

Measuring the sign of the Htt coupling at the LHC

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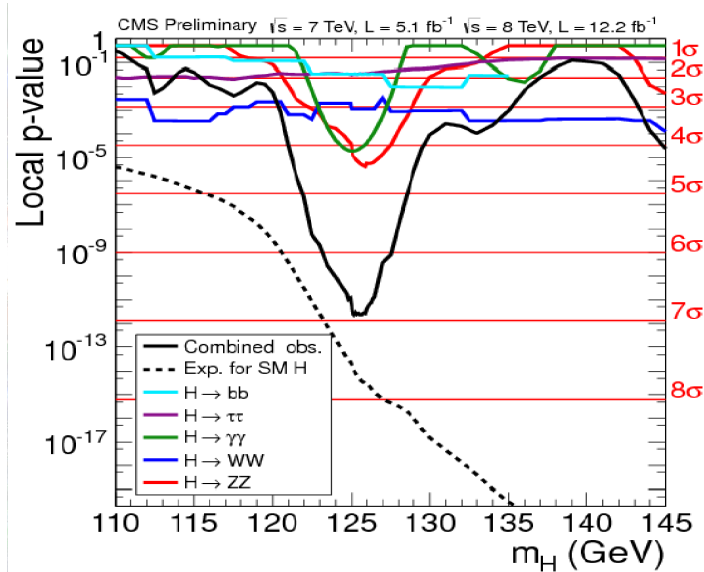
CERN 21-Feb 2013

Where are we ?

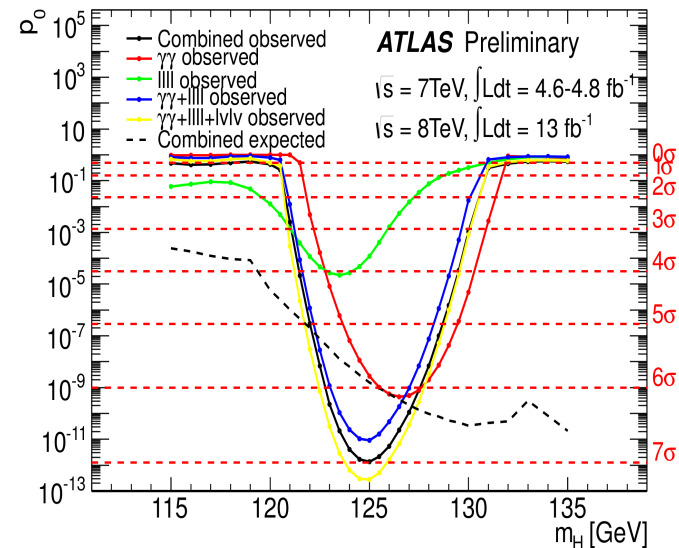
■ a new particle (resonance) has been discovered → consistent with the long-awaited **SM Higgs boson**

■ **fully confirmed in all its most sensitive channels**

CMS $m_H = 125.8 \pm 0.4(\text{stat}) \pm 0.4(\text{syst}) \text{ GeV}$



ATLAS $m_H = 126 \text{ GeV} \pm 0.4(\text{stat}) \pm 0.4(\text{syst}) \text{ GeV}$



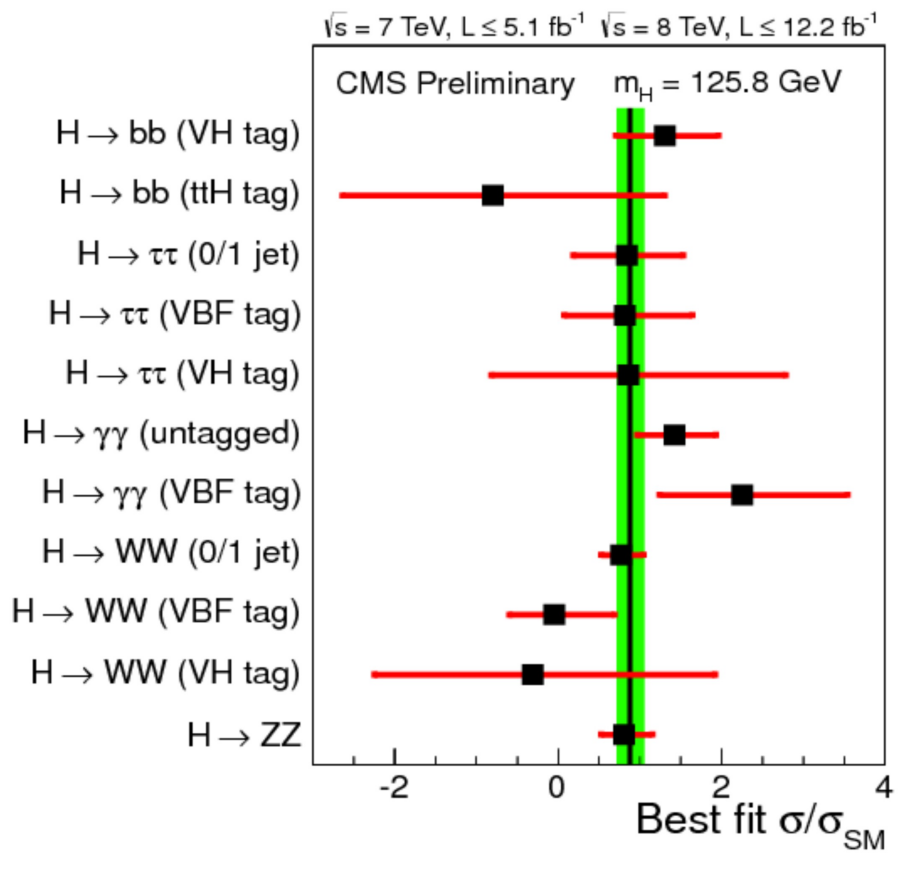
■ Local probability p for a bckg-only experiment to be more signal like than the observation versus M_H

