PRAMANA — journal of physics
© Indian Academy of Sciences
Vol. 79, No. 4
October 2012
pp. 825–828

# Measurements of the electron and muon inclusive cross-sections in proton–proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector

MORITZ BACKES, on behalf of the ATLAS Collaboration
Département de Physique Nucléaire et Corpusculaire, Université de Genève, 1211 Geneva 4, Switzerland
E-mail: moritz.backes@cern.ch

**Abstract.** We present the measurements of the differential cross-sections for inclusive electron and muon production in proton–proton collisions at a centre-of-mass energy of $\sqrt{s} = 7$ TeV, using $\sim$1.4 pb$^{-1}$ of data collected by the ATLAS detector at the Large Hadron Collider. The muon cross-section is measured as a function of muon transverse momentum $p_{\mathrm{T}}$ in the range $4 < p_{\mathrm{T}} < 100$ GeV and within pseudorapidity $|\eta| < 2.5$. In addition, the electron and muon cross-sections are measured in the range $7 < p_{\mathrm{T}} < 26$ GeV and within $|\eta| < 2.0$, excluding $1.37 < |\eta| < 1.52$. After subtraction of the $W/Z/\gamma^*$ contribution, the differential cross-sections are found to be in good agreement with theoretical predictions for heavy-flavour production obtained from fixed order NLO calculations with NLL high-$p_{\mathrm{T}}$ resummation, and to be sensitive to the effects of NLL resummation.

**Keywords.** Quantum chromodynamics; heavy quark production; lepton production; experimental results; Large Hadron Collider; ATLAS.

**PACS Nos 12.38.−k; 14.65.−q**

## 1. Introduction

The inclusive production of electrons and muons is dominated by decays of charm and beauty hadrons after subtraction of the $W/Z/\gamma^*$ components and may be used to constrain theoretical predictions for heavy-flavour (HF) production. In this analysis [1], the inclusive muon cross-section is measured as a function of muon transverse momentum $p_{\mathrm{T}}$ in the range $4 < p_{\mathrm{T}} < 100$ GeV and within pseudorapidity $|\eta| < 2.5$. In addition, the electron and muon cross-sections are measured in the range $7 < p_{\mathrm{T}} < 26$ GeV and within $|\eta| < 2.0$, excluding $1.37 < |\eta| < 1.52$. The measurements are based on $\sim$1.4 pb$^{-1}$ of ATLAS data.

The main components of the ATLAS detector [2] are the inner detector (ID), the electromagnetic (ECAL) and hadronic calorimeters, and the muon spectrometer (MS). The ID provides precise track reconstruction within $|\eta| < 2.5$, employing pixel detectors close to the beam pipe, silicon microstrip detectors (SCT) at intermediate radii and a transition radiation tracker (TRT) at outer radii. Within $|\eta| < 2.0$ the TRT provides substantial discriminating power between electrons and charged hadrons for energies up to 200 GeV. The ECAL is a lead/liquid argon sampling calorimeter with four longitudinal layers, fine lateral granularity, and a coverage of $|\eta| < 2.5$. The MS covers the $|\eta|$ region up to 2.7 and consists of three superconducting air-core toroids and a precise tracking system.

The differential cross-section is determined with a bin-by-bin unfolding from the expression

$$\frac{\Delta\sigma_i}{\Delta p_{\mathrm{T}_i}} = \frac{N_{\mathrm{sig}_i}}{\Gamma_{\mathrm{bin}_i} \cdot \mathcal{L}} \cdot \frac{C_{\mathrm{migration}_i}}{\epsilon_{(\mathrm{reco+PID})_i} \cdot \epsilon_{\mathrm{trigger}_i}}, \tag{1}$$

where $N_{\mathrm{sig}_i}$ is the number of extracted signal electrons or muons with reconstructed $p_{\mathrm{T}}$ in bin $i$ of width $\Gamma_{\mathrm{bin}_i}$, $\mathcal{L}$ is the integrated luminosity, $\epsilon_{\mathrm{trigger}_i}$ is the trigger efficiency and $\epsilon_{(\mathrm{reco+PID})_i}$ is the combined reconstruction and identification efficiency. $C_{\mathrm{migration}_i}$ is the bin-migration correction factor, defined as the ratio of the number of charged leptons in bin $i$ of true $p_{\mathrm{T}}$ and the number in the same bin of reconstructed $p_{\mathrm{T}}$.

## 2. Signal selection and efficiency determination

Both electron and muon events are selected with hardware-based first-level triggers. The trigger efficiencies are extracted from the data using independent or lower-threshold triggers.

The reconstruction of electron candidates is seeded by a preliminary set of clusters in the ECAL using a sliding-window algorithm, with those clusters having a match to a suitable ID track being reconstructed [3]. Further identification criteria are the number of ID hits, track-cluster matching, the transverse impact parameter, and electromagnetic shower shape information. Dominant backgrounds after the selection are hadrons faking electrons (∼70% of electron candidates) and photon conversions (∼20%). The number of signal electrons (∼10%) from HF decays including a small contribution from $W/Z/\gamma^*$ is extracted with an extended binned maximum likelihood technique (as in [4]) using the fraction of high-threshold hits in the TRT, the ratio of electron cluster energy and ID track momentum, and the number of hits in the first layer of the pixel detector as discriminating variables.

