First observation of the $\pi 0h_{11/2} \otimes \nu 0h_{9/2}$ partner orbital configuration in the odd-odd ^{138}I nucleus

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The β-decay scheme of ^{138}Te and the level structure of ^{138}I is reported for the first time. The experiment was performed at the Radioactive Isotope Beam Factory of RIKEN, as one of the EUROBALL-RIKEN Cluster Array campaigns. Secondary radioactive ions, including ^{138}Te and ^{138}Sb, were produced by the in-flight fission of a ^{238}U beam with the energy of 345 MeV per nucleon. From the β decay of ^{138}Te, the level scheme of ^{138}I was supplemented with new spin and parity assignments, such as the low-lying negative-parity states and a positive-parity 1^+ state. This 1^+ state can be interpreted as being associated with the $\pi 0h_{11/2} \otimes \nu 0h_{9/2}$ partner orbital configuration populated by the Gamow-Teller transition between a neutron in the $0h_{9/2}$ orbital and a proton in the $0h_{11/2}$ orbital. Details of the structure of ^{138}I are discussed in terms of the proton-neutron interactions and Gamow-Teller transition strength within the theoretical context of shell-model calculations.

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I. INTRODUCTION

Recently, the scientific significance of the region beyond the doubly magic nucleus ^{132}Sn has arisen in terms of nuclear structure studies. In two neutron-rich Sn isotopes, new

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seniority schemes were observed through the isomeric decay transitions from the 6_1^+ states at $N = 86$ and 88 [1]. In addition, the dominance of excited valence neutron configurations in the 2_1^+ state wave function for ^{136}Te is still one of the actively discussed topics [2–4]. In more neutron-rich isotopes, vibrational collective motion was observed, which is quite unusual for systems close to a doubly magic nucleus [5–8]. Furthermore, the proton shell evolution in odd-mass (A) Sb isotopes was investigated in detail and experimental data suggested a possible inversion of the $\pi 0g_{7/2}$ and $\pi 1d_{5/2}$ orbitals with increasing neutron number [9,10]. It is also worth noting that some states in odd-A Sb and Te isotopes were interpreted within the seniority scheme, by considering, respectively, seniority-2 and seniority-3 configurations in the $\nu 1f_{7/2}$ orbit [8,9].

In contrast to even-even or odd-A isotopes, odd-odd nuclei have not been well investigated in this region due to their complex structure, mainly caused by the high-level density arising from proton-neutron coupling configurations in high-j orbitals. However, their intricate configurations may provide important nuclear structure information. For instance, the presence of positive-parity states in this region is favored by the partner orbital configuration $\pi 0h_{11/2} \otimes \nu 0h_{9/2}$. In this respect, observing 1^+ states from the β decay of the parent nucleus provides some perspectives on the evolution of the single-particle states beyond ^{132}Sn and the proton-neutron coupling features. Moreover, these states can also provide an indication of quadrupole nuclear deformation. The 1^+ states populated by the β decay of an even-even nucleus have the opposite parity compared to the other negative-parity states in this region, since they are strongly governed by the allowed Gamow-Teller transition. For this reason, a specific Nilsson configuration can be determined that provides the expected deformation parameter of the daughter nucleus [11]. Therefore, the observation of the 1^+ states populated by the β decay of even-even nuclei is one of the essential observables when investigating the new isotopes in this region of nuclides.

In this paper, the β-decay scheme of ^{138}Te is reported together with the level scheme of ^{138}I for the first time. The observed levels are extensively interpreted in the context of shell-model calculations.

II. EXPERIMENT

The experiment was performed at the Radioactive Isotope Beam Factory (RIBF) operated by the RIKEN Nishina Center for Accelerator-Based Science and the Center for Nuclear Study of the University of Tokyo. Secondary beams were produced by the in-flight fission of a primary ^{238}U beam at 345 MeV per nucleon, impinging on a ^{9}Be target [12]. The produced rare-isotope beams were selected in the first stage of the BigRIPS spectrometer, and identified by the $B\rho$-ΔE-TOF (time-of-flight) method in the second stage of the BigRIPS and the Zero-Degree Spectrometer [13]. Since the magnetic spectrometers were optimized for the transmission of ^{142}Te, the fully stripped ^{138}Te isotope was not transported to the experiment site. Instead, the hydrogen-like ^{138}Te^{51+} ions, about 1.35×10^4 in statistics, were transmitted for decay spectroscopy. In addition, approximately 1.4×10^5 fully-stripped ^{138}Sb^{51+} ions were transmitted, providing additional statistics through the ^{138}Sb $\rightarrow$ ^{138}Te $\rightarrow$ ^{138}I β-decay chain.

