Comparisons of the results of software packages GEANT4 & SRNA-18

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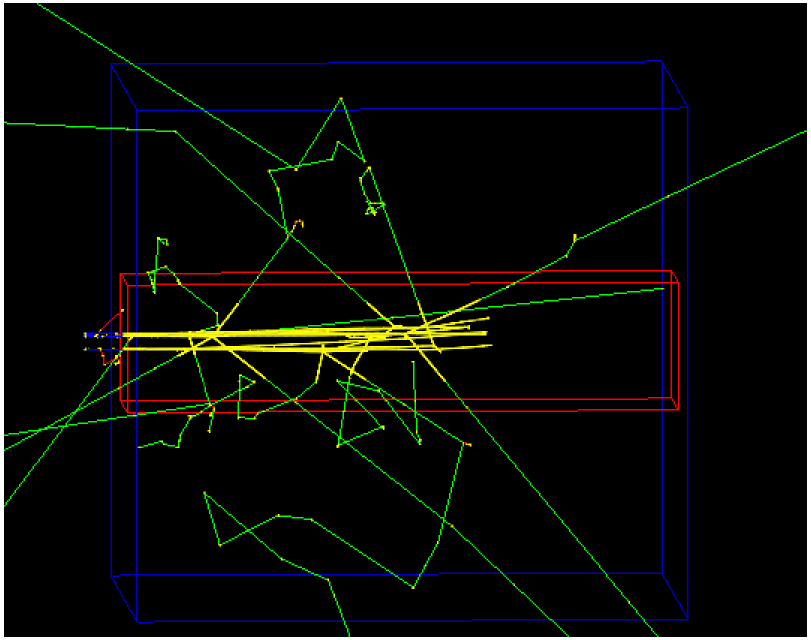
Introduction

- One of the main advantages of proton therapy over the other types of RT is the increased accuracy and conformity of irradiation. One of the main tasks of RT is to bring the prescribed dose to PTV with minimal impact on nearby healthy tissues. However, high accuracy of irradiation requires high accuracy of calculations. Nowadays most of the modern planning systems rely in one way or another on the Monte Carlo method in their calculations, because it is one of the most accurate tools for calculating the radiation passage through matter.
- There are many programs using this method to simulate the process of radiation passing through a substance and numerical calculations of the absorbed dose. One of them is a toolkit for C++ "GEANT4", developed at CERN. It is widely used for practical calculations, and has proven itself well, repeatedly showing good agreement with the results of experiments.

Introduction

* There are many alternatives to GEANT4, one of which is the SRNA program, which uses a simplified physical model in calculations, and its operation does not require a complex description of the geometry. SRNA does not take into account the contribution to the dose from secondary neutrons, electrons, gamma quants in its calculations, which can be significant for high-energy protons with an energy of about 200 MeV. The aim of this work is to compare the results of two software packages GEANT4 and SRNA based on the simplest model installations, and then analyze the effectiveness of their use for calculating passive systems of proton beam formation.

The modeling task



The water phantom was irradiated with a proton beam of R=1cm radius with an energy of 209 MeV. As a detector, the central part of the phantom with the dimensions of 10*10*40 cm. For a qualitative assessment of the scattering in both software packages, PMMA plates of different thicknesses were placed between the source and the phantom.

The modeling task

* For comparative analysis, the following distributions were selected:
* depth dose distribution throughout the detector;
* depth dose distribution in the center of the detector (approximate location of the beam entering the phantom);
* dose profiles at the beam entrance to the phantom and at the Bragg peak;
* dose distribution on the XZ plane in the center of the phantom in the form of isodose curves.

Modeling results

The peak position was 274 and 277 mm for the SRNA and GRANT 4 models, respectively. The peak absorbed dose values were 3.43 Gy for SRNA and 3.28 Gy for GEANT4. The distal falloff for all simulations is identical and was 4 mm. As a result of the SRNA program, a characteristic decline was observed in the pre-peak region, which is clearly visible on the distribution in the center of the phantom.

