NEA/NSC/DOC(98)10

NUCLEAR SCIENCE COMMITTEE

Working Party on International Nuclear Data Measurement Activities

INTERNATIONAL NUCLEAR DATA MEASUREMENT ACTIVITIES

Newsletter No. 3

December 1998

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter; Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996) and the Republic of Korea (12th December 1996). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consist of all OECD Member countries, except New Zealand and Poland. The Commission of the European Communities takes part in the work of the Agency.

The primary objective of the NEA is to promote co-operation among the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source.

This is achieved by:

- *encouraging harmonization of national regulatory policies and practices, with particular reference to the safety of nuclear installations, protection of man against ionising radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;*
- *assessing the contribution of nuclear power to the overall energy supply by keeping under review the technical and economic aspects of nuclear power growth and forecasting demand and supply for the different phases of the nuclear fuel cycle;*
- *developing exchanges of scientific and technical information particularly through participation in common services;*
- *setting up international research and development programmes and joint undertakings.*

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has concluded a Co-operation Agreement, as well as with other international organisations in the nuclear field.

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FRANCE

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CNRS/IN2P3: F. Brochard, D. Durand, C. Lebrun, J.F. Lecolley, F.R. Lecolley, F. Lefebvres, M. Louvel, S. Ménard, G. Milleret, J.P. Schapira, L. Stuttge, C. Varignon

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Facilities

No more facilities after the closing of SATURNE accelerator, end of 1997.

Detectors: Magnetic spectrometers, NE213 liquid scintillators.

Measurements recently completed or in progress

1. Neutron production double differential cross-sections on thin targets induced by protons and deuterons at 800 MeV, 1.2 and 1.6 GeV on Al, Fe, Zr, W, Pb and Th measured at SATURNE.

2. Angular and energy distributions of neutron produced on thick Al, Fe, W and Pb targets by protons and deuterons at 800 MeV, 1.2 and 1.6 GeV measured at SATURNE.

Recent publications

1. F. Borne, *et al*., Spallation Neutron Spectra Measurements: Part 1: Time-of-Flight Technique, *Nucl. Instr. and Meth. in Phys*. A385 (1997) 339.

2. E. Martinez, *et al*., Spallation Neutron Spectra Measurements: Part 2: Proton Recoil Spectrometer, *Nucl. Instr. and Meth. in Phys*. A385 (1997) 345.

3. Leray, *et al*., Conf. Proceedings Vol. 59, Nucl. Data for Sci. and Techn., eds., G. Reffo, A. Ventura and C. Grandi, SIF, Bologna (1997) 1426.

4. Patin, *et al*., "Studies of Spallation Neutron at Saturne", GLOBAL 97, Japan, 1997.

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IRMM: C. Bastian, A. Brusegan, F. Corvi, E. Macavero, J. Gonzalez

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Facilities

Geel linear accelerator GELINA: 150 MeV electron pulsed white neutron source.

Detectors used: C_6D_6 liquid scintillators, Li-glass scintillators and boron chambers.

Measurements recently completed or in progress

1. Measurements of the neutron capture and total cross-section of ^{99}Tc in the energy range from 3 eV to 100 keV have been performed. The experiments concern several sample thicknesses and two partial energy ranges. The measurements are finished, the analysis is underway.

2. Several measurements of the total neutron cross-section of ^{237}Np have been done from 0.3 eV up to 2 keV with different sample thicknesses and energy ranges. Three different temperatures were used in order to study the Doppler broadening. A capture measurement of ^{237}Np has been performed from 0.3 to 50 eV.

Measurements planned for the near future

1. Measurements of the ^{237}Np(n,γ) cross-section from 50 eV to 2 keV are planned for late 1998.

2. Measurements of the neutron capture and total cross-section of ^{129}I are planned for the near future.

Recent publications

1. C. Raepsaet, C. Bastian, F. Corvi, F. Gunsing and A. Leprêtre, “Measurement of the Neutron Capture Cross-Section of ^{99}Tc in the Energy Range from 3 to 400 eV”, Proc. Int. Conf. Nuc. Data for Science and Technology, Trieste, 1997.

2. F. Gunsing, A. Brusegan, A. Leprêtre, C. Mounier and C. Raepsaet, “Measurement of the Neutron Total Cross-Section of ^{99}Tc in the Energy Range from 3 to 600 eV”, Proc. Int. Conf. Nuc. Data for Science and Technology, Trieste, 1997.

3. F. Gunsing, A. Leprêtre, C. Mounier, C. Raepsaet, A. Brusegan, F. Corvi, E. Macavero, L. Zanini and H. Postma, “Investigation of ^{99}Tc Neutron Resonances”, Proc. 6th Int. Sem. on Interaction of Neutrons with Nuclei, Dubna, 1998.

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Facilities

1. Turnable CV28 compact cyclotron.
   Pulse width: 1.0 ns, repetition frequency: 0.5-10 MHz, deuterium gas target, incident deuteron energy: 3-14 MeV, neutron production via the D(d,n) reaction, facility mainly used for nuclear data measurements.

2. Fixed multi-angle time-of-flight spectrometer.
   Five channels each separated by 12.5 degrees, 12 m flight paths (extendable up to 25 m), NE213 liquid scintillators.

3. 3.75 MV Van de Graaff accelerator.
   DC or pulsed (2 ns). Monoenergetic neutrons sources: ^{45}Sc(p,n), ^{7}Li(p,n), T(p,n), D(d,n) and T(d,n). White neutron sources with thick targets: Be(p,n) and Be(d,n).

Measurements recently completed or in progress

1. Double differential neutron emission cross-sections of elemental lead.
   Energy range: 7.9-14.2 MeV; final report in progress.

2. Double differential neutron emission cross-sections of elemental chromium.
   Energy range: 8.0-14.8 MeV; report in preparation.

3. Angular distributions of elastic and inelastic neutron scattering on vanadium.
   Energy range: 8.0-14.3 MeV; analysis in progress.

4. Activation cross-section measurements of ^{46}Ti(n,p)^{46}Sc, ^{47}Ti(n,p)^{47}Sc and ^{48}Ti(n,p)^{48}Sc.
   Energy range: 7.5-14.4 MeV; analysis in progress.

5. Angular distributions of elastic and inelastic neutron scattering on titanium.
   Energy range: 8.0-14.3 MeV; measurement completed, analysis in progress.

6. Activation cross-sections measurements of $^{27}Al(n,p)^{27}Mg$, $^{58}Ni(n,np)^{57}Co$, $^{58}Ni(n,2n)^{57}Ni$ and of the isomeric ratio of the $^{58}Ni(n,p)^{58}Co$ reaction (collaboration with A. Filatenkov, KRI, St. Petersburg).
   Energy range: 8.0-14.4 MeV; measurement completed, analysis in progress.

7. Double differential neutron emission cross-sections of elemental vanadium.
   Energy range: 8.0-14.3 MeV; analysis in preparation.

8. Double differential neutron emission cross-sections of elemental titanium.
   Energy range: 8.0-14.3 MeV; analysis to be done.

Measurements planned for the near future

1. Activation cross-section measurement of $^{39}K(n,p)^{39}Ar$ at neutron energies between 1.5-4.0 MeV (together with TU Munich).
   Aim: Improved neutron dosimetry for the Hiroshima bomb.

2. Neutron scattering on SiN/Si samples at neutron energies between 8 and 15 MeV.
   Aim: Scattering data of N (and Si, as a by-product).

Recent publications

1. M.M.H. Miah, B. Strohmaier, H. Vonach, W. Mannhart, D. Schmidt, Cross-Section for the $^{103}Rh(n,n')^{103m}Rh$ Reaction in the Energy Range 5.7-12 MeV, *Phys. Rev*. C54 (1996) 222-226.

2. A.B. Smith, D. Schmidt, "Neutron Scattering and Models – Chromium", Report ANL/NDM-138 (1996), Argonne National Laboratory.

3. D. Schmidt, W. Mannhart, Xia H., "Differential Cross-Sections of Neutron Scattering on Elemental Lead at Energies between 8 MeV and 14 MeV", Report PTB-N-27 (November 1996), Phys.-Technische Bundesanstalt, Braunschweig.

4. A.B. Smith, D. Schmidt, Neutron Scattering and Models – Chromium, *J. Physics G: Nucl. Part. Phys*. 23 (1997) 197-209.

5. D. Schmidt, Comparison of Different Methods to Correct Differential Neutron Scattering Cross-Sections, *Nucl. Instrum. & Meth*. A390 (1997) 336-344.

6. W. Mannhart, D. Schmidt, D.L. Smith, "Measurement of the $^{52}Cr(n,p)^{52}V$, $^{52}Cr(n,2n)^{51}Cr$, $^{51}V(n,p)^{51}Ti$ and $^{51}V(n,\alpha)^{48}Sc$ Cross-Sections between 7.9 and 14.4 MeV", Nuclear Data for Science and Technology, Conference Proceedings, Italian Physics Society, Bologna, Vol. 59 (1997) 505-507.

7. D. Schmidt, W. Mannhart, B.R.L. Siebert, "Measurement of Elastic, Inelastic and Double Differential Neutron Scattering Cross-Sections on V, Cr and Pb at Energies between 8 MeV and 15 MeV", Nuclear Data for Science and Technology, Conference Proceedings, Italian Physics Society, Bologna, Vol. 59 (1997) 407-409.

8. U. Fischer, H. Freiesleben, H. Klein, W. Mannhart, D. Richter, D. Schmidt, K. Seidel, S. Tagesen, H. Tsige-Tamirat, S. Unholzer, H. Vonach, Y. Wu, “Application of Improved Neutron Cross-Section Data for ^{56}Fe to an Integral Fusion Neutronics Experiment”, Nuclear Data for Science and Technology, Conference Proceedings, Italian Physics Society, Bologna, Vol. 59 (1997) 1137-1139.

9. W.D. Newhauser, H.J. Brede, V. Dangendorf, W. Mannhart, J.P. Meulders, U.J. Schrewe, H. Schuhmacher, “Measurement of the ^{238}U Fission Cross-Section at 34-MeV, 46-MeV and 61-MeV Neutron Energies”, Nuclear Data for Science and Technology, Conference Proceedings, Italian Physics Society, Bologna, Vol. 59 (1997) 1236-1238.

10. D. Schmidt, Zhou Ch., Long-Term Stability of a Neutron Detector, Internal report PTB-6.42-97-1 (October 1997).

11. D. Schmidt, W. Mannhart, “Differential Cross-Sections of Neutron Scattering on Elemental Chromium at Energies Between 8.0 MeV and 14.8 MeV”, Report PTB-N-31 (January 1998).

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Ph.D. students: University of Koeln: E. Heß, A. Hohn, S. Kastleiner, P. Reimer
Other universities: C. Nesaraja (Malaysia), M. Ibn Majah (Morocco)

Recent visitors: F. Cserpak, J. Csikai, S. Sudar, F. Tarkanyi (Hungary), Yu.N. Shubin (Russia), F.M. Nortier (South Africa)

Contact: S.M. Qaim

Facilities

1. Compact cyclotron CV 28: Variable energy p: 2-4 MeV; d: 3-14 MeV; ^{3}He: 5-36 MeV; ^{4}He: 6-28 MeV.

2. Injector cyclotron of COSY – internal beam p: 45 MeV.

3. Radiochemical laboratories.

4. Detectors: Si(Li), Ge(Li), HPGe. Equipment for low-level β counting.

Measurements recently completed or in progress

1. Neutron activation cross-sections in the energy range of 4 to 15 MeV.

   Cr, Ni, Fe: Measurements on (n,x) and (n,n′x) reactions completed (co-operation with IRMM Geel), part of the work recently published, manuscripts dealing with other parts in preparation.

   Zn, Ga, Ge: Measurements on several (n,p), (n,α) and (n,2n) reactions completed, manuscript in preparation.

   Y: Measurements on (n,n′γ) and (n,α) reactions leading to the formation of short-lived products completed (co-operation with KLTE Debrecen, Hungary) manuscript in press for publication.

   Ag: Measurements on (n,x) reactions, especially those leading to short-lived products, reaching completion (co-operation with KLTE Debrecen, Hungary).

2. Isomeric cross-section ratios in neutron and charged particle induced reactions.

   ^{69m,g}***Zn,*** ^{71m,g}***Zn***: Experimental studies and nuclear model calculations on their formation in (n,x) reactions completed, manuscript in preparation.

   ^{197m,g}***Au***: Formation in ^{196}Pt(^{3}He,2n) and ^{194}Pt(α,n) reactions under investigation (co-operation with KLTE Debrecen, Hungary)

3. Excitation functions relevant to medical radioisotope production.

   ^{15}***O***: Measurements on ^{14}N(d,t)^{13}N and ^{14}N(d,αn)^{11}C reactions completed, work recently published (co-operation with ATOMKI Debrecen, Hungary). These reactions lead to positron emitting impurities ^{13}N and ^{11}C in ^{15}O produced via the ^{14}N(d,n)^{15}O reaction.

   ^{18}***F***: Measurements on the ^{18}O(p,n)^{18}F reaction in the 3 to 8 MeV region initiated (co-operation with ATOMKI Debrecen, Hungary) since existing data show discrepancies.

   ^{51}***Mn***: Radiochemical measurements on ^{50}Cr(d,n) and ^{52}Cr(p,2n) processes completed, manuscript in preparation.

   ^{120g}***I***: Measurements on ^{120}Te(p,n) reaction up to 25 MeV completed, manuscript in press for publication.

   ^{124}***I***: Studies on ^{125}Te(p,2n) and ^{126}Te(p,3n) reactions in the energy region up to 70 MeV initiated (co-operation with NAC Faure, South Africa).

   ^{99m}***Tc***: Measurements on the ^{100}Mo(p,2n)^{99m}Tc, ^{100}Mo(p,pn)^{99}Mo and ^{98}Mo(p,γ)^{99m}Tc processes completed under a technical contract with the IAEA, manuscript in press for publication.

   ^{67}***Cu***: Investigation on the ^{70}Zn(p,α)^{67}Cu reaction from threshold up to 35 MeV completed.

4. Activation products formed in the interactions of biological and beam collimator materials with 250 MeV protons (proton therapy related nuclear data). Irradiations done at Uppsala, SATURNE and PSI. Measurements and nuclear model calculations completed. Several papers published, a few others in press.

Ph.D. theses recently completed

F.-O. Denzler: Produktion und radiochemische Abtrennung von ^{147}Gd zur Markierung und in vivo SPET-Evaluierung von Magnetopharmaka, University of Koeln (1997).
Printed as Report Juel-3338 (1997).

M. Fassbender: Aktivierungsquerschnitte von (p,x)-Prozessen an biologisch relevanten Elementen im Energiebereich von 50 bis 350 MeV für medizinisch-therapeutische Anwendungen, University of Koeln (1997).
Printed as Report Juel-3348 (1997).

A. Fessler: Activation cross-sections and isomeric cross-section ratios in neutron induced reactions on Cr-, Fe- and Ni-isotopes in the energy range 9 to 21 MeV, University of Koeln (1997).
Printed as Report Juel-3502 (1998).

A.T. Klein: Produktion von n.c.a. ^{51}Mn zur in vivo PET-Evaluierung von Kontrastmitteln für die Magnetresonanztomographie (MRT), University of Koeln (1997).
Printed as Report Juel-3553 (1998).

Recent publications

1. S.M. Qaim, F. Cserpák, J. Csikai, Excitation Functions of ^{109}Ag(n,2n)^{108m}Ag, ^{151}Eu(n,2n)^{150m}Eu and ^{159}Tb(n,2n)^{158}Tb Reactions from Threshold to 15 MeV, *Appl. Radiat. Isotopes* 47, 569-573 (1996).

2. S.M. Qaim, St. Spellerberg, F. Cserpák, J. Csikai, Radiochemical Measurement of Excitation Function of ^{63}Cu(n,p)^{63}Ni Reaction from 7.2 to 14.6 MeV, *Radiochimica Acta* 73, 111-117 (1996).

3. S. Sudár, S.M. Qaim, Isomeric Cross-Section Ratio for the Formation of ^{58m,g}Co in Neutron, Proton, Deuteron and Alpha-Particle Induced Reactions in the Energy Region Up to 25 MeV, *Phys. Rev*. C53, 2885-2892 (1996).

4. Zaman, S.M. Qaim: Excitation Functions of (d,n) and (d,α) Reactions on ^{54}Fe: Relevance to the Production of High Purity ^{55}Co at a Small Cyclotron, *Radiochimica Acta* 75, 59-63 (1996).

5. Kloprie, R. Dóczi, S. Sudár, J. Csikai, S.M. Qaim, Excitation Functions of Some Neutron Threshold Reactions on ^{89}Y in the Energy Range of 7.8 to 14.7 MeV, *Radiochimica Acta* 76, 3-9 (1997).

6. B. Scholten, S. Tákács, Z. Kovács, F. Tárkányi, S.M. Qaim, Excitation Functions of Deuteron Induced Reactions on ^{123}Te: Relevance to the Production of ^{123}I and ^{124}I at Low and Medium Sized Cyclotrons, *Appl. Radiat. Isotopes* 48, 267-271 (1997).

7. S. Takács, M. Sonck, B. Scholten, A. Hermanne, F. Tárkányi, Excitation Functions of Deuteron Induced Nuclear Reactions on ^{natr}Ti up to 20 MeV for Monitoring Deuteron Beams, *Appl. Radiat. Isotopes* 48, 657-665 (1997).

8. S. Merchel, S.M. Qaim, Excitation Functions of (^{3}He,^{7}Be)-Reactions on Light Mass Target Elements, *Radiochimica Acta* 77, 137-142 (1997).

9. Fenyvesi, S. Merchel, S. Takács, F. Szelecsényi, F. Tárkányi, S.M. Qaim, Excitation Functions of ^{nat}Ne(^{3}He,x)^{22,24}Na and ^{nat}Ne(α,x)^{22,24}Na Processes: Investigation of Production of ^{22}Na and ^{24}Na at a Medium-Sized Cyclotron, *Radiochimica Acta* 79, 207-216 (1997).

