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Progress Report to the INDC from Austria

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PROGRESS REPORT TO INDC FROM AUSTRIA

March 1983

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Editor

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This report contains abstracts about work performed at

Institut für Radiumforschung und Kernphysik der Österr.
Akademie der Wissenschaften und der Universität Wien,

Atominstitut der Österreichischen Universitäten, Wien,

Institut für Experimentalphysik der Universität Wien.

INSTITUT FÜR RADIUMFORSCHUNG UND KERNPHYSIK DER ÖSTERREICHISCHEN AKADEMIE DER WISSENSCHAFTEN UND DER UNIVERSITÄT WIEN,
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INVESTIGATION OF NEUTRON OPTICAL POTENTIALS IN THE A = 45 - 60 REGION

B. Strohmaier

As a continuation of an evaluation of neutron induced cross sections for structural materials /1/, the applicability of the parameter set determined for this work to the calculation of neutron cross sections of the lighter isotopes of elements in this mass region was studied. Special interest was taken in the (n,2n) cross sections of ^{46}Ti, ^{50}Cr, ^{54}Fe. As the simultaneous reproduction of these as well as of the cross sections of the competing reactions with charged particles in the exit channel could not be achieved by solely adjusting level density and preequilibrium model parameters, the influence of the neutron optical potential was investigated. Starting from potential parameters given by Prince /2/ for several isotopes of Cr, Fe and Ni separately, a global parametrization of this potential was attempted in order to be able to use consistent potential parameters also for the other nuclei which are involved in the statistical model calculations. Several versions of such a global potential were developed and compared with respect to their ability to reproduce experimental strength function data, potential scattering radii, differential elastic (fig. 1) and total (fig. 2) cross sections (also for odd mass nuclei), cross sections of particular compound nucleus reactions and of direct inelastic scattering /3/. Remaining discrepancies necessitate further investigations.

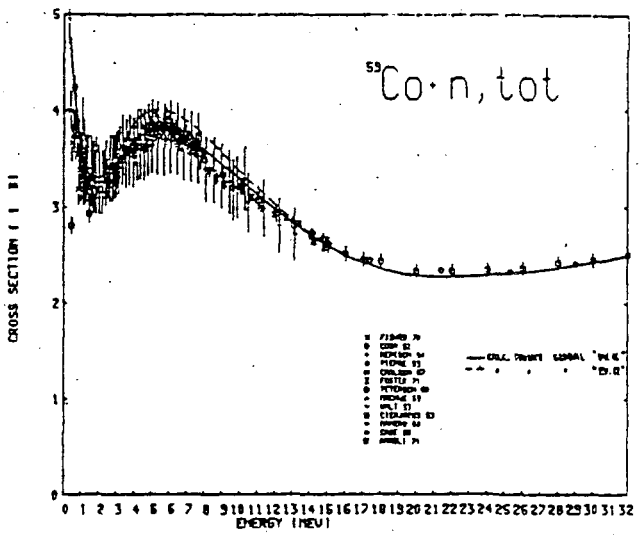


Fig. 2. Total neutron cross section for ^{59}Co obtained with two different parametrizations of the Prince potential compared to experimental data.

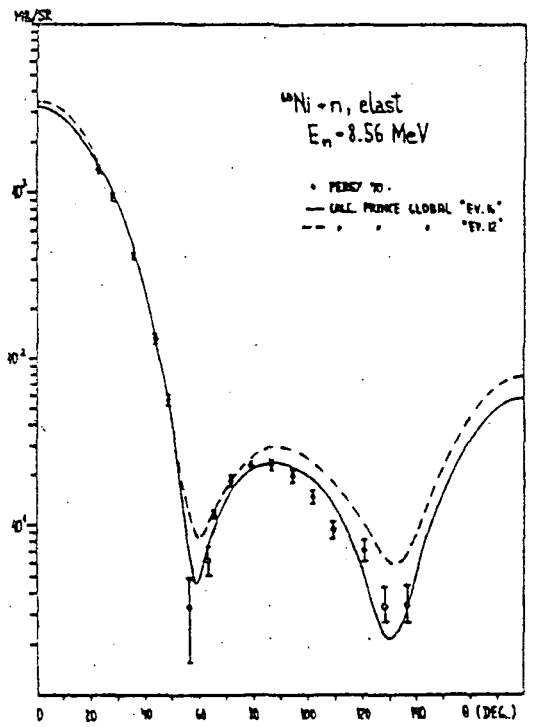


Fig. 1. Differential elastic neutron cross section for ^{60}Ni at 8.56 MeV incident energy obtained with two different parametrizations of the Prince potential compared to experimental data.

/1/ B. Strohmaier, M. Uhl, Progress Rept. 1981;
B. Strohmaier, M. Uhl, W. Reiter, Proc. IAEA Advisory Group Meeting on Nuclear Data for Radiation Damage Assessment and Related Safety Aspects, Vienna, Oct. 12-16, 1981. IAEA-TECDOC-263, 135 (1982);
B. Strohmaier, M. Uhl, Proc. Int. Conf. Nuclear Data for Science and Technology, Antwerp, Sept. 6-10, 1982, in press
/2/ A. Prince, Proc. Int. Conf. Nuclear Data for Science and Technology, Antwerp, Sept. 6-10, 1982, in press
/3/ M. Uhl, "Calculation of direct (n,n') cross sections", this report

PROTON AND ALPHA OPTICAL POTENTIALS FOR STRUCTURAL MATERIALS

M. Uhl

Neutron cross sections for structural materials are important for the design of fast breeders and of fusion reactors. Due to the relatively low charge number of the relevant elements reactions with protons and alphas in the exit channel represent an appreciable fraction of the neutron absorption cross-section. Thus the evaluation of neutron cross sections of structural materials by model calculations require among many other parameters also reliable optical potentials for protons and alphas. The applicability of such potentials may be investigated by comparing experimental (p,n) and (α,n) cross sections to predictions of the statistical model as those cross sections in general represent the major fraction of the compound nucleus formation cross section. This procedure was applied to cross sections available in the literature. Satisfactory results for protons were obtained with the potential proposed by Mani et al. /1/ and for alphas with the following potential which is derived from that of McFadden and Satchler /2/

$$U(r) = -(173.0-0.30\ E_L)f(x) - i(20.5+0.1\ E_L) \cdot f(x) + U_{coul}(r)$$

$$x = (r-1.445\ A^{1/3})/0.51$$

Coulomb radius: $R_c = 1.3\ A^{1/3}$,

where E_L is the energy in the lab-system.

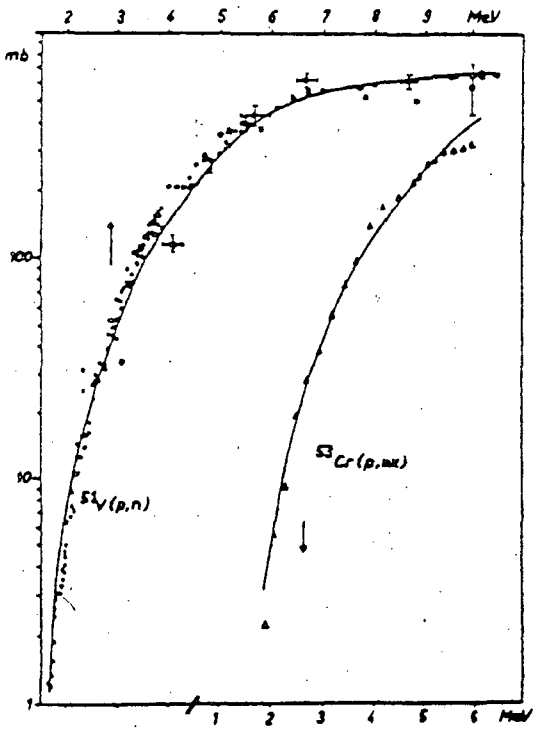


Fig. 1. (p,nx) and (p,nγ) cross sections for ^{51}V and ^{53}Cr. Energy in lab. system. Solid lines: calculation.
□ (p,nγ) S. Tanaka et al., J. Phys. Soc. Jap. 15, 1547 (1960)
•Δ (p,nx) C.H. Johnson et al., Rept. ORNL-2910 (1960) and Rept. ORNL-2501 (1958)
o (p,nγ) J. Wing et al., Phys. Rev. 128, 280 (1962)
x (p,nγ) G.F. Dell et al., Nucl. Phys. 64, 513 (1965)

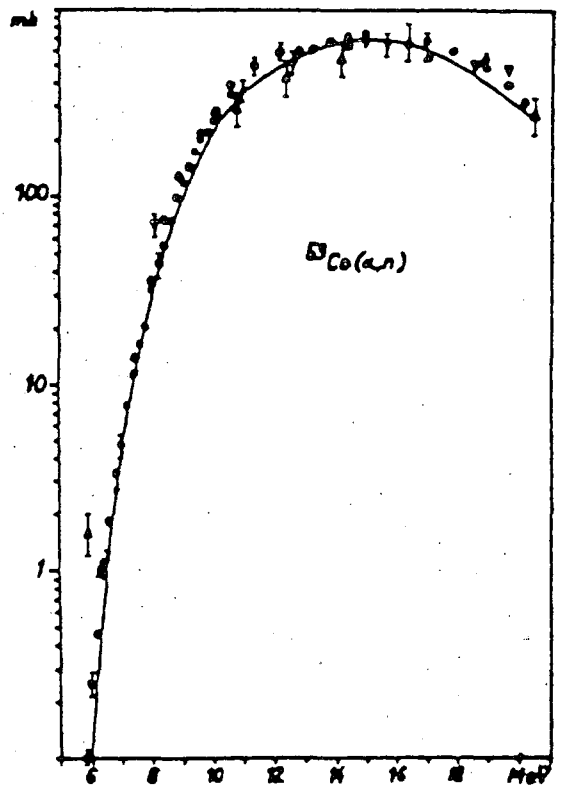


Fig. 2. ^{59}Co(α,n) cross section. Energy in lab. system. Solid line:calculation.
• (α,nx) P.H. Stelson et al., Phys. Rev. 133, B911 (1964)
▽ (α,nγ) J.M. D'Auria et al., Phys. Rev. 168, 1224 (1968)
Δ (α,nγ) O.A. Zhukova et al., Sov. J. Nucl. Phys. 16, 134 (1973)
o (α,nγ) F.M. Mann et al., Nucl. Phys. A255, 287 (1975)

Examples of the reproduction of experimental data are shown in figs. 1 and 2. For neutrons a potential proposed for iron by Arthur et al. /3/ was used for all considered nuclei. All these potentials are further supported by the simultaneous reproduction of many (n,px) and (n,αx) cross sections for structural materials /4/.
As a byproduct of this investigation it turned out that the popular potential for alpha particles proposed by Huizenga and Igo /4/ does not reproduce the available (α,n) cross sections and hence should not be used in the mass region $45 \leq A \leq 60$.

