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Decay pattern of the Pygmy Dipole Resonance in ^{130}Te

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Abstract. The electric dipole strength distribution in ^{130}Te has been investigated using the method of Nuclear Resonance Fluorescence. The experiments were performed at the Darmstadt High Intensity Photon Setup using bremsstrahlung as photon source and at the High Intensity $\vec{\gamma}$-Ray Source, where quasi-monochromatic and polarized photon beams are provided. Average decay properties of ^{130}Te below the neutron separation energy are determined. Comparing the experimental data to the predictions of the statistical model indicate, that nuclear structure effects play an important role even at sufficiently high excitation energies. Preliminary results will be presented.

1 Introduction

The isovector electric dipole strength ($E1$) in atomic nuclei has been investigated intensively in the last decades, especially in the region of the Giant Dipole Resonance (GDR) [1]. However, for many nuclei additional low-lying $E1$ strength below and in the vicinity of the particle separation energies have been observed, which is usually denoted as Pygmy Dipole Resonance (PDR) [2]. The properties of the PDR have been mostly studied in closed-shell nuclei, e.g. in the Z=50 and N=82 mass region [2]. To extend the systematic of the PDR to open-shell nuclei Nuclear Resonance Fluorescence (NRF) experiments at two facilities were used to investigate the electric dipole response in ^{130}Te.

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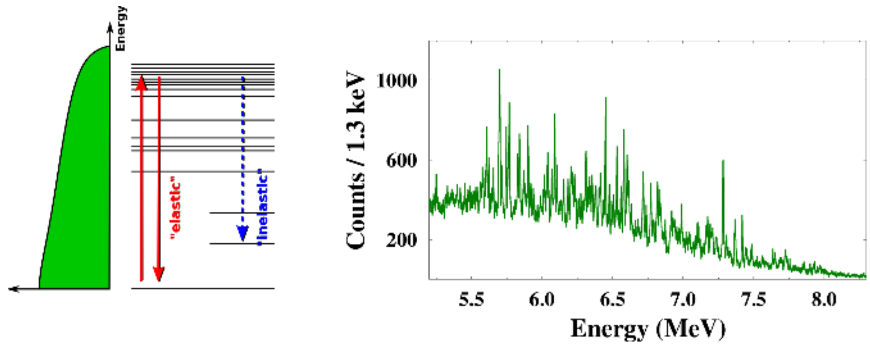

Figure 1. Left panel: Incoming spectral photon distribution and excitation scheme. The shown level scheme is just a random realization. Right panel: Spectrum of ^{130}Te measured at an endpoint energy of 8.5 MeV.

2 Experiments and preliminary results

The first experiment was performed at the Darmstadt High Intensity Photon Setup (DHIPS) [3] using continuous-energy bremsstrahlung. A large excitation-energy range reaching from hundreds of keV up to the endpoint energy of several MeV can be investigated simultaneously. The target of interest consisted of 1.988 g highly enriched (99.5 %) ^{130}Te in metallic form.

In Figure 1 a scheme of the spectral photon distribution together with an example of the excitation and de-excitation process is shown. NRF experiments are well suited for the investigation of dipole-excited states. In the spectrum for the endpoint energy of 8.5 MeV a high peak density corresponding to nuclear transitions was observed between 6 and 8 MeV (see Fig. 1).

The integrated scattering cross section $I_{s,0}$ for an individual excited state, that decays directly to the ground state, can be determined by analyzing the measured peak intensities A_{peak}: $A_{\text{peak}} \propto I_{s,0} \propto \Gamma_0 \cdot \frac{\Gamma_0}{\Gamma}$. To determine the absolute $E1$ and $M1$ transition strength, respectively, Γ_0 has to be extracted. If no branching transitions to other excited states are known or directly observed, $\Gamma_0/\Gamma \approx 1$ is assumed. For more details of the analysis see e.g. [4, 5]. However, this kind of experiment is not sensitive to the character of dipole transitions. Hence, an additional NRF experiment with quasi-monoenergetic and linearly polarized photons was performed at the High Intensity γ-Ray Source (HI$\vec{\gamma}$S) [6] at Triangle Universities Nuclear Laboratory, USA. Due to the linear polarization of the incoming photons it is possible to access parity information of the excited $J = 1$ states and hence one can distinguish between $E1$ and $M1$ strength [7]. Exemplarily, the spectral photon distribution is shown in Fig. 2.

