A Monte Carlo simulation of DNA double strands break cross-sections for proton and secondary electrons

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Introduction

DNA double strands break (DSB) is the main effect cause the cell death or loss function. In proton therapy, there are three major way to cause the DSB. 1) directly ionization radiation, such as proton itself. When the proton slowing down, the LET increase suddenly and cause the Bragg Peak. The higher LET especially at Bragg peak can induce huge number of DSB. 2) Secondary electrons induced by proton. When proton interact with material, it may induce some delta ray and these electrons can also cause DSB. 3) The free radicals created by ionization radiation can also cause some DSB. In this study, the Monte Carlo simulation is applied to simulate the proton and electron induced DSB including the free radical induce by them.

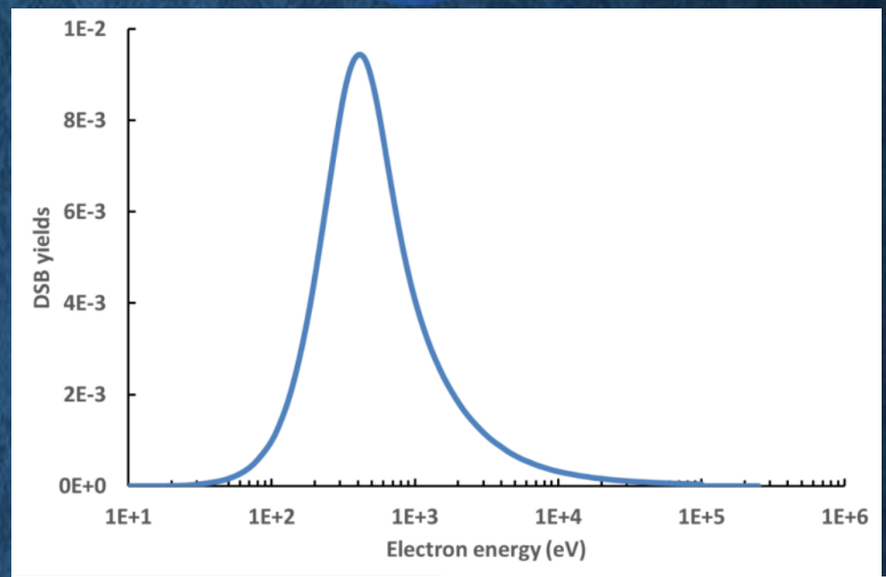

Fig1. DSB cross-section of electron. Energy from 10 eV to 1 MeV

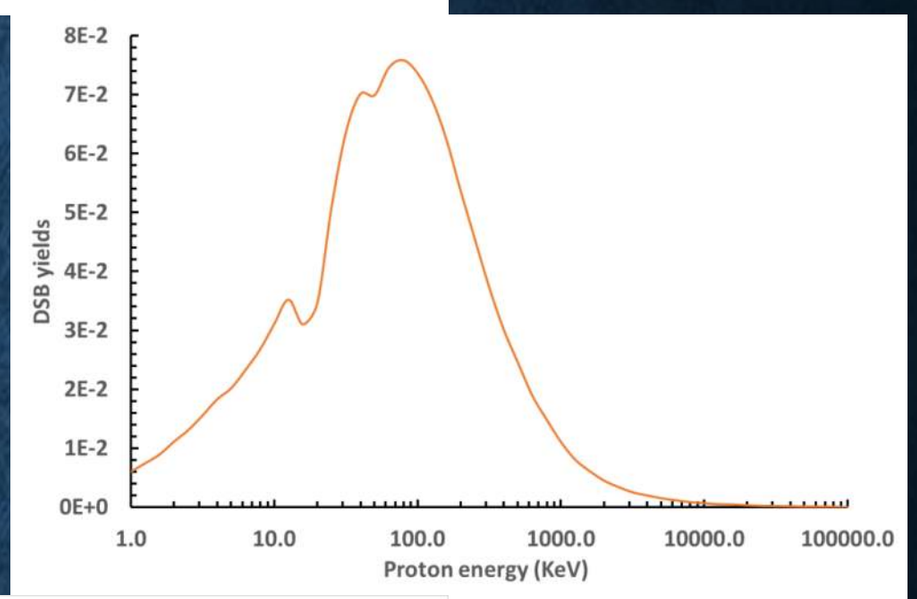

Fig2. DSB cross-section of proton. Energy from 1 MeV to 100 MeV

Materials and methods

In this study, 70 MeV pencil beam spectra in each depth have beam generated by PTSim using CGMH G3 system. The field size is 30 * 30 cm^2 and only the center 5 * 5 cm cm^2 is used to do the DSB calculation. The resolution in depth is 4 mm per layer. Totally 10 million proton have been simulated in this study. The DSB simulation is done by GEANT4-DNA, the target is 1ZBB protein which is a simple geometry of a piece double stands. For proton cross-section study, the energy is select from 1 keV to 100 MeV. And the electron cases is 10 eV to 1 MeV because the LET of electron and proton is quite different. The energy bin is this study is 20 bins per decade. And using the cubic spline to do the interpolation. The DSB vs. Depth is calculated by the energy spectra in each depth and multiply by the cross-section. Due to the number cells that the proton will passing through is unknown. In this study, only relative value is presented .

