Study of Higgs Properties in the CMS Experiment

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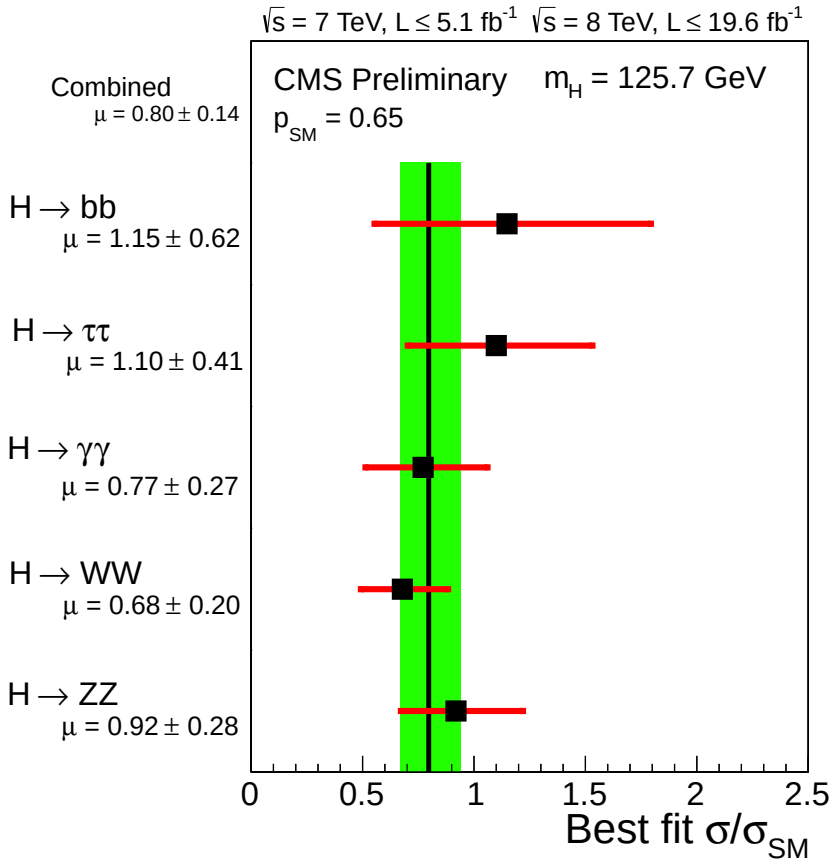
Introduction

- A Higgs Boson discovered last summer with $\sim 5 + 5\text{fb}^{-1}$ at $7 + 8$ TeV
- Preliminary results for main channels available since the winter with full $7 + 8$ TeV dataset ($\sim 5 + 20\text{fb}^{-1}$)
- Results Presented Here:
  - Combined coupling fits for $\gamma\gamma, ZZ \to 4\ell, WW \to 2\ell 2\nu, \tau\tau, bb$ decay modes (CMS-HIG-13-005)
  - Combined mass measurement from $\gamma\gamma$ and $ZZ \to 4\ell$ channels (CMS-HIG-13-005)
  - Spin and parity from $\gamma\gamma, ZZ \to 4\ell, WW \to 2\ell 2\nu$ (CMS-HIG-13-002, CMS-HIG-13-003, CMS-HIG-13-005, CMS-HIG-13-016)

Observed Signal: A Summary

Channel	Expected	Observed
ZZ	7.1σ	6.7σ
$\gamma\gamma$	3.9σ	3.2σ
WW	5.3σ	3.9σ
bb	2.2σ	2.0σ
$\tau\tau$	2.6σ	2.8σ
(bb+$\tau\tau$)	3.4σ	3.4σ

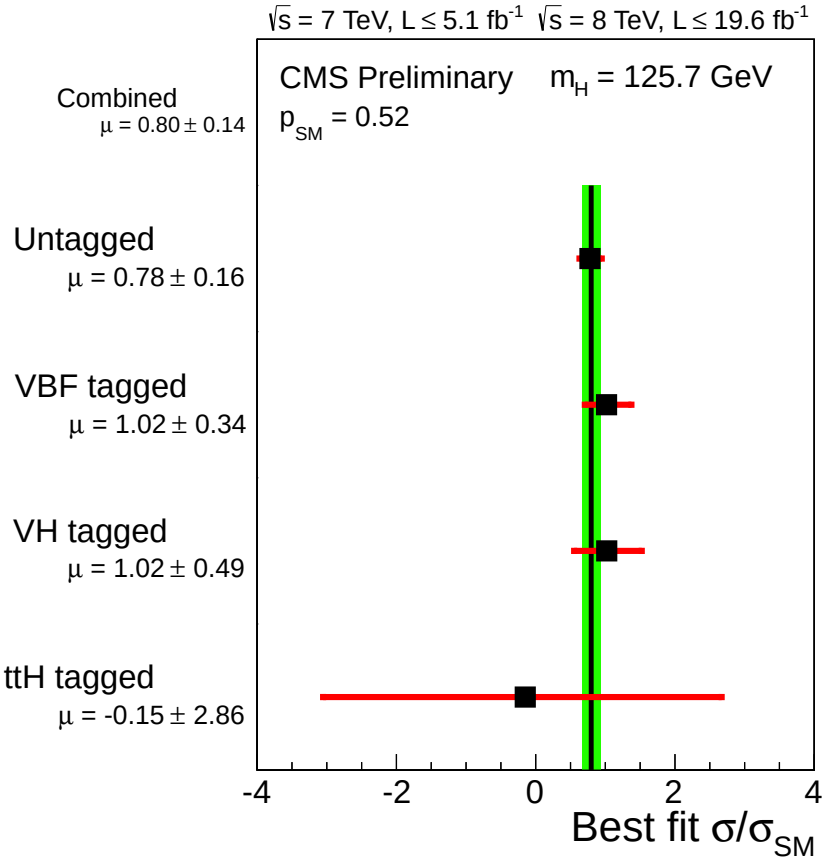
- Overall best-fit
  $\mu = 0.80 \pm 0.14$



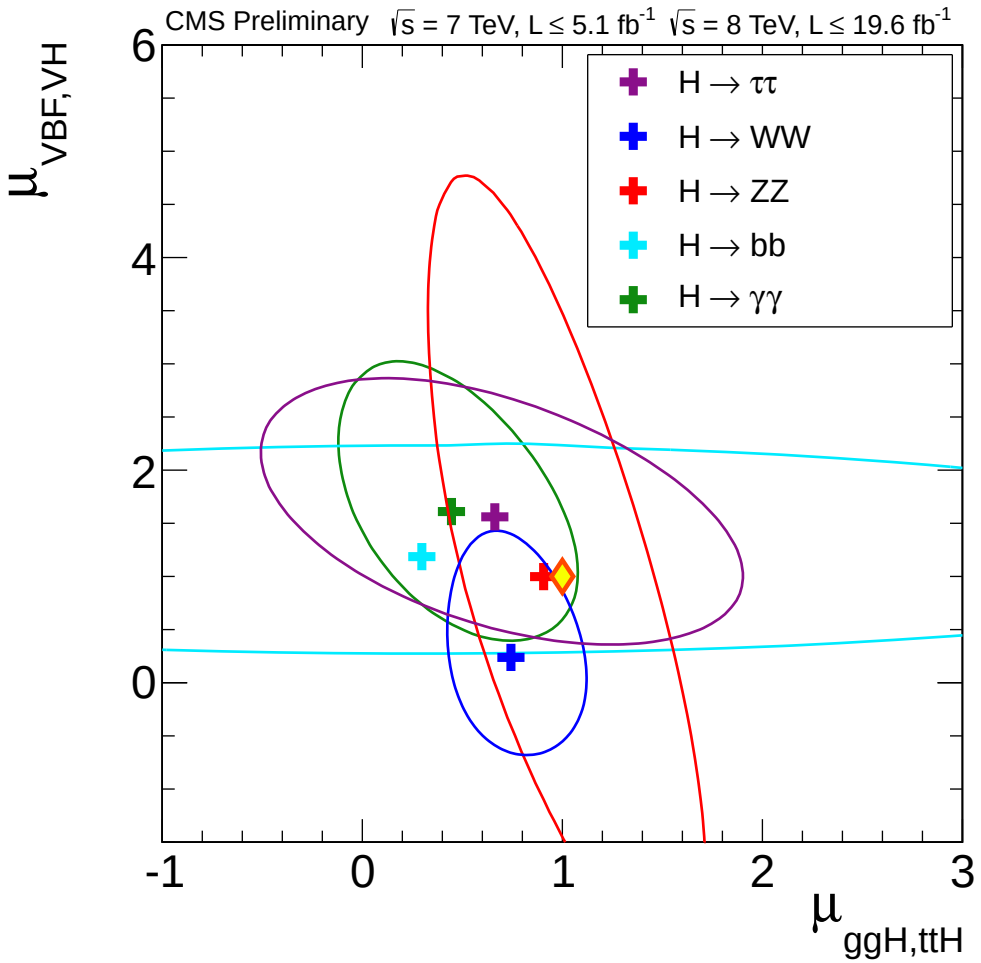
Observed Signal: Exclusive Tags

Channel	Sub-channels
ZZ	Untagged, VBF
$\gamma\gamma$	Untagged, VBF, VH
WW	Untagged, VBF, VH
bb	VH, ttH
$\tau\tau$	Untagged, VBF, VH

