Standard Model Physics with ATLAS

16th Lomonosov Conference on Elementary Particle Physics, Moscow

Luke Lambourne on behalf of the
ATLAS collaboration

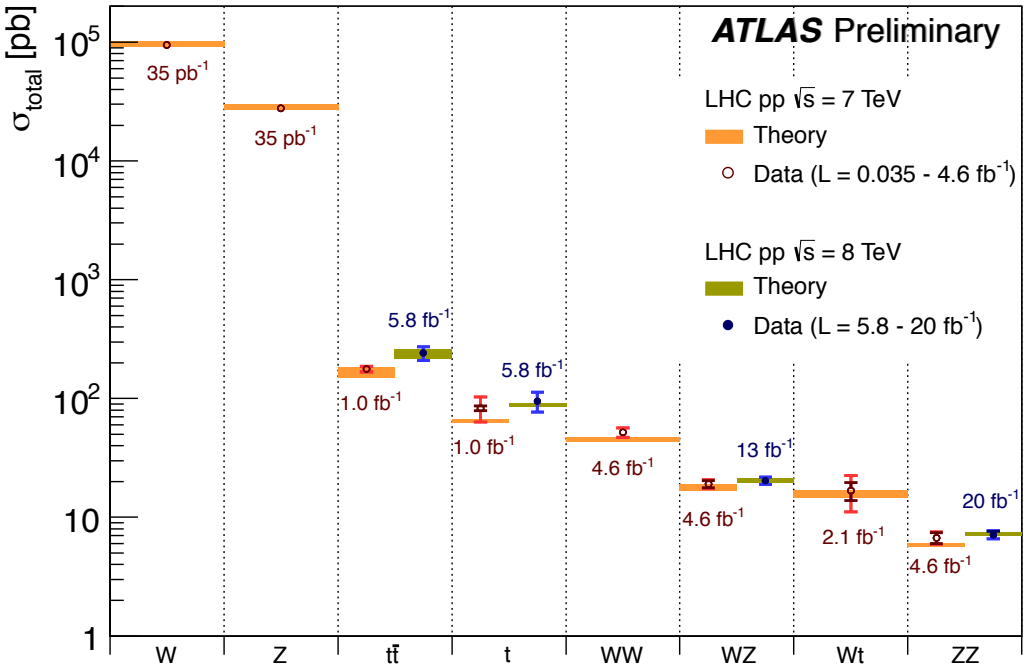
27/08/13

Introduction

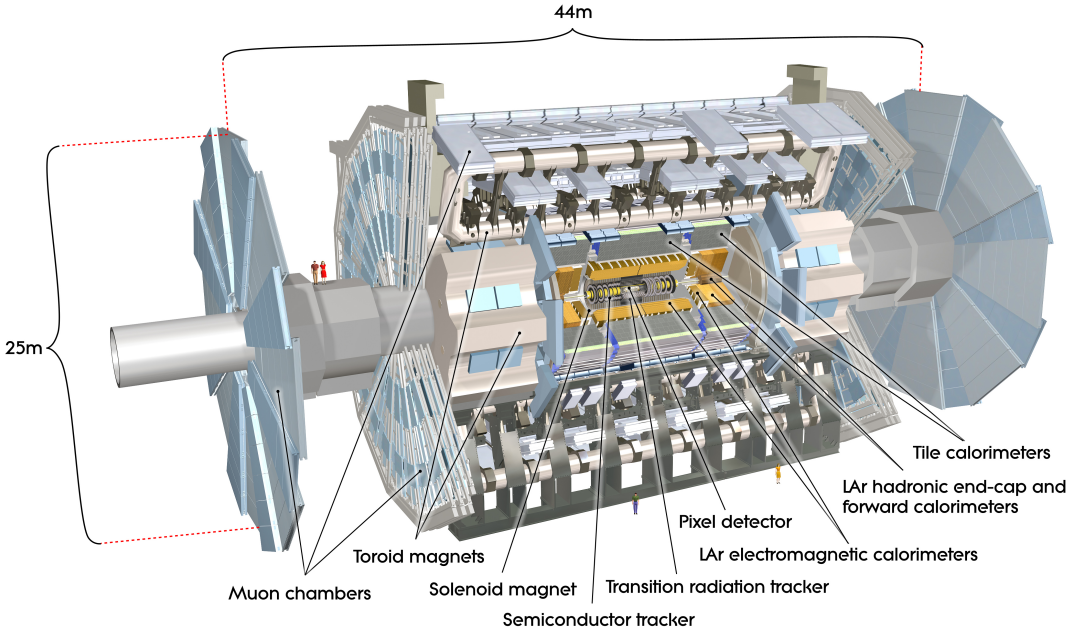
There have been many SM results released by ATLAS. I don't have time to cover them all here!

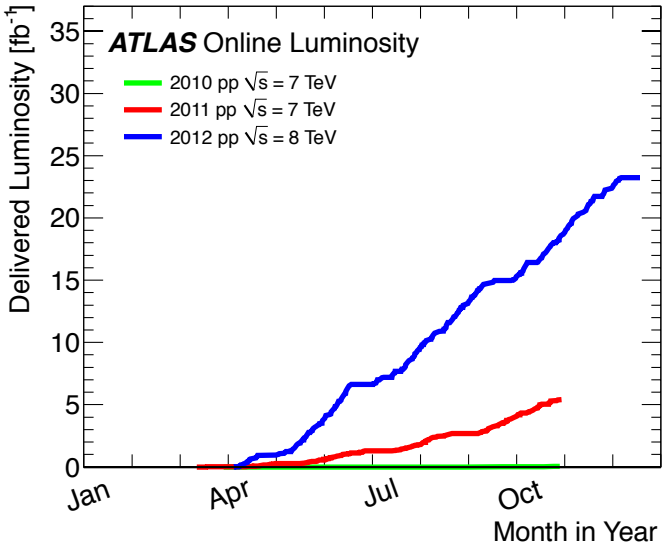
I'll present a selection of some of the more recently released results:

- Inclusive Jets
- Photon + Jet Dynamics
- High Mass Drell-Yan
- Z + Jets
- W + charm
- W + b-jets
- WZ
- ZZ

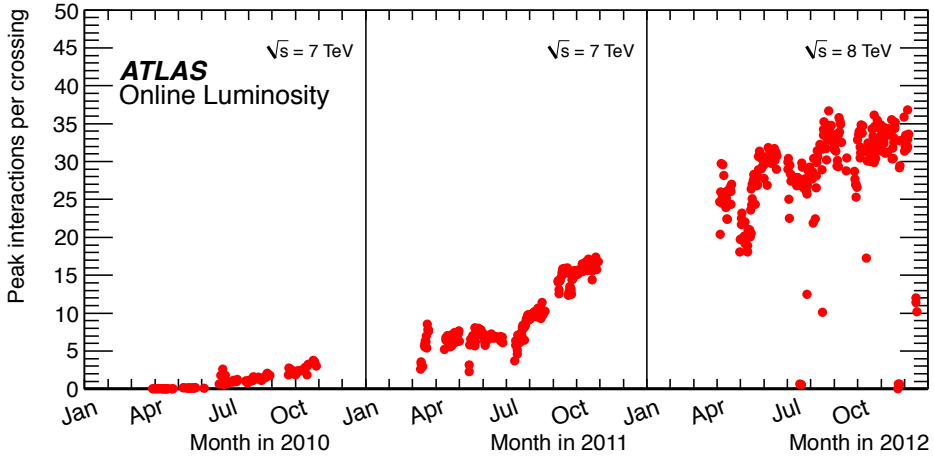


The ATLAS Detector





2010: L = 40 pb^{-1}, √s = 7 TeV
2011: L = 5 fb^{-1}, √s = 7 TeV
(+ L = 0.2 pb^{-1}, √s = 2.76 TeV)
2012: L = 25 fb^{-1}, √s = 8 TeV

