Purpose: To develop the theoretical framework for the increased LET of proton clusters and to explain the recently measured elevated RBE value of laser-accelerated protons. When protons are generated in a laser-plasma interaction the initial inter-particle distances are small enough in order to facilitate the observation of the effects of proton clustering.

Methods: Applying the dynamic linear response theory we investigate the increased LET of a group of closely separated protons and find how the experimentally obtained RBE(LET) curves are modified as a result. Analysis of the dependence of RBE on residual range of closely separated protons offers insight into the increased RBE of the whole cluster.

Results: The theoretical model suggests that the LET of a cluster of protons depends on the velocity and inter-particle distance through an interference term. Closely separated fast particles exhibit larger deviation from the well known stopping power of a single proton. The residual range of particles with elevated RBE is therefore extended, offering explanation of the recent experimental observations. When the inter particle distance is 0.5 microns and the velocity of the cluster is 0.1c, the traveling range of protons with RBE=1.25 is extended such that 30% more cells are being damaged. Based on the theoretical predictions of this study we suggest modified experiment in which the RBE increase due to proton clustering will be better observed.

Conclusions: In this study the experimentally observed enhanced RBE of laser accelerated protons is explained in terms of proton clustering. Closely separated projectiles (cluster of protons) experience modified LET dependence on velocity and as a result travel longer distances with an elevated RBE as compared to single protons. Proton clustering is an efficient way of increasing the RBE of protons and can be explored in the future clinical applications of laser-particle accelerators.