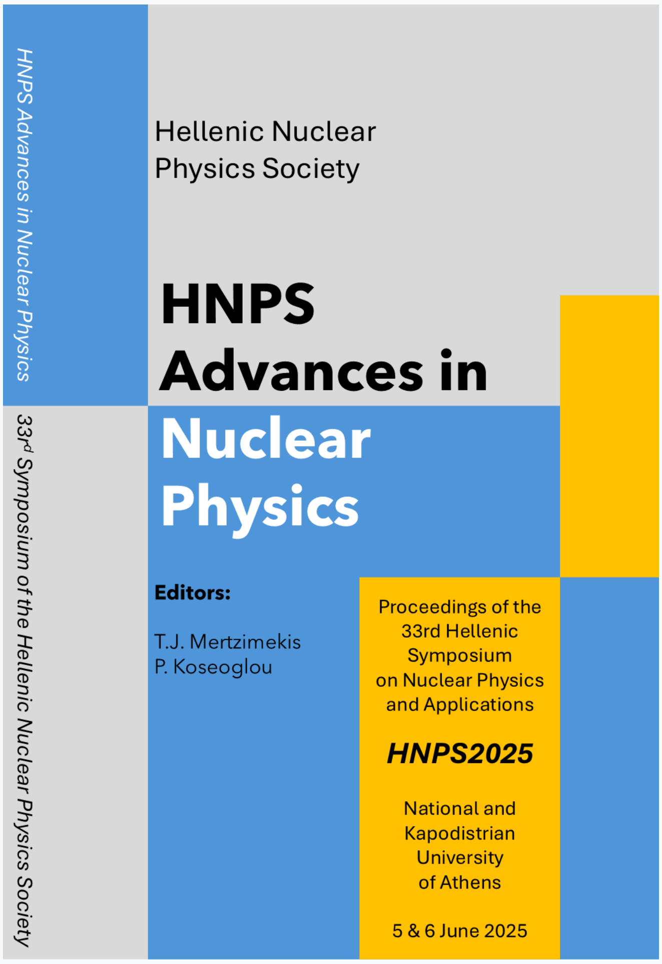
HNPS Advances in Nuclear Physics

Vol 32 (2026)

HNPS2025



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doi: [10.12681/hnpsanp.8684](https://doi.org/10.12681/hnpsanp.8684)

HNPS Advances in Nuclear Physics Vol. **32**, 73–78 (2025)
doi: 10.12681/hnpsanp.8684

Hellenic Nuclear Physics Society
Advances in Nuclear Physics
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ARTICLE

Investigating the nuclear structure of ^{116,118}Te

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(Received: 18 Oct 2025; Accepted: 01 Dec 2025; Published: 01 Dec 2025)

Abstract
The ^{116,118}Te isotopes, similar to the Cd mid-shell isotopes which are their mirror partners across the $Z = 50$ shell, show vibrational features on their ground-band states. However, recent density functional theory calculations and proxy-SU(3) studies also predict shape coexistence in these nuclei. More experimental data are needed in order to verify this. An experiment was conducted at the 9MV Tandem Accelerator at IFIN-HH in Magurele, Romania, in order to populate excited states in ^{116,118}Te by the fusion-evaporation reaction mechanism. An ^{11}B beam at beam energy of 35 MeV was impinged on a ^{107,109}Ag target. The subsequent gamma decay was detected using the RoSPHERE array, equipped with 15 HPGe and 10 $LaBr_3$(Ce) detectors. The experiment provided data for spectroscopic analysis and highlighted the need for further refinement in experimental techniques, potentially incorporating the plunger technique to measure the ground-state band lifetimes in the future. In this contribution the gamma-spectroscopy analysis on ^{116,118}Te will be presented. Consecutive work will focus on fast-timing measurements to determine the lifetimes of excited states.

