

Contents

1	Introduction	1
	References	4
Part I Theory and Motivation		
2	The Standard Model of Particle Physics	7
2.1	Survey of Fundamental Particles and Their Interactions	7
2.2	Electroweak Interaction and Symmetry Breaking	10
2.3	Quantum Chromodynamics	15
2.4	Open Questions and Extensions	17
	References	19
3	Dark Matter	21
3.1	Basics of Cosmology	21
3.2	Relic Density	24
3.3	Evidence for Dark Matter	26
3.4	Dark Matter Candidates	31
3.5	WIMP Searches	34
3.5.1	Direct Detection	34
3.5.2	Indirect Detection	39
	References	40
4	Proton-Proton Collisions	45
4.1	Terminology	45
4.2	Parton Density Functions	46
4.3	Cross Sections	49
4.4	Event Simulation	54
4.4.1	Final State Particle Generation	55
4.4.2	Event Generators	57
	References	58

5	Mono-Jet Events as Dark Matter Signature at Colliders	61
5.1	Mono-Jet Signature of WIMP Pair Production	61
5.2	Effective Field Theory for Maverick Dark Matter	62
5.2.1	Validity of the Effective Theory	65
5.3	Simplified Models	67
5.4	Standard Model Background Processes	68
5.5	Mono-X Results After 2011	69
	References	71

Part II Experimental Facilities

6	The Large Hadron Collider	75
6.1	The Accelerator Complex	75
6.2	The LHC Bunch Structure	76
6.3	Luminosity	77
6.4	The LHC Experiments	78
6.5	Performance and Perspectives	79
	References	81
7	The ATLAS Experiment	83
7.1	General Information	83
7.1.1	The Coordinate System	83
7.1.2	Variables Used to Describe Particle Properties	84
7.1.3	Detector Overview	84
7.2	Tracking System	86
7.2.1	The Pixel Detector	87
7.2.2	The Semi-Conductor Tracker	87
7.2.3	The Transition Radiation Tracker	88
7.3	Calorimeter System	88
7.3.1	Electromagnetic Calorimeter	89
7.3.2	Hadronic Calorimeter	91
7.4	Muon System	92
7.5	Special Systems	93
7.5.1	Forward Detectors	94
7.5.2	Beam Pickup Systems	94
7.5.3	Beam Conditions Monitors	94
7.6	Trigger System	95
7.6.1	Overview	95
7.6.2	Level-1 Trigger	96
7.6.3	Central Trigger	99
7.7	Data Handling	102
7.7.1	Data Taking	102
7.7.2	Data Processing and Storage	103
7.8	Detector Simulation	104

7.9	Object Reconstruction	105
7.9.1	Electrons	105
7.9.2	Muons	106
7.9.3	Jets	107
7.9.4	Missing Transverse Energy	109
7.10	Luminosity Determination	111
	References	113

Part III Operation and Upgrade of the Central Trigger

8	Operation of the Central Trigger During Run-I	117
8.1	Orbit Monitoring	118
8.2	Bunch Group Monitoring	119
8.2.1	Histogram Digitisation	120
8.2.2	Comparing Bunch Patterns	122
8.2.3	Application to Real Data	125
8.3	Testing of Trigger Menus	129
	References	130
9	Upgrade of the Central Trigger	131
9.1	Upgrade of the Hardware During the Long-Shutdown-I	132
9.2	Central Trigger Simulation	134
9.2.1	Event Format	135
9.2.2	Inputs and Internal Objects	137
9.2.3	Simulation of Special Triggers	137
9.2.4	Trigger Decision	138
9.2.5	Output	138
9.2.6	Modifications for Running on Data	139
9.2.7	Data Quality Monitoring	139
9.3	Upgrade of the Central Trigger Simulation	141
9.3.1	Updated Event Format	141
9.3.2	New Software Packages	143
9.3.3	Adaption to New Hardware	145
	References	146

Part IV Analysis

10	Analysis Strategy	149
10.1	Signal Characteristics and Parameters	149
10.2	Estimation of Main Background Contributions	150
10.2.1	Transfer from Control Regions	150
10.2.2	Method for Combination of $Z(\rightarrow \nu\bar{\nu}) + \text{jets}$ Estimates	154
10.3	Small Background Contributions	155
10.4	Statistical Analysis	156
	References	158