These ions were implanted into the Wide-range Active Silicon Strip Stopper Array for β and ion detection (WAS3ABi) system [14], composed of five layers of 1-mm-thick double-sided silicon strip detectors (DSSSD) with an active area of $60 \times 40\,\text{mm}^2$. The implantation and decay position information was provided by 60 and 40 strips with 1-mm pitch along the x and y axes, respectively. The γ rays emitted from implanted ions and daughter nuclei were detected by the EUROBALL-RIKEN Cluster Array (EURICA), comprised of 12 cluster detectors with seven hexagonal-tapered high-purity germanium crystals each [15]. The detection efficiencies of the emitted γ rays with and without the add-back algorithm were 11.3(6)% and 8.7(4)% at 1 MeV, respectively.

III. EXPERIMENTAL RESULTS

The level scheme of ^{138}I was previously established by the spontaneous fission of ^{248}Cm [16]. A rotational band structure from a (7^-) state was assigned, but the ground state of ^{138}I could not be explicitly determined. An isomer with $T_{1/2} = 1.26(16)$ μs was observed with a 68-keV γ-ray transition. In the NNDC database [17], following the assignment proposed by Ref. [16], the spin-parity of this isomeric state is tentatively assigned as (3^-) and that of the ground state as (1^-). In the present work, the excited states, particularly the low-spin states, are investigated through the β decay of ^{138}Te.

Figure 1(a) shows the β-delayed γ-ray energy spectrum of ^{138}Te. Since the available statistics of ^{138}Te was low, the spatial correlation condition between an implanted ion and emitted β rays in a layer of WAS3ABi was limited to less than 2 mm for higher correlation purity. Moreover, the timing condition, which is defined as the time difference between the ions and β rays, was set as 0-4000 ms. On the other hand, the β-delayed γ-ray spectrum of ^{138}Sb is represented in Fig. 1(b). For this energy spectrum, the spatial condition was strictly imposed to select the β events in the same pixel to reduce background correlations. As a result, candidate γ-ray transitions of ^{138}I could be obtained by gating on the delayed ion-β correlated time condition of 1500–2500 ms. For the comparison, the prompt-timing energy spectrum with the ion-β correlation time of 0–500 ms is shown by the red-dashed line, with predominant peaks at 443 and 461 keV belonging to the transitions in ^{138}Te. From this analysis, we obtained six γ-ray transitions which belong to ^{138}I, as shown in Figs. 1(a) and (b). It is worth noting that the 118- and 155-keV transitions, which were previously observed in Ref. [16], are also present from the β decay of ^{138}Te.

In order to establish the level scheme of ^{138}I, the γ-γ coincidence method was employed. As Fig. 1(c) indicates, the 155-keV line coincides with the 1153- and 1809-keV transitions. The γ-ray energy-sum information was also used to construct the level scheme. For example, $155 + 1153 = 1308$ and $155 + 1809 = 1964$ produce the same energy gaps of about 17 keV by subtracting 1290 keV and 1948 keV, respectively. From these estimates, the 1290- and 1948-keV transitions are placed as shown in Fig. 2. Although many of the transitions could be reasonably placed in the level scheme,

