

LEE-1: Neutron Beam and Radiation Protection Considerations for Boron Neutron Capture Therapy Using a Tandem Accelerator

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TAE Life Sciences' Alphabeam™ is a complete system for hospital-based boron neutron capture therapy (BNCT) that includes a tandem electrostatic accelerator and high energy beam lines (HEBL) capable of delivering treatments in up to three separate rooms. Alphabeam uses an intense 2.5-MeV proton beam striking a solid lithium target to produce neutrons for BNCT with estimated treatment times of 30 to 60 minutes. Installation of the first tandem for clinical use is expected to begin in 2020 following extensive laboratory testing.

The tandem accelerator consists of a series of nested conductive shells, insulated from each other, whose applied voltages increase outward from the innermost shell. A separate component directs a high current of negatively-charged hydrogen ions to a narrow port through the tandem. The voltage drop across the shells accelerates the hydrogen ions to half the desired kinetic energy at the center of the tandem, where a charge exchange component strips the ions of both electrons. This charge reversal allows the same voltage drop to further accelerate the protons to the desired kinetic energy when they exit the tandem on the opposite side. This fully electrostatic design is expected to result in high reliability and system up-time with low lifetime operating costs. The compact design, which is advantageous for hospital space constraints, also supports energy tunability.

The proton beam is directed from the tandem to the lithium target along the HEBL via beam splitters, bending magnets and diagnostic components. The lithium target is cooled via water channels in a copper backing disk and is tightly coupled to the beam shaping assembly (BSA). The lithium, target assembly materials and HEBL components are exposed to intense and unique energy spectra and angular distributions of both neutrons and prompt gammas while the proton beam is turned on. As with other BNCT neutron sources, irradiation of all these components will produce a wide range of activities that can create a complicated spatial- and time-dependent radiation protection challenge after the beam is turned off.

Monte Carlo simulations have been used to model Alphabeam's geometry of tandem accelerator, target, HEBL components and surrounding walls in order to reduce or eliminate these hazards. Different radiation types and operational regimes require different material, shielding and geometry considerations, and these choices can be contradictory. The optimization problem must also take room access, interlock design and personnel training into account in order to realize As Low As Reasonably Achievable (ALARA) goals. Examples of ALARA hazard reduction choices will be described. The innovative combination of tandem accelerator design and downstream radiation protection design results in a neutron source that is ideally suited for a high throughput BNCT program in a compact hospital environment.