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PROGRESS REPORT FOR AUSTRIA

FOR THE PERIOD 1987/88

Andreas Pavlik
Institut für Radiumforschung und Kernphysik
der Universität Wien

June 1989

IAEA NUCLEAR DATA SECTION, WAGRAMERSTRASSE 5, A-1400 VIENNA

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Nondispersive Sample Arrangement in Neutron Interferometry

H. Rauch E. Seidl, D. Tuppinger, D. Petrascheck[1] and R. Scherm[2]

Reference: Z. Phys. B - Condensed Matter **69**,313(1987)

Abstract: The visibility of the interference at high order decreases due to the longitudinal coherence length of the beam which is determined by its wavelength spread. Much higher interference orders can be observed if the surfaces of the phase shifting sample is placed parallel to the reflecting planes of the interferometer crystal. In this case the contrast of the interference pattern is determined by the transverse coherence length. Moreover the pattern is nearly independent from the wavelength spread of the beam. This feature has been shown by experiments performed at the high flux reactor at Grenoble. This method permits higher intensities and therefore higher accuracies in neutron interferometer measurements. An accuracy of $\Delta\chi/\chi = 2.2.10^{-5}$ has been achieved for the phase shift of a nondispersively cut Bismuth sample whose coherent scattering length has been determined as $b_c = 8.521(4)$fm.

[1] Johannes Kepler Universität, Linz, Austria
[2] PTB, Braunschweig, F.R. Germany

Novel Measuring Methods in Neutron Interferometry

D. Tuppinger, H. Rauch and J. Summhammer

Reference: Physica **B 151**,96(1988)

Abstract: Perfect crystal interferometry is becoming a standard tool for precise measurements of coherent scattering lengths. So far accuracy was limited by the resolution achieved with the determination of the wavelength and the wavelength distribution. The newly tested nondispersive sample arrangement avoids this shortcoming because the phase shift becomes independent of the wavelength. Arbitrarily shaped samples can be measured by an adapted Christiansen filter method, where the scattering length density of the powdered sample is matched to the scattering length density of a surrounding liquid. The following values for the bound scattering lengths were determined: b_c(Bi) = 8.5165(62) fm by the standard method, b_c (Bi) = 8.521(4) fm by the non-

dispersive method and b_c(Si) = 4.157(3)fm by the Christiansen filter method. A phase sensitivity of 2.2 x 10^{-5} was achieved, which could easily be increased to a level of 10^{-6}.

Measurement of the Electric Polarizability of Neutron

J. Schmiedmayer, H. Rauch, and P. Riehs

Reference: Phys.Rev.Letters **61**,1065(1988)

Abstract: At the HELIOS neutron source in Harwell, the neutron transmission of Pb and C was very precisely measured within the 50 eV < E < 50 keV energy range, with use of a 150-m flight path, newly developed time-of-flight electronics, and a ^{10}B-loaded liquid scintillator. After correction for neutron-electron, Schwinger, and resonance scattering, the electric polarizability of the neutron was determined to be α_n = (1.2±1.0)x10^{-3}fm^3 from the energy dependence of the total scattering cross section.

The measurement of accurate Total Cross sections for Lead and Carbon in the Energy range 50 eV to 100 keV

J. Schmiedmayer and M.C. Moxon[1]

Reference: Proc. Int. Conf. on Nuclear Data for Science and Technology, Mito, May 30 - June 3, 1988, p.165, Saikon Publ. Co, Tokyo 1988

Abstract: The transmission of Pb and C has been accurately measured in the neutron energy range 50 eV to 100 keV using a 150 m flight path on the fast neutron target cell of HELIOS. The measurements were made with a ^{10}B loaded liquid scintillator using a new fast electronics system capable of recording simultaneously, with a dead time of 10 ns, both time-of-flight and pulse amplitude. The neutron time-of-flight resolution and backgrounds in the experiment were determined from measurements on W, Co, Mn, and ^{238}U by using the REFIT resonance analysis code. The ^{10}B loaded scintillator gave better signal to background ratios than other normally used systems and recording both time-of-flight and pulse height information enabled accurate cross-section values to be obtained from the data. The zero energy free atom scattering cross-sections for Pb and C are determined to be 11.258±0.005 and 4.7438±0.0020 barns respectively. After correcting for neutron-electron, Schwinger and resonance scattering effects the electric polarizability of the neutron (α_n) is determined from the energy dependence of the Pb total cross-section to be (1.2±1.0)x10^{-3}fm^3. The experimental measurements and the analysis of the results are discussed.

