

**Measurement of the $W \rightarrow \ell\nu$ and $Z \rightarrow \ell\ell$
production cross section in proton-proton
collisions at $\sqrt{s} = 7$ TeV
with the ATLAS detector**

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On behalf of the ATLAS collaboration

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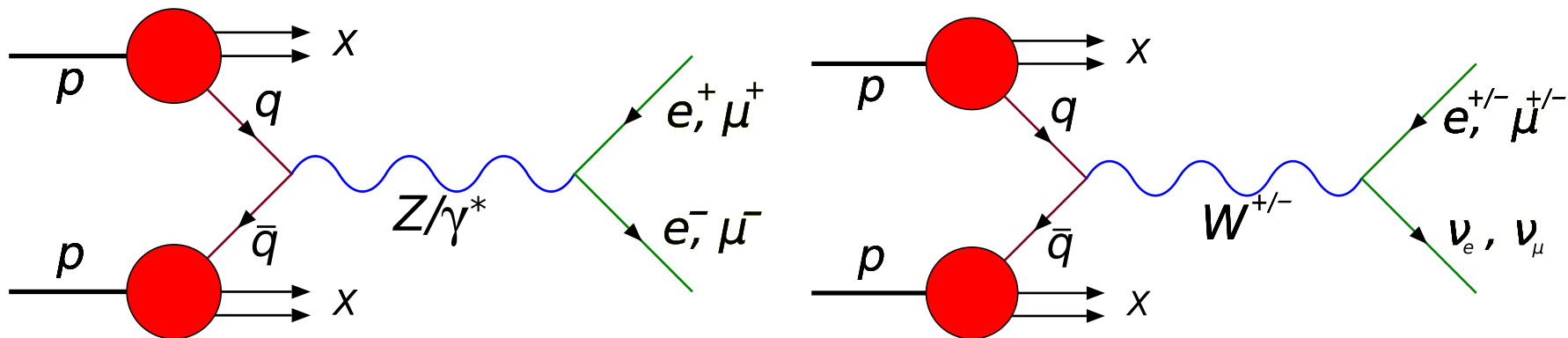
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Introduction

- Inclusive production of W^\pm and Z bosons is a high cross section process, total σ known to $\sim 4\%$, dominated by PDF uncertainties

$$\sigma_{W^+ \rightarrow \ell^+ \nu}^{NNLO} = 6.16 \text{ nb} \quad \sigma_{W^- \rightarrow \ell^- \bar{\nu}}^{NNLO} = 4.30 \text{ nb} \quad \sigma_{Z/\gamma^* \rightarrow \ell\ell}^{NNLO} = 0.96 \text{ nb}$$

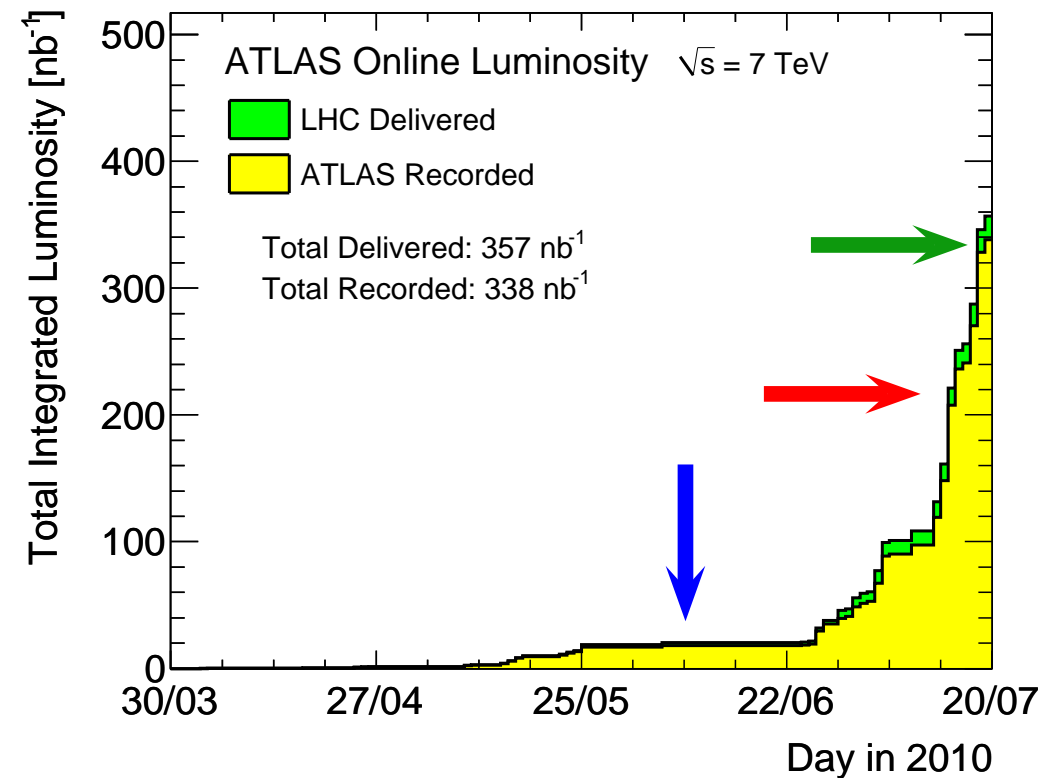
$\sqrt{s} = 7 \text{ TeV}$, calculated with FEWZ using MSTW2008NNLO PDFs



- Measurements in the electron and muon channels are important:
 - Precise tests of QCD in unexplored regions of low parton momentum fraction at large scales; eventually constrain PDFs
 - Detector commissioning and calibration especially using $Z/\gamma^* \rightarrow \ell\ell$
— Paving the road to precision measurements and new Physics!

Data and MC Samples

- W cross sections:
 $\mathcal{L} \approx 17 \text{ nb}^{-1}$ taken until June
- Z cross sections: $\mathcal{L} \approx 225 \text{ nb}^{-1}$
- Preview: $\mathcal{L} \approx 300 - 330 \text{ nb}^{-1}$
- Luminosity calibrated to 11% using van-der-Meer scans
- Recorded using single electron and muon hardware triggers with low thresholds



- MC signal and background with many 10^6 events per sample, fully simulated with GEANT4
- Pythia signal MC generated with MRST LO* PDFs, norm. to σ^{NNLO}
- Cross checks and acceptance calculations with latest MC@NLO version and CTEQ6.6 and HERAPDF1.0 PDFs
- QCD background is determined mostly directly from the data

