Acceptance Definitions and Studies

for W→eν and Z→ ee

Max Klein
WZ - Acceptances
CERN 13.4.10

DRAFT for ELAN 12.4.

Based on and with input from:

An Analysis of the Z,W Cross Section Determination in the Electron Channels with ATLAS

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Much of what follows, for W's, was presented in a comprehensive talk by Jan Kretzschmar to the WZ meeting (14.2.2010)

ATLAS NOTE

April 12, 2010

to appear

Basic Definition

For illustration use η as variable (may be any two or integrated over).

For each bin and a chosen value of η inside this bin one has:

$$\frac{\Delta\sigma}{\Delta\eta} = \frac{N_{Data} - N_{Bgd}}{A_{\varepsilon} \cdot L_{Data}} \cdot \frac{1}{\Delta\eta}$$

Bin averaged (or total) cross section

$$\frac{d\sigma}{d\eta} = \frac{N_{Data} - N_{Bgd}}{A_{\varepsilon} \cdot L_{Data}} \cdot \beta_{BC}$$

OR: Differential cross section

$$\beta_{BC} = \frac{d\sigma_{thy}/d\eta}{\int_{bin} d\sigma_{thy}}$$

Bin centre and size correction

N_{data} number of reconstructed signal (W or Z) events in bin after all cuts
N_{bgd} number of reconstructed fake events in bin after all cuts
A_{ε} combined correction for acceptance and efficiency

Two Remarks

$$\frac{\Delta\sigma}{\Delta\eta} = \frac{N_{Data} - N_{Bgd}}{A_{\varepsilon} \cdot L_{Data}} \cdot \frac{1}{\Delta\eta}$$

Bin averaged (differential or total) cross section

Independently of the data statistics, the analysis is better done multidimensional: the MC statistics, at least initially, is much larger than the experimental one, i.e. one better adds up differential cross sections to obtain integrated ones than separately the numerator and denominator. This allows for local corrections (and observations) even for the total cross section measurement.

We also believe that N_{data} shall be obtained by counting and not fitting to avoid biases. For the background one wants data driven methods and MC methods. This is not discussed here further.

Combined Acceptance and Efficiency Correction

Integrate smearing, RC, cuts and D/MC efficiency differences in definition of A_ε

$$\frac{\Delta\sigma}{\Delta\eta} = \frac{N_{Data} - N_{Bgd}}{A_\varepsilon \cdot L_{Data}} \cdot \frac{1}{\Delta\eta}$$

Cross section formula

$$A_\varepsilon = \frac{N_r}{N_g}$$

Correction Factor

$$N_g = N_{gen}^{nocuts,noRC}$$

Generated events in a bin
(based on all events, for Z with M_Z cut)

$$N_r = N_{rec}^{cuts,RC} = \sum_{ev} w_{ev}$$

Reconstructed events in a bin:
after all cuts, corrected for D/MC efficiency
and including h.o. QED radiative corrections

MC: MC@NLO+HERWIG+PHOTOS:
Use documentary particle level (before radiation)
to determine simultaneously the generation and
reconstruction event samples.

Acceptance Correction for $W^{\pm}$

Trigger: e10_medium

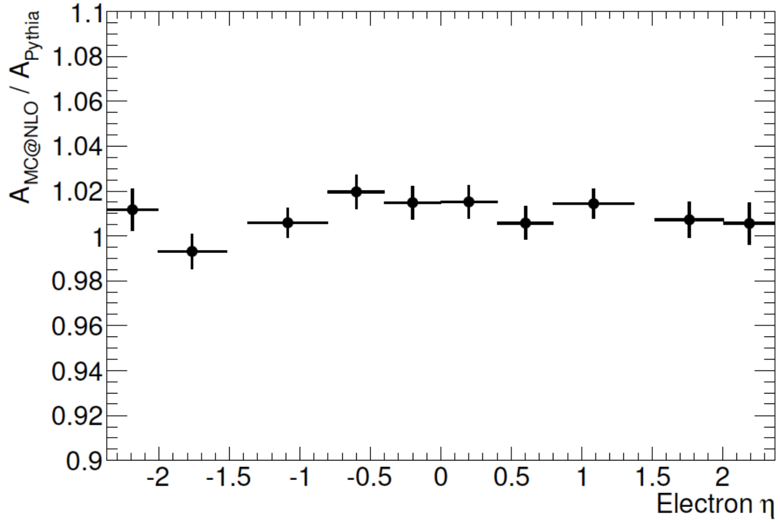
Reconstructed electrons with E_T > 25 GeV, IsEM medium, egamma AUTHOR

