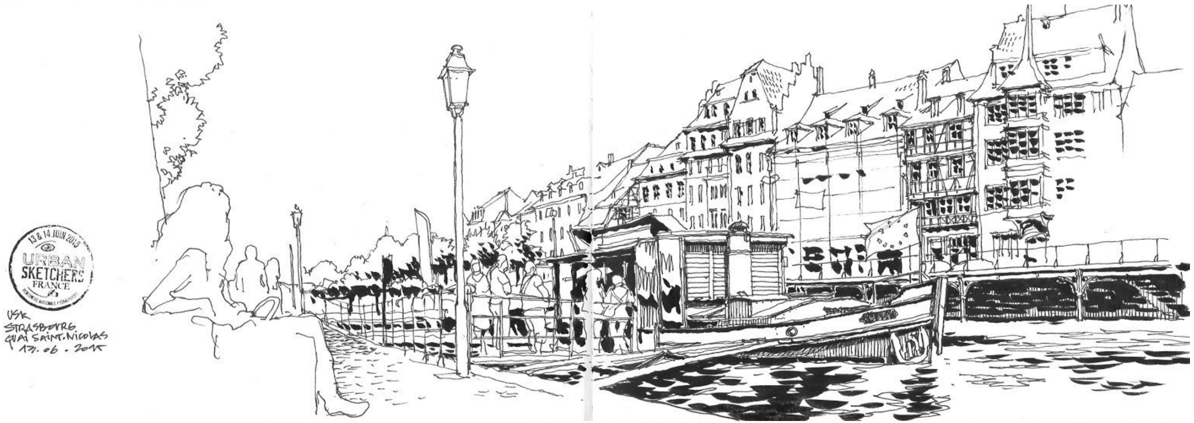


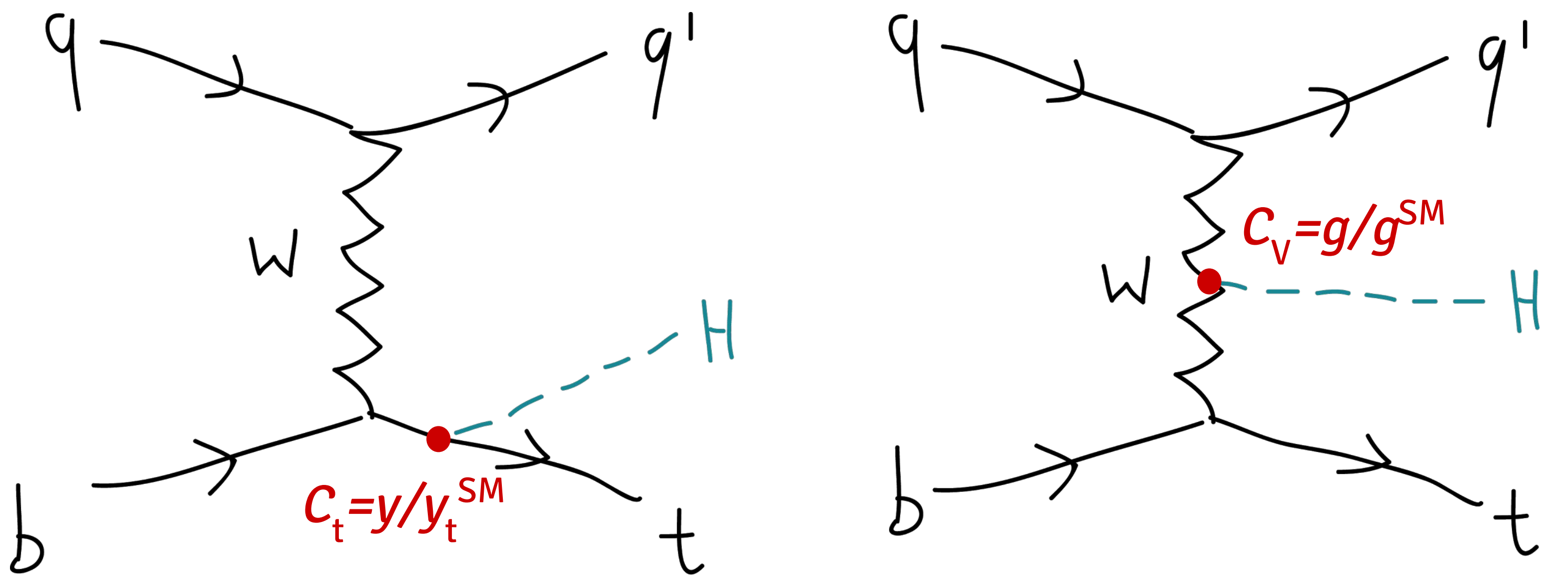
single top + higgs. experimental results

… with a short theoretical introduction

Benedikt Maier, MIT

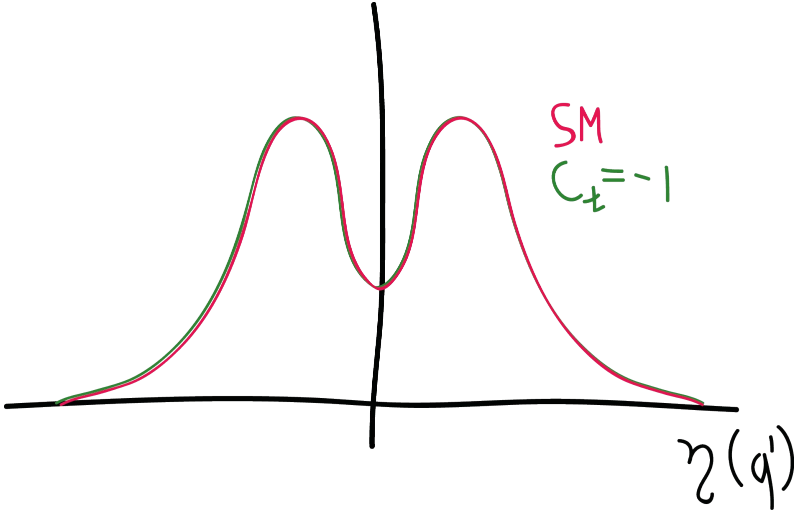
3rd CMS single top workshop, June ‘16

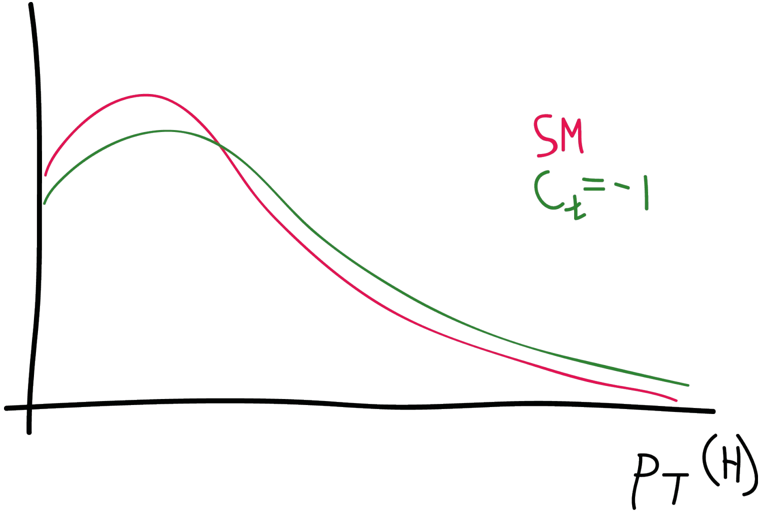
introduction



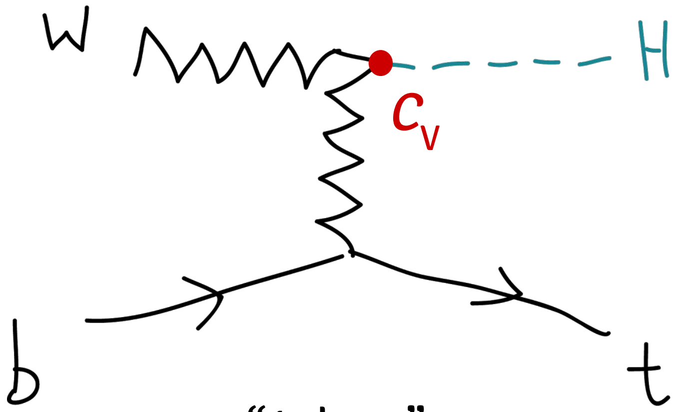
$$A \sim (c_V - c_t)\sqrt{s} + \text{other terms}$$