10. M. Faßbender, Yu.N. Shubin, V.P. Lunev, S.M. Qaim, Experimental Studies and Nuclear Model Calculations on the Formation of Radioactive Products in Interactions of Medium Energy Protons with Copper, Zinc and Brass: Estimation of Collimator Activation in Proton Therapy Facilities, *Appl. Radiat. Isotopes* 48, 1221-1230 (1997).

11. B. Strohmaier, M. Faßbender, S.M. Qaim, Production Cross-Sections of Ground and Isomeric States in the Reaction Systems ^{93}Nb + ^{3}He, ^{92}Mo + α and ^{94,95}Mo + p, *Phys. Rev*. C56, 2654-2665 (1997).

12. S.M. Qaim, "Radioactivity in Medicine: Achievements, Perspectives and Role of Nuclear Data", in Nuclear Data for Science and Technology, eds., G. Reffo, A. Ventura, C. Grandi, Italian Physics Society, Vol. 59 (1997) p. 31.

13. B. Strohmaier, M. Faßbender, F.-O. Denzler, F. Rösch, S.M. Qaim, "Isomeric Cross-Section Ratio for the Formation of ^{94m,g}Tc in Various Charged-Particle Induced Reactions", *ibid.*, p. 287.

14. A. Fessler, Y. Ikeda, J.W. Meadows, S.M. Qaim, D.L. Smith, E. Wattecamps, "Neutron Activation Cross-Sections for Short-Lived Isotopes in the Energy Range 16-20 MeV", *ibid.*, p. 399.

15. C. Nesaraja, F. Cserpák, S. Sudár, R. Dóczi, S.M. Qaim, "Excitation Functions of (n,p) and (n,α) Reactions on Some Isotopes of Zn, Ge, Y and Ag", *ibid.*, p. 583.

16. B. Scholten, A. Hohn, S. Takács, Z. Kovács, F. Tárkányi, H.H. Coenen, S.M. Qaim, "Cross-Section Measurements Relevant to the Production of Medically Interesting Positron Emitting Radioisotopes ^{120g}I and ^{124}I", *ibid.*, p. 1634.

17. M. Faßbender, B. Scholten, Yu.N. Shubin, S.M. Qaim, "Activation Cross-Section Data for (p,x) Processes of Therapeutic Relevance", *ibid.*, p. 1646.

18. Fenyvesi, S. Takács, S. Merchel, G. Petö, F. Szelecsényi, T. Molnar, F. Tárkányi, S.M. Qaim, "Excitation Functions of Charged Particle Induced Reactions on Neon: Relevance to the Production of ^{22,24}Na and ^{18}F", *ibid.*, p. 1707.

19. Szücs, W. Hamkens, S. Takács, F. Tárkányi, H.H. Coenen, S.M. Qaim, Excitation Functions of ^{14}N(d,t)^{13}N and ^{14}N(d,αn)^{11}C Reactions from Threshold to 12.3 MeV: Radionuclidic Purity of ^{15}O Produced via the ^{14}N(d,n)^{15}O Reaction, *Radiochimica Acta* 80, 59-63 (1998).

20. P. Reimer, S.M. Qaim, Excitation Functions of Proton Induced Reactions on Highly Enriched ^{58}Ni with Special Relevance to the Production of ^{55}Co and ^{57}Co, *Radiochimica Acta* 80, 113-120 (1998).

21. Molla, S. Basunia, M.R. Miah, S.M. Hossain, M.M. Rahman, S. Spellerberg, S.M. Qaim, Radiochemical Study of ^{45}Sc(n,p)^{45}Ca and ^{89}Y(n,p)^{89}Sr Reactions in the Neutron Energy Range of 13.9 to 14.7 MeV, *Radiochimica Acta* 80, 189-191 (1998).

22. A. Hohn, B. Scholten, H.H. Coenen, S.M. Qaim, "Excitation Functions of (p,xn) Reactions on Highly Enriched ^{122}Te: Relevance to the Production of ^{120g}I, *Appl. Radiat. Isotopes* 49, 93-98 (1998).

23. A. Hohn, H.H. Coenen, S.M. Qaim, Nuclear Data Relevant to the Production of ^{120g}I via the ^{120}Te(p,n) Process at a Small-Sized Cyclotron, *Appl. Radiat. Isotopes*, in press.

24. M. Faßbender, B. Scholten, S.M. Qaim, Radiochemical Studies of (p,^{7}Be) Reactions on Biologically Relevant Elements in the Proton Energy Range of 50 to 350 MeV, *Radiochimica Acta*, in press.

25. A. Fessler, E. Wattecamps, D.L. Smith, S.M. Qaim, Excitation Functions of (n,2n), (n,p), (n,np + pn + d) and (n,α) Reactions on Isotopes of Chromium, *Phys. Rev.* C., in press.

26. R. Dóczi, S. Sudár, J. Csikai, S.M. Qaim, Excitation Functions of the ^{89}Y(n,n′γ)^{89m}Y and ^{89}Y(n,α)^{86m}Rb Processes, *Phys. Rev*. C, in press.

27. B. Scholten, R.M. Lambrecht, M. Cogneau, H. Vera Ruiz, S.M. Qaim, Excitation Functions for the Cyclotron Production of ^{99m}Tc and ^{99}Mo, *Appl. Radiat. Isotopes*, submitted.

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Facilities

1. 3.7 MV single stage Van de Graaff, DC (200 μA) or pulsed (0.7 ns, 2 μA at 250 kHz repetition rate); monoenergetic neutrons with ^{7}Li(p,n), T(p,n), D(d,n) reactions; white neutron source with thick targets: ^{7}Li(p,n)^{7}Be or T(p,n)^{3}He, quasi-stellar neutron spectra for kT = 25 and 52 keV.

2. Detectors: 4π BaF_2 detector array for accurate (n,γ) measurements; Moxon-Rae detectors; GeClover detectors and HPGe detectors for activation measurements.

Main research interests: Stellar nucleosynthesis

s-process

Measurement of (n,γ) cross-sections between 3 and 300 keV, determination of stellar averages for thermal energies kT = 10 to 100 keV.

- Topics:
  - (n,γ) data for nucleosynthesis studies in the Big Bang and in stars;
  - accurate cross-sections of stable s-only isotopes;
  - neutron magic isotopes;
  - radioactive branch point isotopes.
- Complementary investigations:
  - stellar β-decay rates, by direct measurements or via nuclear structure studies;
  - compilation of stellar (n,γ) rates.

p-process

Measurement of (p,γ) cross-sections from 1.5 to 3.5 MeV in the Mo/Ru region.

Measurement of (n,γ) cross-sections along complete isotope chains for improved extrapolations to p-process region, stellar averages for temperatures between 1.5 and 4×10^9 K.

Measurements recently completed or in progress

Measurement of neutron capture cross-sections with the 4π BaF_2 detector:

- in preparation/in press: ^{170}Yb-^{176}Yb/^{160}Dy-^{164}Dy, ^{141}Pr;
- currently measured: ^{110}Cd-^{116}Cd, ^{180}Ta, ^{232}Th;
- planned: ^{128}Xe-^{130}Xe, ^{127}I, ^{129}I.

Measurement of (n,γ) cross-sections with the activation technique:

- in preparation/in press: ^{19}F, ^{26}Mg, ^{34}S, ^{50}Ti, ^{122,124}Sn, ^{151,153}Eu, ^{164,170}Er/^{7}Li;
- currently measured: ^{11}B, ^{15}N, ^{22}Ne, ^{30}Si, ^{40}Ar, ^{46}Ca;
- planned: ^{126}Te, ^{128}Te, ^{130}Te, ^{137}Cs, ^{179}Ta.

Measurement of (n,γ) cross-sections with high-resolution together with IRMM Geel:

- in preparation/in press: ^{207}Pb/^{136}Ba, ^{209}Bi;
- currently measured: ^{84,86}Kr.

Other activities

- in preparation/in press: Photoexcitation of ^{180}Ta together with Univ. Stuttgart, Munich, Darmstadt/lifetime studies on ^{176}Lu together with ILL Grenoble, Coulomb excitation of ^{180}Ta;
- currently measured: ^{14}N(α,γ)^{18}F and ^{13}C(α,α) together with Univ. Notre Dame;
- planned: ^{18}O(α,γ), ^{19}F(α,p) together with Univ. Notre Dame.

Recent publications

1997

1. H. Beer, F. Corvi and P. Mutti, Neutron Capture of the Bottleneck Isotopes ^{138}Ba and ^{208}Pb, s-Process Studies and the r-Process Abundance Distribution, *Ap. J*. 474 (1997) 843.
2. T. Sauter and F. Käppeler, (p,γ) Rates of ^{92}Mo, ^{94}Mo, ^{95}Mo, ^{98}Mo: Towards an Experimentally Founded Database for p-Process Studies, *Phys. Rev*. C (1997) 3127.

3. Z.Y. Bao, H. Beer, F. Käppeler, F. Voss and K. Wisshak, Stellar Cross-Sections for s-Process Studies, *Nucl. Phys.* A 621 (1997) 595.

4. H. Beer, C. Coceva, R. Hofinger, P. Mohr, H. Oberhummer, P.V. Sedyshev, Y.P. Popov, Measurement of Direct Neutron Capture by Neutron-Rich Sulfur Isotopes, *Nucl. Phys*. A 621 (1997) 235.

5. F. Corvi, P. Mutti, K. Athanassopulos, H. Beer, The Stellar Capture Rate of ^{136}Ba, *Nucl. Phys*. A 621 (1997) 262.

6. S. Jaag, The Stellar (n,γ) Cross-Section of the Stable Iridium Isotopes, *Nucl. Phys*. A 621 (1997) 251.

7. S. Jaag, F. Käppeler, P. Koehler, The Stellar (n,γ) Cross-Section of the Unstable ^{135}Cs, *Nucl. Phys*. A 621 (1997) 247.

8. K. Wisshak, F. Voss, F. Käppeler, L. Kazakov, Neutron Capture in Neodymium Isotopes: Implications for the s-Process, *Nucl. Phys*. A 621 (1997) 270.

9. F. Käppeler, Laboratory Studies of Heavy Element Formation, *Nucl. Phys*. A 621 (1997) 221.

10. P. Mohr, H. Oberhummer, H. Beer, W. Rochow, V. Koelle, G. Staudt, P.V. Sedyshev, Y.P. Popov, Direct Neutron Capture of ^{48}Ca at kT = 52 keV, *Phys. Rev*. C56 (1997) 1154.

11. M. Schumann, F. Käppeler, R. Boettger, H. Schoelermann, Survival of ^{180}Ta at s-Process Temperatures, *Nucl. Phys*. A 621 (1997) 274.

12. G. Wallerstein, I.Jr. Iben, P. Parker, A.M. Boesgaard, G.M. Hale, A.E. Champagne, C.A. Barnes, F. Käppeler, V.V. Smith, R.D. Hoffman, F.X. Timmes, C. Sneden, R.N. Boyd, B.S. Meyer, D.L. Lambert, Synthesis of the Elements in Stars: Forty Years of Progress, *Rev. Mod. Phys*. 69 (1997) 995.

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1. K. Wisshak, F. Voss, F. Käppeler, L. Kazakov and G. Reffo, Stellar Neutron Capture Cross-Sections of the Nd Isotopes, *Phys. Rev*. C57 (1998) 391.

2. C. Theis, F. Käppeler, K. Wisshak and F. Voss, On the Puzzling Origin of the Rare In and Sn Isotopes, *Ap. J*. 500 (1998) 1039.

3. M. Heil, F. Käppeler, M. Wiescher and A. Mengoni, The (n,γ) Cross-Section of ^{7}Li, *Ap. J*. (1998) in print.

4. C. Doll, H.G. Börner, S. Jaag, F. Käppeler and W. Andrejtscheff, A Lifetime Measurement in ^{176}Lu and its Astrophysical Consequences, *Phys. Rev*. C (1998) in print.

5. J. Bork, H. Schatz, F. Käppeler and T. Rauscher, Proton Capture Cross-Section of the Ruthenium Isotopes, *Phys. Rev*. C58 (1998) 524.

6. F. Käppeler, F.-K. Thielemann and M. Wiescher, Current Quests in Nuclear Astrophysics and Experimental Approaches, *Annual Review of Nucl. and Part. Science* (1998) in print.

7. M. Schumann, F. Käppeler, R. Boettger and H. Schoelermann, Coulomb Excitation of ^{180m}Ta, *Phys. Rev*. C (1998) in print.

8. K. Wisshak, F. Voss, F. Käppeler, Neutron Capture Resonances in ^{142}Nd and ^{144}Nd, *Phys. Rev*. C57 (1998) 3452.

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Facilities

Radiochemical laboratory and facilities for α-, β-, and γ- spectrometry at ZSR; accelerator experiments were/are performed externally for the investigation of:

- charged particle induced reaction at CERN/Geneva, FZ Jülich, LNS/Saclay, PSI/Villigen, and TSL/Uppsala for proton energies up to 2.6 GeV;
- neutron induced reactions at PSI/Villigen, TSL/Uppsala and UCL/Louvain La Neuve for neutron energies between 30 MeV and 180 MeV.

Non-radiometric measurements are performed in collaborations: Accelerator mass spectrometry (AMS) in collaboration with the PSI/ETH Tandem AMS Laboratory, Institute for Particle Physics, ETH Hönggerberg, Zurich.

Stable rare gas isotopes are investigated by conventional rare gas mass spectrometry in collaboration with CEN Bordeaux Gradignan; Institute for Isotope Geology and Mineral Resources, ETH Zurich; MPI Chemie, Mainz; Physical Research Laboratory, Ahmedabad.

Collaborations

CEN Bordeaux Gradignan; Centre d'Etudes de Bruyères-le-Châtel; Dept. of Nuclear Chemistry, University of Cologne; ICH 1 and IKP, FZ Jülich; Institute for Isotope Geology and Mineral Resources, ETH Zurich; Institute for Particle Physics, ETH Hönggerberg, Zurich; Khlopin Radium Institute, St. Petersburg; Max Planck Institute for Chemistry, Mainz; Physical Research Laboratory, Ahmedabad; PTB, Braunschweig; the Svedberg Laboratory, University of Uppsala.

Measurements recently completed or in progress

1. Measurements of thin-target cross-sections for the production stable and radioactive nuclides by proton and ^{4}He induced reactions on cosmo-chemically relevant target elements from thresholds up to 2.6 GeV.

2. Simulation of the interaction of galactic cosmic ray protons with meteoroids: Thick target experiments with isotropically irradiation of stony and iron spheres of various radii with 1.6 GeV protons.

3. Evaluation of neutron excitation functions for the production of residual nuclides for neutron energies up to 900 MeV: Model calculations and deconvolution of experimental thick-target production rates.

4. Measurements of thin-target cross-sections for the production of radioactive nuclides by proton induced reactions for target elements relevant for spallation neutron sources and accelerator-based technologies as waste transmutation and energy amplification for proton energies between 70 MeV and 2.6 GeV.

5. Activation experiments with medium-energy neutrons at PSI/Villigen, TSL/Uppsala and UCL/Louvain La Neuve for neutron energies between 30 MeV and 180 MeV.

Measurements planned for the near future

1. Measurements of thin-target cross-sections for the production of radioactive nuclides by proton-induced reactions for target elements relevant for spallation neutron sources and accelerator-based technologies such as waste transmutation and energy amplification for proton energies up to 70 MeV.

2. Activation experiments with medium-energy neutrons at PSI/Villigen, TSL/Uppsala and UCL/Louvain La Neuve for neutron energies between 30 MeV and 180 MeV for the determination of integral excitation functions for residual nuclide production for target elements of interest for cosmo-chemistry and accelerator based technologies.

Recent publications

1. R. Bodemann, H.-J. Lange, R. Michel, T. Schiekel, R. Rösel, U. Herpers, H.J. Hofmann, B. Dittrich, M. Suter, W. Wölfli, B. Holmqvist, H. Condé, P. Malmborg, Production of Residual Nuclides by Proton-Induced Reactions on C, N, O, Mg, Al, and Si, *Nucl. Instr. Meth. Phys. Res*. B82 (1993) 9-31.

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4. R. Michel, H.-J. Lange, M. Lüpke, U. Herpers, R. Rösel, D. Filges, P. Cloth, P. Dragovitsch, Measurement and Modeling of Radionuclide Production in Thick Spherical Targets Irradiated Isotropically with 1600 MeV Protons, Proceedings Intl. Conf. Nuclear Data for Science and Technology, 9-13 May 1994, Gatlinburg, Tennessee, USA, ed., J.K. Dickens, pp. 377-379 (1994) American Nuclear Society, Inc., La Grange Park, Illinois.

5. R. Michel, Nuclear Data for the Interpretation of Cosmic Ray Interactions with Matter, Proceedings Intl. Conf. Nuclear Data for Science and Technology, 9-13 May 1994, Gatlinburg, Tennessee, USA, ed., J.K. Dickens, pp. 337-343 (1994) American Nuclear Society, Inc., La Grange Park, Illinois.

6. Th. Schiekel, R. Rösel, U. Herpers, I. Leya, M. Gloris, R. Michel, B. Dittrich-Hannen, P.W. Kubik, H.-A. Synal, M. Suter, Cross-Sections for the p-Induced Production of Long-Lived Radionuclides for the Interpretation of Cosmogenic Nuclides, Proceedings Intl. Conf. Nuclear Data for Science and Technology, 9-13 May 1994, Gatlinburg, Tennessee, USA, ed., J.K. Dickens, pp. 344-346 (1994) American Nuclear Society, Inc., La Grange Park, Illinois.

7. R. Michel, Nuclide Production at Intermediate Energies, Proc. 8e Journées Saturne, 5-6 May 1994, Saclay, Accelerators Applied to the Nuclear Waste Problem, eds., S. Leray, Y. Patin, pp. 37-43, Laboratoire National Saturne, Saclay, LNS/Ph/94-12.

8. H.-J. Lange, T. Hahn, R. Michel, T. Schiekel, R. Rösel, U. Herpers, H.J. Hofmann, M. Suter, B. Dittrich-Hannen, W. Wölfli, Production of Residual Nuclei by ^{4}He-Induced Reactions on C, N, O, Mg, Al, and Si Up to 170 MeV, *Appl. Rad. Isotop*. 46 (1994) 93-112.

