Exploring the $f_{7/2}p_{1/2}$ shell Using the Magnetic Moments of the Radioactive $^{48}_{24}$Cr Nucleus

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Abstract

In this proposal the study of the magnetic moments of the excited states of the radioactive $^{48}_{24}$Cr nucleus ($Z = N$), $T_{1/2} = 21.56$ h, using the Transient Field technique and the fusion-evaporation reaction ^{24}Mg+^{27}Al at a beam energy of 70 MeV, with the Pelletron accelerator at São Paulo University is presented. The results could confirm the nucleus ^{48}Cr as one of the best examples of a perfect quantum rotor.

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Introduction and Justification

The systematic experimental and theoretical study of the $f_{7/2}p_{1/2}$ shell has given us a deep understanding of the evolution of the microscopic behavior of nuclei from collective to single particle. By $f_{7/2}$-shell one denotes those nuclei with proton numbers between the magic numbers 20 and 28; the extremes of the shell is characterized by single-particle effects, but moving to the middle of the region large collective effects are dominant. The study of $N = Z$ nuclei allows the calibration of nuclear models to include effects such as proton-neutron pairing, and to predict the behavior of heavier $N = Z$ nuclei [8].

The ^{48}Cr isotope, with its position right at the middle of the $f_{7/2}$ shell, and its four valence protons and four valence neutrons, is considered one of the best examples of a good rotor [6]. Low spin states have been theoretically investigated using several approaches such as large scale shell model calculations [7] with realistic interactions, as for example the GXPF1 [9], molecular models using the ^{40}Ca+$\alpha + \alpha$ configuration[4], the interacting boson model with isospin (IBM-3) [1], and the Cranked Nilsson-Strutinsky model [5].

Model-independent magnetic moment measurements provide one of the most outstanding tools to discriminate between nuclear models. For the case of the $N = Z$ ^{48}Cr nucleus, while an extensive experimental work has been performed to obtain $B(E2)$'s, there is a lack of experimental information on g factors. In the single-j shell model a value of $g = \frac{g_{j\pi}+g_{j\nu}}{2} = 0.55$ in the $f_{7/2}$-shell is expected [10]. Large-Scale Shell-Model calculations, using the GXPF1 and the FPD6 interactions, have been performed putting special attention to predict $B(E2)$'s and g factors, these results are summarized in Fig. 1. The predicted g factors are all consistent with the collective $g = Z/A = 0.5$ for ^{48}Cr, i.e., an average value of $\langle g \rangle \sim 0.5$ over the states of the yrast band can be expected, thus, producing a complete confirmation of the collective behavior of the nucleus.

Experimental details

The so-called Transient Field (TF) technique, for the measuring of nuclear Magnetic Moments, will be utilized in conjunction with a fusion-evaporation reaction to populate the yrast states of ^{48}Cr. The TF technique allows to measure magnetic moments of states with lifetimes of the order of picoseconds or less, making use of the spin-orbit interaction

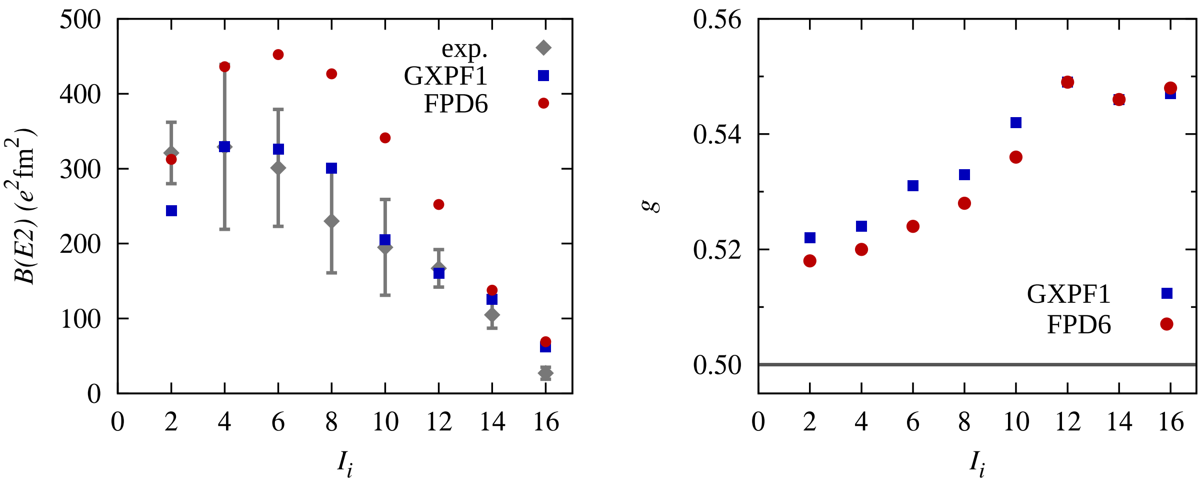

Figure 1: Left: $B(E2;\downarrow)$ for the yrast states of ^{48}Cr, the experimental values were taken from Ref. [3]. Right: predicted g factors for the yrast states of ^{48}Cr using Large-Scale Shell-Model calculations for two realistic interactions, the GXPF1 and the FDP6 from Ref. [11]. No experimental g-factor values has been measured to date.

produced by fast moving ions in ferromagnetic environments [2]. The fusion-evaporation reaction ^{24}Mg+^{27}Al will be utilized at a beam energy of 70 MeV, the use of a symmetric system ensure a large recoil velocity for the ions, as requested for the TF technique. The accelerator Pelletron in conjunction with the g-factor Sao Paulo setup will be used. Pace calculations predict the $p2n$ (^{48}Cr) evaporation channel as one of the strongest channels with a cross section of 105.8 mb. The strongest channel, $^{48}_{23}$V, has a 4^+ isomeric state of 16 days. The daughter nucleus, ^{48}V has no coincident γ-ray lines with ^{48}Cr. A total of 6 days + 1 day of preparation is required.

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