understanding the interference

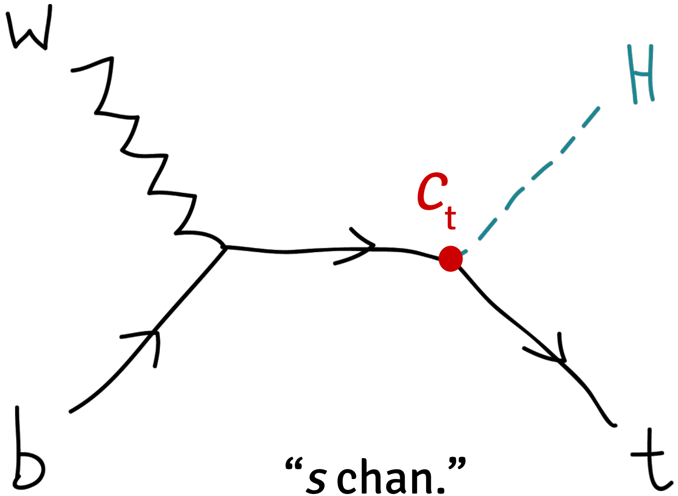




effective W approximation



"*t* chan."



"*s* chan."

$$\sigma \sim c_V^{\,2} + c_t^{\,2} - 2c_V c_t$$ + other terms

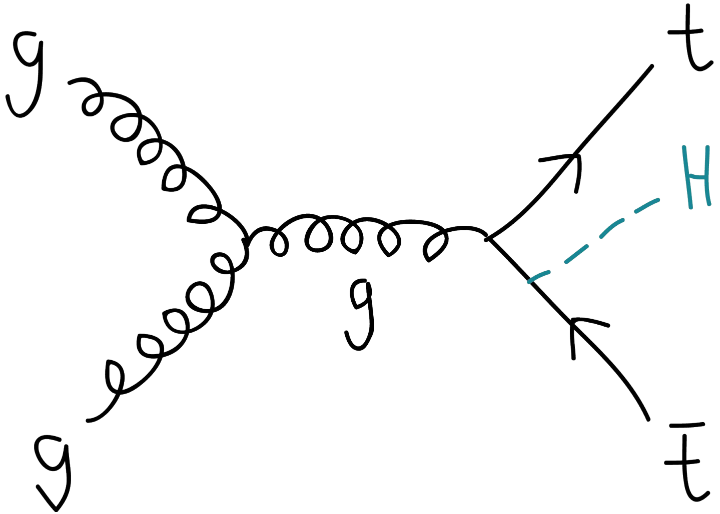
SM: $c_t = c_V \rightarrow$ perfect cancellation, no hard component from c_t amplitudes survives

c_t=-1: $-2c_V c_t$ becomes $+2c_V c_t \rightarrow$ objects are relatively harder (because "more *s* channel")

this means ...

. th production is the only channel for which at LO the xsec AND kinematics change under C_t=+1 ↔-1

. this is NOT the case for ttH production



CMS and ATLAS ...

. address the question about C_t differently:

ATLAS: indirect searches in the context of ttH analyses

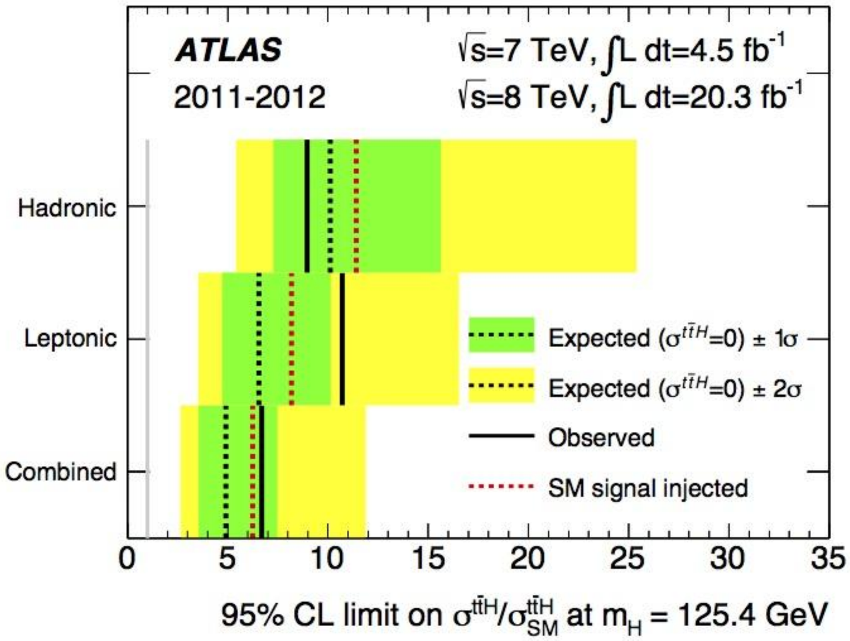
CMS: direct searches for anomalous coupling scenario

what ATLAS did

. utilize ttH, H→γγ search

. interpret upper limits on $\sigma^{ttH}/\sigma_{SM}^{ttH}$ in terms of κ_t

. include contribution of tH as background



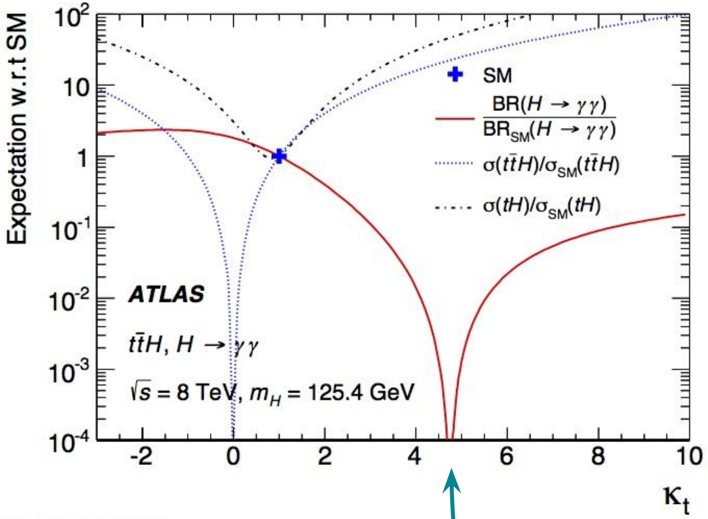
what ATLAS did

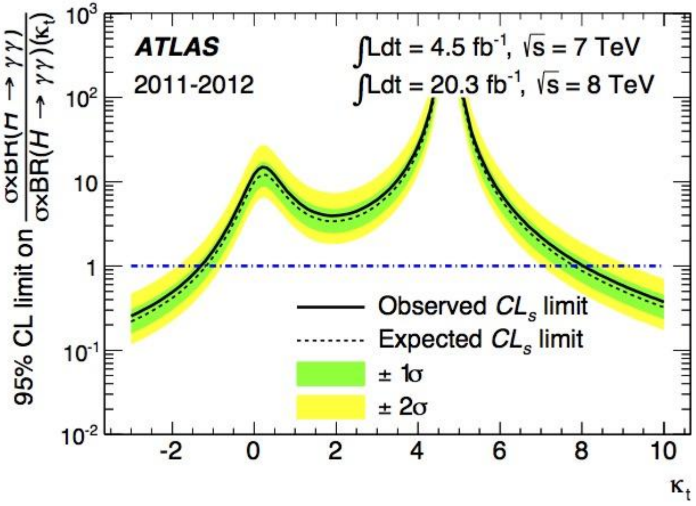
. scan over κ_t, leave other couplings as in SM

