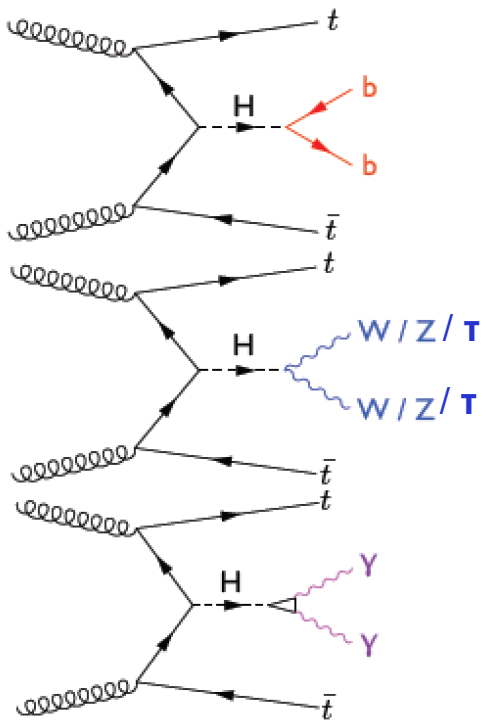
STXS for ttH

June 12th 2019



Link to last discussion within WG2_HiggsProperties
https://indico.cern.ch/event/825370/

12:00 → 12:05 **Introduction** 5m
Speakers: Frank Tackmann (Deutsches Elektronen-Synchrotron (DE)), Lorenzo Viliani (Universita e INFN, Firenze (IT)), Nicolas Berger (Centre National de la Recherche Scientifique (FR))

12:05 → 12:15 **Theory background** 10m
Speaker: Frank Tackmann (Deutsches Elektronen-Synchrotron (DE))
2019-06-06_ttH.pdf

12:15 → 12:30 **CMS Contribution** 15m
Speaker: Julie Malcles (Université Paris-Saclay (FR))
ttH-STXS-06June19...

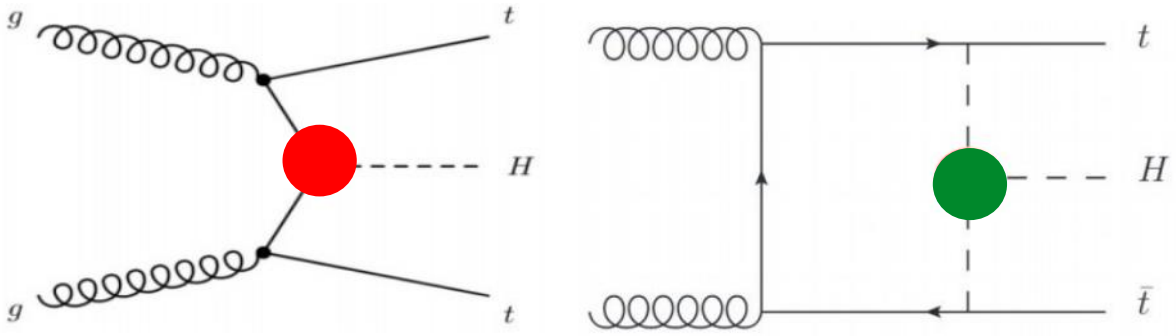
12:30 → 12:45 **ATLAS Contribution** 15m
Speaker: Jelena Jovicevic (CERN)
ttH_STXS_binning.p...

