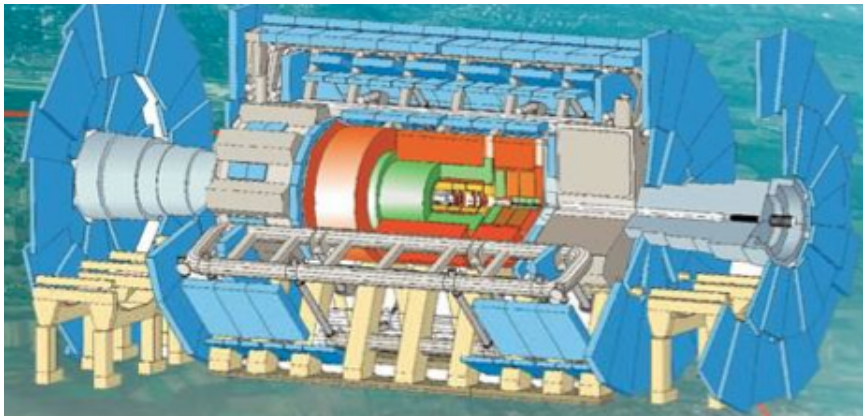
"Хиггс бозон как коммунистическая партия – он контролирует массы"

L.Alvarez-Gaume

Summary of LHC Higgs Results: ATLAS&CMS



Научная сессия ученого совета ОФВЭ ПИЯФ
23-26 декабря 2013 года
Олег Федин

Publications

ATLAS

Phys.Lett. B 716 (Discovery)

Phys.Lett. B 726 (Spin, Couplings)

ATLAS-CONF 2013-040 (Spin Combi.)

ATLAS-CONF-2013-034 (Coupling Combi.)

ATLAS-CONF 2013-014 (Mass Combi.)

ATLAS-CONF 2013-029 (γγ Spin)

ATLAS-CONF 2013-031 (WW* Spin)

ATLAS-CONF 2013-030 (WW*)

ATLAS-CONF 2013-012 (γγ)

ATLAS-CONF 2013-013 (ZZ*)

ATLAS-CONF 2013-079 (VH,H→bb)

ATLAS-CONF 2013-072 (H ->γγ, diff σ)

ATLAS-CONF 2013-075 (VH,H→WW)

ATLAS-CONF-2013-011 (Z(ll)H, H→Inv)…

CMS

Phys. Lett. B 716 (Discovery)

Phys. Rev. Lett. 110 (ZZ*, Spin)

CMS-PAS-HIG-13-005 (Mass, Couplings)

CMS-PAS-HIG-13-016 (Properties γγ)

CMS-PAS-HIG-13-001 (γγ)

CMS-PAS-HIG-13-003 (WW*)

CMS-PAS-HIG-13-002 (ZZ*, Spin)

CMS-PAS-HIG-13-012 (H→bb)

CMS-PAS-HIG-13-013(VBF, H→Inv)

CMS-PAS-HIG-13-018 (Z(ll)H, H→Inv)

CMS-PAS-HIG-13-018 (Z(bb)H, H→Inv)

CMS-PAS-HIG-13-004 (ττ)…

LHC Higgs Cross Section Working Group

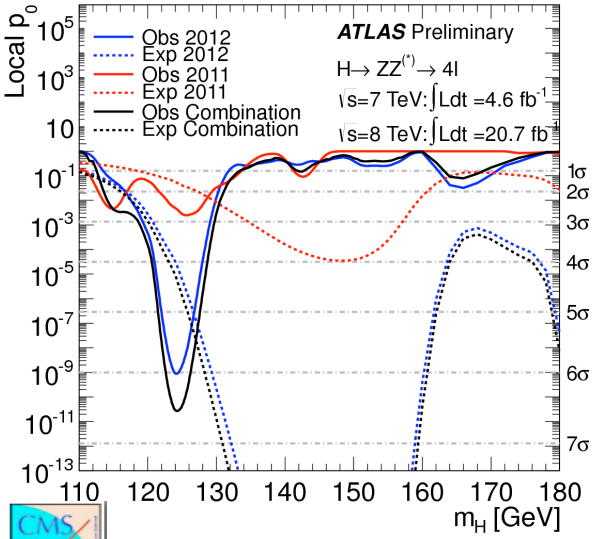
http://twiki.cern.ch/twiki/bin/view/LHCPhysics/CrossSections

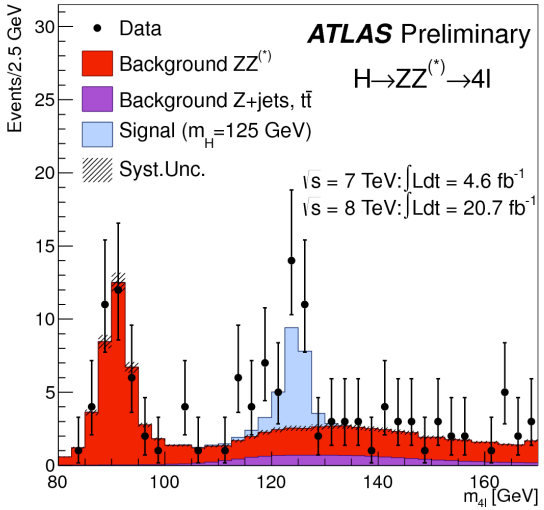
arXiv:1307.1347 (CERN Yellow Report 3: σ, BR, coupling, spin/CP…)

Higgs discovery channels update with "RUN-I" statistics

6.6σ, (4.4σ exp.) $m_H = 124.3^{+0.6}_{-0.5}\,\text{stat}^{+0.5}_{-0.3}\,\text{sys}$ GeV

H→ ZZ→4l

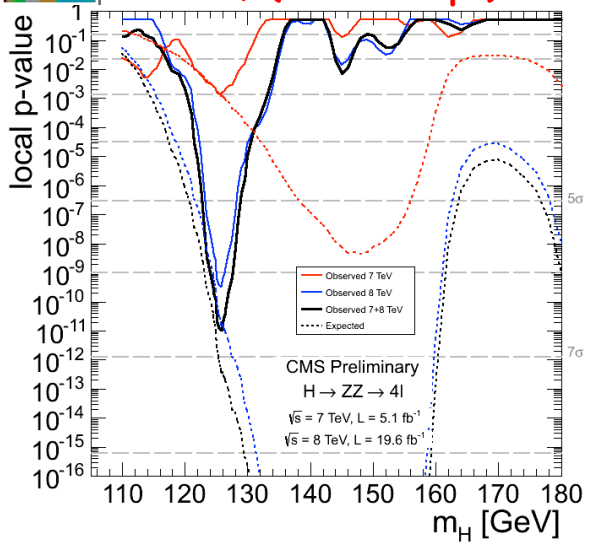


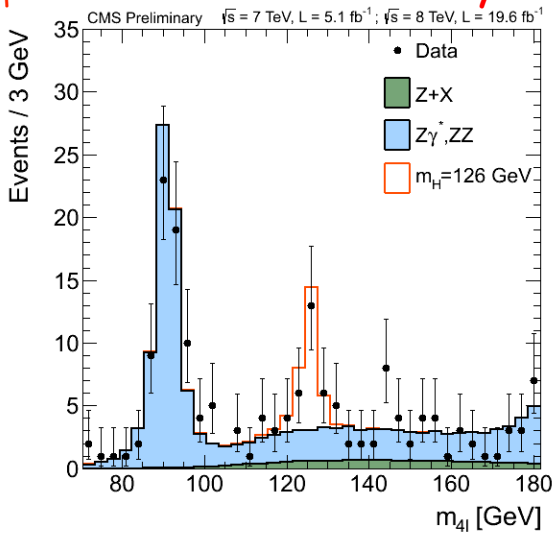


ATLAS-CONF-2013-013

Channel	4e	4μ	2e2μ	4l
ZZ background	6.2±0.5	14.6±0.6	17.2±0.9	38.0±1.2
Z+X (+tt̄)	4.5±0.6	2.1±0.6	8.5±1.6	15.1±1.9
All background expected	10.8±0.9	16.7±0.8	25.6±1.9	53.2±2.2
m_H=123 GeV	2.2±0.4	4.4±0.6	5.4±0.8	12.0±1.2
m_H=125 GeV	2.9±0.4	5.8±0.7	7.0±0.9	15.7±1.2
m_H=127 GeV	3.4±0.4	6.7±0.9	8.4±1.2	18.5±1.6
Observed	15	35	33	83