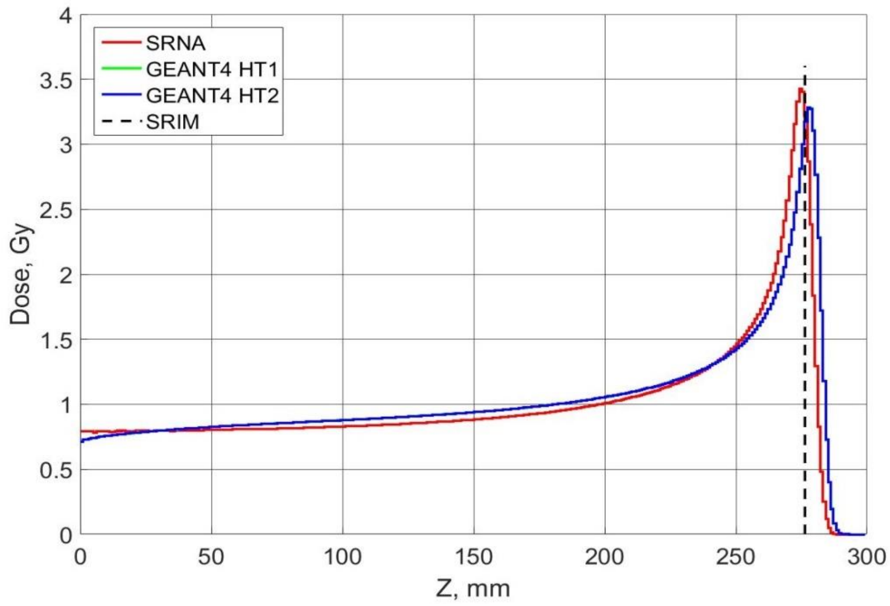


Fig. 1 Depth dose distribution

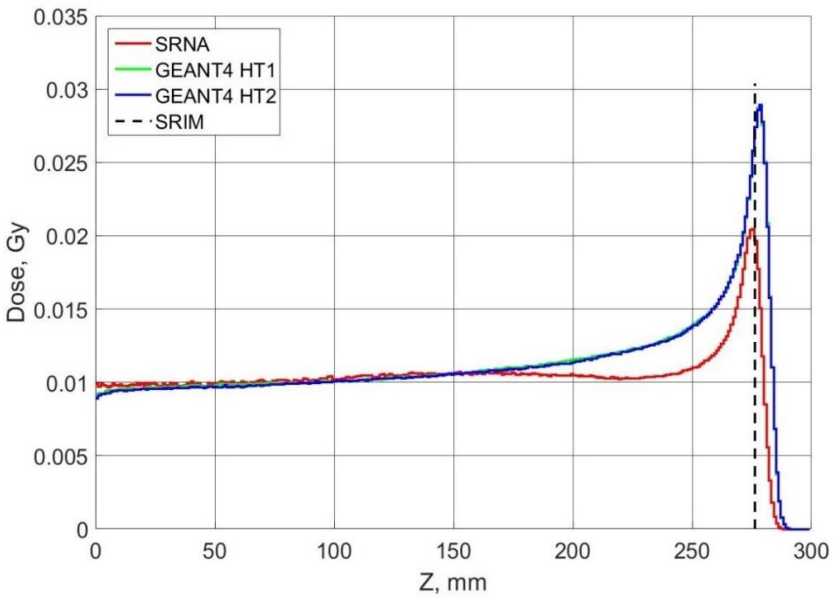


Fig. 2 Depth dose distribution in the center of the detector

Modeling results

The ratio of the values of the maxima of the GEANT4 profiles to the SRNA at the entrance to the phantom is 0.92, and at the peak – 1.38. The value of the penumbra at the entrance in all simulations was 0 mm, at the Bragg peak of the SRNA penumbra is 11 mm, at GEANT4-9 mm.

