ATLAS results on inclusive top quark pair production cross section

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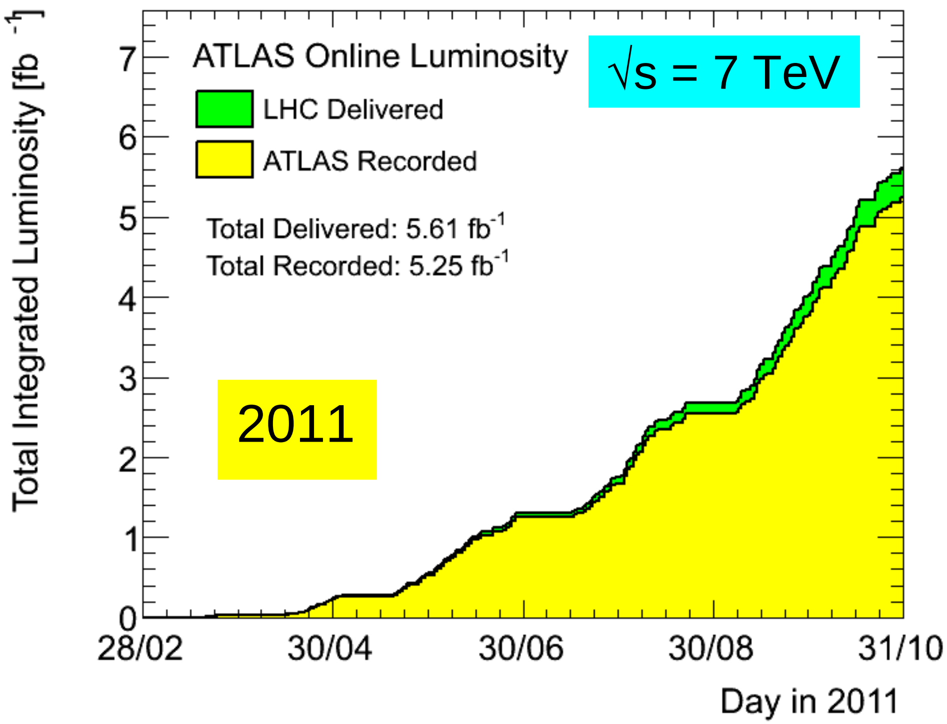
(on behalf of the ATLAS collaboration)

36th International Conference on High Energy Physics, ICHEP2012, Melbourne, Australia



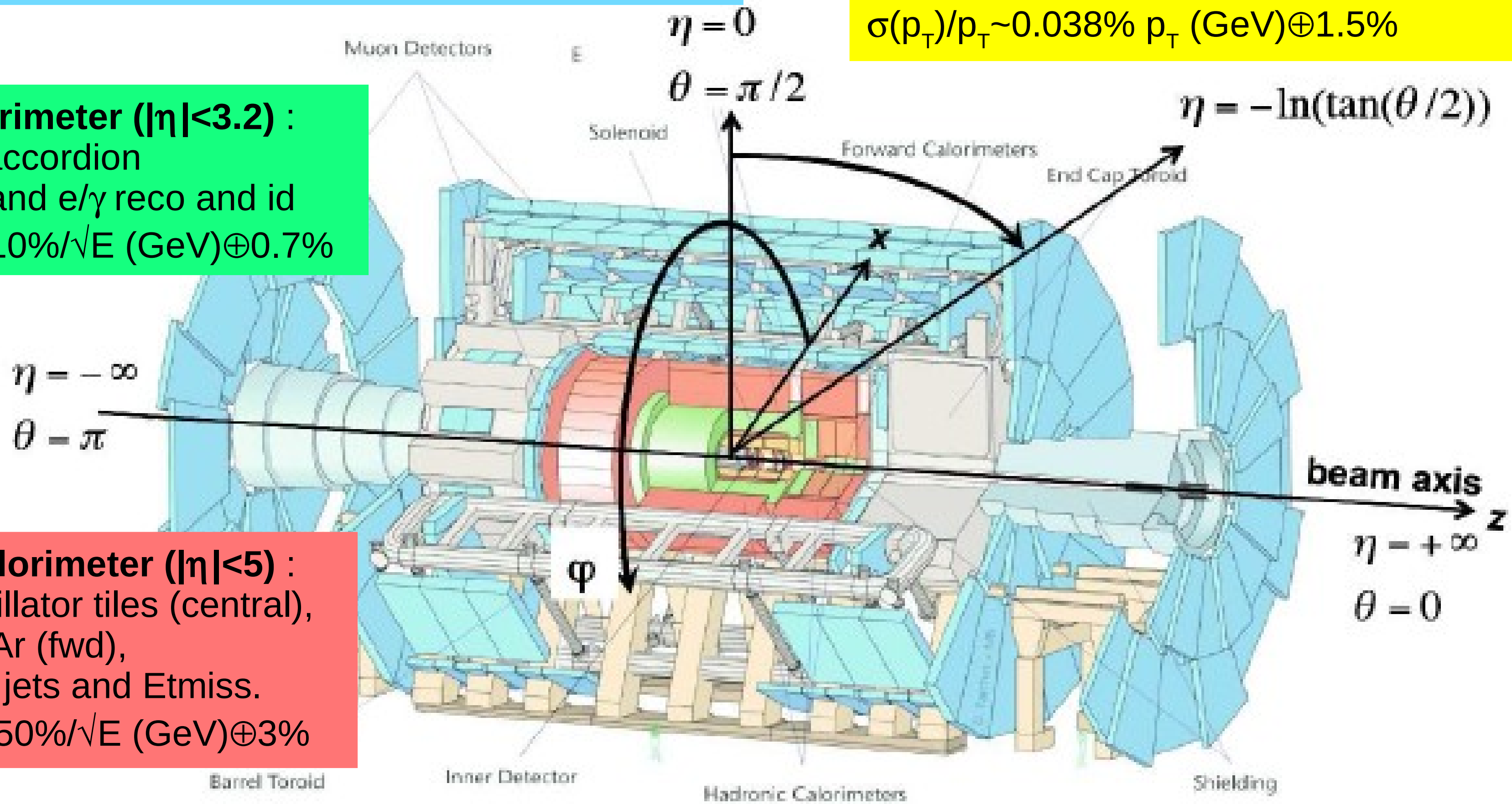
ATLAS and objects
dilepton (e,μ,τ)
lepton + jets
fully hadronic
additionnal results

