Constraining new physics from Higgs measurements with Lilith

(light likelihood fit for the Higgs)

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based on work with Jérémy Bernon (LPSC Grenoble)

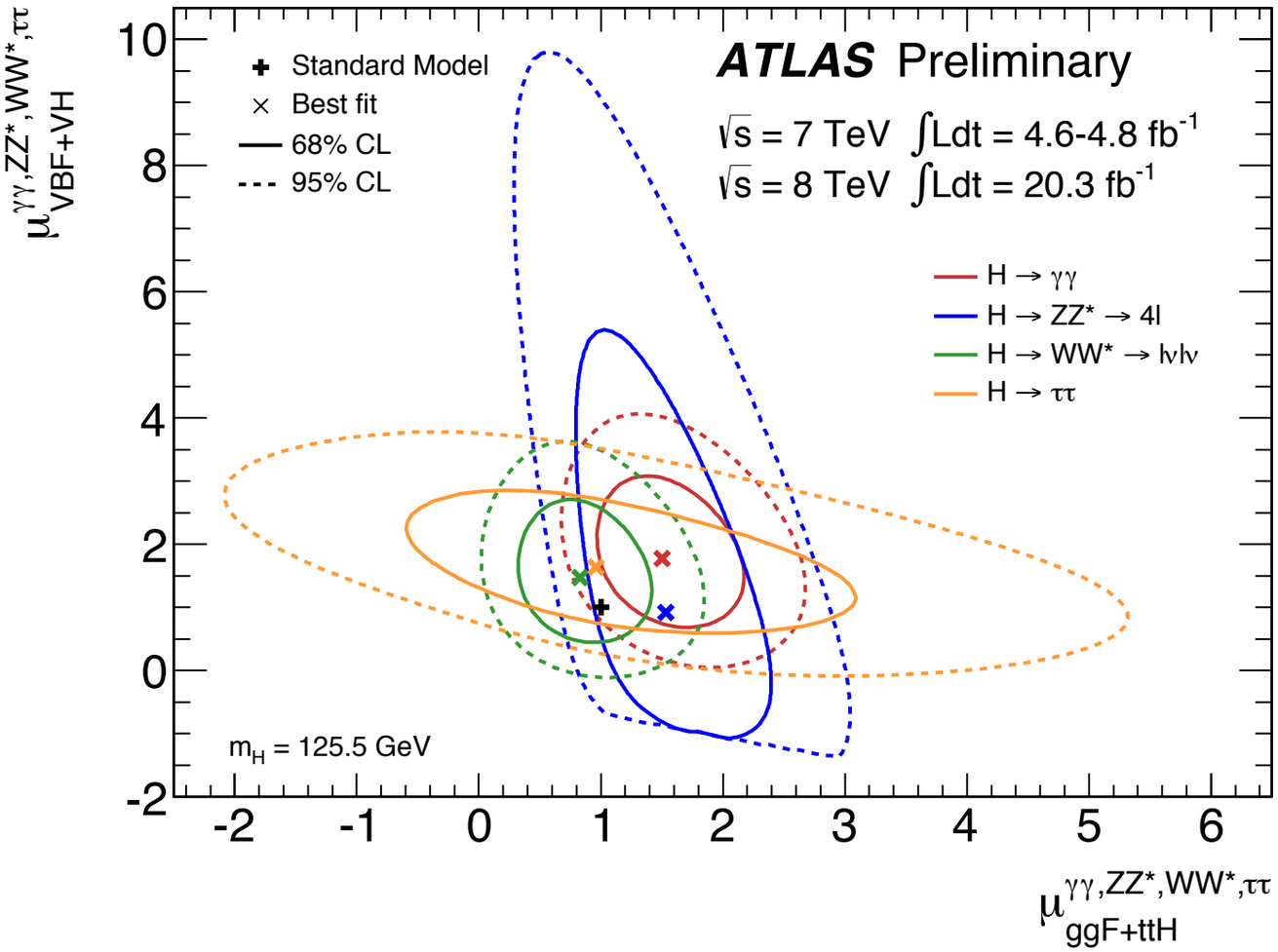
manual in preparation…but beta version available!
information and download at http://lpsc.in2p3.fr/projects-th/lilith/

Higgs Hunting 2014

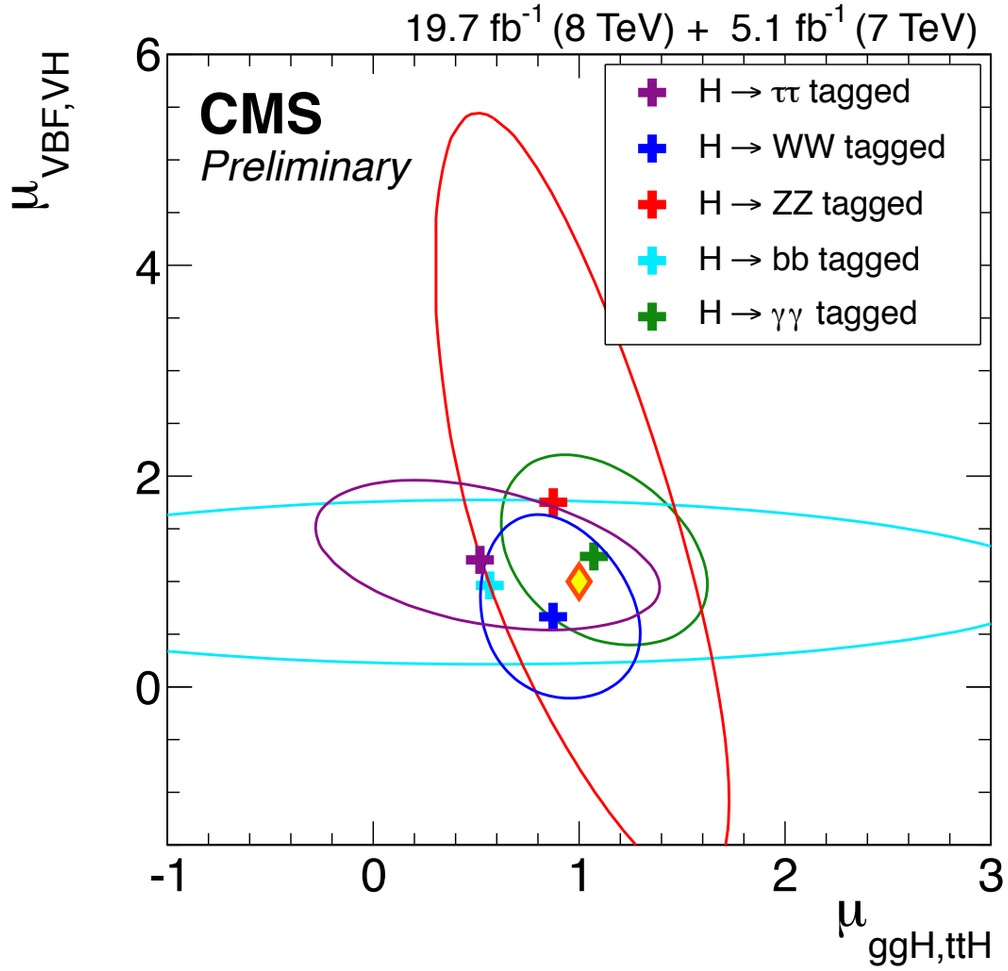
July 21, 2014

Higgs signal strengths

[ATLAS-CONF-2014-009]

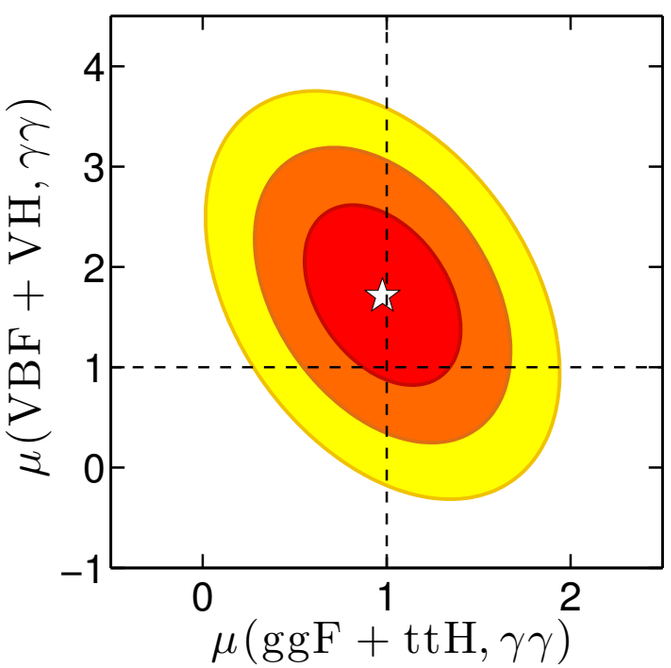


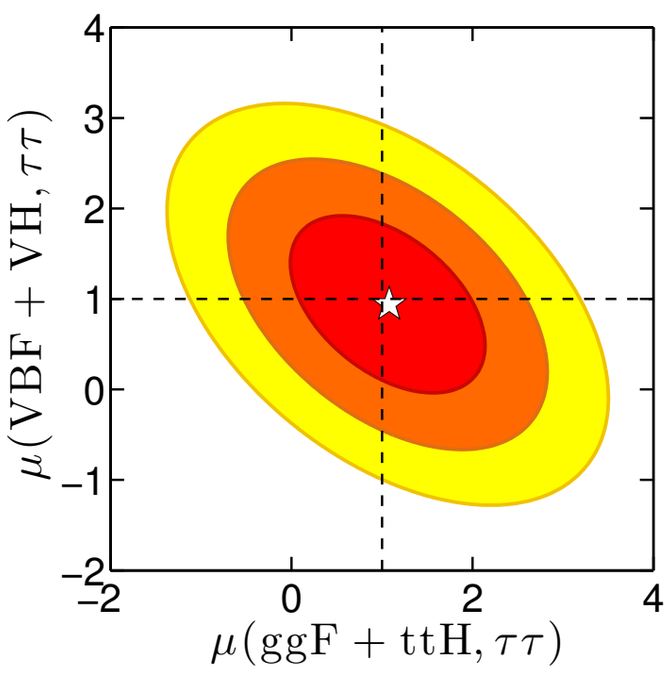
[CMS-PAS-HIG-14-009]



in order to construct an approximation to the Higgs likelihood, one can:
i) fit a 2D Gaussian using the 68% CL contour for each final state
ii) combine the measurements from ATLAS and CMS final state by final state

