



Single top ATLAS+CMS combinations

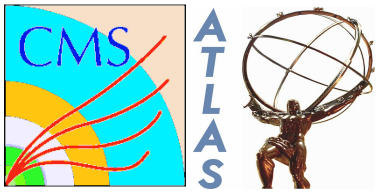
Open TOPLHCWG session

22/05/2014

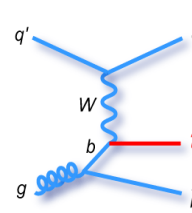
Alberto Orso Maria Iorio, Luca Lista, Julien Donini
for the CMS and ATLAS collaborations

Outline:

- t -channel: current combination, methodology and perspectives
- tW : available measurements and combination plans
- Perspective for a combined $|V_{tb}|$ measurement



t -channel single-top quark: current combination



- **First combination** of single-top quark measurements between **ATLAS** and **CMS**. The inputs can be found in:

ATLAS-CONF-2012-132

CMS-TOP-12-011

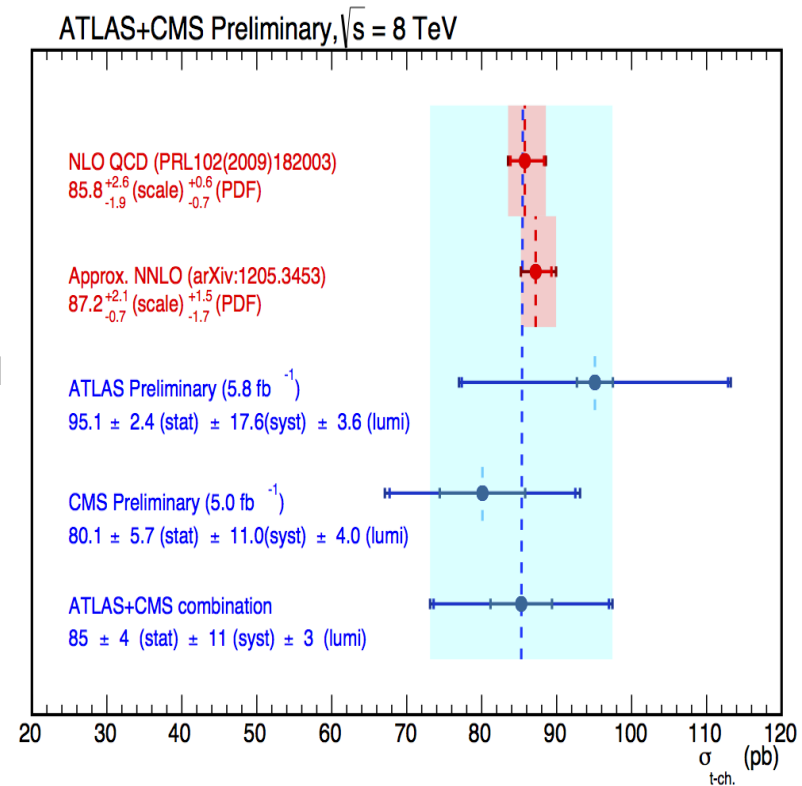
- Performed on preliminary results @ 8 TeV with data samples of 5.8 fb^{-1} (ATLAS) and 5.0 fb^{-1} (CMS)

- **Measurement precision improved by 10-20%**

- Combination performed with iterative blue, implemented with a dedicated code.

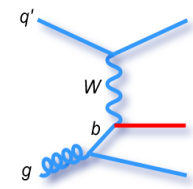
- **Resulting measurement:**
- $\sigma(t\text{-channel}) = 85 \pm 4 \text{ (stat)} \pm 11 \text{ (syst)} \pm 3 \text{ (lumi)} \text{ pb}$

