Measurement of W and Z production at $\sqrt{s}$ =7 TeV with the ATLAS Detector

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on behalf of the ATLAS collaboration

Motivation pp → WX, ZX
↳ eν, μν ↳ ee, μμ

- Commissioning and performance issues
  - First sample of isolated high p_T leptons : identification, calibration, energy/momentum scales + efficiency with Tag and Probe
  - Study of missing $\not{E}_T$

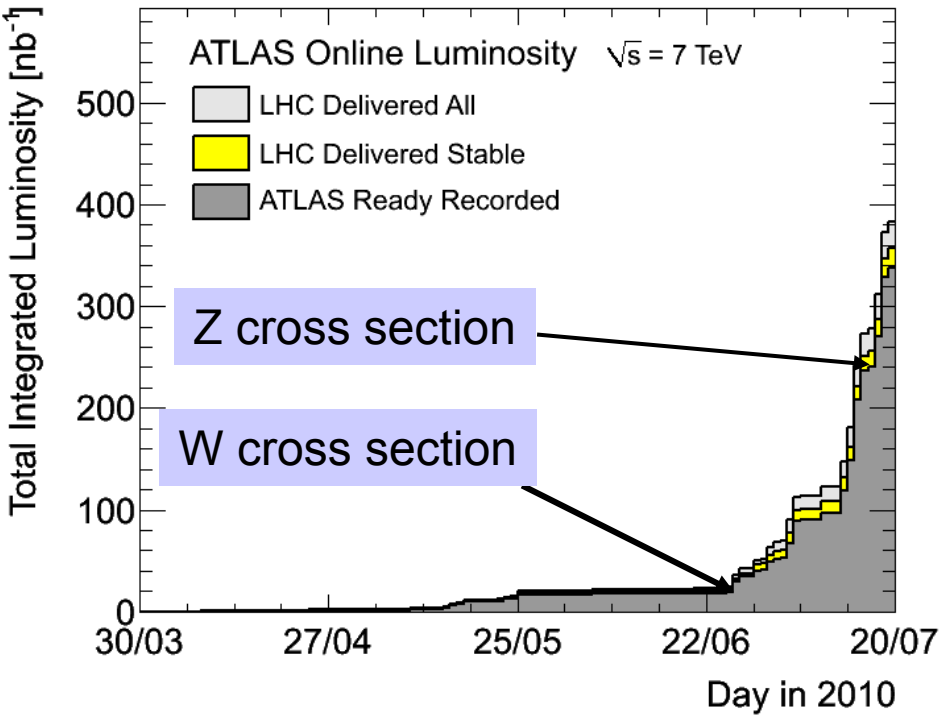
- Long term physics issues
  - Z and W cross section measurement : test of QCD with higher order correction and parton density functions in a new energy regime (7 TeV)

$$\sigma^{NNLO}_{W\to\ell\nu} = 10.46 \text{ nb} \quad (\sigma^{NNLO}_{W^+\to\ell^+\nu} = 6.16 \text{ nb} \quad \text{and} \quad \sigma^{NNLO}_{W^-\to\ell^-\nu} = 4.30 \text{ nb}) \quad \text{and} \quad \sigma^{NNLO}_{Z/\gamma^*\to\ell\ell} = 0.99 \text{ nb}.$$

computed with FEWZ and MSTW2008, ~4 % theoretical uncertainty
Additional measurements on W^+/W^- cross section and charge asymmetry as a function of pseudorapidity to constraint pdf

- Important background for several new physics searches (di-lepton, lepton + E_T…)

Data sample



ATLAS Recorded : 338 nb^{-1} (@94.8 %)

Require detectors in nominal conditions + event cleaning

For W cross section : 16.9 (16.7) nb^{-1} for $e^{\pm}$ ($\mu^{\pm}$) channel

For Z cross section : 219 (229) nb^{-1} for $e^{\pm}$ ($\mu^{\pm}$) channel

And some recent updated plots with all the integrated luminosity

Uncertainty on absolute luminosity from van der Meer scan : 11 %
(See talk by M Ferro-Luzzi in LHC session)

MC samples

W & Z signals : Pythia 6.4 with MRST LO* through Geant 4
Cross section corrected to NNLO cross section
(FEWZ + MSTW2008)

Backgrounds to W analysis:

Physics process	Cross section (nb) [× BR]	Luminosity (nb^{-1})
$W\rightarrow \tau\nu$ (electron channel analysis)	10.46	1.9×10^5
$W\rightarrow \tau\nu \rightarrow \mu\nu\nu$	3.68	3.1×10^5
$Z\rightarrow ee$ ($m_{\ell\ell} > 60$ GeV)	0.99	4.8×10^6
$Z\rightarrow \mu\mu$ ($m_{\ell\ell} > 60$ GeV)	0.99	5.1×10^6
$Z\rightarrow \tau\tau$ ($m_{\ell\ell} > 60$ GeV)	0.99	2.0×10^6
$t\bar{t}$	0.16	2.5×10^6
Dijet (electron channel, $\hat{p}_T > 15$ GeV)	1.15×10^6	100
Dijet (muon channel, $8 < \hat{p}_T < 17$ GeV)	9.86×10^6	0.05
Dijet (muon channel, $17 < \hat{p}_T < 35$ GeV)	6.78×10^5	0.74
Dijet (muon channel, $35 < \hat{p}_T < 70$ GeV)	4.10×10^4	12.20
Dijet (muon channel, $70 < \hat{p}_T < 140$ GeV)	2.20×10^3	227.74
Dijet (muon channel, $140 < \hat{p}_T < 280$ GeV)	0.88×10^2	5.70×10^3
Dijet (muon channel, $280 < \hat{p}_T < 1120$ GeV)	2.35	2.13×10^5

Fake $\not{E}_T$

e/μ channel

Fake lepton + b→leptons data driven methods

Event reconstruction

See ATLAS talks in LHC session for detector status and performance

$e^{\pm}$

Sliding window cluster (with 2.5 GeV E_T seed) matched to track.
Identification relies mostly on track quality, transverse profile in EM calorimeter and transition radiation signal :
10^5 rejection against jet with pt > 20 GeV for 72 % efficiency for $e^{\pm}$ for tight (7.10^3 & 90 % for medium)

$\mu^{\pm}$

Stand alone

Spectrometer only + trigger chamber extrapolated to IP

Combined

Association with ID track
Combination of parameters

Reconstruction and identification > 94 % for pT > 10 GeV

$$E_{x,y}^{Electron,miss} = E_{x,y}^{Calo,miss} = -\sum_i E_{x,y}.$$

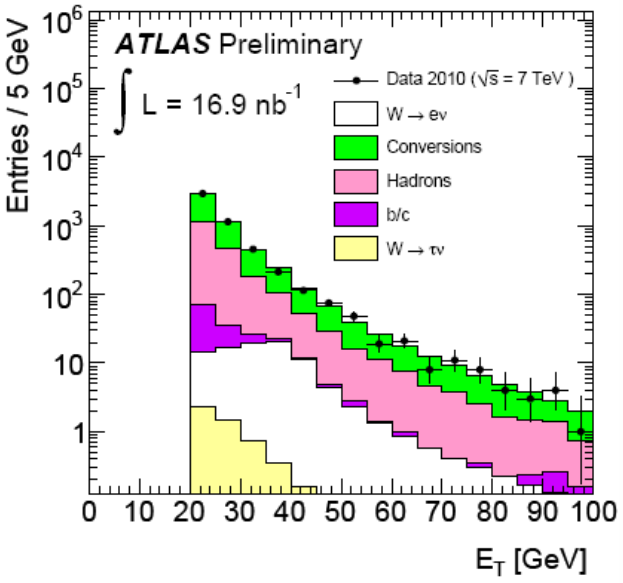
Using calibrated 3-dimensional topological cluster (hadron/e±/γ, dead material energy loss…)

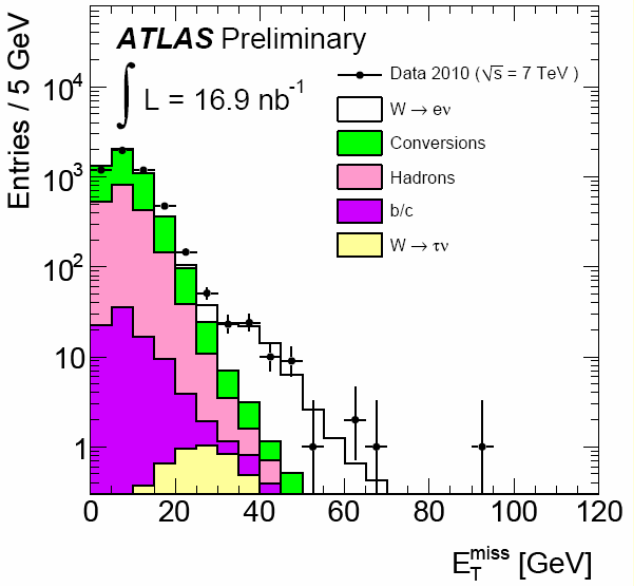
$$E_{x,y}^{Muon,miss} = -\left(\sum_{Muons} E_{x,y} + \sum_i E_{x,y}\right)$$

Energy deposited in calorimeter by μ removed from calorimeter contribution.

