Beam Characteristics of the First Clinical 360°-rotational Single Gantry Room Scanning Pencil Beam Proton Treatment System and Comparisons against a Multi-room System

Charles Shang[1] , **Grant Evans**[1], **Mushfiqur Rahman**[1], **Liyong Lin**[2]

[1]South Florida Proton Therapy Institute, Delray Beach, FL; [2]Emory Proton Therapy Center, Atlanta, GA

2020 JULY 12–16 VIRTUAL JOINT AAPM COMP MEETING

Introduction

The first 360°-rotational single gantry room scanning pencil beam proton treatment system - ProBeam Compact™ (Varian Medical, Palo Alto, CA) was implemented in a clinical setting in November 2019. Its major components include 1) a superconducting cyclotron which accelerates and injects 250 MeV protons to the beamline; 2) open-air energy selection system for clinical beam energies ranging from 70 MeV to 220 MeV; 3) shortened single-room dedicated beam transport system with a 45° and a 135° major bending magnets; 4) 360-degree rotating gantry equipped by two orthogonally arranged on-board kV imaging systems with CBCT capability; and 5) 6D robotic patient support system.

Aim

The purpose of this study is to present the proton beam characteristics of this single-room ProBeam Compact™ proton therapy system (SRPT) and comparison against a comparable commissioning data set of a multi-room ProBeam™ system (MRPT).

Materials and Methods

A newly designed SRPT with proton beam energies ranging from 70MeV to 220MeV was commissioned in late 2019. IDDs were scanned using 81.6mm diameter Bragg peak chambers and normalized by outputs at 15 mm WET and 1.1 RBE offset, following the methodology of TRS 398. The in-air beam spot profiles were acquired by a planar scintillation device respectively at ISO, upper and down streams, fitted with single Gaussian distribution for beam modeling in Eclipse v15.6. The field-size effect was adjusted for the best overall accuracy of clinically relevant field QAs. The halo effects at near surface were quantified by a pin-point ionization chamber. Its major dosimetric characteristics were compared against MRPT comparable beam data set.

Results

Contrast to MRPT, an increased proton straggling in the Bragg peak region was found with widened beam distal falloffs and elevated proximal transmission dose values. IDDs showed 0.105 to 0.221 MeV (energy sigma) or 0.30 to 0.94 mm broader Bragg peak widths (R_{b80} - R_{a80}) for 130 MeV or higher energy beams and up to 0.48-0.79 mm extended distal falloffs (R_{b20}- R_{b80}), as displayed in figure 1 and 2. Minor differences were identified in beam spot sizes, spot divergences (figure 3). High passing scores are reported for independent end-to-end dosimetry checks by IROC (see table 1) and 100% pass rate for initial 180 field specific QAs at 3%/3mm Gamma index with fields regardless with or without range shifters.

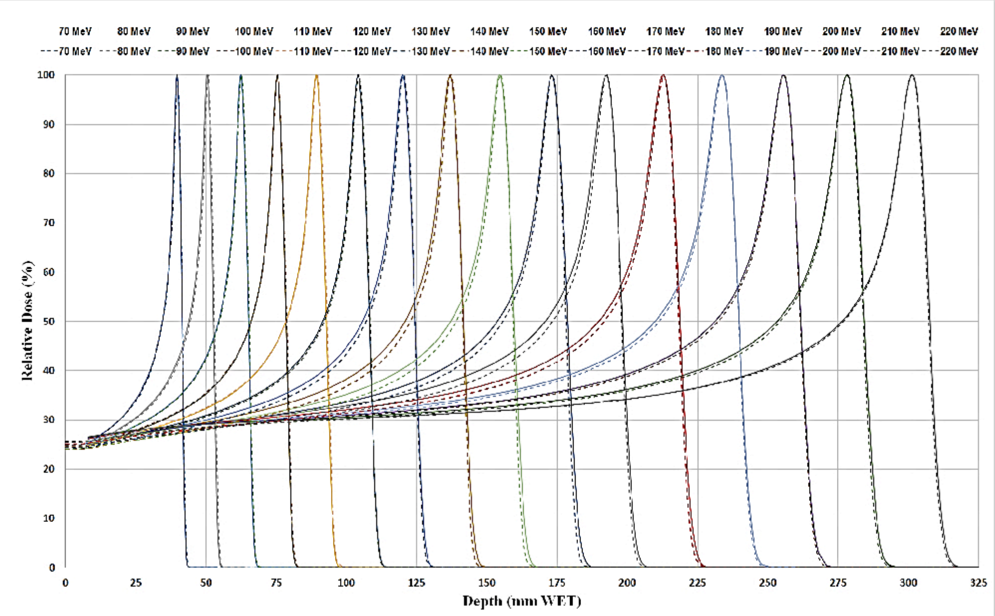

Figure 1. Comparison of the peak normalized IDDs between SRMT (solid curves) and MRPT (dotted curves) in every 10 MeV steps

