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Development of a Phase Space Conversion Tool for TOPAS and MCNP Monte Carlo Codes

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1. Introduction

Monte-Carlo methods are the gold standard for dose calculation in heterogeneous mediums and are particularly important for radiation therapy[1,2]. However, an accurate description of the treatment beam is required to perform reliable simulations.

In Monte Carlo simulations, the results of particles tracking through the radiation head or nozzle can be recorded in a phase space for later use. A phase space is a file containing the typical kinetic parameters of a large number of particles, such as energy, directional cosine, position, and particle type[3].

The purpose of the phase space file is to minimize the computational calculation time since it can be reused for multiple simulations with many geometric combinations while maintaining the same field characteristics under study. In addition, a phase space file permits to simulate beams produced by commercial accelerators without revealing proprietary equipment data[4].

Phase space can be set on a particular surface by recording all particles crossing it (e.g., particles entering a specific device). For dose calculations, phase space is usually defined in a plane perpendicular to the beam axis between the nozzle and the patient or phantom. In rereading a phase space file, each particle is reintegrated as a point in space containing some of its very own characteristics[3].

Phase space can ensure that the source particles are correctly reproduced in the many Monte Carlo codes, however, the format and content of these files vary from code to code. In this work, we develop an algorithm that performs the conversion between TOPAS[5] and MCNP[6] phase spaces and also a Graphical User Interface (GUI) that makes this process user-friendly.

2. Methodology

Different Monte Carlo codes have particular file structures for phase space and thus are not interchangeable. Nonetheless, when comparing similar simulations employing distinct Monte Carlo codes, it is crucial to ensure that both use the same radiation field. To solve this problem, a GUI was developed in Python language, which allows the conversion between TOPAS and MCNP phase space files. Figure 1 shows the initial version of this GUI, called Phase Space Converter.

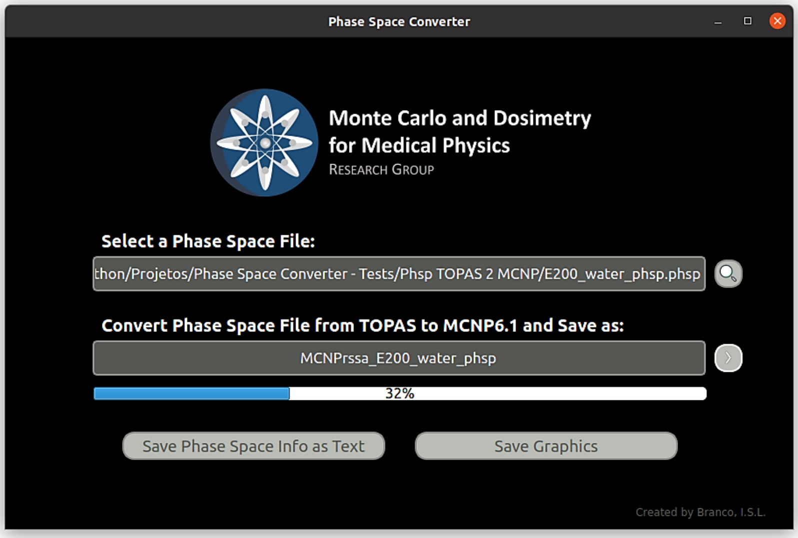

Figure 1: An initial version of Phase Space Converter, a GUI designed to support the conversion from TOPAS to MCNP phase space and vice versa.

The phase space structure of the MCNP is described elsewhere[7] and was vital to understanding where the particle information was allocated. TOPAS describes the phase space structure in a straightforward simulation file, with ASCII format.

In the current version of Phase Space Converter, it is possible to convert phase spaces from TOPAS to MCNP and vice versa, and also save the information from these binary files in a readable file (with a .txt extension) and create graphs to visualize the many characteristics of the incident beam. In the graphs generated by the GUI, it is possible to observe histograms with incident energy frequencies, beam positions, and directions, as well as graphs of spatial distributions for various simulated particle types.

A preliminary study about the Phase Space Converter results analyzed dose distributions for proton beams with incident energies of 70 MeV, 150 MeV, and 200 MeV. For each of the energies and codes (TOPAS and MCNP), 3 different simulations were run. All simulations were performed on a water phantom, with dimensions 20.0 x 20.0 x 40.0 cm^3, divided into 800 bins in the longitudinal direction, each having 20.0 x 20.0 x 0.05 cm^3.

3. Results and Discussion

The graphs shown in Figure 2 on the left are from simulations performed with the MCNP code and those on the right refer to TOPAS. The first simulations are called 'Source' and concern a simulated monoenergetic beam (with the respective energy indicated) incident on a water phantom. Besides tallying the dose, the first simulations were also responsible for generating a phase space file at 1.0 cm distance from the phantom object, i.e., the particles were recorded in a plane placed in a vacuum between the monoenergetic source and the water simulator object. In the following two simulations referenced as 'MCNP Phsp' and 'TOPAS Phsp,' the phase spaces generated with TOPAS and MCNP were read out.