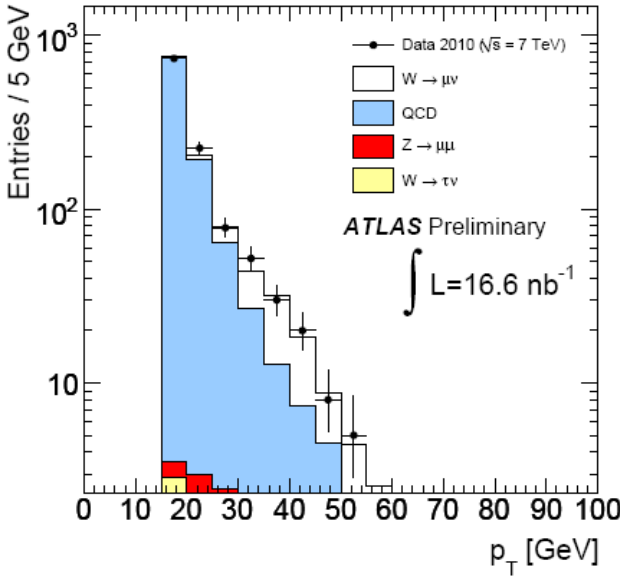
Pre-selection (17 nb^{-1})

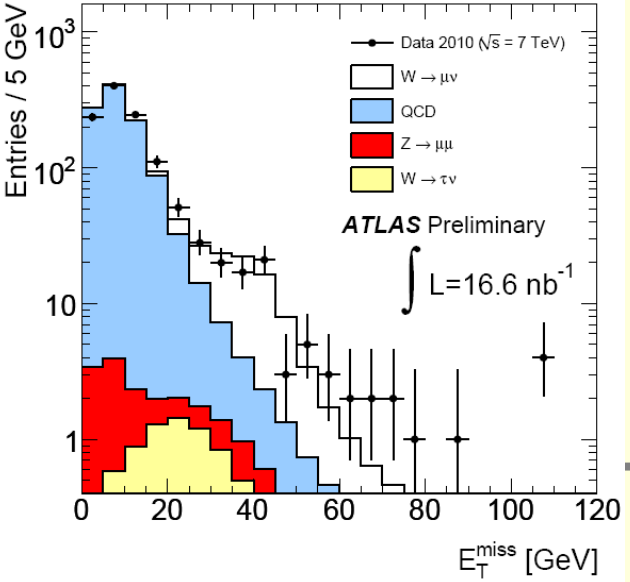
$e^{\pm}$: $|\eta| < 2.47$ + cracks
L1 calo trigger (5 GeV)
Loose electron with
$P_T > 20$ GeV
(jet rejection of 1100)
5.1 10^3 candidates
QCD over estimated
by 2.6 with MC





$\mu^{\pm}$: $|\eta| < 2.4$
L1 muon trigger
well measured combined
muon with $P_T > 15$ GeV
($\Delta p_T < 15$ GeV, $\Delta z < 1$ cm)
1155 candidates
QCD over estimated by
1.7 with MC

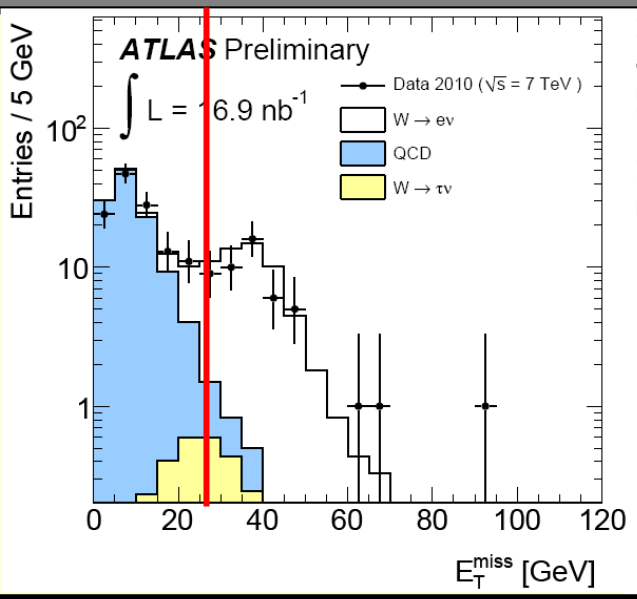


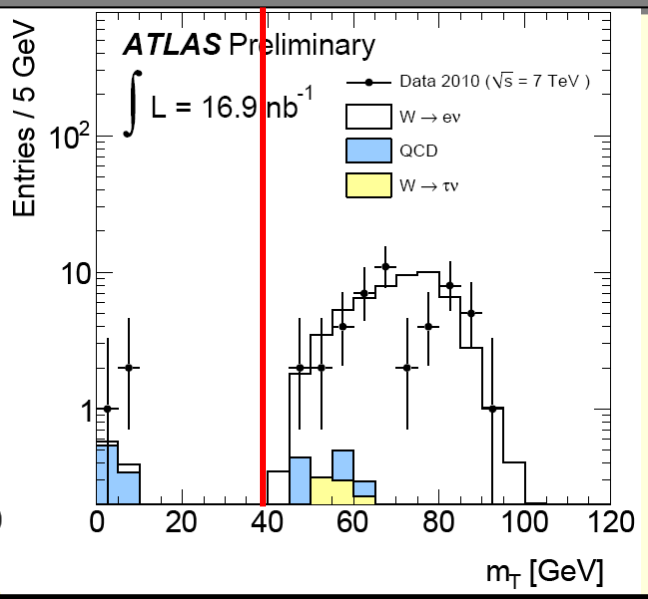


Tight selection (17 nb^{-1})

Electrons

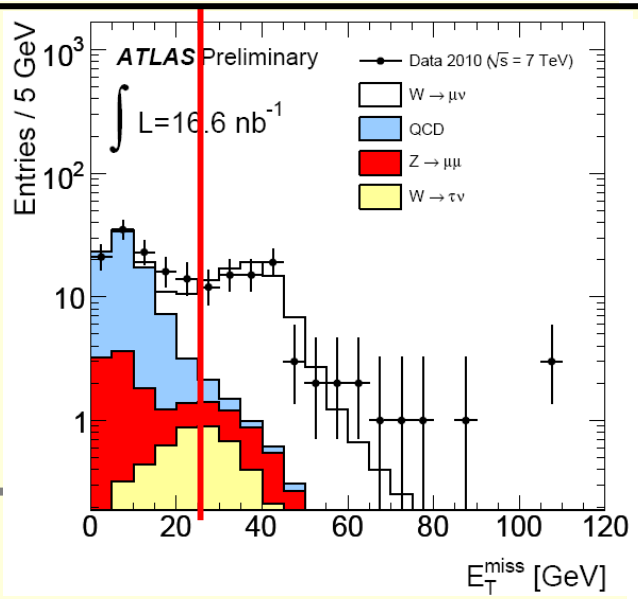
Tight electron
$\not{E}_T$ > 25 GeV
m_T > 40 GeV
→ 46 candidates

