NUCLEAR DATA ACTIVITY AT THE DALAT NUCLEAR RESEARCH INSTITUTE (VIETNAM)

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ABSTRACT

Nuclear data activity at the Dalat Nuclear Research Institute (DNRI) including theoretical calculations of nuclear reactions, nuclear data measurements using filtered neutron beams and the thermal column of the reactor will be presented. The information presented is based mainly on the results of the National Research Contracts 50A-01-01-03, KT-04-3.2.3 and KC-09-08 for the period 1985-1995.

1. INTRODUCTION

It is essential for any country which has any reactor programme to maintain a nuclear data group who can do data evaluation for input to their reactor physicists even when the reactors are commercially supplied with fixed period guarantees or are copies of well tested working model put up with technical collaboration. With this policy, Vietnam Atomic Energy Commission and the Vietnam National Research Programs on Nuclear Science and Technology, and Fundamental Sciences have supported nuclear data activities at the Dalat Nuclear Research Institute in the framework of the National Research Contracts 50A-01-01-03, KT-04-3.2.3 and KC-09-08. In this paper we will present the main activity of Nuclear Data Sector (DNRI) in the field of nuclear data calculations and measurements using filtered neutron beams and the thermal column of the Dalat reactor. Nuclear data processing, reactor physics calculations and reactor physics experiments which are an important activity of DNRI will not be included in this presentation.

2. NUCLEAR DATA CALCULATIONS

2.1 The exciton model calculation of the (n,p) cross sections

We have carried out investigations on preequilibrium emission of protons and isotopic effect in the fast neutron-induced (n,p) reactions on heavy elements /1/. The (n,p) cross sections, contributions of both evaporation and preequilibrium exciton mechanisms and the emitted proton spectra have been calculated for series of Sm, Dy and Er isotopes. By fitting the experimental data the exciton model free parameter K characterizing the transition rate between exciton states has been determined for each isotope chain. It has been found that more than 85% of the preequilibrium protons are emitted from the exciton state n=3. Based on this result a rather simple formula has been found and can be used for the evaluation of the (n,p) cross sections on heavy nuclei.

2.2 Modified statistical calculations of neutron radiative capture cross sections

The precision of neutron capture cross section evaluations for the keV-MeV region is still not enough to satisfy the required accuracy of 10-30%. It seems likely that the uncertainty might partly come from the gamma ray strength functions and partly from the neutron transmission coefficients used in compound-nucleus model calculations. So, we have made a modification of the statistical approach to the neutron capture problem in which the energy dependence of the average total electric dipole radiative width is connected to the relative variance of the exciton number D_n/n. On the basis of this modification, the calculations of the average neutron radiative capture cross sections carried out for a number of nuclei in the mass region A=50-250 and for neutron energies up to 2 MeV with using experimental neutron strength functions for s- and p-waves to estimate transmission coefficients have shown a good agreement with experimental data /2/. Therefore, we have developed the code for analyses of average neutron radiative capture cross sections $\sigma_{n\gamma}$ allowing estimate the average radiative width and neutron strength functions from experimental data of $\sigma_{n\gamma}$ /3/.

3. NUCLEAR DATA MEASUREMENTS

3.1 Filtered neutron beams

Since the pioneer work of Sympson and his co-workers /4/, neutron transmission filters have been successfully used to produce quasi-monoenergetic neutrons for nuclear physics experiments. At the Dalat reactor the neutron flux at the piercing horizontal beam port is $6x10^8$ n/cm^2/s, and about one tenth of which are epithermal neutrons. Single crystal silicon (980 mm long), aluminum (1023 mm long), iron (200 mm long) and sulphur (45 g/cm^2) filters with possibility for insertion of additional filters like ^{10}B, Ti have recently been installed to produce neutrons of 24 keV, 25 keV, 55 keV, 75 keV, 144 keV as well as thermal neutrons /5/. The fluxes of quasi-monoenergetic neutrons measured at 25 cm from the beam port outlet by activation of Au-foils together with other characteristics of filtered neutron beams are given in Table 1. In the near future other types of filters using Sc, U, Pb and polyethylene permitting transmission of 2 keV, 186 eV, 1.2 MeV and 2 MeV neutrons will expectedly be installed.