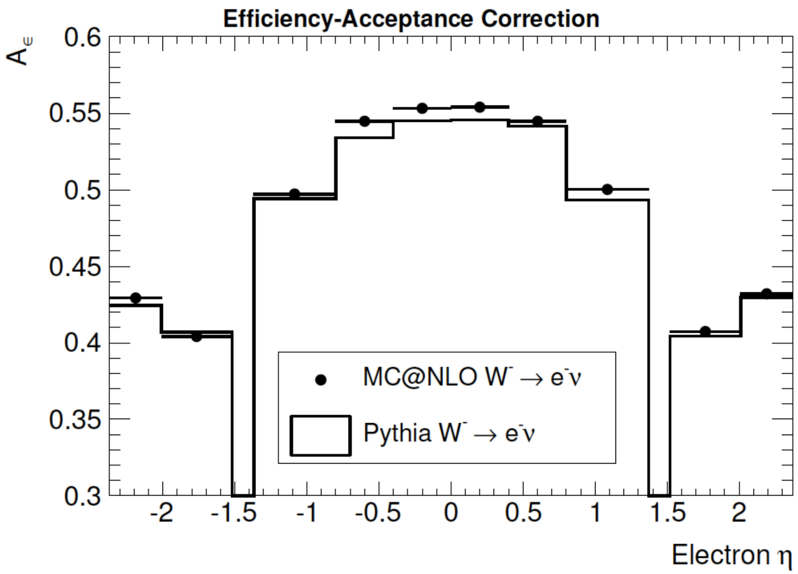
$|\eta| < 2.37$ and exclude $1.37 < |\eta| < 1.52$

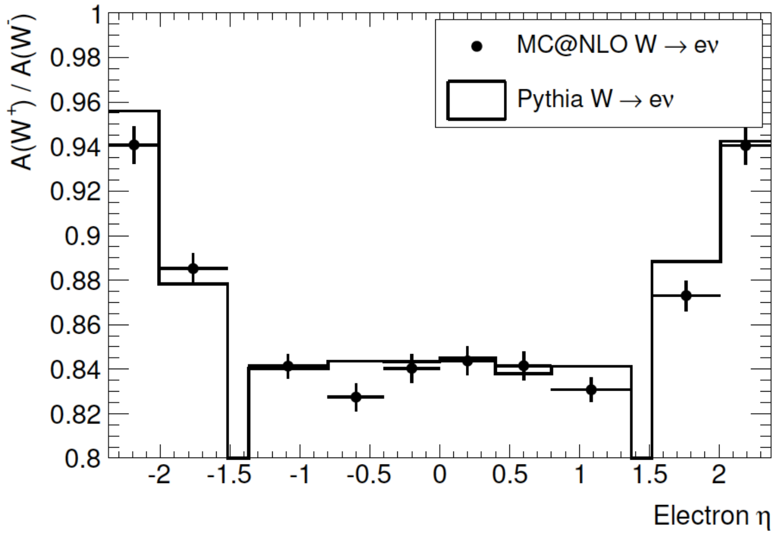
No further medium electron with $E_T > 25$ GeV

MET > 25 GeV

$M_T > 40$ GeV







Acceptance Correction for Z

Trigger: e10_medium

Reconstructed electrons with E_T > 15 GeV,
IsEM medium both ee, egamma AUTHOR

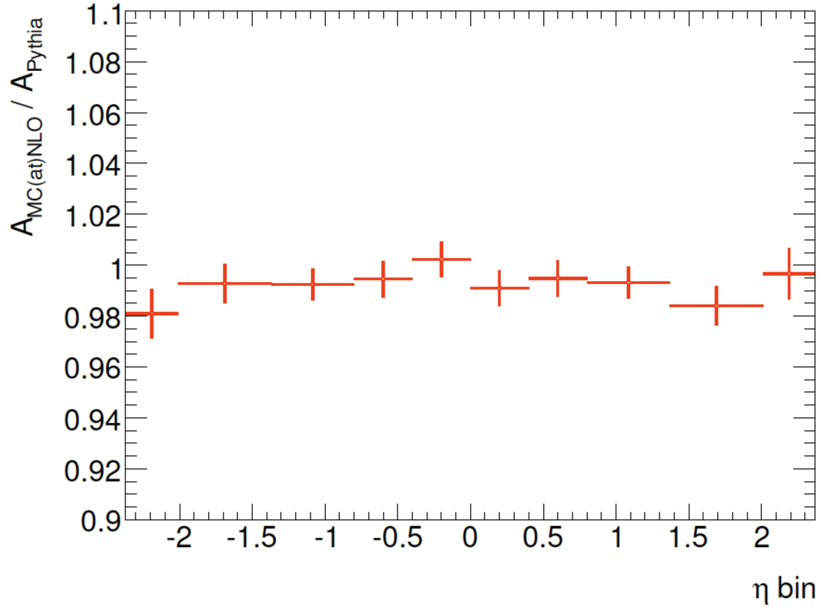
|η| < 2.37 and exclude 1.37 < |η| < 1.52