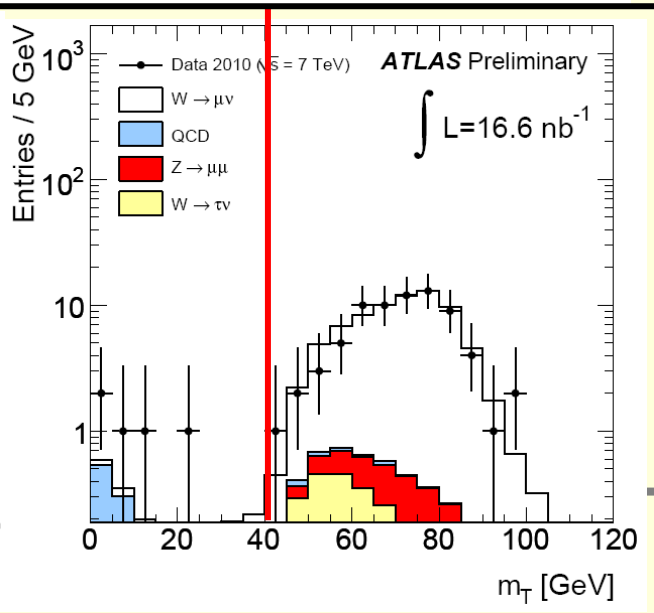




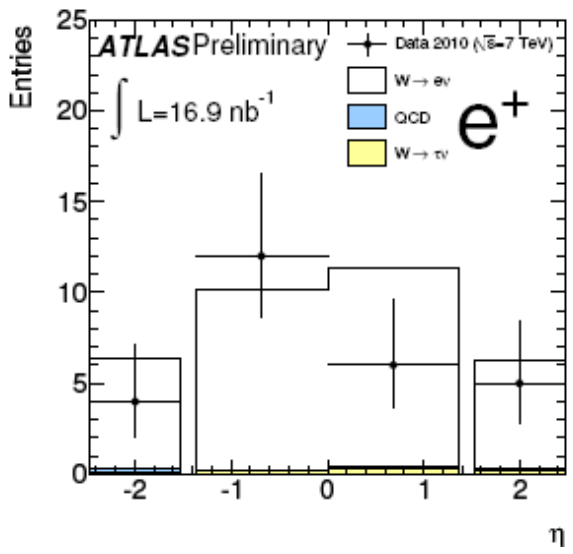
Muons

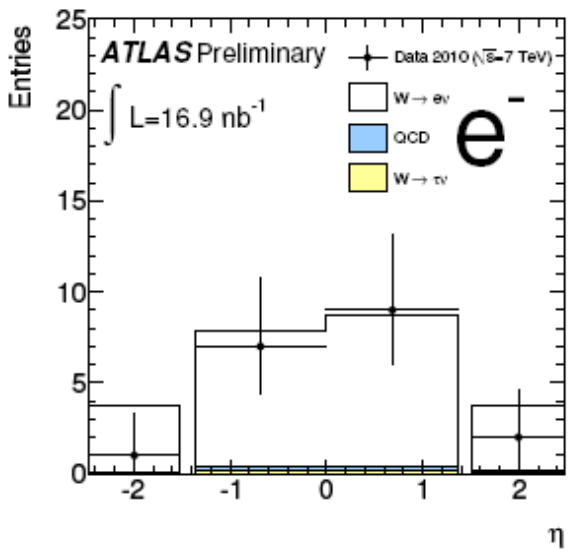
P_T > 20 GeV
Track isolation
$\not{E}_T$ > 25 GeV
m_T > 40 GeV
→ 72 candidates

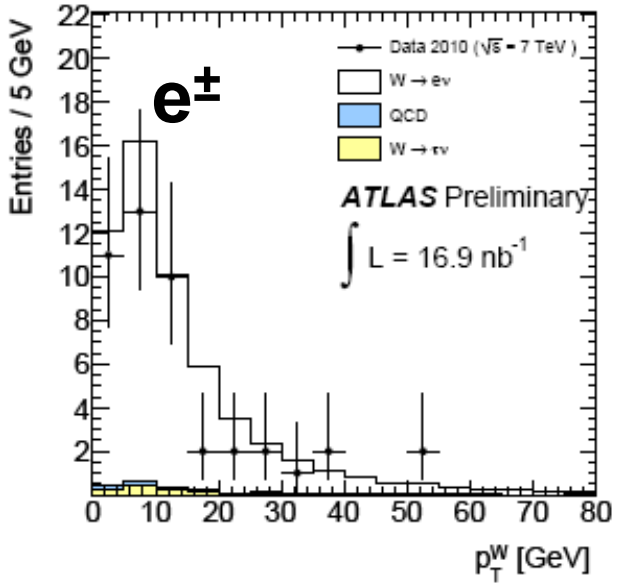


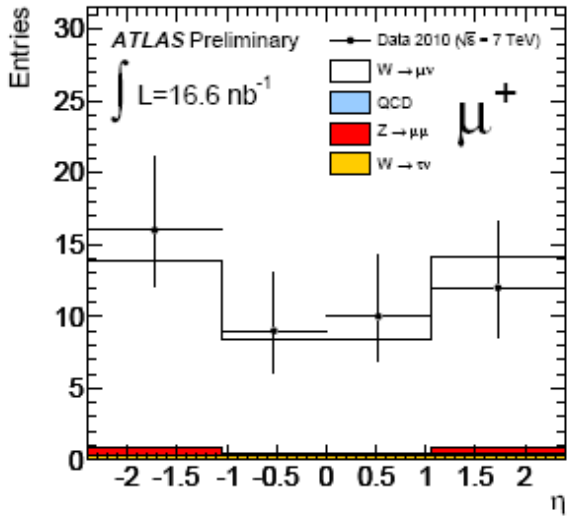


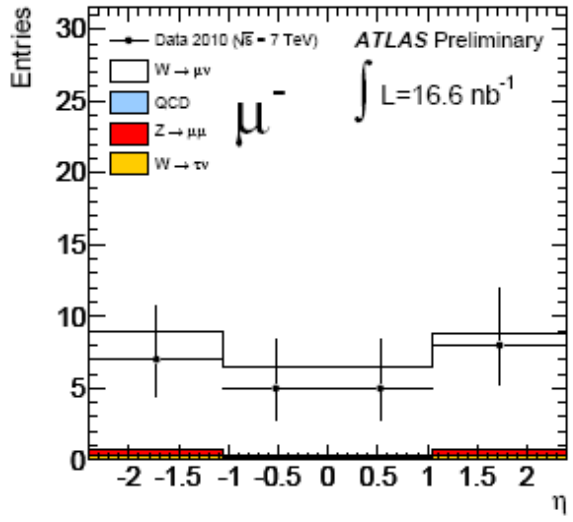
Signal kinematics distributions (17 nb^{-1})

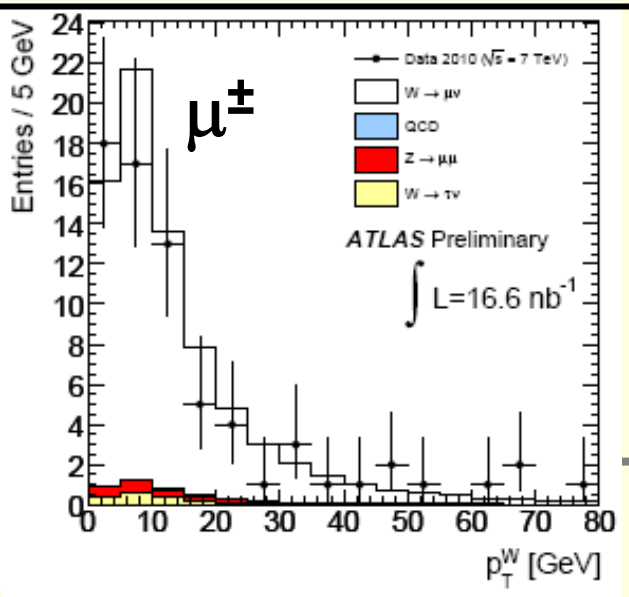








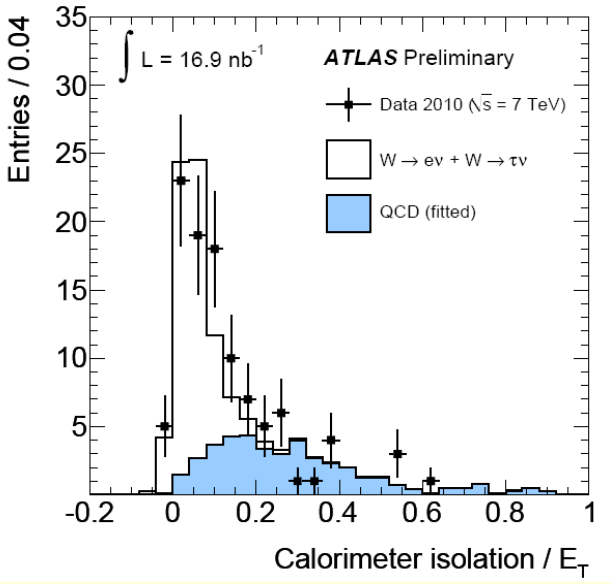




Background (17 nb^{-1})

$e^{\pm}$

QCD background estimated on data using calorimeter isolation variable extrapolated from loose → tight $e^{\pm}$



QCD loose : 40.6±8

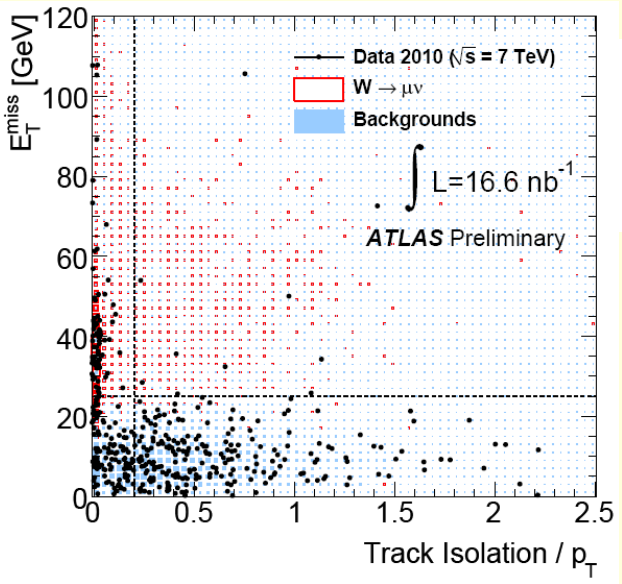
Rejection: 38±15

N_{QCD} (tight) = 1.1 ±0.2(stat)±0.4(syst)