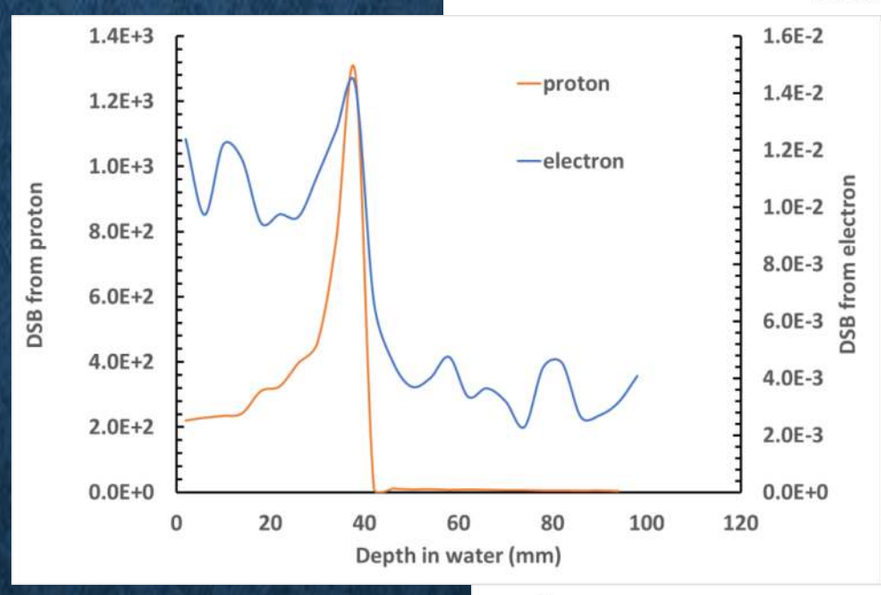

Fig3. Comparison of DSB cause from proton and electron for different depth

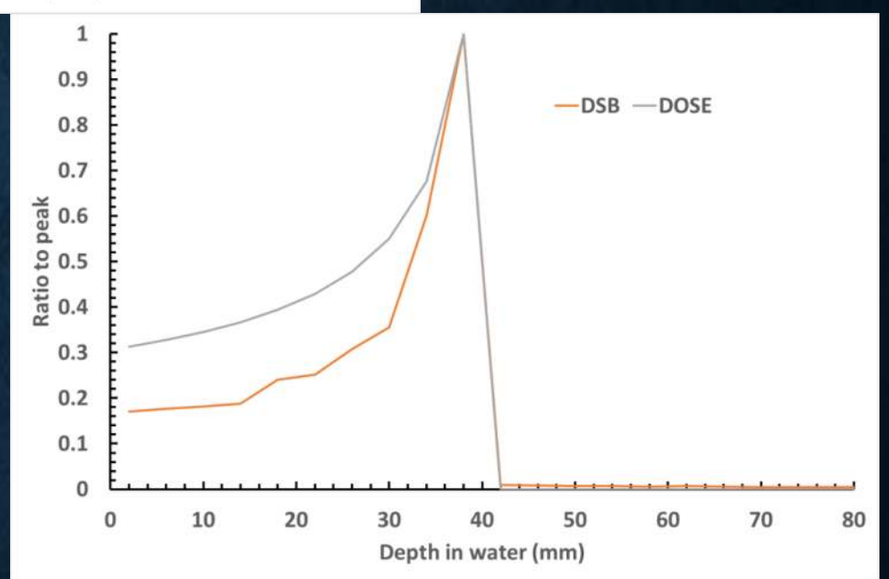

Fig3. Comparison of DSB and dose for different depth

Results

The DSB cross-section of electron and proton are plotted in Fig1 and Fig2. The maximum DSB cross-section of electron occurred in 400 eV and for proton is 100 keV. In proton result, the DSB cross-section in energy higher than 10 MeV is much less than energy in hundreds keV. In other word, in most beam path, the DSB rate will only depend on the flux . In Fig3. the comparison DSB caused by proton and electron shows that delta ray cause almost ignorable DSB. However it also shows that secondary electron can has some effect after Bragg peak. Finally, compare to dose, the DSB curve is much sharp at Bragg peak. It may cause that the effect biological dose in SOBP under estimate due to Bragg peak on DSB is not wide enough.