CMS-TOP-12-002/ATLAS-CONF-2013-098



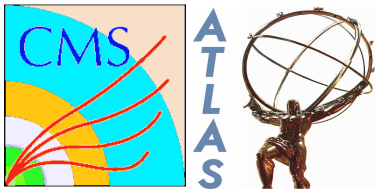


Combination strategy and main uncertainties

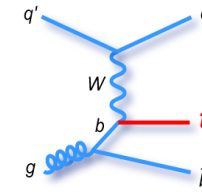


- **Main systematic Uncertainties :**
signal modeling and jet energy scale
- **Iterative BLUE:**
- BLUE method is applied and for each iteration, uncertainties are rescaled to the new results
- **Correlation between uncertainties:**
- Established source-by-source
- Stability tests performed varying the correlation for the dominant uncertainties

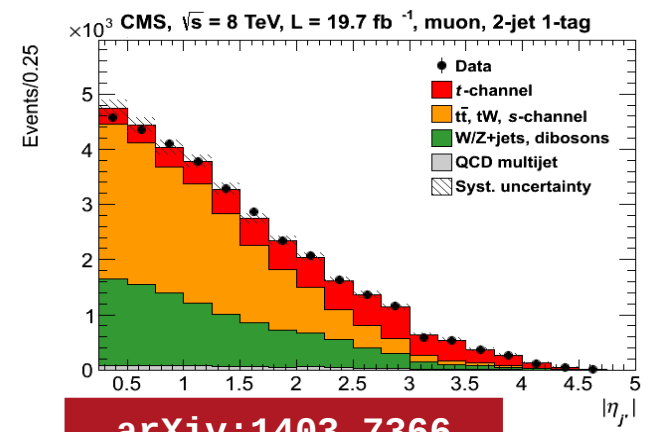
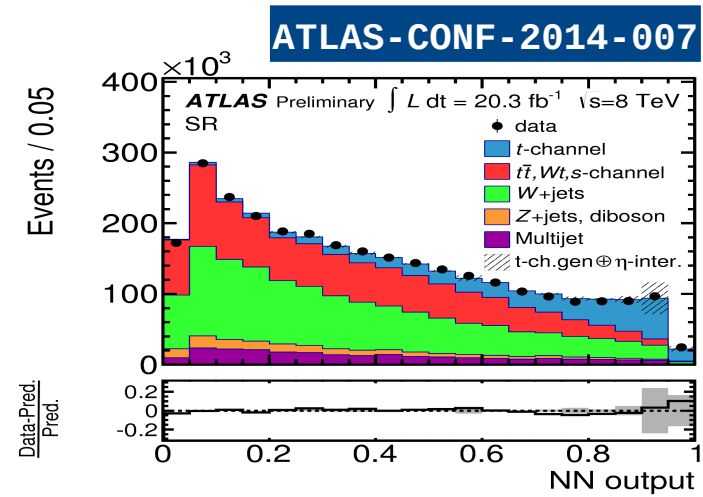
Category	ATLAS		CMS		ρ
Statistics	Stat. data	2.4%	Stat. data	7.1%	0
	Stat. sim.	2.9%	Stat. sim.	2.2%	0
Total	3.8%		7.5%		0
Luminosity	Calibration	3.0%	Calibration	4.1%	1
	Long-term stability	2.0%	Long-term stability	1.6%	0
Total	3.6%		4.4%		0.78
Simulation and modelling	ISR/FSR	9.1%	Q^2 scale	3.1%	1
	PDF	2.8%	PDF	4.6%	1
	t-ch. generator	7.1%	t-ch generator	5.5%	1
	tt generator	3.3%			0
	Parton shower/had.	0.8%			0
Total	12.3%		7.8%		0.83
Jets	JES	7.7%	JES	6.8%	0
	Jet res. & reco.	3.0%	Jet res.	0.7%	0
Total	8.3%		6.8%		0
Backgrounds	Norm. to theory	1.6%	Norm. to theory	2.1%	1
	Multijet (data-driven)	3.1%	Multijet (data-driven)	0.9%	0
			W+jets, tt (data-driven)	4.5%	0
Total	3.5%		5.0%		0.19
Detector modelling	b-tagging	8.5%	b-tagging	4.6%	0.5
	E_T^{miss}	2.3%	Unclustered E_T^{miss}	1.0%	0
	Jet Vertex fraction	1.6%			0
			pile up	0.5%	0
	lepton eff.	4.1%			0
			μ trigger + reco.	5.1%	0
	lepton res.	2.2%			0
	lepton scale	2.1%			0
Total	10.3%		6.9%		0.27
Total uncert.	19.2%		16.0%		0.38



