Experimental study of resonant states in ^{27}P via elastic scattering of ^{26}Si+p †

H.S. Jung,[*1] C.S. Lee,[*1] Y.K. Kwon,[*1] J.Y. Moon,[*1] J.H. Lee,[*1] C.C. Yun,[*1] S. Kubono,[*2] H. Yamaguchi,[*2] T. Hashimoto,[*2] D. Kahl,[*2] S. Hayakawa,[*2] S. Choi,[*3] M.J. Kim,[*3] Y.H. Kim,[*3] Y.K. Kim,[*4,*5] J.S. Park,[*4] E.J. Kim,[*6] C.-B. Moon,[*7] T. Teranishi,[*8] Y. Wakabayashi,[*9] N. Iwasa,[*10] T. Yamada,[*10] Y. Togano,[*11] S. Kato,[*12] S. Cherubini,[*13,*14] and G.G. Rapisarda[*13,*14]

We studied proton resonant states in ^{27}P via elastic scattering to investigate the ^{26}Si(p,γ)^{27}P reaction, which is an important in the rp-process path for the understanding of the nucleosynthesis in explosive hydrogen burning[1,2]. This reaction is also relevant to the production of ^{26}Al[3]. The knowledge of the structure of ^{27}P is still insufficient because of uncertain resonance parameters, such as resonance energies and spin-parity assignments.

The measurement of the ^{26}Si+p elastic scattering was performed at the low-energy RI beam facility CRIB (CNS Radioactive Ion Beam separator) of the Center for Nuclear Study (CNS), the University of Tokyo[4,5], by bombarding a H_2 gas target with a ^{26}Si radioactive ion beam in inverse kinematics[6] and detecting scattered protons using silicon detectors for a ΔE-E telescope. We applied the thick-target method [7,8] to scan the entire energy region of interest simultaneously. The excitation function was obtained from the scattered proton energy spectrum by a kinematics conversion process. A ^{24}Mg primary beam with an energy of 7.5 MeV/A and an intensity of 1.6 eμA extracted from the AVF cyclotron bombarded a ^{3}He gas target which was at 550 Torr and 90 K. The secondary beam was produced by the ^{3}He(^{24}Mg,^{26}Si)n reaction. Protons elastically scattered to the forward angles in the laboratory frame were detected by a ΔE-E telescope.

By calculating the kinematics, including energy loss in the target, the measured proton energy of each event was converted to a center-of-mass energy. We performed an analysis using the R-matrix calculation code (SAMMY-8.0.0)[9] to deduce resonance parameters such as excitation energy E_x, spin J, parity π, and proton partial width Γ_p of resonance states. Figure 1 shows best-fit results for the excitation function.

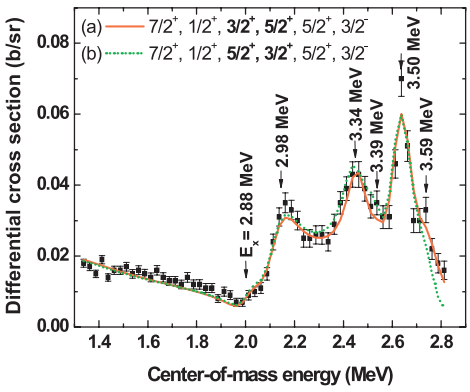

Fig. 1. Final results for the excitation function of ^{26}Si+p as the best fits are shown but without firm spin-parity assignment for the doublet around 3.3 MeV.

Six new resonant states in ^{27}P have been suggested, and we mostly determined their resonance parameters such as resonance energy, width, and spin-parity with the R-matrix calculation. Two small bumps around 3.39 MeV and 3.59 MeV were introduced to improve the fitting because exclusion of these resonances resulted in a less satisfactory fit for near resonant states. Parameters of resonant states in ^{27}P are expected to contribute to the nuclear data for the nuclear reaction network calculation of the rp-process nucleosysnthesis. The previous estimate of the total reaction rate of ^{26}Si(p,γ)^{27}P, which was evaluated by Iliadis *et al.*[10], should be reanalyzed with the nuclear physics input newly obtained in present work.

† Condensed from the article in Phys. Rev. C. **85**, 045802 (2012)

*1 Department of Physics, Chung-Ang University
*2 Center for Nuclear Study, University of Tokyo
*3 Department of Physics and Astronomy, Seoul National University
*4 Department of Nuclear Engineering, Hanyang University
*5 Institute for Basic Science
*6 Department of Education, Chonbuk National University
*7 Faculty of Sciences, Hoseo University
*8 Department of Physics, Kyushu University
*9 Advanced Science Research Center, JAEA
*10 Department of Physics, Tohoku University
*11 RIKEN Nishina Center
*12 Department of Physics, Yamagata University
*13 Laboratori Nazionali del Sud-INFN
*14 Dipartimento di Fisica e Astronomia, Universita di Catania

References

1) H. Herndl et al.: Phys. Rev. C **52**, 1078 (1995).
2) J. L. Fisker et al.: Astrophys. J. **174**, 261 (2008).
3) R. Diel et al.: Astron. Astrophys. **298**, 445 (1995).
4) S. Kubono et al.: Eur. Phys. J. A **13**, 217 (2002).
5) Y. Yanagisawa et al.: Nuc. Instrum. Methods Phys. Res. Sect. A **539**, 74 (2005).
6) K.P. Artemov et al.: Nuc. Phys. **52**, 408 (1990).
7) W. Galster et al.: Phys. Rev. C **44**, 2776 (1991).
8) S. Kubono: Nuc. Phys. A **693**, 221 (2001).
9) A.M. Lane and R.G. Thomas: Rev. Mod. Phys. **30**, 257 (1958).
10) C. Iliadis et al.: Nuc. Phys. A **841**, 31 (2010).