

# W/Z and Di-Boson Results from ATLAS



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On behalf of the  
ATLAS Collaboration



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Madison, Wisconsin

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# Outline

- W, Z Measurements with Electrons and Muons
  - W and Z Inclusive Cross-section
  - Forward Z Cross-section
  - W Charge Asymmetry

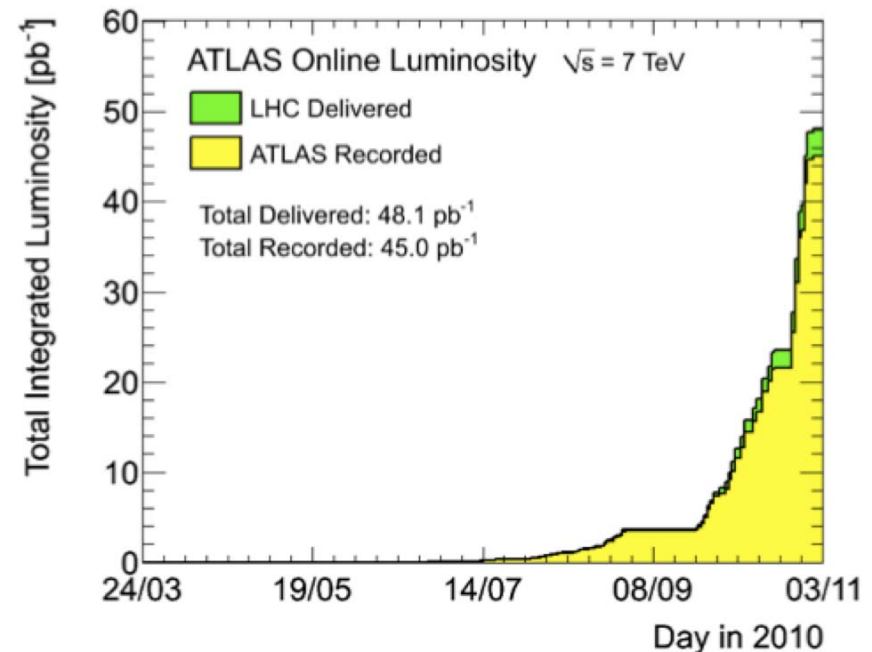
- W, Z Observation with Taus

- W and Z + jets

- Diboson Results

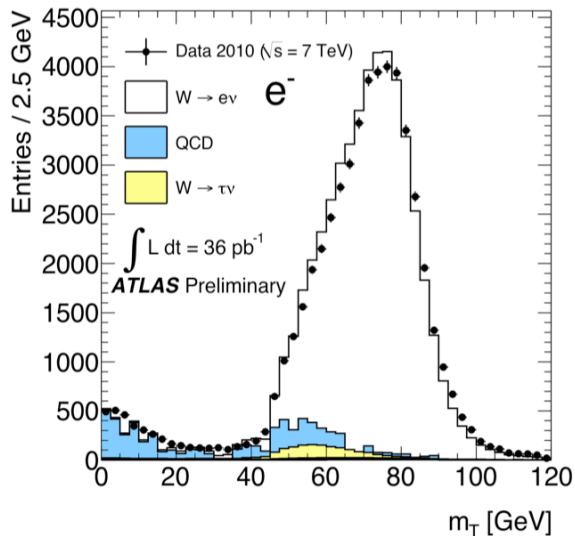
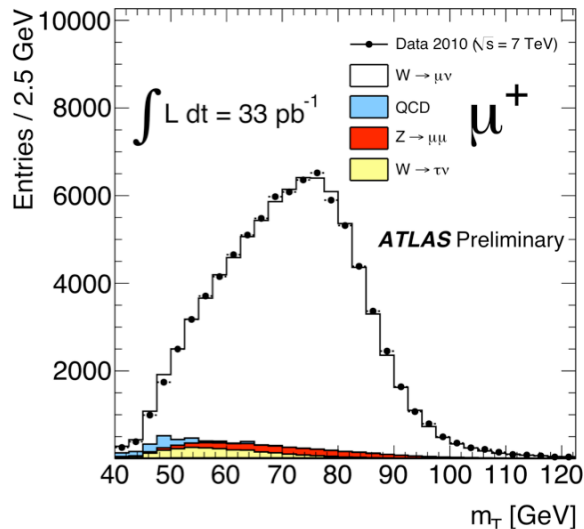
- $W\gamma$  and  $Z\gamma$
- WW Cross-section

- Most results for full 2010 dataset
- $L_{\text{INT}} 31\text{-}37 \text{ pb}^{-1}$  depending on analysis
  - Uncertainty brought down to 3.4%



# W and Z/ $\gamma^*$ Inclusive Cross-Section

ATLAS-CONF-2011-041



- Compare to theory at NNLO in QCD
- Vital for detector performance
  - High  $p_T$  leptons: reconstruction / trigger / identification efficiencies, resolution, scale...
  - $E_T^{\text{miss}}$  resolution and scale
- Update  $320 \text{ nb}^{-1}$  result with  $\times 100$  data
- Improved analysis e.g. tag-and-probe, binning
- Systematics reduced by factor of three
  - $E_T^{\text{miss}}$  scale/resolution largest experimental uncertainty (2%)

EXCELLENT AGREEMENT BETWEEN ELECTRON  
AND MUON RESULTS

# W and Z/ $\gamma^*$ Inclusive Cross-Section

ATLAS-CONF-2011-041

- Define fiducial cross-sections using analysis kinematic requirements

- All detector corrections included

	FIDUCIAL CROSS-SECTION [nb]
$W \rightarrow \mu\nu$	$4.959 \pm 0.015$ (sta) $\pm 0.120$ (sys) $\pm 0.181$ (lum)
$W \rightarrow e\nu$	$4.877 \pm 0.015$ (sta) $\pm 0.138$ (sys) $\pm 0.166$ (lum)
$Z \rightarrow \mu\mu$	$0.456 \pm 0.004$ (sta) $\pm 0.005$ (sys) $\pm 0.015$ (lum)
$Z \rightarrow ee$	$0.433 \pm 0.004$ (sta) $\pm 0.016$ (sys) $\pm 0.015$ (lum)

- Most precise experimental measurements for theory comparison

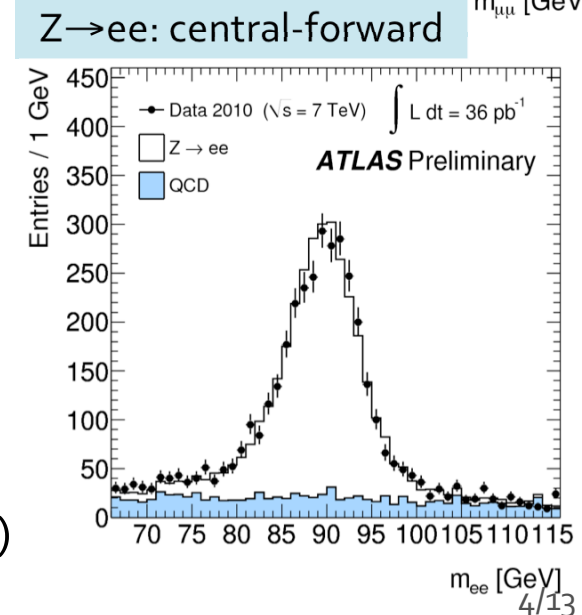
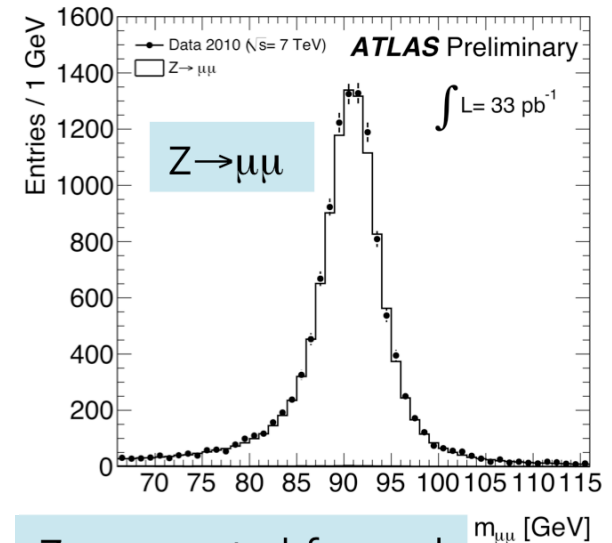
- Extend Z cross-section measurement using forward electrons ( $2.5 < |\eta| < 4.9$ )