/1/ G.S. Mani et al., Rept. C.E.A.-2379 (1963)
/2/ L.McFadden and G.R. Satchler, Nucl. Phys. 84, 177 (1966)
/3/ E.D. Arthur and P.G. Young, Rept. LA-8626-MS (ENDF-304) (1980)
/4/ B. Strohmaier and M. Uhl, Proc. Conf. Nuclear Data for Science and Technology, Antwerp 1982, to be published
/5/ J.R. Huizenga and G.J. Igo, Rept. ANL-6373 (1961)

SYSTEMATICS OF LEVEL DENSITY PARAMETERS IN THE MASS REGION 45 ≤ A ≤ 65

M. Uhl

Calculations of nuclear reaction cross sections require an accurate knowledge of nuclear level densities. Most cross section codes employ for the level density phenomenological models - as the Gilbert-Cameron model /1/ or the back-shifted Fermi gas model /2/ - with parameters adjusted to reproduce experimental information on low lying levels and resonance spacings. As these simple models are essentially based on equidistant single particle states the resulting level density parameters for neighbouring nuclei exhibit strong fluctuations, in particular near closed shells, and hence are hard to extrapolate to nuclei with no resonance data available.

Recently new semi-empirical level density models were proposed by Kataria et al. /3/, Jensen /4/ and by Ignatyuk et al. /5/. These models account for shell effects in terms of the empirical shell correction to the ground state mass. Compared to the aforementioned phenomenological models they provide an improved description of the energy dependence of the level density and therefore represent also a better basis for the extrapolation of level density parameters to nearby nuclei.

In connection with extensive calculations of neutron induced reaction cross sections for structural materials /6/ the systematics of level density parameters corresponding to different models were studied. In addition to the results from resonance and level data we included also level density parameters which were determined indirectly by simultaneously fitting experimental cross sections either of different reactions populating the same nucleus or of competing reactions. Some of the preliminary results are compiled in fig.1. Fig.1a shows as a function of the mass number A the ratio a/A where a is the "a-parameter" of the back-shifted Fermi gas model. Strong fluctuations around the average are evident as well as the correlation of a/A with the shell correction energy E_{sh} (fig. 1b); this correlation is even more pronounced for the Gilbert-Cameron model. The ratio a/A where a is the asymptotic level density parameter of the model of Kataria and Ramamurthy /3/ is displayed in fig. 1c. Compared to fig. 1a the fluctuations are significantly reduced and appart from a few exceptions one can observe a smooth behaviour of a/A suitable for extra- or interpolations. As the level density formula of ref. /3/ considers pairing only in terms of a conventional back-shift it was supplemented at lower energies by a constant temperature formula with parameters according to the Gilbert-Cameron prescription /1/. Similar results as shown in fig. 1c were also obtained for the model of Ignatyuk et al. /5/.

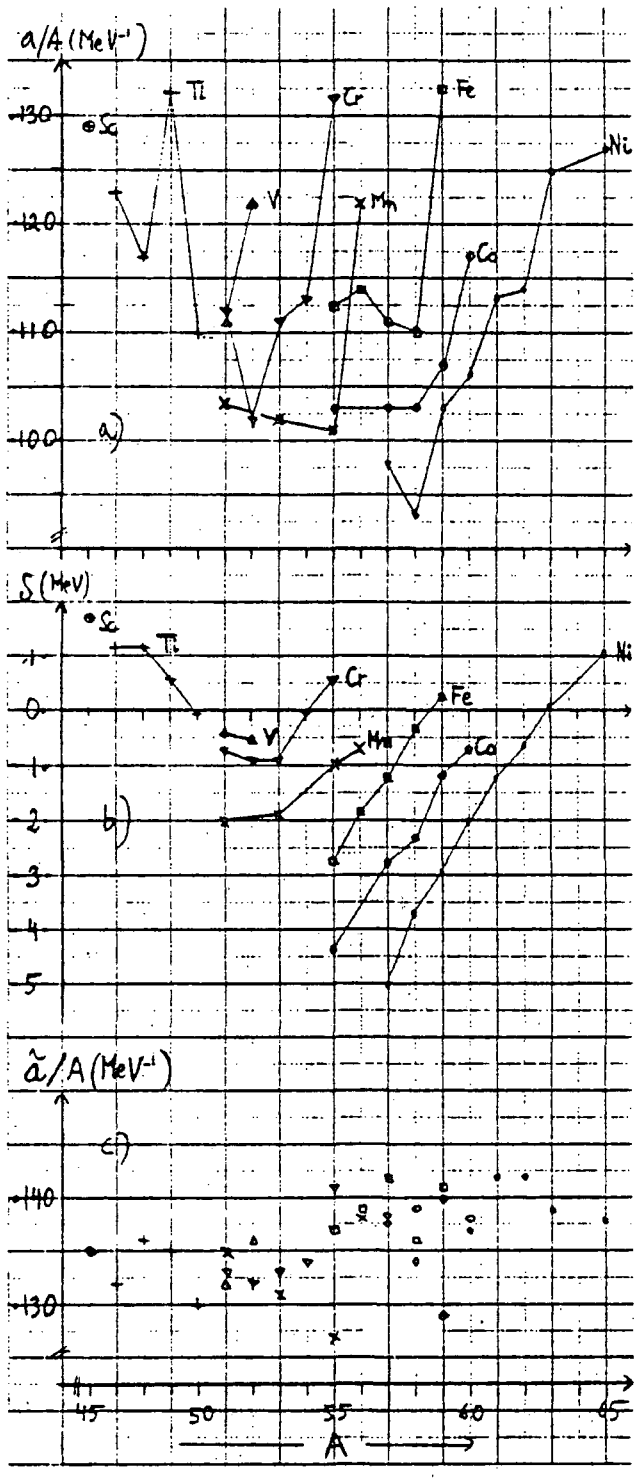


Fig.1

/1/ A. Gilbert and A.G.W. Cameron, Can.J. Phys. 43, 1446 (1965)
/2/ W. Dilg et al., Nucl. Phys. A217, 269 (1973)
/3/ S.K. Kataria et al., Phys. Rev. C18, 549 (1978)
/4/ A.S. Jensen, Physica Scripta 17, 107 (1978)
/5/ A.V. Ignatyuk et al., Sov. J. Nucl. Phys. 29, 450 (1979)
/6/ B. Strohmaier and M. Uhl, Proc. Conf. Nuclear Data for Science and Technology, Antwerp 1982, to be published

CALCULATION OF DIRECT (N,N') CROSS SECTIONS

M. Uhl

The direct reaction components of (n,n') processes for several spherical medium weight even nuclei were calculated between threshold and 30 MeV in the frame of the deformed optical model. In spite of its limitations the DWBA method is known to give reasonable results for spherical nuclei. Hence in general the DWBA code DWUCK /1/ was used; in some selected cases the applicability of the DWBA method was verified by comparison to much more expensive coupled channels calculations. The required deformation lengths were taken from the literature. Besides the scarce neutron data also deformation lengths derived from charged particle inelastic scattering data were considered; for the 2_1^+ transition in closed shell nuclei the theoretical relations /2/ between deformation parameters measured with different probes were accounted for.
The consideration of direct (n,n') processes is important for the analysis of many types of experimental data. As an example fig. 1 shows the calculated neutron production spectrum for iron at 14 MeV incident energy compared to experimental data; the calculated spectrum comprises an equilibrium and a pre-equilibrium component as well as direct (n,n') contributions to 11 low lying levels grouped in 0.5 MeV bins.

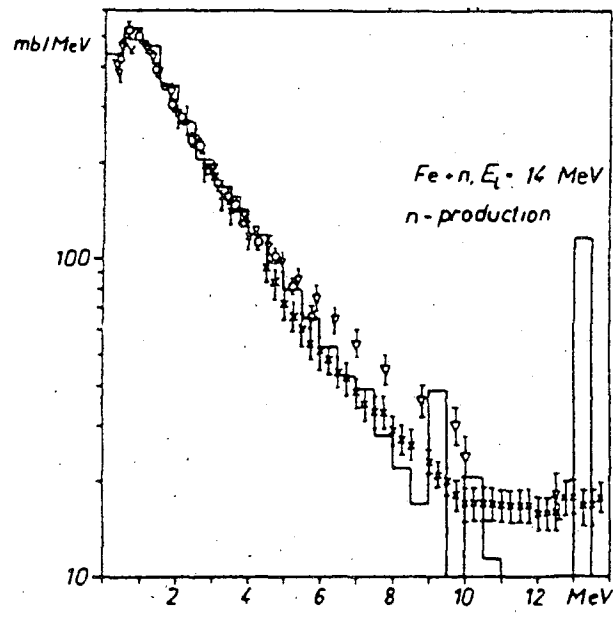


Fig. 1. Neutron production spectrum for Fe at 14 MeV incident neutron energy (lab. system). Outgoing neutron energy C.M. system . Histogram: calculation for ^{56}Fe. Measurements for natural iron.
o H. Vonach et al., Proc. Int. Symp. Neutron Cross Sections from 10-50 MeV, Brookhaven, 1980, p. 343
X G. Seeliger, priv. Comm. to H. Vonach, 1980
∇ O.A. Salnikov et al., Sov. J. Nucl. Phys. 12, 620 (1971)

/1/ P.D. Kunz, unpublished
/2/ A.M. Bernstein et al., Phys. Lett. 103B, 255 (1981)

COMPUTER CODES FOR NUCLEAR CROSS SECTION CALCULATIONS

M. Uhl

The system of programs available at the IRK for cross section calculations has been extended by implementing the coupled channels code ECIS by Raynal /1/ and the DWBA-code for continuum spectra ORION-TRISTAR1 by Tamura et al. /2/. In addition some extensions of our available programs and the following new developments were performed.

i) New level density routines employing the semi-empirical models of Kataria et al. /3/ and Ignatyuk et al. /4/ have been included into our statistical compound-precompound code STAPRE.
ii) A flexible program SLEVPA for level density parameters has been developed. This code can be used to determine parameters for several level density models from a variety of experimental data.
iii) To combine the results of direct reaction cross section calculations with those of statistical compound-precompound codes the program DIRXSEC has been written. For the time being this code establishes the connection between STAPRE and the DWBA-code DWUCK by Kunz /5/; extensions to the coupled channels codes JUPITOR /6/ and ECIS /1/ are planned. Finally DIRXSEC will be included into the general nuclear cross section code MAURINA which is being developed since 1978 and will replace STAPRE in future.

