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TITLE

FISSION CROSS SECTION RATIOS FOR ^{233,234,236}U RELATIVE TO ^{235}U FROM 0.5 TO 400 MeV

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Fission Cross Section Ratios For ^{233,234,236}U Relative to ^{235}U From 0.5 to 400 MeV

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ABSTRACT: Neutron-induced fission cross section ratios from 0.5 to 400 MeV for samples of ^{233,234,236}U relative to ^{235}U have been measured at the WNR neutron Source at Los Alamos. The fission reaction rate was determined using a fast parallel plate ionization chamber at a 20-m flight path. Cross sections over most of the energy range were also extracted using the neutron fluence determined with three different proton telescope arrangements. Those data provided the shape of the ^{235}U(n,f) cross section relative to the hydrogen scattering cross section. That shape was then normalized to the very accurately known value for ^{235}U(n,f) at 14.1 MeV to allow us to obtain cross section section values from the ratio data and our values for ^{235}U(n,f).

Introduction

Neutron induced fission is quite possibly the most important nuclear reaction used by man in modern technology. Especially for ratio measurements to ^{235}U, the experimental techniques involved are relatively simple compared to most nuclear physics experiments; yet, there are substantial disagreements among published data. In the region above about 20 MeV, there is virtually no information at all, except for the work of this group. Because of the availability of the Los Alamos WNR neutron source [1], it is now possible to perform fission cross section measurements for multiple samples in a single experiment covering a broad energy range. The measurements that we are reporting here are part of a series designed to help resolve discrepancies for all of the long-lived actinides and to provide information about fission cross sections at energies above 20 MeV.

Experimental Procedure

The Los Alamos National Laboratory high-intensity source [1] uses 800 MeV pulsed proton beam from the Clinton P. Anderson Meson Physics Facility (LAMPF) incident on a 7.5-cm long, 3-cm diam tungsten target to produce a 'white' source of neutrons extending to hundreds of MeV. This experiment was performed using a 20-m flight path which viewed the neutron source at a production angle of 60^o. The proton beam consisted of 150 ps wide pulses separated by 3.6 μs with about $3x10^8$ protons in each pulse. The macroscopic duty factor of LAMPF gave a rate of about 8000 of these proton pulses/second.

The neutron beam was contained in an evacuated flight tube and passed through a 2.54 cm thick polyethylene (CH_2) filter to reduce frame overlap; a permanent magnet to sweep out charged particles; and a system of three iron collimators as shown in Ref. 2, giving a beam diameter of 12.7 cm at the fission sample location. Monte Carlo calculations performed to determine neutron inscattering from the collimators showed the amount to be less than 0.01% at 10 MeV.

The fission reaction rate was measured in a fast parallel plate ionization chamber holding multiple foils of oxide fission material 10.2 cm in diameter. In contrast to earlier fission-foil deposits which were vacuum deposited, these were electroplated onto 50 $\mu g/cm^2$-aluminum covered 127 μm thick stainless steel backings. The foils used in this measurement were added to the chamber used earlier[2,3] and additional statistics for ^{232}Th, ^{237}Np, ^{238}U, and ^{239}Pu fission ratios to ^{235}U were also taken. A ^{252}Cf deposit was included in the chamber to gain match pulse height spectra and for diagnostic purposes. Flight paths used for these results were obtained using ^{12}C neutron transmission resonances.

After passing through the fission chamber the neutron flux was determined using two detector systems. Although the setup for these fission measurements is similar to that described in [3], there are some differences: In our previous experiments, we were limited in energy range by kinematic resolution and by the thickness of the Si(Li) detector used in the Annular Proton Telescope (APT) for flux measurements. More importantly, the APT design made adding a second instrument downstream to cover a higher energy region impossible. We therefore replaced the APT with a low-energy telescope (LET) which covered the region from about 3 MeV up to 30 MeV using a single 0.5-cm thick Si(Li) detector. The LET employed a 2.54 x 10^{-4} cm thick CH_2 radiator located in an evacuated cylinder with an arm positioned in the vertical plane at an angle of 16.4^o to allow us to measure protons from H(n,p) scattering. We then installed a second flux measuring detector system, a medium-energy proton recoil telescope (MET), to cover the neutron energy range from about 26 MeV to 250 MeV. That device consisted of one 7.62-cm square x 0.16-cm thick plastic scintillator paddle, a second 7.62-cm square 0.64 cm thick paddle, and a 7.62 x 7.62 x 17.78 cm^3 CsI(Tl) total energy detector aligned at a scattering angle of 15^o relative to the incident neutron beam axis. Two thicknesses of carefully matched CH$_2$ and high-purity graphite targets were used in this system. The beam was then dumped in a concrete shield 15 meters from the MET. A measurement of the neutron fluence obtained using the ^{235}U(n,f) yield rate and the fission cross section results is shown in Ref 4, where the solid line is an intra-nuclear cascade calculation. These measurements agree with the fluence data up to 30 MeV previously obtained using the APT. Additional measurement details are available in another contribution to this conference [5].

An off-line analysis of the data was performed to subtract a small time-uncorrelated background, correct the fission rate spectra for the background resulting from high-energy (E_n > 35 MeV) neutron interactions in the steel backing and oxide content of the fission deposits, and to correct for neutron transmission through any upstream material in the chamber. The chamber was also disassembled and the fission foils were alpha counted to determine their thicknesses. The results of a mass spectroscopic analysis provided by ORNL was used to identify contaminant mass contributions in cases where individual alpha particle peaks could not be resolved. We measured fission cross section ratio data for all of the major actinide contaminants during this experiment and those data were used to correct the results shown here.

Results and Conclusions

Values of our fission cross section ratios in 3% energy bins are shown in Fig. 2 for ^{233}Th,^{234}U, and ^{236}U relative to ^{235}U. This is more than half of the total data taken. The solid lines show ENDF/B-V or, in the case of ^{236}U and ^{238}U, ENDF/B-VI ratios which for ^{234}U and ^{236}U have differences of about 2 - 4% from our new values. Also included in Fig. 1 is data for ^{238}U, obtained using this same apparatus and including data taken at the same time as these measurements and which seems to agree with ENDF/B-VI ratio within counting statistics. For ^{233}U, the ENDF/B-V ratio evaluation is about 4% lower than our results up to about 10 MeV and differs by as much as 15% above that. The data of Meadows [6] is about 2% lower than these results. In general, ^{234}U and ^{236}U show reasonable agreement with ENDF/B-V whereas ^{233}U has a larger than expected discrepancy.

Final analysis of all of the fission ratio data is nearly complete. Small corrections for fission fragment detection inefficiency still have to be applied to these data; those corrections are expected to have no effect in the ratio above about 30 MeV and be substantially below 1% at lower energies. We plan to use our ^{235}U(n,f) data to convert these ratio results to cross sections.

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Fig. 1. Fission cross section ratios for ^{233,234,236,238}U from the present measurement. The sollid line extending to 20 MeV is from ENDF/B=V for ^{233}U and ^{234}U and from ENDF/B-VI for ^{236}U and ^{238}U,