- Expands range of sensitivity to parton-x
- Reduces extrapolation uncertainty

- $\sigma_{\text{FID}} = 0.179 \pm 0.004$  (sta)  $\pm 0.017$  (sys)  $\pm 0.006$  (lum)

09 May 2011

Srivas Prasad, Harvard University

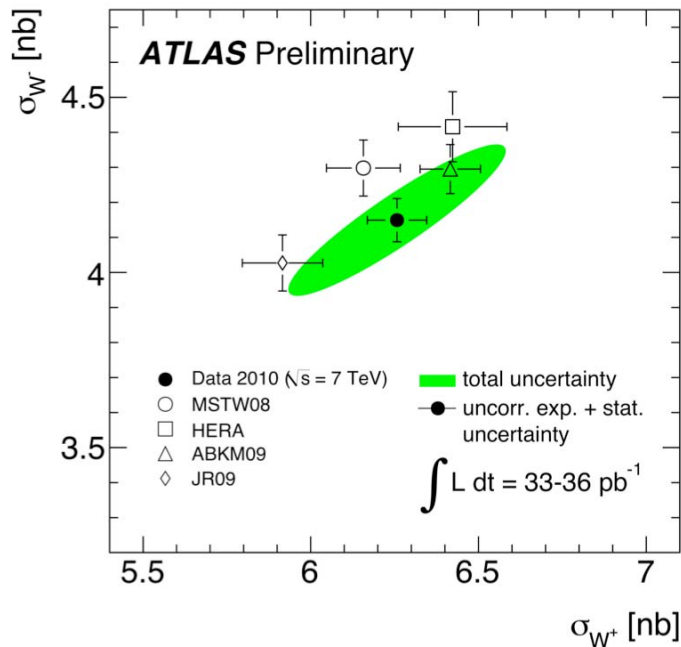


# W and Z/ $\gamma^*$ Inclusive Cross-Section

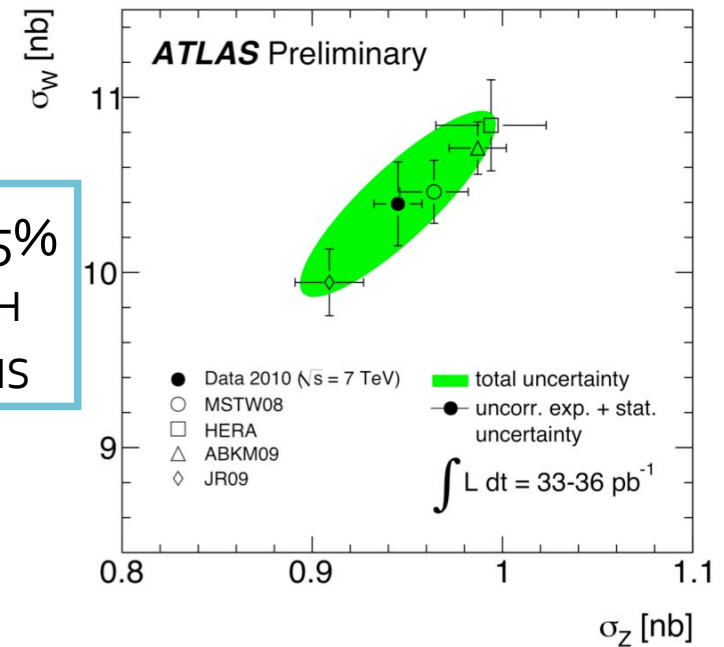
ATLAS-CONF-2011-041

	$\sigma_{W(\pm)}^{\text{tot}} \cdot \text{BR}(W \rightarrow \ell\nu)$ [nb]
$W^+$	$6.257 \pm 0.017(\text{sta}) \pm 0.152(\text{sys}) \pm 0.213(\text{lum}) \pm 0.188(\text{acc})$
$W^-$	$4.149 \pm 0.014(\text{sta}) \pm 0.102(\text{sys}) \pm 0.141(\text{lum}) \pm 0.124(\text{acc})$
$W$	$10.391 \pm 0.022(\text{sta}) \pm 0.238(\text{sys}) \pm 0.353(\text{lum}) \pm 0.312(\text{acc})$
$\sigma_{Z/\gamma^*}^{\text{tot}} \cdot \text{BR}(Z/\gamma^* \rightarrow \ell\ell)$ [nb], $66 < m_{ee} < 116$ GeV	
$Z/\gamma^*$	$0.945 \pm 0.006(\text{sta}) \pm 0.011(\text{sys}) \pm 0.032(\text{lum}) \pm 0.038(\text{acc})$

Uncertainty from extrapolation to full phase space, using Pythia / MRST LO\*



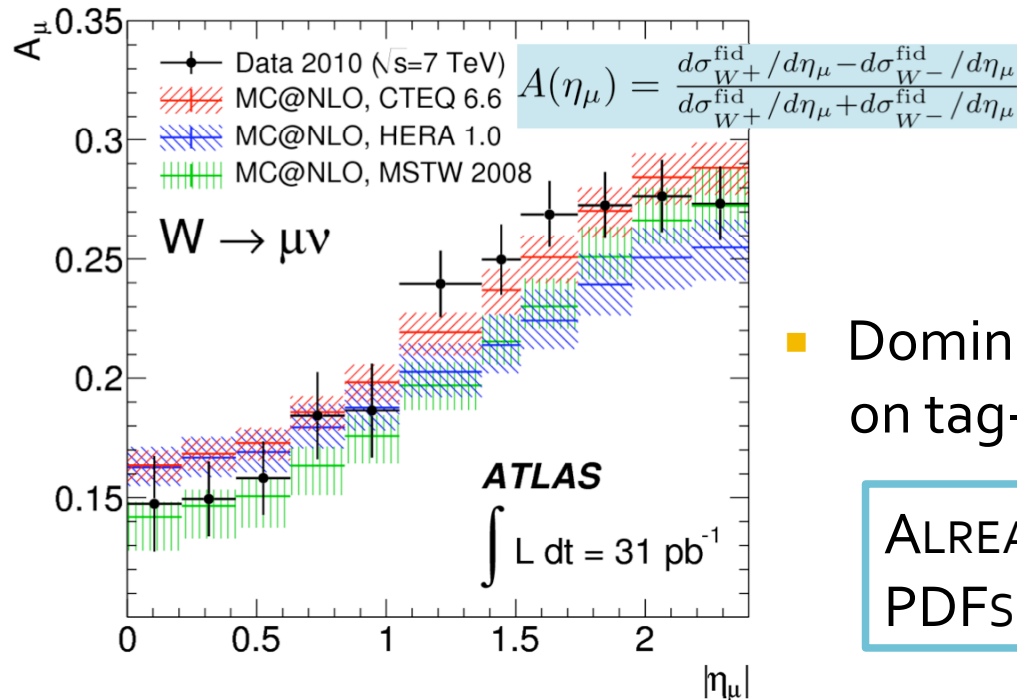
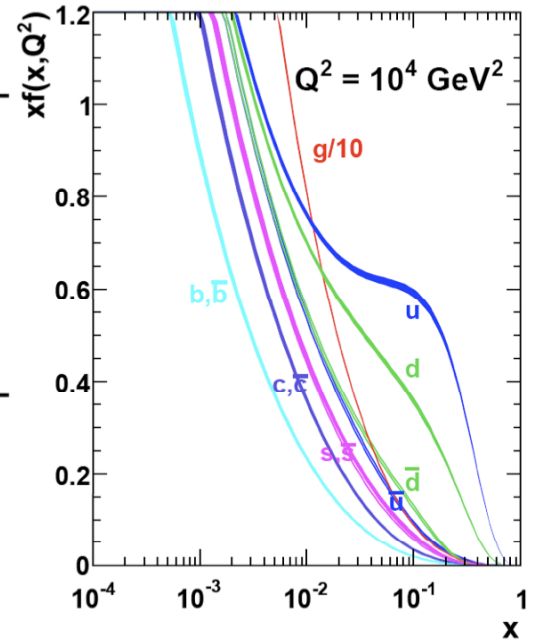
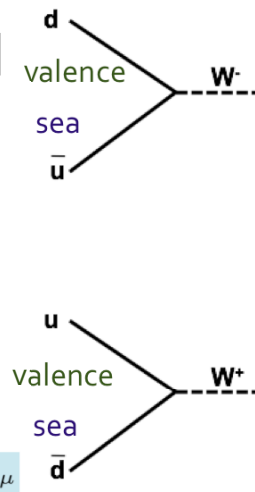
RESULTS AGREE ( $\sim 5\%$  UNCERTAINTY) WITH NNLO PREDICTIONS



