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The continuous-angle Doppler-shift attenuation method – sub-picosecond lifetime measurements with position-sensitive HPGe detector arrays

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The Doppler-shift attenuation method (DSAM) is a well-established technique for the determination of sub-picosecond nuclear level lifetimes. It is based on analyzing the characteristic shape of Doppler-broadened photo-peaks from nuclear transitions observed at specific observation angles in in-flight γ-ray spectroscopy experiments, when the de-excitation of a nuclear level occurs while the emitting nucleus is being decelerated in a thick target.
We have extended the method in order to exploit the possibilities arising from state-of-the-art position sensitive HPGe detector arrays by analyzing the Doppler-broadened peaks not only as a function of the Doppler-shifted γ-ray energy, but also as a continuous function of the polar angle of γ-ray detection with respect to the incident beam direction. This approach significantly boosts the sensitivity and applicability of the method. The corresponding two-dimensional fit algorithm in the energy – polar detection angle (E_γ, θ_γ) space is also applicable to conventional HPGe detector arrays without intrinsic position-sensitivity. We have furthermore extended this new technique to experiments with relativistic ion beams, where we analyze Doppler-corrected, two-dimensional γ-ray spectra in the (E_γ, θ_γ) space without stopping the beam ions in the target. This is especially useful for experiments with radioactive and/or cocktail beams, because it avoids the accumulation of radioactivity at the target position and makes ion identification behind the reaction target possible. With this "differential" DSAM technique, a second sensitivity region for level lifetimes in the range of 100ns arises from geometric effects.

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