By measuring the asymmetry $\epsilon = \frac{N_{\parallel}-N_{\perp}}{N_{\parallel}+N_{\perp}}$ of the resonantly scattered photons perpendicular ($N_{\perp}$) and parallel ($N_{\parallel}$) to the polarization plane (see Fig. 2), one can unambiguously assign parity quantum numbers to $J = 1$ states: In principal, the asymmetry is $\epsilon = +1$ and $\epsilon = -1$ for $J^{\pi} = 1^{+}$ and $J^{\pi} = 1^{-}$, respectively. Figure 3 shows preliminary results of both NRF experiments. In the left panel the $B(E1)$ strength is shown for the energy range from 3 MeV to 8.5 MeV, while in the right panel the asymmetries for all observed transitions in the measured energy range between 5.5 MeV and 8.5 MeV can be seen. The combination of both data sets reveals a strong accumulation of $E1$ strength in the energy range below the neutron separation threshold.

In addition, the mono-energetic character of the HI$\vec{\gamma}$S photons allows for investigating the average decay properties of the dipole-excited states as a function of the excitation energy [8]. To extract the total photoabsorption cross section $\sigma_{tot} = \sigma_{elast} + \sigma_{inelast}$, the contribution of photo-excited states which directly decay to the ground state (σ_{elast}) and from cascade transitions ($\sigma_{inelast}$) have to be

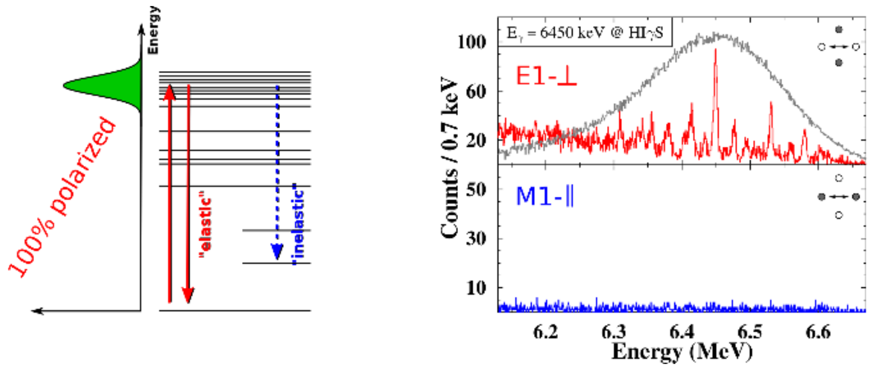

Figure 2. Left panel: Incoming spectral photon distribution and excitation scheme. Right panel: Exemplarily for all other measurements at HI$\vec{\gamma}$S, spectra of ^{130}Te using a photon beam with $E_\gamma = 6.45$ MeV. Spectra taken perpendicular (upper panel) and parallel (lower panel) to the polarization plane of the incoming photon beam.

determined, following the idea presented in Refs. [8–10]. Even though the incoming mono-energetic photon beam exclusively excites states in a narrow energy range ($\sim 10^2$ keV), the decays of the first few 2^+ excited states were observed. This indicates that these levels are populated via cascade transitions of the initially excited states. Their intensities are used to estimate $\sigma_{inelast} \approx \sum_i \sigma_{2_i^+}$ [8].

Results are shown on the left side of Fig. 4 together with data from a (γ, n) experiment [11]. The extrapolation of the GDR to energies below the neutron separation threshold underestimates the experimental values between 6.5 MeV and 8 MeV, while it seems to overestimate the absolute values for the region below 6.5 MeV. This type of additional $E1$ strength was observed in several other magic and off-shell nuclei so far [2].

