Single top t-channel ATLAS+CMS combination

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Outline

- ATLAS and CMS single-top t-channel results
- Combination method
- Treatment of systematic uncertainties

- Results were not fully approved by both collaborations, so combined cross section will not be presented

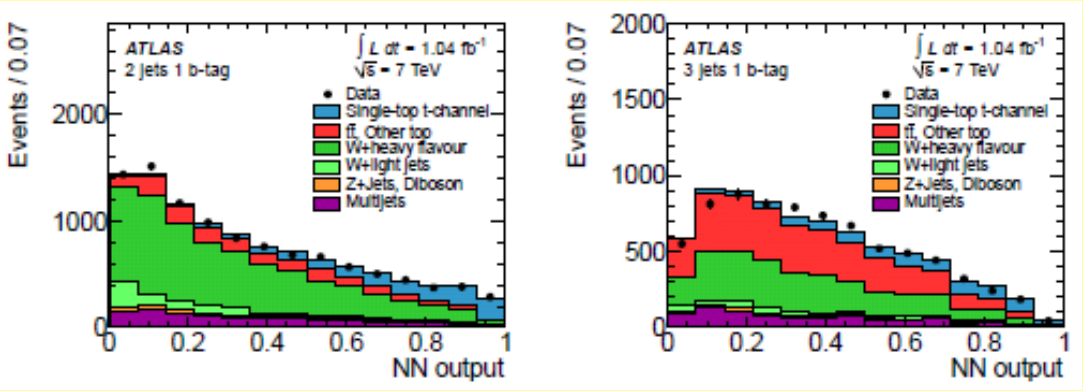
ATLAS t-channel results

Updated result (1,04 fb^{-1})
arXiv:1205.3130, sub. to PLB

- NN measurement: main result

→ lep+2/3-jet, exploit full NN shape

$$\sigma_t = 83 \pm 4\,(\text{stat.})\,^{+20}_{-19}\,(\text{syst.}) = 83 \pm 20\ \text{pb}$$



- Cut-based measurement: cross-check, separate top-antitop meas.

Source	$\Delta\sigma_{obs}/\sigma_{obs}$ [%] NN	cut-based
Data statistics	±5	±8
Detector modeling		
Jets	±6	+3/-4
b-tagging efficiency	±13	±12
Mistagging rate	±1	±1
Lepton	±2	±4
E_T^{miss}, calorimeter readout	±2	±2
Simulation		
PDF	±3	±4
Generator	±4	±7
Parton shower	±5	±11
ISR/FSR	±14	+19/-18
Forward jet modeling	+6/-4	+7/-5
MC statistics	±3	±4
Background normalisation		
Multijets	±4	±2
Other backgrounds	±1	±6
Luminosity	±4	±4
Total systematic uncertainties	+24/-23	+30/-27
Total uncertainty	+24/-24	+31/-28

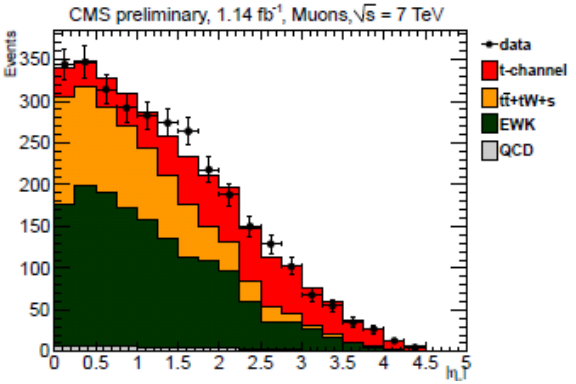
CMS t-channel results

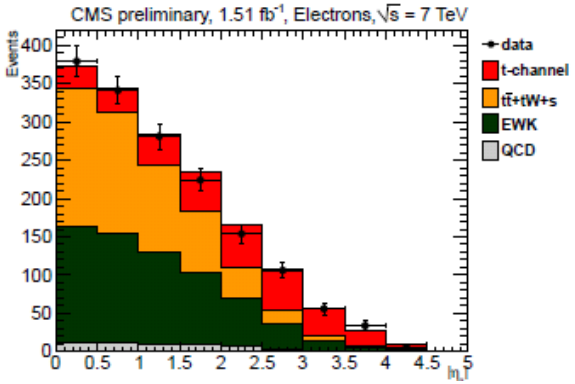
New Moriond result: 1.14/1.51 fb^{-1} (muon/electron)
CMS-PAS-TOP-11-021, update for journal paper in progress

