THE ASPECTS OF LOW ENERGY ACCELERATOR APPLICATIONS IN VIETNAM

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Abstract

In Vietnam two low energy accelerators, a 14 MeV neutron generator and a 15 MeV microtron have been operated since 70' s. Some results in studies on nuclear structure and nuclear reaction as well as nuclear activation analysis based on these facilities are carried out.

A 200 keV ion implantor (MBP-200) had been set up in 1978 and repaired in 1992 for material science and analytical techniques, including stable isotope mass-spectrometry.

In the last few years four linac accelerators for medical radiotherapy have been installed and operated.

At present some another accelerators have been to be installing or planning to establish for different purposes, such as medicine therapy, non-destructive testing (NDT) in industry, containers inspection in custom and radiation technology.

This paper presents brief overviews of the status of the different activities on the development and application based on the above maintained accelerators. Submission of Papers

INTRODUCTION

In Vietnam, the activities connected with nuclear physics and techniques during last 40 years have been carried out on nuclear instruments listed in table 1.

Table 1

Instruments	Parameters	Institu--tions /*/
1 Reactor VVR-9	500kW	NRI
1 Microtron MT-17	e, γ, n 15 MeV	IOP
1 Neutron Generator	n 14 MeW	IOP
1 Ion Implantor	$^{+}$He,$^{+}$N50 keV	HSRI
1 Gamma Cell	Co60, 16 kCi	NRI
1 Gamma Irradiator	Co60, 110 kCi	INST
1 Gamma Center	Co60, 300 kCi	VAEC
4 Linac Accelerators	e, γ 6-15 MeV	Hospitals

** NRI : Nuclear Research Institute, Dalat*
IOP : Institute of Physics, Hanoi (HN)
HSRI : Hanoi Semi-Conductor Research Institute
INST : Institute for Nuclear Science &Technology,HN
IC : Irradiation Center, Ho-Chi-Minh City (HCMC)

Forty years ago, in 1962, the first research nuclear reactor (TRIGA Mark II) had been operated in Dalat city. Twenty years after, in 1982-1983, it had been reconstructed with upgrading from 250 KW to 500 kW power renamed VVR-9, and became the key tool for training, researching and producing radioisotopes.

The appearance of accelerator technology in Vietnam have been started 30 years back, then, a neutron generator in 1974 and a microtron in1982, acquired and put into operation at the Institute of Physics (belong to National Institute for Natural Science and Technology). Basing on these facilities the nuclear structure and nuclear reaction research as well as the applied study have been carried out.

An ion implantor had been set up in 1978 at the Hanoi Semi-conductor Research Institute, then stopped its operation for ten years. In 1992 it had been repaired and reconstructed for some R-D activities.

In the last two years four linac accelerators for medical diagnostics and therapy have been installed and operated at hospitals. Three Siemens linacs (PRIMUS type) have been installed and operated in Hanoi Cancer Institute (with 1 unit) and HCMC Choray General Hospital (with 2 units). Another one, Phillip linac (Elekta type), also had been set up at HCMC France-Vietnam Hospital.

At present some another electron accelerators have been installing or planning to establish for different purposes, such as medicine therapy, non-destructive testing (NDT) in industry, containers inspection in custom and radiation technology. Moreover two heavy charge accelerator (cyclotron facility) project is currently developing. The main application areas of this facility involve the production of short-life positron isotopes used for medical diagnostics.

MAIN ACCELERATOR CHARACTERISTICS

Neutron generator

The neutron generator, named NA-3C and made in Hungary, bases on a Cockcroft-Walton high voltage generator with a maximum voltage of 120 kV and produces 14 MeV neutrons via the ^{3}T(D,n)^{4}He reaction with total yield of 10^{11} n/s .

Microtron

The Microtron MT-17 electron accelerator was made in JINT (Dubna, near Moscow, Russia) and had been transferred to Institute of Physics, Hanoi. This machine is

possible to accelerate electron beam of up to 18μA and produces both:

i/ bremsstrahlung photons with E ≤ 15MeV

ii/ fission neutrons with total out put $\approx 10^{11}$ n/s

The bremsstrahlung photons are produced in channel 56^{O} by bombarding electron beam into a tungsten (W) target:

$$e \rightarrow W \rightarrow bremsstrahlung.$$

The fission neutrons are produced in channel 0^{O} with the aid of two converts, Tungsten (W) and Uranium (U):

$$e \rightarrow W \rightarrow \text{bremsstrahlung} \rightarrow U \rightarrow fission\ neutrons$$

Ion Implantor

A Cockcroft-Walton type ion accelerator or a ion implantor was made in Swizerland and named MBP-200 with original 200keV energy of ions.