Updated t -channel cross sections



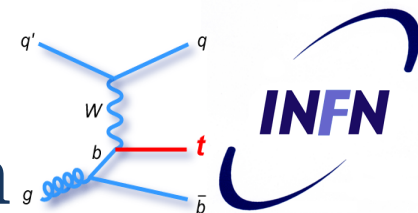
- **Both experiments** recently updated their respective cross section measurements at 8 TeV with 20 fb^{-1} of data
- **ATLAS** measures fiducial cross section using AcerMC (matched scheme) as nominal:
 - comparing with aMC@NLO to get modelling systematics
 - Scale and matching uncertainties are considered covered by the comparison with aMC@NLO
 - extrapolating to full phase space with aMC@NLO 4FS
 - $\sigma(t\text{-channel}) = 82.6 \pm 12.1 \text{ pb}$
- **CMS** measures total cross section using POWHEG 5FS as nominal:
 - Scales varied by factors 2/0.5
 - comparing with CompHEP (matched scheme) to get modelling systematics
 - $\sigma(t\text{-channel}) = 83.6 \pm 7.8 \text{ pb}$



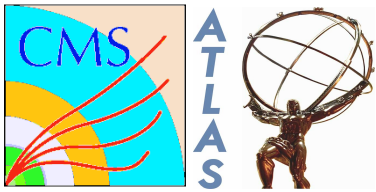
arXiv:1403.7366



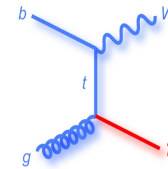
Status and perspectives of the t -channel combination



- Strategy will follow the steps of the previously approved combination
- **Modelling uncertainties** still to be made uniform (that will also be discussed also tomorrow in [Jose's talk](#))
- Assumptions used previously on the **b-tagging and JES will be reviewed**, e.g. using the definitions and categorisation from TOPLHCWG for JES and b-tagging uncertainties.
- Luminosity correlation will be updated as well
- **For the future measurements:**
 - converging on 2 \rightarrow 3 NLO generators for nominal samples
 - combination of other properties: R_t , V_{tb} ...
 - combination of 7 TeV, when legacy measurements will be ready.



