COMITATO NAZIONALE ENERGIA NUCLEARE
DIPARTIMENTO RICERCA TECNOLOGICA DI BASE ED AVANZATA

PROGRESS REPORT ON NUCLEAR DATA ACTIVITIES IN ITALY

for the period from January to December 1978

RELAZIONE TECNICA INTERNA
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for the period from January to December 1978

Compiled by

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Bologna, Italy

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1. C.N.E.N. - DIVISIONE DI FISICA - LABORATORIO DATI NUCLEARI - Via Mazzini, 2 - 40138 BOLOGNA (Italy)

1.1 Fission Barrier Penetrability in Statistical Cross Section Calculations

T. MARTINELLI, E. MENAPACE, A. VENTURA

The semiclassical formulae of multiple-humped barrier penetrabilities published in "Lettere al Nuovo Cimento, 20 (1977)267" were compared with "exact" penetrabilities /1/ and inserted in the code HAUSER (F.M. Mann, Hanford rep. HEDL-TME 76-80 (1976) for statistical cross section calculations within the framework of the Hauser-Feshbach formalism; fission cross sections can be calculated in the extreme limits of no damping and complete damping of vibrational states in intermediate wells of the fission barrier; the introduction of partial damping is currently under study.

/1/ T. Martinelli, E. Menapace, A. Ventura: "On the Penetrability of Multiple-Humped Fission Barriers", CNEN rep. RT/FI(78)7.

1.2 Level Density of Statically Deformed Nuclei

G. MAINO(°), E. MENAPACE, A. VENTURA

Level densities for a number of deformed nuclei in lanthanide and actinide regions were calculated with statistical methods, starting from single particle states in a Nilsson potential and taking into account pairing interactions within the framework of the BCS formalism: collective effects were included by treating deformed nuclei as pure rotors with axial and reflection symmetry. In order to estimate the s-wave level spacing $\overline{D}$ at the neutron binding energy, the same ground state gap parameter $\Delta(o)$ was assumed for protons and neutrons: its

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(°) Guest researcher

average trend versus mass number A is given by curve (a) of Fig. 1, while curve (b) is an average pairing energy δ (expected to be of the same order of $\Delta(o)$) obtained by Nemirowsky (Kurchatov rep. IAE-2530 (1975)). Fig. 2 shows the ratio of calculated to experimental $\overline{D}$'s for a number of deformed nuclei; the average $\Delta(o)$ of Fig. 1 used in preliminary calculations seems to be rather poor for odd-Z and odd-odd nuclei; a more accurate treatment of the level blocking due to odd nucleons is currently in progress. These preliminary results were accepted for publication in "Il Nuovo Cimento A" (dec. 1978). Comments on the limits of the model and its possible improvements (presently in progress) were published in ref. /1/. The main purpose of these level density calculations for heavy deformed nuclei is their future application to the actinide fission theory.

/1/ G. Maino, E. Menapace, A. Ventura: "Comments on BCS Level Density Calculations for Deformed Nuclei", CNEN rep.RT/FI(78)24.

1.3 Fission Cross Section in the Continuum

V. BENZI, G. MAINO(°), E. MENAPACE

A semiempirical approach for calculating the trend of the ratio Γ_n/Γ_f as a function of excitation energy, applied to U-235, Pu-238 and Pu-241 has been studied /1/ . The same method has been applied to the study of the fission cross section of Am-241. As a consequence, the separate contributions of "first chance" and "second chance" terms to the total fission have been calculated. The results agree with purely theoretical predictions, in particular for Am-241, obtained by Hauser-Feshbach calculations in the "complete damping" limit.

/1/ V. Benzi, G. Maino, E. Menapace: "On the Fission Probability for ^{235}U, ^{239}Pu and ^{241}Pu", Lettere al Nuovo Cimento 21, 231 (1978).

(°) Guest researcher

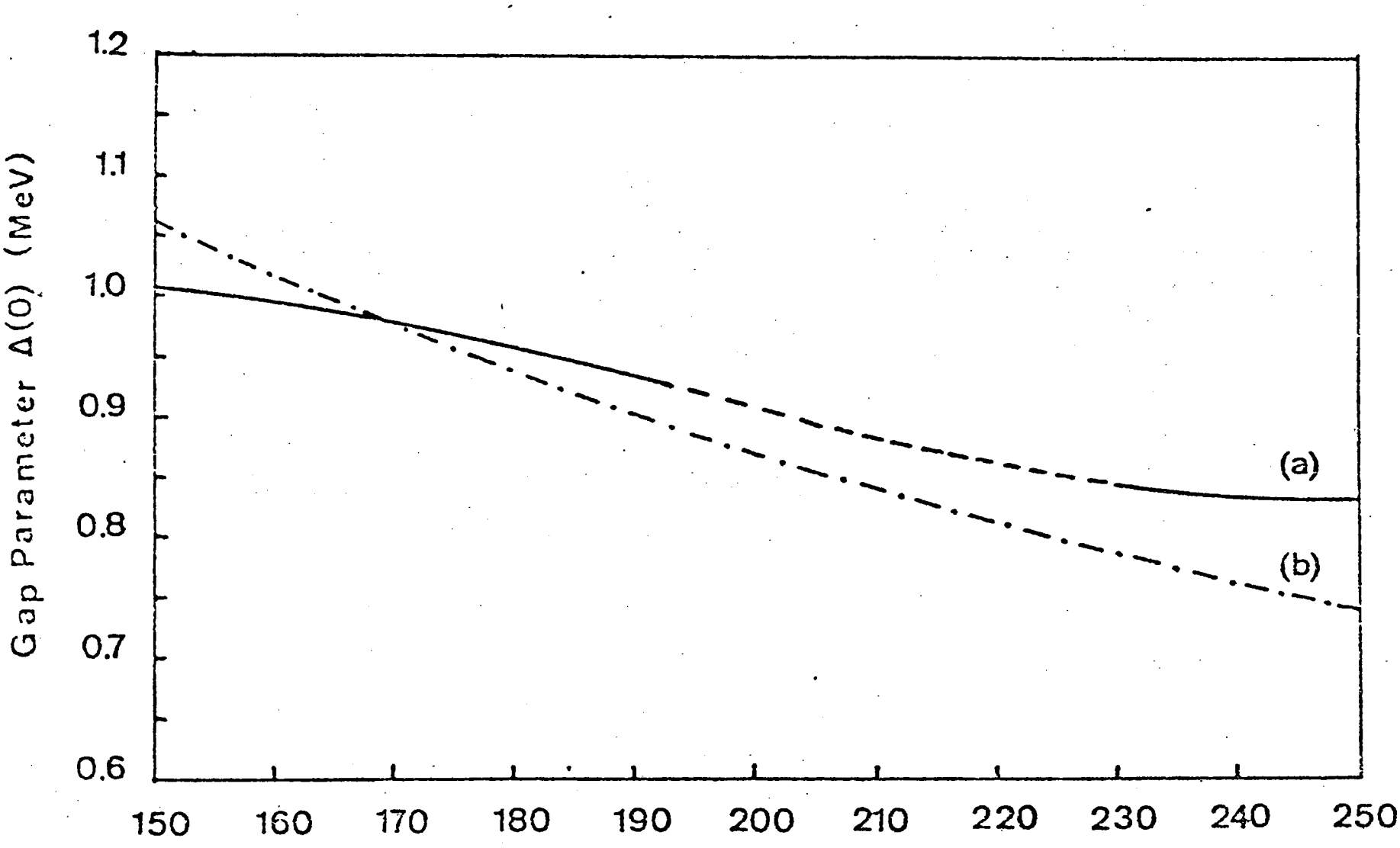
Gap Parameter Δ(0) (MeV)
1.2
1.1
1.0
0.9
0.8
0.7
0.6
150
160
170
180
190
200
210
220
230
240
250
(a)
(b)
Mass Number A

