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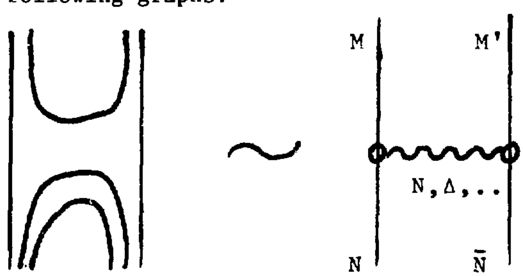
THEORETICAL PHYSICS

THEORETICAL COMMENTS TO PRESENT AND FUTURE LEAR-EXPERIMENTS

H. Baier

1) Study of low-energy $N\bar{N}$ annihilation could help to disentangle quark effects from more conservative representations of hadron interactions. From a critical search of literature we propose to extend already existing methods and to do more elaborate and systematic calculations of 2- and 3-meson decay channels. More explicitely we just started to investigate the following graphs:



We hope to be able to develop the quark model approach (rearrangement; multigluon exchange with confined quarks and gluons; quark creation methods) in parallel with a more conservative baryon and meson exchange picture of the $\bar{p}p$-annihilation processes. Analogously relevant 3-meson annihilation channels should be studied. The models obtained with the graphs just mentioned must of course be supplemented by the usual models and give roughly a 10% contribution to the overall annihilation.

The presently available theoretical branching ratios give only a qualitatively good fit to the branching ratios already known /1/. Better annihilation models might be of value to a theoretically more justified model of $N\bar{N}$-annihilation /2/.

2) The main use of the ASTERIX-experiment should come from its principal ability to identify a large number of mesons of the low lying nonetts in an unambigous way. Only a much more refined knowledge of

all low lying nonetts would provide a starting point for the hunting of glueballs, hybrids and other exotica.

Glueballs: From a critical search of theoretical literature one can conclude that already now experimental meson spectroscopy requires the existence of "glue-rich" (that is glueball-like or hybrid-like) pseudoscalar states in the relevant low-energy region. Whether such a state can be seen depends to a large degree on the (theoretically completely ambigous) width of the states. In case of scalar glueballs Ellis /3/ finds very large widths using nearly "model independent" (sum rule) estimates. The conclusion coincides in this respect with recent work of Gounaris /4/. The latter finds, however, that the lowest PS-glueball should have observable decay properties of the ι.

3) Future extensions of LEAR should strongly investigate the η-η'-system (and radial excitation). There exist a lot of calculations showing significant glueball admixtures without agreeing in detail with each other /5/.

4) In our seminary on $N\bar{N}$-annihilation we found out that future investigations of radial excitations of vector mesons might be especially interesting.

Furthermore it became clear that the theoretical interpretation of already existing scalar-meson data are still in a rather controversial state, favouring once more the $K\bar{K}$-molecular picture of $\delta^*(975)$ and $\delta(980)$ leading additionally to a solution of the ι-δ puzzle. From that a detailed experimental investigation of the scalars seems to be of the greatest interest /6/.

5) It seems to us that future work on mesonic and baryonic decay processes should proceed from variants of the quark-string-picture of hadronic structure like the flux tube model of Isgur /7/. The latest version of this model gives remarkable good meson decay rates wherever it was compared with existing data.

/1/ M. Maruyama, T. Ueda, Progr. of Theoret. Phys. 73, 5 (1985) 1211

/2/ A.N. Green, J.A. Niskanen, Int. Rev. of Nucl. Phys. 1 (1984) 570
/3/ J. Ellis, J. Lanik, Phys. Lett. 150B, 5 (1985) 289
/4/ G.J. Gounaris, J.E. Perchalis, R. Kögerler, Bielefeld-Preprints, BI-TP-85/18, Sept. 1985, BI-TP-85/32, Nov. 1985
/5/ M. Frank, P. O'Donnell, Phys. Rev. D32, 7 (1985) 1739
I. Bediaga, F. Caruso, E. Predazzi, Torino-Preprint, 85/20/1985
C. Amsler, 3. Lear Workshop-85 (U. Gestaldi et al., ed.), p. 353, 381
H. Koch, ibd., p. 389
E. Klempt et al., ibd., p. 347
/6/ T. Barnes, Toronto-Preprints (to appear in Phys. Lett.), UTPT-85-26
J. Weinstein, Toronto-Preprints, UTPT-85-27
/7/ N. Isgur, J. Paton, Phys. Rev. D31, 11 (1985) 2910
N. Isgur, R. Kokoshi, Toronto-Preprints, UTPT-85-05
J. Paton, Nucl. Phys. A446, 1,2 (1985) 419

PIONIC CONTRIBUTIONS TO THE CHARGE ASYMMETRY IN 2N- AND 3N-SYSTEMS

H. Baier and W. Bentz [1]

Theoretically, there has been quite a lot of activity recently to understand the phenomena of charge asymmetry in nuclear systems. Meson exchange between nucleons and the internal quark structure of nucleons offers a great number of possible symmetry breaking mechanisms. Recently the importance of π-η-η' and ρ-ω mixing effects was shown in a series of papers (lit. cit. in /1/). In this work we reconsidered π-exchange contributions ($\pi\gamma$- and 2π-exchange) tc the charge asymmetry in 3N-bound states and to NN-scattering. Since there were conflicting conclusions on the charge symmetry breaking 2π-exchange contributions to the scattering length in NN-scattering we tried to clarify some of the problems related to this problem. Contrary to the frequently articulated optimistic view the above mentioned exchange processes

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increase the discrepancy between theory and experiment considerably: they are seen to act as a counterweight against the beneficial contributions from meson mixing calculations.
Within our framework and using PS-ΠN coupling only we come to believe that simple minded meson theories cannot explain the above mentioned charge assymetry effects.

/1/ W. Bentz, H. Baier, Nuovo Cimento 90A, 1 (1985) 1-24

SPECTRAL DISTRIBUTION METHODS FOR CALCULATING NUCLEAR LEVEL DENSITIES

A) Comparison of Lanczos methods and moment methods in calculating the level density of ^{20}Ne

B. Strohmaier [1], S.M. Grimes [2], S.D. Bloom [3]

Calculations of the level density, spin cutoff parameter, and parity ratio have been performed for ^{20}Ne in a dsd and a dsdf basis. We have obtained some low-lying eigenvalues in order to compare the level density calculations with exact values at low energy. Two methods were used for the calculations: a conventional moment method expansion and a Lanczos calculation. The two techniques seem to represent these quantities comparatively well. Both methods yield similar results for spin cutoff parameters and agree that the energy dependence differs between the dsd basis and the dsdf basis; they also give similar results for the parity ratio in the dsdf calculation. The effects of the two-body interaction are evident from the difference between these results and those for a Fermi gas with the same single particle energies. A significant advantage of the Lanczos technique is that it

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[1] Collaborator with Los Alamos National Laboratory, Los Alamos, NM, USA from April 1984 through May 1985 in the frame of a Max Kade Fellowship
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[3] Lawrence Livermore National Laboratory, Livermore, CA, USA

provides a better representation of the level density at low excitation. Two drawbacks are associated with this new method: we do not have proven techniques for dealing with basis truncation effects and excited center of mass states. Both of these problems can potentially be solved with further work, but, for the present, it appears that the moment method will have an advantage in very large spaces.

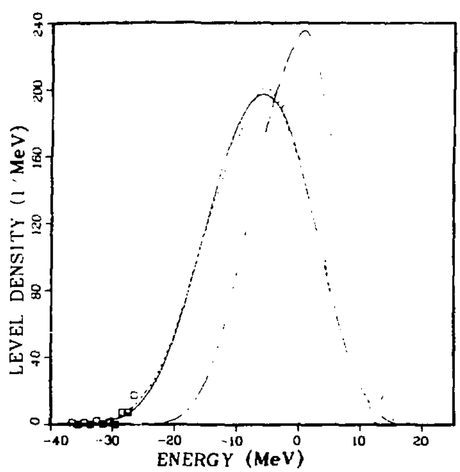

Fig. 1. Level density for ^{20}Ne in a dsdf basis calculated by means of exact diagonalization (squares), the moment method (whole basis expansion: solid curve; configuration expansion: dashed curve), the Lanczos technique (dotted curve), and for a Fermi gas (dash-dotted curve).

B) Moment method calculations of the level density of ^{24}Mg and comparison to experimental data

B. Strohmaier [1], S.M. Grimes [2]

Whereas for ^{20}Ne the calculations could not be expected to reproduce experimentally found level densities, since there were only four active nucleons outside an ^{16}O core, the actual application of the moment method should be for a nucleus such that the description of

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experimental data was feasible with regard to both physical assumptions and computational resources.
For this purpose, ^{24}Mg was chosen, with 8 nucleons outside an ^{16}O core. In fact, the total level density was described well by calculations using a $d_{5/2}$ $s_{1/2}$ $d_{3/2}$ $f_{7/2}$ basis and the same interaction as had been used for previous ^{28}Si work, but the spin cutoff and the positive parity fraction were overestimated. Both effects suggested the consideration of p shell orbitals to reduce the average J_Z^2 and to get negative parity states at lower energies. Therefore, calculations with 20 particles outside a ^{4}He core were performed, with and without consideration of the $f_{7/2}$ orbital in addition to the p and sd shell. Also, calculations with just the $p_{1/2}$ orbital in addition to $d_{5/2}$ $s_{1/2}$ $d_{3/2}$ $f_{7/2}$ (12 nucleons outside a ^{12}C core) were done. Despite extensive parameter variations, all these calculations suffer from the fact, that due to the relative values of third and fourth moments the Hermite polynomial expansions for state densities and $\langle J_Z^2 \rangle$ show strong fluctuations and large negative excursions. Alternative expansion techniques are being investigated; a multiple Gaussian distribution seems to be promising.

EXPERIMENTAL MEDIUM ENERGY PHYSICS

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

M. Botlo, Ch. Laa and H. Vonach

The ASTERIX experiment /1/ (Antiproton Stop Experiment with Trigger on Inital X-rays), located at the LEAR facility (see Progress Report 1984, p. 5-6) at CERN, represents one of the new possibilities for meson spectroscopy at low energies. Antiprotons, typically some 10^4/s, with a momentum as small as 100 MeV/c enter a gaseous hydrogen-target and are stopped there due to capture at high principle quantum number states ($n \sim 30$) of the hydrogen molecule. The antiproton and the proton form then protonium which one is able to study especially at low n, where strong interaction effects occur. The $\bar{p}p$-annihilation which takes place at rest allows to perform exclusive meson spectroscopy in the center of mass system up to one reconstructable neutral particle in the final state and to search for resonances in the region from 300 to 1600 MeV. The advantages of ASTERIX are at least a factor 100 more statistics compared to all bubble chamber data, the possibility to trigger on several specific event conditions like X-ray energies and final state kinematics and a better on line control of recorded events. Technical improvements which were done or continued this year were the implementation of a VAX 11/750 in the ASTERIX computer-equipment in order to have an on line and off line analysis machine close to the experiment and the development of new triggers which consist of microprocessor technology and microcode software.

In October 1985 we performed a data taking period where we were able to record roughly 15 million events onto tape (see table 2 for selected triggers during that run). All these raw data will be processed at the Landesrechenzentrum Mainz, FRG, where a modified tracking programm-package has been installed.

In order to show the physics output of ASTERIX in a systematical way we want to discuss first the annihilation in two and then in four

charged mesons. For a detailed analysis of protonium-spectroscopy see /2/.
For the final state $\pi^+\pi^-\pi^o$ we have developed a partial wave analysis. We estimated the relative branching ratios of the main resonant contributions and the nonresonant part to that channel and come to the following - preliminary - results /3/.

