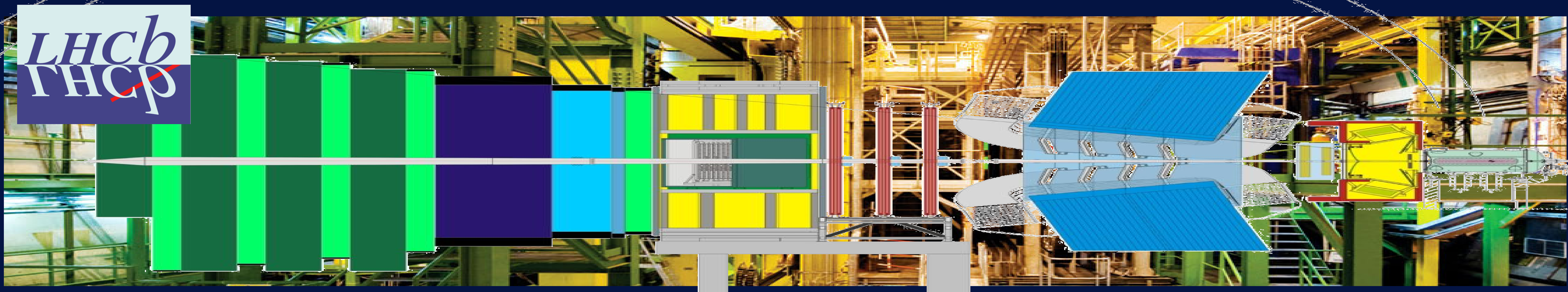

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W and Z Production at LHCb

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1. Introduction

Electroweak measurements test standard model predictions at LHC energies. LHCb has the ability to make complementary measurements to ATLAS and CMS, as the forward LHCb detector covers a different pseudorapidity range (1.8<η<4.9) (Figure 1 shows the acceptance of LHCb relative to ATLAS and CMS). Electroweak measurements at LHCb can also be used to constrain parton distribution functions in regions where they are not well understood.