combined 2D μ plots

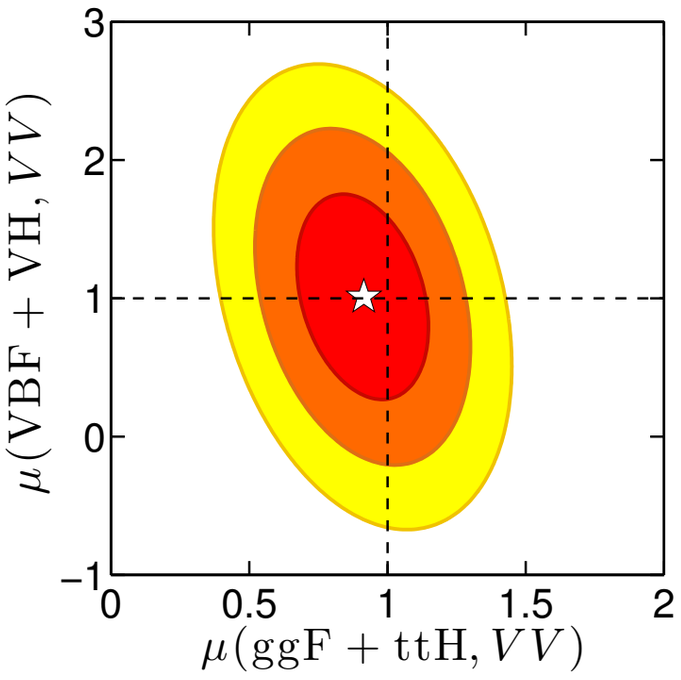


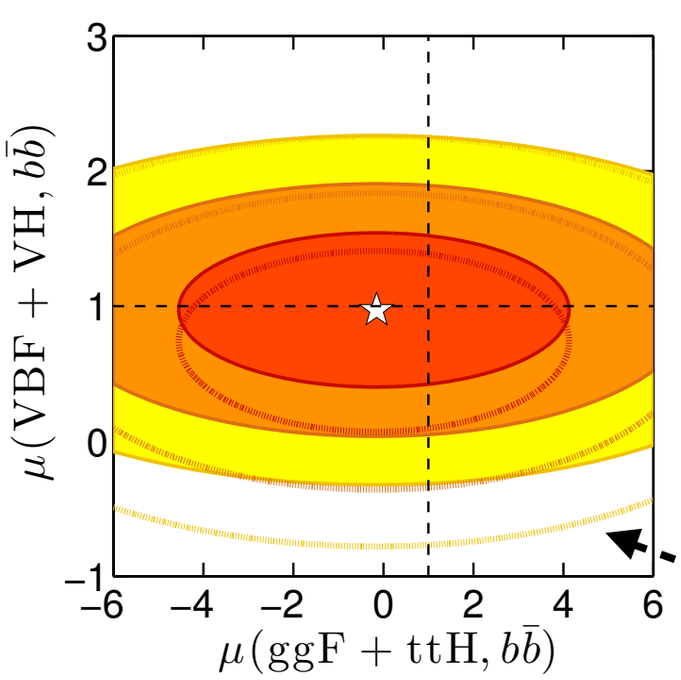


[Bélanger, BD, Ellwanger, Gunion, Kraml, arXiv:1306.2941]

include all results up to the LHCP 2013 conference

$$\chi^2_i = a_i(\mu_{\mathrm{ggF},i} - \hat{\mu}_{\mathrm{ggF},i})^2 + 2b_i(\mu_{\mathrm{ggF},i} - \hat{\mu}_{\mathrm{ggF},i})(\mu_{\mathrm{VBF},i} - \hat{\mu}_{\mathrm{VBF},i}) + c_i(\mu_{\mathrm{VBF},i} - \hat{\mu}_{\mathrm{VBF},i})^2$$





	$\hat{\mu}_{\mathrm{ggF}}$	$\hat{\mu}_{\mathrm{VBF}}$	a	b	c
$\gamma\gamma$	0.98	1.72	14.94	2.69	3.34
VV	0.91	1.01	44.59	4.24	4.58
$b\bar{b}/\tau\tau$	0.98	0.97	2.67	1.31	10.12
$b\bar{b}$	−0.23	0.97	0.12	0	7.06
$\tau\tau$	1.07	0.94	2.55	1.31	3.07

going beyond the Gaussian approx.

Information | References (121) | Citations (208) | Files | Plots | Data

Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC

ATLAS Collaboration (Georges Aad (Freiburg U.) *et al.*) *Show all 2923 authors*

Jul 4, 2013 - 32 pages

Phys.Lett. B726 (2013) 88-119
(2013)
DOI: 10.1016/j.physletb.2013.08.010
CERN-PH-EP-2013-103
e-Print: arXiv:1307.1427 [hep-ex] | PDF
Experiment: CERN-LHC-ATLAS

INSPIRE

Abstract (arXiv)
Measurements are presented of production properties and couplings of the recently discovered Higgs boson using the decays into boson pairs, H --> gamma-gamma, H --> ZZ* --> 4 leptons and H --> WW --> 2 leptons + 2 neutrinos. The results are based on the complete pp collision data sample recorded by the ATLAS experiment at the CERN Large Hadron Collider at centre-of-mass energies of 7 TeV and 8 TeV, corresponding to an integrated luminosity of about 25/fb. Evidence for Higgs boson production through

$\mu_{\mathrm{ggH+ttH}}$	$\mu_{\mathrm{VBF+VH}}$	$-2\log\mathcal{L}$
8.42000000e-01	1.05000000e+00	6.41334200e+00
8.94000000e-01	1.05000000e+00	5.56393000e+00
9.46000000e-01	1.05000000e+00	4.80295200e+00
9.98000000e-01	1.05000000e+00	4.12083200e+00
1.05000000e+00	1.05000000e+00	3.51680200e+00
1.10200000e+00	1.05000000e+00	2.98699400e+00
1.15400000e+00	1.05000000e+00	2.52739800e+00
1.20600000e+00	1.05000000e+00	2.13516200e+00
1.25800000e+00	1.05000000e+00	1.80247000e+00
1.31000000e+00	1.05000000e+00	1.52729800e+00

meet Lilith

- what is Lilith?
  - a new public and user-friendly Python tool for applying the Higgs constraints on a wide class of new physics models

  - experimental results are stored in a flexible XML database, easy to modify and extend
    can take any Higgs results given in terms of signal strengths as input

  - two different input modes:
    - reduced couplings
    - signal strengths

XML user input: reduced couplings

```
<?xml version="1.0"?>

<lilithinput>

<mh>125.5</mh>

<reducedcouplings>
  <C to="tt">1.0</C>
  <C to="cc">1.0</C>
  <C to="bb">1.0</C>
  <C to="tautau">1.0</C>
  <C to="VV">1.0</C>

  <C to="gammagamma">1.0</C>
  <C to="Zgamma">1.0</C>
  <C to="gg">1.0</C>

  <precision>BEST-QCD</precision>
</reducedcouplings>

<extraBR>
  <BR type="invisible">0.0</BR>
  <BR type="undetected">0.0</BR>
</extraBR>

</lilithinput>
```

or "uu" and "dd" (for up- and down-type particles),
or "ff" (universal reduced coupling to the fermions)

or "WW" and "ZZ" instead of "VV"

optional; if not given computed from SM processes

uses (N)NLO QCD results from HDECAY and/or HIGLU for $H \to \gamma\gamma$, $gg \to H$, $H \to gg$ and $H \to Z\gamma$

[Spira, hep-ph/9510347;
Djouadi, Kalinowski, Spira, hep-ph/9704448]

XML user input: signal strengths

```
<?xml version="1.0"?>

<lilithinput>

<mh>125.5</mh>

<signalstrengths>
  <mu prod="ggH" decay="gammagamma">1.0</mu>
  <mu prod="ggH" decay="VV">1.0</mu>
  <mu prod="ggH" decay="bb">1.0</mu>
  <mu prod="ggH" decay="tautau">1.0</mu>
```

← or "WW" and "ZZ" instead of "VV"

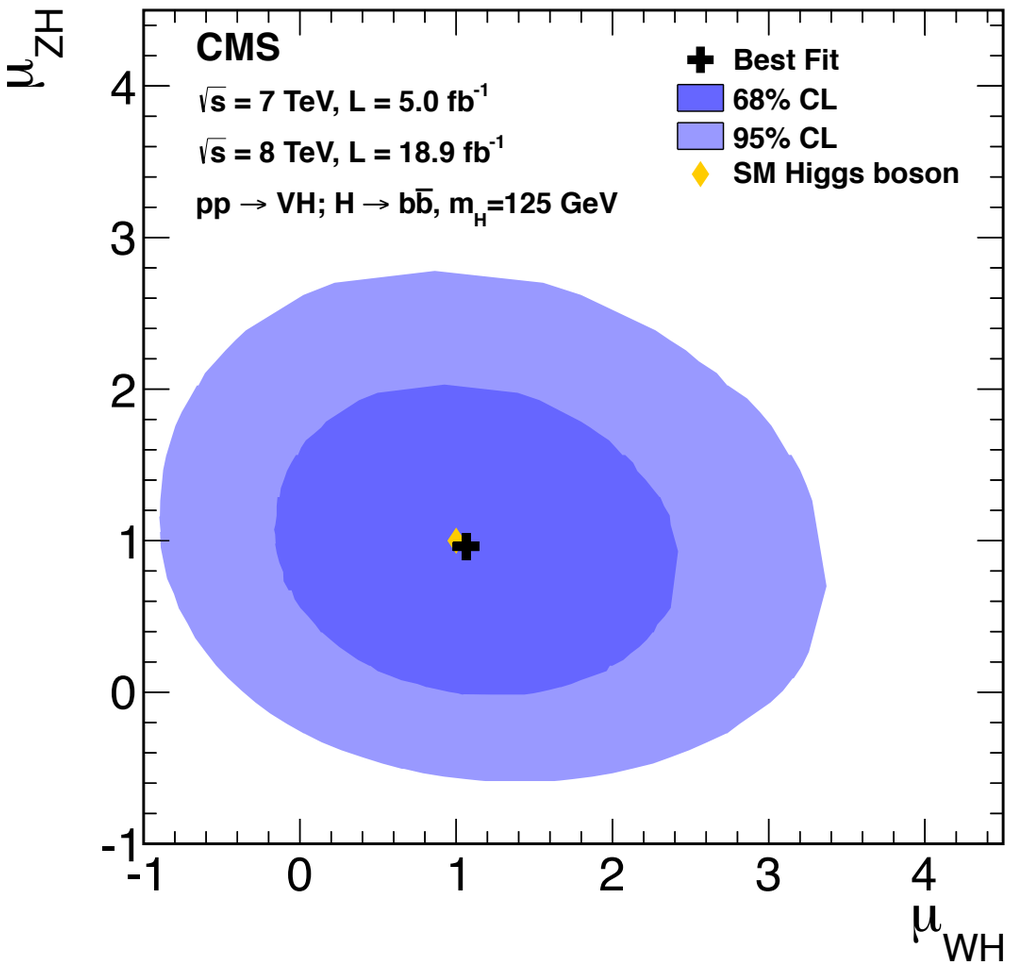
```
  <mu prod="VVH" decay="gammagamma">1.0</mu>
  <mu prod="VVH" decay="VV">1.0</mu>
  <mu prod="VVH" decay="bb">1.0</mu>
  <mu prod="VVH" decay="tautau">1.0</mu>

  <mu prod="ttH" decay="gammagamma">1.0</mu>
  <mu prod="ttH" decay="VV">1.0</mu>
  <mu prod="ttH" decay="bb">1.0</mu>
  <mu prod="ttH" decay="tautau">1.0</mu>

  <redxsBR prod="ZH" decay="invisible">0.0</redxsBR>
  <redxsBR prod="VBF" decay="invisible">0.0</redxsBR>
</signalstrengths>

</lilithinput>
```