	S-wave	P-wave		
		$^1P_1$	$^3P_1$	$^3P_2$
$\pi\rho$	18	12	2	< 0.05
πf	1	-	22	3
non-resonant	8	12	12	9
sum	27	24	36	12

Table 1 Results of the partial wave analysis of the $\pi^+\pi^-\pi^o$ annihilation channel

As far as η-physics is concerned, we see a clear η-signal nearly free of background in the $\pi^+\pi^-$-missing mass spectrum, if we require signals from both gammas of the η-decay (see fig. 1). In the invariant mass spectrum of $\eta\pi^\pm$ (s. fig. 2) we detect δ and A_2 (fig. 1), in the $\bar{p}p \to K^+K^-\eta$ we can reconstruct the $\emptyset$.
Another result is $\bar{p}p \to K_S{}^oX$, where X is either a $K_L{}^o$ which escapes the apparatus or an unseen $K_S{}^o$ /4/.

Name	Required conditions	Physics application
XDC-multiplicity	K_S^o-decay pattern	selection of K_S^o events
Ga 103 processor	a) $\sum Q_i = 0$, ≥ 4 prongs b) $\sum Q_i = 0$, ≥ 2 prongs	rejection of events that cannot be reconstructed in off line analysis
	c) $\sum Q_i = 0$, E_{tot}^{trans} in $\pi\pi KK$ window or e^+e^- pair or $\pi^+\pi^-$ from K_S^o decay	enhancement of $\pi\pi KK$ events, γ events and K_S^o events
MALU	multiplicity of final states	
One-Gap	X-ray pattern	collection of an almost pure sample of events from P-wave annihilation

Table 2 Used triggers and their function in the October 1985 run

With the applied conditions that both charged pions reach the outer-

most chamber, that the missing mass-squared window is $0.125 < MM^2 < 0.375\ GeV^2$ and the total $\pi^+\pi^-$-momentum is more than 650 MeV/c we end with 80 signal events out of 1.6×10^5. This corresponds to an absolute branching ratio into K_S^oX of $(3.8 \pm 0.4)\times10^{-4}$.
In the four charged pion channel we searched for $K_S^oK_S^o$. Except an invariant mass $m(\pi^+\pi^-)$ cut we required an at least 3 cm vertex-separation of two neutral pion combinations. We find an absolute branching ratio of $(2.2 \pm 0.5)\times10^{-5}$. This number is corrected for undetected $K_S^o \to \pi^o\pi^o$ events. If one compares our K_SX, $K_S^oK_S^o$ results with bubble chamber we can estimate a relative S-wave annihilation contribution of $(46 \pm 10)\%$ in gaseous hydrogen under NTP. Another remarkable result in this respect is that $(K_SK_S + K_LK_L)$ is suppressed by a factor of 10 compared with the mode K_SK_L. For a theoretical explanation see /5/.
Other detected resonances in the four charged pion final state are η,ρ,ω and an indication of η'.
dE/dx information becomes important whenever a charged kaon is registered in the decay pattern. Some of the particles which can be constructed out of this are listed in table 3.

	Resonant state		Final state
$\bar{p}p \to$	$\left\{ K_S^oK^\pm\pi^\mp ;\ K\bar{K}^* \right\}$	$\to$	$K^\pm\pi^\mp\pi^+\pi^-$
$\to$	$\left\{ \pi^oK_S^oK^\pm\pi^\mp ;\ \pi^oE ;\ \pi^oD \right\}$	$\to$	$K^\pm\pi^\mp\pi^+\pi^-\pi^o$
		$\to$	$K^\pm\pi^\mp\pi^+\pi^-K^o$
$\to$	$\{K^o\bar{K}^*, \pi^+\pi^-\emptyset\}$	$\to$	$K^+K^-\pi^+\pi^-$
$\to$	$\{\pi^+\pi^-D, \pi^+\pi^-\omega\emptyset\}$	$\to$	$K^+K^-\pi^+\pi^-\pi^o$

Table 3 Main resonant states which decay into four charged particles where at least one of five is a kaon

In the final state $\pi^+\pi^-K^+K^-$ the prominent resonance $K^* \to \pi K$ was seen with a relative branching ratio of $(K^{*+}K^-/\pi\pi KK \geq 0.35)$. Studies are under way to estimate the absolute branching ratios of Ø (Ø → K^+K^-) in the same end channel in order to be able to explain the enhanced Ø production already known from bubble chamber data.

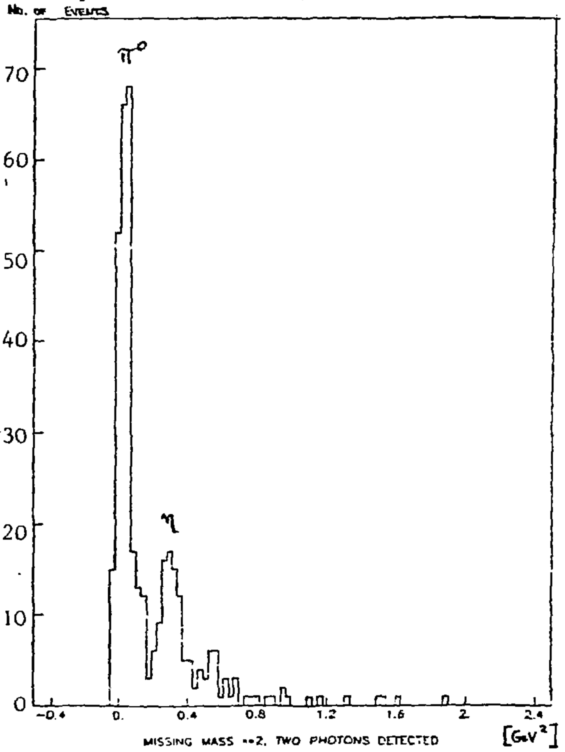

Fig. 1. Missing mass squared distribution recoiling against two pions of opposite charge with a fully reconstructed decay $X^0 \rightarrow \gamma\gamma$, and $|m_x{}^2 - \text{missing mass}^2| \leq 0.05\ GeV^2$

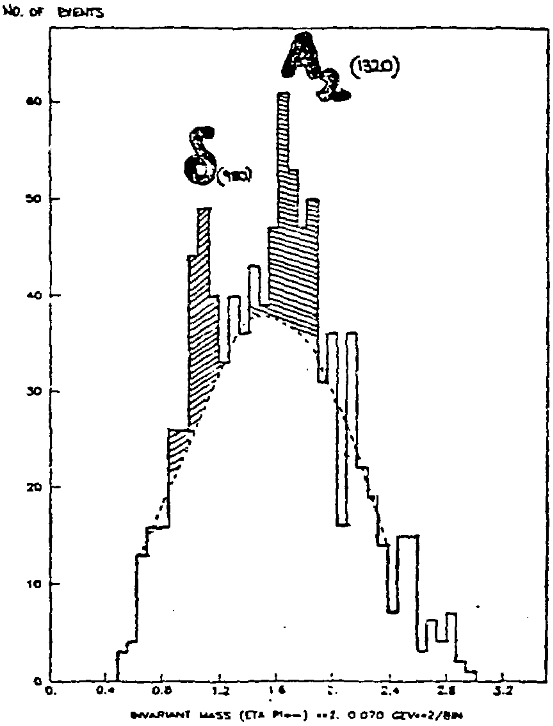

Fig. 2. $(\eta\pi)^\pm$ invariant mass squared for events $\bar{p}p \rightarrow \pi^+\pi^-\eta$ (→ 2 detected γ's)

Outlook

An interesting result reachable in the near future should be the evaluation of spin and parity of the so-called E/i-signal which was found in our data and a subsequent separation of the two possible particles in that mass region.

One of the next main steps of ASTERIX will be the development of a standard method to determine the absolute branching ratios of $\bar{p}p$-annihilations into mesons which are detectable with our apparatus. We hope to be able to report on some final results of particle states in the low mass range in one year.

The above progress report refers to the work of the whole ASTERIX Group (CERN-Mainz-München-Orsay-TRIUMF-Wien-Zürich Collaboration). The Austrian group members participated in most of the work described before; specifically they were in charge of the incorporation of the VAX 750 into the ASTERIX Computer Centre, including the development of all necessary software, the energy calibration of the central X-ray detector by analysis of the data of a test run ($\bar{p}$-annihilation in nitrogen).

/1/ R. Armanteros et al., CERN-Report PSCC/80-101, PSSC/P28, 1980

/2/ Ahmad et al., Phys. Lett. 157B (1985) 333

/3/ F. Kayser, CERN, priv. comm.

/4/ C. Amsler, ..., M. Botlo, C. Laa, H. Vonach, $\bar{p}$p-annihilation into neutral kaons, Proc. of the 3rd LEAR Workshop, Tignes-Savoie-France, Jan. 19-26, 1985, p. 353-358

/5/ J.A. Niskanen, Phys. Lett. 154B (1985) 351

NUCLEAR MODEL CALCULATIONS

CONTRIBUTION TO THE STUDY OF THE COMPETITION BETWEEN NEUTRONS AND γ-RAYS NEAR THE (N,2N) THRESHOLD

F. Cvelbar [1], B. Strohmaier

We are analysing some experimental γ-ray production spectra already reported in the literature, of nuclei in the mass region A = 45 through 60 and around 90. By means of a comparison of nuclear model calculations for the spectral intensities in the γ-ray energy interval between 11.5 and 14 MeV to those extracted from the experimental data we aim at determining whether the enhanced γ-ray competition found in ^{56}Fe /1/ is true for the considered nuclei, also.

/1/ G. Stengl, M. Uhl and H. Vonach, Nucl. Phys. A290 (1977) 109

DEVELOPMENT OF THE GENERAL NUCLEAR REACTION CROSS CODE MAURINA

M. Uhl

The development of the code MAURINA has been described in previous annual reports. In the frame of a collaboration with a group of the Euratom Center Ispra (Italy) additional capabilities of the code are required. These concern the calculation of the distribution of the kinetic energy of the heavy reaction products ("recoil spectra") and the representation of the calculated data. The inclusion of these new features resulted in a considerable extension of the program.

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[1] J. Stefan Institute and Faculty of Natural Sciences and Technology, E. Kardelj University, Ljubljana, Yugoslavia

Recoil Spectra:

A procedure to calculate the kinetic energy distribution of the light and the heavy products of reactions with an arbitrary number of sequentially emitted particles was developed. The main problem with the calculation of recoil spectra under consideration of angular momentum and parity conservation is the substantial increase of computation time and memory requirements for the higher chance processes; the recoil spectra resulting from first chance emission are obtained as a byproduct of a standard calculation under consideration of the respective angular distributions.

To make the calculation of recoil spectra feasible on computers of moderate capacity the following approximations were adopted for the treatment of (sequential) higher chance emission:

i) the change of the recoil energy due to gamma-ray emission is neglected compared to that resulting from particle emission.

ii) higher chance emission is isotropic in the rest system of the decaying nucleus.

iii) correlations between spin-parity and recoil energy distributions are neglected. The distribution of the energy of relative motion of each decay process, however, is calculated under consideration of angular momentum and parity conservation.

Due to these simplifications the calculation of the recoil spectra increases the computation time only by a factor of about two. The spectra of light and heavy reaction products can be calculated either in the CM-system or in the LAB-system. In the LAB-system only angle-integrated spectra are given while in the CM-system also the double differential cross sections are made available.

Representation of the Results:

As for incident energies of 40 MeV about 30 residual nuclei are produced, the amount of the calculated data is very large, in particular if, for applied purposes, the data are required over a wide range of bombarding energies. Special subroutines were developed which provide the calculated cross sections in a format which is compatible with the international computer readable ENDF-VI format.

