JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING EASTERN TIME [GMT-4]

Measurement Based Halo Characterization for Secondary MU Check in PBS Proton Therapy Plans

L. Yin[1], C. Ainsley[2], E. Garver[1] and L. Dong[1]
1. University of Pennsylvania, Philadelphia, PA, USA
2. Thomas Jefferson University, Philadelphia, PA, USA

Penn Medicine Radiation Oncology Excellence is Standard

INTRODUCTION

The accuracy of independent dose verification relies on precisely modeling the lateral dose spread from proton pencil beams. It can be modelled by the summation of primary and secondary Gaussian distributions. Primary Gaussian kernel accounts for the broadening of pencil beam due to multiple coulomb scattering which is well explained by the Moliere theory and accurately parameterized by Highland formula. A smaller but much wider secondary Gaussian, i.e. halo, is necessary to model the spray tails from in-air spot profiles as well as the hard scatter from nuclear interactions in the medium. However, it is challenging to directly characterize secondary Gaussian due to several reasons. Low dose tails from in-air spot profiles vary between different sites and treatment rooms, whereas commercially available scintillator cameras do not provide enough pixel depth to record these tails. Meanwhile, parameterizations of nuclear halos in the water are not consistent in the literature (M. Soukup, et al. 2005, B.Clasie, et al. 2010). Monte Carlo simulations would provide accurate results but requires significant efforts up-front. Therefore, we propose a method which provides accurate halo characterization but requires less effort and is more efficient than Monte Carlo simulations.

AIM

In this study we propose an independent approach to characterize the secondary Gaussians for calculating lateral dose deposition for secondary MU check of proton pencil beam scanning (PBS) treatment plans.

METHOD

For verification of treatment planning system (TPS) dose calculations, pencil beam convolution superposition algorithm was employed to calculate point doses in patient QA plans and compared to the TPS calculations. Lateral dose profile from each proton pencil beam was modeled with two Gaussian distributions. Dose deposition from multiple Coulomb scatter was first approximated with a primary Gaussian distribution with its sigma analytically calculated from Highland formula. Dose contributed by in-air tails of spot profile and nuclear interactions in water was modeled approximately as a secondary Gaussian distribution (Halo). Sigma and weight of secondary Gaussian were derived from the scatter effect in field size factor measurements using uniformly spaced, mono-energetic proton beams at various energy and depths.

RESULTS

In each of the four proton treatment rooms, output factors were measured for five mono-energetic proton beams with field size from 40 x 40 mm to 248 x 248 mm at 3-5 depths per energy. Similar measurements were also carried out for mono-energetic beams with a 7.4cm WET range shifter. Sigma and weight of secondary Gaussians were derived from each set of the field size factor curves (Figure 1), and fit as third degree polynomial functions of energy and depth (Figure 2).

