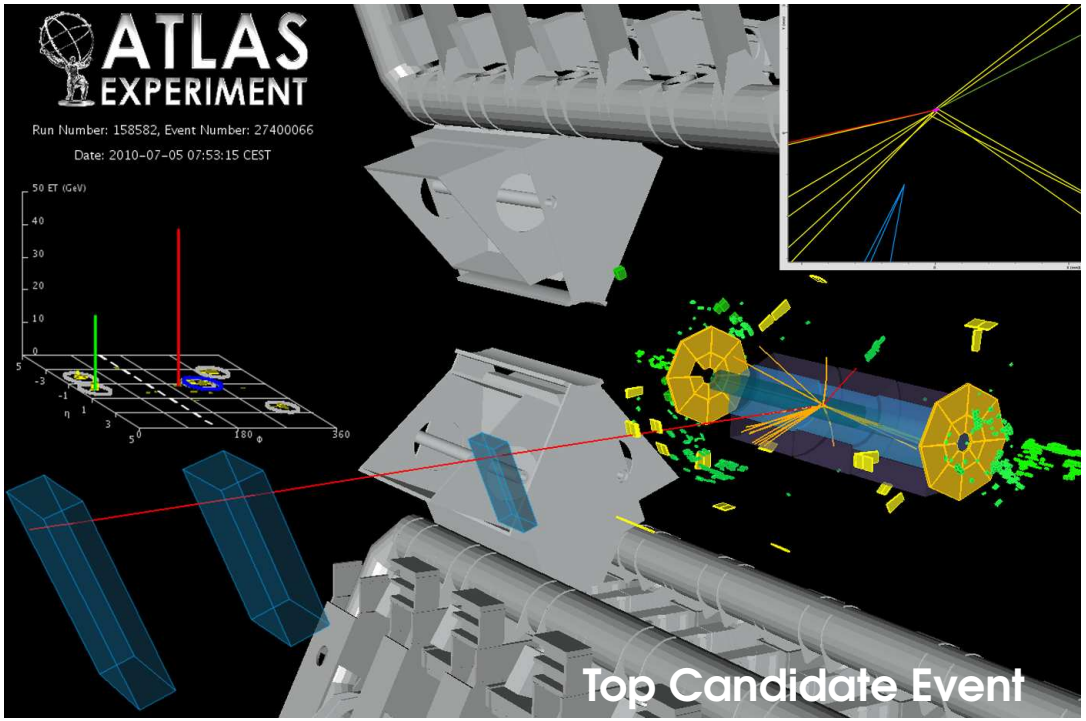
Top, W and Z in ATLAS



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for the ATLAS Collaboration

From the Standard Model to New Physics

See yesterday's ATLAS plenary by A. Belloni

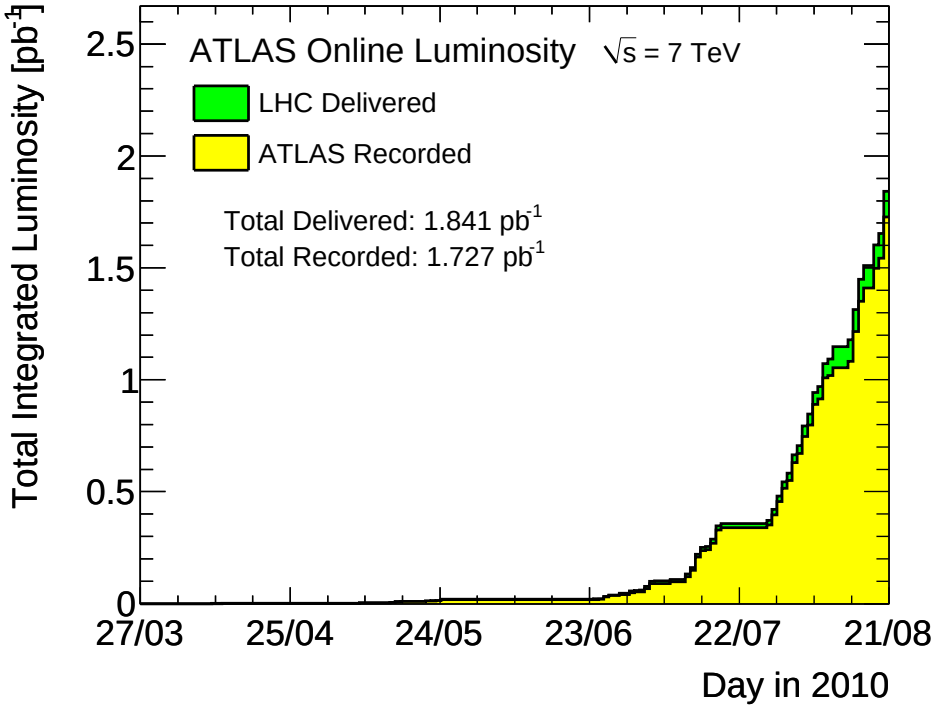
- Built LHC and ATLAS to find new physics.
- Often involves high p_T leptons and missing energy.
- Well known SM processes are excellent to study these objects.
- Detector commissioning
- Trigger efficiency
- Lepton identification
- Lepton energy scale and resolution
- Missing transverse energy
- Jet reconstruction and b-tagging
- Backgrounds to new physics
- Test QCD and EW at new energy

Isn't it a little 80s?

Data Sample

- ATLAS has recorded over 1.5 pb^{-1} at > 90 % data-taking efficiency.

- W and Z performance plots use 0.3-1.1 pb^{-1}.
- W cross section uses 17 nb^{-1}.
- Z cross section uses 219-229 nb^{-1}.
- Top analyses use 280-295 nb^{-1}.



Object Reconstruction

Electrons

- Sliding window algo with seed $E_T > 2.5$ GeV. Track match.
- Loose: shower shapes
- Medium: more shower shapes, track match quality
- Tight: E/p, transition radiation
- Efficiency 94-72 % for rejection 1.1k-92k.

Muons

- Standalone muons reconstructed only from muon system information, extrapolate to IP.
- Combined muons use both muon and Inner Detector information to obtain one set of track parameters.