- Some additional and updated exclusive sub-channels not yet included in the combination!



Observed Signal: Decomposing Production Mechanisms

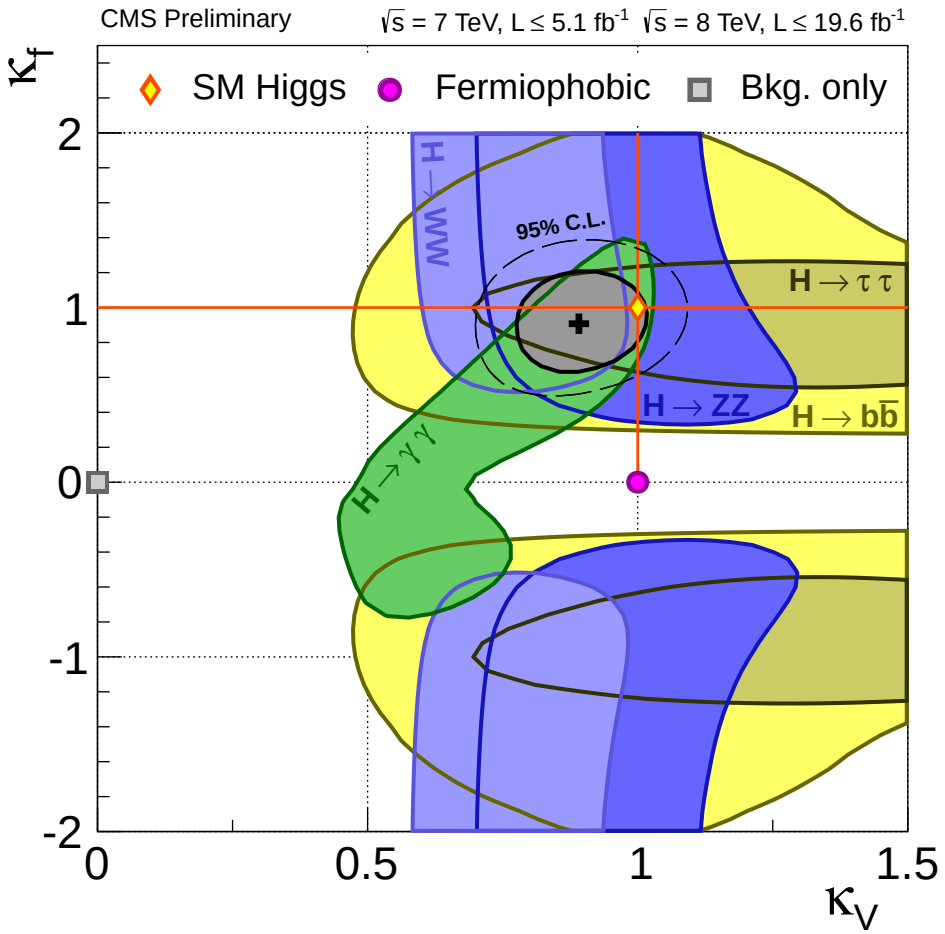


- Untagged channels dominated by Gluon fusion
- Tagged channels (jets/leptons/MET) sensitive to other production mechanisms
- Each channel well compatible with SM, but combining channels in this picture requires some additional formalism

Coupling Fits

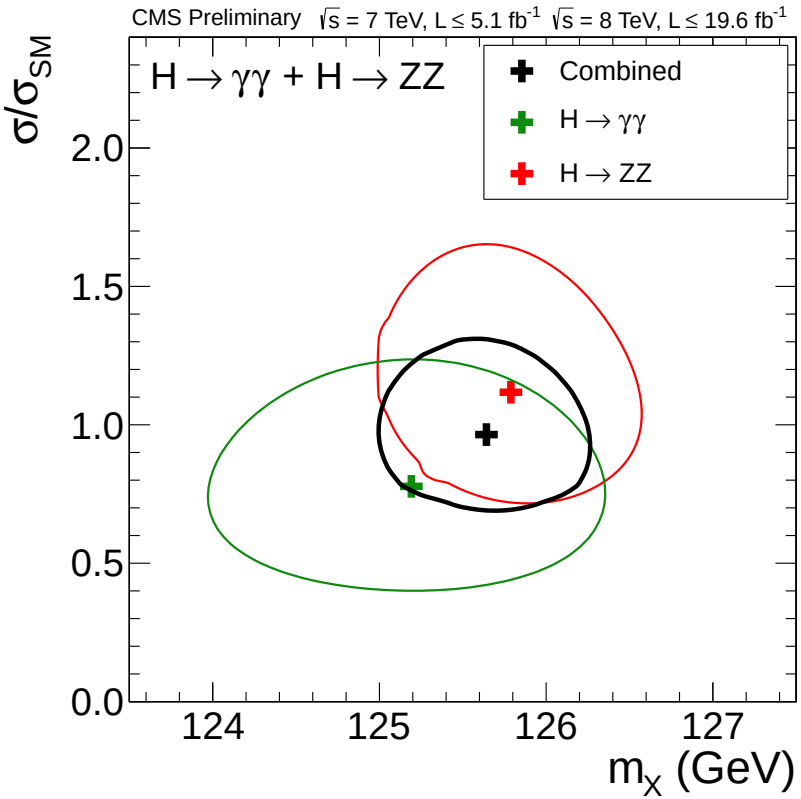
- Coupling fits serve as a compatibility test for the observed particle with the standard model
- Fit for κ_i: scaling factors to LO Higgs couplings
  $\kappa_W, \kappa_Z, \kappa_b, \kappa_t, \kappa_\tau$
- Decompose gluon and photon loops into t and W couplings, or introduce independent κ_g, κ_γ parameters to allow for BSM loop contributions
- Couplings can also be grouped together eg κ_V, κ_f

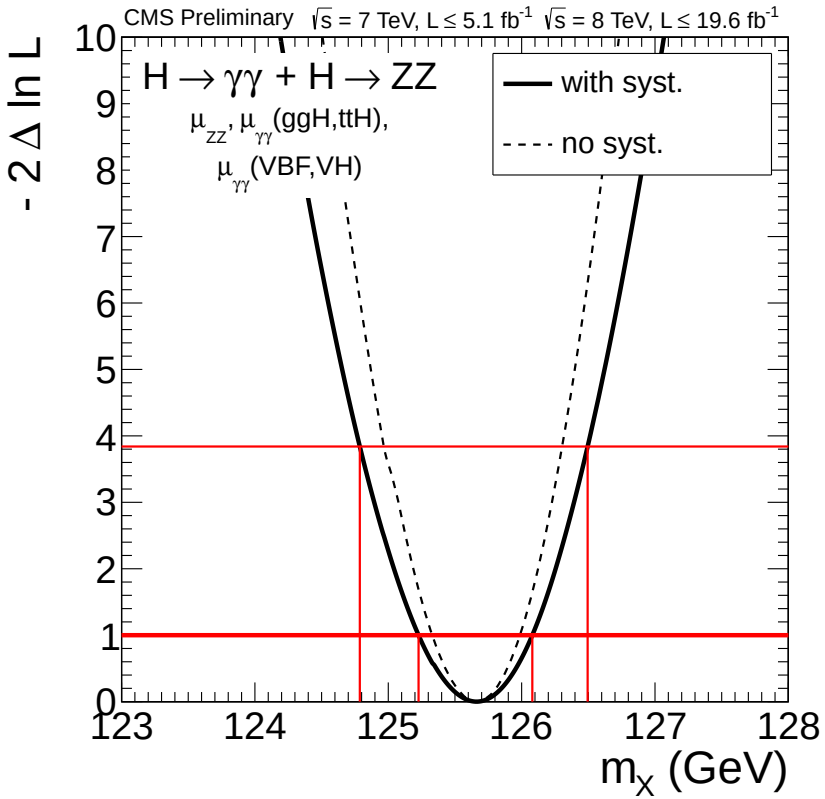
Coupling Fits: κ_V vs κ_f



- Group together vector boson and fermion couplings
- Result compatible with Standard Model expectation
- Reversed fermion coupling sign allowed by coupling formalism, degeneracy broken by interference of t and W in $H\gamma\gamma$ loop

