Revised level structure of ^{120}Te

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The level scheme of the nucleus ^{120}Te, populated in the reaction ^{80}Se(^{48}Ca,$\alpha 4n$), was reinvestigated using γ-ray coincidence data measured with the Gammasphere spectrometer. Previously, five high-spin rotational bands were discovered in this nucleus. The present reinvestigation revealed that the decay of band $b1$ is more complex than suggested in the earlier work and that it cannot be uniquely determined. Furthermore, a number of new transitions are added to the level scheme. The implications for the spin assignments and excitation energies of the five bands and for comparisons with cranked Nilsson-Strutinsky calculations are discussed.

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In several near-spherical nuclei in the mass $A = 120$ region, high-spin rotational bands associated with large deformation have been observed in recent years [1–8]. Quadrupole moments were estimated from lifetime measurements for several bands in ^{125,126}Xe [5,6] from which quadrupole deformation parameters around $\varepsilon_2 = 0.3$ were deduced. The bands generally start around spin $I = 20$–25 and continue in rather regular sequences up into the spin $I = 50$–60 range. Most of them are weakly populated and are not linked to lower-lying levels; their intensities generally amount to a few percent of the reaction-channel strength. Only in ^{125}I [4] and ^{125,126}Xe [5,6] have linking transitions been detected. In our recent work on ^{120}Te [1], a connection between one of the five bands discovered in this nucleus, band $b1$, and lower-spin states was proposed. The principal aim of the present work is to show that this decay is more complex than suggested earlier.

The structure of the bands has been investigated within the framework of the cranked shell model (CSM) [9] as well as within the cranked Nilsson-Strutinsky (CNS) [10–12] approach. It was suggested that the bands are formed in configurations with two $g_{9/2}$ proton holes in the $Z = 50$ core coupled to one or two $h_{11/2}$ proton particles and that the favored neutron configurations have five or six particles in the $h_{11/2}$ subshell as well as neutrons excited across the $N = 82$ gap in some cases. However, even for the bands connected to lower-lying levels which are thought to have known excitation energies and spins [4–6], several configuration assignments appear problematic when the spin values and absolute energies are considered in detail [13].

A comparison of the excitation energies of the five bands, $b1$–$b5$, discovered in ^{120}Te with the results of CNS calculations revealed differences of the order of 2 MeV for all reasonable configurations [1]. In particular, the energy differences were observed to increase for high spins where agreement between experiment and calculations is expected to be good. Discrepancies at low spin are less problematic, since pairing correlations are neglected in the CNS calculations. These observations motivated a reinvestigation of the previously suggested decay of band $b1$ to lower-spin levels and of the level scheme of ^{120}Te in general.

Details of the experiment and the data analysis are presented in [1]. In the present analysis, care was taken to select only the cleanest coincidence gates to avoid contaminations from the many close-lying γ-ray transitions in the spectra. Examples of such spectra are displayed in Figs. 1 and 2.

The present investigation led to several revisions of the level structure of ^{120}Te, as displayed in Fig. 3. It turned out that the decay-out of band $b1$ is more complex than suggested previously [1]. The 795-keV transition is not directly depopulating the band, but is located in parallel to the lowest in-band transitions and feeds into structure e. A new, weak transition of 1238 keV is tentatively placed at the bottom of the band. The 1246-keV γ ray, previously assigned as the lowest band member, is in coincidence with the 795-keV line and lies parallel to the new in-band 1238-keV transition. The newly assigned band head of $b1$ decays predominantly into the 23^+ state of structure f at 9140 keV. Furthermore, a relatively strong decay path exists parallel to the 1305-keV band member to the $I^\pi = 25^{(-)}$ state of sequence e. However, consistent decay paths could not be constructed on the basis of the available data.