An average ground state branching ratio $\langle b_0 \rangle = \sigma_{elast}/\sigma_{tot}$ has been determined from the HI$\vec{\gamma}$S measurement and is shown as a function of the excitation energy in Fig. 4. The results are compared to simulations within the statistical model using the DICEBOX code [12]. This code has two major input parameters: the Photon Strength Function (PSF) for the transitions involved and the level density

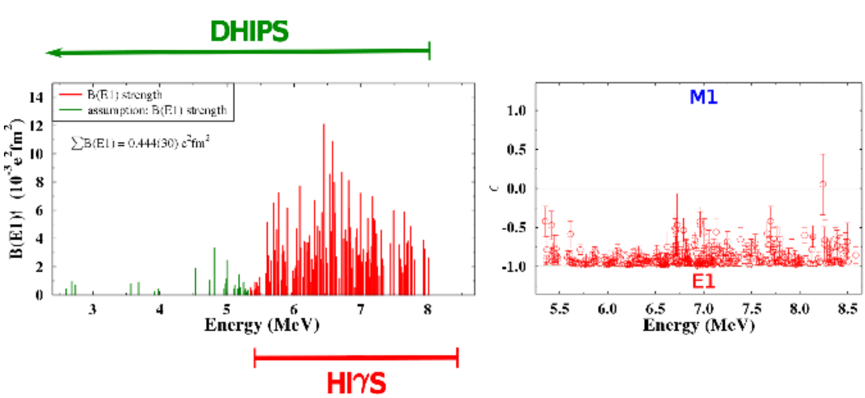

Figure 3. Left panel: $E1$ strength distribution for ^{130}Te up to the neutron separation energy. Right panel: Asymmetry of all observed transitions in the covered energy range from 5.5 to 8.5 MeV of the HI$\vec{\gamma}$S measurements.

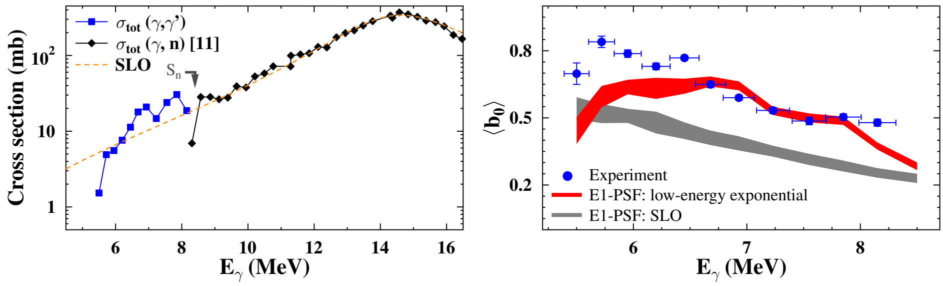

Figure 4. Left panel: Photoabsorption cross sections for the energy range from 5.5 MeV up to 16 MeV. For details see text. Right panel: Experimental $\langle b_0 \rangle$ (blue filled circles) compared to DICEBOX simulations.

for the nucleus of interest. For details of the used input parameters see Ref. [13]. Neither the variation of the parameters within their uncertainties nor the choice of one of the commonly used level density models [14] has a significant influence on the results below. The Single Particle approach was chosen for the $M1$-PSF. For the $E1$-PSF two models were tested. The first one is the Standard Lorentzian (SLO) model. However, this model is not able to describe the experimental results, which show much higher values for $\langle b_0 \rangle$ at all energies. This indicates a larger relative difference of the $E1$-PSF values at the excitation energy and the energy range below. Therefore, a second model using the experimental data points as input in combination with a very steep decrease of the $E1$-PSF to lower γ-ray energies was used. This model shows a better agreement at $E_\gamma > 6.5$ MeV. However, between 5.5 MeV and 6.5 MeV the absolute values for $\langle b_0 \rangle$ cannot be reproduced. This may indicate that the concept of the statistical model with the parameters used fails at the observed excitation energies. Nuclear structure effects seem to play an important role in this energy regime [10].

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