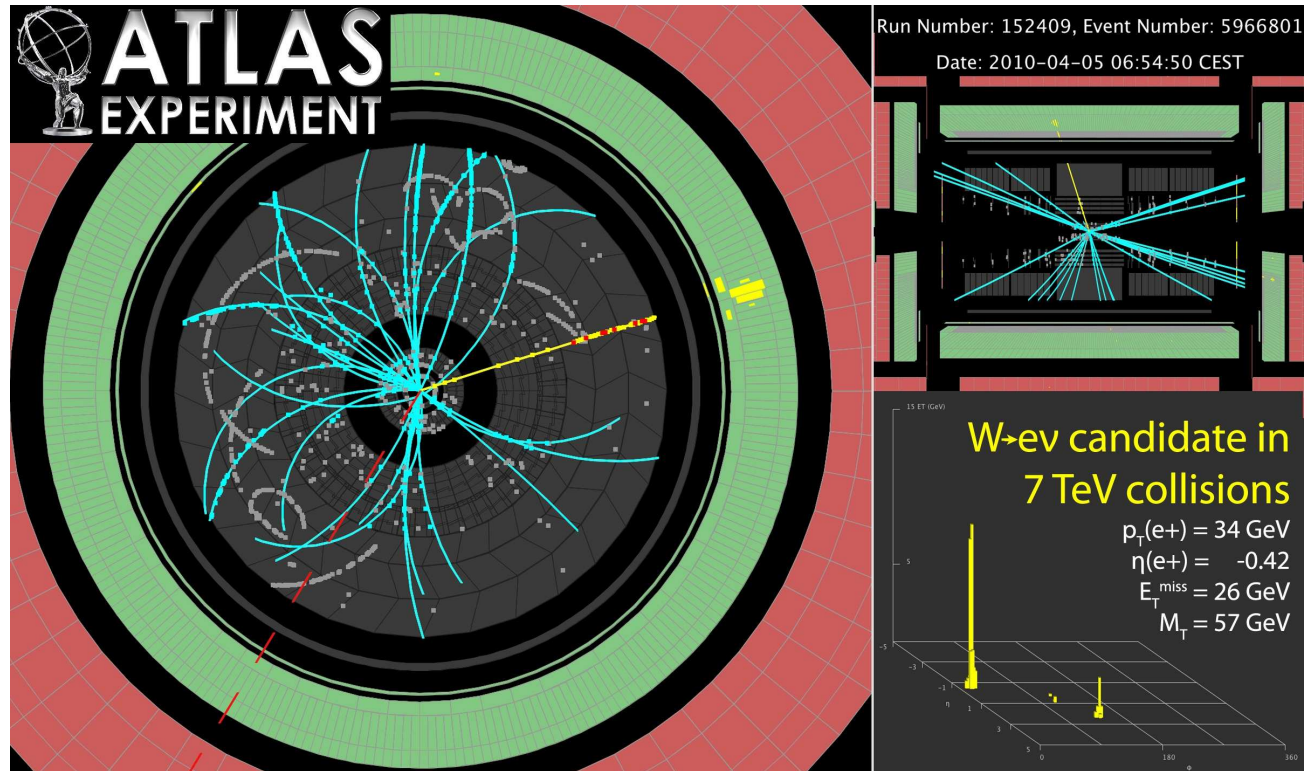
Electron Reconstruction and Identification

Central $|\eta| < 2.47$: Calorimeter Cluster + Track

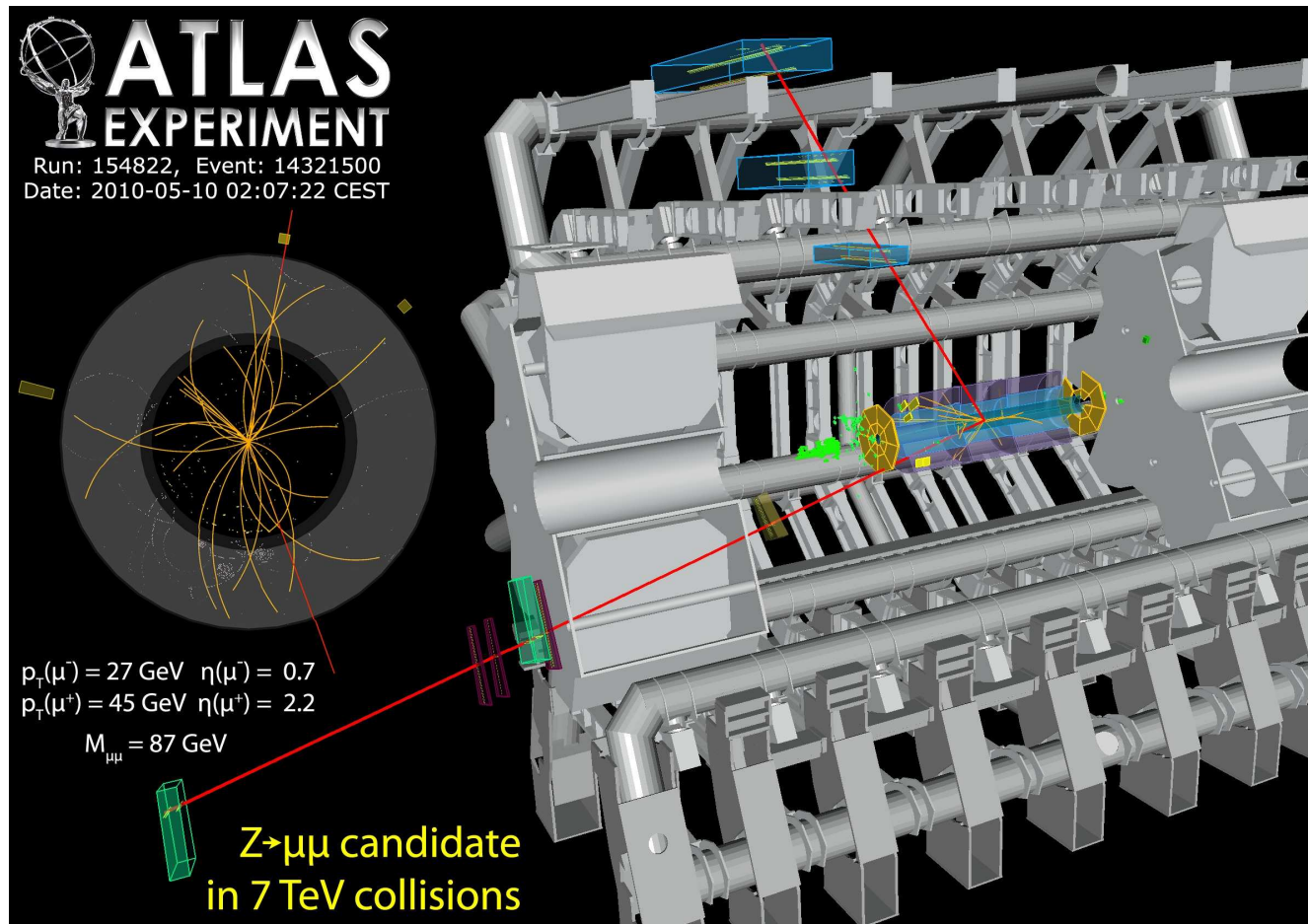
- *Loose Preselection*: Calorimeter 2nd sampling shapes and leakage
- *Medium* for $Z \rightarrow ee$: add Calorimeter 1st sampling shapes, Si tracker hits and impact parameter, track-cluster matching
- *Tight* for $W \rightarrow e\nu$: add b-layer hits and TRT high threshold hits, conversion rejection, E/p matching

Forward $2.5 < |\eta| < 4.9$: Only Calorimeter Cluster

- *forward Loose Preselection*
- *forward Tight* for $Z \rightarrow ee$ with one central + one forward electron



Muon Reconstruction



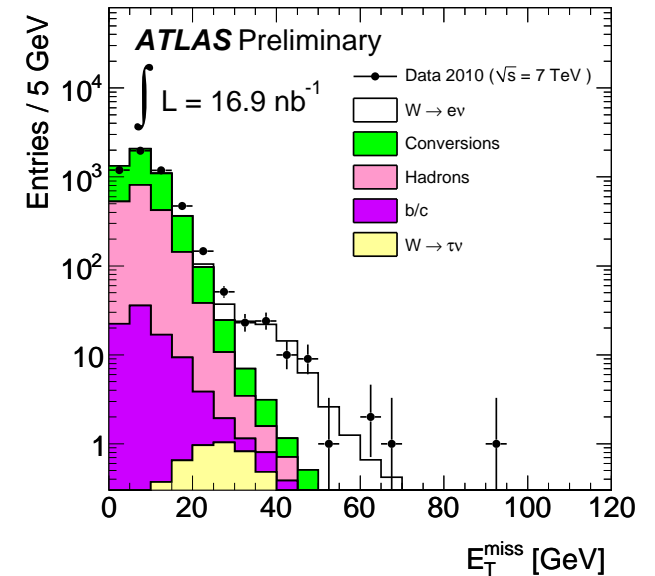
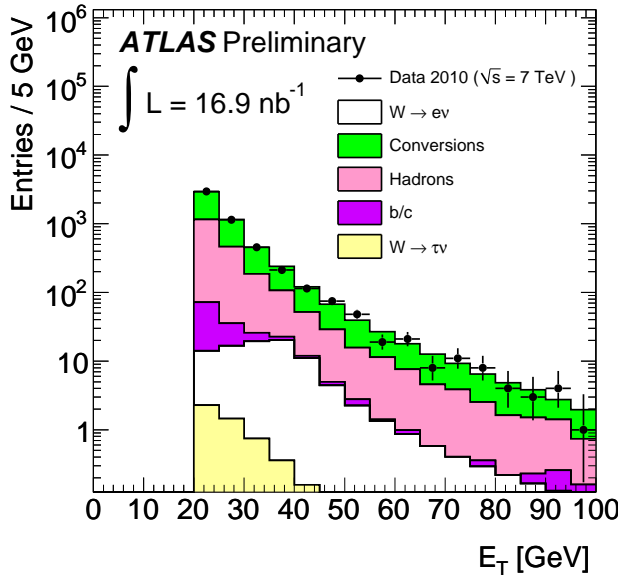
- Combined muon $|\eta| < 2.4$:
muon spectrometer (MS) + inner detector (ID) track
- Decays in flight, cosmics and other background reduced by p_T and spacial matching cuts between MS and ID