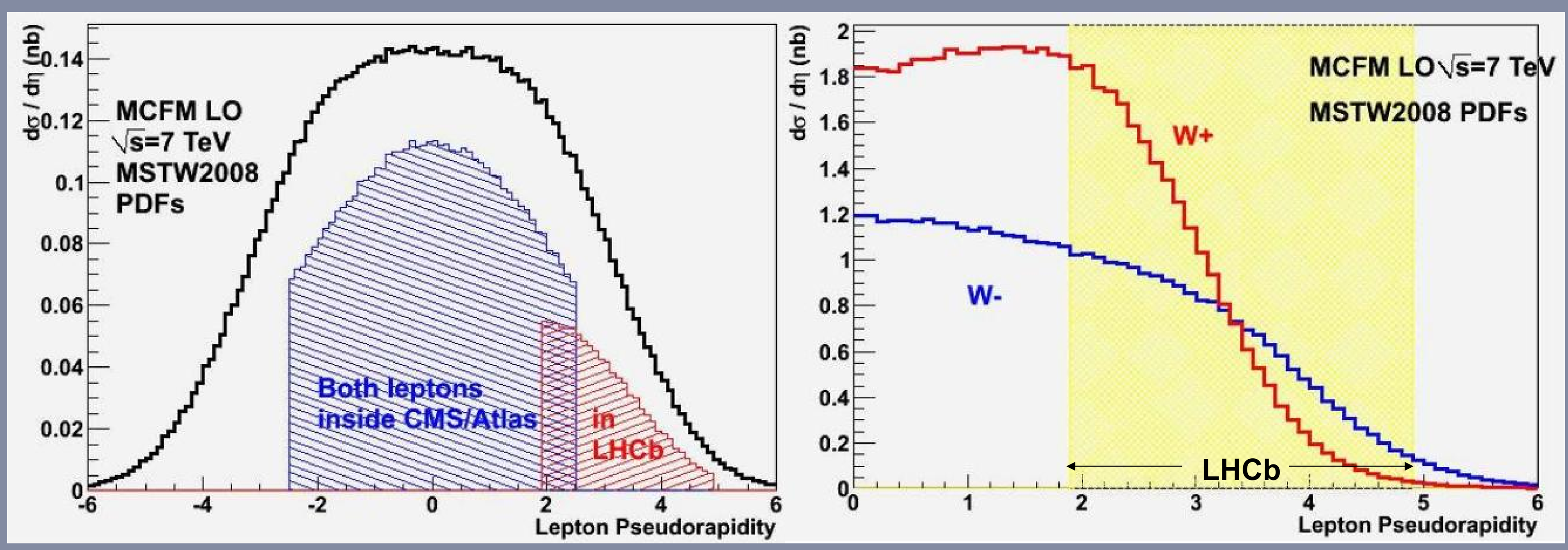

Figure 1: The acceptances of the LHCb detector for W and Z bosons. 8% of Z bosons decay with both final state leptons within LHCb's acceptance. 17% of W+ bosons decay in our acceptance, and 16% of W- bosons decay in our acceptance.

2. Z Boson Production

The dimuon decay of the Z boson leaves a clear signal in the LHCb detector (see Figure 2).

Muons associated with Z events are required to have significant transverse momentum (pT > 20GeV), and to be well within the LHCb detector (2<η<4.5). Track quality cuts are also applied. Finally, the dimuon invariant mass (plotted below in Figure 3) must lie between 81GeV and 101GeV. Events which satisfy these criteria form our Z candidates. For the first $16.5pb^{-1}$ of data collected at LHCb, we saw 833 candidate events.

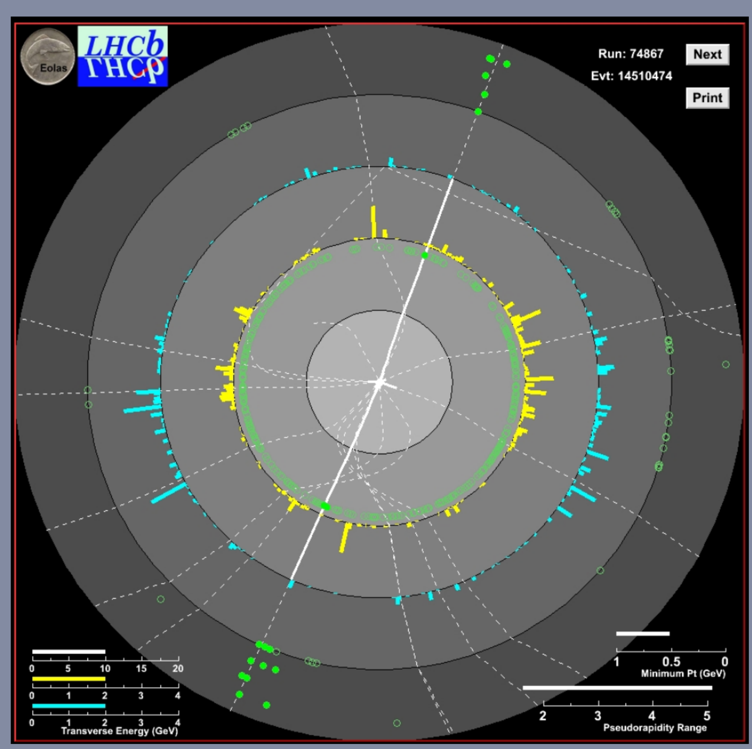

Figure 2: A Z -> μμ event observed in LHCb. The phi direction in the plot represents the phi direction in the detector. Increasing radius in the plot corresponds to increasing z-direction in the detector. Here, we see two muons approximately 180° apart, which have left hits in the muon chambers (green dots).

