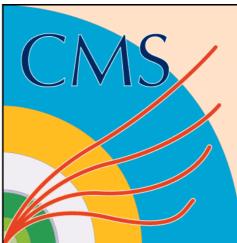




Status of "other" ongoing combinations

Jeremy Andrea, Veronique Boisvert **On behalf of the ATLAS and CMS top working groups**











- ATLAS-CMS combinations the main purpose of the LHCtopWG :
 - it allows to improve precisions of measurements,
 - but also to better compare results and understand the differences.
- In the past few years, several combinations performed, using usually the BLUE method with deep understanding of systematics and correlations.
- Ongoing/future combinations are going one step further :
 - Combination of more top-properties measurements, Ac (see <u>link</u>), top mass (see <u>link</u>), *V_{tb}* from single top cross section, W-helicity,
 - Associated production, $t\overline{t}b\overline{b}$ (see <u>link</u>);
 - Combination of differential measurements, Ac (see <u>link</u>), *t*t cross section,
 - New combination techniques, going beyond BLUE, inclusive $t\bar{t}$ cross section.

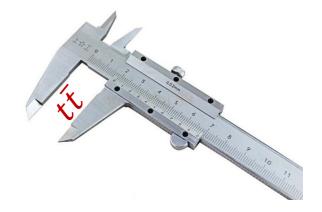
Discussed in this talk





tt inclusive cross section (Run I)

Contact persons : Barbara Alvarez Gonzalez, Veronique Boisvert (ATLAS) Jan Kiesler (CMS)

