ISBN: 978-3-95450-197-7 doi:10.18429/JACoW-RUPAC2018-WEPSB56

METHODICAL ISSUES OF THE USE OF DETECTORS FOR DOSIMETRY IN BEAMS OF THE CARBON NUCLEI OF THE ACCELERATOR U-70

A.G. Alexeev, E.V. Altuhova, I.I. Degtarev, V.A. Pikalov, O.V. Sumaneev, A.A. Yanovich, F.N.Novoskoltsev, NRC «Kurchatov Institute» – IHEP, Protvino
O. Kiryuhin, MSU, Moscow

Abstract

In the SRC "Kurchatov Institute"-IHEP are working on the project "Center for Ion Radiation Therapy". At present, the first stage of this project has been implemented is the creation of the Center Use "Radiobiological Stand on Carbon Beam of U-70 (RSU) [1]. RSU is used for radiobiological experiments. The research and testing of systems for radiotherapy by a carbon ions beam are tested at RSU. In this paper the result of methodologilal issue of the use of thermoluminescent detectors (TLD) and radiochromic films for dosimetry in a beam of carbon ions are used.

MEASURING INSTRUMENTS USED

In this work, 2 types of thermo luminescent detectors were used (DTG-4 and MMT-7). DTG-4 is single-crystal TLD, produced by the Angarsk branch of URALPRIBOR MMT-7 is polycrystalline, manufactured by RADCARD Poland (LiF). These TLD are specially designed for dosimeter for ions beam with large LET. The HARSHAW-4000 was used for the reading of TLD (NTC "Praktica-TL, Moscow).

Together with the TLD, the radiochromic EBT3 film was used [2]. All dissymmetric measurements were performed in a water phantom, which is a container with external dimensions of 590x360x375 mm. The material of the phantom walls is polycarbonate. The thickness of the front wall (relative to the direction of the beam) is 30 mm, the lateral - 15 mm. Inside the water phantom, an air chamber (caisson) is fixed with external dimensions of 130x240x265 mm. Detectors and dosimeters were placed in the caisson. The scheme of measurement is present on Fig. 1.

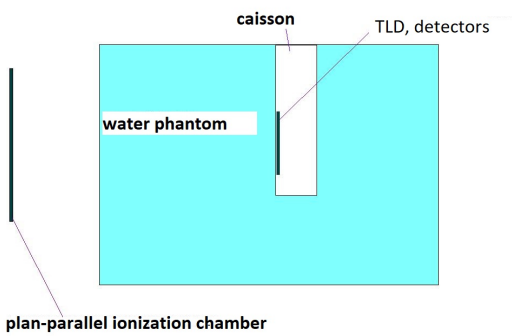

Figure 1: Measurement scheme.

CALCULATION OF THE BRAGG CURVE

The calculation of the Bragg curve and the estimation of the contribution of thermal neutrons to the TLD readings was made on the basis of calculations for 3 codes. MCNPX, FLUKA [3] and RT&T code system [4] were used for calculations. Absorbed dose (secondary charged particles contributions) in the water phantom is present on Fig. 2. The calculation is carried out by FLUKA. Carbon ions energy is 400 MeV/ nucleon. A comparison of the calculation of the Bragg peak and the experiment [5] is shown in Fig. 3. The calculation of the average LET value with the help of Fluke is shown in Fig. 4.

Neutron flux (thermal neutrons (En<0.4 eV) and in total energy range (TOTAL)) in the water phantom is present on Fig 5a, b. MCNPX, FLUKA and RT&T code system were used for calculations. A good agreement between the results of calculations for different codes is observed.

Estimation of contribution of thermal neutrons to the indication of DTG-4 (after the Bragg peak) is not more then 2 %.

