Resonance States in ^{26}Si for Reaction Rates in the rp-Process

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Explosive nuclear hydrogen burning at high temperature conditions on the surface of accreting white dwarfs is dominated by the hot CNO cycles[1]. Explosive hydrogen burning on the surface of accreting neutron stars leads to considerably higher temperatures and break-out from the hot CNO cycles triggers the rp-process[2, 3]. Network calculations are well capable of qualitatively reproducing characteristics of these phenomena. Their quantitative interpretation, however requires a better understanding of the nuclear processes during these explosive events by the measurement of reaction rates and structure of unstable, proton rich nuclei[4]. Even though new facilities are now able to directly measure relevant reaction rates by using radioactive beams and reversed kinematics, measurements will also benefit from level structure information with excitation energies in the resonance regions of interest. In order to study the precise level structure of relevant nuclei, a good energy resolution is required. The advantage of the (^{4}He,^{6}He) reaction is its possibility to achieve high resolution.

The measurements were performed at the Research Center for Nuclear Physics (RCNP), Osaka University by using a 205 MeV ^{4}He beam from the $K = 400$ ring cyclotron and the Grand Raiden spectrometer[5] placed at 0°. The extracted beam from the ring cyclotron was transported to the West Experimental Hall via the WS beam line[6]. In order to integrate the current of the beam, new Faraday cups were installed inside, near the exit of the first dipole magnet of the spectrometer. The reaction products continue to travel through the spectrometer and are measured by a focal plane detector system, consisting of two vertical drift chambers (VDC) that allow the determination of the horizontal and vertical positions and angles in the focal plane. Three plastic scintillators, 1 mm, 10 mm, and 10 mm thick, mounted behind the VDC system allowed particle identification, time of flight measurements, and light particles rejection. For best vertical scattering angle definition the spectrometer was operated in over focus mode which allows reconstruction of the vertical component of the scattering angle from the measured vertical position in the focal plane[7]. For good resolution in momentum and horizontal scattering angle component, full dispersion matching[8] was applied.

Figure 1 shows the measured energy spectra of the ^{28}Si(^{4}He,^{6}He)^{26}Si reaction at several scattering angles around p-threshold. The resolution of measurement was 60, 64, and 64 keV at 0°-1°, 1°-2°, and 2°-3°, respectively. We cannot see the state at 5.515 MeV reported by (p,t) measurements[9]. This suggests that the state has an unnatural parity, because (^{4}He,^{6}He) reaction cannot excite a state with unnatural parity, but (p,t) reaction can excite it. Energy levels above 5.518 MeV are relevant to the production rate of ^{26}Al in its ground state which provides a valuable constraint on models used to understand the explosive hydrogen burning

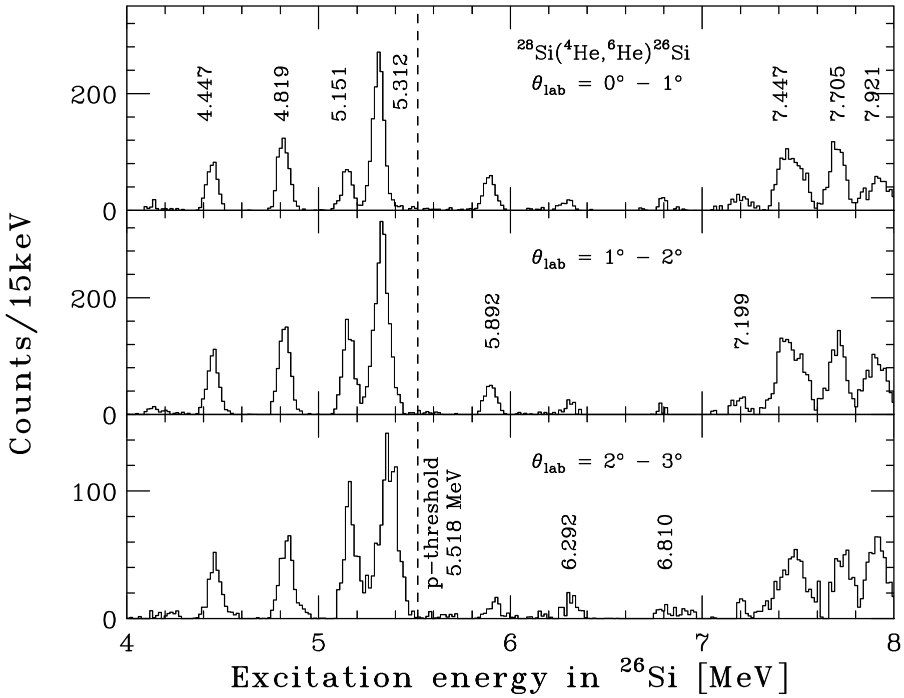

Figure 1: Excitation energy of ^{26}Si spectrum at several scattered angles. The dashed line shows p-threshold (E_x = 5.518 MeV).

process in novae and supernovae[10].

In future works, the spin and parity will be assigned to the observed levels which are necessary by the Network calculation. We have measured angular distributions of these levels. They will be compared with a DWBA calculation. Now Network calculation based on our results is in progress. This experiment was performed under Program No. E163 and E187 at the RCNP.

References

[1] S. Starrfield *et al.*, Ap. J. Suppl. **127**, (2000) 485.

[2] R.K. Wallace and S.E. Woosley, Ap. J. Suppl. **45**, (1981) 389.

[3] H. Schatz, L. Bildsten, A. Cumming, and M. Wiescher, Ap. J. **524**, (1999) 1014.

[4] H. Schatz, J. Görres, H. Herndl, N.I. Kaloskamis, E. Stech, P. Tischhauser, M. Wischer, A. Bacher, G.P.A. Berg, T.C. Black, S Choi, C.C. Foster, K. Jiang, and E.J. Stephenson, Phys. Rev. Let. **79**, (1997) 3845.

[5] M. Fujiwara *et al.*, Nucl. Instrum. Meshodos Phys. Res. A **422**, 484 (1999).

[6] T. Wakasa *et al.*, Nucl. Instrum. Methods Phys. Res. A **482**, 79 (2002).

[7] Y. Fujita *et al.*, Nucl. Instrum. Methods Phys. Res. A **469**, 55 (2001).

[8] Y. Fujita *et al.*, Nucl. Instrum. Methods Phys. Res. B **126**, 274 (1997).

[9] D.W. Bardayan, J.C. Blackmon, A.E. Champagne, A.K. Dummer, T. Davinson, U. Greife, D. Hill, C.Iliadis, B.A. Johnson, R.L. Kozub, C.S. Lee, M.S. Smith, and P.J. Woods, Phys. Rev. C **65**, 032801 (2002).

[10] R. Diehl *et al.*, Astron. Astrophys. **97**, 181 (1993).