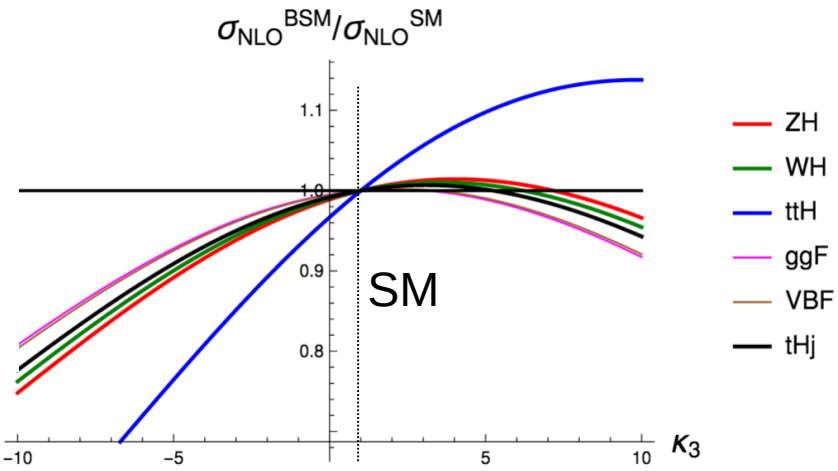
12:45 → 13:00 **Discussion** 15m

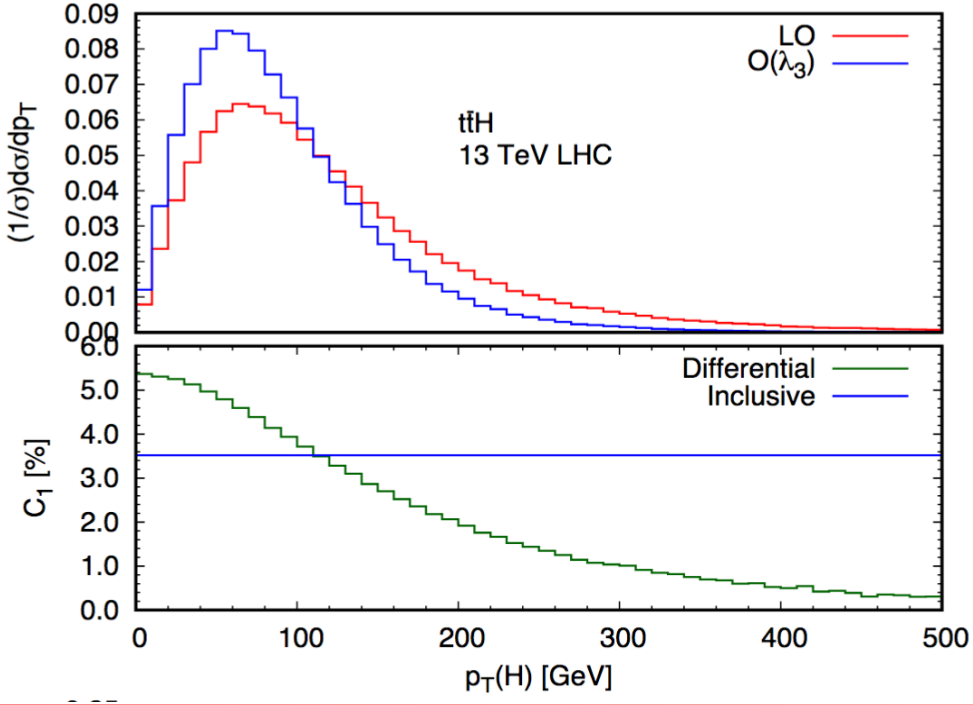
Imagine *ttH* is measured to be different from SM…

Who is the responsible ?

Eur. Phys. J. C (2017) 77: 887







The power of differential measurements:

Variations in Higgs-self coupling (λ_3) will affect the shape of kinematic, e.g. **low p_T(H)** region would be highly affected while it is not deformed in the tail…

Imagine *ttH* is measured to be different from SM…

Who is the responsible ?

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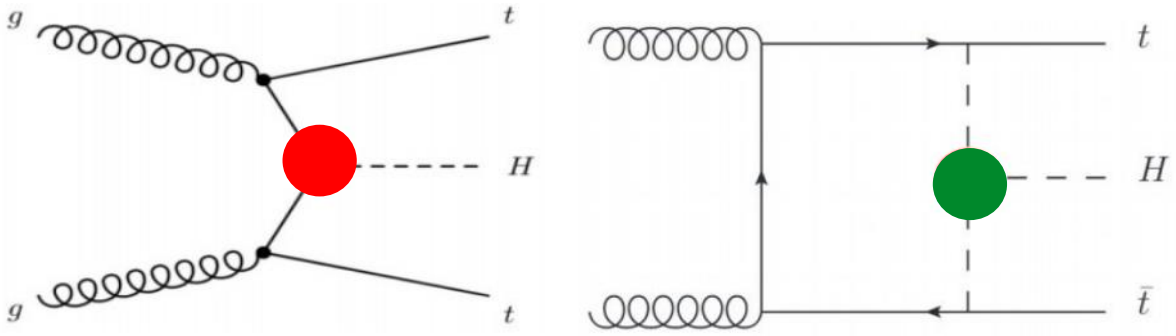
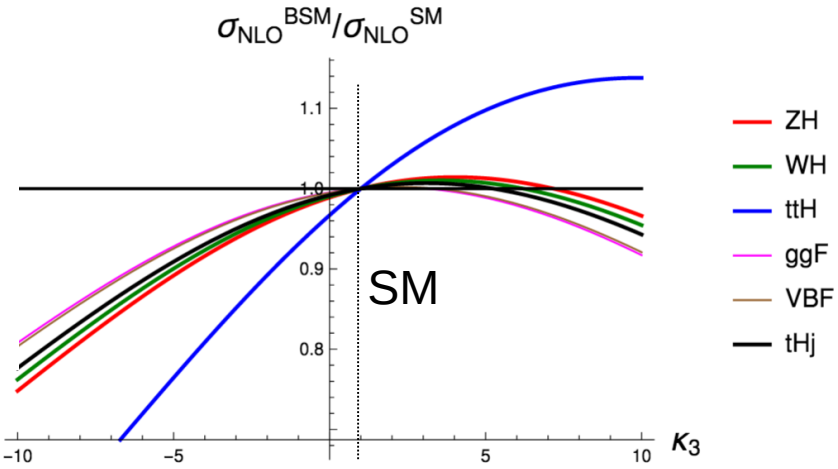
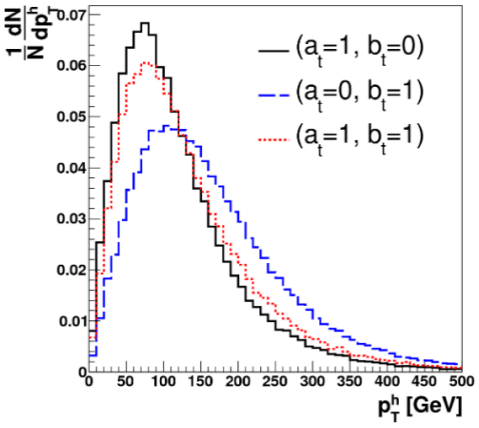
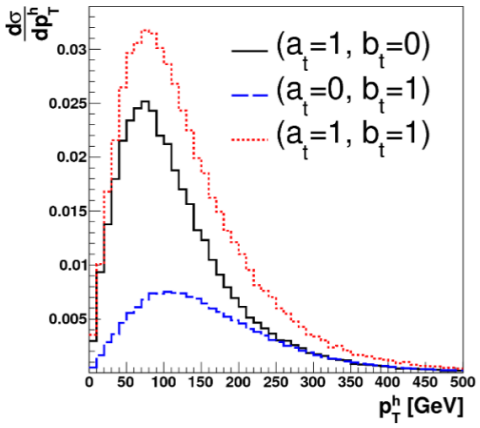