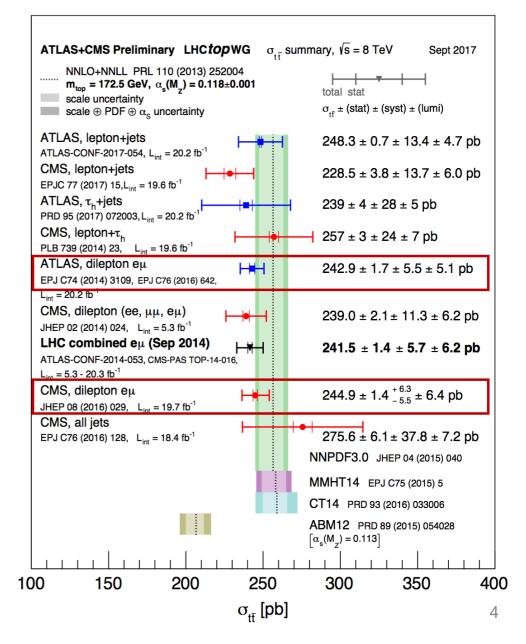




Latest results



ATLAS+CMS Preliminary LHC <i>top</i> WG	σ _{tī} summary, √ s = 7 TeV	May 201
NNLO+NNLL PRL 110 (2013) 252004		
$m_{top} = 172.5 \text{ GeV}, \ \alpha_{s}(M_{Z}) = 0.118 \pm 0.001$		
scale uncertainty	total stat	
scale \oplus PDF $\oplus \alpha_s$ uncertainty	$\sigma_{_{\rm ff}} \pm ({ m stat}) \pm ({ m syst}) \pm ({ m lumi})$	
	, , , , , , , , , , , , , , , , , , ,	
ATLAS, I+jets	179 $\pm 4 \pm 9 \pm 7$ pb	L _{int} =0.7 fb ⁻¹
ATLAS, dilepton (*)	173 $\pm 6^{+14}_{-11}$ + $^{8}_{-7}$ pb	L _{int} =0.7 fb ⁻¹
ATLAS, all jets (*)	167 ± 18 ± 78 ± 6 pb	L _{int} =1.0 fb ⁻¹
ATLAS combined	177 ± 3 ^{+ 8} _{- 7} ± 7 pb	L _{int} =0.7-1.0
CMS, I+jets (*)	$164 \pm 3 \pm 12 \pm 7 \text{ pb}$	L _{int} =0.8-1.1
CMS, dilepton (*)	170 ± 4 ± 16 ± 8 pb	$L_{int}=1.1 \text{ fb}^{-1}$
CMS, τ_{had} + μ (*)	$149 \pm 24 \pm 26 \pm 9 \text{ pb}$	$L_{int}=1.1 \text{ fb}^{-1}$
CMS, all jets (*)	$136\pm20\pm40\pm8~\text{pb}$	L _{int} =1.1 fb ⁻¹
CMS combined	166 \pm 2 \pm 11 \pm 8 pb	L _{int} =0.8-1.1
LHC combined (Sep 2012)	$173 \pm 2 \pm 8 \pm 6 pb$	L _{int} =0.7-1.1
ATLAS, I+jets, b \rightarrow X μ v \blacksquare	$165 \pm 2 \pm 17 \pm 3$ pb	L _{int} =4.7 fb ⁻
ATLAS, dilepton eµ, b-tag	$182.9 \pm 3.1 \pm 4.2 \pm 3.6 \text{ pb}$	L _{int} =4.6 fb ⁻
ATLAS, dilepton eμ, Ν _{jets} -E ^{miss}	■ 181.2 ± 2.8 ^{+9.7} _{-9.5} ± 3.3 pb	L _{int} =4.6 fb ⁻¹
ATLAS, thad+jets	194 ± 18 ± 46 pb	L _{int} =1.7 fb ⁻¹
ATLAS, all jets	168 ± 12 ⁺⁶⁰ ₋₅₇ ± 7 pb	L _{int} =4.7 fb ⁻¹
ATLAS, τ _{had} +I	183 ± 9 ± 23 ± 3 pb	L _{int} =4.6 fb ⁻¹
CMS, I+jets	161.7 ± 6.0 ± 12.0 ± 3.6 p	b L _{int} =5.0 fb ⁻
CMS, dilepton eµ Het	173.6 \pm 2.1 $^{+4.5}_{-4.0}$ \pm 3.8 pb	L _{int} =5.0 fb ⁻
CMS, τ _{had} +l	143 \pm 14 \pm 22 \pm 3 pb	L _{int} =2.2 fb ⁻
CMS, τ _{had} +jets	$152\pm12\pm32\pm3~pb$	L _{int} =3.9 fb ⁻
CMS, all jets	$139\pm10\pm26\pm3~pb$	L _{int} =3.5 fb ⁻
(*) Superseded by results shown below the line		10
	NNPDF3.0 JHEP 04 (2015) 04	Ю
	MMHT14 EPJ C75 (2015) 5	
	CT14 PRD 93 (2016) 033006	
	ABM12 PRD 89 (2015) 054028 [α _s (M _z) = 0.113]	
50 100 150	200 250 300	350
0	. <u>.</u> [pb]	

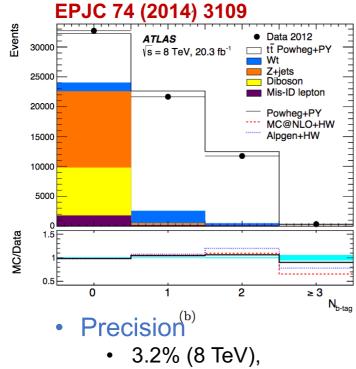


Most precise ATLAS and CMS results

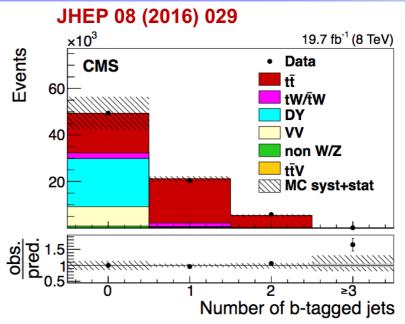


Inputs





- 3.5% (7 TeV).
- Dominant uncertainties
 - Luminosity,
 - Statistics (7 TeV),
 - Signal modelling and PDF,
 - tW background.



- Precision
 - 3.7% (8 TeV),
 - 3.6% (7 TeV).
- Dominant uncertainties
 - Luminosity,
 - Lepton ID/Iso,
 - Z+jets background,
 - Trigger,
 - Statistics (7 TeV).

Dominant exp. systematics are different between ATLAS and CMS. A significant gain can be expected.



