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JOINT RESEARCH CENTRE
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IRMM

Experimental Activities in Europe

WPEC Report May 2004

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Facility: Variable energy multiparticle MGC-20E cyclotron (K = 20; repetition frequency (ν): 8.2-23.5 MHz; beam pulse width: $(0.1\text{-}0.15)*\nu^{-1}$)

- protons: 5-18 MeV; deuterons: 3-10 MeV; ^{3}He: 8-24MeV; ^{4}He: 6-20 MeV,
- d+D quasi-monoenergetic neutron source,
- broad spectrum neutron sources with thick Be-target.

Activities:

Neutron related nuclear data:

- measurement of activation cross-sections via the activation technique,
- leakage spectrum measurements via Pulse Height Response Spectrometry (PHRS),
- validation of excitation function data via spectrum integrated cross-section measurements,
- validation of excitation function data sets of libraries via comparing measured leakage spectra and results of Monte-Carlo transport calculations.

This program is carried out co-operating with the group of the Institute of Experimental Physics of Debrecen University (IEP-DE) lead by Prof. J. Csikai.

Charged particle related nuclear data:

- activation cross-section measurements via the activation technique.

Three members of the HAS-ATOMKI group (R. Dóczi, A. Fenyvesi and B. Király) participate in this activity, too. This activity is carried out by a different group of ATOMKI which is lead by F. Tárkányi. A detailed topic list of this activity is under preparation and it will be presented by F. Tárkányi for an other OECD/NEA work group.

Centre d'Etudes Nucléaires de Bordeaux-Gradignan (CENBG)

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Research group : ACEN (Aval du Cycle et Energie Nucléaire)

Members :
Permanent staff : G. Barreau, S. Czajkowski, D. Dassié, B. Haas.
PhD. Students. S. Boyer, C. Grosjean.

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Collaborations : LPSC Grenoble, IPN Orsay, CEN Saclay, CEA/DAM Bruyères le châtel, Los Alamos and Argonne laboratories.

Facilities :

The 4MV Van de Graaff accelerators at CEN Bordeaux-Gradignan and Bruyères le châtel (neutrons sources: ^{7}Li(p,n), T(p,n) and D(d,n)).
The 15 MV Tandem accelerator at the IPN Orsay.

Detectors: Silicon and solar cells detectors for light particles and fission fragments. Germanium (HPGe) and C_6D_6 liquid scintillators for γ-detection
^{3}He and CH_4 proportional counters for neutron detection.

Measurements recently completed or in progress.

- Neutron induced capture cross section of ^{232}Th. (this work has been published)
- Determination of the ^{233}Pa(n,f) and ^{233}Pa(n,γ) cross sections using the transfer reaction ^{232}Th(^{3}He,p) reaction. The surrogate ^{232}Th(^{3}He,pf) reaction is assumed to populate, on the average, the same compound system as the ^{233}Pa(n,f) reaction before fission. The ^{233}Pa(n,f) work has been published. The ^{233}Pa(n,γ) measurements are completed and the analysis is in progress.
- Fast neutron flux measurements using a proton recoil telescope spectrometer. Application to high precision measurements of neutron induced fission of ^{232}Th, ^{233}U and ^{238}U. The measurements are completed and the analysis is in progress.

Measurements planned for the near future.

- Determination of the (n,f) and (n,γ) cross sections of ^{241}Am and ^{242,243,244}Cm using the transfer reactions:

  ^{243}Am (^{3}He,p)^{245}Cm(f/γ) for ^{244}Cm(n, f/γ)
  ^{243}Am (^{3}He,d)^{244}Cm(f/γ) for ^{243}Cm(n, f/γ)
  ^{243}Am (^{3}He,t)^{243}Cm(f/γ) for ^{242}Cm(n, f/γ)
  ^{243}Am (^{3}He,^{4}He)^{242}Am(f/γ) for ^{241}Am(n,f/γ)

- Measurements of the fast neutron induced fission of ^{243}Am in the 0.5-6 MeV neutron energy range.

Institute of Experimental Physics, Debrecen University, Hungary

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PhD students:	B. Király, K. Hámori
Recent visitors:	M. Fayez-Hassan, M. Ali, J. Jodranova, I. Spahn, K. Doubali Th. Bastian, B. Leshchenko, I. I. Penev, S. M. Qaim, V. Avrigenau
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Facilities: Low-voltage ~200kV D-D and D-T neutron generators
Pu-Be, Cf252 neutron sources
MGC-20 variable energy cyclotron with D_2 gas and thick Be targets
Si(Li), Ge(Li), HPGe, BGO gamma-, ^{6}Li, NE-213, BF_3, ^{3}He neutron-detectors, GM-β counters

Investigations recently completed or in progress:

a) Activation cross sections for dosimetry reactions and the excitation functions of neutron induced reactions with an emphasis on the problem range;
b) Leakage spectra of neutrons from different sources (Pu-Be, D-T, ^{2}H(d,n), ^{9}Be(d,n), ^{252}Cf) using spherical and slab samples.
c) Spectra of elastically backscattered neutrons from a Pu-Be source
d) Reflection cross sections of thermal neutrons
e) Model calculations both for neutron and charged particle induced reactions.
f) Some applications of neutron-based techniques.

A new program for the measurements and calculations of the excitation functions of the proton and deuteron induced reactions using the CYRIC cyclotron in Sendai (Japan) was started 3 years ago. A number of elements were irradiated with 50, 70 and 80 MeV proton energies as well as 40 MeV deuterons assuring the determination of cross section curves in the intermediate energy regions.

ELBE-n-ToF at Dresden-Rossendorf: Status of the Project

A. R. Junghans, C. Beckert, E. Grosse (E.Grosse@fz-rossendorf.de), and F. P. Weiss (FZ Rossendorf) for the n-TOF collaboration

The ELBE-n-TOF facility is based on a 40 MeV superconducting electron-linac with sub-ns pulses. It will be used for the measurement of the energy dependence of neutron interaction cross sections in the keV to MeV range. For the production of neutrons a liquid Pb converter flowing in a square Mo pipe will be installed in 2004.

Extensive numerical simulations were performed to optimize the radiator geometry and to predict the expected neutron beam properties. A compromise had to be found between the neutron intensity and the neutron energy resolution to be obtained from the measurement of their time of flight (tof) in a rather short flight path allowing a large solid angle for a given size of the target to be hit by the neutrons. Optimum values are a pipe cross section of 11 mm x 11 mm and a neutron emission perpendicular to the e-beam into a collimator imbedded into the 2.8 m thick shielding wall. The intensity peak of the neutrons produced by 30-40 MeV electrons in Pb lies at about 1.5 MeV and it allows to well cover the range of 0.2 to 8 MeV, when an absorber containing ^{6}Li is used to suppress all slower neutrons. The repetition rate matched to these energies and to the total neutron flight path of 3.6 m is 1.6 MHz, the 8th subharmonic of the ELBE 'standard' of 13 MHz.

At 1.6 MHz the electron current from the present thermionic gun can be varied between 0.1 and 0.2 mA. A NdYAG-laser driven photoelectric injector, which is presently being developed, will allow a beam power in the 10 kW range at this repetition rate and a frequency reduction down to 51 kHz in the case that lower neutron energies of 3 keV up to 200 keV are to be used (after moderation). The neutron beam intensities predicted on the basis of the present e-beams are in the range of 10^6 n/s cm². Due to the narrow electron bunches produced by the superconducting linac an energy resolution of <1 % is to be expected.

To match the sub-ns time resolution of the ELBE beam the development and construction of fast detectors is the main activity at present. A channel plate detector for fission fragments will be tested at the ELBE bremsstrahlung beam soon, fast plastic scintillator paddles are being mounted on fast phototubes and resistive plate chambers (RPC) of a novel type have been brought to ELBE to verify their time resolution predicted to be below 0.2 ns. A BaF_2 scintillator array consisting of 2*30 crystals is being set-up for fast gamma-ray detection. Worth mentioning is also the existence of hot cells near the accelerator which may be used for the preparation of radioactive targets.

Recent nuclear data activities at FZK

F. Käppeler (kaepp@ik3.fzk.de)

1. Determination of stellar reaction rates for the description of the nucleosynthesis processes during He burning in red giant stars. This concerns essentially (n,γ) cross-sections in the 3-220 keV energy range at the Van de Graaff accelerator of the FZK-IKP. Presently, these are:
   - (n,γ) cross-section measurements with the Karlsruhe 4p BaF2 detector for $^{176\text{-}180}$Hf, ^{175,176}Lu, ^{151}Sm from 3 keV up to 220 keV
   - (n,γ) cross-section measurements using the activation technique on ^{62}Ni, ^{135}Cs, ^{139}La in a quasi-stellar spectrum for kT= 25 keV
2. Determination of rection rates for the explosive nucleosynthesis in supernovae, an area where experimental data ar still missing:
   - neutron induced reactions: measurement of the (n,α) cross-section of ^{95}Mo from 1 eV up to 500 keV
   - proton induced reactions: measurement of the (p,γ) cross-section of ^{116}Sn from 2 MeV up to 5 MeV
   - α induced reactions:
     measurement of the (α,n) cross-section of ^{92,94}Mo from 8 MeV up to 12 MeV,
     measurement of the (α,γ) cross-section of ^{112}Sn from 8 MeV up to 12 MeV.
3. Participation in experiments at the n_TOF spectrometer at CERN and installation of a 4π BaF_2 calorimeter:
   - hig-resolution (n,γ) cross-sections of ^{90,91,92,93,94,96}Zr, ^{139}La, ^{151}Sm, ^{186,187,188}Os , ^{204,208,207,208}Pb, ^{209}Bi from 1 eV up to 1 MeV
   - set-up of the 4π BaF_2 detector.

Collaborations:

Universities of Basel, Bochum, Darmstadt, Jerusalem, München, Notre Dame (USA), Prague, Stuttgart; Turin, Vienna;
Reasearch Labs: Argonne National Laboratory, PTB Braunschweig, JINR Dubna, IRRM Geel (Euratom), CERN Genf, Oak Ridge National Laboratory, IPPE Obninsk, Los Alamos National Laboratory

n_TOF collaboration at CERN

chairman: E. Chiaveri (enrico.chiaveri@cern.ch)
project leader: A. Mengoni (alberto.mengoni@cern.ch)

(n,γ) cross section measurements with C_6D_6 detectors:

^{nat,25,26}Mg, ^{90,91,92,94,96}Zr, ^{139}La, ^{151}Sm, ^{186,187,188}Os

^{204,206,207,208}Pb, ^{209}Bi, ^{232}Th

calibration measurements on Au, Pb, C, S, Ir, ^{238}U

(n,f) cross section measurements:

^{209}Bi, ^{232}Th, ^{233,234,236}U, ^{237}Np, ^{241,243}Am, ^{245}Cm

calibration measurements on ^{235}U, ^{238}U

Capture campaign 2004: 3 May 2004 - 26 September 2004 (21 weeks)

(n,γ) cross section measurements with BaF_2 calorimeter:

^{237}Np, $^{233,234,(236)}$U, ^{240,242}Pu, ^{241,243}Am

calibration measurements on C, Au, Pb, etc.

(^{236}U(n,γ) at GELINA)

Fission campaign 2004: 4 October 2004 - 31 October 2004 (4 weeks)

Neutron Scattering Measurements at PTB (status 2004)

R. Nolte (ralf.nolte@ptb.de)

sample	**MeV**	**cross sections** DX (elast. + ... , | Q | in MeV)	DDX
^{16}O	6.42 - 14.89	<6.09>	---
^{12}C	13.33 - 15.82	4.439	---
^{nat}Fe	9.41 - 15.20	0.847 (^{56}Fe)	E_{ex} < 6.5 MeV
^{nat}Pb	7.93 - 14.23	<2.64> (^{nat}Pb)	DDX
^{nat}Cr	7.95 - 14.76	1.434 (^{52}Cr)	DDX
^{51}V	7.99 - 14.37	el.+0.320, 0.929, 1.609+1.813	DDX
^{nat}Ti	7.93 - 14.72	**I** : 0.98 (^{46}Ti/^{48}Ti), <1.58> (^{47}Ti/^{50}Ti), <2.38> (^{nat}Ti) **II** : 0.98 (^{46}Ti/^{48}Ti), 1.55 (^{50}Ti), 2.01 (^{46}Ti), 2.30 + 2.42 (^{48}Ti), 2.65 (^{46}Ti/^{50}Ti)	DDX
^{nat}Si	7.89 - 13.85	1.778, 4.617, 4.975, 6.272, 6.691, 6.887, 7.415 (^{28}Si) 1.273, 3.068 (^{29}Si), 2.235, 3.674 (^{30}Si)	---
^{14}N	7.89 - 13.85	2.313, 3.948, 4.915, 5.106, <5.76>, 6.204, 6.446, 7.029	---
^{nat}Cu	7 - 14	elast. + ... (in progress, meas. completed)	DDX
^{nat}W	7 - 14	elast. + ... (planned)	DDX

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Study of proton-induced fission of actinide nuclei between 20 and 80 MeV bombarding energies

D. Belge, Ch. Dufauquez, Y. El Masri, Th. Keutgen, A. Ninane, R. Prieels, and J. Van Mol, Université Catholique de Louvain and R. Charity, University of Washington, St Louis, USA

Long-range program:

cross section measurements for proton-induced fission

first measurements: ^{238}U and ^{239}Pu nuclei at 26.5 and 62.9 MeV incident proton energies

DEMON detector array

measurements will be extended to other actinide nuclei such as ^{232}Th ^{237}Np and ^{241}Am

Experimental Activities at IRMM

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➢ Total and capture

^{206}Pb(n,γ) and σ_{tot}
^{209}Bi(n,γ)^{210}Bi branching ratio ^{210m}Bi/^{210g}Bi (collab. with CEA Saclay, CRC-HAS Budapest)
^{232}Th(n,γ) and σ_{tot} (collab. with INRNE Sofia, contribution to IAEA-CRP)
^{236}U(n,γ) (for n_TOF collab.)
^{238}U(n,γ) (measurements postponed in favour of ^{236}U measurements)
Doppler broadening: ^{240,242}Pu resonances (n_TOF collab.)

➢ Inelastic scattering, (n,2n)

^{207}Pb(n,n') and (n,2n) (collab. with IReS-Strasbourg, TU+Univ. Vienna, Univ. Belgrade, NIPNE Bucharest, Univ. Debrecen)
^{209}Bi(n,n') (collab. with NIPNE Bucharest)

➢ light charged particles

^{10}B(n,α) (collab. with IPPE Obninsk**)**
^{36}Cl(n,α)^{33}P , ^{26}Al(n,p) , (n,α) (Univ. Gent, SCK Mol)

➢ Activation

^{14}C production on nitrogen (collab. with FZJ**)**

➢ Fission

Stable fission product studies (collab. with CEA Saclay and Cadarache):
^{103}Rh , ^{155}Gd and ^{157}Gd (no targets available yet)
Pa fission cross sections (collab. with Univ. Örebro, Univ. Uppsala, Univ. Bucharest):
^{233}Pa(n,f), ^{231}Pa(n,f)
^{234}U and ^{236}U fission cross sections (Univ. Gent, SCK Mol)
^{239}Pu(n,f) prompt neutrons (collab. with CEA Cadarache)
prompt fission neutron spectrum of ^{235}U (collab. with LANL, IPPE Obninsk, CEA Cadarache)
(in planning phase)
tritium production by ternary fission (Univ. Gent, SCK Mol)**:**
^{246}Cm(SF), ^{244}Cm (under preparation)

➢ Applications

Neutron resonance capture analysis (NRCA) (collab. with Univ. Delft and FBFC-Framatome):
first measurements on uranium pellets (UO_2 loaded with Gd_2O_3) from FBFC.