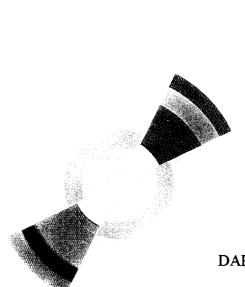


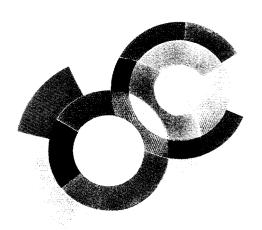






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MEASUREMENT OF THE NEUTRON TOTAL CROSS SECTION OF 99Tc IN THE ENERGY RANGE FROM 3 TO 600 eV

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Abstract

Within the framework of a collaboration between the Institute for Reference Materials and Measurements (IRMM) and the Commissariat à l'Energie Atomique (CEA), a project has been started to measure neutron cross sections for nuclear waste transmutation purposes. We describe the measurements of the total neutron cross section of ⁹⁹Tc, performed at the pulsed white neutron source Gelina of the IRMM. We used the time-of-flight method to obtain neutron spectra in the energy range from 3 to 600 eV. Preliminary results of 69 resonance parameters derived with the resonance shape fitting program Refit are presented here.

1 Introduction

The lack of reliable and sufficient data on neutron cross sections of long-living fission products and minor actinides is a major problem in the design of nuclear waste transmutation systems. Therefore in the past few years a renewed interest in neutron cross section measurements has arisen. One of the possible candidates for transmutation is 99 Tc. Several measurements of its resonance parameters have been performed in the past, see for example ref. [1, 2] and for a more complete evaluation ref. [3], but a demand for more precise parameters exists [4]. The resonance parameters of the $9/2^+$ nucleus 99 Tc may also contribute to the investigation of the neutron strength function in the mass A = 100 region, of interest for the development of nuclear models. Finally, a more detailed knowledge of the cross section of 99 Tc is also an important factor for nucleosynthesis models in astrophysics [5, 6].

2 Experimental Setup

The total cross section measurements of 99 Tc were performed at the pulsed neutron facility of the Geel Linear Electron Accelerator Gelina using the time-of-flight technique. Three 99 Tc samples with thicknesses of 0.16, 0.44 and 4.0 g/cm² have have been used for the transmission measurements. For the two smallest samples, the experiment was set up to cover the energy range from 3 to 600 eV, with the Geel linac operating to provide electron bursts of 100 MeV average energy and 15 ns width at a repetition frequency of 200 Hz and an average beam current of 20 μ A. For the thickest sample, intended for a measurement from 20 eV to 100 keV, the linac was functioning at 800 Hz with an average beam current of 60 μ A and a pulse width of 2 ns.

The neutrons produced via Bremsstrahlung by the electron beam hitting a rotating uranium target were moderated by two slabs of 4 cm thick water canned in beryllium. The partially moderated neutrons were collimated into the flight paths through evacuated aluminum pipes of 50 cm diameter with collimators consisting of either borated wax or copper. In order to absorb slow neutrons that otherwise overlap with the next machine cycle, a filter containing ¹⁰B was placed in the neutron beam.

At a distance of 23 m from the neutron source the 99 Tc sample was placed in a automatic sample changer, also containing isotopes with large resonances filtering the neutron flux at specific energies in order to determine the background. The sample changer was driven by the data acquisition system, allowing to store data with the sample in and out of the beam as well as background measurements. In order to diminish systematic errors these measurement sequences were recorded alternatively within a cycle of four sequences lasting about one hour in total. The neutrons passing through the sample were further collimated and detected by a NE912 lithium-glass detector placed at a distance of 49.33 m. The timing signals of the photomultiplier, detecting the scintillation of the glass due to the 6 Li(n, α) reaction, were electronically processed and converted to a neutron time-of-flight and then stored by the data acquisition system for further analysis.

3 Analysis and Results

Data have been recorded during 70, 150 and 450 hours of effective beam time for the samples of 0.16, 0.44 and 4.0 g/cm² thickness respectively. The background on the time-of-flight spectra was estimated by means of several "black" resonances and subtracted from the spectra corresponding to the sample in and out of the beam respectively. The transmission factor was derived as the ratio of these spectra, normalized by the ratio of the number of incoming neutrons. The in-house developed data processing package AGS [7] was used to apply the various spectrum manipulations as dead time correction and background fitting on the recorded histograms in order to obtain the transmission factor together with the components allowing to construct the full covariance matrix.

The neutron resonance shape fitting program REFIT [8] was used in order to fit the resonance parameters E_0 , the resonance energy, the radiative width Γ_{γ} and the neutron width Γ_n . Since the resonance spins are not known, in the table we rather give the statistical spin factor g multiplied by the neutron width Γ_n . The used spin values are also given assuming the orbital momentum $\ell = 0$. The energy scale was calibrated

Table 1: Preliminary parameters of 69 resonances of 99 Tc. The errors are only the standard deviations from the fit. For small resonances Γ_{γ} has been fixed at 200 meV.

