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NEANDC (E) 322 "U" Vol. III Euratom
INDC (EUR) 025/G

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ANNUAL PROGRESS REPORT ON NUCLEAR DATA 1990

CENTRAL BUREAU FOR NUCLEAR MEASUREMENTS

GEEL (BELGIUM)

May 1991
EUR 13555 EN

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CATALOGUE N°: CD-NA-13555-EN-C

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Editor: H.H. Hansen

Note : For further information concerning the Project Nuclear Measurements (Nuclear Data, Nuclear Metrology), please contact A.J. Deruytter, Project Manager.

EXECUTIVE SUMMARY

A. J. Deruytter

In 1990 the efforts for the improvement of the set of **standard neutron cross-sections** and other quantities selected whithin the INDC/NEANDC Standards File continued. In particular additional information on the nuclear charge distribution and the odd-even effects for mass, charge and neutron number in the cold spontaneous fission of ^{252}Cf was obtained and the results of an evaluation of X- and γ-ray emission probabilities of 23 radionuclides used in detector calibration were reported in the frame of an IAEA-Coordinated Research Project. An investigation to improve the knowledge of the ratio of two important standard cross-sections ^{235}U(n,f)/H(n,n) based on the use of octacosanol layers, as hydrogen containing component, was started.
In the field of **nuclear data for fission technology** work was concentrated on European requests in the NEA High Priority Request List. The final results for the subthermal fission cross-sections of ^{233}U, ^{235}U and ^{239}Pu and η of ^{235}U were reported at the Physics of Reactors (PHYSOR) Meeting in Marseille, April 1990. They were used in JEF2. Also new subthermal fission cross-sections were obtained for ^{241}Pu and the g_f factor calculated. In the framework of the NEANDC Task Force on the 1.15 keV resonance of ^{56}Fe the experimental weighting function of C_6D_6 n-capture detectors which solved the discrepancy between capture and transmission data was investigated for its dependence on the sample thickness. This experimental weighting function could then be used in the analysis of the capture cross-section of ^{60}Ni below 300 keV neutron energy. Parameters were obtained for 178 resonances of which 19 were observed for the first time in these high resolution measurements. Also a measurement station was made operational for the measurement of γ-ray decay spectra from single resonances and first observations were made for capture in ^{53}Cr.
In the field of **nuclear data for fusion technology** measurements continued aiming at an improvement of relevant data for neutron transport calculation in the blanket and for prediction of gas production, in particular double differential neutron-emission cross-sections of ^{9}Be were analysed and the results transmitted for use in EFF. Also a light ion telescope with improved time- and energy resolution was developed and tested for (n, charged particle) reaction studies.
The **radionuclide metrology** subproject follows three lines : determination of decay-scheme data, preparation of special standards and the improvement of measurement techniques including international comparisons. In 1990 the detailed study of the response of silicon detectors to electrons, deuterons and

α-particles was finalised and published. Also an international cooperation in the frame of an EUROMET project was started to provide air kerma rate and activity standards of ^{192}Ir wires and to develop a scanning device for the assessment of the longitudinal homogeneity of such ^{192}Ir wires used in radiotherapy.

In the frame of an international collaboration between scientists from the University of Sussex, UK, NIST, USA, the Scottish Universities Research and Reactor Center, Glasgow, UK, and CBNM new measurements on the **free neutron lifetime** resulted in a value of (893.6 $\pm$ 5.3) s. CBNM's contribution consisted in the extremely careful preparation and very accurate characterization of sets of ^{10}B and ^{6}Li deposits on silicon wafers.

NUCLEAR DATA

NUCLEAR DATA FOR STANDARDS

Neutron Data for Standards

Standard Cross Section Ratio $^{235}U(n,f)/H(n,n)$

F.-J. Hambsch, R. Vogt, G. Willems*, J. Pauwels, J. Van Gestel, R. Eykens, A. Rodríguez

As already outlined in the previous progress report[(1)], an investigation has started aiming at an improved determination of the cross section ratio $^{235}U(n,f)/H(n,n)$.

In the present reporting period, deposits of various compounds (tetracosane, tetracosanol, pentacosane, heptacosane, octacosane, octacosanoic acid and octacosanol) were evaporated onto several substrate materials. Mainly on the basis of electron microscopy studies, octacosanol (CH_3-$(CH)_{26}$-CH_2OH), was chosen as the most appropriate compound. Several evaporations of this compound on highly polished tantalum were carried out to prepare deposits of various thickness (300, 650, 1000 $\mu g \cdot cm^{-2}$) for first test measurements to check the homogeneity by means of the cosine-dependence of the ionization chamber signals. The schematical view of the experimental set-up is shown in Fig. 1. During the experiment many problems with electronics and vibrations of the experimental platform have been encountered. Due to this data acquisition has been delayed. A conclusion as to whether the new component is suitable or not could therefore not be drawn yet.

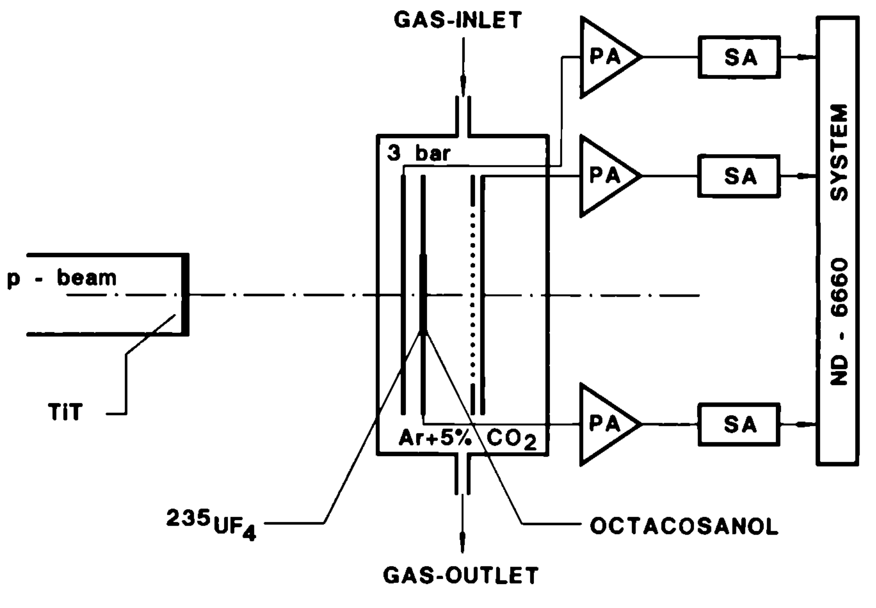

Fig. 1. Schematic experimental set-up

* Scientific Visitor from KU Leuven, Belgium

(1) CBNM Annual Report 89, EUR 12615 EN

Investigation of the Correlation Between Prompt Gamma-Ray Emission and Fission Fragments from $^{252}Cf(sf)$

F.-J. Hambsch, R. Vogt, B. Jäckel*

In the present reporting period the set-up described in the last progress report(1) has been completed and tests have been performed on the fission fragment detector together with the γ-ray detector. It has been found that the available γ-ray detector could not be used due to a neutron damage which results in a poor energy-resolution. This delayed the whole measurement and only recently data acquisition could be started. Until now, approximately $9 \cdot 10^6$ events were recorded in coincidence with the γ-ray detector and about the same number of events to be used for calibration purposes.

New Results from Cold Spontaneous Fission of ^{252}Cf

F.-J. Hambsch, H.-H. Knitter

In addition to the evaluation mentioned in the previous progress report (1), further investigation has been performed on the spontaneous fission of ^{252}Cf in the so-called cold fragmentation region, were the reaction Q-value is nearly exhausted by the total kinetic energy, TKE, of the fission fragments.
The nuclear charge information has been obtained from the experimental double-ratio

$$R(Z_L) = \frac{(P_{anode,L} - P_{sum,L})/P_{anode,L}}{(P_{anode,H} - P_{sum,H})/P_{anode,H}} = \frac{\overline{X}_L(E_L, A_L, Z_L)}{\overline{X}_H(E_H, A_H, Z_H)}$$

$\overline{X}$ is the distance between the centre of gravity of the charge distribution and the fragments' ion trace. P_{anode} is the anode and P_{sum} the sum signal of anode and grid(2). Fig. 2 shows the experimental nuclear charge distribution for a total excitation energy, TXE, of 11 MeV and for two selected masses A_L = 106 and 109, together with the convolution of individual charges (dashed lines). Since the nuclide yields for each bin are measured, it is possible to sum up the nuclides with even-even, odd-odd, even-odd and odd-even proton and neutron numbers respectively. Also the odd-even effects for the mass δ_A, nuclear charge δ_Z and neutron number δ_N can be obtained. These numerical values are given in Table 1.

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* Scientific Visitor from Philipps University, Marburg, Germany

(1) CBNM Annual Report 89, EUR 12615 EN

(2) C. Budtz-Jørgensen, H.-H. Knitter, Ch. Straede, F.-J. Hambsch and R. Vogt, Nucl. Instr. Methods A258 (1987) 209

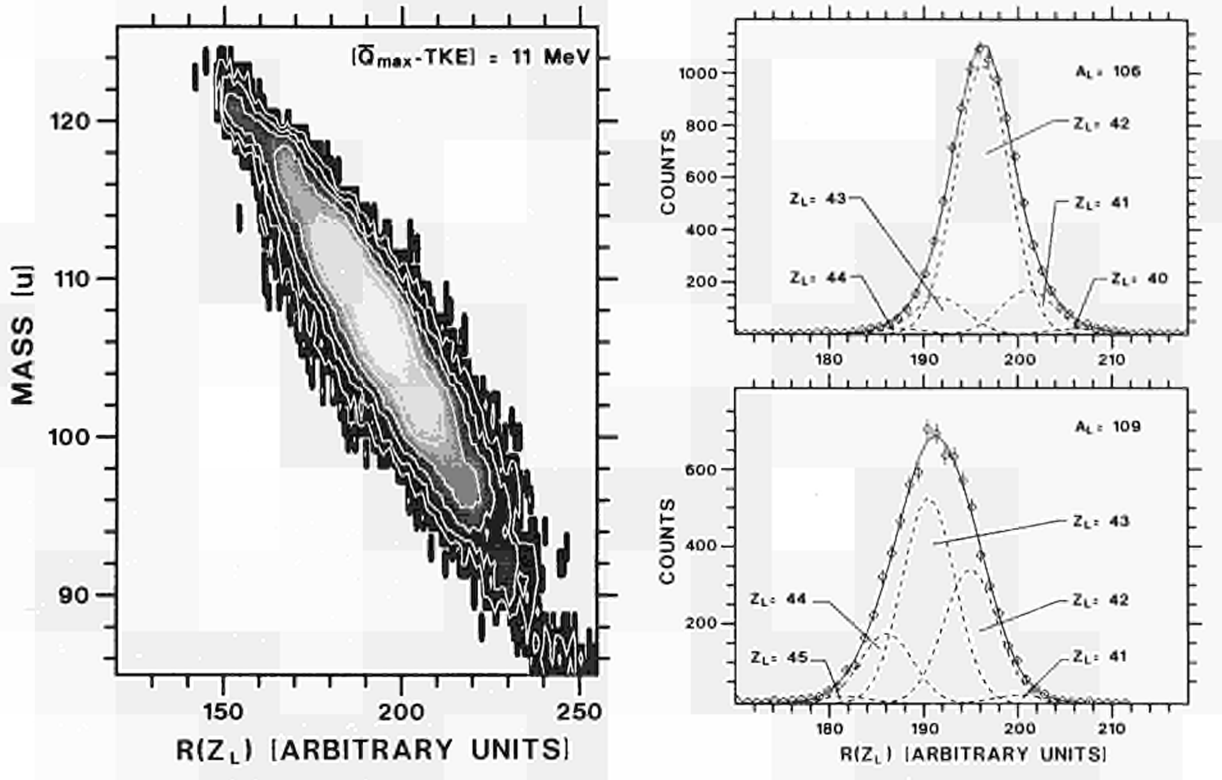

Fig. 2 . *Experimental nuclear charge distribution for Q_{max}–TKE = 11 MeV. Left : contour - image representation of the mass–charge correlation. Right : cut through the left picture for two selected masses and convolution of individual charges (dashed lines).*

