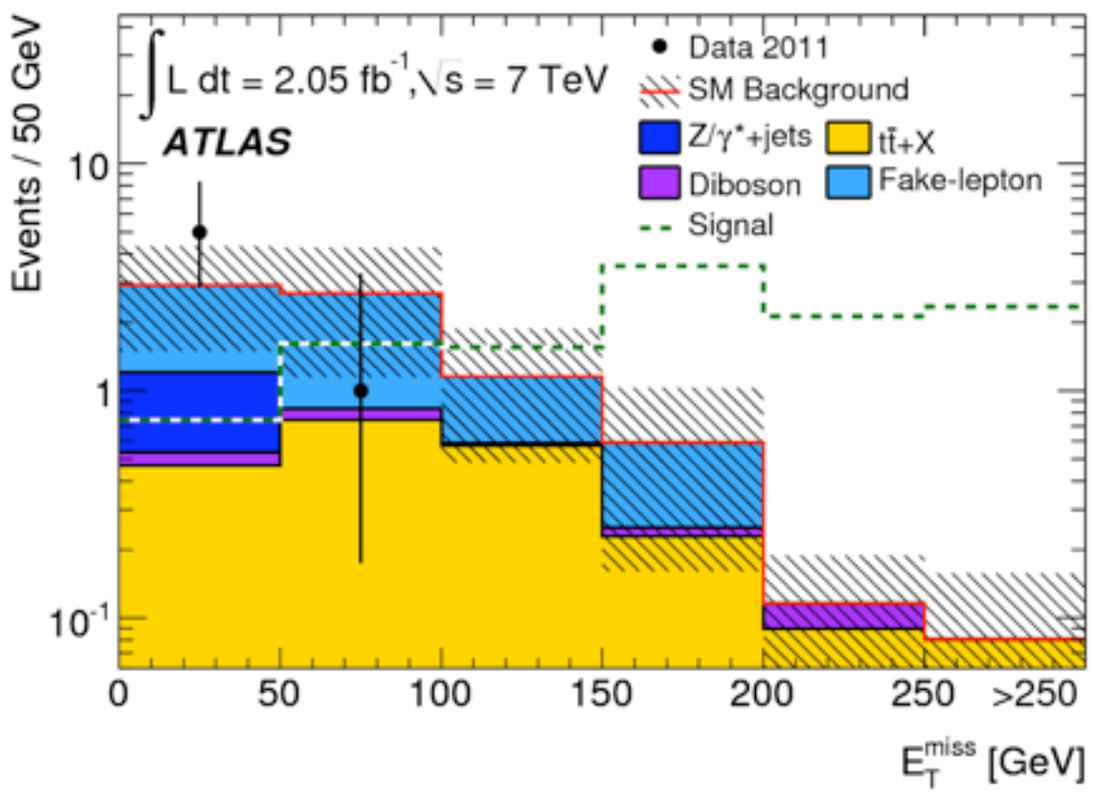


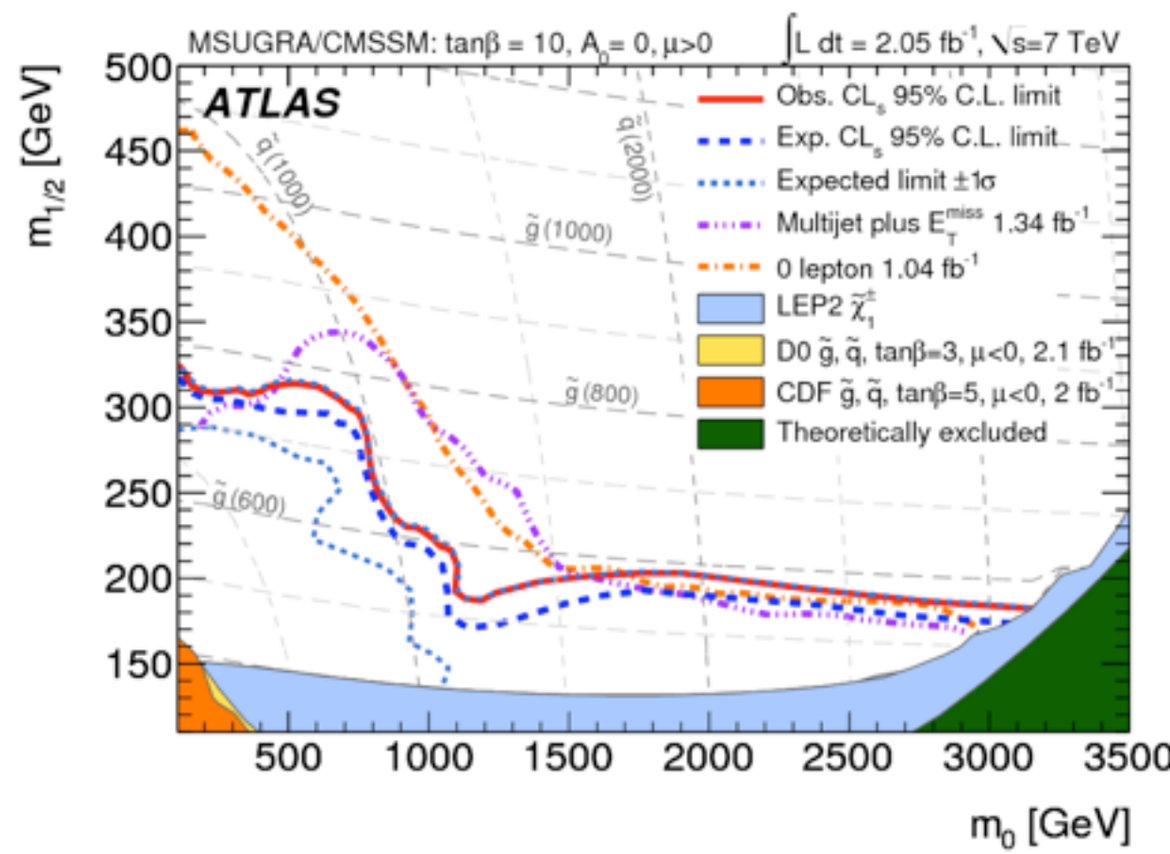


Dilepton

- Same sign dileptons
