#### Single top, Wt combination + plans for legacy paper

#### LHCtopwg

Reinhard Schwienhorst Michigan State University Abideh (Nadjieh) Jafari Université Catholique de Louvain



LHC top WG meeting, 17 May 2016



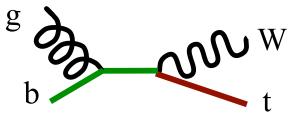






- Wt cross-section combination at 8 TeV
- Not-yet updated single top summary plots
- Plans for Vtb combination

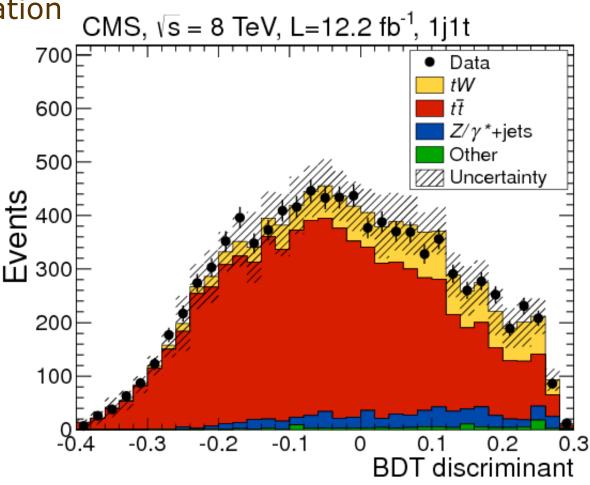
Combination of single top Wt cross-sections at 8 TeV



- Update to previous combination ATLAS-CONF-2014-052; CMS-PAS-TOP-14-009
  - Fall 2014: combination of CMS publication and ATLAS preliminary result at 8 TeV
    - ▶ 25.0 ± 1.4 ± 4.4 ± 0.7 pb (18.7%)
- Now: Updated ATLAS input
   JHEP01(2016)064
- Same procedure as before
  - Iterative BLUE
- Small update to systematic uncertainty categories
  - ATLAS result follows LHC top WG recommendations for theory uncertainties
    - https://indico.cern.ch/event/340357/sessions/153187
    - https://twiki.cern.ch/twiki/bin/view/LHCPhysics/TheorySystematics

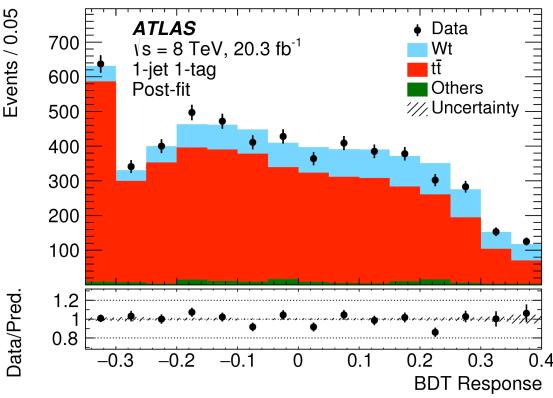
#### CMS result

- 8 TeV, 12.2 fb<sup>-1</sup>, ee, eµ, µµ, 1-jet and 2-jet with b-tag
- Boosted decision trees to isolate signal
- Profiling experimental systematics, not theory modeling
- Including uncertainty due to top quark mass
  - -9%, corresponding to 2 GeV shift
  - Not considered in combination
- Cross section
   23.4 ± 5.4 pb (23%)
- 6.1 s.d. significance
- PRL 112 (2014) 23180
  - Analysis from 2013
  - Final 8 TeV result for Wt



### ATLAS result

- 8 TeV, 20 fb<sup>-1</sup>
- Dilepton final state (ee, µµ, eµ)
- One or two b-quark jets
- Boosted decision trees
- Theory systematic uncertainties according to LHC top WG
- Roostats profile likelihood fit to extract cross-section
  - Profile all systematic uncertainties
  - Verified that systematic uncertainty determination gives the same result despite different methods used by ATLAS and CMS
- Cross-section measurement
  - $23.0 \pm 1.3 (\text{stat.})^{+3.2}_{-3.5} (\text{syst.}) \pm 1.1 (\text{lumi.}) \text{ pb}$
  - 16% uncertainty
  - 7.7 $\sigma$  significance
- JHEP01 (2016) 064