Table 1. *The odd–even effects for fragment mass, nuclear charge and neutron number as well as the nuclear charge variance, are given for the different TKE–evaluation bins. The four lower lines give the relative yields for even–even, odd–odd, even–odd and odd–even nuclear charge and neutron number respectively*

	BIN 1 (0-2)MeV	BIN 2 (2-4)MeV	BIN 3 (4-6)MeV	BIN 4 (6-8)MeV	BIN 5 (8-10)MeV	BIN 6 (10-12)MeV	BIN 7 (12-14)MeV	BIN 8 (14-16)MeV
δ_A	0.19 ± 0.06	0.06 ± 0.03	0.014 ± 0.014	0.007 ± 0.008	0.000 ± 0.005	0.009 ± 0.003	0.000 ± 0.002	0.003 ± 0.002
δ_Z	-	0.48 ± 0.04	0.45 ± 0.01	0.506 ± 0.007	0.370 ± 0.005	0.304 ± 0.003	0.238 ± 0.002	0.183 ± 0.002
δ_N	-	0.13 ± 0.05	0.06 ± 0.02	0.068 ± 0.008	0.045 ± 0.005	0.033 ± 0.003	0.018 ± 0.002	0.013 ± 0.002
$<\sigma_Z^2>$	-	0.16 ± 0.09	0.32 ± 0.11	0.33 ± 0.66	0.40 ± 0.04	0.45 ± 0.03	0.48 ± 0.02	0.50 ± 0.02
EE[%]	(59)	37.6 ± 4	36.9 ± 1.2	40.7 ± 0.6	35.1 ± 0.3	33.6 ± 0.2	31.4 ± 0.2	29.7 ± 0.2
OO[%]	(0)	6.7 ± 2	11.4 ± 0.5	12.0 ± 0.3	14.8 ± 0.2	16.8 ± 0.1	18.6 ± 0.1	19.8 ± 0.1
EO[%]	(33)	36.7 ± 3	35.6 ± 1.0	34.6 ± 0.5	32.9 ± 0.3	31.6 ± 0.2	30.5 ± 0.2	9.5 ± 0.1
OE[%]	(7)	19.8 ± 1	16.1 ± 0.6	12.7 ± 0.3	17.1 ± 0.2	18.0 ± 0.2	19.5 ± 0.1	21.0 ± 0.1

δ_A is essentially zero giving indication for the randomness of the neck-rupture at scission even at very small TXE. δ_Z and δ_N on the contrary show linear dependence with TXE, however the magnitude of δ_Z is about five times larger than that of δ_N.

The odd-even effects for proton and neutrons have been also evaluated as function of mass-split, an example of which is shown in Fig. 3.

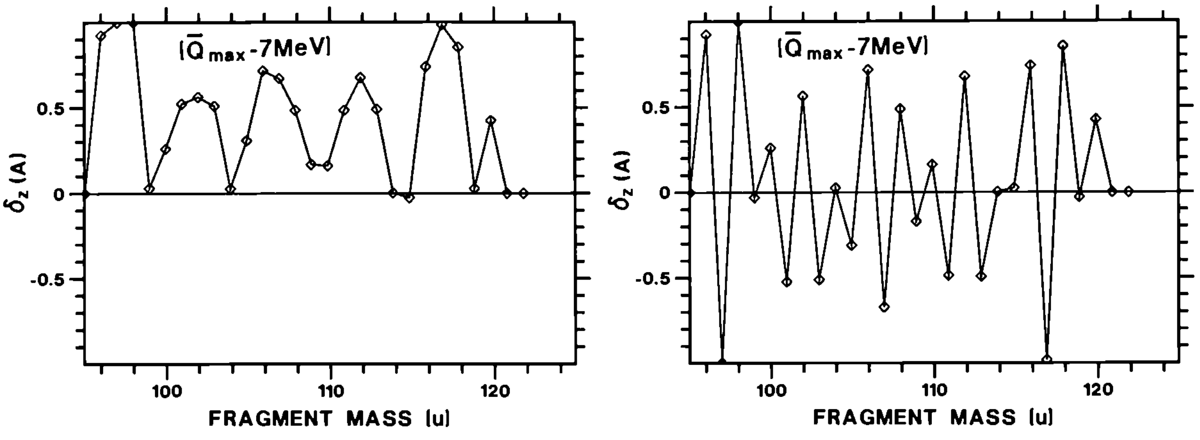

Fig. 3. ***Local odd-even efffects for protons (left) and neutrons (right) as function of fragment mass.***

A clear undulatory structure with a period of five mass units is seen in $\delta_Z(A)$, whereas $\delta_N(A)$ shows strong fluctuations from one mass to the other. The measured nuclide yields are a direct picture of the structures visible in the Q-value energy surface Q(A,Z) (Fig. 4), which accounts for the undulatory structure seen in $\delta_Z(A)$ and other parameters. Following the behaviour of Q(A,Z) which means cutting not parallel to the highest Q-value but parallel to individual Q-values for single charges, changes the picture drastically as seen in Fig. 5. The undulatory structure seen in the picture on the left essentially disappears in the picture on the right, where $\delta_Z(A)$ is evaluated for a constant excitation energy TXE(A, Z). The remaining structure in the picture on the right can be understood by level density considerations. The level densities close to the ground state are larger for odd-odd fragments than for even-even fragments and therefore fragmentations with broken nuclear pairs are favoured. Furthermore δ_Z or δ_N can no longer be interpreted as being a measure of the excitation energy of the fissioning nucleus at the moment of scission, because these values are close to zero or even slightly negative. This would give intrinsic excitation energies close to infinity, if they are calculated as in proposed models (TXE $\sim$ ln δ)(1).

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(1) H. Nifenecker, G. Marolopoulos, J.P. Bocquet, R. Brissot, Ch. Hamelin, J. Crançon and Ch. Ristori, Z. Phys. A308 (1982) 39

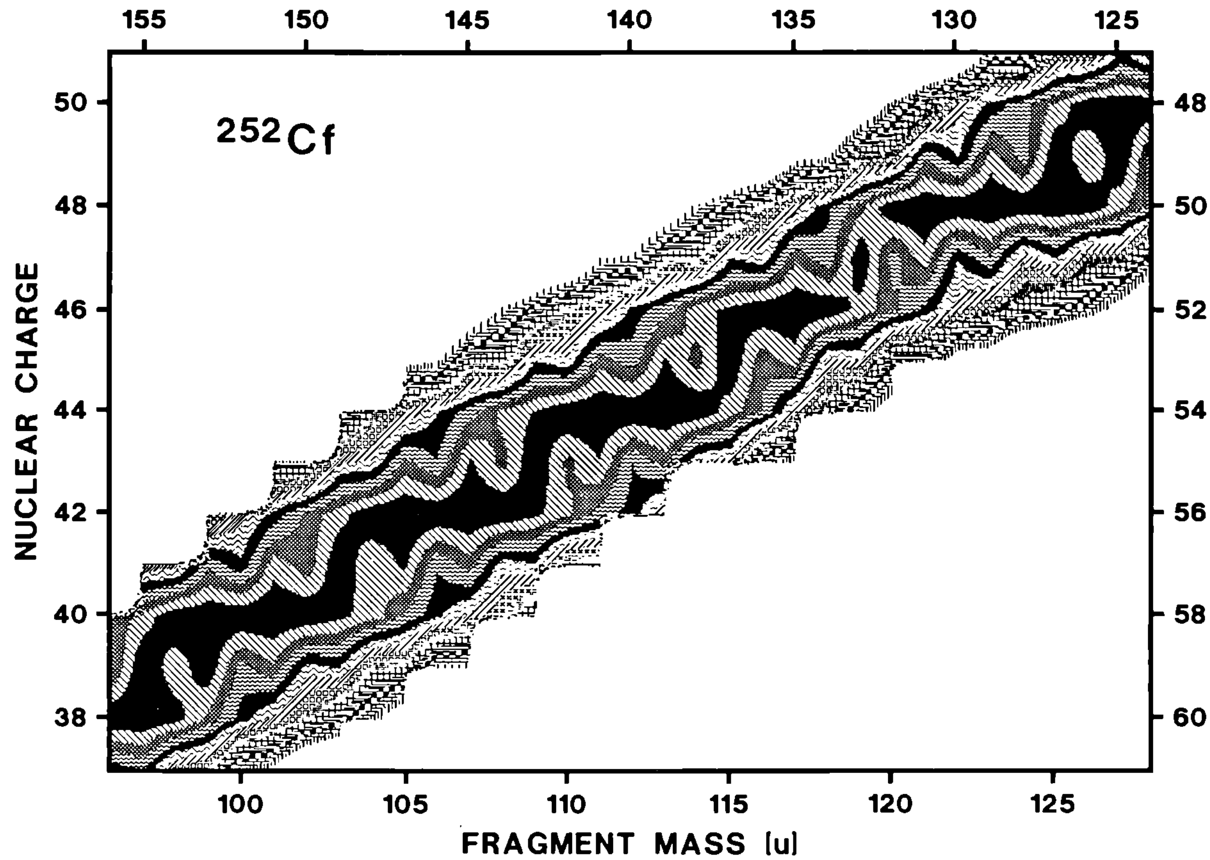
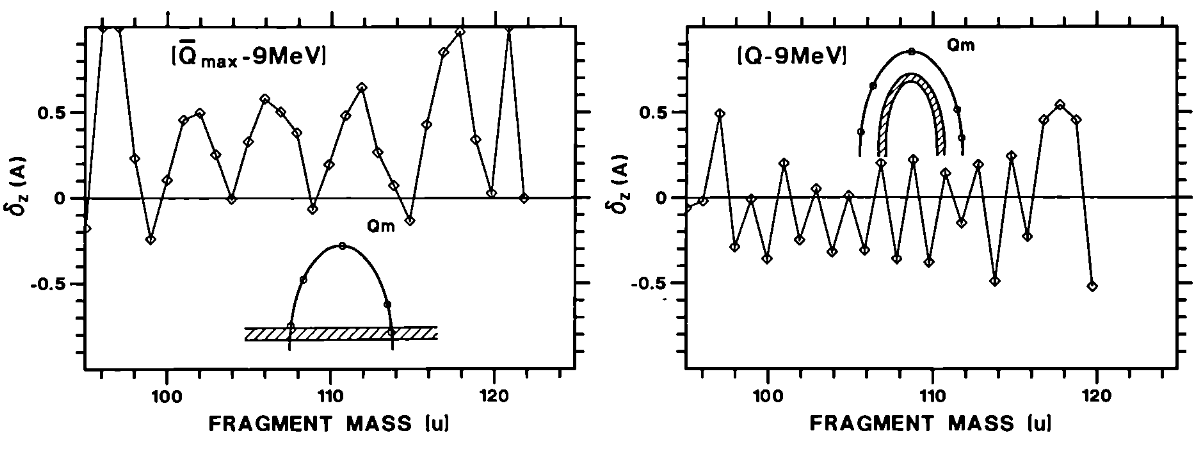


Fig. 4. *The Q-value energy surface Q(A,Z) in a grey-shaded representation.*



Fig, 5. *Local proton odd-even effect at (Q-9 MeV). Left : for cuts parallel to Q_{max}. Right : for cuts with constant distance from Q(A,Z).*

Non-Neutron Nuclear Data For Standards

Half Life of ^{125}I

T. Altzitzoglou

The evaluation of the measurements to determine the half life of ^{125}I has been finished. The data, corrected for background, dead time and pile-up, were fitted using a weighted least-squares fitting routine. Table 2 shows the results obtained from this work. They are in good agreement with the most recent results from the literature.

