Inelastic nuclear interactions in Monte Carlo simulations for clinical proton beams

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ABSTRACT

Due to the ballistic properties of protons and the small ranges of secondary electrons, the modelling of electromagnetic processes in proton Monte Carlo simulations is relatively easy. The major uncertainty thus comes from the poorly known inelastic nuclear interaction cross sections that contribute substantially to the total energy transfer and total dose deposition at high-energy clinical proton beams. ICRU report 63 [1] for example, which provides until now the most comprehensive compilation of data, quotes standard uncertainties of up to 10 % on total inelastic cross sections.

In this work, the importance of these contributions from inelastic nuclear interactions was investigated in various topics related to proton dosimetry and dose calculations by Monte Carlo simulations, using the PTRAN [2], GEANT4 [3] and MCNPX [4] codes. These cover perturbation factors in ionisation chambers, fluence perturbation factors to convert dose from one medium to another, water equivalence of graphite for water calorimetry and dose calculations in tissue compositions for treatment planning. The first three topics are summarising and extending earlier work.

Results show that the inelastic nuclear interactions:

1. have small effects in ionisation chamber perturbation factors (though not negligible in corrections of tenths of a percent),

2. can cause fluence perturbations of up to 5 % in the conversion of doses from plastic phantoms and from graphite to water, which show large variations from one inelastic nuclear interaction data set to another,

3. can cause considerable errors in high-energy clinical protons (up to 4% of the total dose) when dose contributions resulting from inelastic interactions are converted from tissue to water or vice versa applying proton stopping power ratios.

We conclude that inelastic nuclear interactions contribute substantially to uncertainties in present day dosimetry and dose calculation practice in proton beams and that more experimental work is needed for quantitatively evaluating the size of their effects.

REFERENCES

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2. M. J. Berger (1993) Proton Monte Carlo transport program PTRAN National Institute for Standards and Technology Report NISTIR 5113 (Gaithersburg, USA: NIST)

3. Geant4 (2003) developed at CERN (http://wwwinfo.cern.ch/asd/geant4/geant4.html)

4. L. Waters (1999) MCNPX 2.1.5 User's manual, LANL