Towards W: Lepton Preselection

- Largely dominated by QCD background, W signal at large \cancel{E}_T

Electron channel

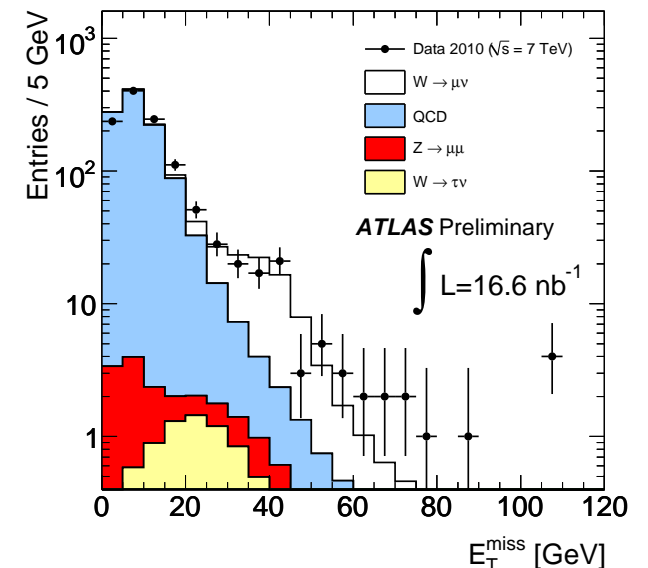
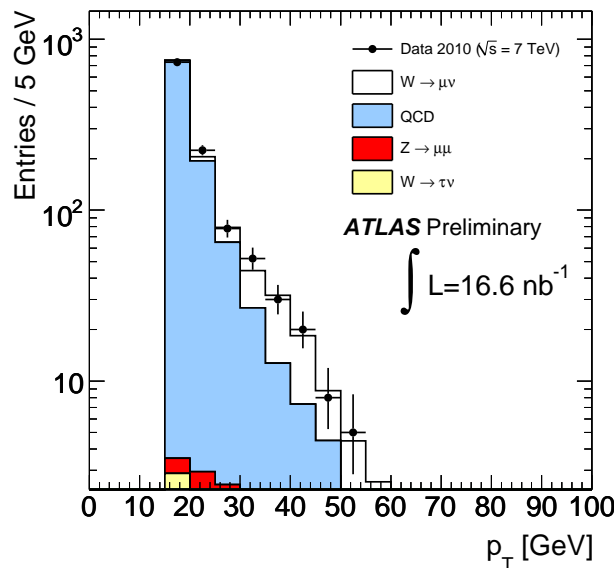
- $|\eta| < 1.37$ or $1.52 < |\eta| < 2.47$
- $E_T > 20$ GeV
- Loose identification
- QCD scaled $\times 0.4$



Muon channel

- $|\eta| < 2.4$
- $p_T > 15$ GeV
- QCD scaled $\times 0.6$

\cancel{E}_T calibrated for different EM/hadronic response

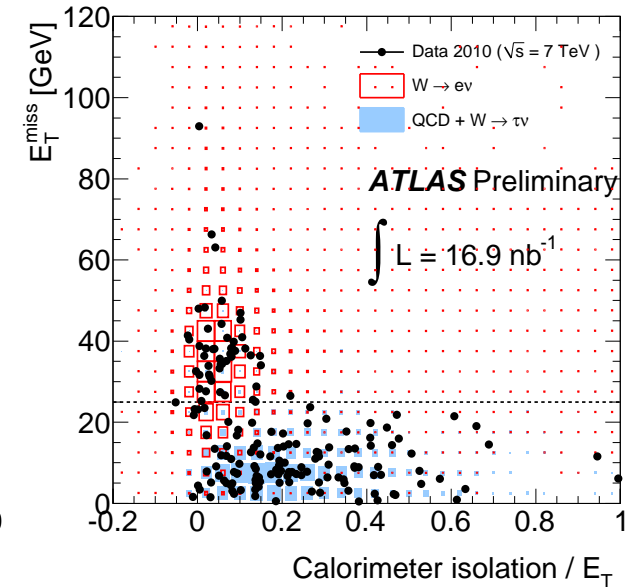
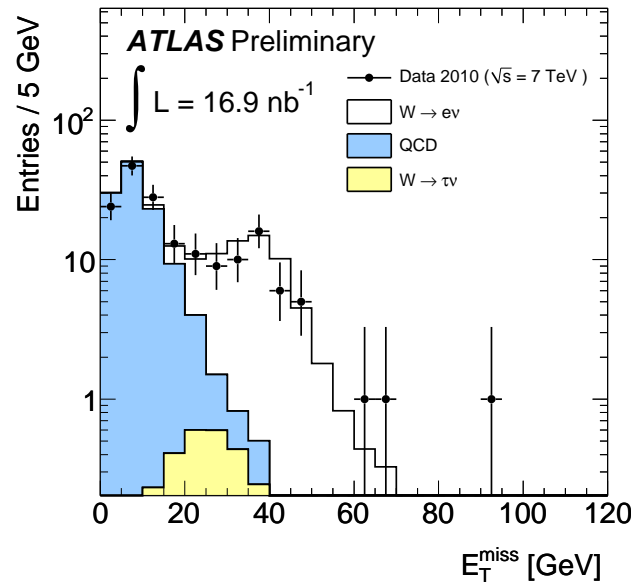