- ML fit to the light jet pseudorapidity in 2-jet 1-tag events

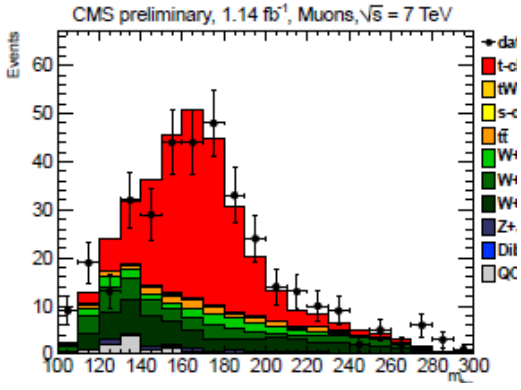
$$\sigma_{t-\mathrm{ch.}} = 70.2 \pm 5.2(\mathrm{stat.}) \pm 10.4(\mathrm{syst.}) \pm 3.4(\mathrm{lumi.})\ \mathrm{pb}$$

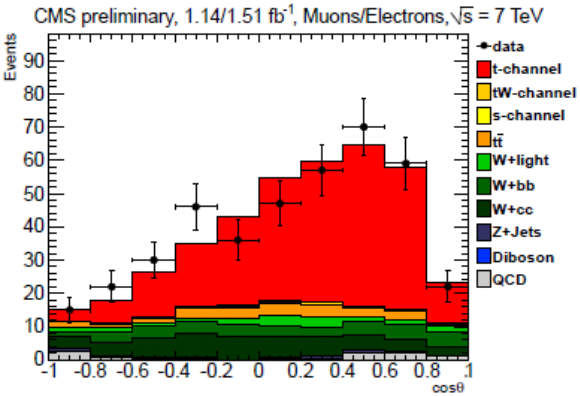
Data-driven: QCD, W+light, ttbar (rate),W+HF (shape)





Control plots ($|\eta_j'|>2.8$)





Uncertainty source	in pb	in %
Statistical	±5.2	±7.4%
W+heavy flavours extraction	±5.0	±7.1%
Jet energy scale	−4.4/+6.5	−6.2/+9.2%
Jet energy res.	−0.48/+0.87	−0.69/+1.2%
Unclustered $\not{E}_T$	±0.37	±0.53%
tt̄ rate	−2.4/+2.8	−3.5/+4.0%
Q^2, tt̄	−2.8/+1.5	−4.0/+2.1%
Q^2, t-channel	±4.9	±7.0%
t-channel generator	±3.5	±5.0%
Muon trigger + reco.	−1.1/+1.2	−1.5/+1.7%
Electron trigger + reco.	−0.53/+0.66	−0.76/+0.94%
Pile up	−0.23/+0.13	−0.33/+0.18%
QCD, muon	−0.67/+0.63	−0.95/+0.89%
QCD, electron	−0.26/+0.21	−0.37/+0.29%
s-, tW-channel, dibosons	±0.38	±0.54%
b-tagging	±2.2	±3.1%
Hadronic trigger	±0.95	±1.4%
PDF	±1.8	±2.5%
Total syst.	±10	±15%
Total	±12	±17%

Combination methodology

- Combination of measurements with BLUE
  - Best Linear Unbiased Estimator: L.Lyons et al. NIM A270 (1988) 110
    - Find linear combination of results: $x = \Sigma\, w_i x_i$
    - Weights minimize variance of estimator
    - Take properly into account correlations between measurements
    - Equivalent to χ^2 minimization = max. likelihood for Gaussian errors

Simple example:

- Two measurements: $x_1 \pm \sigma_1$, $x_2 \pm \sigma_2$ with correlation ρ
- The weights that minimize the χ^2:

Cov. matrix

$$\chi^2 = \begin{pmatrix} x_1 - x & x_2 - x \end{pmatrix} \begin{pmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix}^{-1} \begin{pmatrix} x_1 - x \\ x_2 - x \end{pmatrix}$$

are:

$$w_1 = \frac{\sigma_2^2 - \rho\sigma_1\sigma_2}{\sigma_1^2 - 2\rho\sigma_1\sigma_2 + \sigma_2^2} \qquad w_2 = \frac{\sigma_1^2 - \rho\sigma_1\sigma_2}{\sigma_1^2 - 2\rho\sigma_1\sigma_2 + \sigma_2^2} \qquad (w_1 + w_2 = 1)$$

Combination methodology

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    - Weights minimize variance of estimator
    - Take properly into account correlations between measurements
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Simple example:

- Two measurements: $x_1 \pm \sigma_1$, $x_2 \pm \sigma_2$ with correlation ρ
- The combined result is: $x = w_1 x_1 + w_1 x_2$
- And the uncertainty on the combined measurement is:

$$\sigma_x = \sqrt{\frac{\sigma_1^2 \sigma_2^2 (1-\rho^2)}{\sigma_1^2 - 2\rho\sigma_1\sigma_2 + \sigma_2^2}}$$

Uncertainty

- Identified 6 categories of common uncertainties (A)
- Estimated correlations of uncertainties between ATLAS and CMS
  - Based on our current knowledge
- Performed combination using BLUE method
- Vary correlation assumptions & perform stability check
  - Largest deviations are added to total uncertainty (B)

Source	Uncertainty (pb)	
Statistics	4.5	A
Luminosity	3.3	
Theory	8.0	
Jets	4.7	
Bkg sensitive to MC	4.2	
Detector modeling	3.0	
Total systematics (excl. lumi)	10.7	
Total uncertainty	12.0	
Uncertainty in ρ		B
Theory	1.5	
Jets	0.8	
b-tagging	0.7	
Iterative BLUE shift	1.0	
Total systematics (excl. lumi)	10.9	
Total uncertainty	12.2	

Uncertainties and correlations

Relative cross-section uncertainties

Category	ATLAS		CMS		ρ
Statistics	Stat. data	5.1%	Stat. data	7.4%	
	Stat. sim.	3.4%			
Total		**6.1%**		**7.4%**	**0**
Luminosity		**3.8%**		**4.7%**	**1**
Theory	ISR/FSR	13.9%	Q^2 scale	7.6%	
	Parton shower	5.0%			
	Generator	3.6%	Generator	5.0%	
	PDF	3.3%	PDF	2.5%	
			Cross sections	3.8%	
Total		**15.7%**		**10.2%**	**1**
Jets	*JES, light flavor*	5.2%	*JES, light flavor*	7.6%	0
	JES, heavy flavor	1.1%	*JES, heavy flavor*	1.5%	1
	JES (tot)	5.3%	JES (tot)	7.7%	0.04
	Jet res. & reco.	1.5%	Jet res.	1.0%	0
Total		**5.5%**		**7.8%**	**0.04**
Bkg sensitive to MC	$W\bar{b}b$, $W\bar{c}c$, Wc	**1.0%**	$W\bar{b}b$, $W\bar{c}c$, Wc	**7.1%**	**0**
Detector modeling	b-tagging	13%	b-tagging	3.1%	0
	$E_{\mathrm{T}}^{\mathrm{miss}}$	0.8%	$E_{\mathrm{T}}^{\mathrm{miss}}$	0.5%	0
	QCD norm.	4.4%	QCD norm.	1.0%	0
	lepton eff.	2.0%	lepton eff.	1.8%	0
	pile up	0.9%	pile up	0.3%	0
	Fwd jet modeling	5.2 %	had. trigger	1.2%	0
	Calorimeter readout	0.9 %			0
Total		**14.9%**		**4.0%**	**0**

Correlation (baseline values)

Current status

First combination (February)

• ATLAS EPS result (0.7 fb^{-1}) & CMS Moriond '11 result (0.036 fb^{-1})

$\sigma_{t-\mathrm{ch.}} = 90 \pm 9(\mathrm{stat.})^{+31}_{-20}(\mathrm{syst.})\ \mathrm{pb}$ ⊕ $\sigma_{t-\mathrm{ch.}} = 84 \pm 30(\mathrm{stat.} + \mathrm{syst.}) \pm 3(\mathrm{lumi.})$

= OMISSIS

Second combination (June)