The representation of the results makes use of file 3 (reaction cross

sections), file 4 (angular distributions) and the recently extended file 6 (energy-angle distributions of reaction products). For the time being these ENDF-output routines can handle only neutron induced reactions; the special representation of the elastic cross section for charged particles will be included in next future.
In addition to these new developments MAURINA has also been applied to analize experimental data for $^{nat}Ag(n,p)$ and $^{nat}In(n,p)$ as described elsewhere in this report /1/.

/1/ R. Fischer et al., this report, p. 28

EXPERIMENTAL NUCLEAR PHYSICS, NEUTRON INDUCED REACTIONS

INVESTIGATION OF THE ENERGY AND ANGULAR DISTRIBUTION OF THE HIGH-ENERGY PART OF INELASTICALLY SCATTERED 14 MEV NEUTRONS *)

A. Pavlik, G. Staffel, G. Winkler and H. Vonach

The continuation of the measurements described in the last year's report /1/ was hampered by the necessary reinstallation of the building's electric power supply lines.
The double-scattering correction for the inelastic part of the secondary neutrons mentioned in the last year's report /1/ was based on the simplifying assumption taking inelastic scattering as to be isotropic. In order to estimate whether the angular dependence of inelastic neutron scattering may significantly change the double-scattering correction, an analytical method was developed which takes into account angular distributions for the scattered neutrons. Since cylindrical samples typically 2 cm in diameter and 12 cm long are used in this experiment, the path of a secondary neutron and hence the probability of being scattered twice depends strongly on the first scattering angle. In order to account for this fact, the average path of neutrons, scattered into directions with the same angle θ with respect to the sample cylinder axis, was described by a Legendre polynomial series with θ as argument. The differential cross sections for the first and the second scattering process, respectively, were also represented by Legendre polynomial expansions in a second and a third coordinate system, each of which was rotated against the others. The number of neutrons hitting the detector after two scattering events can be calculated using the relationship between the Legendre polynomials and the spherical harmonics, and the mathematical formalism well-known from the quantum-mechanical theory of angular momenta. Using available angular distribution systematics information /2,3/, the calculations show, that compared to the assumption of isotropic

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*) Supported by Jubiläumsfonds der Österreichischen Nationalbank

secondary neutron emission, there will be a decrease of double scattering events as a whole, but not more than about 8%. There may be an enhancement of double scattering events in the forward direction by about 20%, a reduction in the backward direction by about 30%, in comparison with the previous results assuming isotropy.

/1/ A. Pavlik, G. Staffel, G. Winkler and H. Vonach, Progress Report 1984, p. 9-10

/2/ J.M. Akkermans, H. Gruppelaar and G. Reffo, Phys. Rev. C22 (1980) 73

/3/ C. Costa, H. Gruppelaar and J.M. Akkermans, Phys. Rev. C28 (1983) 587

PRECISE MEASUREMENTS OF CROSS SECTIONS FOR THE REACTIONS $^{59}CO(N,2N)^{58m+g}CO$ AND $^{59}CO(N,P)^{59}FE$ AROUND 14 MEV

S.J. Hasan [1], A. Pavlik, G. Winkler, M. Uhl and M. Kaba [2]

The final version of this work, the preliminary results of which have been given in the last year's report /1/ is in print in Journal of Physics G: Nuclear Physics. It includes the full experimental details and the analysis of the various uncertainty contributions, as well as details concerning the nuclear reaction model calculations for the above reactions, relevant parameter sets, and the results thereof.

/1/ S.J. Hasan, A. Pavlik, G. Winkler and M. Kaba, Progress Report 1984, p. 10-11

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MEASUREMENT OF CROSS SECTIONS FOR THE ^{93}NB(N,N'γ)^{93M}NB REACTION

M. Wagner, G. Winkler and H. Vonach

The reaction ^{93}Nb(n,n'γ)^{93m}Nb is of special importance in reactor dosimetry. Application of this reaction requires a careful determination of the excitation function. In view of the existing literature values a measurement at a neutron energy of about 2.8 MeV with an accuracy of $\sim$ 5% would provide particularly useful information. In order to measure the production cross section of the 30.7 keV ^{93}Nb isomer by activation, the characteristic Nb X-rays emitted after internal conversion of the isomeric transition have to be detected.

Therefore as a first step a Si(Li) X-ray-detector was calibrated with respect to its efficiency for the K-X-rays of Nb ($K_{\alpha 1}$ = 16.62 keV and $K_{\alpha 2}$ = 16.52 keV; $K_{\beta 1}$ = 18.95 keV and $K_{\beta 2}$ = 18.62 keV). Since for intensity reasons Nb foils about 0.125 mm thick and 20 mm in diameter are planned to be used for the activation, the self absorption in such foils was experimentally studied. For this purpose a stack of inactive Nb foils with a thickness of about 0.006 mm each and 20 mm in diameter was used: Each of these foils was subsequently replaced by a Nb foil of the same diameter and thickness, homogeneously activated by 14 MeV neutrons, in order to simulate the activity sitting in different layers of a thicker sample. The procedure was performed for stacks amounting to a total thickness of about 0.065 mm and 0.125 mm; the K_α-peak only and the (K_α+K_β)-peaks together were evaluated. The foil stack was clamped between two perspex disks in a specially constructed sample holder sitting in a position close to the surface of the Si(Li)-detector. The uncertainty of the self-absorption factors finally determined by integration over the different sample layers will be $\leq$ 1%.

Absolute efficiency values were obtained by means of a thin ^{93m}Nb reference source ($\sim$ 30 kBq) about 2.5 mm in diameter. This source was also used to study the variation of the efficiency with a displacement from the axis of the detector set-up in order to account for efficiency modifications in case of an extended sample.

MEASUREMENT OF SOME (N,P), (N,α), (N,2N) AND (N,N'γ)-CROSS SECTIONS AT A NEUTRON ENERGY OF 14.52 (± 0.23) MEV AND EVALUATION OF THE RESPECTIVE CROSS SECTIONS

M. Wagner and G. Winkler

Activation measurements using high-purity samples of KBr, Sc, As, Zr, Mo, Ru, In, Sb, CsCl, Ta and Re in natural isotopic composition, which primarily served for obtaining a systematic survey of (n,γ)-cross sections at E_n = 14.5 MeV, were evaluated in order to redetermine several (n,p)-, (n,α)-, (n,2n)- and (n,n'γ)-cross sections. Neutrons were produced via the reaction $T(d,n)^4He$ using a low-mass solid-state target construction; the energy of the incident deuterons was around 190 keV. The samples employed (16 mm in diameter and 0.1-2.0 mm thick) were placed at a mean angle of 0° relative to the incident d^+-beam relatively close to the neutron source, which resulted in an average neutron energy of 14.52 MeV with a spread of 0.23 MeV (half FWHM). In order to monitor the neutron fluence via the well known cross section of the reaction $^{27}Al(n,\alpha)^{24}Na$, the samples were sandwiched between two Al foils during irradiations.

The γ-ray spectra of the irradiated samples were recorded by means of a Ge(Li) detector with 27 cm^3 active volume and a resolution of 2.2 keV at 1332.5 keV (^{60}Co). Each reaction product was identified by its characteristic photopeaks and its half-life. Decay data compiled in "Table of Isotopes", (C.M. Lederer and V.S. Shirley, ed., Wiley, New York, 7th ed. 1978),and from the most recent editions of the Nuclear Data Sheets were used to convert the measured activities into cross sections.

The effect of low-energy neutrons produced by (n,2n)-reactions and by inelastic scattering of the primary neutrons in the sample and the target construction was estimated and found to exceed 1% of the measured activity only in a few cases, i.e. for $^{92}Mo(n,p)^{92m}Nb$, $^{113}In(n,n'\gamma)^{113m}In$ and $^{115}In(n,n'\gamma)^{115m}In$. The experimental results are listed in the second column in table 1.

The new experimental results were evaluated together with available results from the literature in the neutron-energy range 14.5-14.9 MeV for the reactions in question. The previous results were critically reviewed and obviously erroneous data were disregarded. If necessary, the data were renormalized in order to account for recent evaluations of the reference cross sections as well as for up-to-date decay data for the reaction products. In cases of an apparent significant energy dependance of the cross sections between 14.5 and 14.9 MeV the data, including those of the present work, were related to a neutron energy of 14.7 MeV using a graphical estimate of the slope of the respective excitation function between 14 and 15 MeV. The various uncertainty contributions were analyzed in terms of equivalent standard deviations, taking into account correlations between the results from different authors, and eventually adding uncertainty components not properly considered by the authors. Weighted averages of the corrected cross section values were calculated together with their internal and external errors, the larger of which was taken as the final error of the evaluated cross sections. The preliminary results of this evaluation are presented in table 1, column 4. In order to compare the evaluated results with the experimental ones from the present work, the latter were equally referred to 14.7 MeV neutron energy as listed in table 1, column 3.

With a few exceptions there is a very good consistency between the evaluated and the new experimental data, regarding the numerical values of the cross sections as well as the uncertainties. In most cases the errors of the evaluated cross sections are of course smaller than those in column 3; however, in the case of $^{181}Ta(n,p)^{181}Hf$, $^{187}Re(n,p)^{187}W$, $^{81}Br(n,\alpha)^{78}As$ and $^{133}Cs(n,\alpha)^{130}J$ ($\sigma^{cum.}$) the new experimental data seem to be more precise than the respective evaluated ones, due to only very few or inconsistent data in the literature. In case there was only one literature value available in addition to the new own experimental result, this literature value - renormalized and referred to E_n = 14.7 MeV - was given in column 4 instead of an evaluated cross section.