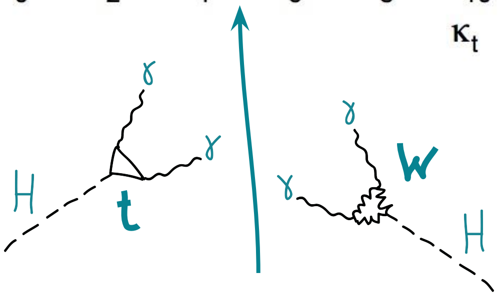
. null hypothesis: backgrounds + other SM Higgs

. obs. upper limit on κ_t
8.0

. obs. lower limit on κ_t
-1.3







perfect (accidental) cancellation for κ_t=4.7

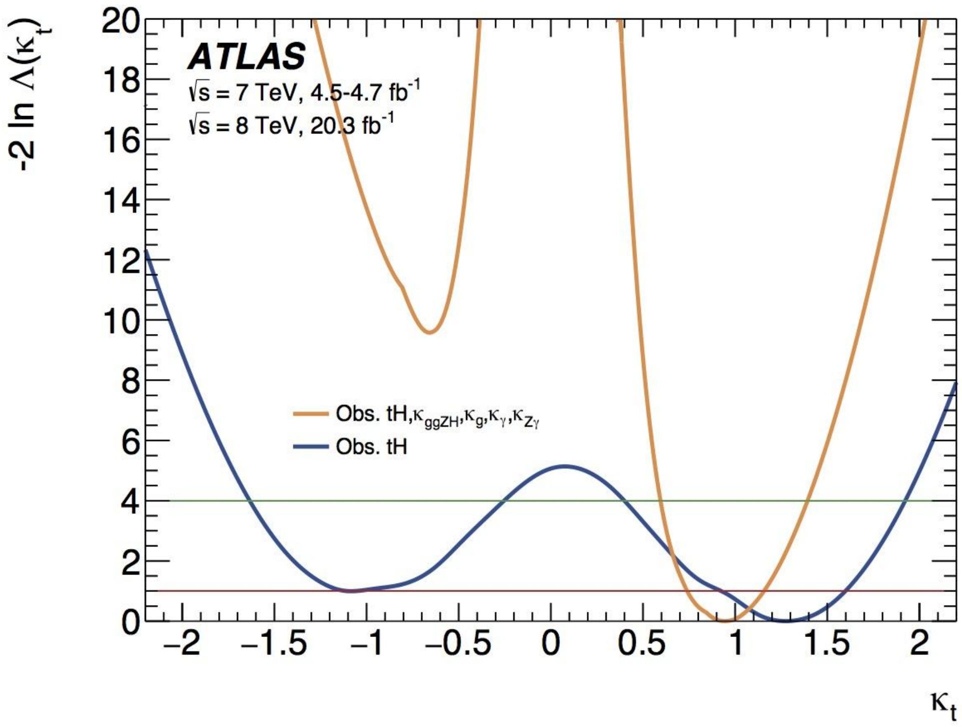
what ATLAS did

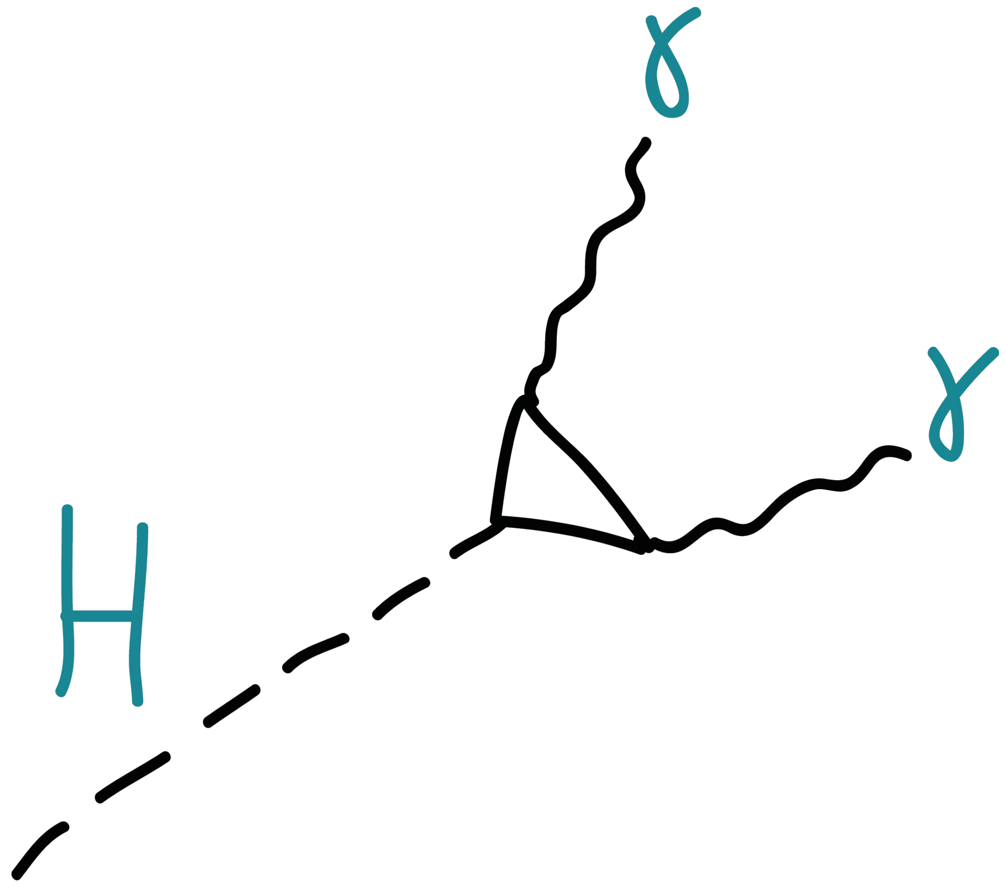
. global kappa fit to Run-I data

. if loops (ggF, ggZH, H to $\gamma\gamma$) can be fully resolved into SM particles, κ_t=-1 case greatly disfavored

. if loops described by effective couplings (parameters free in fit) → only sensitivity from LO tH

. disfavoring κ_t=-1 at 1σ (95% C.L.)




H
γ
γ

h to γγ

Main challenge: modelling the non-resonant bkg.

event selection

. higgs: 2 photons with p_T> 50 · $m_{\gamma\gamma}$/120 and 25 GeV

. top: 1 lepton with p_T> 10 GeV

1 b tagged jet with p_T> 20 GeV

No cut on E_T^{miss}

. recoil jet: hardest additional jet, must have p_T> 20 GeV and $|\eta|$ > 1

. selection efficiency for tHq: ~17%

process	yield
tHq (C_t=-1)	0.67
ttH (C_t=-1)	0.03 ± 0.05
VH	0.01 ± 0.01
(other	0)