← "WH", "ZH" and "VBF" can also be specified separately

← $\frac{\sigma}{\sigma_{\mathrm{SM}}} \times \mathrm{BR}(H \to \mathrm{inv.})$

XML experimental input

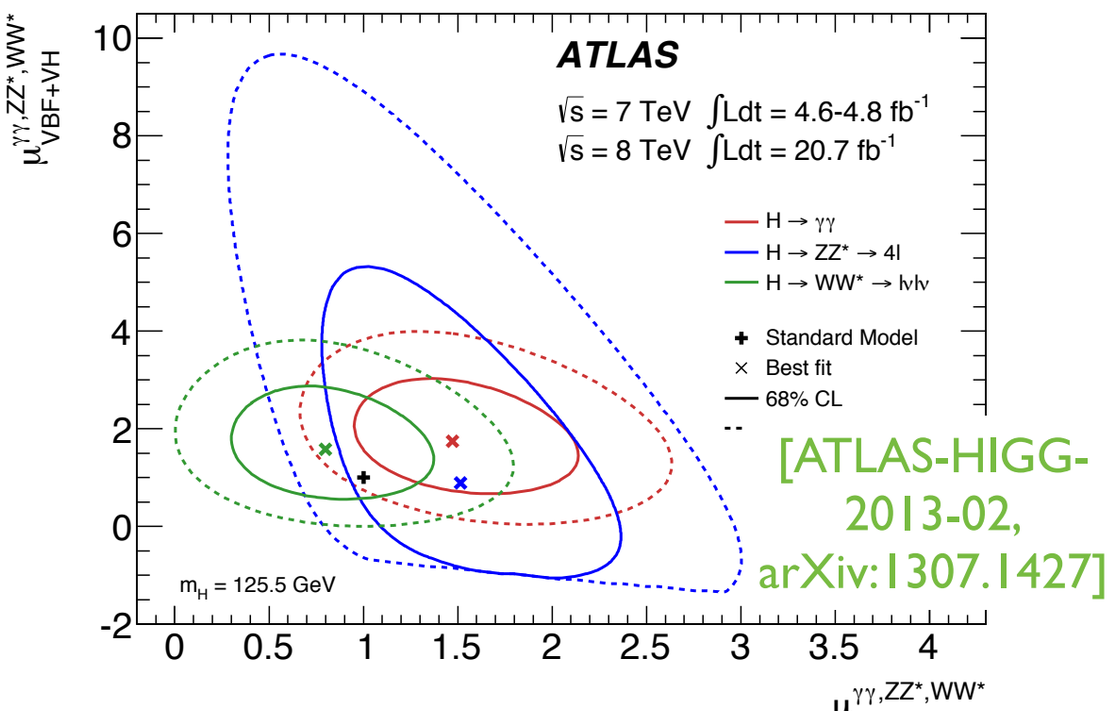
[CMS-HIG-13-012
arXiv:1310.3687]




```
<expmu decay="bb" dim="2" type="n">
  <experiment>CMS</experiment>
  <source type="published">HIG-13-012-003</source>
  <sqrts>7+8</sqrts>
  <mh>125</mh>
  <CL>68%</CL>

  <eff axis="x" prod="WH">1.0</eff>
  <eff axis="y" prod="ZH">1.0</eff>

  <bestfit>
    <x>1.123</x>
    <y>0.997</y>
  </bestfit>

  <param>
    <a>1.393</a>
    <b>0.190</b>
    <c>2.217</c>
  </param>
</expmu>
```

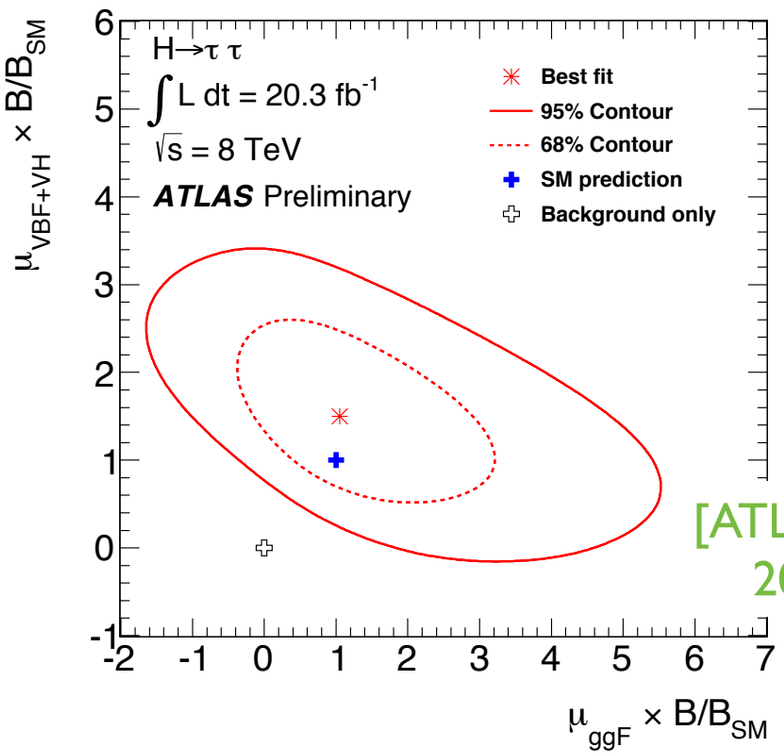
ATLAS experimental input

$H \to \gamma\gamma, ZZ^*, WW^*$



[ATLAS-HIGG-2013-02, arXiv:1307.1427]

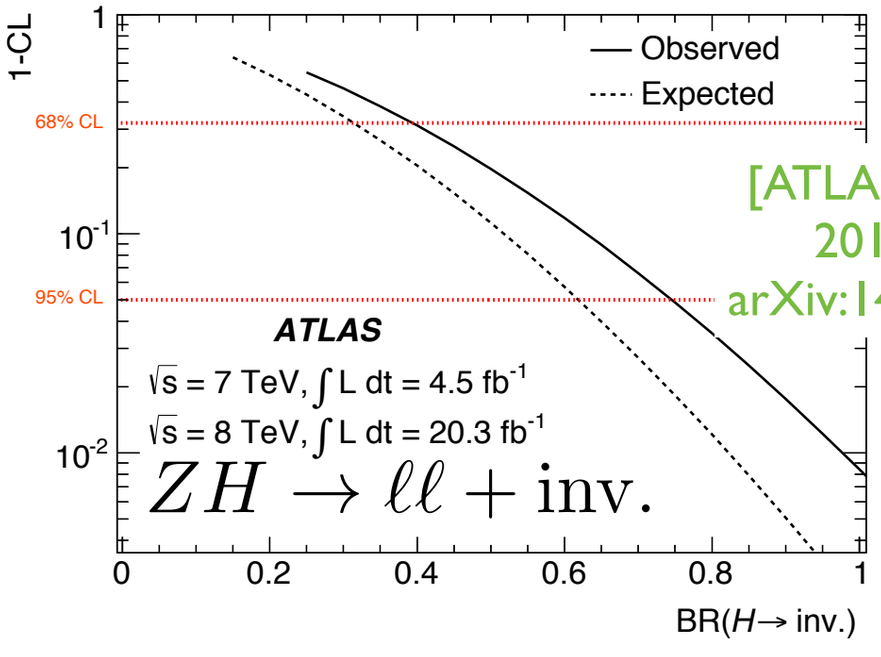
$H \to \tau\tau$



[ATLAS-CONF-2013-079]

[ATLAS-CONF-2013-108]

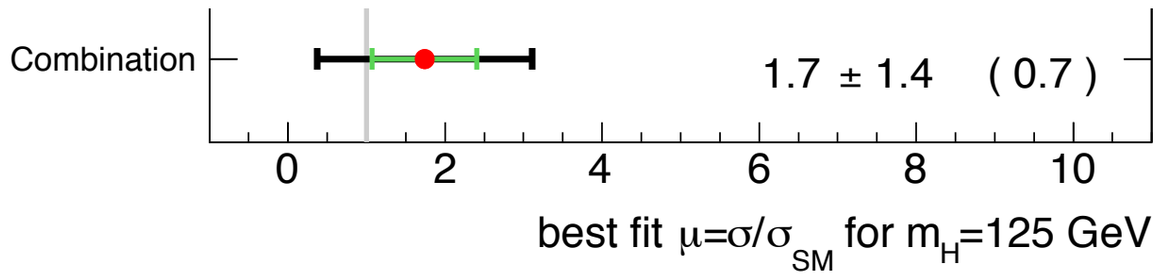
W,Z H → bb̄
Preliminary
$\mu = 0.2^{+0.7}_{-0.6}$



[ATLAS-HIGG-2013-03, arXiv:1402.3244]