6.7σ, (7.2σ exp.) $m_H = 125.8 \pm 0.5\,\text{stat} \pm 0.2\,\text{sys}$ GeV





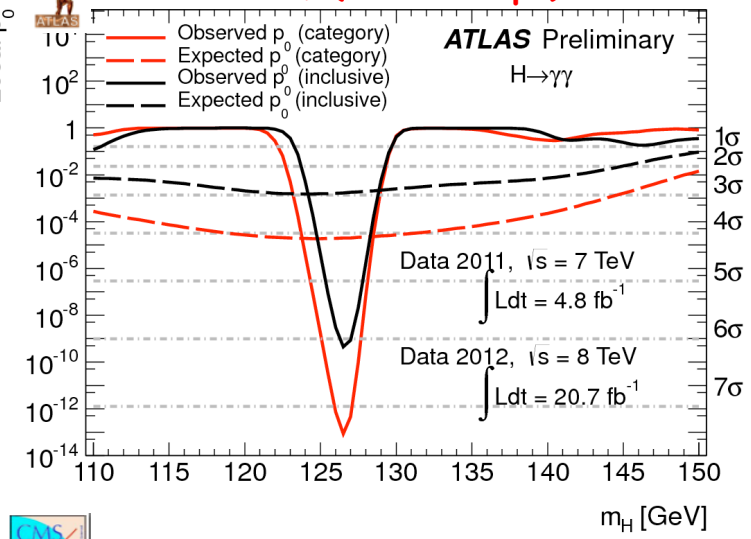
CMS-PAS-HIG-002

Channel	4e	4μ	2e2μ	4ℓ
ZZ background	6.6 ±0.8	13.8 ±1.0	18.1 ±1.3	38.5 ±1.8
Z+ X	2.5 ± 1.0	1.6 ± 0.6	4.0 ± 1.6	8.1 ±2.0
All background expected	9.1 ± 1.3	15.4 ± 1.2	22.0 ± 2.0	46.5 ±2.7
m_H = 125 GeV	3.5 ±0.5	6.8 ±0.8	8.9 ±1.0	19.2 ±1.4
m_H = 126 GeV	3.9 ±0.6	7.4 ±0.9	9.8 ±1.1	21.1 ±1.5
Observed	16	23	32	71

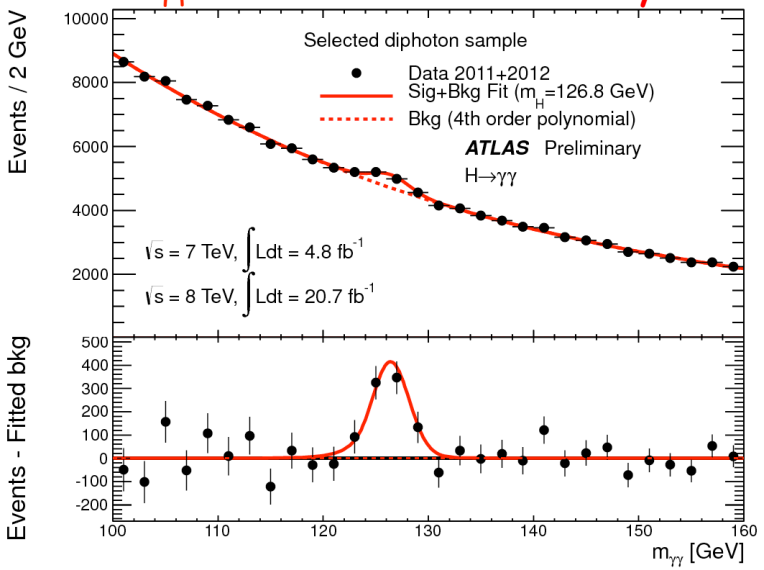
Higgs discovery channels update with "RUN-I" statistics

ATLAS-CONF-2013-012

7.4σ, (4.3σ exp.)



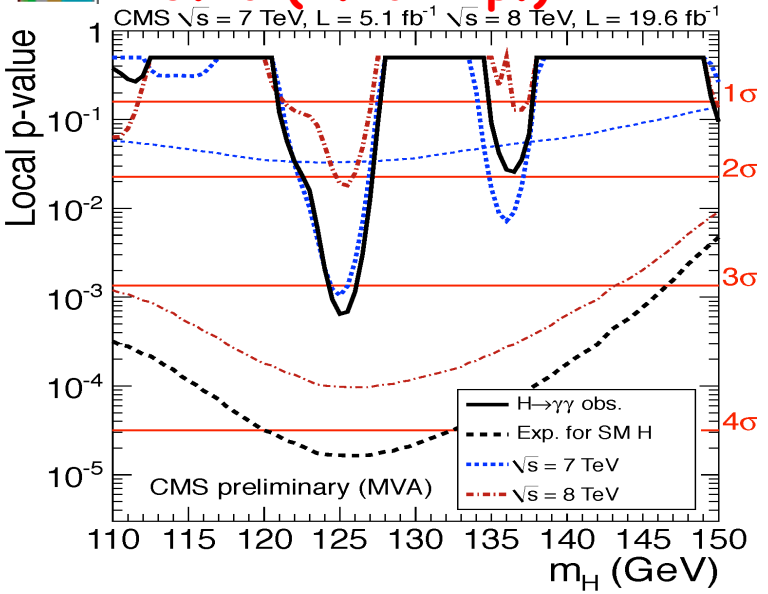
m_H=126.8±0.2stat±0.7sys GeV



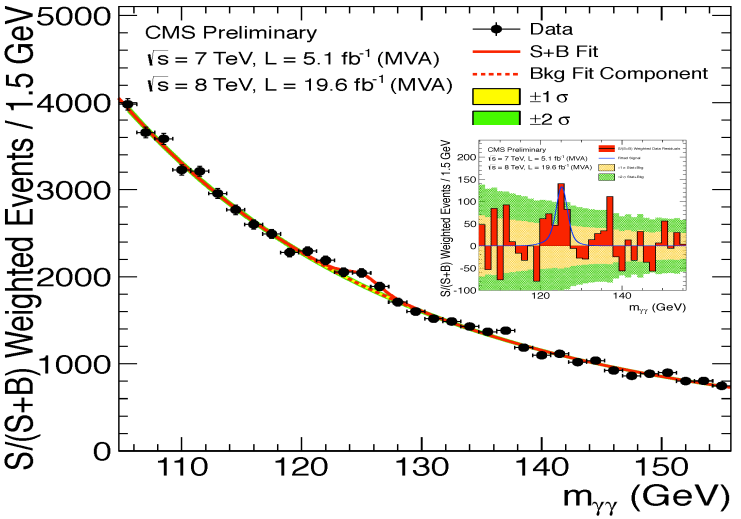
H→ γγ

CMS-PAS-HIG-001

3.2σ (4.2σ exp.)



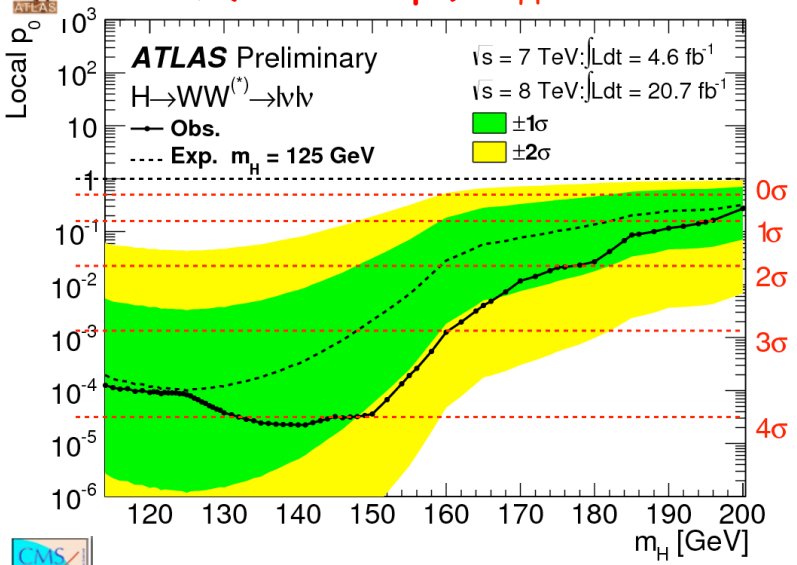
m_H=125.4±0.5 stat±0.6 sys GeV



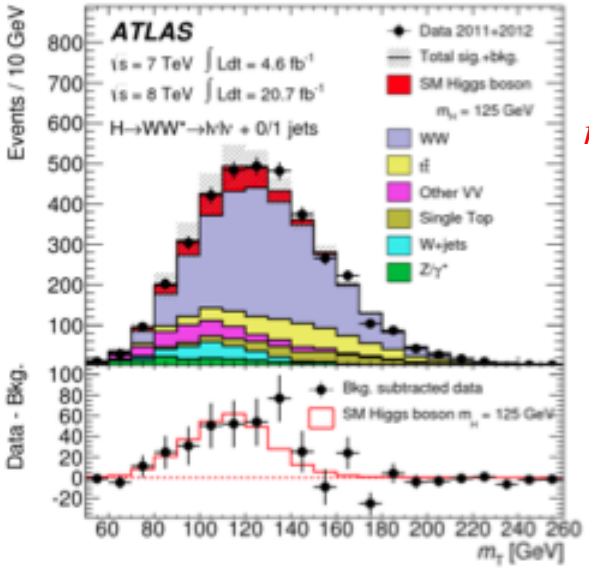
Higgs discovery channels update with "RUN-I" statistics

