Purpose: This work investigates the variation of x-ray flat field intensity (I_0) as the illumination volume size changes with different collimator settings, an important phenomenon that is commonly ignored in the current implementations of x-ray volumetric imaging and results in significant reconstruction errors.

Methods: A relationship between I_0 and the collimator width is first derived. We propose to calculate the focal spot distribution from flat field projections acquired with different collimator widths. I_0 variation effects on reconstruction and scatter measurement accuracy are evaluated using phantom studies. We compare CT images of an evaluation phantom reconstructed from fan-beam projections using I_0 acquired in fan-beam and cone-beam geometries. Conventional methods measure scatter as the difference between cone-beam and fan-beam projections, which results in measurement errors due to the I_0 variation. We improve the scatter measurement method by considering the I_0 difference in the two projections. Results are compared in projection domain and reconstruction domain.

Results: The full width of the measured focal spot distribution is 0.68mm at half maximum, and increases to 2.76mm at 5% maximum. This results in an I_0 value difference up to 17% as the geometry varies from cone-beam to fan-beam, and a reconstruction error of ~ 20 HU if the I_0 is assumed to be unchanged. The improved scatter measurement method achieves more accurate scatter signals and reduces the reconstruction error from ~20 HU to less than 6 HU. The method also eliminates the skin-line artifacts with a magnitude of ~50 HU.

Conclusions: The I_0 variation due to large focal spot sizes at low intensities causes CT number inaccuracy and image artifacts, which are often misinterpreted in the current research. Our finding of the I_0 effect identifies one potential error source in the reconstruction, and may facilitate scatter correction algorithm designs which require accurate characterization of scatter signals.