Contents

Preface v

1. The LHC — A "Why" Machine and a Supersymmetry Factory 1

G. Kane

1.1 A "Why" Machine 3
1.2 A Superpartner Factory 5
1.3 Our String Vacuum 9
1.4 After the Champagne 10

2. Dark Matter at the LHC 13

A. Pierce

2.1 Introduction 13
2.2 Weighing the Universe, or Why Expect Dark Matter? . . 13
2.3 What is the Dark Matter? 16
2.4 A Test Case: Supersymmetric Dark Matter 18
2.4.1 Neutralinos at the LHC 19
2.5 Simple Dark Matter 20
2.6 What If We Don't See Dark Matter at LHC? 21
2.7 Conclusions 21
References 22

3. LHC's ATLAS and CMS Detectors 25

M. Spiropulu & S. Stapnes

3.1 Introduction 25
3.1.1 LHC: The machine 26

PERSPECTIVES ON LHC PHYSICS
© World Scientific Publishing Co. Pte. Ltd.
http://www.worldscibooks.com/physics/6686.html

3.1.2 LHC: Figures of challenge 31
3.2 Detection, Particles and Physics 32
3.3 ATLAS and CMS 37
3.3.1 ATLAS/CMS duality 39
3.3.2 Magnet systems 40
3.4 ATLAS and CMS: Challenges Addressed 43
3.4.1 Inner detectors 43
3.4.2 Calorimetry 45
3.4.3 Muon detectors 47
3.5 Trigger Architecture 49
3.5.1 Googles of data and the grid 50
3.6 To Be Continued 52
References 52

4. Understanding the Standard Model, as a Bridge to the Discovery of New Phenomena at the LHC 55

M. L. Mangano

4.1 Introduction 55
4.2 Signals of Discovery 57
4.2.1 Mass peaks 58
4.2.2 Anomalous shapes of kinematical distributions . . 59
4.2.3 Counting experiments 65
4.3 Measuring Parameters 68
4.4 Conclusions 70
References 71

5. Thoughts on a Long Voyage 75

L. Susskind

5.1 The Landscape 75
5.2 The Hierarchy 77
5.3 Linkages 81
5.3.1 The strong CP problem 83
5.4 Supersymmetry Breaking and the Landscape 84
5.5 Black Holes at the LHC? 84

6. The "Top Priority" at the LHC 87

T. Han

6.1 Brief Introduction 87

PERSPECTIVES ON LHC PHYSICS
© World Scientific Publishing Co. Pte. Ltd.
http://www.worldscibooks.com/physics/6686.html

6.2 Top Quark in The Standard Model 88
6.2.1 Top-quark decay in the SM 89
6.2.2 Top-quark production in the SM 90
6.3 New Physics in Top-Quark Decay 93
6.3.1 Charged current decay: BSM 93
6.3.2 Neutral current decay: BSM 94
6.4 Top Quarks in Resonant Production 95
6.4.1 $X \to t\bar{t},\ t\bar{b}$ 95
6.4.2 $T \to tZ,\ tH,\ bW$ 97
6.5 Top-Rich Events for New Physics 98
6.5.1 $T\bar{T}$ pair production 98
6.5.2 Exotic top signatures 101
6.6 Summary and Outlook 102
References 102

7. LHC Discoveries Unfolded 109

J. Lykken and M. Spiropulu

7.1 Escape from Theory Space 109
7.2 Dark Matter and Missing Energy 112
7.3 Missing Energy at the LHC 114
7.4 A Strategy for Early Discovery with Missing Energy . . 117
7.5 Look-Alikes at the Moment of Discovery 119
7.6 Twenty Questions 121
7.7 Spin Discrimination with 100 pb^{-1} 121
7.8 More Look-Alikes 123
7.9 Simple Robust Discriminators 129
7.10 Outlook 130
References 130

8. From BCS to the LHC 133

S. Weinberg

References 142

9. Searching for Gluinos at the Tevatron and Beyond 143

J. Alwall, M.-P. Le, M. Lisanti and J. G. Wacker

9.1 Introduction 143
9.2 Event Generation 145
9.2.1 Signal 145

PERSPECTIVES ON LHC PHYSICS
© World Scientific Publishing Co. Pte. Ltd.
http://www.worldscibooks.com/physics/6686.html

9.2.2 Backgrounds 147
9.3 Projected Reach of Searches 148
9.4 Implications for the LHC 150
9.5 Conclusions and Outlook 152
References 154

10. Naturally Speaking: The Naturalness Criterion and Physics at the LHC 155

G. F. Giudice

10.1 Naturalness in Scientific Thought 155
10.2 Drowning by Numbers 157
10.3 A Quantum Complication 161
10.4 The Naturalness Criterion as a Principle 163
10.5 An Account of Events 165
10.6 The Paths Chosen by Nature 167
10.7 Measuring Naturalness 170
10.8 Anthropic Reasoning 172
10.9 Naturalness versus Criticality 174
10.10 Conclusions 175
References 176

11. Prospects for Higgs Boson Searches at the LHC 179

K. Jakobs and M. Schumacher

11.1 Introduction 179
11.2 Higgs Boson Production and Decay 181
11.3 Search for the Standard Model Higgs Boson 184
11.3.1 Inclusive Higgs boson searches 184
11.3.2 Higgs boson searches using vector boson fusion . 188
11.3.3 Higgs boson searches using the associated $t\bar{t}H$ production 190
11.3.4 Combined signal significance 191
11.4 Determination of Higgs Boson Properties 193
11.4.1 Mass and total decay width 193
11.4.2 Partial decay widths and couplings 194
11.4.3 Spin and CP quantum number 195
11.5 Search for MSSM Higgs Bosons 196
11.5.1 Search for heavy MSSM Higgs bosons 197

