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 1980

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PROGRESS REPORT ON NUCLEAR DATA ACTIVITIES IN ITALY

for the period from January to December 1980

Compiled by

C. Coceva and E. Menapace

COMITATO NAZIONALE ENERGIA NUCLEARE,
Bologna, Italy

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CONTENTS

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

1.1 ^{100}Ru and ^{102}Ru Spectroscopy by means of Low-Energy γ-Rays from Resonance Neutron Capture

C. COCEVA, P. GIACOBBE, G. VALLONE (°)

The observation of the low-energy gamma-rays following neutron capture in s-wave resonances of the isotopes ^{99}Ru and ^{101}Ru supplied information on the low-excitation level spectra of the compound nuclei ^{100}Ru and ^{102}Ru, and in particular on the spin of these levels. The method is described in ref a); it is based on the measurement of the relative population probability of a given low-lying level by gamma cascades starting from neutron capture in resonant states of different spin. Such a probability depends on the spins of the initial and final states. The measurement is in general possible for s-waves resonances only. Provided the target is A-odd, s-wave neutrons induce resonances of two spins. The ratio of the population probability for the two spins is a quantity independent of the detection efficiency and consequently a measurable function of the spin of the populated level.

The effectiveness of the method is actually limited to Z-even targets for several reasons. These conditions are satisfied by the two Ruthenium isotopes.

Gamma spectra were measured for five ^{99}Ru and seven ^{101}Ru resonances having energies below 200 eV. The resonance spin assignments given in the literature, which are a fundamental information for applying the method, are fully confirmed by our spectra. Experimental details are contained in the 1979 Laboratory Activity Summary Report. Some difficulties were met with in normalizing gamma peaks to the corresponding resonances capture areas, mainly because of the unreliability of pile-up corrections. We got out of these difficulties by a cumbersome procedure which possibly introduced a bias in the measured population ratios, but did not cancel or distort the spin effect.

Fig. 1 shows a tentative plot of the measured population ratio of the observable peaks vs. the spin of the state for both isotopes.

The peak allocation into coherent decay schemes given in Tab. I and II is fully consistent with the indication of Fig. 1. It results also to be in

(°) Istituto di Fisica dell'Università di Bologna overall agreement with the main results of the preceding spectroscopical work on these nuclei. The data allowed in some cases giving narrower limits to the spin range found in the literature or to assign the spin definitively. Some assignments were also made in few cases for which no spin value was previously reported.

Figg. 2 and 3 give the resulting decay schemes, for ^{100}Ru and ^{102}Ru, respectively.

A paper containing the complete results of the experiment and some considerations on the character of the excitation schemes is in press.

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a) C. Coceva, P. Giacobbe, F. Corvi and M. Stefanon, Method of spin assignment of Bound Levels populated by (n,γ) Reactions, Nucl. Phys. A218 (1974) 61.

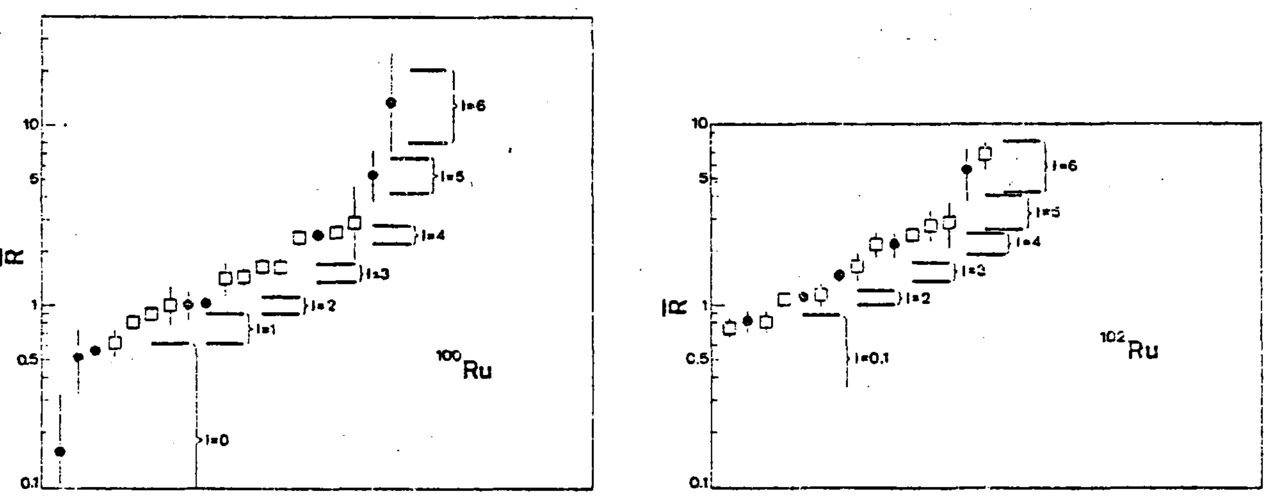

Fig. 1 - Tentative plot of the measured population ratios of the observable peaks vs. the spin of the state for Ru-100 and Ru-102.

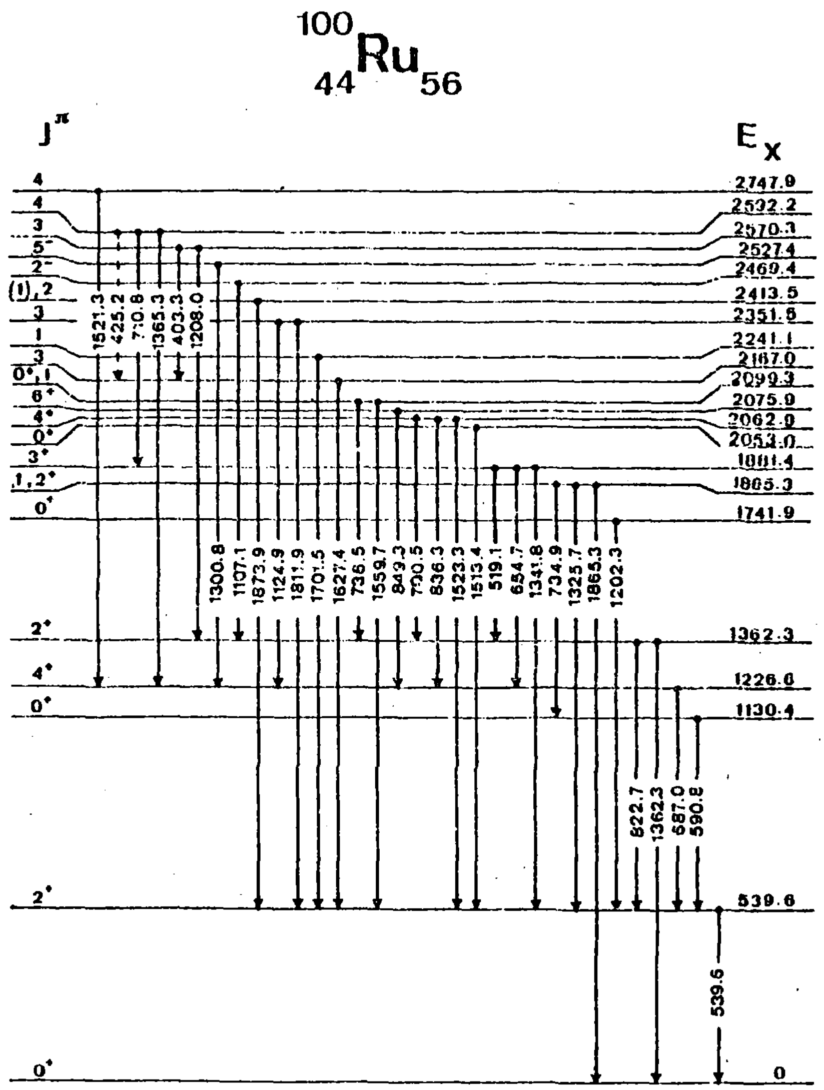

Fig. 2 - Excitation spectrum and decay scheme for ^{100}Ru.

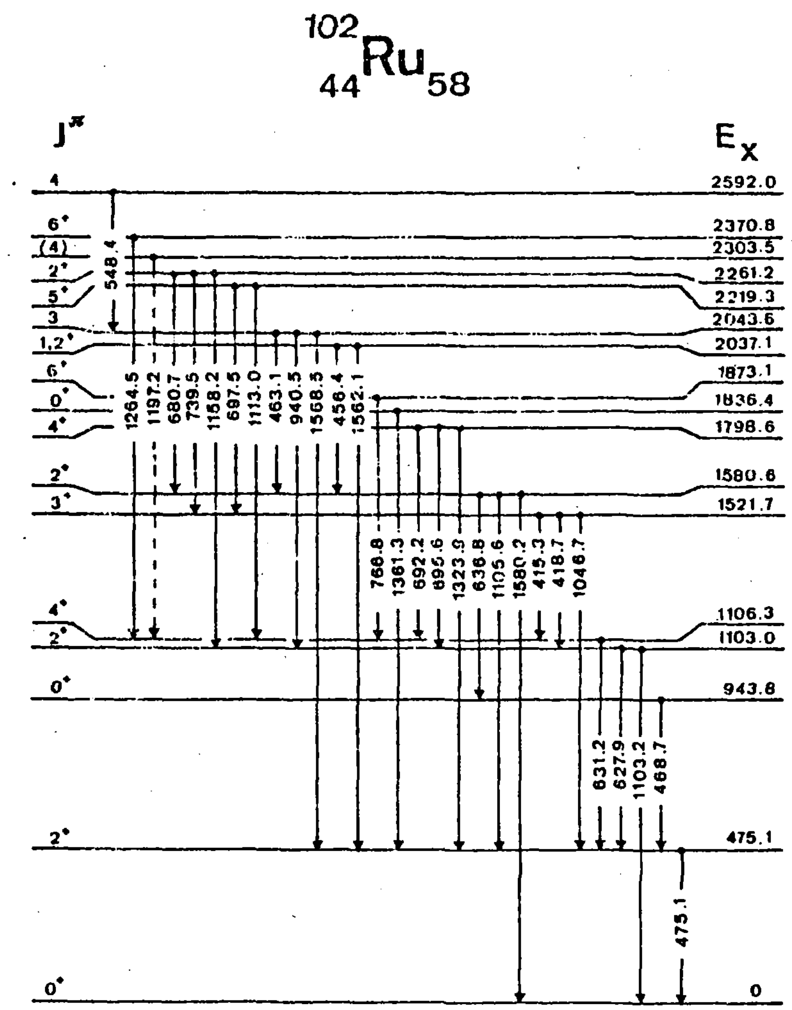

Fig. 3 - Excitation spectrum and decay scheme for ^{102}Ru.

Table 3

Gamma-line allocation and spin assignment in the ^{100}Ru level scheme

E_x (keV)	E_γ (keV)	E_f (keV)	R	$\bar{R}$	I^π Previous works	I^π Present work
539.6	539.6	0	1.29 ± 0.01	1.29 ± 0.01	2^{+} a,b	2
1130.4	590.8	539.6	0.50 ± 0.02	0.56 ± 0.02	0^{+} a,b	0
1226.6	687.0	539.6	2.44 ± 0.07	2.44 ± 0.07	4^{+} a,b	4
1362.3	1362.3 822.7	0 539.6	1.12 ± 0.11 1.00 ± 0.08	1.04 ± 0.06	2^{+} a,b	2
1741.9	1202.3	539.6	$0.16^{+0.16}_{-0.08}$	$0.16^{+0.16}_{-0.08}$	0^{+} a	0
1865.3	1865.3 1325.7 734.9	0 539.6 1130.4	0.95 ± 0.20 0.87 ± 0.06 0.91 ± 0.04	0.90 ± 0.03	$1,2^{+}$ a	1,2
1881.4	1341.8 654.7 519.1	539.6 1226.6 1362.3	1.91 ± 0.31 2.17 ± 0.60 1.63 ± 0.07	1.65 ± 0.07	$2^{+},3^{+}$ a (3^{+}) b	3
2053.0	1513.4	539.6	0.51 ± 0.20	0.51 ± 0.20	0^{+} a	0
2062.9	1523.3 836.3 * 700.5	539.6 1226.6 1362.3	2.47 ± 1.29 2.44 ± 0.27 2.20 ± 0.57	2.40 ± 0.24	$(3^{-},4^{+})$ b	4
2075.9	849.3	1226.6	13^{+10}_{-6}	13^{+10}_{-6}	6^{+} b	6
2099.3	1559.7 736.5	539.6 1362.3	0.66 ± 0.15 0.59 ± 0.13	0.62 ± 0.10	$1^{-},2^{-}$ a 2^{-} c	0,1
2167.0	1627.4	539.6	1.65 ± 0.21	1.65 ± 0.21	$1^{-},2^{-}$ a 2^{-} c	3
2241.1	1701.5	539.6	0.81 ± 0.06	0.81 ± 0.06	1,2 a	1
† 2351.5	* 1811.9 * 1124.9	539.6 1226.6	1.30 ± 0.36 1.62 ± 0.45	1.42 ± 0.28	-	3
† 2413.5	* 1873.9	539.6	1.01 ± 0.25	1.01 ± 0.25	-	(1),2
2469.4	1107.1	1362.3	1.01 ± 0.19	1.01 ± 0.19	2^{-} a	2
2527.4	1300.8	1226.6	$5.3^{+2.0}_{-1.6}$	$5.3^{+2.0}_{-1.6}$	(5^{-}) b	5
2570.3	* 1208.0 * 403.3	1362.3 2167.0	1.40 ± 0.38 1.46 ± 0.19	1.45 ± 0.17	2,3 c	3
2592.2	* 1365.3 * 710.8 * (425.2)	1226.6 1881.4 (2167.0)	2.54 ± 0.20 2.63 ± 0.28 2.21 ± 0.62	2.55 ± 0.16	2,3,4 c	4
2747.9	* 1521.3	1226.6	$2.9^{+1.6}_{-1.1}$	$2.9^{+1.6}_{-1.1}$	-	4

a - Berzins (1969) : β-decay
b - Lederer (1971) : ^{98}Mo (α,2nγ)
c - Rimawi (1974) : resonance neutron capture

† proposed new level

* new allocation.

Table 4

Gamma-line allocation and spin assignment in the ^{102}Ru level scheme

E_x (keV)	E_γ (keV)	E_f (keV)	R	$\bar{R}$	I^π Previous works	I^π Present work
475.1	475.1	0	1.20 ± 0.02	1.20 ± 0.02	2^{+} abcde	2
943.8	468.7	475.1	0.81 ± 0.10	0.81 ± 0.10	0^{+} bcd	0
1103.0	1103.2 627.9	0 475.1	1.07 ± 0.08 1.13 ± 0.10	1.09 ± 0.06	2^{+} abcde	2
1106.3	631.2	475.1	2.17 ± 0.11	2.17 ± 0.11	4^{+} abce	4
1521.7	1046.7 418.7 415.3	475.1 1103.0 1106.3	1.45 ± 0.16 1.47 ± 0.15 1.47 ± 0.86	1.46 ± 0.11	3 ab 3^{+} c	3
1580.6	1580.2 1105.6 636.8	0 475.1 943.8	1.34 ± 0.20 0.96 ± 0.11 1.09 ± 0.08	1.07 ± 0.06	$(1,2)^{b}$ $(1,2^{+})^{c}$ 2^{+} d	2
1798.6	1323.9 695.6 692.2	475.1 1103.0 1106.3	2.54 ± 0.54 2.41 ± 0.21 2.39 ± 0.40	2.42 ± 0.18	$(2,3,4)^{b}$ $(4^{+})^{c}$	4
1836.4	1361.3	475.1	0.81 ± 0.10	0.81 ± 0.10	0^{+} acd	0,1
1873.1	766.8	1106.3	5.5 ± 1.9	5.5 ± 1.9	6^{+} ce	6
2037.1	1562.1 456.4	475.1 1580.6	0.72 ± 0.10 0.93 ± 0.26	0.75 ± 0.10	2^{+} ac	0,1
2043.6	* 1568.5 * 940.5 * 463.1	475.1 1103.0 1580.6	1.56 ± 0.40 1.64 ± 0.37 1.71 ± 0.75	1.62 ± 0.26	2,3 f	3
2219.3	1113.0 697.5	1106.3 1521.7	2.71 ± 0.64 2.92 ± 0.97	2.77 ± 0.53	3 a, 5^{+} c	4,5
2261.2	1158.2 739.5 680.7	1103.0 1521.7 1580.6	1.06 ± 0.33 1.01 ± 0.25 1.23 ± 0.20	1.13 ± 0.14	$(1,2)^{b}$ $(1^{+},2^{+})^{c}$ 2^{+} f	2
2303.5	* 1197.2	1106.3	2.83 ± 0.80	2.83 ± 0.80	$(2)^{f}$	4,5
2370.8	1264.5	1106.3	6.8 ± 1.2	6.8 ± 1.2	$(5^{-})^{e}$	6
2592.0	* 548.4	2043.6	2.16 ± 0.35	2.16 ± 0.35	-	4

a - McGowan (1961) : β-decay
b - Gehrke (1969) : β-decay
c - Konijn (1969) : β-decay
d - De Frenne (1978) : β-decay
e - Lederer (1971) : ^{100}Mo (α,2nγ)
f - Rimawi (1974) : resonance neutron capture

* new allocation.

1.2 Statistical Properties of Neutron Resonances

M. STEFANON and P. GIACOBBE

Diagonalization of random matrices was performed in order to see how fast the classical statistical properties of the Gaussian Orthogonal Ensemble are reached by increasing the standard deviation of non diagonal matrix elements of simmetric matrices.

The main question is whether in real physical cases one is more likely to observe deviations from GOE behaviour of level energies or of reaction widths. We found convenient to work with GOE subspaces of the full N-dimensional space, which are allowed to interact by random Gaussian matrix elements. The model random matrices are then a sequence of diagonal blocks from GOE linked by random matrix elements $x_{ij}=x_{ji}$ with given standard deviation σ_x.

This kind of model has the advantage that it has a physical meaning and allows good statistical accuracy in testing eigenvector components, thanks to the possibility to exploit rotational symmetry in the subspaces.

Letting the standard deviation of the coupling matrix elements vary from 0 to 1 , we move from a situation in which there is a superposition of independent sets of eigenvalues of GOE matrices to the case in which a unique set of eigenvalues of a GOE matrix of larger dimension exists.

The initial situation corresponds to the case in which there is a symmetry in the hamiltonian a subdivision of the full space in subspace labelled by different values of some quantum numbers; the symmetry can then be gradually broken by residual random interaction. The full GOE case, with no privileged transformations, is reached for $\sigma_x=1$.