Fig.1

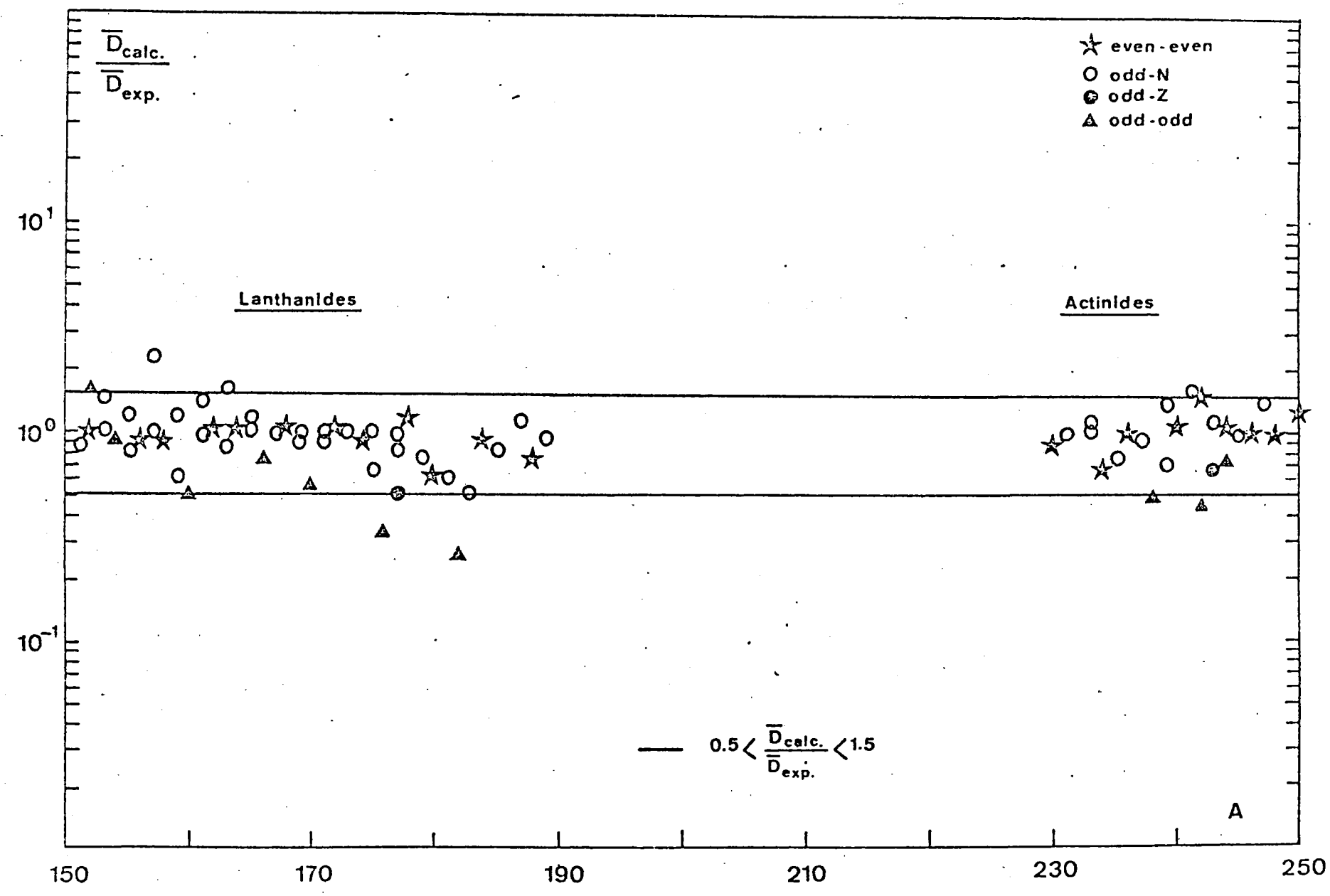
$\frac{\overline{D}_{calc.}}{\overline{D}_{exp.}}$
even-even
odd-N
odd-Z
odd-odd
10^1
10^0
10^{-1}
Lanthanides
Actinides
$0.5 < \frac{\overline{D}_{calc.}}{\overline{D}_{exp.}} < 1.5$
A
150
170
190
210
230
250

Fig.2

1.4 Formalism for Fission Cross Section Calculations in the Resolved Resonance Region

T. MARTINELLI, E. MENAPACE, M. MOTTA

In order to obtain an appropriate description of fission cross section in the region of resolved resonances, a formalisms has been studied which is suitable for reactor calculations, particularly for the temperature dependence of resonance cross section.

In past years the code PIUME was prepared for the analytical Doppler broadening of the cross section profile. The fission cross section is there calculated in the frame of a multilevel Breit-Wigner approximation, with one fission channel. However, the fission process requires, for a better description, the presence of two or more reaction channels, as provided by the Reich-Moore formalism. Unfortunately, such a formalism does not permit an analytical Doppler broadening of resonances and, once more, numerical methods must be used. Thus, theoretical studies have been undertaken in order to obtain:

1) An extended multilevel Breit-Wigner formalism with two or more fission channels.
2) A proper reduction of the formalism to the expressions which permit the use of the classical ψ and χ functions for Doppler broadening.
3) The transformation of parameters from the Reich-Moore type to the Kapur-Peierls parameters, giving rise to the formalism which equivalently permits the use of the ψ and χ functions.
4) The general problem of conversion from one formalism to the other.

The above studies are in progress.