Jets

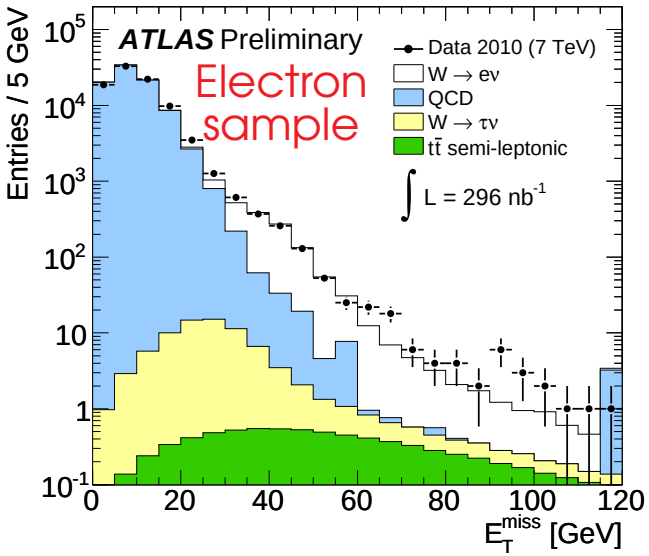
- Reconstructed using the anti-kT algorithm with $R = 0.4$.

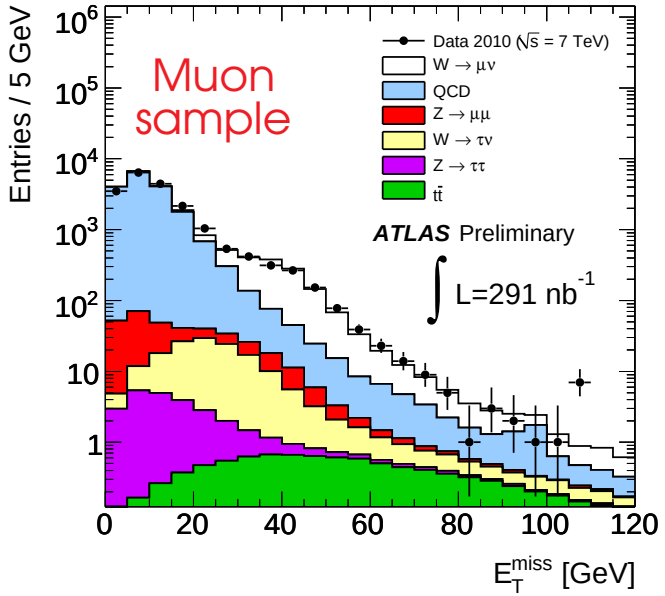
$E_{\mathrm{T}}^{\mathrm{miss}}$

- Uses calibrated 3D topological clusters. Corrected for muon p_T in muon analyses.

W/Z Event Preselection

- Single lepton trigger. Primary vertex with at least 3 tracks.
- Loose electron, $p_T > 20$ GeV, $|\eta| < 1.37$ or $1.52 < |\eta| < 2.47$.
- Combined muon, $p_T > 15$ GeV, $|\eta| < 2.4$ ($p_T^{MS} > 10$ GeV, $\Delta p_T < 15$ GeV, $\Delta z < 1$ cm).



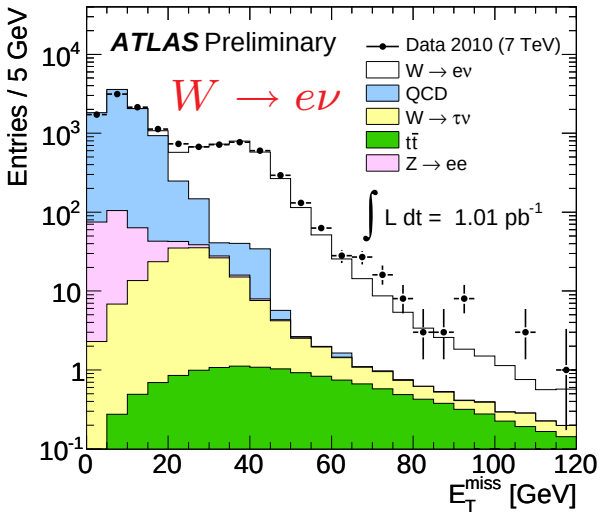


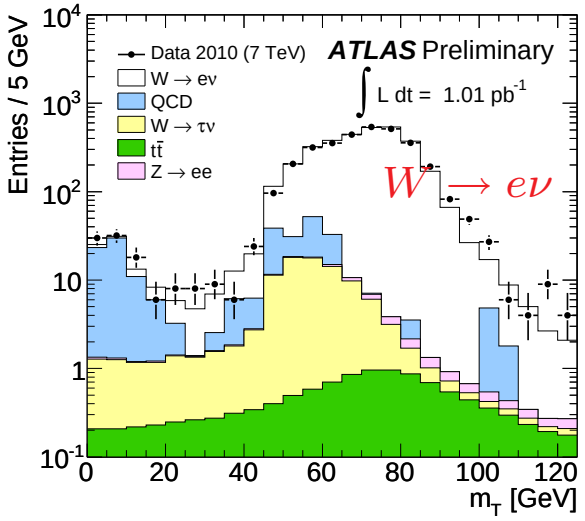
- Sample dominated by QCD. MC cross section is too large by approximately $\times 2$. Normalization from data-driven method.