Norm. (shapes effect)



Not norm. (rates effect)



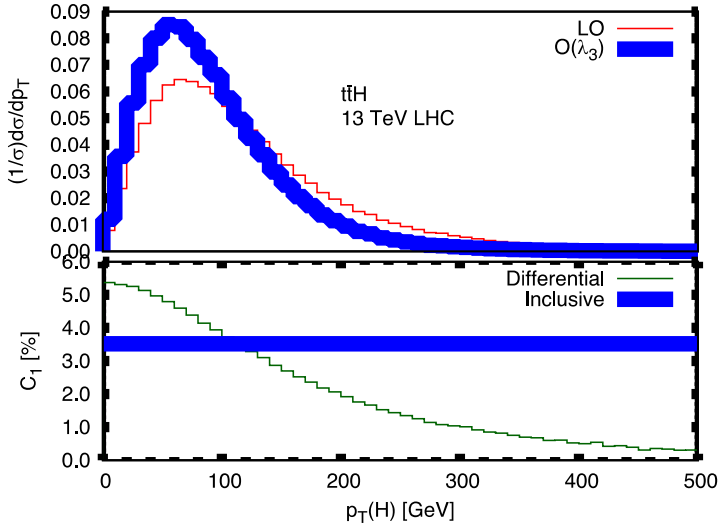
The power of differential measurements:

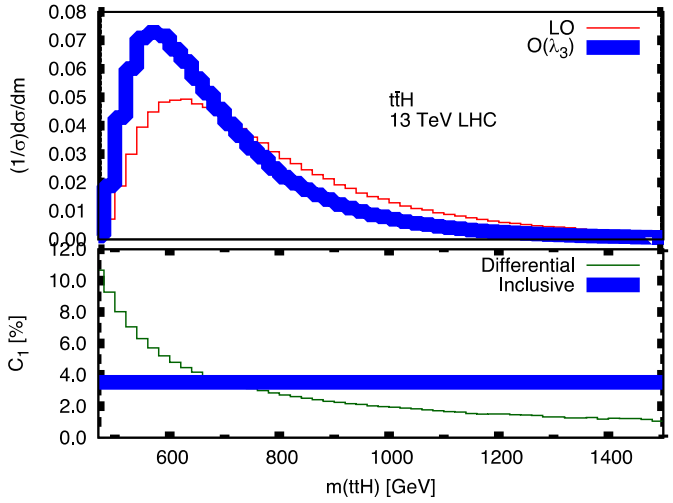
Variations in Higgs-self coupling (λ_3)
will affect the shape of kinematic,
e.g. low p_T (H) region would be highly affected
while it is not deformed in the tail…

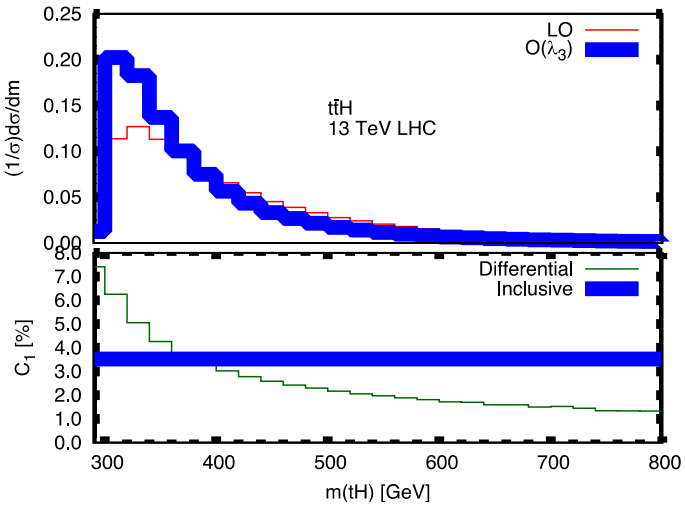
Also could be due to **CP-violating effects**...

: fiducial differential measurements

For STXS: observable and binning choice?







* Best variable to probe production @threshold?

p_T(H), m(ttH), H_T, …

advantage of p_T(H): no need to define truth-level top

→ To start, propose to test these options:

1) p_T (Higgs):

1.a) 2 bins, boundary at 150 GeV or 120 GeV (to align with ggH)

1.b) 3 bins, boundaries at 120, 200 GeV

(dashed 200 GeV to allow further split ~300, 350,400?)