Table 2. Results of the ^{125}I half-life measurements

Source detector distance [mm]	Number of data points	Measuring time t / Halflife $T_{1/2}$	$T_{1/2}$ [d]
16	52	1.0	59.37 ± 0.04
54	163	1.7	59.37 ± 0.02
94	72	0.7	59.35 ± 0.06

The uncertainties quoted are those resulting from the weighted fitting. In the final calculation of the uncertainty, the following components were added to the statistical uncertainty : dead-time correction 0.01 %, background 0.05 %, timing 0.005 %, accidental coincidences 0.1 %, and threshold setting 0.1 %. An attempt was made to fit the data to a mixture of ^{125}I and ^{126}I, but with no success, which is in agreement with no detection of ^{126}I impurity. In order to check the results further, the data were divided into subgroups and each subgroup was analyzed independently by the method described by Walz et al. in 1983[(1)].
The adopted value for the half life of ^{125}I is (59.37 ± 0.06) d. A publication describing these measurements is in press.

Evaluation of X- and Gamma-Ray Emission Probabilities

W. Bambynek

In the frame of an IAEA Coordinated Research Project (CRP) on X- and Gamma-Ray Standards for Detector Efficiency Calibration the evaluated values of decay data for 23 radionuclides were communicated to the IAEA to be printed in the final document.

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(1) K.F. Walz, K. Debertin and H. Schrader, Int. J. Appl.Radiat. Isot. 34 (1983) 1191

Reorganization of Atomic Shells after Radioactive Decay
W. Bambynek

The principles to produce inner-shell vacancies after nuclear decay by (a) orbital electron capture of the nucleus and (b) by internal conversion of gamma rays were summarized. In addition, the principles of the reorganization of atomic shells by radiative and radiationless (Auger and Coster-Kronig) transitions after radioactive decay were reviewed. Two invited lectures were given at the Second International Summer School on Low-Level Measurements of Man-Made Radionuclides in the Environment, La Rábida, Spain.

NUCLEAR DATA FOR FISSION TECHNOLOGY

Neutron Data of Actinides

Subthermal Fission of the Common Fissile Isotopes

C. Wagemans*, P. Schillebeeckx**, A.J. Deruytter, R. Barthélémy, J. Van Gils

The measurements of the subthermal fission cross-section of ^{233}U, ^{235}U, ^{239}Pu and ^{241}Pu have been finalized. For these experiments, a liquid nitrogen cooled methane moderator has been installed at GELINA to enhance the neutron production below 20 meV neutron energy. The accelerator was operated at a 40 Hz repetition frequency with 2 µs burst width and with an average electron current of 15 µA. An evaporated layer of 25 µg $^{6}LiF/cm^2$ for the neutron flux determination and a thin fissile layer were mounted back-to-back in the centre of a large vacuum chamber. The fission fragments and the particles from the $^{6}Li(n,\alpha)t$ reaction were detected with two large surface barrier detectors placed outside the neutron beam.

For the $^{6}Li(n,\alpha)t$ reaction cross-section, a 1/v-shape was assumed in the energy region below 20 eV. The ratio of the background corrected fission and $(\alpha+t)$ counting-rates yields the $\sigma_f(E)\sqrt{E}$-shape, which still needs to be normalized. This normalization was done in the thermal region relative to the σ_f°-value of the ENDF/B6 file.

Final results for ^{233}U, ^{235}U, and ^{239}Pu and partial results for ^{241}Pu have been presented at PHYSOR 90 in Marseille. These data had a strong impact on the JEF-2 evaluated data file for the actinides, as illustrated in Fig. 6 for $^{239}Pu(n,f)$.

In the first series of measurements of the $^{241}Pu(n,f)$ cross-section a 8 µg/cm² ^{241}Pu layer (deposited as an acetate) was used. For the present experimental campaign, a 27 µg ^{241}Pu layer has been prepared. In both cases, a chemical Am/Pu separation was performed prior to the sample preparation. Two runs have been performed with the neutrons bombarding a Li/Pu respectively a Pu/Li sample configuration. This was done to make sure that no absorption phenomena occurred. Since the results obtained in both runs were in agreement, they were converted into a single $\sigma_f(E)$ data set.

These new data have a much better statistical accuracy than those obtained with the 8 µg/cm² sample, with which they agree however within the experimental uncertainties. Fig. 7 shows the $\sigma_f(E)$ data from 0.002 eV up to 20 eV obtained in the present experiments. These data confirm the interference effect near 2 eV recently observed [(1)].

* Rijksuniversiteit Gent, Belgium
** Present address : JRC, Ispra, Italy
(1) H. Derrien and G. de Saussure, ORNL/TM-11123 (1989)

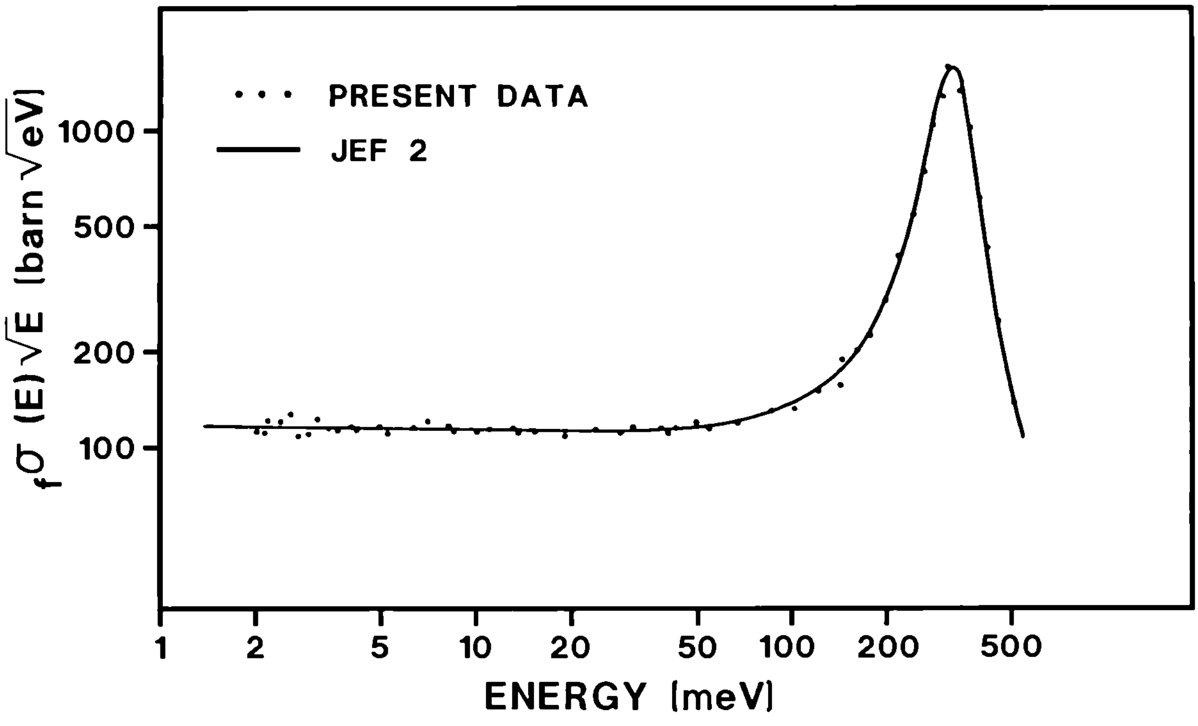

Fig. 6. *Comparison of the present $^{239}Pu(n,f)$ cross-section data with the JEF-2 data file*

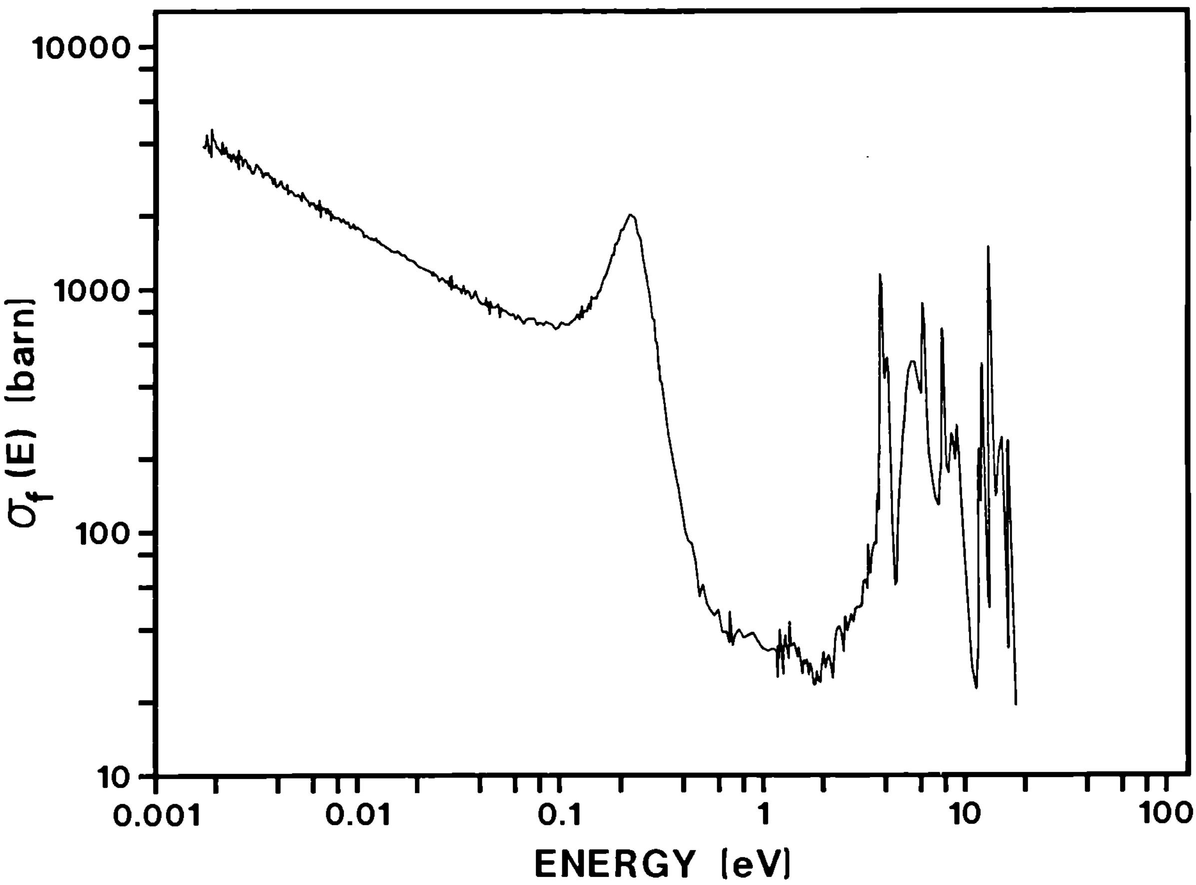

Fig. 7. *The $^{241}Pu(n,f)$ cross section from 2 meV up to 20 eV*

From the present $\sigma_f(E)$-data, a value of 1.041 ± 0.003 was calculated for the Westcott g_f-factor, which is lower than generally adopted. This is due to the fact that the older g_f-values were based on a very poor and discrepant $\sigma_f(E)$-data base for < 1 eV.

Development of a Multi-Purpose Charged Particle Detection System

C. Wagemans*, F. Verhaegen*, S. Druyts**, R. Barthélémy, J. Van Gils

During the ternary fission process as well as in some neutron induced reactions, light particles with different charge (Z) are emitted.

To investigate these phenomena, a detection system has been developed consisting of two gridded gas-flow ionization chambers and a 20 cm^2 large, 1000 μm thick surface barrier detector.

Using only one gridded ionization chamber, the detector can be applied e.g. to the study of (n,p) and (n,α)-reactions as a function of the incident neutron energy. As an extreme case, the 0.6 MeV protons produced in the $^{35}Cl(n,p)$ reaction have been studied.