- MET > 150 GeV, 4 or more jets

ATLAS
arXiv:1203.5763
submitted to PRL

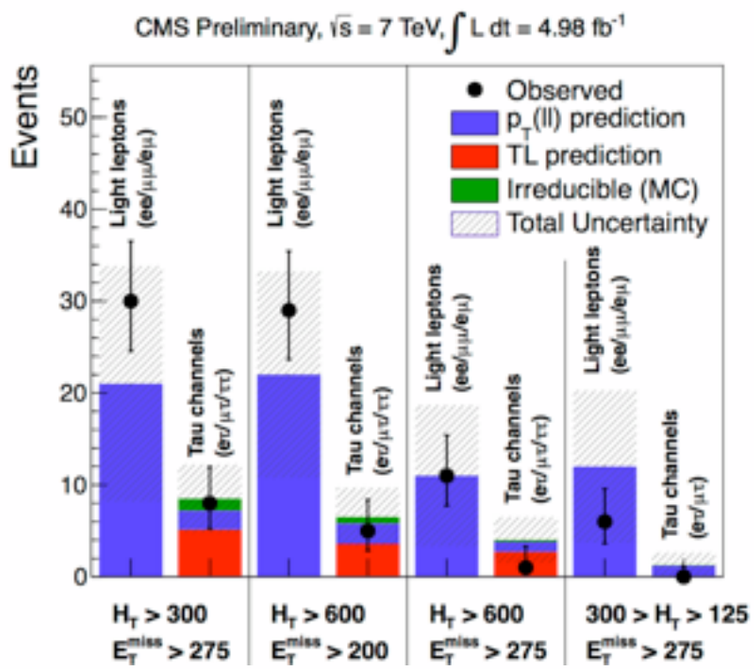


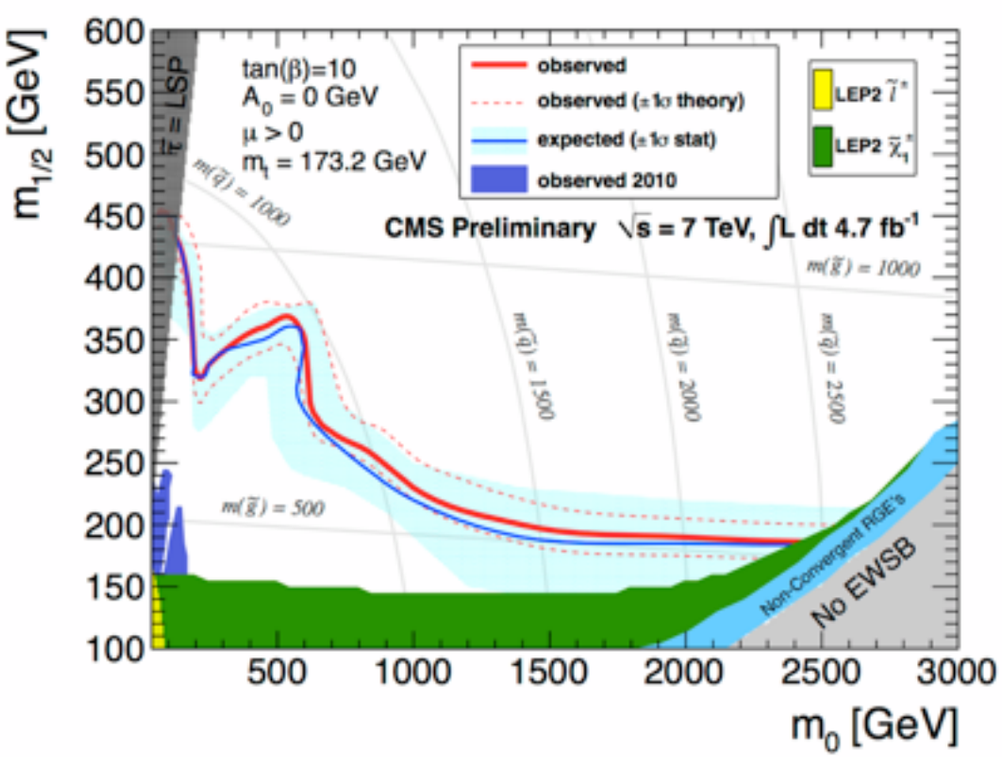


