

## Contents

<i>Acronyms</i>	<i>page</i> ix
<i>Preface</i>	xiii
1 Introduction	1
1.1 Historical background	1
1.2 Gaseous detectors: a personal recollection	4
1.3 Basic processes in gaseous counters	20
1.4 Outline of the book	23
2 Electromagnetic interactions of charged particles with matter	24
2.1 Generalities on the energy loss process	24
2.2 The Bethe–Bloch energy loss expression	28
2.3 Energy loss statistics	29
2.4 Delta electron range	40
3 Interaction of photons and neutrons with matter	43
3.1 Photon absorption and emission in gases	43
3.2 Photon absorption: definitions and units	44
3.3 Photon absorption processes: generalities	46
3.4 Photon absorption in gases: from the visible to the near ultra-violet domain	49
3.5 Photo-ionization: near and vacuum ultra-violet	53
3.6 Photo-ionization in the X-ray region	56
3.7 Compton scattering and pair production	62
3.8 Use of converters for hard photons detection	63
3.9 Transparency of windows	67
3.10 Detection of neutrons	68
4 Drift and diffusion of charges in gases	76
4.1 Generalities	76

4.2	Experimental methods	76
4.3	Thermal diffusion of ions	80
4.4	Ion mobility and diffusion in an electric field	82
4.5	Classic theory of electron drift and diffusion	87
4.6	Electron drift in magnetic fields	90
4.7	Electron drift velocity and diffusion: experimental	91
4.8	Electron capture	106
4.9	Electron drift in liquid noble gases	112
4.10	Transport theory	114
5	Collisional excitations and charge multiplication in uniform fields	129
5.1	Inelastic electron–molecule collisions	129
5.2	Excitations and photon emission	130
5.3	Ionization and charge multiplication	143
5.4	Avalanche statistics	149
5.5	Streamer formation and breakdown	153
6	Parallel plate counters	160
6.1	Charge induction on conductors	160
6.2	Signals induced by the motion of charges in uniform fields	161
6.3	Analytical calculation of charge induction	165
6.4	Signals induced by the avalanche process	172
6.5	Grid transparency	175
6.6	Applications of parallel plate avalanche counters (PPACs)	177
7	Proportional counters	182
7.1	Basic principles	182
7.2	Absolute gain measurement	188
7.3	Time development of the signal	188
7.4	Choice of the gas filling	191
7.5	Energy resolution	194
7.6	Scintillation proportional counters	198
7.7	Space-charge gain shifts	201
7.8	Geiger and self-quenching streamer operation	206
7.9	Radiation damage and detector ageing	207
8	Multi-wire proportional chambers	211
8.1	Principles of operation	211
8.2	Choice of geometrical parameters	215
8.3	Influence on gain of mechanical tolerances	216
8.4	Electrostatic forces and wire stability	218

*Contents*

vii

8.5	General operational characteristics: proportional and semi-proportional	221
8.6	Saturated amplification region: Charpak's 'magic gas'	226
8.7	Limited streamer and full Geiger operation	230
8.8	Discharges and breakdown: the Raether limit	231
8.9	Cathode induced signals	234
8.10	The multi-step chamber (MSC)	245
8.11	Space charge and rate effects	249
8.12	Mechanical construction of MWPCs	252
9	Drift chambers	264
9.1	Single wire drift chambers	264
9.2	Multi-cell planar drift chambers	265
9.3	Volume multi-wire drift chambers	275
9.4	Jet chambers	280
9.5	Time expansion chamber	282
9.6	Determination of the longitudinal coordinate from current division	284
9.7	Electrodeless drift chambers	287
9.8	General operating considerations	290
9.9	Drift chamber construction	290
10	Time projection chambers	292
10.1	Introduction: the precursors	292
10.2	Principles of operation	293
10.3	TPC-based experiments	297
10.4	Signal induction: the pad response function	301
10.5	Choice of the gas filling	312
10.6	Coordinate in the drift direction and multi-track resolution	315
10.7	Positive ion backflow and gating	318
10.8	TPC calibration	323
10.9	Liquid noble gas TPC	324
10.10	Negative ion TPC	325
11	Multi-tube arrays	327
11.1	Limited streamer tubes	327
11.2	Drift tubes	329
11.3	Straw tubes	335
11.4	Mechanical construction and electrostatic stability	340
12	Resistive plate chambers	344
12.1	Spark counters	344

12.2	Resistive plate counters (RPCs)	346
12.3	Glass RPCs	353
12.4	Multi-gap RPCs	355
12.5	Simulations of RPC operation	360
13	Micro-pattern gaseous detectors	365
13.1	The micro-strip gas counter	365
13.2	Novel micro-pattern devices	373
13.3	Micro-mesh gaseous structure (Micromegas)	378
13.4	Gas electron multiplier (GEM)	383
13.5	MPGD readout of time projection chambers	392
13.6	Active pixel readout	395
13.7	MPGD applications	398
14	Cherenkov ring imaging	399
14.1	Introduction	399
14.2	Recalls of Cherenkov ring imaging theory	403
14.3	First generation RICH detectors	407
14.4	TMAE and the second generation of RICH detectors	410
14.5	Third generation RICH: solid caesium iodide (CsI) photocathodes	417
14.6	CsI-based RICH particle identifiers	423
14.7	Micro-pattern based RICH detectors	424
15	Miscellaneous detectors and applications	430
15.1	Optical imaging chambers	430
15.2	Cryogenic and dual-phase detectors	434
16	Time degeneracy and ageing	441
16.1	Early observations	441
16.2	Phenomenology of the radiation damages	443
16.3	Quantitative assessment of the ageing rates	449
16.4	Methods of preventing or slowing down the ageing process	451
16.5	Ageing of resistive plate chambers	455
16.6	Micro-pattern detectors	457
	<i>Further reading on radiation detectors</i>	460
	<i>References</i>	461
	<i>Index</i>	494