

Validation of mechanical accuracy and impact on dose sensitivity for a proton dynamic collimation system

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INTRODUCTION

The Dynamic Collimation System (DCS) is a nozzle mounted proton spot scanning accessory that provides a minimal airgap between the patient and collimator. While the linear motors used to move the collimators are very accurate in a laboratory environment, larger errors as part of an assembly may be possible and must be investigated.

AIM

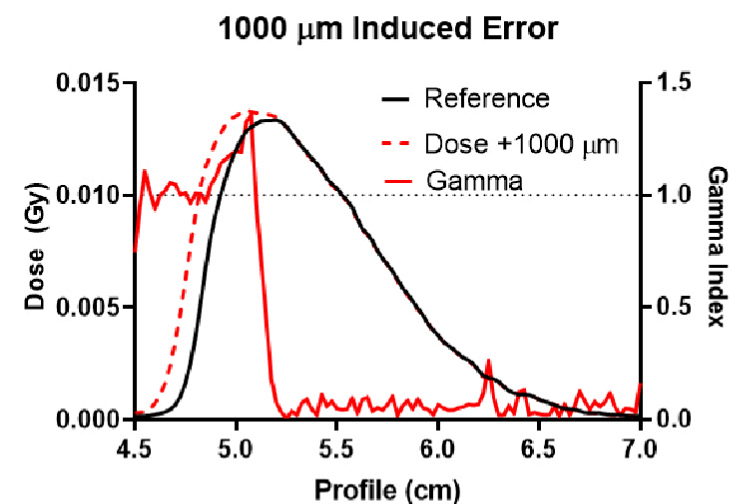
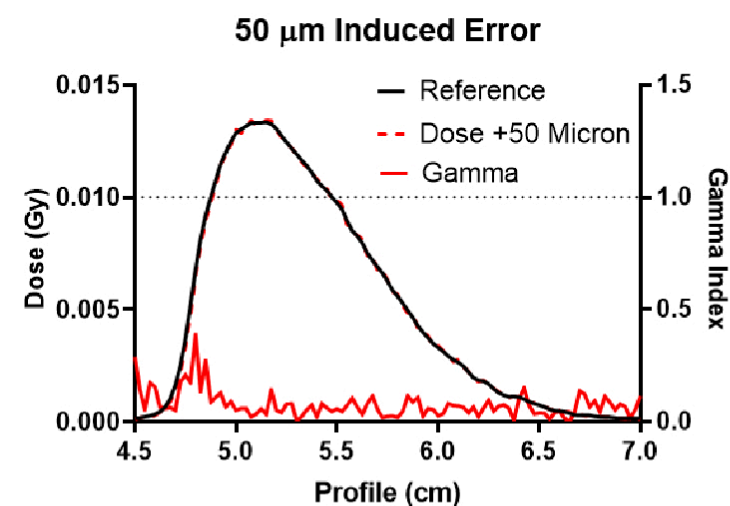
The DCS is a proton collimator comprised of four nickel trimmers that move in synchrony with a scanned proton beam to sharpen the lateral penumbra. To enable focused collimation, a simple mechanism which rotates the trimmers as they translate was developed. Herein, the mechanical and dosimetric accuracy of a prototype focused DCS is evaluated.

