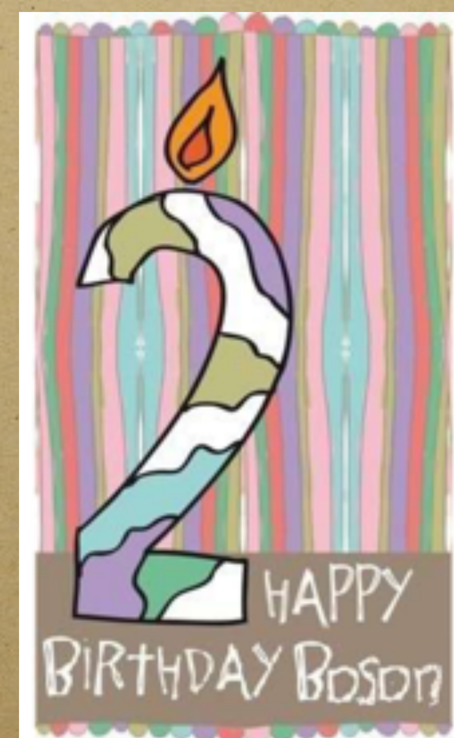
(some) news from ICHEP 2014

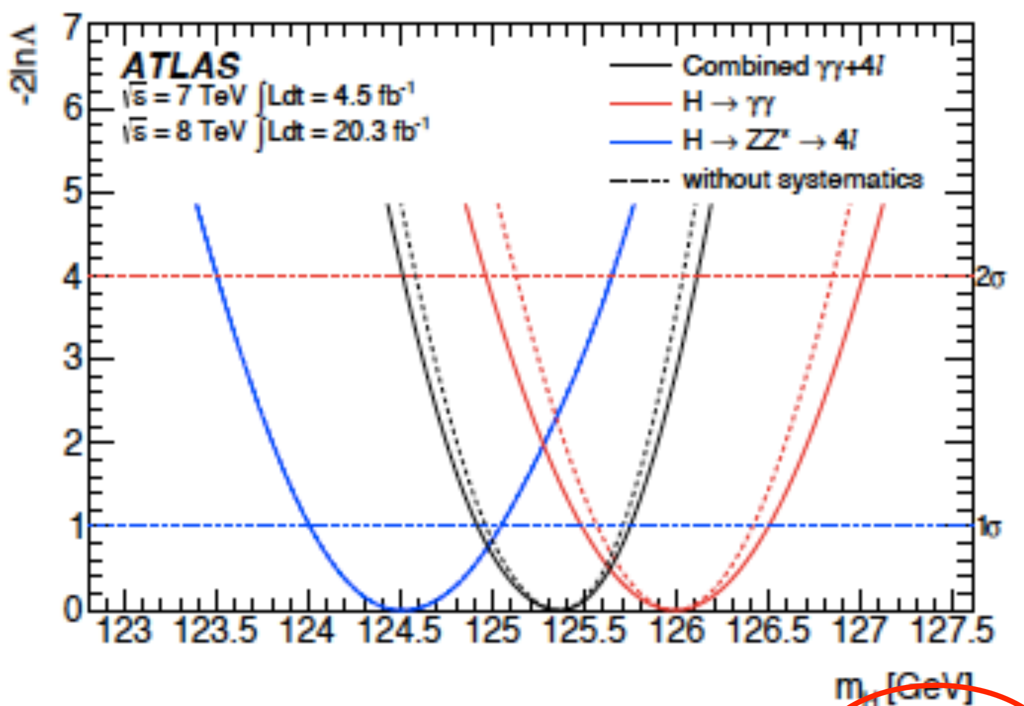
- 15 Parallel Sessions
- 536 Parallel Talks
- 55 Plenary Talks
- 18 Additional Talks

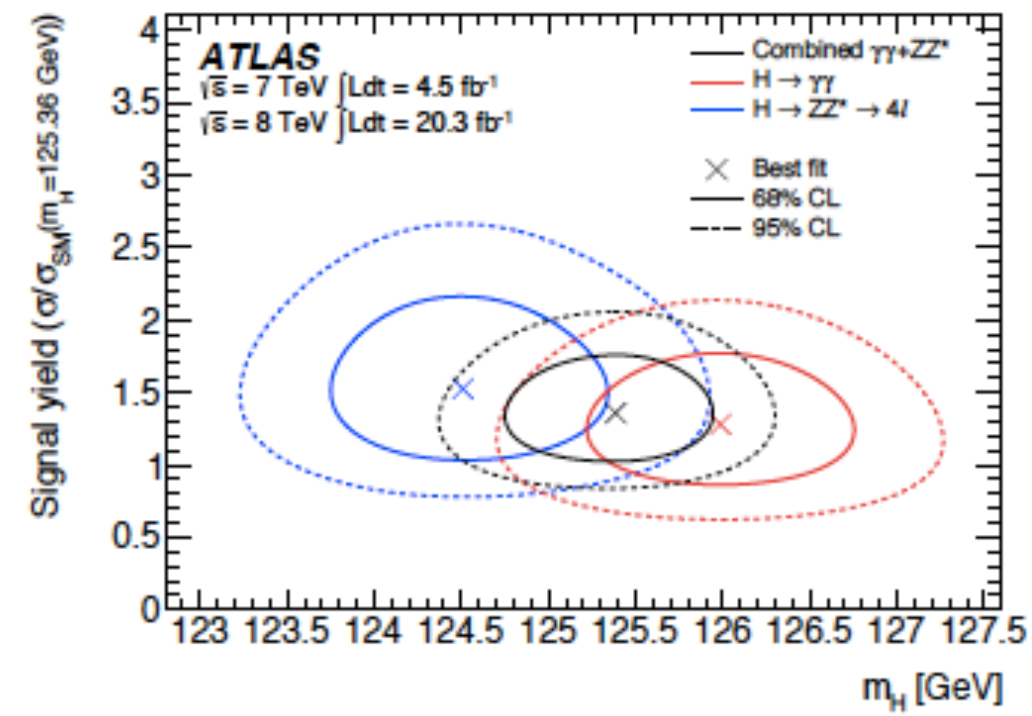


Junping Tian

IPNS-ILC Friday Meeting, Jul. 11 @ KEK

Higgs Mass





$$m_H = 125.36 \pm 0.37(\text{stat}) \pm 0.18(\text{sys})\ \text{GeV}$$
$$= 125.36 \pm 0.41\ \text{GeV}$$

Previous result: $m_H = 125.5 \pm 0.2(stat)^{+0.5}_{-0.6}(sys)\ GeV$

$$m_H = 125.98 \pm 0.42(\text{stat}) \pm 0.28(\text{sys})\ \text{GeV}$$
$$= 125.98 \pm 0.50\ \text{GeV}$$
$$\mu = 1.29 \pm 0.30 \qquad H \to \gamma\gamma$$

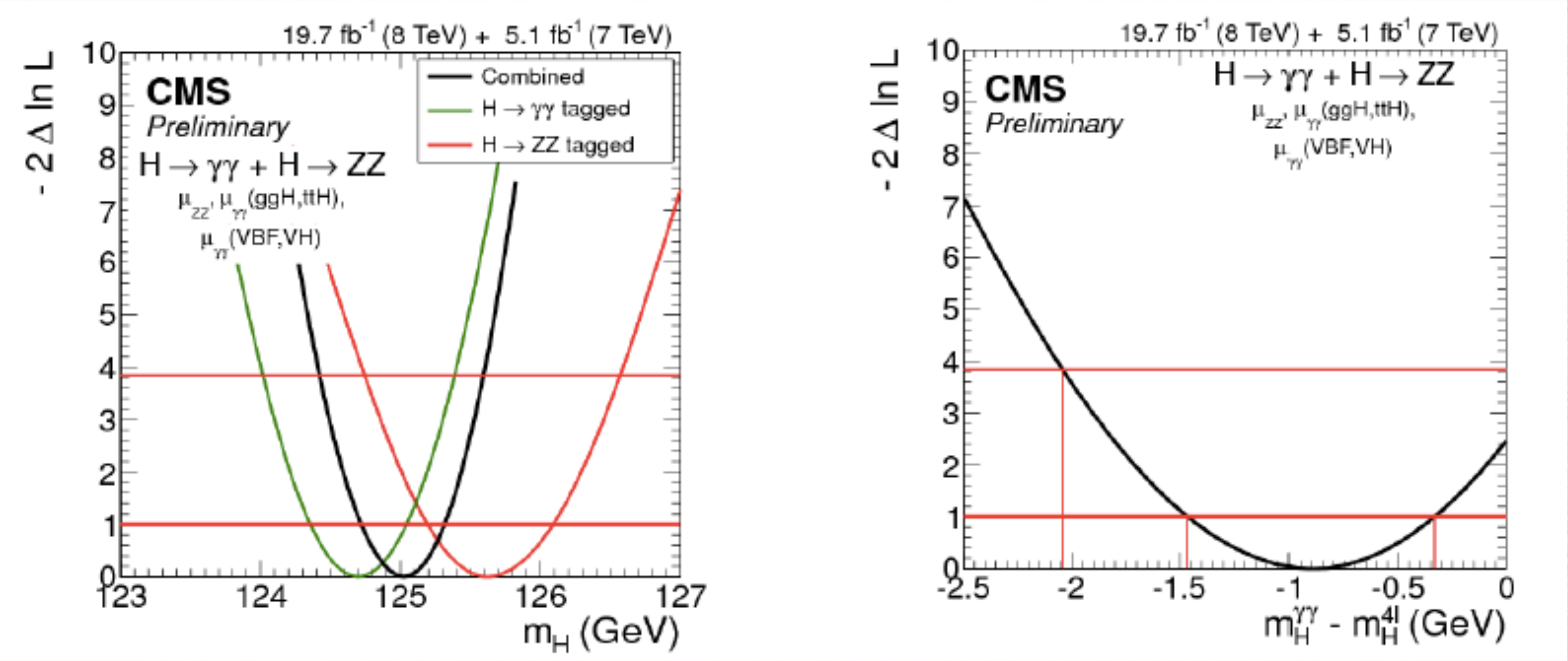
$$m_H = 124.51 \pm 0.52(\text{stat}) \pm 0.06(\text{sys})\ \text{GeV}$$
$$= 124.51 \pm 0.52\ \text{GeV}$$
$$\mu = 1.66^{+0.45}_{-0.38} \qquad H \to ZZ^* \to 4l$$

Previous result

$m_H = 126.8 \pm 0.24(\text{stat}) \pm 0.7(\text{sys})\ \text{GeV}$ $\mu = 1.55^{+0.33}_{-0.28}$

$m_H = 124.3^{+0.6}_{-0.5}(stat)^{+0.5}_{-0.3}(sys) GeV,\ \mu = 1.43^{+0.40}_{-0.35}$

Higgs Mass



$$m_H = 125.03 \,^{+0.26}_{-0.27}\,(stat)\,^{+0.13}_{-0.15}\,(syst) = 125.03 \,^{+0.29}_{-0.31}\,(tot)\; GeV$$

H→γγ

$$m_H = 124.70 \pm 0.31\,(stat) \pm 0.15\,(syst)\; GeV$$

H→ZZ→4l

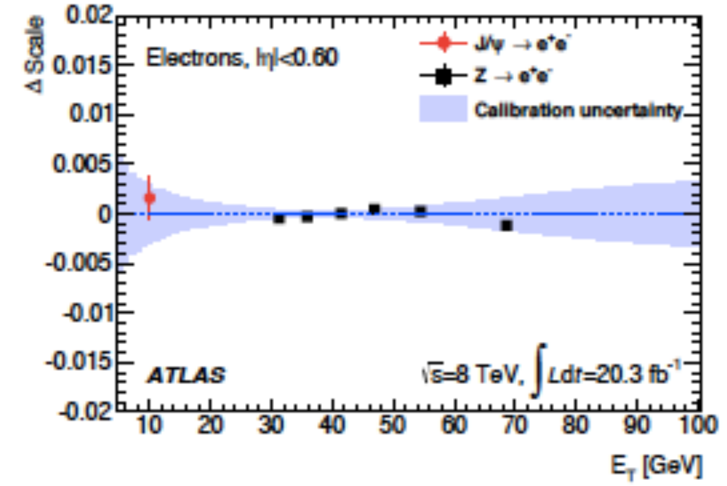
$$m_H = 125.6 \pm 0.4\,(stat) \pm 0.2\,(syst)\; GeV$$