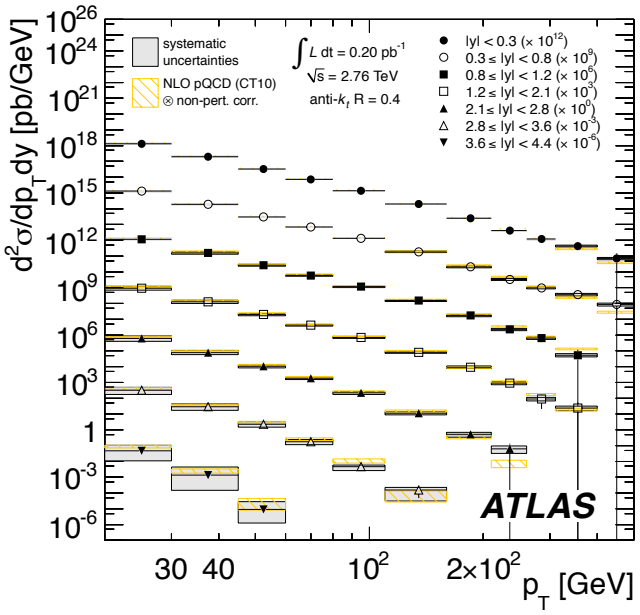


Inclusive Jet Cross Section

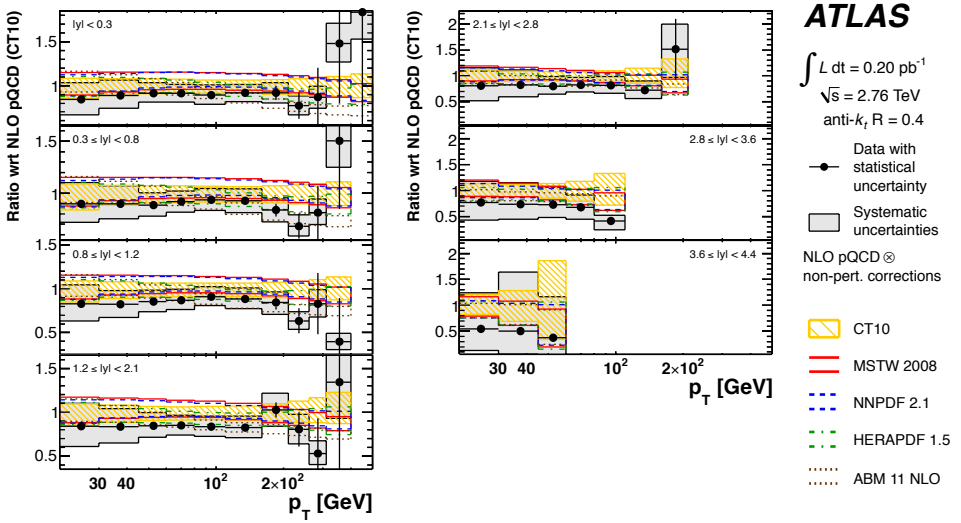
Process Inclusive Jets
- Anti-k_t 0.4 & 0.6

Data Sets 0.2 pb^{-1}, 2.76 TeV / 37 pb^{-1}, 7 TeV

Measurement Double differential σ w.r.t. p_T & y
- $20 \le p_T \le 430$ GeV, $|y| < 4.4$

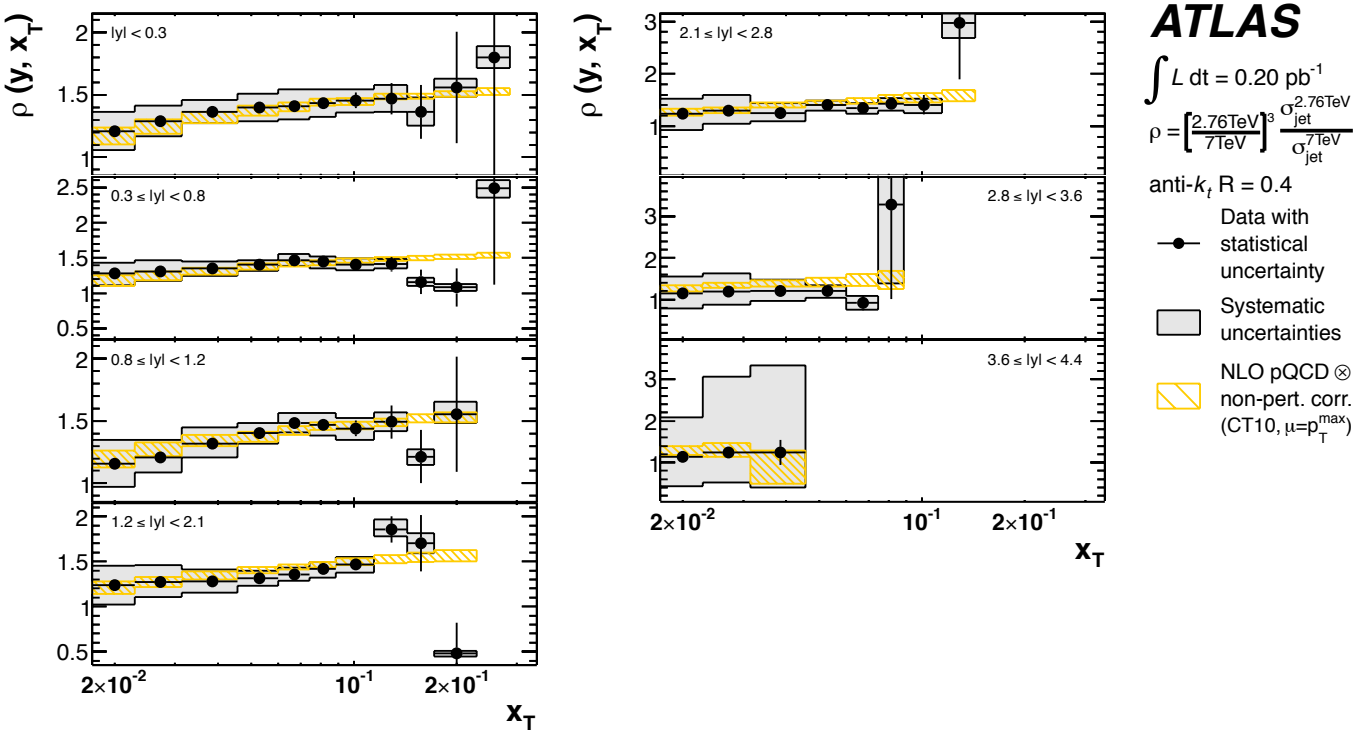


- Predictions are made using `NLOJet++`
- Use 2.76 and 7 TeV cross sections together with HERA data to produce PDF fits
  - Inclusive jet cross section is sensitive to gluon momentum distribution at high x
- Take ratio of σ(2.76 TeV)/σ(7 TeV)
  - Large cancellation of uncertainties



arXiv:1304.4739

Inclusive Jet Cross Section



Take **ratio** of σ(2.76 TeV)/σ(7 TeV)

- **Large cancellation of uncertainties**
- Used, together with HERA data to produce PDF fits
- Shown here as a function of $\mathbf{X_T = 2p_T/\sqrt{s}}$, (dimensionless) which reduces theoretical uncertainties, giving a very precise test of pQCD
- Ratio vs. X_T is flat at 1 for simple quark-gluon model but in reality has deviations due to scale dependence of PDFs and α_S

Photon + jet

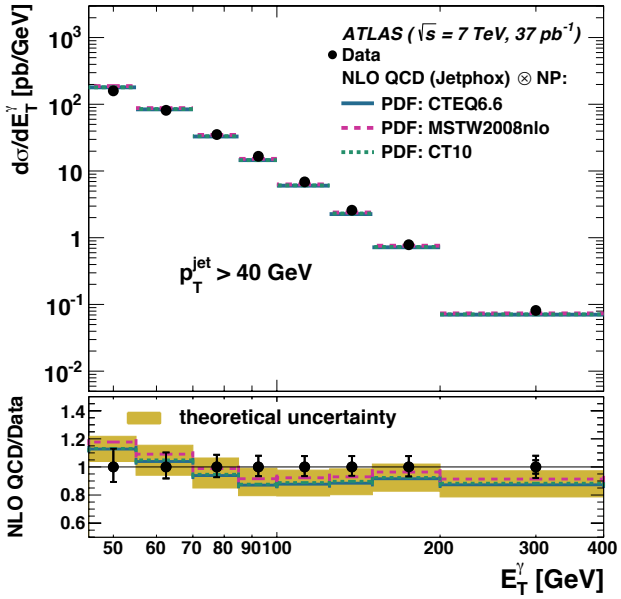
Process p p → γ + jet + X
- Using anti-k_T 0.6 jets

