2 - 1 Research Progress of Nuclear Structure Research Group

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The Group of Nuclear Structure Research at IMP has devoted much effort to the study of in-beam γ-ray spectroscopy and β-decay spectroscopy. One terminal for in-beam γ-ray spectroscopy has been newly built up in 2016. As for β-decay spectroscopy, two points need to be emphasized.

In order to study the in-beam γ-ray spectroscopy, a γ ball was placed at the terminal of new TL2 beam line. Three quadrupole magnets following the dipole magnet are the main building blocks along the beam line. The γ ball consists of 8 clover and 16 HPGe detectors with a CsI ball inside to select the charged particle channel. A wall isolating the γ ball from the quadrupoles was used to shield the radiation produced by the accelerator and depositing energy in the detectors, which may result in a high background. The installation was finished in 2016 and the experiment for in-beam γ-ray spectroscopy is expected to perform in 2017.

Three experiments have been performed during the past few years at the radioactive beam line RIBLL[1] and gas-filled recoil separator SHANS[2]. Lifetimes of low-lying excited states were measured via $\beta-\gamma$ and $\gamma-\gamma$ fast timing coincidence.

We noticed that the $7/2^-.\!\to 3/2^-$ excited energy along the N=21 isotonic chain possibly involving the odd neutron outside the N=20 shell closure across the N=28 shell is 1 943, 1 267, 646 and 910 keV for ^{41}Ca, ^{39}Ar, ^{37}S and ^{35}Si, respectively[3]. The minimum value for ^{37}S implies the collapse of the N=28 shell closure. The collapse of the shell closure may provide sufficient valence nucleons for nuclear deformation. In order to check whether the ^{37}S is deformed, the lifetime for the $3/2^-$ state in neutron-rich nucleus ^{37}S was measured at RIBLL by using the fast timing coincidence between the parent nucleus ^{37}P β^- decay and daughter nucleus $3/2^-.\!\to 7/2^-$ 646 keV γ transition. The primary beam of 70 AMeV ^{40}Ar beam was delivered by the Heavy Ion Research Facility in Lanzhou (HIRFL). The secondary beam of ^{37}P was separated and purified by the RIBLL and then deposited into the Si detector to observe its β^-decay. The plastic scintillator and $LaBr_3$ detectors with good timing performance were used to measure the time signals of β^- particles of parent nucleus ^{37}P and γ rays of daughter nuclei, respectively. A lifetime 193(4) ps has been obtained for the $3/2^-$ state in neutron-rich nucleus ^{37}S. The deduced quadrupole deformation parameter manifests that the ^{37}S is deformed. The result was published in Physical Review C of 2016[4].

With the ^{32}S beam delivered from the HIRFL, the nuclei ^{87}Nb and ^{87}Mo were produced by the respective heavy-ion fusion-evaporation reactions ^{58}Ni (^{32}S, 3p) and ^{58}Ni (^{32}S, 2pn) at a beam energy of 100 MeV through the 8 μm Al degrader. A self-supported 400 μg/cm^{2}^{58}Ni foil was employed as the target in the experiment. After evaporation residues were separated from the projectile beams by the SHANS, the nuclei of interest ^{87}Nb and ^{87}Mo have been obtained with a higher purity and then implanted into a 300 μm silicon detector to observe the positive electron decays. The time signals of emitted β^+ particles and γ rays following β^+ decays were detected by plastic scintillator and $LaBr_3$ detectors, respectively. The preliminary mean lifetimes 502 , 390 , 771 and 304 ps have been extracted for the levels at 266.9 and 400.7 keV in daughter nucleus ^{87}Nb and at 200.9 and 470.3 keV in daughter nucleus ^{87}Zr[3].

The nuclei ^{143}Eu were produced by the fusion-evaporation reaction ^{123}Sb (^{24}Mg, 4n) at a beam energy of 97.5 MeV. A 400 μg/cm^{2}natural antimony foil, sandwiched by two carbon foils with thickness of 40 and 10 μg/cm^2, was used as the target. It took about 1.4 μs for the evaporation residues at ground- or long-lived isomeric states to flight through the SHANS. For ^{143}Eu most nuclei ware at the $11/2^-$gsomeric yrast state with a lifetime of 50 μs. In the detection terminal, γ transitions depopulating this $11/2^-$ state to ground state $5/2^+$ and the first $7/2^+$ were detected by $LaBr_3$ detectors. Analyzing the coincidence events including 117 and 272 keV transitions feeding and depopulating the first $7/2^+$ state, we deduced the lifetime of this state as 109(17) ps. So far this is the shortest lifetime obtained by $LaBr_3$ detectors in China. Based on this measured lifetime, l-forbidden M1 transition and configuration mixing were investigated.

References

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