Improvements to electron and photon calibration

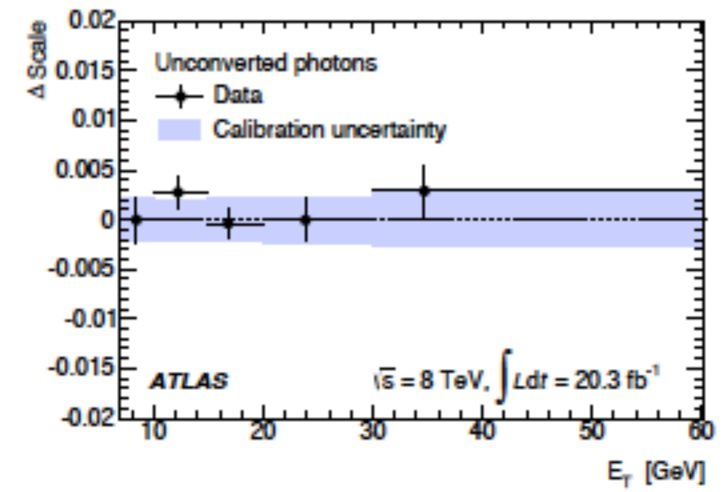
- From simulation: EM cluster energy correction via multivariate regression: resolution 10% better for $H \to \gamma\gamma$
- Corrections from data:
  - Intercalibration of calorimeter layers using $Z \to \mu\mu$ events: 1-2% for EM layers 1&2
  - Accurate knowledge of material in front of EM calorimeter: ~2-10% radiation lengths
- Calorimeter response verified to be stable w.r.t. time, pileup to $< 0.05\%$
- Energy scale accuracy from $Z \to ee$:
  - 0.03% for $|\eta| < 1.37$, 0.05% for $|\eta| > 1.82$ for e
  - 0.2% for $|\eta| < 1.37$, 0.3% for $|\eta| > 1.82$ for γ
- Resolution accuracy from $Z \to ee$:
  - 0.3 (0.5)% in barrel (endcap)
- Independent cross-checks using $J/\psi \to ee$ and $Z \to ll\gamma$

For more details, see dedicated talk: J-B. Blanchard

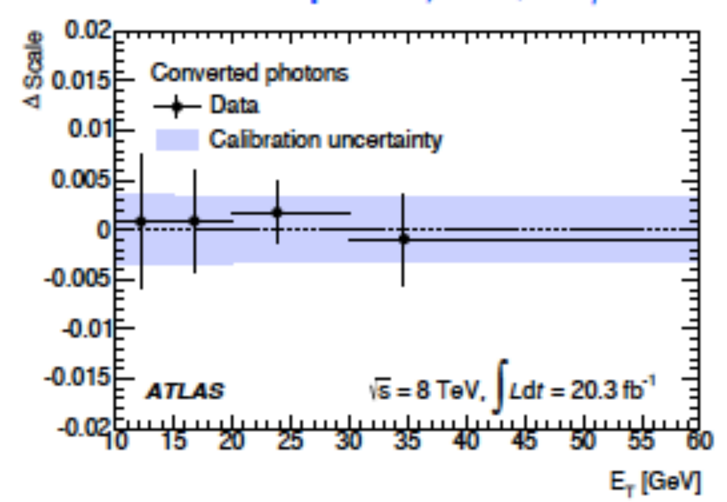
Electrons



Unconverted photons, $Z \to ll\gamma$



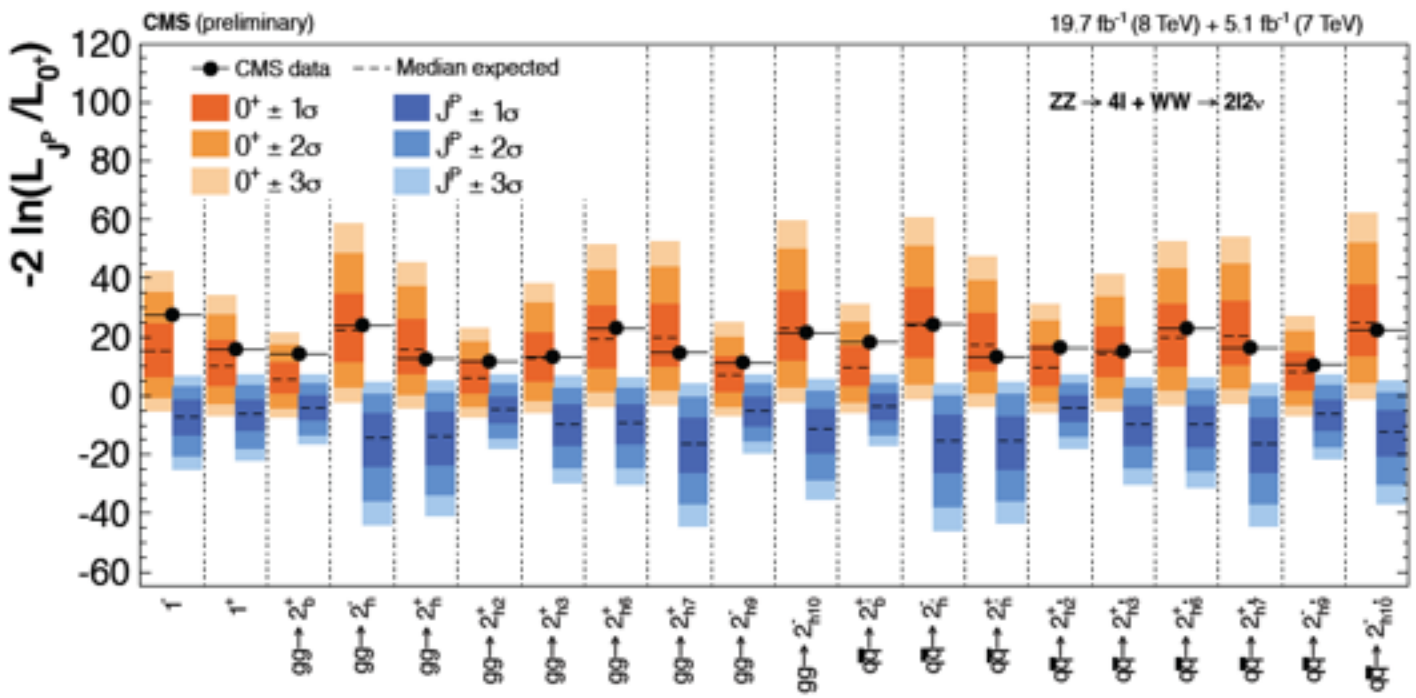
Converted photons, $Z \to ll\gamma$



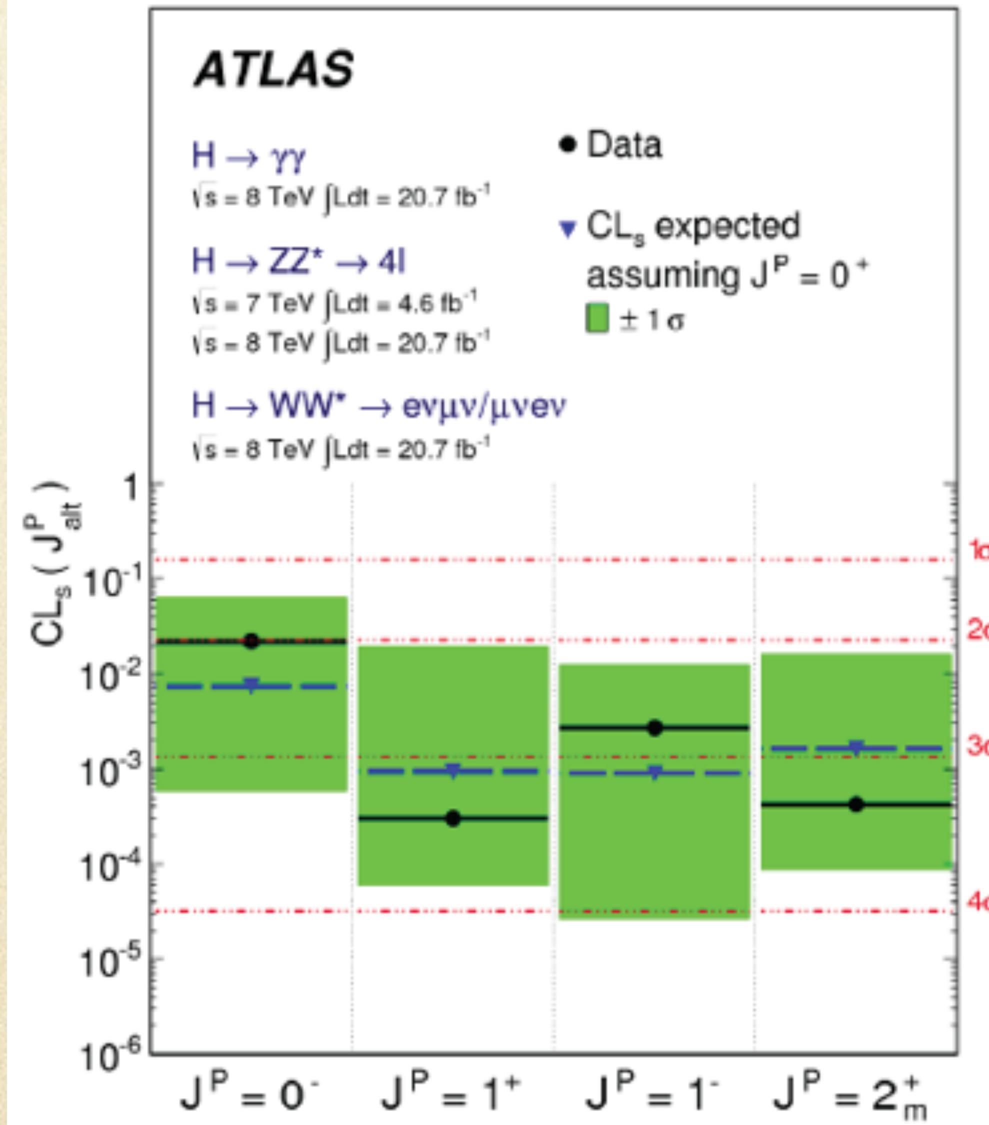
Higgs J^{CP}

J=1,2: ZZ+WW combined

- By combining ZZ and WW, **all** the exotic models are excluded at **more than 99.9% C.L.**
  - ZZ and WW yields fitted separately
  - Spin-1: exclusive qq production
  - Spin-2: ZZ test is production-independent; WW test is done f_{qq}-dependent



- combination always result in a stronger constraint than the ZZ, WW channel alone



- **spin-1 excluded** by the $\gamma\gamma$ observation (5.7σ) and ZZ+WW combination (**at ≥ 99.9% C.L.**)
- **spin-2 excluded at ≥ 99.9% C.L.** by the ZZ and WW combination

$J^P=2^+$ at >99.9% CL independently of f_{qq} (ZZ+WW+γγ);
$J^P=0^-$ at 97.8% CL (ZZ);
$J^P=1^-$ at 99.73% CL; $J^P=1^+$: 99.97% CL. (ZZ+WW).

Anomalous couplings: J=0

- Decay amplitude of X to V_1V_2 (V=Z,W) parameterised in terms of *complex* and *momentum-dependent* couplings (up to q^2 terms)
  - valid in the limit of small deviations from SM ($a_i \sim 0$, $i \neq 1$)

SM tree level + leading momentum expansion

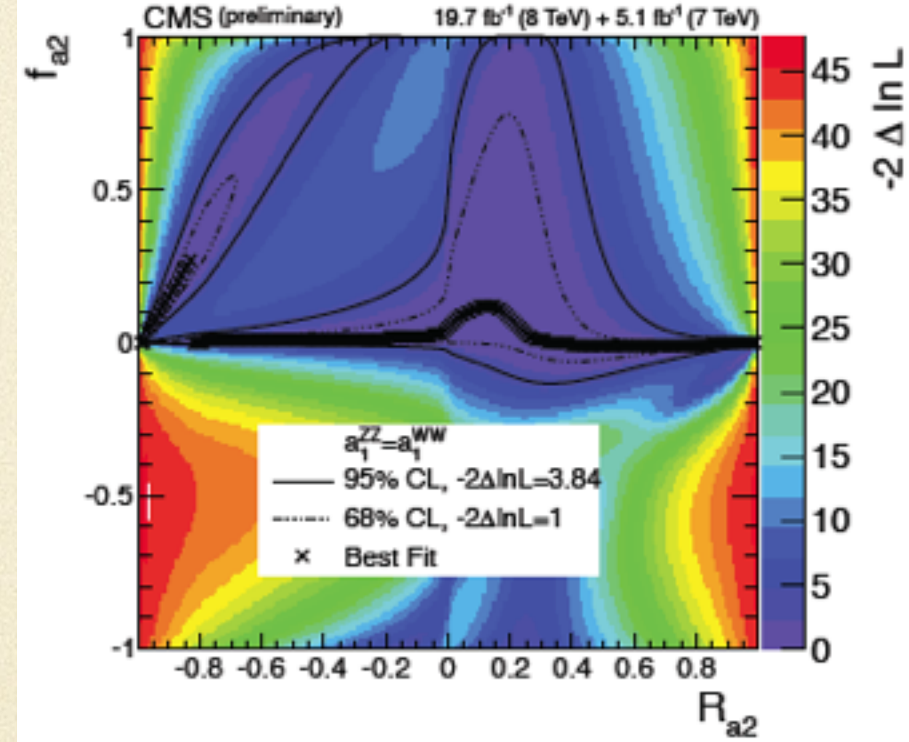
$$A(X_{J=0} \to V_1V_2) = v^{-1}\left(\left[a_1 - e^{i\phi_{\Lambda_1}}\frac{q^2_{Z_1}+q^2_{Z_2}}{(\Lambda_1)^2}\right] m_Z^2 \epsilon^*_{Z_1}\epsilon^*_{Z_2}\right.$$
$$+ a_2 f^{*(Z_1)}_{\mu\nu} f^{*(Z_2),\mu\nu} + a_3 f^{*(Z_1)}_{\mu\nu} \tilde{f}^{*(Z_2),\mu\nu} \quad \} \text{ VV couplings}$$
$$+ a_2^{Z\gamma} f^{*(Z)}_{\mu\nu} f^{*(\gamma),\mu\nu} + a_3^{Z\gamma} f^{*(Z)}_{\mu\nu} \tilde{f}^{*(\gamma),\mu\nu} \quad \} Z\gamma^* \text{ couplings}$$
$$\left.+ a_2^{\gamma\gamma} f^{*(\gamma_1)}_{\mu\nu} f^{*(\gamma_2),\mu\nu} + a_3^{\gamma\gamma} f^{*(\gamma_1)}_{\mu\nu} \tilde{f}^{*(\gamma_2),\mu\nu}\right) \quad \} \gamma^*\gamma^* \text{ couplings}$$

