Experimental Studies of the Mechanism of Photon Absorption on Light Nuclei

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A thesis submitted to the University of Edinburgh for the degree of

Doctor of Philosophy

in the Department of Physics & Astronomy

September 13, 2000

Abstract

A measurement of the reaction $^{12}\text{C}(\gamma, p\gamma')$ has been made with tagged photons in the range $49.47 < E_\gamma < 70.24$ MeV. The relative population of a triplet of states, $(7/2^-, 1/2^+, 5/2^+)$ at $E_{ex} \simeq 7$ MeV in the residual nucleus ^{11}B , following the reaction $^{12}\text{C}(\gamma, p)$, has been made by directly resolving their de-excitation γ -ray decay to the ground state of ^{11}B . This measurement constitutes the highest resolution ever achieved in determining the excitation function of the residual nucleus after a (γ, p) reaction (~ 48 keV FWHM at $E_{ex} \simeq 7$ MeV). Comparison has been made with the data of Kuzin *et al.*, who also measured the relative populations, with a resolution of ~ 270 keV at $E_{ex} \simeq 7$ MeV. The $7/2^-$ state at 6.74 MeV has been observed to be the most strongly excited state of the triplet in agreement with Kuzin *et al.* Disagreement has been found for the relative strengths of the $1/2^+$ and $5/2^+$ states in the triplet. An estimation of the maximum effect of angular correlations, between the ejected proton and de-excitation γ -ray, has been included in the analysis. This effect increases the disagreement between the 2 measurements.

A study of the reaction $^{12}\text{C}(e, e'p)$ has been made in the missing momentum region $260 < \mathbf{p}_m < 320$ MeV/c. A Rosenbluth separation of the reaction cross section has been carried out in parallel kinematics to measure the structure functions W_L and W_T . The experimental data have been compared with Complete Distorted Wave Impulse Approximation calculations and Random Phase Approximation calculations. The latter, when including virtual photon absorption on 2-body currents (Meson Exchange Currents + Isobar Currents) are seen to describe the reduced cross sections better than 1-body current or Complete Distorted Wave Impulse Approximation calculations.

For the 1st time a comparison between the $^{12}\text{C}(\gamma, p)$ reaction and the transverse part of $^{12}\text{C}(e, e'p)$ reaction cross section has been made. This comparison suggests that the mechanism of the 2 reactions converge when both are studied in equivalent kinematics, resolving the long standing issue of anomalous excitation of the ~ 7 MeV triplet in ^{11}B , following $^{12}\text{C}(\gamma, p)$, not seen in the $^{12}\text{C}(e, e'p)$ case.

In a further use of the $(\gamma, p\gamma')$ reaction, the relative population of the 4.44 MeV (T=0) & 15.1 MeV (T=1) states in ^{12}C , following $^{14}\text{N}(\gamma, pn)$, have been measured, with tagged photons in the range $50.20 < E_\gamma < 71.40$ MeV. A strong suppression for population of the T=1 state in the residual nucleus, as compared to the T=0 state was observed. This is consistent with the picture of photon absorption on T=0 (3S_1) p-n pairs in nuclei. A measurement of the $^{14}\text{N}(\gamma, d)$ reaction has also been made, in which the converse population of states in ^{12}C was observed.

Declaration

The data presented in this thesis were obtained in experiments carried out by the Edinburgh University Nuclear Physics group, in collaboration with the Nuclear Physics groups at the Universities of Lund and Glasgow and the EMIN group at the National Instituut voor Kernfysica en Hoge-Energiefysica (NIKHEF), Amsterdam. I have played a major role in the experiments performed at MAX-LAB, Lund. The data analysis and interpretation are my own work. This thesis has been written by myself.