The muon reconstruction is based on the combination of tracks in the MS and in the ID, where at least two MS track segments and an ID track with hits in two different sub-detectors are required. The selected muons include muons from HF decays and $W/Z/\gamma^*$ and backgrounds from pion and kaon decays inside the ID (‘early $\pi/K$’), as well as late $\pi/K$ and hadronic shower remnants wrongly matched to an ID track (‘fakes’). The background muon fraction is determined with a fit to the difference between the two independent $p_{\mathrm{T}}$ measurements in the ID and the MS.

The overall efficiency and migration correction factor ($C_{\mathrm{migration}}/\epsilon_{\mathrm{reco+ID}}$) for electrons is determined from PYTHIA-simulated samples of HF electrons. Systematic uncertainties are estimated from the difference expected with an increased amount of material in the ID as well as from a direct data measurement using a tag & probe (T&P) technique with heavy quark pair events.

The muon reconstruction and identification efficiency is determined from simulated samples of HF and $W/Z/\gamma^*$ decays. The simulated track efficiency is corrected with

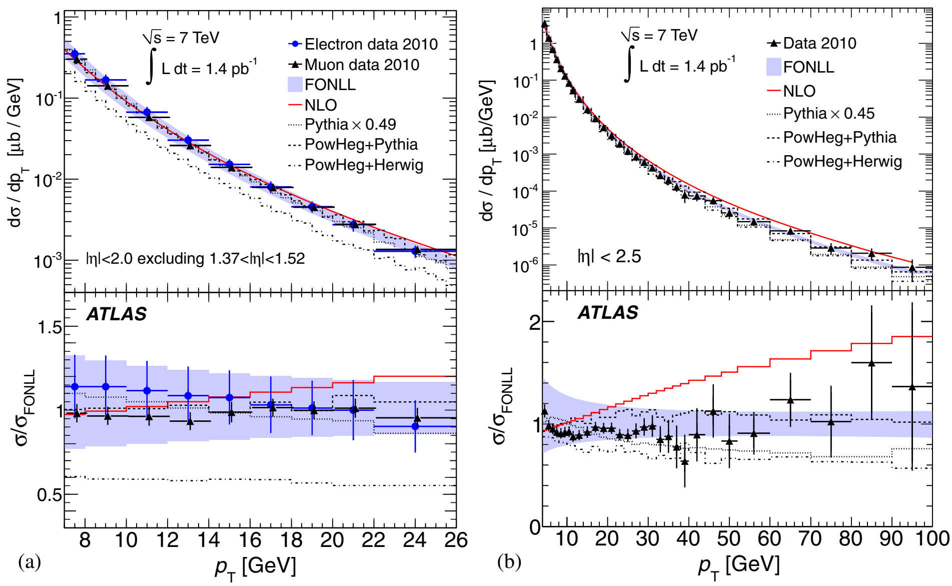


**Figure 1.** HF production cross-section for (**a**) electrons and muons and (**b**) muons only in an extended $p_{\mathrm{T}}$-range.

scale factors from independent data measurements; the identification efficiency and the migration correction are evaluated with a T&P method based on $J/\Psi$ and $Z$ events [5–7].

## 3. Conclusion

The differential cross-section for electrons and muons from HF production obtained from eq. (1) is shown in figure 1a in the $p_{\mathrm{T}}$-range 7–26 GeV and in figure 1b for the extended range of muon measurement. The overall systematic uncertainty of the electron measurement (up to 17%) is dominated by the uncertainties of the signal-extraction method (up to 8%) and the material uncertainty in the detector volume upstream of the ECAL (up to 10%). For the muon measurement, the statistical uncertainty of the signal extraction templates (up to ∼8%) and integrated luminosity (3.4%) make up the largest part of the overall uncertainty (up to 8%). A comparison is made to the prediction of the `FONLL` [8] theoretical framework, in which the HF production cross-section is calculated in pQCD by matching the fixed order NLO terms with NLL high-$p_{\mathrm{T}}$ resummation. The measured results are fully compatible within the overall 20–40% `FONLL` uncertainty, which is dominated by the renormalization and factorization scales (up to 35% at low $p_{\mathrm{T}}$) and the uncertaintiy on the choice of the heavy quark masses (up to 9% at low $p_{\mathrm{T}}$). The deviation of the NLO-only prediction of `FONLL` indicates that the measurement is sensitive to the NLL correction.

## References


[1] The ATLAS Collaboration, arXiv:1109.0525 [hep-ex]
[2] The ATLAS Collaboration, *J. Instrum.* **3**, S08003 (2008)
[3] The ATLAS Collaboration, arXiv:1110.3174 [hep-ex]
[4] The ATLAS Collaboration, ATL-PHYS-PUB-2009-077 (2009), https://cdsweb.cern.ch/record/1177160
[5] The ATLAS Collaboration, ATLAS-CONF-2011-046 (2011), https://cdsweb.cern.ch/record/1338575
[6] The ATLAS Collaboration, ATLAS-CONF-2011-008 (2011), https://cdsweb.cern.ch/record/1330715
[7] The ATLAS Collaboration, ATLAS-CONF-2011-021 (2011), https://cdsweb.cern.ch/record/1336750
[8] M Cacciari, M Greco and P Nason, *J. High Energy Phys.* **9805**, 007 (1998)