

Top quark production at ATLAS

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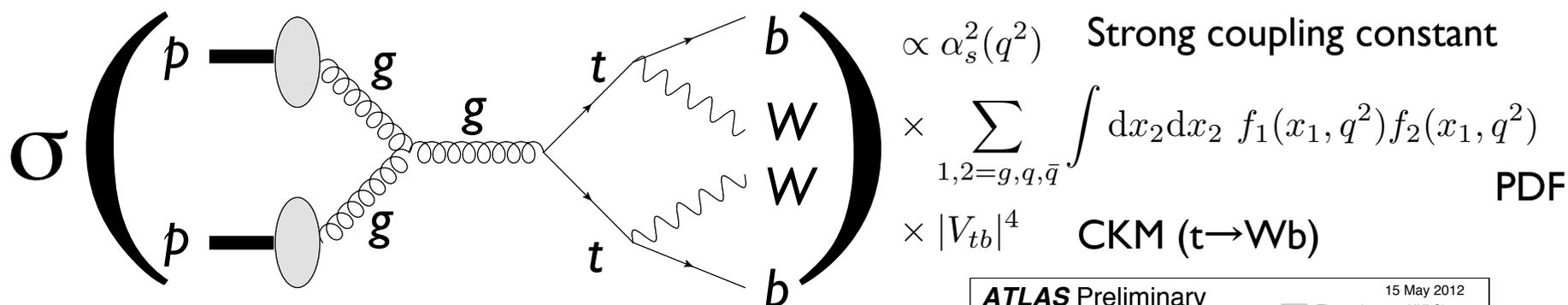
On behalf of the ATLAS collaboration

7, June, PLHC 2012 @ Vancouver

Introduction

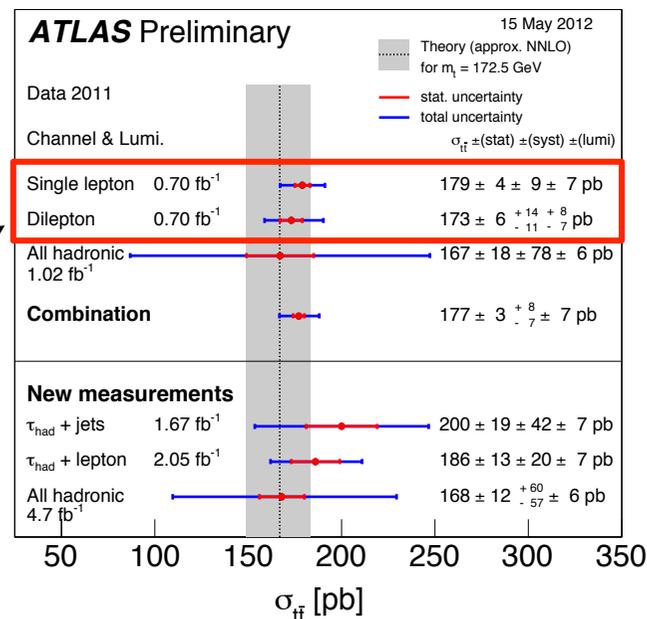
- LHC is the top quark factory**

- $\sigma_{tt} = 165 \text{ pb}$, $\sigma_t = 85 \text{ pb}$ @ NNLO approx.
- Provides an unique opportunity to test the SM @ high- q^2



- Precise measurement has been performed on σ_{tt}**

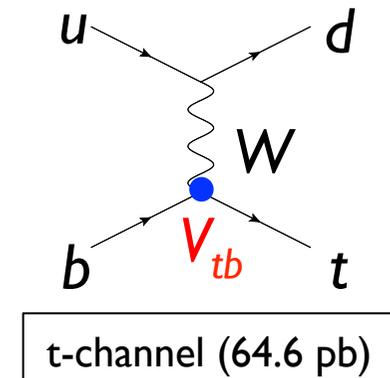
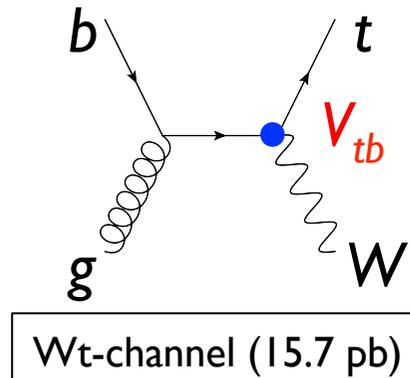
- Dilepton ($tt \rightarrow ll\nu\nu bb$) and Single-lepton ($tt \rightarrow lvjjbb$) channel
- Measured uncertainty (6%) < Theoretical accuracy (10%)



