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RESEARCH ON

NEUTRON RESONANCE PARAMETERS OF FISSILE NUCLEI

- Mean resonance-parameter testing by transmission experiments.
- Multilevel parametrization of fissile nuclei resonance cross-sections.
- Evaluation of group constants for Pu-241 in the unresolved resonance region.

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RESEARCH ON NEUTRON RESONANCE PARAMETERS OF FISSILE NUCLEI

Mean resonance-parameter testing by transmission experiments

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Multilevel parametrization of fissile nuclei resonance cross-sections

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Evaluation of the group constants for Pu-241 in the unresolved resonance region (Progress Report)

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MEAN RESONANCE PARAMETER TESTING BY TRANSMISSION EXPERIMENTS

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At present the accuracy of neutron data continues to be important for the fast reactors design calculations[1,2]. This underlines the significance of the macro- and microscopic experiments and benchmark testing of nuclear data for an accurate prediction of fast reactor properties.

In particular, the resonance structure of the neutron cross sections has a great influence on the values of reactor parameters. The unresolved resonance region, where the resonance structure effects are significant, is different for various isotopes, but the neutron reactions which occur in this region give a valuable contribution to the fast reactor neutron balance. This determines the influence of the neutron cross sections shielding on reactor characteristics.

The methods for generation the group average reactor constants and estimation of their uncertainties are available based on the series of approximations.

An improved method for group averaged constants evaluation has been developed, including as a first step the analysis of the measured shielded cross sections. The detailed analysis of a broad set of experimental data is to be performed utilizing a strict theory of resonance reactions with neutrons. This permits avoiding the necessity of "background" cross sections, as used in the ENDF/B system reproducing[3].

Our method for evaluation of nuclear data (the average cross section functionals, self-shielding factors etc.) is a stochastical simulation of neutron cross sections (ladder method) on the basis of the multilevel formalism. We adopt the approximation of reduced R-matrix, whose elements for the state with given angular momentum and parity are:

$$R_{cc'} = \sum_{\lambda} \frac{\gamma_{\lambda c}\gamma_{\lambda c'}}{E_\lambda - E - i\bar{\Gamma}_\gamma/2}$$

here $\gamma_{\lambda c}$ is the reduced width amplitude in the reaction channel c, E_λ - level energy, $\bar{\Gamma}_\gamma$ - mean radiative width.

It is convenient to use the K-matrix related to collision S-matrix by[4]:

$$S = \Omega\left[(1+iK)(1-iK)^{-1}\right]\Omega$$

Including the values $\beta_{\lambda c} = \gamma_{\lambda c}/\bar{\gamma}_c$ (normally distributed) and $(E_\lambda - E_{\lambda-1})/\bar{D}$ (following Wigner distribution law), the K-matrix elements are expressed as:

$$K_{cc'} = \frac{\bar{\gamma}_c \bar{\gamma}_{c'}}{2\bar{D}} \sum_{\lambda} \frac{\beta_{\lambda c}\beta_{\lambda c'}}{(E_\lambda - E)/\bar{D} - i\bar{\Gamma}_\gamma/2\bar{D}}$$

the neutron cross sections are:

$$\sigma_t = 2\pi\lambda^2 \sum_{J^\pi} g(J) \sum_{l_j l'_{j'}} \left(1 - \mathrm{Re}\, S^{J^\pi}_{nl_j, nl'_{j'}}\right)$$

$$\sigma_c = \pi\lambda^2 \sum_{J^\pi} g(J) \sum_{l_j l'_{j'}} \left|S^{J^\pi}_{nl_j, cl'_{j'}}\right|^2$$

$$\sigma_{el} = \pi\lambda^2 \sum_{J^\pi} g(J) \sum_{l_j l'_{j'}} \left|1 - S^{J^\pi}_{nl_j, nl'_{j'}}\right|^2$$