Steven A. Morrow

Acknowledgements

I would like to thank my supervisor, Prof. Derek Branford, for his help during this project. I would also like to thank my second supervisor, Prof. Alan Shotter. My thanks go to the other students who have been in the Edinburgh Nuclear Physics group during my time (esp. Alison, Will, Darren, Jason and Feraidoun) and also Alessia for creating an enjoyable atmosphere in which to work. More recently Frédéric Sarazin has been a great help in keeping me sane during the last hectic months of my PhD. An especially big thanks goes to Tom Davinson, without whom most of the experiments with which I was involved could not have happened and whose help with analysis was invaluable. Also thanks go to Gordon Turnbull for his technical help during experiments.

A very big thank you must go to my family (Mum, Dad and Jane) for their unwavering support, both moral and financial. I am sure it seemed to them that I would never finish! Also the Porters, from Dunfermline; the frequent Sunday dinners reminded me of living at home.

To the people in Lund, I would like to thank Bent Schröder for his hospitality, and the many times he arranged accommodation for me. I would especially like to thank Jan-Olof Adler for his kindness as well as the opportunity to analyse the ^{14}N data presented in this thesis. And to Jan-Olof an extra thank you is required for paying for my last trip to Lund in February '00 to discuss the analysis. Thanks to Magnus Lundin for the many conversations which helped pass the long night shifts. Thanks also to all the other students and staff at MAX-LAB who helped on the experimental shifts and of course the Melbourne people, who kept us all in craic.

I would like to thank Cameron McGeorge for being present to offer his help during my experiments and also to Klaus Föhl, both of whom helped on many long hours of shifts when only 3 people were available to give 24 hour attention to the experiments. I'd also like to thank John Annand from Glasgow for his technical help.

The people I met at NIKHEF were all very helpful, mostly for having put up with my many stupid questions. Thank you to Louk Lápikus and Gerard van der Steenhoven, who have both been very helpful. Louk Lápikus especially for undertaking to teach me, in 3 weeks, everything I needed to know to analyse (e,e'p) data and for arranging my accommodation during my visits. I'd also like to thank Marcel van Batenburg, without whose tireless assistance, patience and willingness to help, I would not have managed.

Jan Ryckebusch was kind enough to provide calculations to compare with the data presented here. Also calculations were provided by Dimitri Van Neck,

but were finally not used.

A big thank you goes to my friend Glenn Cunningham for dutifully proof reading this thesis. This is despite the fact that he never saw fit to return his corrections to me; Cheers Glenn!

Finally I wish to acknowledge the financial support of the Engineering and Physical Sciences Research Council (EPSRC) throughout the 1st three years of this project.

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List of Abbreviations

ADC	Analogue-to-Digital-Converter
AMP	AMPlifier
AmPS	Amsterdam Pulsed Stretcher
CDWIA	Complete Distorted Wave Impulse Approximation
DE	Double Escape peak
CFD	Constant-Fraction-Discriminator
DKO	Direct KnockOut
DSSSD	Double Sided Silicon Strip Detector
DWIA	Distorted Wave Impulse Approximation
FSI	Final State Interaction
FWHM	Full Width at Half Maximum
Ge	Germanium
GLANCE	GLobal Analysis of Coincidence Experiments
gs	ground state
HPGe	High Purity Germanium
IA	Impulse Approximation
IC	Isobar Current
IPSM	Independent Particle Shell Model
J^π	Spin-Parity
LEGe	Low Energy Germanium
LN ₂	Liquid Nitrogen
L-T	Longitudinal-Transverse
MAXLAB	Microtron Accelerator for X-rays LABoratory
MEA	Medium Energy Accelerator
MEC	Meson Exchange Currents
MWDC	Multi-Wire Drift Chamber
NIKHEF	National Instituut voor Kernfysica en Hoge-EnergieFysica
PA	Pre-Amplifier
Pb	Lead
PP	PhotoPeak
PWIA	Plane Wave Impulse Approximation
QDD	Quadrupole-Dipole-Dipole
QDQ	Quadrupole-Dipole-Quadrupole
QFK	Quasi Free Knockout
RPA	Random Phase Approximation
SE	Single Escape peak
Si	Silicon
TDC	Time-to-Digital-Convertor
TFA	Timing-Filter-Amplifier