Physics Motivation

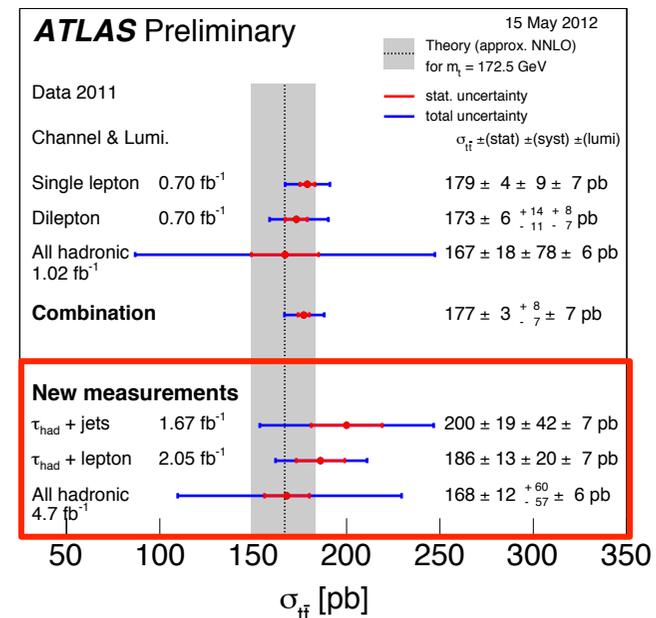
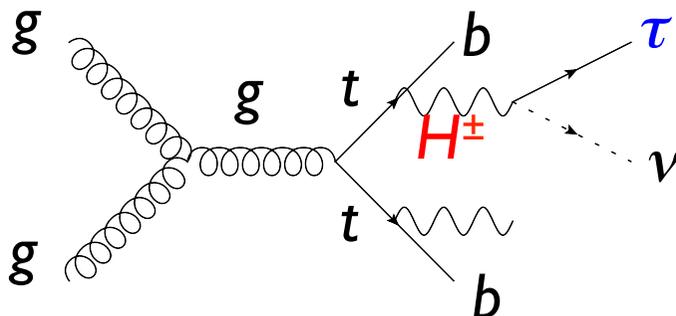
Validation of the SM \rightarrow Search for the new physics

- **Measurement of σ_t**
 - Direct measurement of V_{tb}
 - Wt-channel and t-channel



- **Measurement of σ_{tt} in alternative decay channel**

- e.g.) σ_{tt} in τ final state is sensitive to the charged Higgs boson



Single top Production Cross Section

Wt-channel (2.05 fb^{-1})

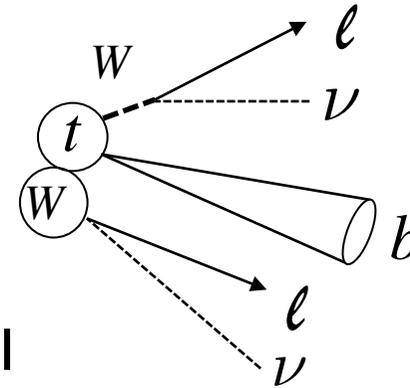
What's unique ?

- Sensitive to V_{tb}
- Not observed yet due to its small cross section @ Tevatron

Selection

Make use of di-leptonic decay

- 2 Opposite sign lepton
- ≥ 1 jet
- $E_T^{\text{miss}} > 50 \text{ GeV}$
- $|m_{\parallel} - m_Z| > 10 \text{ GeV}$ to reduce $Z \rightarrow \ell\ell$



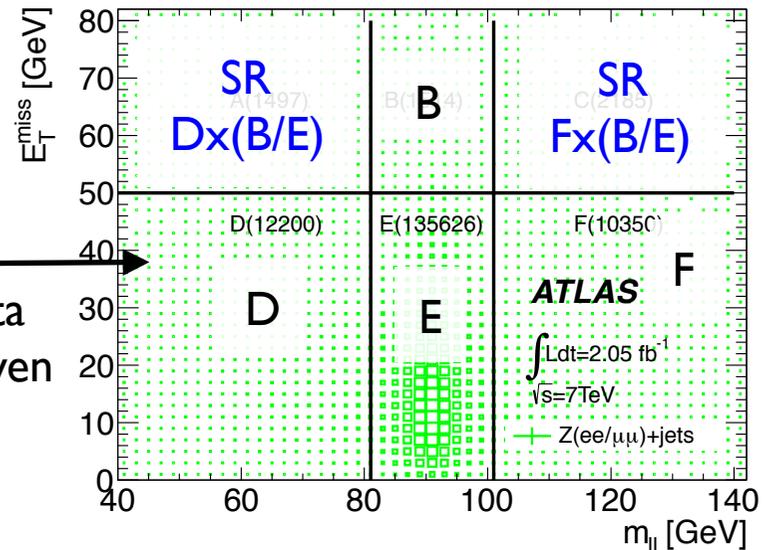
Yield & BG model

	1-jet
Wt	147 ± 13
$t\bar{t}$	610 ± 110
Diboson	130 ± 17
$Z \rightarrow ee$	20 ± 2
$Z \rightarrow \mu\mu$	29 ± 3
$Z \rightarrow \tau\tau$	9 ± 6
Fake dileptons	11 ± 11
Total bkgd.	810 ± 120
Total expected	960 ± 120
Data observed	934

15%
64% (MC)

