# THE WAY TO IMPROVE CONFORMITY OF PROTON THERAPY

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*Abstract*

In the case of small tumors, the pencil beam width may be comparable with the target size. In these cases, the application of classic method of passive beam scattering with a one-stage formation of dose distribution may be reasonable. However, the last method in its standard implementation fails to provide the dose conformity: either the maximal dose exceeds the tumor volume on its proximate site or the dose deviates too much within the tumor. In order to overcome this shortcoming of the passive scattering method, we suggest a new construction of a two-component ridge filter (the corresponding patent is pending). We have performed a series of calculations with the Monte-Carlo code SRNA in order to find the optimal construction from the point of view of dose delivery accuracy and of the device manufacturability. With that ridge filter the 95% isodose does not notably leave the tumor volume. The usual "wings" of isodoses on proximate side are now absent and the volume of irradiated healthy tissue is significantly reduced. The experimental tests with proton beams are now in progress.

## PROTON THERAPY AND DOSE FORMATION METHODS

Proton therapy has remarkable advantages over conventional photon radiation therapy. The depth dose distribution shows the increase with penetration depth leading to a maximum energy deposition near the end of range in matter (Bragg peak). This feature allows to spare healthy tissue while delivering maximal dose to the tumor [1].

Today proton therapy is represented by two techniques of dose formation: methods of passive spreading, mostly known as passive scattering and of active spreading or scanning. The first one implies installation of various beam-forming devices on the beam path. These devices alter the width of the beam by scattering and modify its energy spectrum. This method also implies the use of custom-made collimators and compensators for conforming the dose to the target volume. The active scanning technique uses magnets for deflecting and steering the proton beam. The depth of penetration can be varied by adjusting the beam energy. Thus, voxel by voxel, target volume can be covered by maximum dose.

Both methods of formation have their pros and cons. The letter one is considered as more advantageous as it provides the conformance of dose delivery to a tumor of any size with no significant radiation damage to healthy surrounding tissues. Also, due to absence of scattering materials fewer amount of stray radiation is generated. However, this method has the risk of target voxel misses because of organ motion. Small targets with the size comparable to the beam's width can be an additional difficulty for this technique. In these cases, the "old" method of proton scattering may be more effective as it allows to irradiate the whole target volume simultaneously. But in this case, distal edge formation by compensators of standard type inevitably leads to the emergence of hot lesions in the proximal region, beyond the borders of the target volume. Thereby, for better conformity the target has to be irradiated from multiple directions which themselves demand additional forming devices (i.e. custom-made collimators and compensators).

## OUR PREVIOUS EXPERIMENTS

In our earlier study the technique of passive spreading was tested on proton beams of INR linac. The system of double scattering for the beam widening and a ridge filter for spread-out Bragg peak (SOPB) formation was used (see Fig. 1).

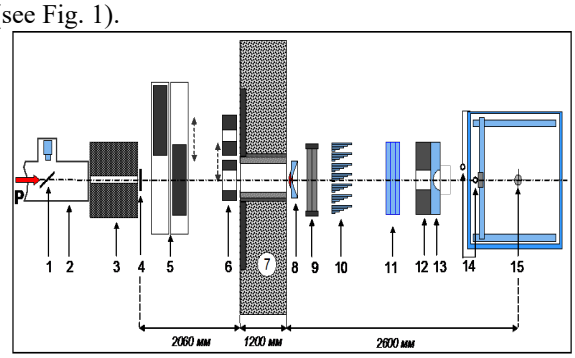


Figure 1: Formation system of INR medical proton beam. 1 – luminophor with TV-camera, 2 - beam channel; 3 - graphite collimator, 4 - the primary scatterer (S1), 5 – beam stop, 6 – beam aperture collimators of 40 and 70 mm, 7 - shielding, 8 – secondary scatterer (S2), 9 - ion chamber, 10 - ridge filter, 11 - energy degrader, 12 – individual collimator, 13 – bolus, 14 - ion chambers in a water phantom, 15 – target isocenter.

A number of measurements with the beams of 160 and 209 MeV was carried out, some results are presented in figs. 2-4.

In order to form a wider beam, we used scatterers S1 and S2 which are represented by copper foils and contoured scatterer with Lucite compensator. This formation system was calculated with the program NEU [2].



