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THEORETICAL PHYSICS

QUARK MODELS IN LOW AND HIGH ENERGY PHYSICS

H. Baier

1. One controversial question in high energy nuclear physics is the possible formation, expansion and hadronic or leptonic manifestation of quark gluon plasma in superhigh heavy-ion collision (50-100 GeV per nucleon; experiments have been done and will be continued at CERN 1986/87). Work has been started to get acquainted with theoretical methods in this field of research and first studies have been made to learn more about possible plasma signatures, plasma formation time and hydrodynamical approaches to plasma evolution.

2. The problems related to nucleon antinucleon annihilations into specific hadronic channels have been specified using the results of detailed literature searches. Unfortunately until now none of the open theoretical problems can be solved on a quantitative basis. The models used (rearrangement and/or quark-annihilation) are at best semiquantitative and first LEAR (CERN) data have given no clue whatsoever to possible refinements of the usual models mentioned above.

For the moment no one sees manageable alternatives to the semiquantitative QCD-inspired (but not deduced from QCD) nonperturbative models used by the so-called Japanese and Helsinki groups.

EXPERIMENTAL MEDIUM ENERGY PHYSICS

ANTIPROTON-PROTON ANNIHILATION AT REST (ASTERIX EXPERIMENT AT LEAR FACILITY AT CERN)

M. Botlo, Ch. Laa, H. Vonach and Asterix Collaboration

1) Experiment and data analysis

A final data taking period took place successfully in 1986. Thereafter it was dismantled in order to release the experimental area for future use by new experiments. The final experiment was mainly devoted to select special types of events using very restrictive triggers like a K_S^0 trigger based on a Motorola 6800 device or a $4 \pi \eta$ trigger realized with a GA103 microprocessor. At the same time the raw data tapes (~ 300) recorded in October 1985 were tracked in the Landesrechenzentrum Mainz, FRG, and at the Computer Centre of the University of Zürich, Switzerland, and the results were stored in so-called data summary tapes (DST). The tracking program package was partly modified with respect to the pattern recognition and momentum resolution in order to make the analysis of certain complicated events more precise. From the DST several second level data sets (so-called DST' tapes) were produced which contain the information of certain selected types of events, like events with exactly 2 or 4 charged particles and sum of charge equal to zero (with 3.5 respectively 3 million events).

2) Results

The major physics results which will be described in more detail in this report are the determination of fundamental absolute branching ratios, the search for the a_0 -meson, the former S-invariance decay modes, the observation of the decay $b_1(1235) \rightarrow \emptyset \pi$ and the search for events where the $f_1(1420)$, $f_1(1285)$ and $\eta(1410)$ (former D, E, j) resonances appear.

Absolute branching ratios (BR) for specific decay modes are an important tool to test theoretical models about the annihilation dynamics of the $p\bar{p}$ system especially if it is possible to determine separately

such ratios for annihilation from pure s- and p-wave initial states. As a first part in this program such BR values were determined for the two-body channels $p\bar{p} \rightarrow \pi^+\pi^-$ and K^+K^- /1/ both for the "average" Asterix events (mixture of about 50% s-wave and 50% p-wave annihilation) and for events observed in coincidence with an X-ray signal in the L-X-ray region (almost pure p-wave annihilation). The result of this analysis is shown in table 1.

	liquid H_2 (pure s-wave annihil.)	H_2 -gas	H_2 -gas coinc. with L-X-ray	value derived for pure p-wave annihilation	$(BR)_{p\text{-wave}}/(BR)_{s\text{-wave}}$
BR $\pi^+\pi^-$	$3.7 \pm .30$	$4.68 \pm .33$	$5.54 \pm .60$	$5.72 \pm .70$	$1.6 \pm .20$
BR K^+K^-	$.96 \pm .08$	$.80 \pm .08$	$.45 \pm .06$	$.39 \pm .07$	$.40 \pm .08$

Table 1 Dependence of the absolute branching ratios $p\bar{p} \rightarrow \pi^+\pi^-$ and $p\bar{p} \rightarrow K^+K^-$ on the amount of p-wave annihilation (in units of 10^{-3} per annihilation)

Also shown are the results of earlier bubble chamber measurements /2/ which can be assumed to be pure s-wave annihilation and the branching ratios for pure p-wave capture. The latter were derived from the results of the Asterix data in coincidence with L-X-rays in the following way. For the X-ray window chosen in the coincidence analysis it could be calculated /3,4/ that about $82 \pm 4\%$ of the X-ray signals corresponded to true L-X-ray events and the remainder of $18 \pm 4\%$ were due to a background of inner bremsstrahlung. From this the s-wave "contamination" of the coincidence data could be estimated as $9 \pm 3\%$ and using the liquid H_2 result the given extrapolation of the BR to 100% p-wave annihilation was possible.

A significant dependence of the BR's on the initial state of the annihilating system is observable (s. table 1); in the pion case the ratio $(BR)_{p\text{-wave}}/(BR)_{s\text{-wave}}$ is 1.6 and for kaons this ratio is .40 giving an indication of the complicated structure of the annihilation process. There are theoretical explanations for the decrease of the K^+K^- branching ratio /5/ but it is not understood why the corresponding $\pi^+\pi^-$ branching ratio increases. Work is in progress to determine also the branching ratio for decay modes $p\bar{p} \rightarrow \pi^+\pi^-\pi^+\pi^-$ and $p\bar{p} \rightarrow \pi^+\pi^-K^+K^-$ and $p\bar{p} \rightarrow K_O^S K_C^L$ both for events with and without coincidence

with the L-X-rays of the $p\bar{p}$ system. The decay $p\bar{p} \rightarrow K_0^S K_0^L$ is strictly forbidden for $p\bar{p}$ annihilation from a $\ell = 1$ state; thus the branching ratio for this decay in the H_2 gas with and without L-coincidence will give accurate values for the relative contributions of s- and p-wave annihilation in these two cases, especially a more accurate value for the "s-wave contamination" of the coincidence data (at present estimated to $9 \pm 3\%$).

We have searched for the $a_0(980)$ decaying into $\eta\pi$ or to $K\bar{K}$. The $a_0 \rightarrow \eta\pi$ mode is clearly seen by extracting an η signal nearly free of background as discussed already in the last progress report /6/ while the other channel was detected this year. Asterix is the first experiment which sees the a_0 decay into both channels.

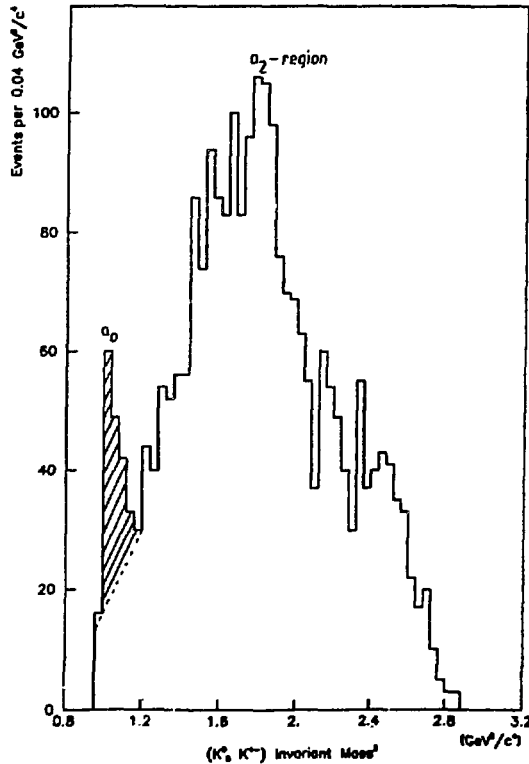


Fig. 1. K_S^0 invariant mass spectrum in the reaction
 $p\bar{p} \rightarrow \pi^{\mp} K_S^0 K^{\pm}$

However (see fig. 1) the decay $a_1 \rightarrow K\bar{K}$ occurs just at threshold and it is therefore difficult to analyze the a_1 peak with respect to mass and width. The broad structure also seen in fig. 1 is due to the a_2 decay.

The so-called E,j puzzle is still unsolved and we continue to work on a Dalitz-plot analysis of the $f_1(1420)$ from where we will get the quantum numbers of the object seen in the $(K\bar{K}\pi)$ mass distribution, which is shown in fig. 2. At 1420 ± 60 MeV the f_1 appears clearly; the small peak at about 1300 MeV is an indication of the $f_1(1285)$. There seems to be a chance to collect enough $f_1(1285)$ events to perform a spin parity analysis on that structure so that it can be decided whether one or two particles exist at this mass region.

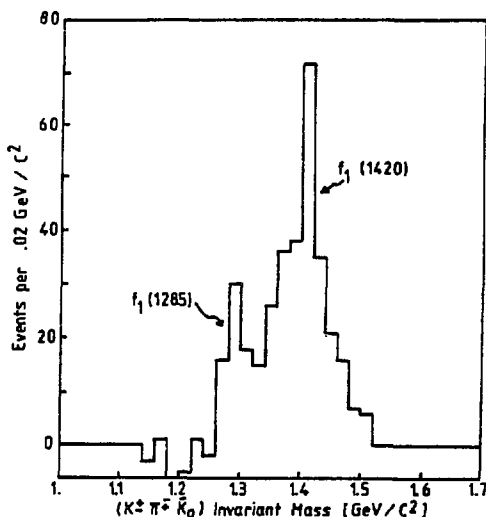


Fig. 2. The $f_1(1285)$ and $f_1(1420)$ in the $K^+\pi^+\bar{K}^0$ invariant mass spectrum in the reaction $\pi^+\pi^-K^+\bar{K}^0$. This spectrum was background reduced by subtracting double-charged mass contributions, which are pure phase space, from neutral combinations.

The last item which should be mentioned is the analysis of the reaction $\bar{p}p \rightarrow \pi^+\pi^-K^+K^-$ where many interesting resonances appear /7/. In this channel we have discovered the decay of the $b_1(1235)$ into $\emptyset\pi$ which is Zweig-rule forbidden, because of the strange quark content of the \emptyset . A comparison with $B_1(1235) \rightarrow \omega\pi$ will give interesting results on annihilation dynamics.

The above progress report refers to the work of the whole Asterix group (CERN-Mainz-München-Orsay-Triumpf-Wien-Zürich Collaboration). The Austrian group members participated in a large part of the work described above, specifically they were in charge of the described determination of the absolute branching ratios for the $\pi^+\pi^-$, K^+K^- , $\pi^-\pi^+\pi^+$ and $\pi^+\pi^-K^+K^-$ channels.

Although the Asterix experiment itself has been finished in 1986, a large contribution to the physics of the $p\bar{p}$ annihilation process is still to be expected from further analysis of the accumulated information.

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EXPERIMENTAL NUCLEAR PHYSICS, NEUTRON INDUCED REACTIONS

MEASUREMENT OF THE ACTIVATION CROSS SECTION FOR THE DOSIMETRY REACTION
 $^{93}\text{Nb}(n,n')^{93\text{m}}\text{Nb}$ AT $E_n \sim 2.9$ MEV

M. Wagner, G. Winkler, H. Vonach and G. Petö ¹

The reaction $^{93}\text{Nb}(n,n')^{93\text{m}}\text{Nb}$ is particularly important as long-term activation monitor in reactor dosimetry due to the long half-life of the produced $^{93\text{m}}\text{Nb}$ isomer $\{t_{1/2} = (16.13 \pm 0.10) \text{ a}\}$ and its low reaction threshold (~ 31 keV). A careful determination of the excitation function is necessary for this purpose. The only activation results reported so far in the literature were obtained by D.B. Gayther et al. /1/ in the energy ranges 1.10 - 2.10 MeV and 3.30 - 5.80 MeV, and by T.B. Ryves et al. /2/ at $E_n = 14.3$ MeV. The goal of our work was to measure the production cross section of the 30.7 keV niobium isomer around $E_n = 2.9$ MeV which should give new useful information in view of the existing literature data and its application.

