Top-quark pair cross-section measurement in the lepton+jets channel at ATLAS

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Electroweak Interactions and Unified Theories

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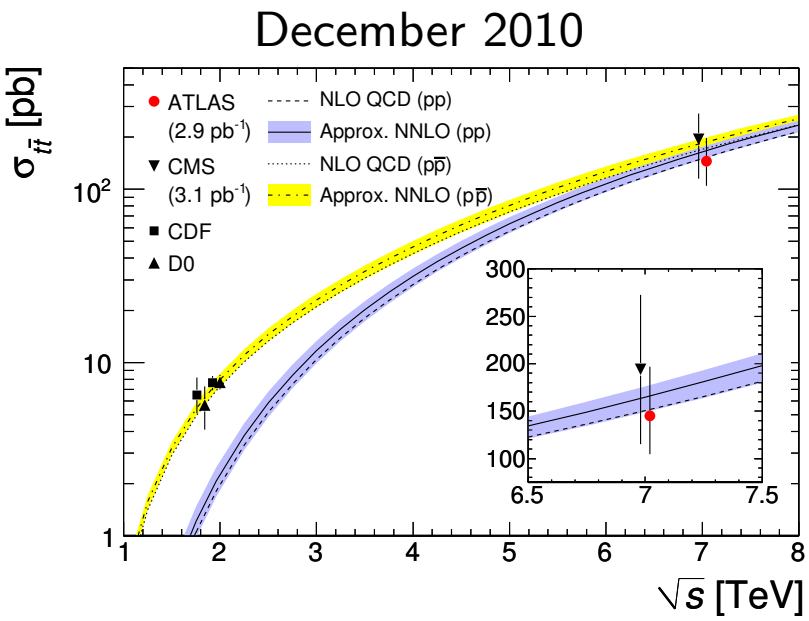
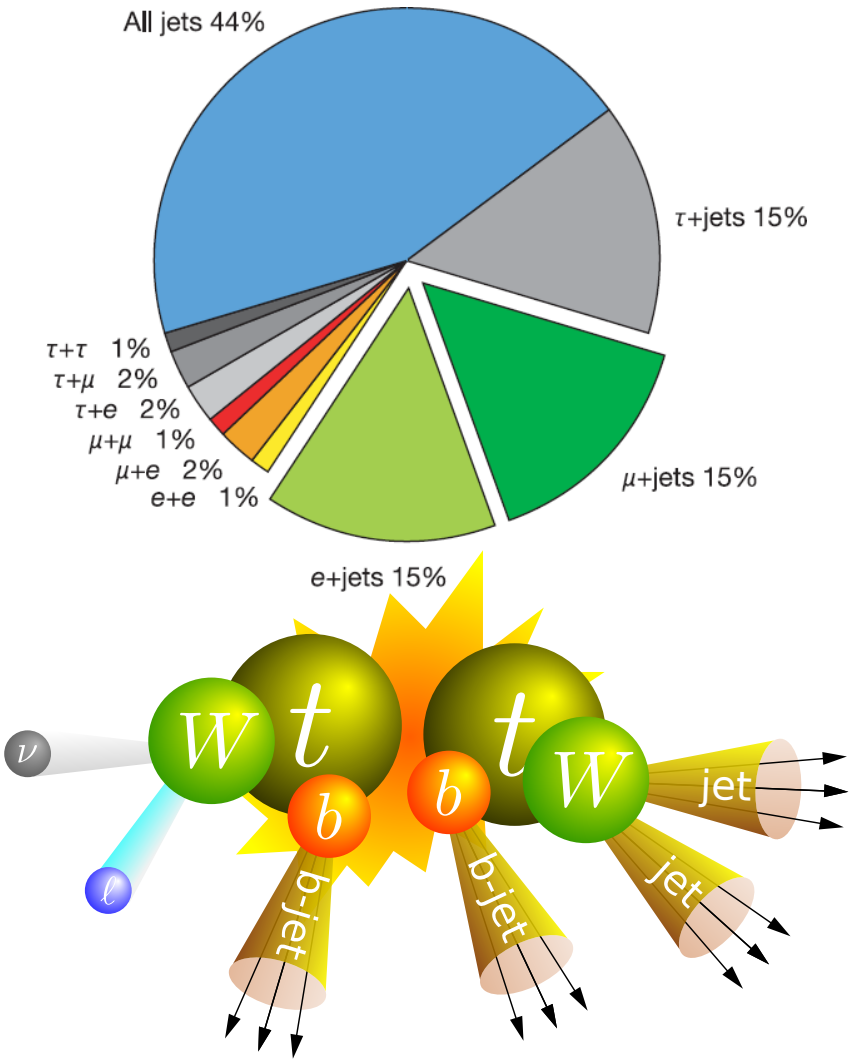
Top pairs at LHC