■ **Significance:** ATLAS local 7.0 global 5.9 → in 122-131 GeV ($p = 1.7 \times 10^{-9}$)
 CMS local 6.9

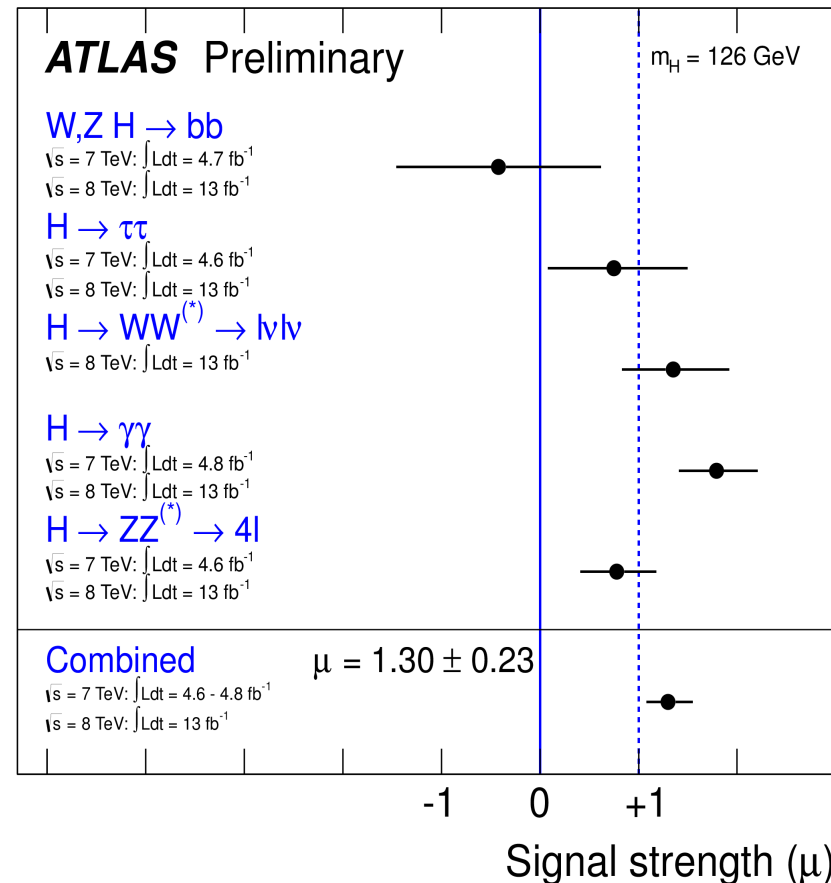
■ $H \rightarrow \gamma\gamma$ rules out spin-1. While spin-0 and spin-2 viable