Two transitions, with energies of 1215 and 1305 keV, have been added at the bottom of band $b3$. Note, however, that

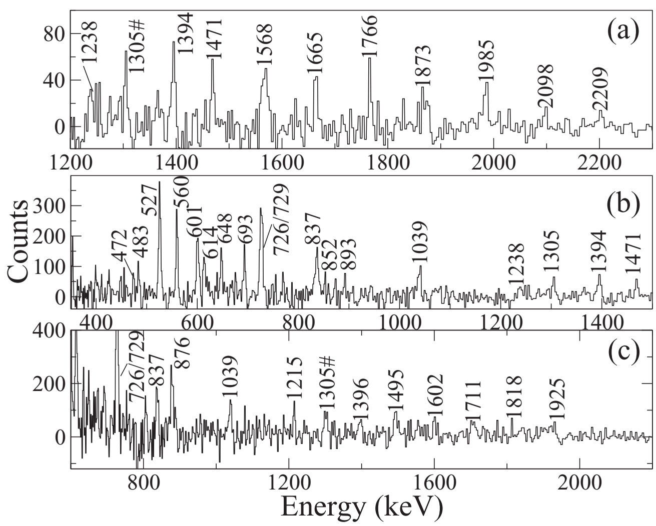

FIG. 1. Summed triple-gated γ-ray coincidence spectra of bands $b1$ and $b3$. (a) and (b): Spectrum of band $b1$ generated with a double gate from the list of $b1$ transitions from 1471 to 2209 keV and a single gate from the list of the 184-, 648-, and 693-keV transitions. (c) Spectrum of band $b3$ generated with a double gate from the list of $b3$ transitions, except for 1305 keV, together with a single gate on the list with transitions of 560, 601, 425, 1039, 325, 693, and 483 keV. The hash mark points to the 1305-keV transition which exists also in band $b1$.

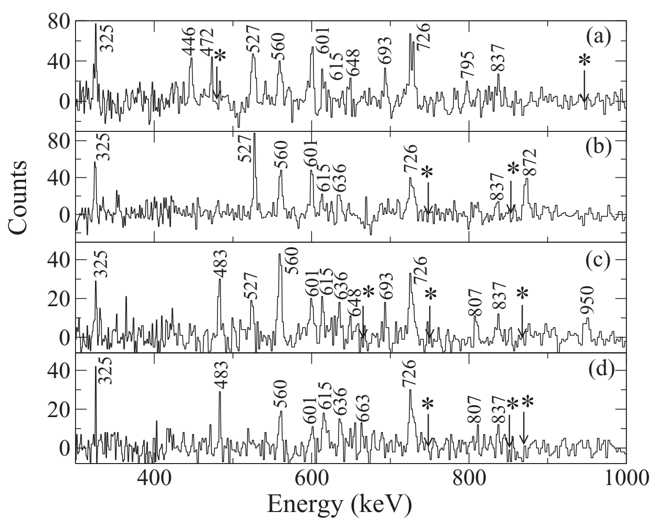

FIG. 2. Summed triple-gated γ-ray coincidence spectra demonstrating revisions in the level scheme in the medium-spin range. (a) Spectrum produced by gating on one γ ray from the list of 648-, 693-, and 184-keV transitions and on the 1397- and 505-keV lines. The asterisks point to the missing 483- and 950-keV transitions. (b) Spectrum created with gates on the 482-, 1598-, and 663-keV transitions. The asterisks mark the absence of the 746- and 852-keV γ rays. (c) Spectrum created with a gate on the 505-, 472- and 1732-keV γ rays. The asterisks point to the missing 663-, 746-, and 872-keV transitions. (d) Spectrum produced with a gate on the 950-, 505-, and 1541-keV lines. The asterisks indicate the positions of the missing transitions with energies of 746, 852, and 872 keV.

1305-keV lines exist also in band $b1$ near the bottom and in the new structure labeled g, which renders a safe assignment of a transition with the same energy in $b3$ problematic. Furthermore, the previous suggestion that bands $b4$ and $b5$ decay into lower members of band $b1$ is probably not correct.

Tentatively, spin $I = 24$ is assigned to the $b1$ band head. However, larger spin values are possible if multistep decays from this band to the lower-lying levels are considered. In accordance with the lowered spins of band $b1$, the tentative spins of bands $b2$,$b3$ and $b4$,$b5$ have also been decreased by 3 and 2 $\hbar$, respectively, compared with the previous assignments of Ref. [1].