EW background : W→τν (1.4)
+ Z→ee : 0.1
N_{EW}=1.5±0.0(stat)±0.1(syst))±0.1(lumi)

$\mu^{\pm}$

QCD background estimated on data using with ABCD method in track isolation-$\not{E}_T$ plane



No transverse mass cut applied

N_{QCD} (tight) = 0.9 ±0.3(stat)±0.6(syst)

EW background : Mainly Z→μμ (2.2)
and W→τν (1.9)
N_{EW}=4.4±0.0(stat)±0.3(syst)± 0.5(lumi)
Cosmic ray negligible

Cross section measurement

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

N^{sig} background subtracted signal events. L_{int} integrated luminosity

A_W : Geometrical and kinematics acceptance from MC (computed at born level). Limited by knowledge of proton pdf and W production at LHC :

MC	A_W $W^+ \to e^+\nu$	A_W $W^+ \to \mu^+\nu$	A_W $W^- \to e^-\nu$	A_W $W^- \to \mu^-\nu$	A_W $W \to e\nu$	A_W $W \to \mu\nu$
PYTHIA MRSTLO*	0.466	0.484	0.457	0.475	0.462	0.480
MC@NLO HERAPDF1.0	0.475	0.494	0.454	0.472	0.465	0.483
MC@NLO CTEQ6.6	0.478	0.496	0.452	0.470	0.465	0.483

With CTEQ6.6 PDF error eigenvectors, 1 % (1.8%) uncertainty on W^+ (W^-)
Pythia/MC@NLO : up to 2.6 % difference in positron channel

→use 3% conservative systematic uncertainty from generators

Correction factors C_W and systematics

C_W : includes triggering, reconstruction and identification efficiency + some selection cuts within acceptance. To be measured on data with Z.

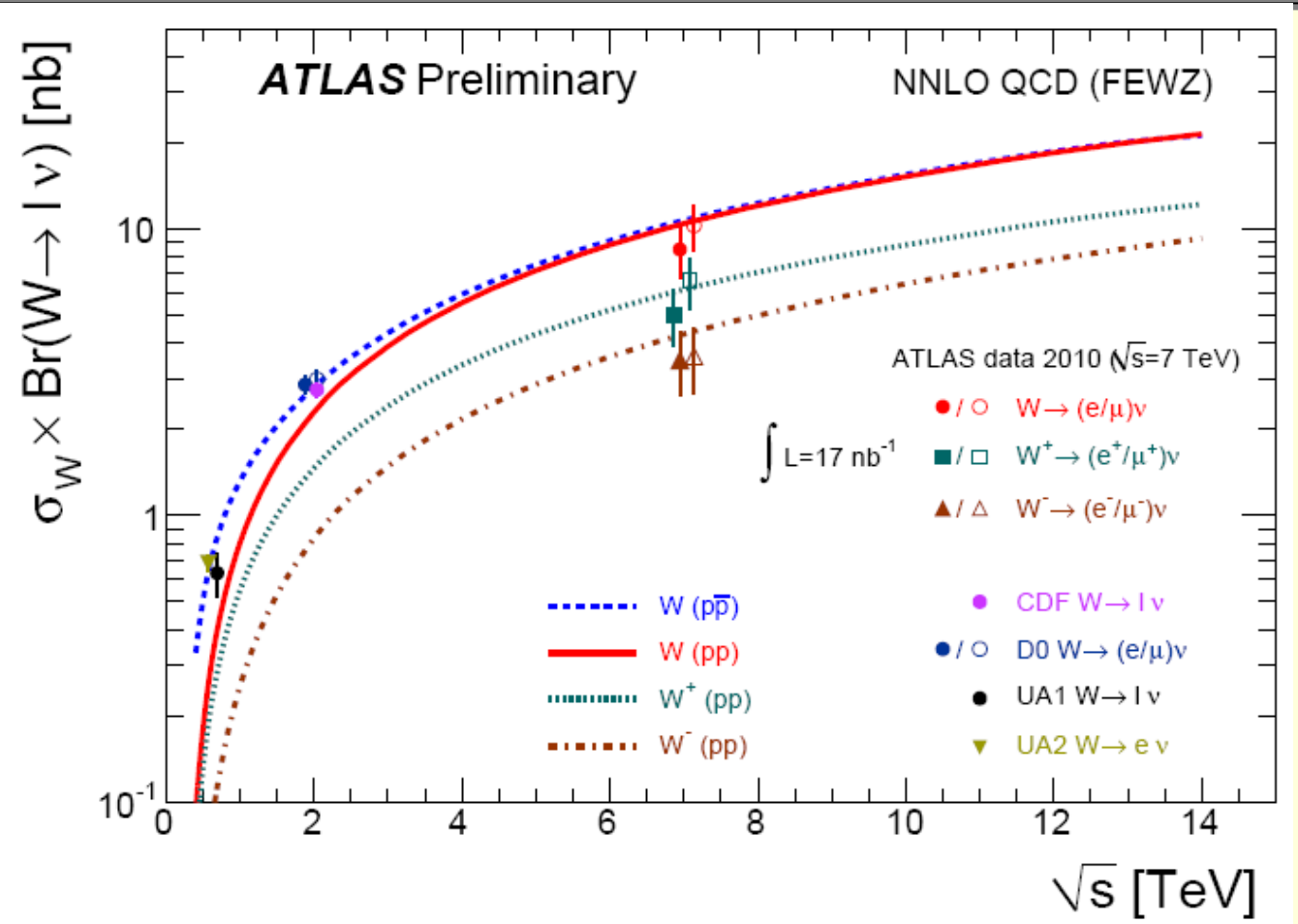
Electrons	syst on C_W
Trigger efficiency : (ε>99.9 %)	<0.5 %
Identification : (ε= 78 %)	
discrepancy data/MC	6 %
material effect	4 %
EM energy scale	3 %
$\not{E}_T$ scale & resolution	2 %
	8 %

$C_W = (65.6 \pm 5.3)$ %

Muons	syst on C_W
Trigger : (ε=88 %)	4 %
Identification (ε= 97 %)	4 %
μ p_T scale & resolution	4 %
$\not{E}_T$ scale & resolution	2 %
	7 %

$C_W = (81.4 \pm 5.6)$ %

W cross section (17 nb^{-1})



