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Short note

High-spin multiparticle-hole excitations in ^{148}Eu

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Abstract. Studies by means of 155 MeV ^{27}Al bombardment on a ^{130}Te target revealed in ^{148}Eu high-spin structures up to spin $31\hbar$, in addition to a cascade extended to the 11088.1 keV excitation. The observed levels are tentatively assigned as complex multiparticle-hole proton and neutron configurations.

PACS. 27.60.+j $90 \leq A \leq 149$ – 23.20.Lv Gamma transitions and level energies – 21.60.Cs Shell model

Previous studies of nuclei in the vicinity of the magic $N = 82$ and semi-magic $Z = 64$ numbers revealed excitations due to multiparticle-hole, as well as quasi-vibrational structures. The latter are mostly found as low-lying levels. This is in particular valid for $^{146-149}$Eu [1–4]. The high-spin states in the double-odd nucleus ^{148}Eu were studied by J.R. Jongman *et al.* by means of a ^{13}C-induced reaction [3]. The low-energy levels are there understood in terms of a 3^- octupole-phonon coupling to multiparticle-hole states. On the other hand, most of the high-spin states are ascribed to multiparticle-hole excitations and the highest state 26^- observed was primarily assigned as a three proton-three neutron configuration. The aim of the present study was to extend the level scheme of ^{148}Eu to even higher-spin states. The experiment was carried out at the Lawrence Berkeley Laboratory. A 0.5 mg/cm^2 thick ^{130}Te target was bombarded with a 155 MeV ^{27}Al beam from the 88-inch cyclotron. The emitted gamma-rays were recorded by means of the Gammasphere Ge detector array [5]. The ^{148}Eu isotope was produced in the (H.I,α5n) reaction. The Microball, a 4π CsI(Tl) charged particle detector array [6], was used in conjunction with the Gammasphere to detect the evaporated charged particles, mainly alphas and protons. This enabled a high selectivity for the exit channels. The Ge detector gamma coincidence events were sorted off-line into an alpha-particle gated E_γ-E_γ matrix and an E_γ-E_γ-E_γ cube, later analysed using the Radware data analysis package [7]. Both the 2D matrix and the 3D cube sorted in this way contained data for three Eu isotopes, ^{146,147,148}Eu, due to the α-7n, 6n and 5n reaction channels, respectively. However, only the data for ^{148}Eu provided significant new information concerning the level structure. Based on the coincidences with the known ^{148}Eu transitions, thirteen new γ-rays were identified, which made it possible to extend the level scheme up to 11088.1 keV excitation energy, as presented in fig. 1. Intensity relations determined the order of the transitions in the cascades. The spin assignments of the new levels are based on DCO ratios. The geometry of the Gammasphere detector system made it possible to extract the DCO values by using coincident spectra from detectors close to 37° and 79° relative to the beam direction. Strong transitions with known multipolarity were used here as references. Due to the limited statistics, our DCO analysis was restricted to the new γ-lines 325.5 keV, 498.5 keV and 562.5 keV. The results indicate a dipole character of these transitions. In this way spin assignments $27^{(-)}$, $28^{(-)}$ and $28^{(-)}$ for levels 7028.4 keV, 7526.9 keV and 7590.9 keV were established, respectively. In the coincidence spectra the 267.8 keV ($26^- \rightarrow 25^-$) transition shows up with much higher intensity than that in the ^{13}C beam experiment [3]. However, this is explained by the fact that all the new transitions were found to be in coincidence with this line.

The main features of the excited states established in the present study are two cascades depopulating a 9245.8 keV level with the tentative spin assignment 31, in addition to a cascade extended to a 11088.1 keV level.

The newly observed high-spin levels may be interpreted in terms of complex multiparticle-hole configurations. In particular, Jongman *et al.* [3] suggested a $\pi(h_{11/2}d^{-1}_{5/2}g^{-1}_{7/2}) \otimes \nu(f_{7/2}h_{11/2}i_{13/2})$ configuration

