Plans for ATLAS/CMS single-top combination(s)

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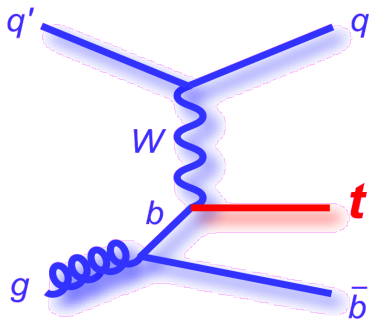
Julien Donini (LPC/Université Blaise Pascal – Clermont-Ferrand)
Luca Lista (INFN Napoli)

Objective

- Combination of single-top cross-section measurements

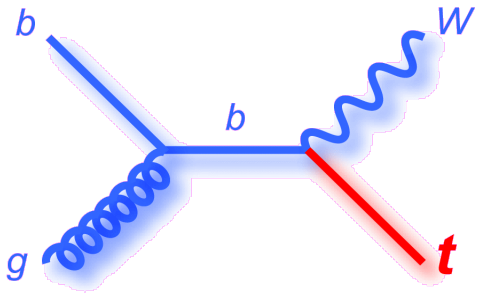
  → Test SM and search for BSM



t-ch

88pb @ 8 TeV

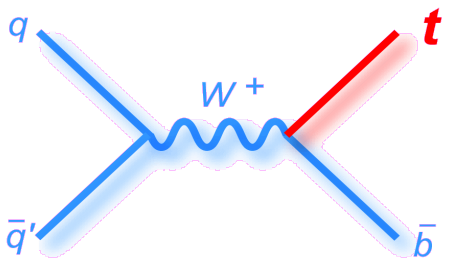
$V_{tb,}$ FCNC, anomalous couplings



W+t

22pb @ 8 TeV

$H^{\pm}$, process visible only at LHC



s-ch

5.6pb @ 8 TeV

$H^{\pm}$,W'

Status

First combination attempt

- t-channel xs measurement (1-1.5 fb^{-1} @ 7 TeV)
- Based on BLUE and mapping of common systematic categories
- Not approved
  - No improvement w.r.t CMS result alone
  - ATLAS measurement: large syst uncertainties (ISR/FSR, b-tagging)

Current status

- Recent results from both experiments
  - t-channel and Wt @ 7/8 TeV
  - Dominant uncertainties more uniform between ATLAS/CMS

t-channel @ 7 TeV

ATLAS

NN @ 1.04 fb^{-1}	PLB http://arxiv.org/abs/1205.3130
σ_t = 83 ± 4 (stat.) +20 -19 (syst) pb → **24%**	
|Vtb| = 1.13 +0.14 -0.13, |Vtb| > 0.75 @ 95 C.L	

NN @ 4.7 fb^{-1}	Conf note http://cdsweb.cern.ch/record/1453783
$\sigma_t(t)$ = 53.2 ± 10.8 pb and $\sigma_t(t^-)$ = 29.5 +7.4 −7.5 pb R_t= 1.81 +0.23 −0.22	
σ_t = 82.7 ± 18.1 pb → **22%**	

CMS

LL/BDT/NN @ 1.17 – 1.56 fb^{-1}	JHEP http://arxiv.org/abs/1209.4533
σ_t = 67.2 ± 3.7 (stat) ± 3.0 (syst) ± 3.5 (th) = 67.2 +- 6.1 pb → **9%**	
|Vtb|=1.020 +- 0.046 (exp) +- 0.017 (th), |Vtb|>0.92 @ 95 C.L	

No sizable gain expected by combination of these results

Combination method

- 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	
Luminosity	
Theory	
Jets	
Bkg sensitive to MC	
Detector modeling	
Total systematics (excl. lumi)	
Total uncertainty	
Uncertainty in ρ	
Theory	
Jets	
b-tagging	
Iterative BLUE shift	
Total systematics (excl. lumi)	
Total uncertainty	