Keywords: Nuclear structure; Gamma-ray spectroscopy; ^{116}Te; ^{118}Te

1. Introduction

In this work gamma-spectroscopic techniques were used in order to study the level schemes of the ^{116,118}Te. Both of the isotopes proximity to the Z=50 shell closure was the main motivation for this work as there is a lack of experimental nuclear structure data in this mass region. This could also be a first step towards the deformed region of their isotonic Xe, Ba, Ce and Sm isotopes whose structural properties could aid the continuous effort in understanding the deformation evolution in this region. The region near the magic number Z=50 shell closure is also known to contain nuclei that exhibit shape coexistence shown by recent density functional theory calculations [1] and by the proxy-SU(3) model [2]. In [2] theoretical calculations for shape coexistence are presented for several tellurium isotopes interpreted by particle-hole excitations, showing that shape coexistence is present in both ^{116,118}Te isotopes. Also, according to theory, both isotopes are expected to show vibrational features portrayed as intraband equal level energy spacing. To populate the excited states of both isotopes a natural Ag target (51.838% ^{107}Ag, 48.161% ^{109}Ag) of 5.2365 mg/cm^2 thickness was used. The target was bombarded with a ^{11}B beam at 35 MeV beam energy. The isotopes of interest ^{116}Te and ^{118}Te were produced by the fusion evaporation reactions $^{107}\mathrm{Ag}(^{11}\mathrm{B}, 2n)^{116}$Te and $^{109}\mathrm{Ag}(^{11}\mathrm{B}, 2n)^{118}$Te. In Figure 1 one can see the target mounted in the center of the target chamber. In order to detect the

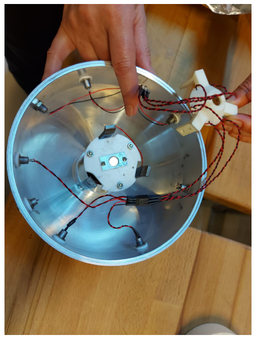

Figure 1. The target used to populate the isotopes of interest

gamma rays emitted by the produced isotopes the RoSPHERE array [3] was used equipped with 15 HPGe detectors and 10 $LaBr_3$(Ce) detectors. The RoSPHERE array is a multiple detector array which is used in cooperation with the 9MV Tandem accelerator at IFIN-HH. The array has 5 rings oriented at 37°, 70°, 90°, 110°, 143° with respect to the beam axis. Each ring can hold up to 10 detectors, in this work specifically rings 1, 3, 5 were equipped with HPGe detectors whereas rings 2, 4 were equipped with $LaBr_3$ detectors. Additionally the solar cell array SORCERER [4] consisting of 6 Silicon particle detectors was mounted. In this present work only the analysis of the HPGe data will be shown. In Figure 2 one can see a CAD view of the experimental setup.

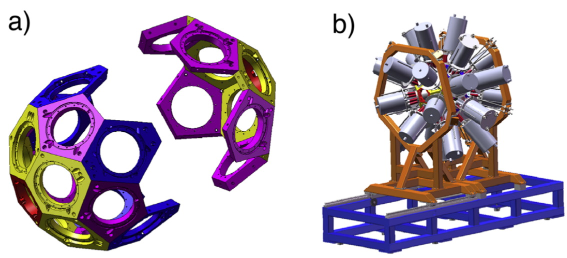

Figure 2. Artistic representation of the detector array. a) Part of the holding structure. Each of the five rings of the detector array is shown in a distinct color corresponding to the different detector-angles with respect to the beam axis(more information in the text) b) The complete detector array [3].

In order to calibrate the detector a ^{152}Eu source was used and Debertin function was used to create the efficiency curves for each ring and for the whole detector setup (see Fig 3). The equalization factors of the Debertin function were calculated using a curve fitting model on the data that were obtained spectroscopically. In Figure 3 the mean efficiency graph for all rings is shown, this graph is a result of the average efficiency for all rings in each energy region. In Figure 3 the Debertin function as well as the equalization factors are shown.