#### Systematic uncertainties and correlations

Category	ATLAS		CMS		ρ
Theory modeling	ISR/FSR	8.8%	Ren./fact. scale	12.4%	1.0
	NLO matching method	2.5%			_
	Parton shower	1.7%	ME/PS match. thr.	14.1%	1.0
	PDF	0.6%	PDF	1.7%	1.0
	Wt/tt overlap	3.5%	DR/DS scheme	2.1%	1.0
			Top $p_{\rm T}$ reweight.	0.4%	—
Category subtotal	10.0%		19.0%		0.75
Background normalization	bkg. mod.	2.8%	$t\bar{t}$ cross section	1.7%	0.0
			Z+jets	2.6%	—
Category subtotal	2.8%		3.1%		0.0
Jets	JES common	5.3%	JES	3.8%	0.0
	JES flavour	1.9%			
	Jet id	0.2%			
	Jet res.	6.5%	Jet resolution	0.9%	0.0
Category subtotal	8.6%		3.9%		0.0
Detector modeling	Lepton modeling	3.0%	Lepton modeling	1.8%	0.0
	MET scale	5.5%	MET modeling	0.4%	0.0
	MET resolution	0.2%			
	b-tagging	1.0%	b tagging	0.9%	0.0
	Pileup	2.7%	Pileup	0.4%	0.0
Category subtotal		6.9%		2.0%	0.0
Total		16.8%		21.7%	0.40

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#### Wt cross-section combination

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Iterative BLUE
Weights:

ATLAS 0.70
CMS 0.30

chi2 = 0.01
p-value 0.94

LHC*top*WG **ATLAS+CMS** Preliminary May 2016 Data 2012, √s = 8 TeV, m = 172.5 GeV total stat NLO+NNLL (PRD82 (2010) 054018) MSTW2008<sub>NNLO</sub> scale uncertainty scale ⊕ PDF uncertainty  $\sigma_{wt} \pm (stat) \pm (syst) \pm (lumi)$ ATLAS,  $L_{int} = 20.3 \text{ fb}^{-1}$ 23.0 ± 1.3 ± 3.5 ± 1.1 pb arXiv:1510.03752 CMS,  $L_{int} = 12.2 \text{ fb}^{-1}$  $23.4 \pm 2.0 \pm 4.6 \pm 0.7 \text{ pb}$ PRL 112 (2014) 231802 LHC combined (May 2016) **23.1** ± **1.1** ± **3.3** ± **0.8** pb ATLAS-CONF-2016-023, CMS-PAS-TOP-15-019 Effect of LHC beam energy uncertainty: 0.38 pb (not included in the figure) 0 10 20 30 40 50  $\sigma_{Wt}$  [pb]

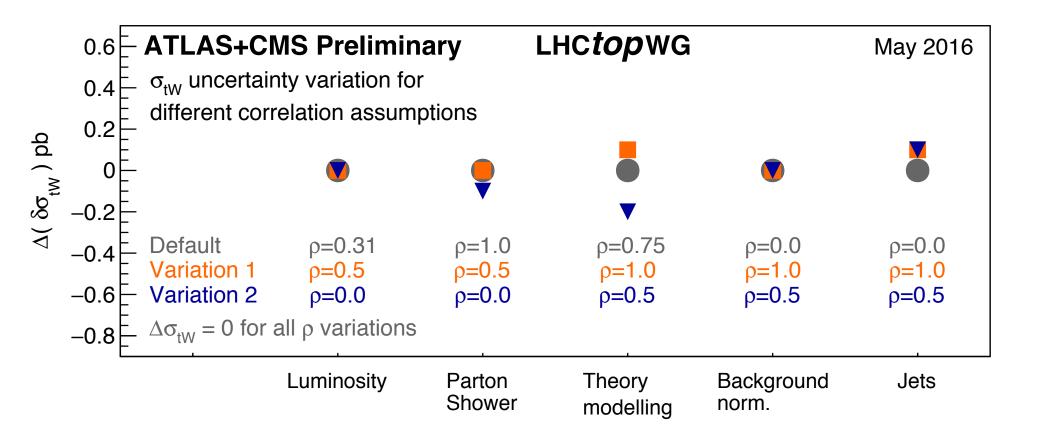
#### Uncertainty breakdown for combined result