Towards W: Final Lepton Selection

- W signal emerging clearly after further cuts to reduce fake leptons

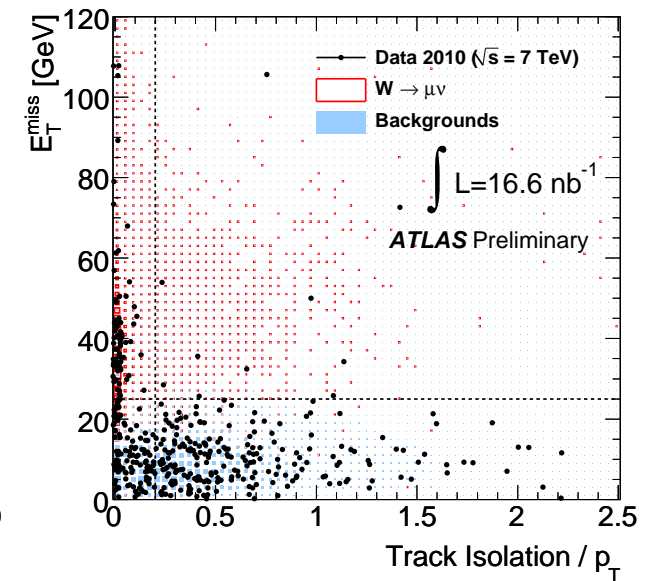
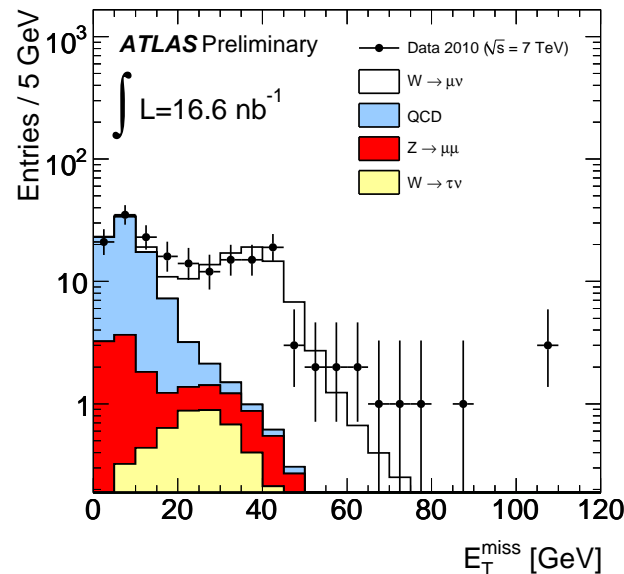
Electron channel

- Using *tight* identification
- Calorimetric isolation in $\Delta R = 0.3$ cone used for QCD background estimation



Muon channel

- Cut on rel. Track isolation < 0.2 in $\Delta R = 0.4$ cone for lepton selection



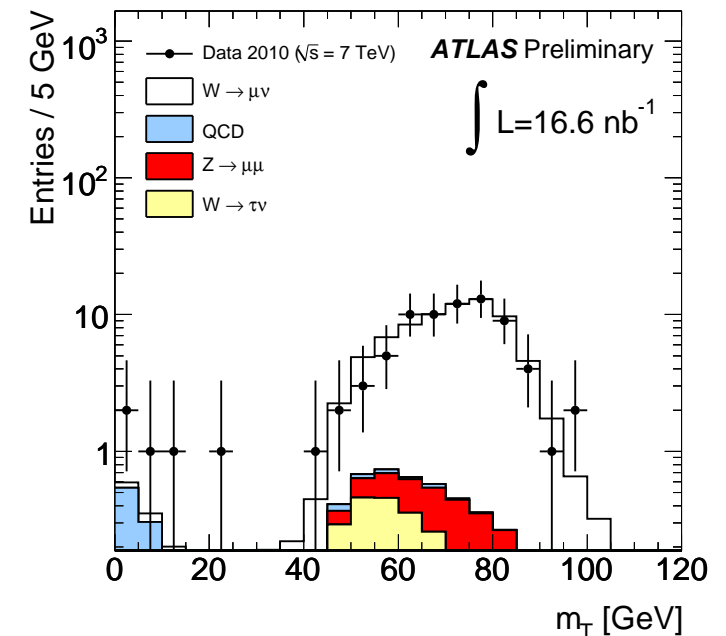
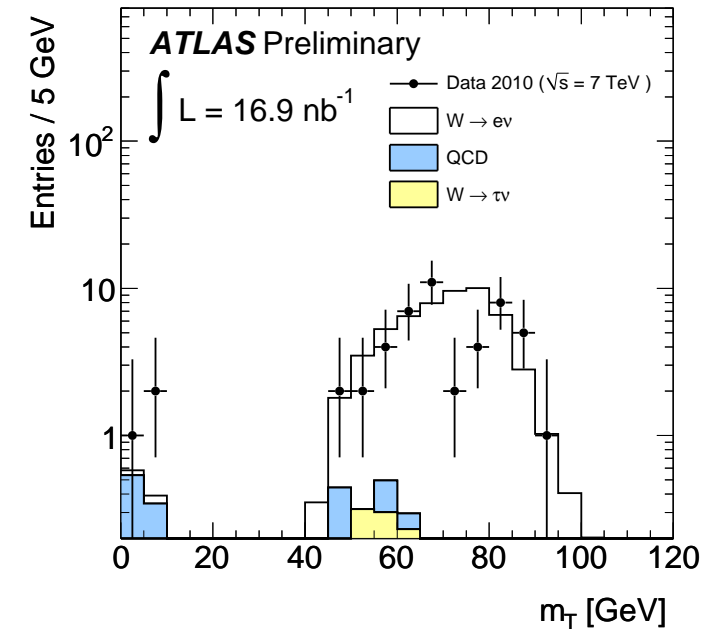
Final W Signal and Background

- Requires $\cancel{E}_T > 25$ GeV and transverse mass

$$m_T = \sqrt{2p_T^\ell p_T^\nu (1 - \cos(\phi^\ell - \phi^\nu))} > 40 \text{ GeV}$$

