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Photon strength functions and nuclear level densities: Recent developments in photonuclear reaction studies

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Photons provide a particularly clean probe for studying a wide range of nuclear structure phenomena [1]. Their interaction with the nucleus is described by the electromagnetic interaction, so that the nuclear response can be separated almost model-independently from the details of the reaction mechanism. Thus, photon-induced reactions are important tools in nuclear physics for determining the properties of low-spin excited states in atomic nuclei.

Important quantities for the modeling of nuclear and stellar reaction rates are photon strength functions (PSF) and nuclear level densities (NLD). Systematic studies of PSFs and NLDs across the nuclear chart are an important testing ground for benchmarking microscopic and macroscopic models, allowing extrapolation from mostly stable isotopes to experimentally unreachable exotic neutron-rich isotopes.

Many different experimental approaches and nuclear reactions are used to investigate PSFs, either by studying photoabsorption cross sections or by observing the γ-decay behaviour of excited nuclear states [2]. One advantage of photo-induced nuclear reactions is the selectivity towards nuclear levels with predominantly J=1 spin quantum numbers. Hence, in contrast to reactions with hadronic probes, the spin quantum numbers of the populated nuclear levels are explicitly known and well defined in scattering experiments with real photons. Using γ-γ coincidence spectroscopy following photoexcitations, PSFs can be determined in both the absorption and emission channels independently. This new experimental technique makes it possible to test the Brink-Axel hypothesis directly and model-independently over a wide excitation energy range in a single experiment [3].

In addition to the study of PSFs, the nuclear self-absorption method offers a completely new approach to the determination of NLDs of J=1 states in the energy range below the neutron separation energy. The idea of this measurement method is based on the fact that for a given excitation energy range the strength of nuclear self-absorption depends only on the number of nuclear levels present, i.e. NLD, and their strength distribution. This requires experimental conditions with intense photon beams, the possibility to vary the energy of the photon beams and very low background radiation. All these conditions are met by the use of quasi-monochromatic photon beams [4,5].

In this contribution, recent results for PSFs and a pilot experiment for the determination of NLDs conducted at the High Intensity γ-Ray Source [6] at Duke University are presented and discussed.

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