1.5 Nuclear Model Development and Application for Reactor Purposes

F. FABBRI, G. REFFO

Under this heading the following main lines of activity have been carried on.

a) Nuclear Model Development

Statistical Model

Properties of the width fluctuation factor have been identified which have led to a generalization of the formalism including outgoing channels feeding excited states in the continuum of final nuclei reached.
In addition, taking care of all properties of statistical width fluctuations we have introduced approximations which allow for a considerable computing time reduction. In ref. 1 it has been shown that such corrections can affect total neutron inelastic scattering up to 50% in certain e-e nuclei, while the spectrum of emitted neutrons is changed in shape and magnitude compared to pure Hauser-Feshbach calculations.

/1/ F. Fabbri, G. Reffo: "Extension of the Width Fluctuation Correction to Reactions Involving Continuum Level Excitations", Nucl. Sci. and Eng., vol, 66, 251 (1978).

b) Nuclear Model Parametrization

This activity line is aimed both at checking certain nuclear models widely used for the purpose of reactor data evaluation and at providing with suitable parameters where no experimental information is available as to normalize model predictions.
Basing on nuclear models as far as possible the systematic behaviour of the following main parameters have been determined together with their associated uncertainties (probable errors): level density paramer "a" , radiative width Γ_γ at the neutron binding energy, neutron capture cross section at 25 keV, giant resonance parameters, nuclear temperature and matching energies in the Gilbert-Cameron level density formula.
In addition a particular care has been devoted to the consistent use of models and parameters, and to relate certain necessary parameters (such as spin cut off factor) to available experimental information through theory as far as possible /2/ .

/2/ G. Reffo: "Parameter Systematics for Statistical Theory Calculations", CNEN Report RT/FI(78)11.

c) Nuclear Model Code Development

A new code PENELOPE is in progress. At present the complete deexcitation process of compound and residual nuclei via particle emission (only) can be considered.

d) Cross Section Evaluation for Fast Reactors

As an application, the results following actions a and b above have been used in the evaluation of fast neutron induced reactions for 63 isotopes required within the CNEN-CEA agreement for Super-Phoenix project /3/ .

/3/ M. Darrouzet et al.: "An Evaluated Fission Product Data Library for Super-Phoenix Project" presented by G. Reffo at "Int. Conf. on Neutron Physics...", Harwell, 25-29 Sept. (1978).

1.6 Evaluation of Fission Products (Neutron Data)

F. FABBRI, E. MENAPACE, A. MONTAGUTI, M. MOTTA, G.C. PANINI, G. REFFO, M. VACCARI, A. VENTURA

The activity for the evaluation of fission products (FP) continued in 1978. The conclusive report on the work for the FP evaluation was prepared with the Cadarache French Group and presented (by G. Reffo) at the Harwell Conference on Neutron Physics and Nuclear Data /1/.
A description of multigroup cross sections obtained and a comparison with other important sources is given in /2/ . Neutron resonance data and parameters, as well as computed thermal cross sections and calculated resonance integrals are given in /3/ .
The complete evaluated data for 63 fission products are available in ENDF/B format.
The results obtained in integral experiments performed at Cadarache and Petten (STEAK) suggested a revision of some evaluated data in the FP files previously prepared within the framework of the CNEN-CEA agreement on Fast reactor project.
The discussion on the discrepancies between differential and integral data of FP cross sections implied the revision of four isotopes, i.e. Pd-105, Nd-143, Sm-149, Sm-151, belonging to the list of the 22 most

important products in the contribution to total FP neutron capture. This revision is now completed in the resolved resonance region. The evaluation of cross section in the statistical region and preparation of the group-averaged cross sections in CARNAVAL format will be completed in 1979.

For a more profitable work in the field of evaluation, a policy based on a larger use of desk calculators has been developed. The interactive operating mode of a small computer is particularly efficient for nuclear data preparation /4/ . New programs in BASIC language for data collection and checking or for calculation of cross sections in resonance region have been prepared. The programs have greatly reduced the amount of time required in the evaluation work.

/1/ M. Darrouzet, F. Fabbri, E. Fort, J. Krebs, J. Langlet, L. Martin-Deidier, A. Montaguti, E. Menapace, M. Motta, G.C. Panini, G. Reffo, P. Ribon, Tran Quoc Thuong, M. Vaccari, A. Ventura: "An Evaluated Fission Product Data Library for Super-Phenix Project", presented at the Int. Conf. on Neutron Physics and Nuclear Data for Reactors and Other Applied Purposes", Harwell, 25-29 Sept. 1978.

/2/ A. Montaguti, G.C. Panini, M. Vaccari: "Multigroup Cross Sections of 63 Fission Product Nuclei from Different Nuclear Data Files", CNEN rep. RT/FI(78)16.

/3/ A. Montaguti, M. Vaccari: "Tables of Neutron Resonance Data and Parameters for 63 Fission Products Evaluated and Compiled at the Bologna Centre (1977)", CNEN rep. RT/FI(78)23.

/4/ M. Motta: "The Role of Desk Calculators in Nuclear Data Evaluation", IAEA Winter Courses on Nuclear Physics and Reactors - SMR/43-15, Trieste (febr. 1978).

.7 Evaluation of Actinides (Neutron Data)

G. MAINO(°), T. MARTINELLI, E. MENAPACE, M. MOTTA, M. VACCARI, A. VENTURA

Within the framework of national programs on Actinide evalution in thermal and fast reactors and of a European Cooperation (mainly CNEN-CEA) and under an IAEA research agreement (no. 2114/CF) the evaluation of the following isotopes has been undertaken:

a) Pu-241, Pu-242, Am-243, Cm-242 in the resonance region;

b) Am-241 over the neutron energy range from thermal to 15 MeV, to be completed in Spring 1979.

The evaluation of Pu-242 cross sections in the resolved resonance region was sent as a contribution to the Brookhaven Specialist Meeting on higher Pu and Am isotope data (November 1978) /1/ .
The evaluation of nuclear data on Pu-241, Am-241 and Cm-242 will be published as CNEN reports in 1979.

/1/ E. Menapace, M. Motta, A. Ventura: "Pu-242 Evaluation in the Resolved Resonance Region", contribution to the Specialist Meeting on the Nuclear Data of Higher Pu and Am Isotopes", (Brookhaven, Nov. 20-22, 1978).

.8 Nuclear Data Library

G.C. PANINI, M. VACCARI, A. MONTAGUTI (part-time)

Nuclear Data from the LDN libraries were supplied on request of both CNEN requestors and external users. The information were transmitted in various forms (tape, listing, cards or graphs): successive interactions with the requestors often occurred.
The home evaluated F.P. data have been added to the library and have

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(°) Guest researcher

been sent to the following laboratories: NEA (Saclay), ECN (Petten), JAERI (Tokyo), HEDL (Hanford). The following evaluated data of foreign origin were also included in the library: JNDL-1, JNDL-2, RCN-2, RCN-2 Rev.
The addition of these new data gave the opportunity of a new structure of the libraries of the LDN, based upon high density tapes (6250 bpi), in order to reduce the high number of tapes (about 60) in charge and to have more than one security copy of the same data.
As far as the experimental data is concerned, nuclear data for actinides were obtained from the NEA.