$\sigma(W \to e^{\pm}\nu)$ = 8.5 ± 1.3 (stat) ± 0.7(syst)±0.9(lumi) nb

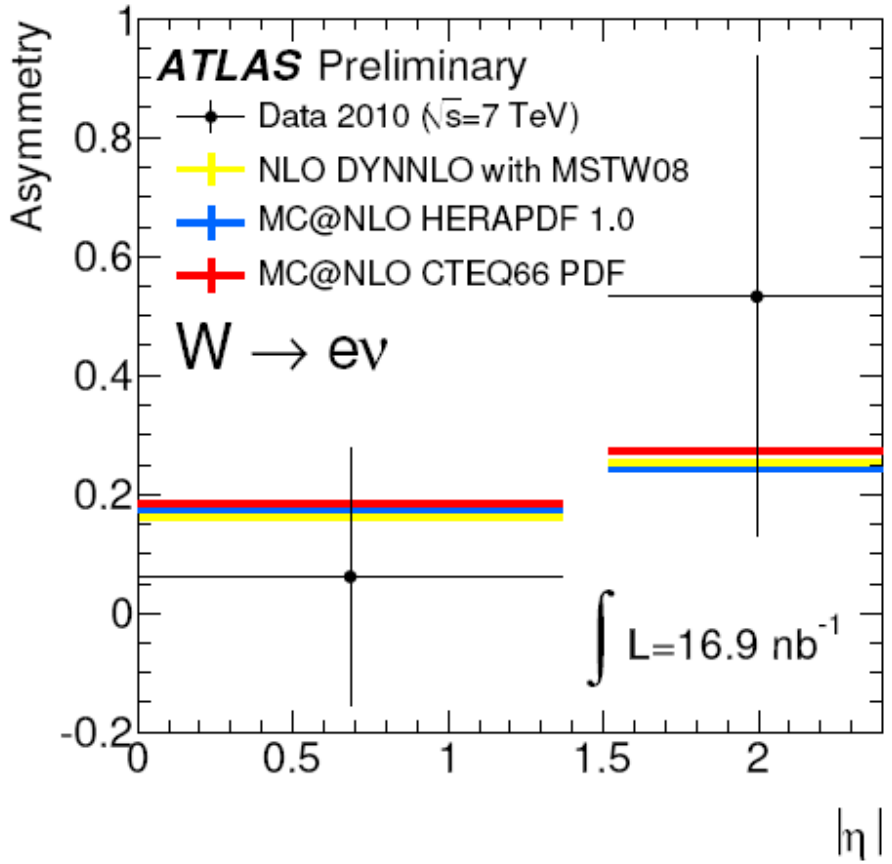
Theory : 10.46 ± 0.42

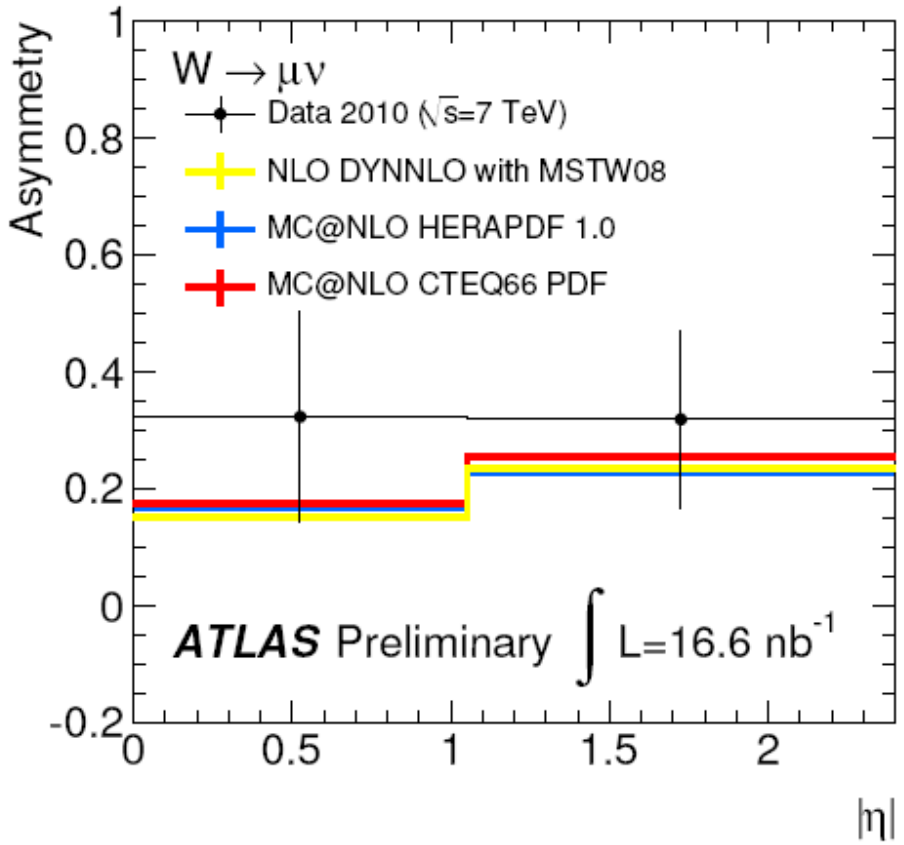
$\sigma(W \to \mu^{\pm}\nu)$ = 10.3 ± 1.3 (stat) ± 0.8(syst)±1.1(lumi) nb

Charge asymmetry

$$A = \frac{N_{\ell^+} - N_{\ell^-}}{N_{\ell^+} + N_{\ell^-}}$$

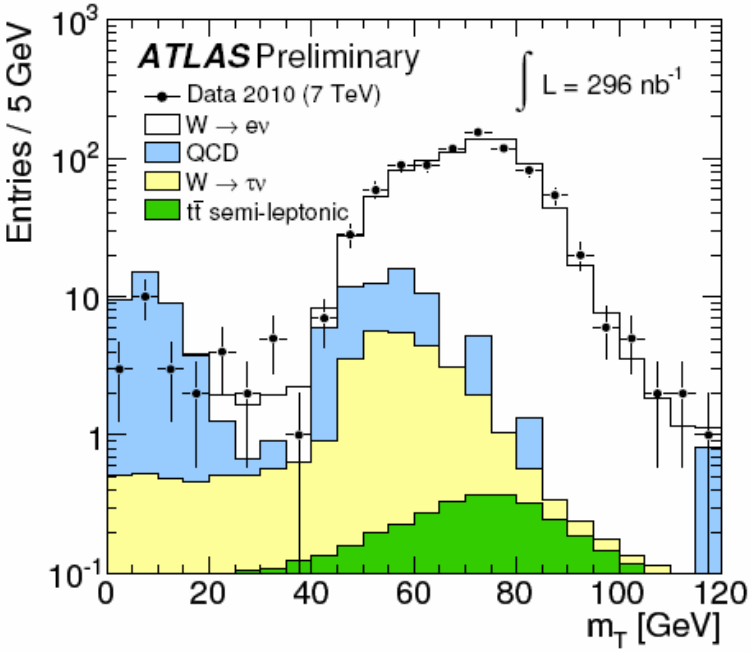
Expected to be different from zero and increasing with η
Sensitive to valence quark distribution
Will provide important information about pdf



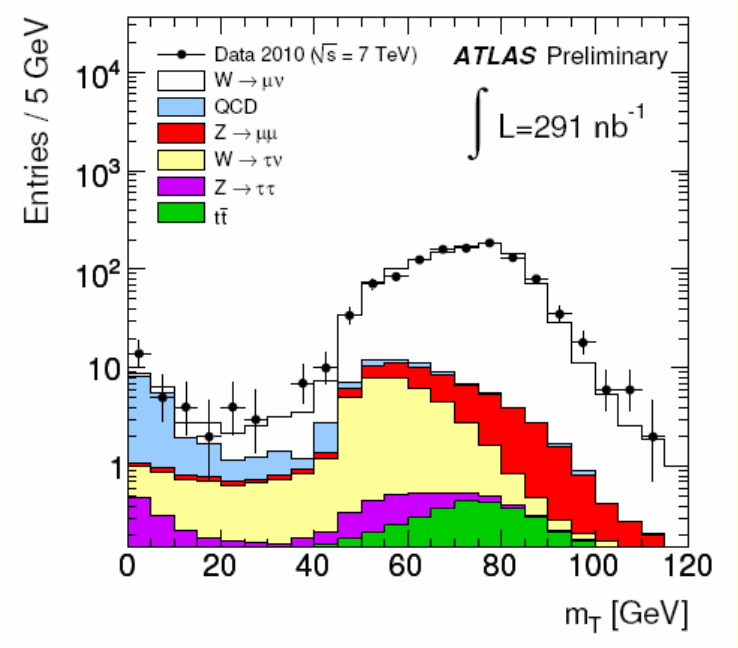


W candidates with ~300 nb^{-1}

Higher instantaneous luminosity→ different condition with pile-up !
- about 40 % of the events with more than one vertex
- need to use higher E_T trigger



815 electron candidates



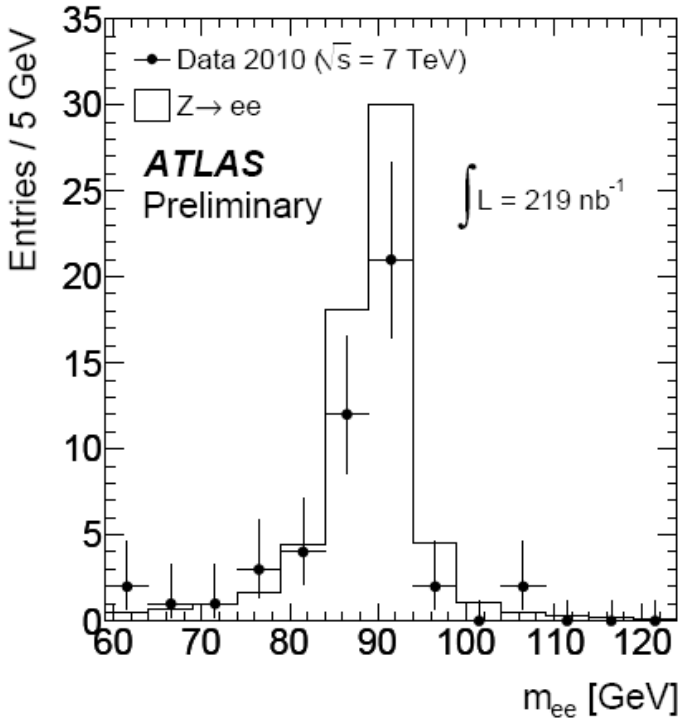
1111 muon candidates

In agreement with expectation from cross section measurement
Total cross section no more statistically dominated, should focus work on systematic using Z

Z selection and candidates (~225 nb^{-1})