The ATLAS detector

Muon spectrometer (|η|<2.7) : air-cores toroids with gas-based chambers. Trigger and measurement. Momentum resolution <10% up to Eμ~1 TeV

Inner Detector (|η|<2.5) :
Si pixel, SCT, TRT
Tracking and vertexing. e/π separation
$\sigma(p_T)/p_T \sim 0.038\%\ p_T\ (\mathrm{GeV}) \oplus 1.5\%$

EM calorimeter (|η|<3.2) :
Pb/LAr accordion
Trigger and e/γ reco and id
$\sigma(E)/E \sim 10\%/\sqrt{E}\ (\mathrm{GeV}) \oplus 0.7\%$



HAD calorimeter (|η|<5) :
Fe/scintillator tiles (central),
Cu/W LAr (fwd),
Trigger, jets and Etmiss.
$\sigma(E)/E \sim 50\%/\sqrt{E}\ (\mathrm{GeV}) \oplus 3\%$

$$\vec{p}_T = (p_x, p_y) \qquad p_T = p\sin\theta, \quad E_T = E\sin\theta \qquad \vec{E}_T^{miss} = -\sum_{\text{clusters}\,i} E_i \hat{n}_i$$

Trigger :
L1 : hardware, L2-EF, ~200 Hz in output

Object reconstruction

To study top quark it implies good understanding of many different objects reconstructed in all different ATLAS subdetectors

Muons

combined fitted tracks

tight identification

central : $|\eta|<2.5$, $p_T>20$ GeV

isolated

Tau (based on jets)

matched calo cluster + 1 or 3 tracks

identification using a BDT

$20<p_T<100$ GeV, $|\eta|<2.3$

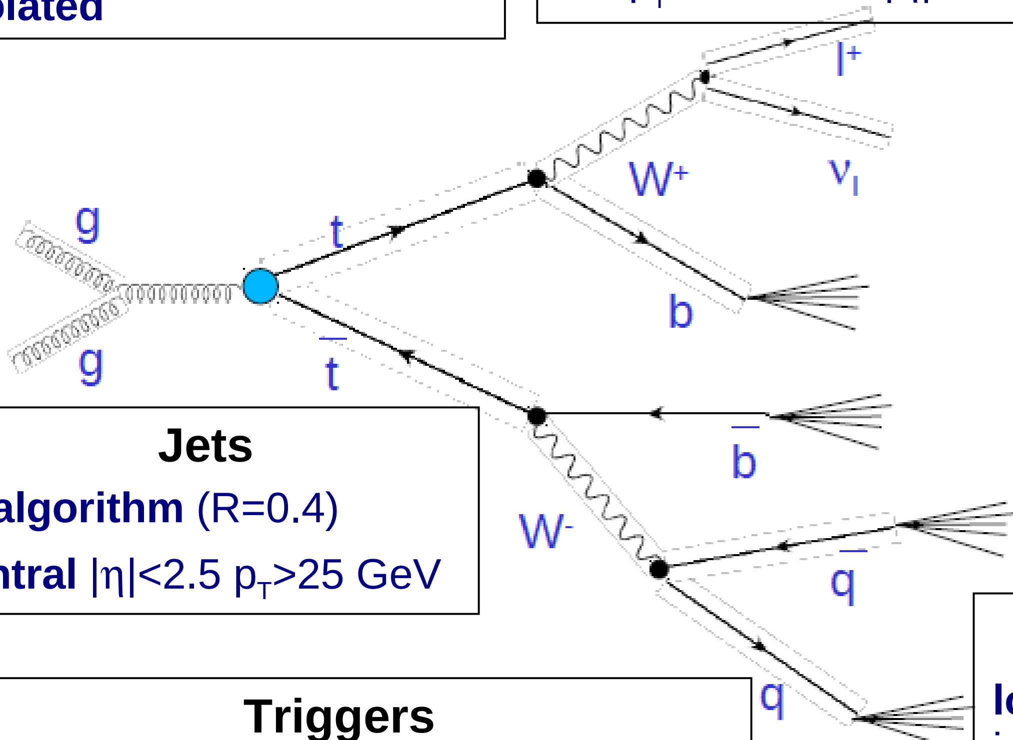
Electrons

matched track and EM cluster

tight identification using shower shape variables, ID

central : $|\eta|<2.5$, $p_T>25$ GeV

isolated



E_T^{miss}

vector sum of energy in calorimeter cells, ID, spectro projected in transverse plane, associated with high p_T object and dead material loss