Combined Mass Measurement



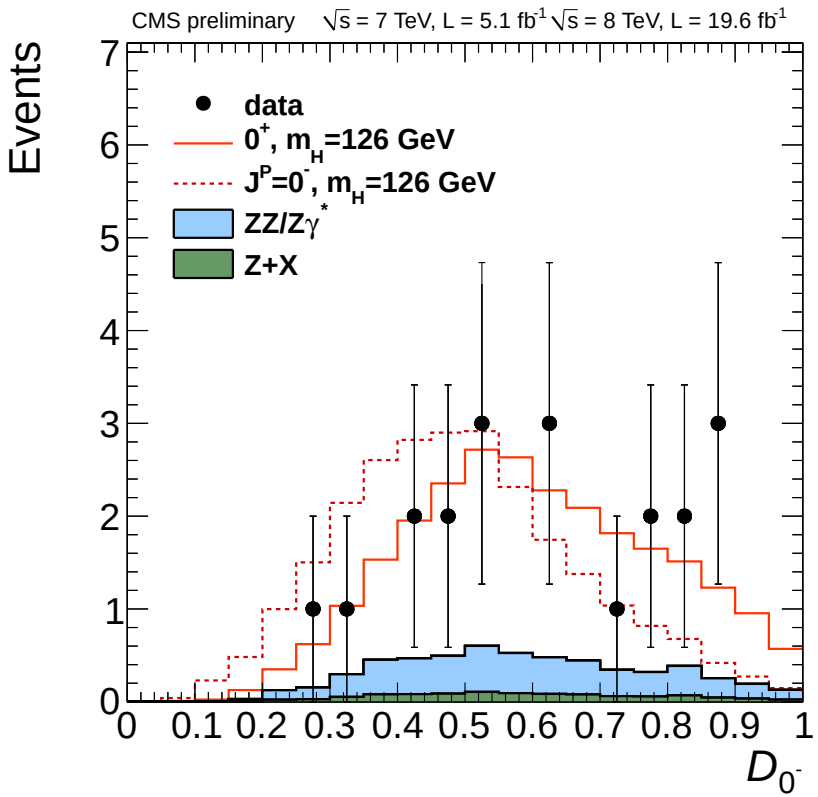


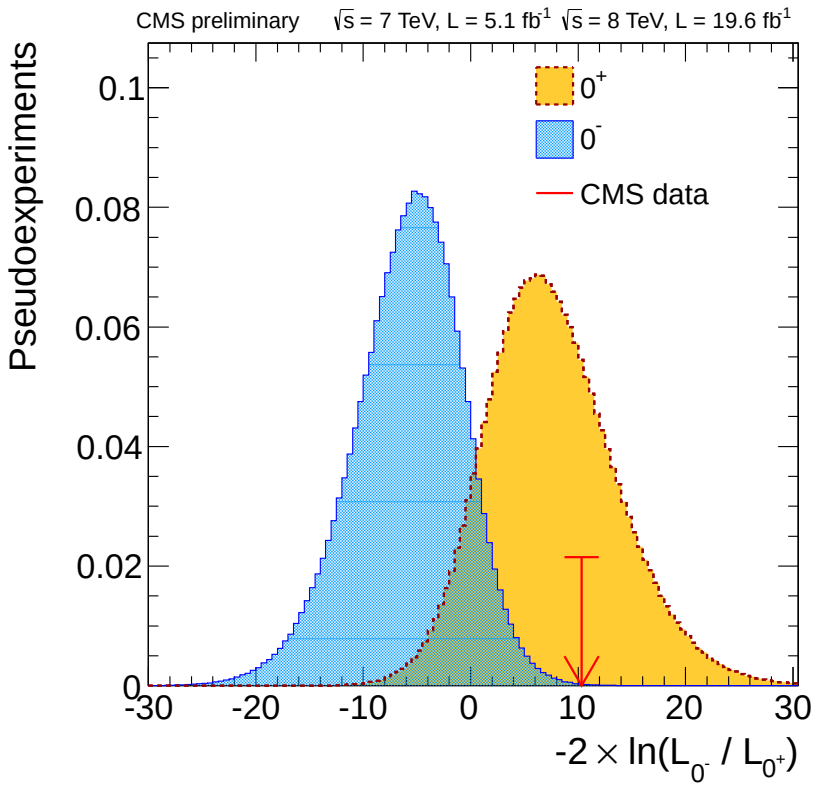
$H \to \gamma\gamma$: $m_H = 125.4 \pm 0.5$ (stat.) ± 0.6 (syst.) GeV

$H \to ZZ \to 4\ell$: $m_H = 125.8 \pm 0.5$ (stat.) ± 0.2 (syst.) GeV

Combined: $\mathbf{m_H = 125.7 \pm 0.3}$ **(stat.)** $\mathbf{\pm 0.3}$ **(syst.) GeV**