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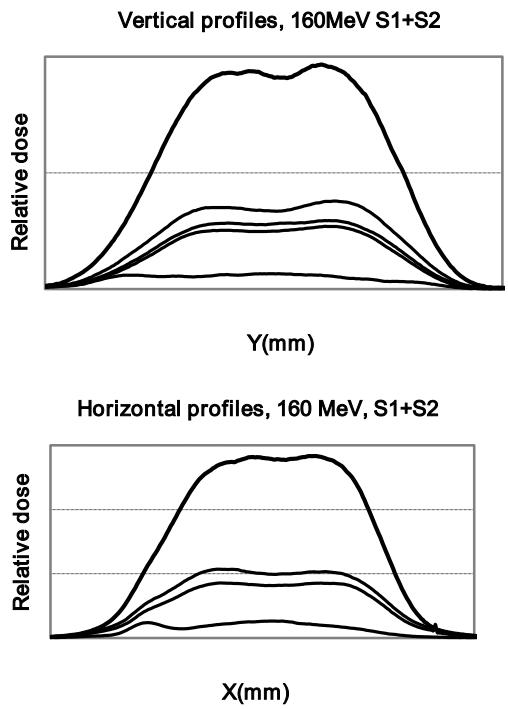



Figure 2: Vertical and horizontal profiles of the 160 MeV proton beamwith scatterers S1, S2.

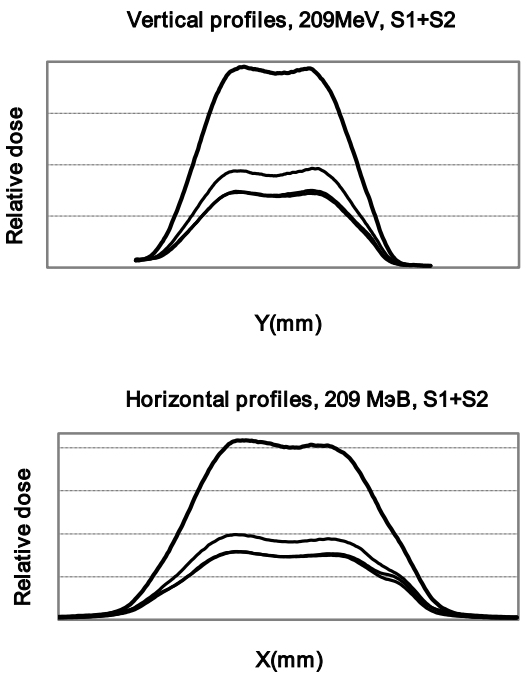
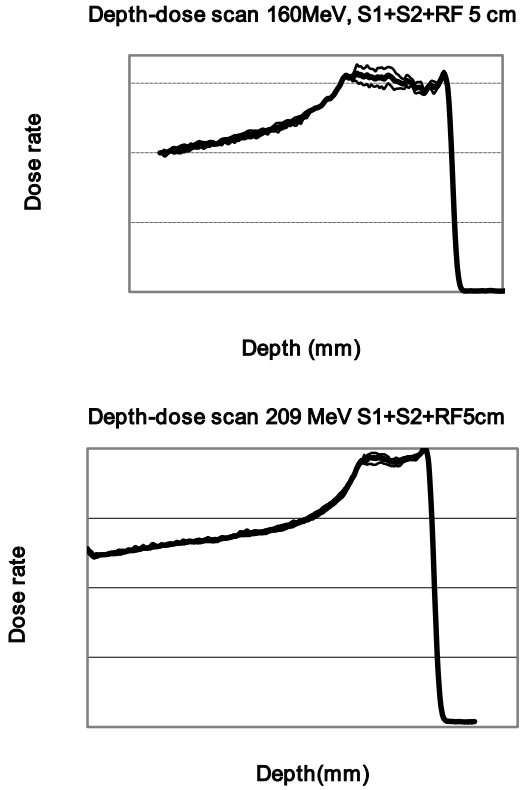



Figure 3: Vertical and horizontal profiles of the 209 MeV proton beam with scatterers S1, S2.

The depth dose distribution generator was a number of degraders with different width and thickness. The combination of which gives us SOBP with a rated modulation width. The results of measurements are presented in figs. 4-5.




Figures 4 (above) and 5 (bottom): The depth dose distribution for the ridge filters with 5 cm modulation for 160 MeV and for 209 MeV.

For the energy160 MeV the dose deviation on the plateau is within 10 %. For the energy 209 MeV the dose deviation on a plateau is within 6 %, but a small overestimation of the high-energy components of a proton beam is observed. Measurements with other filters have shown an increase of up to 20 % of high-energy components and required insignificant adjustments.