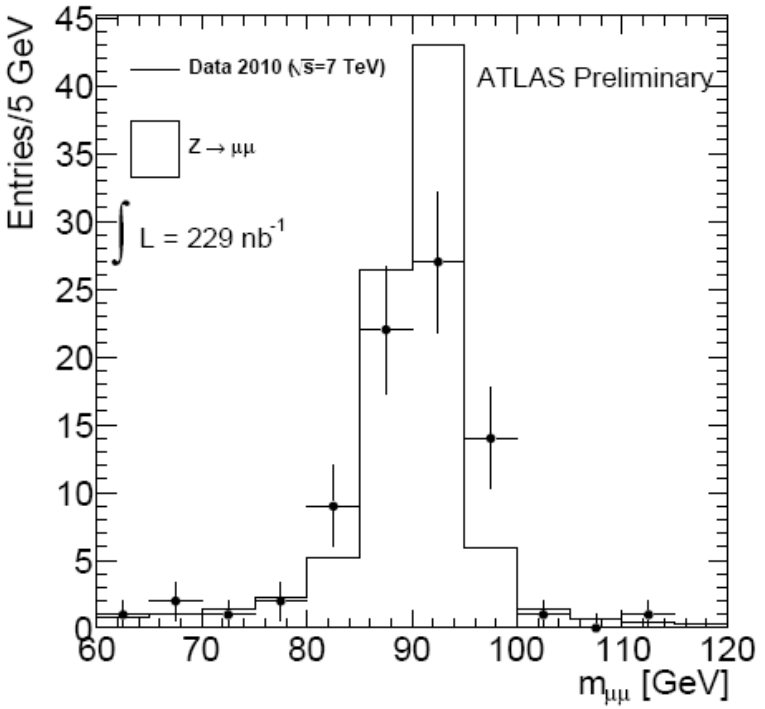
electron channel, 219 nb^{-1}

Preselection + two candidates of opposite charge with p_T > 20 GeV
Medium identification (R(jet)=6800)



muon channel 229 nb^{-1}

Preselection + two candidates of opposite charge with p_T > 20 GeV + Track isolation



Z→ee : 46 candidates (66-116 GeV)

Z→μμ :79 candidates (66-116 GeV)

Z cross section with ~225 nb^{-1}

electron channel 219 nb^{-1}			muon channel 229 nb^{-1}		
Background : 0.49±0.07±0.05 QCD : 0.31 EW : 0.18 (W→eν, $t\bar{t}$, Z→ττ)			Background : 0.17±0.01±0.01 QCD : 0.02 EW : 0.15 (Z→ττ, $t\bar{t}$, $b\bar{b}$…)		
Similar procedure as used for W for cross section					
Correction factor C_Z = 64.5 %		14%	Correction factor C_Z = 79.7%		7 %
Acceptance	A_Z = 44.6 %	3 %	Acceptance	A_Z = 48.6 %	3 %

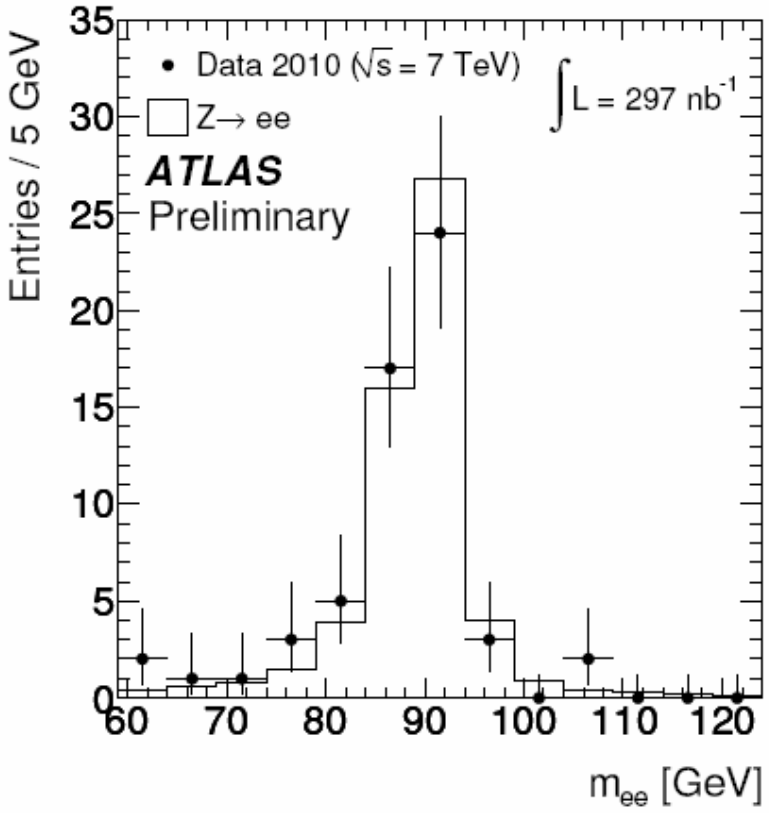
Total cross section

$\sigma(Z \rightarrow e^+ e^-)$ = 0.72 ± 0.11 (stat) ± 0.10 (syst) ± 0.08 (lumi) nb

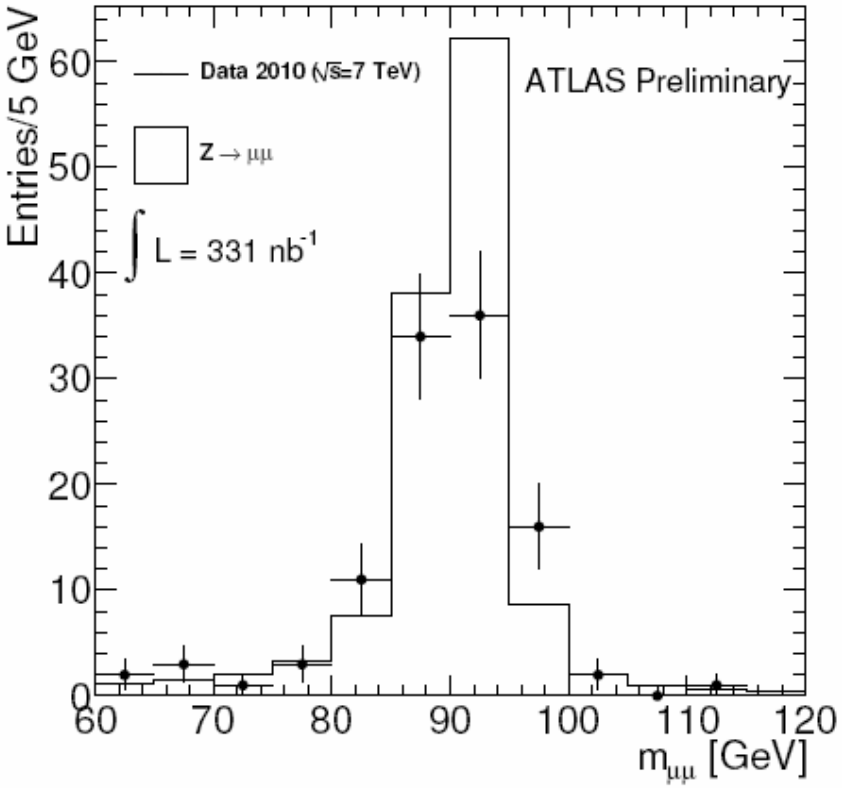
Theory : 0.96± 0.04 for [66-116] GeV mass window

$\sigma(Z \rightarrow \mu^+ \mu^-)$ = 0.89 ± 0.10 (stat) ± 0.07(syst) ± 0.10 (lumi) nb

Z candidates with ~300 nb^{-1}



56 electron candidates



106 muon candidates

Conclusion

- LHC and ATLAS fully operational to start physics !

- 815 (1111) W candidates measured by ATLAS in electron (muon) channel

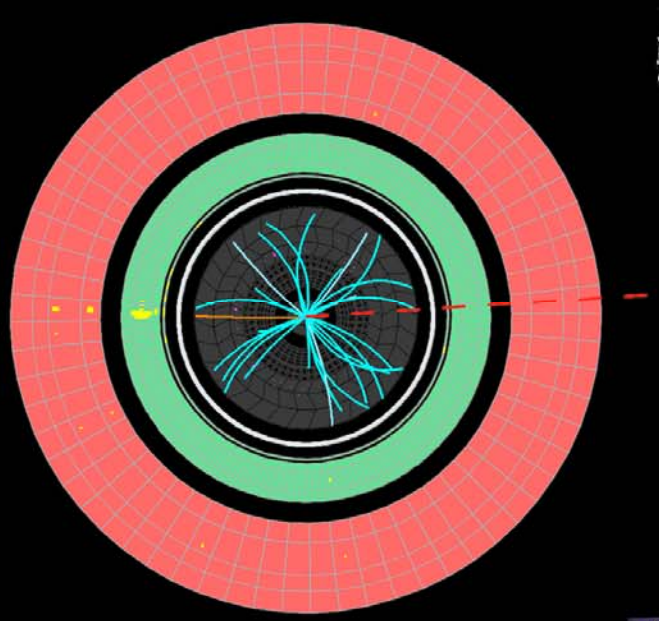
  → First measurement of cross section & charge asymmetry at 7 TeV with 17 nb^{-1}, in agreement with expectation based on NNLO QCD prediction
  → With full recorded luminosity, no more statistically dominated

