A Comparison Study of the Designing Models of Range Modulator by Using FLUKA Simulation Codes

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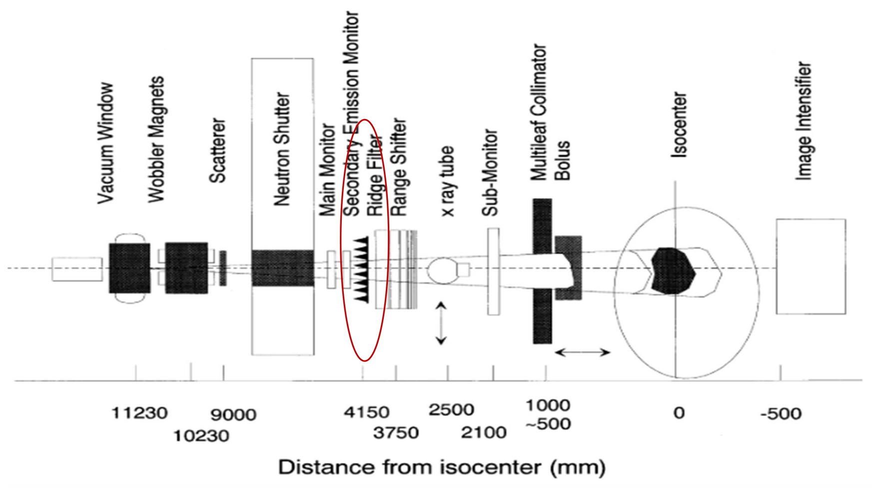
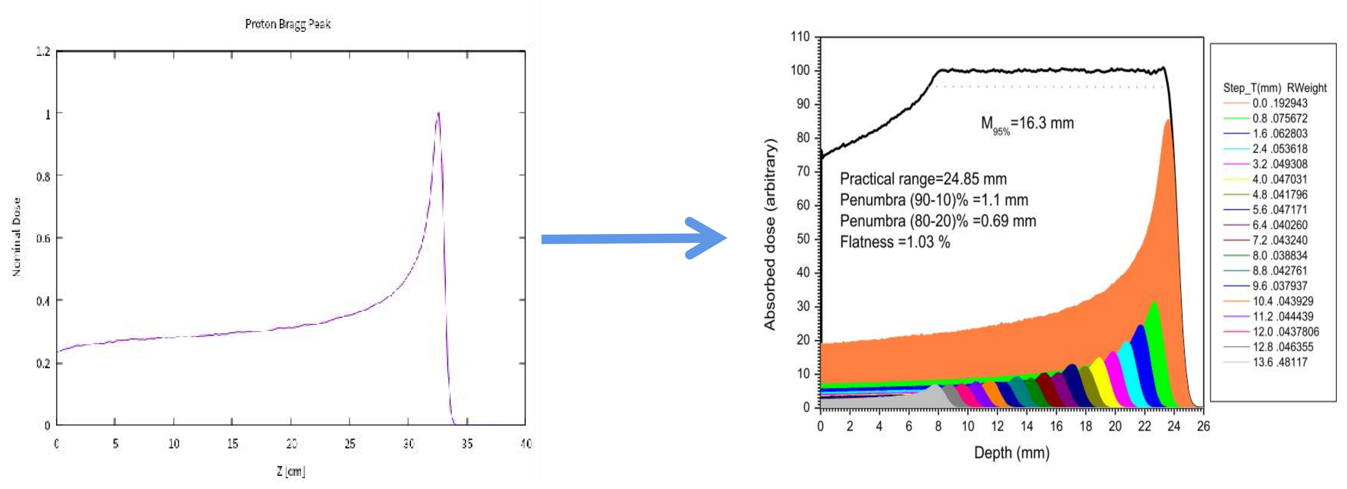
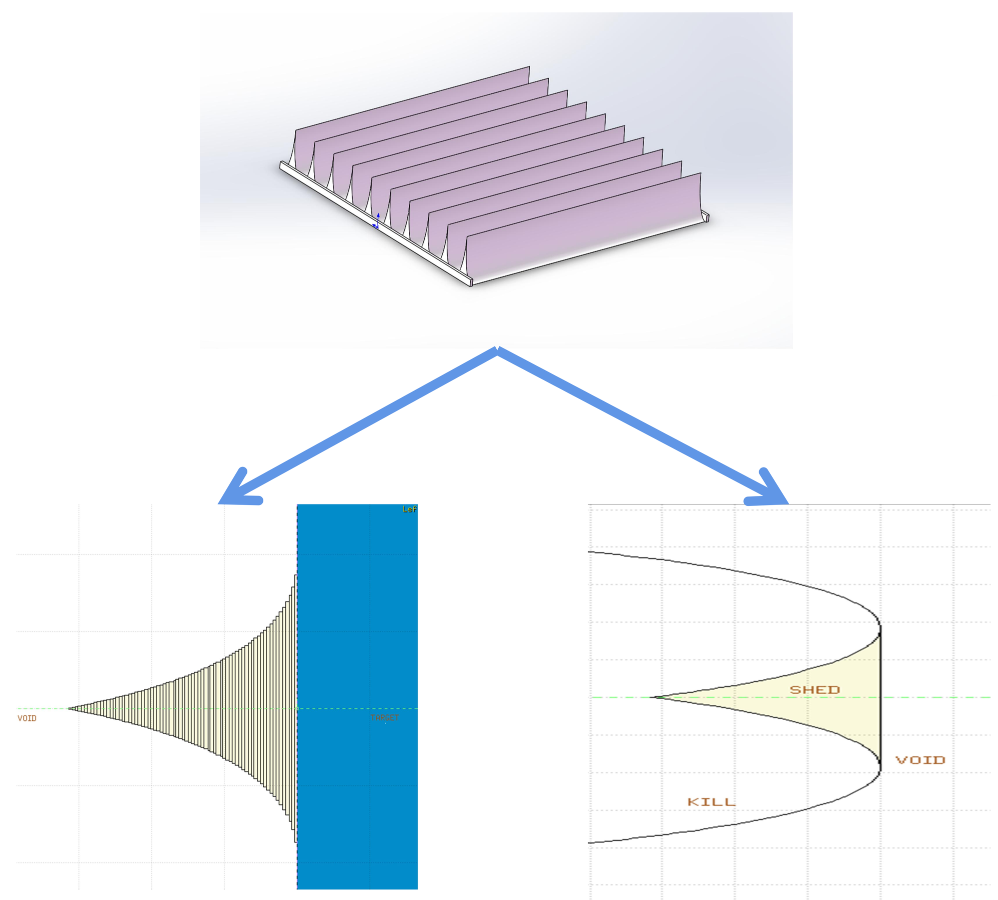
INTRODUCTION