(meV)	E_0		J	Γ_{γ}	40000	<u>Γ΄</u>		-C C /C
***14.596 ±0.027	(eV)		.,	(meV)	error %	$g\Gamma_n$ (meV)	error %	$g\Gamma_n\Gamma_\gamma/\Gamma$ (meV)
**14.596 ±0.027		±0.001	(5)					
20.274 ±0.009 (4) 150.3 0.6 3.795 0.4 3.594 *22.371 ±0.029 (4) 200.0 0.0052 9.8 0.005 39.841 ±0.001 (5) 136.9 1.2 0.580 0.4 0.575 56.677 ±0.001 (4) 154.6 1.0 1.703 0.4 1.662 *58.709 ±0.038 (4) 200.0 0.010 11.3 0.010 61.430 ±0.012 (5) 200.0 0.045 2.9 0.045 80.951 ±0.012 (4) 200.0 0.045 2.9 0.045 80.951 ±0.012 (4) 200.0 0.059 2.9 0.059 81.721 ±0.012 (4) 200.0 0.055 3.1 0.055 *102.832 ±0.059 (4) 200.0 0.020 12.3 0.020 *109.153 ±0.042 (4) 200.0 0.031 7.8 0.031 *111.218 ±0.001 (5) 150.2 1.2 5.348 0.4 5.023 *114.204 ±0.031 (5) 200.0 0.038 6.9 0.038 *123.775 ±0.001 (4) 170.2 1.5 1.829 0.3 1.787 *148.336 ±0.045 (5) 200.0 0.062 10.4 0.060 *161.289 ±0.053 (5) 200.0 0.062 10.4 0.060 *167.461 ±0.048 (4) 200.0 0.072 6.3 0.072 *177.461 ±0.048 (4) 200.0 0.072 6.3 0.072 *177.461 ±0.048 (4) 200.0 0.072 6.3 0.072 *191.721 ±0.001 (5) 183.7 1.0 29.563 0.5 22.871 *191.721 ±0.001 (4) 148.7 1.4 20.070 0.5 15.439 *196.330 ±0.023 (5) 200.0 0.040 0.145 4.0 0.145 *206.406 ±0.010 (4) 200.0 0.275 2.4 0.274 *225.982 ±0.032 (5) 200.0 0.275 2.4 0.274 *221.434 ±0.007 (4) 200.0 0.275 2.4 0.274 *221.434 ±0.008 (4) 200.0 0.354 2.7 0.228 *279.79 ±0.001 (5) 200.0 0.365 3.2 0.364 *271.444 ±0.018 (4) 200.0 0.365 3.2 0.364 *279.9984 ±0.001 (4) 217.0 1.5 15.660 0.3 13.496 *305.039 ±0.026 (5) 200.0 0.271 4.8 0.270 *331.38 ±0.048 (4) 200.0 0.365 3.2 0.364 *341.209 ±0.026 (5) 200.0 0.271 4.8 0.270 *335.032 ±0.025 (4) 200.0 0.628 2.8 0.664 *342.909 ±0.015 (5) 200.0 0.425 3.7 0.423 *356.932 ±0.052 (4	*14.596	± 0.027		200.0		0.0035	12.9	
*22.371 ±0.029 (4) 200.0 0.0052 9.8 0.005 39.841 ±0.001 (5) 136.9 1.2 0.580 0.4 0.575 56.677 ±0.001 (4) 154.6 1.0 1.703 0.4 1.662 *58.709 ±0.038 (4) 200.0 0.010 11.3 0.010 61.430 ±0.012 (5) 200.0 0.035 3.3 0.035 80.951 ±0.012 (5) 200.0 0.059 2.9 0.059 81.721 ±0.012 (4) 200.0 0.055 3.1 0.055 *102.832 ±0.059 (4) 200.0 0.031 7.8 0.031 *111.248 ±0.001 (5) 150.2 1.2 5.348 0.4 5.023 *114.204 ±0.031 (5) 200.0 0.038 6.9 0.038 *123.775 ±0.001 (4) 170.2 1.5 1.829 0.3 1.787	20.274	± 0.000		150.3	0.6	3.795		
39.841	*22.371	± 0.029		200.0		0.0052	9.8	
56.677 ±0.001 (4) 154.6 1.0 1.703 0.4 1.662 *58.709 ±0.038 (4) 200.0 0.010 11.3 0.010 61.430 ±0.012 (5) 200.0 0.035 3.3 0.035 67.651 ±0.012 (4) 200.0 0.059 2.9 0.059 80.951 ±0.012 (4) 200.0 0.059 2.9 0.059 *102.832 ±0.059 (4) 200.0 0.020 12.3 0.020 *109.153 ±0.042 (4) 200.0 0.031 7.8 0.031 *111.218 ±0.001 (5) 150.2 1.2 5.348 0.4 5.023 *114.204 ±0.031 (5) 200.0 0.038 6.9 0.038 123.775 ±0.001 (4) 170.2 1.5 1.829 0.3 1.787 148.336 ±0.045 (5) 200.0 0.062 10.4 0.062	39.841	± 0.001		136.9	1.2			
**58.709 ±0.038 (4) 200.0 0.010 11.3 0.010 61.430 ±0.012 (5) 200.0 0.035 3.3 3.3 0.035 67.651 ±0.012 (5) 200.0 0.045 2.9 0.045 80.951 ±0.012 (5) 200.0 0.059 2.9 0.059 81.721 ±0.012 (4) 200.0 0.055 3.1 0.055 102.832 ±0.059 (4) 200.0 0.020 12.3 0.020 109.153 ±0.042 (4) 200.0 0.031 7.8 0.031 111.218 ±0.001 (5) 150.2 1.2 5.348 0.4 5.023 111.218 ±0.001 (5) 150.2 1.2 5.348 0.4 5.023 1123.775 ±0.001 (4) 170.2 1.5 1.829 0.3 1.787 148.336 ±0.045 (5) 200.0 0.040 9.1 0.040 1161.289 ±0.053 (5) 200.0 0.040 9.1 0.040 1161.289 ±0.053 (5) 200.0 0.062 10.4 0.062 163.017 ±0.001 (5) 143.0 1.3 32.401 0.5 22.947 173.126 ±0.032 (4) 