# LIU-1: Design considerations and recommendations of a BNCT beam shaping assembly

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Beam Shaping Assembly (BSA) is a pivotal part of a BNCT system, no matter what kind of neutron source is utilized. The BSA directly affects the neutron beam quality as well as the radiation safety of a facility. Previously in the IAEA-TECDOC-1223 document, the BSA described is only for the reactor-based facility and by the time there was no BSA built specifically for an AB-BNCT (accelerator-based BNCT) system. Therefore, this report describes practical considerations and recommendations regarding designing and constructing a BSA, basing on the ones built already for the THOR BNCT facility and the BNCT center at the Xiamen Humanity Hospital. This report consists of two parts: the first part describes the neutron beam design technique for an AB-BNCT source, and the second part recommends a series of safety requirement for the BSA.

A good BSA can effectively moderate the generated high energy neutrons from the target (reactor core if an RB-BNCT facility is referred), and can filter out most of the undesired contamination components, e.g. gamma rays and thermal neutrons (if an epithermal neutron beam is desired); the last step of BSA is to collimate the neutron beam for a better focusing irradiation. This requires a good combination of materials, geometries, and arrangement among the target station, cooling pipes, moderator, reflector, shielding, and collimator. A series of desired beam parameters and performance will be described elsewhere in other reports prepared by the Physics Working Group of International Society for Neutron Capture Therapy, and will not be further described.

Through a considerable large number of computer modeling and simulations, we have identified some common key features to produce a good neutron beam for BNCT. One of the features shows a bi-cone shaped moderator provides a better reflection of backward neutrons and a better collimation of forward ones; the bi-cone shaped moderator apparently provides a higher beam intensity than a regular cylinder or single-cone shape one. Another key feature is placing the target station within the moderator which is surrounded by the reflector/shielding part; such an arrangement results in a better beam quality as well as a higher beam intensity.

The second part of this article describes the engineering considerations as well as recommendations for how to construct a robust, safe and reliable BSA. First of all, the deformation of the BAS must be taken into consideration and the use of rigidness supporting and containing structure is a recommended solution. The BSA of THOR has suffered from a significant deformation attributed to the heavy weight of lead used as reflector and gamma-ray shielding, and it must be carefully realigned once a while. It is recommended to monitor the deformation of the BSA regularly using an appropriate measure. The recommended criteria of maximum deformation are <0.5 mm in settlement, and <0.5 degree in tilt. Any deformation higher than the recommended values must be calibrated by appropriate tools or methods to ensure the beam central line and the positioning system is in alinement.

The neutron activation and the correspondingly induced radioactive byproduct profile are other key factors that must be considered; for example, materials contain cobalt and bismuth should be avoided. The accumulated activity of the BSA should be less than the limitation of low-level radioactive waste after a reasonable decay time, for instance, 1 years. That is to say, the BSA can be dismantled without the management need as a radioactive waste. The design and evaluation must follow the ALARA principal.

Another important consideration is the radiation leakage of BSA. One part is the out-of-field leakage in the beam-exit surface, and the other important but a much less discussed part is the leakage in the rear surface. For the out-of-field neutron leakage, it is suggested to be less than 5% of the average beam intensity within the beam aperture at 10 cm away from the beam exit edge, and 1% at 30 cm distance. For the rear-end radiation leakage (exclude the inevitable backward neutron directly from the vacuum tube), it is recommended to be less than 10% of the main therapeutic beam. Further details and other points will be described in the presentation. Further details, suggestions and recommendations will be presented in our completed report and presentation.