PERSPECTIVES ON LHC PHYSICS
© World Scientific Publishing Co. Pte. Ltd.
http://www.worldscibooks.com/physics/6686.html

11.5.2 Discovery potential in various benchmark scenarios . . . 197
11.6 Conclusions . . . 201
References . . . 202

12. A Review of Spin Determination at the LHC 205

L.-T. Wang and I. Yavin

12.1 Introduction . . . 205
12.2 Rate and Mass Measurement . . . 208
12.3 Angular Correlations in a General Decay Topology . . . 211
12.4 Mis-Pairing and Background . . . 212
12.5 Spin Determination of Electroweak Gauge-Boson Partners . . . 214
12.5.1 Charged boson partner's spin — Jet-$W^{\pm}$ correlations . . . 214
12.5.2 Charged boson partner's spin — Jet-Z^0 correlations . . . 216
12.5.3 Neutral boson partner's spin . . . 217
12.6 Spin Determination of Standard Model Matter Partners 218
12.6.1 Non-degenerate spectrum . . . 221
12.6.2 Degenerate spectrum . . . 221
12.6.3 Slope information . . . 222
12.6.4 Long cascade decays and total spin determination 222
12.7 Off-Shell Decays . . . 224
12.7.1 Simulation tools to study spin correlations . . . 226
12.8 Conclusion and Outlook . . . 228
References . . . 229

13. Anticipating a New Golden Age 233

F. Wilczek

13.1 Where We Stand . . . 233
13.1.1 Celebrating the standard model . . . 233
13.1.2 An unfinished agenda . . . 235
13.2 Electroweak Symmetry Breaking . . . 236
13.2.1 The cosmic superconductor . . . 236
13.2.2 Minimal model and search . . . 236
13.3 Unification and Supersymmetry . . . 237
13.3.1 Unification of charges . . . 237

PERSPECTIVES ON LHC PHYSICS
© World Scientific Publishing Co. Pte. Ltd.
http://www.worldscibooks.com/physics/6686.html

13.3.2 Unification of couplings 239
13.3.3 Unification ♡ SUSY 241
13.3.4 SUSY as calibration 246
13.4 Dark Matter 246
13.4.1 Dark matter from supersymmetry 246
13.4.2 "Mission accomplished"? 247
13.5 Hidden Sectors and Portals 253
13.5.1 Might the LHC see nothing? 253
13.5.2 Motivations for hidden sectors 255
13.5.3 Bringing method to the madness 256
13.6 Summary and Conclusions 256
References 257

14. Strongly Interacting Electroweak Theories and Their Five-Dimensional Analogs at the LHC 259

A. Pomarol

14.1 Introduction 259
14.2 Higgsless Models 261
14.2.1 The original technicolor model. Achievements and pitfalls 261
14.2.2 5D Higgsless models 264
14.3 Composite Higgs Models 268
14.3.1 Higgs potential and vacuum misalignment 270
14.3.2 Fermionic resonances 272
14.4 LHC Phenomenology 274
14.4.1 Heavy resonances at the LHC 274
14.4.2 Experimental tests of a composite Higgs 276
References 280

15. How to Find a Hidden World at the LHC 283

J. D. Wells

15.1 Particle Physics in the LHC Era 283
15.2 Hidden Worlds 285
15.3 Hidden Abelian Higgs Model (HAHM) 286
15.4 Precision Electroweak 288
15.5 Example LHC Phenomena of HAHM 289
15.6 Beyond the Standard Model and the Hidden World . . . 295
References 297

PERSPECTIVES ON LHC PHYSICS
© World Scientific Publishing Co. Pte. Ltd.
http://www.worldscibooks.com/physics/6686.html

16. *B* Physics at LHCb **299**

M. P. Altarelli and F. Teubert

16.1 Introduction 299
16.2 *b* Physics at the LHC: Environment, Background, General Trigger Issues 300
16.3 Detector Description and Performance 302
16.3.1 Trigger 303
16.3.2 VELO and tracking system 305
16.3.3 Particle identification 306
16.4 Physics Objectives 307
16.4.1 Introduction of formalism 308
16.4.2 Measurement of the B_s mixing phase ϕ_s 309
16.4.3 $B_s \to \phi\phi$ as a probe for new physics 311
16.4.4 Measurement of the weak decay-phase γ from tree-level processes 312
16.4.5 Example of radiative penguins: $B_s \to \phi\gamma$ 315
16.4.6 Example of an electroweak penguin: $B \to K^*\mu\mu$. 316
16.4.7 Example of a Higgs-penguin: $B_s \to \mu^+\mu^-$ 318
16.5 Conclusions and Outlook 319
References 320

17. The LHC and the Universe at Large **323**

P. Binétruy

17.1 Introduction 323
17.2 The Dark Side of LHC 324
17.3 The Gravitational Side of LHC 330
17.3.1 Phase transitions at the terascale: the LHC-LISA connection 331
17.3.2 Black hole physics and the LHC 333
17.4 Conclusion 335
References 336

PERSPECTIVES ON LHC PHYSICS
© World Scientific Publishing Co. Pte. Ltd.
http://www.worldscibooks.com/physics/6686.html