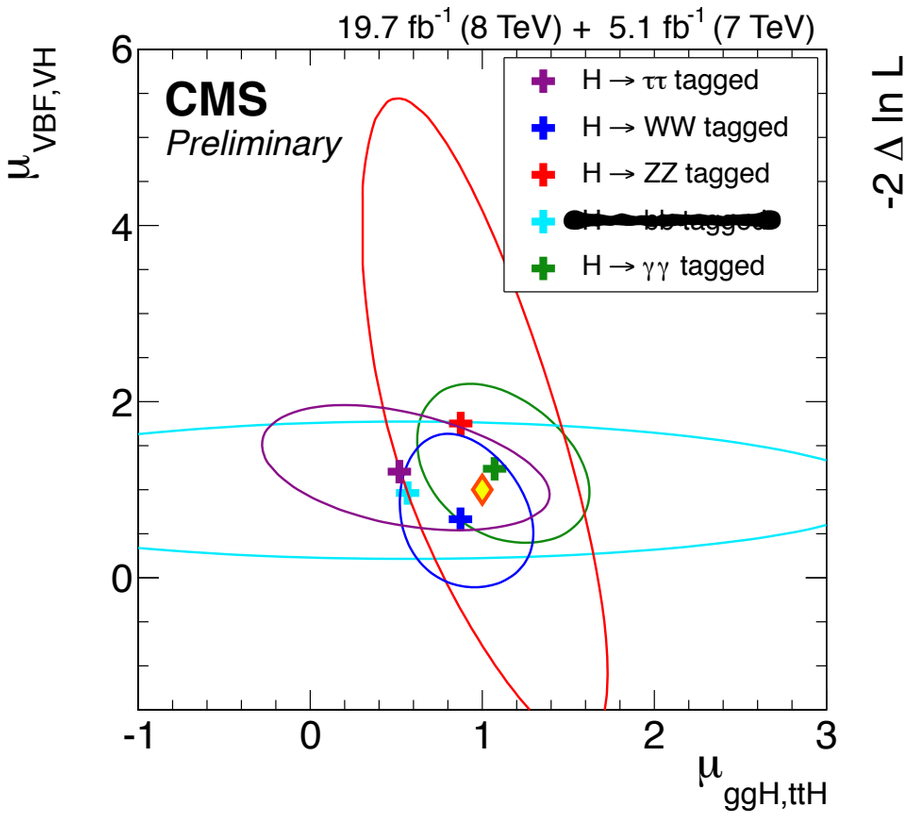
$t\bar{t}H \to b\bar{b}$

[ATLAS-CONF-2014-011]

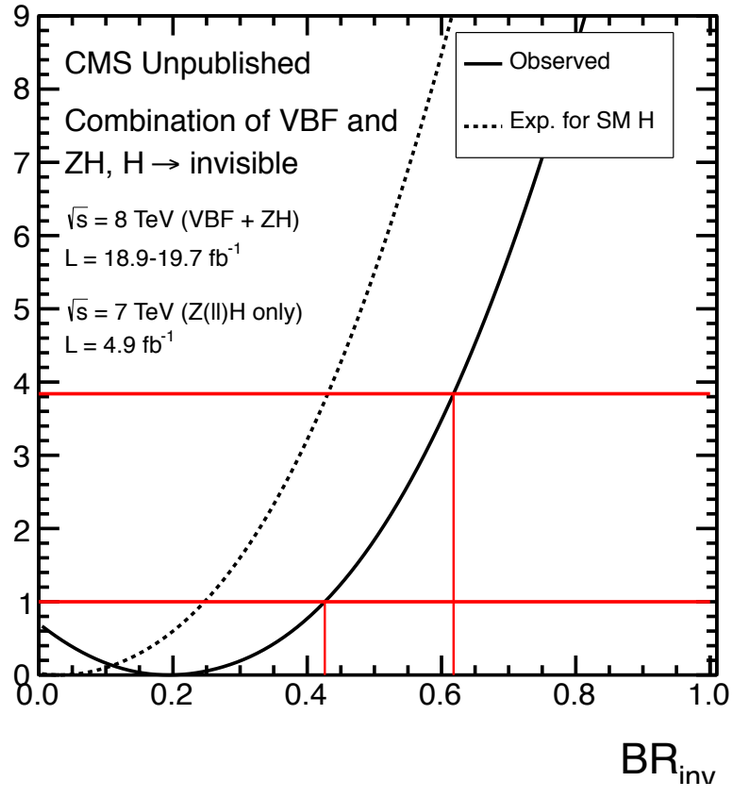


CMS experimental input

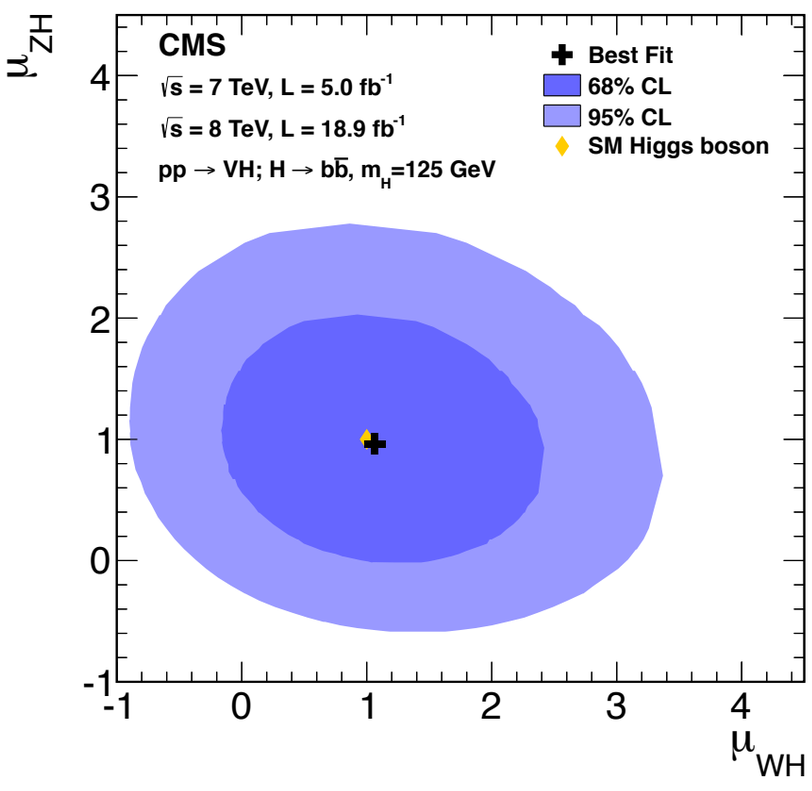
[CMS-PAS-HIG-14-009]



[CMS-HIG-13-030, arXiv:1404.1344]



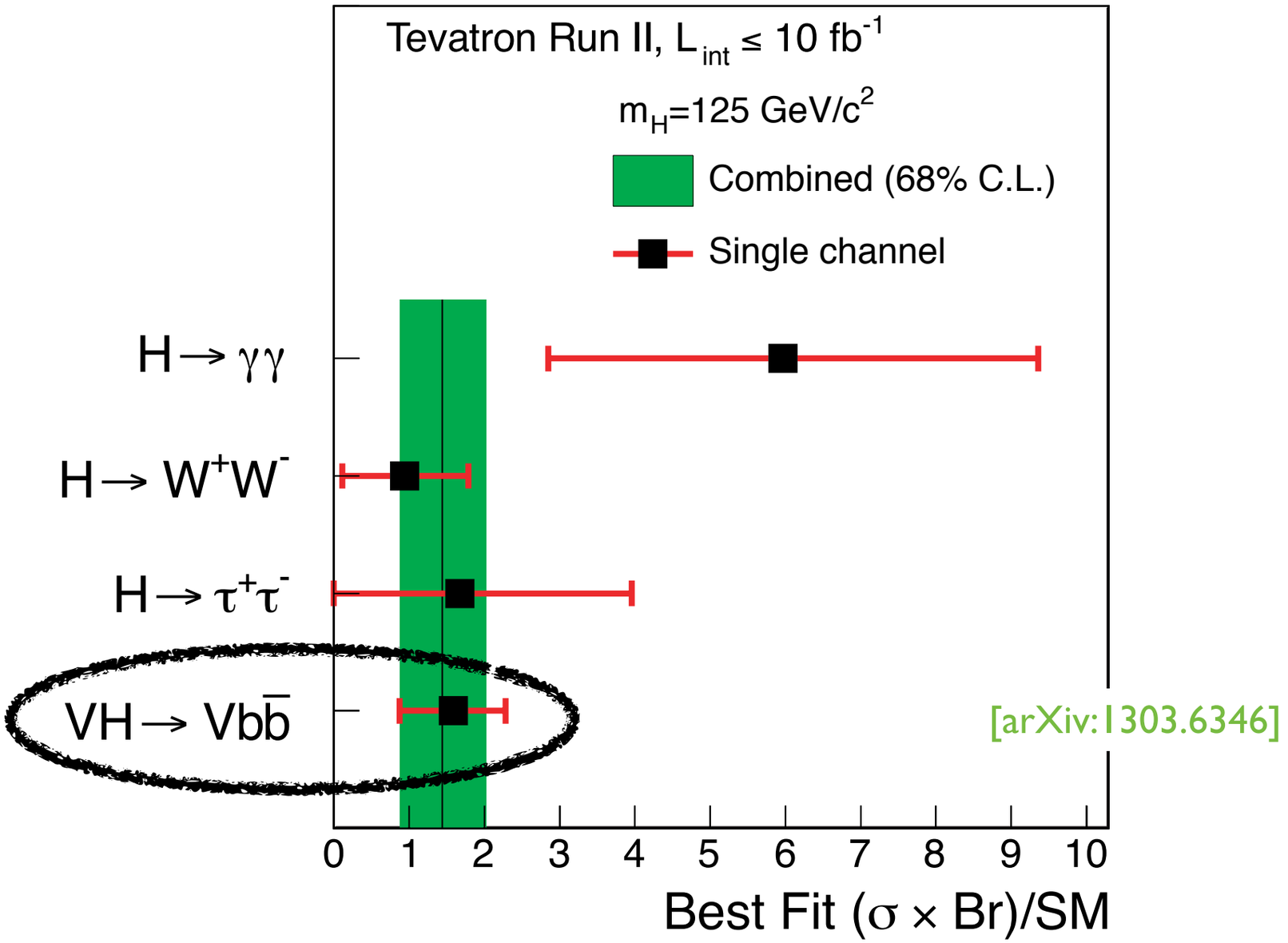
[CMS-HIG-13-012, arXiv:1310.3687]



ttH Channel	$\mu = \sigma/\sigma_{SM}$ $(m_H = 125.7\ \text{GeV})$
$\gamma\gamma$	$-0.2^{+2.4}_{-1.9}$
$b\bar{b}$	$+1.0^{+1.9}_{-2.0}$
$\tau\tau$	$-1.4^{+6.3}_{-5.5}$