By combining one ionization chamber with the surface barrier detector, a ΔE-E telescope is formed enabling the separation of Z = 1 and Z = 2 particles.

By activating the second ionization chamber finally, a F- detector is obtained, enabling a correlation of the charge-identified ternary particles with one of the accompanying fission fragments (F).

Capture to Fission Ratio, α, of ^{235}U

H. Weigmann, J.A. Wartena, C. Bürkholz

The detailed energy dependence of neutron cross sections and related parameters of fissile nuclei for sub-thermal neutron energies has recently found considerable attention because of its effect on the temperature coefficient of reactivity of thermal reactors.

Among others, measurements of η, the number of fission neutrons emitted per neutron absorbed, of ^{235}U, have shown a decrease with decreasing neutron energy in the sub-thermal region, in rough agreement with conclusions drawn from integral experiments.

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** EC Fellow

The measured effect on eta is small, about 2 %, which is only about twice the experimental uncertainties. Furthermore, it has been argued that the apparent variation of η might have been produced by a solid state effect - coherent backscattering of the incident neutrons from the metallic sample used. Therefore, an independent verification is desirable.
Under the assumption that the average number of neutrons per fission, $\bar{\nu}$, is constant, the decrease of eta implies an increase of the capture to fission ratio, α, by a much larger fraction. Therefore, a measurement of α, although experimentally more difficult, might be as sensitive to the effect under investigation.
We have set up an experiment to measure α of ^{235}U by measuring specific low energy capture γ rays and prompt fission γ rays with a germanium detector. The liquid methane moderator of GELINA is used as a pulsed source of sub-thermal neutrons, and the neutron energy is determined by time-of-flight. The method requires that the relative yields of the measured γ rays per capture and fission event, respectively, do not vary over the energy range considered.
A series of measurements has been performed during a three weeks period when GELINA was operated with the liquid methane moderator. Analysis of the data is in progress.

Neutron Data of Structural Materials

The ^{56}Fe 1.15 keV Resonance Task Force

F. Corvi, G. Fioni*, A. Mauri**, K. Athanasopoulos

A point not sufficiently clarified in the previous works on the weighting method to be applied to neutron capture detectors(1) was the dependence of the weighting function on the sample thickness. To investigate this effect, we performed a series of measurements of the 1.15 keV ^{56}Fe resonance normalized to capture in gold for a variety of iron samples. The thickness of the reference gold sample was 0.1 mm and normalization has been done on top of the 4.9 eV resonance according to the saturated resonance method. Two different detector arrangements normally used in neutron capture were studied : if θ is the angle between the neutron beam direction and the axis of the cylindrical C_6D_6 scintillators, the first consisted of two detectors at $\theta = 90°$ and the second of four detectors at $\theta = 125°$.

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** National Expert from ENEA, Bologna, Italy

(1) F. Corvi, A. Prevignano, H. Liskien and P.B. Smith, Nucl. Instr. Meth. Phys. Res. A265 (1988) 475

The results, uncorrected for γ-ray and electron self-absorption, are listed in Table 3. For the $\theta = 90°$ case, the measured neutron width stays approximately constant and agrees with the transmission value $\Gamma_n = 61.7 \pm 0.9$ meV up to a thickness of 0.8 g/cm² corresponding to a 1 mm metallic sample. Then it decreases steadily.

Samples thicker than 1 mm were used in neutron capture of ^{56}Fe and ^{60}Ni but in these cases the data were normalized to the capture area of the lowest energy resonance of each isotope (E_0 = 1.15 and 2.25 keV, respectively). These parameters had been independently determined. The question was, however, whether the weighting function used is still able to deal correctly with the degraded γ-ray spectral shapes emerging from a thick sample.

Table 3. ***Values of the neutron width of the 1.15 keV resonance obtained from capture measurements normalized to the 4.9 eV gold resonance***

Sample		Γ_n [meV]	
Thickness [g/cm²]	Chemical/Isot. Composition	90° Geom.	125° Geom.
0.3874	^{56}Fe	60.1 ± 1.7	62.0 ± 1.6
0.7973	^{56}Fe	61.3 ± 1.8	62.7 ± 1.8
1.1847	^{56}Fe	56.2 ± 1.7	
1.987	Fe_2O_3	53.8 ± 1.8	
1.970	)22.7 % Fe))77.3 % Ni	52.3 ± 1.7	
1.826 [a]	)93.5 % Fe)) 6.5 % Au	63.6 ± 2.0	65.3 ± 2.0
ORNL Transmission		61.7 ± 0.9	

[a] Self-calibration sample

This was investigated using a mixed sample of iron and gold : the neutron width obtained by normalizing to capture in the gold contained in the sample was only 5 % larger than the thin-sample value. This is acceptable as the differences in spectrum shapes amongst the various ^{56}Fe resonances are much less than that between ^{56}Fe and gold spectra. Tests for $\theta = 125°$ give similar results as for $\theta = 90°$. It shows that the weighting function, which was experimentally determined only for the $\theta = 90°$ geometry, can also be applied to the $\theta = 125°$ case.

Resonance Neutron Capture in ^{60}Ni

G. Fioni*, F. Corvi, A. Mauri**, K. Athanasopoulos

Neutron capture measurements of ^{60}Ni were performed at GELINA in the energy range from 1 to 700 keV. Two metal samples in the form of disks of 8 cm diameter were prepared with nickel enriched to 99.07 % ^{60}Ni : a sample of N = 0.0180 atoms/b and of 90.953 g was used in the high resolution run at a 58.6 m flight path ; a sample of N = 0.0041 atoms/b and 20.51 g was used at 28.4 m distance for calibration purposes and for measurements with energies of up to 100 keV. A new detector set-up was employed, consisting of four C_6D_6 scintillators viewing the sample at an angle of 125° with respect to neutron beam direction. This system was designed to minimize possible systematic errors due to the anisotropy of radiation emitted from resonances with spin larger than J = 1/2.

The data were normalized to the capture area of the 2.25 keV resonance which was measured relative to gold capture at 4.9 eV, using the thin sample. Values of the neutron width obtained at fixed $\Gamma_\gamma = 0.60$ eV, are given in Table 4 for two different detector geometries and are compared with ORNL transmission results. The most recent of these values is in reasonable agreement with capture.

Table 4. ***Values of the neutron width of the 2.25 keV resonance of ^{60}Ni obtained from capture measurements normalized to gold, and from transmission measurements***

Measurement			Sample Thickness [atoms/b]	$g\Gamma_n$ [meV]
Lab-Year	Type	Geometry		
CBNM-'89	Capture	$\theta = 90°$	0.00410	60.2 ± 1.4
CBNM-'90	Capture	$\theta = 125°$	0.00410	62.2 ± 1.4
ORNL-'82	Transmission[(1)]			53.0
ORNL-'90	Transmission[(2)]		0.0393, 0.0837	59.3 ± 0.8

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* EC Fellow

** National Expert from ENEA, Bologna, Italy

(1) C.P. Perey et al., Phys. Rev. C27 (1983) 2556

(2) F.G. Perey, Private Communication (1990)

Since preliminary γ-spectroscopy measurement had indicated a spin J = 3/2 for the 2.25 keV resonance, the value measured at θ = 125° was chosen to normalize all $^{60}Ni(n,\gamma)$ data.
At low energy, capture in ^{60}Ni is dominated by the broad s-wave resonance at 12.42 keV. A fit obtained with the FANAC code for the thin sample run is shown in Fig. 8. Two p-waves sitting on its top are also shown.

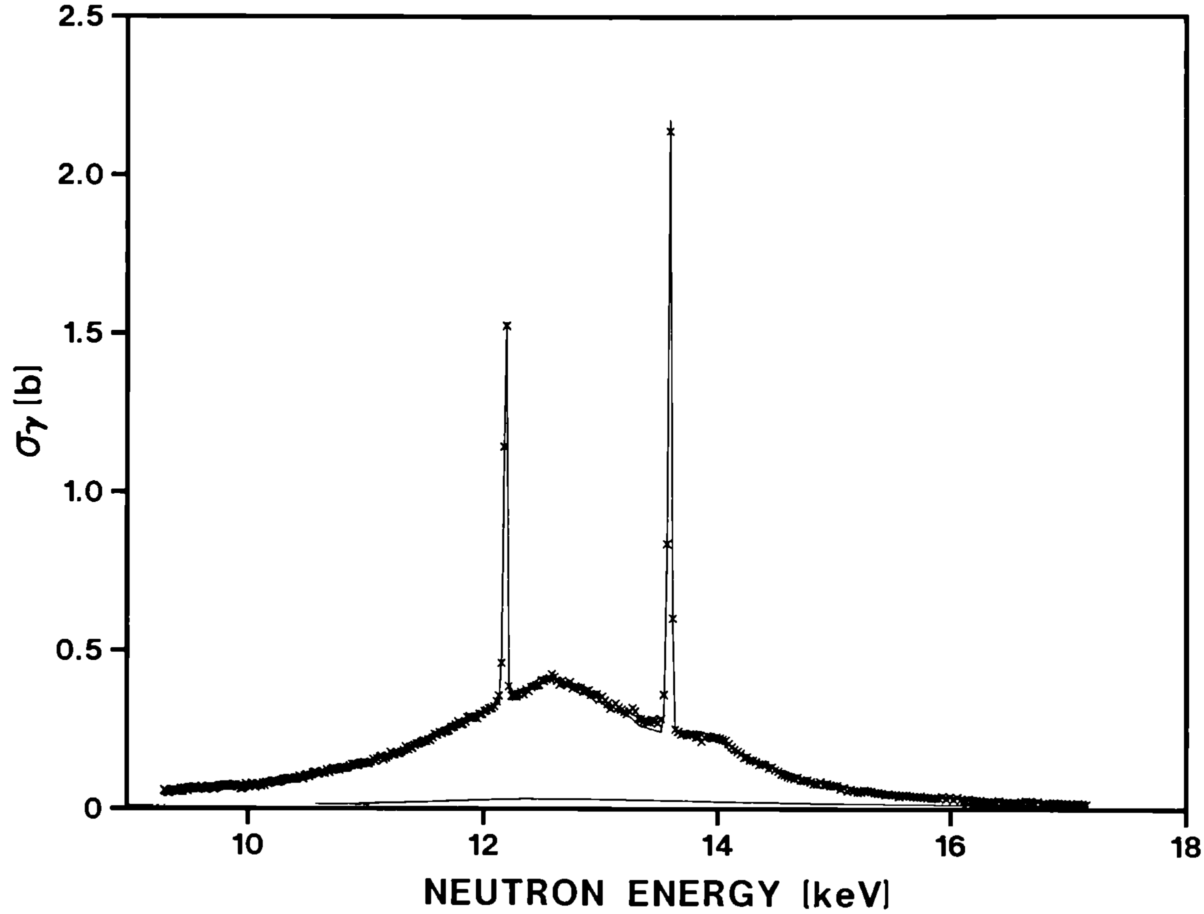

Fig. 8. Shape fit of the triplet of resonances at 12.22, 12.42 and 13.62 keV

Values of the capture width of the 12.42 keV resonance from the present and previous works are compared in Table 5. The two results from the present work are in good agreement in spite of the fact that the multiple scattering correction factor for the thick sample run is of the order of 4 to 5.
The energy region from 1 to 300 keV was analyzed with the area code TACASI and/or with the shape code FANAC. The parameters of 178 resonances were determined, 19 of which seen for the first time. From this data set the ^{60}Ni capture cross section was calculated averaging over a Maxwellian neutron energy distribution centred around various kT values in the keV region. The results, which are of interest for the study of stellar nucleosynthesis, are reported in Table 6.