tW single-top quark



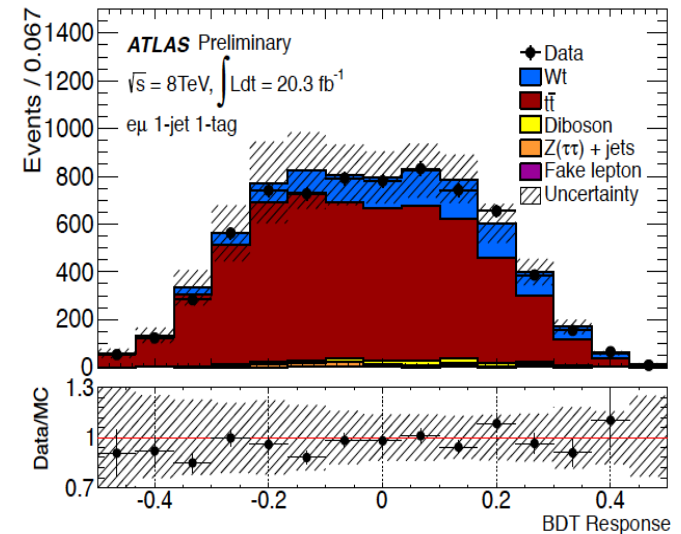
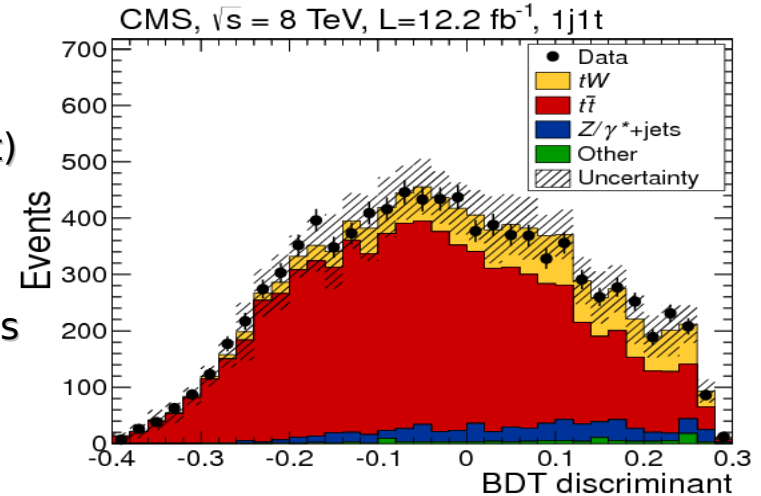
- **ATLAS** and **CMS** both reported evidence of associated production of a W boson and a single-top quark tW (or Wt)
- Data sample **dominated by large ttbar background**
- **Multivariate BDT discriminant** used by both analyses
- Combination of **8 TeV measurements**: larger data sample and higher significance

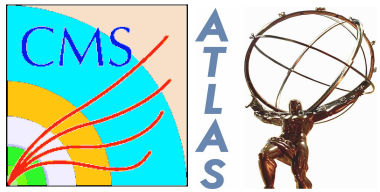
- **CMS:**
 - 12.2 fb⁻¹, all leptonic decays,
 - $\sigma(tW) = 23.4 +5.5 -5.4$ pb
 - 6.1 σ obs (5.4 +1.5-1.4 exp.)

arXiv:1401.2942

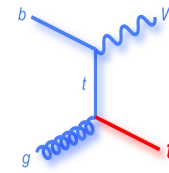
- **ATLAS:**
 - 20.3 fb⁻¹, μe only decays
 - $\sigma(tW) = 27.2 \pm 2.8$ (stat) ± 5.4 (syst) pb
 - 4.2 σ obs (4.0 exp.)

ATLAS-CONF-2013-100





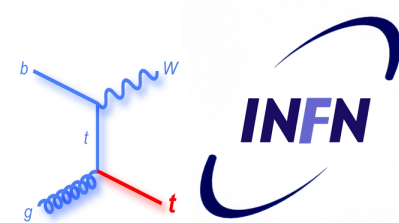
tW: combination strategy



- Using the same approach as the t -channel combination
- **Categorisation** of systematics by groups
- Adopting BLUE for the combination using a new implementation
- **Stability checks** to see robustness over the exact choice of correlations



Uncertainties categorisation



◦ **Plan to use same categories** as for the t-channel combination

- Statistics
- Luminosity
- Theory
- Jets
- Detector modeling

◦ **Signal modelling uncertainties:**

ISR/FSR and matching scheme for atlas, fact-renorm for CMS.

◦ **Luminosity and JES**

correlations **to be updated** wrt *t*-channel comb.

◦ **top mass uncertainty** is

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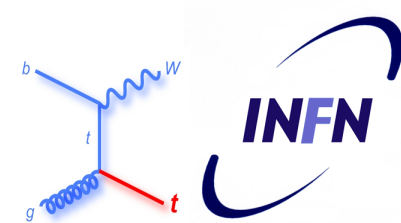
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	observed	expected
Data statistics	7.1	8.6
MC statistics	2.8	3.5
Experimental uncertainties		
Lepton modeling	2.4	2.4
Jet identification	0.2	0.6
Jet energy scale	10	12
<i>b</i> -jet energy scale	5.0	6.3
Jet energy resolution	0.7	0.2
E_T^{miss} scale	4.1	5.0
E_T^{miss} resolution	4.5	5.3
Flavor tagging	8.4	9.4
Theory uncertainties		
<i>Wt/t\bar{t}</i> overlap modeling	1.4	1.6
PDF	2.5	3.2
Background normalization	3.6	4.4
ISR/FSR	5.9	6.0
<i>Wt</i> generator and PS	11	11
<i>t\bar{t}</i> generator and PS	7.5	9.2
Luminosity	3.7	3.9
Total (syst)	20	23
Total (syst+stat)	21	24

