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PHOTO-ACTIVATION METHOD FOR DETERMINATION ELECTRON ENERGY OF LINEAR ACCELERATOR*

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Abstract

Unknown energy of electron beam of linear accelerator LINAC-200 was estimated by photo activation of only one activation detector – foil of natural indium. Four different photonuclear reactions were considered: ^{115}In(γ, γ')^{115m}In, ^{115}In(γ, n)^{114m}In , ^{115}In(γ, 2n)^{113m}In and ^{113}In(γ, 2n)^{111}In. Ratio of saturation activities R(^{113m}In)/R(^{115m}In), R(^{114m}In)/R(^{115m}In) and R(^{111}In)/ R (^{115m}In) were determined by standard gamma spectroscopy in electron energy region of interest (10 MeV – 23 MeV) using indium foils exposed in the FLNR Microton MT25 bremsstrahlung beam. The choice of cyclic accelerator MT25, as a reference machine, was made due to the fact, that the energy of its electrons is known with accuracy not worse than 1%. Same ratios of saturation activities were determined after exposition of In activation detectors in photon beam of linear accelerator. The fact that both irradiations, by Microton MT25 and accelerator LINAC-200, were performed in identical geometry using same target (3 mm of Tungsten) allowed us to estimate electron energy of accelerator by comparison of ratios of saturation activities obtained by both machines. Small variation in accelerator electron current was taken in consideration [1].

INTRODUCTION

The energy of electrons accelerated in linear accelerator wave guide (and maximal energy of bremsstrahlung produced as well) is one of the most important parameters. Although the principle of electron acceleration by EM wave is well known, determination of maximal accelerating potential and electron energy is not straightforward. The photoactivation reactions are usually method of choice for energy calibration of bremstrahlung endpoint energy. Direct measurement of energy spectra of accelerated electrons using some solid state detector (BGO or LaBr) can be very fast and confident method for linear accelerator monitoring. However, accurate energy calibration of detectors in MeV region is a problem that cannot be ignored.

In this work we would like to present simple method developed at JINR for fast determination of electron energy of linear accelerator LINAC-200. Method consists of three stages:

i) determination of ratios of saturation activities of several products of photonuclear reactions on selected target exposed to photon beam of Microtron MT25. Obtained ratios of saturation activities of several products of photonuclear reactions determined in the broad region of Microtron photon energies were used as calibration ones considering that energy of electrons accelerated in MT25 is known with accuracy up to 1%;

ii) exposition of same activation detectors in photon beam of linear accelerator. It is very important to underline that photon beam of LINAC-200 is produced in Tungsten target of Microtron. Ratios of obtained saturation activities obtained were determined and used to estimate energy of accelerated electrons by comparison with Microtron derived ratios of saturation activities

iii) measurement of single electron spectra by the use of BGO detectors positioned directly in the electron beam of linear accelerator. Estimated electron energies were used to calibrate BGO detectors in high energy region.

DESCRIPTION OF METHOD

The yield of products of photonuclear reaction can be described by the saturation activity R:

$$R = \int_{E_{th}}^{E_{max}} \sigma(E) \cdot \Phi(E) \cdot dE \qquad (1)$$

where σ (E) is cross section for observed nuclear reaction Φ (E) is flux of photons, E_{th} is the energy threshold for nuclear reaction and E_{max} is the maximal energy of photons. The activity of the isotopes after the exposure was measured by the HPGe spectrometer. The saturation activity can be experimentally determined using the intensity of a single gamma line in recorded gamma spectra as:

$$R = \frac{N_\gamma \, \lambda \, M}{m \, N_{Av} \, \varepsilon \, \eta \, p_\gamma e^{-\lambda \Delta t}\left(1-e^{-\lambda t_{irr}}\right)\left(1-e^{-\lambda t_m}\right)} \qquad (2)$$

where N_γ is the number of detected gamma photons of chosen energy, λ is the decay constant, M and m are the mass number and the mass of the activation detector used, N_{Av} is Avogadro number, ε is the efficiency of the detector at the chosen energy, η is the natural abundance of activated isotope, p_γ is the quantum yield of detected photons, Δt, t_{irr} and t_m are cooling, irradiation and measurement time respectively.

