Design of experiment for search of ^{10}N resonances with resonant scattering of ^{9}C off polarized proton

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The ^{9}C+p elastic resonant scattering has been proposed for search of resonances in the unbound ^{10}N nucleus whose structure is almost unknown at present. Theoretically, four low-lying ^{10}N levels are expected as two very broad $2s_{1/2}$ and two very broad $1p_{1/2}$ proton single-particle resonances, each of which has a width much larger than 1 MeV. These resonances overlap each other and may not be clearly identifiable in the ^{9}C+p excitation function. The level information obtained in the experiment is useful for discussing resonances in ^{10}Li because ^{10}N and ^{10}Li are mirror partners that are expected to have similar structures. The ^{10}Li structure provides us with valuable information for constructing the three-body model of the borromean ^{11}Li nucleus.

We proposed to measure analyzing power to resolve these broad resonances[1]. The combined information of the excitation function and an analyzing power spectrum will enable us to impose more strict constraints on analysis of the resonances.

The range of center-of-mass energy was set to 1–5 MeV to cover the ground state of ^{10}N, predicted at around 1.5 MeV, and several excited states (one experimentally observed at 2.6 MeV[2]). For the measurement of analyzing power and excitation function, we considered to adopt the thick-target method in inverse kinematics (TTIK), where the excitation function can be scanned with a single beam energy utilizing the energy loss of the beam particle in the target.

We conducted LISE++ simulation to produce ^{9}C beam on RIPS with a low energy of 5 MeV/A. In the simulation, using a ^{12}C primary beam with 70 MeV/A and 200 pnA, 3.5 mm-thick Be target, and 583 mg/cm^2-thick Al wedge degrader at F1, beam intensity obtained at F2 was ~3.5 × 10^4 pps with a purity of >90%. RF deflector can be used to reduce the rate of contamination because the rate of contaminations such as ^{8}B and ^{7}Be is one order magnitude larger than the simulated value in the proton rich side. We also planned to replace Al wedges with $(CH_2)_n$ wedges to decrease the multiple scattering effect.

Polarized target is required for the measurement of analyzing power. A polarized proton solid target for low-energy beam experiments[3] has been designed based on existing system for intermediate energies[4]. A single crystal of p-terphenyl doped with pentacene molecules with a concentration of 0.05 mol% was chosen as the target material, which allows us to operate the target in vacuum environment at room temperature. Thickness of the target was chosen to be 110 μm to cover the range of the secondary ^{9}C beam. Strength of the magnetic field was chosen to be 0.2 T to maintain the polarization, and this does not severely affect the particle trajectory. The estimated polarization was 15% at this magnetic field. Production and polarization of thin films (7 μm) have recently been realized at Osaka University[5], where the size of the grown single crystal was 3 × 4 mm^2. However, production of large sized single crystals, with a desired diameter of 2 cm, remains a challenge. We designed a technique to grow a crystal between two thin films.

We consider use of silicon detector for detection of protons with energies of 3–18 MeV. Each telescope consists of one 65 μm-thick double sided silicon detector (DSSD) and two 1.5 mm-thick DSSDs with a detection area of 50 mm × 50 mm. Two telescopes are planned to be placed at both left and right sides of the beam line at a laboratory angle of ±22.5◦, where the vector analyzing power is expected to have large absolute values. We plan to place another telescope at 0◦. The distance between the target and the telescopes is 250 mm.

TTIK method allows us to archive an E_{CM} resolution of approximately 76 keV with a proton energy resolution of 120 keV.

$$E_{CM} = \frac{1}{4\,cos^2\,\theta_p}\frac{A+1}{A}E_p \qquad (1)$$

Equation 1 shows dependence of E_{CM} on recoil proton energy, where A= 9 for ^{9}C and θ_p is proton scattering angle in laboratory frame.

In conclusion, we proposed the first low energy RI experiment with polarized proton target. RIKEN polarized proton target has been redesigned for use with low energy RI beam. We plan to construct the target in the next fiscal year.

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