Acceptance Definitions and Studies

for W→eν and Z→ ee

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University of Liverpool
for ELAN

WZ – Acceptance Workshop
CERN 14.4.10

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 13, 2010

to appear

https://twiki.cern.ch/twiki/bin/view/AtlasProtected/ElectronAnalysisInitiative

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

We 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.

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. That should be extended over a definite kinematic range to avoid extrapolations.

Total Cross section

for given range of phase space

$$\Delta\sigma = \sum_{ij} \frac{\Delta^2\sigma_{ij}}{\Delta\eta_i \Delta p_{t,j}} \Delta\eta_i \Delta p_{t,j} = \frac{1}{L_{Data}} \cdot \sum_{ij} \frac{N_{Data}^{ij} - N_{Bgd}^{ij}}{A_{\varepsilon}^{ij}}$$

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)
MC: MC@NLO+HERWIG+PHOTOS: Use documentary particle level (before radiation) to determine N_{gen}.

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

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

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

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

cl=geometry, elec=cluster in e-container, id=medium ID, trig=trigger

cf NOTE + backup

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.
A.Baroncelli et al., ATL-COM-PHYS-2010-124

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

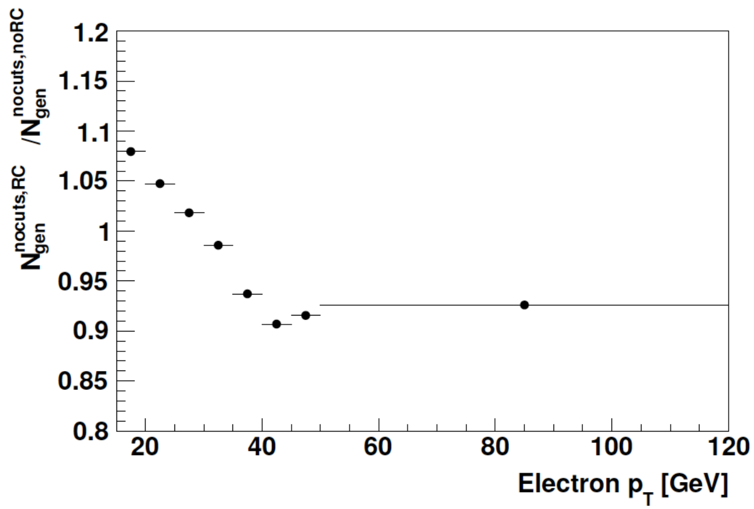
Radiative Corrections

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.

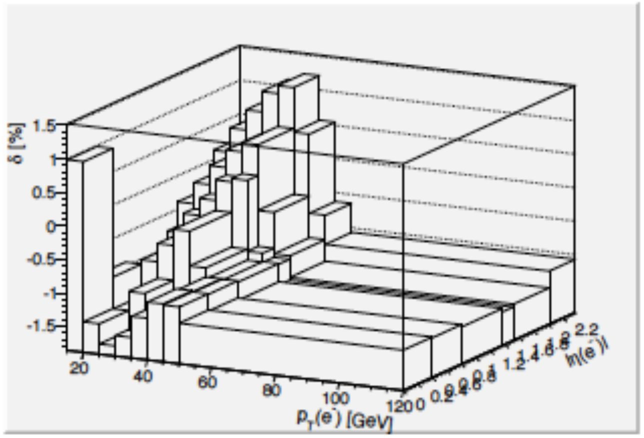


[RC (over)estimate on generator level, PYTHIA, W. flat in rapidity]

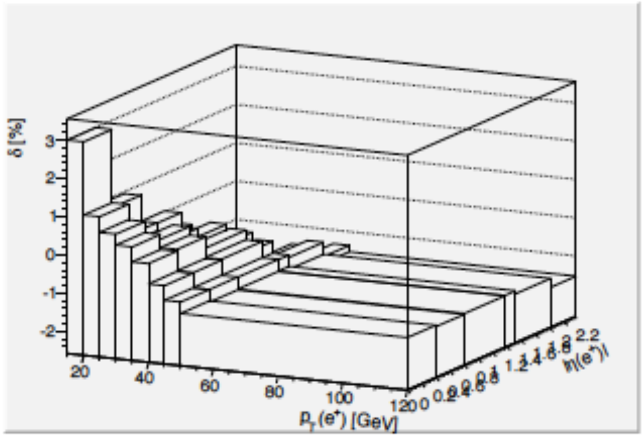
Pure Weak Corrections

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 but to quote the numbers as part of the measurement.

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



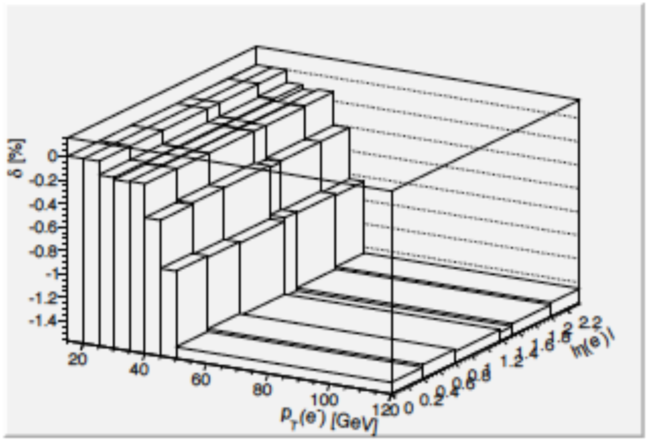
Z(e-)



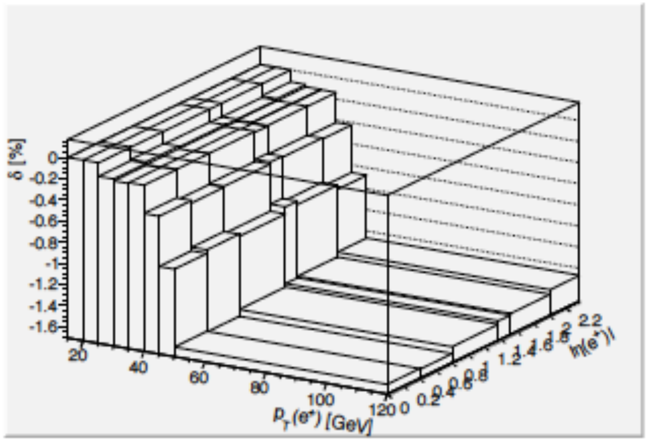
Z(e+)

7 TeV

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



W-



W+

SANC:

[1] A. Andonov *et al.*, *Comput. Phys. Commun.* **174** (2006) 481–517, hep-ph/0411186.