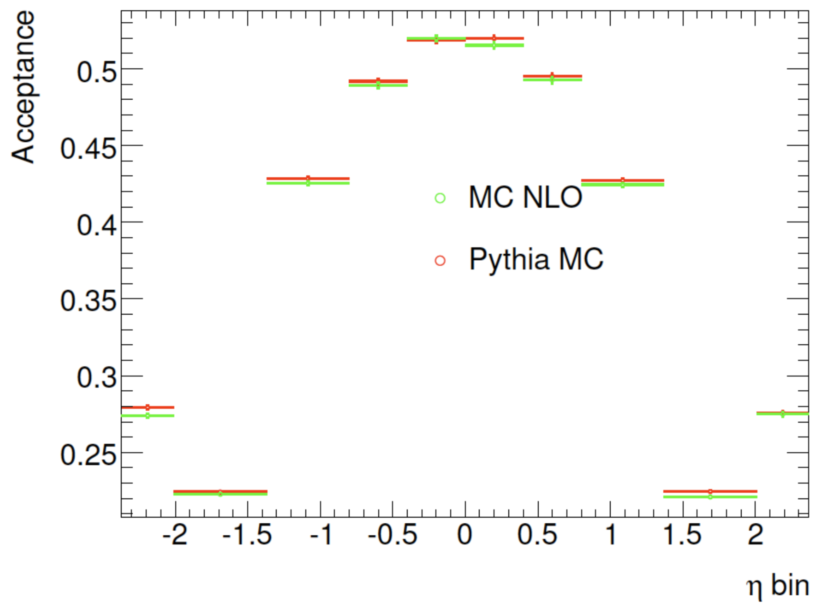
70 < Mee (Loose < 110 GeV

ElOppCharge: -1

P_T (Z) < 120 GeV

Generated events: 70 < M_ee < 110 GeV





Efficiency Treatment

$$N_r = N_{rec}^{cuts,RC} = \sum_{ev} w_{ev} = \sum_{ev} \frac{\varepsilon_{ev,data}}{\varepsilon_{ev,MC}}$$

Each event reconstructed in a bin contributes a weight w_{ev} which is the [event wise] product of ratios of Data/MC efficiencies*) as of trigger, eID... It may depend on any variable such as η, p_t, … It thus is generally not a global correction factor.

The reconstruction efficiency can be estimated as

$$\varepsilon(\eta_e, p_T^e, \ldots) = \varepsilon^{cl}(\eta_e, p_T^e, \ldots) \times \varepsilon^{elec}(\eta_e, p_T^e, \ldots)|_{cl} \times \varepsilon^{id}(\eta_e, p_T^e, \ldots)|_{cl\&elec} \times \varepsilon^{trig}(\eta_e, p_T^e, \ldots)|_{cl\&elec\&id}.$$

cf ATLAS NOTE to appear

Any external efficiency ratio may be imported here.

In a rough first approximation, limited by data statistics, all weights are 1,
IF data and MC are in reasonable agreement.

*) termed 'event selection weighting' in muon WZ study
M.Bellomo 14.2.2010 WZ meeting. ATLAS COM

$$w_V = \sum_{\{mc\}} \frac{\epsilon_V{}^{data}(p_T, \eta)}{\epsilon_V{}^{mc}(p_T, \eta)}$$

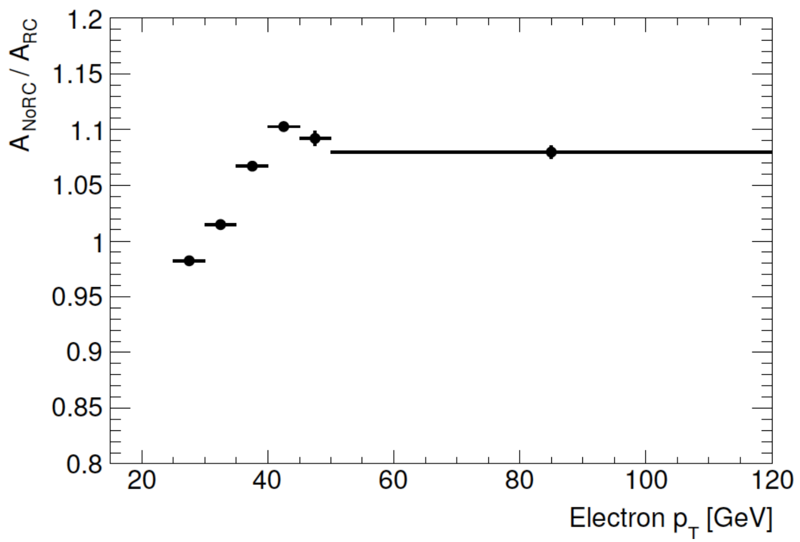
Radiative Corrections

The cross section is measured to the Born level in terms of QED h.o.

$$A_{\varepsilon} = \frac{N_{rec}^{cuts,RC}}{N_{gen}^{nocuts,noRC}} = \frac{N_{rec}^{cuts,RC}}{N_{rec}^{cuts,noRC}} \cdot \frac{N_{rec}^{cuts,noRC}}{N_{gen}^{nocuts,noRC}} \approx (1+\delta_{RC}) \cdot \frac{N_{rec}^{cuts,noRC}}{N_{gen}^{nocuts,noRC}}$$

Any valid estimate of the radiative QED corrections δ_{RC} should be on reconstruction level as the reconstruction combines electrons and FSR photons to a large extent.