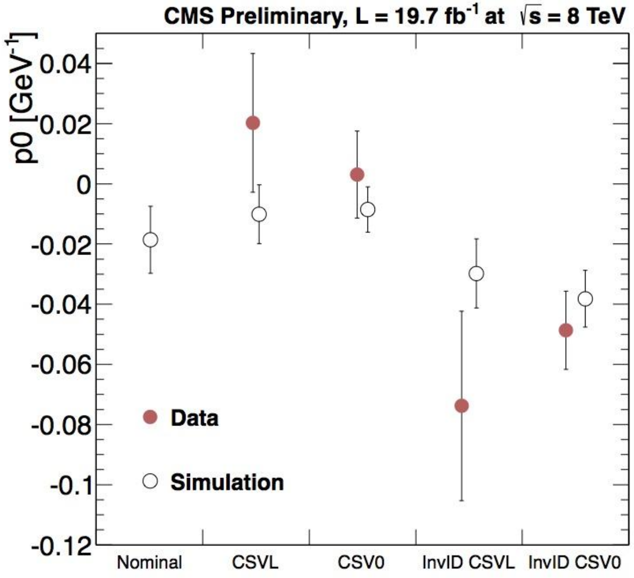
h to γγ

. employing 5-variables likelihood discriminant to suppress ttH background

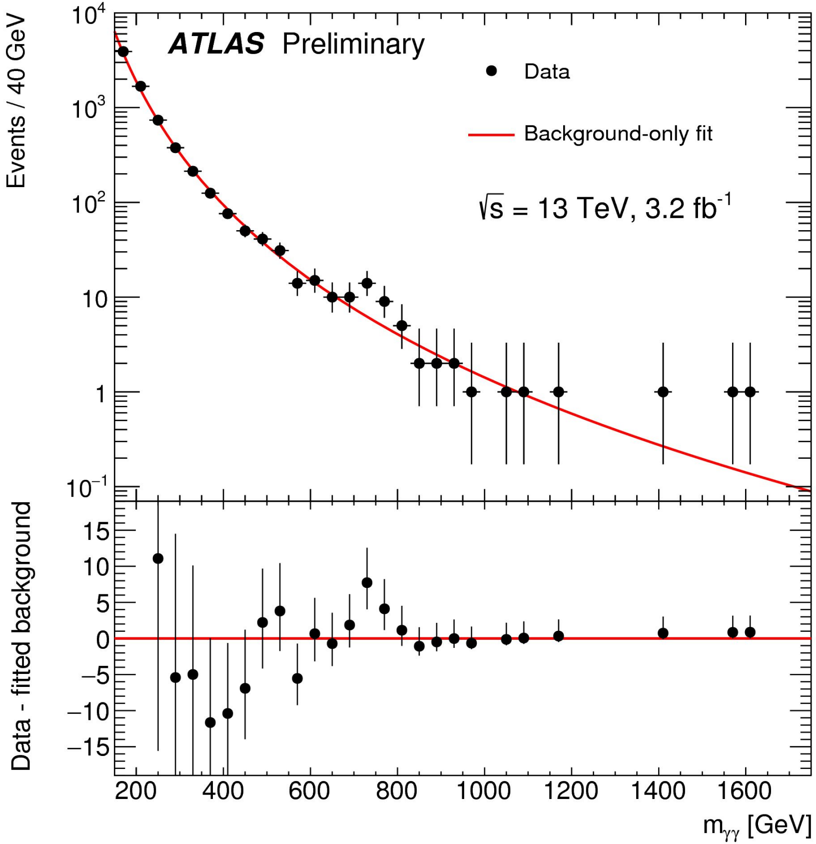
. lepton charge, jet multiplicity, ...

. cut on LD to keep ttH contamination < 10%

. shape of non-resonant backgrounds (mainly γγ+jets) derived from fit to $m_{\gamma\gamma}$ sidebands with inverted selection cuts



h to γγ


ATLAS Preliminary
Data
Background-only fit
$\sqrt{s}$ = 13 TeV, 3.2 fb^{-1}
Events / 40 GeV
Data - fitted background
$m_{\gamma\gamma}$ [GeV]

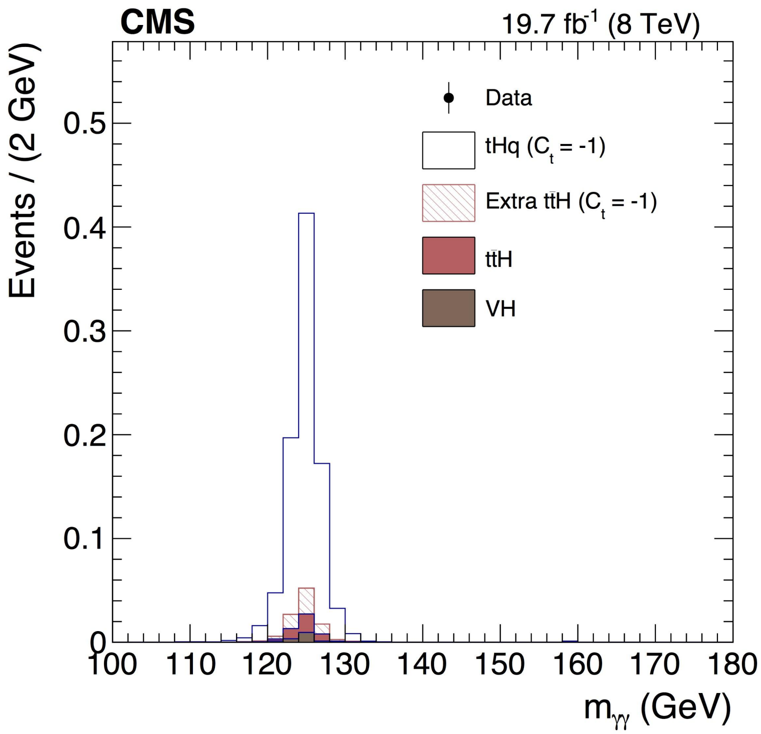
h to γγ

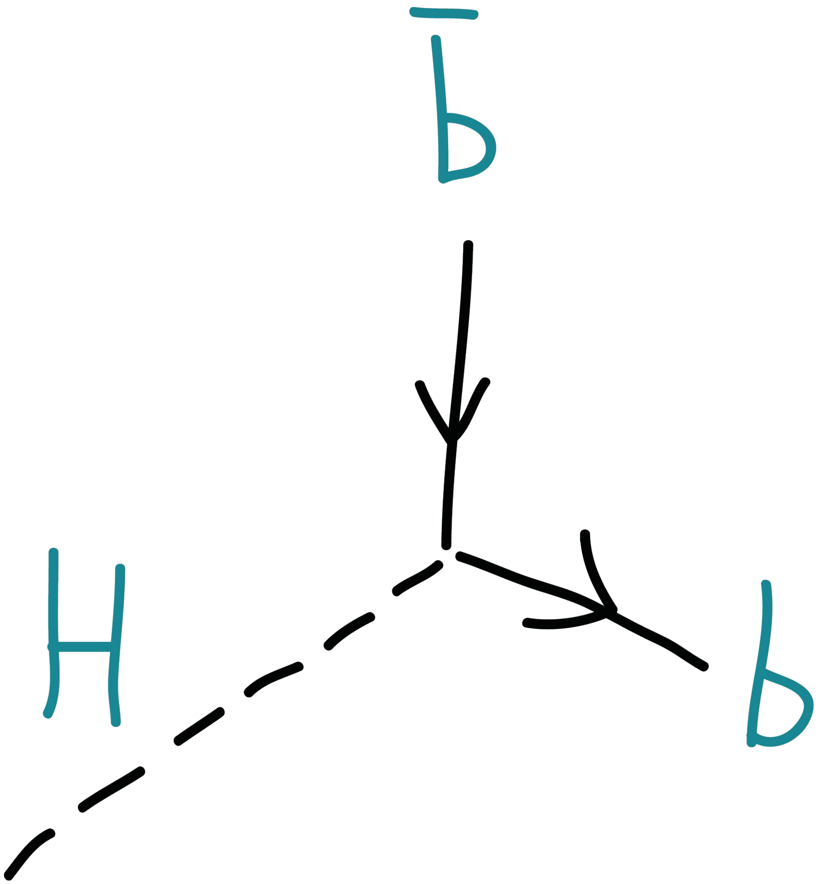
. zero events in sidebands

. zero events in signal region

. obs. limit = exp. Limit

$4.1 \times \sigma\ (C_t\text{=-}1)$




b̄
H
b

h to $b\bar{b}$

Main challenge:
controlling the ttbar
background

. largest branching fraction (58%)

. only feasible quark channel (other decays Yukawa suppressed)

