Associated top pair and heavy boson production: latest 13 TeV results and combination

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LHC TOP WG

Outline

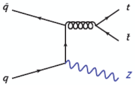
- 8 TeV combination status in ATLAS and CMS for ttW and ttZ
- Summary of recent new measurements at 13 TeV
- Limits on the couplings and constraints on dimension-six operators in EFT with 7 and 8 TeV data

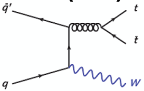
ttV, V=W,Z

ttZ and ttW are rare SM processes, predicted at NLO QCD
ttZ: directly sensitive to neutral current top coupling
ttW: source of same-sign leptons, sensitive to new couplings,
background for new physics searches with SS leptons

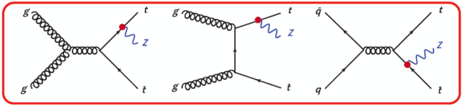
ttZ (ISR and FSR) **ttW (ISR)**

ISR





FSR



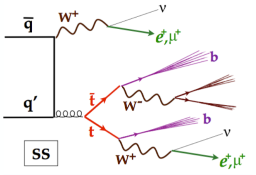
$$\gamma^{\mu}(C_V^{SM} - \gamma_5 C_A^{SM})$$

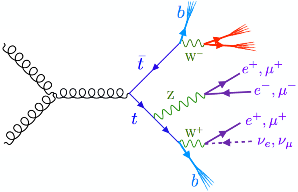
The *tZ* vertex allows the measurement of weak neutral current interaction of the top quark → weak isospin T_3

$$C_V^{SM} = T^3 - 2Q_t sin^2(\theta_W) \qquad C_A^{SM} = T^3$$

→ Cross-sections can be modified by new physics
→ Important irreducible background for ttH(multilep), VLQ, SUSY, etc.

ttV final states





$t\bar{t}W \to (bjj)(bjj)(jj)$

$t\bar{t}W \to (bjj)(bjj)(l\nu)$

$t\bar{t}W \to (b\ell\nu)(bjj)(\ell\nu)$ *2 lepton(SS)*

$t\bar{t}W \to (bl\nu)(bl\nu)(l\nu)$ *3 lepton*

$t\bar{t}Z \to (bjj)(bjj)(jj)$

$t\bar{t}Z \to (bjj)(bjj)(\ell\ell)$ *2 lepton(OS)*

$t\bar{t}Z \to (b\ell\nu)(bjj)(\ell\ell)$ *3 lepton*

$t\bar{t}Z \to (b\ell\nu)(b\ell\nu)(\ell\ell)$ *4 lepton*

2 lepton(SS) most sensitive to tt̄W

3 lepton most sensitive to tt̄Z

4 lepton smallest BR, high purity

Overview: separate 8 TeV results

ttW and ttZ measurements		ttW				ttZ			
		Cross section		Significance		Cross section		Significance	
Data	**Analysis**	**Theory***	**Obs.**	**Exp.**	**Obs.**	**Theory***	**Obs.**	**Exp.**	**Obs.**
8 TeV ($20\ fb^{-1}$)	CMS[1]	203^{+20}_{-22}	382^{+117}_{-102}	3,5	4,8	206^{+19}_{-24}	242^{+65}_{-55}	5,7	6,4
	ATLAS[2]		369^{+100}_{-91}	3,2	5		176^{+58}_{-52}	4,5	4,2

- Observation of ttZ in CMS (2*l* OS, 3*l*, 4*l* channels)
- Observation of ttW in ATLAS and CMS (2*l* SS, 3*l*)
    - **Unexpected!** In 2*l* SS channel, ATLAS gets 5.0σ observed significance (vs. 2.8σ expected), CMS gets 4.9σ observed (3.4σ expected) ... back-of-the-envelope **2.7σ excess?**

[1] https://arxiv.org/abs/1510.01131
[2] https://arxiv.org/abs/1509.05276

* NLO cross sections with scale uncertainties from Garzelli et. al., JHEP 11 (2012) 056