In this notation the efficiencies moved to the non-radiative reconstructed events. However, when one determines the data/MC efficiency ratio one then compares efficiencies for non-radiative MC events with radiative data. Thus such a factorisation ansatz is questionable.



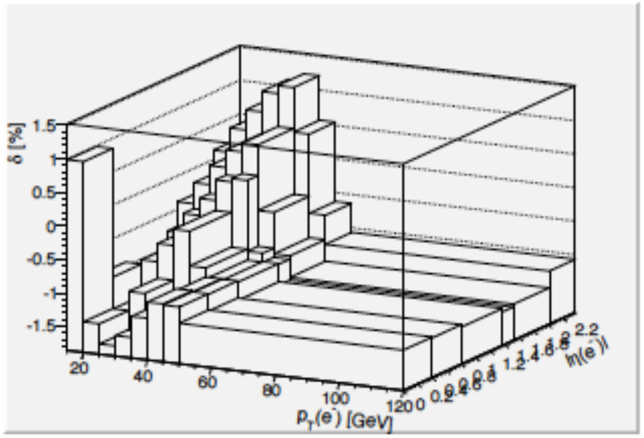
[RC (over)estimate on generator level, PYTHIA, W]

Pure Weak Corrections

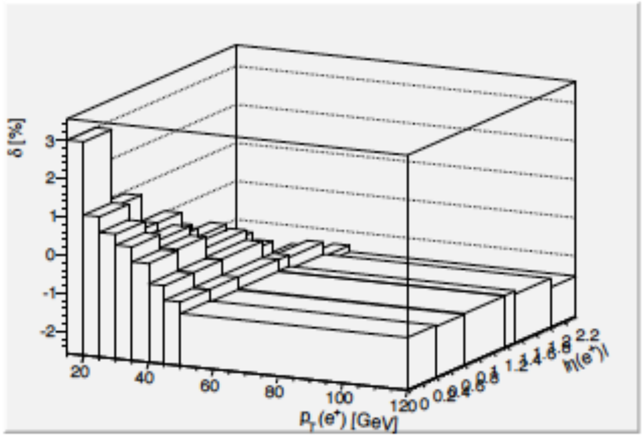
Pure weak and ISR-FSR interference corrections in G'_{μ} scheme. They are larger in the $\alpha(0)$ and in the $\alpha(M_Z^2)$ schemes. It is proposed to not correct for these to not introduce a scheme dependence of our measurement.

SANC: see ATLAS-COM- for results and further ref.

Z(e-)



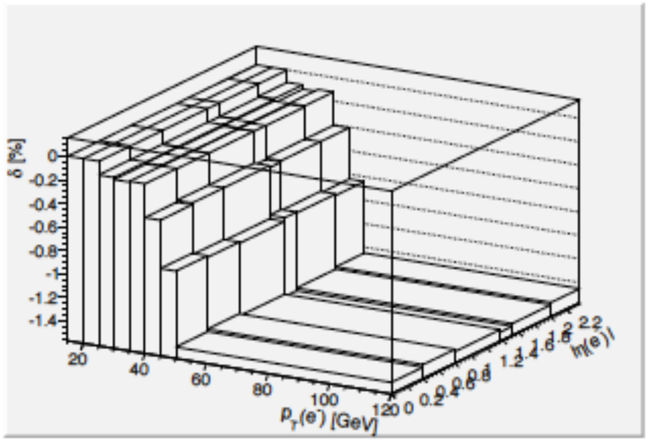
Z(e+)