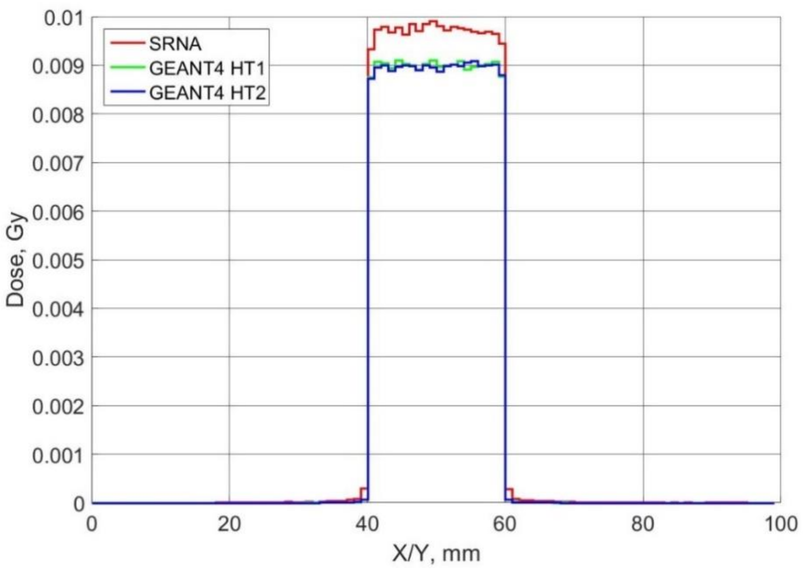


Fig 3. Dose profile at the beam entrance to the phantom

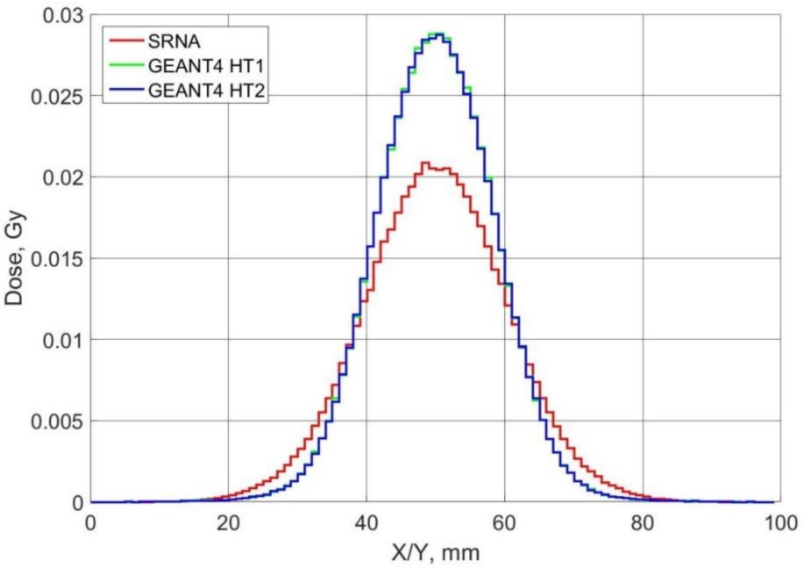


Fig 4. Dose profile at the Bragg peak

Modeling results

The figure shows the types of differences in the simulation: Thus, in the SRNA simulation, a local dose rise is observed in the depth range of 110-190 mm, followed by a decline, which is also noticeable in the figure 2. In the results of GEANT4, a similar effect is not observed.