.9 Multigroup Cross Sections

G.C. PANINI, M. VACCARI, A. MONTAGUTI (part-time)

A critical version of some CARNAVAL multigroup set lead to recalculate the corresponding isotopes. Multigroup cross sections were in addition calculated in order to satisfy the requestors from both inside and outside the CNEN. The data were requested for activation calculations for Montecarlo calculations for the Caorso power plant in the framework of CNEN-ENEL agreement for the thermal reactors, for CANDU-like reactors calculations and for structural material check up.
The FOURACES code have been completed in the ENDF/B and UKNDL sections; the KEDAK section is near the completion for which the MIGROS code has been implemented on the CNEN computer system. This task required a particular effort in simulating a direct-access KEDAK library which was not furnished together with the code when requested from KFK.
Six month-man were employed in implementing MC^2-2 in cooperation with LFSR. Some interface codes were written in order to obtain compatibility with the other codes of the computation system. Due to the lack of the code SDX, in which the heterogeneous case is included, the MC^2-2 work has been delayed.

1.10 Total Neutron Cross Section Measurement in ^{91}Zr and ^{96}Zr

C. COCEVA, P. GIACOBBE, M. MAGNANI

Transmission measurements of metallic samples of natural Zr were analyzed for neutron energies below 2.5 keV. An effective temperature of 313 ± 13 °K for the oxide samples at a room temperature of 20 ± 2 °C was deduced by comparing metal and oxide transmission data. The final

results for ^{91}Zr were presented at the International Conference on Neutron Physics and Nuclear Data for Reactors and Other Applied Purposes, Harwell, 25 to 29 September 1978, with the following abstract." The results of time-of-flight measurements of neutron transmission, neutron capture cross section, and of γ-spectra from neutron capture in single resonances are reported. They concern the determination of resonance parameters and potential scattering radius of ^{91}Zr , and the deduction of the s- and p-wave strength functions. The measurements were performed with high statistical accuracy in several enriched and natural samples. Details on the characteristics of the analysis are given. A consistent set of parameters resulted from the ensemble of such measurements; comparison with some results of previous works is made".
The analysis of transmission measurements of ^{96}Zr enriched samples was temporarily stopped to settle definitly the question of the oxide effective temperature; the analysis will be resumed next year .

1.11 Experimental Aspects of the Statistical Theory of Nuclear Spectra Fluctuations

C. COCEVA, M. STEFANON

A research aimed at describing the effect of experimental limitations on the statistical behaviour of measured neutron resonance parameters was completed and is to be published in Nucl. Phys.
The subject and the results of this work are the following.
A measurements of neutron resonance parameters of ^{156}Gd was performed, up to a neutron energy of 2240 eV, in an attempt to realize favourable conditions for testing statistical theories of spectra fluctuations. The experiment was carried out at the electron linear accelerator of Geel (Euratom). The comparison between the measured resonances and the predictions of the random-matrix theory was faced by analysing also the set of $g\Gamma_n$ values and by including in the theoretical model the effects of the finite observability threshold and of the presence of resonances excited by p-wave neutrons. Average spacing, $D=35.5\pm2$ eV, s- and p-wave strength functions, $10^4 S_o=1.83\pm0.34$, $10^4 S_1=2.1\pm0.5$, were determined without assigning the parity of the resonances.
The statistical properties of the sequence of the measured resonance parameters were found to be in agreement with the predictions of the Gaussian Orthogonal Ensemble. The "purity" of a sequence of resonances was found to be better determined by measuring their $g\Gamma_n$ values than by the use of purity tests based on their energies. The limitations to the detectability of possible deviations from the theory are discussed.

1.12 Low-Energy Gamma Spectra from Resonance Neutron Capture in ^{191}Ir

C. COCEVA, P. GIACOBBE

The initial (resonance) spin dependence of low energy gamma-ray intensities was re-determined by extending the analysis to the gamma spectra of more resonances, whose spin had been previously assigned by us. This was particularly needed to improve the statistical accuracy of the estimate of the low-lying level populations in the case of resonance-spin J=1.

Table 1 gives, for 21 gamma transitions between low-lying states of ^{192}Ir, the possible spin values I of the decaying level, as determined by our analysis.

Table 1

E_γ(keV)	I	E_γ(keV)	I
118.8	$\geq$ 3	193.7	3,4,5
124.8	3	206.2	3
126.9	$\geq$ 5	216.9	3
144.9	4,(5)	222.2	1,2
148.8	2,3	226.3	2,3
151.6	4	250.7	3
179.0	1,2	254.3	2
180.7	1,(2)	259.3	3,4
183.6	3	261.9	3
187.5	1,2	267.4	(2),3
190.2	(1),2,3,4		

These results, and the spin assignment of 10 resonances of ^{191}Ir were presented at the Third International Symposium on Neutron Capture Gamma-Ray Spectroscopy and Related Topics, BNL, September 18-22, 1978.

This work is part of an international effort on the nuclear spectroscopy of ^{192}Ir, involving also experimental groups of Fribourg, Riga, Brookhaven, Argonne, Livermore and Munich.

1.13 Nucleon Radiative Capture Through Collective M1 Excitation

F. SAPORETTI, G. GUIDOTTI (°), F. FABBRI

The direct-semidirect model for nucleon radiative capture proceeding via giant E1 and E2 resonance states is extended to account for capture through collective M1 excitation. The $^{208}Pb(N,\gamma_o)$ and $^{140}Ce(N,\gamma_o)$ reactions are investigated in the 2-10 MeV energy interval. The model proves to be an appropriate framework for discussing the E1-M1 and E2-M1 interference processes, giving useful suggestions as to effects arising from the presence of the M1 collectivity.
The results are reported in papers /1/, /2/ and /3/.

References

/1/ F. Saporetti, R. Guidotti: "Nucleon Radiative Capture Through Collective M1 Excitation", Lettere al Nuovo Cimento 22 (1978) 202.

/2/ F. Saporetti, R. Guidotti: "Collective M1 Excitation on Photon Angular Distributions from the $^{140}Ce(n,\gamma_o)$ Reaction", contribution to the "3rd International Symposium on Neutron Capture Gamma Ray Spectroscopy and Related Topics", BNL, Upton, Sept. 18-22, 1978.