Combination techniques Out of the BLUE



- Analysis strategies are different :
 - ATLAS : Simultaneous determination of fiducial cross section and b-tagging efficiency,
 - CMS : Multi-differential simultaneous fit of fiducial cross section at 7 and 8 TeV.
- BLUE not well suited for combination of measurements where the sources of systematics are significantly correlated (eg from a likelihood fit with multiple nuisance parameters).
- Move away from the BLUE combination, develop a more elaborated technique.
- New combination technique and tool ("Convino") has been developed (J. Kieseler, arXiv <u>1706.01681</u>, accepted by JHEP) and is being deployed :
 - Use postfit covariant matrices,
 - Account for correlations of systematics.
- Discussed within statistics committees at both ATLAS and CMS.

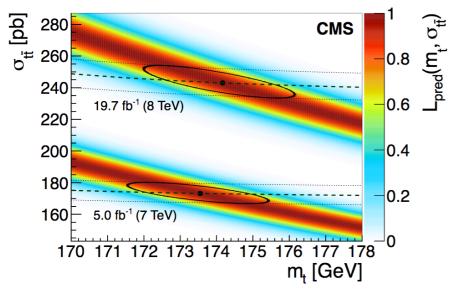




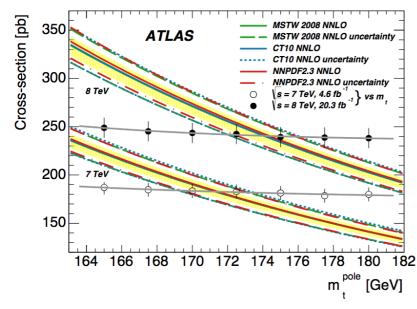
Status and Summary



EPJC 74 (2014) 3109



Eur. Phys. J. C 76 (2016) 642



- All ingredients of the combination are there:
 - inputs to the combination prepared (central values, covariance matrices, splitting of uncertainties),
 - combination method ready, accepted by EPJC and citable for the combination paper,
 - Complete results (not approved yet) results look very promising.

- Also extraction of pole mass and α_s investigated :
 - compare measurements to the theoretical cross sections $\sigma_{t\bar{t}}(m_t)$ or $\sigma_{t\bar{t}}(\alpha_s)$





Differential tt cross section (run I and run II)

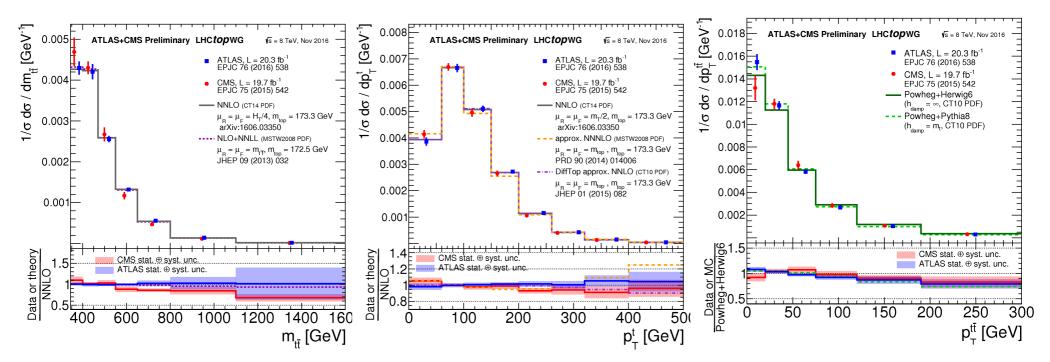
Contact persons : Run I : Francesco Spano (ATLAS), Maria Aldaya (CMS) Run II : James Howarth (ATLAS), Otto Hindrichs (CMS)



Differential cross section run 1



- Differential cross sections in $t\bar{t}$: crucial to better understand the modelling.
- Combination of the most precise measurements in I+jets :
 - Parton level,
 - Uses the same binning,
 - Uses the same phase space definition (fully inclusive phase space).