It was chosen to use ratios of saturation activities of two or more products of photonuclear reactions for energy calibration. In this case a number of parameters related to exposition and measurements of activation detector disappear. Due to the difference in the energy dependences of the cross sections for different photonuclear reactions, ratio of saturation activities is still function of bremsstrahlung endpoint energy. Natural Indium, in the form of tiny discs was chosen to be activation detector because four photonuclear reactions can be followed

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simultaneously. Used photonuclear reactions and several relevant data are presented in Table 1.

Table 1: Data Relevant to the Nuclear Reactions Being Monitored

reaction	$T_{1/2}$	$E\gamma$ [keV] ($p\gamma$)
^{115}In (γ, γ')^{115m}In	4.486 h	336.26 (0.458)
^{115}In (γ,n) ^{114m}In	49,51 d	190.29 (0.156)
^{115}In (γ,2n) ^{113m}In	1.658 h	391.69 (0.642)
^{113}In (γ,2n) ^{111}In	2.81 d	245,4(0,94)

Irradiated indium coins were measured by HPGe detector having relative efficiency of 25 %. Detector was shielded by 5 cm of lead. All Indium activation detectors were located directly on the vertical dipstick of the detector. Three different ratios of saturation activities were followed: R(^{114m}In)/R(^{115m}In), R(^{113m}In)/R(^{115m}In) and R(^{113}In)/R(^{115m}In). Mentioned ratios were determined in Microtron's photon beam in broad energy region, from 11 MeV to 23 MeV. Obtained values were used to construct a kind of "calibration graphs" showing energy dependence of ratios of saturation activities. In the next stage, Indium coins were exposed to photon beam of linear accelerator. Same ratios of saturation activities were calculated and using "calibration graphs" energy of electrons accelerated by LINAC-200 were directly determined.

In the last phase electron energy spectra were directly measured using BGO and LaBr detectors consistently with exposition of In coins. Considering that estimation of electron energies was provided by activation, calibration of BGO and LaBr detectors in energy region from 11 MeV to 23 MeV was possible.

RESULTS AND DISCISSION

The method was tested in two different ways:

i) one fixed energy of linear accelerator was determined using three different ratios of saturation activities

ii) one chosen ratio of saturation activity (R(^{114m}In)/R(^{115m}In)) was used to estimate several different accelerator energies. Electron spectra were recorded by BGO and LaBr detectors at same energies. The results of first approach are presented at Fig. 1. Ratios of saturation activities (R(^{114m}In)/R(^{115m}In), R(^{113m}In)/R(^{115m}In) and R(^{113}In)/R(^{115m}In)) obtained in Microtron photon beam, in the energy region from 18 MeV to 23 MeV are presented by points. Horizontal lines represent values of saturation activities obtained in photon beam of linear accelerator. It can be seen that all three methods give very consistent estimation of electron energy of linear accelerator. Difference between obtained values is not higher than 0.2 MeV. Values of R(^{114m}In)/R(^{115m}In) ratio collected in Microtron beam in energy region from 11 MeV to 23 MeV were used to estimate several energies of linear accelerator. Figure 2 presents ratios of saturation activities obtained by Microtron (points nd line to guide the eye) and by horizontal lines are presented values of saturation activities measured after exposition of In activation detectors in photon beam of linear accelerator.

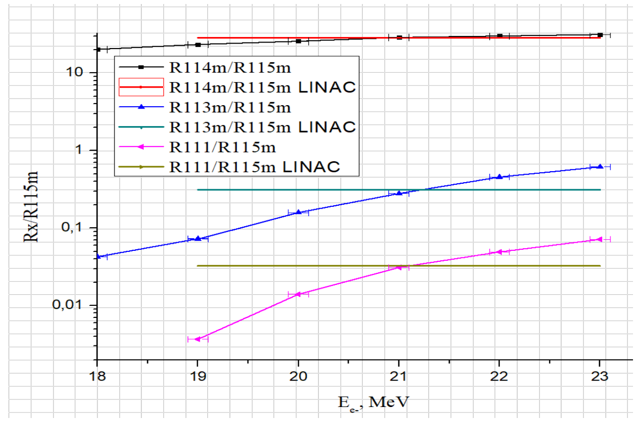

Figure 1: Energy of 21±0,1 MeV measured on LINAC by the ratio of different isotopes of indium.

