LIU-2: Design considerations and recommendations of a BNCT on-line monitoring system - The development of BNCT on-line beam monitoring systems in the Xiamen

Yuan-Hao Liu[1,2], Chao Wang[1], Wei-Lin Chen[1], Neng Pu[1], Diyun Shu[1,2]
[1]*Neuboron Medtech Ltd., Nanjing, Jiangsu Province, P.R. China*
[2]*Nanjing University of Aeronautics and Astronautics, Nanjing, Jiangsu Province, P.R. China*

The on-line monitoring system (OMS) is the 'eyes' of a BNCT beam, which counts for the accuracy of dose delivery. OMS is also the pivotal normalization reference among different experiments/measurements. It is the first detector to be built for the BNCT neutron beam. Without the OMS, there is no way to conduct accountable beam measurement and thus no one can perform the vital beam characterization. A reliable and trustworthy OMS relies on a series of carefully designed and calibrated detectors, dedicated control logics and algorithms, carefully verified beam characterization, as well as a thorough and periodical calibration. To develop an ideal OMS, it requires a highly sophisticated development work and it also relies on lots of nuclear radiation measurement experiences and control design. This report gives practical suggestions as well as recommendations for a 'minimal' OMS, which can meet the minimum need of clinical need for BNCT, according to the developed OMS systems for the THOR, HFR, and the new AB-BNCT center at the Xiamen Humanity Hospital.

A good OMS must consider a) truthiness, b) reliability, c) availability, d) maintainability, and e) rigidness. The following design considerations and recommendations are proposed to achieve a good OMS.

The choice of detectors and some considerations – A set of 3 to 4 neutron detectors should be deployed in the OMS, and additional one or two gamma-ray sensitive detectors are suggested to be included, for the sake of redundancy and safe margin. The neutron detectors must have a good neutron (N) and gamma ray (G) discrimination that a G/N ratio should be <0.1% in its counting result. The deployed N detector should have an extraordinary signal to noise ratio as well, that a ratio <0.1% should be achieved. The N detector should be dead-time insensitive; otherwise, it has to be carefully calibrated and corrected for the dead-time contribution by a function of counting rate covering wide range. The dead-time correction algorithm must be carefully built in the OMS control system, and be verified, and validated. The N or G detector lifetime should be no less than 1 year under regular operation, and the burnup (if there is any) or decline should be <1% in 1 year.

The installation of detectors – The 3 or 4 detectors (N) are recommended to be installed within the beam shaping assembly (BSA), but not within the beam center to avoid influence attributed to the beam quality and also avoid influence from objects presented in front of the beam (back scattering contribution). Furthermore, it is recommended to install them around the BSA to obtain the relative spatial information of the beam (e.g. top, left, right, and bottom); it may not be necessary to be installed symmetrically. The detectors are recommended to be installed from the rear end of the BSA to avoid influence during patient positioning and other activities in the irradiation room. The installation channels are suggested to be as straight as possible to avoid significant bending of the signal cables (i.e. make a turn of the channel), which will cause possible stress to the cable and induce noises; furthermore, the turn may make a difficulty to the detector installation as well as positioning. Lastly, an immobilization device is recommended to fix the detector from the rear end of the BSA.

The statistics requirement – the counting rate of one of the N channels should be more than 10,000 counts per second in order to achieve a statistical error less than 1% in every reading; the OMS should provide a good counting rate covering a wide range, saying from 20% to 100% of the nominal beam intensity. This can be achieved by several different techniques.

Other consideration – the OMS should be insensitive to the environment change, i.e. temperature, humidity, light, sound, and radiation (both ionization and non-ionization). The OMS must be resistant to electromagnetic interference. In addition, a compensation to the voltage change within a given range is required. An uninterruptible power supply (UPS) is mandatory for the OMS.

More considerations and recommendations will be given in the complete report and our presentation.