

Contents

	Preface	<i>ix</i>
	Acknowledgments	<i>xi</i>
	Abbreviations	<i>xiii</i>
	Introduction	<i>1</i>
1	“Classical” Gaseous Detectors and Their Limits	5
1.1	Ionization Chambers	5
1.2	Single-Wire Counters Operated in Avalanche Mode	7
1.3	Avalanche and Discharge Development in Uniform or Cylindrical Electric Fields	8
1.3.1	Fast Breakdown	14
1.3.2	Slow Breakdown	16
1.4	Pulsed Spark and Streamer Detectors	16
1.5	Multiwire Proportional Chambers	18
1.6	A New Idea for Discharge Quenching and Localization	20
	References	24
2	Historical Developments Leading to Modern Resistive Gaseous Detectors	27
2.1	Introduction: the Importance of the Parallel-Plate Geometry	27
2.2	First Parallel-Plate Counters	30
2.3	Further Developments	34
2.4	The First RPC Prototypes	35
2.5	Pestov’s Planar Spark Chambers	37
2.6	Wire-Type Detectors with Resistive Cathodes	41
	References	42
3	Basics of Resistive Plate Chambers	45
3.1	Introduction	45
3.2	Santonico and Cardarelli’s RPCs	45
3.3	Glass RPCs	52
3.4	Avalanche and Streamer Modes	55
3.4.1	Streamer Mode	55
3.4.2	Avalanche Mode	60

3.5	Signal Development	64
3.5.1	Signal Formation	64
3.5.2	Charge Distribution	74
3.5.3	Efficiency	76
3.5.4	Time Resolution	78
3.5.5	Position Resolution	80
3.6	Choice of Gas Mixtures	81
3.6.1	Main Requirements for RPC Gas Mixtures	81
3.6.2	Quenching Gas Mixtures	84
3.6.2.1	General Information	84
3.6.2.2	Historical Review about Gas Mixtures for Inhibiting Photon Feedback	86
3.6.2.3	Some Considerations on Delayed Afterpulses	90
3.7	Current in RPCs	92
3.8	Dark Counting Rate	96
3.9	Effects of Temperature and Pressure	99
	References	106
4	Further Developments in Resistive Plate Chambers	111
4.1	Double Gap RPCs	111
4.2	Wide-Gap RPCs	113
4.3	The Multi-gap RPCs	117
4.4	“Space-Charge” Effects	127
4.5	Review of Analytical Models of RPC Behavior	129
4.5.1	Electron Avalanches Deeply Affected by Space Charge	131
4.5.2	Highly Variable Currents Flowing through Resistive Materials	134
4.5.3	Electrical Induction through Materials with Varied Electrical Properties	135
4.5.4	Propagation of Fast Signals in Multiconductor Transmission Lines	135
4.6	Timing RPCs	138
4.7	The Importance of Front-End Electronics for Operation in Streamer and Avalanche Modes	143
4.8	Attempts to Increase Sensitivity via Secondary Electron Emission	143
	References	154
5	Resistive Plate Chambers in High Energy Physics Experiments	161
5.1	Early Experiments Using RPCs	161
5.2	RPCs for the L3 Experiment at LEP	169
5.3	The Instrumented Flux Return of the BaBar Experiment	172
5.4	The ARGO-YBJ Detector	176
5.5	The “BIG” Experiments: ATLAS, ALICE, and CMS at LHC	180
5.5.1	ATLAS	182
5.5.2	CMS	187
5.5.3	Some Common Themes to ATLAS and CMS	193
5.5.4	ALICE	193

5.6	The RPC-TOF System of the HADES Experiment	195
5.7	The Extreme Energy Events Experiment	201
5.8	Other Experiments	206
	References	208
6	Materials and Aging in Resistive Plate Chambers	211
6.1	Materials	211
6.1.1	Glasses and Glass RPCs	213
6.1.2	Bakelite	221
6.1.3	Methods to Measure Bakelite Resistivity	223
6.1.4	Semiconductive Materials	228
6.2	Aging Effects	229
6.2.1	Aging in RPCs Operated in Streamer Mode	229
6.2.1.1	L3 and Belle	229
6.2.1.2	Experience Gained in BaBar	230
6.2.2	Melamine and Bakelite RPCs without linseed oil treatment	235
6.3	Aging Studies of RPC Prototypes Operated in Avalanche Mode Designed for the LHC Experiments	237
6.3.1	Temperature Effects	240
6.3.2	Effects of HF and Other Chemical Species	241
6.3.3	Other Possible Changes in Bakelite Electrodes	244
6.3.4	Closed-Loop Gas Systems for LHC RPCs	244
6.4	Aging Studies on Multi-Gap RPCs	246
	References	248
7	Advanced Designs: High-Rate, High-Spatial Resolution Resistive Plate Chambers	253
7.1	The Issue of Rate Capability	253
7.2	The “Static” Model of RPCs at High Rate	257
7.3	The “Dynamic” Model of RPCs at High Rate	261
7.4	The Upgrade of the Muon Systems of ATLAS and CMS	266
7.5	Special High Rate RPCs	269
7.5.1	High-Rate, High-Position Resolution RPCs	276
7.6	High-Position Resolution Timing RPCs	279
	References	282
8	New Developments in the Family of Gaseous Detectors: Micropattern Detectors with Resistive Electrodes	285
8.1	“Classical” Micropattern Detectors with Metallic Electrodes	285
8.2	Spark-Proven GEM-like Detectors with Resistive Electrodes	289
8.3	Resistive Micromesh Detectors	294
8.4	Resistive Microstrip Detectors	298
8.5	Resistive Micro-Pixel Detectors	300
8.6	Resistive Microhole-Microstrip and Microstrip-Microdot Detectors	301
	References	304

9	Applications beyond High Energy Physics and Current Trends	307
9.1	Positron Emission Tomography with RPCs	307
9.2	Thermal Neutron Detection with RPCs	310
9.3	Muon Tomography and Applications for Homeland Security	314
9.4	X-Ray Imaging	322
9.5	Cost-Efficient Radon Detectors Based on Resistive GEMs	326
9.6	Resistive GEMs for UV Photon Detection	331
9.6.1	CsI-Based Resistive GEMs for RICH	332
9.6.2	Flame and Spark Detection and Visualization with Resistive GEMs	337
9.7	Cryogenic Detectors with resistive electrodes	338
9.8	Digital Calorimetry with RPCs	341
	References	344
	Conclusions and Perspectives	349
A	Some Guidelines for RPC Fabrication	353
A.1	Assembling of Bakelite RPCs	353
A.2	Assembling of Glass RPCs	356
A.3	Assembling of Glass MRPCs	361
	References	365
	Glossary	367
	Index	373