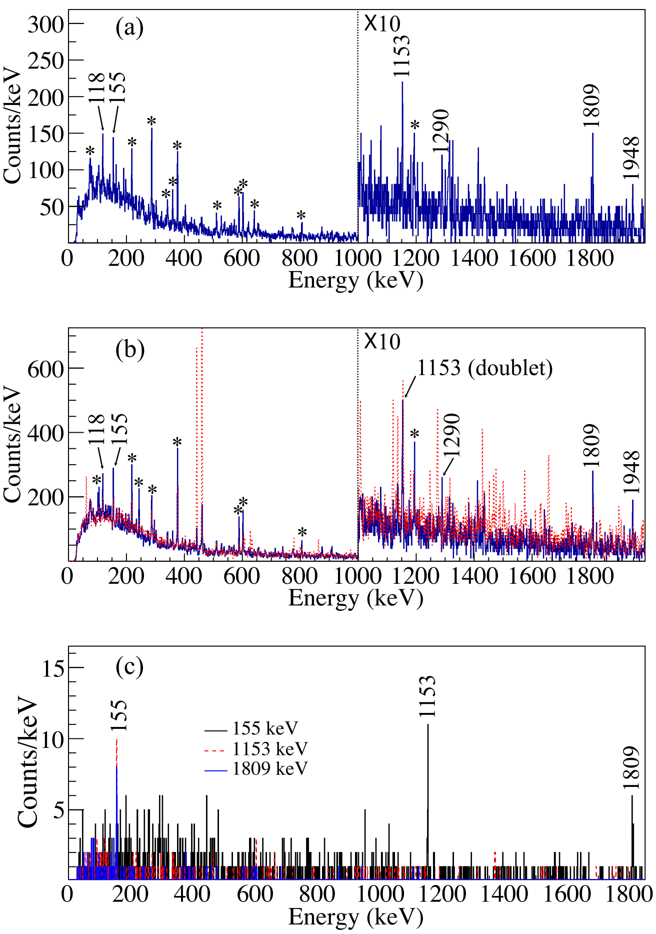

FIG. 1. (a) β-delayed γ-ray singles spectrum of ^{138}Te. (b) β-delayed γ-ray singles spectrum of ^{138}Sb. The red-dotted and blue-solid lines are the spectra gated by the ion-β correlated time conditions of 0–500 ms and 1500–2500 ms, respectively. The background contaminants are indicated by the asterisks. (c) γ-γ coincidence spectra of 155 keV (black solid line), 1153 keV (red dotted line), and 1809 keV (blue solid line).

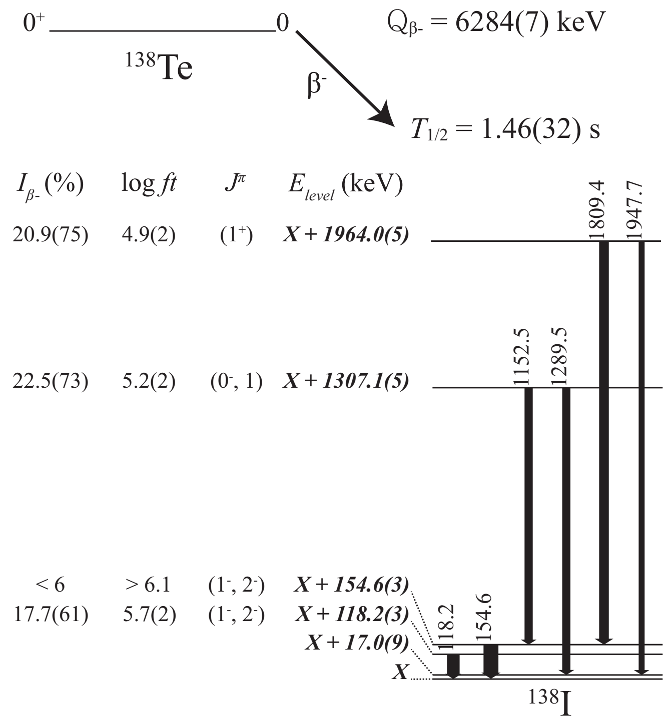

FIG. 2. Decay scheme of ^{138}Te. The half-life and Q_{β^-} are quoted from Refs. [18,19]. The level information, such as excitation energies, expected spin-parities, β-branching ratios, and log ft values are from the present work. Note that the ground state of ^{138}I is still ambiguous, and thus the excitation energies are relative to the current lowest-lying level, denoted by X. The given log ft values are calculated by assuming $X = 0$.

the placement of the 118-keV transition is still uncertain. This ambiguity is mainly caused by the absence of the coincident γ-ray information with this transition. In Ref. [16], the authors encountered a similar ambiguity, and they tentatively assigned this transition to populate the lowest-lying level. Since no further information could be obtained from the current work, this transition is also tentatively placed in the level scheme, as shown in Fig. 2. The experimental details of the γ-ray transitions are summarized in Table I.