Electron accelerators

All mentioned earlier Siemens linacs are variable-energy accelerators with the electron energy values of 6, 8, 10, 12, 15 MeV and with photon of 6, 15 MeV, and provide both X-ray and electron beam therapy. Their beam current can be presented as average radiation absorbed in water dose about 200cGy/min (maximum dose up to 500cGy/min) at 1m distance from source for X-ray and about 300cGy/min for electron beam.

International accelerators for collaborating

Vietnamese research groups have been collaborated with several accelerator facilities in Europe and Asia, such as Dubna (Russia), Darmstadt (Germany), RIKEN (Japan) and Pohang (Korea).

Concerning studies with ion beam, a group from Institute of Physics (Le Hong Khiem, etc.) had been sent to join experiments at heavy ion accelerators system in GSI, Darmstadt and also at RIKEN Accelerator Research Facility. Their experiments were performed in Darmstadt and Tokyo and most data were analyzed in Hanoi.

As MT-17 microtron is limited an physicists group (Tarn duc Thiep, etc.) had used MT-22 and-25 microtrons at Dubna to carry out investigations in a wide energy range of photons from 10 to 25 MeV. Recently, another group (Nguyen van Do, etc.) had participated the experiments at Pohang Neutron Facility consisted an 75 MeV electron linac and another devices, such as magnets and etc.

STUDIES WITH 14 MEV NEUTRONS

These work were done mainly by Institute of Physics groups and their obtained results have been summarized and published in [1,2].

Determination of reaction cross – sections

Typical results of (n,p), (n,n'p) and (n,α) cross - sections induced by 14 MeV neutrons on Cr, Ti, Zr, Zn, Mo, Rb and Mn isotopes are shown in [1]. Besides, isomeric cross - sections ratios of values 0.46±04; 0.70±0.06; 0.31±0.02 and 0.41± 0.03 had been determined for (n,2n) reactions forming isomeric pairs $Nd^{141m,g}$, $Sm^{143m,g}$, $Zr^{89m,g}$ and $Pd^{109m,g}$ respectively.

Neutron Activation Analysis (NAA)

The different proposed analytical procedures have been successful established for routine analysis of various kinds of samples. This 14 MeV NAA method has been used for determination of elements having large reaction cross - sections and short half - lives such as aluminium, silicon and iron in bauxite. The analysis of Al, Si, Fe (in bauxite), N (in soybean) and F (in fluorite ore) has been performed.

Fission neutrons from MT - 17 microtron have been slowed down to thermal energy and used as thermal neutron activation source for a large number of elements such as Mn, In, Au, U, and Dy with the sensitivity of about 10 to 0.1 ppm.

STUDIES WITH PHOTONS

Photofission

Photofission induced by 15 MeV (maximum energy value) bremsstrahlung has been studied at the MT-17 microtron [2,3].

Photofission products were identified by determination of their half-lives and energy of gamma transitions. The mass and charge distributions of fission fractions of ^{238}U and ^{232}Th were presented. For ^{232}Th, 7 independent and 34 cumulative yields as well as 28 mass chains have been obtained in the region of A from 88 to 149 [2,3].

Isomeric ratios ($R=\sigma_m/\sigma_g$)

Isomeric ratios were studied, in particular at NA-3C in the (n,2n) reaction induced by 14 MeV neutrons but, mainly, by the photoreaction induced by bremsstrahlung at the MT-17 microtron. Both the isomeric state and ground state in the target were obtained, and their corresponding cross-sections or σ_m and σ_g, either $R=\sigma_m/\sigma_g$ were been estimated.

These measurements have been performed by T.D. Thiep et al. [1,2] for ^{142}Nd, ^{144}Sm, ^{89}Zr, ^{109}Pd, ^{120}Sb, ^{122}Sb and ^{85}Sr.

Studies on nuclear structure

This study have been carried out by Tran Thanh Minh group [4]. Some results on decay of Sn119, Sn119, Ba129 isomers and the characteristics of beta decay from Ba129m isomeric states and the structure parameters such as energy, spin, parity of Cs137 nucleus were obtained.