[2] D. Bardin *et al.*, *Comput. Phys. Commun.* **177** (2007) 738–756, hep-ph/0506120.

Systematic Error Estimates

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

A_{geom}(pdf): cf FE talk

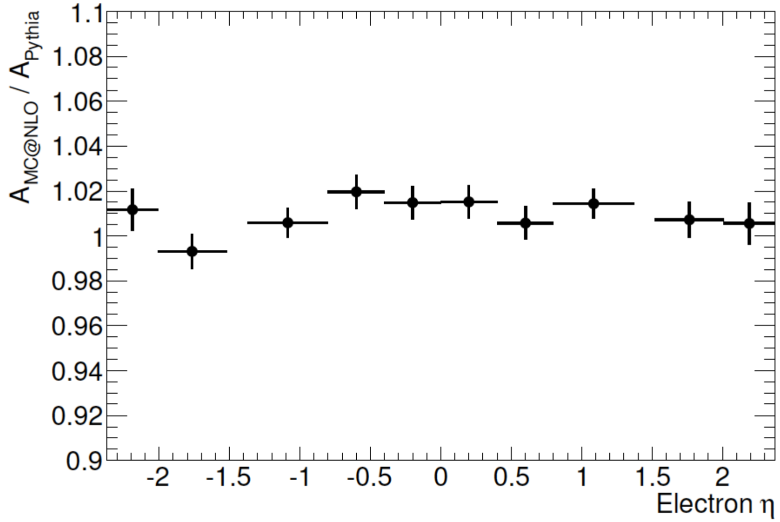
Such a factorisation ansatz is useful for systematic error estimates.

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 be applied event wise to the radiative, reconstructed events.

A_ε for $W^\pm$

MC@NLO/PYTHIA



Trigger: e10_medium

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

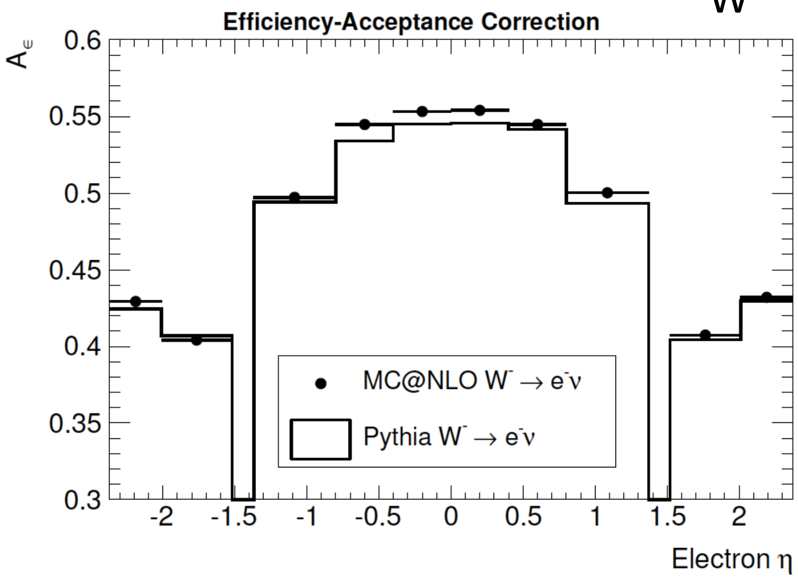
|η| < 2.37 and exclude 1.37 < |η| < 1.52