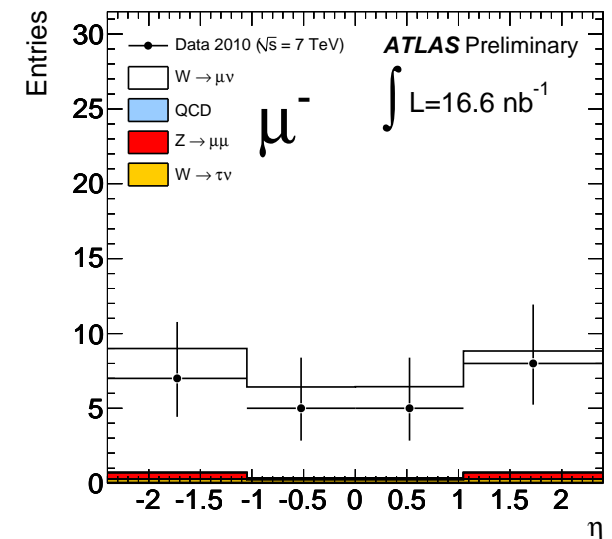
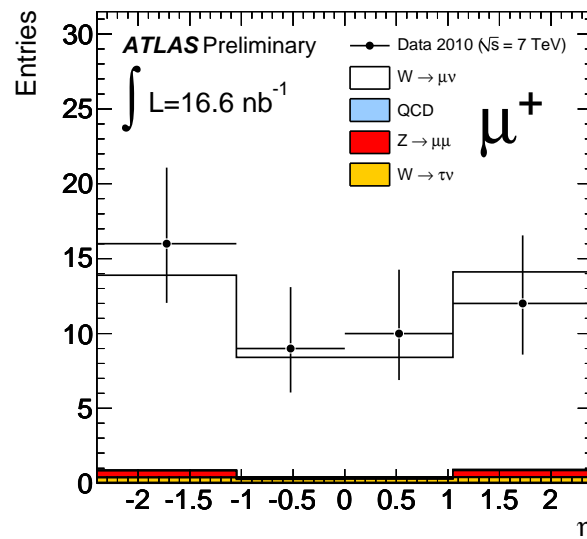
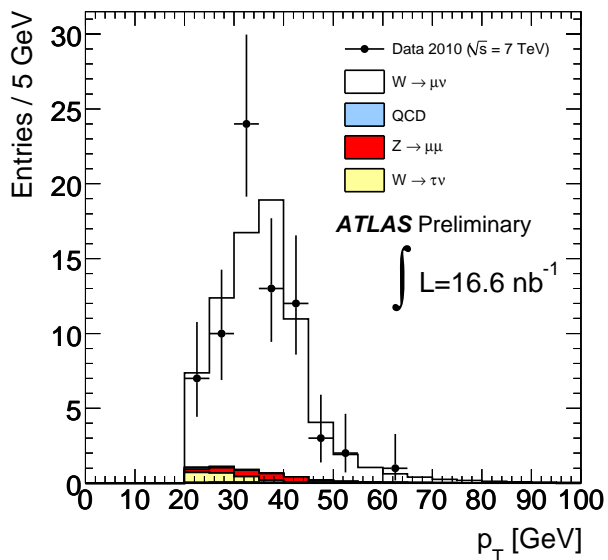
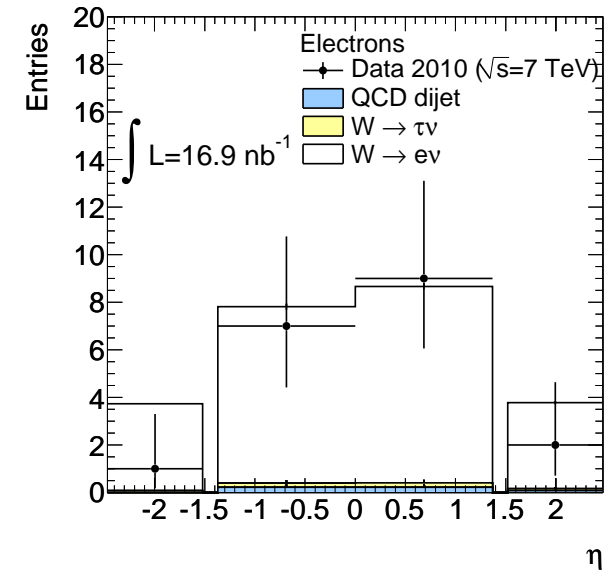
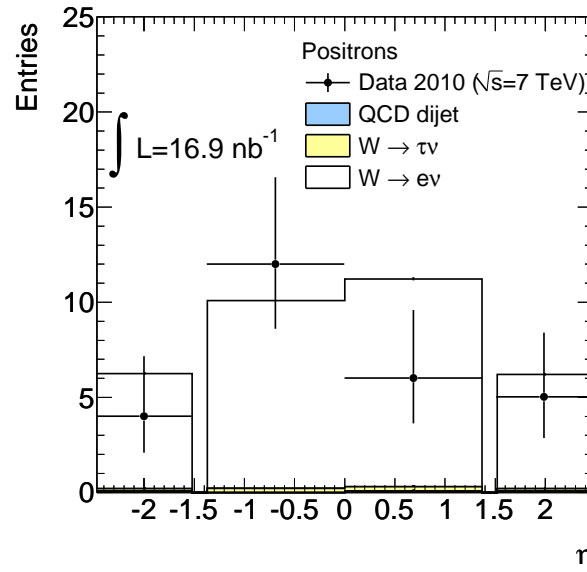
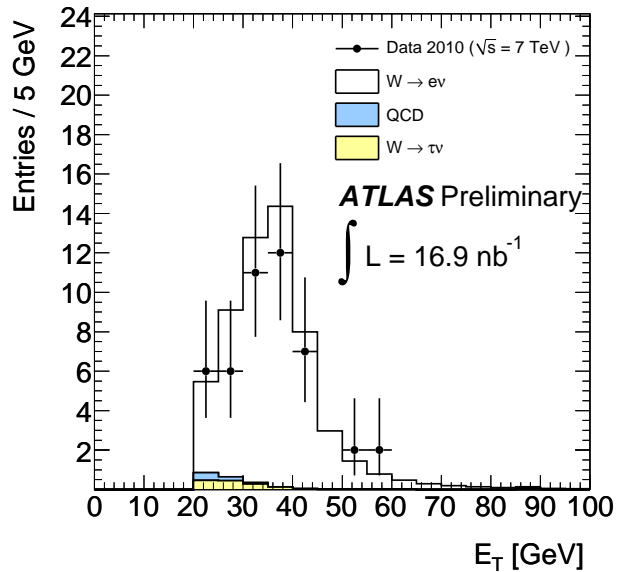
- Observe 46 e^\pm and 72 μ^\pm candidates
- Electroweak backgrounds (mainly $W \rightarrow \tau\nu$ in electron, $Z \rightarrow \mu\mu$ in muon channel) largest, taken from MC with $\lesssim 10\%$ sys. uncertainty
- QCD small, estimated with data driven techniques with $\approx 50\%$ sys. uncertainty

	Observed	EW Bkg.	QCD Bkg.
e^+	27	0.9	0.6
e^-	19	0.6	0.6
e^\pm	46	1.5	1.1
μ^+	47	2.4	0.7
μ^-	25	2.0	0.2
μ^\pm	72	4.4	0.9



Lepton Kinematics with Full W Selection

- Good description of lepton kinematics, also separated by charges



Measurement of the W Cross Sections

- Fiducial cross section inside the acceptance defined by geometrical and kinematic cuts

$$\sigma_W^{\text{fid}} \times \text{BR}(W \rightarrow \ell\nu) = \frac{N^{\text{obs}} - N^{\text{bkg}}}{C_W \mathcal{L}_{\text{int}}}$$

- Correction for reconstruction, identification, trigger efficiencies and radiative effects performed with a single factor C_W taken from MC
- Total cross section is obtained using the geometrical acceptance A_W

$$\sigma_W^{\text{tot}} \times \text{BR}(W \rightarrow \ell\nu) = \frac{\sigma_W^{\text{fid}}}{A_W} \quad \text{where} \quad A_W = \left(\frac{N_{\text{acc}}}{N_{\text{all}}} \right)_{\text{gen}}$$

	A_W $W^+ \rightarrow e^+\nu$	A_W $W^+ \rightarrow \mu^+\nu$	A_W $W^- \rightarrow e^-\bar{\nu}$	A_W $W^- \rightarrow \mu^-\bar{\nu}$
PYTHIA MRSTLO*	0.466	0.484	0.457	0.475
MC@NLO HERAPDF1.0	0.475	0.494	0.454	0.472
MC@NLO CTEQ6.6	0.478	0.496	0.452	0.470

- also $W^+ + W^-$ averaged; systematics from different generators $\approx 3\%$

Contributions and Uncertainties to C_W

- Much work has been invested to determine corrections and uncertainties to the MC derived C_W factors
- Done using data as far as possible with current statistics, partially using other channels like $\pi^0 \rightarrow \gamma\gamma$, J/ψ or QCD dijets: e.g. trigger, μ reconstruction
- Employ special MC samples with additional material or misalignments
- $Z \rightarrow \ell\ell$ will soon become basis for systematic studies