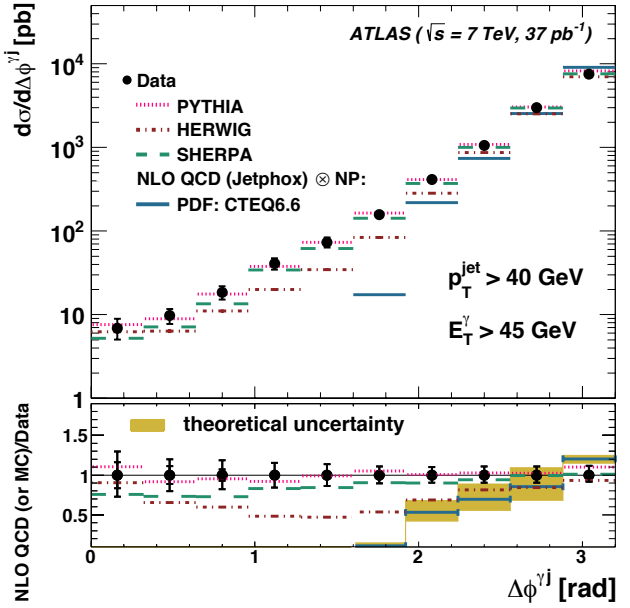
Data Set 37 pb^{-1}, 7 *TeV*

Cuts $E_T^{\gamma} > 45$ GeV, $|\eta^{\gamma}| < 2.37$, $p_T^{jet} > 40$ GeV, $|y^{jet}| < 2.37$ and $\Delta\eta^{\gamma j} + \Delta\varphi^{\gamma j} > 1$

Measurement σ as a function of $\mathbf{E_T^{\gamma}}$, p_T^{j}, y^{j}, $\mathbf{\Delta\varphi^{\gamma j}}$, $m^{\gamma j}$, $\cos\theta^{\gamma j}$

- Main reducible background to H→γγ
- Looking for prompt photon production (qg→γq) so have an isolation requirement on the γ
  - To cut out photons produced from the decay of neutral hadrons
  - Cutting on the E_T in a cone of R=0.4 around the γ, not including the most central contributions
- **NLO pQCD prediction gives good description of all variables other than $\Delta\varphi^{\gamma j}$, which is well described by Pythia LO + PS prediction**
  - Dependant on the extra jets modelled by the shower
- Investigate the relative contributions of direct and fragmentation γ production to test MC modelling





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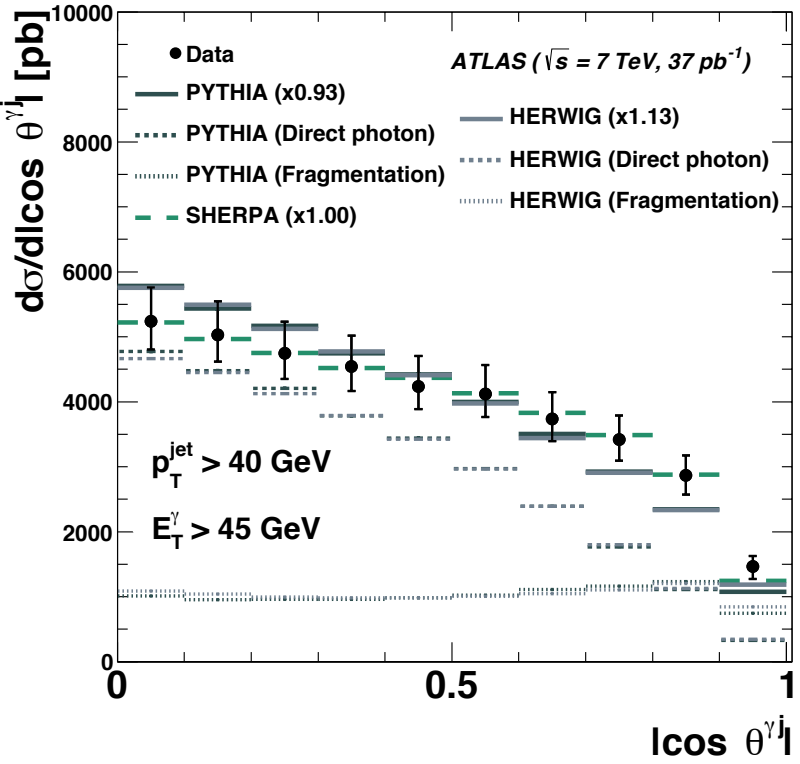
Measurement σ as a function of E_T^{γ}, p_T^{j}, y^{j}, $\Delta\varphi^{\gamma j}$, $m^{\gamma j}$, $\cos\theta^{\gamma j}$

arXiv:1307.6795



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  - To cut out photons produced from the decay of neutral hadrons
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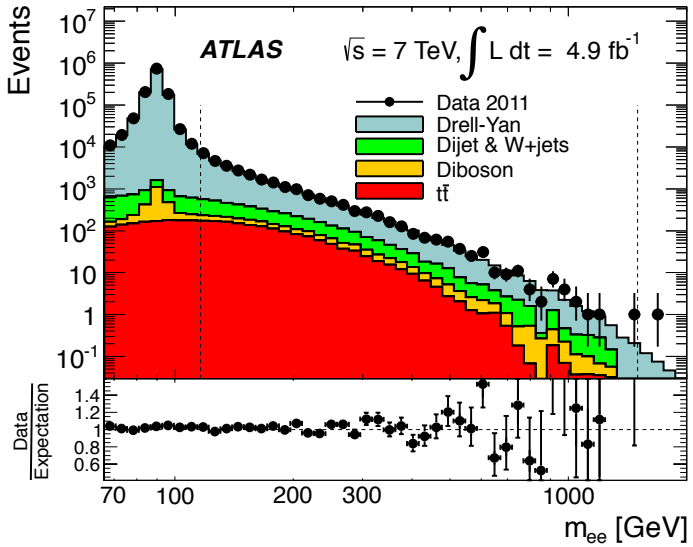
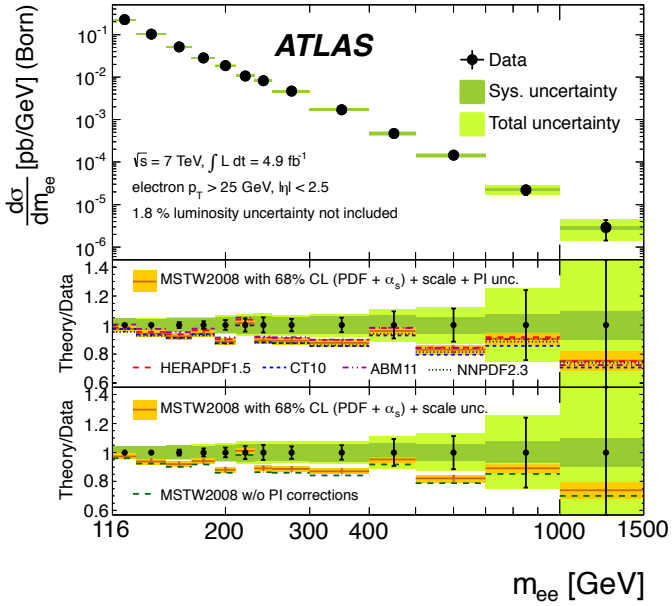
  - Dependant on the extra jets modelled by the shower
- **Investigate the relative contributions of direct and fragmentation γ production to test MC modelling**

High Mass Drell-Yan

Process p p → Z/γ* → $e^+ e^-$
Data Set 4.6 fb^{-1}, 7 *TeV*
Cuts p_T^e > 25 GeV, $|\eta^e|$ < 2.5
Measurement σ as a function of m_{ee}
116 < m_{ee} < 1500 GeV

- NNLO QCD + NLO EW calculation from `FEWZ 3.1`
  - Includes $\gamma\gamma \rightarrow e^+e^-$ contribution using MRST2004 that includes QED corrections to the proton PDF
  - Also includes contribution from real W and Z emission in single-boson production (MadGraph)
- Results are compatible with theory
- Sensitive to PDFs
  - In particular the distribution of anti-quarks at high *x*, which is poorly known



