Physics Program

of the experiments at

Large Hadron Collider

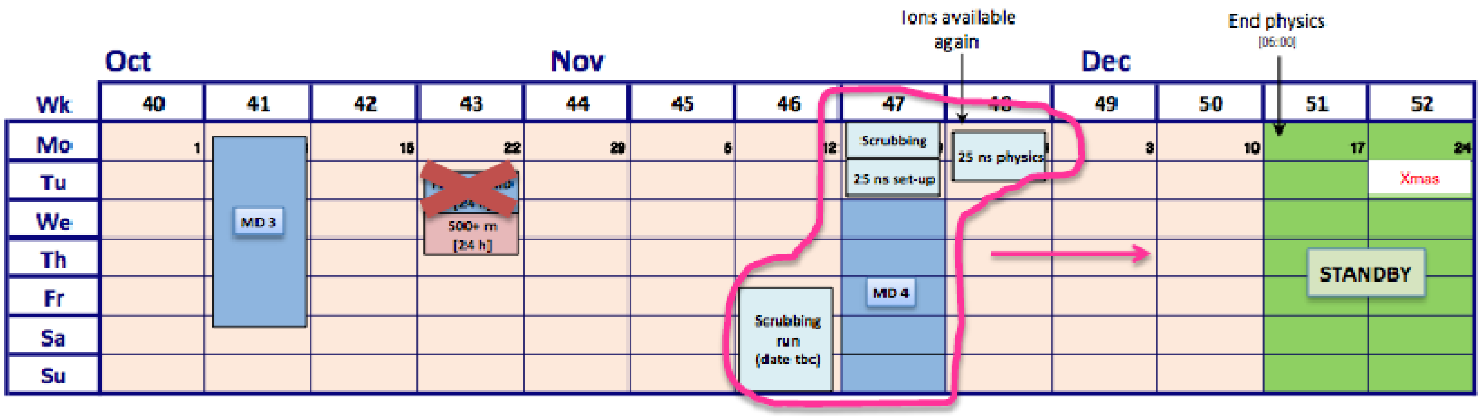
Physics with W and Z bosons:

Latest news

- 12-18 November: HCP conference in Japan

Data taking with *pp* for about 4 more weeks **Data collected so far: $\sim$18.3 fb^{-1}. Peak luminosity at $7.3 \cdot 10^{33}$!**

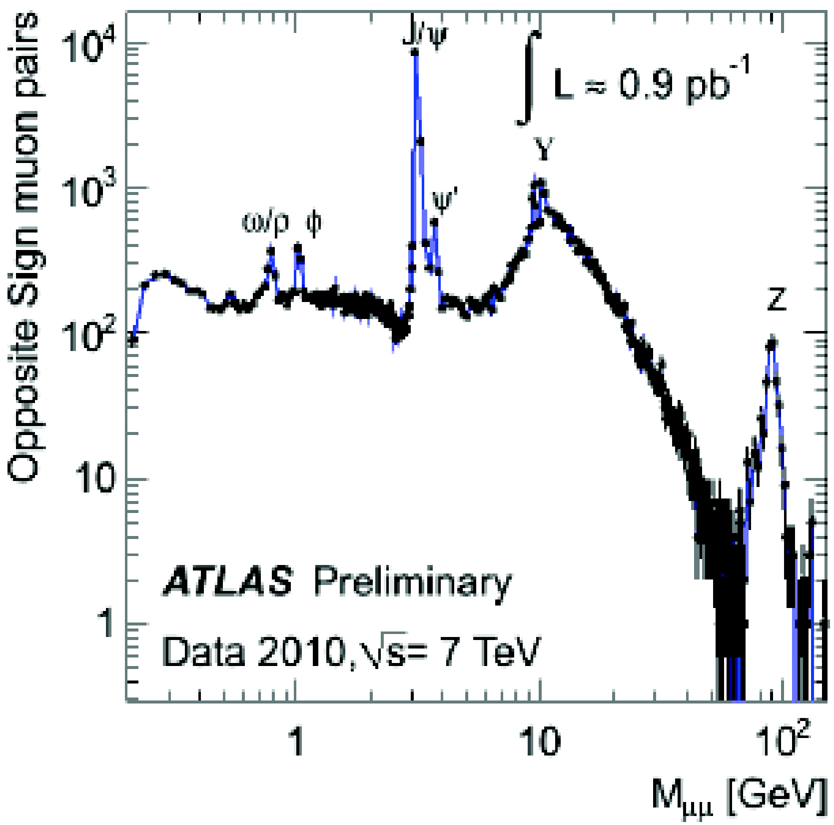
Data signed off for data up to period H5, this week up to I2



New schedule: 25ns runs (1-2 fills stable beam) at the end of data-taking

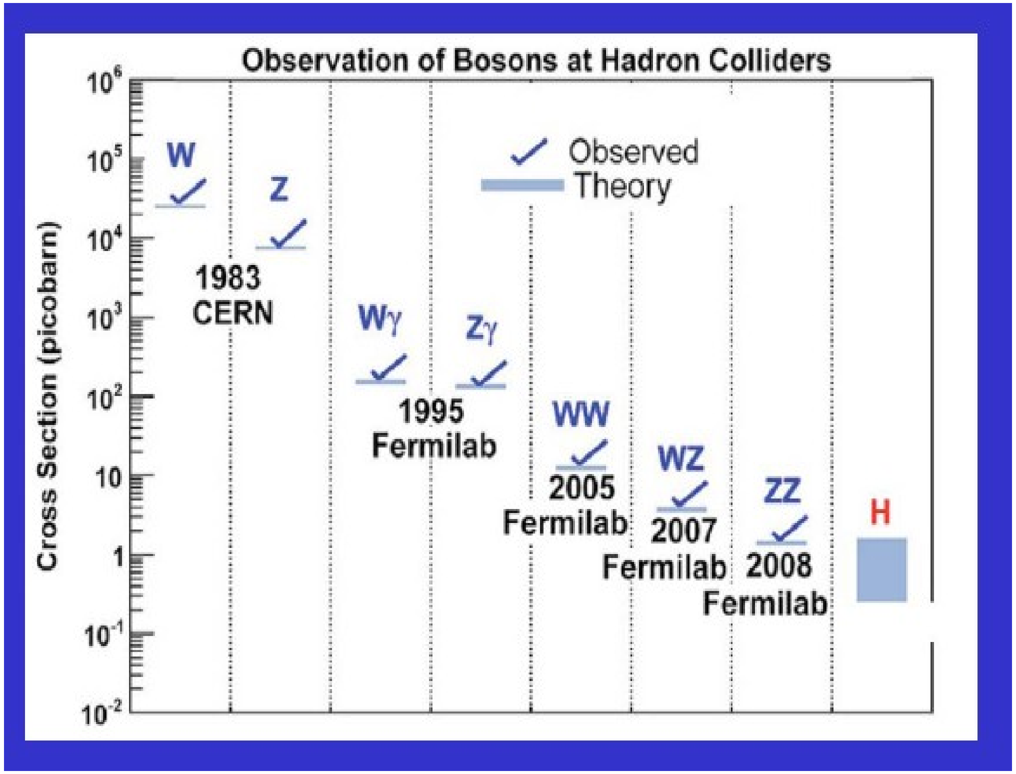
Retracing history of particle physics

- With up to 1pb^{-1} (public results) we made it up to 80's
- Results at sumer conferences 2010
- Onia(J/Psi, Ψ, Y,...) + first hundreds of W,Z in the leptonic channels



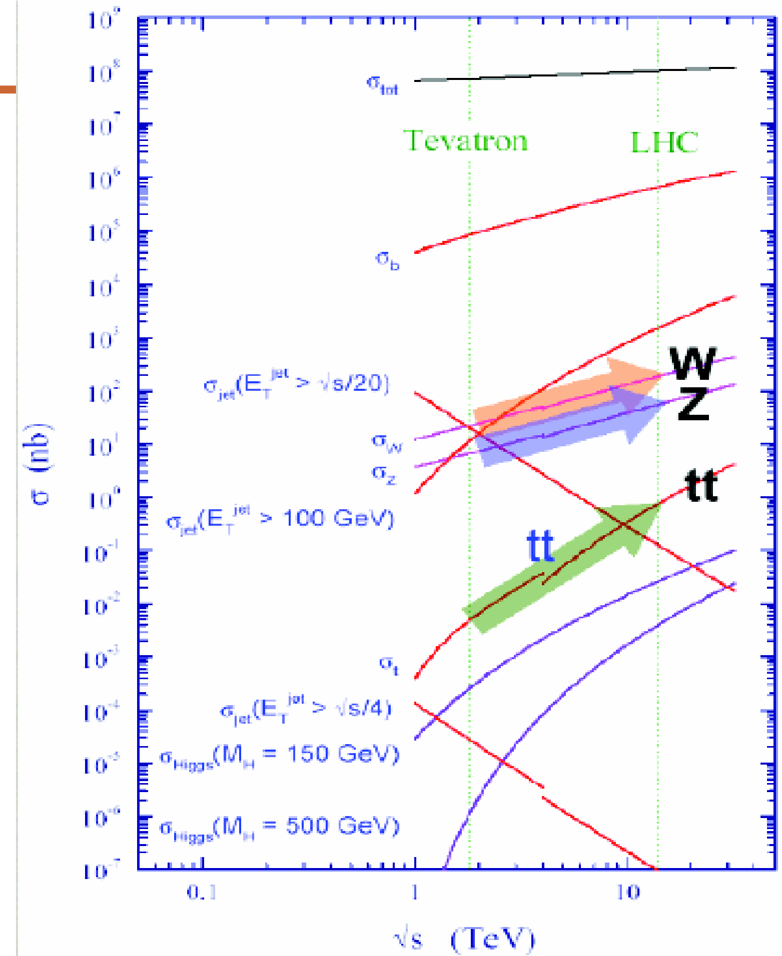
Bosons at hadron colliders

- So far the primary channel is through leptonic decays
  - BR(W→e ν) ~ 10%
  - BR(Z→ ee) ~ 3%
- It means that we are probing σ x BR values orders of magnitude smaller
- At LHC cross-section 5-10 x higher than at Tevatron at Fermilab.



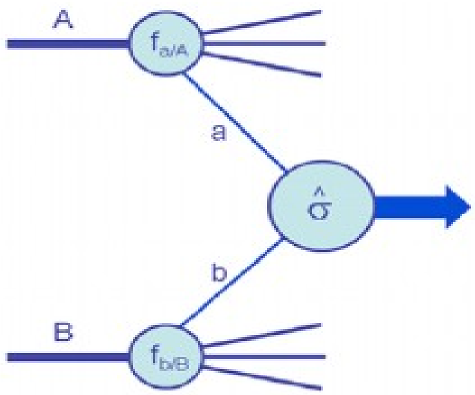
Bosons at LHC

- Well measured by previous experiments
  - Inclusive cross sections, $R(W^+/W^-)$, $R(W/Z)$
  - Differential distributions, associated jet multiplicity, A_{FB}, etc.
- Yet still educational at the LHC
  - Cross sections at $\sqrt{s} = 7 TeV$
  - New pdf constraints possible
- "Standard candles" for high-p_T analyses
  - Calibration, alignment
  - Independent luminosity measurements



Just departure point for high-p_T Beyond Standard Model analyses

Drell-Yan cross-section



- Keywords:
  - factorisation μ_F and renormalisation μ_R scales
  - universal parton distribution functions
  - LO, NLO, NNLO matrix elements and DGLAP kernels

$$\sigma_{AB} = \int dx_a dx_b \; f_{a/A}(x_a, Q^2) f_{b/B}(x_b, Q^2) \; \hat{\sigma}_{ab \to X}$$

also depends on μ_R and μ_F, so as to cancel scale dependence in PDF's and α_s, to this order

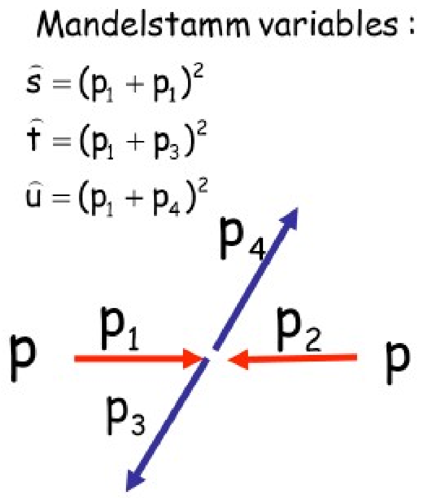
$$\sigma_{AB} = \int dx_a dx_b \; f_{a/A}(x_a, \mu_F^2) \; f_{b/B}(x_b, \mu_F^2) \; \times \; [\, \hat{\sigma}_0 + \alpha_S(\mu_R^2)\,\hat{\sigma}_1 + \cdots]_{ab \to X}.$$

- All orders cross section has no dependence on μ_F and μ_R; a residual dependence remains (to order α_s^{n+1}) for a finite order (α_s^{n}) calculations.

W and Z production

- Cross sections for on-shell W and Z production (in narrow width limit) given by

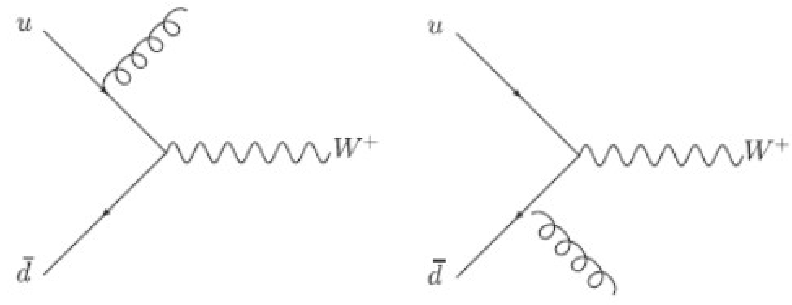
$$\hat{\sigma}^{q\bar{q}'\to W} = \frac{\pi}{3}\sqrt{2}G_F M_W^2 |V_{qq'}|^2 \delta(\hat{s} - M_W^2),$$
$$\hat{\sigma}^{q\bar{q}\to Z} = \frac{\pi}{3}\sqrt{2}G_F M_Z^2 (v_q^2 + a_q^2)\delta(\hat{s} - M_Z^2),$$



- Where $V_{qq'}$ is appropriate CKM matrix element and v_q and a_q are the vector and axial couplings of the Z to quarks
- At LO there is no α_s dependence; EW vertex only
- NLO contribution to the cross section is proportional to α_s; NNLO to α_s^2; ...

