Purpose: To develop a novel superposition/convolution based algorithm which eliminates the poly-energetic transport approximation.

Methods: We leveraged the hardware functionality of the GPU texture unit to allow our modern dual-source superposition/convolution based dose calculation engine to efficiently perform multiple transports simultaneously. We experimented with dividing the spectrum in half (dual-energetic), quarters (quad-energetic) or N energy bins (multi-energetic). These divisions were applied after the TERMA was computed using the exact, full-spectrum attenuation. We have benchmarked the dosimetric properties of poly-, dual-, quad- and multi-energetic superposition against a series of Monte Carlo dose accuracy benchmarks based on the ICCR 2000 benchmark and have performed a manual commissioning for an Elekta Infinity operating at 6MV.

Results: The performance cost of dual-energetic superposition was 11%-50%. The performance cost of quad-energetic superposition was 39%-151%. Performance varied depending on GPU architecture and cache effects. The slower performance of quad-energetic superposition was due to a smaller CUDA block size and the use of a separate density texture: we normally pack TERMA and density into a single texture. TERMA performance costs were 1% and 10%, respectively. The traditional, poly-energetic superposition overestimated dose, particularly within the first 10 cm and in bone/aluminum. Dual-energetic superposition greatly reduced this overestimation. Quad-energetic and multi-energetic superposition produced nearly identical results. Good agreement was achieved in air, water, bone and aluminum; all methods had trouble matching the fall off in lung due to the small treatment field. We based our manual commissioning of our Elekta Infinity linear accelerator on a published spectrum. We modeled the extra-focal source as being very soft, which necessitated a slight hardening of the primary source.

Conclusions: We have completed a multi-energetic, GPU-accelerated superposition/convolution based algorithm, which improves accuracy over the traditional, poly-energetic approach and allows the use of physically accurate spectrums.