Electroweak Physics in ATLAS

Justin Griffiths
University of Washington
On Behalf of the ATLAS Collaboration
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Why Study Electroweak Physics?

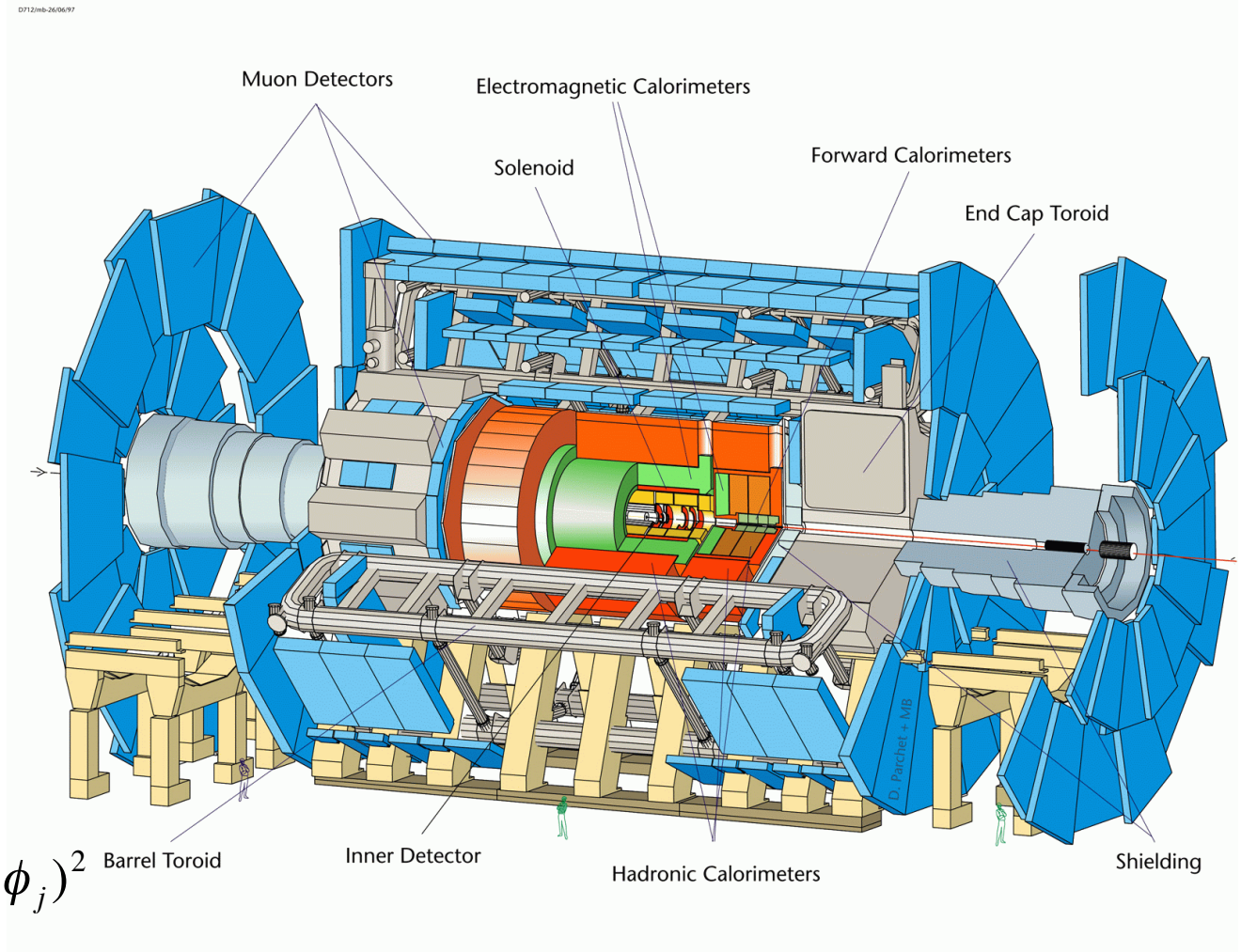
- Validate Standard Model Predictions at 7TeV
- Understanding the Detector
  - Calibration: energy scale, resolution, …
  - Detector Alignment
- Major background for new physics searches
  - H→ZZ/WW/ττ …, SUSY, …
- Constrain Parton Density Functions
- Precision EWK Measurements (TGC,…)

What's Covered in This Talk

- W/Z cross sections with e/μ/τ
  - Differential cross sections (η_l , y_Z)
  - W/Z Cross Section Ratios
  - Lepton Universality e/μ Final States
- W/Z p_T Measurements
- W/Z +b jet Cross Sections
- WW/WZ/ZZ Cross Sections
  - Triple Gauge Boson Coupling Limits