/3/ F. Saporetti, R. Guidotti: "Giant M1 Resonance in the Direct--Semidirect Model for Nucleon Radiative Capture", Nuclear Physics A311 (1978) 284.

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1.14 Investigation of Angular Distributions by the E1-E2 Direct-Semidirect Model

F. SAPORETTI, G. LONGO, R. GUIDOTTI(°), F. FABBRI

The direct-semidirect model for dipole and quadrupole fast nucleon radiative capture has been developed to calculate the angular distributions of emitted photons. Application has been made to the $^{208}Pb(N,\gamma)$ reaction in the 6-40 MeV energy interval. It has been shown how the model can supply a valuable aid in analysing angular distribution data and in obtaining indications as to presence of isoscalar and isovector giant quadrupole resonances.
The results are published in /1/ and /2/

References

/1/ F. Saporetti, G. Longo, R. Guidotti: "Investigation of Angular Distributions by the E1-E2 Direct-Semidirect Model", Phys. Letters 76B(1978)15.

/2/ G. Longo, F. Saporetti, R. Guidotti: "Interference between Dipole and Quadrupole Radiative Capture of Fast Nucleons", Nuovo Cimento 46A (1978) 509.

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2.1 Lifetime of Nuclear States

F. MALAGUTI, A. UGUZZONI, E. VERONDINI

The blocking technique has been applied to a direct measurement of the lifetime of the 12.441 MeV state in ^{28}Si, excited as a compound state in the $^{27}Al(p,\alpha)^{24}Mg$ resonance at $E_p = 887$ keV. The obtained value /1/ is $\tau = 38^{+10}_{-9}$ as, the corresponding total width $\Gamma = 17^{+5}_{-4}$ eV is in good agreement with the value deduced from (p,α), (p,γ) and (α,γ) yields /2/.

References

/1/ F. Malaguti, A. Uguzzoni, E. Verondini: to be published in Phys. Rev. C

/2/ J.W. Maas et al.: Nucl. Phys. A301, 213 (1978).

3. ISTITUTO NAZIONALE DI FISICA NUCLEARE - SEZIONE DI CATANIA - CENTRO SICILIANO DI FISICA NUCLEARE E STRUTTURA DELLA MATERIA - Corso Italia, 57 - 95129 CATANIA (Italy)

3.1 Measurements on Neutrons Polarization from $H^3(d,n)He^4$ at E_d=700 keV

G. CALVI, Seb. CAVALLARO, A.S. FIGUERA, R. FONTE, C. MILONE

The polarization of neutrons from the $H^3(d,n)He^4$ at E_d=0.7 MeV and 0°, 10°, 20°, 30°, 40°, 50° emission angles has been measured by means of a liquid Helium polarimeter. The results indicate that waves other than S' contribute to the above reaction.

3.2 Fission Cross Section of ^{238}U Induced by a Coherent Photon Beam from 1000 MeV Electrons

V. BELLINI, V. EMMA, A.S. FIGUERA, S. LO NIGRO, C. MILONE, G. PAPPALARDO and G. BOLOGNA (°)

The photofission yields of ^{238}U induced by a coherent bremsstrahlung beam from 1000 MeV electrons striking a diamond single crystal have been measured.
The experiment has been performed at sixteen different energies of the main peak of the photon spectrum, in the energy range between 220 MeV and 550 MeV, by detecting the fission fragments with glass sandwiches. The photofission cross section has been deduced from the experimental yields by using an appropriate unfolding method. The obtained curve clearly shows a first resonance centred at photon energy K≈320 MeV with a FWHM 140 MeV, while there is only a hint of a second resonance at K≈750 MeV. Information on the energy dependence of the nuclear fissility from 100 MeV to 1000 MeV has been deduced. It has been found that the photomesonic model of the fission process permits to explain the energy dependence of our photofission cross section if a nuclear fissility increasing with photon energy is assumed.

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3.3 Deep Subthreshold Photofission of ^{238}U

G. BELLIA, L. CALABRETTA, A. DEL ZOPPO, G. INGRAO, E. MIGNECO
and R.C. BARNA'(°), D. DE PASQUALE (°)

An integral yield measurements on ^{238}U in the (3.8÷5.7) MeV energy range has been performed at the 13 MeV microtron of Catania University. The electron energy was measured using the microtron as a magnetic spectrometer and the position of the electron beam was defined by a copper circular aperture in front of the bremsstrahlung converter; fission tracks detectors consisted of 60 μm thick makrofol foils. Although the bremsstrahlung spectrum has a smoothing action on the sub-threshold photofission cross section, in this measure two effects are clearly observed: the so-called "isomeric shelf" in the (3.8÷4.5) MeV energy range and two bumps at 4.8 MeV and 5.3 MeV indicating the presence of partially damped vibrational states in the second well of the fission barrier.

3.4 $^{12}C(^{6}Li,d)^{16}O$ Reaction in the 20-34 MeV Incident Energy Range

A. CUNSOLO, A. FOTI, G. PAPPALARDO, G. RACITI
and N. SAUNIER (°°)

The reaction $^{12}C(^{6}Li,d)^{16}O$ has been studied in the 20-34 MeV incident energy range. Angular distributions have been taken at 28 MeV and 34 MeV incident ^{6}Li energies; the data have been analyzed in terms of Hauser-Feshbach and exact finite range distorted-wave Born-approximation theories. The extracted α spectroscopic strengths are compared with the predictions of SU(3) shell model.

3.5 Energy Dependence of the Quasi-Free $^{9}Be(^{3}He,\alpha\alpha)^{4}He$ Reaction Near the Coulomb Barrier

N. ARENA, D. VINCIGUERRA, M. LATTUADA, F. RIGGI, C. SPITALERI

The coincidence detection of two α-particles emitted in the $^{9}Be(^{3}He,\alpha\alpha)^{4}He$ reaction shows evidence for quasi-free processes even for low incident energies. At 2.5 and 2.7 MeV the impulse distribution of the α-cluster in ^{9}Be can be deduced in the PWIA.

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(°°) Département de Physique, CEN Saclay

The excitation function has been obtained at $\theta_{c.m.}=90°$ together with that of the sequential reaction proceeding through the 16.6 and 16.9 MeV levels of ^{8}Be. The behaviour of the excitation functions for energies around the Coulomb barrier is also discussed.

3.6 Prevalence of the ^{8}Be Formation in the $^{7}Li(d,\alpha\alpha n)$ Reaction at $E_d=7.0$ MeV

N. ARENA, Seb. CAVALLARO, R. POTENZA
and V. D'AMICO (°), G. FAZIO (°), S. FEMINO' (°), G. GIARDINA (°),
S. JANNELLI (°)
and M. LOMBARDI (°°)

The $^{7}Li(d, \alpha\alpha n)$ reaction (α,α) bidimensional spectra at $E_d= 7.0$ MeV $\theta_1=82$ and θ_2 variable from 50° to 90° have been measured and projected on the relative kinematical curves. The $^{5}He_{g.s.}$ and ^{9}Be (17 and 20 MeV regions) contributions have been separated and evaluated.