9. R. Michel, M. Gloris, H.-J. Lange, I. Leya, M. Lüpke, U. Herpers, B. Dittrich, R. Rösel, Th. Schiekel, D. Filges, P. Dragovitsch, M. Suter, H.J. Hofmann, W. Wölfli, P.W. Kubik, H. Baur, R. Wieler, Production of Radionuclides from Target Elements ($Z < 29$) by Proton-Induced Reactions Between 800 and 2600 MeV, *Nucl. Instr. Meth. Phys. Res*. B 103 (1995) 183-222.

10. R. Michel, I. Leya, L. Borges, Production of Cosmogenic Nuclides in Meteoroids – Accelerator Experiments and Model Calculations to Decipher the Cosmic Ray Record in Extraterrestrial Matter, Proceedings ECAART 4, 4th European Conference on Accelerators in Applied Research and Technology, 29 Aug.-2 Sept. 1995, Zürich, *Nucl. Instr. Meth. Phys. Res*. B113 (1996) 434-444.

11. M. Gloris, R. Michel, U. Herpers, F. Sudbrock, Production of Residual Nuclides from Irradiation of Thin pb-Targets with Protons Up to 1.6 GeV, Proceedings ECAART 4, 4th European Conference on Accelerators in Applied Research and Technology, 29 Aug.-2 Sept. 1995, Zürich, *Nucl. Instr. Meth. Phys. Res*. B113 (1996) 429-433.

12. B. Dittrich-Hannen, F. Ames, M. Suter, Ch. Schnabel, R. Michel, U. Herpers, E. Günther, Determination of ^{41}Ca Production Cross-Sections Using a 7 MV Van de Graaf Accelerator. Proceedings ECAART 4, 4th European Conference on Accelerators in Applied Research and Technology, 29 Aug.-2 Sept. 1995, Zürich, *Nucl. Instr. Meth. Phys. Res*. B113 (1996) 453-456.

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15. R. Michel, Le cosmos en accéléré – Simulation of Cosmic Ray Interactions at Saturne, Proc. 7e Journées d'Études Saturne, Ramatuelle, 29 Jan.-2 Feb.1996, CEA/IN2P3 (1996) pp. 432-439.

16. R. Michel, M. Gloris, A. Krins, I. Leya, H. Reinhardt, U. Herpers, Th. Schiekel, F. Sudbrock, B. Holmqvist, H. Condé, P. Malmborg, M. Suter, P.-W. Kubik, H.-A. Synal, D. Filges, Thin-Target and Thick-Target Experiments as Basis for the Modelling of Nuclide Production at Medium Energies, in Proc. 2nd Int. Conf. on Accelerator-Driven Technologies and Applications, 3-7 June 1996, Kalmar, Sweden, Uppsala University, Gotab, Stockholm, ed., H. Condé (1997) 448-454.

17. M. Gloris, R. Michel, U. Herpers, F. Sudbrock, D. Filges, B. Holmqvist, H. Condé, P. Malmborg, P.-W. Kubik, H.-A. Synal, M. Suter, Proton-Induced Nuclide Production in Heavy Target Elements at Medium Energies, in Proc. 2nd Intl. Conf. on Accelerator-Driven Technologies and Applications, 3-7 June 1996, Kalmar, Sweden, Uppsala University, Gotab, Stockholm, ed., H. Condé (1997) 549-555.

18. Ch. Schnabel, H.-A. Synal, M. Suter, R. Michel, M. Gloris, I. Leya, U. Herpers, Determination of Proton-Induced Cross-Sections and Production Rates of ^{129}I from Te in the Medium Energy Range, *Radiocarbon* 38 (1996) 107-108.

19. R. Michel, P. Nagel, International Codes and Model Intercomparison for Intermediate Energy Activation Yields, NSC/DOC(97)-1, NEA/OECD, Paris, 1997.

20. R. Michel, R. Bodemann, H. Busemann, R. Daunke, M. Gloris, H.-J. Lange, B. Klug, A. Krins, I. Leya, M. Lüpke, S. Neumann, H. Reinhardt, M. Schnatz-Büttgen, U. Herpers, Th. Schiekel, F. Sudbrock, B. Holmqvist, H. Condé, P. Malmborg, M. Suter, B. Dittrich-Hannen, P.-W. Kubik, H.-A. Synal, Cross-Sections for the Production of Residual Nuclides by Low- and Medium-Energy Protons from the Target Elements C, N, O, Mg, Al, Si, Ca, Ti, Mn, Fe, Co, Ni, Cu, Sr, Y, Zr, Nb, Ba and Au, *Nucl. Instr. Methods in Phys. Res*. B 129 (1997) 153-193.

21. R. Michel, P. Nagel, International Codes and Model Intercomparison for Intermediate Energy Activation Yields, Conf. Proc. Vol. 59 “Nuclear Data for Science and Technology”, eds., G. Reffo, A. Ventura and C. Grandi, Società Italiana di Fisica, Bologna, 1997, pp. 879-883.

22. M. Gloris, R. Michel, F. Sudbrock, U. Herpers, D. Filges, P. Malmborg, B. Holmqvist, H. Condé, Proton-Induced Nuclide Production in Heavy Target Elements at Medium Energies, Conf. Proc. Vol. 59 “Nuclear Data for Science and Technology”, eds., G. Reffo, A. Ventura and C. Grandi, Società Italiana di Fisica, Bologna, 1997, pp. 1468-1472.

23. R. Michel, R. Bodemann, H. Busemann, R. Daunke, M. Gloris, H.-J. Lange, B. Klug, A. Krins, I. Leya, M. Lüpke, S. Neumann, H. Reinhardt, M. Schnatz-Büttgen, U. Herpers, Th. Schiekel, F. Sudbrock, B. Holmqvist, H. Condé, P. Malmborg, M. Suter, B. Dittrich-Hannen, P.-W. Kubik, H.-A. Synal, A New Experimental Database of Cross-Sections for the Production of Residual Nuclides by Proton-Induced Reactions on the Target Elements C, N, O, Mg, Al, Si, Ca, Ti, V, Mn, Fe, Co, Ni, Cu, Sr, Y, Zr, Nb, Ba and Au from Thresholds Up to 2.6 GeV, Conf. Proc. Vol. 59 “Nuclear Data for Science and Technology”, eds., G. Reffo, A. Ventura and C. Grandi, Società Italiana di Fisica, Bologna, 1997, pp. 1458-1462.

24. I. Leya, R. Michel, Determination of Neutron Cross-Sections for Nuclide Production at Intermediate Energies by Deconvolution of Thick-Target Production Rates, Conf. Proc. Vol. 59 “Nuclear Data for Science and Technology”, eds., G. Reffo, A. Ventura and C. Grandi, Società Italiana di Fisica, Bologna, 1997, pp. 1463-1467.

25. S. Neumann, R. Michel, F. Sudbrock, U. Herpers, P. Malmborg, O. Jonsson, B. Holmqvist, H. Condé, P.W. Kubik, M. Suter, A New Facility at the Svedberg Laboratory for Activation Experiments with Medium Energy Neutrons, Conf. Proc. Vol. 59 "Nuclear Data for Science and Technology", eds., G. Reffo, A. Ventura and C. Grandi, Società Italiana di Fisica, Bologna, 1997, pp. 379-383.

26. S. Neumann, M. Gloris, R. Michel, E. Gilabert, B. Lavielle, Th. Schiekel, U. Herpers, Measurement and Calculation of Proton-Induced Integral Cross-Sections of Stable Krypton Isotopes for Energies Up to 1.6 GeV on Rb, Sr, and Y, Conf. Proc. Vol. 59 "Nuclear Data for Science and Technology", eds., G. Reffo, A. Ventura and C. Grandi, Società Italiana di Fisica, Bologna, 1997, pp. 1519-1521.

27. C. Schnabel, P. Gartenmann, J.M. Lopez-Guitierrez, B. Dittrich-Hannen, M. Suter, H.-A. Synal, I. Leya, M. Gloris, R. Michel, F. Sudbrock, U. Herpers, Determination of Proton-Induced Production Cross-Sections and Production Rates of ^{129}I and ^{41}Ca, Conf. Proc. Vol. 59 "Nuclear Data for Science and Technology", eds., G. Reffo, A. Ventura and C. Grandi, Società Italiana di Fisica, Bologna, 1997, pp. 1559-1561.

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31. E. Gilabert, B. Lavielle, S. Neumann, M. Gloris, R. Michel, Th. Schiekel, F. Sudbrock, U. Herpers, Cross-Sections for the Proton-Induced Production of Krypton Isotopes from Rb, Sr, Y, and Zr for Energies Up to 1600 MeV, *Nucl. Instr. Meth. Phys. Res*. B, in press, 1998.

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36. I. Leya, H. Busemann, H. Baur, R. Wieler, M. Gloris, S. Neumann, R. Michel, F. Sudbrock, U. Herpers, Cross-Sections for the Proton-Induced Production of He and Ne Isotopes from Magnesium, Aluminium and Silicon, *Nucl. Instr. Meth. Phys. Res*. B, in press, 1998.

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Facilities

1. MV pulsed Dynamitron accelerator (>1.5 ns), terminal chopper and buncher, post-acceleration chopper.

2. Monoenergetic n-source: 8 keV-7 MeV, 13-20 MeV ^{45}Sc(p,n), ^{7}Li(p,n), T(p,n), D(d,n), T(d,n). Quasi-monoenergetic n-sources: ^{14}N(d.n), ^{15}N(d,n). Continuous n-sources: Li(p,n), Li(d,n), Be(d,n).

3. Detectors: NE213 detectors: 5" diam. × 2" thick, 14 cm diam. × 10 cm thick, 80 cm × 6 cm × 10 cm; HPGe, NaI, gamma-ray spectrometers; gridded-ionisation chamber for (n,α), (n,p) measurements; counter-telescope for (n,z) measurements in tens MeV region; parallel-plate fission chamber for fission cross-section measurements; proton-recoil telescope, ^{6}Li-SSD flux detector.

Measurements recently completed or in progress

1. Neutron scattering and emission cross-section of ^{238}U: Elastic and inelastic scattering cross-section for 0.4-0.8 MeV neutrons, neutron emission cross-sections at En = 2.5 MeV.

2. Prompt fission neutron spectrum of ^{237}Np at 0.6 MeV.

3. Differential (n,xα) cross-section of carbon and oxygen at En = 11.5-15 MeV: Emission spectra and cross-section, gridded-ionisation chamber and gas-sample.

4. Double differential (n,z) cross-section at En = 75 MeV: Wide range counter telescope, C, Al, Fe. In collaboration with JAERI Takasaki.

5. Fission cross-section of ^{237}Np in 10-100 keV region: Relative to ^{235}U.

Measurements planned for the near future

1. Double-differential neutron emission cross-sections of ^{232}Th, ^{238}U at En = 11.5 MeV.

2. Prompt fission neutron spectrum of ^{233}U at En = 0.5-2 MeV region.

3. Neutron elastic scattering cross-section at En = 75 MeV: JAERI Takasaki, TOF methods.

4. Double-differential (n,xα) cross-section between 2-18 MeV: C, N, O, Si: Gridded-ionisation chamber and counter-telescope.

5. Double-differential (n,z) cross-section at En = 75 MeV for z = p, d, t, α.

6. Fission cross-section of minor actinides relative to ^{235}U, 10-100 keV region.

Recent publications

1. S. Matsuyama, T. Ohkubo, M. Baba, S. Iwasaki, D. Soda M. Ibaraki and N. Hirakawa, "Development of a Long Liquid Scintillation Detector for Fast Neutron Time-of-Flight Experiments, *Nucl. Instrum. Meth*. A372,1996, pp. 246-252.

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3. Y. Nauchi, M. Baba, S. Matsuyama, N. Hirakawa and S. Tanaka, "Development of Wide Range Charged Particle Spectrometer for Tens MeV Neutrons", JAERI-Conf. 96-008 (1996) pp. 152-156.

4. T. Sanami, M. Baba, S. Matsuyama, T. Kawano, T. Kiyosumi, Y. Nauchi, K. Saito and N. Hirakawa, "Measurement of Double Differential Neutron-Induced Alpha-Particle Emission Cross-Sections of ^{58}Ni and ^{nat}Ni", JAERI-Conf. 96-008 (1996) pp. 231-235.

5. S. Matsuyama, D. Soda, M. Baba, S. Iwasaki, M. Ibaraki, T. Ohkubo, Y. Nauchi and N. Hirakawa, "Air Gap Effect on the Properties of a Long Liquid Scintillation Detector", *Nucl. Instrum. Meth*. A384, 1997, pp. 439-443.

6. T. Sanami, Mamoru Baba, Isamu Matsuyama, Shigeo Matsuyama, Takehide Kiyosumi, Yasushi Nauchi and Naohiro Hirakawa, "Measurement of $^{14}N(n,p)^{14}C$ Cross-Section for KT = 25.3 KeV Maxwellian Neutrons Using Gridded Ionization Chamber", *Nucl. Instru. Methods*. A394, 1997, pp. 368-373.

7. Y. Nauchi, M. Baba, T. Kiyosumi, T. Iwasaki, T. Sanami, S. Matsuyama, N. Hirakawa, S. Tanaka, S. Meigo, H. Nakashima, T. Nakamura, Y. Watanabe and M. Harada, "Measurements of Double Differential Charged Particle Emission Cross-Sections and Development of Wide Range Charged Particle Spectrometer for Tens MeV Neutrons", JAERI-Conf 97-005 (1997) pp. 126-131.

8. M. Ibaraki, M. Baba, S. Matsuyama, T. Sanami, Than Win, T. Miura and N. Hirakawa, "Measurement of Double-Differential Neutron Emission Cross-Sections of ^{6}Li and ^{7}Li for 18 MeV Neutrons", JAERI-Conf 97-005 (1997) pp. 164-168.

9. T. Sanami, M. Baba, K. Saito, Y. Ibara and N. Hirakawa, "(n,α) Cross-Section Measurements of Gaseous Samples Using a Gridded-Ionization Chamber", JAERI-Conf 97-005 (1997) pp. 176-181.

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Facilities

1. Research reactors: Japan Material Testing Reactor and Japan Research Reactor 3M2. Accelerator: JAERI Tandem Accelerator.

2. Chemistry: Target preparation by electrodeposition method and chemical separation by ion exchange chromatography, etc.

3. Detectors: Common α- and γ-ray detectors used for determining the reaction products.

Measurements recently completed or in progress

1. Fission product yields from neutron-induced fission of ^{241}Am; manuscript in preparation.

2. Thermal neutron cross-section of ^{243}Am(n,γ)^{244g,m}Am reaction; further analysis in progress.

3. Effective thermal cross-section of ^{134}Cs by triple neutron capture reaction with PNC (Tokai); further analysis in progress.

4. Isomeric yield ratios of iodine in the proton- and heavy ion-induced fission of actinides with Tohoku University (Sendai); manuscript in preparation.

Measurements planned for the near future

1. Neutron capture cross-sections of ^{237}Np by using a research reactor.

2. Yields of minor actinides and fission products in spent fuels by chemical method with co-workers.

3. Analysis of actinide fuels irradiated by fast neutron reactor with co-workers. Collaboration with ORNL.

Recent publications

1. M. Magara, N. Shinohara, Y. Hatsukawa, K. Tsukada, H. Iimura, S. Usuda, S. Ichikawa, T. Suzuki, Y. Nagame, Y. Kobayashi, M. Oshima and T. Horiguchi, “Decay Properties of ^{245}Cf”, *Radiochim. Acta* 72, 39 (1996).

2. N. Shinohara and N. Kohno, “Chemical and Isotopic Characteristics of a Neptunium Sample for Nuclear Data Measurements”, *J. Nucl. Sci. Technol*. 34, 398 (1997).

3. T. Katoh, S. Nakamura, H. Harada, Y. Hatsukawa, N. Shinohara, K. Hata, K. Kobayashi, S. Motoishi and T. Tanase, “Measurement of Thermal Neutron Cross-Section and Resonance Integral of the Reaction $^{135}Cs(n,\gamma)^{136}Cs$”, *J. Nucl. Sci. Technol*. 34, 431 (1997).

4. N. Shinohara, Y. Hatsukawa, K. Hata and N. Kohno, “Radiochemical Determination of Neutron Capture Cross-Sections of ^{241}Am”, *J. Nucl. Sci. Technol*. 34, 613 (1997).

5. H.H. Saleh, T.A. Parish, S. Raman and N. Shinohara, “Measurements of Delayed Neutron Decay Constants and Fission Yields from ^{235}U, ^{237}Np, ^{241}Am and ^{243}Am”, *Nucl. Sci. Eng*. 125, 51 (1997).

6. S. Yamamoto, K. Kobayashi, M. Miyoshi, I. Kimura, N. Shinohara and Y. Fujita, “Fission Cross-Section Measurements of ^{241}Am Between 0.1 eV and 10 keV with Lead Slowing-Down Spectrometer and at Thermal Neutron Energy”, *Nucl. Sci. Eng*. 126, 201 (1997).

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Facilities

Fusion Neutronics Source (FNS)
Type of facility: 14 MeV neutron source
$^{3}H(d,n)^{4}He$
d+ beam specification: 350 keV, up to 20 mA
Neutron yield up to 3 × 1012 n/s

Measurements recently completed or in progress

1. *Activation cross-section measurement*
Activation cross-section measurements have been continued at JAERI using the FNS D-T neutron source. In 1996 fiscal year, 12 reaction cross-sections were measured at an energy range from 13.3 to 14.9 MeV. The reactions measured are listed in Table 1.

