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Measurement of the $h_{11/2}$ Band of ^{117}Cs

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A new rotational band was identified in the reaction of ^{28}Si+^{92}Mo by means of in-beam γ-ray methods. By carefully analyzing the band intensity and structure properties, the band is considered likely as the $h_{11/2}$ proton band of ^{117}Cs。

Key words: in-beam γ, ^{117}Cs levels.

$Z = 55$ odd-A neutron deficient Cs nuclei are in the transitional region from $Z = 50$ spherical nuclei to $Z \geq 58$ well-deformed nuclei. The proton in the $h_{11/2}$ orbit is favorable to be excited. The odd-A Cs nuclei with $N = 64$ to 72 were studied by in-beam γ-rat spectroscopy, and the $h_{11/2}$ band was the strongest populated band observed in all of the measurements[1-4]. When N varies towards the middle of the 50 and 82 shell closures, the γ-transition energy decreases, and the deformation increases. It is consistent with the theoretical predictions. Due to experimental difficulties, level structure of ^{117}Cs was not studied previously. The only information about ^{117}Cs obtained in the measurements[5] of β^+ or γ-rays decayed from isotopically separated ^{117}Cs sources produced by 600 MeV proton beam bombarding La target is that it may have two isomers with half-life 8.4s and 6.5s, respectively. The in-beam γ-ray studies show that its isotope ^{115}I has strong collective features which follow well the systematic of the odd-A I isotopes [6]. Therefore one can expect that the $h_{11/2}$ band in ^{117}Cs will be the strongest populated band, and it also should follow the systematic of the odd-A neutron deficient Cs isotopes. The band should be likely observed in experiments.

This experiment was carried out at the 13 MV tandem accelerator of the Institute of Atomic Energy, Beijing with ^{28}Si beam bombarding an isotopically enriched ^{92}Mo target. The target was made

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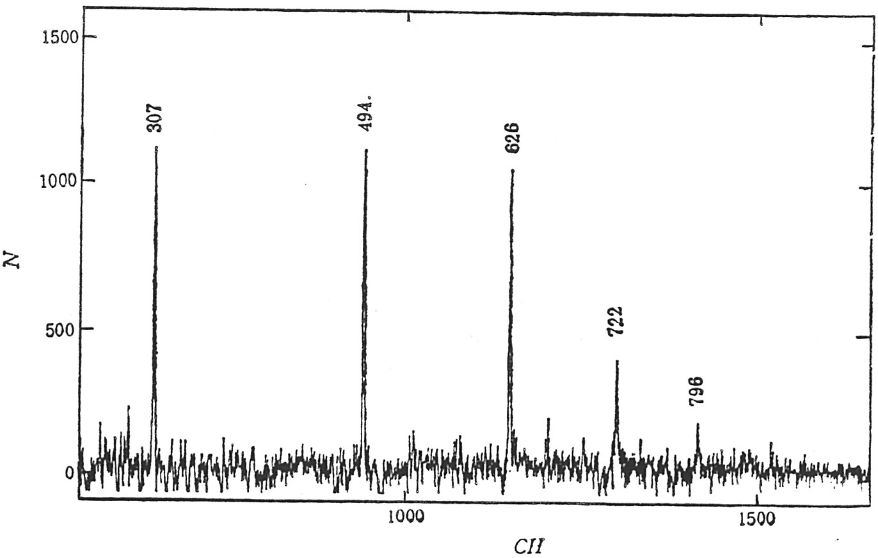

Fig. 1
Sum of coincidence spectra gated on the 307 and 494 keV transitions.

by rolling. A 6 mg/cm^2 lead layer was evaporated on the back side of the target to stop the recoil nuclei in order to minimize the Doppler shift of γ peaks. The beam was stopped in a lead stopper at 50 cm behind the target. Emitted γ-rays from the reaction residues were detected with 7 BGO(AC) HPGe detectors. Their relative coefficients were 15-30%. The two Ge detectors with 30% relative coefficient were set at 35° above the horizontal plane. The other five were placed in the horizontal plane at 143°, 90°, 28°, −28° and −75° with respect to the beam direction. The distances from the Ge detectors to the target were different, ranging from 17 to 20 cm, in order to have almost equal counting rate in all Ge detectors. The detector energy and efficiency calibrations were implemented with a ^{152}Eu source placed at the target position. The energy resolutions of the Ge detectors measured for the 1408 keV peak of ^{152}Eu were 1.9-2.2 keV. The Lanzhou tiny crystal ball consisted of 14-cell hexagonal prism BGO detectors was used as a γ-ray multiplicity filter. The ball was divided into two hemispheres located at 2 cm to the target on top and bottom, respectively. The electronics in this measurement was described in [7]. Limited by the capability of the data acquisition system, the sum energy measured by the ball was not recorded. Only the fired BGO cell number (fold) N_F was recorded as a parameter of an event. In off line data analysis N_F was taken as a condition to sort the events into a 4096 × 4096 symmetrical matrix. Even only with requirement of $N_F \geq 1$, the suppression against the coincidence with X-rays, 511 keV peak and decay γ-rays was very efficient. The γ-γ coincidence time resolution measured with two BGO Compton suppressed Ge detectors was 14 ns. A total of 90 million γ-γ coincidence events were recorded on tapes.