The $^{93\text{m}}\text{Nb}$ activity induced can be determined only by detection of the characteristic Nb K x rays ($K_{\alpha 1} = 16.63$ keV, $K_{\alpha 2} = 16.52$ keV, $K_{\beta 1} = 18.95$ keV, $K_{\beta 2} = 18.62$ keV) emitted after internal conversion of the isomeric transition. The calibration of a Si(Li) x-ray detector with respect to its efficiency for the K x rays of Nb was described in the last year's progress report.

For intensity reasons Nb foils 20 mm in diameter and ~ 0.130 mm thick were used for the activation measurements. Very pure Nb foils (better than 99.9%) were supplied by Goodfellow Metals Ltd. (England) together with a spectrochemical analysis of the metallic impurities of the sample. Special attention had to be paid to interfering Ta impurities due to the formation of the radionuclide ^{182}Ta by the capture of neutrons in the resonance region with a rather high cross section $\{\sigma(n,\gamma)_{\text{res.int.}} = (750 \pm 50) \text{ b for } ^{181}\text{Ta}\}$ and by capture of primary neutrons $\{\sigma(n,\gamma) \sim 30 \text{ mb at } E_n = 2.9 \text{ MeV}\}$. The radionuclide ^{182}Ta

¹ Institute of Experimental Physics, Kossuth University, Debrecen, Hungary

decays to ^{182}W ($t_{1/2} = (114.8 \pm 0.2) \text{ d}$) producing low-energy γ rays with a high abundance and W K x rays after internal conversion which induce characteristic Nb x rays via photoelectric absorption in Nb. In order to estimate the enhancement of the count rate in the Nb K x-ray peaks due to Ta impurities in the Nb sample (350 ppm in our case), a 0.1 mm thick Ta foil with a diameter of 20 mm was irradiated together with the Nb foil. The activity induced was measured by detecting the γ rays from the decay of ^{182}Ta by means of a Ge(Li) detector. The enhancement of the Nb K x-ray count rate for the Nb foil amounted to only $\sim 0.4\%$ six weeks after the end of the irradiation with 2.9 MeV neutrons.

In order to get a Nb K_{α} activity of about 1 count per minute, which is roughly equal to the background count rate in the K_{α} peak, a neutron fluence of about $0.65 \times 10^{13} \text{ n/cm}^2$ at the sample position was required. Therefore, placing the Nb foil at a distance of $\sim 1 \text{ cm}$ from the neutron source, the irradiation had to last for approximately 200 hours with a solid-state neutron producing target employing the $\text{D(d,n)}^3\text{He}$ reaction and a deuteron current of $\sim 250 \mu\text{A}$. The irradiation was carried out at the neutron generator of the Institute of Experimental Physics of Kossuth University at Debrecen/Hungary using an analyzed d^+ beam with a incident energy of $(220 \pm 5) \text{ keV}$. An air-jet cooled solid-state deuterated Ti target thicker than the range of the deuterons with a 0.33 mm Mo backing was employed in a low-mass beam line construction. The target was arranged in a low-scattering geometry to reduce contributions from room-scattered neutrons.

The reaction $^{238}\text{U}(n,f)$ was used as an absolute neutron fluence monitor. Therefore a fission chamber operated as a ionization chamber with a continuous gas flow of pure Ar as counting gas served to measure the neutron fluence. The fissionable material was ^{238}U enriched to 99.98%, 10 mm in diameter, its mass calibrated by alpha counting and relative to the mass of an Al disk in an irradiation experiment at 14.8 MeV using the well-known ratio of the cross sections for the reactions $^{27}\text{Al}(n,\alpha)^{24}\text{Na}$ and $^{238}\text{U}(n,f)$. During the irradiations the fission chamber with the Nb foil and monitor foils inside and outside the chamber (see fig. 1) was placed at 0° relative to the incident d^+ beam. The Ni foils shown in fig. 1 served to measure the fluence gradient via the ^{58}Co activity induced. They also provided an additional check and normalization in case of several partial irradiations joined together.

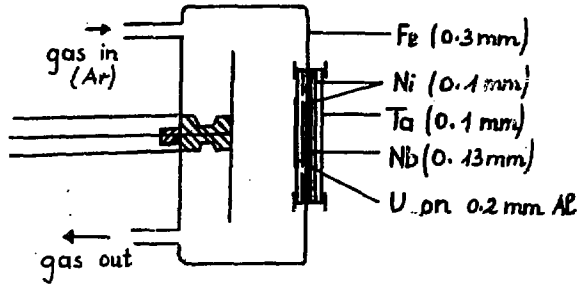


Fig. 1. Sample arrangement inside and outside the fission chamber

Assuming a fluence dependence like $1/r^\alpha$ (r ... distance sample-neutron source) the value of the exponent α was determined from the ^{58}Co γ -ray activities induced in the Ni foils to be 1.45 ± 0.05 (which includes neutron absorption effects). The conversion factor for the fluence in the foils with 20 mm in diameter to the fluence in the U layer with 10 mm in diameter was experimentally determined by measuring the activity of the ring-shaped part and the central part of the inner Ni foil separately, thus considering the decrease of the neutron flux with increasing angle.

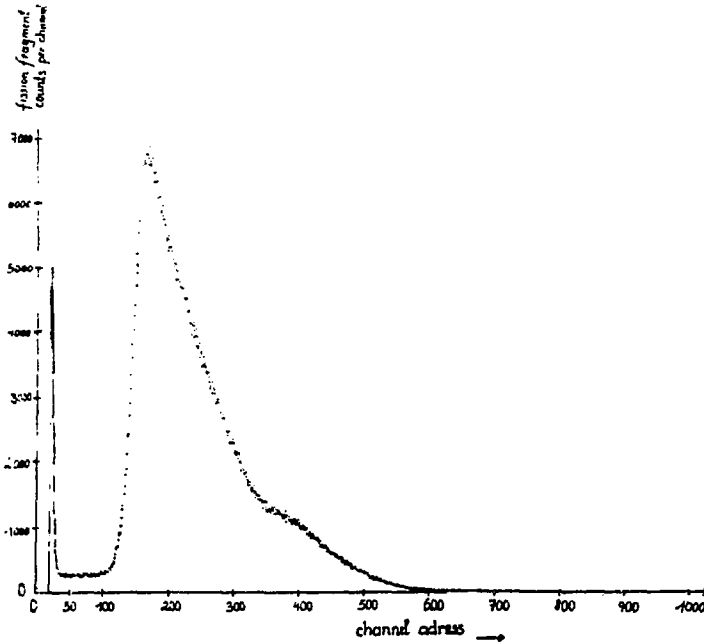


Fig. 2. Fission fragment spectrum recorded with the ^{238}U layer at ~ 2.9 MeV

Corrections had to be applied to the recorded fission spectra (see an example in fig. 2) for extrapolation to zero pulse height and for self-absorption of the fission fragments considering reaction kinematics and the angular distribution of the fragments.

The effective neutron energy profiles and the average neutron energies for the Nb and Ni foils and the ^{238}U layer were calculated by means of the Monte Carlo simulation code PROFIL /3/ adapted to the $\text{D(d,n)}^3\text{He}$ reaction taking into account the slowing down and the energy dependent scattering of the deuterium ions in the target. The uncertainty of the mean neutron energy was estimated considering uncertainties of the energy of the incident deuterons ($dE_d^+ = \pm 5 \text{ keV}$), the distance between the neutron source and the sample stack ($dx = \pm 0.25 \text{ mm}$), the radius of the beamspot ($dr = \pm 1 \text{ mm}$), and probing different possible profiles of the deuterium concentration in the Ti layer. The mean energies of the neutrons incident on the different samples together with the uncertainties resulting from the various uncertainty components mentioned above are listed in table 1.

Sample	mean neutron energy E_n /MeV/ for a constant deuterium concentration in the Ti target	$dE_d^+ = \pm 5 \text{ keV}$	$dx = \pm 0.25 \text{ mm}$	$dr = \pm 1 \text{ mm}$	other deuterium concentration profiles (see fig. 3)		
					b)	c)	d)
^{93}Nb	2.86	$\pm 5 \text{ keV}$	$\pm 3 \text{ keV}$	$\pm 1.5 \text{ keV}$	+20 keV	-32 keV	-58 keV
^{238}U and Ni ($\phi=10 \text{ mm}$, inside the fission chamber)	2.90	$\pm 5 \text{ keV}$	$\pm 2 \text{ keV}$	$\pm 5 \text{ keV}$	+22 keV	-36 keV	-62 keV
Ni ($\phi=20 \text{ mm}$, outside the fission chamber)	2.86	$\pm 5 \text{ keV}$	$\pm 2 \text{ keV}$	$\pm 1.5 \text{ keV}$	+20 keV	-34 keV	-58 keV

Table 1 Principal sources of uncertainties and uncertainty components of the average effective neutron energy

The dominant uncertainty contribution stems from the different possible assumptions for the deuterium concentration profiles.

The average net count rate of the K x rays emitted by the irradiated Nb foil, which was measured by means of the calibrated Si(Li) detector during eight measurements of 100 000 s live time each, interspaced by background measurements, amounted to 1.80 counts per minute (summed areas in the K_α and K_β x-ray peaks) with a statistical uncertainty of $\pm 0.9\%$. The x-ray spectra of the irradiated Nb sample recorded in a

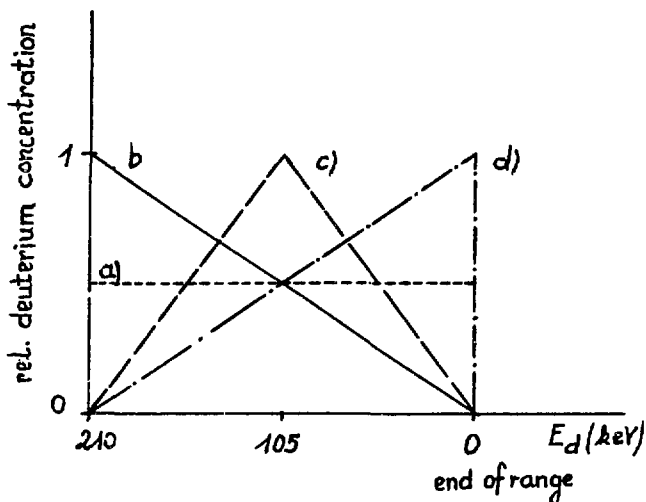


Fig. 3. Relative deuterium target concentration profiles assumed to estimate the uncertainty of the mean neutron energy

period of 2-6 weeks after the end of the irradiation showed two weak peaks at 15.75 keV and 17.70 keV which stemmed from the decay of ^{92m}Nb produced via the reaction $^{93}\text{Nb}(n,2n)^{92m}\text{Nb}$ due to a slight tritium contamination of the beam line system. An estimate of the corresponding 14 MeV neutron fluence resulted in an increase of 0.3% of the total number of fission events.