a_2 terms: CP-even scalar

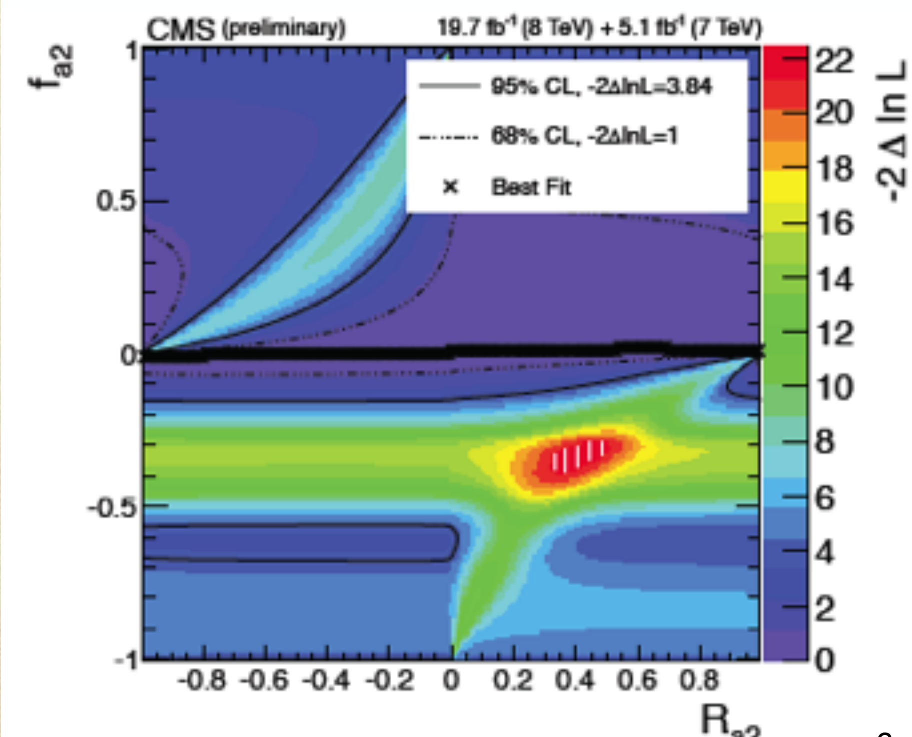
a_3 terms: CP-odd pseudo-scalar

  - $Z\gamma$ and $\gamma\gamma$ couplings only considered for the 4l analysis
  - Λ_1 = scale of new physics affecting the tree level VV coupling
- Analysis fits for the terms of the expansion: a_2, a_3, Λ_1, $a_2^{Z\gamma}$, $a_3^{Z\gamma}$, $a_2^{\gamma\gamma}$, $a_3^{\gamma\gamma}$

1. $a_1^{ZZ} = a_1^{WW}$



2. $a_1^{ZZ} \neq a_1^{WW}$



Higgs signatures explored at CMS

m_H fixed at *125.0* GeV

Decay tag	incl.(ggH)	VBF tag	VH tag	ttH tag		Obs.	Exp.
H→ZZ	✔	✔			→	6.5	6.3
H→γγ	✔	✔	✔	✔	→	5.6	5.3
H→WW	✔	✔	✔	✔	→	4.7	5.4
H→ττ	✔	✔	✔	✔	→	3.8	3.9
H→bb		✓	✔	✔	→	2.0	2.3
H→Zγ	✓	✓					
H→μμ	✓	✓					
H→inv.		✓	✓				

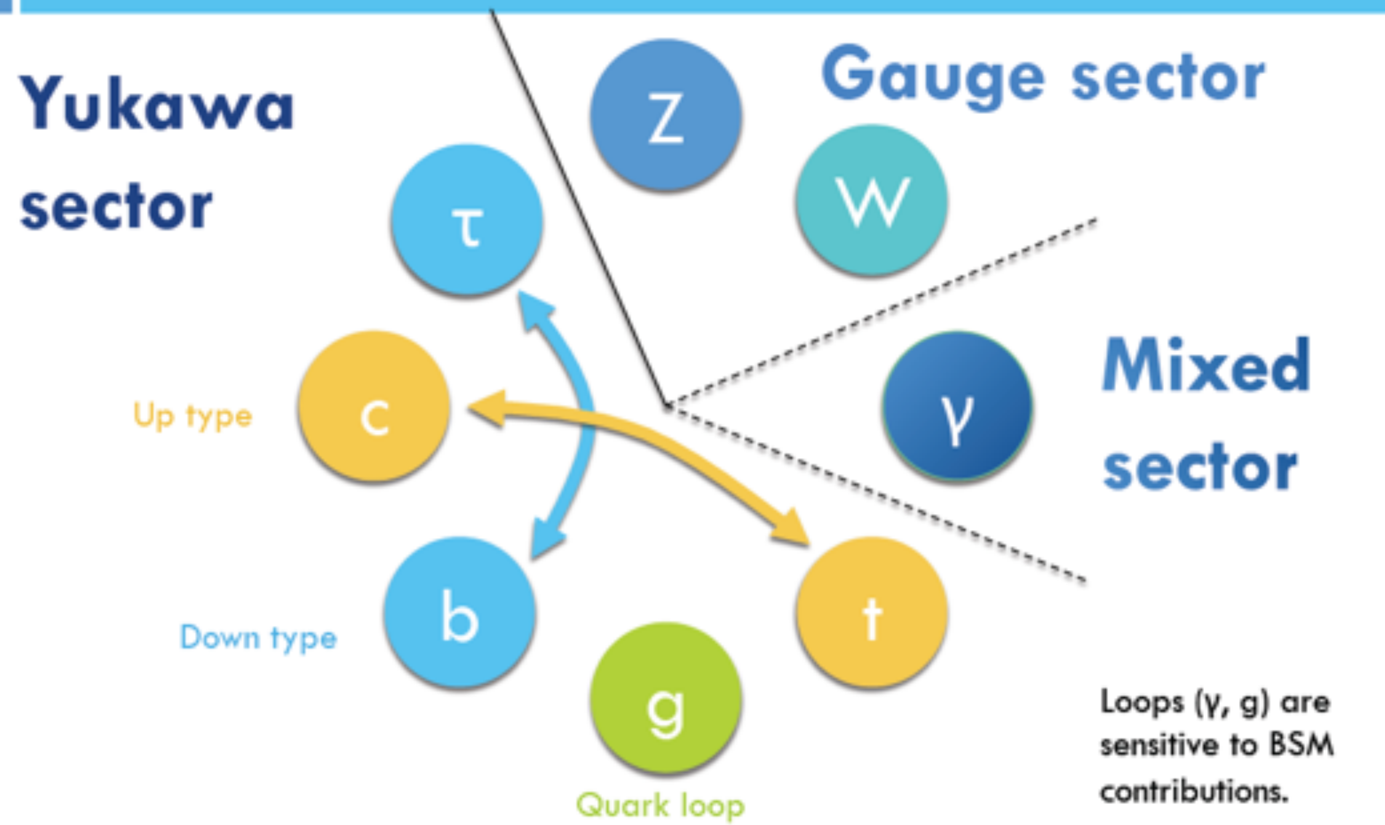
✔ **Used in the NEW combination**

CMS-PAS-HIG-14-009

207 (sub-)categories, 2519 nuisance parameters

ATLAS	Significance observed
H→γγ	7.4 σ
H→ZZ(*)→4l	6.6 σ
H→WW(*)→lνlν	3.8 σ
H→ττ	4.2 σ

Scalar coupling structure



Scalar coupling deviations framework

[arXiv:1307.1347]

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

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

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

$$\frac{\Gamma_{b\bar{b}}}{\Gamma_{b\bar{b}}^{SM}} = \kappa_b^2$$

$$\frac{\Gamma_{\tau^-\tau^+}}{\Gamma_{\tau^-\tau^+}^{SM}} = \kappa_\tau^2$$

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

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

Currently undetectable decay modes

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

$$\frac{\Gamma_{gg}}{\Gamma_{gg}^{SM}} : \text{see Section 3.1.2}$$

$$\frac{\Gamma_{c\bar{c}}}{\Gamma_{c\bar{c}}^{SM}} = \kappa_t^2$$

$$\frac{\Gamma_{s\bar{s}}}{\Gamma_{s\bar{s}}^{SM}} = \kappa_b^2$$

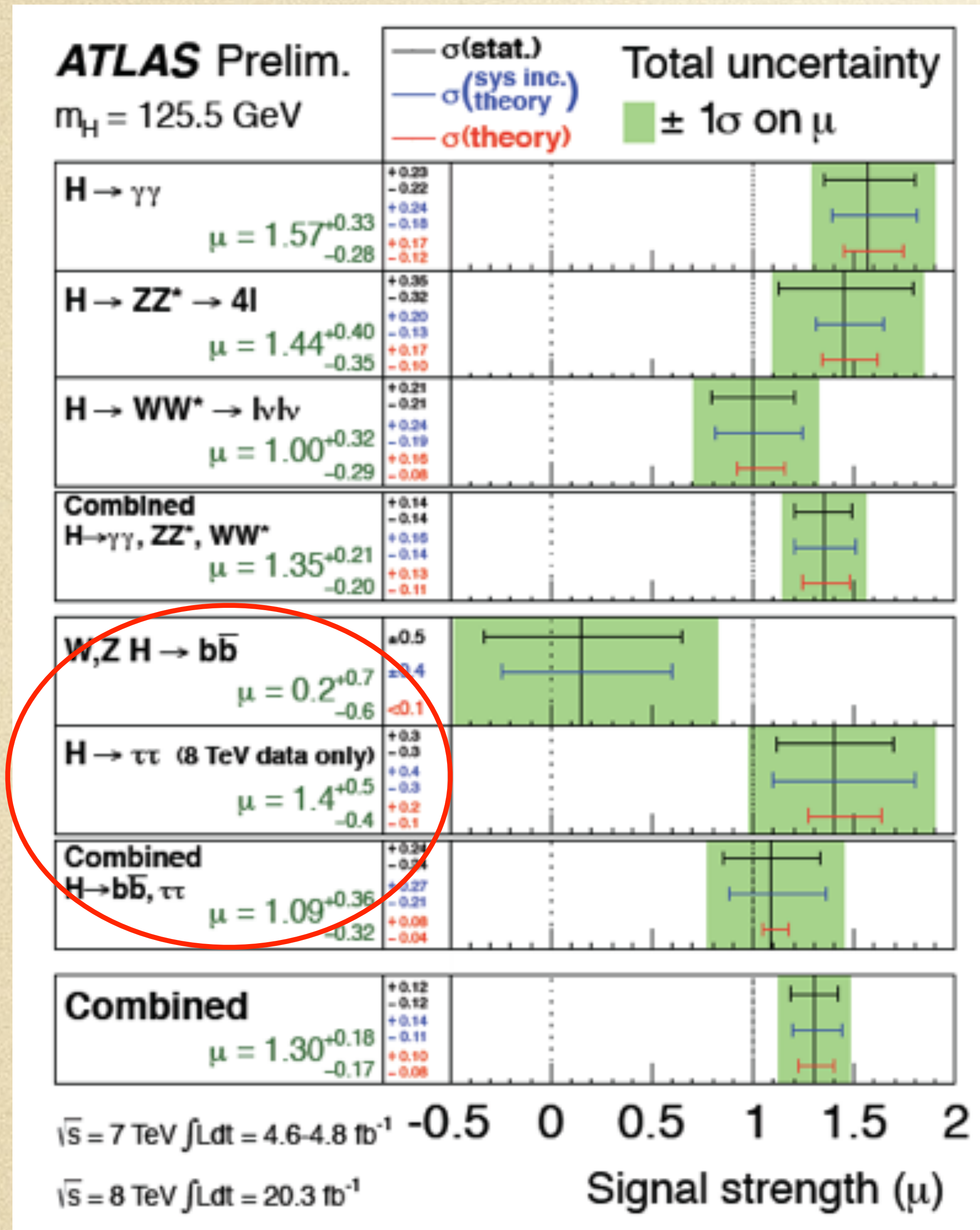
$$\frac{\Gamma_{\mu^-\mu^+}}{\Gamma_{\mu^-\mu^+}^{SM}} = \kappa_\tau^2$$