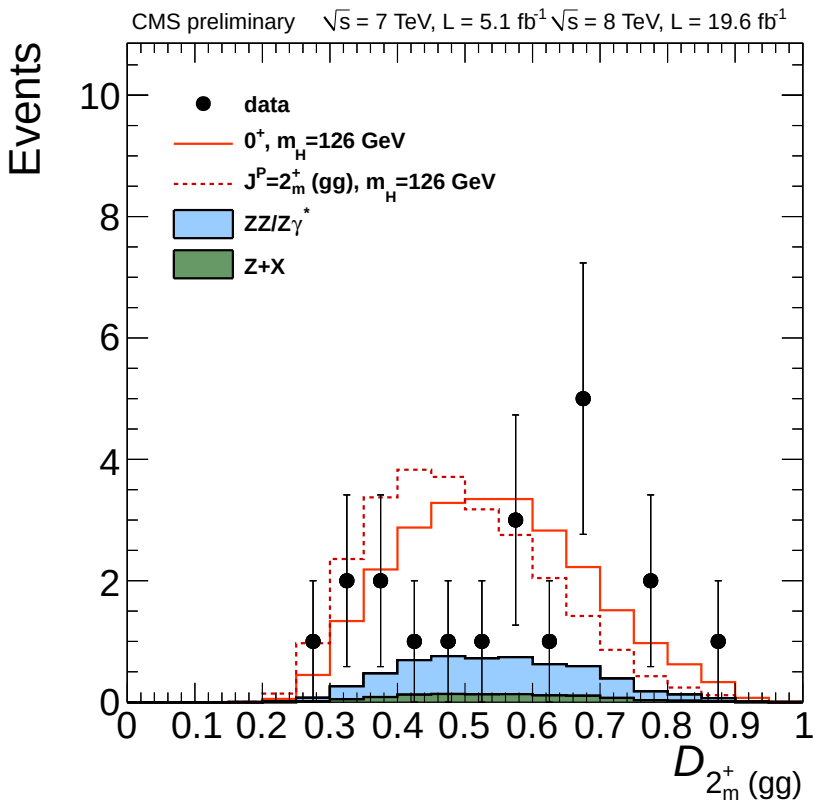
$H \to ZZ \to 4\ell$: Parity Test

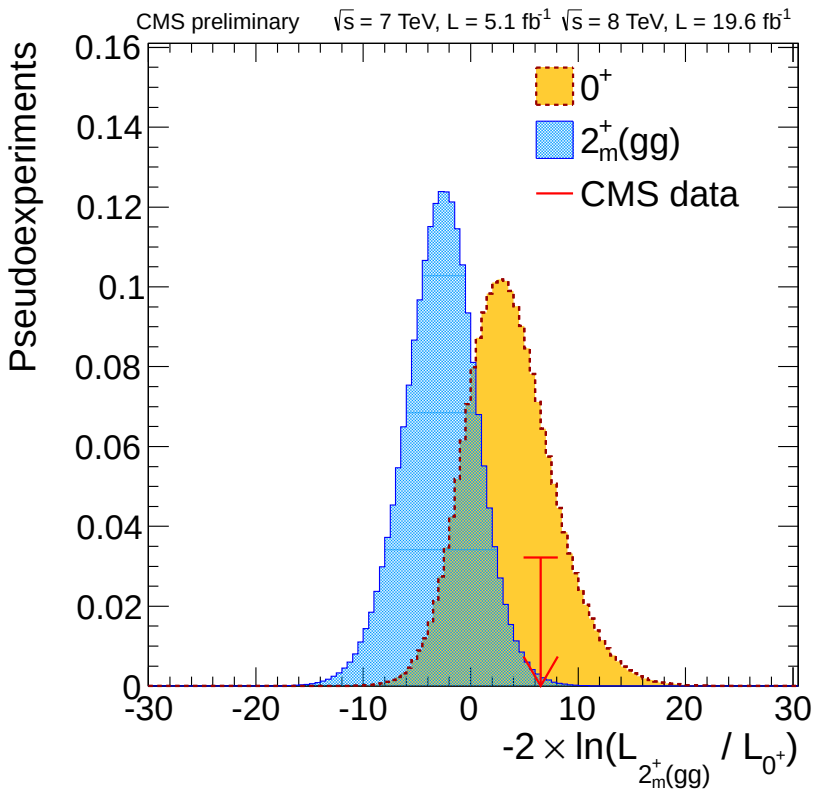




- Spin and parity tests for $H \to ZZ \to 4\ell$ conducted using matrix-element based discriminator based on decay angles and Z masses
- Pure pseudoscalar hypothesis excluded at 3.3 σ (2.8 σ expected for $\mu = 1$)

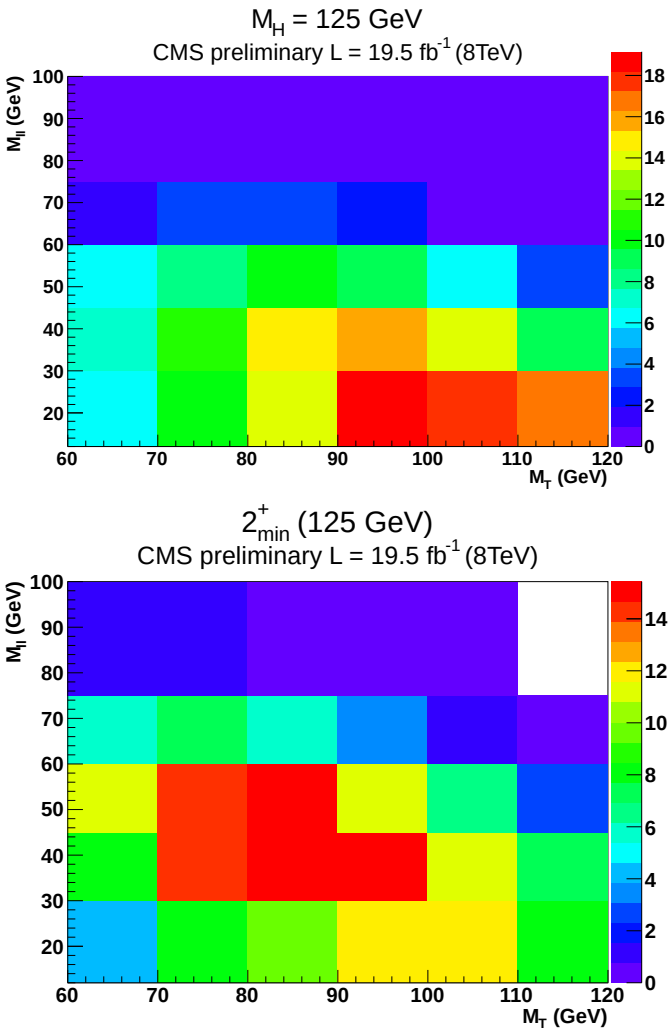
$H \to ZZ \to 4\ell$: Spin Test (gg production)

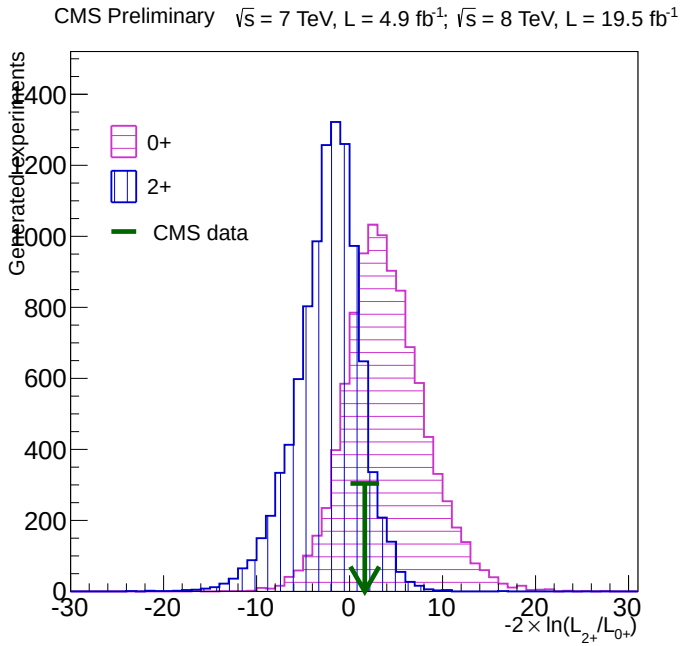




- 2^+_m (pure gluon-gluon production) hypothesis excluded at 2.7 σ (1.9 σ expected for $\mu = 1$)
- Other hypothesis also tested, 2^+_m(qq) and exotic vector/pseudovector hypothesis excluded at ≥ 4.0 σ

