Journal Entry - Week Five - Entry Four - Draft

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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
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Reference: Phys. Rev. C 73, 054316, May 2006.
Link: Article abstract.
Word count: 745.

Context

Theoretical calculations that make use of accepted models of the structure of nuclei predict that several nuclei with proton numbers Z around 56 and neutron numbers N around 88 should exhibit octupole correlations. These correlations occur most strongly when there is a strong interaction between nuclear orbitals that for principal, orbital angular momentum and total angular momentum quantum numbers n, l and j, have differences $\Delta n = 1$ and $\Delta l = \Delta j = 3$. The correlations themselves occur due to the octupole interaction component of the nuclear Hamiltonian having a significant magnitude relative to the other terms in that Hamiltonian. The observation of octupole correlations in nuclei is evidence that the charge distribution of the nucleus may exhibit octupole deformation, so that its shape is no longer spherical. There remain various nuclei near $Z = 56$ and $N = 88$ for which experimental evidence of octupole correlations had not been recorded. Ultimately, observation of these correlations can provide useful information about the energy level structure and shape of these nuclei.

Purpose

In this work, the authors perform experiments to hunt for signs of octupole correlations in ^{148}Ce. This isotope has $Z = 58$ and $N = 90$, so it is one such nuclide that should exhibit this type of correlation. The authors also seek to extend the level scheme of this nucleus.

Approach

A sample of ^{252}Cf was placed inside a gamma ray detector array. Spontaneous fission of this sample produced (among other isotopes) ^{148}Ce. Gamma rays that were emitted from excited states of ^{148}Ce were measured by the detector array. By analysing those that were recorded sufficiently close together in time for it to be concluded that they were emitted in succession, a picture (*level scheme*) of the excited states of ^{148}Ce was built. Then, the relative intensities of and the measured total internal conversion coefficients for different gamma ray transitions were used to infer the spin-parities of the states they observed.

Contribution

20 new transitions and nine new levels were added to the energy level structure of ^{148}Ce as a result of their analysis. Spins and parities were able to be 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 (where an electron is emitted instead of a gamma ray) for some transitions were also measured.

Analysis of the differences in energies between bands of opposite parity (positive and negative) led the authors to suggest that the octupole correlation they observed in ^{148}Ce has similarities to that observed within the nearby isotopes ^{144,146}Ce. However, they found that different bands of energy levels within ^{148}Ce (which relate to energy states of the nucleus that arise when it is rotated, each with different rotational symmetries) may have octupole correlations with different strengths. This conclusion was also supported 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 octupole deformation seen in this nucleus may be unstable, prompting further theoretical study.

Relevance

Following disruptions caused by the COVID-19 pandemic, we have had to come up with an alternate path for my Honours project to pursue whilst we may not access ANU's experimental facilities. This back-up plan involves the analysis of data generated from an experiment that was 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 clearly written and the analysis was detailed, as the authors thoroughly describe how they developed their final level scheme via gamma ray spectroscopic analysis of their collected data. I did have to refer to some other sources to clarify parts of the paper that I was not familiar with. Fortunately, however, clear and precise explanations of these details were easy to come by. These authors also provided multiple pieces of evidence for their conclusion that they did observe octupole correlations in ^{148}Ce, making their conclusions trustworthy.

Questions/Directions

After reading this paper, it is clear to me that I need to brush up on my knowledge of the finer details of nuclear structure. The best way to do this would be referring back to the notes I have made when I took Physics of Matter last year. Before I start to analyse the experimental data I referred to in the *Relevance* section, reading more deeply about the theoretical models that predict the existence of these octupole correlations (starting from the references in this paper) would also be worthwhile.