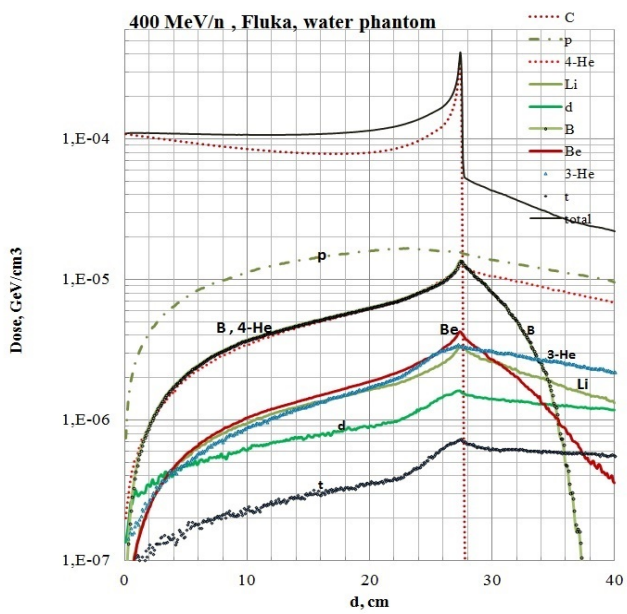

Figure 2: Absorbed dose (secondary charged particles contributions) in the water phantom.

ISBN: 978-3-95450-197-7 doi:10.18429/JACoW-RUPAC2018-WEPSB56

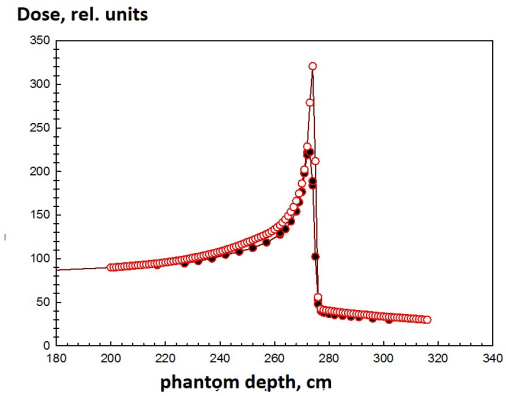

Figure 3: Absorber dose in the water phantom. FLUKA calculation is not filled circles; the measurements is filled circles.

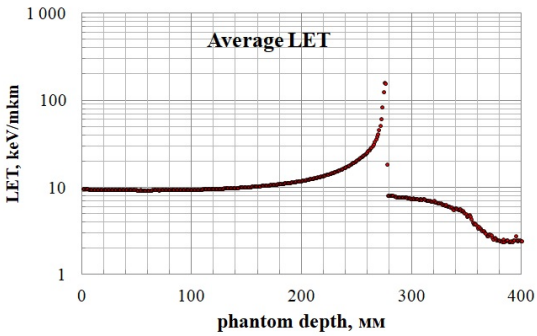

Figure 4: The average LET in water phantom.

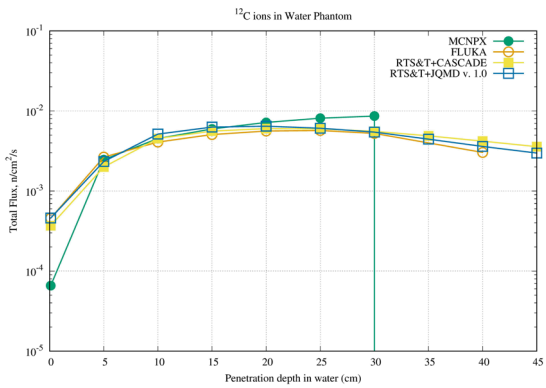

Figure 5a: Total neutron flux in the water phantom.

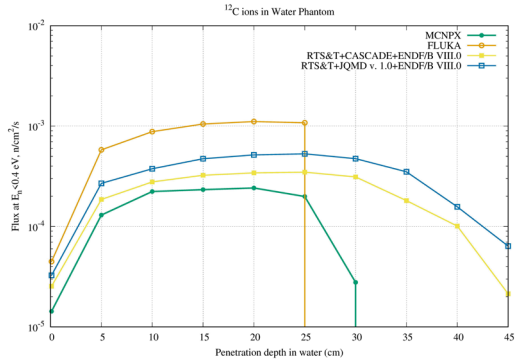

Figure 5b: Thermal neutrons (En<0.4 eV) flux in the water phantom.

TLD METHOD FOR MEASURING DOSE

The TLD dose measurement methodology includes the following:

- Annealing order of TLD (temperature and annealing time for each type of TLD in accordance with the manufacture's recommendations);
- Individual calibration of each detector on a calibration source (performed in each measurement cycle);
- calibration of the detectors is performed before each accelerator ran;
- measuring (heating) mode is performed in accordance with the manufacturer recommendation;
- The time interval between annealing and exposure does not exceed 10 days [6] ;
- The time interval between exposure and measurement does not exceed 4 days [6];
- The dependence of the sensitivity of the TLD in the dose value is taken into account (for each type there is a dependence);
- The correction for the dependence of MMT-7 sensitivity on LET is done using the HTR-method (High Temperature Ratio) [7].