It should be emphasized that the ground state of ^{138}I cannot yet be determined from the present data. The main reason for this difficulty is due to the 68-keV isomeric transition, previously observed in Ref. [16]. This retarded 68-keV γ-ray transition could also be observed from our data set, which are the β-delayed one-neutron emission of ^{139}Te and the cascading β decays of $^{138}\mathrm{Sb} \rightarrow {}^{138}\mathrm{Te} \rightarrow {}^{138}\mathrm{I}$ (not shown in the current work). The half-life of the isomer was deduced as 1.0(1) μs, which is consistent with the previously measured value of 1.26(16) μs [16]. However, this transition also could not be placed in the level scheme because of the absence of γ-γ coincidences, similarly to Ref. [16]. This problem was often manifest in heavy odd-odd nuclei, in which the existence of long-lived isomers and highly converted low-energy transitions made it difficult to establish the level scheme. Therefore, we tentatively introduce the current lowest-lying level with an excitation energy, X, which can be either 0 or 68 keV as assigned by NNDC [17]. Hereafter, the excitation energies are abbreviated as their relative energies with respect to X keV, e.g., 1964.0 keV implies $X + 1964.0$ keV.

For the otherlevels, the experimental log ft information is employed to propose the most probably spin-parities [20–23]. With this respect, the 118.2-keV and 154.6-keV levels are assigned to be $(1^-, 2^-)$. The spin-parity of 0^- is ruled out since the logft values of these levels are quite high. It is worth noting that the spins of both levels depopulated by these two γ-ray transitions were assigned as (4^-) in Ref. [16]. However, these levels cannot have spin values larger than 2 due to the selection rules for not only the β transition but also the γ transition. For instance, the 118.2-keV level might be directly populated by the β decay. In this case, the first forbidden transition allows a spin change up to 2. On the other hand, the 154.6-keV level is strongly populated by the upper levels, particularly, the 1964-keV level. This 1964-keV level is a strong candidate for 1^+ so that only an $E1$ transition is allowed. The assumed multipolarities for calculating internal

TABLE I. Summary of transition energies (E_γ), relative γ-ray intensities (I_γ), and placements of γ rays emitted following the β decay of ^{138}Te. The numbers in the parentheses represent the errors in the last digits. Systematic errors of 0.25 keV and 5% for E_γ and I_γ, respectively, are included. The relative intensity should be multiplied by a factor of 0.23(4) to obtain the absolute intensity per 100 decays. This factor is deduced by the ratio between the 154.6-keV γ-ray events and the total β-ray events after background subtraction.

E_γ (keV)	I_γ (rel.)[a]	$E_{\text{level},i}$ (keV)[b]	$E_{\text{level},f}$ (keV)[b]
118.2(3)	77(23)[c]	X + 118.2	X
154.6(3)	100(23)[d]	X + 154.6	X
1152.5(4)	50(17)	X + 1307.1	X + 154.6
1289.5(4)	48(21)	X + 1307.1	X + 17.0
1809.4(3)	57(20)	X + 1964.0	X + 154.6
1947.7(4)	34(20)	X + 1964.0	X + 17.0

[a]The relative γ-ray intensity, I_γ, is normalized to the intensity of the 154.6-keV transition.
[b]The excitation energies are based on the present work. The ground state could not yet be determined explicitly.
[c]I_γ reported here is the sum of the γ-ray and internal conversion intensities, calculated assuming $M1$ multipolarity.
[d]I_γ reported here is the sum of the γ-ray and internal conversion intensities, calculated assuming $E2$ multipolarity.

conversion coefficients, in order to determine the total transition intensities of the 118- and 155-keV γ rays, were $M1$ and $E2$, respectively. These assumptions are mainly due to the branching ratios. For example, the 154.6-keV transition is likely $E2$ rather than $M1$, since the latter assumption leads to a smaller internal conversion coefficient, and thus a total intensity smaller than the feeding intensity. On the other hand, the branching ratio of the 118.2-keV level would become unphysically large if its transition multipolarity is assumed to be $E2$ rather than $M1$. Consequently, the 118.2-keV transition is assigned as $M1$.