[ttHCombinationTWiki]

Tevatron experimental input

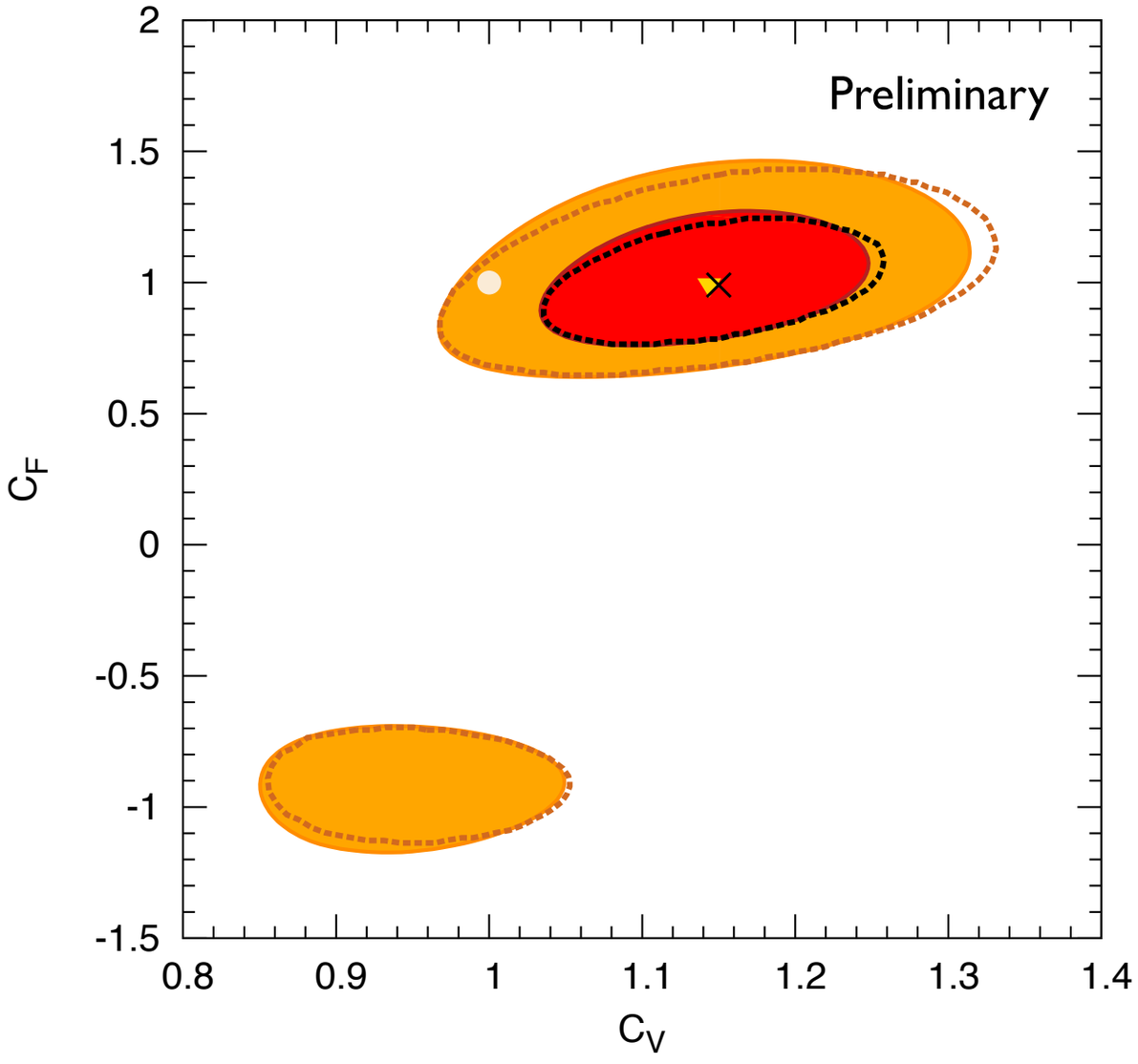


[arXiv:1303.6346]

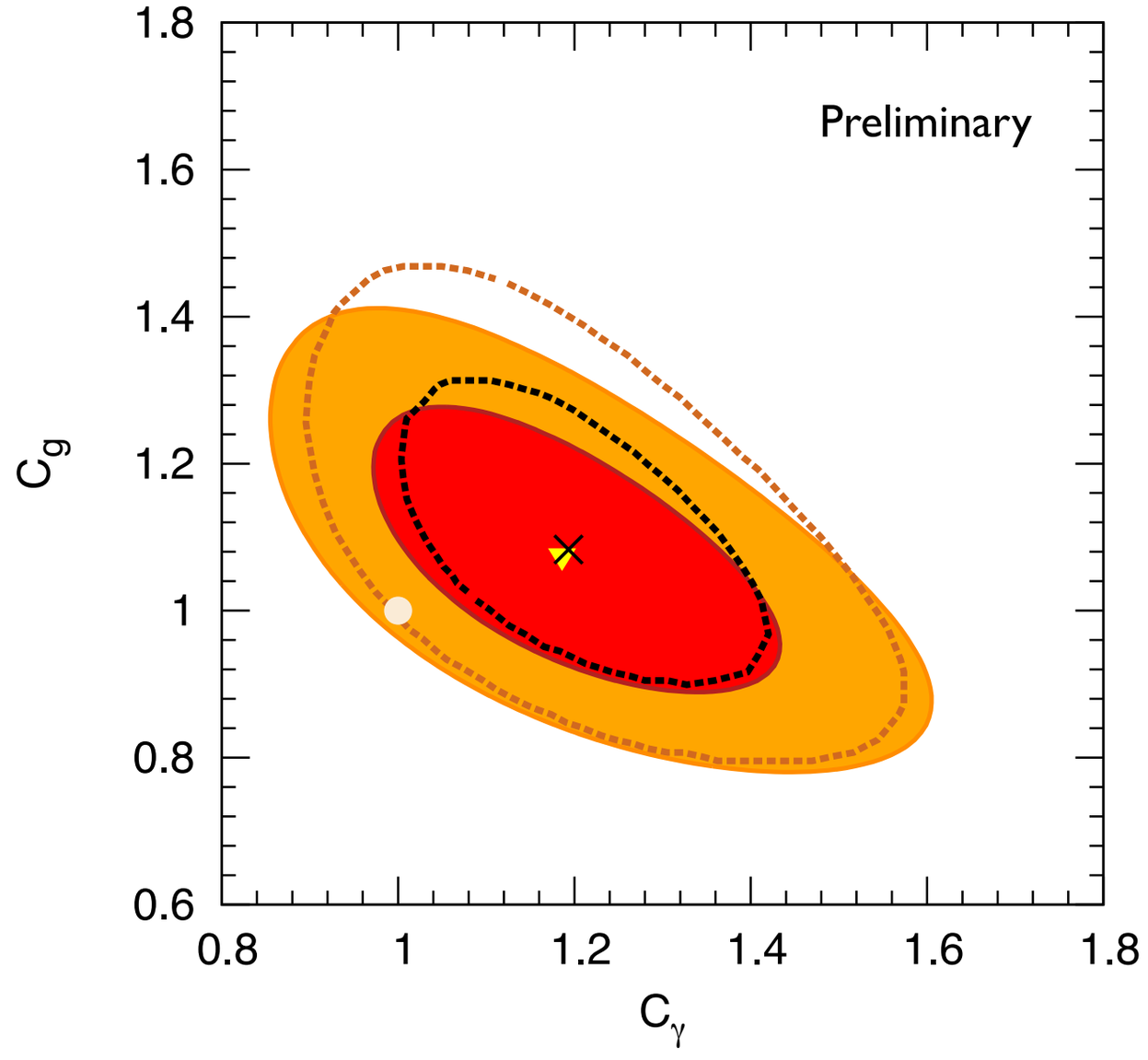
Validation: ATLAS

based on [ATLAS-CONF-2014-009]