# W Charge Asymmetry

arxiv:1103.2929  
Submitted to Phys. Lett. B

- More valence u in proton:  $W^+$  favored
  - Rapidity dependence probes u and d quark parton distribution functions
- Measurement versus *muon* rapidity
- Luminosity and systematics cancel



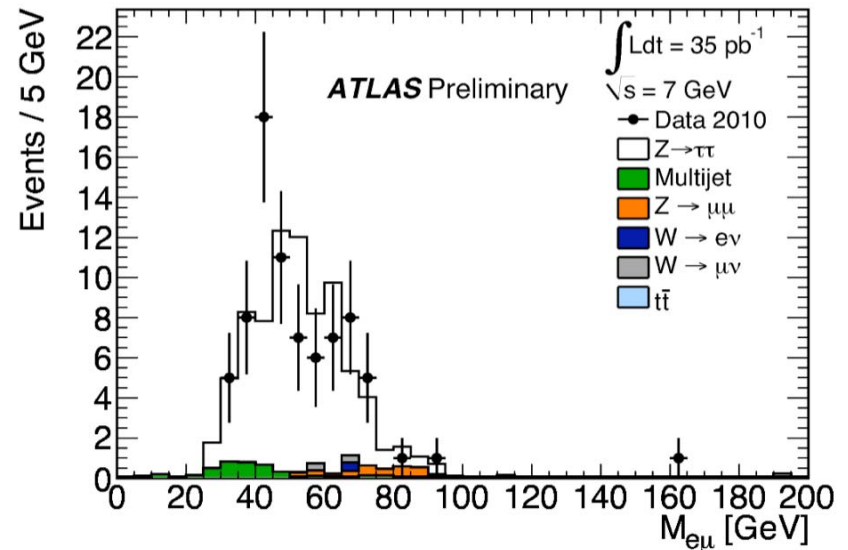
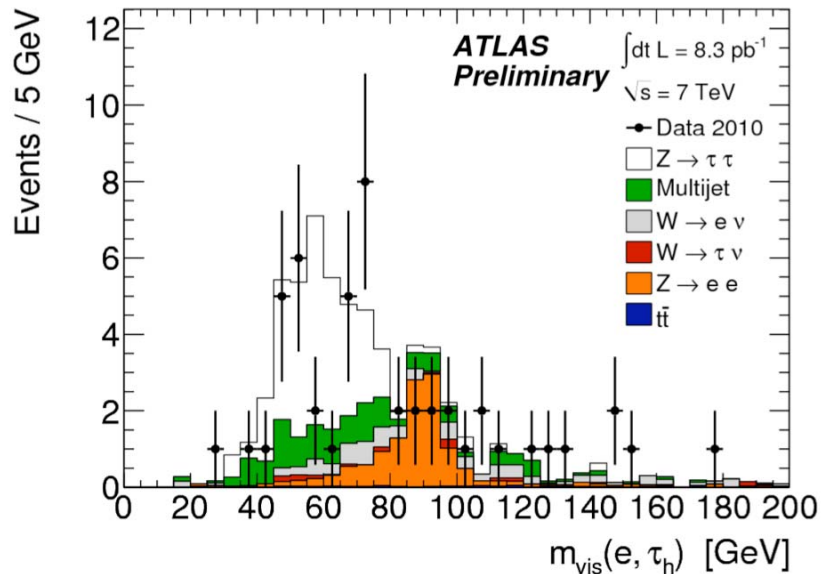
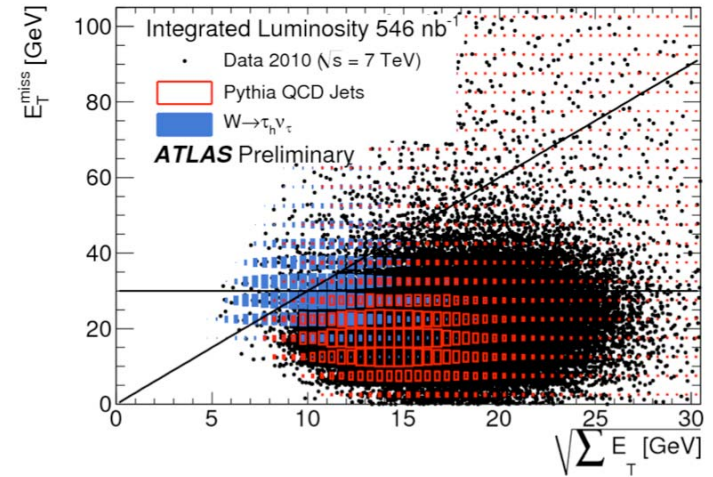
- Dominant systematic from statistics on tag-and-probe studies

ALREADY CONSTRAINS LIGHT QUARK PDFS FOR MEDIUM AND LOW-X

# W/Z Observation with Taus

ATLAS-CONF-2011-010  
ATLAS-CONF-2011-045

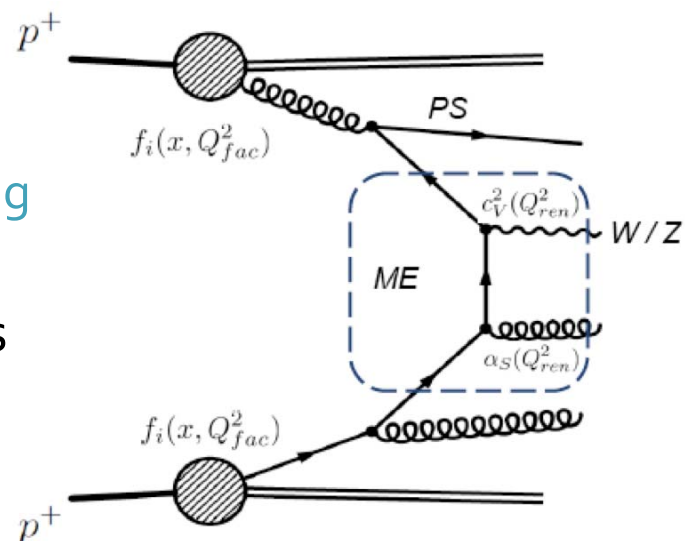
- Impressive control over  $\tau$  reconstruction
- $W \rightarrow \tau_{\text{hadronic}} \nu$  observation with  $546 \text{ nb}^{-1}$
- Z observed with  $e\mu\nu\nu$ ,  $e\nu \tau_{\text{hadronic}}$  and  $\mu\nu \tau_{\text{hadronic}}$  modes
- Important stepping stone toward  $H \rightarrow \tau\tau$
- Yields compatible with SM expectations