Combination progress

- Agreed on common cross sections and systematic uncertainties
- Made initial list of correlated nuisance parameters[1]
  - Luminosity; ttW, ttZ, and ttH cross sections + uncertainties
- Most nuisance parameters could not be correlated
  - Backgrounds from mis-reconstruction (charge flip, non-prompt lepton)
  - Rare processes used only by CMS or only by ATLAS (tZ, tbZ, ttγ, ttγ^*, WWW/WWZ, single top, tttt)
- Processes with extra jets/b-tags (Z/WZ/ZZ+jets)
  - Depends on both theory/MC generator and detector / RECO algos

[1] See backups. Originally at https://indico.cern.ch/event/485676/contributions/2004785/attachments/1244941/1835270/2016_03_18_ttV_combination_proced_syst.pdf

Combination struggles

- Persistent issues with the workspaces
  - CMS combine tool unable to run on some of the ATLAS workspaces[1]
  - Couldn't reproduce paper results using ATLAS workspaces and Frameworks for a long time
  - ATLAS switched to ATLAS-wide tools, this will make future combinations much easier
- Not clear if these problems are surmountable, or worth the effort for legacy combination which is mostly statistics-limited
  - Workspaces are still available … if anyone wants to try them out, contact Andrew Brinkerhoff and Markus Cristinziani

[1] https://hypernews.cern.ch/HyperNews/CMS/get/higgs-combination/827/1/2.html

ttV 13 TeV @ ATLAS: strategy

arXiv:1609.01599 (2015, 3.2 / fb)

Consider 3 channels according to # of leptons

Define signal regions (SRs) for the 3 channels
- depending on the number of jets and *b*-jets

Define two control regions (CRs)
to extract WZ and ZZ normalisations

Define validation regions (VRs)
to check fake lepton estimate (not included in the fit)

Combined profile likelihood fit to SRs & CRs
- cut-and-count analysis
- extract $\mu(ttZ)$, $\mu(ttW)$,
and *WZ* and *ZZ* normalisation factors

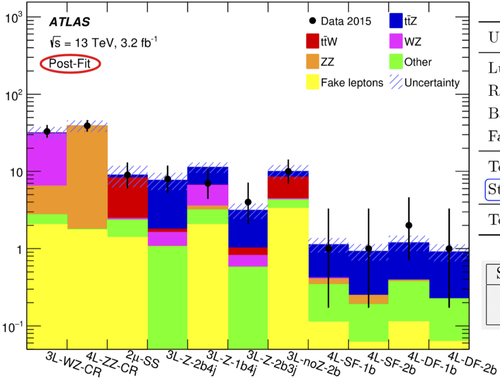
2μSS	1 b-tag	≥ 2 b-tags
No $E_{T,miss}$ cut	2μSS-VR	2μSS-VR
$E_{T,miss}$ cut		2μSS-SR

3ℓ-Z	0 b-tag	1 b-tag	≥2 b-tags
2 jets		3ℓ-Z-VR	3ℓ-Z-VR
3 jets	3ℓ-WZ-CR	3ℓ-Z-VR	3ℓ-Z-2b3j
≥4 jets		3ℓ-Z-1b4j	3ℓ-Z-2b4j

3ℓ-noZ	1 b-tag	≥2 b-tags
2 jets	3ℓ-noZ-VR	3ℓ-noZ-2b
3 jets	3ℓ-noZ-VR	3ℓ-noZ-2b
4 jets		3ℓ-noZ-2b

4ℓ	SF	DF
≥ 0 b-tags low $E_{T,miss}$ Z window	4ℓ-ZZ-CR	
1 b-tag	4ℓ-SF-1b	4ℓ-DF-1b
≥ 2 b-tags	4ℓ-SF-2b	4ℓ-DF-2b

ttV 13 TeV @ ATLAS: systematics and results



Uncertainty	$\sigma_{t\bar{t}Z}$	$\sigma_{t\bar{t}W}$
Luminosity **2015 data (unc. 2.5%)**	2.6%	3.1%
Reconstructed objects	8.3%	9.3%
Backgrounds from simulation	5.3%	3.1%
Fake leptons and charge misID	3.0%	21%
Total systematic	11%	22%
Statistical	31%	48%
Total	32%	53%

Signal significance	Expected	Observed
ttW	1.0	2.2
ttZ	3.4	3.9

ttZ and ttW simultaneous cross-section measurement (9 SRs + 2CRs)