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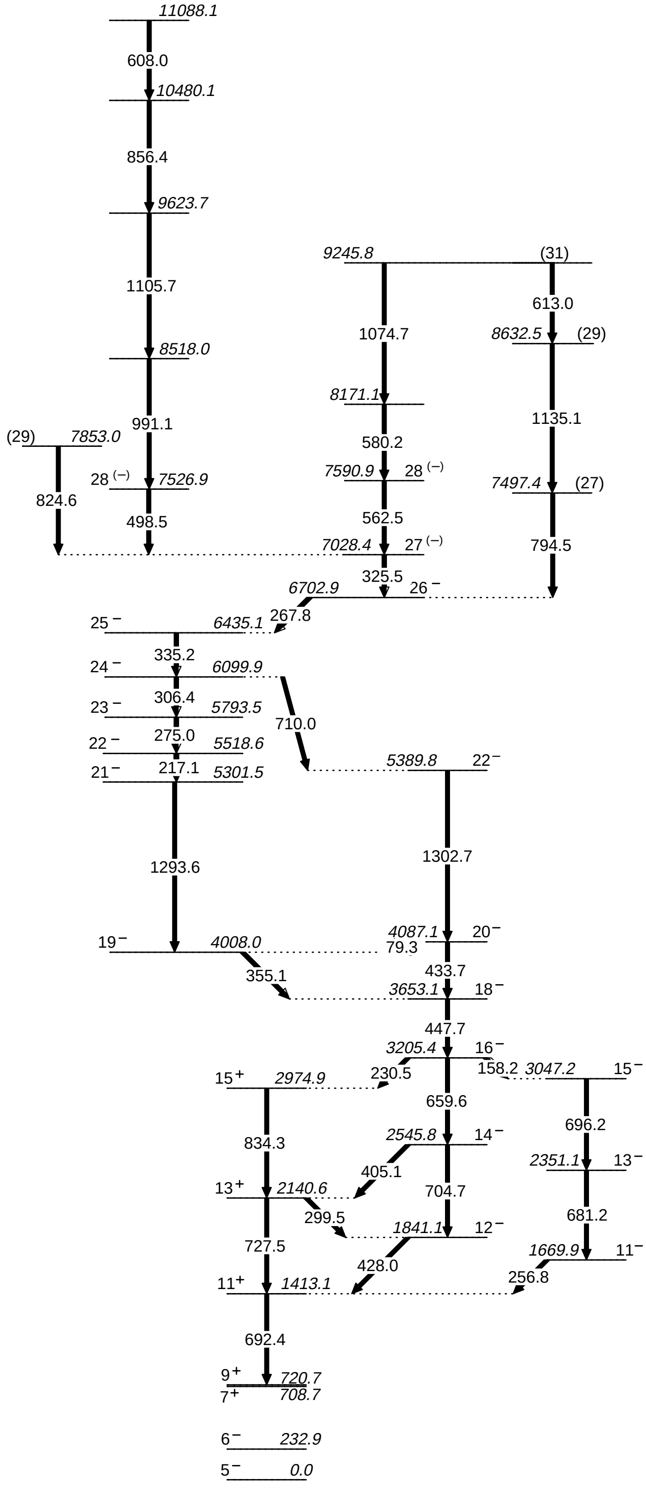

Fig. 1. The level scheme of ^{148}Eu, as observed in the present experiment. All energies are given in keV.

for the 26^- 6702.9 keV state. However, according to Woods-Saxon calculations [8], the $\nu h_{11/2}$ is found at much too low excitation energies and instead rather the $\nu h_{9/2}$ contributes to the 26^- structure. Since the calculations indicate the $\nu g_{9/2}$ and $\nu j_{15/2}$ orbitals at very high excitation energies, the composition of the spin (31) 9245.8 keV state is most probably due to additional either proton or neutron particle-hole excitations, *i.e.* $\pi((h_{11/2})^3(d_{5/2}g_{7/2})^{-4}) \otimes \nu(f_{7/2}h_{9/2}i_{13/2})$ or $\pi(h_{11/2}d^{-1}_{5/2}g^{-1}_{7/2}) \otimes \nu(h^{-2}_{11/2}i_{13/2}(h_{9/2}f_{7/2})^4)$. If the above is correct, one may expect to find these configurations at high-spin excitations in the neighbouring odd-A isotopes, at least partly. In fact, in ^{147}Eu [2] the levels observed up to spin 45/2 are understood in terms of $d^{-1}_{5/2}$ and $g^{-1}_{7/2}$ proton coupling. Higher-spin levels were observed in ^{149}Eu, up to 55/2 [4] and the structure up to $45/2^+$ is interpreted as due to the configuration $\pi h_{11/2}$ coupled to $\nu(i_{13/2}h_{9/2}(f_{7/2})^2)$. Further, at $49/2^+$ a breaking of the proton core is expected. J. Borggreen *et al.* [9] by means of heavy ion reactions observed in the nucleus ^{147}Gd high-spin states up to 79/2. The levels in the spin region 59/2–67/2 are there believed to be members of the $\pi((h_{11/2})^3d^{-1}_{5/2}) \otimes \nu(f_{7/2}h_{9/2}i_{13/2})$, alternatively the $\pi(((h_{11/2})^3g^{-1}_{7/2})$ multiplet, while for spin members 69/2–79/2 there is a slightly different neutron configuration, namely $\nu(d^{-1}_{3/2}f_{7/2}h_{9/2}(i_{13/2})^2)$. The multiplet structure in the odd-A nucleus may hardly be transformed directly to the corresponding odd-odd nucleus. However, one may note the fact that both the neutron and proton components for the multiplets suggested for the high-spin states in ^{148}Eu are found in configurations in the neighbouring odd-A isotopes. Furthermore, in none of the odd-A cases the $\nu h_{11/2}$ structure is present at high spins, which supports the above suggestion concerning the less importance of this parentage for the discussed levels in ^{148}Eu. The statistics obtained in the present data were not sufficient enough to extract the DCO values for all the transitions within the 498.5-991.1-1105.7-856.4-608.0 keV cascade. Therefore it is hardly possible to establish if this cascade is an indication of a collective structure or just a depopulation from another multiparticle state. In fact, the Woods-Saxon calculations indicate a possibility for a nuclear softness towards deformed states attributed to neutron-hole $\nu h_{11/2}$ structure. The interpretation in terms of complex multiparticle-hole configurations as presented above should be here considered as rather tentative, since spin and parity assignment could be determined not for all of the of the new observed levels.

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