AbstractID: 8159 Title: Normalized Bragg Peak Curves for Various Proton Incident Energies in Water Phantom: A Simulation with GEANT4 Monte Carlo Code

Normalized Bragg Peak Curves for Various Proton Energies in Water Phantom: A Simulation with GEANT4 Monte Carlo Code

Introduction: Proton radiation therapy offers highly conformal treatment and is becoming increasingly popular in the US. Monte Carlo simulations using both electromagnetic interactions (EMI) and hadronic interactions (HI) are currently being performed by many institutions to accurately simulate the interaction of proton in a medium. When a mono-energetic beam of proton passes through a medium, it stops with the deposition of a large portion of its energy at a certain depth near the end of its range. This property benefits the delivery of maximum dose to the tumor with an abrupt drop of dose to normal tissues surrounding tumor. The CERN developed Monte Carlo code GEANT4 toolkit (version 4.8.3) utilizes recent physics models based on theory and experimental data. The EMI cover proton's energy loss and straggling with atomic electrons and multiple scattering with atomic nuclei; where as the HI cover proton's elastic, inelastic scattering, and nuclear interactions with the atomic nuclei in the medium. The objective of the present study was to simulate the interaction of proton (energy from 60 to 250 MeV with intervals of 10 MeV) in a cylindrical water phantom using GEANT4 to determine accurately the proton ranges from Bragg peak. The distal depth at 90% of the maximum dose deposition was defined as proton range.

Materials and Methods: A cylindrical water phantom (length=100 cm, diameter= 30 cm, density = 1 g/cm3, mean excitation energy = 75 eV) consisted of 1000 packed circular sensitive detector discs (diameter = 2 cm, thickness= 1mm) was used in this simulation (Fig. 1.). Electromagnetic energy loss processes for hadrons and leptons are categorized in Geant4 as either "standard" or "low energy". The low energy process provides tools that extend down particle energies below the standard processes (for example: Protons 1 keV, electrons and photons 250 eV) in order to precisely simulate ionization around Bragg peak. If the range of a particle is less than the production threshold (range cut), a continuous energy loss of the parent particle is utilized instead of a secondary particle being generated. The range cut is lowered from the default value of 1mm to 15μm to improve the accuracy of simulation. The HI for proton are simulated using low energy elastic interactions and inelastic scattering that consists of a pre-compound nuclear interaction based on a pre-equilibrium decay model below 170 MeV, and a Bertini cascade model for energies above 150 MeV.

There are two kinds of proton beam protocols used in this study, pencil beam and 5cm x 5cm field size beam. The simulations were carried by 2 million incident proton particles with each proton energy for pencil beam where as only five energies (60, 100, 150, 200 and 250 MeV) were studied with 5cm x 5cm field size beam. Energy deposited in each sensitive disc was monitored to produce the Bragg peak.

Results: The normalized Bragg peak curves are shown in Figures 2a-2c. Our simulated results were then compared with the Continuing Slowing Down Approximations (CSDA) data from the United States National Institute of Standards and Technologies (NIST) in Fig. 3. CSDA data is obtained by integrating the reciprocal of the total stopping power with respect to energy of proton in water.

Conclusions: Our proton Bragg peak simulation results are in excellent agreement with NIST data. The proton beam penetrates further with increasing energy broadening the Bragg peak with proximal shoulder dose increase from 20% to 40%. We have demonstrated that the GEANT4 tool kit has the ability for the radiation therapy proton beam simulation and will be used for proton facility design in our institution.

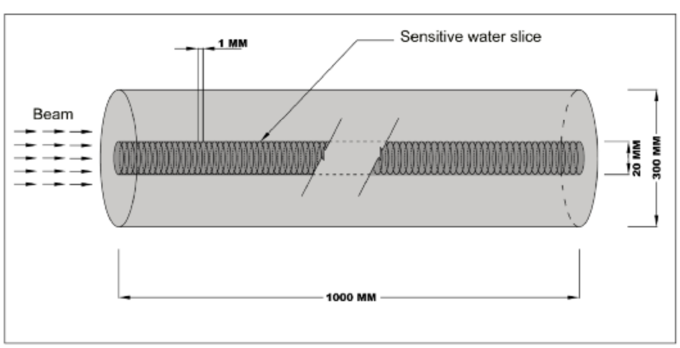

Fig. 1. Setup for the cylindrical water phantom with sensitive water slice

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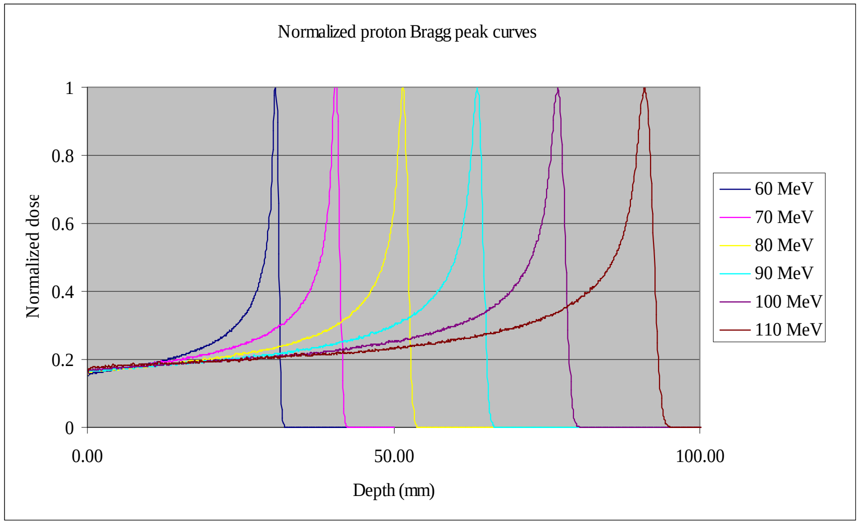