$S_{ETmiss} = E_{Tmiss}/(0.5\times\sum E_T)$

Jets

k_T-algorithm (R=0.4)

central $|\eta|<2.5$ $p_T>25$ GeV

b-tagging

long lifetime of B hadrons : NN based on impact parameter, secondary vertex, fragmentation properties, resonance mass

Triggers

based on single lepton high p_T or N jets

Top quark production and decays

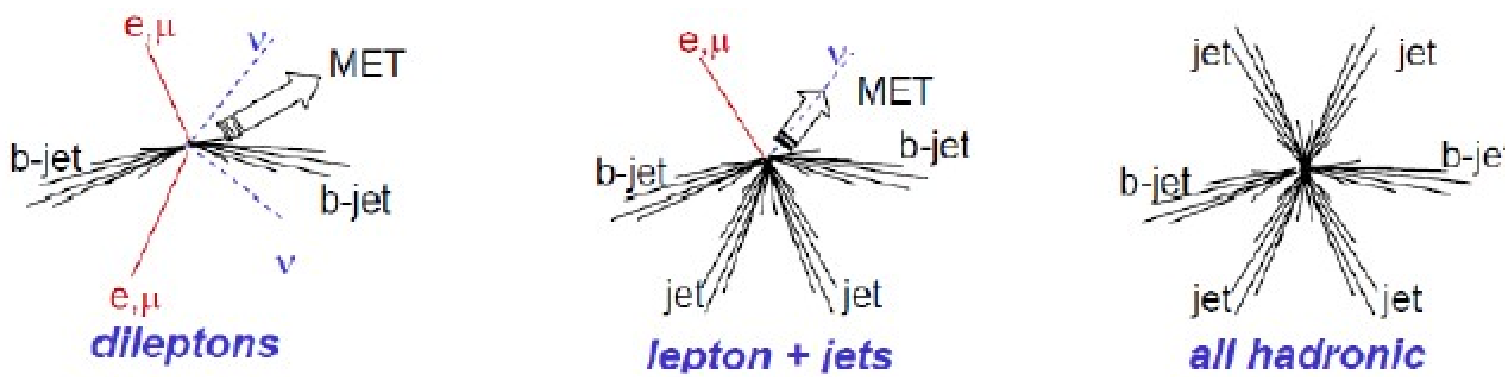
- **Production mechanism**
  - $t\bar{t}$ pair, 85% by gluon fusion, ~15% by $q\bar{q}$ production
  - single top (electroweak)

Predictions $\sqrt{s}$= 7 TeV

$\sigma(pp \rightarrow t\bar{t})_{NNLOapprox} = 167^{+17}_{-18}$ pb

Computed with: Aliev et. al., HATHOR, arXiv:1007:1327 (2011)

- **Top pair event classification according to W decays**



	dileptons	lepton + jets	all hadronic
Branching ratio	4.9%	29.6%	45.7%
Final state	2 isolated leptons large E_T^{miss} 2 b-jets	1 isolated lepton E_T^{miss} 2 b-, 2 light jets	no lepton no E_T^{miss} 2 b-, 4 light jets
Backgrounds	few (mainly Z+jets)	moderate (mainly W+jets)	huge (mainly QCD)