Inelastic scattering at E $<$ 20 KeV is neglected. The radiative capture cross section is determined as the difference between the total cross section and the sum of fission and elastic scattering cross sections. In the energy range under consideration the contributions of s and p neutrons are accounted for. The parameters Γ_n and φ_l which depend on l are expressed as usual:

$$\varphi_0 = kR_0$$

$$\varphi_1 = kR_1 - \mathrm{arctg}(kR_1)$$

$$\Gamma_{nl} = \Gamma^0_{nl}\sqrt{E}\, V_l$$

V_0, V_1 are the penetrative coefficients for s and p neutrons, R_0, R_1 are the potential scattering radii for s and p neutrons, usually assumed to be equal.

In our approach some problems of the ladder method are overcome. For the Doppler broadening calculation we employ the statistical sampling in the form of multiple "emission" of neutrons at the energy points of a uniform lethargy mesh, avoiding the point-to-point quadrature. In every "emission" Doppler random samplings for a set of temperatures are performed. Correlated statistical runs cover prescribed lethargy intervals, where a random picture (realization) of neutron multilevel cross sections with many resonances for the all quantum states is defined.

Actually a 10-level approximation turns to be sufficient. In our case the K-matrix is of rank three - the number of channels: one neutron channel and two fission channels. Information about given realization is stored in the computer memory. There is a code option where the probability table method is applied for calculation of mean group average nuclear constants. The distribution function of total cross section $P(\sigma_t)$ and correlation function $\sigma_x(\sigma_t)$ are stored to calculate any functional $F(\sigma_t, \sigma_x)$:

$$\langle F \rangle = \int F[\sigma_t, \sigma_x(\sigma_t)]\, P(\sigma_t)\, d\sigma_t$$

The estimates of calculated functional dispersions are determined as:

$$D_F = \langle F^2 \rangle - \langle F \rangle^2$$

it does not depend on the number of Monte Carlo realizations of specified energy interval ΔE . This gives us an opportunity for an exact functional averaging over isotopical mixture (a goal for preparing group constants).

The resonance parameters values X of a neutron cross section model is evaluated adjusting experimental data for average cross sections and transmission functions using statistical procedure with a-priori information. The a-posteriori estimates of the parameters are given by expressions

$$\hat{X} = X^{apr} + D(X^{apr})K^T[KD(X^{apr})K^T + D(\hat{Y})]^{-1}(Y - KX^{apr})$$

$$\hat{D}(\hat{X}) = D(X^{apr}) - D(X^{apr})K^T[KD(X^{apr})K^T + D(\hat{Y})]^{-1}KD(X^{apr})$$

here D is covariance matrix, K - matrix of the sensitivity coefficients.

The computer code incorporates a loop of ($p+\delta p$) parameter perturbation for sensitivity calculations.

Our experimental data on the transmission and self indication functions are involved in this procedure to obtain the best values of the average resonance parameters of ^{235}U and ^{239}Pu [5,6]. The resulting estimates of the mean resonance parameters are given in Table 1 and 2.

In Fig. 1 the ^{239}Pu corresponding calculated group constants are shown in comparison with the evaluation [1]. We calculated the group constants of ^{232}Th, ^{240}Pu, ^{242}Pu too. The results are shown in Fig. 2 compared to ENDF/B-V[3] and ABBN78[1].

Table I. a) Mean resonance parameters for ^{235}U

l	J	D(eV)	Γ_γ(meV)	$S_n \cdot 10^4$	Γ_f(eV)	f_1	f_2	ν_n	ν_f
0	3^-	0,967	30	VAR	VAR	0,5	0,5	1	2
0	4^-	0,801	30	VAR	VAR	0,5	0,5	1	2
1	2^+	1,256	30	1,68	0,468	0,5	0,5	1	2
1	3^+	0,967	30	1,68	0,165	1,0	1,0	2	1
1	4^+	0,801	30	1,68	0,332	0,5	0,5	2	1
1	5^+	0,770	30	1,68	0,130	1,0	0,0	1	1