The experimental dependence of HTR parameter for MMT-7 from LET is present on Fig. 6. The dependence was obtained by irradiation of TLD by 30, 50, 70, and 120 MeV protons and carbon ions. The LET correction factors for DTG-4, MMT-7, EBT3 are presents on fig. 7. The calculated data of the mean value of the LET in the water phantom (Fig. 4) is used to determine this dependence.

ISBN: 978-3-95450-197-7 doi:10.18429/JACoW-RUPAC2018-WEPSB56

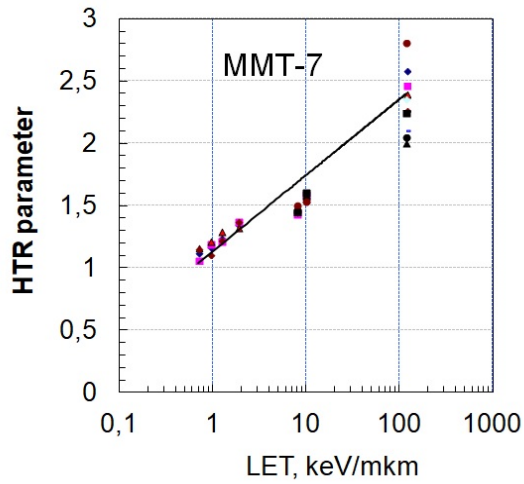

Figure 6: Dependence of HTR parameter for MMT-7 from LET.

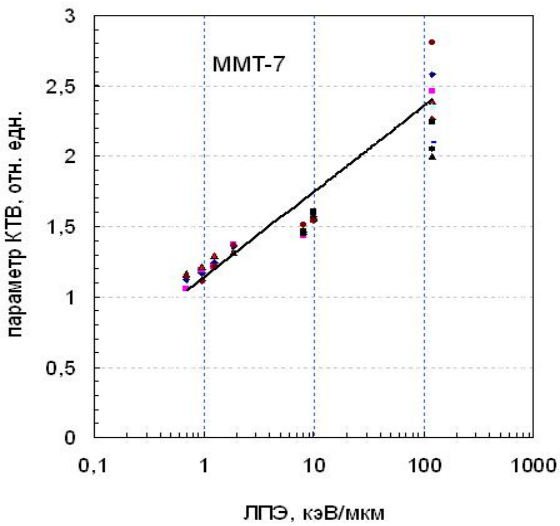

Figure 7: LET correction factors for DTG-4, MMT-7 EBT3

CONCLUSION

The special method for measuring the absorber dose of carbon ions by TLD for the purposes of dose measurement support of radiobiological research at RBS was developed. The procedure includes all the main factors affecting the accuracy of the measurement. This makes it possible to measure the absorbed dose with an error of not more then 5%.

REFERENCE

[1] S. Ivanov. Status of U70, Proceedings of RuPAC2016. Paper TUZM01, P.44-49. www.ihep.ru/pages/main/6580/8769/index.shtml

[2] GAFChromic™ EBT3 film specifications, Available at www.gafchromic.com.

[3] "The FLUKA Code: Developments and Challenges for High Energy and Medical Applications" T.T. Bohlen, F. Cerutti, M.P.W. Chin, A. Fasso`, A. Ferrari, P.G. Ortega, A. Mairani, P.R. Sala, G. Smirnov, and V. Vlachoudis, Nuclear Data Sheets 120, 211-214 (2014)

[4] I.I. Degtyarev, F.N. Novoskoltsev, O.A. Liashenko, E.V. Gulina, L.V. Morozova, The RTS&T-2014 code status, Nuclear Energy and Technology, v.1, Issue 3, November 2015, p.222-225.

[5] Troshina M. V.- Private communication. Measurement protocol. -MRNC- branch of FGBU "NMI of radiology". Obninsk. 2017.

[6] O.I.Batuhtina –private communication/ Report on the study of parameters of DTG-4. Angarsk branch of LLC URALPRIBOR. Angarsk. 2017.

[7] M.Noll, N.Vana, W.Schıner, M.Fugger, H.Brandl, Dose Measurements in Mixed (n, γ) Radiation Fieldsin Aircraft with TLDs under Consideration of the High Temperature Ratio. Radiat. Prot. Dosim. 66(1-4), 119-124 (1996).