Compatibility with SM Higgs hypothesis

CMS-HIG-12-045



ATLAS-CONF-2012-170



■ overall signal strength normalized to SM

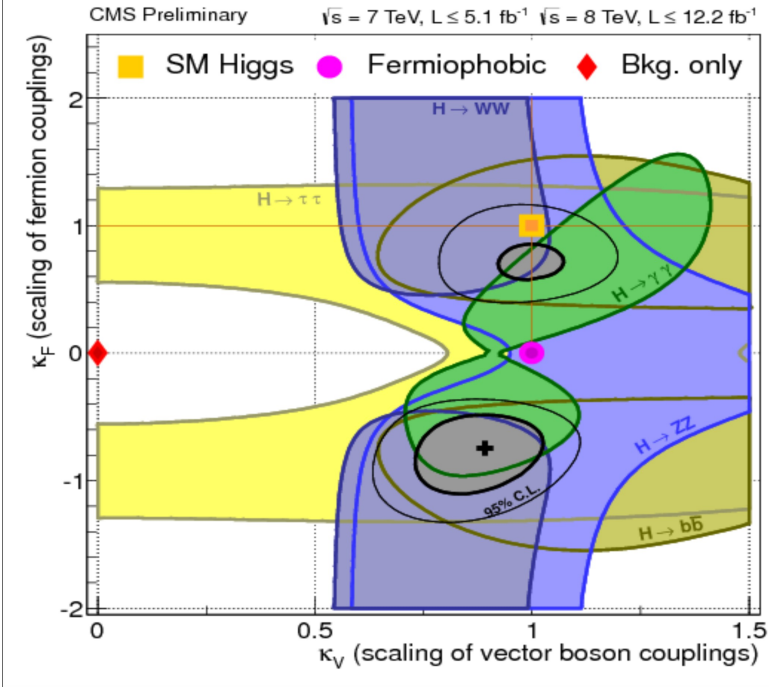
CMS = 0.88 ± 0.21 ATLAS = 1.4 ± 0.23

■ di-photon rate enhancement is more pronounced in VBF

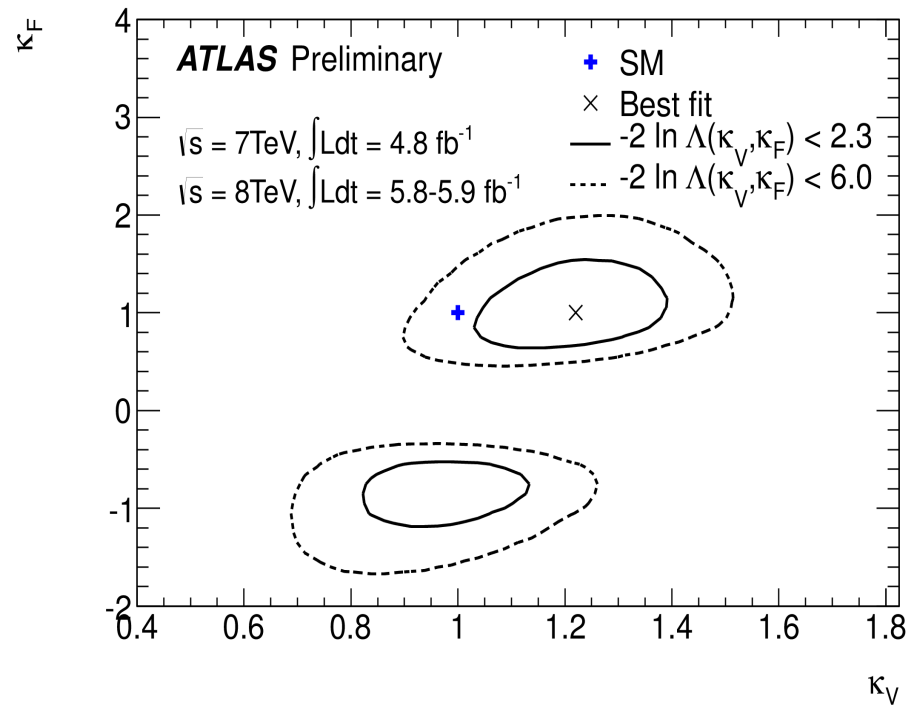
Combination of couplings

Assuming K_F scaling of all fermion couplings and K_V scaling of all vector boson couplings

CMS-HIG-12-045



ATLAS CONF-2012-127

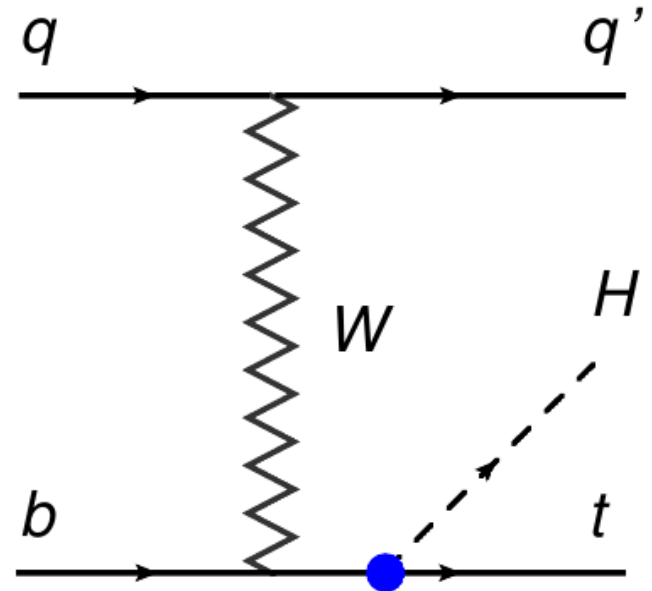
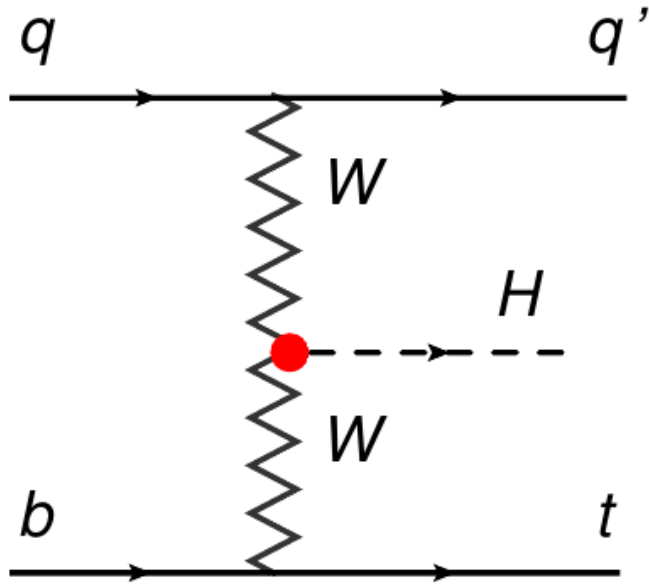