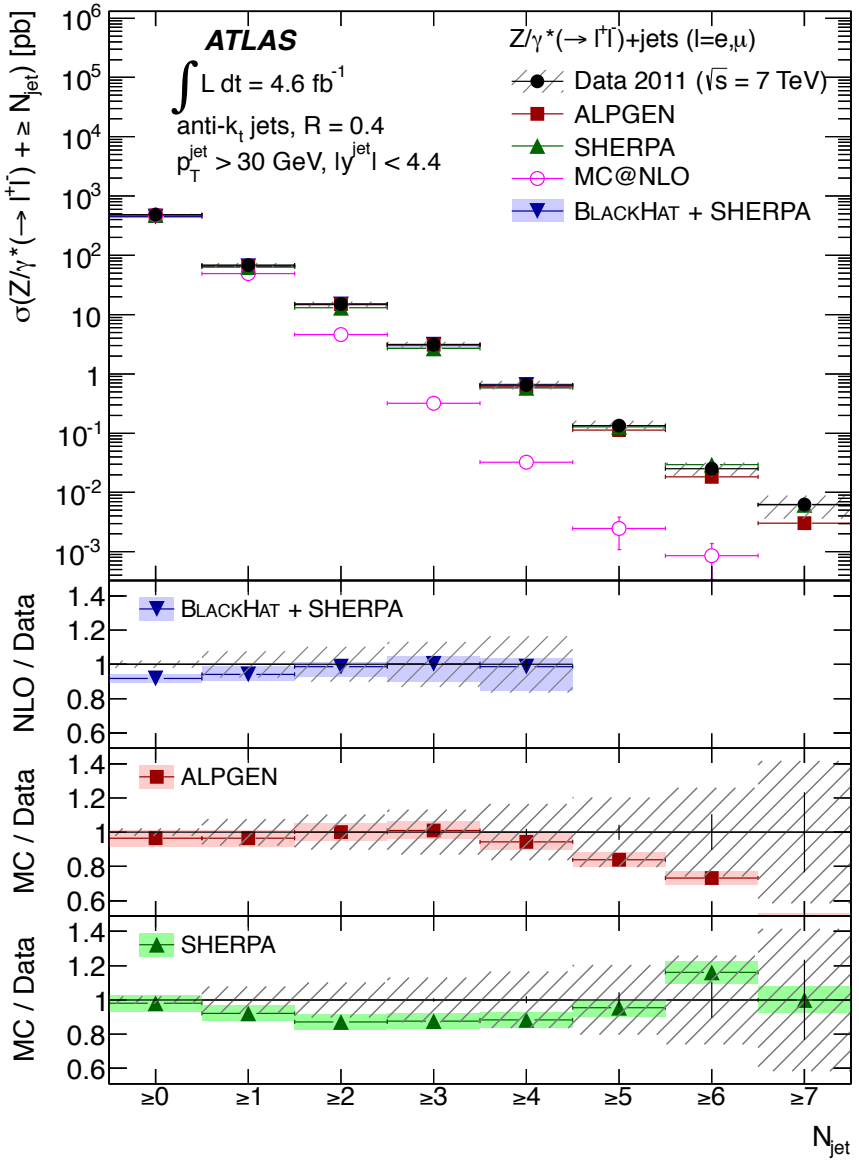


arXiv:1305.4192

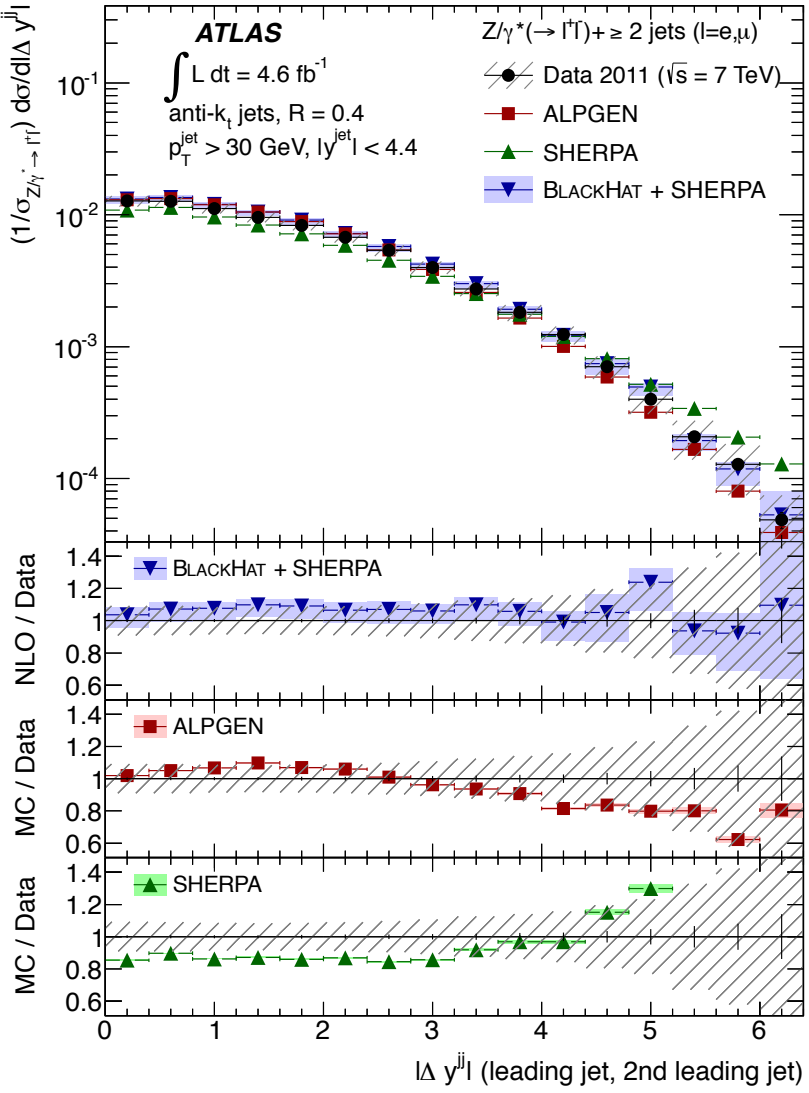
Z + jets

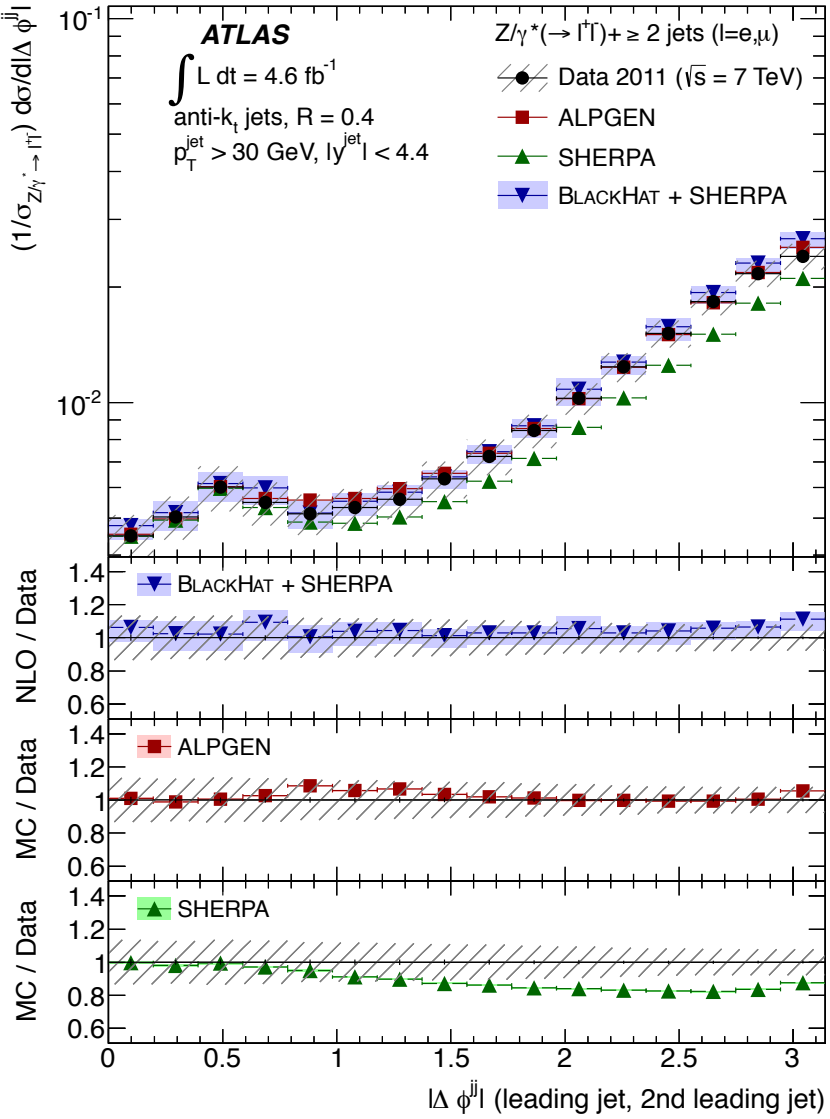
Process p p → Z(→$e^+e^-/\mu^+\mu^-$) + jets
Data Set 4.6 *fb*$^{-1}$, 7 TeV
Cuts Jets: p_T > 30 GeV, |*y*| < 4.4
Measurement σ as a function of: $\mathbf{N_{jet}}$, $p_T^{\ell\ell}$, $p_T^{jet,i}$, $y^{jet,i}$, $\Delta y^{i,j}$, $\Delta\varphi^{i,j}$,…….