For the 1307.1-keV level, the estimated $\log ft$ value of 5.2(2) is sufficiently low and consistent with an allowed Gamow-Teller transition. Nevertheless, the excitation energy might be too low to be 1^+, based on the theoretical predictions which will be introduced in the next section and the systematic approach. In the iodine isotopic chain, ^{136}I and ^{140}I have the first 1^+ states at 2656 keV and 926 keV, respectively [11,17]. On the other hand, in the $N = 85$ isotonic chain, these levels are located at 2641 keV and 1428 keV in ^{136}Sb and ^{140}Cs, respectively [9,17]. Therefore, we leave the 1307.1-keV level as $(0^-, 1)$ including the possibility of a fast forbidden transition of $0^+ \to 0^-$ with a very low $\log ft$ value. A similar case can be found among neutron-rich Sb isotopes in Ref. [9] which supports this statement by assigning a level as (0^-) with a $\log ft$ value of 5.3(1). In contrast, a level at 1964.0 keV is a strong candidate for the (1^+) state in terms of the $\log ft$ value of 4.9(2) and its excitation energy. Thus, this level might be formed by the configuration between the partner orbitals of $\pi 0h_{11/2}$ and $\nu 0h_{9/2}$, and populated by the allowed Gamow-Teller transition.

IV. DISCUSSION

To understand quantitatively the observed level structure of ^{138}I, large-scale shell-model calculations with two different effective interactions, namely N3LOP and Napoli, were performed. Both calculations adopt the same model space, which consists of the $0g_{7/2}$, $1d_{5/2}$, $1d_{3/2}$, $2s_{1/2}$, $0h_{11/2}$ proton orbitals and the $1f_{7/2}$, $0h_{9/2}$, $2p_{3/2}$, $1f_{5/2}$, $2p_{1/2}$, $0i_{13/2}$ neutron orbitals outside the doubly magic ^{132}Sn core with $Z = 50$ and $N = 82$. The N3LOP and the Napoli interactions were derived within the framework of many-body perturbation theory starting from the free nuclear potentials renormalized by the low-momentum potential approach [24]. In particular, the $\hat{Q}$-box-folded-plus-folded-diagram method [25,26] was adopted by including in the perturbative diagrammatic expansion of the $\hat{Q}$ box one- and two-body diagrams up to second order in the interaction. The N3LOP interaction is based on the N3LO force developed within the chiral perturbation theory [27], while the Napoli interaction is derived from the CD-Bonn nucleon-nucleon potential [28]. These two interactions have been broadly employed to investigate nuclei in the northeast region of ^{132}Sn, by predicting features revealing a single particle as well as a collective nature [29–36]. The recently observed levels in Sb and Te isotopes from β-decay experiments were also described by using these interactions [8,9]. The N3LOP calculations are achieved using the ANTOINE shell model code [37,38], while the Napoli results are obtained by means of the KSHELL code [39].

The spectra provided by the two shell-model calculations are reported in Fig. 3, and compared to the experimental excitation energies, relative to the lowest-lying level identified in the present work. First of all, we see that the results of the two calculations are quite similar to each other. In particular, both of them predict the spin and parity of 0^- for the ground state, and a first excited 1^- state at an excitation energy of only a few tens of keV. The same result was obtained by using the SMPN Hamiltonian as described in Ref. [16], however, the possible 1^- spin and parity for the ground state was also proposed, based the semiempirical calculation and some experimental observations.