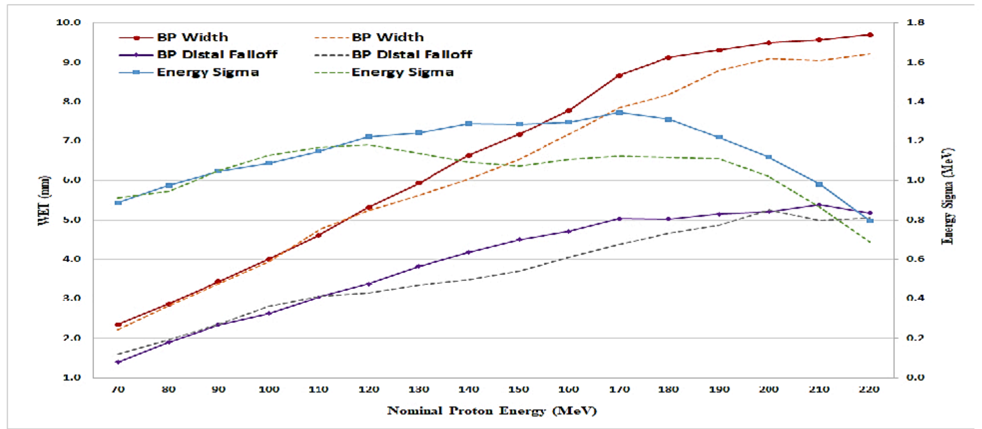

Figure 2. Comparison of Bragg peak (BP) dosimetry characteristics between SRPT (solid curves) and MRPT (dotted curves)

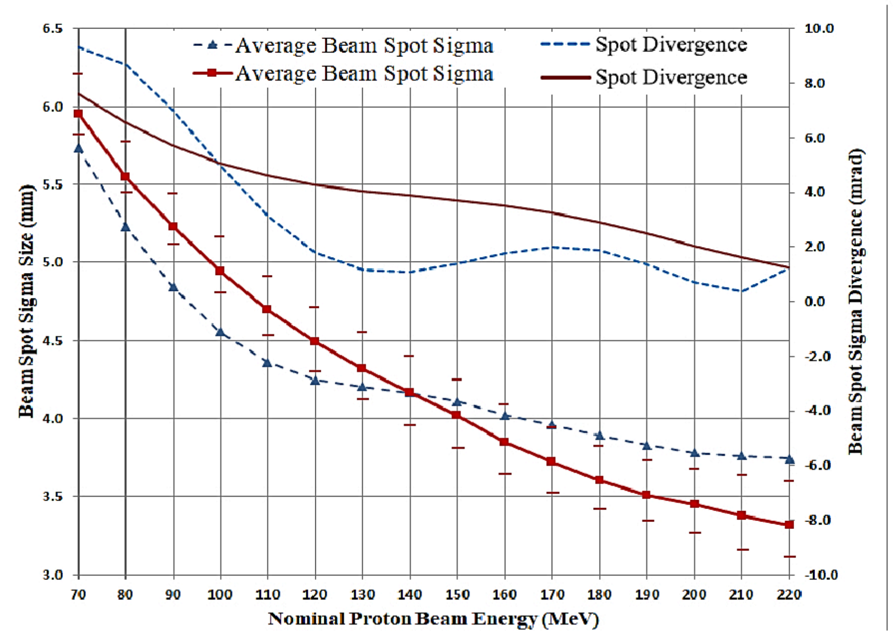

Figure 3. Proton beam spot comparison between SRPT (solid curves) and MRPT (dotted curves)

OSL Point Dose	IROC vs AcurosPT	Passing Criteria
cGy at dose point	273 : 273	
Ratio	1.00	0.95 - 1.05
Protate IMPT to Pelvic Phantom		
TLD Point Dose	IROC vs AcurosPT	Criteria
Center Prostate (L)	1.03	0.93 - 1.07
Center Prostate (R)	1.04	0.93 - 1.07
Film Plane Dose	IROC vs AcurosPT	Criteria
Coronal	96%	≥ 85%
Sagittal	96%	≥ 85%

Table 1. IROC proton output and end-to-end dosimetry on a pelvic phantom against Eclipse AcurosPT Plans and delivery

Conclusions

We highlighted the dosimetry differences in IDDs mainly introduced by a shortened beam transport system in ProBeam Compact™, for which new acceptance criteria were adapted. This report offers a unique reference for future commissioning, beam modeling and planning on different systems, as well as analysis of dosimetric QA and clinical studies. With current beam modeling, a satisfactory planning quality and delivered dose accuracy are suggested by independent end-to-end tests and patient's specific beam QA's when mixed proton energies were used. However, beam modeling with more comprehensive methodology for all applicable planning algorithms is warranted for the future investigations.

References

Varian Medical System -Particle Therapy GmbH, ProBeam Compact: "Energy Selection System (ESS)", 2020.

Varian Medical System, "ProBeam Administration and Physics – ProBeam Compact ver. 4.2, DCID: PC4.2-TRM-0090-01," 2018.

C. Chang, S. Huang, J. Harms, J. Zhou, Z. R, A. Dhabaan, R. Slopsema, K. M, L. T, M. McDonald, K. Langen and L. Lin, "A standardized commissioning framework of Monte Carlo dose calculation algorithms for proton pencil beam scanning treatment planning systems," Med. Phys., no. doi:10.1002/mp.14021, 2020.

J. Harms, C. Chang, R. Zhang and L. Lin, "Nuclear halo measurements for accurate prediction of field size factor in a Varian ProBeam proton PBS system," J Appl Clin Med Phys, vol. 21, no. doi:10.1002/acm2.12783, pp. 197-204, 2020.

Acknowledgement

Authors would like to thank Varian engineering team and Proton International LLC for providing unparalleled technical, logistic support; and Tim Williams, MD for his guidance on key components of clinical implementation.

Contact info: CSHANG@SFPTI.COM