Dilepton

CMS-SUS-11-011

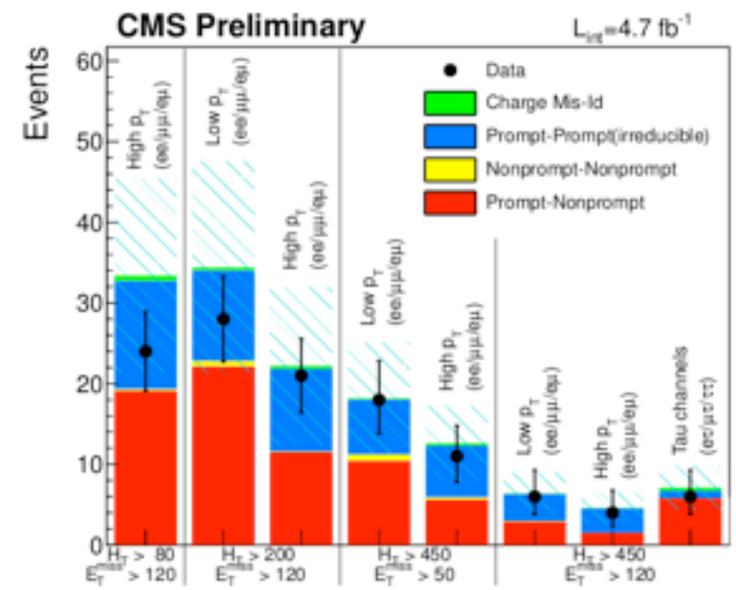
- Opposite sign leptons

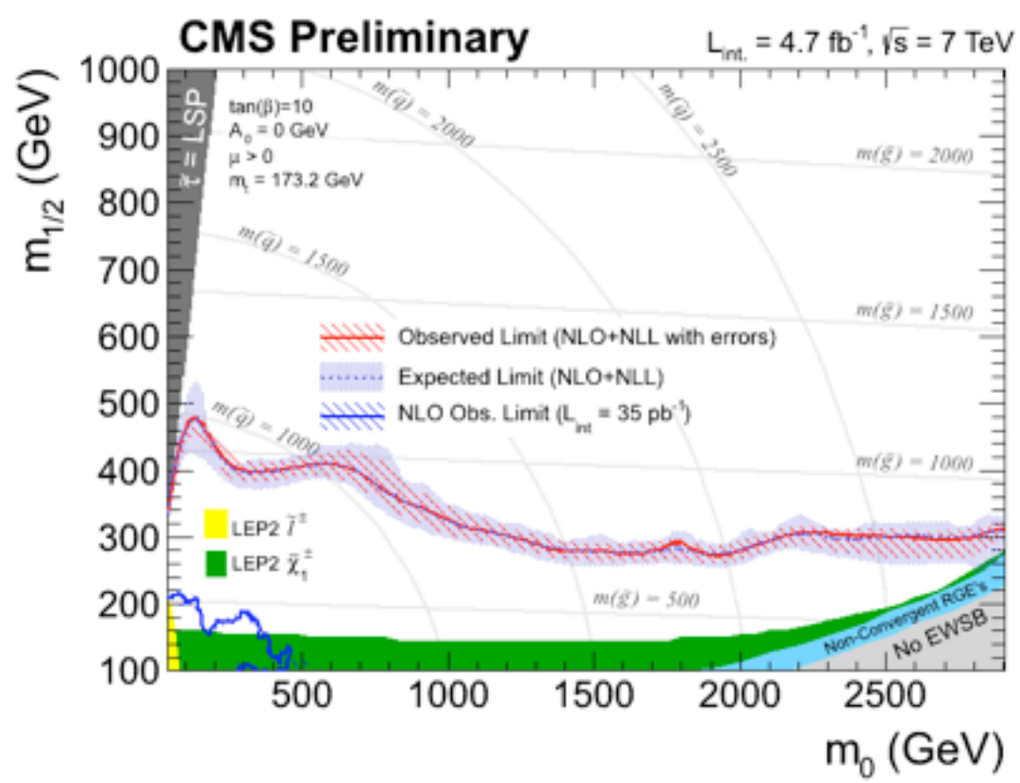




