

Consensus Guide on Hounsfield Look-Up Table Generation – Adjustments for Photon Therapy

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INTRODUCTION

Radiotherapy dose calculation is typically based on a computed tomography (CT) scan and requires a conversion of CT numbers to the relevant physical parameter – mass density (MD) or relative electron density (RED) for photon therapy, and stopping-power ratio (SPR) for particle therapy, so-called Hounsfield look-up tables (HLUTs). Recently, a consensus guide [1] was published for generating SPR HLUTs for particle therapy, but similar considerations can be used for HLUT creation in photon therapy. **This study extends the consensus guide to be applicable also in photon therapy.**

AIM

Extending the code for HLUT creation to also work for MD and RED HLUT generation, to standardize HLUTs across photon and particle therapy dose calculation, and ease the commissioning process.

METHODS AND MATERIALS

As tissue equivalence of phantom inserts is an important aspect of HLUT generation, it was evaluated specifically for photon-based HLUTs (i.e. MD and RED). The open-source code (<https://github.com/CTinRT/HLUT-guide>) for SPR HLUT generation was updated to also include MD and RED HLUT generation for photon therapy, as well as for vendor-specific CT reconstructions such as DirectDensity (Siemens Healthineers), a kV-independent MD, RED, and SPR prediction. To show the wide applicability of the open-source code, it was evaluated in several scenarios, including four different CT scanners from different vendors (Canon Medical Systems, GE Healthcare, Philips Healthcare, and Siemens Healthineers), several tube potentials (from 70 kV to Sn140 kV; Sn: tin-filtrated) as well as dual-energy CT virtual monoenergetic images, three tissue-equivalent CT phantoms (CIRS EPTN, Gammex Advanced Electron Density, QRM Multi-Energy QA; see sketch), and both regular and DirectDensity reconstructions.

REFERENCES

1. Peters N, Taasti VT, Ackermann B, Bolsi A, Dahlgren CV, Ellerbrock M, Fracchiolla F, Gomà C, Góra J, Lopes PC, Rinaldi I, Salvo K, Tarp IS, Vai A, Bortfeld T, Lomax A, Richter C, Wohlfahrt P. *Consensus guide on CT-based prediction of stopping-power ratio using a Hounsfield look-up table for proton therapy*. Radiother Oncol. 2023;184:109675. <https://doi.org/10.1016/j.radonc.2023.109675>.

RESULTS

Code updates: Limited tissue equivalence was identified for MD of phantom inserts which were otherwise tissue-equivalent in terms of RED and SPR (**Figure 1**). The strategy for generating MD HLUTs was therefore slightly modified compared to RED and SPR HLUT generation to account for this behavior: HLUT fitting was based only on tabulated human tissues for MD HLUTs, while both tabulated human tissues and phantom inserts were included in RED and SPR HLUT fitting. Further, special consideration was implemented for HLUTs for DirectDensity reconstructions.