The influence of lower energy neutrons inelastically scattered by the Mo backing of the Ti-D target, which increase both the fission rate in the U layer and the activity in the Nb foil, was almost negligible since the excitation functions for $^{93}\text{Nb}(n,n')^{93m}\text{Nb}$ and $^{238}\text{U}(n,f)$ are rather similar for neutron energies from the reaction threshold up to 2.9 MeV. Similar considerations apply to corrections for inelastic neutron scattering by the surroundings of the sample.

The preliminary evaluation of the measurements resulted in $\sigma(n,n') = (260.2 \pm 12.6)$ mb for $E_n = 2.83 \pm 0.04$ MeV. The final cross section value and its uncertainty will be based on the final result for the mass calibration of the ^{238}U reference layer, which will be obtained from alpha counting and a repeated 14 MeV irradiation experiment employing the most recent evaluation /4/ of the ^{238}U fission cross section for the Evaluated Neutron Data File ENDF/B-VI. The present status concerning the $^{93}\text{Nb}(n,n')^{93m}\text{Nb}$ activation cross sections including our preliminary value is shown in fig. 4.

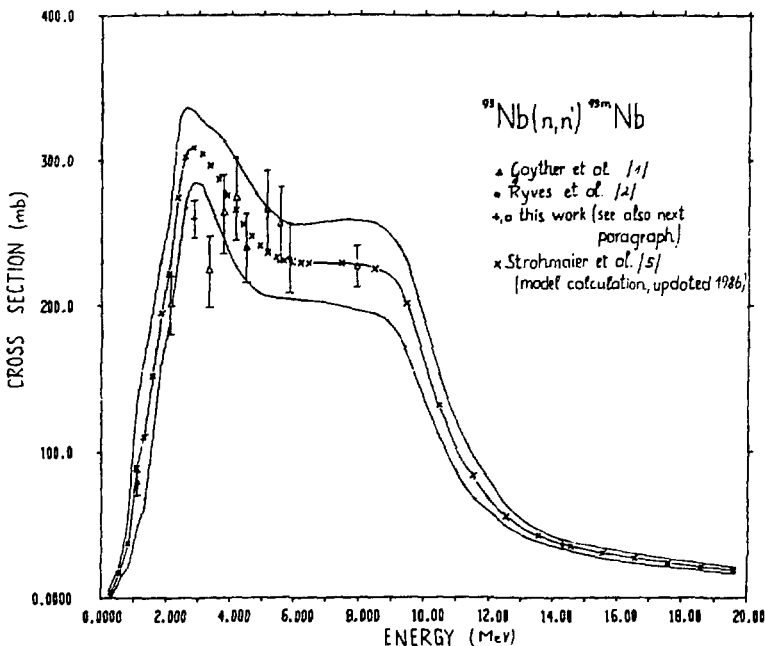


Fig. 4. Status of the $^{93}\text{Nb}(n,n')^{93m}\text{Nb}$ activation cross section

The model calculation results by B. Strohmaier et al. /5/ have been updated by inclusion of the recent precise experimental cross section value at 14.3 MeV by T.B. Ryves /2/, which provided tighter constraints on the model parameters (S. Tagesen, private communication). As a byproduct and check of the above measurement the total cross section of the reaction $^{58}\text{Ni}(n,p)^{58}\text{Co}$ was determined in the energy range considered. The ^{58}Co activity was precisely measured by means of a 12.7 cm x 12.7 cm NaI(Tl) well-type crystal and integral counting. Very good agreement was found with the recommended literature values.

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MEASUREMENT OF THE CROSS SECTION OF THE REACTION $^{93}\text{Nb}(n,n')^{93\text{m}}\text{Nb}$ AT $E_N \sim 7.9$ MEV BY ACTIVATION

M. Wagner, G. Winkler, H. Vonach and H. Liskien ¹

In order to establish the excitation function of the dosimetry reaction $^{93}\text{Nb}(n,n')^{93\text{m}}\text{Nb}$ more precisely, an activation measurement close to 8 MeV neutron energy seemed to be very informative since no other experimental result for the production of the 30.7 keV isomer of Nb in that particular energy region could be found in the literature. An irradiation was carried out at CBNM, Geel. The reaction $D(d,n)^3\text{He}$ was used as a neutron source employing a deuterium gas cell. The incident deuteron energy was ~ 5.09 MeV where a contribution of deuterium break-up neutrons has not to be taken into account. The average beam current was ~ 4 μA for 60 hours. The same fission chamber as described in the preceding paragraph served to monitor the neutron fluence; the arrangement of the Nb and control foils (Ni, Ta) was also almost the same. A distance of only 0.6 cm between the Nb sample and the front of the gas cell (at 0° relative to the d^+ beam) was chosen to obtain a $^{93\text{m}}\text{Nb}$ activity of 0.8 - 1.0 counts per minute. The effective neutron energy averaged across the sample was about 7.9 MeV. The incident primary neutron fluence was obtained from the recorded fission fragment spectrum by folding the ^{238}U excitation function (as given in ENDF/B-V) with the spectrum of the primary neutrons.

A background run lasting for about 29 hours was performed with the gas cell filled with He instead of D_2 . The number of fission events due to background neutrons normalized to the same d^+ charge integral as in the foreground run amounted to $\sim 4.4\%$ of the total fission counts with the deuterium-filled gas cell. The irradiated Ni foils were evaluated with respect to the induced ^{58}Co activity; the contribution of ^{60}Co , produced by the reaction $^{60}\text{Ni}(n,p)^{60}\text{Co}$, to the integral γ -ray activity amounted to only 0.35% two months after the end of the irradiation. Background neutrons contributed 2.4 - 3.0% (dependent on the diameter of the foil) to the total ^{58}Co count rate. No ^{57}Co activity was detected, thus excluding the presence of 14 MeV neutrons during the

¹ Van de Graaff Lab., Central Bureau for Nuclear Measurements, Geel, Belgium

irradiations (compare the preceding paragraph). A procedure analogous to the one described in the preceding paragraph provided the neutron fluence gradient parameter $\alpha = 1.9 \pm 0.1$ and the averaged neutron fluence to which the Nb foil was exposed.

The measurements of the induced ^{93m}Nb activity are going on, especially for the foil which was exposed to the background neutrons, which delivers ~ 0.35 counts per minute only, normalized to the same integral d^+ current as in the foreground run. The stability of the Si(Li) detector is checked periodically.

A very preliminary value for the cross section of the reaction $^{93}\text{Nb}(n,n')^{93m}\text{Nb}$ at $E_n = 7.9$ MeV is (227 ± 14) mb, which is also shown in fig. 4 of the preceding paragraph.

^{252}Cf FISSION NEUTRON SPECTRUM ABOVE 15 MEV *)

A. Chalupka, L. Malek, S. Tagesen and R. Böttger ¹

The high energy tail (up to ~ 30 MeV) of the neutron spectrum from the spontaneous fission of ^{252}Cf was first investigated in 1982 by the TUD group /1/ using the time-of-flight (TOF) method. The authors found a clear deviation from a Maxwellian shape with a temperature parameter $T = 1.42$ MeV above 20 MeV neutron energy (see fig. 1 and crosses in fig. 3). A second TOF experiment was done in collaboration between the TUD and PTB /2,3/, and one set of results thereof ("detector 1 data") seemed to confirm the earlier measurement (fig. 3, histograms 1 and 2) though the experimental uncertainty above 21 MeV amounts to 80 to 100 per cent (1 standard deviation).

Despite many advantages of the TOF method its applicability to the determination of this part of the spectrum suffers from the background due to cosmic particle radiation. Background reduction may be achieved by sophisticated apparatus provisions or heavy shielding. We decided on the latter and performed a TOF experiment in a mine in Bad Blei-

*) supported by IAEA

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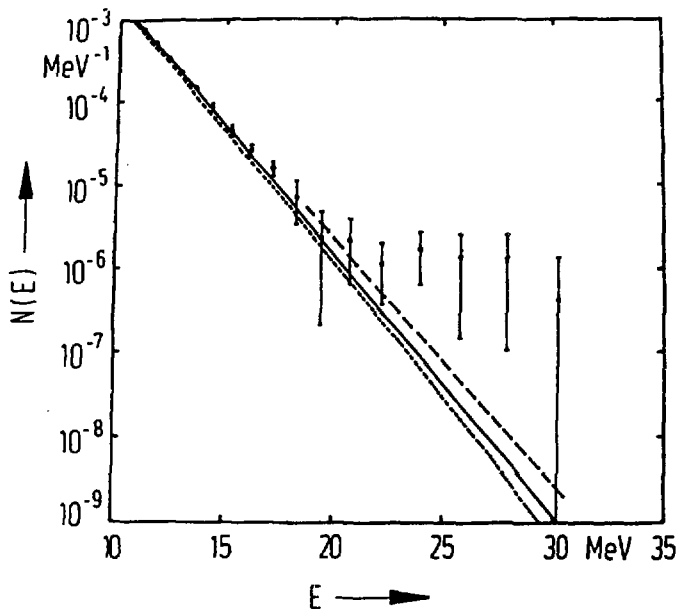


Fig. 1. This figure is taken from Ref. 1 (fig. 8) and shows the measured spectral neutron yield $N(E)$ of a ^{252}Cf source versus neutron energy E compared with the NBS spectrum (solid line) and the cascade evaporation model (dotted line). A Maxwellian with a temperature parameter $T = 1.42$ MeV (dashed line) is added.

berg, Carinthia, early this year. Prior to the experiment, background measurements had been performed on sites in question for the experiment. For results of these measurements compare Progress Report 1985, p. 31. A site at the end of an adit about 600 m below ground was chosen.

A micro-processor controlled measuring and data collection system capable of withstanding the environmental conditions in the mine was developed (see this report, p. 51). A TOF experiment with a four parametric event by event data collection was performed applying a calibrated NE213 neutron detector (25.4 cm in diameter, 5.08 cm in height) from the PTB and a fast fission chamber. Besides TOF data, also light output and pulse shape information from the neutron detector signal and the energy loss signal from the fission chamber were recorded. A recently developed "pile up unit" /4/ allowed an identification of events with a unique time measurement. Characteristics of

the experiment are summarized in table 1.

Median flight path	(279.6 ± 0.2) cm
Time channel width	0.2085 ns
TAC-range	400 ns
Time resolution (FWHM)	0.91 ns
^{252}Cf source strength (Jan. 1, 1986)	$1.564 \cdot 10^5$ fissions/s ± 0.2 per cent
Fission chamber efficiency	0.995 ± 0.002
Neutron detector: diameter	25.4 cm
thickness	5.08 cm
Run times: run 1	79.86 h
run 2	247.58 h
Bias setting: bias 1	4 MeV equiv. electron energy
bias 2	5 MeV equiv. electron energy
Background (TOF): bias 1	0.144 counts per channel ± 8 per cent
bias 2	0.088 counts per channel ± 10 per cent

Table 1 Characteristics of the TOF-experiment

A comprehensive discussion of the design and properties of the fission chamber is to be found in earlier papers /5,6/. The neutron detection efficiency of the scintillator in the energy region from 18 to 30 MeV was calculated from hydrogen cross section data /7/. For energies between 14 and 18 MeV, the result of the code NEFF4 /8/ was used.

