

Production cross sections of ^{16}N isomer with ^9Be target + ^{18}O beam at 230 and 350 MeV/nucleon

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The neutron halo, which is a common phenomenon in nuclei, is also observed in excited states. Recent experimental studies indicate that the isomeric state of ^{16}N ($J^\pi = 0^-, E_x = 120$ keV, $T_{1/2} = 5.25$ μs) has halo-like properties.¹⁻³⁾

To extract the properties of the ^{16}N isomer, the proton elastic scattering from the ^{16}N isomer should be measured in inverse kinematics with two different intermediate energies, typically 200 and 300 MeV/nucleon. This kind of experiments can extract the proton and neutron density distributions from the data.⁴⁾ For an efficient measurement, a secondary ^{16}N beam with high intensity and high isomeric ratio is required. To this end, we conducted a test experiment for ^{16}N beam generation.

We measured the production cross sections of ^{16}N isomer at the Heavy Ion Medical Accelerator in Chiba (HIMAC) of the National Institutes for Quantum Science and Technology (QST) in February, 2023. Figure 1 shows a schematic of the experimental setup at the HIMAC SB2 secondary beam course. Particle identification was performed with the $B\rho$ -ToF- ΔE method using two dipole magnets and two plastic scintillators, to estimate the production cross sections of ^{16}N as in our previous report.⁵⁾

The isomeric state of ^{16}N was tagged using the de-excitation γ rays from isomeric decay. Energy degraders were installed after the plastic scintillator at F3 to halt ^{16}N at the center of 10-mm-thick acrylic stopper. The γ rays were detected by the 2-inch-diameter and 2-inch-thick cylindrical CeBr_3 scintillator placed downstream of the stopper. The isomeric ratio was calculated by the ratio of the number of ^{16}N to ^{16}N isomer including the ground and isomeric states within the same ^{16}N gate determined by the upstream detectors. In addition to ToF- ΔE gate by two plastic scintillators, a gadolinium orthosilicate (GSO) scintillator was used as another ΔE counter to separate ^{16}N from other nuclear species through reactions between the beam particles and degrader materials. A strip-readout parallel-plate avalanche counter (SR-PPAC) was also used to limit the

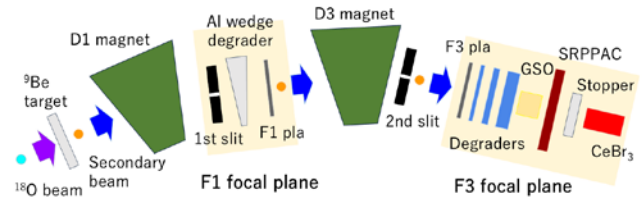


Fig. 1. Schematic view of the experimental setup at HIMAC SB2 secondary beam course.

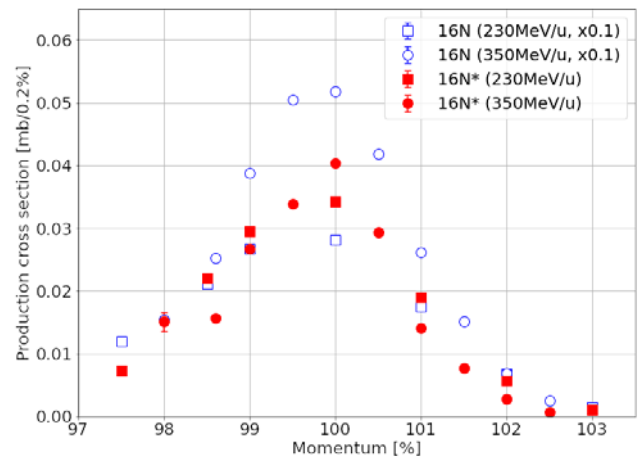


Fig. 2. Production cross sections of both ground and isomeric states (blue) with the only isomeric state (red) of the ^{16}N . The primary beam energies at 230 (square) and 350 (circle) MeV/nucleon were used.

beam position within the size of CeBr_3 . The isomeric ratios were multiplied by the inclusive production cross sections of ^{16}N , to obtain the production cross sections of the ^{16}N isomer.

Figure 2 shows the momentum distributions. The integrated cross sections of ^{16}N including the ground and isomeric states are approximately less than one tenth those of EPAX calculations (48.8 Mb). The isomeric ratio is about one half that obtained from the ^{18}O primary beam at 160 MeV/nucleon (24.2(6)%).³⁾

These results will enable the proton elastic scattering experiment of the ^{16}N isomer.

References

- 1) T. L. Tang *et al.*, Phys. Rev. C **105**, 064307 (2022).
- 2) E. T. Li *et al.*, Chin. Phys. C **40**, 114104 (2016).
- 3) M. Fukutome *et al.*, Few-Body Syst. **63**, 37 (2022).
- 4) Y. Matsuda *et al.*, Phys. Rev. C **87**, 034614 (2013).
- 5) R. Yoshida *et al.*, RIKEN Accel. Prog. Rep. **57**, 21 (2024).

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