- $pp \to t\bar{t}$ @ 7 TeV:
  theoretical approx. NNLO $\sigma_{t\bar{t}} = 165^{+11}_{-16}$ pb
  $\Rightarrow$ with 35 pb^{-1} >5000 $t\bar{t}$ pairs expected
- A first ATLAS x-section measurement (combining ℓ+jets with b-tagging and di-lepton channels) already performed with 2.9 pb^{-1}:
  $\sigma_{t\bar{t}} = 145 \pm 31$ (stat.) $^{+42}_{-27}$ (syst.+lumi.)
  [CERN-PH-EP-2010-064, December 8, 2010]
- With 35 pb^{-1} and with more sophisticated techniques a precision measurement is possible
- A measurement in ℓ+jets channel only and without any use of b-tagging is here presented
  [ATLAS-CONF-2011-023, March 14, 2011]
- Complementary measurements are being finalized:
  - ℓ+jets channel with b-tagging
  - di-lepton channel
  - all-hadronic channel



Single lepton $t\bar{t}$ event selection



The following final state selection has been chosen to isolate e/μ+jets $t\bar{t}$ events and to keep sufficient statistics for the measurement:

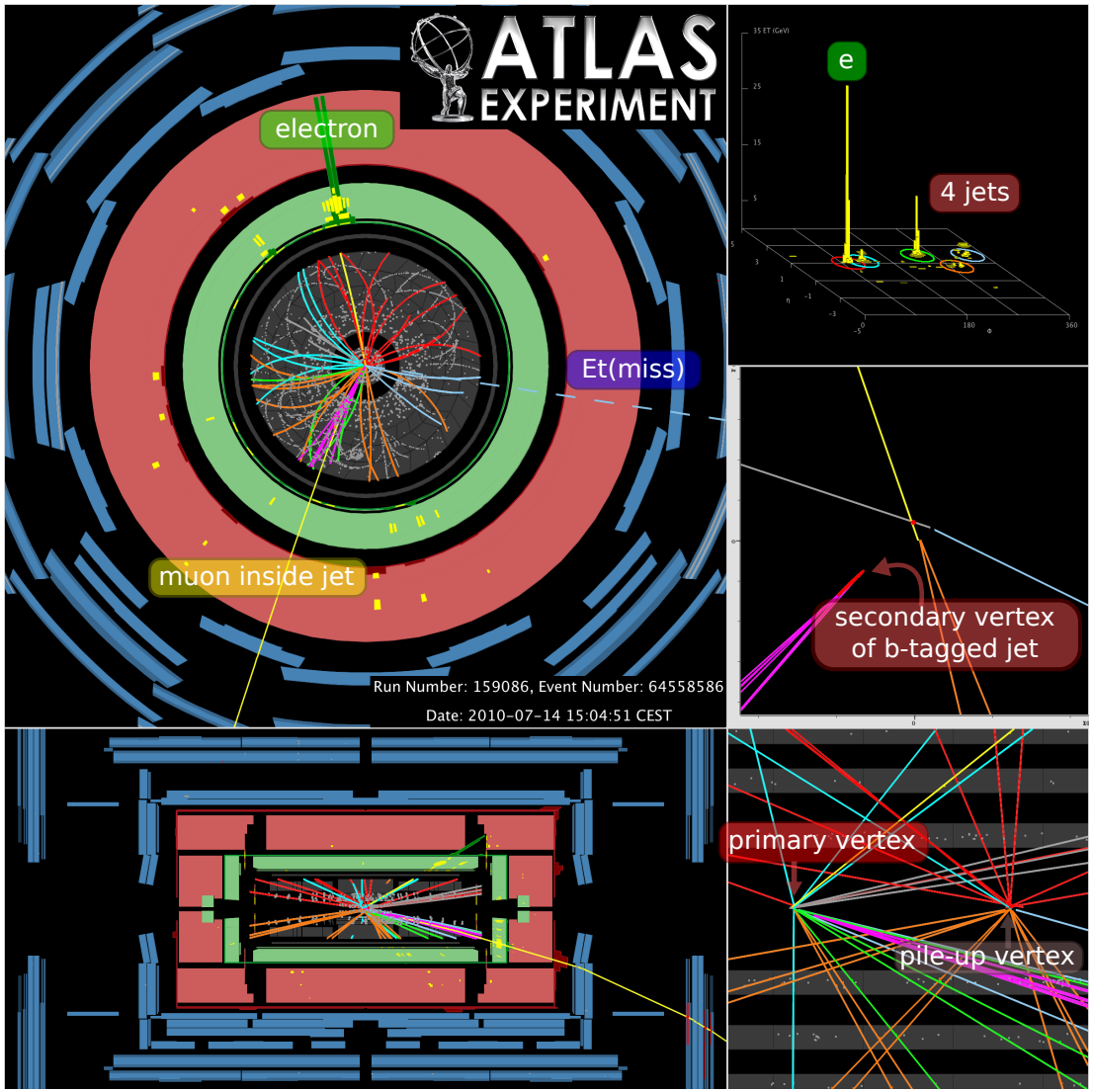
e+jets

- 1 isolated e with $p_T > 20$ GeV
- $\not{E}_T > 35$ GeV
- $m_T(W) > 25$ GeV
- 3 or more jets with $p_T > 25$ GeV

μ+jets

- 1 isolated μ with $p_T > 20$ GeV
- $\not{E}_T > 20$ GeV
- $\not{E}_T + m_T(W) > 60$ GeV
- 3 or more jets with $p_T > 25$ GeV

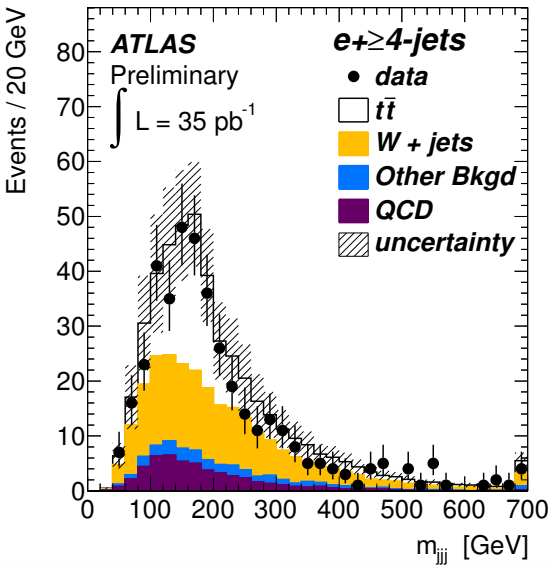
$t\bar{t} \rightarrow e$+jets event display

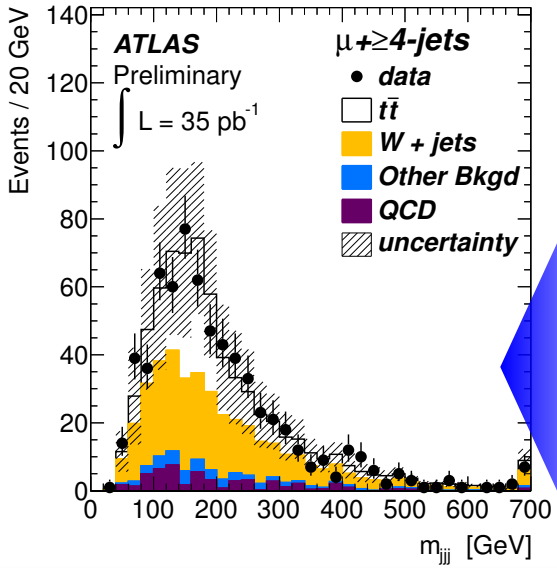


Selected events and MC expectations

events	e + 3 jets	e + $\geq$4 jets	μ + 3 jets	μ + $\geq$4 jets
$t\bar{t}$	116	194	161	273
QCD*	62	22	120	51
W+jets	580	180	1100	310
Z+jets	32	18	70	25
single t	22	11	32	15
WW, WZ, ZZ	9	3	16	4
Data	**781**	**400**	**1356**	**653**