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(°°) Laboratori Nazionali di Legnaro

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4.1 Further Investigation of ^{98}Tc

M. BINI, A.M. BIZZETI-SONA, P. BLASI, E. FOCARDI, N. TACCETTI

The ^{98}Tc nucleus has been produced with the ^{98}Mo(p,nγ)^{98}Tc reaction at the 7.5 MV Van de Graaff accelerator of Laboratori Nazionali di Legnaro of INFN. New information on the energy levels and γ-ray transitions, in addition to those reported in ref./1/, have been obtained from excitation functions and γ - γ coincidence measurements, they are summarised in fig. 1. Further information have been derived from the energy and intensity balance in γ-ray cascades.
In particular, indirect evidence for a transition from the 81.6 keV level to the 73.4 keV one, follows from the fact that the intensity of the 122 keV γ-ray (feeding the 81.6 keV level) is about 6 times larger than the one of the 59.8 keV γ-ray. The calculated conversion coefficient for the 59.8 keV transition (of M1 or E1 character, as implied by the short lifetime of the parent level) is < 1.2. As a consequence, an alternative decay of this level should exist.
No decay to the ground or to the first excited state has been observed. The absence of coincidence between the 122 keV and the 43 keV transition suggests that the alternative decay of the 81.6 keV level is trapped in a state of long lifetime (probably the 20.3 μs isomer) before feeding the 65.4 keV level.
Therefore, the isomeric state of 20.3 μs mean life is most probably the one at 73.4 instead of the state at 90.8 keV, as proposed in the ref./2/.

References

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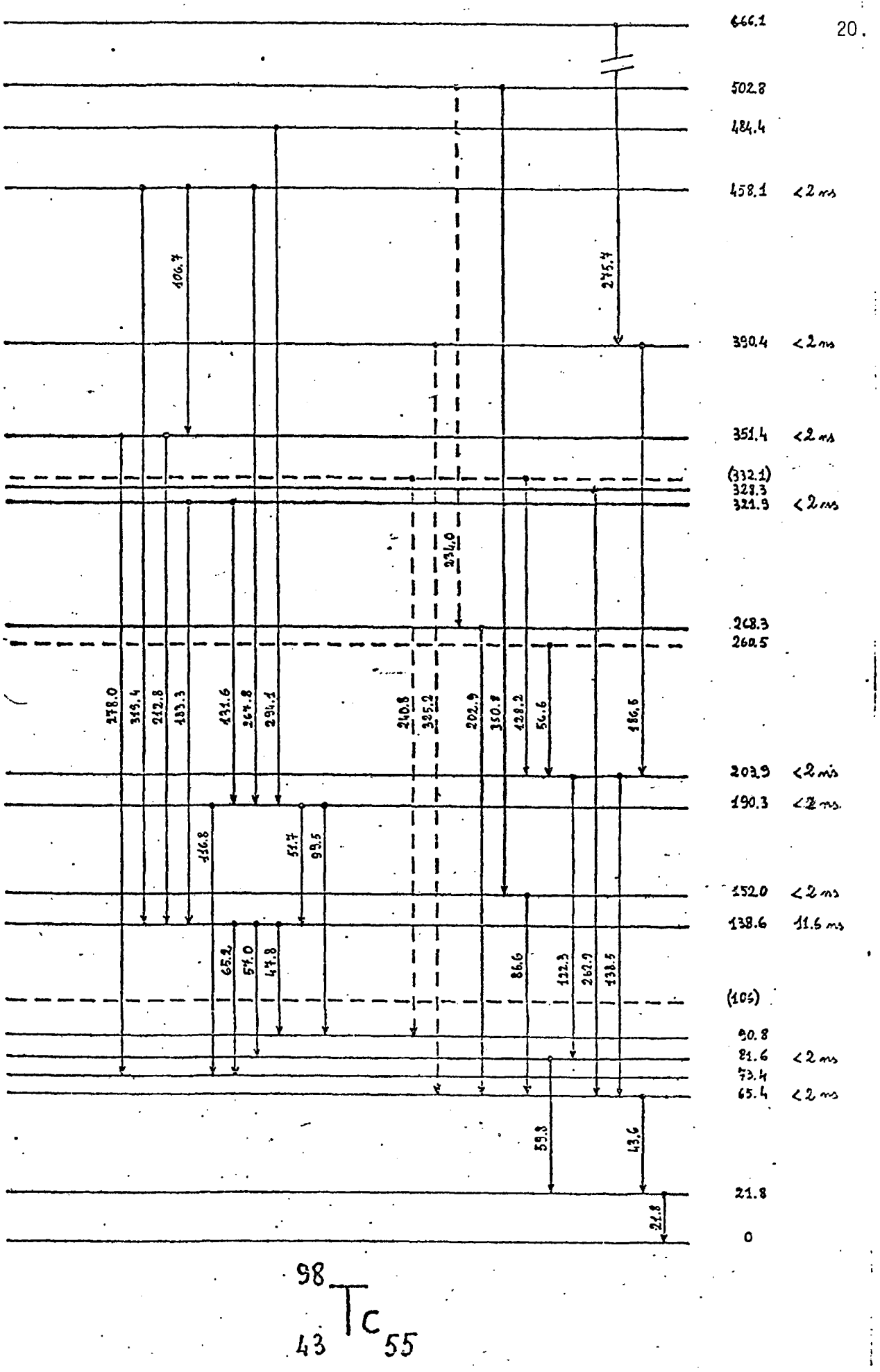
/2/ D.E. Miracle, E.C. Hagen, B.D. Kern: Phys. Rev. 16 C (1977) 111.



98
C
43 55

Fig. 1

4.2 New Isomeric Level in ^{100}Tc

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The previous investigation /1/ of ^{100}Tc with the ^{100}Tc(p,nγ)^{100}Mo reaction has been extended to higher proton energies, E=6.5 MeV and 6.8 MeV. At these energies a new isomeric transition with energy E_γ = 43.3 keV has been observed. This transition has been attributed to the decay of the 6^+ level at 244 keV to the 4^+, 12 μs isomeric level at 200.6 keV.

The presence of the higher-lying isomer is apparent from the decay curve of the 200.6 keV level, which deviates downwards from a pure exponential decay at the short-time side.