CMS

Systematic uncertainty	$\Delta\sigma$ (pb)	$\Delta\sigma/\sigma$
ME/PS matching thresholds	3.3	14%
Renormalization/factorization scale	2.9	12%
Top-quark mass	2.2	9%
Fit statistical	1.9	8%
Jet energy scale	0.9	4%
Luminosity	0.7	3%
Z+jets data/simulation scale factor	0.6	3%
<i>tW</i> DR/DS scheme	0.5	2%
$t\bar{t}$ cross section	0.4	2%
Lepton identification	0.4	2%
PDF	0.4	2%
Jet energy resolution	0.2	1%
<i>b</i> -tagging data/simulation scale factor	0.2	<1%
$t\bar{t}$ spin correlations	0.1	<1%
Pileup	0.1	<1%
Top-quark p_T reweighting	0.1	<1%
E_T^{miss} modeling	0.1	<1%
Lepton energy scale	0.1	<1%
Total	5.5	24%



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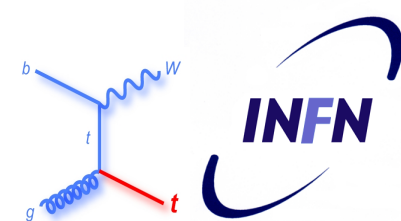
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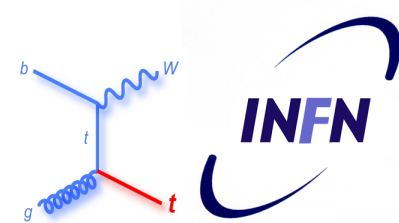
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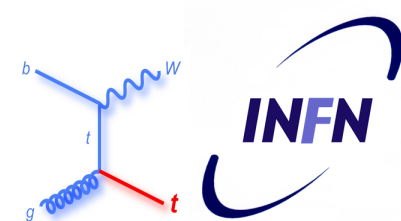
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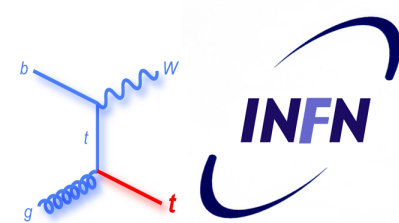
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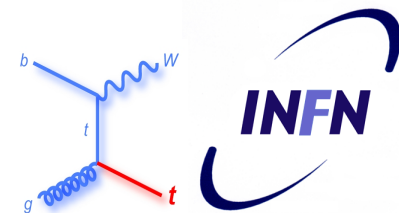
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tW: status and perspectives of the combination



- On the to do list: **JES** to be split by CMS, top **mass dependency** to be mentioned explicitly by ATLAS
- Combined significances is not the goal of this combination and will not be included this iteration although it would be possible to add some details on the profiling and test statistics for p-value determination.
- **Work is ongoing** to finalize the systematics harmonisation and the combination. **Stay tuned!**



Further combinations: V_{tb} measurements

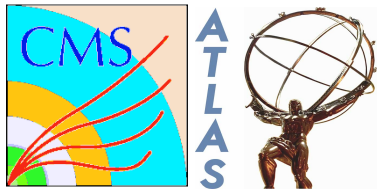


- All single-top channels cross section are sensitive to $|V_{tb}|$
- All single-top analyses present a $|V_{tb}|$ **measurement** assuming

$$|V_{td}|, |V_{ts}| \ll |V_{tb}| \rightarrow |V_{tb}| = \sqrt{(\sigma_{observed} / \sigma_{theo.})}$$