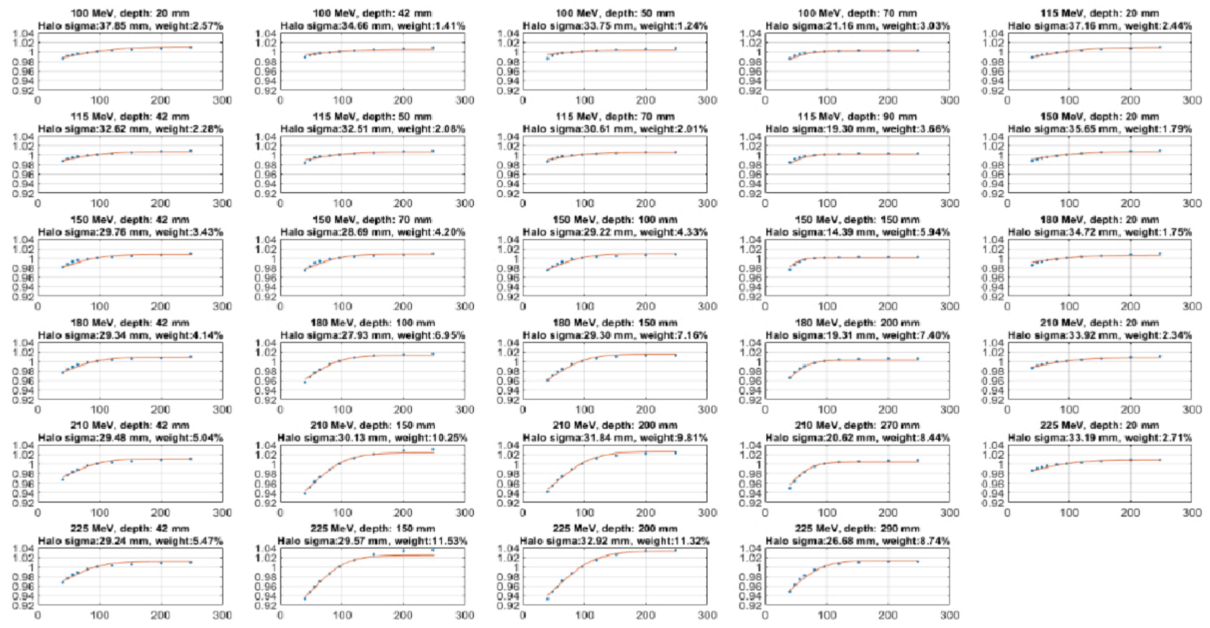

Figure 1 Field size factors: measurement (blue dot) and calculated from derived secondary Gaussian parameters (red line) for mono-energetic beams without range shifter in one of the treatment rooms

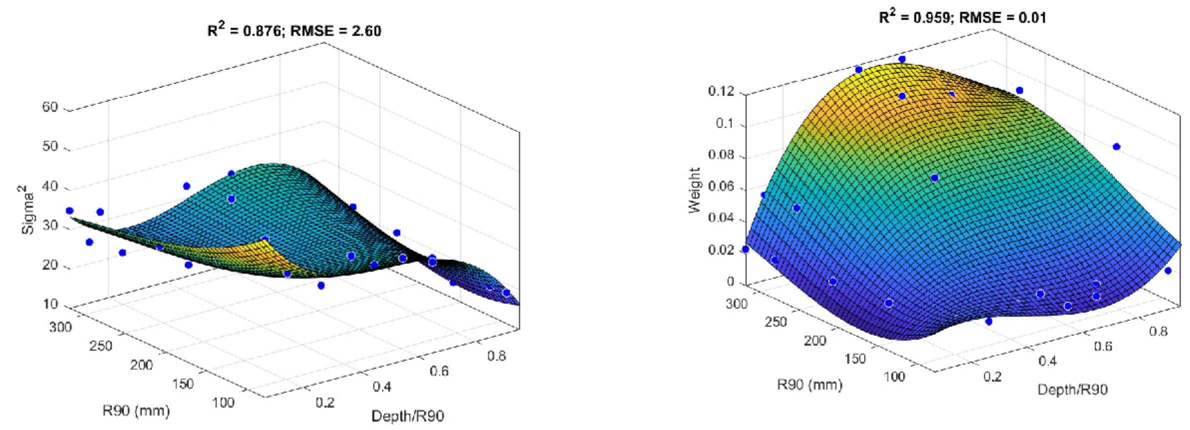

Figure 2 Sigma (left) and weight (right) of secondary Gaussian fitted to a polynomial function of energy (R90) and depth

An in-house secondary MU check program was implemented with the proposed halo model in 2019. We retrospectively analyzed point dose calculated in this program as compared to TPS calculation and QA measurement for 1785 treatment fields and 474 patients treated in our proton center in the last 12 months. Excellent agreement was found between results from secondary MU verification vs TPS calculations (0.20% ± 1.83%, Figure 3), as well as QA measurements vs TPS calculations (0.35% ± 1.94%). No significant variations were found between treatment fields with or without range shifter or different beam characteristics (field sizes, ranges, etc.)

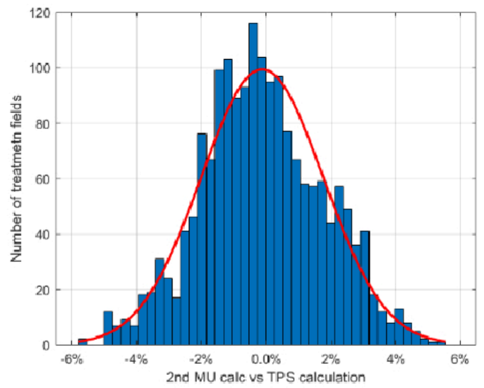

Figure 3 Histogram of percentage difference between point dose calculated from in-house MU check program and TPS

CONCLUSIONS

We proposed and validated an effective approach for secondary Gaussian characterization which can be incorporated for secondary MU check of proton PBS plans.

CONTACT INFORMATION

Lingshu Yin Ph.D.
Medical Physicist
University of Pennsylvania, Perelman School of Medicine
Department of Radiation Oncology
Lingshu.yin@pennmedicine.upenn.edu

REFERENCES

Soukup M, Fippel M, Alber M. A pencil beam algorithm for intensity modulated proton therapy derived from Monte Carlo simulations. Phys. Med. Biol. 2005;50:5089–5104
Clasie B, Depauw N, Fransen M, Goma C, Panahandeh H, Seco J, Flanz J, Kooy H. Golden beam data for proton pencil beam scanning. Phys. Med. Biol. 2010;57:1147-58