- 56 (106) Z candidates measured by ATLAS in electron (muon) channel

  → Cross section measured with 225 nb^{-1} in agreement with expectation at NNLO QCD
  → More Z will be helpful to reduce systematic on cross section (trigger/reconstruction/ identification efficiency from Tag & Probe method)

- Also ready for W→τ ν …

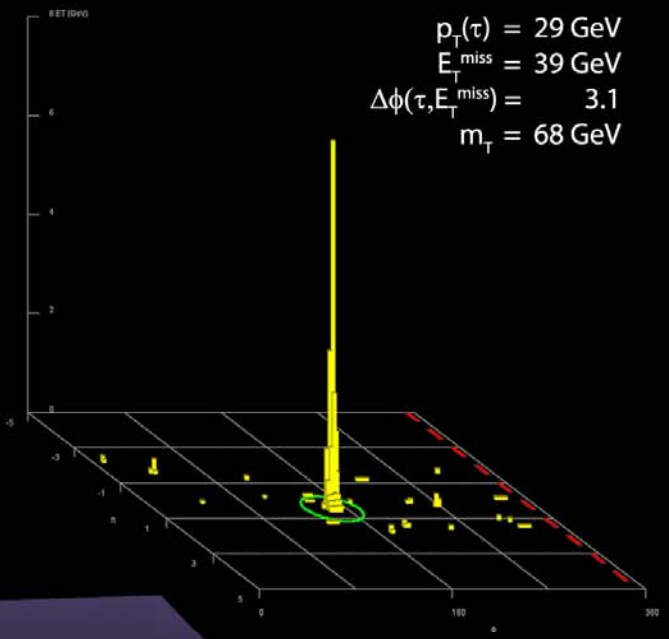
First W→τν candidate: single prong τ candidate with $\not{E}_T$