3.2 Measurement of the thermal neutron absorption cross section for small samples by poisoning method

The knowledge of the macroscopic thermal neutron absorption cross section is indispensable in the quantitative interpretation of the neutron lifetime logs. We have developed the new approach to the problem of its determination /6/. The experiments were carried out in the thermal column of the reactor where the neutron flux in the sample center was measured by activation Au-foils at different values of absorption cross section Σ_a obtained by poisoning with suitable chemicals. The absorption cross section $\Sigma_{a,s}$ of the unknown sample is found from the intersection of the measured curve of relative fluxes Φ/Φ_0 and the line $\Phi/\Phi_0=1$, it is corresponding to the negative poisoning so that the neutron flux at the measurement position is not disturbed by the sample.

3.3 Total neutron cross sections

It is well known that the total neutron cross section studies in the keV-energy region for fissile, breeding, cooling and shielding materials are immediate important to fast reactor technology because the average kinetic energy of neutrons in fast reactors lies in the keV region /7/. Besides, average neutron resonance parameters can be evaluated if resonance self-shielding effect in total neutron cross sections is studied /8/. It is neutron resonance existence that makes the observed total cross section to be dependent upon sample thickness. At the Dalat reactor, the system for total neutron cross section measurements was set up and experiments for ^{238}U and ^{12}C on the 55 keV and 144 keV filtered neutron beams have been carried out /9/. Fig.1 shows our experimental data together with fitting curves using Monte-Carlo IBM programme /10/ with the account of both Porter-Thomas and Wigner distributions and Doppler-broadening. The Comparison of total neutron cross sections and average resonance parameters obtained in our work with the values of other authors are given in /11/.

3.4 Average neutron radiative capture cross sections

The keV neutron radiative capture cross sections are of interest to Astrophysics for calculating the nuclear abundances of heavy elements and also to nuclear reactor design and nuclear reaction theory. Experiments for ^{238}U and ^{98}Mo were carried out by activation method. Fig.2 shows our experimental data for ^{238}U together with the results of other authors /12/. In the frame of experimental errors, our data (292.3±8.5 mb and 152.5±4.6 mb) are in good agreement with the results of the work /13/, but the accuracy of our data is better (approximately 3%). The detail information about these experiments are given in /14/.

3.5 Gamma spectra from neutron capture for reactor materials

In order to assess gamma ray production in a fast reactor and thereby estimate the shielding requirements, it is necessary to know the prompt gamma ray spectrum varies with neutron capture energy. These prompt capture gamma rays will constitute much of the"hard" component of the reactor photon spectrum and will therefore have the most stringent shielding requirement. Besides, these data are also needed for radiation damage estimate and for radiation heating calculations. However, the data are scanty, especially in the keV neutron region /15/. So, we have carried out measurements of capture gamma ray spectra for materials like Si, Ti, C, Al, Fe, Cr on the filtered keV-neutron beams. Our results presented in /16/ shows that the intensities and energies of the keV neutron capture gamma rays change substantially as neutron energy increases.

3.6 The energy dependence of isomeric ratio

Measurements of neutron cross sections for formation of ground state σ^g and isomeric state σ^m or isomeric ratio $R=\sigma^m/(\sigma^m+\sigma^g)$ are useful for description of nuclear reaction characteristics. The nuclear level density plays an important role in statistical theory of nuclear reaction. One of the procedures to get more accurate information about the nuclear level density, its energy and spin dependence is to analyze nuclear reactions with formation of isomeric states /17/. So, we have carried out this research. Fig.3 shows the decay of the 828 keV gamma line of $^{82g,m}Br$ after irradiation of NH_4Br-sample on the 144 keV filtered neutron beam. Calculation curves are given with different values of ratio σ^m/σ^g /18/. Experiments for the other nuclei and on the other filtered neutron beams are going on.

3.7 Average resonance capture (ARC)

Discrete resonance capture may be studied by neutron time-of-flight method, but the statistical accuracy of this method is limited by low intensity of pulsed neutron beams. Another limitation stems from the distribution of partial radiative widths for the statistical decay /19/. The ARC technique greatly reduces the statistical fluctuations in primary intensities that would arise in single resonance or thermal neutron capture. That is the result of the spread in the energy of filtered neutron beams, which encompasses a large number of individual resonances /20/. These results are very valuable for the completeness of level schemes because all levels of given spin-parity groups are equally populated and identified. At the Dalat reactor ARC investigations are being carried out on the filtered neutron beams using Compton-suppressed and pair spectrometer from a HPGe-90 cc detector and 2 NaI(Tl) scintillators with 200x200 mm sizes. Fig.4 shows relative reduced gamma transition intensities from neutron capture resonances to low lying levels of ^{239}U in the reaction $^{238}U(n,\gamma)^{239}U$ on the 55 keV filtered neutron beam. It was seen that the p-wave neutron radiative capture cross section of ^{238}U at the 55 keV neutron energy is significantly larger than s-wave neutrons. Other ARC experiments are being carried out at the Dalat reactor.