Table 1 Experimental cross sections and preliminary evaluated cross sections

Reaction	experimental cross section /mb/ (E_n=14.52 MeV)	experimental results of this work, referred to E_n=14.7 MeV /mb/	preliminary evaluated cross sections at E_n=14.7 MeV /mb/
$^{41}K(n,p)^{41}Ar$	47.5 ± 3.2	45.1 ± 3.2	47.73 ± 1.38
$^{75}As(n,p)^{75}Ge$	22.8 ± 2.7	22.2 ± 2.7	17.62 ± 1.27 1) (Prestwood & Bayhurst)
			16.69 ± 2.96 1) (Vinitskaya et al.)
			20.15 ± 2.14 2)
$^{81}Br(n,p)^{81m}Se$	13.0 ± 1.3	13.0 ± 1.3	14.27 ± 1.29
$\{^{90}Zr(n,p)+^{91}Zr[(n,n'p)+(n,pn')+(n,d)]\}^{90m}Y$	12.68 ± 0.80	12.68 ± 0.80	11.58 ± 0.37
$^{92}Zr(n,p)^{92}Y$	19.7 ± 1.8	19.7 ± 1.8	18.63 ± 1.26
$^{92}Mo(n,p)^{92m}Y$	69.1 ± 4.4	69.1 ± 4.4	64.67 ± 3.75
$\{^{96}Mo(n,p)+^{97}Mo[(n,n'p)+(n,pn')+(n,d)]\}^{96}Nb$	25.0 ± 1.6	25.0 ± 1.6	23.02 ± 1.41
$^{96}Mo(n,p)^{96}Nb$	23.0 ± 1.6 (corrected for $^{97}Mo[(n,n'p)+..]$)	23.0 ± 1.6	19.81 ± 1.45
$^{97}Mo(n,p)+^{98}Mo[(n,n'p)+(n,pn')+(n,d)]\}^{97}Nb$	22.4 ± 1.6	22.4 ± 1.6	24 ± 2.1 (O. Artem'Ev et al.)
$^{97}Mo(n,p)^{97}Nb$	17.2 ± 1.7 (corrected for $^{98}Mo[(n,n'p)+..]$)	17.2 ± 1.7	17.16 ± 1.07
$^{96}Ru(n,p)^{96}Tc$	153.1 $^{+15.5}_{-11.7}$	153.1 $^{+15.6}_{-11.7}$	169.6 ± 31.7 (P.R. Gray et al.)
$^{115}In(n,p)^{115g}Cd$	4.62 ± 0.32	4.62 ± 0.32	4.67 ± 0.99 (V.N. Levkovskij et al.)
$^{123}Sb(n,p)^{123m}Sn$	1.87 ± 0.15	1.87 ± 0.15	1.75 ± 0.41 (V.N. Levkovskij et al.)
$^{181}Ta(n,p)^{181}Hf$	3.05 ± 0.21	3.19 ± 0.21	3.62 ± 0.43
$^{187}Re(n,p)^{187}W$	3.81 ± 0.30	3.81 ± 0.30	4.17 ± 0.54
$^{45}Sc(n,\alpha)^{42}K$	55.1 ± 4.3	54.3 ± 4.2	54.92 ± 1.64
$^{75}As(n,\alpha)^{72}Ga$	10.7 ± 0.7	10.7 ± 0.7	11.24 ± 0.44
$^{79}Br(n,\alpha)^{76}As$	13.0 ± 1.0	13.0 ± 1.0	12.14 ± 0.82
$^{81}Br(n,\alpha)^{78}As$	6.0 ± 0.5	6.0 ± 0.5	4.29 ± 0.58
$\{^{90}Zr(n,\alpha)+^{91}Zr(n,n'\alpha)\}^{87m}Sr$	4.19 ± 0.27	4.19 ± 0.27	3.82 ± 0.11
$^{94}Zr(n,\alpha)^{91}Sr$	4.81 ± 0.43	4.95 ± 0.44	4.86 ± 0.33
$^{115}In(n,\alpha)^{112}Ag$	2.40 ± 0.28	2.40 ± 0.28	2.537 ± 0.161
$^{113}Cs(n,\alpha)^{130}J$ ($\sigma=\sigma^{cum.}=(\sigma^{g}+(0,83\pm0,03)\sigma^{m})$	1.83 ± 0.12	1.83 ± 0.12	1.60 ± 0.19
$^{181}Ta(n,\alpha)^{178m}Lu$ ($t^{m}_{1/2}$ = 22.7 ± 0.4 min)	0.224 ± 0.016	0.224 ± 0.016	0.14 ± 0.04 ($t^{m}_{1/2}$=16min) (J.L. Meason et al.)
$^{187}Re(n,\alpha)^{184}Ta$	0.68 ± 0.06	0.68 ± 0.06	0.94 ± 0.14 (R.F. Coleman et al.)
$^{45}Sc(n,2n)^{44m}Sc$	134.3 ± 10.0	138.2 ± 10.3	134.0 ± 3.0
$^{45}Sc(n,2n)^{44g}Sc$	177.8 ± 14.6	187.1 ± 15.4	188.1 ± 5.3
$^{45}Sc(n,2n)^{44}Sc$ (σ^{total})	312.0 ± 17.6	325.3 ± 18.6	322.6 ± 7.4
$^{75}As(n,2n)^{74}As$	1056 ± 82	1056 ± 82	1076.0 ± 42.1
$\{^{96}Zr(n,2n)+^{94}Zr(n,\gamma)+^{96}Zr[(n,n'p)+(n,pn')+(n,d)]^{95}Y+\}^{95}Zr$	1441 ± 79	1441 ± 79	1436.1 ± 47.9
$\{^{104}Ru(n,2n)+^{102}Ru(n,\gamma)+^{104}Ru[(n,n'p)+(n,pn')+(n,d)]^{103}Tc+\}^{103}Ru$	1510 ± 117	1525 ± 118	1200 3) (S.M. Qaim et al.)

Reaction	experimental cross section /mb/ (E_n=14.52 MeV)	experimental results of this work, referred to E_n=14.7 MeV /mb/	preliminary evaluated cross sections at E_n=14.7 MeV /mb/
$^{121}St(n,2n)^{120m}Sb$	532 ± 38	541 ± 39	559.2 ± 18.5
$^{123}Sb(n,2n)^{122}Sb$ (σ^{total})	1606 ± 146	1606 ± 146	1480.0 ± 100.0
$^{133}Cs(n,2n)^{132}Cs$	1496 ± 102	1496 ± 102	1499.5 ± 53.1
$^{181}Ta(n,2n)^{180g}Ta$	1333 ± 94	1315 ± 94	1197.0 ± 143.7 [1]
			1295.0 ± 61.9 [2]
$^{113}In(n,n'\gamma)^{113m}In$	56.5 ± 3.6	56.0 ± 3.6	55.37 ± 3.38
$^{115}In(n,n'\gamma)^{115m}In$	59.7 ± 3.6	58.9 ± 3.6	57.89 ± 2.82

1) results of works, in which β-ray counting methods were employed

2) results obtained by γ-ray (and X-ray) spectroscopy

3) value taken from a graphical data representation; the quoted uncertainties were 6-15%

MEASUREMENT OF DIFFERENTIAL (N,CHARGED PARTICLE) CROSS SECTIONS BY MEANS OF THE VIENNA MULTI-TELESCOPE SYSTEM

R. Fischer, P. Maier-Komor [1], M. Uhl and H. Vonach

A) ^{93}Nb(n,p). The results of the first (thin target) experiment have been published in Nucl. Sci. and Eng. /1/. In the mean-time the results of the second experiment using an infinitely thick target (see /2/) have been combined to give more accurate proton emission cross sections. These final data on the ^{93}Nb(n,p) reaction will be published together with the In(n,p) and Ag(n,p) results (see section C).

B) The ^{55}Mn(n,α) and ^{59}Co(n,α) results (see /2/) have been analyzed. The angle-integrated spectra can be well described by standard compound and precompound statistical model calculations except for the high-energy end - where some direct contribution seems to be present - as shown in fig. 1.

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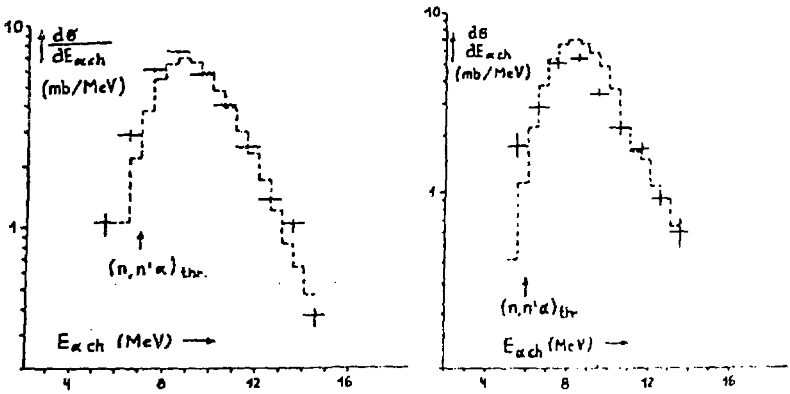


Fig. 1. (a) The angle-integrated α-particle spectrum for the $^{59}Co(n,x\alpha)$ reaction; + exp. values, --- result of STAPRE calculation with standard parameters
(b) Same for $^{55}Mn(n,x\alpha)$ reaction.

The calculation shown in the figure was done using the code STAPRE /3/ and a standard parameter set for the mass region of the structural materials /4/ without any special parameter adjustment. Angular distributions (see fig. 2) are very similar to those found in earlier work on ^{56}Fe and ^{60}Ni /5/.

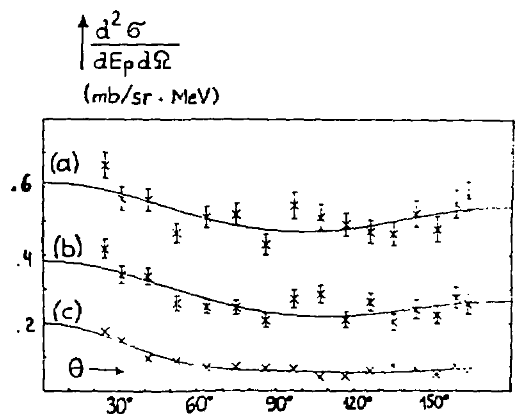


Fig. 2. Angular distributions for different α-energy bins for the $^{59}Co(n,\alpha)$ reaction.
(a) $E_{\alpha ch}$ = 7 - 10 MeV,
(b) $E_{\alpha ch}$ = 10 - 12 MeV,
(c) $E_{\alpha ch}$ = 12 - 14 MeV.
The solid curves denote the Legendre fits to the data.

In the region of the evaporation peak the angular distributions are approximately symmetrical around 90° and show a small minimum as expected according to the Hauser Feshbach theory. Our present result is consistent with an effective nuclear moment of inertia equal to the full rigid body value. Total α-emission cross sections were found to be 22.7 ± 1.3 mb for ^{55}Mn and 32.8 ± 1.7 mb for ^{59}Co. These results are in excellent agreement with the results of recent He-accumulation /6/ measurements.

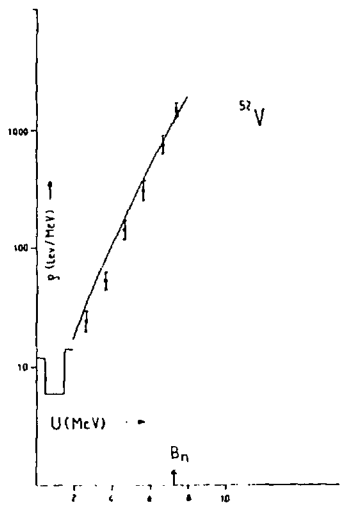
For the target nuclei ^{55}Mn and ^{59}Co absolute level densities have been determined at U = 11 MeV. These values and those derived earlier for ^{56}Fe and ^{60}Ni are summarized in table 1 and compared to the predictions of the back-shifted Fermi-gas model using either the parameters of Dilg et al. /7/ or those of Strohmaier and Uhl /4/. In addition the average nuclear temperatures in the excitation energy range 3-11 MeV derived from the experimental level density values of 11 MeV and the density of discrete levels around 3 MeV are also given.

Nucleus	ρ_{exp} lev/MeV	ρ_{Dilg} lev/MeV	$\rho_{Strohm.-Uhl}$ lev/MeV	T_{exp} (U=3-11 MeV) MeV
^{55}Mn	$6.4 \cdot 10^3$ ± 25%	$8.2 \cdot 10^3$	$5.6 \cdot 10^3$	1.55 ± .07
^{56}Fe	$3.05 \cdot 10^3$ ± 25%	$2.9 \cdot 10^3$	$3.4 \cdot 10^3$	1.41 ± .07
^{59}Co	$17.4 \cdot 10^3$ ± 25%	$10.25 \cdot 10^3$	$18.3 \cdot 10^3$	1.26 ± .07
^{60}Ni	$3.85 \cdot 10^3$ ± 25%	$3.6 \cdot 10^3$	$6.0 \cdot 10^3$	1.39 ± .07

Table 1 Measured and calculated nuclear level densities at U = 11 MeV

As the table shows there is rather good agreement with the level density parameters derived by Strohmaier and Uhl from a simultaneous evaluation of neutron cross sections of structural materials whereas the global parameters of Dilg et al. /7/ for the A = 40-65 mass range predict level densities which may deviate somewhat more from the experimental values at least for the case of ^{59}Co. Absolute nuclear level densities both for the residual nuclei reached by α-emission (^{52}V and ^{56}Mn) and those reached by neutron emission, that is the target nuclei were derived by the method described in our work on the $^{56}Fe(n,\alpha)$ and $^{60}Ni(n,\alpha)$ reactions /5/.