Gamma, Neutron Activation Analysis (GAA, NAA)

Besides of NA-3C neutron generator, the MT-17 microtron have been used to analyze some light elements in geological and environmental samples. The protein content in rice also was determined by detecting

annihilation gamma ray 511 keV of $^{14}N(\gamma,n)^{13}N$ reaction in coincidence regime [1].

A combination of bremsstrahlung target (W) and thermal neutron target (U-238) was used to develop a combined analysis method based on photon and thermal neutron activation. Such a mixed photo-neutron activation has significantly improved the sensitivity of the analysis, e.g., for $^{114,116}Cd$ and $^{122,124}Sn$, the sensitivity has been improved by the factor of 2 and 10, respectively[5].

STUDIES WITH MPB-200

In 1992 the MPB-200 ion implantor was carried out to repair. And the implantor has further served as an useful on-job-training facility on accelerator techniques, such as vacuum, high voltage, electro-magnetic focus, beam monitoring, electronic and mechanical control system etc. The successful reparation has opened an opportunity to carry out a series of research studies at the MPB-200 in the material science and analytical techniques, including stable isotope mass-spectrometry.

N^+ or He^+ ions at 50 keV were implanted into steel/Nickel specimens to study the modification of mechanical properties [6]. In particular, the amorphisation was investigated in iron implanted by N^+ ions.

The magnetic mass-separator of the MPB-200 at acceleration energy of 50 keV has been tested for mass-spectrometry of light stable isotopes. The result obtained by Vo van Thuan, etc. group [7,8] shows a clear resolution of pure natural N-29 (^{14}N + ^{15}N), O-34 (^{16}O + ^{18}O) and some estimation of D/H [9].

ANOTHER STUDIES ON NUCLEAR REACTION

Studies with Dubna Microtrons

At the MT-22 and MT-25 Microtron 25 mass chains of ^{242}Pu photofission had been obtained with the appearance of a weak fine structure in mass region 133-135 due to the closed neutron shell N = 82. For ^{235}U the cumulative yields for 44 mass chains have been determined. A fine structure in mass region 133-135 and 140-142 was observed [1].

The experiments on isomeric ratios for ^{142}Nd, ^{144}Sm, ^{89}Zr, ^{109}Pd, ^{120}Sb, ^{122}Sb and ^{85}Sr were repeated at Dubna MT-25 Microtron by T.D. Thiep et al [1].

Studies with Pohang Linac

Some experiments were performed during 2002-2003 years at Pohang 100 MeV Electron Linac by Nguyen van Do group from Institute of Physics. These are following :

a) Search for neutron and gamma distribution at electron beam of 35 mA current and 65 MeV energy

b) Search for the fast neutron spectrum from a thick Ta target based on reactions, such as $^{27}Al(n,p)^{27}Mg$ (Eth= 1.9MeV), $^{27}Al(n,\alpha)^{24}Na$ (Eth= 3.2 MeV), $^{24}Mg(n.p)^{24}Na$ (Eth=4.94 MeV), $^{51}V(n.p)^{51}Ti$ (Eth= 5.84 MeV)

c) Search for (p,xn) reactions on Cu, Mo, Zr and Ni with 30 MeV protons

d) Search for (γ,xn) reactions on Cu, Mo, Zr and Ni with 65 MeV Bremsstrahlung

e) Search for fast neutron (up to 100 MeV) spectrum based on 209Bi(n,xn) reactions with n=1,2,3,…10).

Their experimental results are under processing [10].

Studies with RIKEN Accelerator Research Facility

Studies on production of neutron-rich isotopes by fragmentation of 80 MeV/nucleon ^{59}Co beam were carried out by Le Hong Khiem in participation with Japanese colleagues at RIKEN, Japan. Some typical obtained results are following [11] :

i/ Mass spectrum of Ca fragments from ^{59}Co fragmentation at 80 MeV/nucleon obtained for a Bρ value of 2.995 Tm.

ii/ Experimental production cross-sections for the neutron-rich fragments produced with ^{59}Co beam in a beryllium target.

Related research in nuclear physics and high energy

Nuclear theory research began in INST since the early 1990's by Tran huu Phat, etc. group from INST. Later, for last 5 years Dao Tien Khoa, etc. group also from INST have mainly focused on the nuclear reaction with ions, such as "Folding model analysis of elastic and inelastic proton scattering on sulfur isotopes" [12], "Probing the isovector transition strength of the low-lying nuclear excitations induced by inverse kinematics proton" [13] and "Microscopic study of interaction cross sections measured at relativistic energies for stable and unstable" [14].

