A simulation study with Geant4 investigating the secondary prompt gamma emissions from incident 40 MeV protons onto various materials.

Introduction: Beams of protons are used in particle therapy for conformal irradiation of a tumor while sparing surrounding healthy tissues and organs at risk. Current range verification systems for incident carbon-ions utilize PET systems based on the phenomenon of positron-emitting nuclei (PEN)[1]. However, recent investigations[2] into the use of prompt gamma rays suggest that the range of protons can be verified by measuring the prompt gamma emissions generated in nuclear reactions between the incident proton and the target material. The purpose of this study is to investigate the secondary prompt gamma spectrum of 40 MeV protons incident into various materials utilizing the Geant4 Monte Carlo Toolkit.

References:

1. Pshenichnov et al., *Distributions of positron-emitting nuclei in proton and carbon-ion therapy studied with GEANT4,* Physics in Medicine and Biology, 2006. **51**(23): p. 6099-6112
2. Bom et al., *Real-time prompt gamma monitoring in spot-scanning proton therapy using imaging through a knife-edge-shaped slit,* Physics in Medicine and Biology, 2011. **57**(2012): p. 297-308.

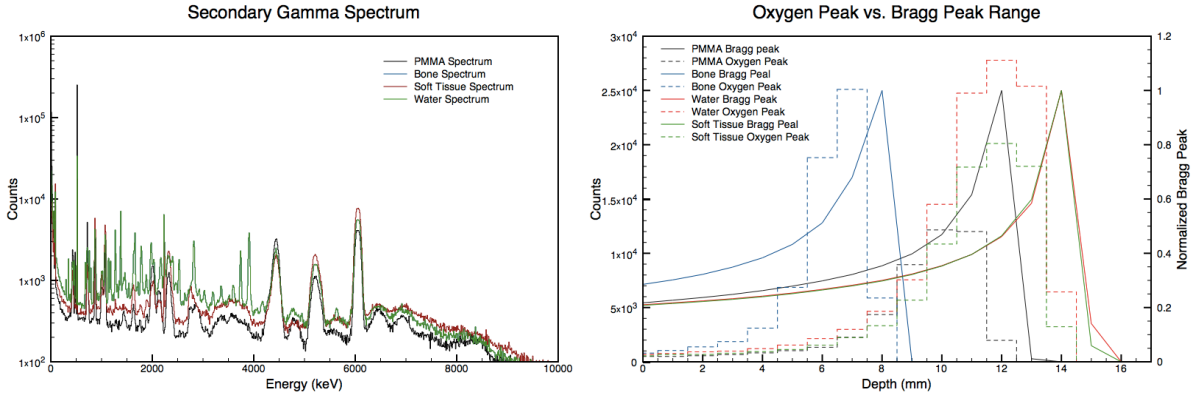

Figure 1: The secondary prompt gamma spectrum from the materials considered in the study (left) as well as the secondary Oxygen de-excitation peak vs. the incident normalized Bragg Peak (right).

Table1: The type of material, the location of the Bragg Peak depth, the location of the Oxygen Peak, and the difference between these two locations are shown.

Material	Bragg Peak Depth (mm)	Oxygen Peak Depth (mm)	Difference (mm)
Bone	8	7	1
PMMA	12	10	2
Water	14	12	2
Soft Tissue	14	12	2