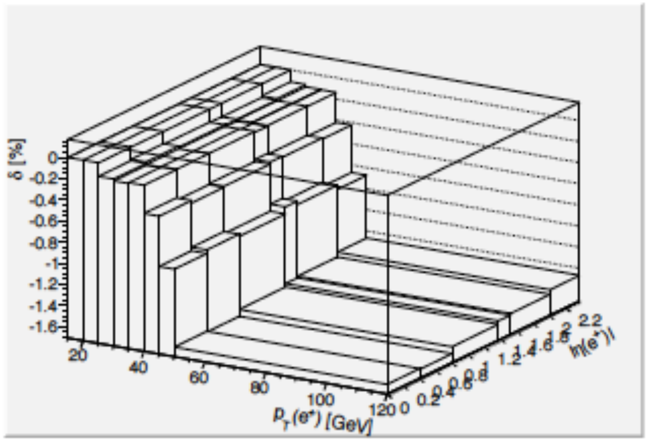
7 TeV

An example for non-trivial local variations and a small net effect

W-



W+

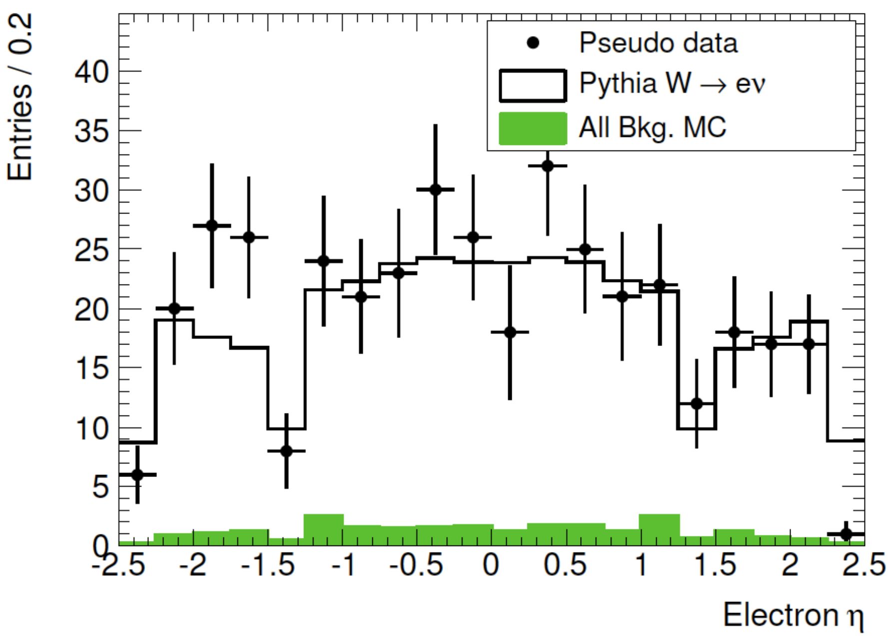


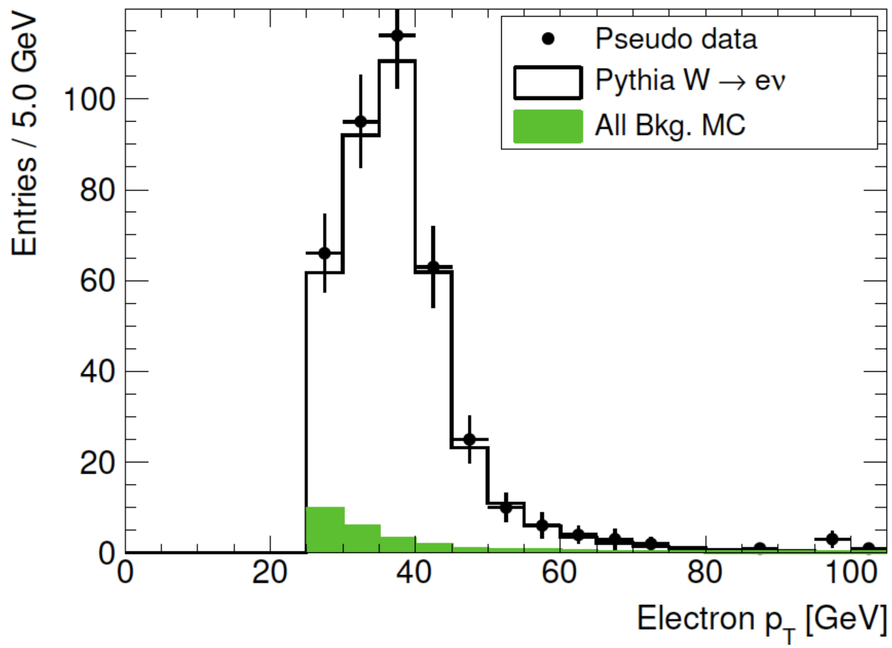
Systematic Error Estimates

$$A_\varepsilon = \frac{N_{rec}^{cuts,RC}}{N_{gen}^{nocuts,noRC}} \approx (1+\delta_{RC})\cdot \frac{N_{rec}^{cuts,noRC}}{N_{gen}^{nocuts,noRC}} \approx (1+\delta_{RC})\cdot \frac{N_{rec}^{cuts}}{N_{gen}^{cuts}}\cdot \frac{N_{gen}^{cuts}}{N_{gen}^{nocuts}} = (1+\delta_{RC})\cdot A_{rec}\cdot A_{cuts}$$

Such a factorisation ansatz is useful for systematic error estimates. A_{rec} may be used to estimate reconstruction uncertainties and A_{cuts} to study pdf effects, for example. For the calculation of the adequate correction factor, however, these are approximate weights only (from potentially inconsistent MC samples). The genuine data/MC efficiency corrections need to applied event wise to the radiative, reconstructed events.