/1/ J. Raynal, "Computing as a language of physics", IAEA-SMR 9/8 (1972)
/2/ T. Tamura et al., to be published
/3/ S.K. Kataria et al., Phys. Rev. C18, 549 (1978)
/4/ A.V. Ignatyuk et al., Sov. J. Nucl. Phys. 29, 450 (1979)
/5/ P.D. Kunz, unpublished
/6/ T. Tamura, Rept. ORNL-4152 (1967)

MEASUREMENT OF $^{65}CU(N,2N)^{64}CU$ CROSS SECTIONS IN THE 14 MEV REGION

Y done

G. Winkler and B. Ryves[1]

In order to clarify existing discrepancies between experimental results reported by different authors for this dosimetry reaction new precise measurements were performed at 13.69, 14.47 and 14.82 MeV relative to $^{27}Al(n,\alpha)^{24}Na$ using the $T(d,n)^{4}He$-reaction as neutron source. The activity measurements were carried out with a 12.7 cm x 12.7 cm NaI(Tl) well-type detector.
For the conversion of the activity data into cross sections, values for the branching ratios of ^{64}Cu obtained from a recent investigation of its decay scheme the authors have been involved in (see section RADIONUCLIDE METROLOGY, this report), could be used. The new preliminary results indicate that the discrepancy problems for this cross section have been solved, especially there is now agreement between the results based on total β-counting and on the measurements of the annihilation gammas from the β^{+}-branch. The new precise cross section values will be incorporated in a new evaluation of the $^{65}Cu(n,2n)$ cross section simultaneously with other cross sections (see /1/) at 14.70 MeV making use of the new ^{64}Cu decay scheme branching ratios.

[1] National Physical Laboratory, Teddington, England

/1/ J.G. Hayes and T.B. Ryves, Annals of Nuclear Energy 8, 469 (1981)

PRECISE MEASUREMENT OF CROSS SECTIONS FOR THE $^{90}ZR(N,2N)^{89}ZR$ REACTION FROM THRESHOLD TO 20 MEV

Y done

A. Pavlik, G. Winkler, H. Vonach, A. Paulsen[1], H. Liskien[1]

The experimental procedure has been briefly outlined already in the last year's report. The data obtained for the excitation function of this dosimetry reaction have been published in detail in J. Phys. G.: Nucl. Phys. 8, 1283 (1982) together with an updated evaluation using the new results (see section EVALUATIONS, this report).

[1] CEC-JRC Central Bureau for Nuclear Measurements, Geel, Belgium

NEUTRON INDUCED REACTIONS ON ^{58}NI

Y done

G. Winkler, A. Pavlik, M. Uhl, A. Paulsen[1], H. Liskien[1]

The excitation functions for the reactions $^{58}Ni(n,2n)^{57}Ni$ and $^{58}Ni(n,np+pn+d)^{57}Co$ were measured precisely in the energy region 12.3 MeV (close to (n,2n)-threshold) to 19.6 MeV in steps of 0.2 to 0.8 MeV using activation techniques. The reaction $T(d,n)^{4}He$ was used to produce the neutrons. Neutron fluences were determined by means of a proton-recoil telescope at zero degree and the differential neutron production cross sections. Activity measurements were performed using a 12.7 cm x 12.7 cm NaI(Tl) well-type detector. The accuracies achieved for the cross sections were typically ∿ 4.5% and ∿ 6% for the (n,2n)- and (n,np+pn+d)-reaction, respectively. In the energy range 13.4 to 14.8 MeV measurements were performed in smaller energy steps (0.02 to 0.15 MeV) relative to well known cross sections for the reference reaction $^{27}Al(n,\alpha)^{24}Na$ achieving an accuracy of typically 2% and 3%, respectively. The $^{58}Ni(n,p)^{58}Co$ cross section was also determined at 17 energy points in the 14 MeV region with an accuracy of typically 2%. The new (n,p)-data are significantly lower than several previous results from the literature and about 15% below the ENDF/B-V evaluation. An explanation for the previously too high cross sections may be interference from lower energy neutrons, especially those stemming from the D(d,n)-reaction. The results for the (n,2n)-excitation function should meet priority 1 requests from WRENDA (World Request List for Nuclear Data) concerning the use of this

→13

reaction for activation-detector dosimetry and spectrum unfolding or as a reference reaction, also in an energy region above 15 MeV, where differences > 30% between the results of different authors have questioned the reliability of existing evaluations.
The results for the above mentioned reactions have been consistently interpreted by model calculationsachieving an excellent overall agreement.
The results for the $^{58}Ni(n,2n)^{57}Ni$ reaction have been presented at the Internat. Conf. on Nuclear Data for Science and Technology, Antwerp, Sept. 6-10, 1982. A more detailed publication is being prepared. A reevaluation of the $^{58}Ni(n,2n)$ cross section has also been performed from threshold to 20 MeV (see section EVALUATIONS, this report). The new experimental results are shown in fig. 1 together with evaluated data and the results from the model calculations (see section MODEL CALCULATIONS, this report).

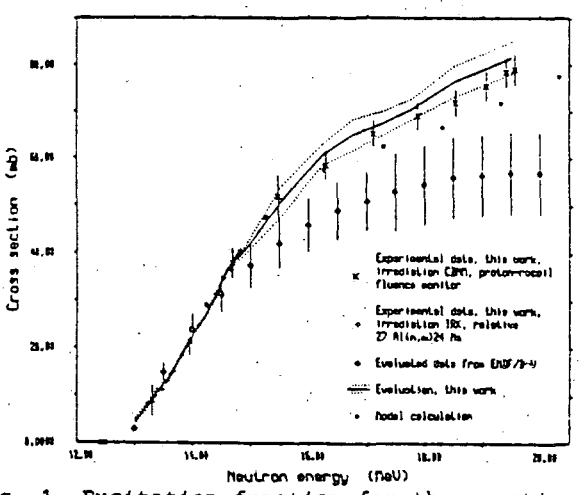


Fig. 1. Excitation function for the reaction $^{58}Ni(n,2n)^{57}Ni$ measured in the course of this work (x Irradiation CBNM, proton recoil fluence monitor, + Irradiation IRK, relative $^{27}Al(n,\alpha)^{24}Na$) and from evaluations (◇ Evaluated data from ENDF/B-V, ═══ Evaluation, this work) and model calculations (□).

[1] CEC-JRC Central Bureau for Nuclear Measurements, Geel, Belgium

MEASUREMENT OF DIFFERENTIAL (N, CHARGED PARTICLE) CROSS SECTIONS BY MEANS OF A MULTITELESCOPE SYSTEM *)

R. Fischer, G. Traxler, H. Vonach, A. Chalupka and P. Maier-Komor [1]

Y Alone WIEGRAF

1) $^{56}Fe(n,\alpha)$ and $^{60}Ni(n,\alpha)$

The Vienna multitelescope system /1/ was used to study the $^{56}Fe(n,\alpha)^{53}Cr$ and $^{60}Ni(n,\alpha)^{57}Fe$ reactions at E_n = 14.1 MeV. α-particle spectra were measured simultaneously at 16 angles with an energy resolution of ∿ 1 MeV. About 23500 resp. 32500 events were collected for the two reactions. The analysis of the data is still in progress. Fig. 1 and fig. 2 show preliminary results both for the angle integrated α-emission cross sections and the angular distributions for different α-energy regions for the $^{56}Fe(n,\alpha)^{53}Cr$ reaction. The results for the $^{60}Ni(n,\alpha)$ reaction are very similar with respect to both the shapes of the energy and angular distributions; preliminary values for the total helium production cross sections are 45 ± 4 mb for the $^{56}Fe(n,\alpha)$ and 77 ± 5 mb for the $^{60}Ni(n,\alpha)$ reactions in excellent agreement with the quadrupole spectrometer results of Grimes /2/ and the helium accumulation measurements of Kneff et al. /3/.

2) $^{93}Nb(n,p)$

After completion of major improvements of both the multiwire counter and its associated electronics /4/ the measurements were extended to the study of (n,p) reactions. In the first experiment the $^{93}Nb(n,p)$ reaction was studied, as there exists a serious discrepancy between existing data and predictions based on a complete cross section evaluation for ^{93}Nb /5/.
During a total run time of about 3 weeks alternating measurements were performed with a thin ^{93}Nb foil (10 mg/cm²), a thick ^{93}Nb target and a 2.9 mg/cm² polyethylene foil for calibration purposes. Determination of the (absolute and relative) neutron flux was achieved by activation of a thick ^{27}Al target.