*: QCD numbers come from data-driven estimate

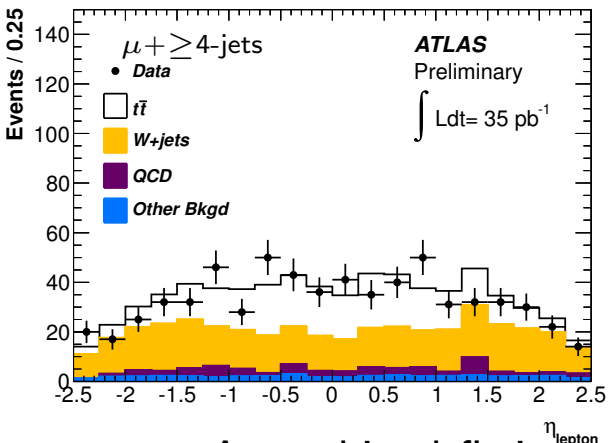


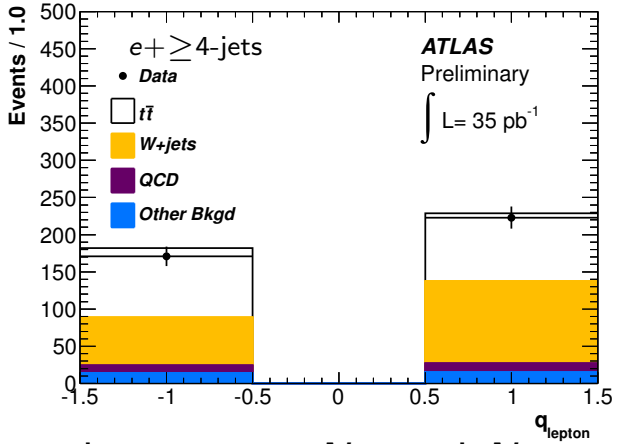


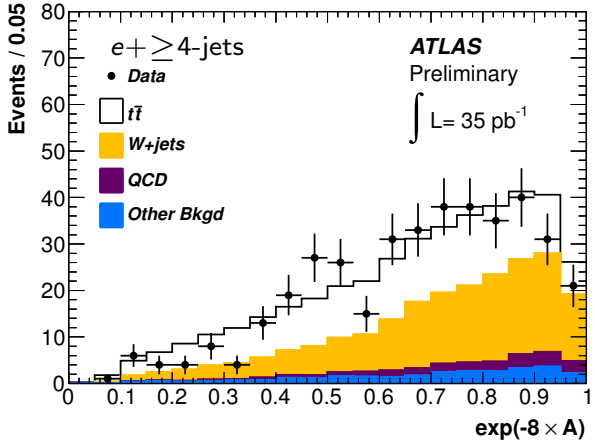
Top mass reconstructed as the mass of the highest-p_T 3-jet combination in the event

Multivariate Kinematic measurement

- For each of the 4 channels a Likelihood discriminant is built
- Using 3 variables with different distributions between $t\bar{t}$ and W+jets:
  1. lepton pseudorapidity $\eta(e/\mu)$ (ℓ from $t\bar{t}$ more central)
  2. lepton charge $q(e/\mu)$ (W production in pp collisions is charge-asymmetric)
  3. exponential of the event Aplanarity $exp(-8 \times A)$ (*) ($t\bar{t}$ events more isotropic)







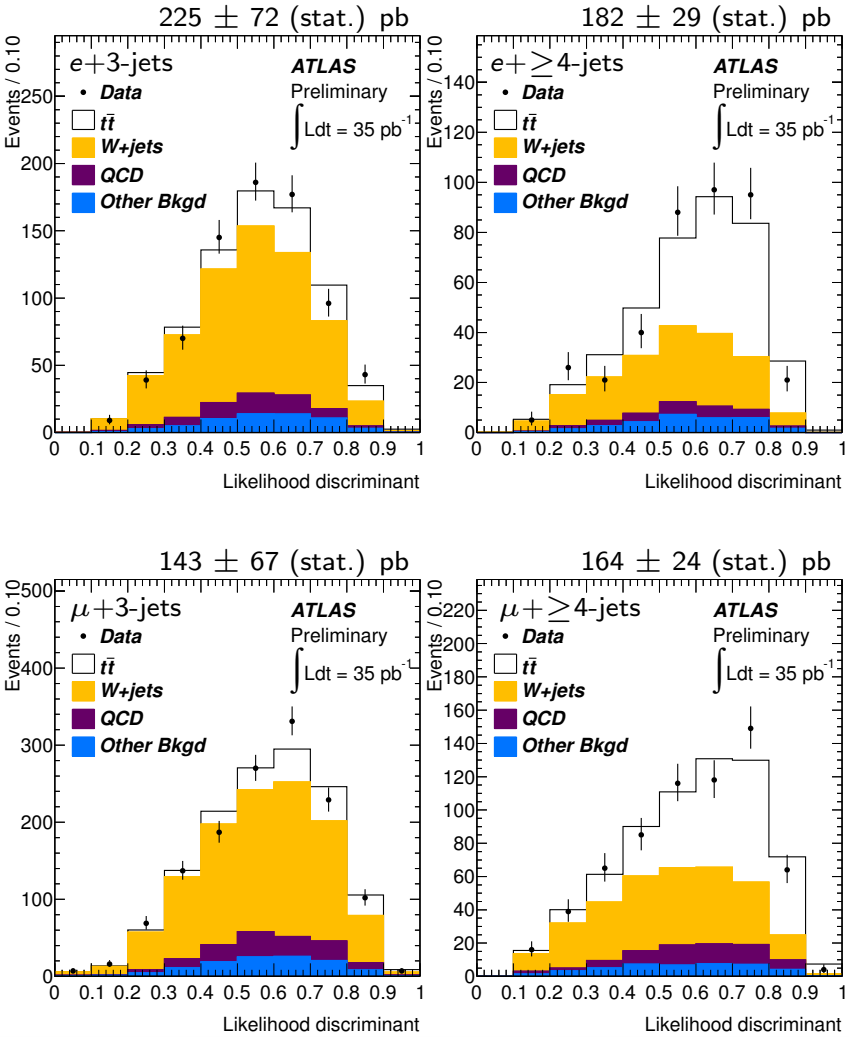
- A combined fit is performed to extract $N_{t\bar{t}}$ and N_{W+jets} (with fixed QCD and other backgrounds)
- The cross-section is obtained as $\sigma_{t\bar{t}} = \dfrac{N_{t\bar{t}}}{\epsilon \cdot \int L}$