τ channels : 13.5% for τ+jets and 6.3% for τ+e/μ+jets

pair production with 2 leptons + jets

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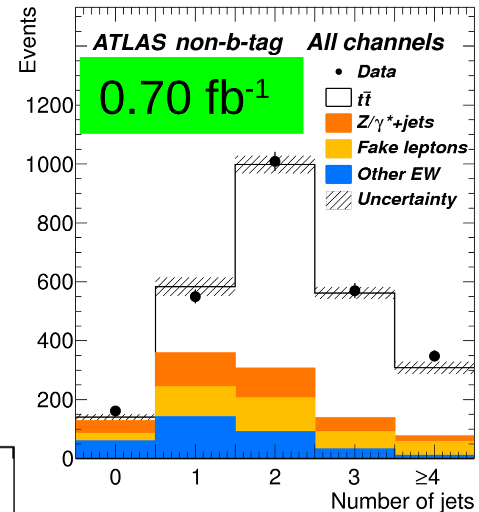
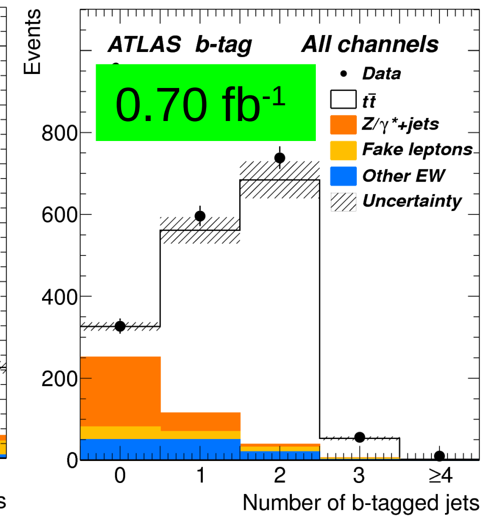
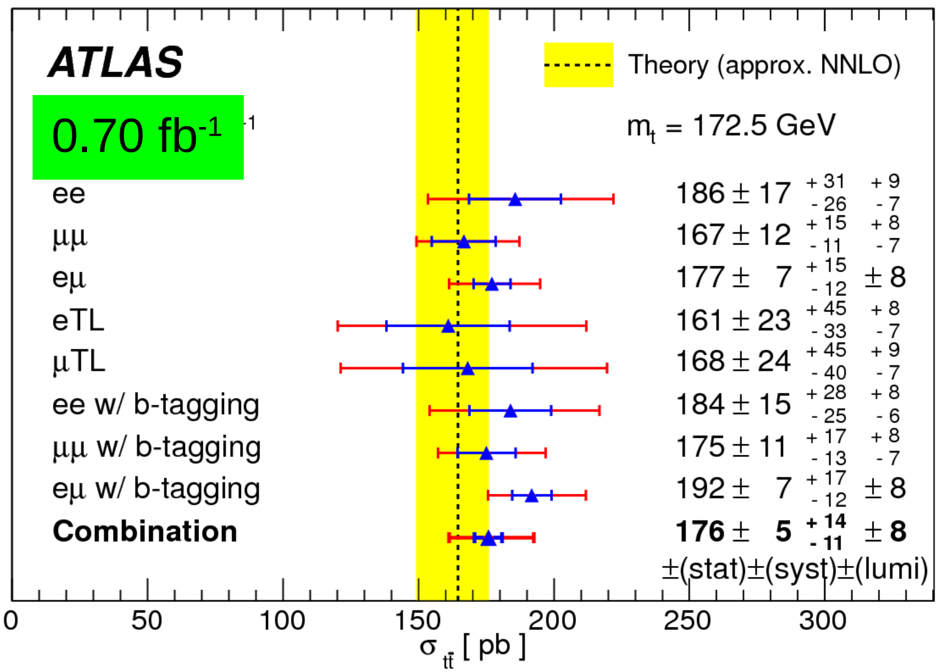
<u>**Signature**</u> **:**
2 isolated e/μ + E_T^{miss} + jets (1b)

<u>Trigger</u> : 1 single isolated lepton
<u>Offline</u> : opposite sign leptons + E_T^{miss}>30 GeV, $\Sigma E_T(e\mu)$, m_{ll} (Z veto)
<u>Analysis Strategy</u> : counting experiment
data driven estimation of Z+jets, W+jets and QCD backgrounds







$\sigma_{tt} = 176 \pm 5\ \text{(stat)}\ ^{+14}_{-11}\ \text{(syst)} \pm 8\ \text{(lumi) pb}$

overall precision ~9%,
limited by systematic uncertainties

<u>Systematics</u> : in eμ : Jet/E_T^{miss}(~4 pb), generator (~4.5 pb), fake lepton (~3 pb)

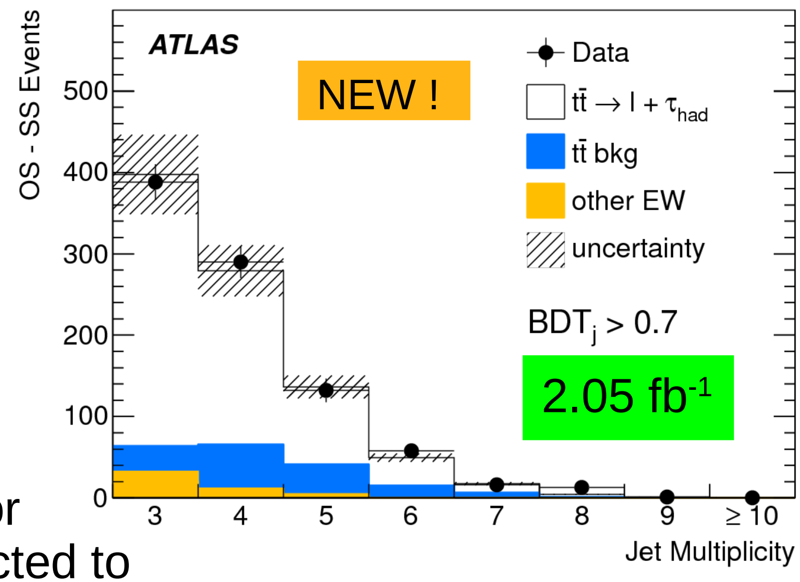
pair production with e/μ + τ + jets

arXiv 1205.2067 (2012)

BR could be enhanced by the existence of $H^{\pm}$

Signature :

1 isolated e/μ + τ + E_T^{miss} + jets (1b)