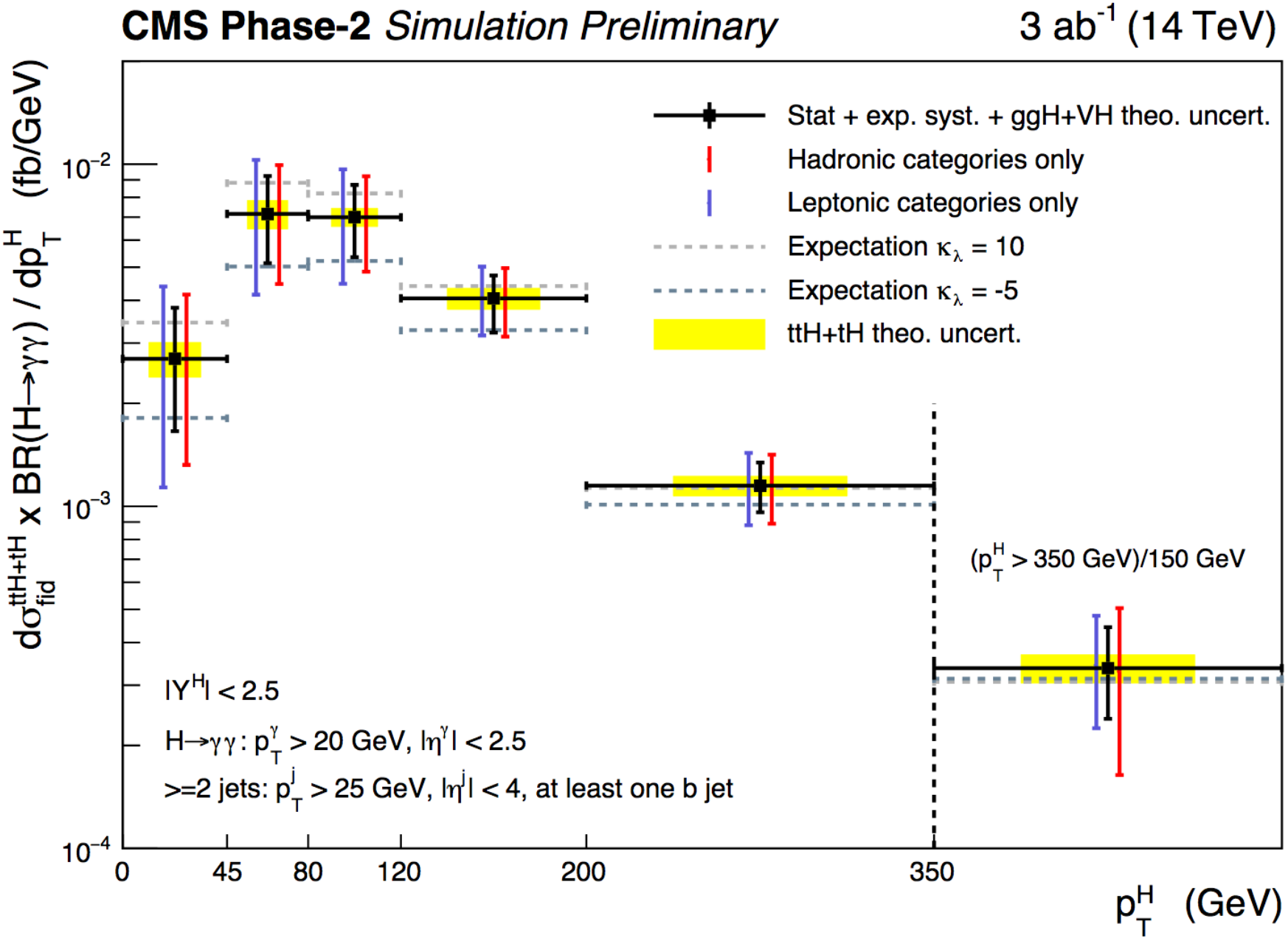
→ Also evaluate experimental acceptance and sensitivity in each of the channels (γγ, bb, and multileptons)

* What happens with additional QCD radiation?
Can we further split bins with 0/1 additional jets?

* What about tH?

BACK-UP

Category	$t\bar{t}H$ Signal	non-$t\bar{t}H$ Higgs	Continuum Background	Total (Expected)	Data
$t\bar{t}H$ "Lep" Category 1	7.9 ± 1.5	0.42 ± 0.12	4.6 ± 0.9	12.9 ± 1.8	15
$t\bar{t}H$ "Lep" Category 2	3.9 ± 0.6	0.43 ± 0.15	7.5 ± 1.2	11.8 ± 1.3	11
$t\bar{t}H$ "Lep" Category 3	1.45 ± 0.24	0.49 ± 0.19	7.5 ± 1.2	9.5 ± 1.2	6
$t\bar{t}H$ "Had" Category 1	6.9 ± 1.6	0.8 ± 0.5	4.5 ± 0.9	12.2 ± 1.9	15
$t\bar{t}H$ "Had" Category 2	5.6 ± 1.0	1.1 ± 0.8	16.5 ± 1.7	23.2 ± 2.3	31
$t\bar{t}H$ "Had" Category 3	7.7 ± 1.3	3.1 ± 2.2	56.0 ± 3.0	67 ± 4	82
$t\bar{t}H$ "Had" Category 4	4.9 ± 0.8	5 ± 4	101 ± 4	111 ± 6	105