As expected, the Δ_3 Mehta-Dyson statistic applied to linearized eigenvalue sequences (i.e. unfolded for secular density variation), rapidly approaches the GOE limit as the interaction increases (Fig. 1). Furthermore, it is noticeable that even if the interaction is sufficiently low to lead to an expected Δ_3 sensibly larger than the GOE value, it happens that a considerable fraction of cases have Δ_3 in accordance with GOE, due to the large statistical fluctuations. This fact is in accordance with what we observed in the analysis of experimental sequences of neutron resonances in connection with missed or spurious levels [a], and makes the obtaining of information on actual interactions from statistical properties of level energies still more hopeless. A detailed study of the behaviour of Δ_3 with increasing N requires diagonalisation of very large matrices and good statistical accuracy. Calculations are still in progress.

As far as amplitudes are concerned it appears that also for weak coupling the diaviations from the Porter-Thomas law for individual widths are not very large except quite near to zero and it would be difficult to detect them in real experiments (Fig. 1).

An interesting result concerns the sum of widths over a particular subspace, i.e. the quantity

$$S_\lambda = \sum_1^n | < \phi_i | \psi_\lambda > |^2$$

where ϕ_i , i=1,2....n are the basis vectors of the first subspace and ψ_λ , λ=1,2.....N are the eigenvectors. Obviously S_λ will be 1 or 0 for zero coupling (σ_x=0) and will have approximately a χ^2_ν distribution with ν=n and average n/N for σ_x=1. In the case of weak, non-zero interactions it happens that the distribution of S_λ may simulate a χ^2_ν with low ν value and even the Porter-Thomas law (ν=1).

In this case the strength S_λ over the full subspace behaves as if it were a single vector component in GOE. More effort is required to get the asymptotic behaviour for very large matrices and to understant the physical implications of the present results.

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a) C. Coceva and M. Stefanon, Nucl. Phys. A315 (1979) 1.
C. Coceva and M. Stefanon, Proc. Int. Conf. on the Interactions of Neutrons with Nuclei, Lowell 1976, CONF-760715-P2, p. 1456.

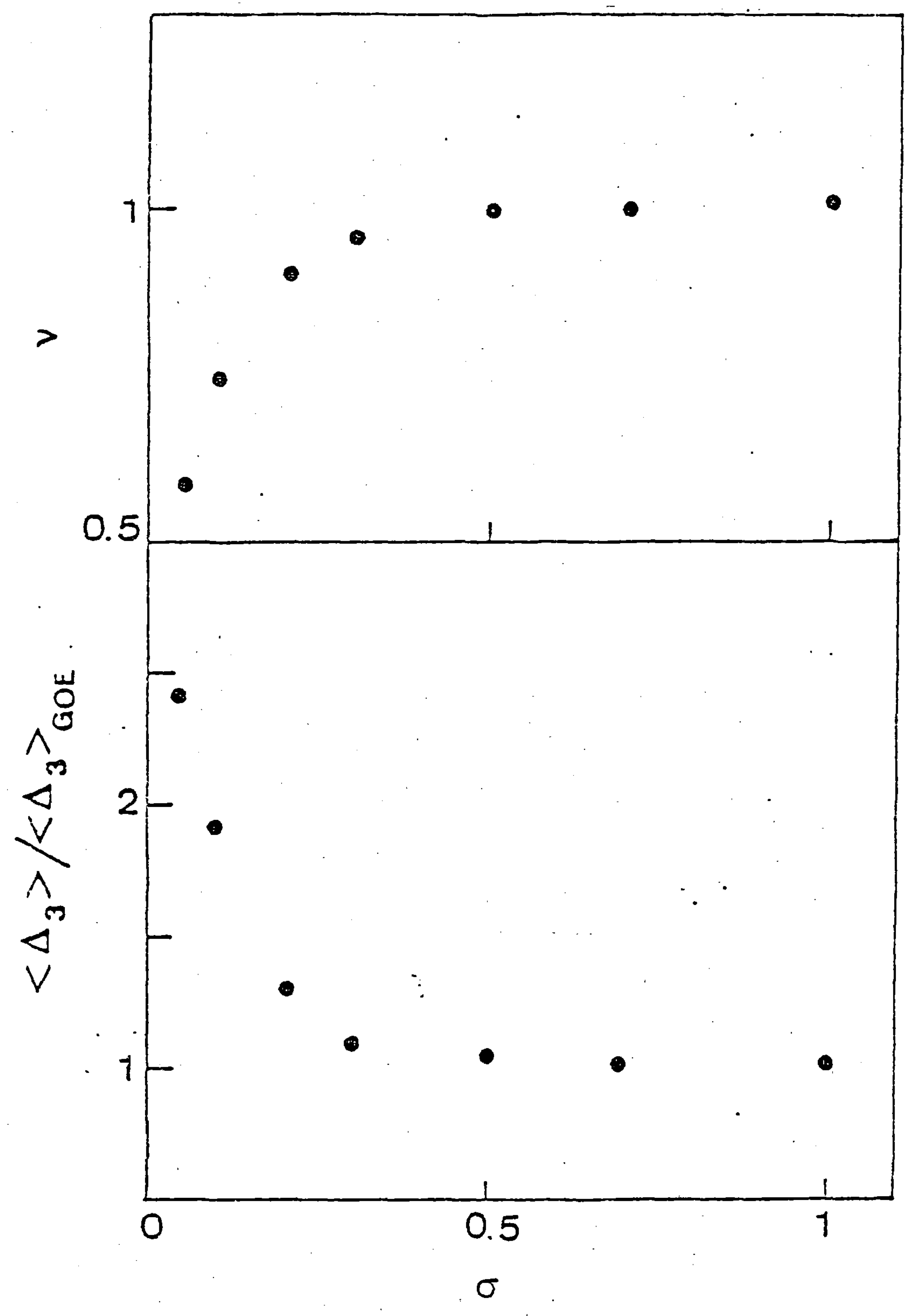

Fig. 1 - Number of degrees of freedom ν of squared amplitudes and Mehta-Dyson Δ_3 statistic in the case of model matrices 80x80 consisting of four 20x20 GOE blocks coupled with random matrix elements of standard deviation σ .

1.3 Neutron Capture γ-rays in Resolved ^{173}Yb Resonances

C. COCEVA and M. STEFANON

This work is within a co-operation with Oak Ridge National Laboratories. It consists in the study of a measurement of neutron capture γ-rays in resolved resonances of ^{173}Yb performed at Oak Ridge Electron Linear Accelerator (ORELA). The importance of this experiment is twofold: first because sensible positive correlations were found in this nucleus between neutron widths and partial radiation widths [a], second because it should be possible in principle to observe also in this nucleus the same effect recently discovered in ^{177}Hf [b,c] suggesting that in deformed nuclei collective features could be present also in compound nucleus resonances. In the measurement, spectra are obtained for 50 resonances up to a neutron energy of 530 eV. The analysis of low energy radiation allows to assigne the spin of the resonances and to normalize the results to obtain absolute intensity for primary radiation. The absolute intensity values are analyzed with statistical tecniques [b]; preliminary results show that the correlation previously observed between neutron widths and partial γ-widths is not statistically significant. At low neutron energy, partial widths seem to exibit a systematic k-dependence as observed in ^{177}Hf. A more detailed study is necessary to extend the analysis to higher neutron energy. The work is in progress.

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a) S.F. Mughabghab, in Nuclear Structure Study with Neutrons, Plenum Press 1974, p. 167.

b) M. Stefanon and F. Corvi, Nucl. Phys. A281, 240 (1977).

c) P. Giacobbe, M. Stefanon, Proc. Int. Conf. on Selected Topics in Nucl. Structure, Dubna 1976 and CNEN RT/FI(81)4.

1.4 Threshold Photoneutron Reactions

L. BIGNARDI, C. COCEVA, M. MAGNANI, A. MAURI

No isotopically enriched sample was available for new measurements during this year.
The activity was completely devoted to the improvement and the extension of the experimental installation at the electron linear accelerator.
Measurements have been performed to understand the main origin of background neutrons and to improve the shielding of detectors. As a result, a better control of the focussing conditions of the electron beam had to be devised. Also, the shielding around neutron detectors was completely redesigned.
Two new 10 m flight-paths were added, at 105° and 120° with the bremsstrahlung direction, respectively. All four flight-paths were equipped with an improved collimation and shielding system along the neutron channels. The necessary changes and additions to the electronic equipment and data acquisition system were made to obtain the possibility of measuring simultaneously four time-of--flight spectra.

1.5 Slow-neutron interaction with moderators studied with a pulsed neutron source

C. COCEVA, C. LABANTI

Possibilities have been studied of performing experimental checks of theoretical calculations about the scattering kernels of neutrons near thermal equilibrium in moderating materials. The method was considered of measuring the time behaviour of the neutron flux leaking out from moderators having different geometrical dimensions, bombarded with a pulsed neutron source.
The neutron are obtained from the direct beam of the linear accelerator by means of bremsstrahlung radiation on a thick Berillium target.
Several neutron detectors have been tried, with the requirement of being insensitive to the strong gamma background. A detector consisting of activated Zn S scintillator mixed with ^{6}Li was found satisfactory.

The effect of the gamma flash on the photomultiplier itself was found very disturbing. To avoid this difficulty, an experimental set up has been studied, with the multiplier phototube heavily shielded, removed from the scintillator. Such a set up minimizes also the disturbing effect of materials surrounding the moderator.
Measurements have been planned, first using H_2O at room temperature as moderator, in cylindrical geometry.

1.6 *Isobaric analog state excitation in proton radiative capture*

F. FABBRI, R. GUIDOTTI(^), F. SAPORETTI

The direct-semidirect model for proton radiative capture so far formulated is unable to describe the observed (p,γ) excitation functions in the energy region where the isobaric analog resonances are located. To remove this difficulty, an extension of the model to include capture proceeding via isobaric analog state (IAS) excitation is proposed in ref./a/ . The calculated results are compared with the measured 90° excitation curve of the $^{208}Pb(p,\gamma_1)^{209}Bi$ reaction, and satisfactory agreement is achieved (see Fig. 1). The model seems to provide a useful tool for study of the striking effects arising from IAS excitation.

Some additional IAR effects on the 90° differential cross section when the incident proton is "polarized" are also analysed by the model in ref. /b/ .

1.7 Asymmetry effects in (p,γ) reactions through isobaric analog states

F. FABBRI, R. GUIDOTTI(^), F. SAPORETTI

The extended direct-semidirect model /a/ is applied in ref. /c/ to investigate the asymmetry observed in the γ-ray angular distributions from the $^{208}Pb(p,\gamma)$ reaction. The model proves to be successful in providing a detailed description of the measured effects (see Fig. 2).

(^) Facoltà di Ingegneria dell'Università di Bologna.

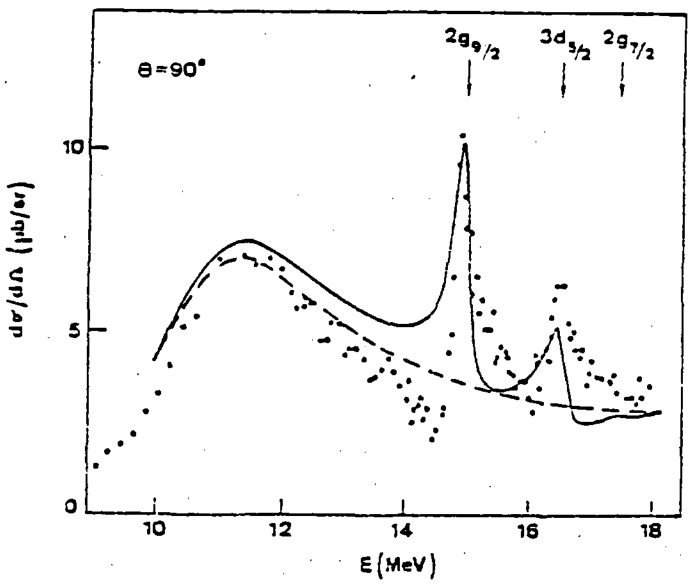


Fig. 1. Comparison between the measured and calculated 90° cross sections for the $^{208}Pb(p,\gamma_1)^{209}Bi$ reaction. Dashed curve: E1 (direct + semidirect via GDS) + E2 (direct + isoscalar and isovector semidirect) capture processes only. Continuous curve: E1+E2+E1 (semidirect via IAS) capture processes. The location of the single-neutron resonances involved in the reaction is indicated by arrows.

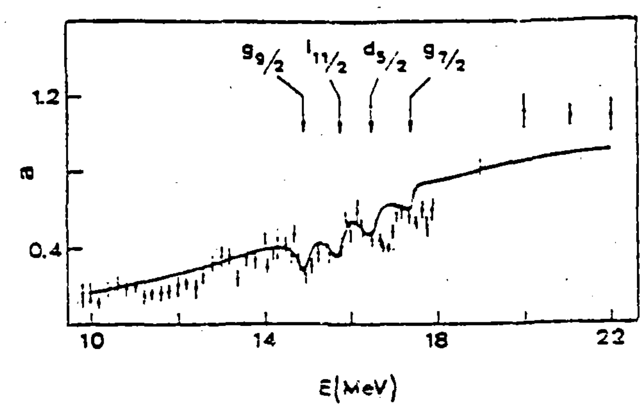


Fig. 2. Comparison between the asymmetry factor predicted by the model for proton capture to the $1h_{9/2}$ and $2f_{7/2}$ single-proton final states in ^{209}Bi and the experimental points for the $^{208}Pb(p,\gamma_0\gamma_1\gamma_2)$ reaction. The configurations of the single-neutron analog resonances involved in the calculations are indicated by arrows.

a) F. SAPORETTI and R. GUIDOTTI, "Isobaric analog state excitation in proton radiative capture", Nucl. Phys. A346 (1980) 449.

b) F. SAPORETTI and R. GUIDOTTI, "Collective M1 excitation effects on photon angular distributions from the $^{140}Ce(n,\gamma_0)$ reactions", contr. to Third Int. Symposium Nuclear Physics, Berkeley, August 24-30, 1980, pag. 213 and on Neutron capture Gamma-Ray Spectrometry, ed. E. Chrien and R. Kane, Plenum Press (1980), pag. 741.

c) F. SAPORETTI and R. GUIDOTTI, "Asymmetry effects in (p,γ) reactions through isobaric analog states", Phys. Lett. 90B (1980) 29.

1.8 Reaction mechanisms for nuclear radiative capture

F. FABBRI, G. LONGO

The development and refinement of models to throw light on nuclear structure and nucleon radiative capture mechanisms in the 5-20 MeV energy range has been continued in two directions:

a) Study by means of the direct-semidirect model of the interference between radiations of different multipolarities (see, e.g., ref. ([a])).

b) Investigation of the forms and strengths of optical potentials and particle-vibration couplings more adequate to satisfactorily reproduce experimental data in the energy range considered.

(a) G. Longo and F. Fabbri, "Angular distributions in photonucleon and nucleon radiative capture reactions", Phys. Lett. 84B (1979) 285.

1.9 Nuclear models

G. REFFO, F. FABBRI

The master equation approach [a] for preequilibrium has been reformulated with the inclusion of angular momenta conservation [b].

Pairing and shell corrections as well as spin distribution of particle hole level density are under investigation [c].

1.10 Nuclear model codes

G. REFFO, F. FABBRI

Preequilibrium reaction mechanism with angular momenta conservation and spin dependent particle hole level density have been introduced into our computer code chain for multiple emissions.

The fission competition with width fluctuation correction was introduced into our code chain.

1.11 Cross section evaluation

G. REFFO, F. FABBRI

Theoretical estimates of σ_T, σ_{el}, $\sigma_{n,n'}$, $\sigma_{n,\gamma}$, isomeric ratios, γ-ray spectra, γ-ray multiplicities were carried out based on statistical and generalized optical models for ^{241}Am [d] and ^{103}Rh, ^{93}Nb, ^{181}Ta, ^{197}Au [e]. (See figs. 1-3).

(a) J.M. Akkermans, H. Gruppelaar, G. Reffo: Phys. Rev. C. Vol. 22 p. 73 (1980).

(b) G.Reffo: to be published.

(c) G. Reffo, M. Herman: in progress.

(d) K. Wisshak, F. Käppeler, G. Reffo, F. Fabbri: submitted to Nucl. Sci. Eng.

(e) G. Reffo, F. Fabbri, K. Wisshak, F. Käppeler: to be submitted to Nucl. Sci. Eng.

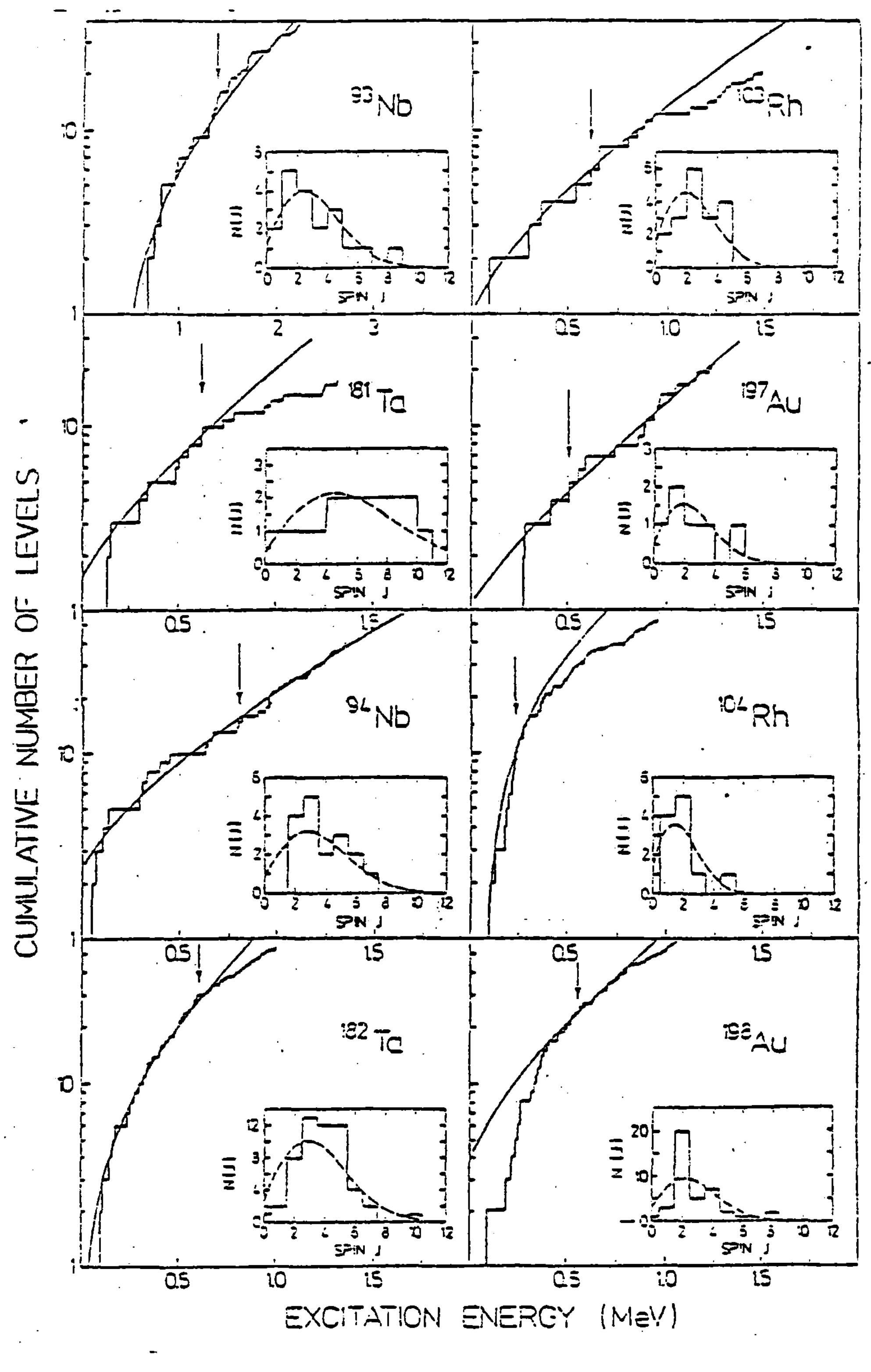


Fig. 1 - Cumulative number of levels as a function of excitation energy .