Several new γ-ray transitions have been added to the previous level scheme [1] in the medium-spin region. They are the 832-keV crossover transition from the 19^- to the $17^{(-)}$ level in sequence b, the 446- and 1397-keV γ rays connecting the $22^{(+)}$ level of structure e with the 19^- state of b, and the 1541- and 1732-keV transitions between structures e and f. The placement of the 1541- and 1732-keV γ rays confirms the previously assigned 663-keV transition. The ordering of the 446- and 1397-keV transitions remains uncertain. Moreover, a 1598-keV γ ray was placed in parallel with the 852–746-keV sequence of structure f. Thus, the 872- and 746-keV transitions were reordered. A coincident cascade with 463- and 344-keV lines was found in parallel with the 807-keV transition in sequence f. The position of the 807- and 1013-keV γ rays was reversed because of the higher intensity of the 807-keV transition in some of the coincidence spectra. The 1598-keV transition from the $I = 24$ state of sequence f to the 22^+ level of the ground band is probably of $E2$ character, suggesting positive parity for the $I = 24$ state. The 872-keV transition has an angular distribution ratio compatible with a stretched quadrupole. It is most likely of $E2$ multipolarity and, therefore, $I^\pi = 26^+$ is assigned to the level above the 24^+ state in sequence f.

The parities of the higher-spin states of sequences e and f remain uncertain. The tentatively chosen assignments, see Fig. 3, are in agreement with the theoretical predictions for the configurations of energetically favored states (as discussed below) and are consistent with the following experimental results. The 950- and 472-keV lines of structure e exhibit angular distribution ratios compatible with a stretched dipole character. The assumption that both transitions are of $E1$ multipolarity leads to two parity changes in this sequence. Thus, $I^\pi = 22^{(+)}$ and $24^{(+)}$, respectively, are assigned to the two levels above the 950-keV line in e. The next higher-lying state would then have $I^\pi = 25^{(-)}$. This choice is consistent with the 1541-keV quadrupole transition, probably of $E2$ character, connecting the 26^+ level of sequence f with the $24^{(+)}$ state of structure e. The 663-keV transition of sequence f exhibits an angular distribution ratio compatible with a stretched dipole. If it is of $E1$ multipolarity, the higher-spin states of f have negative parity, as tentatively shown in Fig. 3. The 1732-keV γ ray, probably of $E2$ character, competes with the 663-keV transition and feeds into the $I^\pi = 25^{(-)}$ level of cascade e.

Three γ rays with energies of 1305, 994, and 1055 keV are placed on top of the cascade of the 795- and 1246-keV lines.