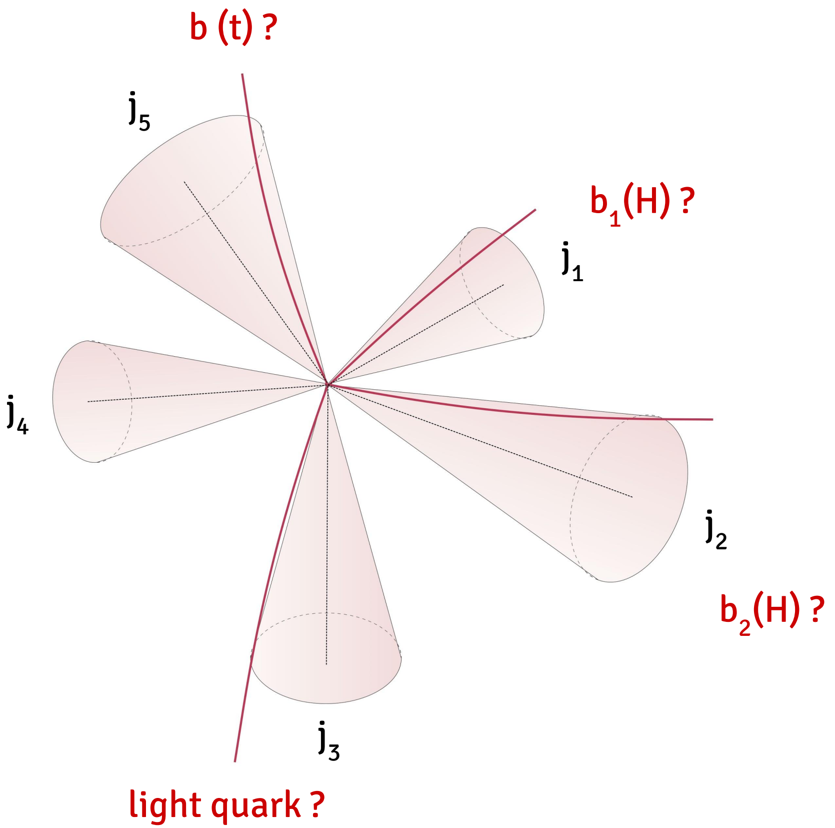
. huge ttbar background

. event selection:

- . one isolated lepton
- . MET > 35 / 45 GeV
- . 3 or 4 b tagged jets
- . at least one untagged jet

process	yield: 3tag	yield: 4tag
tHq (C_t=-1)	13	1.4
ttbar	1800	50
ttH	20	3.1
(other	80	11)

h to $b\bar{b}$



. many ways to match four quarks to reconstructed jets

. let MVA decide

. train correct vs. wrong assignments

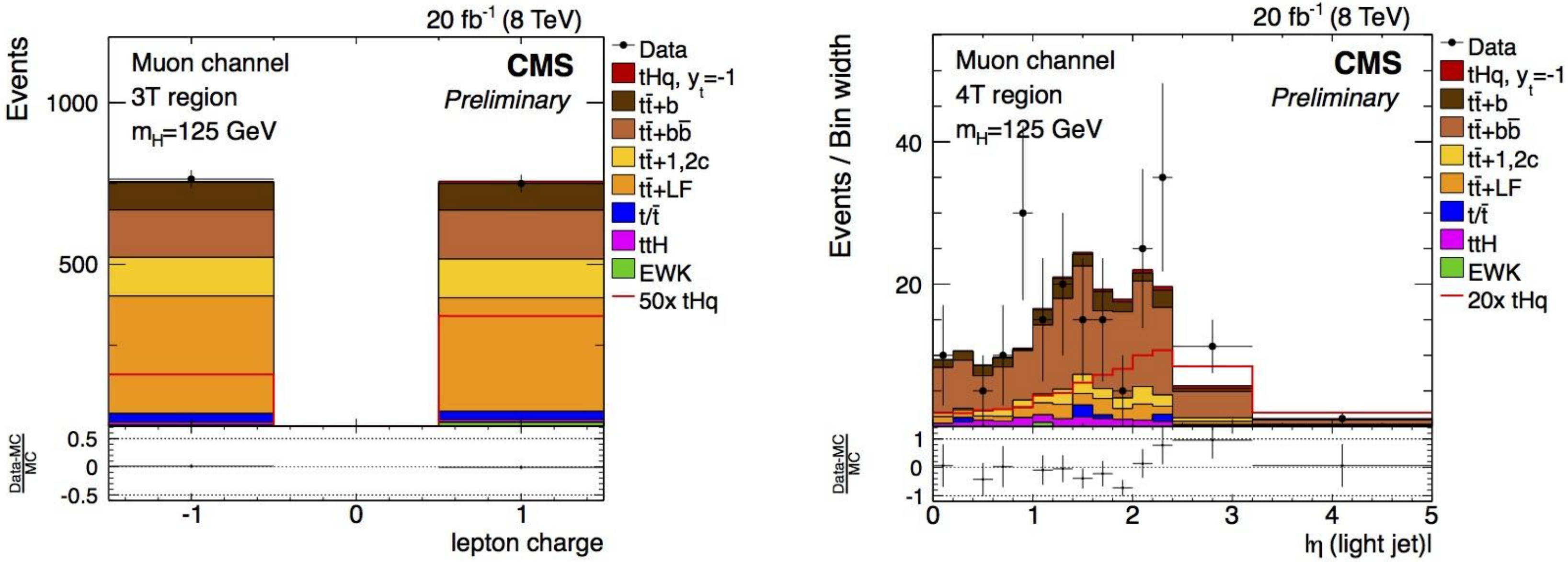
. correct: perfect match of quars/reco jets

. wrong: random other assignment

. application: pick interpretation yielding highest BDT score

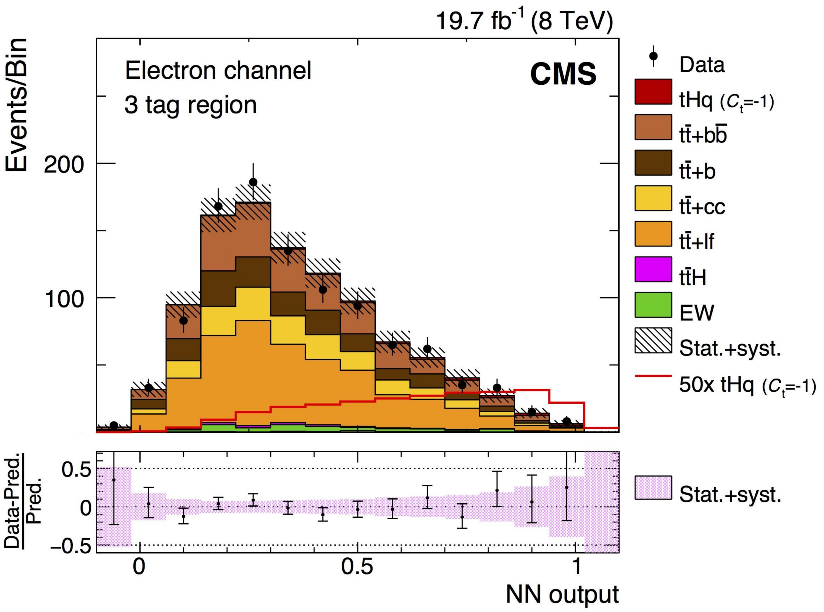
. then train tHq vs. background classification