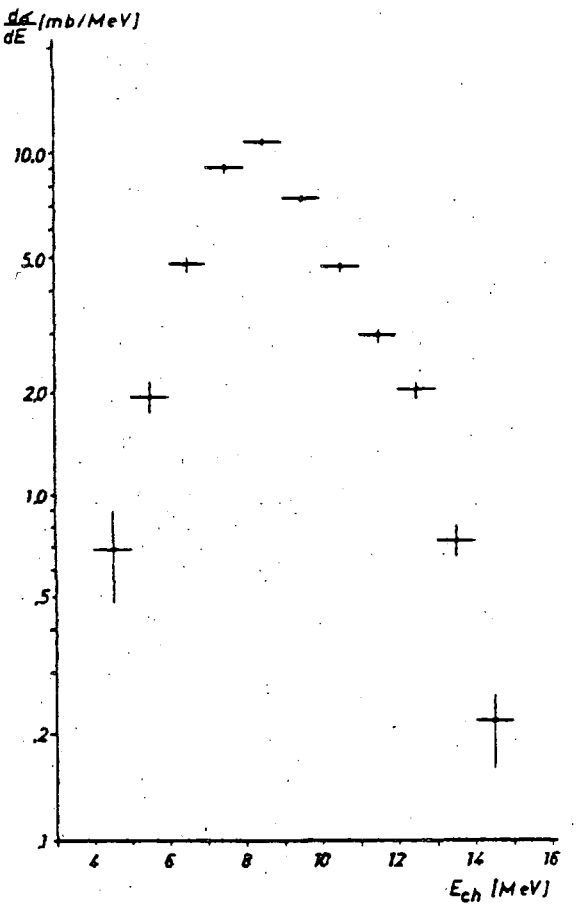


Fig. 1. Angle-integrated α-emission cross section from the $^{56}Fe(n,\alpha)$ reaction at E_n = 14.1 MeV; errors only statistical.

^{93}Nb(n,p) data were collected for a total of 220 hours and stored by the PDP 11 multi-parameter data acquisition system /6/. Data analysis is in progress; the results have not yet been converted to cross sections, however the raw data (see fig. 3) indicate that the results will be of the same quality as the (n,α) data.

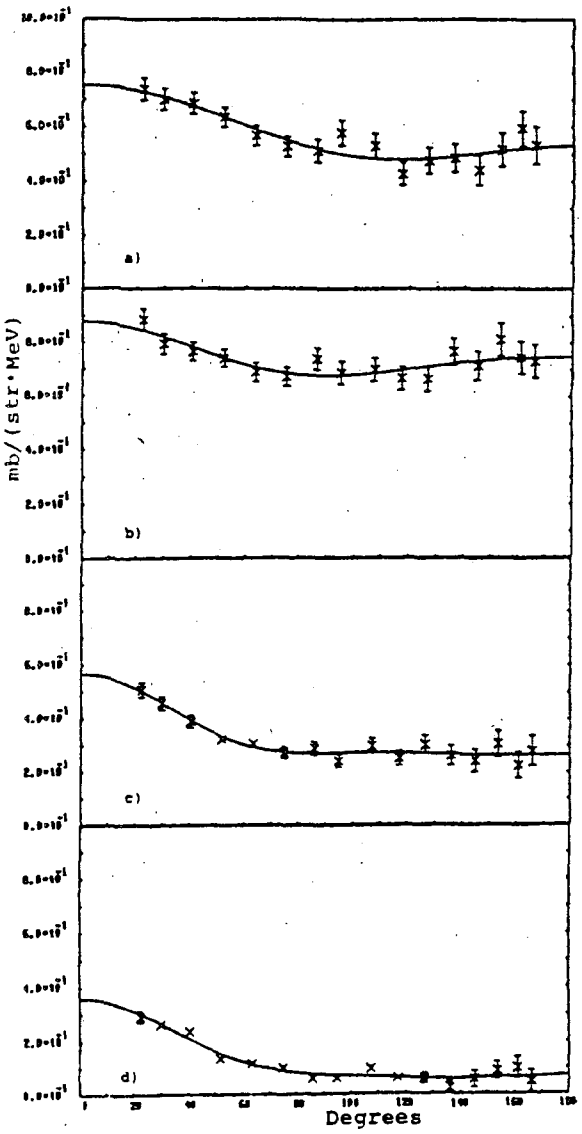


Fig. 2. Angular distribution of α-particles from the ^{56}Fe(n,α) reaction at E_n = = 14.1 MeV for different α-energy regions
(a) $E_{\alpha ch}$ = 6-8 MeV
(b) $E_{\alpha ch}$ = 8-10 MeV
(c) $E_{\alpha ch}$ = 10-12 MeV
(d) $E_{\alpha ch}$ = 12-14 MeV; errors only statistical.

3) ^{93}Nb(n,α)

The results of the (n,α) measurements on ^{93}Nb reported in the last annual report have been published /7/.

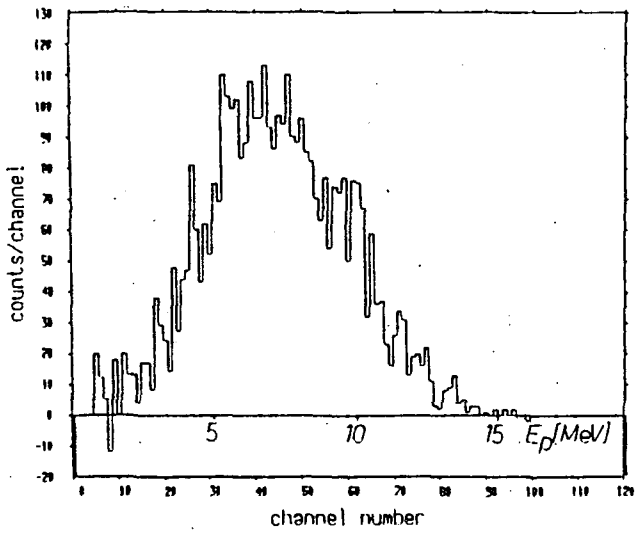


Fig. 3. Background-subtracted proton spectrum from the ^{93}Nb(n,p) reaction summed over all telescope angles, result of 46 hours of running time.

/1/ C. Derndorfer et al., Nucl. Instr. & Meth. 187, 423 (1981)
/2/ S.M. Grimes et al., Phys. Rev. C19, 2127 (1979)
/3/ D.W. Kneff et al., BNL-NCS-3/052, p. 144 (1982)
/4/ G. Traxler et al., An improved multi-telescope for double differential (n,charged particle) cross section measurements, this report
/5/ B. Strohmaier, Ann. Nucl. Energy 9, 397 (1982)
/6/ S. Tagesen, Proc. 2nd Int. Symp. on CAMAC, Brussels, EUR 5485 d-e-f (1976), p. 267
/7/ R. Fischer et al., Ann. Nucl. Energy 9, 409 (1982)

[1] Physikdepartment der TU München, BRD

* supported by Fonds zur Förderung der wissenschaftlichen Forschung in Österreich

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

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

Design work on the new experimental facilities for neutron scattering measurements has been almost completed and construction work is in progress.
The aim of the work is to measure the double-differential inelastic cross sections on elements interesting both for nuclear physics and as possible fusion reactor materials under better experimental conditions as previously possible (especially working at constant incident neutron energy and avoiding air scattering).
Fig. 1 shows a schematic view of the scattering geometry. Source neutrons in the 14 MeV region are produced via the $^{3}T(d,n)^{4}He$ reaction by a pulsed deuteron beam. The tritium target is of hemispherical shape specially manufactured for this measurement to achieve minimal attenuation of source neutrons in 90° direction. The variation of the scattering angle is performed by moving the sample along the collimator axis of the neutron detector. Sample and neutron source will be located in an evacuated tube of 80 cm diameter to eliminate the influence of the air-scattering. Remotely controlled transfer of the scattering sample to a stand-by sample container will permit the necessary background measurements under unchanged conditions. Much attention is paid to the performance of the sample positioning system. Via CAMAC a PDP 11 computer will control the position. Between successive measurements the bias of a NE 213 liquid scintillation detector (dimensions 5" x 2") will be checked under computer control using ^{137}Cs and ^{22}Na sources.
The vacuum tube and pumping system have already been installed and tested, the polyethylene collimator has been machined and the neutron detector was set up and its long term stability tested.

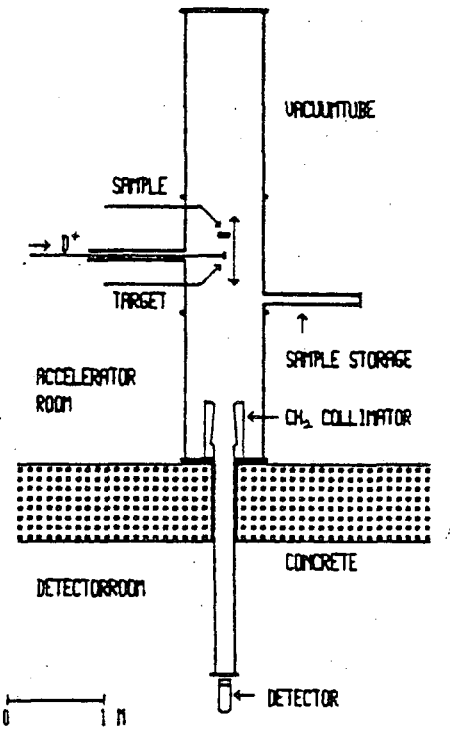


Fig. 1. Scattering geometry, the scattering sample is on the axis of the vacuum tube, the target is about 15 cm off-axis in direction perpendicular to the figure.

In addition detailed investigations were carried out to determine the optimal shape and size of the scattering sample and a software package to process the measured data automatically to obtain final cross sections was developed.
Test measurement in early 1983 will allow to optimize the final scattering geometry (e.g. shape of the shadow-bar, best material for the throat of the neutron detector collimator) and show the performance of the new evacuated neutron scattering system.