The 43.3 keV γ-ray of ^{100}Tc cannot be distinguished in energy from the 43.6 keV, 20.3 μs isomeric transition of ^{98}Tc, produced with the ^{98}Mo(p,nγ)^{98}Tc reaction on ^{98}Mo residue in the enriched ^{100}Mo target. The fig. 1 shows the time spectrum of the 43 keV radiation after subtraction of the 20.3 μs contribution of the ^{98}Tc, 43.6 keV transition. From a preliminary analysis of the experimental results, a mean life $\tau_m \approx 5 \pm 1$ μs can be attributed to the 244 keV level. In addition, measurements of γ-γ coincidences have been performed at E_p = 4 MeV in order to investigate the low-energy level scheme of ^{100}Tc. The γ detectors used for the coincidence measurements were a Ge(Li) counters of about 60 cm^3 volume and an intrinsic Ge counter. The results, summarised in the fig. 2, are in agreement with those obtained by Heck at al./2/ with the ^{99}Tc(n,γ)^{100}Tc reaction and by Slater and Booth with the ^{99}Tc(d,p)^{100}Tc reaction /3/.

The measurements have been carried out at the 7.5 MV Van de Graaff accelerator of Laboratori Nazionali di Legnaro and at the 3 MV Van de Graaff of the Sezione di Firenze of INFN; in both cases, a pulsed beam in the microsecond range has been produced by means of an electrostatic chopper.

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/2/ D. Heck, J.A. Pinston, H. Boerner, F. Braumandi, P. Jeuch, H.R. Koch, W. Mampe, R. Roussille, K. Schrecenbach: Kernforshungzentrum Karlsruhe KFK 2223 (1975) p. 47.

/3/ D.N. Slater, W. Booth: Nucl. Phys. A267 (1976) 1.

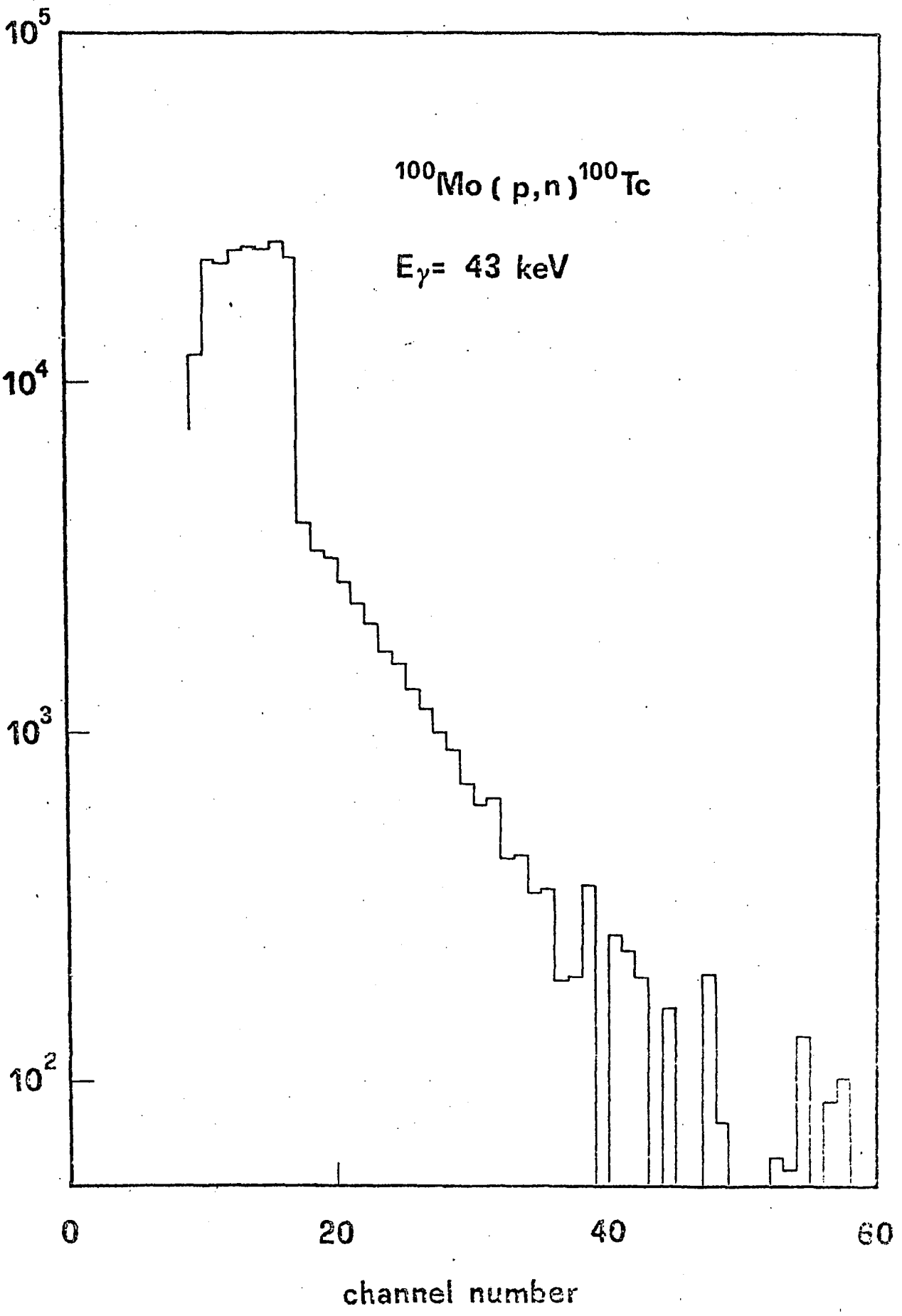

Fig. 1 - Time spectrum of the 43 keV radiation after subtraction of the contribution of the 43.6keV isomeric transition of ^{98}Tc. The time calibration is 0.664 μs/channel.