CMS-SUS-11-010

- Sam sign leptons

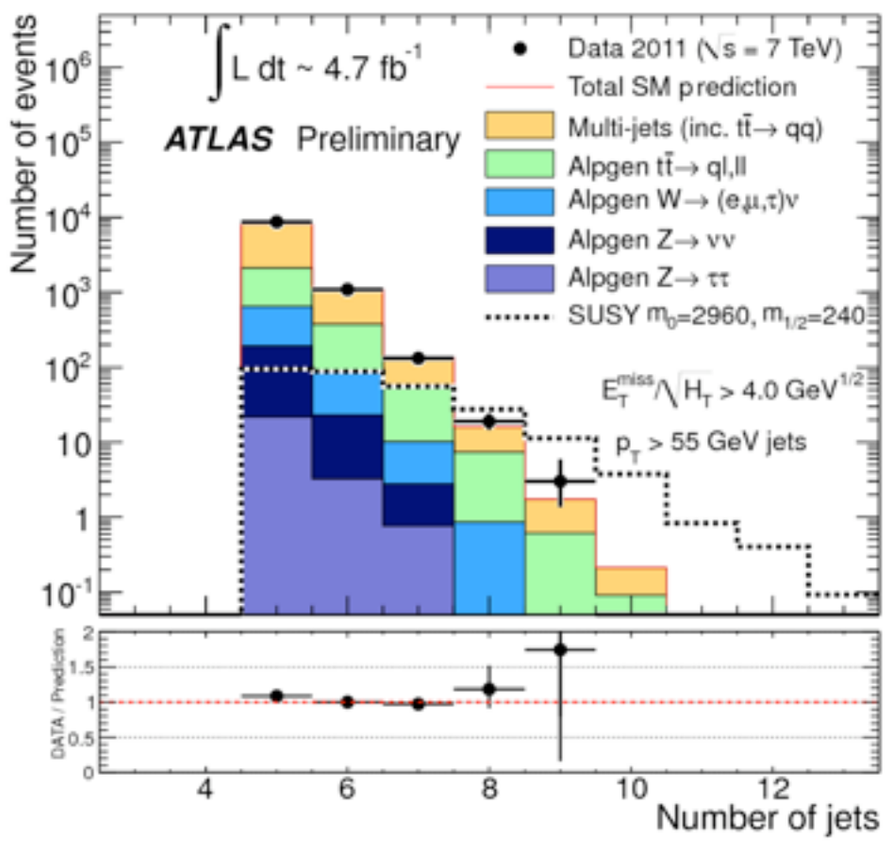




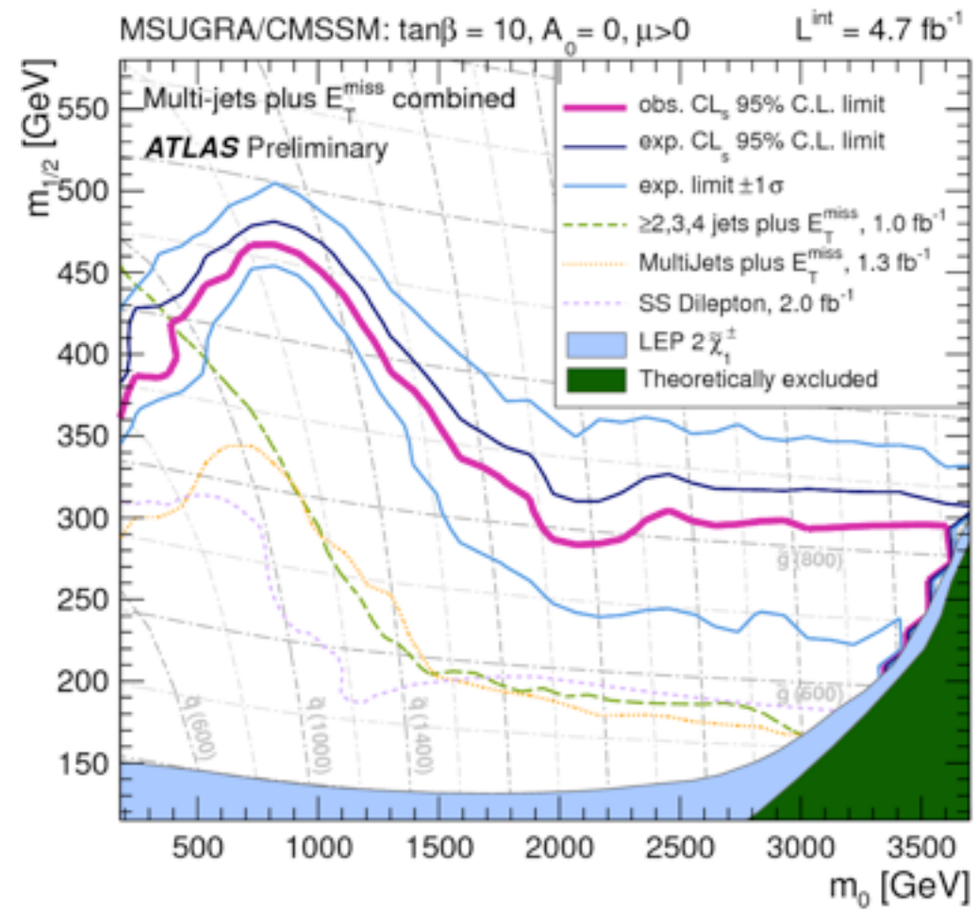
Large multi-jets and MET

- No isolated leptons
- Six different signal regions
  - Jet p_T > 55, 80 GeV
  - Number of jets > 7,8,9