  (ϵ is the $t\bar{t}$ selection efficiency $\times$ acceptance)

*: $A = \frac{3}{2}\lambda_3$, where λ_3 is the smallest eigenvalue of the normalized momentum tensor calculated using the jets and lepton in the event

Results and uncertainties

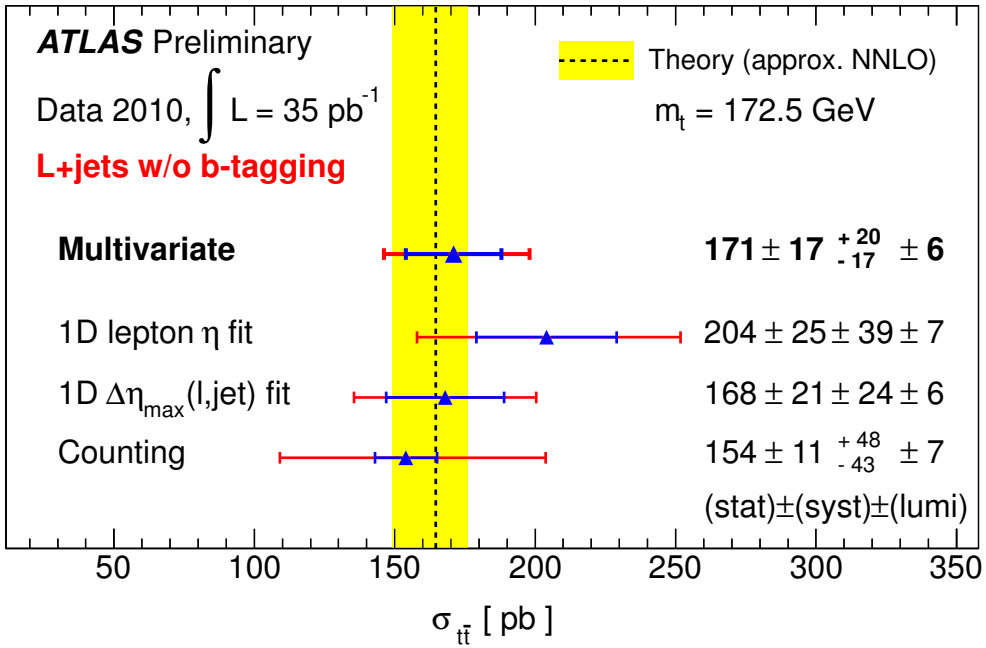
$$\sigma_{t\bar{t}} = 171 \pm 17(\text{stat.}) \ {}^{+20}_{-17}(\text{syst.}) \ \pm 6(\text{lumi.}) \ \text{pb}$$



Source	$\Delta\sigma/\sigma$[%]
Stat.	9.7
ℓ reco, ID, trigger	-1.9 / +2.6
Jet energy reco	-6.1 / +5.7
QCD norm.	±3.9
QCD shape	±3.4
W+jets shape	±1.2
Other backg.	±0.5
ISR/FSR	-2.1 / +6.1
PDFs	-3.0 / +2.8
Parton shower	±3.3
NLO generator	±2.1
MC statistics	±1.8
Pile-up	±1.2
Total syst.	-10.2 / +11.6
Luminosity	3.4

Summary of the current results

- A measurement of the $t\bar{t}$ cross-section in 7 TeV pp collisions in ℓ+jets channel, using the full 35 pb^{-1} of data collected by ATLAS, has been shown
- The measurement doesn't use any b-tagging information
- The total uncertainty is $\sim$ 15% (mainly due to statistics and jet energy scale)



- 3 cross-check measurements using different methods show good agreement
- Good agreement with the previous measurement ($145 \pm 31^{+42}_{-27}$ pb)
- ℓ+jets with b-tagging, di-lepton & all-hadronic channels are under approval