W and Z p_T distributions

- Most of W/Z produced at low p_T but can be produced at non-zero p_T due to the diagrams with emitted gluon



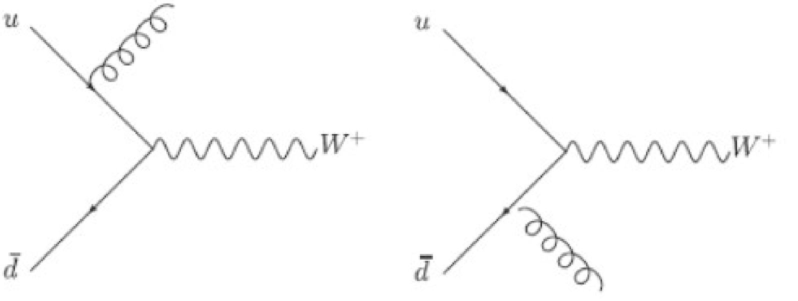
$$\sum |\mathcal{M}^{q\bar{q}' \to Wg}|^2 = \pi \alpha_S \sqrt{2} G_F M_W^2 |V_{qq'}|^2 \, \frac{8}{9} \, \frac{\hat{t}^2 + \hat{u}^2 + 2M_W^2 \hat{s}}{\hat{t}\hat{u}} \, ,$$

$$\sum |\mathcal{M}^{gq \to Wq'}|^2 = \pi \alpha_S \sqrt{2} G_F M_W^2 |V_{qq'}|^2 \, \frac{1}{3} \, \frac{\hat{s}^2 + \hat{u}^2 + 2\hat{t} M_W^2}{-\hat{s}\hat{u}} \, ,$$

- Sum over colors and spins in initial states and average over same in final states
- Transverse momentum distribution obtained by convoluting these matrix elements with pdf's in usual way

W and Z p_T distributions

- Back to 2->2 subprocess, where Q^2 is virtuality of the W



$$|\mathcal{M}^{u\bar{d}\to W+g}|^2 \sim \left(\frac{\hat{t}^2 + \hat{u}^2 + 2Q^2\,\hat{s}}{\hat{t}\,\hat{u}}\right)$$

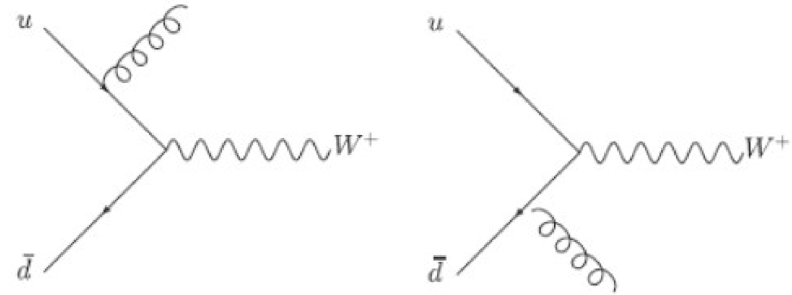
- Convolute with pdf's

$$\sigma = \int \mathrm{d}x_1 \mathrm{d}x_2\, f_u(x_1, Q^2)\, f_{\bar{d}}(x_2, Q^2)\, \frac{|\mathcal{M}|^2}{32\pi^2 \hat{s}}\, \frac{\mathrm{d}^3 p_W}{E_W}\, \frac{\mathrm{d}^3 p_g}{E_g}\, \delta(p_u + p_{\bar{\mathrm{d}}} - p_g - p_W)$$

- Transform into differential cross-section

$$\frac{\mathrm{d}\sigma}{\mathrm{d}Q^2 \mathrm{d}y \mathrm{d}p_T^2} \sim \frac{1}{s} \int \mathrm{d}y_g\, f_u(x_1, Q^2)\, f_{\bar{\mathrm{d}}}(x_2, Q^2)\, \frac{|\mathcal{M}|^2}{\hat{s}}$$

W and Z p_T distributions



- In the limit of leading divergence we can write

$$\frac{\mathrm{d}\sigma}{\mathrm{d}Q^2\mathrm{d}y\mathrm{d}p_T^2} \sim \frac{2}{s}\frac{1}{p_T^2}\int \mathrm{d}y_g\, f_u(x_1, Q^2) f_{\bar{\mathrm{d}}}(x_2, Q^2) + (\text{sub-leading in } p_T^2)$$

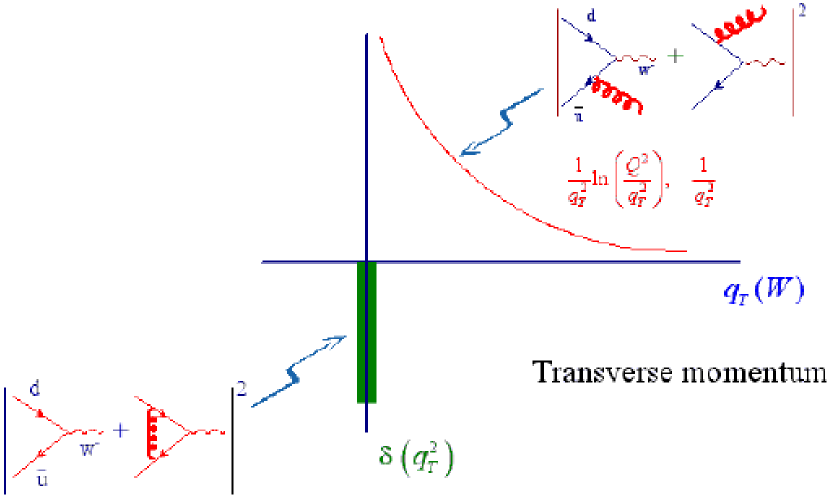
- As p_T of W becomes small, limits on y_g integration are given by +- $\log(s^{1/2}/p_T)$
- The results is then

$$\frac{\mathrm{d}\sigma}{\mathrm{d}Q^2\mathrm{d}y\mathrm{d}p_T^2} \sim \frac{\log(s/p_T^2)}{p_T^2}$$

- It diverges unless we apply a p_T^{min} cut; final distribution depends on α_s times log

Shortcomings of fixed order calculations

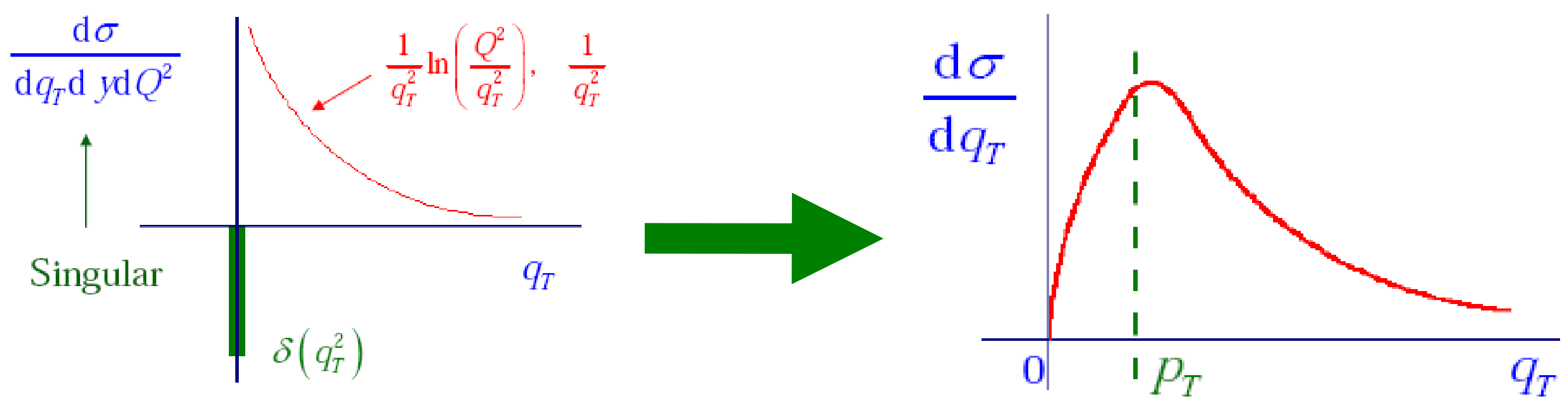
- Divergent, without cut on p_T^{min}, cannot describe the data



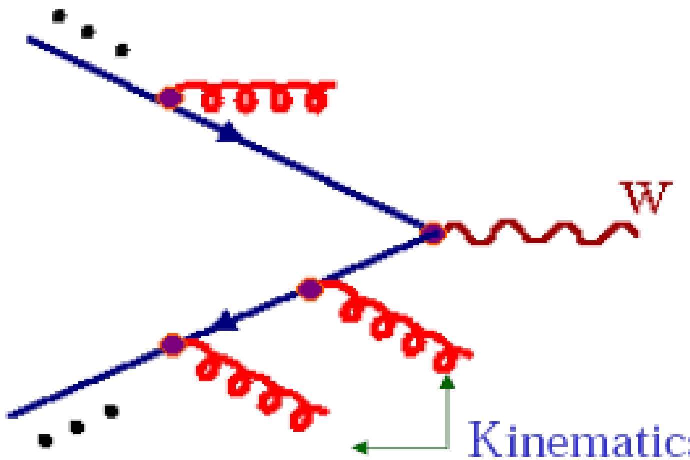
(at NLO)

QCD resummation

- Resummation: reorganise calculations in terms of large Logs $L(Q^2/p_T^2)$; regularised at low p_T range;
- Different schemes: CSS which includes also non-perturbative effects; Sudakov form factors; exponentation;



Monte Carlo approach example: Parton Shower



Backward Radiation
(Initial State Radiation)

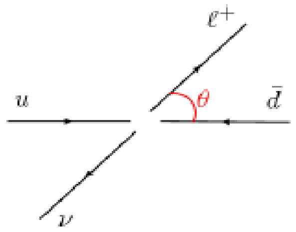
Kinematics of the radiated gluon, controlled by Sudakov form factor with some arbitrary cut-off. (In contrast to perform integration in impact parameter space, i.e., b space.)

The shape of q_T (w) is generated. But, the integrated rate remains the same as at Born level (finite virtual correction is not included).

Recently, there are efforts to include part of higher order effect in the event generator.

Transverse momenta of charged lepton

- In (ud) c.m. system,

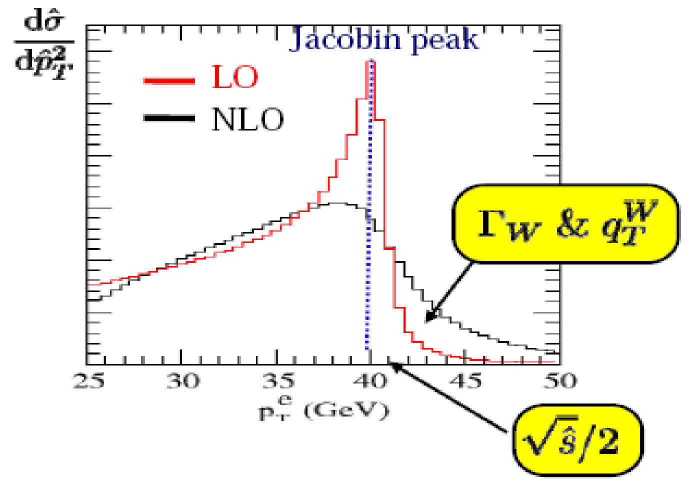


$$\hat{p}_T^2 = \frac{1}{4}\hat{s}\sin^2\theta$$

Jacobin factor

$$\frac{\mathrm{d}\cos\theta}{\mathrm{d}\hat{p}_T^2} = -\frac{2}{\hat{s}}\frac{1}{\sqrt{1-\frac{4\hat{p}_T^2}{\hat{s}}}}$$

$$\Longrightarrow \frac{\mathrm{d}\hat{\sigma}}{\mathrm{d}\hat{p}_T^2} \sim \frac{\mathrm{d}\hat{\sigma}}{\mathrm{d}\cos\theta} \times \frac{1}{\sqrt{1-4\hat{p}_T^2/\hat{s}}}$$

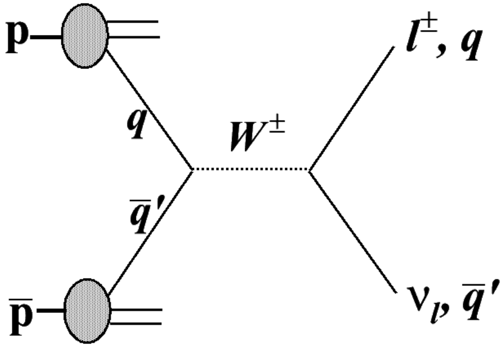


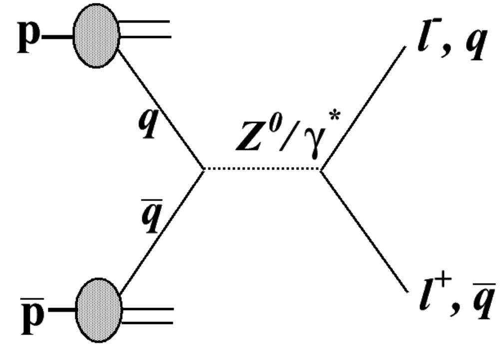
sensitive region for measuring

M_W : $p_T^e \sim 30 - 45$ GeV

Γ_W : not a good observable

Cross-section at LHC (7TeV)





$$\sigma^{NNLO}_{W^+\to\ell\nu} = 6.15\,\mathrm{nb}$$

$$\sigma^{NNLO}_{W^-\to\ell\nu} = 4.3\,\mathrm{nb}$$

$$\sigma^{NNLO}_{W\to\ell\nu} = 10.45\,\mathrm{nb}$$

$$\sigma^{NNLO}_{Z/\gamma*\to\ell\ell} = 0.989\,\mathrm{nb}$$

$$\sigma(W^+) \neq \sigma(W^-)$$

W^+ production: $u\bar{d} + c\bar{s}$

W^- production: $d\bar{u} + s\bar{c}$

Z production: $u\bar{u} + d\bar{d} + s\bar{s} + c\bar{c} + b\bar{b}$

Test QCD (up to NNLO) in production

Hard and soft gluon emission

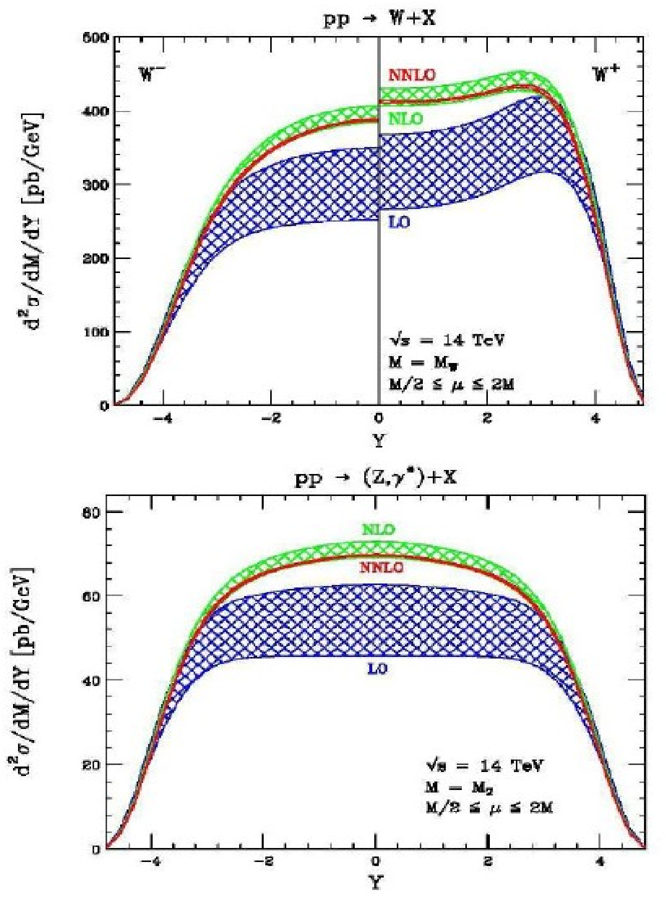
Sensitive to parton distribution functions