Nguyen Mong Giao, etc. group from Ho-Chi-Minh branch of IOP have participated in the DO-collaboration at the FERMILAB, USA and experiments at CERN [15].

Joining the Pierre Auger International Collaboration on searching for highest energy cosmic rays, at the VATLY laboratory (INST), the atmospheric muon spectrum has been measured in Vietnam first time by Darriulat group [16] and some phenomenological study of neutrino oscillation was also carried out. [17].

ACCELERATORS FOR MEDICINE AND OTHER USES AT PRESENT AND FUTURE

The four first electron linacs located in Hanoi and HCMC hospitals has opened a new era in radiotherapy in country. For last two years many thousands patients have been treated by these machines.

However, at present among 80 millions population of Vietnam there are around the total new cancer patients expected to be about 100.000 per year. So 15 radiotherapy centers equipped with the cobalt irradiators and 3 hospitals with 4 linacs are not enough to meet the constantly growing demand.

Therefore a rapid growth of linac therapy is expected. About ten another medicine electron accelerators have been installing or planning to establish at the new Hanoi

Cancer Hospital (Thanh Nhan), HCMC Cancer Hospital, Hue Hospital etc. Moreover, two heavy charge accelerators (PET-cyclotrons) in Hanoi and Ho Chi Minh city projects are currently developing. The main application areas of such facilities involve the production of short-life positron isotopes used for medical diagnostics.

Besides, some projects to set up accelerators for different purpose, such as nuclear research, non-destructive testing (NDT) for industry, containers inspecting for custom, irradiation technology etc. have began to start.

CONCLUSION

In Vietnam, the low energy particle accelerator technology time by time have found usefull applications, starting from basic and applied sciences and contributing widely to economical-technical areas. The collaboration between our colleagues with international accelerator community, especially in APAC organization also have been expanded wide and wider. We believe that this status will strongly effort to the development of accelerator technology up to a new scale in the near future.

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REFERENCES

[1] Tarn duc Thiep, Nguyen van Do et al, Nuclear Physics A722 (2003) 568c-572c
[2] Nguyen Van Do and Tarn Duc Thiep, Proc.of the APAC'98, KEK, Tsukuba, March 23-27, 1998, p.49.
[3] Nguyen Van Do et al., (VN) Comm. in Phys., Vol.8 (1998) 113.
[4] Tarn Thanh Minh and Nguyen van Do, Proc.of the APAC'01, Beijing, September 17-21, China, 2001, p.806.
[5] Nguyen Van Do et al., Radioanal. Nucl. Chem. Letters, Vol.107(1988)39.
[6] Hoang Dac Luc and Nguyen Nhu Thieu, Comm. in Phys., Vol.5(1995)34.
[7] Nguyen Tien Dung et al., Proc.of the 1rst Vietnam Conference on Nucl. Physics and Techniques, Hanoi, May 14-15, 1996. VAEC, 1996, p.208.
[8] Vo Van Thuan et al., Comm. in Phys., Vol.4 (1994)186.
[9] Nguyen Duc Thanh et al., Proc.of the 1rst Vietnam Conference on Nucl. Physics and Techniques, Hanoi, May 14-15, 1996, VAEC, 1996, p.213.
[10] Nguyen van Do et al (to be completed for publication).
[11] Le Hong Khiem et al, Nuclear Physics A722 (2003) 484c-488c.
[12] Dao Tien Khoa et al, Nuclear Physics A, 706, 61-84 (2002).
[13] Dao Tien Khoa, Physical Review C, 68, 011601(R) (2003).
[14] Dao Tien Khoa et al, Nuclear Physics A, 722, 92c-97c (2002).
[15] Nguyen Mong Giao, Proc. of the VN Conf. On Nucl. Phys. And Techniques, Dalat, 22-24 March 1999, VAEC, 2000, p.10.
[16] Dang Nguyet Anh, Nguyen Mau Chung, P.Darriulat et al, Conf. On from the largest to the smallest distances, Moscow, 23-26 May 2001.
[17] Vo van Thuan et al, Proc. of the 1rst workshop on Neutrino oscillations and their origin, Fuji-Yoshida, Japan, 11-13 February 2000, Universal Academy Press , Tokyo, 2000, p.139.