# W/Z+Jets

ATLAS-CONF-2011-042  
ATLAS-CONF-2011-060

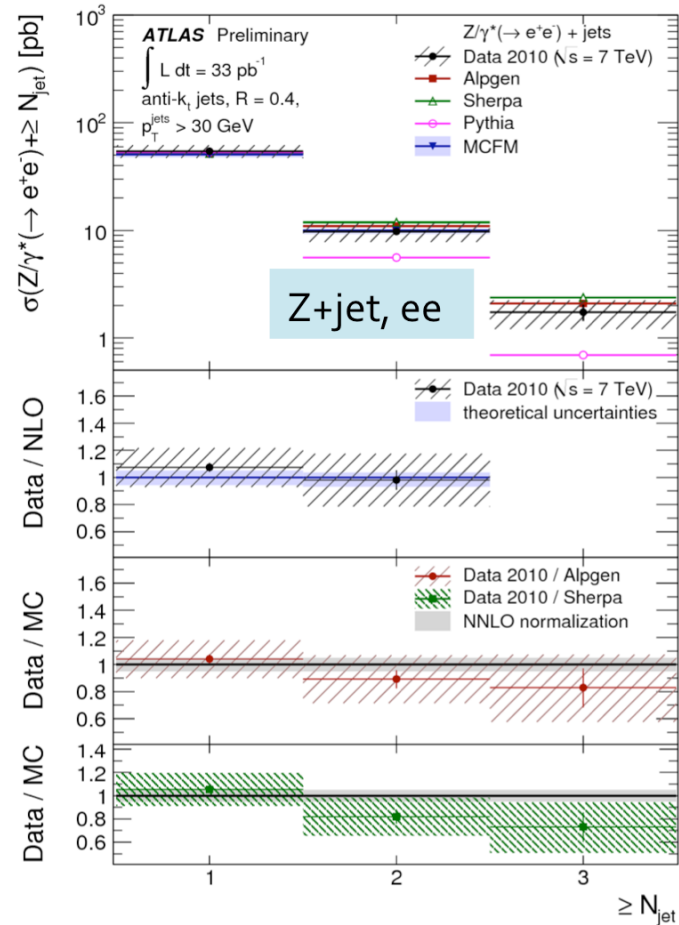
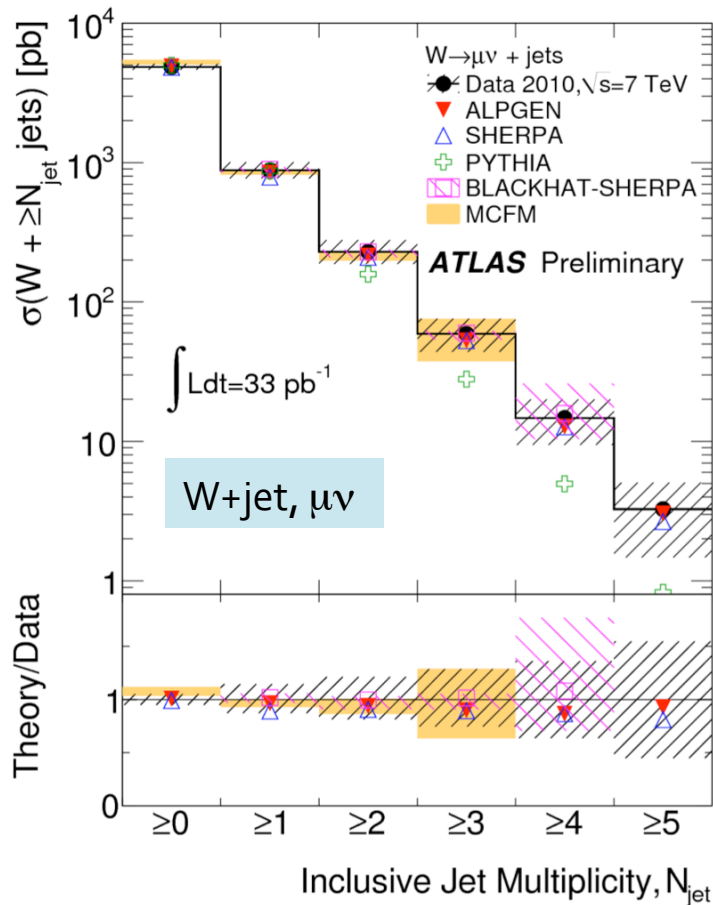
- Test of QCD and Monte Carlo predictions
  - NLO predictions
  - Matrix element and parton shower, matching
  - Dependence on QCD scale
- Background to top, di-bosons, new physics
- Jet defined with anti- $k_T$  algorithm ( $R=0.4$ )
  - $|\eta^{\text{jet}}| < 2.8$
  - $p_T > 20$  GeV for W+jet, 30 GeV for Z+jet
  - Jets from pileup or near leptons ( $\Delta R \leq 0.5$ ) removed
- Background:
  - Mainly top at higher multiplicities
  - QCD especially in electron channel (estimated from data)
- Bin-by-bin unfolding for detector and acceptance
- Systematics: jet scale (dominant, 10-20%), pileup removal





# W/Z+Jets Cross-section vs $N_{jet}$

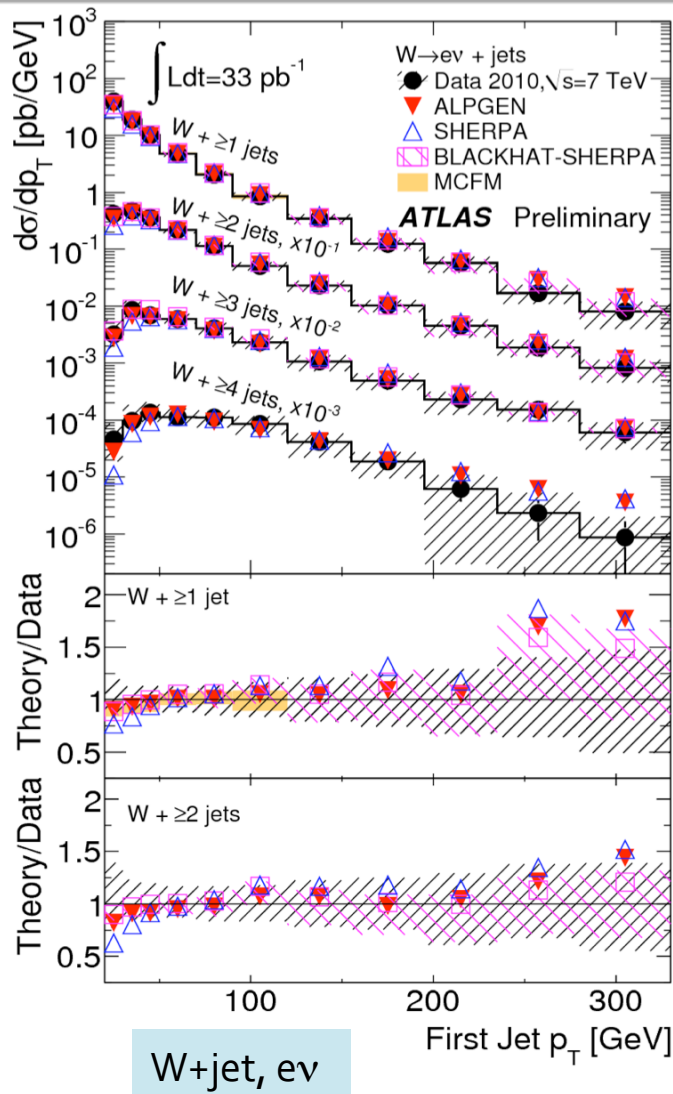
ATLAS-CONF-2011-042  
ATLAS-CONF-2011-060