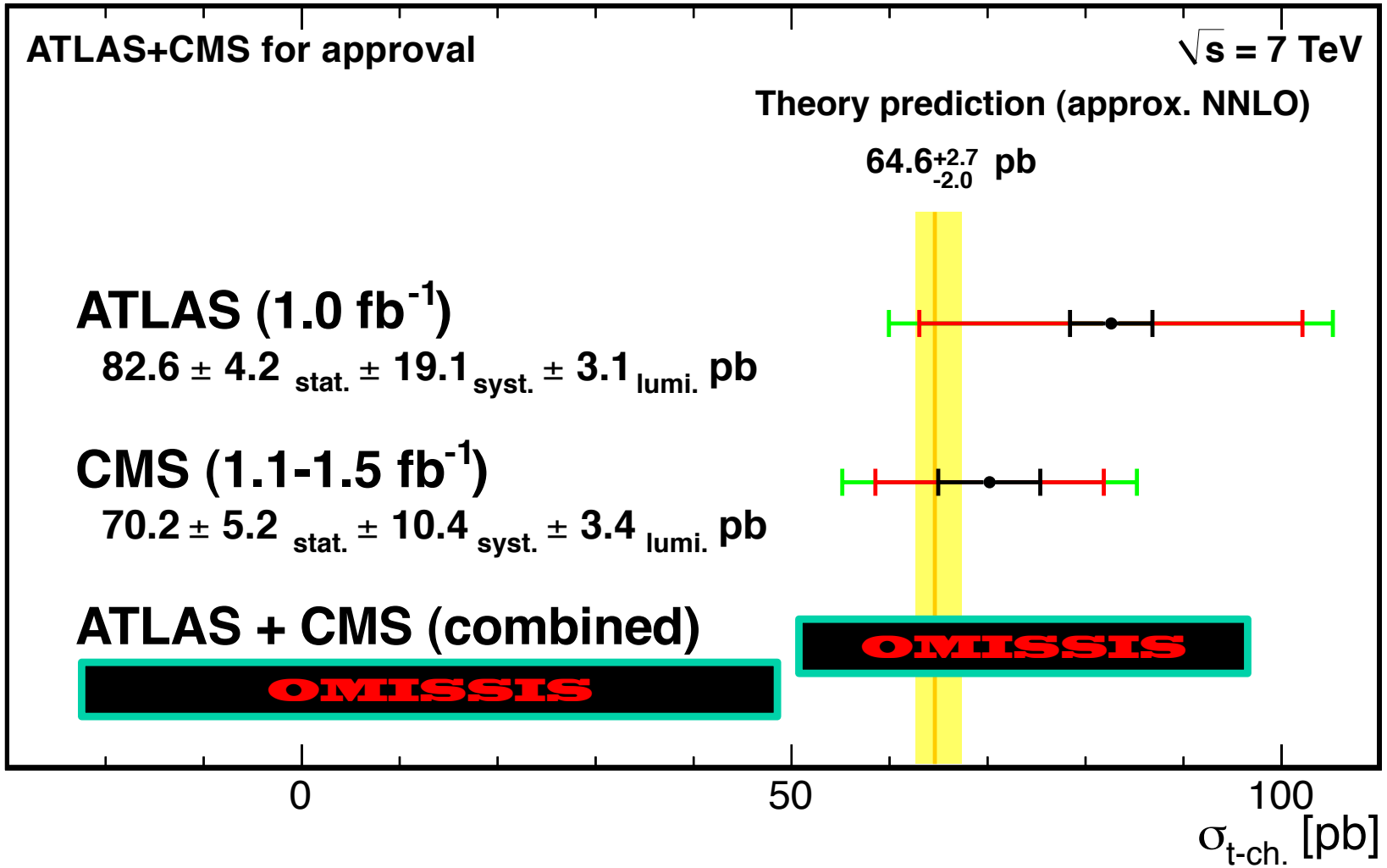
• ATLAS paper result (1.04 fb^{-1}) & CMS Moriond '12 result (1.14/1.51 fb^{-1})

$\sigma_{t-\mathrm{ch.}} = 83 \pm 4(\mathrm{stat.})^{+20}_{-19}(\mathrm{syst.})$ ⊕ $\sigma_{t-\mathrm{ch.}} = 70.2 \pm 5.2(\mathrm{stat.}) \pm 10.4(\mathrm{syst.}) \pm 3.4(\mathrm{lumi.})$

= OMISSIS

- Both approved by CMS but rejected by ATLAS because of ATLAS/CMS differences in treatment of systematics

Summary plot



Stat. and Lum. uncertainties

- Statistics category
  - CMS: negligible MC stat. error as most BG are data-driven
- Luminosity
  - Assume 100% correlation

Category	ATLAS		CMS		ρ
Statistics	Stat. data Stat. sim.	5.1% 3.4%	Stat. data	7.4%	
Total		**6.1%**		**7.4%**	**0**
Luminosity		**3.8%**		**4.7%**	**1**

Theoretical uncertainties

- Theory category
  - ATLAS and CMS followed different prescriptions:

Source	ATLAS	CMS
Top modeling	ISR/FSR for single-top and ttbar PS: Pythia vs Herwig	Q^2 scale: ttbar, t-channel, Wt No PS uncertainty
Generator	t-channel: AcerMC vs MCFM ttbar: MC@NLO vs Powheg	t-channel: Powheg vs Comphep
PDF	Included for all processes	Included for all processes
Cross section	N/A	Single-top (s,Wt), ttbar, diboson