● positive Yukawa $\rightarrow$ SM solution is out of 1σ region

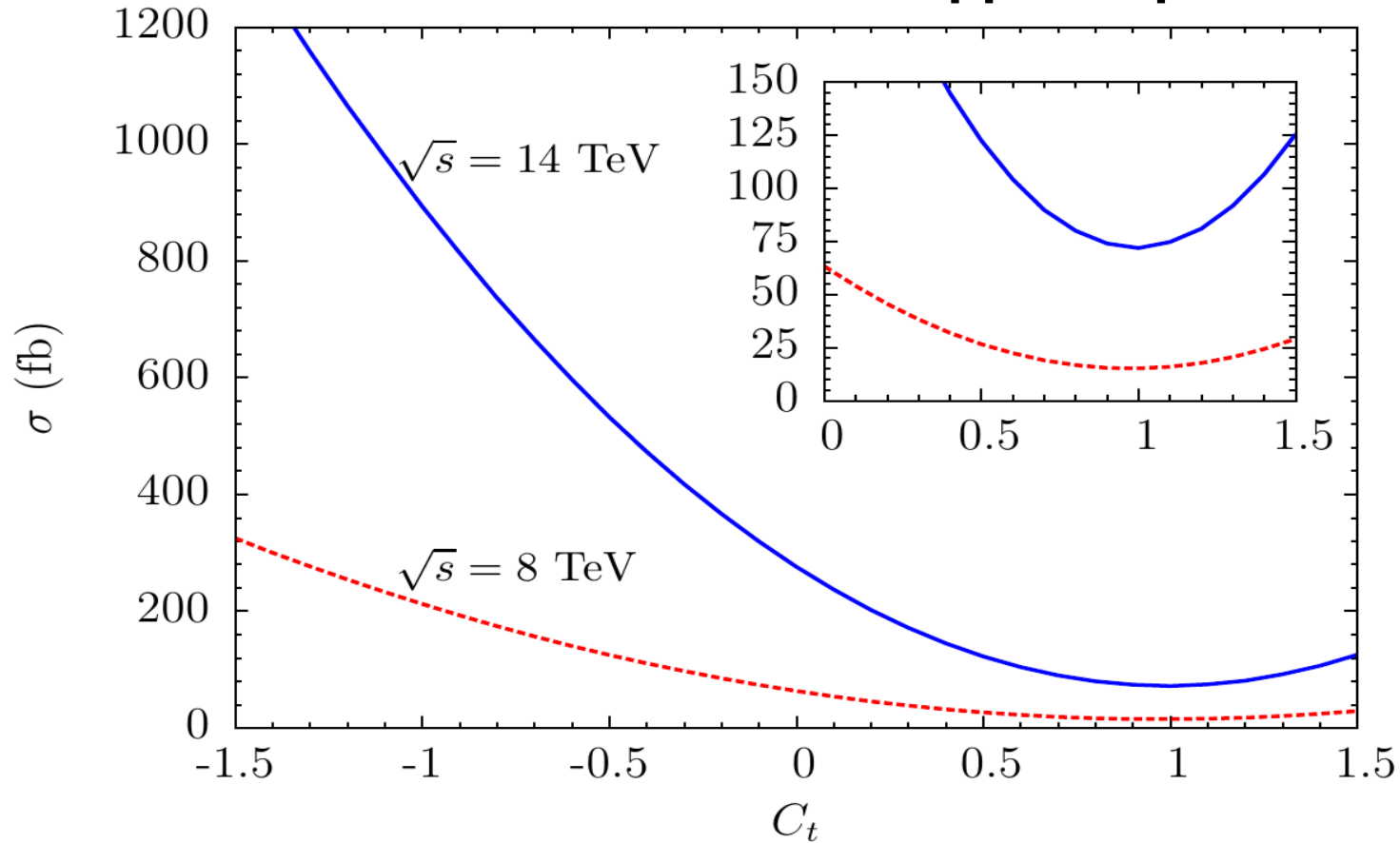
● negative Yukawa $\rightarrow$ far from SM solution
 $\rightarrow$ dramatic implications for EWSB