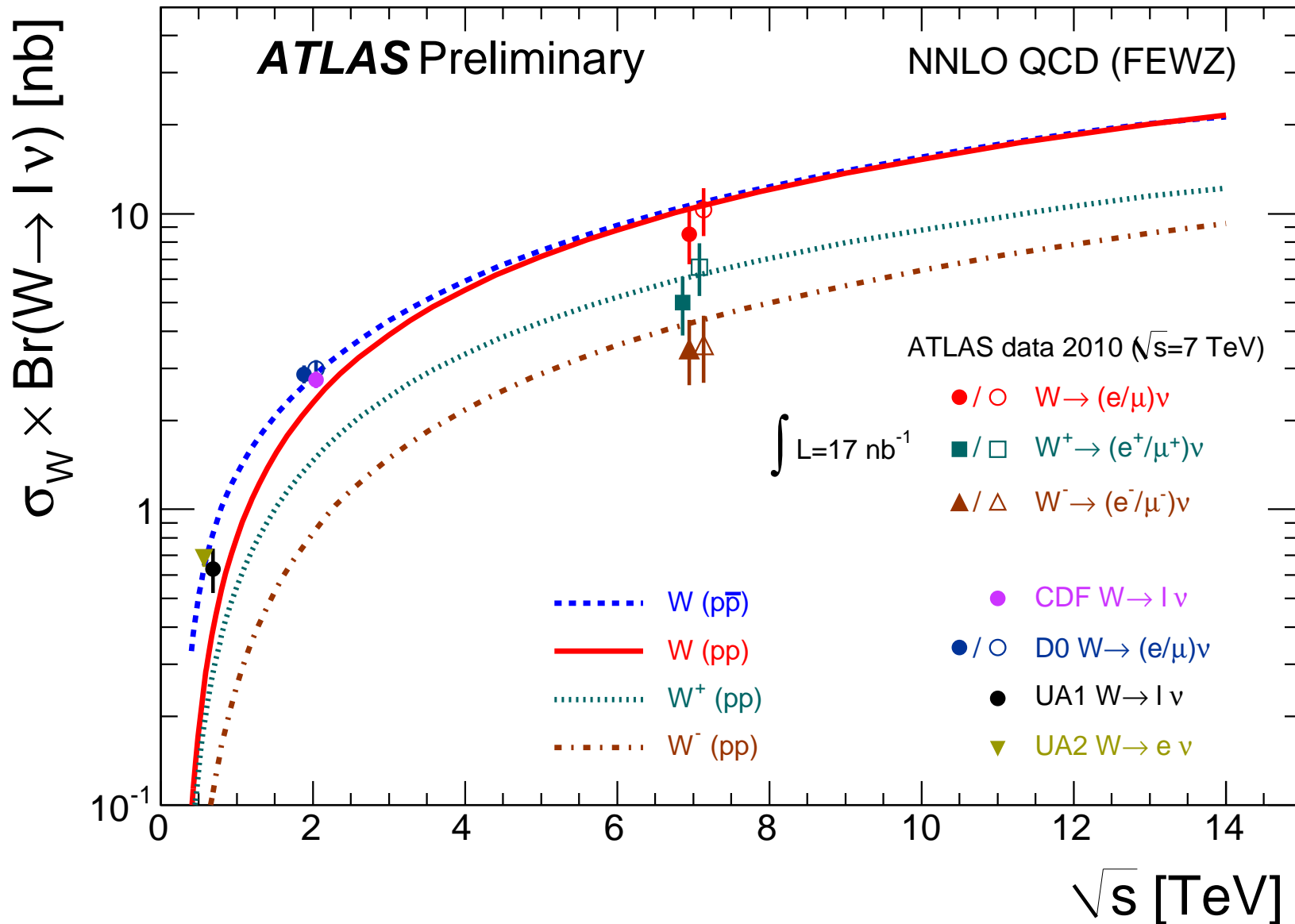
	$W \rightarrow e\nu$	$W \rightarrow \mu\nu$
Trigger	$99.9 \pm 0.1\%$	$88\% \pm 4\%$
Lepton reconstruction + identification	$78 \pm 6\%$	$97\% \pm 4\%$
Material + dead regions	$\pm 4\%$	—
Lepton scale & resolution	$\pm 3\%$	$\pm 4\%$
\cancel{E}_T scale & resolution	$\pm 2\%$	
charge averaged C_W	$66 \pm 8\%$	$81 \pm 7\%$

W Cross Section Results $\mathcal{L} = 17 \text{ nb}^{-1}$

	W^+	W^-	W^\pm
Electron channel $\sigma \pm \text{stat} \pm \text{sys} \pm \text{lumi}$			
σ_{fid} [nb]	$2.3 \pm 0.5 \pm 0.2 \pm 0.3$	$1.6 \pm 0.4 \pm 0.1 \pm 0.2$	$3.9 \pm 0.6 \pm 0.3 \pm 0.4$
σ_{tot} [nb]	$5.0 \pm 1.0 \pm 0.4 \pm 0.5$	$3.5 \pm 0.9 \pm 0.3 \pm 0.4$	$8.5 \pm 1.3 \pm 0.7 \pm 0.9$
Muon channel $\sigma \pm \text{stat} \pm \text{sys} \pm \text{lumi}$			
σ_{fid} [nb]	$3.2 \pm 0.5 \pm 0.2 \pm 0.4$	$1.7 \pm 0.4 \pm 0.1 \pm 0.2$	$4.9 \pm 0.6 \pm 0.4 \pm 0.5$
σ_{tot} [nb]	$6.6 \pm 1.0 \pm 0.5 \pm 0.7$	$3.6 \pm 0.8 \pm 0.3 \pm 0.4$	$10.3 \pm 1.3 \pm 0.8 \pm 1.1$
Theory Expectations			
σ_{tot} [nb]	6.16 ± 0.25	4.30 ± 0.17	10.46 ± 0.42

- The limited data statistics is (still) dominating the result
- Good agreement with theory expectation within uncertainties so far

Inclusive $W \rightarrow \ell\nu$ at Hadron Colliders

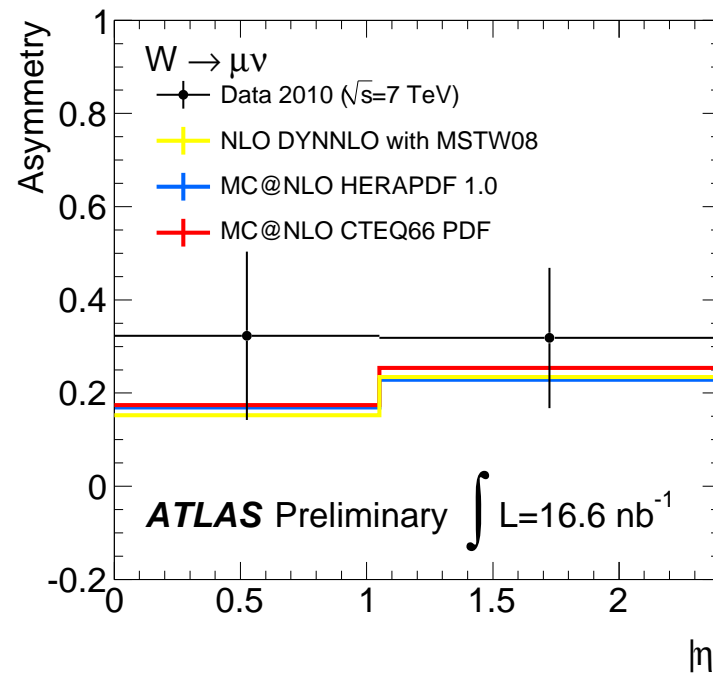
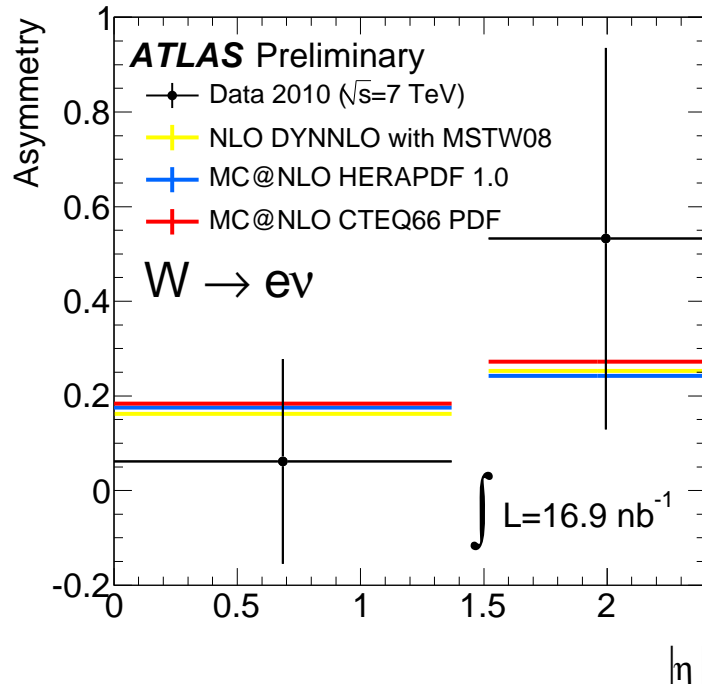


Lepton Charge Asymmetry

- Difference of W^+ and W^- production can be measured via the lepton charge asymmetry

$$A = \frac{\sigma^{l^+} - \sigma^{l^-}}{\sigma^{l^+} + \sigma^{l^-}}$$

- Constrains u/d quark ratio in proton, perform as function of η_l (correlated to parton momentum fraction x)
- Many uncertainties cancel fully (luminosity) or partially (lepton efficiencies)