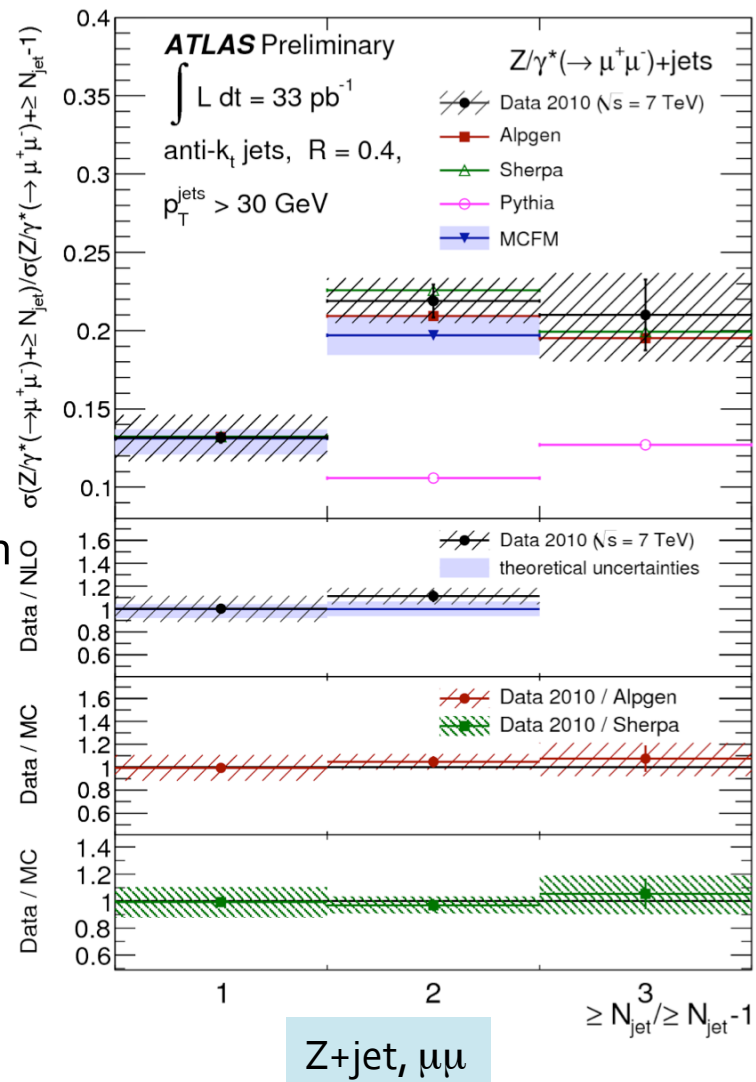
- Similar results in electron and muon channels
- Good agreement with MCFM, Alpgen and Sherpa
  - Pythia not expected to describe distributions for more than one jet

# W/Z+Jets

ATLAS-CONF-2011-042  
ATLAS-CONF-2011-060



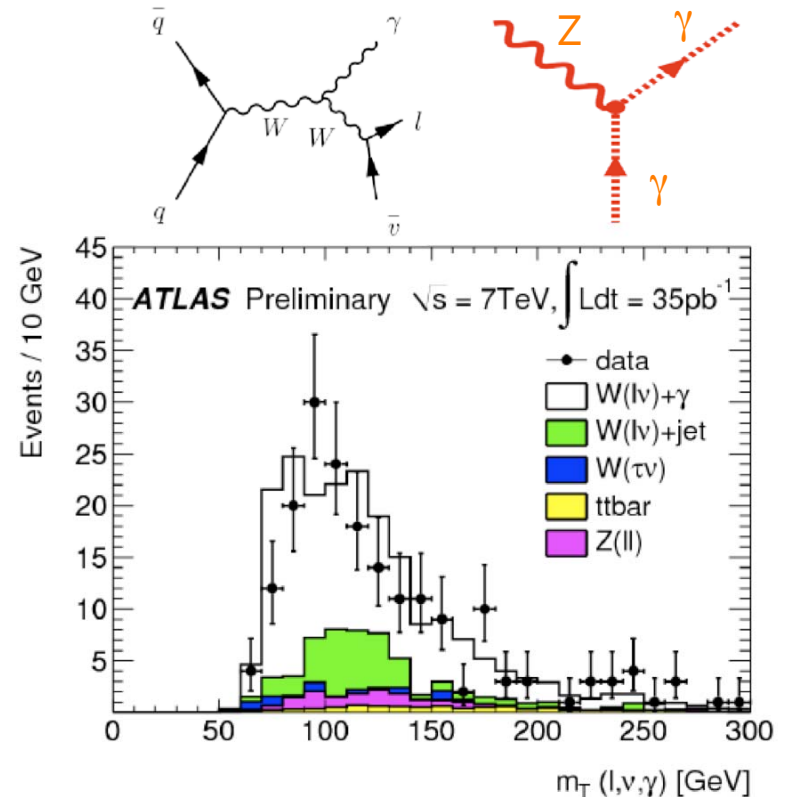
- $p_T$  spectra, multiplicities useful in background estimation
- Ratios constrain  $\alpha_{SI}$  PDFs



# $W\gamma$ and $Z\gamma$ Cross-Sections

ATLAS-CONF-2011-013

- Highest  $\sigma$  di-boson processes
- Study triple gauge couplings (TGC)
- Probe  $ZZ\gamma$  and  $Z\gamma\gamma$  (forbidden at tree level in Standard Model)
- Signature: add isolated  $\gamma$  to  $W/Z$  signature (isolation energy, distance from lepton)
- **192 (48)  $W\gamma$  ( $Z\gamma$ ) candidates**
- Signal extracted from 2D sideband using photon isolation: 80% purity



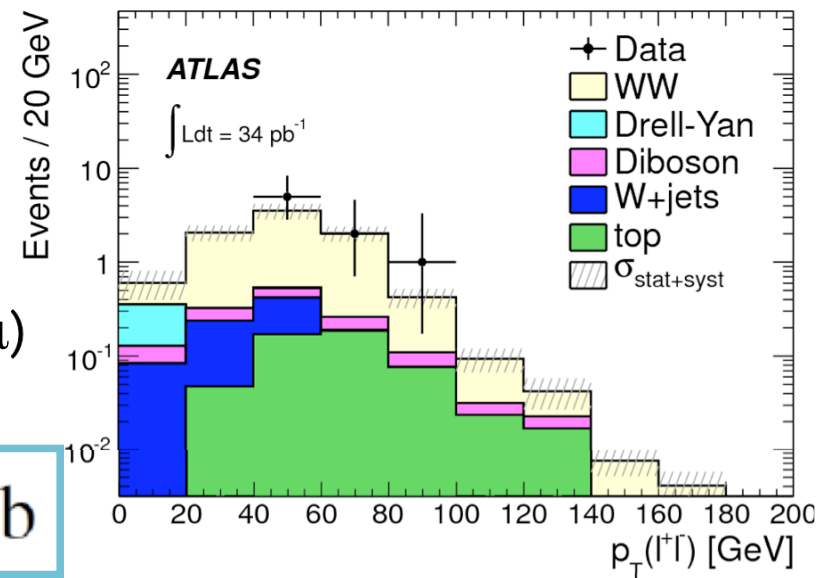
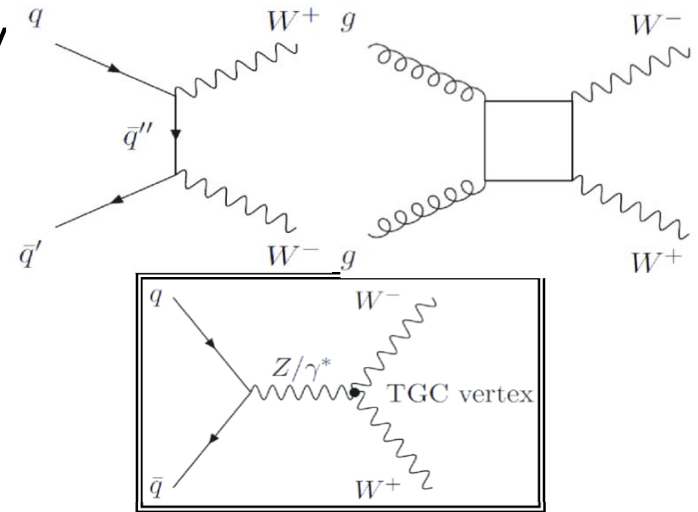
	$\sigma^{total} [pb](\text{measured})$	$\sigma^{total} [pb](\text{predicted})$
$pp \rightarrow e\nu\gamma$	$73.9 \pm 10.5(\text{stat}) \pm 14.6(\text{syst}) \pm 8.1(\text{lumi})$	$69.0 \pm 4.6(\text{syst})$
$pp \rightarrow \mu\nu\gamma$	$58.6 \pm 8.2(\text{stat}) \pm 11.3(\text{syst}) \pm 6.4(\text{lumi})$	$69.0 \pm 4.6(\text{syst})$
$pp \rightarrow e^+e^-\gamma$	$16.4 \pm 4.5(\text{stat}) \pm 4.3(\text{syst}) \pm 1.8(\text{lumi})$	$13.8 \pm 0.9(\text{syst})$
$pp \rightarrow \mu^+\mu^-\gamma$	$10.6 \pm 2.6(\text{stat}) \pm 2.5(\text{syst}) \pm 1.2(\text{lumi})$	$13.8 \pm 0.9(\text{syst})$