ATLAS-CONF-2013-030

3.8σ, (3.7σ exp.) m_H=125.5 GeV



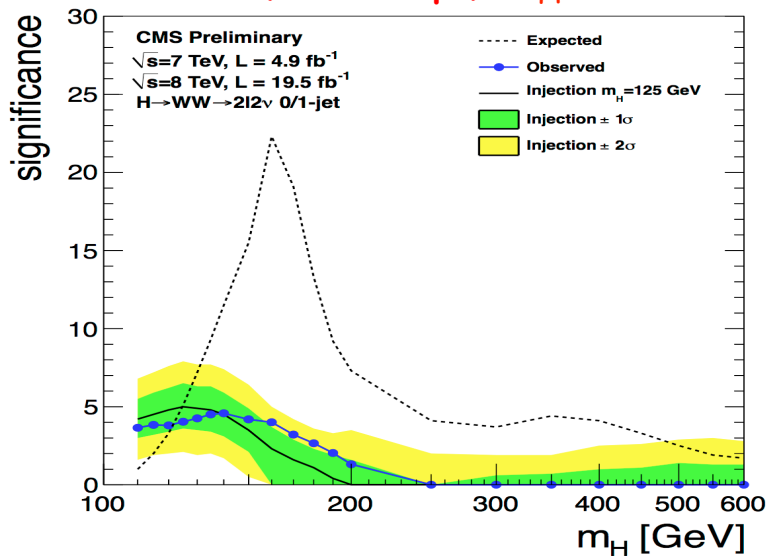
H→ WW→2l2ν

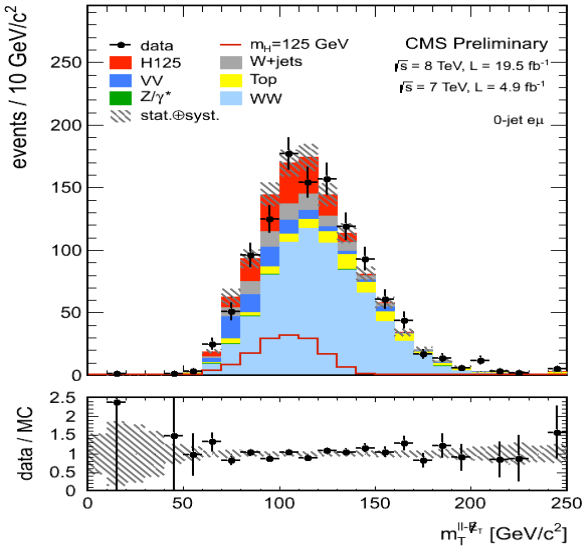


$$m_T = \sqrt{(E_T^{\ell\ell} + E_T^{miss})^2 - |\vec{p}_T^{\,\ell\ell} + E_T^{miss}|}$$

CMS-PAS-HIG-003

4.0σ, (5.1σ exp.) m_H=125GeV

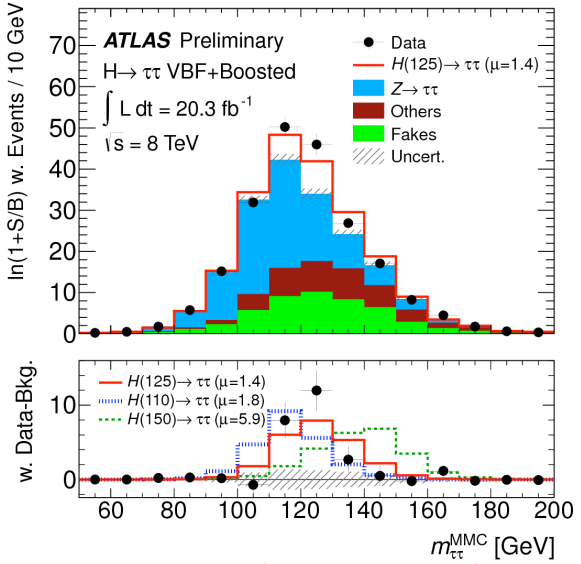




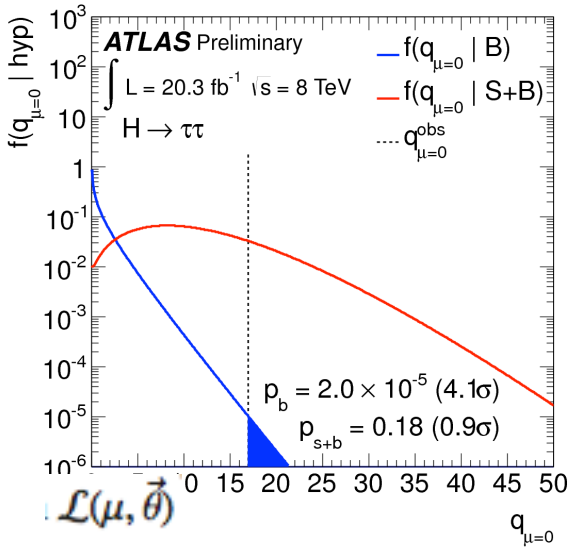
H→ττ

ATLAS-CONF-2013-108

4.1σ (3.2σ exp.)



μ (m_H=125 GeV)= $1.4^{+0.5}_{-0.4}$

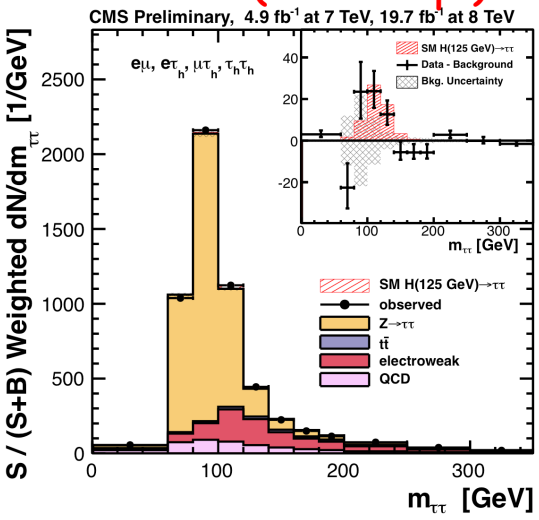


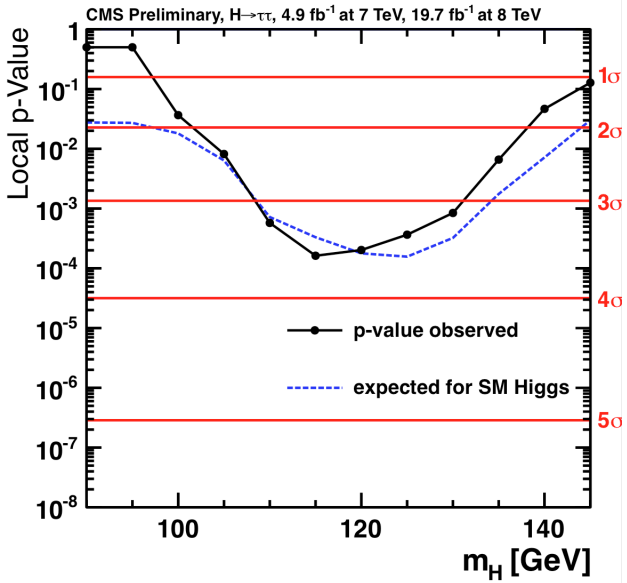
$$q_\mu = -2\ln(\mathcal{L}(\mu,\hat{\hat{\vec{\theta}}})/\mathcal{L}(\hat{\mu},\hat{\vec{\theta}}))$$

q_μ – test statistics;
$\mathcal{L}(\mu,\vec{\theta})$ binned likelihood function
μ and θ parameters that maximize the likelihood

CMS-HIG-13-004

3.3σ (3.4σ exp.)