Table 1. Reactions and half-lives of products

Reaction			T1/2	Energy (keV)	Int. (%)
^{17}O	(n,p)	^{17}N	4.17s	870.8	3
^{74}Ga	(n,a)	^{71g}Zn	2.4 m	121.5	9.3
^{104}Ru	(n,p)	^{103}Tc	50 s	346.4	17.5
^{106}Pd	(n,np)	^{105m}Rh	42.4 s	129.6	20
^{108}Gd	(n,np)	^{105m}Ag	7.23 m	319.2	4.6
^{113}Cd	(n,p)	^{113m}Ag	1.15 m	316.1	10
^{124}Te	(n,p)	$^{124m1,2}Sb$	1.55 m	498.4	25
^{150}Nd	(n,np)	^{149}Pr	2.3 m	138.5	138.5
^{164}Dy	(n,np)	^{163}Tb	19.5 m	494.5	22.5
	(n,a)	^{161}Gd	3.7 m	360.9	60.6
^{180}W	(n,2n)	^{179m}W	6.4 m	238.7	0.22
^{188}Os	(n,p)	^{188m}Re	18.6 m	105.9	10.8
^{188}Os	(n,np)	^{188m}Re	18.6 m	105.9	10.8

The data processing is underway and results will be available soon.

2. *Fusion neutronics integral experiment*
   Integral neutronics experiments were conducted on several advance structural and breeder materials, i.e. $Li_2Zr_2O_4$, $Li_2Ti_2O_4$, vanadium and vanadium alloy, driven by 14 MeV neutrons at FNS. The experiments were carried out under the IEA collaboration framework on fusion reactor technology. Neutronics responses for neutron spectra, gamma-ray spectra, gamma-ray heating, foil activation rates, fission rates were measured in the systems consisted of those materials. The experimental data were analysed with state-of-the-art calculation codes and nuclear data, e.g. FENDL-1, FENDL-2, JENDL-Fusion file. The experimental data are to be available after discussion with participants in the IEA collaboration.

3. *Induced radioactivity characteristics measurements for low activation materials*
   Induced radioactivity measurements on so-called low activation materials for fusion reactors were carried out in the framework of the above mentioned IEA collaboration. The F82H ferretic steel, SiC, vanadium and vanadium alloy along with SS-316LN(EG) were irradiated with a d-Be and d-Li neutron sources at FZK, in which the deuteron beam energies were 20 and 40 MeV, respectively. Low activation characteristics of the materials were demonstrated experimentally in comparison with that of the SS-316LN(EG) reference steel.

4. *Decay heat measurement for fusion reactor materials*
   In order to provide experimental data for validation of decay heat calculation codes and relevant nuclear data, decay heats of radioactivities induced in various materials irradiated by 14 MeV neutron were measured with a newly developed whole energy absorption spectrometer (WEAS). WEAS consisted of twin large size BGO scintillators facing each other. A sample was placed between the two scintillators and all radiation (β-ray and γ-ray) energies associated with decay of radioactivities were detected and the total summed energy spectrum were converted to the decay heat. Samples of Al, Ti, V, Fe, Co, Ni, Cu, Zr, Nb, Mo, Ta, W, Pb, SS304, SS316, Inconel-600, NiChrom, CF_2, B_4C, Na_2CO_3, SiO_2, S, K_2CO_3, CaO, Cr, Mn, $SrCO_3$, Y_2O_3, SnO, $BaCO_3$, Re, Bi were studied. They were irradiated with 14 MeV neutrons at FNS and decay heats of them were measured with WEAS at remote location under low background. Irradiation and cooling times were 5 min. and 0.5 min. ~1 hour, respectively, for short-lived activities and 7 hours and 1 day ~several years, respectively, for long-lived.

   The decay heat experimental data were compared with calculations using ACT4 code with FENDL/A-1, A-2, JENDL-ACT96 activation libraries, decay libraries based on ENSDF. It was found that FENDL/A-2 is adequate for the ITER relevant nuclear design.

5. *Secondary gamma-ray production cross-section measurement with 14 MeV neutron beam*
   We have started a measurement of secondary gamma-ray production cross-sections at 14.1 MeV at FNS. A collimated 14 MeV neutron beam through a heavy collimator shielding which separates 14 MeV neutron source and gamma-ray detector was employed DC mode, i.e. without a pulsed mode, in order to make the system more efficient in terms of overall measurement time. The shield collimator consists of 500 mm pre-collimator made of iron, 1 600 mm thick iron layer, 400 mm polyethylene layer and 200 mm lead layer. The size of the collimated neutron beam was 20 mm in diam. The ratio of neutron flux to the background was measured to be more than 104. A Compton suppressed (BGO scintillator) germanium detector was used for a prompt gamma-ray spectrum. Preliminary measurements were carried out on Al, Mg, Ti, Fe, Ni, Cu, Nb, Mo and W target materials whose dimension was 15 mm in diam. × 15 mm thick. According to a preliminary data analysis, the system significantly decreased the overall experimental time comparing to the conventional scheme with pulsed neutrons. Final data analysis is now underway.

Recent publications

1. Y. Kasugai, Y. Ikeda, H. Yamamoto and K. Kawade, "Systematics for (n,p) Excitation Functions in the Neutron Energy Between 13.3 and 15.0 MeV", *Ann. Nucl. Energy* 23, 1429 (1996).

2. Y. Kasugai, H. Yamamoto, K. Kawade and T. Iida, "Measurement of (n,p) Cross-Sections for Short-Lived Products by 13.4-14.9 MeV Neutrons", *Ann. Nucl. Energy* 25, 23 (1998).

3. Y. Kasugai, Y. Ikeda, H. Yamamoto and K. Kawade, "Systematics for (n,a) Excitation Functions in the Neutron Energy Between 13.3 and 15.0 MeV", *Ann. Nucl. Energy* 25, 421 (1998).

4. F. Maekawa and Y. Ikeda, "Development of Whole Energy Absorption Spectrometer for Decay Heat Measurement on Fusion Reactor Materials", Proc. '96 Symposium on Nuclear Data, 21-22 Nov. 1996, JAERI, Tokai, JAERI-Conf 97-005, pp. 182-186 (1997).

5. F. Maekawa, Y. Ikeda and M. Wada, "Decay Heat Measurement on Fusion Reactor Materials and Validation of Calculation Code Systems", Proc. '97 Symposium on Nuclear Data, 27-28 Nov. 1997, JAERI, Tokai, JAERI-Conf 98-003, pp. 162-167 (1998).

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Facilities

1. TIARA: K-110 AVF Cyclotron (Ep = 90 MeV). Pulse width sub nsec, frequency typically 20-40 MHz without chopper, reduced by 1 factor of 6 with chopper. Quasi-monoenergetic neutron sources 43, 53, 57, 68 and 87 MeV through ^{7}Li(p,n) reaction.

2. Detectors: Neutron detectors; liquid scintillators (NE-213, BC501A), proton recoil counter telescope, fission counter, solid state nuclear track detector, Bonner-detector. Charged particle detector; counter telescope. γ-detector; Hp-Ge.

Measurements recently completed or in progress

1. Development of p-Li quasi-monoenergetic neutron fields, with Tohoku University. Published at “Gensikaku Kenkyu”.

2. Carbon, silicon and iron (n,xp) and (n,xd) DDX at 75 MeV, with Tohoku University. Presented at Gatlinburg Conference.

3. Carbon and aluminium (p,xp) and (n,xd) DDX at 70 MeV, with Kyushu University.

4. Carbon, iron and lead (n,xn) DDX at 75 MeV, with Tohoku University.

5. Spallation reaction cross-sections between 44 and 87 MeV, with Tohoku and Tokyo University and RIKEN. Presented at JAERI Symposium on Nuclear Data.

6. Thick target yields of neutrons and photons produced by charged particles of several tens MeV/nucleon, with Kyoto University. Presented at JAERI Symposium on Nuclear Data, Intl. Conf. Radn. Dosim. Safety.

7. Shielding experiments, with Tohoku University. Published in *Nucl. Sci. Eng.* and *J. Nucl. Sci. Tech.*

8. Development of new neutron detector.

Measurements planned for the near future

1. Carbon and aluminium (p,xn) DDX with Kyushu University.

2. Iron (n,xγ) cross-section with Kyoto University.

Recent publications

1. M. Baba, T .Iwasaki, T. Kiyosumi, Y. Nauchi, M. Yoshioka, S. Matsuyama, T. Nakamura, Su. Tanaka, H. Nakashima, S. Meigo, Sh. Tanaka and N. Nakao, "Characterization of ^{7}Li(p,n) Neutron Source", *Gensikaku Kenkyu* Vol. 41, No. 3 (1996) 3.

2. Y. Nauchi, M. Baba, T. Kiyosumi, T. Iwasaki, T. Sanami, S. Matsuyama, N. Hirakawa, S. Tanaka, S. Meigo, H. Nakashima, T. Nakamura, Y. Watanabe and M. Harada, "Measurement of Double Differential Charged Particle Emission Cross-Sections and Development of a Wide Range Charged Particle Spectrometer for Tens MeV Neutrons", Proc. 1996 Symp. on Nuclear Data, JAERI-Conf. 97-005 (1997) 126.

3. Y. Nauchi, M. Baba, T. Sanami, T. Nakamura, S. Tanaka, S. Meigo, Y. Watanabe, M. Harada and H. Takada, "Measurement of (n,xp), (n,xd) Double Differential Cross-Sections of Al and C for Tens MeV Neutrons", Proc. Intl. Conf. on Nucl. Data for Science and Technology, (Trieste, May 1997) to be published.

4. M. Harada, Y. Watanabe, K. Sato and S. Meigo, "Development of a System of Measuring Double Differential Cross-Sections for Proton-Induced Reactions", Proc. of the 1996 Symp. on Nuclear Data, 21-22 Nov. 1996, JAERI, Tokai, Japan, JAERI-Conf 97-005 (1997), pp. 240-245.

5. E. Kim, T. Nakamura, A. Konno, M. Imamura, N. Nakao, S. Shibata, Y. Uwamino, N. Nakanishi, Su. Tanaka, H. Nakashima and Sh.Tanaka, "Measurement of Neutron Spallation Cross-Sections", Proc. 1995 Symp. on Nuclear Data, JAERI-Conf 96-008 (1996) 236.

6. E. Kim, T. Nakamura, M. Imamura, N. Nakao, S. Shibata, Y. Uwamino, N. Nakanishi and Su. Tanaka, "Measurement of Neutron Spallation Cross-Sections (2)", Proc. 1996 Symp. on Nuclear Data (Tokai, Nov. 1996) JAERI-Conf 97-005 (1997) 194.

7. S. Meigo, H. Takada, H. Nakashima, T. Nakamura, T.S. Soewarsono, Y. Uno, T. Sasa, Su. Tanaka, K. Shin and S. Ono, "Measurement of Neutron Spectra from Stopping-Length Targets Bombarded with Light Ions", Proc. 1995 Symp. on Nuclear Data, (Tokai, Nov. 1995) JAERI-Conf. 96-08 (1996) 217.

8. K. Shin, S. Ono, S. Meigo, H. Takada, H. Nakashima, T. Sasa, S. Tanaka, "Thick Target Neutron Yields of C, Fe, Zr for 220-MeV C and 460-MeV Ar Ions", Proc. 1997 Intl. Conf. on Radiation Dosim. and Safety, 31 March-2 April 1997, Taipei.

9. N. Nakao, M. Nakao, H. Nakashima, Su. Tanaka, Y. Sakamoto, Y. Nakane, Sh. Tanaka and T. Nakamura, "Measurements and Calculations of Neutron Energy Spectra Behind Polyethylene Shields Bombarded by 40- and 65-MeV Quasi-Monoenergetic Neutron Sources", *J. Nucl. Sci. Tech*. 34 (1997) 348.

10. N. Nakao, H. Nakashima, T. Nakamura, Sh. Tanaka, Su. Tanaka, K. Shin, M. Baba, Y. Sakamoto and Y. Nakane, "Transmission Through Shields of Quasi-Monoenergetic Neutrons Generated by 43- and 68-MeV Protons – I: Concrete Shielding Experiment and Calculation for Practical Application", *Nucl. Sci. Eng*. 124 (1996) 228.

11. H. Nakashima, N. Nakao, Sh. Tanaka, T. Nakamura, K. Shin, Su. Tanaka, H. Takada, S. Meigo, Y. Nakane, Y. Sakamoto and M. Baba, “Transmission Through Shields of Quasi-Monoenergetic Neutrons Generated by 43- and 68-MeV Protons – II: Iron Shielding Experiment and Analysis for Investigating Calculational Method and Cross-Section Data”, *Nucl. Sci. Eng*. 124 (1996) 243.

12. T. Iwasaki, Y. Sakuya, T. Tabei, N. Hirakawa, Y. Sakamoto, H. Nakashima and Su. Tanaka, “Fission Reaction Rate Distribution of ^{237}Np in Polyethylene System for 65 MeV Neutron”, Proc. Int. Conf. Future Nuclear Systems (Yokohama, Oct. 1997).

13. S. Meigo, “Measurements of the Response Function and the Detection Efficiency of an NE213 Scintillator for Neutrons Between 20 and 65 MeV”, *Nucl. Instr. and Meth*. A401 p. 365 (1997).

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Facilities

1. Detectors: Ge-detectors; NE213 liquid scintillators; ^{3}He counters; high-resolution and high-energy photon spectrometer(HHS).

2. Mass analyser: Quadrupole mass analyser for RI target analysis.

Measurements recently completed or in progress

1. Photoabsorption cross-section on ^{18}O to 13 MeV with electrotechnical lab (Tsukuba).

2. Thermal neutron capture cross-section and resonance integrals on ^{135}Cs.

Measurements planned for the near future

1. Photoabsorption cross-section on ^{13}C.

2. Thermal neutron capture cross-section and resonance integrals on ^{133}Cs and ^{127}I.

Recent publications

1. T. Katoh, S. Nakamura, H. Harada, Y. Hatsukawa, N. Shinohara, K. Hata, K. Kobayashi, S. Motoishi, and M. Tanase, “Measurement of Thermal Neutron Cross-Section and Resonance Integral of the Reaction ^{135}Cs(n,γ)^{136}Cs”, *J. Nucl. Sci. Technol*. 34, 431 (1997).

2. H. Harada, Y. Shigetome, H. Ohgaki, T. Noguchi and T. Yamazaki, “High-Resolution Measurement of Fine Structure in the Photoabsorption Cross-Section of ^{18}O”, *Phys. Rev. Lett*. 80, 33 (1998).

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Facilities

1. 3U-HC Pelletron: 3 MV single end Pelletron, DC or pulsed(1 ns) beam, monoenergetic neutron sources about 10 keV to 6 MeV through ^{7}Li(p,n), D(d,n) and other reactions.

2. Detectors: Gamma-ray detectors(anti-Compton NaI(Tl)s, anti-Compton HPGe, large NaI(Tl)s with an annular plastic scintillator); plastic and liquid scintillators; gas scintillation drift chamber.

Measurements recently completed or in progress

1. (n,γ) on ^{140}Ce, ^{141}Pr, ^{143,145}Nd, ^{147,148,149,150,152,154}Sm, ^{153}Eu, ^{161,162,163}Dy and ^{167}Er from 10 to 550 keV, some results in a paper at Global'97.

2. (n,γ) on ^{237}Np from 10 to 100 keV, result recently obtained.

3. (n,γ) on ^{6}Li from 10 to 100 keV, result recently obtained.

Measurements planned for the near future

1. (n,γ) on ^{3}He, ^{18}O and ^{22}Ne from 10 to 100 keV.

2. (n,γ) on ^{16}O from 300 to 600 keV.

3. (n,γ) on ^{146}Nd, ^{151}Eu and ^{166}Er from 10 to 550 keV.

4. (n,γ) on ^{237}Np from 100 to 550 keV.

Recent publications

1. H. Kitazawa, K. Go and M. Igashira, "Direct Neutron Capture in a Generalized Optical Potential", Proc. 9th Intl. Symp. on Capture Gamma-Ray Spectroscopy and Related Topics, Budapest, Hungary, 1996, eds., G.L. Molnar, T. Belgya and Zs. Revay (Springer Hungarica, Hungary, 1997) 348-352.

2. M. Igashira, S.Y. Lee, S. Mizuno and H. Kitazawa, "Measurements of Gamma Rays from keV-Neutron Resonance Capture by Odd-Z Nuclei in the 2s-1d Shell Region", *ibid*., 430-431.

3. S. Mizuno, M. Igashira and H. Kitazawa, “Measurements of keV-Neutron Capture Gamma Rays of ^{161,162,163}Dy”, *ibid*., 434-435.

4. Y. Nagai, T. Shima, T. Kikuchi, T. Kii, T. Kobayashi, F. Okazaki, T. Baba, K. Takaoka, S. Naito, A. Tomyo, M. Igashira, T. Ohsaki and S. Ishikawa, “Nuclear Astrophysics Studies by Neutron Capture Reaction on Light Nuclei”, *ibid*., 501-507.

5. M. Igashira, S. Mizuno, Y. Ohkawachi, T. Wakabayashi, “Measurement of keV-Neutron Capture Cross-Sections of Rare Earth Nuclides”, Proc. Intl. Conf. on Future Nuclear Systems: Global’97, Yokohama, Japan, 1997 (1997) 1360-1364.

6. Y. Nagai, T.S. Suzuki, T. Kikuchi, T. Shima, T. Kii, H. Sato and M. Igashira, “Measurement of ^{1}H(n,γ)^{2}H Reaction Cross-Section at a Comparable M1/E1 Strength”, *Phys. Rev*. C, 56 (1997) 3173-3179.

7. H. Kitazawa, K. Go and M. Igashira, “Low-Energy Neutron Direct Capture by ^{12}C in a Dispersive Optical Potential”, *Phys. Rev*. C, 57 (1998) 202-209.

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Facilities

1. Kyoto University Reactor (KUR) of 5 MW: A light water moderated, tank type research reactor with 93% enriched fuels. Beam tubes: Fe-filtered beam, triple-axis neutron spectrometer, four-circle neutron diffractmeter, neutron mirror guide and neutron scattering experiments, irradiation for general purposes, neutron radiography, neutron mirror guide and neutron spin echo experiments, low temperature irradiation loop, isotope separator on-line. Irradiation facilities: Hydraulic conveyor located at the core centre, three pneumatic irradiation tubes located in the reflector, slant exposure tube located outside the reflector. Thermal columns: Graphite thermal column (cold neutron source), heavy water thermal column (neutron standard field, BNCT and radiation biology).

2. MeV Electron Linear Accelerator: Maximum beam power 10 kW, 180 Hz (for 4 micro-sec width) to 400 Hz (for 10 to 100 nano-sec), a water-cooled Ta target with about 10E + 12 n/sec neutron production. Neutron time-of-flight (TOF) method for neutron total and capture cross-section measurements, lead slowing-down spectrometer coupled to the linac.

3. MeV neutron generator. This is attached with Kyoto University Critical Assembly (KUCA). 14 MeV neutrons are generated through T(d,n) reaction. It can be operated in both DC and pulsed mode. Peak neutron yield is about 1011 n/sec for pulsed operation and 109 n/sec for DC operation, respectively. A neutron flight path (9 m) is equipped for TOF measurement. Neutron pulses with 200 nano-sec or wider width are available.

Measurements recently completed or in progress

1. Fission cross-section measurements of ^{241}Am between 0.1 eV and 10 keV with lead slowing-down spectrometer and at thermal neutron energy, paper published by *Nuclear Science and Engineering*, Vol. 126, No. 2, 201-212 (1997).

2. Measurement of fission cross-sections for nuclear transmutation on ^{241}Am, ^{242m}Am and ^{243}Am using lead slowing-down spectrometer, paper accepted for publication for the International Conference on Future Nuclear System, Global'97 on 5-10 October 1997, Yokohama, Japan.

3. Measurement of the ^{243}Am(n,f) cross-section between 0.1 eV and 10 keV using lead slowing-down spectrometer, paper accepted for publication by the International Conference on Nuclear Data for Science and Technology, on 19-24 May 1997, Trieste, Italy.

4. Fission cross-section measurement of ^{242m}Am using lead slowing-down spectrometer, paper accepted by the 1997 Symposium on Nuclear Data at Tokai-mura, JAERI, on 27-28 Nov. 1997.

5. Fission cross-section measurement of ^{242m}Am between 0.003 and 4 eV by linac neutron time-of-flight method, in progress.

6. Measurement of thermal neutron induced fission cross-section for ^{243}Am(n,f) using a pure Maxwellian distribution thermal neutron field, in progress.

7. Fission cross-section measurement of ^{231}Pa using lead slowing-down spectrometer, in progress.

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Facilities

1. OKTAVIAN (Osaka University Intense 14 MeV Neutron Source Facility): Pulsed and DC DT neutron source and ion beams such as proton, deuteron and helium up to 350 keV. Pulsed neutrons and ions with about 2 nsec pulse width and repetition frequency of 2 MHz to 1 kHz for TOF experiments. DC neutrons with fixed water-cooled tritium target in stead of rotating tritium target are available since last year.

2. Detectors: Various detectors including neutron detectors (large NE213 scintillators (10" dia. $\times$ 10 cm, 5" dia. $\times$ 5") for neutron DDX measurement, Li-glass scintillator for lower energy neutron measurement), charged particle detectors (ΔE-E system with SSD and Cd-Te detector for RBA, NRA and other ion beam implantation experiment, CsI scintillator for charged particle emission reaction cross-section measurement), gamma-ray detectors (large HpGe detector and large NaI scintillator for gamma-ray production cross-section measurement), fission chamber and proportional counters.

Measurements recently completed or in progress

1. Proton and α-particle emission reaction cross-sections of Zr, V and Ti for 14 MeV neutrons; manuscript in preparation.

2. Low energy deuteron induced particle emission cross-sections for Be; investigations continue.

3. Gamma-ray production cross-section of fusion structural materials for 14 MeV neutrons; further experimental data obtained.

4. (n,2n) reaction cross-sections of fission products for 14 MeV neutrons; investigations continue.

Measurements planned for the near future

1. Charged particle emission reaction cross-sections for light nuclides.

2. Low energy charged particle induced reaction cross-sections.

3. Reaction cross-sections of fission products.

4. Preliminary improvement of neutron induced charged particle measurements.

5. Preliminary investigation of (n,xγ) reaction cross-section measurements.

Recent publications

1. A. Takahashi, I. Murata, Kokooo, S. Ogino, Y. Murakami, H. Nishizawa and T. Kondo, "A Time-of-Flight Spectrometer with Pulse-Shape Discrimination for the Measurement of Double Differential Charged-Particle Emission Cross-Sections", *Nucl. Instr. Meth*. 401, 93 (1997).

2. Kokooo, I. Murata and A. Takahashi, "Measurements of Double Differential Cross-Sections of Charged Particle Emission Reactions by 14.1 MeV Incident Neutrons", Proc. Intl. Conf. on Nucl. Data for Sci. and Technol., Trieste, May 1997 (to be published).

3. I. Murata, D. Nakano and A. Takahashi, "Measurement of DT Neutron Cross-Section of ^{129}I with Foil Activation Method", Proc. Intl. Conf. on Nucl. Data for Sci. and Technol., Trieste, May 1997 (to be published).

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Facilities

10 MV Tandem Van de Graaf accelerator (Kyushu University Tandem Laboratory (KUTL), Department of Physics): DC operation. Unpolarised and polarised proton and deuteron beams with energies up to 20 MeV. Other heavy ions are also available.

Measurements recently completed or in progress

1. Double differential cross-sections (DDXs) of (p,p′) for ^{56}Fe and ^{93}Ni at an incident energy of 14.1 MeV.

2. DDXs of (p,p′) and (p,α) for ^{12}C at incident energies of 14 and 18 MeV.

3. DDXs of (p,p′) for ^{54,56}Fe, ^{90}Zr and ^{93}Nb at an incident energy of 26 MeV using JAERI tandem accelerator in collaboration with JAERI nuclear data group.

Measurements planned for the near future

1. DDXs of light-ions emitted from proton-induced reactions on several targets (^{12}C, ^{27}Al, ^{90}Zr, etc.) at three incident energies of 45, 70 and 90 MeV using JAERI/Takasaki AVF cyclotron facility.

2. Development of a quasi-monoenergetic neutron source for energies between 7 and 11 MeV using ^{1}H(^{13}C,n) or ^{1}H(^{11}B,n) reaction at KUTL and measurements of activation cross-sections in the energy region.

Recent publications

1. S. Yoshioka, Y. Watanabe, M. Harada, K. Sato, Y. Nakao, H. Ijiri, S. Chiba, T. Fukahori, S. Meigo, O. Iwamoto, N. Koori, “A Consistent Analysis of (p,p′) and (n,n′) Reactions Using the Feshbach-Kerman-Koonin Model”, Proc. of the 1996 Symp. on Nuclear Data, 21-22 Nov. 1996, JAERI, Tokai, Japan, JAERI-Conf 97-005 (1997), pp. 301-306.

2. M. Harada, Y. Watanabe, K. Sato, and S. Meigo, “Development of a System of Measuring Double Differential Cross-Sections for Proton-Induced Reactions”, Proc. of the 1996 Symp. on Nuclear Data, 21-22 Nov. 1996, JAERI, Tokai, Japan, JAERI-Conf 97-005 (1997), pp. 240-245.

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Facilities

None (experiments are carried out by the use of the 12-GeV proton synchrotron of High Energy Accelerator Research Organisation (KEK)).

Measurements recently completed or in progress

1. (p,pn) and (p,2p) quasi-elastic scattering cross-sections for C and He at an incident proton energy of 1 GeV.

Measurements planned for the near future

1. (pi,xn) double differential cross-sections at pi energies around 1 GeV.

2. (p,xn) yield for thick W target at a proton energy of 1.5 GeV, in collaboration with JAERI.

Recent publications

1. K. Ishibashi, H. Takada, T. Nakamoto, N. Shigyo, K. Maehata, N. Matsufuji, S. Meigo, S. Chiba, M. Numajiri, Y. Watanabe, T. Nakamura, “Measurement of Neutron-Production Double Differential Cross-Sections for Nuclear Spallation Reaction Induced by 0.8, 1.5 and 3.0 GeV Protons”, *J. Nucl. Sci. Technol*., Vol. 34, 529 (1997).

2. T. Nakamoto, K. Ishibashi, N. Matsufuji, N. Shigyo, K. Maehata, H. Arima, S. Meigo, H. Takada, S. Chiba, M. Numajiri, “Experimental Neutron-Production Double Differential Cross-Section for the Nuclear Reaction by 1.5-GeV Pi+ Mesons Incident on Iron”, *J. Nucl. Sci. Technol*., Vol. 34, 860 (1997).

3. K. Iga, N. Shigyo, N. Matsufuji, T. Nakamoto, K. Maehata, K. Ishibashi, M. Numajiri, S. Meigo, H. Takada, S. Chiba, T. Nakamura, Y. Watanabe, “Photon-Production Differential Cross-Sections for Spallation Reaction at Incident Proton Energies of 0.8-3.0 GeV”, Proc. of International Conference on Nuclear Data for Science and Technology, Trieste, May 1997 (to be published).

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Facilities

1. 4.5 MV single stage Van de Graaf EG-1, DC or pulsed (1-2 ns); average current: ~30 μA (DC), ~5 μA (2 MHz); monoenergetic n-sources: ^{7}Li(p,n), T(p,n), D(d,n), T(d,n); white n-source with thick target ^{7}Li(p,n), Be(d,n).

2. 2.5 MV cascade accelerator KG-2.5, DC (<500 μA); monoenergetic n-sources: ^{7}Li(p,n), T(p,n), D(d,n), T(d,n).

3. 4.5 MV tandem accelerator EGP-10M, DC or pulsed (1 nsec), monoenergetic n-sources: T(p,n), D(d,n)-solid and gas targets, ^{7}Li(p,n) metal target.

4. 14 MeV neutron source on the base cascade accelerator KG-0.3, DC or pulsed (2 MHz, 1-2 ns) d average current: DC < 50 μA, pulsed mode ~10 μA, flight path up to ~10 m.

5. 7.5 MV tandem accelerator EGP-15, in progress for neutron data measurements.

Detectors: Plastic and liquid scintillator; Li glass scintillator, NaI, BGO and Ge(Li) detectors, fast fission chambers, gridded ionisation chambers; time of flight neutron spectrometers.

Measurements recently completed or in progress

1. ^{244}Cm, ^{246}Cm, ^{248}Cm fission cross-sections. Cross-sections measured between 130 keV and 7 MeV, Van de Graaf monoenergetic neutrons. Measurements were supported by ISTC foundation and already completed.

2. ^{237}Np fragment mass, energy and nuclear charge distribution. Measurement at cascade accelerator with on-line pulse shape analysis. Measurements were supported by ISTC foundation and already completed.

3. ^{232}Th fragment mass, energy and nuclear charge distribution. Measurement at cascade accelerator with on-line pulse shape analysis. The measurements are in progress now.

4. Inelastic neutron scattering for ^{237}Np. EG-1 TOF spectrometer, neutron energy 1-2.5 MeV. Measurements were supported by ISTC foundation and already completed.

5. ^{237}Np total cross-section. Measurements were carried out in resonance region from 1 eV to 100 keV with pulsed reactor IBR-30 and in energy range 200 keV-8 MeV with ^{252}Cf neutron source. The resonance data are being evaluated now.

6. Delayed neutron yield for ^{237}Np. Measurements were supported by ISTC foundation and are already completed.

7. Prompt fission neutron spectra for ^{235}U at incident energy 5-13 MeV.

8. (α,n) double differential cross-section (collaboration with CIAE, Beijing-IPPE). CIAE HI-13 tandem accelerator, ^{56}Fe, ^{93}Nb, ^{115}In data are being evaluated now.

9. Elastic proton scattering for ^{56}Fe at 3-4.3 MeV energy range.

Measurements planned for the near future

1. Cm isotopes fission cross-section in the energy range from 30 eV to 50 keV with slowing-down spectrometer of Moscow Meson Facility.

2. Detailed measurement of mass yields and energy distribution of the fission fragments for ^{238}U spontaneous fission.

3. ^{232}Th, ^{233}U delayed neutron yields at incident energy range 1-5 MeV and ~14 MeV.

4. Inelastic neutron scattering on separate levels of ^{232}Th at 0.2-0.6 MeV incident energy range.

5. Leakage neutron spectra for ^{232}Th sphere and total cross-section for ^{232}Th and ^{233}U.

Recent publications

1. N.S. Rabotnov, *et al*., Measurements and Analysis of the Basic Neutron Data for Minor Actinides, final report for ISTC-304 project, 1997.

2. A.F. Gurbich, A.V. Ignatyuk, Cross-Section Database for Ion Beam Analysis, report for Intl. Conf. NDST-97 (Trieste, Italy, 1997).

3. A.F. Gurbich, Evaluation of Non-Rutherford Proton Elastic Scattering Cross-Section for Carbon, *Nucl. Instr. and Meth*. B, in press.

4. A.F. Gurbich, PIGE with Pulsed Beam for High Sensitivity, *Nucl. Instr. and Meth.* V. B129 (1997) p. 439.

5. G.N. Lovchikova, *et al*., Energy Distribution of (n,f) Neutrons for Th-Pu Nuclei, *J. Nucl Phys*., in press.

6. B.I. Fursov, V.N. Polynov, B.F. Samylin, V.S. Shorin, Fast Neutron Induced Fission Cross-Sections of Some Minor Actinides, in Proc. Intl. Conf. on Nuclear Data for Science and Technology, Trieste, Italy, 14-19 May 1997.

7. S.A. Badikov, B.I. Fursov, V.S. Shorin, Evaluation of the Fast Neutron Induced Fission Cross-Sections of $^{242-248}$Cm, in Proc. Intl. Conf. on Nuclear Data for Science and Technology, Trieste, Italy, 14-19 May 1997.

8. V.A. Khryachkov, A.A. Goverdovski, V.V. Ketlerov, V.F. Mitrofanov, N.N. Semenova, Direct Experimental Determination of Frisch Grid Inefficiency in Ionization Chamber, NIM, 1997, Vol. A394. pp. 261-264.

9. A.A. Goverdovski, Energy Dependence of Fission Product Yields, in IAEA-TECDOC, 1997, Vienna, Austria.

10. V.A. Khryachkov, A.A. Goverdovski, V.V. Ketlerov, V.F. Mitrofanov, N.N. Semenova, Fission Fragments Spectrometer Based on Ionization Chamber and Wavefopm Digitizer, in Proc. Intl. Symp. ISINN-5, Dubna, May 1997.

11. A.A. Goverdovski, V.A. Khryachkov, V.V. Ketlerov, V.F. Mitrofanov, N.N. Semenova, Yu.B. Ostapenko, Fast Neutron Induced Fission of ^{237}Np: Mass Spectra at High Kinetic Energies, in Proc. Intl. Symp. ISINN-5, Dubna, May 1997.

12. A.A. Goverdovski, V.A. Khryachkov, V.V. Ketlerov, V.F. Mitrofanov, N.N. Semenova, Yu.B. Ostapenko, Measurements of Fission Products Yields for Fast Neutron Induced Fission of ^{237}Np, in Proc. Intl. Conference on Nuclear Data for Science and Technology, Trieste, Italy, 14-19 May 1997.

13. V.V. Ketlerov, Multiparameter PC-CAMAC Acquisition Systems, in Proc. Intl. Sem. DANEF'97, Dubna, June 1997.

14. A.A. Goverdovski, Yu.B. Ostapenko, Time Scale of Fission Process of Cold Heavy Nuclei, in Proc. Intl. Symposium: Nuclear Physics-III, Tours, France, 2-5 September 1997.

15. A.A. Goverdovski, V.F. Mitrofanov, New Fission Mode of Uranium, in Proc. Intl. School Seminar on Heavy Ions Physics, Dubna, September 1997.

16. V.A. Khryachkov, *et al*., Method for Energy Calibration of Ionization Chamber, submitted to PTE, in Russian.

17. A.A. Goverdovski, V.A. Khryachkov, V.V. Ketlerov, V.F. Mitrofanov, N.N. Semenova, Yu.B. Ostapenko., Measurements of Fission Products Yields Data in Fast Neutron Induced Fission of Reaction of ^{237}Np, INDC, Vienna, 1998, in press.

18. A.S. Soldatov, Photofission Reaction Cross-Section for ^{234}U for Energy Range 5-9 MeV in Compare with Data for ^{232}Th and ^{237}Np, VANT, *Nucl. Data*, 1997, in Russian.

19. A.S. Soldatov, Photofission Reaction Cross-Section for ^{238}Pu, ^{240}Pu and ^{242}Pu, VANT, *Nucl. Data*, 1997, in Russian.

20. D.L. Shpak, Fission Fragment Angular Anisotropy of ^{233}U for Neutron Induced Fission in the Energy Range 0.02-6.38 MeV, *J. Nucl. Phys.*, 1997, in press.

21. Yu.V. Grigoriev, V.V. Sinitsa, *et al*., Resonance Structure and Temperature Dependence of ^{239}Pu Cross-Section, VANT, *Nucl. Data*, 1997, 1-3, p. 3, in Russian.

22. Yu.V. Grigoriev, V.V. Sinitsa, H. Fajkov-Stanczyk, G.P. Georgiev and Hyon Syng Ho, The Gamma-Ray Multiplicity Spectra and the Alpha Value for ^{239}Pu in Groups and Resolved Resonances, Proc. of 5th Intl. Seminar on Interaction of Neutrons with Nuclei, Dubna, 14-17 May 1997, Proc. of Intl. Conf. on Nuclear Data for Science and Technology, Trieste, Italy, 24-27 May 1997.

23. H. Faikov-Stanczyk, G.P. Georgiev, Yu.V. Grigoriev, Hyon Syng Ho, Measurements of Gamma-Ray Multiplicity Spectra and the Alpha Value for ^{239}Pu in Groups and Resolved Resonances, pre-print JINR E3-97-212, Dubna, 1997.

24. A.A. Lychagin, B.V. Zhuravlev, V.I. Trykova, V.G. Demenkov, Neutron Total Cross-Section of ^{237}Np in Energy Range (0.5-9) MeV, Proc. of 5th Intl. Seminar on Interaction of Neutrons with Nuclei, Dubna, 14-17 May 1997.

25. B.V. Zhuravlev, N.N. Titarenko, V.I. Trykova, Zhou Zuying, Tang Hongqing, Qi Bujia, Zhou Chenwei, Du Yanfeng, Nuclear Level Density of ^{59}Ni from Measurements and Analysis of Differential Neutron Emission Cross-Sections in ^{56}Fe(α,n)^{59}Ni Reaction, Proc. of 5th Intl. Seminar on Interaction of Neutrons with Nuclei, Dubna, 14-17 May 1997.

26. B.V. Zhuravlev, Nuclear Level Density Near A = 208, Proc. of European Conf. on “Advances in Nuclear Physics and Related Areas”, Thessaloniki, Greece, 8-12 July 1997.

27. N.V. Kornilov, A.B. Kagalenko, V.Ya. Baryba, *et al*., Inelastic Neutron Scattering and Fission Neutron Spectra for ^{237}Np, Proc. of Intl. Conf. on Nuclear Data for Science and Technology. Trieste, Italy, 19-25 May 1997.

28. N.V. Kornilov, A.B. Kagalenko, V.G. Demenkov, *et al*., Fission Neutron Spectra for ^{237}Np at 0.52 MeV Incident Neutron Energy, Proc. of 5th Intl. Seminar on Interaction of Neutrons with Nuclei, Dubna, 14-17 May 1997, in press.

29. N.V. Kornilov, A.B. Kagalenko, V.G. Demenkov, V.Ya. Baryba, *et al*., Inelastic Neutron Scattering on ^{237}Np, Proc. of 5th Intl. Seminar on Interaction of Neutrons with Nuclei, Dubna, 14-17 May 1997, in press.

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31. N.V. Kornilov, A.B. Kagalenko, F.-J. Hambsch, The Calculation of the Fission Neutron Spectra on the Basis of New Systematic of the Experimental Data, *J. Nucl. Phys*, 1997, in press.

32. B.V. Devkin, M.G. Kobozev, S.P. Simakov, *et al*., Evaluation of Corrections for Spherical-Shell Neutron Transmission Experiments by the Monte Carlo Technique, VANT, *Nucl. Data*, 1997.

33. V.G. Pronyaev, V.P. Lunev, S.P. Simakov, Absolute Level Density from Analyses of Complete Set of Partial Cross-Sections, Proc. of Intl. Conf. on Nuclear Data for Sciences and Technology, Trieste, Italy, 19-25 May 1997, VANT, *Nucl. Data*, 1997, 1-2, p. 45.

34. S.P. Simakov, Status of Experimental and Evaluated Data for Discrete Gamma-Ray Production Data at 14.5 MeV Neutron Incident Energy, will be published in IAEA TEC DOC.

35. K.I. Zolotarev, *et al*., Evaluation of the ^{237}Np Cross-Sections, VANT, *Nucl. Data*, 1997, in Russian.

36. K.I. Zolotarev, A.V. Ignatjuk, V.A. Tolstikov, Neutron Capture Cross-Section for ^{241}Am, VANT, *Nucl. Data*, 1997, in Russian.

37. V.G. Pronyaev, V.M. Piksaikin, Factors Determining the Energy Dependence of Delayed Neutron Yields in Neutron Induced Fission, VANT, *Nucl. Data*, 1997, 1-2, p. 32.

38. V.M. Piksaikin, *et al*., Measurement of Delayed Neutron Yield and Periods for the ^{237}Np Fast Neutron Induced Fission, VANT, *Nucl. Data*, 1997, 1-2, p. 18, in Russian.

39. V.M. Piksaikin, *et al*., Absolute Efficiency of the 4π Neutron Detector, VANT, *Nucl. Data*, 1997, 1-2, p. 26, in Russian.

40. V.M. Piksaikin, *et al*., Measurements of Periods, Relative Abundances and Absolute Total Yields of Delayed Neutrons from Fast Neutron Induced Fission of ^{235}U and ^{237}Np, Proc. Intl. Conference on Nuclear Data for Science and Technology, Trieste, Italy, 19-24 May 1997.

41. V.M. Piksaikin, S.G. Isaev, *et al*., Absolute Calibration of Neutron Detector with ^{252}Cf Neutron Source, Monte Carlo Calibrations and Activation Technique, Proc. of Intl. Conference on Nuclear Data for Science and Technology, Trieste, Italy, 19-24 May 1997.

42. D.I. Tambovctsev, L.K. Kozlovski, *et al*., Investigation of Energy Dependence for Fission Fragment Angular Anisotropy in Resonance Neutron Induced Fission of ^{235}U, *J. Nucl. Phys*, 1997, Vol. 60, 6, p. 981.

43. W.I. Furman, N.N. Gonin, J. Kliman, Yu.N. Kopach, L.K. Kozlovsky, A.B. Popov, H. Postma, N.S. Rabotnov, D.I. Tambovtsev, Energy Dependence of Fission Fragment Angular Anisotropy in Resonance Neutron Induced Fission of ^{235}U", Dynamical Aspects of Nuclear Fission (DANF'96), Proc. of 3rd Intl. Conf., Casta-Papernicka, Slovakia, 30 Aug.-4 Sep. 1996, JINR E6 7-07-49, p. 356, Dubna, 1997.

44. A.A. Bogdzel, W.I. Furman, N.N. Gonin, Yu. Kopach, L.K. Kozlovsky, A.B. Popov, N.S. Rabotnov, D.I. Tamdovtsev, J. Kliman, H. Postma, Analysis of Energy Dependence of Fission Fragment Angular Anisotropy in Resonance Neutron Induced Fission of ^{235}U Aligned Target, ISINN-5, Abstracts, p. 82, Dubna, 14-17 May 1997, JINR E3-97-93, Dubna, 1997.

45. W.I. Furman, N.N. Gonin, Yu. Kopach, L.K. Kozlovsky, A.B. Popov, N.S. Rabotnov, D.I. Tamdovtsev, J. Kliman, H. Postma, Energy Dependence of Fission Fragment Angular Anisotropy in Slow Neutron Induced Fission of ^{235}U Aligned Target, Intl. Conf. on Nuclear Data for Science and Technology, Trieste, 19-24 May 1997.

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Facilities

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Gustaf Werner cyclotron: Isochronous mode <100 MeV protons and 196 Q^2/A MeV heavy ions. Synchrocyclotron mode <180 MeV protons. Unpolarised and polarised light ion sources as well as a heavy ion source. Neutron facility for production of 20-180 MeV quasi-monoenergetic neutrons, using the ^{7}Li(p,n) reaction.

The CELSIUS ring: Ions from the Gustaf Werner cyclotron can be injected, stored, cooled and accelerated in CELSIUS. The maximum energy for protons is 1360 MeV and for heavy ions with charge-to-mass ratio of one-half 470 MeV/nucleon. Cluster-jet, fibre and hydrogen pellet target systems in operation.

The Neutron Research Laboratory, Studsvik, S-61182 Nykoeping

The R2, 50 MW high flux swimming-pool reactor. About 10 different experimental channels are used for neutron scattering experiments with different types of neutron diffractometers. The R2-0, 1 MW reactor, is used as a neutron source for the on-line isotope separator OSIRIS, built for studies of short-lived fission products.

Measurements recently completed or in progress

Uppsala

1. Studies of nuclear structure by the (n,p) reaction and tests of intermediate-energy nuclear reaction cross-section calculation models.

2. Studies of neutron-proton scattering in the energy region 100-160 MeV.

3. Measurement of double-differential neutron-induced charged-particle production cross-sections for application in fast neutron cancer therapy.

4. Studies of neutron-induced single-event upsets in air plane electronics (in collaboration with Ericsson-SAAB Avionics, Linkoeping, Sweden).

5. Neutron-induced fission cross-section measurements of ^{208}Pb, ^{209}Bi and ^{238}U in the intermediate energy region (in collaboration with the Khlopin Radium Institute, St Petersburg, Russia).

6. Studies of the dynamics in the fission process (in collaboration with the Khlopin Radium Institute, St. Petersburg, Russia).

7. Measurements of residual nuclide production cross-sections of proton and neutron-induced reactions relevant for cosmology and accelerator-driven nuclear waste transmutation (in collaboration with Universitaet Hannover and Koeln).

8. Installation and test of a neutron spectrometer (magnetic proton recoil spectrometer (MPR)) at JET, Culham, UK. The spectrometer is used for neutron diagnostics of burning fusion plasmas.

Studsvik

1. Fundamental studies of nuclear spectroscopy for exotic neutron-rich nuclei (fission products) at the OSIRIS facility.

2. Measurement of the fission product yield for thermal fission of ^{233}U and ^{235}U, and for fast fission of ^{232}Th and ^{233}U.

3. Development of a radioactive beam facility (PIAFE) and experimental methods for radioactive beam research (NSCL, ATLAS) (in collaboration with several laboratories).

4. Studies of intermediate-energy nuclear reaction cross-section calculation models.

Measurements planned for the near future

1. Further high-precision measurements of neutron-proton scattering in the energy region 70-180 MeV.

2. Measurements of neutron elastic and inelastic scattering differential cross-sections at 100 MeV.

3. Measurements of double differential cross-sections for neutron-induced charged-particle production in the energy range 40-100 MeV of interest for fast neutron cancer therapy.

4. Studies of neutron-induced single event upsets in civil aviation electronics.

Recent publications

1. N. Olsson, Studies of Spin-Isospin Excitations with the (n,p) Reaction, *Nucl. Phys.* A599 (1996) 185c.

2. V.P. Eismont, A.V. Prokofyev, A.N. Smirnov, K. Elmgren, J. Blomgren, H. Conde, J. Nilsson, N. Olsson, T. Roennqvist and E. Traneus, Relative and Absolute Neutron-Induced Fission Cross-Sections of ^{208}Pb, ^{209}Bi and ^{238}U in the Intermediate Energy Region, *Phys. Rev*. C53 (1996) 2911.

3. A. Ringbom, A. Haakansson, G. Tibell, R. Zorro, H. Conde, J. Blomgren, J. Nilsson, N. Olsson, E. Ramstroem, T. Roennqvist, O. Jonsson, L. Nilsson, P.-U. Renberg and S.Y. van der Werf, The ^{208}Pb(n,p)^{208}Tl Reaction at En = 97 MeV, *Nucl. Phys*. A617 (1997) 316.

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Facilities

No relevant experimental facilities are available currently at Argonne National Laboratory.

Measurements recently completed or in progress

1. Neutron activation cross-sections measurements from 7.9-14.4 MeV at the cyclotron accelerator facility, Physikalisch-Technische Bundesanstalt (PTB), in collaboration with W. Mannhart and D. Schmidt (PTB), for the reactions ^{52}Cr(n,p)^{52}V, ^{52}Cr(n,2n)^{51}Cr, ^{51}V(n,p)^{51}Ti, and ^{51}V(n,α)^{48}Sc, have been analysed and the results were reported at the 1997 Trieste Conference (see *Recent publications* list).

2. An accurate measurement (±1.4%) has been performed for the ^{53}V half-life in collaboration with A. Fessler (IRMM). This radioactivity was generated through Cr(n,Xp) reactions induced by fast neutrons, produced at the IRMM Van de Graaff accelerator facility and incident on elemental chromium metal samples. The results of this work, which led to a 3.5% reduction in the ^{53}V half-life from the latest value quoted in the Nuclear Data Sheets and ENSDF, have been published in *Radiochimica Acta* (see *Recent publications* list).

3. The analysis of data for neutron activation cross-section measurements from 13-15 MeV performed at the JAERI-Tokai FNS neutron source on the reactions ^{11}B(n,p)^{11}Be, ^{16}O(n,p)^{16}N, ^{19}F(n,α)^{16}N, ^{19}F(n,p)^{19}O, ^{23}Na(n,p)^{23}Ne, ^{28}Si(n,p)^{28}Al, ^{37}Cl(n,p)^{37}S, ^{46}Ti(n,p)^{46m}Sc, ^{52}Cr(n,p)^{52}V, ^{53}Cr(n,p)^{53}V, ^{55}Mn(n,α)^{52}V, ^{64}Ni(n,np)^{63}Co, ^{89}Y(n,n′)^{89m}Y, ^{119}Sn(n,p)^{119m}In, ^{138}Ba(n,2n)^{137m}Ba, ^{141}Pr(n,2n)^{140}Pr, ^{186}W(n,2n)^{185}W, and ^{204}Pb(n,2n)^{203m}Pb is now nearly completed and a journal paper is being prepared. This work has been carried out in collaboration with Y. Ikeda (JAERI) and A.A. Filatenkov (KRI). Enriched samples from KRI and JAERI were used in several of these measurements.

4. Neutron activation cross-section measurements involving relatively short lived reaction products have been performed in the energy range 16-20 MeV at the IRMM Van de Graaff accelerator facility for the following reactions: ^{57}Fe(n,p)^{57}Mn, ^{57}Fe(n,np)^{56}Mn, ^{54}Fe(n,2n)^{53g}Fe, ^{54}Fe(n,2n)^{53m}Fe, ^{52}Cr(n,p)^{52}V, ^{23}Na(n,p)^{23}Ne, ^{23}Na(n,α)^{20}F, ^{25}Mg(n,p)^{25}Na, ^{29}Si(n,p)^{29}Al, ^{35}Cl(n,2n)^{34m}Cl, ^{28}Si(n,p)^{28}Al, ^{37}Cl(n,p)^{37}S, ^{54}Fe(n,t)^{52m}Mn, ^{46}Ti(n,p)^{46m}Sc, ^{55}Mn(n,α)^{52}V, ^{119}Sn(n,p)^{119g}In, ^{138}Ba(n,2n)^{137m}Ba, ^{50}Ti(n,p)^{50}Sc, ^{54}Cr(n,np)^{53}V, ^{93}Nb(n,α)^{90m}Y, ^{54}Cr(n,p)^{54}V, ^{54}Cr(n,α)^{51}Ti, ^{53}Cr(n,p)^{53}V, ^{62}Ni(n,p)^{62g}Co, ^{62}Ni(n,p)^{62m}Co, ^{53}Cr(n,np)^{52}V, ^{51}V(n,p)^{51}Ti, ^{31}P(n,α)^{28}Al, ^{16}O(n,2n)^{15}O, ^{19}F(n,p)^{19}O, and ^{11}B(n,p)^{11}Be. The work has been carried out in collaboration with A. Fessler and E. Wattecamps (IRMM), and Y. Ikeda (JAERI). Enriched isotopes were used in some of the irradiations. These measurements also utilised a pneumatic transport system which facilitated the study of reaction products with half-lives on the order of 10 sec or greater. The data analysis process is essentially completed and journal publications are being prepared. A preliminary report on this work was presented at the 1997 Trieste Conference (see *Recent publications* list).

Measurements planned for the near future

1. A programme, initiated earlier, of activation cross-section measurements from 16-20 MeV for neutron-induced reaction leading to products with relatively short half-lives, will be continued during an experimental period in May/June 1998 at the Van de Graaff accelerator facility, IRMM, Geel, Belgium, in collaboration with A. Plompen, A. Fessler (IRMM), and Y. Ikeda (JAERI). Natural element samples and enriched isotopes obtained from the JAERI collection will be used in this investigation.

Recent publications

1. D.L. Smith and A. Fessler, "A Determination of the ^{53}V Half-Life", *Radiochimica Acta* Vol. 79, 1 (1997).

2. D. Smith, J. Daly, L. Van Wormer, and M. Wiescher, "Data Compilation and the Derivation of Reaction Rates at Stellar Energies for (p,γ) and (p,α) Reactions in the Mass Range A = 30-50", Proceedings of the International Conference on Nuclear Data for Science and Technology, Trieste, Italy, 19-24 May (1997).

3. D.L. Smith, Y. Ikeda, Y. Uno, and F. Maekawa, "Neutron Spectrum Adjustment Using Reaction Rate Data Acquired with a Liquid Dosimetry System", Proceedings of the International Conference on Nuclear Data for Science and Technology, Trieste, Italy, 19-24 May (1997).

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7. W. Mannhart, D. Schmidt, and D.L. Smith, "Measurement of $^{52}Cr(n,p)^{52}V$, $^{52}Cr(n,2n)^{51}Cr$, $^{51}V(n,p)^{51}Ti$, and $^{51}V(n,\alpha)^{48}Sc$ Cross-Sections between 7.9 and 14.4 MeV", Proceedings of the Intl. Conference on Nuclear Data for Science and Technology, Trieste, Italy, 19-24 May (1997).

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Facilities

1. LANSCE (Los Alamos Neutron Science Centre): Spallation neutron sources of pulsed neutrons. The WNR fast neutron source is not moderated, Manuel Lujan Jr. Neutron Scattering Centre source is.

2. WNR: Spallation source with proton energy of 800 MeV. Micropulse width ps, which, with neutron scattering in production target gives neutron pulse width of 1 ns or less for MeV neutrons. Neutron energies from 100 keV to 800 MeV: Spallation neutron spectrum. Six neutron flight paths with lengths from 9 to 90 meters.

3. Manuel Lujan Jr. Neutron Scattering Centre: Moderated spallation neutron source; subthermal to about 100 keV neutron energy. Five flight paths dedicated to neutron nuclear physics and fundamental physics.

4. Detectors: Various detectors including charged particle detectors (two types, for example for 1-50 MeV protons and alphas and 50-300 MeV protons); gamma-ray detectors (GEANIE array, BGO, NaI(Tl)); fission detector arrays; particle-tracking detectors (wire chamber arrays); plastic and liquid scintillators.

Measurements recently completed or in progress

1. Total cross-sections for 36 materials from hydrogen through uranium from 5 MeV to 600 MeV (Livermore, Ohio, Los Alamos); preliminary report by F.S. Dietrich, W.P. Abfalterer, R.C. Haight, G.L. Morgan, F.B. Bateman and R.W. Finlay, “Recent Measurements of Neutron Total Cross-Sections on a Wide Range of Targets from 5 to 600 MeV”, Proc. Intl. Conf. on Nuclear Data for Science and Technology, 19-24 May 1997, eds., G. Reffo, A. Ventura and C. Grandi (Italian Physics Society, 1997) pp. 402-6.

2. Total cross-sections on ^{1}H and ^{2}H from 5 to 600 MeV; (Livermore, Ohio, Bochum, Jagellonian, Los Alamos): W.P. Abfalterer, F.B. Bateman, F.S. Dietrich, Ch. Elster, R.W. Finlay, W. Glöckle,

J. Golak, R.C. Haight, D. Hüber, G.L. Morgan and H. Witala, "Inadequacies in the Faddeev Description of the n + d Total Cross-Section above 100 MeV", *Phys. Rev. Letters* (accepted for publication).

3. (n,xα) on ^{59}Co from threshold to 50 MeV (Ohio University, IRK (Vienna), NIST, Los Alamos): S.M. Grimes, C.E. Brient, F.C. Goeckner, F.B. Bateman, M.B. Chadwick, R.C. Haight, T.M. Lee, S.M. Sterbenz, P.G. Young, O.A. Wasson, and H. Vonach, "The ^{59}Co(n,α) Reaction from 5 to 50 MeV", *Nucl. Sci. Eng*. 124, 271 (1996).

4. (n,xα) on ^{58,60}Ni from threshold to 50 MeV, with Ohio University, IRK (Vienna), NIST, TU Munich: "The ^{58,60}Ni(n,xα$_0$) Reactions from Threshold to 50 MeV", R.C. Haight, F.B. Bateman, S.M. Sterbenz, M.B. Chadwick, P.G. Young, S.M. Grimes, O.A. Wasson, P. Maier-Komor, and H. Vonach, Proc. Intl. Conf. on Nuclear Data for Science and Technology, 19-24 May 1997, eds., G. Reffo, A. Ventura and C. Grandi (Italian Physics Society, 1997) pp. 603-6.

5. (n,charged particle) reactions on Be, Au, others from threshold to 50 MeV: Preliminary report by R.C. Haight, "Charged Particles Produced in Neutron Reactions on Nuclei from Beryllium to Gold", Proc. Intl. Conf. on Nuclear Data for Science and Technology, 19-24 May 1997, eds., G. Reffo, A. Ventura and C. Grandi (Italian Physics Society, 1997) pp. 500-504.

6. (p,xγ) studies on ^{27}Al and Fe at 800 MeV (IRK (Vienna), JAERI, Los Alamos): H. Vonach, A. Pavlik, A. Wallner, M. Drosg, R.C. Haight, D.M. Drake and S. Chiba, "Spallation Reactions in ^{27}Al and ^{56}Fe Induced by 800 MeV Protons", *Phys. Rev*. C55, 2458 (1997).

7. Ericson fluctuations in ^{28}Si(n,α) and (n,p) reactions (Ohio, Los Alamos): F.B. Bateman, S.M. Grimes, N. Boukharouba, V. Mishra, C.E. Brient, R.S. Pedroni, T.N. Massey, and R.C. Haight, "Determination of the ^{29}Si Level Density from 3 to 22 MeV", *Phys. Rev*. C55, 133 (1997).

8. Astrophysics reaction, ^{17}O(n,α) (Obninsk, Oak Ridge, Ohio, Los Alamos): V.V. Ketlerov, A.A. Goverdovski, V.A. Khryachkov, V.F. Mitrofanov, Yu.B. Ostapenko, R.C. Haight, P.E. Koehler, S.M. Grimes, and R.S. Smith, "Detailed Study of Double Differential Cross-Sections for the ^{17}O(n,α)^{14}C Reaction", *Nuclear Physics* A621, 243-246 (1997).

9. Gamma-ray production by neutrons as an indicator of inclusive reactions (IRK (Vienna), Los Alamos): A. Pavlik, H. Hitzenberger-Schauer, H. Vonach, M.B. Chadwick, R.C. Haight, R.O. Nelson, and P.G. Young, "^{27}Al(n,xγ) Reactions for Neutron Energies from 3 to 400 MeV", *Phys. Rev*. C57, 2416 (1998).

10. Neutron resonance spectroscopy (TRIPLE collaboration): ^{106}Pd and ^{108}Pd for En = 20 to 2000 eV (completed); ^{117}Sn from En = 1 to 2100 eV.

11. Neutron-proton bremsstrahlung (MIT, Los Alamos, others): Preliminary results

12. Neutron-proton elastic scattering at 10 MeV (Ohio, NIST, Los Alamos): Angular distribution from 60 to 180 degrees in cm; first measurements reported; improved measurement being analysed.

13. (n,xγ) studies for nuclear reaction cross-sections and mechanisms up to 200 MeV (Livermore, Kentucky, Los Alamos): L.A. Bernstein, J.A. Becker, D.E. Archer, K. Hauschild, W. Younes, D.M. Drake, G.D. Johns, R.O. Nelson and W.S. Wilburn, "^{196}Pt(n,xn) Reactions for x ≤ 15", *Phys. Rev.* C. (in press).

14. Neutron capture on off-stable nuclei from thermal to 300 keV: ^{171}Tm further investigation, probably others which are branch points in s-process astrophysics.

15. A programme to measure accurately the shape of Doppler-broadened resonances is underway at LANSCE with the goal of deducing moments of the phonon spectra of materials. The basic concept is described by J.E. Lynn and W.J. Trela *in Nuclear Instruments and Methods in Physics Research* B 108, 147-158 (1996). The present research is focused in five areas: (1) the development of well-characterised targets and moderators for use in spallation neutron sources; (2) development and comparison of detectors for current-mode and pulse-counting approaches; (3) measurements of resonance properties with good resolution and excellent statistics; (4) determination of moments of phonon spectra in pure elements through analysis of resonance line shapes; and (5) determination of these moments for alloyed elements. The radiation width of the 2.67 eV resonance in ^{242}Pu was found to be considerably smaller than reported in the literature. Radiation widths of two gallium resonances were shown to have a strong isotopic effect not apparent in earlier data, which were of much inferior accuracy. Moments of phonon spectra were determined for pure plutonium and gallium and alloys of these two materials by detailed analyses of the resonance shapes observed for sample temperatures from 15 to 300 K. This research is continuing with the investigation of other neutron source configurations and other samples.

Measurements planned for the near future

1. (n,xα) and (n,xp) from threshold to 30 MeV (maybe higher) on silicon, oxygen, ^{89}Y, ^{93}Nb, tantalum, etc. Collaboration with Ohio Univ. and Vienna.

2. (n,xγ) on materials to be selected. This will use the GEANIE array of 26 Compton-suppressed gamma-ray detectors. Collaboration with Livermore, Kentucky, others.

3. Preliminary investigation of non-elastic cross-section measurements. Collaboration with University of South Carolina, Ohio University and IGNS New Zealand.

4. Neutron-proton elastic scattering: Region near 180 degrees in cm to be investigated from 50 to 250 MeV.

5. Neutron capture on off-stable nuclei from thermal to 300 keV: ^{171}Tm preliminary results.

Recent publications

1. R.C. Haight, D.W. Kneff, B.M. Oliver, L.R. Greenwood and H. Vonach, "Helium Production by 10 MeV Neutrons in Elemental Iron, Nickel, and Copper, and in ^{56}Fe and ^{58,60,61}Ni", *Nucl. Sci. Eng*. 124, 219 (1996).

2. S.M. Grimes, C.E. Brient, F.C. Goeckner, F.B. Bateman, M.B. Chadwick, R.C. Haight, T.M. Lee, S.M. Sterbenz, P.G. Young, O.A. Wasson, and H. Vonach, "The ^{59}Co(n,α) Reaction from 5 to 50 MeV", *Nucl. Sci. Eng*. 124, 271 (1996).

3. R.C. Haight, F.B. Bateman, S.M. Sterbenz, S.M. Grimes, O.A. Wasson, P. Maier-Komor and H. Vonach, "An Update on (n,charged particle) Research at WNR", Proc. Intl. Workshop on Nuclear Data, Del Mar, California, December 1995, *Fusion Engineering and Design* 37, 73-77 (1977).

4. R.C. Haight, F.B. Bateman, S.M. Grimes, C.E. Brient, T.N. Massey, O.A. Wasson, A.D. Carlson, and H. Zhou, "Measurement of the Angular Distribution of Neutron-Proton Scattering at 10 MeV", Proc. Intl. Workshop on Nuclear Data, Del Mar, California, December 1995, *Fusion Engineering and Design* 37, 49-56 (1997).

5. J.W. Meadows, D.L. Smith, L.R. Greenwood, R.C. Haight, Y. Ikeda, and C. Konno, "Measurement of Fast-Neutron Activation Cross-Sections for Copper, Europium, Hafnium, Iron, Nickel, Silver, Terbium and Titanium at 10.0 and 14.7 MeV and for the Be(d,n) Spectrum", *Ann. Nucl. Energy* 23, 877-899 (1996).

6. H. Vonach, A. Pavlik, A. Wallner, M. Drosg, R.C. Haight, D.M. Drake and S. Chiba, "Spallation Reactions in ^{27}Al and ^{56}Fe Induced by 800 MeV Protons", *Phys. Rev*. C55, 2458 (1997).

7. M.B. Chadwick, P.M. DeLuca, Jr., and R.C. Haight, "Nuclear Data Needs for Neutron Therapy and Radiation Protection", *Radiation Protection Dosimetry* 70, 1 (1997).

8. F.B. Bateman, S.M. Grimes, N. Boukharouba, V. Mishra, C.E. Brient, R.S. Pedroni, T.N. Massey and R.C. Haight, "Determination of the ^{29}Si Level Density from 3 to 22 MeV", *Phys. Rev*. C55, 133 (1997).

9. V.V. Ketlerov, A.A. Goverdovski, V.A. Khryachkov, V.F. Mitrofanov, Yu.B. Ostapenko, R.C. Haight, P.E. Koehler, S.M. Grimes and R.S. Smith, "Detailed Study of Double Differential Cross-Sections for the ^{17}O(n,α)^{14}C Reaction", *Nuclear Physics* A621, 243-246 (1997).

10. W.P. Abfalterer, F.B. Bateman, F.S. Dietrich, Ch. Elster, R.W. Finlay, W. Glöckle, J. Golak, R.C. Haight, D. Hüber, G.L. Morgan and H. Witala, "Inadequacies in the Faddeev Description of the n + d Total Cross-Section above 100 MeV", *Phys. Rev. Letters* (accepted for publication).

11. C.M. Bartle and R.C. Haight, "Small Inorganic Scintillators as Neutron Detectors", Summary for 1998 Symposium on Radiation Measurements and Applications, Ann Arbor, Michigan, 12-14 May 1998, LA-UR-98-499.

12. A. Pavlik, H. Hitzenberger-Schauer, H. Vonach, M.B. Chadwick, R.C. Haight, R.O. Nelson, and P.G. Young, "^{27}Al(n,xγ) Reactions for Neutron Energies from 3 to 400 MeV", *Phys. Rev*. C57, 2416 (1998).

13. B.E. Crawford, J.D. Bowman, P.P.J. Delheij, T. Haseyama, L.Y. Lowie, J.N. Knudson, A. Masaike, Y. Matsuda, G.E. Mitchell, S.I. Penttila, H. Postma, N.R. Roberson, S.J. Seestrom, E.I. Sharapov, S.L. Stephenson and V.W. Yuan, "Neutron Resonance Spectroscopy of ^{106}Pd and ^{108}Pd from 200-2000 eV", *Phys. Rev*. C (accepted for publication).

14. L.A. Bernstein, J.A. Becker, D.E. Archer, K. Hauschild, W. Younes, D.M. Drake, G.D. Johns, R.O. Nelson and W.S. Wilburn, "^{196}Pt(n,xn) Reactions for x ≤ 15", *Phys Rev* C (in press).

15. J.A. Becker and R.O. Nelson, "New Opportunities in Nuclear Science with GEANIE at LANSCE/WNR", *Nuclear Physics News International*, 7 (No. 2) 11, June 1997.

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Facilities

The major facility is a 5.5 MV, type CN Van de Graaff accelerator with nanosecond terminal pulsing and a Mobley post-acceleration compression system. Nominal pulse duration is 500 ps with proton beam current up to 10 μA; burst durations as short as 250 ps have been measured with a concomitant reduction in beam current. An inclined field accelerating tube has recently been installed to improve voltage stability. Plans for the near future call for the installation of an electrostatic quadrupole focusing lens between the exit of the acceleration tube and the analysing magnet to improve beam current intensity. The quadrupole lens has been designed and fabrication is underway.

The accelerator laboratory is equipped with a variety of radiation detectors: Plastic and liquid scintillators, barium fluoride detectors for very fast timing applications, HPGe and NAI(Tl) detectors, fission chambers, and a nearly 100% efficient black neutron detector of the Poenitz type. Ancillary nuclear electronic module, data acquisition systems and computers for data analysis are available.

Measurements recently completed or in progress

Neutron cross-section data

1. ^{235}U measurements. Cross-sections for neutron "elastic" (ground state + 77 eV + 13 keV levels) and inelastic (46 keV + 52 keV levels) scattering have been measured for eleven angles ranging from 35 to 135 degrees at 700 keV incident neutron energy and for nine angles at 570 keV. The results at 700 keV for the "elastic" angular distribution are in reasonable agreement with the earlier work of Haouat *et al.*[1], while the inelastic data show less marked fore-aft asymmetry than that of Haouat *et al*. The cross-section at 570 keV, a lower energy than the measurements of Haouat *et al.*[1], is higher than that listed in ENDF/B-VI for the "elastic" level group, but agrees with ENDF for the inelastic group.

   [1] G. Haouat *et al*., *Nucl. Sci; and Eng*. 81, 213 (1982).

2. ^{169}Tm and ^{159}Tb measurements. We have initiated (n,n′γ) measurements on ^{169}Tm as the first phase of neutron scattering measurements on these odd-A spheroidal nuclei. This will help to determine which levels are excited in neutron scattering and, because of the sensitivity of the technique near

the level thresholds, can provide valuable cross-section data at energies where the (n,n′) method is unfeasible. We have observed 34 transitions from levels up to 878 keV excitation. Excitation functions have been measured at 125 degrees from 0.2-1 MeV in 50-keV steps. These measurements will be used to complement (n,n′) data which will be undertaken later. We plan to begin a series of similar measurements on ^{159}Tb in the near future. A report on the ^{169}Tm work will be presented at the APS Division of Nuclear Physics meeting in Santa Fe, NM in October 1998.

3. High resolution total cross-section measurements in the 200-400 keV range for ^{235}U, ^{159}Tb, and ^{169}Tm. Previous high resolution total cross-section measurements on ^{235}U show considerable structure in the few hundred keV range, while broad resolution measurements average over this structure and lead to smoothly varying cross-section curves. Such structure in the elastic cross-section would present a formidable obstacle in the unfolding and interpretation of neutron scattering time-of-flight spectra, since they must be acquired with high resolution in order to distinguish the inelastic from the elastic contributions. In order to check this reported structure we examined the total cross-section of ^{235}U in the region 200 to 400 keV with better than 10 keV resolution. The technique involves using a thick lithium target to generate a "pseudo-white" neutron spectrum via the ^{7}Li(p,n)^{7}Be reaction. Neutrons transmitted through the sample are observed by a scintillation detector in conjunction with the pulsed-beam neutron time-of-flight (TOF) technique. The time resolution of the TOF spectrometer was better than 2 ns, and the energy resolution for neutrons varied from 2 to 4 keV over the 200 to 400 keV range. In order to check on our technique we measured the carbon total cross-section. The carbon results agreed well with ENDF/B-VI showing no structure in this energy range. As a check on our ability to see structure at high resolution we measured the aluminium total cross-section which is known to have sharp resonances and considerable structure in this region. The structure exhibited in the ENDF evaluation of aluminium is present in our data. We made measurements on three samples, ^{235}U, ^{159}Tb and ^{169}Tm in the 200 to 400 keV range with 2 to 4 keV resolution and observed no significant structure in any of the cross-sections. Preliminary results on the ^{235}U work was presented at the Trieste Conference in 1997. A report on the ^{159}Tb and ^{169}Tm work will be presented in Santa Fe in October 1998.

4. The ^{14}N(n,n′γ) cross-section for the 2.313-MeV first excited state. The neutron-induced gamma-ray production cross-section for the first excited state of ^{14}N was measured for neutron energies from 2.65 to 3.55 MeV at intervals of 100 keV. The angular distribution was measured from 45 to 135 degrees in ten degree steps at 3.45 MeV. The results were published in 1997.

Fission spectrum measurements

1. Prompt fission spectrum measurements for energies less than the energy of the incident neutrons. We have measured fission neutron spectra for ^{235}U and ^{239}Pu for 1.5 and 2.5 MeV incident neutrons. The detection system was optimised for neutrons below the incident energy in order to complement our earlier work which concentrated on the region of the spectrum at energies higher than the incident energy. The data were acquired via the time-of-flight technique using a coincidence signal from any two of three BaF_2 gamma detectors placed near the sample to signal a fission event in order to distinguish fission neutrons from elastically and inelastically scattered neutrons. A report on the use of BaF_2 detectors to distinguish fission events from scattering events was presented at the Trieste Conference in 1997.

Mean life of ^{7}Be in different chemical environments

1. We are examining the mean lifetime of ^{7}Be embedded in tantalum compared to the mean life of ^{7}Be in a lithium environment. Preliminary results of the ratio of count rates vs. time indicate that ^{7}Be in tantalum decays at a faster rate than ^{7}Be in lithium with approximately a 1% difference. This difference is an order of magnitude larger than differences observed for ^{7}Be decay rates in various light media.

Recent publications

1. P. Staples, J.J. Egan, G.H.R. Kegel and A. Mittler, The ^{14}N(n,n′γ) Cross-Section of the 3.313-MeV First Excited State, *Nucl. Sci. Eng*. 126, 168-175 (1997).

2. G.H.R. Kegel, D.J. DeSimone, J.J. Egan, Y.J. Ko, A. Mittler and P.-N. Seo, High Resolution Neutron Total Cross-Sections of ^{235}U from 200 to 400 keV, International Conference on Nuclear Data for Science and Technology, Trieste, Italy, 19-24 May, 1997, eds., G. Reffo, A. Ventura and C. Grandi, Società Italiana di Fisica, Bologna, 1997, p. 577.

3. J.J. Egan M.L. Woodring, D.J. DeSimone, G.H.R. Kegel, A. Mittler, P. Stapels, D.J. Souza and J.R. Tedesco, Use of BaF_2 Detectors to Signal Fission Events in Fission Neutron Spectroscopy, Intl. Conference on Nuclear Data for Science and Technology, Trieste, Italy, 19-24 May 1997, eds., G. Reffo, A. Ventura and C. Grandi, Società Italiana di Fisica, Bologna, 1997, p. 544.

4. D.J. DeSimone, G.H.R. Kegel, J.J. Egan, C.K.C. Jen, M. O'Connor, and C. Narayan, Fluence Determination for a Pseudo-White Neutron Spectrum, International Conference on Nuclear Data for Science and Technology, Trieste, Italy, 19-24 May, 1997, eds., G. Reffo, A. Ventura and C. Grandi, Società Italiana di Fisica, Bologna, 1997, p. 1245.

5. D.J. DeSimone, G.H.R. Kegel, J.J. Egan, P. Bertone and P. Stapels, Studies of a Poenitz-Type Black Neutron Detector as a Neutron Flux Monitor, *Nucl. Instr. Meth.* in *Phys. Res*. A388, 443 (1997).

6. G.H.R. Kegel, J.J. Egan, D.J. DeSimone, P. Bertone and C.K.C. Jen, Problems of Neutron Dosimetry, *Nucl. Instr. Meth*. in *Phys. Res*. A388, 440 (1997).

7. Gunter H.R. Kegel and David DeSimone, Facilities for Gamma and Neutron Irradiation, accepted for publication in *Nucl. Instr. Meth*. in *Phys. Res*. (1998).

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Facilities

NIST 20 MW research reactor: It has a liquid hydrogen cold neutron source (moderator) and neutron guide tubes.

NIST Neutron Interferometer Facility: Measurements of coherent neutron scattering lengths with very high accuracy can be made at this facility. These data can be used in the evaluation of neutron cross-sections.

NIST Californium Neutron Irradiation Facility: For measurements of cross-sections integrated over the ^{252}Cf spontaneous neutron fission spectrum, and cross-section consistency checks.

A National Repository for Fissionable Isotope Mass Standards: Well characterised deposits and reference deposits belonging to NIST as well as those obtained from other laboratories are stored and made available for experiments.

Detectors: Plastic and liquid scintillators, Li glass detectors, hydrogen gas ionisation chambers, Ge(I) detectors, black neutron detectors, dual thin scintillator, proton recoil telescope.

Most of the experimental work by this group is/was performed at the LANL WNR, Ohio University Van de Graaff or ORNL ORELA facilities.

Measurements recently completed or in progress

1. New measurements of the H(n,n) angular distribution at 10 MeV neutron energy [collaboration with LANL and Ohio University]. These measurements are a continuation of earlier work by this collaboration which incorporate many changes to provide more accurate results with smaller systematic errors. The experimental data has been obtained. The analysis of the data is now underway. The measurements were made at the Ohio University Accelerator Laboratory (improvement of standard cross-section).

2. Measurements of the ^{10}B(n,$\alpha_1\gamma$) cross-section from 10 keV to 1 MeV at ORELA [collaboration with ORNL]. This measurement is completed (contribution to subgroup on the ^{10}B(n,α) standard).

3. Total neutron cross-section measurements of ^{10}B and ^{11}B, made at ORELA [collaboration with ORNL]. The data was obtained from 20 keV to 20 MeV neutron energy. The analysis is nearly completed (contribution to subgroup on the ^{10}B(n,α) standard).

4. Measurements of the $^{10}B(n,\alpha_1\gamma)$ cross-section from 300 keV to 20 MeV at WNR [collaboration with LANL]. This measurement is completed (contribution to subgroup on the $^{10}B(n,\alpha)$ standard).

5. Measurements of the neutron fission cross-sections of ^{232}Pa and ^{238}Np in the resonance region made at the LANSCE facility [collaboration with LANL and ORNL]. This work has been completed (needed for transmutation work).

Measurements planned for the near future

1. Continue the work on the measurement of the H(n,n)H Angular Distribution at Ohio University by making measurements at 14 MeV neutron energy. Continue work focused on reducing uncertainties.

2. ^{10}B total cross-section determinations at low energies (~4 MeV) with very high accuracy.

3. Measurement of coherent scattering length for ^{208}Pb.

Recent publications

1. R.C. Haight, F.B. Bateman, S.M. Grimes, C.E. Brient, T.N. Massey, O.A. Wasson, A.D. Carlson and H. Zhou, Measurement of the Angular Distribution of Neutron-Proton Scattering at 10 MeV, *Fusion Eng. & Design* 37, 49 (1997).

2. R.C. Haight, F.B. Bateman, S.M. Sterbenz, M.B. Chadwick, P.G. Young, S.M. Grimes, O.A. Wasson, P. Maier-Komor, and H. Vonach, The $^{58,60}Ni(n,\alpha)$ Reactions from Threshold to 50 MeV, Proc. of the International Conference on Nuclear Data for Science and Technology, Trieste, Italy, 19-24 May 1997.

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Facilities

1.5 MV tandem accelerator, pulsed beams of p, d, ^{3}He and ^{4}He available; 30 m flight path; two (n,z) spectrometers; GeLi, NE-213, Si surface barrier and Li glass detectors.

Measurements recently completed or in progress

Activities at Ohio University during the past two years have included projects devoted to improving our knowledge of neutron-proton scattering, low energy deuteron-induced reactions, white sources of neutrons and nuclear level densities.

1. Angular distributions for the n-p elastic scattering process have been measured at 10 MeV in a collaboration between Ohio University, Los Alamos and NIST. Data were taken at 0°, 12°, 24°, 36°, 48° and 60°. The goal was to obtain very accurate relative measurements which could then be normalised to the total n-p cross-section. During the past year, data acquisition has been completed and a preliminary analysis is available. These results are slightly closer to Arndt's phase shifts than to ENDF/B-VI. It is expected that final values will be available within the next six months.

2. A study of deuteron induced reactions on ^{27}Al and ^{56}Fe has recently been completed. Measurements of the elastic cross-section, the (d,d′) cross-section, and the (d,p), (d,α) and (d,n) cross-sections have been made at 3, 5 and 7 MeV. Analysis of these data has yielded optical model parameters and fractions of the low energy reaction cross-section which are due to compound and direct reactions. Particularly at the top energy, it appears that as much as 20-25% of the reaction cross-section consists of processes which have an initial direct stage (stripping to an unbound state) followed by a compound step. At all energies included in the study, more than 50% of the reaction cross-section consists of compound nuclear reactions.

3. Stopping target measurements of the neutron spectra from ^{9}Be(p,n), ^{9}Be(d,xn) and ^{27}Al(d,xn) have been made. Results for the ^{27}Al(d,xn) reaction at E_d = 7.44 MeV will appear in the June 1998 issue of *Nuclear Science and Engineering*. The range of outgoing neutron energies is 0.15 to 15 MeV and make this a useful spectrum for calibrating neutron detectors.

   The ^{9}Be(p,n) measurements were made at bombarding energies of 3.4, 3.7 and 4.0 MeV. This reaction is considered to be a promising candidate for boron neutron capture therapy for cancer. Final cross-sections for this reaction are expected to be available in August.

Measurements of spectra for the ^{9}Be(p,n) reaction at seven energies between 3 and 7 MeV have been made. We expect to have final results for these measurements by December.

4. A detailed study of level density parameters for $20 \leq A \leq 40$ is underway. Most compilations have focused on fitting data at the neutron binding energy. We have extended the region of comparison to include the excitation energy region from 0 to 4 MeV. Although discrepancies have been found, the adjustment of the energy shift normally brings calculation into good agreement with experiment. The revised level density parameters are being compared with calculations based on the two-body force.

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Facilities

1. IBR-30+LUE-40: Subcritical pulsed reactor driven by electron LINAC, high intensity pulsed neutron spectrometer (pulse width 4 microseconds) with eight neutron flight paths (up to 1 km).

2. 4-MV single stage Van de Graaff, DC, monoenergetic neutron sources: ^{7}Li(p,n) reaction.

3. IBR-2: Powerful pulsed reactor (pulse width 200 microseconds, 5 Hz, peak power 1.5 GWt).

4. Detectors: Liquid scintillators, multi-sectional NaI(Tl) and liquid scintillator detectors, HPGE, and Ge(Li) spectrometers, multi-detector systems for neutron and gamma-ray registration, fast gridded ionisation chambers, systems for polarisation of neutron and nuclei, for alignment of nuclei.

Measurements recently completed or in progress

1. Investigations of the angular anisotropy of fission fragments A2(En) with respect to the ^{235}U target spin orientation are continued on beam number 5 of IBR-30 , the experimental data for A2(En) are now available in energy bins of 0.05 eV with an accuracy of 3-5%, up to energy En < 30 eV. (collaboration IPPE, Obninsk-FLNP)

2. The experimental data on ^{237}Np subbarrier fission obtained last year were improved and the fission widths Gf were determined for 13 resonances. Also, the cross-section energy dependence was determined in the energy region 1-50 eV.

3. For an examination of the new methodic (the fast ionisation chamber which makes it possible to register the fission fragments against a high background of alpha-particles (Nf/Nalpha~10E-10)) the neutron resonances in the ^{243}Am(n,f) reactions were measured.

4. In the frame of the systematic study of the compound nuclei cascade decay the coincidence gamma spectra of two quanta-cascades were studied for ^{140}La and ^{188,190}Os target nuclei. The energy of the cascade final levels lies below 0.8 MeV.

5. First experiments to measure the effects of resonance self-shielding on the value of $\alpha = \sigma\_\gamma/\sigma\_f$ for ^{235}U target nuclei in the 20-2000 eV energy region were performed. Multiplicity spectra were also measured for the ^{239}Pu target to refine the α-value for ^{239}Pu in the 0.007-20 keV energy region. As a result, the α-values were obtained for 80 resonances and several energy groups (collaboration IPPE Obninsk and FLNP).

6. The investigation of the ^{48}Ca(n,γ) reaction for a Maxwellian neutron spectrum with kT = 25 keV was completed. The ^{50}Ti(n,γ) reaction was studied for neutron Maxwellian spectrum with kT = 25 keV as well as for 29 keV and 145 keV monoenergetic neutrons (collaboration Forschung Zentrum, Karlsruhe, Germany and FLNP).

7. Using the created unique ionisation chamber (IC) with a gas target the number of reactions were measured, including the reactions ^{17}O(n,α)^{14}C, ^{36}Ar(n,α)^{33}S and ^{21}Ne(n,α)^{18}O.

8. New information on the variation of fission modes in resonance region was obtained according to the measurements of the mass and energy distributions of the fission fragments of ^{235}U for the separate resonances.

Measurements planned for the near future

1. Measurements of the self-indication cross-section by means of the γ-quanta multiplicity detectors with the different thickness of transmission samples for ^{235}U and ^{239}Pu in the 1 eV-20 keV energy interval.

2. Measurements of the γ-quanta multiplicity spectra of the ^{165}Ho and ^{115}In samples for resonance spin determination.

3. Measurements of delayed neutron yields for the ^{241}Am, ^{242m}Am and ^{245}Cm samples.

4. Measurements of mass and energy distributions of the ^{235}U fission fragments for the separate resonances by the refined technique.

Recent publications

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Facilities

1. GELINA: 150 MeV electron linac pulsed white neutron source (pulse width 1 ns) with 10 neutron flight paths.

2. 7 MV single stage Van de Graaff, DC or pulsed (1-2 ns); monoenergetic n-sources: ^{7}Li(p,n), T(p,n), D(d,n), T(d,n); white n-source with thick targets: ^{7}Li-Be(p,n) or (d,n).

3. Detectors: Plastic and liquid (NE-213, C6D6) scintillators; Li glass scintillators; NaI, BaF_2, BGO and HP Ge detectors; gridded ionisation chambers, proton recoil telescope.

Measurements recently completed or in progress

1. High resolution inelastic scattering cross-sections. Yield of inelastic gamma-rays from lowest levels of Na, Al measured from 0.2 to 2 MeV; data are at NEA Data Bank. For Na resonance analysis (SAMMY) together with ORELA total cross-section data; paper at Trieste meeting. Measurements on ^{208}Pb in energy range from threshold to 4 MeV performed recently; data analysis in progress.

2. Fe(n,n′) (collaboration CEA Cadarache, IRMM). High resolution measurement (1 ns/200 m) in energy region from threshold to 2.7 MeV. Measured fluctuation factors used for JEFF-3 evaluation (A. Trkov, Ljubljana); paper at Trieste Conference.

3. ^{99}Tc total and capture cross-sections (collaboration CEA Saclay, IRMM). Measurements (transmission and radiative capture) performed up to E_n = 100 keV; resonance analysis in the lower energy region in progress; paper at Trieste Conference.

4. ^{237}Np total and capture cross-sections (collaboration CEA Saclay, IRMM) (relevant to WPEC Subgroup 8). Measurements done in resonance region: Total cross-section up to 1 keV, capture up to 100 eV; planned continuation of capture measurements up to 1 keV end 1998. Resonance parameter analysis (REFIT) of total cross-section data in progress.

5. Doppler broadening of resonances. Measurements done for the lowest resonances on samples of U, UO_2, UO_3, NpO_2, Hg_2Cl_2, Ta, at temperatures between 14 and 300 K. Analysis of U and UO_2 data shows that simple solid state model can describe the resonance shapes much better than usual gas model; paper at Trieste Conference.

6. Capture cross-section of Bi and ^{207,208}Pb (relevant to ADSs as well as astrophysical interest). Determined resonance parameters up to 500 keV (^{207}Pb), 1 MeV (^{208}Pb), 80 keV (Bi) incident energy; results sent to NEA Data Bank; paper at Trieste Conference.

7. Inelastic scattering from lowest levels of Mo isotopes (relevant to WPEC Subgroup 10). Measurements at Van de Graaff white source; detecting gamma-rays with HP Ge detector; natural sample. Data sent to NEA Data Bank; paper at Trieste Conference.

8. Measurement of inelastic scattering cross-section of ^{238}U by time-of-flight of the scattered neutrons, using monoenergetic neutrons from IRMM Van de Graaff (relevant to WPEC Subgroup 4). Measurements of inelastic scattering from groups of levels (0.63-0.89 MeV, 0.89-1.32 MeV, 1.32-1.67 MeV and 1.76-2.20 MeV) performed at four incident energies between 2 and 3.5 MeV.

9. Activation cross-sections (collaboration ANL, KFA Jülich, IRMM). Measurements performed for about 30 reactions leading to short lived activation products; neutron energy range from 9 to 12 MeV at Jülich and from 16 to 21 MeV at IRMM; paper at Trieste Conference.

10. ^{238}U(n,f) fragment mass and TKE distributions. Measurements at Van de Graaff (monoenergetic neutrons) performed for energies between 1.2 and 5.8 MeV; analysis in terms of multi-modal fission (Brosa) model; paper at Seyssins meeting.

11. Ternary (LRA) fission in ^{239}Pu resonances (collaboration University of Gent, IRMM). Measurements performed in the resonance region at linac white source; analysis in connection with point 12 (next).

12. ^{239}Pu(n,f) fragment mass distribution. Measurements in progress in the resonance region at linac white source; analysis in terms of multi-modal fission (Brosa) model.

13. Ternary (LRA) fission in spontaneous fission of even-even Pu isotopes (collaboration University of Gent, IRMM); dE(ion ch.)/E(s.b.det.) telescope to separate α and t. LRA emission is correlated with “standard-2” mode; paper at Seyssins meeting.

14. Spins of resonances (s- and p-waves) in Ag isotopes, ^{99}Tc and ^{115}In (collaboration TU Delft, TUNL, IRMM). In connection with P-violation experiments (LANL); papers at Trieste Conference.

15. Total cross-section of ^{10}B (contribution to ILC on ^{10}B(n,α)). Total cross-section measured between 0.1 and 2.5 MeV with monoenergetic neutrons at Van de Graaff, allowing background discrimination by time-of-flight. Analysis of earlier measurements at linac (80 eV to 500 keV) repeated.

16. At ILL: ^{234}U(n,f) thermal cross-section. First measurement of thermal cross-section yields (300 ± 20) mb.

Measurements planned for the near future

1. High resolution measurement of inelastic scattering cross-sections from lowest levels of ^{52}Cr and ^{58}Ni by detection of inelastic gamma-ray with linac white source.

2. ^{232}Th capture cross-section (collaboration FZK, IRMM). Measurements planned at FZK Van de Graaff and at Geel linac by gamma-detection and at Geel Van de Graaff by activation.

3. Capture cross-section of ^{84}Kr and ^{86}Kr (collaboration FZK, IRMM). Measurements planned at FZK Van de Graaff and Geel linac.

4. The investigation of resonance Doppler broadening is planned to be continued by measurements on samples of UO_2 at elevated temperatures (>2000 K).

5. Activation cross-sections (collaboration ANL, KFA, Jülich, IRMM). Measurements of several activation cross-sections are planned including reactions yielding long-lived activation products like ^{14}N(n,p)^{14}C and ^{204}Pb(n,p)^{204}Tl.

6. ^{10}B(n,α) and branching ratio α_0/α_1: Gridded ion chamber; planned measurements at Van de Graaff (MeV region) and later at linac (keV region).

7. Investigation of neutron resonances in ^{178m2}Hf ($J^{\pi} = 16^{+}$, E_x = 2.44 MeV, $T_{1/2}$ = 31 y) (collaboration Kurchatov Institute, CNRS Orsay, CEA Bruyères-le-Châtel, IRMM). Search for neutron resonances by neutron capture experiment.

8. Measurement of the ^{234}U(n,f) cross-section in the low resonance region at the linac (collaboration University of Gent, IRMM).

9. Continuation of ternary (LRA) fission study of ^{235}U up to 30 keV (collaboration University of Gent, IRMM).

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