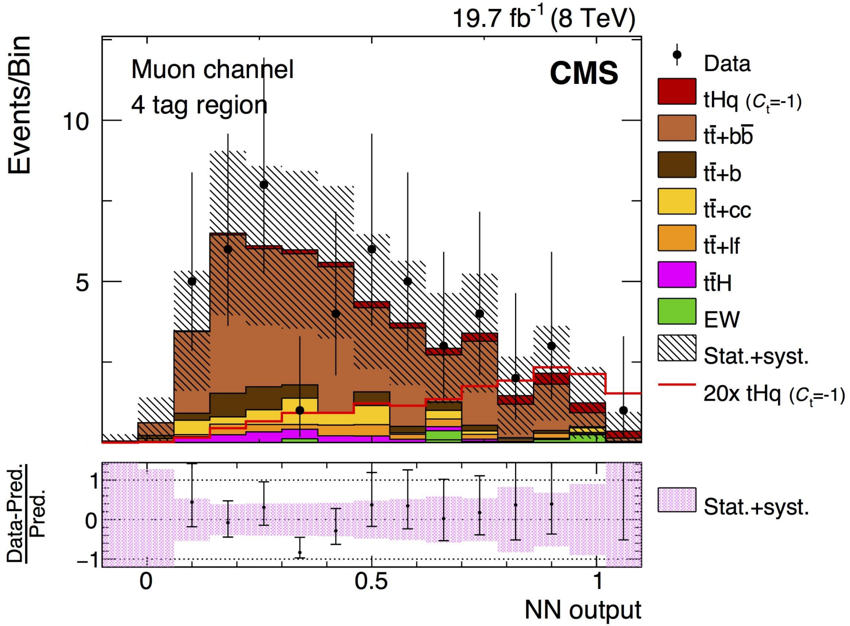
h to $b\bar{b}$



20 fb⁻¹ (8 TeV)
Muon channel
3T region
mH=125 GeV
CMS
Preliminary
Events
Data-MC / MC
lepton charge
Data
tHq, yt=-1
tt̄+b
tt̄+bb̄
tt̄+1,2c
tt̄+LF
t/t̄
ttH
EWK
50x tHq
20 fb⁻¹ (8 TeV)
Muon channel
4T region
mH=125 GeV
CMS
Preliminary
Events / Bin width
Data-MC / MC
|η (light jet)|
20x tHq

h to $b\bar{b}$





. obs. limit

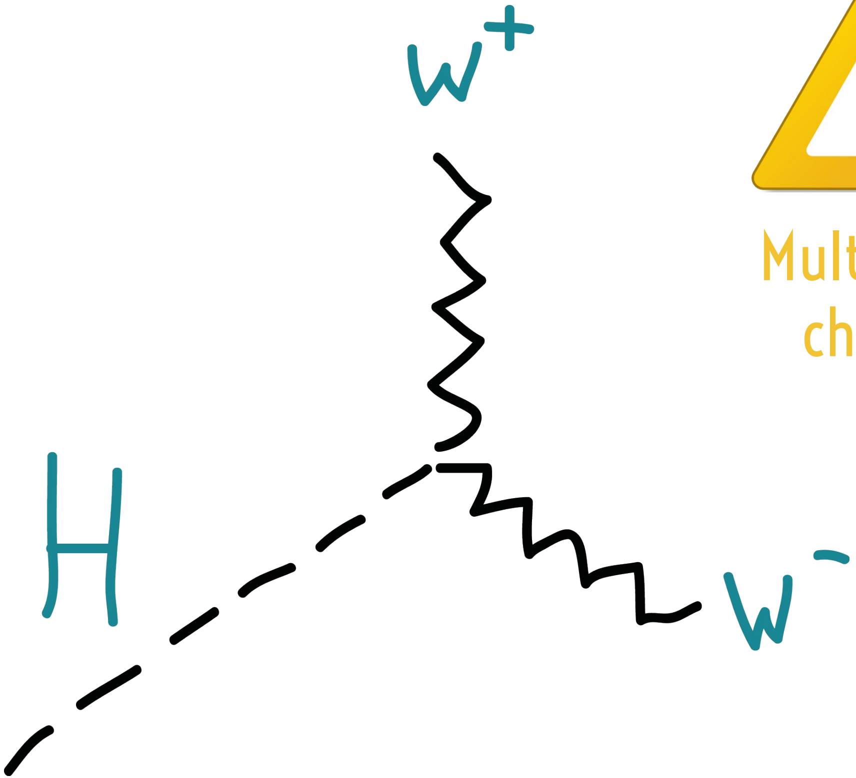
$7.6 \times \sigma$ (C_t=-1)

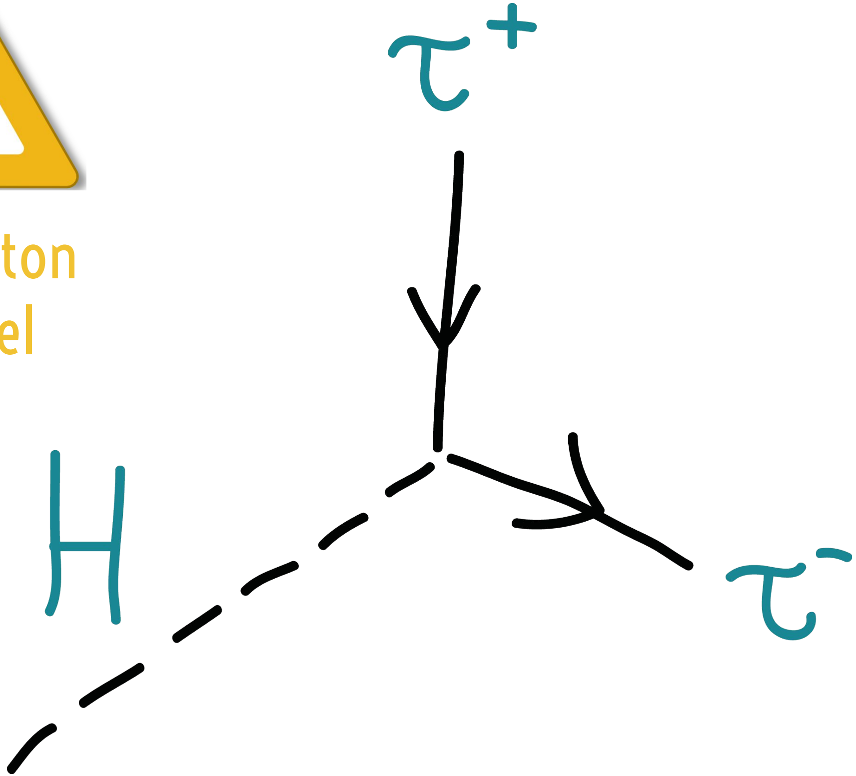
. exp. limit

$5.4 \times \sigma$ (C_t=-1)

Data driven ttbar cross check gives similar results

Multilepton channel





h to WW/$\tau\tau$

. μμμ, μμe, μee, eee or μμ, ee

. one b jet (at least one for same sign)

. at least one untagged, forward jet

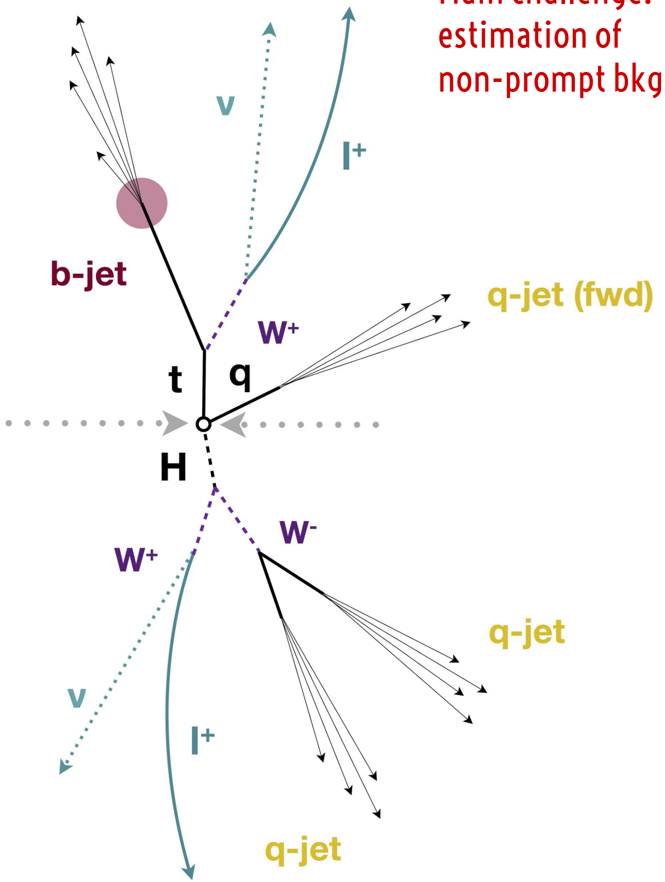
. MET, Z veto for tri-leptons

S/B for C_t=-1:

tri-leptons: 2.8/40

Same-sign: 8.7/172

Main challenge: estimation of non-prompt bkg.