Control of the Acceptance Correction [W, 0.1pb^{-1}]

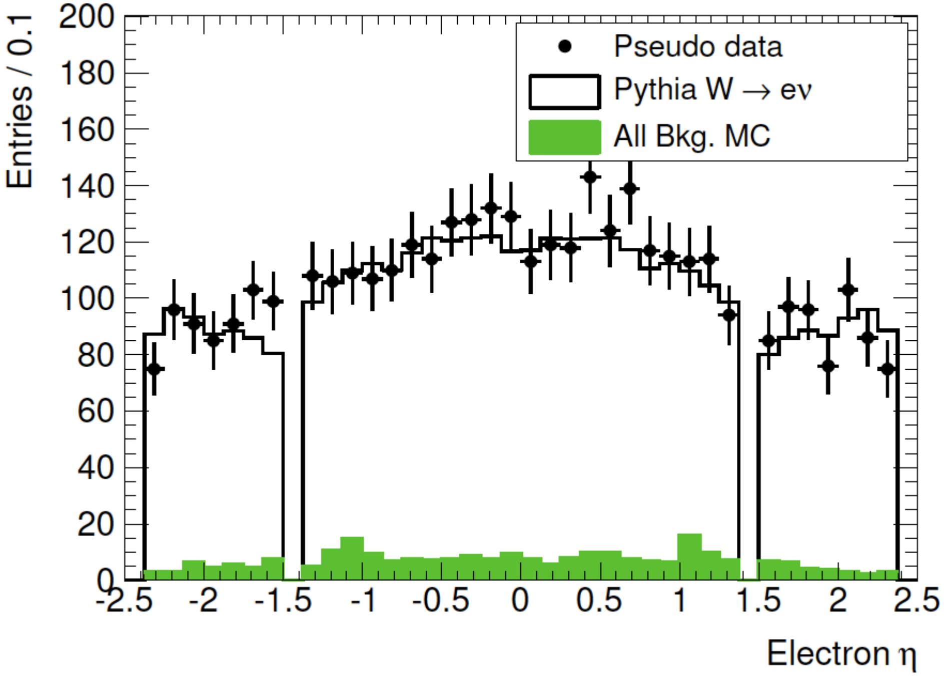


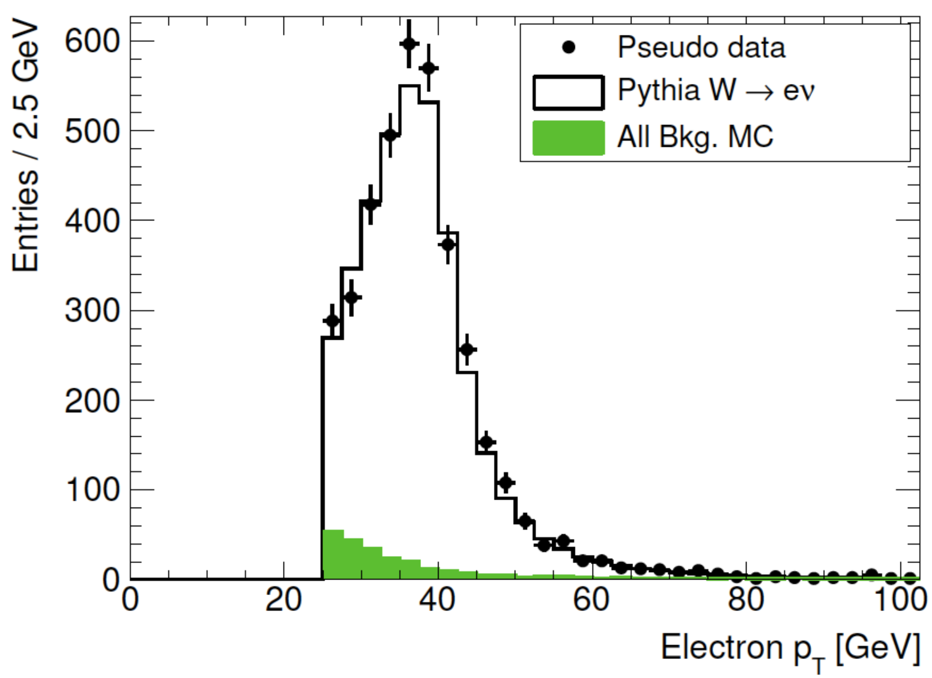


Data=MC@NLO(08)
MC=PYTHIA
bgd=JF17
0.1pb^{-1} 10 TeV

Check variety of distributions for correct description of data by the simulation.