20%
1%

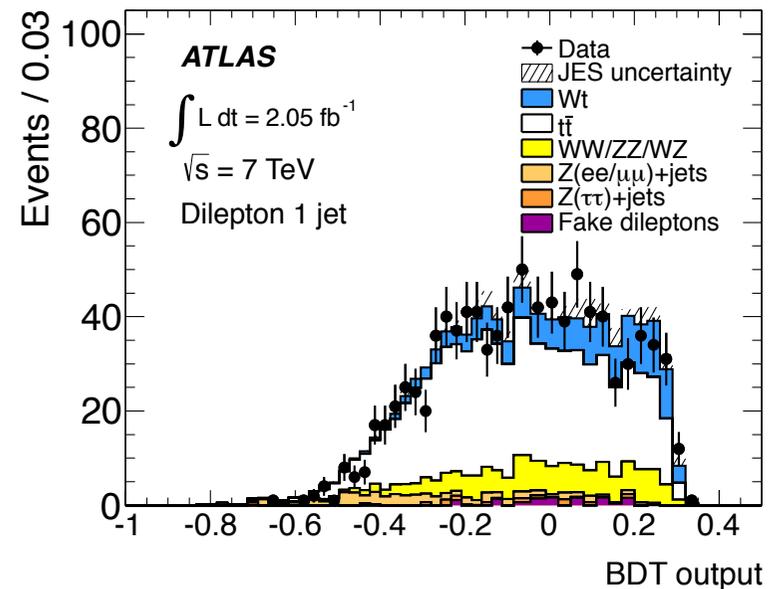
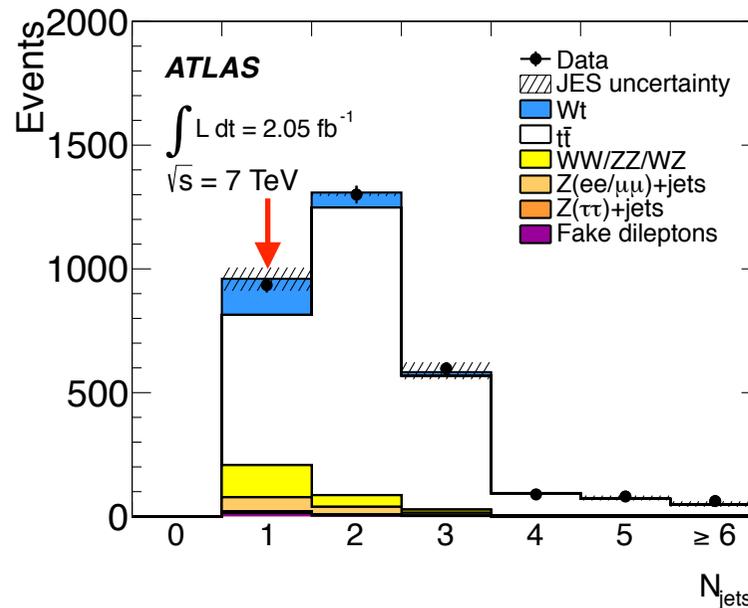
Data driven



Wt-channel (2.05 fb^{-1})

Signal
extraction

- Calculate Boosted Decision Tree (BDT) score of the event based on 18 kinematic variables
- Likelihood fitting using BDT score for each jet bin



Results

- $16.8 \pm 2.9 \text{ (stat)} \pm 4.9 \text{ (syst) pb}$ (exp. 15.7 pb)
 - $3.3\sigma \rightarrow$ First evidence at LHC
 - Systematics : Statistics, JES, Parton shower
- $V_{tb} = 1.03^{+0.16}_{-0.19}$ (assuming $|V_{tb}| \gg |V_{ts}|, |V_{td}|$)

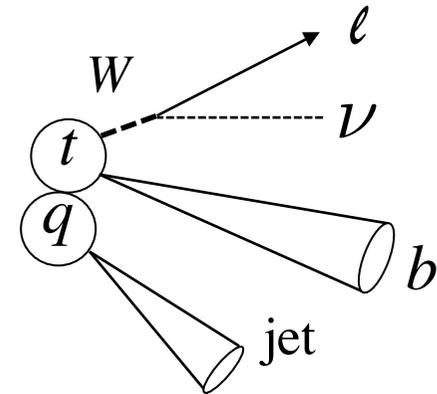
t-channel (1.04 fb^{-1})

What's unique ?

- Promising channel for the single top production observation (Highest cross section among single top production)

Selection

- One lepton and $E_T^{\text{miss}} > 25 \text{ GeV}$
- 2 or 3 jets, exactly one of them is b-tagged
- $M_T(\ell, E_T^{\text{miss}}) + E_T^{\text{miss}} > 60 \text{ GeV}$



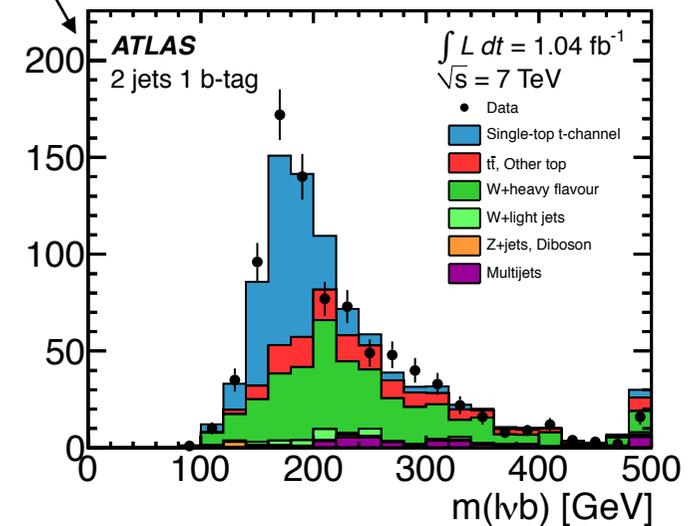
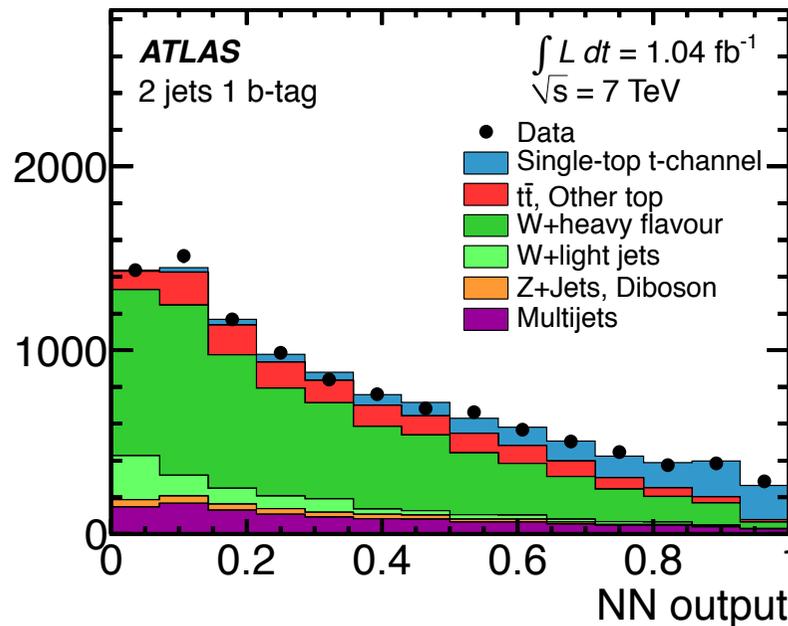
Yield & BG model