200.0 0.036 11.2 0.036 182.087 ±0.001 (5) 183.7 1.0 29.563 0.5 22.871 191.721 ±0.001 (4) 148.7 1.4 20.070 0.5 15.439 1196.330 ±0.023 (5) 200.0 0.032 1 1.9 0.320 209.941 ±0.014 (5) 200.0 0.321 1.9 0.320 209.941 ±0.014 (5) 200.0 0.0229 2.7 0.228 214.834 ±0.007 (4) 200.0 0.275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.0275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.0275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.0275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.0275 2.4 0.274 225.982 ±0.004 (5) 200.0 0.365 1.4 15.768 0.4 13.499 261.630 ±0.013 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.984 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 29.331.38 ±0.048 (4) 200.0 0.867 1.7 0.860 0.3 6.28 2.8 0.3 7.760 2.356.351 ±0.002 (4	56.677	± 0.001	(4)		1.0	1.703		
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80.951 ±0.012 (5) 200.0 0.059 2.9 0.059 81.721 ±0.012 (4) 200.0 0.055 3.1 0.055 3.1 0.055 102.832 ±0.059 (4) 200.0 0.020 12.3 0.020 109.153 ±0.042 (4) 200.0 0.031 7.8 0.031 111.218 ±0.001 (5) 150.2 1.2 5.348 0.4 5.033 114.204 ±0.031 (5) 200.0 0.038 6.9 0.038 123.775 ±0.001 (4) 170.2 1.5 1.829 0.3 1.787 148.336 ±0.045 (5) 200.0 0.040 9.1 0.040 161.289 ±0.053 (5) 200.0 0.062 10.4 0.062 163.017 ±0.001 (5) 143.0 1.3 32.401 0.5 22.947 173.126 ±0.032 (4) 200.0 0.072 6.3 0.072 6.3 0.072 177.461 ±0.048 (4) 200.0 0.036 11.2 0.036 182.087 ±0.001 (5) 183.7 1.0 29.563 0.5 22.871 191.721 ±0.001 (4) 148.7 1.4 20.070 0.5 15.439 196.330 ±0.023 (5) 200.0 0.029 2.7 0.228 214.834 ±0.001 (4) 200.0 0.229 2.7 0.228 214.834 ±0.001 (4) 200.0 0.229 2.7 0.228 214.834 ±0.001 (5) 200.0 0.275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.0275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.0275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.0275 2.4 0.274 227.9 ±0.001 (4) 200.0 0.036 1.2 0.036 1.2 0.036 1.2 0.036 241.212 ±0.001 (4) 200.0 0.036 1.2 0.546 1.2 0.543 220.604 ±0.013 (5) 200.0 0.275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.354 2.7 0.352 279.979 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 299.984 ±0.001 (4) 200.0 0.366 1.4 15.660 0.3 13.496 1.20 273.144 ±0.018 (4) 200.0 0.354 2.7 0.352 279.979 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 299.984 ±0.001 (4) 200.0 0.366 3.2 0.294 4.3 0.293 317.689 ±0.026 (5) 200.0 0.271 4.8 0.270 333.138 ±0.048 (4) 200.0 0.366 7.1 7 0.860 350.129 ±0.029 (5) 200.0 0.271 4.8 0.270 335.138 ±0.048 (4) 200.0 0.366 7.1 7 0.860 350.129 ±0.029 (5) 200.0 0.271 4.8 0.270 335.6032 ±0.052 (4) 200.0 0.425 3.7 0.423 356.032 ±0.052 (4) 200.0 0.425 3.7 0.423 356.032 ±0.052 (4) 200.0 0.628 2.8 0.624 364.940 ±0.001 (5) 282.1 1.7 66.275 0.6 46.439	67.651	± 0.010						
81.721 ±0.012 (4) 200.0 0.055 3.1 0.055 *102.832 ±0.059 (4) 200.0 0.020 12.3 0.020 *109.153 ±0.042 (4) 200.0 0.031 7.8 0.031 *111.218 ±0.001 (5) 150.2 1.2 5.348 0.4 5.023 *114.204 ±0.031 (5) 200.0 0.038 6.9 0.038 *133.775 ±0.001 (4) 170.2 1.5 1.829 0.3 1.737 *148.336 ±0.045 (5) 200.0 0.040 9.1 0.040 *161.289 ±0.053 (5) 200.0 0.062 10.4 0.062 *163.017 ±0.001 (5) 143.0 1.3 32.401 0.5 22.947 *173.126 ±0.032 (4) 200.0 0.036 11.2 0.036 *182.087 ±0.001 (5) 183.7 1.0 29.563 0.5 22.871 *191.721 ±0.001 (4) 148.7 1.4 20.070 0.5 15.439 *196.330 ±0.023 (5) 200.0 0.145 4.0 0.145 *206.406 ±0.010 (4) 200.0 0.321 1.9 0.320 *209.941 ±0.014 (5) 200.0 