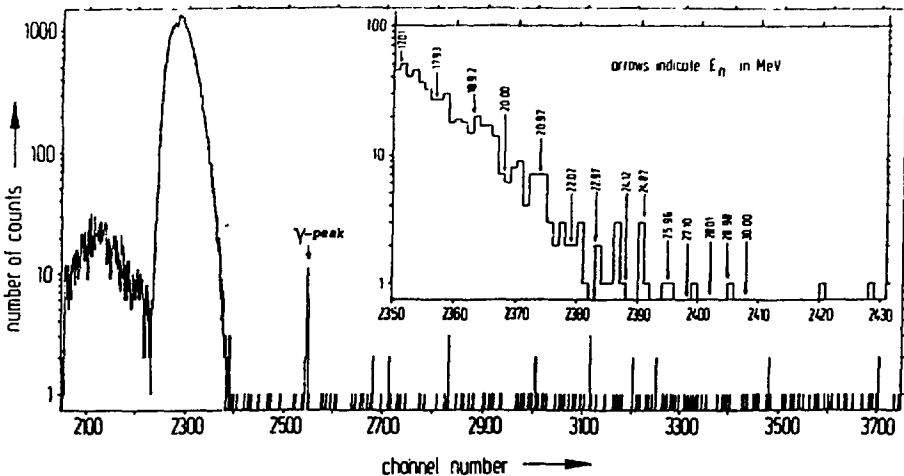


Fig. 2. Detector event numbers versus neutron time-of-flight (0.2085 ns/channel). Total time of accumulation was 327.44 h. (Sum of run 1 and 2).

An uncertainty of 5 to 8 per cent was assigned to the efficiency data. Off line data reduction was performed for two bias settings: at 4 MeV (bias 1) and at 5 MeV (bias 2) equivalent electron energy.

The TOF spectrum after data reduction is shown in fig. 2. The background was determined in the region from channel 2561 to channel 3740. A refined data reduction with bias settings at 2.0 MeV and 2.75 MeV and a neutron energy limit of 10 MeV is in progress and will be published in 1987.

Assuming a neutron source with a Maxwellian energy distribution and taking the experimental parameters of table 1, the efficiency function and a value of $\nu = 3.77$ for the mean number of neutrons per fission event /9/, we calculated the yield to be expected. The geometrical resolution function was taken to be rectangular with a width equal to the detector thickness, and the time resolution function was assumed to be Gaussian. The result is shown in fig. 3 (bias 1 data only).

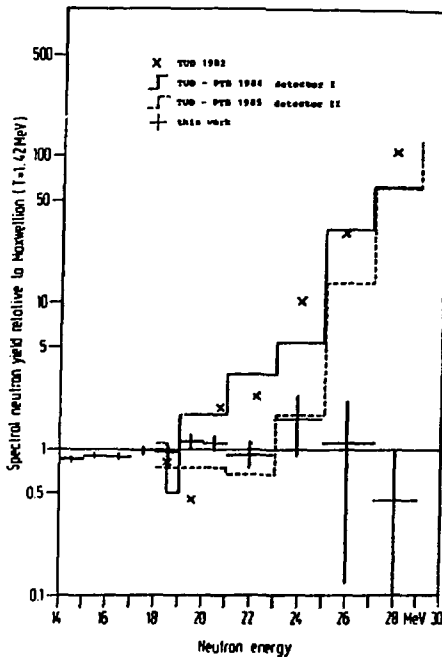


Fig. 3. Measured spectral neutron yield from Ref. 1-3 and this work relative to a Maxwellian with $T = 1.42$ MeV. Bars indicate the statistical uncertainty and the energy bin width, respectively.

We do not find any significant deviation from the Maxwellian shape. This finding is in accordance with recent results from integral measurements /10/ which do not indicate any neutron excess in the high energy wing of the ^{252}Cf spectrum.

Acknowledgements: Without the generous support of the Bleiberger Bergwerksunion this investigation would have been impossible. We also appreciate the help of many colleagues of the scientific and technical staff of the IRK.

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RADIOACTIVE DECAY OF ^{223}Ra BY ^{14}C EMISSION *)

D. Weselka, A. Chalupka, L. Malek, P. Hille and H. Vonach

In summer 1986 the etching of polycarbonat track recording foils which were exposed to the radiation of a ^{227}Ac -source was started. This source contains about 20 μCi ^{223}Ra . Approximately 150 cm^2 foil were etched for 8 hours in NaOH (6.25 n, 70°C) and scanned with a micro-

*) supported by Fonds zur Förderung der wissenschaftlichen Forschung in Österreich (grant no. P5985P)

scope. Up to now (Feb. 87) 7 tracks with suitable track parameters were found. This leads to a branching ratio of $(5.3 \pm 2.0) \cdot 10^{-10}$ relative to alpha emission which is in good agreement with the mean value of $(6.0 \pm 1.0) \cdot 10^{-10}$ obtained by other authors /1/. The next plans are to continue the search for ^{14}C tracks from ^{223}Ra to improve the statistics and then to etch foils which were already exposed to a thin ^{226}Ra -source made by A. Chalupka and F. Hernegger /2/. Furthermore the spontaneous emission of heavy clusters from ^{232}Th will be studied.

We are again indebted to our colleagues in Munich who gave us the opportunity to use the Tandem accelerator of the Munich Universities again to calibrate different track-etch detectors with C-, O- and Mg-ions.

Special thanks are due to Prof. Morinaga and Dr. G. Korschinek for their kind support and to W. Carli and the Tandem crew for their help and good cooperation.

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NUCLEAR MODEL CALCULATIONS

ASSESSMENT OF NEUTRON INDUCED DEUTERON- AND TRITIUM PRODUCTION CROSS SECTIONS FOR STRUCTURAL MATERIALS

M. Uhl

Experimental data regarding (n,d)- and (n,t) reactions are scarce for neutron energies beyond 15 MeV. An assessment of these cross sections for higher incident energies can be obtained from nuclear model calculations relying on models and parameters which reproduce in the mass- and energy region of interest available experimental (p,d)- and (p,t) data.

The model calculations, performed with the code MAURINA, consider the compound nucleus evaporation model, the exciton model and a phenomenological direct reaction model for continuum final states proposed by Kalbach /1/.

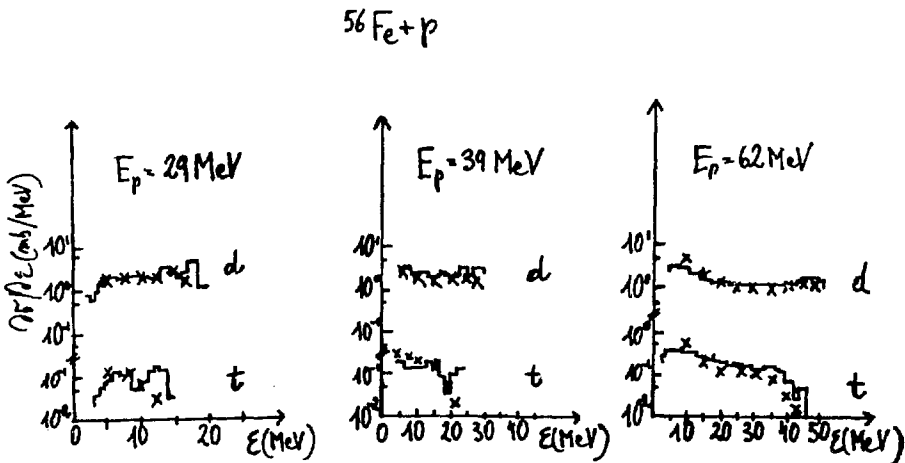


Fig. 1: Experimental (-) and calculated (x) angle-integrated (p,dx) and (p,t_x)-spectra

Fig. 1 shows that the (p,dx) and (p,t_x)-spectra for ^{56}Fe , measured by Bertrand et al. /2/ at three different incident energies are reasonably well described by these calculations; essential for the reproduction is Kalbach's model /1/ as the exciton model contributions for complex particle emission are much smaller than the experimental

data. The calculated deuteron and triton production spectra are displayed in fig. 2.

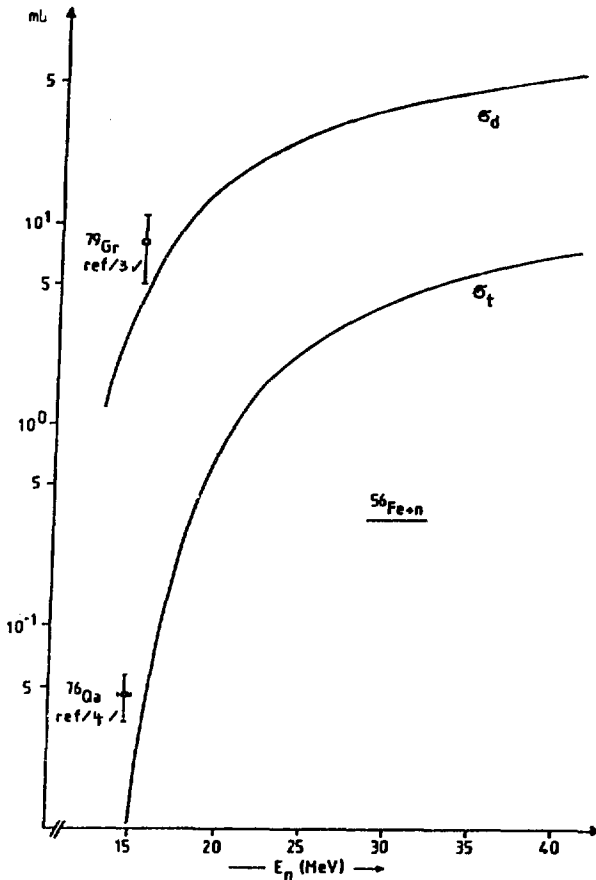


Fig. 2: Experimental and calculated (-) deuteron and triton production cross sections

The calculations underpredict the experimental data of Grimes et al. /3/ and Qaim et al. /4/ between 14 and 15 MeV. This is presumably due to the fact that direct pick-up processes which populate specific low lying levels are not accounted for in the calculations. As the relative contributions of those processes decrease with increasing energy the calculations should become more reliable in the energy region of interest.

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CALCULATION OF RECOIL SPECTRA

M. Uhl

The distributions of the kinetic energies of the heavy reaction product ("recoil spectra") in nuclear reactions is of interest in biomedical and technological applications.