Table I. b) Mean energy dependent resonance parameters for ^{235}U

Group number	E_n, keV	R' (fm)	$S_o \cdot 10^{+4}$	$\bar{\Gamma}_f^{3-}$
17	0,100-0,215	9,5	0,950	120
16	0,215-0,465	9,2	0,940	144
15	0,465-1,00	9,2	1,050	176
14	1,00-2,15	9,2	0,910	170
13	2,15-4,65	9,2	0,901	243
12	4,65-10,0	9,2	0,964	170
11	10,0-21,5	9,1	1,05	153

Table II. a) Mean resonance parameters for ^{239}Pu

l	J	D(eV)	$S_n \cdot 10^{-4}$	$\Gamma_\gamma \cdot 10^{-3}$(eV)	$\bar{\Gamma}_J \cdot 10^{-3}$(eV)	$P_{fJ}^{(1)}$
0	0^+	9,36	VAR	41,5	1820	VAR
0	1^+	3,17	VAR	51,5	VAR	1
1	0^-	9,36	2,3	51,0	0	0
1	1^-	3,17	2,3	30,3	1009	0,5
1	2^-	1,96	2,3	36,3	603	0,5

Table II. b) Mean energy dependence resonance paramaters for ^{239}Pu

Group number	E_n,keV	$S_1(l=0) \cdot 10^{-4}$	$\bar{\Gamma}_f^{1+}$(eV)	$P_{fl}^{(1)}(J^\pi = 0^+)$
18	0,0465-0,100	1,82	0,052	0,8
17	0,100-0,215	1,20	0,057	0,8
16	0,215-0,465	1,35	0,035	0,8
15	0,465-1,00	1,25	0,060	0,8
14	1,00-2,15	0,82	0,045	0,8
13	2,15-4,65	0,98	0,035	0,8
12	4,65-10,0	0,83	0,030	0,8
11	10,0-21,5	0,81	0,032	0,8

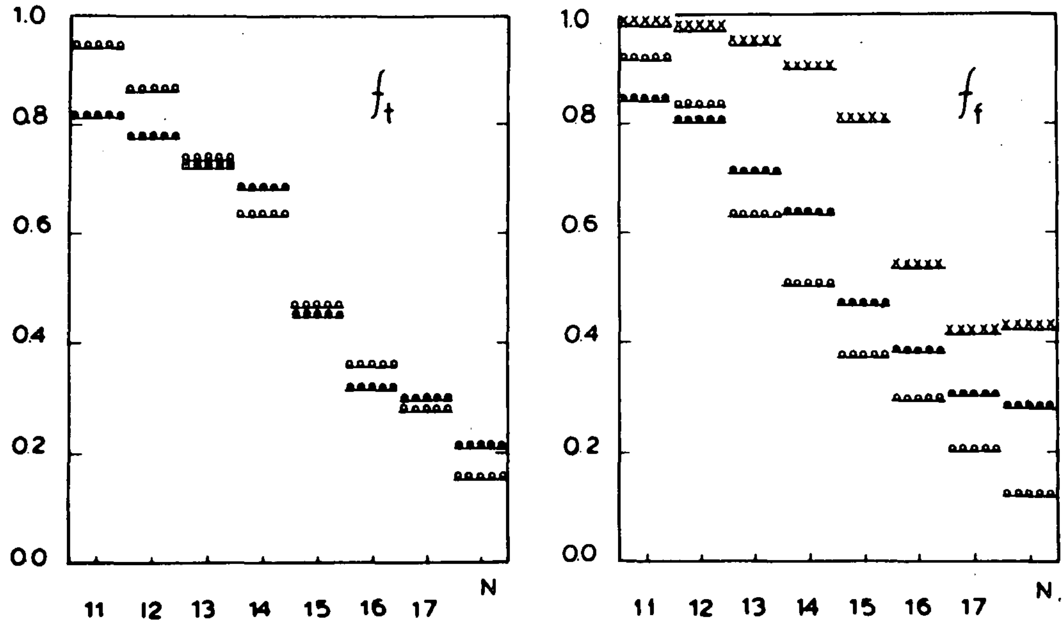

Fig. 1. Resonance self-shielding factors for ^{249}Pu.
ooo ABBN, ... /6/, xxx UKNDL.