EXCELLENT  
AGREEMENT  
WITH SM  
PREDICTIONS

# WW Cross-section

arXiv:1104.5225  
Submitted to PRL

- Probe electroweak theory at high energy
- Study triple gauge couplings
  - BSM expectations of anomalous values
- Important background to  $H \rightarrow WW$
- $\sigma_{WW}^{\text{NLO}} = [44 \pm 3] \text{ pb}$
- Signature has opposite sign leptons, large  $E_T^{\text{miss}}$ , reduced jet activity
- Backgrounds:  $1.7 \pm 0.6$  events
  - Veto on Z mass, high  $p_T$  jet
  - W+jets from loose lepton control
- **Eight** candidate events seen (5 in  $e\mu$ )
  - $3\sigma$  signal significance

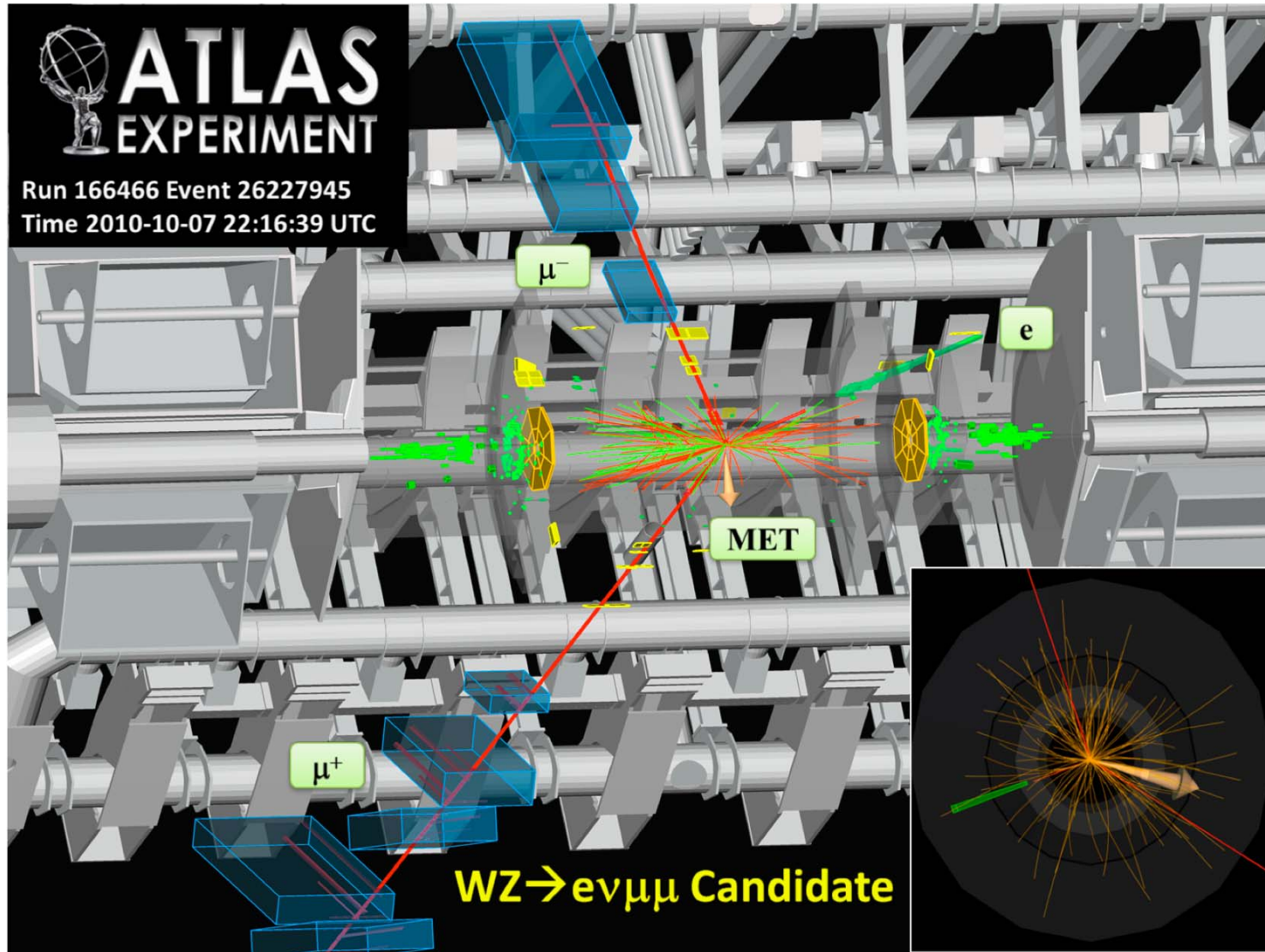


$$\sigma_{WW} = 40_{-16}^{+20}(\text{stat}) \pm 7(\text{syst}) \text{ pb}$$

# Conclusion and Outlook

- Reviewed W/Z results from ATLAS with 2010 dataset
  - Powerful tests of pQCD theoretical predictions; constraining PDFs
  - Excellent understanding of detector performance demonstrated
  - W/Z Observations with  $\tau$  made; demonstrate reconstruction
  - More differential measurements upcoming
- First Diboson results for WW,  $W\gamma$  and  $Z\gamma$ 
  - In agreement with Standard Model expectations
  - Currently limited statistically
- 2011 data will dramatically sharpen results
  - Allow WZ and ZZ measurements
  - TGC will become interesting!
  - Differential W/Z measurements will further constrain PDFs