2 jet bin (1 b-tagged)	electron	muon	
single-top t -channel	447 ± 11	492 ± 12	9%
$t\bar{t}$, other top	785 ± 52	801 ± 53	16% (MC)
W +light jets	350 ± 100	510 ± 150	} 58% : shape from MC, normalized by data
W +heavy flavour jets	2600 ± 740	3130 ± 880	
Z +jets, diboson	158 ± 63	166 ± 61	3% (MC)
Multijet	710 ± 350	440 ± 220	14%
TOTAL expected	5050 ± 830	5530 ± 930	
DATA	5021	5592	

t-channel (1.04 fb^{-1})

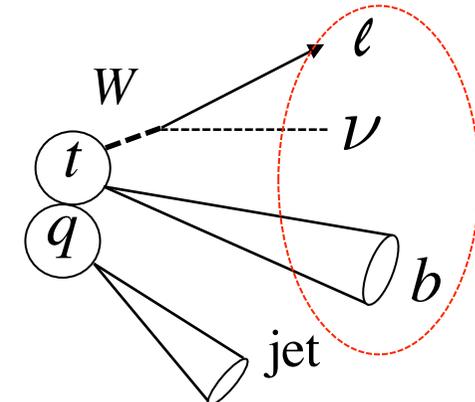
Signal
extraction

- Introduce NN discriminant based on 12 (18) variables for 2 (3) jet bin followed by Maximum likelihood fit
 - As a cross check, cut-based analysis is performed



Results

- $83 \pm 4 \text{ (stat)}^{+20}_{-19} \text{ (syst) pb}$ (exp. 64.6 pb)
 - Systematics : ISR / FSR, btag efficiency
- $|V_{tb}| = 1.13^{+0.14}_{-0.13}$
 - $|V_{tb}| > 0.75$ @ 95% C.L assuming $|V_{tb}| \leq 1$



t-channel (4.7 fb^{-1})

Analysis updated for the ratio measurement of $R_t = \sigma_t(t)/\sigma_t(\bar{t})$

What's unique ?

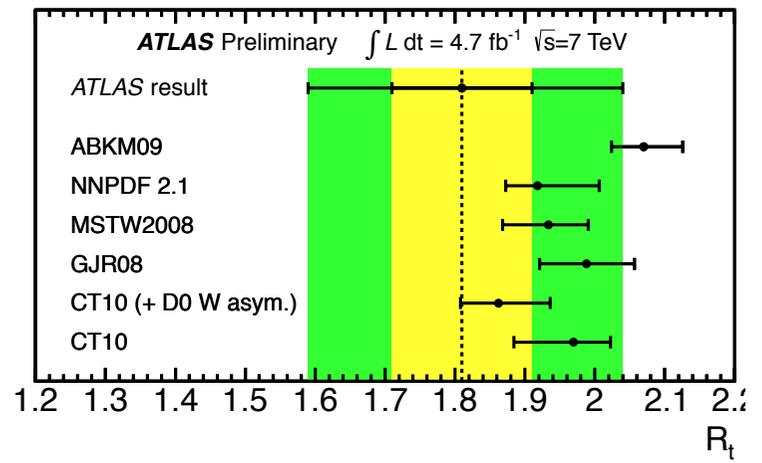
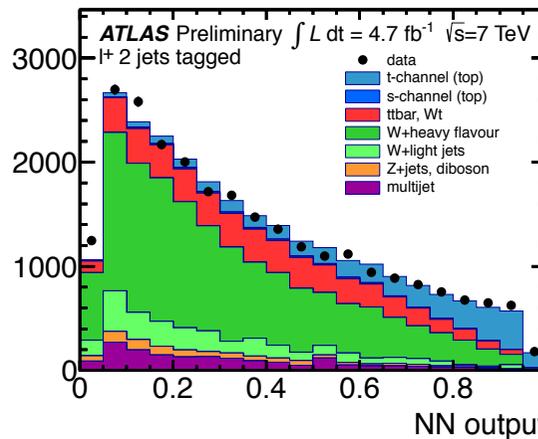
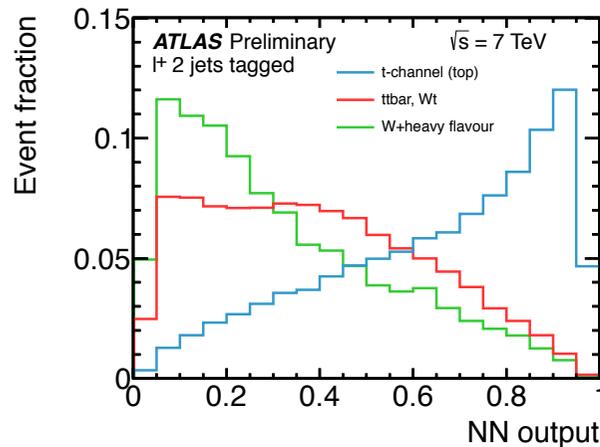
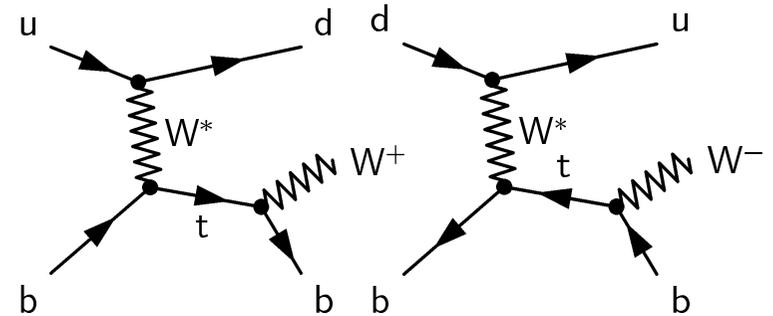
- Sensitive to PDF
- Cancel out common syst.