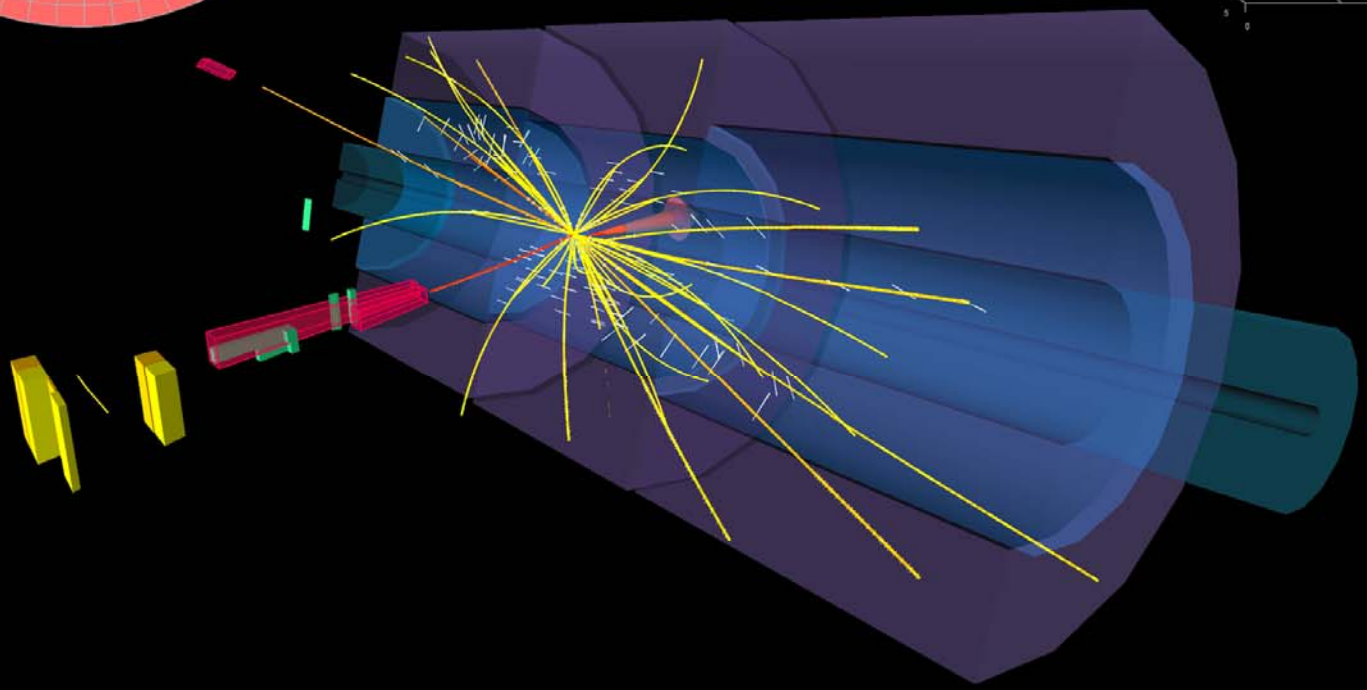


ATLAS EXPERIMENT

Run 155697, Event 6769403
Time 2010-05-24, 17:38 CEST

W→τν candidate in
7 TeV collisions

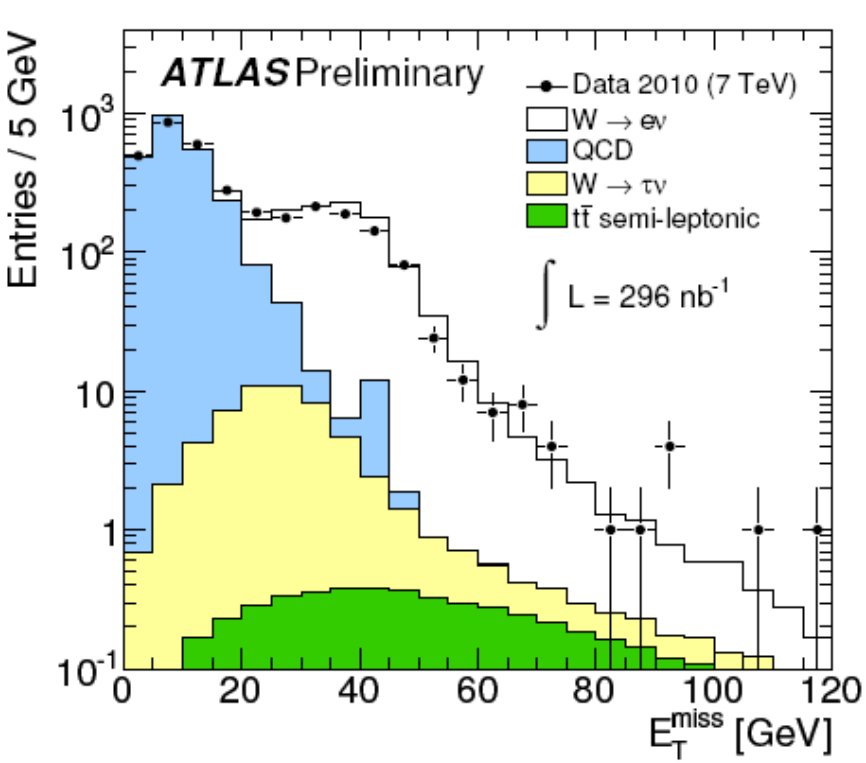


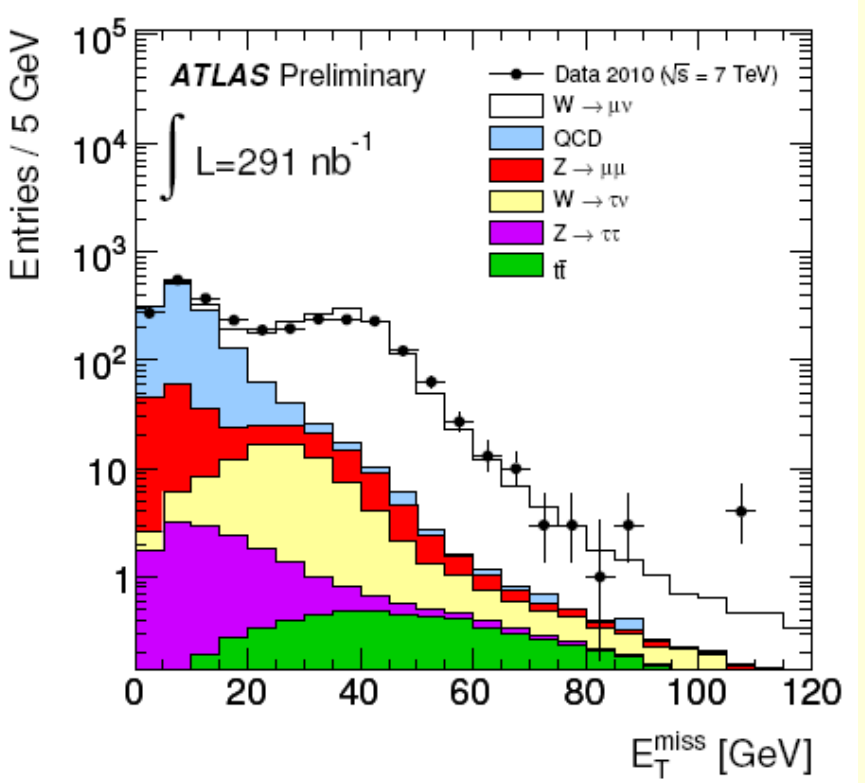


More results…

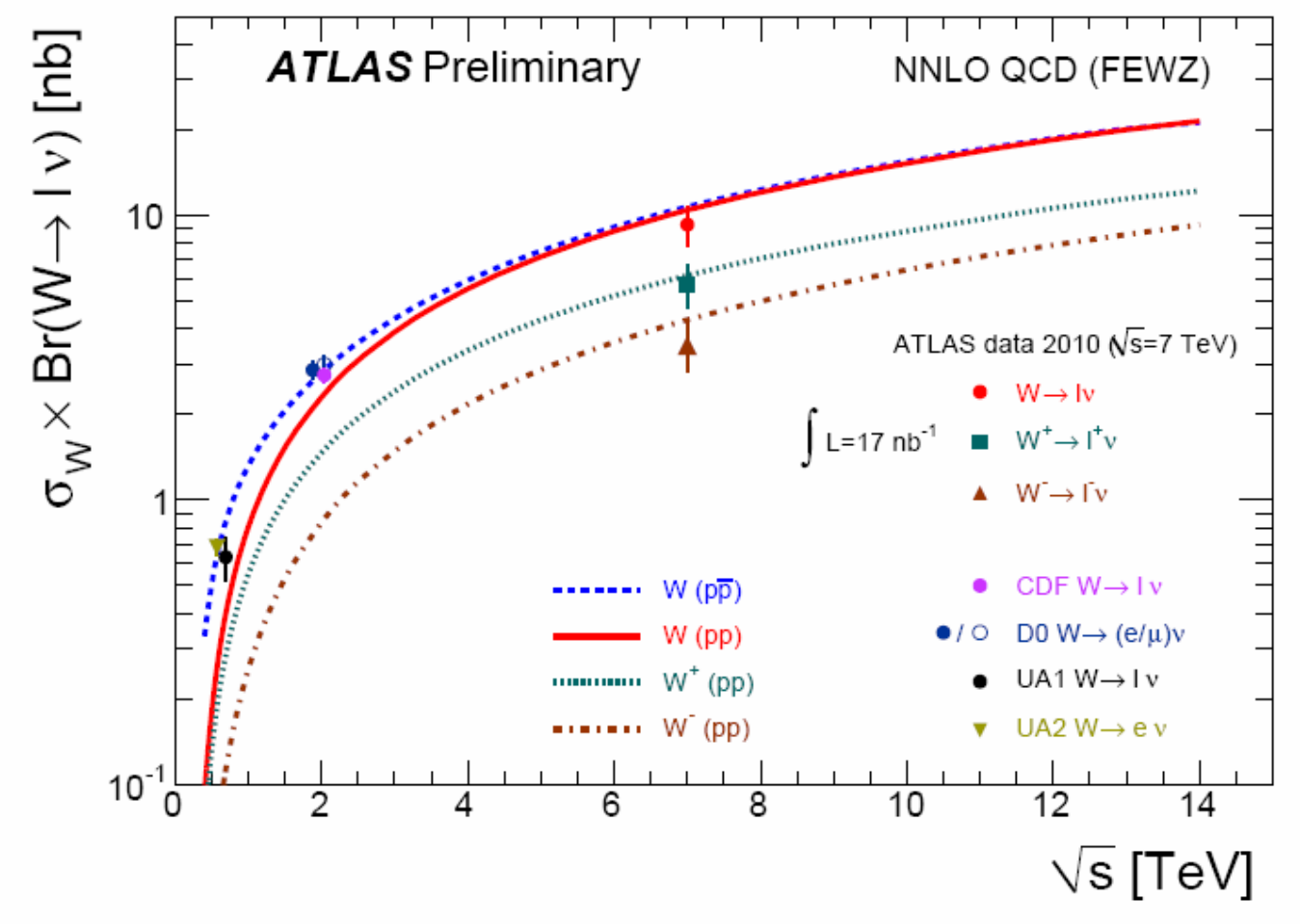
W candidates with ~300 nb^{-1}

After tight selection cuts :



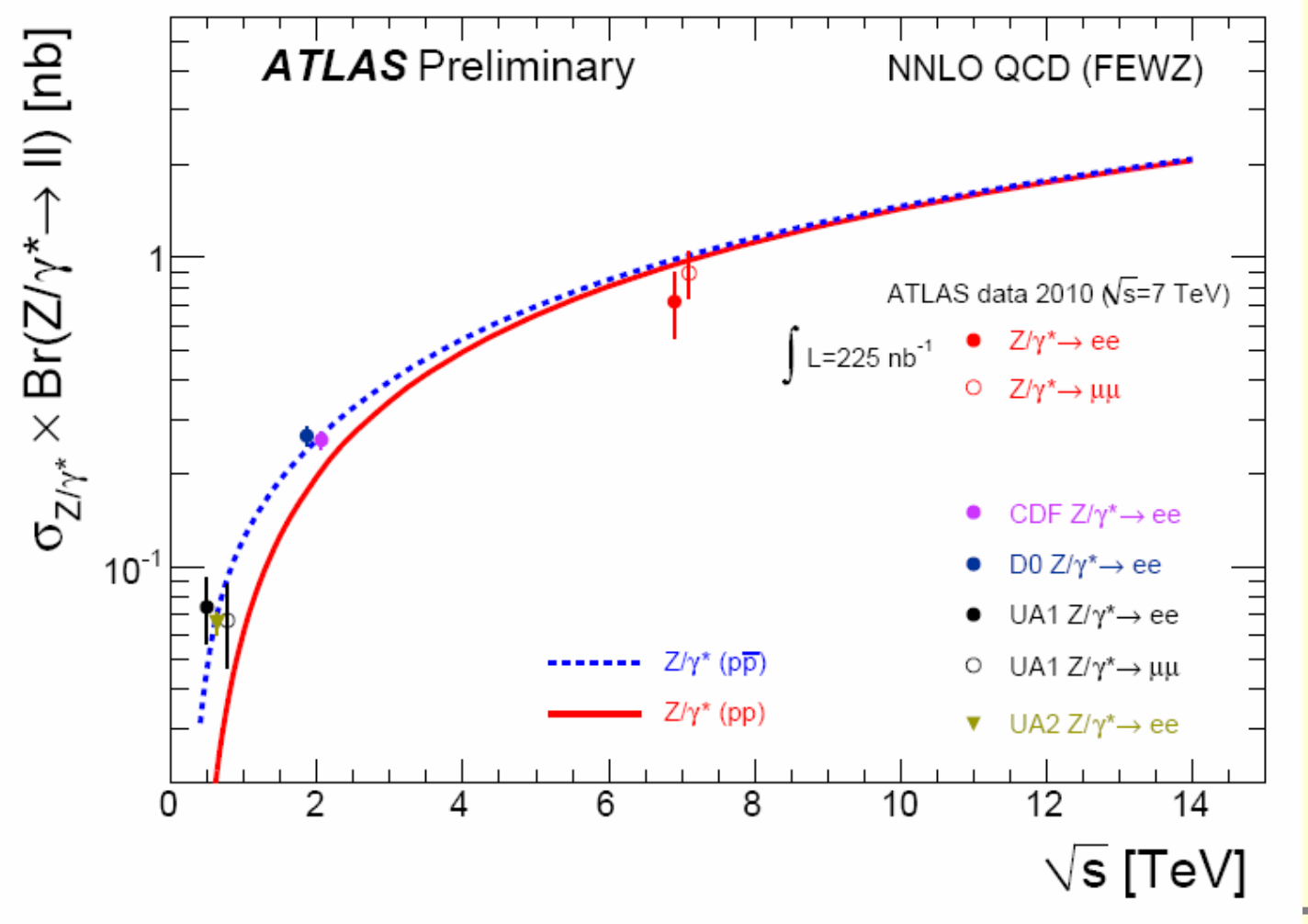


Combined cross section with ~17 nb^{-1}



Z cross section with ~225 nb^{-1}

Mass window 66-116 GeV



Z mass parameters (~225 nb^{-1})

	Data		MC
Electron	**89.6±0.8 (stat)**	**σ=3.6±0.8(stat)**	**91.6 and 1.7**
Muons	**90.5±0.8 (stat)**	**σ=4.2±0.8(stat)**	**92.1 and 1.8**

Scale in agreement within 2% (stat errors only)
Width larger in data (calibration, alignment,…..)