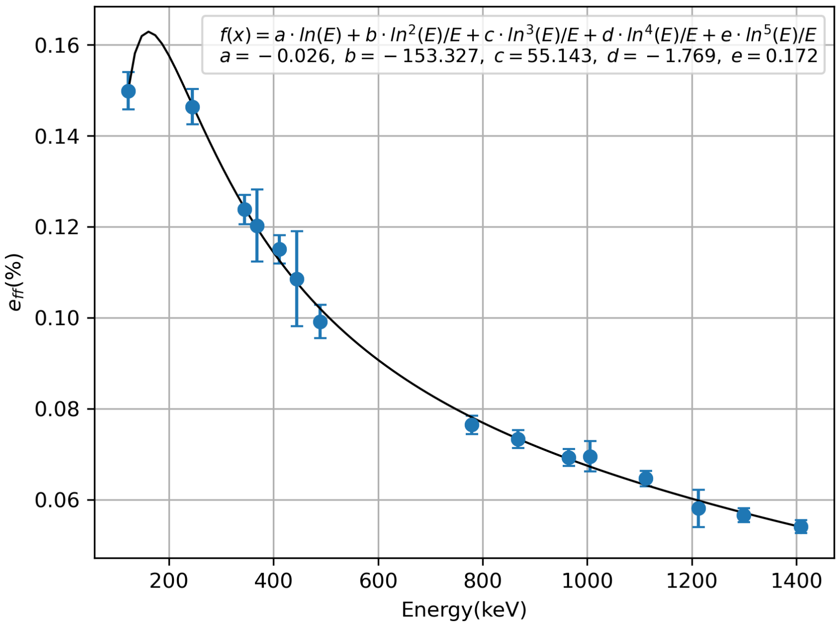

Figure 3. Mean efficiency graph for all HPGe detector rings

2. Results and Discussion

After spectroscopic analysis the reconstructed level schemes of ^{116}Te and ^{118}Te, are shown in figures 4 and 5. A widely used indicator of the nuclear shape is the quantity $R_{4/2}$ which equates to the energy of the 4^+ ground band state divided by the energy of the 2^+ ground band state ($R_{4/2} = E(4^+)/E(2^+)$), if the value of $R_{4/2}$ is approximately equal to 2 it is safe to assume that the nucleus is a spherical vibrator [5]. After calculating the $R_{4/2}$ values for the nuclei ^{116,118}Te we can confirm the preconceived notion that both of these isotopes are spherical nuclei as they do lie closely to the Z=50 shell closure and they also present vibrational ground-band states, as is apparent by the intraband equal level energy spacing presented in figures 4 and 5. Both of the level schemes shown in the figures below (Fig:4,5) were reconstructed using spectroscopic techniques such as setting gates on the photopeaks and looking for coincidences in the data. The data analysis was done with the use of the specialized program Xtrackn (also known as GASPware) that was specifically developed for all spectroscopy data coming from the IFIN-HH lab. In Figures 6, 7, 8 the spectra that resulted during the analysis are shown, as one can see the isotopes of interest are well populated and as a result many of the identifying peaks of each isotope are visible.

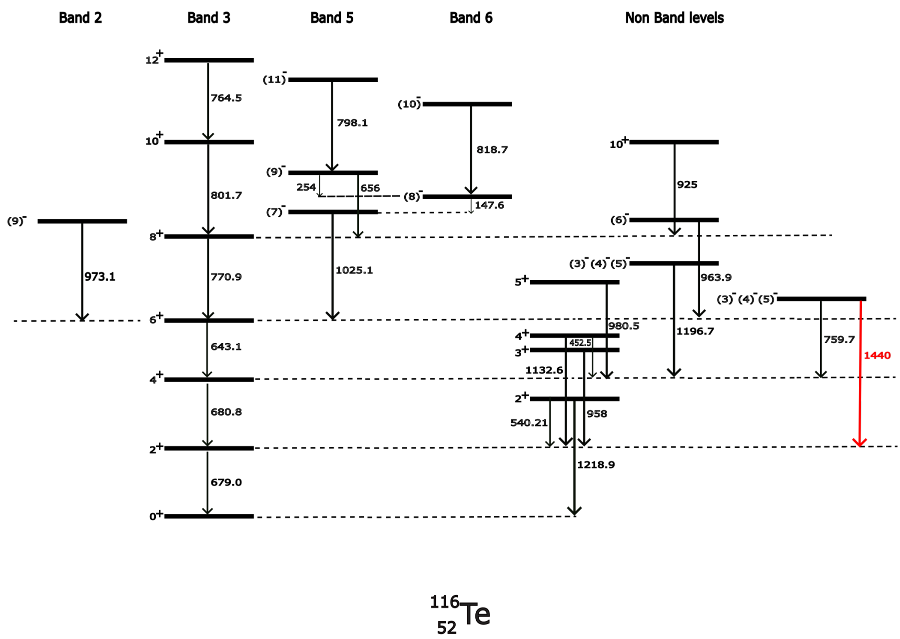

Figure 4. Observed level scheme from the analysis of ^{116}Te.The energy spin states $5^+, 4^+, 3^+, 2^+$ that appear above belong in Band 8. All energy values are taken from the literature. [6]