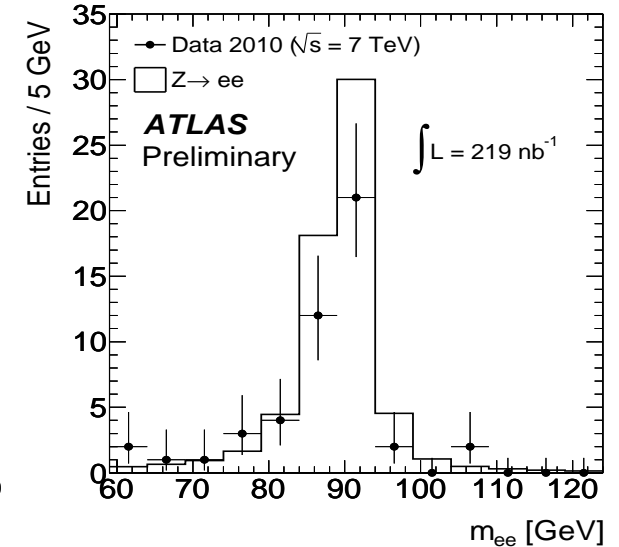
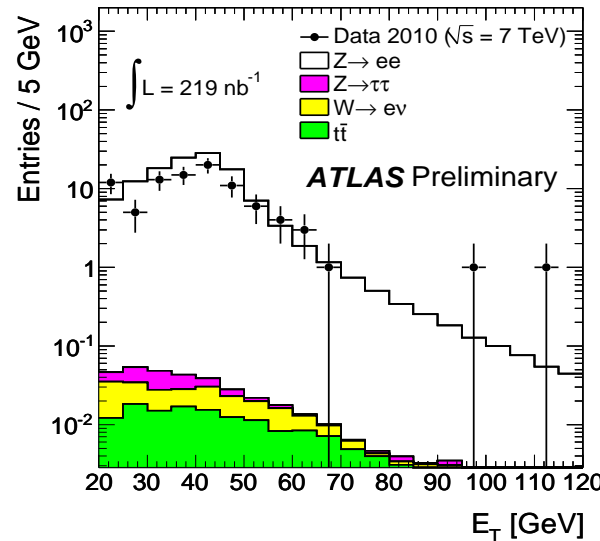


Z → ll Selection

- Relaxed cuts compared to W analysis, but same preselection
- Measurement in invariant mass window $66 < m_{\ell\ell} < 116$ GeV

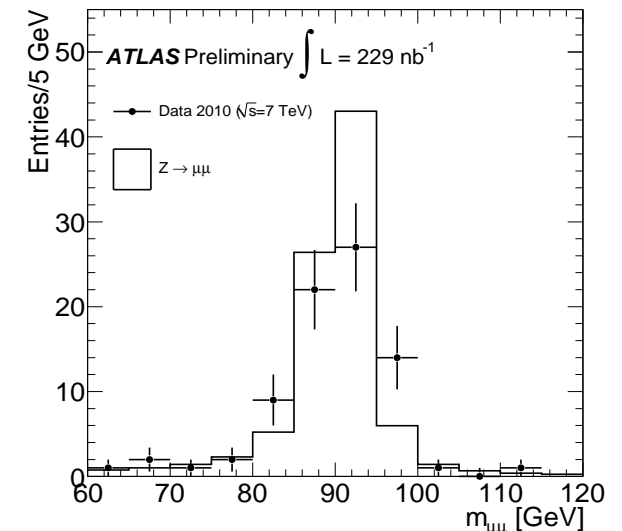
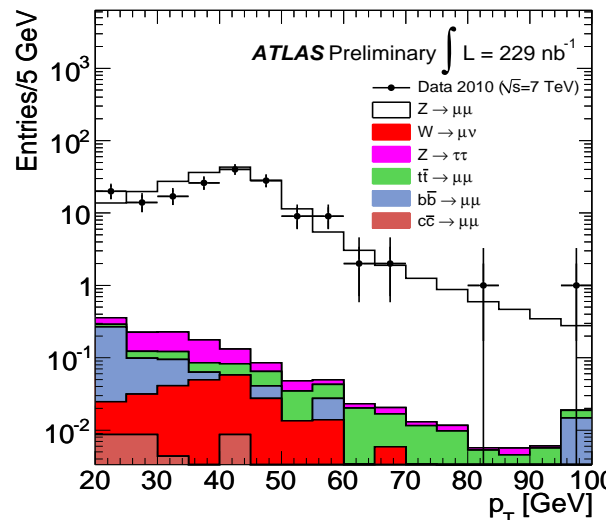
Electron channel

- Medium cuts, opposite charge
- 46 candidates for background of 0.5 ± 0.1 events (dominated by QCD)



Muon channel

- Track isolation, opposite charge
- 79 candidates for background of 0.17 ± 0.02 events ($t\bar{t}$, $Z \rightarrow \tau\tau$, $b\bar{b}$)



Measurement of the Z/γ^* Cross Section

- Same Procedure as for the W is used to determine σ^{fid} and σ^{tot} :

$$\sigma_Z^{\text{fid}} \times \text{BR} = \frac{N^{\text{obs}} - N^{\text{bkg}}}{C_Z \mathcal{L}_{\text{int}}} \quad \sigma_Z^{\text{tot}} \times \text{BR} = \frac{\sigma_Z^{\text{fid}}}{A_Z}$$

- Uncertainties on C_Z correction factor

	$Z \rightarrow ee$	$Z \rightarrow \mu\mu$
Trigger	$\pm 0.2\%$	$\pm 2\%$
Effect of Lepton reconstruction + identification	$\pm 14\%$	$\pm 7\%$
Lepton scale & resolution	$\pm 2\%$	$\pm 1\%$
C_Z	$65 \pm 14\%$	$80 \pm 7\%$

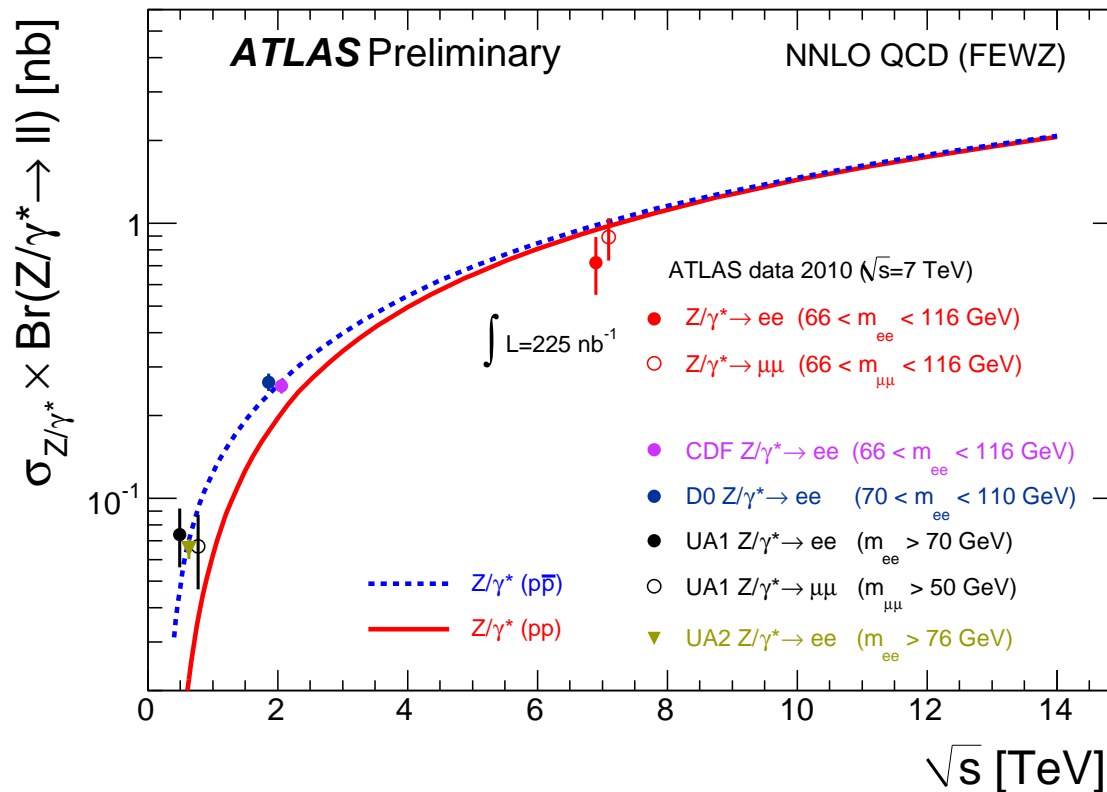
- Geometrical acceptance values A_Z known to at least $\approx 3\%$