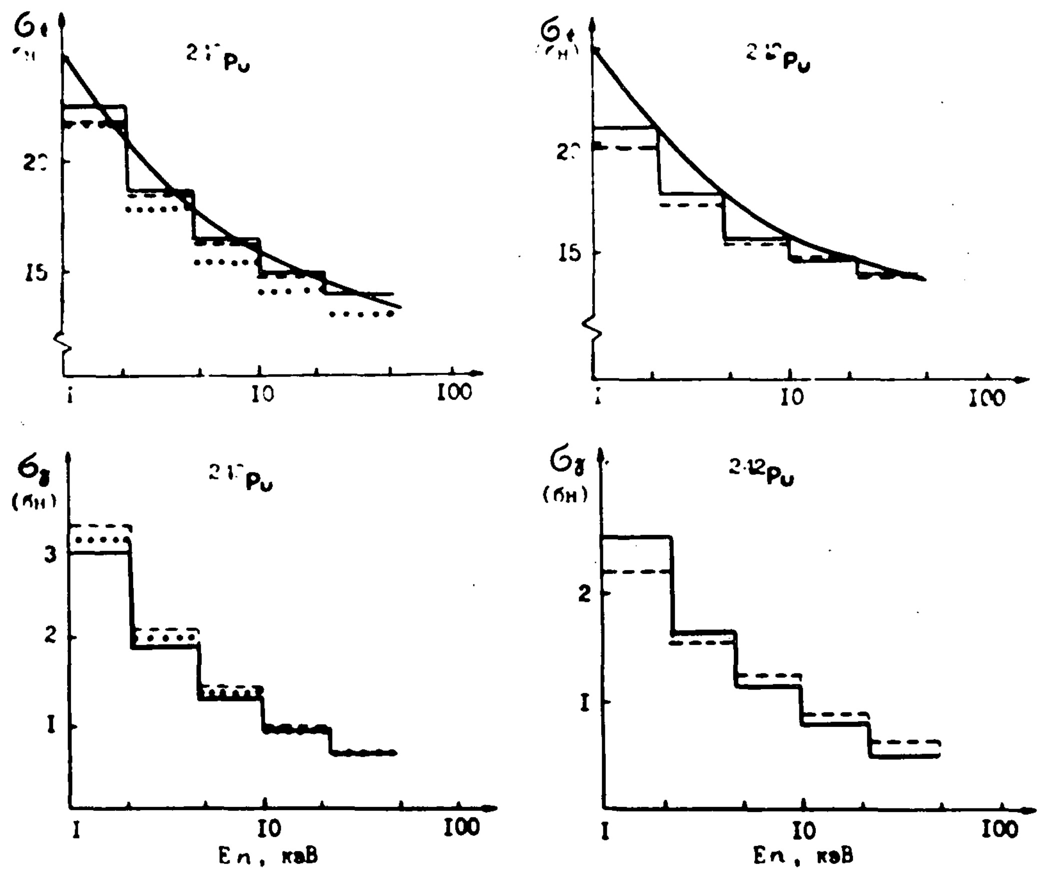

Fig. 2 Group total cross sections and capture cross sections for ^{240}Pu and ^{242}Pu. ----ENDF/13-V, ...ABBN78, statistical model calculations/7/, optical model calculations.