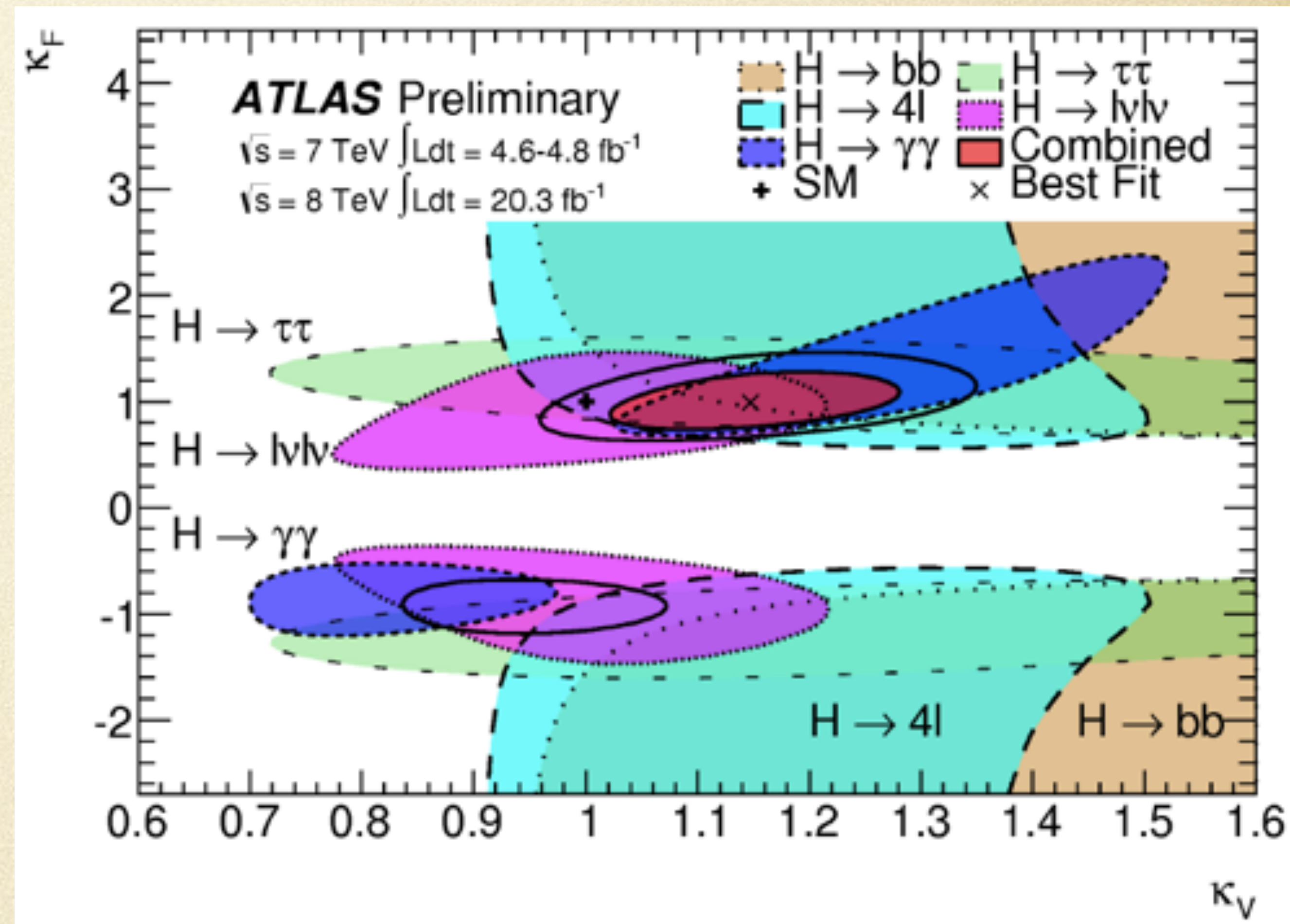
Total width

$$\frac{\Gamma_H}{\Gamma_H^{SM}} = \begin{cases} \kappa_H^2(\kappa_i, m_H) \\ \kappa_H^2 \end{cases}$$

- Single state, spin 0, and CP-even.
- Narrow-width approximation: $(\sigma \times BR) = \sigma \cdot \Gamma / \Gamma_H$

signal strength & Higgs Couplings





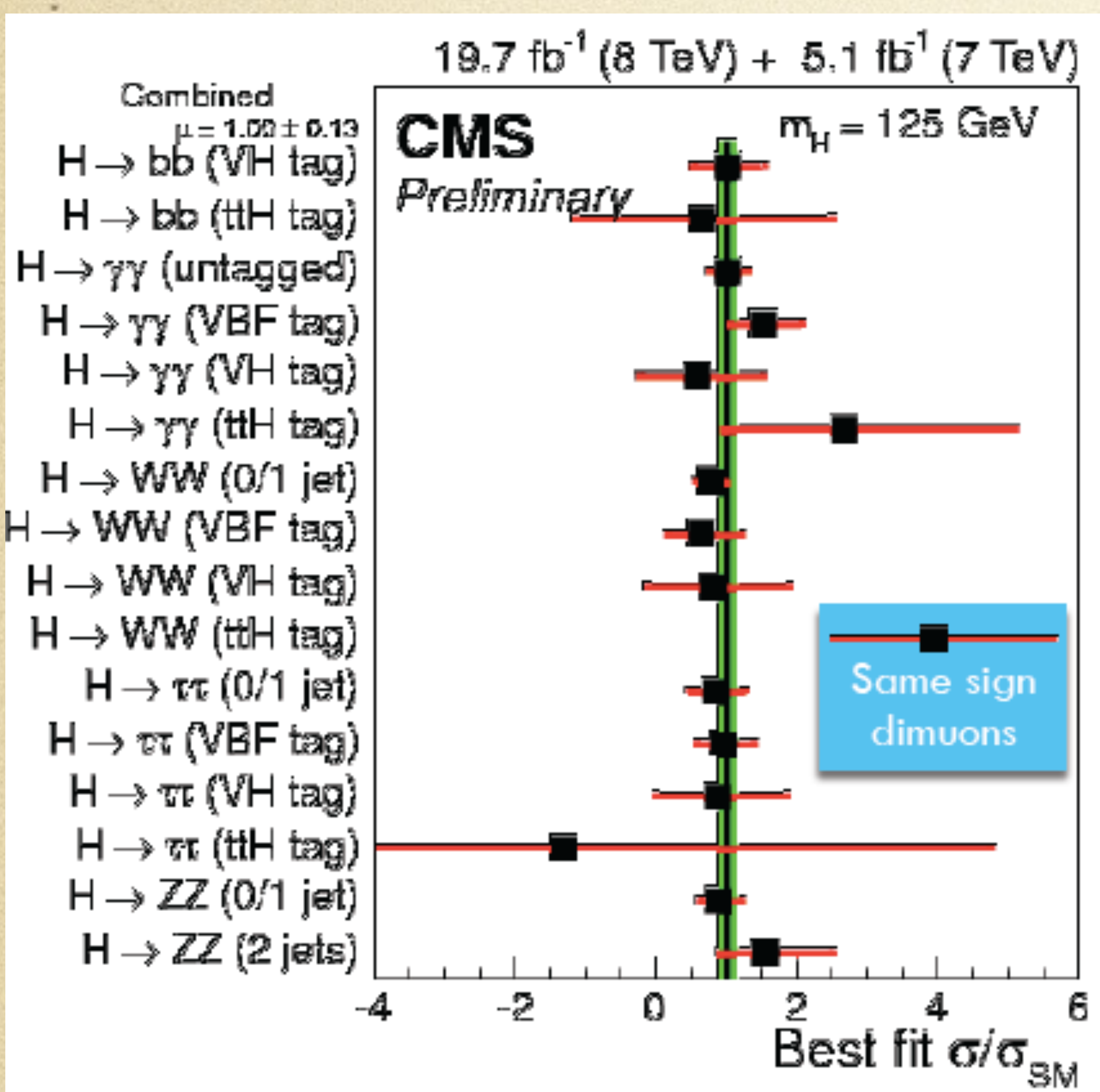
$$\mu = 1.30 \pm 0.12\ (\text{stat})\ \pm 0.10\ (\text{th})\ \pm 0.09\ (\text{syst})$$

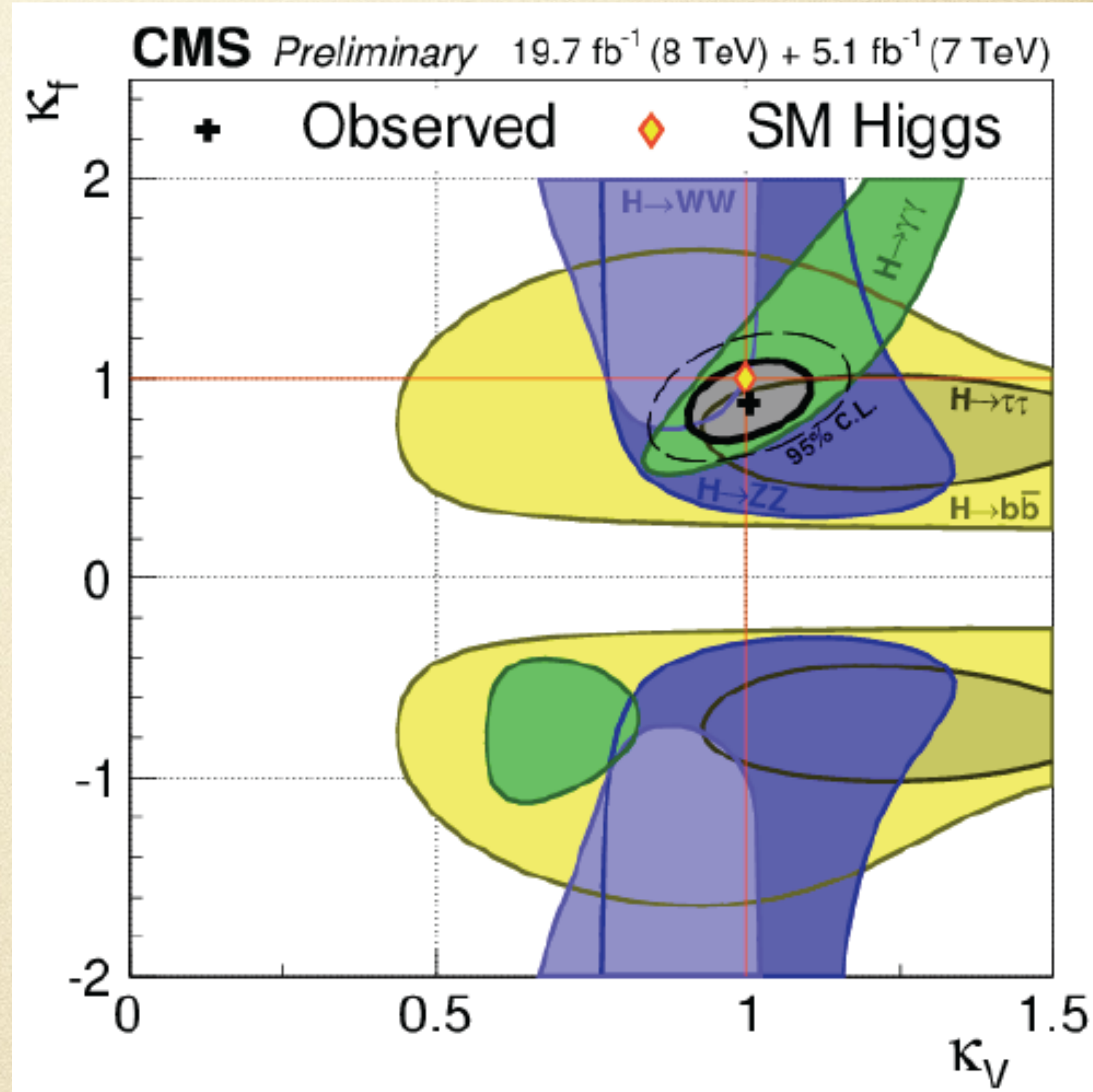
Assuming no BSM in the production and decay

- Compatible with SM
- Negative κ_t (relative to κ_V) disfavored (but still possible solution)
- Already excluding composite models

All channels couplings updated soon

signal strength & Higgs Couplings



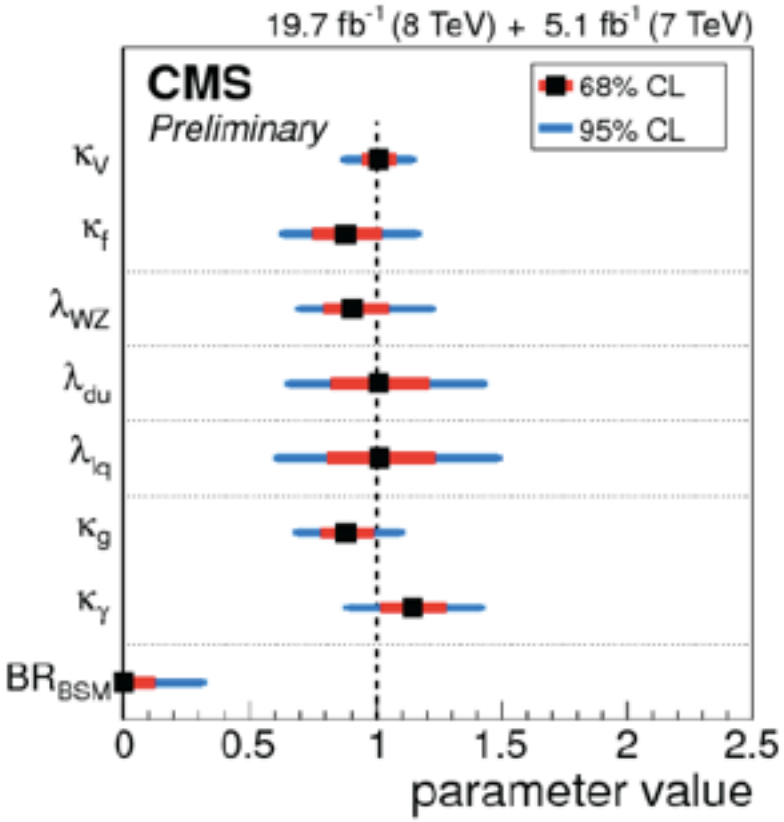


$$\sigma/\sigma_{\rm SM} = 1.00 \pm 0.13 \left[\pm 0.09(\text{stat.})^{+0.08}_{-0.07}(\text{theo.}) \pm 0.07(\text{syst.})\right]$$