Control of the Acceptance Correction [W, $1pb^{-1}$]

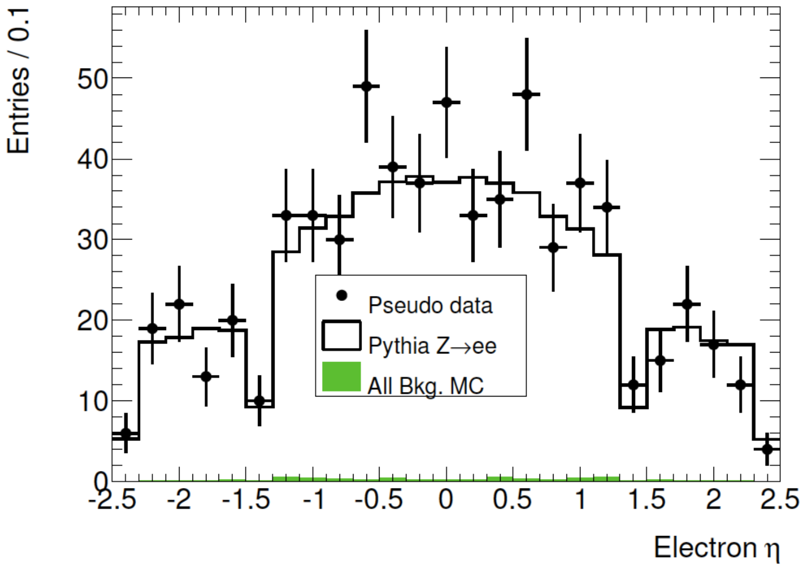


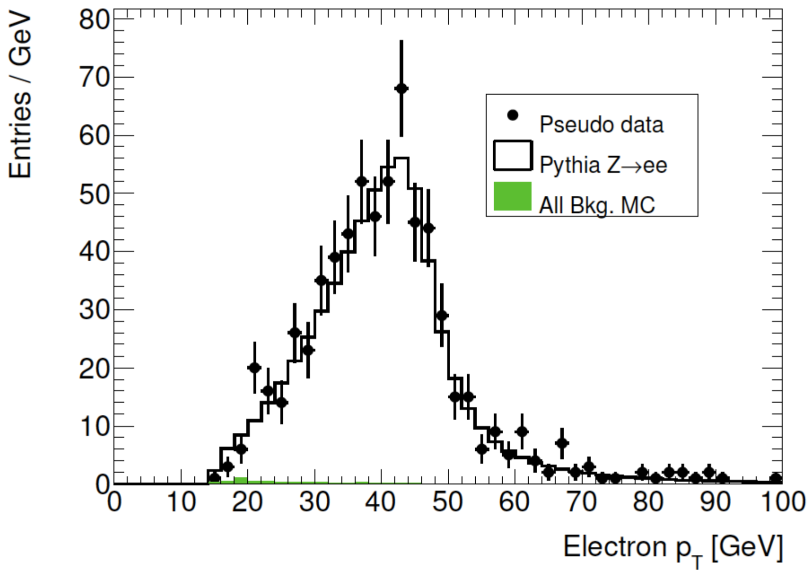


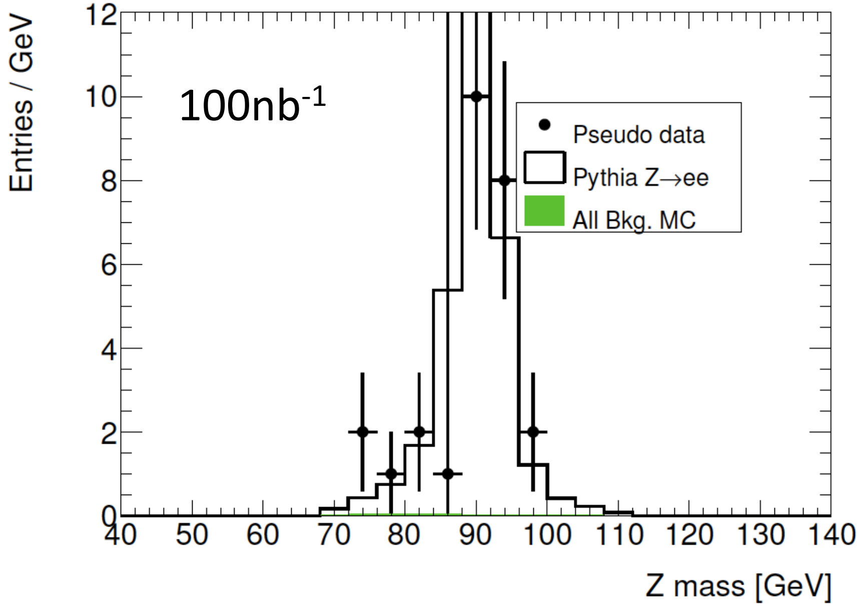
Data=MC@NLO(08)
MC=PYTHIA
bgd=JF17
$1pb^{-1}$ 10 TeV

Check variety of distributions for correct description of data by the simulation.

