Relativistic Configuration-interaction Density Functional Theory: Triaxial Effects and Nuclear Matrix Elements for $\beta\beta$ Decay

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The relativistic configuration-interaction density functional theory is developed for even-even and odd-odd nuclei and is used to predict the nuclear matrix element of the neutrinoless $\beta\beta$ ($0\nu\beta\beta$) decay in triaxial nucleus ^{76}Ge. The triaxiality, which is crucial to the structural properties of ^{76}Ge and poses challenges in evaluating the nuclear matrix element, is incorporated within a full model space for the first time. With the consideration of triaxiality, the spectroscopic properties of the $\beta\beta$-decay partners ^{76}Ge and ^{76}Se, and the nuclear matrix element governing the two-neutrino $\beta\beta$ ($2\nu\beta\beta$) decay in ^{76}Ge are well reproduced, providing solid benchmarks for the theoretical calculations. The inclusion of the triaxial degree of freedom slightly enhances the nuclear matrix element of the $2\nu\beta\beta$ decay while raises that of the $0\nu\beta\beta$ decay significantly by a factor around two. The present results highlight the importance of nuclear triaxial deformation for a high-precision prediction of the $0\nu\beta\beta$-decay nuclear matrix element and indicate that the goals of next-generation experiments searching for the $0\nu\beta\beta$ decay in ^{76}Ge can be achieved using only a quarter of experimental materials.