Extract electroweak parameters

sinΘ_W, m_W, quark-boson couplings

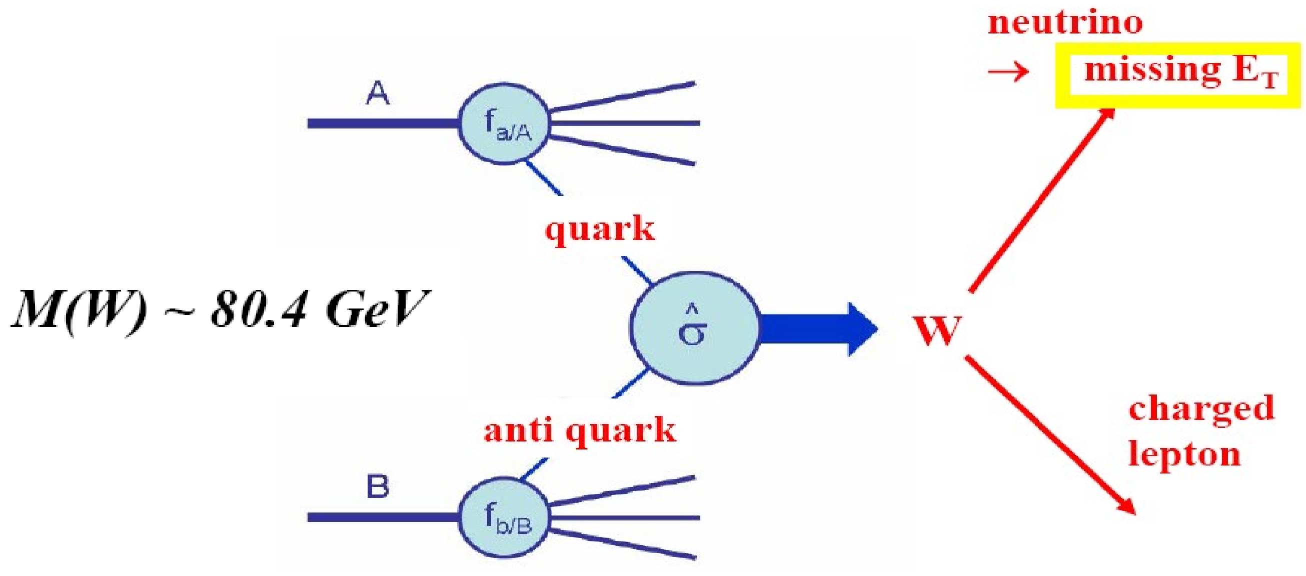
Monte Carlo simulations

- Base-line generators:
  - Pythia, Herwig (LO),
  - MCatNLO (NLO)
  - POWHEG (NLO)
- Used as components of for cross-checks
  - FEWZ: complete NLO, NNLL
  - ResBos: NNLL resumation
  - Horace: full 1-loop electroweak
  - PHOTOS:final state QED (exponentiated)



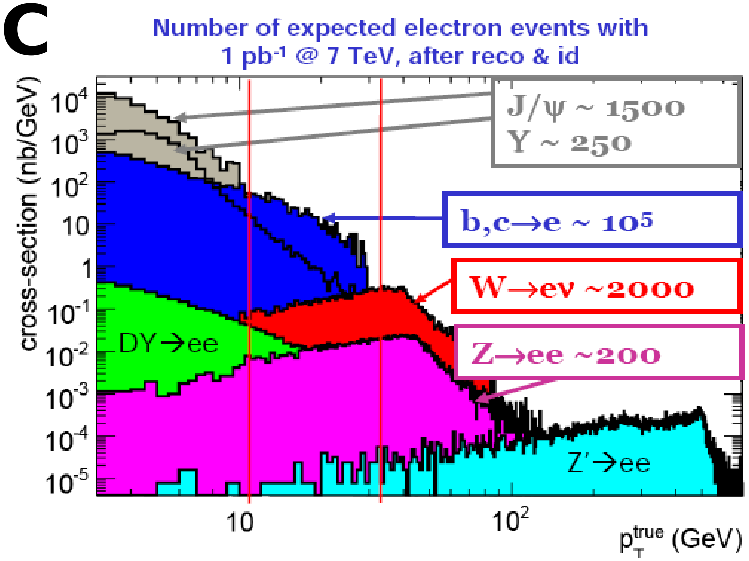
Measurement: $W \rightarrow l\,\nu$

- Signature:
  - Single charged lepton and missing transverse energy (MET)
  - Leptons are high p_T and isolated
  - MET from neutrino
  - Peaking at transverse invariant mass



Electrons and jets

MC



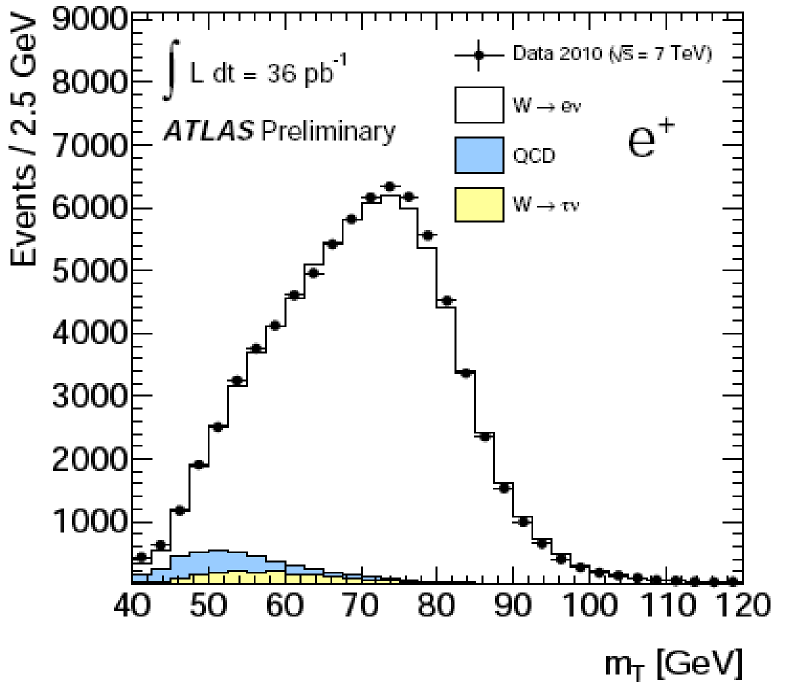
- There is also lot of true electrons from semileptonic decays inside jets

- Jets can look like electrons
  - Photon conversion from π^0's
  - Early showering charged pions
- And there is lot of jets
- Difficult to model in Monte Carlo
  - Detailed simulation in tracking and calorimeter volume

Event selection

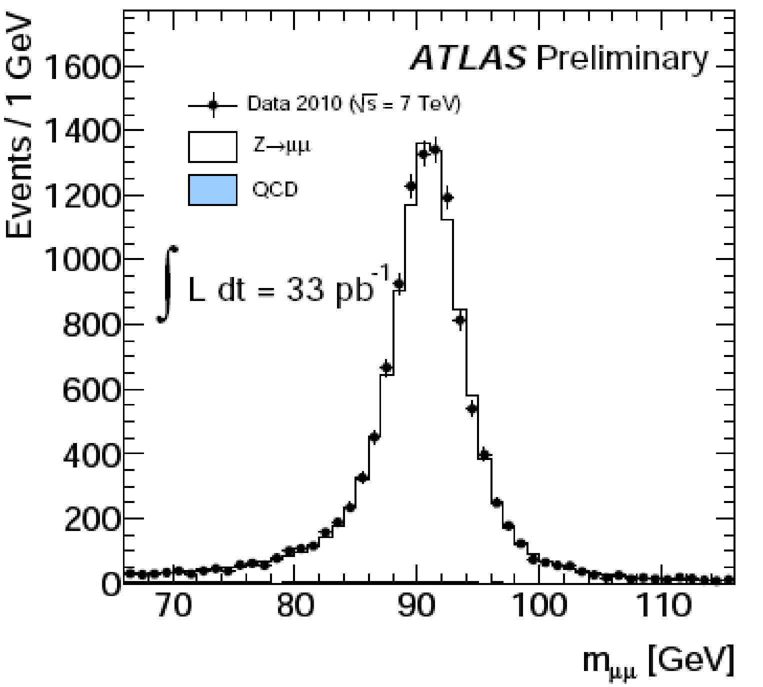
$W \to \ell\nu$

- One e/μ with $p_T > 20$ GeV
- $E_T^{miss} > 25$ GeV
- $m_T(\ell, E_T^{miss}) > 40$ GeV

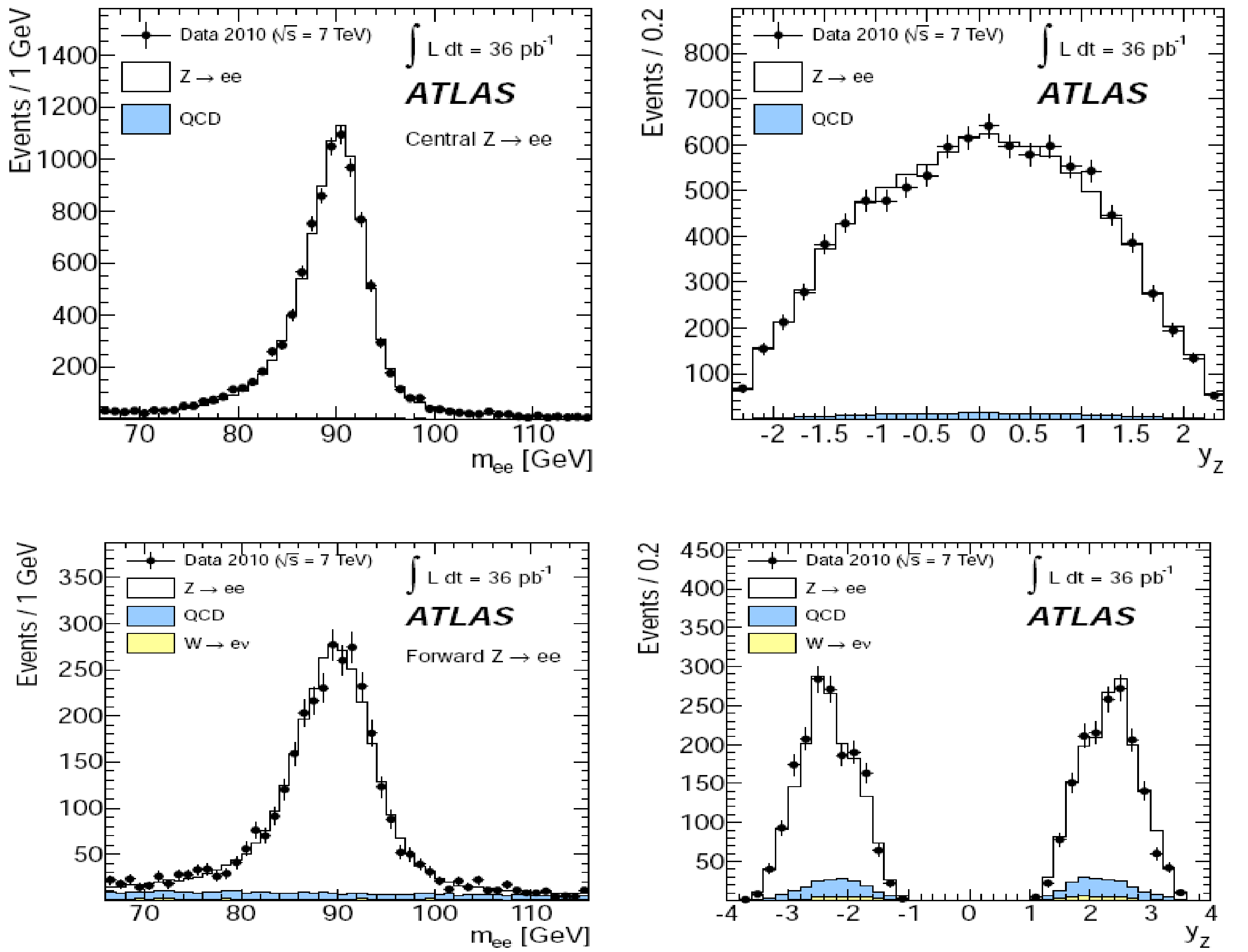


$Z \to \ell\ell$

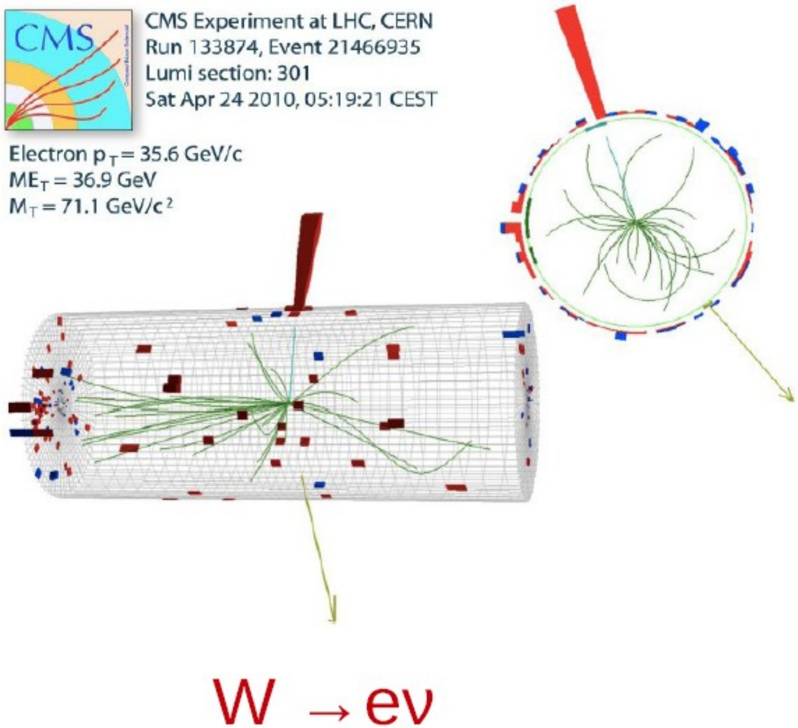
- Two e/μ with $p_T > 20$ GeV
- $m_{\ell\ell} = 66\text{–}116$ GeV

