1 of 1

Conf-940507--5

LA-UR- 94-1377

Title: MEASUREMENT AND ANALYSIS OF THE NEUTRON-INDUCED FISSION CROSS SECTIONS OF ^{247}Cm, ^{250}Cf AND ^{254}Es

Author(s): Y. Danon, Rensselaer Polytechnic Institute

M.S.Moore and P.E. Koehler, LANL

R.W. Lougheed and R.W. Hoff, LLNL

N.W. Hill, ORNL

Submitted to: International Conference on Nuclear Data for Science and Technology
May 9-13, 1994
Gatlinburg, Tennessee

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Los Alamos
NATIONAL LABORATORY

MEASUREMENT AND ANALYSIS OF THE NEUTRON-INDUCED FISSION CROSS SECTIONS OF ^{247}Cm, ^{250}Cf AND ^{254}Es

Y. Danon
Rensselaer Polytechnic Institute, Department of Nuclear Engineering and Engineering Physic, Gaerttner Linac Laboratory, Troy, New York 12180-3590

M. S. Moore and P. E. Koehler
Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, New Mexico 87544

R. W. Lougheed and R. W. Hoff
Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, California 94550

N. W. Hill
Oak Ridge National Laboratory, P.O.Box 2008, Oak Ridge, Tennessee 37831

ABSTRACT

A series of fission cross section measurements were performed on ^{247}Cm, ^{250}Cf and ^{254}Es. This paper summarizes the most recent results and details the resonance parameter analysis done on ^{247}Cm.

I. INTRODUCTION

This paper presents results of three neutron induced fission cross section measurements of ^{247}Cm, ^{250}Cf and ^{254}Es. The first set of measurements was done at the RPI Intense Neutron Spectrometer[1] (RINS) in November 1989 as previously described by Danon et al.[2]. This was the first fission cross section measurement of ^{254}Es and ^{250}Cf in the energy range of 0.1 eV to 80 keV, and of ^{247}Cm below 20 eV. A most interesting result was the shape of the ^{254}Es fission cross section, it follows 1/v with a high thermal cross section (~ 2180 barns) and no distinct resonance structure resolved.

To obtain higher resolution information on ^{254}Es and assess the performance of a proposed lead spectrometer at the WNR/PSR, a second set of measurements was done at the Los Alamos Neutron Scattering Center (LANSCE) in July 1990.[3]. The fission chamber and samples used at RPI were also used in this experiment. The ^{254}Es ($t_{1/2}$=276 days) had decayed by almost one half life and only 0.117 μg were left. The decay product ^{250}Cf caused high spontaneous fission background which degraded the signal to background ratio. This experiment confirmed the results obtained at RPI, that is, no distinct resonance structure in ^{254}Es was observed.

The last set of measurements done was again at LANSCE in November 1992. This experiment used the same fission chamber as the previous LANSCE experiment but the einsteinium sample was replaced. About 0.2 μg of ^{254}Es were deposited and the ^{250}Cf spontaneous fission background was much lower (about 45 fissions/sec).

These data have been reduced to cross section and a multilevel R-Matrix resonance parameter fit to the fission cross section of ^{247}Cm was done in the energy range from 0.01 to 100 eV.

II. EXPERIMENTS and RESULTS

As described earlier by Moore et al.[3] the LANSCE has a slightly better neutron yield per pulse relative to the RINS. The RINS normally operates at a repetition rate of 90 Hz and the LANSCE operates at 20 Hz. This requires about four times longer at LANSCE to obtain the same statistical quality data as RINS. The main advantage of the LANSCE setup is the improved resolution at a 7.4 m flight path relative to the RINS which uses a lead slowing down spectrometer with a resolution of about 35%. Another advantage of LANSCE is the high thermal flux that allows measurements below 0.1 eV which is the practical resolution limit of the RINS.

The 1990 and 1992 LANSCE experiments were conducted in a similar setup except for different filling gas in the fission chamber. In 1992 the hemispherical fission chamber was filled with 1 atm of P-10 gas (Argon + 10% methane) instead of pure methane used in the 1990 experiment. This was done in order to reduce fission events caused by neutrons scattered off CH_4 molecules that were observed in the ^{247}Cm 1990 data. The chamber was positioned at a 7.4 m flight path distance, and about 50 hours of data were collected.

A. Californium 250

The 1990 LANSCE measurement was about two times longer than the 1992 one, and has superior data.

Both LANSCE runs and the RINS data show a resonance at 0.53 eV. Fig. 1 shows the RPI and 1990 LANSCE cross sections for the 0.53 eV resonance in ^{250}Cf. The resonance area of both experiments agrees within the experimental errors.

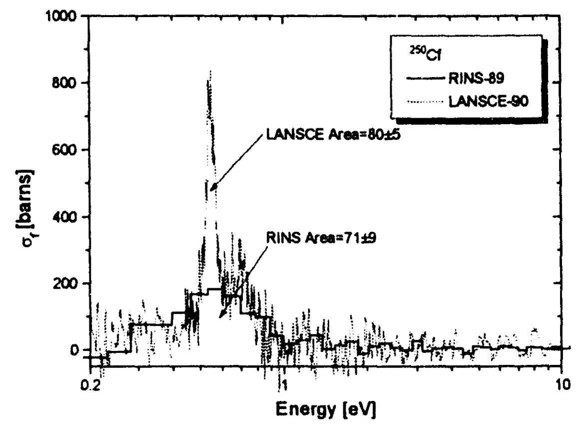

Fig. 1. Fission cross section of ^{250}Cf as determined at RINS (solid line) and LANSCE (dotted line).

