Nuclear Reactions in Hadron Therapy

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Hadron therapy encompasses a new class of treatments for cancer where a beam of highly energetic protons or carbon ions is used to kill tumours. When charged particles pass through matter they deposit the majority of their energy at the end of their track, forming the Bragg peak. This gives hadron therapy two advantages over conventional radiotherapy: (a) a larger fraction of the dose is deposited in the tumour, sparing healthy tissue in the beam path, and (b) little dose is given to tissue beyond the tumour as the ions stop at the Bragg peak.

Worldwide there are 56 proton therapy and 10 carbon beam therapy facilities currently operating, with many more planned [1]. The first proton beam therapy centre in Australia is currently under construction at the South Australian Health and Medical Research Institute (SAHMRI) in Adelaide, and there are plans for a National Particle Treatment and Research Centre at the Westmead Precinct in Sydney.

One significant challenge in the planning of hadron therapy treatments are the nuclear reactions that occur as the beam passes through the body. In carbon beam therapy, up to 70% of the beam particles undergo a nuclear reaction before reaching the tumour [2], increasing the dose in healthy tissue, causing beam divergence, and creating a dose tail beyond the Bragg peak from low charge reaction products. These effects must be incorporated into treatment planning through careful modelling (often performed with GEANT4 [3]), requiring the total reaction cross section, and the energy and angle differential probabilities for all possible reaction products. A wide variety of nuclear reaction phenomena are possible over this range of energies, including inelastic excitation, nucleon knockout [4, 5], or fragmentation. Not only do we need to understand these reactions for the primary incident beam, but also for all the secondary reaction products produced. It is not feasible to measure all the reactions required, so models must be used.

Here we discuss ongoing work to improve the nuclear reaction models used in treatment planning, and consider what new measurements would optimally guide further progress. We will also discuss the potential and requirements for future measurements in Australia at the Bragg Centre, the proposed Westmead facility, and the Heavy Ion Accelerator Facility.

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[1] Queensland Health Policy Advisory Committee, Proton and Heavy Ion Therapy: An overview (2017).

[2] E. Haettner, H. Iwase and D. Schardt, Radiation Protection Dosimetry 122, 485 (2006).

[3] GEANT4 Physics Reference Manual, geant4.cern.ch

[4] E. C. Simpson, P. Navratil, R. Roth and J. A. Tostevin, Physical Review C 86, 054609 (2012)

[5] E. C. Simpson, Physica Medica 32, 1813 (2016).