3.8 (n,2γ) reactions

For excited levels below 2 MeV their detail spectroscopic information was known very well from investigations of (n,γ), (n,e), (d,p),... reactions. However, for higher excited levels the information is not enough because of low intensity of transitions and bad resolution of detectors with increasing energy of transitions. In this case, the method of summation of amplitudes of coinciding pulses (SACP) from two Ge(Li) detectors for detecting gamma rays emitted in (n,2γ) reaction allows obtaining the spectroscopic information for higher excited levels /21/. The scheme of the SACP spectrometer designed by ourself is given in Fig.5. The experiments are being prepared for some nuclei of rare earth region, for which possibility of cascade transitions in the (n,2γ) reaction is high enough. Besides, the SACP spectrometer is also used to study complex decay schemes of radioactive nuclei and in neutron activation analysis thanks to its very low gamma backgrounds.

4. CONCLUSIONS

To further promote nuclear data activity in Vietnam, it is necessary to join all physicists working in the field of nuclear data from different institutes and universities in the country and to improve international collaboration with the advanced nuclear data centers like Nuclear Data Center, JAERI. We consider a regional nuclear data center for Asia and Pacific being the most important promotion in the nuclear data activity in the region. Under the circumstances the scientists from developing countries in the region like Vietnam can make active contributions in the international nuclear data activity.

REFERENCES

1. P. Z. Hien et al. : *Neutron Physics*, **Vol.3** (Moscow, 1988) p. 236.
2. V. H. Tan et al. : *Nuclear Data for Science and Technology*, 1992, p.860.
3. P. Z. Hien et al.: *The 4th National Conference on Physics*, Hanoi 1993.
4. O. D. Sympson, L.G. Miller: *Nucl. Ins. Meth.*, **Vol.61**, No.3, 1968
5. P. Z. Hien et al.: *The 4st National Conference on Physics*, Hanoi, Oct. 1993.
6. V.D. Bang et al.: *The International Workshop RCM on Nucl.Tech. in Exploration of Natural Resources*, Debrecen, Hungary, 15-19/4/1991.
7. Manokhin V.N., Usachev L.N.: *Neutron Physics*, **Vol.1** (Moscow 1984) p.18.
8. Tsubone I., Nakajima Y, Furuta I.: *Nucl. Sci. and Engineering*, **88**, 579 (1981).
9. P.Z. Hien, V.H. Tan,N.P. Xuan: *INDC(NDS)-265*, Vienna, Oct. 1992.
10. Novosolov G.M. et al.: Preprint of KINR, *KINR-89-25*, Kiev 1989.
11. V.H.Tan et al.: *The International Workshop on Utilizations of research reactors*, Sydney, Australia, Apr.- May 1994.
12. F.H. Frohner: *Nucl. Sci. Eng.* **103**, 119 (1989)
13. Kobayashi S. et al.: *Nuclear Data for Science and Technology*, 1992, p.65.
14. P.Z.Hien et al.: *The International Conference on Nucl. Phys.*, Hanoi, Feb. 1994.
15. Igashira M. et al.: *Nuclear Data for Science and Technology*, 1992, p.48.
16. V.H.Tan et al.: *The 4th National Conference on Physics*, Hanoi 1993.
17. Dubenski A.P. et al.: Preprint of JINR, *P4-89-180*, Dubna 1989.
18. V.H.Tan: *The International Conference on Nuclear Physics*, Hanoi, Feb. 1994.
19. Kopecky J.: *Neutron Capture Gamma Ray spectroscopy and Relative Topics* (1984),p.318
20. Warner D.D. et al.: *Phys. Rev.* **C27**, 2292 (1983).
21. Boneva S.T. et al.: *Physics of Elementary Particles and Atomic Nuclei*, V.22, 1991.