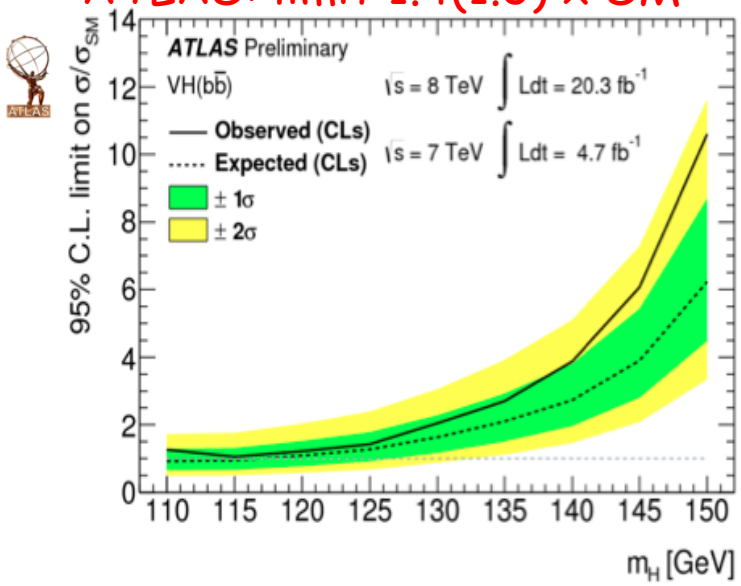


Search in exclusive categories, ll, lh, hh and jets (0,1,2)
Optimized ττ mass reconstruction

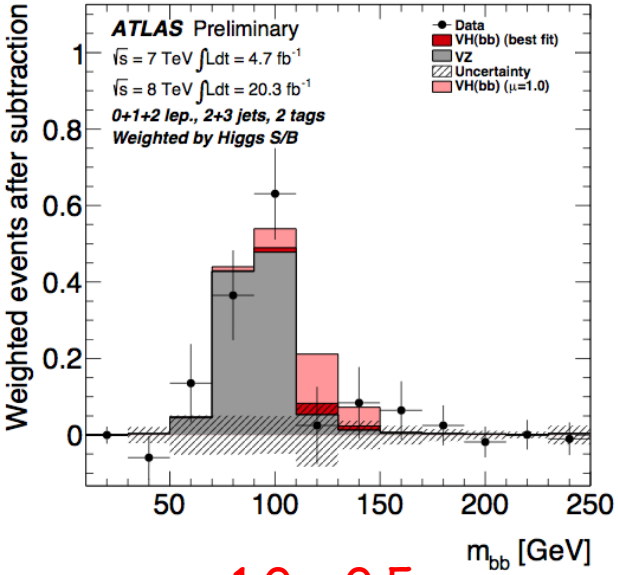
H→bb

ATLAS-CONF-2013-108

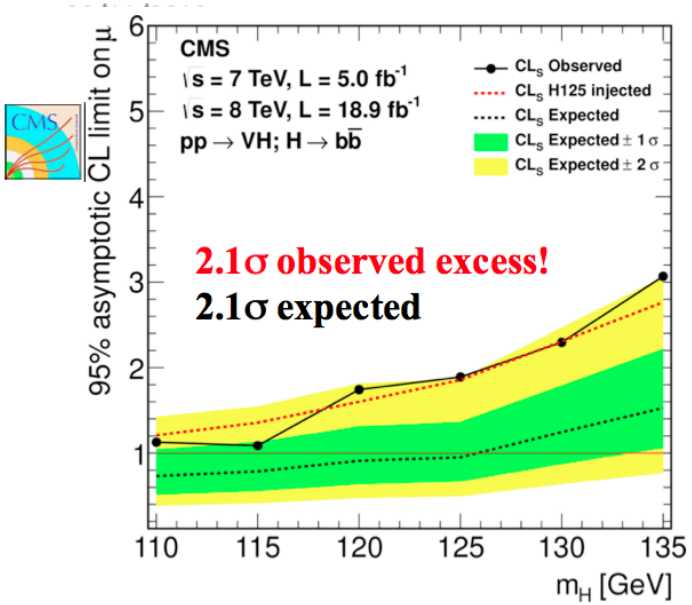
ATLAS: limit 1.4(1.3) x SM



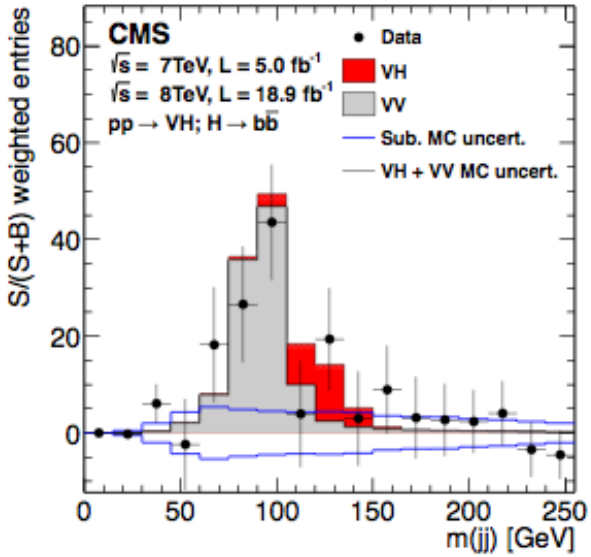
μ = 0.2 ± 0.5(stat.) ± 0.4(syst.)



CMS-HIG-13-012



μ = 1.0 ± 0.5



Signal Strength

μ = 1.23 ± 0.18

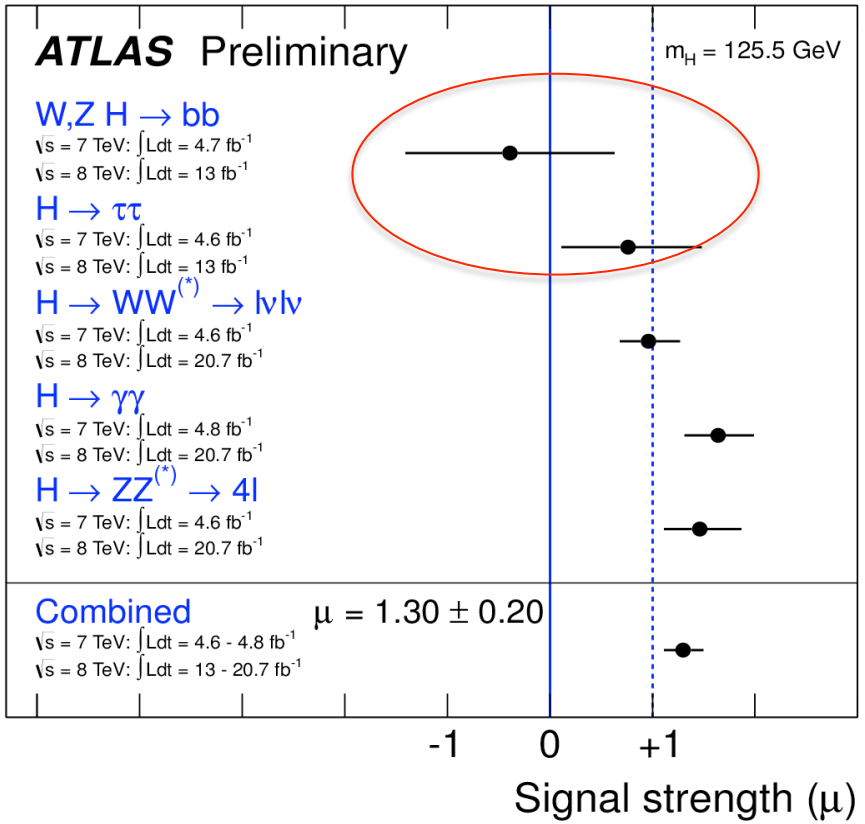
γγ: μ = 1.55 $^{+0.33}_{-0.28}$
WW: μ = 0.99 $^{+0.31}_{-0.28}$
ZZ: μ = 1.43 $^{+0.40}_{-0.35}$
ττ: μ = 1.4 $^{+0.50}_{-0.4}$
bb: : μ = 0.2±0.5