[1] Harwell Laboratory, Didcot, Oxon., UK

High-precision Cross section measurement on a Pulsed white Neutron source

J. Schmiedmayer

Reference: Kerntechnik 53,218(1989)

Abstract: An experimental setup for high-precision total cross-section measurements was developed at the HELIOS neutron source at Harwell. Both time-of-flight and pulse amplitude are recorded simultaneously by a newly developed fast electronic system having a dead time of 10 ns. Neutrons were detected with a ^{10}B-loaded liquid scintillator and ^{6}Li-glass detectors at flight paths between 8 and 150 m. Recording both time-of-flight and pulse height information enabled very accurate background determination. For the cross-sections relative standard deviations below 10^{-3} were achieved up to 50 keV neutron energy.

Summary of Neutron Scattering Lengths

L. Koester[1], H. Rauch and E. Seymann

Reference: Atomic Data and Nuclear Data Tables, to be published

Abstract: All available neutron-nuclei scattering lengths are collected together with their error bars in a 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. The data bank is available on magnetic tape too. Recommended values of these data serve for an uncomplicated use of these quantities. This is an updated version of a summary first published in 1981.

[1] Reaktorstation Garching, Garching, F.R. Germany

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(Experimental work done at Los Alamos National Laboratory, Los Alamos, N.M. 87545, USA and at JAERI, Tokai-mura, Japan)

Responsible scientist: Manfred Drosg

Coworkers (on some but not all projects):

D. M. Drake (LANL, USA)

P.W. Lisowski (LANL, USA)

M. Mizumoto (JAERI, Japan)

S. Chiba (JAERI, Japan)

K. Hasegawa (JAERI, Japan)

O. Schwerer (NDS of IAEA, Vienna)

I. Production of fast monoenergetic neutrons:

1. The use of the $^{1}H(^{11}B,n)^{11}C$ and the $^{1}H(^{15}N,n)^{15}O$ reaction was proposed to be used for monoenergetic neutron production up to 25.7 MeV neutron energy. The $^{1}H(^{11}B,n)^{11}C$ source has consequently been developed at JAERI, Tokai-mura, Japan. It has been used succesfully in the "gap" region, at the 11.4 MeV resonance for neutron gamma-work.

2. An evaluation of the traditional sources has been published as a contribution to the "Handbook on Nuclear Activation Data".

3. A computer-code, DROSG-87 was made public and is available through the Nuclear Data Section of IAEA, Vienna. It calculates energies and cross sections (and yields) of 11 monoenergetic neutron source reactions.

II. Gamma production by 8.5 to 14.2 MeV neutrons in Fe, Si and Al:

In cooperation with JAERI a code has been developed to correct for the neutron and gamma transport in the samples. It will be applied both to the new JAERI data and some old Los Alamos data.

III. Neutron emission spectra of ^{6}Li, ^{7}Li, ^{10}B, ^{11}B and Carbon at 14.1 MeV incident neutron energy:

The final report was published.

IV. Double differential cross sections of $^{3}H(t,n)$:

Work is dormant.

List of recent publications:

M. Mizumoto, K. Hasegawa, S. Chiba, Y. Yamanouti, Y. Kawarasaki, M. Igashira, T. Uchiyama, H. Kitazawa, M. Drosg: "Gamma-Ray Production Sections of some Structural and Shielding Materials" Proc. Int. Conf. on Nucl. Data Sci. and Tech., Mito, Japan 1988.