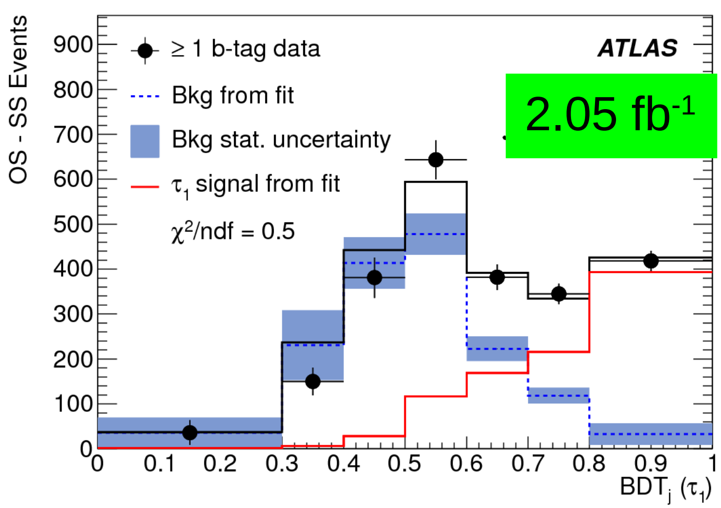
Trigger : 1 single isolated lepton

Offline : opposite sign lepton + τ

E_T^{miss}>30 GeV, $\sum E_T$>200 GeV, 2 jets at least one of them is b-tagged

Analysis Strategy : perform template fit of BDT

- background distribution is different with jet flavor
- to reduce # of templates, SS events are subtracted to remove b, gluon originated τ candidates (charge symmetric)



$\sigma_{tt}(\mu+\tau)$ = 186 ± 15 (stat) ± 20 (syst) ± 7 (lumi) pb

$\sigma_{tt}(e+\tau)$ = 187 ± 18 (stat) ± 20 (syst) ± 7 (lumi) pb

σ_{tt} = 186 ± 13 (stat) ± 20 (syst) ± 7 (lumi) pb

overall precision ~14%,
limited by systematic uncertainties

Systematics : b-tag (~9 pb), τ-ID (~4 pb)

pair production with lepton + jets

Signature :
1 isolated e/μ + E_T^{miss}+ jets

Analysis Strategy : multivariate discriminant based on: η_l,$p_{T,\text{lead jet}}$,Aplanarity,$H_{T,3p}$
data driven estimation of Z+jets and QCD backgrounds
W+jets normalized to data

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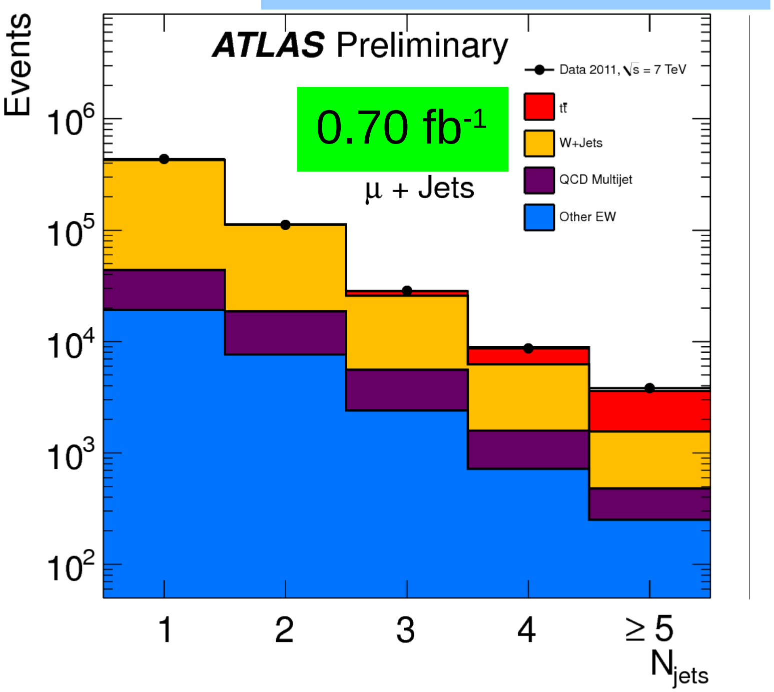