* supported by Jubiläumsfonds der Österreichischen Nationalbank

(α,N) AND TOTAL α-REACTION CROSS SECTIONS FOR ^{48}TI AND ^{51}V

R.C. Haight[1] , H. Vonach, G. Winkler

The $^{48}Ti(\alpha,n)^{51}Cr$ and $^{51}V(\alpha,n)^{54}Mn$ cross sections were measured in the energy range 6 - 13 MeV to an accuracy of about 3%. The activation method was used for the determination of the reaction yields and the product of incident flux and target thickness was determined from measurements of Rutherford scattering. Using known information on the competing charged particle emission and extensive statistical model calculations the total reaction cross-sections for α-particles on ^{48}Ti and ^{51}V could be derived with similar accuracy. Especially at lower energies our results are considerably smaller than the predictions of the widely-used Huizenga-Igo /1/ optical potential and support the potential of Satchler and McFadden /2/ (see fig. 1).
Thus our results strongly support the suggestion of Uhl and Strohmaier that at least in the mass range around A = 50 the potentials of ref. 2 or 3 should be used to predict α-particle reaction cross-sections and transmission coefficients.
Correspondingly nuclear temperature and level density parameters derived from statistical model analysis of evaporation spectra using the Huizenga-Igo potential should be revised. Changes in nuclear temperatures and level density parameters of up to 10% resp. 20% can be expected if the same experimental data are analysed with either the potential of ref. 1 or one of the two other potentials.

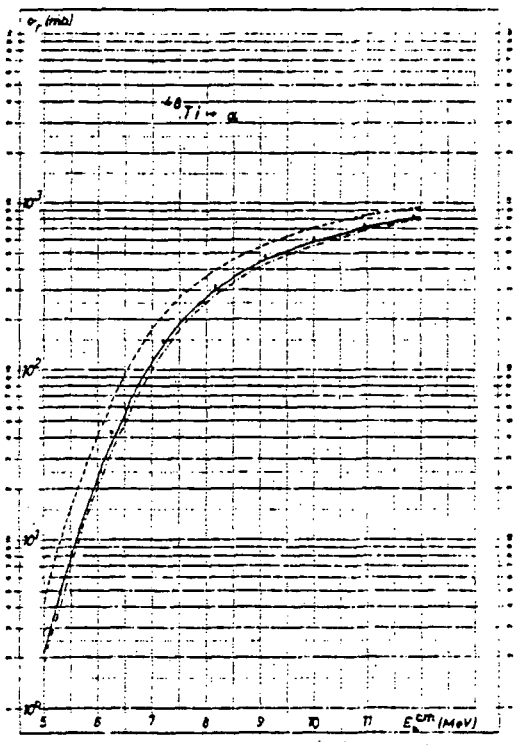


Fig. 1. Comparison of the measured total reaction cross sections of ^{48}Ti with optical model predictions
. present experimental results
— calculated from potential of ref. /3/
--- calculated from potential of ref. /1/
-.- calculated from potential of ref. /2/

/1/ J.R. Huizenga and G.R. Igo, ANL-6373 (1961)
/2/ L. McFadden and G.R. Satchler, Nucl. Phys. 84, 177 (1966)
/3/ E. Arthur and Ph. Young, LA 8626-MS (ENDF-304) (1980)
/4/ B. Strohmaier, M. Uhl and W. Reiter, IAEA Advisory Group Meeting on Nuclear Data for Radiation Damage Assessment and Related Safety Aspects, Vienna 12-16 Oct 1981

[1] Lawrence Livermore National Laboratory, Livermore, California, USA

ALPHA PARTICLE STOPPING POWER FOR TITANIUM AND VANADIUM

R.C. Haight [1] and H. Vonach

A method for accurate measurement of the specific energy loss of α-particles was developped and applied to titanium in the α-energy range 5.25 - 13 MeV and for vanadium in the range 5.25 - 12 MeV with total uncertainties of about 3%. The results are in excellent agreement with the stopping power predictions of Ziegler /1/ and earlier precision measurements of the stopping power of protons and deuterons in Ti and V /2/.

/1/ J.F. Ziegler, The stopping and ranges of ions in matter, Vol. 1-5, Pergamon Press (1977)
/2/ H.H. Andersen et al., Phys. Rev. 175, 389 (1968)

[1] Lawrence Livermore National Laboratory, Livermore, California, USA

THE NEUTRON ENERGY SPECTRUM FROM THE SPONTANEOUS FISSION OF ^{252}CF IN THE ENERGY RANGE 2 MEV ≤ E_N ≤ 14 MEV

Y done

R. Böttger[1] , H. Klein[1] , A. Chalupka, B. Strohmaier

Data analysis of the measurements of the fission neutron spectrum of ^{252}Cf which were performed during 1981 using the PTB multi-angle neutron time-of-flight spectrometer and the IRK fast fission chamber was completed this year. Particular attention was paid to the analysis of errors introduced by the measuring systems and to corrections necessitated by the time-of-flight method.
The efficiency of the neutron detectors was taken from the calibration measurements /1/ and neutron TOF spectra were converted to energy spectra by means of the position of the γ-peak, time channel width and length of flight path. A ^{252}Cf neutron energy distribution $I(E_n)/\varepsilon_d(E_n)$ covering the energy range between 2 MeV and 14 MeV is analyzed according to fig. 1 assuming a pure Maxwellian distribution $N(E) = c\sqrt{E}\exp(-E/E_o)$.

The best fit between 3 MeV and 13 MeV yields a temperature parameter $E_o = 1.355 \pm 0.015$ MeV. For comparison, a Maxwellian distribution with $E_o = 1.425$ MeV, normalized between 3 MeV and 4 MeV, is shown and obviously does not fit the data.
In fig. 2 the deviations between the experimentally determined distribution and the following three reference spectra
1.) NBS segment fit
2.) Maxw. distribution: $E_o = 1.355$ MeV
3.) Maxw. distribution: $E_o = 1.425$ MeV
are displayed in the energy range 3 MeV ≤ E_n ≤ 13 MeV.

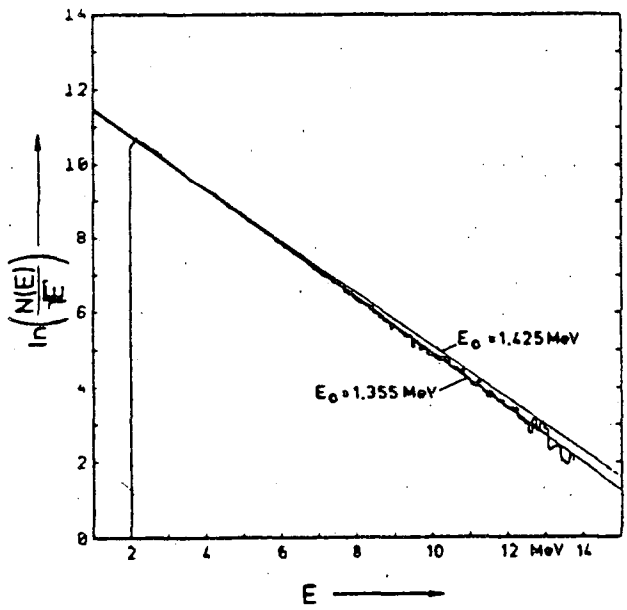


Fig. 1. The neutron energy spectrum of ^{252}Cf (histogram) in comparison with two Maxwellian distributions.

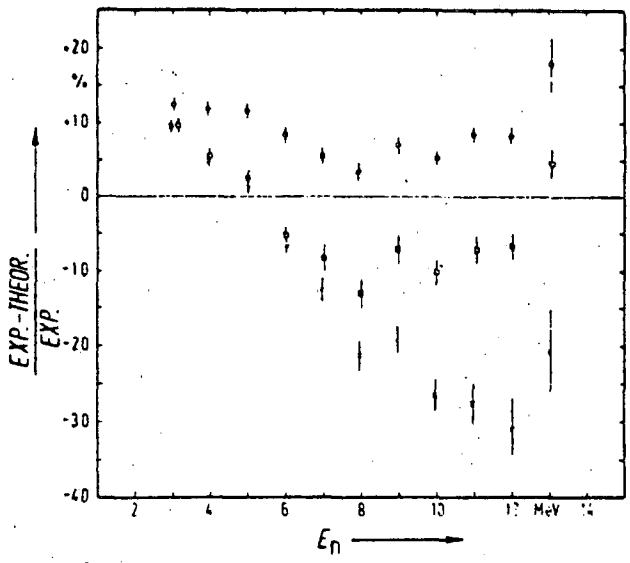


Fig. 2. The relative deviation of the normalized neutron yield (EXP) to the NBS segment fit (□) and Maxwellian-distributions with temperature parameters $E_o = 1.355$ MeV (o) or 1.425 MeV (x) (THEOR). The error bars indicate the full uncertainties due to statistics and normalization.

The shape of the neutron energy distribution is described by the NBS segment fit as well as the pure Maxwellian with $E_o = 1.355$ MeV between 6 MeV and 13 MeV, but the scaling factors differ by about 15%.
There is no justification for describing our data by a pure Maxwellian with $E_o = 1.425$ MeV due to deviations from + 10% to - 33% in the energy range investigated. With a scaling factor of 1.08 applied to the reference spectrum with $E_o = 1.355$ MeV which is extracted from the shape analysis, we find the best agreement in shape as well as in the absolute scale with deviations not exceeding 5% between 3 MeV and 12 MeV.
A summary of the work was presented at the Antwerp Conference /2/; a detailed publication is forthcoming.

