Assessment of Geant4 nuclear cross-sections of proton-induced reactions for therapy

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Background: The renewed interest for protontherapy drives the necessity of the improvement of the treatment planning tools used for an accurate delivered dose calculation. In protontherapy, TPS are usually based on analytical modelling of the dose, but an increasing interest in the use of Monte Carlo simulation codes in these TPS is emerging. One of the main advantages of these codes is to account for the nuclear reactions undergone by the incident beam. These nuclear reactions are responsible for the production of many secondary particles, which will potentially contribute to an additional dose in the patient, and therefore need to be correctly estimated. However, numerous studies demonstrated that commonly used Monte Carlo codes do not always correctly reproduce these nuclear reactions, which are handled by hadronic models. Therefore, it is essential to quantify the influence of these hadronic models on the secondary particles.

Material and Methods: This work aims to assess the precision of several hadronic models of the Geant4 simulation code in reproducing nuclear reactions, by comparing existing data extracted from published studies, mainly from the EXFOR database [1], with results obtained by simulation. The hadronic models that were tested within this study are the binary cascade (BIC), the intra-nuclear cascade of Liège (INCL), as well as the pre-defined physics list QBBC and particleHP (using evaluated data from the TENDL database) available in Geant4.

Preliminary results: Figure 1 shows an example of comparison between experimental and simulated cross-sections of the $^{12}C(p,p'\gamma_{4.44})^{12}C$ reaction (producing a 4.44 MeV gamma-ray), with different models available in Geant4 (INCL, the Bertini cascade, BIC, QBBC and ParticleHP). In addition to specific reactions cross-sections, comparisons of differential cross-sections at energies of interest for protontherapy will also be presented. It will be demonstrated that important discrepancies up to a factor 10 can be observed between simulations and measurements.

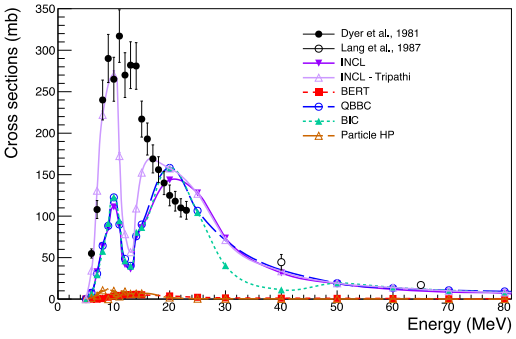

Figure 1: Comparison of measured cross-sections of the $^{12}C(p,p'\gamma_{4.44})^{12}C$ reaction (extracted from Dyer et al., 1981 [2], and Lang et al., 1987 [3]) and simulated cross-sections with different hadronic models of Geant4 (INCL, Bertini, QBBC, BIC and ParticleHP). The INCL model was tested with and without the Tripathi cross-sections dataset.

[1] N. Otuka *et al.*, Nucl. Data Sheets, 120 (2014) 272.
[2] P. Dyer et al., Phys. Rev. C, 23 (1981), 1865.
[3] F. L. Lang et al., Phys. Rev. C, 35 (1987), 1214.