M. Drosg: "Angular Dependences of Neutron Energies and Cross Sections for 11 Monoenergetic Neutron Source Reactions", Computer Code DROSG-87: Neutron Source Reactions (O. Schwerer, ed.), Documentation series of the IAEA Nuclear Data Section, October 1987

M. Drosg, P.W. Lisowski, D.M. Drake, R.A. Hardekopf, M. Muellner: "Cross Sections for Neutron-Producing Reactions induced by 14.1 MeV Neutrons incident on ^{6}Li, ^{7}Li, ^{10}B, ^{11}B and Carbon", Report LA-11367-MS, LANL 1988

M. Drosg, O. Schwerer: "Production of Monoenergetic Neutrons between 0.1 and 23 MeV: Neutron Energies and Cross Sections", in Handbook on Nuclear Activation Data, K. Okamoto, ed., IAEA Techn. Rep. Ser. **273**, Vienna 1987

M. Drosg: "Novel Monoenergetic Neutron Sources for Energies between 2.5 and 25.7 MeV", Nucl. Instr, Meth. Phys. Res. **A254**, 466 (1987)

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Applications of the $H(t,n)^3He$ reaction to neutron cross section measurements in the energy range 8-12 MeV

H. Vonach, M. Wagner and R.C. Haight[1],

Measurements of neutron cross sections in the energy range 8-12 MeV have been difficult as in this range most reactions used for production of monoenergetic neutron do have substantial "contamination" by low energy neutrons and provide only modest neutrons fluences. Some time ago it has been pointed out /1/ that the $^1H(t,n)^3He$ reaction does produce truly monoenergetic neutrons up to 17.6 MeV and also provides rather high neutron flux in forward direction, because of kinematic focusing due to the strong c. m. motion. Recently a high-pressure hydrogen gas-target has been developed at the Los Alamos tandem accelerator for use of this reaction in conjunction with the triton beam of this accelerator /2/.

As an application of this system the cross sections for the reactions $^{58}Ni(n,p)^{58}Co$, $^{58}Ni(n,np+pn+d)^{57}Co$ and $^{60}Ni(n,p)\ ^{60}Co$ were measured relative to the ^{238}U-deposit of a fission chamber at zero degree with typical neutron fluences of 2-3 10^{12} n/cm^2. The neutron energy resolution was 1 MeV. Gas-out runs were performed in all cases as neutrons from triton break-up in the Mo window of the gas-target and the gold backing do produce a significant neutron background. The contribution of the breakup neutrons to the various reaction rates varied between 9 and 39% (see table 1).

The induced activities of ^{57}Co, ^{58}Co and ^{60}Co were measured by standard techniques using an intrinsic Ge-detector. The analysis of the data is still in progress, however even at present it can be stated that the strange structure found in the $^{60}Ni(n,p)^{60}Co$ cross-section /3/ cannot be confirmed and that the results of ref. 3 need some revision for the whole energy range 8-12 MeV. Furthermore it can be expected that the uncertainties of the cross-section measurements will be 5%.

[1]Los Alamos Nat. Lab.

Table 1: Contribution of neutrons from window and backing to reaction rate from $H(t,n)^3He$ gas target

E_t(MeV)	E_n(MeV)	(Reaction rate) gas-out / (Reaction rate) gas-in			
		$^{238}U(n,f)$	$^{58}Ni(n,p)$	$^{60}Ni(n,p)$	$^{58}Ni(n,np+pn+d)$
13.57	≈ 8	0.17	0.134	0.092	
15.18	≈ 9	0.27	0.24	0.15	
16.55	≈10	0.37	0.33	0.20	
17.44	≈11	0.42	0.36	0.19	0.384
18.95	≈12	0.47	0.43	0.225	0.255

/1/ M. Drosg et al., Report LA 6459-MS, Los Alamos Nat. Lab. 1976
/2/ R. C. Haight, to be published
/3/ A. Paulsen, Nukleonik **10**, 91 (1967)

Measurement of the excitation function for the reaction $^{52}Cr(n,2n)^{51}Cr$ from 12.7 to 19.5 MeV

H. Liskien[1], M. Uhl, M. Wagner, G. Winkler

The excitation function for the (n,2n)-reaction on the main isotope of the structural material chromium, ^{52}Cr, has been determined from threshold to about 19.5 MeV using the activation technique.