Table 1 The characteristics of filtered neutron beams at the Dalat reactor

Neutron	Filter combination	Flux[$n/cm^2/s$]	R_{Cd} or FWHM
Thermal	98cmSi+10cmTi+ $35g/cm^2S$	$1.8x10^7$	143
144 keV	98cmSi+10cmTi+ $0.2g/cm^2B^{10}$	$1.2x10^7$	22 keV
55 keV	98cmSi+$35g/cm^2S$+ $0.2g/cm^2B^{10}$	$4.0x10^6$	8 keV
25 keV	102.3cmAl+$0.2g/cm^2$ B^{10}	$1.2x10^6$	
24 keV	20cmAl+20cmFe+ $25g/cm^2S+0.2g/cm^2B^{10}$	$1.0x10^6$	
75 keV	$45g/cm^2S+0.2g/cm^2$ B^{10}	$1.1x10^6$	

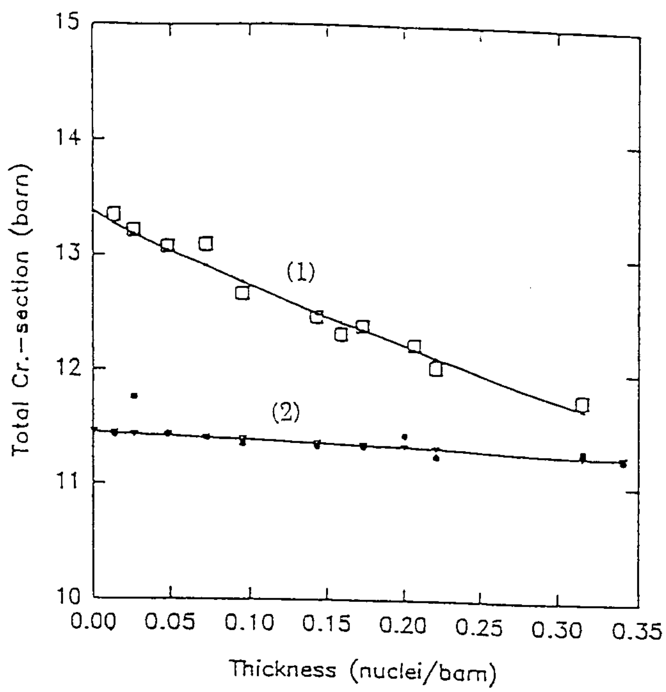

Fig. 1 Thickness dependence of total cross section of ^{238}U.
(1) 55 keV □ experimental data — fitted curve.
(2) 144 keV ■ experimental data — fitted curve..