Selection

- Optimized to $E_T^{\text{miss}} > 30 \text{ GeV}$
- $M_T(\ell, E_T^{\text{miss}}) > 30 \text{ GeV}$

Signal extraction

- Maximum likelihood fit separately for ℓ^+ and ℓ^- sample



Results

- $\sigma_t(t) = 53.2 \pm 10.8 \text{ pb}$ (exp. 41.9 pb), $\sigma_t(\bar{t}) = 29.5^{+7.4}_{-7.5} \text{ pb}$ (exp. 22.7 pb)
- $R_t = 1.81^{+0.23}_{-0.22}$ (exp. 1.86 – 2.07)
 - Systematics : Background normalization, ISR/FSR, JES

$t\bar{t}$ Production Cross Section

τ + lepton channel (2.05 fb^{-1})

What's unique ?

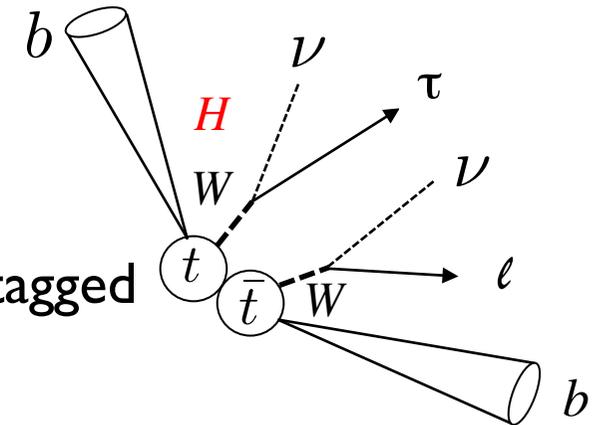
- BR could be enhanced by the existence of H^\pm

Selection

- Opposite sign lepton + τ candidate
- $E_{T \text{ miss}} > 30 \text{ GeV}$
- $\Sigma E_T > 200 \text{ GeV}$
- ≥ 2 jets and at least one of them is b-tagged

Event yield

Signal	737
tt \rightarrow lepton + jet	4127
W + jet	1429
Multi-jet	577
Others (tt \rightarrow dilepton, Z + jet)	65
Total expected	6935
Data	7188



