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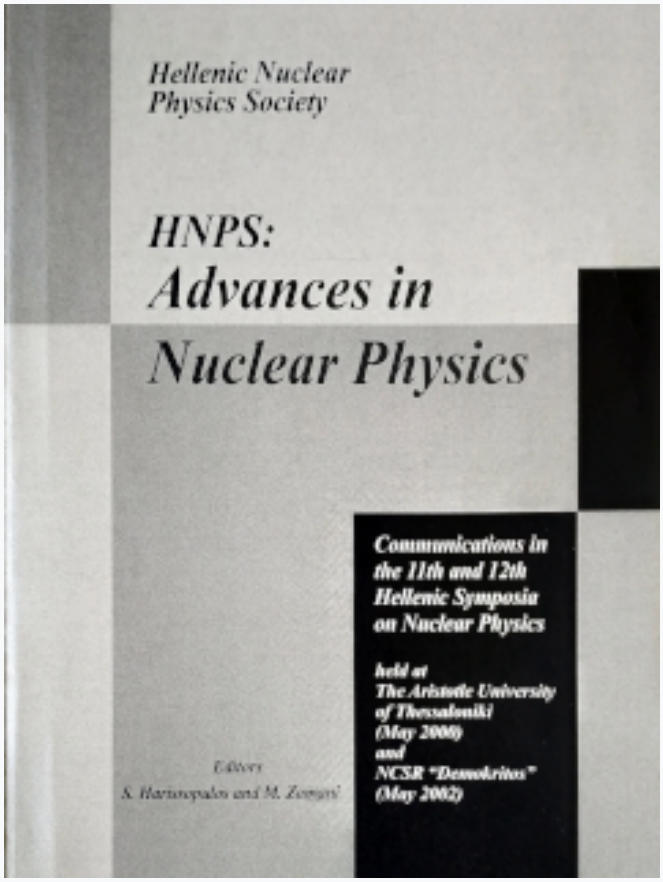

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Systematic study of the muon-nucleus overlap integrals for various processes in muonic atoms

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Abstract

As it is known, the bound muon of a muonic atom can participate in many electroweak processes as the allowed channels of the ordinary μ^--capture by the atomic nucleus, $\mu^- + (A, Z) \rightarrow (A, Z-1) + \nu_\mu$, and the muon decay in orbit, $\mu^- \rightarrow e^- + \nu_\mu + \bar{\nu}_e$, as well as the exotic channels of the muon-to-electron, $\mu^- + (A, Z) \rightarrow (A, Z)^* + e^-$, and muon-to-positron, $\mu^- + (A, Z) \rightarrow (A, Z-2) + e^+$, conversions. The latter reactions have not been seen by experiments up to now, but they are predicted by various extensions of the standard model (they violate the flavor and/or lepton quantum numbers).

For all the above muonic processes, the muon-nucleus overlap integrals are necessary in order to calculate the relevant rates. These integrals can be evaluated if, in addition to the nuclear states, the wave function of the bound muon (also that of the outgoing-lepton) are known. In the present work, we perform precise calculations of the muon (and electron/positron) wave functions for both the Schrödinger and Dirac equations. We use modern neural network techniques to overcome the difficulties arising from the finite size of the nucleon and nuclear Coulomb potential. As some applications, the obtained muon-nucleus integrals for various muonic atoms are going to be used for evaluating exclusive muon-capture rates and muon to electron/positron conversion branching ratios.