Table 5. Values of the capture width of the E_0 = 12.42 keV s-wave resonance obtained in the present and in previous works

Author	Γ_γ [eV]
Present work - thin sample	2.33 ± 0.20
Present work - thick sample	2.22 ± 0.22
Stieglitz et al. (1971)	3.3 ± 0.3
Fröhner (1977)	2.73 ± 0.50
Perey (1983)	2.6 ± 0.8
Wisshak (1984)	2.92 ± 0.19

Table 6. Maxwellian-averaged (n,γ) cross sections of ^{60}Ni for various kT values

kT [keV]	$<\sigma_\gamma V>/V_T$ [mb]
12	48.1 ± 3.5
20	34.3 ± 2.0
25	29.4 ± 1.6
30	26.0 ± 1.4
40	21.5 ± 1.1
52	18.2 ± 0.9

Measurement of γ-Ray Decay Spectra from Single Levels Excited by Neutron Capture in ^{53}Cr

C. Coceva*, A. Spits**, A. Mauri***

The Ge telescope detector(1) was used to study the spectrum of gamma rays emitted upon neutron capture in resonances of ^{53}Cr. A 32.4 g sample of isotopically enriched ^{53}Cr and the Ge detector were placed on a 25 m flightpath at the GELINA facility. Time of flight and amplitude of pulses from the central

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(1) CBNM Annual Report 89, EUR 12615 EN

Ge crystal, satisfying the anticoincidence conditions, are analysed simultaneously, with a resolution $\Delta t = 15$ ns and $\Delta E = 4.8$ keV at 6 MeV, respectively.
Neutron resonances can be resolved up to about 110 keV ; new resonances are observed at 24.3, 47.8, 55.2 and 64.8 keV. From a rough examination of the spectra being collected, it can be deduced that the spin of the 8.17 keV resonance is $J = 1$, in disagreement with the value reported by Allen et al.[(1)].
In $J = 1$ resonances a close correlation is apparent between the E1 primary transitions to the ground state and to the first excited state of ^{54}Cr, roughly in the same ratio as the population of these two final states by the (d,p) reaction. This strongly hints to an effective valency capture mechanism.
It is believed that significant spectra can be seperately collected for 8 s-wave and 3 p-wave resonances below 30 keV. At neutron energies between 30 and 70 keV, an average gamma spectrum can be obtained over 15 p-wave resonances. The measurements are still in progress.

Transmission measurements of ^{58}Ni, ^{60}Ni and ^{61}Ni

A. Brusegan, C. van der Vorst

The total cross sections of ^{58}Ni, ^{60}Ni and ^{61}Ni have been measured. Three independent high resolution transmission runs, one for each isotope, have been performed at GELINA running with 1 ns burst width.
The sample thicknesses and enrichments were 0.044 atoms/b (99.927 %), 0.074 at/b (99.07 %) and 0.019 atoms/b(91.78 %) for ^{58}Ni, ^{60}Ni and ^{61}Ni, respectively.
Neutrons were detected at about 49 m flight distance by a 0.5 cm thick sintered $^{10}B_4C$ slab, which was viewed by 4x(10 cm x 5 cm) C_6F_6 liquid scintillators, kept in a 10 cm thick lead screen.
Those detectors have been chosen instead of NaI(Tl) crystals because, in spite of their relatively low efficiency, they show very good timing properties and moreover a quite low sensitivity to neutrons. This last property helps in reducing those energy dependent systematic errors arising from local and not detectable fluctuations in the background, when this is mainly due to neutrons captured in the detectors and scattered by the boron slab itself.
The total cross section was measured in the energy range from 16 eV up the 1 MeV : the extension to low energy, where no resonances of the nickel isotopes are present, allows a consistent determination of the potential scattering radius together with the resonance parameters of the negative energy levels. In order

(1) B.J. Allen, A.R. de L. Musgrove, Neutron Data of Structural Materials for Fast Reactors, Geel, 1977, K.H. Böckhoff (ed.), p. 447

to estimate the systematic error induced by the measurement technique, the background and the data reduction procedure, a measurement of the transmission of a carbon sample (0.143 atoms / b thick), absorbing on average 50 % of the neutron beam, has been added to each.
The carbon cross section is a standard and the comparison to our results states a deviation on the transmission curves of 5 % from 100 up to 700 eV, of 2.5 % above 700 eV and below 1 keV and of 1.3 % up to 600 keV.

Development of a Li-Glass Detector for Neutron Transmission Experiments

A.Brusegan, C. van der Vorst

In neutron time of flight spectroscopy, when the detector needs to register only the arrival time of the neutron, the $^{6}Li(n,\alpha)t$ reaction is probably as popular as the $^{10}B(n,\alpha\gamma)^{7}Li^{*}$ reaction.
In the ^{10}B reaction, the detection of the 478 keV gamma ray, emitted by the excited ^{7}Li nucleus, demands at least 2 relatively large, fast scintillators having moreover a low sensitivity to neutrons, which are scattered mainly by the boron itself.
Below a few hundred keV neutron energy, a lithium-glass scintillator may simplify the detection set-up, facilitate to solve stability problems, even keeping good detection efficiency and good time and amplitude resolution.
The lithium detector (NE912, 7.5 % enriched in ^{6}Li, low background), consists of a glass cylinder, with a diameter of 15 cm and a thickness of 0.6 cm, kept in the equatorial plane of an aluminium sphere of 20 cm diameter and 0.06 cm thickness.
The internal surface of the sphere is coated with barium sulphate. The circular surface of the glass is placed orthogonally to the neutron beam and to the photocathode of a 12.5 cm photomultiplier (EMI 9823 KQB, boron free quartz window),which is positioned in the aluminium sphere surface (Fig.9).
Fig. 10 shows the overall detector response to neutrons with energies above 30 eV in the moderated GELINA beam. It is the measured convolution of the actual Linac neutron flux with

a) the intrinsic efficiency of the detector;
b) the change of the total energy available to the reaction with the change of the neutron kinetic energy;
c) non linearity effects in the light output associated with high energy neutrons;
d) gamma-ray and neutron background.

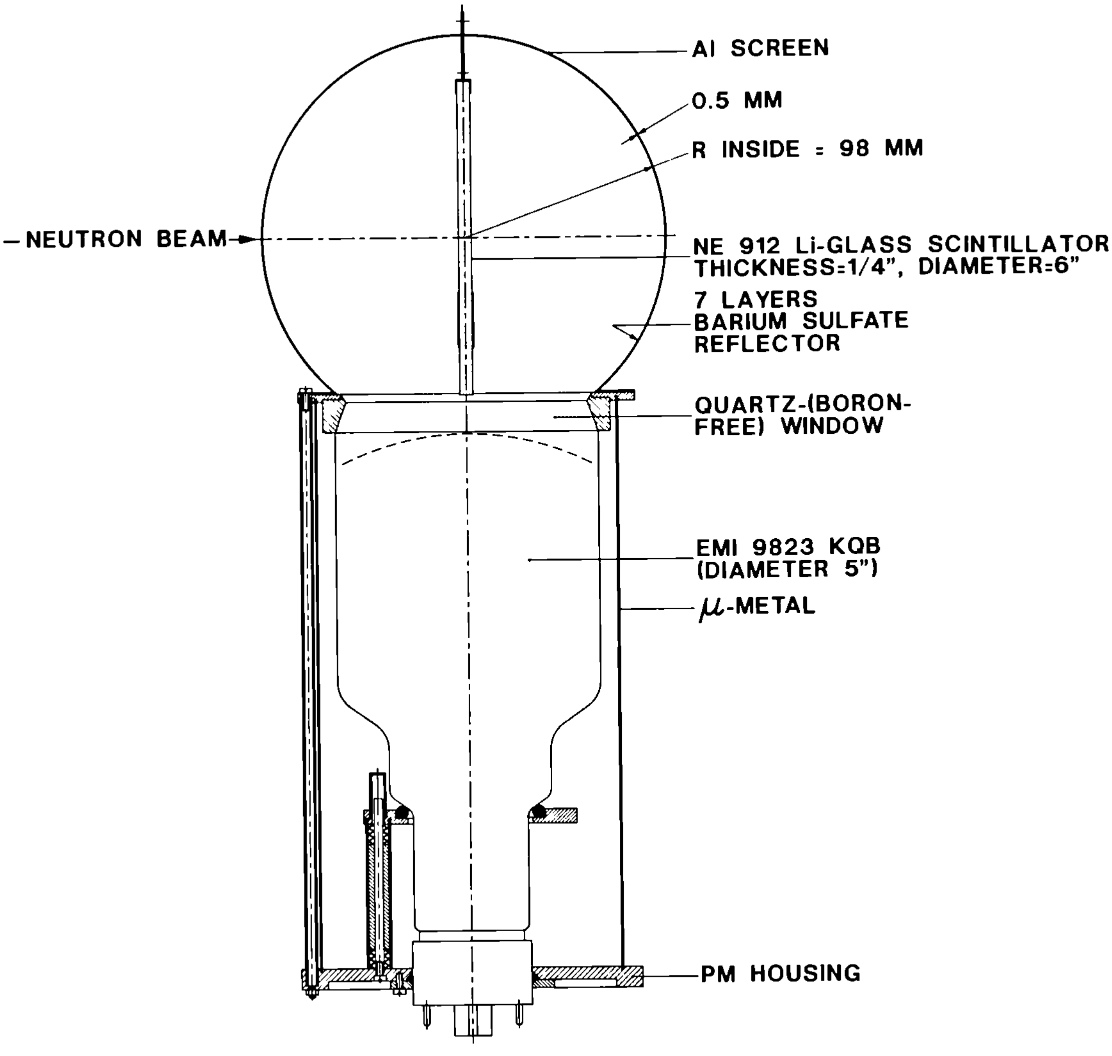

Fig. 9. Longitudinal cross section of detector showing the lithium-glass, the aluminium sphere, the photomultiplier and its housing

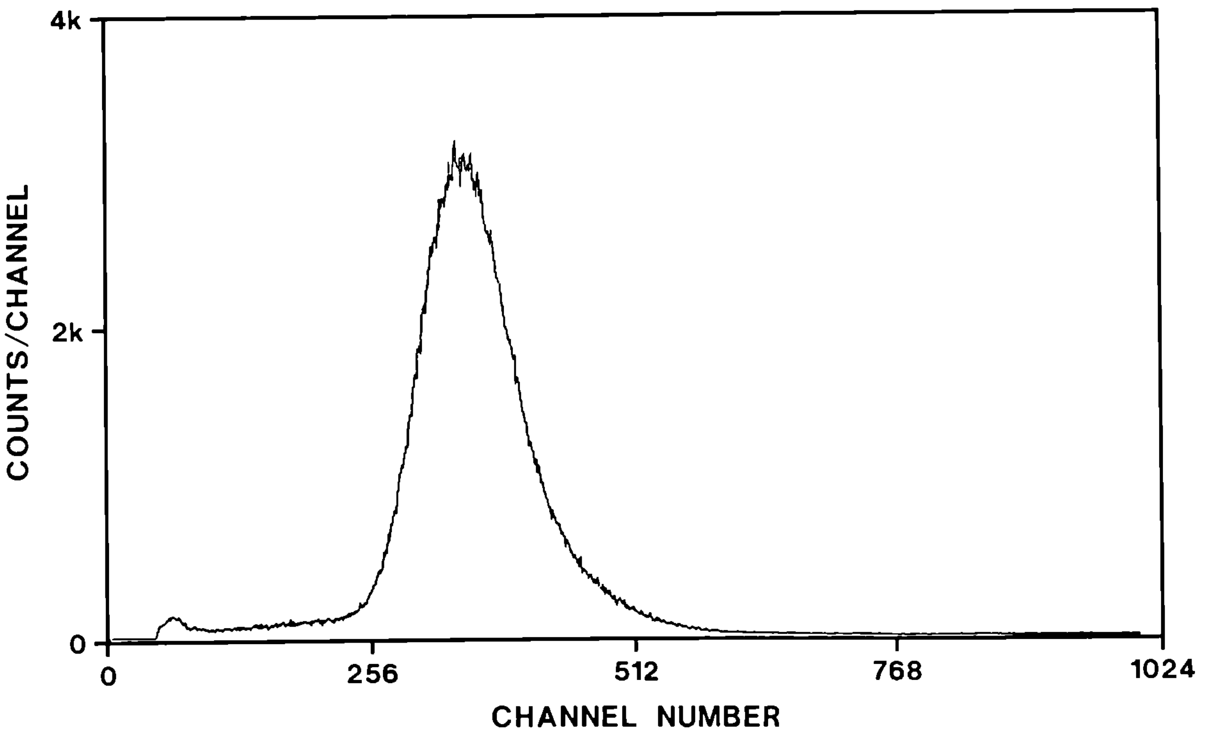

Fig. 10. Pulse height of NE912 in the moderated GELINA beam

The pulse height resolution is 29 %. The time resolution of the detector is about 3 ns, when measured on the spread of the attenuated gamma-ray flash and with 1 ns beam burst width.
Multiple scattering effects are of the order of 5 % and the total count rate at 100 m flight distance is about the same as that measured with a 0.5 cm thick sintered $^{10}B_4C$ slab viewed by the C_6F_6 liquid scintillators placed at 50 m flight distance.