11%

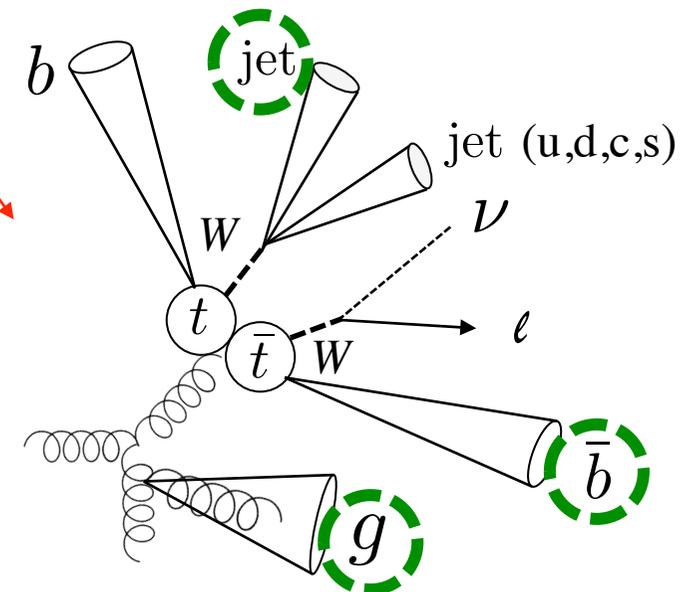
BG arises by jet faking τ candidate

60%

20%

8%

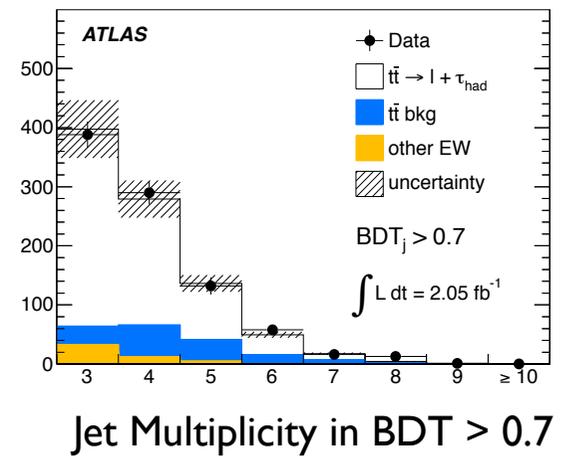
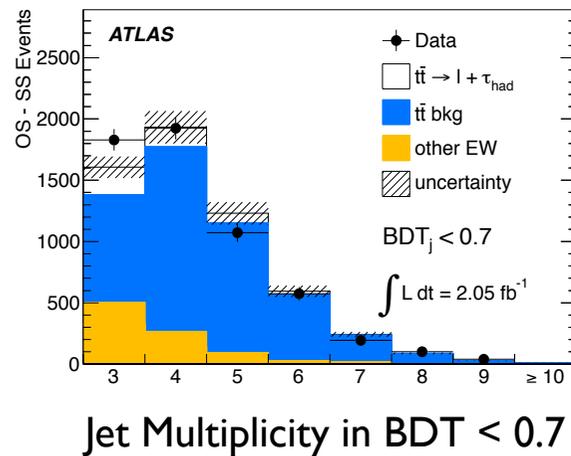
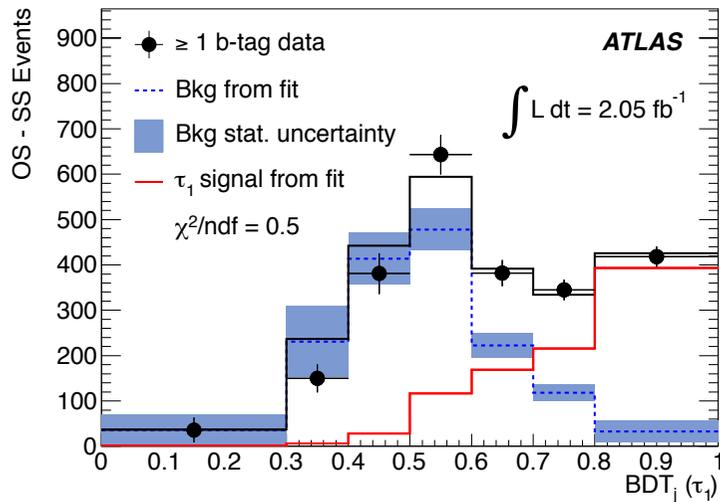
1%



$\tau + \text{lepton channel (2.05 fb}^{-1}\text{)}$

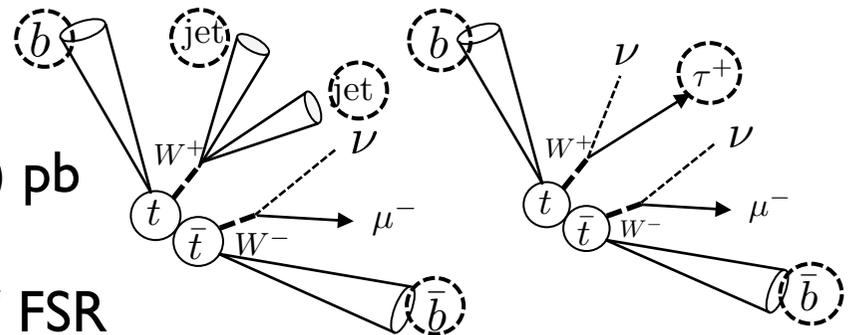
Signal extraction

- BDT score is calculated to the selected τ candidate
- Perform template fitting
 - BG distribution is different by jet type (b, g, light jet)
 - To reduce # of template, SS events are subtracted to remove b, gluon originated τ candidate (charge symmetric)



Results

- $186 \pm 13 \text{ (stat)} \pm 20 \text{ (syst)} \pm 7 \text{ (lumi)} \text{ pb}$
(exp. $165^{+11}_{-16} \text{ pb}$)
- Systematics : btag efficiency, ISR / FSR



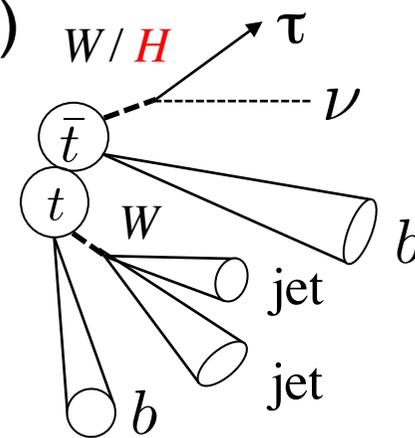
$\tau + \text{jet}$ channel (1.67 fb^{-1})

What's unique ?

- BR could be enhanced by the existence of H^\pm (Complementary with $\tau + \text{lepton}$ channel)

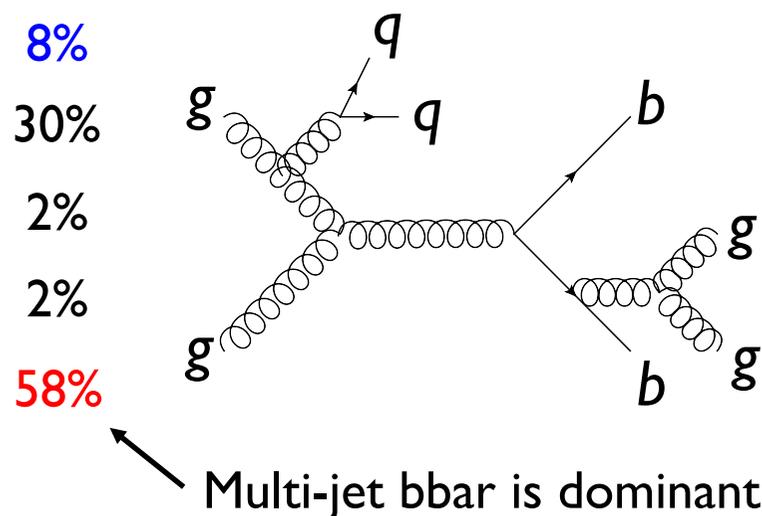
Selection

- ≥ 5 jets and ≥ 2 of them is b-tagged
- E_T^{miss} significance $E_T^{\text{miss}}/\sqrt{\sum E_T} > 4$
- 1 τ candidate selected among jets
 - Reconstruct 3 jets to be M_{top}
 - select remaining non b-tagged jet with $p_T > 40 \text{ GeV}$



