Superconducting radiation detectors and nuclear clocks

Abstract:

The desire to build nuclear clocks with an unprecedented accuracy of 1 part in $10^{19}$ is currently driving the interest in accurate measurements of the first excited nuclear state in $^{229}$Th, which lies only $7.8 \pm 0.5$ eV above the ground state and thus in the range of tunable lasers. Superconducting tunnel junction (STJ) radiation detectors operated at temperatures of ~0.1K have an energy resolution of ~1 to 2 eV FWHM in this energy range, and we are using them to measure the decay energy of metastable $^{229m}$Th accurately. In this experiment, recoiling $^{229m}$Th ions from the alpha decay of $^{233}$U are embedded in the STJ detectors, and their subsequent decay into the ground state is expected to produce a signal at $7.8 \pm 0.5$ eV. We show that this approach works well to characterize the decay of metastable $^{235m}$U with a very high accuracy of ±0.018 eV. However, no signal from $^{229m}$Th has been observed so far. This can be explained by recent measurements of the $^{229m}$Th half-life of only $7 \pm 1$ μs.

This talk will discuss experiments with superconducting radiation detectors and the modifications required to measure the energy of metastable $^{229m}$Th with an accuracy of order 10 meV. This would enable the development of nuclear clocks based on the transition between $^{229}$Th and $^{229m}$Th. These clocks could be used to measure changes in the fine structure constant as postulated by certain grand unifying theories, or to measure gravity waves or dark matter objects such as topological defects.