Journal Entry - Week Five - Entry Four

Caspian Nicholls, u1027945

April 2, 2020

I give permission for portions of this work to be used as examples in future science communication course notes.

Article title: Search for octupole correlations in neutron-rich ^{148}Ce nucleus
Authors: Y. J. Chen, S. J. Zhu, J. H. Hamilton, A. V. Ramayya, J. K. Hwang, M. Sakhaee, Y. X. Luo, J. O. Rasmussen, K. Li, I. Y. Lee, X. L. Che, H. B. Ding, and M. L. Li
Reference: Phys. Rev. C 73, 054316, May 2006.
Link: Article abstract.
Word count: 750.

Context

Interactions between nucleons within nuclei can affect nuclear shapes. One such interaction is that of octupole correlations, the observation of which can provide evidence that a nucleus possesses a non-spherical (often pear-shaped) charge distribution. These correlations arise when nucleons in nuclear orbitals that have opposite parity (positive and negative) and a precise relationship between their quantum numbers interact strongly. Specifically, the interacting orbitals will satisfy $\Delta n = 1$ and $\Delta l = \Delta j = 3$, where n, l and j denote the principal, orbital angular momentum and total angular momentum quantum numbers.

Theoretical calculations that utilise accepted models of nuclear structure predict that several nuclei with proton number $Z \sim 56$ and neutron number $N \sim 88$ should exhibit these correlations. Yet, there remain various nuclei near $Z = 56$ and $N = 88$ for which experimental evidence of octupole correlations has not been recorded. Thus, observation of these correlations can provide useful information about the energy level structure and shape of nuclei with mass number $A \sim 144$.

Purpose

In this work, experiments are performed to hunt for signs of octupole correlations in ^{148}Ce, which with $Z = 58$ and $N = 90$, should display this type of interaction. The authors also seek to extend the existing picture (*level scheme*) of the excited states of this nuclide.

Approach

A sample of ^{252}Cf was placed inside a gamma ray detector array, the spontaneous fission of which produced (among other isotopes) ^{148}Ce. Then, gamma rays that were emitted from excited states of the radioisotopes produced by fission events were measured by the detector array. Signals from sources other than ^{148}Ce were filtered out during the analysis phase.

Gamma rays that are recorded with a small enough separation in time (typically $\sim$ns) can be attributed to the decay of an individual nucleus, if enough of these *coincident* detections are made. By using this fact and focussing on gamma rays that are known to be emitted by ^{148}Ce during their data analysis, a level scheme for ^{148}Ce was built. Then, the relative intensities of and the measured total internal conversion (where an electron is emitted instead of a gamma ray) coefficients for different gamma ray transitions were used to infer the spin-parities of the observed excited states.

Contribution

20 new transitions and nine new levels were added to the level scheme of ^{148}Ce. Spins and parities were assigned (tentatively in some cases) for some of the newly discovered states and either confirmed or refined for some other existing levels. Internal conversion coefficients for some transitions were also measured, by taking the ratio of the intensity of the electron emission process to the total intensity of transitions from a given excited state.

Nuclei can rotate (or vibrate) in various ways. Within their level schemes, each possible rotation (vibration) is represented by a group of energy levels (*band*) with different energies. Such a band could describe rotation around a given axis at different speeds, for example. By analysing the differences in energies between certain rotational bands of opposite parity, the observed octupole correlations in ^{148}Ce were suggested to be similar to those found in ^{144,146}Ce. However, it was proposed that the different bands within ^{148}Ce may exhibit octupole correlations with different strengths. This conclusion was reinforced by further analysis of the relative transition energies and intensities within each rotational band.

Yet, analysis of the moment of inertia as a function of the rotational energy of the nucleus led the authors to suggest that the deformation of this nucleus due to these octupole correlations may be unstable, prompting further theoretical study.

Relevance

While access to ANU's experimental facilities remains heavily restricted due to the COVID-19 pandemic, I will be analysing data from an experiment performed to gauge octupole collectivity in the neutron-rich nuclides ^{150,152}Ce. These are located near $Z = 56$ and $N = 88$, but remain unstudied. As such, having an understanding of what octupole correlations are and how they can be investigated is vital.

Quality

This work was written clearly and the analysis was detailed, with the development of their final level scheme via gamma ray spectroscopic analysis described in detail. However, I did have to refer to some other sources to clarify parts of the paper that I was not familiar with.

These authors also provided multiple pieces of evidence for their conclusion that they did observe octupole correlations in ^{148}Ce, making their conclusions trustworthy. Seeing explicit discussion of how they reached these conclusions was also worthwhile, given I will be performing a similar analysis for my thesis.

Questions/Directions

After reading this paper, I should do the following.

- Brush up on my knowledge of the finer details of nuclear structure, by referring to my notes from PHYS3105 and relevant textbooks.
- Explore the references of this paper to better understand the theoretical models that predict the existence of these octupole correlations.