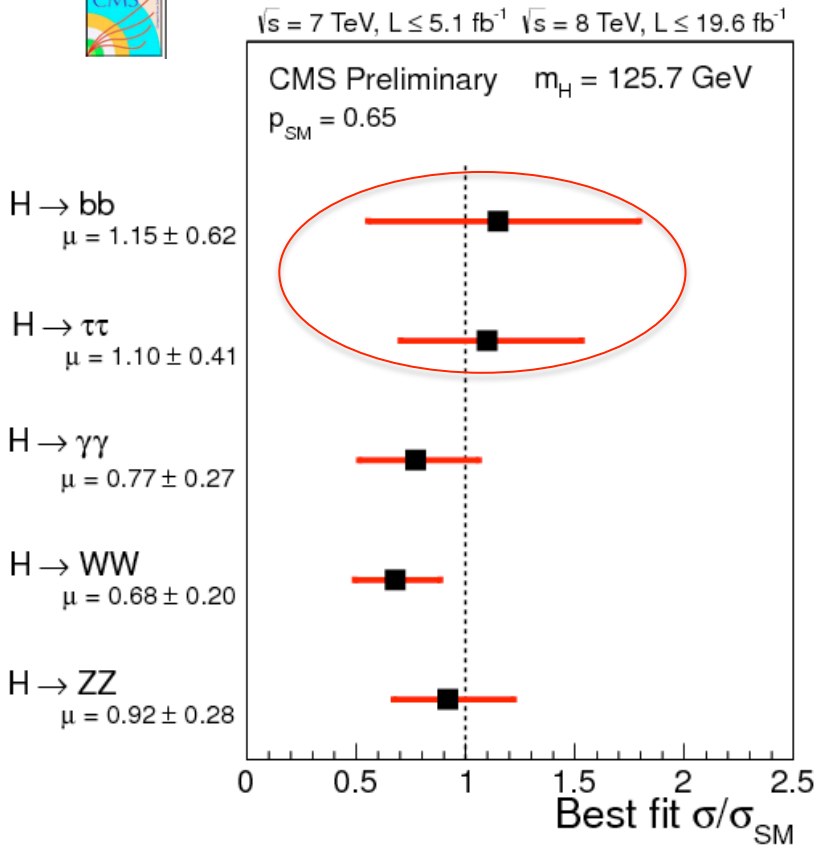
$$\mu = \frac{\sigma_{obs}}{\sigma_{SM}}$$

μ = 0.80 ± 0.14

γγ: μ = 0.77±0.27
WW: μ = 0.68±0.20
ZZ: μ = 0.92±0.28
ττ: μ = 0.87±0.28
bb: : μ = 1.0±0.5

ATLAS-CONF-2013-034





Higgs Mass measurement

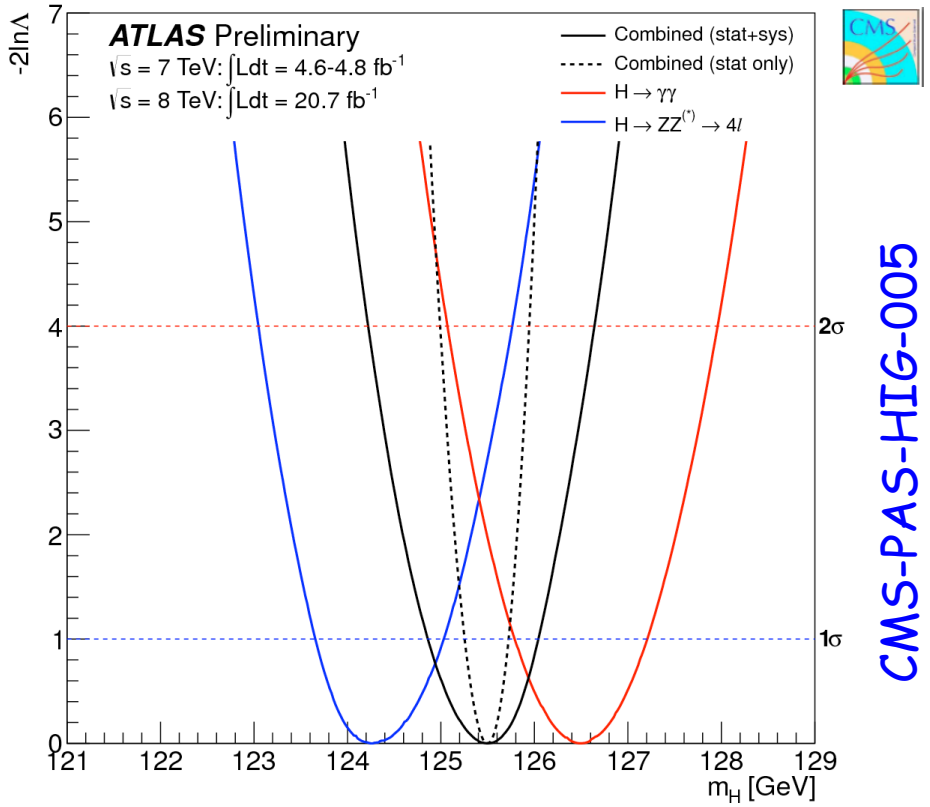
$m_H^{\gamma\gamma} = 126.8 \pm 0.2\ \text{stat} \pm 0.7\ \text{sys GeV}$

$m_H^{4l} = 124.3^{+0.6}_{-0.5}\ \text{stat}^{+0.5}_{-0.3}\ \text{sys GeV}$

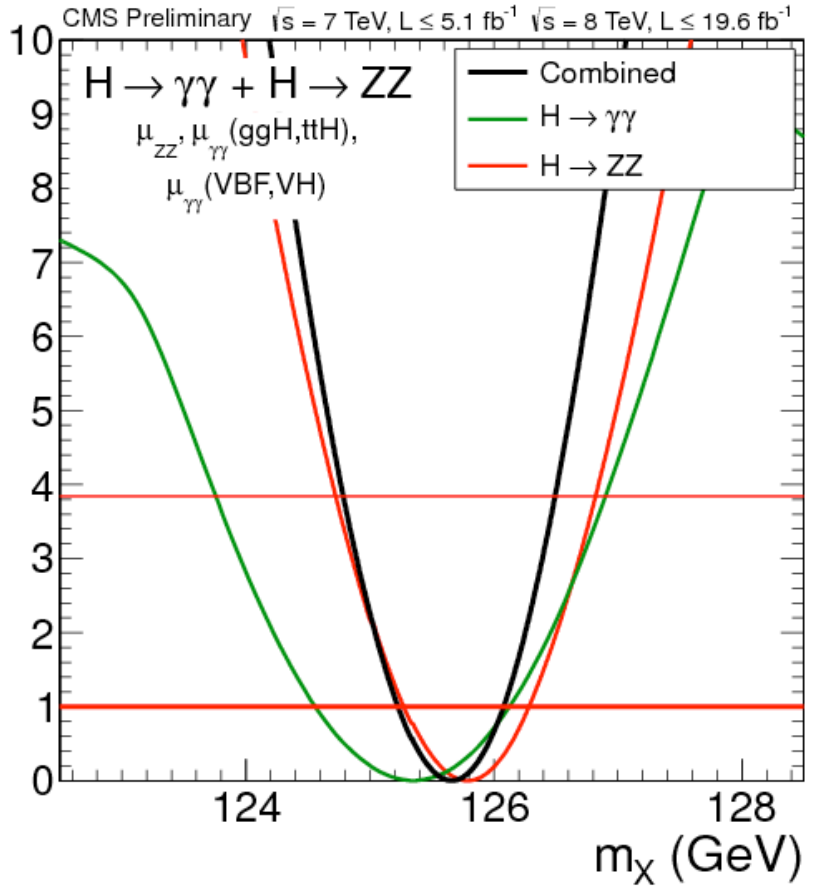
$m_H^{\gamma\gamma} = 125.4 \pm 0.5\text{stat} \pm 0.6\text{sys GeV}$

$m_H^{4l} = 125.8 \pm 0.5\text{stat} \pm 0.2\text{sys GeV}$

ATLAS-CONF-2013-014



CMS-PAS-HIG-005



$m_H = 125.5 \pm 0.2\ \text{stat}\ ^{+0.5}_{-0.6}\ \text{sys GeV}$

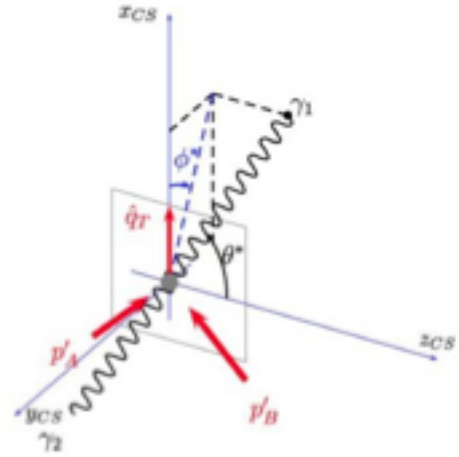
$m_H = 125.7 \pm 0.3\ \text{stat} \pm 0.3\ \text{sys GeV}$

