

**Brigitte Falkenburg**

# **PARTICLE METAPHYSICS**

**A Critical Account  
of Subatomic Reality**

**With 30 Figures**

 **Springer**

# Contents

<b>1</b>	<b>Scientific Realism</b> .....	1
1.1	Empirical Knowledge and Metaphysics .....	4
1.2	More or Less Empiricist Demarcations .....	11
1.3	The Real and the Actual .....	17
1.4	Realism and Quantum Theory .....	25
1.5	The Metaphysics of Physics .....	31
1.6	Towards a Realism of Properties .....	38
<b>2</b>	<b>Extending Physical Reality</b> .....	41
2.1	Introducing Physical Quantities .....	43
2.2	Idealization and the Experimental Method .....	48
2.3	Discovery or Manufacture? .....	53
2.4	Phenomena and Their Causes .....	60
2.5	Observation Generalized .....	65
2.6	The Empirical Reality of Physics .....	71
<b>3</b>	<b>Particle Observation and Measurement</b> .....	77
3.1	Two Particle Concepts .....	80
3.2	Evidence for a Particle: Two Case Studies .....	83
3.2.1	The Electron .....	84
3.2.2	The Photon .....	88
3.3	Theorizing the Observations .....	92
3.3.1	Position Measurement .....	94
3.3.2	Particle Tracks .....	96
3.3.3	Scattering Events .....	101
3.3.4	Resonances .....	105
3.4	The Track of the Positron .....	110
3.5	Particle Identification and Quantum Electrodynamics .....	114
3.6	Are There Subatomic Particles? .....	119
<b>4</b>	<b>Probing Subatomic Structure</b> .....	125
4.1	Scattering Experiments .....	127
4.2	Rutherford Scattering and Scale Invariance .....	132
4.3	Pointlikeness in the Quantum Domain .....	136
4.3.1	Classical Form Factors .....	138

4.3.2	Relativistic Generalizations .....	142
4.4	A Chain of Models .....	148
4.5	Analogy with the Optical Microscope .....	153
4.6	Looking Into The Atom .....	158
<b>5</b>	<b>Measurement and the Unity of Physics .....</b>	<b>161</b>
5.1	Incommensurability and Measurement .....	163
5.2	A Heterogeneous Measurement Theory .....	169
5.3	Particle Tracks .....	174
5.3.1	Mott's Prediction of Classical Tracks .....	175
5.3.2	Bethe's Calculation of Energy Loss .....	178
5.3.3	How the Classical Picture Breaks Down .....	183
5.3.4	Data Analysis in Scattering Experiments .....	185
5.4	Building Bridges: Unifying Principles .....	187
5.4.1	Bohr's Correspondence Principle .....	188
5.4.2	Correspondence Generalized .....	190
5.4.3	Other Unifying Principles .....	194
5.5	The Scales of Physical Quantities .....	198
5.6	Questions of Semantic Consistency .....	202
<b>6</b>	<b>Metamorphoses of the Particle Concept .....</b>	<b>209</b>
6.1	Classical Particles .....	210
6.2	The Shift to Quantum Particles .....	213
6.2.1	Matter Waves .....	215
6.2.2	Light Quanta .....	217
6.3	The Operational Particle Concept .....	220
6.4	More Quantum Particles .....	222
6.4.1	Field Quanta .....	224
6.4.2	The Group Theoretical Definition .....	229
6.4.3	Virtual Particles .....	233
6.4.4	Quasi-Particles .....	238
6.5	The Parts of Matter .....	246
6.5.1	Matter Constituents Generalized .....	246
6.5.2	The Quark Model .....	250
6.6	What Kinds of Particles Remain? .....	257
<b>7</b>	<b>Wave-Particle Duality .....</b>	<b>265</b>
7.1	Light Particles and Matter Waves .....	267
7.2	Wave-Particle Duality in Quantum Mechanics .....	268
7.2.1	Born's Probability Waves .....	269
7.2.2	Bohr's Complementarity View .....	272
7.2.3	Heisenberg's Analogies .....	277
7.3	Prepare Waves, Detect Particles .....	278
7.3.1	What Makes the Difference .....	280
7.3.2	Two Lasers, One Photon .....	284

7.3.3	Polarized Photons .....	285
7.4	The Double Slit Reconsidered .....	289
7.4.1	How to Store and Erase Path Information .....	291
7.4.2	Complementarity Without Uncertainty? .....	296
7.4.3	Duality Relations .....	301
7.5	Recent Which-Way Experiments .....	305
7.6	The Causes of the Phenomena .....	316
<b>8</b>	<b>Subatomic Reality .....</b>	<b>321</b>
8.1	Scientific Realism Reconsidered .....	322
8.2	The Meaning of Quantum Concepts .....	324
8.3	The Mereological Particle Concept .....	326
8.4	The Causal Particle Concept .....	329
8.5	Wave-Particle Duality .....	330
8.6	Subatomic Reality: A Critical View .....	334

---

## Appendices

---

<b>A</b>	<b>Measurement Theory .....</b>	<b>343</b>
A.1	Empirical Relational Structures .....	343
A.2	Physical Quantities .....	344
A.3	The Archimedean Axiom .....	345
A.4	The Metaphysics of Measurement .....	345
<b>B</b>	<b>The <math>\Pi</math>-Theorem of Dimensional Analysis .....</b>	<b>349</b>
<b>C</b>	<b>The Effective Cross-Section .....</b>	<b>351</b>
<b>D</b>	<b>Dimensional Analysis of Rutherford Scattering .....</b>	<b>355</b>
<b>E</b>	<b>Mereology .....</b>	<b>357</b>
E.1	Axioms of Mereology .....	357
E.2	Mereology and Physics .....	358
E.3	Matter Constituents .....	360
	<b>References .....</b>	<b>363</b>
	<b>Name Index .....</b>	<b>383</b>