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MULTILEVEL PARAMETRIZATION OF FISSILE NUCLEI RESONANCE CROSS SECTIONS

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The effects of resonance interference exert an important influence on the resonance structure of neutron cross sections energy dependence at lowest energies. In practice, this reflects on the group averaged self shielding factors and, experimentally, on the specifical dependence of the group averaged transmission on the sample thickness. For the description of the detailed energy structure of the fissile nuclei: resonance cross sections with the same precision in the regions of the interferencial maximum and minimum, it is necessary to use the multilevel schemes of the cross section parametrization taking into account the resonance interference. The R-matrix theory results in the schemes of Reach-Moore and Vogt or S-matrix Adler-Adler formalism/1,2/ are to be used in such a case/1,2/. The Adler Adler scheme is most convenient for practical aims, as it gives the simplest representation of the resonance cross sections energy description as a sum of the usual Breit-Wegner resonances/2,1/. The total cross section is parametrized as:

$$\sigma(E) = \sigma_p + \pi \kappa^{-2} \sqrt{E} \sum_{J} \sum_{K(J)} \frac{G_K \nu_K + (\mu_K - E) H_K}{(\mu_K - E)^2 + \nu_K^2} \qquad (1)$$

where σ_p is the potential cross section: μ_K, ν_K, G_K and H_K are resonance parameters; the sum contains all possible levels in the energy region in question with the total momentum J

and parity (for low energy fissile nuclei resonances only two systems of resonances with different J are possible). Similarly, the reaction cross section (n,c) can be expressed as

$$\sigma_c(E) = \sum_J \sigma_c^J(E) = \pi K^{-2}\sqrt{E}\sum_J\sum_{K(J)} \frac{G_K^c \nu_K + (\mu_K - E) H_K^c}{(\mu_K - E)^2 + \nu_K^2} \qquad (2)$$

with the additional parameters G_K^c and H_K^c.

At present the use of Adler's scheme for the fissible cross sections resonance structure representation in nuclear data libraries assumes the independent determination of the resonance parameters, G_K^c, H_K^c as constant (in energy) values for each of the cross sections - fission, capture and elastic scattering. In such a case, a violation is possible of one of the nuclear physics fundamental principles - collision matrix unitarity, which characterizes the intensity balance over all the channels/1/. Taking into account the unitarity, as shown in /3/, the absorption cross section parameters (fission plus capture) can be expressed by the total cross section parameters/1/ as

$$G_K^a + iH_K^a = (G_K + iH_K)\exp 2i\varphi -$$

$$- i\frac{\sqrt{E}}{2g(J)}\sum_{K'(J)} \frac{(G_K G_{K'} + H_K H_{K'}) + i(H_K G_{K'} - H_{K'} G_K)}{(\mu_{K'} - \mu_K) + i(\nu_{K'} + \nu_K)} \qquad (3)$$

where φ is the potential scattering phase shift; $g(J)$ spin factor; Summing comprises the same level system with spin J. In such a way the total cross section parameters obtained in the multilevel analysis are assumed to be independent of the energy, but the expression for absorption cross section (2) contains the parameters G_K and H_K depending somehow on energy (3). A similar energy dependence is also existing in the elastic scattering parameters/3/:

$$G_K^n = G_K - G_K^a, \quad H_K^n = H_K - H_K^a \qquad (4)$$

The most important interference effects are observed in the fission cross section energy dependence $\sigma_F(E)$. We obtain fission cross section parameters not dependent on energy (2) using the Adler's scheme for analysis of experimental data and the absorption parameters from expression (3) which allows to determine the capture resonance parameters $\sigma_\gamma(E)$ (2):

$$G_K^\gamma = G_K^a - G_K^F \quad , \quad H_K^\gamma = H_K^a - H_K^F \qquad (5)$$

with the same energy dependence/3/ as in G_K^a and H_K^a.

