Spectroscopic Analysis of Re-190

M.R. Griffiths[1], C. Wheldon[1], Tz. Kokalova[1], A. Turner[1], S. Pirrie[1], V. Ziman[1], N.I. Ashwood[1], J.D. Malcolm[1], M. Barr[1], M. Freer[1], Th. Faestermann[2], H.-F. Wirth[3], R. Hertenberger[3], R. Gernhäuser[2] and R. Krücken[2].

[1]School of Physics and Astronomy, University of Birmingham, Birmingham, B15 2TT, United Kingdom.
[2]Physik Department, Technische Universität München, D-85748 Garching, Germany.
[3]Fakultät für Physik, Ludwig-Maximilians-Universität München, D-85748 Garching, Germany.

Corresponding author: m.r.griffiths@pgr.bham.ac.uk in: mgriffiths96 : @MRGriffiths96

Introduction

- An experiment was performed using the Q3D magnetic spectrograph in order to investigate the mass and energy level structure of Re-190.
- Re-190 is of particular interest as, prior to this work, its atomic mass and energy level structure were poorly known.
- It is also of interest as it lies in a region of the nuclear chart known for containing large numbers of K-isomers which exhibit large quadropole deformations.
- Currently, one isomeric state in Re-190 has been observed at an energy of 204 ± 10 keV, with a spin-parity configuration of $J^\pi = (6^-)$ [1].

Experimental Procedure and Mass Measurement

- An 18 MeV deuteron beam was directed towards targets of Os-192 and Pt-194 in order to produce Re-190 and Ir-192 respectively, alongside α-particle ejectiles.
- The Q3D magnetic spectrograph, shown in figure 1, was used to measure the energy of the α-particle ejectiles at several angles with respect to the beamline in order to produce an energy spectrum for both Re-190 and Ir-192.
- By comparing the measured Q-values for the two reactions and using kinematic calculations, the atomic mass of Re-190 was measured to be 176948297 ± 5 keV. Importantly, this is below 10 keV which is useful for astrophysical calculations [3].
- The uncertainty has been significantly decreased compared to the previous literature value of 176948240 ± 70 keV [4].

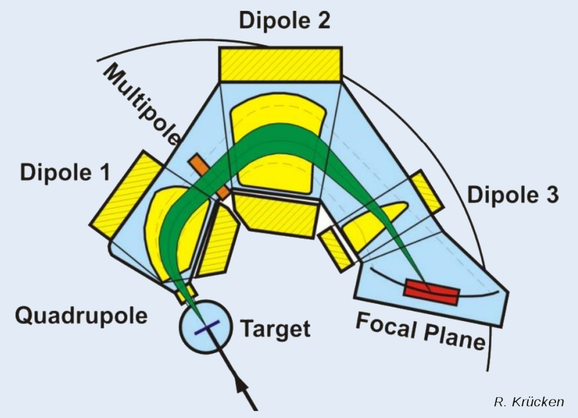

Figure 1: The Q3D Magnetic Spectrograph [2].

Level Scheme

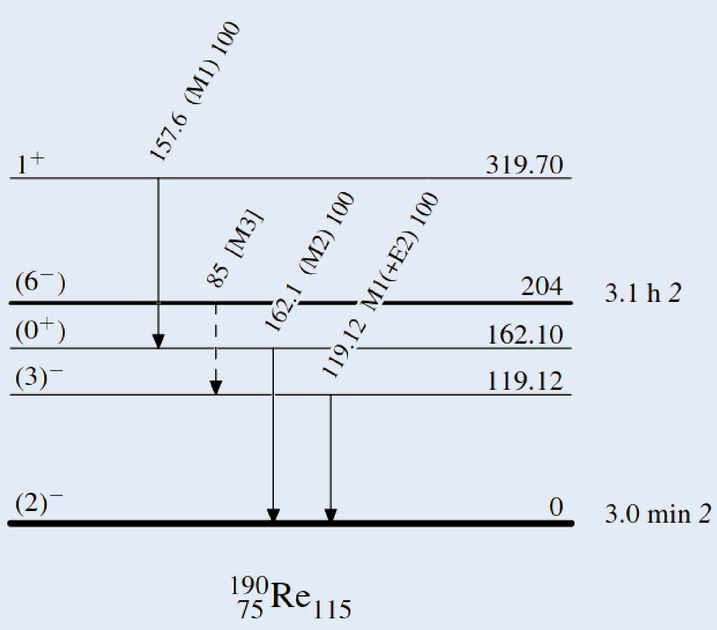

Figure 2: The currently published level scheme for Re-190, including the $J^\pi = (6^-)$ isomeric state [5].