The ATLAS Detector

- 3000 Collaborators
- 174 Institutions
- 38 Countries

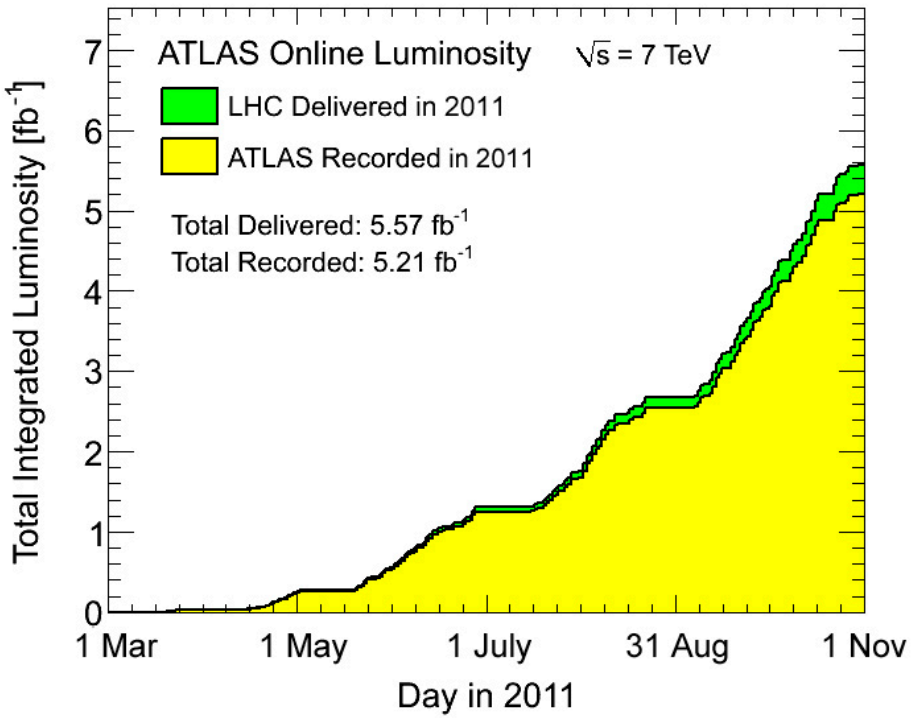


$$\eta = -\ln(\tan\frac{\vartheta}{2})$$

$$\Delta R_{ij} = \sqrt{(\eta_i - \eta_j)^2 + (\phi_i - \phi_j)^2}$$

Data Collection

- Collected 36 pb^{-1} 2010
- Collected >5 fb^{-1} 2011
  - 94% efficiency
- Luminosity Error 3.4%



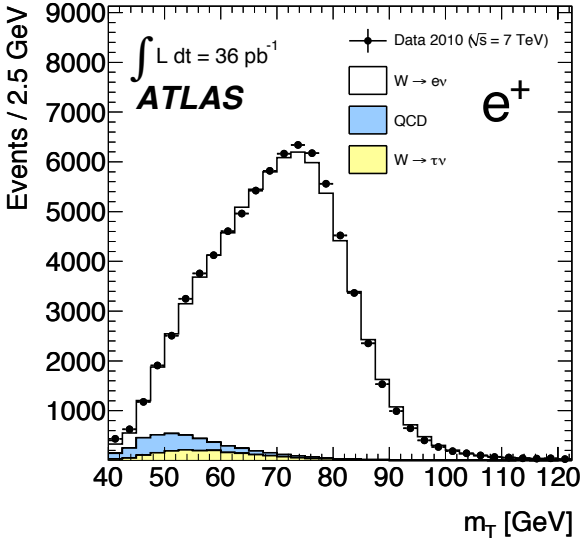
Common Object Selections

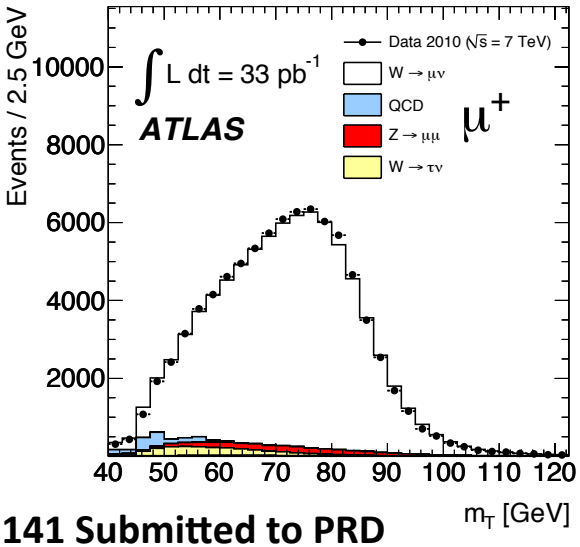
- Electrons:
  - $|\eta| < 1.37$ or $1.52 < |\eta| < 2.47$ (Calorimeter transition region removal)
- Muons:
  - Combined Inner Detector and Muon Spectrometer Track. $|\eta|<2.4$
- MET:
  - Σ Clusters + Muon Corrections

