Purpose: This study aims to investigate the prompt secondary gamma spectrum and the depth-dose distributions of incident 40 MeV protons onto various phantom materials. The goal is to find a relationship between the secondary prompt gamma emissions and the range of the incident particles.

Methods: An application was constructed using the Geant4 Monte Carlo Toolkit utilizing various physics packages. Several phantom materials were irradiated with a pencil beam of 40 MeV protons. These materials include PMMA (C5H8O2, density 1.18 g/cm3) and the built-in Geant4 materials bone, soft-tissue, and water. For each simulation, the energy deposited from the incident proton was recorded every 1 mm increment of depth in the phantom. The resulting prompt secondary gamma emissions were recorded from 0 to 10 MeV in energy bins of 10 keV.

Results: The secondary prompt gamma spectrum has various peaks. The peaks located about 4.4 and 6 MeV correspond to the carbon and oxygen de-excitation photons, respectively. Our simulations show greater production of the higher-energy gamma particles closer to the Bragg-Peak. When we plot the oxygen peak against the normalized Bragg-Peak we found that in all materials the difference between Bragg-Peak and the oxygen de-excitation photon peak to be about 2 mm. The oxygen peak could be used in the clinic for range verification of the incident proton beam.

Conclusions: Our Geant4 Monte Carlo application was used to investigate the secondary
prompt gamma emissions from incident 40 MeV protons. A relationship was between the 6 MeV peak and the incident proton Bragg Peak. We believe that prominent peaks around 4 and 6 MeV can be used to locate the range of the incident beam provided a detector system is built that can count these high-energy gamma particles.