No further medium electron with $E_T > 25$ GeV

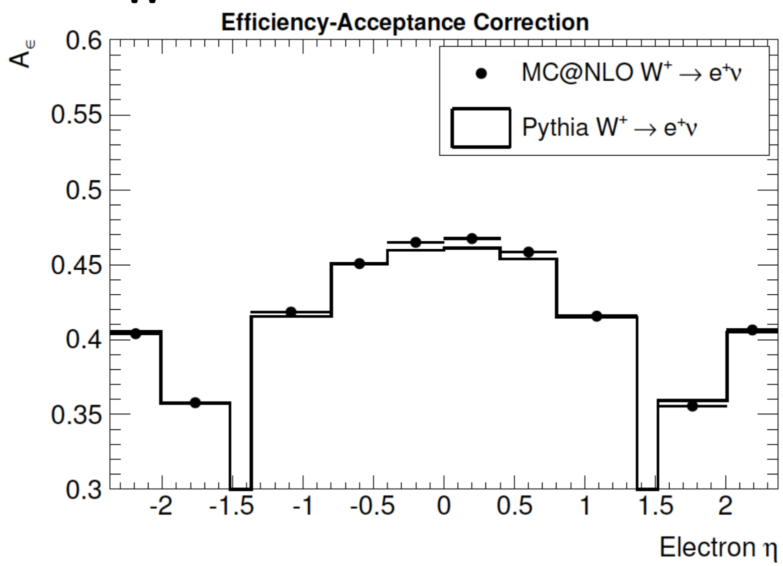
MET > 25 GeV

$M_T > 40$ GeV

W^-



W^+



A_ε for Z

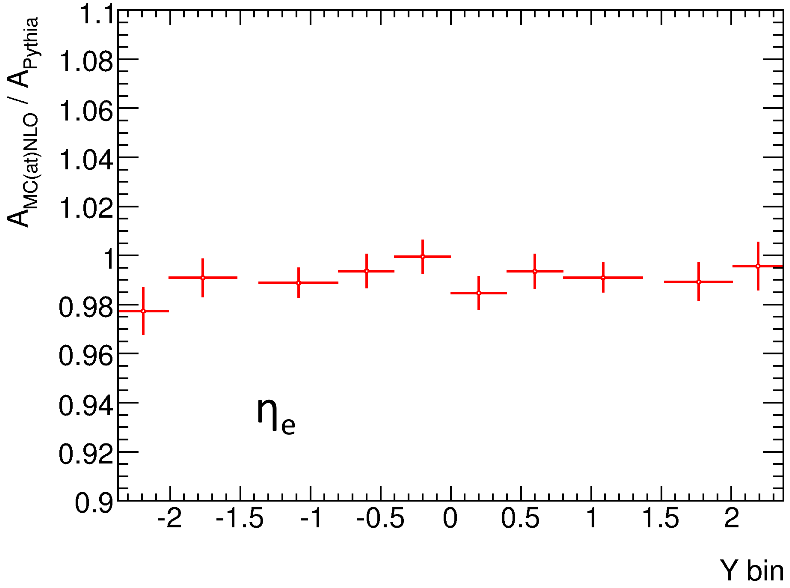
Trigger: e10_medium

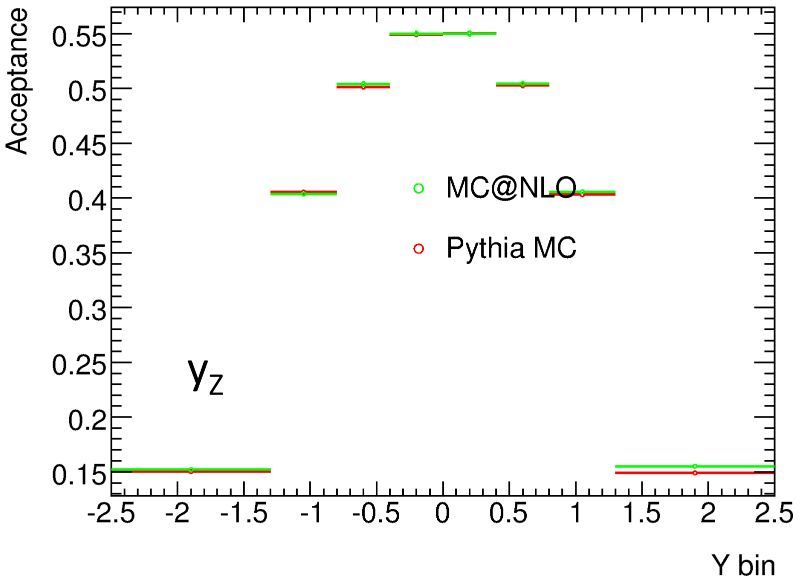
Reconstructed electrons with E_T > 15 GeV,
IsEM medium both e, egamma AUTHOR

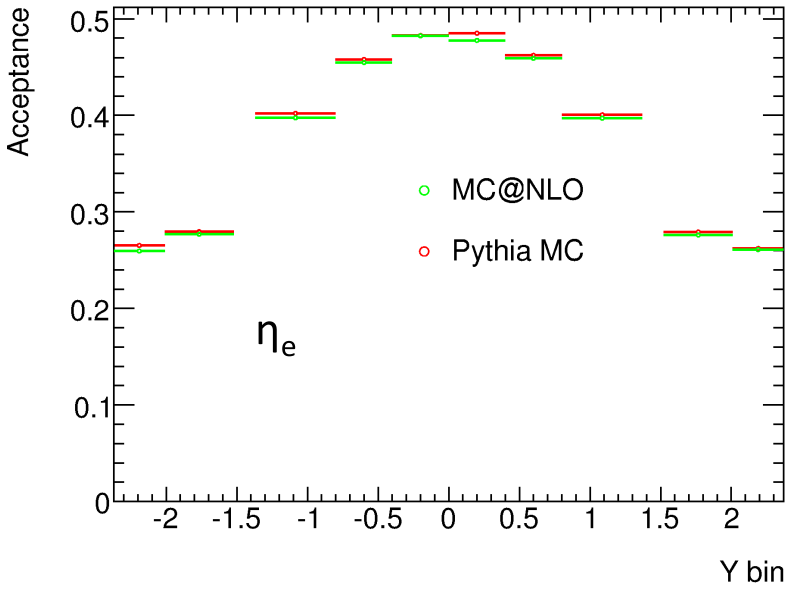
|η| < 2.37 and exclude 1.37 < |η| < 1.52