High-purity chromium samples of natural isotopic composition were irradiated at the 8 MV Van de Graaff accelerator of the Central Bureau for Nuclear Measurements at Geel, Belgium, employing the $T(d,n)^4He$ reaction as a source of quasi-monoenergetic neutrons and making use of the neutron energy variation with emission angle. The effective energy of the deuterons incident onto a solid-state 4.4 mg cm^{-2} TiT target was 3.000 ± 0.015 MeV. 24 Cr samples were arranged symmetrically relative to the direction of the deuteron beam on an Al support ring with a diameter of 20 cm at angles from 9° to 135° in steps of 12° and 6°. The neutron fluences incident on to the samples were determined relative to the well-known angular distribution of the source neutrons and the n-p scattering cross section using a proton-recoil telescope counter at 0°. In addition they were checked around 14 MeV against the well-evaluated $^{93}Nb(n,2n)^{92m}Nb$ cross section. The activity ratios in all employed samples were used to precisely establish the position of the deuterium beam spot by means of a least-squares procedure using the source neutrons' angular distribution and the shape of the respective excitation functions.

[1]Central Bureau for Nuclear Measurements, Geel, Belgium

The induced ^{51}Cr γ-ray activities were measured relative to each other by means of an intrinsic solid-state Ge γ-ray detector and normalized by an absolute measurement with a high-efficiency well-type NaI(Tl) crystal. In the 14-MeV region the results obtained in our work agree with the main body of the experimental results published hitherto. However, above 15 MeV they disagree with the outcome of two earlier experimental works on the excitation function of $^{52}Cr(n,2n)^{51}Cr$, one of which was published quite recently /1,2/. We have also performed theoretical calculations based on direct inelastic scattering, on preequilibrium emission and on sequential evaporation from the equilibrated compound nucleus. The results show satisfying agreement with our own experimental data and similar theoretical results obtained by Hetrick et al. /3/.
The paper on this work has been submitted to Annals of Nuclear Energy for publication.

/1/ M. Bormann, A. Behrend, I. Riehle and O. Vogel, Nucl. Phys. **A 115**, 309 (1968).
/2/ S.K. Ghorai, J.R. Williams and W.L. Alford, J.Phys. G: Nucl.Phys. **13**, 405 (1987).
/3/ D.M. Hetrick, C.Y. Fu and D.C. Larson, Report ORNL/TM-10417 (1987).

Measurement of the cross sections of the reactions $^{52}Cr(n,2n)^{51}Cr$, $^{66}Zn(n,2n)^{65}Zn$, $^{89}Y(n,2n)^{88}Y$ and $^{96}Zr(n,2n)^{95}Zr$ from 13.5 to 14.8 MeV

M. Wagner, G. Winkler, H. Vonach, J. Csikai[1] and Cs. M. Buczkó[1]

In view of their practical importance in the context of the operation of future fusion reactor devices and material test facilities, the cross sections of the above reactions were remeasured in the 14 MeV neutron energy range. Rectangular metallic samples of natural Cr, Zn and Zr, and Y_2O_3 powder in a cylindrical perspex container were irradiated with neutrons from a $T(d,n)^4He$ source, using an analyzed d^+ beam with (190 ± 10) keV incident energy, at the Cockcroft Walton neutron generator of the Institute of Experimental Physics of the Kossuth University, Debrecen. The total neutron yield achieved was $\approx 10^{14}$ neutrons in approximately 275 hours. Five samples of each material were fastened to an Al support ring (diameter 23 cm) with an air-jet cooled 0.5 mm Al backed Ti-T target at the center. The neutron production target was tilted at an angle of 145° relative to the incident deuteron beam. The angular positions of the samples were properly chosen in order to result in roughly equally distributed energy points in the available energy region; angular positions close to 90° were symmetrically occupied in order to detect shifts of the beam spot. Properly shaped fluence monitor foils of metallic Nb were attached to each sample, such that all cross sections could be measured relative to the well-evaluated cross section of the reference reaction $^{93}Nb(n,2n)^{92m}Nb$ /1,2/. This reference reaction was chosen by reason of the sufficiently long half-life of the reaction product ^{92m}Nb. The time distribution of the neutron production was monitored by means of a

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

Geiger-Müller counter, wrapped in a Cd foil, in a moderator block, several meters away from the neutron source, and by a low-mass ^{238}U-fission chamber positioned close to the source.
The energy scale was verified by measuring the ratio of ^{89}Zr to ^{92m}Nb activities induced in Zr and Nb foils, exposed as a sandwich at 12.7° and 97.5°. For the ^{90}Zr(n,2n)^{89}Zr reaction the accurate cross section data from Pavlik et al. /3/ were used. Neutron energy profiles were calculated for each sample using the code PROFIL /4/.