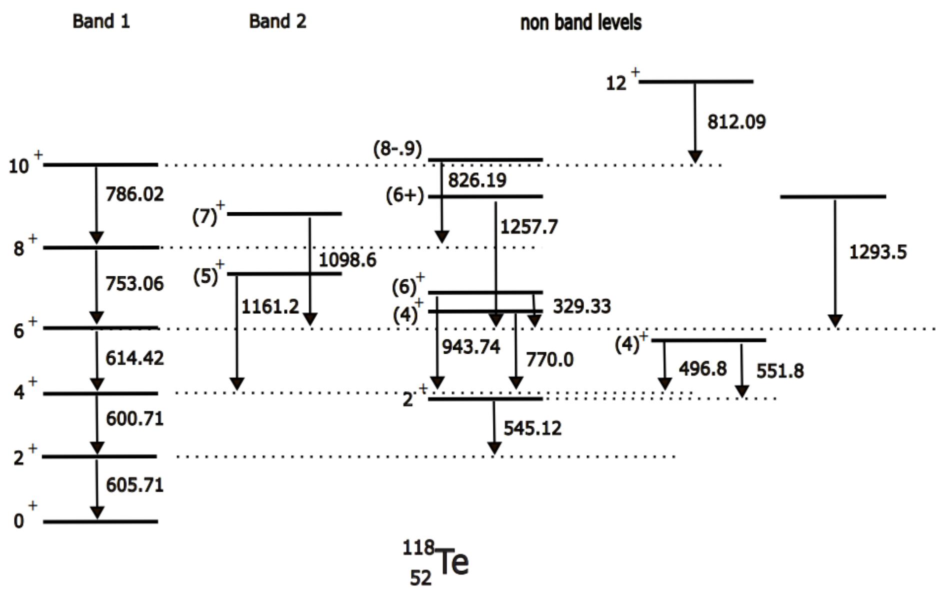

Figure 5. Observed level scheme from the analysis of ^{118}Te. All energy values are taken from the literature. [6]

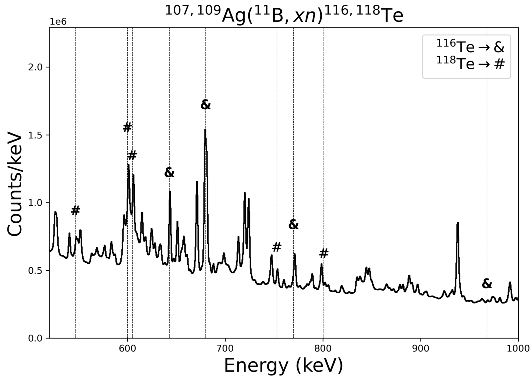

Figure 6. Identified peaks in the total projection of the γ - γ matrix. The gamma-rays from ^{116}Te and ^{118}Te are marked in the spectra.