CMS Phase-2 Simulation Preliminary
3 ab-1 (14 TeV)
Stat + exp. syst. + ggH+VH theo. uncert.
Hadronic categories only
Leptonic categories only
Expectation κλ = 10
Expectation κλ = -5
ttH+tH theo. uncert.
dσfidttH+tH x BR(H→γγ) / dpTH (fb/GeV)
10−2
10−3
10−4
|YH| < 2.5
H→γγ : pTγ > 20 GeV, |ηγ| < 2.5
>=2 jets: pTj > 25 GeV, |ηj| < 4, at least one b jet
(pTH > 350 GeV)/150 GeV
0
45
80
120
200
350
pTH (GeV)

l+jets

	$SR_3^{\geq 6j}$		$SR_2^{\geq 6j}$		$SR_1^{\geq 6j}$	
Sample	Prefit	Postfit	Prefit	Postfit	Prefit	Postfit
$t\bar{t}H$	85 ± 10	71 ± 52	81 ± 10	68 ± 50	62 ± 11	51 ± 38
$t\bar{t}$ + light	750 ± 370	586 ± 98	210 ± 210	96 ± 33	14 ± 10	12.1 ± 5.8
$t\bar{t} + \geq 1c$	880 ± 350	1330 ± 190	350 ± 100	473 ± 99	53 ± 33	44 ± 20
$t\bar{t} + \geq 1b$	2100 ± 420	2290 ± 170	1750 ± 370	1850 ± 130	1010 ± 240	1032 ± 59
$t\bar{t} + V$	51.2 ± 7.4	50.8 ± 5.9	40.8 ± 5.7	40.3 ± 4.8	25.8 ± 3.7	25.3 ± 3.2
Non-$t\bar{t}$	303 ± 82	267 ± 63	155 ± 52	134 ± 46	75 ± 20	58 ± 17
Total	4140 ± 850	4590 ± 110	2550 ± 510	2657 ± 82	1220 ± 250	1223 ± 42
Data	4698		2641		1222	

l+jets

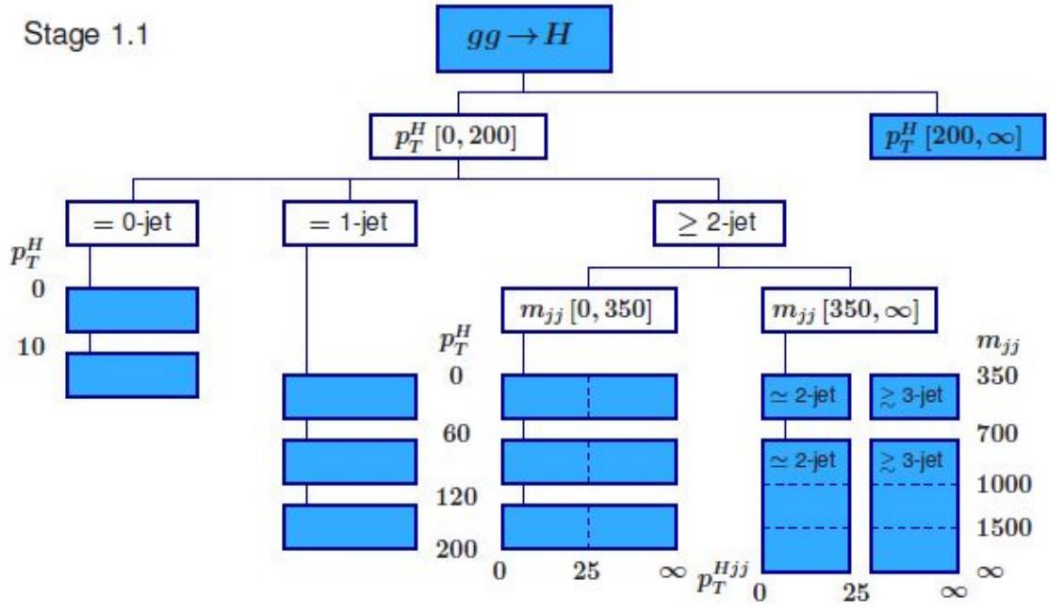
	SR_2^{5j}		SR_1^{5j}		$SR^{boosted}$	
Sample	Prefit	Postfit	Prefit	Postfit	Prefit	Postfit
$t\bar{t}H$	40.1 ± 5.1	34 ± 25	15.9 ± 2.1	13.3 ± 9.8	16.9 ± 1.9	14 ± 10
$t\bar{t}$ + light	500 ± 210	393 ± 67	15 ± 33	12.5 ± 9.3	180 ± 120	112 ± 32
$t\bar{t} + \geq 1c$	436 ± 92	610 ± 100	30 ± 17	28 ± 14	168 ± 70	235 ± 39
$t\bar{t} + \geq 1b$	1230 ± 200	1450 ± 110	273 ± 53	335 ± 25	236 ± 89	229 ± 33
$t\bar{t} + V$	19.9 ± 2.9	19.7 ± 2.4	6.4 ± 1.3	6.4 ± 1.2	16.1 ± 2.9	16.6 ± 2.4
Non-$t\bar{t}$	269 ± 64	220 ± 52	54 ± 11	28.1 ± 8.4	104 ± 30	101 ± 26
Total	2440 ± 390	2724 ± 70	371 ± 68	423 ± 23	710 ± 200	708 ± 40
Data	2798		426		740	