The 0^- ground state is dominated by the $\pi(0g_{7/2})^3 \otimes \nu(1f_{7/2})^3$ configuration with a wave function contribution of 32% in both N3LOP and Napoli calculations. In all the low-lying negative-parity states neutrons appear mainly as the $(1f_{7/2})^3$ configuration, while the three valence protons are distributed in the $0g_{7/2}$ and $1d_{5/2}$ orbitals. For instance, the leading components of the 1^-_1 state obtained by employing the N3LOP (Napoli) interaction are $\pi(0g_{7/2})^3 \otimes \nu(1f_{7/2})^3$ and $\pi(0g_{7/2})^1(1d_{5/2})^2 \otimes \nu(1f_{7/2})^3$ with percentages of 14% (21%) and 18% (14%), respectively.

Although the scenario that the observed lowest-lying level is the 0^- ground state cannot be verified from the present experimental data, it may be justified by considering that this choice leads to a reasonable agreement between the calculated and observed level schemes, as shown in Fig. 3. Some additional support to the models are from the experimental data for ^{134}Sb ($Z = 51, N = 83$) and ^{142}Cs ($Z = 55, N = 87$). Similar to ^{138}I, they have the same number of valence protons and neutrons outside the ^{132}Sn core. Both of them feature the first

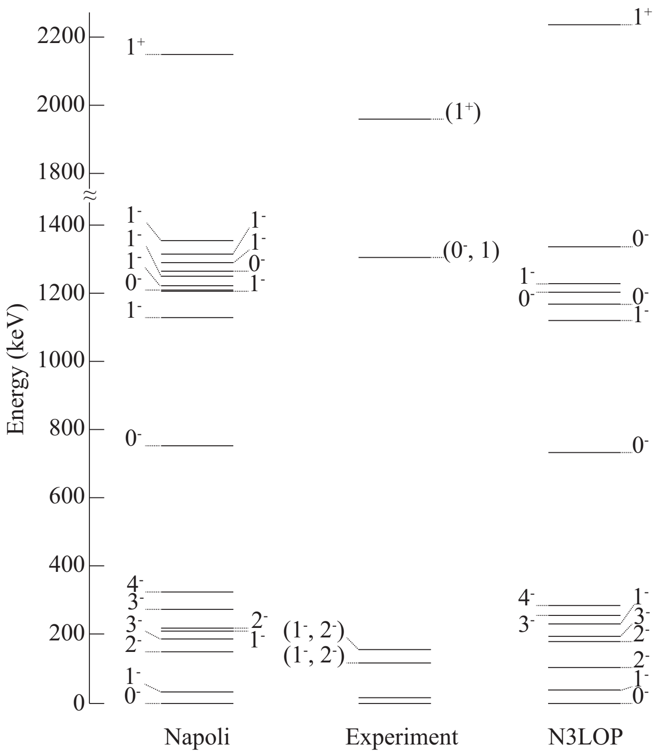

FIG. 3. Comparison between the experimentally established levels of ^{138}I (middle) and theoretical predictions. The Napoli (left) and N3LOP (right) interactions are employed in the large-scale shell-model calculations. The experimental results are based on the lowest-lying level X assumed with zero excitation energy. The y axis above 1400 keV is truncated due to the absence of excited states.

excited states at 13 keV, and the spin-parity was assigned as (1^-) in ^{134}Sb. These first excited states may correspond to the 17-keV level in ^{138}I. Therefore, the 68-keV $E2$ isomeric transition might populate the 17-keV level from an unobserved 3^- state. This state is predicted at around 200 keV from both calculations.

Alternatively, the observed lowest-lying level can be suggested as a 3^- isomeric state. As proposed in Refs. [16,17], this state would populate the low-lying 1^- state by the 68-keV isomeric transition. This scenario may then explain why the 1964.0-keV level, which is proposed to be a (1^+) state, does not directly decay to the lowest-lying state. However, more supporting evidence would be needed to confirm this decay scheme, such as a clear γ-γ coincidence between the 1^- and 3^- states, which is absent in the present experiment as well as in Ref. [16]. In the meantime, it is worth mentioning that the 2^- or 3^- option for the ground state of ^{138}I can be reasonably ruled out. In fact, from the β-decay data of ^{138}I to ^{138}Xe, the branching ratio of the first 4^+ state is assigned to be 0% while that of the first 2^+ state is 30% [40]. This result is strongly consistent with a 1^- ground state of ^{138}I, possibly 0^- as well, even though it is assigned as $(2^-, 3^-)$ in Ref. [40] based on the observation of the (3^-) state in ^{138}Xe. However, it should be emphasized that the branching ratio of this (3^-) state is too low to be considered as an allowed Gamow-Teller transition. Additionally, the systematic behavior of the ground states in $N = 85$ isotones, where the (1^-) state is observed as the ground state in ^{136}Sb and ^{140}Cs, supports that the ground state of ^{138}I could be assigned as (1^-).