Event yield (MC)

Signal	149	8%
ttbar combinatorics	542	30%
W + jet	45	2%
Single top	36	2%
Multi jet, bbar	1050	58%
Total expected	1822	

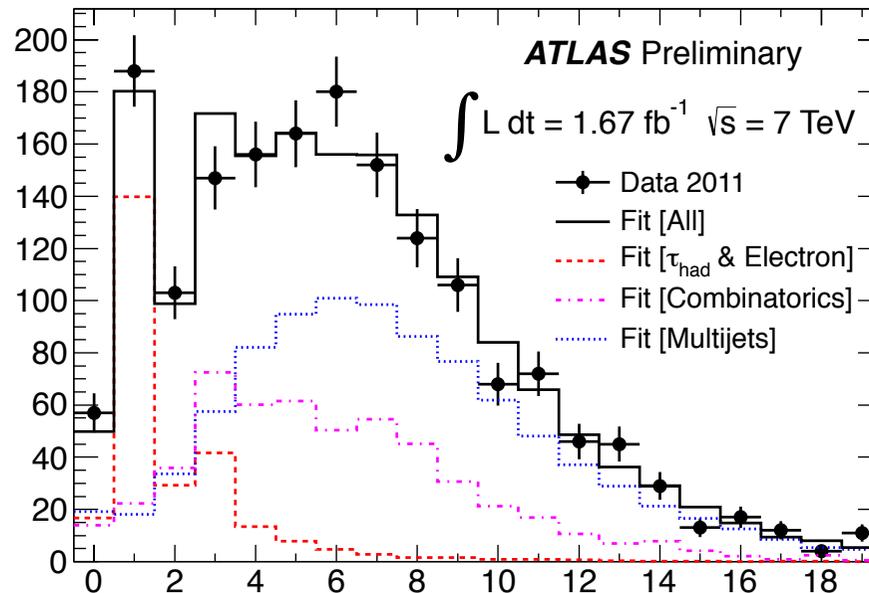


Multi-jet bbar is dominant

$\tau + \text{jet}$ channel (1.67 fb^{-1})

Signal extraction

- Binned likelihood fit to the number of charged track distribution of the τ candidate
 - **Multi-jet** : From $1.5 < E_T^{\text{miss}} \text{ sig.} < 2$ control region
 - **tt combinatorics** : From $tt \rightarrow \mu + \text{jet}$ control region
 - **Signal** : From MC



Source	Number of events
$t\bar{t}$ (τ_{had})	150 ± 30
$t\bar{t}$ (electrons)	44 ± 9
Single top	12 ± 3
$Wb\bar{b}$	13 ± 14
Total expected	219 ± 34
Fit results	$268 \pm 24 \text{ (stat.)} \pm 17 \text{ (syst.)}$

Number of tracks

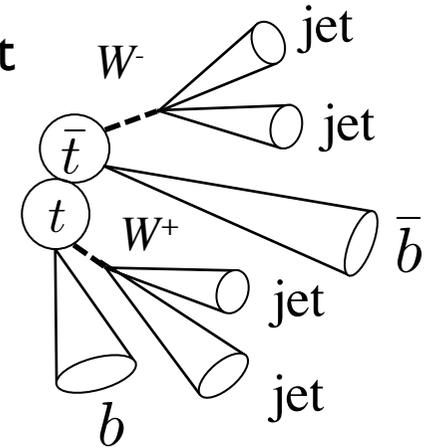
Result

- $200 \pm 19 \text{ (stat)} \pm 43 \text{ (syst)} \text{ pb (exp. } 165^{+11}_{-16} \text{ pb)}$
- Systematics : btag efficiency, ISR / FSR

All hadronic channel (4.7 fb⁻¹)

Selection

- ≥ 5 jets with $p_T > 55$ GeV and ≥ 2 b-tagged jet
- 6th jet with $p_T > 30$ GeV
- E_T^{miss} significance < 3
- Kinematical likelihood fit to find correct association of jets to reconstruct M_{top}