Figs. 3 and 4 show the level densities of ^{52}V and ^{56}Mn obtained in this way. As the figures show there is good agreement with both the level density information from resolved levels and neutron resonances.



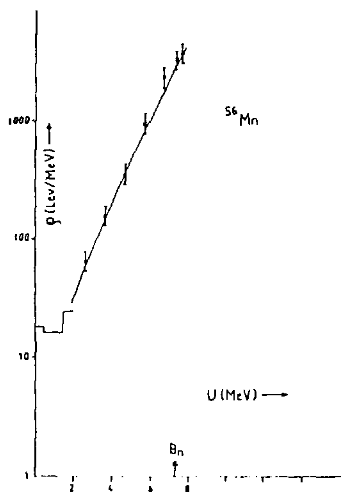
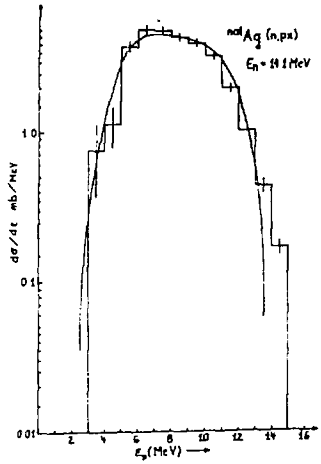


Fig. 3. Level density of ^{52}V. The histogram is derived from the counting of discrete levels; o denotes the level density from $d\sigma/dE_\alpha$ values; x denotes the level density derived from s-wave neutron resonance spacing assuming a rigid body moment of inertia (σ=3.96); - denotes back-shifted Fermi-gas with a=6.16 MeV^{-1} and Δ=-1.46 MeV

Fig. 4. Level density of ^{56}Mn. x denotes level density derived from s-wave neutron resonance spacing assuming a rigid body moment of inertia (σ=4.1); - denotes Fermi-gas with a=6.81 MeV^{-1} and Δ=-1.5 MeV.Other symbols are as in fig. 3.

C) nat-Ag(n,p) and nat-In(n,p) reactions. The data from these experiments (see /2/) were also completely analyzed and compared to the predictions of nuclear model calculations.

The angle integrated proton spectra are rather similar to our previous ^{93}Nb(n,p) results and can be well described by statistical model calculations assuming precompound particle emission and subsequent compound nucleus decay as shown in figs. 5 and 6. The STAPRE calculations shown use the same parameters for the precompound emission as previously used in our work on the ^{93}Nb(n,p) reaction /1/, especially the normal pairing correction was used for exciton state densities used in the calculation of precompound particle emission. The angular



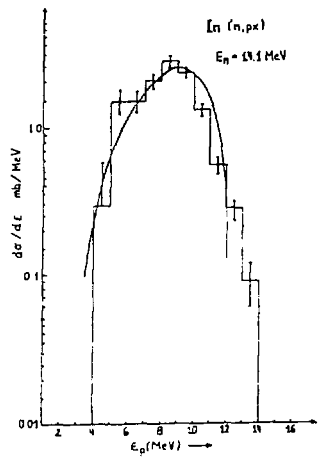


Fig. 5. Angle-integrated proton spectrum from the reaction nat-Ag(n,px) at E_n=14.1 MeV. solid line: result of STAPRE calculations.

Fig. 6. Angle-integrated proton spectrum from the reaction nat-In(n,px) at E_n=14.1 MeV. solid line: result of STAPRE calculations for ^{115}In.

distributions for all proton energies can be adequately described by a three term Legendre series

$$\frac{d\sigma}{d\Omega}(\theta) = a_o + a_1 P_1(\cos\theta) + a_2 P_2 (\cos\theta)$$

Therefore the information on the angular distribution is given in figs. 7 and 8 in form of the relative Legendre coefficients a_1/a_o and a_2/a_o as function of proton energy. Our results for these quantities (see figs 7 and 8) are in good agreement with the empirical systematics of Kalbach and Mann /8/.

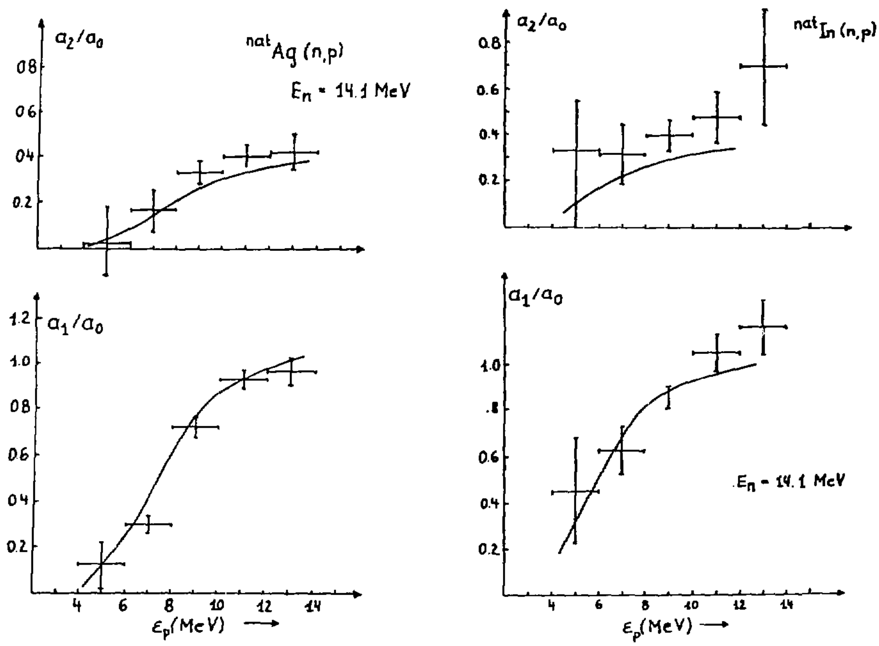


Fig. 7. Reduced Legendre coefficients of proton angular distribution from the reaction nat-Ag(n,px) at E_n=14.1 MeV. Solid line: systematics of Kalbach-Mann.

Fig. 8. Reduced Legendre coefficients of proton angular distributions from the reaction nat-In(n,px) at E_n=14.1 MeV. Solid line: systematics of Kalbach-Mann.

/1/ G. Traxler et al., Nucl. Sci. and Eng. 90 (1985) 174

/2/ R. Fischer, P. Maier-Komor, B. Strohmaier, G. Traxler, M. Uhl and H. Vonach, Progress Report 1984, p. 11-15

/3/ B. Strohmaier and M. Uhl, Proc. Course Nucl. Theory for Applications, Trieste, 1978, IAEA-SMR-43, p. 313, IAEA, 1980

/4/ B. Strohmaier and M. Uhl, Proc. Int. Conf. on Nuclear Data for Science and Technology, Antwerp, 1982, p. 552

/5/ R. Fischer et al., Phys. Rev. C30 (1984) 72

/6/ D.W. Kneff et al., Reports BNL-NCS-31052, 1982, p. 144 and BNL-NCS-34291, 1983, p. 173

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/8/ C. Kalbach and F.M. Mann, Phys. Rev. C23 (1981) 112

DETERMINATION OF THE HIGH-ENERGY WING OF THE ^{252}CF NEUTRON SPECTRUM [*]

A. Chalupka, L. Malek, S. Tagesen, R. Böttger [1]

The investigation of the neutron spectrum from spontaneous fission of ^{252}Cf is a topic of particular relevance as this spectrum has been recommended by the IAEA/INDC as an international neutron spectrum standard. In the course of the collaboration of IRK and PTB the ^{252}Cf neutron spectrum was measured between 2-14 MeV /1-3/. Recently time-of-flight (TOF) experiments at the University of Dresden /4,5/ show in the high-energy wing an excessive amount of neutrons - up to two orders of magnitude - relative to a Maxwellian shape with T = 1,42 MeV (fig. 1).

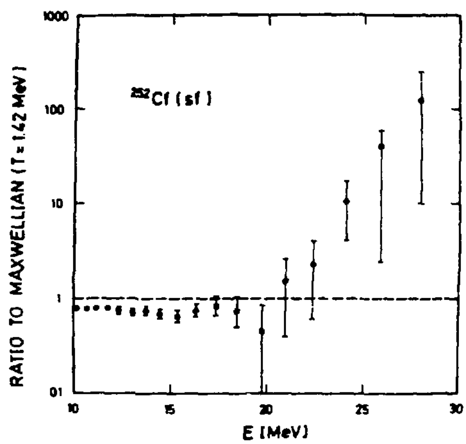

Fig. 1. Experimental data on the high-energy end of the ^{252}Cf(sf) neutron spectrum as measured at the University of Dresden

In contrary W. Mannhart evaluating integral measurements with threshold reactions /6/ did not find such a deviation. Despite many advantages of the TOF method its applicability for the determination of this part of the spectrum suffers from the cosmic-muon background. Background reduction may be established by sophisticated apparative pro-

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*) Supported by the IAEA

visions or heavy shielding. We decided on the latter and shall perform an TOF experiment in a mine in Bleiberg, Carinthia. With generous support of the Bleiberger Bergwerksunion background measurements were done in an adit at the depth of approximately 500 m.
It turned out, that the cosmic-muon background is attenuated to less than 10^{-4} of its value above ground (fig. 2).

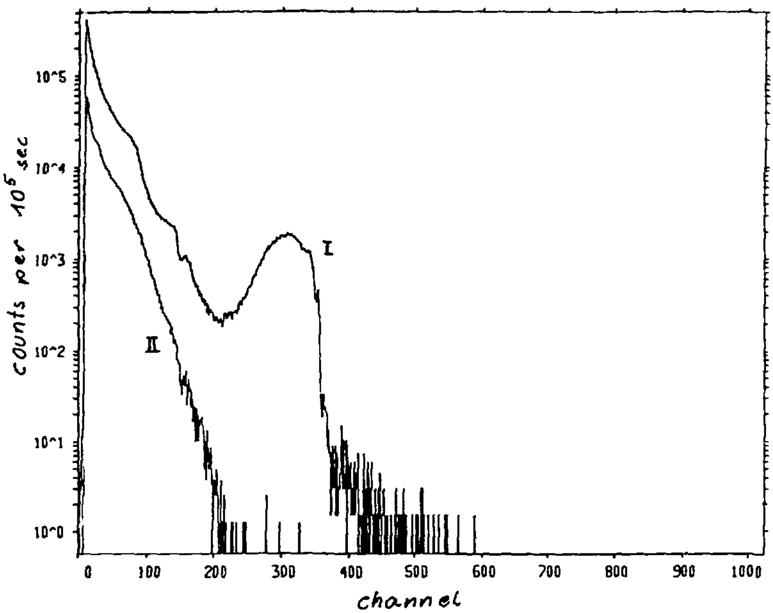

Fig. 2. Pulse height spectrum from background measurements:
I above ground
II in the mine

The two spectra are pulse-height spectra from a neutron detector with a 5" Ø - 1" thick NE213 cell. The broad peak is due to energy loss signals from cosmic radiation. Data are normalized to a total collection time of 10^5 sec.
Presently a computer controlled measuring and data collection system capable of withstanding environmental conditions in a mine is developed. Thus, a neutron detector (calibrated at PTB) and a fission chamber will be transferred to Bleiberg and installed in an adit (10. Lauf-West). There a TOF experiment will be performed with 4-parametric data collection. Besides TOF-data, also light output and pulse shape

from the neutron detector signal and ΔE_f from the fission chamber will be recorded. A recently developed "pile up unit" /7/ will allow identification of events with ambiguous time measurement. The net running time of the experiment is estimated to be 5 weeks. First data analysis will be performed in Bleiberg, final analysis at IRK.
The result of the experiment should clarify the above mentioned discrepancies and may be used to test the validity of the competing Madland-Nix model /8/ and the Complex Cascade Evaporation model /4/, respectively.

/1/ R. Böttger, H. Klein, A. Chalupka, B. Strohmaier, Int. Conf. on Nuclear Data for Science and Technology, 6-10 Sept 1982, Antwerp, p. 484

/2/ H. Klein, R. Böttger, A. Chalupka, B. Strohmaier, IAEA Consultants Meeting on the ^{252}Cf Fission Neutron Spectrum, 28.3.-1.4.1983, Smolenice, Czechoslovakia, p. 191

/3/ A. Chalupka, B. Strohmaier, R. Böttger, H. Klein, IAEA Consultants Meeting of the ^{252}Cf Fission Neutron Spectrum, 28.3.-1.4.1983, Smolenice, Czechoslovakia, p. 187

/4/ H. Märten, D. Seeliger, IAEA Advisory Group Meeting on Nuclear Standard Reference Data, 12-16 Nov 1984, p. 255

/5/ R. Böttger, W.D. Fromm, H. Klein, H. Märten, D. Richter, D. Seeliger, Int. Conf. on Nuclear Data for Basic and Applied Science, 13-17 May 1985, Santa Fé, USA, p.

/6/ W. Mannhart, IAEA Consultants Meeting on Nuclear Data for Radiation Damage Estimates for Reactor Structural Materials, 20-22 May 1985, Santa Fé, USA

/7/ A. Chalupka, S. Tagesen, Progress Report 1984, p. 16-19 (accepted for publication in Nucl. Instr. Meth.)

/8/ D.G. Madland and J.R. Nix, Nucl. Sci. Eng. 81 (1982) 213

INSTRUMENTATION AND DETECTORS

STUDIES CONCERNING AN EXPERIMENTAL SETUP FOR THE SEARCH FOR NONINTEGRAL ELECTRIC CHARGES IN STABLE MATTER: ACCELERATION AND OBSERVATION OF NIOBIUM TEST OBJECTS

A. Chalupka and R. Fischer

In the course of the ongoing project study of this subject discussed by the authors in the last year's report /1/ some preparatory experiments were performed. First it was examined if niobium particles with sizes of several µm can be charged and accelerated by an electrostatic field. A polished stainless steel plate carrying niobium powder, an accelerating grid and a collecting foil were arranged in an evacuated chamber as sketched in fig. 1. Different field strengths between 10 kV/cm and 60 kV/cm were applied and then the collected particles were counted and measured using a microscope.

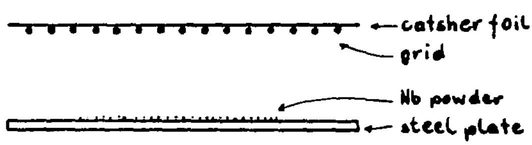

Fig. 1. Schematic sketch of the particle extraction test

Resulting particle size distributions are given in fig. 2 and allow rough estimates of the influenced charge which sufficiently agree with results from very simple calculations.

The setup for the second test is shown in fig. 3. Using an intensive light source simple optics and a system of slit-diaphragms we defined two illuminated regions (compare fig. 2 and text of ref. 1). Particles passing this regions scatter light into the entrance window of the photomultiplier tube. Though the anode current of the photomultiplier raised to about 600 µA when the light source was turned on large signals were observed when the accelerating field was applied. It seems very promising to obtain good timing signals.

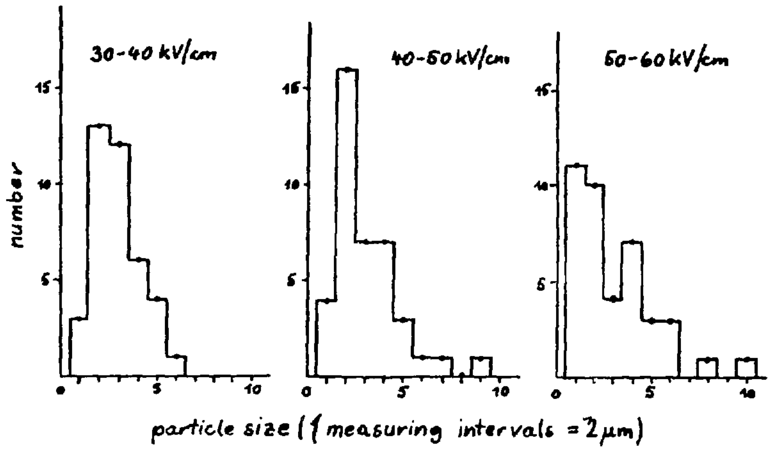

Fig. 2. Particle size distribution for different electrostatic fields

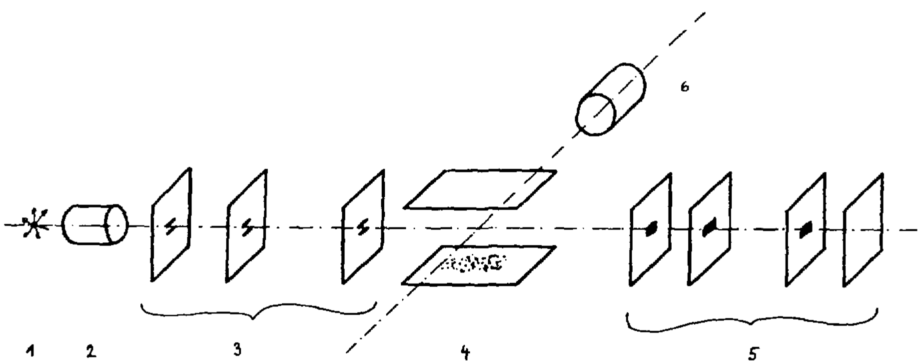

Fig. 3.
1 light source
2 collimator
3 slit diaphragms
4 condensor plates with Niobium particles, applied field strength 10-60 kV/cm
5 beam dump
6 photomultiplier tube

On the occasion of visiting the Stanford group we thoroughly discussed their results and our project. We learned that this group has reanalized its older measurements and located some possible sources for inconsistent data. They were about to start a new series of measurements late in 1985.

As the justification of our project is based on the reliability of the Stanford experiments we are looking forward to the new results.

/1/ A. Chalupka, R. Fischer, Progress Report 1984, p. 20-24

ELECTRO SPRAY - A VERSATILE TECHNIQUE FOR RADIOACTIVE SAMPLE PREPARATION

A. Chalupka and F. Hernegger

As the studies concerning the spontaneous emission of heavy clusters proceed at IRK /1,2/ there is demand for suitable radioactive sources. These sources must show both sufficient strength ($\sim$ 10 μCi) and negligible self absorption because the energy of the emitted particle is one of its identification marks. Therefore sources made from materials with relatively long half lives must necessarily be thin and homogeneous layers of large area. Since the origins of radioactivity research source preparation has been one of its main tasks and a tremendous amount of publications deals with this problem. For our purposes we need the preparation of a ^{226}Ra (about 30 mm² active area) source and of a few ^{232}Th (about 10^4 mm² active area) sources. After attempts with several techniques we decided to set up an apparatus for electro spraying, a technique which is described in ref. 3 and sketched in fig. 1. A telescope together with high intensity illumination allowed to observe the spray itself and especially its development when the applied voltage was raised. Typical configurations of sprays and resulting sources are shown in fig. 2. All our systematic studies were done with a solution of 14,4 μg BaCl/cm³ alcohol. The quality of the layers was judged by microscopic inspection. Results 2a-2c are of rather poor quality but 2d-2f generally yielded very homogeneous and thin layers.

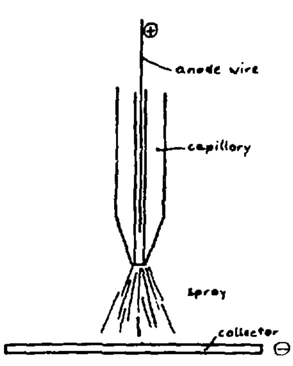

Fig. 1. Schematic arrangement for source preparation by the electro spray technique

However, some larger crystals (a total of ∿ 2-5% of the sample mass), probably due to larger droplets, could be observed. This drawback was overcome by turning the setup upside down (fig. 3). No larger crystals were observed anymore. Using the electro spray technique large area sources of high quality can be made within reasonable time (20--40 hours).

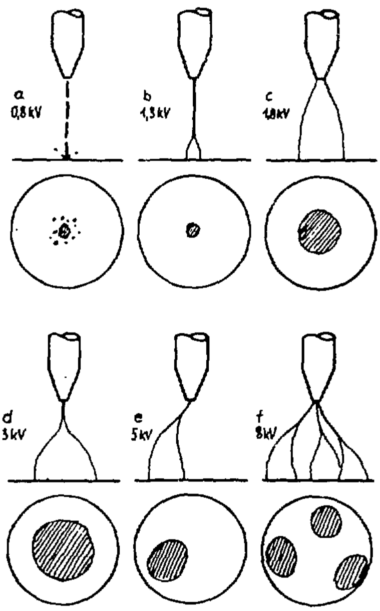

Fig. 2. Typical configurations of sprays and resulting sources as they vary with applied voltage

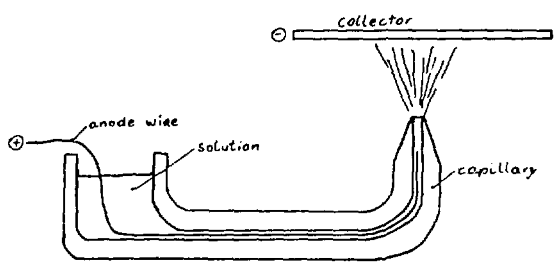

Fig. 3. Refer to text

/1/ A. Chalupka, F. Hernegger, P. Hille, W. Schmidt, H. Vonach and D. Weselka, Progress Report 1984, p. 37-39

/2/ A. Chalupka, F. Hernegger, P. Hille, W. Schmidt, H. Vonach and D. Weselka, this report, p.

/3/ E. Bruninx, G. Rudstam, Nucl. Instr. Meth. 13 (1961) 131

EVALUATION OF NUCLEAR DATA AND NUMERICAL DATA PROCESSING

NEUTRON SPECTRUM CALCULATIONS FOR THE GKSS FACILITY KORONA *)

A. Pavlik, G. Winkler

The knowledge of the effective neutron energy distribution is necessary for the interpretation of neutron activation cross section measurements at the GKSS facility KORONA (sealed neutron tube with cylindrical acceleration structure, filled with a D-T gas mixture) /1/. The primary neutron spectrum at the irradiation position and the contribution of neutrons, scattered elastically by structure materials, was already calculated at GKSS /1/. In this work the contribution and energy distribution of neutrons, produced by nonelastic processes in the structure materials, was calculated, using neutron emission spectra derived from model calculations with the STAPRE code. The contribution of these neutrons to the total neutron yield was found to be $\sim$ 9%, the contribution of elastically scattered neutrons is $\sim$26% /1/.

/1/ B.M. Bahal, H.-U. Fanger, Nucl. Instr. Meth. 211 (1983) 469

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*) In collaboration with GKSS-Forschungszentrum Geesthacht, Geesthacht, FRG

NEW KINDS OF RADIOACTIVITY

NEW KINDS OF RADIOACTIVITY

A. Chalupka, F. Hernegger, P. Hille, W. Schmidt, H. Vonach and D. Weselka

As mentioned in our last report /1/ we started investigating the new kind of (natural) radioactivity discovered recently by Rose and Jones /2/. Up to now (Jan. 1986) observation of spontaneous ^{14}C emission from 4 Ra-isotopes ($^{222,223,224,226}Ra$), including the natural ones, has been claimed by different authors /3,4/. In the case of the naturally occuring ^{223}Ra this new radioactivity could be established beyond any doubt by several groups using different methods. It could be shown directly by simultaneous measurement of charge (Z) and mass number (A) of the clusters, that it is indeed radiocarbon (^{14}C), that is emitted /5/. For the other 3 Ra-isotopes independent verifications of the claimed ^{14}C-radioactivities are still missing. Concerning other kinds of rare radioactive decay modes, like emission of heavy isotopes of N, O and Ne which have been predicted theoretically /6/, to our knowledge, only ^{24}Ne-decay of ^{232}U has been found experimentally by a Berkeley-group /7/.

There is a startling discrepancy between the ^{14}C-alpha-branching ratios measured directly in the decay of the naturally occurring Ra-isotopes and the radiochemically determined ^{14}C-contents of U- and Th-ores, measured by accelerator mass spectrometry (AMS), as reported recently by a University of Arizona group /8/. The amount of ^{14}C detected in a given mineral was found to be proportional to the concentration of uranium in that mineral, but in excess of what could be expected from the ^{14}C-decay of the Ra-daughters in the U-series. Since all other known sources of radiocarbon, by ^{14}C-background producing reactions, had been taken into account /8/, the origin of the excess of ^{14}C by about a factor of 2 remains unclear. (From the Q-value it is rather unlikely that other elements than radium in the decay-series of uranium are responsible for the high ^{14}C-concentrations, found in the uranium-bearing minerals.)

After some preliminary investigations, already reported in the last year's Progress Report /1/, we started systematic studies in the new field, using special plastic foils as selective track etch detectors. (An other line of experimental activities was the development of techniques for the production of suitable Ra-targets and is described elsewhere in this report.) In order to calibrate the track etch detectors about 80 plastic-foils (Rodyn-P & Hostaphan) were irradiated with ions of ^{12}C, ^{14}C and ^{18}O of different energies at the Tandem Van de Graaff accelerator of the Munich Universities. (We are very grateful to our colleagues in Munich for their kind support and help.) In this calibration experiment the following parameters were varied to test their influence on the response of the detector foils.

1) the storage time between irradiation and etching of the foils.
2) The etching time.
3) The application of an alpha-dose corresponding to the high doses to be expected in the actual experiments.

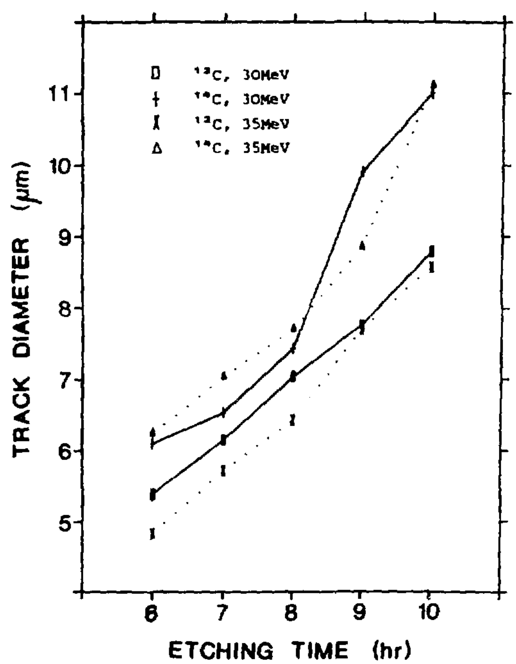

Fig. 1. Diameter of etched tracks versus etching time

Fig. 1 shows the diameters of the etched tracks, versus etching time, for the 3 kinds of ions and the different energies used in this experiment (which lie in the range calculated to be emitted in those rare radioactive decays we want to look at). These are the results for Rodyn-P-foils without any additional alpha-dose. In order to get good resolution (small scattering of the measured track-diameters) a waiting-time of about 1 month between irradiation and etching turned out to be necessary. (This is concerning track etch detector foils which were stored in air under normal pressure and kept in darkness.) There is a surprisingly clear difference to be seen between the diameters of tracks of different isotopes of ^{12}C and ^{14}C respectively - it seems to be possible to discriminate between ions of neighbouring isotopes of the same energy.

Untill calibration is completed we want to etch track detector foils already exposed to the radiation of a ^{227}Ac-source (containing ^{223}Ra as a daughter). This will show us hopefully very soon whether the technical aspects of detection of ^{14}C-projectiles are under control. (The ^{14}C-decay of ^{223}Ra can now be regarded as well known.) We also will evaluate detector foils exposed to a ^{232}U-source, containing ^{224}Ra, for which ^{14}C-radioactivity has also been claimed /3/, as mentioned above. Further investigations in the field will hopefully be supported by a grant we have applied for at the Fonds zur Förderung der Wissenschaftlichen Forschung.

/1/ A. Chalupka, F. Hernegger, P.Hille, W. Schmidt, H. Vonach and D. Weselka, Progress Report 1984, p. 37-39

/2/ H.J. Rose and G.A. Jones, Nature 307 (1984) 245

/3/ P.B. Price, J.D. Stevenson, S.W. Barwick and H.L. Ravn, Phys. Rev. Lett. 54, 4 (1985) 297

/4/ E. Hourani, M. Hussonois, L. Stab, L. Brillard, S. Gales and J.P. Schapira, preprint (1985)

/5/ W. Kutschera et al., priv. comm., Argonne Nat. Lab. preprint (1985), subm. to Phys. Rev. C.

/6/ D.N. Poenaru, M. Ivascu, A. Sandulescu and W. Greiner, Phys. Rev. C32, 2 (1985) 572

/7/ S.W. Barwick, P.B. Price and J.D. Stevenson, Phys. Rev. C31 (1985) 1984

/8/ D. Barker, A.J.T. Jull and D.J. Donahue, Geophys. Res. Letts. 12, 10 (1985) 737

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. Details concerning the application of the method for users are summarized in /1/.
Annual reports on the dating work are given in Anzeiger der mathem.-naturw. Klasse der Österreichischen Akademie der Wissenschaften /2,3/ and in Radiocarbon /4,5/.

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/3/ H. Felber, Altersbestimmungen nach der Radiokohlenstoffmethode am Institut für Radiumforschung und Kernphysik XXI, Anz. Österr. Akad. Wiss., mathem.-naturw. Kl., 121 (1985) 19-27

/4/ H. Felber, Vienna Radium Institute Radiocarbon Dates XIV, Radiocarbon 26, (3), (1984) 441-448

/5/ H. Felber, Vienna Radium Institute Radiocarbon Dates XV, Radiocarbon 27, (3), (1985) in press

STABLE ISOTOPE INVESTIGATIONS

E. Pak

Sulfur isotope measurements have attained great interest for the solution of many problems, especially in the earth sciences. In 1985, the collaboration with several institutions was continued or begun: age classification of sulfate rocks, genetic investigations on base metal deposits (in Austria, Germany, Yugoslavia, Bulgaria, Cyprus), hydrological studies (Lake Neusiedl, Danube River) and environmental measurements (sulfate in precipitation).
Carbon isotopes in natural gas were investigated in collaboration with ÖMV.

ABSOLUTE DATING OF AUSTRIAN LOESS DEPOSITIONS TO RECONSTRUCT THE LOCAL CLIMATE DURING THE LAST ICE AGE PERIOD

P. Hille, E. Wild, G. Wallner, W. Schmidt [1]
in cooperation [2] with:
G. Rabeder, Inst. f. Paläontologie d. Univ. Wien
G. Grabner, N. Getoff, Inst. f. Theoret. u. Strahlenchemie d. Univ. Wien
S. Verginis, H. Nagl, Inst. f. Geographie d. Univ. Wien
I. Steffan, Inst. f. Anal. Chemie d. Univ. Wien

As announced in our last report /1/, we started an interdisciplinary program dealing with the absolute dating of loess deposits in Lower Austria. The ultimate aim of this project is a chronological correlation of the presumably best available local record of palaeoclimate with the now very well known and precisely dated marine deep sea climatic record of the last about 2.5 million years. We have already tried to give a very short description of the status of international

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[1] Now with Klinik für Strahlentherapie und 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.

research (see /1/ and refs. cited there), concerning the accuracy of the geochronology of the deep sea stratigraphy in connection with the spectacular revival of the Milankovitch-theory of palaeoclimate. We also have tried /1/ to show, that this new project is just the logical consequence of our previous work, dealing with the absolute dating of cave bear bones from mount Ramesch and the astonishing conclusion that had to be drawn from the results: During the last glaciation cycle there must have been a period of rather favourable climate in our Alpine region from about 65.000 to 35.000 years before present. Finally we tried to give some arguments /1/, why we believe that our local loess deposits are especially well suited for our purpose: On the one hand they are thin enough to be readily accessible at several places, on the other hand they seem to contain in principle the whole climatic record of all the glaciation cycles of the last ice age period, i.e. of the last about 2.5 Myr. In a recent work by Shackleton et al. /2/, dealing with the history of glaciation in the North Atlantic region, an undisturbed sequence of alternating white deep-sea carbonate oozes and dark-coloured layers that are rich in glacial debris was studied. This core, recovered from the west flank of Rockall Bank, together with detailed nannofossil and palaeomagnetic stratigraphy shows that the earliest horizons of ice-rafted debris in the region occured at about 2.5 Myr. At this time obviously a very long period of rather quiet climate was terminated and followed by the unstable conditions of the ice age period. Since loess deposits seem to offer the best possibility to develop a relatively complete regional stratigraphy that may be compared with the deep-sea record /3/, absolute dating of our Austrian loess deposits is of great interest and a very rewarding task.

We started with 2 absolute dating methods directly applicable to loess deposits. The first one uses the effect of radio-thermoluminescence (see e.g. /4/) and is rather wellknown as a method for dating ancient pottery. When this method is applied to loess there are certainly several non-trivial problems to be solved, but it seems to work in principle, at least under favourable conditions (see e.g. /3/ and ref. cited there. It might be worthwhile to note here that pioneering work dealing with the mechanism of thermoluminescence was done at the

Vienna Radiuminstitut 50 to 60 years ago by Urbach and Przibram among others.) The second method has been pioneered very recently by a Canadian group /5/, applying it to sediment sample sequences spanning a period of about 0-700 kyr. The new method determines the time since the sediment was last exposed to sunlight. The samples were irradiated with visible light (wavelength 514.5 nm from an argon-ion laser) to excite electrons from thermally-stable light-sensitive traps and the subsequent luminescence was used to measure the radiation dose accumulated since the last exposition to sunlight. (It might be interesting to note that to our knowledge it was again Przibram in Vienna, who first observed the effect and had called it "Radio-Photolumineszenz" some 60 years ago.)

To begin with calibration experiments for both dating methods mentioned above, fractions of the original loess samples (within a grain-size range of 4-11 µm) were selected by sedimentation. Thin samples were prepared on aluminium disks and irradiated with known dose of ^{60}Co gamma-rays of the order 100 Gy.

Fig. 1 shows an example of a thermoluminescence-glowcurve of a loess sample treated as described above.

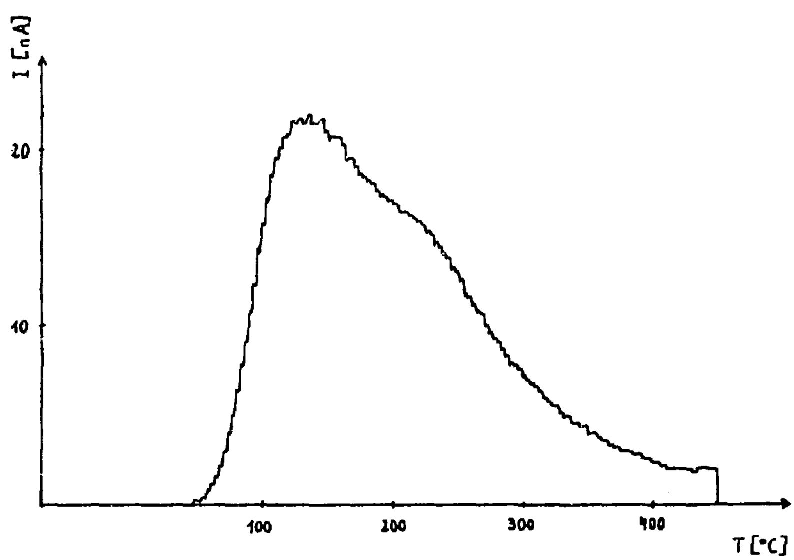

Fig. 1. TL glow curve for Stillfried loess exposed to an artificial γ-dose of 100 Gy.