Source	Uncertainty		]
Source	(%)	(pb)	]
Data statistics	4.7%	1.1	
Simulation statistics	0.8%	0.2	
Luminosity	3.6%	0.8	
Theory modeling	11.8%	2.7	
Background normalization	2.2%	0.5	
Jets	6.2%	1.4	
Detector modeling	4.9%	1.1	
Total systematics (excl. lumi)	14.4%	3.3	]
Total systematics (incl. lumi)	14.8%	3.4	
Total uncertainty	15.6%	3.6	
Theory modelling source		Uncertainty	
Theory modelling source		(%)	(pb)
ISR/FSR, Scale		9.9	2.3
Parton shower, ME/PS mat	5.4	1.2	
PDF	0.9	0.2	
DR/DS	3.1	0.7	
Other theory modelling	1.8	0.4	
Total theory modelling	11.8	2.7	

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#### Stability checks

- Vary correlation assumption for important systematic uncertainties
  - or uncertainty categories
- Result very stable
  - Central value unchanged



# |V<sub>tb</sub>| determination

- tW cross section is proportional to |Vtb|<sup>2</sup>
- ⇒ Direct determination of |Vtb|
  - Divide experimental cross-section by theory prediction
     NLO+NNLL (PRD82 (2010) 054018)
  - No assumptions about # of generations or CKM unitarity
  - Only assume that top decay is dominated by |Vtb|
  - -tW provides additional information beyond t-channel
- Additional uncertainties
  - Theoretical cross-section (2.3 pb)
  - Top quark mass (1.1 pb, corresponding to shift of 1 GeV)
  - Beam energy (0.38 pb)
- Result for |V<sub>tb</sub>|:

 $|f_{\rm LV}V_{tb}| = 1.02 \pm 0.09$ 

#### <u>Coming soon:</u> <u>Updated single top summary plots</u>

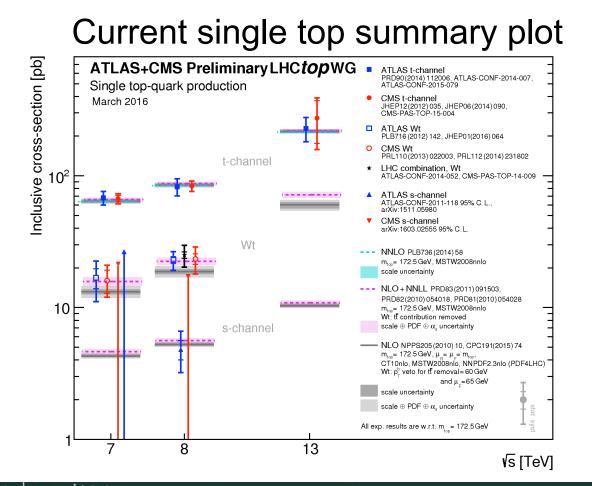
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Coming soon: updated summary plot

- Updated Wt combination at 8 TeV
- CMS t-channel updated at 13 TeV (TOP-16-003)
   15% uncertainty
- Show limits from individual 7 TeV and 8 TeV fits and combined fit for CMS s-channel



#### Coming soon: updated Vtb summary

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- Updated Wt combination at 8 TeV
- CMS t-channel updated at 13 TeV (TOP-16-003)
  - 7% uncertainty on  $|f_LV_{tb}|$

