# Beta Decay and Structure of Exotic Nuclei in the Mass Regions N=Z, A$\simeq$70 and Near the N=20 Closed Shell

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Received on 30 September, 2003

This paper describes two beta decay experiments performed at the CERN/ISOLDE mass separator. The structure of $^{74}$Kr has been studied using a total absorption $\gamma$ spectrometer (TAgS). The measured Gamow-Teller strength is presented and compared to HFBCS+QRPA calculations. The $^{33}$Na decay is also presented. The structure of the $^{33}$Mg daughter nucleus is compared to shell-model calculations, showing for the first time an inversion of states in the A$\simeq$35 mass region.

## 1 Introduction

The study of beta decay gives informations on the $\beta$-decay process itself as well as on nuclear masses and on the properties and structure of the nuclear states populated in the decay.

In allowed cases, the beta decay process is governed by simple operators, $\sigma.\tau$ for a Gamow-Teller transition and $\sigma$ for a Fermi transition. In the case of Gamow-Teller transitions, a good description of the ground state of the parent nucleus and the states populated in the daughter nucleus should provide a good value of the beta Gamow-teller strength, $B_{GT}$. This strength can be expressed as follows:

$$B_{GT} = \frac{g_A^2}{g_V^2} | < f || \sigma.\tau || i > |^2$$

where $g_A$ and $g_V$ are the weak interaction coupling constants. The experimental determination of this force is not straightforward, its value being the difference between the intensity of a transition populating a state and the intensity of the transition which depopultates it. Germanium detectors are commonly used to measure these intensities but the beta feeding at high excitation energy is often fragmented over many states and the deexcitation of these states often proceeds via high energy $\gamma$-rays. This leads to large systematic errors in the determination of $B_{GT}$. Thus we have decided to use a total absorption gamma spectrometer (TAgS), resulting from a collaboration between the CERN (Switzerland), the IReS (France), the university of Madrid (Spain), Valencia (Spain) and Surrey (UK). This detector consists of a NaI(Tl) monocristal (38X38 cm), manufactured by *S$^t$ Gobain Crystals and detectors*. Its resolution is 5.5 % at 1.33 MeV and its efficiency is close to 90 % over the whole Q$_{EC}$ window open in our studied decay.

In this paper, we also present results on neutron-rich nuclei in the island of inversion. For this study we have used high resolution $\gamma$ detectors as well as a set of low energy neutron counters.

## 2 Krypton isotopes in the N=Z, A$\simeq$70 region

The N=Z, A$\simeq$ 70 mass region has been the object of numerous studies, concerning nuclear deformations, shape coexistence and pairing. Theoretical calcultations show that, in this region, near the proton drip-line, a large part of the Gamow-Teller resonance may be located below the ground state of the parent nucleus. Thus, it is interesting to study the $\beta$-decay of nuclei in this region, since an oblate-prolate shape transition is predicted [1]. Hartree-Fock + QRPA calculations show for $^{74}$Kr a strong dependance of B(GT) on multiparticle-multihole excitations. Following the study of the $^{76}$Sr $\beta$ decay by Miehé et al. [2] showing a strong indication for a prolate deformation in the ground state, we have decided to the investigate $^{72-76}$Kr $\beta$-decay using the TAgS spectrometer. The Kr isotopes have been produced at the CERN/ISOLDE mass separator using a 1.4 GeV proton beam on a 43 g.cm$^-$2 Nb target. Spallation products were ionized using a cold plasma ion source. The production rate obtained was typically from $10^4$ to $10^5$ atoms per second. A 7.5 cm hole is drilled in the NaI cristal, perpendicular to its axis allowing to install the collection point of radioactives species at the center of the scintillator and to place additonal detectors. In the present study, we have used a Ge-Ge telescope for X and $\gamma$ detection and a plastic scintillator for the detection of $\beta$ particles. TAgS-$\gamma$ coincidences have been recorded with 1% efficiency at 1.33 MeV, TAgS-$\beta$ coincidences with 20% efficiency and TAgS-X coincidences with 4% efficiency at 9 keV. The TAgS works as a sum spectrometer: instensities of the observed $\gamma$-rays directly reflect the feeding of excited states populated in the decay of the parent nucleus. The response function of the detector has been measured using known sources and used to determin the $\beta$

Gamow-Teller strength in the studied nuclei. Details about the detection system as well as a complete description of the analysis method can be found in E. Poirier et al. [3]. Fig. 1 shows the Gamow-Teller strength in $^{74}$Kr and the corresponding HF+BCS+QRPA calculations and Fig. 2. shows the accumulated experimental Gamow-Teller strength [3] compared to HF calculations. These results may indicate a mixing of configurations in this isotope.