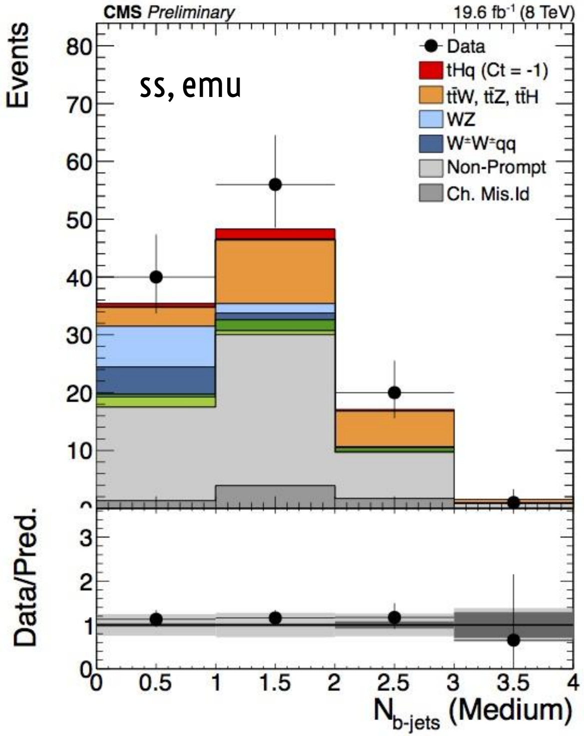
h to WW/$\tau\tau$

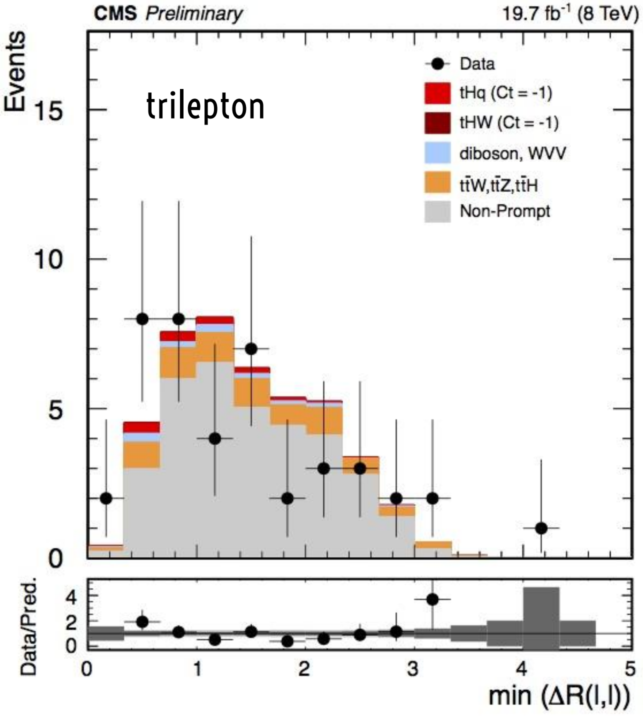
. employ "tight-to-loose" method to estimate lepton fake rate from control data samples, apply rate in sidebands to extrapolate into SR

. use Z peak to estimate charge misidentification for same-sign

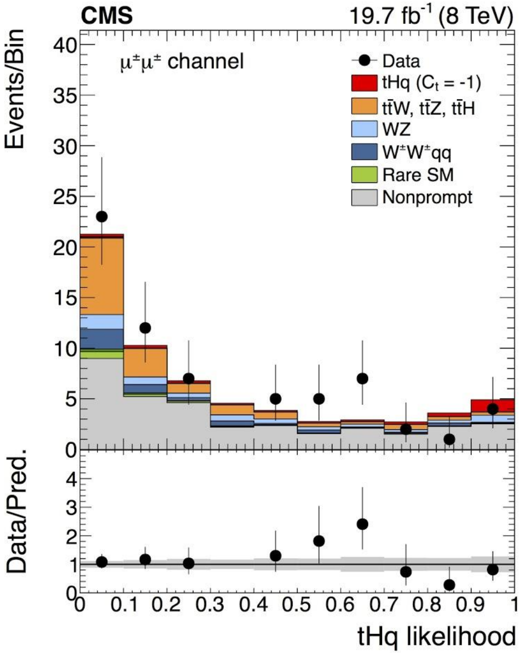
. limit derived from fit to likelihood with information on forward activity, lepton kinematics & charge, (b) jet multiplicity