Not public

A

B

Uncertainties and correlations

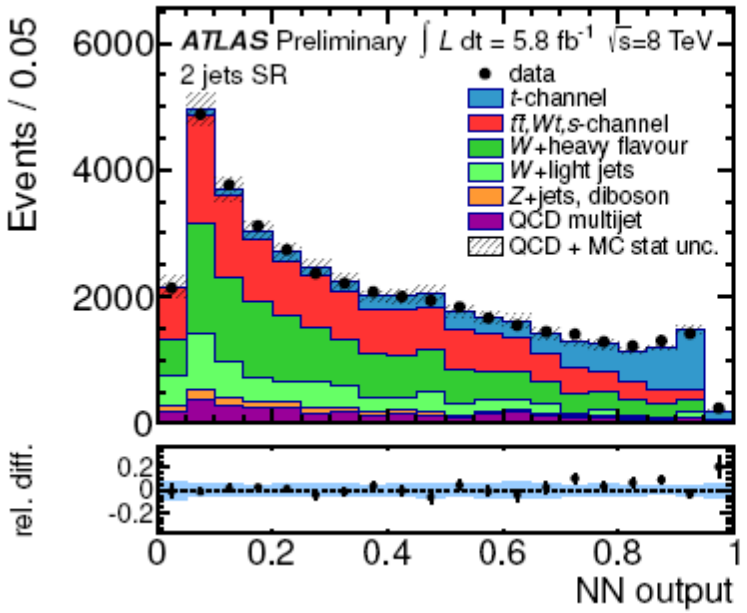
Relative x-section uncertainty

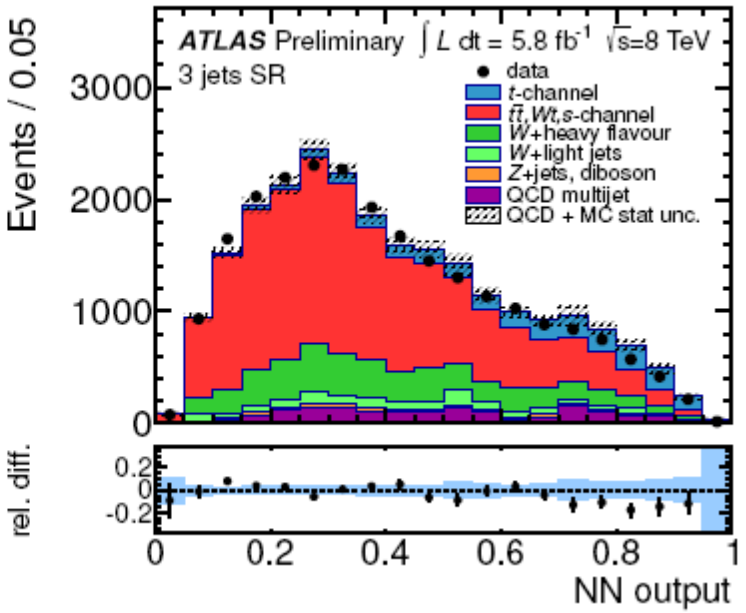
Correlation (default values)

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**

ATLAS

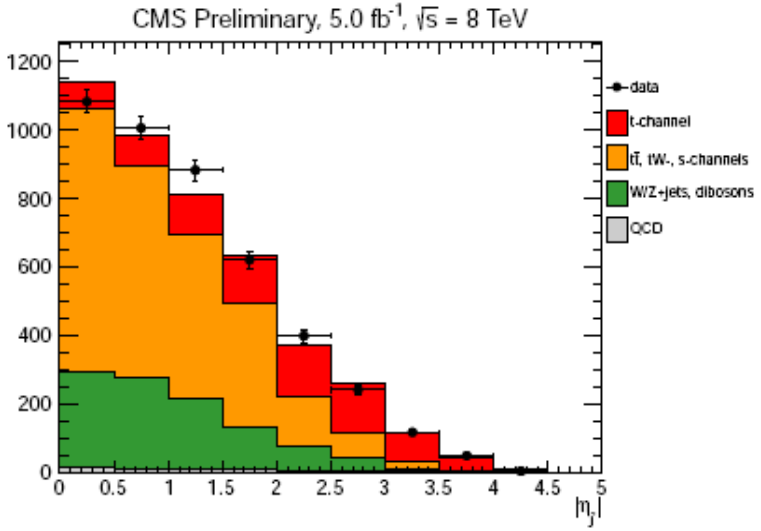
NN @ 5.8 fb^{-1}	Conf note: http://cdsweb.cern.ch/record/1478371
σ_t = 95 ± 2(stat.) ± 18(syst.) pb= 95 ± 18 pb → **19%**	
|Vtb| = 1.04 +0.10 −0.11, |Vtb| >0.80 @ 95 C.L.	