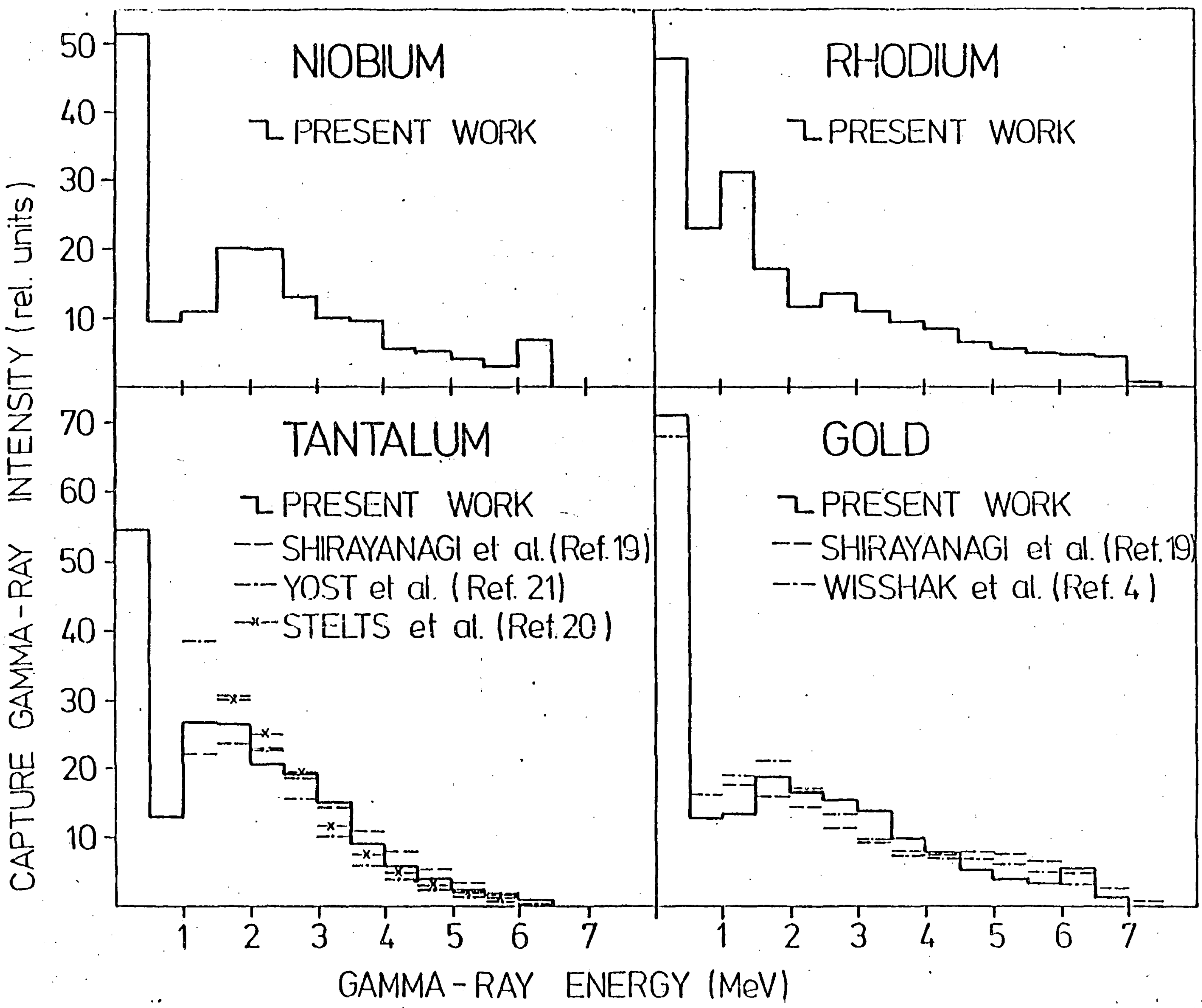


Fig. 2 . Capture gamma-ray spectra

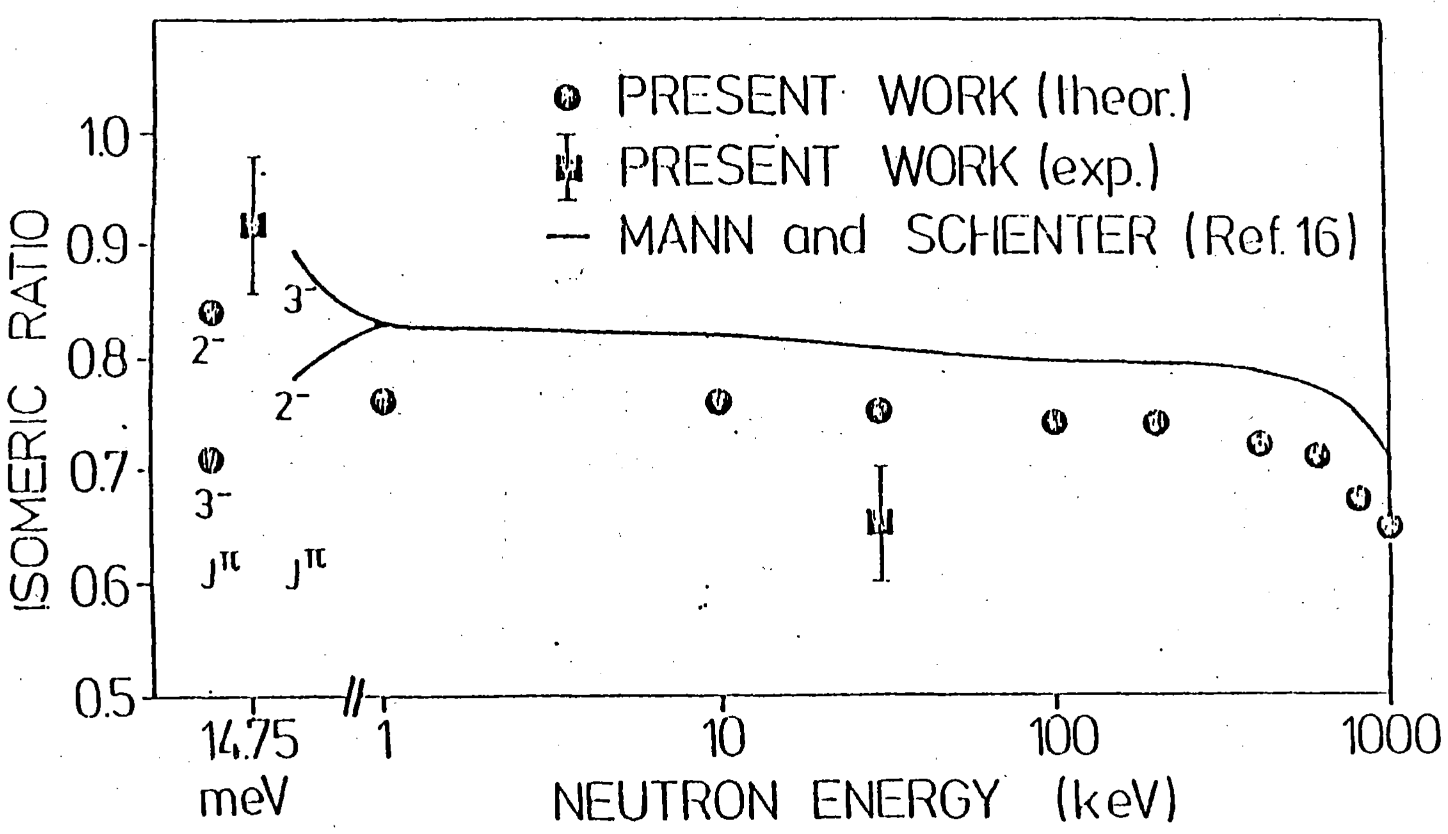


Fig. 3 - Am-241 Isomeric ratio

1.12 Blocking effect at finite temperature for deformed nuclei.

V. BENZI, G. MAINO, E. MENAPACE, A. VENTURA .

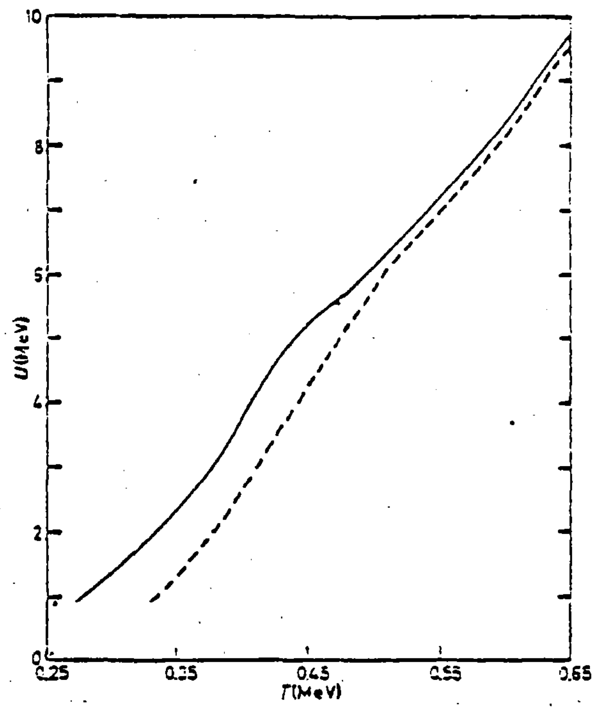
Within the framework of a grand canonical approximation, a microscopic formalism has been derived for the computation of thermodynamic functions, level densities in particular, of deformed nuclei with an odd number of neutrons and/or protons.
The formalism is based on a Nilsson potential plus a residual pairing interaction. In our procedure, odd systems have unpaired nucleons, which occupy single-particle levels above the corresponding chemical potential at zero or finite temperature.
These levels are then blocked in the pairing interactions and become inaccessible to excited pairs.

A comparison between blocked and unblocked formalism / a / is shown in Figs. 1, 2, 3 for excitation energy, U, nuclear entropy, S , and intrinsic state density, ω , of Gd-159 .

The blocked formalism, originally developed for nuclei in the lanthanide and actinide regions, has been extended to a large number of isotopes in the mass region $90 \leq A \leq 250$. (V.Benzi, G.Maino, E.Menapace, to be published) .

This work aims at the investigation and the correct application of macroscopic effective formulae for level density in cross section and emitted spectra calculations, including both statistical and pre-equilibrium components .

Fig. 1. – [illegible]Gd: excitation energy U vs. temperature T in the blocked (solid line) and the unblocked (dashed line) formalism. Ground-state gap parameters for the unblocked solution: $\Delta_N = \Delta_o = 0.898$ MeV, $\Delta_z = 0.765$ MeV.



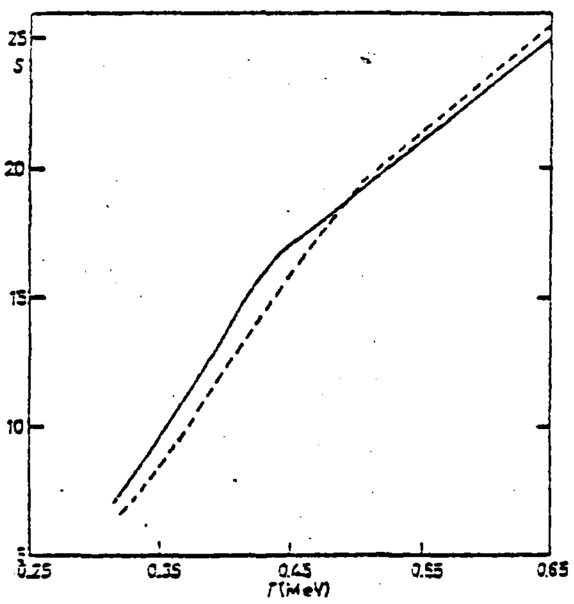


Fig. 2. – [illegible]Gd: total entropy S vs. temperature T in the blocked (solid line) and the unblocked (dashed line) formalism. Ground-state gap parameters for the unblocked solution as in fig. 3.

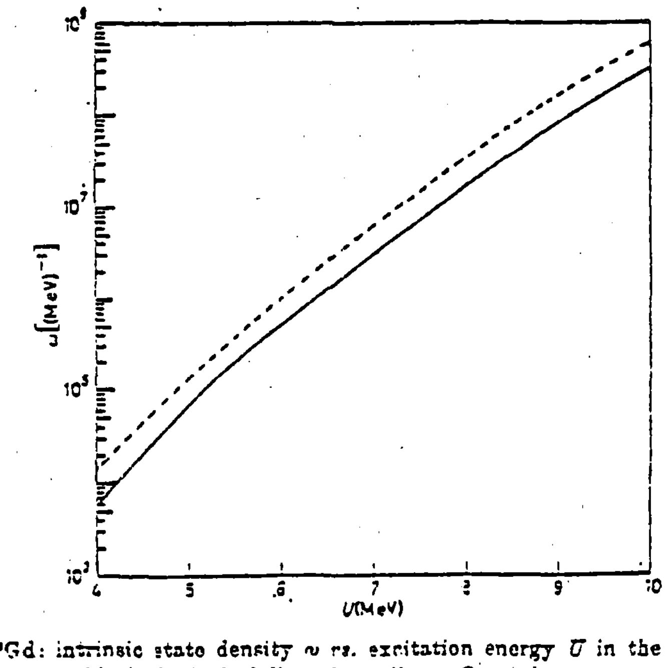


Fig. 3 – [illegible]Gd: intrinsic state density ω vs. excitation energy U in the blocked (solid line) and in the unblocked (dashed line) formalism. Ground-state gap parameters for the unblocked solution as in fig. 3.

1.13 Hartree-Fock-Bogoliubov calculations at finite temperature.

M. GIROD[(°)], A. VENTURA .

Nuclear level density calculations for spherical (Sn-116) and deformed nuclei (Gd-156) were performed at Bruyères-le-Châtel by means of a finite temperature Hartree-Fock-Bogoliubov formalism, using the D1 effective interaction of Gogny . Preliminary results indicate that some improvements are necessary in the formalism, in order to obtain a more compressed single particle spectrum around the Fermi energy .
The problem has been shortly discussed in /b/ .

1.14 Low energy spectra of actinide nuclei .

G. MAINO, T. MARTINELLI, E. MENAPACE, A. VENTURA

An analysis of low lying collective states of Uranium isotopes has been undertaken in the frame of the Interacting Boson Model . To this end, computer codes provided by O. Scholten (University of Groningen) have been modified and utilized. Preliminary results have been obtained. The activity will continue in 1981 and will be devoted to the model parametrisation in the actinide region and to the estimate of low-energy spectra when data are lacking or incomplete, for application to the calculations of actinide and fission product cross sections and emitted spectra.

1.15 Multilevel formalism for resolved resonance cross sections.

T.MARTINELLI, E. MENAPACE, M. MOTTA .

The temperature dependence of resolved resonance cross-sections for Pu-241 has been calculated. Reich-Moore parameters of ref.(i) have been transformed into Kapur-Peierls equivalent ones for Doppler broadening through usual Ψ and χ functions.
The energy dependence of transformation parameters has been investigated for next application. The work has been performed

(°) C.E.A., Bruyères-le-Châtel

(i) J.Blons, H.Derrien, Journal de Physique 37(1976)659 .

in cooperation with N. Davidovitch (Reactor Theory and Calculation Laboratory of CNEN-Casaccia Centre) .

1.16 Resonance statistical analysis for mean parameter estimate.

C.BONIFAZZI, E.MENAPACE, M.MOTTA ,M. VACCARI .

The statistical analysis of Cm isotopes (-242,-244, -245, -246, -247, -248) was performed.

For D_{obs} and S_o estimates different methods were used, such as linear statistics, Missing Level Estimator (by Moore and Keyworth) and Maximum Likelihood analysis on reduced neutron widths by means of CAVE code (author M. Stefanon) .
The resulting D_{obs} as a function of the lower energy limit(threshold Γ^0_{ns}, above which Γ^0_n are considered in the analysis, is shown, e.g. for Cm-242 target, in. fig. 1 .. Analogously the likelihood function has been considered (X-2 distributions with different degrees of freedom ν) for average Γ_f and effective ν_f estimate . These results have been utilised for statistical model calculations directed to cross-section evaluation.