	$Z \rightarrow e^+e^-$	$Z \rightarrow \mu^+\mu^-$
PYTHIA MRSTLO*	0.446	0.486
MC@NLO HERAPDF1.0	0.440	0.479
MC@NLO CTEQ6.6	0.445	0.485

Z/ γ^* Cross Section Results

	Electron channel	Muon channel
	$\sigma \pm \text{stat} \pm \text{sys} \pm \text{lumi}$	
σ_{fid} [nb]	$0.32 \pm 0.05 \pm 0.05 \pm 0.04$	$0.43 \pm 0.05 \pm 0.03 \pm 0.05$
σ_{tot} [nb]	$0.72 \pm 0.11 \pm 0.10 \pm 0.08$	$0.89 \pm 0.10 \pm 0.07 \pm 0.10$

- Agreement with theory expectation of $\sigma_{\text{tot}} = 0.96 \pm 0.04$ nb

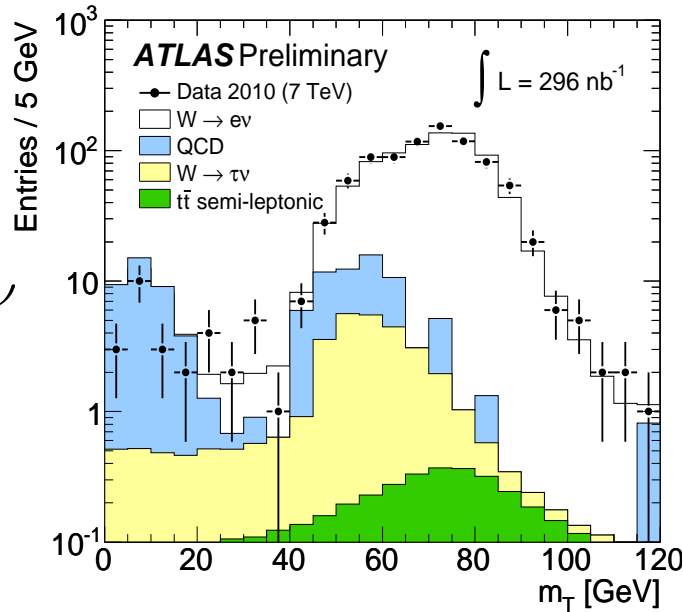


Summary

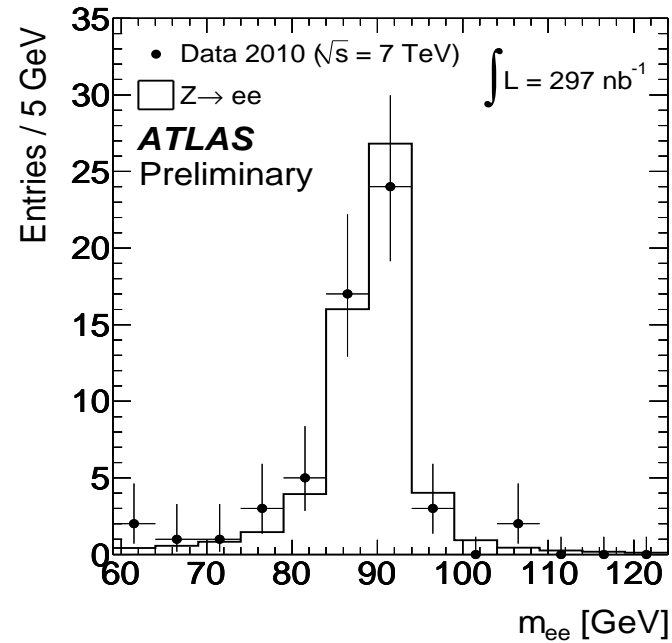
- A large rate of W and Z are expected to be recorded with the ATLAS in the electron and muon channels: important to calibrate the detector, precision tests of QCD and constraining PDFs
- Using the first 17 nb^{-1} of data
 - 46 $W \rightarrow e\nu$ candidates over 2.6 background events
 $\sigma_{\text{tot}} = 8.5 \pm 1.3(\text{stat}) \pm 0.7(\text{sys}) \pm 0.9(\text{lumi}) \text{ nb}$
 - 72 $W \rightarrow \mu\nu$ candidates over 5.3 background events
 $\sigma_{\text{tot}} = 10.3 \pm 1.3(\text{stat}) \pm 0.8(\text{sys}) \pm 1.1(\text{lumi}) \text{ nb}$
 - Agrees with SM expectation $\sigma_{\text{tot}}^{\text{NNLO}} = 10.46 \pm 0.42 \text{ nb}$
- Using the first 225 nb^{-1} of data
 - 46 $Z \rightarrow ee$ candidates over 0.5 background events
 $\sigma_{\text{tot}} = 0.72 \pm 0.11(\text{stat}) \pm 0.10(\text{sys}) \pm 0.08(\text{lumi}) \text{ nb}$
 - 79 $Z \rightarrow \mu\mu$ candidates over 0.2 background events
 $\sigma_{\text{tot}} = 0.89 \pm 0.10(\text{stat}) \pm 0.07(\text{sys}) \pm 0.10(\text{lumi}) \text{ nb}$
 - Agrees with SM expectation $\sigma_{\text{tot}}^{\text{NNLO}} = 0.96 \pm 0.04 \text{ nb}$

An exciting start with much more to come...

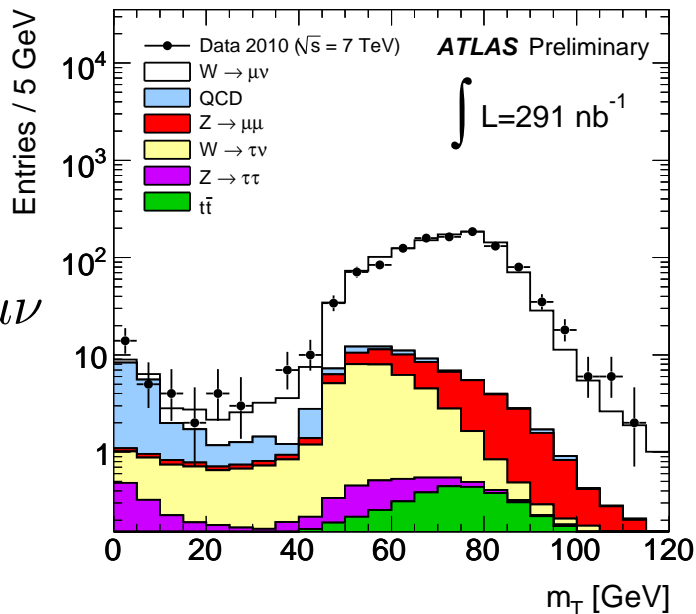
815 $W \rightarrow e\nu$



56 $Z \rightarrow ee$



1111 $W \rightarrow \mu\nu$



106 $Z \rightarrow \mu\mu$