We performed selfconsistent analysis of the ^{239}Pu total and fission cross sections and obtained the set of Adler's parameters: μ_K, ν_K, G_K, H_K, G_K^F, H_K^F not dependent on energy/4,5/. The absorption, capture and elastic scattering cross sections constructed by using these parameters, the above described scheme of unitarity calculations and the existing information about the level spin identification are in good agreement with the recently obtained experimental information about these cross sections/3-6/. This can confirm the correctness of our scheme. For other fissile nuclei the difficulties in multilevel parametrization can be met because of lack of experimental data about neutron cross sections and information about level spin identification. Nevertheless, the use of the relation between the resonance parameters due to unitarity properties can be recommended for the analysis of the available experimental data and for the construction of cross sections where no possibilities exist to perform direct measurements/6/. The precision of the constructed cross sections can be the same as the precision of the measured total and fission cross section in the resonance region.

For practical use of the resonance cross section parametrization results in the proposed scheme, the problem of presentation of these results in ENDF/B format has been discussed. Using the accepted identification (/7/p.No.10A), the section of the resolved levels resonance parameters can be described in our case in a form similar to the accepted representation of Adler parameters (LRU=1 LRU=4). The proposal is to include the following sums not dependent on the energy instead of parameters

$$G_{\kappa}' + i H_{\kappa}' = \frac{1}{2} \sum_{\kappa'(J)} \frac{(G_{\kappa} G_{\kappa'} + H_{\kappa} H_{\kappa'}) + i (H_{\kappa} G_{\kappa'} - H_{\kappa'} G_{\kappa})}{(\mu_{\kappa'} - \mu_{\kappa}) + i (\nu_{\kappa'} + \nu_{\kappa})} \qquad (6)$$

and to construct the parameters of capture, absorption and elastic scattering cross section according to our scheme (3),(4),(5). In such a way the inclusion of this method in the ENDF/B format is realized as a separate block (with its own LRF /7/) in any code complex, without additional change of all remaining elements of the library.

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/7/ ENDF-102 Data Formats and Procedures for the Evaluated Nuclear Data File, ENDF/B-V, BNL-NCS-50496.

PROGRESS REPORT

on Research Contract No. 4237/RB

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Evaluation of the group constants for ^{241}Pu in the unresolved resonance region

We developed the method for modelling neutron cross sections for actinides in the unresolved resonances energy region. This method is described in detail in /1/ and has been used for evaluation of the group constants (the energy intervals of the groups can be taken equal to those from ABBN Soviet nuclear data library) and average resonance parameters of ^{235}U, ^{238}U, ^{239}Pu on the base of our experimental data for transmission and self-indication with a big variety of sample-absorbers (see /2/).

The essential characteristic of our method is the possibility of taking into account the multilevel interference which, as we demonstrated in /3/, has a significant contribution in the region of overlapping resonances. The neutron cross section of heavy nuclei are calculated using the S-matrix elements simulated by Monte Carlo method following the expression:

$$(1)\quad S = \Omega\left[(1+iK)(1-iK)^{-1}\right]\Omega\ , \quad K_{cc'} = \frac{\Gamma_c \Gamma_{c'}}{2D}\sum_{\lambda} \frac{\beta_{\lambda c}\beta_{\lambda c'}}{E_\lambda - E - i\Gamma_\gamma}$$

Γ_c , D are energy averaged resonance parameters, are normally distributed (0,1) random numbers and $Z_\lambda = E_{\lambda+1} - E_\lambda$ are random numbers obeying the Wigner law with mean value equal to 1, N is the number of the interfering levels (usually N=10 or 30). From $S_{cc'}$ we can obtain all neutron cross section values averaged over the energy interval, the self-shielding factors at different temperatures and dillution cross sections. The best values of the average resonance parameters are determined by a test fitted to the experimental data. For the purpose the statistical Bayessian procedure is used. All this practical scheme for neutron constant evaluation can be realized by our code MNCARL [4].

We performed an evaluation of the ^{241}Pu group constants in the region 100 eV - 30 keV. Some of the results will be presented here. A more complete presentation of our results can be found in the paper that is in preparation now.