Control of the Acceptance Correction [Z, 1pb^{-1}]







Data=MC@NLO(08)
MC=PYTHIA
bgd=JF17
1pb^{-1} 10 TeV

Conclusions

The method suggested for use is based on a combined acceptance and efficiency factor.

The acceptance as defined encorporates inefficencies, resolution and radiative correction effects.

The acceptance as defined here is independent of the MC used (PYTHIA vs MC@NLO08) to within 1-2%.
For systematic and pdf uncertainties cf. talk of Frank E.

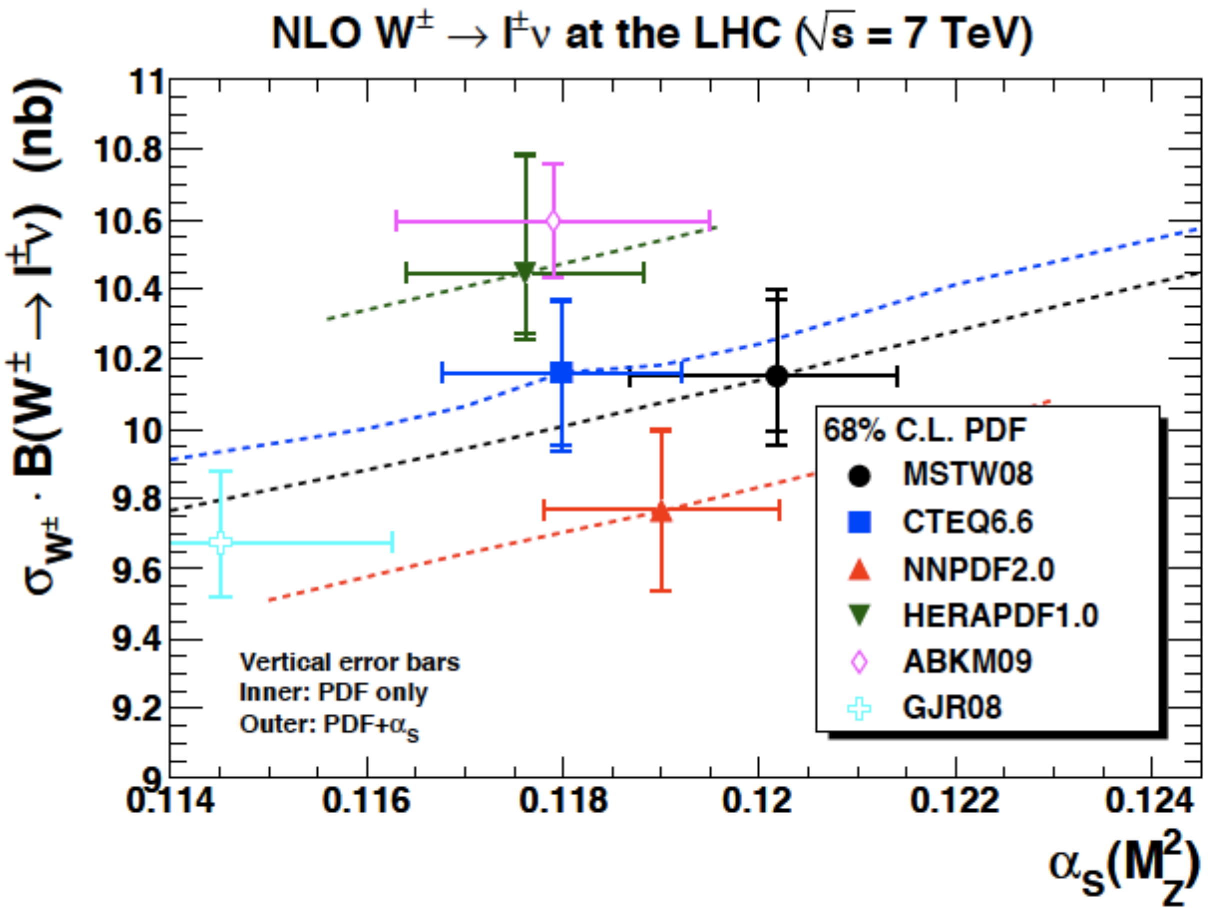
Any D/MC inefficiency determination can be imported as the method uses an "event selection weighting".

The h.o. RC are small. The residual FSR-ISR interference and pure weak corrections are proposed to not be applied but left to theoretical analyses of our data.

A "long write up" is imminent.

Dependence on Parton Distributions

Predictions on total W cross sections differ by about 10%.



G.Watt: pdf4lhc meeting , 26.3.2010 [sum of W^+ and W^-]