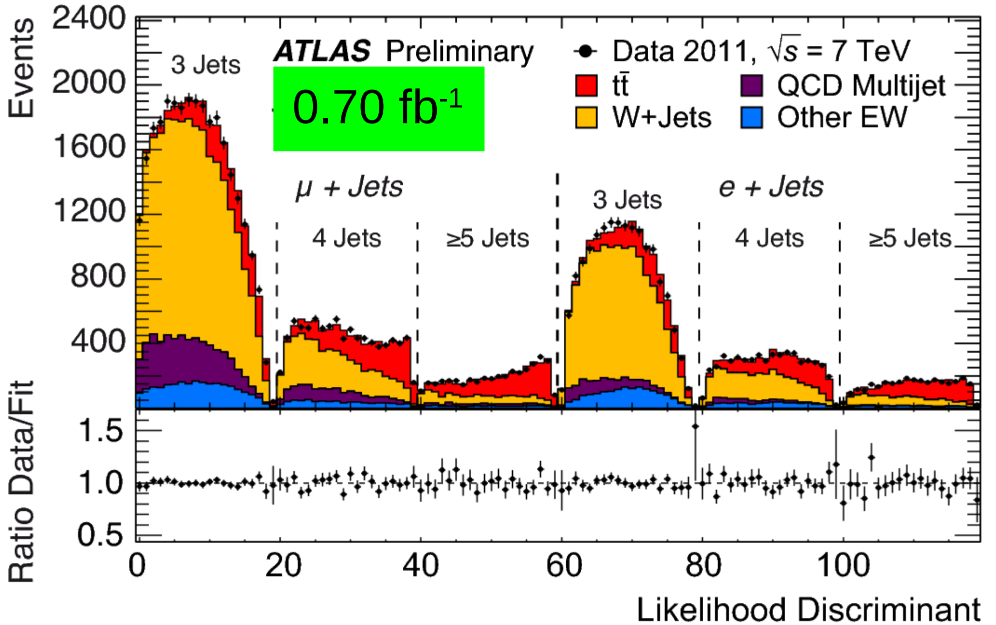

overall precision ~6.5%,
limited by systematic uncertainties

σ_{tt}= 179.0 ± 3.9 (stat) ± 9.0 (syst) ± 6.6 (lumi) pb

Systematics : generator (5.4 pb), muon (4.1 pb), lumi (6.6 pb)

pair production in hadronic modes

Signature :
no E_T^{miss} + jets (2b)
Trigger : 5 jets with p_T>30 GeV
Offline : ≥ 5 jets with p_T > 55 GeV
and ≥ 2 b-tagged jet
- 6^{th} jet with p_T > 30 GeV
- S_{ETmiss}< 3
- Kinematical likelihood fit to find correct association of jets to reconstruct m_t

Signal and background modelling :
data driven estimation of background
35% signal and 65% multijet by the pre-btagged sample in the data

Analysis Strategy :
Unbinned likelihood fit to m_t,
6 ≤ Njet ≤ 10,
χ2 for m_t and m_w is calculated
and satisfy χ2 < 30

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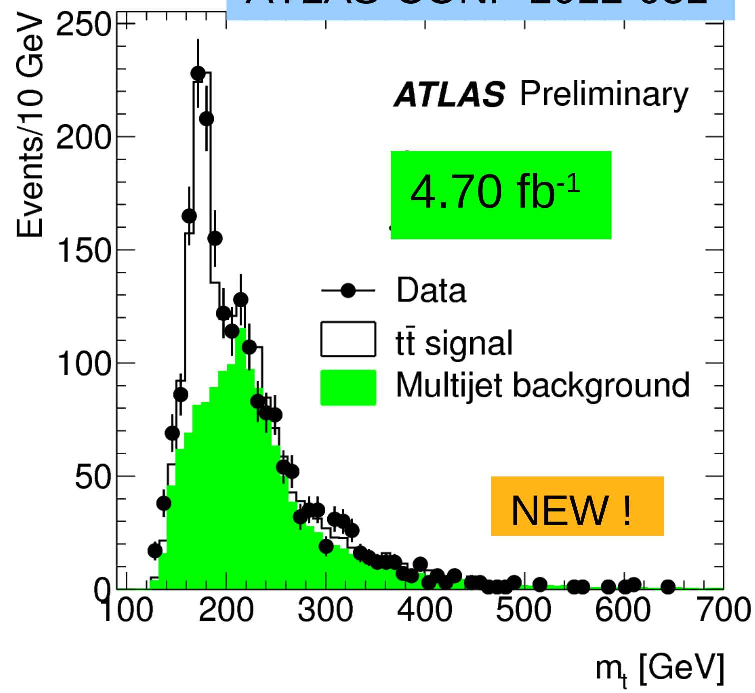

$\sigma_{tt} = 168 \pm 12\ (stat)\ ^{+60}_{-57} (syst) \pm 7\ (lumi)$ pb

overall precision ~37%,
limited by systematic uncertainties

Systematics : JES (+20, -17 pb),
b-tagging (17 pb), ISR/FSR (17 pb)

pair production in hadronic modes with τ

~10% of all tt events, BR enhanced by $H^{\pm}$

Signature :

τ_{had} + E_T^{miss} + jets (2b)

Trigger : ≥ 4 jets (p_T>10 GeV @L1),
≥ 2 b-tagged at EF

Offline : ≥ 5 jets, ≥ 2 of them b-tagged
- S_{ETmiss} > 4
- 3 jets (one is b-tagged) with highest p_T sum to be m_{top}
- select remaining non b-tagged jet with p_T > 40 GeV as τ candidate
- e/μ veto