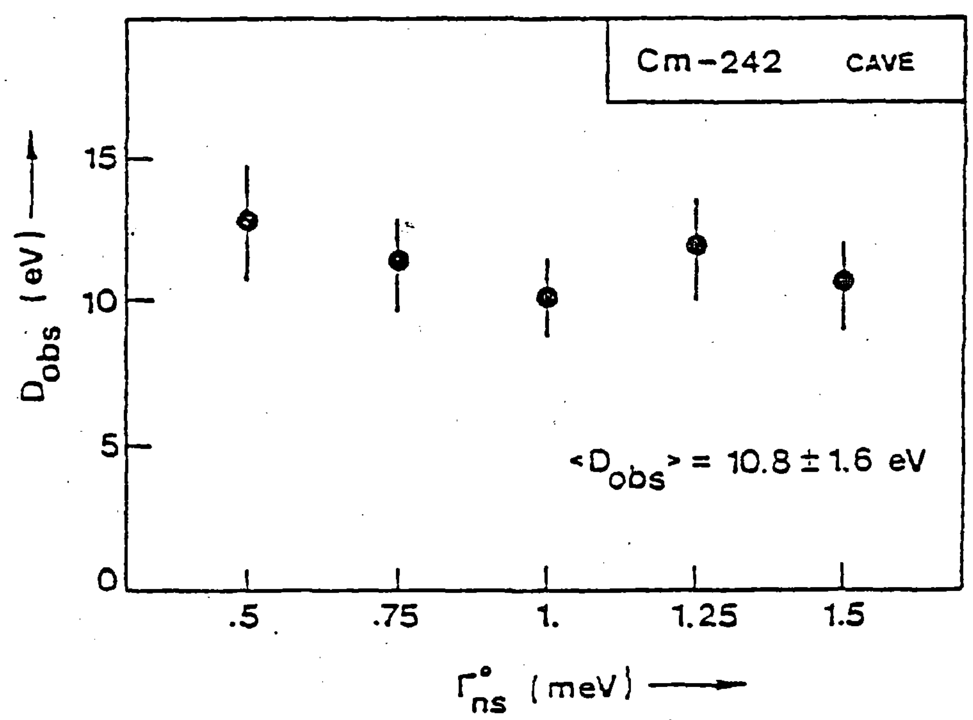


Fig. 1

1.17 Fission cross-sections.

G. MAINO, E. MENAPACE, A.VENTURA

First and second chance contributions to the total fission cross section have been calculated through the code HAUSER-5 (by F.M. Mann-HEDL) for Cm-242, -243, -245, -246, -247, -248.
The results for the last three isotopes are presented in the figures of the evaluation section. For second chance fission calculations, experimental fission probability data by H.C. Britt and collaborators (LASL, private communication) have been properly approximated by our theoretical estimates.
In addition, recent data for fission cross section by F.Käppeler (KFK, private communication) for Cm-244 have been reproduced in a consistent way with the parameter systematics.

The results are partly presented in / d , e, f /, partly in nextcoming pubblications.

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a) G. MAINO, E. MENAPACE, A. VENTURA, "Blocking effect at finite temperature for deformed nuclei", Nuovo Cimento 57A (1980) 427.

b) M. GIROD, A. VENTURA, "Problems in Hartree-Fock calculations of nuclear level densities", in From Collective States to Quarks in Nuclei, Bologna, November 25-28, 1980, contributed papers, p. 24.

c) M. VACCARI, "Tables of neutron resonance parameters and multigroup cross-sections for Pd-105, Nd-143, Sm-149, Sm-151 (1979 evaluation)", CNEN Report, RT/FI(80)1, 1980.

d) T. MARTINELLI, E. MENAPACE, M. MOTTA, M. VACCARI, A. VENTURA, "Evaluation of Cm-246 neutron cross sections in the resonance region", CNEN Report, RT/FI(80)7, 1980.

e) T. MARTINELLI, E. MENAPACE, M. MOTTA, M. VACCARI, "Evaluation of Cm-247 neutron cross sections in the resonance region", Proceedings of the Second Technical Meeting on the Nuclear Transmutation of Actinides", Ispra, April 21-24, 1980, pag. 171-190.

f) T. MARTINELLI, E. MENAPACE, M. MOTTA, M. VACCARI, A. VENTURA, "Evaluation of Cm-248 neutron cross sections in the resonance region", CNEN Report, RT/FI(80)10, 1980.

1.18 Evaluation of actinide neutron data

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

1.18.1 Cm-246,Cm-247,Cm-248 neutron data evaluation.

Neutron Cross sections for Cm-246,247,248 were evaluated in the resonance region, up to E_n = 10 KeV , in the frame of an IAEA coordinate research program .

The results are described in / d , e , f / .

The resolved resonance characteristics of these isotopes are summarized in the following Table .

Table I. Resolved resonance region

Isotope	^{246}Cm	^{247}Cm	^{248}Cm
Upper limit of the region (eV)	381	61	1300
Number of resonances	11	34	32
Resonance parameters	Breit-Wigner (single level)	Reich-Moore (multilevel-2 fission channel)	Breit-Wigner (single level)

Evaluated resonance parameters for Cm-246 are listed in Table II ; Table III and IV show the adopted parameters for Cm-247 and Cm-248 respectively .

Table II .

Cm-246. PARAMETERS FOR RESOLVED REGION
KEY# 6: PRINT OF THE RECALLED FILE <CM246>

ZAI	ABN	b	LFW	NER	b
9.62460E+04	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00	0.00000E+00
EL	EH	LRU	LRF	b	b
1.00000E-05	3.35000E+02	1.00000E+00	1.00000E+00	0.00000E+00	0.00000E+00
SPI	AP	b	b	NLS	NE
0.00000E+00	9.50000E-01	0.00000E+00	0.00000E+00	1.00000E+00	0.00000E+00
AWRI	AM	L	b	6*NRS	NRS
2.43932E+02	0.00000E+00	0.00000E+00	0.00000E+00	6.60000E+01	1.10000E+01
ER	AJ	GT	GN	GG	GF
4.31000E+00	5.00000E-01	3.98800E-02	3.38000E-04	3.50000E-02	4.55800E-03
1.52300E+01	5.00000E-01	3.53890E-02	5.38000E-04	3.50000E-02	7.59000E-04
8.44300E+01	5.00000E-01	5.96607E-02	2.19587E-02	3.79000E-02	7.80000E-04
9.12400E+01	5.00000E-01	5.61449E-02	1.39749E-02	3.79000E-02	1.79000E-04
1.32400E+02	5.00000E-01	6.56771E-02	2.89471E-02	3.79000E-02	7.22900E-04
2.08700E+02	5.00000E-01	4.57217E-02	9.34177E-03	3.79000E-02	3.80000E-04
2.73300E+02	5.00000E-01	4.53863E-02	7.08637E-03	3.79000E-02	1.30000E-03
2.33200E+02	5.00000E-01	9.67275E-02	5.34175E-02	3.79000E-02	3.10000E-04
3.13400E+02	5.00000E-01	6.19343E-02	2.47943E-02	3.79000E-02	1.30000E-04
3.61000E+02	5.00000E-01	9.29937E-02	5.56790E-02	3.79000E-02	3.13720E-04
3.81100E+02	5.00000E-01	1.54310E-01	1.17130E-01	3.79000E-02	1.38000E-04

Table III .

Resolved resonance parameters for Cm-247.
FKEY# 6: PRINT OF THE RECALLED FILE <CM247>

ZAI	ABN	b	LFW	NER	b	ref.
9.62470E+04	1.00000E+00	0.00000E+00	0.00000E+00	1.00000E+00	0.00000E+00	
EL	EH	LRU	LRF	b	b	
1.00000E-05	6.10000E+01	1.00000E+00	3.00000E+00	0.00000E+00	0.00000E+00	
SPI	AP	b	b	NLS	NE	
4.50000E+00	9.50000E-01	0.00000E+00	0.00000E+00	1.00000E+00	0.00000E+00	
AWRI	AM	L	b	6*NRS	NRS	
2.44960E+02	0.00000E+00	0.00000E+00	0.00000E+00	2.10000E+02	3.50000E+01	
ER	AJ	GN	GG	GF1	GF2	
-6.00000E-01	4.49999E+00	1.34846E-06	4.00000E-02	5.39590E-02	0.00000E+00	0
1.24700E+00	4.50001E+00	5.00000E-04	4.00000E-02	4.10000E-02	0.00000E+00	1
2.91900E+00	4.50002E+00	1.20000E-04	4.00000E-02	5.60000E-02	0.00000E+00	2
3.19000E+00	4.50003E+00	1.00000E-03	4.00000E-02	4.29000E-02	0.00000E+00	3
9.55000E+00	4.50004E+00	9.10000E-04	4.00000E-02	1.25000E-01	0.00000E+00	4
1.31000E+01	4.50005E+00	3.70000E-03	4.00000E-02	1.64380E-01	0.00000E+00	5
2.13660E+01	4.50000E+00	1.24610E-04	4.00000E-02	9.49363E-02	-3.09044E-01	6
2.48300E+01	4.50000E+00	4.41193E-05	4.00000E-02	-1.06382E-01	-2.75184E-02	7
2.53300E+01	4.50000E+00	1.00597E-05	4.00000E-02	-1.31356E-03	-7.46843E-02	8
2.61960E+01	4.50000E+00	1.53530E-05	4.00000E-02	-8.71297E-02	-1.32879E-01	9
2.80400E+01	4.50000E+00	5.82480E-05	4.00000E-02	3.55633E-02	1.74365E-02	10
3.02500E+01	4.50000E+00	3.44850E-03	4.00000E-02	-1.24639E-05	-3.99854E-03	11
3.06200E+01	4.50000E+00	1.88140E-04	4.00000E-02	3.96000E-02	-1.39000E-02	12
3.22300E+01	4.50000E+00	5.85265E-04	4.00000E-02	-3.15673E-05	-2.39683E-02	13
3.63600E+01	4.50000E+00	1.62387E-03	4.00000E-02	3.79736E-02	-2.31214E-02	14
3.77400E+01	4.50000E+00	2.45731E-05	4.00000E-02	-4.40618E-01	-1.14290E-01	15
3.77600E+01	4.50000E+00	1.33344E-03	4.00000E-02	-1.29849E-02	-1.00337E-05	16
3.95200E+01	4.50000E+00	6.28643E-05	4.00000E-02	-6.44736E-01	-6.02543E-02	17
3.99500E+01	4.50000E+00	9.46999E-05	4.00000E-02	1.49299E-01	1.77811E-02	18
4.05100E+01	4.50000E+00	3.19629E-05	4.00000E-02	-2.31624E-02	-2.44375E-02	19
4.12200E+01	4.50000E+00	5.61529E-04	4.00000E-02	-1.33975E-03	1.66683E-02	20
4.17600E+01	4.50000E+00	5.16975E-05	4.00000E-02	5.25121E-01	-1.38799E-02	21
4.33900E+01	4.50000E+00	1.91925E-06	4.00000E-02	-8.24429E-06	3.17557E-03	22
4.40700E+01	4.50000E+00	2.09563E-03	4.00000E-02	3.09349E-02	1.15506E-03	23
4.52100E+01	4.50000E+00	5.72218E-04	4.00000E-02	-1.41924E-02	-4.08976E-02	24
4.79200E+01	4.50000E+00	1.15939E-03	4.00000E-02	1.09959E-02	-1.53014E-01	25
4.89500E+01	4.50000E+00	6.59656E-03	4.00000E-02	6.73343E-02	1.44437E-02	26
5.00200E+01	4.50000E+00	2.36362E-03	4.00000E-02	-1.39290E-02	-3.50000E-02	27
5.06300E+01	4.50000E+00	3.10250E-03	4.00000E-02	4.47929E-02	7.29717E-03	28
5.17900E+01	4.50000E+00	1.64222E-03	4.00000E-02	-1.12996E-02	-2.59037E-03	29
5.21900E+01	4.50000E+00	1.25424E-03	4.00000E-02	1.75994E-03	-2.20964E-03	30
5.36300E+01	4.50000E+00	4.54441E-04	4.00000E-02	-4.39436E-02	2.20854E-01	31
5.51000E+01	4.50000E+00	5.34431E-04	4.00000E-02	4.62930E-05	3.79537E-02	32
5.61800E+01	4.50000E+00	5.39589E-04	4.00000E-02	1.42214E-02	5.47756E-02	33
5.96600E+01	4.50000E+00	1.57337E-02	4.00000E-02	1.59976E-02	-9.38624E-02	34

Table IV. Cm-248. Parameters of the resolved resonances

FXSYS 5: PRINT OF THE RECALLED FILE <ENDFB>

ZAI	ABN	0	LFW	NER	0
9.62480E+04	1.00000E+00	0.00000E+00	0.00000E+00	1.00000E+00	0.00000E+00
EL	EH	LRU	LRF	0	0
1.00000E-05	1.20000E+03	1.00000E+00	1.00000E+00	0.00000E+00	0.00000E+00
SPI	AP	0	0	NLS	NE
0.00000E+00	9.50000E-01	0.00000E+00	0.00000E+00	1.00000E+00	0.00000E+00
AWRI	AM	L	0	6*NRS	NRS
2.45941E+02	0.00000E+00	0.00000E+00	0.00000E+00	1.98000E+02	3.30000E+01
ER	AJ	GT	GN	GG	GF
-9.00000E+00	5.00000E-01	4.29999E-02	1.59999E-02	2.70000E-02	1.00000E-03
7.24700E+00	5.00000E-01	2.63757E-02	1.77573E-03	2.33000E-02	1.30000E-03
2.63000E+01	5.00000E-01	5.16421E-02	1.95531E-02	3.20000E-02	8.90000E-05
3.51000E+01	5.00000E-01	4.49155E-02	1.17155E-02	3.02000E-02	3.00000E-03
7.61000E+01	5.00000E-01	1.25731E-01	9.66311E-02	2.60000E-02	3.10000E-03
9.09500E+01	5.00000E-01	1.73818E-01	1.49218E-01	2.40000E-02	6.00000E-04
1.40300E+02	5.00000E-01	2.80279E-02	1.32798E-03	2.54000E-02	1.30000E-03
1.86400E+02	5.00000E-01	3.15462E-02	4.24620E-03	2.60000E-02	1.30000E-03
2.37900E+02	5.00000E-01	4.38636E-02	1.65636E-02	2.60000E-02	1.30000E-03
2.53790E+02	5.00000E-01	9.00281E-02	6.27281E-02	2.60000E-02	1.30000E-03
3.21900E+02	5.00000E-01	5.36780E-02	2.63780E-02	2.60000E-02	1.30000E-03
3.30600E+02	5.00000E-01	1.28943E-01	9.76430E-02	2.60000E-02	1.30000E-03
4.15790E+02	5.00000E-01	7.72523E-02	4.99523E-02	2.60000E-02	1.30000E-03
4.37790E+02	5.00000E-01	1.02828E-01	7.55280E-02	2.60000E-02	1.30000E-03
4.84900E+02	5.00000E-01	3.69889E-02	9.68890E-03	2.60000E-02	1.30000E-03
5.41900E+02	5.00000E-01	4.11363E-01	3.84063E-01	2.60000E-02	1.30000E-03
6.05300E+02	5.00000E-01	1.01188E-01	7.38880E-02	2.60000E-02	1.30000E-03
6.47900E+02	5.00000E-01	1.36673E-01	1.09373E-01	2.60000E-02	1.30000E-03
6.80600E+02	5.00000E-01	6.40376E-02	3.67376E-02	2.60000E-02	1.30000E-03
6.94300E+02	5.00000E-01	2.30191E-01	2.02891E-01	2.60000E-02	1.30000E-03
7.21500E+02	5.00000E-01	1.18625E-01	9.13250E-02	2.60000E-02	1.30000E-03
7.59400E+02	5.00000E-01	8.83237E-02	6.10237E-02	2.60000E-02	1.30000E-03
8.63990E+02	5.00000E-01	5.18717E-01	4.91417E-01	2.60000E-02	1.30000E-03
8.87100E+02	5.00000E-01	1.25387E-01	9.80870E-02	2.60000E-02	1.30000E-03
9.33600E+02	5.00000E-01	1.35364E-01	1.08064E-01	2.60000E-02	1.30000E-03
9.34290E+02	5.00000E-01	1.50279E-01	1.22979E-01	2.60000E-02	1.30000E-03
1.04290E+03	5.00000E-01	2.17732E-01	1.90432E-01	2.60000E-02	1.30000E-03
1.10330E+03	5.00000E-01	2.46525E-01	2.19225E-01	2.60000E-02	1.30000E-03
1.19360E+03	5.00000E-01	3.55510E-01	3.28210E-01	2.60000E-02	1.30000E-03
1.20970E+03	5.00000E-01	6.20887E-02	3.47887E-02	2.60000E-02	1.30000E-03
1.25200E+03	5.00000E-01	2.87237E-01	2.59937E-01	2.60000E-02	1.30000E-03
1.27560E+03	5.00000E-01	2.05947E-01	1.78647E-01	2.60000E-02	1.30000E-03
1.29810E+03	5.00000E-01	8.11331E-02	5.38331E-02	2.60000E-02	1.30000E-03

The following table V contains the adopted values of the average parameters in the unresolved resonance region :

Table V . Average parameters for the unresolved region

Isotope	^{246}Cm	^{247}Cm	^{248}Cm
$\bar{D}$ (eV)	21.3	1.2	24.5
$S_o(\times 10^4)$	0.77	1.0	1.2
$S_1(\times 10^4)$	2.6	1.8	3.0
$\bar{\Gamma}_\gamma$ (meV)	33	35	27

In the continuum region, only fission cross sections were measured: Figs. i,ii,iii show a comparison of experimental data and calculated values for Cm-246, Cm-247, Cm-248 respectively.

The evaluation of neutron cross sections and related data for these isotopes, up to E_n = 15 MeV will be completed in near future. A file in ENDF/B-4 format containing neutron resonance parameters will be distributed in 1981 through the IAEA (INDL-A, Bologna Evaluations) .