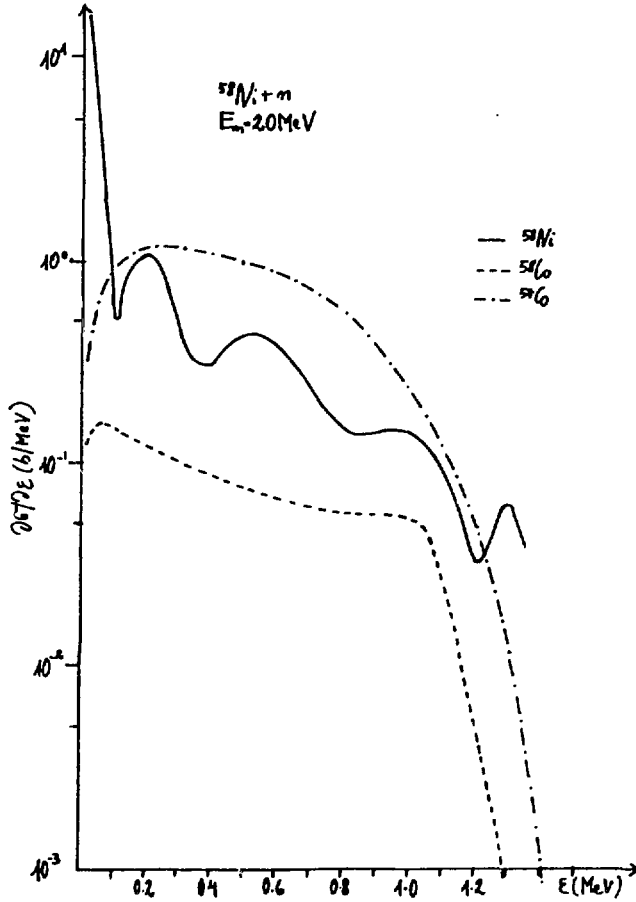


Fig. 1: Kinetic energy distribution of the residual nuclei resulting from the reaction $^{60}\text{Ni} + n$ at $E_n = 20 \text{ MeV}$

In the context with the development of a European test facility for fusion reactor materials /1/ recoil spectra resulting from neutron induced reactions were calculated for ^{52}Cr , ^{55}Mn , ^{56}Fe , ^{58}Ni and ^{60}Ni ; the incident energies ranged from 7 MeV to 40 MeV. The calculations were performed by means of the code MAURINA and rely on the following

models: direct reactions populating collective levels by inelastic scattering, the exciton model for first chance particle emission and the compound nucleus evaporation model for first and higher chance emission of particles and photons. Typical examples of angle integrated recoil spectra for the reaction system $^{58}\text{Ni}+n$ are displayed in fig. 1. The spectra refer to the LAB-system and were calculated for $E_n = 20$ MeV. The shape of the spectrum of the target nucleus ^{58}Ni is dominated by the angular distribution of elastic scattering. The influence of the forward peaked preequilibrium component in the first chance proton emission spectrum can be seen in the recoil spectrum of ^{58}Co . The spectrum for ^{57}Co results from only higher chance nucleon emission as the small (n,d)-contribution is neglected. To simplify the calculations isotropy is assumed for higher chance particle emission.

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EVALUATION OF NUCLEAR DATA AND NUMERICAL DATA PROCESSING

EVALUATION OF (N,N') CROSS SECTIONS FOR FORMATION OF ISOMERIC STATES
AT $E_n = 14$ MEV AND STUDY OF THEIR SYSTEMATIC DEPENDENCE ON SPIN

H. Vonach

- 1) Compilation and evaluation of cross sections σ^m for formation of isomeric states in (n,n') reactions

The existing information on σ^m values for 14 MeV neutrons is summarized in table 1. The table lists all metastable states of stable nuclei with half-lives above 1 sec and their characteristic properties and gives - when ever possible - recommended values for cross sections at $E_n = 14.7$ MeV. In a number of cases the metastable state is not the lowest excited state and there are several excited levels (which all decay to the ground state) below the metastable state. In this case the table gives (in parenthesis) also the spin of that level below the metastable state which is closest in spin to the metastable state. The recommended cross section values do contain some necessarily subjective judgements. For ^{113}In and ^{115}In it was decided to rely only on the precision measurement of Ryves et al. /13/ as this is much better in quality than all the numerous other measurements as will be discussed later; for the other reactions about one third of the papers were rejected because at least one of the given cross sections was obviously wrong (for example exceeding the total (n,n') cross section etc.) and some of the accepted results were renormalized in order to take into account the present values of standard cross sections, e.g. $\text{Al}(n,\alpha)$ or γ -emission probabilities for the produced isomers (in case of ^{199}Hg). In those cases where several measurements are listed, the recommended cross sections are weighted averages derived from all the mentioned results.

As obvious from table one, the experimental situation is still very unsatisfactory. For about one third of the isomers no cross section measurements exist, for another third there is just one measurement and only in three cases (for ^{93}Nb , ^{113}In and ^{115}In) precise measure-

ments with uncertainties below 5% have been performed. Actually the situation is even worse than table 1 seems to indicate.

Target Nuclide	$T_{1/2}$	I_{γ}	I_m	σ_m (nb)	Ref.	$Q_{n,2n}$ (MeV)
77Se	17.5 m	1/2 ⁻	7/2 ⁺	--		- 7.4
79Br	4.9 m	3/2 ⁻	9/2 ⁺	273. ± 20	4 ^a ,5	- 10.7
83Kr	1.03 h	9/2 ⁺ (7/2)	1/2 ⁻	--		- 7.5
87Br	2.01 h	9/2 ⁺	1/2 ⁻	74. ± 10	6	- 8.4
88Y	16 s	1/2 ⁻	9/2 ⁺	460. ± 50	2,7,8	- 11.5
93Nb	13.6 m	9/2 ⁺	1/2 ⁻	36.5 ± 3	9	- 8.8
103Rh	56.1 m	1/2 ⁻	7/2 ⁺	260. ± 15	2	- 9.3
107Ag	44.3 s	1/2 ⁻	7/2 ⁺	304. ± 37	10	- 9.5
109Ag	39.6 s	1/2 ⁻	7/2 ⁺	291. ± 35	10	- 9.2
111Cd	49 m	1/2 ⁺ (5/2)	11/2 ⁻	150. ± 15	6,7,11,12	- 7.0
113In	99.48 m	9/2 ⁺	1/2 ⁻	53.4 ± 2.1	13	- 9.4
115In	4.5 h	9/2 ⁺	1/2 ⁻	53.1 ± 2.2	13	- 9.0
117Sn	14.0 d	1/2 ⁺ (3/2)	11/2 ⁻	284. ± 32	14	- 6.9
119Sn	245 d	1/2 ⁺ (3/2)	11/2 ⁻	--		- 6.5
123Te	119.7 d	1/2 ⁺ (5/2)	11/2 ⁻	--		- 6.9
125Te	58 d	1/2 ⁺ (3/2)	11/2 ⁻	--		- 6.6
129Xe	0.89 d	1/2 ⁺ (3/2)	11/2 ⁻	--		- 6.9
131Xe	12.0 d	3/2 ⁺	11/2 ⁻	--		- 6.6
135Ba	20.7 h	3/2 ⁺	11/2 ⁻	--		- 7.0
137Ba	2.55 m	3/2 ⁺	11/2 ⁻	214. ± 15	12	- 6.9
167Er	2.3 s	7/2 ⁺	1/2 ⁻	252. ± 10	5	- 6.4
176Yb	12 s	0 ⁺ (8)	(8) ⁻	16. ± 2	4,5 ^a	- 6.9
180Hf	5.5 h	0 ⁺ (8)	0 ⁻	12. ± 1.	15 ^a	- 7.4
183W	5.3 m	1/2 ⁻ (9/2)	(11/2) ⁺	127. ± 14	5	- 6.2
189Os	6 h	3/2 ⁻	9/2 ⁻	--		- 5.9
190Os	9.9 m	0 ⁺ (8)	10 ⁻	13. ± 1.	5,11,16,17	- 7.8
192Os	5.9 s	0 ⁺ (8)	(10) ⁻	2.6 ± .3	5	- 7.6
191Ir	4.80	3/2 ⁺ (5/2)	11/2 ⁻	221. ± 22	5	- 8.1
193Ir	11.9 d	3/2 ⁺	11/2 ⁻	240. ± 21	18	- 7.8
195Pt	4.02 d	1/2 ⁻ (5/2)	13/2 ⁺	--		- 6.1
197Au	7.8 s	3/2 ⁺ (5/2)	11/2 ⁻	268. ± 15	4 ^a ,19,20	- 8.1
199Hg	42.6 m	1/2 ⁻ (5/2)	13/2 ⁺	142. ± 15	21 ^b ,22 ^b	- 6.6
204Pb	66.9 m	0 ⁺ (5 ⁺)	9 ⁻	55. ± 7	21,23	- 8.4
235U	26 m	7/2 ⁻	1/2 ⁺	--		- 5.3

a) renormalized to present value of ²⁷Al(n,e) cross section
 b) renormalized to present values of gamma emission probabilities of ¹⁹⁹Hg decay

Table 1 Cross sections σ_m for formation of isomers in (n,n') reactions at $E_n = 14.7$ MeV

The uncertainties attached to the recommended cross section values are based on the estimates of the respective authors. Unfortunately most of the authors including some very recent work have not considered one of the most important source of error, the impurity of the used 14 MeV neutron field. Every 14 MeV neutron field is contaminated by evaporation neutrons ($E_n \sim 0-4$ MeV) which are produced by (n,n') and (n,2n) reactions in all materials in the vicinity of the neutron producing tritium target, especially in the target backing and in the activation

samples themselves. Even in carefully designed low-mass target assemblies this contamination is of the order of 1% and in many conventionally used target assemblies this contamination may well be of the order of 5%. This does not produce problems for the investigation of reactions with high threshold, like (n,2n) reactions, in the case of (n,n') reactions the cross section at $E_n \sim 2$ MeV is several (2-5) times higher than at 14 MeV. This means that a 5%-contribution of evaporation neutrons may produce a cross section error of 10-25%. Thus it is to be expected that for some cases the true cross sections may be lower by 10-20% than the recommended values given in table 1. The sensitivity of the cross section values to the presence of low-energy neutrons is largest for low-spin isomers and decreases considerably with increasing spin of the isomer; thus it will probably not be important for the very high spin isomers ($I_m \geq 6$).

2) Systematics of (n,n') cross sections for population of isomers at
 $E_n = 14$ MeV

As the isomer production cross section σ^m is a product of the total (n,n') cross section $\sigma(n,n')$ and the specific branching ratio f^m in principle both factors can be responsible for the observed variations in cross section (see table 1). Actually the σ_{nn}^m values are very similar for most cases. With the exception of ^{79}Br and ^{89}Y all the listed nuclei have (n,2n) Q-values smaller than - 9.5 MeV and accordingly at $E_n = 14.5$ MeV the (n,2n) cross section should amount about 80% of the total reaction cross section and σ_{nn}^m is probably around 400 mb for most of the nuclei /1/ and the different σ^m values have to be attributed to variations of f^m and one expects a systematic behaviour on the spin of the metastable state. Accordingly we will separately treat the low- and the high-spin isomers.

a) Low-spin isomers

There is the group of 5 spin $1/2^-$ isomers above a spin $9/2^+$ ground-state in a narrow mass range $A = 83-115$ and an additional spin $1/2^-$ isomer in ^{167}Er above a spin $7/2$ ground-state. From any statistical model calculation using smoothly varying parameters it can be concluded, that all five $1/2$ isomers above $9/2$ ground-state should be almost equal and that the $^{167}\text{Er}(n,n')^{167m}\text{Er}$ should be similar and probably somewhat smaller than the other ones.