METHOD

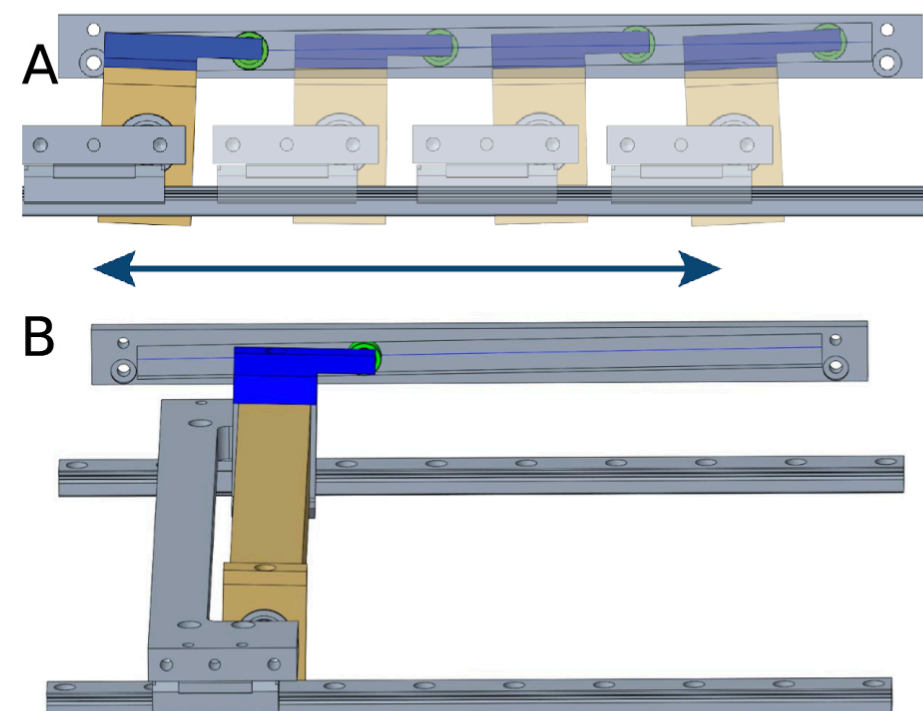
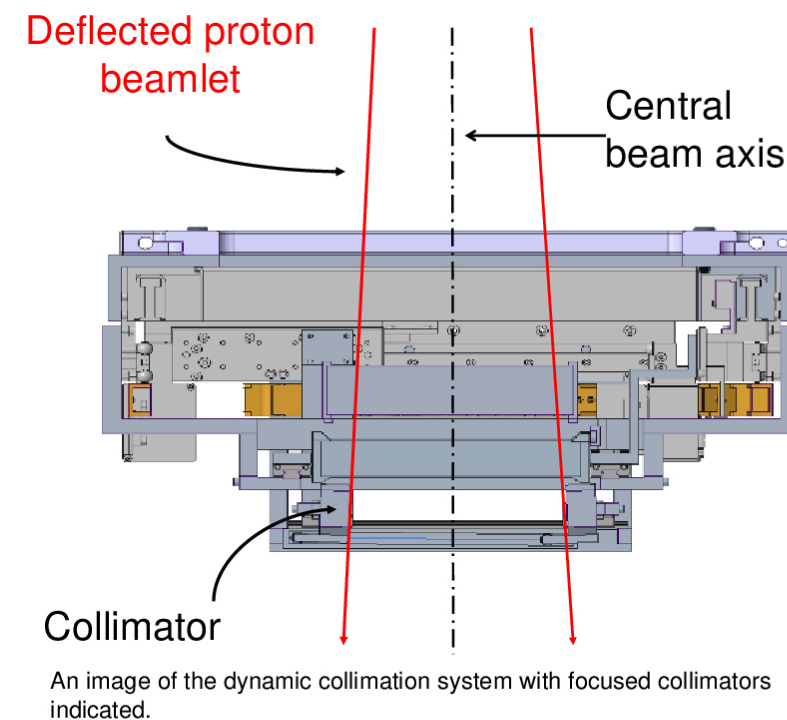
- Positional and angular accuracy of the trimmers were measured to within 25 μm using a FARO® Edge ScanArm.
- An IBA Proteus Plus treatment delivery system was modeled in TOPAS along with the DCS at an energy of 100 MeV.
- Dosimetric sensitivity to trimmer position and rotation errors was evaluated with the TOPAS Monte Carlo calculation system.
- Trimmer position errors of ± 250 , ± 500 , ± 750 , ± 1000 μm were also simulated and a sensitivity analysis was performed. While errors of this magnitude are not expected, these simulations serve to set an upper bound to the required positional accuracy of the DCS.

RESULTS

For a range of clinically expected trimmer positions, the maximum positional and angular error as measured using the FARO® Edge ScanArm was found to be ± 50 μm and $\pm 0.25^\circ$, respectively. This level of accuracy resulted in negligible changes to shape, position or fluence of the beamlet when compared to the baseline TOPAS simulations. When the positional error increased to ± 1000 μm or greater, the 1%/1 mm gamma pass rate degrades to 90%.



Trimmer spots of a 100 MeV proton beam reference vs 50 μm and 1000 μm induced error and 1%/1mm gamma index.



A single trimmer (gold) mounted on bearings to allow for rotation, shown at four positions to show movement. The lever arm (blue) follows the guide rail and rises as it translates from left to right, rotating the trimmer. Note, actual DCS will have two trimmers mounted on each axis.

CONCLUSIONS

The mechanical accuracy of the DCS, which was validated to be within ± 50 μm and $\pm 0.25^\circ$, does not have a clinically relevant impact on the dose distributions of single proton beamlets. If inaccuracies from mounting misalignment or spot center drift compound and reach 1000 μm or greater, the beamlets are meaningfully altered and fail the gamma test.

ACKNOWLEDGEMENTS

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REFERENCES

- Geoghegan TJ, Nelson NP, Flynn RT, Hill PM, Rana S, Hyer DE. Design of a focused collimator for proton therapy spot scanning using Monte Carlo methods. *Med Phys*. March 2020;mp.14139. doi:10.1002/mp.14139

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