0.546 1.2 0.543 *220.604 ±0.013 (5) 200.0 0.546 1.2 0.543 *220.604 ±0.013 (5) 200.0 0.128 5.4 0.128 *241.212 ±0.001 (4) 208.5 1.4 15.768 0.4 13.499 *261.630 ±0.044 (5) 200.0 0.354 2.7 0.352 *279.979 ±0.001 (4) 217.0 1.5 15.660 0.3 13.496 *305.039 ±0.026 (4) 200.0 0.365 3.2 0.364 *279.984 ±0.001 (4) 200.0 0.365 3.2 0.364 *305.039 ±0.026 (4) 200.0 0.294 4.3 0.293 *306.811 ±0.002 (5) 200.0 0.271 4.8 0.270 *333.138 ±0.048 (4) 200.0 0.365 3.2 0.364 *324.609 ±0.026 (5) 200.0 0.271 4.8 0.270 *335.6032 ±0.052 (4) 200.0 0.425 3.7 0.423 *356.032 ±0.052 (4) 200.0 0.2425 3.7 0.423 *356.032 ±0.052 (4) 200.0 0.211 6.6 0.162 *362.158 ±0.018 (4) 200.0 0.628 2.8 0.624 *364.940 ±0.001 (5) 282.1 1.7 66.275 0.6 46.439 *364.940 ±0.001 (5) 282.1 1.7 66.275 0.6	80.951	± 0.012	(5)	200.0		0.059		
*102.832 ±0.059 (4) 200.0 0.020 12.3 0.020 *109.153 ±0.042 (4) 200.0 0.031 7.8 0.031 111.218 ±0.001 (5) 150.2 1.2 5.348 0.4 5.023 *114.204 ±0.031 (5) 200.0 0.038 6.9 0.038 123.775 ±0.001 (4) 170.2 1.5 1.829 0.3 1.787 148.336 ±0.045 (5) 200.0 0.062 10.4 0.062 163.017 ±0.001 (5) 143.0 1.3 32.401 0.5 22.947 173.126 ±0.032 (4) 200.0 0.062 10.4 0.062 163.017 ±0.001 (5) 143.0 1.3 32.401 0.5 22.947 173.126 ±0.032 (4) 200.0 0.072 6.3 0.072 *177.461 ±0.048 (4) 200.0 0.036 11.2 0.036 182.087 ±0.001 (5) 183.7 1.0 29.563 0.5 22.871 191.721 ±0.001 (4) 148.7 1.4 20.070 0.5 15.439 196.330 ±0.023 (5) 200.0 0.321 1.9 0.320 209.941 ±0.010 (4) 200.0 0.321 1.9 0.320 209.941 ±0.014 (5) 200.0 0.229 2.7 0.228 214.834 ±0.007 (4) 200.0 0.546 1.2 0.543 220.604 ±0.013 (5) 200.0 0.275 2.4 0.274 220.604 ±0.013 (5) 200.0 0.275 2.4 0.274 220.604 ±0.013 (5) 200.0 0.275 2.4 0.274 221.212 ±0.001 (4) 208.5 1.4 15.768 0.4 13.499 261.630 ±0.044 (5) 200.0 0.354 2.7 0.352 279.979 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 299.984 ±0.001 (4) 200.0 0.365 3.2 0.364 324.609 ±0.026 (5) 200.0 0.271 4.8 0.293 306.811 ±0.002 (5) 200.0 0.271 4.8 0.293 305.039 ±0.026 (4) 200.0 0.365 3.2 0.364 324.609 ±0.026 (5) 200.0 0.271 4.8 0.270 333.138 ±0.048 (4) 200.0 0.365 3.2 0.364 343.209 ±0.013 (5) 200.0 0.271 4.8 0.270 333.138 ±0.048 (4) 200.0 0.365 3.2 0.364 343.209 ±0.013 (5) 200.0 0.271 4.8 0.270 333.138 ±0.048 (4) 200.0 0.365 3.2 0.364 343.209 ±0.013 (5) 200.0 0.271 4.8 0.270 335.6032 ±0.026 (4) 200.0 0.628 2.8 0.624 364.940 ±0.018 (4) 200.0 0.628 2.8 0.624 364.940 ±0.010 (5) 282.1 1.7 66.275 0.6 46.439	81.721	± 0.012		200.0		0.055		
*109.153 ±0.042 (4) 200.0 0.031 7.8 0.031 11.1218 ±0.001 (5) 150.2 1.2 5.348 0.4 5.023 *114.204 ±0.031 (5) 200.0 0.038 6.9 0.038 123.775 ±0.001 (4) 170.2 1.5 1.829 0.3 1.737 148.336 ±0.045 (5) 200.0 0.062 10.4 0.062 163.017 ±0.001 (5) 143.0 1.3 32.401 0.5 22.947 173.126 ±0.032 (4) 200.0 0.072 6.3 0.072 *177.461 ±0.048 (4) 200.0 0.036 11.2 0.036 182.087 ±0.001 (5) 183.7 1.0 29.563 0.5 22.871 191.721 ±0.001 (4) 148.7 1.4 20.070 0.5 15.439 196.330 ±0.023 (5) 200.0 0.321 1.9 0.320 209.941 ±0.014 (5) 200.0 0.321 1.9 0.320 209.941 ±0.014 (5) 200.0 0.229 2.7 0.228 214.834 ±0.007 (4) 200.0 0.275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.128 5.4 0.128 241.212 ±0.001 (4) 208.5 1.4 15.768 0.4 13.499 261.630 ±0.044 (5) 200.0 0.354 2.7 0.352 279.979 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 299.984 ±0.001 (4) 217.0 1.5 15.660 0.3 13.496 *305.039 ±0.026 (5) 200.0 0.294 4.3 0.293 306.811 ±0.002 (5) 200.0 0.271 4.8 0.270 333.138 ±0.048 (4) 200.0 0.271 4.8 0.293 306.811 ±0.002 (5) 200.0 0.271 4.8 0.270 331.318 ±0.048 (4) 200.0 0.271 4.8 0.270 331.318 ±0.048 (4) 200.0 0.271 4.8 0.270 3356.032 ±0.026 (5) 200.0 0.275 3.7 0.423 *356.032 ±0.032 (5) 200.0 0.271 6.6 0.162 343.209 ±0.013 (5) 200.0 0.271 6.6 0.162 343.209 ±0.013 (5) 200.0 0.271 6.6 0.162 343.209 ±0.013 (5) 200.0 0.271 6.6 0.162 343.209 ±0.013 (5) 200.0 0.271 6.6 0.162 343.209 ±0.013 (5) 200.0 0.271 6.6 0.162 343.209 ±0.013 (5) 200.0 0.271 6.6 0.162 343.209 ±0.013 (5) 200.0 0.271 6.6 0.210 355.651 ±0.002 (4) 200.0 0.262 3.7 0.423 *356.032 ±0.052 (4) 200.0 0.271 6.6 0.210 358.651 ±0.002 (4) 200.0 0.271 6.6 0.210 358.651 ±0.002 (4) 200.0 0.271 6.6 0.210 358.651 ±0.002 (4) 200.0 0.271 6.6 0.210 356.2158 ±0.018 (4) 200.0 0.211 6.6 0.210 356.2158 ±0.018 (4) 200.0 0.211 6.6 0.220 362.258 ±0.018 (4) 200.0 0.228 364.940 ±0.001 (5) 282.1 1.7 66.275 0.6 46.439 364.940 ±0.001 (5) 282.1 1.7 66.275 0.6 46.439 364.940 ±0.001 (5) 282.1 1.7 66.275 0.6 46.439 364.940 ±0.001 (5) 282.1 1.7 66.275 0.6 46.439 364	*102.832	± 0.059	(4)	200.0		0.020		
111.218	*109.153		(4)	200.0		0.031	7.8	0.031
*114.204 ±0.031 (5) 200.0 0.038 6.9 0.038 123.775 ±0.001 (4) 170.2 1.5 1.829 0.3 1.787 148.336 ±0.045 (5) 200.0 0.040 9.1 0.040 161.289 ±0.053 (5) 200.0 0.062 10.4 0.062 163.017 ±0.001 (5) 143.0 1.3 32.401 0.5 22.947 173.126 ±0.032 (4) 200.0 0.072 6.3 0.072 177.461 ±0.048 (4) 200.0 0.036 11.2 0.036 182.087 ±0.001 (5) 183.7 1.0 29.563 0.5 22.871 191.721 ±0.001 (4) 148.7 1.4 20.070 0.5 15.439 196.330 ±0.023 (5) 200.0 0.145 4.0 0.145 200.406 ±0.010 (4) 200.0 0.321 1.9 0.320 209.941 ±0.014 (5) 200.0 0.229 2.7 0.228 214.834 ±0.007 (4) 200.0 0.546 1.2 0.543 220.604 ±0.013 (5) 200.0 0.275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.128 5.4 0.128 241.212 ±0.001 (4) 208.5 1.4 15.768 0.4 13.499 261.630 ±0.044 (5) 200.0 0.354 2.7 0.352 279.979 ±0.001 (5) 210.0 1.9 6.694 0.3 13.496 1.20 273.144 ±0.018 (4) 200.0 0.354 2.7 0.352 279.979 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 299.984 ±0.001 (4) 217.0 1.5 15.660 0.3 13.496 306.811 ±0.002 (5) 200.0 0.271 4.8 0.293 306.811 ±0.002 (5) 200.0 0.271 4.8 0.293 306.811 ±0.002 (5) 200.0 0.271 4.8 0.293 306.811 ±0.002 (5) 200.0 0.271 4.8 0.293 333.138 ±0.048 (4) 200.0 0.365 3.2 0.364 324.609 ±0.026 (5) 200.0 0.271 4.8 0.270 333.138 ±0.048 (4) 200.0 0.365 3.2 0.364 324.609 ±0.026 (5) 200.0 0.271 4.8 0.270 333.138 ±0.048 (4) 200.0 0.6867 1.7 0.860 350.129 ±0.029 (5) 200.0 0.271 4.8 0.270 333.138 ±0.048 (4) 200.0 0.662 3.8 0.201 (4) 200.0 0.662 3.7 0.423 356.032 ±0.052 (4) 200.0 0.662 3.8 0.201 (4) 200.0 0.662 3.7 0.423 356.032 ±0.052 (4) 200.0 0.662 3.8 0.3 7.660 350.129 ±0.029 (5) 200.0 0.271 4.8 0.270 335.651 ±0.002 (4) 191.5 2.9 8.528 0.3 7.660 362.4 364.940 ±0.001 (5) 282.1 1.7 66.275 0.6 46.439	111.218	± 0.001	(5)	150.2	1.2		0.4	
123.775	*114.204	± 0.031	(5)	200.0		0.038	6.9	
148.336 ±0.045 (5) 200.0 0.040 9.1 0.040 *161.289 ±0.053 (5) 200.0 0.062 10.4 0.062 163.017 ±0.001 (5) 143.0 1.3 32.401 0.5 22.947 173.126 ±0.032 (4) 200.0 0.036 11.2 0.036 182.087 ±0.001 (5) 183.7 1.0 29.563 0.5 22.871 191.721 ±0.001 (4) 148.7 1.4 20.070 0.5 15.439 196.330 ±0.023 (5) 200.0 0.145 4.0 0.145 206.406 ±0.010 (4) 200.0 0.321 1.9 0.320 209.941 ±0.014 (5) 200.0 0.229 2.7 0.228 214.834 ±0.007 (4) 200.0 0.546 1.2 0.543 225.982 ±0.032 (5) 200.0 0.128 5.4 0.128	123.775	± 0.001	(4)	170.2	1.5	1.829	0.3	1.787
