

# Contents

<b>Abstract</b>	<b>i</b>
<b>Zusammenfassung</b>	<b>iii</b>
<b>Acknowledgement</b>	<b>v</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Physics motivation . . . . .	1
1.2 Next generation LAr TPCs . . . . .	3
1.2.1 Neutrino detection with LAr TPCs . . . . .	3
1.2.2 The novel LAr LEM-TPC . . . . .	5
1.3 Organization of the thesis . . . . .	7
<b>2 The double phase argon LEM-TPC</b>	<b>9</b>
2.1 Basic LAr properties . . . . .	9
2.2 Energy loss by heavy charged particles . . . . .	10
2.3 Ionization . . . . .	13
2.3.1 The production of electron ion pairs . . . . .	13
2.3.2 Electron ion recombination . . . . .	13
2.4 Scintillation in LAr . . . . .	14
2.5 Electron transport . . . . .	15
2.5.1 Drift in liquid argon . . . . .	15
2.5.2 Emission of hot electrons . . . . .	17
2.5.3 Townsend avalanche in a LEM . . . . .	18
2.6 Charge collection on a 2D anode readout . . . . .	20
<b>3 Readout electronics and data acquisition</b>	<b>23</b>
3.1 General overview . . . . .	23
3.2 Design criteria . . . . .	25
3.3 The readout electronics . . . . .	26
3.4 The charge sensitive preamplifier . . . . .	28

3.4.1	Preamplifier circuit design . . . . .	28
3.4.2	Performance measurements . . . . .	32
3.5	Charge and light data acquisition . . . . .	35
<b>4</b>	<b>Event reconstruction and simulation</b>	<b>37</b>
4.1	The Qscan software . . . . .	38
4.2	Event simulation . . . . .	39
4.2.1	Particle propagation in detector geometries . . . . .	40
4.2.2	Waveform generation . . . . .	41
4.3	Event Reconstruction . . . . .	42
4.3.1	Signal processing . . . . .	44
4.3.2	Hit identification and reconstruction . . . . .	47
4.3.3	Cluster finding . . . . .	49
4.3.4	Track reconstruction . . . . .	50
4.3.5	Three dimensional track reconstruction . . . . .	52
<b>5</b>	<b>A 120 L LAr TPC exposed to a charged particle beam</b>	<b>55</b>
5.1	The experimental setup . . . . .	56
5.1.1	The beamline instrumentation . . . . .	56
5.1.2	The 120 L LAr TPC . . . . .	58
5.2	The charged particle beam . . . . .	62
5.3	Run description . . . . .	64
5.4	Event reconstruction and selection . . . . .	68
5.5	Detector calibration . . . . .	71
5.5.1	Free electron lifetime measurements with cosmic rays . . . . .	72
5.5.2	Charge response of the detector . . . . .	73
5.6	The Monte Carlo simulation . . . . .	75
5.7	Results . . . . .	78
5.7.1	Stopping power and charge recombination . . . . .	79
5.7.2	Validation of the LAr MC simulation . . . . .	81
<b>6</b>	<b>The large area double phase LEM-TPC</b>	<b>85</b>
6.1	Experimental setup . . . . .	86
6.1.1	Overview of the LEM-TPC . . . . .	86
6.1.2	Design and construction of the charge readout sandwich . . . . .	87
6.1.3	The HV layout . . . . .	91
6.1.4	Data acquisition and trigger . . . . .	94
6.1.5	Cryostat, slow control and LAr purification systems . . . . .	94
6.2	Operation of the detector . . . . .	95
6.2.1	First operation with an Ar-isobutane gas mixture . . . . .	96

6.2.2	Double phase operation . . . . .	98
6.3	Reconstruction of cosmic ray events . . . . .	101
6.4	Calibration of the readout electronics . . . . .	103
6.5	Results . . . . .	105
6.5.1	Free electron lifetime measurements . . . . .	105
6.5.2	Readout efficiency . . . . .	106
6.5.3	Drift field uniformity . . . . .	107
6.5.4	Gain and signal to noise ratio . . . . .	109
6.5.5	Delta ray study . . . . .	111
<b>7</b>	<b>Conclusions</b>	<b>113</b>