Precision of the ATLAS muon spectrometer
Woudstra, M.J.

Citation for published version (APA):
Woudstra, M. J. (2002). Precision of the ATLAS muon spectrometer

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: http://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
# Contents

## Introduction ................................. .11

## Chapter 1  The Large Hadron Collider and the ATLAS experiment ...................... .19
1.1 The Large Hadron Collider .................. .19
1.2 The LHC physics program in a nutshell  ... .20
1.3 The ATLAS experiment  ...................... .22
    1.3.1 The inner detector .................. .22
    1.3.2 The calorimeters .................... .24
    1.3.3 The muon spectrometer ............... .24
    1.3.4 The trigger system ................. .26

## Chapter 2  Muon spectrometer design .................. .29
2.1 Overview ................................... .29
2.2 Muon measurement principle ............... .31
2.3 Monitored drift tube chambers ............. .31
    2.3.1 Operating principle ............... .32
    2.3.2 Single drift tube .................... .33
    2.3.3 Full chamber ........................ .34
    2.3.4 Projective tower .................... .37
2.4 Rasnik alignment monitor ................... .38
    2.4.1 Basic principle ..................... .38
    2.4.2 The mask, lens, sensor and read-out ... .38
    2.4.3 Image analysis ....................... .40
    2.4.4 Performance ......................... .40
2.5 Alignment of the chambers .................. .44
    2.5.1 In-plane system ...................... .44
    2.5.2 Projective system .................... .45
    2.5.3 Praxial and other systems .......... .45
    2.5.4 Calibration of the alignment systems ... .47
2.6 Muon momentum resolution ................... .48

## Chapter 3  Muon chamber mechanical precision .................. .51
3.1 The X-ray tomograph ....................... .51
    3.1.1 Principle of operation ............... .51
    3.1.2 The X-ray beams and scintillator counters ... .52
    3.1.3 The interferometers .................. .52
    3.1.4 The calibration rulers ............... .53
    3.1.5 X-ray tomograph scan output: the shadowgrams ... .54
3.2 Wire reconstruction algorithms ............ .55
Chapter 4  Muon chamber measurement precision  .............. 87
  4.1  The BOL cosmic ray test stand  .............. 87
      4.1.1  The muon drift chambers  .............. 87
      4.1.2  The muon trigger  .............. 88
  4.2  Calibration of the drift tubes  .............. 89
      4.2.1  Signal propagation along the drift tube  .............. 89
      4.2.2  Time of flight of the muon  .............. 92
      4.2.3  $t_0$ and $t_{\text{max}}$ calibration  .............. 93
      4.2.4  $r$-$t$ calibration and resolution determination  .............. 95
  4.3  Track reconstruction  .............. 100
      4.3.1  Pattern recognition  .............. 100
      4.3.2  Track fit  .............. 102
      4.3.3  Drift tube detection efficiency and hit-on-track efficiency  .............. 105
  4.4  Results on BOL chambers  .............. 107
      4.4.1  Dead and noisy channels  .............. 107
      4.4.2  Uniformity of the operating point  .............. 108
      4.4.3  Efficiency  .............. 109
      4.4.4  Resolution  .............. 109
      4.4.5  Track reconstruction precision  .............. 110

Chapter 5  Muon chamber alignment precision  .............. 113
  5.1  Method of verification  .............. 113
  5.2  Description of the DATCHA set-up  .............. 114
## Precision of the ATLAS muon spectrometer

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2.1 Scintillating hodoscope</td>
<td>114</td>
</tr>
<tr>
<td>5.2.2 Resistive plate chambers</td>
<td>115</td>
</tr>
<tr>
<td>5.2.3 Muon trigger</td>
<td>115</td>
</tr>
<tr>
<td>5.2.4 Muon drift tube chambers</td>
<td>115</td>
</tr>
<tr>
<td>5.2.5 Detector control</td>
<td>117</td>
</tr>
<tr>
<td>5.2.6 Alignment systems</td>
<td>118</td>
</tr>
<tr>
<td>5.3 Simulation of the DATCHA set-up</td>
<td>118</td>
</tr>
<tr>
<td>5.4 Analysis framework</td>
<td>120</td>
</tr>
<tr>
<td>5.5 Global track reconstruction and sagitta calculation</td>
<td>120</td>
</tr>
<tr>
<td>5.6 Geometry reconstruction using straight muon tracks</td>
<td>125</td>
</tr>
<tr>
<td>5.6.1 Geometrical model</td>
<td>125</td>
</tr>
<tr>
<td>5.6.2 Determination of the geometrical parameters</td>
<td>125</td>
</tr>
<tr>
<td>5.6.3 Monte Carlo results</td>
<td>127</td>
</tr>
<tr>
<td>5.6.4 Real data results</td>
<td>128</td>
</tr>
<tr>
<td>5.7 Alignment system sagitta compared to muon track sagitta</td>
<td>131</td>
</tr>
</tbody>
</table>

### Chapter 6 Conclusions

### Appendix A X-ray tomograph analysis details

- A.1 Systematic effects due to X-ray beams a-planarity | 137
- A.2 Geometrical parameters | 142

### Appendix B Twin tubes

- B.1 Concept | 145
- B.2 Results | 147
- B.3 Conclusion | 148

### Appendix C Fitting a model to data using $\chi^2$ minimisation

- Bibliography | 153
- Summary | 157
- Samenvatting | 161
- Acknowledgements / Dankwoord | 165

---

**Contents**

9