- Also have results after VBF preselection
- Very high s/b
  - Dominant background is top
    - Estimated from data sample
- Systematic uncertainties are dominant
  - Largest uncertainty is JER/JES
- Predictions:
  - BlackHat + SHERPA: NLO of up to Z + 4 partons
  - ALPGEN/SHERPA: LO of up to Z + 5 partons
  - MC@NLO: NLO of Z + 1 parton



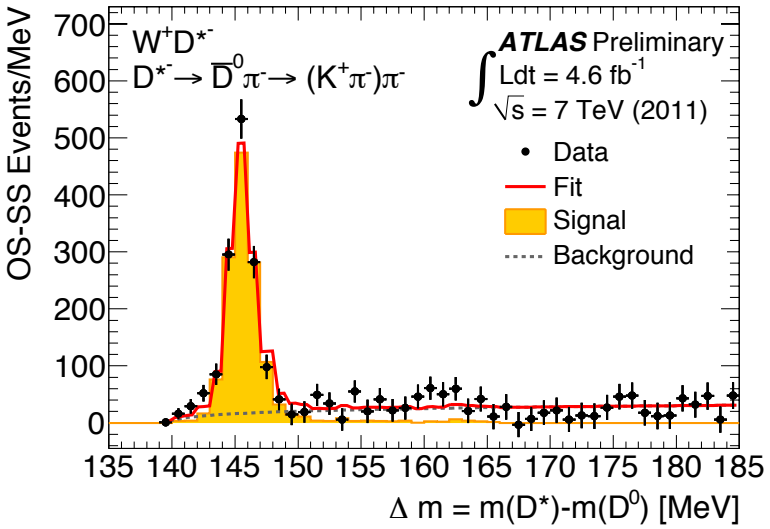
Z + jets (continued…)



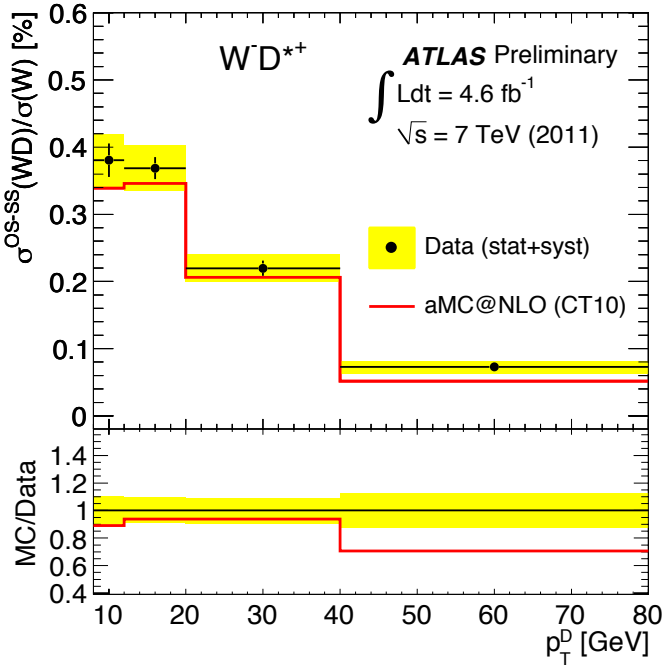


JHEP07(2013)032

Process p p → $W(\rightarrow \mu\nu_\mu / e\nu_e)$ + c
Data Set 4.6 fb^{-1}, 7 *TeV*
Cuts $p_T^l > 20$ GeV, $|\eta^l| < 2.5$, $p_T^\nu > 25$ GeV, $m_T^W > 40$ GeV, $p_T^D > 8$ GeV, $|\eta^D| < 2.2$
Measurement $\sigma(W^{\pm}D^{(*)\mp})/\sigma(W^{\pm})$ as a function of $\boldsymbol{p_T^D}$ and η^l



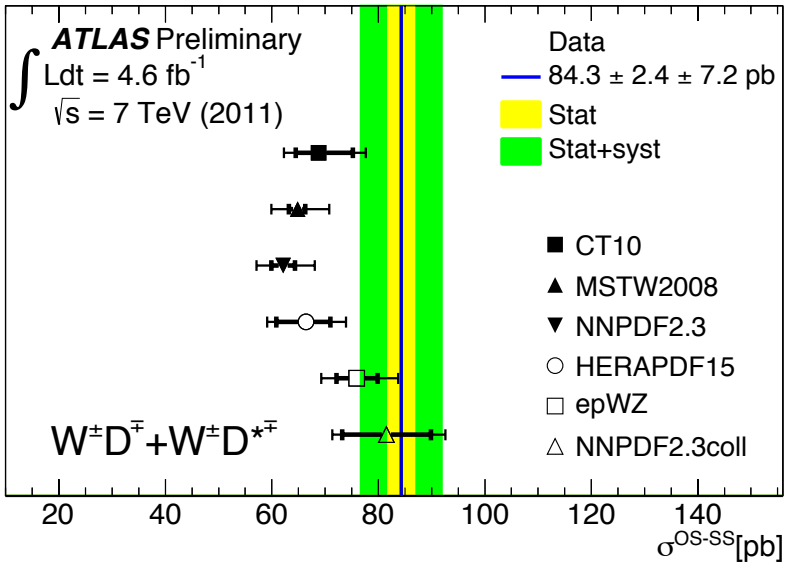
- Decay modes:
  - $D^+ \rightarrow K^-\pi^+\pi^+$
  - $D^{*+} \rightarrow D^0\pi^+$,
    - $D^0 \rightarrow K^-\pi^+$
    - $D^0 \rightarrow K^-\pi^+\pi^0$
    - $D^0 \rightarrow K^-\pi^+\pi^-\pi^+$
- Obtain D decay candidates from tracks
  - Exploit opposite charge of W and D by binning in OS – SS events to help remove backgrounds
  - W+D yield obtained by fitting by m(D±) or m(D*)-m(D0)
- Measurement constrains the *s*-quark PDF

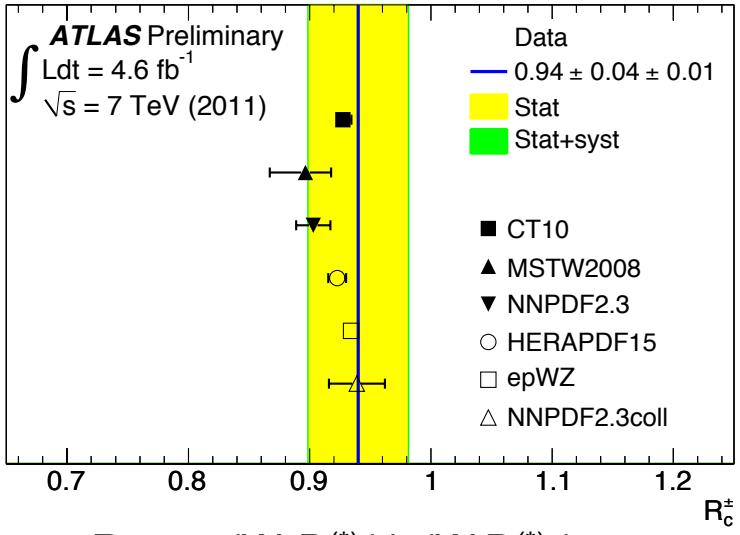


ATLAS-CONF-2013-045

Process p p → $W(\rightarrow \mu\nu_\mu/e\nu_e)$ + c
Data Set 4.6 fb^{-1}, 7 *TeV*
Cuts $p_T^l > 20$ GeV, $|\eta^l| < 2.5$, $p_T^\nu > 25$ GeV, $m_T^W > 40$ GeV, $p_T^D > 8$ GeV, $|\eta^D| < 2.2$
Measurement $\sigma(W^\pm D^{(*)\mp})/\sigma(W^\pm)$ as a function of p_T^D and η^l

- Decay modes:
  - $D^+ \rightarrow K^-\pi^+\pi^+$
  - $D^{*+} \rightarrow D^0\pi^+$,
    - $D^0 \rightarrow K^-\pi^+$
    - $D^0 \rightarrow K^-\pi^+\pi^0$
    - $D^0 \rightarrow K^-\pi^+\pi^-\pi^+$
- Obtain D decay candidates from tracks
  - Exploit opposite charge of W and D by binning in OS – SS events to help remove backgrounds
  - W+D yield obtained by fitting by m(D±) or m(D*)-m(D^0)
- Measurement constrains the *s*-quark PDF