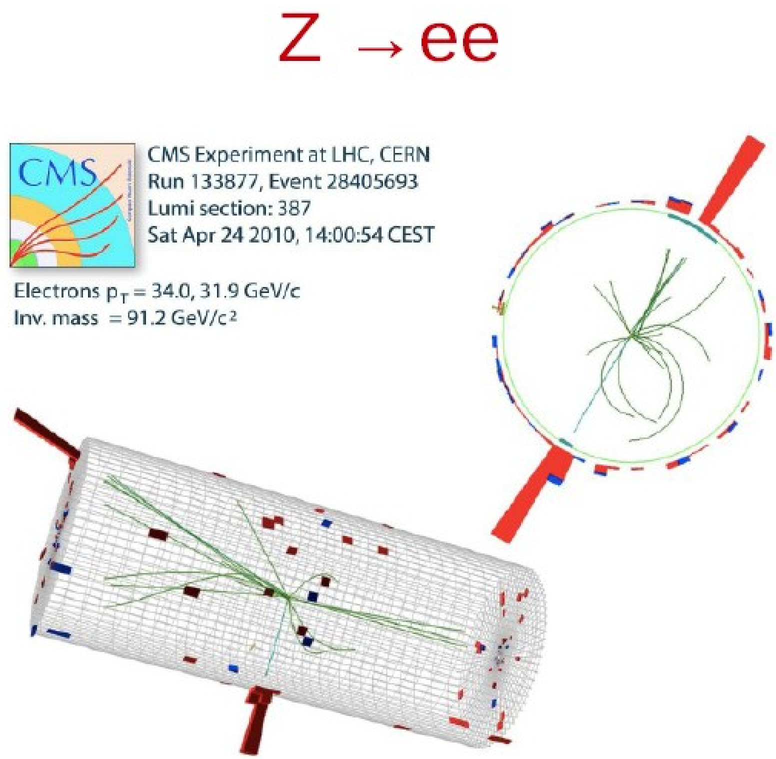


Event selection



Electron channel W and Z events





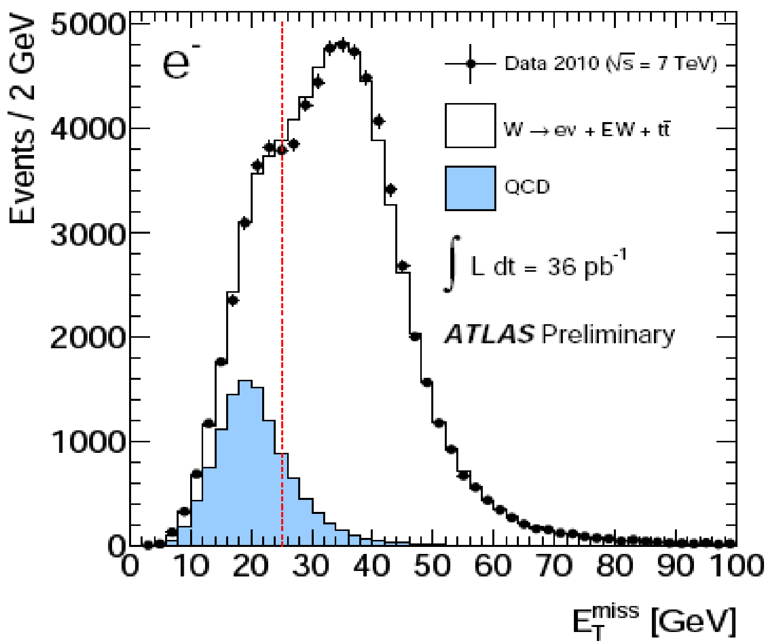
QCD background estimation

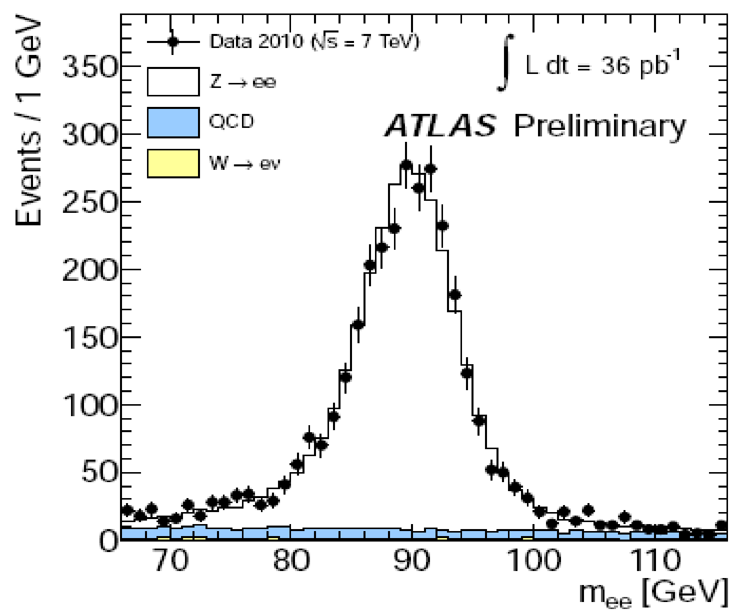
$W \to e\nu$: template fit to E_T^{miss}. Template derived from data with inverted electron ID and isolation.

$Z \to ee$: template fit to $m_{\ell\ell}$ to a sample with looser electron ID, extrapolated to the signal region.

$W \to \mu\nu$: matrix method using track isolation.

$Z \to \mu\mu$: ABCD method with track isolation in $m_{\mu\mu}$ side-band.





Cross-section measurement

$$\sigma = \frac{N_{\rm obs} - N_{\rm bkg}}{A \cdot C \cdot \int dt\, \mathcal{L}}$$

$N_{\rm obs}$: number of observed events in the signal region

$N_{\rm bkg}$: estimated number of background events

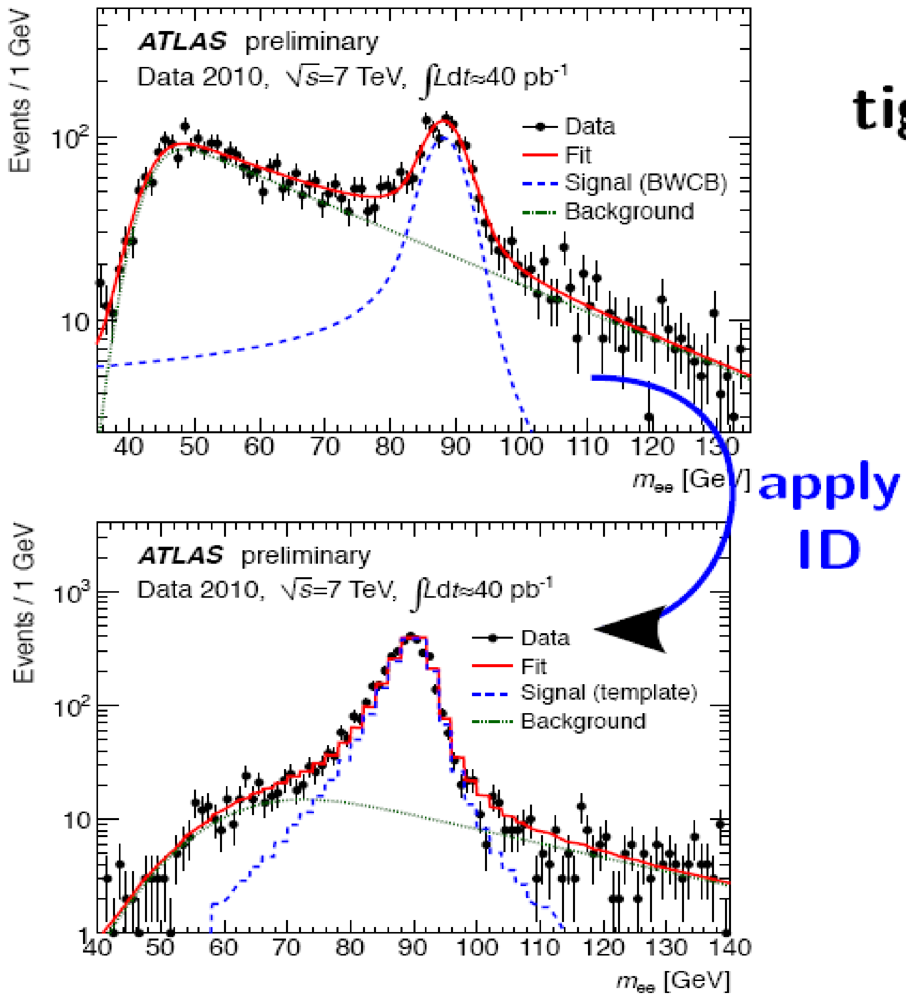
- EW backgrounds are estimated with Monte Carlo, constrained to data with performance scale factors.
- QCD backgrounds are estimated with **data-driven** methods.

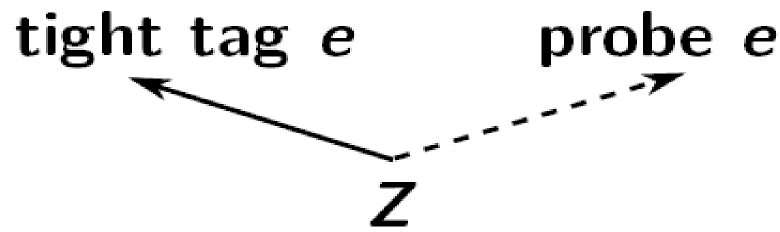
A: kinematic acceptance factor, estimated with generator-level Monte Carlo.

C: summarizes reconstruction efficiency, estimated with reconstructed Monte Carlo, corrected with **scale factors**.

$\int dt\, \mathcal{L}$: integrated luminosity.

Scale factor: tag-and-probe studies





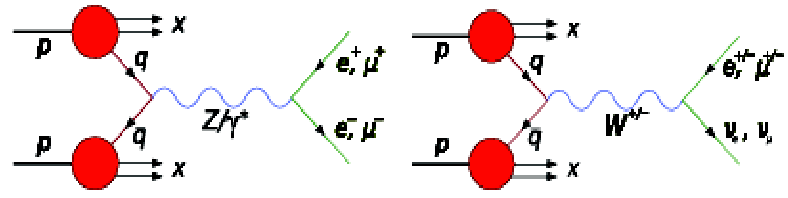
- **"Tag"** events with sufficient purity, leaving an unbiased **"probe"** object.
- Measure probe ID efficiency *in situ*.
- Constrains the performance of our object identification.
- Derive **scale factors** for correcting our simulation.

[4] ATLAS-PERF-2010-04-001

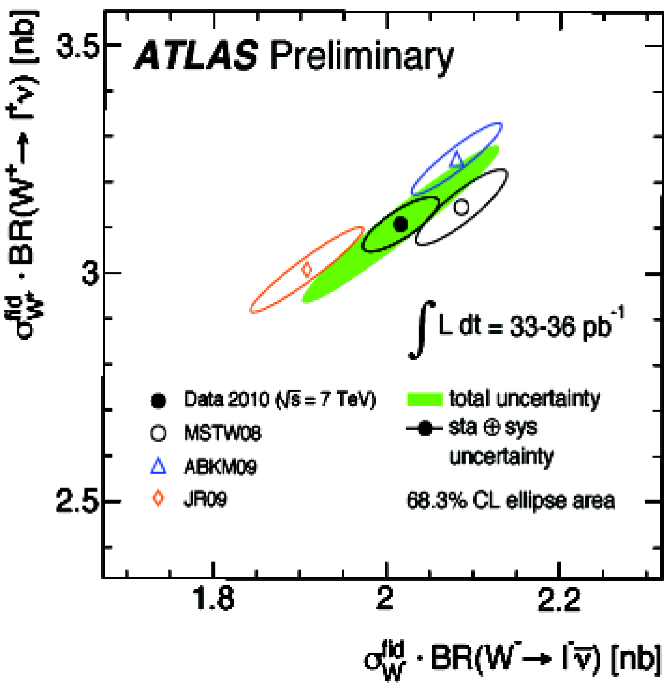
Systematic error

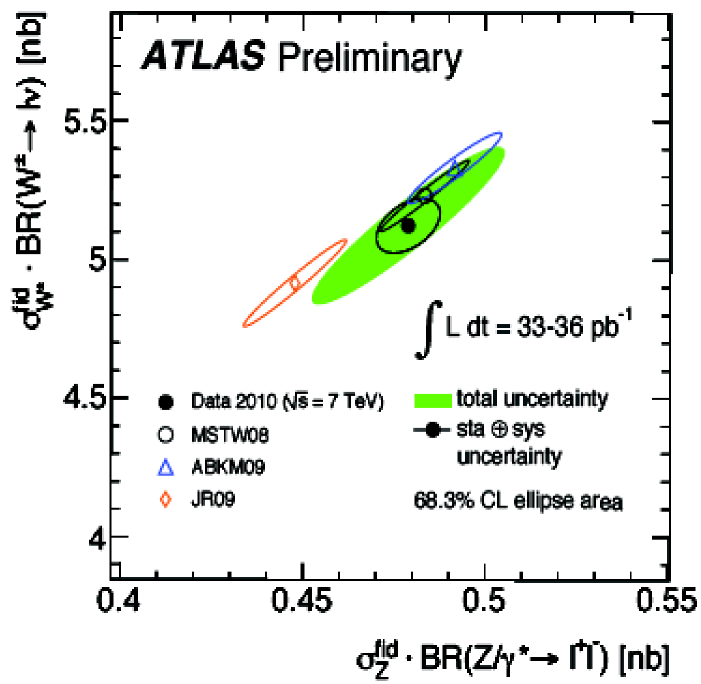
	$\delta\sigma_{W^\pm}$	$\delta\sigma_{W^+}$	$\delta\sigma_{W^-}$	$\delta\sigma_Z$
Trigger	0.4	0.4	0.4	<0.1
Electron reconstruction	0.8	0.8	0.8	1.6
Electron identification	0.9	0.8	1.1	1.8
Electron isolation	0.3	0.3	0.3	—
Electron energy scale and resolution	0.5	0.5	0.5	0.2
Non-operational LAr channels	0.4	0.4	0.4	0.8
Charge misidentification	0.0	0.1	0.1	0.6
QCD background	0.4	0.4	0.4	0.7
Electroweak+$t\bar{t}$ background	0.2	0.2	0.2	<0.1
$E_{\mathrm{T}}^{\mathrm{miss}}$ scale and resolution	0.8	0.7	1.0	—
Pile-up modeling	0.3	0.3	0.3	0.3
Vertex position	0.1	0.1	0.1	0.1
$C_{W/Z}$ theoretical uncertainty	0.6	0.6	0.6	0.3
Total experimental uncertainty	1.8	1.8	2.0	2.7
$A_{W/Z}$ theoretical uncertainty	1.5	1.7	2.0	2.0
Total excluding luminosity	2.3	2.4	2.8	3.3
Luminosity		3.4		

W, Z inclusive measurements



- Inclusive in number of jets, allow to reach high accuracy in QCD predictions.
- Computation available at NNLO on the total cross-section, at NNLO error dominated by PDF's

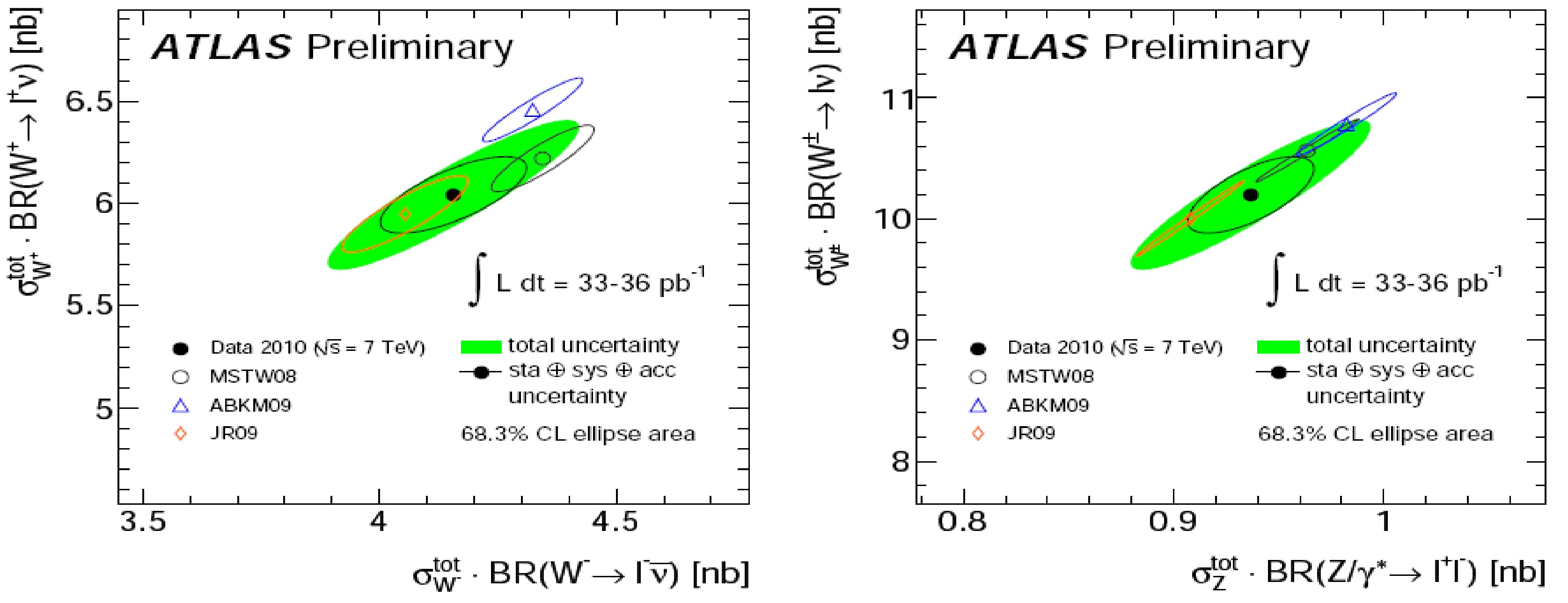




Fiducial cross-section. Theory predictions including acceptance. Sensitive to pdf's set.