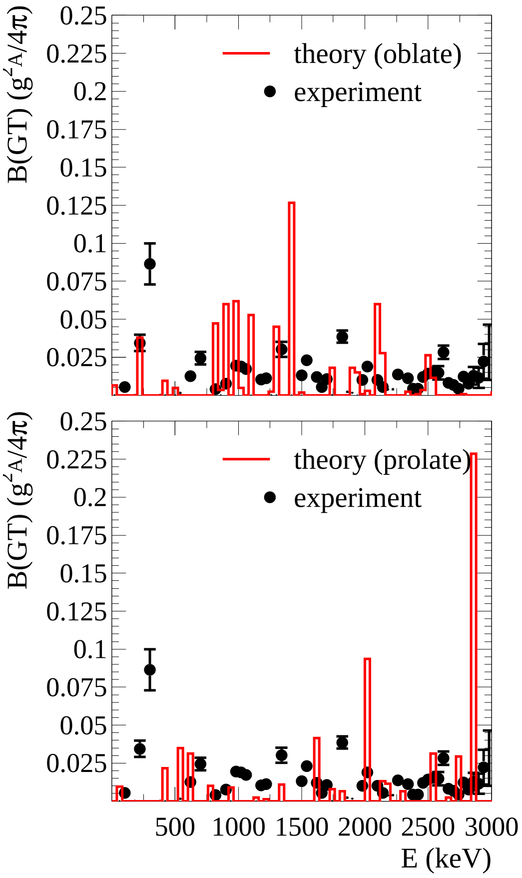


Figure 1. Experimental Gamow-Teller strength distribution in $^{74}$Kr and the corresponding HF+BCS+QRPA calculations.

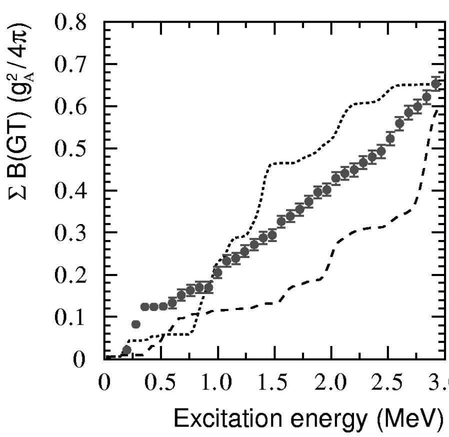


Figure 2. Accumulated GT strength in $^{74}$Kr as a function of the excitation energy of the daughter nucleus. The dotted and dashed lines correspond respectively to oblate and prolate solutions of the HF calculations [3].

# 3 The island of inversion at N≃21, A≃33

Indications for an inversion of the shell-model states at N=21 have been observed for the first time by Thibault at al. [4] in neutron-rich isotopes near A=32. Hartree-Fock calculations as well as Shell-Model investigations successfully describe binding energies in nuclei of this region if they suppose deformed nuclei in their ground states. In this mass region we have studied the structure of $^{33}$Mg populated by the $^{33}$Na $\beta$-decay. The studied isotopes have been produced at the CERN/ISOLDE mass separator using a 1.4 GeV proton beem impinging on a 46 g.cm$^{-2}$ UC$_2$ target. The resulting atoms were ionized on a tungsten surface ionization source. The target and source system was optimized to observe short-lived species (t$_{1/2}$ $^{33}$Na $\simeq$ 8ms). The production yield for $^{33}$Na was 2 atoms per second. The activity was put on an aluminized mylar tape and a tape transport system allowed to move periodically the tape to avoid long lived daughter nuclei accumulation. In this experiment, we have used a plastic scintillator ($\Omega$ = 70%) for the detection of $\beta$ particles at the collection point, two large volume germanium detectors allowing to record $\beta-\gamma$ and $\beta-\gamma-\gamma$ coincidences, and low-energy neutron counters ($\epsilon_{int}$ = 15%) for $\beta-n$ and $\beta-\gamma-n$ coincidences.

In this experiment, we have measured the $^{33}$Na period, t$_{1/2}$ = 8,0(3) ms, which is in very good agreement with previous studies [5]. The first decay scheme of this nucleus has been built. Absolute intensities of $\gamma$ transitions and the neutron emission probabilities have been measured in order to obtain the $\beta$ branching ratios of $^{33}$Na $\longrightarrow$ $^{33}$Mg and the corresponding logft values [6]. The $\beta$ feeding of the ground state of $^{33}$Mg (allowed transition) indicates that its spin-parity is $J^\pi$ is 3/2$^+$. These results have been compared to F. Nowacki shell-model calculations showing that this ground state is built on a 1 particle - 1 hole excitation.

This study shows the first observation of an inversion of states in this region.

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