Leading partonic contribution to $pp \rightarrow Htq$

$qb \rightarrow q' H t$



Production cross section for $pp \rightarrow t q H$ versus C_t



SM total $\sigma \times \text{BR}(\gamma\gamma)$ is small

$$\begin{aligned} \sigma(q b \rightarrow t q' H)^{SM} &\simeq 15.2 \text{ fb} & \text{at } \sqrt{s} = 8 \text{ TeV} \\ \sigma(q b \rightarrow t q' H)^{SM} &\simeq 71.8 \text{ fb} & \text{at } \sqrt{s} = 14 \text{ TeV} \end{aligned}$$

$$BR_{\gamma\gamma}^{SM} \simeq 2.29 \cdot 10^{-3}$$

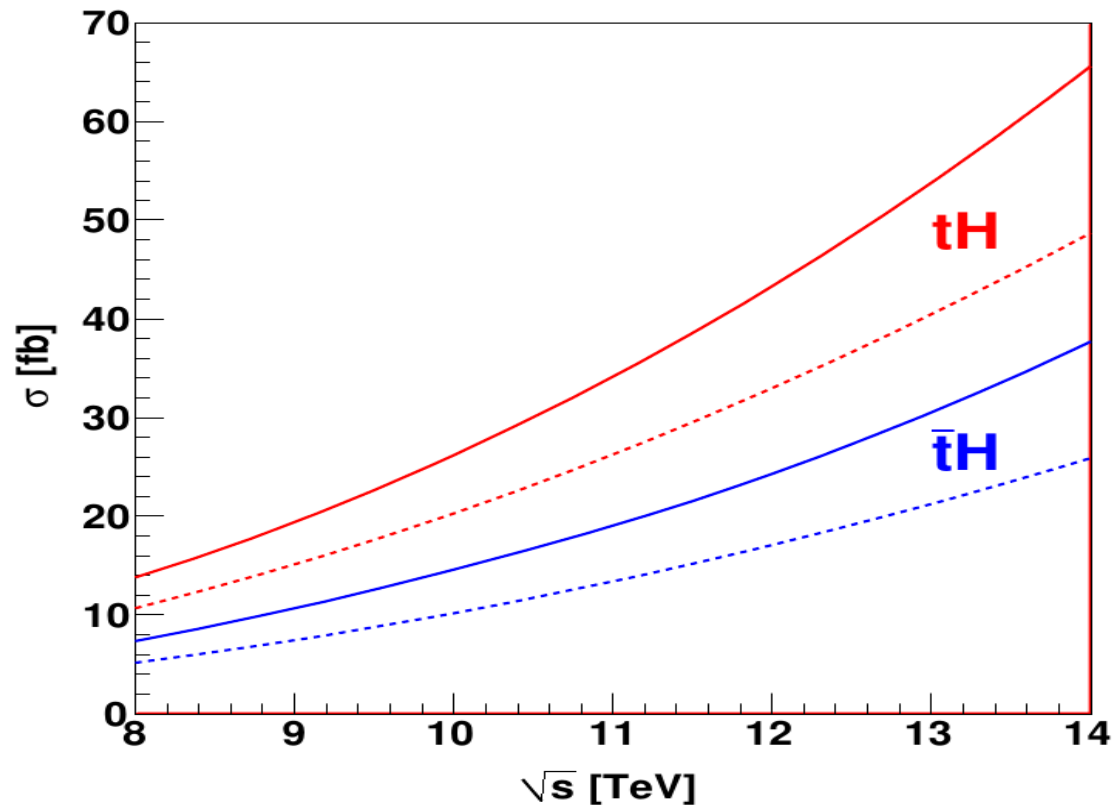
NLO corrections to single top production in association with a Higgs boson