Coupling deviations summaries

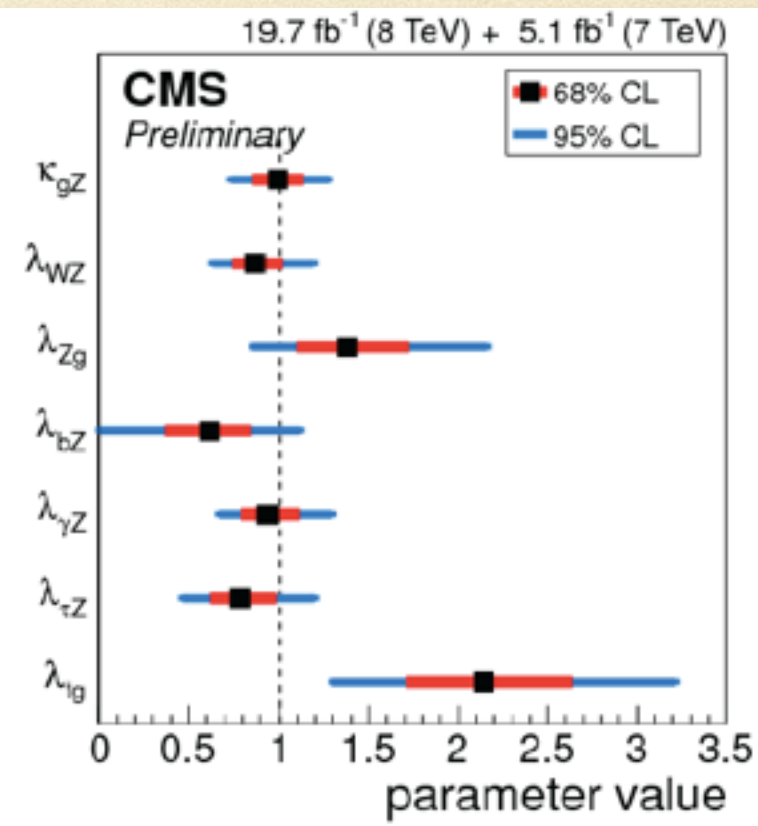
66 [CMS-PAS-HIG-14-009] [arXiv:1307.1347]

- Summary of the fits of **six benchmarks models** probing:
  - Fermions and vector bosons.
  - Custodial symmetry.
  - Up/down fermion coupling ratio.
  - Lepton/quark coupling ratio.
  - BSM in loops: gluons and photons.
  - Extra width: BR_{BSM}.
- **No significance deviations from SM.**



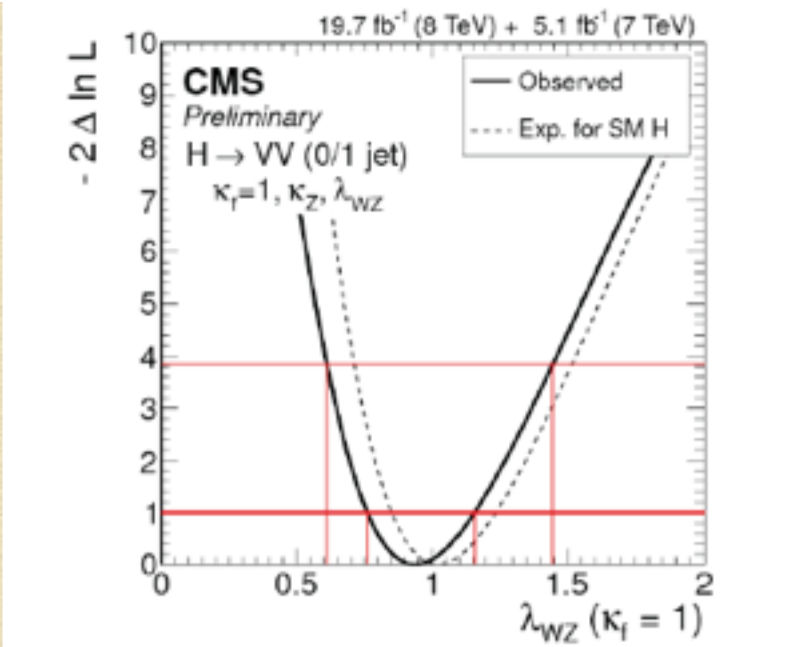
$\lambda_{xy} = \kappa_x/\kappa_y$

- Most general benchmark floating the total width.
  - Same ttH-related excess in $\lambda_{tg} = \kappa_{top}/\kappa_{gluon}$.



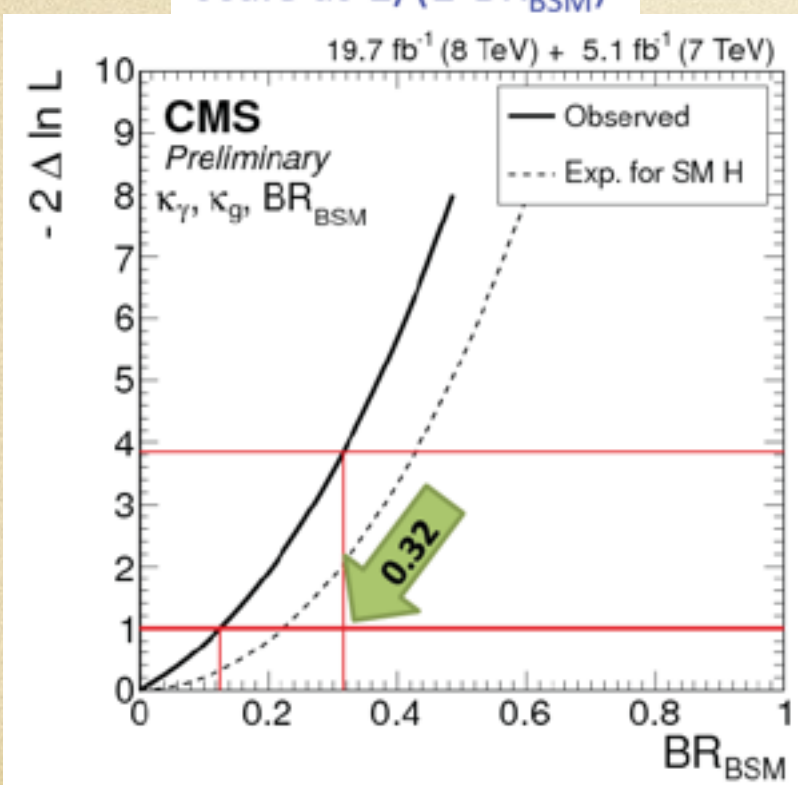
$\lambda_{xy} = \kappa_x/\kappa_y$; $\kappa_{xy} = \kappa_x\kappa_y/\kappa_H$

Custodial symmetry



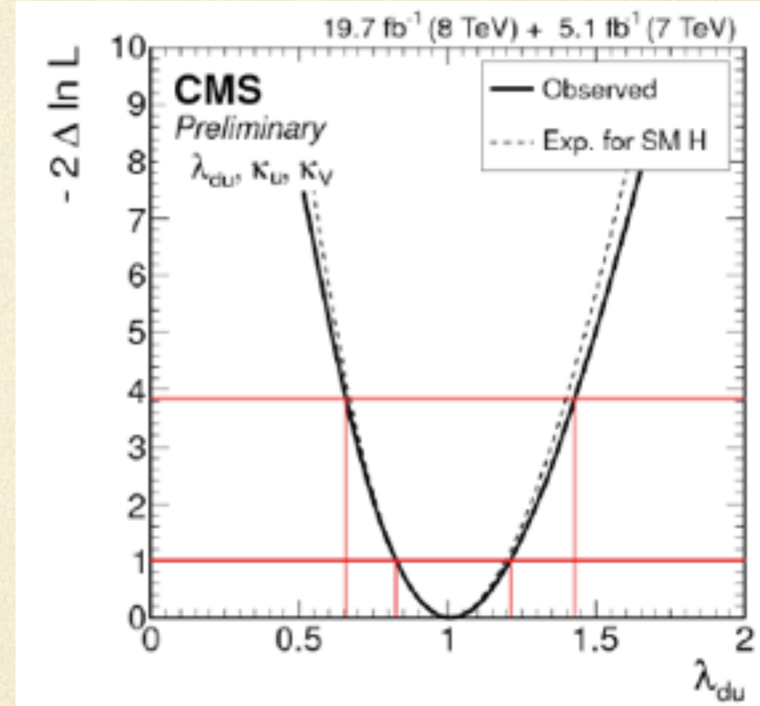
$$\lambda_{WZ} = \frac{\kappa_W}{\kappa_Z} = 0.94^{+0.22}_{-0.18}$$