/1/ R. Böttger, H.J. Brede, M. Cosack, G. Dietze, R. Jahr, H. Klein, H. Schölermann, B.R.L. Siebert, Proc. Int. Conf. on Nuclear Data for Science and Technology, 6-10 Sept. 1982, Antwerp, Belgium
/2/ R. Böttger, H. Klein, A. Chalupka, B. Strohmaier, ibidem

[1] Physikalisch-Technische Bundesanstalt, Braunschweig, BRD

AN IMPROVED MULTITELESCOPE FOR DOUBLE DIFFERENTIAL (N, CHARGED PARTICLE) CROSS SECTION MEASUREMENTS *)

G. Traxler, R. Fischer, H. Vonach

In order to extend the possibilities of the institute's multitelescope system /1/ to the measurement of proton spectra from (n,xp) reactions the cylindrical multiwire proportional counter and its electronic were completely redesigned and put into operation in 1982 /2/. Fig. 1 shows the new design of the multitelescope system. The main modification is the introduction of a second (inner) ring of 16 sense wires between the central CsI(Tl) scintillation counter and the 32 counting wires of the (outer) detector ring. Each wire is devised with a new developed low noise charge sensitive preamplifier (max. equivalent input noise is 8 fC). Fast data reduction is established by demanding triple coincidence of outer ring, inner ring and central counter and position matching of the two proportional counters. This is done by a new fast logic unit which also supplies the encoded position to the data collecting computer. For each event the analog signals from each 8 outer proportional counters are summed giving the dE/dx and the photomultiplier (PM) output the E_{rest} information, resp., needed for particle discrimination. Additional information is supplied by an improved PSD-system applied to the PMs D11-signal. Also the time difference, Δt, between the wire and the PM-signal is recorded. Finally each event is characterized by dE/dx, E_{rest}, Δt, PSD and position and stored in list mode by the PDP 11-computer to save all data for off-line replay. A block diagram of the whole electronic is given in fig. 2. The first experiment with the new multitelescope /2/ showed its excellent performance. The most important improvements are:

1) By means of the second proportional counter ring and the improvement of the time resolution (from .5 to .30 μsec base width) random coincidences could be suppressed by about a factor of 5 better than with the previous system.
2) The low noise and large dynamic range of the new preamplifiers allow simultaneous measurement of protons and α-particles from (n,charged particle) at E_n = 14 MeV at the low counter pressure of 100 mb required for the detection of low energy α-particles. Fig. 3a and b show the dE/dx spectra of the outer MWPC ring for both high and low-energy α-particles and protons recorded simultaneously in the ^{93}Nb(n,charged particle) experiment.
3) The dead-time of the fast logic was reduced from 4 to 2 μsec which is especially important at the high count-rates of the MWPC at the low thresholds required for recording high energy protons from (n,p) reactions.

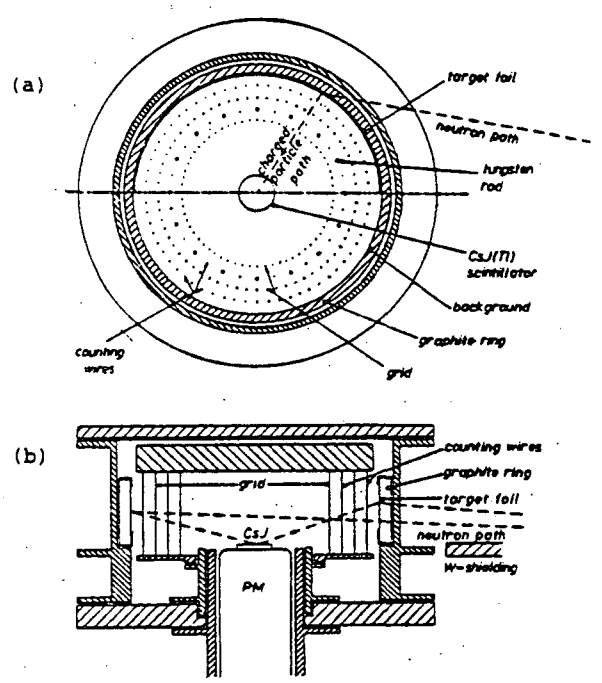


Fig. 1. The improved Vienna multitelescope system
(a) top view,
(b) side view.

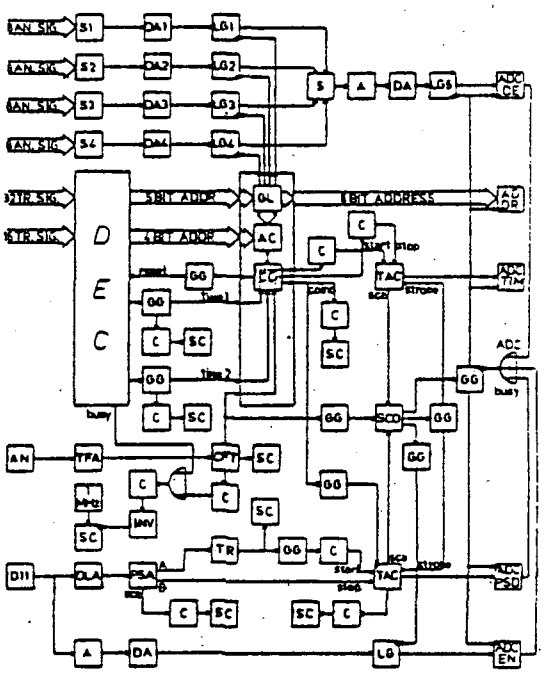
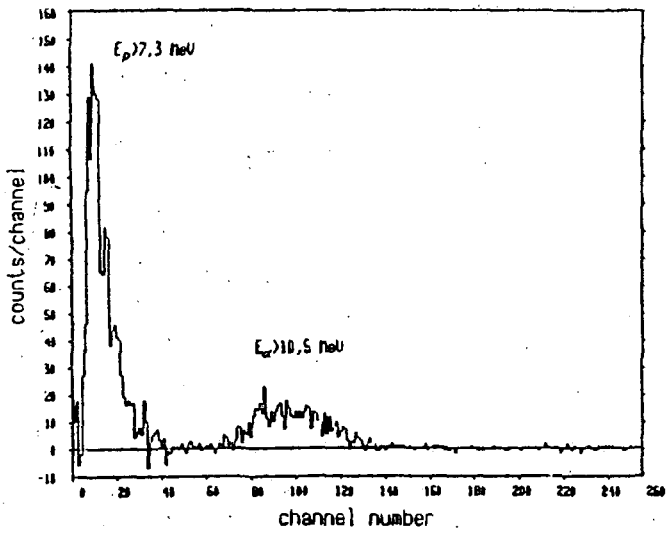


Fig. 2. Block diagram of the electronics of the new multitelescope system: A-amplifier, AC-address comparator, AN-anode of photomultiplier, C-TTL-NIM converter, CC-coincidence-anticoincidence, CFT-constant fraction trigger, D11-dynode 11, DA-delay amplifier, DEC-decoding unit, DLA-delay line amplifier, GG-gate generator, GL-gate logic, INV-inverter, LG-linear gate, PSA-pulse shape analyzer, S-summing amplifier, SC-scaler, SCO-slow coincidence, TAC-time-amplitude converter, TFA-timing filter amplifier, TR-trigger



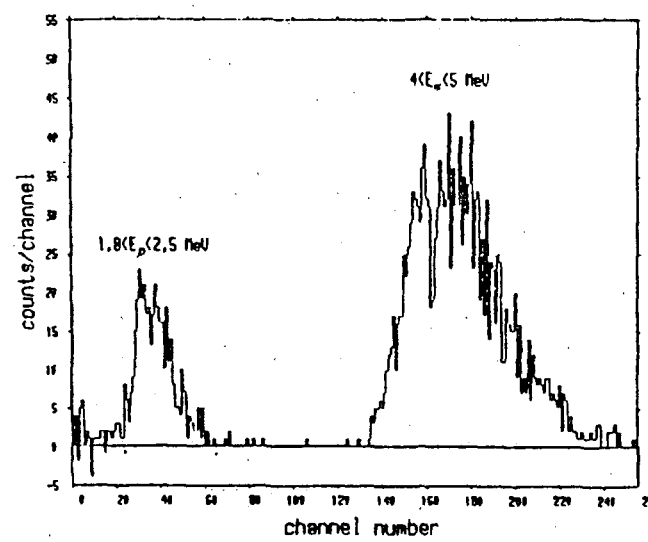


Fig. 3. Pulse-height spectra of the outer proportional counter ring for selected particle-energy bins
a) energy bin corresponding 7.3-15 MeV protons, resp. 10.5-19 MeV α-particles
b) energy bin corresponding to 1.8-2.5 MeV protons, resp. 4-5 MeV α-particles;
data from ^{93}Nb(n,charged particle) measurements, background from accidental coincidences subtracted.

/1/ C. Derndorfer et al., Nucl. Instr. & Meth. 187, 423 (1981)
/2/ G. Traxler et al., Measurement of the energy and angle differential cross section of the ^{93}Nb(n,p) reaction for E_n = 14 MeV, this report

* supported by Fonds zur Förderung der wissenschaftlichen Forschung in Österreich

EVALUATION OF THE EXCITATION FUNCTIONS FOR THE REACTIONS $^{90}ZR(N,2N)^{89}ZR$ AND $^{58}NI(N,2N)^{57}NI$ FOR THE ENERGY RANGE FROM THRESHOLD TO 20 MEV

A. Pavlik, G. Winkler, H. Vonach

Based on new precise experimental data for these dosimetry reactions (see section NEUTRON INDUCED REACTIONS, this report) the evaluation by Tagesen at al. /1/ for $^{90}Zr(n,2n)^{89}Zr$ has been updated; the input data were now restricted to purely experimental values (presented at Int. Conf. on Nuclear Data for Science and Technology, Antwerp, Sept. 6-10,1982, and published in detail in J. Phys. G.: Nucl. Phys. 8, 1283 (1982)). The $^{58}Ni(n,2n)^{57}Ni$ cross section was reevaluated in the same manner including new results (see section NEUTRON INDUCED REACTIONS, this report) and critically reviewing the available data from the literature, normalizing if necessary, to account for adjustments in standard cross sections and decay schemes (briefly presented at Int. Conf. on Nuclear Data for Science and Technology, Antwerp, Sept. 6-10, 1982, to be published in detail).