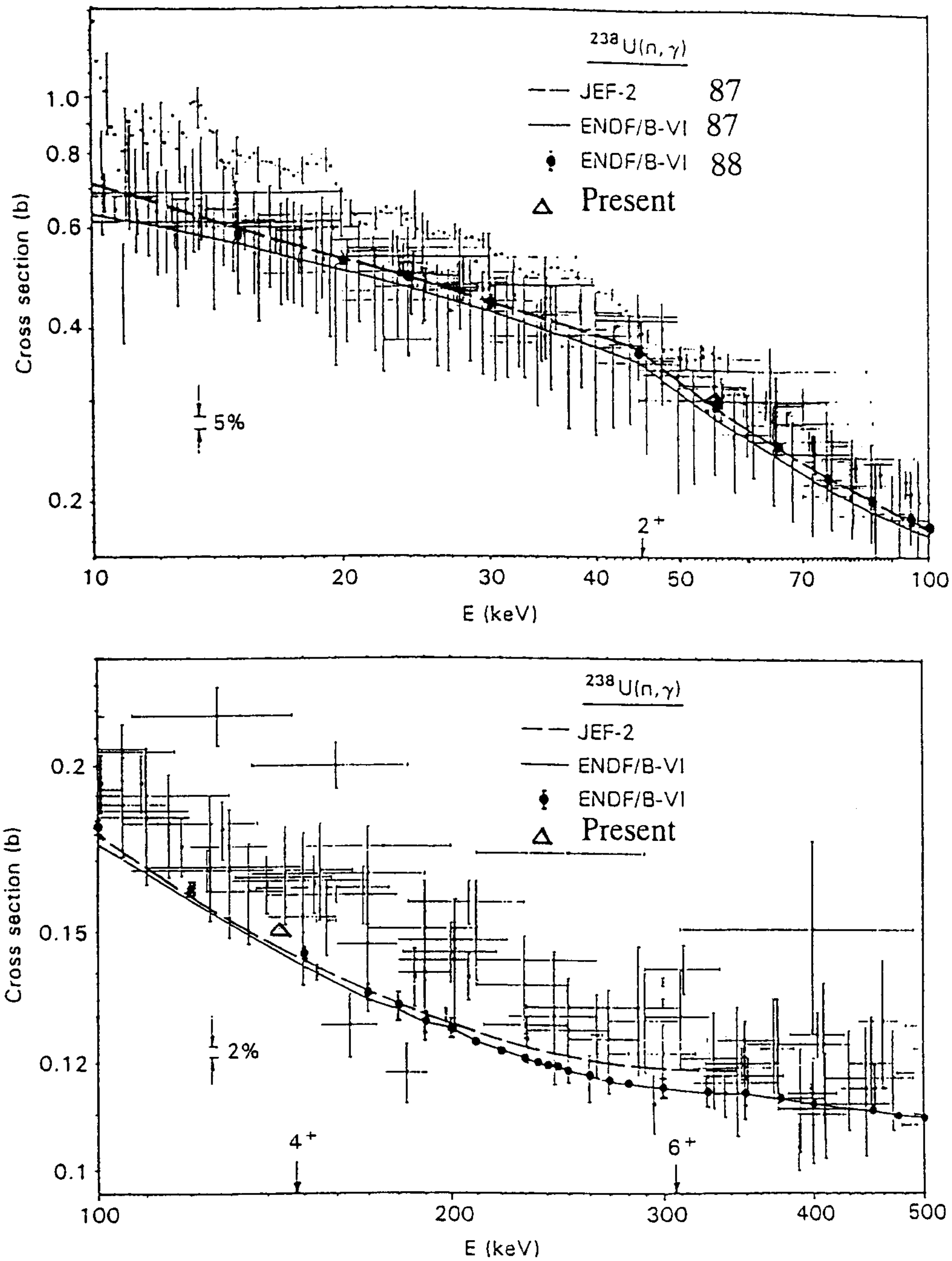

Fig. 2 Average neutron radiative capture cross sections of ^{238}U.

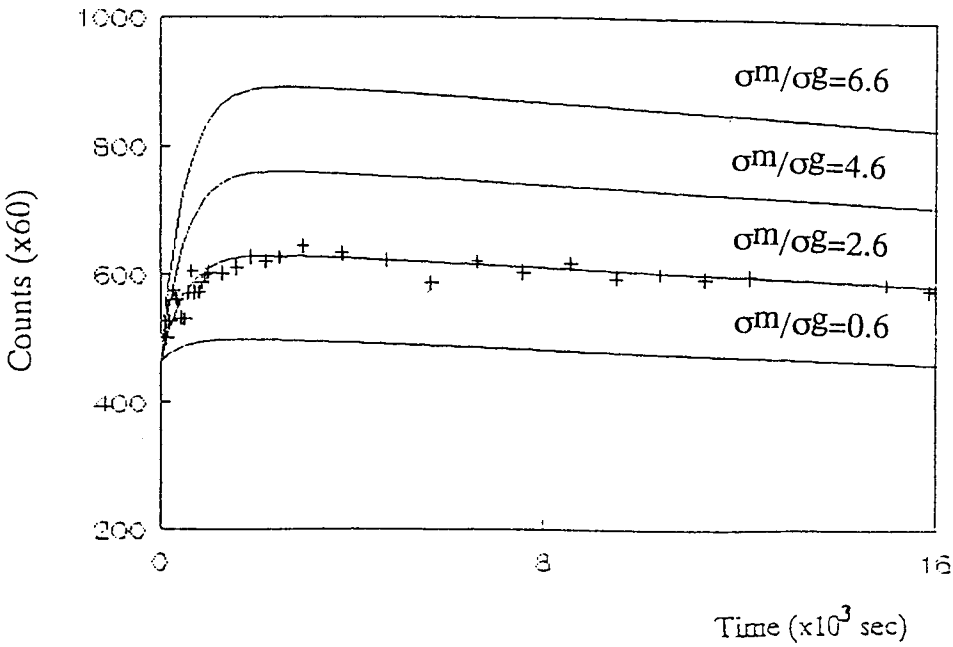

Fig. 3 The time decay of the 828 keV gamma-ray intensity of $^{82g,m}Br$.