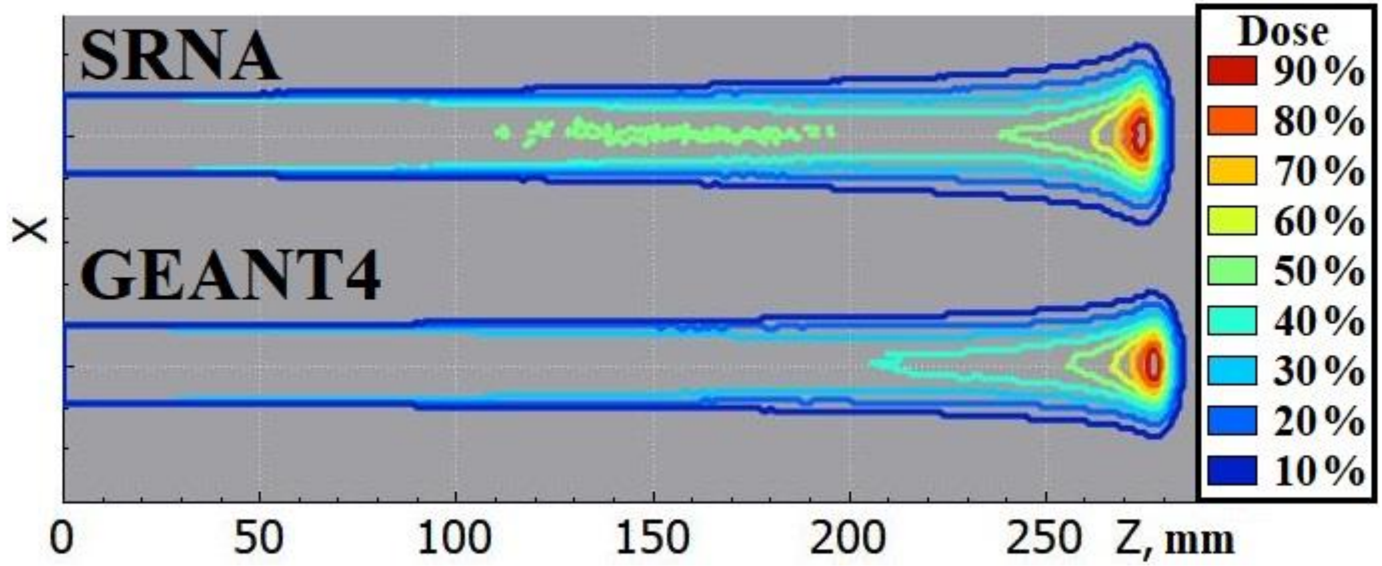


Fig. 5 Dose distribution on the XZ plane in the center of the phantom in the form of isodose curves

Scattering comparison

- The installation of a 1cm thick scatter resulted in a maximum shift of 13 mm for both software packages. Further work is related to the analysis of discrepancies.
- To compare the scattering, the beam profiles were taken at the entrance to the phantom after passing through a PMMA Plexiglass plate with the following thickness values: 0.1, 0.2, 0.5, 0.75, 1 and 2 cm.
- The scattering parameter r_0 was selected according to the formula $f(r)\, r\, dr\, d\varphi = \frac{1}{2\pi r_0^2} e^{-\frac{1}{2}\left(\frac{r}{r_0}\right)^2} dr d\varphi$ using the RMS method.

Scattering comparison

The obtained curves clearly show the previously systematically observed slightly greater scattering for the results of the SRNA program.