NLO corrections of order of $O(40\%)$ larger than LO

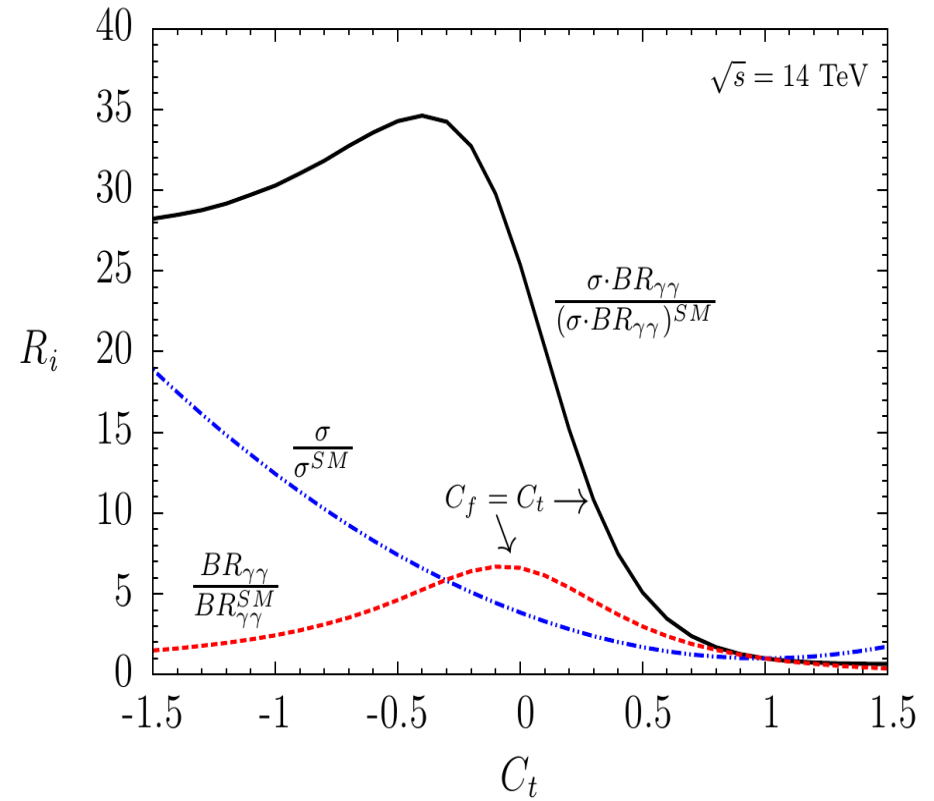
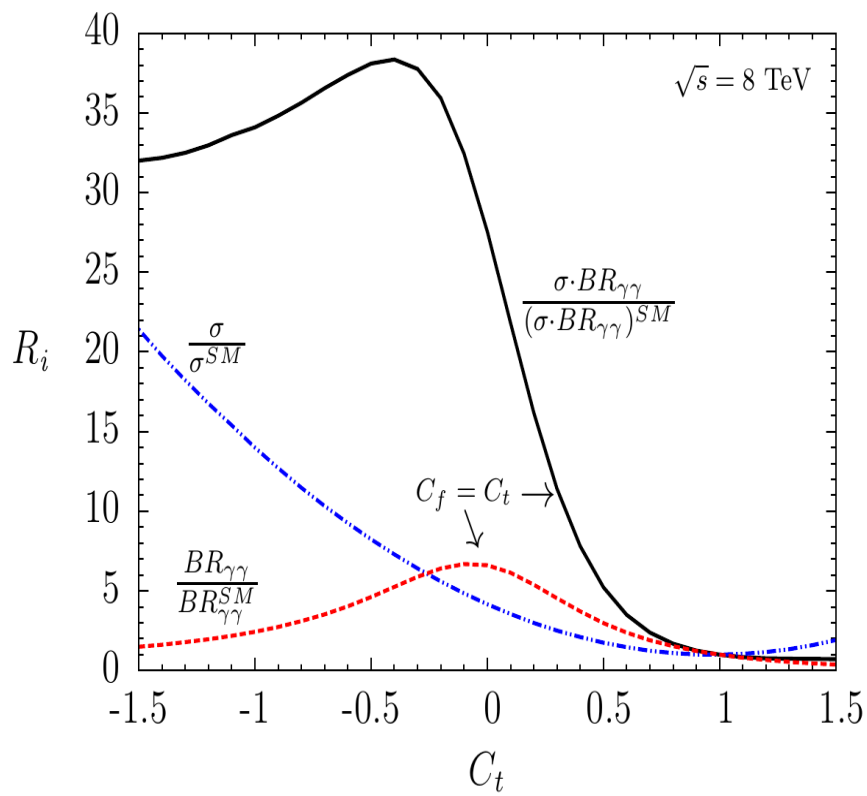
SM results ($C_t=1$), $M_H = 126$ GeV

J.Campbell, R.K.Ellis, R.Rontsch 1302.3856

dashed LO, continuous NLO



Under $C_t = C_v$ hypothesis $\rightarrow \sigma \times BR / (\sigma \times BR)^{SM}$ tends to a plateau when $|C_t| \gg 1$



