PORRAS-1: Desired beam parameters for accelerator-based Boron Neutron Capture Therapy from in-phantom simulations and Nuclear Data Needs

I. Porras, P. Torres-Sánchez, F. Arias de Saavedra and J. Praena

Departamento de Física Atómica, Molecular y Nuclear, Facultad de Ciencias, Universidad de Granada, E-18071 Granada, Spain.

The features of the neutron beam from a charged particle accelerator via a specific nuclear reaction with a suitable target can be very different to the one obtained from a nuclear reactor. The combination of the charged particle energy and the beam shape assembly increases the possibilities of optimizing the spectrum in the epithermal range, which may expand the therapeutic region inside the body for treatments of deep seated tumors.

We have explored what is the optimal neutron energy which produces the widest range in the body where the tumor dose exceeds at least twice the maximum dose delivered to normal tissue, by means of Monte Carlo simulations of monoenergetic neutron beams in different phantoms. This lies in the range from 1 to 7 keV, close to the upper bound limit for epithermal neutrons of 10 keV previously considered. As this limit has been the subject of some discussion, we have also analyzed neutrons above this limit and we find that neutrons up to energies in the range 15-20 keV (depending on the tissue) are still useful for BNCT (Figure 1). As some accelerator-based neutron beam designs present their maximum near the epithermal limit of 10 keV, this quantity (which previously was just an order of magnitude for separating the high energy tail from the spectrum) is key for a spectrum to qualify in the recommendations for desired beam parameters. Then, we have performed dose-depth profiles and map doses for realistic spectra obtained from low energy protons on lithium and moderated with different beam shape assemblies complying with the actual recommendations from the IAEA when raising this epithermal limit up to 20 keV. Results show a very good therapeutic ability.

In addition to this, we have analyzed the nuclear data which are required for the Monte Carlo simulations of both the beam shape assembly and the dose profiles in tissue. Although most of these data are well known, we found some discrepancies between experimental values and evaluations or data missing in some reactions relevant to BNCT. Our group, which is part of the neutron time of flight (n_TOF) collaboration at CERN, has carried out recent measurements of the neutron capture reactions on ^{14}N and ^{35}Cl[1], which can increase the accuracy of the dose calculations by means of Monte Carlo simulations. Also, some other nuclear data needs for the design of beam shape assemblies will be also discussed for future measurements.

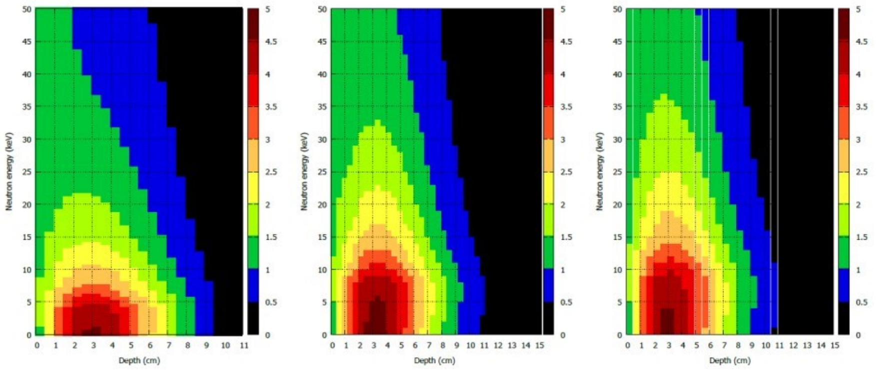

Figure 1. Ratio between tumor dose and maximum normal tissue dose (color) as a function of depth (Xaxis) and neutron energy (Y-axis) for brain (left), neck (center) and abdomen (right).

[1]**Praena J, Porras I, Sabaté-Gilarte M** et al. 2017. The $^{14}N(n,p)^{14}C$ and $^{35}Cl(n,p)^{35}S$ reactions at n_TOF-EAR2: dosimetry in BNCT and astrophysics. Proposal to the ISOLDE and Neutron Time-of-Flight Committee. *CERN Document Server:* https://cds.cern.ch/record/2266484.
Porras I, T. Wright T, Bennett S et al. 2018. Measurement of the $^{35}Cl(n,\gamma)$ cross section at n_TOF EAR1. Proposal to the ISOLDE and Neutron Time-of-Flight Committee. *CERN Document Server:* http://cds.cern.ch/record/002299695.