# Proton Beam Delivery to a Moving Lung Tumor and Monte Carlo Simulation with TOPAS

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**Purpose:** To estimate the dose delivered to a moving lung tumor by proton therapy beams of different modulation types, and compare with Monte Carlo predictions.

**Methods and Materials:** A radiology support devices (RSD) phantom was irradiated with therapeutic proton radiation beams using two different types of modulation: uniform scanning (US) and double scattered (DS). The Eclipse© dose plan was designed to deliver 1.00Gy to the isocenter of a static ~3x3x3cm (27cc) tumor in the phantom with 100% coverage. The peak to peak amplitude of tumor motion varied from 0.0 to 2.5cm. The radiation dose was measured with an ion-chamber (CC-13) located within the tumor. The time required to deliver the radiation dose varied from an average of 65s for the DS beams to an average of 95s for the US beams.

**Results:** The amount of radiation dose varied from 100% (both US and DS) to the static tumor down to approximately 92% for the moving tumor. The ratio of US dose to DS dose ranged from approximately 1.01 for the static tumor, down to 0.99 for the 2.5cm moving tumor. A Monte Carlo simulation using TOPAS included a lung tumor with 4.0cm of peak to peak motion. In this simulation, the dose received by the tumor varied by ~40% as the period of this motion varied from 1s to 4s.

**Conclusion:** The radiation dose deposited to a moving tumor was less than for a static tumor, as expected. At large (2.5cm) amplitudes, the DS proton beams gave a dose closer to the desired dose than the US beams, but equal within experimental uncertainty. TOPAS Monte Carlo simulation can give insight into the moving tumor – dose relationship.