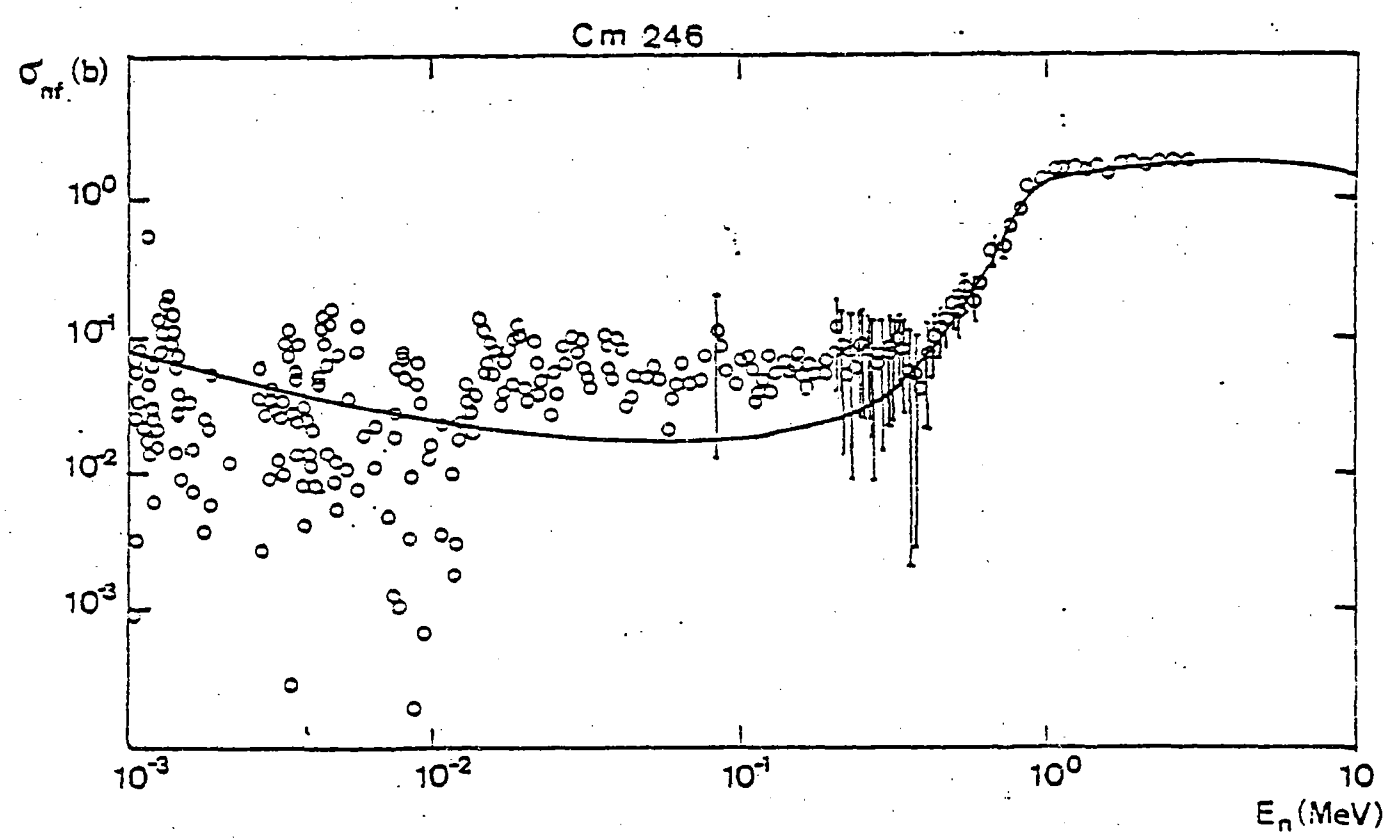

Fig.i

o M.S. Moore & G.A. Keyworth : Phys. Rev. C3, 1656 (1971)

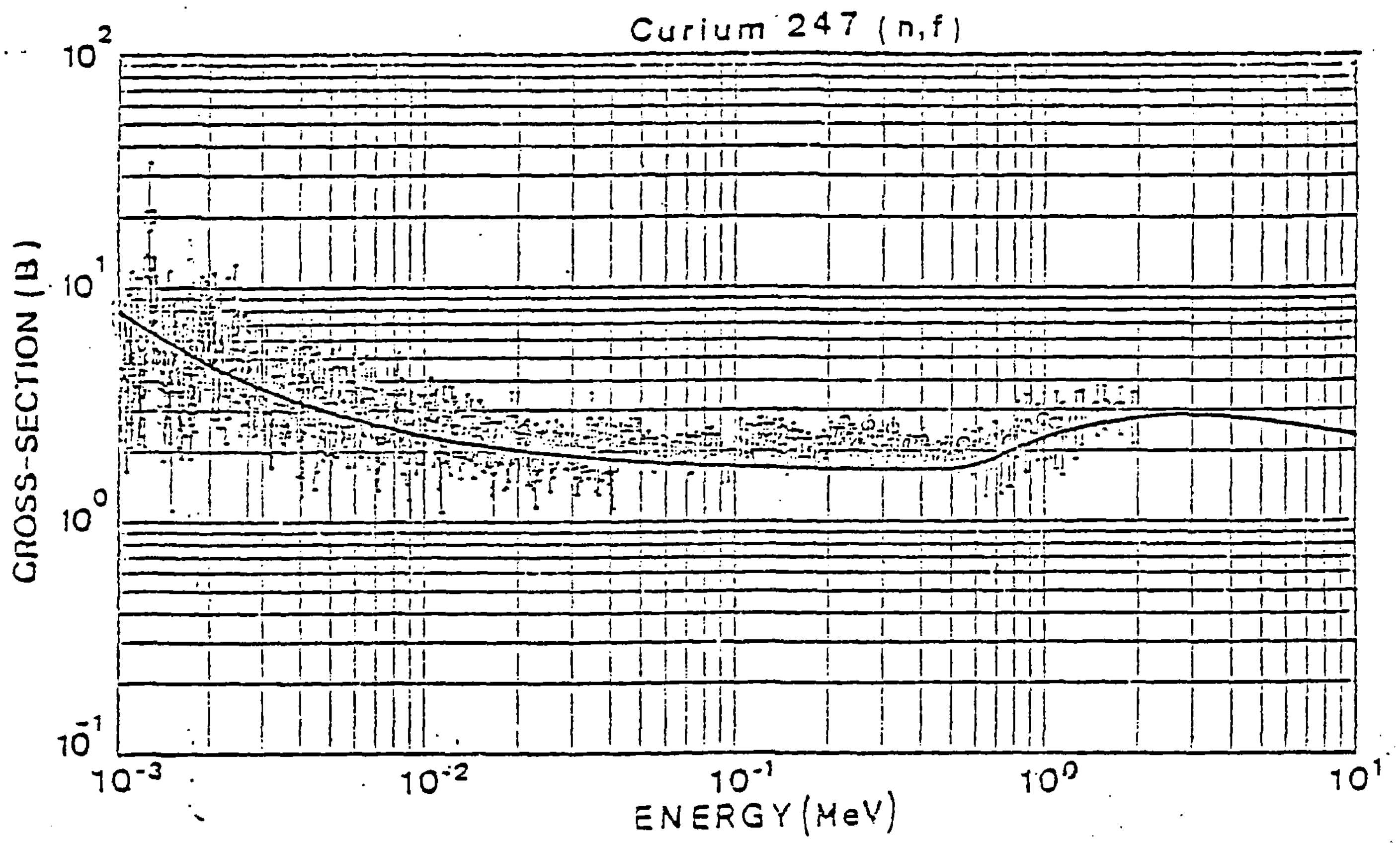

Fig.ii

○ ; □ : M.S. Moore & G. A. Keyworth , Phys. Rev. C3 , 1656 (1971)

Δ : E. F. Fomushkin et al. , Sov. Nucl. Phys. 17 , 12 (1973)

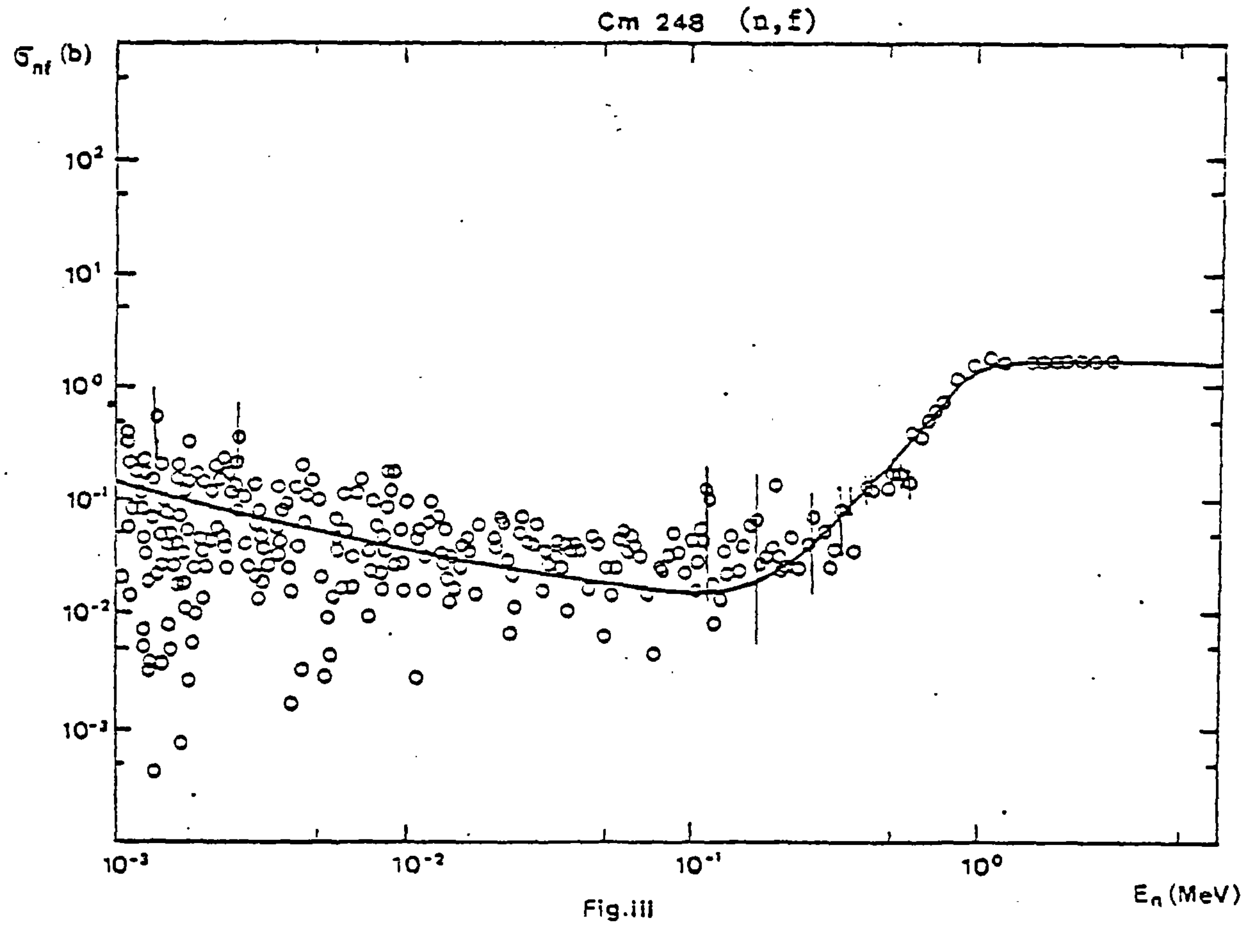

Fig.iii

○ M.S. Moore & G. A. Keyworth : Phys. Rev. C3, 1656 (1971)

1.18.2 Cm-242,Cm-243,Cm-245 neutron data evaluation.

In the frame of the official CNEN-CEA agreement for fast reactors, preliminary evaluations of neutron cross sections for Cm-242, 243, 245 have been performed over the complete range of interest for thermal and fast reactors (from 10^{-5} to 15 MeV) .

About this preliminary evaluation in ENDF/B-4 format, including neutron angular distributions and energy distributions of emitted neutrons, the critical intercomparison with ENDF/B-V and JENDL is underway, with respect both to the adopted procedures and to the reference experimental data taking into account discrepancies among 25-group libraries from these sources .

Final data will be discussed in the next Progress Report and in proper publications. Anticipations for the adopted resonance parameters can be found in the following Table I, II, III .

Table I .

Cm-242. RESOLVED RESONANCE PARAMETERS

FKEY# 6: PRINT OF THE RECALLED FILE <CM242>

ZAI	ABN	b	LFW	NER	b
9.62420E+04	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00	0.00000E+00
EL	EH	LRU	LRF	b	b
1.00000E-05	2.80000E+02	1.00000E+00	1.00000E+00	0.00000E+00	0.00000E+00
SPI	AP	b	b	NLS	ME
0.00000E+00	8.90000E-01	0.00000E+00	0.00000E+00	1.00000E+00	0.00000E+00
AWRI	AM	L	b	6*NRS	NRS
2.39979E+02	0.00000E+00	0.00000E+00	0.00000E+00	7.80000E+01	1.30000E+01
ER	AJ	GT	GN	GG	GF
-2.40000E+00	5.00000E-01	3.89073E-02	9.07324E-04	3.80000E-02	0.00000E+00
1.36200E+01	5.00000E-01	3.60000E-02	1.82000E-03	3.41800E-02	0.00000E+00
3.03300E+01	5.00000E-01	5.80000E-02	3.10000E-03	5.49000E-02	0.00000E+00
3.74900E+01	5.00000E-01	8.04000E-02	4.40000E-03	7.60000E-02	0.00000E+00
6.51000E+01	5.00000E-01	6.15000E-02	2.35000E-02	3.80000E-02	0.00000E+00
8.93000E+01	5.00000E-01	5.05000E-02	1.25000E-02	3.80000E-02	0.00000E+00
1.03400E+02	5.00000E-01	4.34000E-02	5.40000E-03	3.80000E-02	0.00000E+00
1.30300E+02	5.00000E-01	4.16000E-02	3.60000E-03	3.80000E-02	0.00000E+00
1.48790E+02	5.00000E-01	6.20000E-02	2.40000E-02	3.80000E-02	0.00000E+00
1.54600E+02	5.00000E-01	4.95000E-02	1.15000E-02	3.80000E-02	0.00000E+00
2.35200E+02	5.00000E-01	8.90000E-02	5.10000E-02	3.80000E-02	0.00000E+00
2.45300E+02	5.00000E-01	1.09000E-01	7.10000E-02	3.80000E-02	0.00000E+00
2.65000E+02	5.00000E-01	1.06000E-01	6.80000E-02	3.80000E-02	0.00000E+00

Table II. Cm-243. PARAMETERS OF THE RESOLVED RESONANCES

Cm-243. PARAMETERS OF THE RESOLVED RESONANCES

FKEY# 6: PRINT OF THE RECALLED FILE <CM243>

ZAI	ABN	b	LFW	NER	b
9.52430E+04	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00	0.00000E+00
EL	EH	LRU	LRF	b	b
1.00000E-05	2.50000E+01	1.00000E+00	3.00000E+00	0.00000E+00	0.00000E+00
SPI	AP	b	b	NLS	NE
2.50000E+00	8.55000E-01	0.00000E+00	0.00000E+00	1.00000E+00	0.00000E+00
AWRI	AM	L	b	6*NRS	NRS
2.40973E+02	0.00000E+00	0.00000E+00	0.00000E+00	9.60000E+01	1.60000E+01
ER	AJ	GN	GG	GF1	GF2
-4.00000E-01	2.50000E+00	1.22150E-04	4.00000E-02	2.04350E-02	0.00000E+00
1.43000E+00	2.50000E+00	2.58544E-04	4.00000E-02	-1.00000E-01	3.50000E-01
2.27900E+00	2.50000E+00	1.39930E-03	4.00000E-02	2.25000E-01	3.25000E-01
3.00000E+00	2.50000E+00	7.38292E-04	4.00000E-02	-1.30000E-01	0.00000E+00
3.34000E+00	2.50000E+00	2.92410E-04	4.00000E-02	8.00000E-02	0.00000E+00
3.74000E+00	2.50000E+00	7.73563E-04	4.00000E-02	-1.10000E-01	0.00000E+00
5.40000E+00	2.50000E+00	8.13326E-04	4.00000E-02	1.50000E-01	0.00000E+00
5.95000E+00	2.50000E+00	3.33235E-03	4.00000E-02	-1.50000E-01	1.00000E+00
8.80000E+00	2.50000E+00	9.15580E-04	4.00000E-02	3.00000E-01	0.00000E+00
1.03200E+01	2.50000E+00	5.13996E-03	4.00000E-02	1.00000E-01	1.40000E+00
1.18750E+01	2.50000E+00	3.32715E-03	4.00000E-02	-3.00000E-02	0.00000E+00
1.45500E+01	2.50000E+00	9.53611E-04	4.00000E-02	2.50000E-01	0.00000E+00
1.56000E+01	2.50000E+00	1.73795E-03	4.00000E-02	-2.50000E-01	0.00000E+00
2.15800E+01	2.50000E+00	4.29368E-03	4.00000E-02	2.50000E-01	0.00000E+00
2.44400E+01	2.50000E+00	2.95620E-03	4.00000E-02	-1.50000E-01	0.00000E+00
2.58400E+01	2.50000E+00	2.34965E-03	4.00000E-02	1.50000E-01	0.00000E+00

Table III. RESONANCE PARAMETERS FOR THE RESOLVED REGION OF Cm-245

FKEY# 6: PRINT OF THE RECALLED FILE <CM245>

ZAI	ABN	b	LFW	NER	b
9.62450E+04	1.00000E+00	0.00000E+00	1.00000E+00	1.00000E+00	0.00000E+00
EL	EH	LRU	LRF	b	b
1.00000E-05	6.10000E+01	1.00000E+00	3.00000E+00	0.00000E+00	0.00000E+00
SPI	AP	b	b	NLS	NE
3.50000E+00	9.50000E-01	0.00000E+00	0.00000E+00	1.00000E+00	0.00000E+00
AWRI	AM	L	b	6*NRS	NRS
2.42960E+02	0.00000E+00	0.00000E+00	0.00000E+00	2.42000E+02	4.00000E+01
ER	AJ	GN	GG	GF1	GF2
-1.00000E-01	3.50001E+00	4.55000E-05	5.00000E-02	3.00000E-01	0.00000E+00
8.50000E-01	3.50001E+00	1.62900E-04	4.00000E-02	8.00000E-01	0.00000E+00
1.90000E+00	3.50001E+00	2.40000E-04	4.00000E-02	1.75000E-01	0.00000E+00
2.45000E+00	3.50001E+00	1.10000E-04	4.00000E-02	3.00000E-01	0.00000E+00
4.60000E+00	3.50001E+00	2.10000E-03	4.00000E-02	3.25000E-01	0.00000E+00
5.75000E+00	3.50001E+00	1.10000E-04	4.00000E-02	3.00000E-01	0.00000E+00
7.53000E+00	3.50001E+00	1.91000E-03	4.00000E-02	3.20000E-01	0.00000E+00
8.65000E+00	3.50001E+00	5.30000E-04	4.00000E-02	5.00000E-01	0.00000E+00
9.15000E+00	3.50001E+00	3.90000E-04	4.00000E-02	2.00000E-01	0.00000E+00
1.01500E+01	3.50001E+00	4.80000E-04	4.00000E-02	2.00000E-01	0.00000E+00
1.13400E+01	3.50001E+00	9.20000E-04	4.00000E-02	1.50000E-01	0.00000E+00
1.35800E+01	3.50001E+00	5.90000E-05	4.00000E-02	4.50000E-02	0.00000E+00
1.37500E+01	3.50001E+00	3.40000E-04	4.00000E-02	1.70000E-01	0.00000E+00
1.50000E+01	3.50001E+00	1.20000E-03	4.00000E-02	4.00000E-01	0.00000E+00
2.13600E+01	3.50000E+00	2.11211E-03	4.00000E-02	4.48151E-01	-3.68483E-02
2.49900E+01	3.50000E+00	2.59978E-03	4.00000E-02	-5.53051E-03	2.20469E-01
2.58400E+01	3.50000E+00	3.55831E-05	4.00000E-02	1.67229E-04	5.48832E-01
2.68300E+01	3.50000E+00	7.61425E-04	4.00000E-02	-1.15673E-01	1.53240E-02
2.76300E+01	3.50000E+00	5.99232E-04	4.00000E-02	0.00000E+00	1.63000E-01
2.94200E+01	3.50000E+00	3.46852E-03	4.00000E-02	-3.19973E-01	-8.02573E-03
3.17100E+01	3.50000E+00	4.95542E-04	4.00000E-02	8.87434E-02	-6.02256E-01
3.29900E+01	3.50000E+00	3.67596E-04	4.00000E-02	9.48150E-04	-3.05984E-03
3.45900E+01	3.50000E+00	2.29371E-04	4.00000E-02	-9.31292E-03	5.16870E-02
3.53100E+01	3.50000E+00	7.58227E-03	4.00000E-02	1.44933E+00	2.74566E+00
3.63200E+01	3.50000E+00	1.54291E-03	4.00000E-02	-1.38482E-01	5.17530E-04
3.94500E+01	3.50000E+00	6.53216E-04	4.00000E-02	-3.52481E-02	-6.67598E-02
4.04400E+01	3.50000E+00	4.48329E-03	4.00000E-02	-2.21737E-01	3.63252E-01
4.24500E+01	3.50000E+00	5.36866E-03	4.00000E-02	3.12597E-03	6.87303E-03
4.31000E+01	3.50000E+00	1.73317E-03	4.00000E-02	1.75667E-01	-3.50332E-01
4.45700E+01	3.50000E+00	2.61834E-03	4.00000E-02	1.85953E-01	-5.38946E-01
4.57400E+01	3.50000E+00	5.88392E-04	4.00000E-02	8.78958E-01	-2.29439E-02
4.75100E+01	3.50000E+00	3.55665E-03	4.00000E-02	2.18297E-02	5.17130E-03
4.92000E+01	3.50000E+00	5.03624E-03	4.00000E-02	3.92859E-01	1.09614E+00
5.04300E+01	3.50000E+00	1.79044E-03	4.00000E-02	-9.14730E-04	7.50085E-01
5.15400E+01	3.50000E+00	6.25190E-04	4.00000E-02	-1.57279E-02	1.91272E-01
5.36300E+01	3.50000E+00	1.23543E-02	4.00000E-02	-8.82592E-01	-1.33875E-02
5.46300E+01	3.50000E+00	3.32584E-04	4.00000E-02	-1.04545E+00	1.15489E-02
5.63200E+01	3.50000E+00	1.39586E-03	4.00000E-02	1.74473E-01	3.30525E-01
5.85400E+01	3.50000E+00	1.38562E-02	4.00000E-02	-3.55471E-01	3.75281E-02
5.99900E+01	3.50000E+00	5.11880E-04	4.00000E-02	3.12943E-01	-2.05150E-01