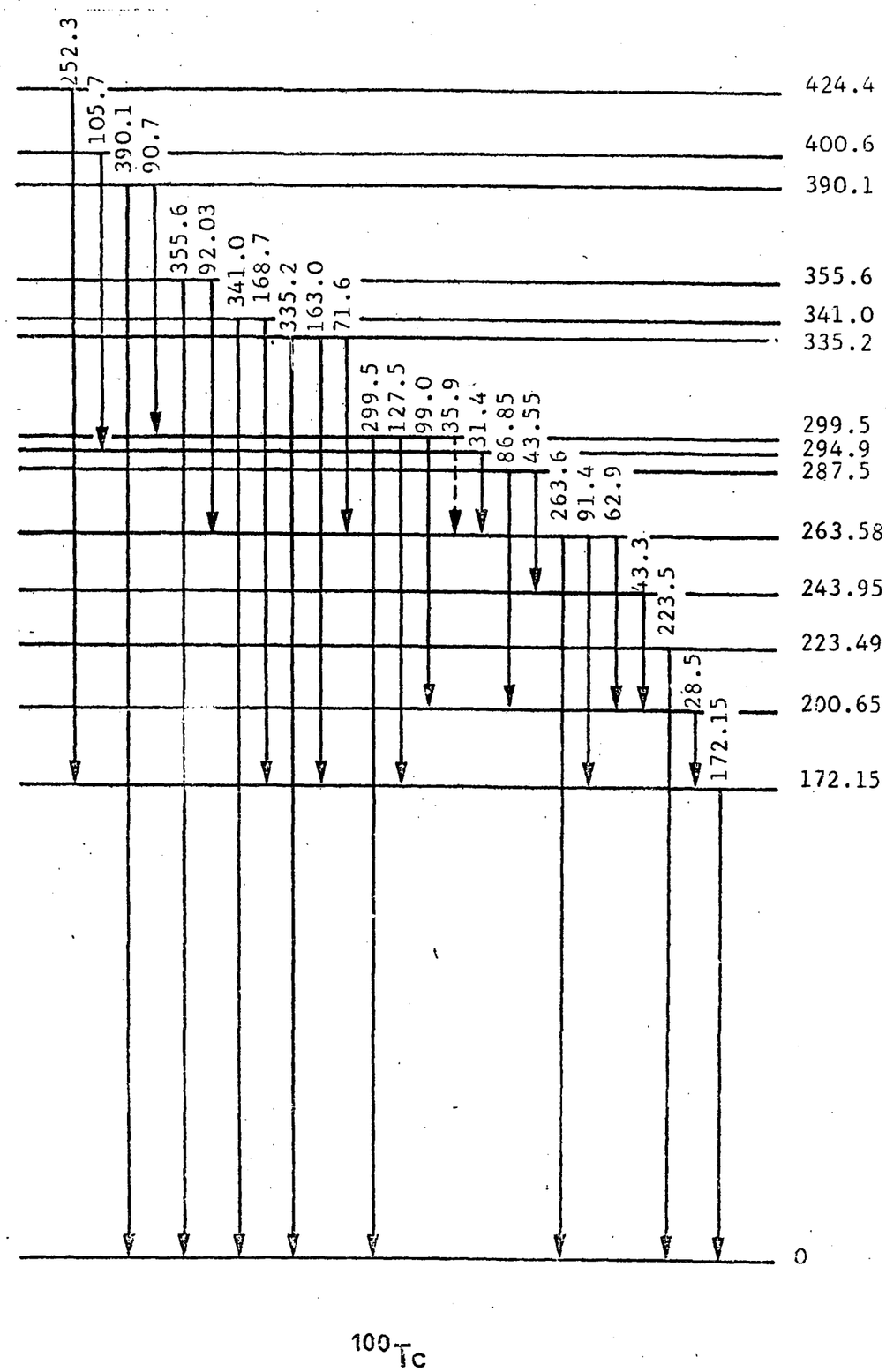

Fig. 2 - Low lying level scheme of ^{100}Tc below 424 keV.

4.3 The $0_1^+ - 0^+$ Electric Monopole Transition in ^{112}Cd

A. GIANNATIEMPO, G. LIBERATI, P. SONA

The low -lying levels of ^{112}Cd have been populated in the decay of ^{112}In ($T_{1/2} = 14^m$) produced through the $^{112}Cd(p,n)^{112}In$ reaction at $E_p = 6.5$-7 MeV. The intensity ratio of the E0 to E2 K - conversion electrons from the 0_1^+, 1223 keV level to the ground (0^+) and to the first excited state (2^+) has been measured. From the obtained result:

$$\frac{Ik\ (1223;\ 0_1^+ - 0^+)}{Ik\ (606;\ 0_1^+ - 2^+)} = 0.302 \pm 0.035$$

the ratio:

$$X\ (E0/E2) = \frac{B\ (E0:\ 0_1^+ - 0^+)}{B\ (E2;\ 0_1^+ - 2^+)} = 0.025 \pm 0.003$$

has been deduced.

The results have been compared with the predictions of current macroscopic models.

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5.1 Nondestructive Quantitative Analysis of Actinide Samples

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and G. SANDRELLI (°)

Samples of few milligrams of ^{232}Th, ^{233}U, ^{235}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{241}Am sealed in small vials of stainless steel or zircaloy were nondestructively analysed by passive gamma-ray counting. The results were further checked by neutron activation analysis (for ^{232}Th, ^{235}U, ^{238}U, ^{237}Np) and delayed neutron counting following fission (for all the samples).

For the passive gamma-ray analysis the spectra were taken on a 60 cc Ge-Li detector connected with a 4096 channel pulse-height analyzer. Since no information was available on the distribution of the sources within the vials, gamma-ray intensities were determined at different distances from the detector. This allowed us to determine an effective source to detector distance with good accuracy for every sample. Using calibrated sources the detector efficiency was carefully calculated as a function of energy and source to detector distance. Selfabsorption was determined experimentally in the samples by comparing the counting rates corrected for efficiency and gamma-ray branchings at different energies.

In some cases a first choice among different files of gamma-ray branchings has been allowed by selfabsorption determination and the consistency of the results obtained from gamma-rays emitted by different daughters.

Neutron activation analysis was performed to determine the activities of

^{233}Pa produced from $^{232}Th + n \longrightarrow {}^{233}Th \longrightarrow {}^{233}Pa \longrightarrow$

^{239}Np produced from $^{238}U + n \text{ --- } {}^{239}U \text{ --- } {}^{239}Np \longrightarrow$

^{238}Np produced from $^{237}Np + n \text{ --- } {}^{238}Np \text{ ---}$

^{103}Ru, ^{131}I, ^{140}La produced from $^{235}U + n$ --- fission

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Irradiations were performed in the thermal column of our L54 reactor and gold foils were used to monitor the flux.
In the case of delayed neutron counting analysis irradiations were performed near the core of the reactor in a neutron flux filtered by a thick boron shield, in order to strongly reduce the interference of thermal neutron fissionable impurities in samples as ^{238}U, ^{237}Np, etc... The neutron spectrum was determined by an integral method using twenty neutron reactions.
Delayed neutron counter was a BF_3 cylindrical detector embedded in paraffin, the efficiency of which was determined by counting delayed neutron emission from a calibrated ^{235}U source. For these measurements we derived the cross section data from the ENDFB/V file.
A comparison of the results allowed us to choose a consistent set of files for ^{232}Th, ^{235}U, ^{238}U, ^{237}Np, ^{239}Pu, ^{241}Pu, ^{241}Am.
The same could not be said for ^{233}U and ^{240}Pu, while for ^{238}Pu the shortage of nuclear data made any comparison impossible.