(C_F, C_V) fit



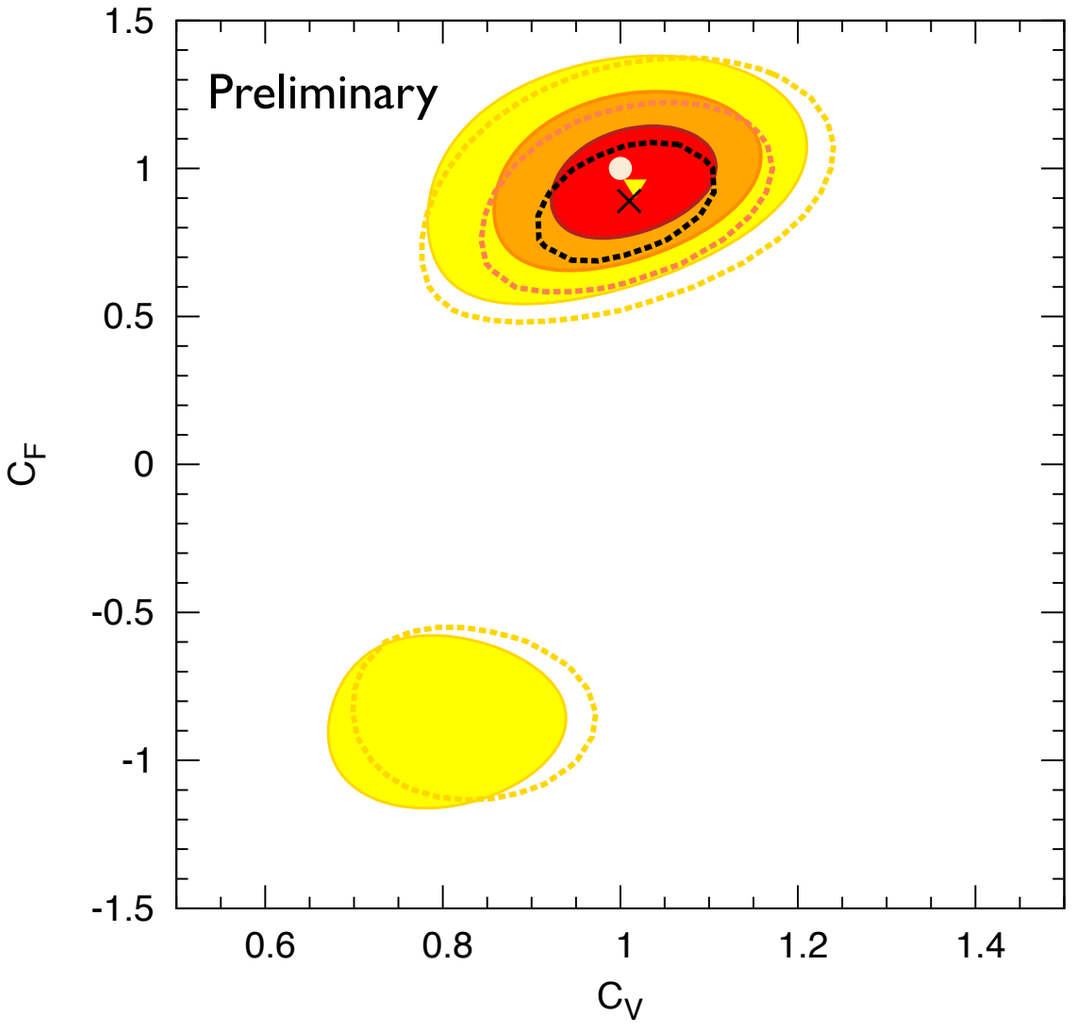
(C_γ, C_g) fit



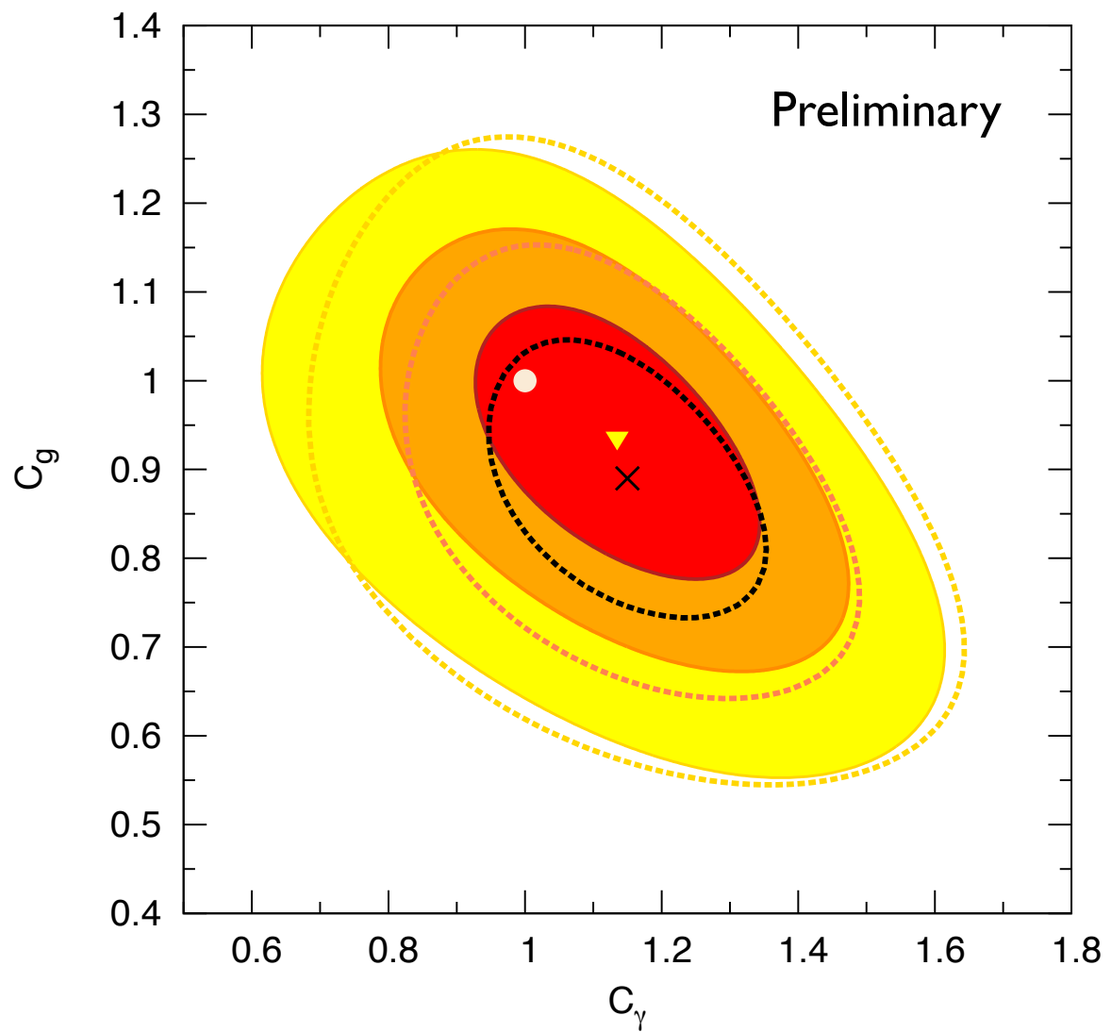
Validation: CMS

based on [CMS-PAS-HIG-14-009]

(C_F, C_V) fit



(C_γ, C_g) fit



Conclusions

- Lilith is a new public tool for applying the Higgs constraints on a wide class of new physics models

- you can download the beta version at http://lpsc.in2p3.fr/projects-th/lilith/

- it's easy to run: `./lilith.py model_input_xml [experimental_input_list]`

```
---------------------------
Lilith version 1.0beta
---------------------------
Entering signal strengths mode...

-2*log(L) = 13.111668
ndf = 26
```

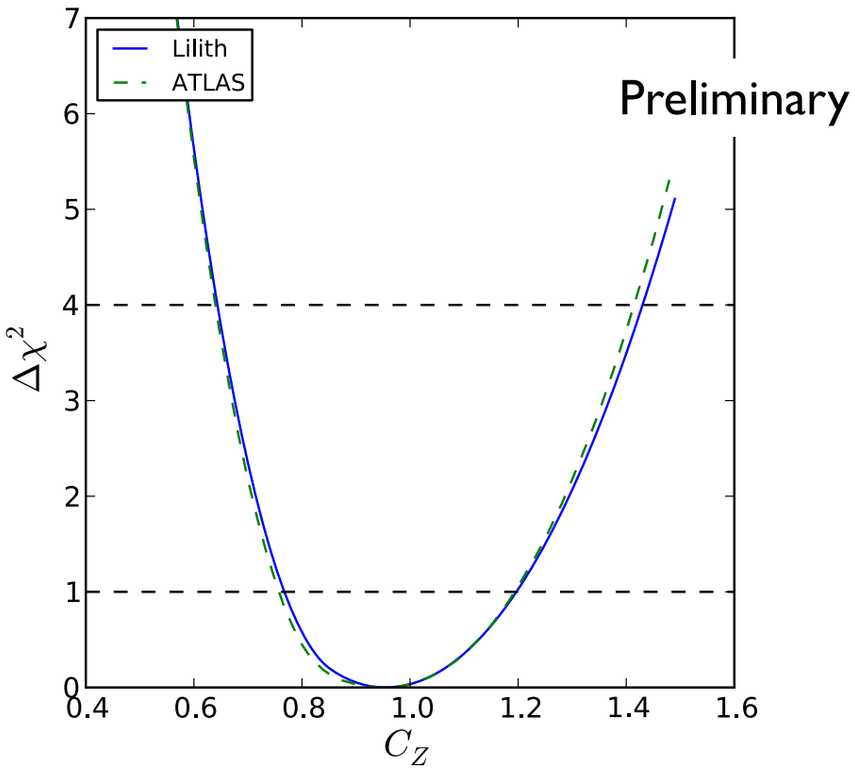
- can be easily embedded into any Python code (e.g. with for minimization with MINUIT) examples are shipped with the code

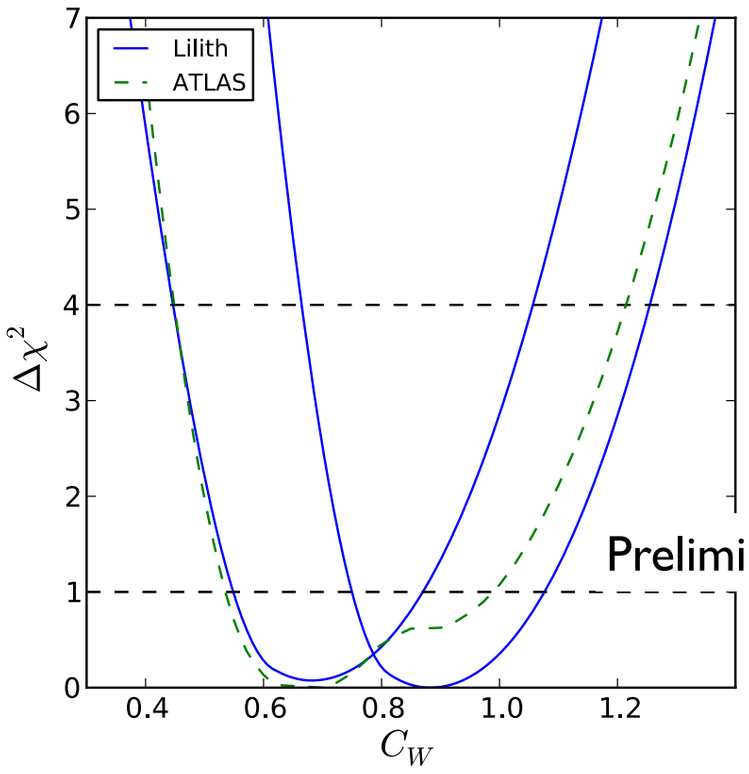
- try it and send us your feedback!