Backup Slides

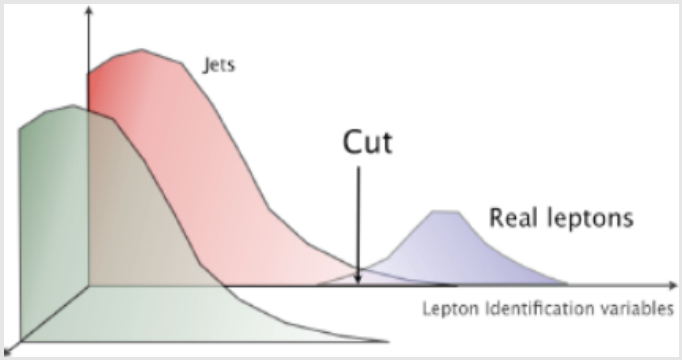
Fake leptons or 'QCD' background

QCD multi-jet can enter the ℓ+jets selection:

- e/μ from heavy quarks decays
- $\gamma \rightarrow e^+e^-$
- jets reconstructed as e

Fit Method - used in e+jets channel

- Extract the $\not\!\!E_T$ distribution shape for QCD from loose non-tight lepton selection
- Fit $\not\!\!E_T$ in data with tight lepton selection



Data Driven estimation

Basic idea:

- Use a looser ℓ definition (non isolated or failing some identification requirement)
- Assume the same shape of $\not\!\!E_T$ for QCD events with default and loose ℓ selection

Matrix Method - used in μ+jets channel

- Solve the 2 equation system:

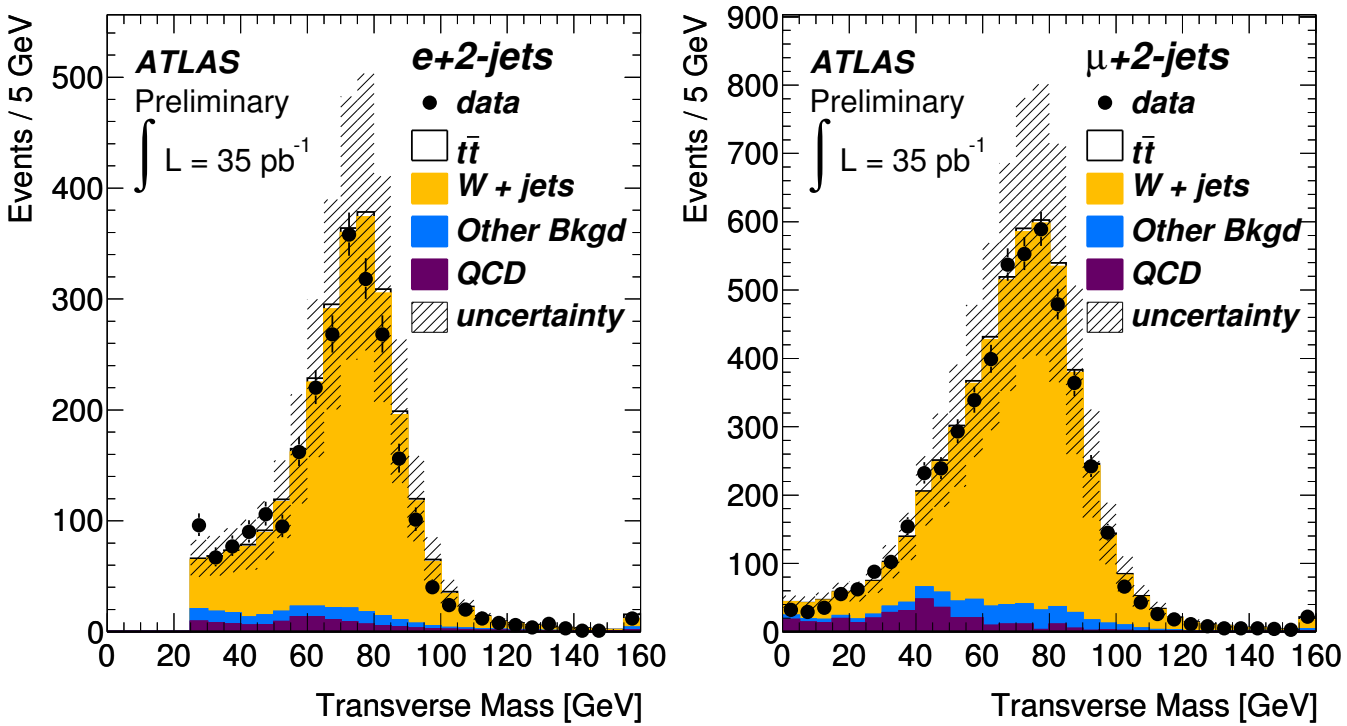
$$N^{loose} = N^{loose}_{fake} + N^{loose}_{real}$$

$$N^{tight} = \epsilon_{fake} N^{loose}_{fake} + \epsilon_{real} N^{loose}_{real}$$

- measuring ϵ_{fake} from low $\not\!\!E_T$ region,
- and ϵ_{real} from $Z->\ell\ell$ events (*)

*: ϵ_{fake} and ϵ_{real} are the efficiencies for a loose ℓ event to pass the tight selection, for fake lepton (QCD) and real lepton (from W, Z, top) events.