- Range modulator is an important part of the therapeutic head in the proton and heavy ion therapy system.

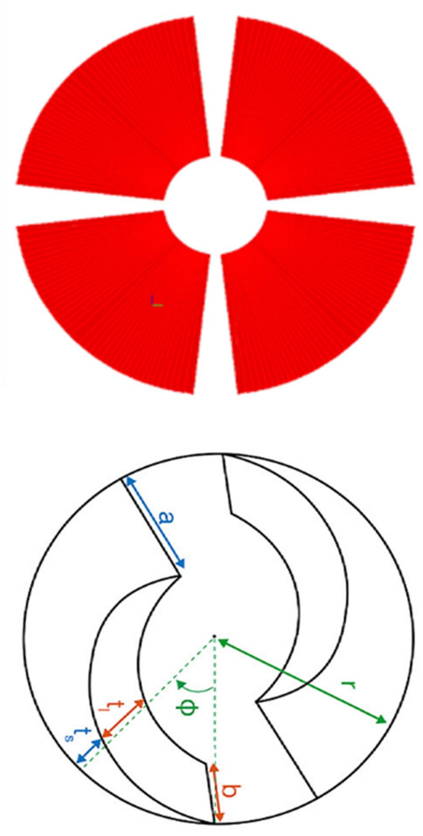


- The Bragg peak of the single energy particle beam is broadened to a flat dose distribution region by the modulator's geometry and relative motion.





uneven &smooth ridge filter



uneven &smooth range modulator wheel.

Mathematical Principles of SOBP

- The essence of SOBP is that particle beams with different energies are irradiated at the same time. The fundamental problem is the weight ratio of particle beams with different energies.

$$\begin{cases} \omega_1 D_{11} + \omega_2 D_{12} + \cdots\cdots + \omega_N D_{1N} = D_{max} \\ \omega_1 D_{21} + \omega_2 D_{22} + \cdots\cdots + \omega_N D_{2N} = D_{max} \\ \vdots \\ \vdots \\ \omega_1 D_{N1} + \omega_2 D_{N2} + \cdots\cdots + \omega_N D_{NN} = D_{max} \end{cases}$$

- the most basic and commonly used numerical solution proposed by Thomas Bortfeld in 1996.
- This study uses a simplified adaptation function method.

$$W(R) = \begin{cases} M\left[\left(d_{max} - R + \frac{\Delta}{2}\right)^{1-\frac{1}{p}} - \left(d_{max} - R - \frac{\Delta}{2}\right)^{1-\frac{1}{p}}\right] & While R = d_{max} - n\Delta \\ MD_0(\Delta/2)^{1-1/p} & While\ R = d_{max} \end{cases}$$