Analysis	$ V_{tb} $ measured
t-channel ATLAS, 8TeV	0.97 +0.09-0.10 (exp + theo)
t-channel CMS, 8TeV	0.978 ± 0.045 (exp) ± 0.016 (theo)
t-channel ATLAS, 7TeV	1.13 +0.14-0.13 (exp + theo)
t-channel CMS, 7TeV	1.020 ± 0.046 (exp) ± 0.017 (theo)
tW ATLAS, 8 TeV	1.10 ± 0.12 (exp) ± 0.03 (theo)
tW CMS, 8 TeV	1.03 ± 0.12 (exp) ± 0.04 (theo)
Tevatron, t+s channels (arXiv:0908.2171)	0.88 ± 0.07 (exp + theo)

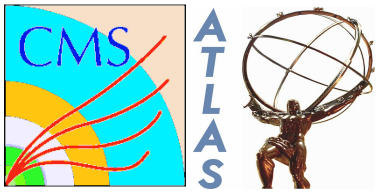
- **Combination of the cross sections** → can be used in the same way for $|V_{tb}|$
- **Combination in between channels and energies:** different modeling systematics between t-channel and tW!
- **This is a specific assumption:** can we define a set of cases for this measurement?



Conclusion and outlook



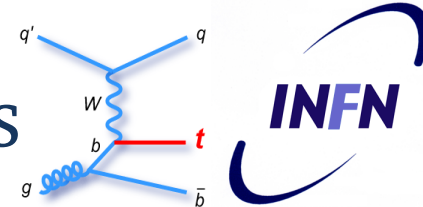
- **First t -channel combination was presented** already at top 2013: now needs to be updated after new results
- Some work will still be needed to correctly match systematics and define correlations
- Combination for tW production is on its way after the 8 TeV results, **harmonisation of systematics (m_{top} , but also $t\bar{t}$ modeling)** will be useful for the future analyses
- **Vtb combination:** several measurements available at **different centre-of-mass energies** and in **different channels!**



Backup



New t-channel uncertainties



ATLAS

Source	$\Delta\sigma_{td}/\sigma_{td}$ [%]
Data statistics	± 1.5
MC statistics	± 1.1
Multijet normalisation	+2.3-1.4
Other background normalization	± 0.8
JES η intercalibration	± 7.9
JES physics modelling	± 3.0
JES detector	< 0.5
JES statistical	< 0.5
JES mixed detector and modelling	< 0.5
JES single particle	< 0.5
JES pile-up	< 0.5
JES flavor composition	± 0.8
JES flavor response	± 0.5
b -JES	< 0.5
Lepton uncertainties	± 2.9
E_T^{miss} modelling	± 3.0
b -tagging efficiency	± 3.5
c -tagging efficiency	< 0.5
Mistag efficiency	< 0.5
Jet energy resolution	± 1.7
Jet reconstruction eff.	< 0.5
Jet vertex fraction	< 0.5
t -channel generator	± 7.9
W +jets generator	± 1.4
PDF	± 1.1
$t\bar{t}, Wt$ and s -channel generator	< 0.5
ISR / FSR ($t\bar{t}$)	< 0.5
Total Systematic	± 14
Total	± 14

CMS

Uncertainty source	$\sigma_{t\text{-ch.}}$ (%)
Statistical uncertainty	± 2.7
JES, JER, MET, and pileup	± 4.3
b -tagging and mis-tag	± 2.5
Lepton reconstruction/trig.	± 0.6
QCD multijet estimation	± 2.3
W +jets, $t\bar{t}$ estimation	± 2.2
Other backgrounds ratio	± 0.3
Signal modeling	± 5.7
PDF uncertainty	± 1.9
Simulation sample size	± 0.7
Luminosity	± 2.6
Total systematic	± 8.9
Total uncertainty	± 9.3
Measured cross section	$83.6 \pm 7.8 \text{ pb}$