Even though the theoretical calculations predict the ground state as 0^-, its spin-parity assignment still needs to be corroborated by experimental data. Thus, it should be explicitly determined by a future experiment with a more dedicated detection system.

As mentioned earlier, the 118.2- and 154.6-keV levels may have spin-parity of $(1^-, 2^-)$ because of the β-decay properties. In fact, the Napoli and N3LOP calculations predict 1^- and 2^- states in the same energy region, as shown in Fig. 3. The first 4^- state is predicted at around 300 keV from both calculations, and this state may play an important role in the connection to the $\pi 0g_{7/2} \otimes \nu 1f_{7/2}$ band structure [16]. Unfortunately, this state could not be observed from the present work due to the limit of the β-decay selection rule.

As described previously, the observed level at 1307 keV might be a (0^-) state with the possible spin-flip transition of $0^+ \rightarrow 0^-$, based on its anomalously low $\log ft$ value of 5.2(2). As a matter of fact, both interactions predict 0_3^- and 0_4^- states at the excitation energies between 1200 and 1300 keV. However, if one presumes that this state is an 1^+ state, there is a large energy difference with the calculated 1^+ states. On the other hand, the discrepancy between the experimental excitation energy and the shell-model calculation is also encountered in ^{140}I [11]. However, for the ^{140}I case, the 925.5-keV level could be firmly determined as (1^+) due to its low $\log ft$ value and a deformed Nilsson model with a deformation parameter $\varepsilon_2 \approx 0.1$ introduced to explain the formation of this 1^+ state. Similarly, the deformed Nilsson model is employed for ^{138}I, and the $\pi[541]3/2 \otimes \nu[541]1/2$ deformed configuration is obtained at 1436 keV with the deformation parameter $\varepsilon_2 \approx 0.06$ by using the proton and neutron pairing parameters of $\Delta_p = 0.777$ MeV and $\Delta_n = 0.511$ MeV, respectively [41,42]. Despite the above considerations, the possibility of a 1^- assignment cannot be completely ruled out since the measured log ft value is generally a lower limit due to the pandemonium effect [43]. For these reasons, we leave this state with spin and parity as $(0^-, 1)$. Consequently, in addition to the calculated 0^- states, several 1^- candidates are represented in Fig. 3.

A level at 1964 keV is a strong candidate of the 1^+ state in terms of the excitation energy and the $\log ft$ value. From N3LOP (Napoli), the calculated first, second, and third 1^+ states are predicted at 2.21 (2.15), 2.64 (2.54), and 2.68 (2.63) MeV, respectively. It should be noted that only the first 1^+ states for both calculations are displayed in Fig. 3. The excitation energy of the observed 1^+ state agrees fairly well with both theoretical results of the 1_1^+ states. However, the two theoretical states are quite different in nature. The N3LOP interaction predicts that the 1_1^+ and 1_2^+ states are contributed by the neutron intruder $\nu 0i_{13/2}$ orbital, for instance, through the $\pi(0g_{7/2})^3 \otimes \nu(1f_{7/2})^2(0i_{13/2})^1$ configuration with wave function contributions of 15% and 20%, respectively. On the other hand, the 1_3^+ state is governed by the $\pi(0g_{7/2})^2(0h_{11/2})^1 \otimes \nu(1f_{7/2})^2(0h_{9/2})^1$ configuration with a ratio of 38%. This result is similar to that obtained in recent study on the odd-odd ^{136}Sb isotope, which is an isotone with $N = 85$ [9]. In