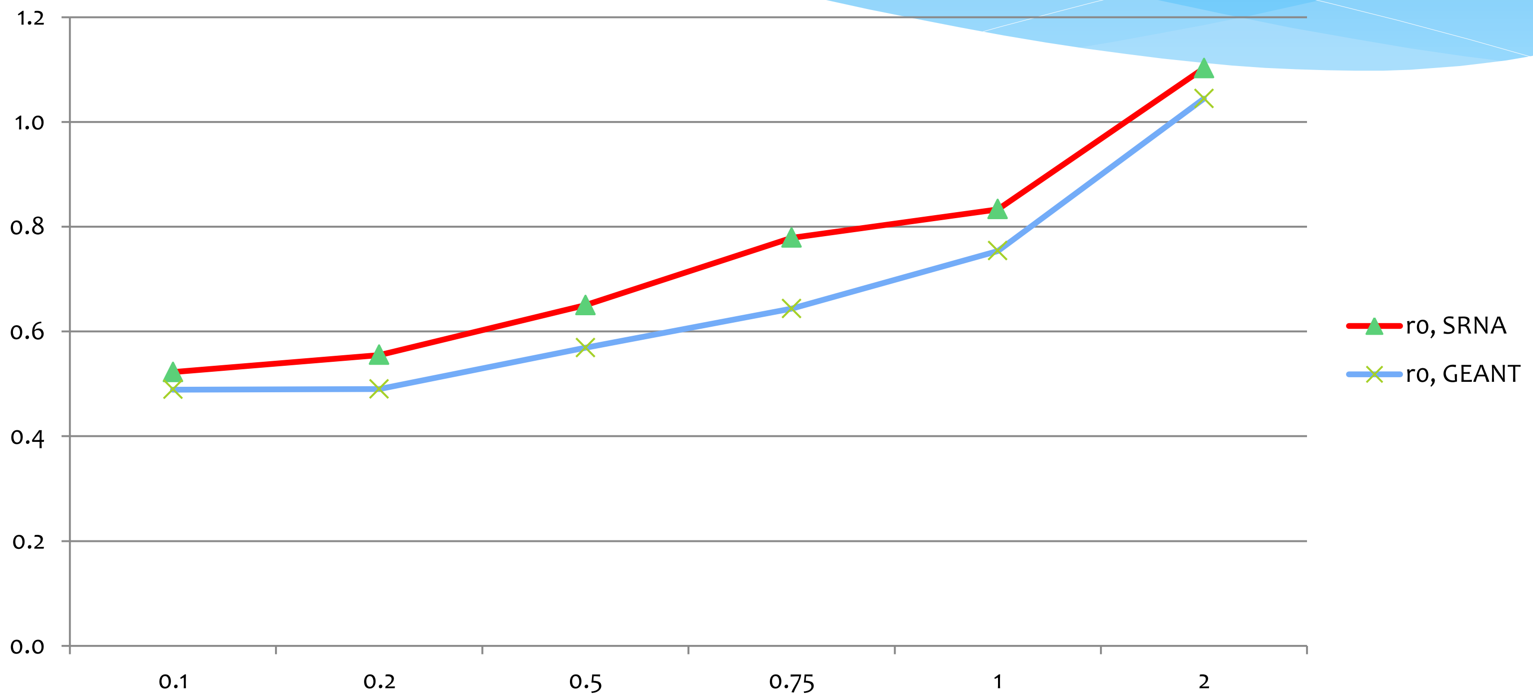


Fig. 6 Dependence of the scattering parameter r_0 on the thickness of the plate.

Comparison of dose profiles at the different depth

* To determine the position and behavior of the data discrepancy, it was decided to compare the dose profiles for different values of the depth of radiation penetration into the substance when scattered by a 1 cm thick Plexiglass PMMA plate. Profiles were used at a depth of 5, 10, 15 cm, as well as in the area of Bragg peak.

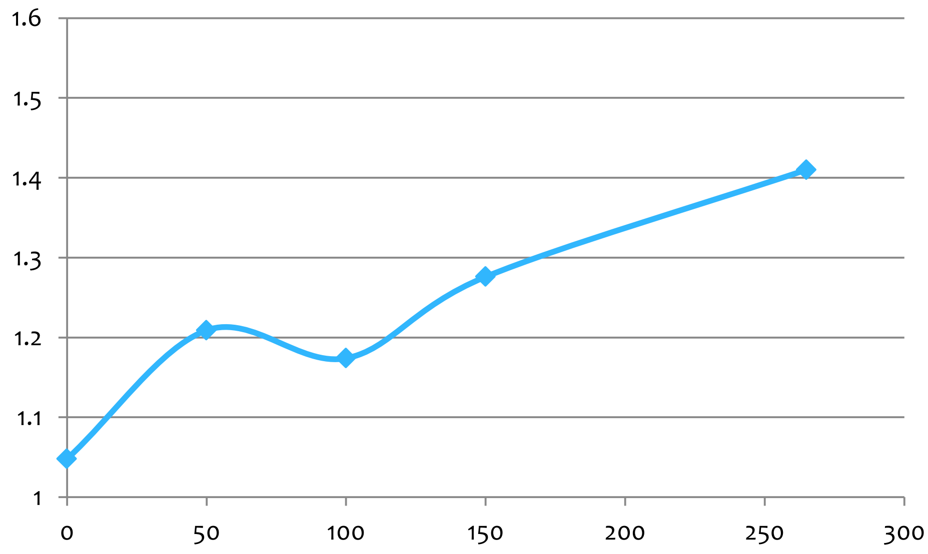


Fig.7 Dependence of the ratio of the maxima Dmax(GEANT4)/Dmax(SRNA) profiles for different penetration depth.

Conclusions

* The depth and isodose curves of the dose distributions clearly show the difference between the calculated models for the two software packages. Since SRNA takes into account the transport of only secondary protons, this can lead to a failure of the dose in the sub-peak region. This may also be due to the deviation of the protons from the initial trajectory due to their systematically greater scattering.
* The peak dose obtained in the two programs differs by 4% , which can be attributed to the modeling error.
* During the calculations, SRNA's performance was noted in comparison with GEANT4: the program requires about 20 times less machine calculation time.