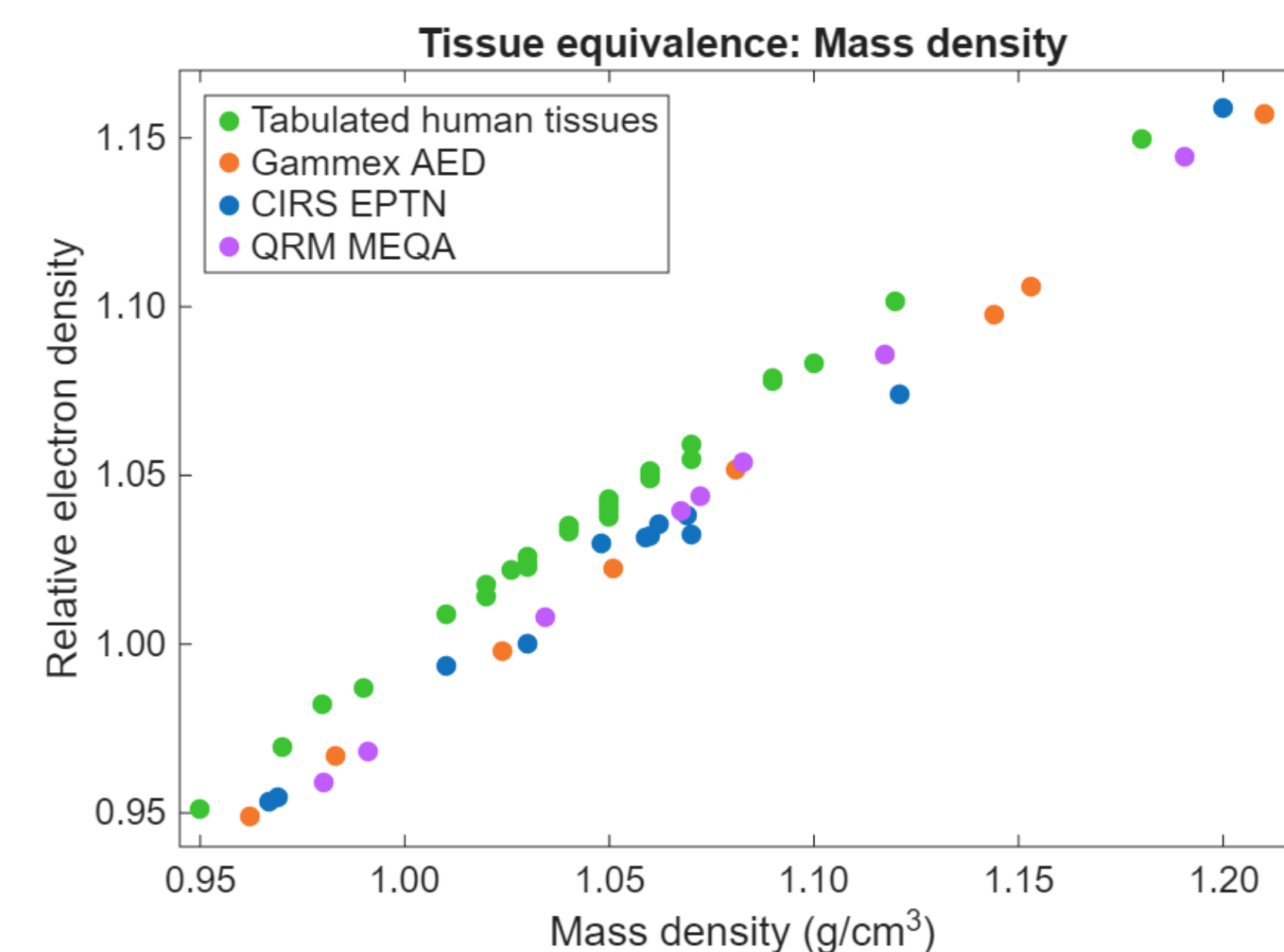
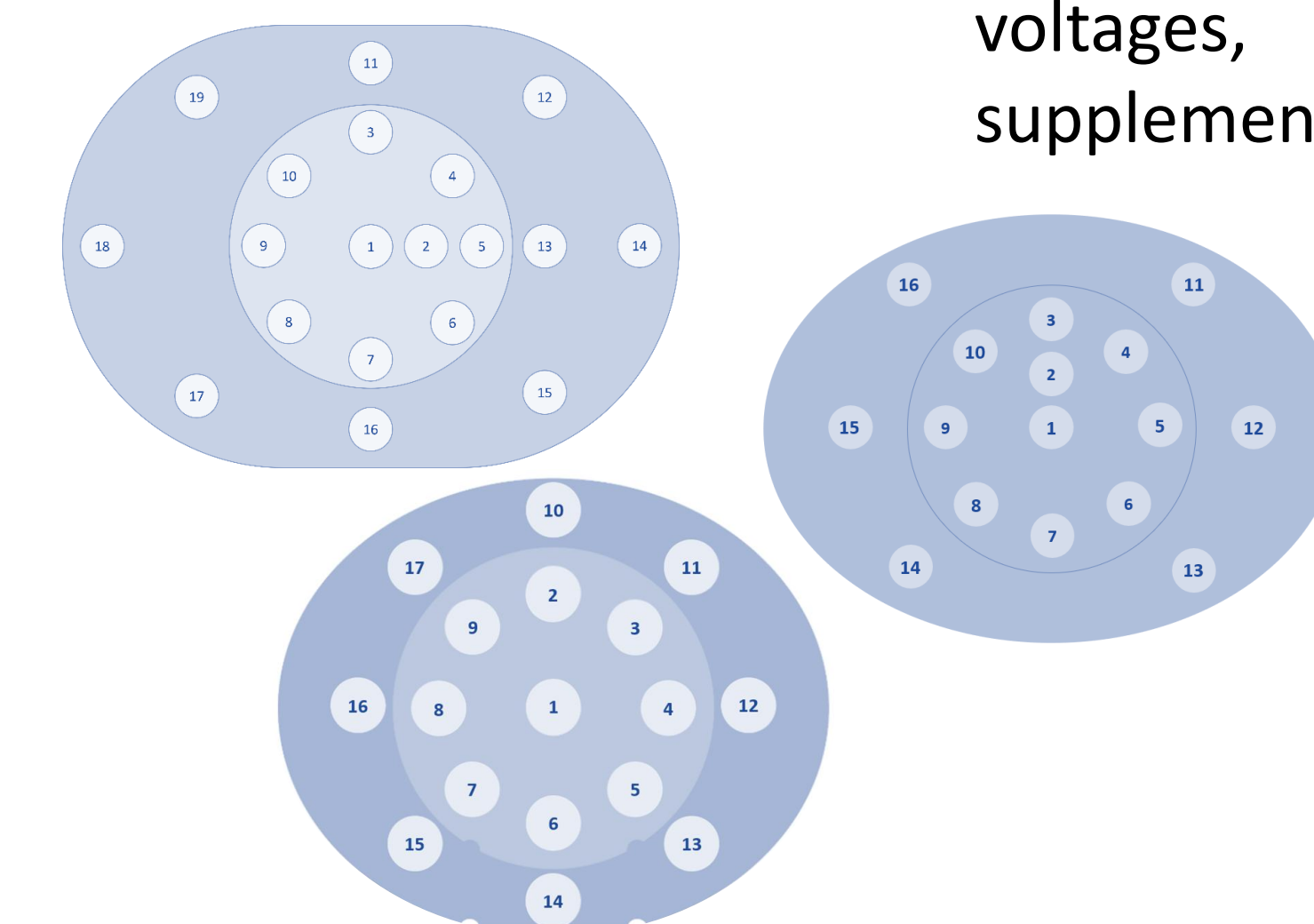


