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Proton alignment in ^{82}Sr investigated by *g*-factor measurements*

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Abstract The proton alignment in ^{82}Sr has been investigated by the g-factor measurements of the ground state rotational band levels up to spin $I=8^+$. The g-factors were measured by a transient-magnetic-field ion implantation perturbed angular distribution method. The obtained g-factors increase with the increasing of spin along the band and clearly show the $g_{9/2}$ proton alignment that starts at $I=6^+$.

Key words g-factor, proton alignment, TMF-IMPAD, ^{82}Sr

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1 Introduction

Measurements of g-factors or magnetic moments play an important role in studying nuclear structure. The magnetic moments can provide direct information on the nuclear structure of excited states. One of the interesting features in mass $A=80$ region is interplay between the rotation and the quasi-particle alignment[1]. It is attractive to know whether the nuclei gain its spin through collective motion or quasi-particle alignment. The magnitude and sign of the magnetic moments are dramatically affected by the quasi-particle alignment[2]. Hence, g-factor or magnetic moment is a very sensitive probe to investigate the quasi-particle alignment. The present work was motivated to measure the g-factors of the ground state rotational band states in ^{82}Sr and to study the quasi-particle alignment.

2 Experimental details

g-factors of the rotational band states in ^{82}Sr were determined by a transient-magnetic-field ion implantation perturbed angular distribution (TMF-IMPAD) method. The TMF-IMPAD set-up used in the experiment is mainly composed of the multi-layer target and target chamber, the polarizing electromagnet, the γ-ray detector system etc,as shown in Fig. 1.

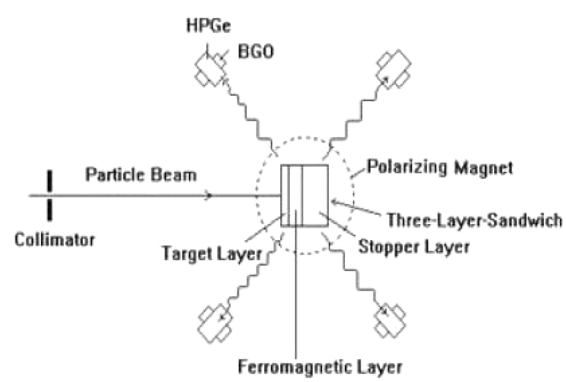

Fig. 1. TMF-IMPAD set-up schematic drawing.

The details of the TMF-IMPAD can be found in Ref. [3]. The rotational band states in ^{82}Sr were populated by the fusion-evaporation reaction ^{58}Ni(^{28}Si, 4p)^{82}Sr with a 110 MeV Si beam from the HI-13 tan-

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dem accelerator at China Institute of Atomic Energy. The reaction cross section calculated by a Cascade program is ~104 mb at 110 MeV. A 400 μg·cm^{-2} target layer of ^{58}Ni enriched to 99.3% was evaporated onto a annealed natural Fe layer of 1.575 mg·cm^{-2}. A Cu stopper layer of 14 mg·cm^{-2} was evaporated on the other side of the Fe layer. The ^{82}Sr recoiling nuclei passed through the Fe layer and stopped in the Cu stopper layer. The ferromagnetic Fe layer was polarized by a 0.16 T magnetic field, the direction of which was perpendicular to the beam-detector plane and automatically reversed up and down every 100 seconds during the measurement. As the nuclei moved along the polarized Fe layer, they experienced a transient magnetic field, and the nuclear precession about the direction of the polarizing magnetic field took place. The nucleus completed its decay to the ground state in the perturbation-free Cu stopper. The emitted γ rays were detected by the four BGO Compton suppressed HPGe detectors placed in the beam-detector plane to the beam direction at ±55° and ±125°. The coincidence data were recorded in a multi-parameter event-by-event mode.

In data analysis eight singles spectra were constructed according to 4 detectors and two polarizing field directions. In case γ ray peaks of interest are not well separated, gated spectra were generated. The nuclear precession of a state was inferred from a double ratio ρ obtained through single ratios $\rho(\pm\theta_i)$, which were formed with the counting rates of an adjacent pair of detectors at $\pm\theta_i$ for an observed transition. The counts were obtained from the singles or gated spectra.