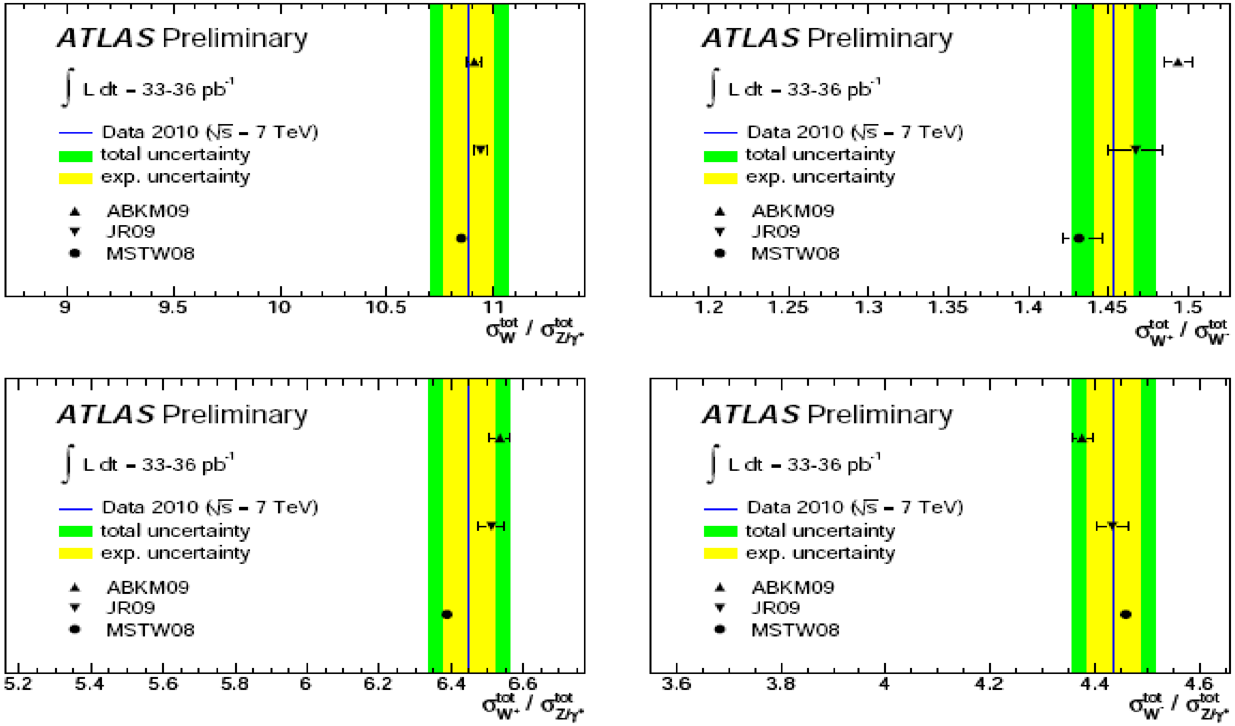
Theory comparison: total cross-section

- Overall remarkable agreement with NNLO PDF predictions
- A few differences between different PDFs (w/ only 68 % CL PDF errors)
- Comparing total cross sections, the acceptance uncertainty accounts for effect of different PDFs on the unmeasured phase space . . .



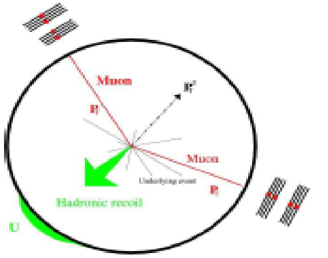
Theory comparison: total cross-section ratios

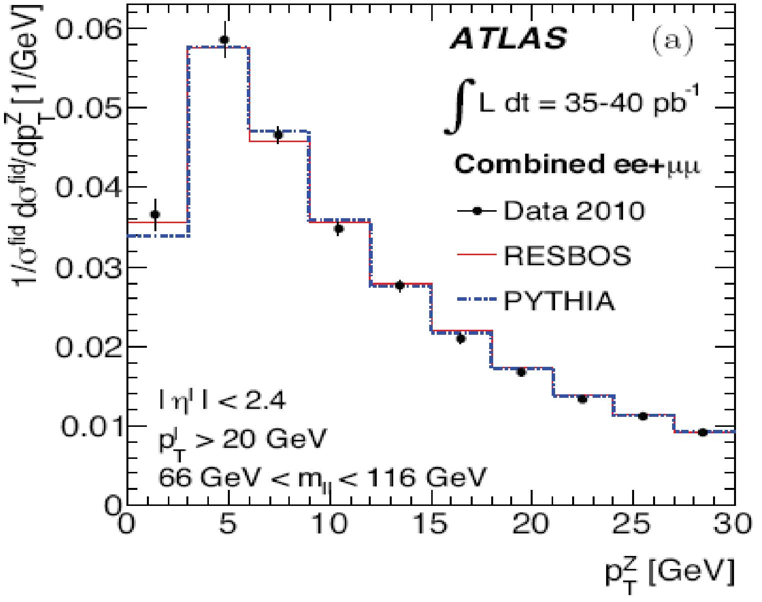
- $W^{\pm}/Z$, W^{+}/W^{-} ratios profit from exp. and theor. systematics cancellation
- $W^{\pm}/Z$ ratio measured with total uncert. of $1.5\,\%$, W^{+}/W^{-} with $1.7\,\%$



Z boson p_T measurement

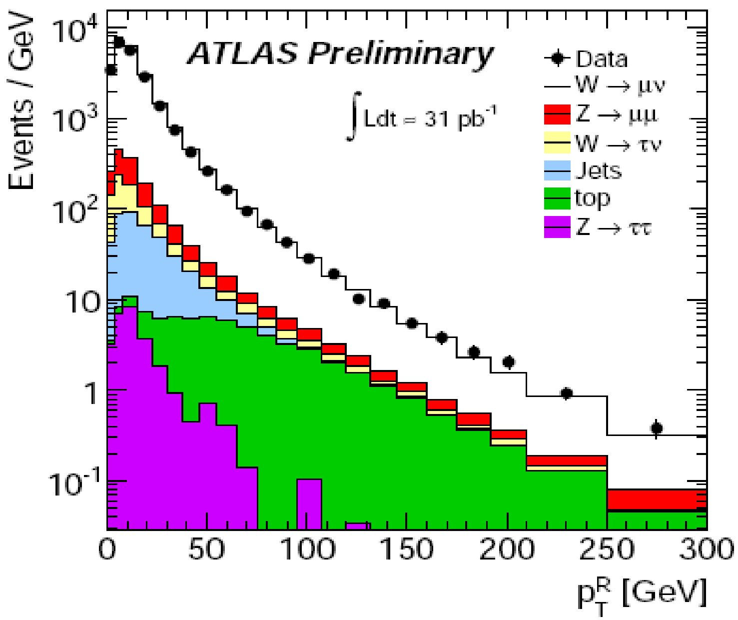
- Important for modeling high-p_{T} lepton kinematics.
- At leading order, $p_{\mathrm{T}}^{W/Z} = 0$
- Non-zero $p_{\mathrm{T}}^{W/Z}$ is generated through the hadronic recoil of ISR, p_{T}^{R}.
- p_{T}^{Z} reconstructed directly from $p_{\mathrm{T}}(\mu_1) + p_{\mathrm{T}}(\mu_2)$, while p_{T}^{W} reconstructs p_{T}^{R}.
- Detector and FSR effects removed with a bin-by-bin unfolding.
- 3-4% precision per bin.

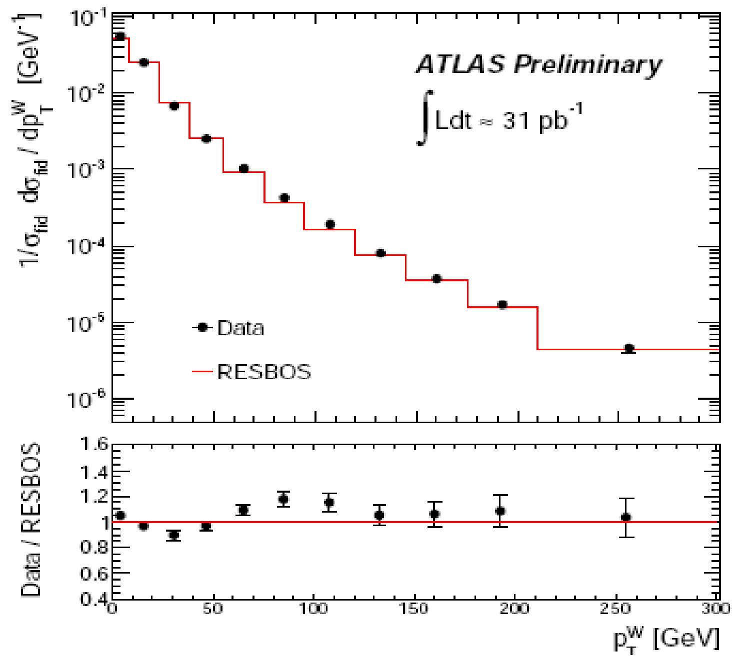




W boson p_T measurement

- Necessary for a future precision W mass measurement.
- Detector and FSR effects removed by inverting a response matrix parametrizing the probabilistic mapping of p_{T}^{R} to p_{T}^{W}.

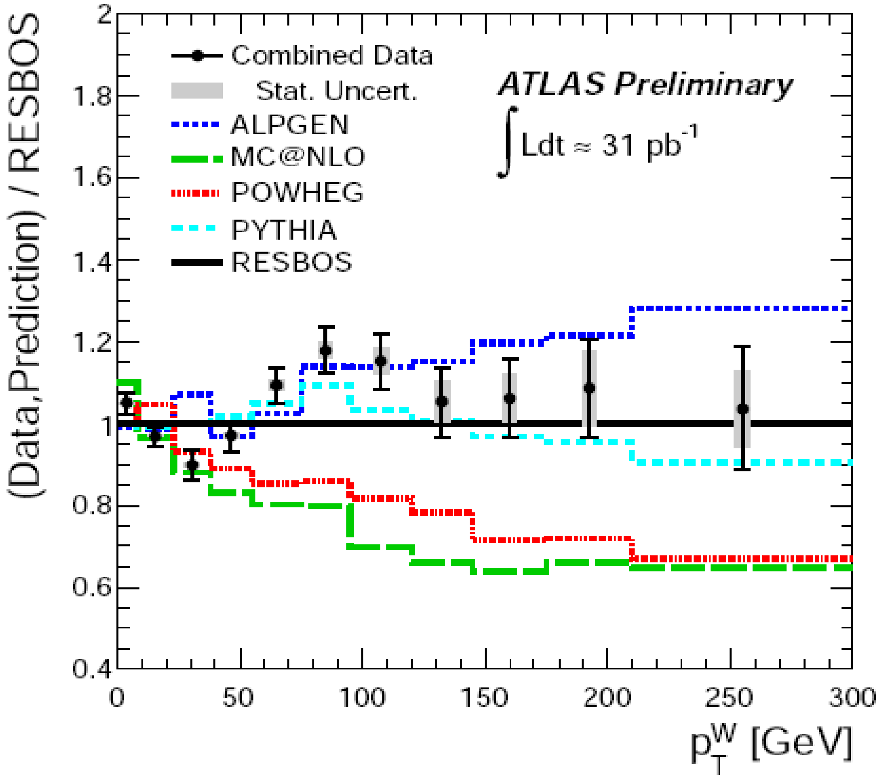




[8] STDM-2011-15

W, Z boson p_T reweighting

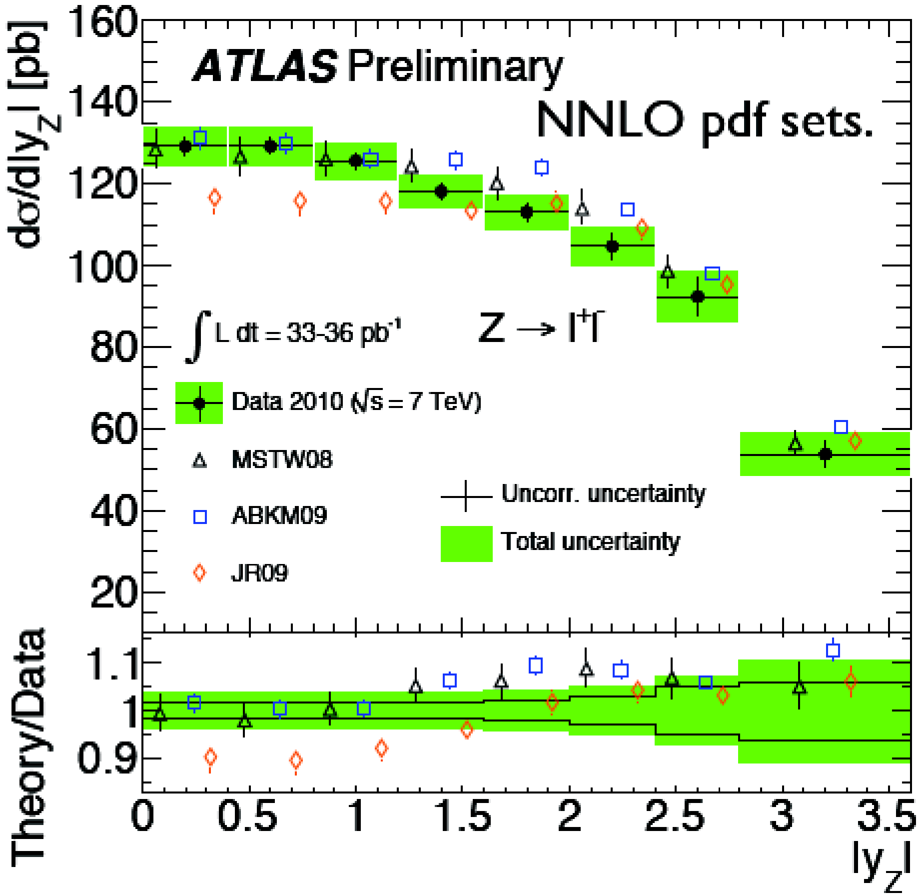
- The modeling of $d\sigma/dp_T^{W/Z}$ can have significant effects on the expected efficiency and acceptance.
- NLO generators MC@NLO and POWHEG have deficits at high $p_T^{W/Z}$.
- NLO effects are important at high $p_T^{W/Z}$ because the W/Z is polarized by higher order QCD.