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

CALCULATION OF THE EFFECTS ON THE MEASURED NEUTRON SPECTRUM OF CONSTRUCTION MATERIAL AND LOSS OF FISSION TRACKS OF THE I R K FAST FISSION CHAMBER

A. Chalupka, B. Strohmaier

In order to study the influence of the fission chamber /1/ on the ^{252}Cf neutron energy spectrum computer codes were developed to calculate scattering and neutron production in the construction material and the loss of fission signals resulting in deformation of the neutron energy distribution. The program COGOLD calculates the relative n-spectrum $I(E_n)/I_{Cf}(E_n)$ due to the construction material which has to be considered as a correction to the measured neutron spectrum /1/. Also, a comparison of such calculations for Au and Fe are to verify the preference for gold to stainless steel as chamber material. For the Au calculations, input data for neutron production spectra were calculated with the code STAPRE /2/, differential elastic and total cross sections were taken from Ref. 3 and the ^{252}Cf n-spectrum from Ref. 4. Compilation of the input data for Fe is in progress.
Although the total mass of the chamber is about 1 g only, it turned out that considerable enhancement of the n-spectrum below 1 MeV occurs. Fig. 1 shows the contributions for the golden fission chamber.
Another distortion due to losses of small pulses from the fission detector is dealt with by the code KAMM. The basic assumption is that fission products emitted nearly parallel to the surface of the backing may lose part or all of their energy what results in a reduction of pulse height in the fission chamber spectrum. The aim was to simultaneously reproduce pulse height spectra and chamber efficiencies measured at several angles with respect to the n-emission and various efficiencies of the neutron detector by only introducing one parameter which may be interpreted as "roughness", R , of the surface onto which the ^{252}Cf source is de-

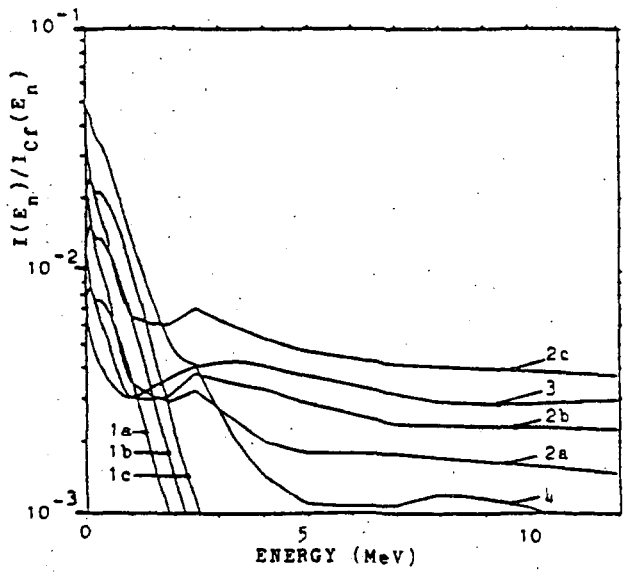


Fig. 1. Corrections in terms of relative neutron intensities $I(E_n)/I_{Cf}(E_n)$ for the components
1a = isotropic neutron production from chamber can
1b = isotropic neutron production from backing
1c = sum of 1a + 1b
2a = anisotropic scattering from chamber can
2b = anisotropic scattering from backing
2c = sum of 2a + 2b
3 = absorption
4 = total correction calculated as 1c + 2c - 3

posited. The code is based on experimental data (e.g. the distribution of the fragments with respect to mass M_{fr} and energy E_{fr} /5/, the average number of neutrons per fragment $\bar{\nu}(M_{fr})$ and the average neutron energy $\bar{n}(M_{fr})$ /6/, $dE_{fr}/dx(M_{fr},E_{fr})$ values in Au and Ch /7/, scission neutron data /5/) assuming isotropic Maxwellian neutron emission spectra in the fragment's frame. Data in fig. 2 and fig. 3 were obtained with $\bar{R}$ = 0.7 µm which gives a total efficiency of ε = 95.4 ± 0.3%.

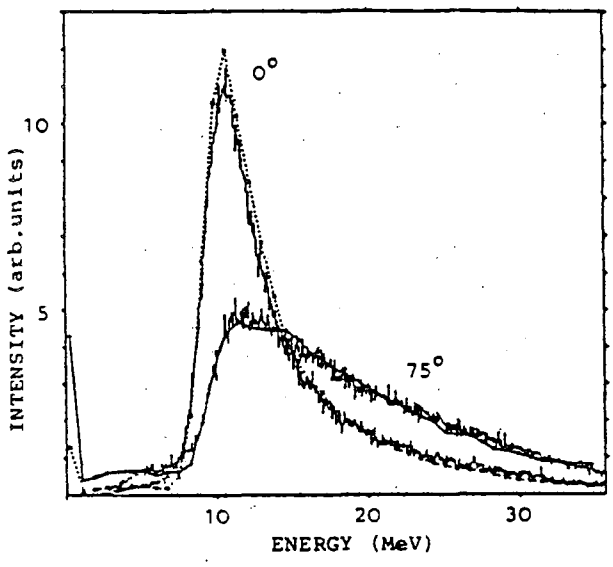


Fig. 2. Energy loss spectra ΔE of fission fragments in the parallel plate ionization chamber (histogram) compared with calculated spectra (+,x)

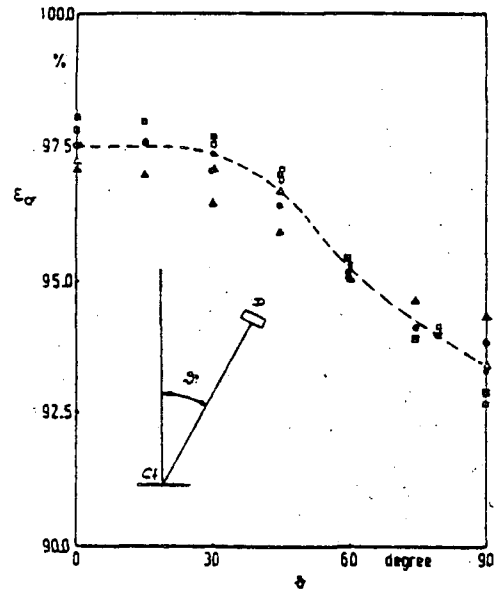


Fig. 3. Efficiencies ε_{Cf} for fragment detection in dependence on the position of the coincident neutron detector for a threshold of E_o = 250 keV (Δ,▲), 500 keV (o,•), 1 MeV (□,■). Full symbols indicate calculations.

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

/2/ B. Strohmaier, M. Uhl, Proc. Winter Course Nuclear Theory for Application, Trieste, 1978, IAEA-SMR-43, 313 (1980)

/3/ BNL 400 Third Edition, Vol.II
BNL 325 Third Edition, Vol.II

/4/ J.A. Grundl, C.M. Eisenhauer, NBS-425, 250 (1975)

/5/ M. Forte, Phys. Rev. B14, 956 (1976)

/6/ V.M. Piksaikin, P.P. D'yachenko, L.S. Kutsaeva, Sov. J. Nucl. Phys. 25, 385 (1977)

/7/ L.C. Northcliffe, R.F. Schilling, Nucl. Data Tables A7, 233 (1970)

SURVEY OF STANDARDIZATION POSSIBILITIES WITH A NaI(TL) WELL-TYPE DETECTOR

A. Pavlik, G. Winkler

For a series of nuclides of practical interest total efficiencies and their uncertainties are calculated for the $4\pi\gamma$-detector system (12.7 cm x 12.7 cm NaI(Tl) well-type detector) installed at our institute. Special attention is paid to the possible calibration accuracy for some multigamma-sources (^{110m}Ag, ^{133}Ba, ^{56}Co, ^{134}Cs, ^{152}Eu, ^{182}Ta,...) which in turn may be used to conveniently determine single-gamma efficiencies for other detectors. Efficiencies are calculated as well for low-mass point-like sources as for 1 cm^3 aqueous solutions or the nuclides being homogeneously distributed in a 1 g solid (mostly metal) sample with 20 mm diameter consisting of material with the same or adjacent atomic number. The main features of the code used for the relevant calculations have been already mentioned in the last year's report. More detailed information on the FORTRAN program used is in print (A. Pavlik, "NAJ5EF, Ein Computerprogramm zur Berechnung der Nachweiswahrscheinlichkeit von $4\pi\gamma$-Detektoren unter Verwendung des verallgemeinerten Fehlerfortpflanzungsgesetzes", in Sitzungsberichte der Österr. Akademie der Wissenschaften, in German)

THE DECAY SCHEME OF ^{64}CU

P. Christmas[1], B. Ryves[1], D. Smith[1], G. Winkler

To clarify longstanding discrepancies concerning the β^+- and β^--branching ratios (a and b, respectively) in the decay scheme of ^{64}Cu new measurements were carried out involving different experimental techniques:

(1) measurements with a β-ray magnetic spectrometer giving b/a and precise data for the end point energies
(2) conventional $4\pi\beta$-γ-coincidence counting by means of a $4\pi\beta$-proportional flow-through counter (methane) and two NaI(Tl)-detectors, giving b/a
(3) liquid scintillation counting to yield the total activity N_0 employing a multidimensional extrapolation method combined with β-efficiency tracing, giving a + b
(4) absolute counting of the gamma- and annihilation radiation with a calibrated Ge(Li) detector, giving aN_0, a and the branching to the 1.35 MeV level in ^{64}Ni
(5) counting with a calibrated well-type NaI(Tl) crystal the total γ-rays from a copper foil of known activity, which had previously been irradiated in a standard thermal neutron field, giving a.

The (partly correlated) results from (1)-(5) are combined by a least-squares procedure to give the beta-minus, beta-plus and electron-capture branch and 1.35 MeV gamma-ray intensity.

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1. SUMMARY OF NEUTRON SCATTERING LENGTHS[1)]

L.Koester[x)], H.Rauch, M.Herkens[xx)], K.Schröder[xx)]

All available neutron-nuclei scattering lengths are collected together with their error bars in an uniform way.
Bound scattering lengths are given for the elements, the isotopes and the various spin states. They are discussed in the sense of their use as basic parameters for many investigations in the field of nuclear and solid state physics. Recommended values, printed in a KFA-report[1)], and a map of these data serve for an uncomplicated use of these quantities. The data bank is available on magnetic tape too.

1) L.Koester, H.Rauch, M.Herkens, K.Schröder, Jül-1755, Dec.1981, ISSN 0366-0885, KFA-Jülich

2. NEUTRON INTERFEROMETRIC MEASUREMENT OF THE NEUTRON-LITHIUM SCATTERING LENGTH[1)]

E.Granzer, H.Rauch, U.Kischko[xxx)]

Liquid solutions of LiCl in H_2O and D_2O have been used as phase shifting material within the neutron interferometer. From the observed intensity modulation a coherent neutron-Lithium scattering length of -1.98 ± 0.02 fm has been extracted.

