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Quadrupole and Hexadecapole moments of ^{238}U, ^{232}Th from 65 MeV polarized proton inelastic scattering

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Differential cross sections and analyzing powers of polarized proton elastic and inelastic scattering from ^{238}U, ^{232}Th have been measured at 65 MeV, using high resolution spectrograph RAIDEN. The targets used were natural UO_2 and ThO_2 with nickel backing, prepared by the electrodeposition method[2] from inorganic solution. For ^{232}Th, aluminum backing targets prepared by the electrodeposition method from organic solution were also used especially at forward angle, where Ni elastic peak cannot be separated kinematically.

Complete separation of elastic and first 2^+ state peak, whose level spacing is only 45 KeV for ^{238}U, was expected to be difficult even with the use of RAIDEN. Therefore a new peak fit method was developed to keep the data quality as high as that of our previous data in rare earth region nuclei. The use of a new analytic peak function (asymmetric Gaussian shape with double exponential tails) and the constraint that the peak shape and the position of spin up spectrum should be equal to those of spin down, have made possible to separate those peaks unambiguously in reasonably good fits (χ^2 1.0 to 1.5). In Fig. 1, a typical result of the peak fit is shown. With the help of this peak fit method, the level of the data quality is successfully kept as high as previous one.

0^+ to 6^+ states of ground state rotational bands were analyzed using coupled-channel calculations and remarkably good fits have been obtained up to 6^+ state. The results of the coupled-channel calculation using automatic search code ECIS79 are shown in Fig. 2. Extracted Q_2(quadrupole), Q_4(hexadecapole), Q_6(hexacontatetrapole) moments are shown in Fig. 3 compared with those of the electron scattering data of MIT[7,8]. Fig. 5 shows that Q_2 moments of the real part of the deformed optical potential(DOP) are only 1.5 - 2.5% larger than those of charge distribution, whose differences are significantly smaller than those of our previous rare earth region nuclei(4-5% larger). According to Satchler's theorem, if DOP is obtained by folding local and density independent N-N effective interaction with target nucleon density, multipole moments of DOP should be equal to those of underlying matter density, independent of the shape of the effective interaction and the matter density. However, as a result of Brueckner-Hartree-Fock calculation, realistic effective N-N interaction is density dependent. Considering this effect which enlarges Q_2 of DOP about 4%[1], these results of this experiment suggest importance of other nonlocal effect of effective interaction.

To explain these new phenomena, a realistic folding calculation based on microscopically confirmed N-N interaction 'CEG' by Nagata et al.[3] was performed. This calculation shows that the effect of Coulomb potential through energy dependence of effective interaction (Coulomb correction) decreases each potential moment by 3% and for the Q_2 moments almost cancels out the effect of density dependence. In case of the rare earth region nuclei, this effect becomes relatively small because of the decrease of the target charge. Calculated deviations of DOP Q_2 moment from that of matter distribution is 1% for ^{238}U and 2.5% for ^{176}Yb. Although calculated Q_2 moments are slightly smaller, this trend is quite consistent with our data, and also consistent with 35 MeV proton inelastic scattering data by King et al.[4]. Fig. 4 shows calculated moments in several cases compared with those from our experiment.

For the Q_4 moments, those of DOP are larger by 15-18% than those of charge distribution. The effect of density dependence is at most 8%. Therefore different hexadecapole deformation between protons and neutrons is strongly expected. In ^{232}Th case, Hartree-Fock calculation[6,4] also predicts about 10% difference (see Fig. 3), which agrees well with the result of this experiment.

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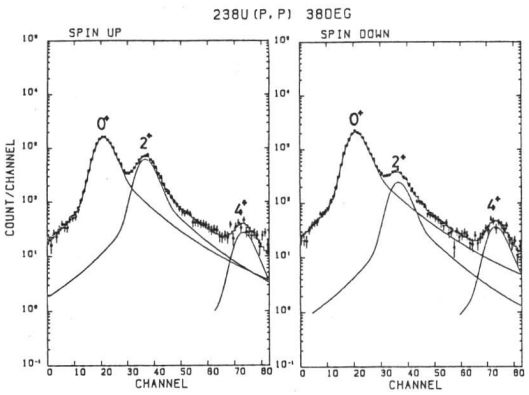

Fig. 1 Typical result of the peak fit. Spin up spectrum and spin down one are fitted simultaneously with same peak shape and position parameters.

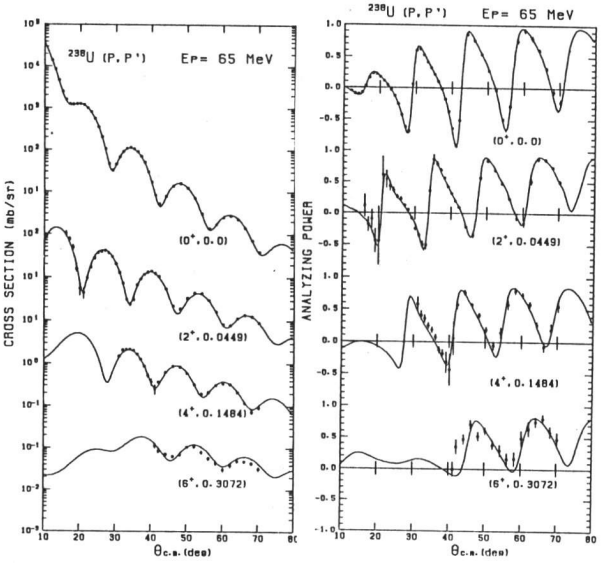

Fig. 2 Measured cross section, analyzing power and the result of the C.C. calculation of ^{238}U.

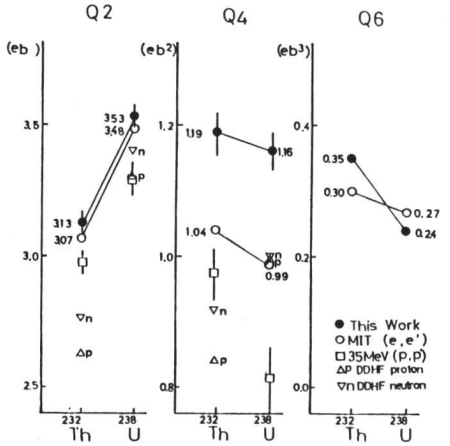

Fig. 3 Extracted multipole moments compared with other result. Electric multipole moments are from Ref. 7, 8. 35 MeV (p,p') are from Ref. 4. DDHF (density dependent Hartree-Fock) are from Ref. 6 and 4.

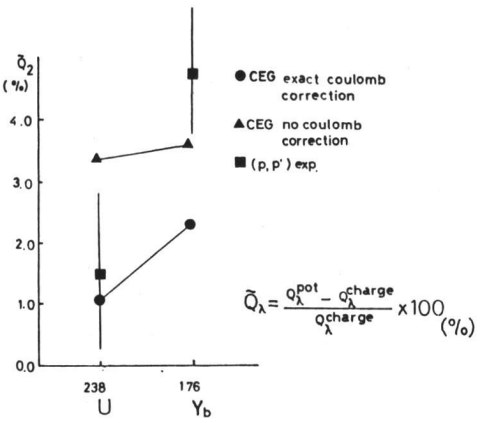

Fig. 4 Result of folding calculation using CEG compared with 65 MeV (p,p') data.

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