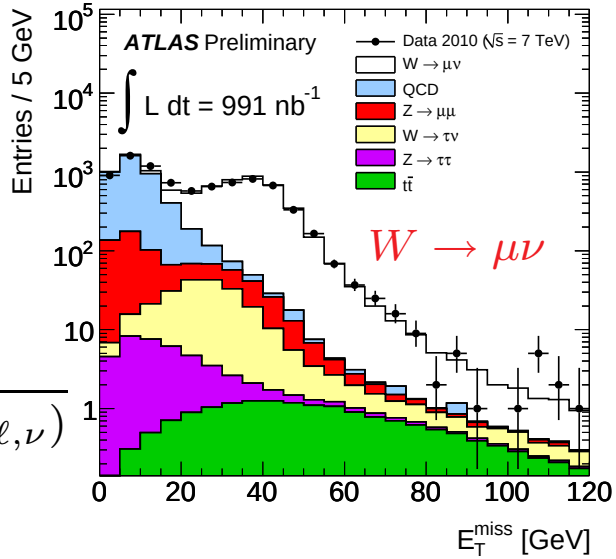
W Selection

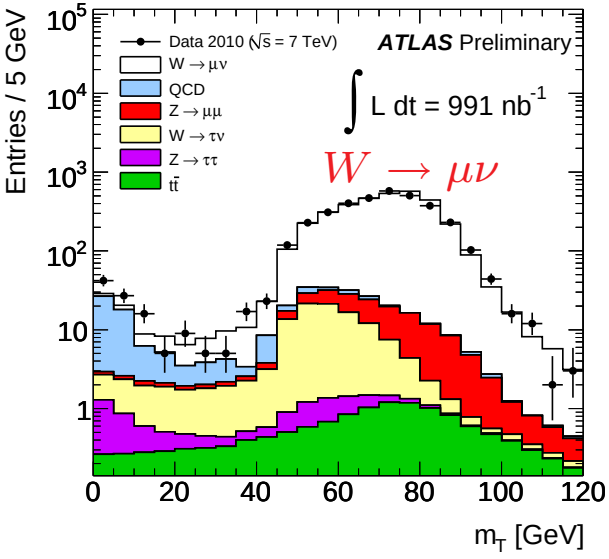
- Tight electron.
- Muon with $p_T > 20$ GeV.
- Muon isolation $\sum_{\Delta R<0.4} p_T^{trk}/p_T^{\mu} < 0.2$
- $E_{\mathrm{T}}^{\mathrm{miss}} > 25$ GeV.
- $m_T > 40$ GeV.

$$m_T = \sqrt{2 p_T^{\ell} p_T^{\nu} (1 - \cos(\Delta\phi_{\ell,\nu})}$$





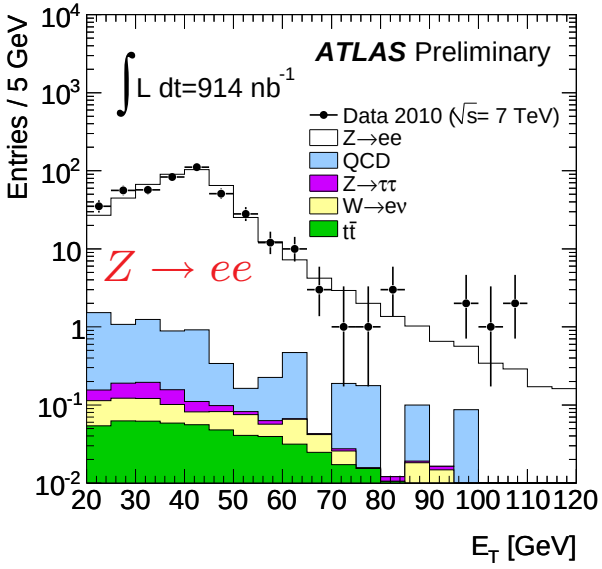


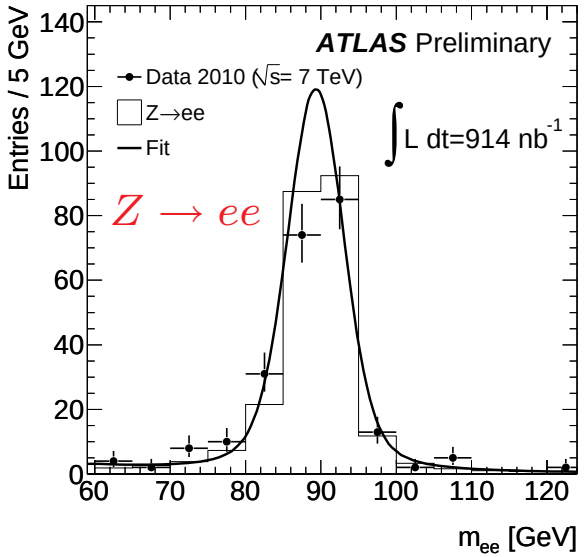


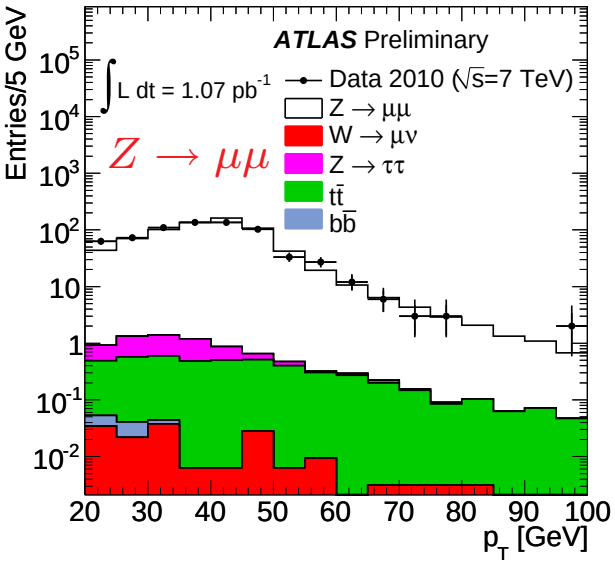
$E_{\mathrm{T}}^{\mathrm{miss}}$ m_T

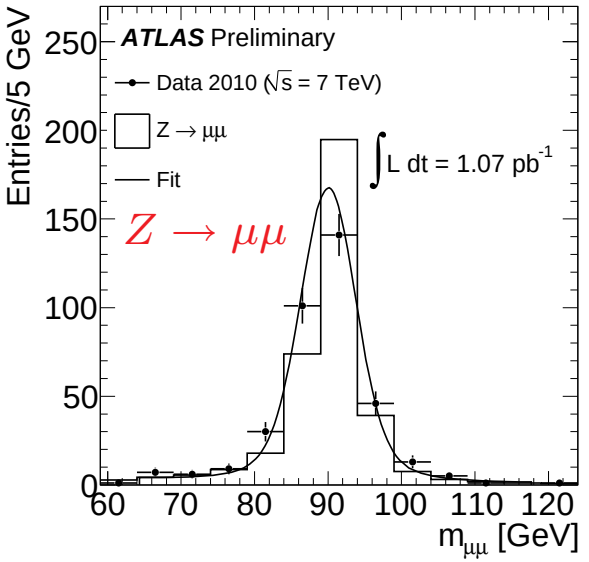
Z Selection

- Two oppositely charged leptons (e/μ).
- Same lepton selection as W analysis except medium electrons.
- Invariant mass $66 < m_Z < 116$ GeV.