WZ_norm 1.11 ± 0.30

ZZ_norm 0.94 ± 0.17

μ(ttZ) = 1.10 ± 0.37 → **σ(ttZ) = 0.92 ± 0.29 (stat) ± 0.10 (syst) pb**

μ(ttW) = 2.49 ± 1.32 → **σ(ttW) = 1.50 ± 0.72 (stat) ± 0.33 (syst) pb**

ttV 13 TeV @ CMS: strategy

CMS-TOP-16-009 (2015, 2.7 / fb) and CMS-TOP-16-017 (2016, 12.9 / fb)

- For ttW in same-sign 2L channel MVA was developed using 11 variables, signal regions are built in jets and bjets multiplicities
- For ttZ 3L and 4L are considered, signal regions are built in jets and bjets multiplicities
- WZ and ZZ backgrounds are validated in the control regions (high purity: 85% and 99%)
- For nonprompt background (ttbar) data-driven approach is used for estimation

CMS-TOP-16-017 (2016, 12.9 / fb)

Source	Syst. uncertainties	Effect on x-section measurement ttW	Effect on x-section measurement ttZ
Luminosity	6.2%	7-10%	8-14%
Jet Energy Scale/Resolution	1-6%	$\leq$ 1%	< 1%
Trigger	2-5%	4-7%	3-6%
BTagging	1-8%	2-6%	3-6%
PU modeling	1%	<1%	<1%
Lepton Id., Eff.	7-10%	5-9%	7-16%
μ_R/μ_F scale choice	2%	<1%	<1%
PDF choice	1%	<1%	< 1%
Non-prompt background	30%,100%	12%	7-10%
WZ background cross section	20%	<1%	5-6%
ZZ background cross section	20%	-	4%
Charge mis-identification	20%	2%	-
Rare SM bkg	50%	5%	1-2%
ttH/tZq bkg	25%	2%	0-6%
Stat nonprompt	5-50%	8%	5%
Stat rare SM processes	20-100%	5%	3%
Total	-	23%	20%

Channel	Expected significance	Observed significance
$2\ell ss$ analysis ($t\bar{t}W$)	2.6	3.9
3ℓ analysis ($t\bar{t}Z$)	5.4	3.8
4ℓ analysis ($t\bar{t}Z$)	2.4	2.8
3ℓ and 4ℓ combined ($t\bar{t}Z$)	5.8	4.6

$$\sigma_{t\bar{t}Z} = 0.70^{+0.16}_{-0.15}(\text{stat.})^{+0.14}_{-0.12}(\text{sys.})\ \text{pb}$$

$$\sigma_{t\bar{t}W} = 0.98^{+0.23}_{-0.22}(\text{stat.})^{+0.22}_{-0.18}(\text{sys.})\ \text{pb}$$

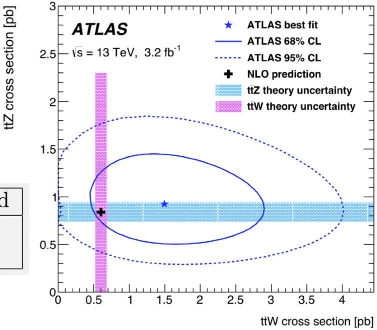
ttV: 13 TeV results

ATLAS, 2015 data, 3.2 fb^{-1}

σ(ttZ) =0.92 ±0.29 (stat) ±0.10 (syst) pb

σ(ttW)=1.50 ±0.72 (stat) ±0.33 (syst) pb

Signal significance	Expected	Observed
ttW	1.0	2.2
ttZ	3.4	3.9

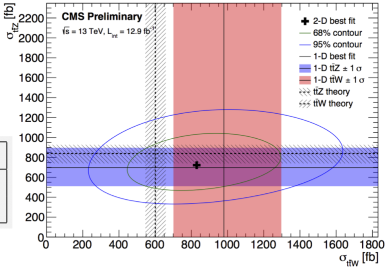


CMS, (2016) 12.9 fb^{-1}, CMS PAS TOP-16-017

$$\sigma_{t\bar{t}Z} = 0.70^{+0.16}_{-0.15}(\text{stat.})^{+0.14}_{-0.12}(\text{sys.})\ \text{pb}$$

$$\sigma_{t\bar{t}W} = 0.98^{+0.23}_{-0.22}(\text{stat.})^{+0.22}_{-0.18}(\text{sys.})\ \text{pb}$$