CMS

LL @ 5.0 fb^{-1}	Conf note: http://cdsweb.cern.ch/record/1478935
σ_t = 80.1 ± 5.7 (stat) ± 11.0 (syst.) ± 4.0 (lumi.) → **16%**	
|Vtb| = 0.96 +/- 0.08 (exp) +/- 0.02 (th)	



Both measurements show similar uncertainties

Combination of cross-sections result is ongoing (with BLUE)

W+top channel @ 7 TeV

ATLAS

BDT @ 2.0 fb^{-1}	PLB: http://arxiv.org/abs/1205.5764
σ_{Wt} = 16.8 ± 2.9 (stat) ± 4.9 (syst) pb → **sign. 3.3 σ**	
|Vtb| = 1.03 +0.16 -0.19	

CMS

BDT/CB @ 4.9 fb^{-1}	PRL: http://arxiv.org/abs/1209.3489
σ_{Wt} = 16 +5 -4 → **sign. 4.0 σ**	
|Vtb| = 1.01 ± 0.15 ± 0.04	

A combination would bring closer to observation

Reaching 5σ seems difficult

Investigate other combination method (likelihood)

Conclusion and plans

Single-top combination

- t-channel @ 7 TeV
  - no gain expected with current results
- t-channel @ 8 TeV:
  - combination of results ongoing
  - methodology well established (BLUE)
- Wt @ 7 TeV
  - 5σ seems difficult to reach. Wait for updated results
- Vtb combination
  - combine results from t- and Wt channel at 7 and 8 TeV.
  - longer term task.

Backup

BLUE method

- **Best Linear Unbiased Estimator:** L.Lyons et al. NIM A270 (1988) 110
  - Find linear (unbiased) combination of results: $x = \Sigma\, w_i x_i$

    with weights w_i that give minimum possible variance σ_x^2
  - Account properly of correlations between measurements

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:

$$w_1 = \frac{\sigma_2^2 - \rho\sigma_1\sigma_2}{\sigma_1^2 - 2\rho\sigma_1\sigma_2 + \sigma_2^2}$$

$$w_2 = \frac{\sigma_1^2 - \rho\sigma_1\sigma_2}{\sigma_1^2 - 2\rho\sigma_1\sigma_2 + \sigma_2^2}$$

$(w_1+w_2=1)$

BLUE method

- **Best Linear Unbiased Estimator:** L.Lyons et al. NIM A270 (1988) 110
  - Find linear (unbiased) combination of results: $x = \Sigma\, w_i x_i$

    with weights w_i that give minimum possible variance σ_x^2
  - Account properly of correlations between measurements

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:

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

t-channel @ 8 TeV

Uncertainty source	in pb	relative
Statistical	±5.7	±7.2 %
W+jets and $t\bar{t}$modeling	±3.6	± 4.5 %
JES	− 6.2 / + 4.7	− 7.8 / + 5.8 %
JER	− 0.8 / + 0.3	− 1.0 / + 0.4 %
Unclustered $\not{E}_T$	− 0.8 / + 0.7	− 1.0 / + 0.9 %
Pileup	− 0.5 / + 0.3	− 0.6 / + 0.4 %
Muon trigger + reconstruction	− 4.1 / + 4.0	− 5.1 / + 5.1 %
Q^2	±2.5	±3.1 %
$t\bar{t}$, rate	− 1.5 / + 1.7	− 1.9 / + 2.1 %
QCD, rate	±0.7	±0.9 %
t−channel generator	±4.4	±5.5 %
Other backgrounds, rate	±0.5	±0.6 %
b-tagging	±3.7	±4.6 %
PDF	± 3.7	±4.6 %
Simulation statistics	±1.8	±2.2 %
Total systematics	±11.0	±13.7 %
Luminosity uncertainty	±4.0	±5.0 %
Total	±13.0	±16.3%

Source	$\Delta\sigma_t/\sigma_t$ [%]
Data statistics	± 2.4
MC statistics	± 2.9
Background normalisation	± 1.5
QCD multijet normalisation	± 3.1
Jet energy scale	± 7.7
Jet energy resolution	± 3.0
Jet reconstruction	± 0.5
Jet vertex fraction	± 1.6
Mistag modeling	± 0.3
c-tagging efficiency	± 0.4
b-tagging efficiency	± 8.5
E_T^{miss}	± 2.3
Lepton efficiencies	± 4.1
Lepton energy resolution	± 2.2
Lepton energy scale	± 2.1
PDF	± 2.8
W+jets shape variation	± 0.3
W+jets extrapolation	± 0.6
t-channel generator	± 7.1
$t\bar{t}$ generator	± 3.3
ISR / FSR	± 9.1
Parton shower	± 0.8
Luminosity	± 3.6
Total systematic	± 18.8
Total	± 19.0