# AbstractID: 5624 Title: A Monte Carlo study on carbon RBE for carbon therapy

**Purpose:** To estimate carbon RBE for radiotherapy planning based on a RBE-LET model using Monte Carlo (MC) simulations.

**Method and Materials:** The MC method has been implemented for carbon ($C^{6+}$) dose calculations for radiation therapy treatment planning. The FLUKA code is used to generate carbon ion tracks in medium and incorporate them into MCDOSE for patient dose calculation. A two-step optimization scheme is used to yield 3-D conformal and homogeneous dose distributions. First, we select the small carbon beams (beamlets) with proper energy spectra to generate SOBPs based on Boltzmann transport equation. Those beamlets with SOBPs can be used for conventional particle therapy (CPT) and can be further used for intensity-modulated particle therapy (IMPT). We have either used a constant RBE (=5) or a variable RBE in the beamlet dose calculation. RBE is calculated based on the RBE-LET model:

$$\mathrm{RBE}(\mathrm{D}, \mathrm{L}, \alpha_0, \lambda, \alpha, \beta) = \frac{\sqrt{\alpha^2 + 4\beta\mathrm{D}(\alpha_0 + \lambda\mathrm{L} + \beta\mathrm{D})} - \alpha}{2\beta\mathrm{D}}$$

where $\alpha_0, \lambda, \alpha, \beta$ are determined by experiments. L is energy linear transfer (LET) that can be calculated by the Bethe-Bloch formula:

$$\mathrm{L} = -\frac{\mathrm{dE}}{\mathrm{dx}} = 2\pi \mathrm{N_a} \mathrm{r_e^2} \mathrm{m_e c^2} \rho \frac{\mathrm{Z}}{\mathrm{A}} \frac{\mathrm{z}^2}{\beta^2} \left[ \ln\left( \frac{2\mathrm{m_e}\gamma^2\beta^2\mathrm{W_{max}}}{\mathrm{I}^2} \right) - 2\beta^2 \right] \quad .$$

**Results:** Ten prostate treatment plans were generated using carbon beams for this study. The target dose was prescribed to 76 Gy (Co-equivalent), and 7-9 beams were used for all the plans. Comparisons were made between carbon CPT and carbon IMPT with a constant RBE and variable RBE. The ratio of mean doses with a constant RBE and with variable RBE varied depending on the plan and the organ. Generally, for CPT plans, the ratio was 1.06 for the target dose, 1.26 for the bladder, and 1.3 for the rectum. Through optimization, these differences were reduced for IMPT plans; the ratio for the target was about 1.0, 1.11 for the bladder and 1.03 for the rectum after RBE-corrected optimization.

**Conclusion:** The RBE-based optimization is needed to correct the RBE effect for optimal target coverage and critical structure sparing in IMPT treatment planning.