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Jana Nováková

Standard Model Measurements with the ATLAS Detector

Monte Carlo Simulations of the Tile Calorimeter and Measurement of the $Z \rightarrow \tau\tau$ Cross Section

Doctoral Thesis accepted by
the Charles University in Prague, Czech Republic

Springer

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ISSN 2190-5053 ISSN 2190-5061 (electronic)
ISBN 978-3-319-00809-7 ISBN 978-3-319-00810-3 (eBook)
DOI 10.1007/978-3-319-00810-3
Springer Cham Heidelberg New York Dordrecht London

Library of Congress Control Number: 2013942990

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Publications Related to This Thesis

1. "Measurement of the Z to tau tau Cross Section with the ATLAS Detector"

   The ATLAS Collaboration

   Phys. Rev. D84 (2011) 112006

2. "Readiness of the ATLAS Tile Calorimeter for LHC collisions"

   The ATLAS Collaboration

   Eur. Phys. J. C (2010) 70

3. "$Z \to \tau\tau$ cross section measurement in proton–proton collisions at 7 TeV with the ATLAS experiment"

   The ATLAS Collaboration

   ATLAS public document ATLAS-CONF-2012-006, CERN, 2012

4. "Description of the Tile Calorimeter Electronic Noise"

   A. Artamonov, L. Fiorini, B. T. Martin, J. Nováková, A. Solodkov, I. Vichou

   ATLAS internal document ATL-TILECAL-INT-2011-002, CERN, 2011

Supervisor's Foreword

The Large Hadron Collider (LHC) at CERN has been built to explore the world of elementary particles and their interactions at an unprecedented high energy and luminosity. The goal is to extend our understanding of the constituents of matter and associated physics processes by precise measurements of features of known particles and their interactions in the frame of the Standard model and, even more importantly, to search for new yet unobserved particles, whose existence would eventually establish an extension of the current theory of elementary particles.

ATLAS is one of the two general-purpose experiments at the LHC. It consists of inner tracking detector immersed in 2 T magnetic field, surrounded by electromagnetic and hadronic calorimeters and a powerful muon spectrometer. The hadronic Tile Calorimeter, made of alternating layers of steel and plastic scintillators, covers the central pseudorapidity region in the ATLAS experiment. Its main tasks are—together with other calorimeters—to provide accurate energy and position measurements of electrons, photons, isolated hadrons, taus, and jets. It also contributes in particle identification and in muon momentum reconstruction.

Jana Nováková started her Ph.D. studies in 2007, still before the LHC began its operation. She joined the Tile Calorimeter group and participated in the detector commissioning. With the advent of LHC collision data she moved to detector operations and, more importantly, she took the leading role in the Tile Calorimeter Monte Carlo simulations. Among other items, she contributed significantly in improving the calorimeter noise description and its modeling in Monte Carlo, which is non-trivial due to specific features of the calorimeter electronics. The proper noise description is critical for the reconstruction of jets as well as for other physics objects' measurements.

Simultaneously, Jana participated in the ATLAS collision data analysis. Her studies of identification and trigger efficiencies of electrons represent important contribution to reconstruction of leptonic τ decays and the cross section measurement of the process $p + p \rightarrow Z \rightarrow \ \tau + \tau$. These studies become even more important due to the recent discovery of a Higgs-like particle. The mentioned process constitutes the dominant background to the Higgs boson decay to a pair of τ leptons, which is now being extensively studied by the ATLAS collaboration.

The thesis combines two topics, reflecting Jana's work in the Tile Calorimeter group as well as her inputs in the Z boson production cross section measurements using the $Z \to \tau\tau$ decay channel. Jana often brought genuine ideas in solving problems and she demonstrated how well and accurately things can be done. I appreciated very much being her supervisor.

Prague, April 2013 Tomáš Davídek

Acknowledgments

First of all, I would like to thank Tomáš Davídek, my supervisor, for his help and guidance especially in the work related to the Tile Calorimeter. I appreciate that he was always available for discussions of various problems. He was also very helpful with technical aspects of the work.

I would like to thank my colleagues working at the Tile Calorimeter for helping me in understanding the detector properties. Especially, I would like to express my gratitude to Alexander Solodkov who taught me a lot about the Tile Calorimeter software.

Then I wish to thank the $Z \rightarrow \tau\tau$ analysis team, especially Elias Coniavitis who was the leader of the effort and who took care about the machinery to make results of our analysis public.

I am very grateful to Rupert Leitner who continuously supported my work and was available for discussions.

Last but not least, I would like to thank my family for their support and patience.

I acknowledge the financial support by grants of Ministry of Education, Youth and Sports under the reference MSM0021620859 ("Research plan") and LA08032 ("INGO Atlas").

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Abstract

Monte Carlo simulations of the Tile Calorimeter in the ATLAS experiment at the Large Hadron Collider (LHC), especially the electronic noise and multiple interactions (so-called pile-up), are discussed in the thesis. A good agreement in the cell energy distribution between data and Monte Carlo simulations is found. The cross section measurement of $Z \rightarrow \tau\tau$ events with the invariant mass between 66 and 116 GeV with the ATLAS experiment is described in the next part of the thesis. Data samples collected during 2011 corresponding to the integrated luminosity of $1.34-1.55$ fb^{-1} are used for the analysis. The measurements are performed in three different final states depending on the decay mode of the τ leptons. The measurement in the channel with one τ lepton decaying leptonically into the electron + neutrinos (schematically $\tau \rightarrow e+ \nu_e+ \nu_\tau$) and the other one hadronically (schematically $\tau \rightarrow$ hadrons $+ \nu_\tau$), especially the calculation of the nominal cross section and the evaluation of the systematic uncertainties, is discussed in details in the thesis.