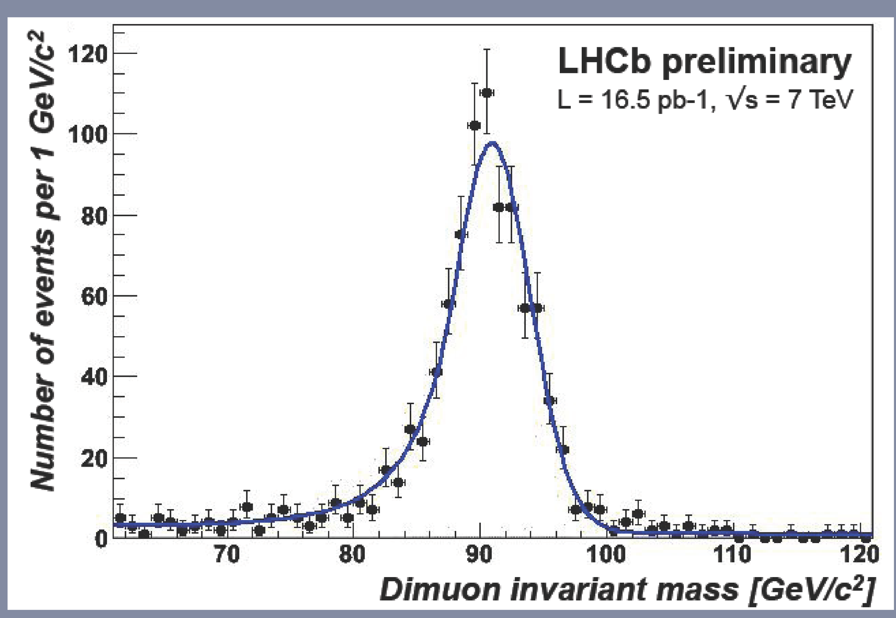

Figure 3: The Z mass peak seen with the LHCb detector.

The overall efficiency can be written as a product of various different efficiencies:

$$\varepsilon = A\, \varepsilon^{trigger}\, \varepsilon^{track}\, \varepsilon^{muon}\, \varepsilon^{selection}$$

where A is the geometric acceptance (1 by definition, as we only measure the cross-section inside our acceptance). $\varepsilon^{selection}$, the efficiency of our selection, is also 1, as we do not exclude true Z events.

The trigger, track detection and muon detection efficiencies were calculated directly from data using tag and probe methods. The results are summarised in Table 1.

The background, determined from studying minimum bias events, was found to be very small.

Overall, the efficiencies and background studies enabled calculation of a cross-section within our acceptance. (The results are outlined in Table 1).

N_Z^{tot}	833
$Z \to \tau\tau$	0.2 ± 0.2
Heavy flavours	1 ± 1
Misidentified π/K	$<< 1$
N_Z^{bkg}	1.2 ± 1.2
ϵ_{trig}^Z	0.86 ± 0.01
ϵ_{track}^Z	0.83 ± 0.03
ϵ_{muon}^Z	0.97 ± 0.01
ϵ_{sel}^Z	1.
A^Z	1.
ϵ_Z	0.69 ± 0.03
L	$16.5 \pm 1.7pb^{-1}$
$\sigma_Z(2. < \eta_1, \eta 2 < 4.5, 81 < m_Z < 101)$	$73 \pm 4 \pm 7$ pb.

Table 1: The efficiencies associated with the detecting Z bosons, and the calculated Z-boson cross-section within LHCb.

3. W Boson Production

Similar cuts are used to study W boson events. There must be an isolated high pT muon (>20GeV) associated with the event. The rest of the event must have a small pT and a small invariant mass. Track quality requirements are also applied. The efficiency is defined similarly to the Z efficiency and was measured using tag and probe techniques, and by considering Z events with one muon removed.

	$W+$	$W-$
N_W^{tot}	7624	5732
$W \to \tau\nu$	151	90
$Z \to \tau\tau$	2	2
$Z \to \mu\mu$	460	506
QCD	2194 ± 150	1654 ± 150
N_W	4817 ± 165	3480 ± 161
ϵ_{trig}^W	0.725 ± 0.03	
ϵ_{track}^W	0.73 ± 0.03	0.78 ± 0.03
ϵ_{muon}^W	0.982 ± 0.005	
ϵ_{sel}^W	0.55 ± 0.01	
A^W	1	1
ϵ_W	0.29 ± 0.01	0.31 ± 0.01
N_W^{tot}	16610 ± 800	11226 ± 650
L	16.5 ± 1.7 pb^{-1}	16.5 ± 1.7pb^{-1}
$\sigma_W(2.0 < y < 4.5)$	$1007 \pm 48 \pm 100$ pb	$682 \pm 40 \pm 68$ pb

Table 2: The measured W boson detection efficiencies, and the calculated cross-sections within LHCb.