Category	ATLAS		CMS		ρ
Theory	ISR/FSR	13.9%	Q^2 scale	7.6%	
	Parton shower	5.0%			
	Generator	3.6%	Generator	5.0%	
	PDF	3.3%	PDF	2.5%	
			Cross sections	3.8%	
Total		**15.7%**		**10.2%**	**1**

Jets uncertainties

- Jets category
  - Different approaches, in particular for b-JES uncertainty

Source	ATLAS	CMS
b-JES	Includes specific b-JES uncert.	Systematic derived from ratio in jet response in gluon and lq jets, derived using Pythia/Herwig
Jet reco & res.	Measured separately	Jet reco accounted in JES

Category	ATLAS		CMS		ρ
Jets	*JES, light flavor*	5.2%	*JES, light flavor*	7.6%	0
	JES, heavy flavor	1.1%	*JES, heavy flavor*	1.5%	1
	JES (tot)	5.3%	JES (tot)	7.7%	0.04
	Jet res. & reco.	1.5%	Jet res.	1.0%	0
Total		**5.5%**		**7.8%**	**0.04**

BG uncertainties

- BG determination sensitive to MC
  - Affects uncertainties on rate/shape of data-driven W+jets BG
  - Expected correlation due to generator assumptions (variable shape)

Source	ATLAS	CMS
W+HF: rate	Data-derived from control regions	Data sideband region
W+HF: kinematics	ALPGEN	Data sideband region

Category	ATLAS		CMS		ρ
Bkg sensitive to MC	$Wb\bar{b}$, $Wc\bar{c}$, Wc	**1.0%**	$Wb\bar{b}$, $Wc\bar{c}$, Wc	**7.1%**	**0**

Detector modeling

- Detector category
  - Uncertainties related to detector effects

Source	ATLAS	CMS
b-tagging	SF(b):10-15%, SF(light):20-50%	TCHP (~track counting) SF(b)<5%, SF(light):9-16%
Fwd jet modeling	Specific uncertainty to cover data/MC discrepancy	No mismodeling observed

Category	ATLAS		CMS		ρ
Bkg sensitive to MC	$W\bar{b}b$, $W\bar{c}c$, Wc	**1.0%**	$W\bar{b}b$, $W\bar{c}c$, Wc	**7.1%**	**0**
Detector modeling	b-tagging	13%	b-tagging	3.1%	0
	$E_{\mathrm{T}}^{\mathrm{miss}}$	0.8%	$E_{\mathrm{T}}^{\mathrm{miss}}$	0.5%	0
	QCD norm.	4.4%	QCD norm.	1.0%	0
	lepton eff.	2.0%	lepton eff.	1.8%	0
	pile up	0.9%	pile up	0.3%	0
	Fwd jet modeling	5.2 %	had. trigger	1.2%	0
	Calorimeter readout	0.9 %			0
Total		**14.9%**		**4.0%**	**0**

Test correlation assumptions

- Vary correlation factors ρ from baseline value
- Measure change of combined cross-section result w.r.t default value

Source	Default ρ	Test ρ	Shift: central value (pb)	Shift: uncertainty (pb)
Luminosity	1	0.5/0	+0.2/+0.3	-0.1/-0.7
Theory	1	0.5/0	+1.5/+0.9	-0.6/-1.4
Jets	0.04	1	-0.8	+0.1
BG MC	0	0.5/1	<0.1	<0.1
b-tagging	0	0.5/1	-0.3/-0.7	+0.1/+0.2

Checks of result stability

- Bias
  - Appear when uncertainties not Gaussians or when uncertainties and correlation are not exact value
  - Reduced if covariance matrix determined as if the central value is the one obtained from combination
    - Rescale uncertainties to combined value

      ex: for measurement 1, and category i: $\sigma_{i,1}^{rescaled} = \sigma_{i,1} \cdot x_1/x_{blue}$
    - Iterate until central value converges to stable value

Source	Shift: central value (pb)	Shift: uncertainty (pb)	weights
Iterative BLUE	+1.0	+0.22	w_{ATLAS}: +0.08

Status

- Single-top t-channel cross section combination effort started last October with the TOPLHC WG
- Two attempts at combining ATLAS/CMS result
  - Both approved by CMS but not by ATLAS
- Postponed presumably to next round of results at 7 TeV