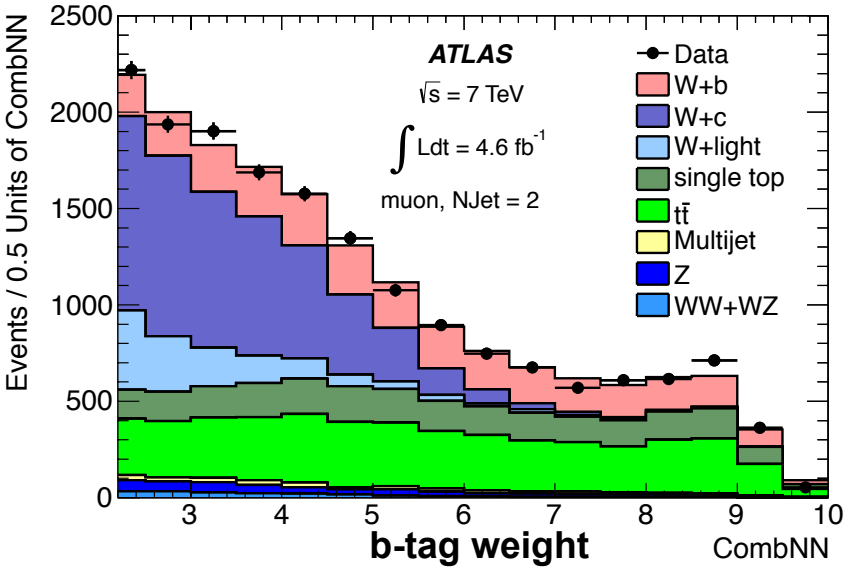


$R_c^\pm = \sigma(W^+D^{(*)-})/\sigma(W^-D^{(*)+})$

ATLAS-CONF-2013-045

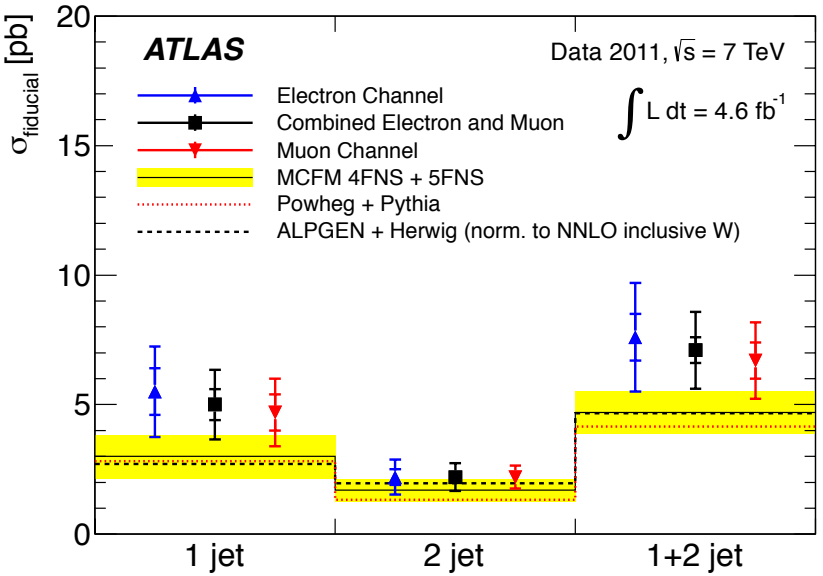
W + b-jets

Process p p → $W(\rightarrow \mu\nu_\mu / e\nu_e)$ + b-jets
Data Set 4.6 fb^{-1}, 7 TeV
Cuts b-tagged jets, p_T > 25 GeV, |η| < 2.1
Measurement σ as a function of p_T for 1 and 2 b-jets



- $W(\rightarrow l\nu)$ + bb: key background to $W(\rightarrow l\nu)H(\rightarrow bb)$ search
- Testing pQCD with a heavy quark final state

- Fit the b-tag weight, get the templates from `Pythia` MC
  - Do the fit for each p_T bin for the differential measurement
- $\sigma_{fiducial}$ = 7.1 ± 0.5 (stat) ± 1.4 (syst) pb
  - Consistent within 1.5σ to NLO prediction
  - Jet energy measurement results in the dominant systematics



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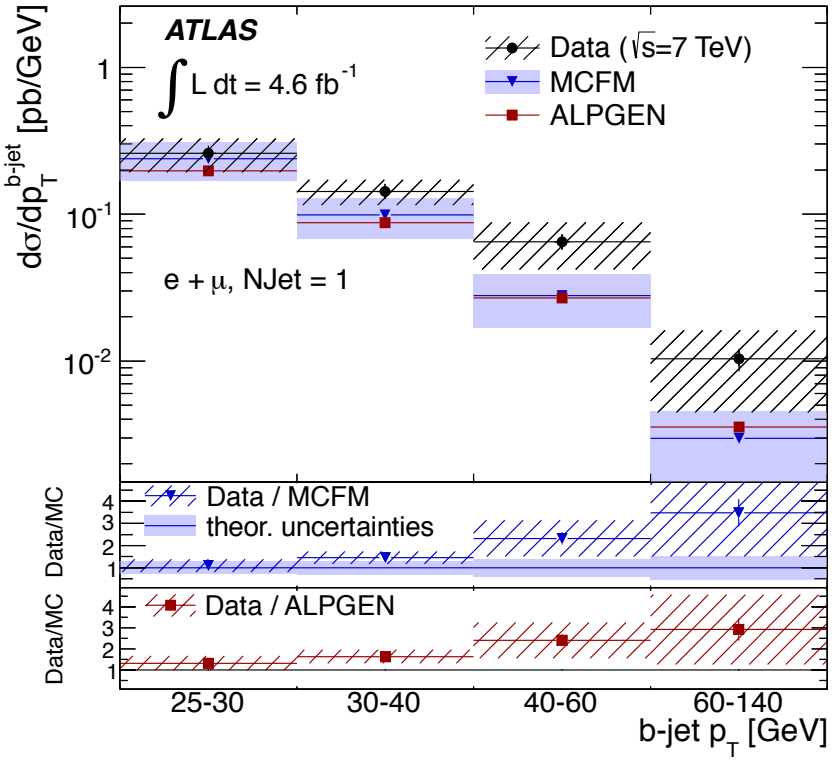
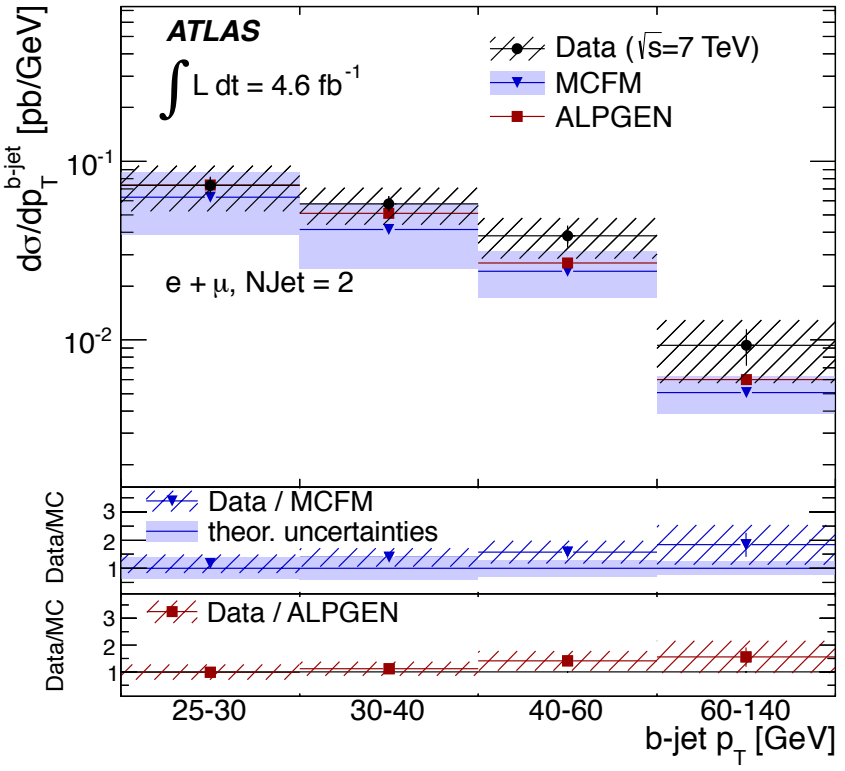
W + *b*-jets (continued…)

b-jet p_T Spectrum:

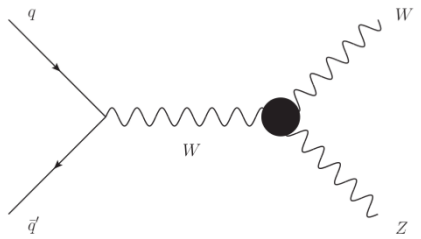
W* + *b



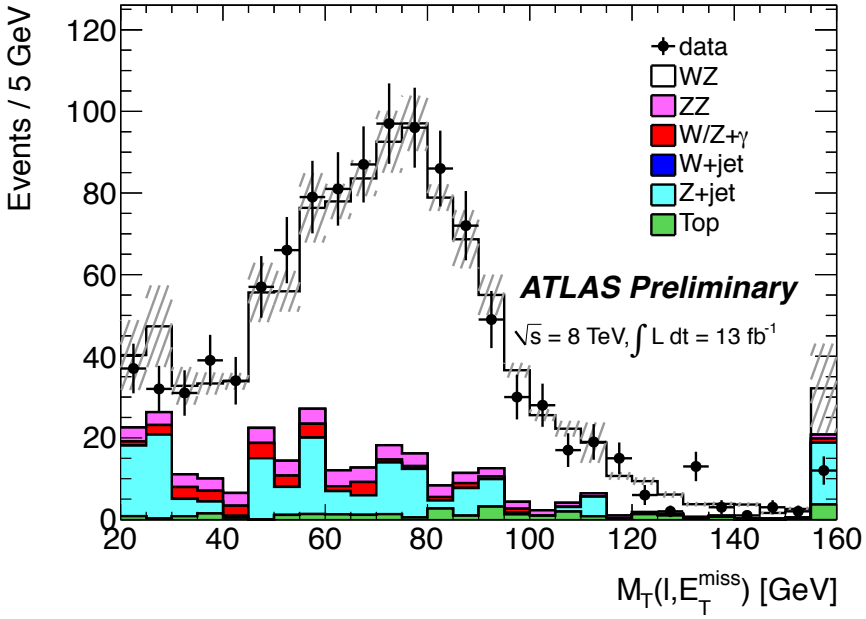
W* + *bb

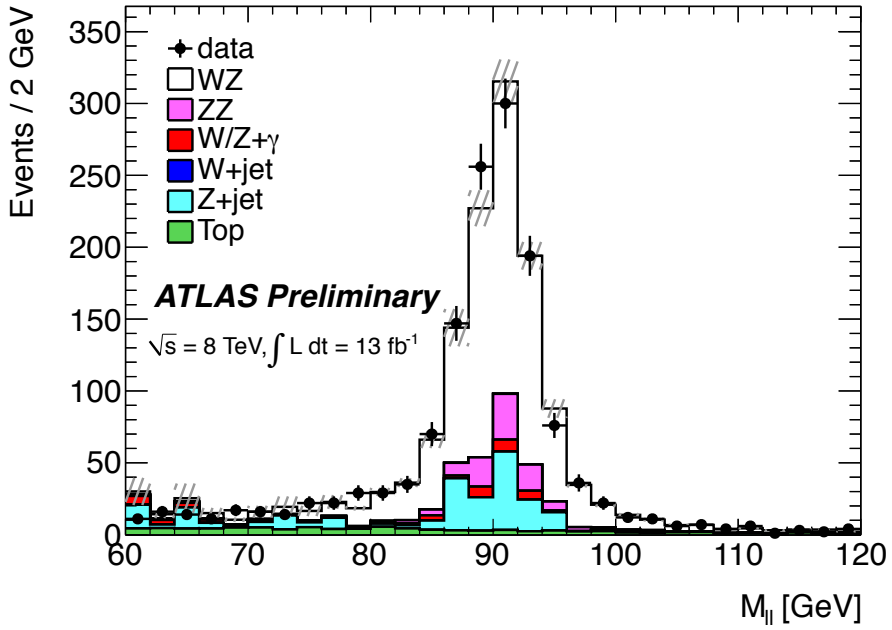


Process p p → W± Z, with e/μ final states
Data Set 13 *fb*$^{-1}$, 8 *TeV*



- Want to measure triple gauge coupling (TGC)
  - Test EW interaction at high energies
- Diboson production can be enhanced in *W'* and H± models
- Cut based analysis: Look for high p_T isolated leptons + E_t^{miss}
- Observe 1094 candidate events; estimated background 277 ± 9 (stat.) ± 24 (syst.)





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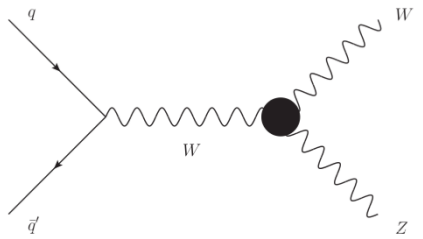

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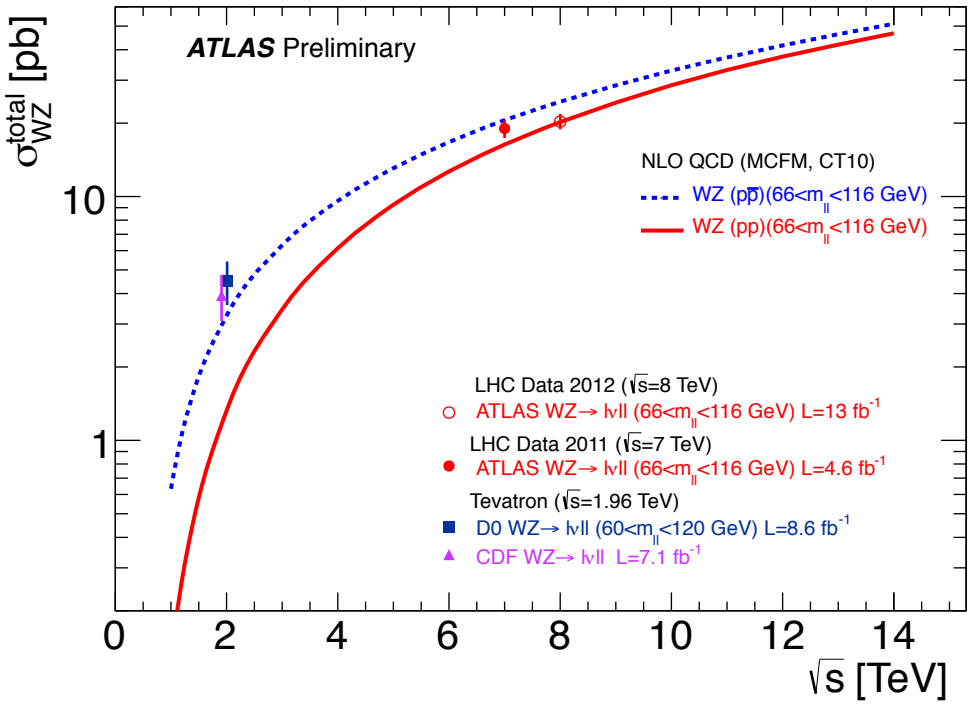
- Cut based analysis: Look for high p_T isolated leptons + E_t^{miss}
- Observe 1094 candidate events; estimated background 277 ± 9 (stat.) ± 24 (syst.)

Unfolding for fiducial cuts and BR:

$$\sigma_{WZ}^{tot} = 20.3^{+0.8}_{-0.7}(\text{stat.})\ ^{+1.2}_{-1.1}(\text{syst.})\ ^{+0.7}_{-0.6}(\text{lumi.})\ \text{pb}$$

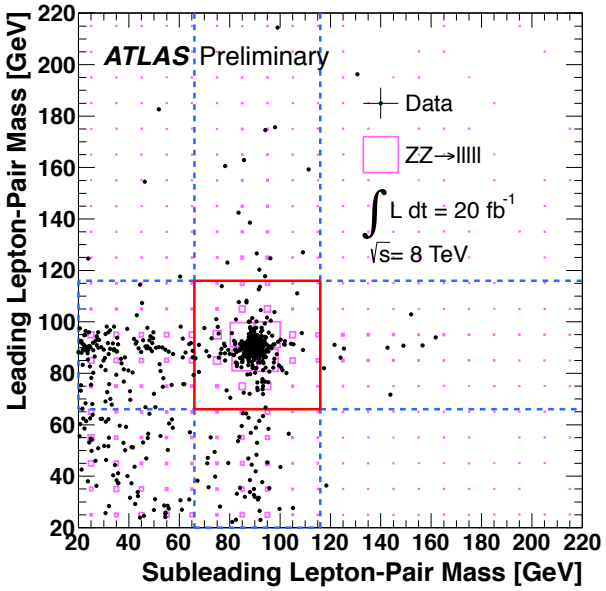
In agreement with SM prediction of 20.3 ± 0.8 pb