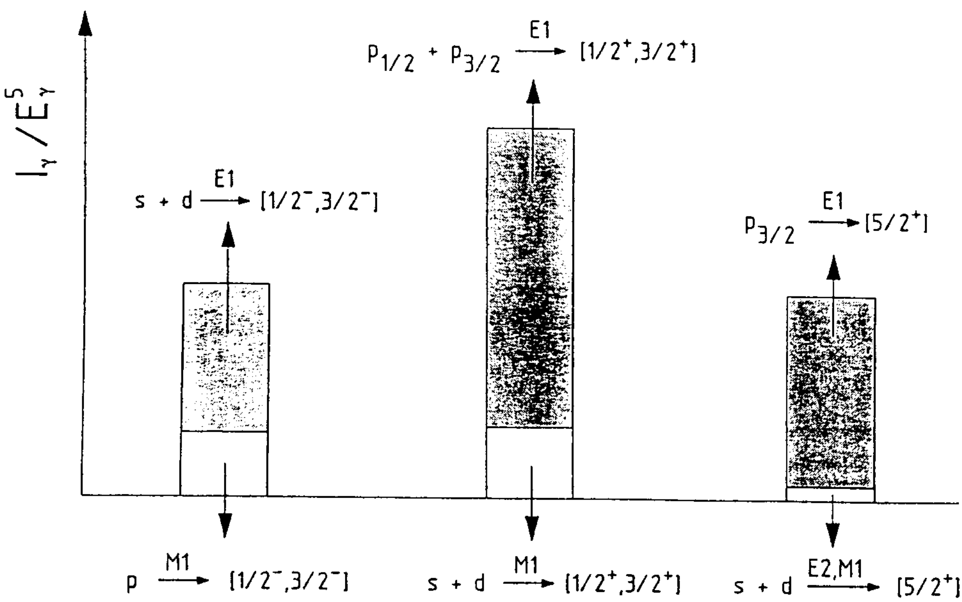

Fig. 4 The relative reduced gamma transition intensities of ^{239}U.

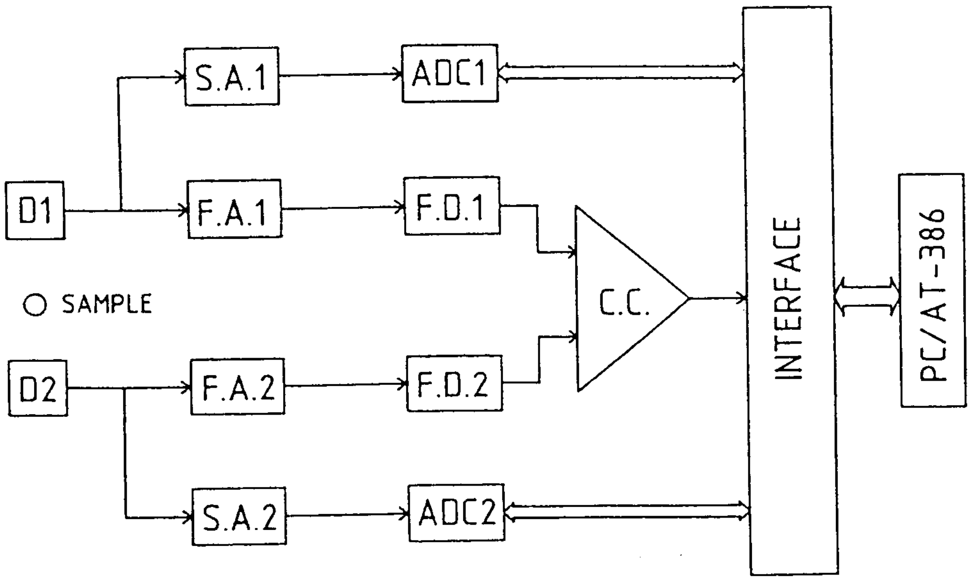

Fig. 5	The scheme of the SACP spectrometer at the Dalat reactor.	
	D: HPGe detector	S.A.: Spectroscopy Amplifier
	F.A.: Fast Amplifier	F.D.: Fast Discriminator
	C.C.: Coinciding Circuit	A.D.C.: Analog to Digital Convertor