Signal significance	Expected	Observed
ttW	2.6	3.9
ttZ	5.8	4.6



Constraints on the axial and vector components of the top-Z coupling

➡ the ttZ SM interaction Lagrangian can be written in terms of axial and vector components of the top-Z coupling $\gamma^\mu(C_V^{SM} - \gamma_5 C_A^{SM})$

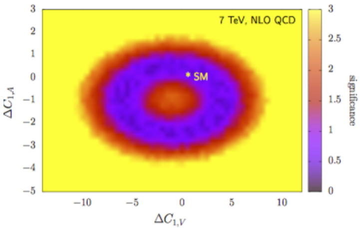
➡ new physics contributions introduced by higher dimensional operators by the EFT approach

$$C_{1,V} = C_V^{\rm SM} + \frac{1}{4\sin\theta_w\cos\theta_w}\frac{v^2}{\Lambda^2}{\rm Re}[\bar{c}'_{HQ} - \bar{c}_{HQ} - \bar{c}_{Hu}], \quad C_{1,A} = C_A^{\rm SM} - \frac{1}{4\sin\theta_w\cos\theta_w}\frac{v^2}{\Lambda^2}{\rm Re}[\bar{c}'_{HQ} - \bar{c}_{HQ} + \bar{c}_{Hu}].$$

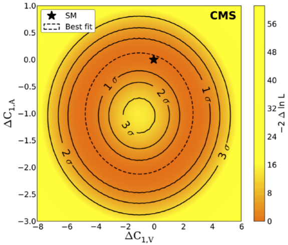
➡ the cross section depends on these couplings and can be written:

$$d\sigma = s_0 + s_1 C_{1,V} + s_2 C_{1,V}^2 + s_3 C_{1,A} + s_4 C_{1,A}^2 + s_5 C_{1,V} C_{1,A}.$$

Rontsch and Schulze
JHEP 07 (2014) 091



JHEP01(2016)096



Constraints on dimension-six operators in EFT

Potential deviations from the SM can be described by extending the SM Lagrangian with higher order operators using EFT

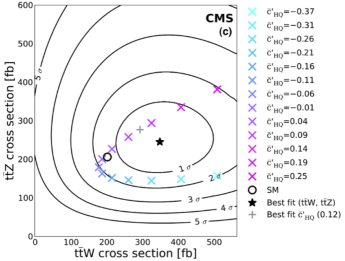
$$\mathcal{L} = \mathcal{L}_{\mathrm{SM}} + \sum_i \bar{c}_i \mathcal{O}_i$$

In JHEP 01 (2016) 096 one operator at a time was considered

$$\mathcal{M} = \mathcal{M}_0 + c_1 \mathcal{M}_1$$

$$\sigma(c_1) \sim |\mathcal{M}|^2 \sim s_0 + s_1 c_1 + s_2 {c_1}^2$$

- Five operators considered, which affect ttW/Z and ttV
- have small effect on Higgs and tt production



Conclusions

- 8 TeV combination of ATLAS and CMS results on ttV is ongoing
- So far cover only approx. 1 / 3 of the 13 TeV dataset, no EFT re-interpretations have not yet been performed
- For ttV at 13 TeV with full 2016 dataset (41 / fb delivered):
  - will be analysed both by ATLAS and CMS
  - More advanced analysis techniques will be used
  - Constraints on new physics
- Potentially 100 / fb will be analysable at the end of 2017

Back-up

Lessons learned

- Advice for future combinations (especially ttV)
  - Establish technical workflow first: running on each others' workspaces, creating combined workspaces
  - Make sure those responsible for creating the workspaces are available from the beginning - or better, active collaborators in the combination
  - If possible, use common signal and background cross sections in the initial CMS/ATLAS analyses (ttW, ttZ, ttH, WZ+jets, etc.)
  - If possible, use common predictions for +jets and +b-tags processes
  - Use common phase space, especially m(*ll*) cuts on ttZ/WZ processes
    - Theory predictions use pole mass, translation to mixed Z/γ^* non-trivial

Cross sections: signal & bkg.