The relative activities of the samples and fluence foils were measured with a Ge(Li) gamma-ray detector at Debrecen and a 15% intrinsic Ge gamma-ray detector at IRK, Vienna. For normalization purposes, absolute activity measurements were performed on some Cr, Zr, Zn and Nb foils and on the Y_2O_3 samples by integral gamma-ray counting at IRK, employing a 12.7 cm x 12.7 cm NaI(Tl) well-type detector. For these latter measurements proper waiting times had to be observed to minimize the contribution of interfering activities.
So far final results were obtained for ^{52}Cr(n,2n)^{51}Cr. The measured cross sections are listed in table 1. They agree well with the results from an independent irradiation experiment at CBNM, Geel.

Table 1: Cross sections for the reaction ^{52}Cr(n,2n)^{51}Cr as measured in this work

Average neutron energy (MeV)	cross section (mb)
14.783 ± 0.013	400.6 ± 6.8
14.397 ± 0.011	339.3 ± 6.2
14.040 ± 0.010	270.5 ± 4.8
13.528 ± 0.010	172.9 ± 3.6

/1/ T.B. Ryves, A simultaneous evaluation of some important cross sections at 14.70 MeV , Report at the Central Bureau for Nuclear Measurements, Geel, to be published 1989.
/2/ J. Csikai, Zs. Lantos, Cs. M. Buczkó, Investigations on the properties of D + D and D + T neutron sources, in: Proceedings of an advisory group meeting on properties of neutron sources, Leningrad, 9 - 13 June 1986, IAEA-TECDOC **410**, p. 296, Vienna 1987.
/3/ A. Pavlik, G. Winkler, H. Vonach, A. Paulsen and H. Liskien, J. Phys. G: Nucl. Phys. **8**, 1283 (1982)
/4/ A. Pavlik and G. Winkler, Report INDC(AUS)-011/LI, IAEA Nuclear Data Section, Vienna 1986

Evaluation of Cross sections for 14 important Dosimetry Reactions

H. Vonach, J.Martinez-Rico, A. Pavlik, B. Strohmaier, S. Tagesen and M. Wagner

In cooperation with the IAEA an update of the dosimetry part of the International Reactor Dosimetry File IRDF-85 is planned. For that purpose the excitation functions for 14 important dosimetry reactions are evaluated. Evaluations previously performed at our institute are updated if necessary and four new reactions are added to our evaluation program. The reactions considered are summarized in table 1. With the exception of ^{93}Nb (see the following contribution by B. Strohmaier) the evaluations are mainly based on the available experimental data, which are critically reviewed and renormalised, if necessary.

Table 1: Dosimetry reactions considered in the present evaluation

Reaction	Status
^{19}F(n,2n)^{19}F	update not necessary
^{24}Mg(n,p)^{24}Na	update in progress
^{27}Al(n,a)^{24}Na	update in progress
^{31}P(n,p)^{31}Si	update not necessary
^{52}Cr(n,2n)^{51}Cr	new evaluation
^{59}Co(n,2n)^{58}Co	new evaluation
^{58}Ni(n,2n)^{57}Ni	update in progress
^{63}Cu(n,2n)^{62}Cu	update not necessary
^{64}Zn(n,p)^{64}Cu	update in progress
^{90}Zr(n,2n)^{89}Zr	update in progress
^{93}Nb(n,n')^{93m}Nb	update in progress
^{93}Nb(n,2n)^{92m}Nb	new evaluation
^{103}Rh(n,n')^{103m}Rh	update not necessary
^{197}Au(n,2n)^{196}Au	new evaluation

Revised evaluation of neutron induced reaction cross sections on ^{93}Nb by means of nuclear reaction model calculations

B. Strohmaier

Starting from a model calculation of the ^{93}Nb(n,n')^{93m}Nb excitation function, a series of evaluations of various neutron induced cross sections on ^{93}Nb was performed in the years 1980-1983, mainly challenged by the measurement of emission spectra of charged particles at the IRK. The measurements of the ^{93}Nb(n,n')^{93m}Nb cross section performed at energies between 1 and 8 MeV at AERE Harwell /1/ as well as at the IRK /2/ since these calculations were last revised suggest

another updating of these. This is particularly desirable since also for the level schemes and the adjustment of level densities entering into statistical model calculations, there exist more recent data than had been used previously. The new version of this evaluation which is presently being performed, makes also use of data for some neutron induced cross sections on nuclei which are close to Nb in mass for the determination of a consistent set of model parameters.