High Resolution Transmission Measurements for Sc and Sc+Mn* Thick Composite Filter

A. Brusegan, C. van der Vorst

Intense filtered neutron reactor beams, applied in the fields of neutron physics, health physics, dosimetry and radiobiology, demand a modest resolution, but can tolerate only a low contribution from neutrons outside the energy range of interest.
Large amounts of scandium remove practically all the neutrons from the impinging beam except in 'windows' where the total cross section approaches zero, i.e. where a strong resonance-potential scattering interference is present.
Neutron transmission measurements on thick scandium and scandium + manganese filters have been carried out at the 50 m flight path station of GELINA (1 ns burst width).
The measurements covered the neutron energy range from 15 eV up to 0.5 MeV.
The detection system consisted in a 0.5 cm thick $^{10}B_4C$ slab viewed by 4x(10 cm x 7.5 cm) NaI(Tl) scintillators.
Transmission data have been obtained for the scandium and for the scandium (32 cm thick) + manganese (1,5 mm thick) composite filters.
The scandium + manganese attenuates the 2 keV main line of the scandium filter, but does hardly effect other lines in the spectrum.
The present transmission experiment allows a better and higher resolution description of the neutron spectrum effectively transmitted by the scandium and scandium + manganese filters, i.e. it defines possible systematic errors associated with the filter 'difference' technique.

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* Filter supplied by PTB, Braunschweig, Germany

NUCLEAR DATA FOR FUSION TECHNOLOGY

Double-Differential Neutron-Emission Cross-Sections of ^{9}Be

F.Poortmans*, J.Wartena, H. Weigmann, C. Bürkholz

Because of its large (n,2n) cross section beryllium is a preferred candidate material for future fusion reactor blankets. For the calculation of neutron transport in beryllium containing blankets, a detailed knowledge of the neutron-emission cross section of beryllium, including the secondary neutron energy and angular distributions, is required. Therefore measurements of the double-differential neutron-emission cross sections of ^{9}Be have been performed.
The experimental methods applied in these measurements have been previously described [(1)]. Extensive measurement series had been conducted in 1986 and 1989, including measurements on ^{12}C which serve for normalization of the data obtained for ^{9}Be, to the differential elastic-scattering cross section of ^{12}C below 2 MeV.
The analysis of the data from both experiments is almost complete. Apart from dead-time and background corrections, the analysis mainly includes the unfolding of the experimental pulse-height distributions to yield secondary neutron energy spectra. These have to be corrected for self screening and multiple scattering in the sample. The Monte-Carlo code written earlier[(1)] for the multiple scattering corrections has been extended to include the (n,2n) reactions ; an approximate description of the secondary neutron energy distributions associated with these processes is used as an input to the code.
The results will be available in the form of double-differential neutron-emission cross sections as a function of secondary neutron energy and laboratory emission angle, for incident neutron energies from about 2 to 11 MeV. Above 11 MeV the incident neutron flux drops too quickly to give statistically meaningful results. It is expected that with the uranium-beryllium sandwich target available only recently, the useful energy range can be extended.
As an example of the results obtained, Fig. 11 shows double-differential neutron-emission cross sections for four emission angles and for the incident neutron energy interval from 6.5 to 7.1 MeV.

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* SCK-CEN, Mol, Belgium
(1) CBNM Annual Progress Report 1988, EUR 12267 EN

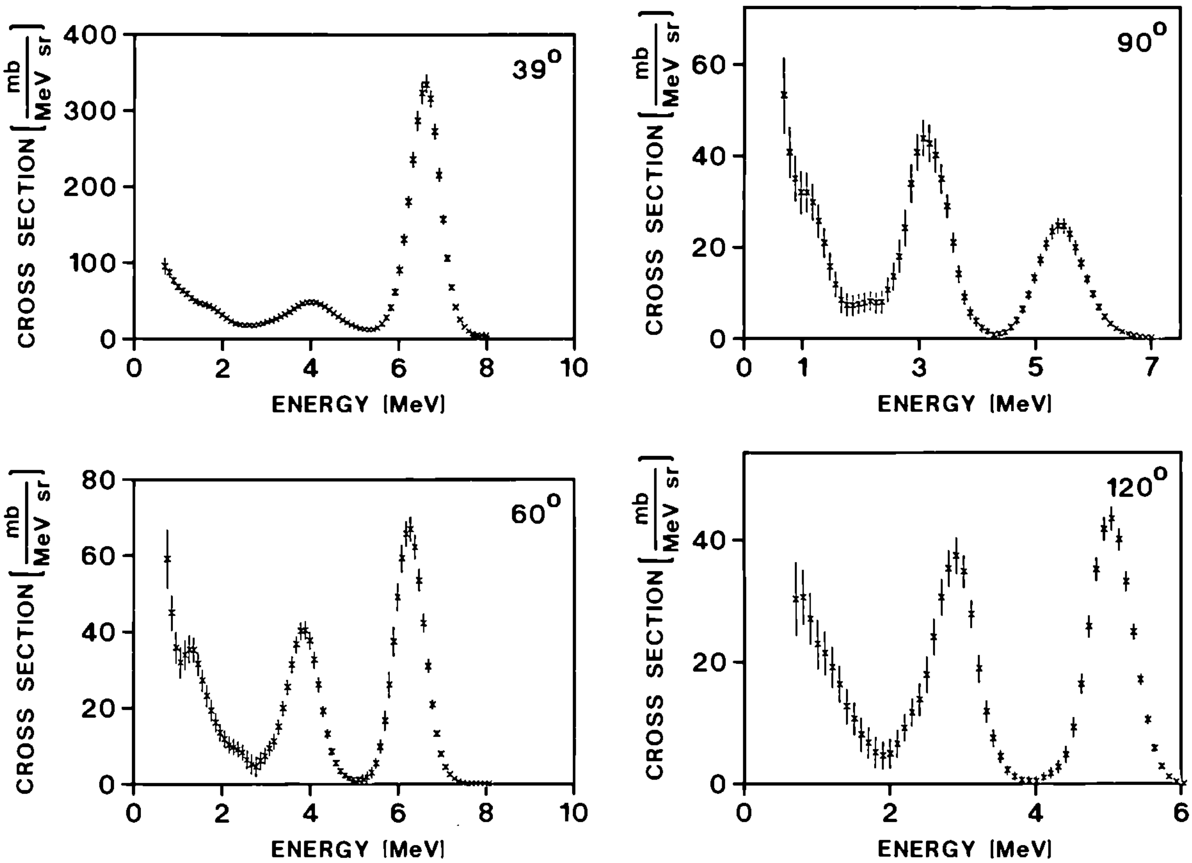

Fig.11. ***Double-differential neutron-emission cross section of ^{9}Be for incident neutron energies from 6.5 to 7.1 MeV***

Excitation Functions of $^{nat}Ti(n,x)^{46,47,48}Sc$ Processes in the Energy Range of 12.5 to 19.6 MeV

N.I. Mollar*, S.M. Qaim*, H. Liskien, W. Widera

Titanium is an important component of structural materials used in fission and future fusion reactors. Cross sections were measured for the $^{nat}Ti(n,x)^{46,47,48}Sc$ processes over the neutron energy range of 12.5 to 19.6 MeV. Use was made of the activation technique in combination with high resolution γ-ray spectroscopy. The neutron fluence rates were determined using two independent methods, viz. proton recoil and $^{27}Al(n,\alpha)^{24}Na$ monitor reaction. The present results strenghten the data base above 15 MeV, especially for the formation of ^{47}Sc.

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* KFA, Jülich, Germany

A Scintillator for Use in a Light Ion Telescope with Improved Time- and Energy-Resolution

E. Wattecamps, G. Rollin

Neutron induced light ion particle-production cross-section data are needed in fusion reactor design. A telescope was built at the Van de Graaff laboratory to measure such data. The telescope consists of three detectors in line : two multiwire parallel plate avalanche counters (MWPPAC) of circular area with 5 cm diameter, and an hexagonal pilot-U scintillator of approximately 6 cm side length and 1 mm thickness which is located at 38 cm distance from the first MWPPAC[(1)]. Two opposite scintillator sides are viewed by two photomultipliers (Fig. 12a and b).

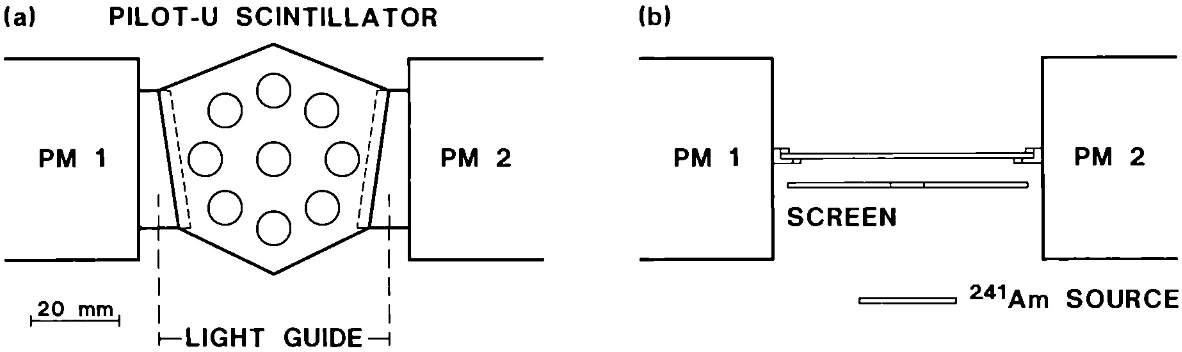

Fig. 12. ***Schematic view of the scintillator mounting : (a) vertical section, (b) horizontal section***

In order to improve the energy- and time-resolution of the pilot-U scintillator a systematic investigation of time- and energy-response behaviour was made. Energy- and time-spectra of α-particles from a small ^{241}Am source have been measured for the entire scintillator as well as for nine spots of 9 mm diameter across the surface of the scintillator.

Typical results of the measurements of the energy, of the energy-resolution and of the start-stop time distribution for the nine spots across the surface are illustrated in Fig.13a, b and c.