- Combination done with BLUE "a la Ac". Accounts for bin-by-bin correlations within and across experiments.
- Also testing the use of Convino together with J. Kieseler



Differential cross section run 2



- Challenges for run 2 combinations :
 - 1. Same definition of parton level (after radiation, before decay), to be checked carefully. Discussed at the last open meeting <u>link</u>,
 - 2. Also, different binnings are used.
- Possible solutions/investigated approaches :
 - 1. Compare the two definitions of parton-level using MC, determine a migration matrix,
 - 2. Agree on a similar binning for next measurements (possible two set of binnings, one following LHCtopWG recommendations). Existing tool for combination with different binning ?
- Other opportunity : particle level combination. Harmonization of particle level definitions required.







Single top cross section and V_{tb} combinations (Run I)

Contact persons : Carlos Escobar, Reinhard Schwienhorst (ATLAS) Nadjieh Jafari, Jeremy Andrea(CMS)



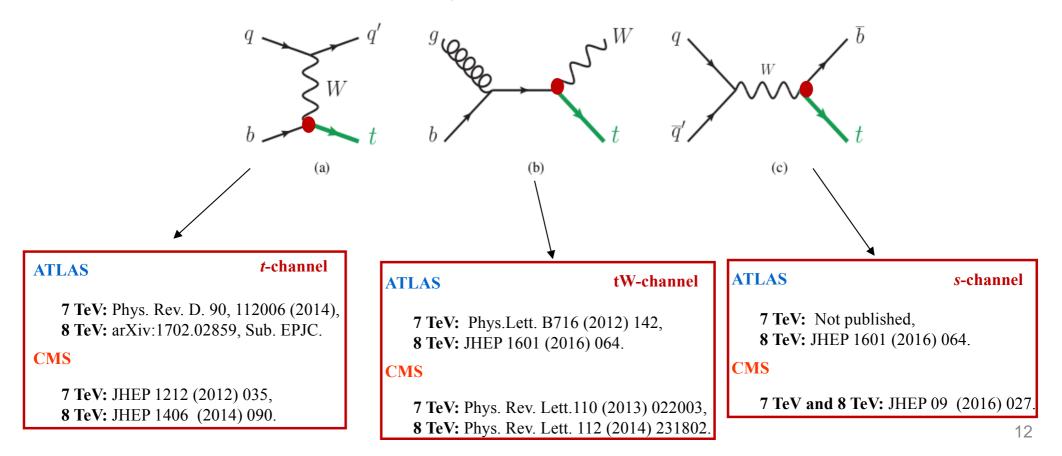
Single top cross section and V_{tb} combinations



- An estimator for the size of V_{tb} extracted from single top cross section measurements (assuming $|V_{tb}| >> |V_{ts}|$, $|V_{td}|$):

$$|f_{LV}V_{tb}|^2 = \frac{\sigma_{t,exp}}{\sigma_{t,theo}}$$

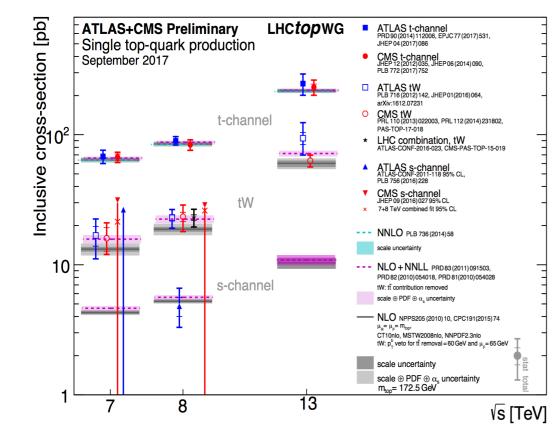
• The single top cross section, σ_t , determined for different channels:





