Proton Beam Characterization Using Monte Carlo Simulation Technique

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Abstract

High energy proton beam radiation therapy offers many advantages. Secondary particles, however, particularly neutrons production through inelastic nuclear interactions that may contribute additional flux outside the primary treatment field leading to dose in patients[1,2] is concern. Secondary neutrons produced in scattering proton beam were simulated using MC code MCNPX. The comparisons of calculated neutron dose with relative dose measurement[3] are presented. A polymer gel dosimeter is used in the experiment presented in ref [3] due to its tissue equivalent physical properties. The results can be further used in designing of proton treatment facilities

MCNPX

MCNPX (Monte Carlo N-Particles eXtended) is a 3-D computational transport program that simulates nuclear processes in practically all particles and all energies. It has been used in a variety of applications. In this study, all calculations were performed using MCNPX code version 2.7.0 installing on 16 nodes computer cluster and were executed using 2 x 10^7 source histories

Simulation design

It is noted that measured data for gel dosimeter and ion chamber were reproduced with permission. The details can be found in ref. [3]. The simulation was designed closely to the experimental setup in ref. [3]. The 250 MeV proton beam was passing through layers of solid water, PMMA lid, and cylinder containing soft tissue or gel dosimeter as shown in fig. 1. We calculated proton and neutron absorbed dose and compare with published measured data from gel dosimetry systems and ion chamber[3].

References: [1] Schneider, U et al (2002) Int J Rad Onc Biol Phys. 53, 244-251 [2] Wroe A et al (2007) IEEE Trans Nucl Sci 54, 2264-2271 [3] Zeidan, O A et al (2010) Med Phys 37, 2145-2152 [4] MCNPX 2.7.0 Manual (2011) Los Alamos Report LA-CP-11-00438

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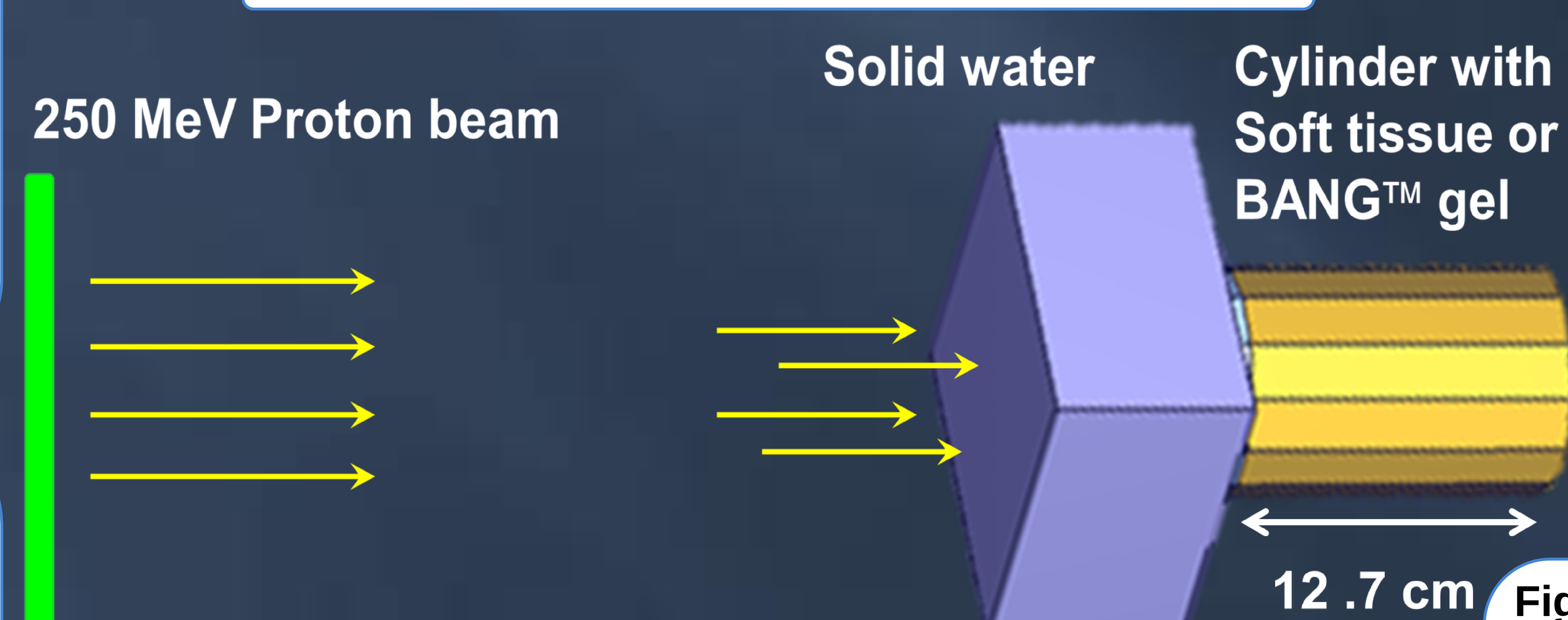
Results and discussion