Target Nucleus	I_g	I_m	σ_m (mb)	Ref.	$Q_{n,2n}$ (MeV)
^{87}Sr	9/2	1/2	$74 \pm 10^*$	6	- 8.4
^{93}Nb	9/2	1/2	36.5 ± 3	9	- 8.8
^{113}In	9/2	1/2	53.4 ± 2.1	13	- 9.5
^{115}In	9/2	1/2	53.1 ± 2.2	13	- 9.2
^{167}Er	7/2	1/2	252 ± 18	5	- 6.4

*) Cross-section probably about 20% too high as measurement of the $^{115}\text{In}(n,n')^{115m}\text{In}$ cross-sections by same authors are also too high

Table 2 Cross sections for formation of low-spin isomers in (n,n') reactions at $E_n = 14.7$ MeV

As table 2 shows this is the case with one exception, the cross section for formation of ^{167m}Er . All other σ^m values are quite similar of the order of 50 mb; the cross section for formation of ^{167m}Er , however, is about 5 times larger. This is not explainable by the discussed effect of contamination by low energy neutrons, nor can any reasonably theoretical model explain this result. Thus a new measurement of this cross section is highly desirable.

b) High-spin isomers

It can be expected that the branching ratio f^m depends mainly on the spins of the two competing levels (that is the spin I_H of the isomer and the spin I_L (which is either the ground state or the highest spin of all levels below the isomer also given in table 1) and the average angular momentum transferred to the target nucleus by the incident neutrons. At a fixed neutron energy this latter quality is proportional to the nuclear radius and thus to $A^{1/3}$. Therefore in fig. 1 σ^m values for all high-spin isomers are plotted versus the quantity $R = (I_H + I_L)/A^{1/3}$.

As the figure shows there is a remarkably smooth dependence of the measured cross section on the chosen variable $R = (I_H + I_L)/2A^{1/3}$ and with exception of a few cases (^{89}Y , ^{190}Os and ^{192}Os) all measured values do not deviate more than 30% from a smooth curve drawn through the data. One of the exceptions - the high cross section for the $^{89}\text{Y}(n,n')^{89m}\text{Y}$ reaction - can be

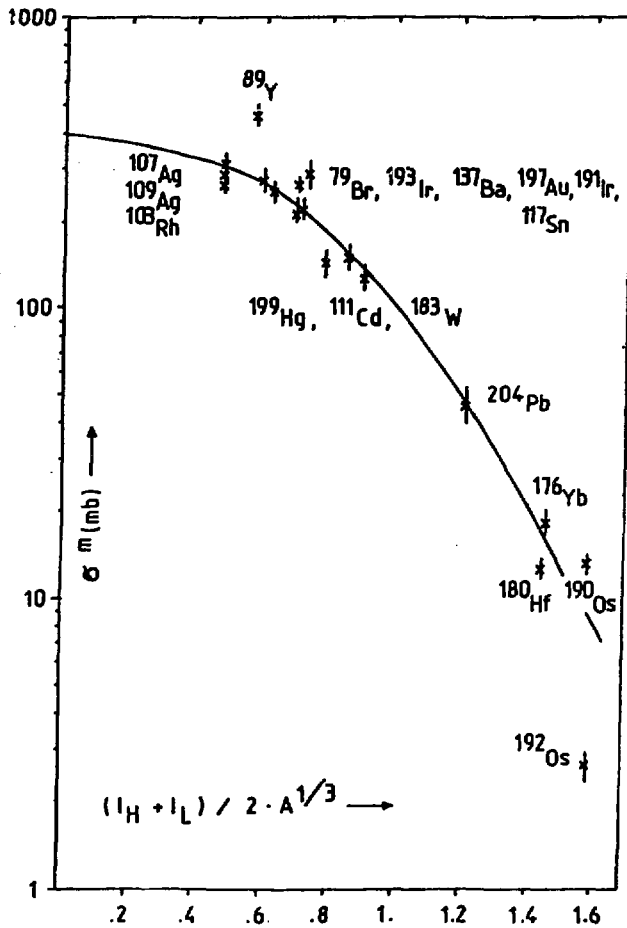


Fig. 1. Systematics of the cross sections σ^m for formation of high-spin isomers in (n, n') reactions at $E_n = 14.7$ MeV (cross sections from table 1)

easily understood; it is due to the fact that ^{89}Y has a much more negative Q -value for the $(n, 2n)$ reaction than all other nuclei listed in table 2. Thus at $E_n = 14$ MeV the total (n, n') cross section for ^{89}Y is about a factor of 1.5 higher than the common value of ~ 400 mb of all the other nuclei and accordingly also the isomer production cross section exceeds the prediction of the systematics by about the same factor.

The other case, the large difference of the σ^m values for production of ^{190}Os and ^{192}Os is not easily understood. Both nuclei have isomers with the same quantum number 8^- at similar excita-

tion energy and thus any theoretical description using smoothly varying parameters will predict very similar cross sections. Thus either the σ^m value of ^{192}Os is in error (the value for ^{190}Os is confirmed by several independent measurements) or the σ^m values for very high-spin isomers (where the cross sections are only a few percent of the total (n,n') cross section) are extremely sensitive to details of the nuclear level scheme. Apart from this question, the systematics shown in fig. 1 seems to be able to predict unknown σ_m values with an accuracy of better $\pm 50\%$ which is comparable to much more complicated nuclear model calculations. It has to be kept in mind, however, that most cross sections given in the figure may be systematically somewhat too high for the reasons discussed in section 2. Thus in order to make really reliable estimates the data base of the systematic should be improved by more accurate new measurements.

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EVALUATION OF SECONDARY NEUTRON EMISSION CROSS SECTIONS ^{*)}

A. Pavlik, H. Vonach and S. Tagesen

Based on available experimental data for incident neutron energies around 14 MeV angle-integrated secondary neutron emission cross sections are evaluated for the elements Cr, Fe, Ni, Cu, Nb, Mo, Ta, W, Pb and Bi in natural isotopic composition. All available data sets were critically reviewed and obviously erroneous data sets were disregarded. Some data sets were restricted to a limited energy range of the secondary neutrons. The accepted data were corrected to a unique incident neutron energy of 14.1 MeV. If only double-differential cross sections were given, angle-integrated cross sections were obtained by fitting Legendre polynomials to the data. In some cases additional corrections were applied for multiple scattering not taken into account by the authors or for changes in the reference standards used. Special attention was paid to the error analysis in order to describe the uncertainties by effective standard deviations which are used to derive the weight factors in the final evaluation process. The uncertainty analyses of the authors were critically reviewed and systematic uncertainties, if not included, were estimated according to the

^{*)} Supported by Bundesministerium für Wissenschaft und Forschung

experimental details given. The final evaluations including the derivation of the covariance matrices of the evaluated data sets will be done using computer codes developed at IRK for the evaluation of excitation functions /1/ which easily can be modified for the evaluation of neutron emission cross sections.

/1/ S. Tagesen, H. Vonach and B. Strohmaier, Physics Data 13-1 (1979)

DATING AND ISOTOPE GEOLOGY

I R K RADIOCARBON DATING LABORATORY

H. Felber

The Vienna Radium Institute Radiocarbon Dating Laboratory is concerned with interdisciplinary cooperation in the fields as archaeology, prehistory, palynology, geography, glaciology, limnology, climatology, geology, mineralogy, hydrology, oceanography, botany, forestry, soil sciences, mining, etc., preferably with Austrian universities, museums and other scientific institutions, but also cooperation with foreign universities is practised in case of free capacity. Dating up to 40.000 years B.P. is done by a methane proportional counter low level system with internal screening counter arrangement.

Annual reports on the dating work are given in Anzeiger der mathem.-naturw. Klasse der Österreichischen Akademie der Wissenschaften and in Radiocarbon /1/.

/1/ H. Felber, Vienna Radium Institute Radiocarbon Dates XV, Radiocarbon 27, (3), (1985) 616-622

STABLE ISOTOPE INVESTIGATIONS

E. Pak

Sulfur isotope measurements have attained great interest for the solution of many problems, especially in the earth sciences.

In 1986, the collaboration with several institutions was continued: age classification of sulfate rocks, genetic investigations on numerous base metal deposits and other sulfide occurrences, hydrological studies and environmental measurements.

ABSOLUTE DATING OF AUSTRIAN LOESS DEPOSITIONS

G. Wallner, E. Wild, W. Schmidt¹ and P. Hille
in cooperation² with:

G. Rabeder, Inst. f. Paläontologie d. Univ. Wien

G. Grabner, Inst. f. Theoret. u. Strahlenchemie d. Univ. Wien

S. Verginis, Inst. f. Geographie d. Univ. Wien

I. Steffan, Inst. f. Anal. Chemie d. Univ. Wien

As already outlined in our last year's report /1/ we try to apply the TL-method to absolute dating of Austrian loess deposits. Several technical difficulties had to be overcome, e.g. to achieve good thermal contact between the heater plate of the TL-apparatus (Harshaw

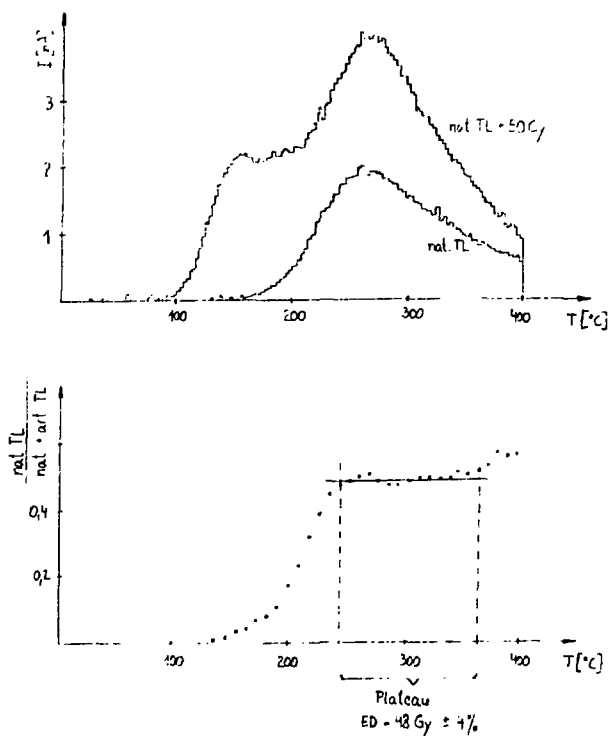


Fig. 1. Plateau test: a) glow curves of Austrian loess corresponding to natural TL and to natural plus artificial TL induced by a γ -dose of 50 Gy; b) ratio of natural to natural plus artificial TL versus temperature

¹ Now with Klinik f. Strahlentherapie u. Strahlenbiologie d. Univ. Wien
² These co-authors are however not responsible for the content of the present progress report, especially not for eventual errors.

Model 2000-A) and the Al-disks used as backings for homogeneous layers of the loess samples produced by sedimentation. By pressing the TL-samples on the heater plate with a spring we could improve the thermal contact and we obtain plateau-tests with a standard deviation of $\sim 5\%$ in a plateau region from 245°C to 370°C .

In this test the ratio of natural TL to artificial TL is plotted as a function of temperature (fig. 1).

Above a certain temperature this ratio should be constant in an interval of at least 50°C . The plateau indicates the stable region of the glow curve where the traps are deep enough that leakage since the deposition time is negligible. Only this region can be used for dating.

We still have to improve our sample preparation technique. We now are calibrating and checking the whole procedure by applying it to loess and soil horizons of known age (e.g. STB: ^{14}C age = $28\ 200 \pm 290$ a /2/) before we are able to apply the method to loess samples for routine dating.

- /1/ P. Hille, E. Wild, G. Wallner, W. Schmidt, Progress Report 1985, p. 43-46
- /2/ J.C. Vogel, W.H. Zagwijn, Groningen Radiocarbon Dates VI, Radiocarbon 9 (1967) 63-106

APPLICATIONS IN MEDICINE

COMPARISON OF RADIATION DOSE FOR DACRYOCYSTOGRAPHIC EXAMINATIONS *)

F. Karnel ¹, F.J. Steinkogler ², R. Nowotny and G. Canigiani ¹

For the comparison of the conventional technique for dacryocystography with examinations performed in a DSA-unit the radiation dose burden was determined in two ways: a somatic dose index was deduced by means of the technique factors used in the studies, and further, skin dose was measured at various points on the skull with thermoluminescence dosimeters.