The single ratios are given by Eq. (1) and Eq. (2)

$$\rho(\pm\theta_1)=\left(\frac{N(+\theta_1)\uparrow\times N(-\theta_1)\downarrow}{N(+\theta_1)\downarrow\times N(-\theta_1)\uparrow}\right)^{\frac{1}{2}} , \tag{1}$$

$$\rho(\pm\theta_2)=\left(\frac{N(+\theta_2)\uparrow\times N(-\theta_2)\downarrow}{N(+\theta_2)\downarrow\times N(-\theta_2)\uparrow}\right)^{\frac{1}{2}} , \tag{2}$$

where $N(\theta_1)$ is the γ-ray count of interest detected by a detector located at θ_i and the arrows ↑ and ↓ specify the up and down field directions of the polarizing magnetic field, respectively. The double ratio is defined as:

$$\rho=\left(\frac{\rho(\pm\theta_2)}{\rho(\pm\theta_1)}\right)^{\frac{1}{2}} . \tag{3}$$

Then, the precession angle $\Delta\phi$ can be obtained by

$$\Delta\phi=\varepsilon/S(\theta) , \tag{4}$$

where the term ε is an experimental ratio defined as

$$\varepsilon=\frac{\rho-1}{\rho+1} \tag{5}$$

and $S(\theta)$ is the logarithmic slope of γ-ray angular distribution:

$$S(\theta)=\frac{1}{W(\theta)}\frac{\mathrm{d}W(\theta)}{\mathrm{d}\theta} . \tag{6}$$

The precession angle $\Delta\phi$ depends on the nuclear g factor and the transient magnetic field strength $B_{\mathrm{TMF}}(t)$ experienced by a nucleus:

$$\Delta\phi=-\frac{g\mu_{\mathrm{N}}}{\hbar}\int_{\mathrm{en}}^{\mathrm{ex}}B_{\mathrm{TMF}}(t)\mathrm{e}^{-t/\tau}\mathrm{d}t , \tag{7}$$

where μ_{N} is the nuclear magneton and τ is the mean lifetime of nuclear state. The integration runs over the recoiling ion entry to exit times of ferromagnetic Fe layer. The transient magnetic field $B_{\mathrm{TMF}}(t)$ given by Shu et al[4] was used:

$$B_{\mathrm{TMF}}(\nu)=924(\nu/\nu_0)^{0.45}T , \tag{8}$$

where ν_0 is the Bohr velocity and ν is the velocity of a recoiling nucleus. $B_{\mathrm{TMF}}(t)$ depends on the instantaneous velocity ν or time of recoiling nucleus in Fe layer. Then, g factor for a given nuclear state can be obtained with Eqs. (4) and (7).

In data reduction the precession transfer was taken into account. The precession of a lower state also includes the precessions of higher spin states in cascade transitions and side feeding states and is therefore an algebraic sum of precessions of itself and all states that feed it. To get g-factor of a state it is necessary to know the net precession of this state. A computer program was written for precession transfer correction. After precession transfer corrected we obtain the net precession and then g-factor of a state.

3 Results and discussion

The measured g factors of the ground state rotational band levels in ^{82}Sr are shown as a function of spin I in Fig. 2.

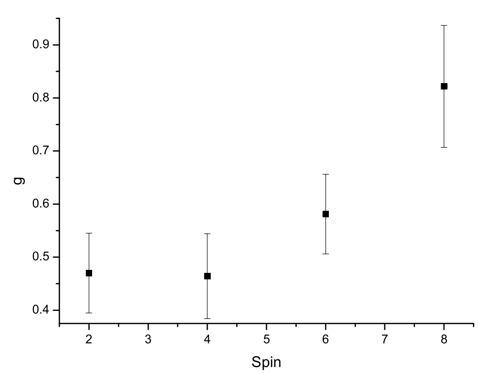

Fig. 2. g-factors of rotational band states in ^{82}Sr.

It can be seen that the measured g-factors increase with the increasing of the spin along the band. The proton alignment causes an increase of the g-factors, while the neutron alignment leads to a decrease of the g-factor[5]. The present results of the measured g-factors along the ground state rotational band illustrate a clear picture of the $g_{9/2}$ proton alignment in ^{82}Sr. The proton alignment starts at spin of $I=6^+$ and the degree of the alignment enhances with the rising of the spin. The calculation of g-factors by means of the particle-rotor model with two quasi-particles and an axially symmetrical rotor is under way.

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