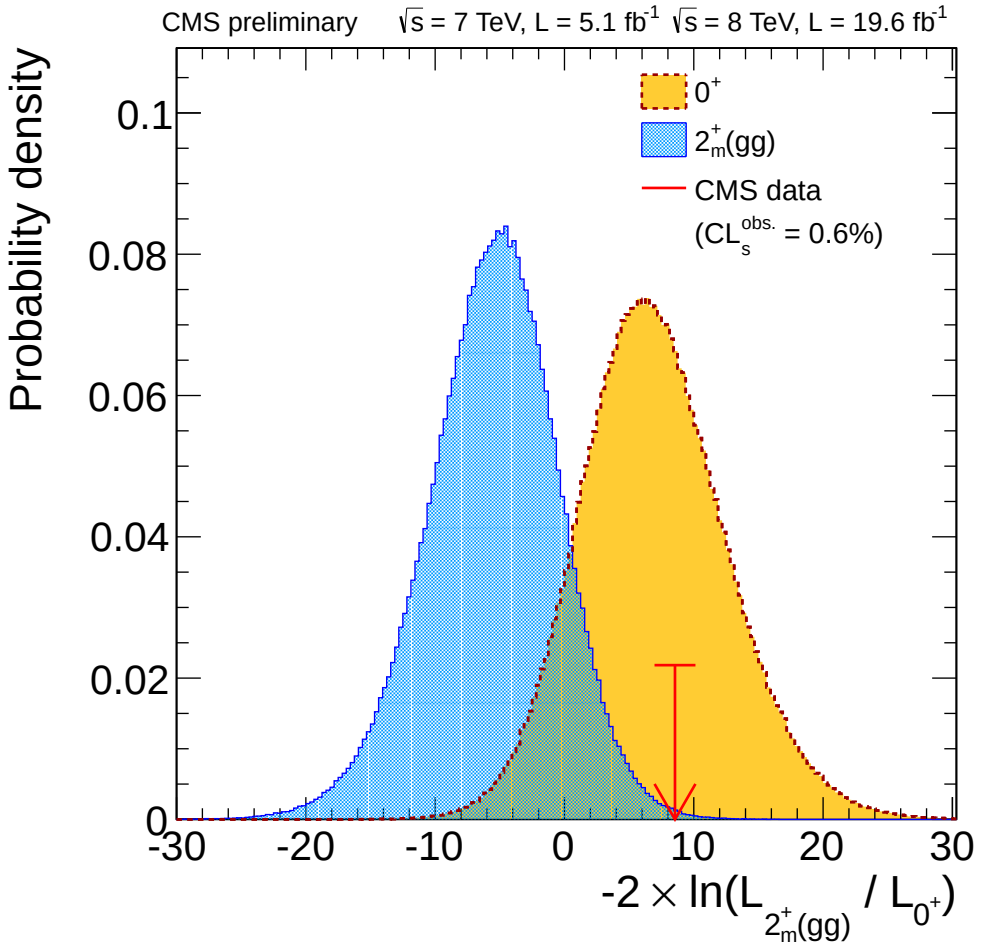
$H \to WW \to 2\ell 2\nu$: Spin Test





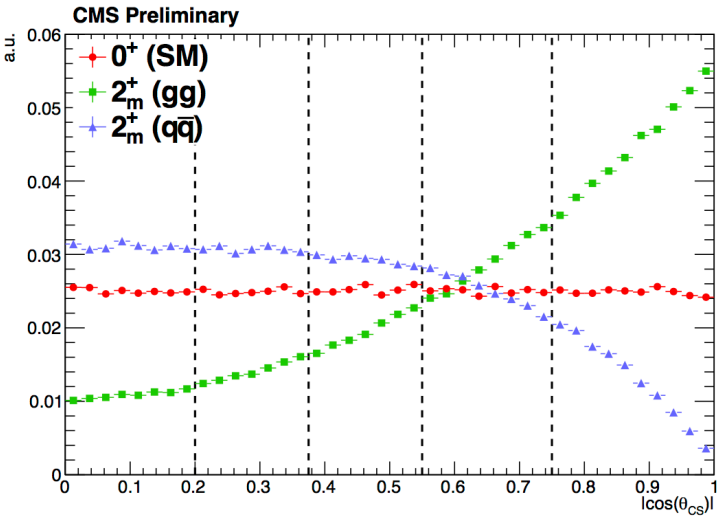
- Spin hypothesis discrimination using 2d $M_{\ell\ell}$, M_T distribution
- No significant discrimination yet

Spin Test: $WW + ZZ$ Combination

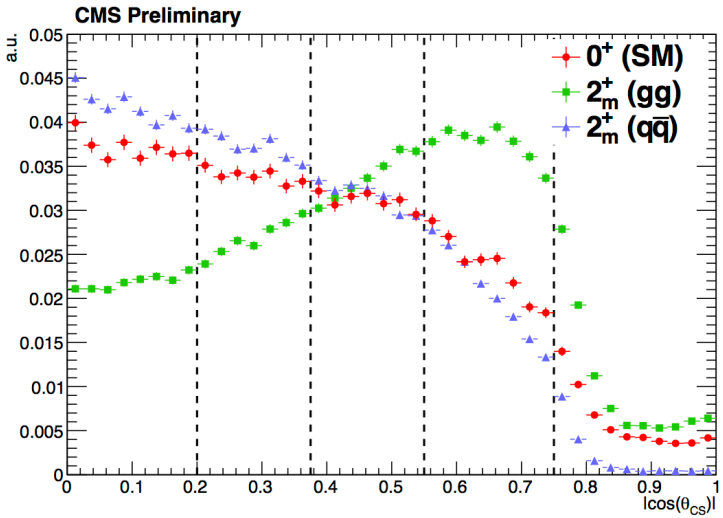


- Combined hypothesis test for WW and ZZ channels excludes 2^+_m (gluon-gluon) hypothesis at 2.84 σ. (3.0 σ expected for $\mu = 1$)

Spin Test: $H \to \gamma\gamma$



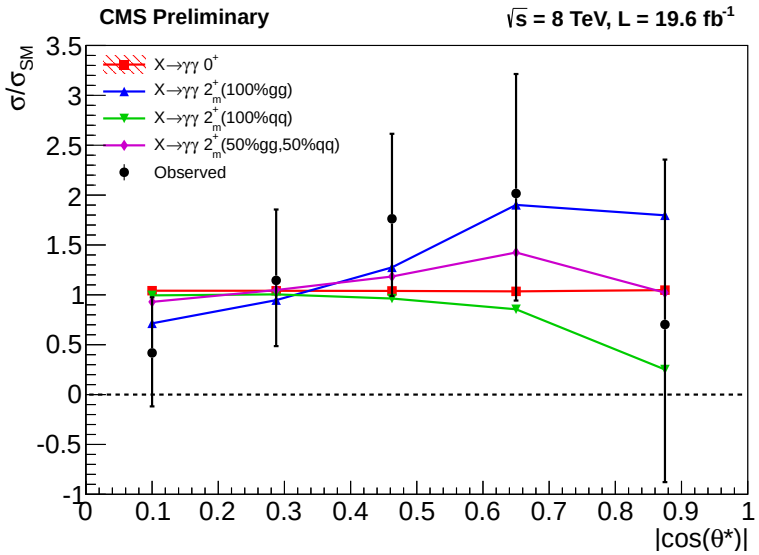
(a) Before Selection

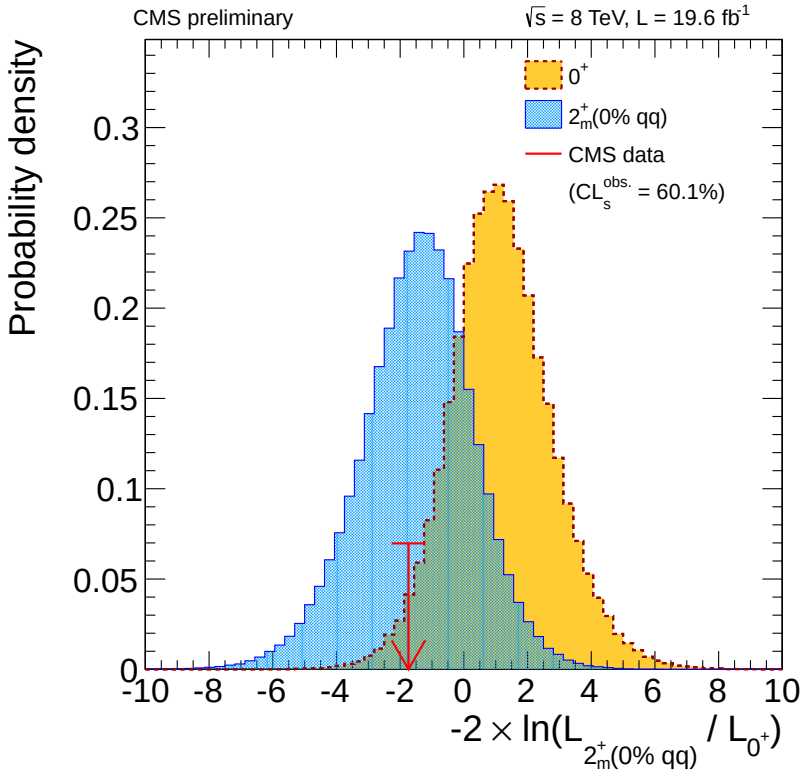


(b) After Selection

- Spin tested using $H \to \gamma\gamma$ channel, using the $\cos\theta^*$ distribution to discriminate (decay angle relative to the beam axis)
- Shaping of distribution by acceptance cuts reduces discriminating power