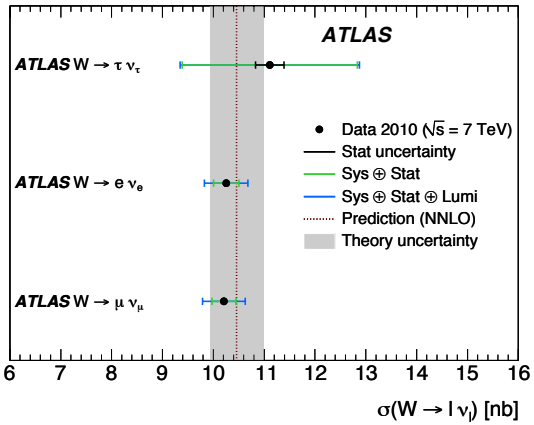
Total W Cross Section

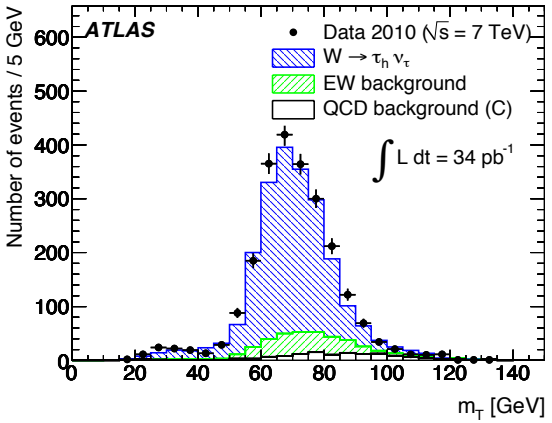
- Cross sections measured in all three leptonic channels
- e/u
  - p_T>20 GeV, E_t^{miss}> 25 GeV, m_T > 40 GeV
- τ
  - 20< p_T < 60 GeV, E_t^{miss}> 20 GeV, S > 6

$$S_{E_{\mathrm{T}}^{\mathrm{miss}}} = \frac{E_{\mathrm{T}}^{\mathrm{miss}}[\mathrm{GeV}]}{0.5\sqrt{\mathrm{GeV}}\sqrt{(\sum E_{\mathrm{T}}[\mathrm{GeV}])}}$$