Spin and Parity

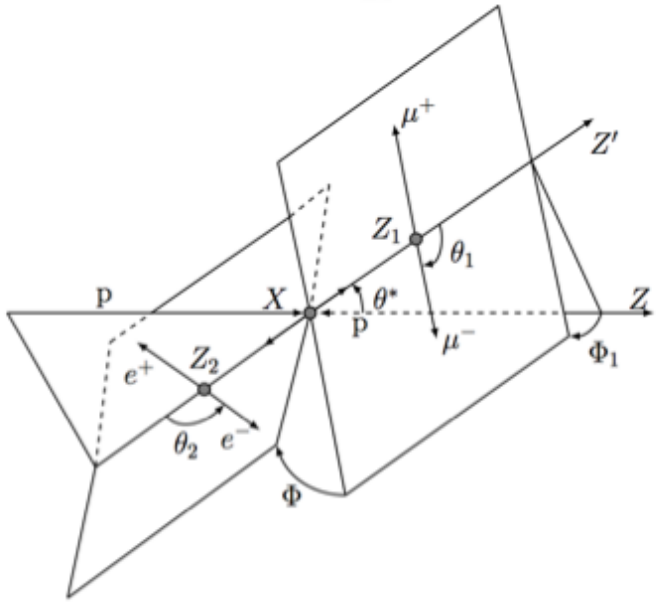
SM Higgs predicted JP = 0+

Studied in three decay modes:

$$\cos\theta^* = \frac{\sinh(\eta_{\gamma_1} - \eta_{\gamma_2})}{\sqrt{1 + \left(p_T^{\gamma\gamma}/m_{\gamma\gamma}\right)^2}} \cdot \frac{2p_T^{\gamma_1} p_T^{\gamma_2}}{m_{\gamma\gamma}^2}$$



- ✧ H→γγ Fully reconstructed:
  - Use of production angle
  - Background understanding critical
- ✧ H→ZZ(*) →4l Fully reconstructed:
  - Use of up to 5 angular and 2 mass distributions
  - and BDT or ME Discriminant if all combined
- ✧ H→WW(*) →2l2
  - direct angle calculation not possible
  - Use kinematic distribution such as M_{ll} and $\Delta\varphi_{ll}$
  - Combined BDT or 2D fit
- ✧ Different models for J^P compared to SM Higgs 0^+

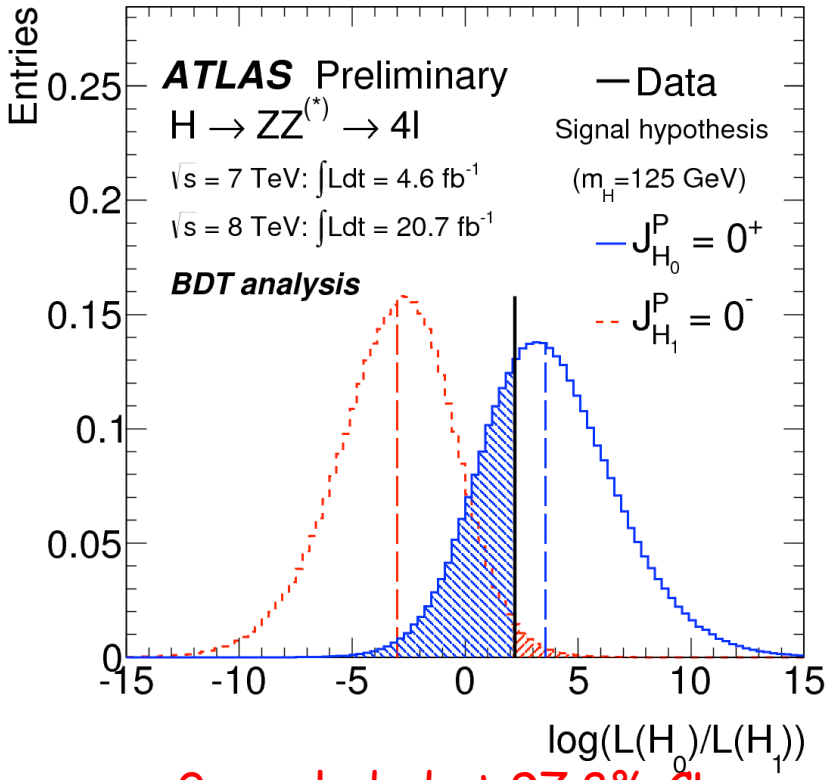


JP = 0⁻ vs 0⁺

H→ZZ*→4l channel also used in ATLAS and CMS to probe 1^{+-}, $2^{+}m$

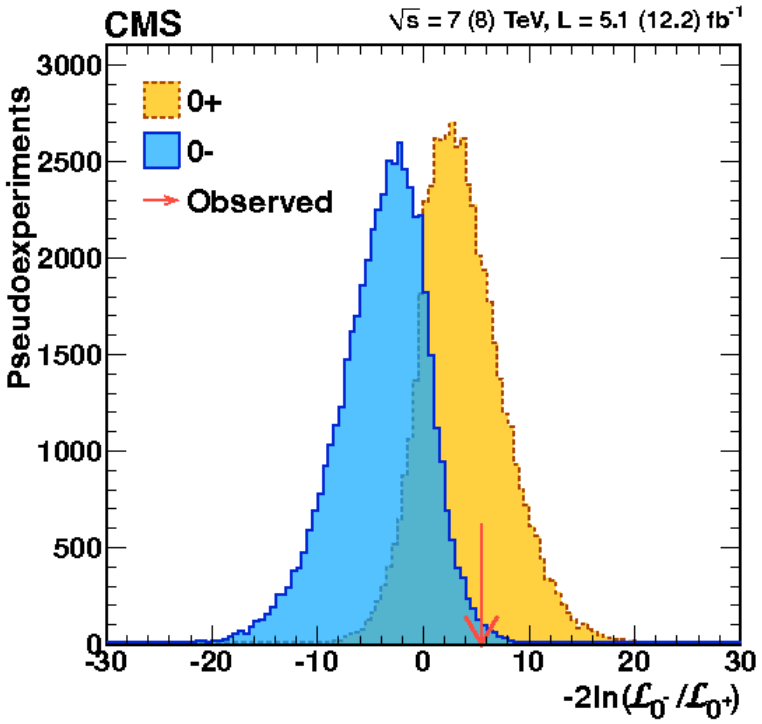
All favor 0+ Hypothesis

ATLAS-CONF-2013-013



0^{-} excluded at 97.8% CLs

CMS-HIG-12-041

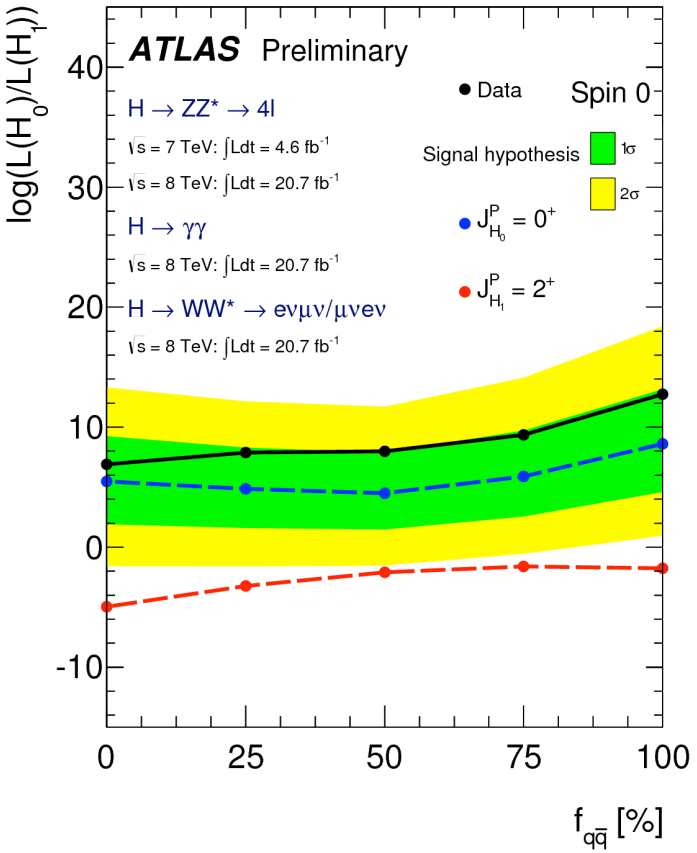


0^{-} excluded at 99.8% CLs

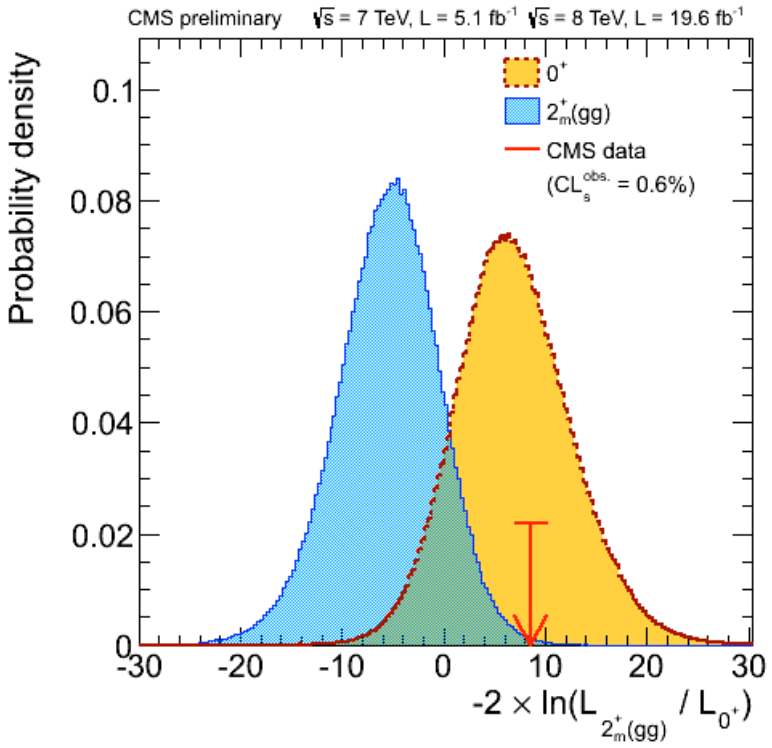
$J^P = 2m^+$ vs 0^+

Graviton inspired model, produced via gg or qq with a fraction fqq and minimal coupling: Minimal model 2^+m tested (LO QCD): fqq =4%)