#### **Current Vtb summary**

ATLAS+CMS Preliminary	LHC <i>top</i> WG	March 2016			
$ f_{LV}V_{tb}  = \sqrt{\frac{\sigma_{meas}}{\sigma_{heo}}}$ from single top quark production					
σ <sub>theo</sub> : NLO+INNLL MST W2008nnio PRD83 (2011) 091503, PRD82 (2010) PRD81 (2010) 054028	054018,				
$\Delta \sigma_{\text{theo}}$ : scale $\oplus$ PDF		total theo			
m <sub>top</sub> = 172.5 GeV		$ f_{LV}V_{tb}  \pm (meas) \pm (theo)$			
t-channel:					
ATLAS 7 TeV <sup>1</sup> PRD 90 (2014) 112006 (4.59 fb <sup>-1</sup> )	┝─┼═┼─┨ ┋	$1.02 \pm 0.06 \pm 0.02$			
ATLAS 8 TeV ATLAS-CONF-2014-007 (20.3 fb <sup>-1</sup> )	<mark>⊦</mark> 1	$0.97 \pm 0.09 \pm 0.02$			
CMS 7 TeV JHEP 12 (2012) 035 (1.17 - 1.56 fb <sup>-1</sup> )	<b>⊢</b> ∎•⊢-1	$1.020 \pm 0.046 \pm 0.017$			
CMS 8 TeV JHEP 06 (2014) 090 (19.7 fb <sup>-1</sup> )	⊢ <mark>+●</mark> -1	$0.979 \pm 0.045 \pm 0.016$			
CMS combined 7+8 TeV JHEP 06 (2014) 090	<mark>⊨+++</mark>	0.998 $\pm$ 0.038 $\pm$ 0.016			
CMS 13 TeV CMS-PAS-TOP-15-004 (42 pb <sup>-1</sup> )	<b>↓</b>	1.12 ± 0.24 ± 0.02			
ATLAS 13 TeV ATLAS-CONF-2015-079 (3.2 fb <sup>-1</sup> )	⊧ <del></del>	$1.03 \pm 0.11 \pm 0.02$			
Wt:					
ATLAS 7 TeV PLB 716 (2012) 142-159 (2.05 fb <sup>-1</sup> )	<b>⊢</b>	$1.03  {}^{+ 0.15}_{- 0.18} \pm 0.03$			
CMS 7 TeV PRL 110 (2013) 022003 (4.9 fb <sup>-1</sup> )	F1	$1.01^{+0.16}_{-0.13} \ -0.04$			
ATLAS 8 TeV (*) ATLAS-CONF-2013-100 (20.3 fb <sup>-1</sup> )	+++++++++++++++++++++++++++++++++++++++	$1.10 \pm 0.12 \pm 0.03$			
CMS 8 TeV <sup>1</sup> PRL 112 (2014) 231802 (12.2 fb <sup>-1</sup> )		$1.03 \pm 0.12 \pm 0.04$			
LHC combined 8 TeV <sup>1,2</sup> ATLAS-CONF-2014-052, CMS-PAS-TOP-14-009	<mark>⊢ + <del>-</del> + − −</mark> 1	$1.06 \pm 0.11 \pm 0.03$			
s-channel:					
ATLAS 8 TeV <sup>2</sup> arXiv:1511.05980 (20.3 fb <sup>-1</sup> )		$0.93^{+0.18}_{-0.20}\pm0.04$			
Wt:					
ATLAS 8 TeV <sup>1.2</sup> JHEP 01 (2016) 064 (20.3 fb <sup>-1</sup> )	┣──┼═┼──┨	$1.01 \pm 0.10 \pm 0.03$			
(*) Superseded by results shown below	/ the line	<sup>1</sup> including top-quark mass uncertainty <sup>2</sup> including beam energy uncertainty			
0.4 0.6 0.8	3 1 1.2	1.4 1.6 1.8			
f <sub>LV</sub> V <sub>tb</sub>					

#### Reinhard Schwienhorst

#### Plans for Vtb

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## Vtb combination plans

- $\bullet$  Single top-quark production cross-sections are proportional to  $|V_{tb}|^2$
- $\bullet$  Extract value for  $|f_L V_{tb}|^2$  by dividing experimental measurement by theory prediction
- $\bullet$  Combine values for  $|f_L V_{tb}|^2$ 
  - Then take square root
- Publish as paper
  - Include published single top measurements
  - All 7 TeV and 8 TeV measurements
  - 13 TeV measurements only if published
- Should discuss theory predictions
  - Currently Hathor (NLO) for t-channel and s-channel, Kidonakis (NLO+NNLL) for Wt
    - Could switch to NNLO for t-channel
    - Could switch to NLO for Wt
  - Theory uncertainties
    - And their correlations

#### Vtb combination assumptions

- $\bullet$  Assume  $V_{ts}$  and  $V_{td}$  are negligible
  - In single top production
  - In top quark decay
- Assume coupling is left-handed vector coupling
  - SM-like kinematics
- No assumptions about CKM unitarity
  - Sensitivity to new physics
  - Top could be mixing with top partner or other NP particles
- For future ideas, see Orso's talk from last year <u>https://indico.cern.ch/event/403826</u>

#### Conclusions

- Final combination of ATLAS and CMS 8 TeV Wt cross-section measurements
  - Combination of published results
- Combined Wt cross-section measurements: 23.1  $\pm$  1.1  $\pm$  3.4  $\pm$  0.8 pb = 23.1  $\pm$  3.6 pb
- Result is stable against correlation variations
- Uncertainty of 15.6% compared to ATLAS: +15.9-16.9%
- $|f_{\rm LV}V_{tb}| = 1.02 \pm 0.09$
- Summary plots with updated Wt combination and latest CMS 13 TeV t-channel result will be approved soon
- Vtb combination in preparation
  - All channels and CM energies
  - Of published results