Total reaction cross sections in the island of inversion near $N = 40$[†]

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A systematic analysis of the deformation phenomena of Ti, Cr, and Fe isotopes is performed to understand the nuclear structure in the "island of inversion"[1)] near the neutron number $N = 40$. As large nuclear deformations are expected in this mass region, we describe various nuclear deformations using the Skyrme-Hartree-Fock method in the three-dimensional coordinate space.[2)] A detailed analysis of the obtained nuclear structure information not only the quadrupole deformation but also the hexadecapole deformation increases significantly in the island of inversion. This is because of the excess neutrons occupying elongated intruder orbits. This characteristic is manifested as a change in the density distribution at the nuclear surface and can be observed as a significant increase in the total reaction cross section (σ_R).

Figure 1 plots the quadrupole (β_2) and hexadecapole (β_4) deformation parameters of Ti, Cr, and Fe isotopes as a function of the neutron number N. The results with two Skyrme density functionals, SkM*[3)] and SLy4,[4)] are shown. SkM* predicts large quadrupole deformation for $N > 34$, which is consistent with empirical $|\beta_2|$ values found in Ref. 5), while the SLy4 results show less deformed ground states for those isotopes. We find that the hexadecapole deformation also enhances for $N > 34$ with SkM* owing to the occupation of the $[nn_z\Lambda]\Omega = [330]1/2$ Nillson orbit, where the hexadecapole moment becomes the largest for the most prolately elongated orbitals among the orbits belonging to the same n, *i.e.*, for $n = n_z$ and $\Lambda = 0$.

These different deformations are well reflected in the density profiles near the nuclear surface and can be distinguished by total reaction or interaction cross section measurements. Figure 2 displays the calculated σ_R on a carbon target at 240 MeV/nucleon of these nuclei. The cross sections with SkM* are significantly larger than those obtained with SLy4 for N = 36–40, where the magnitudes of the nuclear deformations are quite different. The difference is at most approximately 2%, which is significant considering the precision of recent interaction cross section measurements was $\lesssim 1\%$.[6)] Such a systematic cross section measurement is desired to clarify the nuclear properties in the island of inversion near $N = 40$.

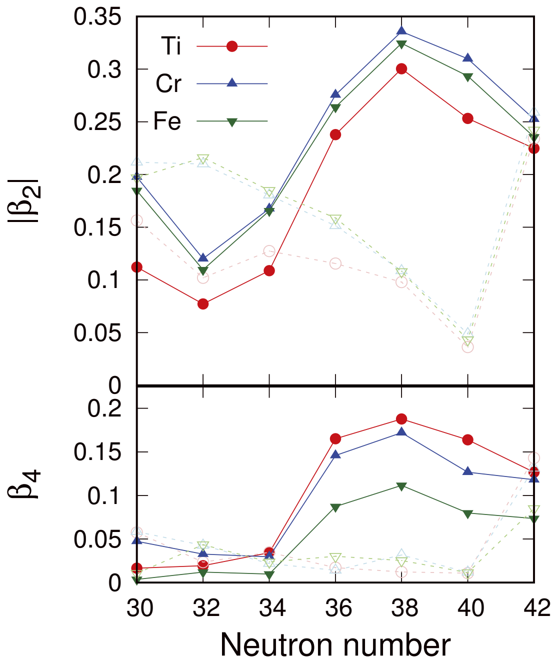

Fig. 1. Quadrupole (β_2) and hexadecapole (β_4) deformation parameters of Ti, Cr, and Fe isotopes calculated with SkM* (closed symbols with solid lines) and SLy4 (open symbols with dashed lines).

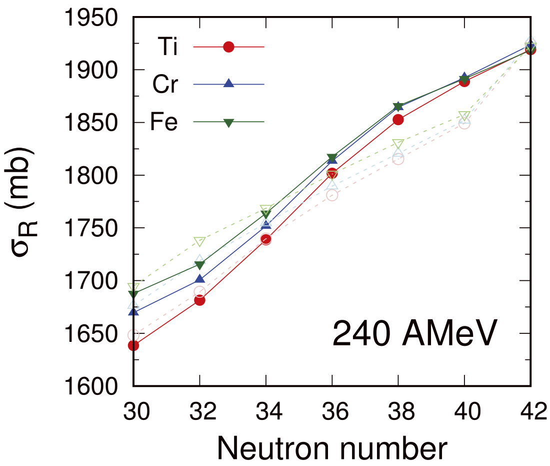

Fig. 2. Total reaction cross sections of Ti, Cr, and Fe isotopes calculated with SkM* (closed symbols with solid lines) and SLy4 (open symbols with dashed lines).

† Condensed from the article in Phys. Rev. C **105**, 014316 (2022)

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