$2m^+$ excluded at > 99% CLs All favor 0^+ Hypothesis



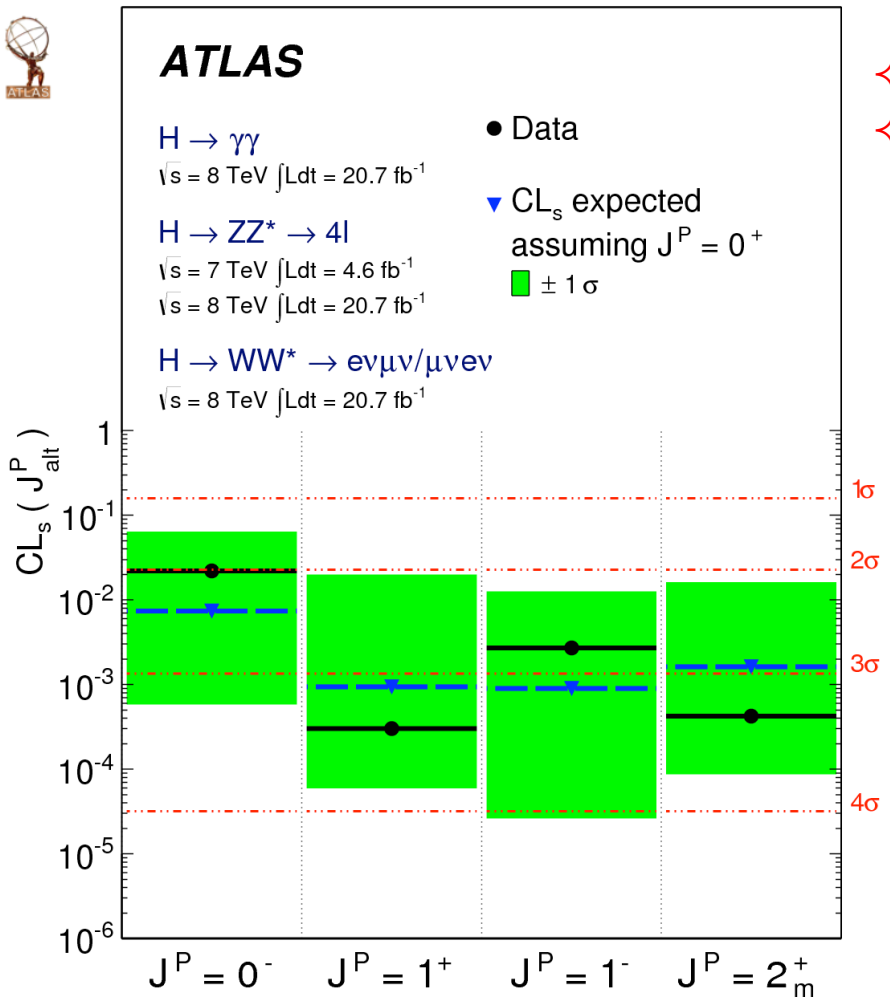
ATLAS-CONF-2013-040



CMS-PAS-HIG-13-005

Spin Overview

Phys. Lett. B 726 (2013), pp. 120-144



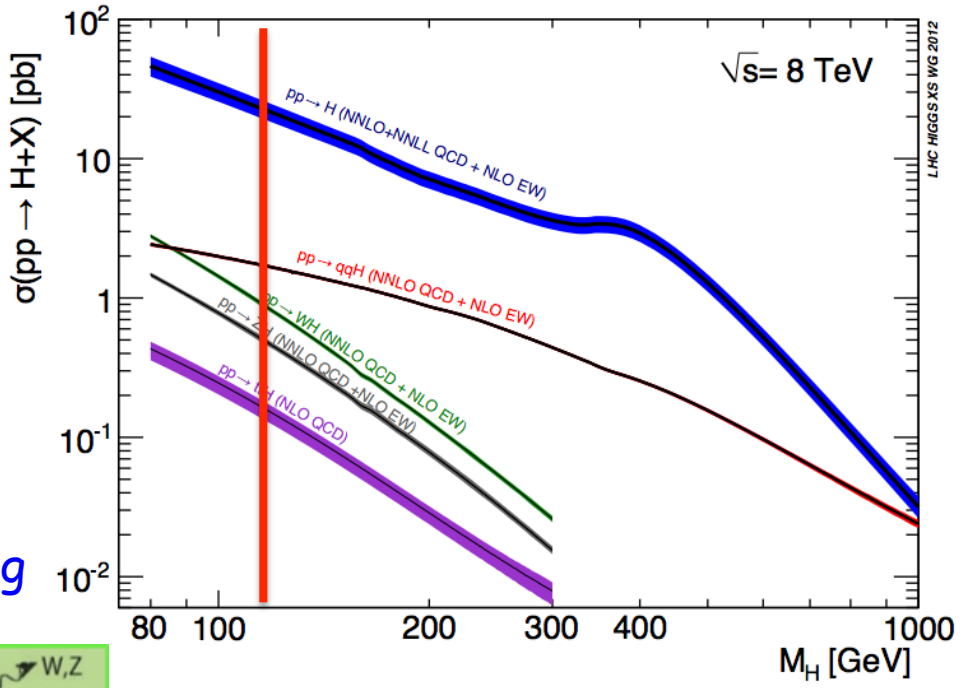
- ATLAS and CMS strongly favor JP = 0+
- Other models excluded @ > 95% CLs

BACK UP SLIDES

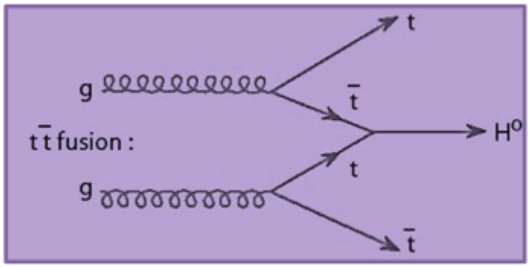
Higgs boson production

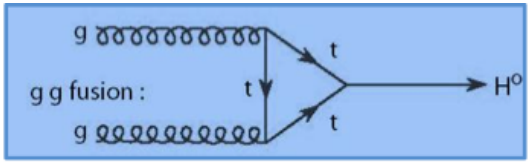
ggF: 19 pb, 87%
VBF WW, ZZ Fusion: 1.6 pb, 7.3%
W/ZH: 0.70 pb, 0.41 pb
ttH: 0.13 pb