- Signal: **ttW** and **ttZ** - **should be correlated**
- Bkg: **prompt** lepton, non-prompt (**NP**), charge-flip (**QF**)
  - **Prompt**: **rare** processes whose phase space overlaps with signal (tZ, tbZ, WtZ, ttH, ttγ, ttγ*, ttWW, tttt), common processes which only enter the signal region with **extra jets / b-tags** (ttbar, single top, Z, WZ, ZZ, $W^{\pm}W^{\pm}$, WWW, WWZ)
  - **NP**: ttbar, W, and Z (or 4*l* WZ) events with ≥1 non-prompt lepton
  - **QF**: opposite-sign (OS) ttbar or Z events where an electron was assigned incorrect charge, so event passes the SS selection

Cross sections: correlation

- **Rare prompt**
  - **ttH** cross section is well known and **should be correlated**
  - **top+Z:** ATLAS uses separate tZ (s- and t-channel) and WtZ (W-channel) samples. CMS uses only tbZ (s-channel). These processes have different cross sections and **cannot be correlated**
  - **ttγ** and **ttγ^*** are only included as bkg. by CMS, **cannot correlate**
  - **ttWW** and **$W^{\pm}W^{\pm}$** are at LO with 50% uncertainty. Exp. yields of 3% and 6% of signal, respectively, so **no point to correlate**
  - **WWW/WWZ** only in CMS, **single top** and **tttt** only in ATLAS (very small expected yields) - **cannot correlate**

Cross sections: correlation

- **Prompt + extra jets**: yields in signal region scaled by sideband data with fewer b-tagged jets
  - Because CMS and ATLAS use different jet reconstruction and b-tagging algorithms, correlation is not straightforward
    - Partial correlation is theoretically possible, but would require a generator-level comparison of CMS and ATLAS samples, and new correlations of nuisance parameters to generator info
    - In CMS, only b-tag eff. is significantly correlated to sig. strength, but is not constrained. ttbar/Z+jets yields have 6^{th} and 7^{th} highest correlation to ttZ (-0.15 and 0.14), constrained to 70%/50% of pre-fit values.
  - In the end, **correlation is not worth it**
  - **NP & QF**: sideband data estimate, **cannot be correlated**

Signal cross sections

- **ttW** cross sections: 232 fb (ATLAS[2]), 203 fb (CMS[1])
- **ttZ** cross sections: 215 fb (ATLAS[3]), 206 fb (CMS[1])
  - Both from NLO calculations - the only difference is choice of central scale μ_0. To check this, ATLAS ran **MCFM** with the same μ_0 as **PowHel**, and got an identical result.
  - Choice of μ_0 is arbitrary; following the ATLAS-CMS Higgs combination[4], use $\mu_0 = m_t + m_V/2$ for both ttW and ttZ

[1] Garzelli et. al., NLO **PowHel**, central scale $\mu_0 = m_t + m_V/2$, range $\{\mu_0/2, 2\mu_0\}$: arXiv:1208.2665
[2] Campbell & Ellis, NLO **MCFM**, central scale $\mu_0 = m_t$, range $\{\mu_0/4, 4\mu_0\}$: arXiv:1208.2665
Also include PDF+α_S uncertainties at 90% C.L.
[3] Actually, ATLAS used Madgraph5 aMC@NLO for both ttW and ttZ, with $\mu_0 = m_t$. The ttW cross section agreed perfectly with [2]
[4] aMC@NLO with on-shell Z and $\mu_0 = H_T/2$ gives ttW(Z) = 204 (197.5) fb: arxiv:1504.03446
[4] CMS: https://cds.cern.ch/record/2053103, ATLAS: http://cds.cern.ch/record/2052552
CMS internal note: http://cms.cern.ch/iCMS/analysisadmin/cadi?ancode=HIG-15-002

Signal cross sections

- Difference in definition of ttZ signal: ATLAS includes same-flavor l^+l^- with masses > 5 GeV; CMS only > 10 GeV[1]
  - 5 GeV < m(l^+l^-) < 10 GeV events constitute 4% of the inclusive ATLAS ttZ sample. Thus its xSec should be 206 × 1.04 = **214 fb**
  - ATLAS scaling by 214 and CMS by 206 is **consistent**, because the MC samples cover a different **phase space**. We can report final cross section measurements for either **PS**: > 5 GeV or > 10 GeV