Summary plots





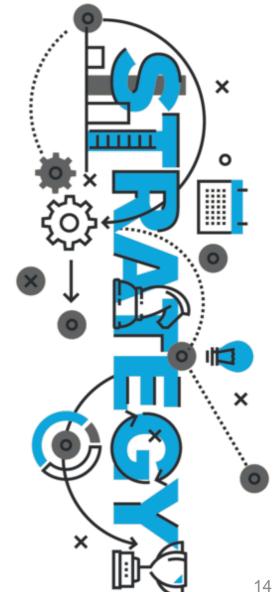
ATLAS+CMS Preliminary	LHC <i>top</i> WG	May 2017
$ f_{LV}V_{tb} = \sqrt{\frac{\sigma_{meas}}{\sigma_{theo}}}$ from single top qu	ark production	
σ _{theo} : NLO+NNLL MSTW2008nnlo PRD 83 (2011) 091503, PRD 82 (2 PRD 81 (2010) 054028	2010) 054018,	total theo
$\Delta \sigma_{\text{theo}}$: scale \oplus PDF		
m _{top} = 172.5 GeV		$ f_{LV}V_{tb} \pm (meas) \pm (theo)$
t-channel:	_	
ATLAS 7 TeV ¹ PRD 90 (2014) 112006 (4.59 fb ⁻¹)	⊢ ∔∎⊢-I	$1.02 \pm 0.06 \pm 0.02$
ATLAS 8 TeV ^{1.2} arXiv:1702.02859 (20.2 fb ⁻¹)	┝╪═┼┨	$1.028 \pm 0.042 \pm 0.024$
CMS 7 TeV	, <mark>Hiel</mark>	1.020 ± 0.046 ± 0.017
CMS 8 TeV JHEP 06 (2014) 090 (19.7 fb ⁻¹)	∕ ⊢ <mark>⊦●</mark> ₽-1	$0.979 \pm 0.045 \pm 0.016$
CMS combined 7+8 TeV JHEP 06 (2014) 090	<mark>⊢∔ë⊢1</mark>	$0.998\ \pm\ 0.038\ \pm\ 0.016$
CMS 13 TeV ² arXiv:1610.00678 (2.3 fb ⁻¹)	⊢ ∔●∔⊸1	$1.03 \pm 0.07 \pm 0.02$
ATLAS 13 TeV ² JHEP 04 (2017) 086 (3.2 fb ⁻¹)	<mark>⊧ ; =</mark> ;1	$1.07 \pm 0.09 \pm 0.02$
Wt:		0.45
ATLAS 7 TeV PLB 716 (2012) 142 (2.05 fb ⁻¹)		$1.03 {}^{+ 0.15}_{- 0.18} \pm 0.03$
CMS 7 TeV PRL 110 (2013) 022003 (4.9 fb ⁻¹)	⊢ → + + → → - - - - - - - - - -	$1.01^{+0.16}_{-0.13} \begin{array}{c} + 0.03 \\ - 0.04 \end{array}$
ATLAS 8 TeV ^{1,3} JHEP 01 (2016) 064 (20.3 fb ⁻¹)	⊢ <mark>⊨</mark>	$1.01 \pm 0.10 \pm 0.03$
CMS 8 TeV ¹ PRL 112 (2014) 231802 (12.2 fb ⁻¹)	<mark>⊢∔● ┼</mark> ┥	$1.03 \pm 0.12 \pm 0.04$
LHC combined 8 TeV ^{1,3} ATLAS-CONF-2016-023, CMS-PAS-TOP-15-019	<mark>► + ▼ + −</mark>	$1.02 \pm 0.08 \pm 0.04$
ATLAS 13 TeV ² arXiv:1612.07231 (3.2 fb ⁻¹)	▶ + ■ +	1.14 ± 0.24 ± 0.04
s-channel:		0.18
ATLAS 8 TeV ³ PLB 756 (2016) 228 (20.3 fb ⁻¹)		$0.93 {}^{+ 0.18}_{- 0.20} \pm 0.04$
		¹ including top-quark mass uncertainty ² σ _{thec} : NLO PDF4LHC11 ₃ NPPS205 (2010) 10, CPC191 (2015) 74 ₃ including beam energy uncertainty
0.4 0.6	0.8 1 1.2	1.4 1.6 1.8
	$ \mathbf{f}_{LV}\mathbf{V}_{tb} $	13



Strategy



- Combination of $|f_{IV}V_{tb}|^2$:
 - rely on the cross sections,
 - does not depends on the production mode nor the beam energy => combine all the channels at all (run I) energies,
 - predicted cross sections for t- and s-channels from HATHOR (NLO) and NLO+NLL (Kidonakis) for tW.
- Combination of cross sections :
 - done per production mode and per beam energies, 3 channels*2 beam energies (7+8TeV) -1 (8 TeV only for s-channel),
 - => 5 different combinations.
- Combination strategy :
 - use a simple and robust method : iterative BLUE method,
 - "usual" studies of correlations.
- Dominant sources of systematics in both experiments :
 - signal modelling, highly correlated among experiments,
 - Jet Energy Scale, not correlated.