1.19 <u>Evaluation of neutron data for structural materials.</u>

E. MENAPACE, M. MOTTA, G.C. PANINI .

An "ad hoc" evaluation for Fe-56 has been undertaken for comparison with the results from integral measurements in RB-2 coupled F-T facility , obtained by P.Azzoni CNEN, Physics Division and collaborators in the frame of CNEN-CEA Agreement for Fast Reactors, ref. (a, b) .
With respect to ENDF/B-IV, more recent measurements from ORNL (ref.(c)) and CBNM (ref.(d)) have been included in the new file after intercomparison of the data . Computer codes were developed for this purpose.
Total capture averaged over the RB-2 spectrum from the new file is 15% lower than the one from ENDF/B-IV, in agreement with the indication from the integral data (that is partly due to the more correct calculation of the self-shielding due to the extension of the resonance region). The work on the new file has been performed in cooperation also with A. Gandini and N.Davidowidch (CNEN Casaccia Center), who calculated sensitivity coefficients with respect to the parameter variation.

Fo the next year an analogous evaluation in the frame of the same cooperations is planned for Cr isotopes, for which even stronger discrepancies exists between calculated capure from ENDF/B-IV and the experimental integral value.

(a) P.AZZONI,A.SALOMONI -CNEN ; P.L.CHIODI,C.GIULIANI,R.MARVASI-AGIP NUCLEARE : " Measurements of structural Material to U-235 Fission-Rate Ratios in Intermediate and Fast Spectra", IAEA-SM-244/64, pag. 147 .

(b) P.Azzoni,V.Benzi,A.Salomoni- CNEN; P.L.Chiodi,C.Giuliani, R.Marvasi-AGIP Nucleare; S.Guardini,S.Tassan-CCR Euratom Ispra: "Measurements of Structural Material Capture to U-235 Fission-Rate Ratios in an Intermediate Spectrum Assembly", NSE 76 (1980)70 .

(c) F.G.Perey et al. "Recent Results for Ni-58 and Fe-56 at ORELA", Proc.Spec.Meet.on Neutron Data of Struct.Mater.for Fast Reactors, Geel 1977, p. 530 .

(d) A.Brusegan et al.:"Neutron Capture cross section measurements of Fe-56", Proc.Int.Conf.Nucl.Cross.Sect.for Techn.,Knoxwille 1980., p. 613 .

1.20 Nuclear Data Library

G.C. PANINI, M. VACCARI

The service for supplying nuclear data on request from internal and external users continued in 1980 as well as the work of assistance to other groups in the field of Nuclear Data.

A collaboration was established with the Health Physics Laboratory in Bologna for the theoretical estimates of track etching detector efficiency for neutron fluxes, by supplying nuclear data for H, C, N, O, B.

An important effort was made for the closing of the "Specialists' Meeting on Neutron Cross Sections of Fission Product Nuclei", held in Bologna on December 12-14, 1979; the conclusive report was published in June /a/ .

The "BC" plotting system for general graphical purposes was written in Fortran IV /b/ . The system of routines is now available to all CNEN users on the IBM 370/168 installation and is widespreadly used as a standard package. The package was used in writing a plotting code for noise analysis on request from LFSR. Some examples of graphs obtained by means of the system are given in fig. 1,2,3.

The new ENDF/B-V format and the differences with ENDF/B-IV were studied and the program CONV5TO4 for a conversion from ENDF/B-V to ENDF/B-IV format of the main sections was written. The report will be published in 1981.

The system of codes SYSMF to generate a Nuclear Data File in ENDF/B format starting from "raw" evaluated data was largely modified in order to treat actinide evaluations in progress. The system was intensively used for Cm-242, 243, 245 neutron data preliminary evaluations for the Superphoenix Project in the frame of CEA/CNEN agreement and proved to be a very useful tool.

A revision of the codes for the selection and plotting of NEUDADA experimental data was necessary to obtain information for Curium evaluations.

The ENDF/B-V management codes CHECKER5 and RIGEL5 were implemented on the IBM 370/168 installation and are now in production.

As far as the file management was concerned, a new organization of files on tapes and disks was adopted in order to have more protection from accidents.

As usual, new experimental or evaluated data, mainly obtained through the NEA Data Bank, were incorporated in the laboratory files.

The following data were acquired during 1980:

a) Neutron resonance data of Cm-246, Cm-247, Cm-248 evaluations performed in Bologna in the framework of IAEA research agreement for the "European file".

b) 25 ENDF/B-V material on the "Dosymetry tape" No. 531. Tape was checked, as well as all ENDF/B-V tapes received in 1979, by the CHECKER5 code.

c) The Activation Cross Section Library "ACTL" from Livermore Laboratory. At present it contains data for 255 materials, many of which are generally not included in other Libraries. The format and content was studied and codes written to use the data.

d) Experimental data and parameters for Ag and Nb-93 in EXFOR format.

e) A preliminary version of complete neutron cross section evaluations for Cm-242, Cm-243, Cm-245 in ENDF/B format. As above said, these data were originated in Bologna.

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a) C. COCEVA, G.C. PANINI, Editors , " Proceedings of the Specialists' Meeting on Neutron Cross Sections of Fission Product Nuclei", Bologna, December 12-14, 1979. NEANDC(E)209"L" (1980) and CNEN Report RIT/FIS/LDN(80)1 .

b) G.C. PANINI, "Il sistema grafico BC - guida per l'utente", CNEN Report RT/EDP(80)6 and RIT/FIS/LDN(80)3.

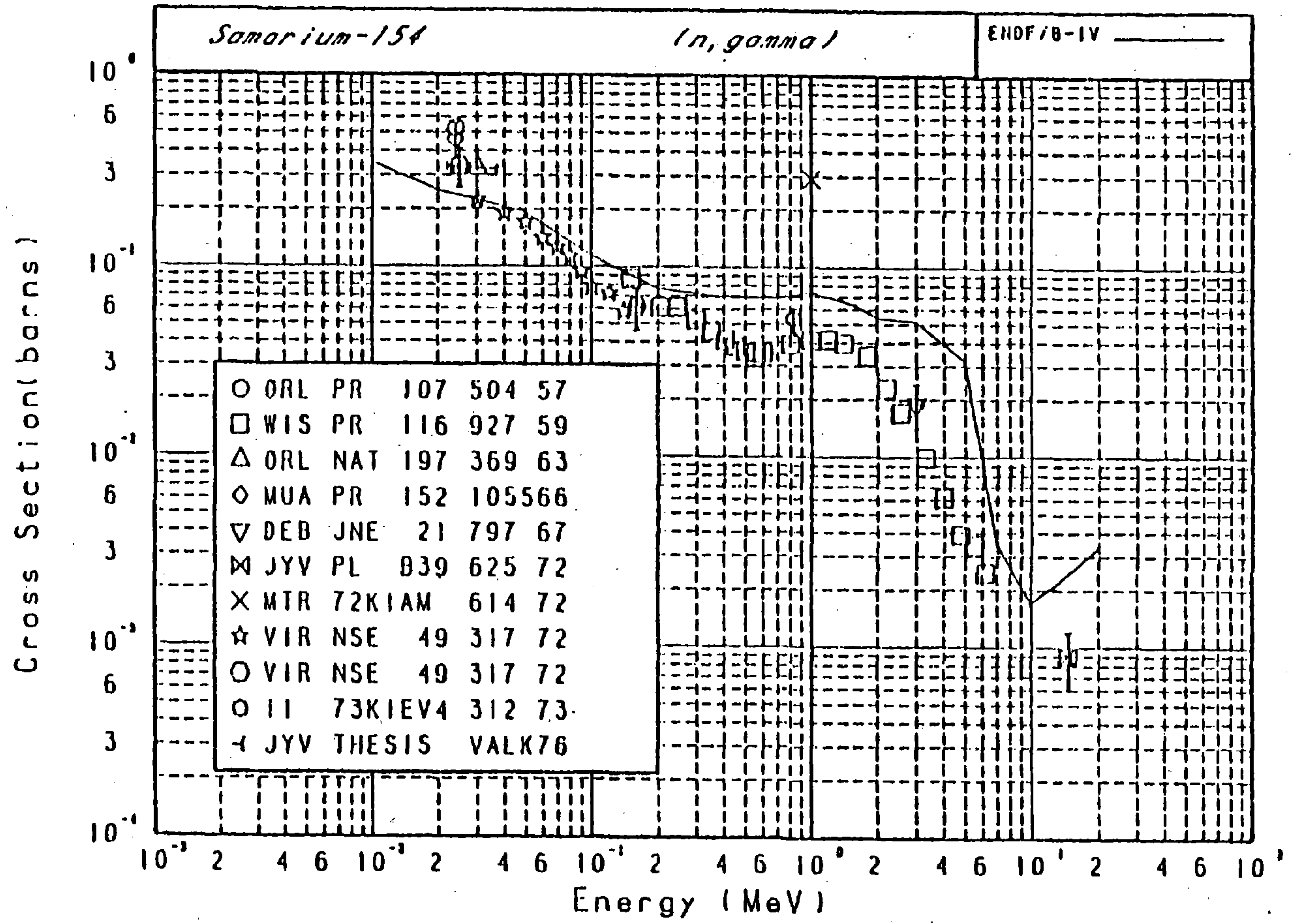
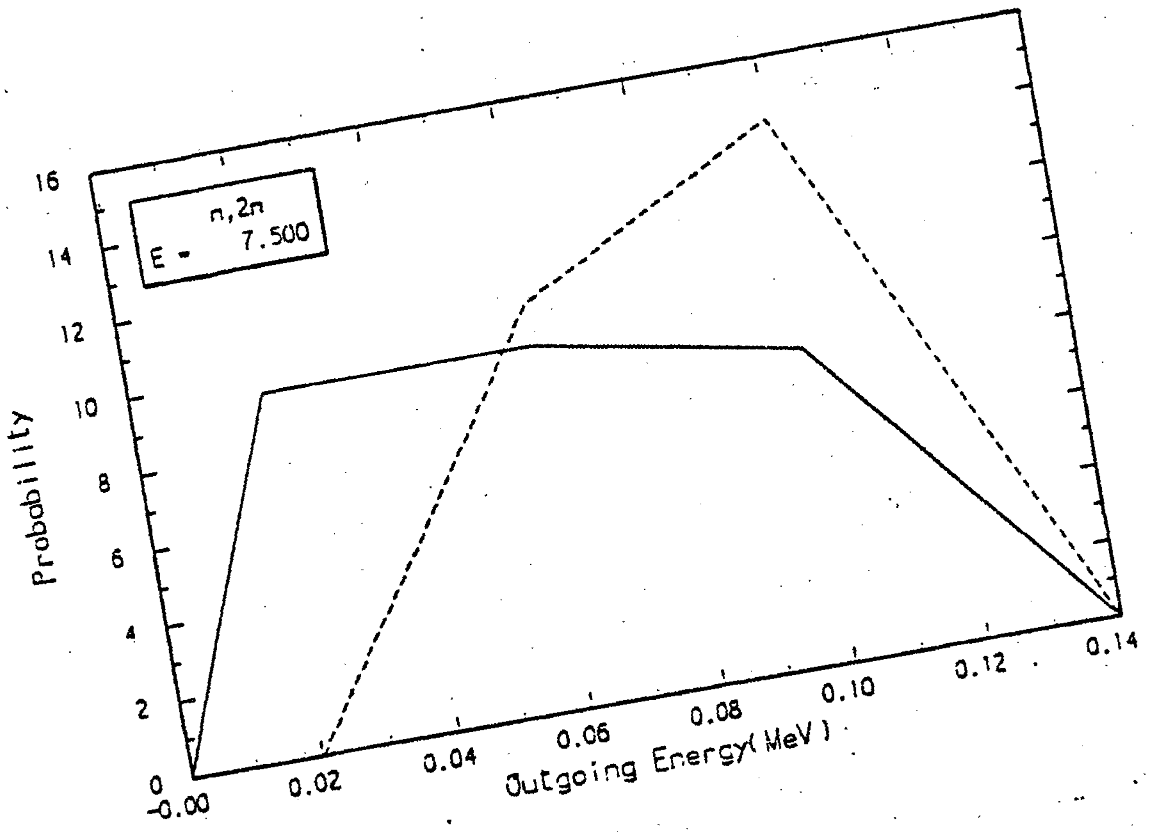


Fig. 1 . Example of plotting by the "BC" system.



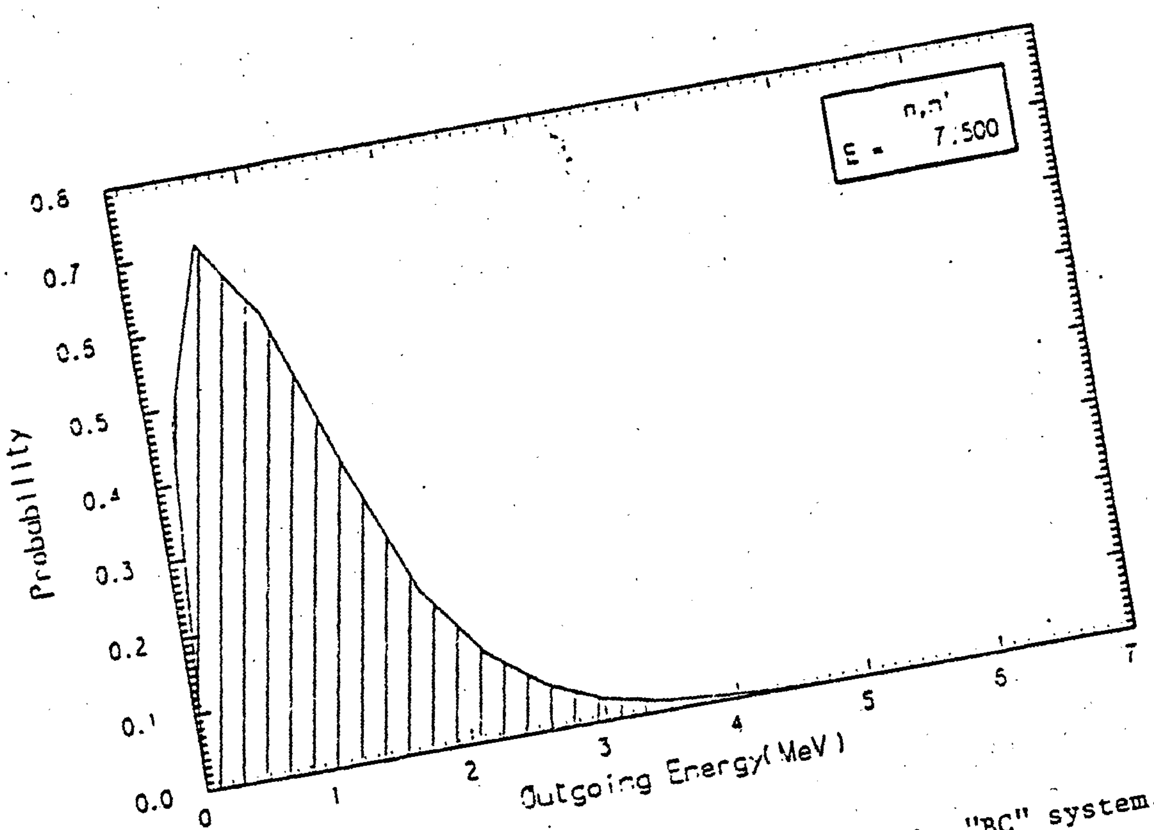


fig. 2-3 . Examples of plotting by the "BC" system.

1.21 Multigroup cross sections

G.C. PANINI, M. VACCARI

In this framework, activity has been performed in the field of both multigroup code implementation and data library production.

A version of the FOURACES code has been implemented at CEA during a stage at Cadarache.

The ROLAIDS ([a]) code for the accurate treatment of resonance overlapping in the AMPX-II modular system ([b]) has been corrected in several fatal errors due to the FORTRAN compiler in use at CNEN, which is quite different from the one in use at ORNL. The code is now running both as part of the AMPX-II system and stand-alone. Work has been done with the aim of using AMPX-II for calculating $1/\Sigma_t$ weighted library for the Montecarlo Code KIM ([c]); being the results not satisfactory, the strategy has been discarded for the present time.

