

Contents

1	Introduction	1
1.1	The Standard Model and Beyond	1
1.2	High Energy Physics Experiments and the Large Hadron Collider	4
1.3	This Thesis: Dijet Angular Distributions at LHC Energies	6
1.4	Author's Contribution	7
	References	8
2	Introduction to QCD and Collider Physics	11
2.1	Quantum Chromodynamics (QCD)	11
2.1.1	Perturbative QCD (pQCD)	12
2.2	The Parton Model	14
2.3	Hard Scattering Processes in Hadron Collisions	17
2.4	Parton Branching	18
2.5	Hadronization	21
2.6	Monte Carlo Event Generators	22
	References	23
3	NLO Monte Carlo Techniques	25
3.1	Introduction	25
3.2	The Dipole Subtraction Method	26
3.2.1	General Method	26
3.2.2	NLOJET++	30
3.3	The Phase Space Slicing Technique	30
3.3.1	General Method	30
3.3.2	JETRAD	32
3.4	Comparison of the Subtraction Method and the Phase Space Slicing Technique	32
	References	33

4	Dijet Physics at Colliders	35
4.1	Leading-Order Jet Pair Production	35
4.1.1	Massless Partons	35
4.1.2	Massive Particles	38
4.2	Dijet Angular Distributions	39
4.2.1	Parton Level Considerations	39
4.2.2	Hadron Level Considerations	41
4.3	Conclusion.	43
	References	43
5	Gravitational Scattering and Black Holes in Large Extra Dimensions	45
5.1	Extra Dimensions	45
5.1.1	Kaluza-Klein Mode Expansion and Reduction	45
5.1.2	Compactification on an Orbifold	47
5.1.3	Types of Extra Dimensions	48
5.1.4	Bounds on Extra Dimensions	48
5.2	The ADD-Model	49
5.2.1	Concept.	49
5.2.2	Lowering the Planck Scale	49
5.2.3	Implications for Low Energy Phenomenology	51
5.2.4	Kinematic Regimes.	52
5.2.5	Definitions.	52
5.3	Gravitational Scattering in the ADD Model	53
5.3.1	KK Reduction of the Graviton	53
5.3.2	Scattering Amplitude	54
5.3.3	Large Momentum Transfers: $\sqrt{s} \gg M_s$	55
5.3.4	Small Momentum Transfers: $\sqrt{s} \ll M_s$	56
5.3.5	Experimental Limits	57
5.4	Black Holes in the ADD Model	57
5.4.1	Production	58
5.4.2	Decay	58
5.5	The GravADD Generator.	59
5.5.1	Introduction	59
5.5.2	Monte Carlo Generators in Athena	60
5.5.3	Model Parameters.	60
5.5.4	Implementation in the ATLAS Software Framework Athena	61
5.5.5	Use From Inside Athena	62
	References	63

6	The ATLAS Experiment	65
6.1	Detector Layout	65
6.2	Trigger	72
6.2.1	The Jet Trigger Slice	73
6.3	Event Reconstruction	74
6.4	Data Quality	74
6.4.1	Automatic Evaluation and Display of Data-Quality Histograms: Han and Handi	75
6.4.2	Prompt Assessment of Data-Quality During Data Taking	79
	References	81
7	Jet Reconstruction	83
7.1	General Approach	83
7.1.1	Jet Reconstruction Performance Studies	84
7.2	Jet Finding Algorithms in ATLAS	85
7.2.1	Cone Algorithms	85
7.2.2	Sequential Recombination Algorithms	86
7.2.3	Anti- k_T : the ATLAS Default Algorithm	87
7.3	Input for Jet Finding Algorithms	87
7.4	Jet Energy Calibration	89
7.4.1	Overview	89
7.4.2	Step 1: Energy Hadronic Calibration	91
7.4.3	Step 2: Offset Correction	94
7.4.4	Step 3: (η, ϕ) Correction	95
7.4.5	Step 4: Response Correction	95
7.4.6	Step 5: Resolution Improvement	96
7.4.7	Step 6: Topology and Flavor Corrections	97
	References	97
8	Jet Reconstruction with 2010 ATLAS Data	99
8.1	Jet Algorithm and Jet Calibration	99
8.2	Data Quality Requirements and Event Cleaning	99
8.2.1	Run Selection	99
8.2.2	Event Selection	100
8.2.3	Jet Selection	101
8.3	Jet Reconstruction Performance	101
8.3.1	Jet Energy Scale Uncertainty	101
	References	103
9	Dijet Angular Distributions at $\sqrt{s} = 14$ TeV: A Phenomenology study	105
9.1	Introduction	105
9.2	Kinematics Cuts	105

9.3	QCD Calculations.	107
9.4	Gravitational Scattering and Black Hole Formation in Large Extra Dimensions	116
9.5	Conclusions	122
	References	123
10	Preparing ATLAS for the Measurement of Dijet Angular Distributions at $\sqrt{s} = 7$ TeV	125
10.1	Introduction	125
10.2	Trigger Study.	126
	10.2.1 Trigger Menu.	126
	10.2.2 Trigger Efficiency Using the Tag and Probe Method	126
10.3	Kinematic Cuts and Histogram Binning	129
	10.3.1 Kinematic Cuts	129
	10.3.2 Binning in χ	130
	10.3.3 QCD Distributions and Statistical Uncertainties for 10 pb^{-1}	132
10.4	NLO QCD Calculations and k-Factors	133
	10.4.1 Calculating k-Factors: General Method	133
	10.4.2 NLO QCD Calculations and k-Factors for the Dijet Angular Distributions	134
10.5	Theoretical Uncertainties.	136
	10.5.1 Renormalization and Factorization Scale Uncertainties	136
	10.5.2 PDF Uncertainties	138
10.6	Experimental Uncertainties	139
	10.6.1 General Considerations	139
	10.6.2 Estimate of Experimental Uncertainties.	141
10.7	Data Unfolding	143
10.8	Sensitivity to Black Hole Production and Gravitational Scattering in Large Extra Dimensions	145
10.9	Conclusions	148
	References	148
11	Measurement of Dijet Angular Distributions by ATLAS	151
11.1	Introduction	151
11.2	Data Selection	151
11.3	Monte Carlo Samples	152
11.4	Physics Selection Cuts	152
11.5	Results	154
	11.5.1 Systematic Uncertainties	154
	11.5.2 Distributions	155
	References	156

12 Conclusions and Outlook 157

 12.1 Conclusions 157

 12.2 Outlook 158

**Appendix A: Statistical Hypothesis Testing Using the Frequentist
Method 159**

Curriculum Vitae 165