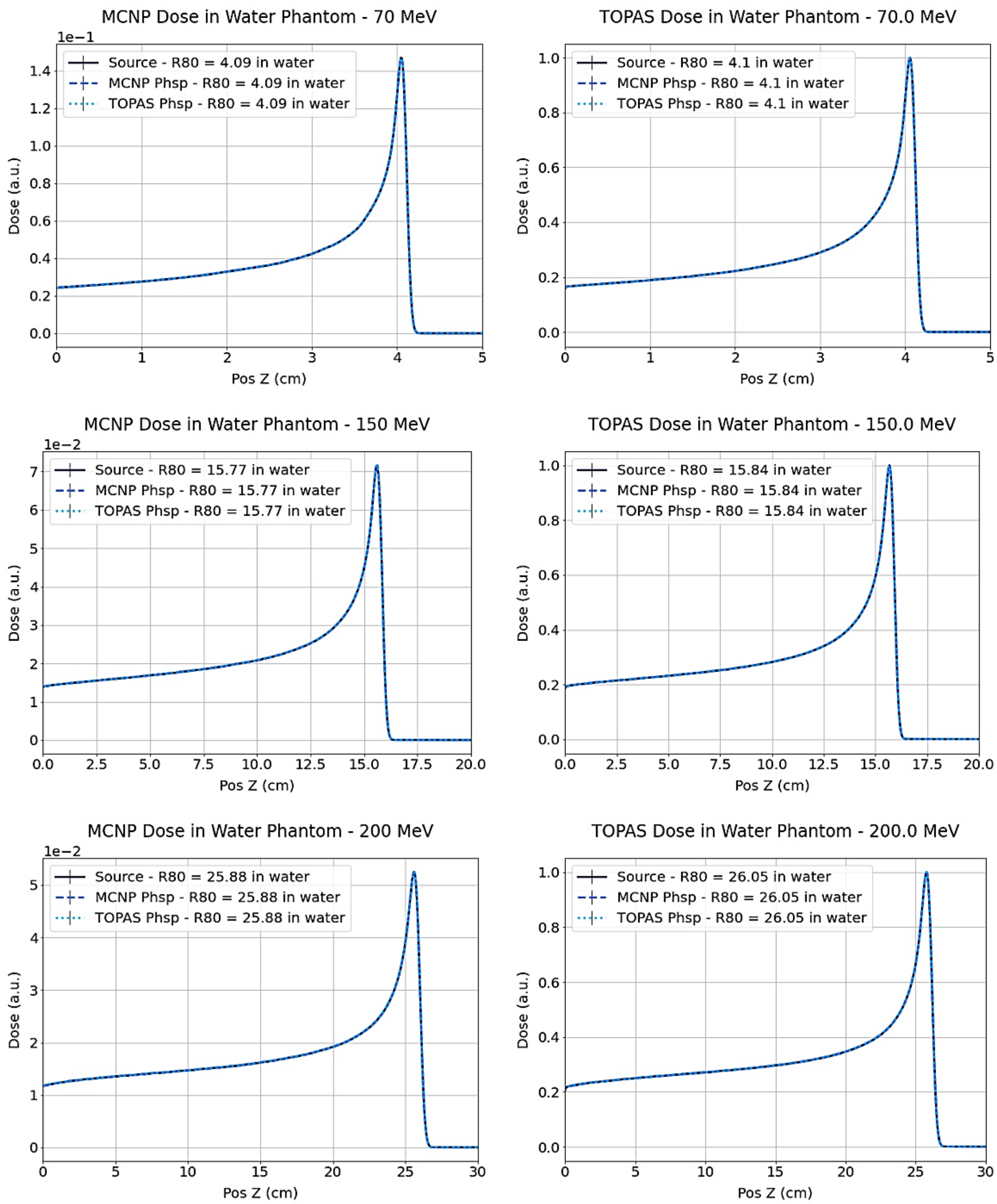

Figure 2 : Energy deposition along depth for proton beams with incident energies of 70 MeV, 150 MeV and 200 MeV, comparing the simulations performed without phase space, the simulations performed in rereading the phase space of the code itself, and the simulations resulting from the conversion and reading of the phase space from the other code.

In the left graphs of Figure 2, resulting from simulations with MCNP, the curve indicated by 'MCNP Phsp' refers to the reading of the phase space generated by this code, and the curve indicated by 'TOPAS Phsp' refers to the conversion of the phase space generated with TOPAS by the Phase Space Converter, so that it could be read by MCNP. The graphs on the right were all simulated with TOPAS, so the curve indicated by 'TOPAS Phsp' refers to the reading of its own phase space, and the one indicated by 'MCNP Phsp' refers to the converted phase space.

When comparing the simulations with the same code, the dose differences found for the same incident energies were not statistically significant when using the converted phase spaces and those from the code itself. Minor differences in energy deposition between the simulations with both codes can be attributed to the different radiation transport models. Future studies will extend the use of Phase Space Converter to multiple source types in the simulations.

4. Conclusions

A Phase Space Converter was created in python language to be used between the MCNP and TOPAS Monte Carlo codes. To validate its algorithm, we present a comparison between depth dose distributions in water between both codes. The statistical uncertainties of the simulations involving each one of the codes and its converted phase space were greater than the relative differences between the simulations, validating the developed Phase Space Converter.

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