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Giant dipole resonance parameters of ground-state photoabsorption: Experimental values with uncertainties

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ABSTRACT

Updated values and corresponding uncertainties of Isovector Giant Dipole Resonance (GDR) parameters which are obtained by the least-squares fitting of theoretical photoabsorption cross sections to experimental data are presented. The theoretical photoabsorption cross sections are taken as a sum of the components corresponding to the excitation of the GDR and quasideuteron photodisintegration. The current compilation is an extension and improvement of the earlier compilations of Lorentzian parameters for ground-state photoneutron and photoabsorption cross sections and covers experimental data made available up to June 2017.

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Contents

1. Introduction and general description of the updates

Isovector Giant Dipole Resonances (GDR) are fundamental modes of nuclear collective excitations beyond the binding energy per nucleon. Nuclear collective states correspond to vibrations of the nucleons and are strongly manifested in electric dipole (E1) gamma-transitions which dominate over transitions of other monopole order when they occur simultaneously (see, for example, [1–3] for references). This allows us to obtain information on the GDR characteristics (i.e., resonance energy, width and contribution of the GDR to the energy-weighted sum rule (EWSR)) from investigations of the electromagnetic processes of photoabsorption and gamma-decay. However, E1 transitions are dominant near the maximum of the photoabsorption cross sections, but not at lower photon energies closer to the neutron binding energies. There, other physical phenomena like pygmy resonances [4] and scissors mode [5,6] need to be considered. Those low-energy collective phenomena have little impact on the nuclear GDR characteristics and are neglected in this work. It can be also noted that collective states like GDR have been extensively studied, both experimentally and theoretically, in atomic physics [7,8], metallic clusters [7,9,10], and quantum-dots [4,11].

A comprehensive experimental database with reliable data for the GDR parameters and their uncertainties is very important for the reliable modeling of E1 gamma-ray cascades in highly excited nuclei, for the study of nuclear reaction mechanisms as well as for verifying different theoretical approaches used to describe the GDR and other nuclear structure properties (deformations, contribution of velocity-dependent forces, shape-transitions, etc.), and forms an integral part of modern nuclear reaction computer codes, such as [12,13]. The experimental values of the GDR parameters in cold atomic nuclei are most reliably deduced from experimental photoabsorption cross sections. Compilations of the parameters of Lorentz curves fitted to the total photoneutron cross section data were presented in Refs. [14–16]. The data from Ref. [16] including GDR parameters for light nuclei ^{12}C, ^{14}N, ^{16}O, ^{27}Al and ^{28}Si were listed in the RIPL-1 database [1] as well as in the RIPL-3 [3] /gamma/gdr-parameters-exp.dat file. Assuming that the contribution of photoproton cross sections to the total photoabsorption cross section is small, then the Lorentzian parameters of the total photoneutron cross sections in spherical and axially deformed nuclei can be identified with the GDR parameters. However, note that this assumption is poor for light nuclei where photo-charged particle reactions are important.

Updated tables of GDR parameters with estimates of their uncertainties were subsequently given in Ref. [17]. In this compilation, the GDR parameters were treated as variables in the fitting of calculated total photoabsorption cross sections to the experimental data using the least-squares method.

Comprehensive databases of photonuclear reaction parameters are also published in Refs. [18,19]. The photoproton contribution was included in the database, but the parameters were obtained without performing any specific fit of an analytical function but were extracted directly by digitizing the characteristics of the experimental data peaks. Microscopic predictions of the GDR energies and widths for about 6000 nuclei between the proton and the neutron drip lines are given in the RIPL-3 database [3]. These GDR parameters resulted from a fit of microscopic calculations of the nuclear gamma-strength function to the existing experimental data [20,21]. The calculations were performed on the basis of the Hartree–Fock–BCS plus quasi-particle random-phase-approximation as well as the microscopic Hartree–Fock–Bogoliubov plus quasi-particle random phase approximation model with a realistic Skyrme interaction.

For heated atomic nuclei, the GDR parameters are determined by gamma-decay data. Compilation and parameterization of the GDR built on excited states are given in Refs. [22,23].

Tables of updated values of the GDR parameters with estimates of their uncertainties (one-sigma standard deviation) are given in this contribution. This work was performed within an IAEA Coordinated Research Project on Updating the Photonuclear Data Library and generating a Reference Database for Photon Strength Functions [24]. The presented database updates and extends the above-mentioned compilations for the GDR built on cold nuclear states. The parameters are calculated following the prescription of Ref. [17] by fitting Lorentz-like curves to photonuclear cross section data using the least-squares method. For experimental data, the total photoabsorption cross sections retrieved from the EXFOR database [25] or a combination of experimental partial cross sections best suited for approximating the total photoabsorption cross section are used. The evaluated data of [26,27] are also considered as experimental values. Parameters are given for 144 isotopes from ^{6}Li to ^{239}Pu atomic nuclei and for 19 elements of natural isotopic composition (in total 475 entries).

The updated values of the GDR parameters with their associated uncertainties (one-sigma standard deviation) are given in Tables 1 and 2. They were obtained by fitting the data with two different models of the GDR excitation: a Standard Lorentzian (SLO) model and a Simplified version of the Modified Lorentzian (SMLO) approach [2,3,17,28] (see below Eqs. (2)–(5)). The updated tables include the following improvements with respect to the previous results reported in Ref. [17]:

- GDR parameters were determined for 164 datasets, including the GDR parameters for 14 new isotopes and 13 natural elements, i.e. for ^{6}Li, ^{7}Li, ^{9}Be, ^{108}Pd, ^{112}Sn, ^{114}Sn, ^{122}Sn, ^{151}Eu, ^{152}Gd, ^{154}Gd, ^{158}Gd, ^{185}Re, ^{203}Tl, ^{205}Tl and for ^{nat}C, ^{nat}Mg, ^{nat}Cu, ^{nat}Rb, ^{nat}Sr, ^{nat}Pd, ^{nat}Ag, ^{nat}Cd, ^{nat}Sb, ^{nat}Ba, ^{nat}Re, ^{nat}Ir, ^{nat}U.
- GDR parameters were corrected for 23 datasets by revising the energy intervals of the fitting procedure.
- GDR parameters for 7 datasets, namely for isotopes ^{12}C, ^{15}N, ^{nat}Ar, ^{nat}Fe, ^{59}Co, ^{nat}Zr were excluded due to the poor quality of the fit of the experimental data.