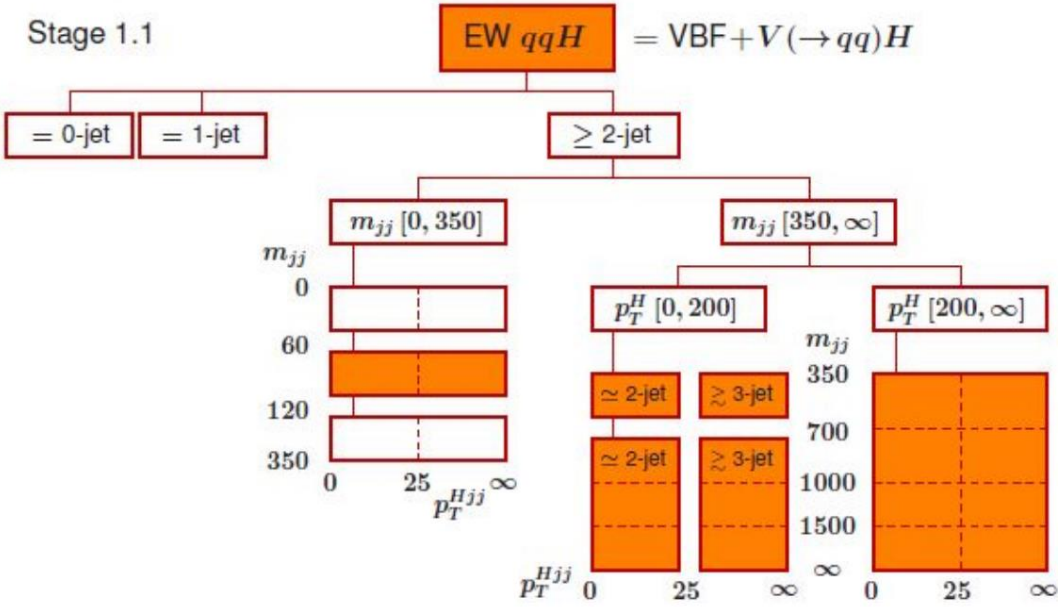
dilepton

	$SR_3^{\geq 4j}$		$SR_2^{\geq 4j}$		$SR_1^{\geq 4j}$	
Sample	Prefit	Postfit	Prefit	Postfit	Prefit	Postfit
$t\bar{t}H$	21.9 ± 2.5	18 ± 13	29.1 ± 4.2	25 ± 18	15.6 ± 2.5	12.9 ± 9.5
$t\bar{t}$ + light	83 ± 41	95 ± 30	250 ± 110	215 ± 43	6.4 ± 9.9	11.1 ± 9.3
$t\bar{t} + \geq 1c$	235 ± 61	313 ± 53	340 ± 210	427 ± 89	12.6 ± 9.4	25.8 ± 7.8
$t\bar{t} + \geq 1b$	819 ± 85	917 ± 71	590 ± 96	669 ± 59	247 ± 61	263 ± 20
$t\bar{t} + V$	15 ± 35	15 ± 34	22 ± 38	22 ± 39	7 ± 56	7 ± 57
Non-$t\bar{t}$	75 ± 17	78 ± 16	115 ± 36	121 ± 29	13.6 ± 3.8	14.6 ± 3.8
Total	1250 ± 140	1436 ± 55	1350 ± 320	1479 ± 66	302 ± 85	334 ± 59
Data	1467		1444		319	

STXS in Higgs production

- The STXS framework for Higgs measurement is used by ATLAS and CMS to report fine grained kinematic measurements for ggH, VBF and VH
- Recent update to V1.1: [1906.02754]





ttH or tH for possible CP-mixing angles

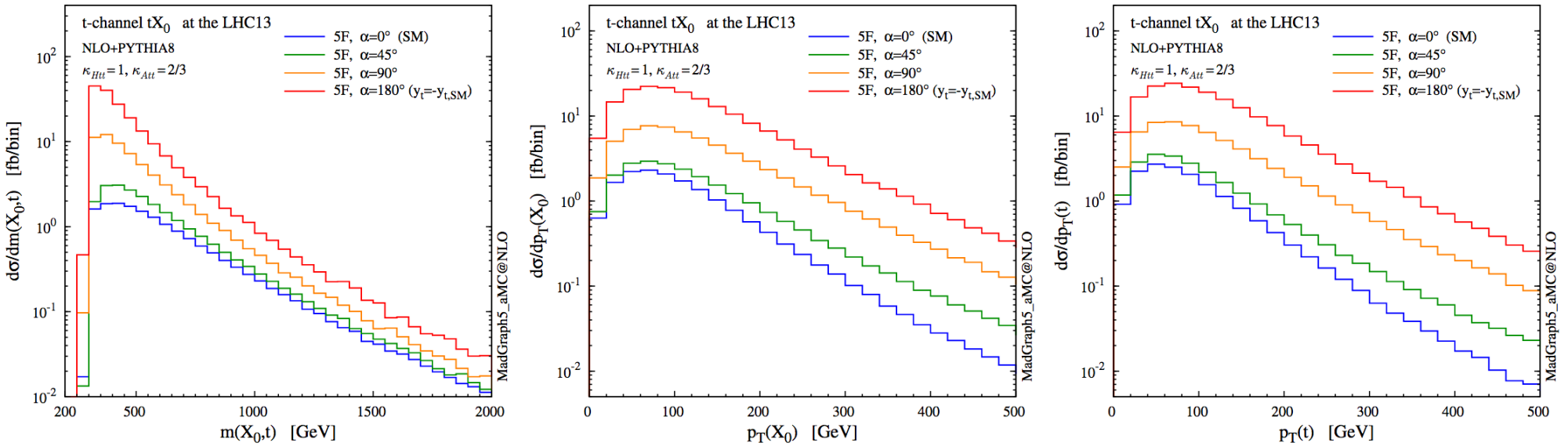
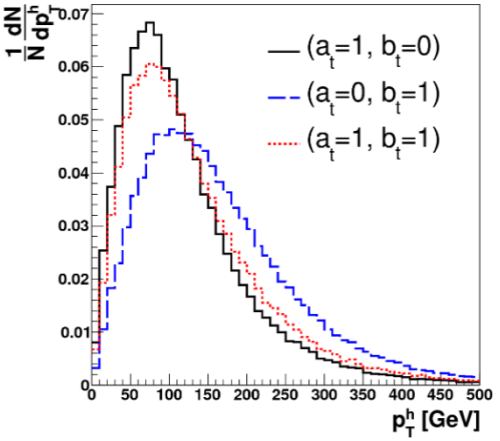


