Design of a thin-film polarized proton target system for low-energy RI beam experiments

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The search for unknown resonances of unbound ^{10}N via ^{9}C+p elastic resonant scattering is proposed. Theoretically, four broad and overlapping low-lying ^{10}N resonances that may not be clearly identifiable in the ^{9}C+p excitation function are expected.The vector analyzing power is measured to determine these broad resonances[1]. The level information obtained in the experiment is useful for discussing resonances in ^{10}Li since ^{10}N and ^{10}Li are mirror nuclei that are expected to have a similar structure. The ^{10}Li structure provides us with valuable information for constructing the three-body model of the borromean ^{11}Li nucleus.

A polarized target is required for the measurement of the analyzing power. A polarized proton solid target for low-energy beam experiments[2] has been designed based on an existing system for intermediate energies [3]. In the target, proton polarization is obtained by transferring the electron polarization of photo-excited triplet state of pentacene to protons of p-terphenyl. Polarization transfer is done by microwave irradiation that satisfies the condition that the Rabi frequency of electron spin is matched to the Larmor frequency of the proton[2].

We select a magnetic field strength of 0.2 T. This value is a tradeoff between the magnitude of proton polarization and magnetic field effect for the trajectory of recoil particles. At this field strength, the resonance frequency of electron spins is ∼4.8 GHz and the proton resonance frequency is ∼8.5 MHz.

For the detection of low-energy recoil protons emitted with respect to ±22.5° where the analyzing power is expected to be the largest, the microwave resonator must be sufficiently short to avoid interference with the trajectory of scattered protons.A three-loop two-gap resonator[4] (LGR) was chosen as the microwave resonator, as shown in Fig. 1 (Left). Its structure allows us to sufficiently shorten the resonator and to implement NMR coil close to the resonator without affecting its performance[4].

We conducted a simulation of the LGR using the electromagnetic field simulation software CST Microwave Studio. In the simulation, the LGR was placed inside a brass shield to reduce microwave radiation losses, as shown in Fig. 1 (Right). The shield was designed to allow beam particles and recoil protons to pass through the resonator freely. The LGR was excited by an antenna placed close to one of edge loops.

The resonance frequency of LGR and the strength of the oscillating microwave field were simulated at 1-W incident power. The power required for optimal polarization transfer was evaluated. Simulations were performed for different central loop diameters. We found that the resonator with 18-mm diameter and 5-mm length was the tradeoff between the target size and required incident power of 20 W.

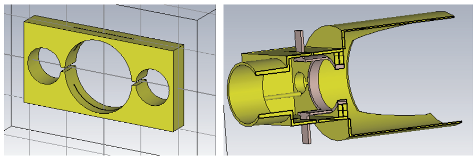

Fig. 1. Three-loop two-gap resonator (LGR) (Left). LGR placed in the shield (Right).

The thickness of the target was chosen to be 110 μm to cover the range of the ^{9}C beam with an energy of 5.6 MeV/nucleon. A novel thin crystal production method is proposed. In this method, the crystal prepared by the Bridgmann method is placed in a vacuum tube and heated. The crystal sublimates and its thickness slowly decreases. The sublimation speed is controlled by the heater temperature. A test sample prepared by the sublimation method is shown in Fig. 2.The sample thickness is approximately 700 μm.

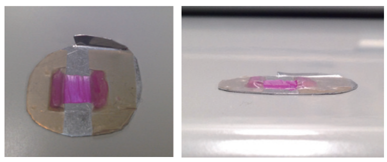

Fig. 2. Sample prepared by the sublimation method.

In conclusion, the microwave resonator was designed for the thin-film polarized proton target at 0.2 T. The sublimation method was proposed to produce thin crystals. In the next fiscal year, the resonator will be built and tested. A thin crystal with a thickness of approximately ∼100 μm will be produced by the sublimation method.

References
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