Following the suggestion of Wintle et al. (see /3/ and refs. given there), optical filters were used in front of the photomultiplier to suppress the quartz-component of the luminescence-light.
Differing from the Canadian experiment /5/ mentioned above we used a pulsed Nd:YAG-laser to see whether the second dating-method by "radio-photoluminescence" is suitable for loess dating. Preliminary results indicate that gamma-irradiated loess samples do indeed emit luminescence-light after being hit by the green light of the laser pulse. The decay time of the luminescence is long compared to the laser pulse thus offering the possibility of a time-discrimination against the background of scattered laser-light, not absorbed by filters in front of the multiplier. We also could observe annealing of the effect by a series of laser-pulses; this gives us confidence that the effect of radio-photoluminescence can really be used to date the last exposure of the loess to sunlight.
At present we are trying to get the financial support to continue the interdisciplinary research just started.

/1/ P. Hille, G. Rabeder, W. Schmidt, S. Verginis, G. Wallner, E. Wild, Pleistocene climate and the problem of dating periods of loess deposition and soil formation in Austria, Progress Report 1984, p. 42

/2/ N.J. Shackleton, J. Backman, H. Zimmerman, D.V. Kent, M.A. Hall, D.G. Roberts, D. Schnitker, J.G. Baldauf, A. Desprairies, R. Homrighausen, P. Huddlestun, J.B. Keene, A.J. Kaltenback, K.A.O. Krumsiek, A.C. Morton, J.W. Murray, J. Westberg-Smith, Oxygen isotope calibration of the onset of ice-rafting and history of glaciation in the North Atlantic region, Nature 307 (1984) 620

/3/ A.G. Wintle, N.J. Shackleton, J.P. Lautridou, Thermoluminescence dating of periods of loess deposition and soil formation in Normandy, Nature 310 (1984) 491

/4/ H. Felber, P. Hille, Anwendung der Radioisotopen-Datierung in der Archäologie, Sitzber. Öster. Akad. Wiss., math.-naturw. Kl. 191 (1982) 149

/5/ D.J. Huntley, D.I. Godfrey-Smith, M.L.W. Thewalt, Optical dating of sediments, Nature 313 (1985) 105

APPLICATIONS IN MEDICINE

MEASUREMENT OF SURFACE ROUGHNESS OF X-RAY TUBE ANODES *)

R. Nowotny

The surface roughness of the focal spot track on X-ray tube anodes exhibits some effect on X-ray tube output particular at the low-energy end of the X-ray spectrum. The usage of the X-ray tubes produces an increasing roughness of the surface due to sputtering and local heating. Hence the absorption of the X-ray beam in the anode increases and finally, at about 50-60% of the initial output the tube can be considered to be worn out.

To obtain some data on the actual surface roughness of discarded tubes 7 anode surfaces were scanned with a Perthen roughness measuring

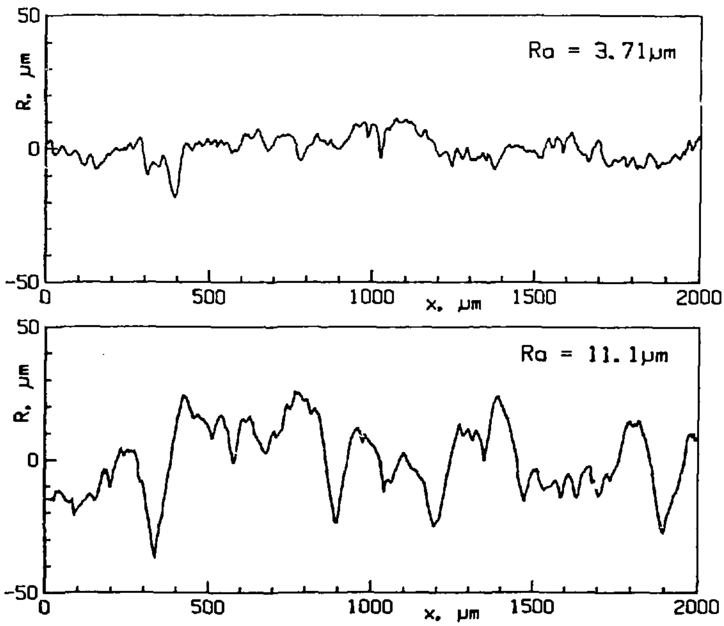

Fig. 1. Surface roughness of a tungsten anode (16.5° anode angle) across the small focus track (bottom) and across the large focus track (top).

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*) in collaboration with Zentrales Institut für Radiodiagnostik, Univ. Wien and L. Boltzmann-Institut für radiol.-physik. Tumordiagnostik

instrument (5 µm-90° diamond stylus). A total of 10 anode tracks (large and small focus tracks) were measured. A result is shown in fig. 1.
The roughness of a new anode is given by the manufacturer as Ra=0.3 µm for sand-blasted and Ra = 0.7 µm for ground surfaces, resp. Surface roughness increases for the anodes measured here to Ra=3.7 - 11.1 µm with excursions of up to 37 µm from the initial plane.
It has been shown /1/ for a 100 kV X-ray spectrum (40°, 3.6 mm Be, 2.03 mm Al, 75 cm air) that already an additional average absorption layer of 3 µm tungsten reduces the dose output by 20%. Unfortunately, there exist no dose output measurements for the anodes investigated here. Therefore no direct correlation of dose reduction with a suitable surface roughness parameter could be made but we intend to use a code for the calculation of X-ray spectra described in /1/ for a calculation of the influence of surface roughness on spectral data and dose output using the data for anode roughness from this study.

/1/ R. Nowotny and A. Höfer, Fortschr. Röntgenstr. 142 (1985) 685

INFLUENCE OF SYRINGE SIZE AND HANDLING ON PRESSURE IN BALLOON CATHETERS

H. Schurawitzki [1], G. Wittich [1], R. Nowotny, E. Salomonowitz [1] and W. Kumpan [1]

It is essential to limit the hydrostatic pressure in catheters particularly during vascular dilatation procedures to prevent rupture of the balloon. It was suggested in the literature /1/ to achieve this goal by simply choosing syringes with the appropriate cross section of the piston according to the individual physical strength and handling habits.
As such a simple method would be an attractive choice we tried to evaluate its applicability in routine work. This was done by measuring

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[1] Zentrales Institut für Radiodiagnostik and L. Boltzmann-Institut für radiol.-physik. Tumordiagnostik.

catheter pressures of up to 17.2 bar with a pressure transducer (Honeywell 242PC250) and a DVM coupled to a personal computer. Maximum obtainable pressures were determined for 1, 2, 5, 10 and 20 ml syringes each filled with 25%, 50%, 75% and 100% of nominal volume and for 5 probands.
The results indicate that a limitation of catheter balloon pressure by a selection of syringe size is not a practicable method as the maximum pressures vary to a large extent on the degree of filling and the momentary working conditions even if the syringe size is individually selected. We rather recommend an instrumental surveillance of catheter pressure during dilatation or when a possibility of catheter rupture is immanent.

/1/ M.A. Jaffree et al., Brit. J. Radiol. 58 (1985) 9

APPLICATIONS IN GEOPHYSICS

RADON MEASUREMENTS FOR EARTHQUAKE PREDICTION RESEARCH *)

K. Aric [1], H. Friedmann, R. Gutdeutsch [1], F. Hernegger, C.Y. King [2]

The observation of the radon (^{222}Rn) concentration in the spring of Warmbad Villach (Carinthia/Austria) and in the spring of Bolu (Turkey) is carried on. Fluctuations in the radon concentration in the spring of Warmbad Villach might have partly their origin in the process of continuous deemanation of the water. Therefore a new type of deemanation unit is under construction.

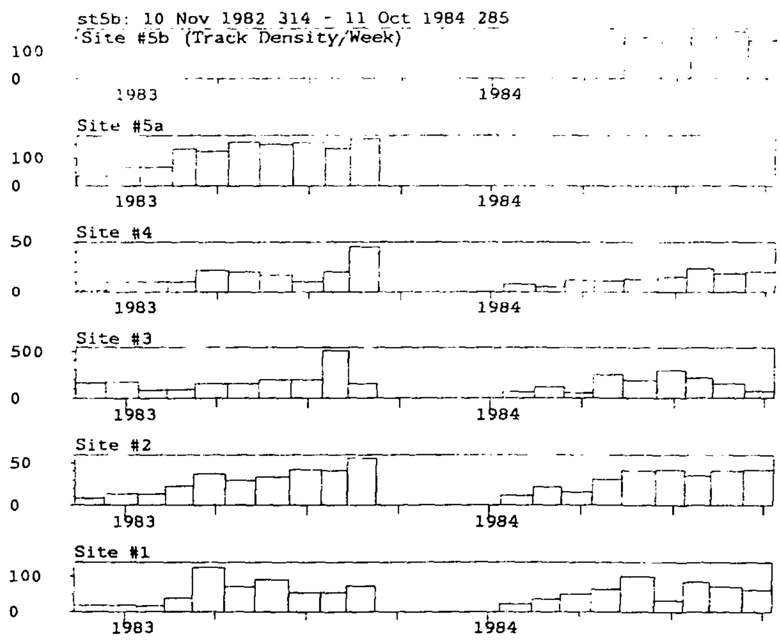

Fig. 1. Soil-gas radon data (Turkey)

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1 Inst. f. Meteorologie u. Geophysik d. Univ. Wien
2 Geological Survey, Office of Earthquake Studies, Menlo Park, California, USA

*) Supported by Fonds zur Förderung der Wissenschaftlichen Forschung in Österreich (Grant nos. 3295, 4305, 4688)

Concerning the measurements in Bolu (Turkey) no problems appeared with the apparatus, however, the seismic data of the area are still not available, so it could not completely be tested if a correlation between seismicity and radon concentration exists.
The soil gas measurements with track etch detectors are carried on as well, however, instead of the foils supplied by Terratex we are now using foils which are supplied by SGAE Seibersdorf. Fig. 1 shows the results of the soil gas measurements with Terratex foils. The sites are numbered from east to west, site # 1 is Ismetpasa, site # 3 is Bolu, near to the observed thermal spring, site # 5 is Yongalik. The results of the measurements show variations, however, there are existing also similar tendencies in different stations, which correspond partly with the results of the radon measurements in the spring of Bolu.

DOSIMETRY AND ENVIRONMENTAL STUDIES

DOSIMETRY AND ENVIRONMENTAL STUDIES

H. Friedmann, F. Hernegger, G. Winkler

a) The concentrations of ^{226}Ra in bottled mineralwater and from springs were measured for radiation protection purposes.

b) The concentrations of ^{222}Rn in air samples were measured for radiation protection purposes, as well as for calibrating track etch detector systems.

c) In order to clear problems when comparing the results of low-level measurements, standard concepts, signs and symbols, for the treatment of uncertainties in the evaluation of measurements should be used. For this purpose a working group was formed to prepare the publication of a recommendation in the form of a standard sheet (ÖNORM).

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