*161.289 ±0.053 (5) 200.0 0.062 10.4 0.062 163.017 ±0.001 (5) 143.0 1.3 32.401 0.5 22.947 173.126 ±0.032 (4) 200.0 0.072 6.3 0.072 *177.461 ±0.048 (4) 200.0 0.036 11.2 0.036 182.087 ±0.001 (5) 183.7 1.0 29.563 0.5 22.871 191.721 ±0.001 (4) 148.7 1.4 20.070 0.5 15.439 196.330 ±0.023 (5) 200.0 0.145 4.0 0.145 206.406 ±0.010 (4) 200.0 0.321 1.9 0.320 209.941 ±0.014 (5) 200.0 0.229 2.7 0.228 214.834 ±0.007 (4) 200.0 0.546 1.2 0.543 220.604 ±0.013 (5) 200.0 0.275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.128 5.4 0.128 241.212 ±0.001 (4) 208.5 1.4 15.768 0.4 13.499 261.630 ±0.044 (5) 200.0 0.354 2.7 0.352 279.979 ±0.001 (5) 210.0 1.9 6.894 0.3 6.327 299.984 ±0.001 (4) 217.0 1.5 15.660 0.3 13.496 *305.039 ±0.026 (4) 200.0 0.294 4.3 0.293 306.811 ±0.002 (5) 200.0 0.294 4.3 0.29	148.336	± 0.045		200.0		0.040	9.1	0.040
163.017	*161.289	± 0.053						
173.126 ±0.032 (4) 200.0 0.072 6.3 0.072 *177.461 ±0.048 (4) 200.0 0.036 11.2 0.036 182.087 ±0.001 (5) 183.7 1.0 29.563 0.5 22.871 191.721 ±0.001 (4) 148.7 1.4 20.070 0.5 15.439 196.330 ±0.023 (5) 200.0 0.145 4.0 0.145 206.406 ±0.010 (4) 200.0 0.321 1.9 0.320 209.941 ±0.014 (5) 200.0 0.229 2.7 0.228 214.834 ±0.007 (4) 200.0 0.546 1.2 0.543 220.604 ±0.013 (5) 200.0 0.275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.128 5.4 0.128 241.212 ±0.001 (4) 208.5 1.4 15.768 0.4 13.499 261.630 ±0.044 (5) 200.0 0.354 2.7 0.352	163.017	± 0.001		143.0	1.3	32.401	0.5	
*177.461 ±0.048 (4) 200.0 0.036 11.2 0.036 182.087 ±0.001 (5) 183.7 1.0 29.563 0.5 22.871 191.721 ±0.001 (4) 148.7 1.4 20.070 0.5 15.439 196.330 ±0.023 (5) 200.0 0.145 4.0 0.145 206.406 ±0.010 (4) 200.0 0.321 1.9 0.320 209.941 ±0.014 (5) 200.0 0.229 2.7 0.228 214.834 ±0.007 (4) 200.0 0.546 1.2 0.543 220.604 ±0.013 (5) 200.0 0.275 2.4 0.274 225.982 ±0.032 (5) 200.0 0.128 5.4 0.128 241.212 ±0.001 (4) 208.5 1.4 15.768 0.4 13.499 261.630 ±0.044 (5) 200.0 0.354 2.7 0.352 279.979 ±0.001 (4) 200.0 0.354 2.7 0.352 279.979 ±0.001 (5) 210.0 1.9 6.694 0.3 6.327 299.984 ±0.001 (4) 217.0 1.5 15.660 0.3 13.496 305.039 ±0.026 (4) 200.0 0.294 4.3 0.293 306.811 ±0.002 (5) 200.0 0.271 4.8 0.270 333.138 ±0.048 (4) 200.0 0.365 3.2 0.364 324.609 ±0.026 (5) 200.0 0.271 4.8 0.270 333.138 ±0.048 (4) 200.0 0.271 4.8 0.270 333.138 ±0.048 (4) 200.0 0.271 4.8 0.270 335.039 ±0.026 (5) 200.0 0.271 4.8 0.270 335.039 ±0.026 (5) 200.0 0.271 4.8 0.270 333.138 ±0.048 (4) 200.0 0.271 4.8 0.270 333.138 ±0.048 (4) 200.0 0.265 3.2 0.364 324.609 ±0.026 (5) 200.0 0.271 4.8 0.270 335.039 ±0.026 (5) 200.0 0.271 4.8 0.270 335.039 ±0.026 (5) 200.0 0.271 4.8 0.270 335.039 ±0.026 (5) 200.0 0.271 4.8 0.270 335.039 ±0.026 (5) 200.0 0.271 4.8 0.270 335.039 ±0.026 (5) 200.0 0.271 4.8 0.270 335.039 ±0.026 (5) 200.0 0.271 4.8 0.270 335.603 ±0.052 (4) 200.0 0.265 3.7 0.423 356.032 ±0.052 (4) 200.0 0.265 3.7 0.423 356.032 ±0.052 (4) 200.0 0.265 3.7 0.423 356.032 ±0.052 (4) 200.0 0.265 3.7 0.423 356.032 ±0.052 (4) 200.0 0.268 2.8 0.624 364.940 ±0.001 (5) 282.1 1.7 66.275 0.6 46.439		± 0.032	(4)	200.0				
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	*177.461	± 0.048		200.0		0.036	11.2	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	182.087	± 0.001		183.7	1.0	29.563	0.5	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	191.721	± 0.001	(4)					
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	196.330	± 0.023	(5)					