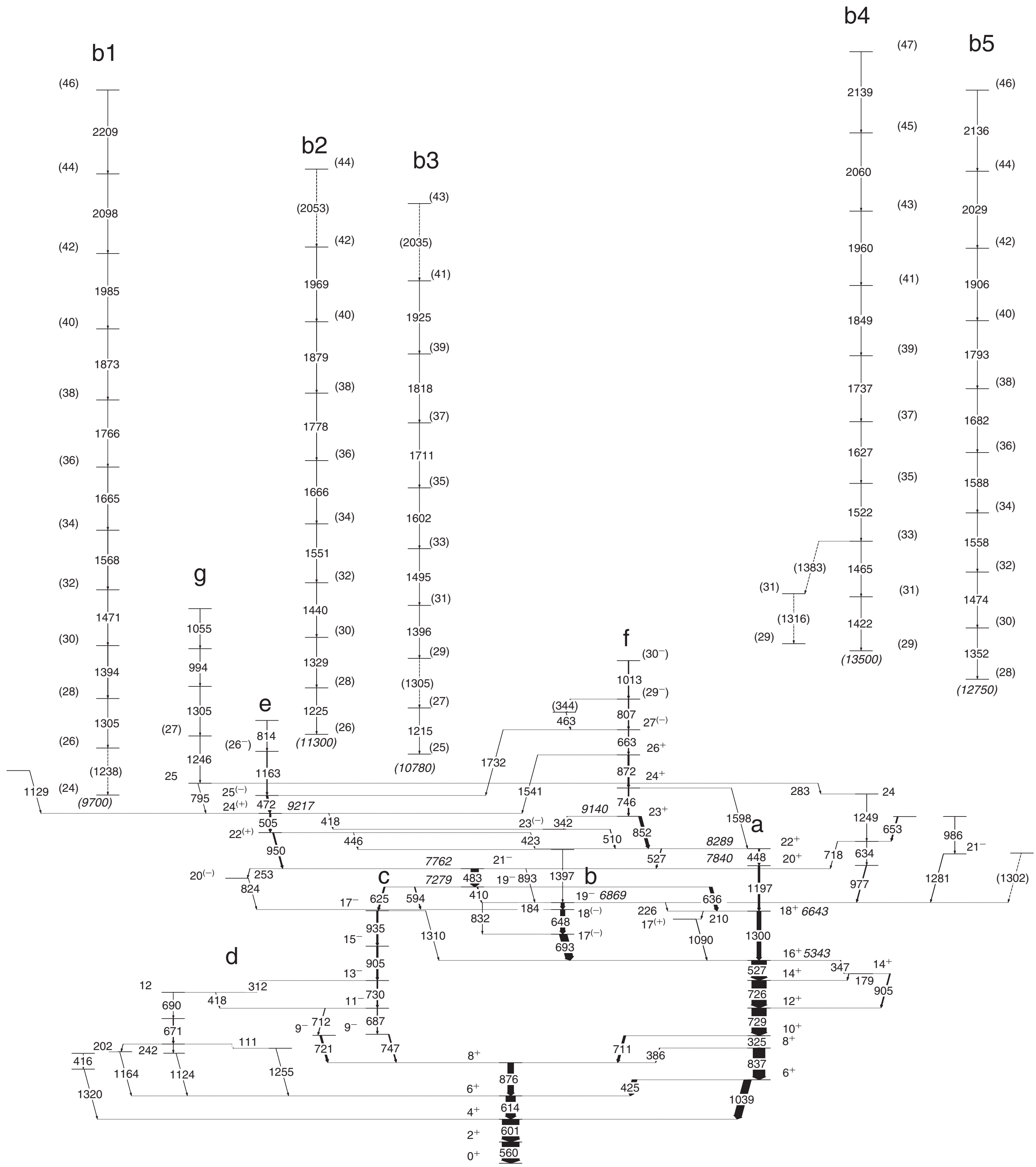

FIG. 3. Level scheme of ^{120}Te based on previous work [1] and on the present results.

This new sequence is labeled *g* in Fig. 3. However, no angular distribution could be measured for these transitions and their ordering remains tentative.

The relative intensities of the high-spin bands have been redetermined since the rather strong 1246-keV line is excluded from band *b*1. Band *b*1 remains the strongest with about 5% of the channel population. Bands *b*2–*b*5 have respective intensities of about 1.1, 0.6, 1.3, and 1.0%.

Excitation energies of the bands *b*1–*b*5 in ^{120}Te have been estimated in comparison with similar bands in ^{125,126}Xe, where

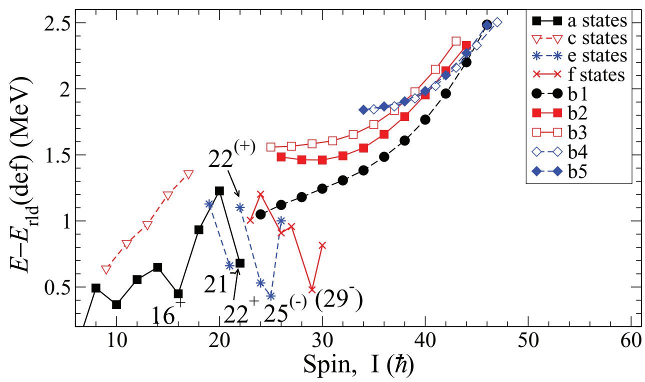

FIG. 4. (Color online) Energies, relative to a rotating liquid-drop reference, as a function of spin for excited states in ^{120}Te. For bands $b1$–$b5$, energies and spins are estimates.

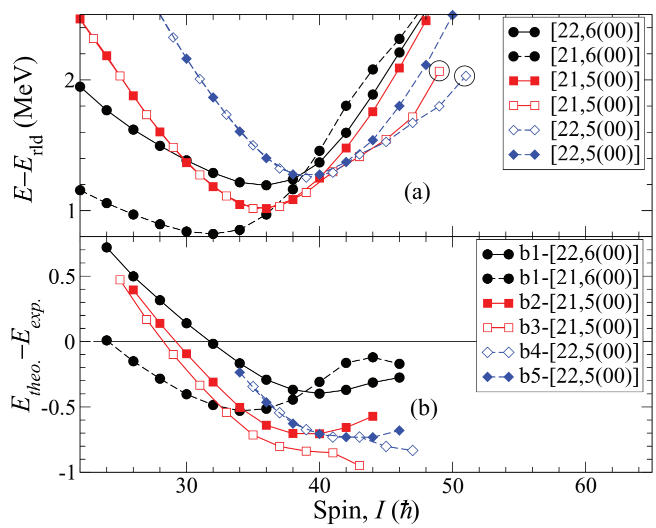

FIG. 5. (Color online) (a) Calculated energies relative to a rotating liquid-drop reference for low-energy configurations. (b) Differences between the observed and calculated energies.

