Contents

Resumen 5
Resum 9
Summary 13

1 Framework of the thesis: ANTARES Neutrino Telescope 17
1.1 Why Neutrino Astrophysics? 17
1.2 ANTARES: The first Undersea Neutrino Telescope 22
1.2.1 Detection principle 23
1.2.2 Detector overview 25
1.2.3 The AMADEUS system 28
1.2.3.1 System overview 29
1.2.3.2 Acoustic Storeys 31
1.3 KM3NeT 33

Part I: Design and Development of an Acoustic Calibrator for Deep-Sea Neutrino Telescopes 37

2. Part I Introduction: Acoustic detection of Neutrinos 39
2.1 Acoustic Detection of Ultra-High Energy Neutrinos 40
2.1.1 The Thermo-Acoustic Model 42
2.1.2 Acoustic Neutrino signature 45
2.1.3 Underwater conditions in the Mediterranean Sea. 48
2.1.3.1 Attenuation 48
2.1.3.2 Sound speed 52
2.1.3.3 Background in acoustic neutrino detection in the Mediterranean Sea 54

2.2 Calibrator for Acoustic Detection of Ultra High Energy Neutrinos in Underwater Telescope 57
2.3 Parametric Acoustic Sources 58

3. Evaluation of the Parametric Technique for the Compact Acoustic Calibrator 63
3.1 Planar Transducers 63
3.1.1 Experimental Setup 64
3.1.2 Methods, Analysis and Results 65
3.2 Cylindrical Transducers 68
3.2.1 Experimental Setup 69
3.2.2 Methods, Analysis and Results 71
3.3 Array Configuration Evaluation 79

4. Prototype of the Versatile Compact Array 85
4.1 Design philosophy 85
4.2 Transducer versatility 87
4.3 Mechanics 90
4.4 Electronics 94
4.4.1 Electronic Emission Board 94
4.4.1.1 Basic block diagram 95
4.4.2 Register System 100
4.5 Tests with the Array 101
4.5.1 Array characterization 102
4.5.2 Low frequency tests 102
4.5.2.1 Laboratory tests 104
4.5.2.2 Field tests 109
4.5.3 High frequency tests 111
4.6 Current state and future steps 115

Part II: First Seach for Secluded Dark Matter 117

5. Part II Introduction: Dark Matter and Secluded Dark Matter 119
5.1 Dark Matter 119
5.1.1 Indirect Evidences 121
5.1.1.1 Galactic Rotation Curves 121
5.1.1.2 Galaxy Clusters 122
5.1.1.3 Gravitational Lensing 122
5.1.1.4 Velocity Dispersions of Galaxies and Mass to Light Ratio 124
5.1.1.5 Cosmic Microwave Background 125
5.1.2 WIMP as the Dark Matter Candidate 127
5.2 Dark Matter Detection Methods 128
5.2.1 Direct Detection 128
5.2.2 Indirect Detection 130
5.3 Dark Matter Searches with ANTARES Neutrino Telescope 133
5.3.1 The Galactic Center 134
5.3.2 The Earth 135
5.3.3 The Sun 136
5.3.3.1 Standard Dark Matter search 136
5.3.3.2 Search for Secluded Dark Matter in the Sun. 137
5.3.3.2.1 DM annihilation in the Sun. 139
5.3.3.2.2 Mediator decay products and bounds from neutrino detection. 140
5.3.3.2.3 Decay probabilities 144

6. Tools and Methods 147
6.1 Signal expectations 148
6.1.1 Di-Muon Generator (*DiMuGen*) 152
6.1.1.1 Inputs and outputs 154
6.1.1.2 Code description 155
6.1.1.2.1 Primary (mediator) direction 156

6.1.1.2.2 Inside decay 157
6.1.1.2.3 Outside decay 160
6.2 Background obtained using the scrambled data 170
6.3 Optimization of the event selection criteria 171
6.4 Other interesting cases in Secluded Dark Matter 173
6.4.1 Di-muon decay into neutrino 173
6.4.2 Mediator decay into neutrino 174

7. Analysis and Results 177
7.1 Flux sensitivities 177
7.2 Unblinding Strategy 180
7.3 Sensitivity in terms of annihilation rates 183
7.4 Cross Section Sensitivities 188
7.5 Final Results after unblinding the data 190
7.5.1 Unblinding results following MultiLine reconstruction strategy 191
7.5.2 Unblinding results following SingleLine reconstruction strategy. 193
7.6 Limits obtained for Secluded Dark Matter models 194
7.6.1 Annihilation Rates 195
7.6.2 Limits on Cross Sections for SDM 198

Conclusions 201
Bibliography 205
Acknowledgements / Agradecimientos 223
Table List 225
Figure List 227
Acronyms 237
Annex A 239