- As expected, proton spectra in soft tissue and in gel dosimeter (fig. 3A) show an excellent agreement due to similar properties between gel dosimeter and soft tissue
- At low energy, nuclear interactions are dominant and important for energy loss resulting in higher dose response in shallow depth in fig. 3B
- The shapes of Bragg peak from measurements and calculations are slightly different; the measured peaks are shifted to left and broadened compare to the calculated peaks due to straggling effects (fig. 3B)
- Investigations of beam broadening and straggling effects are ongoing by modifying several adjustable parameters
- Flux contributions from neutrons and photons in soft tissue are as high as from protons (fig. 5A).
- Dose contribution in soft tissue, however, are mainly from primary protons (fig. 5B).

Figure 1. Diagram of MCNPX geometry setup



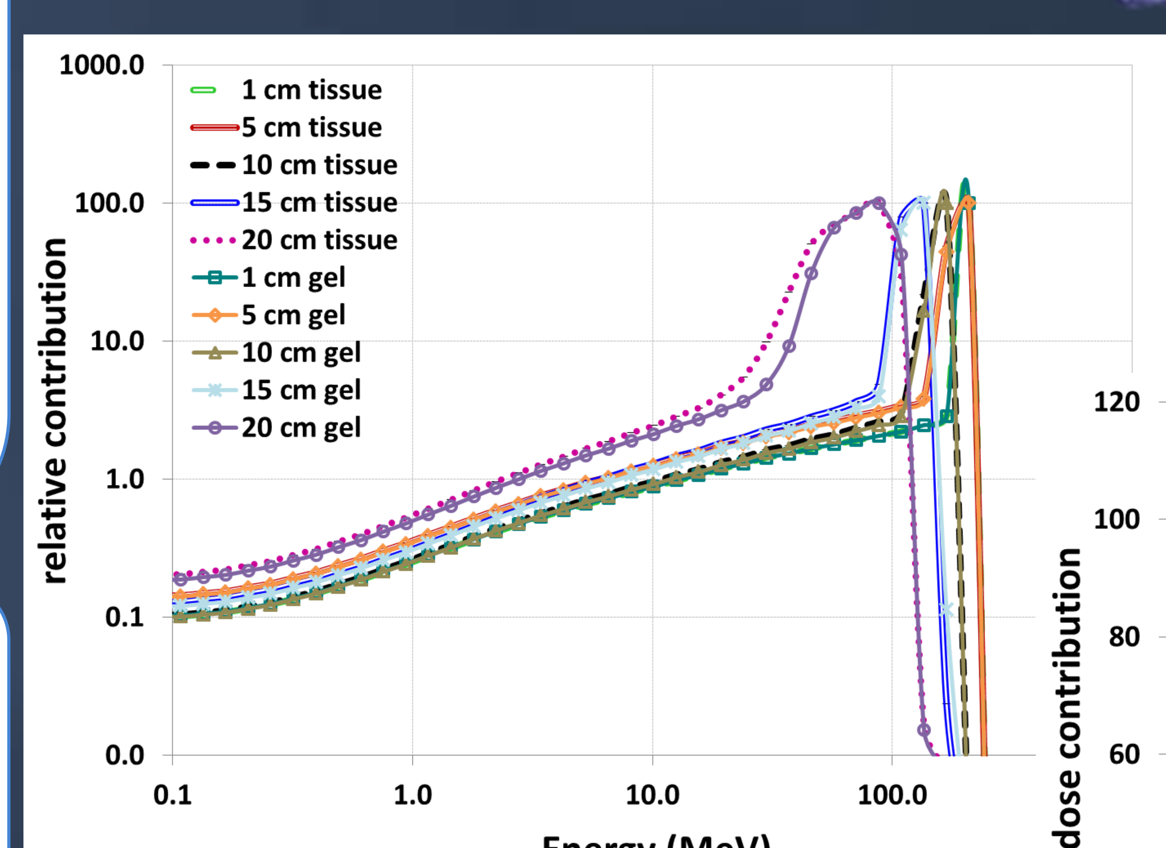


Figure 3A. Proton spectra deposited in soft tissue and gel dosimeter

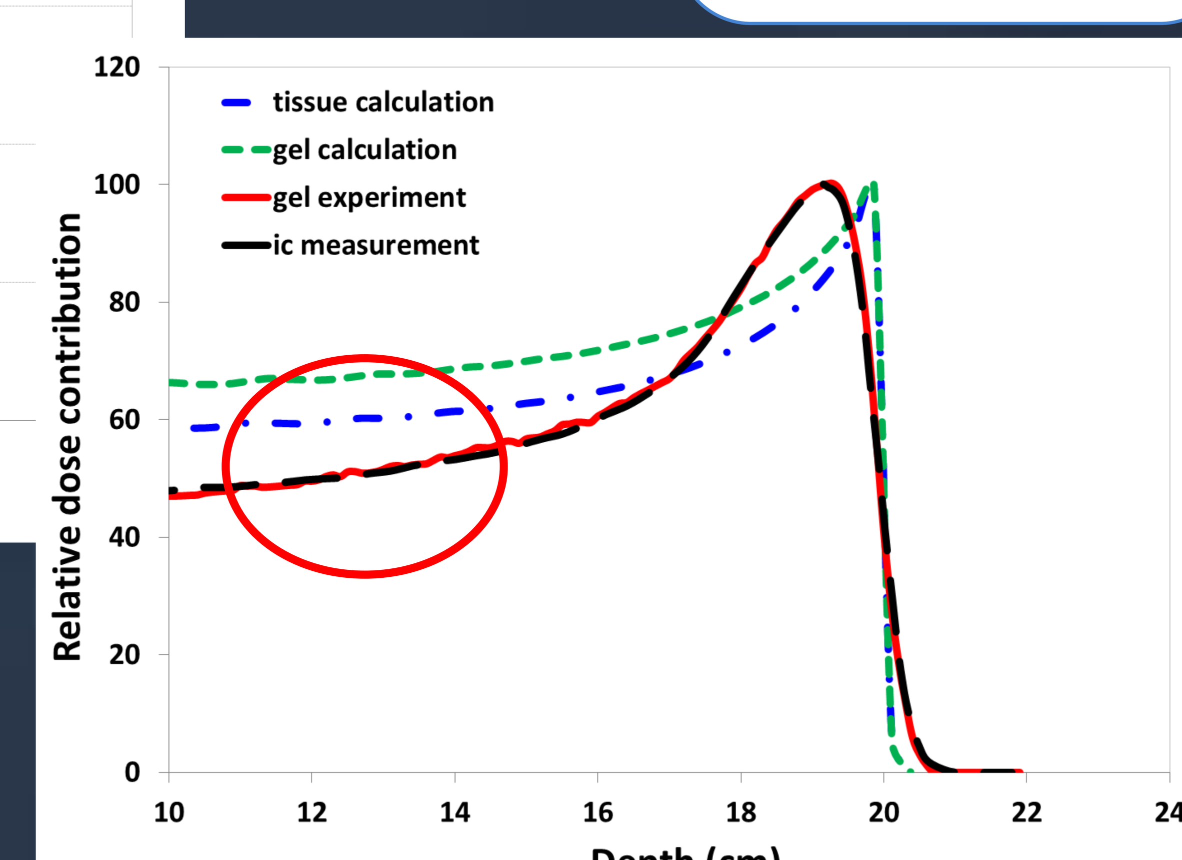


Figure 3B. Calculated proton dose responses were compared with measured data for gel dosimeter and ion chamber