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	206.406	± 0.010	(4)	200.0		0.321	1.9	0.320
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	209.941	± 0.014		200.0		0.229		
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	214.834	± 0.007		200.0		0.546	1.2	0.543
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	220.604	± 0.013						
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	225.982	± 0.032		200.0		0.128		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	241.212	± 0.001		208.5	1.4	15.768	0.4	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	261.630	± 0.044		200.0			6.8	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	273.144	± 0.018		200.0		0.354	2.7	0.352
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	279.979	± 0.001		210.0	1.9	6.694	0.3	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	299.984	± 0.001	(4)	217.0	1.5	15.660	0.3	13.496
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	*305.039	± 0.026		200.0		0.294	4.3	0.293
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	306.811	± 0.002		200.0			0.3	7.292
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	317.689	± 0.021		200.0		0.365	3.2	0.364
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	324.609	± 0.026	(5)	200.0		0.271	4.8	0.270
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	333.138	± 0.048	(4)	200.0		0.162	6.6	0.162
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		± 0.013	(5)	200.0		0.867	1.7	0.860
358.651 ± 0.002 $\langle 4 \rangle$ 191.5 2.9 8.528 0.3 7.760 362.158 ± 0.018 $\langle 4 \rangle$ 200.0 0.628 2.8 0.624 364.940 ± 0.001 $\langle 5 \rangle$ 282.1 1.7 66.275 0.6 46.439		± 0.029	(5)	200.0		0.425	3.7	0.423
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	*356.032	± 0.052	(4)	200.0		0.211	6.6	0.210
$364.940 \pm 0.001 \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ $		± 0.002	(4)	191.5	2.9	8.528	0.3	7.760
$364.940 \pm 0.001 \langle 5 \rangle$ 282.1 1.7 66.275 0.6 46.439	*362.158		(4)			0.628	2.8	0.624
			(5)					
373.000 ±0.002 (4) 233.4 2.2 11.402 0.3 10.342	379.856	± 0.002	(4)	235.4	2.2	11.462	0.3	10.342
$386.086 \pm 0.032 \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \$	386.086	± 0.032	(5)	200.0		0.385	4.4	0.383
$398.104 \pm 0.118 \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ $	398.104	± 0.118	(4)	200.0		0.176	9.5	0.176
*402.710 ±0.108 (5) 200.0 0.144 12.5 0.144	*402.710	± 0.108	(5)	200.0		0.144	12.5	0.144
*412.916 ±0.033 (5) 200.0 0.417 5.0 0.415	*412.916	± 0.033	(5)	200.0		0.417	5.0	0.415
$416.817 \pm 0.001 \mid \langle 5 \rangle$ 242.8 1.4 26.912 0.4 22.398	416.817	± 0.001	(5)	242.8		26.912	0.4	22.398
426.552 ± 0.001 $\langle 4 \rangle$ 210.5 2.0 31.739 0.5 23.773	426.552		(4)	210.5	2.0			23.773
$439.710 \pm 0.107 \mid \langle 5 \rangle$ 200.0 0.150 14.7 0.150	439.710		(5)	200.0				0.150
447.713 ± 0.008 (5) 200.0 1.211 1.9 1.198	447.713	± 0.008	(5)	200.0				1.198
459.917 ± 0.002 $\langle 4 \rangle$ 226.5 2.2 18.144 0.3 15.402	459.917		(4)	226.5	2.2	18.144		15.402
465.465 ± 0.035 $\langle 5 \rangle$ 200.0 0.543 4.3 0.541	465.465		(5)	200.0			4.3	0.541
$478.789 \pm 0.005 \mid \langle 4 \rangle$ 266.4 4.9 5.904 0.7 5.627	478.789	± 0.005	(4)	266.4	4.9		0.7	5.627
$486.585 \pm 0.008 \left \langle 5 \rangle \right 200.0$ 2.900 1.0 2.826	486.585	± 0.008	(5)	200.0		2.900	0.1	2.826
							·	