W transverse mass



Details on Likelihood Discriminant

Projective likelihood approach:

- TMVA package used
- The likelihood discriminant D_i for an event i is defined as:

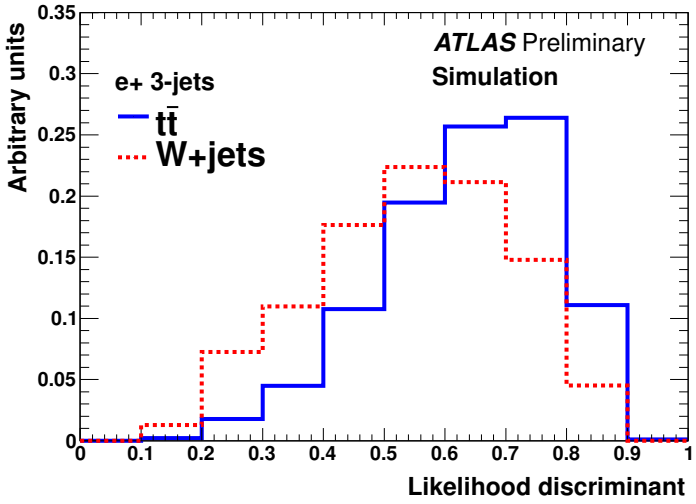
$$D_i = \frac{L_{signal}(i)}{L_{signal}(i) + L_{bkgd}(i)}$$

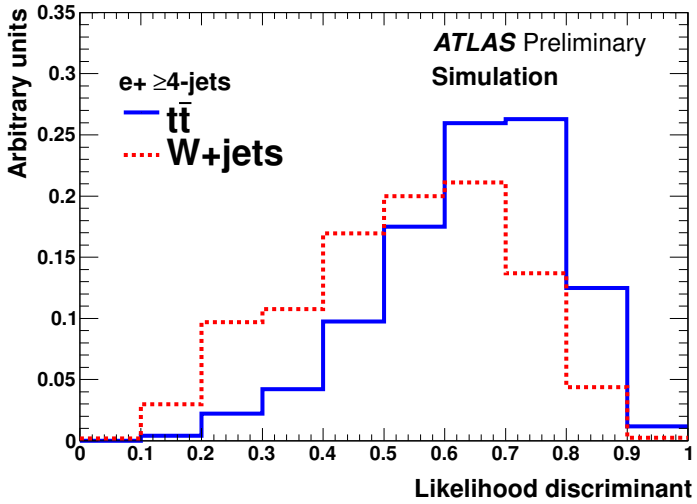
- The individual likelihoods are products of the corresponding probability densities of the discriminating input variables x_k:

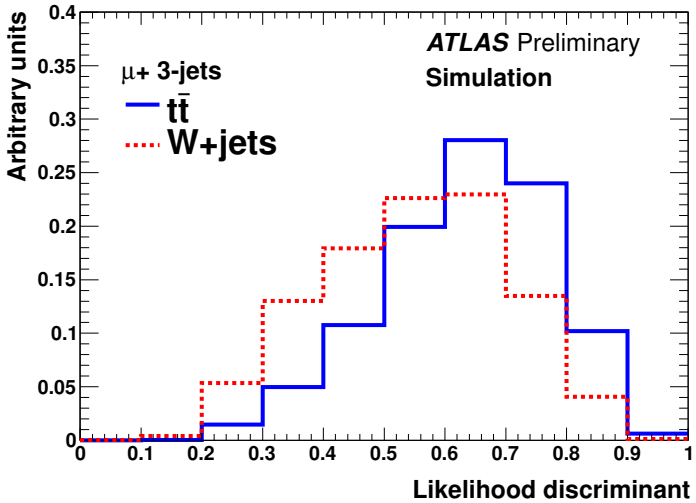
$$L_{signal}(i) = \prod_{k=1}^{3} p^k_{signal}(x_k(i))$$