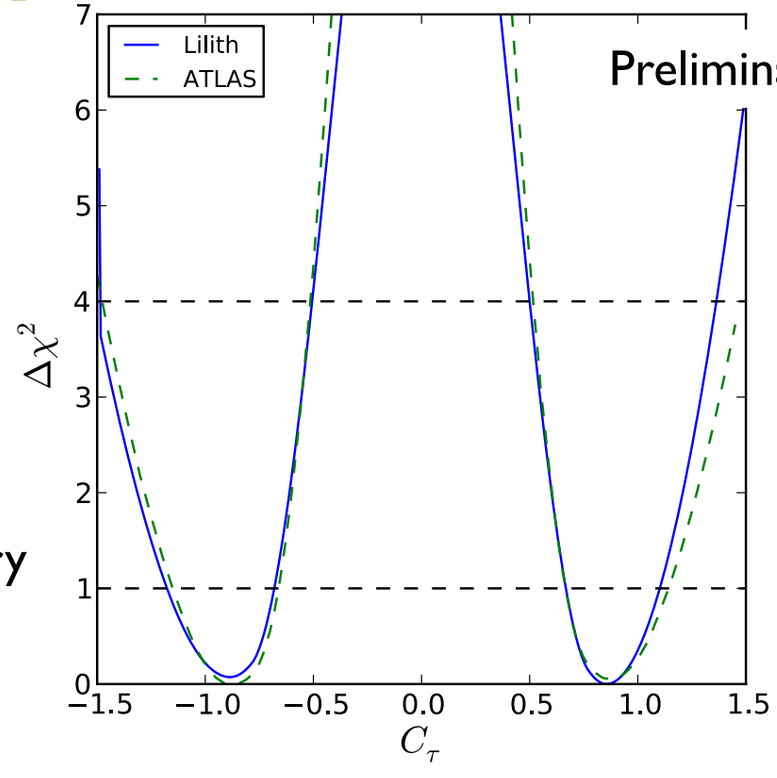
backup slides

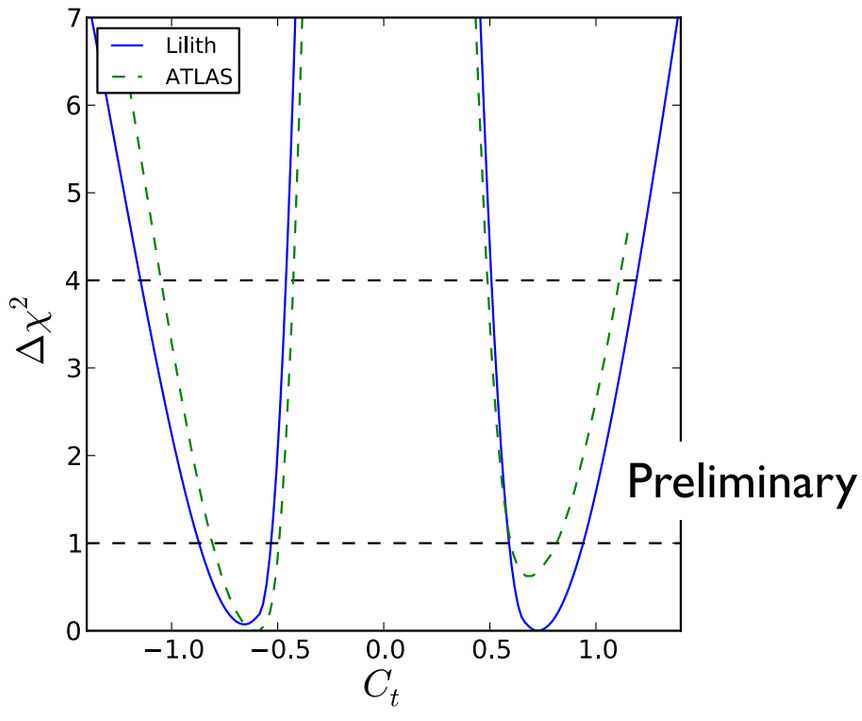
Validation: ATLAS 5-param. fit

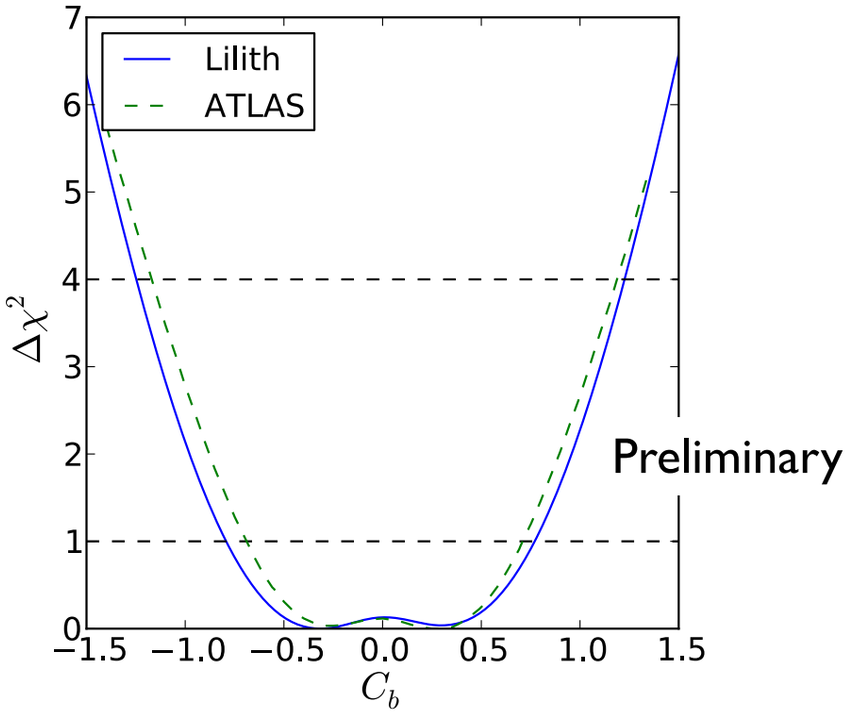
based on [ATLAS-CONF-2014-009]





