

Contents

1	Introduction	1
2	Theory elements	3
2.1	The Standard Model of particle physics	3
2.1.1	Quantum electrodynamics	5
2.1.2	Quantum chromodynamics	8
2.1.3	Electroweak unification	11
2.2	The Drell-Yan process	12
2.2.1	Collinear factorization	13
2.2.2	The partonic cross section	16
2.3	Beyond fixed order	18
2.3.1	Transverse momentum resummation	20
2.3.2	Parton showers	24
2.3.3	Parton branching solution of DGLAP evolution	27
2.4	Small q_T factorization	27
2.5	Summary	30
3	Experimental setup	33
3.1	The Large Hadron Collider	33
3.1.1	Injection chain	34
3.1.2	Luminosity	35
3.2	The CMS detector	38
3.2.1	Superconducting solenoid magnet	39
3.2.2	Inner tracker	40
3.2.3	Electromagnetic calorimeter	42
3.2.4	Hadron calorimeter	45
3.2.5	Muon detectors	47
3.2.6	Trigger system	50
3.2.7	Luminosity meters	51

4	Drell-Yan measurement	53
4.1	Observables	54
4.2	Existing measurements	57
4.3	Data and signal samples	57
4.4	Event reconstruction and selection	59
4.4.1	Tracks and vertices	60
4.4.2	Electrons	60
4.4.3	Electron triggers	62
4.4.4	Muons	67
4.4.5	Muon triggers	73
4.4.6	Jets	74
4.4.7	Event selection	76
4.4.8	Backgrounds	81
4.5	Kinematic distributions	84
4.5.1	Individual objects	85
4.5.2	Measured observables	89
4.6	Additional background checks	94
4.6.1	“Fake” electrons	94
4.6.2	Top quark pair production	104
4.7	Unfolding	111
4.7.1	Generator level phase space	112
4.7.2	Response matrices	113
4.7.3	Number of iterations	118
4.7.4	Modeling uncertainties	119
4.8	Uncertainties	122
4.9	Combination	126
4.9.1	Comparison at the detector level	126
4.9.2	Combination of the results	130
4.9.3	Uncertainties in the combined results	135
4.10	Cross section ratios	142
4.11	Predictions	149
4.11.1	MadGraph5_aMC@NLO	149
4.11.2	ArTeMiDe	150
4.11.3	CASCADE	155
4.11.4	MiNNLO _{PS}	156
4.11.5	Geneva	156
4.11.6	Cross section ratios	158
4.11.7	Formal accuracy	158
4.12	Results	161
4.12.1	Transverse momentum	161

4.12.2	φ_η^* variable	172
4.12.3	Transverse momentum, one or more jets	182
5	Conclusion	191
A	Statistical framework	197
A.1	Properties of the variance	198
A.2	Weighted events	199
A.3	Systematic uncertainties	199
A.4	Differential cross sections	200
A.5	Particular covariance matrices	201
A.6	Correlation and interpretation	202