11 Data and Simulated Samples	159
11.1 Data	159
11.2 Simulated Samples	160
11.2.1 Signal Process	161
11.2.2 Background Processes	162
References	168
12 Physics Objects Definitions	171
12.1 Jets	171
12.2 Electrons	172
12.3 Muons	173
12.4 Missing Transverse Energy	174
References	175
13 Event Selection	177
13.1 Preselection	177
13.2 Optimisation Studies	179
13.2.1 Quantification of Sensitivity	179
13.2.2 Cut Studies	182
13.3 Complete Signal Region Selection	192
References	193
14 Background Estimation	195
14.1 Systematic Uncertainties	196
14.1.1 Trigger	196
14.1.2 Jet Energy Scale and Resolution	196
14.1.3 Lepton Uncertainties	197
14.1.4 Soft Terms in Missing Transverse Energy	198
14.1.5 Pile-Up	199
14.1.6 Track Veto	199
14.1.7 Luminosity	199
14.1.8 Background Subtraction in the Control Regions	199
14.1.9 PDF	200
14.1.10 Shower Modeling	201
14.1.11 Matching Scale	201
14.1.12 Renormalisation and Factorisation Scales	201
14.1.13 Electroweak Radiative Corrections on the W to Z Ratio	202
14.2 Estimation of $Z(\rightarrow \nu\bar{\nu}) + \text{jets}$ Background	202
14.2.1 Estimation from a $Z + \text{jets}$ Control Region with Two Muons	202
14.2.2 Estimation from a $Z + \text{jets}$ Control Region with Two Electrons	214
14.2.3 Estimation from a $W + \text{jets}$ Control Region with a Muon	220

14.2.4	Estimation from a W + jets Control Region with an Electron.	229
14.2.5	Combination of $Z(\rightarrow \nu\bar{\nu})$ + jets Estimates	236
14.3	Estimation of $W^\pm(\rightarrow \ell^\pm\bar{\nu})$ +jets Backgrounds	238
14.3.1	$W^\pm(\rightarrow \mu^\pm\bar{\nu})$ +jets Estimation from a W + jets Control Region with a Muon.	238
14.3.2	$W^\pm(\rightarrow e^\pm\bar{\nu})$ +jets and $W^\pm(\rightarrow \tau^\pm\bar{\nu})$ +jets Estimation from a W + jets Control Region with an Electron.	239
14.4	$Z(\rightarrow \ell^+ \ell^-)$ + jets Backgrounds Taken from Simulation	246
14.5	Top and Diboson Backgrounds	247
14.6	Multi-jet and Non-collision Background	248
	References	249
15	Results and Interpretation	251
15.1	Background Summary and Model Independent Results	251
15.2	Inputs for Limit Calculation	256
15.2.1	Luminosity	257
15.2.2	Jet Energy Scale and Resolution.	257
15.2.3	E_T^{miss} Soft Terms.	258
15.2.4	Beam Energy.	258
15.2.5	Factorisation and Renormalisation Scale	259
15.2.6	PDF	259
15.2.7	ISR and FSR.	260
15.3	Dark Matter Limits	261
15.3.1	Effective Operator Limits	261
15.3.2	Simplified Model	271
15.4	Results Summary.	274
	References	274
16	Prospects with Future LHC Data	277
16.1	Estimation of Event Yields	277
16.2	Reach of the Mono-Jet Search in the EFT Framework	279
16.3	Comparison to a Simplified Model.	283
16.4	Summary of 14TeV Studies	284
	References	285
Part V Conclusion		
17	Conclusion.	289
Appendix A: Signal Simulation Samples.		293
Appendix B: Signal Tables		299
Curriculum Vitae		321

Search for Dark Matter with ATLAS

Using Events with a Highly Energetic Jet and Missing
Transverse Momentum in Proton-Proton Collisions at \sqrt{s}
= 8 TeV

Pöttgen, R.

2016, XV, 322 p. 134 illus., 124 illus. in color.,

Hardcover

ISBN: 978-3-319-41044-9