(1) CBNM Annual Report 89, EUR 12615 EN

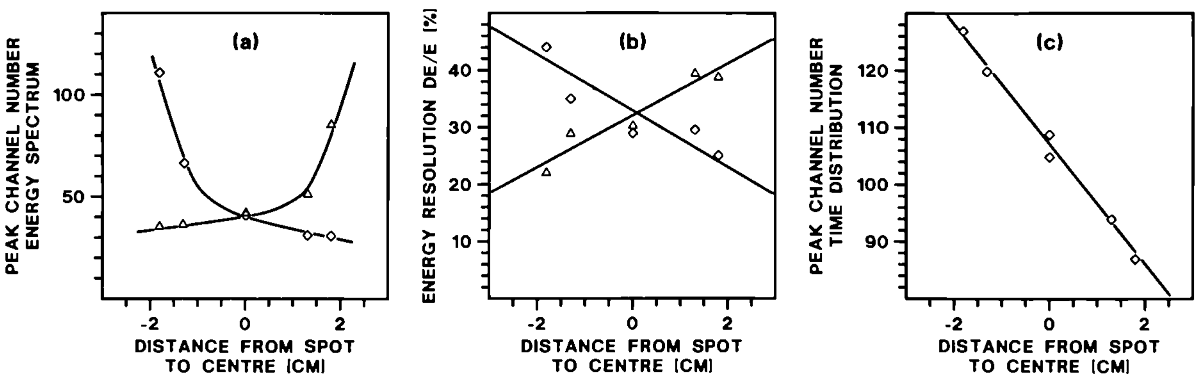

Fig. 13. *Energy (a), energy resolution (b) and start-stop time (c) versus the location of the irradiation on the scintillator*

On the basis of the light attenuation and the time delay across the scintillator determined experimentally, a correction programme COMMND2. EETP has been written to correct the energy and time information of each event.
A detailed description of the experiment and correction procedure will be published. The energy- and time-spectra for total surface irradiation before and after correction are shown in Fig. 14a and b. It can be seen that the energy resolution improves from 31 % to 25 % and that the time resolution reduces from 988 to 355 ps. This result is quite satisfactory having in mind that the burst width of the accelerator is about the same value.

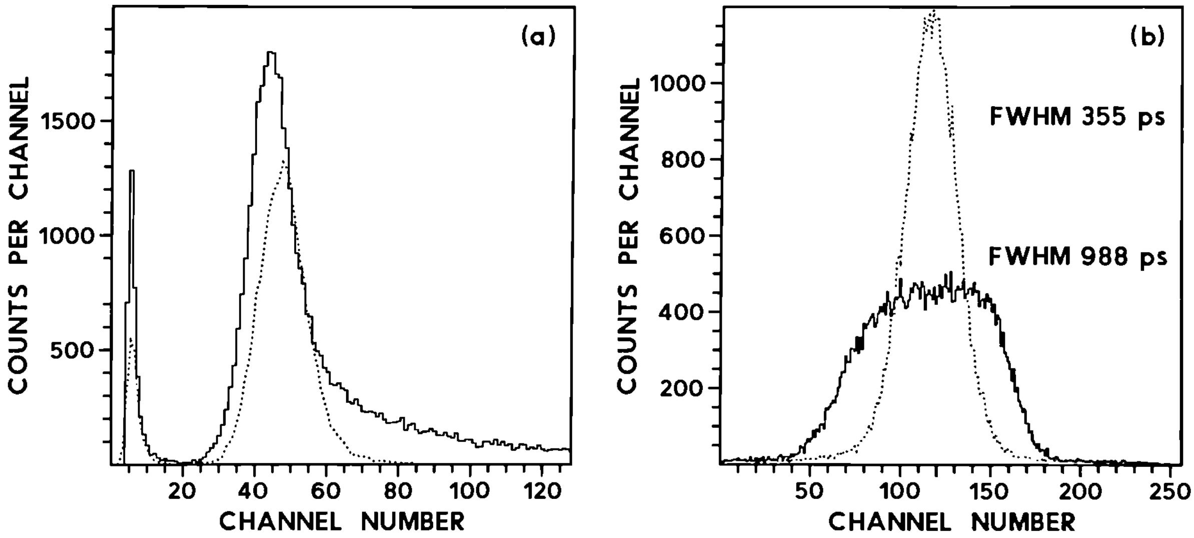

Fig. 14. *(a) energy spectrum and (b) time spectrum for total scintillator irradiation ; full line : uncorrected, dotted line : corrected.*

SPECIAL STUDIES

Study of Fundamental Nearest Level Spacing Distribution of Neutron Resonances
G. Rohr

The nearest level spacing distribution of neutron resonances is of particular interest for nuclear physics, since it is a fingerprint of the dynamics of nucleons in a nucleus. In general the level structure is too complicated to obtain physical information about the process involved. Such information can be retrieved, however, if one restricts oneself to those levels which are created in single two-body collision processes (2p-1h states). One obtains then spacings which are elements of what one could call a fundamental nearest level distribution. Additional states (3p-2h, 4p-3h etc.) from more than one collision processes would obscure the fundamental spacing distribution with no possibility to reconstruct it, since in general it is not possible to distinguish experimentally between resonances of different seniority. Such simple structures are expected at neutron separation energy for medium light nuclei ($A<38$) and closed shell nuclei, since for these nuclides there is a reasonable agreement between the level density of neutron resonances and the calculated level density of 2p-1h states(1).

Simple s-wave resonances in medium-light target nuclei ^{28}Si, ^{32}S, ^{40}Ca, ^{52}Cr, ^{54}Fe, ^{58}Fe and ^{96}Zr are studied. Their nearest level spacing distributions disagree with the Wigner and favour the Gaussian-like distribution which has no spacing smaller than half of the average level spacing.

The Gaussian-like spacing distribution corresponds to a spectrum of almost equidistant spacings, as in a vibration (or phonon) spectrum. The standard deviation of this distribution is a measure for the lifetime of phonons and the latter agrees quite well with the lifetime of neutron resonances calculated from the average neutron width. However, the values for six nuclides correspond better to the phonon picture and favour the lattice model for a nucleus. An oral presentation about this subject has been given at the Seventh International Symposium on Capture Gamma-Ray Spectroscopy and related tipocs in Asilomar California, October 1990.

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(1) G. Rohr, Z. Phys. A318 (1984) 299

Characterisation of ^{10}B and ^{6}LiF Reference Deposits

J. Pauwels, R. Eykens, A. Lamberty

The characterisation of ^{10}B and ^{6}LiF reference deposits prepared last year[1] was completed. The ^{10}B and ^{6}LiF surface densities were determined on the basis of isotope dilution mass spectrometry on selected samples from a range of deposits, counting rates of which were compared in a neutron beam at the BR1 reactor at SCK/CEN, Mol. A set of ^{10}B IDMS determinations including a chemical purification step confirmed earlier results obtained without purification.
^{10}B and ^{6}LiF surface densities could finally be certified with accuracies of 0.30 % and 0.35 %, respectively. An intercomparison of the ^{10}B and ^{6}Li calibrations using the ^{10}B and ^{6}Li neutron cross sections showed their consistency at <0.1 %. In the frame of a collaboration between the University of Sussex, NIST Gaithersburg, SURRC Glasgow and CBNM one of the ^{10}B deposits was used as a reference for the accurate determination of the lifetime of the free neutron at the Institute Laue-Langevin, Grenoble. An improved neutron lifetime value $\tau_n = (893.6 \pm 5.3)$ s was determined and jointly published. This value is in good agreement with the value predicted by precise mesurement of the β-decay asymmetry parameter A and the standard model: $\tau_n = (897.4 \pm 3.7)$ s.

NUCLEAR METROLOGY

RADIONUCLIDE METROLOGY

Response of Silicon Detectors to Electrons, Deuterons and Alpha Particles

P. Bauer*, G. Bortels

The response of silicon detectors to electrons from the decay of ^{109}Cd, ^{233}Pa and ^{137}Cs, to deuterons in the energy range 35 to 440 keV from a Van de Graaff accelerator and to alpha particles from a mixed ^{239}Pu, ^{241}Am, ^{244}Cm source has been measured. The results were found to be in agreement with the model proposed by Lennard at al. (1986)(1) which describes the nonlinear detector response in particular in the case of light ions. For electrons, the non-linearity was found to be negligible within experimental uncertainties. For deuterons, the non-linearity observed in Rutherford- backscattering measurements at low energies was used to accurately measure the window thickness of the detectors. For alpha particles in silicon it has been confirmed that the energy required to create an electron-hole pair depends on the stopping power. The non-linearity parameter in the Lennard model has been measured. This offers a reliable way of measuring the energy corresponding to peaks in alpha-particle spectra from a calibrated semiconductor system. The work was presented at the 7th Symposium on Radiation Measurements and Applications, Ann Arbor.

Low-Energy X-Ray Standards

B. Denecke, C. Ballaux**, W. Bambynek, G. Grosse, A. Srivastava***, U. Wätjen

After the successful demonstration of the use of the indirectly excited fluorescence sources for the efficiency calibration of a Si(Li) detector the production of ten sets of fluorescence layers was ordered and is nearly finished. In this type of reference sources many different fluorescence layers can be used with the same high-activity ^{55}Fe excitation source. The procedure to produce such ^{55}Fe sources as deposits on thin copper rings has been established using an inactive iron-chloride solution. The fabrication of the active sources is in progress. In addition, the prototype system for the counting-gas regulation was rebuilt using better equipment for the gas-flow control and the pressure regulation.

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** SCK/CEN, Mol, now at AIB Vinçotte, Brussels, Belgium

*** Scientific visitor from the University of Mainz, Germany

(1) W. Lennard, H. Geissel, K.B. Winterbon, D. Phillips, T.K. Alexander and J.S. Forster, Nucl. Instr. and Meth. A248 (1986) 460

Efficiency Calibration of Photon Detectors

T. Altzitzoglou, L. Delfosse

An efficiency re-calibration of the photon detectors currently in use for X- and gamma-ray measurements is in progress. The spectra analysis is performed using the program RETEOH and the data reduction and analysis are done by custom-made spreadsheets. The fitting of the final results is made using spline or polynomial fitting routines.

A High-Purity-Germanium Detector System for the Measurement of Low-Level Radioactivity in Environmental Samples

D. Mouchel

A high-purity-germanium detector system designed to measure low-level radiation has been set up 25 m above sea level in an area where the exposure rate is about 60 nSv/h. It is operated in a normal laboratory without special provisions with respect to the building construction. Nevertheless, by careful selection of the materials for the detector assembly and the shielding with respect to their very low radioactivity, the background could be reduced by a factor of 70. The system has been described in a seminar lecture at the Second International Summer School on Low-Level Measurements of Man-Made Radionuclides in the Environment, La Rábida.
At present, the detector system is being calibrated with suitable radionuclides emitting gamma rays in the energy range 50 to 2000 keV. Well-defined matrices have been prepared in Marinelli beakers of the type IEC-450 and spiked with standard sources at various environmental radioactivity levels. Measurements of various organic samples are in progress.

Measurement of K-Shell Fluorescence Yields

A. Solé*, B. Denecke, D. Mouchel, W. Bambynek

Following a review on K-shell fluorescence yields for elements with atomic numbers between 20 and 30, the feasibility to measure fluorescence yields by means of (gamma-ray)-(X-ray) coincidence methods has been investigated. It is estimated that these methods will yield results with an accuracy below 2 % (1). Sources of ^{58}Co were prepared by evaporation in vacuum to minimize attenuation of the X rays in the source. The source purity was checked by

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* EC fellow

(1) A. Solé, CBNM Internal Report GE/R/RN/11/90

gamma- and X-ray spectrometry, and the source homogeneity by auto-radiography. A gas-flow proportional-counter system for the measurement of the X rays and a NaI(Tl) scintillation detector to measure the gamma rays were set up. First measurements with ^{58}Co were performed. Data evaluation is in progress.

Metrology of ^{192}Ir Brachytherapy Sources

D.F.G. Reher, T. Altzitzoglou, B. Denecke, E. De Roost

On request of the Belgian Association of Hospital Physicists and in the frame of the EUROMET project Nr. 219 an international co-operation was started to provide air-kerma rates and activity standards of ^{192}Ir wires and their traceability to national and international standards, and to develop a scanning device for the assessment of the longitudinal homogeneity of such ^{192}Ir wires used in radiotherapy.

During the reporting period, an intercomparison of measurements of eight ^{192}Ir wires of 10 mm length was organized. NPL, RIVM, and RUG did air-kerma rate measurements, CBNM and NPL did ionization-chamber measurements, and CBNM additionally gamma-ray spectrometry.