- $W \to \ell\nu$ and $Z \to \ell\ell$ cross section measurements use MC@NLO reweighted to match $p_T^{W/Z}$ for LO Pythia, which agrees with the data because it has been tuned well to the Tevatron data.

Z differential

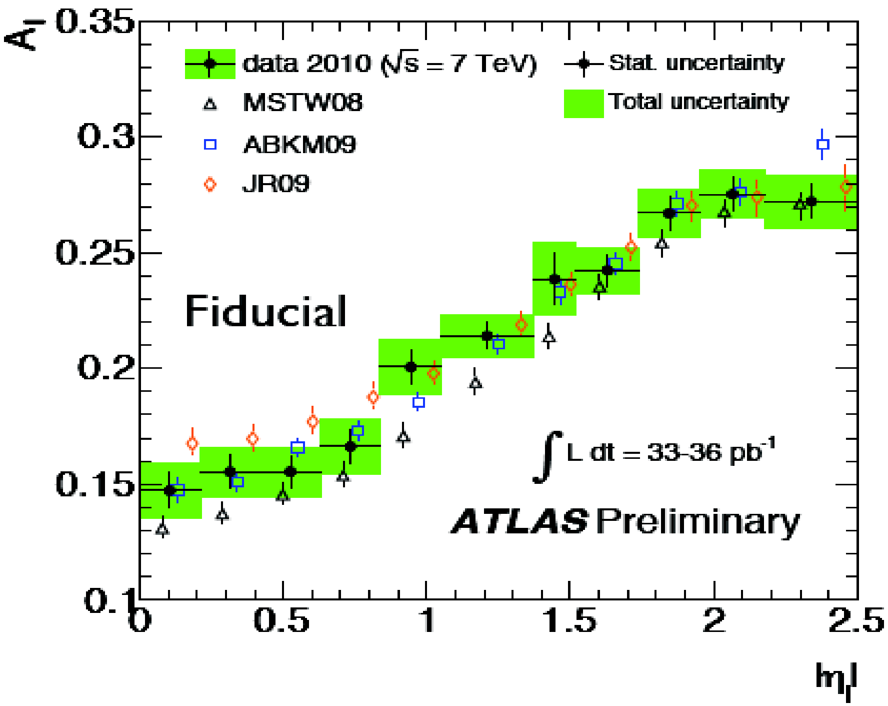
- Inclusive production as a function of the Z pseudorapidity.
- Lepton flavours combined together taking into accoun all correlations.
- Z rapidity reaches |y|<3.5 with special electron reconstruction outside tracking volume (|y|<2.5)

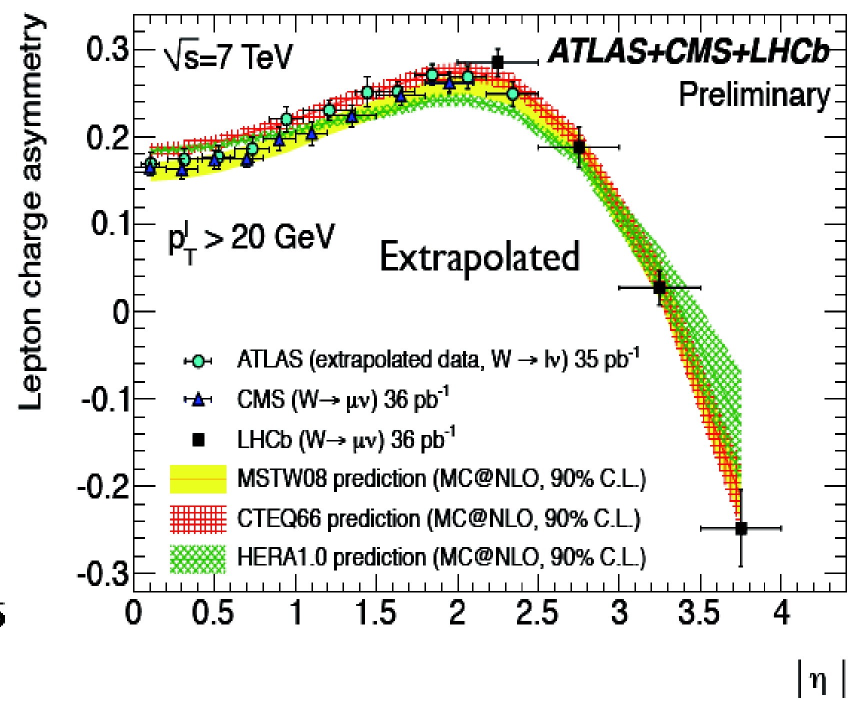


W^{+-} asymmetry

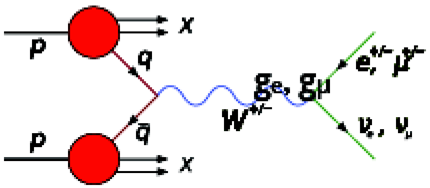
$$A(\eta_l) = \frac{\sigma^{W^+}(\eta_l) - \sigma^{W^-}(\eta_l)}{\sigma^{W^+}(\eta_l) + \sigma^{W^-}(\eta_l)}$$

- Asymmetry induced by the different flavours contributing to W^+ and W^- production and by asymmetry in flavour content of pp interaction
- Measured as function of lepton η





Lepton universality



$$R_W = \frac{\sigma_W^e}{\sigma_W^\mu} = \frac{Br(W\to e\nu)}{Br(W\to\mu\nu)} = 1.006 \pm 0.004\,(\text{sta}) \pm 0.006\,(\text{unc}) \pm 0.023\,(\text{cor}) = 1.006 \pm 0.024$$

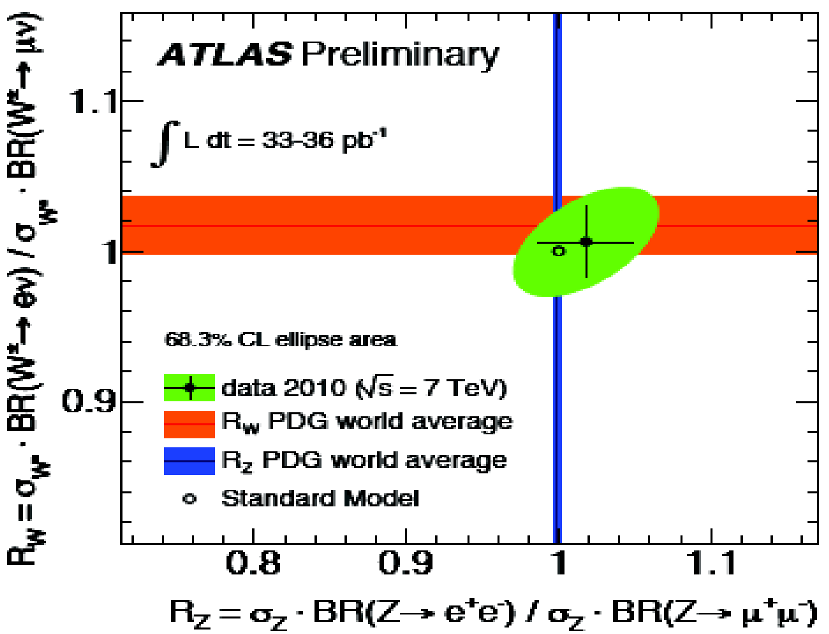
$$R_Z = \frac{\sigma_Z^e}{\sigma_Z^\mu} = \frac{Br(Z\to ee)}{Br(Z\to\mu\mu)} = 1.018 \pm 0.014\,(\text{sta}) \pm 0.016\,(\text{unc}) \pm 0.028\,(\text{cor}) = 1.018 \pm 0.031$$

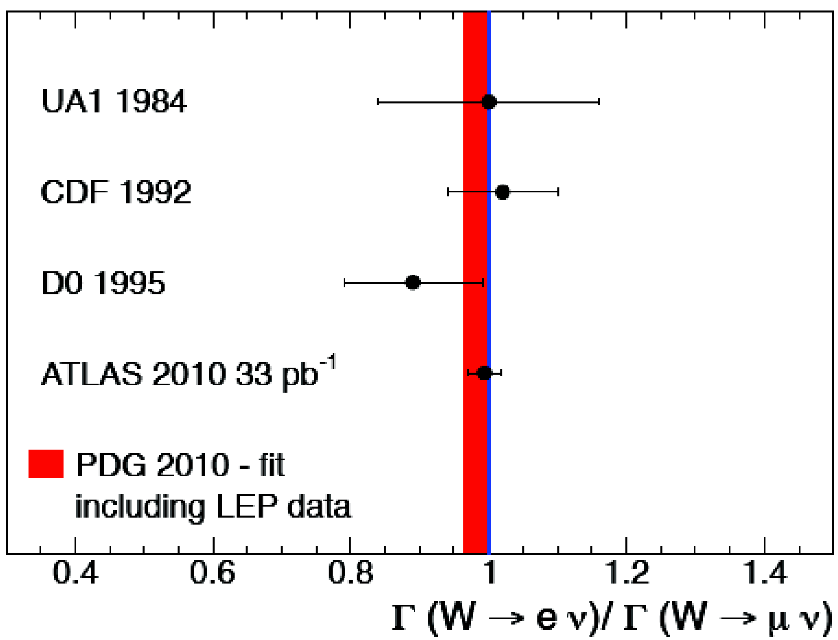
$R_W^{PDG} = 1.017 \pm 0.019$

$R_Z^{PDG} = 0.991 \pm 0.0024$

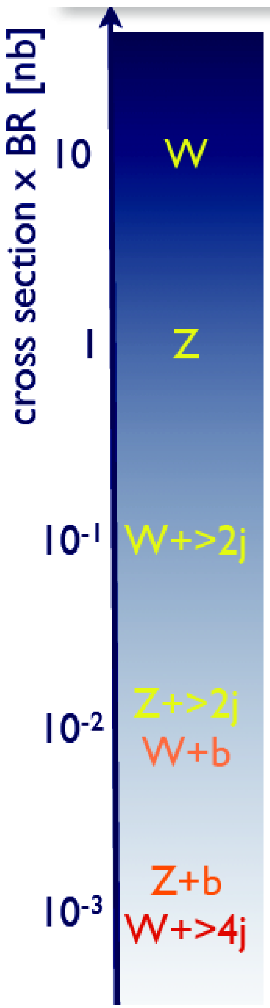
$R_W = g_e^2/g_\mu^2$ (neglecting loop correction)

$$R_Z = \frac{g_e^2\,(2\sin\theta^e_W - 1) + 4\sin^2\theta^e_W}{g_\mu^2\,(2\sin\theta^\mu_W - 1) + 4\sin^2\theta^\mu_W}$$





W/Z + jets physics

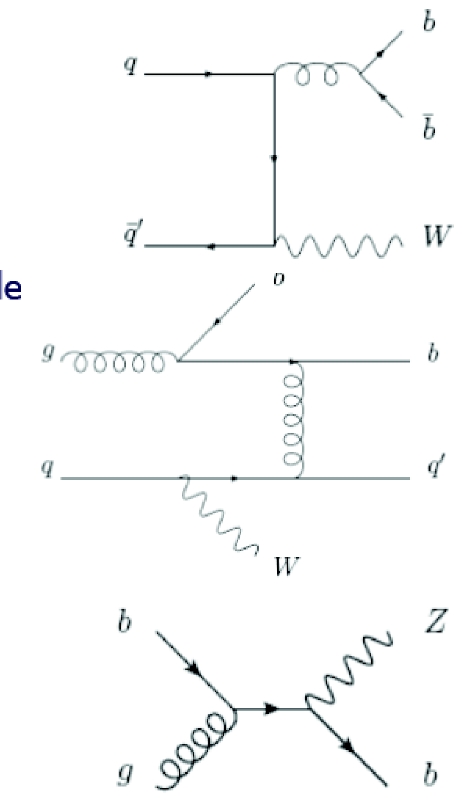


- W/Z+jets physics is a fundamental ingredient for reestablishing the Standard Model (SM) in pp collisions at 7 TeV

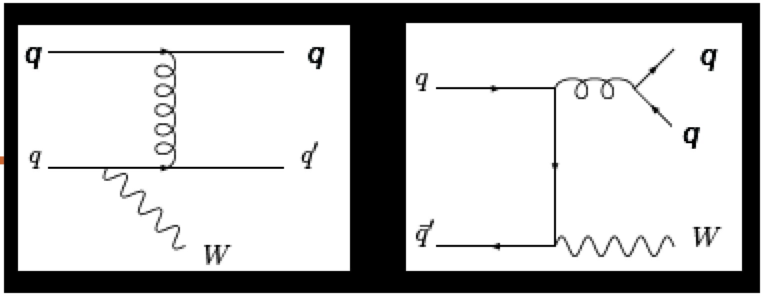
  ✓ larger available energy than at Tevatron:
    => more jets; larger kinematic reach
    => cross sections spanning several orders of magnitude

  ✓ higher relevance of processes initiated by qg and gg scattering
    => different contribution to the cross section compared to Tevatron
    => processes with heavy flavour in the initial state become important

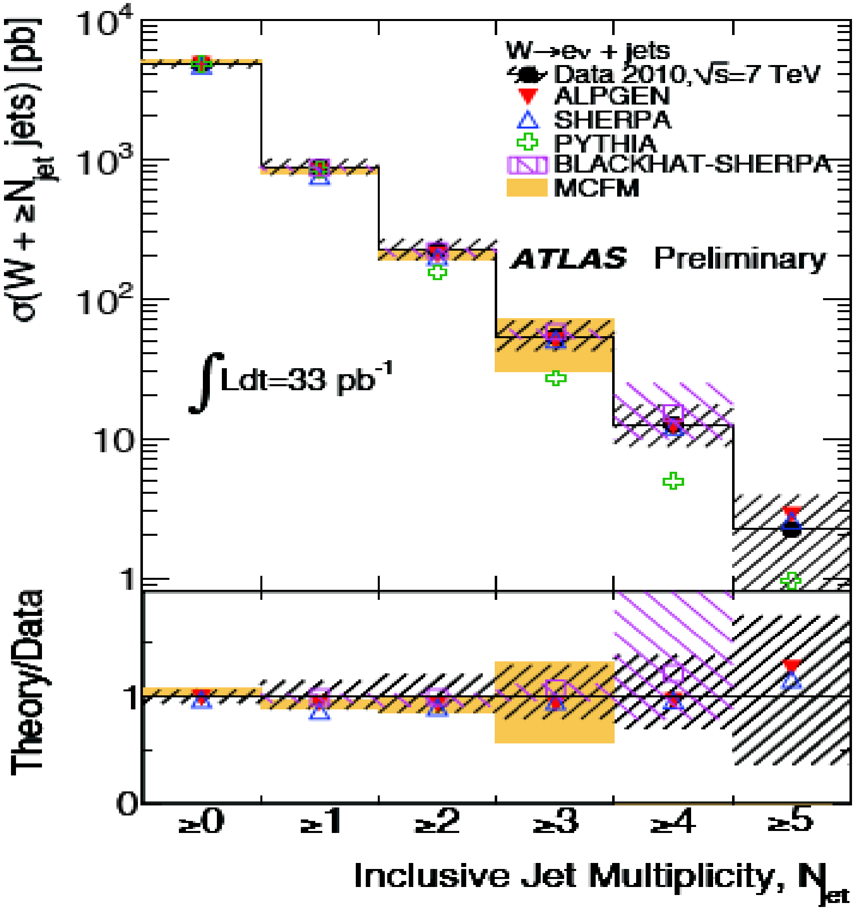
- compelling test for the new NLO pQCD calculations of W/Z+(b)jets (up to 4jet for light- and 2 for b-jets)