Figure 2A. Neutron flux

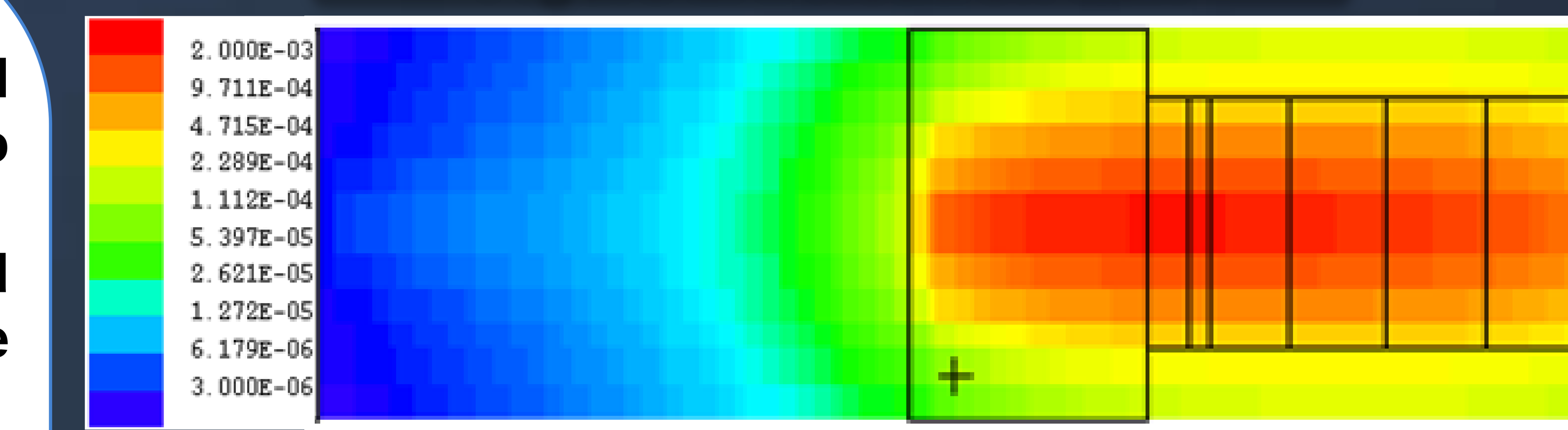


Figure 2B. Neutron absorbed dose

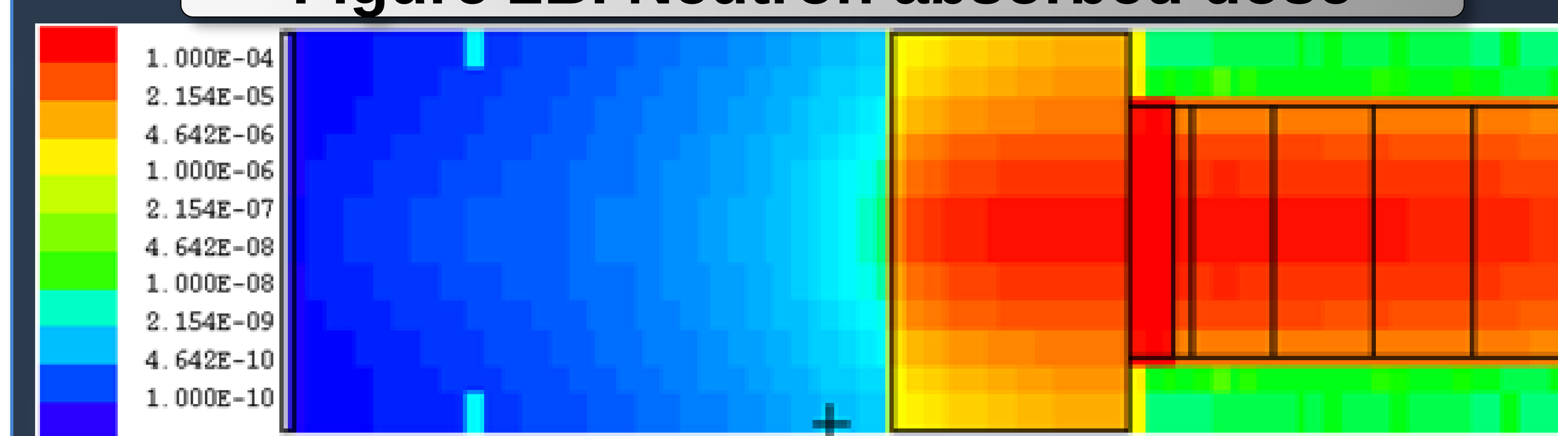


Figure 4. Particles track plots in zx and xy view