Composition & BG modeling

Signal (35%), **Multi jet (65%)**

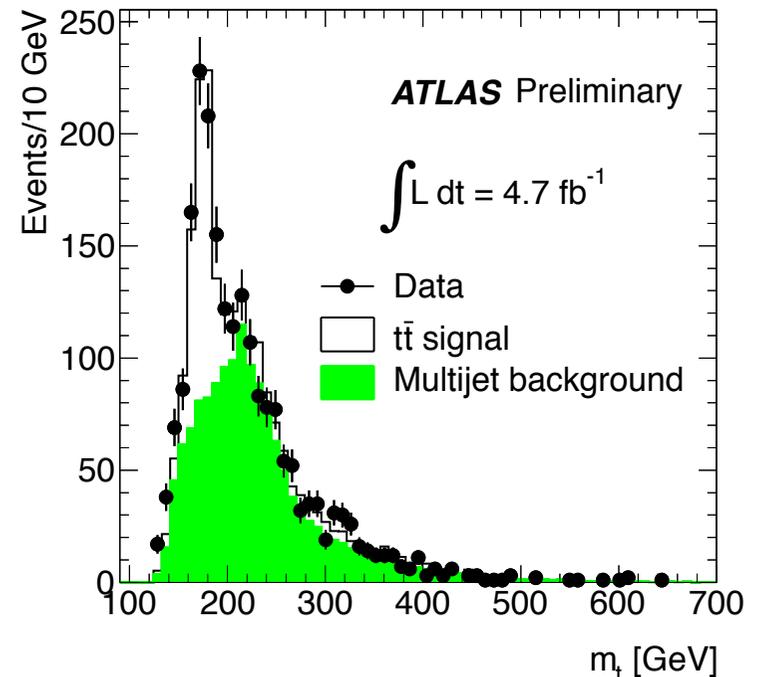
Modeled by the pre b-tagged sample in data

Signal extraction

- Unbinned likelihood fit to M_{top}
- $6 \leq N_{\text{jet}} \leq 10$
- χ^2 for M_{top} and M_W is calculated and satisfy $\chi^2 < 30$

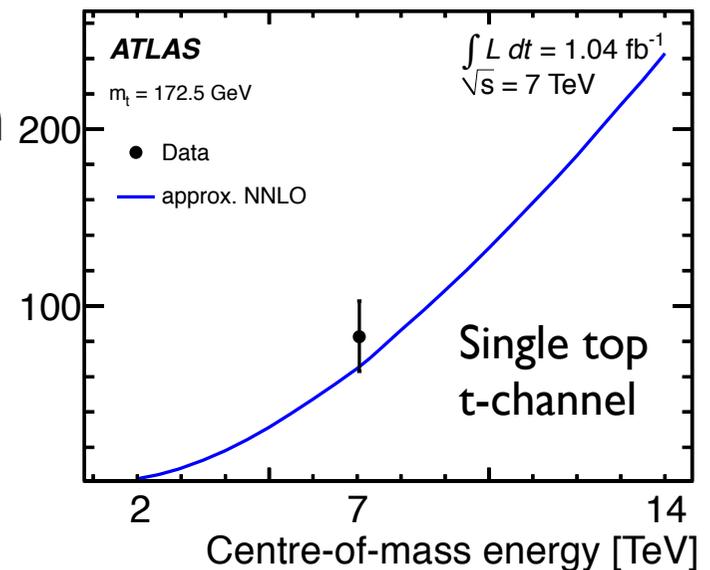
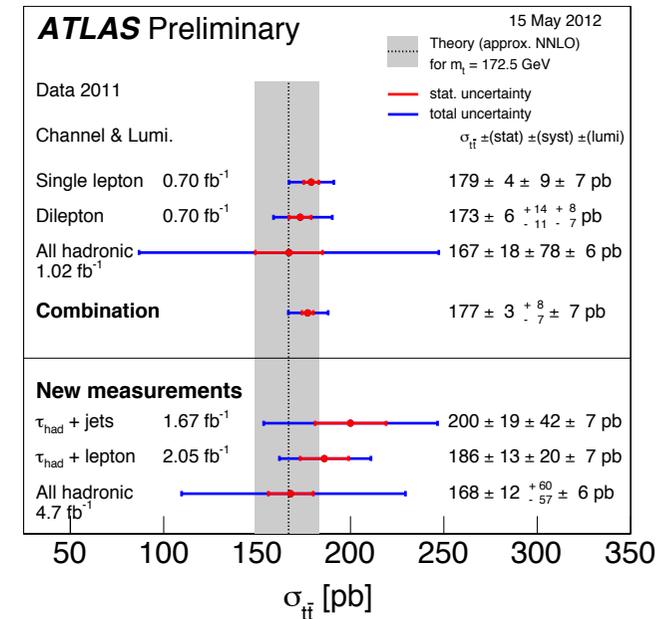
Result

- 168 ± 12 (stat) $^{+60}_{-57}$ (syst) ± 6 (lumi) pb
- Systematics : JES



Summary

- LHC is the top-quark factory
 - Validation of the SM @ high- q^2
 - Search for the New physics
- $t\bar{t}$ production cross section
 - Measured accuracy < Theoretical accuracy
 - $\sigma_{t\bar{t}}$ is measured in alternative decay channel with τ , showing SM is applicable at LHC
- Single top production cross section
 - First evidence of Wt -channel
 - Interpretation to $|V_{tb}|$
- 2012 will be the exciting year !
 e.g.) $\sigma_{t\bar{t}} @ 8 \text{ TeV} = 1.4 \times \sigma_{t\bar{t}} @ 7 \text{ TeV}$



Thank you for your attention

17/16

- References of this talk

ttbar	Data (fb ⁻¹)	Reference
lepton + lepton	0.70	CERN-PH-EP-2011-223
lepton + jet	0.70	ATLAS-CONF-2011-121
lepton + τ	2.05	CERN-PH-EP-2012-102
jet + τ	1.67	ATLAS-CONF-2012-032
jet + jet	4.70	ATLAS-CONF-2012-031

Single top	Data (fb ⁻¹)	Reference
t-channel	1.04	CERN-PH-EP-2012-082 ATLAS-CONF-2012-056 (R _t)
Wt-channel	2.05	CERN-PH-EP-2012-117
s-channel	0.70	ATLAS-CONF-2011-118