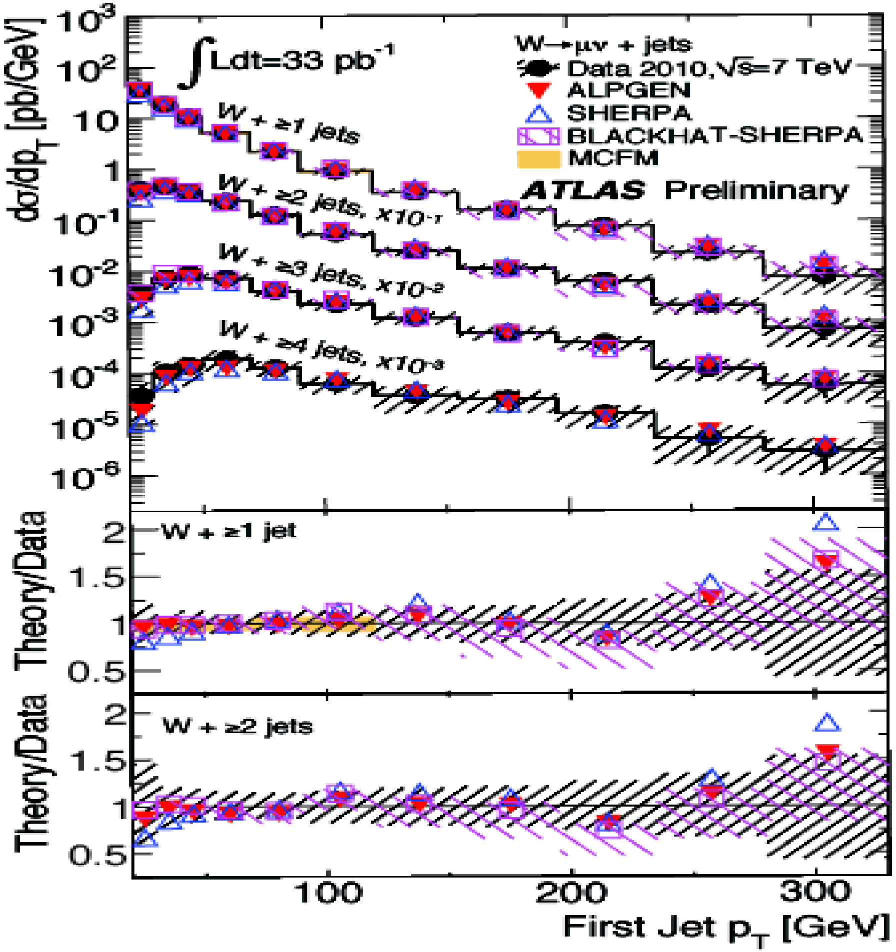


W/Z + jets



- Measure up to 4-5 jets and up to E_T = 300 GeV



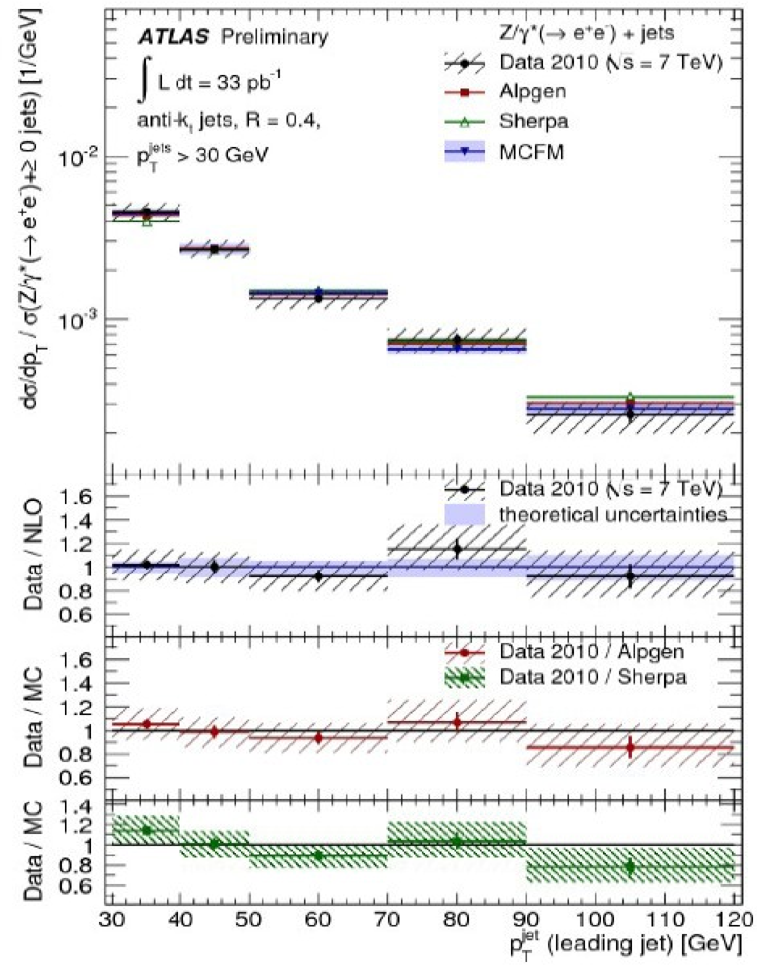


W/Z+jets

- cross section measured as a function of several kinematic variables
- very good agreement with NLO predictions from MCFM and Blackhat-Sherpa in the total and differential cross sections
- good agreement with matched LO prediction from AlpGen and Sherpa once normalized to the NNLO prediction
- Poor agreement with LO PYTHIA in the high jet multiplicity

dominant systematics

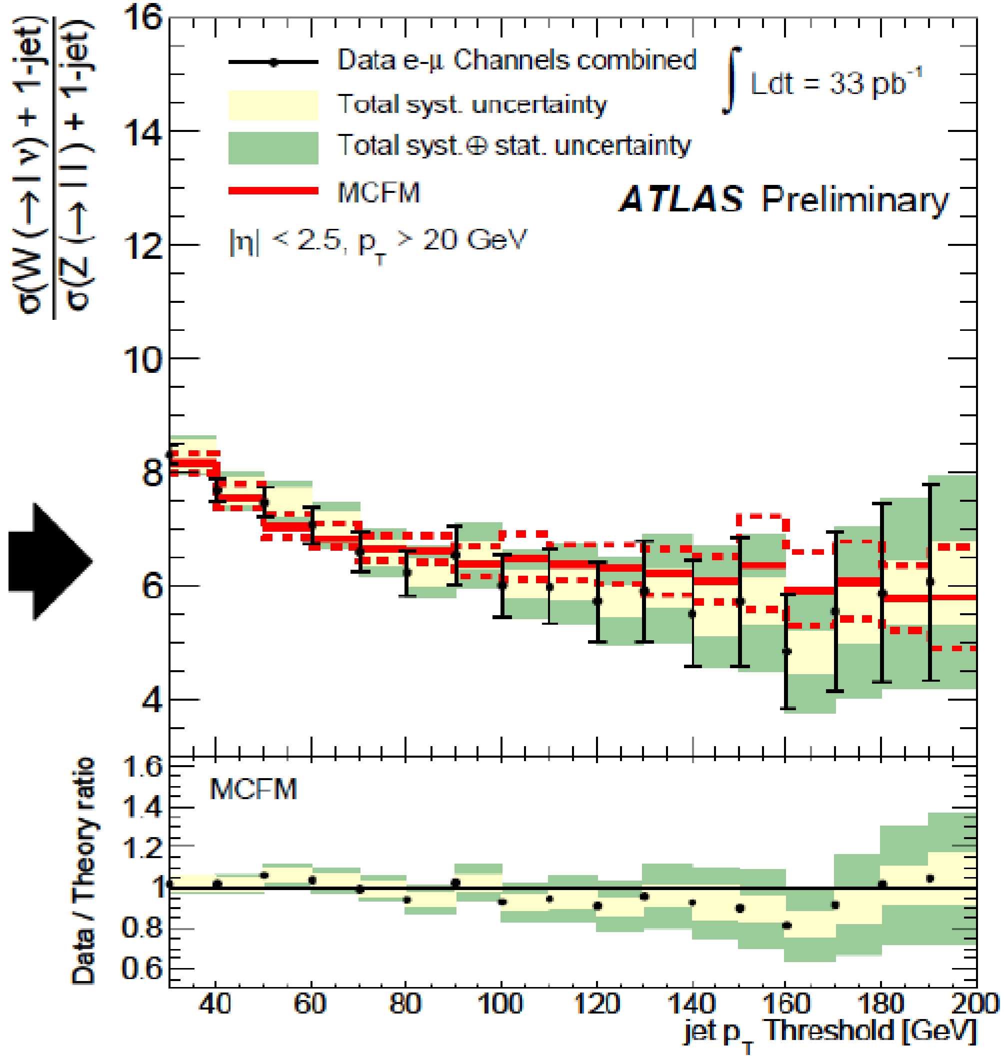
- JES: 8(26)% for $N_j \geq 1(4)$
- jets from pile-up ≈7%
- lep. reco. ≈ 2%
- QCD bkgd ≈ 2%
- unfolding ≈ 2%



Rjets = ratio W+1jet/Z+1jet

- This is the first time this ratio is measured
  - Sensitive to new physics
  - Very small sensitivity to PDF's
    - CTEQ6.6: 0.5%
    - MSTW2008: 0.3%

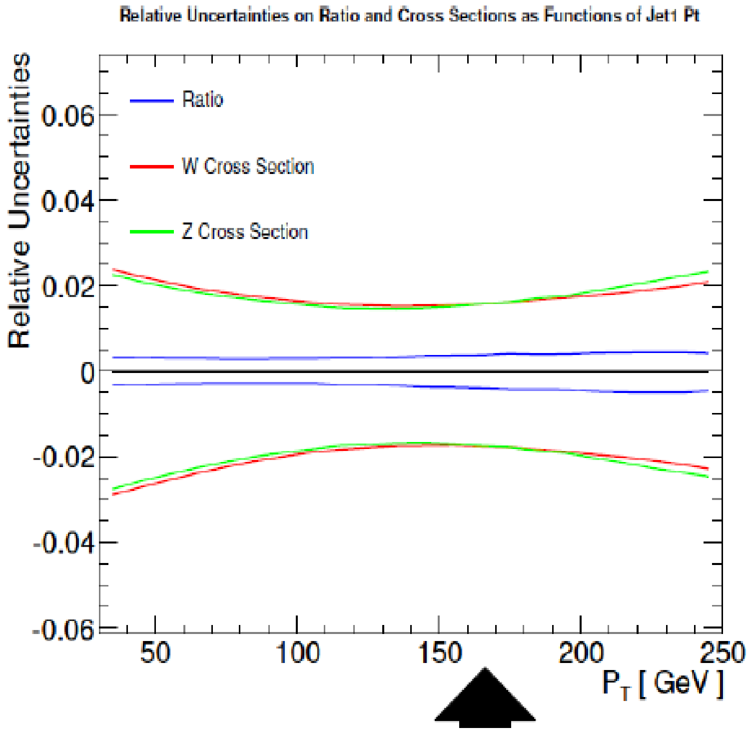
$$R_{\text{jets}}\,(p_T > x) = \frac{\sigma_{W+1\text{-jet}}(p_T > x)}{\sigma_{Z+1\text{-jet}}(p_T > x)}$$