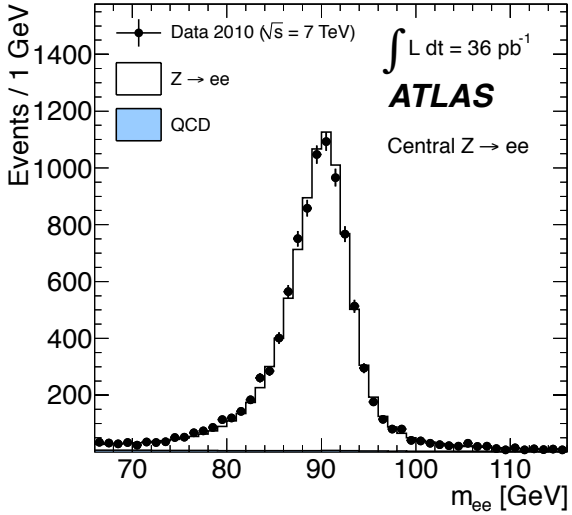


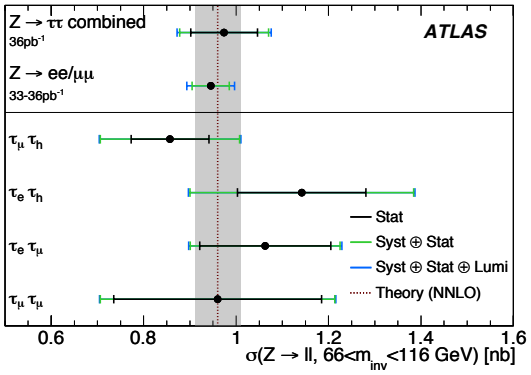
arXiv:1109.5141 Submitted to PRD

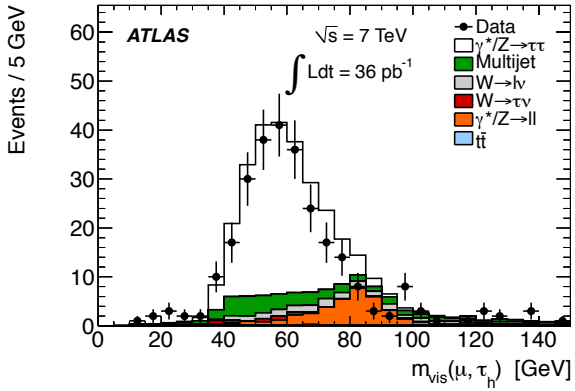
arXiv:1108.4101 Submitted to PLB

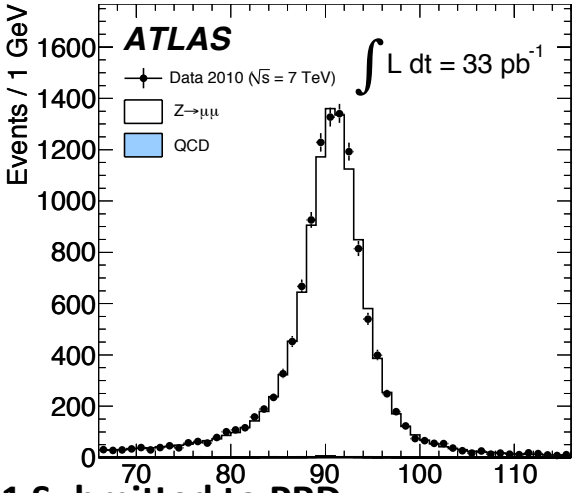
Total Z Cross Section

- Cross sections measured in all three leptonic channels
- e/u
  - p_T>20 GeV, OS, 66 < m_{ll} < 116 GeV
- τ ($e\tau_h/\mu\tau_h/e\mu/\mu\mu$)
  - $p_T(\tau)$ > 20 GeV, $p_T(e)$ > 16 GeV, $p_T(\mu)$ > 15 GeV(10 eμ/ sub leading μμ)







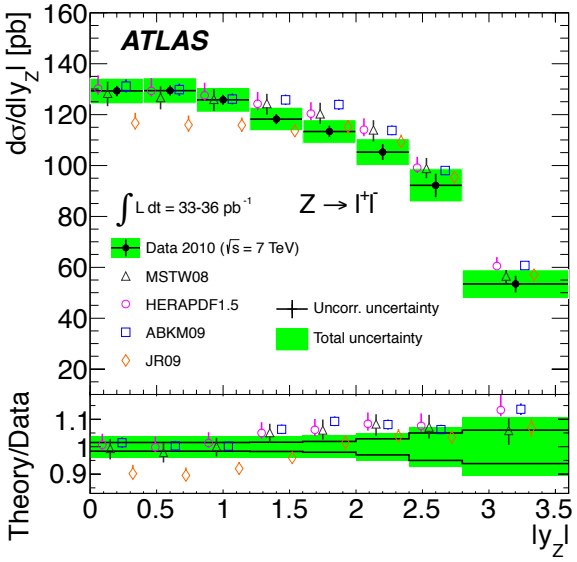


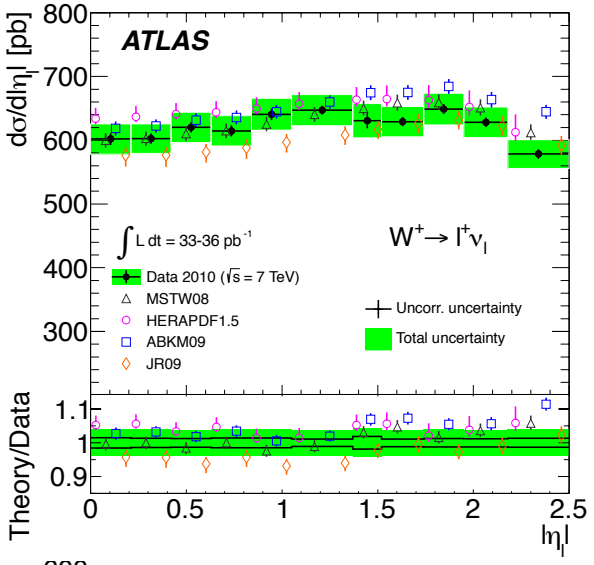
arXiv:1109.5141 Submitted to PRD

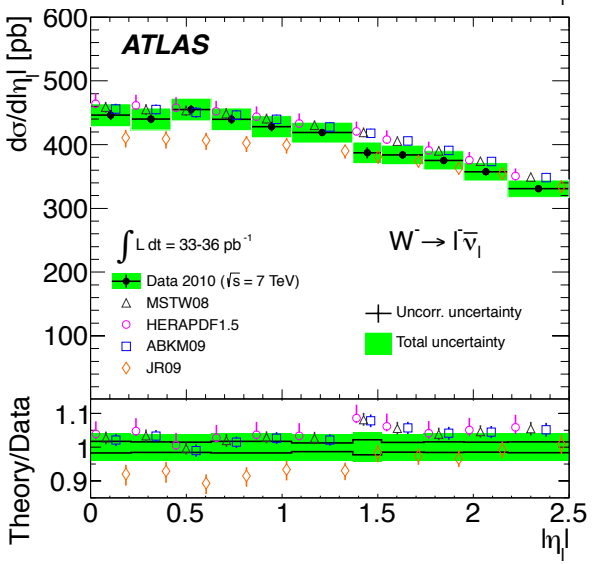
arXiv:1108.2016 Accepted to PRD

Differential W/Z Cross Sections

- W→e(μ)ν
  - $d\sigma/d|\eta_l|$
- Z→ee/μμ
  - $d\sigma/d|y_Z|$
- Extend ee in y
  - 1 tight central e 1 loose e $|\eta| < 4.5$