Figure 1: Evaluation of tissue equivalence for mass density (MD). For the phantom inserts (orange, blue and purple datapoints) to be tissue-equivalent, they should have aligned with the tabulated human tissues (green datapoints), but a clear shift is seen.



Sketch: Sketches of the tissue-equivalent phantoms (QRM MEQA, Gammex AED, and CIRS EPTN) satisfying the requirements in the consensus guide.

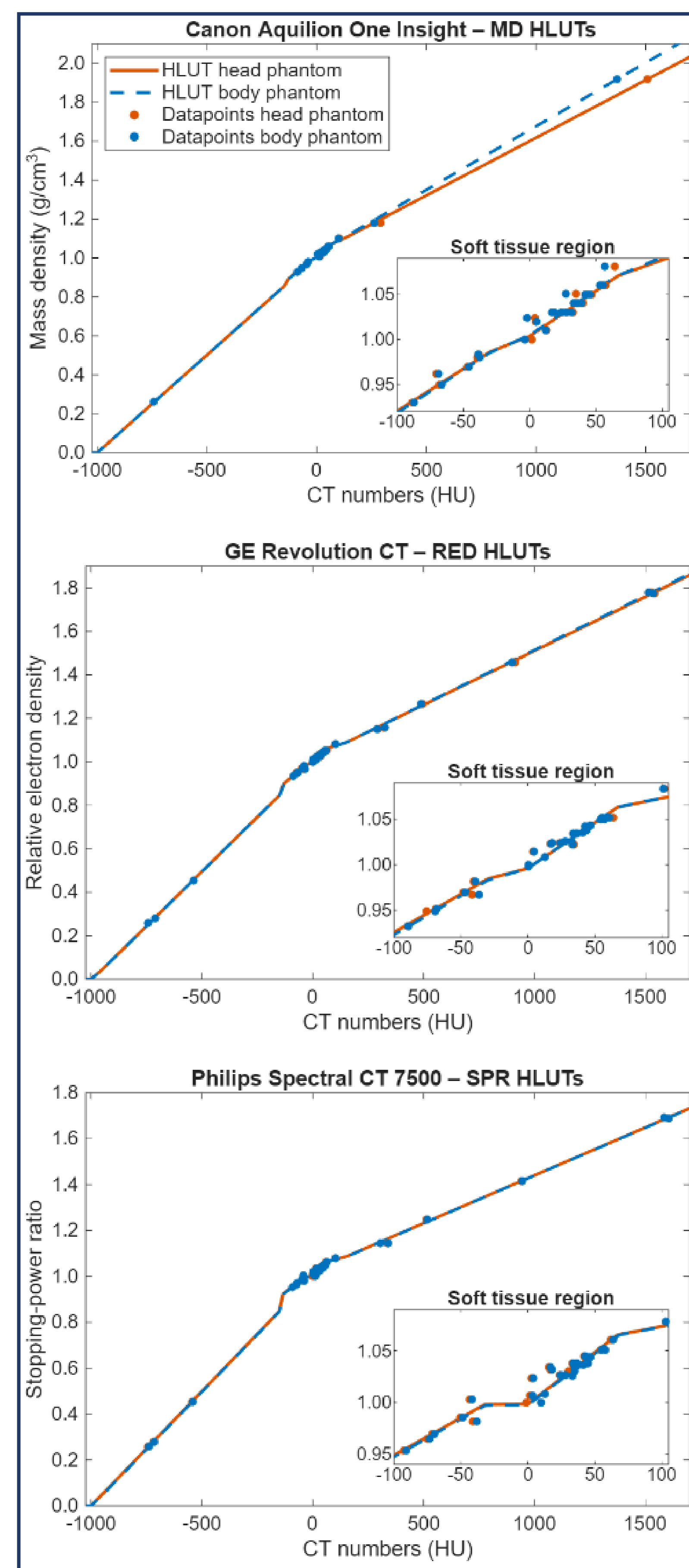


Figure 2: Assessment of HLUTs created for three different CT scanners based on the Gammex AED phantom, including curves based on the small head-sized phantom (full orange lines) and the large abdomen-sized phantom (dashed blue lines), for mass density (MD, left), relative electron density (RED, middle), and particle stopping-power ratio (SPR, right). Note, fewer datapoints are included on the left plot for the MD HLUT, as this curve is fitted based on only tabulated human tissues, while the fitting of the RED and SPR HLUTs additionally include the phantom inserts.