ATLAS-CONF-2013-021

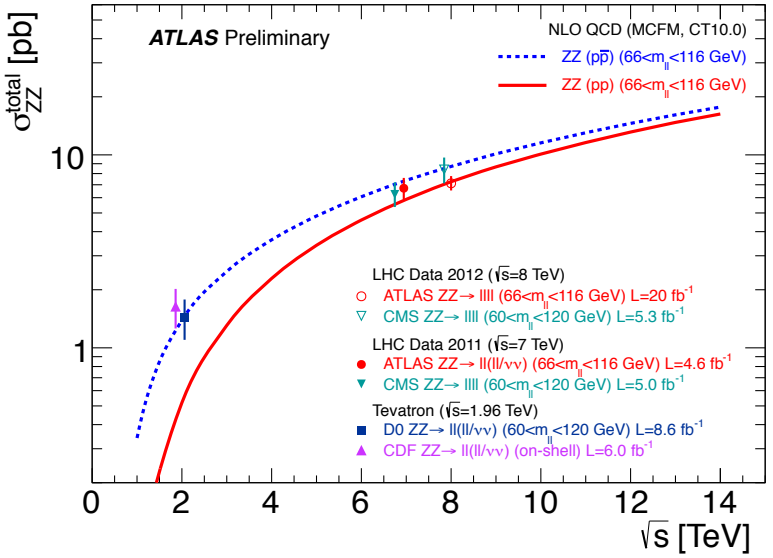
Process p p → ZZ with e/μ final states
Data Set 20 fb^{-1}, 8 *TeV*

- Sensitive to new resonances decaying to Z's
- Look for 2 opposite sign, same flavour lepton pairs ($e^+e^-/\mu^+\mu^-$) with $66 < m_{ll} < 116$ GeV
- Observe 305 candidate events with expected background 20.4±2.9(stat)±5.0(syst.)



$$\sigma_{ZZ}^{tot} = 7.1^{+0.5}_{-0.4}(stat.) \pm 0.3(syst.) \pm 0.2(lumi.)\ pb$$

In agreement with SM NLO prediction of $7.2^{+0.3}_{-0.2}$ pb



ATLAS-CONF-2013-020

Summary

I've shown a small selection of the more recent ATLAS results. These have:

- Tested the Standard Model up to the TeV scale
  - So far no significant deviations from SM predictions
- The results of these measurements are being used to:
  - Constrain PDFs
  - Improve and constrain the accuracy modeling of backgrounds to Higgs and new physics searches

Many more ATLAS SM analyses to be published in the near future!

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/StandardModelPublicResults

Thank you for listening!

Backup Slides

Luke Lambourne

Inclusive Jet Cross Section

- Inclusive Jets
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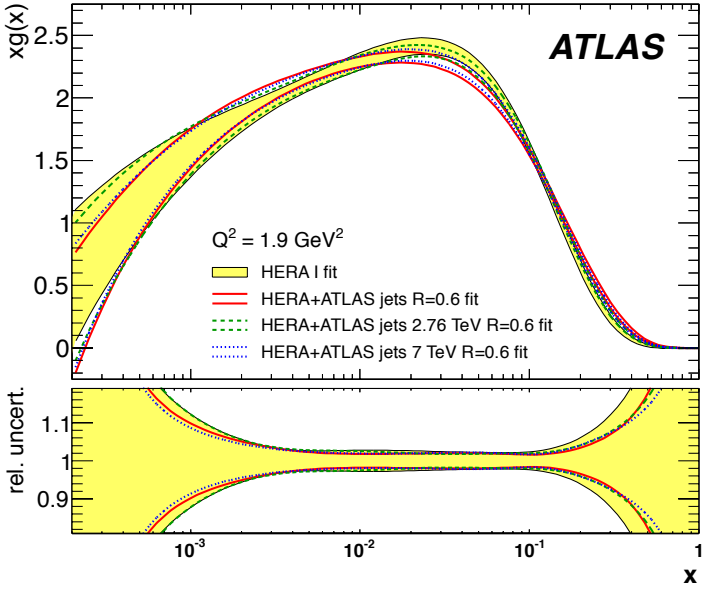
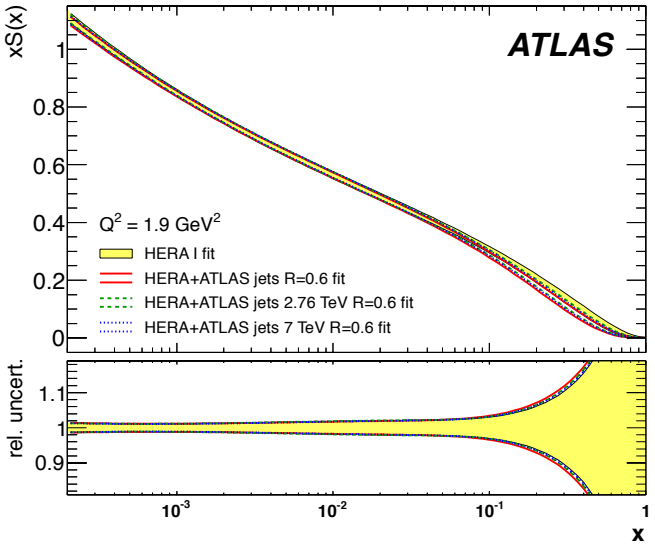
- Anti-k_t 0.4 & 0.6
- Double differential σ w.r.t p_T & y
  - $20 \leq p_T \leq 430$ GeV, $|y| < 4.4$
- Predictions are NLOJet++
- Take ratio of σ(2.76 TeV)/σ(7 TeV)
  - Large cancellation of uncertainties
  - **Used, together with HERA data to produce PDF fits**





High Mass Drell-Yan

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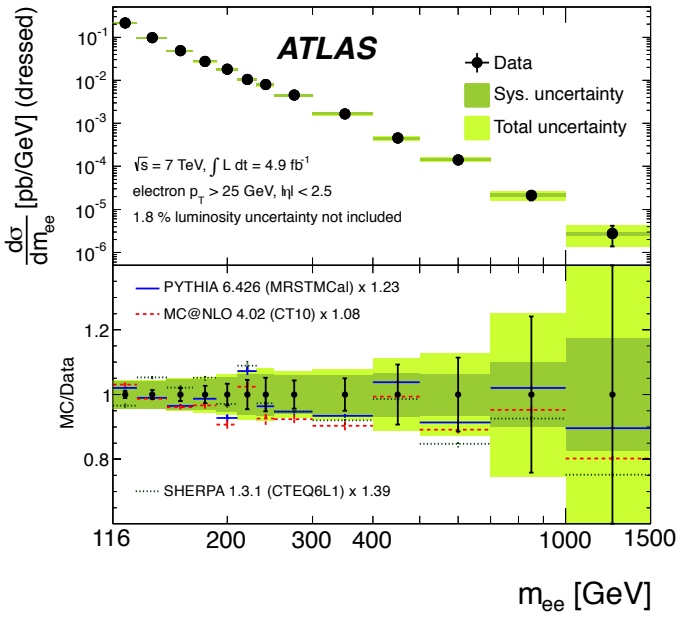

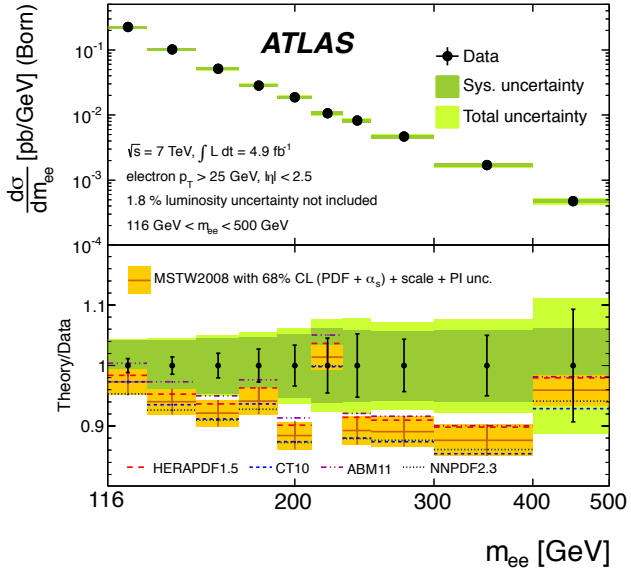

arXiv:1305.4192