Calibration Energy Spectrum

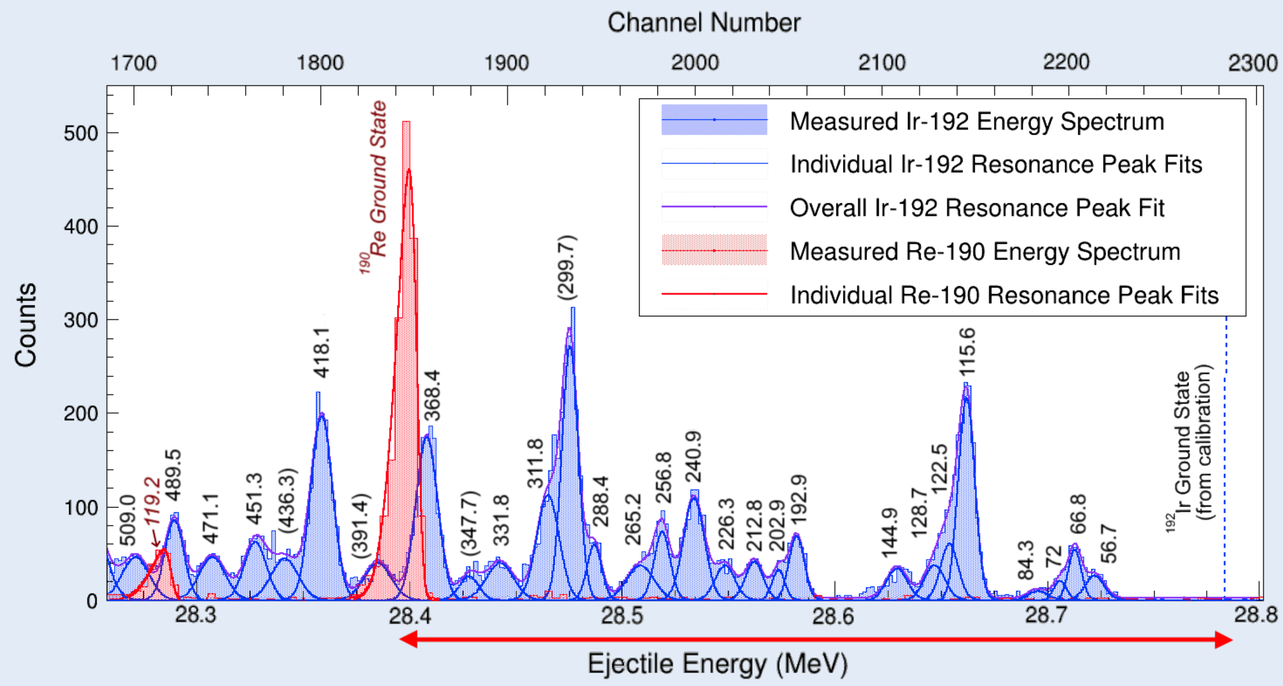

Figure 3: The measured energy levels of Ir-192 and Re-190. The assigned energy for each peak is given in units of keV. The red line shows the difference in ejectile energy between the ground states in Ir-192 and Re-190, used to find the difference in Q-value between the two reactions [6].