Allow total width to scale as $1/(1-BR_{BSM})$



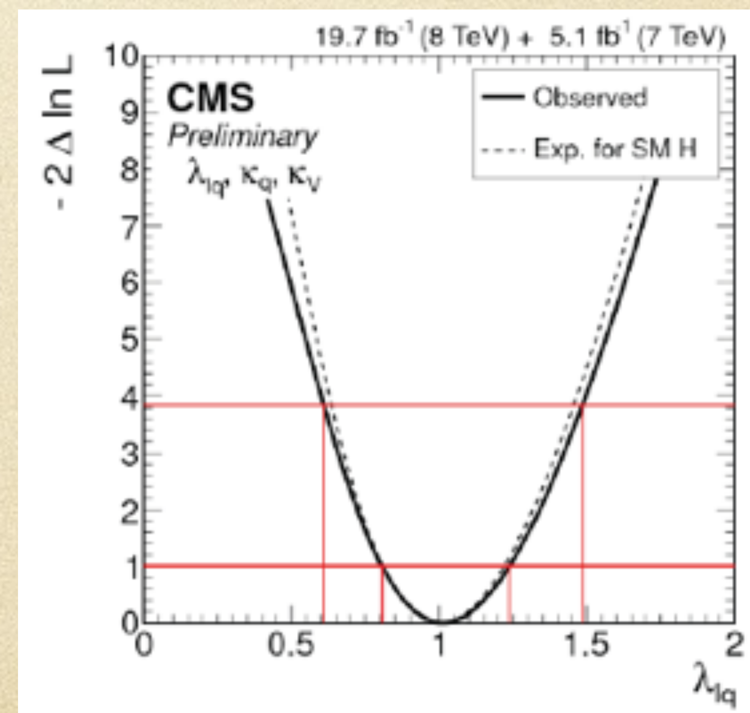
Up-type quarks vs down-type quarks

$$\lambda_{du} = \frac{\kappa_d}{\kappa_u} = 1.01^{+0.20}_{-0.19}$$

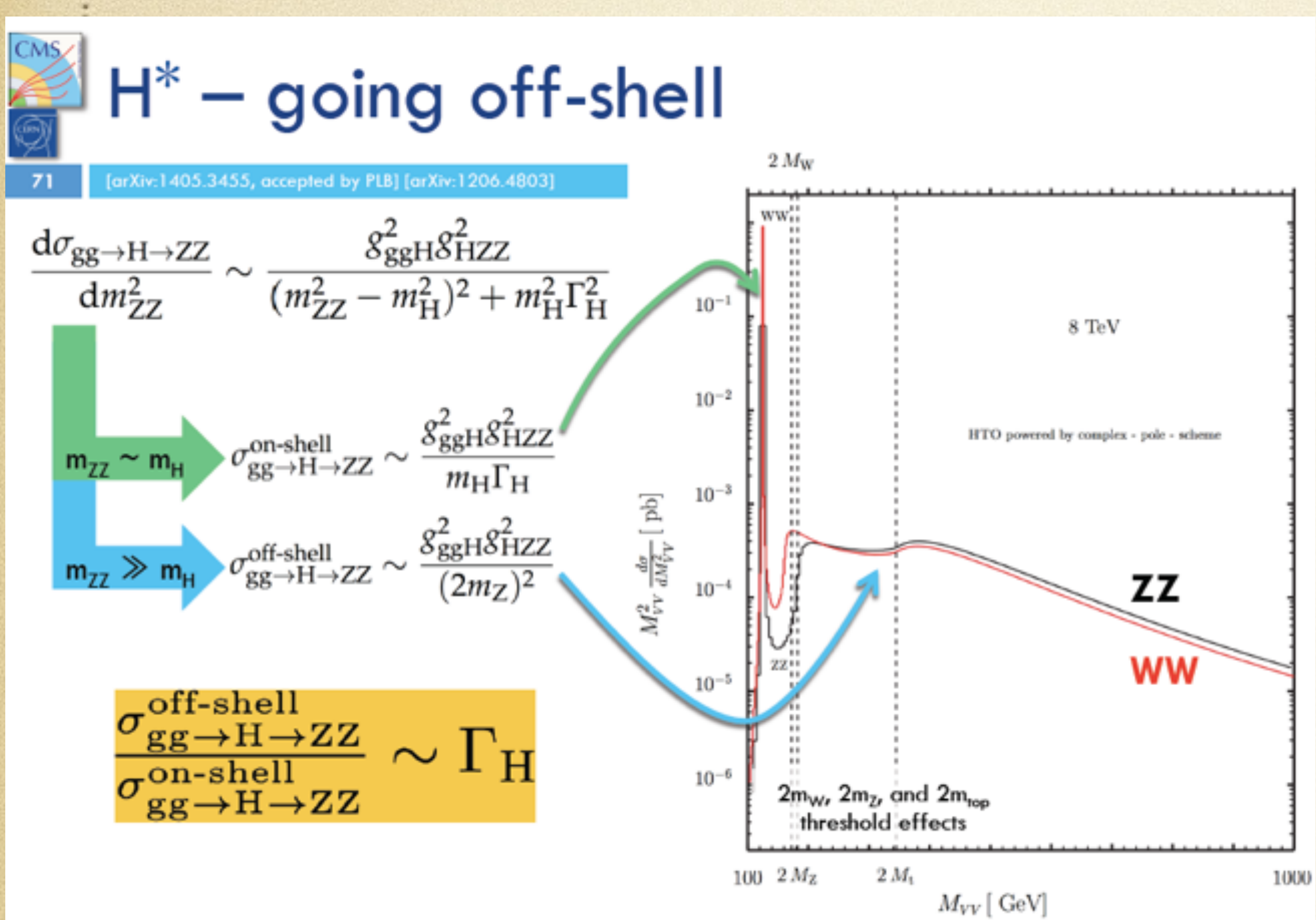


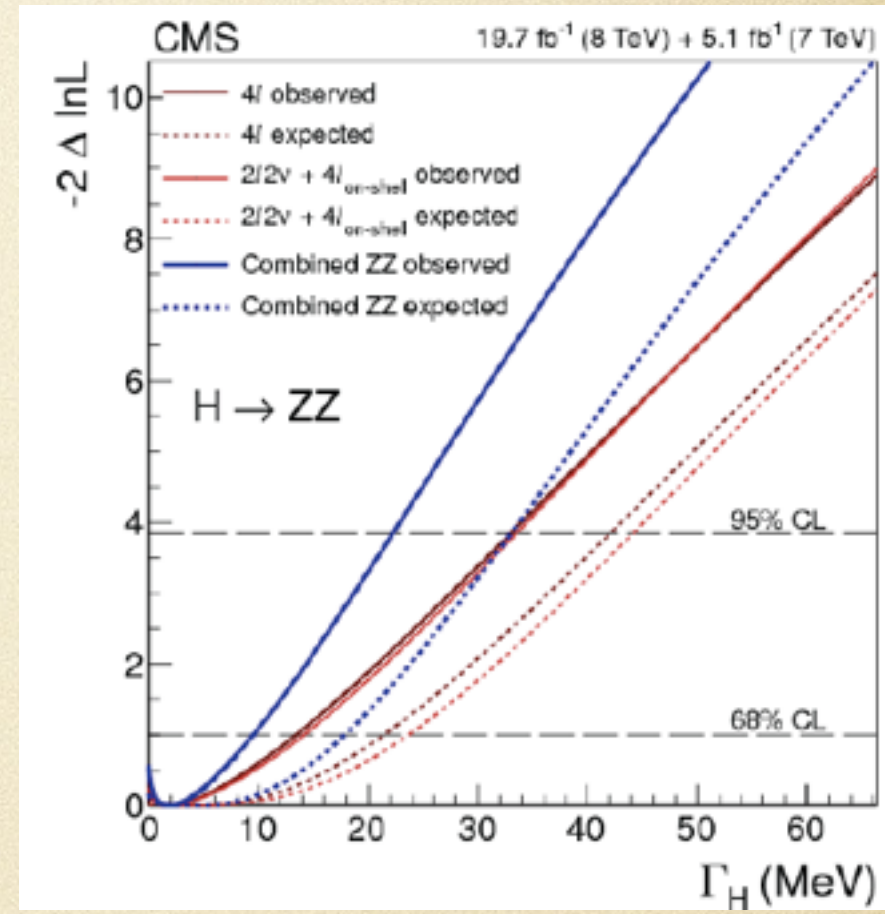
Leptons vs quarks

$$\lambda_{lq} = \frac{\kappa_l}{\kappa_q} = 1.02^{+0.22}_{-0.21}$$



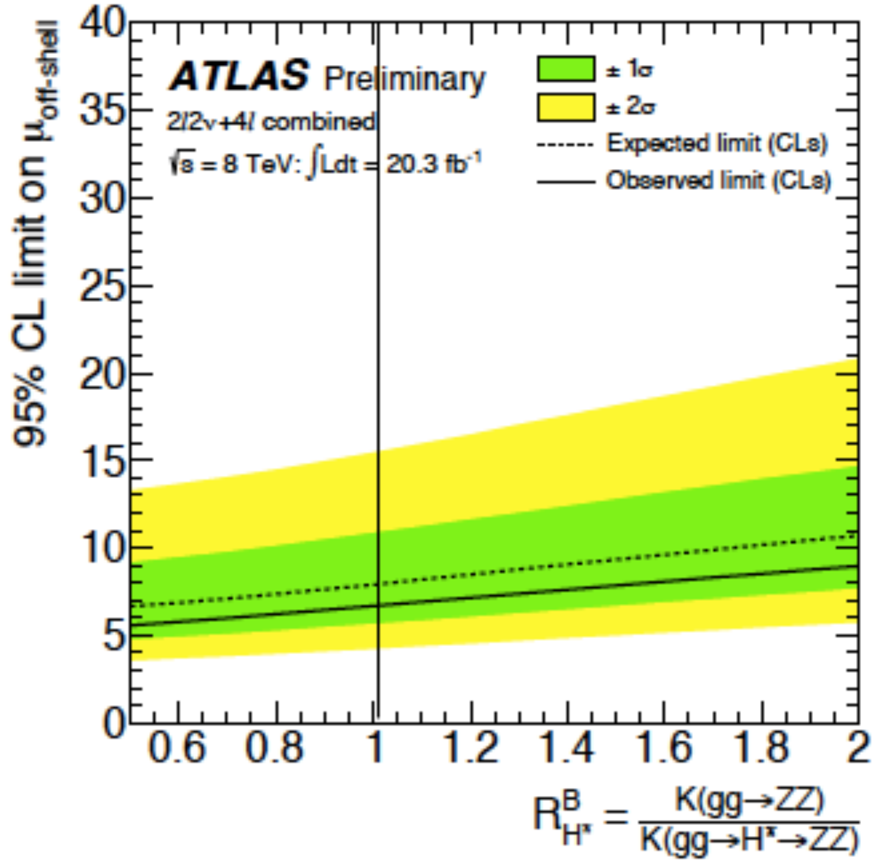
Higgs total width

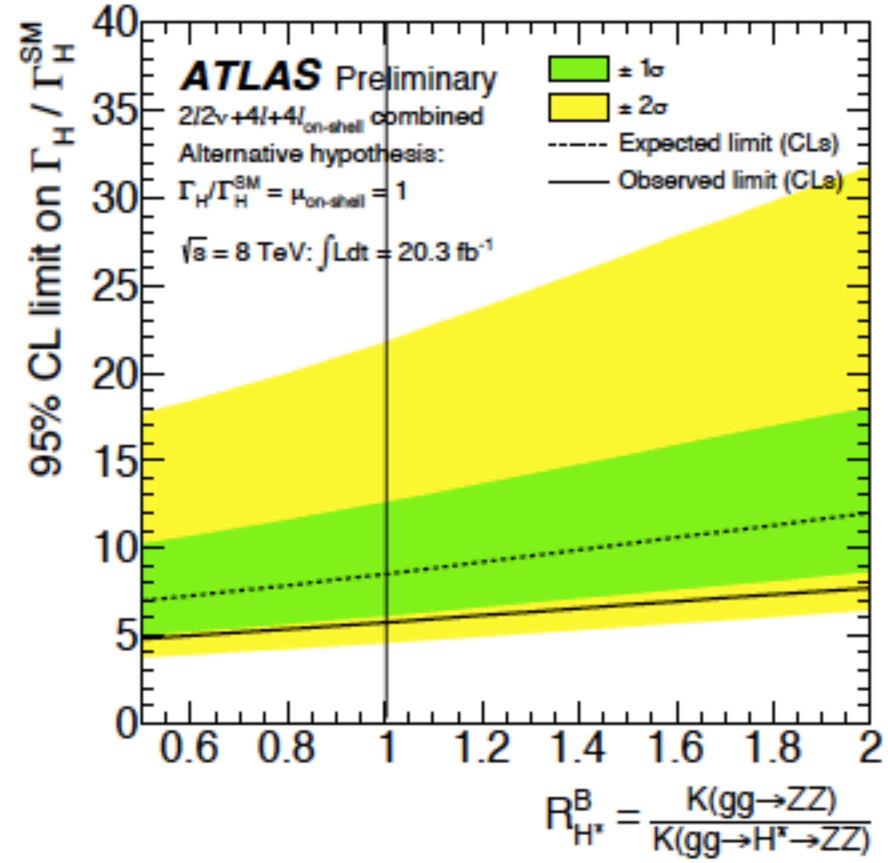




Obs. (exp.)	4ℓ	2ℓ2ν	Combined
Γ_H/Γ_H^{SM} (95% CL)	< 8.0 (10.1)	< 8.1 (10.6)	< 5.4 (8.0)

CLs limits on Off-Shell signal strength





Agnostic to k-factor!

R=1 (Verified in the soft colinear approximation)
(G. Passarino)

95% CL limit obs. (exp.)
$\mu_{OffShell} < 6.7\ (7.9)$

...and on the total width

$$\mu_{OnShell} \equiv \frac{\kappa_t^2 \kappa_V^2}{\Gamma_H / \Gamma_H^{SM}}$$

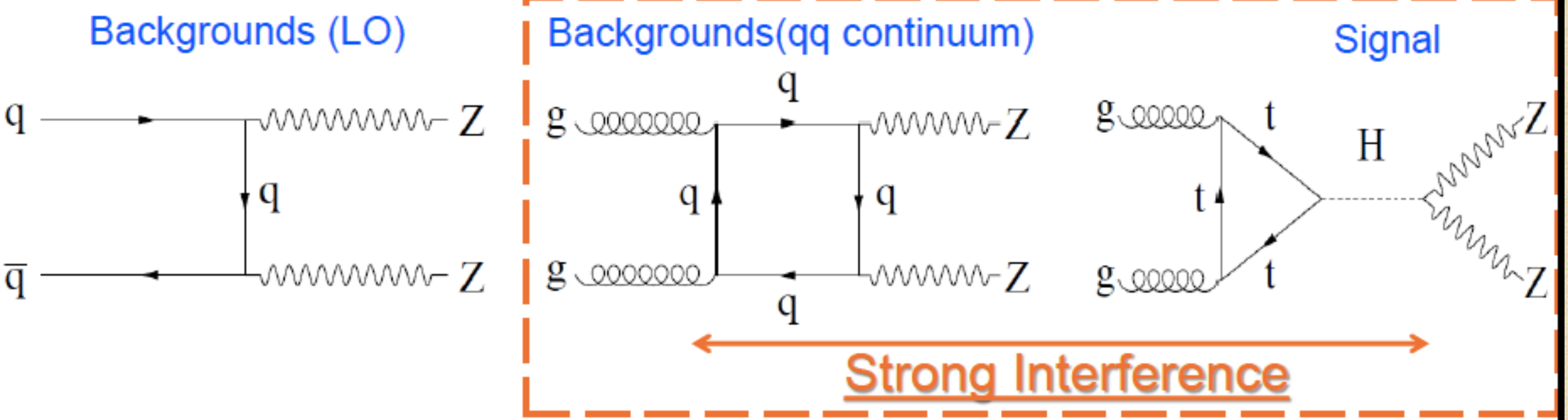
Assuming $\mu_{OffShell} = \mu_{OnShell}$