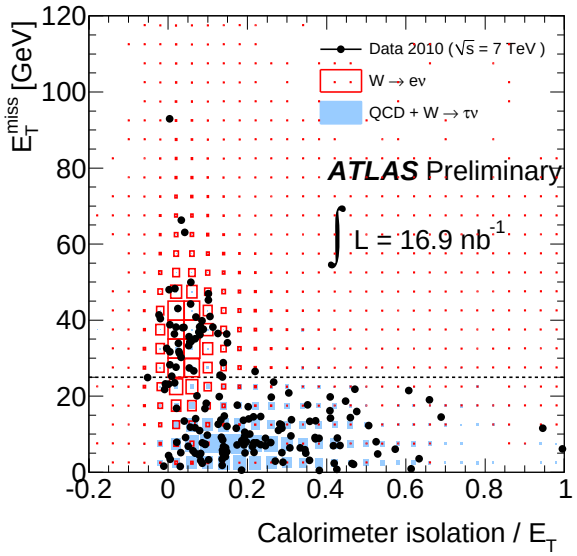






Signal and Background Estimates

- Signal estimate and EW backgrounds from Monte Carlo.
- QCD background mainly from data-driven methods.
- $W \to e\nu$: Binned likelihood fit to electron isolation.
- $W \to \mu\nu$: $E_{\mathrm{T}}^{\mathrm{miss}}$/track-isolation plane divided in 4 regions.
- $Z \to ee$: N loose electron pairs from MC. Data-driven loose-to-medium rejection factor.
- $Z \to \mu\mu$: From Monte Carlo.



	$W \to e\nu$	$W \to \mu\nu$	$Z \to ee$	$Z \to \mu\mu$
Luminosity	16.9 nb^{-1}	16.6 nb^{-1}	219 nb^{-1}	229 nb^{-1}
Observed	46	72	46	79
QCD	1.1	0.9	0.31	0.02
$W \to e\nu/\mu\nu$	-	-	0.06	0.01
$W \to \tau\nu$	1.4	1.9	-	-
$Z \to ee/\mu\mu$	0.1	2.2	-	-
$Z \to \tau\tau$	-	0.08	0.04	0.06
$t\bar{t}$	-	0.2	0.08	0.08

Systematic Uncertainties

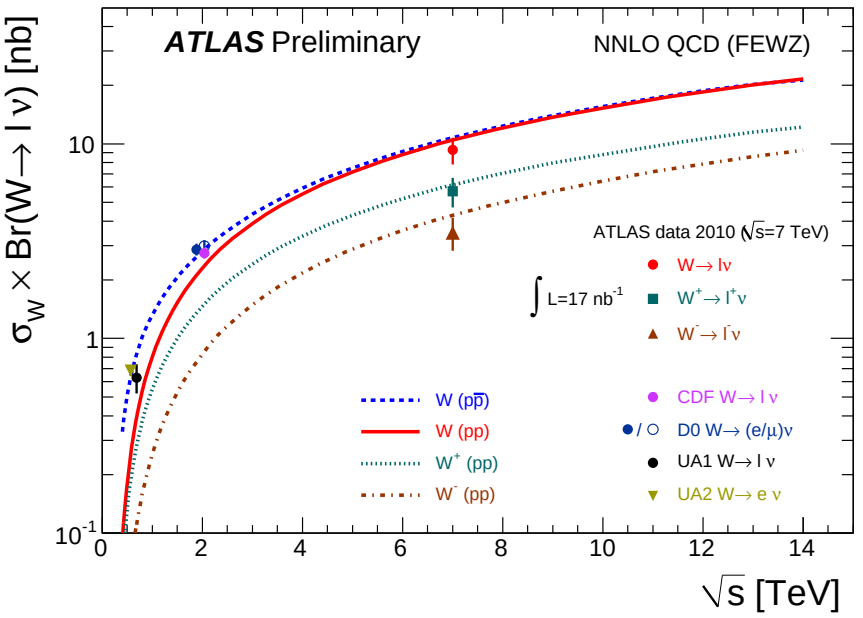
- Backgrounds are small, so systematic uncertainties come from acceptance, signal efficiency and luminosity.

	$W \to e\nu$	$W \to \mu\nu$	$Z \to ee$	$Z \to \mu\mu$
Acceptance	3 %	3 %	3 %	3 %
Trigger efficiency	$<$ 0.1 %	4 %	0.2 %	2 %
EM ID modelling	6 %	-	10 %	-
Muon reconstruction & ID	-	4 %	-	7 %
Material effects	4 %	-	9 %	-
EM energy scale	3 %	-	2 %	-
Muon p_T scale & resolution	-	4 %	-	1 %
$E_{\mathrm{T}}^{\mathrm{miss}}$ scale & resolution	2 %	2 %	-	-
Pileup	-	-	2 %	$<$ 0.1 %
Luminosity	11 %	11 %	11 %	11 %

W Cross Section

$$\sigma = \sigma_W \times BR(W \to \ell\nu) = \frac{N_W^{sig}}{A_W C_W L_{int}}$$

- N_W^{sig} Number of background-subtracted signal events.
- A_W Acceptance.
  46 % ($W \to e\nu$), 48 % ($W \to \mu\nu$)
- C_W Selection efficiency for in-fiducial events
  65-66 % ($W \to e\nu$), 80-82 % ($W \to \mu\nu$)
- L_{int} Integrated luminosity.
- pp collider, W production is not charge symmetric.