[1] http://cms.cern.ch/iCMS/prep/requestmanagement?dsn=TTZJets_8TeV-madgraph
generate p p > t t~ l l / h @1 ... (+1 jet, +2 jets)
add process p p > t t~ vl vl / h @2 ... (+1 jet, +2 jets)
add process p p > t t~ z / h, z > q q @3 ... (+1 jet, +2 jets)
10 = mmll ! min invariant mass of l+l- (same flavour) lepton pair

Uncertainties: signal shape

- Both CMS and ATLAS assess uncertainties in the signal shape using different PDF sets and Q^2 values in the matrix element and the Pythia parton shower
- ATLAS primarily uses binned selection (nJets, nBtags) as final discriminant; CMS uses BDT output shape
  - Even within CMS analysis, these uncertainties are evaluated using arbitrary shape deformations within an envelope
  - Mapping between ATLAS and CMS would be hopelessly complex - **cannot be correlated**

Uncertainties: detector

- Uncertainties on object reconstruction, such as jet energy scale, jet energy resolution, b-tagging efficiency, and lepton trigger and reconstruction efficiencies, can affect both signal and background yields
  - Of these, only b-tagging efficiency and jet energy scale have a significant effect on the measurements
  - Jet definitions are not correlated between ATLAS and CMS (e.g. R=0.4 for ATLAS, R=0.5 for CMS; different b-tag algorithms), and in general the scale factors and uncertainties on object RECO parameters are detector specific - **cannot be correlated**

Uncertainties: luminosity

- As in the Higgs combination[1], split into correlated and uncorrelated parts
  - Correlated (lumi_2012) : 1.1%
  - ATLAS only (ATLAS_lumi_2012) : 2.5%
  - CMS only (CMS_lumi_2012) : 1.5%

[1] CMS: https://cds.cern.ch/record/2053103, ATLAS: http://cds.cern.ch/record/2052552
CMS internal note: http://cms.cern.ch/iCMS/analysisadmin/cadi?ancode=HIG-15-002

Uncertainties: cross section

- **Correlate** cross section uncertainties for ttH, ttW, and ttZ, adding scale and PDF uncertainties in quadrature
- ttH = 10.8% : Q^2 = +3.8% / -9.3%[1, 2], PDF = 8.1%[1, 2]
- ttW = 12.6%: Q^2 = +9.9% / -10.7%[3], PDF = 7.2%[4]
- ttZ = 13.8%: Q^2 = +9.3% / -11.7%[3], PDF = 8.8%[4]
- Comparable to original ATLAS uncertainties: ttH = 12.0%, ttW = 13.8%, and ttZ = 14.0%

[1] https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CERNYellowReportPageAt8TeV
[2] ATLAS-CMS combined Higgs mass (7 and 8 TeV): arXiv:1503.07589
[3] Garzelli et. al., NLO **PowHel**, central scale $\mu_0 = m_t + m_V/2$, range $\{\mu_0/2, 2\mu_0\}$: arXiv:1208.2665
[4] CMS ttV paper (8 TeV): arXiv:1510.01131. Typo has 8.2% ttZ PDF uncertainty, rather than 8.8%.

Correlating tt+X uncertainties

- ttH, ttW, and ttZ have similar mass scales, and ttH and ttZ are both dominantly produced by gluon fusion at 8 TeV
- Can we correlate PDF / scale uncertainties? Does it matter?
    - **Cannot affect** measured cross section or uncertainties: ttW / ttZ are left unconstrained, ttH is not constrained in the fit
    - **Cannot affect** central μ(ttW) or μ(ttZ) signal strength values: ttH is not constrained, and nothing else can pull the ttW / ttZ scale / PDF nuisance parameters, since μ is left unconstrained in the fit
    - **Could only affect** signal strength μ uncertainties
    - Without theoretical justification for level of correlation, **leave uncorrelated** (see next slide)

Correlating tt+X uncertainties

- Do we know how correlated ttH, ttW, and ttZ are?
  - Only paper we could find studies ttH-ttZ correlation at 13 TeV[1]
  - At 13 TeV, normalization/factorization scale and PDF+α_S uncertainties are > 50% correlated between ttH and ttZ
  - But this does not map cleanly to 8 TeV, where q-q production plays a larger role. Also does not tell us anything about ttW.