ATLAS-CONF-2012-037



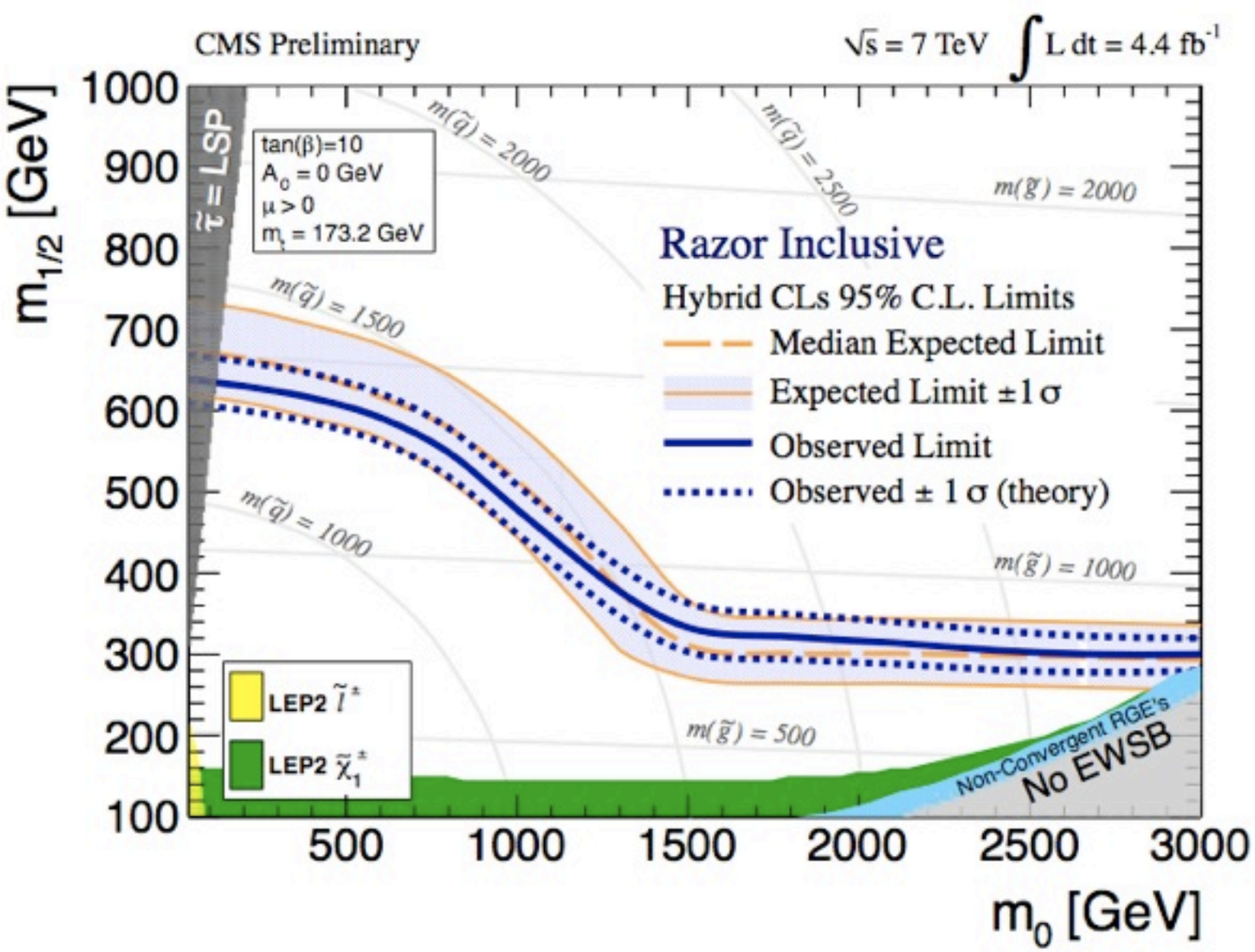
- Jet p_T > 55 GeV



gluino mass excluded up tp 850 GeV when large m_0

Inclusive with razor variables

- Razor kinematics based on the generic process of the pair production of two heavy particles.
- Two mega jets.
- Extend the limit.



CMS-SUS-12-005

1.35 TeV
when m(squark) ≈ m(gluino)

Summary

- All results are consistent with SM prediction.
- Excluded high mass ranges for SM higgs boson.
- Need more data to confirm the significance in low mass range.
- We are collecting 8 TeV data which should increase the sensitivity as well as extending search ranges.
- Look forward to many more exciting results this year.

For more information about all the results from LHC

- https://twiki.cern.ch/twiki/bin/view/AtlasPublic/WebHome
- https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults