EANDC (OR) - 116 "L"
INDC (SWT) - 3 "G"

PROGRESS REPORT TO EANDC FROM SWITZERLAND

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Swiss Federal Institute for Reactor Research

Würenlingen

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PREFACE

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CONTENTS

I. Institut de Physique, Université de Neuchâtel

(Dir.: Prof. Dr. Jean Rossel)

1. Test of the Pole Graph with the Treiman-Yang Criterion for the Reaction ^{6}Li (p,dp) ^{4}He at 50 MeV

Collaboration Université de Neuchâtel - ISN Grenoble

Measurements presented in EANDC (OR)-90"L" in which the Treiman-Yang test was applied to deuteron breakup by proton [1] have been continued in the investigation of the T-Y criterion for the case of the ^{6}Li (p,pd) ^{4}He reaction at 50 MeV. Preliminary results indicate the fullfillment of the criterion within the experimental errors which implies that at an incident energy of 50 MeV quasifree scattering in the reaction ^{6}Li (p,pd) ^{4}He can be described by a single peak graph [2]. The energy dependence of this reaction is also being studied between 35 and 56 MeV under quasifree kinematic conditions which keep two of the three invariants in the pole graph amplitude constant. Further experiments and analysis of present data are in progress.

The experimental arrangement and particle identification made possible the simultaneous collection of many two particle coincidence spectra unconnected with the primary experiment. Of interest in these spectra are the eventual existence of excited states of ^{3}He, excited states of ^{4}Li, the (α-d) and (^{3}He-t) cluster structure of ^{6}Li and off-shell effects in quasifree scattering. Some analysis has been done [3] and work on other aspects is in progress.

References

[1] R. Corfu et al., Phys. Rev. Lett. 27, 1661 (1971)

[2] J.P. Egger, thesis, Université de Neuchâtel 1971 (unpublished)

[3] J.L. Beveridge et al., Helv. Phys. Acta 45

2. Polarization Measurements in the D(nn) Elastic Scattering at 2.6 MeV*

D. Bovet, S. Jaccard, J. Piffaretti, R. Viennet and J. Weber

$P_2(\theta)$ has been measured at three more angles θ_L : 30^0, 71^0 and 110^0 . $P_2(\theta_L)$ has been found to be: $-0.07\pm 0.96\%$, $4.9\pm0.96\%$ and $0.42\pm0.91\%$ resp. (The errors are statistical + experimental. Multiple scattering has been taken into account.)

We have shown that with the new type of polarimeter described elsewhere[1] it would be possible to measure simultaneously $P_2(\theta_L)$ for both neutron groups from the reaction $^9Be(\alpha,n_0, n_1)$ ^{13}C [2] that is for neutron energies around 8 and 3 MeV resp. It is currently planned to measure $\frac{d\sigma}{d\Omega}(n_0)/\frac{d\sigma}{d\Omega}(n_1)$ in order to obtain essentially the shape of $\frac{d\sigma}{d\Omega}(n_1)$ which is important to estimate false asymmetries [1] .

The determination of the values of the Wolfenstein's parameters as predicted by a J-degenerate model, taking into account published phase-shift sets has been made [3] .

Measurements of the Wolfenstein's parameters are in progress. We should get preliminary results by late summer.

References

[1] J. Piffaretti, Helv. Phys. Acta 44, 763 (1971)

[2] T. Stammbach, G. Palek, J. Taylor and R.L. Walter, N.I.M. 80, 304 (1970)

[3] S. Jaccard and R. Viennet, Nucl. Phys. A182, 541 (1972)

* EANDC (OR)-112"L", 1971

3. Neutron-neutron quasi-free scattering in the D(n,nn)p reaction at 14.1 MeV

E. Bovet, F. Foroughi, J. Rossel

Following the study of the final state interaction in the D(n,nn)p reaction at 14.1 MeV [1] we have set up the experimental arrangement for a kinematical situation in which the energy of the proton is zero (in the Lab system) for enhancing quasi-free scattering. Our choice of the geometrical configuration is $\theta n_1 = \theta n_2 = 39.6^\circ$, $\phi n_1 = 0^\circ$ and $\phi n_2 = 180^\circ$. the target is D_2O. The two neutron detectors are NE 213 liquid scintillators allowing n-γ discrimination.

A PDP-15 computer is used on line (via a CAMAC system) for the data acquisition in the multiparametric complete 3 body experiment.

Preliminary measurements have been started.

References

[1] C. Lunke, J.P. Egger, J. Rossel, Nucl. Phys. A158, 278 (1970)

II. Institut de Physique Nucléaire, Université de Lausanne

(Dir.: Prof. Ch. Haenny)

^{10}B (n, Charged Particles) Reactions at 14.0 MeV

Ch. Sellem, J.P. Perroud

Simultaneous measurements of the angular distribution of light and heavy particles emitted in reactions induced by 14.0 MeV neutrons in ^{10}B are carried out in the angular range of $2^0 \leq \bar{\theta}_L \leq 135^0$.

The experimental set-up consists of one proportional counter and of one fully depleted, thin (150 μ) semiconductor to measure the heavy particles and an extra 1 mm thick semiconductor coupled to the preceding thin one to measure the light particles allowing thus a unique normalization for all the reactions induced by 14 MeV neutrons on ^{10}B leading to a charged particle in the exit channel.

Preliminary analysis of the obtained data shows that reactions producing p, d, t and α are perfectly separated by the one or the other telescope in the energy range 0.5 to 15 MeV.

The evaluation of the cross-sections for ^{10}B (n, d_0), ^{10}B (n, d_1), ^{10}B (n, t_0), ^{10}B (n, $\alpha_0 + \alpha_1$), ^{10}B (n, α_2) is very simple and shows good agreement with previous measurements, for example [1] for (n, d), [2] for (n, t) and [3] for (n, α) reactions.

More refined analysis will permit to separate the α_0 and α_1 emitted in the ^{10}B (n, α) X reaction and determine the corresponding angular distributions. The time of flight also measured in the device will allow the evaluation of the very small cross-sections for(n, p) reactions as well as cross-sections for heavier particles leading to higher excited states, like ^{10}B (n, d_2), ^{10}B (n, α_3), or ^{10}B (n, t) ^{8}Be*(2.9 MeV).

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V. Valkovic, P. Thomas, I. Slaus and M. Cerineo.

[2] V. Valkovic.
Nucl. Phys. 54 (1964) 465.

[3] B. Antolkovic, J. Hudomalj, B. Janko, G. Paic and M. Turk.
Nucl. Phys. A. 139 (1969) 10.

III. Institut de Physique, Université de Fribourg

(Dir.: Prof. Otto Huber)

1. Study of Heavy Nuclei by (n,γ) Reactions*

by M. Gasser, O. Huber, V. Ionescu, J. Kern, A. Raemy

Gamma ray measurements have been made of the following (n,γ) reactions on heavy nuclei: ^{nat}Ir (n,γ) ^{192}Ir + ^{194}Ir; ^{191}Ir (n, γ) ^{192}Ir; ^{232}Th (n,γ) ^{233}Th; ^{237}Np (n,γ) ^{238}Np; ^{241}Am (n,γ) ^{242}Am. Spectra at high and low energies were taken with a pair and anticompton spectrometer [1] and a 2.4 cm^3 Ge(Li) detector [2]. The measurements were performed at the tangential channel of the reactor "SAPHIR" in Würenlingen. The thermal neutron flux at the target position is about 2×10^7 neutrons/cm^2 . s at a reactor power of 4 MW. Figures 1 and 2 present some sample spectra.

Natural iridium has 2 isotopes: ^{191}Ir (37.3 %) and ^{193}Ir (62.7 %). In our experiments we have used natural iridium and a target enriched to 86 % of ^{191}Ir. Comparing the spectra of both reactions allows to separate the contributions of each isotope.

The reason for the appearance of comparatively large ^{28}Al peaks, in the ^{242}Am spectrum (Figure 2), is due to the encapsulation of the α-active ^{241}Am (3.4 Curies) powder in Al. ^{242}Am gives rays of surprisingly weak intensity although its capture cross section is high (700 b) and our target's mass sufficient (1.1 g). There are two possible explications. Between 2 and 4 MeV the transition density is exceptionnally high so that each line, even close to the 5.475 MeV Q value, is weak. The second possibility is that the nucleus has a different deformation in the ground and in the capture state. The transitions to the first excited states are then hindered.

References

[1] B. Michaud, J. Kern, L. Ribordy et L. A. Schaller
Etude de la réaction ^{176}Lu (n, γ) ^{177}Lu au moyen d'un spectromètre à paires et anticompton.
Helv. Phys. Acta (in press)

[2] We thank Prof. H.J. Leisi (EPF, Zürich) for lending us this diode.

* Work supported by the Fonds National Suisse de la Recherche Scientifique.

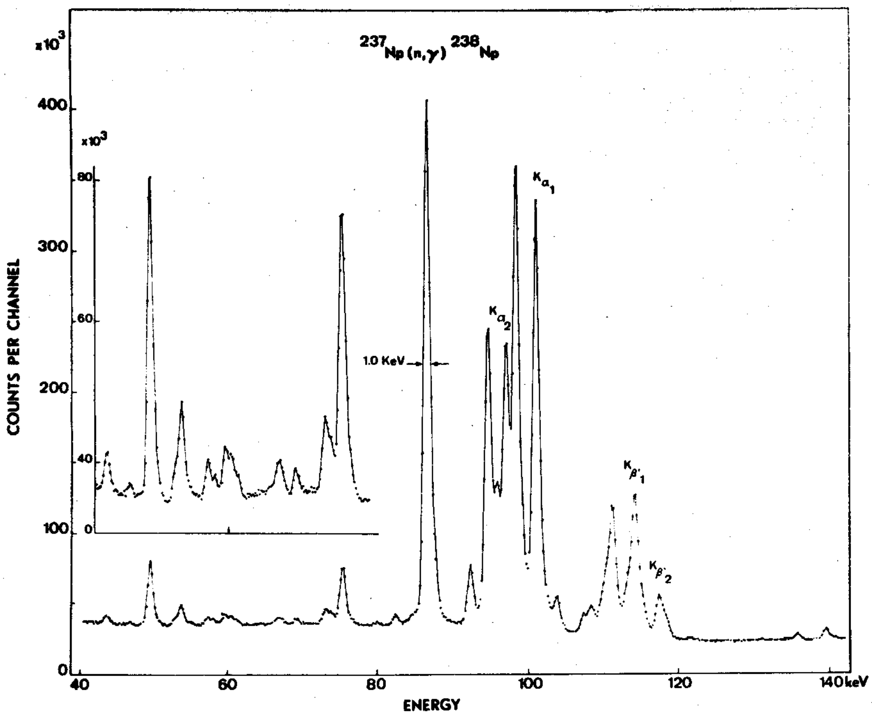

Fig. 1. Low energy portion of the ^{237}Np (n,γ) spectrum measured with the 2.4 cm³ diode.

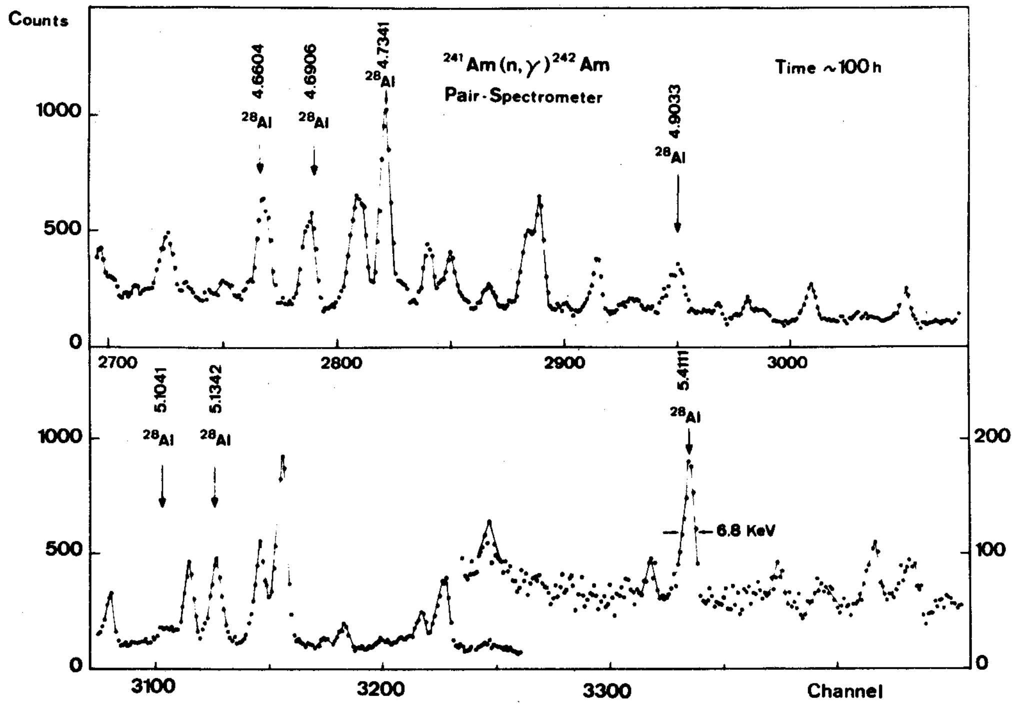

Fig. 2. High energy portion of the ^{241}Am (n,γ) spectrum measured with the pair spectrometer.

2. Level Scheme of ^{165}Ho.*

G. Mauron, J. Kern and O. Huber

The level scheme of ^{165}Ho has been investigated using the β-decays of ^{165}Dy(2.35 h) and ^{165m}Dy (75 s). With the help of a Ge(Li) detector a total of 54 and 12 transitions respectively have been observed. In the ground state decay 22 low-energy conversion lines have been resolved in the Fribourg double-focussing magnetic spectrometer. With these data it has been possible to obtain the multipolarities of several transitions and to construct a scheme of the ^{165}Ho levels having seven rotational bands. The precision in the energy-level determination varies between 3 and 90 eV. Deviation of the simple rotational prediction in the [411↑] and [411↓] bands could be satisfactorily explained by introducing a Coriolis coupling. The wave functions obtained in this way are shown to explain the observed γ-branching ratios and multipolarity mixing ratios very well. The other bands are discussed in terms of the Nilsson model. A very precise energy standard at 995.089±0.008 keV has been established. Intensity standards are proposed.

* Full paper in Nuclear Physics A 181 (1972), 489

IV. Eidgenössisches Institut für Reaktorforschung, Würenlingen

(Dir.: Prof. Heini Gränicher)

The Effective Cross Section for the $^{16}O(d,n)^{17}F$ Reaction for Fission Neutrons Moderated by D_2O

H.S. Pruys and B.D. Ganapol

The effective cross section for the $^{16}O(d,n)^{17}F$ reaction for fission neutrons moderated by D_2O is defined as

$$\Sigma_n = \int_{E_{th}}^{\infty} \phi(E) N_0 \sigma_r(E) dE,$$

where

$\phi(E)$	- recoiling deuteron flux at energy E per unit neutron flux
N_0	- density of ^{16}O atoms in D_2O
$\sigma_r(E)$	- microscopic $^{16}O(d,n)^{17}F$ reaction cross section
E_{th}	- threshold energy for the $^{16}O(d,n)^{17}F$ reaction (1.84 MeV)

This effective cross section has been calculated, using the recoiling deuteron formalism of Hammar and Forsén[1] and the $^{16}O(d,n)^{17}F$ reaction cross section data from Marmier et al.[2]. The result is

$$\Sigma_n = 4.8 \times 10^{-7} \text{ cm}^{-1}.$$

This value compares favorably with the experimentally determined values (see Table b). The value calculated by Hammar and Forsén[1] (see Table a) is an order of magnitude too low, mainly due to the insufficient $^{16}O(d,n)^{17}F$ reaction cross section data available at that time.

Table a): Theoretical values of Σ_n

Σ_n	Contributor
0.6×10^{-7} cm^{-1}	Hammar and Forsén [1]
4.8×10^{-7} cm^{-1}	This work

Table b): Experimental values of Σ_n

Σ_n	Contributor
$(3.5 \pm .7) \times 10^{-7}$ cm^{-1}	Hammar and Forsén [1]
5.6×10^{-7} cm^{-1}	Amiel and Peisach [3]

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[3] S. Amiel and M. Peisach, Anal. Chem. 34, 1305 (1962)

V. Physikalisches Institut der Universität Basel

1. "Differential Elastic and Inelastic Scattering Cross-Sections of ^{28}Si (Q = 0, Q = -1.78 MeV) and ^{32}S (Q = o, Q = -2.24 MeV) for 14-MeV-Neutrons."

E Mangold, Z. Lewandowski* and R. Wagner

Differential cross-sections for the elastic and inelastic scattering of 14-MeV-neutrons from ^{28}Si (Q = 0 and Q = -1.78 MeV) and from ^{32}S (Q = 0 and Q = -2.24 MeV) have been measured using an associated-particle time-of-flight spectrometer.

The efficiency of the neutron-detector was determined by the scattering of 14-MeV-neutrons from the protons of a plastic scintillator.

Performance and stability of the spectrometer have been tested by the elastic and inelastic scattering of 14-MeV-neutrons from Carbon.

Fig. 1 shows a typical neutron time-of-flight spectrum for Carbon with the elastic and inelastic (Q = -4.43 MeV) peaks and in Fig. 2 the differential elastic and inelastic cross-sections are given, together with the results of other authors.

The experimental data have been corrected for multiple scattering, angular resolution and attenuation of the neutron-flux in the scattering samples (C, Si and S-Sample dimensions: cylindrical, diameter: 3.2 cm, length: 6.4 cm).

Fig. 3, 4 and 5 show the experimental results for ^{28}Si and ^{32}S.

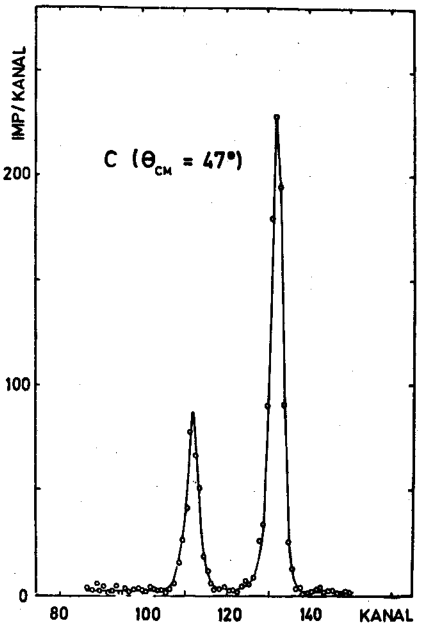
The solid curves are optical-model potential-and DWBA-fits obtained using the computer-code DWUCK of P.D. KUNZ, Univ. of Colorado.

The analysis of the inelastic differential cross-sections gave the following quadrupol-deformation parameters β_2:

$$^{28}\text{Si} \ (Q = -1.78 \text{ MeV}) : \beta_2 = 0.42 \pm 0.02$$

$$^{32}\text{S} \ (Q = -2.24 \text{ MeV}) : \beta_2 = 0.33 \pm 0.02$$

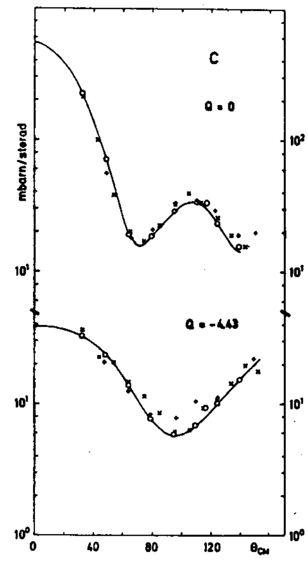
* On leave of absence from the Instytut Fizyki Jadrowej, Krakow, Poland



<u>Fig. 1</u>

Typical neutron time-of-flight spectrum for the elastic and inelastic (Q = -4.43 MeV) scattering of 14-MeV-neutrons from Carbon.

Time resolution: 0.5 ns/Channel
Flight path: 2.4 m



<u>Fig. 2</u>

Differential cross-sections for the elastic and inelastic scattering of 14-MeV-neutrons from Carbon.

The solid curves are only to guide the eye.

Experimental data:
+ R. Bouchez[1)]
x G.A. Grin et al.[2)]
o: our results

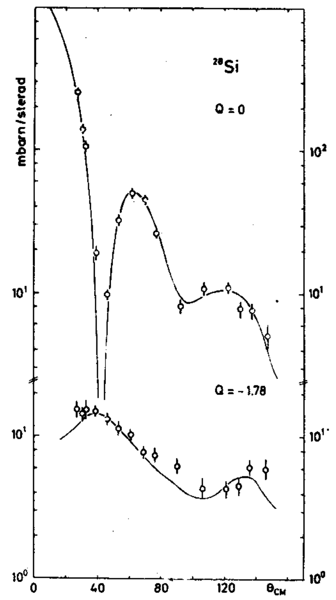


Fig. 3

Differential cross-sections for the elastic and inelastic scattering of 14-MeV-neutrons from ^{28}Si.

The solid curves are optical-model potential-and DWBA-fits, β_2 = 0.42

ɸ: our experimental results.

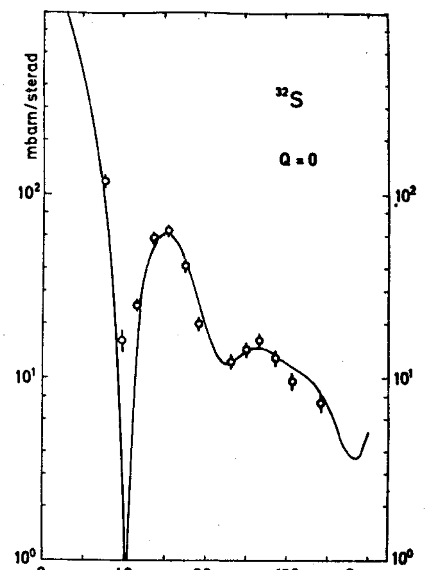


Fig. 4

Differential cross-section for the elastic scattering of 14-MeV-neutrons from ^{32}S.

The solid curve is an optical-model-fit.

ɸ: our experimental result.

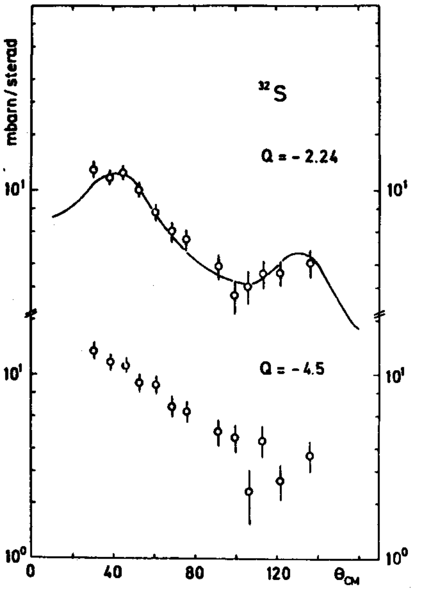


Fig. 5

Differential cross-sections for the inelastic scattering of 14-MeV-neutrons from ^{32}S.

The solid curve is a DWBA-fit, β_2 = 0.33 (Q = -2.24 MeV).

ϕ: our experimental results.

Also shown is the differential cross-section for the inelastic scattering over unresolved states (Q ≅ -4.5 MeV).

1) R. Bouchez, CCDN Nr. E 00047, Grenoble (1966)

2) G.A. Grin et al. Helv.Phys.Acta, 42 990 (1969)

2. "Fragment Blocking Effect in the 14-MeV-Neutron Induced Fission of ^{238}U."

U. Noelpp, R. Abegg, J. Schacher* and R. Wagner

Fission of ^{238}U with 14-MeV-neutrons may occur through different channels: (n,f), (n,nf) and (n,2nf). Near the threshold of the ^{238}U(n,2nf)-reaction, at a neutron energy of about 14 MeV, one expects especially interresting effects, e.g. in the lifetime of the compound nucleus and in the angular anisotropy of the fragments. A method to determine the lifetime of the compound nucleus for this special reaction is given by a fragment blocking experiment.

A UO_2 single crystal** is oriented by means of proton-blocking patterns[1] (fig. 2). Then, the crystal is irradiated (see fig. 1) with 14-MeV-neutrons. Fission fragments emerging from a circular surface of 1.5 mm diameter (given by a lacquer mask) hit the glass detector. The fragment-tracks are made visible by etching [2] and give the fragmentogram of fig. 3. The structure of the fragmentogram agrees with that of the protonogram (fig. 2). Following Gibson and Nielsen [3] a pair of fragmentograms, taken at different angles between neutron- and fragment direction, should enable us to estimate the lifetime(s) of the compound system(s). Such an experiment is now in progress.

* Now at the Physikalisches Institut der Universität Bern.

** We are grateful to Dr. J.L. Whitton, Chalk River Nuclear Laboratories, Canada, for loaning us such crystals.

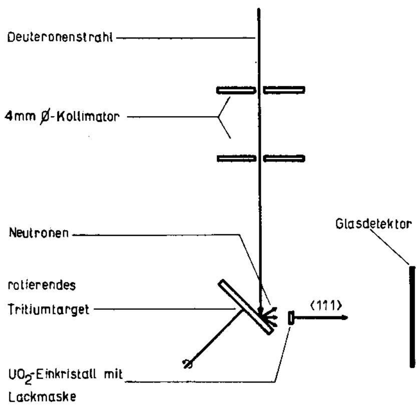


Fig. 1

Experimental arrangement to obtain fragmentograms. The 14-MeV-neutrons were produced by the T(d,n) ^{4}He-reaction
(deuteron energy: 150 keV).

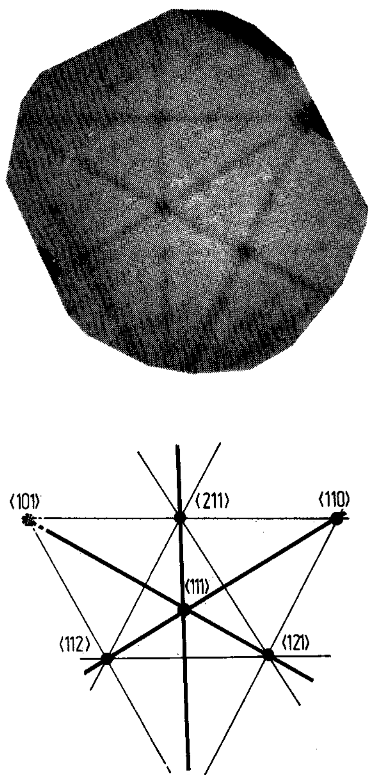
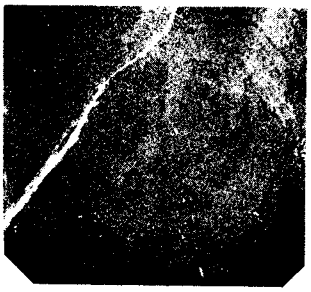


Fig. 2

Protonogram of a UO_2 single crystal and geometrical interpretation of the blocking pattern (⟨111⟩ - axes normal to the plane of the photographic plate)
(proton energy: 140 keV).



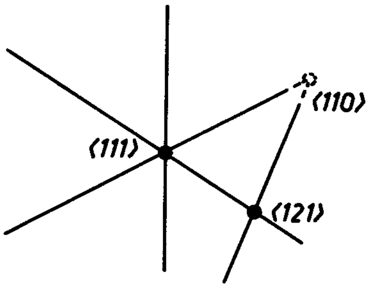


Fig. 3

Fragmentogram of a UO_2 single crystal and geometrical interpretation of the blocking pattern (<111> - axes normal to the plane of the glass detector).

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[1] A.F. Tulinov, Soviet Phys.-Dokl. 10, 463 (1965).

[2] R.L. Fleischer, P.B. Price and R.M. Walker, Ann. Rev. Nucl. Sci. 15, 1 (1965).

[3] W.M. Gibson and K.O. Nielsen, Proc. of the II Symposium of the Physics and Chemistry of Fission, Vienna, 1969.