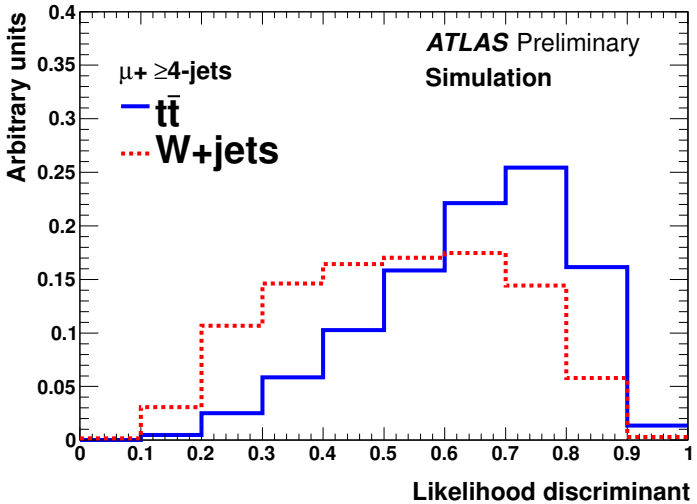
$$L_{bkgd}(i) = \prod_{k=1}^{3} p^k_{bkgd}(x_k(i))$$

Likelihood Discriminant Templates



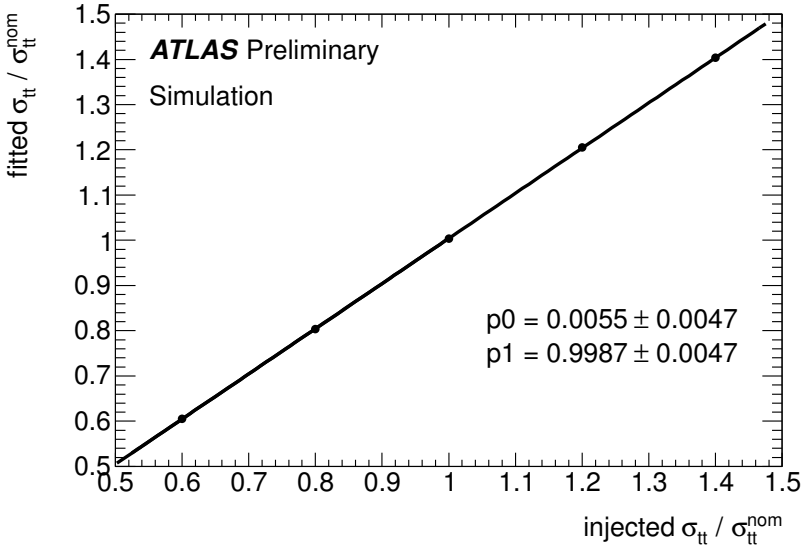




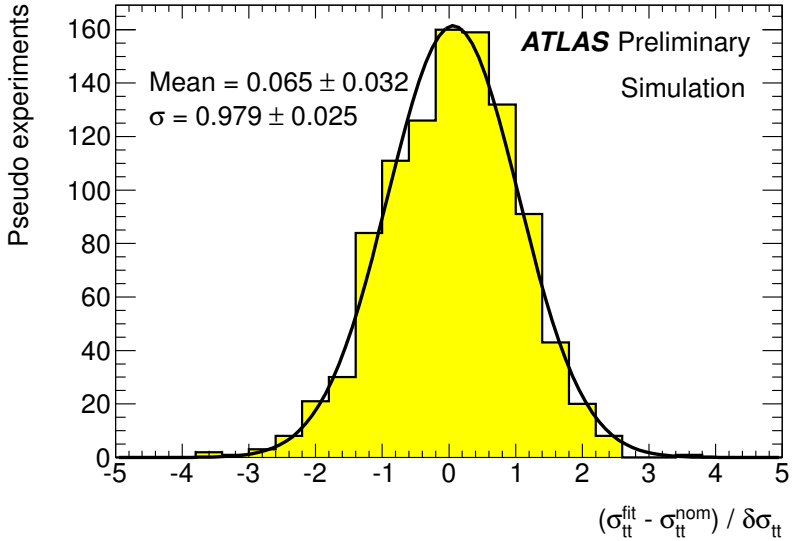


Likelihood Fit Details

A binned maximum likelihood fit is applied to the discriminant shapes. Likelihood functions are defined for each of the four channels and are multiplied together in a combined fit to extract the total number of $t\bar{t}$ events.



Fit stability for different pseudo-experiments with different input x-sec



Pull distribution of the likelihood fit at the nominal x-sec

Event Aplanarity

The aplanarity is defined as:

$$A = \frac{3}{2}\lambda_3,$$

where

$$\lambda_1 \geq \lambda_2 \geq \lambda_3,$$

are the three eigen values of the momentum tensor

$$S^{\alpha\beta} = \frac{\sum_i p_i^\alpha p_i^\beta}{\sum_i |\vec{p}_i|^2},$$

where α and β are spatial components and the i runs over jets & leptons