

**École de Physique des Houches**

Session XCVII, 1–26 August 2011

**Theoretical Physics to Face the  
Challenge of LHC**

Edited by

Laurent Baulieu, Karim Benakli, Michael R. Douglas,  
Bruno Mansoulié, Eliezer Rabinovici,  
and Leticia F. Cugliandolo

**OXFORD**  
UNIVERSITY PRESS

# Contents

<b>List of participants</b>	<b>xviii</b>
<b>1 The Large Hadron Collider</b>	
<b>Lyndon EVANS</b>	<b>1</b>
1.1 Introduction	3
1.2 Main machine layout and performance	4
1.3 Magnets	12
1.4 Radiofrequency systems	17
1.5 Vacuum system	20
1.6 Cryogenic system	24
1.7 Beam instrumentation	27
1.8 Commissioning and operation	30
Acknowledgments	33
References	33
<b>2 The LHC machine: from beam commissioning to operation and future upgrades</b>	
<b>Massimo GIOVANNOZZI</b>	<b>35</b>
2.1 LHC layout, parameters, and challenges	37
2.2 Digression: the chain of proton injectors	47
2.3 Proton beam commissioning and operation	48
2.4 Future upgrade options	52
Acknowledgments	55
References	55
<b>3 The LHC detectors and the first CMS data</b>	
<b>Dan GREEN</b>	<b>67</b>
3.1 EWSB and LHC	69
3.2 LHC machine	69
3.3 Global detector properties	71
3.4 The generic detector	73
3.5 Vertex subsystem	76
3.6 Magnet subsystem	77
3.7 Tracking subsystem	78
3.8 ECAL subsystem	80
3.9 HCAL subsystem	82
3.10 Muon subsystem	85
3.11 Trigger/DAQ subsystems	88
References	89

<b>4</b>	<b>About the identification of signals at LHC: analysis and statistics</b>	
	<b>Bruno MANSOULIÉ</b>	<b>91</b>
4.1	Introduction	93
4.2	Search for the Standard Model Higgs boson decaying into $WW$ (in ATLAS)	93
4.3	Backgrounds	94
4.4	Global model of the analysis	97
4.5	Statistics	100
4.6	Global Higgs analysis	103
4.7	Conclusion	106
	References	106
<b>5</b>	<b>Introduction to the theory of LHC collisions</b>	
	<b>Michelangelo L. MANGANO</b>	<b>107</b>
5.1	Introduction	109
5.2	QCD and the proton structure at large $Q^2$	110
5.3	The final-state evolution of quarks and gluons	119
5.4	Applications	129
5.5	Outlook and conclusions	137
	References	138
<b>6</b>	<b>An introduction to the gauge/gravity duality</b>	
	<b>Juan M. MALDACENA</b>	<b>141</b>
6.1	Introduction to the gauge/gravity duality	143
6.2	Scalar field in $AdS$	148
6.3	The $N = 4$ super Yang–Mills/ $AdS_5 \times S^5$ example	152
6.4	The spectrum of states or operators	157
6.5	The radial direction	159
	Acknowledgments	161
	References	161
<b>7</b>	<b>Introduction to the AdS/CFT correspondence</b>	
	<b>Jan de BOER</b>	<b>163</b>
7.1	About this chapter	165
7.2	Introduction	165
7.3	Why AdS/CFT?	166
7.4	Anti-de Sitter space	169
7.5	Correlation functions	171
7.6	Mapping between parameters	172
7.7	Derivation of the AdS/CFT correspondence	172
7.8	Tests of the AdS/CFT correspondence	174
7.9	More on finite temperature	177
7.10	Counting black hole entropy	179
7.11	Concluding remarks	180
	Acknowledgments	182
	References	182