The MINX ([d]) code for multigroup cross section and Bondarenko factor calculations is also running: it has been extensively used for sensitivity tests on a modified ENDF/B-IV iron taking into account new resonance data originated at ORNL and Geel. The code is operative within the CNEN computing facilities.

A system of routines in form of run-time callable library has been implemented for the manipulation and averaging of the ENDF/B formatted data.

The system is based upon the BNL package SLAVE3 ([e]).

The following calculations have been carried out in the field of multigroup cross sections from the users:

1) Si and Ce (all isotopes) for Montecarlo calculations (KIM code);

2) Br isotopes in Carnaval scheme for RB-2 calculations;

3) Several rare earth isotopes on the 620-group SAND-2 scheme, for CESNEF (Milano);

4) Ta and Be-9 for KIM code;

5) Several transactinide isotopes for burn-up calculations in the Carnaval scheme;

6) Structural and activation materials in Carnaval scheme for PEC calculations;

7) Cm-242, 243, 245 of Bologna preliminary evaluations in the Carnaval scheme; same isotopes from ENDF/B-IV and V for comparison. Work will continue in 1981.

All the computations have been carried out using the FOURACES code, followed, in the case of Montecarlo data, by the PROKIM code.

(a) R.M. Westfall: "ROLAIDS-AMPX module for treating resonance shielding in multiregion geometries", Sect. 9.11 of ref. (b).

(b) N.M. Green et al.: "AMPX-II. A modular code system for generating coupled multigroup neutron-gamma cross-section libraries from ENDF/B", ORNL/TM-3706 (1978).

(c) E. Cupini et al.: "KIM - A two-dimensional Montecarlo program for thermal reactors", CNEN Report RT/FIMA(80)2 (1980).

(d) C.R. Weisbin et al.: "MINX - A multigroup interpretation of nuclear x-sections from ENDF/B", LA-6486-MS (1976).

(e) "ENDF-110 - Description of the ENDF/B processing codes and retrieval subroutines" O. Ozer ed., BNL-50300 (1971).

2. C.N.E.N. - DIVISIONE DI FISICA - LABORATORIO FISICA SPERIMENTALE DEI REATTORI - Via Mazzini, 2 - 40138 BOLOGNA, Italy

2.1 Measurements of Structural Material Capture to U-235 Fission Rate Ratios in Fast Spectra

P. AZZONI, A. SALOMONI, C. PETRELLA
G. BRIGHENTI (*), C. GIULIANI (*), R. MARVASI (*)

In order to contribute to improving knowledge on capture cross sections of Fe, Cr, Ni and Stainless Steel, an experimental program was undertaken by CNEN utilizing the RB2 Reactor at the AGIP Nucleare Montecuccolino Laboratories.

To obtain the integral capture cross sections of the structural materials the "Null Reactivity Technique" was used.

By means of that, the structural material capture to U-235 fission rate ratios were evaluated and then compared with the theoretical results.

The measurements were carried out in a fast spectrum, in order to increase the neutron captures in the 1 keV-1 MeV energy range, where the uncertainties in the structural material capture cross sections are large.

By means of the "Null Reactivity Technique" one works in an infinite medium of near unit K_∞ and, consequently, the experimental results are more ready compared with theory. To achieve this the asymptotic spectrum of the radium was yielded in the central Test Zone of the Reactor.

The difficulties related to heterogeneity effects were reduced by using quasi homogeneous media made up of materials in the form of microspheres ($\simeq$ 1 mm diameter) and the influence of the leakage was greatly reduced by flattening the neutron flux in the central Test Zone.

Flux-measurements were carried out by means of the "Proton-recoil method" and threshold detectors at the center and in the midplane of the reactor.

A general good agreement has been obtained between calculated and experimental results.

The comparison between experimental and theoretical values of $R^s_\infty = \bar{\sigma}^s_c / \bar{\sigma}^{U5}_f$ shows a systematic trend of ENDF/B-IV calculated data to

(*) AGIP NUCLEARE Nuclear Laboratories, Montecuccolino, Bologna, Italy greatly overestimate the experimental "Null Reactivity" results (Table 1). On the contrary, the CARNVAL IV calculated results shows a systematic trend to underestimate the experimental results of some per cent (Table 1).

P. Azzoni et al., "Esperienze Integrali Veloci nel Reattore RB-2/TV di Montecuccolino (gennaio-dicembre 1980)", RIT/FIS(81)3.

TABLE 1 – Experimental values of $R^{s}_{\infty} = (\bar{\sigma}^{s}_{c} / \bar{\sigma}^{U5}_{f})$ and comparison with the calculated ones.

The errors shown take into account the experimental uncertainties only.

	MC^{2}II / CITATION$^+$			MC^{2}II / DOT^{++}			HETAIRE / CITATION$^+$			HETAIRE / DOT^{++}		
	SPER	CALC	$\frac{C-S}{C}$ %	SPER	CALC	$\frac{C-S}{C}$ %	SPER	CALC	$\frac{C-S}{C}$ %	SPER	CALC	$\frac{C-S}{C}$ %
Fe 6	3.571 ± 4.0%	4.670	23.5	3.497 ± 4.0%	4.671	25.1	2.988 ± 4.0%	2.955	-1.1	2.988 ± 4.0%	2.959	-1.0
Fe 8	3.666 ± 4.5%	4.533	19.1	3.588 ± 4.5%	4.535	20.9	3.200 ± 4.5%	2.831	-13.0	3.213 ± 4.5%	2.836	-13.3
Cr 6	4.902 ± 3.0%	8.129	39.7	4.856 ± 3.0%	8.129	40.3	4.811 ± 3.0%	4.496	-7.0	4.808 ± 3.0%	4.502	-6.8
SS 6	8.220 ± 3.0%	9.778	15.9	8.210 ± 3.0%	9.771	16.0	7.733 ± 3.0%	7.620	-1.5	7.791 ± 3.0%	7.627	-2.2
Ni 6	10.673 ± 3.0%	11.540	7.5	10.715 ± 3.0%	11.556	7.3	10.870 ± 3.0%	9.650	-12.6	10.918 ± 3.0%	9.674	-12.9

\+ 2D – Diffusion Code

++ 2D – S_n Transport Code

3. C.N.E.N. - DIVISIONE DI FISICA - LABORATORIO FISICA E CALCOLO DEI REATTORI - CSN, CASACCIA, ROMA

3.1 Uncertainty Evaluation in Nuclear Data

M. PETILLI

The trial of giving some contribute to the needs of nuclear data uncertainties, strongly required for reactor dosimetry purpose, has been the object of development of two codes GIADA and TASHI.

The program GIADA can generate a file of point energy cross sections, with their variance-covariance matrix, starting by differential cross section measurements.

The first application has been done for the Mg^{24} activation cross section.

The TASHI code represents the next step in this evaluation because it can calculate multigroup cross sections and their uncertainties, using, as input, data files in the form obtained by GIADA.

The code TASHI, in its first version, gives the multigroup cross sections by using, as a weighting function, a flat flux in each group.

In a 100 groups subdivision of the energy range 10^{-5} eV-18 MeV, a good agreement has been found with results from previous calculations, by D.E. Cullen (private communication).

For a 15 group structure in the same energy range, some discrepancies were found.

A new version of TASHI is in program assuming a 1/E flux spectrum in the calculations, in order to reduce this discrepancy, as it partially depends on the choice of the weighting function.

4. ISTITUTO DI FISICA DELL'UNIVERSITA' DI BARI - ISTITUTO NAZIONALE DI FISICA NUCLEARE - SEZIONE DI BARI - Via Amendola 173 - 70126 Bari (Italy)

4.1 Differential cross section and spin-flip probability data in 14-45 MeV proton scattering from ^{12}C, ^{24}Mg, ^{28}Si and ^{32}S (ref. /a/)

R. DE LEO, G. D'ERASMO, E.M. FIORE, S. MICHELETTI[(°)], A. PANTALEO AND M. PIGNANELLI[(°)]

The measurements of differential cross sections and spin-flip probabilities in the scattering of 14-45 MeV have been undertaken to study the virtual excitation of giant resonances.
The data have been collected at the Milan AVF Cyclotron.

4.2 Proton elastic scattering on light nuclei I. Energy dependence (ref. /b/)

R. DE LEO, G. D'ERASMO, J.L. ESCUDIE'[(+)], E. FABRICI[(°)], S. MICHELETTI[(°)], A. PANTALEO, M. PIGNANELLI[(°)], F.G. RESMINI[(°)] AND A. TARRATS[(+)]

Differential cross sections for proton elastic scattering by ^{15}N, ^{18}O, ^{24}Mg, and ^{40}Ar were measured at several proton energies between 14 and 44 MeV. Previous data on ^{12}C, ^{16}O, ^{24}Mg, ^{28}Si, and ^{40}Ca have also been considered. Evidence has been found for a strong enhancement in proton emission at backward angles for scattering by spherical nuclei at incident energies higher than 26 MeV.

A phase-shift analysis of all the differential cross sections showed that the partial waves involved are those near grazing. Optical-model fits of good quality have been obtained for collective nuclei, while for spherical nuclei the cross sections at backward angles are not reproduced. The disagreement is not substantially modified when nonstandard radial dependences are given to the optical potential.

4.3 II. Nuclear structure effects (ref. /c/)

R. DE LEO, G. D'ERASMO, E. FABRICI(°), S. MICHELETTI(°), A. PANTALEO, M. PIGNANELLI(°), AND F.G. RESMINI(°)

Differential cross sections for proton scattering on 61 nuclei with mass numbers between 9 and 70 were measured at 35.2 MeV incident energy. To extend previous measurements further data were collected at 29.7 MeV on 10 nuclei. From a detailed inspection of the data a definite correlation emerges between the elastic and inelastic cross section values at backward angles and the quadrupole deformation parameters β_2. Nuclear structure effects are also evident at forward angles at the filling of the 1p shell. A set of mass dependent optical-model parameters which produces acceptable fits at forward angles was derived. The imaginary part was found to contain terms connected with the above structure effects. The results of this and of a coupled-channels analysis are discussed.

4.4 Energy dependence of optical-model parameters for the $p+{}^{32}S$ system between 15 and 35 MeV (ref. /d/)

R. DE LEO, G. D'ERASMO, E.M. FIORE, G. GUARINO, S. MICHELETTI(°) AND A. PANTALEO

Cross sections for proton scattering to the ground and to the 2^+, 2.23 MeV states of ^{32}S have been measured at 18.24, 20.37, 23.24, 26.55 and 29.64 MeV incident energies. The experimental data and those found in the literature at 17.5, 30.3 and 35.2 MeV have been analysed in the framework of macroscopic coupled-channel calculations. A set of energy averaged optical-model parameters with fixed geometries and depths linearly dependent on the energy is deduced.

4.5 13.9 MeV neutron spin-flip in ^{32}S 2^+ (2.23 MeV) excitation (ref. /e/)

R. DE LEO, G.D'ERASMO, E.M. FIORE, A. PANTALEO AND G. PASQUARIELLO(x)

The spin-flip probability for 13.9 MeV neutron inelastic scattering to the 2^+ (2.23 MeV) level of ^{32}S has been determined by measuring the neutron time-of-flight spectrum in coincidence with the de-excitation γ radiation emitted perpendicularly to the reaction plane. A comparison has been made between neutron and proton spin-flip probabilities at nearby incident energies.

4.6 **Neutron and proton spin-flip probability comparison in T=0 nuclei** (ref./f/)

R. DE LEO, G. D'ERASMO, E.M. FIORE AND A.PANTALEO

The spin-flip probability(SFP) in the scattering of 21.2 MeV protons from the 2^+(2.23 MeV) level of ^{32}S is presented together coupled-channel calculations in the framework of the symmetric rotational model. Neutron and proton induced SFP on symmetric T=0 nuclei are compared at equivalent energies.

4.7 **Proton excitation of ^{24}Mg, ^{26}Mg, and ^{32}S γ-bands**(ref./g/)

R.DE LEO, G. D'ERASMO, M.N. HARAKEH[(-)], S. MICHELETTI[(o)], A. PANTALEO, AND M. PIGNANELLI[(*)]

Differential cross sections for proton scattering to the first three levels of the ground-state ($0_1^+,2_1^+,4_1^+$) and γ-bands ($2_2^+,3_2^+,4_2^+$) of ^{32}S have been measured at E_p=20.37 MeV. These data, together with similar ones on $^{24,26}Mg$ available in literature, have been analyzed by means of coupled channel calculations in ~~which a~~ $\Delta l=4$ vibration, accounting for a direct excitation of the 4_2^+ state, is added to the asymmetric rotor model. Satisfactory fits have been obtained for all the transitions considered except the 3_2^+ cross sections; these remain unreproduced even if the direct spin-flip mechanism is considered. The importance of the missing contribution in the excitation of the 3_2^+ levels is estimed for the three nuclei considered.

4.8 <u>Excitation of the isoscalar E2 resonance in ^{12}C by proton inelastic scattering</u> (ref. /h/)

G. D'ERASMO, I. IORI(°), S. MICHELETTI(°), AND
A. PANTALEO

Proton inelastic excitation spectra of ^{12}C have been measured imposing a coincidence with alpha decay to $^8Be_{g.s.}$ and $^8Be_{2.9\ MeV}$. In plane angular correlations have been obtained for the main structures in the spectra. Comparison with DWBA correlation functions permits a 2^+ assignement for all the groups in the 20-30 MeV excitation range. The percentage of the E2-EWSR exhausted in the same range is about 20% and in agreement with that derived from alpha inelastic scattering.

(°) Istituto di Fisica dell'Università and INFN-Sezione di Milano- Milano (Italy)
(+) Departement de Physique Nucléaire, CEN Saclay (France)
(x) Laboratori Nazionali INFN, Frascati (Italy)
(-) Kernfysisch Versneller Instituut, Groningen (The Netherlands)

/a/ R. De Leo et al. Report INFN/BE-80/3
/b/ E. Fabrici et al. Phys. Rev. C21 (1980) 830
/c/ E. Fabrici et al. Phys. Rev. C21 (1980) 844
/d/ R. De Leo et al. Il Nuovo Cimento 59A (1980) 101
/e/ R. De Leo et al. Phys. Rev. C22 (1980) 337
/f/ R. De Leo et al. Lett. Nuovo Cimento 28 (1980) 161
/g/ R. De Leo et al. Phys. Rev. C, in print
/h/ G. D'Erasmo et al. Z. fur Physik, in print

5. ISTITUTO DI FISICA DELL'UNIVERSITA' - ISTITUTO NAZIONALE DI FISICA NUCLEARE - SEZIONE DI BOLOGNA - Via Irnerio, 46 - 40126 BOLOGNA, Italy

5.1 Blocking Measurements of Nuclear Decay Times

E. FUSCHINI, F. MALAGUTI, A. UGUZZONI, E. VERONDINI

Carrying on the programme of measuring the lifetimes of several isolated resonances in the $^{27}Al(p,\alpha)^{24}Mg$ reaction, during 1980 the lifetime of the 632-keV resonance was measured by means of the blocking method in Al single-crystals. A 250 nA proton beam from the 2-MeV Van de Graaf generator was impinging on a 2 mm thick Al single-crystal whose axes $\langle 110 \rangle$ and $\langle 1\bar{1}0 \rangle$ were directed at 87 and 177 degrees respectively to the beam. The corresponding blocking dips were simultaneously recorded by LR-115 type I Kodak plastic detectors 6 μm thick covered by 3 μm Mylar foils to suppress α-particles coming from lower-energy resonances. Seven measurements with seven different single-crystals have been performed for a total 0,25 C proton charge.

To extract the lifetime of the compound system from the measured blocking dips, the procedure of Ref. 1 was followed, obtaining

$$\tau = 120 \pm 20 \text{ as}$$

hence the width of the 12.195 MeV level of ^{28}Si is found to be

$$\Gamma = 5.3^{+0.9}_{-0.8} \text{ eV}$$

This result is in good agreement with other blocking measurement[2] but lower than thatdeducible from resonance reaction yields[3].

The meaning of such discrepancy which was not found in previous studies of shorter lifetimes[1,4] will be further investigated by exten= ding measurements to the long-lived 505 KeV resonance.

1) F. Malaguti, A. Uguzzoni and E. Verondini, Phys. Rev. C 19, 1606 (1979)

2) H. Nakayama, M. Ishii, K. Hisataka, F.Fuyimoto and K. Komaki, Nucl. Phys. A 208, 545 (1973).

3) R.P. Sharma, J.U. Andersen and K.O. Nielsen, Nucl. Phys. A 204, 371 (1973)

3) P.M. Endt and C. Van der Leun, Nucl. Phys. A 310, 1 (1979)

4) E. Fuschini; F. Malaguti, A. Uguzzoni and E. Verondini Phys. Rev. C 21, 1646 (1980).

6. ISTITUTO NAZIONALE DI FISICA NUCLEARE - SEZIONE DI FIRENZE - ISTITUTO DI FISICA DELL' UNIVERSITA' - Largo E.Fermi 2 FIRENZE (Italy)

6.1 Decay properties of ^{85}Rb

T.F.FAZZINI, P.R. MAURENZIG, G. POGGI, N. TACCETTI

With respect to the previous report /a/, further DSAM runs and accurate relative intensity measurements allowed a better understanding of the decay mode of the first $1/2^-$ level: the lifetime we obtained from DSAM measurements for the $1/2^- - 3/2^-$ transition is 60 ± 20 ps, while a value of $450 {}^{+50}_{-120}$ ps was reported in literature /b/; this value was obtained from Coulomb excitation measurements and from the branching ratio (4.5 %) for the decay $1/2^-$ - g.s. with respect to the $1/2^- - 3/2^-$. New Coulomb excitation measurements have been performed confirming the known value ($B(E2)\uparrow = .0016 \pm .0002 \; e^2 b^2$) while for the branching ratio we obtained $.5 \pm .2$ % ; therefore a lifetime of 50 ± 20 ps is obtained, in agreement with the value obtained from DSAM measurements.