Spin Test: $H \to \gamma\gamma$





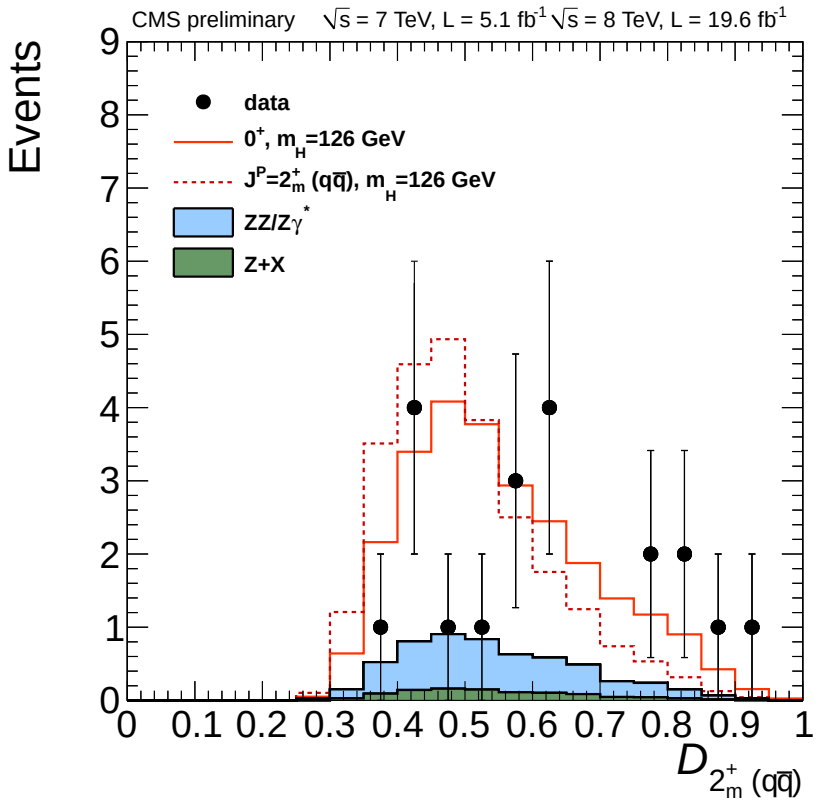
- No significant discrimination yet

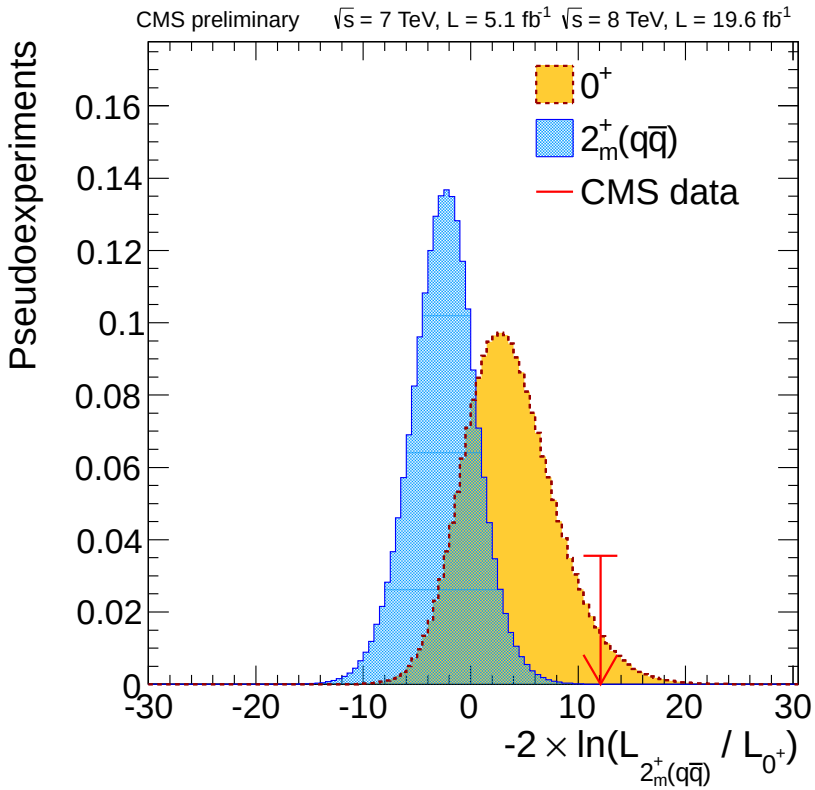
Conclusions

- Preliminary results on combined Higgs couplings and mass with full 7 TeV and 8 TeV dataset for the most important channels
- Observed Higgs properties are broadly consistent with the Standard Model predictions within the present uncertainties
- Some additional channels, plus final papers still to come
- Additional data post-LS1 very exciting as the precision of these results will increase...

Backup

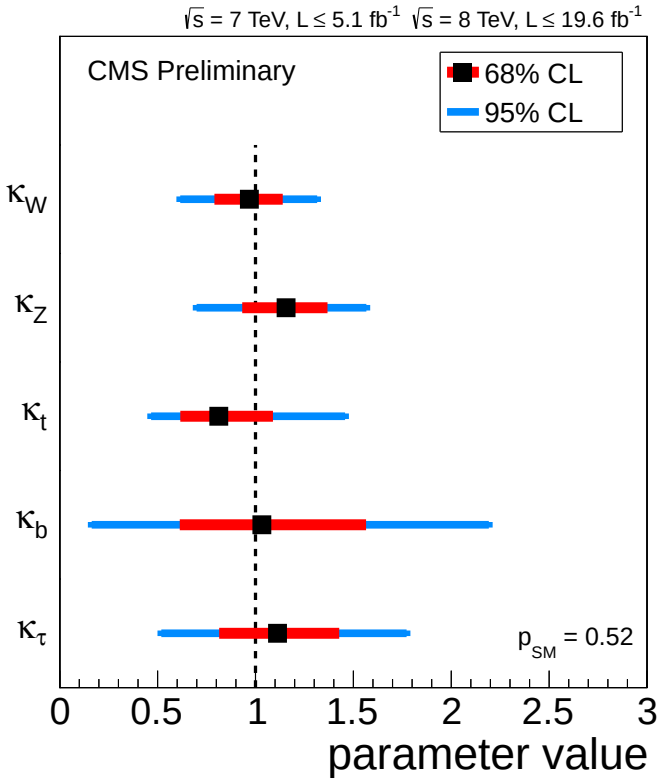
Backup: $H \to ZZ \to 4\ell$: Spin Test (qq production)