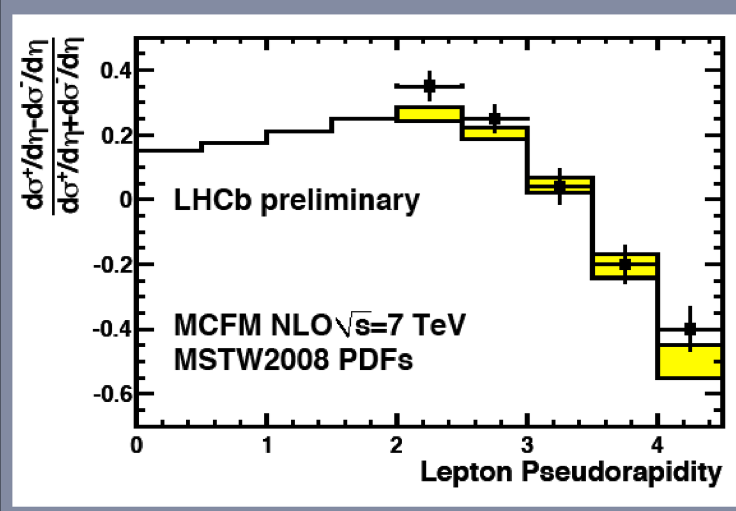

Figure 4: The W charge asymmetry as a function of lepton pseudorapidity. NLO Predictions are shown in yellow. The values of the asymmetry measured at LHCb are overlaid.

The main backgrounds are Z and QCD events. These are outlined in Table 2. The rates were extracted using shape fitting.

The W charge asymmetry was also found, and compared to NLO predictions (calculated using MCFM). This is shown in Figure 4. The measurement is made in the region 2<η<4.5, where the asymmetry changes rapidly, passing through zero.

4. Tests of the Standard Model

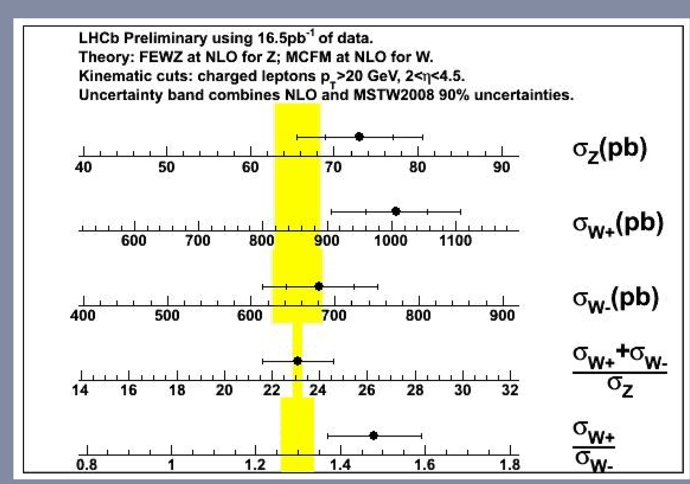

Figure 5: The measured Z and W boson cross-sections within the acceptance of LHCb compared to theoretical predictions (yellow band).

Comparisons of theoretical predictions and the LHCb measured cross-sections are shown in Figure 5.

The most precise tests of the standard model come from measuring the ratios of cross-sections. This reduces both uncertainties in the measurement and theoretical uncertainties from parton distribution functions.

We find no significant deviation from the Standard Model.

5. Outlook

The electroweak measurements made at LHCb are particularly sensitive to parton distribution functions (PDFs)(see Figure 6). Low mass Drell Yan studies probe a region of phase space that has not been measured directly before. Measurements at LHCb have a great potential to constrain the PDFs in this region.

The W charge asymmetry is also particularly sensitive to PDFs. By placing different pT cuts on the leptons, we have the potential to precisely probe the up and down sea quark distributions.

