# Investigation of the Uncertainties Involved in Secondary Neutron/gamma Production in Geant4/MCNP6 Monte Carlo Codes for Proton Therapy Application☆

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## 1. Purpose

A major concern in proton therapy is the production of secondary neutrons causing secondary cancers, especially in young adults and children. Most utilized Monte Carlo codes in proton therapy are Geant4 and MCNP. However, the default versions of Geant4 and MCNP6 do not have suitable cross sections or physical models to properly handle secondary particle production in proton energy ranges used for therapy. In this study, default versions of Geant4 and MCNP6 were modified to better handle production of secondaries by adding the TENDL2012 crosssection library.

## 2. Methods

Inwater proton depthdose was measured at the The Svedberg Laboratory in Uppsala (Sweden). The proton beam was monoenergetic with mean energy of 178.25±0.2 MeV. The measurement setup was simulated by Geant4 version 10.00 (default and modified version) and MCNP6. Proton depthdose, primary and secondary particle fluence and neutron equivalent dose were calculated. In case of Geant4, the secondary particle fluence was filtered by all the physics processes to identify the main process responsible for the difference between the default and modified version.

## 3. Results

The proton depthdose curves and primary proton fluence show a good agreement between both Geant4 versions and MCNP6. With respect to the modified version, default Geant4 underestimates the production of secondary neutrons while overestimates that of gammas. The ProtonInElastic process was identified as the main responsible process for the difference between the two versions. MCNP6 shows higher neutron production and lower gamma production than both Geant4 versions.

## 4. Conclusions

Despite the good agreement on the proton depth dose curve and primary proton fluence, there is a significant discrepancy on secondary neutron production between MCNP6 and both versions of Geant4. Further studies are thus in order to find the possible cause of this discrepancy or more accurate crosssections/models to handle the nuclear interactions of protons with energy ranges used for therapy.

☆This is the peer reviewed version of the following article: Mirzakhanian, L. , Giusti, V. and Enger, S. (2015), SU-E-T-521: Investigation of the Uncertainties Involved in Secondary Neutron/gamma Production in Geant4/MCNP6 Monte Carlo Codes for Proton Therapy Application. Med. Phys., 42: 3455-3455, which has been published in final form at https://doi.org/10.1118/1.4924883. This article may be used for non-commercial purposes in accordance with Wiley Terms and Conditions for Use of Self-Archived Versions.

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