B. Einsteinium 254

For the 1992 experiment a fresh ^{254}Es sample was deposited in the fission chamber. The sample contained 0.2 μg of ^{254}Es compared with the 0.139 μg used in the 1990 LANSCE experiment and 0.21 μg used in the RINS experiment. The spontaneous fission from the sample was 45 fission/sec. The cross section is plotted in Fig. 2. with the RINS data.

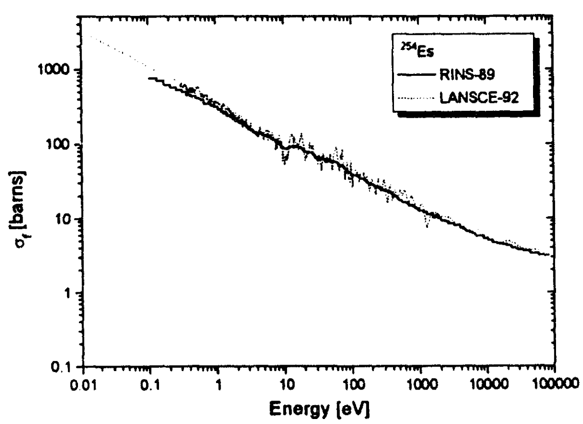

Fig. 2. The ^{254}Es fission cross section as measured at RINS (solid line) and as measured in LANSCE (dotted line).

The LANSCE data shows a higher cross section below 2 eV. The thermal cross section obtained from the LANSCE experiment is σ_f(0.0253 eV)=2180±50 barn, and the resonance integral is I_f=1010±80 barn. These values are higher than the RINS measurement and in better agreement with the Halperin et al.[4] experiment.

The LANSCE and RINS data show similar structure at ~ 10 eV, this is the only structure observed in ^{254}Es and might indicate that the fission widths are much wider than the average level spacing. A similar cross section shape has been reported[5] for the odd-odd nuclei ^{236}Np, but more structure was resolved around 2 eV and 10 eV.

C. Curium 247

The ^{247}Cm sample used in the 1992 LANSCE experiment was the same sample used at RPI and in the 1990 LANSCE experiment. The ^{247}Cm cross section was corrected for other curium isotopes in the sample and is plotted in Fig. 3 with the RINS data.

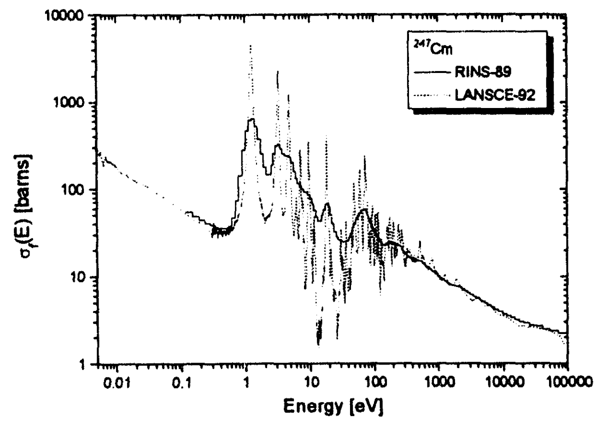

Fig. 3. Fission cross section of ^{247}Cm as measured at RINS (solid line) and at the LANSCE 1992 experiment (dotted line).

The ^{247}Cm fission cross section resonance parameters were obtained by fitting the observed data with the SAMMY code[6]. The data obtained by Moore and Keyworth[7] were also included, and analysis was done in the energy range 0.01 eV to 100 eV. The Moore and Keyworth experiment provided data from 20 eV to 100 eV and had been measured with a 250 m flight path. The LANSCE experiment was measured with 7.4 m flight path. This large difference in flight paths and neutron sources required knowledge of the resolution functions for both experiment. The ^{235}U data taken in both experiments were calculated with ENDF-VI parameters to fit the experimental resolution functions. The fitted resolution functions were then used in the SAMMY analysis. The higher energy range from 30 - 100 eV was fitted first and the obtained parameters and covariance matrix were used to fit the low data range. The statistical weight factor g was set to 0.5 for all resonances. The radiation width Γ_γ was held constant at 40 meV. The parameters were fitted with two partial fission widths. The total fission width is thus given by $\Gamma_f = \sqrt{(\Gamma_{f1}^2 + \Gamma_{f2}^2)}$. For the low-energy range the fission cross section and fit are plotted in Fig. 4 and the high-energy range is shown in fig. 5.