95% CL limit obs. (exp.)
$\Gamma_H / \Gamma_H^{SM} < 5.7\ (8.5)$

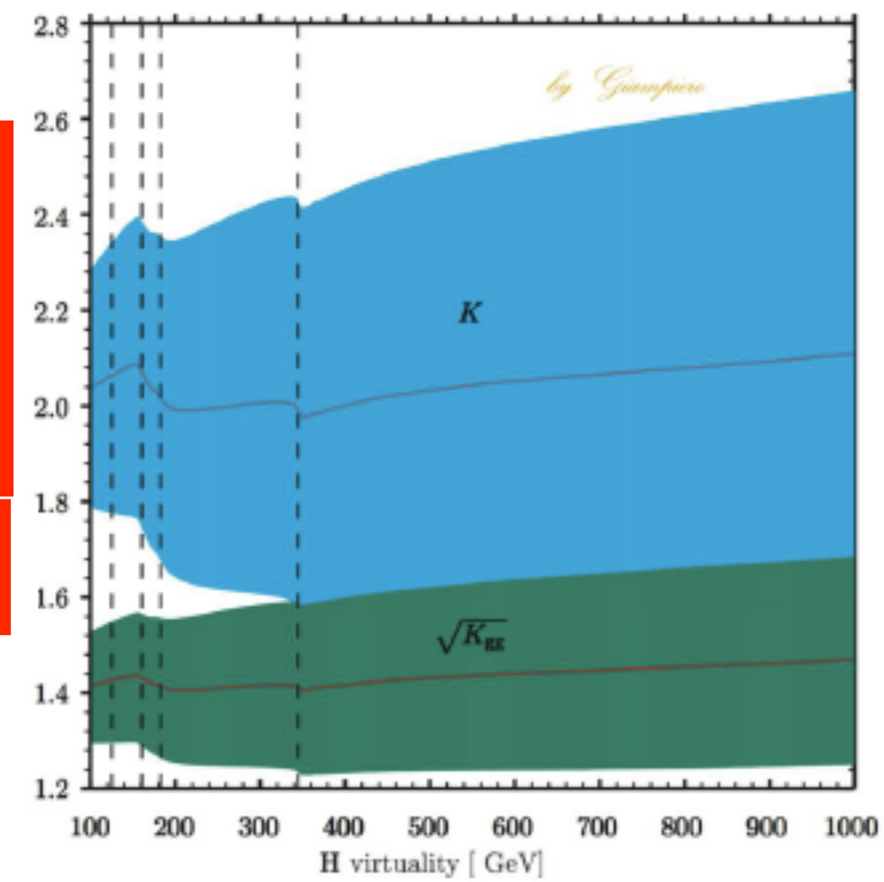
ATLAS-CONF-2014-042

50

ZZ production and KFactors

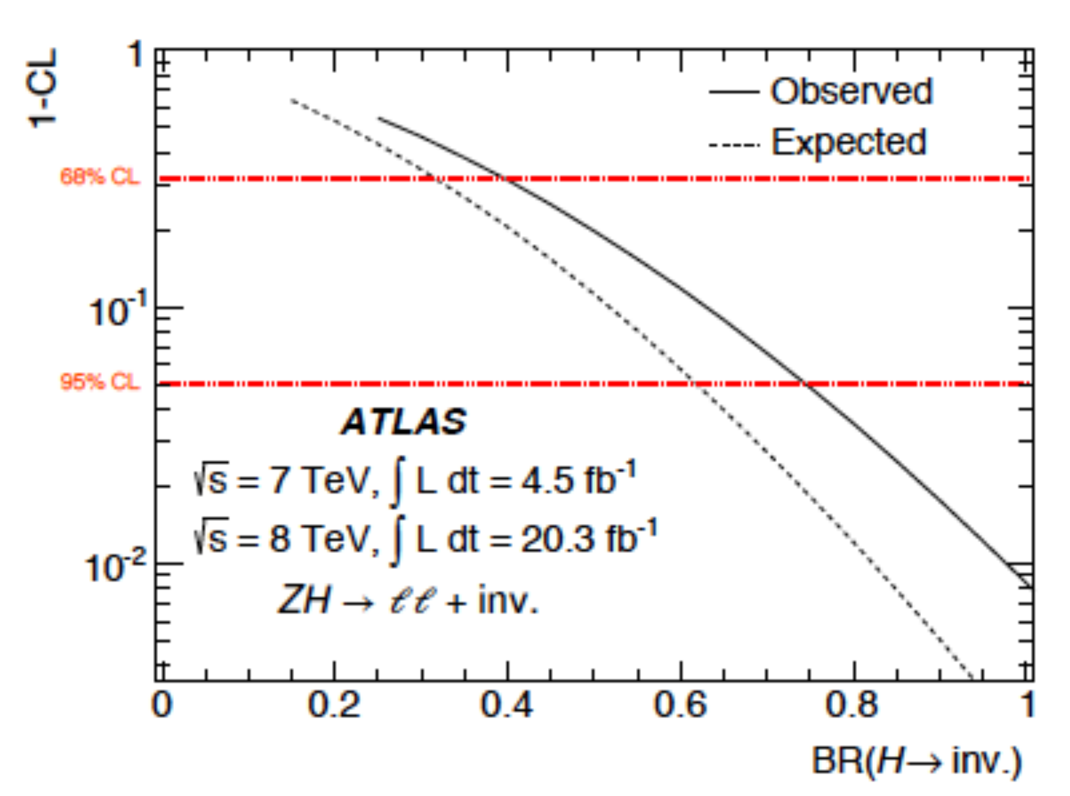


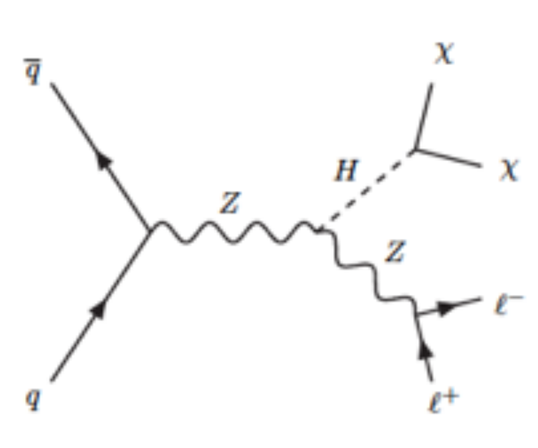
- Signal / background / interference
- NNLO/LO kFactors depend on mZZ
  G. Passarino (arXiv:1312.2397)
- Use the same kFactors for signal and gg continuum
  M. Bonvini et al.(Phys.Rev.D 88 2013)
- Mild model-dependence
- NLO EWK corrections
  $q\bar{q} \rightarrow ZZ/WZ$ (5% decrease @700GeV)
  up to 10% uncertainty



Higgs invisible decay

- Observed limit at 95% C.L. is **75%**
- Expected in absence of invisible decays is **62%**





For m_H = 125 GeV/c^2 at 95% CL

VBF: 0.65 (expected 0.49)

ZH ($\ell\ell$ + $b\bar{b}$): 0.81 (expected 0.83)

VBF + ZH: 0.58 (expected 0.44)

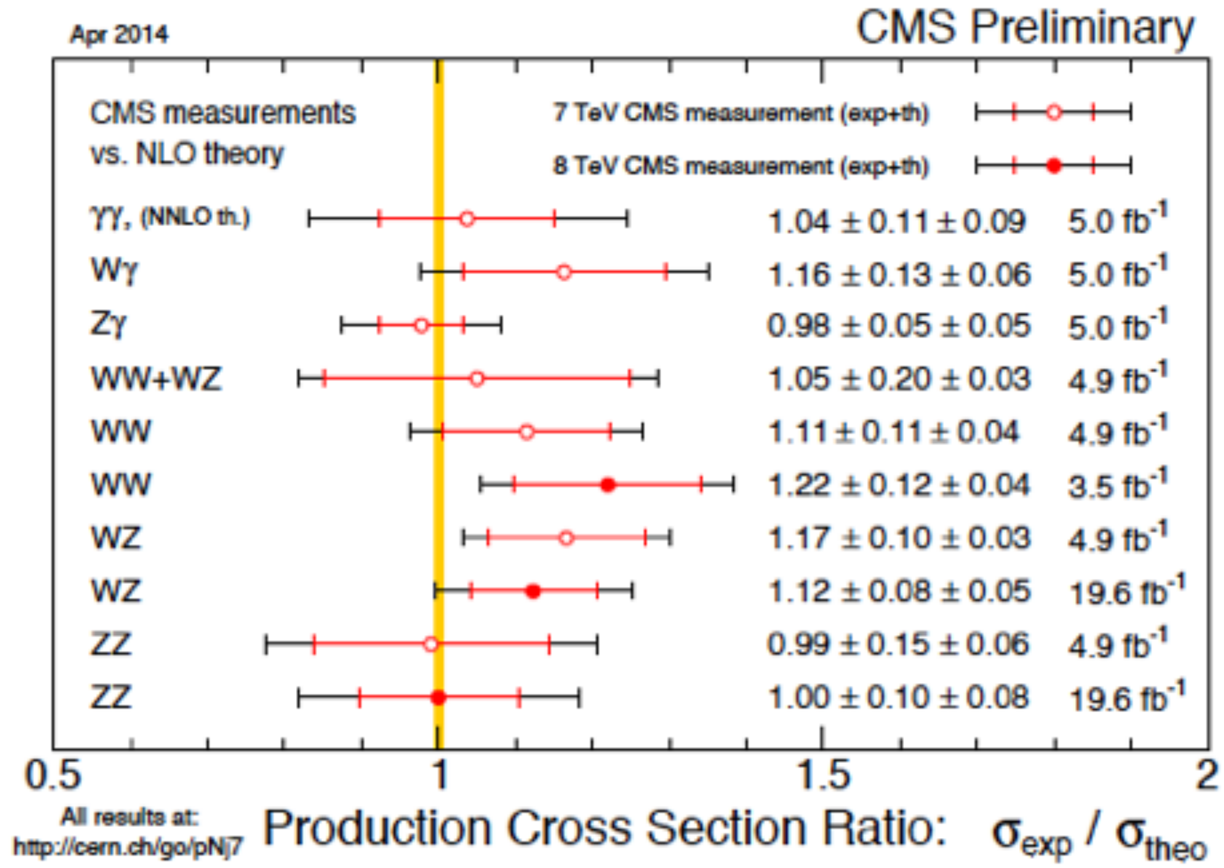
Indirect limits

- Indirect limits on the BR to invisible can be derived from the combination of rates in $\gamma\gamma$, $ZZ^* \to 4l$, $WW \to l\nu l\nu$, $\tau\tau$, $b\bar{b}$ channels
  - Fix H couplings to SM values

- If ZH$\to$ $ll + E_T^{miss}$ is included in the fit the limit becomes **BR$_{i,u}$ <0.37**

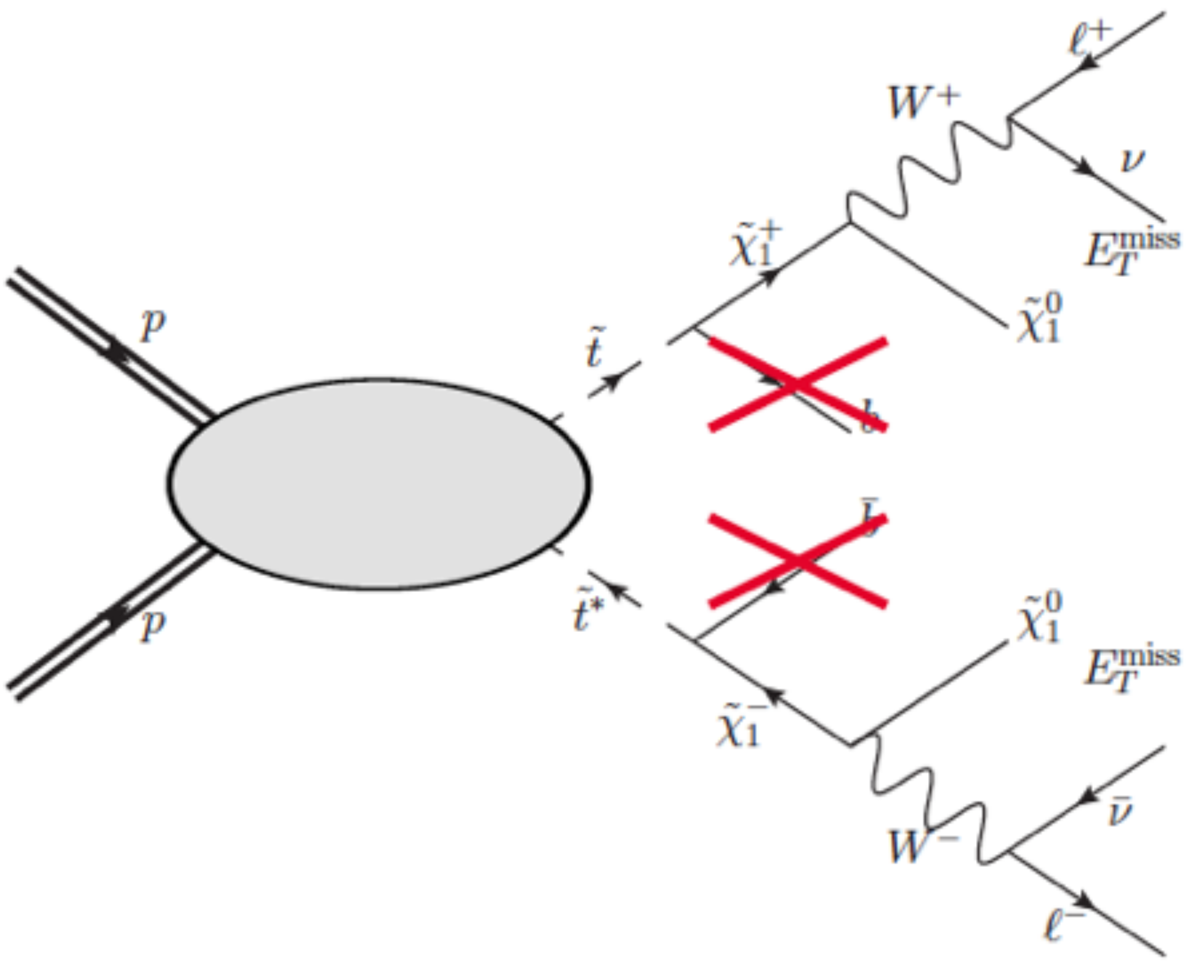
WW cross section at the LHC

- SM NLO prediction:
  $\sigma = 46 \pm 2$ pb @ 7 TeV
  $\sigma = 57.3^{+2.4}_{-1.6}$ pb @ 8 TeV
- ATLAS and CMS reported an excess in SM WW cross section measurements



- 7 TeV, full data set:
  $\sigma = 51.9 \pm 2.0\ (\mathrm{stat}) \pm 3.9\ (\mathrm{syst}) \pm 2.0\ (\mathrm{lumi})$ pb ATL-2012-242
  $\sigma = 52.4 \pm 2.0\ (\mathrm{stat}) \pm 4.5\ (\mathrm{syst}) \pm 1.2\ (\mathrm{lumi})$ pb CMS-12-005
- 8 TeV, $\mathcal{L} = 3.54\ \mathrm{fb}^{-1}$:
  $\sigma = 69.9 \pm 2.8\ (\mathrm{stat}) \pm 5.6\ (\mathrm{syst}) \pm 3.1\ (\mathrm{lumi})$ pb arXiv:1301.4698
- nothing more so far, but...