Maximum achieved for $C_t = C_f \sim -0.5$

Signal versus irreducible background

Cuts on diphoton invariant mass are crucial

$\sqrt{s} = 8 \text{ TeV} (60 \text{ fb}^{-1})$	Signal (S)			Background (B)			
Cut	$C_t = -1$	$C_t = 0$	$C_t = 1$	$2\gamma + t + j$	$2\gamma + t\bar{t}$	$2\gamma + b + 3j$	B_{tot}
$2\gamma + b + (\geq 3j)$	7.7	6.1	0.21	9.8	11	299	320
$ \eta_j^F > 2.5 \ \& \ p_T^F > 30 \text{ GeV}$	3.7	3.0	0.09	4.0	0.46	26	31
$ M_{bjj} - m_t < 20 \text{ GeV}$	3.6	2.9	0.09	4.0	0.29	6.5	11
$ M_{jj(top)} - M_W < 15 \text{ GeV}$	3.4	2.8	0.08	3.8	0.23	2.1	6.1
$ M_{\gamma\gamma} - m_H < 3 \text{ GeV}$	3.4	2.8	0.08	0.14	0.02	0.68	0.84

Table 1: Number of events passing sequential cuts for the signal $pp \rightarrow tqH \rightarrow tq\gamma\gamma$ and irreducible SM backgrounds at $\sqrt{s} = 8 \text{ TeV}$, and integrated luminosity of 60 fb^{-1} , assuming $C_f = C_t$.

$\sqrt{s} = 14 \text{ TeV} (600 \text{ fb}^{-1})$	Signal (S)			Background (B)			
Cut	$C_t = -1$	$C_t = 0$	$C_t = 1$	$2\gamma + t + j$	$2\gamma + t\bar{t}$	$2\gamma + b + 3j$	B_{tot}
$2\gamma + b + (\geq 3j)$	311	249	8.9	407	396	12079	12881
$ \eta_j^F > 2.5 \ \& \ p_T^F > 50 \text{ GeV}$	121	99	3.5	161	19	551	731
$ M_{bjj} - m_t < 20 \text{ GeV}$	118	97	3.5	161	11	136	308
$ M_{jj(top)} - M_W < 15 \text{ GeV}$	112	92	3.3	154	8.3	43	205
$ M_{\gamma\gamma} - m_H < 3 \text{ GeV}$	112	92	3.3	7.2	0.28	14	22

Table 2: Number of events passing sequential cuts for the signal $pp \rightarrow tqH \rightarrow tq\gamma\gamma$ and irreducible SM backgrounds at $\sqrt{s} = 14 \text{ TeV}$, and integrated luminosity of 600 fb^{-1} , assuming $C_f = C_t$.

Significance versus C_t

Max effect

SM

$\sqrt{s} = 14 \text{ TeV (600 fb}^{-1}\text{)}$	$C_t = -1.5$	$C_t = -1.$	$C_t = -0.5$	$C_t = 0$	$C_t = 0.5$	$C_t = 1.$	$C_t = 1.5$
$S [2\gamma + b + (\geq 3j)]_{tag}$	287	311	338	249	47	8.9	6.6
$S [passing cuts]$	104	112	122	92	17	3.3	2.2
$S/\sqrt{S+B}$	9.3	9.7	10.	8.6	2.7	0.67	0.45

$\sqrt{s} = 14 \text{ TeV (60 fb}^{-1}\text{)}$	$C_t = -1.5$	$C_t = -1.$	$C_t = -0.5$	$C_t = 0$	$C_t = 0.5$	$C_t = 1.$	$C_t = 1.5$
$S [2\gamma + b + (\geq 3j)]_{tag}$	29	31	34	25	4.7	0.89	0.66
$S [passing cuts]$	10	11	12	9.2	1.7	0.33	0.22
$S/\sqrt{S+B}$	2.9	3.1	3.2	2.7	0.86	0.21	0.14

$\sqrt{s} = 8 \text{ TeV (60 fb}^{-1}\text{)}$	$C_t = -1.5$	$C_t = -1.$	$C_t = -0.5$	$C_t = 0$	$C_t = 0.5$	$C_t = 1.$	$C_t = 1.5$
$S [2\gamma + b + (\geq 3j)]_{tag}$	7.4	7.7	8.7	6.1	1.1	0.21	0.16
$S [passing cuts]$	3.2	3.4	3.8	2.75	0.52	0.08	0.06
$S/\sqrt{S+B}$	1.6	1.7	1.8	1.5	0.45	0.08	0.06