Fig. 13 Differential distributions for the Higgs boson and the top quark at NLO + PS accuracy in t-channel tH associated production at the 13-TeV LHC, with different values of the CP-mixing angles, where κ_{Htt} and κ_{Att} are set in Eq. (16) to reproduce the SM GF cross section for every value of α

Norm. (shapes effect)



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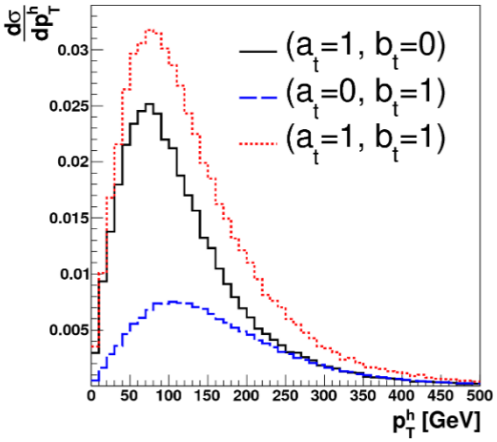
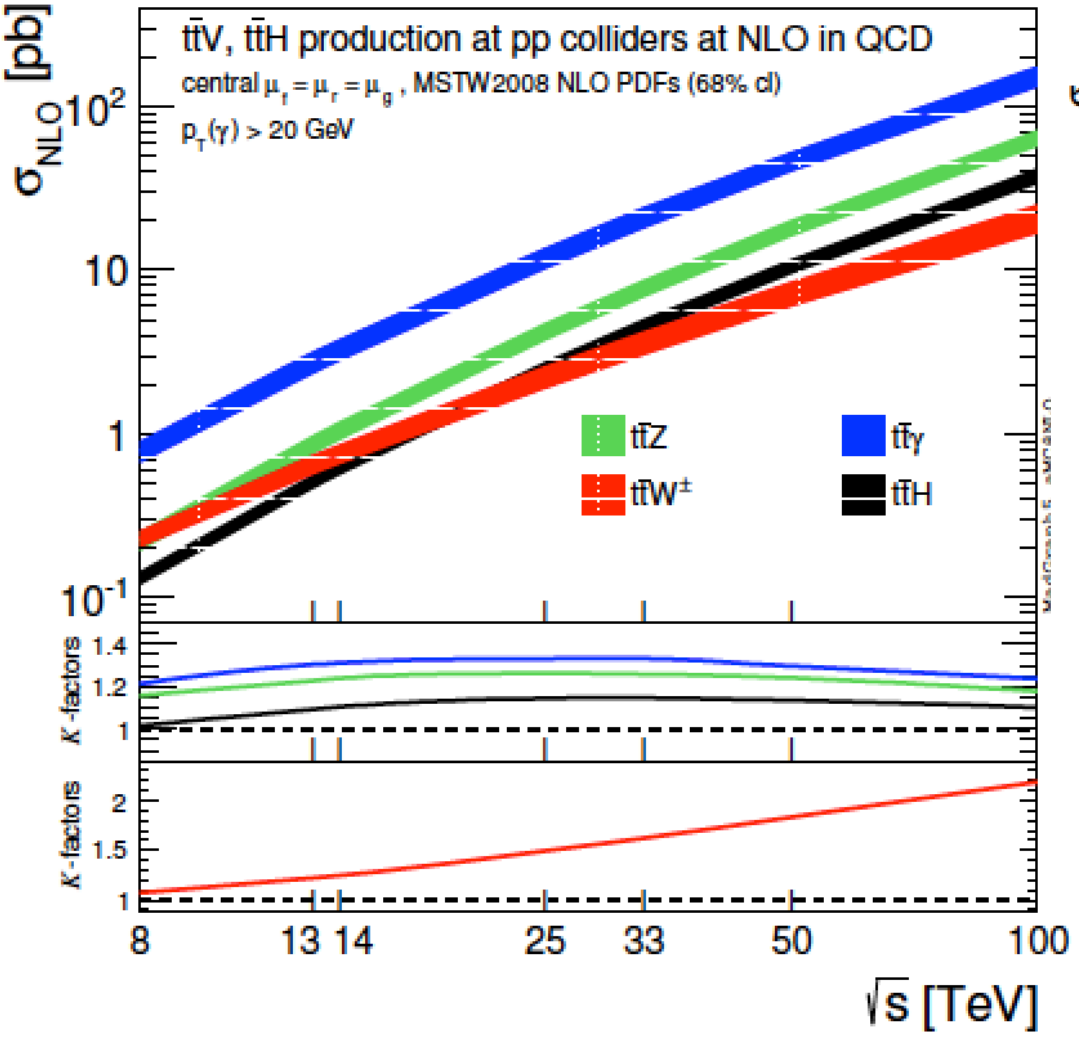
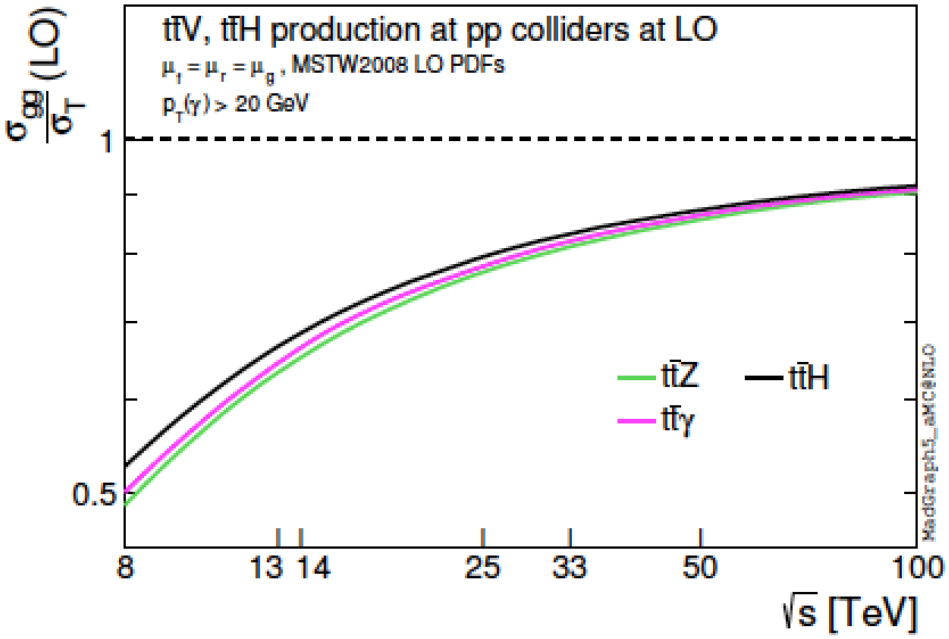