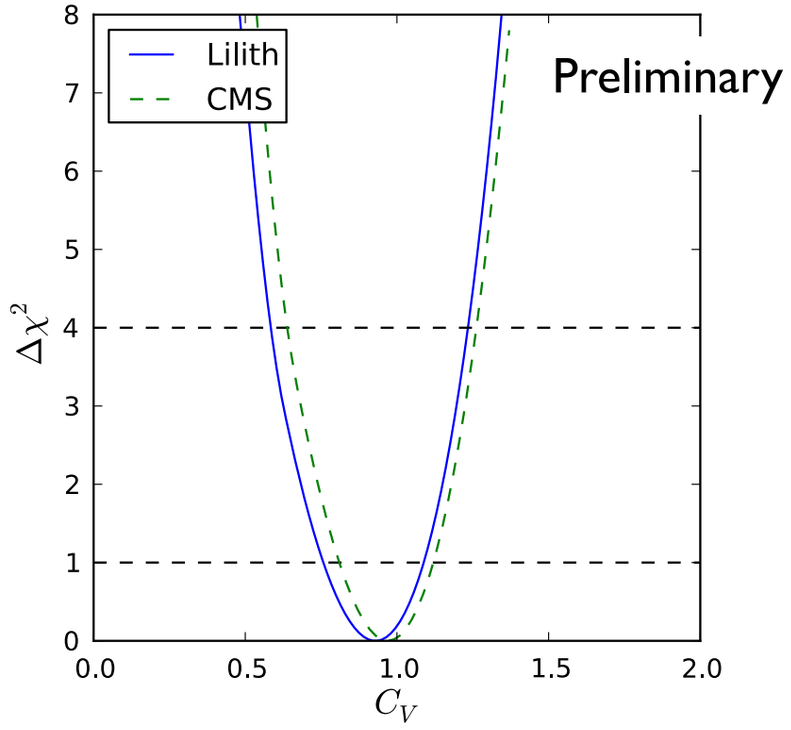


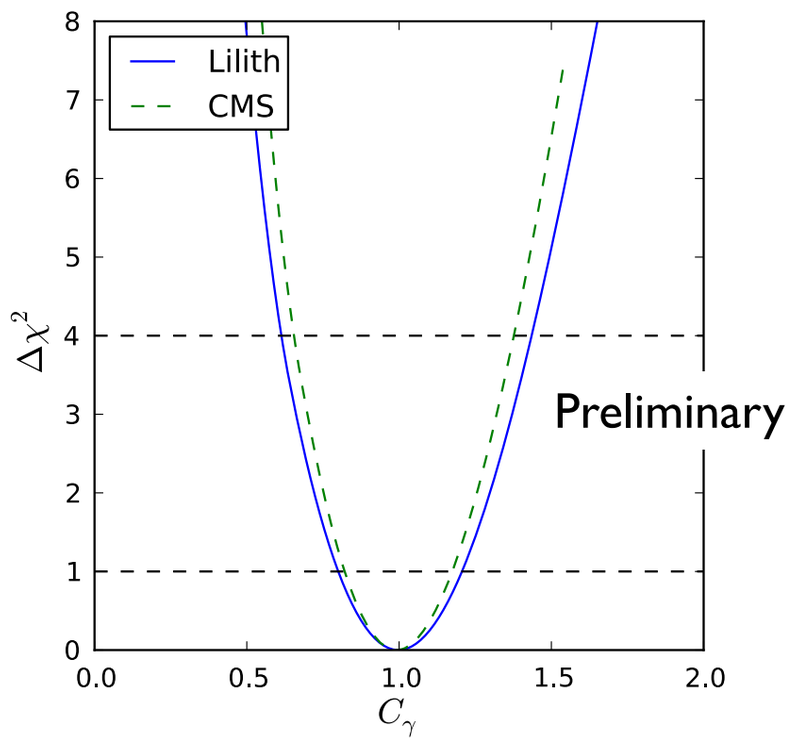


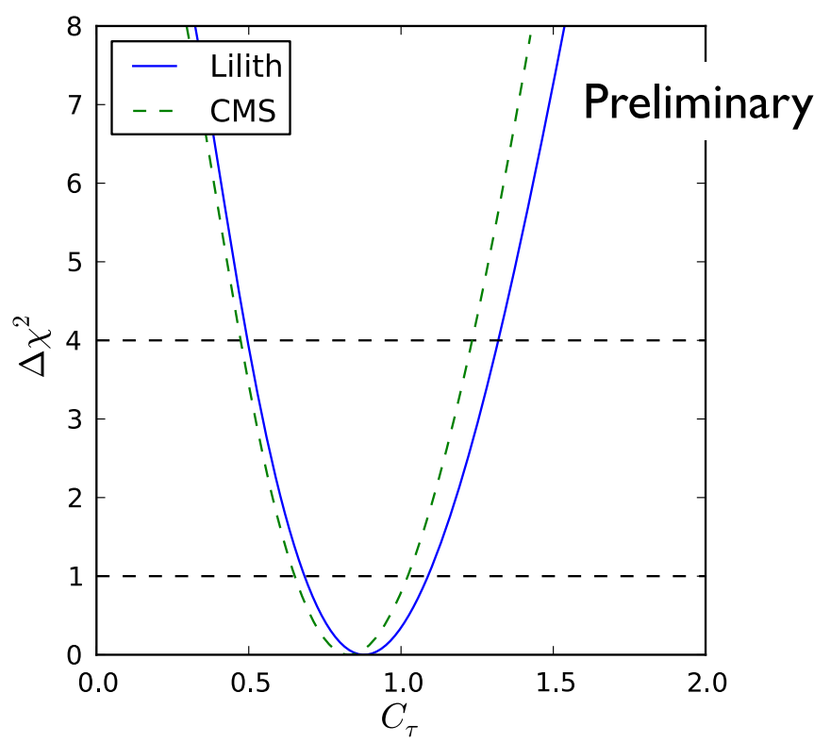


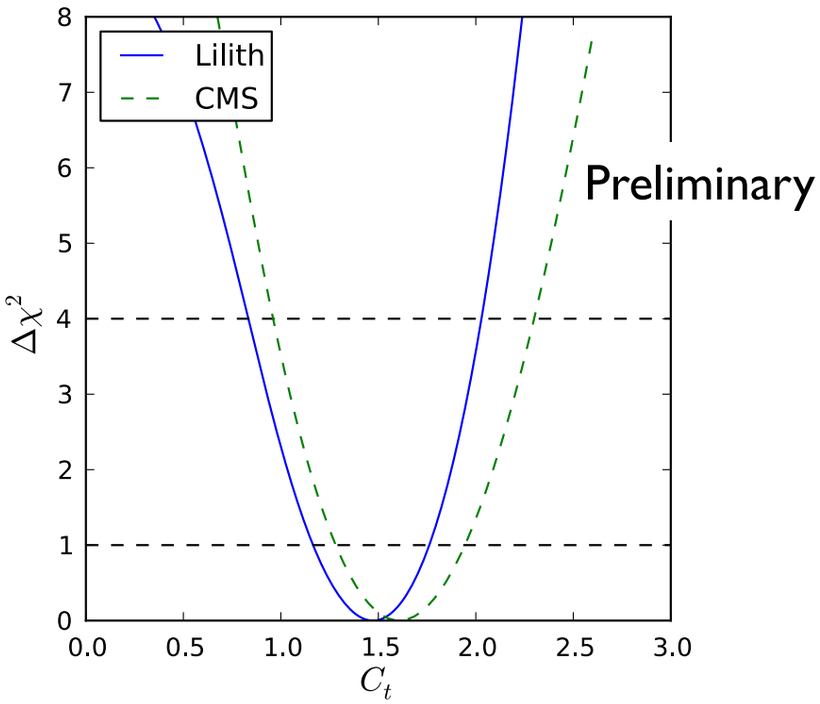
Validation: CMS 6-param. fit

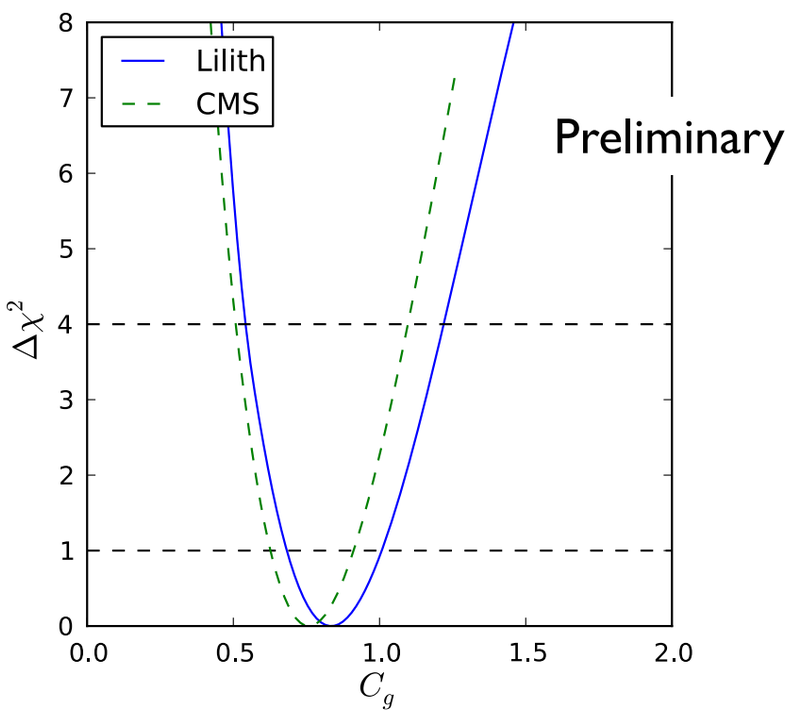
based on [CMS-PAS-HIG-14-009]

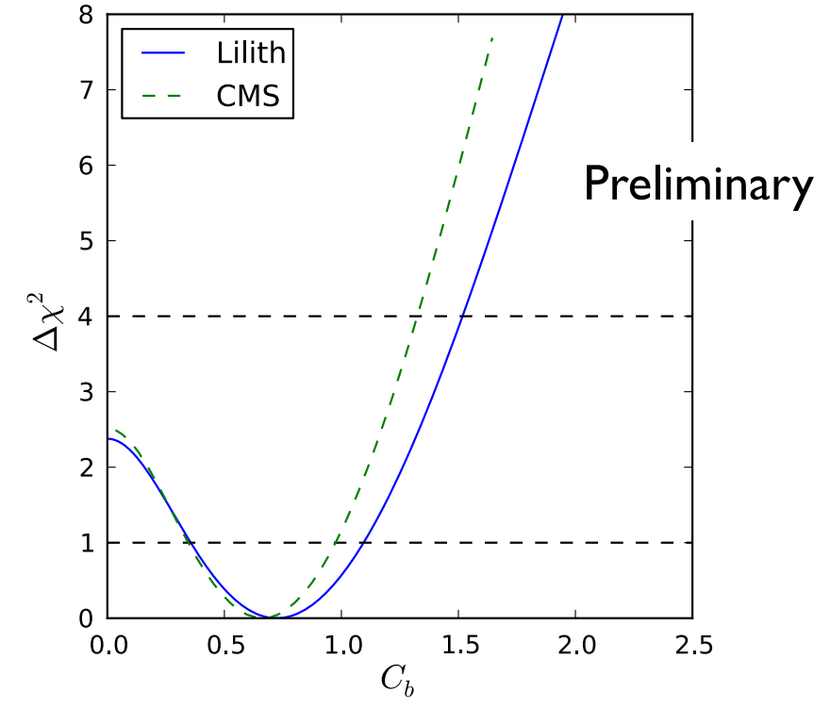








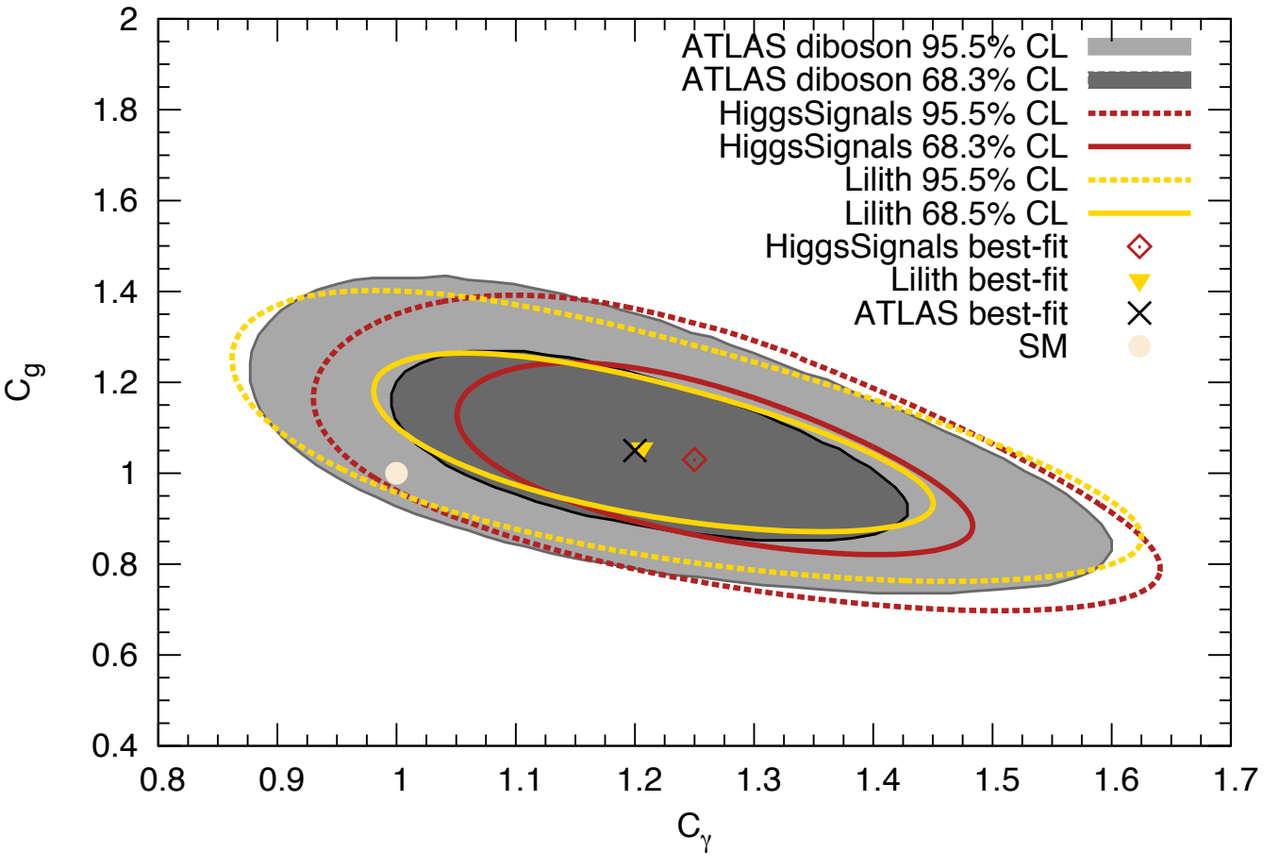




Comparison with HiggsSignals

(C_γ, C_g) fit

[ATLAS-HIGG-2013-02]



[CMS-PAS-HIG-13-005]