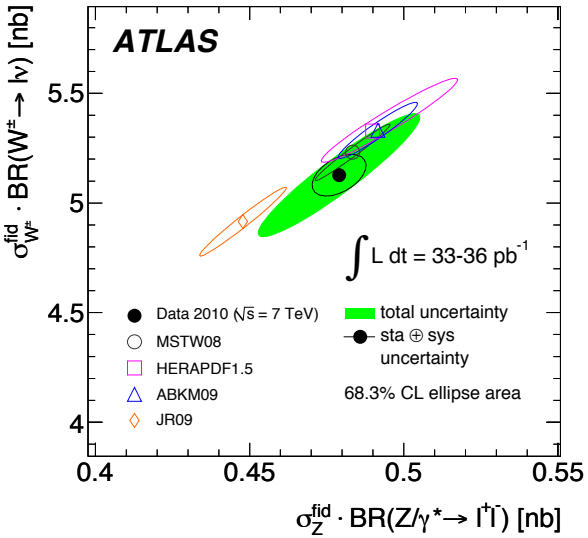


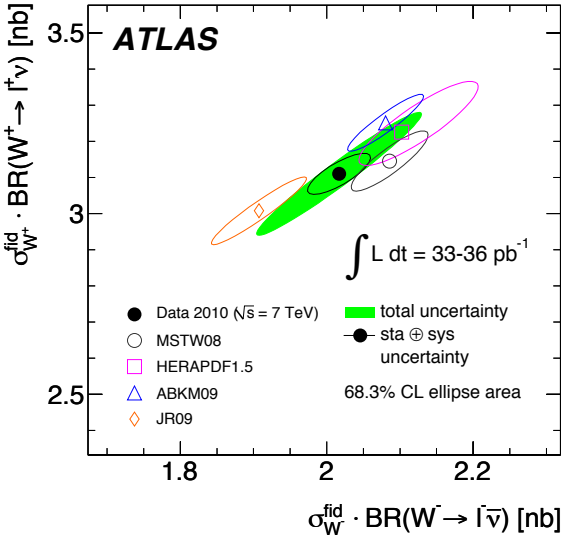
- 2% Data Accuracy in Central Region
  - 6(10%) at y_Z ~2.6(3.2)
- Excellent Agreement with Simulation
- Results should reduce PDF uncertainties and influence their central values

arXiv:1109.5141 Submitted to PRD

W/Z Integrated Cross Section

- e/μ W/Z channels combined to common fiducial region
  - 1% syst err, <1% stat, 3.4% lumi
- Ratios in fiducial region preferred since extrapolation to full phase space 2% err
- PDFs rely on HERA
  - evolution of PDFs and pQCD at high orders into LHC W/Z kinematic range works well ⇒ universality





arXiv:1109.5141 Submitted to PRD

Lepton(e/μ) Universality

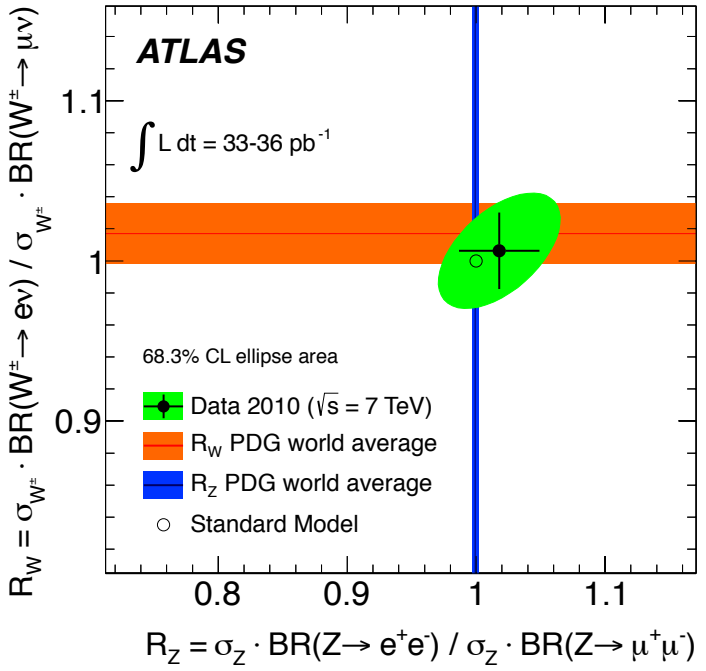
- Ratios computed in common fiducial region

$$R_W = \frac{\sigma_W^e}{\sigma_W^\mu} = 1.006 \pm 0.024$$

$$R_Z = \frac{\sigma_Z^e}{\sigma_Z^\mu} = 1.018 \pm 0.031$$

- World Average
  - 1.017 ± 0.019 (W)
  - 0.9991 ± 0.0024 (Z)
- Using World Average (Z) as constraint:

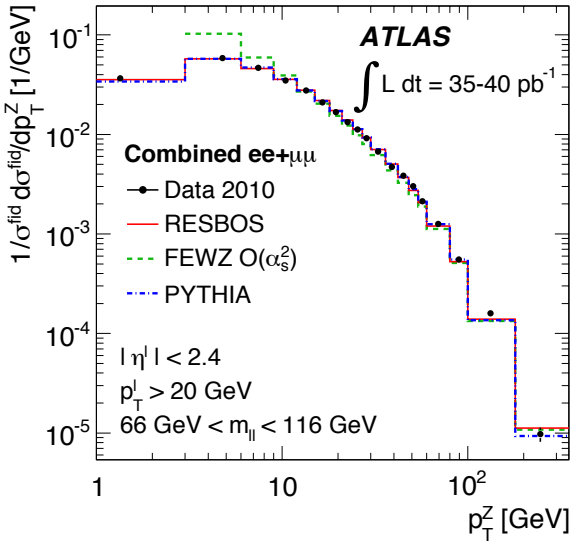
$$R_W = \frac{\sigma_W^e}{\sigma_W^\mu} = 0.999 \pm 0.020$$

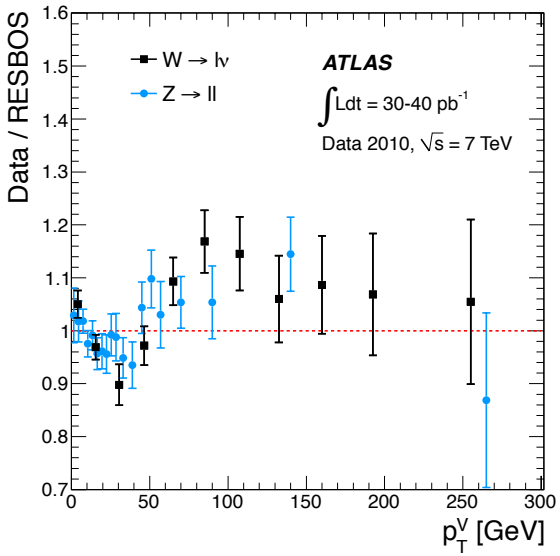


arXiv:1109.5141 Submitted to PRD

W/Z p_T Measurements

- Event Selection same as for W/Z Cross sections
- p_T(Z) formed from 2 leptons
- p_T(W) formed from hadronic recoil (subtracting lepton)
  - UE/Pileup added back
  - Unfold p_T^R to p_T^W using a response matrix
- The two independent Analyses yielded consistent results





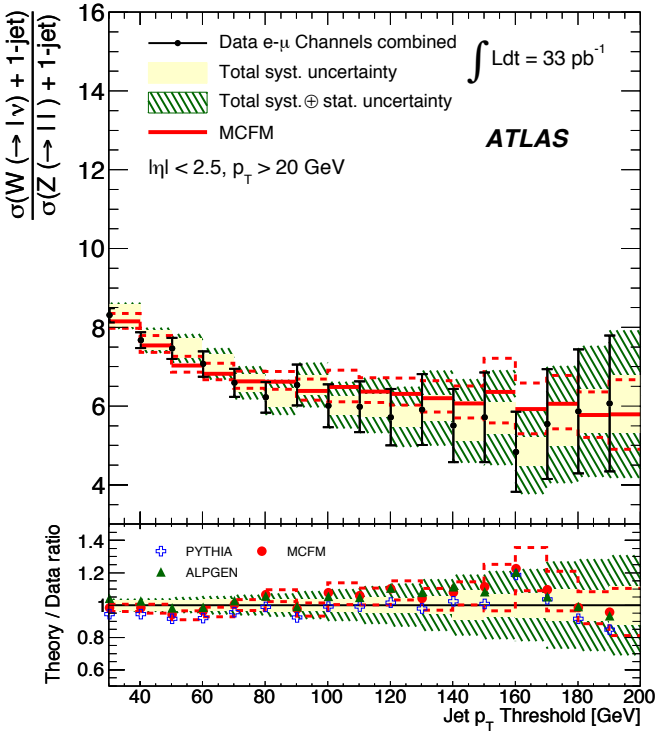
[Phys. Lett. B 705 (2011) 415-434]

arXiv:1108.6308 accepted PRD

Ratio W and Z cross sections with Exactly One Jet

- Require One Jet
  - $p_T > 30$ GeV, $|\eta| < 2.8$, $\Delta R(e, jet) > 0.6$, JVF > 0.75
- $R_{Jet}=N^{l,W}/N^{l,Z}$
  - N corrected for Detector effects
  - Jet Energy Scale(Resultion) systematics generally cancel
- $R_{jet} = 8.29 \pm 0.18(stat) \pm 0.28(syst)$
- Foundation for precision model ind. test of SM
- Agreement with LO and NLO pQCD