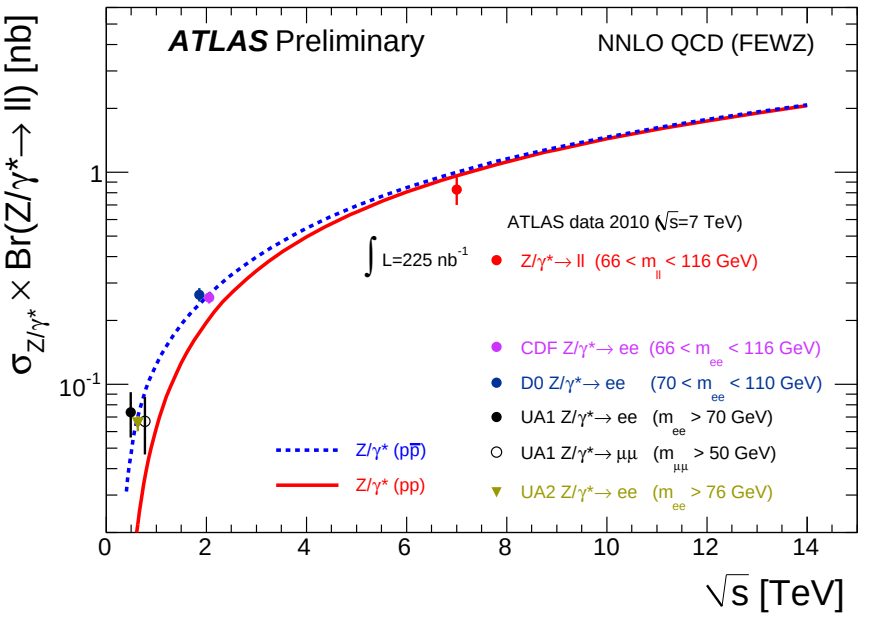


$$\sigma(W^+) = [5.7 \pm 0.7(\text{stat}) \pm 0.4(\text{syst}) \pm 0.6(\text{lumi})] \text{ nb}$$
$$\sigma(W^-) = [3.5 \pm 0.5(\text{stat}) \pm 0.2(\text{syst}) \pm 0.4(\text{lumi})] \text{ nb}$$
$$\sigma(W^\pm) = [9.3 \pm 0.9(\text{stat}) \pm 0.6(\text{syst}) \pm 1.0(\text{lumi})] \text{ nb}$$

Z Cross Section

$$\sigma = \sigma_Z \times BR(Z \to \ell\ell) = \frac{N_Z^{sig}}{A_Z C_Z L_{int}}$$

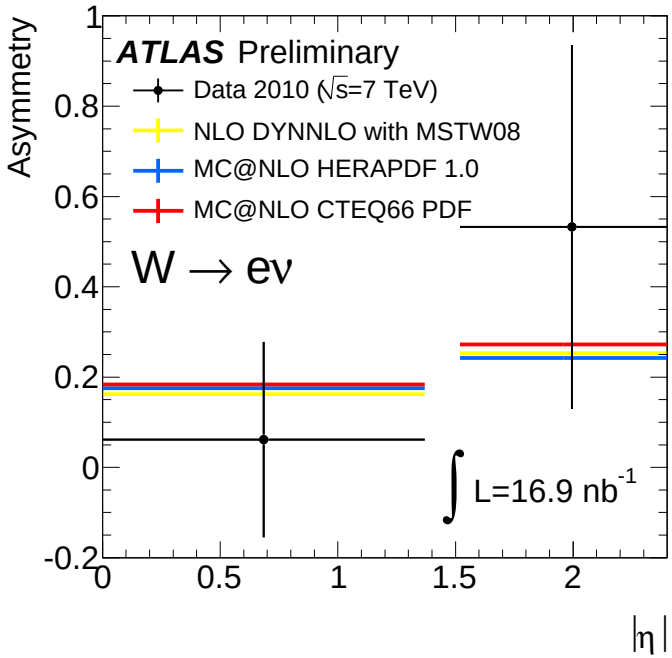
- N_Z^{sig} Number of background-subtracted signal events.
- A_Z Acceptance.
  45 % ($Z \to ee$), 49 % ($Z \to \mu\mu$)
- C_Z Selection efficiency for in-fiducial events.
  65 % ($Z \to ee$), 78 % ($Z \to \mu\mu$)
- L_{int} Integrated luminosity.

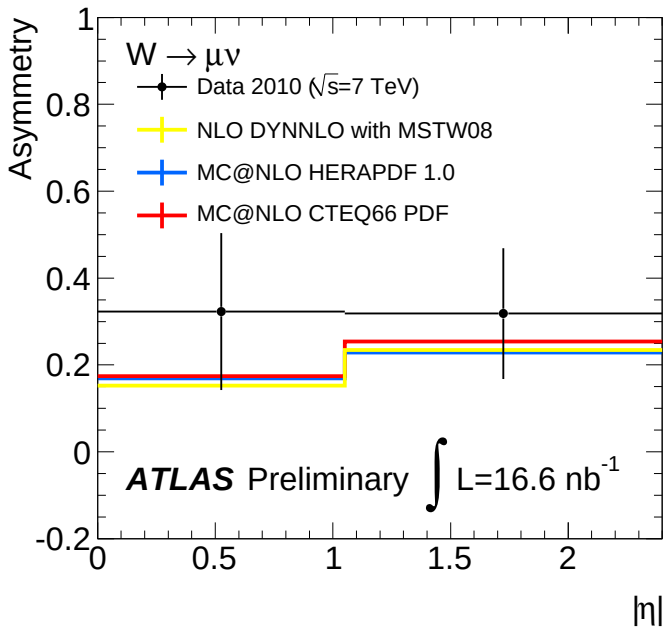


$$\sigma(Z)\ [66 < m_Z < 116] = [0.83 \pm 0.07(\text{stat}) \pm 0.06(\text{syst}) \pm 0.09(\text{lumi})]\ \text{nb}$$

W Charge Asymmetry

- Asymmetry, $A = \frac{\sigma^{l^+} - \sigma^{l^-}}{\sigma^{l^+} + \sigma^{l^-}}$, depends on lepton η.
- Important information about parton distribution functions.
- Tool to estimate W background in new physics searches.