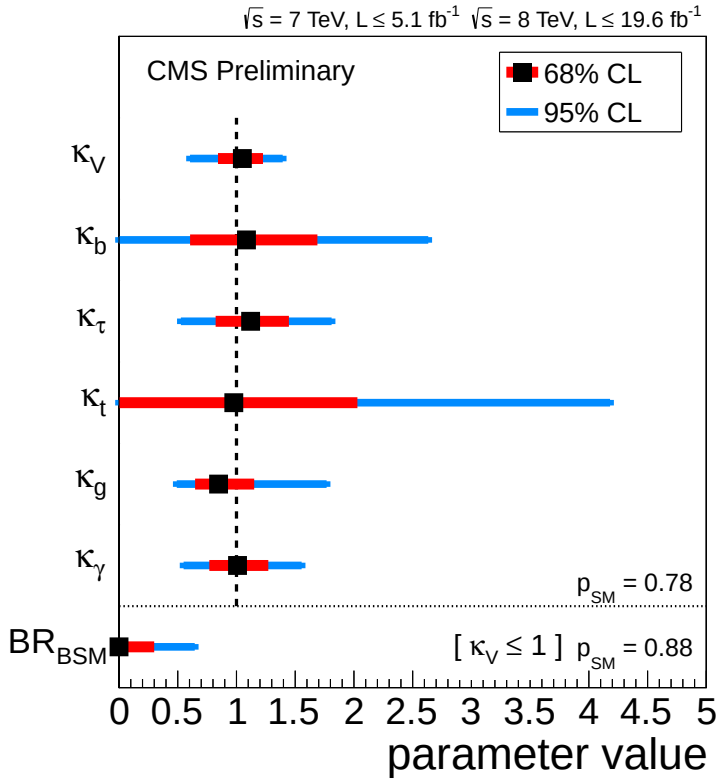




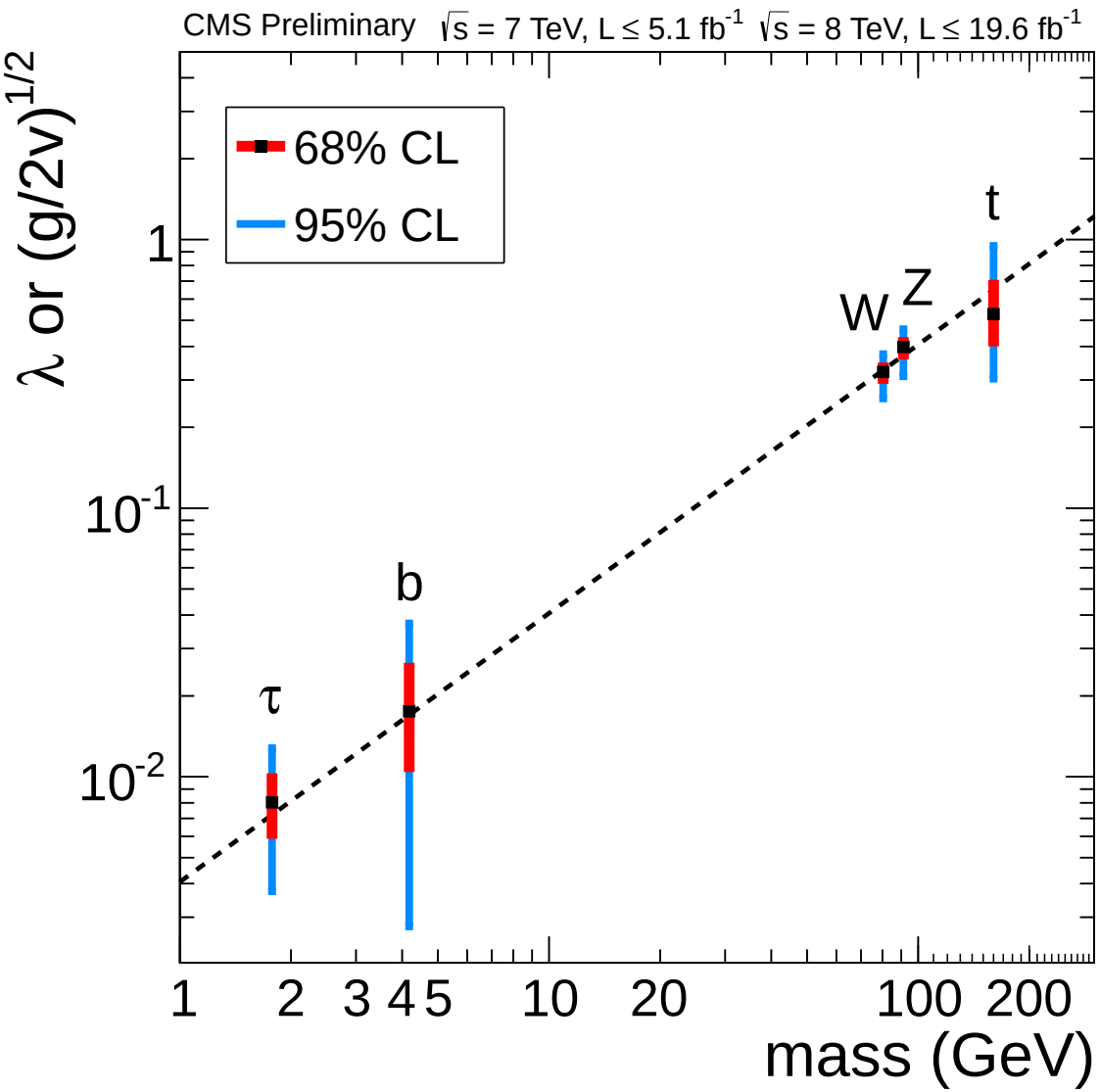
- 2^+_m (pure quark-quark production) hypothesis excluded at 4.0 σ (1.9 σ expected for $\mu = 1$)

