

Contents

Introduction	1
Chapter I: The ratio method	8
1 Halo nuclei	9
1.1 The halo structure	9
1.2 Experimental probes of the halo structure	13
1.3 Summary	19
2 Model the reactions of one-nucleon halo nuclei	21
2.1 Elastic scattering and breakup of two-body projectiles	21
2.2 Continuum Discretised Coupled Channel method (CDCC)	25
2.3 The Dynamical Eikonal Approximation (DEA)	28
2.4 The Recoil Excitation and Breakup model (REB)	31
2.5 Interaction potentials	33
3 The ratio method	36
3.1 The ratio observable	36
3.2 Neutron halos at low energy	39
3.2.1 Numerical details for reactions involving ^{11}Be	39
3.2.2 Sensitivity to the projectile structure	40
3.2.3 Analysis of the ratio method at low energy	43
3.3.1 Proton halos	49
3.3.1.1 Numerical details for reactions involving ^8B	50
3.3.2 Analysis of the ratio for proton halos	52
3.3.3 Sensitivity to the projectile structure	57
3.3.4 Sensitivity to the choice of continuum energy	59
3.3.5 Extension to other proton-rich nuclei: ^{17}F , ^{25}Al and ^{27}P	61
3.3.5.1 Numerical details	61
3.4 Summary and prospects of the analysis	69
Chapter II: The neutral-pion photoproduction as a tool to measure the neutron skin	72
4 State of the art in neutron skin measurements	73
4.1 Hadronic probes	74
4.2 Parity-violating electron scattering	76
4.3 Electric dipole resonances	77
4.4 Coherent neutral-pion photoproduction (a primer)	79
4.5 Summary	80
5 Experiments on neutral-pion photoproduction	82
5.1 The recent measurement at the MaMi facility	82
5.2 GEANT4 simulation and random event generator	85

5.2.1	Random number distributions	86
6	Nuclear densities	90
6.1	One- and two-nucleon densities	90
6.2	Mean field and shell model calculations	91
6.2.1	Relativistic mean-field calculations (FSU model)	92
6.2.2	Shell model and harmonic oscillator	93
6.3	Phenomenological and experimental densities	94
6.3.1	Fermi-Dirac shape (São-Paulo group)	94
6.3.2	Experimental density	95
6.4	Removal of the center-of-mass motion	96
6.5	Comparison of the different densities	98
7	Pion-nucleus interaction in the Kerman-McManus-Thaler formalism	104
7.1	The Kerman-McManus-Thaler formalism	104
7.1.1	The impulse approximation	107
7.2	Elementary pion-photoproduction	110
7.3	Pion-photoproduction on a nucleus	113
7.3.1	Plane Wave Impulse Approximation (PWIA)	115
7.3.2	Energy of the active photon-nucleon system	121
7.3.3	Distorted Wave Impulse Approximation (DWIA)	124
8	Modeling the final state interactions	127
8.1	Elementary pion-nucleon interaction	127
8.2	Interaction of a pion with a nucleus	130
8.2.1	First order of the interaction	130
8.2.2	Second order of the interaction and absorption	133
8.2.3	MSU total potential	135
8.3	Resolution of the Lippmann-Schwinger equation	137
8.3.1	Partial wave decomposition	138
8.3.2	Numerical resolution	140
8.3.3	Comparison to pion-nucleus elastic scattering data	146
9	Detailed analyses of experimental π^0 -photoproduction	148
9.1	Comparison to previous data: ^{12}C , ^{40}Ca and ^{208}Pb	148
9.2	Recent experiments: Sn isotopic chain and ^{48}Ca	157
9.3	Summary and prospects of this model	162
	Conclusion	166
	Appendices	172
A	The completeness relation of the REB form factor	173
B	Fresco	174
B.1	Input file	174
B.2	Output files	177
C	KMT	178
D	Photoproduction of a pion on a single free nucleon	180
E	Kinematics and change of frame	183
F	Random number generation	186
F.1	The inversion method	186
F.2	Box-Muller transforms for normal distributions	187
G	The treatment of the Coulomb interaction in momentum space	188
H	Development of the second order potential in the $t\rho$ approximation	195

H.1	General form of the second-order potential	195
H.2	Particularisation to ^{12}C in the HO model	200
I	Some mathematical developments for the second order of the interaction .	204
I.1	The integral I_0	204
I.2	The integral I_1	206
I.3	The integral I_2	209
J	The Hilbert Transform and the Dawson integral	212
Bibliography		228