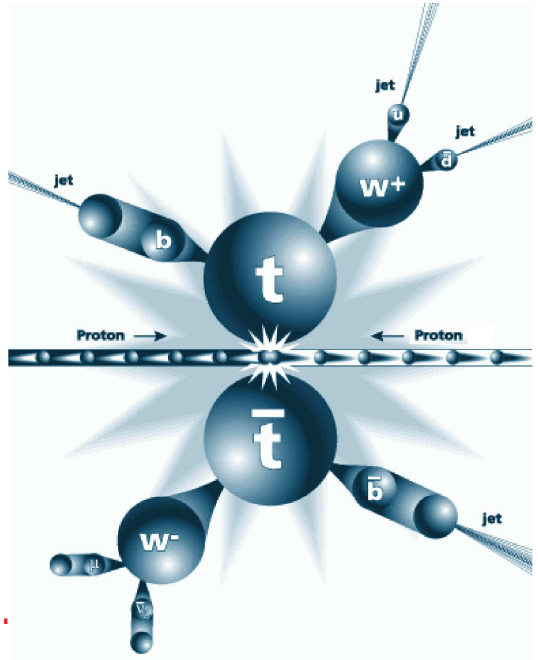




- Measurements consistent with expectation from MC.

Top Quark Production

- Top quarks so far only seen at Fermilab. Much larger cross-section at LHC $\Rightarrow$ Detailed measurements possible.
- Dominant background to much new physics such as SUSY.
- In the SM, top decays to Wb almost 100% of the time.
- Thus the final state is determined by the decay of the W.
- In the lepton+jets channels:
  - One W boson decays leptonically.
  - One W boson decays hadronically.
  - Final state contains $\geq$ 4 jets, one lepton and $E_{\mathrm{T}}^{\mathrm{miss}}$.
- In the dilepton channels:
  - Both W bosons decay leptonically.
  - Final state contains $\geq$ 2 jets, 2 leptons and $E_{\mathrm{T}}^{\mathrm{miss}}$.



Top Event Selection

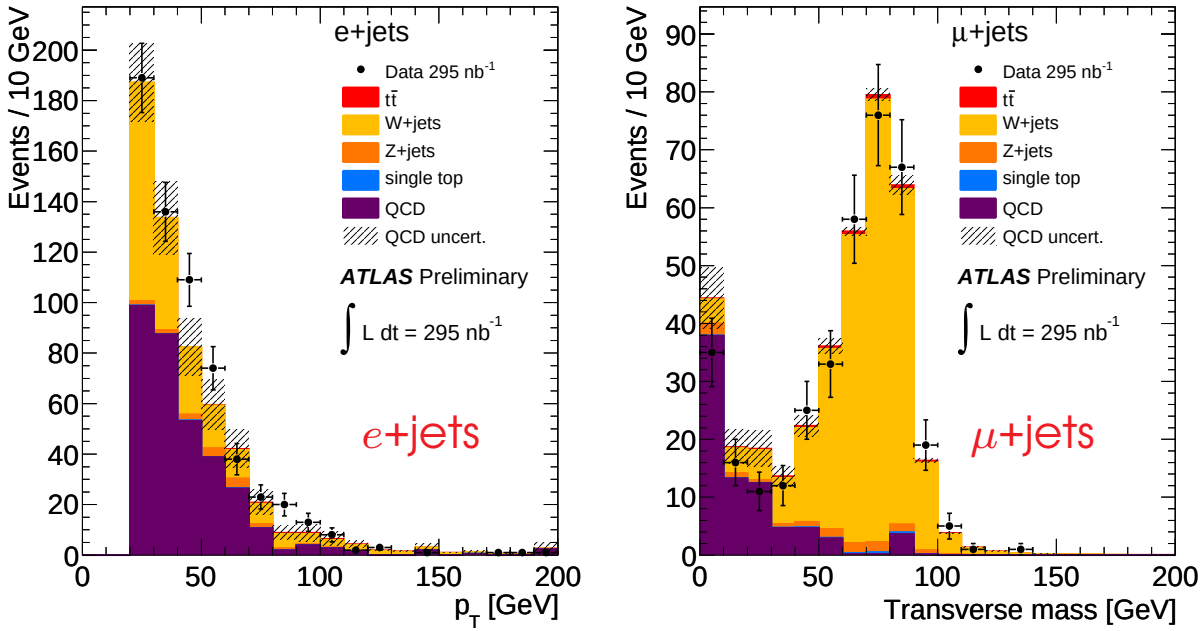
- At least one medium e or combined μ associated with the trigger object.
- Primary vertex with at least 5 tracks.

- Lepton+jets:
  - Exactly 1 e/μ with $p_T > 20$ GeV.
  - ≥ 4 jets with $p_T > 20$ GeV, $|\eta| < 2.5$.
  - ≥ 1 b-tagged jet.
  - $E_{\mathrm{T}}^{\mathrm{miss}} > 20$ GeV.
- 7 candidate events in 280 nb^{-1}.