The initial guess parameters have been taken from the evaluation[5]. The energy averaged values of ^{241}Pu total and radiative cross sections obtained by the code MNCARL are presented in Table 1

TABLE 1

E (keV)	σ_t MNCARL	σ_t [5]	σ_t [6]	σ_γ MNCARL	σ_γ [5]	σ_γ [6]
0.10 - 0.15	44.917	44.450	45.684	9.068	6.220	6.708
0.15 - 0.25	47.570	46.450	46.447	8.700	6.960	6.347
0.25 - 0.35	45.460	44.500	44.497	7.075	6.900	6.853
0.35 - 0.45	39.730	39.950	39.894	7.560	6.530	6.518
0.45 - 0.55	36.040	36.500	36.414	5.772	5.740	5.699
0.55 - 0.65	29.902	31.450	31.883	4.258	4.560	4.553
0.65 - 0.75	25.487	27.300	28.127	2.249	3.410	3.436
0.75 - 0.85	26.370	25.700	26.707	4.175	2.760	2.789
0.85 - 0.95	22.866	26.030	26.792	2.604	2.810	2.809
0.95 - 1.50	25.187	25.850	26.142	2.840	2.780	2.760
1.50 - 2.50	21.979	22.850	23.288	2.011	2.170	2.180
2.50 - 3.50	19.818	20.350	21.332	1.736	1.620	1.638
3.50 - 4.50	18.726	20.150	20.422	1.430	1.460	1.458
4.50 - 5.50	17.305	19.050	19.316	1.138	1.300	1.290
5.50 - 6.50	16.415	18.300	18.602	1.122	1.120	1.112
6.50 - 7.50	16.470	17.950	18.209	1.138	1.100	1.094
7.50 - 8.50	15.990	17.700	17.900	0.985	1.080	1.075
8.50 - 9.50	15.542	17.500	17.484	0.937	0.870	0.869
9.50 -15.00	17.466	16.400	16.644	0.805	0.770	0.762
15.00 -25.00	13.561	15.550	15.752	0.570	0.680	0.686
25.00 -30.00	12.584	14.800	15.335	0.353	0.540	0.611

E (keV)	σ_f MNCARL	σ_f [5]	σ_f [6]	σ_{nn} MNCARL	σ_{nn} [5]	σ_{nn} [6]
0.10 - 0.15	24.086	25.500	25.031	11.766	12.720	13.895
0.15 - 0.25	26.579	26.200	25.746	12.091	13.290	13.854
0.25 - 0.35	25.920	23.900	23.864	12.465	13. 700	13.780
0.35 - 0.45	18.940	19.600	19.655	13.230	13.820	13.696
0.45 - 0.55	17.185	17.050	17.041	13.083	13.720	13.674
0.55 - 0.65	13.089	13.550	13.700	12.555	13.340	13.630
0.65 - 0.75	12.186	10.950	11.099	11.052	12.940	13.592
0.75 - 0.85	10.138	10.200	10.361	12.057	12.740	13.557
0.85 - 0.95	8.617	10.400	10.457	11.645	12.840	13.526
0.95 - 1.50	10.171	10.010	9.940	12.176	13.060	13.442
1.50 - 2.50	7.568	7.770	7.822	12.400	12.910	13.284
2.50 - 3.50	6.162	6.480	6.564	11.920	12.760	13.130
3.50 - 4.50	5.554	5.950	5.954	11.742	12.750	13.010
4.50 - 5.50	4.590	5.130	5.120	11.577	12.620	12.908
5.50 - 6.50	3.715	4.700	4.671	11.578	12.480	12.819
6.50 - 7.50	3.671	4.380	4.374	11.661	12.470	12.703
7.50 - 8.50	3.535	4.150	4.152	11.470	12.480	12.673
8.50 - 9.50	3.152	4.010	4.008	11.453	12.620	12.606
9.50 -15.00	3.477	3.500	3.454	13.184	12.140	12.427
15.00 -25.00	2.015	2.960	2.970	10.976	11.900	12.096
25.00 -30.00	1.697	2.660	2.816	10.534	11.600	11.908

in comparison with the same values (averaged, if necessary) from /5/ and /6/. The same values for fission and elastic scattering cross sections can be seen in Table 2. The values of ^{241}Pu neutron cross sections at temperatures 900^o and 2100^{o}K are in tables 3 and 4. All those calculations have been made at zero dillution cross section.