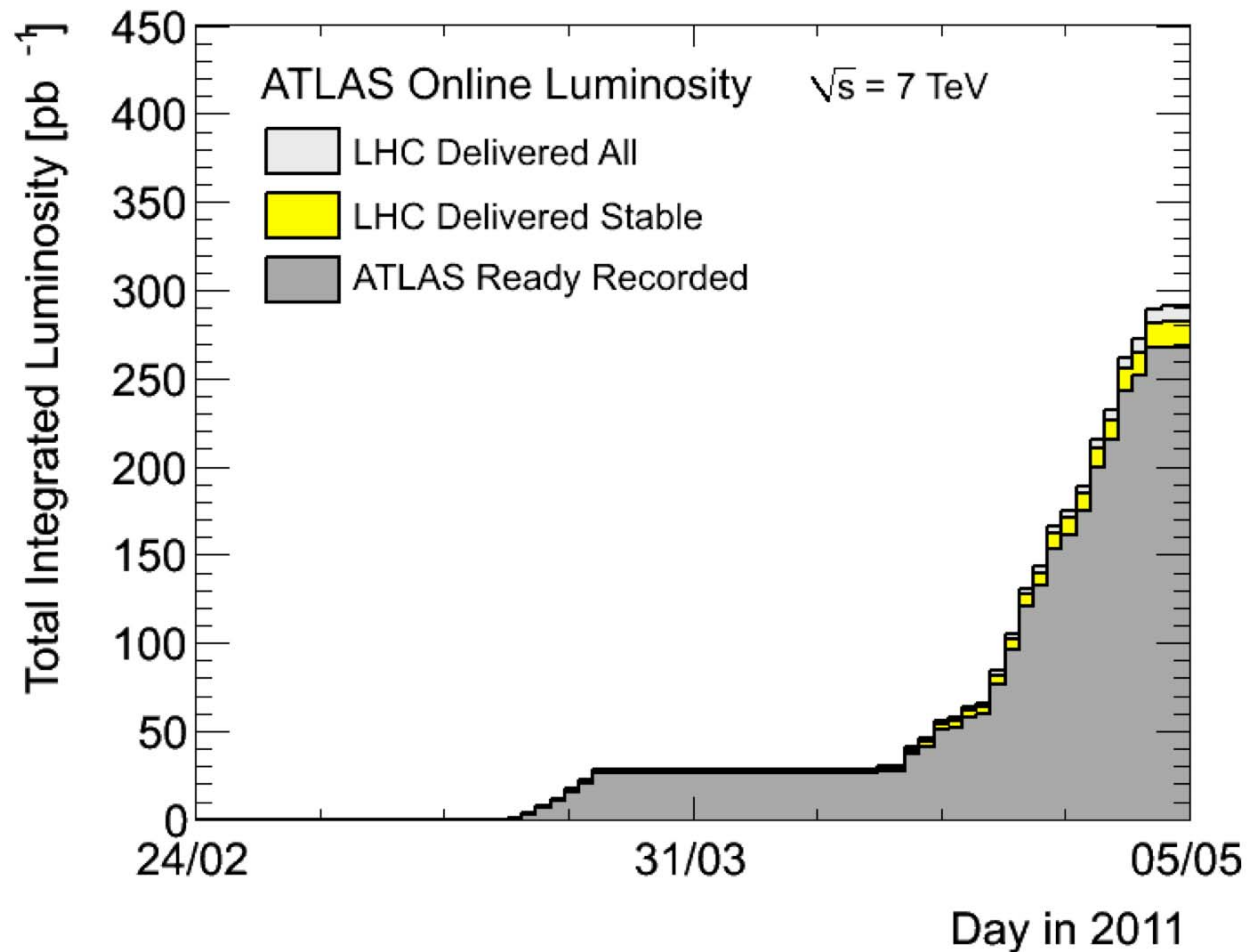
# WZ Candidate Event



# BACKUP

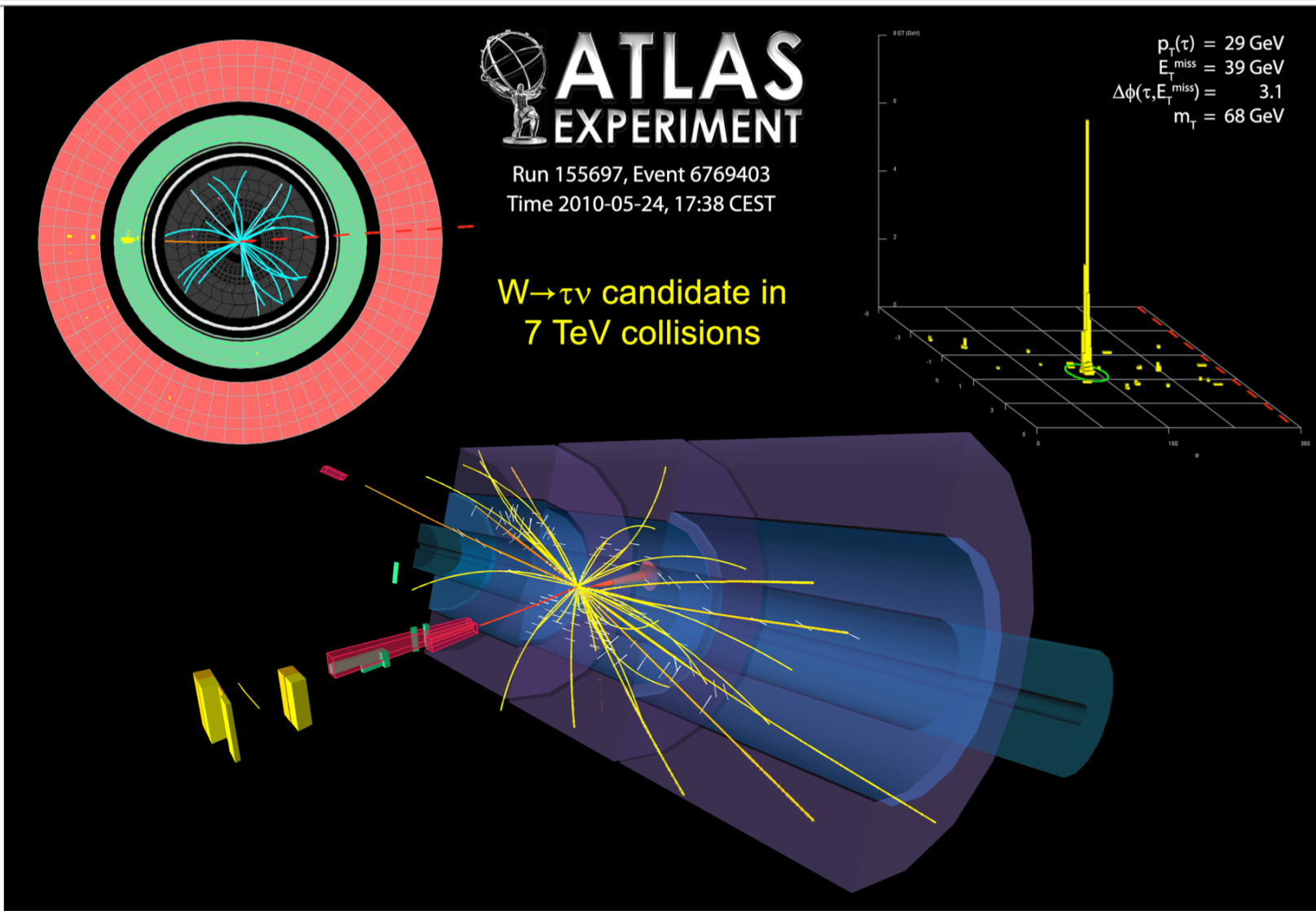
# 2011 Luminosity and Collected Data

- Maximum instantaneous luminosity of  $8.8 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ !





# $W \rightarrow \tau_h \nu$ Candidate



# $Z \rightarrow \tau_{had} \tau_{\mu}$ Candidate

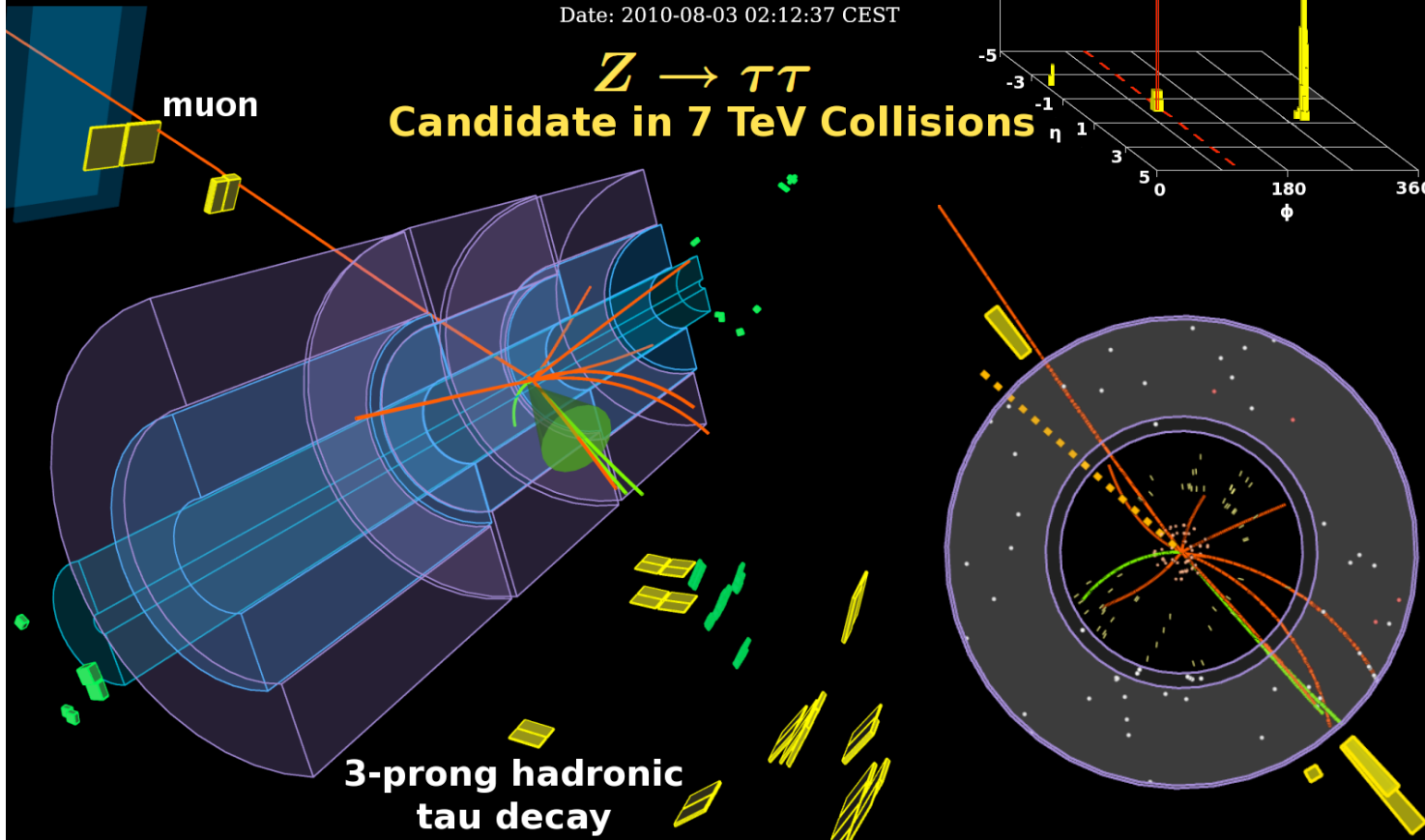
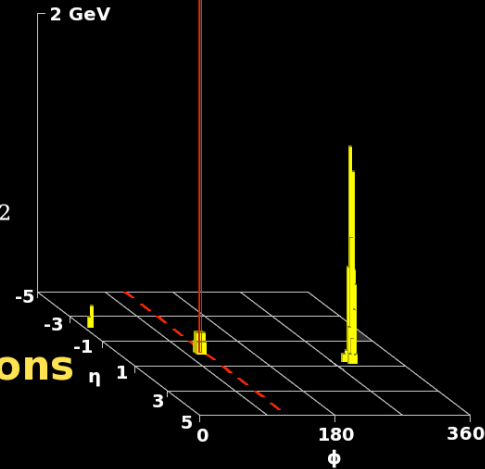
$p_T(\mu) = 18 \text{ GeV}$   
 $p_T^{vis}(\tau_h) = 26 \text{ GeV}$   
 $m_{vis}(\mu, \tau_h) = 47 \text{ GeV}$   
 $m_T(\mu, E_T^{miss}) = 8 \text{ GeV}$   
 $E_T^{miss} = 7 \text{ GeV}$



Run Number: 160613, Event Number: 9209492

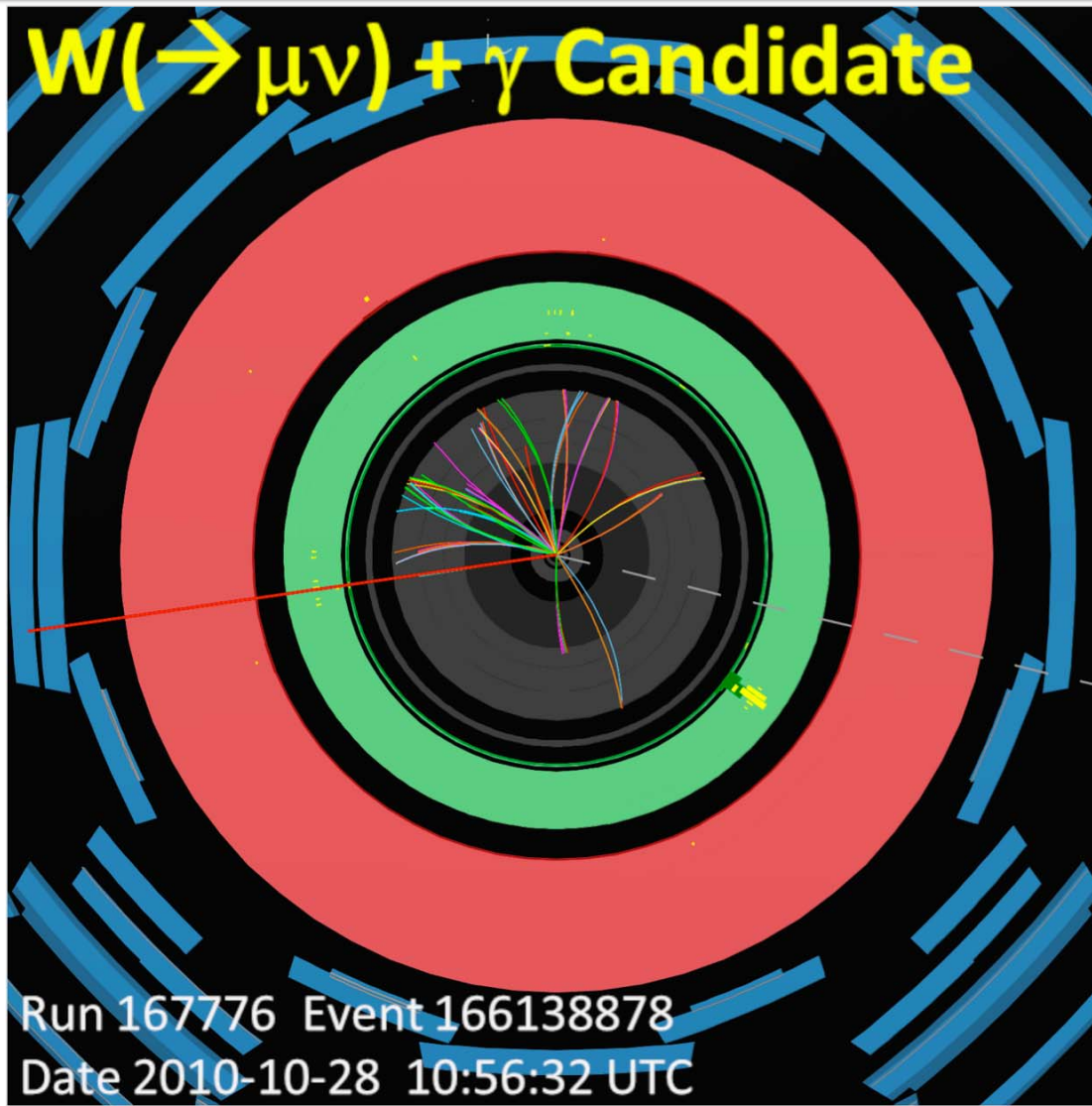
Date: 2010-08-03 02:12:37 CEST

$Z \rightarrow \tau\tau$   
Candidate in 7 TeV Collisions



# $W\gamma$ Event

## $W(\rightarrow \mu\nu) + \gamma$ Candidate



Run 167776 Event 166138878  
Date 2010-10-28 10:56:32 UTC