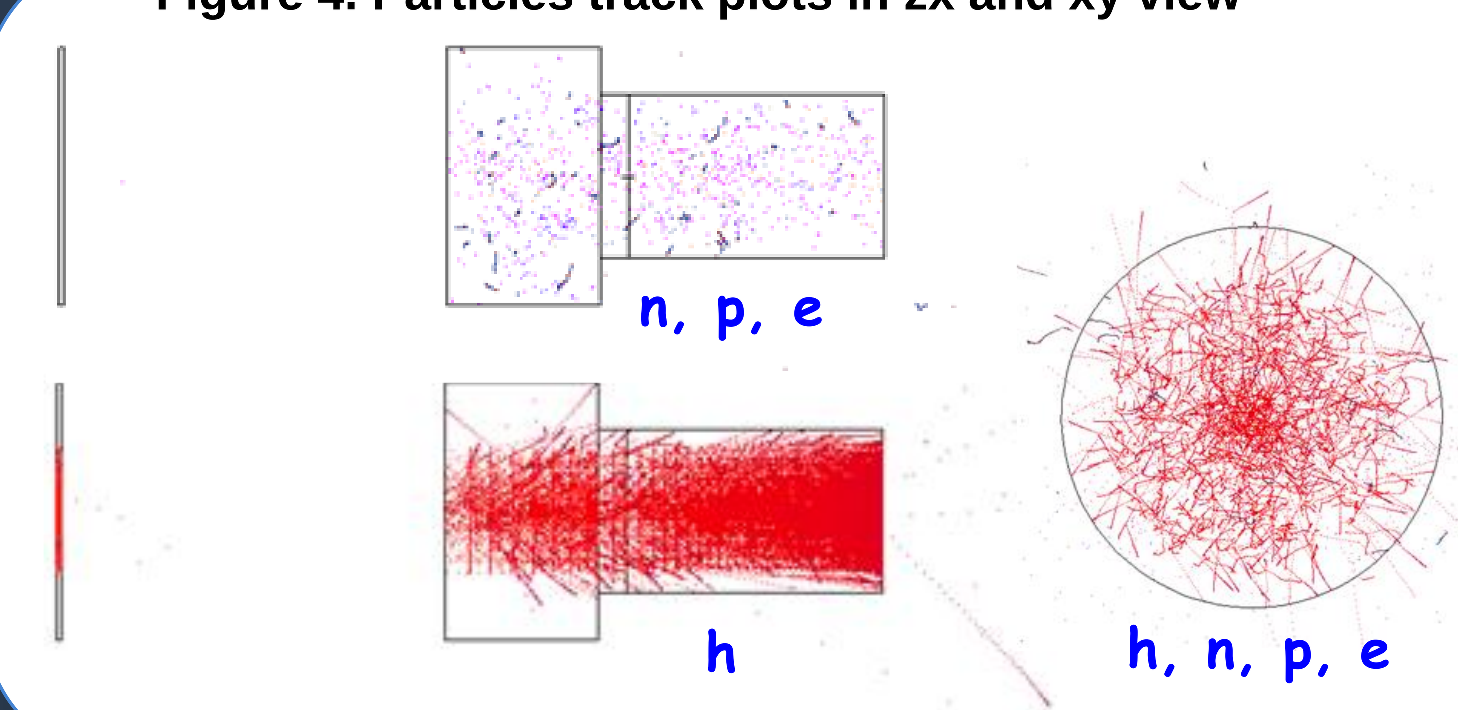


Figure 5A. Total flux of n, h, p and e in soft tissue

Figure 5B. Absorbed dose of n, h, p and e in soft tissue