## TWO COMPONENT RIDGE FILTER

As mentioned before, traditional scattering techniques of dose formation with a standard ridge filter, a compensator and a collimator fails to provide the conformal dose distribution: either the maximal dose exceeds the tumor volume on its proximate site or the dose changes too much within the tumor volume. To solve this problem, we suggest a new construction of two component ridge filters. It is supposed to eliminate maximal dose exceeding the limits of target volume. We have performed a series of calculations with the help of the original Monte-Carlo code SRNA [3] in order to find the optimal construction from the point of view of dose distribution accuracy and of the device manufacturability.

Some examples of dose distributions calculated with the SRNA program are presented in the figs. below.



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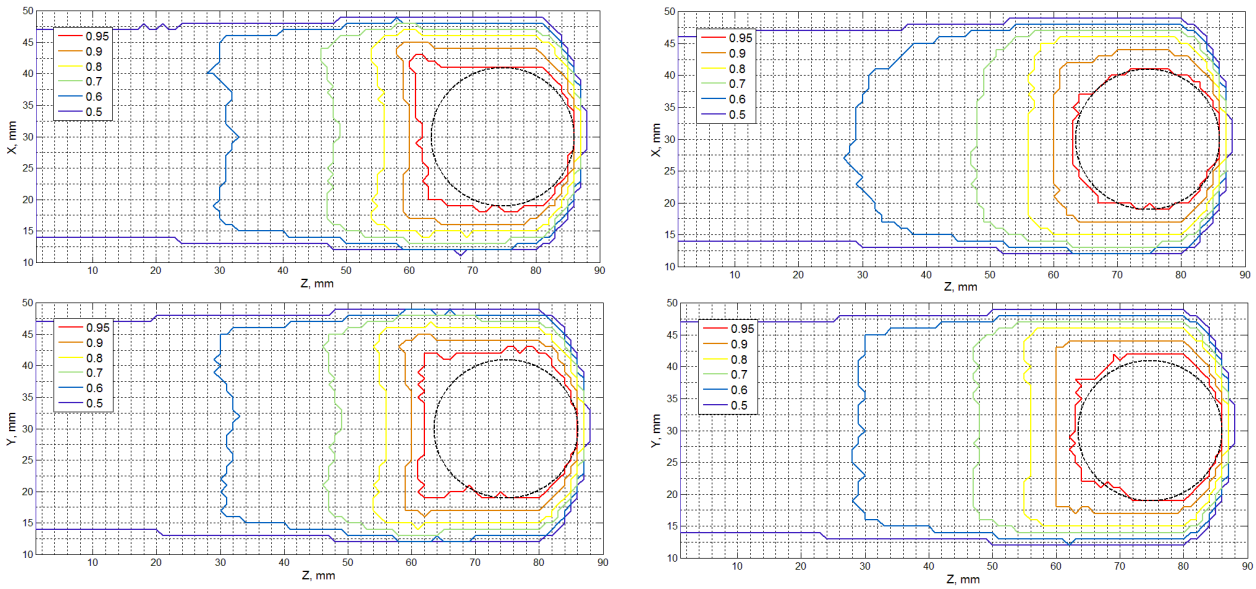


Figure 6: The dose distributions of 110 MeV protons in water, calculated with the Monte-Carlo code SRNA on horizontal (upper plots) and vertical (lower plots) planes. The dose distributions, obtained with conventional ridge filter (left) are compared with the same distributions, obtained with the new two component ridge filter (right). The target is represented by black circle.

As follows from fig. 6, the 95% isodose lines with the new ridge filter do not notably exceed the tumor volume. The usual "wings" of high-dose distributions on their proximate side, seen on the left plots, are absent on right plots. We conclude that new construction of ridge filters allows to improve the proton/ion therapy quality, especially in case of small targets, as e.g. eye tumors or small brain metastasis. The experimental tests of this method with proton beams are now in progress.

## REFERENCES

[1] H. Paganetti, T. Bortfeld "Proton Radiotherapy" New Technologies in Radiation Oncology, 2005 p 345-363.

[2] B. Gottschalk, "NEU User Guide", Laboratory for Particle Physics and Cosmology, 2006.

[3] R. D. Ilić, D. Lalić, S.J. Stanković. "SRNA – Monte Carlo codes for proton transport simulation in combined and voxeled geometries", Nuclear Technology & Radiation Protection, 1-2 / 2002.



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