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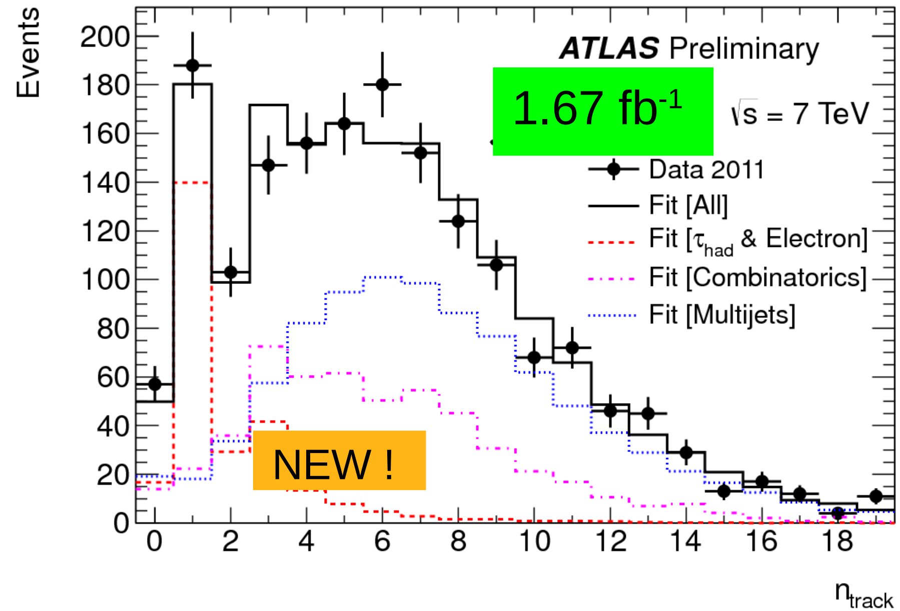


Analysis Strategy : Fit to number of good quality tracks associated to tau lepton, with 3 templates

Signal : from tt MC sample

tt combinatorics : from tt μ + jets control region

Multi-jet : from 1.5 < S_{ETmiss} < 2 control region

σ_{tt} = 200 ± 19 (stat) ± 43 (syst) pb

overall precision ~23%,
limited by systematic uncertainties

Systematics : ISR/FSR (12 pb), b-tag (10 pb), Fit (7 pb)

Additional features of top pair production

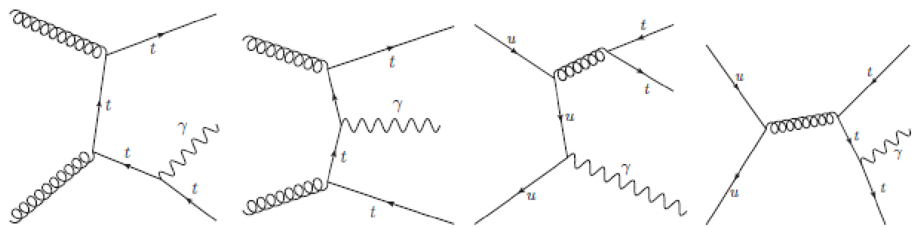
$t\bar{t}$ + photon

Signature : 1 e/μ + E_T^{miss} + jets (1b) + γ

Offline : similar to lepton+jets analysis
tight photon with p_T>15 GeV

Signal and background modelling :
signal, hadron fakes and QCD+γ templates are obtained by data driven methods
electron fakes, $t\bar{t}\gamma$, W+jets+γ templates are obtained from MC

Analysis Strategy : Fit to track isolation of γ



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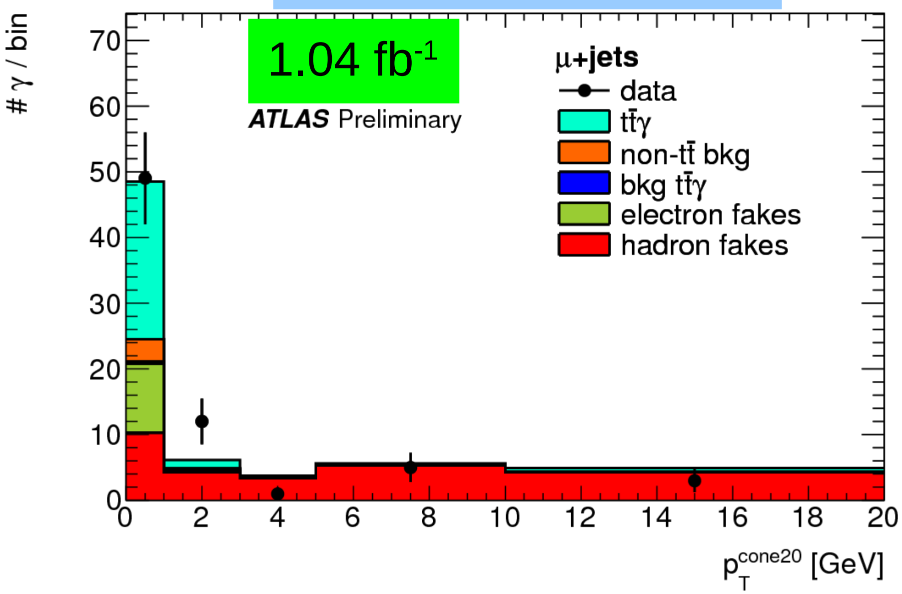


$\sigma_{t\bar{t}\gamma}(p_T,\gamma>8\text{ GeV})\times BR(LJ,DL)$ =
2.0 ± 0.5 (stat) ± 0.7 (syst) ± 0.08 (lumi) pb
expected (NLO) = 2.1 ± 0.4 pb

overall precision ~43%,
limited by systematic uncertainties

Systematics : γ-ID (0.33 pb),
ISR/FSR (0.31 pb),
JES (0.28 pb)