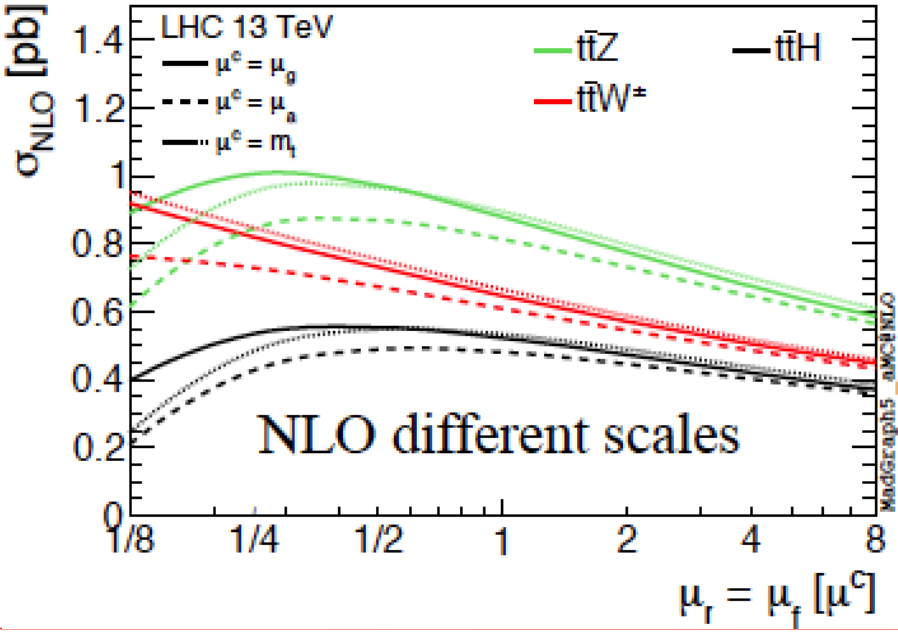



ttV, ttH production at pp colliders at NLO in QCD
central $\mu_f = \mu_r = \mu_g$, MSTW2008 NLO PDFs (68% cl)
$p_T(\gamma) > 20$ GeV
σ_{NLO} [pb]
ttZ
ttγ
ttW±
ttH
K-factors
K-factors
√s [TeV]


ttV, ttH production at pp colliders at LO
$\mu_f = \mu_r = \mu_g$, MSTW2008 LO PDFs
$p_T(\gamma) > 20$ GeV
σ_{gg}/σ_T (LO)
ttZ
ttH
ttγ
√s [TeV]


LHC 13 TeV
$\mu^c = \mu_g$
$\mu^c = \mu_a$
$\mu^c = m_t$
ttZ
ttH
ttW±
σ_{NLO} [pb]
NLO different scales
$\mu_r = \mu_f$ [μ^c]