Contents

Table of Particles and Resonances ix

Chapter 1 History and Basic Concepts

1.1 Introduction 1
1.2 Historical development 3
1.3 Broad classification of particle states 12
1.4 Types of interaction 17
1.5 Conservation rules 21
1.6 Units 22

Chapter 2 Experimental Methods

2.1 Ionization loss of charged particles in matter 25
2.2 Range-energy relation 28
2.3 Cerenkov radiation 30
2.4 Coulomb scattering 31
2.5 Absorption of γ-rays in matter, and radiation loss by fast electrons . . 34
2.6 Electron-photon showers 41
2.7 Methods of accelerating and detecting high-energy particles 44
2.8 Examples of application of detection techniques to experiments . . . 63

Chapter 3 Conservation Laws and Invariance Principles

3.1 Invariance in classical mechanics 73
3.2 Invariance in quantum mechanics 74
3.3 Parity 78
3.4 Spin of the pion 79
3.5 Parity of the pion 83
3.6 Intrinsic parity of particles and antiparticles 84
3.7 Conservation of parity—experimental tests in strong and electromagnetic interactions 86

3.8 Isospin and its conservation 87
3.9 Isospin assignments for pions and strange particles 91
3.10 Isospin functions for a pair of nucleons 95
3.11 Isospin in the pion-nucleon system 98
3.12 Charge conjugation invariance 103
3.13 Eigenstates of the C-operator 105
3.14 Positronium decay 106
3.15 Experimental tests of C-invariance 110
3.16 G-parity and nucleon-antinucleon annihilation 113
3.17 Time reversal invariance, CP-violation, and the CPT theorem . . . 116
3.18 Electric dipole moment of the neutron 120
3.19 Conclusions 124

Chapter 4 Weak Interactions

4.1 Leptonic, semileptonic and nonleptonic interactions 127
4.2 Nuclear β-decay; a brief review 128
4.3 Lepton polarization in β-decay 137
4.4 The V-A interaction 141
4.5 Parity violation in Λ-decay 147
4.6 Pion and muon decay 149
4.7 The current-current interaction 154
4.8 The decays of strange particles 157
4.9 Conservation of lepton number and muon number 160
4.10 Neutrino interactions 162
4.11 K°-decay 168
4.12 CP-violation in K°-decay 179

Chapter 5 Electromagnetic Interactions and Form Factors

5.1 Gyromagnetic ratio of electron and muon 187
5.2 Anomalous magnetic moment of the nucleon 193
5.3 Scattering of spinless charged particles by nuclei in the Born approximation 194
5.4 4-momentum transfer: Mott scattering 197
5.5 The form factor of the nucleus 199
5.6 Form factors of proton and neutron 201
5.7 Interpretation of nucleon form factors 206
5.8 Form factors in the timelike region: the reaction $p\bar{p} \to e^+e^-$ . . . 209
5.9 The reactions $e^+e^- \to \pi^+\pi^-$ and $\pi^+\pi^-\pi^0$ 211
5.10 Inelastic electron-proton scattering 214
5.11 Scale invariance and partons 219
5.12 Weak form factors 221

Chapter 6 Strong Interactions I—Unitary Symmetry and the Quark Model

6.1 Unitary symmetry—terminology and introduction 224
6.2 Pions as nucleon-antinucleon combinations 226

6.3 The Sakata model 228
6.4 Baryon states and the quark model 230
6.5 U,- V-, and I-spin. Symmetry breaking and mass formulas 234
6.6 Electromagnetic properties in SU3 240
6.7 The vector meson nonet; SU6, quark spin, and ϕ–ω mixing . . . 243
6.8 Magnetic moments of neutron and proton 246
6.9 Further considerations on the quark model. Free quarks? 248

Chapter 7 Strong Interactions II—Dynamical Models

7.1 Dalitz plots: examples of determination of quantum numbers . . . 252
7.2 Scattering amplitude and the resonance condition 265
7.3 The Breit-Wigner formula 269
7.4 A pion-nucleon resonance—the N^* (1236) 274
7.5 A pion-pion resonance—the ρ (765) 275
7.6 Experimental techniques in the detection of boson and baryon resonances 280
7.7 Total and elastic cross sections; the black disc model 283
7.8 The one-particle-exchange (OPE) model 288
7.9 The Regge pole model 291
7.10 Application of Regge poles to high energy reactions 296
7.11 Other developments 300

Tables

I Atomic constants 328
II Spherical harmonics 329
III Clebsch-Gordan coefficients 330

Appendixes

Appendix A Relativistic kinematics 305
Appendix B The Dirac equation 308
Appendix C Clebsch-Gordan coefficients 318
Appendix D Lorentz-invariant phase-space 323
Appendix E G-parity of the pion 326

Answers to Problems 334

Worked Solutions to Selected Problems 337

References 344

Index 348