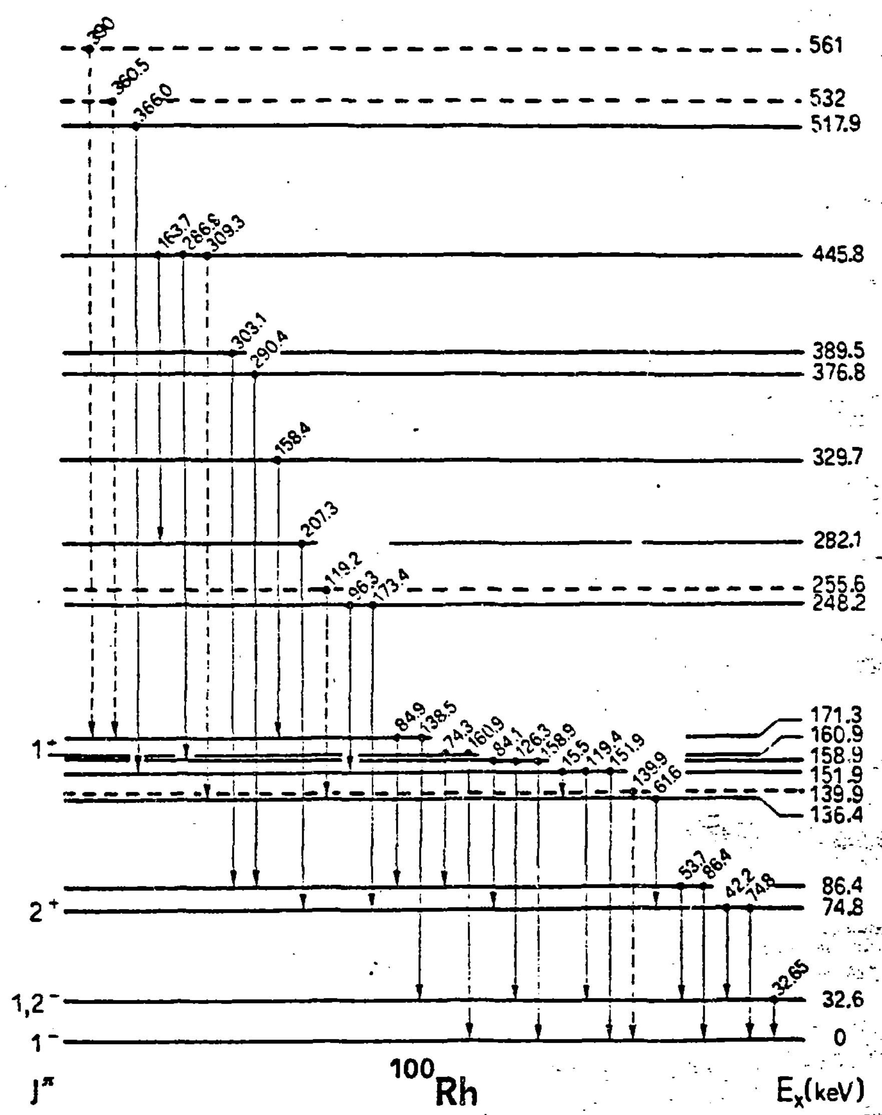
/a/ T.F. Fazzini, P.R.Maurenzig, G.Poggi, N.Taccetti, NEANDC(E)212 Vol. 7 (1980) p. 42.

/b/ P.D. Bond, G.J. Kumbartzki, Nucl. Phys. A205 , 239 (1977)

6.2 Level scheme of ^{100}Rh

A.M. BIZZETI - SONA, P. BLASI, P.A. MANDO'

Prompt γ rays following the ^{100}Ru(p,n)^{100}Rh reaction have been studied in order to determine the excited levels of ^{100}Rh and their decay properties. Gamma excitation functions have been measured in the energy range E_p = 4.5 - 5.5 MeV and $\gamma - \gamma$ coincidence measurements have been performed at E_p = 6 MeV. All measurements have been made with the 7.5 MV Van de Graaff accelerator of the Laboratori Nazionali di Legnaro. From our results the level scheme shown in figure is obtained.



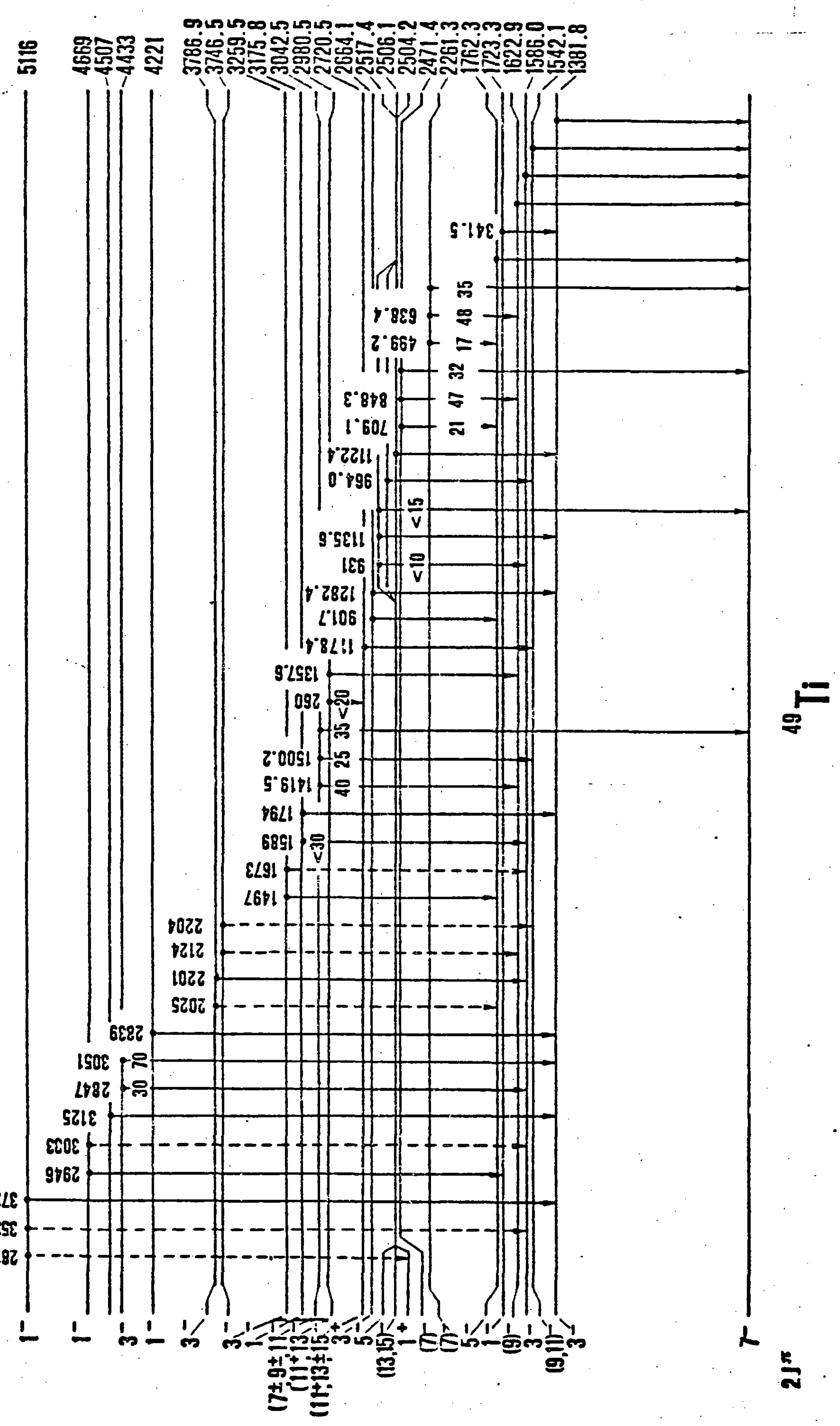
6.3 Level structure of ^{49}Ti up to E_x = 5.5 MeV

P.A. MANDO', G. POGGI, P. SONA, N.TACCETTI

In the previous report /a/ details on the experimental methods and analysis were described and preliminary results were presented. Further measurements using the ^{49}Ti(p,p'γ) reaction made it possible to define the level scheme presented in figure. Lifetime or lifetime limits are determined for 15 levels by Coulomb excitation or by DSAM. The final results concerning the DSAM are summarized in the Table.
These results will soon be published /b/.

/a/ P.A.Mandò, G.Poggi, P.Sona, N.Taccetti, NEANDC(E) 212 Vol.7 (1980) p. 39.

/b/ P.A.Mandò, G.Poggi,P.Sona and N.Taccetti, "Gamma decay and lifetimes of excited levels in ^{49}Ti" - to be published in Phys. Rev. C.


5116
4669
4507
4433
4221
3786.9
3746.5
3259.5
3175.8
3042.5
2980.5
2720.5
2664.1
2517.4
2506.1
2504.2
2471.4
2261.3
1762.3
1723.3
1622.9
1586.0
1542.1
1381.8
49Ti
2J^π

Level energy (keV)	γ-ray energy (keV)	$F(\tau)$	τ (DSAM)
1382	1382	$.002 \pm .026$	> 4000
1542	1542	$.100 \pm .022$	1070^{+360}_{-240}
1586	1586	$.072 \pm .044$	1520^{+2700}_{-640}
1623	1623	$.756 \pm .024$	51^{+8}_{-7}
1723	341	$-.023 \pm .186$	> 500
1762	1762	$.748 \pm .039$	52^{+12}_{-11}
2261	2261	$.680 \pm .124$	85^{+24}_{-19}
	638	$.615 \pm .071$	
	499	$.534 \pm .175$	
2471	2471	$.633 \pm .086$	75^{+25}_{-20}
	848	$.685 \pm .158$	
	709	$.652 \pm .135$	
2504	1122	$-.210 \pm .220$	> 400
2506	964	$-.160 \pm .280$	> 300
2517	1136	$.080 \pm .077$	> 600
2664	1282	$.111 \pm .145$	> 310
	902	$.240 \pm .290$	
2720	1178	$.627 \pm .100$	82^{+39}_{-29}
2981	1357	$.392 \pm .111$	185^{+115}_{-65}
3043	3043	$.886 \pm .132$	34^{+21}_{-20}
	1500	$.649 \pm .181$	
	1419	$.868 \pm .195$	

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7.1 Radiative Proton Capture above the G.D.R. in C^{12}

P. CORVISIERO, G. RICCO, M. SANZONE, A. ZUCCHIATTI

Photon absorption above the Giant Dipole Resonance in ^{12}C has been investigated via a proton capture reaction in the energy range $20 \leq Ep \leq 40$ MeV at the Laboratorio del Ciclotrone of Milano. Photons were detected at $\theta = 90°$ by a large (22 ∅ x 7 cm) NaI(Tl) detector while neutron background has been rejected by a time of flight technique and care has been taken to avoid pulse pile-up. Differential cross section for the section $^{11}B(p,\gamma_0)^{12}C$ and $^{11}B(p,\gamma_1)^{12}C^*$ have been obtained fitting the experimental spectra by the computed response functions of the detector. The cross sections, reported in figure, show a slow decrease in the high- -energy region which confirms the existence of important absorption mechanisms above the GDR.

The g.s. (p,γ_0) cross-section seems to show a wide resonance around 40 MeV excitation energy, but the present 90° data do not afford any definite conclusion.

Sistematic yield measurements at $20 \leq Ep \leq 43$ MeV and $30° \leq \theta \leq 120°$, by means of an improved anticoincidence NaI detector (resolution FWHM = 1.95 MeV at E_γ = 60 MeV) are in progress.

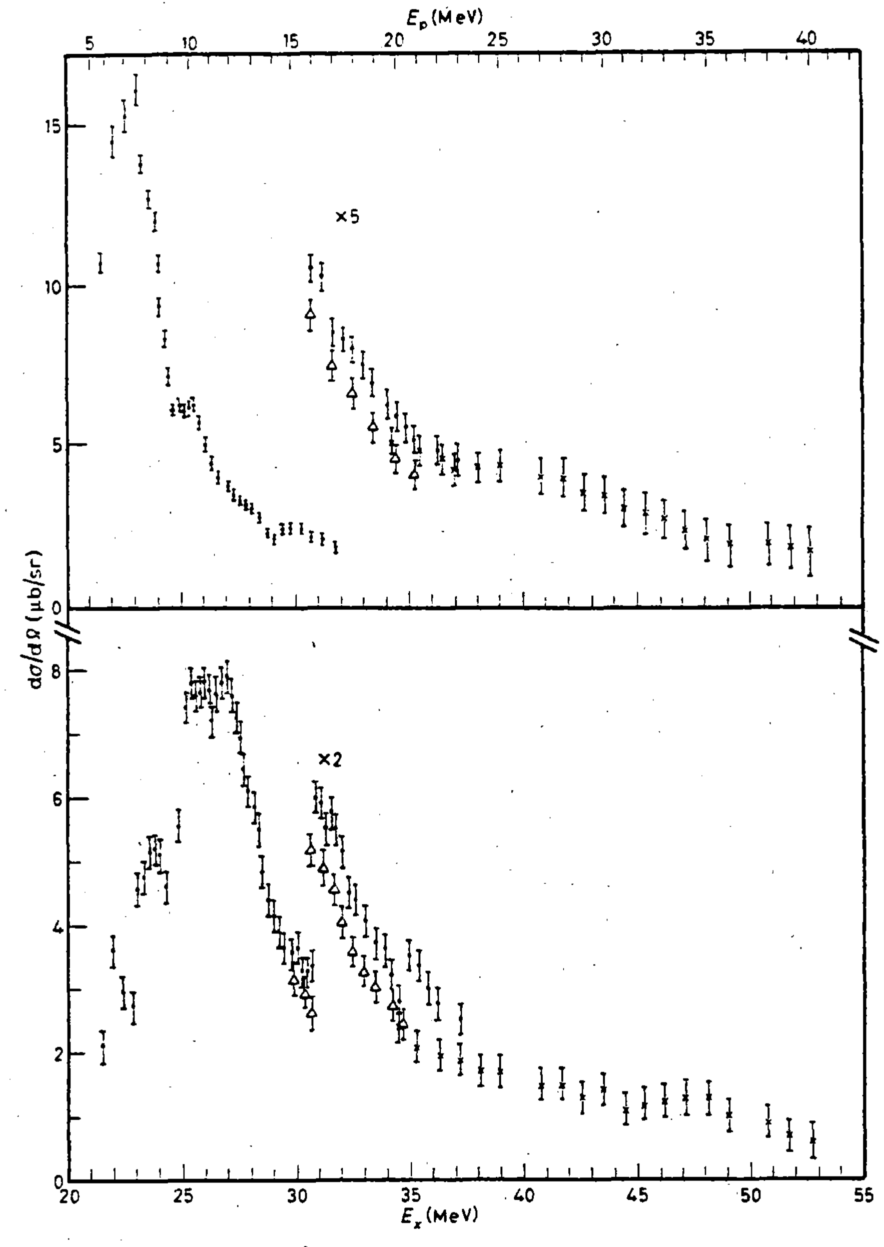

Fig. 2. – *a*) Differential cross-section for the $^{11}B(p, \gamma_0)^{11}C$ reaction at $\theta_{lab} = 90°$. *b*) Differential cross-section for the $^{11}B(p, \gamma_1)^{11}C^*$ reaction at $\theta_{lab} = 90°$. • ref. (7), △ ref. (8), × present work.

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ISTITUTO NAZIONALE DI FISICA NUCLEARE -SEZIONE DI NAPOLI-
Via A. Tari n°3 - 80138 NAPOLI (Italy) -

8.1 Direct Proton Capture on ^{40}Ca

A.BRONDI, P.CUZZOCREA, G.LA RANA, R.MORO, F.TERRASI(+)

The study of the proton direct capture on ^{40}Ca for extracting spectroscopic factors for the ground and first excited states in ^{41}Sc is in progress.
Excitation functions for the $^{40}Ca(p,\gamma)^{41}Sc$ capture reaction have been measured in the proton energy range 1.8-3.1 MeV. Measurements have been performed at the 4 MV Dynamitron Tandem accelerator of the University of Bochum using proton beam currents up to 50 μA.
Direct capture to the ground state and first excited state in ^{41}Sc has been observed and preliminary analysis of the spectra shows that relative values of the observed yields are in agreement with cross sections calculated using a simple square well model.

(+)- in collaboration with B. Gonsior, N. Notthoff and E. Kabuss- Institut für Experimentalphysik der Ruhr-Universität-Bochum.

8.2 Lifetime measurement for the level at 1701 keV in ^{18}F

A.BRONDI, P.CUZZOCREA, A.D'ONOFRIO, R.MORO, M.ROMANO,F.TERRASI

The Doppler-shift attenuation method by the inverse reaction $^{3}He(^{16}O,p\gamma)^{18}F$, for producing high-velocity recoiling nuclei which are slowed down in alluminum and tantalum, has been used for measuring the lifetime of the 1701 keV level in ^{18}F. The oxigen beam of 15.18 and 21 MeV energy was produced by the Tandem accelerator of the University of Naples. The analysis of the γ-ray lineshape of 660 keV line deexciting the level at 1701 keV with the stopping power data of Northcliffe and Schilling yields the following results: 1.41 $\pm$ 0.28 ps and 1.07 $\pm$ 0.14 ps for the backings tantalum and alluminum respectively.

8.3 Cluster induced pre-equilibrium reactions

R.BONETTI°, L.COLLI-MILAZZO°, A.DE ROSA, G.INGLIMA, E.PERILLO, V.RUSSO, M.SANDOLI

The study of the pre-compound emission has been continued by measuring angular distributions and excitation functions of the protons exciting some low-lying states in the $^{25}Mg(^{3}He,p)^{27}Al$ and $^{27}Al(^{3}He,p)^{29}Si$ reactions in the ^{3}He energy range between 9 and 14 MeV. For the second reaction also the emitted total proton spectrum was measured at 13 MeV incident energy.

°Istituto di Scienze Fisiche Università di Milano
INFN Sezione di Milano

The results have been compared with the quantum-mechanical description for the pre-compound emission recently developed by Feshbach. This theory predicts the existence of two independent processes relative to two different kinds of statistical approximations.
The first(statistical multistep compound emission: SMCE) must be applied when all the excited particles in the intermediate nucleus are bound, while the second one (statistical multistep direct emission: SMDE) describes the emission of particles when at least one particle is excited to unbound levels.
The shape of the angular distributions would allow evidentiating the presence of these two different mechanisms as the SMCE angular distribution is expected to be symmetrical to 90°, while the SMDE one should be forward peaked.
The angular distributions of the $^{25}Mg(^{3}He,p)^{27}Al$ show the effect of interference in the entrance channel and the proton spectra show the presence of fluctuations in the SMCE.
The excitation functions of the $^{27}Al(^{3}He,p)^{29}Si$ reaction show the presence of statistical fluctuations in the multistep compound emission. The coeherence energies are of the order of 250 keV clearly different from that of the evaporation emission|1||2|.

|1| A.De Rosa, G.Inglima, E.Perillo, M.Sandoli, R.Bonetti, L.Colli-Milazzo and F. Shahin: Phys. Rev. C, 21(1980)816.

|2| A.De Rosa, G.Inglima, V.Russo, M.Sandoli: Nuovo Cimento 58A(1980) 254.

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