<b>8</b>	<b>Hydrodynamics and black holes</b>	
	<b>Yaron OZ</b>	<b>185</b>
8.1	Introduction	187
8.2	Field theory hydrodynamics	187
8.3	Relativistic hydrodynamics	188
8.4	Nonrelativistic fluid flows	192
8.5	Holographic hydrodynamics: the fluid/gravity correspondence	194
	Acknowledgments	197
	References	197
<b>9</b>	<b>Supersymmetry</b>	
	<b>Gian F. GIUDICE</b>	<b>199</b>
<b>10</b>	<b>Spontaneous breakdown of local conformal invariance in quantum gravity</b>	
	<b>Gerard 't HOOFT</b>	<b>209</b>
10.1	Introductory remarks	211
10.2	Conformal symmetry in black holes	211
10.3	Local conformal invariance and the stress-energy-momentum tensor	217
10.4	Local conformal symmetry in canonical quantum gravity	220
10.5	Local conformal invariance and the Weyl curvature	225
10.6	The divergent effective conformal action	228
10.7	Nonconformal matter	233
10.8	Renormalization with matter present	237
10.9	The $\beta$ functions	239
10.10	Adding the dilaton field to the algebra for the $\beta$ functions	242
10.11	Discussion	245
10.12	Conclusions	248
	Acknowledgments	250
	References	250
<b>11</b>	<b>Renormalization group flows and anomalies</b>	
	<b>Zohar KOMARGODSKI</b>	<b>255</b>
11.1	Two-dimensional models	257
11.2	Higher-dimensional models	260
	References	270
<b>12</b>	<b>Models of electroweak symmetry breaking</b>	
	<b>Alex POMAROL</b>	<b>273</b>
12.1	Introduction	275
12.2	The original technicolor model: achievements and pitfalls	276
12.3	Flavor-changing neutral currents and the top mass	277
12.4	Electroweak precision tests	277
12.5	Composite PGB Higgs	278
12.6	Little Higgs	279

12.7	The AdS/CFT correspondence, Higgsless and composite Higgs models	280
12.8	LHC phenomenology	281
	References	286
<b>13</b>	<b>String phenomenology</b>	<b>289</b>
	<b>Luis IBÁÑEZ</b>	<b>289</b>
13.1	Branes and chirality	291
13.2	Type II orientifolds: intersections and magnetic fluxes	294
13.3	Local F-theory GUTs	298
13.4	The effective low-energy action	300
13.5	String model building and the LHC	307
	References	310
<b>14</b>	<b>The string landscape and low-energy supersymmetry</b>	<b>315</b>
	<b>Michael R. DOUGLAS</b>	<b>315</b>
14.1	The goal of fundamental physics	317
14.2	Low-energy supersymmetry and current constraints	321
14.3	The gravitino and moduli problems	324
14.4	The set of string vacua	326
14.5	Eternal inflation and the master vacuum	329
14.6	From hyperchemistry to phenomenology	331
	Acknowledgments	335
	References	335
<b>15</b>	<b>The description of <math>\mathcal{N} = 1</math>, <math>d = 4</math> supergravity using twisted supersymmetric fields</b>	<b>339</b>
	<b>Laurent BAULIEU</b>	<b>339</b>
15.1	Introduction	341
15.2	$\mathcal{N} = 1$ , $d = 4$ supergravity in the new minimal scheme	342
15.3	Self-dual decomposition of the supergravity action	345
15.4	Twisted supergravity variables	346
15.5	The supergravity curvatures in the $U(2) \subset SO(4)$ -invariant formalism	350
15.6	The 1.5-order formalism with $SU(2)$ -covariant curvatures	351
15.7	Vector supersymmetry and nonvanishing torsion	356
15.8	Matter and vector multiplets coupled to supergravity	358
15.9	Conclusions and outlook	361
	Appendix A: The BSRT symmetry from horizontality conditions	361
	Appendix B: Tensor and chirality conventions	363
	Appendix C: The action of $\gamma$ matrices on twisted spinors	363
	Appendix D: Algebra closure on the fields of matter and vector multiplets	364
	Acknowledgments	365
	References	366

<b>16 AdS crunches, CFT falls, and cosmological complexity</b>	
<b>José Luis BARBÓN and Eliezer RABINOVICI</b>	<b>367</b>
16.1 Introduction	369
16.2 AdS crunches and their dS duals	370
16.3 Facing the CFT crunch time is complementary	375
16.4 Attempt at a ‘thin-thesis’	383
16.5 Falling on your sword	389
16.6 Conclusions	392
Acknowledgments	394
References	394
<b>17 High-energy collisions of particles, strings, and branes</b>	
<b>Gabriele VENEZIANO</b>	<b>397</b>
17.1 Motivations and outline	399
17.2 Gravitational collapse criteria: a brief review	400
17.3 The expected phase diagram	402
17.4 The small-angle regime: deflection angle and tidal excitation	404
17.5 The string-gravity regime: a precocious black hole behaviour?	406
17.6 The strong-gravity regime: towards the large-angle/collapse phase?	407
17.7 High-energy string–brane collisions: an easier problem?	410
17.8 Summary and outlook	412
Acknowledgments	413
References	413