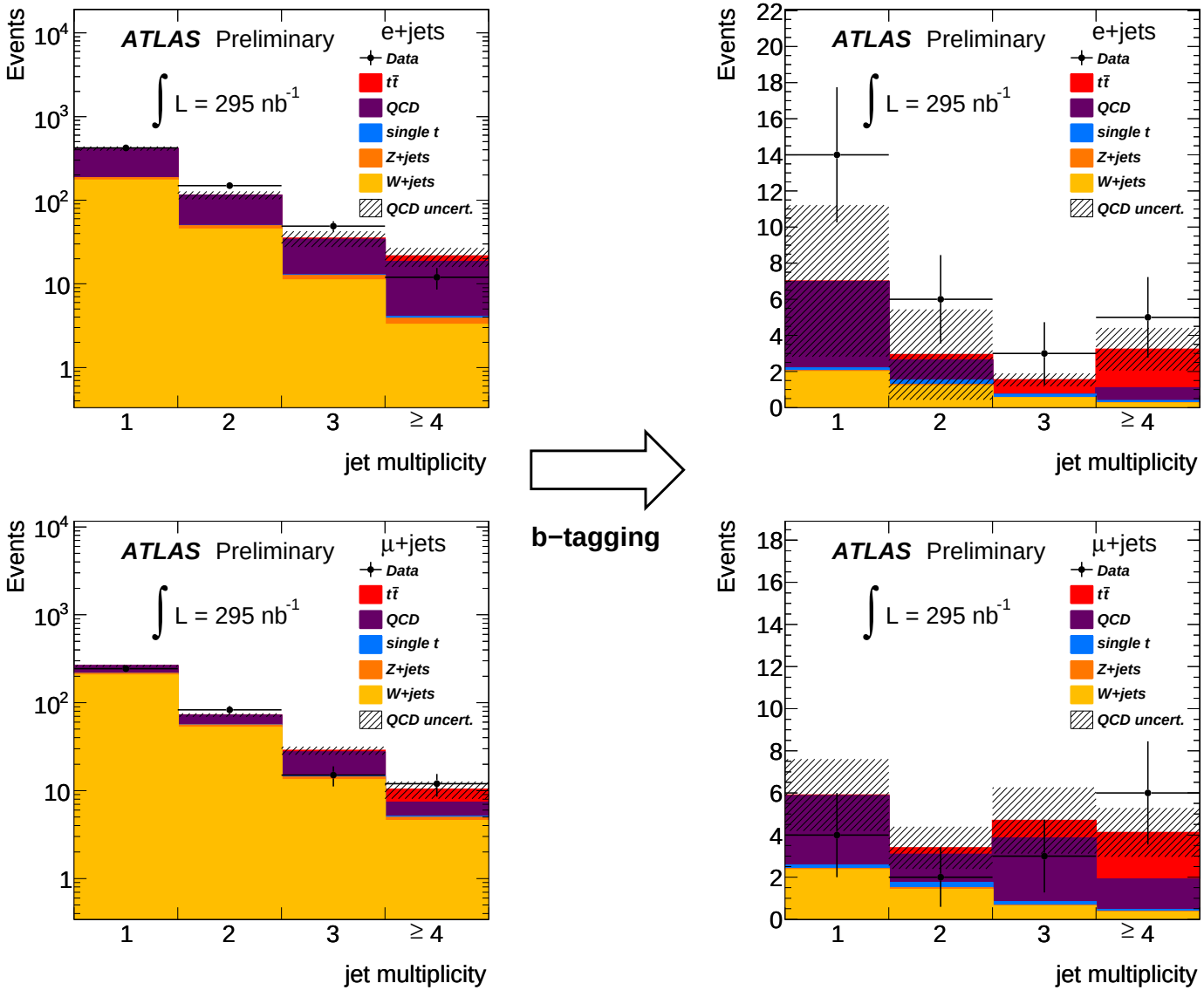
- Dilepton:
  - 2 oppositely charged e/μ with $p_T > 20$ GeV.
  - ≥ 2 jets with $p_T > 20$ GeV.
  - $E_{\mathrm{T}}^{\mathrm{miss}} > 40(30)$ GeV in ee ($\mu\mu$) channel.
  - $|m_{ee} - m_Z| > 5$ GeV, $|m_{\mu\mu} - m_Z| > 10$ GeV.
  - $H_T > 150$ GeV in $e\mu$ channel.
- 2 candidate events in 280 nb^{-1}.

Background Estimate in Lepton+Jets

- Main backgrounds are W+jets and QCD multijet (misID lepton).
- EW backgrounds estimated from MC.
- QCD background from data-driven method using tight (signal) sample and loose (relaxed lepton selection) sample.
- QCD and W backgrounds well modelled:

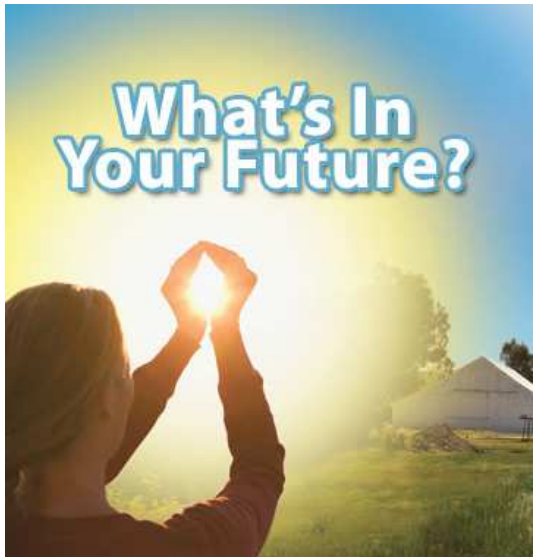


$\geq$ 1 jet, no b-tag selection


ATLAS Preliminary
e+jets
∫ L = 295 nb-1
Data
tt̄
QCD
single t
Z+jets
W+jets
QCD uncert.
Events
jet multiplicity
1
2
3
≥ 4
b−tagging
ATLAS Preliminary
μ+jets
∫ L = 295 nb-1
Data
tt̄
QCD
single t
Z+jets
W+jets
QCD uncert.
Events
jet multiplicity