E ₀ (eV)		J	Γ _γ (meV)	error %	gΓ _n (meV)	error %	$g\Gamma_n\Gamma_\gamma/\Gamma$ (meV)
							` <u>*</u>
507.616	± 0.087	(4)	200.0		0.270	9.8	0.269
516.443	± 0.005	(5)	253.1	6.0	5.946	0.8	5.702
520.570	± 0.002	(4)	249.7	2.7	16.187	0.4	14.148
527.397	± 0.035	(5)	200.0		0.814	3.7	0.808
536.615	± 0.003	(4)	287.8	2.7	13.869	0.4	12.527
563.237	± 0.007	(5)	200.0		4.414	0.8	4.243
*567.037	± 0.050	(5)	200.0		0.697	5.0	0.692
*588.720	± 0.117	(5)	200.0		0.276	12.1	0.275
593.729	± 0.013	$\langle 4 \rangle$	200.0		2.629	1.4	2.555
598.261	± 0.003	(5)	458.9	2.1	16.489	0.4	15.478
606.769	± 0.003	(4)	263.5	3.2	16.929	0.4	14.814

using the well studied resonances of ²³⁸U. The time resolution of the spectrometer was represented by an optimized resolution function for the used flight path.

We used the input data only with their uncorrelated uncertainties in accordance with the possibilities of REFIT. The errors on the resonance parameters are the standard deviations resulting from the fit. Correlated or "systematic" uncertainties are under study. Where possible, a simultaneous fit of the experimental data sets have been performed. A number of 15 new resonances, not given in the JEF2 evaluation, have been found and are indicated in the table with an asterisk.

A simultaneous fit of the data of this transmission experiment and the capture experiment [9] may improve the resonance parameters. Data have been taken up to 100 keV, both for capture and transmission. These data are currently under analysis.

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