70 < M_ee < 110 GeV
Opposite charge
P_T (Z) < 120 GeV

Generated events: 70 < M_ee < 110 GeV

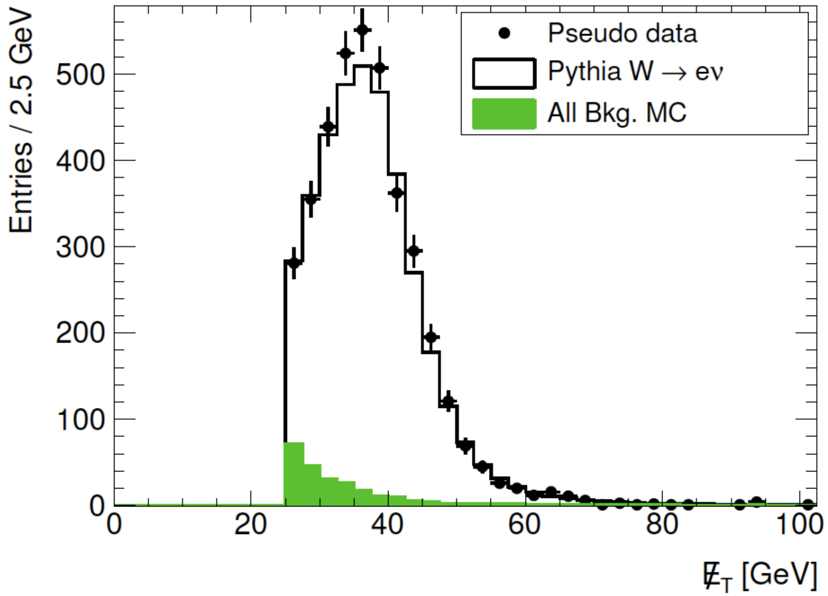


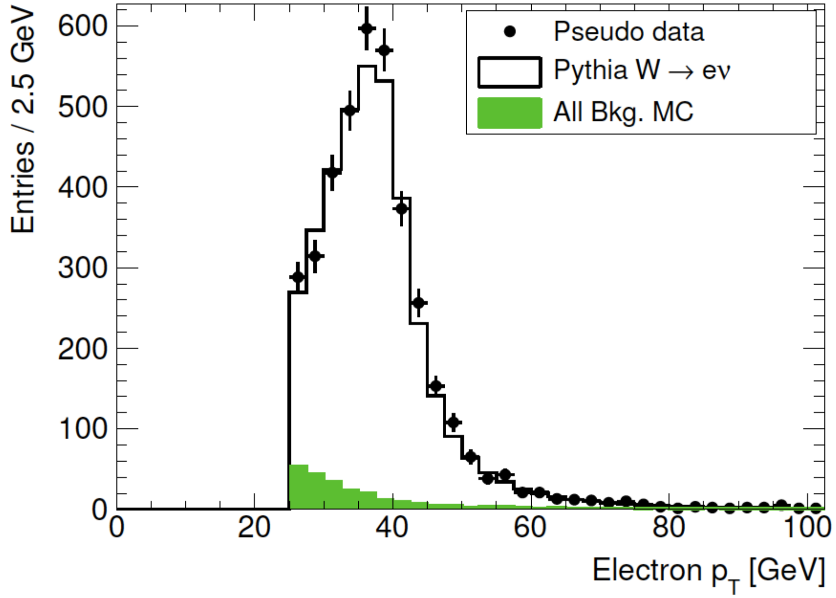


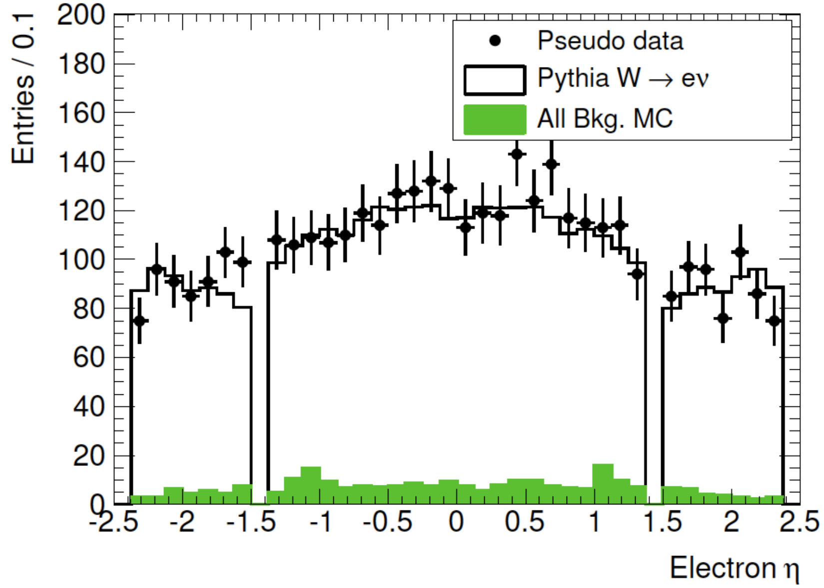


Control of the Acceptance Correction [W, $1pb^{-1}$]

Check variety of distributions for correct description of data by the simulation, e.g:

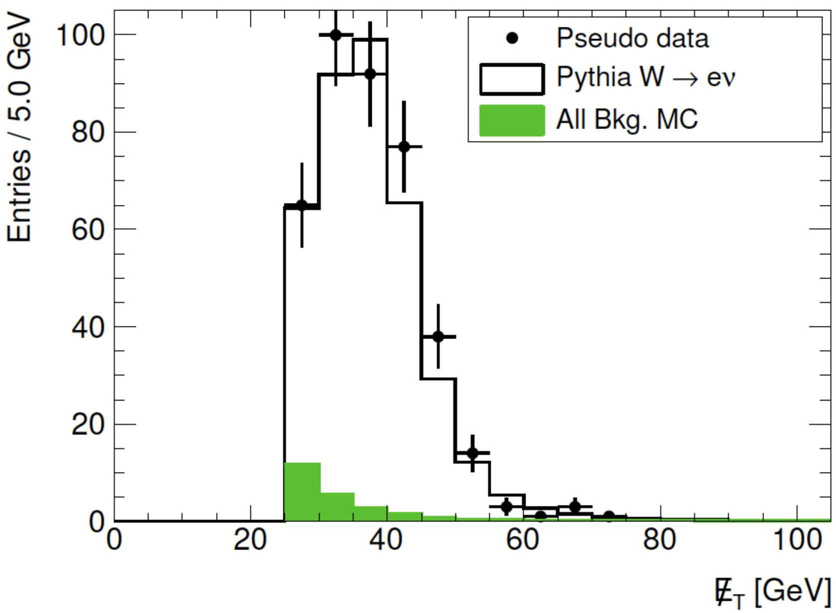


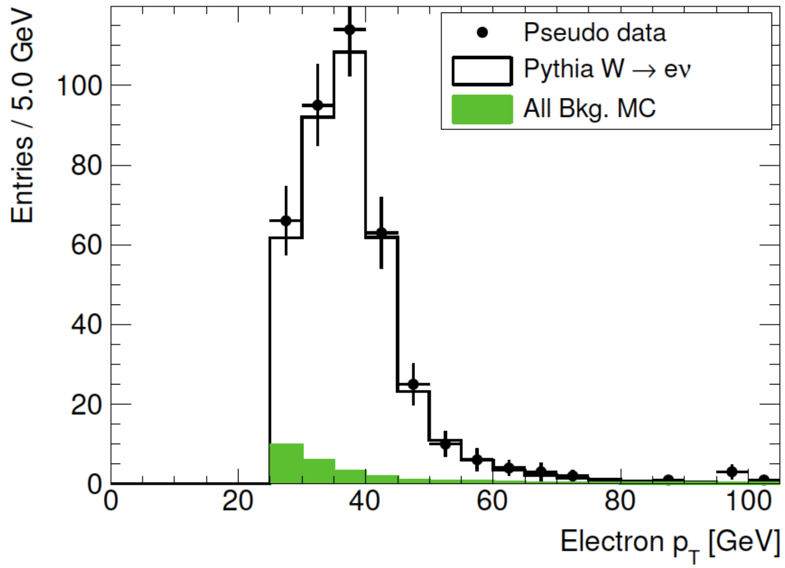


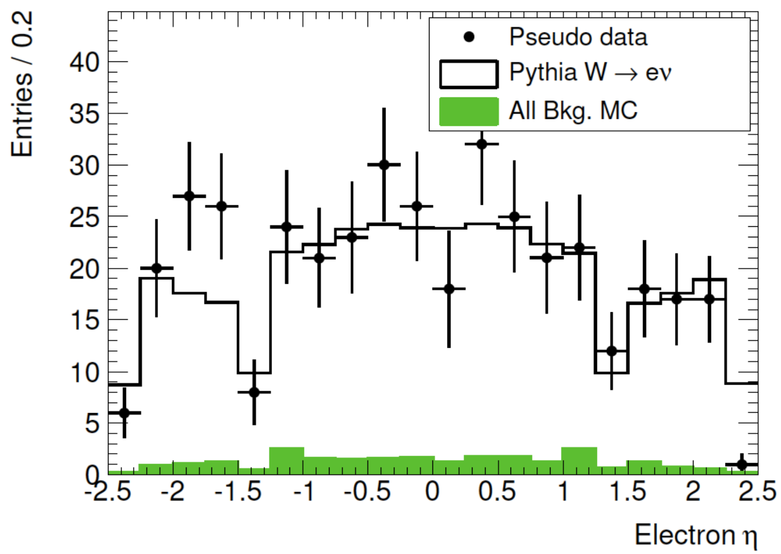


PseudoData=MC@NLO(08)
MC=PYTHIA
bgd=QCD+τν+tt̄+..
$1pb^{-1}$ 10 TeV

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



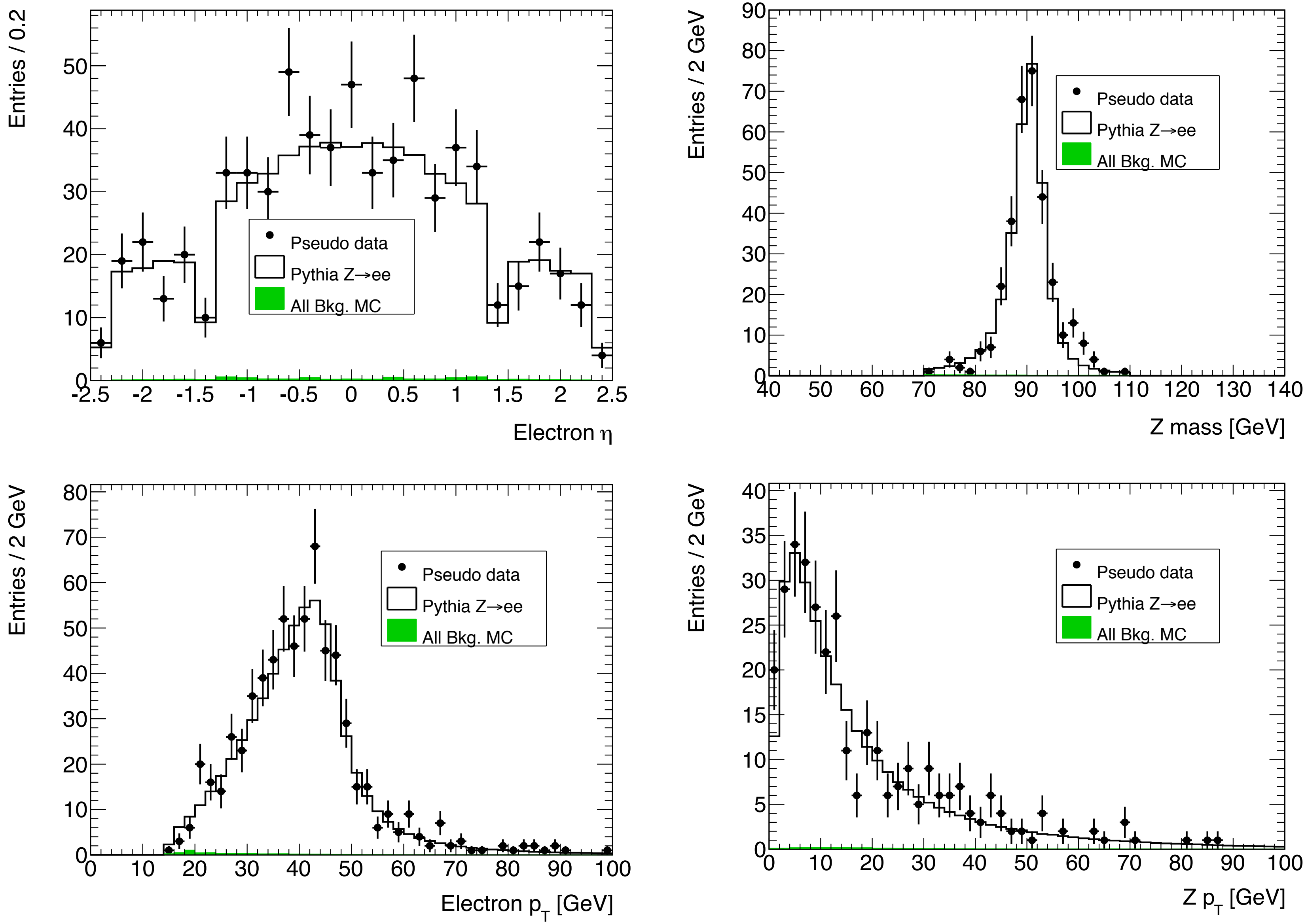




PseudoData=MC@NLO(08)
MC=PYTHIA
bgd=QCD+τν+t$\bar{t}$+..
0.1pb^{-1} 10 TeV

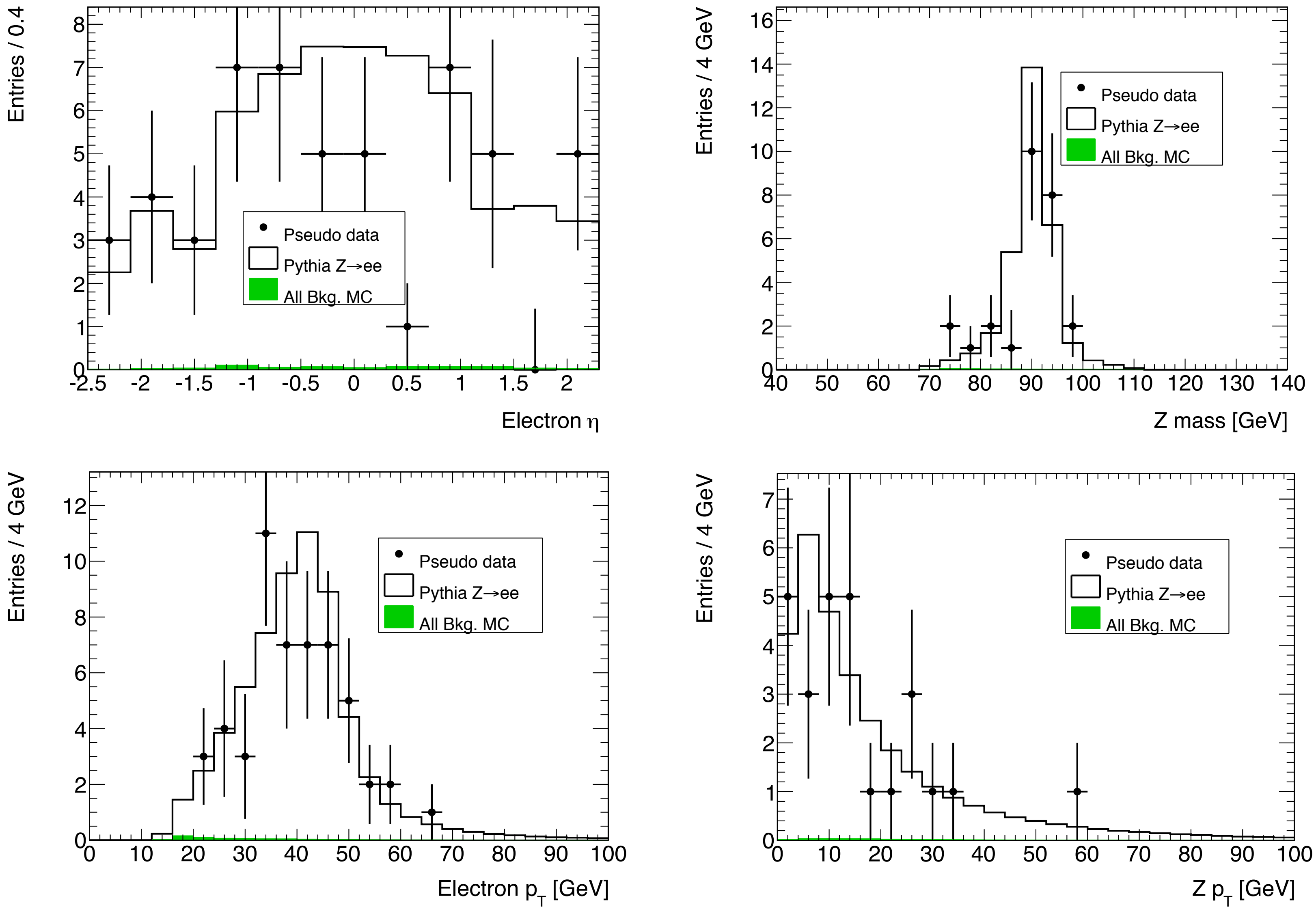
Control of the Acceptance Correction [Z, 1pb^{-1}]

PseudoData=MC@NLO(08)
MC=PYTHIA
bgd=QCD+$t\bar{t}$+.
1pb^{-1} 10 TeV



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

PseudoData=MC@NLO(08)
MC=PYTHIA
bgd=QCD+tt̄+..
1pb^{-1} 10 TeV



Summary

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

This acceptance definition incorporates inefficiencies, resolution and radiative correction effects.

The acceptance as defined here is independent of the MC used (PYTHIA vs MC@NLO08) to within 1-2%.

Any Data/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 to be also provided with the measurement.

backup

Efficiencies

The reconstruction efficiency can be estimated as

$$\varepsilon(\eta_e, p_{\mathrm{T}}^{e}, \ldots) = \varepsilon^{\mathrm{cl}}(\eta_e, p_{\mathrm{T}}^{e}, \ldots) \times \varepsilon^{\mathrm{elec}}(\eta_e, p_{\mathrm{T}}^{e}, \ldots)|_{\mathrm{cl}} \times \varepsilon^{\mathrm{id}}(\eta_e, p_{\mathrm{T}}^{e}, \ldots)|_{\mathrm{cl\&elec}} \times \varepsilon^{\mathrm{trig}}(\eta_e, p_{\mathrm{T}}^{e}, \ldots)|_{\mathrm{cl\&elec\&id}}. \tag{17}$$