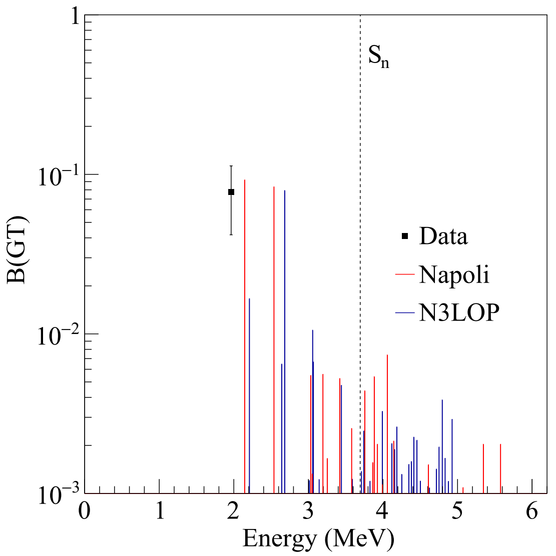

FIG. 4. Measured and calculated $B(GT)$ values of β transitions from the 0^+ ground state of ^{138}Te to 1^+ states of ^{138}I. The one-neutron separation energy is represented by a dashed line.

contrast, with the Napoli interaction we find that the contributions of the $\pi(0g_{7/2})^2(0h_{11/2})^1 \otimes \nu(1f_{7/2})^2(0h_{9/2})^1$ configurations in 1_1^+ and 1_2^+ are 19% and 28%, respectively. As pointed out in Refs. [9,11], the only possible transition from the 0^+ ground state of ^{138}Te to the 1^+ state of ^{138}I is the allowed Gamow-Teller transition $\nu 0h_{9/2} \rightarrow \pi 0h_{11/2}$. Consequently, the observed 1^+ state might correspond to the 1_3^+ state from N3LOP and the 1_1^+ state from Napoli.

To support this argument, we have calculated the Gamow-Teller strengths with a quenching factor of 0.55, as shown in Fig. 4 (see Ref. [38] for the $B(GT)$ value evaluation). Typically, this Gamow-Teller strength is supposed to be enhanced when the state of the daughter nucleus is significantly dominated by the configurations containing the spin-orbit partners of $\pi 0h_{11/2}$ and $\nu 0h_{9/2}$. Indeed, as shown in Fig. 4, the calculated levels with such a kind of configuration in both N3LOP and Napoli interactions show the largest strength. It is worth noting that the measured $B(GT)$ value from the present work is consistent with the calculated $B(GT)$ values of these levels. To conclude, this agreement in the $B(GT)$ value supports that the observed 1^+ level at 1964 keV is mainly built on the proton-neutron coupling in the spin-orbit partners $\pi 0h_{11/2}$ and $\nu 0h_{9/2}$.

Another shell-model calculation, employing the same model space described above and the CWG Hamiltonian [44,45], gives similar results. From this calculation, the first 1^+ state at 1855 keV is predicted to be 0.738 for the proton occupancy in $\pi 0h_{11/2}$ and 0.628 for the neutron occupancy in $\nu 0h_{9/2}$. These results agree well with the observed (1^+) state in terms of the excitation energy. Moreover, the calculated Gamow-Teller strength of $B(GT) = 0.045$ is slightly smaller but agrees reasonably well with the experimental data. As a consequence, the CWG interaction also predicts the partner orbital configuration formed in the observed (1^+) state.

V. CONCLUSION

In the present work, the first β-delayed γ-ray spectroscopy result of ^{138}Te is reported. Several newly observed γ-ray transitions are placed in the level scheme of ^{138}I, based on the γ-γ coincidence and γ-ray energy sum methods. From the β-decay events, we could tentatively assign the spin-parities of the observed levels, and some of them are different from the previous results obtained by the spontaneous fission experiment.

By employing shell-model calculations with two different interactions, N3LOP and Napoli, the observed levels could be reasonably explained. The observed 1^+ state at 1964 keV is described within the shell-model framework. It is dominated by the partner orbital configuration of $\pi 0h_{11/2} \otimes \nu 0h_{9/2}$, which is important for examining the evolution of the single-particle states beyond ^{132}Sn as well as the Gamow-Teller strength of β decays in this region.

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