Extending the ionisation cluster size distribution of the Associated Volume algorithm to ν=0 using Statistical Learning methods

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In a recent work, we introduced the use of the Associated Volume (AV) algorithm, first described by (Lea, 1946), in computational nanodosimetry. Unlike the Uniform Sampling (US) algorithm, which randomly places sensitive volumes (SVs) inside an encompassing volume ('scoring region'), the AV algorithm places SVs around randomly selected ionisations of the track and checks for additional ionisations inside the SV. This unique characteristic makes the AV algorithm a more efficient option to calculate conditional Ionisation Cluster Size Distributions (ICSDs, $f(\nu)$), i.e., distributions conditioned on ν (cluster size, i.e., number of ionisations inside an SV) greater than a given threshold. However, in the recently explored application of nanodosimetry to charged-particle treatment planning we need unconditional distributions (Ramos-Méndez et al., 2018; Faddegon et al., 2023). Therefore, to leverage the computational efficiency and accuracy of the AV algorithm in this application, one needs an efficient way to estimate the number of clusters with $\nu = 0$ and combine it with the conditional ICSD to calculate the respective unconditional distribution. This work explores the design of a two-step approach to extend the AV conditional distribution to $\nu = 0$ using statistical learning methods to predict $f(\nu = 0)$ based on the initial kinetic energy of the primary particle, E.