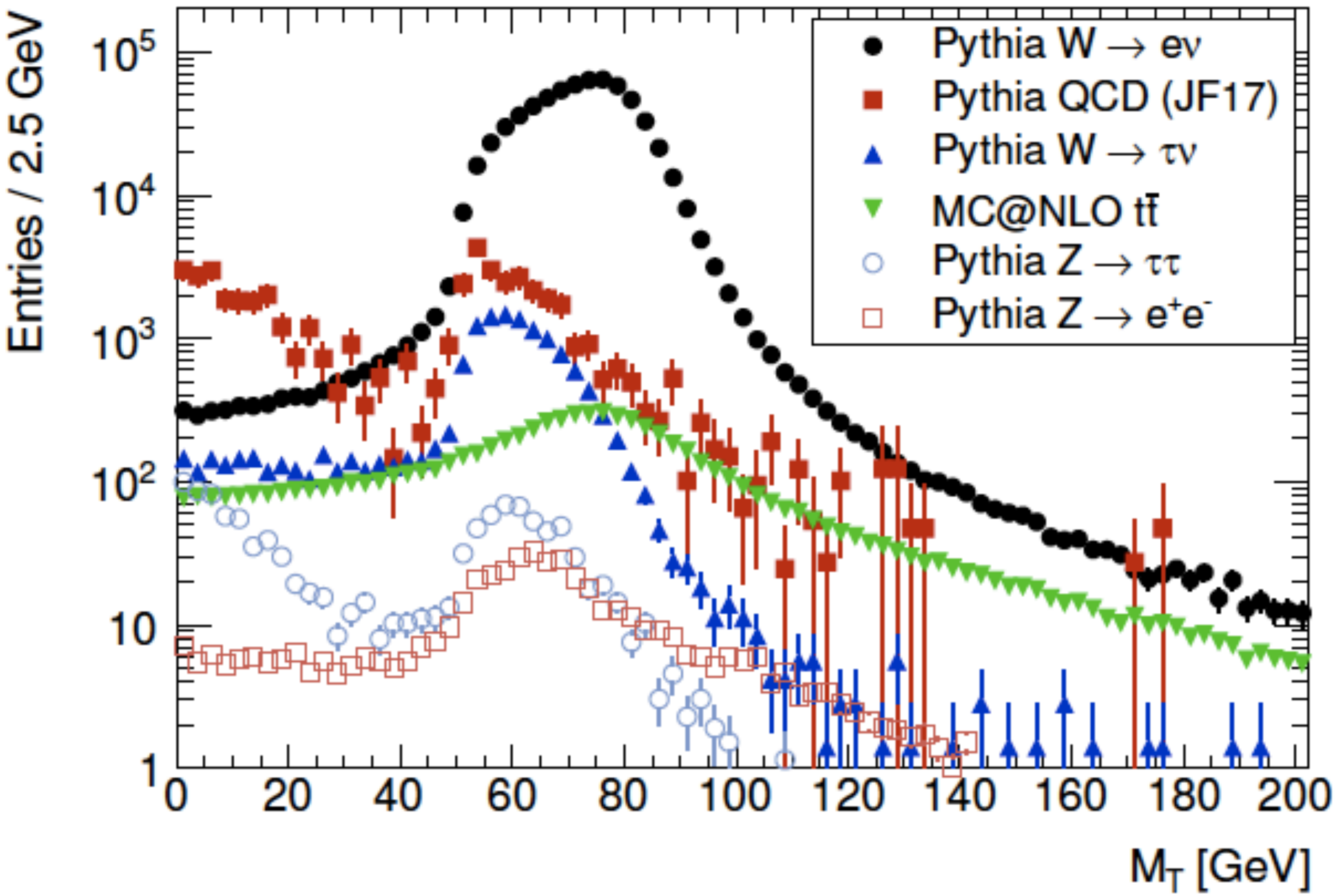
Here:

- $\varepsilon^{\mathrm{cl}}(\eta_e, p_{\mathrm{T}}^{e}, \ldots)$ is efficiency to reconstruct (two) electromagnetic cluster(s), satisfying η, p_{T} cuts (including crack cut);
- $\varepsilon^{\mathrm{elec}}(\eta_e, p_{\mathrm{T}}^{e}, \ldots)|_{\mathrm{cl}}$ is efficiency for the (two) reconstructed cluster(s) to be found in the electron container;
- $\varepsilon^{\mathrm{id}}(\eta_e, p_{\mathrm{T}}^{e}, \ldots)|_{\mathrm{cl\&elec}}$ is efficiency for the (two) reconstructed cluster(s) to pass the medium identification cuts;
- $\varepsilon^{\mathrm{trig}}(\eta_e, p_{\mathrm{T}}^{e}, \ldots)|_{\mathrm{cl\&elec\&id}}$ is the trigger efficiency for events passing all reconstruction cuts.