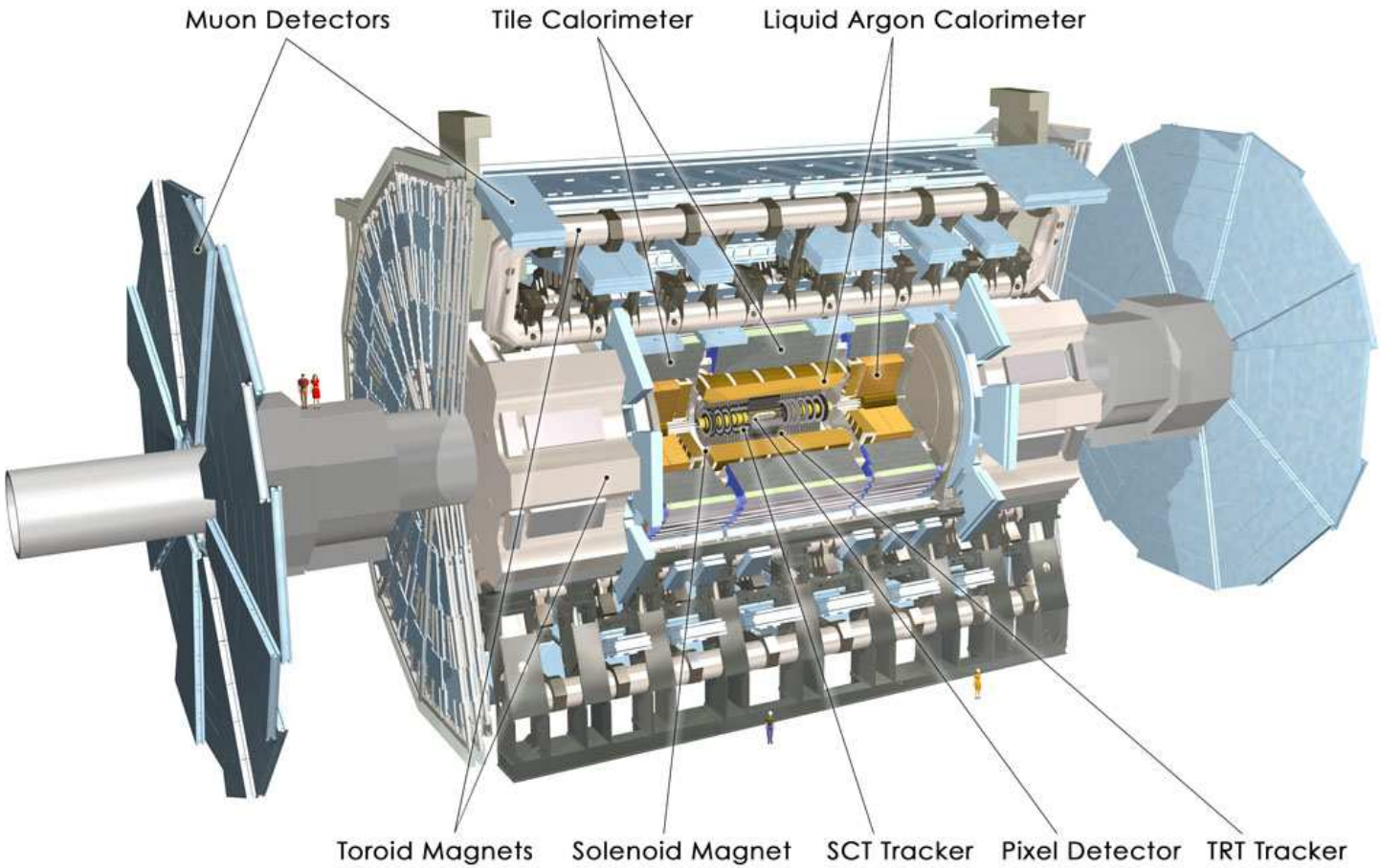
Summary and Outlook

- The LHC is working very well and ATLAS keeps collecting data with high efficiency.
- Already many solid SM measurements.
- First measurement of W and Z production cross sections as well as W charge asymmetry.
- So far everything consistent with SM expectations.
- 9 top candidate events in 280 nb^{-1}.
  Working on background estimates.
  Cross-section to come soon - stay tuned!
- This is only the beginning!



Background Material

The ATLAS Detector



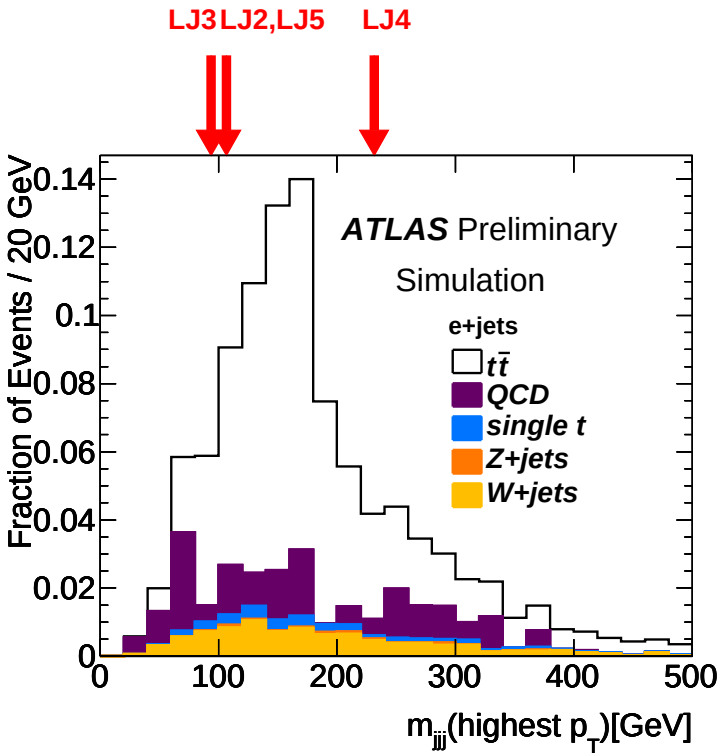
QCD Estimate in Top Analysis

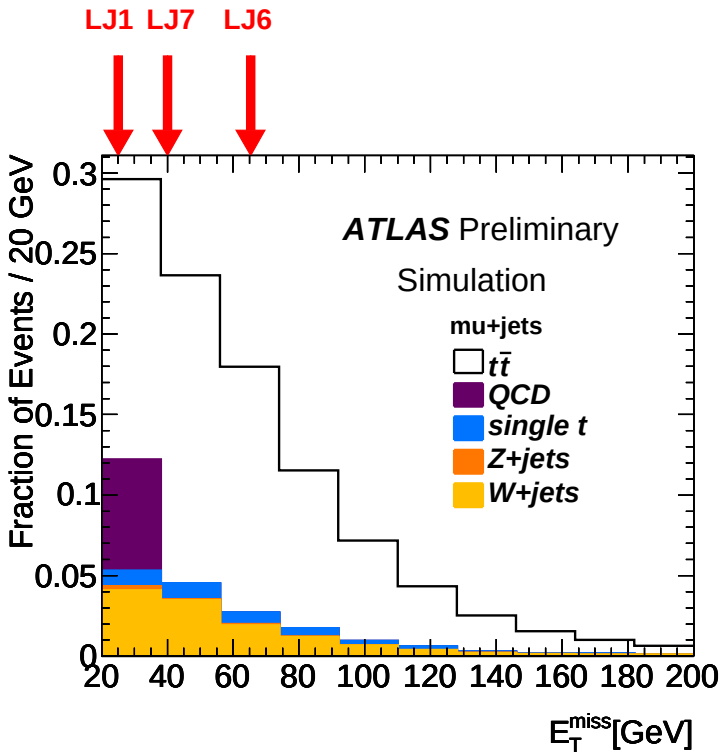
$$N^{loose} = N^{loose}_{real} + N^{loose}_{fake}$$

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

- ε_{real} from $Z \to \ell\ell$ MC.
- ε_{fake} from jet+low $E_{\mathrm{T}}^{\mathrm{miss}}$ sample.

Lepton+Jets Candidate Events





Dilepton Candidate Events