Di-lepton signal from $\tilde{t}_1 \tilde{t}_1^*$



- large QCD cross section $\mathcal{O}(20\text{ pb})$ for $m_{\tilde{t}_1} \sim 200\text{ GeV}$
- for small mass difference, $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^\pm}$, b-jets are soft, $p_T^b \lesssim 20\text{ GeV}$
- jet veto would not have effect
- observed final state similar to WW: $\ell^+ \ell'^- + E_T^{\rm miss}$

KR, Sakurai arXiv:1303.5696

Kim, KR, Sakurai, Tattersall arXiv:1406.0858

- another possibility with stops and sbottoms, see:

Curtin, Meade, Tien arXiv:1406.0848

Best fit compared to SM

Study	SR	Obs	Exp	SM s.d.	Best fit exp	Best fit s.d
ATLAS W^+W^- (7 TeV) [arXiv:1210.2979]	Combined	1325	1219 ± 87	1.1-σ	95	0.1-σ
CMS W^+W^- (7 TeV) [arXiv:1306.1126]	Combined	1134	1076 ± 62	0.8-σ	77	0.3-σ
CMS W^+W^- (8 TeV) [arXiv:1301.4698]	Combined	1111	986 ± 60	1.8-σ	65	0.9-σ
ATLAS Higgs [ATLAS-CONF-2013-031]	WW CR	3297	3110 ± 186	0.9-σ	293	0.5-σ
	Higgs SR	3615	3288 ± 220	1.4-σ	376	0.2-σ
ATLAS $\tilde{q}$ and $\tilde{g}$ (1-2 ℓ) [ATLAS-CONF-2013-062]	Di-muon	7	1.7 ± 1	2.5-σ	0.8	2.1-σ
ATLAS Electroweak (3 ℓ) [arXiv:1402.7029]	SR0τa01	36	23 ± 4	2.1-σ	4.1	1.4-σ
	SR0τa06	13	6.6 ± 1.9	1.9-σ	2.2	1.3-σ
	SR0τa10	24	16.4 ± 2.4	1.6-σ	0.4	1.5-σ

⇒ overall reduction of 12.3 in log-likelihood compared to SM at minimum

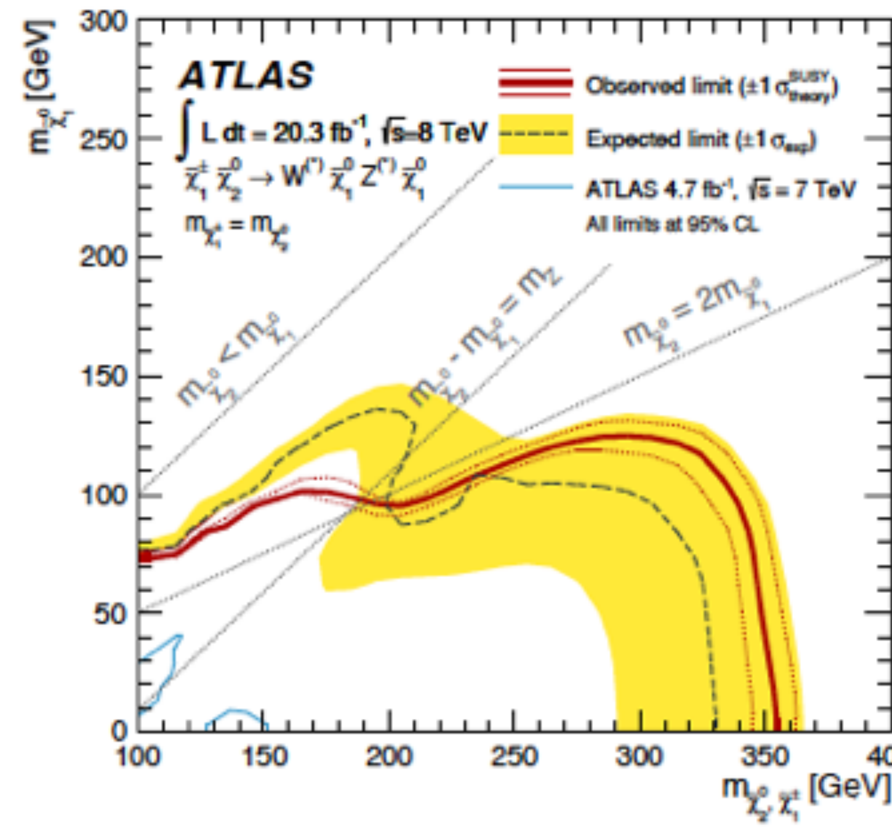
⇒ best fit point:

$$m_{\tilde{t}_1} = 212^{+35}_{-35}\ \text{GeV}$$

$$m_{\tilde{\chi}^0_1} = 150^{+30}_{-20}\ \text{GeV}$$

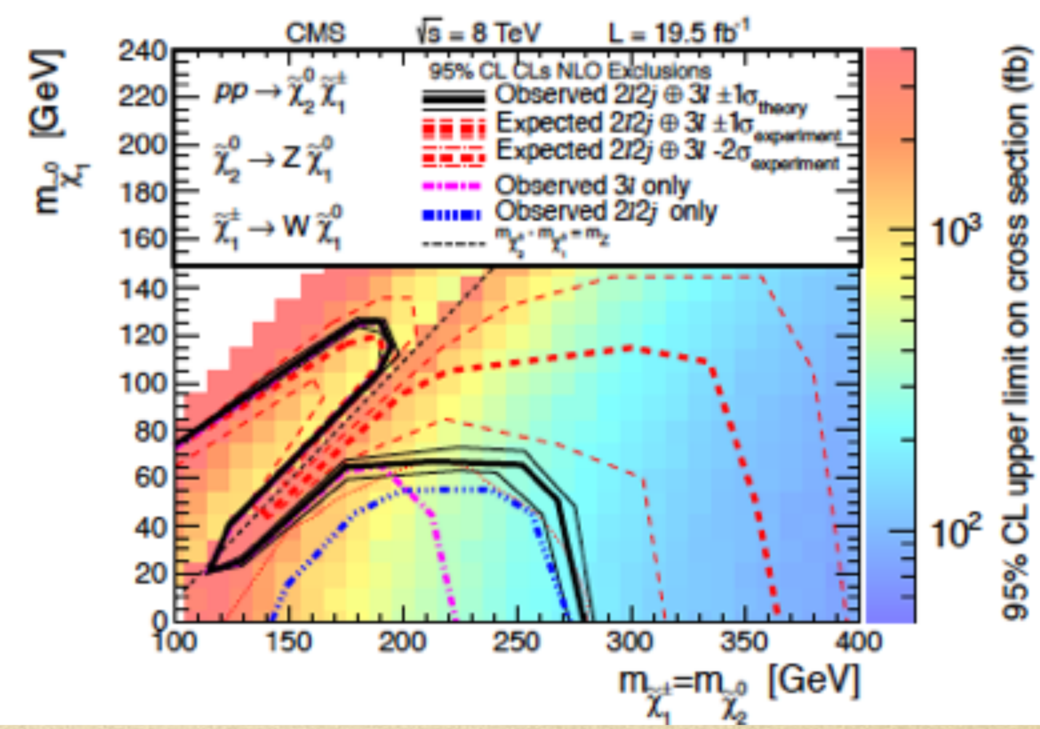
Slight excess in 3-lepton electroweakinos?

- constraints on chargino/neutralino parameter space are also becoming serious
- typically tri-lepton channel most constraining

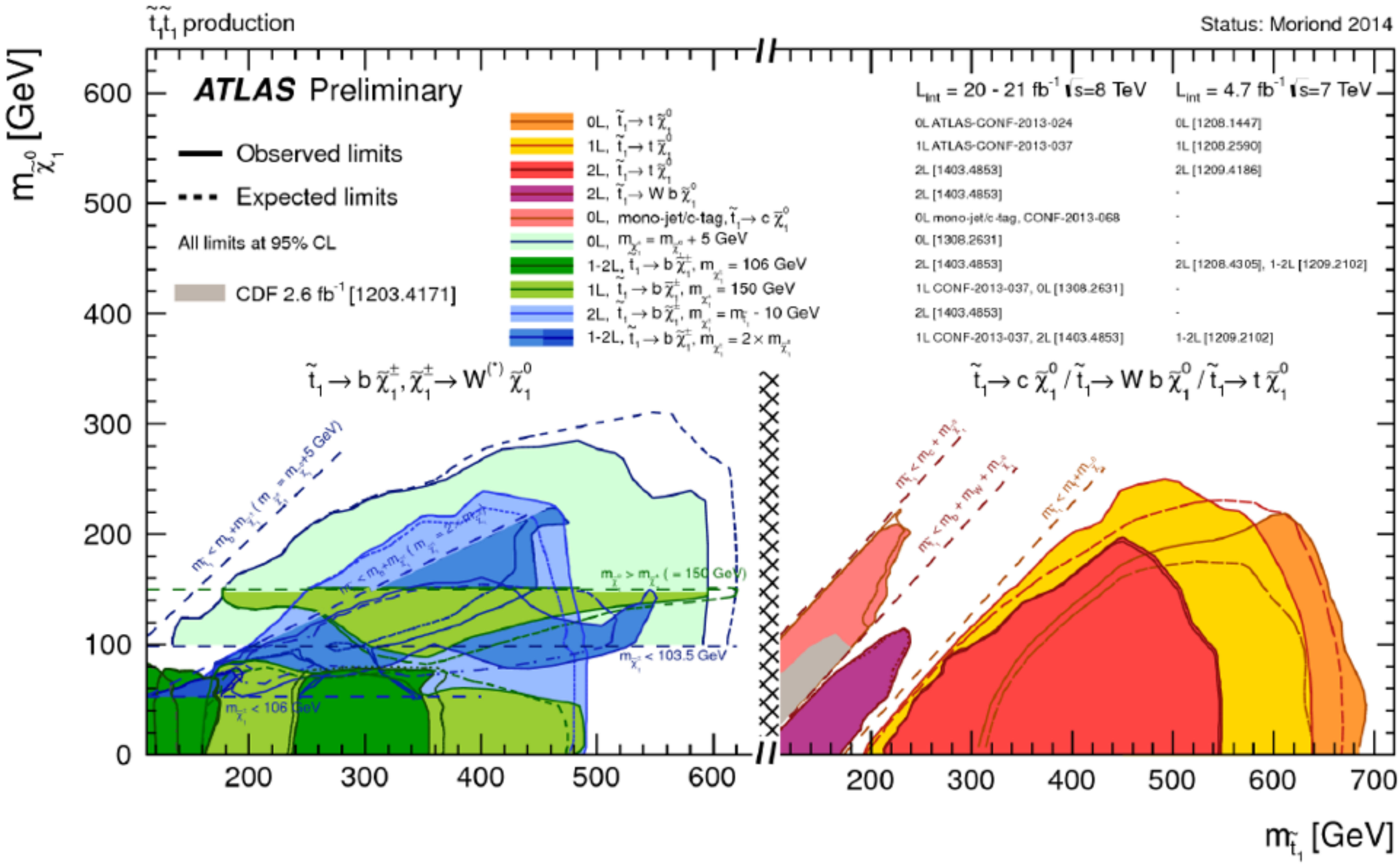


$$pp \to \tilde{\chi}_1^{\pm}\,\tilde{\chi}_2^0 \to \ell'^{\pm}\tilde{\chi}_1^0\ell^+\ell^-\tilde{\chi}_1^0$$

- still some parameter space allowed around $m_{\tilde{\chi}_1^{\pm}} \sim 200\ \mathrm{GeV}$
- the final word at $\sqrt{s} = 8\ \mathrm{TeV}$ but will be significantly improved at $14\ \mathrm{TeV}$
- the bounds can be relaxed if e.g. $\mathrm{BR}(\tilde{\chi}_2^0 \to h^{(*)}\tilde{\chi}_1^0)$ significant



LHC vs stops



t̃₁t̃₁ production
Status: Moriond 2014
ATLAS Preliminary
Observed limits
Expected limits
All limits at 95% CL
CDF 2.6 fb⁻¹ [1203.4171]
L_int = 20 - 21 fb⁻¹ √s=8 TeV
L_int = 4.7 fb⁻¹ √s=7 TeV
0L ATLAS-CONF-2013-024
1L ATLAS-CONF-2013-037
2L [1403.4853]
0L mono-jet/c-tag, CONF-2013-068
0L [1308.2631]
1L CONF-2013-037, 0L [1308.2631]
1L CONF-2013-037, 2L [1403.4853]
0L [1208.1447]
1L [1208.2590]
2L [1209.4186]
2L [1208.4305], 1-2L [1209.2102]
1-2L [1209.2102]
m_χ̃₁⁰ [GeV]
m_t̃₁ [GeV]