Fiducial Region

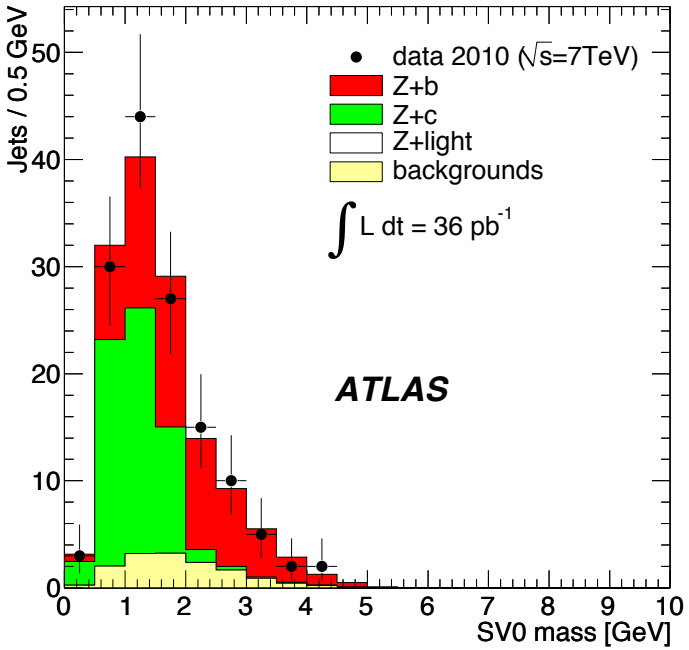


Jet Vertex Fraction (JVF) = $\Sigma p_T (trk_{PMV\&jet})/\Sigma p_T(trk_{jet})$

arXiv:1108.4908 submitted to PLB

b jet Cross Sections in Association W/Z

- Require standard W/Z(e/μ) Analysis cuts w/ at least one jet:
  - p_T > 25 GeV, |y| < 2.1, ΔR(jet, l) > 0.5
  - SV0 > 5.85 (Secondary Decay vertex length sig.)
- Extract W/Z+b jet with binned maximum likelihood fit on SV0 mass

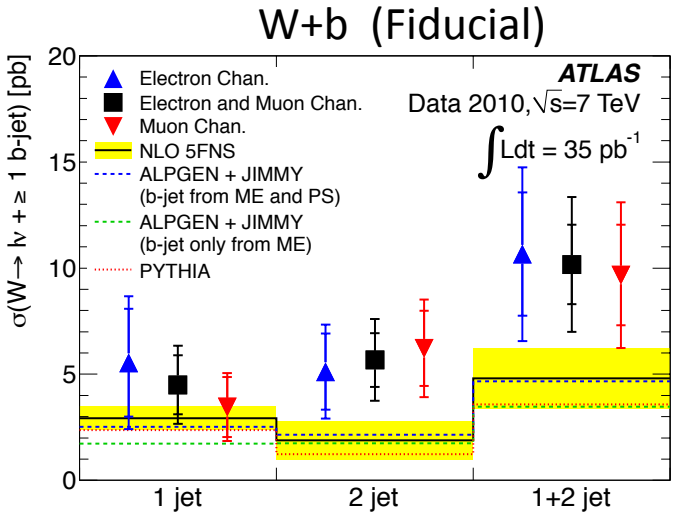


arXiv:1109.1470 submitted to PLB
arXiv:1109.1403 submitted to PLB

b jet Cross Sections in Association W/Z

- W+b cross section consistent to 1.5σ
- Z+b cross section Consistent w/ Theory
  - Statistics limited
- Successful validation

of b tagging algorithms



Z+b

Experiment	$3.55^{+0.82}_{-0.74}(\text{stat})^{+0.73}_{-0.55}(\text{syst}) \pm 0.12(\text{lumi})$ pb
MCFM	3.88 ± 0.58 pb
ALPGEN	2.23 ± 0.01 (stat only) pb
SHERPA	3.29 ± 0.04 (stat only) pb

arXiv:1109.1470 submitted to PLB
arXiv:1109.1403 submitted to PLB

WW Cross Section (1.02 fb^{-1})