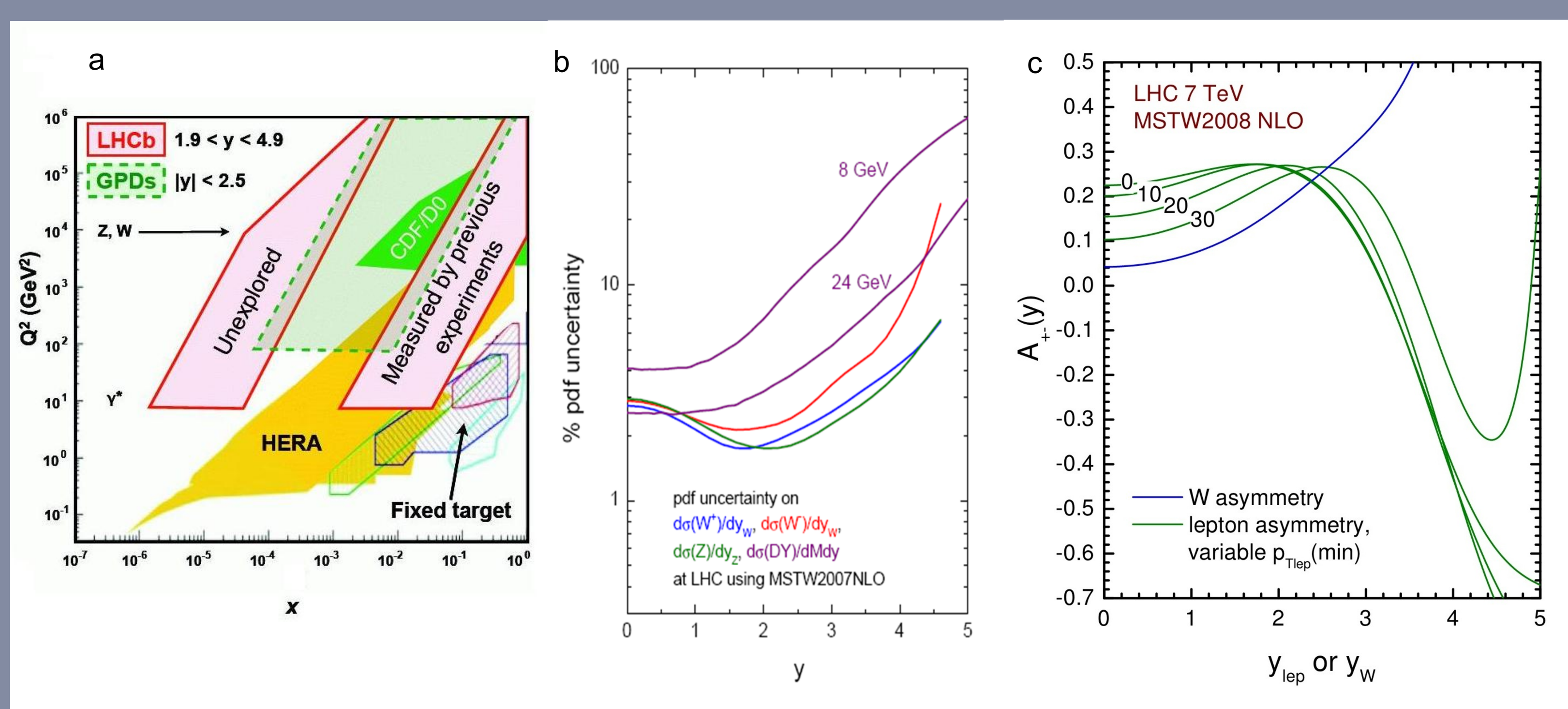

Figure 6: Low Mass Drell-Yan (and W and Z) events allow LHCb to probe previously unexplored regions of phase space. High rapidity measurements can be used to constrain the parton distribution functions, as shown in plots a and b. Plot c shows the W charge asymmetry. The different lepton curves correspond to different pT cuts on the lepton (pT>0GeV, 10GeV, 20GeV, 30GeV). b from [1]. c from [2], based on [3].

6. References

1. R.S. Thorne, A.D. Martin, W.J. Stirling, G. Watt, Proceedings DIS 2008, arXiv:0808.1847 [hep-ph].

2. W. J. Stirling, Private Communication.

3. A. D. Martin, W. J. Stirling, R. S. Thorne and G. Watt, Eur. Phys. J. C 63, 189 (2009), arXiv:0901.0002 [hep-ph].