the connections are established [5,6]. The excitation energies, relative to a rotating liquid-drop reference [12], of levels of various low- and medium-spin structures as well as the adopted values of the five rotational bands are displayed as a function of spin in Fig. 4. The positions and slopes of $b1$–$b5$ with respect to the noncollective structures suggest that the chosen excitation energies and spins are reasonable, likely within about 2 MeV and 3 $\hbar$, respectively.

In the CNS calculations, the most favored valence states are those with $I^\pi = 22^+$ and 25^-. They are formed in configurations with a closed ^{114}Sn core when the proton configurations $(g_{7/2},d_{5/2})^2$ with $I_{\max} = 6$ and $[(g_{7/2},d_{5/2})^1,h_{11/2}]$ with $I_{\max} = 9$ are combined with the neutron configuration $h^4_{11/2}$ with $I_{\max} = 16$. The observed energetically favored states with $I = 22^+$ and $25^{(-)}$, see Fig. 4, may correspond to these configurations. Furthermore, relatively low-lying $I^\pi = 26^+$ and 29^- states are calculated when a neutron is excited from the $d_{5/2}$ subshell in the core to the $d_{3/2}$ or $h_{11/2}$ shells, adding 4 $\hbar$ to the original $I = 22^+$ and 25^- computed values. The observed favored (29^-) level of sequence f probably has such a configuration.

The energies of the five bands $b1$–$b5$, relative to a rotating liquid-drop energy [12], are compared with the results of CNS calculations in Fig. 5. In Fig. 5(a), the relative energies calculated within the framework of the CNS model for low-energy configurations [1] are displayed, and the differences between experimental and calculated energies are shown in Fig. 5(b). The configurations are labeled according to the number of valence particles in different j shells or groups of j shells. For ^{120}Te, it is convenient to use the labels $[p_1p_2,n_1(n_2n_3)]$ [1]. The bands $b1$–$b5$ are assigned to have two $g_{9/2}$ holes in the $Z = 50$ core ($p_1 = 2$) and no neutrons excited across the $N = 82$ gap ($n_2 = n_3 = 0$), which means that they are characterized by the number of $h_{11/2}$ protons and neutrons, p_2 and n_1, respectively.

The calculations indicate that the structures [21,6(00)] and [22,6(00)] with negative and positive parity, respectively, are expected to lie low in energy at low spins, with the former being lowest below $I = 36$. Both may be candidates for the configuration of band $b1$, as was already pointed out earlier [1]. With the chosen spins, bands $b2$,$b3$ and $b4$,$b5$ could be signature partners. As discussed in Ref. [1], the configurations [21,5(00)] and [22,5(00)], respectively, may be assigned to these bands. The energy differences of Fig. 5(b), with these configurations show the expected behavior: they decrease with increasing spin, as pairing, neglected in the calculations, plays a minor role at high angular momentum. However, one of the two lowest theoretically expected configurations, [21,6(00)] or [22,6(00)], is missing experimentally. Without firm connections to known yrast states for any of the long bands, experimental spins and excitation energies are uncertain within larger limits than assumed previously and more definite configuration assignments have to await the discovery of the connecting transitions between these long cascades and the lower-spin states.

In summary, the level scheme of ^{120}Te, populated in the ^{80}Se(^{48}Ca,$\alpha 4n$) reaction, was reinvestigated. Several new transitions were added in the medium-spin region, the ordering of some transitions was corrected, and spins and parities were assigned to a number of states. Previously, one of the five high-spin bands, $b1$, was suggested to be linked to lower-lying levels. This connection was shown to be incorrect. The decay of band $b1$ seems to be fragmented and could not be resolved unambiguously with the present data. Nevertheless, with the tentatively adopted excitation energies and spin values, configuration assignments are suggested for the five bands.

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