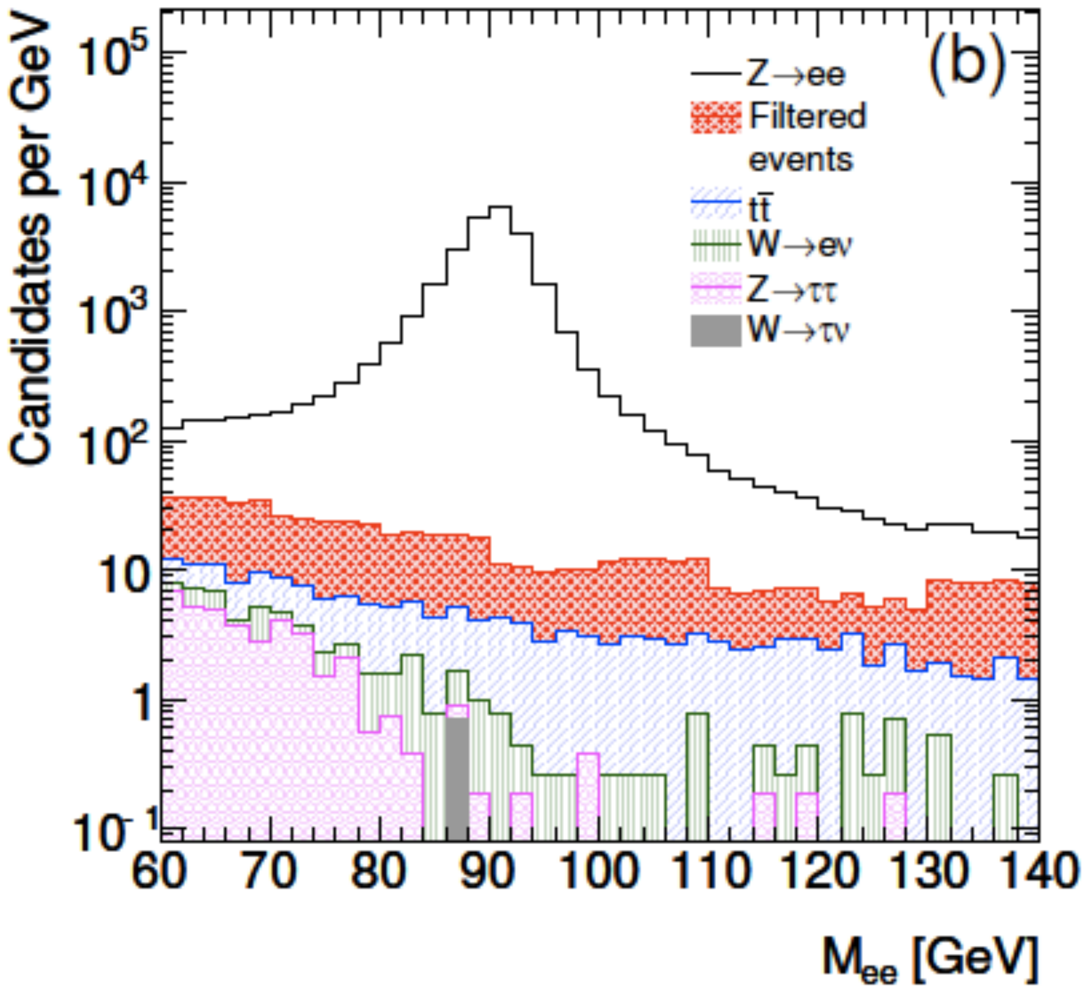
The cluster reconstruction efficiency $\varepsilon^{\mathrm{cl}}$, also know as "geometrical acceptance" is estimated for MC simulation only and assumed to be the same in data and MC. The details of the efficiency estimation for other efficiencies are given in the following sections.

From ATLAS Note to appear

W Background

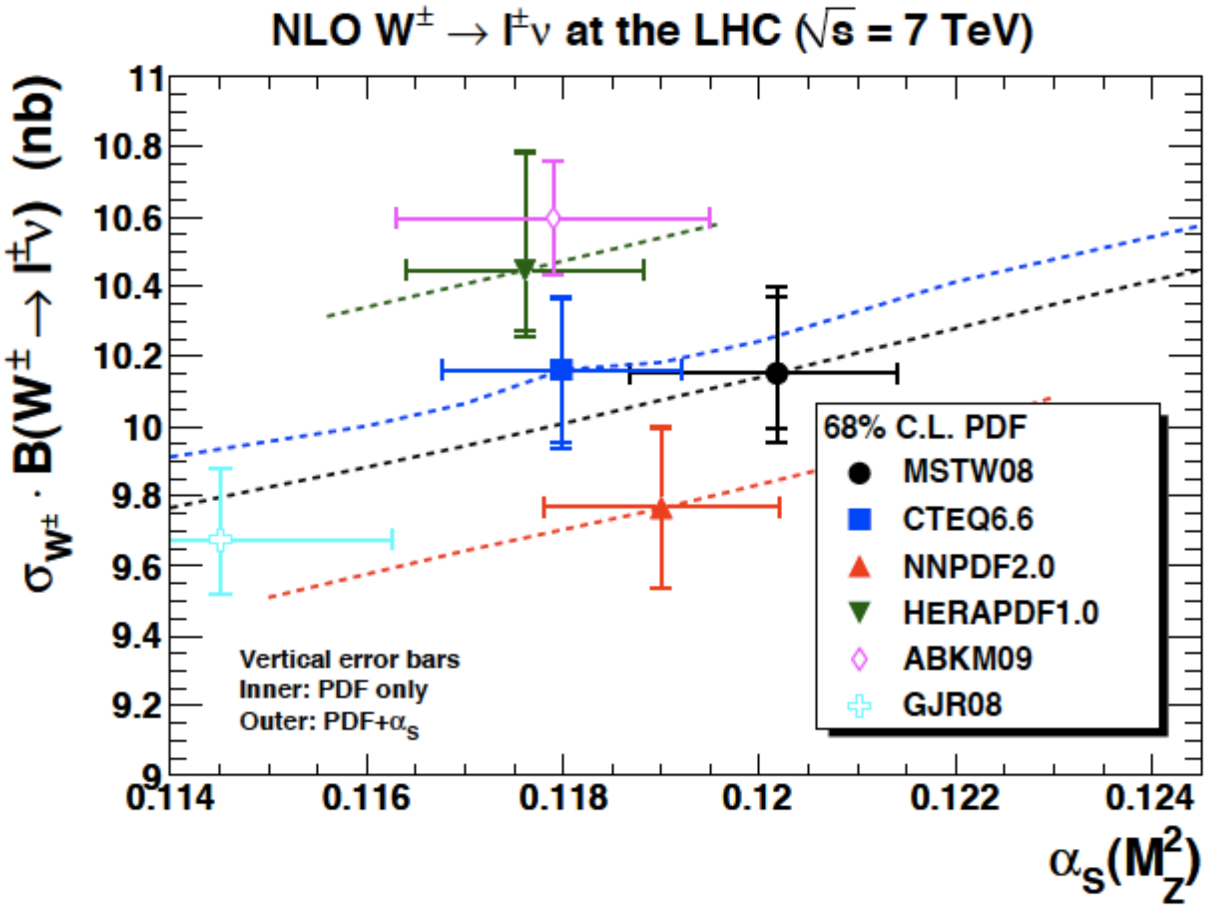


Z Background



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^-]