To obtain comparable figures for the radiation burden the somatic dose index was determined for both types of examinations. For this purpose exposure rate and half-value layer (Al) were measured for the two radiographic devices and the kVp range in question. The technique factors (kVp, mAs, distance, number of exposures,...) used in each examination were gathered, and finally, the corresponding averages for all the cases included in this study were obtained. Using these data and the tables from Kereiakes and Rosenstein /1/ the total somatic dose indices for both examination regimes were derived. Since the tables give only data for a full exposure of the skull it was not feasible to include the effect of individual beam collimation. The figures for total somatic dose index given in table 1 should therefore be taken as a relative measure of the radiation burden in both types of examinations.

	I_D , mGy (mrad)	
	conv.	DSA
males	0.602 (60.2)	3.79 (379)
females	0.358 (35.8)	2.13 (213)

Table 1 Total somatic dose index per examination, I_D , for conventional and DSA dacryocystography

*) in collaboration with Zentrales Institut für Radiodiagnostik, Univ. Wien, and L. Boltzmann-Institut für radiol.-phys. Tumordiagnostik
¹ Zentrales Institut für Radiodiagnostik, Univ. Wien
² II. Univ. Augenklinik, Univ. Wien

To gain a view on the actual radiation dose delivered to selected points of the skull TL-dosimeters were applied with adhesive tape to nasion and eyelid to cover the region of the eye lens, and further to the back skull and the temporal region as the radiation entrance areas. Each dosimeter consisted of three LiF rods contained in a small polythene bag. The relative dose response compared to ^{60}Co radiation was taken as 1.4. Errors from batch inhomogeneity and calibration were < 3%. Dose data averaged for all examinations are shown in table 2.

	Absorbed dose, mGy (mrad)	
	conv.	DSA
nasion	6.78 (678)	0.916 (91.6)
eyelid	6.43 (643)	0.584 (58.4)
back skull/temple	4.54 (454)	30.95 (3095)

Table 2 Average of the absorbed dose measured on the skin for conventional and DSA-technique

It can be seen that dose to the lens region is markedly less for the DSA-technique due to the lateral oblique projection used. On the other hand the increased entrance dose reflects the higher radiation consumption. The ratio of the entrance doses for both procedures is comparable to the according ratio for the somatic dose index.

/1/ J.G. Kereiakes and M. Rosenstein, Handbook of Radiation Doses in Nuclear Medicine and Diagnostic X-Ray, CRC Press, Boca Raton, FA, 1980

APPLICATIONS IN GEOPHYSICS

RADON MEASUREMENTS FOR EARTHQUAKE PREDICTION RESEARCH ^{*})

K. Aric ¹, H. Friedmann, R. Gutdeutsch ¹, F. Hernegger, C.Y. King ²,
C. Altay ³ and H. Sav ³

The measurements of the radon concentrations in a spring in Warmbad Villach (Carinthia/Austria) and in a spring in Bolu (Turkey) (ionisation chamber measurements) as well as the measurements of the radon concentration (track etch foils) in soil gas in 5 stations along the North Anatolian Fault Zone (NAFZ) /1/ are continued.

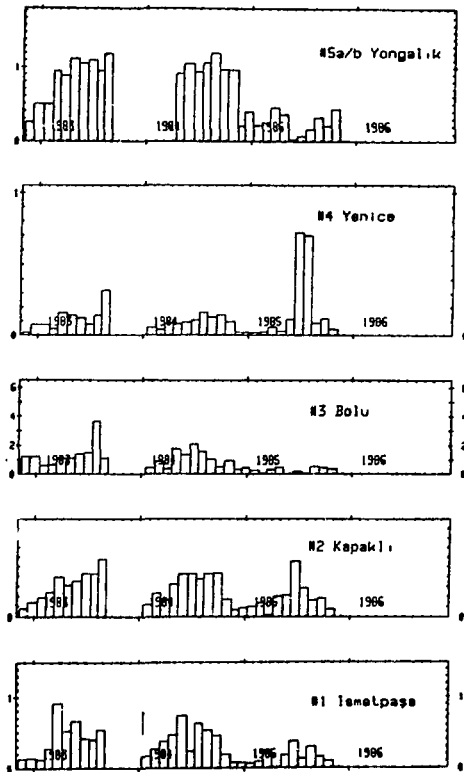


Fig. 1. Radon concentration in soil gas from 5 different stations along the NAFZ

^{*}) Supported by Fonds zur Förderung der wissenschaftlichen Forschung in Österreich
¹ Inst. f. Meteorologie und Geophysik d. Univ. Wien, Austria
² Geological Survey, Office of Earthquake Studies, Menlo Park, California, USA
³ MTA, Ankara, Turkey

Fig. 1 shows the data from the spring of Bolu and fig. 2 shows the soil gas radon concentration on the NAFZ. An extraordinary behaviour could be observed in 1985 in all stations, however, no correlation analyses with seismicity could be done because the latter data are still not available.

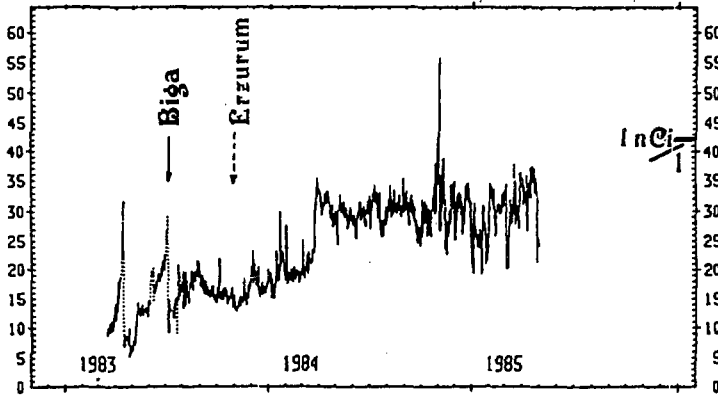


Fig. 2. Radon concentration in the spring of Bolu

/1/ H. Friedmann, K. Aric, C.Y. King, C. Altay, H. Sav, Radon Measurements for Earthquake Prediction along the North Anatolian Fault Zone: A Progress Report (to be published in Tectonophysics)

DOSIMETRY AND ENVIRONMENTAL STUDIES

MEASUREMENT OF THE ATTENUATION OF 14 MEV NEUTRONS IN BUILDING MATERIALS USED FOR HOUSES IN AUSTRIA

G. Staffel, G. Winkler and H. Vonach

The attenuation of 14 MeV neutrons in common building materials was studied experimentally on behalf of the Austrian "Ministerium für Bauten und Technik" in order to estimate the shielding effect against radiation from thermonuclear weapon explosions.

The measurements were performed using a beam of neutrons (~ 19 cm in diameter) which was produced by scattering the primary source neutrons from the $T(d,n)^4\text{He}$ reaction by a graphite scatterer (cylinder, 5 cm thick and 10 cm in diameter) through a ~ 2 m long collimator. Since as for the shielding the reduction of the biological effectiveness was of interest, the attenuation of the neutron flux density by a series of representative samples was determined by means of a neutron rem counter (Alnor 2202 D) measuring directly the dose equivalent (in mSv) or dose equivalent per unit time (in mSv/h) without and with the sample inserted into the neutron beam. The distortion of the neutron spectrum by the shielding material was taken into account by using such a neutron dose monitor.

In view of the practical application, attenuation data for a broad beam were required. Scattered radiation produced in the shielding material causes less attenuation as compared with measurements in a well collimated beam where essentially such neutrons are detected only which were not involved in any interaction. For a broad beam the influence of scattered neutrons increases with the lateral dimensions, i.e. with the sectional area of the incident neutron beam. Both the dimensions of the samples and the neutron beam applicable in the laboratory were limited for practical reasons. In order to determine the effective attenuation for broad incident neutron beams the dose buildup as compared to the attenuation of a collimated beam had to be measured. This was done by measuring the dose equivalent additionally aside of the collimator axis for distances so far as there were significant contributions of the scattered radiation. Assuring cylin-

drical symmetry around the collimator axis each response had to be weighted with the corresponding area of the circular ring element. Since the collimated beam showed a half-shadowed area off the central part such measurements had to be performed without the shielding slabs, too. The background effects with and without the shielding samples could be accurately determined by removing the carbon scatterer which produced the collimated neutron beam. The results for the dose buildup factors did not differ much for different building materials. They could be expressed as a function of the penetrated mass per unit area or as a function of the attenuation in the collimated beam, only.

The experimental results for the dose attenuation factor, i.e. the inverse of the respective transmission factor, are shown in fig. 1 for the different shielding samples investigated as a function of the surface related mass ρ_s . In the case of inhomogeneous samples the data are values averaged across the sample.

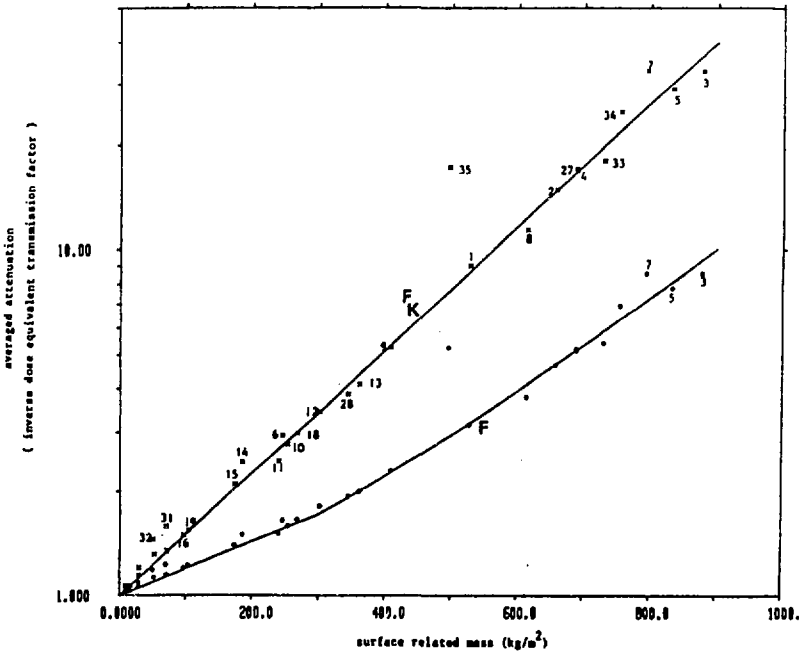


Fig. 1. Experimental results for the averaged attenuation power, i.e. the inverse of the dose equivalent transmission factor, in a collimated beam (F_K , crosses) and for a broad beam taking into account the dose buildup (F , squares), for the different building materials examined versus its mass per unit area. The solid line corresponds to the fitted analytical expression given in the text.