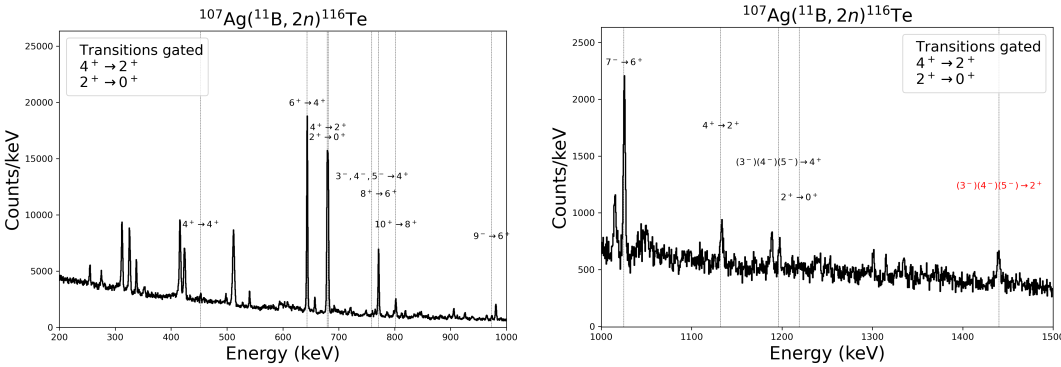

Figure 7. Coincidence spectra. The energy gate-condition was performed in the Eγ=678-681 keV region, including both the gamma-rays emitted by the $4_3^+ \longrightarrow 2_3^+$ and $2_3^+ \longrightarrow 0_3^+$ transitions from the ground state band of the ^{116}Te isotope. (Left): Energy region 200-1000 keV (Right) : Energy region 1000-1500 keV.

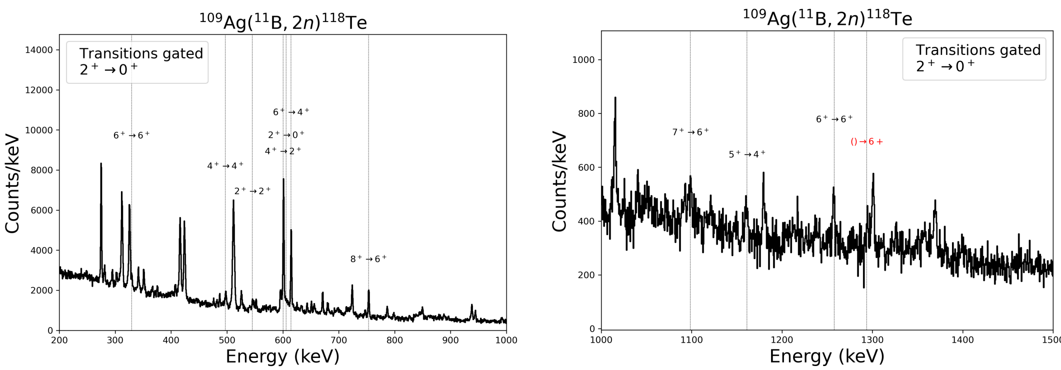

Figure 8. Coincidence spectra. The energy gate-condition was performed in the Eγ=604-606 keV region, including the gamma-rays emitted by the $2_1^+ \longrightarrow 0_1^+$ transitions from the Ground state band of the ^{118}Te isotope. (Left): Energy region 200-1000 keV (Right) : Energy region 1000-1500 keV

An interesting observation regarding the level scheme of the ^{116}Te shown in Figure 4 is the observation of the photopeak at E_γ = 1440 keV originating from the E_{level} = 2119 keV level (marked red in Figure 4). The spin of this specific state remains an open question. This transition was recently observed in an ^{116}Sn(^{12}C, ^{8}Be) measurement [7]. On the contrary the same transition was not observed in the ^{116}Sn(^{3}He, $3n$) measurement [8]. Further analysis is needed in order to measure the spin of that state which is noted as $(3^-), (4^-), (5^-)$ in the literature [6]. Another notable observation regarding the level scheme of the isotope ^{118}Te shown in Figure 5 is the observation of the non-band transition at gamma energy $E_\gamma = 1293.5$ (marked as red in Figure 5). According to the literature, the state from which this specific transition originates (E_{level} =3114.34 keV) has not been assigned a spin-parity. In conclusion this work is centered around the gamma ray spectroscopic analysis of the ^{116,118}Te isotopes. Through this analysis the level schemes in figures 5, 4 were recreated and the shape of the nuclei was determined. Furthermore, evidence pointing to the existence of the ^{116}Te isotope's $(3^-), (4^-), (5^-) \rightarrow 2^+$ transition (marked as red in Figure 4) was presented contributing to the open question regarding the spin parity of the $(3^-), (4^-), (5^-)$ state.

Acknowledgements

This project has received funding from the European Union's Horizon Europe Research and Innovation programme under Grant Agreement No 101057511 (EURO-LABS). PK was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)-539757749

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