^{241}Pu resonance parameters

The method for multilevel analysis of neutron cross sections in the region of resolved resonances described in /7/ is using now for

TABLE 3

E (keV)	σ_t	900° σ_γ	σ_f	σ_{nn}
0.10 - 0.15	43.955	10.999	22.856	10.100
0.15 - 0.25	47.575	8.912	26.675	11.988
0.25 - 0.35	45.474	7.470	25.772	12.232
0.35 - 0.45	39.600	7.520	19.058	13.022
0.45 - 0.55	35.728	6.012	17.024	12.692
0.55 - 0.65	30.055	4.265	13.415	12.375
0.65 - 0.75	25.389	2.338	12.208	10.843
0.75 - 0.85	26.113	4.056	10.207	11.850
0.85 - 0.95	22.618	2.512	8.671	11.435
0.95 - 1.50	25.067	2.749	10.321	11.997
1.50 - 2.50	21.971	2.010	7.553	12.408
2.50 - 3.50	19.643	1.624	6.217	11.802
3.50 - 4.50	18.604	1.346	5.608	11.650
4.50 - 5.50	17.268	1.079	4.672	11.517
5.50 - 6.50	16.327	1.057	3.765	11.505
6.50 - 7.50	16.468	1.133	3.675	11.660
7.50 - 8.50	16.019	1.000	3.547	11.472
8.50 - 9.50	15.579	0.931	3.148	12.500
9.50 -15.00	17.485	0.802	3.489	13.194
15.00 -25.00	13.562	0.562	2.014	10.986
25.00 -30.00	12.512	0.288	1.762	10.462

determination of the complete set of ^{241}Pu resonance parameters. This work is in progress.

Measurement of the neutron cross sections by the method of γ-ray multiplicity spectrometry on the research reactor in Sofia

The multisectional scintillation detector and the additional apparatus /8/ have been used for measurement of the ^{235}U α - value at the thermal point/9/. This work is developing now in the direction of measurement of the γ-ray multiplicity spectra of nonfissile

TABLE 4

E (keV)		2100°		
	σ_t	σ_γ	σ_f	σ_{nn}
0.10 - 0.15	46.725	8.657	25.662	12.406
0.15 - 0.25	47.635	9.705	26.277	11.653
0.25 - 0.35	45.134	7.602	25.635	11.897
0.35 - 0.45	39.353	7.647	19.066	12.640
0.45 - 0.55	35.014	5.976	16.826	12.212
0.55 - 0.65	30.068	5.144	13.591	12.030
0.65 - 0.75	24.995	2.212	12.279	10.504
0.75 - 0.85	26.392	1.710	10.209	14.473
0.85 - 0.95	22.735	3.001	8.706	11.028
0.95 - 1.50	25.020	2.875	10.446	11.699
1.50 - 2.50	22.014	2.005	7.587	12.422
2.50 - 3.50	19.458	1.511	6.306	11.641
3.50 - 4.50	18.454	1.258	5.678	11.518
4.50 - 5.50	17.185	0.984	4.775	11.426
5.50 - 6.50	16.234	0.972	3.843	11.419
6.50 - 7.50	16.495	1.135	3.678	11.682
7.50 - 8.50	16.011	0.997	3.539	11.475
8.50 - 9.50	15.569	0.932	3.155	11.482
9.50 -15.00	17.474	0.792	3.477	13.205
15.00 -25.00	13.562	0.567	2.014	10.977
25.00 -30.00	12.409	0.192	1.852	10.365

nuclei. For ^{238}U such a spectrum has been measured with high precision. The code for Monte Carlo simulation of the response function of the detector has been prepared. At present, the verification of the code with the ^{238}U data is in progress.

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