- Three channels considered
  - ee/eμ/uu (τ→eμ included)
- Event Selection:
  - p_T > 25(20) lead e (μ/second e)
  - $m_{ee/\mu\mu}$ > 15 GeV(15 GeV Z pole veto), $m_{e\mu}$>10 GeV
  - E_t^{miss}(rel) and Veto Events w/ Jet (p_T>30 GeV and |η|<4.5)

$$E_{\mathrm{T,\ Rel}}^{\mathrm{miss}} = \begin{cases} E_{\mathrm{T}}^{\mathrm{miss}} \times \sin\left(\Delta\phi_{\ell,j}\right) & \text{if } \Delta\phi < \pi/2 \\ E_{\mathrm{T}}^{\mathrm{miss}} & \text{if } \Delta\phi \geq \pi/2 \end{cases}$$

PRL 107, 041802 (2011)

WZ Cross Section (1.02 fb^{-1})

- Four final states:
  - eee,eeμ,μμe,μμμ (τ→e/μ included)
- Event Selection:
  - 2 OSSF leptons and 1 Tighter lepton(W)
  - E_t^{miss} >25 GeV, $|m_{ll}-m_Z|$<10 GeV, m_T>20 GeV, triggered lepton on plateau

http://cdsweb.cern.ch/record/1369214

ZZ Cross Section (1.02 fb^{-1})

- Three Final States Considered
  - eeee/μμμμ/eeμμ
- Event Selection:
  - $p_T(l) > 15$ GeV; p_T (triggered l) > 20(25) GeV μ(e)
  - 2 OSSF pairs, $66 < m_{ll} < 116$ GeV

Channel	Observed	BG(data-driven)	Expected ZZ
$e^+e^-e^+e^-$	2	$0.01^{+0.03+0.05}_{-0.01-0.01}$	$1.53\pm0.03\pm0.10$
$\mu^+\mu^-\mu^+\mu^-$	8	$0.3 \pm 0.3 \pm 0.3$	$3.03\pm0.04\pm0.06$
$e^+e^-\mu^+\mu^-$	2	$< 0.01^{+0.03}_{-0.01}$	$4.37\pm0.04\pm0.14$
$\ell^+\ell^-\ell^+\ell^-$	12	$0.3 \pm 0.3^{+0.4}_{-0.3}$	$8.9\pm0.1\pm0.3$

3.2% chance
3.3→8

arXiv:1110.5016 submitted to PRL

Diboson Cross Section Results

- Cross Sections Consistent with NNLO Predictions

$$\sigma^{\text{fid}}_{ZZ\to\ell^+\ell^-\ell^+\ell^-} = 19^{+6}_{-5}(\text{stat.}) \pm 1(\text{syst.}) \pm 1(\text{lumi.}) \text{ fb}$$

- Limits on Anomalous Neutral Triple Gauge Boson Couplings were derived (Backup)

$$\sigma^{fid}_{WZ\to\ell\nu\ell\ell} = 118^{+18}_{-16}(\text{stat})\ ^{+6}_{-6}(\text{syst})\ ^{+5}_{-5}(\text{lumi})\ \text{fb}$$

WW

Channels	expected σ^{fid} (fb)	measured σ^{fid}(fb)	$\Delta\sigma_{stat}$(fb)	$\Delta\sigma_{syst}$(fb)	$\Delta\sigma_{lumi}$(fb)
$e\nu e\nu$	66.8	90.1	$\pm$ 18.9	$\pm$ 11.3	$\pm$ 3.3
$\mu\nu\mu\nu$	63.8	62.0	$\pm$ 12.1	$\pm$ 10.7	$\pm$ 2.3
$e\nu\mu\nu$	245.1	252.0	$\pm$ 24.6	$\pm$ 29.4	$\pm$ 9.3

Summary

- The Total Cross Section was measured for W/Z with e, μ, and τ's in the final state
  - e/μ final states systematic error < 1%
- The W/Z differential Cross Sections were measured as a function of y_Z, $\eta_{l(W)}$, and p_T
- b jet cross sections in association with W/Z bosons were measured
- WW/WZ/ZZ Diboson cross section measurements made
- With the addition of 5 fb^{-1}, the above measurements can be made with even more precision

References

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- arXiv:1108.2016, Accepted to PRD
- arXiv:1108.4101, Submitted to PLB
- Phys. Lett. B 705 (2011) 415-434
- arXiv:1108.6308, accepted PRD
- arXiv:1108.4908, submitted to PLB
- arXiv:1109.1470, submitted to PLB
- arXiv:1109.1403, submitted to PLB
- PRL 107, 041802 (2011)
- http://cdsweb.cern.ch/record/1369214
- arXiv:1110.5016, submitted to PRL

Backup

ZZ and WZ TGC Limits

- Anomalous a(n)TGC 95% Confidence Intervals
  - Statistics Limited