1) Internal Report, Atominstitut 1982

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x) Reaktorstation Garching, D-8046 Garching
xx) Zentralbibliothek, KFA-Jülich, D-5170 Jülich
xxx) Institut Laue-Langevin, F-38042 Grenoble

3. CAPSULE TRANSPORT EVALUATION OF A RAPID He-TRANSFER SYSTEM WITH A ^{6}LiD-CONVERTER[1)]

A.Salahi, F.Grass, F.Bensch, G.Zugarek, J.O.Schmidt[x)]

Within a program on activation analysis using short lived radionuclides a rapid He-driven irradiation facility with a ^{6}LiD neutron converter[2)] has been constructed for insertions in the light water reactor TRIGA Mark II in Vienna. Sample management and irradiation processing are controlled by a microprocessor, photosensors, magnetic valves, optical encoders, and revolving stations. This way the range of analytical applications is increased for elements like O, Si, P, K, As, Y, Ba, and Pb.

1) Contribution to the "CONFERENCE INTERNATIONALE SUR LA TECHNOLOGIE DES IRRADIATIONS", Grenoble, France, Sep.1982
2) A.Salahi, F.Grass, J.Radioanal.Chem. 61(1981)63

4. DETERMINATION OF THE THERMAL NEUTRON FLUX DENSITY BY Au AND V FOILS AND CALIBRATION OF A VANADIUM DETECTOR

H.Böck, El-Isa, J.Hammer

By activation analysis with Au and V foils the thermal neutron flux density has been measured for the experimental facilities of the TRIGA Mark II reactor. As this method is unconvenient for a quick application we have carried out an absolute calibration of a Vanadium self-powered neutron detector, V-SPND, by means of a comparison of flux densities from the activation and from the V-SPND. By this way immediate determinations of flux densities are possible.

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x) Isotope Div.,Risø Nat.Lab., DK-4000 Roskilde, Denmark

5. DETERMINATION OF THE FAST FLUX DENSITY IN THE TRIGA MARK II REACTOR, VIENNA

F.Bensch, H.Böck, H.Zillner

The energy spectra of fast neutrons have been measured by threshold detectors at various experimental facilities of the TRIGA Mark II reactor. The informations about spectrum shapes is deduced by calculations with the computer code SAND II. Absolute values for flux densities of neutrons with $E_n > 1$ MeV are evaluated too.

6. MEASUREMENTS OF THE EMISSION OF PROMPT FISSION NEUTRONS

H.Jasicek, Z.Lewandowski[x)], E.Mersits, H.H.Müller[xx)], W.Reichart[xx)], P.Riehs, P.Schober[xx)], S.Steiner[xx)], R.Wagner[x)]

Investigations on the angular correlation of neutrons with fission fragments have been continued. Fragment energies and neutron time of flights are measured by solid state detectors and liquid scintillation counters at 0°- and 90°-positions. Assuming that neutrons are emitted isotropically in the relevant center of mass systems we try to assign neutron decay rates to stages during the acceleration process of the system which is leading to the two fragments. After a careful test of the equipment with an examination of the neutron emission of ^{252}Cf, we continue our work with measurements of the reaction $^{205}Tl(\alpha,f)$, $E_\alpha = 118$ MeV. Here it was possible to characterize neutron emission by the intensities of the groups a) to c): a) $< 5\%$ prefission neutrons from the heavy system before fission takes place, b) $\leq 20\%$ postfission neutrons due to fragments of maximum velocity and c) $> 75\%$ early emitted neutrons, which may come from preformed fragments at 40-50 per cent of the maximum fragment velocity.

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7. ANALYSING POWER AND DIFFERENTIAL CROSS SECTION AT 9.9 11.9 AND 13.9 MEV FOR Ca(n,n)Ca[1)]

W.Tornow[x)], E.WOYE[x)], G.Mack[x)], C.E.Floyd[xx)], K.Murphy[xx)], P.P.Guss[xx)], S.A.Wender[xx)], R.C.Byrd[xx)], R.L.Walter[xx)], T.B.Clegg[xxx)], H.Leeb

The analysing power and differential cross section for elastic neutron scattering from calcium have been measured using the $^2H(d,n)^3He$ source reaction and neutron time of flight techniques to detect the scattered neutrons. Polarized beams were produced via the polarization transfer reaction $^2H(d,n)^3He$ at $\theta = 0^o$. None of the global neutron nucleus optical model parameter sets usually referred to in the literature reproduces the present cross section and analysing power data. Individual as well as energy-averaged fits of the data resulting from new optical model searches are presented. It is shown that the quoted uncertainties of a recent empirical determination of the real part ΔV_C of the Coulomb correction term are probably underestimated. Our imaginary Coulomb correction term ΔW_C agrees quite well with both, a very recent empirical determination and theoretical studies. No definite conclusions can be drawn from the present data as to whether or not l-dependent potentials are important in neutron-calcium scattering in the energy range investigated. The data have also been analysed using a Fourier-Bessel series description of the real central optical potential.

1) Nucl.Phys. A385(1982)373

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x) Physikalisches Inst.Univ.Tübingen, D-7400 Tübingen
xx) Dep.of Physics, Duke Univ., Durham, NC27706, USA
xxx) Univ. of North Carolina, Chapel Hill, NC27514, USA

Institut für Experimentalphysik, University of Vienna
A-1090 Wien, AUSTRIA
(Experimental work done at Los Alamos National Laboratory, Los Alamos NM. 87545, USA).
Responsible scientist: Manfred DROSG.
Coworkers (on some but not all projects):
D.M.Drake, LASL, USA
G. Haouat, Bruyères-le-Châtel, FRANCE
W.Stoeffl, Florida State Univ., USA
M.Muellner, Univ.Vienna, AUSTRIA
F.Vesely, Univ.Vienna, AUSTRIA

Reporting date: February 9, 1983
General remark: Only those projects are mentioned that are worked on in Vienna and which are not included into LANL's Progress Report to INDC.

I. Production of monoenergetic neutrons

1) $^{3}H(p,n)^{3}He$ reaction between 0 and 10 MeV:

Between 1.99 and 5.5 MeV proton energy differential cross sections for the back angles were measured by means of the inverse reaction, $^{1}H(t,n)^{3}He$. These data have been included into an energy dependent evalution covering 2 to 10 MeV proton energy. Unfortunately only few previous data are reliable. Even the backbone of previous evalutions, the data of Perry et al. (PE59), show systematic errors of the order of 5 %. Thus they tend to distort evaluations appreciably. The present evaluation is in its final state and will be published soon. A zero-degree uncertainty of $\pm$ 0.5^{o} and a shape uncertainty and a scale uncertainty of less than $\pm$ 3 % will probably be accomplished.

2) $^{3}H(d,n)^{4}He$ reaction between 4 and 11 MeV:

Back angle data for 4, 5, 7 and 11 MeV deuteron energy measured by the inverse reaction $^{2}H(t,n)^{4}He$, agree at a one-percent-level with the predictions of the latest evaluation (Z.Phys.A300, 315 (1981)) except for the 4 MeV data which suggest a small modification at lower energies. The data are ready for publication.

II. High intense neutron sources

Both the $^{3}H(t,n)$ and the $^{7}Li(t,n)$ reaction could be a serious competitor for high intense neutron sources.

With the t-T reaction it takes more than 34 MeV triton energy for the complete break-up. Two thirds of the nucleons are neutrons thus needing 8.5 MeV per neutron in the breakup reaction.
^{7}Li would be more convenient as a target. However, for the complete break up more than 68 MeV triton energy is needed with 60 % of the nucleons being neutrons. This reaction requires 11.4 MeV per neutron for the complete break-up.

Neutron yields were measured for both reactions at 19.2 MeV triton energy, the highest energy available at the LASL Tandem Van de Graaff. Although background runs were taken, too, background subtraction from the continuous spectra will be very difficult and no predictions of the uncertainties are yet possible. Of course, these results will only allow better guessing of the cross sections above the threshold for complete break-up.

III. Fusion relevant data

Double differential neutron production cross sections by the reaction $^{3}H(t,n)$ at 5.96, 7.45, 10.44, 16.42 and 19.15 MeV have been measured between 0° and 145° in the lab.system.

As expected the background runs give too much background. A best correction for this overshoot must still be found.

IV. Gamma ray production

The analysis of some old data on gamma ray production by 8.51, 10.00, 12.24 and 14.24 MeV neutrons at 35°, 55°, 75° and 90° from iron, aluminium and silicon has been revived and will be concluded within this year.

V. $^{6}Li(n,t)^{4}He$ reaction

New data of this neutron detection standard were obtained from its reciprocal reaction $^{4}He(t,n)^{6}Li$ between 2.32 and 5.34 MeV corresponding neutron energy. It was found that the previous 5.34 MeV angular distribution published in LA-9129-MS must be lowered by about 8 % in the forward part due to contamination by the hydrogen peak which stems from a 0.4 volume % hydrogen impurity of the helium gas. Unfortunately the new 2.32 MeV back angle data will have big uncertainties due to a not so well established efficiency curve at low energies.

List of Recent Publications:

M.Drosg: "Neutron Sources", Proceedings XIth Internat.Symp. on the Interaction of Fast Neutrons with Nuclei, Nov.30-Dec.4 1981, Rathen near Dresden, Report ZfK-476, July 1982.

M.Drosg: "Increasing the Dynamic Range of Neutron-Gamma Discrimination by Gain Switching", Nucl.Instr.Meth.196, 449 (1982)

M.Drosg: "Differential Cross Sections of the Reaction $^{4}He(t,n)^{6}Li$ between 8.5 and 16.5 MeV and the n-^{6}Li Cross-Section Standard" Report LA-9129-MS, Los Alamos National Laboratory of the Univ. of California (1982).

M.Drosg: "The $^{1}H(^{7}Li,n)^{7}Be$ Reaction as a Neutron Source in the MeV Range", Report LA-8842-MS, Los Alamos Scientific Laboratory (LASL) (1981)