	$\sigma(t\bar{t}H)$[pb]	$\sigma(t\bar{t}Z)$[pb]	$\frac{\sigma(t\bar{t}H)}{\sigma(t\bar{t}Z)}$
13 TeV	$0.475^{+5.79\%+3.33\%}_{-9.04\%-3.08\%}$	$0.785^{+9.81\%+3.27\%}_{-11.2\%-3.12\%}$	$0.606^{+2.45\%+0.525\%}_{-3.66\%-0.319\%}$
100 TeV	$33.9^{+7.06\%+2.17\%}_{-8.29\%-2.18\%}$	$57.9^{+8.93\%+2.24\%}_{-9.46\%-2.43\%}$	$0.585^{+1.29\%+0.314\%}_{-2.02\%-0.147\%}$

norm./fact.
PDF+α_S

[1] Mangano et. al., Top Yukawa Coupling at 100 TeV, $\mu_0 = M_T$ (ttH/ttZ): arXiv:1507.08169
[2] Nice set of talks on scale and PDF uncertainties: https://indico.cern.ch/event/251810/
[3] More on theoretical uncertainties: arXiv:1307.1843

Workspaces for combination

- Some workspaces in new format are available
  - ATLAS workspaces
    - All four workspaces available since this week
    - $3l$ workspace readable, combine-able in CMS software framework
    - OS, SS, and $4l$ workspaces not readable as is ... being worked on
  - CMS workspaces
    - All available in consistent format since early March
    - Markus has not yet tested it with the ATLAS ttV combination software framework

First results: 3*l* ttW+ttZ

- Running the 3*l* workspaces in the CMS combine tool
  - **ATLAS** μ(ttW) +0.764 -0.713 / +0.942 (68%) +1.331 / -2.173 (95%)
    μ(ttZ) +0.779 -0.287 / +0.385 (68%) +0.517 / -0.794 (95%)
  - **CMS** μ(ttW) +0.830 -0.987 / +1.105 (68%) +1.930 / -2.354 (95%)
    μ(ttZ) +1.297 -0.367 / +0.478 (68%) +0.644 / -1.075 (95%)
  - **Comb.** μ(ttW) +0.770 -0.598 / +0.681 (68%) +1.108 / -1.483 (95%)
    μ(ttZ) +1.030 -0.229 / +0.269 (68%) +0.419 / -0.578 (95%)

Run in CMSSW_7_1_5 (slc6_amd64_gcc481), following https://twiki.cern.ch/twiki/bin/viewauth/CMS/SWGuideHiggsAnalysisCombinedLimit#ROOT5_SLC6_release_CMSSW_7_1_X

[1] combine -M MultiDimFit ATLAS/workspaces/2016_March16/ttv_3l.root --optimizeSimPdf 0 -w combined --modelConfigName ModelConfig -D obsData --algo=singles --redefineSignalPOIs SigXsecOverSMTTW,SigXsecOverSMTTZ,SigXsecOverSMZZ,SigXsecOverSMWZ -P SigXsecOverSMTTW -P SigXsecOverSMTTZ --floatOtherPOIs=1 --saveInactivePOI=1 --robustFit=1 --minimizerTolerance=0.001 --do95=1 --rMin=-4 --rMax=8

[2] combine -M MultiDimFit CMS/workspaces/2016_March01/workspace.MultiDim.ttW_3l_ttZ_3l_2016_March1_2D_realData_someStat_FinalBDT.root --optimizeSimPdf 0 --algo=singles -P r_TTW -P r_TTZ --robustFit=1 --minimizerTolerance=0.001 --do95=1 --rMin=-4 --rMax=8

[3] combine -M MultiDimFit combined/output_workspaces/combined_3l_ttW_ttZ_2D.root --optimizeSimPdf 0 --algo=singles --redefineSignalPOIs r_TTW,r_TTZ,SigXsecOverSMZZ,SigXsecOverSMWZ -P r_TTW -P r_TTZ --floatOtherPOIs=1 --saveInactivePOI=1 --robustFit=1 --minimizerTolerance=0.01 --do95=1 --rMin=-2 --rMax=4