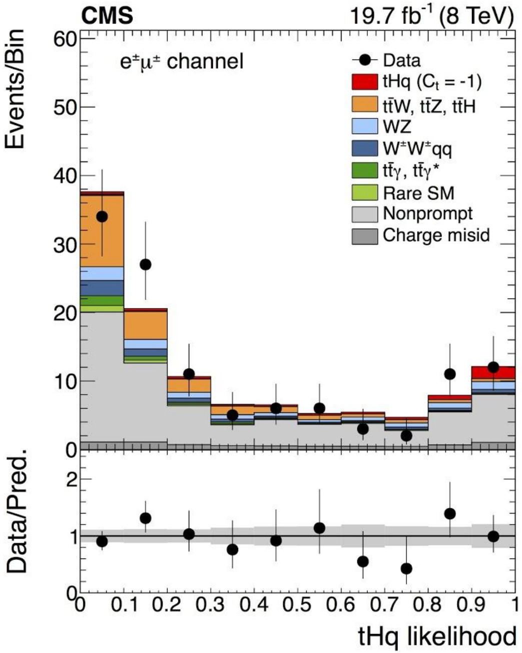
h to WW/$\tau\tau$

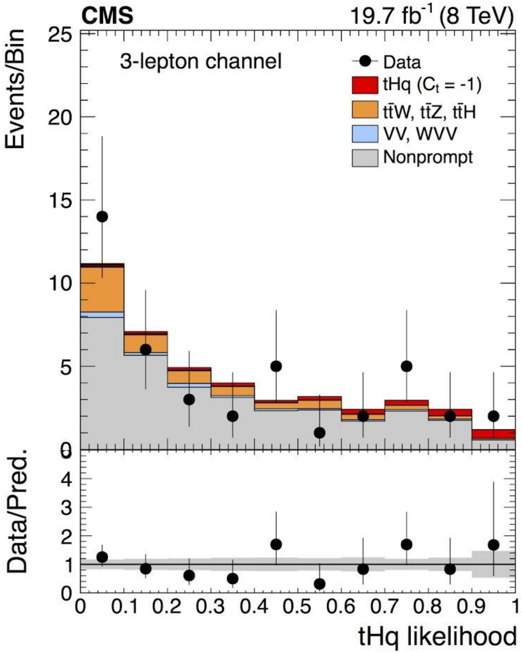




h to WW/$\tau\tau$





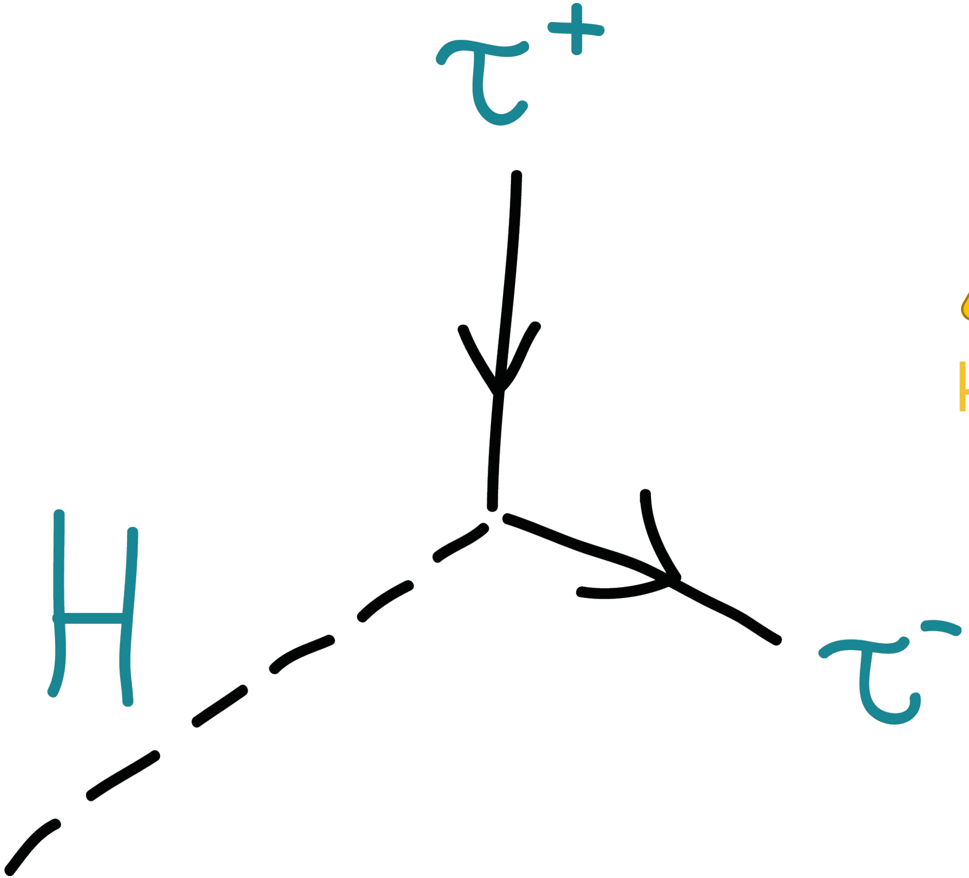


. obs. limit

6.7 x σ (C_t=-1)

. exp. limit

5.0 x σ (C_t=-1)



Hadronic tau decays

h to $\tau\tau$

Main challenge:
estimation of
non-prompt bkg.

. same sign μμ, ee

. at least one b jet

. τ_{had} candidate required to have opposite charge of same-sign leptons

. S/B for C_t=-1:
0.78/14.9

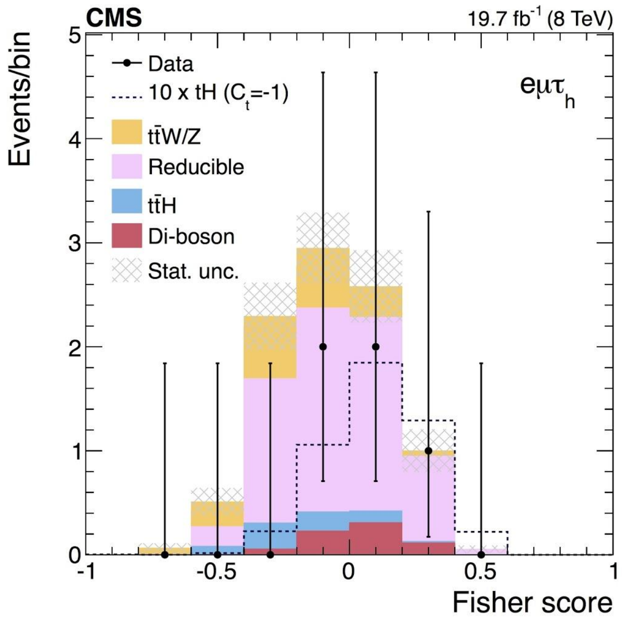
. irreducible backgrounds from simulation

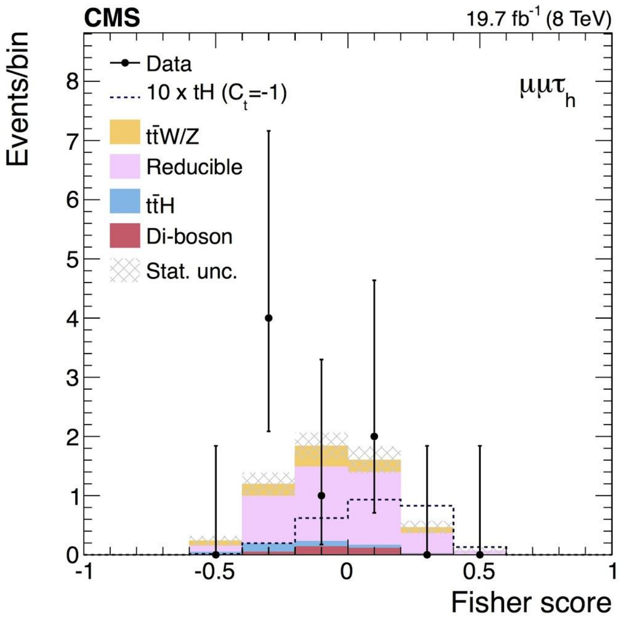
. estimate lepton fake rate with "tight-to-loose" method in ttbar & W+jets CRs, apply rate in sidebands to extrapolate into SR

. train MVA in region with inverted τ isolation (statistics!)

. variables: b jet multiplicity, forward jet kinematics, ...

h to $\tau\tau$





. obs. limit

9.8 x σ (C_t=-1)

. exp. limit

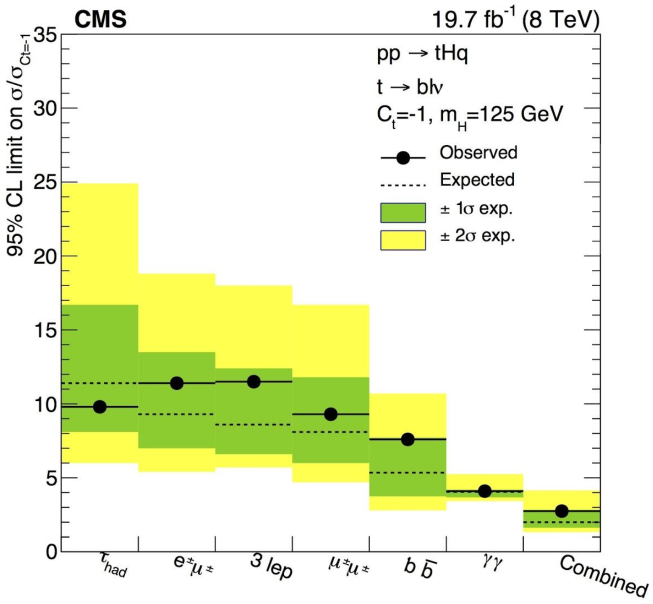
11.4 x σ (C_t=-1)

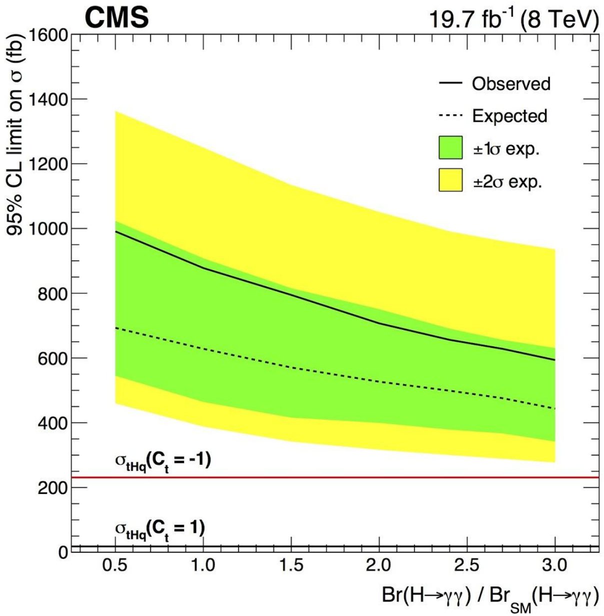
combination

combination

arXiv:1509.08159
submitted to JHEP

	$b\bar{b}$	mult.lept.	$\gamma\gamma$	$\tau\tau$	comb.	**comb. [pb]**
observed	7.6	6.7	4.1	9.8	2.8	**0.65**
expected	5.4	5.0	4.1	11.4	2.0	**0.47**





summary

. thq production can help lifting degeneracies in the top-Yukawa coupling

. searches will full Run-1 lumi at 8 TeV

. ATLAS and CMS approach the channel differently

. first upper limits on anomalous thq production set by CMS

. more to come at 13 TeV