Cross Section Comparison

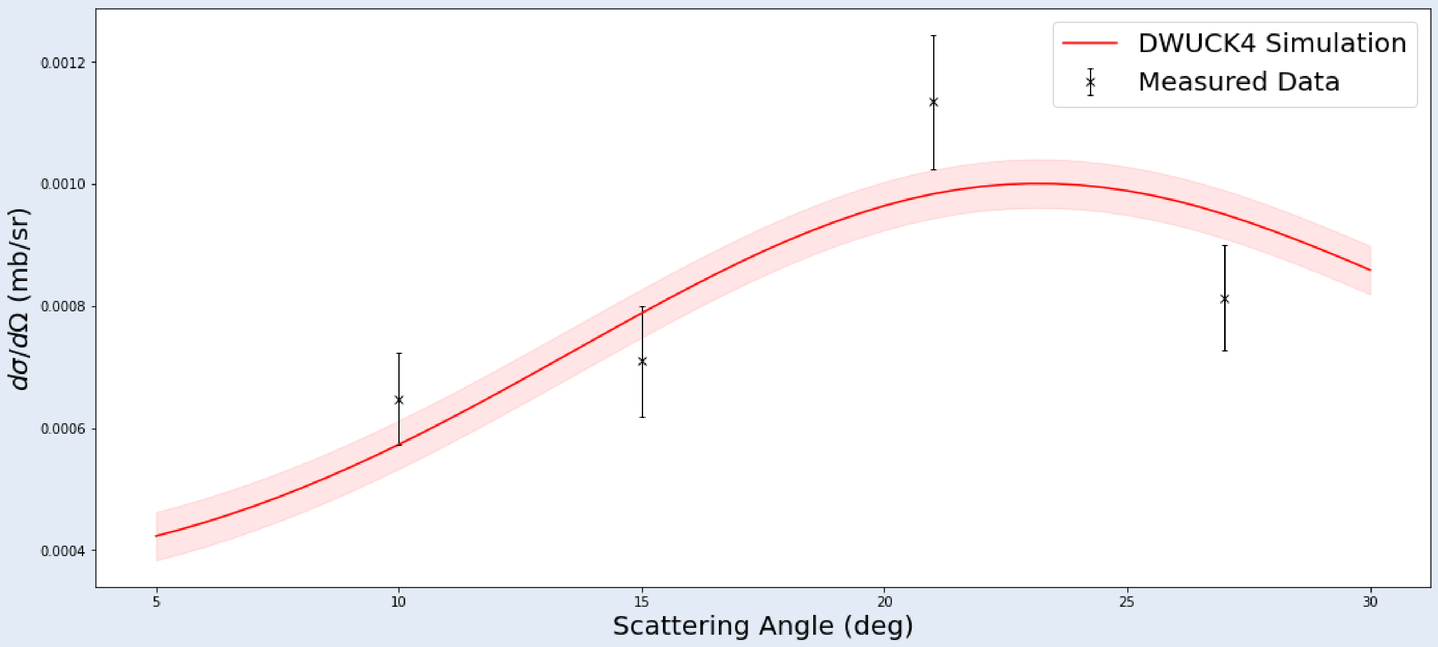

Figure 4: Simulated differential cross-sections for the Os-192(d, α)Re-190 reaction where the Re-190 is produced in a state with a spin-parity configuration of $J^\pi = 3^-$. Measured differential cross-sections for the $E = 119.12$ keV energy level have been overlaid, allowing for comparison between the two. A $\pm 5\%$ confidence interval has been added to the simulations.

Results

- The differential cross-section for each excited state in Re-190 was calculated with the Q3D magnetic spectrograph placed in four different positions.
- The program DWUCK4 was used to perform Distorted-Wave Born Approximation (DWBA) calculations in order to simulate the differential cross-section for various allowed spin-parity configurations.
- By comparing the simulations with the calculated data, spin-parity configurations for the states in Re-190 can be assigned.
- Initial simulations suggest that the current $J^\pi = (3)^-$ assignment for the $E = 119.12$ keV state is correct, as shown in figure 4.
- In the future, the energy, spin and parity of observed levels in Re-190, including the $J^\pi = (6^-)$ isomeric state, will be deduced. This will confirm, constrain and expand on current literature.

References

[1] M. W. Reed et al. Long-lived isomers in neutron-rich Z=72-76 nuclides. *Phys. Rev. C*, **86**:054321, (2012).
[2] R. Krücken. Private communication.
[3] H. Schatz. *Int. J. Mass Spectrom.*, **251**(2):293 – 299, (2006).
[4] Meng Wang et al. *Chinese Phys. C*, **41**(3):030003, (2017).
[5] B. Singh and J. Chen. . *Nucl. Data Sheets*, **169**:1 – 390, (2020).
[6] M. R. Griffiths et al. *J. Phys. G*, **47**:085104, (2020).

Publications

To read more on this research, particularly the mass measurement of Re-190, please scan this QR code.