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Determination of level widths in ^{15}N using nuclear resonance fluorescence

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Abstract. Level widths in ^{15}N have been measured with the nuclear resonance fluorescence (NRF) technique. Solid nitrogen compounds, bremsstrahlung, and HPGe detectors have been used as target, beam, and detectors, respectively. The preliminarily level widths are in agreement with the literature values, but more precise.

1 Introduction

Most of the ^{15}N level widths below the nucleon emission thresholds are known from just one nuclear resonance fluorescence (NRF) measurement published more than 30 years ago [1]. A recent experiment with the AGATA demonstrator array aimed to determine level widths using the Doppler Shift Attenuation Method (DSAM) in ^{15}O and ^{15}N populated in the ^{14}N+^{2}H reaction [2]. In order to set benchmark values for the upcoming AGATA demonstrator data, the widths of several ^{15}N levels have been remeasured with high precision using NRF.

2 The new NRF experiment

2.1 Experimental technique

In case of an NRF experiment the observed γ-ray yields are proportional to the total widths of the levels, because both of them are proportional to the energy- and solid angle-integrated resonant scattering cross sections of the excited state. The proportionality factor contains the impinging flux, the number of target atoms, the detection efficiency, the angular correlation factor, the spin and energy of the level, and the branching ratio of the ground state transition. The first three are determined by the experiment, the angular correlation depends on the spin and parity of the involving states, which can be taken from the literature [3].

2.2 Setup used

For the measurement presented here the photon scattering facility [4] at the superconducting electron accelerator ELBE [5, 6] of Helmhotz-Zentrum Dresden-Rossendorf (HZDR) was used. Bremsstrahlung was produced with an electron beam of 12.5 MeV kinetic energy impinging on a niobium radiator foil. The low-energy γ photons have been filtered out by a 10 cm thick aluminum absorber, before the γ beam reached the photon scattering chamber through a collimator. The energy distributions of the bremsstrahlung have been precisely determined by measuring the proton energy distribution originating from a deuterated-polyethylene target experiencing the same bremsstrahlung as the nitrogen target.

A ^{11}B target was always combined with the ^{15}N target, and the absolute number of impinging γ photons has been derived from photon scattering from well known ^{11}B levels. Using the literature widths, branchings, mixing ratios, and scattering cross sections of ^{11}B states [7–9], the impinging flux was determined at the energies of the ^{11}B levels. The previously determined energy distribution of the bremsstrahlung is scaled to match these values, and used henceforward in the analysis.

The scattered photons were detected by four high purity germanium (HPGe) detectors equipped with bismuth germanate (BGO) scintillators, as active shielding to reduce the Compton background. 10 cm thick lead collimators and 3 cm lead shieldings were applied to reduce the environmental and the beam induced background. Two detectors were placed at 127° and two at 90° with respect to the γ-beam direction, located at a distance of 32 cm and 28 cm to the target, respectively. The number of low energy photons entering the detector collimators were suppressed by 3 mm (8 mm) thick lead and 3 mm thick copper absorbers for the detectors at 127° (90°). The whole setup including the HPGe detectors, the BGO shields, the collimators, the lead shieldings, the target and detector holders were implemented in a GEANT4 [10] simulation.

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The reliability of the simulation was tested by comparing simulated spectra with measured ones as described in e.g. [11]. The absolute detection efficiencies of the HPGe detectors were measured using calibrated gamma sources. The shape of the measured efficiency is consistent with the simulated one and the absolute value differed by a few percents.

Targets were produced from two different solid nitrogen compounds (ammonium-nitrate and ammonium-chloride) enriched in ^{15}N. The original target powder was compressed to form a disk with 2 cm diameter, and used for the experiment in this form. Altogether four targets were used, one thicker and one thinner from both material, to investigate the effect of the self absorption which was found to be negligible.

2.3 Obtained spectra

The spectra measured for ammonium-nitrate are shown in fig. 1. No unknown peak is present. Beside the lines from ^{15}N and ^{11}B, two lines from ^{16}O are also observable. The oxygen present in the target material can be used as a cross check of the target stoichiometry. Beside the marked full energy and single escape peaks few double escape peak and weak neutron induced background lines from iron are observable, but well separated from the others. Therefore they do not disturb the analysis.

3 Preliminary results

The preliminary analysis shows level widths that are consistent with the earlier data. The statistical uncertainty of the observed γ peaks in the spectra corresponding to levels with the lowest widths is below 11%. For other γ peaks the statistical uncertainty is between 0.5%–3%. The precise analysis of systematic uncertainties is ongoing. Considering an overestimated 10% systematic uncertainty, most of the new values are more precise than those in the literature.

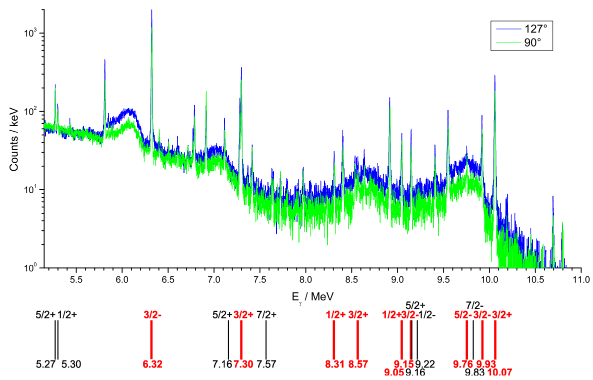

Figure 1. The obtained spectra during irradiation of ammonium-nitrate + boron target at different angles. The level scheme of ^{15}N from the first excited state up to the proton separation is shown below. The investigated levels are highlighted, two levels above the separation threshold are also observed.

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