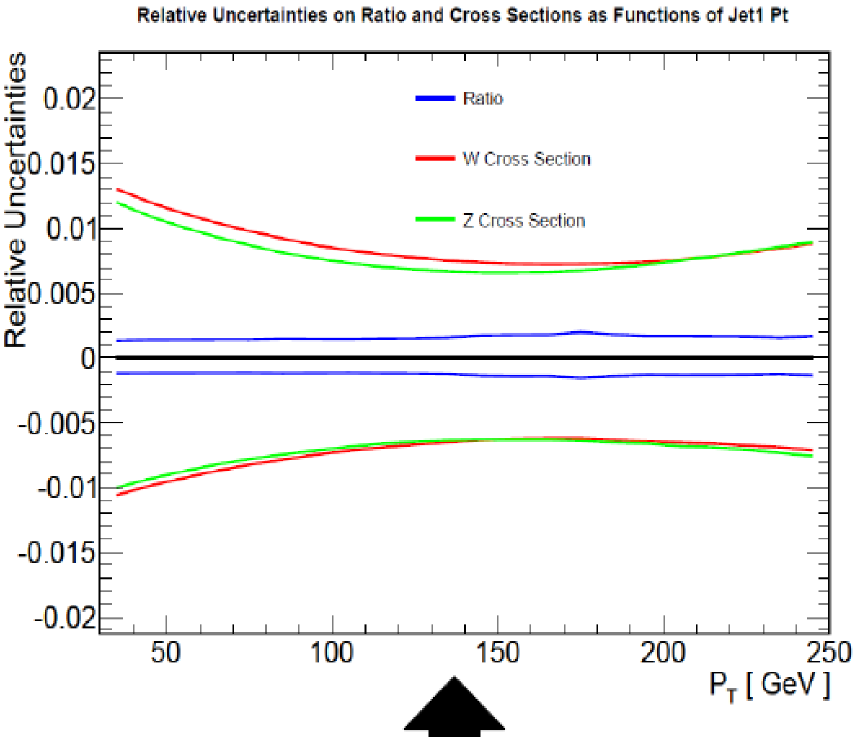
PDF uncertaintity on Rjets

- Very small uncertaintity on PDF's

  CTEQ6.6: 0.5%, MSTW2008: 0.3%



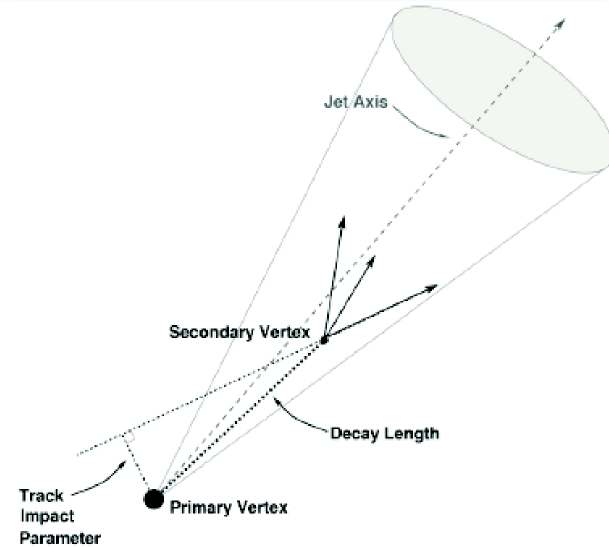
CTEQ6.6

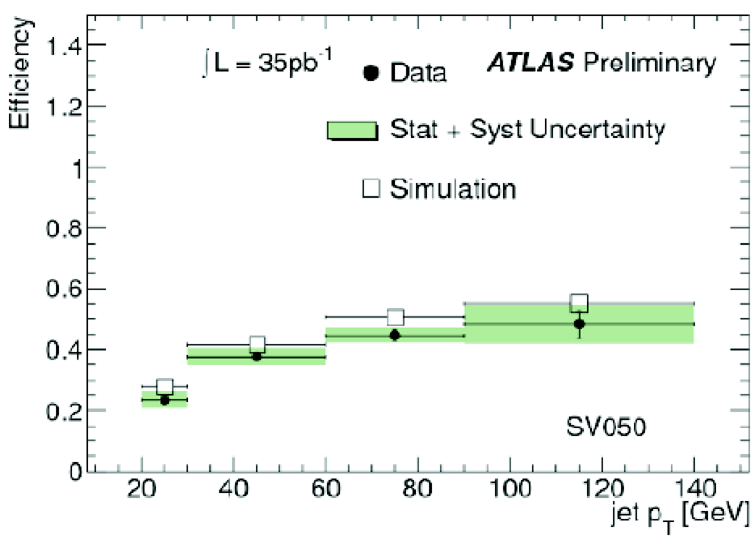


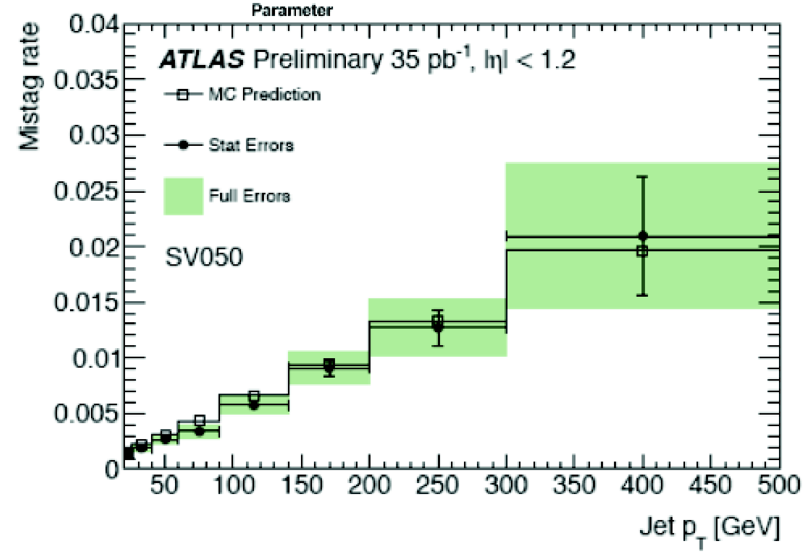
MSTW2008

W/Z + b-jets: b-tagging

- b-jets are selected exploiting the long lifetime (1.5 ps) and the large mass of B-hadrons
- The SV0 b-tagging algorithm is based on requiring a displaced secondary vertex reconstructed within a jet with a decay length significance > 5.85
- The b-tagging efficiency and its systematics is estimated by studying semi-leptonic B decays in QCD muti-jet events, and top events







W/Z+bjets: backgrounds

The b-tag changes the composition of backgrounds with respect to W/Z+jet measurements

Z+b-jet signal / background > 10

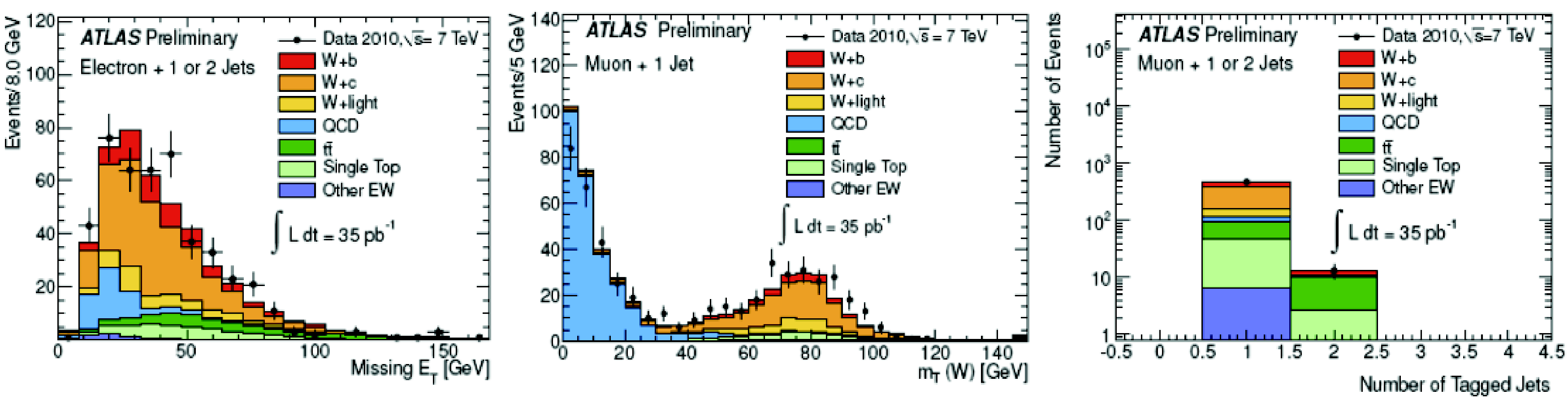
W+b-jet signal / background ≈ 0.5

non-W background

- comes from QCD multi-jet heavy flavour production.
- Tighten lep. ID to keep bkgd <30% with 50% uncertainty

top background

- t-tbar largest background (partially irreducible)
- single-top estimated with MC (partially irreducible)
- top yield measured in the ≥4 jet bin and extrapolated to 1, 2 jet wit MC
  - uncertainty ≈ 30% (JES)
  - b-tag uncertainty reduced to 2%



W/Z+bjets: extraction of b-jets fraction

A maximum likelihood fit to the SV0 mass distribution is used to separate b-jets from c- and light-jets, and extract the flavour fraction on a statistical basis.

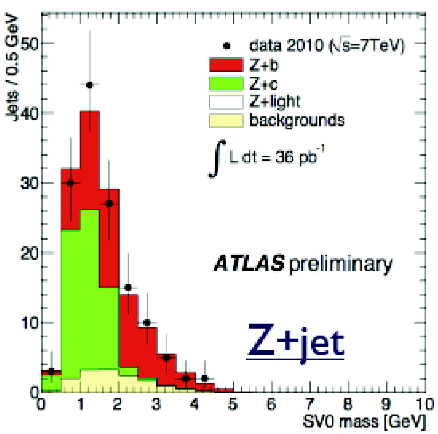
- SV0 mass template are modeled with MC
- template systematics: data vs. MC in multi-jet events enriched in light-, c-, and b-jets.

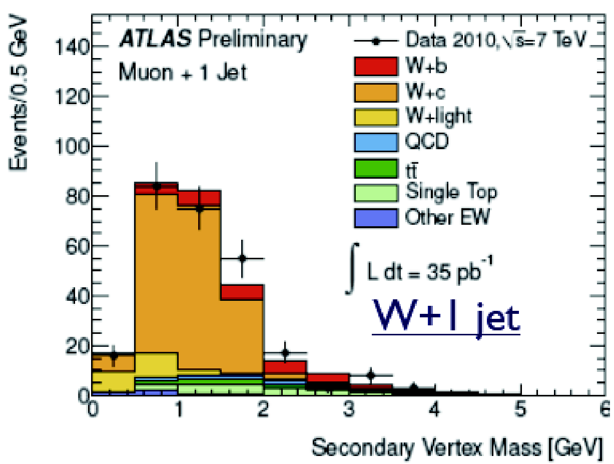
Z+bjet

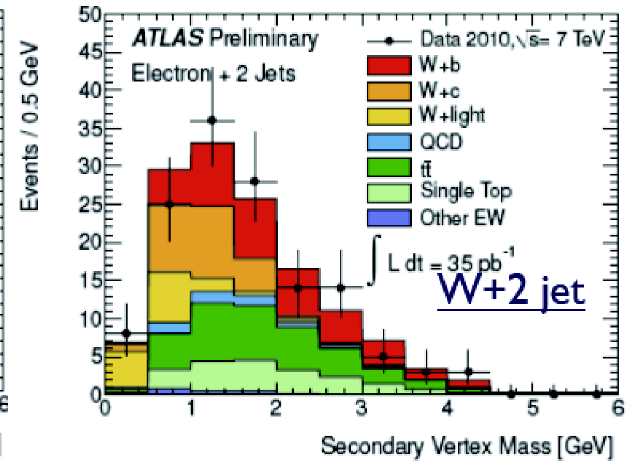
- Fit the combined e and μ samples and each b-tagged jet in the event
- At least 1 b-tagged jet

W+bjet

- 1 b-tagged jet
- about 10% of events have 2 b
- 1 or 2 jet
- fit each jet bin separately for e and μ





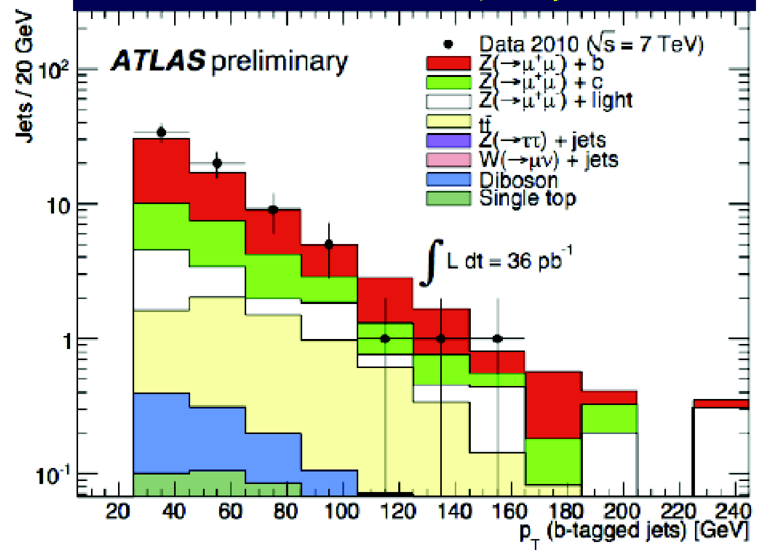


Z+b-jets: results

$$\sigma = \frac{N_b}{C_e \times \mathcal{L}_e + C_\mu \times \mathcal{L}_\mu}$$

- Inclusive b-jet production cross section in association with a Z boson
- Jet fitted yield is corrected for all detector effects with MC LO matched prediction for Zjet (including heavy flavour) from ALPGEN and SHERPA
- uncertainty: ≈ 20% stat. and ≈23% syst.
- dominant systematics:
  - b-tagging & SV mass template ≈10%
  - Z+b-jet modeling ≈10%
  - Jet + bjet energy scale ≈4%
- MCFM in good agreement with data within uncertainty

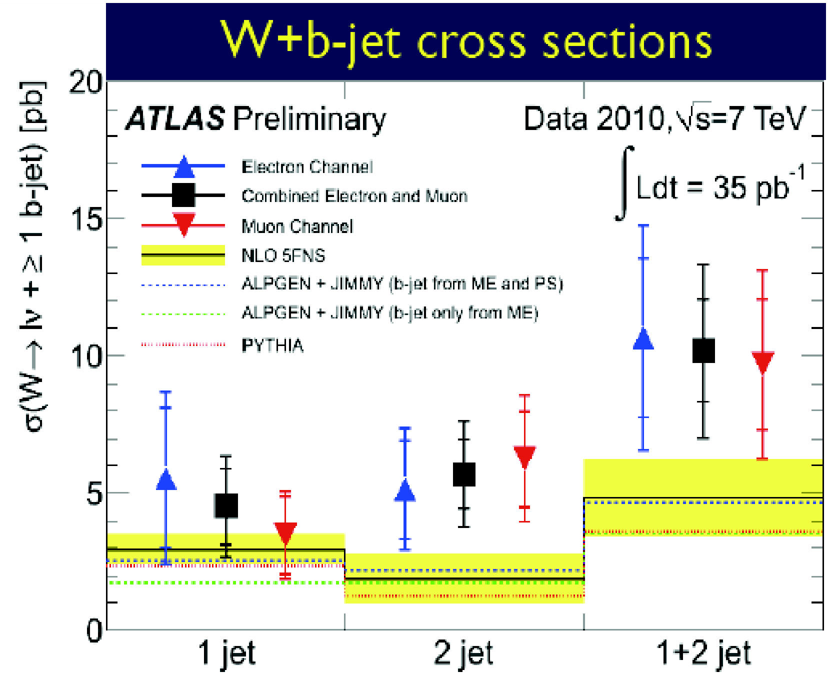
Z+b uncorrected b-jet spectrum



Experiment	$3.55^{+0.82}_{-0.74}(\text{stat})^{+0.73}_{-0.55}(\text{syst}) \pm 0.12(\text{lumi})$ pb
MCFM	3.40 ± 0.44 pb
ALPGEN	2.23 ± 0.01(stat only)pb
SHERPA	3.33 ± 0.04(stat only) pb

W+b-jets: results

$$\sigma_{W+b\text{-jet}} \times \mathcal{B}(W \to \ell\nu) = \frac{n^{\text{tag}} \cdot f_{W+b\text{-jet}}}{\int Ldt \cdot \mathcal{U}}$$



- W+b-jet cross section (event level)
- First measurement in exclusive jet bins
- event fitted yield is corrected for all detector effects with MC LO matched prediction for Wjet (including heavy flavour) from ALPGEN
- uncertainty: ≈ 20% stat. and ≈25% syst.
- dominant systematics:
  - b-tagging & SV mass template ≈16%
  - top background ≈12%
  - QCD background ≈7%
  - W+b-jet modeling ≈10%
  - Jet + bjet energy scale ≈7%

- NLO prediction obtained in the 5 flavour number scheme [F. Caola *et al.* arXiv:1107.3714]
- NLO agrees within 1.5σ with the measurements

	σ_{vis} [pb]
1 jet	$2.9^{+0.40}_{-0.36}$ (scale) $^{+0.18}_{-0.02}$ (PDF) $^{+0.19}_{-0.10}$ (m_b) $\pm$ 0.20 (non-pert)
2 jet	$1.9^{+0.81}_{-0.37}$ (scale) $^{+0.14}_{-0.02}$ (PDF) $^{+0.06}_{-0.05}$ (m_b) $\pm$ 0.13 (non-pert.)
1+2 jet	$4.8^{+1.20}_{-0.73}$ (scale) $^{+0.32}_{-0.03}$ (PDF) $^{+0.25}_{-0.15}$ (m_b) $\pm$ 0.34 (non-pert.)

Summary

- The LHC era allowed us to verify QCD in new kinematic regimes, good testing ground for predictions
- Current understanding of detectors allows to do <u>precision</u> measurements in W/Z sector
- Extensive set o measurements also in W/Z+jets differential cross-sections, also with b-tagging
- Overall impressive agreement with MC predictions

Next topics

- 14.11 – W, Z bosons:precise measurements
- 21.11 – Top: xsection, mass
- 28.11 – Dibosons and anomalous couplings
- 5.12, 12.12 - **Higgs**
- 19.12 – **SUSY**
- 9.1 – other searches for New Physics
- 16.1 - B-physics programme
- 23.1 – heavy ion programme