Status of the paper



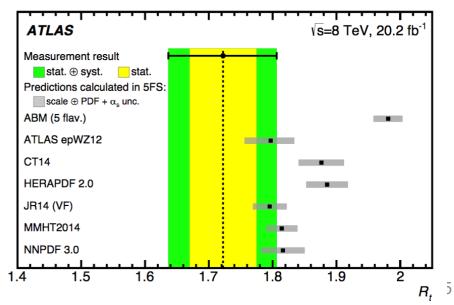
- Analysis pasted through almost all reviews steps of both collaborations.
 - ATL-COM-PHYS-2017-1039,
 - CMS-TOP-17-006.
- Authors are working on implementing the remaining (editorial) corrections to the paper draft, performing the remaining checks.

- Main open question : feasibility of combination of R_t (ratio of top and anti-top cross sections).
 - Gathering the needed inputs.
 - Understand (anti) correlations of systematic in the ratio.





Eur. Phys. J. C 77 (2017) 531







W helicity (Run I)

Contact persons : Mohammad Kareem (ATLAS) Mara Senghi (CMS)



W-helicity (run I)



- First plan for combing W-helicity fraction measurements.
- Baseline plan (under discussion)
 - combine the most precise measurements at 8 TeV,
 - use a BLUE method.
- Open questions :
 - should we include dilepton channels ? Single top ?
 - Should we include 7 and 8 TeV ?
 - Combination of e+jets and mu+jets (CMS) with I+jets (ATLAS) ?
 - BSM interpretation : still anomalous couplings or move to EFT ?

ATLAS+CMS Preliminary LHC <i>top</i> WG May 2017			▼ stat
Theory (NNLO QCD) PRD 81 (2010) 111503 (R)	F _R	FL	Fo
→ → Data $(F_R/F_1/F_0)$			
ATLAS 2010 single lepton, √ s=7 TeV, L _{int} =35 pb ⁻¹	⊪ • - +1	H - H	+
ATLAS 2011 single lepton and dilepton, Vs=7 TeV, L _{int} =1.04 fb ⁻¹	нн	H	⊢ ∔ <mark>≜</mark> ∔-I
CMS 2011 single lepton, √s=7 TeV, L _{int} =2.2 fb ⁻¹ * ^{CMS-PAS-TOP-11-020}		⊨+=+-1 k	 ▲
LHC combination, Is=7 TeV ATLAS-CONF-2013-033, CMS-PAS-TOP-12-025	HeH	H≡H	₽ ↓ ▲ ↓
ATLAS 2012 single lepton, √ s=8 TeV, L _{int} =20.2 fb ⁻¹ EPJC 77 (2017) 264		•	H-H
CMS 2011 single lepton, √s=7 TeV, L _{int} =5.0 fb ⁻¹ JHEP 10 (2013) 167	M	Hell	H
CMS 2012 single top, v s=8 TeV, L _{int} =19.7 fb ⁻¹	I el	H=H	H <mark>▲</mark> H
CMS 2012 single lepton, √ s=8 TeV, L _{int} =19.8 fb ⁻¹ PLB 762 (2016) 512	i.	-	ын
CMS 2012 dilepton, √s=8 TeV, L _{int} =19.7 fb ⁻¹	HH	H	Hall
CMS-PAS-TOP-14-017			







- Combination is the key for :
 - accessing higher precision,
 - better understand and compare ATLAS and CMS results.

• The LHCtopWG continues to be very active, with a large and ambitious program of combinations.

- What's next at 13 TeV ? Open for discussion.
 - $t\bar{t}$ inclusive and differential cross section, spin correlations ?
 - Single top t-channel, tW-channel ?
 - EFT ?