The data marked by crosses represent the attenuation in the collimated beam, i.e. along the axis of the collimator (F_K), the data marked by squares show the lower attenuation for a broad beam (F) including the dose buildup due to scattered radiation. The measured attenuation can be fitted versus the surface related mass, ρ_s , approximately independent of the building material by the following relations:

in a collimated beam:

$$F_K(\rho_s) = \exp(0.0041 \rho_s) \quad \rho_s \text{ in kg/m}^2$$

for a broad beam:

$$F(\rho_s) = \exp(0.00182 \rho_s) \quad \text{for } 0 \leq \rho_s \leq 300 \text{ (kg/m}^2\text{)}$$

$$= \exp(0.0723 + 0.0041 \rho_s - \sqrt{0.625(0.0041 \rho_s - 0.312)^2}) \quad \text{for } 300 \leq \rho_s \leq 900 \text{ (kg/m}^2\text{)}$$

DETERMINATION OF RADIOACTIVE ISOTOPES FROM THE CHERNOBYL ACCIDENT IN VIENNA

H. Friedmann, F. Hernegger, M. Wagner, D. Weselka, E. Wild

The concentration of radioactive isotopes in the air from the Chernobyl accident were determined by filter measurements. With this method only isotopes fixed on aerosols could be found. The results for ^{131}J , ^{132}J , $^{134,137}\text{Cs}$ are shown in figs. 1 and 2.

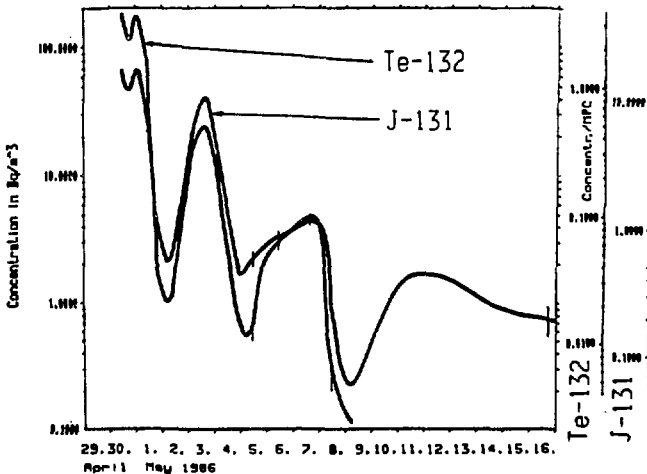


Fig. 1. ^{132}Te , ^{131}J concentration in the air in Vienna in Bq/m^3 and relative to the maximum permissible concentration (MPC) according to the Austrian radiation protection regulations ("Strahlenschutzverordnung")

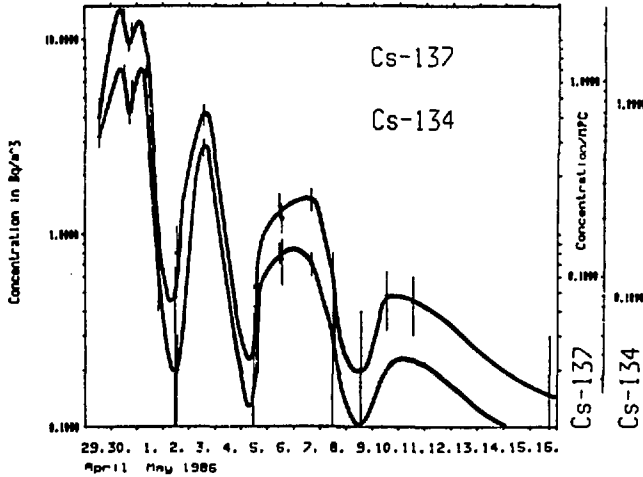


Fig. 2. ^{137}Cs , ^{134}Cs concentration in the air in Vienna in Bq/m^3 and relative to the maximum permissible concentration (MPC) according to the Austrian radiation protection regulations ("Strahlenschutzverordnung")

In addition smear tests, γ -dose measurements, α - and β -measurements and measurements of the contamination of food with ^{134}Cs and ^{137}Cs were carried out /1/.

/1/ H. Friedmann, M. Wagner, D. Weselka, E. Wild, Sitzber. d. Österr. Akad. Wiss, MIR 745 (1987) (in press)

INSTRUMENTATION AND DETECTORS

PREPARATION OF THIN ^{226}Ra SOURCES BY THE ELECTRO-SPRAY TECHNIQUE ^{*})

F. Hernegger and A. Chalupka

For the investigation of exotic radioactivity of ^{226}Ra (/1/ and this report, p. 24) thin and homogenous layers of this isotope are needed. We decided to apply the electro-spray technique which is described in detail in the last year's report /2/. In order to achieve thin layers we started with a high purity $^{226}\text{RaCl}_2$ solution with $3.9628 \cdot 10^{-7} \text{ g/cm}^3$. This solution was originally prepared by Hönigschmid for ^{226}Ra atomic weight determination in 1911 /3/ and especially did not contain any Ba. Extensive analysis of the chemical composition of this solution reconfirmed the quoted purity beside a small amount of silicates probably desolved from the walls of the glass vessel. This impurity was removed by evaporation to dryness and treating the residue with hydro fluoric acid. It turned out that the RaCl_2 remaining in the platinum disk could not be resolved in ethanol or acetone, the preferable solvents for electro-spraying. So the dry residue was taken up in $\sim 100 \text{ ml HCl conc.}$ Subsequently $1 \text{ ml H}_2\text{O}$ and 2 ml ethanol were added and this solution was sprayed onto glass backings. Four sources were prepared, each preparation starting with an activity of $\sim 19 \mu\text{Ci } ^{226}\text{Ra}$ (equivalent to 50 ml of the original solution). The amount of activity transferred in the various steps of the chemical procedure was monitored by means of α -spectrometry. The yield of the final process (i.e. the spraying) was about 70-80%. There, the remainders of ^{226}Ra were mostly found on the surfaces in the capillary tube and on the Pt-electrode.

The quality of the sources was checked by α -spectrometry with a Si-surface barrier detector system. One of the obtained spectra is

^{*}) Supported by Fonds zur Förderung der Wissenschaftlichen Forschung in Österreich

shown in fig. 1. The widths of the peaks (FWHM = 53 keV) essentially represent the intrinsic energy resolution of the detector. No peak broadening or shift due to absorption is observed. The sources are already used for the intended purpose (see this report, p. 24).

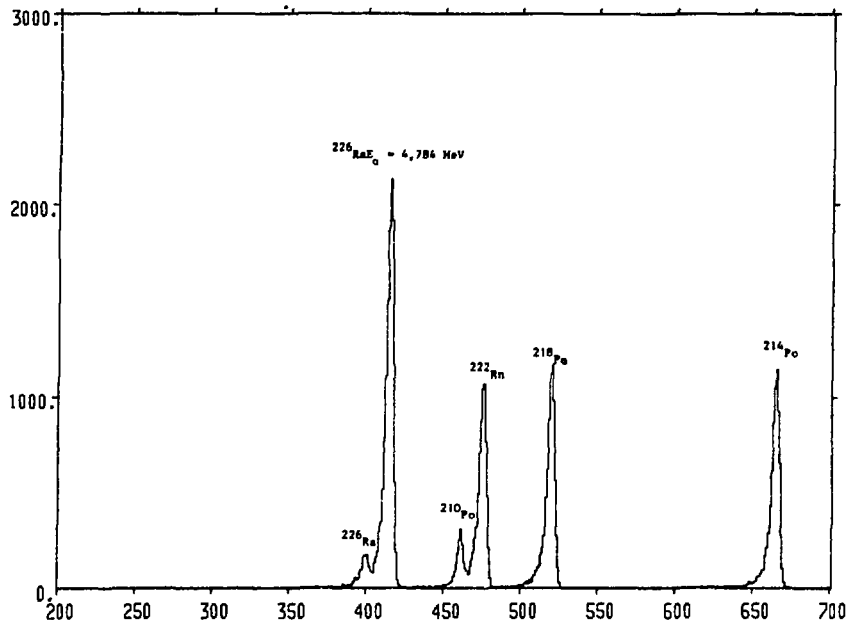


Fig. 1. α -spectrum taken from one of the ^{226}Ra sources prepared by the electro-spray technique

- /1/ A. Chalupka, F. Hernegger, P. Hille, W. Schmidt, H. Vonach and D. Weselka, Progress Report 1985, p. 39-41
- /2/ A. Chalupka and F. Hernegger, Progress Report 1985, p. 36-37
- /3/ O. Hönigschmid, Mitt. d. Instituts für Radiumforschung VIII, 1911, p. 29-36

A SIMPLE MULTIPARAMETER DATA ACQUISITION SYSTEM

L. Malek

As announced in the last year's report /1/ a neutron time of flight experiment in the mine in Bleiberg, Carinthia, was performed during March and April. The aim of the work reported here was to develop a data acquisition system suitable to cope with the rather unusual experimental conditions in an adit approximately 600 m below ground, i.e. humidity above 95%, temperature about 8°C and an unreliable power supply with a voltage fluctuating between 160 and 240 V. The system should be capable of accepting and storing data from up to 4 ADCs. Occuring errors should be monitored too, without interrupting the measurement.

We decided to use a home computer (Commodore C 64) in connection with 3 floppy drives. One of the important advantages was the possibility of easy replacement in the case of failure, because repairing on the spot of any device was considered to be impossible.

The power system consisted of a regulated transformer (60 kVA) to supply the necessary 220 V ac and for the computer and the floppy drives and a 12 V dc supply which was buffered by means of a consealed battery with 20 Ah capacity.

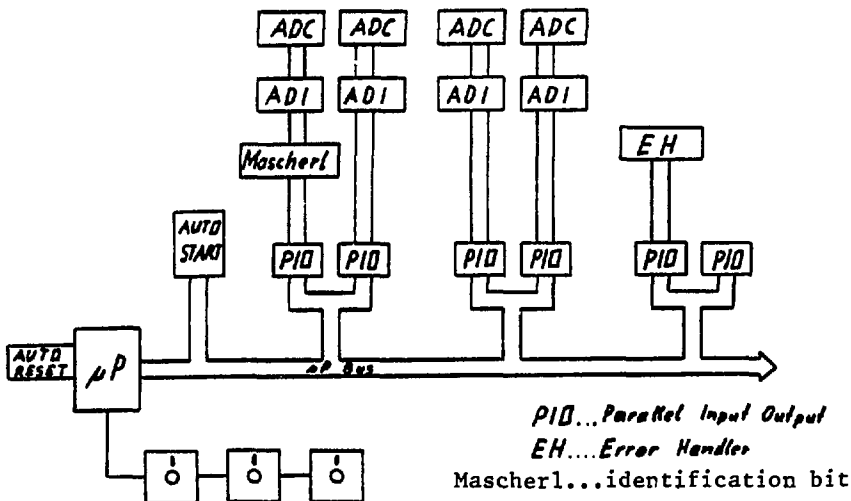


Fig. 1. Acquisition system controlled by the C 64 microprocessor

The data acquisition system (fig. 1) was controlled by the C 64 which accepted data from the ADCs in a hand shake mode, checked them for validity and stored them in the data buffer. To reduce the large amount of data which was expected in distinct regions of the TOF spectrum the event rate in 6 arbitrarily definable regions could be divided by integers < 255 . Detected error conditions such as power failure also were stored in the data buffer together with the time of occurrence. When the buffer was full it was emptied onto a floppy disk. In the case of any computer system error an automatic restart was initialised by a hardware module. For set up adjustments and calibration checks during the run of the experiment the data could be accumulated and displayed in a so-called multichannel mode. Based on this successfully used system a somewhat more comfortable multichannel analyzer for 2 independent ADCs was developed for count rates up to 3 KHz. Presently this system is applied with a NaJ low level counting set up.

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