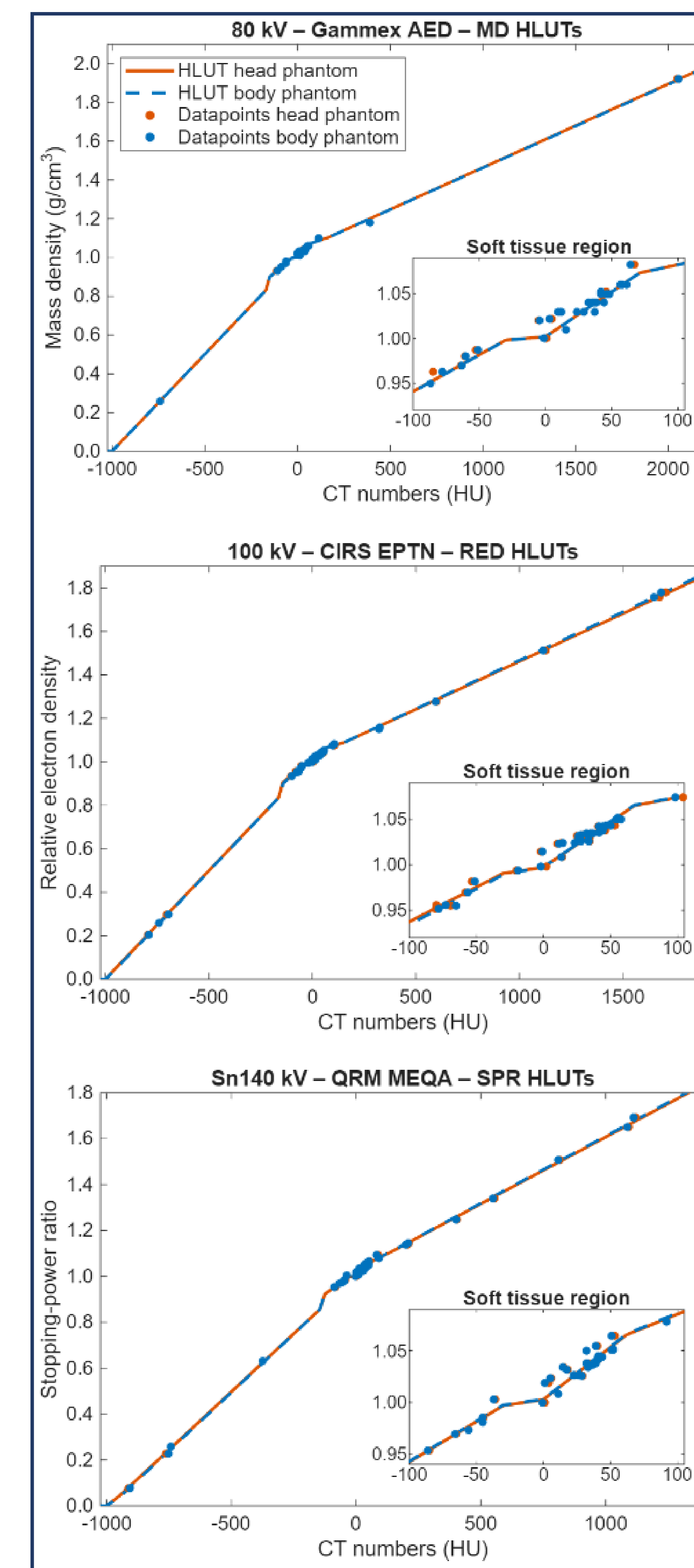


Figure 3: Assessment of HLUTs created based on three different phantoms and three different tube potentials. All scans have been acquired with a Siemens go.Open Pro CT scanner.

IMPACT

The extended open-source code will help **ease and standardize** the generation HLUTs across both photon and particle therapy, to ensure consistent and **accurate dose calculation** across radiotherapy clinics.

CONCLUSION

The extended open-source code has been tested in several scenarios and has been shown to work as intended in all cases.

The code is publicly available and several example input files for different phantoms, CT scanners, tube voltages, and reconstruction settings are supplemented.

ACCESS THE CODE:



CONTACT

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