Summary

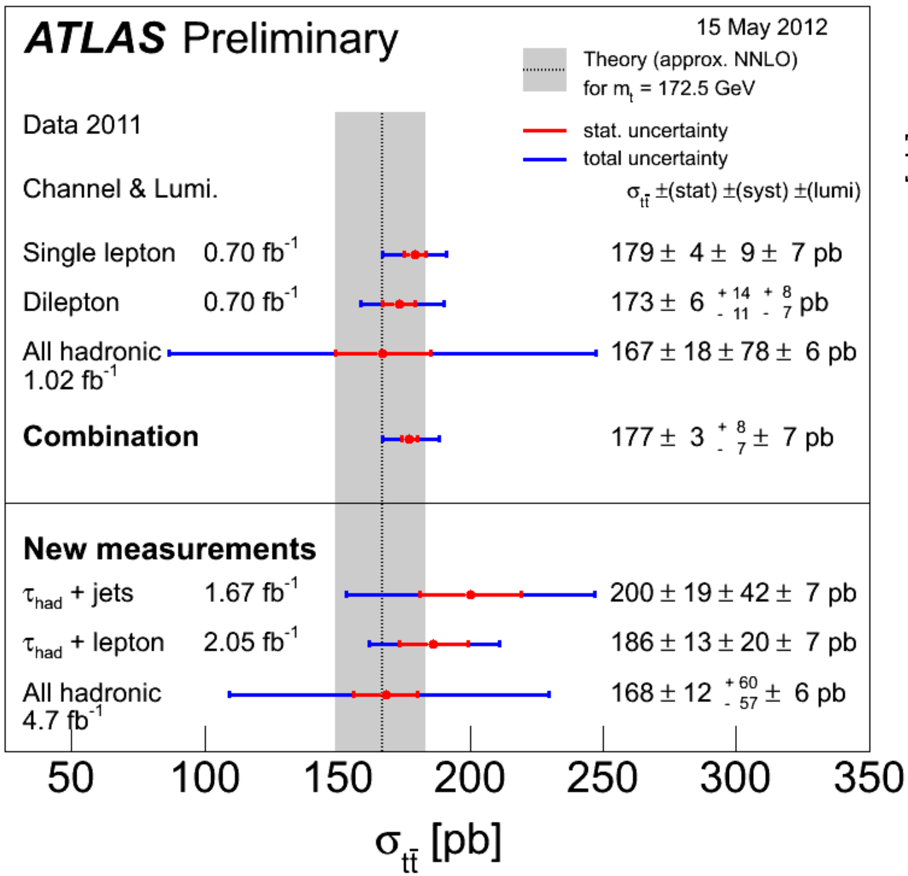
- **ttbar production cross section**

– measured accuracy < theoretical one

– σ_{tt} is measured in alternative channels (τ), showing SM is applicable at LHC

- additional features are explored (tt+jets)

- **more results in talk on differential measurements !**



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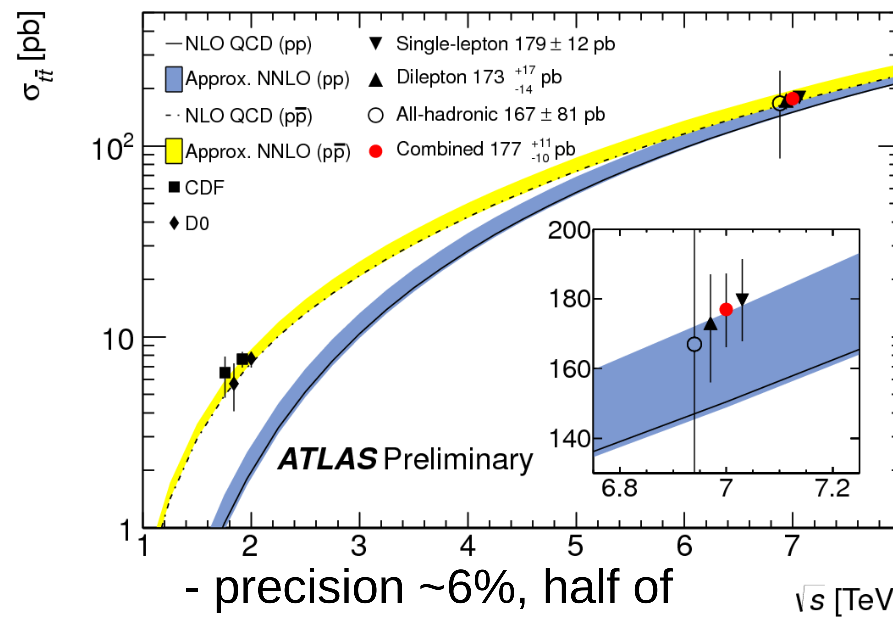

- precision ~6%, half of theory uncertainty
- agreement of channels within uncertainties

Backup slides

Simulation

- simulated tt events generated using MC@NLO with PDFs from CTEQ6.6 (mt ≡ 172.5 GeV); sample normalized to 164.6 pb (from NNLO prediction using [5])
  - parton showering modeled with HERWIG
  - underlying event modeled with JIMMY
- single tops generated using MC@NLO
- W/Z bosons in association with jets generated with ALPGEN interfaced to HERWIG/JIMMY with CTEQ6.1
- di-boson events generated by HERWIG with MRST2007lomod
- pile-up is simulated with a value of 4-8 interactions per bunch crossing in order to reflect what is seen in the data