SM Higgs boson production cross sections
m_H=125.5 GeV, σ = 21.84 pb @ 8TeV

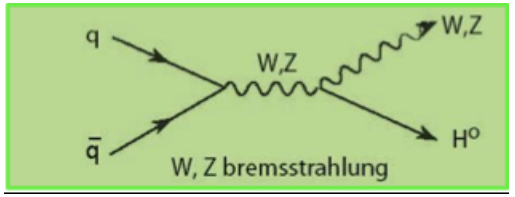


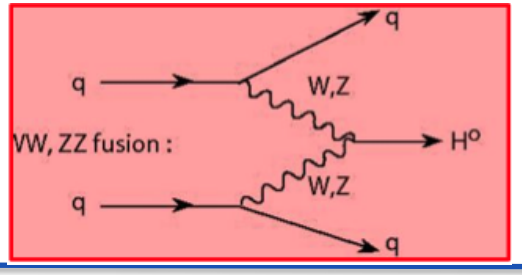
Fermion Coupling





Vector Boson Coupling

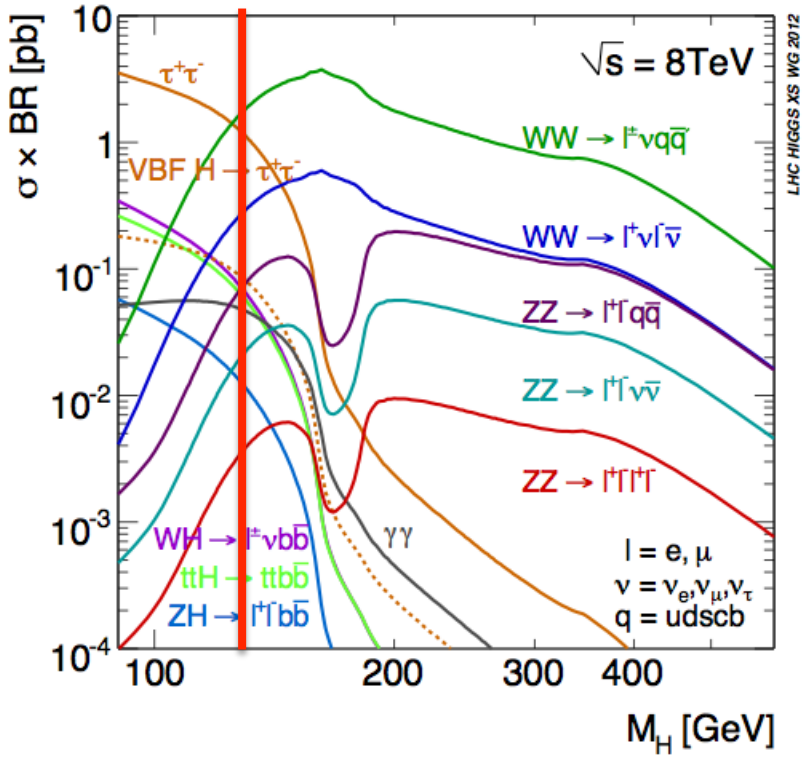




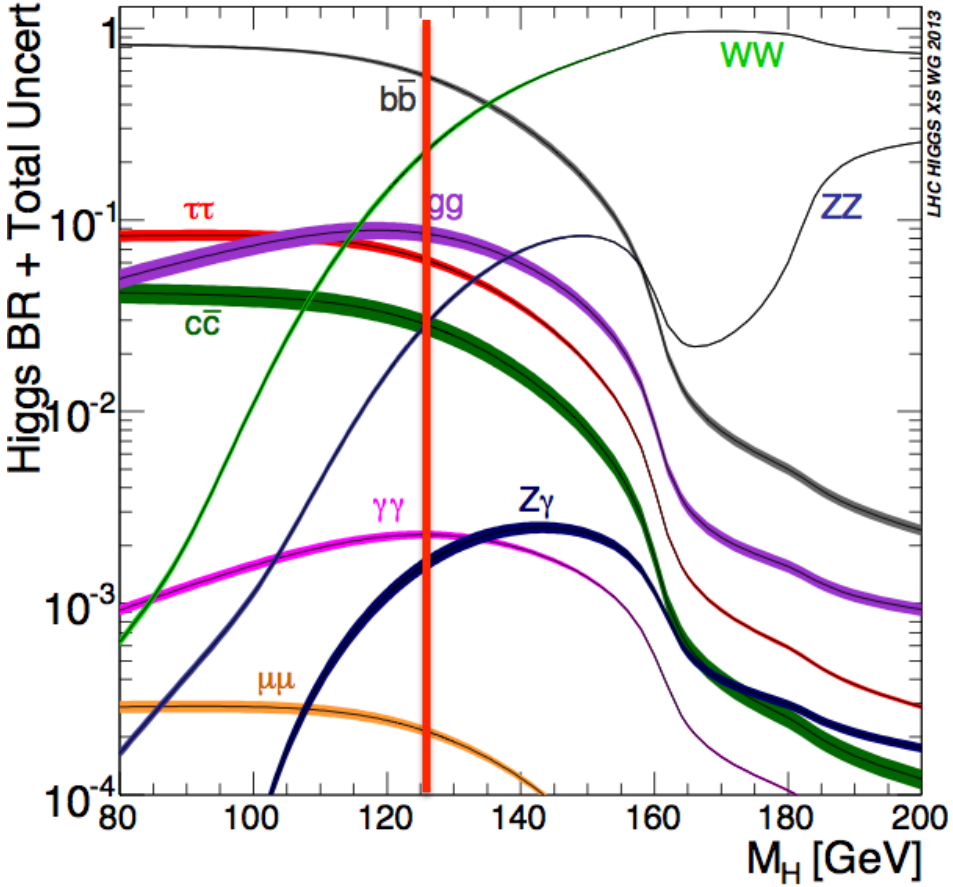
Higgs boson decays @ m_H=125.5 GeV

- H→bb : 56.9% (Yukawa coupling)
- H→WW* : 22.3% (Gauge coupling)
  - H→WW*→2l2ν: 1.1%
- H→ττ : 6.2% (Yukawa coupling)
- H→γγ : 0.28% (Yukawa/Gauge (loop) coupling)
- H→ZZ* : 2.8% (Gauge coupling)
  - H→ZZ*→4l : 0.013%
- H→Zγ : 0.16%
- H→μμ : 0.02%

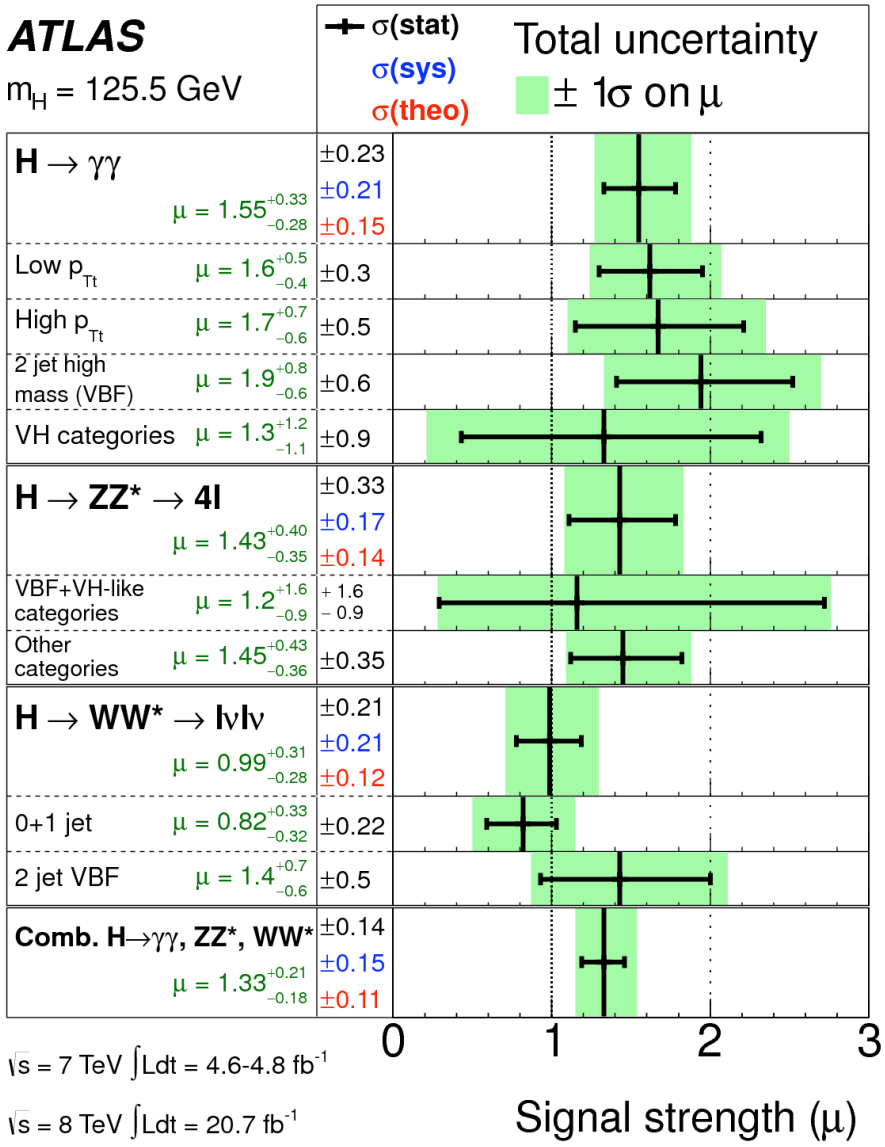
SM Higgs boson production cross section times branching ratio



SM Higgs boson decay branching ratios



Signal Strength - summary



Phys. Lett. B 726 (2013), pp. 88-119