Backup: Full Couplings Fits

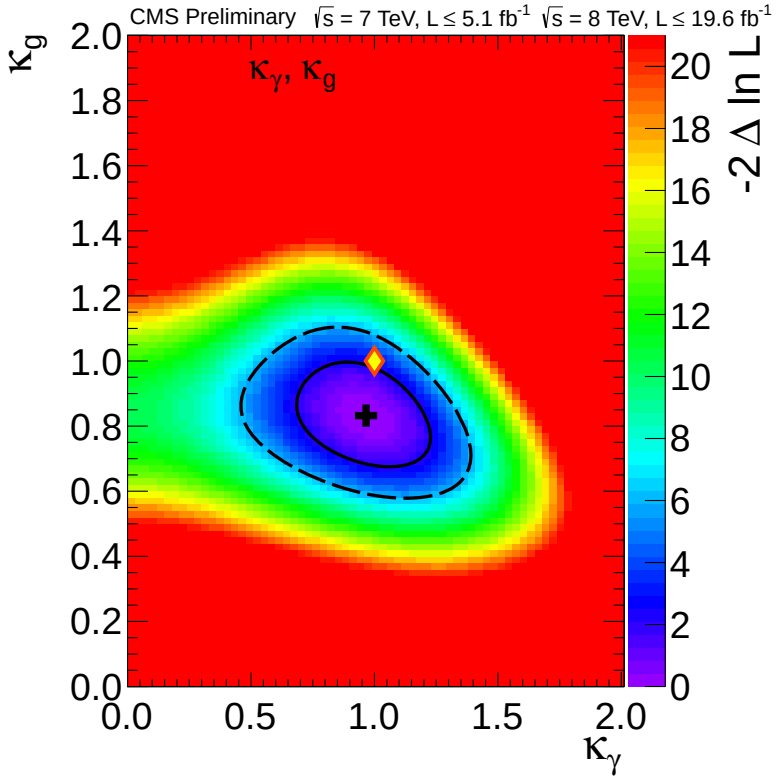


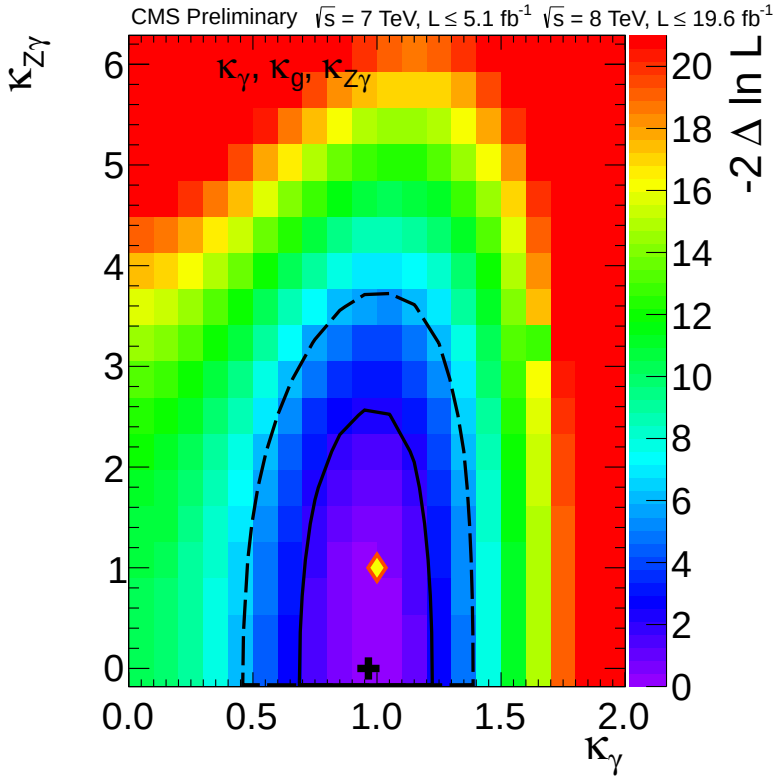


Backup: Couplings Summary

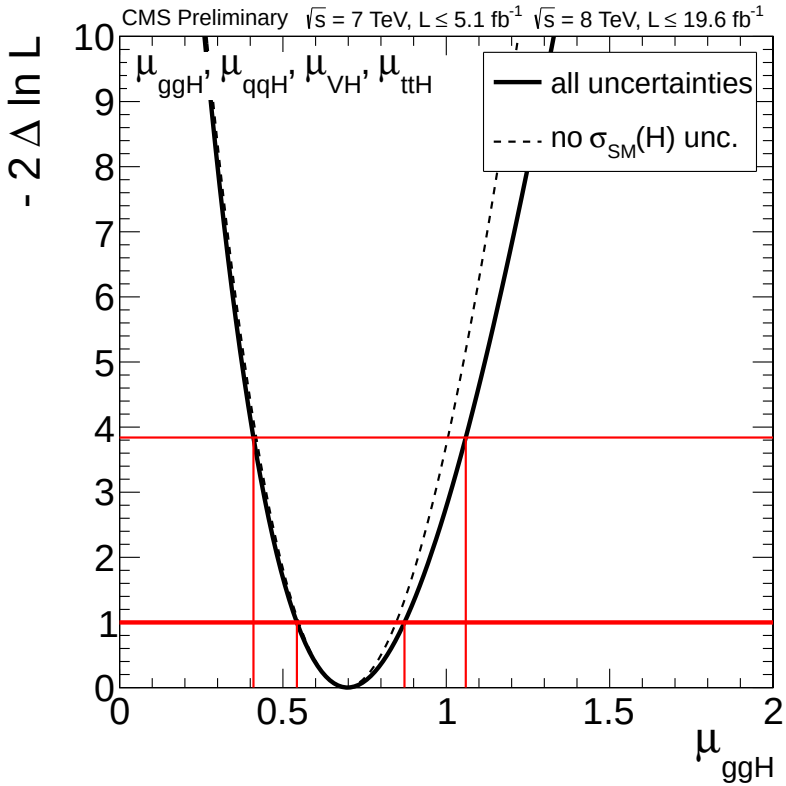


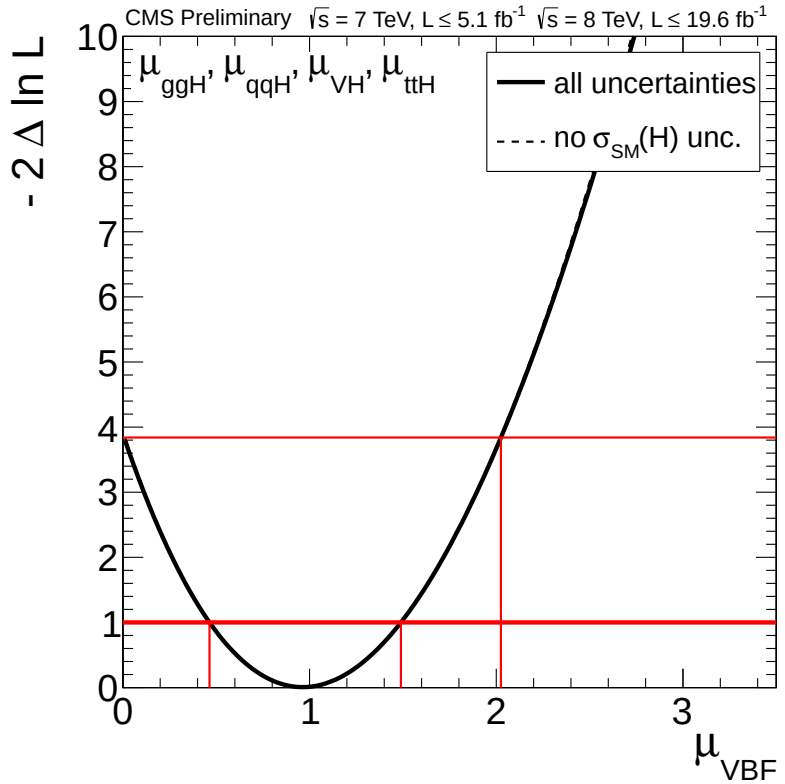
Backup: Loop Effective Couplings





Backup: Production Cross Sections





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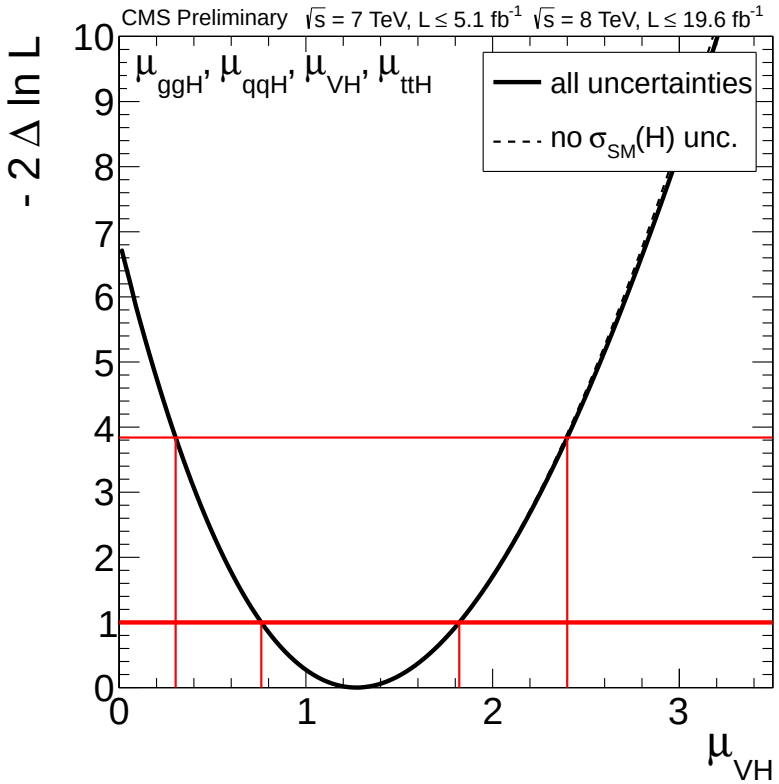
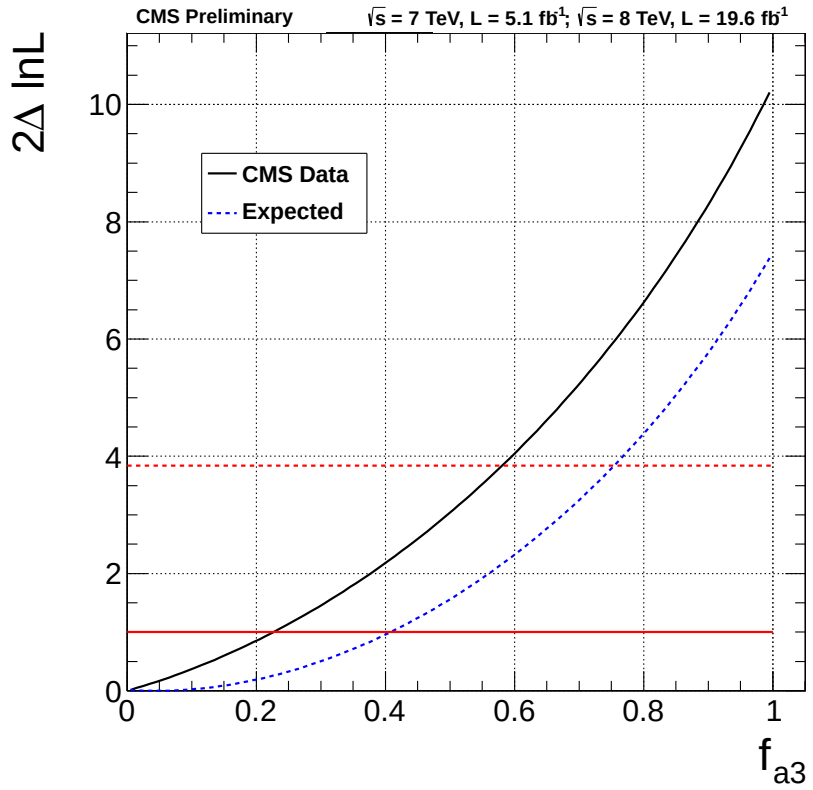


Backup: $H \to ZZ \to 4\ell$: Pseudoscalar Component



- Pseudoscalar component < 0.58 at 95% C.L.