Two solutions of ^{192}Ir were standardized and used for calibration of an ionization chamber and a Ge detector. Ampoules of these solutions were exchanged between NPL and CBNM. Each of the two laboratories sent a set of ampoules to the BIPM as input to SIR.

A study for the development of a ^{192}Ir wire scanner started at CBNM in collaboration with the Belgian Association of Hospital Physicists. NPL made relative efficiency measurements using external sources and an ionization chamber.

A study (CBNM and NPL) about the decay scheme of ^{192}Ir revealed that the accuracy of the half life, the gamma-ray emission probabilities and some other decay-scheme data need to be improved.

The air-kerma rate measurements and the activity standardization have shown that the achieved accuracies need to be improved. Furthermore an effort to improve the decay-scheme parameters is necessary.

TECHNICAL APPENDIX

LARGE FACILITIES

Electron Linear Accelerator

J. M. Salomé

Neutrons are produced in a rotary uranium target via (γ,n) and (γ,f) reactions. According to the requested neutron energies, moderators of water or liquid methane are placed on both sides of the target. Twelve flight paths are equipped for neutron time-of-flight experiments. On the average, 4.6 neutron beams were used simultaneously when GELINA was operated at very short bursts and 2.7 when operated at 40 Hz with the methane moderator.
A neutron measurement campaign with the liquid nitrogen cooled methane moderator was disturbed due to a leak in the isolated pipes. The concept of the circuit was slightly modified to minimize the repair time in case of defect.
For limited periods of time, the accelerator was operated with special parameters suited for the Transition Radiation (TR) experiments. Very low peak currents, down to 10 μA can be obtained with derated rf power and very low cathode temperature. In these conditions, the "dark currrent" and background are sufficiently low to carry out X-ray TR spectrum measurements.
A 35-MeV magnetic deflexion has been ordered in view of reconstructing the photo-activation facility. The three-position switching magnet will be installed in the target room. Following the requests, the electron beam will become available for the neutron cross-sections, transition radiation or photo-activation measurements.

Study of Transition Radiation

X. Artru*, P. Dhez**, P. Goedtkindt***, M. Jablonka•, N. Maene••, F. Poortmans••, P. Rullhusen, J.M. Salomé, P. ter Meer, F. Van Reeth, L. Wartski•••

Transition Radiation (TR) is generated when energetic electrons cross the boundary between two media. The radiation can extend from microwave to X-ray frequencies and is emitted into a narrow cone in forward direction.

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••• Université de Paris XI, Orsay, France

Different types of radiators have been studied by computer simulation in order to optimize the parameters such as thickness and number of foils, formation length and X-ray absorption for various materials. Successful experiments have been achieved using the 550 MeV electron beam of the Accélérateur Linéaire de Saclay (ALS). The X-ray angular distribution was measured for various radiators of one or several thin foils of kapton, mylar, aluminium or copper. Strong enhancement of the radiated intensity due to interference effects was observed using multi-foil radiators. Microlithography with 300 nm resolution was achieved. The results have been presented at two conferences.

Measurements of the radiation spectrum in the X-ray energy range are under current investigation at GELINA using a Si(Li) detector.

Optical transition radiation (OTR) will be used for electron beam characterization. A complete optical system has been set up and will be transferred to the target room in January 1991, in order to allow on-line energy and divergence measurements of the GELINA electron beam.

Van de Graaff Accelerators

A. Crametz

CN - 7MV: Twice the tank has been opened to replace the ion source. Adjustment work was necessary due to modification of the experimental set-up on the four installed beam extensions and to test runs for experiments concerning work for third parties; the determination of the neutron spectrum produced by a 7 MeV deuteron bombardment of a 1 mm thick Be target is in progress. For the measurements it is necessary to condition the accelerator during the night in order to maintain a stable voltage during the day.

KN - 3.7 MV: The tank has been opened once to replace the ion source after 1320 hours of operation. Beside RBS and PIXE experiments the microbeam line has been put into working; the unique feature of the scanning proton microprobe (SPM) is obtained by focusing the beam to a few micrometers and scanning it over the target area.

CBNM Computer Network

T. Babeliowsky, C. Bernard, C. Cervini, H. Horstmann, C. Van den Broeck*, P. Van Roy

The CBNM computer network for scientific data processing and office automation has been upgraded, in particular for external communications.

- All IBM and XEROX terminals and all computers on Ethernet with 3270 emulation software can be used to send and receive electronic mail based on the UCLA/Mail 400 message handling system (CCITT X.400). By means of an X.400 relay (Namur) and gateways in Germany (DFN) and Belgium all important scientific computer networks can be reached (EARN, BITNET, ARPANET, EUNET, UUCP, JANET and many others).
- A connection to IXI (International X.25 Interconnect), the European backbone net for research, has been established. In this way telecommunication with JRC Ispra could be improved in speed and stability.
- Users of IBM 4381 and other computers on the network can access remote computer systems on X.25 networks reachable via the Belgian public data transmission network (DCS).
- Special software has been installed for the connection of a computer in the Mass Spectrometry to the ECSAM Office in Luxemburg via DCS.

Multiparametric Event Acquisition and Analysis Using Transputers

C. Bastian, S. de Jonge, J. Gonzalez

A multiplexer module combining the inputs of 4 ADC's to a (up to) 4-parametric event was built and tested. Such a module uses 2x16-bit transputers and may be combined with similar modules to build up events of up to 16 (possibly 64) parameters. The event stream is passed to an array of 32-bit transputers sorting the events by coincidence pattern and processing them in parallel. Event sorting and analysis is thus performed outside of the host machine- a microVAX in this case.

Bench tests of the multiplexer have shown that a throughput of more than 50000 events/s can be ensured. Nevertheless, the multiplexer is being improved by adding an input FIFO buffer in order to reduce the deadtime.

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* Comparex, Brussels, Belgium

Interval Digitizer
S. de Jonge, B. Denecke

A prototype of an interval digitizer has been delivered and tested. The instrument is a single width NIM module, which converts the time interval between subsequent input signals into a binary value and is intended to measure distorsion in time distributions. The instrument contains a 512 word buffer memory, has a selectable channel width of 10 to 2560 ns, a range and offset of 4096 channels, and can resolve 3 input signals within 25 ns. It can be connected as a ND ADC.

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BAMBYNEK, W.
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GLOSSARY

A E R E	Atomic Energy Research Establishment, Harwell (GB)
A L S	Accélérateur Linéaire de Saclay, Saclay (F)
A N L	Argonne National Laboratory, Argonne (USA)
B A L	Broncho-Alveolar Lavages
B I P M	Bureau International des Poids et Mesures, Sèvres (F)
C B N M	Central Bureau for Nuclear Measurements (JRC-Geel), Geel (B)
C E A	Commissariat à l'Energie Atomique, Paris (F)
C E C	Commission of the European Communities
C E R N	Centre Européen pour la Recherche Nucléaire
C I E M A T	Centro de Investigación Energética, Medio Ambiental y Tecnología
C R N S	Centre National de la Recherche Scientifique
C R P	Coordinated Research Programme
D F N	Deutsches Forschungsnetz
D G	Direction Générale
D Ph N/ S T A S	Département de Physique Nucléaire / Services des Techniques d'Accélération Supraconductrice, Saclay (F)
E C	European Community
E C N	Energieonderzoek Centrum Nederland, Petten (NL)
E F F	European Fusion File
E N D F	Evaluated Nuclear Data File
E N E A	Comitato Nazionale : Energia Nucleare e Energia Alternative
E T L	Electrotechnical Laboratory, Ibaraki (Japan)
F W H M	Full Width at Half Maximum
G E L I N A	Geel Electron Linear Accelerator
I A E A	International Atomic Energy Agency, Vienna (A)
I C R M	International Committee for Radionuclide Metrology
I L L	Institut Laue-Langevin, Grenoble (F)
I N D C	International Nuclear Data Committee
I P N	Institut de Physique Nucléaire, Lyon (F)
I R K	Institut für Radiumforschung und Kernphysik, Wien (A)
J E F	Joint European File
J E N D L	Japanese Evaluated Data Library
J R C	Joint Research Centre
K F A	Kernforschungsanlage, Jülich (D)
K F K	Kernforschungszentrum Karlsruhe, Karlsruhe (D)
K U	Katholieke Universiteit, Leuven (B)
L S A I	Laboratoire de Spectrométrie Atomique et Ionique
L U R E	Laboratoire pour l'Utilisation du Rayonnement Electromagnétique
M O X	Mixed Oxide

NEA	Nuclear Energy Agency, Paris (F)
NEANDC	Nuclear Energy Agency's Nuclear Data Committee
NIST	National Institute of Standards and Technology, Gaithersburg (USA)
NPL	National Physical Laboratory, Teddington (GB)
PHYSOR	International Conference on the Physics of Reactors, 1990, Marseille (F)
PIXE	Particle Induced X-Ray Emission
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig (FRG)
RBS	Rutherford Backscattering
RIVM	Rijksuniversiteit voor Volksgezondheid en Milieuhygiëne, Bilthoven (NL)
RUG	Rijksuniversiteit Gent, Ghent (B)
SCK/CEN	Studiecentrum voor Kernenergie/ Centre d'Etudes Nucléaires, Mol (B)
SIR	Système International de Référence
SURRC	Scottish Universities Research and Reactor Centre (UK)
TH	Technische Hochschule
TOF	Time of Flight
TR	Transition Radiation
WRENDA	World Request List for Neutron Data Measurements

CINDA ENTRIES LIST

ELEMENT		QUANTITY	TYPE	ENERGY		DOCUMENTATION		LAB	COMMENTS
S	A			MIN	MAX	REF VOL PAGE	DATE		
U	233	NF	EXPTL-PROG	10-3	20 + 1	INDC(EUR)025012	-91	GEL	DERUYTTER + WAGEMANS SUBTHERMAL FISS.
U	235	NF	EXPTL-PROG	10-3	20 + 1	INDC(EUR)025012	-91	GEL	DERUYTTER + WAGEMANS SUBTHERMAL FISS.
Pu	239	NF	EXPTL-PROG	10-3	20 + 1	INDC(EUR)025012	-91	GEL	DERUYTTER + WAGEMANS SUBTHERMAL FISS.
Pu	241	NF	EXPTL-PROG	10-3	20 + 1	INDC(EUR)025012	-91	GEL	DERUYTTER + WAGEMANS SUBTHERMAL FISS.
Fe	56	NG	EXPTL-PROG	11 + 3	12 + 3	INDC(EUR)025015	-91	GEL	CORVI + FIONI 1.15keV Fe56 TASK FORCE
Ni	60	NG	EXPTL-PROG	90 + 3	10 + 4	INDC(EUR)025017	-91	GEL	FIONI + CORVI RESONANCE CAPTURE
Cr	53	NG	EXPTL-PROG	80 + 3	65 + 4	INDC(EUR)025019	-91	GEL	COCEVA CAPTURE DECAY SPECTRA
Ni	58	TOT	EXPTL-PROG	16 + 1	10 + 6	INDC(EUR)025020	-91	GEL	BRUSEGAN TRANSM. MEASUREMENT
Ni	60	TOT	EXPTL-PROG	16 + 1	10 + 6	INDC(EUR)025020	-91	GEL	BRUSEGAN TRANSM. MEASUREMENT
Ni	61	TOT	EXPTL-PROG	16 + 1	10 + 6	INDC(EUR)025020	-91	GEL	BRUSEGAN TRANSM. MEASUREMENT
Be	9	N2N	EXPTL-PROG	20 + 6	11 + 7	INDC(EUR)025024	-91	GEL	WEIGMANN DOUBLE DIFF NEUTR. EMISSION

European Communities - Commission

EUR 13555 - ANNUAL REPORT 90 of the
Central Bureau for Nuclear Measurements

H.H. Hansen (ed.)

Luxembourg: Office for Official Publications of the European Communities

1991 - pag. 41 - 21.0 x 29.7 cm

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