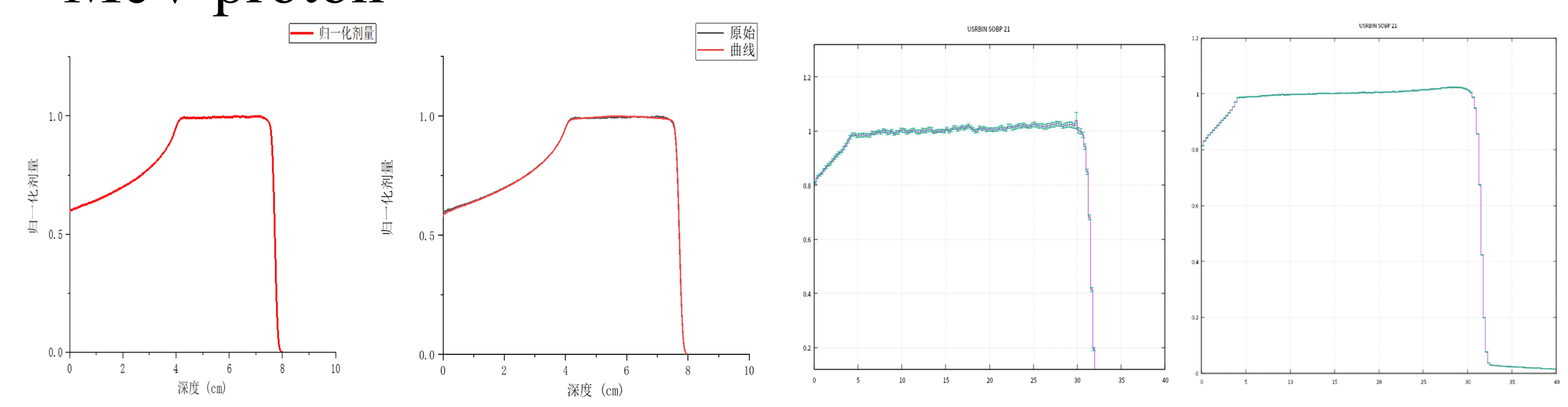
$$F(R) = \left(\frac{1}{a + bR}\right)^k$$

Models of Range Modulator

- Based on the theory of Thomas Bortfeld and simplified adaptation function method, four different range modulator models were designed and compared by using the FLUKA simulation codes. The four models are: **uneven ridge filter, smooth ridge filter, uneven range modulator wheel, and smooth range modulator wheel.**

Comparison of four Models

- SOBP effects of four models by stimulating 100/230 MeV proton



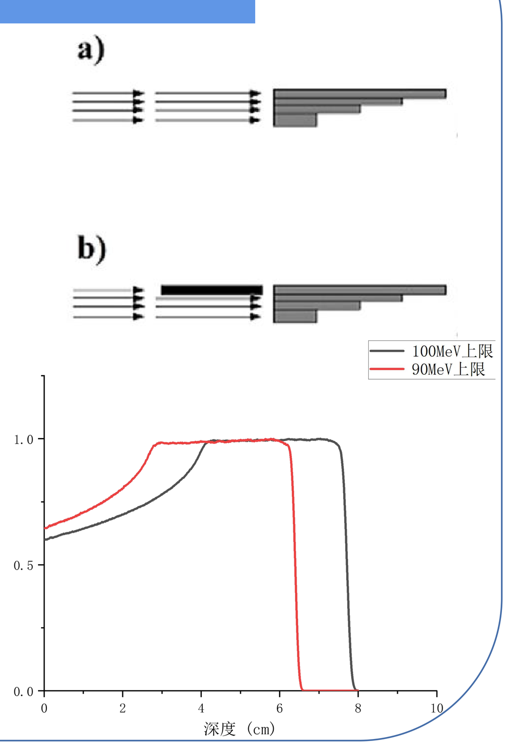
- Comparsion of the average value of the difference

average value of the difference	uneven ridge filter	smooth ridge filter	uneven range modulator wheel	smooth range modulator wheel
100MeV-3cm SOBP	0.99%	0.86%	0.92%	0.88%
100MeV-5cm SOBP	1.18%	1.02%	1.10%	1.06%
230MeV-10cm SOBP	1.21%	0.94%	1.24%	0.96%
230MeV-20cm SOBP	1.62%	1.08%	1.52%	1.06%

- The results showed that in ideal motion condition, the four models all showed the ideal range modulation effect. The average value of the difference was less than 2%. **The evenness of the smooth models is improved compared with the uneven models. The smooth ridge filter model performed best.**

Potential Optimization

- On the basis of smooth RF model, we tried to realize the movement of the SOBP region by adding a binary shielding layer. The results showed that the SOBP region can move in a small range at the expense of acceptable accuracy error.



CONCLUSION

- This study provides a design reference for the range modulator in proton therapy, and provides a new scheme to fill the target area for precise therapy.

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