/1/ D. B. Gayther et al., Rept. AERE-R-12612, Harwell 1987

/2/ M. Wagner et al., Proc. Int. Conf. Nucl. Data for Science and Technology, Mito, Japan, May 30 - June 3, 1988, p. 1049 and M. Wagner et al., Ann. Nucl. En. **15**, 363 (1988)

Publications

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$^{93}Nb(n,xp)$, $^{nat}Ag(n,xp)$, and $^{nat}In(n,xp)$ reactions at 14.1 MeV, Phys. Rev. C **37** 578 (1988)

R. Nowotny, M. Uhl
Calculation of excitation functions for charged particle induced reactions, Handbook an Nuclear Activation Data, Techn. Rep. Ser. **273**, p. 441, IAEA, Vienna 1987

A. Pavlik,
Calculation of excitation functions for radioisotope procuction, Proc. IAEA Consultants' meeting on Data Requirements for Medical Radioisotope Production, Tokyo 20-24 April 1987, K. Okamoto ed., Report INDC(NDS)-195, p. 124, IAEA, Vienna 1988

A. Pavlik and H. Vonach,
Evaluation of the angle integrated neutron emission cross sections from the interaction of 14 MeV neutrons with medium and heavy nuclei, Physics Data **13-4**, Fachinformationszentrum, Karlsruhe 1988

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Application of Covariances in the Evaluation of Dosimetry Reaction Excitation Functions, invited lecture presented at the Interregional Training Course, Riga and Leningrad, 18 - 30 May 1987, IAEA-TECDOC-**469**, p. 128, IAEA, Vienna 1988

M. Uhl,
Calculation of Recoil Spectra Resulting from Nuclear Reactions with Multiple Particle Emission, Nucl. Sci. Eng. **100**, 77 (1988)

H. Vonach,
Excitation of isomeric states in (n,n') reactions, IAEA-TECDOC-**457**, p. 127, IAEA, Vienna 1988

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Charged Particle Nuclear Cross Section Library

R. Feldbacher

A light charged particle nuclear reaction cross section library is beeing developed at the Alternate Energy Physics Program. The library aims are a systematic compilation, evaluation and representation of cross section data and pertinent quantities for nuclear reactions among the first light isotopes (^{1}H - ^{11}B). In particular, reactions are considered which play a significant role in the investigation and evaluation of various fusion fuels (D-T and advanced fuels).

Emphasis is put on:
- Reactions among the main fuel isotopes, including side channels
- Reactions of isotopic impurities in the fuel
- Reactions of reaction products undergoing subsequent reactions with the background fuel nuclei and among each other (reactions of the 2^{nd}, 3^{rd}, .. generation)

The library shall be an appropriate nuclear reaction data base for investigation of the energy production in the fuel by the exothermic main reactions, of the dynamic behaviour of the plasma burn (competing channels, progeny reactions, nuclear scattering), and of the production of neutrons, gamma radiation and radionuclides in the fuel.
Both experimental and evaluated data are being compiled from existing local libraries, from a small number of available international files (e.g. ECPL, EXFOR) and mainly from the original literature. Thus, a comprehensive bibliography is included.
The library may be a convenient base for nuclear data reviews, as it shows clearly the data status of the various reactions like discrepancies between different data sources, lacks of data, and the reliability of the existing evaluations. As a first preliminary result of an own data evaluation, recommended cross sections are beeing defined and also included in the library. The performance of a thorough physical model based evaluation is intended.
The data are presented both as graphs and numerically on file. The library is subject to continuing development and improvement. Presently it contains about 300 data sets of appr. 80 reaction channels.

Publications:

R. Feldbacher, The AEP Barnbook DATLIB, Report INDC(AUS)-12/G, IAEA, Vienna 1987

R. Feldbacher, Charged Particle Nuclear Cross Sections for Advanced Fusion Fuels, Proc. Int. Conf. Nuclear Data for Science and Technology, Mito 1988 (S. Igarasi, ed.), p. 217, Saikon Publ. Co., Tokyo 1988