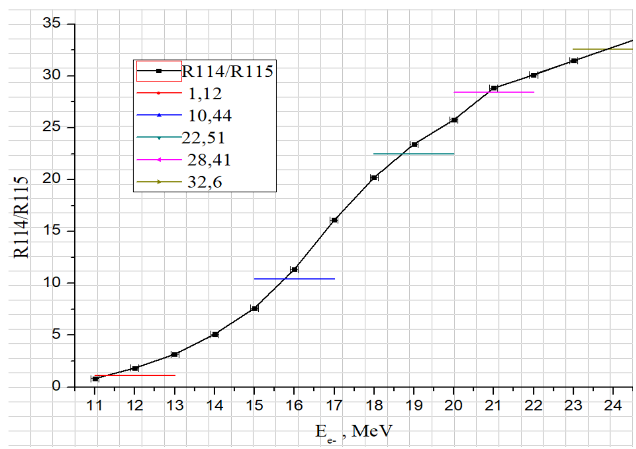

Figure 2: Dependence of the ratio of the activity of indium isotopes ^{114}In/^{115}In on the energy of electrons accelerated on a Microtron.

The energy spectra of the electrons obtained on all the energies used, on both detectors, have a similar structure. Peaks with a very sharp edge are observed, which correspond to the maximum energy of the electron. The structure observed at lower energies corresponds to the events ьхен the part of the energy of the electron avoided detection. Figure 3 shows two energy spectra of electrons of 11.3 MeV and 23.8 MeV obtained by a LaBr detector. The division on the x-axis is given in relative units corresponding to energy. It can be noticed that with the increase in the energy of the electron cut-off edge of the spectrum moves toward higher values.

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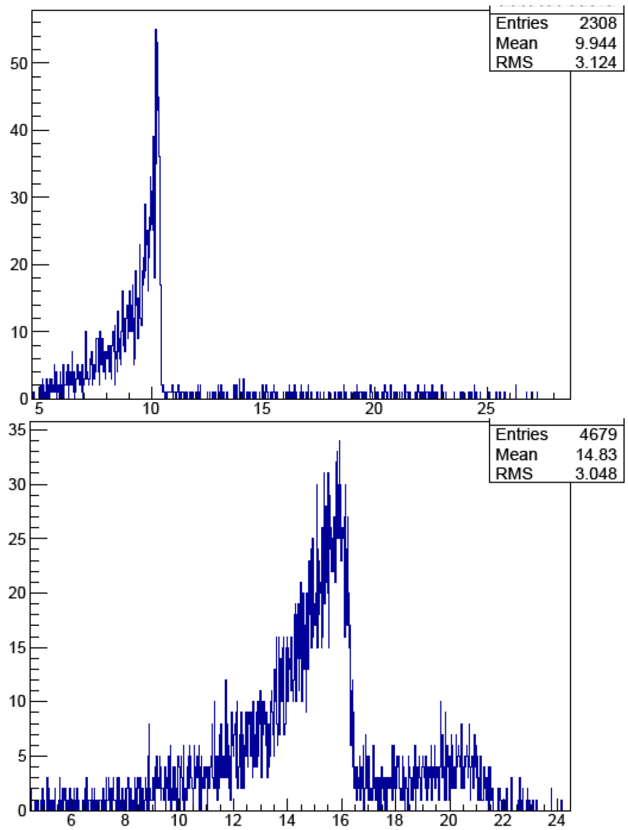

Figure 3: LaBr spectra: 11.3 MeV up and 23.8 MeV down.

CONCLUSION

It has been shown that the energy dependence of the saturation ratios of the products of photonuclear reactions obtained on the Mikrotron can be used to determine the energy to which the electrons in some other accelerators are accelerated, as in our case with LINAC-200. With various ratios of saturation activities of photonuclear reaction products (natural indium has 4 in the energy range observed), very consistent estimates of energy on another accelerator are obtained. The energy spectra of the linear accelerator BGO and LaBr detectors were recorded. On each of them there is a sharp edge corresponding to the energy of the electron. It opens the possibility of obtaining a sensitive method able to provide reliable value of the maximum energy of the electron by direct measurement.

REFERENCES

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