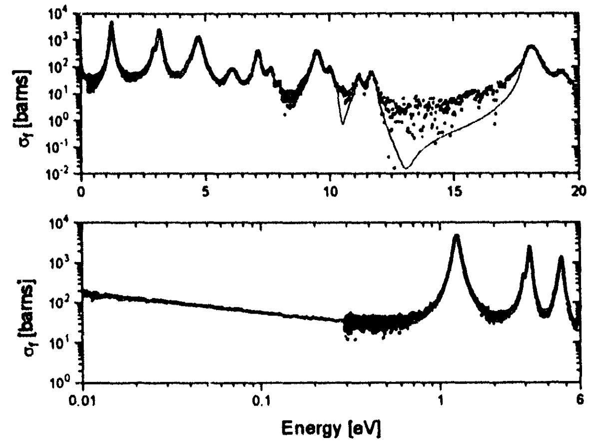

Fig. 4. The measured (scattered points) and fitted ^{247}Cm (smooth line) fission cross section in the low energy range.

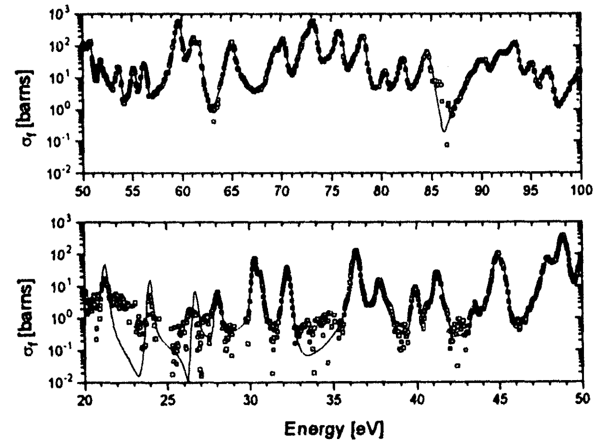

Fig. 5. The measured (scattered points) and fitted ^{247}Cm (smooth line) fission cross section in the high energy range.

The fitted resonance parameters below 22 eV are listed in Table-I. The neutron widths obtained are in good agreement with the results of Belanova et al.[8] except for the 1.23 eV resonance which is 63% higher. The obtained fission widths are higher than the widths reported in the RINS experiment. The latter were calculated from the RINS measured area and the total width measured by Belanova et al. The level average level spacing <*D*> was found to be 1.47±0.03 eV. The thermal fission cross section of ^{247}Cm was found to be 115±8 barns and the resonance integral is 1091±80 barn, which is in good agreement with the experimental value of Halperin et al[9].

TABLE I - Low energy ^{247}Cm resonance parameters.

E [eV]	Γ_γ [meV]	Γ_n [meV]	Γ_{f1} [meV]	Γ_{f2} [meV]
-0.88	40	0.078	-1.241	-40.546
1.23	40	0.917	42.144	-0.074
2.97	40	0.203	1.661	6.829
3.16	40	1.305	0.071	89.959
4.66	40	1.434	-257.670	0.708
6.04	40	0.115	2.899	210.730
7.11	40	0.555	1.967	-97.356
7.69	40	0.126	-0.792	118.770
7.94	40	0.704	0.018	0.932
9.44	40	0.896	55.853	149.900
10.16	40	0.137	-2.083	-215.950
11.19	40	0.110	-0.273	-96.922
11.67	40	0.184	140.970	0.038
18.03	40	3.772	296.810	-18.933
19.25	40	0.852	-908.550	0.158
21.24	40	0.273	-1.768	53.595

REFERENCES

1. R. E. Slovacek, D. S. Cramer, E. B. Bean, J. R. Valentine, R. W. Hockenbury and R. C. Block, *Nucl. Sci. Eng.*, **62** 455 (1977).
2. Y. Danon, R. E. Slovacek, R. C. Block, R. W. Lougheed, R. W. Hoff, M. S. Moore, *Nucl. Sci. Eng.*, **109**, 341-349, (1991).
3. M. S. Moore, P. E. Koehler, A. Michaudon, A Shelberg, Y. Danon, R. C. Block, R. E. Slovacek, R. W. Hoff, R. W. Lougheed, *AIP conf. Proc.* **238**, *Capt. Gamma ray spectroscopy, pasific grove, CA* , 253 (1990).
4. J. Halperin, G. D. O'Kelley, J. H. Oliver, J. E. Bigelow, and J. T. Wiggins, *Nucl. Sci. Eng.*, **90** 298 (1985)
5. G.V. Valskiy et al., *Proc. of the Int. Conf on Nuclear Data*, Kiev, **3**, 99-103, (1987)
6. N. Larson, ORNL/TM-9179/R2, Oak Ridge National Laboratory, (1989).
7. M. S. Moore and G. A. Keyworth, *Phys. Rev. C*, **3**, 1656 (1971).
8. T. S Belanova, A. G. Kolesov, A. V. Klinov, S. N. Nikol'skii, V. A. Poruchikov, V. N. Nefedov, V. S. Artamonov, R. N. Ivanov, and S. M. Kalebin, *Sov. At. Energy*, **47**, 772 (1979).
9. J. Halperin, J. H. Oliver, and P. W. Stoughton, *ORNL-4581, Oak Ridge National Laboratory* (1970)

DATE FILMED

6/14/94

END