Fig. 2a. Normalized proton Bragg peak curves for energies from 60 to 110 MeV

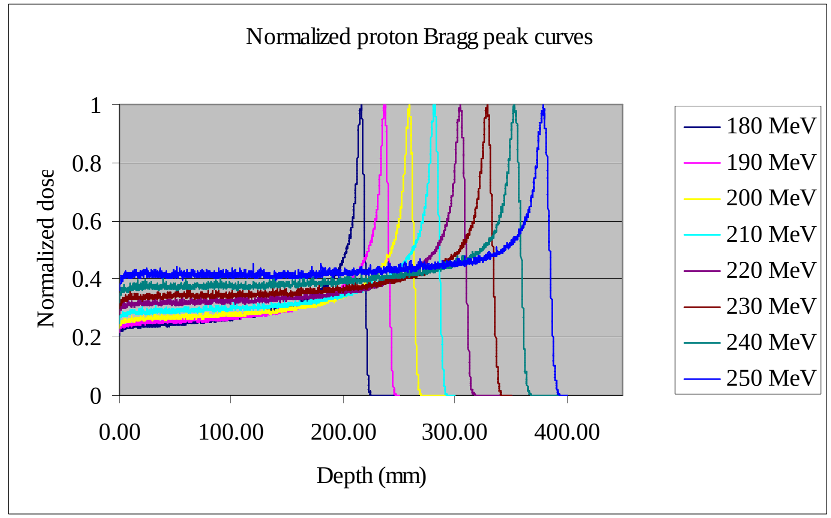

Fig. 2c. Normalized proton Bragg peak curves for energies from 180 to 250 MeV

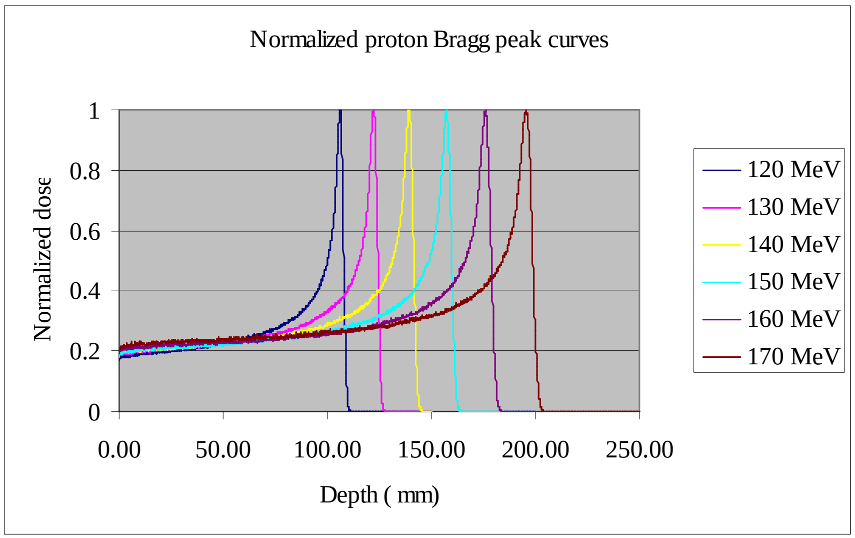

Fig. 2b. Normalized proton Bragg peak curves for energies from 120 to 170 MeV

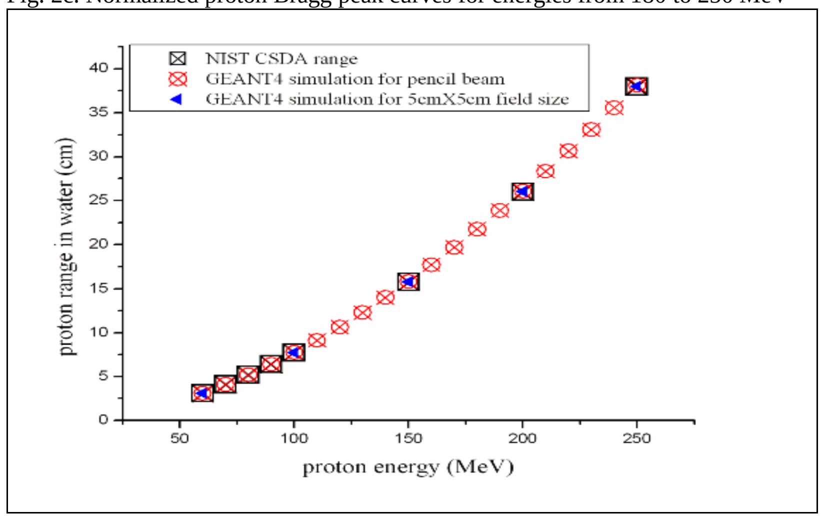

Fig. 3. Comparison of NIST CSDA ranges with GEANT4 simulation for various proton beam energies (pencil beam and 5cmX5cm field size)