The ^{92}Mo target being isotopically enriched to 94.1%, contains other stable Mo isotopes (^{94}Mo 0.98%, ^{95}Mo 1.09%, ^{96}Mo 1.13%, ^{97}Mo 0.53%, ^{98}Mo 1.65%, and ^{100}Mo 0.52%). The measured γ-ray excitation functions agree with the CASCADE code calculations which were made before the experiment. The strongest reaction channels are 2pn→^{117}Xe (99.5 mb, which is the calculated cross section at 115 MeV ^{28}Si beams weighted by the isotope abundances) and 3p→^{117}I (104.1 mb). The cross sections via α2p→^{114}Te (54.5 mb) and 2p→^{118}Xe (25.8 mb) are also large, while the channels of 3p2n→^{115}I (7.5 mb) and p2n→^{117}Cs (3.9 mb) have small cross sections. ^{120}Xe was produced from ^{95,96}Mo isotopes contained in the target with an isotope abundance weighted cross section of 2.9 mb.

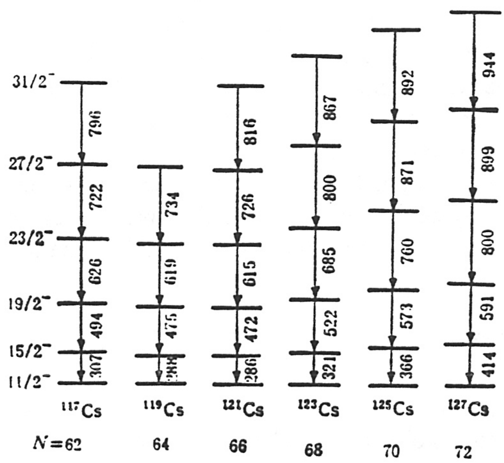

Fig. 2
Systematic of the $h_{11/2}$ bands in odd A Cs nuclei.

^{121}Cs was produced from ^{96,97}Mo with the weighted cross section of 2.1 mb. Although the cross sections for nuclei ^{120}Xe and ^{121}Cs are small, but their γ-rays were clearly seen in our data.

A large number of known γ-cascades from the nuclei produced in the reaction are confirmed. New cascades of γ-rays are identified and assigned to ^{117}Xe and ^{114}Te. In addition, there are several cascades, which are not related with all the known transitions of the dominant reaction residues. The cascade shown in Fig. 1, forming a clean rotational band, is the most interesting among them. Its intensity is about half of ^{115}I in the gated spectra. According to the CASCADE calculations, the possible residual nuclei with such intensity are ^{110}Sn (3.6 mb), ^{113}Te (4.3 mb) and ^{117}Cs (3.9 mb). The level structure of even-even nucleus ^{110}Sn is known, and the cascade transitions in Fig. 1 are not belong to it. The levels of ^{113}Te are unknown, but from the level structure properties of its neighboring odd-A ^{115,117}Te, the new band can not be assigned to ^{113}Te. Therefore, ^{117}Cs is the only nucleus to which the new band may be assigned. The cascade transitions of Fig. 1 is likely the $h_{11/2}$ band of ^{117}Cs. In order to confirm this, we compared the intensities of the first two transitions of the new band with the $h_{11/2}$ bands of ^{115}I and ^{121}Cs in gated spectra under an assumption that the $h_{11/2}$ band in these three nuclei has the same decay fraction, which is supported by experiments on neighboring nuclei. To minimize the effect of background subtraction, the spectra gated on the first two transitions were chosen. For example, for the band of Fig. 1 in the 307 keV gated spectrum the 494 keV peak area was obtained, and in the 494 keV gated spectrum the 307 keV peak area was obtained. The average of these two peak areas was taken as the intensity I_{117} of the new band. The intensity I_{115} and I_{121} was obtained from the 411 and 517 keV peaks of ^{115}I and the 286 and 473 keV peaks of ^{121}Cs with the same procedure. The measured relative detection efficiency ratios of these γ-rays were $\varepsilon_{411}/\varepsilon_{307} = 0.86$, $\varepsilon_{517}/\varepsilon_{494} = 0.92$, $\varepsilon_{286}/\varepsilon_{307} = 1.12$ and $\varepsilon_{473}/\varepsilon_{494} = 1.02$. The deduced intensity ratios with the efficiency correction are:

$$R_{115/117} = \frac{I_{115}}{I_{117}} \cdot \frac{\varepsilon_{307}}{\varepsilon_{411}} \cdot \frac{\varepsilon_{495}}{\varepsilon_{517}} = 1.92,$$

$$R_{121/117} = \frac{I_{121}}{I_{117}} \cdot \frac{\varepsilon_{307}}{\varepsilon_{286}} \cdot \frac{\varepsilon_{494}}{\varepsilon_{473}}$$

They agree well with the CASCADE calculated values 1.94 and 0.44, respectively.

Another evidence for the cascade of Fig. 1 being the $h_{11/2}$ band of ^{117}Cs is that it fully fits the systematical features of the odd-A Cs nuclei shown in Fig. 2. It can be seen in Fig. 2 that the level spacing of the $h_{11/2}$ proton band of the odd-A Cs nuclei varies regularly. It indicates deformation increases from $N = 72$ towards the middle of $N = 82$ and 50 two shell closures. In the middle $N =$ 64-66, level spacing reaches a minimum. From $N = 62$ the level spacing increases and deformation decreases again. This is consistent with both the theoretical predictions and the systematic of the $h_{11/2}$ bands observed in $Z = 53$ odd-A I nuclei.

In summary, a new rotational band was identified in the reaction of ^{28}Si+^{92}Mo by means of in-beam γ-ray methods. By comparing its population intensity and structure features with theoretical calculations and the structure of the known reaction residues the band is considered likely as the $h_{11/2}$ proton band of ^{117}Cs.

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