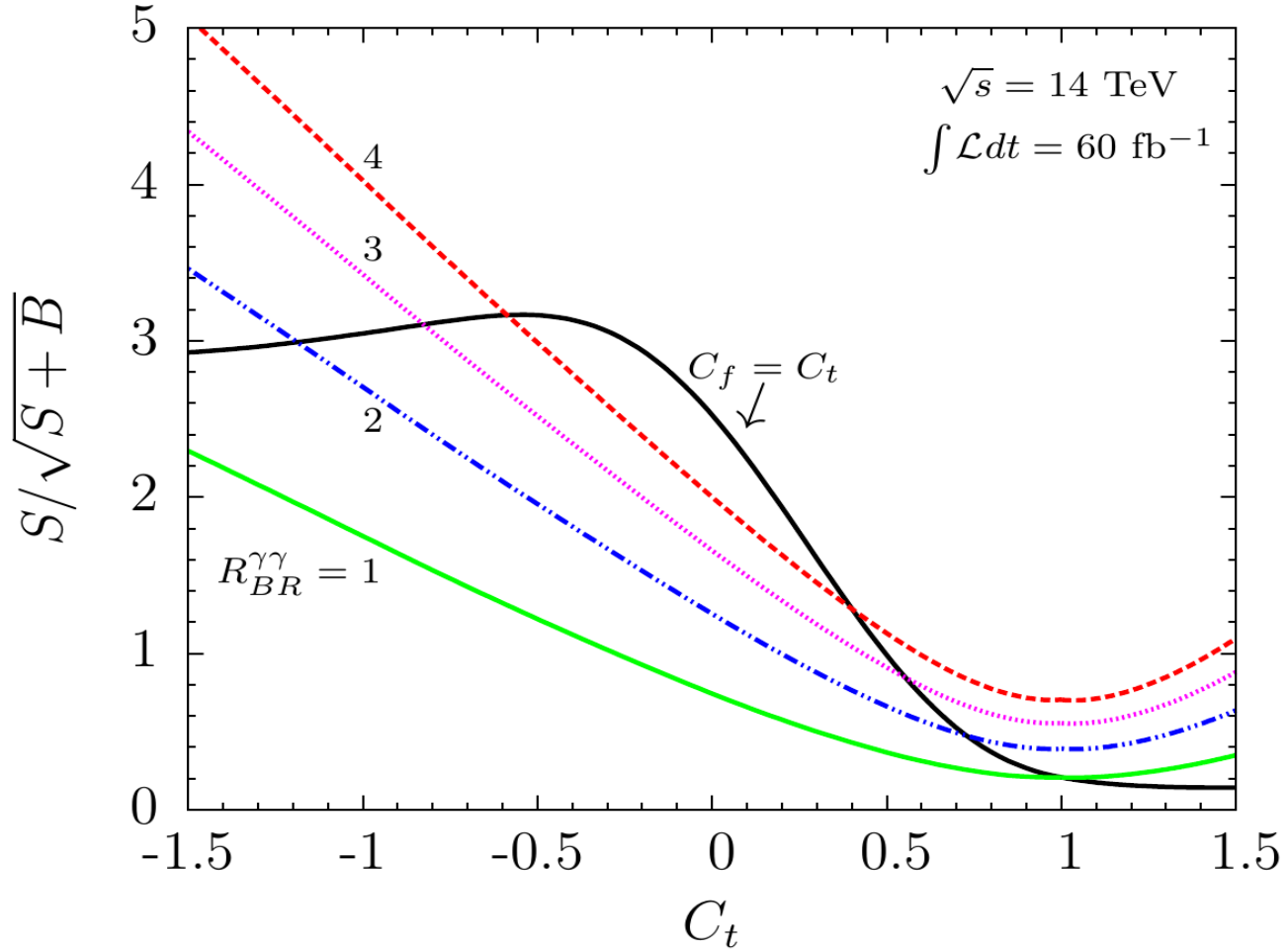


Figure 6: *Signal significance versus C_t . Different assumptions are made for the value of $R_{BR}^{\gamma\gamma} = BR_{\gamma\gamma} / BR_{\gamma\gamma}^{SM}$. The black solid line represents the Yukawa universal-rescaling hypothesis, where $R_{BR}^{\gamma\gamma}$ is just a function of C_t , with $C_b = C_\tau = C_t$. The remaining (colored) lines refer to the constant $R_{BR}^{\gamma\gamma} = 1, 2, 3, 4$ hypothesis.*

Conclusions

- We analyzed the t-channel $pp \rightarrow t \bar{q} H \rightarrow t \bar{q} \gamma\gamma$ potential for determining the relative sign of $t\bar{t}H$ and WWH couplings
- Parton level analysis of $H \rightarrow \gamma\gamma$ signal for the $pp \rightarrow t \bar{q} H$ channel
- only irreducible backgrounds considered
- quite conservative set of selection cuts on kinematics applied

Main results

- If $C_f = C_t < 0$, first running of LHC @ 14 TeV is sufficient to have considerable number of events with moderate bckg
- $L = 60 \text{ fb}^{-1}$ @ 14 TeV $\rightarrow$ 10 signal events expected with less than 0.3 of bckg
- SM would require HL-LHC luminosity to see significant number of events
- **News:** including other decay channels it is possible to reach a significant sensitivity on the negative sign already with present luminosity @ 8 TeV (Biswas, Margaroli, Mele in preparation)
- If negative sign of Yukawa top will be confirmed $\rightarrow$ dramatic implications for ChSB and EWSB mechanisms